Deutsche Physikalische Gesellschaft DPG

# DPG-Frühjahrstagung 2024

(DPG Spring Meeting 2024)

*of the Division*

Particle Physics

*as well as the Working Groups*

Equal Opportunities, Young DPG

© Cornelia Schneider-Frank

## 04 – 08 March 2024

## Karlsruhe Institute of Technology (KIT)

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Verantwortlich für den Inhalt: Dr. Bernhard Nunner, DPG e. V., Hauptstraße 5, 53604 Bad Honnef
Telefon: +49 (0)2224 9232-0; E-Mail: dpg@dpg-physik.de

# Content

Dear Participants,

On behalf of the German Physical Society (DPG), as President, I would like to welcome you to the DPG-Frühjahrstagung (DPG Spring Meeting) on the campus of the Karlsruhe Institute of Technology organised by the DPG division Particle Physics and working groups on Equal Opportunities and Young DPG.

With around 55,000 members, the DPG and its conferences with up to ten thousand participants provide the largest platform for professional exchange in physics in Germany with an impact on Europe and the whole world. Science thrives on exchange and discourse! Moreover, in times of increasing tensions and fake news, scientific exchange strengthens not only physics as a science but helps to promote acceptance and awareness of the importance of basic research and scientific facts in the general public.We are very keen to make our DPG conferences even more international. I am therefore very pleased that, thanks to the support of the Wilhelm and Else Heraeus Foundation, we are now able to award around 80 scholarships to scientists from countries in Central and Eastern Europe and from those being members of the SESAME synchrotron collaboration in the near east.

The DPG is in close contact with its scientific sister societies and scientific institutions around the world. Together with 16 other physical societies (including the American, the Chinese and the European Physical Society), we published „Principles & Policies for International Scientific Collaboration“ at the end of December 2023. This calls on all stakeholders, national governments, research institutions and professional societies to set clear and well-communicated standards for integrity, transparency, and reciprocity, the foundations of any value-based scientific collaboration. In addition, as part of a joint and large international effort, we are preparing for the Year of Quantum Science and Technology in 2025, one hundred years after the consistent formulation of quantum theory, shedding light on its enormous successes, its origins and its outstanding future potential in quantum sensing and metrology, quantum computing or cryptography. Quantum theory has fundamentally changed our view of the world and is having an impact on all areas of our culture, science, technology, and art!

In order to strengthen physics as a science and scientific exchange, the commitment of each individual physicist is essential. I would therefore like to thank all participants of this DPG conference for their contributions and their support to make the conference a success and would like to encourage you all to become members of the DPG, if you have not already done so.

The success of this DPG Spring Meeting is only possible with the greatest commitment of many science enthusiasts involved – thanks to you all! My special thanks go to the conference organiser, Prof. Ulrich Husemann, Karlsruhe Institute of Technology, Institute of Experimental Particle Physics (ETP), and the programme committee with the chairs of the division and the participating working groups: They have put together excellent speakers and an extensive and outstanding programme. Further, I would like to express my sincere thanks to the Wilhelm and Else Heraeus-Stiftung for again providing generous financial support to our young members. Last but not least, my particular thanks go to the very motivated staff of the DPG Head Office for their support at all DPG conferences.

I wish you all an exciting conference, good discussions, and many new insights.

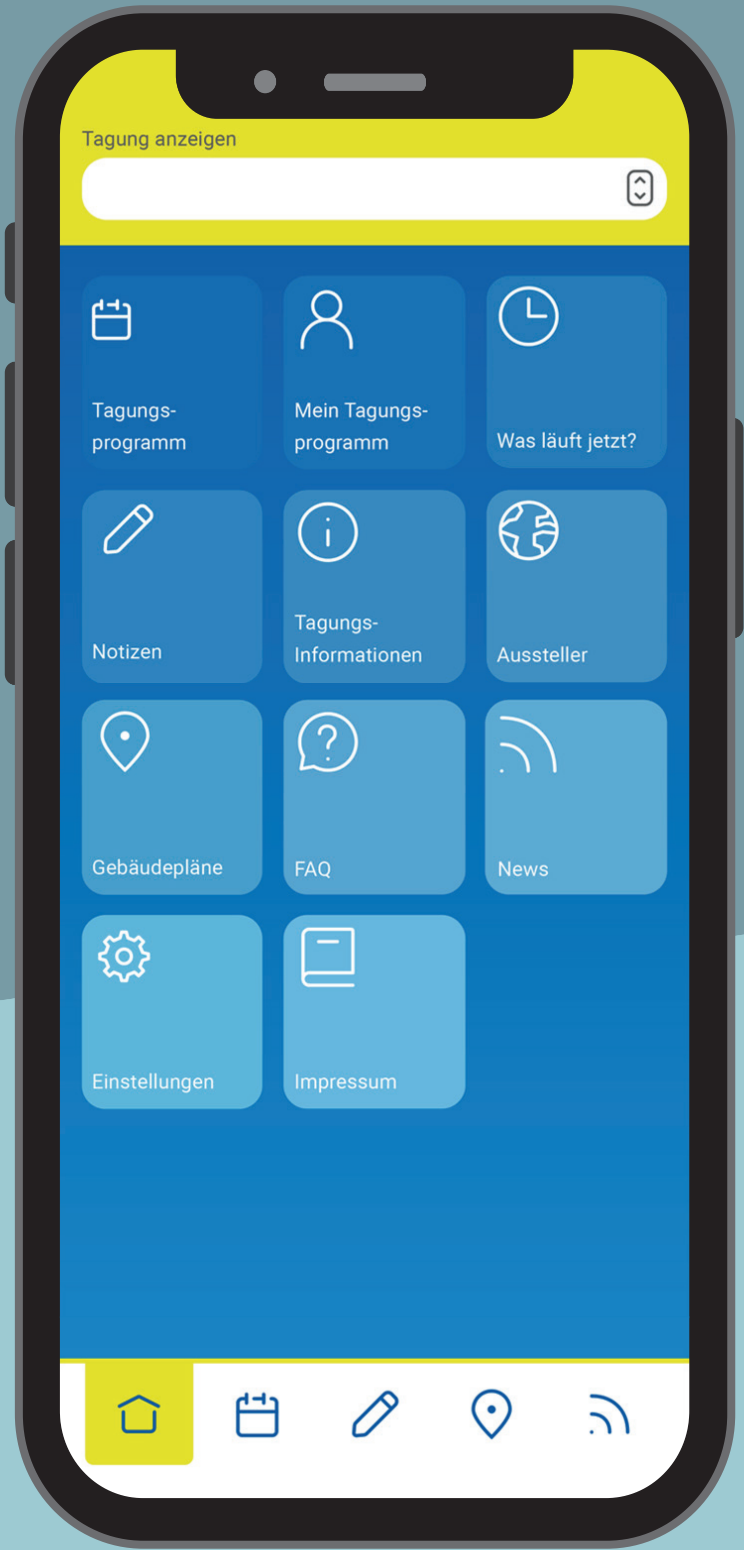
Prof. Dr. Joachim Ullrich
President
Deutsche Physikalische Gesellschaft e.V.

# DOWNLOAD OUR APP

## DPG-FRÜHJAHRSTAGUNGEN

Android

iOS



# Organisation

**Organiser**

Deutsche Physikalische Gesellschaft e. V.
Hauptstraße 5, 53604 Bad Honnef

| | |
|---|---|
| Phone | +49 (0) 2224 9232-0 |
| Fax | +49 (0) 2224 9232-50 |
| Email | dpg@dpg-physik.de |
| Homepage | www.dpg-physik.de |


## Scientific Organisation

**Local Organiser**

Prof. Dr. Ulrich Husemann
Karlsruher Institut für Technologie
Institut für Experimentelle Teilchenphysik
Hermann-von-Helmholtz-Platz 1
Phone +49 (0) 721 608-24038
Email ulrich.husemann@kit.edu


**Chair of the Participating Division**

| | | | |
|---|---|---|---|
| (T) | Particle Physics | – | Prof. Dr. Johannes Haller (johannes.haller@uni-hamburg.de) |

**Chairs of the Participating Working Groups**

| | | | |
|---|---|---|---|
| (AKC) | Equal Opportunities | – | OStR Agnes Sandner (akc@dpg-physik.de) |
| (jDPG) | Young DPG | – | Sonja Schneidewind (schneidewind@jdpg.de) |

**Programme**

The scientific programme consists of **879** contributions:

| | |
|---|---|
| 3 | Plenary talks |
| 1 | Evening talk |
| 1 | Ceremonial talk |
| 4 | Invited talks |
| 17 | Invited overview talks |
| 18 | Invited topical talks |
| 833 | Talks |
| 2 | Tutorials |

**The programme stated in this document corresponds to the status of the programme publication January 22, 2024 and will not be updated!**

# Information for Participants

The conference will be held March 04 – 08, 2024.

## Conference Information

**Conference Venue**
Karlsruhe Institute of Technology (KIT)
Campus South
Kaiserstraße 12
76131 Karlsruhe

The conference will take place at Karlsruhe Institute of Technology (KIT), Campus South, in the following building complexes:

- Audimax:
  Hörsaal-Gebäude am Forum (Straße am Forum 1), Building 30.95
- Physics:
  Physik-Flachbau (Engesserstraße 7–9), Buildings 30.21, 30.22
  Physik-Hochhaus (Wolfgang-Gaede-Straße 1), Building 30.23
- Electrical Engineering and Information Technology (ETIT):
  Elektrotechnik-Hörsäle (Engesserstraße/Fritz-Haber-Weg), Buildings 30.33 – 30.35
- Chemistry:
  Chemie-Hörsäle (Fritz-Haber-Weg 2–6), Building 30.41
- Mathematics:
  Kollegiengebäude Mathematik (Englerstraße 2), Building 20.30

For a detailed map of the campus and the buildings please see “Maps” at the end of this document.

**Conference Office / Information Desk**
The conference office and the information desk are located in seminar room A/B (room 0121) of the Audimax Building (30.95). The opening hours are the following:

| | | Registration | Information Desk |
|---|---|---|---|
| Monday | March 04 | 11:00 – 19:00 | 11:00 – 19:30 |
| Tuesday | March 05 | 08:00 – 16:30 | 08:00 – 21:00 |
| Wednesday | March 06 | 08:00 – 16:30 | 08:30 – 18:00 |
| Thursday | March 07 | 08:00 – 16:30 | 08:30 – 18:00 |
| Friday | March 08 | 08:00 – 12:00 | 08:30 – 13:00 |

You will receive your name tag, a receipt for your conference fee, and the login-password for using Wi-Fi as well as food and drink vouchers for the Welcome Evening at the registration. The name tag must be worn visibly during the entire conference.

The organisers, staff of the conference desk, and the student assistants will be identifiable by coloured name tags or Φ-T-shirts. Please contact them if you have any questions. Do not hesitate to inquire about all necessary information concerning the conference, orientation in Karlsruhe, accommodation, restaurants, going out, and cultural events at the information desk.

**Use the DPG app for the DPG Spring Meetings!**
Create your own conference programme, find out about the conference venue or the latest conference news. With the help of the building plans you can orientate yourself on site. The updated DPG app is ready released in mid february and also contains completely new features: You can now save your own notes and store your participant number in the settings in order to conveniently use the express check-in on site.

**Presentations**
Scientific presentations will be held either orally and will be given in English (conference language) or German.

Usually, presentations will have the following durations:

- For contributed talks a total of 15 minutes including discussion time and speaker change (12 min talk + 3 min discussion/speaker change).
- For invited talks a total of 30 minutes including discussion time and speaker change (25 min talk + 5 min discussion/speaker change).
- For plenary talks 45 minutes (40 min talk + 5 min. discussion).

All lecture halls and seminar rooms will be equipped with a projector (16:9 or 16:10) and a laptop computer. Speakers are requested to upload their presentations on the conference website one day before the corresponding session. An email with the access data and the upload deadlines will be sent to the speakers before the conference. If you require to change your uploaded contribution, you may again upload the document at latest four hours before the session (not the talk) starts. In any case you should also bring a copy of your presentation on a USB drive as a backup.

The file formats accepted for all parallel sessions are pdf and PowerPoint. Own laptops cannot be used for the presentation. The presentations will be transferred to the provided laptops in the lecture hall or seminar room before the session.

All lecture halls and seminar rooms will be opened, at the latest, 30 minutes prior to the talks. Speakers are requested to be in the room at least 20 minutes prior to the start of the session, reporting to the chairperson of the session as well as the technical staff to ensure that the presentation upload was successful and to receive a brief introduction to the equipment in the lecture hall or seminar room. If you need other presentation facilities, please ask for availability at the information desk as soon as you arrive at the conference.

**Broadcast of Plenary Talks**
For all plenary talks in the Audimax (building 30.95), we will offer a live stream to Gerthsen lecture hall (Physics, building 30.21).

**Wilhelm and Else Heraeus Communication Programme**
Important notes for participants who apply for a grant of the Wilhelm and Else Heraeus Foundation:
At the beginning of the conference you will receive an identification form at the conference office. The participation in the conference must be certified by the conference desk. You have the possibility to leave this certificate with the staff members of the DPG at the conference office (preferably) or submit it to the DPG head office (DPG-Geschäftsstelle, Hauptstr. 5, 53604 Bad Honnef, Germany) by **April 5, 2024 at the latest.** For more detailed information refer to *http://karlsruhe24.dpg-tagungen.de*.

The Deutsche Physikalische Gesellschaft thanks the Wilhelm and Else Heraeus Foundation for the generous financial support of young academic talents. We hope that young physicists will continue to seize the offered opportunity for active scientific communication at scientific conferences. A total of about 41,900 young academics were supported by this programme so far.

**Communication / Internet Access**
To use the Wi-Fi network at KIT Campus South with your own mobile devices, access data, login and password will be issued with the registration documents.
KIT is a member of the eduroam union. If your university is also part of the eduroam union, you can also use the university Wi-Fi in all buildings via your own eduroam access.

**Catering**
During the breaks between the lecture sessions, free coffee, tea, and water will be served to conference participants at four points on KIT Campus South: Audimax (building 30.95, morning and afternoon), Physics (building 30.22, morning and afternoon), Mathematics (building 20.30, only afternoon), Chemistry

(building 30.41, only afternoon). Lunch in the cafeteria (building 01.12) requires a guest card. There are restaurants, bakeries, snack bars, and food trucks in various price categories in the immediate vicinity of KIT Campus South, e.g., around Kaiserstraße.

**Cloakroom**
Participants are asked to look carefully after their wardrobe, valuables, laptops, and other belongings. The organisers decline any liability. In the Audimax (building 30.95) you will find a cloakroom managed by student assistants. During the Welcome Evening, a luggage room will be available (building 20.30, seminar room 0.016). The opening hours are as follows:

| | | |
|---|---|---|
| Monday | March 04 | 11:00 – 19:00 |
| Tuesday | March 05 | 08:30 – 21:00 |
| Wednesday | March 06 | 08:30 – 19:00 |
| Thursday | March 07 | 08:30 – 19:00 |
| Friday | March 08 | 08:30 – 14:30 |

**Notice Board**
All changes to the conference programme (i.e. cancellation of presentations, change of rooms, etc.) are also transferred directly to the online version of the programme which will be updated continuously and is available in different formats (sorted by publication date, filterable by conference parts, and as an RSS feed). Please use the form *https://karlsruhe24.dpg-tagungen.de/programm/notice-board-form* to notify changes or cancellations.

**Lost Property**
You can hand in lost property at the information desk. You can also collect your lost property there.

**Liability Exclusion**
Participants are asked to look carefully after their wardrobe, valuables, laptops and other belongings. There can be no liability assumed.

**SAY CHEESE!**
The DPG Spring Meetings are basically public to the press. Please note: On behalf of DPG, photos and videos will be recorded during the Spring Meetings. In the context of public relations, these recordings (as the case may be) will be published on our website, in social media or within prints of the DPG for example.

**$CO_2$ compensation for the DPG conferences**
By decision of its council, the DPG will compensate for fossil $CO_2$ emissions resulting from mobility for DPG conferences and committee meetings.

**Care and Awareness Team**
A care and awareness team (CAT) will be available throughout the conference as the first point of contact in case of questions, problems and complaints. If you are interested in becoming part of the CAT, please contact Felix Kahlhoefer (kahlhoefer@kit.edu). We aim to make the CAT as diverse as possible, so we very much encourage participation from non-local participants, underrepresented groups and across all academic ages and career stages.

**Equality, Diversity, and Inclusion**
We expect that all conference participants treat others with tact, courtesy, and respect, and abstain from, and actively discourage, discrimination in all forms, in particular on the basis of sex, gender identity, sexual orientation, age, beliefs, culture, ethnicity, disability, or family situation. We encourage participants wishing to report any inappropriate behaviour or harassment to get in touch with our team (see list on conference website) either in person at the conference, via the email address dpg2024-edi@physik.kit.edu or via the website https://www.kceta.kit.edu/report.php . Any issues raised will be treated strictly confidentially.

**Acknowledgement**
The Deutsche Physikalische Gesellschaft (DPG) and the local organisers want to thank the following institutions for supporting the conference:

- Wilhelm and Else Heraeus Foundation, Hanau
- KIT
- and all staff, who make the success of the conference possible.

## Social Events

**Opening of the Conference**
A short opening address will be given by the chair of the Division Particle Physics (T), the local conference organising committee, and the KIT executive board on Monday, March 04, from 13:30 until 14:00 in the Audimax.

**Welcome Evening**
The Welcome Evening will be held on Monday, March 04, from 19:00, in the Mathematics Foyer (building 20.30). All registered conference participants are kindly invited.
You will receive your badge as well as food and drink vouchers for the Welcome Evening during conference registration. The Physikerchor (Physicists' Choir) Karlsruhe will open the evening. Vegan food, beer and soft drinks will be served. Register in time (11:00 to 19:30) and do not miss the opportunity to meet people in informal atmosphere. Please wear your name tag which you have received during registration.

**Laboratory Visits at KIT Campus North**
During the lunch break and early afternoon (12:45 – 15:45) on Tuesday March 05, Wednesday March 06, and Thursday March 07, you have the opportunity to visit the unique research infrastructure at KIT Campus North, including KATRIN, KARA, GridKa, TLK and the cleanrooms and manufacturing facilities of CMS, Auger, and IceCube. A bus transfer to and from KIT Campus North and snacks will be provided. You can sign up for the visits at the information desk.

**Exhibition of Scientific Instruments and Literature**
From Tuesday, March 05, to Thursday, March 07, there will be a small exhibition of scientific instruments and literature in the foyer Audimax. Companies (see list of exhibitors at the end of this booklet) will present their products. Opening hours are from 10:30 to 19:00. All conference participants are welcome to attend the exhibition. The entrance is free.

**Public Evening Talk**
The Public Evening Talk will take place on Tuesday, March 05, 19:30 – 21:00 in the Audimax (building 30.95). Kathrin Valerius from KIT will speak about "Dem unsichtbaren Universum auf der Spur: Neutrinos und Dunkle Materie". The talk is open for the interested public and all conference participants. It will be given in German. The entrance is free.

**Ceremonial Session Herwig Schopper**
On Wednesday, March 06, at 11:00 the Ceremonial Session will take place in 30.95 Audimax. The programme is as follows:

**Welcome**
Dr. Lutz Schröter
Deutsche Physikalische Gesellschaft e.V.

Prof. Dr. Oliver Kraft
Prof. Dr. Thomas Müller
Karlsruhe Institute of Technology

**Laudatory Speech**
Prof. Dr. Albrecht Wagner
Deutsches Elektronen-Sychrotron DESY and Universität Hamburg

**Ceremonial Lecture**
Prof. Dr. Beate Heinemann, Deutsches Elektronen-Synchrotron DESY and Universität Hamburg
*„Particle Physics Through the Ages: A Century of Discoveries and the Road Ahead"*

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**Physikertheater (Physicists' Theatre)**

Wednesday, March 06, 18:45 – 19:30, Gaede Lecture Hall (building 30.23)

At the DPG Spring Meeting, the Physikertheater Karlsruhe will perform the play "Weltuntergang oder »Die Welt steht auf kein' Fall mehr lang«" by Jura Soyfer. The Physikertheater is a group of of theatre-loving physicists, geophysicists, meteorologists, and further members founded in 2003.

**jDPG Lunch**

Thursday, March 07, 12:45 – 13:45

Meeting Spot: Physics coffee station (building 30.22)

The jDPG regional group Karlsruhe meets for lunch. The aim is for the young conference participants to get to know each other better at the start of the conference and to establish contacts with local students and doctoral candidates. There will also be an intensive exchange of experiences on important topics, such as starting a doctorate and mental health during studies and doctoral studies.

**jDPG Pub Crawl**

Thursday, March 07, 19:15 Uhr

Meeting Spot: Physik Flachbau

In case you need some time to take a rest during the conference and you are looking for conversations beyond physics, you are cordially invited to a pub crawl through the nightlife in Karlsruhe.

**Members' Assembly of the Division Particle Physics (T)**

The Members' Assembly of the divisions Particle Physics will take place on Thursday, March 07, 19:00 – 21:00, in the Lehmann Lecture Hall (building 30.22) with drinks and pretzels. All DPG members of the division are cordially invited to attend. A Zoom connection will be provided for members who cannot attend in person.

**Closing Session**

On Friday, 08 March, at 12:45 a Closing Session will be given in 30.95 Audimax. All participants are cordially invited.


Deutsche Physikalische Gesellschaft DPG
Gefördert durch
WILHELM UND ELSE HERAEUS-STIFTUNG
Leading for Tomorrow
Physikerinnen und Physiker in *Führungspositionen*?
*Trotz* oder *wegen* Physikstudiums?
*Wirtschaft* oder *Wissenschaftsmanagement*?
Ist das überhaupt was für *mich*?
Bild: © ARochau - Fotolia.com
Mehrtägige Intensivworkshops und Learning Expedition
Bewerbung möglich vom 1. bis 31. März 2024
Mehr Informationen und
die Möglichkeit zur Bewerbung:
leading-for-tomorrow.dpg-physik.de

# Synopsis of the Daily Programme

## Monday, March 4, 2024

| | | | |
|---|---|---|---|
| 13:30 | Geb. 30.95: Audimax | S 1 | **Opening of the Conference** |
| | | | **Plenary Talk** |
| 14:00 | Geb. 30.95: Audimax | PV I | Overview and perspectives in LHC physics<br>•Marumi Kado |

### T

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| | | | **Invited Overview Talk** |
| 14:45 | Geb. 30.95: Audimax | T 1.1 | Evidence for a gravitational-wave background at nanohertz frequencies<br>•Kai Schmitz |
| | | | **Sessions** |
| 14:45 | Geb. 30.95: Audimax | T 1 | Invited Overview Talks 1 |
| 16:00 | Geb. 20.30: 1.067 | T 2 | Search for new particles 1 (LHC) |
| 16:00 | Geb. 20.30: 2.058 | T 3 | Search for new particles 2 |
| 16:00 | Geb. 20.30: 2.059 | T 4 | Cosmic rays 1 |
| 16:00 | Geb. 20.30: 2.066 | T 5 | Methods in particle physics 1 (e/gamma, SciFi) |
| 16:00 | Geb. 20.30: 2.067 | T 6 | Methods in astroparticle physics 1 |
| 16:00 | Geb. 30.21: Gerthsen-HS | T 7 | Neutrino physics 1 |
| 16:00 | Geb. 30.22: Gaede-HS | T 8 | Neutrino physics 2 |
| 16:00 | Geb. 30.22: Lehmann-HS | T 9 | Cosmic rays 2 |
| 16:00 | Geb. 30.22: kl. HS A | T 10 | Gamma astronomy 1 |
| 16:00 | Geb. 30.22: kl. HS B | T 11 | Silicon trackers 1 |
| 16:00 | Geb. 30.23: 2/1 | T 12 | Detectors 1 (electronics) |
| 16:00 | Geb. 30.23: 2/17 | T 13 | Detectors 2 (scintillators, other) |
| 16:00 | Geb. 30.23: 3/1 | T 14 | Detectors 3 (muon detectors) |
| 16:00 | Geb. 30.23: 6/1 | T 15 | Neutrino astronomy 1 |
| 16:00 | Geb. 30.33: MTI | T 16 | Data, AI, Computing 1 (anomaly detection) |
| 16:00 | Geb. 30.34: LTI | T 17 | Data, AI, Computing 2 (analysis tools) |
| 16:00 | Geb. 30.35: HSI | T 18 | Search for Dark Matter 1 |
| 16:00 | Geb. 30.41: HS 1 | T 19 | Methods in particle physics 2 (alignment, luminosity) |
| 16:00 | Geb. 30.41: HS 2 | T 20 | Higgs 1 (boson final states) |
| 16:00 | Geb. 30.41: HS 3 | T 21 | BSM Higgs 1 (extended Higgs sectors) |
| 16:00 | Geb. 30.41: HS 4 | T 22 | Flavour physics 1 |
| 16:00 | Geb. 30.95: Audimax | T 23 | Top physics 1 |

### AKjDPG

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| | | | **Tutorials** |
| 09:00 | Geb. 30.23: 3/1 | AKjDPG 1.1 | Meet the Higgs boson<br>•Sarah Heim |
| 10:45 | Geb. 30.23: 3/1 | AKjDPG 1.2 | Introduction to particle physics detectors<br>•Michael Lupberger |
| | | | **Session** |
| 09:00 | Geb. 30.23: 3/1 | AKjDPG 1 | Tutorials |

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|---|---|---|---|
| 19:00 | Geb. 20.30 Mathematics Foyer | | **Welcome Evening** (for registered participants) |

## Tuesday, March 5, 2024

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|---|---|---|---|
| | | | **Plenary Talk** |
| 11:00 | Geb. 30.95: Audimax | PV II | Twenty years of ultra-high-energy cosmic-ray physics with the Pierre Auger Observatory<br>•Ralph Engel |

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| | | | **Invited Overview Talks, Invited Topical Talks** |
| 09:00 | Geb. 30.95: Audimax | T 24.1 | Latest results of the LHCb experiment<br>•Dominik Stefan Mitzel |
| 09:30 | Geb. 30.95: Audimax | T 24.2 | Belle II at the start of Run2 and physics highlights<br>•Carsten Niebuhr |
| 10:00 | Geb. 30.95: Audimax | T 24.3 | Overview of the ECFA Detector R&D Roadmap and status of the implementation of its recommendations<br>•Susanne Kuehn |
| 11:45 | Geb. 30.95: Audimax | T 25.1 | Extensive air shower simulations – successes and challenges<br>•Tim Huege |
| 12:15 | Geb. 30.95: Audimax | T 25.2 | The muon anomalous magnetic moment<br>•Christoph Lehner |
| 14:00 | Geb. 30.21: Gerthsen-HS | T 26.1 | New physics searches through the Higgs and atomic windows<br>•Elina Fuchs |
| 14:30 | Geb. 30.21: Gerthsen-HS | T 26.2 | Study of electroweak interactions via vector boson scattering at the ATLAS detector<br>•Gia Khoriauli |
| 15:00 | Geb. 30.21: Gerthsen-HS | T 26.3 | AI-aided searches for new physics<br>•Benedikt Maier |
| 14:00 | Geb. 30.22: Gaede-HS | T 27.1 | Start up of Run 3 and performance of the upgraded LHCb experiment<br>•Elena Dall'Occo |
| 14:30 | Geb. 30.22: Gaede-HS | T 27.2 | Fully-inclusive measurement of $B^{0,}$ ± -> $XJ/\psi$ processes at Belle II<br>•Sviatoslav Bilokin |
| 15:00 | Geb. 30.22: Gaede-HS | T 27.3 | Probing Axion Dark Matter with Flavor Factories<br>•Robert Ziegler |

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| | | | **Sessions** |
| 09:00 | Geb. 30.95: Audimax | T 24 | Invited Overview Talks 2 |
| 11:45 | Geb. 30.95: Audimax | T 25 | Invited Overview Talks 3 |
| 14:00 | Geb. 30.21: Gerthsen-HS | T 26 | Invited Topical Talks 1 |
| 14:00 | Geb. 30.22: Gaede-HS | T 27 | Invited Topical Talks 2 |
| 16:00 | Geb. 20.30: 1.067 | T 28 | Search for new particles 3 (ALPS) |
| 16:00 | Geb. 20.30: 2.058 | T 29 | Neutrino physics 3 |
| 16:00 | Geb. 20.30: 2.059 | T 30 | Cosmic rays 3 |
| 16:00 | Geb. 20.30: 2.066 | T 31 | Methods in particle physics 3 (lepton reconstruction) |
| 16:00 | Geb. 20.30: 2.067 | T 32 | Methods in astroparticle physics 2 |
| 16:00 | Geb. 30.21: Gerthsen-HS | T 33 | Neutrino physics 4 |
| 16:00 | Geb. 30.22: Gaede-HS | T 34 | Neutrino physics 5 |
| 16:00 | Geb. 30.22: Lehmann-HS | T 35 | Cosmic rays 4 |
| 16:00 | Geb. 30.22: kl. HS A | T 36 | Gamma astronomy 2 |
| 16:00 | Geb. 30.22: kl. HS B | T 37 | Silicon trackers 2 |
| 16:00 | Geb. 30.23: 2/0 | T 38 | Standard model 1 (electroweak/bosons) |
| 16:00 | Geb. 30.23: 2/1 | T 39 | Detectors 4 (calorimeters) |
| 16:00 | Geb. 30.23: 2/17 | T 40 | Detectors 5 (scintillators) |
| 16:00 | Geb. 30.23: 3/1 | T 41 | Trigger+DAQ 1 |
| 16:00 | Geb. 30.23: 6/1 | T 42 | Neutrino astronomy 2 |
| 16:00 | Geb. 30.33: MTI | T 43 | Data, AI, Computing 3 (pointclouds \& graphs) |
| 16:00 | Geb. 30.34: LTI | T 44 | Data, AI, Computing 4 (workflow) |
| 16:00 | Geb. 30.35: HSI | T 45 | Search for Dark Matter 2 |

# Tuesday, March 5, 2024

## T

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|---|---|---|---|
| 16:00 | Geb. 30.41: HS 1 | T 46 | Di-Higgs 1 (bbττ) |
| 16:00 | Geb. 30.41: HS 2 | T 47 | Higgs 2 (ttH & tH production) |
| 16:00 | Geb. 30.41: HS 3 | T 48 | BSM Higgs 2 (extended Higgs sectors) |
| 16:00 | Geb. 30.41: HS 4 | T 49 | Flavour physics 2 |
| 16:00 | Geb. 30.95: Audimax | T 50 | Top physics 2 (top pair cross section) |

## AKC

**Invited Talk**

| | | | |
|---|---|---|---|
| 11:45 | Geb. 30.22: Lehmann-HS | AKC 1.1 | The tragic destiny of Mileva Marić Einstein<br>•Pauline Gagnon |

**Sessions**

| | | | |
|---|---|---|---|
| 11:45 | Geb. 30.22: Lehmann-HS | AKC 1 | AKC |
| 12:45 | Geb. 30.22: Lehmann-HS | AKC 2 | Women in Physics Lunch |

## AKjDPG

**Invited Talks**

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|---|---|---|---|
| 19:00 | Geb. 30.22: Lehmann-HS | AKjDPG 2.1 | "I could *Never* work for Industry!" – How life ignores your resolutions.<br>•Isabel Braun |
| 19:25 | Geb. 30.22: Lehmann-HS | AKjDPG 2.2 | Als Physiker*in Krankenhäuser digitalisieren? Klar doch!<br>•Charles Majer |
| 19:50 | Geb. 30.22: Lehmann-HS | AKjDPG 2.3 | From giant particle physics experiment to giant corporation<br>•Florian Herrmann |

**Session**

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|---|---|---|---|
| 19:00 | Geb. 30.22: Lehmann-HS | AKjDPG 2 | Physicists beyond Academia |

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10:30 Foyer Audimax **Exhibition of Scientific Instruments and Literature**
*(free entrance)*

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**Public Evening Talk (free admission)**

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|---|---|---|---|
| 19:30 | Geb. 30.95: Audimax | PV III | Dem unsichtbaren Universum auf der Spur: Neutrinos und Dunkle Materie<br>•Kathrin Valerius |

## Wednesday, March 6, 2024

| | | | |
|---|---|---|---|
| 11:00 | Geb. 30.95: Audimax | | **Ceremonial Session Herwig Schopper** |
| | | | **Ceremonial Talk** |
| | | PV IV | Particle Physics Through the Ages: A Century of Discoveries and the Road Ahead<br>•Beate Heinemann |

## SYFU

| | | | |
|---|---|---|---|
| | | | **Invited Overview Talks** |
| 14:00 | Geb. 30.95: Audimax | SYFU 1.1 | Future in Collisions – The need for an $e^+e^-$ Higgs Factory<br>•Jürgen Reuter |
| 14:30 | Geb. 30.95: Audimax | SYFU 1.2 | Exploring the Gravitational Wave Universe with the Einstein Telescope and LISA<br>•Katharina-Sophie Isleif |
| 15:00 | Geb. 30.95: Audimax | SYFU 1.3 | Sustainable Partnerships: Navigating the Environmental Challenges in Modern Particle and Astroparticle Physics<br>•Michael Düren |
| | | | **Session** |
| 14:00 | Geb. 30.95: Audimax | SYFU 1 | Symposium Future |

## T

| | | | |
|---|---|---|---|
| | | | **Invited Overview Talks** |
| 09:00 | Geb. 30.95: Audimax | T 51.1 | The top quark: a precision probe and a window to new phenomena<br>•Jan Kieseler |
| 09:30 | Geb. 30.95: Audimax | T 51.2 | Fundamental tests of the Standard Model at ATLAS and CMS<br>•Baptiste Ravina |
| 10:00 | Geb. 30.95: Audimax | T 51.3 | Mastering challenges of High-Luminosity LHC data with innovative computing solutions<br>•Michael Boehler |
| | | | **Sessions** |
| 09:00 | Geb. 30.95: Audimax | T 51 | Invited Overview Talks 4 |
| 16:00 | Geb. 20.30: 1.067 | T 52 | Search for new particles 4 (leptoquarks, LHC) |
| 16:00 | Geb. 20.30: 2.058 | T 53 | Neutrino physics 6 |
| 16:00 | Geb. 20.30: 2.059 | T 54 | Cosmic rays 5 |
| 16:00 | Geb. 20.30: 2.066 | T 55 | Methods in particle physics 4 (HCAL, jets) |
| 16:00 | Geb. 20.30: 2.067 | T 56 | Methods in astroparticle physics 3 |
| 16:00 | Geb. 30.21: Gerthsen-HS | T 57 | Neutrino physics 7 |
| 16:00 | Geb. 30.22: Gaede-HS | T 58 | Neutrino physics 8 |
| 16:00 | Geb. 30.22: Lehmann-HS | T 59 | Outreach 1 |
| 16:00 | Geb. 30.22: kl. HS A | T 60 | Gamma astronomy 3 |
| 16:00 | Geb. 30.22: kl. HS B | T 61 | Silicon trackers 3 |
| 16:00 | Geb. 30.23: 2/0 | T 62 | Standard model 2 (electroweak/bosons) |
| 16:00 | Geb. 30.23: 2/1 | T 63 | Detectors 6 (calorimeters) |
| 16:00 | Geb. 30.23: 2/17 | T 64 | Detectors 7 (gas detectors) |
| 16:00 | Geb. 30.23: 3/1 | T 65 | Trigger+DAQ 2 |
| 16:00 | Geb. 30.23: 6/1 | T 66 | Neutrino astronomy 3 |
| 16:00 | Geb. 30.33: MTI | T 67 | Data, AI, Computing 5 (normalising flows) |
| 16:00 | Geb. 30.34: LTI | T 68 | Data, AI, Computing 6 (ML utilities) |
| 16:00 | Geb. 30.35: HSI | T 69 | Search for Dark Matter 3 |
| 16:00 | Geb. 30.41: HS 1 | T 70 | Di-Higgs 2 (4b & other) |
| 16:00 | Geb. 30.41: HS 2 | T 71 | Higgs 3 (coupling to b and c quarks) |
| 16:00 | Geb. 30.41: HS 3 | T 72 | BSM Higgs 3 (extended Higgs sectors) |
| 16:00 | Geb. 30.41: HS 4 | T 73 | Flavour physics 3 |

## Wednesday, March 6, 2024

**T**

| | | | |
|---|---|---|---|
| 16:00 | Geb. 30.95: Audimax | T 74 | Top physics 3 (single top) |
| 19:45 | Geb. 30.22: Gaede-HS | T 75 | Annual Meeting of Young Scientists in High Energy Physics (yHEP) |

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|---|---|---|
| 10:30 | Foyer Audimax | **Exhibition of Scientific Instruments and Literature** *(free entrance)* |

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|---|---|---|
| 18:45 | Geb. 30.22: Gaede-HS | **Physikertheater (Physicists' Theatre)** |

## Thursday, March 7, 2024

**T**

**Invited Overview Talks, Invited Topical Talks**

| | | | |
|---|---|---|---|
| 09:00 | Geb. 30.95: Audimax | T 76.1 | Origin of heavy elements: r-process in neutron star mergers and core-collapse supernovae<br>•Almudena Arcones |
| 09:30 | Geb. 30.95: Audimax | T 76.2 | Radio Detection of Neutrinos<br>•Anna Nelles |
| 10:00 | Geb. 30.95: Audimax | T 76.3 | High precision gravitational wave physics from quantum field theory<br>•Jan Plefka |
| 11:00 | Geb. 30.21: Gerthsen-HS | T 77.1 | Track reconstruction for the ATLAS Phase-II Event Filter using GNNs on FPGAs<br>•Sebastian Dittmeier |
| 11:30 | Geb. 30.21: Gerthsen-HS | T 77.2 | Searches for Long-Lived Particles at LHC<br>•Lisa Benato |
| 12:00 | Geb. 30.21: Gerthsen-HS | T 77.3 | Searches for long-lived particles at accelerators<br>•Maksym Ovchynnikov |
| 11:00 | Geb. 30.22: Gaede-HS | T 78.1 | Signatures of quantum gravity in neutrino telescopes<br>•Alba Domi |
| 11:30 | Geb. 30.22: Gaede-HS | T 78.2 | Development, characterization, and integration of the Silicon Drift Detector array TRISTAN for KATRIN<br>•Frank Edzards |
| 12:00 | Geb. 30.22: Gaede-HS | T 78.3 | New Chapter in Neutrino Physics with JUNO<br>•Yury Malyshkin |
| 14:00 | Geb. 30.21: Gerthsen-HS | T 79.1 | Construction, Commissioning, and Performance of the new ATLAS Level1-Trigger System for Run 3<br>•Ralf Gugel |
| 14:30 | Geb. 30.21: Gerthsen-HS | T 79.2 | Hadronic signals at the LHC: timing as a handle to face the challenges of higher luminosity<br>•Margherita Spalla |
| 15:00 | Geb. 30.21: Gerthsen-HS | T 79.3 | The LHCb Mighty Tracker – Getting ready for flavour physics at the HL-LHC<br>•Klaas Padeken |
| 14:00 | Geb. 30.22: Gaede-HS | T 80.1 | The advent of TeV gamma-ray astronomy with gamma-ray bursts<br>•Alessio Berti |
| 14:30 | Geb. 30.22: Gaede-HS | T 80.2 | Multi-messenger models of active galaxies: achievements and future directions<br>•Xavier Rodrigues |
| 15:00 | Geb. 30.22: Gaede-HS | T 80.3 | Acceleration and transport of relativistic electrons in the par sec-scale jets of the microquasar SS 433<br>•Laura Olivera-Nieto |

# Thursday, March 7, 2024



| | | | Sessions |
|---|---|---|---|
| 09:00 | Geb. 30.95: Audimax | T 76 | Invited Overview Talks 5 |
| 11:00 | Geb. 30.21: Gerthsen-HS | T 77 | Invited Topical Talks 3 |
| 11:00 | Geb. 30.22: Gaede-HS | T 78 | Invited Topical Talks 4 |
| 14:00 | Geb. 30.21: Gerthsen-HS | T 79 | Invited Topical Talks 5 |
| 14:00 | Geb. 30.22: Gaede-HS | T 80 | Invited Topical Talks 6 |
| 16:00 | Geb. 20.30: 1.067 | T 81 | Search for new particles 5 (SUSY) |
| 16:00 | Geb. 20.30: 2.058 | T 82 | Neutrino physics 9 |
| 16:00 | Geb. 20.30: 2.059 | T 83 | Cosmic rays 6 |
| 16:00 | Geb. 20.30: 2.066 | T 84 | Methods in particle physics 5 (tagging) |
| 16:00 | Geb. 20.30: 2.067 | T 85 | Methods in astroparticle physics 4 |
| 16:00 | Geb. 30.21: Gerthsen-HS | T 86 | Neutrino physics 10 |
| 16:00 | Geb. 30.22: Gaede-HS | T 87 | Neutrino physics 11 |
| 16:00 | Geb. 30.22: Lehmann-HS | T 88 | Outreach 2 |
| 16:00 | Geb. 30.22: kl. HS A | T 89 | Gamma astronomy 4 |
| 16:00 | Geb. 30.22: kl. HS B | T 90 | Silicon trackers 4 |
| 16:00 | Geb. 30.23: 2/0 | T 91 | Standard model 3 (strong/QCD) |
| 16:00 | Geb. 30.23: 2/1 | T 92 | Detectors 8 (semiconductors) |
| 16:00 | Geb. 30.23: 2/17 | T 93 | Detectors 9 (gas detectors) |
| 16:00 | Geb. 30.23: 3/1 | T 94 | Trigger+DAQ 3 |
| 16:00 | Geb. 30.23: 6/1 | T 95 | Gravitational waves 1 |
| 16:00 | Geb. 30.33: MTI | T 96 | Data, AI, Computing 7 (uncertainties, likelihoods) |
| 16:00 | Geb. 30.34: LTI | T 97 | Future colliders |
| 16:00 | Geb. 30.35: HSI | T 98 | Search for Dark Matter 4 |
| 16:00 | Geb. 30.41: HS 1 | T 99 | Di-Higgs 3 (bbWW) |
| 16:00 | Geb. 30.41: HS 2 | T 100 | Higgs 4 (coupling to taus, CP, rare decays) |
| 16:00 | Geb. 30.41: HS 3 | T 101 | BSM Higgs 4 |
| 16:00 | Geb. 30.41: HS 4 | T 102 | Flavour physics 4 |
| 16:00 | Geb. 30.95: Audimax | T 103 | Top physics 4 (tt+X) |
| 19:00 | Geb. 30.22: Lehmann-HS | T 104 | Members' Assembly |

10:30 Foyer Audimax — **Exhibition of Scientific Instruments and Literature**
*(free entrance)*

12:45 Geb. 30.22: Physics coffee station — **jDPG Lunch**

19:15 Geb. 30.22: Physik Flachbau — **jDPG Pub Crawl**

## Friday, March 8, 2024

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|---|---|---|---|
| | | | **Plenary Talk** |
| 11:00 | Geb. 30.95: Audimax | PV V | Highlights of Neutrino Physics<br>•Susanne Mertens |

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|---|---|---|---|
| | | | **Invited Overview Talks** |
| 11:45 | Geb. 30.95: Audimax | T 127.1 | Status and Highlights of Higgs Boson Measurements and Searches at the LHC<br>•Marcel Rieger |
| 12:15 | Geb. 30.95: Audimax | T 127.2 | Charting the unknown: results from recent searches for new phenomena at the LHC<br>•Katharina Behr |
| | | | **Sessions** |
| 09:00 | Geb. 20.30: 1.067 | T 105 | Search for new particles 6 |
| 09:00 | Geb. 20.30: 2.058 | T 106 | Search for new particles 7 |
| 09:00 | Geb. 20.30: 2.059 | T 107 | Cosmic rays 7 |
| 09:00 | Geb. 20.30: 2.066 | T 108 | Methods in particle physics 6 |
| 09:00 | Geb. 30.21: Gerthsen-HS | T 109 | Neutrino physics 12 |
| 09:00 | Geb. 30.22: Gaede-HS | T 110 | Search for Dark Matter 5 |
| 09:00 | Geb. 30.22: Lehmann-HS | T 111 | Outreach 3 |
| 09:00 | Geb. 30.22: kl. HS A | T 112 | Silicon trackers 5 |
| 09:00 | Geb. 30.22: kl. HS B | T 113 | Silicon trackers 6 |
| 09:00 | Geb. 30.23: 2/0 | T 114 | Standard model 4 (strong/QCD) |
| 09:00 | Geb. 30.23: 2/1 | T 115 | Detectors 10 (semiconductors) |
| 09:00 | Geb. 30.23: 2/17 | T 116 | Detectors 11 (gas detectors) |
| 09:00 | Geb. 30.23: 3/1 | T 117 | Trigger+DAQ 4 |
| 09:00 | Geb. 30.23: 6/1 | T 118 | Gravitational waves 2 |
| 09:00 | Geb. 30.33: MTI | T 119 | Data, AI, Computing 8 (foundational & transformer models) |
| 09:00 | Geb. 30.34: LTI | T 120 | Data, AI, Computing 9 (generative models & simulation) |
| 09:00 | Geb. 30.35: HSI | T 121 | Search for Dark Matter 6 |
| 09:00 | Geb. 30.41: HS 1 | T 122 | Miscellaneous |
| 09:00 | Geb. 30.41: HS 2 | T 123 | Flavour physics 5 |
| 09:00 | Geb. 30.41: HS 3 | T 124 | BSM Higgs 5 (charged Higgs bosons) |
| 09:00 | Geb. 30.41: HS 4 | T 125 | Flavour physics 6 |
| 09:00 | Geb. 30.95: Audimax | T 126 | Top physics 5 (top mass) |
| 11:45 | Geb. 30.95: Audimax | T 127 | Invited Overview Talks 6 |

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|---|---|---|---|
| 12:45 | Geb. 30.95: Audimax | | **Closing Session** |

Deutsche Physikalische Gesellschaft DPG

# 100 years is just the beginning ...

# Quantum2025 – Shaping the Future with Science and Technology

The formulation of quantum mechanics in 1925 has laid a lasting foundation for our physical understanding of nature.

It came to stretch our imagination, since fundamental concepts such as the superposition of states of matter contradict our everyday experience. At the same time, it has expanded our knowledge about our material environment to such an extent that our society continues to acquire novel technical capabilities till today. Quantum technologies that have emerged from the beginning have not only changed our daily lives, they have also become pillars of our prosperity.

Quantum theory has fundamentally changed our view of the world and is having an impact on all areas of our culture, science, technology, and art.

Enough reason for the German Physical Society (DPG), together with its sister societies and scientific institutions all over the world, to shed light on the role of quantum physics in the light of its results, its future options and its origin in all its facets after one hundred years of a success story in the year 2025.

INTERNATIONAL YEAR OF
Quantum Science and Technology

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# Plenary, Ceremonial, and Evening Talks

**Plenary Talk** PV I Mon 14:00 Geb. 30.95: Audimax

**Overview and perspectives in LHC physics** — •Marumi Kado — Max Planck Institute for Physics, Munich, Germany

After nearly 15 years of operations, the LHC is midway of its third run at the energy frontier. Meanwhile the LHC machine and experiments are also preparing in full steam for major upgrades to operate in the high luminosity phase projected to start in 2029. During this phase the LHC is expected to deliver approximately 15 times its current integrated luminosity. In this talk an overview of the main LHC pp collision results and achievements will be given through selected highlights. Challenges and opportunities at Run 3 and beyond at the High Luminosity LHC will be discussed.

**Plenary Talk** PV II Tue 11:00 Geb. 30.95: Audimax

**Twenty years of ultra-high-energy cosmic-ray physics with the Pierre Auger Observatory** — •Ralph Engel for the Pierre-Auger-Collaboration — Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Since the discovery of the first cosmic particle with an energy of about $10^{20}$ eV, more than one Joule, in the 1960ies, understanding the origin and nature of these particles has been a central goal in astro- and particle physics. The extremely small flux of these particles, which can only be observed indirectly through their gigantic cascades of secondary particles they produce when entering the Earth's atmosphere, has made progress in this field very difficult. With the Pierre Auger Observatory, an detector installation covering an area of 3000 $km^2$ in Argentina, the so-far largest number of these particles has been detected in unprecedented quality. The Auger Observatory began taking data in 2004 and has since revolutionized our understanding of ultra-high energy cosmic rays. In this talk, we will review the main results of the Auger Observatory and discuss their implications in the context of astroparticle physics.

**Evening Talk** PV III Tue 19:30 Geb. 30.95: Audimax

**Dem unsichtbaren Universum auf der Spur: Neutrinos und Dunkle Materie** — •Kathrin Valerius — Institut für Astroteilchenphysik, Karlsruher Institut für Technologie

Moderne Teleskope gewähren uns heute immer tiefere und immer schärfere Einblicke in den faszinierenden Kosmos. Dennoch bleiben wesentliche Bestandteile des Universums für sie unsichtbar: Die Natur der Dunklen Materie, die den überwiegenden Teil der kosmischen Masse ausmacht, bildet eine der großen ungelösten Fragen der modernen Physik. Ebenso geheimnisvoll sind bis heute die „geisterhaften“ Neutrinos – subatomare Teilchen mit extrem geringer Masse und nahezu ohne Wechselwirkung mit Materie, die mit ca. 340 Teilchen pro Kubikzentimeter im Universum omnipräsent sind. Beide Elemente des unsichtbaren Universums spielen Schlüsselrollen für die Struktur des Kosmos und im Erkenntnisgewinn an der Schnittstelle von Astrophysik, Teilchenphysik und Kosmologie. Der Vortrag stellt innovative Experimente vor, mit denen Forscherinnen und Forscher vor Ort in Karlsruhe und an einzigartigen Laborstandorten weltweit den Rätseln der Neutrinos und der Dunklen Materie nachgehen, und beleuchtet den aktuellen Stand der Forschung.

## PV 4: Ceremonial Session Herwig Schopper

Time: Wednesday 11:00–13:00 Location: Geb. 30.95: Audimax

**Ceremonial Talk** PV IV Geb. 30.95: Audimax

**Particle Physics Through the Ages: A Century of Discoveries and the Road Ahead** — •Beate Heinemann — Deutsches Elektronen-Synchrotron DESY — Universität Hamburg

Particle Physics has made tremendous progress during the past 100 years due to major technological advances in the areas of accelerators, detectors and computing. We have discovered the fundamental constituents of matter, and understood what forces interact between them, and how these forces work in detail. I will present the key scientific advances that led to the current status of particle physics. I will also discuss the important open questions in our understanding of fundamental particles and their role in the early Universe, and how we might be able to get answers to those through future experiments. Throughout the talk I will highlight the breakthroughs that were enabled by Herwig Schopper.

**Plenary Talk** PV V Fri 11:00 Geb. 30.95: Audimax

**Highlights of Neutrino Physics** — •Susanne Mertens — Technical University Munich, Munich, Germany

Neutrinos are one of the most facinating particles of the Standard Model. Despite major discovery in the last decades, many of their fundamental properties are still unknown. What is their absolute mass, how are the three neutrino masses ordered, is the neutrino its own anti-particle, is CP violated in the neutrino sector, are there more than three neutrino species? Answering these questions would not only deepen our understanding of Particle Physics, but may reveal physics beyond the Standard Model, and play a key role in cosmology. Beyond studying neutrinos themselves, they are also ideal messenger particles to learn about the most violent processes in our cosmos with the help of neutrino telescopes. In this talk, the current and future neutrino experiments will be reviewed and their perspective to unravel some of the most interesting open questions in physics will be highlighted.

# Symposium Future (SYFU)

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# Overview of Invited Talks and Sessions

## Invited Talks

| | | | | |
|---|---|---|---|---|
| SYFU 1.1 | Wed | 14:00–14:30 | Geb. 30.95: Audimax | **Future in Collisions – The need for an $e^+e^-$ Higgs Factory** — •Jürgen Reuter |
| SYFU 1.2 | Wed | 14:30–15:00 | Geb. 30.95: Audimax | **Exploring the Gravitational Wave Universe with the Einstein Telescope and LISA** — •Katharina-Sophie Isleif, the ET Collaboration, the LISA Consortium, the LVK Collaboration |
| SYFU 1.3 | Wed | 15:00–15:30 | Geb. 30.95: Audimax | **Sustainable Partnerships: Navigating the Environmental Challenges in Modern Particle and Astroparticle Physics** — •Michael Düren |

## Sessions

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|---|---|---|---|---|
| SYFU 1.1–1.3 | Wed | 14:00–15:30 | Geb. 30.95: Audimax | **Symposium Future** |

# Sessions

– Invited Talks –

## SYFU 1: Symposium Future

Time: Wednesday 14:00–15:30 Location: Geb. 30.95: Audimax

**Invited Talk** SYFU 1.1 Wed 14:00 Geb. 30.95: Audimax

**Future in Collisions – The need for an $e^+e^-$ Higgs Factory** — •Jürgen Reuter — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

The European Strategy Update for Particle Physics in 2020 and the corresponding US Particle Physics Prioritization Panel report 2023 as well as strategy processes in the Asian region have selected an $e^+e^-$ Higgs factory as the most important future project in collider physics. In this talk, the motivation and reasoning behind this decision will be laid out why ultrahigh precision measurements of the most unique particle in the cosmos, the Higgs boson, as well as the top quark and the weak gauge bosons chart the path for our deeper understanding of the microcosm (and hence the structure of the universe) in the best possible way. Most of what we take for granted from textbooks needs experimental testing: the flavor structure of particle physics, the mass generation of all fermion generations and the microscopic origin of electroweak symmetry breaking.

**Invited Talk** SYFU 1.2 Wed 14:30 Geb. 30.95: Audimax

**Exploring the Gravitational Wave Universe with the Einstein Telescope and LISA** — •Katharina-Sophie Isleif[1], the ET Collaboration[2], the LISA Consortium[3], and the LVK Collaboration[4] — [1]Helmut Schmidt University, Hamburg, Germany — [2]https://www.et-gw.eu — [3]https://www.elisascience.org — [4]https://www.ligo.org

The detection of gravitational waves has started a new era in astronomy and our understanding of the universe. Since the first detection in 2015, the ground-based detectors LIGO and Virgo have captured more than 100 gravitational wave signals from merging black holes and neutron stars within the audible frequency range. This talk will delve into the next phase in gravitational wave astronomy, focusing on expanding into the low-frequency domain inaccessible with current detectors. We will examine the opportunities afforded by next-generation detectors like the Einstein Telescope, designed to observe gravitational wave signals below 10 Hz, and the space-based LISA mission, which aims to reach the millihertz range. We will discuss how low-frequency gravitational wave detectors unveil cosmic events that promise novel insights into our universe and how they can advance multi-messenger astronomy by acting as early-warning systems for astronomical events. Navigating this low-frequency frontier poses unique challenges for detector design on ground and in space. This talk will also provide a brief overview of some of the technological advancements being developed to mitigate unique noise sources, underlining their crucial role in the successful realization of low-frequency gravitational wave astronomy.

**Invited Talk** SYFU 1.3 Wed 15:00 Geb. 30.95: Audimax

**Sustainable Partnerships: Navigating the Environmental Challenges in Modern Particle and Astroparticle Physics** — •Michael Düren — JLU Giessen, Gießen, Germany

The climate crisis, combined with growing economic and geopolitical turbulence, presents a challenging global landscape for next-generation research projects. The imminent impact of geopolitical tensions on the field is exemplified by FAIR, a nuclear research facility primarily funded by Germany and Russia.

Immediate action is required at individual, research group, and institutional levels to reduce the carbon footprint of existing and future facilities. However, merely abstaining from contributing to global environmental issues is insufficient. Recognizing the interconnectedness of the scientific community and the pressing need for environmental stewardship, it is imperative to transition from being part of the problem to becoming part of the solution.

Leveraging our community's rich history of solving complex problems through sensor technologies, modelling, and global collaboration, there is an opportunity to apply this expertise to address global challenges. To achieve this, we propose forging partnerships with stakeholders in the socio-economic and ecological realm, establishing 1-to-1 collaborations that facilitate the exchange of knowledge, technologies, and international structures. Such partnerships can catalyse a sustainable societal transition, while preserving the invaluable expertise of our global community and attracting a new generation of young minds into our sphere.

# Particle Physics Division
# Fachverband Teilchenphysik (T)

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## Overview of Invited Talks and Sessions

### Plenary, Ceremonial, and Evening Talks

| | | | | |
|---|---|---|---|---|
| PV I | Mon | 14:00–14:45 | Geb. 30.95: Audimax | **Overview and perspectives in LHC physics** — •Marumi Kado |
| PV II | Tue | 11:00–11:45 | Geb. 30.95: Audimax | **Twenty years of ultra-high-energy cosmic-ray physics with the Pierre Auger Observatory** — •Ralph Engel |
| PV III | Tue | 19:30–20:30 | Geb. 30.95: Audimax | **Dem unsichtbaren Universum auf der Spur: Neutrinos und Dunkle Materie** — •Kathrin Valerius |
| PV IV | Wed | 11:00–13:00 | Geb. 30.95: Audimax | **Particle Physics Through the Ages: A Century of Discoveries and the Road Ahead** — •Beate Heinemann |
| PV V | Fri | 11:00–11:45 | Geb. 30.95: Audimax | **Highlights of Neutrino Physics** — •Susanne Mertens |

### Invited Overview Talks

| | | | | |
|---|---|---|---|---|
| T 1.1 | Mon | 14:45–15:15 | Geb. 30.95: Audimax | **Evidence for a gravitational-wave background at nanohertz frequencies** — •Kai Schmitz |
| T 24.1 | Tue | 9:00– 9:30 | Geb. 30.95: Audimax | **Latest results of the LHCb experiment** — •Dominik Stefan Mitzel |
| T 24.2 | Tue | 9:30–10:00 | Geb. 30.95: Audimax | **Belle II at the start of Run2 and physics highlights** — •Carsten Niebuhr |
| T 24.3 | Tue | 10:00–10:30 | Geb. 30.95: Audimax | **Overview of the ECFA Detector R&D Roadmap and status of the implementation of its recommendations** — •Susanne Kuehn |
| T 25.1 | Tue | 11:45–12:15 | Geb. 30.95: Audimax | **Extensive air shower simulations – successes and challenges** — •Tim Huege |
| T 25.2 | Tue | 12:15–12:45 | Geb. 30.95: Audimax | **The muon anomalous magnetic moment** — •Christoph Lehner |
| T 51.1 | Wed | 9:00– 9:30 | Geb. 30.95: Audimax | **The top quark: a precision probe and a window to new phenomena** — •Jan Kieseler |
| T 51.2 | Wed | 9:30–10:00 | Geb. 30.95: Audimax | **Fundamental tests of the Standard Model at ATLAS and CMS** — •Baptiste Ravina |
| T 51.3 | Wed | 10:00–10:30 | Geb. 30.95: Audimax | **Mastering challenges of High-Luminosity LHC data with innovative computing solutions** — •Michael Boehler |
| T 76.1 | Thu | 9:00– 9:30 | Geb. 30.95: Audimax | **Origin of heavy elements: r-process in neutron star mergers and core-collapse supernovae** — •Almudena Arcones |
| T 76.2 | Thu | 9:30–10:00 | Geb. 30.95: Audimax | **Radio Detection of Neutrinos** — •Anna Nelles |
| T 76.3 | Thu | 10:00–10:30 | Geb. 30.95: Audimax | **High precision gravitational wave physics from quantum field theory** — •Jan Plefka |
| T 127.1 | Fri | 11:45–12:15 | Geb. 30.95: Audimax | **Status and Highlights of Higgs Boson Measurements and Searches at the LHC** — •Marcel Rieger |
| T 127.2 | Fri | 12:15–12:45 | Geb. 30.95: Audimax | **Charting the unknown: results from recent searches for new phenomena at the LHC** — •Katharina Behr |

## Invited Topical Talks

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|---|---|---|---|---|
| T 26.1 | Tue | 14:00–14:30 | Geb. 30.21: Gerthsen-HS | **New physics searches through the Higgs and atomic windows** — •Elina Fuchs |
| T 26.2 | Tue | 14:30–15:00 | Geb. 30.21: Gerthsen-HS | **Study of electroweak interactions via vector boson scattering at the ATLAS detector** — •Gia Khoriauli |
| T 26.3 | Tue | 15:00–15:30 | Geb. 30.21: Gerthsen-HS | **AI-aided searches for new physics** — •Benedikt Maier |
| T 27.1 | Tue | 14:00–14:30 | Geb. 30.22: Gaede-HS | **Start up of Run 3 and performance of the upgraded LHCb experiment** — •Elena Dall'Occo |
| T 27.2 | Tue | 14:30–15:00 | Geb. 30.22: Gaede-HS | **Fully-inclusive measurement of $B^{0,\pm} \rightarrow XJ/\psi$ processes at Belle II** — •Sviatoslav Bilokin |
| T 27.3 | Tue | 15:00–15:30 | Geb. 30.22: Gaede-HS | **Probing Axion Dark Matter with Flavor Factories** — •Robert Ziegler |
| T 77.1 | Thu | 11:00–11:30 | Geb. 30.21: Gerthsen-HS | **Track reconstruction for the ATLAS Phase-II Event Filter using GNNs on FPGAs** — •Sebastian Dittmeier |
| T 77.2 | Thu | 11:30–12:00 | Geb. 30.21: Gerthsen-HS | **Searches for Long-Lived Particles at LHC** — •Lisa Benato |
| T 77.3 | Thu | 12:00–12:30 | Geb. 30.21: Gerthsen-HS | **Searches for long-lived particles at accelerators** — •Maksym Ovchynnikov |
| T 78.1 | Thu | 11:00–11:30 | Geb. 30.22: Gaede-HS | **Signatures of quantum gravity in neutrino telescopes** — •Alba Domi |
| T 78.2 | Thu | 11:30–12:00 | Geb. 30.22: Gaede-HS | **Development, characterization, and integration of the Silicon Drift Detector array TRISTAN for KATRIN** — •Frank Edzards |
| T 78.3 | Thu | 12:00–12:30 | Geb. 30.22: Gaede-HS | **New Chapter in Neutrino Physics with JUNO** — •Yury Malyshkin |
| T 79.1 | Thu | 14:00–14:30 | Geb. 30.21: Gerthsen-HS | **Construction, Commissioning, and Performance of the new ATLAS Level1-Trigger System for Run 3** — •Ralf Gugel |
| T 79.2 | Thu | 14:30–15:00 | Geb. 30.21: Gerthsen-HS | **Hadronic signals at the LHC: timing as a handle to face the challenges of higher luminosity** — •Margherita Spalla |
| T 79.3 | Thu | 15:00–15:30 | Geb. 30.21: Gerthsen-HS | **The LHCb Mighty Tracker - Getting ready for flavour physics at the HL-LHC** — •Klaas Padeken |
| T 80.1 | Thu | 14:00–14:30 | Geb. 30.22: Gaede-HS | **The advent of TeV gamma-ray astronomy with gamma-ray bursts** — •Alessio Berti |
| T 80.2 | Thu | 14:30–15:00 | Geb. 30.22: Gaede-HS | **Multi-messenger models of active galaxies: achievements and future directions** — •Xavier Rodrigues |
| T 80.3 | Thu | 15:00–15:30 | Geb. 30.22: Gaede-HS | **Acceleration and transport of relativistic electrons in the parsec-scale jets of the microquasar SS 433** — •Laura Olivera-Nieto |

## Invited Talks of the Symposium Future

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|---|---|---|---|---|
| SYFU 1.1 | Wed | 14:00–14:30 | Geb. 30.95: Audimax | **Future in Collisions – The need for an $e^+e^-$ Higgs Factory** — •Jürgen Reuter |
| SYFU 1.2 | Wed | 14:30–15:00 | Geb. 30.95: Audimax | **Exploring the Gravitational Wave Universe with the Einstein Telescope and LISA** — •Katharina-Sophie Isleif, the ET Collaboration, the LISA Consortium, the LVK Collaboration |
| SYFU 1.3 | Wed | 15:00–15:30 | Geb. 30.95: Audimax | **Sustainable Partnerships: Navigating the Environmental Challenges in Modern Particle and Astroparticle Physics** — •Michael Düren |

## Sessions

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|---|---|---|---|---|
| T 1.1–1.1 | Mon | 14:45–15:15 | Geb. 30.95: Audimax | **Invited Overview Talks 1** |
| T 2.1–2.8 | Mon | 16:00–18:00 | Geb. 20.30: 1.067 | **Search for new particles 1 (LHC)** |
| T 3.1–3.8 | Mon | 16:00–18:00 | Geb. 20.30: 2.058 | **Search for new particles 2** |
| T 4.1–4.8 | Mon | 16:00–18:00 | Geb. 20.30: 2.059 | **Cosmic rays 1** |
| T 5.1–5.7 | Mon | 16:00–17:45 | Geb. 20.30: 2.066 | **Methods in particle physics 1 (e/gamma, SciFi)** |
| T 6.1–6.8 | Mon | 16:00–18:00 | Geb. 20.30: 2.067 | **Methods in astroparticle physics 1** |
| T 7.1–7.8 | Mon | 16:00–18:00 | Geb. 30.21: Gerthsen-HS | **Neutrino physics 1** |
| T 8.1–8.8 | Mon | 16:00–18:00 | Geb. 30.22: Gaede-HS | **Neutrino physics 2** |
| T 9.1–9.8 | Mon | 16:00–18:00 | Geb. 30.22: Lehmann-HS | **Cosmic rays 2** |
| T 10.1–10.8 | Mon | 16:00–18:00 | Geb. 30.22: kl. HS A | **Gamma astronomy 1** |
| T 11.1–11.8 | Mon | 16:00–18:00 | Geb. 30.22: kl. HS B | **Silicon trackers 1** |
| T 12.1–12.7 | Mon | 16:00–17:45 | Geb. 30.23: 2/1 | **Detectors 1 (electronics)** |
| T 13.1–13.8 | Mon | 16:00–18:00 | Geb. 30.23: 2/17 | **Detectors 2 (scintillators, other)** |
| T 14.1–14.7 | Mon | 16:00–17:45 | Geb. 30.23: 3/1 | **Detectors 3 (muon detectors)** |
| T 15.1–15.8 | Mon | 16:00–18:00 | Geb. 30.23: 6/1 | **Neutrino astronomy 1** |

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|---|---|---|---|---|
| T 16.1–16.8 | Mon | 16:00–18:00 | Geb. 30.33: MTI | **Data, AI, Computing 1 (anomaly detection)** |
| T 17.1–17.8 | Mon | 16:00–18:00 | Geb. 30.34: LTI | **Data, AI, Computing 2 (analysis tools)** |
| T 18.1–18.7 | Mon | 16:00–17:45 | Geb. 30.35: HSI | **Search for Dark Matter 1** |
| T 19.1–19.8 | Mon | 16:00–18:00 | Geb. 30.41: HS 1 | **Methods in particle physics 2 (alignment, luminosity)** |
| T 20.1–20.7 | Mon | 16:00–17:45 | Geb. 30.41: HS 2 | **Higgs 1 (boson final states)** |
| T 21.1–21.8 | Mon | 16:00–18:00 | Geb. 30.41: HS 3 | **BSM Higgs 1 (extended Higgs sectors)** |
| T 22.1–22.8 | Mon | 16:00–18:00 | Geb. 30.41: HS 4 | **Flavour physics 1** |
| T 23.1–23.9 | Mon | 16:00–18:15 | Geb. 30.95: Audimax | **Top physics 1** |
| T 24.1–24.3 | Tue | 9:00–10:30 | Geb. 30.95: Audimax | **Invited Overview Talks 2** |
| T 25.1–25.2 | Tue | 11:45–12:45 | Geb. 30.95: Audimax | **Invited Overview Talks 3** |
| T 26.1–26.3 | Tue | 14:00–15:30 | Geb. 30.21: Gerthsen-HS | **Invited Topical Talks 1** |
| T 27.1–27.3 | Tue | 14:00–15:30 | Geb. 30.22: Gaede-HS | **Invited Topical Talks 2** |
| T 28.1–28.8 | Tue | 16:00–18:00 | Geb. 20.30: 1.067 | **Search for new particles 3 (ALPS)** |
| T 29.1–29.8 | Tue | 16:00–18:00 | Geb. 20.30: 2.058 | **Neutrino physics 3** |
| T 30.1–30.7 | Tue | 16:00–17:45 | Geb. 20.30: 2.059 | **Cosmic rays 3** |
| T 31.1–31.8 | Tue | 16:00–18:00 | Geb. 20.30: 2.066 | **Methods in particle physics 3 (lepton reconstruction)** |
| T 32.1–32.8 | Tue | 16:00–18:00 | Geb. 20.30: 2.067 | **Methods in astroparticle physics 2** |
| T 33.1–33.8 | Tue | 16:00–18:00 | Geb. 30.21: Gerthsen-HS | **Neutrino physics 4** |
| T 34.1–34.8 | Tue | 16:00–18:00 | Geb. 30.22: Gaede-HS | **Neutrino physics 5** |
| T 35.1–35.8 | Tue | 16:00–18:00 | Geb. 30.22: Lehmann-HS | **Cosmic rays 4** |
| T 36.1–36.8 | Tue | 16:00–18:00 | Geb. 30.22: kl. HS A | **Gamma astronomy 2** |
| T 37.1–37.8 | Tue | 16:00–18:00 | Geb. 30.22: kl. HS B | **Silicon trackers 2** |
| T 38.1–38.8 | Tue | 16:00–18:00 | Geb. 30.23: 2/0 | **Standard model 1 (electroweak/bosons)** |
| T 39.1–39.8 | Tue | 16:00–18:00 | Geb. 30.23: 2/1 | **Detectors 4 (calorimeters)** |
| T 40.1–40.8 | Tue | 16:00–18:00 | Geb. 30.23: 2/17 | **Detectors 5 (scintillators)** |
| T 41.1–41.8 | Tue | 16:00–18:00 | Geb. 30.23: 3/1 | **Trigger+DAQ 1** |
| T 42.1–42.8 | Tue | 16:00–18:00 | Geb. 30.23: 6/1 | **Neutrino astronomy 2** |
| T 43.1–43.9 | Tue | 16:00–18:15 | Geb. 30.33: MTI | **Data, AI, Computing 3 (pointclouds & graphs)** |
| T 44.1–44.8 | Tue | 16:00–18:00 | Geb. 30.34: LTI | **Data, AI, Computing 4 (workflow)** |
| T 45.1–45.8 | Tue | 16:00–18:00 | Geb. 30.35: HSI | **Search for Dark Matter 2** |
| T 46.1–46.8 | Tue | 16:00–18:00 | Geb. 30.41: HS 1 | **Di-Higgs 1 (bb$\tau\tau$)** |
| T 47.1–47.8 | Tue | 16:00–18:00 | Geb. 30.41: HS 2 | **Higgs 2 (ttH & tH production)** |
| T 48.1–48.7 | Tue | 16:00–17:45 | Geb. 30.41: HS 3 | **BSM Higgs 2 (extended Higgs sectors)** |
| T 49.1–49.9 | Tue | 16:00–18:15 | Geb. 30.41: HS 4 | **Flavour physics 2** |
| T 50.1–50.9 | Tue | 16:00–18:15 | Geb. 30.95: Audimax | **Top physics 2 (top pair cross section)** |
| T 51.1–51.3 | Wed | 9:00–10:30 | Geb. 30.95: Audimax | **Invited Overview Talks 4** |
| T 52.1–52.8 | Wed | 16:00–18:00 | Geb. 20.30: 1.067 | **Search for new particles 4 (leptoquarks, LHC)** |
| T 53.1–53.8 | Wed | 16:00–18:00 | Geb. 20.30: 2.058 | **Neutrino physics 6** |
| T 54.1–54.8 | Wed | 16:00–18:00 | Geb. 20.30: 2.059 | **Cosmic rays 5** |
| T 55.1–55.7 | Wed | 16:00–17:45 | Geb. 20.30: 2.066 | **Methods in particle physics 4 (HCAL, jets)** |
| T 56.1–56.8 | Wed | 16:00–18:00 | Geb. 20.30: 2.067 | **Methods in astroparticle physics 3** |
| T 57.1–57.8 | Wed | 16:00–18:00 | Geb. 30.21: Gerthsen-HS | **Neutrino physics 7** |
| T 58.1–58.8 | Wed | 16:00–18:00 | Geb. 30.22: Gaede-HS | **Neutrino physics 8** |
| T 59.1–59.5 | Wed | 16:00–17:15 | Geb. 30.22: Lehmann-HS | **Outreach 1** |
| T 60.1–60.8 | Wed | 16:00–18:00 | Geb. 30.22: kl. HS A | **Gamma astronomy 3** |
| T 61.1–61.8 | Wed | 16:00–18:00 | Geb. 30.22: kl. HS B | **Silicon trackers 3** |
| T 62.1–62.8 | Wed | 16:00–18:00 | Geb. 30.23: 2/0 | **Standard model 2 (electroweak/bosons)** |
| T 63.1–63.7 | Wed | 16:00–17:45 | Geb. 30.23: 2/1 | **Detectors 6 (calorimeters)** |
| T 64.1–64.7 | Wed | 16:00–17:45 | Geb. 30.23: 2/17 | **Detectors 7 (gas detectors)** |
| T 65.1–65.8 | Wed | 16:00–18:00 | Geb. 30.23: 3/1 | **Trigger+DAQ 2** |
| T 66.1–66.8 | Wed | 16:00–18:00 | Geb. 30.23: 6/1 | **Neutrino astronomy 3** |
| T 67.1–67.7 | Wed | 16:00–17:45 | Geb. 30.33: MTI | **Data, AI, Computing 5 (normalising flows)** |
| T 68.1–68.8 | Wed | 16:00–18:00 | Geb. 30.34: LTI | **Data, AI, Computing 6 (ML utilities)** |
| T 69.1–69.7 | Wed | 16:00–17:45 | Geb. 30.35: HSI | **Search for Dark Matter 3** |
| T 70.1–70.7 | Wed | 16:00–17:45 | Geb. 30.41: HS 1 | **Di-Higgs 2 (4b & other)** |
| T 71.1–71.8 | Wed | 16:00–18:00 | Geb. 30.41: HS 2 | **Higgs 3 (coupling to b and c quarks)** |
| T 72.1–72.7 | Wed | 16:00–17:45 | Geb. 30.41: HS 3 | **BSM Higgs 3 (extended Higgs sectors)** |
| T 73.1–73.8 | Wed | 16:00–18:00 | Geb. 30.41: HS 4 | **Flavour physics 3** |
| T 74.1–74.7 | Wed | 16:00–17:45 | Geb. 30.95: Audimax | **Top physics 3 (single top)** |
| T 75.1–75.1 | Wed | 19:45–21:30 | Geb. 30.22: Gaede-HS | **Annual Meeting of Young Scientists in High Energy Physics (yHEP)** |
| T 76.1–76.3 | Thu | 9:00–10:30 | Geb. 30.95: Audimax | **Invited Overview Talks 5** |

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| T 77.1–77.3 | Thu | 11:00–12:30 | Geb. 30.21: Gerthsen-HS | **Invited Topical Talks 3** |
| T 78.1–78.3 | Thu | 11:00–12:30 | Geb. 30.22: Gaede-HS | **Invited Topical Talks 4** |
| T 79.1–79.3 | Thu | 14:00–15:30 | Geb. 30.21: Gerthsen-HS | **Invited Topical Talks 5** |
| T 80.1–80.3 | Thu | 14:00–15:30 | Geb. 30.22: Gaede-HS | **Invited Topical Talks 6** |
| T 81.1–81.7 | Thu | 16:00–17:45 | Geb. 20.30: 1.067 | **Search for new particles 5 (SUSY)** |
| T 82.1–82.8 | Thu | 16:00–18:00 | Geb. 20.30: 2.058 | **Neutrino physics 9** |
| T 83.1–83.9 | Thu | 16:00–18:15 | Geb. 20.30: 2.059 | **Cosmic rays 6** |
| T 84.1–84.8 | Thu | 16:00–18:00 | Geb. 20.30: 2.066 | **Methods in particle physics 5 (tagging)** |
| T 85.1–85.8 | Thu | 16:00–18:00 | Geb. 20.30: 2.067 | **Methods in astroparticle physics 4** |
| T 86.1–86.8 | Thu | 16:00–18:00 | Geb. 30.21: Gerthsen-HS | **Neutrino physics 10** |
| T 87.1–87.8 | Thu | 16:00–18:00 | Geb. 30.22: Gaede-HS | **Neutrino physics 11** |
| T 88.1–88.6 | Thu | 16:00–17:30 | Geb. 30.22: Lehmann-HS | **Outreach 2** |
| T 89.1–89.8 | Thu | 16:00–18:00 | Geb. 30.22: kl. HS A | **Gamma astronomy 4** |
| T 90.1–90.8 | Thu | 16:00–18:00 | Geb. 30.22: kl. HS B | **Silicon trackers 4** |
| T 91.1–91.8 | Thu | 16:00–18:00 | Geb. 30.23: 2/0 | **Standard model 3 (strong/QCD)** |
| T 92.1–92.7 | Thu | 16:00–17:45 | Geb. 30.23: 2/1 | **Detectors 8 (semiconductors)** |
| T 93.1–93.7 | Thu | 16:00–17:45 | Geb. 30.23: 2/17 | **Detectors 9 (gas detectors)** |
| T 94.1–94.7 | Thu | 16:00–17:45 | Geb. 30.23: 3/1 | **Trigger+DAQ 3** |
| T 95.1–95.8 | Thu | 16:00–18:00 | Geb. 30.23: 6/1 | **Gravitational waves 1** |
| T 96.1–96.9 | Thu | 16:00–18:15 | Geb. 30.33: MTI | **Data, AI, Computing 7 (uncertainties, likelihoods)** |
| T 97.1–97.8 | Thu | 16:00–18:00 | Geb. 30.34: LTI | **Future colliders** |
| T 98.1–98.6 | Thu | 16:00–17:30 | Geb. 30.35: HSI | **Search for Dark Matter 4** |
| T 99.1–99.6 | Thu | 16:00–17:30 | Geb. 30.41: HS 1 | **Di-Higgs 3 (bbWW)** |
| T 100.1–100.8 | Thu | 16:00–18:00 | Geb. 30.41: HS 2 | **Higgs 4 (coupling to taus, CP, rare decays)** |
| T 101.1–101.8 | Thu | 16:00–18:00 | Geb. 30.41: HS 3 | **BSM Higgs 4** |
| T 102.1–102.8 | Thu | 16:00–18:00 | Geb. 30.41: HS 4 | **Flavour physics 4** |
| T 103.1–103.8 | Thu | 16:00–18:00 | Geb. 30.95: Audimax | **Top physics 4 (tt+X)** |
| T 104 | Thu | 19:00–20:00 | Geb. 30.22: Lehmann-HS | **Members' Assembly** |
| T 105.1–105.6 | Fri | 9:00–10:30 | Geb. 20.30: 1.067 | **Search for new particles 6** |
| T 106.1–106.5 | Fri | 9:00–10:15 | Geb. 20.30: 2.058 | **Search for new particles 7** |
| T 107.1–107.6 | Fri | 9:00–10:30 | Geb. 20.30: 2.059 | **Cosmic rays 7** |
| T 108.1–108.6 | Fri | 9:00–10:30 | Geb. 20.30: 2.066 | **Methods in particle physics 6** |
| T 109.1–109.6 | Fri | 9:00–10:30 | Geb. 30.21: Gerthsen-HS | **Neutrino physics 12** |
| T 110.1–110.6 | Fri | 9:00–10:30 | Geb. 30.22: Gaede-HS | **Search for Dark Matter 5** |
| T 111.1–111.6 | Fri | 9:00–10:30 | Geb. 30.22: Lehmann-HS | **Outreach 3** |
| T 112.1–112.6 | Fri | 9:00–10:30 | Geb. 30.22: kl. HS A | **Silicon trackers 5** |
| T 113.1–113.6 | Fri | 9:00–10:30 | Geb. 30.22: kl. HS B | **Silicon trackers 6** |
| T 114.1–114.6 | Fri | 9:00–10:30 | Geb. 30.23: 2/0 | **Standard model 4 (strong/QCD)** |
| T 115.1–115.6 | Fri | 9:00–10:30 | Geb. 30.23: 2/1 | **Detectors 10 (semiconductors)** |
| T 116.1–116.6 | Fri | 9:00–10:30 | Geb. 30.23: 2/17 | **Detectors 11 (gas detectors)** |
| T 117.1–117.6 | Fri | 9:00–10:30 | Geb. 30.23: 3/1 | **Trigger+DAQ 4** |
| T 118.1–118.4 | Fri | 9:00–10:00 | Geb. 30.23: 6/1 | **Gravitational waves 2** |
| T 119.1–119.5 | Fri | 9:00–10:15 | Geb. 30.33: MTI | **Data, AI, Computing 8 (foundational & transformer models)** |
| T 120.1–120.6 | Fri | 9:00–10:30 | Geb. 30.34: LTI | **Data, AI, Computing 9 (generative models & simulation)** |
| T 121.1–121.6 | Fri | 9:00–10:30 | Geb. 30.35: HSI | **Search for Dark Matter 6** |
| T 122.1–122.5 | Fri | 9:00–10:15 | Geb. 30.41: HS 1 | **Miscellaneous** |
| T 123.1–123.6 | Fri | 9:00–10:30 | Geb. 30.41: HS 2 | **Flavour physics 5** |
| T 124.1–124.5 | Fri | 9:00–10:15 | Geb. 30.41: HS 3 | **BSM Higgs 5 (charged Higgs bosons)** |
| T 125.1–125.6 | Fri | 9:00–10:30 | Geb. 30.41: HS 4 | **Flavour physics 6** |
| T 126.1–126.5 | Fri | 9:00–10:15 | Geb. 30.95: Audimax | **Top physics 5 (top mass)** |
| T 127.1–127.2 | Fri | 11:45–12:45 | Geb. 30.95: Audimax | **Invited Overview Talks 6** |

## Members' Assembly of the Particle Physics Division

Thursday 19:00–20:00 Geb. 30.22: Lehmann-HS

# Sessions

– Invited Overview, Invited Topical, and Contributed Talks –

## T 1: Invited Overview Talks 1

Time: Monday 14:45–15:15 Location: Geb. 30.95: Audimax

**Invited Overview Talk** T 1.1 Mon 14:45 Geb. 30.95: Audimax

**Evidence for a gravitational-wave background at nanohertz frequencies** — •Kai Schmitz — University of Münster, Münster, Germany

Pulsar timing arrays (PTAs) are gravitational-wave (GW) detectors of galactic dimensions that search for GWs with light-year wavelength washing through the Milky Way by monitoring arrays of pulsars, highly magnetized fast-spinning neutron stars that act like cosmic lighthouses, over time spans of years and decades. In this overview talk, I will review the 2023 results from PTA collaborations around the globe, which point to the existence of a GW background (GWB) hum permeating our Universe. Indeed, the tell-tale sign of a stochastic GWB signal is a characteristic cross-correlation pattern in the timing data for pairs of pulsars, the so-called Hellings-Downs curve, which is now seen for the first time at different levels of statistical significance in the latest PTA data sets. I will discuss the most likely explanation of this signal, namely, a cosmic population of inspiraling supermassive black-holes binaries at the centers of galaxies, but also highlight exotic sources powered by new particle physics in the early Universe, such as cosmic inflation, phase transitions, and cosmic strings. Finally, I will conclude with a brief outlook on the future of the field, in particular, upcoming measurements that may help in discriminating between a GWB signal of astrophysical origin and a GWB signal from the Big Bang.

## T 2: Search for new particles 1 (LHC)

Time: Monday 16:00–18:00 Location: Geb. 20.30: 1.067

T 2.1 Mon 16:00 Geb. 20.30: 1.067

**Exploring new physics at LHC with Model Unspecific Search in CMS** — Thomas Hebbeker, Yannik Kaiser, Lucas Karwatzki, •Chinmay Seth, and Felipe Torres Da Silva De Araujo — RWTH Aachen University

The Standard Model of Particle Physics, while highly successful, has limitations and fails to provide a comprehensive description of fundamental particles. Beyond Standard Model theories explore alternative explanations for these shortcomings.

The Large Hadron Collider provides access to unprecedented energy for proton-proton collision experiments, generating data to explore theories beyond the Standard Model. Model Unspecific Search in CMS (MUSiC) is one such effort where a model-independent approach is used to look for regions of possible discrepancies between observations from the CMS detector and a statistical model based on a theoretical understanding of the standard model.

MUSiC classifies events into 'event classes' based on the multiplicity of specific physics objects. Kinematic distributions for these classes are generated using three key event variables. The algorithm calculates a p-value, considering systematic and statistical effects, and identifies regions in distributions that deviate from the statistical model. Applying further statistical corrections yields a final value, highlighting the most deviating event classes. If the corrected p-value surpasses a set threshold, it signifies a potential window to new physics in that corresponding region. We discuss the concept of MUSiC, its scope, and challenges in this talk.

T 2.2 Mon 16:15 Geb. 20.30: 1.067

**A new global approach to the Model Unspecific Search in CMS** — Thomas Hebbeker, Yannik Kaiser, •Lucas Karwatzki, Arnd Meyer, Chinmay Seth, and Felipe Torres da Silva de Araujo — III. Physikalisches Institut A, RWTH Aachen University.

Model independent searches are an essential alternative to more specific searches, as new physics may manifest itself in ways that have not been predicted yet. The "Model Unspecific Search in CMS" (MUSiC) is a general approach to the search for new physics. Here, CMS data and Monte-Carlo simulations of the Standard Model are first systematically categorised into classes and then the deviations are quantified. MUSiC is based on a hybrid Bayesian-frequentist approach in which an algorithm finds the region of interest (ROI) where the deviation is evaluated by a given statistical test, taking into account the Look Elsewhere Effect.

Here we present a study on a global search algorithm, based on the Jensen-Shannon-Distance as a complementary MUSiC statistical test. This approach has the advantage of a reduced calculation time and because of the global nature, no ROI scan is performed. The method reduces the complexity of the algorithm in the number of histogram bins from $\mathcal{O}(n^2)$ to $\mathcal{O}(n)$.

We discuss initial results based on Monte-Carlo simulations of the Standard Model as well as possible new physics signals, while using MUSiC as a benchmark.

T 2.3 Mon 16:30 Geb. 20.30: 1.067

**Searching for new physics in dijets using anomaly detection** — •Manuel Sommerhalder, Tobias Quadfasel, Louis Moureaux, and Gregor Kasieczka — Institut für Experimentalphysik, Universität Hamburg

Despite compelling experimental and theoretical motivation as well as extensive new physics searches at the Large Hadron Collider, there have been no discoveries of physics beyond the standard model (BSM) to date. A potential reason for this might be that the common search strategy relies on selecting BSM signal candidate events based on specific signal and background models. Such a dedicated search cannot be performed for every possible BSM theory and phase space region. And even if this was computationally feasible, it would still lack sensitivity to unthought-of models. Thus, model-independent anomaly detection methods are an important addition to the existing search paradigm. These algorithms aim to select signal candidates in a data-driven manner based on anomalous phase space signatures.

One such anomaly detection method is CATHODE. It detects resonant signal peaks by combining neural density estimation in a sideband region with a weakly supervised classification task of distinguishing real data from an in-situ simulation of the background. We present the first application of CATHODE in a search for BSM physics in the CMS experiment targeting a dijet final state.

T 2.4 Mon 16:45 Geb. 20.30: 1.067

**Searching for dijet resonances with the ATLAS trigger** — •Falk Bartels — Kirchhoff-Institut für Physik, Heidelberg

The search for sub-TeV dijet resonances at the LHC is statistically limited due to the reduced readout rate of lower $p_{\mathrm{T}}$ jet triggers. The ATLAS trigger-level analysis covers this part of the spectrum by recording a strongly reduced set of event-level information processed by the High Level Trigger for all events passing the seeding Level-1 trigger. This allows for lowering the minimal detectable dijet resonance mass from above 1 TeV to around 400 GeV.

With more than 1 billion events in the recorded dijet mass spectrum, an exceptional statistical precision can be achieved. This level of precision is required for all steps of the analysis to achieve a high sensitivity for Physics beyond the Standard Model. The analysis is presented with special emphasis on the custom trigger-level jet calibration and the newly implemented fitting strategy to estimate the QCD background.

T 2.5 Mon 17:00 Geb. 20.30: 1.067

**Search for top-antitop quark resonances in the lepton+jets final state with the CMS detector** — Johannes Haller[1], Roman Kogler[2], •Johanna Matthiesen[1], and Daniel Savoiu[2] — [1]Institut für Experimentalphysik, Universität Hamburg — [2]Desy, Hamburg

A search for new physics effects in the top-antitop quark mass spectrum in data of the CMS experiment is presented. Heavy resonances decaying into a top-antitop quark pair and then decaying into a lepton and jets are considered. As a preparation for the analysis of the Run 3 data, an existing analysis is reproduced, using a new columnar-based analysis framework `columnflow`. As a proof of principle and base for the upcoming Run 3 analysis, corrections, event selection, reconstruction of the mass of the top-antitop quark pair, a machine learning-based approach for process classification, and a statistical inference model are implemented and improved. Furthermore, expected limits are derived.

T 2.6 Mon 17:15 Geb. 20.30: 1.067

**Search for new phenomena with top-quark pairs using 140 fb$^{-1}$ of data at $\sqrt{s}$ = 13 TeV with the ATLAS detector** — •Simran Gurdasani, Daniele Zanzi, and Christian Weiser — Albert-Ludwigs-Universitaet Freiburg, Germany

This presentation will highlight the latest search for Beyond Standard Model (BSM) phenomena within the $t\bar{t}$+$E_T^{\text{miss}}$ 1-lepton (1L) final state within the ATLAS experiment. Utilizing proton-proton collision data from LHC Run-2 at $\sqrt{s}$ = 13TeV with 140 fb$^{-1}$ of data, Dark Matter (DM) production via scalar/pseudo-scalar mediators and SUSY stop pair production are explored. The improved approach is heavily inspired by Machine Learning techniques using Neural Nets (NN) to first reconstruct hadronically decaying top quarks and then discern signal events from background. Across various kinematic spaces, signal presence is inferred by template fitting the NN output distributions. Furthermore, the improved 1L results are combined with previously published 0L and 2L results for the $t\bar{t}$+$E_T^{\text{miss}}$ final state yielding the best limits on stop pair production and DM production via scalar/pseudo-scalar mediators for the ATLAS Run-2 dataset. Additionally, a first time ever interpretation is performed in the context of a search for effective vector contact interactions between top quarks and all three generations of left-handed neutrinos (tt$\nu\nu$).

T 2.7 Mon 17:30 Geb. 20.30: 1.067

**Search for excited leptons in the contact interaction and Z decay channels with CMS** — •Fabian Nowotny, Kerstin Hoepfner, and Thomas Hebbeker — III. Physikalisches Institut A, RWTH Aachen University

The Standard Model of particle physics does not provide a comprehensive explanation for the observed hierarchy of three generations of fermions, for both leptons and quarks. A possible explanation is delivered by models postulating that quarks and leptons themselves are composite objects. Their constituents are bound by an asymptotically free gauge interaction below a characteristic scale Λ. Such models of compositeness predict the existence of excited lepton (l$^*$) and excited quark (q$^*$) states at the characteristic scale Λ of the new binding interaction. The theory allows the production of excited leptons via contact interactions in conjunction with a Standard Model lepton. Subsequently the excited leptons can decay into several final states.

This talk focuses on the contact interaction and Z-boson decay channels, both resulting in $l^* \to lq\bar{q}$ transitions where $l$ represents $e$ and $\mu$. Preliminary results are presented on the Run 2 proton-proton dataset of CMS corresponding to a luminosity of 137.6 fb$^{-1}$ at a center of mass energy of $\sqrt{s}$ = 13 TeV.

T 2.8 Mon 17:45 Geb. 20.30: 1.067

**Search for high-mass resonances in dilepton final states with associated $b$-jets at the ATLAS experiment** — Frank Ellinghaus and •Anna Vorländer — Bergische Universität Wuppertal

A search for the $Z'$ boson in high-mass dilepton (ee,$\mu\mu$) final states with associated $b$-jets is presented. The considered $Z'$ model is a candidate explanation for potential anomalies in $B$ hadron decays and couples to $b$ and $s$ quarks in the production. The search is carried out using the dataset collected by the ATLAS detector in Run-2 of the LHC corresponding to an integrated luminosity of 140 fb$^{-1}$. Control, signal and validation regions are defined, and these regions are fitted in a profile-likelihood fit. Expected exclusion limits on the $Z'$ mass are obtained based on the results of the fit.

# T 3: Search for new particles 2

Time: Monday 16:00–18:00 Location: Geb. 20.30: 2.058

T 3.1 Mon 16:00 Geb. 20.30: 2.058

**Feebly Interacting Particles in Numerous Instances Simulated and Tabulated** — •Jonathan Schubert[1,2], Babette Döbrich[2], Jan Jerhot[2], and Tommaso Spadaro[3] — [1]Technical University of Munich; TUM School of Natural Sciences, Department of Physics, Garching, Germany — [2]Max Planck Institut for physics, Garching, Germany — [3]Istituto Nazionale di Fisica Nucleare; Laboratori Nazionali di Frascati, Frascati, Italy

Feebly interacting particles are a commonly considered extension to the Standard Model of Particle Physics. In many theoretical frameworks these particles can explain observed physical phenomena which are at tension with the current model. Beam dump facilities are a natural experimental setup for direct searches of Feebly Interacting Particles. The high intensities and low expected backgrounds provide great parameter reach for searches of decays back into standard model particles. ALPINIST is a simplified Montecarlo framework aimed at evaluating past and future experiments for their sensitivities to different models of Axion Like Particles. We present the extension of this framework to accommodate new classes of Feebly Interacting Particles with emphasis on Heavy Neutral Leptons. This extension is especially well motivated, solving multiple of the standing issues with the Standard Model at the same time. The fundamental importance of inputs on the resulting parameter sensitivity, and thus the need for a unified simulation setup, is highlighted.

T 3.2 Mon 16:15 Geb. 20.30: 2.058

**Search for the $K^+ \to \pi^+\pi^0 A$ decay** — •Marco Ceoletta — Johannes Gutenberg University Mainz

This search aims to provide a new state-of-the art estimation for the branching ratio (BR) of the ultra-rare $K^+ \to \pi^+\pi^0 A$ decay, where $A$ is Feebly-Interacting Particle (FIP) like an Axion-like particle, at the NA62 experiment (CERN). Obtaining a stringent upper limit on BR($K^+ \to \pi^+\pi^0 A$) is important for the verification of BSM theories; in particular the BR is sensitive to axial-vector coupling of hypothetical pseudoscalar particles to quarks. A search on $K^+ \to \pi^+\pi^0 A$ will therefore complement the extensive work already performed on the associated two-body decay $K^+ \to \pi^+ A$, that is sensitive only to the polar-vector coupling current. A preliminary estimation of the BR, as part of a feasibility study done in 2022, already outperformed the best previous limit by two orders of magnitude using less than 20% of the available data. The NA62 search is based on a Monte Carlo event generator exploiting a full differential rate model of the channel. The processing relies on the tried and tested NA62 analysis framework.

T 3.3 Mon 16:30 Geb. 20.30: 2.058

**BDF/SHiP @CERN: Search for Hidden Particles at a Future Beam Dump Facility** — •Annika Hollnagel for the SHiP-Collaboration — JGU Mainz (DE)

In conjunction with the CERN North Area Consolidation, an upgrade of the existing ECN3 experimental hall will enable a diverse physics program at the CERN SPS, complementing research at the energy frontier. At a dedicated Beam Dump Facility (BDF), the Search for Hidden Particles (SHiP) experiment has been proposed to exploit the full potential of the 400 GeV proton beam, covering a wide range of the Hidden Sector while also offering a rich neutrino physics program.

In line with the European Strategy for Particle Physics, BDF/SHiP has been identified as a frontrunner proposal by the CERN Physics Beyond Colliders (PBC) initiative. With the final CERN Research Board decision being imminent, this is the ideal time for new groups to join the project.

This talk will give an overview of the detector technologies and physics capabilities of the proposed experiment.

T 3.4 Mon 16:45 Geb. 20.30: 2.058

**Searches for BSM physics at a gamma-gamma collider with Energy < 12 GeV based on European XFEL** — •Marten Berger[1], Gudrid Moortgat-Pick[1,2], and Monika Alexandra Wüst[1] — [1]Universität Hamburg, Hamburg, Germany — [2]DESY, Hamburg, Germany

The possibility of a GammaGamma collider extension to the Beam dump of the 17.5 GeV European XFEL has been discussed before as a first high energy collider of its sort. It would not just be to study the concept of a gamma-gamma collider but this collider would also be without competition in the region of 5 – 12 GeV for gamma-gamma collision. In this range $bb$ and $cc$ resonances, tetraquarks as well as mesonic molecules can be observed. Furthermore some BSM processes can also be reached in this range. In this talk we want to discuss the possibility of observing ALPs at this collider as well as an extension to a mixed model of ALPs and dark photon (dark axion portal), that introduces the new couplings not as a product of the individual couplings and therefore offers a rich phenomenology.

T 3.5 Mon 17:00 Geb. 20.30: 2.058

**Signatures of strongly interacting dark sectors** — •Nicoline Hemme and Felix Kahlhoefer — Institute for Theoretical Particle Physics (TTP), Karlsruhe Institute of Technology (KIT), Germany

The nature of dark matter continues to be one of the biggest unanswered questions in physics, and many years of null results from experiments looking for the postulated weakly interacting massive particle (WIMP) has sparked interest in other dark matter theories with new and unexplored signatures. One such example is the strongly interacting massive particle (SIMP), which is a composite dark matter particle made up of quark-like dark particles that interact via gluon-like mediators. In analogy to the Standard Model (SM), the dark pseudo-scalar meson, $\pi_D$, is the lightest composite particle. It can be stabilised in the theory, thereby making it the dark matter candidate. The dark vector meson, $\rho_D$, can mix with SM particles, and if the mass of the $\rho_D$ does not exceed twice the mass of the $\pi_D$, as is favored by cosmological and astrophysical arguments, the $\rho_D$ will decay into SM final states. The decays can lead to novel signatures in particle colliders such as the LHC and future beam-dump experiments. In this talk, I will present the model along with the arguments for the light $\rho_D$ case and discuss some of these exciting signatures such as semi-visible jets and displaced vertices.

T 3.6 Mon 17:15 Geb. 20.30: 2.058

**Search for Inelastic Dark Matter with a Dark Higgs at Belle II** — •Patrick Ecker, Giacomo De Pietro, Jonas Eppelt, Torben Ferber, and Pablo Goldenzweig — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Belle II has a unique reach for a broad class of models that postulate the existence of Dark Matter particles in the MeV-GeV mass range. One highly motivated scenario is a model which involves inelastic Dark Matter, consisting of two Dark Matter states with a mass splitting between them, and the presence of a Dark Higgs boson. This model has a signature of up to two displaced vertices, one from the resonant decay of the Dark Higgs and another non-resonant one emerging from the decay of the involved Dark Matter particles. This talk will demonstrate the reach of the search for such signatures, which is not only challenging due to the presence of displaced vertices but also because of the seven-dimensional parameter space of the model.

T 3.7 Mon 17:30 Geb. 20.30: 2.058

**Exploring dark sector physics at a high energy photon-photon collider** — •Monika Wüst, Marten Berger, and Gudrid Moortgat-Pick — Universität Hamburg, Hamburg, Germany

We study the prospects of a future high energy gamma-gamma collider to probe dark sector models. The existence of a dark sector can be explored through different portal interactions, known portals include couplings of SM particles to dark photon, dark Higgs and Axion-Like-Particles (ALPs). We consider combined scenarios such as the Dark-Axion-Portal, where both the dark photon ($\gamma'$) and ALP coexist in the hidden sector, given rise to a rich phenemology.

Probing these models with a gamma-gamma collider via processes such as photon fusion to ALPs is investigated, where the high energy photons can be generated using backward Compton scattering of laser photons off high-energy electron beams.

T 3.8 Mon 17:45 Geb. 20.30: 2.058

**Renormalization of the Dark Abelian Sector Model** — Stefan Dittmaier[1], •Jonas Rehberg[1], and Heidi Rzehak[2] — [1]Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [2]Institute for Theoretical Physics, University of Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

The Dark Abelian Sector Model (DASM) extends the SM by a rather generic dark sector with an additional $U(1)_\mathrm{d}$ gauge symmetry. In detail, this dark sector contains a complex Higgs field and a Dirac fermion, which only carry the charge of the additional $U(1)_\mathrm{d}$, as well as right-handed neutrinos. Using the only two feasible SM operators—the SM Higgs mass operator and the field-strength tensor of the $U(1)_\mathrm{Y}$ of electroweak hypercharge—and the right-handed neutrino fields, allows us to open three portals of the SM, which is a singlet with respect to the $U(1)_\mathrm{d}$, to the dark sector of the DASM.

After a brief introduction of the model, we present the renormalization of the DASM at NLO with a special emphasis on the mixing angles of the model. Finally, we conclude by presenting the W-boson mass prediction derived from muon decay in the DASM at NLO as a first step towards confronting the model with experimental data.

# T 4: Cosmic rays 1

Time: Monday 16:00–18:00 Location: Geb. 20.30: 2.059

T 4.1 Mon 16:00 Geb. 20.30: 2.059

**Investigations of Photon-Hadron Separation at the Pierre Auger Observatory using Monte Carlo Simulations** — •Fiona Ellwanger for the Pierre-Auger-Collaboration — Karlsruhe Institut für Technologie, Karlsruhe, Germany

Cosmic ray detectors like the 3000 km$^2$ surface array of the Pierre Auger Observatory are capable of observing high-energy photons in the range of $10^{18}$ to $10^{20}$ eV if the flux is sufficiently high. Since the mean free path of the photons increases with energy in the ultra-high energy range, extragalactic sources can be probed up to distances of few Mpc. However, no clear candidates for ultra-high energy photons have been identified yet, so simulations must be used to study typical trigger patterns and observables for discriminating photons from hadrons.

Neural networks show promise of improved discriminating variables but require the training data to be very well understood. In contrast to hadron showers, photon-induced showers are expected to penetrate deeper in the atmosphere and have a steeper lateral distribution function, since the secondary particles almost exclusively belong to the electromagnetic component. Therefore, a number of elements in the the existing simulation and reconstruction chain, which has been developed and tuned for hadron-induced showers, need to be revisited for the case of ultra-high energy photons. In this contribution, we examine the parameters used to define how particle thinning in Corsika shower simulations is done and discuss implications for classical and machine learning based shower reconstruction algorithms.

T 4.2 Mon 16:15 Geb. 20.30: 2.059

**Gamma-Hadron Separation at the IceCube Neutrino Observatory** — •Federico Bontempo for the IceCube-Collaboration — KIT, Karlsruhe, Germany

The IceCube Neutrino Observatory is located at the geographic South Pole and composed of two detectors: the surface array, called IceTop, is made of ice-Cherenkov tanks, and the in-ice array made of optical detector modules deep in the ice. The two detectors can be combined for the study of cosmic rays. This work will primarily focus on low energy air-showers. It will use the IceTop response, mainly dominated by the electromagnetic component of cosmic-ray and gamma-ray air showers, for the reconstruction of the air-showers quantities, such as direction or energy. The in-ice array is used to ensure the presence of high energy muons, produced primarily in hadronic air-shower. At PeV energies, only a small fraction of gamma-ray induced showers produce an in-ice signal, but almost all hadronic showers feature an in-ice muon signal. Thus, the in-ice array can be exploited for gamma-hadron separation and the search for primary astrophysical PeV photons.

T 4.3 Mon 16:30 Geb. 20.30: 2.059

**Estimation of cosmic ray mass by correlating muon signals extracted from surface detector stations of the Pierre Auger Observatory using neural networks** — •Steffen T. Hahn, Markus Roth, David Schmidt, and Darko Veberic for the Pierre-Auger-Collaboration — KIT IAP, Karlsruhe, Germany

To fully understand the acceleration and propagation physics of cosmic rays at the highest energies, it is necessary to have an accurate knowledge of their mass composition. However, since information on the mass and energy is degenerate and a direct measurement of the mass is impossible, obtaining information about the composition is non-trivial. One of the observables that break this degeneracy is the number of muons produced during the particle cascade induced by a cosmic ray interacting with the Earth's atmosphere.

The Pierre Auger Observatory is the largest cosmic ray detector on Earth. One of its central components is its surface detector array consisting of uniformly spaced hybrid detector stations. These stations measure time traces of particles produced in the shower cascade.

This contribution presents a method of estimating the number of muons from these signals using machine learning techniques. The signal trace from a single station and a fixed set of shower parameters are used as input of a neural network to infer the fraction of the signal that is due to muons. The fractions obtained from several stations can be spatially correlated to estimate the mass of the primary cosmic ray. Eventually, the estimated muon content of recorded air showers will be presented including a study of systematic uncertainties.

T 4.4 Mon 16:45 Geb. 20.30: 2.059

**Event-by-event reconstruction of air-shower events with IceCube using a two component lateral distribution function** — •Mark Weyrauch for the IceCube-Collaboration — Karlsruhe Institute of Technology (KIT), Institute for Astroparticle Physics (IAP),

The IceCube Neutrino Observatory, located at the geographic South Pole, consists of a surface detector comprised of ice-Cherenkov tanks, IceTop, and an optical in-ice array. This combination allows for coincident measurements of the low-energy ($\sim$ GeV) and high-energy ($\gtrsim$ 400 GeV) muon component in cosmic-ray air shower events. An event-by-event GeV muon estimator can constitute a useful tool for, amongst others, cosmic ray composition analyses and, in combination with the TeV muon component, strongly constrain hadronic interaction models. However, since IceTop does not feature dedicated muon detectors, an estimation of the GeV muon component on basis of individual air showers is challenging. One possibility for an event-by-event estimation of low-energy muons is given by the two component lateral distribution function (two component LDF), combining an analytical description for the electromagnetic and muon lateral distribution of the full detector signal.

T 4.5 Mon 17:00 Geb. 20.30: 2.059

**Sub-PeV Cosmic-Ray Measurements at IceCube** — •Julian Saffer for the IceCube-Collaboration — Institut für Experimentelle Teilchenphysik, Karlsruher Institut für Technologie (KIT)

The surface array of the IceCube Neutrino Observatory is able to record cosmic-ray induced air showers with a primary energy in the range from a few hundred TeV to EeV. Composition analyses at IceCube highly benefit from its multi-detector design. Combining the measurement of the electromagnetic shower component and low-energy muons at the surface with the response of the in-ice array to the associated high-energy muons improves the directional reconstruction accuracy and opens unique possibilities to extract the primary particle's mass. The analysis of air showers below PeV energies provides the potential to test the validity of hadronic interaction models at low energies but also requires special treatment in the event processing. In this talk, a new methodical approach to reconstruct the elemental composition of these low-energy air showers with a convolutional neural network is presented. The achieved performance in primary mass discrimination and energy reconstruction of air-shower events is discussed.

T 4.6 Mon 17:15 Geb. 20.30: 2.059

**An analysis concept to measure atmospheric prompt muons with IceCube** — •Pascal Gutjahr and Mirco Hünnefeld — TU Dortmund University, AG Rhode, Dortmund, Germany

When cosmic rays hit the Earth's atmosphere, extensive air showers are initiated. The secondary particles produced are divided into two components: long-lived, light mesons such as pions and kaons referred to as conventional particles and short-lived, heavy charmed and unflavored mesons referred to as prompt particles. Both components decay further into muons and neutrinos, which are detected with cherenkov and neutrino telescopes. In several air shower experiments, muons have been observed more frequently than expected based on simulation. To understand this discrepancy, also referred to as the muon puzzle, the ratio of pions and kaons may be studied. This ratio can be analyzed by measuring the atmospheric muon and neutrino flux, as muon production is dominated by pions and neutrino production is dominated by kaons. Additionally, hadron production in forward direction and at energies of PeV and above are not well constrained by particle accelerator experiments, leading to large uncertainties in hadronic interaction models. Analyses of the atmospheric muon and neutrino fluxes will provide crucial measurements in this phase space.

In this contribution, a first step towards these goals is presented by a concept to measure the atmospheric muon flux at high energies using the IceCube Neutrino Observatory. The main objective is to measure the normalization of the prompt component to constrain the uncertainties in the hadronic interaction models.

T 4.7 Mon 17:30 Geb. 20.30: 2.059

**Towards the depth-dependent energy spectrum using stopping muons in IceCube** — •Deborah Kramps and Lucas Witthaus for the IceCube-Collaboration — Astroparticle Physics WG Rhode, TU Dortmund, Germany

The IceCube Neutrino Observatory is a cubic-kilometer-scale detection sys- tem located in the Antarctic ice, dedicated to the study of neutrinos. However, the predominant signal comes from atmospheric muons produced in extensive air showers in the atmosphere. These muons traverse the ice at speeds greater than the speed of light, producing Cherenkov light that is captured by optical modules. The muon energies can be reconstructed based on the recorded light patterns.

This talk presents a Monte-Carlo study aimed at unfolding the depth- dependent energy spectrum of atmospheric muons. It is based on a subset of single muons that stop within IceCube's instrumented volume. Deep neural networks are used to perform the event classification and reconstruction tasks.

Supported by BMBF (ErUM) and DFG (SFB 1491)

T 4.8 Mon 17:45 Geb. 20.30: 2.059

**Unfolding the Atmospheric Muon Spectrum Using Stopping Muons in IceCube** — •Lucas Witthaus and Karolin Hymon for the IceCube-Collaboration — Astroparticle Physics WG Rhode, TU Dortmund University, Germany

The IceCube Neutrino Observatory is a neutrino detector built into the ice sheet near the South Pole. Despite its main objective, the observation of neutrinos, most of the detected events are caused by atmospheric muons produced in cosmic-ray-induced air showers in the upper atmosphere. When entering the Antarctic ice, muons experience significant energy losses due to interactions with surrounding matter, which limits their propagation length. This talk presents the unfolding of the stopping muon depth intensity, providing information about the abundance of atmospheric muons in the South Pole ice. The study focuses on a subset of events that includes single muons that stop inside the IceCube detector. Event classification and reconstruction tasks are performed using deep neural networks.

Supported by BMBF (ErUM) and DFG (SFB 1491)

# T 5: Methods in particle physics 1 (e/gamma, SciFi)

Time: Monday 16:00–17:45 Location: Geb. 20.30: 2.066

T 5.1 Mon 16:00 Geb. 20.30: 2.066

**Photon identification at the CMS experiment using transformer networks** — Johannes Erdmann, •Tim Kappe, and Florian Mausolf — III. Physikalisches Institut A, RWTH Aachen University

Particle identification is essential for experiments like CMS at the Large Hadron Collider (LHC). One important physics object is the photon, its main signature being an energy deposition in the electromagnetic calorimeter. In physics analyses as carried out, for example in the diphoton decay of the Higgs boson, it is important to distinguish between the real prompt photons and other physics object which produce similar signatures. For example this can be the case for the two usually strongly collimated photons from the decay of neutral pions, which can be reconstructed as a single photon. The latter often appears in jets, which are abundant at the LHC. Such fake photons tend to have wider and less isolated signatures compared to real photons.

Transformers are state-of-the-art neural networks with a wide range of applications. A vision transformer is a transformer architecture specialized to analyze images like the energy depositions in the electromagnetic calorimeter. In this talk, our study of vision transformers for photon identification and comparisons with convolutional neural networks are presented.

T 5.2 Mon 16:15 Geb. 20.30: 2.066

**Measurement of photon identification efficiencies with the inclusive photon method using 2022 CMS data** — Johannes Erdmann, •Nitish Kumar, and Jan Lukas Späh — III. Physikalisches Institut A, RWTH Aachen University

The measurement of the photon identification efficiency is an essential component of all analyses using photons. Currently, the CMS collaboration uses the tag-and-probe technique to measure the photon identification efficiencies up to photon $p_\mathrm{T}$ of 500 GeV. This method is limited by small event yields in the high-$p_\mathrm{T}$ region and the extrapolation beyond 500 GeV is associated with additional uncertainties, which is relevant for analyses involving high-$p_\mathrm{T}$ photons.

The inclusive photon method, also known as the matrix method, allows a precise measurement of the photon identification efficiencies at high photon $p_\mathrm{T}$. This method uses an inclusive photon sample selected with single photon triggers. It utilizes isolation criteria to obtain the fraction of prompt photons in the whole sample and the subsample meeting the identification criteria. This enables the extraction of the photon identification efficiency in a data-driven way. In this talk, we present the preliminary measurement results of photon identification efficiencies with the inclusive photon method using data collected by the CMS experiment in 2022.

T 5.3 Mon 16:30 Geb. 20.30: 2.066

**Photon identification and associated uncertainties for photons originating from displaced vertices in the search for ALPs with ATLAS** — Peter Krämer, Kristof Schmieden, Matthias Schott, and •Olivera Vujinović — Johannes Gutenberg University, Mainz, Germany

Some puzzling questions in particle physics, such as the strong CP problem or the discrepancy of the muon magnetic moment could be solved by introducing light scalar or pseudo-scalar axion-like particles (ALPs). According to theoretical models, a wide range of ALP-masses and couplings to standard model (SM) particles, such as photons and Higgs bosons, is allowed. A large part of this parameter space can be probed by collider experiments.

In this analysis, conducted within the ATLAS experiment at the LHC, we search for the SM Higgs boson decaying into a pair of ALPs further decaying into two photons each, with a special focus on photons originating from the displaced vertices. This resulted in the development of a dedicated approach estimating the systematic uncertainties, taking into account the displaced origin of the photons from the primary vertex. In this talk, the final results of the analysis will be presented.

T 5.4 Mon 16:45 Geb. 20.30: 2.066

**Modern electron reconstruction for future Higgs factories** — •Leonhard Reichenbach[1,2], André Sailer[1], Christian Grefe[2], Philip Bechtle[2], and Klaus Desch[2] — [1]CERN, Geneva, Switzerland — [2]Universität Bonn, Germany

The precise reconstruction of electrons is an important ingredient for the proposed physics program at future Higgs factories (HF). This becomes especially important in the Standard Model precision measurements with the highest indirect sensitivity for new physics: $m_W$ and triple gauge couplings. These were also identified as two high-priority focus topics of the ongoing HF study of the European Committee for Future Accelerators (ECFA). The track reconstruction is particularly challenging for electrons due to their increased material interaction probability. The ECFA HF study is performed with multiple detectors and accelerators in mind, sharing the common Key4hep "turn-key" software framework. We are extending this framework with a dedicated electron reconstruction algorithm utilizing state-of-the-art methods from LHC experiments. For this, we will investigate the usage of a Gaussian sum filter (GSF) based track fit using the ACTS tracking framework and evaluate its performance in a detector-agnostic Key4hep $e\nu W$ benchmark analysis

T 5.5 Mon 17:00 Geb. 20.30: 2.066

**Measuring time resolution of the LHCb SciFi detector** — •Sebastian Schmitt[1], Guido Haefeli[2], Stefan Schael[1], and Ettore Zaffaroni[2] — [1]RWTH Aachen — [2]École polytechnique fédérale de Lausanne

The LHCb experiment at the LHC is an experiment optimised for the precision measurement of $b$-hadron decays. Following a successful Run I and Run II, the detector underwent upgrades for Run III and IV, known as LHCb Upgrade I. Notably, Upgrade I features a Scintillating Fibre (SciFi) detector as part of its tracking system. Looking ahead to Runs V and VI, the subsequent LHCb Upgrade II will feature a combination of a Silicon Pixel detector and a SciFi tracker, in order to cope with the increased pileup.

Both the Upgrade I and II are going to operate under higher instantaneous luminosities, presenting challenges from increased neutron radiation damage and backsplash from the calorimeter situated downstream of the tracking stations. To address the first issue, the readout will be cooled to cryogenic temperatures, as detailed in the talk by Th. Oeser. Additionally, timing could prove to be a valuable factor, particularly in countering noise originating from ECAL backsplash. In this talk, for the first time, the measured timing resolution of large-scale 2.5 m long SciFi mat is presented.

T 5.6 Mon 17:15 Geb. 20.30: 2.066

**The commissioning and performance of the Scintillating Fibre Tracker of LHCb** — Xiaoxue Han, Blake Leverington, Ulrich Uwer, •Chishuai Wang, Lukas Witola, and Ya Zhao — Physikalisches Institut, Heidelberg, Germany

During LS2, the LHCb collaboration has installed a new tracking detector, the Scintillating Fibre (SciFi) Tracker, as a part of the LHCb Upgrade I.

The detector uses scintillating fibres as active material and silicon photomultiplier arrays for the electronic readout. The detector has been designed to be readout at 40MHz and to be operated at a five times higher instantaneous luminosity than in LHCb Run2.

The SciFi tracker has been completed in early 2022 and has been commissioned since. The commissioning includes the calibration of the thresholds used for digitalisation and the time alignment of the signal integration window with respect to the physics signal.

First performance studies have been performed and will be presented.

T 5.7 Mon 17:30 Geb. 20.30: 2.066

**Concept for a Cryogenic SciFi Detector for the LHCb Upgrade II** — David Fehr, •Thomas Oeser, Stefan Schael, Thorsten Siedenburg, and Michael Wlochal — I. Physikalisches Institut B, RWTH Aachen

The Upgrade II of the LHCb detector at the Large Hadron Collider (LHC), scheduled to be installed during Long Shutdown 4, is intended to prepare the detector for the challenging environment of the High Luminosity LHC, operating at luminosities of around $1.5 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ with the aim of integrating $\sim 300\,\mathrm{fb}^{-1}$ of collision data through its lifetime.

A central part of Upgrade II is the Mighty Tracker, which comprises an inner silicon pixel tracker around the beam pipe and an outer Scintillating-Fibre (SciFi) tracker. The readout silicon photomultipliers of the SciFi tracker are cooled to cryogenic temperatures, significantly reducing the dark count rate and ensuring a high hit efficiency at larger luminosities.

This talk presents a concept for a cryogenic SciFi tracker, focussing on the realisation of the cooling system and its coupling to the readout electronics.

# T 6: Methods in astroparticle physics 1

Time: Monday 16:00–18:00 Location: Geb. 20.30: 2.067

T 6.1 Mon 16:00 Geb. 20.30: 2.067

**Efficiency Measurements of the WOM for the IceCube Upgrade** — •Philipp Kern, Sebastian Böser, Yuriy Popovych, John Rack-Helleis, and Bastian Kessler for the IceCube Collaboration-Collaboration — Institut für Physik, JGU Mainz, Deutschland

The IceCube Neutrino Observatory will undergo an Upgrade to increase its sensitivity to neutrino events. One type of Upgrade Module is the Wavelength-shifting Optical Module (WOM), which uses wavelength-shifting technology to detect UV-Cherenkov photons. The main component of the WOM is a quartz tube coated with wavelength-shifting paint. The absorbed and isotropically re-emitted photons are captured inside the tube by total internal reflection and propagate to both ends coupled to Photomultiplier Tubes for detection.

For the deployment in IceCube different properties of the wavelength-shifting tube, such as the attenuation length, the quality of the optical coupling and the paint homogeneity have to be characterized and an efficiency calibration has to be performed for the whole module. For this purpose a custom test stand was built to characterize the WOM, with the possibility to measure the whole surface of the tube over a large wavelength range. This procedure will be done with a single tube used and the complete built WOMs. Here we present results from the characterization and efforts to investigate systematic effects in them.

T 6.2 Mon 16:15 Geb. 20.30: 2.067

**Mapping the ice stratigraphy in IceCube & IceCube-Gen2 using camera deployment footage** — •Martin Rongen for the IceCube-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen Nürnberg

The IceCube Neutrino Observatory is a cubic-kilometer Cherenkov array deployed in the deep, glacial ice at the geographic South Pole. An important feature of the instrumented ice are undulations of layers of constant optical properties over the footprint of the detector. During detector construction, these layers were mapped using stratigraphy measurements obtained from a stand-alone laser dust logger. While this system is very precise, its cost does not scale to the instrumented volume envisioned for the proposed IceCube-Gen2 Observatory. Here, we explore the possibility of obtaining equivalent stratigraphy data from camera footage recorded during the deployment of IceCube more than a decade ago. If successful, this could be an alternative technique to be considered for IceCube-Gen2.

T 6.3 Mon 16:30 Geb. 20.30: 2.067

**Construction of a Prototype of the Wavelength-Shifting Optical Module for the IceCube Upgrade** — •Yuriy Popovych[1], Sebastian Böser[1], Ioana Caracas[1], Enrico Ellinger[2], Cloe Girard-Carillo[1], Klaus Helbing[2], Philipp Kern[1], Anna Pollmann[3], John Rack-Helleis[1], Lea Schlickmann[1], and Nick Schmeisser[2] for the IceCube-Collaboration — [1]Johannes Gutenberg-Universität Mainz — [2]Bergische Universität Wuppertal — [3]Chiba University, Japan

The Wavelength-shifting Optical Module (WOM) is one of the sensors to be deployed in the upcoming Upgrade for the IceCube Neutrino Observatory in 2025/26 increasing the sensitivity of low-energy neutrino events. The module consists of a tube coated with wavelength-shifting paint and two Photomultiplier Tubes (PMTs) coupled on both ends. UV-Cherenkov photons are shifted into the visible region, captured inside the tube by total internal reflection and propagated to the PMTs at the end. Besides an increased UV-sensitivity this design ensures a low signal-to-noise ratio by decoupling the photosensitive area and the PMTs. The modules have to withstand the harsh ambient conditions at the South Pole, as well as during transportation - most notably pressures of up to 600 bar during deployment. This talk will give an overview of the construction of the WOM prototype for the IceCube Upgrade and its engineering challenges, as well as reporting on the WOM final acceptance tests and the status of the production for the Upgrade deployment.

T 6.4 Mon 16:45 Geb. 20.30: 2.067

**$^{42}$K mitigation studies in liquid argon for LEGEND-1000** — •Christoph Vogl[1], Viacheslav Belov[1], Tommaso Comellato[1], Maximilian Goldbrunner[1], Konstantin Gusev[1], Brennan Hackett[2], Patrick Krause[1], Andreas Leonhardt[1], Béla Majorovits[2], Susanne Mertens[1], Nadezda Rumyantseva[1], Mario Schwarz[1], Stefan Schönert[1], and Michael Willers[1] — [1]Technical University of Munich, TUM School of Natural Sciences, Department of Physics, James-Franck-Str. 1, 85748 Garching, Germany — [2]Max Planck Institute for Physics, Boltzmannstr. 8, 85748 Garching, Germany

The Legend experiment searches for neutrinoless double beta decay ($0\nu\beta\beta$) of $^{76}$Ge using high-purity germanium detectors (HPGe). To reduce background sources at the decay's $Q$-value ($Q_{\beta\beta}$ = 2.039 MeV), the detectors are deployed deep underground in an instrumented liquid argon (LAr) volume. However, commercially available LAr contains the cosmogenically activated isotope $^{42}$Ar, whose daughter nucleus $^{42}$K is a beta emitter ($Q_\beta$ = 3.5 MeV). Beta particles can produce events in the region of interest, mimicking $0\nu\beta\beta$ events. Here, we present measurements on $^{42}$K suppression conducted in the LAr cryostat SCARF at TU-Munich. We explore analysis of the event topology in germanium detectors, enclosure of the detectors inside an optically active barrier made of polyethylene naphthalate (PEN), and read-out of the scintillation light produced by LAr and PEN. This research is supported by the DFG through the Excellence Cluster ORIGINS EXC 2094-390783311 and the SFB1258.

T 6.5 Mon 17:00 Geb. 20.30: 2.067

**Crystallized polyethylene naphthalate as wavelength shifting reflector for LEGEND-1000** — •Maximilian Goldrunner[1], Brennan Hackett[2], Andreas Leonhardt[1], and Stefan Schönert[1] for the LEGEND-Collaboration — [1]Technical University of Munich, TUM School of Natural Sciences, Garching, Germany — [2]Max Planck Institute for Physics, Garching, Germany

The future LEGEND-1000 experiment will search for the neutrinoless double-beta decay of Ge-76. For background suppression, 1,000 kg of high-purity germanium detectors will be employed in a liquid argon (LAr) volume. Particles traversing the LAr induce scintillation light with a wavelength peaking at 128nm. The scintillation light is converted to visible wavelength by wavelength shifters. To improve the background suppression in LEGEND-1000, optically inactive surfaces are covered with wavelength-shifting reflectors (WLSR) that also reflect the scintillation light to the LAr instrumentation. Polyethylene naphthalate (PEN) is a wavelength-shifting polymer already used in the precursor experiment LEGEND-200. PEN thin films can be crystallized to act as a WLSR without a separate reflector. In this work, we studied the crystallization of amorphous PEN by heating, characterized for reflectivity and wavelength-shifting efficiency, to find the optimal configuration. We present the first measurement under the relevant LAr conditions, namely for excitation with LAr scintillation light and at LAr temperature. We compare it with amorphous PEN and the TPB-based WLSR of LEGEND-200. The DFG supports this research through the Excellence Cluster ORIGINS and the SFB1258.

T 6.6 Mon 17:15 Geb. 20.30: 2.067

**Reflectivity measurements of PTFE with VUV light in liquid xenon** — •Robert Braun, Johanna Jakob, Lutz Althueser, and Christian Weinheimer — Institute for Nuclear Physics, University of Münster, Germany

Rare event searches as performed with liquid xenon detectors demand a precise knowledge of the employed materials. Measurements of optical properties at the xenon scintillation wavelength in the vacuum UV (VUV) regime are required for accurate simulations and detector characterization. With the Reflectivity Setup in Münster, the angular dependent reflection properties of a sample under VUV light can be studied in a gaseous (GXe) or liquid xenon (LXe) environment.

Polytetrafluorethylen (PTFE) is used to encapsulate the active volume of all large scale LXe dark matter experiments. Among these experiments are the XENON1T and XENONnT experiments from which PTFE samples of the detector walls were studied in vacuum, GXe and LXe using this setup. This talk will report about the reflectivity measurements of the PTFE depending on its surface treatment and the surrounding material.

T 6.7 Mon 17:30 Geb. 20.30: 2.067

**Development of a Bi-solvent Liquid Scintillator with Slow Light Emission** — •Hans Steiger[1,2], M. Böhles[2], M. R. Stock[1], U. Fahrendholz[1], M. Lu[1], L. Oberauer[1], J. Firsching[1], M. Eisenhuth[2], and M. Wurm[2] — [1]Physik-Department, Technische Universität München, James-Franck-Str. 1, 85748 Garching, Germany — [2]Johannes Gutenberg University Mainz, Cluster of Excellence PRISMA+, Staudingerweg 9, 55128 Mainz, Germany

One of the most promising approaches for the next generation of neutrino experiments is the realization of large hybrid Cherenkov/scintillation detectors made possible by recent innovations in photodetection technology and liquid scintillator chemistry. The development of a potentially suitable future detector liquid with particularly slow light emission is discussed in the present talk. This cocktail is compared with respect to its fundamental characteristics (scintillation efficiency, transparency, and time profile of light emission) with liquid scintillators currently used in large-scale neutrino detectors. In addition, the optimization of the admixture of wavelength shifters for a scintillator with particularly high light emission is presented. Furthermore, the pulse-shape discrimination capabilities of the novel medium was studied using a pulsed particle accelerator driven neutron source. Beyond that, purification methods based on column chromatography and fractional vacuum distillation for the co-solvent DIN (Diisopropylnaphthalene) are discussed. This work is supported by the Clusters of Excellence PRISMA+ and ORIGINS and the Collaborative Research Center 1258.

T 6.8 Mon 17:45 Geb. 20.30: 2.067

**DISCO: A hybrid Cherenkov Scintillation detection experiment for WbLS** — •Amala Augusthy[1], Manuel Böhles[1], Noah Goehlke[1], Daniele Guffanti[2], Benedict Kaiser[3], Tobias Lachenmaier[3], and Michael Wurm[1] — [1]JGU Mainz, Institute for Physics and EC PRISMA+ — [2]University of Milano-Bicocca & INFN Milano-Bicocca — [3]Institute of Physics, University of Tübingen

Water based liquid scintillator (WbLS) is a novel detection medium capable of separating Cherenkov and scintillation components of a signal. The ability to separate the two light components will enable one to construct large low-threshold detectors with directional reconstruction capabilities. DISCO is a lab-scale experiment built to demonstrate such a separation and characterize WbLS. It uses muons as test particles to characterize detection media. It comprises of three main components: an external muon tracker, a test cell, and a light detection system. The test cell can be filled with water, liquid scintillator, or WbLS. The light detection system consists of 16 fast 1-inch PMTs with sub-nanosecond resolution. There is also a provision to include a LAPPD in the near future. This talk discusses the experimental set-up of DISCO and a preliminary tracking algorithm to evaluate the hit patterns produced by the muons on the PMTs. This project is supported by the DFG Graduate School GRK 2796: Particle Detectors.

# T 7: Neutrino physics 1

Time: Monday 16:00–18:00 Location: Geb. 30.21: Gerthsen-HS

T 7.1 Mon 16:00 Geb. 30.21: Gerthsen-HS

**Quantum gravity inspired decoherence models in the context of neutrino oscillations** — •Alba Domi, Thomas Eberl, Max Joseph Fahn, Kristina Giesel, Lukas Hennig, Ulrich Katz, Roman Kemper, and Michael Kobler — Friedrich-Alexander Universität Erlangen-Nürnberg, Germany

We discuss the theoretical background for recent decoherence models inspired by quantum gravity and their application in the context of neutrino oscillations. We compare the properties and predictions of these models with existing models and discuss their similarities and differences. Finally, the effects of different quantisation methods and their impact on the final models are briefly discussed.

T 7.2 Mon 16:15 Geb. 30.21: Gerthsen-HS

**A Look at General Neutrino Interactions with KATRIN** — •Caroline Fengler for the KATRIN-Collaboration — Karlsruhe Institute of Technology, Karlsruhe, Germany

The KATRIN experiment aims to measure the neutrino mass by precision spectroscopy of tritium $\beta$-decay. Recently, KATRIN has improved the upper bound on the effective electron-neutrino mass to $0.8\,\mathrm{eV/c^2}$ at 90 % CL [1] and is continuing to take data for a target sensitivity of better than $0.3\,\mathrm{eV/c^2}$. In addition to the search for the neutrino mass, the ultra-precise measurement of the $\beta$-spectrum can be used to probe physics beyond the Standard Model. In particular, general neutrino interactions (GNI) [2] can be investigated through a search for potential shape variations of the $\beta$-spectrum. For this purpose, all theoretically allowed interaction terms for neutrinos are combined in one effective field theory. This enables a model-independent description of novel interactions, which could provide small contributions to the weak interaction. Such potential modifications can then be identified in the KATRIN $\beta$-spectrum by means of energy-dependent contributions to the rate. The talk will introduce the theoretical background of the general neutrino interactions, give an overview of the analysis method and present recent sensitivity studies.

[1] Nat. Phys. 18 (2022) 160-166 [2] Nucl. Phys. B947 (2019) 114746

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 7.3 Mon 16:30 Geb. 30.21: Gerthsen-HS

**Neutrino directionality with the reaction of inverse beta decay in Double Chooz** — •Yaroslav Nikitenko, Philipp Soldin, Achim Stahl, and Christopher Wiebusch — III. Physikalisches Institut B, RWTH Aachen University

Reconstructing the direction of neutrinos is important for observations of supernovae and geoneutrinos. In liquid scintillator detectors the reaction of inverse beta decay is the main channel for detecting neutrinos from those sources. While the experimental spatial resolution does not allow reconstructing antineutrino direction for a single event, a large sample of prompt (positrons) and delayed (neutrons) events makes that possible on a statistical basis.

The Double Chooz reactor neutrino experiment allows studying neutrino directionality with the reaction of inverse beta decay. Its advantage is the neutrino source of a known direction and almost point-like structure, as well as good spatial resolution compared to other reactor experiments. We present the latest experimental results from Double Chooz, which for the first time in the world is measuring neutrino directionality using total neutron capture on both Gd and H nuclei in the detector.

T 7.4 Mon 16:45 Geb. 30.21: Gerthsen-HS

**Design and first tests of the MANGO scattering setup for characterization of liquid scintillators** — •Daniela Fetzer[1,2], Michael Wurm[1,2], Manuel Böhles[1,2], Hans Steiger[2,3], Arshak Jafar[1,2], and Kai Loo[4] — [1]JGU Mainz, Institute for Physics — [2]EC PRISMA+ — [3]Technical University of Munich, Physics Department — [4]University of Jyväskylä, Department of Physics

Detectors for low-energy particles (MeV) are often calibrated using gamma rays to induce electron-like signals. Yet the energies of standard calibration sources are often not sufficient. For instance, the JUNO reactor neutrino experiment requires excellent understanding of the energy response to energies of 8 MeV and higher. The MANGO experiment will use 9 MeV gamma rays from neutron capture on nickel to characterize scintillator samples. Neutrons are produced by a DD108 fusion generator, which creates mono-energetic neutrons of 2.45 MeV that can also be directly used for neutron irradiation of the detector. Using a secondary detector array of neutron and gamma detectors, the energy and momentum direction of the scattered particles can be determined. This additional information can help to relate the visible scintillation signal to the deposited energy and thus to investigate non-linearity or quenching of the scintillator response. This contribution presents the setup as well as first tests of the experimental components. Once MANGO is fully constructed and understood, it will be used for the characterization of the liquid scintillator of the JUNO neutrino detector. This work is supported by the DFG Graduate School GRK 2796: Particle Detectors and the Cluster of Excellence PRISMA+.

T 7.5 Mon 17:00 Geb. 30.21: Gerthsen-HS

**Investigation of background processes for proton decay search in the JUNO experiment** — •Korbinian Stangler[1], Carsten Dittrich[1], Ulrike Fahrendholz[1], Meishu Lu[1], Sarah Braun[1], Lothar Oberauer[1], Hans Steiger[2], and Matthias Raphael Stock[1] — [1]E15, Physik-Dep., Technische Universität München, James-Franck-Str. 1, 85748 Garching — [2]Cluster of Excellence PRISMA$^+$ , Staudingerweg 9, 55128 Mainz

The Jiangmen Underground Neutrino Observatory (JUNO) is a large liquid scintillator detector, capable to search for the hypothetical proton decay $p \to K^+ + \overline{\nu}$, which is predicted by supersymmetric Grand Unified Theories (GUTs). As the momentum of the daughter kaon is below the Cherenkov threshold in water, JUNO will quickly be able to provide competitive results in comparison to the current lifetime limit of $\tau > 5.9 \cdot 10^{33}$ years by the Super-Kamiokande collaboration. The three-fold coincidence signature generated by the kaon and its daughter particles will be crucial to discriminate proton decay events from possible backgrounds produced by atmospheric neutrinos. This talk will present a brief overview on the proton decay search in JUNO, the different background processes and possible identification criteria to discriminate between the two.
This work is supported by the Clusters of Excellence Origins and PRISMA$^+$.

T 7.6 Mon 17:15 Geb. 30.21: Gerthsen-HS

**JUNO's sensitivity to geoneutrinos** — •Cristobal Morales Reveco — GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — III. Physikalisches Institut B, RWTH Aachen University, 52062 Aachen, Germany — Institut für Kernphysik, Forschungszentrum Jülich, 52425 Jülich, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillator detector experiment being built in China. Its main objective is to determine the neutrino mass ordering by measuring reactor anti-neutrinos at 52.5 km baseline. JUNO is also expected to have a high sensitivity to geoneutrinos, electron antineutrinos from natural radioactivity decays from 238-Uranium and 232-Thorium inside the Earth. The radiogenic heat released in these decays is in a well established relationship with the abundances of Uranium and Thorium. Thus, the measurement of geoneutrino flux can provide an insight on the Earth's energy budget. Even more, distinguishing the signal coming from the Earth's mantle is a key feature, which can unveil its convection scheme and contribution to the total radiogenic heat. Thanks to its large mass, JUNO will be able to measure Uranium and Thorium fluxes individually and to establish their ratio, yet another important parameter for geoscience, giving insights about the Earth's formation process. The talk will report the latest geoneutrino's sensitivity study of JUNO. In just one year, it will be able to collect more geoneutrinos events than KamLAND and Borexino experiments in their more than 10 years of data taking. JUNO will provide the third unique geographical and geological point of geoneutrino measurement.

T 7.7 Mon 17:30 Geb. 30.21: Gerthsen-HS

**Time Reversal Symmetry Violation study in neutrino oscillations** — •Kiran Sharma[1,2], Sabya Sachi Chatterjee[1], and Thomas Schwetz[1] — [1]Institut für Astroteilchenphysik, Karlsruher Institut für Technologie (KIT), 76131 Karlsruhe, Germany — [2]Department of Physics, Indian Institute of Technology (IIT) Bhilai, Bhilai 491001, India

Time reversal symmetry violation is connected to the creation of matter in the early moments of the universe following the Big Bang.The current and upcoming neutrino oscillation experiments will address the $\delta_{13}$ value but also its impact on discrete symmetries such as CP and T. In this work, we extend the idea of the model for T violations that covers a wide range of non-standard scenarios independent of the specific parameterizations adopted for fitting the experimental data. We perform extensive numerical simulations on the complex coefficients and oscillation frequencies in the parameterized transition probabilities. We find that the study hints at the feasibility of T-violation signatures in the proposed experiments.

T 7.8 Mon 17:45 Geb. 30.21: Gerthsen-HS

**Lorentz invariance violation searches with the ANTARES and KM3NeT/ORCA neutrino telescopes** — •Lukas Hennig for the ANTARES-KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

Lorentz invariance is a fundamental symmetry in physics that ensures that the same equations can be used to describe experiments in any inertial laboratory. Many proposed quantum gravity theories predict Lorentz invariance violation (LIV). The "Standard-Model extension" parametrizes physically valid ways of including LIV into the Standard Model of particle physics by introducing a set of operators coupled with coefficients that can be experimentally constrained with neutrino telescopes. The "Quantum GRavity seArches with Neutrino Telescopes" (QGRANT) project aims at performing the first combined fit of these coefficients using data from the three neutrino telescopes ANTARES, IceCube, and KM3NeT, which is expected to give an unprecedented sensitivity for constraining the LIV coefficients. This contribution discusses the current progress in the analysis of the ANTARES and KM3NeT/ORCA data and outlines the next steps that will be taken in the QGRANT analysis.

# T 8: Neutrino physics 2

Time: Monday 16:00–18:00 Location: Geb. 30.22: Gaede-HS

T 8.1 Mon 16:00 Geb. 30.22: Gaede-HS

**LEGEND: Background-free hunt for the neutrinoless double-beta decay** — •Patrick Krause for the LEGEND-Collaboration — Department of Physics, TUM School of Natural Sciences, Technische Universität München, 85748 Garching b. München

The discovery that neutrinos are Majorana fermions would have profound implications for particle physics and cosmology. The Majorana character of neutrinos would make neutrinoless double-beta ($0\nu\beta\beta$) decay, a matter-creating process without the balancing emission of antimatter, possible. The LEGEND Collaboration pursues a phased, $^{76}$Ge-based double-beta decay experimental program. The first phase, LEGEND-200, deploys up to 200 kg of germanium detectors enriched in $^{76}$Ge. A background index of $2 \cdot 10^{-4}$ counts/(keV kg yr) will be achieved. With that background index, when integrated over the exposure, less than one background event in the region around the expected peak position of the $0\nu\beta\beta$ decay will be accumulated. It constitutes a quasi-background-free operation of LEGEND-200, enabling a potential discovery of the $0\nu\beta\beta$ decay at a half-life of at least $10^{27}$ years. The second phase, LEGEND-1000, will deploy 1000 kg of enriched germanium and reach a discovery potential above $10^{28}$ years. This talk will portray the LEGEND project and its goals. Furthermore, first results from the currently ongoing data-taking period of LEGEND-200 are presented.

This research is supported by the DFG through the Excellence Cluster ORIGINS EXC 2094-390783311, the SFB1258, and by the BMBF Verbundprojekt 05A2023.

T 8.2 Mon 16:15 Geb. 30.22: Gaede-HS

**Muon Veto of LEGEND-200** — •Gina Grünauer for the LEGEND-Collaboration — Physikalisches Institut, Eberhard Karls Universität Tübingen

The **L**arge **E**nriched **G**ermanium **E**xperiment for **N**eutrinoless $\beta\beta$ **D**ecay (LEGEND) is an experimental program searching for the neutrinoless double beta ($0\nu\beta\beta$) decay of $^{76}$Ge. To look for such rare events and reach the aimed half-life sensitivity of more than $10^{28}$ years, every opportunity to reduce the background has to be taken. A Water-Cherenkov-Veto is used for this purpose for the current experimental phase LEGEND-200. It uses photomultiplier tubes (PMTs) as detectors in a water-tank faced with a reflective foil to increase the light yield inside the Veto. This contribution presents the working principle and data analysis of the Muon Veto of LEGEND-200.

T 8.3 Mon 16:30 Geb. 30.22: Gaede-HS

**Column Density Determination for the KATRIN Neutrino Mass Measurement** — •Christoph Köhler for the KATRIN-Collaboration — Technische Universität München

The KATRIN experiment aims to model-independently probe the effective electron anti-neutrino mass with a sensitivity of 0.2 eV (90 % CL) by investigating the endpoint region of the tritium beta decay spectrum. To achieve this goal the gas quantity of the windowless gaseous tritium source, characterized by the column density, has to be known with great accuracy.

In this talk we present the principle of measuring the column density with an angular resolved photoelectron source. Further, a method to ensure continuous monitoring of the column density during measurement campaigns of KATRIN is described. The influence of the recent hardware upgrade of the photoelectron source is discussed in light of the column density determination accuracy.

*This work is supported by the Technical University of Munich, the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6). This project has received funding from the European Research Council (ERC) under the European Union Horizon 2020 research and innovation programme (grant agreement No. 852845).*

T 8.4 Mon 16:45 Geb. 30.22: Gaede-HS

**Evolution of the KATRIN energy scale measured with 83mKr.** — •Justus Beisenkötter and Matthias Böttcher for the KATRIN-Collaboration — Universität Münster

To study the energy scale of KATRIN, which is influenced by beamline workfunctions and plasma effects in the gaseous tritium source, 83mKr conversion electron lines are used. Gaseous 83mKr is inserted into the tritium source, which allows us to measure energy shifts and broadenings of the conversion lines that also affect the beta spectrum. This talk gives an overview of the time evolution of the line position of the 83mKr L3-32 and N23-32 lines, which were measured throughout the KATRIN operation. We also present the evolution of the radial dependent coupling of rear wall bias voltage to the line positions and the optimal value for chosen rear wall bias, which are monitored using 83mKr conversion electrons. This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6)

T 8.5 Mon 17:00 Geb. 30.22: Gaede-HS

**Absolute $^{83m}$Kr transition energy determination using the Gaseous Krypton Source of the KATRIN experiment** — •Benedikt Bieringer and Matthias Böttcher for the KATRIN-Collaboration — Institute for Nuclear Physics, University of Münster

The KATRIN experiment aims to determine the neutrino mass with a sensitivity better than 0.3 eV/c$^2$ at 90 % CL. An important cross check to verify the analysis is the comparison of the Q-value derived from the measured endpoint of the tritium beta spectrum to values from literature. This is achieved by calibration of the energy scale with conversion electrons from a gaseous $^{83m}$Kr source. However, reaching the desired accuracy requires an unprecedented knowledge of the energy of $^{83m}$Kr gamma transitions.

This talk presents first results on improving the knowledge on the transition energies through a measurement of conversion electron lines for all three $^{83m}$Kr gamma transitions using a high-luminosity Gaseous Krypton Source. The measurement follows the recent, first direct measurement of the highest $^{83m}$Kr gamma transition, performed with the Condensed Krypton Source of the KATRIN experiment.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 8.6 Mon 17:15 Geb. 30.22: Gaede-HS

**Non contact measurement and stabilization of ultra-high temperatures in a hydrogen atom source** — •Maximilian Hüneborn and Sebastian Böser for the Project 8-Collaboration — Johannes Gutenberg-Universitat Mainz, Mainz, Germany

The Project 8 experiment aims to achieve a 40 meV neutrino mass measurement through the use of atomic tritium, to eliminate rotational and vibrational modes found in molecules, combined with measuring tritium beta decay electrons using cyclotron radiation emission spectroscopy. As a possible starting point, at the Mainz atomic test stand we are currently developing a thermal hydrogen cracker. One major aspect is the on-demand precise temperature control of the filament. This presentation compares the use of a thermocouple and a pyrometer for this purpose. Challenges, including source degradation at temperatures above 2000 K, led to the implementation of a PID loop for accurate temperature maintenance. This advancement not only addresses the issue of source degradation but also enhances the capabilities of the setup, enabling other measurements within the Mainz atomic setup to benefit from the newly acquired stability, precision, and reproducibility.

T 8.7 Mon 17:30 Geb. 30.22: Gaede-HS

**Precise Temperature Characterization of Project 8's Atomic Hydrogen Source** — •Brunilda Mucogllava and Martin Fertl for the Project 8-Collaboration — Johannes Gutenberg Universität Mainz

In order to achieve a neutrino mass sensitivity of 40 meV, the Project 8 experiment aims to use the Cyclotron Radiation Emission Spectroscopy technique to analyze the atomic tritium beta decay spectrum. Due to the radioactive nature of tritium, initial measurements have been carried out using a Hydrogen Atom Beam Source (HABS) at the Mainz atomic test stand. Molecular hydrogen is introduced into the HABS setup, flowing through a 1 mm diameter tungsten capillary which is radiatively heated to ~2300 K by a tungsten filament. This causes the molecules to thermally dissociate in a temperature-dependent way. Accurate capillary temperature measurements with low uncertainty at these high temperatures are required to characterize the source accurately and understand the dissociation efficiency from molecular to atomic hydrogen. This talk will present infrared spectroscopy measurement results of the capillary, addressing challenges arising from uncertain emissivity values, ultra-high vacuum conditions, and device-dependent absolute calibration.

T 8.8 Mon 17:45 Geb. 30.22: Gaede-HS

**Calorimetric measurement of the $^{159}$Dy electron capture spectrum** — •Peter Wiedemann[1], Arnulf Barth[1], Christian Enss[1], Andreas Fleischmann[1], Karl Johnston[2], Ulli Köster[3], and Loredana Gastaldo[1] — [1]Kirchhoff Institute for Physics, Heidelberg, Germany — [2]ISOLDE, CERN, Geneva, Switzerland — [3]Institut Laue-Langevin, Grenoble, France

The neutrino mass can be determined by analyzing the endpoint of electron capture (EC) spectra. Decay processes with a low $Q$-value provide high statistics near the endpoint and are therefore especially suitable. While $^{159}$Dy decays with a $Q$-value of about 365 keV to the ground state of $^{159}$Tb, a decay branch that populates the excited $5/2^-$ state of $^{159}$Tb, has a low $Q$-value of 1.18(19) keV. Therefore it was suggested for the determination of the electron neutrino mass.

Our goal is to measure the $^{159}$Dy EC spectrum for the first time and aim for an energy resolution of about 10 eV. We will use metallic magnetic calorimeters (MMC) with $^{159}$Dy ion-implanted at ISOLDE (CERN) into two electroplated layers of gold absorber. Analyzing this spectrum will allow for a better understanding of the decay of $^{159}$Dy. Even if the decay to the excited nuclear state cannot be discriminated, from the precise measurement of the total EC spectrum, we can infer the contribution of the decay to the excited state. We present the MMC-detectors used for this experiment, with a focus on the properties of the absorber that contains $^{159}$Dy. Finally, we report on the status of the experiment.

# T 9: Cosmic rays 2

Time: Monday 16:00–18:00 Location: Geb. 30.22: Lehmann-HS

T 9.1 Mon 16:00 Geb. 30.22: Lehmann-HS

**Radio Measurements with an IceCube-Gen2 Surface Station installed at the Pierre Auger Observatory** — •Carmen Merx[1], Sara Reina Torres[2], Benjamin Flaggs[2], and Frank Schröder[1,2] for the Pierre Auger and IceCube-Collaboration — [1]Karlsruher Institut für Technologie, Institut für Astroteilchenphysik — [2]University of Delaware, Bartol Research Institute

As radio detection of air showers has become a powerful tool to study high-energy cosmic rays, the surface array of the IceCube Neutrino Observatory at the South Pole is planned to be enhanced by radio antennas. The goal is to improve the accuracy of air shower measurements of energies of several 10 PeV and above. To this end, a prototype station composed of three SKALA antennas and eight scintillation panels is taking data at the South Pole in varying setups since 2020. In addition, an equal prototype station has been deployed at the Pierre Auger Observatory in Argentina in 2022 for tests and comparisons. In this presentation, first measurements of this protype station at the Pierre Auger Observatory will be discussed.

T 9.2 Mon 16:15 Geb. 30.22: Lehmann-HS

**Geometry Alignment of IceAct and the IceCube Neutrino Observatory using Coincident Measurements of Cosmic-Rays** — •Jonas Häussler, Lukas Brusa, Lars Heuermann, Merlin Schaufel, Lea Schlickmann, and Christopher Wiebusch for the IceCube-Collaboration — RWTH Aachen University, Aachen, Deutschland

IceAct is an array of Imaging Air Cherenkov Telescopes located at the South Pole as part of the IceCube Neutrino Observatory. The main goal of IceAct is the hybrid detection of air-showers for cross-calibrating the IceCube in-ice and IceTop surface detectors, enhancing cosmic-ray flux and composition measurements, and vetoing air-shower induced neutrinos. To properly combine the information from IceCube and IceTop with IceAct, the geometric alignment of the telescopes to the detector coordinates has to be known. We have developed a likelihood-based method to determine the alignment using coincident air-shower events. Applying this algorithm to the two already deployed telescopes at the South Pole, we achieve a resolution of a few percent of the pixel resolution.

T 9.3 Mon 16:30 Geb. 30.22: Lehmann-HS

**Radio emission-mechanism of horizontal air showers measured with AERA at the Pierre Auger Observatory*** — •Rukije Uzeiroska for the Pierre-Auger-Collaboration — Bergische Universität Wuppertal, Wuppertal, Deutschland

The Pierre Auger Observatory is the world's largest detector measuring ultra high energy cosmic rays. The Auger Engineering Radio Array (AERA) is an ensemble of 153 antennas covering an area of 17 $km^2$ and is used to detect the radio emissions from extensive air showers (EAS). The radio emission consist of two main components: the geomagnetic and the charge-excess emission. These components can be disentangled by measuring the direction of the electric field vector.

This talk presents current efforts by the Pierre Auger Collaboration to determine the relative contributions of these two processes using the polarization pattern of the antenna stations for events measured with AERA, which helps to understand the development of air showers. The goal is to develop a reliable and robust analysis for determining the emission ratio $a$ for horizontal EAS. Furthermore, theoretical expectations for this quantity within CoREAS simulations of horizontal air showers are verified. The simulations were reconstructed with the analysis framework of the Pierre Auger Observatory, offline. Comparisons of the simulated results with those already measured by LOFAR show agreement within the expected range of uncertainties.

**Supported by BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)*

T 9.4 Mon 16:45 Geb. 30.22: Lehmann-HS

**Transforming AERA into a powerful Terrestrial Gamma-ray Flash detector*** — Markus Cristinziani[1], Qader Dorosti[1], Stefan Heidbrink[2], •Vivek Janardhana[1], Noah Siegemund[1], Jens Winter[2], and Michael Ziolkowski[2] for the Pierre-Auger-Collaboration — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Elektronikentwicklungslabor, Naturwissenschaftlich-Technische Fakultät, Universität Siegen

Terrestrial Gamma-ray Flashes (TGFs) are intense bursts of high-energy gamma rays originating from Earth's atmosphere during thunderstorms. Being under active research, it is assumed that the interactions of relativistic runaway electron avalanches, which are accelerated in large electrical fields of thunderstorms, are responsible for the production of TGFs.

The Pierre Auger Observatory has exploited its surface detectors to measure the TGF events. With AERA's 1-ns timing, the 3D imaging of lightning may be carried out with a metre-precision resolution. Given that the lightning process lasts several seconds, efforts are underway to modify the AERA digitizer board to increase lightning signal readout time from microseconds to several seconds. These efforts aim to enrich our understanding of TGFs by enabling more comprehensive data collection during thunderstorms.

*Supported by the BMBF Verbundforschung Astroteilchenphysik

T 9.5 Mon 17:00 Geb. 30.22: Lehmann-HS

**Search for a mass dependent anisotropy of UHECRs with the Pierre Auger Observatory** — •Edyvania Emily Pereira Martins for the Pierre-Auger-Collaboration — Karlsruhe Institute of Technology, ETP, Karlsruhe, Germany

The origin of cosmic rays (CRs) is an open and exciting topic in astrophysics. On this theme, the Pierre Auger Observatory investigates the anisotropies of the ultra-high-energy cosmic rays (UHECRs) — which possess energies above ~1 EeV — at small, intermediate, and large angular scales. The Observatory (with the surface detector stations spread over 3000 $km^2$) has been collecting data for nearly 20 years, reaching more than 135 000 $km^2$ yr sr of accumulated exposure. So far, one of the most significant discoveries is a large-scale dipole structure with an amplitude of ~7%. This results from a modulation in right ascension for events with energies above 8 EeV, where the dipole equatorial component has a statistical significance of over $5\sigma$. The source of this structure is not yet understood. It could arise from diffusion and deflection of CRs in magnetic fields, and/or could be caused by the anisotropic distribution of nearby sources. In either case, a dependence on the charge and/or mass of the CRs is expected on both the amplitude and direction of the observed dipole. For the first time, the Auger Observatory is preparing to include information on the UHECR composition in a search for a mass-dependence signature on the observed dipole. In this contribution, we discuss the prospects of anisotropy searches in light of mass-composition information of Phase I of the Pierre Auger Observatory.

T 9.6 Mon 17:15 Geb. 30.22: Lehmann-HS

**Depth of Maximum of Air-Shower Profiles above $10^{17.6}$ eV Measured with the Fluorescence Detector of the Pierre Auger Observatory and Mass-Composition Implications** — •Thomas Fitoussi for the Pierre-Auger-Collaboration — IAP, KIT, Karlsruhe, Gerrmany

After seventeen years of operation, the first phase of measurements at the Pierre Auger Observatory finished and the process of upgrading it began. In this work, we present distributions of the depth of air-shower maximum, $X_{max}$, using profiles measured with the fluorescence detector of the Pierre Auger Observatory. The analysis is based on the Phase I data collected from 01 December 2004 to 31 December 2021.

The $X_{max}$ measurements take advantage of an improved evaluation of the vertical aerosol optical depth and reconstruction of the shower profiles. We present the energy dependence of the mean and standard deviation of the $X_{max}$ distributions above $10^{17.6}$ eV. Both $X_{max}$ moments are corrected for detector effects and interpreted in terms of the mean logarithmic mass and variance of the masses by comparing them to the predictions of post-LHC hadronic interaction models. We corroborate our earlier findings regarding the change of the elongation rate of the mean $X_{max}$ at $10^{18.3}$ eV with higher significance. We also confirm, with four more years of data compared to the last results presented in 2019, that around the ankle in the cosmic rays spectrum, the proton component gradually disappears and that intermediate mass nuclei dominate the composition at ultra-high energies.

T 9.7 Mon 17:30 Geb. 30.22: Lehmann-HS

**Updating the hybrid search for photons with the low-energy extensions of the Pierre Auger Observatory*** — •Tim Fehler, Marcus Niechciol, and Markus Risse for the Pierre-Auger-Collaboration — Experimentelle Astroteilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Ultra-high-energy (UHE) photons can reliably be detected with air-shower arrays, which have been primarily designed to efficiently observe cosmic rays at the highest energies. The diverse detector systems of the Pierre Auger Observatory have been utilized to place stringent upper limits on the diffuse, i.e. the direction-independent, unresolved, integral flux of UHE photons across several orders of magnitude in energy. A key focus has been on pushing the energy threshold of these analyses down to $10^{17}$ eV and below, as this energy range offers numerous connections to various aspects of multimessenger astrophysics. Currently, upper limits down to a threshold of $2 \times 10^{17}$ eV have been determined using the low-energy extensions of the Observatory, namely the high-elevation fluorescence telescopes and the sub-array of the surface detector with spacing of 750 m. This contribution details the ongoing studies, based on simulations, to update this analysis and optimize the search strategy. The aim is to leverage the full Phase-1 dataset, which would more than double the statistics compared to the last publication in 2022.

**Supported by the BMBF Verbundforschung Astroteilchenphysik*

T 9.8 Mon 17:45 Geb. 30.22: Lehmann-HS

**Measuring photon-induced air showers with the AugerPrime Radio Detector** — •Jannis Pawlowsky for the Pierre-Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal, Germany

The AugerPrime upgrade represents a significant enhancement in the capability of the Pierre Auger Observatory to detect air showers. Central to this advancement is the installation of a radio antenna atop each existing Surface Detector (SD) station, constituting the Radio Detector (RD). RD enhances the sensitivity of the SD to the electromagnetic component of air showers. Hence, the new detector presents an opportunity for the discovery of rare particles such as ultra-high-energy photons.

This presentation focuses on the detection and reconstruction of photon-induced air showers at the highest energies. The radio trigger designed for the detection of photon events will be outlined and the trigger efficiency and reconstruction accuracy in simulation studies will be discussed. The presentation will conclude by summarizing the effectiveness and discrimination power of the new detector component.

**Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)*

# T 10: Gamma astronomy 1

Time: Monday 16:00–18:00 Location: Geb. 30.22: kl. HS A

T 10.1 Mon 16:00 Geb. 30.22: kl. HS A

**Background estimation for IACTs combining a run matching approach with a background template** — •Tina Wach[1], Alison Mitchell[1], and Lars Mohrmann[2] — [1]Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg — [2]Max-Planck-Institut für Kernphysik

Detecting large, extended gamma-ray structures using IACTs has been a major challenge due to their comparatively small field-of-view. In the case of large extended sources, the separation between background and source signal is challenging, since most techniques rely on the background signal evaluation from source-free regions within the field-of-view of the respective observation. This is however only possible if the gamma-ray emission is well contained within the field-of-view of the telescope array. One way to overcome this challenge is to estimate the background from a separate observation of a source-free region, although this can introduce large systematic uncertainties.

To decrease the systematic uncertainties and their correlation to the choice of the observation of the source-free region, we use the open-source tool gammapy to combine the ON observation / OFF observation method with a 3-dimensional background template, created from a large amount of archival data of the H.E.S.S. array. We then use data from the first public data release of the H.E.S.S. Collaboration to validate the technique and evaluate the systematic errors introduced. We show that this method is a stable approach to estimate the background rate in complicated regions of the sky where other approaches cannot be used.

T 10.2 Mon 16:15 Geb. 30.22: kl. HS A

**Towards a multiwavelength analysis of Pulsar Wind Nebulae at gamma-ray and X-ray energies with Gammapy** — •Katharina Egg and Alison Mitchell — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen Nürnberg

Pulsar wind nebulae (PWNe) are structures produced by the outflow of highly energetic particles from pulsars. As regions harbouring extreme physical conditions, PWNe are possible PeVatron candidates (accelerators of particles to PeV energies). While many PWNe have been detected and even first discovered as sources of gamma-ray emission, the particle winds driving this process are expected to cause the emission of photons across the entire electromagnetic spectrum. Thus the study of PWNe in multiple energy bands is key to constrain their characteristics and environments.

In this vein, data from the eROSITA X-ray telescope, in conjunction with gamma-ray data from the H.E.S.S. telescope array, provides the opportunity of studying even very faint X-ray counterparts of PWNe on large scales. This analysis is undertaken using the Gammapy package that is developed for the handling of gamma-ray data in a Python framework. In this contribution, the capabilities of Gammapy in the combined handling of X-ray and gamma-ray data are explored and the process towards the goal of conducting a joint analysis of X-ray and gamma-ray data is showcased.

T 10.3 Mon 16:30 Geb. 30.22: kl. HS A

**High-energy variability of the gravitationally lensed blazar PKS 1830-211** — •Sarah M. Wagner[1,2], Jeffrey D. Scargle[3], Greg Madejski[2], Andrea Gokus[4], and Krzysztof Nalewajko[5] — [1]Uni Würzburg, Germany — [2]Stanford University, USA — [3]NASA Ames, USA (retired) — [4]Washington University in St. Louis, USA — [5]Polish Academy of Sciences, Poland

Gravitational lenses can be used as microscopes to investigate the origin of the highly variable high-energy emission observed from blazar jets. We study the broad-band spectral properties and the multi-wavelength variability of the gravitationally-lensed blazar PKS 1830-211 to put constraints on the structure and relevant physics of its jet. We utilize Swift/XRT, NuSTAR, and Fermi-LAT observations from 2016 and 2019 to compare periods of low activity and high activity. Additionally, we introduce a novel method to observe short-timescale variability in unbinned NuSTAR data and present an extensive discussion on the gravitationally-induced time delay in the gamma-ray light curve observed with Fermi-LAT. Based on our analysis, we find a delay of ~22 days and illustrate that delicate methods are needed to reliably detect this. The detection of a consistent lag throughout the whole light curve suggests that the production site of the gamma-ray emission is spatially constant. When comparing the 2016 and 2019 datasets, the X-ray part of the SED is remarkably stable in comparison to the dramatic change in the gamma rays. We explain the differences in the activity observed in X-rays and gamma rays as arising due to a change in the break in the electron energy distribution.

T 10.4 Mon 16:45 Geb. 30.22: kl. HS A

**Investigation of the influence of an updated model for the extragalactic background light on the multi-messenger signatures of Blazar 3C279 with CRPropa** — •Yannick Schmidt[1,2], Lukas Merten[1,2], and Julia Becker Tjus[1,2,3] — [1]Theoretical Physics IV, Plasma Astroparticle Physics, Faculty of Physics and Astronomy, Ruhr-University Bochum, 44780 Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — [3]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

In order to come closer to understanding extragalactic sources of cosmic rays and their intrinsic mechanisms, the analysis of various multi-messenger signals has proven to be extremely promising in recent decades. Typically, numerical simulations are undertaken to investigate the validity of various astrophysical scenarios. Predictions considering photonuclear interactions depend significantly on the modeling of extragalactic photon fields. Therefore, in the present work an updated model of the extragalactic background light was implemented in the open-source code CRPropa 3.2 to investigate its effects on gamma-ray signals from blazar 3C279. In particular, the new model showed a higher prediction of produced photons by inverse Compton scattering when simulating electromagnetic cascades, while the opacity of the universe for gamma radiation was lower than in previous models.

T 10.5 Mon 17:00 Geb. 30.22: kl. HS A

**Multi-Messenger Picture of J1048+7143 Consistent with a Supermassive Black Hole Binary Origin*** — •Ilja Jaroschewski[1,2], Emma Kun[1,2,3,4], and Julia Becker Tjus[1,2,5] — [1]Theoretical Physics IV, Plasma Astroparticle Physics, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — [3]Astronomical Institute, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — [4]3CSFK, MTA Centre of Excellence, Hungary — [5]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

Until mid 2022, the Fermi-LAT gamma-ray light curve of the FSRQ J1048+7143 showed three distinct flares, each consisting of two subflares. These flares are accompanied by simultaneous flares in radio wavelengths, without a subflare structure. In a previous work, it was shown that these flares are consistent with a supermassive binary black hole origin and are caused by jet precession due to spin-orbit coupling of the leading jet. The occurrence of the fourth flare in gamma rays was predicted, which is observable in the latest gamma-ray light curve.

In this work, we show how the fourth flare in gamma rays was predicted and how the detection of it tightly constraints the mass ratio of the binary. Such a constraint allows to predict when the binary will merge. In addition, we highlight how jet precession provides an explanation for the subflare structure seen in the gamma-ray light curve. *Supported by DFG (MICRO and SFB 1491)

T 10.6 Mon 17:15 Geb. 30.22: kl. HS A

**Expanding the Multi-Messenger Picture of J1048+7143 with the Optical Light Curve*** — •Johannes Just[1,2], Ilja Jaroschewski[1,2], Emma Kun[1,2,3,4], and Julia Becker Tjus[1,2,5] — [1]Theoretical Physics IV, Plasma Astroparticle Physics, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — [3]Astronomical Institute, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — [4]3CSFK, MTA Centre of Excellence, Hungary — [5]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

The gamma-ray and radio light curves of J1048+7143 reveal a pattern of quasi-periodic oscillations that can be explained by the existence of a supermassive binary black hole inspiral at its core. In such a model, the light curves are explainable via jet precession of the dominant supermassive black hole jet caused by spin-orbit coupling.

In this work, we add optical data in the V and G band to the multi-messenger picture. We determine the duration and occurrence times of the flares with this new, optical data and predict the time of the next flare. With the results obtained using this optical data, we build a consistent model across the wavelengths. The Fermi-LAT gamma-ray and optical light curve of the blazar show a double flare substructure in the main flares while the radio light curve does not show this feature. In our model, we work out a scenario for which the different wavelengths can be explained consistently. *Supported by DFG (SFB 1491)

T 10.7 Mon 17:30 Geb. 30.22: kl. HS A

**On the possible jet contribution to the $\gamma$-ray luminosity in NGC 1068** — •Silvia Salvatore[1,2], Björn Eichmann[1,2], Xavier Rodrigues[2,3,4], Ralf-Jürgen Dettmar[2,4], and Julia Becker Tjus[1,2,5] — [1]Theoretische Physik IV, Ruhr-Universität Bochum, Bochum, Germany — [2]RAPP-Center, Ruhr-Universität Bochum, Bochum, Germany — [3]European Southern Observatory, Garching bei München, Germany — [4]Astronomisches Institut (AIRUB), Ruhr-Universität Bochum, Bochum, Germany — [5]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

NGC 1068 is a widely studied Seyfert II galaxy with a broad energy band, from radio to gamma-ray emissions. A strong evidence for high-energy neutrino emission was recently discovered by IceCube. In this work, we focus on the gamma-ray emission and in particular we discuss whether the radio jet can be a source of the gamma rays between 0.1 and 100 GeV, as observed by Fermi-LAT. We include both leptonic and hadronic processes and use spatially resolved VLBA and ALMA observations of the radio knot structures to constrain our calculations. Our results show that the best leptonic scenario for the prediction of the Fermi-LAT data is provided by the radio knot observed at 15 pc from the central engine. For this knot, a magnetic field strength of about 1 mG is needed as well as a strong spectral softening of the relativistic electron distribution at 1-10 GeV. We show that both these conditions cannot meet and that there is no other jet emission scenario able to explain the gamma-ray signal in the entire Fermi-LAT band.

T 10.8 Mon 17:45 Geb. 30.22: kl. HS A

**Spatially Coherent 3D Distributions of HI and CO in the Milky Way** — •Laurin Söding[1], Philipp Mertsch[1], and Vo Hong Minh Phan[2] — [1]Institute for Theoretical Particle Physics and Cosmology (TTK), RWTH Aachen University, 52056 Aachen, Germany — [2]LERMA, Sorbonne University

The spatial distribution of the gaseous components of the Galaxy is of great importance for interpreting and modelling cosmic ray data and diffuse emission. Reconstructing interstellar gas from doppler-shifted line emission requires knowledge of gas velocities and generally suffers from distance ambiguities.

We overcome these issues by reconstructing the posterior distribution of 3D HI and CO gas densities and velocities in a common Bayesian inference scheme. We explicitly enforce a spatially coherent structure by means of modelling the 3D fields as correlated (log)normal random fields.

For the first time, we include the modelling of absorption effects, which are especially important for the usually optically thick CO emission lines. We also improve on previous reconstructions by promoting the galactic velocity field and the emission line widths to the set of reconstructed fields, and further constrain their values with complementary data from galactic masers.

We provide a spatially coherent large-scale picture of the 3D distribution of gas in the Galaxy and illustrate the value of these maps in predicting diffuse gamma-ray emission.

# T 11: Silicon trackers 1

Time: Monday 16:00–18:00 Location: Geb. 30.22: kl. HS B

T 11.1 Mon 16:00 Geb. 30.22: kl. HS B

**Status update of the ATLAS ITk Pixel cell integration site in Bonn** — •Alexandra Wald, Klaus Desch, Matthias Hamer, Florian Hinterkeuser, Nico Klein, Dominik Hauner, Fabian Hügging, and Jochen Dingfelder — PI, Uni Bonn, Germany

In conjunction with the high luminosity upgrade of the Large Hadron Collider at CERN, the current tracking system of the ATLAS experiment will be replaced by the Inner Tracker (ITk), an all-silicon detector consisting of 5 layers of pixel and 4 layers of strip detectors. More than 8000 modules will be installed in the pixel layers, which together have an active area of approximately 13 $m^2$ and cover a pseudorapidity of up to 4. In order to build such a large detector in time, the integration of the ITk Pixel modules on their local support structures, as well as the quality control of individual loaded local supports will be distributed over several institutes. One of the assembly lines will be setup at the University of Bonn, with technicians from other German locations also helping with cell integration. Due to the serial powering scheme of the ITk Pixel Detector, the quality control of a loaded local support is challenging in several aspects, as the simultaneous operation of multiple modules is necessary for any tests. A large number of different components must hence be integrated into the quality control setup, such as an optical readout system, an interlock system, industrial power supplies and a scalable DCS. In this presentation, the status of the loaded local support assembly line and QC setup in Bonn is presented, with particular attention to the data aquisition system based on a Felix server and the integration into the DCS.

T 11.2 Mon 16:15 Geb. 30.22: kl. HS B

**ATLAS ITk-Pixel DAQ system** — •Wael Alkakhi, Joern Grosse-Knetter, Arnulf Quadt, and Ali Ali — II. Physikalisches Institut, Georg-August-Universität Göttingen

During the ATLAS HL-LHC upgrade, the current inner detector is going to be replaced by an all-silicon Inner Tracker (ITk). The ITk-Pixel DAQ system basic read-out chain includes the YARR software, communicating with the FELIX PCIe board acting as an interface connected through lpGBT transceivers to the on-detector front-end (FE) chips ITkPix. The FEs are grouped in quad modules that are installed on local supports, which are integral parts of the ITk structure. Depending on the specific configuration, each loaded local support (LLS) accommodates between 16 and 28 quad modules for local inclined half rings or 36 quad modules for local longerons. The communication between YARR and FELIX was already validated using NetIO/Felixcore networking interfacing SW module. Nevertheless, the final DAQ system adopts the next generation communication interface called Felixclient (NetIO-Next/Felixstar). Further development was consequently required to validate the new read-out chain achieved first on a lab setup with a couple of ITkPix single chip cards and quad modules. However, as the final ITk-Pixel read-out system will contain about 10000 quad modules, a more representative sub-system on a real LLS should be used. Such a read-out setup can be based on 16 ITkPix quad modules on a real local support from previous serial powering tests and used to validate the YARR software.

T 11.3 Mon 16:30 Geb. 30.22: kl. HS B

**Measurement of the Thermal Runaway of a 2S Module on a TEDD-like Structure for the CMS Phase-2 Outer Tracker Upgrade** — Lutz Feld[1], Katja Klein[1], Martin Lipinski[1], •Vanessa Oppenländer[1], Alexander Pauls[1], Oliver Pooth[2], and Nicolas Röwert[1] — [1]1. Physikalisches Institut B, RWTH Aachen — [2]3. Physikalisches Institut B, RWTH Aachen

The new operating conditions of the future HL-LHC require a replacement of the complete silicon tracking system of the CMS experiment as part of the CMS Phase-2 Upgrade. For the Phase-2 Outer Tracker new silicon strip modules, so-called 2S modules, are being developed that consist of two silicon sensors stacked on top of each other. The radiation conditions of the HL-LHC lead to a high leakage current in the silicon sensors, which is exponentially dependent on the sensor temperature. An evaporative $CO_2$ cooling system will be used to cool the modules and to ensure a successful operation. In an unstable cooling scenario it is possible that the module enters an uncontrolled self-heating loop called thermal runaway. Therefore it is crucial that the thermal properties and performance of the 2S modules and the cooling structure are tested and characterized. In this talk thermal measurements performed on a small realistic cooling structure similar to the structure foreseen for the endcaps of the CMS Outer Tracker will be presented. The $CO_2$ temperature at which thermal runaway occurs has been measured. Sufficient margin to the nominal operating $CO_2$ temperature has been observed.

T 11.4 Mon 16:45 Geb. 30.22: kl. HS B

**Module building and quality control for the ATLAS ITk strip sensor endcap** — •Elizaveta Sitnikova, Sergio Diez Cornell, Christian Sander, Sarah Heim, Serhat Ördek, Kunlin Ran, Céline Gerdts, Eric Hüpel, Lukas Bayer, and Sören Ahrens — DESY, Hamburg, Germany

The current ATLAS Inner Detector, which has both silicon and gaseous parts, will reach the end of its operating life at the end of LHC Run 3. Before the start of the next run it will be completely replaced by an all-silicon tracker (ITk). DESY plays a significant role in building one of the silicon strip endcaps in collaboration with multiple institutes worldwide. The endcaps, positioned at the forward regions of the detector, are designed to capture particle tracks with small angles with respect to the beam axis. Two out of six module types, used in the endcap, are built at DESY Hamburg, and later the final assembly of the endcap will also take place there. The process of building modules takes multiple steps and requires regular strict quality control. This presentation will focus on the individual steps of the module building process at DESY Hamburg and its quality control. This process involves high precision gluing with custom-made tooling and gluing robots, multiple optical metrology steps, and detailed electrical testing of the completed modules at different temperatures.

T 11.5 Mon 17:00 Geb. 30.22: kl. HS B

**A Silicon Pixel Tracker for $\mu$SR Experiments** — •Lukas Mandok for the HD-HVMAPS-Collaboration — Physikalisches Institut Universität Heidelberg

Muon spin rotation ($\mu$SR) is a long existing baseline technique in condensed matter research, facilitating the exploration of magnetic and superconducting phenomena. Traditional reliance on scintillator-based detectors, limited in rate and spatial resolution, hinders the investigation of novel quantum materials. The use of ultra-thin silicon pixel sensors for precise track reconstruction has the potential to revolutionize $\mu$SR spectrometry.

Recent advancements in this direction include the construction of a silicon based $\mu$SR spectrometer. It is comprised of four quad module layers made from MuPix11 sensors. Studies conducted at a polarized muon beamline at PSI, focusing on $\mu$SR samples, highlight the technology's promising capabilities. Preliminary results showcase muon spin precession measurements comparable to traditional techniques, while eliminating accidental background and enabling resolution of details on a 1 mm scale on the sample.

This technology shows great potential for efficient, high-rate investigations of multiple samples simultaneously, enhancing lateral resolution and even extending observation times.

T 11.6 Mon 17:15 Geb. 30.22: kl. HS B

**Characterization of the bi-phase CO2 cooling system MARTA for the ITk pixel detector Quality Control** — Klaus Desch, Matthias Hamer, •Dominik Hauner, Florian Hinterkeuser, Nico Klein, and Alexandra Wald — Physikalisches Institut der Universität Bonn

Due to the upgrade of the Large Hadron Collider (LHC) to the High-Luminosity-LHC, a significant upgrade of the ATLAS detector is required, including the complete replacement of the Inner Detector with the new Inner Tracker (ITk) silicon detector. The ITk consists of a silicon strip detector and a silicon pixel detector.

During production, several building blocks of the ITk pixel detector, the modules, services and local supports, will be combined into so-called Loaded Local Supports (LLS) at several institutes. The LLS will undergo a rigorous quality control (QC) process before being shipped to CERN, where they are integrated into the ITk. During operation, the LLS will be cooled with a bi-phase CO2 system. In order to avoid any contamination of the evaporators, such a system will also be used for the QC of the LLS.

At the University of Bonn, a MARTA CO2 cooling plant has been deployed for this purpose. In this talk I will present the results of a first characterization of MARTA in Bonn and discuss the cooling capacity in regards to the QC.

T 11.7 Mon 17:30 Geb. 30.22: kl. HS B

**Developments for tests with the ITk Pixel Outer-Barrel LLS QC setups** — •Hans Joos[1,2], Benedikt Vormwald[1], Stan Lai[2], and Leyre Flores Sanz De Acedo[1] — [1]CERN — [2]II. Physikalisches Institut, Georg-August-Universität Göttingen

For the upgrade of the LHC to the High-Luminosity LHC (HL-LHC), the ATLAS tracking detector will be replaced with an all-silicon detector, the Inner Tracker (ITk), as the higher luminosity requires radiation hard components. Given the close proximity to the interaction point, the environment is especially challenging for the pixel detector. The Outer-Barrel layers of the pixel detector will comprise quad chip modules that are combined into serially powered (SP) chains and loaded on ring and stave shaped low mass carbon-fibre local supports (LLS) to reduce the material budget of the detector.

The integration from individual detector components to a final detector is one of the big challenges of the HL-LHC detector upgrades. Five institutes will be integrating modules on an Outer Barrel local support and test this building block of the detector in a Quality Control (QC) setup in order to ensure the electrical and thermal performance of the LLS before being sent to the final integration stage of the ITk Pixel detector.

This talk will explain the developments for operating, controlling and monitoring of the QC setups and new approaches for deploying the necessary software components to many sites. A successful commissioning of the setups ultimately enables the project to move to preproduction of the LLSs.

T 11.8 Mon 17:45 Geb. 30.22: kl. HS B

**Design and Production of Pixel Strip Modules for the P2 Tracking Detector** — •Lucas Sebastian Binn for the P2-Collaboration — Institute of Nuclear Physics, Johannes Gutenberg-University Mainz, Germany

The P2 Experiment at the new Mainz Energy-Recovering Superconducting Accelerator (MESA), which is currently under construction in Mainz, will measure the weak mixing angle in electron-proton scattering at low momentum transfer with unprecedented precision.

A key parameter for the analysis, the momentum transfer $Q^2$, is measured by a tracking detector consisting of 4 identical modules arranged in two layers. Each module consists of two sensor planes, with pixel sensors glued and wire-bonded on rigid-flex strips. Different mechanical and electrical designs of the strip module are currently being evaluated. With a total production of 260 strips, processes are semi-automated, with dedicated glue and bonding machines.

This talk gives an overview of the P2 experiment with focus on the tracking detector, as well as the current state of the development of the strip modules.

# T 12: Detectors 1 (electronics)

Time: Monday 16:00–17:45 Location: Geb. 30.23: 2/1

T 12.1 Mon 16:00 Geb. 30.23: 2/1

**SIPM based cosmic muon detector wih FPGA implemented digitization** — •Erik Ehlert, Dmitry Eliseev, Carsten Presser, Markus Merschmeyer, and Thomas Hebbeker — III. Physikalisches Institut A, RWTH Aachen University

A cosmic muon hodoscope which is to be used as a reference detector was designed and is undergoing the first performance tests. This hodoscope consists of an array of scintillator strips which are each coupled to a pair of Silicon-Photomultipliers (SiPMs). The signal digitization is performed directly with a Field-Programmable Gate Array (FPGA). This is achieved by using a Multi-Voltage Thresholding (MVT) approach utilizing solely FPGA's internal comparators, effectively implementing a flash ADC. With this setup a sampling rate of 800 Megasamples per second is reached.

The talk provides an overview of the detector setup, including technical design and electronic readout chain. Performance characteristics of the detector are presented as well.

T 12.2 Mon 16:15 Geb. 30.23: 2/1

**Verification of the new CMS DT on-chamber electronics** — •Dmitry Eliseev, Matej Repik, Carsten Presser, Markus Merschmeyer, and Thomas Hebbeker — III. Physikalisches Institut A, RWTH Aachen University

The Compact Muon Solenoid (CMS) is undergoing the Phase 2 Upgrade, including improvements to the muon-detecting drift tube chambers (DT). The upgrade involves replacing the legacy on-chamber DT electronics with the recently developed On-Board Drift Tube (OBDT) electronics. While moving towards the production and assembly phase, comprehensive quality assurance for the new OBDT electronics gains priority. The CMS DT collaboration developed instruments for testing and verification of the new electronics. These instruments will be deployed at different sites throughout the CMS DT collaboration. This talk gives an overview of the verification setups and methods and presents some initial verification results.

T 12.3 Mon 16:30 Geb. 30.23: 2/1

**Irradiation test campaign on the CMOS LDO components for the ATLAS sMDT on-detector electronics for the HL-LHC Phase-II Upgrade** — Sergey Abovyan, Nayana Bangaru, •Francesco Fallavollita, Markus Fras, Oliver Kortner, Sandra Kortner, Hubert Kroha, Robert Richter, and Elena Voevodina — Max Planck Institut für Physik - Werner Heisenberg Institute, München, Germany

The Muon System of the ATLAS experiment at CERN LHC will be upgraded for the high-luminosity phase of LHC to cope with higher rates and higher radiation levels. Most of the Muon-System on-detector electronics will be replaced. Commercial low-dropout (LDO) voltage regulators have been considered as a robust, low-noise and economic solution to power distribution in the ATLAS sMDT front-end electronics for the HL-LHC Phase-II Upgrade. The LDO components should be selected based on their capability to comply to radiation requirements. For this reason, radiation hardness studies have been extensively performed on different production batches of CMOS LDOs, by constantly monitoring online the relevant parameters during the TID and SEE irradiation test. Irradiations were performed in the Cobalt-60 facility at CERN (Geneva), to test resistance to the TID effects, and at the Proton Irradiation Facility 230 MeV proton beam at PSI (Zurich), to test SEE effects. Additionally, a post radiation accelerated annealing test has been performed on the irradiated samples in order to study any potential long term effects. The experimental setup and the results are presented and discussed in this communication.

T 12.4 Mon 16:45 Geb. 30.23: 2/1

**Towards a High-Performance Readout System for the CMS High Granularity Calorimeter** — •Fabian Hummer, Luis Ardila, and Frank Simon — Karlsruhe Institute of Technology

For the upcoming high-luminosity LHC, the endcap calorimeters of the CMS experiment will be replaced by the high granularity calorimeter (HGCAL), one of the most ambitious detector projects undertaken. Due to the extremely high number of readout and trigger channels, in combination with a high event rate and pile-up, HGCAL requires a high-performance, FPGA-based readout system. Collaborating closely with CERN, DESY and Imperial College London, the CMS group at the Institute for Data Processing and Electronics (IPE) at KIT contributes both to development of firmware and software for the readout and control of HGCAL, as well as to the design of the new Serenity-S1 hardware. In this contribution I will discuss how we address the challenges in data readout that we are facing for HGCAL, and highlight the contributions from IPE at KIT.

T 12.5 Mon 17:00 Geb. 30.23: 2/1

**Code-driven analog design for detector readout ASICs** — •Kennedy Caisley, Marco Vogt, Hans Krüger, and Jochen Dingfelder — University of Bonn, Bonn, Germany

Readout integrated circuits for pixelated radiation detectors have experienced a renaissance in the past two decades, with over 50 full-reticle chip designs reported in the HEP and photon science communities alone. The adoption of smaller process nodes (from 350 nm down to 28 nm) has generally improved performance, density, and power efficiency; but at the cost of increased design effort.

This talk describes workflows using programming languages like Python, C++, and Rust to design analog readout circuits. Procedural-style code is well-suited for automating 'bottom-up' tasks like schematic device sizing, layout generation, and analysis of SPICE simulation, while 'top-down' optimization routines suitably formalize constraints like silicon area and power consumption.

T 12.6 Mon 17:15 Geb. 30.23: 2/1

**Investigation of the Belle II Pixel Detector Power Supply Network** — Patrick Ahlburg, Florian Bernlochner, Jochen Dingfelder, Hans Krüger, •Botho Paschen, and Paula Scholz — University of Bonn

The Belle II PiXel Detector (PXD) is based on modules with DEpleted P-channel Field Effect Transistor (DEPFET) sensors. Each module is powered by 23 dedicated power supply channels. Since the Power Supplies (PS) are located outside the Belle II detector, 15 m long cables and several decoupling capacitor stages are necessary in the powering path.

To better protect modules in case of beam loss events an active shutdown procedure is proposed. In addition to PS regulators shutting down, nets on the PS side are actively shorted by switches to reduce voltage settling times.

Because of the complicated powering path structure a dedicated characterization and simulation of all system components is necessary for a successful implementation of the active shutdown. The status of the investigations using different measurement and simulation tools (a.o. time domain reflectometry, network analyzer, LTspice, HyperLynx) are presented in this talk.

T 12.7 Mon 17:30 Geb. 30.23: 2/1

**New amplifier-shaper discriminator chip in 65 nm CMOS technology for small-diameter muon drift-tube chambers at future hadron colliders** — •Nayana Bangaru, Sergey Abovyan, Francesco Fallavollita, Oliver Kortner, Sandra Kortner, Hubert Kroha, Giorgia Proto, Robert Richter, Elena Voevodina, and Yazhou Zhao — Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), Garching, Germany

Small-diameter muon drift tubes (sMDT) are used for large area muon detection in the ATLAS experiment at HL-LHC and have been proposed for muon tracking and triggering at future hadron collider experiments. sMDTs have been shown to operate with high spatial resolution and efficiency up to a gamma background count rate of 30 kHz/cm$^2$. The background count rates in the muon systems at Future Circular Colliders like the FCC-hh are expected to be 10 kHz/cm$^2$ for $|\eta| \leq 2.0$ and up to 25 kHz/cm$^2$ at $|\eta| \approx 2.5$.

With the new ATLAS ASD chip for operation at HL-LHC, a single tube resolution of 150 micrometers is reached at a counting rate of about 7 kHz/cm$^2$. In order to achieve the required muon angular resolution of 70 $\mu$rad at the FCC-hh, the spatial resolution needs to be improved by suppressing signal pile-up. A new ASD chip in 65nm CMOS technology has been developed with faster baseline recovery which improves the spatial resolution and increases the efficiency at high rates by reducing the dead time by 50%. Performance of the new chip was tested on a sMDT chamber at the CERN GIF++ gamma irradiation facility in comparison with the ATLAS chip.

# T 13: Detectors 2 (scintillators, other)

Time: Monday 16:00–18:00 Location: Geb. 30.23: 2/17

T 13.1 Mon 16:00 Geb. 30.23: 2/17

**A novel cryogenic VUV spectrofluorometer for the characterization of wavelength shifters for the LEGEND-200 experiment** — •Andreas Leonhardt[1], Maximilian Goldbrunner[1], Brennan Hackett[2], and Stefan Schönert[1] — [1]Technical University of Munich, TUM School of Natural Sciences, Garching, Germany — [2]Max Planck Institute for Physics, Garching, Germany

We present a novel cryogenic VUV spectrofluorometer designed to characterize wavelength shifters (WLS) crucial for experiments based on liquid argon (LAr) scintillation light detection. Wavelength shifters like tetraphenyl butadiene (TPB) or polyethylene naphthalate (PEN) are used in these experiments to shift the VUV scintillation light to the visible region. Precise knowledge of the optical properties of the WLS at LAr temperature (87 K) and LAr scintillation wavelength (128 nm) is necessary to model and understand the detector response. The cryogenic VUV spectrofluorometer was commissioned to measure the emission spectra and relative wavelength shifting efficiency (WLSE) of samples between 300 K and 87 K for VUV (128 nm to 190 nm) and UV (310 nm) excitation. The TPB-based wavelength shifting reflector (WLSR) and amorphous PEN featured in the neutrinoless double-beta decay experiment LEGEND-200 were characterized as part of this work. A first measurement of their relative WLSE and emission spectrum at RT and 87 K is presented. Lastly, the response of the wavelength-shifting fibers used in LEGEND-200 to visible blue excitation is studied. This research is supported by the DFG through the Excellence Cluster ORIGINS and the SFB1258.

T 13.2 Mon 16:15 Geb. 30.23: 2/17

**Opaque Scintillator for Neutrino Physics** — Christian Buck[1], Benjamin Gramlich[1], and •Stefan Schoppmann[2] — [1]Max-Planck- Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]JGU Mainz, Exzellenzcluster PRISMA$^+$, Detektorlabor, Staudingerweg 9, 55128 Mainz, Germany

A new scintillator system was developed based on admixtures of wax in organic scintillators. The opacity and viscosity of this gel-like material can be tuned by temperature adjustment and wax concentration. Whereas it is a colourless transparent liquid at temperatures above 40°C, it has a milky wax structure below.

Due to its light confinement, the scintillator system is expected to exhibit unprecedented particle ID via the topology of energy depositions. Moreover, a high degree of metal loading is feasible.

In this presentation, the production and properties of such a scintillator as well as its advantages compared to transparent liquids are described.

T 13.3 Mon 16:30 Geb. 30.23: 2/17

**Spectral Measurements of Liquid Scintillators for a LiquidO Detector System** — •Anatol Tunc, Alfons Weber, and Stefan Schoppmann — Johannes Gutenberg-Universität Mainz

LiquidO denotes an international consortium focusing on a new approach for liquid scintillation detectors (LSDs). In contrast to conventional methods striving for maximum transparency with light readout outside of the detection volume, the LiquidO ansatz utilises a deliberate opacity of the scintillator medium by means of reducing the scattering length via wax loading. The effective confinement of scintillation light around interaction vertices results in a particle specific topology of so-called 'light balls'. Local light readout by a dense array of wavelength shifting fibres running through the detector medium thus enables unprecedented spatial resolution and particle identification/discrimination for LSDs in the MeV range. This talk presents research efforts with a variety of scintillator solvents, wavelength shifters and combinations thereof considering employment in a LiquidO detector system. The research includes emission and absorption spectra, light yield measurements to estimate the response to monoenergetic gammas as well as the development of a small scale LiquidO detector enabling local testing of scintillator performance.

T 13.4 Mon 16:45 Geb. 30.23: 2/17

**Development of a Precision Characterization Facility based on a Tagged 252Cf Neutron Source for Novel Scintillation Materials** — Hans Steiger[1,2], •E. Fischer[1], U. Fahrendholz[1], L. Kayser[1], L. Oberauer[1], and M. R. Stock[1] — [1]Physik-Department, Technische Universität München, James-Franck-Str. 1, 85748 Garching — [2]Johannes Gutenberg University Mainz, Cluster of Excellence PRISMA+, Staudingerweg 9, 55128 Mainz

The techniques used to search for dark matter particles or detect neutrinos usually require the detection of a secondary recoiling nucleus in a detector to indicate the rare collision of such a particle with a nucleus. Therefore, neutrons are ideal probes to study the response of these detection media. For this R&D work, particle accelerator-driven neutron sources are usually used, which allow neutrons and gamma radiation to be distinguished by the Time-of-Flight (ToF) method. The aim of the work presented here was to develop a setup that can be operated on a lab scale and without a particle accelerator. Therefore, a fission-neutron time-of-flight experiment was realized. Several liquid scintillators for future kt-scale neutrino detectors were already irradiated and the neutron spectrum of the 252Cf source characterized. In this talk, the current status and perspectives of this facility is presented. This work has been supported by the Cluster of Excellence PRISMA+, the Cluster of Excellence ORIGINS as well as the Collaborative Research Center Neutrinos and Dark Matter in Astro- and Particle Physics (SFB1258) and the DFG Research Units 2319 and 5519.

T 13.5 Mon 17:00 Geb. 30.23: 2/17

**The "LowRad"-project's cryogenic radon distillation column and heat pump development** — •Philipp Schulte, Lutz Althüser, Volker Hannen, Christian Huhmann, David Koke, Andria Michael, Patrick Alexander Unkhoff, Daniel Wenz, and Christian Weinheimer — Institute for Nuclear Physics, University of Münster

In sense of continuous background reduction in dark matter research, the ongoing "LowRad"-project aims to develop the technology for the next generation of radon and krypton distillation columns. To achieve the science goals of future dark matter detector it is required to reduce the concentration of radon in a 40-tonne liquid xenon detector to less than <0.1 $\mu$Bq/kg - an approximately tenfold reduction compared to the XENONnT limit of 0.8 $\mu\mu$Bq/kg. To attain this reduction, the throughput flow of the column must be increased to 750 kg/h, necessitating 21 kW power in both the evaporation of xenon during the thermal separation process and the reliquefaction of radon-depleted xenon. Therefore, a heat pump concept is needed hermetically separated from the primary circuit of the column. This talk will highlight the theoretical design, projected performance, and initial laboratory setups of this heat pump system.

Acknowledging the support of the ERC AdG project "LowRad" (101055063).

T 13.6 Mon 17:15 Geb. 30.23: 2/17

**Designing cryogenic distillation systems for xenon using new calculation and visualisation tools** — •Patrick Alexander Unkhoff, Lutz Althüser, Volker Hannen, Christian Huhmann, David Koke, Andria Michael, Philipp Schulte, Daniel Wenz, and Christian Weinheimer — Institute for Nuclear Physics, University of Münster

In recent years cryogenic distillation of xenon has proven to be an effective way of reducing the intrinsic radioactive background for rare-event searches. This has been employed in the direct detection of weakly interacting massive particles (WIMPs) to remove the natural occurring isotopes $^{85}$Kr and $^{222}$Rn. Future experiments, such as DARWIN and XLZD, will rely on further reduction.

For this purpose, the core principles behind cryogenic distillation are revisited. Here, the differences in vapor pressure between xenon and the contaminant enable separation by repeated evaporation and condensation. The required number of such stages can be determined using the McCabe-Thiele method as well as a modified version to take advantage of the radioactive decay. Therefore, an interactive tool was developed to obtain prompt solutions using these methods.

However, further challenges in the distillation of xenon are posed by the required cryogenic temperatures. To drastically reduce the amount of external cooling as well as subsequent reheating, an energy-efficient heat pump concept is used. Consequently, another user-friendly tool was developed to solve the complex systems of equations for such thermodynamic systems.

T 13.7 Mon 17:30 Geb. 30.23: 2/17

**A Xenon Cryogenic Distillation System for Krypton Removal in Next-Generation Dark Matter Experiments** — •David Koke, Lutz Althüser, Volker Hannen, Christian Huhmann, Andria Michael, Philipp Schulte, Patrick Alexander Unkhoff, Daniel Wenz, and Christian Weinheimer — Universität Münster, Germany

Future dark matter experiments, such as DARWIN and XLZD, rely on liquid xenon detectors to probe WIMPs down to the neutrino fog. The prerequisite for the success of these experiments is a very low background, and therefore a very low krypton concentration. The LowRad project aims at developing a compact all-in-one xenon purification system for krypton, radon and electronegative impurities. The system's key components include a distillation column for continuous online removal requiring a secondary distillation column as a concentrator, reaching a Kr concentration of below 30 ppq $^{nat}$Kr/Xe. This innovative approach enables a reduction of the amount of offgas and an increase of the offgas concentration, both by a factor of 1000 in comparison to XENONnT, effectively achieving quasi-lossless operation. This krypton removal system paves the way for achieving the ultra-low backgrounds demanded by next-generation dark matter experiments. This work is supported by the ERC AdG project "LowRad" of C. Weinheimer (No. 101055063).

T 13.8 Mon 17:45 Geb. 30.23: 2/17

**Fast neutron production at the LNL Tandem from the 7Li(14N,xn)X reaction** — •Hans Steiger[1,2], P. Torres-Sanchez[3], P. Mastinu[4], M. R. Stock[1], L. Oberauer[1], and I. Porras[3] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department, James-Franck-Str. 1, 85748 Garching, Germany — [2]Cluster of Excellence PRISMA+, Johannes Gutenberg University Mainz, Staudingerweg 9, 55128 Mainz, Germany — [3]Dept. Atomic, Molecular and Nuclear Physics, University of Granada, Spain — [4]Istituto Nazionale di Fisica Nucleare, Legnaro Division, viale dell Universit'a 2, 35020 Legnaro, Italy

Fast neutron sources are of importance not only for basic nuclear physics. The list of other fields of applications includes: dosimetry, neutron detector development, fast neutron oncology, radiation protection shielding materials for accelerator based oncology and Space missions, and the study of single-neutron induced effects in digital and power electronics. This talk introduces fast neutron production using a XTU tandem accelerator at the INFN-LNL, via an 90 MeV beam of 14N6+ onto a lithium target. The commissioning results show clear agreement of the measured spectra with FLUKA simulations. The neutron spectrum is centered around the 8 MeV range with mild tails, and a maximum neutron energy above 50 MeV. This work has been supported by the Clusters of Excellence PRISMA+ and ORIGINS as well as the Collaborative Research Center SFB1258. Moreover, we are grateful for the support from the DFG Research Units 2319 and 5519.

## T 14: Detectors 3 (muon detectors)

Time: Monday 16:00–17:45 Location: Geb. 30.23: 3/1

T 14.1 Mon 16:00 Geb. 30.23: 3/1

**The CMS Muon DT System in Run 3 : Overview & Summary** — •Archana Sharma, Thomas Hebbeker, Kerstin Hoepfner, Markus Merschmeyer, Hans Reithler, and Dmitry Eliseev — III. Physikalisches Institut A, RWTH Aachen University

A high-performance muon detector system is crucial to realise the physics goals of the CMS experiment at the LHC, achieved by the highly efficient muon spectrometer, consisting of different detector technologies across different pseudorapidity ($\eta$) regions. The CMS Drift Tube (DT) chambers instrument the return yoke of CMS, being responsible for identifying, measuring, and triggering on muons in the barrel acceptance region. DTs have been running smoothly in the first two years of Run 3 with negligible contribution to the downtime/luminosity loss during the data-taking, while showing the same excellent detector performance as in Run 2. In addition, to withstand the challenging conditions of increased instantaneous luminosity and higher pileup expected during the high-luminosity LHC (HL-LHC) operation, the DT system plans for an upgrade of its electronics which will be implemented during long shutdown (LS) 3. The operation summary and performance study of the DT system carried out using the first dataset collected at a collision energy of 13.6 TeV in 2022 & 2023 is reported in this presentation. In addition, the ongoing activities for the preparation of LS 3 upgrade are summarised in brief.

T 14.2 Mon 16:15 Geb. 30.23: 3/1

**New small diameter Muon Drift Tube (sMDT) Chambers and new MDT Front End Electronics for the Phase 2 Muon System Upgrade of the ATLAS Detector** — •Daniel Buchin, Alice Reed, Elena Voevodina, Francesco Fallavollita, Oliver Kortner, and Hubert Kroha — Max-Planck-Institut für Physik

In order to improve the muon trigger efficiency and the rate capability of the ATLAS muon detectors for operation at the high luminosity upgrade of the Large Hadron Collider (HL-LHC), the Monitored Drift Tube (MDT) tracking chambers in the innermost barrel layer of the ATLAS Muon Spectrometer will be replaced by small-diameter Muon Drift Tube (sMDT) chambers. In addition, the electronics of the remaining MDT chambers has to be replaced by a new version able to cope with the trigger and data rates at the HL-HC. New Amplifier-Shaper-Discriminator (ASD) and new TDC chips have been developed for the new (s)MDT front-end electronics boards designed at MPP.

The sMDT chambers were in serial production between January 2021 and December 2022 at the MPP Munich. In this talk, the steps for the drift tube production and chamber construction will be presented. The stringent quality control program that assured the reliability and high mechanical precision of the chambers will be discussed as well. This includes tests of individual drift tubes, several mechanical measurements and the final certification using cosmic muons. Finally, the status of the new (s)MDT electronics designed at MPP will be discussed.

T 14.3 Mon 16:30 Geb. 30.23: 3/1

**Impact of chamber deformations of the ATLAS' New Small Wheel on muon reconstruction performance** — •Stefanie Götz[1], Otmar Biebel[1], Valerio D'Amico[1], Ralf Hertenberger[1], Eshita Kumar[1], Roman Lorenz[1], Katrin Penski[1], Nick Schneider[1], Patrick Scholer[2], Chrysostomos Valderanis[1], and Fabian Vogel[1] — [1]LMU München — [2]Carleton University Ottawa

Previous studies demonstrate that the New Small Wheel (NSW) chambers' residual misalignment originating from measurement uncertainties of the alignment system is small enough to allow muon reconstruction with sufficient accuracy for CERN's high luminosity upgrade of the Large Hadron Collider (LHC). However, deformations and heat expansions were assumed to have subordinate effect compared to chamber translations and rotations but they actually might have a contribution that will become relevant for further improvement of the muon momentum measurement. This study therefore investigates the behaviour of alignment uncertainties from deformations/expansions on Monte Carlo samples generated by the simulation software of the ATLAS experiment with regard to their translational/rotational equivalents/compositions. A realistic estimation for the residual uncertainties of the parameters describing deformations/expansions allows finally to evaluate the overall impact on the muon reconstructed performance.

T 14.4 Mon 16:45 Geb. 30.23: 3/1

**Certification of sMDT chambers for the phase II upgrade of the ATLAS muon spectrometer** — •Nick Meier, Oliver Kortner, Hubert Kroha, Elena Voevodina, Francesco Fallavollita, and Giorgia Proto — MPI für Physik, München, Deutschland

For operation at the HL-LHC, the ATLAS experiments will upgrade the inner muon spectrometer barrel layer with stations of thin-gap resistive plate chambers (RPCs) and small diameter muon drift-tube (sMDT) chambers in order to increase the acceptance of the first level muon trigger from current 80% to 95% and prevent deterioration of the spatial resolution and tracking efficiency due to high background irradiation. The MPI for Physics in Munich produced 48 sMDT chambers for this upgrade. The performance of 39 chambers after transportation to CERN was measured with cosmic-ray muons: electronics noise, muon detection efficiency, and the spatial resolution of all chambers were determined. The methods used for the certification and the results of the tests will be explained in this presentation and will be compared to the initial test campaign at MPI for Physics.

T 14.5 Mon 17:00 Geb. 30.23: 3/1

**Development of a cosmic muon and neutron veto system for IAXO and BabyIAXO** — •Dhruv Chouhan, Elisa Ruiz Choliz, and Matthias Schott — Johannes Gutenberg University, Mainz, Germany

The International Axion Observatory (IAXO) experiment is a large-scale helioscope aimed at searching for axions and axion-like particles (ALPs) produced in the Sun. As a first step, the BabyIAXO was proposed as a smaller scale helioscope that will reach a sensitivity on the axion-photon coupling of 1.5 x 10 $^{-11}$Gev$^{-1}$ for masses up to 0.25 eV, covering a very interesting region of the parameter space. To detect the axion signal, a very low background x-ray detector design is required. This talk will focus on the simulation and hardware developments of the BabyIAXO veto system for cosmic rays based on light-guided organic plastic scintillators with Silicon Photo Mutiplier (SiPM) sensors.

T 14.6 Mon 17:15 Geb. 30.23: 3/1

**Study of cosmogenic backgrounds in the JUNO pre-detector OSIRIS** — •Marcel Büchner, Arshak Jafar, George Parker, Michael Wurm, Oliver Pilarczyk, and Tim Charisse — Johannes Gutenberg-University Mainz, Institute of Physics and EC PRISMA+

OSIRIS as the pre-detector of the JUNO reactor neutrino measurement, is meant to monitor the radio-purity of the scintillator used. The monitoring of the scintillators radio-purity relies on an in- situ measurement of radioactive decays in the 20-ton scintillator volume. Therefore, the scintillator volume is surrounded by 500 tons of water for external shielding and all detector materials have been carefully selected for radiopurity. To ensure that the background is as low as possible, OSIRIS is located approximately 700m under- ground. Even at that depth, a relevant level of background events originates from cosmic muons, which not only cause a signal themselves but they can interact with the detector material and cause the creation of radioactive isotopes. This talk presents the ongoing work of the implementation of a muon veto for OSIRIS. Utilizing an array of 12 PMTs mounted in the OSIRIS water tank but also the distinctive timing signal of muon tracks. Based on the tagging of these muons and using spatial and temporal correlations, cosmogenic neutrons and radioactive isotopes (e.g. C-11) can be identified. This Project is funded by the DFG Research Unit FOR 5519.

T 14.7 Mon 17:30 Geb. 30.23: 3/1

**Plans for a neutron tagger for LEGEND-1000** — •Eric Esch for the LEGEND-Collaboration — University Tuebingen

The **L**arge **E**nriched **G**ermanium **E**xperiment for **N**eutrinoless $\beta\beta$ **D**ecay (LEGEND) is a ton-scale experimental program designed to probe the neutrinoless $\beta\beta$ ($0\nu\beta\beta$) decay of $^{76}$Ge with a discovery sensitivity at half-life of more than $10^{28}$ years. To reach such a sensitivity, the background goal is less than $10^{-5}$ cts/(keV·kg·yr). Previous Monte Carlo studies for the GERDA experiment at LNGS identified the delayed decays of $^{77}$Ge and its metastable state $^{77m}$Ge as dominant cosmogenic background. In addressing the cosmogenic production of radioactive isotopes the potential implementation of a neutron detection system is explored. This neutron tagger will be integrated into the Water-Cherenkov-Veto. The design as well as the effects of Gadolinium on the detection efficiency is optimized using Monte Carlo simulations..

# T 15: Neutrino astronomy 1

Time: Monday 16:00–18:00 Location: Geb. 30.23: 6/1

T 15.1 Mon 16:00 Geb. 30.23: 6/1

**Directional solar neutrino analysis in JUNO** — •Marco Malabarba[2,3,1], Livia Ludhova[1,3], Yury Malyshkin[2,1], Cristobal Morales Reveco[2,3,1], Mariam Rifai[1,3], Luca Pelicci[1,3], Hexi Shi[2,1], and Apeksha Singhal[1,3] — [1]Institut für Kernphysik, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [3]III. Physikalisches Institut B, RWTH Aachen University, 52062 Aachen, Germany

JUNO (Jiangmen Underground Neutrino Observatory) is a multipurpose neutrino physics experiment currently under construction in China. Its target consists of 20 kton of organic liquid scintillator. The optical photons are collected by photomultiplier tubes (PMTs) which provide a geometrical coverage of 78%. Thanks to its unprecedented features, JUNO is a perfect candidate to study solar neutrinos. Solar neutrinos mainly interact through elastic scattering reactions with liquid scintillator electrons. Hence, all the beta-like decays of unstable nuclei are backgrounds. The Correlated and Integrated Directionality (CID) analysis, developed by Borexino, can be exploited to statistically separate signal and background events. CID relies on the directionality of the fast Cherenkov light: the PMT hits caused by Cherenkov photons exhibit a correlation with the Sun's position only for solar neutrino events. Our studies show that, in JUNO, the combination of the CID and the spectral analyses (which exploits the different energy spectral shapes of signals and backgrounds) could yield the most precise measurement of 7Be and CNO solar neutrinos ever achieved.

T 15.2 Mon 16:15 Geb. 30.23: 6/1

**Improving DSNB Event Detection at JUNO: Advancements Through 3D Convolutional Neural Networks** — •David Maksimović[1], Daniel Tobias Schmid[1], Dhaval J. Ajana[2], Michael Wurm[1], Marcel Büchner[1], Arshak Jafar[1], George Parker[1], Oliver Pilarczyk[1], and Tim Charisse[1] — [1]Johannes Gutenberg-University Mainz, Institute of Physics — [2]Department of Physics, Florida State University, Tallahassee, FL 32306, USA

The detection and analysis of the Diffuse Supernova Neutrino Background (DSNB) pose a significant challenge in neutrino astronomy, primarily due to backgrounds mimicking the Inverse Beta Decay (IBD) signature events. The Jiangmen Underground Neutrino Observatory (JUNO) uses a liquid scintillator to detect these neutrinos, especially challenged by Neutral-Current (NC) interactions of atmospheric neutrinos in the 12 to 30 MeV range.

In this talk, we introduce a novel method employing 3D Convolutional Neural Networks (3D CNNs) for better discrimination of DSNB events from these backgrounds. This technique analyses time-sequenced data from photomultiplier tube (PMT) hit patterns, arranged in frames like a movie, capturing the spatial-temporal dynamics of particle interactions. Simulation studies within the JUNO detector environment show our 3D CNN method significantly improves background reduction. Compared to previous applied machine learning methods, our approach shows a 30% reduction in background levels and a 17% improvement in detection accuracy.

T 15.3 Mon 16:30 Geb. 30.23: 6/1

**Spectrum unfolding for Core-Collapse Supernova neutrinos in JUNO** — •Thilo Birkenfeld, Achim Stahl, and Christopher Wiebusch — III. Physikalisches Institut A RWTH Aachen, Sommerfeldstraße 16, 52074 Aachen

Since the Supernova of 1987, no core-collapse supernova (CC-SN) has exploded close enough to be observed by terrestrial neutrino telescopes. The Jiangmen Underground Neutrino Observatory (JUNO) is a next-generation liquid scintillator detector with a large target mass of 20 kton. It will provide valuable insight into the details of the CC-SN mechanism by observing the neutrino burst of a galactic CC-SN with high statistics and an unpreceded visible energy resolution of 3 % @ 1 MeV. JUNO will be sensitive to signals from all neutrino flavors via different detection channels. We present a Bayesian-based energy spectrum unfolding for three effective neutrino flavors using an optimized event classification.

T 15.4 Mon 16:45 Geb. 30.23: 6/1

**Detection of solar pp neutrinos with the OSIRIS upgrade** — •Tim Charissé, Marcel Büchner, Arshak Jafar, George Parker, Oliver Pilarczyk, and Michael Wurm — Johannes Gutenberg-University Mainz, Institute of Physics and EC PRISMA+

The OSIRIS detector will monitor the radiopurity of the scintillator during the filling of JUNO. After it has fulfilled this purpose, it can be upgraded for the measurement of solar pp neutrinos on its own. Here, the comparatively small size of its scintillator volume poses an advantage, as it enables the use of a liquid scintillator with an ultra-low abundance of $^{14}$C, the main background source in the pp neutrino energy region. Further upgrades include additional shielding, the use of a slow scintillator, additional PMTs and the installation of reflective light cones, which will result in an excellent photo electron yield. This talk will present the results of recent sensitivity studies on the feasibility of measuring pp neutrinos with the OSIRIS upgrade through a spectral fit and the analysis method called Correlated and Integrated Directionality. The latter makes use of the directional information of the Cherenkov light over a cumulative approach. The spectral fit is expected to yield a measurement of the pp neutrino rate with a sensitivity on the 3.5% level within 5 years, significantly better than the current best experimental measurements. This work is supported by the DFG Research Unit FOR 5519.

T 15.5 Mon 17:00 Geb. 30.23: 6/1

**Development of the First Detector Line for the Pacific Ocean Neutrino Experiment** — •Charlotte Eberhart, •Lea Ginzkey, Simeon Bash, Martin Dinkel, Vincent Gousy-Leblanc, Elisa Resconi, and Christian Spannfellner — Technical University of Munich, TUM School of Natural Sciences, Department of Physics, James-Franck-Straße 1, D-85748 Garching bei München, Germany

The Pacific Ocean Neutrino Experiment (P-ONE) aims to be a multi-cubic-kilometre neutrino observatory of the Northeast Pacific Ocean off the coast of Vancouver Island (Canada). P-ONE will measure high-energy astrophysical neutrinos and characterize the nature of astrophysical accelerators. Currently, its first detector line (P-ONE-1) is in production and planned to be deployed in 2025. The one kilometre long line consists of 20 optical and calibration modules and shall serve as a prototype line for the detector, and ultimately be the blueprint for the following detector lines. The optical modules (P-OMs) aim to detect bioluminescence and Cherenkov light with a multi photo-multiplier tube (PMT) configuration. The multi-PMT design of P-OM allows to cope with the high background rates in the depths of the Northeast Pacific Ocean, while their modular and minimal mechanical design makes them easily scalable in vision of the construction of the full P-ONE detector. In this contribution, we will present an overview over the P-ONE-1 design and the production process of the P-OMs.

T 15.6 Mon 17:15 Geb. 30.23: 6/1

**Production of the Precision Optical Calibration Module (POCAM)** — •Patrick Schaile, Leonhard Eidenschink, and Andrii Terliuk — Technical University of Munich, TUM School of Natural Sciences, Department of Physics, James-Franck-Straße 1, D-85748 Garching bei München, Germany

In the context of the IceCube Upgrade, which mainly aims to improve and extend the scientific capabilities of the IceCube Neutrino Observatory, a Precision Optical Calibration Module, the POCAM, has been developed. It is an isotropic, self-monitoring calibration light source, which will be deployed into the Antarctic ice as a new part of the detector and is meant to investigate and determine the optical detector systematics to high precision. The improved knowledge on parameters like absorption or scattering length will eventually lead to likewise improved detector sensitivity and data analyses. Currently the project is in the production and calibration stage, in which the necessary parts of the devices are either produced or combined respectively to its required functional units which are eventually tested and calibrated. In total there will be 21 POCAMs used in IceCube, while the first devices will be ready for deployment in 2024.

T 15.7 Mon 17:30 Geb. 30.23: 6/1

**Searching for sub-TeV neutrino counterparts with IceCube for sub-threshold Gravitational Wave events** — •Tista Mukherjee for the IceCube-Collaboration — Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

The IceCube Neutrino Observatory, located in the Antarctica, has been actively participating in multi-messenger follow-up of Gravitational Wave events since the first observation run of the LIGO-Virgo collaboration. LIGO-Virgo now also provides sub-threshold gravitational wave (GW) candidate information publicly, since the release of the Gravitational Wave Transient Catalog GWTC-2.1. Using these sub-threshold GW candidates for multi-messenger studies complements the ongoing efforts to identify neutrino counterparts to GW events. Here, we present the current status of the ongoing archival studies with the sub-TeV neutrinos detected by the dense-infill array of IceCube, known as DeepCore. We have performed a selection of the sub-threshold GW candidates from GWTC-2.1 and GWTC-3. Neutrino counterparts are looked for using Unbinned Maximum Likelihood method. We report the 90% C.L. sensitivities and the $3\sigma$ discovery potential of this sub-TeV neutrino dataset for each selected sub-threshold GW candidate, considering spatial and temporal correlation between the GW and neutrino events within a 1000 s time window.

T 15.8 Mon 17:45 Geb. 30.23: 6/1

**Gravitational Wave Follow-up of Ultra-High Energy Neutrinos with the Pierre Auger Observatory** * — •Therese Paulsen for the Pierre-Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal, Germany

Primarily designed to detect ultra-high energy (UHE) cosmic rays, the Pierre Auger Observatory also possesses excellent sensitivity to UHE neutrinos. The Surface Detector array is used to search for highly inclined neutrino-induced air showers, which, though not observed yet, have clear characteristic signatures. Follow-up searches of UHE neutrinos in Gravitational Wave (GW) events are of unique scientific interest.

The fourth observational run (O4) by the gravitational wave network LIGO-Virgo-KAGRA of interferometric detectors started in May 2023. With the substantial increase in sensitivity in the O4 run, a higher frequency of GW alerts is expected. This creates a need for the development of software to reply to the General Coordinates Network (GCN) circulars. This talk presents the work being done by the Pierre Auger Collaboration to get an automated response to these GCN notices. Following the alerts, a specific analysis is conducted to calculate a one-day fluence limit for a point source, in the case no neutrino candidate was identified.

**Supported by BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)*

# T 16: Data, AI, Computing 1 (anomaly detection)

Time: Monday 16:00–18:00 Location: Geb. 30.33: MTI

T 16.1 Mon 16:00 Geb. 30.33: MTI

**Anomaly Detection Using Autoencoders in Belle II Data** — •David Giesegh, Nikolai Hartmann, and Thomas Kuhr — Ludwig-Maximilians-Universität München

At Belle II the search for Beyond the Standard Model (BSM) Physics is an ongoing effort that concentrates mostly on dedicated searches inspired by specific BSM models. Since new effects might be hidden in unexpected observables or correlations thereof, these searches should be complemented by model agnostic methods. For this purpose we explore the application of machine learning models, especially autoencoders, for automated anomaly detection in Belle II data. The main idea is to train a model to compress preprocessed event data and use how well the compression works as an indication for how anomalous an event is. As proof of concept, preliminary results of this method on simulated data scenarios will be presented.

T 16.2 Mon 16:15 Geb. 30.33: MTI

**VAE-based anomaly detection in dijet events at $\sqrt{s} = 13$ TeV** — •Aritra Bal[1], Benedikt Maier[1], Thea Aarrestad[2], Javier Duarte[3], Markus Klute[1], Jennifer Ngadiuba[4], Maurizio Pierini[5], Kinga Wozniak[5], and Irene Zoi[4] — [1]Karlsruhe Institute of Technology — [2]University of Zurich — [3]University of California, San Diego — [4]Fermi National Accelerator Laboratory — [5]CERN

The reconstruction loss of an autoencoder can serve as a generic discriminator enabling anomaly searches. As part of the CMS Anomaly Search Effort (CASE), we present an approach for unsupervised anomaly detection in dijet events, by combining a variational autoencoder (VAE) with a novel technique for decorrelating the anomaly metric (i.e the autoencoder loss) from the dijet mass using a deep Quantile Regression. The resulting unsculpted spectra are then used to perform a bump hunt search that is sensitive to a range of narrow and broad signal resonances.

T 16.3 Mon 16:30 Geb. 30.33: MTI

**Deep neural network reconstruction of muon densities from measurements of the underground muon detector of the Pierre Auger Observatory** — •Anton Poctarev for the Pierre-Auger-Collaboration — Karlsruhe Institut für Technologie Campus Nord, Geb. 425, Eggenstein-Leopoldshafen

Ultra-High Energy Cosmic Rays (UHECRs) are the most energetic particles discovered by mankind. They are of high interest and their sources and the means by which they are accelerated remain undetermined. To get a clearer picture of UHECRs, it is integral to determine the mass of each incoming particle. Furthermore, the deficit of muons produced by simulations using current hadronic interaction models compared to extensive air showers (EAS) leaves a lot of questions open regarding our understanding of hadronic interactions. Since the number of muons in an EAS is directly linked to the number of nucleons in the primary particle, we can study and refine our theories of hadronic interactions and improve our handle on mass composition by measuring muon multiplicities. The Pierre Auger Observatory employs underground muon counters for this task. Simulations of the underground muon detector of the Pierre Auger Observatory are used to train a deep learning neural network to reconstruct muon densities. In this contribution we present the method and compare the bias and resolution to traditional reconstruction methods.

T 16.4 Mon 16:45 Geb. 30.33: MTI

**Neural network identification of highly inclined muons in water-Cherenkov particle detectors** — •Mohsen Pourmohammad Shahvar for the Pierre-Auger-Collaboration — Università degli studi di Palermo, Palermo, Italy — INFN sezione di Catania, Catania, Italy

This contribution focuses on the neural network identification of highly inclined muons in water-Cherenkov detectors, akin to those utilized by the Pierre Auger Observatory. Highly inclined muons serve as a distinctive signature of air showers induced by either neutrinos or cosmic rays arriving at substantial inclinations, offering a lower background rate compared to less inclined atmospheric particles. The transition from conventional statistical approaches to machine learning methodologies is explored to discern highly inclined muons, capitalizing on their unique signatures in the temporal signal distributions of three photosensors uniformly observing the volume of a water-Cherenkov detector. By adopting machine learning, particularly neural network techniques, we seek to improve the identification of highly inclined muons, contributing to the enhancement of triggering schemas designed for detecting neutrino primaries. This study not only advances the identification of highly inclined muons but also investigates the optimization of machine learning models for their efficient recognition within the water-Cherenkov detector setup.

T 16.5 Mon 17:00 Geb. 30.33: MTI

**Nested Machine Learning Models for the Cherenkov Telescope Array** — •Lukas Beiske[1,2] and Maximilian Linhoff[1] for the CTA-Collaboration — [1]Astroparticle Physics, WG Rhode/Elsässer, TU Dortmund University, D-44227 Dortmund, Germany — [2]Institute for Theoretical Physics IV, PAT, Ruhr University Bochum, D-44780 Bochum, Germany

The Cherenkov Telescope Array (CTA) will be the next-generation ground-based very-high-energy gamma-ray observatory covering an energy range from 20 GeV up to 300 TeV. It will operate tens of Imaging Atmospheric Cherenkov Telescopes (IACTs) on the Canary Island of La Palma (CTA North) and at the Paranal Observatory in Chile (CTA South) once construction and commissioning are finished.

Machine Learning techniques are currently being used to analyze data from IACTs. The tools are used to reconstruct the three main properties of the primary particle: its particle type, energy, and origin. A common approach is to train models on parameters extracted from the shower images observed by the telescopes which in turn give one prediction per telescope image. For events triggering multiple telescopes, these individual predictions can be averaged to obtain a single primary particle prediction for every shower event. However, it is possible to improve these averaged predictions by training a second set of machine learning models using all information available about the shower as seen by the whole telescope array. This talk will show the performance of such nested models for CTA.

T 16.6 Mon 17:15 Geb. 30.33: MTI

**Low-frequency noise classification using Machine Learning for the SuperCDMS experiment** — •Sukeerthi Dharani for the SuperCDMS-Collaboration — Karlsruhe Institute of Technology, Institute for Astroparticle Physics — University of Hamburg, Institute for Experimental Physics

The SuperCDMS experiment uses semiconductor crystal detectors operated at cryogenic temperatures to search for low-mass dark matter. Vibrations observed during the SuperCDMS Soudan experiment generated broadband low-frequency (LF) noise, which due to its similarity in the pulse shape to the low-energy signal events are difficult to remove at low energies. In the final low ionization threshold analysis, a strong event selection criterion was applied to remove LF noise events which raised the analysis threshold and thus reduced the sensitivity of the experiment to low-mass dark matter. An LF noise selection criterion using machine learning is currently being studied. Under investigation is a convolutional neural network that yields better signal purity while also retaining signal efficiency. This talk discusses the preliminary results of the machine learning-based classification of LF noise.

T 16.7 Mon 17:30 Geb. 30.33: MTI

**Machine-Learning-based Background Identification for the Radio Neutrino Observatory Greenland** — •Philipp Laub for the RNO-G-Collaboration — ECAP, FAU Erlangen-Nürnberg

The Radio Neutrino Observatory Greenland (RNO-G) is currently being built to detect ultra-high energy (UHE) neutrinos above 10 PeV. UHE neutrinos are detected by measuring radio waves, which are created via the Askaryan effect when UHE neutrinos interact in the ice. Located at Summit Station in Greenland, RNO-G is designed as a wide-spread station array, where each station is equipped with several radio antennas, which are positioned either close to the surface or deep in the ice. Despite the remote and relatively radio-quiet location at Summit, various backgrounds, often of anthropogenic origin, occur in the radio frequency regime. Among them is a rather unexplored background that is correlated to time periods of high wind speed. These "wind events" are impulsive signals of unknown origin, appear in different forms, and can pose a considerable threat to analyses such as cosmic ray searches. Since only little is known about this wind-correlated background and other backgrounds are present in the data, it is difficult to analyze wind events separately from other events.

In this contribution, multiple wind event classes are identified by clustering recorded events into clusters and analyzing event clusters primarily with respect to wind speed. The clustering is performed by first representing events in a low-dimensional latent feature space using a variational autoencoder and then applying the clustering algorithm HDBSCAN to these representations to obtain event clusters.

T 16.8 Mon 17:45 Geb. 30.33: MTI

**ANNs for enhanced Pulse Shape Discrimination in GERDA** — •Vikas Bothe — Max-Planck-Institute for Nuclear Physics, Heidelberg

The GERDA experiment searches for the rare neutrinoless double-beta decay of 76Ge using enriched high-purity Germanium diodes as a source as well as a detector. The experimental sensitivity can be improved significantly by employing active background suppression techniques such as Pulse Shape Discrimination(PSD) based on the analysis of time-profile of signals.

The unique challenge arises from coaxial detectors showcasing spatial dependence of pulse shapes which makes traditional mono-parametric PSD techniques ineffective. To address this, we implement artificial neural networks (ANNs) in a multivariate analysis, leveraging their capacity to model complex patterns. This work presents advancements in ANN based PSD within the GERDA experiment to effectively reject background events, such as alpha particles and Compton scattered photons, while maintaining high signal efficiency for double beta decay-like events.

I will give a brief review of the development of ANNs for PSD in GERDA, highlighting the exploration of various machine learning models and diverse approaches to input feature manipulation to achieve improved PSD performance.

# T 17: Data, AI, Computing 2 (analysis tools)

Time: Monday 16:00–18:00 Location: Geb. 30.34: LTI

T 17.1 Mon 16:00 Geb. 30.34: LTI

**Resource-aware Research on Universe and Matter: Call-to-Action in Digital Transformation** — •Kilian Schwarz — Deutsches Elektronen-Synchrotron (DESY), Notkestraße 85, 22607 Hamburg

Given the urgency to reduce fossil fuel energy production to make climate tipping points less likely, we call for resource-aware knowledge gain in the research areas on Universe and Matter with emphasis on the digital transformation. A portfolio of measures is described in detail and then summarized according to the timescales required for their implementation. The measures will both contribute to sustainable research and accelerate scientific progress through increased awareness of resource usage. This work is based on a three-days workshop on sustainability in digital transformation held in May 2023.

T 17.2 Mon 16:15 Geb. 30.34: LTI

**PUNCH4NFDI und XRootD für Storage4PUNCH: Towards a National Federated Computing Infrastructure** — Philip Bechtle, Oliver Freyermuth, Michael Hübner, •Simon Thiele, and Luka Vomberg — Physikalisches Institut, Universität Bonn

The NFDI (**N**ationale **F**orschungs**D**aten **I**nfrastruktur, engl. National Research Data Infrastructure) has the aim to systematically connect valuable data from science and research and make it available. PUNCH (**P**articles, **U**niverse, **NuC**lei and **H**adrons) is a consortium in the NFDI, dealing with the titular fields of particle, astro, nuclear and hadron physics. PUNCH4NFDI is organised into several task areas focusing on data management and transformation, the access to computing resources, challenges related to data irreversibility, as well as education and outreach. One important aspect of data management is the transfer of data in a federated storage and computing infrastructure and allowing for the preservation of access rights between individuals and groups.

XRootD is a software framework to manage the access to data and a prime candidate for fulfilling the above role. It consists of software with a scaleable architecture and a communication protocol. Several plug-ins are available to extend the functionality for various specific purposes, such as the use of tokens for authorization.

In this talk I will firstly introduce the PUNCH4NFDI project, then go more into detail on the goals of task area for data management and present my work on the use and modification of XRootD for PUNCH to fulfill all requirements needed for the federated storage infrastructure.

T 17.3 Mon 16:30 Geb. 30.34: LTI

**Opportunities for Open Science through Artificial Intelligence** — •Jutta Schnabel for the ANTARES-KM3NET-ERLANGEN-Collaboration — ECAP, FAU Erlangen-Nürnberg

The KM3NeT collaboration is currently constructing neutrino detectors in the Mediterranean Sea, with petabytes of high-quality scientific data to be analysed and shared in the years to come. Targeting both particle and astroparticle research, the opportunities for cooperative data analysis are manifold. The KM3NeT collaboration has implemented an Open Science program to coordinate the efforts in providing FAIR data and scientific workflows in accordance with the developing standards in the respective communities. In the years to come, employing artificial intelligence in discovery, integration and accessibility of scientific data will gain importance. In this contribution, the consequences of these developments will be explored in the context of the KM3NeT Open Science program.

T 17.4 Mon 16:45 Geb. 30.34: LTI

**HELIPORT: An overarching Data Management System at HZDR** — •Stefan E. Müller[1], Thomas Gruber[1], Oliver Knodel[1], Jeffrey Kelling[1], Mani Lokamani[1], David Pape[1], Martin Voigt[1,2], and Guido Juckeland[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany

Researchers at the Helmholtz-Zentrum Dresden-Rossendorf rely on a variety of systems and tools when it comes to administer their research data. Processes involving research data management include the project planning phase (proposal submission to the beamtime proposal management system, the creation of data management plans and data policies), the documentation during the experiment or simulation campaign (electronic laboratory notebooks, wiki pages), backup- and archival systems and the final journal and data publications (collaborative authoring tools, meta-data catalogs, software and data repositories, publication systems). In addition, modern research projects are often required to interact with a variety of software stacks and workflow management systems to allow reproducibility on the underlying IT infrastructure. The "HELmholtz ScIentific Project WORkflow PlaTform" (HELIPORT), which is currently developed by researchers at HZDR and their collaborators, tries to facilitate the management of research data and metadata by providing an overarching guidance system which combines all the information by interfacing the underlying processes and even includes a workflow engine which can be used to automate processes like data analysis or data retrieval.

T 17.5 Mon 17:00 Geb. 30.34: LTI

**dCache: Inter-disciplinary storage system** — •Tigran Mkrtchyan[1], Krishnaveni Chitrapu[3], Dmitry Litvintsev[2], Svenja Meyer[1], Lea Morschel[1], Paul Millar[1], Marina Sahakyan[1], and Kilian Schwarz[1] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Fermi National Accelerator Laboratory (FNAL), Batavia, USA — [3]National Supercomputer Center, Linköping University, Sweden

The dCache project provides open-source software deployed internationally to satisfy ever more demanding storage requirements. Its multifaceted approach provides an integrated way of supporting different use-cases with the same storage, from high throughput data ingest, data sharing over wide area networks, efficient access from HPC clusters and long-term data persistence on tertiary storage. Though it was originally developed for the HEP experiments, today it is used by various scientific communities, including astrophysics, biomed, life science, which have their specific requirements. With this contribution, we would like to highlight the recent developments in the dCache regarding integration with CERN Tape Archive (CTA), advanced metadata handling, bulk API for QoS transitions, RESTAPI to control interaction with tape system and the future development directions.

T 17.6 Mon 17:15 Geb. 30.34: LTI

**Metadata curation efforts at Kascade Cosmic-Ray Data Centre** — •Victoria Tokareva, Andreas Haungs, Doris Wochele, Jürgen Wochele, and Donghwa Kang — Karlsruhe Institute of Technology, Institute for Astroparticle Physics, 76021 Karlsruhe, Germany

Metadata curation plays a pivotal role in advancing the machine-actionability of data, thereby facilitating the fulfillment of FAIR data principles. The KASCADE Cosmic-ray Data Centre (KCDC) has served as a repository for data generated by the high-energy astroparticle physics experiment KASCADE, along with several other research projects, since 2013. Additionally, it functions as an information platform in the field of high-energy astroparticle physics for both the astroparticle community and the general public.

The platform provides users with a diverse set of digital objects. While some of them possess rich sets of metadata (including persistent identifiers such as DOIs and ISNIs), and allow machine access via REST API, efforts to integrate with the broader PUNCH4NFDI Data Portal underscore the necessity of a unified and comprehensive approach to curate a wider range of granted resources. The contribution examines KCDC's digital resources as Digital Research Products and covers recent developments, with a focus on integrating our curation practices into data-intensive physics communities' endeavors and the national data infrastructure landscape.

This work is partially supported by the DFG fund "NFDI 39/1" for the PUNCH4NFDI consortium.

T 17.7 Mon 17:30 Geb. 30.34: LTI

**AUDITOR: Accounting for opportunistic resources** — •Raghuvar Vijayakumar, Michael Böhler, Benjamin Rottler, Dirk Sammel, and Markus Schumacher — Universität Freiburg

In response to the increasing demand for computing resources in High Energy Physics (HEP), we have integrated under-utilized computing resources using COBalD/TARDIS in an opportunistic manner. However, resource sharing requires robust accounting. We present AUDITOR (AccoUnting DatahandlIng Toolbox for Opportunistic Resources), a flexible and extensible ecosystem tailored to address a broad range of use cases and infrastructures. AUDITOR employs specialised collectors that monitor, capture and record accounting data, subsequently stored in a database. The recorded data are then made accessible to plugins, which analyse the accounting information to perform specific tasks, such as computing the CO2 footprint and forwarding the accounting data to other accounting systems. AUDITOR is written in Rust, a modern programming language optimised for performance, type safety and concurrency. The python client pyauditor allows to utilize all AUDITOR functionalities via a python interface. In this talk, we present how AUDITOR works and how Pyauditor can be used to query and analyze large accounting data sets.

T 17.8 Mon 17:45 Geb. 30.34: LTI

**Workflow Optimization for HEP Jobs on Opportunistic Resources with XRootD** — •Robin Hofsaess, Manuel Giffels, Günter Quast, Maximilian Horzela, and Matthias Schnepf — Karlsruher Institut für Technologie

The WorldWide LHC Computing Grid (WLCG) is tailored to support High Energy Physics (HEP) workflows, offering an optimal environment for job execution. However, alongside the mostly homogeneous WLCG infrastructure, we increasingly rely on diverse 'opportunistic resources' such as High-Performance Computing (HPC) centers and cloud service providers. These resources are more heterogeneous and not inherently suited for HEP workflows that for example might require a high throughput of data. Since the future German HEP computing strategy foresees an increased share on such resources, we are currently working on concepts that not only aim to maximize computational throughput, but also align with the broader goals of sustainable resource utilization in an era of exponential data growth.

In this talk, I will present a first Proof of Concept implementation using an XRootD cache to increase the efficiency of HEP jobs on the HoreKa HPC cluster in Karlsruhe.

## T 18: Search for Dark Matter 1

Time: Monday 16:00–17:45 Location: Geb. 30.35: HSI

T 18.1 Mon 16:00 Geb. 30.35: HSI

**Wafer calorimeter development for the Direct Search Experiment for Light Dark Matter with Superfluid Helium (DELight)** — Friedrich Wagner[1], Lena Hauswald[1], Michael Müller[1], Fabienne Bauer[1], and •Sebastian Kempf[1,2] — [1]Institute of Micro- and Nanoelectronic Systems (IMS), Karlsruhe Institute of Technology, Germany. — [2]Institute for Data Processing and Electronics, Karlsruhe Institute of Technology, Germany.

The dark matter (DM)-nucleon scattering parameter space of Light Dark Matter (LDM) has been barely probed, as it requires an energy detection threshold as low as a few eV. The "Direct search Experiment for Light dark matter" (DELight) aims investigating this challenging parameter space by using superfluid $^4$He as target material. Superfluid $^4$He provides not only a low nuclear mass and a high radiopurity level, but also various signal channels for event classification. For signal detection, DELight will use energy- and time-resolving cryogenic wafer calorimeters with eV-scale energy resolution, some of which will be located above the liquid, while others will be immersed in the superfluid. The detectors will be based on magnetic microcalorimeters (MMCs) that are operated in athermal mode, i.e. the energy of an incident particle is converted into an athermal phonon population that is sensed via normal or superconducting phonon collectors heating up a paramagnetic temperature sensor that is situated in a weak magnetic field. Here, we present our most recent R&D efforts related to detector layout and fabrication technology, both ultimately paving the way towards wafer calorimeters with $O(20\,\text{eV})$ energy threshold.

T 18.2 Mon 16:15 Geb. 30.35: HSI

**A GridPix Detector for Axion Searches with IAXO** — •Johanna von Oy, Klaus Desch, Jochen Kaminski, Tobias Schiffer, Sebastian Schmidt, and Markus Gruber — Physikalisches Institut der Universität Bonn

The particle axion was first introduced as a solution for the strong CP problem and has since then also become a good candidate for light dark matter. One experimental concept to discover the axion are helioscopes, which would convert solar axions into X-rays and detect those.

The International AXion Observatory (IAXO) has been proposed to be built as a next-generation helioscope. As a proof of concept and as its own experiment, the intermediate state BabyIAXO will be constructed at DESY in Hamburg.

After the solar axions have coupled to X-rays in the magnetic field of the helioscope, the X-rays are focused onto detectors. One of them is a gas-filled GridPix detector, which has a pixelated readout chip, the Timepix3, as its base with a perfectly aligned mesh on top. Thanks to this, individual electrons produced by the X-rays in the gas volume can be detected. This especially allows for the detection of axion-originated X-rays, with energies as low as ~1 keV. Since the axion-photon coupling is predicted to be small and not a lot of signal events are expected, a very low background is desired and can, among other things, be achieved by building the detector from radiopure materials.

This talk will give a summary of the building principle and challenges of this GridPix detector for IAXO.

T 18.3 Mon 16:30 Geb. 30.35: HSI

**High-voltage electrode development for xenon-based direct Dark Matter detectors** — •Vera Hiu-Sze Wu for the XENON-Collaboration — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

The XENONnT detector is the current-generation experiment of the XENON Dark Matter project dedicated to direct dark matter search. It aims at reaching sensitivity for spin-independent WIMP-nucleon cross-sections down to $1.4 \times 10^{-48}$ cm$^2$ for a 50 GeV/$c^2$ mass WIMP at 90% C.L. with 20 t×yr exposure [1].

XENONnT has been successfully running since more than two years [2]. One of the central elements of two-phase xenon TPCs are the electrodes. With ever larger TPCs, these electrodes and their operation become a technological challenge. Therefore, a set of backup electrodes has been developed. The work encompasses different tasks, including redesigning and testing the mechanical structure of the electrodes and performing electric field and optical simulation. As the realization and manufacturing process progressed, we did extensive optical inspections and high-voltage and mechanical stability tests. Here I present our results, the assembly of these electrodes, and the lessons learned from the project towards future-generation detectors such as DARWIN.

*This work is supported in part through the Helmholtz Initiative and Networking Fund (grant agreement no. W2/W3-118) and through BMBF (ErUM-Pro grant agreement no. 05A23VK3). Support by the graduate school KSETA at KIT is gratefully acknowledged.*

[1] JCAP 11 (2020) 031, [2] PRL 131 (2023) 041003.

T 18.4 Mon 16:45 Geb. 30.35: HSI

**Evaporated Gold Thin-Films on NaI Crystals for remoTES based Detectors** — •Kilian Heim for the COSINUS-Collaboration — Max-Planck-Institut für Physik, Garching, Deutschland

The COSINUS (Cryogenic Observatory for SIgnals seen in Next generation Underground Searches) experiment aims for a model-independent cross-check of the dark matter signal claimed to be observed by the DAMA/LIBRA experiment. Starting its first operational phase at the end of 2024, COSINUS will use the same target material as the DAMA/LIBRA experiment, namely sodium iodide (NaI). The NaI crystals will be operated as cryogenic calorimeters, enabling a dual channel readout of both a scintillation and phonon signal.

The readout of the phonon signal is done with a transition edge sensor (TES), but due to the low melting point and hygroscopicity of the NaI crystal, the TES cannot be deposited directly on the crystal. Therefore, the novel remoTES setup is applied, which locates the TES on a separate wafer, linked to a gold pad on the crystal.

Currently, the circular gold pad is cut from a gold foil and then glued onto the crystal. As a next step, the evaporation of gold on the crystal is investigated, which could enhance the reproducibility and signal strength of the TES. In this contribution, I want to highlight the advantages of an evaporated gold pad and present first results from the way towards an improved detector setup.

T 18.5 Mon 17:00 Geb. 30.35: HSI

**Recent updates on ALPS II's TES detection system** — •Christina Schwemmbauer[1], Katharina-Sofie Isleif[2], Friederike Januschek[1], Axel Lindner[1], Manuel Meyer[3], Gulden Othman[4], and José Alejandro Rubiera Gimeno[1] — [1]Deutsches Elektronen-Synchrotron DESY,Hamburg, Germany — [2]Helmut-Schmidt-University,Hamburg, Germany — [3]University of Southern Denmark, Odense, Denmark — [4]Universität Hamburg, Hamburg, Germany

The ALPS II (Any Light Particle Search II) experiment is a light-shining-through-walls experiment located at DESY Hamburg, searching for axions and Axion Like Particles (ALPs). The experiment has been running successfully since May 2023, employing a heterodyne scheme for the detection of reconverted photons from ALP-photon oscillations. Upon many possible configuration changes in the next months and years is the option of using a NIST Transition Edge Sensor (TES) based detection system as an alternative to heterodyne sensing. We report on recent progress towards a dedicated TES run for ALPS II, including results on the system detection efficiency and backgrounds. Furthermore, our TES detection setup could be used for direct Dark Matter (DM) searches as well, namely through DM-electron-scattering in the superconducting TES layer at sub-eV energies.

T 18.6 Mon 17:15 Geb. 30.35: HSI

**Tests of wire electrodes with the Mainz high resolution scanning set-up** — •Alexander Deisting[1], Jan Lommler[1], Shumit Mitra[1], Uwe Oberlack[1,2], Fabian Piermaier[2], and Quirin Weitzel[2] — [1]Institut für Physik & Exzellenzcluster PRISMA+, Universität Mainz — [2]PRISMA Detector Laboratory, Universität Mainz

When searching for dark matter with dual-phase time projection chambers (TPCs) the quality of the TPC's electrodes is crucial for the experiments success, as the electrodes' performance affects the overall signal quality and smoothness of detector operation. For experiments similar to XENONnT, these electrodes are meshes or grids with wire diameters of $200 - 300\,\mu$m, operated at a high voltage (HV) $\gg 1$ kV. Future experiments as Darwin plan to use a similar technology.

The scanning set-up at the PRISMA Detector Laboratory in Mainz features several tools for metrology mounted on a gantry robot system: A high resolution camera (resolution: $1.4 \times 1.4\,\mu$m$^2$), a 3D confocal microscope (resolution better than 1 $\mu$m), and a laser-distance measurement system, which can be used to measure wire sagging down to the $\mathcal{O}(10\,\mu$m) scale. The set-up allows for electrodes to be tested at HV and in an argon atmosphere.

In this talk we will discuss electrode assays utilising intentional corona discharges at the wires and lessons learned from that. Furthermore, we will report on wire sagging measurements done with XENONnT sized electrodes and on the resulting conclusions for similar studies with Darwin sized electrodes.

T 18.7 Mon 17:30 Geb. 30.35: HSI

**Dark matter-electron search using cryogenic light detectors** — •Vanessa Zema — Max Planck Institute for Physics, Munich, Germany

Dark matter (DM) may be constituted by MeV/$c^2$ particles with coupling to electrons. Nobel gas detectors or solid state materials with electronic energy gaps are employed to investigate this hypothesis. Considering the solid state detectors, the common choice is to use semiconductors and measure the charge using for example CCDs detectors or cryogenic calorimeters subjected to electromagnetic fields. In this talk we report on a different technique for DM-electron interaction search which is based on the measure of the scintillation light stimulated by a particle scattering off electrons in scintillating cryogenic calorimeters, with a focus on sodium iodide targets. We study the phenomenology and calculate the projected sensitivity on the DM-electron cross-section as a function of the DM mass to plan the detector design and estimate what is the aimed background level and energy resolution required to setup a future dedicated experiment.

# T 19: Methods in particle physics 2 (alignment, luminosity)

Time: Monday 16:00–18:00 Location: Geb. 30.41: HS 1

T 19.1 Mon 16:00 Geb. 30.41: HS 1

**Track-Based alignment for the SciFi detector at the LHCb experiment** — •Miguel Ruiz Díaz[1], Giulia Tuci[1], Nils Breer[2], and Biljana Mitreska[2] — [1]Physikalisches Institut, Universität Heidelberg — [2]Technische Universität Dortmund

A precise knowledge of the position and orientation of the different sub-detectors is crucial for the operation of any particle physics experiment. The LHCb detector has undergone a major upgrade for Run 3, and the alignment of its sub-detectors has played a central role in its commissioning.

A central part of the LHCb upgrade is the installation of a Scintillating Fiber (SciFi) detector featuring three layers of tracking stations downstream of the magnet. An accurate alignment of the SciFi tracker is essential to achieve the best possible charged particle momentum resolution and tracking efficiency, impacting most of the measurements conducted at the LHCb experiment.

This talk presents the application of track-based alignment techniques to compute the position and orientation of the SciFi detector. Results from the Run 3 commissioning period are presented, showing the impact of the SciFi alignment on track residuals and mass distributions. The alignment of the SciFi detector will be monitored in real-time during the data-taking period. The alignment constants -rotations and translations of the SciFi components- will be automatically updated if the change in their values exceeds certain thresholds. These thresholds have been evaluated in a precision study employing Monte Carlo simulated data. The results of the study are discussed.

T 19.2 Mon 16:15 Geb. 30.41: HS 1

**Alignment of the CMS tracker with Run 3 data** — •Lucia Ximena Coll Saravia — Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg

The Compact Muon Solenoid (CMS) has the world's largest silicon tracker, comprising 1856 pixel modules and 15148 strip modules that ensure accurate track reconstruction. In order to maintain high precision one must compensate for significant time variations caused by magnet cycles, temperature variations and ageing of modules that lead to changes in the track reconstruction. Consequently, throughout data-taking it is necessary to continuously correct the position, rotation and curvature of these modules in a procedure called tracker alignment. The focus of this talk is on the performance of the CMS tracker alignment in Run 3, with particular attention to the strategies employed to derive alignment calibrations for the reprocessing of the 2022 and 2023 data. Results showing the impact of tracker alignment on physics are also presented.

T 19.3 Mon 16:30 Geb. 30.41: HS 1

**Global alignment of the LHCb SciFi Tracker and Vertex Locator** — •Nils Breer, Biljana Mitreska, and Johannes Albrecht — TU Dortmund University, Dortmund, Germany

The LHCb tracking systems including the Scintillating Fibre Tracker (SciFi) and the VErtex LOcator (VELO) underwent a major upgrade as part of the LHCb upgrade I. As part of the upgrade, it is crucial for the VELO and the SciFi to be aligned to achieve the best possible physics performance and data quality.

A new alignment strategy is developed combining the VELO together with the SciFi to form a combined procedure named global alignment. This allows for studying effects on different constraints and weak modes, that can further enhance the precision, by also using the VELO information for the track reconstruction in the SciFi. A more realistic description of the SciFi modules is implemented to represent the bending of the modules. This is a key piece of the current alignment strategy.

The alignment configuration of multiple detector elements of the VELO and the SciFi is discussed using the 2023 LHCb data. The updates to the alignment strategy by adding a more realistic description of the SciFi modules will be presented.

T 19.4 Mon 16:45 Geb. 30.41: HS 1

**Illuminating heavy ion collisions with tracks: Track-based measurements of the luminosity of Pb+Pb collisions with the ATLAS detector** — •Kartik Deepak Bhide, Valerie Lang, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

Precisely determining the luminosity of collisions delivered by the LHC is the goal of the ATLAS luminosity program. The dedicated sub-detector LUCID is used as the reference luminometer for all types of colliding beams. In p+p collisions, several other sub-detectors and algorithms are used for calibration, cross-checks and long-term stability, both during the LHC Run 2 (2015-2018) and Run 3 (since 2022). In contrast, for heavy ion collisions, mainly luminosity algorithms based on LUCID were available during the LHC Run 2.

In this work, the potential of luminosity measurements using particle tracks reconstructed with the ATLAS Inner Detector, as a new luminometer for heavy ion collisions in the LHC Run 3 will be discussed. The performance of two track-based luminosity algorithms, namely track counting and event counting, will be presented, using Pb+Pb collision data recorded in 2023. The impact of the track selection requirements on the performance of the algorithms, and the statistical precision achieved will be shown. Comparisons to LUCID and Zero Degree Calorimeter-based luminosity will be presented.

T 19.5 Mon 17:00 Geb. 30.41: HS 1

**Emittance Scans at the LHCb Detector in Run 3** — Johannes Albrecht, Elena Dall'Occo, Hans Dembinski, and •Jan Ellbracht — TU Dortmund University, Dortmund, Germany

Luminosity is a key component for daily operations and accurate measurements of cross-sections at the LHCb detector. Therefore, a luminosity calibration is performed once per year and per centre-of-mass energy in dedicated van-der-Meer scans. These are performed under specific beam conditions, leading to a maximum number of visible proton-proton interactions of $\mu \sim 1$ when the beams are colliding head-on.

In Run 3, the LHCb detector operates at a five times higher instantaneous luminosity compared to the previous LHC runs, with a $\mu$ of 5.5. Hereby, it is planned to perform regular emittance scans during data taking fills in order to verify the linearity of luminosity in $\mu$ from calibration to data taking conditions. An important component of these emittance scans is a new set of luminosity counters, needed to determine luminosity. These quantities are expected to scale linear to luminosity. Hence, this is studied extensively to make sure that the counters are linear and, therefore, accurate.

This talk will focus on the emittance scan analysis, procedure, linearity studies and first results of Run 3 data.

*Supported by DFG (SFB 1491)*

T 19.6 Mon 17:15 Geb. 30.41: HS 1

**Luminosity measurements using the ATLAS Forward Proton (AFP) detector** — Jan Broulim, •Petr Fiedler, and Andre Sopczak — Czech Technical University in Prague

The latest results of luminosity measurements using the AFP detector are presented.

T 19.7 Mon 17:30 Geb. 30.41: HS 1

**Studies of ATLAS Forward Proton (AFP) ToF performance with Run-3 data** — •Viktoriia Lysenko and Andre Sopczak — Czech Technical University in Praguw

Performance studies of ATLAS Forward Proton (AFP) ToF with Run-3 data are presented.

T 19.8 Mon 17:45 Geb. 30.41: HS 1

**The Experiment Control System for the LHCb BCM in Run 3** — Johannes Albrecht[1], Federico Alessio[2], Martin Bieker[1], Elena Dall'Occo[1], and •David Rolf[1,2] — [1]TU Dortmund University, Dortmund, Germany — [2]CERN, Geneva, Switzerland

The Beam Conditions Monitor (BCM) is a safety system of the LHCb experiment, designed to prevent radiation damage to sensitive detector components due to bad beam conditions. Should an adverse beam scenario occur, the BCM will trigger a beam dump, thus preventing the beam from damaging the detector.

As part of the comprehensive upgrade of the LHCb detector, the readout of the BCM has been upgraded. The outdated hardware is replaced by a newly designed Machine Interface Beam Abort Decision (MIBAD) board. To operate and monitor the MIBAD a new Experiment Control System (ECS) has been implemented and integrated into the global LHCb control system.

This contribution presents the BCM and MIBAD board, with a focus on the implemented ECS. In particular, the communication protocols and design considerations of the individual components of the ECS are discussed in detail.

# T 20: Higgs 1 (boson final states)

Time: Monday 16:00–17:45 Location: Geb. 30.41: HS 2

T 20.1 Mon 16:00 Geb. 30.41: HS 2

**Higgs Boson Production Cross-section Measurements at $\sqrt{s} = 13.6$ TeV in the $H \to ZZ^* \to 4l$ Channel With the ATLAS Detector** — •Alice Reed, Sandra Kortner, and Oliver Kortner — Max Planck Institut für Physik, München

An important process for the measurement of Higgs boson properties is the Higgs boson decay into two Z bosons, which subsequently decay into a $\mu^+\mu^-$ or $e^+e^-$ pair, $H \to ZZ^* \to 4l$. Due to its clear signature, this decay channel can be studied with the first Run 3 collision data collected with the ATLAS detector in 2022 and 2023, providing measurements at a new centre-of-mass energy of $\sqrt{s} = 13.6$ TeV.

To reduce the model dependence, the cross-section for this process is measured in a fiducial phase space which closely matches the detector-level kinematic selection and is corrected for detector effects. The inclusive fiducial cross-section measured using the 2022 ATLAS dataset, corresponding to 29.0 $fb^{-1}$, is in agreement with the corresponding Standard Model prediction. Expanding upon this measurement, differential fiducial cross-section measurements for observables sensitive to the Higgs boson production and decay can also be performed. Strategies for upcoming differential fiducial cross-section measurements with 56 $fb^{-1}$ of data from the ATLAS detector in 2022 and 2023 will be presented.

T 20.2 Mon 16:15 Geb. 30.41: HS 2

**Machine-learning-based optimisation of Higgs coupling measurements in the $H \to 4l$ decay channel with ATLAS Run 3 data** — •Luca Spitzauer, Sandra Kortner, Alice Reed, and Hubert Kroha — Max-Planck-Institut für Physik

Cross-section measurements for different Higgs boson production and decay processes constitute a key area in the exploration of Higgs properties, with a high sensitivity to potential physics beyond the Standard Model. Due to its exceptionally clear signal, the decay of a Higgs boson into a $ZZ^*$ pair with a subsequent decay of each Z boson into two leptons, $H \to ZZ^* \to 4l$, is one of the most important channels for the Higgs property measurements.

Optimized classification of events according to these 'production bins' is vital to improve the signal sensitivity and reduce sources of uncertainty. Previous round of STXS measurements in the $H \rightarrow 4l$ channel with the Run 2 ATLAS dataset employed a Neural Network classification approach. With the new Run 3 dataset at a centre-of-mass energy of 13.6 TeV, potential optimization of this classification is explored by means of additional machine-learning approaches with improved architectures.

T 20.3 Mon 16:30 Geb. 30.41: HS 2

**Methodological developments for $H \rightarrow \gamma\gamma$ data analyses in Run-3 at the CMS experiment** — Caio Daumann, Johannes Erdmann, Nitish Kumar, •Florian Mausolf, and Jan Lukas Späh — III. Physikalisches Institut A, RWTH Aachen University

In 2022, the Large Hadron Collider resumed operations, with a proton-proton beam at an unprecedented centre-of-mass energy of $\sqrt{s} = 13.6$ TeV. This marked the start of the Run-3 data taking period. Despite the Higgs boson's diphoton decay channel having a relatively low branching ratio of approximately 0.23 %, it offers wide opportunities for precision analyses. Due to a low background level combined with the excellent precision in the reconstruction of photons, this decay channel is already accessible with the data taken so far in Run-3.

This presentation focuses on methodological developments for the $H \rightarrow \gamma\gamma$ analyses in Run-3 at the CMS experiment. A new software framework based on the columar-analysis approach is introduced. The framework's application is demonstrated in the first Higgs boson cross-section measurement using the 2022 dataset taken with the CMS experiment. Furthermore, developments to enhance the sensitivity of this cross-section measurement are presented.

T 20.4 Mon 16:45 Geb. 30.41: HS 2

**First measurement of $H \rightarrow \gamma\gamma$ fiducial cross sections with 13.6 TeV CMS data** — Caio Daumann, Johannes Erdmann, Nitish Kumar, Florian Mausolf, and •Jan Lukas Späh — III. Physikalisches Institut A, RWTH Aachen University

The Higgs boson, which is of fundamental interest for the understanding of matter, has been studied in detail by the ATLAS and CMS collaborations since its discovery in 2012. Measurements of Higgs boson production cross sections are important to probe possible beyond the standard model effects in the scalar sector.

In this talk, the measurement of Higgs boson production cross sections in the diphoton decay channel at $\sqrt{s} = 13.6$ TeV based on a sample of proton-proton collision data collected in 2022 with the CMS experiment is presented. This analysis benefits from the clean topology of the diphoton decay channel. The cross sections are measured in a fiducial phase space at particle level, reducing extrapolation uncertainties and enhancing the model independence of the measurement. In this talk, special emphasis is placed on the statistical analysis, which includes the simulation-based signal modelling and the data-driven background modelling.

This analysis lays the foundation for further measurements of Higgs boson processes in the diphoton decay channel by the CMS collaboration in Run 3 of the LHC and beyond.

T 20.5 Mon 17:00 Geb. 30.41: HS 2

**Measurement of gluon fusion and vector-boson fusion Higgs-boson production cross sections in $H \rightarrow WW^* \rightarrow l\nu l\nu$ decays at $\sqrt{s} = 13$ TeV with the ATLAS detector** — •Ahmed Markhoos, Benedict Winter, Karsten Köneke, and Karl Jakobs — University of Freiburg, Freiburg, Germany

The Higgs-boson decay to two W bosons ($H \rightarrow WW^*$) has proven to be crucial for measuring the Higgs-boson couplings and testing the Standard Model, given that it is the decay mode with the second largest branching ratio. $H \rightarrow WW^* \rightarrow l\nu l\nu$ specifically provides a sizable signal and moderate background yields, allowing for accurate measurements of the total and differential cross-sections through gluon-gluon fusion (ggF), vector boson fusion (VBF) and Higgs Strahlung production modes. In this talk, an overview of the ongoing $H \rightarrow WW^* \rightarrow l\nu l\nu$ ggF and VBF Simplified Template Cross-Section (STXS) analysis is presented, based on the full Run 2 dataset. This analysis improves significantly upon the first full Run 2 analysis by extending the use of multivariate techniques and considering Higgs-boson decays to light leptons of the same flavor ($e\nu e\nu/\mu\nu\mu\nu$) in addition to different flavor decays ($e\nu\mu\nu$). This in return enables a more granular and precise STXS measurement with noticeably higher sensitivity.

T 20.6 Mon 17:15 Geb. 30.41: HS 2

**Search for the Higgs plus charm quark production mode in the H→WW→e$\nu\mu\nu$ channel** — •Ming-Yan Lee[1], Spandan Mondal[2], Alexander Schmidt[1], Andrey Pozdnyakov[1], Alena Dodonova[1], Uttiya Sarkar[1], and Valentyn Vaulin[1] — [1]III. Physikalisches Institut A, RWTH Aachen University, Germany — [2]Brown University, Providence, USA

The Higgs plus charm production mode is another topology to probe Higgs-charm Yukawa coupling complementary to H→cc channels. This topology provides the possibility to access the Higgs-charm coupling via cleaner final states. In this analysis, we aim to consider the Higgs decay into W boson to final states with additional charm-tagged jets. The upper limit to extract H-c coupling is determined using the data-taking period 2016 to 2018 of the CMS experiment at the LHC at $\sqrt{s}$=13 TeV.

T 20.7 Mon 17:30 Geb. 30.41: HS 2

**Jet-Lepton Overlap Removal Optimization in context of the boosted $H \rightarrow WW \rightarrow l\nu qq$ measurement using Run 2 data in ATLAS** — •Jan Philipp Jäkel, Chris Malena Delitzsch, and Carsten Daniel Burgard — Technische Universität Dortmund, Dortmund, Germany

The unprecedented center-of-mass energy of the Large Hadron Collider enables the production of Higgs bosons with a momentum much higher than their mass, resulting in a collimation of its decay products. In this presentation, the $H \rightarrow WW \rightarrow l\nu qq$ decay is explored due to its high branching ratio and the clean event signature. The hadronic decay of the W boson is reconstructed as one large-radius jet using particle flow-like objets as inputs, a combination of signals from the calorimeters and charged-particle tracks from the inner detector. In case of high collimation, the leptons from one of the W boson decays can overlap with the jet from the other W boson decay. In ATLAS, the reconstruction of leptons and jets is conducted independently from another and therefore the deposited energy of a charged lepton in the electromagnetic or hadronic calorimeter can be also reconstructed as part of the jet leading to double counting of the lepton's energy in the event. The usage of particle flow-like objects for jet reconstruction enables the removal of the lepton's energy at the calorimeter cell level to avoid the double counting. Modifications to the currently used particle flow algorithm are explored to optimise the overlap removal between jets and leptons with focus on electrons. The studies use Monte Carlo simulated events of $\sqrt{s} = 13$ TeV proton-proton collisions.

# T 21: BSM Higgs 1 (extended Higgs sectors)

Time: Monday 16:00–18:00 Location: Geb. 30.41: HS 3

T 21.1 Mon 16:00 Geb. 30.41: HS 3

**Unraveling Sum Rules in 2HDM - Beyond Standard Model Implications** — •Sara Chopra[1], Saurav Bania[2], Gudrid Moortgart Pick[3], and Sven Heinemeyer[4] — [1]Universität Hamburg — [2]Universität Hamburg — [3]Universität Hamburg — [4]Consejo Superior de Investigaciones Científicas (CSIC)

In our exploration of particle physics, we comprehensively investigate the profound implications of sum rules within the Two Higgs Doublet Model (2HDM). Beginning with the foundational Standard Model, we derive sum rules to understand particle interactions.

Our focus shifts to the intricacies of 2HDM, meticulously deriving sum rules through examining couplings. We emphasize the behavior of these rules at escalating energy levels, particularly under E2 and E4 dependencies. Crucially, we assess their robustness, specifically scrutinizing unitarity's endurance amidst heightened energies.

This endeavor marks a pivotal step in unraveling 2HDM's behavior at elevated energy levels, offering invaluable insights beyond the Standard Model. Our research not only advances particle physics but also deepens our understanding of sum rules' implications in models beyond the established theoretical framework.

T 21.2 Mon 16:15 Geb. 30.41: HS 3

**Search for a light CP-odd Higgs boson with the ATLAS detector** — •Manuel Gutsche, Asma Hadef, Hannah Jacobi, Tom Kresse, Christian Schmidt, and Arno Straessner — Technische Universität Dresden

While the Standard Model of particle physics (SM) has proven to be a precisely predictive theory, tensions between experimental observations and theoretical calculations have arisen. One such discrepancy originates from Fermilab's measurement of the muon's anomalous magnetic moment $a_\mu$. The flavour-aligned two-Higgs-doublet model (2HDM) is an extension of the SM that introduces a second Higgs doublet, leading to a rich phenomenology with four additional Higgs bosons. One of these particles is the CP-odd and electrically neutral $A$-boson whose mass $m_A$ is a free parameter of the theory. If $A$ is assumed to have a low mass of less than $m_Z$ and large couplings to leptons as well as top quarks, the 2HDM could explain the observed deviation in $a_\mu$.

In this talk, the search for an $A$-boson with a mass between 20 GeV and 110 GeV, produced by gluon fusion and decaying into two $\tau$ leptons, is presented. The analysis focuses on the channel with one electron and one muon in the final state, making use of 140.1 fb$^{-1}$ of data recorded by the ATLAS detector at $\sqrt{s} = 13$ TeV.

An overview of the analysis strategy is given. Different validation and signal-enriched regions along with the employed fake estimation method are introduced. Details on the most impactful systematic uncertainties as well as the expected limits for the production cross-section and model-dependent coupling parameters are presented.

T 21.3 Mon 16:30 Geb. 30.41: HS 3

**Searches for neutral BSM Higgs bosons decaying into tau leptons** — •Jacopo Malvaso — Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg

The CMS Collaboration has reported in Run 2 two excesses above the background expectation in the search for a Beyond Standard Model Higgs boson decaying into tau leptons, at masses of 0.1 and 1.2 TeV and in the gluon fusion production process.

This talk will present the strategy for a similar search with data collected by the CMS experiment in Run 3. First distributions and comparisons of data and Monte Carlo simulations will be shown for 2022 and 2023 data.

T 21.4 Mon 16:45 Geb. 30.41: HS 3

**Exploring a supersymmetric four-Higgs doublet model** — •Lucas Willanzheimer[1], Franziska Lohner[1], and Gudrid Moortgat-Pick[1,2] — [1]Universität Hamburg — [2]Deutsches Elektronen-Synchrotron DESY

Motivated by recent results from the ATLAS and CMS collaborations which reveal excesses in studies of decays into top quark pairs $t\bar{t}$ and tau leptons $\tau^+\tau^-$ at approximately 400 GeV -phenomena that the minimal supersymmetric standard model (MSSM) cannot explain simultaneously- we explore, in this study, the Higgs sector of a supersymmetric four-Higgs doublet model. Assuming a symmetry in which each type of matter, including up-type- and down-type-quarks as well as charged leptons, couples exclusively to its 'own' doublet, our aim is to investigate whether such a supersymmetry-type model, with its Yukawa-sector, could embed excesses of such kind.

T 21.5 Mon 17:00 Geb. 30.41: HS 3

**First shot of the smoking gun: probing the electroweak phase transition in the 2HDM with novel searches for $A \to ZH$ in $\ell^+\ell^- t\bar{t}$ and $\nu\nu b\bar{b}$ final states** — •Thomas Biekötter[1], Sven Heinemeyer[2], Jose Miguel No[2], Kateryna Radchenko[3], and Georg Weiglein[3] — [1]ITP, Karlsruhe, Germany — [2]IFT, Madrid, Spain — [3]DESY, Hamburg, Germany

Recently the ATLAS collaboration has reported the first results of searches for heavy scalar resonances decaying into a $Z$ boson and a lighter new scalar resonance, where the $Z$ boson decays leptonically and the lighter scalar decays into a top-quark pair, giving rise to $\ell^+\ell^- t\bar{t}$ final states. This had previously been identified as a smoking-gun signature at the LHC for a first-order electroweak phase transition (FOEWPT) within the framework of two Higgs doublet models (2HDMs). We analyze the impact of these new searches on the 2HDM parameter space, with emphasis on their capability to probe currently allowed 2HDM regions featuring a strong FOEWPT. Remarkably, the ATLAS search in the $\ell^+\ell^- t\bar{t}$ final state shows a local 2.85 $\sigma$ excess (for masses of about 650 GeV and 450 GeV for the heavy and light resonance) in the 2HDM parameter region that would yield a FOEWPT in the early universe, which could constitute the first experimental hint of baryogenesis at the electroweak scale. We analyze the implications of this excess, and discuss the detectability prospects for the associated gravitational wave signal from the FOEWPT.

T 21.6 Mon 17:15 Geb. 30.41: HS 3

**Search for heavy Higgs bosons in the $t\bar{t}Z$ final state at CMS** — Matteo Bonanomi, Yannick Fischer, Johannes Haller, •Daniel Hundhausen, Christopher Matthies, and Matthias Schröder — Universität Hamburg

All measurements of the properties of the Higgs boson at 125 GeV are compatible with a standard model-like behaviour. However, the observed resonance might well be part of an extended Higgs sector, which is predicted in various scenarios of new physics beyond the standard model. Two Higgs Doublet Models (2HDM) provide a generic description of the phenomenology arising in models with a second Higgs doublet. In this talk, we will present a search for a hypothetical CP-odd heavy Higgs boson $A$ decaying into a CP-even heavy Higgs boson $H$ and a $Z$ boson, with the $H$ boson decaying further into a top quark-antiquark pair ($t\bar{t}$). This decay channel is particularly relevant in the high mass and low $\tan(\beta)$ regime. We will present the strategy and status of the analysis of data collected with the CMS experiment at a centre-of-mass energy of 13 TeV, targeting the fully hadronic $t\bar{t}$ decay.

T 21.7 Mon 17:30 Geb. 30.41: HS 3

**Search for Heavy Higgs Bosons in the $tt\nu\nu$ Final State at CMS** — Matteo Bonanomi, •Lukas Ebeling, Yannick Fischer, Johannes Haller, Daniel Hundhausen, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

Two Higgs Doublet Models extending the Higgs sector of the Standard Model predict additional heavy Higgs states. In this talk, a search for a heavy Higgs boson A decaying into a second heavy Higgs boson H and a Z boson is presented. The search targets the decay of the H boson into a $tt$ pair, which is expected to have dominant contributions in the regime of large Higgs boson masses and small $\tan(\beta)$. In the analysis, the all-hadronic final state of the $tt$ system and the $\nu\nu$ final state of the Z boson decay are explored. Missing transverse momentum is used as a sensitive observable. We will present the status of the analysis using simulated data of the CMS experiment. Furthermore, the results are combined with a similar search in final states with charged leptons and jets.

T 21.8 Mon 17:45 Geb. 30.41: HS 3

**Intermediate Charge-Breaking Phases in the 2HDM** — Mayumi Aoki[1], Lisa Biermann[2], •Christoph Borschensky[2], Igor P. Ivanov[3], Margarete Mühlleitner[2], and Hiroto Shibuya[1] — [1]Institute for Theoretical Physics, Kanazawa University, Kanazawa, Japan — [2]Institute for Theoretical Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — [3]School of Physics and Astronomy, Sun Yat-sen University, Zhuhai, China

The evolution of the early Universe around the electroweak epoch is an ideal testbed for physics beyond the Standard Model and in particular extended scalar sectors. The Universe may have experienced a sequence of phases of exotic nature, one of these being an intermediate phase where the electromagnetic charge is not conserved.

In my talk, intermediate $U(1)_{\mathrm{em}}$ charge-breaking (CB) phases in the CP-conserving 2-Higgs Doublet Model will be investigated. While previously studied only in the approximation of high temperatures, the possibility for their existence in the one-loop effective potential including thermal corrections is confirmed. I will discuss the relation of CB phases with the (non-)restoration of the electroweak $SU(2) \times U(1)$ symmetry at high temperatures, and the consistency with current collider data. For certain selected benchmark scenarios, the features of a CB phase in the evolution of the vacuum will be examined, such as the occurrence of a first-order phase transition to the CB phase from the neutral one.

# T 22: Flavour physics 1

Time: Monday 16:00–18:00 Location: Geb. 30.41: HS 4

T 22.1 Mon 16:00 Geb. 30.41: HS 4

**Analysis of $B^0 \to \rho^0\rho^0$ decays at Belle II** — •Justin Skorupa, Hans-Günther Moser, and Yingming Yang — Max-Planck-Institut für Physik, Garching, Deutschland

Measurements of the sides and angles of the unitary triangle associated to $B$-meson decays are a cornerstone of the Belle II physics program. Of all angles of the unitary triangle, the angle $\alpha/\phi_2$ currently is the least precisely known.. The most precise determination of this angle comes from an analysis of isospin related $B \to \rho\rho$ decays. Of all $B \to \rho\rho$ modes, an improved measurement of $B^0 \to \rho^0\rho^0$ is expected to have the strongest impact on the precision of $\alpha/\phi_2$. In this talk, initial studies on the measurement of $B^0 \to \rho^0\rho^0$ using Belle II data are presented.

T 22.2 Mon 16:15 Geb. 30.41: HS 4

**Search for the $B^0 \to D^0\bar{D}^0$ decay with the LHCb experiment** — Johannes Albrecht, •Jonah Blank, Quentin Führing, and Sophie Hollitt — TU Dortmund University, Dortmund, Germany

With precise measurements of $B$ meson decays the LHCb experiment can test the integrity of the Standard Model of particle physics. Especially $B \to DD$ decays are interesting to examine $CP$ violation and further constrain the unitarity triangle. While decays to charged $D^\pm$ mesons have already been well measured, the $B^0 \to \bar{D}^0D^0$ decay channel has not yet been observed by any experiment.

In this analysis, data collected by the LHCb experiment at $\sqrt{s}$ = 7, 8 TeV and 13 TeV corresponding to an integrated luminosity of 9 fb$^{-1}$ is used to search for the $B^0 \to \bar{D}^0D^0$ decay channel. The topologically similar $B^0 \to \bar{D}^0\pi^+\pi^-$ decay channel is utilized as a normalisation mode to cancel systematic uncertainties. An update on the current status of the analysis will be presented.

T 22.3 Mon 16:30 Geb. 30.41: HS 4

**Towards a full NNLO QCD calculation of $\Delta\Gamma$ in the $B$-$\overline{B}$ system** — •Pascal Reeck[1], Matthias Steinhauser[1], Ulrich Nierste[1], and Vladyslav Shatbovenko[2] — [1]Karlsruhe Institute of Technology — [2]University of Siegen

In this talk I will discuss recent advances made in the calculation of the NNLO

QCD corrections to the width difference between B and $\overline{B}$ mesons. This work focuses on the perturbative high-energy part of the calculation, more specifically the matching coefficients between the $\Delta B = 1$ effective operators of the Weak Interaction and the $\Delta B = 2$ transition operator are calculated as a deep expansion in $m_c/m_b$.

This calculation yields novel results for the NNLO contributions with penguin operators which had not been considered previously at this order. Moreover, the NNLO contributions with two current-current operators, which were previously only known up to $\mathcal{O}(m_c/m_b)$, are calculated to a higher precision.

T 22.4 Mon 16:45 Geb. 30.41: HS 4

**Time-dependent studies of $B_s^0$-meson decays at the LHCb experiment** — Johannes Albrecht and •Quentin Führing — TU Dortmund University, Dortmund, Germany

The system of neutral $B_s^0$ mesons provides experimental access to the CKM sector of the Standard Model. The neutral meson oscillation is not only a measurable observable itself but also enables *CP*-violating effects in the interference of direct decay and decay after mixing.

Flavour-specific decay modes, like $B_s^0 \to D_s^- \pi^+$, can be used for a clean measurement of the oscillation frequency $\Delta m_s$. This frequency itself can be utilized to constrain the sides of the unitarity triangles. More importantly, it is a crucial input to all time-dependent measurements of *CP* violation in $B_s^0$-meson decays.

The decay to a *CP* eigenstate, such as $B_s^0 \to J/\psi\, \phi$, gives access to the *CP*-violating phase $\phi_s$. Together with this information the analysis of $B_s^0 \to D_s^\mp K^\pm$ decays allows for the determination of the CKM angle $\gamma$. While these decay modes, dominated by tree-level processes, allow for clean measurements of the *CP*-violating phases, in other modes effects from the presence of loop processes have to be accounted for.

At the LHCb experiment, these decay-time-dependent studies can be performed with high sensitivity, as the fast $B_s^0$ oscillation can be well resolved due to the $\mathcal{O}(50\,\text{fs})$ decay-time resolution of the detector. The crucial information of the $B_s^0$-meson flavour at the time of its production is derived by various flavour-tagging algorithms.

An overview of the latest published analyses and ongoing developments in this field will be presented.

T 22.5 Mon 17:00 Geb. 30.41: HS 4

**A Generic Search Strategy for CP Violation in B-meson Decays at Belle II** — •Rab Scholz-McCulloch, Nikolai Hartmann, and Thomas Kuhr — LMU, Munich, Germany

CP violation is a fundamental contributor to the observed matter-antimatter asymmetry in our Universe. However, the currently only known sources of CP violation are insufficient to explain the asymmetry that we observe. Therefore, it is crucial to search for previously unaccounted sources of CP violation that may have been overlooked by past measurements targeting specific models. This study aims to measure the asymmetries in the decays of B mesons at the Belle II experiment generically. The goal is to develop an analysis strategy for detecting asymmetries without relying on assumptions about a specific model.

T 22.6 Mon 17:15 Geb. 30.41: HS 4

**Measurement of the branching ratios of the decays $B^0 \to D^- K^+$ and $B^0 \to D^{*-} K^+$ at the Belle II experiment** — •Zeynep Su Selcuk, Sviatoslav Bilokin, and Thomas Kuhr — Ludwig-Maximilians-Universität München

The theoretical predictions for the decay $B^0 \to D^{(*)-} K^+$ have been greatly improved recently and show significant deviations from the current experimental measurements. These deviations may be caused by systematic shifts in the previous experimental measurements or can even indicate contributions from the New Physics. Therefore, the goal of the presented analysis is to investigate this situation by measuring the branching fractions for the decay modes $B^0 \to D^- K^+$ and $B^0 \to D^{*-} K^+$ using Belle II data with an integrated luminosity of 362 fb$^{-1}$. In this analysis particle identification is done using the neural network variables, which leads to enhanced signal efficiency and improved background suppression with respect to the previous analyses at Belle or Belle II.

T 22.7 Mon 17:30 Geb. 30.41: HS 4

**Nonleptonic B decays at NNLO** — •Manuel Egner[1], Matteo Fael[2], Kay Schönwald[3], and Matthias Steinhauser[1] — [1]Karlsruhe Institute of Technology — [2]CERN — [3]University of Zürich

The decay of B mesons can be predicted within the Heavy Quark Expansion as the decay of a free bottom quark plus corrections which are suppressed by powers of $1/m_b$. This talk will describe the calculation of the NNLO corrections to nonleptonic decays of a free bottom quark including charm quark mass effects. In particular we will describe challenges in connection to the computation of master integrals, the renormalization of the effective Hamilton operator and the problems which arise from calculating traces with $\gamma_5$ in $d \neq 4$ dimensions.

T 22.8 Mon 17:45 Geb. 30.41: HS 4

**Dimension-6 HQET Sum Rules for Beyond the Standard Model** — •Zachary Wüthrich, Matthew Black, and Alexander Lenz — University of Siegen, Germany

Precise determination of hadronic matrix elements plays a crucial role for interpreting potential deviations from the Standard Model observed in experiments testing flavor physics. While lattice QCD provides first-principles calculations, current results are still limited to a subset of the operators that may appear in theories of new physics. The sum rule approach allows for a complementary determination of matrix elements directly from QCD, with theoretical uncertainties that can be systematically improved order-by-order in perturbation theory.

Previous research successfully ascertained Standard Model hadronic matrix elements for dimension-six ΔF=0,2 operators, demonstrating competitiveness with lattice findings. Our aim is to expand upon these findings by including the entire set of four-quark QCD operators for lifetimes, crucial in scenarios Beyond the Standard Model, where lattice results are currently absent. This extension includes operators with Dirac structures not previously examined in sum rules analyses documented in existing literature. This will provide for the first time bag parameter results which can increase the precision of a wide variety of new physics theories. The bag parameter results will be determined using HQET sum rules for three-point correlators, which requires a three-loop computation. In addition there is a one-loop computation of the QCD-HQET matching required.

# T 23: Top physics 1

Time: Monday 16:00–18:15 Location: Geb. 30.95: Audimax

T 23.1 Mon 16:00 Geb. 30.95: Audimax

**Quantum Entanglement in Top Quark Pairs in the Lepton+Jets Final State** — Arnulf Quadt, Baptiste Ravina, •Theresa Reisch, and Elizaveta Shabalina — II. Physikalisches Institut, Georg-August-Universität Göttingen

Quantum entanglement is a fundamental prediction of quantum mechanics and the experimental achievements with electrons and photons were recognised by the Nobel Prize in Physics 2022. At the LHC, quantum entanglement can be observed in top quarks, testing quantum mechanics at high energies. Therefore, a sensitivity study for a possible measurement of quantum entanglement in the top quark pair production in the lepton+jets final state is presented.

The angular separation between the decay products of the top quarks can act as an indicator of quantum entanglement, when the two top quarks are produced near threshold. The two strongest spin analysers in this final state are the charged lepton and the down type quark which is accessed via $c$-tagging. The result is then compared to parton level predictions using a calibration curve. As the biggest challenge for this analysis, the parton shower systematic uncertainty, comparing Powheg+Pythia 8 to Powheg+Herwig 7.13 predictions, is discussed.

The study is performed with ATLAS Monte Carlo simulations under Run 2 conditions.

T 23.2 Mon 16:15 Geb. 30.95: Audimax

**Measurement of $t\bar{t}$ spin entanglement in the 1-lepton channel in ATLAS** — Katharina Behr, Eleanor Jones, and •Fiona Ann Jolly — DESY, Hamburg

The top quark, one of the heaviest known elementary particles, is mostly produced in pairs ($t\bar{t}$) at the LHC. These $t\bar{t}$ final states are sensitive to undetected and rare processes predicted by the Standard Model (SM), one of them being the quantum entanglement of $t\bar{t}$ spins. One of the kinematic regions most sensitive to entanglement is characterised by low values of the invariant mass of the $t\bar{t}$ system, just above the kinematic 'turn-on' for $t\bar{t}$ production ($m_{t\bar{t}} \geq 2m_t$) The presence of entanglement is probed via a high-precision measurement of an angular variable sensitive to the $t\bar{t}$ spin correlation in this region.

In this talk, sensitivity studies for using the 1-lepton $t\bar{t}$ decay channel for quantum entanglement measurements in the resolved decay topology are presented. The calculation of the relevant angular variable relies on the identification of the down-type quark jet coming from the W boson decay, which has the highest spin-analysing power among the hadronic top quark decay products. If this jet is not identified, the b-jet coming from the hadronic top quark decay is used. Hence, one of the key challenges is the correct assignment of jets to the $t\bar{t}$ decay products. To achieve this, the $t\bar{t}$ system is reconstructed using a reconstruction approach called SpaNet. Background estimates in the turn-on region are also shown.

T 23.3 Mon 16:30 Geb. 30.95: Audimax

**Measurements of Top-quark Pair Spin Correlation in the $\ell$ + Jets Channel Using the ATLAS Experiment** — •Oleksandr Burlayenko[1], Andrea Knue[2], and Zuzana Rurikova[1] — [1]University of Freiburg — [2]TU Dortmund

The top quark, the heaviest known fundamental particle exhibits a lifetime of $\mathcal{O}(10^{-25}s)$, which is shorter than both the quantum chromodynamic (QCD) hadronization time scale $1/\Lambda_{QCD} \approx 10^{-24}$s and the spin decorrelation time scale $m_t/\Lambda^2_{QCD} \approx 10^{-21}$s. This allows studying the spin properties of a bare quark, as the angular distribution of its decay products preserves its spin information.

Within the Standard Model (SM), $t\bar{t}$ pairs have correlated spins, with the degree of correlation being sensitive to the production mechanism. The most recent measurement performed by ATLAS uses 13 TeV data in the dilepton channel.

This work presents ongoing studies of the $t\bar{t}$ spin correlation in the $\ell$ + jet channel at $\sqrt{s}$ = 13 TeV. While this channel provides a larger dataset, the analyzing power is reduced compared to the dilepton channel.

To improve event reconstruction, machine learning techniques are employed. Combined with an optimization study, these techniques exhibit high performance in eliminating non-reconstructable events. Furthermore, the measurement of SM-like spin correlation in a blinded Asimov profile likelihood template fit will be presented, considering the full impact of systematic uncertainties and various spin correlation sensitive observables.

T 23.4 Mon 16:45 Geb. 30.95: Audimax

**Search for same-sign top pair production with the Standard Model Effective Field Theory at the ATLAS experiment** — Noemi Cavalli[1,2], Merve Nazlim Agaras[3], Maximiliano Sioli[2], Matteo Negrini[2], Kevin Alexander Kroeninger[1], Aurelio Juste Rozas Rozas[3], and •Aaron van der Graaf[1,2] — [1]Technical University of Dortmund — [2]University of Bologna — [3]The Institute for High Energy Physics of Barcelona

Model-independent searches for new physics at high energies by using the Standard Model (SM) Effective Field Theory (SMEFT) are an important part of todays physics program. Same-sign top-quark pair production is highly suppressed in the SM while several models beyond the SM enhance the production. SMEFT is used obtain model-independent predictions for the production of the same-sign top pairs beyond the SM. Three EFT operators are considered to simulate the searched signal. The full Run 2 dataset collected by the ATLAS detector from proton-proton collisions is used for this search for same-sign top-quark pairs, in the dilepton final state. A Neural Network (NN) is employed to build separate signal regions (SR) enriched in same-sign top events resulting from different EFT operators. Within the defined SRs, a second NN is applied to perform a signal-background discrimination. In order to attain an accurate estimation of background contributions in the SRs, several Control Regions (CRs) are defined. The background estimation and the signal search are performed by using a maximum likelihood fit over all analysis regions.

T 23.5 Mon 17:00 Geb. 30.95: Audimax

**Search for $t\bar{t}\gamma\gamma$ production in lepton+jets channel in pp collisions at $\sqrt{s}$=13 TeV with the ATLAS detector** — Diptaparna Biswas[1], Beatrice Cervato[1], Markus Cristinziani[1], Carmen Diez Pardos[1], Ivor Fleck[1], •Arpan Ghosal[1], Gabriel Gomes[1], Jan Joachim Hahn[1], Vadim Kostyukhin[1], Nils Krengel[1], Buddhadeb Mondal[1], Stefanie Müller[1], Katharina Voss[1], Wolfgang Walkowiak[1], Adam Warnerbring[1], and Tongbin Zhao[1,2] — [1]Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen — [2]Shandong University, China

The top quark pair production ($t\bar{t}$) in association with one or more photons is a key Standard Model process for measuring the strength of the electroweak coupling of the top quark with the photon. While the production of $t\bar{t}$ with one photon is well-studied, the rarer $t\bar{t}$ production with two photons ($t\bar{t}\gamma\gamma$) still remains unobserved. The $t\bar{t}\gamma\gamma$ process is not only a good candidate for probing the electroweak coupling of the top quark, but it is also significant as an irreducible background to the $t\bar{t}$ production in association with a Higgs boson decaying to two photons. Understanding the $t\bar{t}\gamma\gamma$ process can help tighten constraints on anomalous electric and magnetic dipole moments, through which new CP-violating sources can manifest. The talk will discuss the ongoing efforts in the search for the $t\bar{t}\gamma\gamma$ process in the single-lepton $t\bar{t}$ decay channel using the full Run 2 dataset collected by the ATLAS detector at $\sqrt{s}$ = 13 TeV.

T 23.6 Mon 17:15 Geb. 30.95: Audimax

**NNLO soft function for 0-jettiness in (associated) $t\bar{t}$ production** — Guido Bell[1], Alessandro Broggio[2], Bahman Dehnadi[3], •Sebastian Edelmann[1], Matthew A. Lim[4], and Rudi Rahn[5] — [1]Theoretische Teilchenphysik, Center for Particle Physics, Universität Siegen, Siegen, Germany — [2]Faculty of Physics, University of Vienna, Wien, Austria — [3]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [4]Department of Physics and Astronomy, University of Sussex, Sussex House, Brighton, UK — [5]Department of Physics and Astronomy, University of Manchester, Manchester, UK

In order to compare theoretical predictions to the exceptionally accurate LHC data, it is essential to have a thorough understanding of $t\bar{t}$ and $t\bar{t}X$ production cross sections, where $X = \gamma, W, Z, H$. Since jettiness slicing has already been successfully applied to compute NNLO corrections including massless partons, our aim is to develop this method for processes that include top quarks. At small values of the 0-jettiness variable, it can be shown that the cross section factorizes into hard, beam, and soft functions. While beam functions are universal and known from massless calculations, our focus consists in computing the relevant soft functions for massive partons. We have already automated the calculation of the real-virtual contribution to the $t\bar{t}$ soft function, utilizing a generic measurement function, that includes all information about the observables, and performing numerical integration over the remaining phase-space variables. This calculation will lay the groundwork for implementing associated $t\bar{t}$ production processes in the Monte-Carlo event generator GENEVA.

T 23.7 Mon 17:30 Geb. 30.95: Audimax

**EFT interpretation of a $t\bar{t}\gamma$ differential cross-section measurement using full Run 2 data with the ATLAS experiment** — Diptaparna Biswas[1], Beatrice Cervato[1], Markus Cristinziani[1], Carmen Diez Pardos[1], Ivor Fleck[1], Arpan Ghosal[1], Gabriel Gomes[1], •Jan Joachim Hahn[1], Vadim Kostyukhin[1], Nils Krengel[1], Buddhadeb Mondal[1], Stefanie Müller[1], Katharina Voss[1], Wolfgang Walkowiak[1], Adam Warnerbring[1], and Tongbin Zhao[1,2] — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Shandong University, China

The production of top quark pairs in association with a photon ($t\bar{t}\gamma$) is an important process to investigate the coupling between the photon and the top quark. Precise measurements of this coupling allow testing the Standard Model (SM) and probe for new physics effects. The Standard Model Effective Field Theory (SMEFT) models physics phenomena beyond the SM via the introduction of higher dimension operators. In this talk, the measurement of the differential $t\bar{t}\gamma$ cross-section using 140 fb$^{-1}$ of data collected by the ATLAS detector in proton-proton collisions at $\sqrt{s}$ = 13 TeV and its interpretation in the context of SMEFT will be presented. The measurement is performed at particle level in the single lepton and dilepton decay channels of the top quarks. The differential cross-section as a function of photon transverse momentum is used to set constraints on the electroweak dipole moments of the top quark.

T 23.8 Mon 17:45 Geb. 30.95: Audimax

**Global EFT Fits using *TopCPToolkit* & *FastFrames*** — Arnulf Quadt, Baptiste Ravina, and •Daniel Werner — II. Physikalisches Institut, Georg-August Universität Göttingen

The Effective Field Theory (EFT) is a promising approach in the search for physics beyond the Standard Model (BSM), without having to adhere to a specific BSM model. The top-electroweak sector ($t\bar{t}Z$, $t\bar{t}W$, $t\bar{t}H$, etc.) is of particular interest to constrain a number of EFT operators, and a global fit to these processes is needed. This in turn requires reliable, robust and efficient analysis software.

With the prospect of rising luminosities in Run 3 and especially the high-luminosity LHC, new analysis frameworks are needed in the ATLAS collaboration with a stronger focus on reducing computing times and disk space usage. Saving disk space is achieved by introducing the common derivation format DAOD_PHYS for most Run 3 ATLAS analyses. For producing individual ntuples from this format, the framework *TopCPToolkit* was developed based on Combined Performance (CP) algorithms, and also featuring dedicated analysis tools that can be inherited from commonly used analysis tools.

Filling histograms with values derived from these ntuples is achieved through the newly developed framework *FastFrames*. This framework uses ROOT's RDataFrames and improves the performance greatly, compared to previous workflows in the ATLAS Top working group.

This talk will focus on work of applying *TopCPToolkit* and *FastFrames* to produce ntuples and histograms to provide the basics for EFT fits of top+X processes in the framework of a Run 3 analysis.

T 23.9 Mon 18:00 Geb. 30.95: Audimax

**Search for charged lepton flavour violation in top-quark production and decay with the ATLAS experiment** — Diptaparna Biswas[1], Beatrice Cervato[1], Markus Cristinziani[1], Carmen Diez Pardos[1], Ivor Fleck[1], Arpan Ghosal[1], •Gabriel Gomes[1], Jan Joachim Hahn[1], Vadim Kostyukhin[1], Nils Krengel[1], Buddhadeb Mondal[1], Stefanie Müller[1], Katharina Voss[1], Wolfgang Walkowiak[1], Adam Warnerbring[1], and Tongbin Zhao[1,2] — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Shandong University, China

In the Standard Model with massless neutrinos, the flavour of charged leptons cannot be altered in weak interactions. However, the observed neutrino oscillations allow for charged lepton flavour violating processes, even though suppressed much below our current experimental sensitivity. Hence, experimental evidence of such rare processes would provide signs of new physics beyond the SM.

Investigations targeting a direct search for charged lepton flavour violation will be presented using proton–proton collision data collected by the ATLAS detector between 2015 and 2018 at $\sqrt{s}$ = 13 TeV. In $t\bar{t}$ pair production, decays of a top quark into an electron–muon pair and an up-type quark are examined as well as single top-quark production in association with an electron–muon pair.

In the $t\bar{t}$ case, the final state of interest is obtained when the SM top-originated $W$ decays hadronically, and similarly for the single top production. A multivariate discriminant, namely a boosted decision tree, is implemented and optimised for signal discrimination purposes.

## T 24: Invited Overview Talks 2

Time: Tuesday 9:00–10:30 Location: Geb. 30.95: Audimax

**Invited Overview Talk** T 24.1 Tue 9:00 Geb. 30.95: Audimax
**Latest results of the LHCb experiment** — •Dominik Stefan Mitzel — TU Technical University Dortmund
Over the last decade, the LHCb collaboration has played a major role in the landscape of flavour physics and recently submitted its 700th paper for publication. The results are mainly based on proton-proton collision data recorded in two run periods, referred to as Run I (2010-2012) and Run II (2015-2018). Outstanding results have been achieved for instance in the areas rare decays, neutral meson oscillations and measurements of CP violation. LHCb continues analysing the previously recorded data set and this talk will highlight some of the most recent results.

During a three year shut-down period, the LHCb detector has been upgraded, aiming at data taking at a higher luminosity and with increased trigger efficiency for a wide range of decay channels. Various changes to the detector were made to reach this goal, including the implementation of a triggerless readout of the full system and the installation of a large-area tracking detector made of scintillating fibres. This presentation will also show first results obtained with the upgraded detector.

**Invited Overview Talk** T 24.2 Tue 9:30 Geb. 30.95: Audimax
**Belle II at the start of Run2 and physics highlights** — •Carsten Niebuhr — Deutsches Elektronen-Synchrotron DESY
In Run 1, which lasted from 2019-2022, Belle II at the SuperKEKB electron-positron collider in Japan collected data corresponding to an integrated luminosity of almost 430/fb, about half the data set accumulated by its predecessor experiment, Belle. While the analysis of this data is still continuing, it has already led to a number of world-leading results. In parallel, the accelerator and the experiment have undergone a number of improvements during the first 1.5 year long shutdown (LS1), including the installation of the complete 2-layer pixel vertex detector and several modifications on the accelerator side. These latter measures are designed to overcome some of the performance limitations experienced in the early years of operation of this novel and challenging machine. An outlook on Run 2, which has just started, will be given.

**Invited Overview Talk** T 24.3 Tue 10:00 Geb. 30.95: Audimax
**Overview of the ECFA Detector R&D Roadmap and status of the implementation of its recommendations** — •Susanne Kuehn — Esplanade des Particules, 1, CH-1211 Meyrin
The European Strategy for Particle Physics Update recommended that 'Organised by ECFA, a roadmap should be developed by the community to balance the detector R&D efforts in Europe, taking into account progress with emerging technologies in adjacent fields'. This Roadmap which is based on the input of the community and was developed within the Detector R&D Panel, was approved by ECFA and published at the end of 2021. Since then work continued by the involved teams to implement its strategic recommendations, including establishing new Detector R&D Collaborations. In this talk the key findings and recommendations of the Task forces and by this the detector technology areas or cross-cutting activities of the ECFA Detector R&D Roadmap will be presented. Moreover, the implementation of the key recommendations and their status will be highlighted and an outlook to future Detector R&D given.

## T 25: Invited Overview Talks 3

Time: Tuesday 11:45–12:45 Location: Geb. 30.95: Audimax

**Invited Overview Talk** T 25.1 Tue 11:45 Geb. 30.95: Audimax
**Extensive air shower simulations – successes and challenges** — •Tim Huege — Karlsruhe Institute of Technology, Institute for Astroparticle Physics, Karlsruhe, Germany — Vrije Universiteit Brussel, Astrophysical Institute, Brussel, Belgium
Monte Carlo Simulations of extensive air showers are an essential foundation of many experimental projects in Astroparticle Physics, be it in imaging atmospheric Cherenkov telescopes, particle detector arrays measuring cosmic rays, or radio detectors for high-energy cosmic rays and neutrinos. The CORSIKA code in particular has shaped the field for over 20 years, yet new challenges arising in ever-more complex detectors are increasingly driving it to its limits. In this talk, I will review the successes and relevance of air-shower simulations, discuss open issues (such as the "muon puzzle") and current limitations, before describing how the independent re-implementation of air-shower simulation functionality in the modern CORSIKA 8 framework will allow us to tackle new challenges as well as profit from new results from particle physics experiments.

**Invited Overview Talk** T 25.2 Tue 12:15 Geb. 30.95: Audimax
**The muon anomalous magnetic moment** — •Christoph Lehner — University of Regensburg
The precise study of the Landé g-factor has lead to significant advances in our understanding of elementary particles ever since the first measurement by Stern and Gerlach for the electron.

Recently, the Fermilab E989 experiment has significantly improved upon the experimental precision of the muon's g-factor which offers an unprecedented view into the inner workings of elementary particle physics. Some challenges remain to match this experimental result with an equally precise theory value.

I will review the current status of both experiment and theory and will give an outlook on new developments to be expected in the coming years.

## T 26: Invited Topical Talks 1

Time: Tuesday 14:00–15:30 Location: Geb. 30.21: Gerthsen-HS

**Invited Topical Talk** T 26.1 Tue 14:00 Geb. 30.21: Gerthsen-HS
**New physics searches through the Higgs and atomic windows** — •Elina Fuchs — Leibniz University Hannover, Germany — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany
The observed matter-antimatter asymmetry of the Universe and the existence of Dark Matter are among the most compelling evidences for the necessity of physics beyond the Standard Model. As these puzzles do not predict at which energy scale to expect a discovery, a variety of observables at different energies is needed to explore viable scenarios. I will present two such avenues.

On the one hand, I will discuss how the precise measurements of the Higgs couplings allow one to determine to which extent CP violation in the interactions of the Higgs boson may contribute to the amount of CP violation needed to explain the observed baryon asymmetry. I will also show examples of Machine Learning approaches to improve the sensitivity to CP violation in Higgs couplings.

In a complementary way, I will present how high-precision frequency measurements in atoms and ions open up a quantum sensing window for searches for ultralight dark bosons.

**Invited Topical Talk** T 26.2 Tue 14:30 Geb. 30.21: Gerthsen-HS
**Study of electroweak interactions via vector boson scattering at the ATLAS detector** — •Gia Khoriauli — Julius-Maximilians-Universität Würzburg
The LHC has opened the possibility of experimental studies of the self-interactions of the electroweak vector bosons in proton-proton collisions at the TeV energy scale. Electroweak vector boson scattering (VBS) processes imply the interactions between two vector bosons that produce two final state vector bosons. The production is accompanied with two energetic back-to-back hadronic jets in the forward regions of the detector. These jets are initiated from the interacting quarks which radiated the scattering vector bosons. Leading order amplitudes of the electroweak VBS processes are sensitive to the triple and

quartic gauge couplings between the vector bosons as well as to their couplings with the Higgs boson. Measurements of these processes are therefore important tests of the Standard Model and its symmetry breaking mechanism. The electroweak VBS final states have relatively low production cross sections at the LHC energies. This makes them sensitive to possible new physics effects that lead to anomalous quartic gauge couplings between the vector bosons and hence, to measurable deviations from the Standard Model predictions. Studies of various electroweak VBS final states at the ATLAS detector are presented. Experimental methods of the measurements and effective field theory interpretations of the results for model-independent searches for anomalous quartic gauge couplings are discussed.

**Invited Topical Talk** T 26.3 Tue 15:00 Geb. 30.21: Gerthsen-HS

**AI-aided searches for new physics** — •Benedikt Maier — KIT, Karlsruhe, Germany

After the discovery of the Higgs boson, LHC experiments have not yet been able to find new, additional elementary particles that could explain the biggest open questions in particle physics and cosmology. To maximize the sensitivity of the searches, artificial intelligence solutions are permeating the analysis strategies, improving the results and sometimes enabling entirely new types of searches. I will present recent highlights of employing machine learning to find new physics at the LHC, and provide a perspective on what can be expected in the coming years leading up to the High Luminosity-LHC.

## T 27: Invited Topical Talks 2

Time: Tuesday 14:00–15:30 Location: Geb. 30.22: Gaede-HS

**Invited Topical Talk** T 27.1 Tue 14:00 Geb. 30.22: Gaede-HS

**Start up of Run 3 and performance of the upgraded LHCb experiment** — •Elena Dall'Occo — TU Dortmund, Dortmund, Germany

The LHCb experiment underwent a major upgrade during the last long shutdown in order to operate at fivefold increase in instantaneous luminosity compared to the previous runs. Among the major changes, the tracking system has been fully replaced and the readout of all subdetectors is now at 40 MHz with a fully software based trigger.

This talk will focus on how to transition from a newly installed detector to a fully functioning and performant system in a process known as commissioning, spanning from the hardware side to reconstruction, trigger, alignment and calibration. The preliminary performance of the detector will be presented, including subsystem specific and global figures such as tracking reconstruction and particle identification efficiencies. The aim of this year is to reach the design operating conditions, and plans to achieve it as well as prospects for this exciting data taking period will be described.

**Invited Topical Talk** T 27.2 Tue 14:30 Geb. 30.22: Gaede-HS

**Fully-inclusive measurement of $B^{0,\pm} \to XJ/\psi$ processes at Belle II** — •Sviatoslav Bilokin — Ludwig Maximilian University, Munich, Germany

Studies of $b \to c\bar{c}s$ processes, such as $B^{0,\pm} \to K^{0,\pm}J/\psi$, were at the core of the physics programs of the first generation of B-factories and served as the basis for the Nobel Prize in Physics 2008. Despite numerous measurements in the last few decades, many physics observables of these processes remain unknown, especially for the higher-order resonances in the final state. Modern high-luminosity frontier experiments, such as Belle II at SuperKEKB, provide an ideal environment for advancing precision studies of $b \to c\bar{c}s$ decays with inclusive final state.

In this contribution, we report the first measurements of the individual branching ratios $BR(B^0 \to XJ/\psi)$ and $BR(B^+ \to XJ/\psi)$ using a fully-inclusive approach at Belle II, where $X$ represents strange-quark or light-quark hadrons. Additionally, the employment of hadronic tagging allows for a novel determination of the differential distributions of the helicity angle for the decay and the momentum magnitudes of the $J/\psi$ in the $B$ rest frame. These fully-inclusive measurements of $B \to XJ/\psi$ decays represent an important milestone towards a fully-inclusive analysis of $B \to X\ell^+\ell^-$ processes in the near future, which will serve as an excellent probe for New Physics searches.

**Invited Topical Talk** T 27.3 Tue 15:00 Geb. 30.22: Gaede-HS

**Probing Axion Dark Matter with Flavor Factories** — •Robert Ziegler — Institut für Theoretische Teilchenphysik (TTP), Karlsruhe Institute of Technology (KIT)

Standard Model extensions with light axions are well-motivated by the observed Dark Matter abundance and the Peccei-Quinn solution to the Strong CP Problem. In general such axions can have large flavor-violating couplings to SM fermions, which arise naturally in scenarios where the Peccei-Quinn symmetry also explains the hierarchical pattern of fermion masses and mixing. I will discuss how these couplings allow for efficient axion production from the decays of SM particles, giving the opportunity to probe axion Dark Matter in precision flavor experiments, core-collapse supernovae and the early Universe.

## T 28: Search for new particles 3 (ALPS)

Time: Tuesday 16:00–18:00 Location: Geb. 20.30: 1.067

T 28.1 Tue 16:00 Geb. 20.30: 1.067

**Search for long-lived axion-like particles in top production** — Juliette Alimena[1], Freya Blekman[1,2], Jeremi Niedziela[1], •Lovisa Rygaard[1,2], Susanne Westhoff[3,5,6], Ruth Shäfer[3], and Sebastian Burgisser[3,4] — [1]Deutsches Elektronen-Synchrotron, Hamburg, Germany — [2]Universität Hamburg, Hamburg, Germany — [3]Heidelberg University, Heidelberg, Germany — [4]Uppsala University, Uppsala, Sweden — [5]Radboud University, Nijmegen, The Netherlands — [6]Nikhef, Amsterdam, The Netherlands

We investigate the discovery potential for long-lived axion-like particles produced in association with a top quark-antiquark pair at the (High-Luminosity) LHC. Compared to inclusive searches for a displaced vertex, top quark associated signals offer new trigger options and an extra handle to suppress background. The search strategy includes axion-like particle decays to a displaced di-muon vertex which further contributes to the suppression of prompt background. For axion-like particles with masses above the di-muon threshold, we find that the (High-Luminosity) LHC can probe effective top-quark couplings as small as $|c_{tt}|/f_a = 0.03(0.002)$ TeV and proper decay lengths as long as 20 (300) m, assuming a cross section of 1 fb, with data corresponding to an integrated luminosity of 150 fb$^{-1}$ (3 ab$^{-1}$). Our predictions suggest that searches for top quark associated displaced di-muons will explore new terrain in the current sensitivity gap between searches for prompt di-muons and missing energy.

In this talk I will present the results of our phenomenology study, and the first results of the CMS analysis searching for this same signature.

T 28.2 Tue 16:15 Geb. 20.30: 1.067

**Search for top quark decays to long-lived axion-like particles with ATLAS** — •Frederic Fischer, Alexander Basan, Lucia Masetti, Jessica Höfner, Eftychia Tzovara, and Doğa Elitez — Universität Mainz

The Standard Model (SM), although confirmed with great precision experimentally, is still insufficient to answer many fundamental questions. Hence, axion-like particles (ALPs) appear in many beyond Standard Model (BSM) theories trying to address these questions.

One way to approach ALPs is to parameterise ALP couplings to Standard Model particles like top quarks. ALPs appear in flavour-changing exotic top decays where the top quark decays into an ALP and an up- or charm-quark. Within this decay mode, parts of the allowed parameter space suggests ALPs to have lifetimes long enough to travel macroscopic distances before decaying. This search is dedicated to top-antitop events with one SM semi-leptonically decaying top quark and one exotically decaying top quark.

In this topology the focus is on ALPs decaying in the hadronic calorimeter at ATLAS with a centre-of-mass energy of 13 TeV. They are assumed to be electrically neutral and thus leave no signal in the ATLAS tracking system. Moreover, the ratio of energy deposits in the electromagnetic calorimeter and hadronic calorimeter are used to suppress SM backgrounds.

This talk presents the search for long-lived ALPs from exotic top decays at ATLAS.

T 28.3 Tue 16:30 Geb. 20.30: 1.067

**Search for ALPs in $e^+e^- \to \gamma a, a \to \gamma\gamma$ at Belle II** — •Alexander Heidelbach, Giacomo De Pietro, Torben Ferber, and Pablo Goldenzweig — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Axion-Like Particles (ALPs), predicted by theoretical extensions of the Standard Model, represent potential Dark Matter mediators. The Belle II collaboration is conducting a search for the $e^+e^- \to \gamma a$ channel, with subsequent ALP decay into a photon pair. This study utilizes the Belle II detectors precision, high luminosity, and unique understanding of the initial state to explore a diverse range of ALP masses and couplings in this fully neutral three-photon final state. Compared to the predecessor analysis based on the 2018 dataset, this analysis uses around 1000 times larger dataset, an improved understanding of the photon reconstruction resolution, and an MVA-based candidate selection. This talk will discuss the current state of the new analysis

T 28.4 Tue 16:45 Geb. 20.30: 1.067

**ALPS II Overview and Data Taking** — •Henry Frädrich for the ALPS-Collaboration — Deutsches Elektronen-Synchrotron (DESY)

The Any Light Particle Search II (ALPS II) is an ongoing 'light-shining-through-a-wall' experiment located at DESY in Hamburg. ALPS II will look for axions and axion like particles, which are hypothetical particles outside the standard model, motivated by exciting hints. The existence of axions would solve the strong CP-problem and could also be an explanation for multiple cosmic phenomena including dark matter, TeV transparency as well as the excess cooling of horizontal branch stars. The ALPS II experiment uses the axion's property of coupling to photons in the presence of magnetic fields, to measure light that has undergone axion-photon conversion and subsequent photon-axion conversion. On the experimental site we use the magnetic fields of 24 superconducting HERA magnets and two state of the art optical cavities with a length of 122 m each, to probe the axion parameter space in new regions. The experiment has been running since May 2023 with multiple successful science runs. In this talk I will give a general overview of the ALPS II experiment and discuss recently acquired data from the first science campaign.

T 28.5 Tue 17:00 Geb. 20.30: 1.067

**Precision Optics and Control for the ALPS II Experiment** — •Daniel Brotherton for the ALPS-Collaboration — University of Florida

The Any Light Particle Search II (ALPS II) is an experiment at DESY which searches for axions via a "light-shining-through-a-wall" scheme. Namely, light is directed through a region of magnetic field where it has a probability of conversion into axions. A barrier beyond this region impedes the light, but axions converted from the light may traverse the barrier and reconvert back into light in a second magnetic field region. The experiment employs 120-meter long high-finesse optical cavities to improve the final photon-axion-photon coupling sensitivity. Currently a "regeneration cavity" (RC) amplifies the reconverted light's amplitude by a demonstrated factor > 7000. A future "production cavity" (PC) will aim to store 150 kW of power to increase the flux of generated axions. This requires a control scheme to maintain the resonance of laser light within the cavities while also mitigating stray light from entering the RC. This talk will discuss the precision optics techniques utilized in ALPS II, including optical offset phase-locking and heterodyne interferometric sensing of ultra-low power fields. Some initial results of the optics performance from ALPS II's current data-taking campaign will also be discussed. Work at Florida is supported by the NSF PHY-2309918.

T 28.6 Tue 17:15 Geb. 20.30: 1.067

**Axion-Like-Particle (ALP) search using ATLAS central and ATLAS Forward Proton (AFP) detectors** — •Ondrej Matousek and Andre Sopczak — Czech Technical University in Prague

The latest results of the ALP search with the AFP detector are presented.

T 28.7 Tue 17:30 Geb. 20.30: 1.067

**Searching for axion like particles in the H->Za->llyy decay with ATLAS** — •Georgios Lamprinoudis — Johannes Gutenberg Universitat Mainz

Axion-like particles (ALPs) are motivated by numerous theoretical models, including the two-Higgs-doublet model (2HDM). ALPs can couple to the Higgs and Z bosons via a 5-dim effective coupling and may decay to photons. Depending on the axion – photon coupling ALPs can have a significant life-time which may lead to displaced decay vertices. While previous analyses assumed a negligible axion lifetime, a finite lifetime with displaced vertex signatures is studied in the present analysis of the h->Za->2l2y channel. The analysis covers a mass range of the axions from 1 GeV to 33 GeV. In the case that no signal is observed, the analysis will establish upper limits on the axion-Higgs-Z coupling.

T 28.8 Tue 17:45 Geb. 20.30: 1.067

**Multivariate photon classification for an axion-like particle (ALP) search in Higgs boson decays at the ATLAS experiment** — •Peter Krämer, Kristof Schmieden, Matthias Schott, and Olivera Vujinović — Johannes Gutenberg Universität Mainz

Some puzzling questions in particle physics, such as the strong CP problem or the discrepancy of the muon magnetic moment could be solved by introducing light scalar or pseudo-scalar axion-like particles (ALPs). Theoretical models allow a wide range of ALP-masses and couplings to SM particles such as photons and the Higgs boson. Therefore, parts of the ALP parameter space could be investigated with collider experiments like the ATLAS experiment at the LHC.

For low mass ALPs, the decay photons can appear strongly collimated. These collimated photon pairs are reconstructed as a single photon. In this talk it will be discussed how multivariate classification techniques can be applied on detector level information to identify these collimated photons.

# T 29: Neutrino physics 3

Time: Tuesday 16:00–18:00 Location: Geb. 20.30: 2.058

T 29.1 Tue 16:00 Geb. 20.30: 2.058

**JUNO's sensitivity to the neutrino mass ordering in presence of a fine structure in the reactor antineutrino spectrum** — •Tobias Heinz, Tanjina Ananya, Lukas Bieger, Marc Breisch, Jessica Eck, Benedict Kaiser, Florian Kirsch, Tobias Lachenmaier, Dhanushka Bandara, and Tobias Sterr — Eberhard Karls Universität Tübingen, Physikalisches Institut

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillator detector with the main goal to determine the neutrino mass ordering (NMO) to $3\sigma$ within 6 years of data taking. It will measure the oscillated electron antineutrino spectrum emitted by two nuclear power plants in a distance of 53 km with an unprecedented energy resolution of better than 3% at 1 MeV. For the identification of the NMO in the oscillated spectrum, a precise knowledge of the unoscillated reactor antineutrino spectrum is crucial. However, new model calculations predict a fine structure in the spectrum that has not been observed with previous detectors due to insufficient energy resolution. For JUNO, these unknown distortions in the spectrum could impact the NMO determination. Therefore, JUNO will feature a satellite detector in a distance of 44 m from one of the reactor cores, the Taishan Antineutrino Observatory (TAO), that will provide a reference spectrum with an energy resolution of better than 2% at 1 MeV. This talk will present studies on possible implications of this fine structure on JUNO's NMO sensitivity and on the important role of the satellite detector TAO to reduce the impact of the unknown spectral distortions. This work is supported by the Deutsche Forschungsgemeinschaft.

T 29.2 Tue 16:15 Geb. 20.30: 2.058

**Feasibility study of tau appearance measurement with the ANTARES neutrino telescope.** — •Michail Chadolias for the ANTARES-KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

The ANTARES detector, a water Cherenkov neutrino telescope located in the Mediterranean Sea at a depth of 2.5 kilometres, operated successfully until its decommissioning in 2022. Primarily designed for detecting high-energy neutrinos of astrophysical origin, it was also sensitive to all neutrino flavours in the atmospheric neutrino flux with an energy threshold of a few GeV. This work focuses on tau neutrino appearance, i.e. the existence of a tau neutrino atmospheric flux component due to neutrino flavour oscillations at this energy range. Exploiting the data of the full 15-year detector lifetime, we report on an exploratory analysis investigating the feasibility to detect and characterise a flux of tau neutrinos with the ANTARES detector. Strategies for the challenging event selection and the current status of the sensitivity to the tau neutrino flux normalisation will be shown.

T 29.3 Tue 16:30 Geb. 20.30: 2.058

**Search for Neutrinoless Double Beta Plus Decays with NuDoubt$^{++}$** — Manuel Böhles[1], Sebastian Böser[1], Magdalena Eisenhuth[1], Cloé Girard-Carillo[1], Bastian Kessler[1], Kyra Mossel[1], •Stefan Schoppmann[2], Alfons Weber[1], and Michael Wurm[1] for the NuDoubt-Collaboration — [1]Johannes Gutenberg-Universität Mainz, Institut für Physik, 55128 Mainz, Germany — [2]Johannes Gutenberg-Universität Mainz, Detektorlabor, Exzellenzcluster PRISMA$^{+}$, 55128 Mainz, Germany

The discovery of neutrino oscillations two decades ago opens the possibility for new physics as to the origin of their masses. Due to their lack of electrical charge, neutrinos could carry Majorana masses causing lepton number violation. This phenomenon could be discovered in neutrinoless double beta decays, where the participating neutrinos are exchanged only internally.

Until now, searches for neutrinoless double beta decays concentrated on double electron emission. With the recent advancement of novel scintillator types capable of unprecedented particle discrimination, the measurement of double positron emission comes into reach.

In this presentation, we introduce NuDoubt$^{++}$, which is going to use loaded hybrid opaque scintillator to search for double positron emission. We present its advanced particle discrimination capabilities based on topological features of energy depositions and ratios of Cherenkov and scintillation light. Moreover, we illustrate its loading techniques, as well as novel highly effective light readout.

T 29.4 Tue 16:45 Geb. 20.30: 2.058

**Development of a High-Pressure Scintillator Test Cell for NuDoubt++** —
Tim Charisse[1], Manuel Böhles[1], Sebastian Böser[1], Marcel Büchner[1], •Magdalena Eisenhuth[1], Cloé Girard[1], Arshak Jafar[1], Bastian Kessler[1], Kyra Mossel[1], Stefan Schoppmann[2], Alfons Weber[1], and Michael Wurm[1] for the NuDoubt-Collaboration — [1]JGU Mainz, Institute of Physics, 55128 Mainz — [2]Exzellenzcluster PRISMA+, 55128 Mainz

The investigation of two-neutrino and neutrino-less double beta decay is crucial for understanding the Dirac or Majorana nature of neutrinos. In this context, the krypton isotope Kr-78 (Q=2.88 MeV) stands out as a promising candidate for a first detection of two-neutrino ECb+ and 2b+ decays. Detectors like the proposed NuDoubt++ experiment featuring opaque scintillator or an upgrade of the OSIRIS detector with hybrid scintillator can profit from solving the krypton gas in the scintillator at high pressure to increase the loading factor. This presentation explores the progress in developing a high-pressure scintillator test cell designed to examine the krypton loading factor. We discuss the design and fabrication of this overpressure test cell and, finally, elaborate on the methodology for measuring the loading factor in the scintillator volume.

T 29.5 Tue 17:00 Geb. 20.30: 2.058

**Radiation hardness studies of the KATRIN detector upgrade to search for keV sterile neutrinos** — •Verena Wallner — TU München, Deutschland

Sterile neutrinos represent a minimal expansion of the Standard Model of particle physics and serve as potential dark matter candidates when their mass falls within the keV range. Tritium beta decay can be used to experimentally observe sterile neutrinos with a mass of up to 18.6 keV. In that case, they would display a kink-like distortion in the electron energy spectrum. Currently, a silicon drift detector upgrade (TRISTAN) is being developed for the KATRIN experiment to search for keV-scale sterile neutrinos. This presentation is about the radiation hardness to electrons of the detector system. To investigate this question, a detection module is irradiated over a short period of time with electrons such that the integrated dose corresponds to one year's data acquisition with TRISTAN.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6) and has received funding from the European Research Council (ERC) under the European Union Horizon 2020 research and innovation programm (grant agreement No. 852845).

T 29.6 Tue 17:15 Geb. 20.30: 2.058

**Development of technologies for a future neutrino mass experiment at KATRIN** — •Caroline Rodenbeck and Magnus Schlösser — IAP-TLK, KIT

The Karlsruhe Tritium Neutrino (KATRIN) experiment determines the neutrino mass by electron spectroscopy of the tritium beta-decay spectrum. After a total measurement time of 1000 days in 2025, a final sensitivity better than 0.3 eV/c$^2$ (90% C.L.) is anticipated.

Ultimately, determining the neutrino mass may require constructing experiments with sensitivities as low as the lower boundaries obtained by neutrino oscillation experiments (40 meV/c$^2$ in case of inverted ordering, or 8 meV/c$^2$ for normal ordering). To reach those sensitivities, we are developing new technologies such as a differential detector with sub-eV resolution, and an atomic tritium source.

For the differential detector, we are currently testing quantum sensors, more precisely, $\mu$m-sized cryogenic (10 mK) calorimeters. We aim to build a demonstrator where we couple a large quantum-sensor array of up to 10$^6$ channels to the existing KATRIN beamline.

Additionally, we are building a first-of-its-kind setup for creating tritium atoms. We plan to make it part of another demonstrator – after solving key challenges for future atomic sources (mK-cooling, storing of atoms) in cooperation with the global community (e.g. Project 8).

Both technology demonstrators will be paramount for the design of the ultimate neutrino mass experiment.

This work is supported by the Helmholtz Association and BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6).

T 29.7 Tue 17:30 Geb. 20.30: 2.058

**Studying atomic hydrogen generation to pave the way to the first atomic tritium source** — •Leonard Hasselmann for the KATRIN-Collaboration — KIT-IAP, Karlsruhe, Germany

The Karlsruhe Tritium Neutrino mass (KATRIN) experiment is currently limited to a sensitivity of 0.2 – 0.3 eV/c$^2$. In order to increase the sensitivity on the neutrino mass a new high resolution differential measurement method is required. The maximum effective resolution which can be achieved is not limited only by the detector, but also by molecular effects in the source gas constraining it to ~1 eV FWHM for $T_2$. Thus, future ultimate neutrino experiments need to use differential detectors combined with atomic tritium sources. Therefore, we move forward with the development of atomic tritium sources.

At the Tritium Laboratory Karlsruhe exists a system handling inactive hydrogen isotopes which acts as a test bed for the development of beam forming and beam diagnostics. In this setup, we recently fully characterized a commercially available hydrogen cracking system.

Based on experiences from the first setup, we deduced a second system capable of handling tritium. This setup, currently under construction, will demonstrate the first dissociation of tritium.

In this talk, we show results from non-radioactive gases like protium and deuterium. Furthermore, the implication for the current design and implementation status of a tritium-compatible system is presented.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6)

T 29.8 Tue 17:45 Geb. 20.30: 2.058

**Investigating Large Area Picosecond Photodetectors for future $\nu$-detectors** —
•Benedict Kaiser, Tanjina Anannya, Lukas Bieger, Marc Breisch, Jessica Eck, Tobias Heinz, Florian Kirsch, Tobias Lachenmaier, Dhanushka Bandara, and Tobias Sterr — Eberhard Karls Universität Tübingen, Physikalisches Institut

Large Area Picosecond Photodetectors (LAPPDs) are novel Microchannel Plate (MCP) based photodetectors. With a gain ranging from 10$^6$ to 10$^7$ and a gain uniformity of 90% across a large active area of 373 cm$^2$ they are capable of detecting single photons. They show a position resolution of 3 mm and an unparalleled time resolution better than 70 ps.

This exceptional performance is achieved by a flat, evacuated glass case accommodating a $K_2NaSb$ photocathode, a chevron arrangement of two MCPs for electron multiplication and 28 silver anode strips dedicated to signal detection. Presently, our focus lies in validating LAPPD performance characteristics using a dedicated test stand.

This talk presents the operational principles and distinctive features of LAPPDs and provides an overview of our measurement findings so far.

# T 30: Cosmic rays 3

Time: Tuesday 16:00–17:45 Location: Geb. 20.30: 2.059

T 30.1 Tue 16:00 Geb. 20.30: 2.059

**The IceCube Surface Array Enhancement and cosmic-ray observation with radio** — •Megha Venugopal for the IceCube-Collaboration — Institute of Astroparticle Physics (IAP), Karlsruhe Institute of Technology, Germany

The IceCube Neutrino Observatory is a unique 3-dimensional detector at the South Pole with its surface cosmic-ray detector, IceTop and its in-ice volume neutrino detector. Primarily motivated by the rising snow accumulation on the surface component, a new configuration of detectors was planned to be set up along the existing 81 pairs of ice-filled Cherenkov tanks of IceTop. The upgrade termed as the Surface Array Enhancement (SAE) is set to consist of up to 30 stations with elevated 8 scintillators and 3 antennas per station. The current status of the SAE radio measurements with the 3 antennas of the single station at the South Pole is discussed. The updates for upcoming stations are also presented.

T 30.2 Tue 16:15 Geb. 20.30: 2.059

**IceCube-Gen2 Surface Array: Science Case and Plans** — •Frank Schröder for the IceCube-Collaboration — Karlsruher Institut für Technologie (KIT), Institut für Astroteilchenphysik — Bartol Research Institute, Department of Physics and Astronomy, University of Delaware

IceCube-Gen2 will be a next-generation extension of the IceCube Neutrino Observatory at the South Pole. In addition to a deep Optical Array and a Radio Array for PeV neutrino astronomy, IceCube-Gen2 will feature a Surface Array to enhance the neutrino science and to provide additional cosmic-ray science. The IceCube-Gen2 Surface Array will consist of elevated scintillation panels and radio antennas above the Optical Array and will detect cosmic-ray air showers in the PeV to EeV energy range. Compared to IceCube, the measurement accuracy at the surface will be enhanced due to the combination of radio and particle detection, and the aperture for surface-deep coincident events will be increased by about a factor of 30. This contribution will present the science case of the IceCube-Gen2 Surface Array and discuss the planned design recently published in the Technical Design Report: https://icecube-gen2.wisc.edu/science/publications/tdr/

T 30.3 Tue 16:30 Geb. 20.30: 2.059

**First results with the Station 0 of the IceCube Surface Array Enhancement** — •S. Shefali for the IceCube-Collaboration — Institut für Astroteilchenphysik, Karlsruher Institut für Technologie (KIT), Karlsruhe, Germany

The IceCube Neutrino Observatory is a multipurpose detector which includes a unique surface array, IceTop, highly instrumental for cosmic ray studies in addition to its capability of vetoing for astrophysical neutrino searches for the IceCube in-ice instrumentation. It consists of frozen water tanks equipped with photomultipliers instrumented to detect secondary particles like electrons, protons and muons from cosmic ray air showers of energies up to 1 EeV.

An enhancement of the surface array, with scintillation and radio detectors, in order to facilitate multi-component cosmic ray studies, as well as improving the IceTop detectors' calibration by accounting for the snow accumulation on them, has been ongoing. The existing prototype station was recently upgraded to the first working station of the enhancement, "Station 0". This contribution will discuss the upgrade, and the first air shower measurements conducted with this station.

T 30.4 Tue 16:45 Geb. 20.30: 2.059

**Charge sign dependence of recurrent Forbush Decreases in 2016** — •Lisa Romaneehsen, Johannes Marquardt, and Bernd Heber — Christian-Albrechts-Universität zu Kiel, Germany

This study investigates the periodicities of cosmic rays attributed to co-rotating interaction regions (CIRs) using AMS-02 data from late 2016 to early 2017. These data enable the first-time examination of recurrent Forbush decrease amplitudes induced by CIRs, considering rigidity and charge sign dependence. The findings from the Lomb-Scargle algorithm and Superposed Epoch Analysis were compared. Results reveal that the rigidity dependence of proton decreases attributed to the northern coronal hole aligns with existing literature, while that of the southern coronal hole does not. The amplitude of the Helium modulation exceeds that of protons, in line with previous observations. For positrons statistical limitation prevent definitive conclusions. In comparison to the positively charged ions the modulation behavior of electrons can not be understood in the current paradigma of modulation by diffusion barriers.

T 30.5 Tue 17:00 Geb. 20.30: 2.059

**Measurment of the cosmic ray electron and positron flux with AMS02** — •Yasaman Najafijozani — Gebäude: 4280 Raum28B203 Sammelbau Physik, Sommerfeldstr. 14, Turm 28 52074 Aachen

The Alpha Magnetic Spectrometer (AMS-02) on the International Space Station has been performing precision measurements of cosmic rays in the GeV to TeV energy range since 2011. The fluxes of electrons and positrons are potential probes of dark matter or new astrophysical phenomena. With AMS-02, electrons and positrons are identified by two independent subdetectors, a transition radiation detector and an electromagnetic calorimeter. I will present my cosmic-ray electron and positron flux analysis from 0.5 to 1000 GeV.

T 30.6 Tue 17:15 Geb. 20.30: 2.059

**Measuring the Cosmic Ray Sun Shadow with IceCube*** — •Niclas Krieger[1,2], Jonas Hellrung[1,2], Lukas Merten[1,2], Frederik Tenholt[1,2], and Julia Becker Tjus[1,2,3] for the IceCube-Collaboration — [1]Theoretical Physics IV, Plasma Astroparticle Physics, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — [3]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

With the IceCube Neutrino Observatory atmospheric muons are detected that are produced when cosmic rays interact with the Earth's atmosphere. On their way to Earth, cosmic rays are blocked by the Sun and the Moon. While the Moon shadow serves as an absolute pointing calibration, the Sun shadow enables an indirect observation of the solar magnetic field. This combination of a turbulent and large-scale field deflects the charged cosmic rays and thus leaves its footprint in the cosmic ray flux. The method of measuring the shadows of these celestial objects will be explained here. Furthermore, it will be shown how these observations help to understand the solar magnetic field better. *Supported by DFG (SFB 1491) and BMBF

T 30.7 Tue 17:30 Geb. 20.30: 2.059

**Twelve Years Observation of the Seasonal Variation of Atmopheric Neutrino Flux with IceCube** — •Shuyang Deng, Jakob Böttcher, Hannah Erpenbeck, Tobias Kramer, and Christopher Wiebusch for the IceCube-Collaboration — III. Physikalisches Institut B RWTH Aachen University

High-energy atmospheric muon neutrinos are detected by IceCube with a high rate of almost a hundred thousand events per year. These neutrinos are produced in the hadronic development of air showers in the upper atmosphere. Their flux is expected to correlate with atmospheric properties such as temperature, and thus features a seasonal variation. In this talk, we present an updated measurement of the seasonal variation of the atmospheric muon neutrino flux, utilizing the 12-year neutrino sample (Northern Tracks) produced by the IceCube Neutrino Observatory. We correlate the measured neutrino rates with the atmospheric temperature profiles measured by satellites. The updated measurement yields results that are compatible with the previous studies, while confirming a tension between the theoretical predictions and experimental measurements with higher statistical significance. Further investigations on systematic effects show that the observation not only exhibits a weaker correlation compared to predictions, but also deviates from the expected linear relation between atmospheric neutrino flux and the atmospheric temperature.

# T 31: Methods in particle physics 3 (lepton reconstruction)

Time: Tuesday 16:00–18:00 Location: Geb. 20.30: 2.066

T 31.1 Tue 16:00 Geb. 20.30: 2.066

**Measurement of the tau lepton identification efficiencies using LHC Run 3 data with the ATLAS detector** — •Baktash Amini, Christian Weiser, Karsten Köneke, and Karl Jakobs — Albert-Ludwigs-Universität Freiburg

Final states with tau lepton decays are crucial components of the ATLAS physics program at the LHC. Efficient and precise reconstruction and identification of tau leptons are required in order to obtain the best possible measurements of processes containing tau leptons. This talk presents measurements of the identification efficiencies of tau leptons that decay to a single neutrino and hadrons ($\tau_{had}$), using LHC data recorded with the ATLAS detector during proton-proton collisions at $\sqrt{s}$ = 13.6 TeV. The so-called Tag-and-Probe method is employed using Z boson decays into two tau leptons, where the “Tag” is the tau lepton that decays to two neutrinos and an electron or muon ($\tau_{lep}$), while the “Probe” is the $\tau_{had}$ decay of interest ($Z \rightarrow \tau_{lep}\tau_{had}$).

T 31.2 Tue 16:15 Geb. 20.30: 2.066

**Reconstruction of boosted di-tau topologies with CMS** — •Olha Lavoryk, Markus Klute, Roger Wolf, Günter Quast, Sebastian Brommer, and Artur Gottmann — Karlsruhe Institute of Technology(ETP), Karlsruhe, Germany

The precise measurement of the Higgs boson properties remain pivotal in understanding the fundamental principles of particle physics. For the CMS experiment, the reconstruction of boosted Higgs bosons presents unique challenges, demanding innovative techniques for accurate identification and analysis. We explore novel approaches leveraging graph neural networks (GNNs) to enhance the reconstruction of boosted Higgs bosons within the CMS experiment, particularly focusing on the Higgs decay channel into a pair of tau leptons. This channel holds significant promise owing to the strong Yukawa coupling between the Higgs boson and the tau lepton. The proposed GNN-based methodologies are targeted for the reconstruction of boosted Higgs boson decays within the Run-2 dataset of the CMS experiment.

T 31.3 Tue 16:30 Geb. 20.30: 2.066

**ML4Taus: Tau decay mode classification using CNNs on Calorimeter Data** — •Jonathan Pampel[1], Jochen Dingfelder[1], Tatjana Lenz[1], Christina Dimitriadi[1], and Duc Bao Ta[2] — [1]Rheinische Friedrich-Wilhelms-Universität, Bonn, Germany — [2]Johannes Gutenberg Universität, Mainz, Germany

The tau-lepton is the heaviest charged lepton with a mass of about twice the mass of the proton. It can decay leptonically into two neutrinos and another lepton or hadronically into one neutrino and some hadrons, the latter being mostly pions. In the ATLAS collaboration at CERN, there are already several algorithms for the decay mode classification of hadronically decaying tau-leptons (tau-jets).

This talk presents a novel technique based on convolutional neural networks to classify the hadronic tau-lepton decay modes. The goal is to determine the number of neutral and charged pions in a tau-jet using calorimeter information. To do this, for each calorimeter layer, an ‘image’ of the tau-jet is generated. These ‘images’ are used as input for a neural network built from several 2D convolution and pooling layers and a flattening layer followed by a number of dense layers.

The talk includes an introduction to tau decay mode classification as well as a visualization of the preprocessed data which is fed into the neural network. Finally, the best performing neural network*s architecture and its performance will be presented. All performance evaluation is done using ATLAS Run 2 $\gamma^* \rightarrow \tau\tau$ Monte Carlo samples.

T 31.4 Tue 16:45 Geb. 20.30: 2.066

**Muon Momentum Scale and Resolution Corrections for CMS** — •Dorian Guthmann[1], Jost von den Driesch[1], Markus Klute[1], and Filippo Errico[2] — [1]Karlsruhe Institute of Technology — [2]Istituto Nazionale di Fisica Nucleare Roma

In the context of the Compact Muon Solenoid (CMS) Experiment at the LHC, a precise measurement of muon momenta plays a crucial role. Muons hold significant importance in various particle physics analyses. However, deviations between recorded data and simulation arise due to detector effects. To address this challenge, scale and resolution corrections are applied to the transverse momentum of muons. These corrections aim to mitigate biases, aligning the theoretical description of muons with their experimental counterpart. This presentation will provide an overview of the current standard method in CMS and outline possible improvements to the procedure for run 3.

T 31.5 Tue 17:00 Geb. 20.30: 2.066

**Muon reconstruction and identification efficiency in ATLAS with run-3 pp collision data** — •giorgia proto and davide Cieri — Max Planck Institute Fur Physik

The identification and precise measurement of processes with muons in the final state is one of the main goal of the ATLAS experiment at the LHC and HL-LHC. Muons are produced in many important physics processes and are detected by the Muon Spectrometer with almost 100%-efficiency and good momentum resolution. Muon reconstruction and identification efficiencies are measured using the tag-and-probe method using $Z \to \mu\mu$ sample in the bulk of the space-phase. In the low-$p_T$ region, the same method is applied on $J/\Psi \to \mu\mu$ sample.
The measured efficiency in Monte Carlo (MC) samples is then compared with that obtained from dataset. The agreement between the efficiency measured in data and the corresponding efficiency in MC is called Scale Factor and is used to quantify the deviation of the simulation from the real detector behaviour and is then used to correct the simulation in physics analyses.
This presentation reports the muon reconstruction and identification efficiency and the relative scale factors measurements in ATLAS during the Run 3 data taking for pp collisions at $\sqrt{s}$ = 13.6 TeV collected in 2022 and 2023.

T 31.6 Tue 17:15 Geb. 20.30: 2.066

**Investigating Shower Generator Dependence of Muon Isolation Efficiency for the ATLAS Collaboration** — •Lars Linden[1], Stylianos Angelidakis[2], Christoph Ames[1], Youn Jun Cho[1], Stefanie Götz[1], Edis Hrustanbegovic[1], Celine Stauch[1], Lukas von Stumpfeldt[1], and Otmar Biebel[1] — [1]Ludwig-Maximilians-Universität, München — [2]National and Kapodistrian University, Athens

Muons originating from bosons are of vital importance for various physics analyses, therefore exact knowledge of the expected efficiencies of both the detectors and algorithms is important. In ATLAS simulations, the isolation efficiency exhibits a dependency on the parton shower generator model used. The corresponding differences for the PYTHIA and Sherpa generators used in simulation contribute a significant systematic uncertainty in muon isolation efficiency measurements. Because of this, the generator dependence is investigated using $Z \to \mu\mu$ samples generated using POWHEGBOX + PYTHIA 8 and Sherpa 2.2.11 Monte Carlo generators This talk presents the results of studies investigating the effect of shower generator differences on variables relevant for muon isolation algorithms.

T 31.7 Tue 17:30 Geb. 20.30: 2.066

**Development of the Prompt Lepton Improved Veto** — Arnulf Quadt, Baptiste Ravina, and •Tim Schlömer — I. Physikalisches Institut, Georg-August-Universität Göttingen

Prompt leptons originate from decays of heavy bosons like the $W$- and $Z$-boson, produced in the hard scattering process. These leptons originate from the primary vertex, due to the short lifetime of the bosons. In contrast, non-prompt, or fake leptons are mostly produced in semileptonic decays of $c$- or $b$-hadrons, which are characterised by a longer lifetime and therefore of a distinct secondary vertex.

The selection is mostly based on isolation observables like the measured energy activity around the lepton candidates. It is very important to select the prompt leptons, and fake leptons are important backgrounds in many multi-lepton analyses. In multi-lepton analyses, like $t\bar{t}H$, $t\bar{t}W$ or $t\bar{t}t\bar{t}$, fake leptons are the dominant background, even with the tightest isolation criteria.

One of the algorithms used in the ATLAS Collaboration that identify prompt leptons and veto fake leptons is the "Prompt Lepton Improved Veto" (PLIV), using several isolation, and additionally lifetime observables to distinguish between prompt and fake leptons. The most important input is a lifetime observable constructed from track information. Other important inputs are isolation observables such as $\Delta R$ between lepton and track jet, and the transverse momentum in a cone around the lepton.

For the improvement of PLIV, studies on new Neural Network architectures and calibration are performed.

T 31.8 Tue 17:45 Geb. 20.30: 2.066

**Prompt Lepton Improved Veto (PLIV) Muon Studies and Application for Multi-Lepton Final States** — •Stephen Eggebrecht, Steffen Korn, Arnulf Quadt, Baptiste Ravina, and Tim Schlömer — II Physikalisches Institut, Georg August Universität Göttingen

Prompt leptons originate from decays of electroweak bosons, like $W$ and $Z$, or from Higgs bosons and are associated with tracks matching with the primary collision vertex. In contrast, non-prompt or fake leptons may be produced in $c$- or $b$-hadron decays and are usually associated with secondary vertices. In multi-lepton $t\bar{t}H$ or four top analyses, fake-leptons are a major background even with tight standard isolation and impact parameter requirement. Other multivariate techniques which identify prompt-leptons while veto non-prompt are needed.
The prompt lepton improved veto (PLIV) uses several input features such as standard isolation variables. Using additional isolation variables constructed with calorimeter information and lepton lifetime information from the combination of direction and impact parameter variables of reconstructed lepton tracks, the performance is improved.
In this talk, new neural network techniques for PLIV for non-prompt muon rejection are presented and discussed. Furthermore, the first steps of calibration and application for multi-lepton final states are shown.

# T 32: Methods in astroparticle physics 2

Time: Tuesday 16:00–18:00 Location: Geb. 20.30: 2.067

T 32.1 Tue 16:00 Geb. 20.30: 2.067

**Preparation for the determination of the absolute X-ray detection efficiency of the TAXO SDD for IAXO** — Joanna Bilicki, •Patrick Bongratz, Frank Edzards, Susanne Mertens, Lucinda Schönfeld, Juan Pablo Ulloa Beteta, Christoph Wiesinger, and Michael Willers — Physik-Department, Technische Universität München, Garching, DE

The International Axion Observatory (IAXO) aims to improve the search for solar axions by at least one order of magnitude with respect to previous helioscope experiments. In a helioscope experiment solar axions are back-converted to X-rays in a strong magnet pointed at the sun. Silicon drift detectors (SDDs) are particularly suited to detect this signal. Good noise performance enables sub-keV thresholds while maintaining high detection efficiency. In this talk, I will report on the TAXO SDD project and the preparations for a measurement of the absolute X-ray detection efficiency at the SOLEIL synchrotron facility. This project has received funding from the European Research Council (ERC) under the European Union Horizon 2020 research and innovation programme (grant agreement No. 852845).

T 32.2 Tue 16:15 Geb. 20.30: 2.067

**TAXO, Towards a low background SDD for IAXO** — Joanna Bilicki, Patrick Bongratz, Frank Edzards, Susanne Mertens, •Lucinda Schönfeld, Juan Pablo Ulloa Beteta, Christoph Wiesinger, and Michael Willers — Physik Department, Technische Universität München, Garching, DE

Axions are a dark matter candidate and could solve the strong CP problem. The International Axion Observatory (IAXO) is a next-generation experiment attempting to find these elusive particles by converting solar axions to X-rays. Silicon Drift Detectors (SDDs) are well suited to detect this rare axion signal. The TAXO project attempts to tackle the challenging IAXO background requirements with an SDD. I will present the current status of the TAXO project, in particular deep-underground and above-ground background measurements as well as simulation studies of cosmic-induced backgrounds. This project has received funding from the European Research Council (ERC) under the European Union Horizon 2020 research and innovation programme (grant agreement No. 852845). It has also been supported by the DFG through the Excellence Cluster ORIGINS.

T 32.3 Tue 16:30 Geb. 20.30: 2.067

**Towards the complete calibration of the LNGS mobile neutron spectrometer** — Melih Solmaz[1] and •Francesco Pompa[2,3] — [1]Karlsruhe Institute of Technology, Institute of Experimental Particle Physics — [2]University of L'Aquila, Department of Physics and Chemistry — [3]INFN-Laboratori Nazionali del Gran Sasso

Laboratori Nazionali del Gran Sasso (LNGS), located 1400 m below Gran Sasso mountains in Italy, hosts numerous rare event searches (e.g., dark matter direct detection and neutrinoless double beta decay experiments). Ambient neutrons produced at the cavern walls are a source of background for these elusive searches, potentially limiting the experimental sensitivity. Since both the neutron flux and spectrum vary with time and location, a mobile neutron counter would not only provide precise knowledge of this laboratory background for the hosted experiments but also resolve some inconsistencies between the past measurements.

In this talk, we present the design and the construction efforts of the portable neutron spectrometer for the LNGS underground laboratory as well as first test measurements. We also give an outlook towards the incoming detector calibration campaign and its final installation at LNGS.

This project is funded by the German Federal Ministry of Education and Research (BMBF) under the grant number 05A21VK1.

T 32.4 Tue 16:45 Geb. 20.30: 2.067

**Development & Commissioning of bHiVE - Bite-sized High Voltage setup for Electrodes** — •Simon Gentner — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

Time projection chambers (TPCs) are used in various particle detectors including in dark matter and neutrino searches. To detect signals TPCs rely on a set of high-voltage electrodes to produce uniform electric fields. The high electric fields could lead to electron and photon emission from the electrode surface, and in worse cases may cause electrical breakdown. To study these effects and potential ways for mitigating them, this work aims to develop and commission a test setup for a variety of small electrode samples. In this way, the influence of various cleaning methods, treatments and coatings on the electron emission of electrodes in different gas environments and in vacuum could be examined and analyzed. The small sample size makes it possible to conduct detailed studies of the impact of defects, such as spikes, scratches or cuts on electrode performance and examine techniques for repairing them. These findings will be key for development of electrodes for the next generation of dark matter detectors such as DARWIN. In this talk I will present the recent status and progress of bHiVE.

T 32.5 Tue 17:00 Geb. 20.30: 2.067

**Development of a spatial resolving scintillator readout system - "MIP-Cube"** — •Philippe Bruder, Ralph Engel, Andreas Haungs, and Thomas Huber — Karlsruhe In- stitute of Technology, Institute for Experimental Physics, Karlsruhe, Germany

High-energy muons from extensive air-showers, originated in the interaction between cosmic rays and the Earth*s atmosphere, can propagate to Earth or even into low-noise facilities, like underground research laboratories and contribute to the noise level of experiments. By measuring the flux and spatial distribution of these muons, systematic background effects can be studied. For this purpose, a monitoring system based on a net of crossed 25 cm long and 5 cm wide plastic-scintillator bars is developed. The scintillator system presented here is readout by Hamamatsu 64-channel Silicon Photomultiplier (SiPM) arrays. The used fermilab scintillator bars and kururay fibers are based on detectors developed for the surface of the IceCube Neutrino Observatory and Auger Prime scintillator-based surface detector (SSD). The baseline design shows a mobile detector system, with an adequate power supply and signal where focus is given on a plug-and-play setup for variable measuring locations. The CAEN Co. Ltd Front-End unit DT5202 as SiPM array readout and trigger electronic is choosen. The DT5202 unit, in conjunction with a specifically crafted Python software, functions as a Data Acquisition System (DAQ). Through this combination, it is possible to reconstruct the direction of an incoming muon, and additionally, a heatmap of individual pixels is generated.

T 32.6 Tue 17:15 Geb. 20.30: 2.067

**Drone-Based Calibration of Radio Antennas at the Pierre Auger Observatory.** — Martin Erdmann, •Alex Reuzki, and Maximilian Straub — III. Physikalisches Institut A, RWTH Aachen University

Ultra-high-energy cosmic rays induce extensive air showers in the Earth's atmosphere. At the Pierre Auger Observatory, those air showers are measured using various detection techniques including Radio detection with Short Aperiodic Loaded Loop Antennas (SALLA) as part of the AugerPrime upgrade.

The SALLA's antenna pattern has been described using simulations and an absolute calibration has been performed utilizing the galactic radio background. Here we introduce a direction-dependent calibration procedure, which uses a well-defined biconical antenna mounted to a drone with active stabilization and precise position tracking. The drone setup allows us to precisely extract the antenna sensitivity from any direction and distance. With that, we performed calibration measurements on a SALLA. First results are presented.

T 32.7 Tue 17:30 Geb. 20.30: 2.067

**Method and first results of the XY-Scanner Calibration of the Fluorescence Detector of the Pierre Auger Observatory** — •Paul Filip and Christoph Schäfer for the Pierre-Auger-Collaboration — Hermann-von-Helmholtz-Platz 1 76344 Eggenstein-Leopoldshafen

The Pierre Auger Observatory is a hybrid instrument designed to detect extensive air showers stemming from ultra-high-energy cosmic rays impinging on the upper atmosphere of the earth. It uses two independent methods of detection. The Fluorescence Detector (FD) observes the evolution of the air shower in the atmosphere, and provides a model independent estimation of the energy of a cosmic ray primary particle. Additionally, data gathered from the FD is used to calibrate the energy scale of the Surface Detector (SD) array, which measures the shower footprint on the ground.

In this talk, we present a novel method of calibration for the FD, which relies on a UV-light source mounted on a motorized XY-stage. The light source exposes the telescope camera sensor to light pulses of known intensity. The presented setup simplifies the calibration procedure drastically and is able to improve the systematic uncertainty of the FD calibration from ~ 9% to ~ 4.4%. In addition, the short- and long term stability of the procedure is analyzed using data from the seven measurement campaigns.

T 32.8 Tue 17:45 Geb. 20.30: 2.067

**Wavelength shifting fibers with high photon capture rate** — Bastian Kessler, John Rack-Helleis, and •Sebastian Böser — JGU Mainz - Institut für Physik

Wavelength-shifting optical fibers are commonly used to collect light from large detector volumes and guide towards photosensors, which makes them particularly interesting for water Cherenkov or scintillator based detectors. However, one problem is their low photon capture rate, leading to a reduction in the energy resolution of fiber-based detectors.

Building on previous work, it was shown that the photon capture rate can be increased by appropriate design of the photon absorption zone. In this work, this concept was applied to wavelength shifting fiber, and the capture rate and absorption mechanism were studied in detail. It was found that initially the attenuation is mainly driven by self-absorption on the wavelength-shifting molecules themselves.

Here we present data from several measurement campaigns to quantify the self-absorbance together with an updated attenuation model.

# T 33: Neutrino physics 4

Time: Tuesday 16:00–18:00 Location: Geb. 30.21: Gerthsen-HS

T 33.1 Tue 16:00 Geb. 30.21: Gerthsen-HS

**Use of micro-structured filters to explore the KATRIN background** — •Dominic Hinz for the KATRIN-Collaboration — Karlsruhe Institute of Technology (KIT)

The key goal of the KATRIN experiment is the measurement of the absolute mass scale of neutrinos with an unprecedented sensitivity of better than $0.3\,\mathrm{eV/c^2}$. Currently, the measured background level exceeds the design value, wherefore a detailed understanding of background processes in the large main spectrometer is required. According to our prior model, background events originate from Hydrogen Rydberg states, generated by the decay of surface-implanted $^{210}$Pb, on the main spectrometer vessel surface. Thermal radiation can ionise such long-lived, highly excited states, resulting in low-energy electrons on the meV-scale. These are then accelerated by the retarding potential, thus possess small transverse energy, which is in contrast to signal beta-electrons. We have performed measurements with a passive transverse energy filter (pTEF) implemented as a micro-structured honeycomb gold plate.

This talk discusses the observed transmission of background electrons through the pTEF at different magnetic field values and compares the initial and refined background model.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6)

T 33.2 Tue 16:15 Geb. 30.21: Gerthsen-HS

**Reduction of Rydberg background in KATRIN by stimulated de-excitation using THz radiation** — •Shivani Ramachandran, Enrico Ellinger, and Klaus Helbing — Bergische Universität Wuppertal (BUW)

The key requirement for the KArlsruhe TRItium Neutrino experiment (KATRIN) to reach its goal sensitivity of 200 meV at 90% (C.L.) in measuring the effective electron anti-neutrino mass is minimising the background which currently exceeds the estimated design value. In order to achieve this and eliminate some known contributors, several background suppression methods have already been implemented. The dominant contribution to the background in the measured signal are electrons produced by thermal ionization of Rydberg atoms. These atoms originate from the walls of the main spectrometer vessel by radioactive decays of a $^{210}Pb$ contamination. THz radiation can be used for stimulated de-excitation inducing $\Delta n = 1$ transitions, which can lead to shorter lifetimes of Rydberg atoms. Different species of excited atoms are sputtered from the walls of the vessel which can lead to two-electron excited states. The influence of THz radiation on such states are investigated. The development and measurements from the test setup built in University of Wuppertal (BUW), as a proof of principle for THz-induced de-excitation is discussed.

T 33.3 Tue 16:30 Geb. 30.21: Gerthsen-HS

**Background investigations for keV sterile neutrino search at KATRIN** — •Moritz Puritscher for the KATRIN-Collaboration — Karlsruhe Institute of Technology (KIT)

Starting in 2026, the KATRIN experiment aims to measure the kink-like distortion of a keV-scale sterile neutrino in the tritium beta spectrum. In order to search for such a signal with the KATRIN setup several changes to the beamline are necessary. The integration of the modular TRISTAN detector into the KATRIN beamline can lead to deteriorated vacuum conditions at the main spectrometer. Together with changed electromagnetic settings at the main spectrometer, the amount of background electrons that are mapped onto the detector is expected to change. To study the effect of these changes on the overall background level, a set of background measurements at different retarding potentials and pressures was performed. Overall, only a slight increase of background at an elevated pressure of $10^{-9}$ mbar can be observed. However, changed trapping conditions for electrons at elevated pressure and low retarding potential can significantly increase the background rate.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6)

T 33.4 Tue 16:45 Geb. 30.21: Gerthsen-HS

**Machine Learning for background discrimination in LEGEND200** — •Sean Sullivan — MPIK, Heidelberg, Germany

The development of Neural Networks has generated an array of powerful analysis techniques for modern scientific experiments. Particularly in areas of classification and background reduction. This talk will discuss the application of such techniques to the LEGEND200 experiment for neutrinoless double beta decay: an as yet unobserved process beyond the standard model for which background reduction is a keystone. LEGEND200 employs High Purity Germanium detectors enriched in Germanium-76 operated in a liquid argon cryostat. Important backgrounds that must be excluded include multi-site events and surface alphas. Established methods for dealing with these backgrounds can be compared with Machine Learning techniques.

T 33.5 Tue 17:00 Geb. 30.21: Gerthsen-HS

**Cosmogenic Background Suppression in LEGEND-1000** — •Moritz Neuberger and Stefan Schönert for the LEGEND-Collaboration — Physik-Department E15, Technische Universität München, James-Franck-Straße, 85748 Garching

The in-situ production of long-lived radioactive isotopes by cosmic muons can generate a non-negligible background for deep underground rare event searches. The delayed decay of $^{77(m)}$Ge is the primary in-situ cosmogenic contributor for a neutrinoless double-beta decay search with $^{76}$Ge [1]. The upcoming ton-scale LEGEND-1000 experiment requires a total background of < $10^{-5}$ cts/(keV·kg·yr) [2]. A combination of passive and active background suppression techniques has been developed using Monte Carlso studies, which show a potential reduction of the background contribution approximately $2 \cdot 10^{-5}$ cts/(keV·kg·yr) to $4 \cdot 10^{-7}$ cts/(keV·kg·yr) without significantly decreasing the selection efficiency for neutrinoless double-beta decay [3]. We acknowledge support by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC 2094 - 390783311 and through the Sonderforschungsbereich (Collaborative Research Center) SFB1258 'Neutrinos and Dark Matter in Astro- and Particle Physics'.

[1] C. Wiesinger et al., Eur. Phys. J. C (2018) 78: 597

[2] LEGEND-1000 pCDR, arXiv 2107.11462

[3] M. Neuberger et al., Constraining the 77(m)Ge Production with GERDA Data and Implications for LEGEND-1000, TAUP2023, poster presentation

T 33.6 Tue 17:15 Geb. 30.21: Gerthsen-HS

**Development of 3D-printable Plastic Scintillators** — •Tobias Woell[1] and Daniel Muenstermann[1,2] — [1]Hochschule RheinMain, FB ING, Wiesbaden — [2]Lancaster University, Physics Department, Lancaster, UK

3D-printing has many benefits and allows to create complex-shaped objects without the need for machining. In low-background experiments (e.g. LEGEND), radiopure scintillators are required, and machining potentially introduces additional contamination. SLA/DLP is a 3D-printing process that uses liquid reactants which could be (radio-)purified by various methods if necessary while classical plastic scintillators produced by casting or injection moulding usually require machining to match the required shapes. However, since the synthesis of polymers in SLA/DLP differs from the classical methods, the properties of the printed pieces may also be different and need to be assessed.

The presentation outlines the properties needed to create 3D-printable scintillators and features optical and mechanical characterisation results of initial samples in comparison to classical reference samples.

T 33.7 Tue 17:30 Geb. 30.21: Gerthsen-HS

**Search for the DSNB in JUNO: Development of new Methods for Background Event Identification** — •Matthias Mayer[1], Lothar Oberauer[1], Hans Steiger[1,2], Simon Basten[1], David Dörflinger[1], Ulrike Fahrendholz[1], Meishu Lu[1], Vincent Rompel[1], Konstantin Schweizer[1], Luca Schweizer[1], Korbinian Stangler[1], and Raphael Stock[1] — [1]Physik-Department, TU München, James-Frank-Str. 1, 85748 Garching b. München, Deutschland — [2]PRISMA+ Cluster of Excellence, Staudingerweg 9, 55128 Mainz, Deutschland

The diffuse supernova neutrino background (DSNB) describes the constant flux of neutrinos from past core-collapse supernovae over the visible universe. The Jiangmen Underground Neutrino Observatory (JUNO), a 20 kton liquid scintillator detector, plans to detect the DSNB in the inverse beta decay (IBD) detection channel. While other $\nu_e$ sources will cause irreducible IBD background, we plan to reduce non-IBD backgrounds such as neutron-induced events and NC interactions of atmospheric neutrinos by careful pulse-shape discrimination (PSD). In this talk, I compare the performance of different PSD techniques in the prospect of increasing the fiducial volume available for the DSNB search with an outlook into the energy dependence of the neutron flourescence time profile in the JUNO scintillator and a look into our recent publication regarding the DSNB detection potential. This work has been supported by the Clusters of Excellence PRISMA+ and ORIGINS as well as the DFG Collaborative Research Center "NDM" (SFB1258) and the DFG Research Units 2319 and 5519.

T 33.8 Tue 17:45 Geb. 30.21: Gerthsen-HS

**Detection of Cherenkov and Scintillation light in hybrid scintillators** — •Dorina Zundel and Michael Wurm — Johannes Gutenberg-Universität Mainz, Institute of Physics and Cluster of Excellence PRISMA+, Staudingerweg 7, 55128 Mainz

Hybrid scintillator detectors aim at the simultaneous detection of Cherenkov and scintillation light. SCHLYP (Scintillation Cherenkov Light Yield Prism) is a newly developed laboratory setup, used to distinguish Scintillation and Cherenkov light in scintillator samples. The setup uses the geometrical advantages of a hollow prism filled with scintillator as a detector, equipped with three ultra-fast photomultipliers, on each side. The photomultipliers have a rise time of a nanosecond and a transit time spread of 200ps. Photons from a close-by $^{137}$Cs source create a signal by Compton scattering in the scintillator. Using a secondary inorganic scintillator detector, recoil electrons are selected to be aligned with the prism geometry, so that two of the PMTs detect both Cherenkov and Scintillation light, while the third PMT is only able to detect scintillation light. In this talk the improved setup and the analysis of first data will be presented.

# T 34: Neutrino physics 5

Time: Tuesday 16:00–18:00 Location: Geb. 30.22: Gaede-HS

T 34.1 Tue 16:00 Geb. 30.22: Gaede-HS

**Scintillation and Cherenkov Light Separation in Organic Liquid Scintillators for Large Scale Neutrino Detectors** — •Meishu Lu[1], Hans Steiger[1,2], M. R. Stock[1], U. Fahrendholz[1], and L. Oberauer[1] — [1]Physik-Department, Technische Universität München, James-Franck-Str. 1, 85748 Garching — [2]Johannes Gutenberg University Mainz, Cluster of Excellence PRISMA+, Staudingerweg 9, 55128 Mainz

The separate observation of Cherenkov and scintillation light in liquid scintillation media and thus the extraction of a directional signal and excellent energy and vertex resolution is of great importance in current R&D projects for large scale neutrino detectors like JUNO or Theia. The expected progress in the field of background suppression is promising. To study this potential in novel liquid scintillators, a new setup exploiting the principle of time-correlated single photon counting with cutting-edge photomultiplier tubes is under commissioning at TUM. The experiment enables detailed studies of the probability density function of the photon emission from the scintillation medium including both Cherenkov, and scintillation light. A separation can be achieved either by direct timing or by chromatic filtering. In this talk the design of this novel table-top experiment is discussed as well as first test measurements with the used photosensors. This work has been supported by the Cluster of Excellence PRISMA+,

the Cluster of Excellence ORIGINS as well as the Collaborative Research Center Neutrinos and Dark Matter in Astro- and Particle Physics (SFB1258) and the DFG Research Units 2319 and 5519.

T 34.2 Tue 16:15 Geb. 30.22: Gaede-HS

**Measurement of the attenuation length and the group velocity of the JUNO liquid scintillators with the CELLPALS method** — •Jessica Eck, Tanjina Anannya, Lukas Bieger, Marc Breisch, Tobias Heinz, Benedict Kaiser, Florian Kirsch, Tobias Lachenmaier, Dhanushka Bandara, and Tobias Sterr — Eberhard Karls Universität Tübingen, Physikalisches Institut

The Jiangmen Underground Neutrino Observatory (JUNO) is in the final stages of completion in southern China and data taking is scheduled to begin this year (2024). In the coming years, JUNO will investigate a broad field of neutrino physics. The main goal of JUNO is to determine the neutrino mass hierarchy, which requires a sufficiently good energy resolution in the detector. The JUNO detector consists of a large spherical vessel filled with 20ktons of highly transparent liquid scintillator based on the solvent linear alkyl-benzene (LAB) and the supplements PPO (fluor) and bis-MSB (wavelength shifter). The transparency of the scintillator is one of the most important factors in achieving a high energy resolution in the detector, thus it is important to quantify the attenuation length for the relevant wavelengths. Since conventional measurements of the attenuation length are affected by large uncertainties for very transparent liquids, the CELLPALS method was introduced, which provides significantly higher precision by using an optical resonator in combination with a modulated laser intensity. This talk will present results on the attenuation length and the group velocity of selected liquids including LAB samples after several stages of JUNOs liquid scintillator production chain.

T 34.3 Tue 16:30 Geb. 30.22: Gaede-HS

**Event Reconstruction in OSIRIS** — •Elisabeth Neuerburg, Achim Stahl, and Jochen Steinmann — RWTH Aachen

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20kton liquid scintillator based neutrino observatory, which is currently under construction in southern China. To ensure the success of JUNO's physics program, stringent limits on the contamination of the scintillator with radioactive isotopes have been defined. OSIRIS (Online Scintillator Internal Radioactivity Investigation System) is a 20t liquid scintillator detector, which monitors the radiopurity during filling of JUNO. It consists of a cylindrical acrylic vessel surrounded by 64 PMTs detecting coincidence signals of the Bi-Po decay in the uranium and thorium series. Using the charge signals of the PMTs, the position and energy of such decay events is reconstructed based on a likelihood method. In this talk the method and performance of the reconstruction is presented.

T 34.4 Tue 16:45 Geb. 30.22: Gaede-HS

**Liquid Handling System of the OSIRIS detector** — Marcel Büchner[1], Arshak Jafar[1], Meishu Lu[2], •Oliver Pilarczyk[1], Hans Steiger[1,2], Tobias Sterr[1], and Michael Wurm[1] — [1]Johannes Gutenberg-University Mainz, Institute of Physics and EC PRISMA+ — [2]Technical University Munich

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillator experiment currently under construction in Jiangmen (China). To achieve its scientific goals the liquid scintillator has to go through several purification plants on site to make sure it meets the optical and radiopurity requirements. The 20m* OSIRIS pre-detector is the last device behind these purification plants. Its task is to monitor the radiopurity of the purified scintillator before it is filled in the JUNO detector and it will reach sensitivity levels of 10-16g/g on uranium and thorium. OSIRIS is expected to be operated in a continuous mode, which means that parts of the scintillator from the main filling line will be redirected into a bypass in which the OSIRIS detector is placed and then being returned to the main filling line. To make sure every batch of the scintillator stays about 24 h inside the OSIRIS detector a temperature gradient will be established in the detection volume to help stratification of the liquid scintillator inside. This talk covers the operation and function of the Liquid Handling System (LHS) and the included Level Measurement system (LM) which control and oversee the operation of OSIRIS as well as the construction and commissioning process. The development is funded by the DFG Research Unit *JUNO* (FOR5519) and the Cluster of Excellence PRISMA+.

T 34.5 Tue 17:00 Geb. 30.22: Gaede-HS

**Track Reconstruction and Geometry Studies of Scintillators Bars for DUNE TMS** — •Asa Nehm for the DUNE-Collaboration — Johannes Gutenberg-Universität Mainz

For the Deep Underground Neutrino Experiment (DUNE), that is currently under construction, a suite of near detectors is in development. DUNE is a long-baseline neutrino experiment that will use a high-intensity neutrino beam from Fermilab and observe the neutrinos in the far-detector complex located at SURF, USA. The primary focus will be on neutrino oscillations to test CP violation, but also neutrino mass ordering and supernova neutrinos will be investigated.

One of the near detectors is The Muon Spectrometer (TMS) that will primarily detect and measure properties of the muons resulting from neutrino interactions exiting the preceding near detector. TMS will consist of alternating layers of plastic scintillators, in form of bars, and steel. The scintillator bars will be read out by WLS fibers and SiPMs and detect the scintillation light created by through-going charged particles.

To extract the properties of the incoming muons a 3D track reconstruction was developed and implemented. This allowed to study different potential geometric layouts of the scintillator bars. In particular a stereo view of alternating 3° tilted layers and a layout that features full 90° rotated layers were studied. With these preceding studies the exiting muons that are reconstructed as stopping in the detector have been investigated and the results will be presented.

T 34.6 Tue 17:15 Geb. 30.22: Gaede-HS

**DUNE-PRISM: An innovative technique for neutrino oscillation analysis** — •Ioana Caracas — JGU Mainz, Mainz, Germany

The Deep Underground Neutrino Experiment (DUNE) will measure the neutrino and anti-neutrinto oscillation probabilities, using a high-intensity neutrino beam produced at Fermilab. With a baseline of 1300 km and large (kton) LArTPC detectors, DUNE will provide an unprecedented precision in measuring the oscillation parameters. The neutrino interaction cross sections represent the main systematic source entering the analysis. Constraining the oscillation parameters space is therefore limited by a good knowledge of the neutrino interaction modeling.

The DUNE Near Detector (ND) complex is designed to move to different positions along the neutrino beam axis. Several neutrino fluxes with different peak energies can thus be sampled as a function of the off-axis position. These ND off-axis results can then be linearly combined in order to match any target spectrum using a data-driven approach. This innovative technique, the Precision Reaction Independent Spectrum Measurement (PRISM), is able to predict the Far Detector (FD) neutrino oscillated spectrum with minimum modeling dependency. The PRISM prediction obtained and the impact of several systematics on the resultant oscillation parameters will be discussed. A case-study showing how PRISM can avoid potential biases resulting from the wrong interaction modeling will also be presented.

T 34.7 Tue 17:30 Geb. 30.22: Gaede-HS

**Large-area MMC-based photon detector operated at mK temperatures** — •Ashish Jadhav, Christian Enss, Andreas Fleishmann, Daniel Hengstler, Andreas Reifenberger, Daniel Unger, and Loredana Gastaldo — Kirchhoff Institute for Physics, Heidelberg, Germany

We present the development of a large area, high-energy resolution photon detector based on low temperature metallic magnetic calorimeters (MMCs). The detector is to be the photon detector in a combined Photon-Phonon (P2) detector to be coupled to molybdate scintillating crystals in the AMoRE experiment. The final P2 detector utilises a 3-inch Si wafer. A central area, weakly coupled to the rest of the wafer is defined to detect visible photons emitted by particle interactions in the scintillating crystal. The outer part of the wafer contains three double-meander MMC detectors as phonon detectors to monitor temperature changes in the crystal resting on gold spacers. The most challenging part is the photon detector based on a stripline pickup coil design. We present the R&D on a large area silicon photon detector with stripline MMC geometry. We discuss the results obtained and the implications of the photon detector for the AMoRE experiment.

T 34.8 Tue 17:45 Geb. 30.22: Gaede-HS

**Search for Ge77(m) in LEGEND-200** — •Marie Pruckner, Moritz Neuberger, and Stefan Schönert for the LEGEND-Collaboration — Physik-Department E15 Technische Universität München James-Franck-Straße 85748 Garching

The delayed decay of $^{77(m)}$Ge ($Q_\beta$ = 2.7 MeV), produced by muon-induced neutron capture on $^{76}$Ge, has been identified as the dominant in-situ cosmogenic background contributor for the neutrinoless double-beta decay search with $^{76}$Ge ($Q_{\beta\beta}$ = 2.039 MeV) in the future LEGEND-1000 experiment at LNGS [1,2,3]. To verify its background contribution estimates, we search for for $^{77(m)}$Ge decays in the ongoing LEGEND-200 experiment and compare them with simulation estimates. In this talk, we will demonstrate how we attempt to identify the $^{77(m)}$Ge decays using delayed coincidence techniques that require new digital signal processing routines to reconstruct all relevant physics parameters.

We acknowledge support by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC 2094 - 390783311 and through the Sonderforschungsbereich (Collaborative Research Center) SFB1258 'Neutrinos and Dark Matter in Astro- and Particle Physics'. We acknowledge support by the BMBF Verbundprojekt 05A2023 - LEGEND: Suche nach dem neutrinolosen doppelten Beta-Zerfall in 76Ge mit LEGEND.

[1] C. Wiesinger et al., Eur. Phys. J. C (2018) 78: 597
[2] LEGEND-1000 pCDR, arXiv 2107.11462
[3] M. Neuberger et al., 2021 J. Phys.: Conf. Ser. 2156 012216

# T 35: Cosmic rays 4

Time: Tuesday 16:00–18:00 Location: Geb. 30.22: Lehmann-HS

T 35.1 Tue 16:00 Geb. 30.22: Lehmann-HS

**Studies on Monte Carlo generator tuning for cosmic-ray induced air shower simulations** * — Kevin Kröninger, Salvatore La Cagnina, and •Michael Windau — TU Dortmund, Fakultät Physik

Monte Carlo (MC) generators are a fundamental tool in particle and astroparticle physics. To achieve a high-quality simulation of physical processes, the hadronic interaction model of the generator must be tuned efficiently. The free parameters of MC generators are optimized with the help of experimental data and Bayesian methods. One area of application for MC generators is the simulation of cosmic-ray induced air showers in the Earth's atmosphere. Since hadronic interactions have a direct influence on the composition of secondary particles in shower formations, tuning the parameters of these hadronic models has an impact on crucial observables such as the muon number.

In this talk, studies on the tuning of the Monte Carlo generator PYTHIA for cosmic-ray induced air showers simulated with CORSIKA 8 are presented.

* Supported by the DFG (SFB 1491)

T 35.2 Tue 16:15 Geb. 30.22: Lehmann-HS

**Tuning of the Pythia 8 hadronic interaction model for UHECR-induced air shower simulations** — •Chloé Gaudu for the Pierre-Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal, Germany

Understanding the properties of extensive air showers (EAS) is of prime importance for extracting the characteristics of ultra high-energy cosmic rays (UHECRs) as observed by the Pierre Auger Observatory. Thorough comparisons of EAS measurements and associated simulations are essential to determine the primary energy and, more importantly, the primary mass of UHECRs. Employing state-of-the-art hadronic interaction models, air shower simulations exhibit a muon deficit compared to measurements, referred to as the Muon Puzzle. The largest uncertainties arise from limited knowledge of high-energy hadronic interactions. The Pythia 8 model, well-tailored for Large Hadron Collider experiments, is rarely used in the context of air showers. However, new features in the Angantyr model of Pythia 8 aim an enhancing of hadron-nucleus interaction descriptions, motivating its potential application in air shower studies.

This contribution focuses on studying $p_T$-integrated identified particle spectra from $\pi^-$ C fixed-target collisions at NA61/SHINE and comparing them to the newest version of Pythia 8. First, the validity of the Angantyr model to describe the experimental datasets is investigated using the RIVET interface. Secondly, a tune of Pythia 8 is discussed, as well as the influence of the fit parameters on muon production in EAS. *Supported by DFG (SFB 1491)*

T 35.3 Tue 16:30 Geb. 30.22: Lehmann-HS

**Cosmic Muon Based Measurement for Ordinary Muon Capture Studies** — •Xianke He, Jansen Andreas, and Kai Zuber — Institute of Nuclear and Particle Physics, TU Dresden, Germany

Ordinary muon capture plays a crucial tool to validate the model describing nuclear matrix elements in neutrinoless double beta decay scenarios. In this context, a proposed experimental framework aims to measure the muon capture rates using cosmic muons.

The experimental design employs high-purity germanium detectors to detect gamma radiation emitted by excited state daughter nuclei following cosmic muon capture. Additionally, coincidence measurement of cosmic muons using scintillator detectors will provide a time reference for the high-purity germanium detectors. Given the inherent disparity in muon flux between cosmic rays and muon beams generated by accelerators within laboratory settings, optimizing the capture rate of cosmic muons becomes imperative.

This work introduces an experimental design based on Geant4 simulation, involving the selection of cosmic muon models and target materials, the configuration of coincidence measurement system, and a preliminary analysis of experimental data. The objective is to explore the potential application of cosmic muons in ordinary muon capture studies.

T 35.4 Tue 16:45 Geb. 30.22: Lehmann-HS

**Reconstruction of Radio Emission from Extensive Air Showers using Information Field Theory** — •Simon Strähnz[1], Tim Huege[1], and Philipp Frank[2] — [1]Karlsruhe Insitute of Technology, Karlsruhe, Germany — [2]Max Planck Institute for Astrophysics, Garching, Germany

The Pierre Auger Observatory is the currently largest observatory for the detection of ultra-high energy cosmic rays. During the development of extensive air showers induced by cosmic rays, the separation of charged particles in the shower creates radio emission. This emission can be used to reconstruct the air shower by determining the arrival direction, energy and mass of the cosmic ray particle. After successful testing at the Auger Engineering Radio Array, antennas are currently being deployed to all 1660 detector stations of the observatory, to increase the exposure of the observatory.

To reconstruct the air shower, it is necessary to first extract the electric field from of the noisy measurements of the voltage in the antenna. This can be achieved using Information Field Theory. The algorithms developed with this formalism based on Bayesian statistics can infer not only the maximum likelihood signal but also its uncertainty from noisy data, given only a forward model of the measurement process. I will present the current advancements in this signal reconstruction using these methods on the radio detector of the Pierre Auger Observatory.

T 35.5 Tue 17:00 Geb. 30.22: Lehmann-HS

**A Noise Library for the Radio Detector of the Pierre Auger Observatory*** — •Sven Querchfeld and Julian Rautenberg for the Pierre-Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal

The ErUM-Wave project aims to develop an AI model to reconstruct 3-dimensional wave fields with the goal to predict the propagation of seismic waves based on only a few measurements. To test the transferability of the developed method to other fields, it will be applied to the propagation of radio waves in the atmosphere. These waves are produced by cosmic ray-induced air showers measured with the Pierre Auger Observatory, which is currently upgrading its 1660 Surface Detector stations with supplementary detectors to be more sensitive to the composition of ultra-high energy cosmic rays. As part of the AugerPrime upgrade, each Water Cherenkov Detector (WCD) is equipped with an additional radio antenna, enlarging the radio detection (RD) technique to the entire array, covering nearly 3000 km$^2$.

The tests will be performed on simulations produced with the CoREAS extension of CORSIKA. Since no realistic noise files are available from these simulations, a method is shown to retrieve them from real events. Relying on the WCD as a trigger, RD stations at larger distances from the shower core should contain predominantly background signal due to the small radio footprint for vertical showers. A detailed study of these traces and a comparison to noise retrieved from a subset of triggered signal traces is shown.

**Supported by BMBF, Vorhaben 05D23PX1*

T 35.6 Tue 17:15 Geb. 30.22: Lehmann-HS

**Radio signal and uncertainty estimation for the Radio Detector of the Pierre Auger Observatory** — •Sara Martinelli[1,2], Tim Huege[1], Diego Ravignani[2], and Harm Schoorlemmer[3] for the Pierre-Auger-Collaboration — [1]IAP, KIT, Karlsruhe, Germany — [2]ITeDA, UNSAM, Buenos Aires, Argentina — [3]IMAPP, RU, Nijmegen, The Netherlands

The Pierre Auger Observatory is the world's largest experiment for hybrid detection of extensive air showers induced by high-energy cosmic rays. The Observatory is currently being upgraded to increase the sky coverage of mass-sensitive measurements of showers having zenith angles beyond 65° and energies up to $10^{20}$ eV. The design of this AugerPrime upgrade includes the deployment of the Radio Detector (RD), consisting of 1661 radio antennas installed on top of each of the water-Cherenkov detectors. Mass-composition studies of highly energetic and inclined showers will be possible by combining the electromagnetic energy estimated by the RD, and the estimation of the muon number obtained through the water-Cherenkov detector. The electromagnetic energy of the shower is proportional to the area integral of the energy deposit per unit area, also referred to as energy fluence. We will present a newly developed method for the reconstruction of the energy fluence, exploiting Rice distributions to determine radio signals and their uncertainties in the presence of noise. In the talk, the theoretical background employed in the new method and the improvements achieved in the energy fluence reconstruction in comparison to the previous approach will be discussed.

T 35.7 Tue 17:30 Geb. 30.22: Lehmann-HS

**Modelling the Radio Emission of Inclined Cosmic-Ray Air Showers in the** 50 − 200 MHz **Frequency Band for GRAND** — •Lukas Gülzow[1], Jelena Köhler[1], Tim Huege[1,2], Markus Roth[1], Kumiko Kotera[2,3], Olivier Martineau[4], Pablo Correa[4], and Marion Guelfand[3,4] — [1]Karlsruher Institut für Technologie, Institut für Astroteilchenphysik — [2]Vrije Universiteit Brussel — [3]Institut d'Astrophysique de Paris — [4]Laboratoire de physique nucléaire et des hautes énergies, Paris

Ultra-high energy (UHE) cosmic rays and neutrinos induce particle cascades in the atmosphere, called extensive air showers. The Giant Radio Array for Neutrino Detection (GRAND) is designed for measuring the radio emission of inclined air showers to cover a larger detection area. It will consist of multiple sub-arrays and a total area of 200 000 km$^2$ with one radio antenna per square kilometre. At full capacity, GRAND will detect UHE neutrinos, gaining information on the sources they share with UHE cosmic rays. In contrast to existing arrays, GRAND will operate on radio events alone, hence efficient radio triggering techniques are in development. We use CORSIKA air-shower simulations to update a detailed signal model of the radio emission of inclined showers for the wide 50 – 200 MHz frequency band GRAND is sensitive to. This talk gives an overview on radio emissions of extensive air showers, details of the signal model, and how it will be instrumental for event reconstruction for large-scale detector systems and the development of the autonomous radio trigger*.

* *NUTRIG project, ANR-DFG Funding Programme (490843803)*

T 35.8 Tue 17:45 Geb. 30.22: Lehmann-HS

**Improved methods for the determination of the Energy Spectrum of UHECRs with the Fluorescence and Surface Detector of the Pierre Auger Observatory** — •Kathrin Bismark for the Pierre-Auger-Collaboration — Karlsruher Institut für Technologie (KIT)

The energy spectrum of ultrahigh-energy cosmic rays (UHECRs) provides information about the extragalactic origin and propagation of cosmic rays. A combination of surface and fluorescence detector measurements of the Pierre Auger Observatory delivers a high-resolution hybrid energy spectrum. The long-term observations of the Pierre Auger Observatory allow us to re-evaluate environmental influences on detection capabilities and selection criteria using measured rather than simulated data.

In this contribution, we will demonstrate improved methods to determine the hybrid energy spectrum of UHECRs and present preliminary results.

# T 36: Gamma astronomy 2

Time: Tuesday 16:00–18:00 Location: Geb. 30.22: kl. HS A

T 36.1 Tue 16:00 Geb. 30.22: kl. HS A

**Automatized Pulsar Analysis for the MAGIC Telescopes** — •Jan Lukas Schubert and Stefan Fröse for the MAGIC-Collaboration — TU Dortmund University, Dortmund, Germany

The MAGIC telescopes are Imaging Air Cherenkov Telescopes which are used for gamma-ray detection in the GeV to TeV range. Thanks to an analog trigger system, dubbed Sum-Trigger-II, low-energy observations with a threshold as low as ~15 GeV can be made, enabling the MAGIC telescopes to perform comparably low energetic analyses such as pulsar analyses. These data requires a dedicated treatment adapted to the low energies. The automatization of the analysis of Sum-Trigger-II data was implemented in the autoMAGIC project, which aims to automatize the entire MAGIC analysis chain. It produces DL3 data, which represent a standard data format for gamma-ray astronomy.

A workflow for the pulsar timing and the pulsar analysis based on DL3 files produced with autoMAGIC was implemented and delivers results comparable to the currently used pulsar analysis tools in MAGIC. In the future, the automatization of the analysis of Sum-Trigger-II data could be used for further optimizations of the low-energy analysis as well as for comparisons of low-energy data from MAGIC and the LST. Combined with the automatic pulsar analysis, this will enable the possibility of performing long-term pulsar analyses with comparably little effort.

T 36.2 Tue 16:15 Geb. 30.22: kl. HS A

**Optimizing the analysis of very-large zenith-angle observations with MAGIC** — •Juliane van Scherpenberg, David Green, and Razmik Mirzoyan for the MAGIC-Collaboration — Max-Planck-Institut für Physik, Boltzmannstr. 8, 85748 Garching

The pursuit of Galactic PeVatrons remains a focal point in high-energy astrophysics, with these sources expected to emit gamma rays beyond 100 TeV. Recent progress, particularly with hybrid water cherenkov and air shower detectors like LHAASO, has identified multiple potential PeVatron candidates in the Galaxy. The MAGIC Telescopes are the only Imaging Atmospheric Cherenkov Telescopes (IACTs) that have detected gamma rays up to 100 TeV so far by conducting observations close to the horizon at very-large zenith-angles (VLZA). IACTs have superior energy and angular resolutions compared to air shower arrays. This advantage allows for a more detailed study of PeVatron candidates. However, VLZA observations come with challenges. The reduction in size of the shower images, crucial for discriminating between hadrons and gamma rays, complicates the separation of the hadronic background from the gamma-ray signal. To address this, I present approaches to enhance background rejection during VLZA observations with MAGIC. These methods leverage not only the geometrical properties of the shower images but also incorporate information on their temporal development.

T 36.3 Tue 16:30 Geb. 30.22: kl. HS A

**Deep-Learning-Based Gamma/Hadron Separation in the Southern Wide-field Gamma-ray Observatory** — •Martin Schneider, Jonas Glombitza, Christopher van Eldik, and Markus Pirke for the SWGO-Collaboration — ECAP, FAU Erlangen-Nürnberg

The Southern Wide-field Gamma-ray Observatory (SWGO) is a next-generation ground-based observatory in the R&D phase. It will feature a large array of water-Cherenkov detectors (WCD) at high elevations in South America, enabling gamma-ray observations at energies from ~100GeV up to the PeV region. The primary challenge in gamma-ray observations is the rejection of hadronic showers to ensure a high signal-to-noise ratio. Various tank designs and layouts are currently evaluated for their gamma/hadron separation capabilities. This talk will explore the application of a deep-learning-based classification algorithm that processes low-level station information via graph neural networks, demonstrating the effective operation across various configurations.

T 36.4 Tue 16:45 Geb. 30.22: kl. HS A

**Modelling Supernova Remnant Spectra to Predict their Detectability by the Southern Wide-field Gamma-ray Observatory** — •Nick Scharrer, Alison Mitchell, and Vikas Joshi for the SWGO-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP) Friedrich-Alexander-Universität Erlangen-Nürnberg, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen

Supernova remnants (SNRs) remain prime candidates for hadronic particle acceleration within our galaxy. Detecting and identifying Cosmic Ray particle accelerators is achieved via the associated gamma-ray emission they produce. Future facilities such as the Southern Wide-field Gamma-ray Observatory (SWGO) will be of crucial importance in identifying new candidate SNRs. We develop a model of the expected SNR gamma-ray emission and validate it for sources that have been observed with current-generation instruments using a Markov chain Monte Carlo (MCMC) approach for energies above 1 GeV. Furthermore, we compare our model predictions to the anticipated SWGO sensitivity to explore the SNR emission phase space and quantify detection prospects for SWGO.

T 36.5 Tue 17:00 Geb. 30.22: kl. HS A

**Optimization of the image cleaning performance of H.E.S.S. telescopes** — •Jelena Celic[1], Stefan Funk[1], Rodrigo Guedes Lang[1], Simon Steinmassl[2], and Jim Hinton[2] for the H.E.S.S.-Collaboration — [1]ECAP, FAU Erlangen-Nürnberg, Deutschland — [2]MPIK, Heidelberg, Deutschland

One of the challenges in the analysis of Imaging Atmospheric Cherenkov Telescope (IACT) data is minimizing the impact of night sky background (NSB) light. The goal is to reduce this noise while retaining a maximum amount of shower light to reconstruct the the physical quantities of the primary particle. Among the current generation of IACTs, the High Energy Stereoscopic System (H.E.S.S.) is the only southern hemisphere IACT system. Comprising five telescopes in Namibia, H.E.S.S. commonly uses a two-threshold image cleaning technique referred to as tailcut cleaning. However, this established method has drawbacks, particularly in dealing with low-energy shower events. These events produce fainter images near the pixel noise level. The upgraded H.E.S.S. cameras, which provide more accurate pixel timing information, inspired the introduction of a novel time-based image cleaning method. This method aims to optimize the retention of shower event light while efficiently cleaning NSB pixels. This presentation evaluates the performance of both traditional two-threshold and novel time-based image cleaning techniques in various image cleaning properties. Additionally, it establishes a new pipeline for optimizing the image cleaning performance at early data processing to achieve a better sensitivity with H.E.S.S. at lower energies.

T 36.6 Tue 17:15 Geb. 30.22: kl. HS A

**A hybrid machine learning-likelihood approach to event reconstruction for IACTs** — •Georg Schwefer[1], Robert Parsons[2], and Jim Hinton[1] for the CTA-Collaboration — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Institut für Physik, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

The imaging atmospheric Cherenkov technique currently provides the highest angular resolution achievable in astronomy at very high energies. High resolution measurements provide the key to progress on many of the key questions in high energy astrophysics. The huge potential of the next generation Cherenkov Telescope Array (CTA) in this regard can be realised with the help of improved algorithms for the reconstruction of the air-shower direction and energy. Hybrid methods combining maximum-likelihood fitting techniques with neural networks represent a particularly promising approach.

Here, we present the FreePACT algorithm, a hybrid machine-learning likelihood reconstruction method for IACTs. In this, the analytical likelihood used in traditional image-likelihood fitting techniques is replaced by a neural network that approximates the charge probability density function for each pixel in the camera. The performance of this improved algorithm is demonstrated using simulations of the planned CTA southern array.

T 36.7 Tue 17:30 Geb. 30.22: kl. HS A

**Providing Uncertainty Predictions for Reconstructed CTA Events Using Neural Networks** — •Cyrus Walther and Maximilian Linhoff for the CTA-Collaboration — TU Dortmund University, Dortmund, Germany

The Cherenkov Telescope Array (CTA) is the next generation of ground-based, gamma-ray astronomy experiments. The multi-telescope arrays in La Palma, Spain, and Paranal, Chile, will outperform the state-of-the-art imaging atmospheric Cherenkov Telescopes (IACTs) by one order of magnitude in sensitivity. In the event analysis of IACTs, the reconstruction of the energy and direction of the primary particle is crucial. Many analysis methods do not provide reliable uncertainty estimations on the reconstructed energy and direction. Based on successful work in the IceCube collaboration, we want to overcome this challenge with a neural network approach. Using a gaussian likelihood loss function, a prediction of uncertainties in energy and direction on CTA simulation data is performed and assessed.

T 36.8 Tue 17:45 Geb. 30.22: kl. HS A

**Ultra-Fast Generation of Air Shower Images for Imaging Air Cherenkov Telescopes using Generative Models** — •Christian Elflein, Jonas Glombitza, and Stefan Funk for the H.E.S.S.-Collaboration — ECAP, Erlangen, Germany

Resource-aware simulation is an important aspect in many fields of modern physics, including astroparticle physics. The continuous progress in machine learning in this day and age and the successful application of generative models to various tasks in particle and astroparticle physics motivate our application of generative models to the simulation of air shower images in gamma astronomy.

In this contribution, we present a novel technique for the fast generation of gamma-ray air shower images from the FlashCam camera of the CT5 telescope, which is part of the High Energy Stereoscopic System (H.E.S.S.). The generative model used for the generation of images with more than 1500 pixels is based on a Wasserstein Generative Adversarial Network (WGAN) and trained using H.E.S.S. simulations. We show that our framework, in comparison to the standard simulation method, speeds up the image generation by up to five orders of magnitude while keeping a competitive image quality. The visual similarity to simulated images and the representation of physical properties in the generated images is verified by analysing several low-level and high-level parameters and their correlations.

Following this work, we additionally investigate diffusion models, which are state-of-the-art generative deep-learning models, as an alternative way to generate air shower images.

## T 37: Silicon trackers 2

Time: Tuesday 16:00–18:00 Location: Geb. 30.22: kl. HS B

T 37.1 Tue 16:00 Geb. 30.22: kl. HS B

**Assembly and testing of ATLAS ITk pixel detector modules during the production phase** — Patrick Ahlburg, Yannick Dieter, Fabian Hügging, Florian Hinterkeuser, Hans Krüger, Maximilian Mucha, •Matthias Schüssler, and Jochen Dingfelder — Physikalisches Institut der Universität Bonn

With the upgrade of the Large Hadron Collider (LHC) to the High-Luminosity LHC (HL-LHC), the instantaneous luminosity will increase by a factor of 5 from 2029 onward. This results in unprecedented hit rates and radiation levels which require major upgrades of the detectors located at the HL-LHC in order to meet these challenging requirements.

For the upgrade of the ATLAS detector, a new all-silicon inner tracking detector (ITk detector) consisting of silicon strip and pixel modules will be installed and replaces the currently operated Inner Detector. In total, approximately 10.000 new pixel detector modules have to be built and carefully tested to ensure that only functional detector modules are installed. At the Forschungs- und Technologiezentrum Detektorphysik (FTD) in Bonn, approximately 1000 pixel detector modules will be built and characterized during the production of the ATLAS ITk pixel detector. For testing the electrical functionality of the detector modules an intensive quality control (QC) with dedicated testing setups is necessary.

This talk gives an overview of the module assembly at Bonn and the electrical QC for ATLAS ITk pixel detector modules.

T 37.2 Tue 16:15 Geb. 30.22: kl. HS B

**ITk Pixel DCS: Pixel System Monitoring Readout** — •Anne Gaa and Stan Lai — II. Physikalisches Institut, Georg-August-Universität Göttingen

The ATLAS experiment is developing the new Inner Tracker (ITk) in preparation for the High-Luminosity LHC Upgrade. The ITk pixel Outer Barrel demonstrator, as a system prototype, recently passed its final design review phase in preparation of the construction of the finished detector. The Detector Control System (DCS) is responsible for monitoring and controlling the detector and its sub-systems.

Part of the DCS is the readout chain of the Monitoring of Pixel System (MOPS), which provides an independent monitoring of the temperature and voltage of the front-end pixel modules. The MOPShub is the bidirectional interface between the local DCS station and the MOPS chips. Testing sites for the Outer Barrel local supports, as well as the OB demonstrator currently use MOPShub4beginners, a preliminary readout chain based on a RaspberryPi. The MOPS chips are connected via CAN buses to the RaspberryPi, which sends the monitored data over an OPC UA server to the local DCS control station. OPC UA is an cross-platform, open-source standard for data exchange. This talk presents new developments of the MOPShub.

T 37.3 Tue 16:30 Geb. 30.22: kl. HS B

**Bump connectivity and efficiency studies on ATLAS ITkPix using a high intensity X-Ray beam** — Yannick Dieter, Fabian Hügging, Hans Krüger, •Andreas Ulm, Marco Vogt, and Jochen Dingfelder — Physikalisches Institut der Universität Bonn

With the upgrade of the Large Hadron Collider (LHC), which will increase the instantaneous luminosity by a factor of approximately 5 to the current luminosity, the ATLAS detector will also be upgraded. In particular, a new all-silicon tracking detector (ATLAS ITk) is installed consisting of strip and hybrid pixel detectors.

Hybrid pixel detectors consist of a passive sensor element and an active readout chip which are connected via small solder bumps. As this interconnection is a quite complex process the bump connectivity of each pixel has to be tested. To test the bumps, a setup inside of an X-Ray machine has been installed. A X-ray machine is used to archive the high statistics needed to identify connected bumps in a short amount of time. In addition to that, the high intensity X-ray beam can also be used to investigate the rate capability of the ATLAS ITk pixel detector readout chip.

In this talk, a setup for the investigation of the bump-connectivity is presented and efficiency studies using a high intensity x-ray beam are shown.

T 37.4 Tue 16:45 Geb. 30.22: kl. HS B

**Performance of CMS Inner Tracker pixel assemblies for the Phase-2 Upgrade** — •Bianca Raciti, Massimiliano Antonello, Erika Garutti, Chin-Chia Kuo, Jörn Schwandt, and Georg Steinbrück — University of Hamburg, 22761, Luruper Chaussee 149, Hamburg, Germany

During Long Shutdown 3, the entire CMS Tracking System will be replaced to operate during the High Luminosity LHC running phase with considerably increased luminosity. The pixel sensor modules for the CMS Inner Tracker will have to fulfill stringent requirements to operate in an extremely harsh radiation environment and to cope with the high data readout rate.

An extensive campaign has taken place to characterize the first half-size pixel chip demonstrator (RD53A), which led to the submission and production of the first full-size prototype chip (RD53B_CMS).

Sensor-readout chip assemblies have been extensively tested both in the laboratory and at the CERN and DESY testbeam facilities.

This study presents results on the analysis of testbeam data acquired with RD53B_CMS assemblies irradiated to fluences up to $\Phi_{eq} = 1.0 \times 10^{16}\ N_{eq}\ cm^{-2}$. For all investigated fluences, the requirement of reaching a hit efficiency $\epsilon_{hit} > 99\%$ has been met, while keeping the percentage of pixels masked as noisy below 1%. Additionally, measurements of crosstalk levels observed in RD53B_CMS assemblies equipped with final design pixel sensors will be presented.

T 37.5 Tue 17:00 Geb. 30.22: kl. HS B

**Quality control for the production of multi-chip modules for CMS Inner Tracker** — •Chin-Chia Kuo, Massimiliano Antonello, Erika Garutti, Bianca Raciti, Jörn Schwandt, and Georg Steinbrück — University of Hamburg, 22761, Luruper Chaussee 149, Hamburg, Germany

Quality control studies of Inner Tracker quad modules for the Phase-2 upgrade of the CMS Inner Tracker are presented. An Inner Tracker quad module is a hybrid detector consisting of a silicon pixel sensor and four $(2 \times 2)$ CMS Readout Chips (CROCs) coupled via fine pitch flip-chip bump bonding. In this design, the space between adjacent readout chips is bridged using large sensor pixels.

Several methods for measuring the yield of missing bumps are presented and compared, which will be part of quality control after mass production. Furthermore, the performance of large pixels is presented with quad modules tested at the DESY testbeam facility, using electrons with an energy of 5.2 GeV.

T 37.6 Tue 17:15 Geb. 30.22: kl. HS B

**Test Beam Analysis of Irradiated, Passive CMOS Strip Sensors** — •Fabian Lex for the CMOS Strips-Collaboration — Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

Nearly all envisioned future high-energy particle detectors will employ silicon sensors as their main tracking devices. Due to the increased demand in performance, large areas of the detectors will have to be covered with radiation hard silicon, facilitating the need for silicon sensors produced in large quantities, reliably and cost-efficiently.

A possible solution to these challenges has been found in the utilization of the CMOS process, which is an industrial standard, offering the advantage of a large choice of vendors and reduced production costs. To create the larger sensor structures typical for silicon strip trackers, the stitching process has to be used.

Three variations of passive CMOS strip sensors have been designed by the University of Bonn and produced by LFoundry in a 150 nm process. Sensor samples have been irradiated up to a fluence of $1 \cdot 10^{16} n_{eq}/cm^2$ with reactor neutrons and up to $1 \cdot 10^{15} n_{eq}/cm^2$ with 23 GeV protons. In order to investigate the general performance of the designs and the influence of the stitching on resolution, hit detection efficiency and charge collection, unirradiated as well as irradiated samples have been tested in the DESY-II test beam facility. This talk will show that even after heavy irradiation signal collection by the different sensor designs is still possible and that the stitching does not impact sensor performance.

T 37.7 Tue 17:30 Geb. 30.22: kl. HS B

**Characterisation and TCAD Simulation of Stitched, Passive CMOS Strip Sensors** — •Iveta Zatocilova for the CMOS Strips-Collaboration — Albert-Ludwigs-Universität, Freiburg, Germany

Silicon sensors play a key role in the tracking detectors of high-energy physics experiments. Due to upcoming upgrades and future particle detectors, the requirements in radiation hardness and reliability of the sensors are constantly increasing. There is a need for alternative silicon sensor concepts that can realise a larger choice of manufactures while meeting the complex requirements.

A promising technology is found in passive CMOS sensors, based on CMOS imaging technology. As this technology is an industry-standard, it can offer a lowered sensor cost, as well as access to fast and large-scale production.

The passive CMOS project is investigating passive CMOS strips sensors fabricated by LFoundry in a 150 nm technology. A total of three different strip designs have been investigated.

Passive CMOS strip sensors were evaluated based on simulated electrical characteristics of the fabricated structures. For this purpose, Synopsys Centaurus TCAD was used. By simulating electric field we were able to look at differences between the designs. On the macroscopic level we have simulated electrical characteristics that are yielding a satisfactory agreement when compared to measured data.

This presentation will provide an insight into the sensor design and a comparison of simulated and measured sensor characteristics will also be presented.

T 37.8 Tue 17:45 Geb. 30.22: kl. HS B

**Characterisation and Simulation of stitched CMOS Strip Sensors** — •Naomi Davis for the CMOS Strips-Collaboration — Deutsches Elektronen-Synchrotron (DESY), Notkestraße 85, 22607 Hamburg

In high-energy physics, upgrades for particle detectors and studies on future particle detectors are largely based on silicon sensors as tracking devices. Consequently, there is a need to investigate silicon sensor concepts that offer large-area coverage and cost-efficiency. Sensors based on the CMOS imaging technology present such an alternative silicon sensor concept for tracking detectors. As this technology is a standardised industry process it can provide a lower sensor production cost, as well as access to fast and large-scale production from a variety of vendors. The CMOS Strips project is investigating passive CMOS strip sensors fabricated by LFoundry in a 150 nm technology. By employing the technique of stitching, two different strip formats of the sensor have been realised. The strip design varies in doping concentration and width of the strip implant to study various depletion concepts and electric field configurations. Unirradiated and irradiated samples have been characterised in several test beam campaigns at the DESY II test beam facility. In addition, the detector response was simulated based on Monte Carlo methods and electric fields provided by TCAD device simulations. This contribution presents studies on the signal distribution, spatial resolution and the hit detection efficiency of the strip sensors. The simulated detector response is presented and compared to test beam data.

# T 38: Standard model 1 (electroweak/bosons)

Time: Tuesday 16:00–18:00 Location: Geb. 30.23: 2/0

T 38.1 Tue 16:00 Geb. 30.23: 2/0

**Determination of the tau polarization in hadronic $Z \to \tau^+\tau^-$ decays from pp collisions at the ATLAS detector** — •Florian Harz, Adrián Álvarez Fernández, and Stefan Tapprogge — Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany

The Z boson arises from the unification of the electromagnetism and weak forces, coupling differently to left- and right-handed particles as indicated by the effective weak mixing angle. Precisely measuring the tau polarization in $Z \to \tau^+\tau^-$ decays provides a means to extract the weak mixing angle. This is accomplished by fitting templates to sensitive kinematic observables derived from decays of purely left-handed or right-handed taus. This method can be verified using simulated samples. The study considers various hadronic tau decay channels and assesses their sensitivity to the tau polarization. The status of these studies is presented, highlighting their potential application to real data, particularly focusing on proton-proton data collected at the ATLAS detector.

T 38.2 Tue 16:15 Geb. 30.23: 2/0

**Studies of the $\tau$ polarization in leptonic Z $\to \tau^-\tau^+$ decays using $\sqrt{s} = 13$ TeV pp collision data** — •Sabrina Saul, Florian Harz, Adrián Álvarez Fernández, and Stefan Tapprogge — Johannes-Gutenberg Universität Mainz, Institut für Physik

This study examines the leptonic $\tau$ decays from Z boson resonant production in pp collisions at LHC with $\sqrt{s} = 13$ TeV measured with the ATLAS detector. As a result of the electroweak interaction, $\tau$ leptons from Z decays are polarized and the degree of polarization is connected to the weak mixing angle. Kinematic properties of the visible decay products of the $\tau$ (muons and electrons in this case) allow to infer the polarization of the parent particle. First, the kinematic properties are investigated without detector effects. Second, detector effects such as resolution, as well as the impact of cuts necessary to suppress background are studied. This contribution will summarize the current status and outlook of the study.

T 38.3 Tue 16:30 Geb. 30.23: 2/0

**Prospects of the longitudinally polarised vector boson scattering processes at the ATLAS detector** — •Aryan Borkar, Thomas Trefzger, Raimund Ströhmer, and Gia Khoriauli — Julius-Maximilians-Universität Würzburg

The electroweak symmetry breaking mechanism can be experimentally tested in the electroweak vector boson scattering (VBS) processes that occur in proton-proton collisions at the LHC. The unitarity of VBS cross sections of longitudinally polarised bosons $V_{1,L}V_{2,L} \to V_{3,L}V_{4,L}$, where $(V = W^{\pm}, Z)$, in the Standard Model are preserved by including the Feynman diagrams with the Higgs boson propagator in calculations. Thus, precise measurements of VBS processes of longitudinally polarised vector bosons are important experimental tests of the validity of the Brout-Englert-Higgs mechanism. We present the preliminary study of the potential of measurements of polarisation observables in the combined Run-2 and Run-3 data sets collected by the ATLAS detector. VBS processes with different heavy vector boson final states are considered in the study.

T 38.4 Tue 16:45 Geb. 30.23: 2/0

**Polarization Measurement in Same-Charged WW Scattering Within the ATLAS Experiment** — •Max Stange, Frank Siegert, Erik Bachmann, Mareen Hoppe, and Tim Herrmann — TU Dresden, Dresden, Germany

In 2023, the ATLAS experiment marked the first differential cross-section measurement of same-charged W boson scattering, a process crucial for understanding electroweak symmetry breaking. Since the W bosons obtain their mass and thus their longitudinal polarization directly from the Higgs mechanism, the longitudinal parts of the W boson scattering are particularly promising for studying the Higgs mechanism and finding physics beyond the Standard Model. As these bosons decay into a charged lepton and a neutrino, directly reconstructing their original polarizations is impossible. To address this, the analysis uses neural networks to separate the background and the polarizations within the same charged W boson signal. The talk gives an overview of the applied machine learning techniques and the study of next-to-leading-order corrections applied for the polarization.

T 38.5 Tue 17:00 Geb. 30.23: 2/0

**Search for scattering of same-sign WW boson pairs in the semi-leptonic channel at the CMS experiment.** — Thorsten Chwalek[1], Nils Faltermann[1], Abideh Jafari[2], Thomas Müller[1], and •Komal Tauqeer[1] — [1]Institut für Experimentelle Teilchenphysik (ETP), Karlsruher Institut für Technologie (KIT), Germany — [2]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

Vector Boson Scattering (VBS) at the LHC is a key process to probe the electroweak symmetry breaking of the standard model (SM). Deviations in VBS cross section measurements point to physics phenomena beyond the SM. Same-sign WW scattering is known as the golden channel to study VBS as it has the best $\sigma_{EW}/\sigma_{QCD}$ ratio. Studying this process in semi-leptonic channel will broaden the search as it provides a much larger branching ratio. The biggest challenge here is to identify the correct bosons ($W^+$, $W^-$, $Z$) in the final state that are decaying into quarks.

To distinguish jets in the final state that are coming from the hadronic decay of the bosons, we have developed a method to identify the charge of the jet using state-of-art machine learning techniques. With the help of this method, we are able to distinguish between jets originating from $W^+$, $W^-$, or $Z$ bosons. In this talk, I will present the techniques used for doing the jet charge tagging and how we are implementing these techniques to study the same-sign WW VBS process in the semi-leptonic channel.

T 38.6 Tue 17:15 Geb. 30.23: 2/0

**Study of polarization fractions in same-sign $W$ boson scattering with the ATLAS detector** — •Prasham Jain[1], Beate Heinemann[2,3], and Oleg Kuprash[1] — [1]University of Freiburg, Freiburg im Breisgau, Germany — [2]DESY, Hamburg, Germany — [3]University of Hamburg, Hamburg, Germany

Polarized same-sign $W$ boson pair production is a crucial process to examine the electroweak symmetry breaking mechanism. A measurement of the fraction of longitudinally polarized $W$ bosons, $W_L^\pm W_L^\pm$, tests the unitarization mechanism of the vector boson scattering amplitude through Higgs boson contributions, and is sensitive to potential new physics effects. This talk presents machine learning (ML) methods for classification of $W^\pm W^\pm$ polarization modes studied with the ATLAS detector using Run 2 LHC data. Results are shown of applying the ML for the extraction of longitudinal polarization fraction.

T 38.7 Tue 17:30 Geb. 30.23: 2/0

**Search for photon-induced semileptonic WW production at the ATLAS Experiment** — •Varsiha Sothilingam — Kirchhoff-Institut für Physik, Universität Heidelberg

This talk will focus on the coupling between W bosons and photons where the W bosons decay semileptonically. They interact via the triple ($\gamma \rightarrow WW$) and quartic ($\gamma\gamma \rightarrow WW$) gauge boson couplings of the SM. This process can be produced via Centrally Exclusive Production at the LHC, where non-colliding protons produce a non-linear electromagnetic field which creates a photon pair. The photons couple to the W bosons, providing the signal of interest while the protons remain intact. These protons can be detected using the ATLAS Forward Proton (AFP) spectrometers, which are located around 200m away from the ATLAS detector, on both sides. Kinematic information from both the AFP and ATLAS central detector can be used to constrain the signal process. Additionally, the final state of this process favours boosted topologies which can also be exploited in the signal optimisation. With the use of the AFP detectors, such a process can be used to search for model independent extensions of the SM. This is done in the Effective Field Theory (EFT) formalisation, which the quartic coupling process is sensitive to. The anomalous quartic coupling is sensitivity to dimension-8 operators of the EFT model. This talk will provide insight to the measurement of this rare process and the methods used to optimise this search. The EFT operators which the process is sensitive to will be studied and expected experimental limits will be set.

T 38.8 Tue 17:45 Geb. 30.23: 2/0

**Measurement of the electroweak production of a W boson accompanied by two jets with the ATLAS experiment** — •Lisa Marie Baltes — Kirchhoff-Institute for Physics, University Heidelberg, Germany

The observation and measurement of electroweak gauge boson self-interaction provides an indirect search for physics beyond the Standard Model. The electroweak production of a W boson in association with two jets includes the vector-boson-fusion (VBF) production of a W boson and is thus sensitive to the triple gauge boson vertices WW$\gamma$ and WWZ. In proton-proton collisions, the characteristic signature of VBF includes two high-momentum jets at small angles with respect to the incoming beams and a centrally produced lepton-neutrino pair originating from the W boson decay. This unique signature provides kinematic discrimination from backgrounds such as strongly produced jets associated with a W boson, $t\bar{t}$ and dijet. In this talk, the current status of the electroweak $Wjj$ analysis including event selection and background estimation is presented.

## T 39: Detectors 4 (calorimeters)

Time: Tuesday 16:00–18:00 Location: Geb. 30.23: 2/1

T 39.1 Tue 16:00 Geb. 30.23: 2/1

**Hadron Calorimeter for the HIKE Experiment** — •Letizia Peruzzo and Rainer Wanke — Johannes Gutenberg University, Mainz

The High Intensity Kaon Experiments (HIKE) is a new proposed project for the ECN3 experimental hall in the North Area of CERN SPS. The long-term, fixed-target experiment would continue the long-standing experience of kaon experiments at CERN after LS3 (2031). The experimental programme will reach an unprecedented sensitivity in kaon physics, from rare and ultra-rare kaon decays to precision measurements and searches for new-physics phenomena, with a staged approach involving charged and neutral beams, as well as operation in beam-dump mode.

The Hadron Calorimeter (HCAL) for HIKE will be one of the main detectors for $\pi/\mu$ identification and separation, with the requirement of achieving an average muon mis-identification probability of $\mathcal{O}(10^{-6})$ or less while preserving at least 85% of the pion efficiency. To achieve the requirements and, at the same time, to sustain the high-intensity environment a cellular design of alternating scintillator and absorber planes has been proposed for the new HIKE HCAL.

The talk will report on the preliminary studies on the concept and design of the HIKE HCAL.

T 39.2 Tue 16:15 Geb. 30.23: 2/1

**Energy calibration of the SND@LHC hadronic calorimeter** — •Eduard Ursov, Andrew Conaboy, Heiko Lacker, and Anupama Reghunath — Humboldt University of Berlin, Berlin, Germany

SND@LHC (Scattering & Neutrino Detector at the LHC) is a compact and stand-alone experiment measuring neutrinos produced in proton-proton collisions at the LHC. The experiment aims to study all three neutrino flavours in the yet unexplored pseudo-rapidity region of $7.2 < \eta < 8.4$, specifically electron neutrinos that are mainly coming from charmed hadron decays. In July 2023, the SND@LHC collaboration reported observation of 8 muon neutrino charged-current candidates with a significance of $6.8\sigma$. To reconstruct the neutrino energy and filter out background from neutral hadrons that are produced from muons downstream of the detector, the energy calibration of the hadronic calorimeter is required. To calibrate the detector, a test beam experiment with 100-300 GeV pion beams has been performed and is compared to a corresponding Geant4-based simulation. The results of the test beam analysis and the simulation are presented in this work.

T 39.3 Tue 16:30 Geb. 30.23: 2/1

**Neutron and Gamma Particle Identification in Compact Plastic Scintillators** — •Sebastian Ritter — Johannes-Gutenberg Universität, Mainz

Particle identification (PID) using pulse shape discrimination (PSD) is a commonly used concept in scintillation detectors to differentiate between gammas and neutrons. Considering highly granular plastic scintillator based calorimeters in development, performing this separation on signals with increasingly small photon statistics constitutes a real challenge.

This setup features small 30x30x3mm scintillator tiles readout by small SiPMs representing a proven readout concept for a large-scale calorimeter. Coincidence gamma and neutron emissions from an AmBe source are used for tagging. In addition, the setup includes cosmic tagging which allows for the identification and rejection of the permanent cosmic background.

To show the feasibility of such an analysis the late light single photon peaks are extracted from the data using different methods such as peak counting and integration and comparing them to the initial signal peak.

This technology could be used in various future detectors to provide tagging information and energy reconstruction for neutrons.

T 39.4 Tue 16:45 Geb. 30.23: 2/1

**ATLAS Tile Calorimeter signal reconstruction in Phase-II** — •Thomas Junkermann — Kirchhoff-Institut für Physik, Heidelberg, Deutschland

The Phase-II Upgrade of the ATLAS Tile Calorimeter remodels it's data read-out to cope with the higher amount of simultaneous proton-proton collisions of future LHC runs. To provide precise information to downstream components like the Phase-II digital trigger new back-end electronics are designed. These process the calorimeter data and prepare it for the trigger as well as buffering them for permanent storage. The energy reconstruction and bunch crossing identification, previously calculated by the trigger itself, are now being performed on the tile electronics. The calorimeter signals properties, energy and time, are reconstructed from digital samples being send from on-detector components to an off-detector pre-processing stage. The upgraded back-end offers various possibilities to reconstruct the cells signal energies and timings. The usage of neural networks is studied as a new approach at the preprocessing stage as it can learn differently than previously used classical reconstruction algorithms like optimal filters. The performance of a neural network will be presented in comparison to an optimal filter based on simulated Phase-II detector signals.

T 39.5 Tue 17:00 Geb. 30.23: 2/1

**Multi-Tilemodule test system using cosmic rays for the CMS HGCAL upgrade** — •Jia-Hao Li — Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

The CMS experiment plans to upgrade its calorimeter endcap for the high luminosity phase of the LHC with the High Granularity Calorimeter (HGCAL). The Tilemodule is one of the basic elements in the hadronic calorimeter part of the HGCAL. It uses small scintillator tiles directly coupled to SiPMs (SiPM-on-tile technology) for particle detection. The Tilemodule is equipped with one or two HGCROC ASICs for data readout. To test and calibrate the Tilemodules, a cosmic ray setup with multiple Tilemodules synchronised with each other is established for quality control and a better understanding of the property of the Tilemodule. The presentation will discuss the idea and current status of the cosmic test setup at DESY.

T 39.6 Tue 17:15 Geb. 30.23: 2/1

**System Validation of the SiPM-on-Tile Section of the CMS High Granularity Calorimeter** — •Gabriele Milella — DESY — University of Hamburg

Calorimetry at the High Luminosity Large Hadron Collider (HL-LHC), especially in the forward regions, encounters two significant challenges: to cope with high radiation levels and manage an unprecedented number of simultaneous events. To address these issues, the CMS Collaboration is planning to replace the endcap calorimeters with a high-granularity calorimeter (HGCAL). This innovative sampling calorimeter uses as active materials silicon sensors and scintillator tiles, which are read out by silicon photomultipliers (SiPMs). The fundamental component of the SiPM-on-tile system is the tile module, which includes a printed circuit board (PCB) equipped with one or two HGCROC ASICs, capable of reading a high number of SiPMs. The tile modules have been studied at the DESY-II test beam and undergone various laboratory trials. The production of the tile modules for the upgrade is scheduled to commence next year. This presentation presents the current status and plans for future production of the SiPM-on-tile region of the CMS HGCAL.

T 39.7 Tue 17:30 Geb. 30.23: 2/1

**Reconstruction of test beam data for the CheapCal prototype detector using Machine Learning** — Alessia Brignoli[1], Andrew Picot Conaboy[1], Valery Dormenev[2], Christian Dreisbach[3], Karl Eichhorn[3], Jan Friedrich[3], Heiko Markus Lacker[1], Martin J. Losekamm[3], Anupama Reghunath[1], •Christian Scharf[1], Ben Skodda[1], Valerian von Nicolai[1], Ida Wöstheinrich[1], and Hans-Georg Zaunick[2] — [1]Humboldt-Universität zu Berlin — [2]Justus-Liebig-Universität Gießen — [3]Technische Universität München

The CheapCal prototype detector is an extruded plastic scintillator detector with wavelength-shifting (WLS) fibers embedded in perpendicular grooves on the front and the back of the $25 \times 25$ cm$^2$ scintillator plate. The WLS fibers are read out on both ends by Silicon Photomultipliers. Due to the short light attenuation length of the scintillator material, photons couple only to the nearest WLS fibers, allowing for reconstruction of the positions of passing particles.

We will present the reconstruction of 100 GeV muon test beam data using Machine Learning. The impact of different read-out schemes on the position resolution of the detector will be evaluated.

We acknowledge the support from BMBF via the High-D consortium.

T 39.8 Tue 17:45 Geb. 30.23: 2/1

**Optimizing the design for a Noble-Liquid-based calorimeter for FCC-ee** — •Martina Koppitz[1,2], Nikiforos Nikiforou[2], Arno Straessner[1], Brieuc Francois[2], and Martin Aleksa[2] — [1]TU Dresden (Germany) — [2]CERN (Switzerland)

The Future Circular Collider (FCC) is currently the most promising candidate for flagship experiments for the era after the LHC. With a circumference of 91 km, it promises unprecedented performance for potentially a lepton collider (FCC-ee) implementation followed by a hadron collider stage (FCC-hh). The broad physics program of the FCC-ee, spanning from high precision measurements around the Z-pole to direct Higgs production, relies strongly on the performance of calorimeters with a focus on highly-granular devices optimized for particle flow methods. Due to the outstanding operation in various previous and current experiments, noble liquid calorimetry solutions have been adapted for the electromagnetic calorimeter of the FCC-ee. The current design of the ALLEGRO (A Lepton coLlider Experiment with highly Granular calorimetry Read-Out) detector involves a sampling calorimeter comprising 1536 cylindrically-stacked lead absorbers and readout electrodes with liquid argon as active material. The baseline geometry is being tested in simulations to optimize the energy and angular resolution as well as the particle identification performance. Special focus is given to the pi0 and photon identification capabilities as a function of the number of layers in the radial direction and the cell granularity in the theta and phi directions.

# T 40: Detectors 5 (scintillators)

Time: Tuesday 16:00–18:00 Location: Geb. 30.23: 2/17

T 40.1 Tue 16:00 Geb. 30.23: 2/17

**Sensitivity Study of a Scintillating Active Transverse Energy Filter for Background Suppression at the KATRIN Experiment** — •Nathanael Simon Gutknecht for the KATRIN-Collaboration — Karlsruhe Institute of Technology (KIT)

The **Ka**rlsruhe **Tr**itium **N**eutrino (KATRIN) experiment aims to determine the mass of the electron antineutrino by precise measurement of the energy spectrum of $\beta$-electrons from tritium decay using a MAC-E-Filter setup. After a total measurement time of 1000 days in 2025, a final sensitivity better than 0.3 eV/c$^2$ (90 % C.L.) is expected.

At the moment, one sensitivity limiting factor is the spectrometer background which consists of electrons that are generated in the mainspectrometer volume. Due to their small initial energy, the background electrons have a different angular distribution than the signal electrons at the point of detection.

A scintillating structure acting as an angular selective detector (scint-aTEF) has potential to discriminate between $\beta$- and background electrons. This talk will discuss the concept of the scint-aTEF and its expected impact on background reduction and neutrino mass sensitivity, based on simulations.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6).

T 40.2 Tue 16:15 Geb. 30.23: 2/17

**Online Radiopurity Analysis with BiPo coincidences in the JUNO Pre-Detector OSIRIS** — •Konstantin Schweizer[1], Lothar Oberauer[1], Kai Loo[4], and Michael Wurm[2,3] — [1]Technische Universität München, Physik Department, James-Franck-Str., 85748 Garching, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz Staudingerweg 7, 55128 Mainz, Germany — [3]Institute of Physics and Excellence Cluster PRISMA+, Johannes-Gutenberg Universität Mainz, Mainz, Germany — [4]University of Jyväskylä, Faculty of Mathematics and Science, Ylistönrinne (YF) Survontie 9 B, Jyväskylä, Finland

The organic liquid scintillator-based JUNO experiment (Jiangmen Underground Neutrino Observatory) aims to resolve the neutrino mass hierarchy. This goal requires the radiopurity of the scintillator to be very high.

The 20$^3$ OSIRIS pre-detector will monitor the level of radioactive contaminations in the liquid scintillator as the last device in the scintillator production chain. OSIRIS will determine the radiopurity right before filling the JUNO central detector. We will measure the level of U/Th contaminations by exploiting the coincident signals of a Bi $\beta$-decay to Po immediately followed by an $\alpha$-decay to Pb. This talk presents the status of developing an in-situ analysis of this method within the OSIRIS online monitoring software framework.

This work is supported by the DFG Research Unit "JUNO" (FOR2319).

T 40.3 Tue 16:30 Geb. 30.23: 2/17

**Testbeam measurements with the first multi-cell prototype of the Surrounding Background Tagger of the proposed SHiP experiment** — •Alessia Brignoli for the SHiP-SBT-Collaboration — Humboldt-Universität zu Berlin

The Surrounding Background Tagger (SBT) is a crucial part of the SHiP experiment to suppress background from muons entering the decay vessel of the experiment or from muon/neutrino inelastic interactions in the decay vessel walls and its surrounding. SBT is based on liquid scintillator (LAB-PPO) filled cells. Light collection is performed through Wavelength-Shifting Modules (WOMs) made of PMMA and dip-coated with a wavelength shifting dye. We present results obtained with the first multi-cell prototype, consisting of four cells, and implemented with improvements over the previous design of a one-cell prototype, which was successfully tested with positrons in October 2022 at DESY, Hamburg [arXiv:2311.07340]. In October 2023, the four-cell prototype has been tested with muons and electrons at CERN's PS. Each cell was equipped with two WOM tubes, equidistant from the center along the vertical axis. A study about timing resolution of the detector was performed to achieve a better comprehension on the possibility of event reconstruction in the final SBT detector. In parallel, an accurate and detailed Geant4 simulation of the prototype has been built, including the simulation of the electronic signal of the detector. The comparison of the simulation results with the data from the testbeam allows us to gather further information about the detector response and the quality of the built prototype.

T 40.4 Tue 16:45 Geb. 30.23: 2/17

**Reflective Coating in the SHiP Surround Background Tagger** — •Patrick Deucher, Annika Hollnagel, Manuel Böhles, and Michael Wurm for the SHiP-SBT-Collaboration — Johannes Gutenberg Universität Mainz, Institut für Physik, Staudingerweg 7, 55128 Mainz

The Surround Background Tagger (SBT) is a liquid-scintillator-based background detector in the SHiP Experiment. Divided into segments, it envelops the vacuum decay vessel made of Corten Steel. WOMs with SiPM arrays are used for light detection with a high angular acceptance. The efficiency of such a detector type can be increased by optimizing the light collection, enhancing the transparency of the scintillator (purification and addition of different fluorophores) and increasing the reflectivity of the inner detector walls. Following results of Photon Transport Simulations that indicate an increase of light yield by a factor of 4-5 by applying a highly diffuse reflector to the inner walls of a detector, a Bariumsulfate-based reflective coating ("OPRC" by Berghof Fluoroplastic Technology GmbH) has been developed. This talk will discuss results of a second large-scale application of the reflective coating in a 4-cell liquid scintillator detector for the test beam 2023 at CERN. Several improvements were made compared to the first application in a 1-cell prototype in 2022, such as using a rust protection primer to prevent yellowing of the coating through a reaction with the Corten Steel. This work is supported by the BMBF Project 05H2018 - High-D and the Cluster of Excellence PRISMA+.

T 40.5 Tue 17:00 Geb. 30.23: 2/17

**Testbeam Performance and Photoelectron Yields of 4-cell Prototype for the SHiP SBT** — •Fairhurst Lyons for the SHiP-SBT-Collaboration — Universitaet Freiburg

We present R&D towards a large-area detector for energy reconstruction and tracking, which consists of many individual cells filled with liquid scintillator. Each cell is equipped with two wavelength-shifting optical modules (WOMs) that capture scintillation light and transfer it to silicon photomultipliers. This design could serve as the surrounding background tagger (SBT) of the proposed Search for Hidden Particles (SHiP) experiment, a general-purpose detector housed at the CERN SPS accelerator to search for light, feebly interacting particles. Four such cells were tested at a CERN $\mu-$ testbeam in October 2023; analysis of performance and photoelectron yields will be presented here.

T 40.6 Tue 17:15 Geb. 30.23: 2/17

**Background suppression in the SHiP experiment with the Surround Background Tagger** — •Anupama Reghunath — Institut für Physik, Humboldt-Universität zu Berlin, Berlin, Germany

The Search for Hidden Particles (SHiP) experiment at CERN is proposed as a dedicated proton beam dump facility in the ECN3 cavern, aiming to explore feebly interacting particles produced by 400 GeV/c protons impinging on a heavy metal target. Over a 15-year span, the objective is to accumulate $6 \cdot 10^{20}$ proton on target with a detector setup that allows suppression of possible background to a negligible level. The experiment focuses on optimizing sensitivity for models featuring long-lived exotic particles below 10 GeV/c$^2$ and minimizing Standard Model (SM) particle flux. The Surround Background Tagger (SBT) is a critical component surrounding the 50 m long decay vessel, instrumental in suppressing background by detecting charged particles either entering the vacuum vessel from outside, or produced in inelastic interactions in the vacuum vessel walls. This is crucial for distinguishing actual signals from background, particularly as long-lived SM particles produced in these interactions can mimic the signatures of hidden sector particles. This presentation will discuss simulation studies showing how different background sources are vetoed robustly with the focus of the Surrounding Background Tagger (SBT).

T 40.7 Tue 17:30 Geb. 30.23: 2/17

**Stilbene scintillation anisotropy for neutron source localisation** — •Glen Kiely, Nina Höflich, and Oliver Pooth — III. Physikalisches Institut B, RWTH Aachen University, 52074 Aachen

Stilbene is a widely used scintillator material which is best known for its pulse shape discrimination capability, allowing for the distinction between neutron and gamma-ray interactions. This ability is utilised in neutron and gamma ray tomography at the neutron detectors research group at RWTH Aachen. Stilbene has also recently been applied in the field of nuclear non-proliferation for the detection of special nuclear materials.

The scintillation properties of stilbene crystals were investigated, with a particular focus on anisotropy of the scintillation light output. The anisotropy has been characterised by previous studies, and the crystal axes of maximum and minimum response have been identified. The scintillation anisotropy was implemented into Geant4 for the first time through a modification of the G4Scintillation class. A Geant4 model of a detector capable of neutron source localisation was then simulated, which leverages the inherent scintillation anisotropy through rotation of the detector, to determine the location of a neutron source relative to the crystal axes.

T 40.8 Tue 17:45 Geb. 30.23: 2/17

**Simultaneous tomography with fast neutrons and gamma rays using the scintillator stilbene** — •Nina Höflich, Glen Kiely, and Oliver Pooth — III. Physikalisches Institut B, RWTH Aachen University, 52074 Aachen

The neutron detectors group at the III. Physics Institute B, RWTH Aachen University, develops a multi-pixel detector for a compact fast neutron imaging setup. Imaging with fast neutrons in addition to X- or gamma ray imaging can provide complementary information about the object of interest.

The scintillator stilbene, cut into 16 cuboids arranged in a $4 \times 4$ array, is used for particle detection. The scintillation light is detected with a SiPM array. The pixel size is $(6 \times 6)\,\mathrm{mm}^2$. The usage of stilbene allows to distinguish neutron- and gamma-induced signals in the detector. An Americium-Beryllium neutron source delivers fast neutrons of up to 11 MeV as well as gamma rays of 4.44 MeV for our measurements. Tomographic measurements of simple test objects were performed, combining the measured fast neutron and gamma attenuation.

Additionally, a Geant4 simulation was developed enabling to simulate various configurations for imaging with fast neutrons and gammas. It allows to simulate tomographies with the current detector, but also various configurations (e.g. detector pixel sizes, arrangements, etc) for tomography with a future, larger detector.

In this talk, setup and results of both the tomographic measurements and the Geant4 simulation will be presented.

# T 41: Trigger+DAQ 1

Time: Tuesday 16:00–18:00 Location: Geb. 30.23: 3/1

T 41.1 Tue 16:00 Geb. 30.23: 3/1

**Towards an Autonomous Trigger for the Detection of Air-Shower Radio Emission** — •Jelena Köhler[1], Lukas Gülzow[1], Tim Huege[1,4], Markus Roth[1], Olivier Martineau[2], Pablo Correa[2], Kumiko Kotera[3,4], and Marion Guelfand[2,3] — [1]Karlsruher Institut für Technologie, Institut für Astroteilchenphysik — [2]Laboratoire de physique nucléaire et des hautes énergies, Paris — [3]Institut d'Astrophysique de Paris — [4]Vrije Universiteit Brussel

Radio detection of air-showers has emerged as a powerful technique for high-energy cosmic ray measurements, leading to the development of a new generation of large-scale radio detectors. The Giant Radio Array for Neutrino Detection (GRAND) represents a significant advancement. It is planned as a vast array of wide-band radio antennas spanning an extensive area of 200 000 km$^2$.

To effectively detect air-shower events in such large-scale arrays, an efficient and autonomous trigger system is needed. This presentation introduces a novel multi-level radio trigger, which is crucial for large-scale experiments like GRAND. The first-level trigger identifies potential air-shower signals at the station level. However, the true innovation lies in the second-level trigger operating at the detector level. By evaluating the time-integrated power, it makes reliable event decisions based on the scientific knowledge of radio emissions.

** NUTRIG project, supported by the ANR-DFG Funding Programme (DFG Projektnummer 490843803)*

T 41.2 Tue 16:15 Geb. 30.23: 3/1

**Development of First Level Trigger Algorithm for Electron Identification in ATLAS** — •Julia Troppens, Maximilian Linkert, Dennis Layh, and Stefan Tapprogge — Institute for Physics, Johannes Gutenberg University, Mainz

As part of the High Luminosity LHC upgrade a new module for the first-level trigger of ATLAS aims to efficiently identify electrons in the very forward region (3.2<|eta|<4.9). These modules with powerful FPGAs shall make use of the full granularity of the calorimeters in this region. The studies performed are based on simulated proton-proton collisions. Firstly, different algorithms - including existing classical algorithms and new machine-learning based approaches - are optimized with respect to signal efficiency and background rejection. Subsequently, the implementation in firmware is investigated. In this contribution different algorithms are compared looking at the interplay of latency, resource usage, signal efficiency and background rejection.

T 41.3 Tue 16:30 Geb. 30.23: 3/1

**Trigger Algorithm for Electron Identification with Neural Networks and Realization in Firmware** — •Moritz Vogt, Dennis Layh, and Stefan Tapprogge — Institute for Physics, Mainz, Germany

As the LHC is upgraded to the High-Luminosity LHC, the instantaneous luminosity will increase significantly. To cope with the additional pile-up and the increase in the rate of background events, the triggering algorithms need to be improved. Following the High-Luminosity upgrade, the new forward Feature Extractor (fFEX) first level trigger module will have real-time access to ATLAS forward ($|\eta| > 2.5$) calorimeter information with full granularity. The accurate identification of electrons in this region should allow a refined measurement of the weak mixing angle using the forward-backward asymmetry of the Z-boson decay.

This contribution will focus on the identification of electrons using neural networks in simulated events of the detector response in the Liquid Argon Endcap Calorimeters of the ATLAS detector ($2.5 < |\eta| < 3.2$). Since the trigger module will be realized with Field Programmable Gate Arrays (FPGA), the optimization of neural networks for deployment in firmware on these components is of utmost importance. Achieving a balance between signal efficiency, background rejection, resource utilization, and latency is the ultimate goal. This talk will present the results of the studies and give an outlook on future extensions.

T 41.4 Tue 16:45 Geb. 30.23: 3/1

**Anomaly detection for the level 1 trigger system of the CMS experiment** — •Sven Bollweg, Gregor Kasieczka, Karim El Morabit, Susan Sefidrawan, and Artur Lobanov — Universität Hamburg, Hamburg, Deutschland

There exist strong hints for the existence of physics beyond the standard model (BSM). At the CMS experiment only events passing the first selection step, the level 1 (L1) trigger, are recorded and available for further analysis. Assuming that BSM events differ from standard model (SM) events, a trigger selection targeting BSM events could be based on the detection of differing, i.e. anomalous, properties instead of criteria predicted by specific BSM models.

This talk discusses a neural network based implementation of such an anomaly detection trigger. An autoencoder (AE) network is trained to reproduce typical collision events. It is found that the reconstruction quality of anomalous events, such as BSM events or rare SM events, is decreased. The reproduction quality can be used as a basis to identify anomalous events, which could be BSM events. The integration of the AE into the existing L1 hardware and avoidance of overlap with the existing triggers presents additional challenges.

T 41.5 Tue 17:00 Geb. 30.23: 3/1

**Convolutional Neural Networks on FPGAs for Processing of ATLAS Liquid Argon Calorimeter Signals** — Anne-Sophie Berthold, Anna Franke, Nick Fritzsche, Markus Helbig, Rainer Hentges, Arno Straessner, and •Johann Christoph Voigt — IKTP, TU Dresden

During the Phase-II upgrade of the ATLAS Liquid Argon Calorimeter, over 500 high-performance FPGAs will be installed to allow for the energy reconstruction of all 182468 detector cells at the LHC bunch crossing frequency of 40 MHz.

We trained 1-dimensional convolutional neural networks (CNNs) to improve the energy reconstruction under high-luminosity conditions with respect to the currently used Optimal Filter. In particular, the performance for overlapping pulses is demonstrated for 6 representative detector cells. The network architecture has been optimized with a hyperparameter search, where the network size is constrained to 100 parameters to be able to fit onto the FPGA.

The inference code of these networks has been implemented in VHDL targeting an Intel Agilex FPGA. This firmware can run at 480 MHz and applies 12-fold time-division multiplexing to reduce the resource requirements. This allows the design to process the readout of up to 384 detector cells per FPGA, while meeting the latency constraints of the ATLAS trigger. Quantization aware training using QKeras is used to adapt the CNNs to 18 bit fixed point numbers. To better evaluate the physics performance, the networks are being integrated into the ATLAS ATHENA detector simulation.

T 41.6 Tue 17:15 Geb. 30.23: 3/1

**Comparison of a Linearized Track Fitting Algorithm, Implemented on GPU and FPGA** — •Joachim Zinsser, Sebastian Dittmeier, and André Schoening — Physikalisches Institut, Heidelberg, Germany

For the Event Filter System of the ATLAS experiment at the High-Luminosity LHC, studies on accelerating the online track reconstruction for the Inner Tracker (ITk) are conducted, which possibly lead to a heterogeneous system using GPUs or FPGAs. This study focusses on the implementation of one block of a linearized track fitting pipeline that can be used for quick fake track rejection and track parameter estimation. This algorithm can be implemented in a highly parallel way and is, therefore, suited for hardware acceleration. The algorithm is implemented on a Intel Stratix 10 FPGA and a NVIDIA A6000 GPU are used. The physics performance of the two implementations, are compared to the results from the fast emulation as presented in the ATL-DAQ-PUB-2023-001 document, using the same data. Furthermore, the computing performance are compared with each other.

T 41.7 Tue 17:30 Geb. 30.23: 3/1

**FPGA-Based Implementation of Graph Neural Networks with FINN for particle track reconstruction in ATLAS** — •Philipp Hematty[1,2], Sebastian Dittmeier[1], Hendrik Borras[2], Andre Schöning[1], and Holger Fröning[2] — [1]Physikalisches Institut, Universität Heidelberg, Heidelberg, Germany — [2]Institut für Technische Informatik, Universität Heidelberg, Heidelberg, Germany

In particle physics, research increasingly focuses on specialized neural network architectures such as Graph Neural Networks (GNN). These models show promising potential to computationally surpass traditional algorithms used in the field, especially in classifying particle hits into track candidates. The GNN4ITK project proposes a pipeline architecture for ATLAS at the HL-LHC which uses GNNs for the identification of track candidates. Because of the relative novelty of GNNs in the field of machine learning, current implementations work primarily with general-purpose hardware, such as CPUs or GPUs. Field Programmable Gate Arrays (FPGAs), however, could potentially deliver large gains in performance and cost. Their innate flexibility allows for compression methods which could greatly improve the efficiency of such networks. Previously, the complexity of programming FPGAs acted prohibitively on the implementation of complex neural networks. The recent rise of frameworks built on top of high-level-synthesis tools, such as FINN, promise to mitigate this hurdle. FINN is part of a software suite that translates high-level neural network definitions into formats that can be used directly on FPGAs. In this work, we analyze the capabilities of this approach in the aforesaid context.

T 41.8 Tue 17:45 Geb. 30.23: 3/1

**Dilepton selections for the LHCb experiment Run 3 trigger** — Johannes Albrecht, •James Andrew Gooding, and Biljana Mitreska — TU Dortmund University, Dortmund, Germany

A central focus of the LHCb experiment is the measurement of $B$ meson decays with multiple leptons in the final state. Multi-lepton $B$ decays provide access to many tests of the Standard Model, e.g., tests of lepton-flavour universality. Measurements of such decays rely on high-quality lepton selection, particularly the selection of dilepton events, i.e., events containing a lepton pair, typically performed through cuts on kinematic and topological variables.

During the Run 3 data-taking period of the LHC, the LHCb experiment will process collisions at 30 MHz, employing a software-based trigger system to select only physics-relevant events in real time. Within this framework, an inclusive cut-based trigger has been developed to select dilepton events, complementing existing selection strategies. This contribution presents the status of the inclusive cut-based dilepton trigger, placing particular emphasis on trigger development and commissioning.

# T 42: Neutrino astronomy 2

Time: Tuesday 16:00–18:00 Location: Geb. 30.23: 6/1

T 42.1 Tue 16:00 Geb. 30.23: 6/1

**Dissecting and Improving the High-Energy Muon Neutrino Track Selection of the IceCube Neutrino Observatory** — •Johanna Hermannsgabner, Jakob Böttcher, Philipp Fürst, Erik Ganster, Michael Handt, Philipp Soldin, and Christopher Wiebusch for the IceCube-Collaboration — RWTH Aachen, Aachen, Germany

The IceCube Neutrino Observatory observes high-energy neutrinos from the atmosphere as well as from astrophysical sources. One important detection channel is up-going muon tracks from charged-current muon-neutrino interactions, called Northern Tracks. This channel includes a Boosted Decision Tree (BDT)-based selection to remove down-going atmospheric muons and other event signatures. By retraining the BDT with updated simulation data and improved input variables, we achieve an increased efficiency. In this talk, we introduce IceCube's Northern Tracks event selection, point out challenges, and present the most recent results.

T 42.2 Tue 16:15 Geb. 30.23: 6/1

**Binning Optimization of the Likelihood Analysis of Astrophysical Muon Neutrinos with IceCube using an Evolutionary Algorithm** — •Matthias Thiesmeyer, Jakob Böttcher, Shuyang Deng, Philipp Fürst, Erik Ganster, Sharif El Mentawi, and Christopher Wiebusch for the IceCube-Collaboration — III. Physikalisches Insitut b, RWTH Aachen University

One important detection channel for astrophysical neutrinos in the IceCube Neutrino Observatory is neutrino-induced muon tracks. The astrophysical flux parameters are estimated using a profile likelihood fit of the measured neutrino data. The binned 2D distribution of reconstructed zenith and energy is compared to the number of expected events from atmospheric and astrophysical neutrino fluxes. To maximize the sensitivity to the astrophysical neutrino flux properties, we optimize the choice of binning. First, we extend the simple Poissonian likelihood to an effective likelihood that includes the uncertainties of the bin predictions caused by limited Monte-Carlo statistics. Then, using the effective likelihood, we apply an evolutionary algorithm for binning optimization. Iteratively, the algorithm creates different candidate binnings, compares them, and selects the best performing binning to create new candidates from. This talk highlights the different properties of both likelihoods for binning optimization, describes the evolutionary algorithm, and discusses the result.

T 42.3 Tue 16:30 Geb. 30.23: 6/1

**Energy-dependent measurement of seasonal variations in the atmospheric muon neutrino spectrum** — •Karolin Hymon, Tim Ruhe, and Lucas Witthaus for the IceCube-Collaboration — Astroparticle Physics WG Rhode, TU Dortmund University, Germany

A large number of atmospheric neutrinos are detected in ground-based neutrino telescopes, such as the IceCube Neutrino Observatory. These neutrinos are generated in extensive air showers initiated by a cosmic rays interacting with air nuclei in the atmosphere. Conventional atmospheric neutrinos originate mostly from kaons and pions that decay into neutrinos. The production of atmospheric neutrinos varies seasonally due to temperature variations in the atmosphere during the year. As the temperature increases, the atmosphere expands and the atmospheric density decreases. The seasonal variation increases with energy, as parent particles interact at higher altitudes in the atmosphere and the interaction cross section increases with energy. Consequently, the probability of decay for the parent mesons increases, leading to a subsequent increase in the neutrino flux. This talk presents the measurement of seasonal variations in the muon neutrino energy spectrum between 125 GeV and 10 TeV. The determination of the neutrino energy presents an ill-conditioned inverse problem, requiring to infer the energy from measured detector quantities. This challenge is addressed by the Dortmund Spectrum Estimation Algorithm (DSEA+), which uses machine learning methods to unfold the neutrino energy using 11.5 years of IceCube data.

Supported by BMBF (ErUM) and DFG (SFB 1491)

T 42.4 Tue 16:45 Geb. 30.23: 6/1

**Prompt neutrino flux with atmospheric neutrinos in IceCube** — •Lars Bollmann, Mirco Hünnefeld, and Pascal Gutjahr for the IceCube-Collaboration — TU Dortmund University, AG Rhode, Dortmund, Germany

One of the main goals of the IceCube neutrino detector, located at the geographic South Pole, is the identification and characterization of the high-energy astrophysical neutrino flux. However, the majority of neutrinos detected by IceCube are atmospheric neutrinos from cosmic ray interactions in the atmosphere. The atmospheric neutrino flux consists of two components: conventional neutrinos from pion and kaon decays, and prompt neutrinos from the decay of charmed or heavier mesons. The precise shape of the prompt neutrino flux is not yet fully understood. A better understanding of this flux could improve measurements of astrophysical neutrinos, as prompt atmospheric neutrinos are their main background at high energies. By looking only for neutrino events with coinciding muons from the same air shower a purely atmospheric neutrino sample can be created. The removed astrophysical component allows for a better characterization of the prompt atmospheric neutrino flux. In this talk first steps toward a measurement of the prompt atmospheric neutrino flux using this approach will be presented.

T 42.5 Tue 17:00 Geb. 30.23: 6/1

**Detector Response Parametrization with Symbolic Regression for Next-Generation Neutrino Telescopes** — •Arsenije Arsenić and Christian Haack — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

Symbolic regression is a machine learning-based tool used to find mathematical expressions which describe a set of datapoints. It differs from normal regression methods in that it does not require a predefined form of the expression, but rather explores the space of various different mathematical expressions.

Neutrino telescopes are observatories for the detection of high-energy neutrinos. These telescopes are typically placed in cubic-kilometer-scale volumes of transparent material (such as ice or water) where sensors capture photons produced by neutrino interactions.

We aim to utilize symbolic regression for the geometry optimization of next-generation neutrino telescopes. As end-to-end Monte Carlo simulations are computationally expensive, symbolic regression offers an alternative by parameterizing the detector response as a function of detector layout. This helps with optimization of the detector configuration, enhances computational efficiency, and thus allows for rapid exploration of new designs.

T 42.6 Tue 17:15 Geb. 30.23: 6/1

**Studying neutrino emission from the galactic plane with PLEnuM** — •Anke Mosbrugger, Lisa Schumacher, and Christian Haack — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

Diffuse neutrino emission from the galactic plane has long been expected given the observed gamma ray flux. One of the recent successes of the IceCube Neutrino Observatory was the observation of high-energy neutrinos from the galactic plane. This observation will give us further insight into cosmic ray propagation and galactic sources. However, due to its location at the geographic South Pole, IceCube's effective area in the direction of the galactic center region is limited. This limitation can be overcome by combining data from multiple neutrino telescopes with different fields of view, thereby increasing the analysis sensitivity. This concept is implemented in the Planetary Neutrino Monitoring System (PLEnuM). The PLEnuM software uses parametrized instrument response functions to facilitate the combination of datasets from multiple detectors. In this talk I will present the implementation of a galactic plane analysis in PLEnuM and show first results from the application of this method to public IceCube data. This work will enable projections and combined analyses for existing and future experiments such as IceCube-Gen2, KM3NeT, and P-ONE.

T 42.7 Tue 17:30 Geb. 30.23: 6/1

**Enhancing neutrino detection efficiency with new triggers at the Pierre Auger Observatory** * — •Srijan Sehgal for the Pierre-Auger-Collaboration — Bergische Universität Wuppertal, Wuppertal, Germany

Besides detecting ultra-high-energy cosmic rays, the Pierre Auger Observatory with its large Surface Detector (SD) array offers a remarkable exposure to neutrinos above $10^{17}$eV. Two new SD triggers, Time-over-Threshold-deconvolved (ToTd) and Multiplicity-of-Positive Steps (MoPS), were implemented in 2014 to further increase the detection capability for low energy neutrino-induced air showers.

This contribution aims to present the impact of the new triggers in the context of neutrino search for the zenith angle range of $60^\circ < \theta < 75^\circ$. An optimised neutrino selection, which includes the MoPS and ToTd, is devised and evaluated on simulated neutrino showers. This selection is then further applied to the data sample, and the results are compared to previous neutrino searches performed at the Pierre Auger Observatory.

*Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)*

T 42.8 Tue 17:45 Geb. 30.23: 6/1

**Constraints on UHE fluxes of $\nu_\tau$, $\tau$, and $\tau$-like particles generated from BSM particles with the Pierre Auger Observatory** — •Baobiao Yue for the Pierre-Auger-Collaboration — Bergische Universität Wuppertal, Wuppertal, Germany

The Fluorescence Detector (FD) of the Pierre Auger Observatory offers a large exposure for Ultra-High Energy (UHE) Upward-Going Showers (UGS) like the ones reported by ANITA. Recently, strong limits on UGS were obtained using 14 years of FD data, which are in tension with the observations made by ANITA-I and III. Furthermore, ANITA-IV has reported new UGS candidates. Both of these observations motivate the exploration of Beyond Standard Model (BSM) scenarios.

In this work, we explore the parameter space to test three classes of BSM models. These unknown BSM particles can interact inside the Earth and produce $\nu_\tau$, $\tau$, and $\tau$-like particles, which can further interact or decay. Subsequently, some of the final products may escape the Earth and induce a UGS in the atmosphere. Due to the non-observation of the UGS by the FD, the upper flux limits of these UHE BSM particles are obtained as a function of their possible cross-sections with matter. In addition, stronger constraints are achieved by combining the Surface Detector and FD data of the Pierre Auger Observatory.

*Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)*

# T 43: Data, AI, Computing 3 (pointclouds & graphs)

Time: Tuesday 16:00–18:15 Location: Geb. 30.33: MTI

T 43.1 Tue 16:00 Geb. 30.33: MTI

**CaloClouds: Fast Geometry-Independent Highly-Granular Calorimeter Simulation** — Erik Buhmann[1], Sascha Diefenbacher[2], Engin Eren[3], Frank Gaede[3,4], Gregor Kasieczka[1,4], •Anatolii Korol[3], William Korcari[1], Katja Krüger[3], and Peter McKeown[3] — [1]Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Physics Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Rd, Berkeley, CA 94720, USA — [3]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany — [4]Center for Data and Computing in Natural Sciences CDCS, Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

Simulating showers of particles in highly granular detectors is a key frontier in applying machine learning to particle physics. Achieving high accuracy and speed with generative machine learning models would enable them to augment traditional simulations and alleviate a significant computing constraint. This contribution marks a significant breakthrough in this task by directly generating a point cloud of O(1000) space points with energy depositions in the detector in 3D-space. Importantly, it achieves this without relying on the structure of the detector layers. This capability enables the generation of showers with arbitrary incident particle positions and accommodates varying sensor shapes and layouts.

T 43.2 Tue 16:15 Geb. 30.33: MTI

**Flow Matching Beyond Kinematics: Generating Jets with Particle-ID and Trajectory Displacement Information** — •Joschka Birk[1], Erik Buhmann[1], Cedric Ewen[1], Gregor Kasieczka[1], and David Shih[2] — [1]Universität Hamburg — [2]Rutgers University

Generative machine learning models are extensively researched in HEP for applications like anomaly detection and fast detector simulation. So far, the development of methods for jet generation has mainly focused on the JetNet dataset. However, as the complexity of generative models trained on the JetNet dataset increased, the lack of statistics in this dataset started to become a bottleneck. We present the first generative model trained on the more complex JetClass dataset, which was originally introduced with the ParT jet tagging algorithm. The JetClass dataset is much larger and contains more jet types as well as additional features that are not included in the JetNet dataset, which opens up new possibilities for jet generation development. Our model generates jets at the constituent level and is a permutation-equivariant continuous normalizing flow (CNF) trained with the flow-matching technique. It is conditioned on the jet type so that a single model can be used to generate the ten different jet types of the JetClass. For the first time, we also introduce a generative model that goes beyond the kinematic features of the jet components by including features such as the particle ID and the track impact parameter. We show that our CNF can accurately model these additional features as well, extending the versatility of existing methods for jet generation.

T 43.3 Tue 16:30 Geb. 30.33: MTI

**Graph Neural Network based Hit Classification for Tracking at Belle II** — •Greta Heine, Torben Ferber, Lea Reuter, and Slavomira Stefkova — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Over the next few years, the Belle II Experiment will increase its instantaneous luminosity, which will also lead to a significant increase in the beam backgound, affecting the efficiency of both online and offline tracking algorithms. To overcome this challenge and to facilitate the identification of displaced vertices for the discovery of new physics phenomena, Belle II needs a more robust tracking algorithm on trigger level.

Graph Neural Networks (GNNs), with their ability to model complex relationships within detector hits, are well suited for tracking and are currently under investigation by Belle II, particularly in the context of object condensation for the Belle II Central Drift Chamber. Due to strict timing constraints, especially in the real-time application in the hardware trigger system, it becomes imperative to clean-up the detector hits from background noise. This talk presents first studies on hit clean-up in the context of anticipated high beam background conditions of the Belle II Experiment based on GNN edge classification using detector-level information.

T 43.4 Tue 16:45 Geb. 30.33: MTI

**Graph Neural Network based Tracking at Belle II** — •Lea Reuter, Giacomo De Pietro, Torben Ferber, and Slavomira Stefkova — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Displaced vertices are an important signature in Standard Model analyses involving $K_S$ and many searches for New Physics. However, the current Belle II tracking algorithm falls short when dealing with particles that decay after a large distance, resulting in a decrease in tracking efficiency with increasing displacement.

In this work, we show a novel track finding algorithm that combines the Object Condensation algorithm with Graph Neural Networks. This approach simultaneously identifies all tracks in an event and determines their respective parameters. Additionally, we integrated the new track finding algorithm into the Belle II analysis software framework, improving the resolution through additional track fitting.

Our results show significant improvements compared to the existing Belle II track finding algorithm for displaced tracks, while keeping a similar efficiency and fake rate for prompt tracks originating from the interaction point.

T 43.5 Tue 17:00 Geb. 30.33: MTI

**Search for fractionally charged particles with Graph Neural Networks** — •Alexander Sandrock and Timo Stürwald — Bergische Universität Wuppertal, Wuppertal, Deutschland

Fractionally charged particles are hypothetical particles with a charge smaller than the electron charge. These particles are predicted in various theories Beyond the Standard Model of particle physics, for instance in versions of supersymmetry. The IceCube neutrino observatory as a very large volume detector shielded by a kilometer-thick ice shield is ideally suited to search for signatures of rare particles such as fractionally charged particles.

Graph neural networks have been successfully applied in the last few years to the classification and reconstruction of events in the IceCube detector. This presentation discusses the application of graph neural networks to the discrimination between simulated fractionally charged particle events and standard model simulations.

T 43.6 Tue 17:15 Geb. 30.33: MTI

**Photon Reconstruction with Graph Neural Networks at Beamdump Experiments** — •Kylian Schmidt, Torben Ferber, Alexander Heidelbach, Jan Kieseler, and Markus Klute — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Axion-Like Particles (ALPs) are hypothetical weakly interacting light particles predicted by theories Beyond the Standard Model which could be mediators between a dark sector and the Standard Model. Some of these theories predict light ALPs which decay into two photons and could be detected at future beamdump experiments such as LUXE-NPOD and SHADOWS.

To investigate the properties of such ALPs, an accurate reconstruction of the decay vertex from the hits measured in the detector can aid the search significantly. For this purpose, the photon shower direction needs to be reconstructed precisely, combining techniques from shower and track reconstruction. This task is a prime candidate for modern methods of photon reconstruction based on Machine Learning such as Graph Neural Networks.

In this talk we present a new application of GravNet, which is able to reconstruct the decay vertex of ALPs from the sparse detector hits of the two photon showers.

T 43.7 Tue 17:30 Geb. 30.33: MTI

**Improvement of GNN energy regression for KM3Net/ORCA with weighted training samples** — •Bastian Setter for the ANTARES-KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

KM3NeT/ORCA is a water Cherenkov detector currently under construction in the Mediterranean Sea, near the coast of France. It specializes in the detection of atmospheric neutrinos in the GeV range. It will be used for many different types of analysis such as the determination of the neutrino mass ordering, constraining the elements of the PMNS matrix or Lorentz invariance violation. For each of these analyses a good resolution in energy regression is important. This talk will present the impact of so-called weighted data-sets in the training of Graph Neural Networks for an early stage of KM3NeT/ORCA with 6 detection units. In addition, it will discuss the increase in performance that could be achieved compared to training strategies without data-set optimisation and to traditional reconstructions using maximum-likelihood estimator techniques.

T 43.8 Tue 17:45 Geb. 30.33: MTI

**Enhancing Neutrino Event Classification in the IceCube Observatory Using a Neural-Network Approach** — •Philipp Soldin, Jakob Böttcher, Philipp Fürst, Erik Ganster, Michael Handt, Johanna Hermannsgabner, and Christopher Wiebusch — RWTH Aachen University

The IceCube Neutrino Observatory is a particle detector located at the geographic south pole. It is a cubic kilometer in size and detects neutrinos by measuring the Cherenkov light from their interaction products. One of the main challenges in IceCube is accurately classifying neutrino events based on these measured signals. Previous attempts achieved high accuracy but had to aggregate large amounts of data for processing. However, new deep learning techniques, such as transformer and graph-based architectures, allow for the use of more signal data without prior aggregation. This pure signal data enables the utilization of intricate signal details and improves the selection efficiency. The talk presents the latest advances in this approach and its results.

T 43.9 Tue 18:00 Geb. 30.33: MTI

**Position reconstruction of Ge-detector events with a deep neural network** — •Christoph Seibt for the LEGEND-Collaboration — Technische Universität Dresden

The LEGEND experiment, a ton-scale experiment focused on neutrinoless double beta decay using enriched Germanium-76, aims to explore half-lives exceeding $10^2$8 years. The complexity of experiment-generated data has led to a growing interest in machine learning analyses, which can provide deeper insights compared to classical methods.

This work presents a machine learning approach for the challenging task of reconstructing event positions within Ge-detectors using differences in detector pulse signals in the LEGEND experiment. Due to the absence of an analytical method for precise position reconstruction, we employ a Long Short-Term Memory (LSTM)-based neural network.

The model is trained and tested using simulated pulses closely resembling real experiment data. While real data analysis is a future prospect, this presentation provides an update on the ongoing progress in implementing an LSTM-based neural network for Ge-detector event position reconstruction. With a future application on real data in plan, the machine learning model may serve as an innovative tool for data analysis and data cleaning and brings machine learning more into the scope of experimental physics.

# T 44: Data, AI, Computing 4 (workflow)

Time: Tuesday 16:00–18:00 Location: Geb. 30.34: LTI

T 44.1 Tue 16:00 Geb. 30.34: LTI

**Testing ATLAS computing resources with HammerCloud** — •Alexander Mario Lory[1], Günter Duckeck[1], Benjamin Rottler[2], Michael Böhler[2], and Otmar Biebel[1] — [1]Ludwig-Maximilians-Universität, München — [2]Albert-Ludwigs-Universität, Freiburg

HammerCloud is a framework for testing and benchmarking distributed resources of the LHC experiments ATLAS and CMS. It is a key component for the operation of the ATLAS distributed computing system, as the test results are used to automatically include or exclude resources from the pool of resources available to users. In this presentation recent use cases and developments within HammerCloud ATLAS are highlighted, including a new feature – the automatic massive recovery mechanism, which efficiently recovers GRID resources on a large scale, addressing massive exclusions resulting from central issues.

T 44.2 Tue 16:15 Geb. 30.34: LTI

**Integration of the Goettingen HPC resources Emmy to the WLCG Tier-2 grid computing environment of GoeGrid and performance results of the ATLAS jobs** — •Saidev Polisetty, Arnulf Quadt, Daniel Schindler, and Sebastian Wozniewski — II. Physikalisches Institut, Georg-August-Universitaet Goettingen

For the upcoming Run 4 of the LHC, there is a necessity to increase the computing resources for simulation, reconstruction and analysis in terms of storage and computing power. In this context, the German community is preparing to integrate the National High Performance Computing (NHR) resources and make them usable within the WLCG under the FIDIUM project.

At Goettingen campus, there is both, a WLCG Tier-2 site (GoeGrid) and a large HPC EMMY cluster by NHR and the North German Supercomputing Alliance (HLRN). In this project, the integration is done by virtually extending the GoeGrid batch system with containers turning the HPC nodes into virtual nodes with own partitionable job scheduling to run the ATLAS jobs. Their performance is studied for quantitative analysis and optimisation of the environment running the jobs. Results and the performance is discussed in this talk.

T 44.3 Tue 16:30 Geb. 30.34: LTI

**The GPU driven journey towards more sustainable HEP computing** — Manuel Giffels, Matthias Schnepf, Günter Quast, and •Tim Voigtländer — Karlsruhe Institute of Technology, Karlsruhe, Germany

Energy efficient usage of our hardware resources has become a topic of ever-increasing importance. Both, high operational costs and environmental concerns are good reasons for us to optimize the way we use hardware. In comparison with CPUs, GPUs are a convenient alternative that has the possibility to achieve a significantly higher energy efficiency in many of the HEP relevant workflows, like simulation, reconstruction, or machine learning based end user analyses. This talk aims to shed some light on how efficient such applications run on different hardware, using the example of a number of GPU benchmarks that have been performed on the Karlsruhe Tier 3 cluster TOpAS.

T 44.4 Tue 16:45 Geb. 30.34: LTI

**Parallelization and benchmarking of a Jupyter based HEP data analysis with Dask** — •Karl Erik Bode, Michael Böhler, and Markus Schumacher — Institute of Physics, Albert-Ludwigs-University Freiburg, Freiburg, Germany

Using the combination of the scientific Python software stack, Jupyter notebooks, and Dask it is possible to scale an interactive HEP data analysis, both on local resources and on a computing cluster.

After vectorisation of the reference Higgs boson to di-photon decay analysis, the required compute time is decreased and it is even possible to analyze larger data sets.

With Dask, the vectorized algorithm can be scaled to utilize all CPU cores of the local machine and at the same time provides data structures to enable analysis of data sets larger than memory.

Only minor changes are required, to port this analysis setup from a laptop to a to a High Throughput Cluster (HTC) or to a High Performance Cluster (HPC).

This contribution introduces the used software stack, specific for scaling the algorithm from single threaded to a mult threaded analysis. Finally we discuss the performance improvement both on a typical laptop as well as on an HPC and HPC cluster.

T 44.5 Tue 17:00 Geb. 30.34: LTI

**Orchestrated columnar-based analysis with Columnflow** — •Mathis Frahm, Johannes Haller, Philip Keicher, Nathan Provoust, Marcel Rieger, Daniel Savoiu, Peter Schleper, Matthias Schröder, and Bogdan Wiederspan — Institut für Experimentalphysik, Universität Hamburg

The large datasets and increasing complexity of modern physics analysis in high energy collider physics pose a major challenge to the analysis workflows. Systems are required that can process large scales of data efficiently, while keeping the execution of the full analysis manageable. In this talk, we present Columnflow, a tool for columnar-based data analysis. Columnflow provides an orchestrated, yet flexible workflow that handles the bookkeeping of results and dependencies automatically. Typical analysis tasks such as propagating systematic uncertainties, machine-learning applications, and statistical inference are transparently included in the workflow. The implemented workflow allows the usage of distributed computing resources and is fully configurable but at the same time accessible to newcomers.

T 44.6 Tue 17:15 Geb. 30.34: LTI

**Workflow Management with Snakemake: A Case Study in Tau Physics at the ATLAS Detector** — •Luka Vomberg[1], Christian Grefe[2], Philip Bechtle[1], and Klaus Desch[1] — [1]Physikalisches Institut, 53115 Bonn — [2]CERN

Data analyses in particle physics often rely on complex software workflows. Reproducing and reusing such analyses is frequently challenging, as it is difficult to keep track of the many interdependent individual steps. This presentation illustrates, through a case study, how the workflow management tool Snakemake contributes to declaratively uniting all necessary steps into a comprehensive package.

The case study focuses on an analysis measuring the TauID efficiencies in Run 3 of the LHC at the ATLAS detector, which uses the ABCD method to estimate the contribution from misidentified tau-leptons. Various ATLAS software packages are integrated into the overall workflow, initially structured to fully reproduce the results of the equivalent Run 2 analysis and then adapted to the requirements of Run 3.

T 44.7 Tue 17:30 Geb. 30.34: LTI

**User-oriented sustainable operation of the VISPA Cloud Services** — Niclas Eich, Johannes Erdmann, Martin Erdmann, Benjamin Fischer, Paul Gilles, •Tim Hauptreif, and Jan Kelleter — RWTH Aachen University

As the effects of climate change become more imminent, scientists from all disciplines are striving to make their research more sustainable. As computing clusters are an essential part of modern research, they need to be improved in terms of sustainability. Various measures to reduce the carbon footprint of our computing centres include monitoring power consumption, increasing the efficiency of hardware and software, and influencing user behaviour.

We present our efforts to increase the sustainability of the VISPA computing cluster (https://vispa.physik.rwth-aachen.de) by introducing resource-aware scheduling and leveraging user interaction. Maintaining the relatively small VISPA cluster puts us in a unique position where we can freely test different energy saving schedules and get direct feedback from academic researchers and students alike. While scheduling is an ongoing research topic for many, especially large computing clusters, few can adapt directly to user feedback. We are sharing our experience in providing more sustainable computing resources with minimal disruption to our users' research progress.

T 44.8 Tue 17:45 Geb. 30.34: LTI

**Search for Hidden Job Failure Risk Factors in ATLAS Job Meta Data** — Arnulf Quadt[1], Sebastian Wozniewski[2], and •Kia-Jüng Yang[3] — [1]II. Physikalisches Institut, Georg-August-Universität Göttingen — [2]II. Physikalisches Institut, Georg-August-Universität Göttingen — [3]II. Physikalisches Institut, Georg-August-Universität Göttingen

The ATLAS Detector records over 10, 000 TB of data per year and it increases even further with the upcoming upgrades. The Worldwide LHC Computing Grid (WLCG) provides a distributed computing infrastructure to store and process these data. It is crucial, that the WLCG is also reliable, meaning that the failure rate of submitted jobs by the users is low. While some job failures can be clearly traced back to known temporary issues, others seem to happen more randomly due to various more hidden reasons. An investigation of the job failure rates depending on the job attributes may reveal correlations, which might allow for mitigating actions in order to further reduce the number of job failures. This task is supported by the training of a neural network, which helps to identify and investigate correlations in the multi-dimensional space of job attributes.

# T 45: Search for Dark Matter 2

Time: Tuesday 16:00–18:00 Location: Geb. 30.35: HSI

T 45.1 Tue 16:00 Geb. 30.35: HSI

**Crystal-based Detectors for Dark Matter & Neutrinos** — •Alexey Elykov — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

With dark matter (DM) still eluding detection by large-scale experiments, and in light of the technical difficulties and expenses that are associated with constructing such detectors, a window has opened for new and daring ideas in the field. One such idea is to utilize the advent of modern microscopy and computational techniques to read out and reconstruct nanometer and micrometer-sized damage tracks produced by interactions of DM and neutrinos with nuclei of ancient natural crystals. Residing in the depths of the Earth for millions of years, certain minerals should have accumulated these minute tracks, allowing us to use such minerals as "paleo-detectors". Despite their small size the Myr-scale lifetime of paleo-detectors provides them with enormous exposure. Uniquely, if realized, such detectors can also probe the distribution of DM in our Galaxy and the evolution of neutrino fluxes over our Galaxy's lifetime. In this talk, I will report on the latest research and developments towards the realization of mineral-based paleo-detectors.

This work is supported in part through the Helmholtz Initiative and Networking Fund (grant agreement no. W2/W3-118). We also gratefully acknowledge the support by the KIT Center Elementary Particle and Astroparticle Physics (KCETA) for this project.

T 45.2 Tue 16:15 Geb. 30.35: HSI

**Current Status of the Direct Search Experiment for Light Dark Matter (DELight)** — •Eleanor Fascione for the DELight-Collaboration — Heidelberg University

Despite the lack of discovery of one of the favoured dark matter candidates, the Weakly Interacting Massive Particle, there is vast parameter space to explore for dark matter masses below a few GeV, and the field of direct dark matter detection is constantly expanding to new frontiers. In particular, low mass dark matter candidates necessitate novel detector designs with lower thresholds and alternative target materials compared to e.g. the xenon-based experiments currently providing the strongest overall constraints on many dark matter models.

The Direct search Experiment for Light dark matter (DELight) will deploy a target of superfluid $^4$He instrumented with magnetic microcalorimeter (MMC) based wafer calorimeters in a setup optimized for low mass dark matter searches. In this talk the motivation, setup, and current status of this novel upcoming experiment will be presented.

T 45.3 Tue 16:30 Geb. 30.35: HSI

**Search for Dark Matter with the Relic Axion Dark-Matter Exploratory Setup (RADES)** — Saiyd Ahyoune[1], Alejandro Álvarez Melcón[2], Sergio Arguedas Cuendis[1], Sergio Calatroni[3], Cristian Cogollos[4], Alejandro Díaz-Morcillo[2], Babette Döbrich[4], Juan Daniel Gallego[5], José María García-Barceló[4], Benito Gimeno[6], Jessica Golm[3,7], Xavier Granados[8], Joffre Gutierrez[8], •Louis Herwig[4,9], Igor García Irastorza[10], Neil Lamas[8], Antonio Lozano-Guerrero[2], William L. Millar[3], Chloé Malbrunot[11], Jordi Miralda-Escudé[1,12], Pablo Navarro[2], Jose R. Navarro-Madrid[2], Teresa Puig[8], Marc Siodlaczek[13], Guilherme Telles[8], and Walter Wuensch[3] — [1]Institut de Ciències del Cosmos, Universitat de Barcelona — [2]Department of Information and Communications Technologies, Technical University of Cartagena — [3]CERN - European Organization for Nuclear Research — [4]Max-Planck-Institut für Physik — [5]Yebes Observatory (IGN) — [6]Instituto de Física Corpuscular (IFIC), CSIC-University of Valencia — [7]Institute for Optics and Quantum Electronics, Friedrich Schiller University Jena — [8]Institut de Ciència de Materials de Barcelona, CSIC — [9]Technical University of Munich — [10]Center for Astroparticles and High Energy Physics (CAPA), Universidad de Zaragoza — [11]TRIUMF — [12]Institució Catalana de Recerca i Estudis Avançats — [13]Technical University of Darmstadt, Institute for Energy Systems and Technology

The axion is a pseudoscalar particle, proposed as an extension to the Standard Model of particle physics, that is theorized to solve the strong CP problem in quantum chromodynamics by introducing a new symmetry that prevents CP violations in strong interactions. Additionally, it is considered a potential candidate for dark matter, offering a solution beyond the existing framework of the Standard Model. The RADES haloscope targets cosmic axions originating from the dark matter halo that surrounds our galaxy like a sphere. In the following, we describe the result of a haloscope axion search performed with an 11.7 T dipole magnet at CERN. We also reinterpreted our findings for dark photon limits, noting that the dark photon, a vector particle, is distinct due to its polarization. The search used a custom-made radio-frequency cavity coated with high-temperature superconducting tape. A set of several hours of data at a resonant frequency of around 8.84 GHz was analysed. In the currently unexplored axion mass range of around 36 $\mu$eV, we present the results of our search. Correspondingly, in this mass range, we also set a limit on the axion to photon coupling strength.

T 45.4 Tue 16:45 Geb. 30.35: HSI

**snax: supernova analysis in xenon** — •Melih Kara — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

During the demise of a massive star, 99% of its energy is emitted as neutrinos, preceding any optical signals. Detection of these neutrinos offers crucial insights into the core collapse and associated mechanisms.

Unlike typical neutrino detectors focusing on single flavors, large dark matter detectors such as XENONnT, LZ, and future models like DARWIN utilize coherent elastic neutrino-nucleus scattering (CE$\nu$NS) in the low-energy range to detect interactions from neutrinos of all flavors.

This presentation outlines how XENONnT and similar dark matter detectors can establish a robust analysis framework for the prompt identification and analysis of galactic supernovae through the CE$\nu$NS channel. Specifically, we look into signal simulation, identification in the data stream, and the implementation of an active software trigger for seamless communication with the Supernova Early Warning System (SNEWS). Probing inverse beta decay from the same flux using the water shield that is usually employed as an ancillary veto system could also enhance the detection significance. We conclude that dark matter detectors can play an important role in the analysis of the next galactic supernova.

This work is supported in part through the Helmholtz Initiative and Networking Fund (grant no. W2/W3-118). Support by the graduate school KSETA at KIT is gratefully acknowledged.

T 45.5 Tue 17:00 Geb. 30.35: HSI

**Direct search for modulated Dark Matter signals with XENON1T** — •Lutz Althueser for the XENON-Collaboration — Institute for Nuclear Physics, University of Münster, Germany

The XENON Dark Matter Project uses a dual-phase xenon time projection chamber (TPC) to directly search for Dark Matter (DM), such as weakly interacting massive particles (WIMPs). DM particles are expected to scatter off xenon nuclei in the active detector region, leading to nuclear and electronic recoils. The measured DM count rate is expected to modulate with a certain amplitude and phase.

The concept of annual modulation assumes that DM exists as a spherical and non-rotating halo in which the Earth and Sun are contained. Given the relative movement of the Sun, Earth and galactic center, one would expect a time-dependent DM interaction rate. Using this time dependent signature of the count rate provides an additional handle for the background discrimination, one of the biggest challenges of any direct detection DM experiment.

The talk will give an introduction to the characteristics of the event rate modulation under the Standard Halo Model and dives into the search for modulations over the runtime of the XENON1T experiment.

The work of the author is supported by Deutsche Forschungsgemeinschaft (DFG) through the Research Training Group "GRK 2149: Strong and Weak Interactions - from Hadrons to Dark Matter".

T 45.6 Tue 17:15 Geb. 30.35: HSI

**A first dark photon search with an open dielectric haloscope** — •Jacob Egge for the MADMAX-Collaboration — Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee149, 22761 Hamburg

The **MA**gnetized **D**isk and **M**irror **A**xion e**X**periment aims to detect axions or dark photons in the mass range of 40-400 $\mu$eV that remains inaccessible to the traditional cavity approach. The key component of MADMAX is the booster: a stack of dielectric disks that forms an open resonator whose volume can scale independently of the resonance frequency. To demonstrate the feasibility of this concept, the MADMAX prototype is currently under construction. Even before operation at cryogenic temperatures and magnetic field, a simple receiver chain and small booster is capable of exploring new dark photon parameter space.

In this talk I will present the results of a first dark photon search with the MADMAX prototype including the characterization and calibration of the receiver system and booster. Using a novel approach, the sensitivity to dark photons is obtained in a model-independent way and cross-checked against simulations.

T 45.7 Tue 17:30 Geb. 30.35: HSI

**Extending light dark matter searches to the neutrino floor with spherical proportional counters** — •Ioannis Manthos — University of Hamburg, Hamburg, Germany

The NEWS-G collaboration is searching for light dark matter candidates using spherical proportional counters (SPC). Access to the mass range from 0.05 to 10 GeV is enabled with the combination of low energy threshold, light gaseous targets (H, Ne, C), and highly radio-pure detector construction. To-date NEWS-G has placed world-leading constraints in both spin-independent and spin-dependent DM-nucleon cross sections. The current status of the experiment will be presented, along with the latest advances in spherical proportional counter instrumentation. The conceptual design and physics potential of DarkSPHERE, a 3m in diameter SPC fully electroformed underground in Boulby Underground Laboratory (UK), will be also presented.

T 45.8 Tue 17:45 Geb. 30.35: HSI

**Illuminating the Invisible: Deep underground dark matter search with COSINUS** — •Mukund Raghunath Bharadwaj for the COSINUS-Collaboration — Max Planck Institute for Physics

The COSINUS experiment (Cryogenic Observatory for SIgnatures seen in Next generation Underground Searches) is a cryogenic, low-background experiment being set up at Laboratori Nazionali del Gran Sasso, Italy. It aims to provide a model independent cross-check of the DAMA/LIBRA findings of a potential dark matter-like modulation signal. COSINUS utilizes a two-channel readout system based on transition edge sensors (TESs) that allows for particle discrimination. It consists of ultrapure scintillating sodium iodide (NaI) crystals read out using a novel remoTES scheme to measure the phonon signal of a particle interaction. A silicon beaker surrounding the crystal is used to measure the light signal from the same particle interaction. Results from the latest prototypes and updates on the setup will be presented in this contribution.

# T 46: Di-Higgs 1 (bb$\tau\tau$)

Time: Tuesday 16:00–18:00 Location: Geb. 30.41: HS 1

T 46.1 Tue 16:00 Geb. 30.41: HS 1

**Application of Deep Sets Neural Networks for the $b\bar{b}\tau^-\tau^+$ Di-Higgs Analysis with the CMS Experiment** — •Stella Felice Schaefer, Peter Schleper, Philip Daniel Keicher, and Bogdan Wiederspan — University of Hamburg, Hamburg, Germany

Machine Learning has found a wide range of applications in particle physics. In the context of the CMS $b\bar{b}\tau^-\tau^+$ Di-Higgs Analysis neural networks are tasked with the classification of signal and background processes in order to measure the Di-Higgs coupling constant $\kappa_\lambda$ as well as the coupling of two Higgs bosons to two vector bosons $\kappa_{2V}$.

Common problems for the proper application of neural networks are the variable number of jets per event, requiring padding of empty jets for a fixed number of input features, as well as the input order of jets passed to the network. Deep Sets neural networks provide a solution to both aforementioned problems, as these networks don't require fixed input shapes and act permutation invariant on the input.

This study aims to thoroughly test Deep Sets neural networks in the context of the CMS $b\bar{b}\tau^-\tau^+$ Di-Higgs Analysis for the application of signal process classification as well as signal vs. background classification and compares the performance to standard feed-forward architectures.

T 46.2 Tue 16:15 Geb. 30.41: HS 1

**Signal-Background Discrimination Using Machine-Learning for the Resonant HH $\rightarrow$ $b\bar{b}\tau^-\tau^+$ Analysis of CMS.** — •Johan Wulff[1,2] and Michele Gallinaro[1,2] — [1]LIP - Laboratory for Instrumentation and Experimental Particle Physics, Lisbon, Portugal — [2]Instituto Superior Técnico, Lisbon, Portugal

After the discovery of the Higgs boson by the CMS and ATLAS collaborations in 2012, various couplings to other particles of the Standard Model were successfully measured. The concrete shape of the Higgs potential, however still remains to be experimentally probed. The search for Higgs boson pair production plays a key role in uncovering the shape of the potential, as it can be expressed in terms of the self-coupling parameter, which in turn can be constrained through measuring the pair production rate. At the LHC, this process can either arise through gluon gluon fusion (ggF) or vector boson fusion (VBF). For both scenarios, the overall production cross section is small whilst dominating backgrounds render the search notoriously challenging.

For this reason, it is essential to discriminate signal from background events in an optimal manner. The use of advanced machine learning algorithms is imperative in tackling this classification problem. This contribution presents the development of such an algorithm aimed at separating signal and background for the search for Higgs boson pair production in the $b\bar{b}\tau^-\tau^+$ final state with the CMS detector.

T 46.3 Tue 16:30 Geb. 30.41: HS 1

**A neural network based regression of the neutrinos in H$\rightarrow$ $\tau\tau$ decays in the context of the CMS resonant HH$\rightarrow$bb$\tau\tau$ analysis** — Philip Keicher, •Tobias Kramer, Marcel Rieger, and Peter Schleper — Universität Hamburg

The CMS resonant HH$\rightarrow$bb$\tau\tau$ analysis searches for the decays of heavy spin 0/2 resonances to a pair of Higgs bosons in the bb$\tau\tau$ final state. It uses the data collected from 2016-2018 (Run 2) at $\sqrt{s}$ = 13 TeV corresponding to an integrated luminosity of 138 fb$^{-1}$. One important challenge is to reconstruct the kinematics of the two Higgs bosons. Especially in the H$\rightarrow$ $\tau\tau$ decay a large fraction of the energy is lost, because the neutrinos resulting from the $\tau$ decays are not detected. This talk presents studies on how to regress the full HH system using deep neural networks and the effects of including an additional classification part as well as parameterized (in mass and spin of the resonance) approaches.

T 46.4 Tue 16:45 Geb. 30.41: HS 1

**Streamlined optimization studies in the search for di-Higgs boson production** — •Steffen Ludwig, Karsten Köneke, Christian Weiser, and Karl Jakobs — University of Freiburg, Institute of Physics, Freiburg im Breisgau, Germany

The Higgs boson has been studied at the Large Hadron Collider at CERN over the last decade with ever-increasing precision. However, one key quantity, the strength of the trilinear Higgs boson coupling, has still eluded direct precision measurements. A measurement of its coupling strength modifier $\kappa_\lambda$, defined as the ratio of the observed value by its Standard Model prediction, that differs from unity would be a sign of new physics.

I will discuss the prospects of the search for the non-resonant production of Higgs boson pairs in the HH $\rightarrow$ bb$\tau^+\tau^-$ channel using 140 fb$^{-1}$ of proton-proton collisions at a centre-of-mass energy of 13 TeV recorded by the ATLAS detector at CERN.

To study the impact of Graph Neural Networks on the analysis, I developed an automatization tool called grid-pipeline to conduct and orchestrate the original analysis pipeline and its derivatives. Due to its versatility, it enables the elementarization of complex computing workflows, even in mixed computing site scenarios. This allows for a highly improved analysis optimization workflow and minimized turn-around time.

T 46.5 Tue 17:00 Geb. 30.41: HS 1

**Improving the sensitivity to the Higgs boson self-coupling in the $HH \rightarrow bb\tau\tau$ channel with the ATLAS experiment** — •Katharina Häussler, Christian Weiser, Karsten Köneke, and Karl Jakobs — University of Freiburg, Germany

The Standard Model (SM) predicts interactions involving multiple Higgs bosons, which have yet to be observed experimentally. Higgs boson pair production provides the most sensitive test of such triple Higgs boson self-interactions and the $bb\tau\tau$ final state presents a good compromise between expected signal yield and background contamination, making it one of the three golden channels to explore this phenomenon.

This talk focuses on improvements that can be made in future analyses to increase the sensitivity to anomalous values of the Higgs boson self-coupling modifier $\kappa_\lambda$. Significant deviations from the SM prediction would provide a strong indication of physics beyond the Standard Model.

T 46.6 Tue 17:15 Geb. 30.41: HS 1

**High Level Trigger Optimization Studies in the Atlas search for Higgs Boson Pair Production in the HH $\rightarrow$ $b\bar{b}\tau^+_{\mathrm{had}}\tau^-_{\mathrm{had}}$ channel** — •Athul Dev Sudhakar Ponnu, Stan Lai, and Andrés Melo — II. Physikalisches Institut, Georg-August-Universität Göttingen.

The Standard Model of particle physics predicts the existence of the trilinear Higgs self coupling vertex. This can be studied through the Higgs boson pair production process, which is yet to be observed. To increase the probability of observing this process, studies for the optimisation of the High Level Triggers for the search of the HH $\rightarrow$ $b\bar{b}\tau^+_{\mathrm{had}}\tau^-_{\mathrm{had}}$ final states have been performed.

The specific goal is to improve signal acceptance and background rejection of the trigger chains relevant for the study of the HH$\rightarrow$ $b\bar{b}\tau^+_{had}\tau^-_{had}$ channel using a trigger emulation framework developed for this purpose. The trigger selection criteria for two different di-$\tau$ trigger and the $b + \tau$ trigger have been fine-tuned to increase signal selection efficiency while maintaining or, in some cases, decreasing background rates.

T 46.7 Tue 17:30 Geb. 30.41: HS 1

**Separation of HH and HZ final states Using Spin Correlations** — •Celine Stauch, Christoph Ames, Otmar Biebel, Youn Jun Cho, Stefanie Götz, Edis Hrustanbegovic, Lars Linden, and Lukas von Stumpfeldt — LMU Munich

At the LHC a prominent background process to the HH production is the production of a H and Z boson. The HH and HZ processes are kinematically very similar since both processes have similar cross sections and the H and Z boson are close in mass. However, the H boson is a scalar particle while the Z boson has a spin of 1. The spin of the Z boson transfers to the final state particles and ultimately impacts their direction.

To investigate the impact of the particle spin on the final states, two approaches based on the Ellis-Karliner angle are applied. Further, methods to improve the selection of the final state jets are investigated. The results of this analysis suggest that a modified Ellis-Karliner angle provides an observable which is usable to distinguish between HH and HZ final states.

T 46.8 Tue 17:45 Geb. 30.41: HS 1

**Methods for the simulation of the Z+jets process at CMS** — Alena Dodonova, Ming-Yan Lee, •Andrey Pozdnyakov, Uttiya Sarkar, Alexander Schmidt, and Valentyn Vaulin — III. Physikalisches Institut A, RWTH Aachen University

The Z+jets process is a major background for searches for the Higgs boson decay to charm or bottom quarks, in associated production with a Z boson (ZH). Its modeling and sufficient statistics of the simulated sample are important factors for a competitive physics analysis. Two methods of the event generation which allow to enhance the statistical power of the samples in a given phases space (called phase space biasing) are discussed in this presentation. The first method is to produce samples binned in a relevant variable at Matrix Element (ME). The other one is to bias the sample at high transverse momentum at ME level, effectively generating more events at higher momenta.

A comparison of the simulated samples produced with Madgraph (LO), amc@NLO and Powheg MiNNLO generators in the phase space relevant for the ZH analysis is also shown.

# T 47: Higgs 2 (ttH & tH production)

Time: Tuesday 16:00–18:00 Location: Geb. 30.41: HS 2

T 47.1 Tue 16:00 Geb. 30.41: HS 2

**$t\bar{t}H$ Multi-Lepton Analysis Results** — •Stephen Eggebrecht, Steffen Korn, Arnulf Quadt, Baptiste Ravina, and Elizaveta Shabalina — II Physikalisches Institut, Georg August Universität Göttingen

The Higgs boson production in association with a top quark pair ($t\bar{t}H$) plays a key role for studying the Yukawa coupling between the Higgs boson and the top quark. The coupling can be determined by measuring the cross-section of the $t\bar{t}H$ production process in various final states using the 140 fb$^{-1}$ Atlas dataset at $\sqrt{s}$ = 13 TeV. Multi-lepton final states are rare but pure since most backgrounds are significantly suppressed. An overview of $t\bar{t}H$ the multi-lepton analysis with a focus on the non-resonant $t\bar{t}H \rightarrow 4\ell$ process is presented.

It is the multi-lepton final state with the lowest production rate and has contributions from Higgs decay modes like $H \rightarrow WW^*$, $H \rightarrow \tau\tau$, and $H \rightarrow Z^*Z^*$. The dominant background arises from $t\bar{t}Z$, $ZZ$, and misidentified leptons from $t\bar{t}$ production. A multiclass dense neural network (DNN) is trained to separate signal events from these backgrounds and to define analysis regions. Additional fake lepton regions are defined to estimate the normalisation of the most important fake contributions. Preliminary fit results for the signal strength are presented for the $4\ell$ channel. Furthermore, the combined performance of other multi-lepton final states is presented and discussed.

T 47.2 Tue 16:15 Geb. 30.41: HS 2

**Reconstruction of the semi-leptonic $t\bar{t}(H \rightarrow WW^*)$ final state** — •Arnulf Quadt, Ireas Tom Raschke, Baptiste Ravina, and Chris Scheulen — Georg-August-Universität, II. Physikalisches Institut, Göttingen, Germany

This talk will cover the analysis of $t\bar{t}(H \rightarrow WW^*)$ events in which the top quark pair decays fully hadronically and the $W$ bosons decay semi-leptonically. The analysis uses the full ATLAS Run 2 dataset. The $t\bar{t}H$ process allows to probe the Yukawa coupling of the top quark directly, and has previously been studied in multi-lepton final states and in the boosted $t\bar{t}(H \rightarrow b\bar{b})$ channel. The semi-leptonic $H \rightarrow WW^*$ channel has not yet been explored.

The reason for this is the difficulty to reconstruct the event from the many jets in the final state. Classical algorithms that use jet kinematics are not suited for this channel. Hence, a modern neural network approach (SPANet) is implemented. It is expected to increase the background suppression. The leptonic $W$ boson is then reconstructed from the single lepton in the event and the missing transverse energy using neutrino weighting.

T 47.3 Tue 16:30 Geb. 30.41: HS 2

**ttH analysis with two light leptons and one hadronically decaying tau lepton with Run-2 ATLAS data** — •Vladyslav Yazykov and Andre Sopczak — Czech Technical University in Prague

The latest results on the analysis with Run-2 ATLAS data are reported on the ttH 2lSS1tau channel.

T 47.4 Tue 16:45 Geb. 30.41: HS 2

**Development of ATLAS Run-3 $t\bar{t}W$ samples** — •Matthias Drescher, Arnulf Quadt, and Baptiste Ravina — II. Physikalisches Institut, Georg-August-Universität Göttingen, Germany

The top-quark pair production in association with a W boson ($t\bar{t}W$) can be used to understand quark-induced $t\bar{t}$ production, since $t\bar{t}W$ does not allow gluons in the initial state at leading order. Furthermore, the $t\bar{t}W$ process is a major background to other important processes such as $t\bar{t}H$ and $4t$ production. To provide the theoretical predictions used to design the analyses of these processes, a set of event data is generated by Monte Carlo event generators.

To be able to analyse the LHC Run 3 data at $\sqrt{s}$ = 13.6 TeV, the existing $t\bar{t}W$ samples used in the ATLAS collaboration need to be updated. This is done separately for the two existing samples generated with the Sherpa and MadGraph5_aMC@NLO + Pythia 8 generators. In order to better assess the modelling uncertainty in future analyses, auxiliary samples containing variations of the generator parameters are derived from the two nominal configurations as systematic variations. Using the Rivet analysis framework, comparisons are made between different generator versions and between the nominal and systematic samples.

T 47.5 Tue 17:00 Geb. 30.41: HS 2

**Progress towards the NNLO amplitude for ttH production** — •Anton Olsson[1], Gudrun Heinrich[1], Jannis Lang[1], Bakul Agarwal[1], Vitaly Magerya[1], Yannick Klein[2], Stephen Jones[3], and Matthias Kerner[4] — [1]Institute for Theoretical Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]Institute for Theoretical Particle Physics and Cosmology, RWTH Aachen University, 52056 Aachen, Germany — [3]Institute for Particle Physics Phenomenology, Durham University, Durham DH1 3LE, UK — [4]Institute for Astroparticle Physics, Karlsruhe Institute of Technology, 76344, Eggenstein-Leopoldshafen, Germany

We present numerical results for the two-loop virtual amplitude entering the NNLO corrections to Higgs boson production in association with a top quark pair at the LHC. We focus on the quark initiated channel and the colour factors containing closed quark loops, as a proof of concept to describe our method. Results for the finite part of the two-loop amplitude are visualized as functions of phase space variables.

T 47.6 Tue 17:15 Geb. 30.41: HS 2

**Associated production of a Higgs boson and a single top quark from t-channel production (tHq) in channels with hadronically decaying tau leptons at ATLAS** — •Florian Kirfel, Ian C. Brock, Oleh Kivernyk, and Christian Kirfel — Physikalisches Institut der Universtiät Bonn, Deutschland

A measurement of single top-quark production in association with a Higgs boson and a spectator light-quark (tHq) gives insight into the properties of not only the top quark but also the Higgs boson. The associated production is uniquely sensitive to the relative sign of the top quark-Higgs boson Yukawa coupling.

The decay of the Higgs boson into two tau leptons is covered by the presented analysis. Both cases in which one or two taus decay hadronically are considered and analysed based on the Run 2 LHC dataset from ATLAS.

The complete analysis workflow is covered, ranging from the treatment of tau lepton misidentification, over the application of a categorical neural network for signal isolation to a binned maximum likelihood estimation for the purpose of cross section estimation.

T 47.7 Tue 17:30 Geb. 30.41: HS 2

**Analysis of tH(bb) production with ATLAS Run-2 data** — •Martin Vatrt and Andre Sopczak — Czech Technical University in Prague

The latest results on the analysis tH(bb) are presented with focus on machine learning optimization using ATLAS Run-2 data.

T 47.8 Tue 17:45 Geb. 30.41: HS 2

**Investigation of the ttH(bb) Reconstruction in Events with High Higgs Boson Momentum at the ATLAS Experiment** — •Doga Elitez, Lucia Masetti, Jessica Höfner, Frederic Fischer, and Eftychia Tzovara — Johannes-Gutenberg Universität Mainz, Mainz, Germany

The coupling of the Higgs boson to the top quark is very sensitive to effects of the physics beyond the Standard Model (BSM) and the most favorable production mode for direct measurement of the top Yukawa coupling is the Higgs production in association with a pair of top quarks, ttH. The decay to two bottom quarks (H to bb) has the largest branching fraction of about 58%. This analysis aims at events in which one of the top quarks decays semi-leptonically and produces an electron or a muon. The so-called boosted topology targets events containing a Higgs boson produced at high transverse momentum, whose decay products are contained in a large radius jet. In this analysis, two methods to identify and reconstruct the Higgs boson decay collimated in a single large-radius jet are compared. Additionally, methods to improve background rejection and event reconstruction are presented.

# T 48: BSM Higgs 2 (extended Higgs sectors)

Time: Tuesday 16:00–17:45 Location: Geb. 30.41: HS 3

T 48.1 Tue 16:00 Geb. 30.41: HS 3

**Revisiting the Yukawa Type I for N2HDM and 2HDMS with a 95 GeV Higgs boson including the recent ATLAS results** — •Dominik Heintz[1], Sven Heinemeyer[3], Gudrid Moortgat-Pick[1,2], and Cheng Li[4] — [1]II. Institut für Theoretische Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]DESY, Notkestraße 85, 22607 Hamburg, Germany — [3]Instituto de Física Teórica UAM-CSIC, Cantoblanco, 28049, Madrid, Spain — [4]School of Science, Sun Yat-Sen University, Gongchang Road 66, 518107 Shenzhen, China

The **2HDM** (Two-Higgs-Doublet Model) can be extended by a real singlet, **N2HDM**, or a complex singlet, **2HDMS**. Both models are promising candidates to describe the excess at ∼ 95 GeV observed both at **CMS** and at **ATLAS** in the $\gamma\gamma$ channel with $\sim 2.9\sigma$ and $\sim 1.7\sigma$, respectively, as well as in the $b\bar{b}$ decay channel at **LEP** with $\sim 2.3\sigma$. The lightest Higgs boson in the models, $h_1$ was interpreted as a new particle at ∼ 95 GeV. Studies so far focused on the Yukawa types II and IV. However, the signal strength in the $\gamma\gamma$ channel went down substantially over the last year. This allows a greater freedom for $\frac{c_{h_1 bb}}{c_{h_1 tt}}$, the ratio of the coupling modifiers of the light Higgs to bottom and top quarks, respectively. This motivates the phenomenological study of the **2HDMS** and **N2HDM** in the Yukawa type I. The study includes current theoretical and experimental constraints using **HiggsTools** (**HiggsBounds** and **HiggsSignals**) and incorporates the most recent signal rates from **ATLAS**.

T 48.2 Tue 16:15 Geb. 30.41: HS 3

**Search for X → YH production in bb$\tau\tau$ final states at the CMS experiment** — •Moritz Molch, Ulrich Husemann, Ralf Schmieder, Nikita Shadskiy, Michael Wassmer, and Roger Wolf — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Extensions of the Standard Model (SM), like the Next-to-Minimal Supersymmetric Standard Model (NMSSM) introduces additional Higgs bosons with different masses next to the already known SM Higgs boson H. This talk presents a search for the resonant decay of a heavier scalar particle X into a lighter resonance Y and H at the CMS experiment. The analysis considers final states, in which either the Y or the H decays into a pair of bottom quarks, and the other one into a pair of $\tau$ leptons.

The analysis presented in this talk uses data recored with the CMS detector in proton-proton collisions during the LHC Run 2. In addition, topologies, in which the four final state particles are well separated from each other, boosted topologies of the bottom quark pair and the $\tau$ lepton pair are considered to improve the sensitivity of the analysis, especially in the high mass regions of X. For signal extraction, a parametric deep neural network is used, which enables the treatment of all signal hypotheses with a single neural network at once.

T 48.3 Tue 16:30 Geb. 30.41: HS 3

**Non-prompt lepton background estimate in the split-boosted 1-lepton $X \to SH \to bbWW$ analysis at ATLAS** — •Lena Schulz, Stan Lai, and Kira Abeling — II. Physikalisches Institut, Georg-August-Universität Göttingen

The known incompleteness of the Standard Model gives rise to many theories of physics beyond the Standard Model. Many of those theories predict the existence of additional particles, motivating the search for new signatures.

This talk will focus on the resonant production of a Higgs boson in conjunction with an additional scalar particle S in the $X \to HS \to b\bar{b}WW$ decay channel with one lepton in the final state. Depending on the masses of the resonance $X$ and the particle $S$, multiple possible topologies arise for this decay channel. The split-boosted topology, which will be the focus of this talk, is characterized by a sufficiently large separation between the two $W$ bosons, allowing for the resolution of the final-state lepton from the jet of the hadronically decaying $W$ boson, whilst the hadronic decay products of the Higgs boson and the $W$ boson are too collimated to be resolved.

In the one lepton final state, non-prompt leptons contribute to the background of the decay channel. A data driven approach is presented to model this non-prompt lepton background.

T 48.4 Tue 16:45 Geb. 30.41: HS 3

**Search for a BSM resonance decaying into two SM Higgs bosons in the bbWW final state with the CMS detector.** — Matteo Bonanomi, Mathis Frahm, Johannes Haller, •Viacheslav Kosterin, Lara Markus, Janek Moels, Alexander Paasch, and Matthias Schroeder — Institut für Experimentalphysik, Universität Hamburg

The study of the pair production of Standard Model (SM) Higgs bosons (HH) allows a direct determination of the trilinear Higgs coupling and enhances our understanding of the Higgs potential. In addition, theories beyond the SM predict the existence of heavy particles that manifest as a resonance in the decay of two SM Higgs bosons.

In this talk we present the search for such heavy particles in final states containing two b quarks and two W bosons, where one of the W bosons decays into a pair of light jets and the other decays into a charged lepton and a neutrino.

We present the analysis strategy and the first results obtained using multiclass classifiers based on deep neural networks to address the main challenge of the analysis, that is the small fraction of signal events compared to the large amount of background.

We present expected results based on the data recorded at the CMS experiment during Run 2 and the preparation of the corresponding Run 3 analysis.

T 48.5 Tue 17:00 Geb. 30.41: HS 3

**Interference Effects in Di-Higgs-Production in the singlet extension of the Standard Model** — •Finn Feuerstake[1], Elina Fuchs[1,2], and Tania Robens[3] — [1]Leibniz Universität Hannover — [2]Physikalisch-Technische Bundesanstalt Braunschweig — [3]Institut Ruder Bošković Bijenička Zagreb

Real singlet models are simple extensions of the SM as these models add a new Higgs-like scalar that transforms as a singlet under the SM gauge group. For the case of an additional particle that is heavier than twice the SM-Higgs this scalar, labelled S, could play a role in resonant-enhanced $pp \to hh$ production. We here simulate samples for such scenarios for the inclusive process, the scenario where $pp \to S \to hh$ only, as well as production without the intermediate resonance. By comparing distributions of these three processes in different observables, such as the invariant mass or the final state transverse momenta, taking the finite width of the heavy scalar into account, we discuss the importance of interference effects for di-Higgs production.

T 48.6 Tue 17:15 Geb. 30.41: HS 3

**Resonant di-Higgs production in the RxSM considering one-loop corrections for the triple Higgs couplings: Pure resonant vs. full cross sections** — •Alain Verduras Schaeidt — DESY

Within the RxSM (the SM extended by a real singlet) we focus on a parameter region giving rise to a Strong First Order Electroweak Phase Transition (SFOEWPT). For the (HL-)LHC we compute the total di-Higgs production cross section and the differential cross section with respect to the di-Higgs invariant mass in the parameter region of interest. We include for the first time the one-loop corrections to the trilinear Higgs couplings using the public tool anyH3. It is shown that only taking into account the purely resonant diagram in di-Higgs production, gg -> H -> hh, as often done in experimental analyses, is not sufficient to obtain reliable results for the resonant di-Higgs production.

T 48.7 Tue 17:30 Geb. 30.41: HS 3

**Effective Field Theories for Heavy Higgs Bosons in Standard Model Extensions** — Stefan Dittmaier, •Sebastian Schuhmacher, and Maximilian Stahlhofen — Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

We consider the extension of the Standard Model by a heavy, real Higgs singlet. In order to obtain a phenomenologically interesting low-energy effective theory, we define a specific decoupling limit. We integrate out the heavy degrees of freedom at the one-loop level directly in the path integral via functional methods, employing the background field method as well as the method of regions. Working in the mass-eigenfield basis we take mixing between the Higgs fields into account. Also the renormalization of the full UV model is performed. We generate the effective Lagrangian up to mass dimension six and discuss the possibility of matching it onto SMEFT/HEFT.

# T 49: Flavour physics 2

Time: Tuesday 16:00–18:15 Location: Geb. 30.41: HS 4

T 49.1 Tue 16:00 Geb. 30.41: HS 4

**First search for the decays $\Xi_b^0 \to \Xi^0 J/\psi$ and $\Xi_b^0 \to \Xi^0\psi(2S)$ at the LHCb experiment** — Johannes Albrecht[1], Vitalii Lisovskyi[3], •Leandra Moeser[1], and Janina Nicolini[1,2] — [1]TU Dortmund University, Dortmund, Germany — [2]IJCLab, Orsay, France — [3]EPFL, Lausanne, Switzerland

Weak decays of heavy-quark baryons offer an attractive laboratory to search for effects beyond the Standard Model, complementary to searches in meson decays. Due to the high masses of $b$-baryons, most of them can only be studied at hadron colliders. The LHCb experiment is investigating such weakly decaying $b$-baryons, the most comprehensively studied of which is the $\Lambda_b$ baryon, where tensions towards theoretical predictions have been observed. Further analyses of $b$-baryon decays would thus be beneficial.

The current status of the first search for the tree-level decays $\Xi_b^0 \to \Xi^0 J/\psi$ and $\Xi_b^0 \to \Xi^0\psi(2S)$ and computation of the ratio of their respective branching fractions $\mathscr{B}(\Xi_b^0 \to \Xi^0\psi(2S))/\mathscr{B}(\Xi_b^0 \to \Xi^0 J/\psi)$ is presented.

The used data was collected at the LHCb experiment from 2016 to 2018, corresponding to an integrated luminosity of 5.4 fb$^{-1}$.

T 49.2 Tue 16:15 Geb. 30.41: HS 4

**Search for exotic states with $c\bar{c}s\bar{c}$ content at Belle** — •Dmytro Meleshko, Elisabetta Prencipe, and Soeren Lange — Justus-Liebig-Universität, Gießen.

We present results for an analysis of $e^+e^- \to D_s^+ D_{sJ}^- A$ + c.c. processes in the continuum (A = anything else) using the whole Belle dataset (980.1 fb$^{-1}$). The goal of the analysis is the study of $D_s^+ D_{s0}^*(2317)^-$ and $D_s^+ D_{s1}(2460)^-$ invariant mass systems to search for possible exotic, resonant states with $c\bar{c}s\bar{c}$ quark content. As the $D_{s0}$ and $D_{s1}$ are often considered themselves as 4-quark candidates, the combined states may contain admixtures of a 6-quark state in the wave function. In addition, precise mass resolution and mass splitting measurements are presented as a test of the chiral perturbation theory. This research is supported by BMBF (05H21RGKB1) and Horizon2020 European Union Marie Slodowska Curie Action in the RISE program (n.822070).

T 49.3 Tue 16:30 Geb. 30.41: HS 4

**Dalitz analysis of $B^- \to D^+\pi^-\pi^-$** — •Bhavesh Narayan Sirvi, Florian Bernlochner, Jochen Dingfelder, and Markus Prim — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

Fully hadronic $B$ meson decays provide a unique tool to study hadronic properties of excited $D$ meson states beyond the 1S ground state. These charm states are not very well explored. In this talk we present the current status of studies of the decay of $B^- \to D^+\pi^-\pi^-$ to study orbitally excited 1P charm states, with the goal to determine widths, masses, spin and other properties. For this we carry out a Dalitz analysis, reconstructing the $B^- \to D^+\pi^-\pi^-$ via $D^+ \to K^-\pi^+\pi^+$ decays. We analyze simulated Belle II data and show the sensitivity to physical parameters assuming the Run 1 integrated luminosity. More precise knowledge of these states will facilitate a better understanding of semileptonic processes, such as $B^+ \to D^*\tau^+\nu_\tau$, for which semileptonic contributions with higher charm states represent an important background, and will help reducing uncertainties in future determinations of matrix elements of the Cabibbo-Kobayashi-Maskawa matrix.

T 49.4 Tue 16:45 Geb. 30.41: HS 4

**Amplitude Analysis of $\longrightarrow K^+\pi^-\pi^0$ Decays** — •Ceren Ay[1,2], Markus Reif[1], Stefan Wallner[1], Thomas Kuhr[2], and Hans-Günther Moser[1] — [1]Max-Planck-Institüte für Physik — [2]Ludwig-Maximilians-Universität München

The measurement of branching ratios and CP asymmetries of $B$ meson decays are essential tools for understanding the underlying physics. These measurements are particularly challenging for the decays of $B$ mesons to multi-body hadronic final states, since elaborate amplitude analyses are required to separate and measure the contributions of the interfering resonances in these final states. We perform a Dalitz plot analysis of data recorded by the Belle II experiment to extract these parameters for $B^0\bar{B}^0 \longrightarrow K^+\pi^-\pi^0$ decays. As part of this, we investigate the model dependence by studying different parameterizations of amplitude models. We also check the dependence on the initial values of the fit and investigate fit biases. Recent results from these studies will be presented.

T 49.5 Tue 17:00 Geb. 30.41: HS 4

**Dalitz analysis on $B^+ \to K_S^0\pi^+\pi^0$** — •Oskar Tittel — Max-Planck-Institut für Physik, München

The Belle II experiment in Tsukuba, Japan, is working at the high-intensity frontier of the search for physics beyond the Standard Model (SM). A direct test of the SM is the verification of the so-called "isospin sum-rule" in the $B \to K^*\pi$ system, which depends on the branching fractions (BF's) and the direct CP asymmetries of all $B \to K^*\pi$ decay modes. These quantities can be extracted from Dalitz analyses on the decay channels $B^0 \to K^+\pi^-\pi^0$ and $B^+ \to K_S^0\pi^+\pi^0$.

I will present the Belle II experiment, introduce the isospin sum rule and show the current state of the analysis on $B^+ \to K_S^0\pi^+\pi^0$.

T 49.6 Tue 17:15 Geb. 30.41: HS 4

**Direct measurement of $R^{\pm 0}$ at Belle II** — Florian Bernlochner, Jochen Dingfelder, •Anna-Maria Heyn, and Markus Prim — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

The ratio of the $\Upsilon(4S) \to B^+B^-$ and $\Upsilon(4S) \to B^0\bar{B}^0$ decay rates, $R^{\pm 0}$, represents a crucial input quantity to convert measured yields into branching fractions at $e^+e^-$ $B$-factory experiments. The most precise present day determinations rely on isospin assumptions. We present the status of a novel approach to determine the $B^\pm$ and $B^0$ production fraction using an inclusive approach. It relies on analyzing the reconstructed number of charged tracks in a collision event. On average the decay of two $B$ mesons results in about 10 charged final state particles and if perfectly reconstructed, the number of charged tracks from $B^\pm$ and $B^0$ differ by two. In this talk, we explore the experimental feasibility to determine $R^{\pm 0}$ from a careful analysis of the number of charged tracks in a collision event. Contributions from continuum processes are suppressed using multivariate methods and the template shapes on the number of charged tracks are determined using fully hadronic control channels of self-tagging decays.

T 49.7 Tue 17:30 Geb. 30.41: HS 4

**Search for Baryon Number Violation by two units in the $B^+ \to p\Lambda\pi^+\pi^-$ decay channel** — •Melanie Hess, Thomas Lück, and Thomas Kuhr — Ludwig-Maximilians-Universität München

Baryon Number Violation is an important topic in the search for an explanation of the matter antimatter asymmetry observed in the universe. This analysis focuses on the violation by two units, which is experimentally less constrained than a violation by one unit. An ideal laboratory to study this are B mesons due to their large variety of hadronic decays. Data recorded by the Belle II experiment at the asymmetric energy $e^+e^-$ collider SuperKEKB in Japan is analyzed. The collider is operated at a center of mass energy corresponding to the mass of the $\Upsilon$(4S) meson, which predominantly decays into a pair of B mesons.

For this analysis, the decay channel $B^+ \to p\Lambda\pi^+\pi^-$ was chosen taking the already established Standard Model channel $B^+ \to p\bar{\Lambda}\pi^+\pi^-$ as reference. The $\Lambda$ is reconstructed via the $\Lambda \to p\pi^-$ decay. Simulated data is used to optimize the sensitivity of the search.

This talk summarizes the current status of the analysis and gives an outlook on the next steps.

T 49.8 Tue 17:45 Geb. 30.41: HS 4

**Higher twist corrections to $B$-meson decays into a proton and dark antibaryon from QCD light-cone sum rules [1]** — •Anastasia Boushmelev and Marcel Wald — Theoretische Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

The $B$-Mesogenesis framework anticipates decays of $B$ mesons into a dark antibaryon $\Psi$ and various Standard Model baryons. Here, we focus on the exclusive decay process $B \to p\Psi$ observed as a proton and missing energy in the final state and determine the decay width by employing the QCD light-cone sum rule framework. We include all contributions up to twist six to the nucleon distribution amplitudes in order to parameterize the non-perturbative effects in the operator product expansion. We obtain the decay width and branching fraction with respect to the mass $m_\Psi$ of the dark antibaryon $\Psi$, normalized to the model-dependent effective four-fermion coupling.

[1] A. Boushmelev and M. Wald, [arXiv:2311.13482 [hep-ph]]

T 49.9 Tue 18:00 Geb. 30.41: HS 4

**Using Gradient Flow to Renormalise Matrix Elements for Meson Mixing and Lifetimes** — •Matthew Black[1], Robert Harlander[2], Fabian Lange[3,4,5,6], Antonio Rago[7], Andrea Shindler[2], and Oliver Witzel[1] — [1]Theoretische Teilchenphysik, Center for Particle Physics Siegen, Universitaet Siegen, Germany — [2]Institute for Theoretical Particle Physics and Cosmology, RWTH Aachen University, Germany — [3]Physik-Institut, Universitaet Zuerich, Switzerland — [4]Paul Scherrer Institut, Villigen PSI, Switzerland — [5]Institut fuer Theoretische Teilchenphysik, Karlsruhe Institute of Technology, Germany — [6]Institut fuer Astroteilchenphysik, Karlsruhe Institute of Technology, Germany — [7]IMADA and Qauntum Theory Center, University of Southern Denmark, Odense, Denmark

Neutral meson mixing and meson lifetimes are theory-side parametrised in terms four-quark operators which can be determined by calculating weak decay matrix elements using lattice QCD. While calculations of meson mixing matrix elements are standard, determinations of lifetimes typically suffer from complications in renormalisation procedures because dimension-6 four-quark operators can mix with operators of lower mass dimension and, moreover, quark-line disconnected diagrams contribute.

We present work detailing the idea to use fermionic gradient flow to non-perturbatively renormalise matrix elements describing meson mixing or lifetimes, which later is to be combined with a perturbative calculation to match to the MS-bar scheme.

# T 50: Top physics 2 (top pair cross section)

Time: Tuesday 16:00–18:15 Location: Geb. 30.95: Audimax

T 50.1 Tue 16:00 Geb. 30.95: Audimax

**Observation of top-quark pair production in proton-lead collisions in the ATLAS experiment at the LHC** — Petr Baroň[1], Iwona Grabowska-Bołd[2], Jiří Kvita[1], Santu Mondal[3], •Patrycja Potepa[1,4], and Yuriy Volkotrub[5] — [1]Palacký University Olomouc, Czech Republic — [2]AGH University of Krakow, Poland — [3]Czech Technical University in Prague, Czech Republic — [4]Johannes Gutenberg University Mainz, Germany — [5]Jagiellonian University, Kraków, Poland

Top quarks, the heaviest elementary particles carrying colour charges, are considered to be promising probes of the quark-gluon plasma produced in heavy-ion collisions at LHC energies. In proton-lead collisions, top-quark production is expected to be sensitive to nuclear modifications of parton distribution functions at high Bjorken-x values, which is a region poorly constrained by other available probes. In 2016, the ATLAS experiment collected proton-lead collisions at centre-of-mass energy of 8.16 TeV per nucleon pair, corresponding to a total integrated luminosity of 165 nb$^{-1}$. In this talk, we present the first measurement of the top-quark pair production cross section in dilepton and lepton+jet channels with the ATLAS experiment. The significance of the measured signal in both decay modes exceeds 5 standard deviations, resulting in the first observation of top-quark pair production in the dilepton channel in proton-lead collisions. The total relative uncertainty amounts to 9%, which makes it the most precise top-quark pair cross-section measurement in heavy-ion collisions at the LHC.

T 50.2 Tue 16:15 Geb. 30.95: Audimax

**Presicion measurement of the top quark pair production cross-section at CMS in Run-2** — Laurids Jeppe, Andreas Meyer, Evan Ranken, and •Konstantin Sharko — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

A precision measurement of the top quark pair production cross section at 13.0 TeV is presented. The data were recorded at the CMS experiment and correspond to an integrated luminosity of 59.8 fb$^{-1}$. Events are selected with one or two charged leptons (electrons or muons) and at least one additional jet in the final state. A maximum likelihood fit is performed to event categories defined by the number and flavors of the leptons, the number of jets and the number jets originating from b hadrons. The currently expected systematic uncertainty, excluding that of the luminosity, is 1.5%.

T 50.3 Tue 16:30 Geb. 30.95: Audimax

**$t\bar{t}$ cross-sections measurement at 13.6 TeV collision energy and its ratio to the 13 TeV result using the ATLAS detector** — •Cédrine Alexandra Hügli — DESY, Zeuthen, Germany

The inclusive $t\bar{t}$ cross-section using proton-proton collisions at 13.6 TeV collision energy using 29 fb$^{-1}$ of data collected with the ATLAS detector in 2022 is measured. This is achieved through the employment of the $b$-jet counting method, using events with an opposite-charge electron-muon pair and $b$-tagged jets. It is interesting to calculate the ratio between this measurement and the 13 TeV result since several uncertainties are correlated. This is particularly true for the theoretical uncertainties. As a consequence, the total uncertainty on the ratio, for measured and predicted values, is smaller than on the individual values. This allows to check the agreement between the measured ratio and the different predictions using various PDF sets. In this talk, the 13.6 TeV measurement and its ratio to the 13 TeV one are presented and the details, how the uncertainty on the ratio is estimated are explained.

T 50.4 Tue 16:45 Geb. 30.95: Audimax

**Extracting the Top Yukawa coupling from the $t\bar{t}$ differential cross section using ATLAS data** — •Sadia Marium — DESY, Zeuthen, Germany

The aim of this analysis is to extract the top-Yukawa coupling ($Y_t$) from the $t\bar{t}$ cross-section. There are loop corrections due to Higgs exchange between the $t\bar{t}$ pair. This virtual Higgs exchange affects the distribution of the mass of the $t\bar{t}$ system $M_{t\bar{t}}$ and the top quark production angle $\cos\theta_t^*$ in the $t\bar{t}$ rest frame. These kinematic variables are therefore sensitive to $Y_t$, and hence, their distributions are used to extract its value. The main focus of this talk is to analyse these kinematic variables. The dileptonic and lepton+jets final states are analysed. In the dileptonic channel, due to missing neutrinos, the full $t\bar{t}$ system cannot be reconstructed, therefore, possible proxy observables are studied. The aim is to use the full Run-II data with an integrated luminosity of 140 fb$^{-1}$ taken by the ATLAS experiment at 13 TeV collision energy.

T 50.5 Tue 17:00 Geb. 30.95: Audimax

**Measurement of the dileptonic tt̄ differential cross section in a BSM phase space at CMS** — Valeria Botta, Lutz Feld, •Danilo Meuser, Philipp Nattland, and Marius Teroerde — I. Physikalisches Insitut B, RWTH Aachen University

Measurements of the tt̄ production cross section yield important precision tests of the Standard Model (SM), while also probing scenarios for physics beyond the SM (BSM). This analysis aims to measure the tt̄ cross section in a phase space where additional contributions from BSM scenarios could be present. It is based on the data set recorded by CMS in the years 2016 to 2018 at a center-of-mass energy of 13 TeV, corresponding to an integrated luminosity of 138 fb$^{-1}$. The BSM scenarios considered include supersymmetric and dark matter models, where, similarly to the dileptonic tt̄ channel, two leptons, b jets and undetected particles are produced.

Unlike previous measurements, where the differential cross sections were mainly measured as a function of kinematic variables of the leptons or top quarks, this analysis focuses on observables related to the neutrinos, like the missing transverse momentum and the angular distance between the missing transverse momentum and the nearest lepton, to separate BSM from SM tt̄ events. In order to increase the sensitivity of the analysis multivariant techniques are used which improve the resolution of the missing transverse momentum in SM tt̄ events. The final results of the differential cross section measurements are compared to monte carlo simulations and fixed order theory predictions.

T 50.6 Tue 17:15 Geb. 30.95: Audimax

**Towards a WbWb differential cross-section measurement** — •Eleonora Loiacono — DESY

The production of a top quark pair is extensively studied at the Large Hadron Collider (LHC). It constitutes a significant background in many searches for physics Beyond the Standard Model (BSM). The final state of this process, WWbb, interferes with the production of a single top quark in association with a W boson at Next Leading Order (tWb).

In this contribution, I will focus on presenting different techniques that are used to correct the data for inefficiencies and limited geometric acceptance for the WWbb single lepton channel, with the goal of improving the modelling of Standard Model (SM) processes for BSM searches.

First differential cross-section measurements in variables that are maximally sensitive to the interference, using data from second run of the LHC, will be presented.

T 50.7 Tue 17:30 Geb. 30.95: Audimax

**Towards a WbWb differential cross-section measurement in a search-like phase space** — •Thomas Mclachlan — DESY

Top quark pair production is a widely studied process at the Large Hadron Collider (LHC) and is a significant background in many searches beyond the Standard Model (BSM). The WbWb final states of this process interfere with the production of a single top quark in association with a W boson and a b-quark (tWb). Inspired by searches for supersymmetry and dark matter, I will measure the WbWb production cross-section in a search-like phase space that is maximally sensitive to the interference effects. Performing such a measurement can allow for new constraints on new physics and improve the sensitivity of future searches through improved background modelling. An event selection using single lepton events has been developed and will be used on the entire Run 2 dataset. In this context, I will present a range of quantities and theoretical parameters that will be used in the differential cross-section measurement.

T 50.8 Tue 17:45 Geb. 30.95: Audimax

**$t\bar{t}\gamma$ production cross section measurements in single-lepton and dilepton final states in proton-proton collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector** — Diptaparna Biswas[1], Beatrice Cervato[1], Markus Cristinziani[1], Carmen Diez Pardos[1], Ivor Fleck[1], Arpan Ghosal[1], Gabriel Gomes[1], Jan Joachim Hahn[1], Vadim Kostyukhin[1], Nils Krengel[1], Buddhadeb Mondal[1], •Stefanie Müller[1], Katharina Voss[1], Wolfgang Walkowiak[1], Adam Warnerbring[1], and Tongbin Zhao[1,2] — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Shandong University, China

Top quark pair production ($t\bar{t}$) in association with an additional photon ($t\bar{t}\gamma$) is the leading process for measuring the coupling strength of the top quark-photon interaction. Precise measurements of the $t\bar{t}\gamma$ process are relevant to test the Standard Model and probing for new physics effects at very high energy scale.

In this contribution $t\bar{t}\gamma$ cross section measurements will be presented using a luminosity of 140 fb$^{-1}$ of data collected by the ATLAS detector in pp collisions at $\sqrt{s}$ = 13 TeV. The studies are performed focussing on $t\bar{t}\gamma$ processes where the $\gamma$ is radiated from initial state production. The toolkit RIVET (Robust Independent Validation of Experiment and Theory) is employed to perform studies with Monte Carlo simulations in the single-lepton and dilepton $t\bar{t}$ decay channels.

T 50.9 Tue 18:00 Geb. 30.95: Audimax

**Simulation of on- and off-shell $t\bar{t}$ production with the MC generator `bb4l` at CMS** — Simone Amoroso[1], Alexander Grohsjean[2], •Laurids Jeppe[1], and Christian Schwanenberger[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Universität Hamburg, Hamburg, Germany

Top quark pair production processes at the LHC are important for precision measurements of observables such as the top quark mass or top quark pair spin correlations and as a background for BSM searches. As such, it is crucial that MC simulation of this process is available for experimental analyses at the highest level of precision possible.

Here, we show an investigation of the NLO MC generator `bb4l` interfaced to Pythia 8 for parton showering. This program not only models top quark pair production, but also single top quark production in association with a W boson, as well as their interference, and correctly takes into account effects from the finite top width. We compare it to simulations using the `hvq` and `ST_wtch` generators for different interference handling schemes, as well as the `ttb_NLO_dec` generator, with possible implications for future top mass measurements.

# T 51: Invited Overview Talks 4

Time: Wednesday 9:00–10:30 Location: Geb. 30.95: Audimax

**Invited Overview Talk** T 51.1 Wed 9:00 Geb. 30.95: Audimax

**The top quark: a precision probe and a window to new phenomena** — •Jan Kieseler — KIT, Karlsruhe, Germany

The top quark is one of the most interesting particles in the Standard Model of particle physics. Its mass exceeds those of all other fundamental particles, which implies a unique relationship with the Higgs Boson and makes it a possible portal to physics beyond the Standard Model. At the same time, its short lifetime allows probing its bare properties before hadronisation and it offers sensitivity to a variety of Standard-Model parameters through comparison to precision calculations. This talk will cover recent advances in the understanding of the top quark and its relation to other fundamental particles as well as give a flavour of what is yet to come in the next years.

**Invited Overview Talk** T 51.2 Wed 9:30 Geb. 30.95: Audimax

**Fundamental tests of the Standard Model at ATLAS and CMS** — •Baptiste Ravina — Georg-August-Universität Göttingen

The remarkable performance of the Large Hadron Collider (LHC), and of the ATLAS and CMS experiments during Run 1 and Run 2 of the LHC, has opened the door to new fundamental tests of the Standard Model. Detailed knowledge of the detectors during Run 1 allows for high-precision measurements of the $W^{\pm}$ and $Z$ bosons, while the large Run 2 dataset has revealed further rare electroweak processes.

This talk will highlight some of the successes of the ATLAS and CMS collaborations over the past year, in targeting fundamental aspects of Standard Model physics. Amongst the topics that will be covered are recent measurements of the mass, width and cross sections of the $W^{\pm}$ and $Z$ bosons; the observation of the elusive, fully electroweak $W^{\pm}W^{\pm}$ production process; extractions of $\alpha_S$ using very different techniques; and a characterisation of jet and tau production mechanisms. A novel field of research, that of quantum information with high-energy fundamental particles, will be introduced with the observation of quantum entanglement in pairs of top quarks.

**Invited Overview Talk** T 51.3 Wed 10:00 Geb. 30.95: Audimax

**Mastering challenges of High-Luminosity LHC data with innovative computing solutions** — •Michael Boehler — Albert-Ludwigs-Universität, Freiburg, Germany

The Worldwide LHC Computing Grid was founded in 2004 to store, distribute, and analyse the huge amounts of data of the LHC experiments. It combines the computing and storage resources of over 170 compute centres in more than 40 countries. Around 10 of these centres are located in Germany. The current data volume of 200 petabytes per year will increase to exabytes per year with the launch of the High-Luminosity LHC in 2029. The demand for computing resources will also increase dramatically unless drastic savings are achieved through aggressive research and development in the area of data processing. In addition, the sharp increase in energy prices in the last year and the general consensus on energy conservation require sustainable computing solutions.

A selection of tools, further developments, and innovative ideas will be presented that are essential for overcoming these challenges. Important building blocks for this task are applications that make it possible to integrate heterogeneous resources transparently and dynamically into existing high-energy physics workflows. The accounting ecosystem AUDITOR and the meta-scheduler CobalD/TARDIS, which were developed in Germany in the FIDIUM project, make it possible to break new ground.

# T 52: Search for new particles 4 (leptoquarks, LHC)

Time: Wednesday 16:00–18:00 Location: Geb. 20.30: 1.067

T 52.1 Wed 16:00 Geb. 20.30: 1.067

**Leptoquark production in a single $\tau$ charm/bottom and $E_T^{miss}$ final state at the ATLAS detector** — •Patrick Bauer, Philip Bechtle, and Klaus Desch — Physikalisches Institut Bonn

The searches for leptoquarks (LQ), as predicted in some Grand-Unified-Theories, have been explored by collider experiments for quite a some time.
Recent results from CMS, showing a 3.4 sigma excess, consistent with contributions from non-resonant LQ processes, renewed the focus on this topic once again. Furthermore some anomalies, observed in decays of the B-hadrons into $D^{(*)}$ and charged Leptons, still persist and could also be explained by LQ processes. These observations once more emphasize the importance of exploitation of all possible LQ production modes. For for LQ masses well above 1 TeV the single- and non-resonant production modes can become a key ingredient for ongoing and future searches. With the single production into final states with $\tau$ lepton(s), bottom or charm jet with large missing transverse momentum, one can directly probe the couplings expected to be involved in the $B \to D^{(*)}\tau\nu$ anomaly. For the inclusion of a non-resonant processes it is crucial to study the interference behaviour of LQ signal with the SM.
This talk will provide an overview over the ongoing search for singly produced LQ in the $\tau$ and charm quark with high $E_T^{miss}$ in the final state. Furthermore ATLAS results for LQ single production in b $\tau\tau$ final state will be shown.

T 52.2 Wed 16:15 Geb. 20.30: 1.067

**Search for resonant leptoquark production with the ATLAS experiment** — •Christopher Maximilian Engel, Adrian Alvarez Fernandez, and Stefan Tapprogge — Institute for Physics, Johannes Gutenberg University, Mainz, Germany

A leptoquark is a hypothetical particle that couples to both leptons and quarks and carries both lepton and quark quantum numbers. Leptoquarks are predicted by many extensions of the Standard Model, including Grand Unified Theories, and might explain the similarities between the lepton and the quark generations. One way of searching for such a particle would be to look for the production of a single leptoquark in proton-proton collisions caused by the interaction of a lepton and a quark coming from the inner structure of protons.

This talk focuses on this resonant production of a single leptoquark decaying into a lepton and a quark, which results in a lepton+jet signal in the detector. This resonant structure in the invariant mass distribution of the lepton and jet system could be identified on top of a smoothly falling background. One of the main goals of this contribution is the optimization of the selection criteria to achieve maximum signal sensitivity. The current state of the studies and future goals will be presented.

T 52.3 Wed 16:30 Geb. 20.30: 1.067

**Search for Leptoquarks in the multilepton channel with ATLAS Run-2 data** — •Janick Böhm and Andre Sopczak — Czech Technical University in Prague

The latest results in the search for leptoquarks in the multilepton channel are presented using ATLAS Run-2 data.

T 52.4 Wed 16:45 Geb. 20.30: 1.067

**The LHC as Lepton–Proton Collider: Search for Resonant Production of Leptoquarks** — •Daniel Buchin, Michael Holzbock, Sandra Kortner, and Hubert Kroha — Max-Planck-Institut für Physik

Searches for leptoquarks constitute an essential part of the physics programme at the ATLAS detector. These hypothetical particles couple to a lepton and a quark and are predicted by many extensions of the Standard Model such as Grand Unified Theories. The existing leptoquark searches at the LHC currently only consider production modes via quark and/or gluon interactions. The small but non-zero lepton content of the proton, however, allows also to study the significantly less explored resonant leptoquark production.

This production mode gives rise to lepton-plus-jet signatures. Thus, leptoquarks would emerge as distinctive peaks over the smoothly falling Standard Model background in the invariant mass spectrum of the lepton-plus-jet system. The talk will give an overview of the analysis strategy and discuss sensitivity estimates to previously unexplored leptoquark masses using this process.

T 52.5 Wed 17:00 Geb. 20.30: 1.067

**Search for heavy right-handed Majorana neutrinos in $t\bar{t}$ decays** — •Tongbin Zhao[1,2], Diptaparna Biswas[1], Beatrice Cervato[1], Markus Cristinziani[1], Carmen Diez Pardos[1], Ivor Fleck[1], Arpan Ghosal[1], Gabriel Gomes[1], Jan Joachim Hahn[1], Vadim Kostyukhin[1], Nils Krengel[1], Buddhadeb Mondal[1], Katharina Voss[1], Wolfgang Walkowiak[1], and Adam Warnerbring[1] — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Shandong University, China

A search for heavy right-handed Majorana neutrinos is performed with the Run-2 dataset recorded from 2015 to 2018 with the ATLAS detector at the CERN Large Hadron Collider and is based on $\sqrt{s}$ = 13TeV proton-proton collision data with an integrated luminosity of 140.1fb$^{-1}$. The targeted process is $t\bar{t}$ : one of the top quarks decays into a pair of same-sign same-flavour leptons (electrons or muons), a $b$-quark and two light quarks, while the other decays into a $b$-quark and two light quarks. The final states feature same-sign dilepton signatures. This analysis is the first search for heavy neutrinos with $t\bar{t}$ events at the mass range of 15 – 75GeV.

The multivariate analysis is performed to set the signal region to improve the significance. Besides, several control regions are defined to estimate the main backgrounds from the ttbar +X samples. After performing the statistical analysis with profile likelihood fit, we could set the best limits on the mixing parameter of $ee/\mu\mu$ channel at the mass region of 15 – 75GeV.

T 52.6 Wed 17:15 Geb. 20.30: 1.067

**Search for new physics in the final state with a lepton and $\vec{p}_T^{\,miss}$.** — •Valentina Sarkisovi, Kerstin Hoepfner, and Thomas Hebbeker — RWTH Aachen University, Aachen, Germany

Various Beyond the Standard Model (BSM) theories anticipate the existence of new particles that could decay into final states characterized by the presence of a charged lepton and missing transverse momentum ($\vec{p}_T^{\,miss}$) as their most distinctive experimental signature. The CMS detector at the CERN LHC is used to hunt for novel physics in the high mass region of final states containing a lepton (electron, muon, tau) and $\vec{p}_T^{\,miss}$. Achievement of a high mass resolution, rejection of the standard model backgrounds, and efficient identification and reconstruction of TeV leptons are crucial in a search for such phenomena. One of the main challenges of this search is represented by the high rate of QCD multi-jet background produced in the LHC proton-proton collisions, leading to the possible misidentification of a jet as a lepton. Data driven methods as well as advanced machine learning technologies are used to model the QCD contamination and to properly identify leptons. The latest CMS data, recorded in 2022 and 2023 at unprecedented center-of-mass energy of 13.6 TeV, have been analysed. The key concepts of the analysis techniques employed in the search for new physics in the final state with a lepton and $\vec{p}_T^{\,miss}$ are addressed.

T 52.7 Wed 17:30 Geb. 20.30: 1.067

**Sensitivity to lepton-flavour-violating decays of $Z$ and $Z'$ bosons using data-driven background estimation with the Atlas Experiment** — •Naman Kumar Bhalla, Valerie Lang, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

One of the primary goals of the Large Hadron Collider (Lhc) program is to look for processes beyond the Standard Model (SM) of particle physics. One such process is lepton flavour violation (LFV), which has already been observed in neutrino oscillations, but never in processes involving charged leptons. A search for LFV decays of $Z$ and $Z'$ bosons with $Z^{(\prime)} \to e\tau_\mu$ and $Z^{(\prime)} \to \mu\tau_e$ final states is motivated by various beyond-SM theories. These searches can be performed using a data-driven background estimation, which takes advantage of the idempotency of SM backgrounds under the exchange of an electron and a muon. This symmetry is broken only by the difference in branching ratios between LFV decays with $e\tau$ and $\mu\tau$ final states.

This talk discusses the achievable sensitivities for the search of LFV decays of $Z$ and $Z'$ bosons using the full Run-2 data set collected by the Atlas detector in $pp$ collisions at $\sqrt{s}$ = 13 TeV, corresponding to an integrated luminosity of 140 fb$^{-1}$. The neural network used to classify the LFV signal against other background processes along with the statistical model used for the analysis are presented.

T 52.8 Wed 17:45 Geb. 20.30: 1.067

**Search for new physics in the top, charm and missing transverse energy final state with the ATLAS detector** — •Marawan Barakat — DESY

A search for new Beyond the Standard Model(BSM) particles in final states with a top quark, charm quark and missing transverse momentum is performed, using a dataset collected with the ATLAS detector during LHC Run 2, corresponding to an integrated luminosity of 139 fb-1 at a centre-of-mass energy 13 TeV. The search is motivated by BSM theoretical models featuring an non-minimal flavor violation in the 2nd and 3rd generation quark sector, giving rise to final states where BSM particles can decay almost equally to a top quark or a charm quark in association with invisible particles. Good agreement is generally found between data and SM background, with slight deviations of atmost 2 sigmas. Exclusion limits are presented for different BSM signal scenarios.

# T 53: Neutrino physics 6

Time: Wednesday 16:00–18:00 Location: Geb. 20.30: 2.058

T 53.1 Wed 16:00 Geb. 20.30: 2.058

**Differential spectrum modeling for keV sterile neutrino search at KATRIN** — •Martin Descher — Karlsruhe Institute of Technology

Starting in 2026, the KATRIN experiment will conduct a high-statistics measurement of the differential tritium $\beta$-spectrum to energies deep below the kinematic endpoint. This enables the search for keV sterile neutrinos with masses $m_4 \leq 18$ keV, aiming for a statistical sensitivity of $|U_{e4}|^2 = \sin^2\theta \sim 10^{-6}$. The differential spectrum is obtained by decreasing the retarding potential of KATRIN's main spectrometer, and by determining the $\beta$-electron energies by their energy deposition in the new TRISTAN SDD array. In this mode of operation, the existing integral model of the tritium spectrum is insufficient, and a novel differential model is developed. So far, the model includes 20 systematics and can perform comprehensive sensitivity studies. The gained insights are employed to find the optimal beamline configuration for the measurement and to investigate potential hardware upgrades that significantly improve the sensitivity. This talk provides a summary of the systematics, the model approach, and shows how the impact of several dominant systematics can be reduced.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6).

T 53.2 Wed 16:15 Geb. 20.30: 2.058

**Mitigation of rear wall backscattering for keV sterile neutrino search at KATRIN** — •Kerstin Trost — Karlsruhe Institute of Technology (KIT)

The Karlsruhe Tritium Neutrino (KATRIN) experiment aims to determine the absolute neutrino mass scale by measuring the endpoint region of the tritium $\beta$-decay spectrum with high precision. Furthermore, a measurement of the differential spectrum to energies deep below the endpoint will be conducted using the new TRISTAN detector. This enables the search for keV-scale sterile neutrinos that would cause subtle distortions several keV below the endpoint. The differential spectrum measurement requires modifications to the beamline setup, and it is subject to many new systematics.

This talk focuses on strategies to minimize the leading systematic effect of rear wall backscattering. Various scenarios are explored with simulations, including the selection of the rear wall material and the influence of magnetic fields at the rear wall and along the beamline. The primary objective is to identify an optimized beamline configuration that significantly enhances sensitivity for the detection of keV-scale sterile neutrinos.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6).

T 53.3 Wed 16:30 Geb. 20.30: 2.058

**Backscattering reduction with a micro-structured rear wall at KATRIN** — •Tom Geigle — Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

The TRISTAN detector upgrade represents the subsequent phase of the KATRIN experiment, designed with the objective of searching a sterile neutrino at the keV scale through its impact on the tritium beta spectrum. A crucial aspect of this project is the detection of beta electrons down to a few keV, which previously did not have to be included in the KATRIN endpoint measurement.

Of particular significance are beta electrons that undergo scattering on the rear wall of the experimental setup before reaching the detector. This phenomenon introduces a distortion in the shape of the measured spectrum within the region of interest, necessitating mitigation strategies to attain the anticipated sensitivity levels.

To address this challenge, diverse configurations of micro-structured rear walls are being examined through Geant4 simulations. These simulations aim to identify an optimal solution that effectively minimizes the impact of scattered beta electrons on the measured spectrum, thereby facilitating the realization of the planned sensitivity goals.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6).

T 53.4 Wed 16:45 Geb. 20.30: 2.058

**Particle Identification in Liquid Argon for LEGEND** — •Niko Lay for the LEGEND-Collaboration — Technical University of Munich, Garching, Germany

The LEGEND experiment searches for neutrinoless double beta ($0\nu\beta\beta$) decay in $^{76}$Ge using high-purity germanium detectors immersed in liquid argon (LAr), which acts both as a coolant and active shield from background radiation. Ionizing particles traversing LAr produce, depending on their linear energy transfer, different ratios of argon unstable singlet and metastable triplet state excimers, which emit 128 nm scintillation light upon their decay. By measuring the time structure of the scintillation events, the LEGEND LAr instrumentation can identify background particles. In this talk, we present the event topology classifier (ETC), which is based on the singlet-to-triplet ratio of scintillation events, and its application to support the tagging of $^{214}$Bi-Po coincidence events. The ETC is used to estimate the $^{222}$Rn activity in the LEGEND LAr cryostat during commissioning. Finally, we explore the ETC performance of a different experimental setup, the shallow-underground LAr cryostat SCARF at TU-Munich, and investigate discriminating fast scintillation light emitted by polyethylene naphthalate (PEN) from LAr scintillation light. This research is supported by the BMBF through the Verbundforschung 05A20WO2 and the SFB1258.

T 53.5 Wed 17:00 Geb. 20.30: 2.058

**Studying neutrinos that oscillate and decay** — •George Parker[1], Joachim Kopp[1,2], and Michael Wurm[1] — [1]Institut für Physik and EC PRISMA+, Johannes Gutenberg Universität Mainz, Germany — [2]CERN Theoretical Physics Department, Geneva, Switzerland

The neutrino has a lifetime that is significantly longer than the Age of the Universe, as it can only decay radiatively via loops involving gauge bosons. However, the presence of physics Beyond the Standard Model could induce 'visible' neutrino decay between neutrino mass eigenstates. This decay process could be identified in laboratory experiments as well as from astrophysical or cosmological observations. To study neutrino systems that involve both oscillation and decay, two main formalisms have been developed—a density matrix approach and a phenomenological approach. In this work, we present an analysis of both, highlighting the physical effects captured by each framework.

T 53.6 Wed 17:15 Geb. 20.30: 2.058

**atmospheric neutrino oscillation analysis with JUNO** — •Mariam Rifai[1,2], Livia Ludhova[1,2], Marco Malabarba[1,2,3], Yury Malyshkyn[1,3], Cristobal Morales reveco[1,2,3], Luca Pelicci[1,2], Hexi Shi[2,3], and Apeksha Singhal[1,2] — [1]Institut für Kernphysik, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]III. Physikalisches Institut B, RWTH Aachen University, 52062 Aachen, Germany — [3]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a multi-purpose liquid scintillator detector. It is currently under construction in Southern China, with its filling set to start in 2024. JUNO has a unique potential to determine the neutrino mass ordering (NMO) with a $3\sigma$ confidence level (C.L.) within 6 years. This goal will be achieved by observing the vacuum oscillation pattern of reactor antineutrinos over a baseline of 52.5 km. Equipped with a 20 kton liquid scintillator target and surrounded by 17,612 20" and 25,600 3" PMTs, JUNO's capabilities extend to probing various aspects of atmospheric neutrinos, including the neutrino interaction model, flavor discrimination, directionality, and energy reconstructions. This capability significantly enhances the NMO analysis of reactor antineutrinos by incorporating the matter-dominated oscillations of atmospheric neutrinos, which will be the main focus of this talk.

T 53.7 Wed 17:30 Geb. 20.30: 2.058

**Calibration and Simulation of a Kaon Quenching Experiment for Proton Decay Search with JUNO** — •Ulrike Fahrendholz[1], Sarah Braun[1], Selina Rudolph[1], Korbinian Stangler[1], Lothar Oberauer[1], Hans Th. J. Steiger[1,2], and Matthias Raphael Stock[1] — [1]TUM School of Natural Sciences, Physics Department, James-Franck-Str. 1, 85748 Garching — [2]PRISMA$^+$ Cluster of Excellence, Staudingerweg 9, 55128 Mainz

Grand Unified Theories (GUTs) are able to describe proton decay processes as they allow conversion reactions between quarks and leptons. The predictions of numerous supersymmetric GUTs are tested by searching for their main proton decay channel $p \rightarrow K^+\bar{\nu}$. Currently, the lower lifetime limit $5.9 \times 10^{33}$ years has been set by the Super-Kamiokande Collaboration using a water-Cerenkov detector. By using a large liquid scintillator target mass, the Jiangmen Underground Neutrino Observatory (JUNO) aims to reach a sensitivity of $9.6 \times 10^{33}$ years based on a total exposure of 200 kton · years.

JUNO's detection efficiency can be further improved by modeling the signal structure of the decay kaon, especially it's quenching behavior. The UniKaon experiment was designed to determine the kaon's Birks' factor by independent detection of the deposited energy and light output. In this talk, I present the current status of calibration and a full light propagation simulation.

This work is supported by the Clusters of Excellence Origins and PRISMA$^+$ and the DFG Collaborative Research Center "NDM" (SFB1258).

T 53.8 Wed 17:45 Geb. 20.30: 2.058

**Measurement of Proton Recoil Quenching Factors in Liquid Scintillators for Neutrino Detectors** — H. Steiger[1,2], •J. Firsching[1], D. Dörflinger[1], U. Fahrendholz[1], and M. R. Stock[1] — [1]Physik-Department, Technische Universität München, James-Franck-Str. 1, 85748 Garching — [2]Johannes Gutenberg University Mainz, Cluster of Excellence PRISMA+, Staudingerweg 9, 55128 Mainz

Several next-generation neutrino detectors, such as JUNO and JUNO-TAO, are currently under construction. They, as well as the planned THEIA observatory, are intended to break new ground in neutrino physics and achieve unprecedented energy and vertex resolution. To exploit the full potential of these detectors, a robust absolute energy scale determination for several particle species is crucial. In this talk, the measurement of neutron-induced proton recoil ionization quenching utilizing quasi-monoenergetic neutrons from the 7Li(p,n)7Be nuclear reaction is presented. Therefore, bunched proton beams with 3.5 MeV to 5.5 MeV energy provided by the INFN-LNL CN Van-De-Graaff accelerator were used. Severel novel liquid scintillation cocktails were investigated. This work is supported by the Cluster of Excellence PRISMA+ at the Johannes Gutenberg University in Mainz, the Cluster of Excellence ORIGINS, the Collaborative Research Center 1258, and the DFG Research Units 2319 and 5519.

# T 54: Cosmic rays 5

Time: Wednesday 16:00–18:00 Location: Geb. 20.30: 2.059

T 54.1 Wed 16:00 Geb. 20.30: 2.059

**Tidal Disruption Events as the origin of UHECR** — •Pavlo Plotko[1], Chengchao Yuan[1], Cecilia Lunardini[2], and Walter Winter[1] — [1]Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, 15738 Zeuthen, Germany — [2]Department of Physics, Arizona State University, 450 E. Tyler Mall, Tempe, AZ 85287-1504 USA

We present a detailed study of the contribution of Tidal Disruption Event (TDE) populations to the spectrum and composition of ultra-high-energy cosmic rays (UHECRs) and the corresponding neutrino flux. We categorize TDEs into three distinct populations: those similar to the AT2019dsg, AT2019fdr, and AT2019aalc events. We find that the dominant contribution to the UHECR and the neutrino flux at EeV energies comes from the aalc-like population. Additionally, we investigate various models of disrupted stars, including Main Sequence (MS), Red Super Giants (RSG), Wolf-Rayet (WR) stars, Carbon-Oxygen White Dwarfs (CO-WD), and Oxygen-Neon-Magnesium White Dwarfs (ONeMg-WD). Our findings indicate that an enhancement in the acceleration of heavy nuclei is essential to account for the observed composition data of UHECRs. We present predictions of the diffuse neutrino EeV fluxes observable by future neutrino observatories such as IceCube-Gen2, RNO-G, and GRAND.

T 54.2 Wed 16:15 Geb. 20.30: 2.059

**The Impact of the Temporal Luminosity Evolution on the Signal of Ultra-High-Energy Cosmic Rays** — •Magdalena Litwin[1,2], Björn Eichmann[1,2], and Julia Becker Tjus[1,2,3] — [1]Theoretical Physics IV, Plasma Astroparticle Physics, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — [3]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

While the origin of cosmic rays at the highest energies remains unclear to date, nearby radio galaxies are considered as potential candidates. Limiting the sources of ultra-high-energy cosmic rays (UHECR) to such a small number, their finite lifetime would have a significant impact on the resulting energy spectrum and mass composition at Earth. This is due to the so-called magnetic horizon effect that yields hard spectra of the individual CR nuclei. In this work, we illustrate this effect and examine its influence by an analysis of different potential source luminosity evolutions. The results demonstrate a good agreement with the experimental data, if the sources have shown an increased luminosity in the past according to either a normal or log-normal evolution.

T 54.3 Wed 16:30 Geb. 20.30: 2.059

**UHECR probability distributions in bursting sources** — •Leonel Morejon — Wuppertal University, Gaußstr. 20, 42119 Wuppertal

The origin of Ultra-High Energy Cosmic Rays (UHECRs) is still unknown, although much progress has been made in understanding the necessary conditions to produce them. The current list of potential sources is reduced to a few classes of extreme phenomena, many of which are transient or experience variable emission (bursts). Source parameters (luminosity, size, magnetic field, etc.) may be inferred from the observed electromagnetic emissions, but estimating the ejected UHECRs requires knowledge of the injected composition and precise modelling of the nuclear interactions producing nuclear cascades. This means computing the energy densities of ~100 nuclear species for a wide range of initial conditions and source scenarios accurately and fast. A framework able to do this within seconds would be a strong asset in the study of UHECR sources. This contribution discusses ongoing efforts to develop such framework with a novel stochastic approach to describe the interactions and cascades of UHECRs up to their escape from the source. Results are shown for examples of bursting sources where possible ejected compositions are obtained with associated likelihoods. The efficiency and simplicity of the approach is demonstrated by comparison with the Monte Carlo code CRPropa widely employed to simulate nuclear interactions in the propagation of UHECRs.

*Funded by the Deutsche Forschungsgemeinschaft through project MICRO (KA/710-5).*

T 54.4 Wed 16:45 Geb. 20.30: 2.059

**The ABC of UHECR source searches: Charting cosmic paths with Bayesian statistics** — Nadine Bourriche and •Francesca Capel — Max Planck Institute for Physics, Garching bei München, Germany

UHECRs at the most extreme energies provide strong constraints on their possible sources. We propose to use the reconstructed properties of individual detected UHECRs to map out three-dimensional constraints on the locations of their unknown sources. In this work, we focus on three events detected by the Pierre Auger Observatory and three events detected by Telescope Array and use CRPropa 3 to model all relevant propagation effects, including deflections in the Galactic and extra-Galactic magnetic fields. We consider key input quantities such as distance, position, and spectral index as free parameters and five mass group representatives, H, He, N, Si, and Fe for the source composition. We use Approximate Bayesian Computation (ABC) to derive constraints on the source locations for these six events and demonstrate the impact of uncertainties in the reconstructed UHECR properties on these results. We also highlight possible astrophysical sources that are compatible with these regions and requirements. This complementary perspective serves as a foundation for building more physically-motivated source catalogues and statistical analyses in the future.

T 54.5 Wed 17:00 Geb. 20.30: 2.059

**Comparison of surface-detector based mass estimators for UHECR observatories** — Lorenzo Apollonio[1,2], Lorenzo Caccianiga[1,2], Martin Erdmann[4], Jonas Glombitza[5], Niklas Langner[4], Markus Roth[3], •Maximilian Stadelmaier[1,2,3], and Darko Veberic[3] — [1]INFN, Milano, Italy — [2]UNIMI, Milano, Italy — [3]KIT, Karlsruhe, Germany — [4]RWTH, Aachen, Germany — [5]ECAP, Erlangen, Germany

Ultrahigh-energy cosmic rays (UHECRs) might be the messengers of the most extreme events in our extra-galactic neighborhood. To conduct arrival direction studies with high-rigidity particles only, however, their mixed mass composition necessitates the discrimination of heavy and light nuclei. Using the surface-detector data of an UHECR observatory, this is challenging and only possible by estimating mass-sensitive observables indirectly.

We present recent developments of event-level mass estimators for UHECRs, using data collected by the surface detector of the Pierre Auger Observatory. In detail, we compare the functionality and performance of classical likelihood-based fit models against deep neural networks. Furthermore, we discuss the expected increase in performance for Phase 2 of the Observatory.

T 54.6 Wed 17:15 Geb. 20.30: 2.059

**Parameterising the lateral distribution function for the SD-750 array of Auger including small signals** — •Philipp Meder for the Pierre-Auger-Collaboration — KIT, IAP

Implementation of triggers sensitive to smaller signals in the surface detector array (SD) of the Pierre Auger Observatory requires changes to the signal likelihood formalism used in the reconstruction of the lateral distribution function (LDF) and the energy of events. In this contribution, we discuss the choice of the LDF shape and changes in the likelihood minimisation for events recorded by the array with 750 m detector spacing (SD-750) of the Observatory. We present a new approach for the SD reconstruction, which will enable us to retune the LDF parameterisation and derive an updated spectrum for the energy range of cosmic rays between $10^{17.5}$ to $10^{18.5}$ eV.

T 54.7 Wed 17:30 Geb. 20.30: 2.059

**Detecting cosmic rays with the LOFAR radio telescope** — •Karen Terveer — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

The LOw Frequency ARray (LOFAR) is the worlds largest radio telescope. With antenna fields distributed across Europe and its core in the Netherlands, it can be used for various astronomical observations. One of the key science questions is the measurement of radio signals from cosmic ray induced air showers.

The existence of radio emission from air showers has been known since the seventies, but only the past decade brought the powerful digital signal processing techniques needed to study it. Now radio is a powerful tool for the investigation of cosmic rays - with various advantages over more traditional methods. LOFAR is one of the pathfinder experiments paving the way for next generation radio telescopes such as the Square Kilometre Array (SKA).

An important challenge to overcome is the high amounts of data, noise and the computationally expensive reconstruction of an air shower event. A new reconstruction method utilising the Bayesian inference based Information Field Theory (IFT) could be a possible solution to this.

T 54.8 Wed 17:45 Geb. 20.30: 2.059

**Accessing the Cosmic-Ray Energy Scale with the Auger Engineering Radio Array** — •Max Büsken[1,2] and Tim Huege[3,4] for the Pierre-Auger-Collaboration — [1]ETP, KIT, Karlsruhe, Germany — [2]ITeDA, UNSAM, Buenos Aires, Argentina — [3]IAP, KIT, Karlsruhe, Germany — [4]Astrophysical Institute, VUB, Brussels Belgium

The Pierre Auger Observatory is the largest ground-based observatory for the detection of extensive particle showers in air induced by ultra-high energy cosmic rays. It is situated in the Argentinian Pampa near the city of Malargüe. Multiple different detectors are operated and allow for hybrid measurements of the same shower. An absolute calibration of the reconstructed cosmic-ray energies is determined with the fluorescence detector (FD) and transferred to the surface detector (SD) through cross-calibrations.

The radio detection of air showers provides an independent access to the cosmic-ray energy scale. At the Pierre Auger Observatory, the radio detection is so far performed with the Auger Engineering Radio Array (AERA), and within the next year will be extended to the highest energies with the upcoming Radio Detector. The hybrid detector environment allows to compare the energy scales set by FD and AERA. In this contribution, we show how we can independently determine the cosmic-ray energy scale at the Pierre Auger Observatory with hybrid measurements from AERA and SD.

*This research was supported by the Bundesministerium für Bildung und Forschung (BMBF) under the contract 05A20VK1.

# T 55: Methods in particle physics 4 (HCAL, jets)

Time: Wednesday 16:00–17:45 Location: Geb. 20.30: 2.066

T 55.1 Wed 16:00 Geb. 20.30: 2.066

**Improving Hadron Reconstruction in the Belle II Electromagnetic Calorimeter using Graph Neural Networks** — •Jonas Eppelt, Isabel Haide, and Torben Ferber — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Our aim is to refine hadron reconstruction in the Belle II Electromagnetic Calorimeter (ECL), specifically addressing overlapping clusters. We are using Graph Neural Network (GNN) architectures, such as GravNet, to enhance clustering accuracy. Improving clustering precision holds significant implications for physics analyses, especially in searches for final states that include missing energy like $B \rightarrow K\nu\bar{\nu}$. These searches will profit from refined selection criteria. This presentation outlines our ongoing efforts to optimize hadron clustering using GNNs, aiming for better precision within the Belle II ECL.

T 55.2 Wed 16:15 Geb. 20.30: 2.066

**Novel techniques for measuring the jet energy resolution from dijet events at CMS** — •Yannick Fischer[1], Johannes Haller[1], Andrea Malara[2], Alexander Paasch[1], Daniel Savoiu[1], and Matthias Schröder[1] — [1]Institut für Experimentalphysik, Universität Hamburg — [2]Université libre de Bruxelles

The jet energy is a key observable in almost all analyses of the CMS experiment at the LHC, and hence, precise knowledge of the jet energy resolution (JER) is crucial for both measurements and searches. In this talk, a brief overview of the basic concept and the techniques used at CMS to measure the JER from dijet events will be given. Then, a new method will be introduced, based on the missing transverse momentum fraction. Latest results with recent CMS data will be shown. Finally, the implementation of the JER measurement in a new, columnar-based framework will be discussed, and the advantages of this framework for the measurement of the JER will be highlighted.

T 55.3 Wed 16:30 Geb. 20.30: 2.066

***In Situ* Calibration of Large-Radius Jets Using the Direct Balance Method with $Z$+jets Events in ATLAS** — •Donna Maria Mattern and Chris Malena Delitzsch — TU Dortmund, Fakultät Physik

The calibration of the jet energy scale (JES) is a critical step in the preparation of jets that are utilized in precision measurements, as well as searches for physics beyond the Standard Model. Large-radius ($R = 1.0$) jets are reconstructed from unified flow objects which combine calorimeter signals with charged-particle tracks in the inner detector of the ATLAS detector to achieve optimal performance across a wide kinematic range. They are groomed in order to remove contributions from pile-up. After a Monte Carlo (MC) based calibration to the energy and mass scale of particle-level jets, an *in situ* calibration of the JES is performed to remove residual differences between data and MC simulated samples due to passive detector material, effects of the jet reconstruction algorithm, fragmentation, or pile-up. Different methods are combined to provide a calibration over a wide kinematic range. The direct balance method using $Z$+jets events, where the $Z$-boson decays into charged-lepton pairs, uses a selection with a back-to-back topology of the large-radius jets and the $Z$-bosons. Scale factors are derived to calibrate the large-radius jet's transverse momentum to the one of the well-calibrated reference object given by the reconstructed $Z$-boson. Data collected by the ATLAS detector in proton-proton collisions of LHC-Run 2, and corresponding MC simulated samples are used for the studies.

T 55.4 Wed 16:45 Geb. 20.30: 2.066

**Measurement of single charged pion energy response of the ATLAS calorimeter from $W^{\pm} \to \tau^{\pm}(\to \pi^{\pm}\nu_{\tau})\nu_{\tau}$ events in LHC Run 2 and Run 3** — •Anubhav Gupta and Chris Malena Delitzsch — TU Dortmund Germany

Jets are collimated sprays of charged and neutral hadrons (or their decay products) resulting from energetic proton-proton collisions. In the ATLAS experiment, the energy of these particles is measured in calorimeters, while the momentum of charged particles is determined by the tracking system. To reconstruct jets, a particle-flow algorithm combines the information from both systems. The calibration of the jet energy scale relies heavily on the accurate simulation of hadron interactions with the calorimeter. Hence, gaining a better understanding of the calorimeter's energy response is essential. A powerful method to achieve this is by analyzing the ratio of the energy ($E$) of hadrons reconstructed in the calorimeter to the momentum ($p$) measured in the well-aligned tracking system. Charged pions from $\tau$-decays provide a sample of high-$p_{\mathrm{T}}$ isolated particles to probe the higher energy regime where the *in-situ* measurements (at jet level) run out of statistics. A $E/p$ measurement was performed using single charged pions events from $\tau$-decays for Run 2 in a previous ATLAS software release. The detector simulation, using GEANT4, has been tuned on the results from this $E/p$ measurement for LHC Run 3. In the talk, $E/p$ measurement using single charged pions events from $\tau$-decays for LHC Run 2 in current software release and for LHC Run 3 is presented.

T 55.5 Wed 17:00 Geb. 20.30: 2.066

**Event reconstruction in the CMS High-Granularity Calorimeter** — •Wahid Redjeb[1,2], Felice Pantaleo[2], Alexander Schmidt[1], and Marco Rovere[2] — [1]III. Physikalisches In- stitut A, RWTH Aachen University, Aachen, Germany — [2]CERN Geneva, Switzerland

The High-Granularity Calorimeter (HGCAL) will be a sampling calorimeter with both lateral and longitudinal fine granularity designed for the High-Luminosity LHC. The calorimeter will use silicon sensors, in the high radiation regions, providing high pile-up mitigation, and scintillators in the low radiation regions. For the physics object reconstruction a dedicated framework for HGCAL is currently under development: The Iterative Clustering (TICL), which utilizes the 5D (x,y,z,t,E) information from the reconstructed hits and returns particle properties and probabilities. Heterogeneous computing will play a fundamental role in the physics object reconstruction software to fully exploit the reach of the HL-LHC. Performance Portability libraries allow writing a single code basis that can be executed on different hardware architectures. In this talk we present and overview of the TICL framework and we show how heterogeneous computing has been integrated in the framework exploiting the Alpaka library. Additionally, we highlight the TICL Framework's capabilities to perform Particle Flow reconstruction in the challenging endcap region.

T 55.6 Wed 17:15 Geb. 20.30: 2.066

**Extending the TICL Framework to the CMS Barrel Calorimeters** — •Alessandro Brusamolino[1], Felice Pantaleo[2], Marco Rovere[2], and Markus Klute[1] — [1]Institut für Experimentelle Teilchenphysik, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]CERN, Geneva, Switzerland

The Iterative CLustering (TICL) is a reconstruction framework which is being developed for the High-Granularity Calorimeter (HGCal), a sampling calorimeter which will be installed in the CMS endcaps for the HL-LHC phase. These reconstruction algorithms aim at reconstructing physical objects starting from 5D hits (position, energy and time), returning particle properties and identification probabilities, and are designed with heterogeneous computing in mind, in order to speed up reconstruction time. In this talk we give an overview of the first efforts in extending TICL to the barrel calorimeters and present the benefits of having the same framework used across all of the CMS calorimeters, both in terms of physics and computing performances. Moreover, we discuss the need for a revision of the data structures used in the reconstruction software, in order to run it in an efficient way, fully exploiting the capabilities of parallel architectures.

T 55.7 Wed 17:30 Geb. 20.30: 2.066

**Studies of the SND@LHC HCAL SiPM PCB using dedicated laser measurements** — •Andrew Conaboy, Heiko Lacker, Anupama Reghunath, and Eduard Ursov — Humboldt University of Berlin

The Scattering and Neutrino Detector at the LHC (SND@LHC) is a compact experiment installed 480 m from the ATLAS interaction point. SND@LHC allows for a novel investigation of all three neutrino flavours in the pseudo-rapidity range $7.2 < \eta < 8.6$, with energies from 100 GeV to the TeV scale. Last year the SND@LHC collaboration published the observation of LHC muon-neutrino deep inelastic scattering (DIS) charged current interactions. The collaboration requires an energy calibration of the HCAL to reconstruct the energy deposition from the hadronic final states of DIS. This requirement necessitates dedicated laser studies in order to understand how effects such as timewalk and signal saturation impact the timing and charge digitisation of the SiPM PCB used in the HCAL of SND@LHC. Latest results from these laser studies are presented in this contribution.

# T 56: Methods in astroparticle physics 3

Time: Wednesday 16:00–18:00 Location: Geb. 20.30: 2.067

T 56.1 Wed 16:00 Geb. 20.30: 2.067

**Design of a co-deployed stratigraphy logger for the IceCube Upgrade and IceCube Gen2** — •Anna Eimer and Martin Rongen for the IceCube-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

A precise understanding of the optical properties of the instrumented Antarctic ice sheet is crucial to the performance of the IceCube Neutrino Observatory and its planned successor, IceCube-Gen2.

The ice optical properties are driven by impurities deposited with the snow that formed the ice and thus layers of constant optical properties form a stratigraphy. Due to the underlying bedrock, these layers undulate over the large lateral footprints of these detectors.

Within IceCube, the layer undulations have originally been mapped using stratigraphy measurements by a stand-alone laser dust logger. It required a dedicated deployment setup, as it was not located on the main sensor cables. This resulted in significantly increased costs.

In this talk, I will summarize the modeling of ice layer undulations and describe a newly started project to replace the stand-alone dust logger. It consists of a light source that can be co-deployed with the photosensor modules and operated during the deployment of the detector. The newly developed device is planned to be tested during the deployment of the IceCube Upgrade in 2025/26, so to ensure success during IceCube-Gen2.

T 56.2 Wed 16:15 Geb. 20.30: 2.067

**Design and Construction of the Acoustic Module for the IceCube Upgrade** — •Andreas Nöll, Jan Audehm, Charlotte Benning, Jürgen Borowka, Pierre Dierichs, Mia Giang Do, Oliver Gries, Christoph Günther, Dirk Heinen, Adam Rifaie, Joëlle Savelberg, Christopher Wiebusch, and Simon Zierke for the IceCube-Collaboration — III. Physikalisches Institut B, RWTH Aachen University

The IceCube Neutrino Observatory is a cubic kilometer size detector located at the geographic South Pole, consisting of 5160 Digital Optical Modules (DOMs). In the Antarctic summer 2025/26 more than 700 new modules will be installed as part of the IceCube Upgrade. These include ten Acoustic Modules (AMs), capable of transmitting and receiving acoustic signals between 5 and 30kHz. Additionally, up to 30 acoustic receivers will be located in new DOMs. Goal of these devices is improving the geometry calibration based on multilateration of the measured acoustic propagation times. This talk presents the design and construction of AMs, including the acoustic transducer and its internal electronics.

T 56.3 Wed 16:30 Geb. 20.30: 2.067

**Calibration and Characterization of the Acoustic Module for the IceCube Upgrade** — •Pierre Dierichs, Jan Audehm, Charlotte Benning, Jürgen Borowka, Mia Giang Do, Oliver Gries, Christoph Günther, Dirk Heinen, Andreas Nöll, Adam Rifaie, Joëlle Savelberg, Christopher Wiebusch, and Simon Zierke for the IceCube-Collaboration — III. Physikalisches Institut B, RWTH Aachen

The IceCube Neutrino Observatory detects high-energy neutrinos from astrophysical sources. One factor limiting the angular resolution is the imprecise knowledge of the detector geometry. A planned extension of the detector, called the IceCube Upgrade, will address this issue. It consists of over 700 additional modules, comprising optical modules and calibration devices, in the central region. These calibration devices include ten Acoustic Modules, each capable of sending and receiving acoustic signals. Their deployment enables the calibration of the detector geometry via multilateration of transit times of these signals. We present the tests to characterize the Acoustic Modules, performed in the laboratory, a swimming pool, and a lake.

T 56.4 Wed 16:45 Geb. 20.30: 2.067

**The LED calibration system of the IceCube Upgrade** — •Martin Rongen for the IceCube-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen Nürnberg

The IceCube Neutrino Observatory, instrumenting about 1 $km^3$ of deep, glacial ice at the geographic South Pole, is due to be enhanced with the IceCube Upgrade. The IceCube Upgrade will be deployed during the 2025/26 Antarctic Summer season, consisting of seven new columns of photo sensors. It targets neutrino oscillations and improvements to the calibration of the optical properties of the instrumented ice, thereby improving the angular and energy resolution of archival and new neutrino events. For this purpose, the Upgrade will include a host of new calibration devices. These include several thousand pulsed LEDs incorporated into the photosensor modules. The array of LEDs and photo sensors will allow us to improve our knowledge on the light propagation in the instrumented ice. Here, we describe the design and production of this LED system as well as testing prior to integration into the sensor modules.

T 56.5 Wed 17:00 Geb. 20.30: 2.067

**Absolute calibration of the light source for the end-to-end calibration of the Fluorescence Detector of the Pierre Auger Observatory** — •Julian Rautenberg and Baobiao Yue for the Pierre-Auger-Collaboration — Bergische Universität Wuppertal, Wuppertal, Germany

The accurate reconstruction of the cosmic ray energy by the Fluorescence Detector (FD) is a most crucial part of the hybrid detection used at the Pierre Auger Observatory. Therefore, the absolute calibration of the FD is vitally important, since it determines the energy scale of the Observatory. However, the previous calibration method was difficult to carry out and required a lot of manpower. To address this issue, a new calibration system, the XY-Scanner, was designed and is currently operating. The system consists of a light source, which scans across the front of each FD telescope with frequent isotropic light pulses. To calibrate the FD with this source, precise measurements of the emitted intensity and the angular profile of the photons in each pulse are needed. A calibration bench was designed for this purpose, which includes measurements from a calibrated photo-diode and a PMT. With the addition of rotation and translation stages, the angular and distance-dependent profiles of the light source are also measured. The current uncertainty of the absolute source calibration is less than 4%. The focus of this contribution is on the setup, operation, and analysis of data on this bench.

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T 56.6 Wed 17:15 Geb. 20.30: 2.067

**Relative Calibration of the Fluorescence Detector of the Pierre Auger Observatory using the Night Sky Background** — •Hendrik Pfau for the Pierre-Auger-Collaboration — Karslruher Institut für Technologie, Germany

The Fluorescence Detector of the Pierre Auger Observatory is used for a calorimetric measurement of the primary energy of cosmic rays. Precise calibration of the Fluorescence Detector is important for accurate energy measurements. Currently, the relative calibration performed every night is monitoring the response of the camera, but changes of the optical efficiency of the mirror and the aperture (e.g. due to accumulation of dust) are not measured. In this presentation we will discuss how the night sky background can be used for a relative calibration of the telescopes. In particular the border regions of neighboring telescopes, which measure the same night sky, are studied to determine the relative calibration of telescopes and to measure its dependence on the elevation angle viewed by the pixel.

T 56.7 Wed 17:30 Geb. 20.30: 2.067

**Development of a high temperature superconducting cable for applications in space** — •Laurenz Klein, Daniel Louis, Irfan Özen, Dominik Pridöhl, Stefan Schael, Thorsten Siedenburg, Christian von Byern, and Michael Wlochal — Physics Institute I B, RWTH Aachen University

While AMS-02 is currently operated on board of the International Space Station, AMS-100, a next generation particle detector is already planned. For a substantial improvement on AMS-02's geometrical acceptance and rigidity range, the AMS-100 particle detectors are placed inside a High Temperature Superconductor (HTS) solenoid core and it is foreseen to operate at L2. For a magnetic field of 0.5T generated by a current of 10kA, the cables will contain multiple HTS tape layers. To keep the magnet transparent for particles, the HTS tapes are stabilized in aluminium profiles with a thickness of only a few millimeters. Suitable cables are currently under development at RWTH Aachen. Starting with short samples with lengths up to a meter, a cable design is tested that is scalable to the 5 km length of the AMS-100 cable. In this talk, electromagnetic HTS simulation and measurement results of different samples and designs will be presented and discussed.

T 56.8 Wed 17:45 Geb. 20.30: 2.067

**Time Resolution of the AMS-100 Time-of-Flight Detector at Cryogenic Temperatures** — •Jule Deiters, Chanhoon Chung, Waclaw Karpinski, Thomas Kirn, Daniel Louis, Stefan Schael, and Michael Wlochal — I. Physikalisches Institut B, RWTH Aachen University

The next generation magnetic spectrometer in space, AMS-100, is designed with a geometrical acceptance of 100 $m^2sr$ for a ten year operation at Sun-Earth Lagrange Point 2. The purpose of AMS-100 is to improve the sensitivity for the observation of new phenomena in cosmic rays by at least a factor of 1000 compared to AMS-02.

The AMS-100 detector consists of a high temperature superconducting solenoid, an electromagnetic calorimeter, a tracking system made out of silicon and scintillating fibre modules, and a Time-of-Flight (ToF) system based on fast plastic scintillators read out by silicon photomultipliers (SiPMs).

The ToF system at Lagrange Point 2 will be operated at temperatures between 50 K and 200 K, so the detectors and scintillators need to be tested at cryogenic temperatures.

At room temperature, ToF-prototypes with (6 x 25 x 90) $mm^3$ EJ-228 scintillators from Eljen Technology read out by either Hamamatsu S14161-6050HS or Broadcom AFBR-S4N66C013 SiPMs yield time resolutions of (38.45 ± 0.19) ps and (42.88 ± 0.98) ps, respectively.

Time resolution measurements with the ToF-prototypes in the temperature range of 243 K to 77 K will be discussed.

## T 57: Neutrino physics 7

Time: Wednesday 16:00–18:00 Location: Geb. 30.21: Gerthsen-HS

T 57.1 Wed 16:00 Geb. 30.21: Gerthsen-HS

**The Taishan Antineutrino Observatory** — •Hans Theodor Josef Steiger — Physik-Department, Technische Universität München, James-Franck-Str. 1, 85748 Garching, Germany — Johannes Gutenberg University Mainz, Cluster of Excellence PRISMA+, Staudingerweg 9, 55128 Mainz, Germany

The Taishan Antineutrino Observatory (TAO or JUNO-TAO) is a satellite detector for the Jiangmen Underground Neutrino Observatory (JUNO). JUNO will use reactor antineutrinos at a baseline of about 53 km to probe the interference effects between the two atmospheric mass-squared differences, which are sensitive to the sign of the mass ordering. Located near the Taishan-1 reactor, TAO independently measures the antineutrino energy spectrum of the reactor with unprecedented energy resolution and by that uncovering its fine structure for the first time. Beyond that, TAO is expected to make world-leading time-resolved measurements of the yield and energy spectra of the main isotopes involved in the antineutrino emission of nuclear reactors. By that TAO will provide a unique reference for other experiments and nuclear databases. In order to achieve its goals, TAO is relying on cutting-edge technology, both in photosensor and liquid scintillator (LS) development which is expected to have an impact on future neutrino and Dark Matter detectors. In this talk, the design of the TAO detector with special focus on its new detection technologies will be introduced. In addition, an overview of the progress currently being made in the R&D for photosensor and LS technology in the frame of the TAO project will be presented.

T 57.2 Wed 16:15 Geb. 30.21: Gerthsen-HS

**Time Profile Measurements of the Cooled TAO Liquid Scintillator** — •Matthias Raphael Stock[1], Hans Th. J. Steiger[1,2], Manuel Böhles[2], David Dörflinger[1], Ulrike Fahrendholz[1], Meishu Lu[1], Lothar Oberauer[1], and Korbinian Stangler[1] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department, James-Franck-Str. 1, 85748 Garching — [2]Johannes Gutenberg University Mainz, Cluster of Excellence PRISMA+, Staudingerweg 9, 55128 Mainz

The main physics goal of Jiangmen Underground Neutrino Observatory (JUNO) is the determination of the neutrino mass ordering by the detection of the oscillated electron antineutrino energy spectrum from reactors at medium-baselines. JUNO will have a satellite detector called Taishan Antineutrino Observatory (JUNO-TAO) to measure the unoscillated spectrum at unprecedented resolution. The novel detector technologies require TAO to have an operation temperature of minus 50 degrees. We studied the fluorescence time profile of the TAO liquid scintillator at room and cold temperatures. We performed measurements using radioactive sources and pulsed neutron beams of different energies at the CN accelerator of INFN Laboratori Nazionali di Legnaro. Different time profiles after recoil electron and recoil proton excitation allow to perform pulse shape discrimination and therefore advance the ability to distinguish the neutrino signal from background.

This work is supported by the Collaborative Research Center NDM (SFB 1258), the DFG Research Units 2319 and 5519, and the Clusters of Excellence PRISMA+ and Origins.

T 57.3 Wed 16:30 Geb. 30.21: Gerthsen-HS

**CRES demonstrator design optimization based on CRES signal decoding with likelihood techniques** — •René Reimann, Florian Thomas, Sebastian Böser, and Martin Fertl for the Project 8-Collaboration — Institute of Physics and Cluster of Excellence PRISMA+, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

While neutrino flavor oscillations prove neutrinos have mass, the absolute neutrino mass remains undetermined. Direct kinetic approaches rely on the high-resolution measurement of the beta decay electron spectrum close to its endpoint. The current state-of-the-art MAC-E filter technique is not scalable to larger sources and statistics; therefore, the cyclotron radiation emission spectroscopy (CRES) method has been proposed as an alternative method with potentially greater sensitivity reach. For CRES, the beta-decay electron emits cyclotron radiation in a magnetic mirror trap. The radiation is picked up by receivers, amplified and digitized. For competitive neutrino mass searches, the CRES technique must be scaled up and demonstrated in large-scale volumes. The signal structure from the measured electron radiation is complex, and the impact of apparatus design choices, e.g. the magnetic trap shape, is not straightforward. Therefore, we apply a likelihood-based reconstruction method to investigate the likelihood landscape with simulated data in the region around the Monte Carlo truth to extract the complete information encoded in the signal. As an example, we discuss the impact of magnetic trap designs on the energy resolution obtained by the likelihood reconstruction.

T 57.4 Wed 16:45 Geb. 30.21: Gerthsen-HS

**Simulation and event reconstruction in NuDoubt++** — Manuel Böhles[1], Sebastian Böser[1], Magdalena Eisenhuth[1], Chloé Girard-Carillo[1], Bastian Kessler[1], •Kyra Mossel[1], Stefan Schoppmann[2], Alfons Weber[1], and Michael Wurm[1] for the NuDoubt-Collaboration — [1]Johannes Gutenberg-Universität Mainz, Institut für Physik, 55128 Mainz, Germany — [2]Johannes Gutenberg-Universität Mainz, Detektorlabor, Exzellenzcluster PRISMA+, 55128 Mainz, Germany

NuDoubt$^{++}$ searches for neutrinoless double beta plus decay with opaque scintillators. These scintillators have a very short scattering length but long absorption length and can be used to confine the light emitted after particle interactions in a small detector volume. A dense grid of wavelength shifting optical fibers deployed in the scintillating material and equipped with SiPMs then enables the detection of a significant fraction of the emitted photons. This approach allows efficient identification of particles as well as a precise reconstruction of the particles energy.

Photon propagation in such a detector can be approximated using diffusion models. However, this does not take into account shadowing effects of the deployed fibers, which can lead to significant differences in the expected photon counts. This effect can be corrected using MC simulations. In this presentation, the event reconstruction based on a diffusion model is shown.

T 57.5 Wed 17:00 Geb. 30.21: Gerthsen-HS

**Update on the ECHo experiment** — •Raghav Pandey for the ECHo-Collaboration — Kirchhoff Institute for Physics, Heidelberg University

In the ECHo experiment large arrays of low temperature metallic magnetic calorimeters (MMCs) enclosing Ho-163 are used for the high resolution measurement of the electron capture spectrum. The goal of the experiment is to achieve the sensitivity to detect an extremely small spectral shape distortion in the end point region due to a finite neutrino mass. Thanks to the modular construction of the experiment, several phases have been foreseen. The first phase, ECHo-1K was designed to test the properties and reproducibility of MMCs with implanted Ho-163. With a small scale experiment a sensitivity on the effective electron neutrino mass 10 times better than the present limit of 150 eV at 90% C.L. can be achieved. Presently, studies to reduce systematic effects on the interpretation of the spectrum and small experiments for the quantification of systematic errors are on-going. At the same time, preparation of large detector arrays and multiplexed readout for the ECHo-100k phase is on-going. Important milestones for detector fabrication, in particular related to Ho-163 implantation on wafer scale, have been reached. We present the status of ECHo-100k and discuss our perspectives for achieving a sensitivity at the 1 eV/c2 level for the effective electron neutrino mass.

T 57.6 Wed 17:15 Geb. 30.21: Gerthsen-HS

**Activity of Ho-163 in wafer-scale implanted ECHo-100k chips** — •Marta Kruhlik[1], Arnulf Barth[1], Sebastian Berndt[2,3], Terese Buchta[1], Holger Dorrer[3], Christoph E. Düllmann[3,4,5], Loredana Gastaldo[1], Daniel Hengstler[1], Nina Kneip[2], Raghav Pandey[1], Daniel Unger[1], and Klaus Wendt[2] — [1]Kirchhoff Institute for Physics, Heidelberg University — [2]Institute of Physics, Johannes Gutenberg-Universität Mainz — [3]Department of Chemistry - TRIGA Site, Johannes Gutenberg-Universität Mainz — [4]GSI Helmholtzzentrum Darmstadt — [5]Helmholtz Institute Mainz

The primary objective of the ECHo collaboration is to determine the neutrino mass scale by analysing the endpoint region of the Ho-163 electron capture spectrum. To be sensitive to the effect of a finite neutrino mass on the spectral shape, high energy resolution and the acquisition of many Ho-163 events are mandatory. Using arrays of many MMCs to acquire the spectrum, an energy resolution better than 5 eV FWHM has already been demonstrated. For the ECHo-100k phase, more than 100 chips are planned, each comprising 64 detector pixels with an activity of around 10 Bq per pixel. An efficient production of these detectors requires the possibility to implant Ho-163 on the entire 3 inch wafer. A first test of the wafer-scale implantation has been performed using the RISIKO facility at Mainz University. We present the results obtained through the characterization of several pixels in three chips and discuss the determined activity and its homogeneity across a chip and the wafer. Then we conclude with a perspective on the fabrication of the required detectors for the ECHo-100k experiment.

T 57.7 Wed 17:30 Geb. 30.21: Gerthsen-HS

**Insight into the Neural Network Analysis of the KATRIN Neutrino Mass Data** — Christoph Köhler, Susanne Mertens, •Jan Plössner, Alessandro Schwemmer, Xaver Stribl, and Christoph Wiesinger for the KATRIN-Collaboration — Chair for Dark Matter E47, Technical University of Munich

The Karlsruhe Tritium Neutrino (KATRIN) experiment probes the effective electron anti-neutrino mass by a precision measurement of the tritium beta-decay spectrum near the endpoint. A world-leading upper limit of 0.8 eV $c^{-2}$ (90 % CL) has been set with the first two measurement campaigns. The combined sensitivity of the first five data sets with six-fold increase in statistics is below 0.5 eV $c^{-2}$ (90 % CL). Since then, the collected statistics was increased by another factor of three.

In this presentation I will talk about the neural network analysis of the KATRIN neutrino mass data and provide an update on the current status beyond the fifth neutrino mass campaign.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6).

T 57.8 Wed 17:45 Geb. 30.21: Gerthsen-HS

**Search for Light Sterile Neutrinos with the KATRIN Experiment using a Neural Network** — •Xaver Stribl and Susanne Mertens for the KATRIN-Collaboration — Chair fo Dark Matter E47, Technical Universityof Munich

Light sterile neutrinos with a mass on the eV-scale could explain several anomalies observed in short-baseline oscillation experiments. The Karlsruhe Tritium Neutrino (KATRIN) experiment is designed to directly determine the effective electron anti-neutrino mass by measuring the tritium beta decay spectrum. The measured spectrum can also be investigated for the signature of light sterile neutrinos.

In this talk we present the status of the light sterile neutrino analysis of the KATRIN experiment. To handle the increasing computational challenge, a neural network is adapted for the analysis and then used to study the sensitivity of the first five measurement campaigns. The obtained sensitivity is compared to current results and anomalies in the field of light sterile neutrinos. Further, the possibility of including the active neutrino mass in the analysis with the neural network is explored.

# T 58: Neutrino physics 8

Time: Wednesday 16:00–18:00 Location: Geb. 30.22: Gaede-HS

T 58.1 Wed 16:00 Geb. 30.22: Gaede-HS

**Synthesis and Applications of Low Background Modified Polyethylene Naphthalate (PEN-G)** — •Brennan Hackett[1], Andreas Leonhardt[2], Maximilian Goldbrunner[2], Peter Bauer[4], Florian Puch[4], and Markus Stommel[3] for the LEGEND-Collaboration — [1]Max-Planck Institut für Physik, Garching, Germany — [2]Technische Universität München, Garching, Germany — [3]Leibniz-Institut für Polymerforschung, Dresden, Germany — [4]Thüringisches Institut für Textil- und Kunststoff-Forschung, Rudolstadt, Germany

Identification of background radiation is of utmost importance for enabling rare event experiments to attain the required sensitivities for probing new physics. Poly(ethylene-2,6-naphthalate) (PEN) has emerged as a highly promising material for such experiments due to its intrinsic scintillating properties and its adaptability as a structural material at both room and cryogenic temperatures. Notably, PEN has been successfully implemented in the LEGEND-200 experiment involving ~200 kg of the target isotope $^{76}$Ge for investigating neutrinoless double beta decay. In LEGEND-200, PEN serves as both an active material and a structural component within the detector assembly. Looking towards the next-generation experiment, LEGEND-1000 will further reduce background radiation by an order of magnitude. To achieve this goal, we are looking to expand more potential applications of PEN-G. To this end, we have successfully synthesized PEN in kilogram batches utilizing unique reagents. The radiopurity of the synthesized PEN has been measured, and we are exploring strategies to improve these values. In this presentation, we will outline the results.

T 58.2 Wed 16:15 Geb. 30.22: Gaede-HS

**Charge Senstive Amplifier R&D for the LEGEND-1000 Experiment** — •Andreas Gieb, Florian Henkes, Susanne Mertens, and Michael Willers for the LEGEND-Collaboration — Physik-Department, Technische Universität München, Germany

The **L**arge **E**nriched **G**ermanium **E**xperiment for **N**eutrinoless $\beta\beta$ **D**ecay (LEGEND) is a ton-scale, $^{76}$Ge-based, experimental program searching for the neutrinoless double-beta ($0\nu\beta\beta$) decay.

The first 200 kg stage of the experiment, LEGEND-200, is currently taking data at Gran Sasso underground laboratory. The 1000 kg phase of the experiment, LEGEND-1000, aims to achieve discovery potential at half- lifes longer than $10^{28}$ years which covers the inverted-ordering neutrino mass scale. In order to achieve this, a significant reduction of background in the signal region of interest is necessary. An important role in this endeavor is a reduction in the background of the readout electronics due to its proximity to the detector, while ultimately improving noise performance and signal fidelity.

This contribution explores a novel approach to ASIC based front-end electronics, and present first results from measurements performed with a high-purity germanium detector.

We acknowledge support by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC 2094 - 390783311 and through the Sonderforschungsbereich (Collaborative Research Center) SFB1258 Neutrinos and Dark Matter in Astro- and Particle Physics.

T 58.3 Wed 16:30 Geb. 30.22: Gaede-HS

**First results of the MONUMENT Experiment; $^{76}$Se partial capture rates** — •Elizabeth Mondragon for the MONUMENT-Collaboration — Chair of Astroparticle Physics, Physics Department, Technical University of Munich, James Franck Str. 85748 Garching, Germany

Extracting particle physics properties from neutrinoless double-beta ($0\nu\beta\beta$) decay requires a detailed understanding of the involved nuclear structures. Still, modern calculations of the corresponding nuclear matrix elements (NMEs) differ by factors 2-3. The high momentum transfer of Ordinary Muon Capture (OMC) provides insight into highly excited states similar to those that contribute virtually to $0\nu\beta\beta$ transitions. The precise study of the $\gamma$'s following the OMC process makes this a promising tool to validate NME calculations and test the quenching of the axial vector coupling $g_A$. MONUMENT performs OMC measurements at the Paul Scherrer Institute and is dedicated primarily to $0\nu\beta\beta$ decay searches. The first results will be presented on the $\beta\beta$ decay daughter isotope $^{76}$Se, corresponding with the LEGEND experiment's isotope $^{76}$Ge. This research was funded by RFBR and DFG, project number 21-52-12040, the DFG Grant 448829699, and by a Department of Energy Grant No DE-SC0019261.

T 58.4 Wed 16:45 Geb. 30.22: Gaede-HS

**Neutron production in neutrino-nucleus interaction** — •Asit Srivastava for the T2K-Collaboration — Johannes Gutenberg-Universität Mainz

T2K is a long-baseline experiment which measures parameters of neutrino oscillations. This can be done by analysing the interaction of neutrinos closer to the point of beam production and 295 km downstream. The detector located near the source of beam production, called ND280, primarily includes the interactions of neutrinos with carbon nuclei. The particles produced as a result of the interactions deposit energy in ND280 which is used to characterise the incoming neutrino flux and neutrino cross-sections before oscillations occur.

Out of all the particles produced in typical neutrino interactions, neutrons are by far the most challenging to detect since they are electrically neutral and do not leave a visible track in the detector. As a result, they provide uncertainties in identifying the interactions happening in the detector and measuring cross-sections. ND280 has a newly installed Super Fine-Grained Detector (SFGD) made of plastic scintillator cubes. The upgraded detector capable of better position resolution and 3D reconstruction opens up the possibilities of improving the efficiency of neutron detection. Analysing a neutron-rich sample and the interactions producing the neutrons can help in understanding nuclear effects better and reducing uncertainties in determining neutrino interaction cross-sections.

The interactions leading to neutron production and how nuclear effects can smear the neutron spectrum will be presented in this talk.

T 58.5 Wed 17:00 Geb. 30.22: Gaede-HS

**Timing properties study in T2K ND280 Upgrade detector** — •Gioele Reina for the T2K-Collaboration — Johannes Gutenberg-Universität Mainz

Detailed models of neutrino interactions with nuclei play a crucial role in long-baseline neutrino oscillation experiments. These models depend on neutron final state interactions (FSI) and, since neutrons are not easily detected and the cross section of these processes is not well-known, they constitute a relevant source of systematic uncertainties. The capabilities of the upgraded T2K ND280 near detector provide an opportunity to improve our knowledge on neutron FSI.

The newly installed Super Fine-Grained Detector (SFGD) consists of small plastic scintillator cubes read out by three wavelength shifting fibers in the three orthogonal directions. It ensures high granularity and 3D reconstruction, which can play a key role in improving the detection of low energy neutrons in neutrino interactions.

Before using real data, efficiency studies of neutron detection need to be performed with simulated events and control samples within the T2K software framework, where neutron reconstruction and selection have been developed. Evaluating how these may vary according to the actual detector performance is important since they will have an impact on the determination of systematic uncertainties in the experiment analysis and can be a source of systematic uncertainties themselves. Simulation-based determination of SFGD detector timing response will be presented along with the impact on efficiency studies for neutron detection.

T 58.6 Wed 17:15 Geb. 30.22: Gaede-HS

**Neutrino-nucleus cross-section measurement strategies from the T2K experiment** — •Liam O'Sullivan — JGU Mainz, Mainz, Germany

In both current and future neutrino oscillation experiments, an accurate understanding of neutrino-nucleus interactions is key to enabling precise determination of the parameters of interest. The physics underpinning the interactions of neutrinos on heavier elements is extremely complex, requiring an accurate description of the initial nuclear state, neutrino-nucleon interactions, and the propagation of particles through the dense nuclear medium.

T2K is a neutrino oscillation experiment with more than a decade's worth of neutrino interaction data with a peak neutrino energy of 0.6 GeV/c. Over this time, T2K's ND280 near detector — a magnetised tracker with hydrocarbon and water targets — has been measuring and characterising neutrino interactions with granular tracking. This allows precise study of the common neutrino interactions, and also enables constraints on less-understood kinematic regions and processes. This talk details the evolution of methods and analysis strategies used in T2K's cross-section analyses — past, present, and future — and how these data can be best used both to challenge current theory, and to motivate new model development.

T 58.7 Wed 17:30 Geb. 30.22: Gaede-HS

**Development of novel water-based liquid scintillator with pulse-shape discrimination capabilities** — •Manuel Böhles[1], Hans Theodor Josef Steiger[2,1], David Dörflinger[2], Ulrike Fahrendholz[2], Meishu Lu[2], Lothar Oberauer[2], Matthias Raphael Stock[2], and Michael Wurm[1] — [1]Johannes Gutenberg University Mainz, Institute of Physics, Staudingerweg 7, 55128 Mainz, Germany — [2]Technical University of Munich, Physics Department, James-Franck-Str. 1, 85748 Garching, Germany

Future hybrid detectors in the field of neutrino physics have to combine high-resolution energy determination down to low thresholds through scintillation light detection and directional reconstruction with the help of Cherenkov radiation. The spectrum of potential applications is broad, ranging from long-baseline oscillation experiments to the measurement of low-energy solar neutrinos. One possible detector medium for these next-generation detectors is Water-based Liquid Scintillator (WbLS). Here, organic scintillators are colloidally dissolved in small quantities in highly pure water with the aid of surfactants. In this talk, a novel WbLS (based on Triton X-100) will be presented. Particular attention will be paid to its key properties, such as micelle size, scattering length, and transparency. Additionally, a study of its light yield as well as pulse-shape discrimination capabilities will be presented. This work is supported by the Clusters of Excellence PRISMA+ and ORIGINS and the Collaborative Research Center 1258.

T 58.8 Wed 17:45 Geb. 30.22: Gaede-HS

**Precision Attenuation Length Measurement of Liquid Scintillators for Future Large Volume Neutrinos Experiments** — •Vincent Rompel, Korbinian Stangler, Florian Kübelbäck, Hans Steiger, and Lothar Oberauer — Technische Universität München, Physik-Department, James-Franck-Straße 1

Upcoming large volume neutrino experiments (like JUNO or THEIA) place high demands on the purity of their scintillators. The optical properties are important to ensure that a large number of photons reach the light detectors. Therefore, scintillators require attenuation lengths >20m for the wavelengths of interest. Measurements of these optical properties have so far been carried out with UV/Vis spectrometers and cuvette lengths of 10cm which leads to overall uncertainties of the same order of magnitude as the attenuation length. In order to obtain precise measurements, the Precision Attenuation Length Measurement (PALM) was developed with light path lengths of up to 2.8m. The setup aims to determine the attenuation length for a wavelength range between 350 and 1000nm with an uncertainty of less than ten percent. So far, initial calibration and test measurements have been performed on linear alkylbenzene (LAB) to ensure and optimize the performance of the setup.

This work is supported by the Cluster of Excellence ORIGINS, the Collaborative Research Center 1258, and the DFG Research Units 2319 and 5519.

## T 59: Outreach 1

Time: Wednesday 16:00–17:15 Location: Geb. 30.22: Lehmann-HS

T 59.1 Wed 16:00 Geb. 30.22: Lehmann-HS

**Bezeichnungen in der Teilchenphysik: Eine deskriptive Analyse unter Verwendung von Ansätzen der Kognitiven Linguistik** — •Tom Stieler, Uta Bilow und Michael Kobel für die Netzwerk Teilchenwelt-Kollaboration — TU Dresden, Institut für Kern- u. Teilchenphysik

In der Teilchenphysik existieren für zentrale Begriffe oftmals Synonyme. Beispielsweise wird für Botenteilchen auch die Bezeichnung Austauschteilchen oder Eichboson genutzt. Im Englischen finden sich analog force carrier, messenger particles oder gauge bosons. Es fehlt bisher an Übersichten über die Nutzung einzelner Termini, wie diese Begriffe im Deutschen und Englischem verwendet werden sowie welche Begründungen und Verstehenskontexte eine Rolle spielen. Aus linguistischer Perspektive zählt nicht nur der einzelne Begriff, sondern insbesondere der Frame der damit evoziert wird. Es wurden Lehrbücher und Interviews ausgewertet und vier zentrale Begriffe (Austausch, Wechselwirkung, Umwandlung, Stoß) mittels qualitativer Inhaltsanalyse über ausgewählte und gegenwärtige Frames in der Teilchenphysik in den Blick genommen. Der Vortrag stellt das methodische Vorgehen der Dokumentenanalyse sowie erste Ergebnisse vor.

T 59.2 Wed 16:15 Geb. 30.22: Lehmann-HS

**"Faszinierende Teilchenphysik": Ein populärwissenschaftliches Buch über Theorien, Experimente und Methoden** — •Philip Bechtle[1], Florian Bernlochner[1], Herbi Dreiner[1], Christoph Hanhart[2], Josef Jochum[3], Jörg Pretz[2,4] und Kristin Riebe[5] — [1]Universität Bonn — [2]Forschungszentrum Jülich — [3]Universität Tübingen — [4]RWTH Aachen — [5]AIP Potsdam

Es gibt viele populärwissenschaftliche Bücher über Teilchenphysik. Uns bot sich die Chance, dank der damaligen und sehr engagierten Lektorin bei Springer Lisa Edelhäuser, ein neuartiges Format für solch ein Buch zu erarbeiten: Es ist in 150 in sich abgeschlossene Doppelseiten gegliedert. Diese stehen in einer sinnvollen Reihenfolge, können aber dank thematischer Verknüpfungen auch als ein "Netz" in Buchform gesehen werden, in dem die Leser_Innen ihren Weg durch das Thema selbst wählen können. Wichtig war uns, auf Konzepte, Theorien und Experimente sowie deren Methoden gleichermaßen einzugehen und diese optimal miteinander zu verknüpfen.

Mit dieser Struktur ergeben sich Vorteile und Herausforderungen. Das Format zwingt dazu, in ein Thema einführende Inhalte kompakt und in sich schlüssig darzustellen, was oft von Vorteil ist. Andererseits gibt es Themen, die zur vollständigen Durchdringung selbst auf populärwissenschaftlichem Niveau ein großes geschlossenes (Vor)wissen benötigen, das sich nur schwer häppchenweise vermitteln lässt.

Im Vortrag soll auf diese Herausforderungen eingegangen werden und einige Beispiele zur Vermittlung komplexer Zusammenhänge präsentiert werden.

T 59.3 Wed 16:30 Geb. 30.22: Lehmann-HS

**FeynGame – Feynman Diagrams for Everyone** — •Robert Harlander, Sven Yannick Klein, and Magnus Schaaf — RWTH Aachen University

The graphical program FeynGame is introduced, which allows access to Feynman diagrams in a playful way. It offers didactic approaches for different levels of experience: from games involving simple clicking and drawing, to practicing the theory of fundamental interactions, to the mathematical representation of scattering amplitudes. FeynGame is also a highly intuitive and flexible tool for simply drawing Feynman diagrams for publications and outreach documents which can be adjusted to personal needs and taste in an very simple way.

T 59.4 Wed 16:45 Geb. 30.22: Lehmann-HS

**Teilchenphysik-Akademie - SchülerInnen an der Uni** — •Heike Enzmann für die Netzwerk Teilchenwelt-Kollaboration — JGU, Mainz, Deutschland

Jedes Jahr kommen 16 Jugendliche an die Uni-Mainz, um sich 10 Tage lang intensiv mit Teilchenphysik zu beschäftigen. In Vorlesungen und Workshops lernen sie Grundlagen der Elementarteilchenphysik, des Detektorbaus sowie der Datenerfassung. Mit dem gelernten Wissen werden dann unter Anleitung von erfahrenen Wissenschaftlerinnen und Wissenschaftlern eigene Teilchendetektoren konstruiert, die am Elektronbeschleuniger MAMI eingebaut und verwendet werden.

In dem Vortrag wird auf die Umsetzung und Durchführung der Teilchenphysik-Akademie eingegangen und verschiedene Gestaltungsformen präsentiert.

T 59.5 Wed 17:00 Geb. 30.22: Lehmann-HS

**Das CERN Science Gateway: Ein Tor zur Welt der Teilchenphysik** — •Sascha Schmeling[1], Julia Woithe[1] und Tobias Treczoks[1,2] — [1]CERN, Genf, Schweiz — [2]TU Dresden

Das neue CERN Science Gateway ist ein aufregendes Wissenschaftszentrum, das sich der Förderung der Teilchenphysik und der Grundlagenforschung widmet. In diesem Vortrag geben wir einen Überblick über seine Hauptaspekte. Die Ausstellung im CERN Science Gateway beleuchtet die Geschichte und Erfolge der Forschung des CERN sowie grundlegende Teilchenphysik-Konzepte, um Besuchern ein tiefes Verständnis zu vermitteln. Das Zentrum fungiert als Bildungs- und Outreach-Plattform, die Schulen, Studierende und die Öffentlichkeit anspricht.

Interaktive Experimente und Workshops bieten die Möglichkeit, die Welt der Teilchenphysik praktisch zu erleben. Zusätzlich werden die neuesten Entwicklungen und zukünftigen Pläne des CERN Science Gateway erörtert, um die Verbindung zwischen Wissenschaft und Gesellschaft zu stärken. Die DPG Frühjahrstagung Teilchenphysik ist die Gelegenheit, das CERN Science Gateway als wichtigen Beitrag zur Wissenschaftskommunikation und Bildung zu präsentieren.

Wir laden alle Teilnehmenden ein, sich mit diesem spannenden Projekt vertraut zu machen und die Faszination der Teilchenphysik auf neue Weise zu entdecken.

# T 60: Gamma astronomy 3

Time: Wednesday 16:00–18:00 Location: Geb. 30.22: kl. HS A

T 60.1 Wed 16:00 Geb. 30.22: kl. HS A

**Searching for photons beyond PeV energies from galactic sources** — •Chiara Jane Papior, Markus Risse, and Marcus Niechciol — Universität Siegen, Siegen, Deutschland

Recently, observations of photons in the low PeV range originating from several galactic sources have been presented. Sources that are responsible for the emission of such energetic photons are candidates for cosmic-ray acceleration as well. Fits to the measured fluxes of the photon signals have been produced for many of the newly found sources. In this contribution, several sources with high photon fluxes at high energies are examined in detail. Their spectra are extrapolated beyond the PeV range to energies that might be accessible by present and future large-scale cosmic-ray observatories (i.e., beyond 10 PeV). Based on the continuation of these spectra and potential propagation effects, the expected photon flux is estimated for each source as a function of energy. The requirements for a detection of such photons with present and future observatories is discussed as well as prospects for actual observations.

This work is supported by the Deutsche Forschungsgemeinschaft (DFG).

T 60.2 Wed 16:15 Geb. 30.22: kl. HS A

**Gamma-ray pulsar glitches: a study of variability in Fermi-LAT data** — •Giovanni Cozzolongo[1,2], Massimiliano Razzano[2,3], Alessio Fiori[2,3], and Pablo Saz Parkinson[4] — [1]Erlangen Centre for Astroparticle Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg — [2]University of Pisa — [3]Istituto Nazionale di Fisica Nucleare — [4]University of California at Santa Cruz

Pulsars are the largest class of Galactic sources detected by NASA's Large Area Telescope (LAT) on the Fermi mission. Pulsars are generally acknowledged as very stable astrophysical rotators, that gradually slow down by emitting radiation at the expense of their rotational energy. Occasionally, pulsars can undergo transient events called glitches, which are rapid changes in their rotational parameters and typically followed by a relaxation phase. Variability in the emission features correlated to glitches has been observed in a small family of radio pulsars and in the radio-quiet PSR J2021+4026, the only variable pulsar observed by the LAT. Here we present a novel analysis of LAT gamma-ray pulsars consisting of a study of variability correlated with changes in the spin-down rate. We perform a maximum likelihood spectral analysis of LAT data around detected glitches, aiming at measuring variations in the gamma-ray flux and spectral parameters. We present results for a subset of glitches that we consider particularly promising. Our study suggests the importance of variability analysis to achieve a deeper understanding of pulsar physics.

T 60.3 Wed 16:30 Geb. 30.22: kl. HS A

**Longterm Variability Study of the Crab Nebula with the MAGIC Telescopes** — •Felix Wersig and Jan Lukas Schubert for the MAGIC-Collaboration — Technische Universität Dortmund, D-44221 Dortmund, Germany

The MAGIC telescopes are two Imaging Air Cherenkov Telescopes designed for observations of gamma rays in an energy range from about ~25 GeV to ~100 TeV.

Like other IACTs, they use the Crab Nebula as standard candle, assuming that the flux is constant for very-high-energy gamma rays. From radio to X-rays, small scale variability has been observed. Further, flares of the Crab Nebula have been observed in the low-energy gamma range.

There are two types of variability that can be tested for: Variations on short timescales such as flares or a longterm increase or decrease of the flux. In this work, tests utilizing maximum likelihood methods are developed that can quantify the variability of the flux and its statistical significance.

These tests are developed based on DL3 data which represents the standard data format in gamma astronomy making use of the open-source gamma-ray analysis package gammapy.

With this the observed variability of the Crab Nebula can be constrained and the assumption that it has a constant flux in the very-high-energy gamma-ray regime can be reevaluated.

T 60.4 Wed 16:45 Geb. 30.22: kl. HS A

**Uncovering axion-like particles in supernova gamma-ray spectra** — •Giuseppe Lucente[1,2,6,7], Francesca Calore[3], Pierluca Carenza[4], Christopher Eckner[3], Maurizio Giannotti[5], Alessandro Mirizzi[6,7], and Francesco Sivo[6,7] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120, Heidelberg, Germany — [2]Universität Heidelberg, Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany — [3]LAPTh, CNRS, F-74000 Annecy, France — [4]The Oskar Klein Centre, Department of Physics, Stockholm University, Stockholm 106 91, Sweden — [5]Centro de Astroparticulas y Fisica de Altas Energias (CAPA), Universidad de Zaragoza, Zaragoza, 50009, Spain — [6]Dipartimento Interateneo di Fisica "Michelangelo Merlin", Via Amendola 173, 70126 Bari, Italy. — [7]Istituto Nazionale di Fisica Nucleare - Sezione di Bari, Via Orabona 4, 70126 Bari, Italy.

A future Galactic Supernova (SN) explosion can lead to a gamma-ray signal induced by ultralight Axion-Like Particles (ALPs) thermally produced in the SN core and converted into high-energy photons in the Galactic magnetic field. The detection of such a signal is in the reach of the Large Area Telescope aboard the *Fermi* Gamma-Ray Space Telescope. The observation of gamma-ray emission from a future SN has a sensitivity to $g_{a\gamma} \gtrsim 4 \times 10^{-13}$ GeV$^{-1}$ for a SN at fiducial distance of 10 kpc and would allow us to reconstruct the ALP-photon coupling within a factor of $\sim 2$, mainly due to the uncertainties on the modeling of the Galactic magnetic field.

T 60.5 Wed 17:00 Geb. 30.22: kl. HS A

**Insights into the broadband emission of TeV blazars during the first X-ray polarization measurements** — •Lea Heckmann[1,2], Axel Arbet-Engels[1], Felix Schmuckermaier[1], David Paneque[1], and Ioannis Liodakis[3,4] — [1]Max-Planck-Institut für Physik, D-85748 Garching, Germany — [2]Universität Innsbruck, Institut für Astro- und Teilchenphysik, Technikerstr. 25/8, 6020 Innsbruck, Austria — [3]Finnish Centre for Astronomy with ESO, 20014 University of 1396 Turku, Finland — [4]NASA Marshall Space Flight Center, Huntsville, AL 35812, USA

Blazars are prime objects to be studied in the current multi-messenger era and even though they have been investigated for decades, the underlying emission mechanisms are far from understood. In 2022, the first detection of X-ray polarization in blazars was obtained by IXPE, which opened a new window for probing blazar acceleration and radiation processes. In this contribution, we investigate the multiwavelength picture during the first IXPE observations of the two blazars Mrk 501 and Mrk 421, including data from the radio regime up to the very-high-energy (>0.1 TeV, VHE) $\gamma$-rays. We examine the X-ray polarization evolution, and compare it to various features in other wavebands including also, for the first time, the VHE band.

T 60.6 Wed 17:15 Geb. 30.22: kl. HS A

**FACT - A Decade of TeV Observations** — •Daniela Dorner[1] and Bernd Schleicher[2] for the FACT-Collaboration — [1]Universität Würzburg, Deutschland — [2]ETH Zürich, Schweiz

Operational since October 2011, the First G-APD Cherenkov Telescope (FACT) has been monitoring bright TeV blazars. A design for remote and automatic operation and the usage of semiconductor photosensors maximize its duty cycle and minimize the gaps in the light curves. An unbiased observing strategy results in unique and unprecedented long-term gamma-ray light curves. Among other results, the time-series analysis of the blazar 1ES1959+650 and a long-term study of the index-vs-flux correlation of blazars will be showcased. The presentation summarizes the lessons learned from ten years of operation and the results of FACT's legacy data sample.

T 60.7 Wed 17:30 Geb. 30.22: kl. HS A

**FACT - Follow-up of Multi-Wavelength and Multi-Messenger Alerts** — •Marcel Vorbrugg and Felix Pfeifle for the FACT-Collaboration — Julius-Maximilians-Universität Würzburg, Fakultät für Physik und Astronomie, Institut für Theoretische Physik und Astrophysik, Lehrstuhl für Astronomie, Emil-Fischer-Str. 31, D-97074 Würzburg, Germany

The First G-APD Cherenkov Telescope (FACT) is a gamma-ray observatory located on the Canary Island of La Palma. Employing Geiger-mode avalanche photodiodes (G-APDs), also known as SiPM, FACT monitors bright gamma-ray sources at TeV energies. The distinguishing aspect of its follow-up program lies in the pursuit of emission from potential gamma-ray candidates, utilizing skymaps for multi-messenger alerts. This program aims to automatically follow up on flare alerts from various channels including different sources types. Among others, FACT conducts target-of-opportunity observations of gamma-ray bursts and public neutrino alerts by IceCube. As the position uncertainty for these alerts tends to be large, a skymap analysis is crucial to the broader understanding of these high-energy phenomena. In this work, the outcomes and automatic observations of FACT's follow-up program will be analyzed. These alerts are essential for exploring possible emissions from unknown sources. The final goal is to search the aforementioned skymaps to potentially detect TeV emission from gamma-ray bursts or neutrino source candidates or set upper limits on their very-high-energy emission. An overview of results from 10 years of follow-ups will be given.

T 60.8 Wed 17:45 Geb. 30.22: kl. HS A

**FACT - Two-Dimensional Analysis of Unidentified Gamma-Ray Sources** — •Katharina Brand[1] and Daniela Dorner[1,2] for the FACT-Collaboration — [1]Julius-Maximilians-Universität Würzburg, Fakultät für Physik und Astronomie, Institut für Theoretische Physik und Astrophysik, Lehrstuhl für Astronomie, Emil-Fischer-Str. 31, D-97074 Würzburg, Germany — [2]ETH Zurich, Institute for Particle Physics and Astrophysics, Otto-Stern-Weg 5, 8093 Zürich, Switzerland

The First G-APD Cherenkov Telescope (FACT) focuses on monitoring a small sample of bright high-energy gamma-ray sources. Additionally, it also responds regularly to alerts from other experiments like IceCube. However the specified position often has a large uncertainty. Therefore a simple analysis on a given source position is not sufficient, but the whole field-of-view needs to be searched for an excess of gamma rays. Furthermore, not all sources are point like. If we want to see the extension of such objects, we need to analyse a larger sky region. To this end, we implemented a database-based skymap analysis technique using FACT data to search for gamma-ray sources at unknown positions. While the method is also used for other source candidates in the multi-wavelength and multi-messenger follow-up program of FACT, this work focuses on a follow-up analysis of LHAASO detected gamma-ray source J2108+5157.

# T 61: Silicon trackers 3

Time: Wednesday 16:00–18:00 Location: Geb. 30.22: kl. HS B

T 61.1 Wed 16:00 Geb. 30.22: kl. HS B

**Results from the pre-producton of the ITk Outer Barrel Bare Cell** — •Nico Klein, Klaus Desch, Matthias Hamer, Florian Hinterkeuser, Alexandra Wald, and Dominik Hauner — Rheinische Friedrich-Wilhelms-Universität Bonn

The high luminosity upgrade for the Large Hadron Collider at CERN requires a complete redesign of the current tracking detector of the ATLAS experiment. The new Inner Tracker, the ITk Detector, will consist of a silicon pixel detector and a silicon strip detector. The ITk Pixel Detector is divided into three subsystems, the Outer Barrel (OB), Outer Endcaps and Inner System. In the OB, modules are loaded on cells (pyrolytic graphite tiles that are glued to an Aluminum-Graphite cooling block) before they are mounted on the local supports. These cells have a crucial role in the thermal performance of the modules, as they provide the connection between the modules and the cooling system. In order to meet the demanding requirements that are placed on the cooling system of the ITk Pixel Detector, the production of the Bare Cells goes through several quality control tests. In this talk I will present the results of the QC tests that have been performed on the pre-production OB bare cells.

T 61.2 Wed 16:15 Geb. 30.22: kl. HS B

**Quality control at wafer level and thermocycling of ATLAS ITk pixel detector modules during the production phase** — Patrick Ahlburg, Yannick Dieter, Fabian Hügging, Hans Krüger, Konstantin Mauer, •Maximilian Mucha und Jochen Dingfelder — Physikalisches Institut, Universität Bonn, Germany

The upgrade of the Large Hadron Collider (LHC) to the High-Luminosity LHC (HL-LHC) presents significant technological challenges. The HL-LHC will see an increase in instantaneous luminosity by a factor of 5, leading to higher hit rates and radiation levels than ever before. To cope with these demanding conditions, extensive upgrades to the detectors are necessary. As part of the upgrade, the ATLAS Inner Detector will be replaced by a new all-silicon inner tracking detector (ITk detector) consisting of silicon strip and hybrid pixel modules. In total, approximately 10.000 new pixel detector modules have to be built and carefully tested to ensure that only fully functional detector modules will be installed. The QC process starts already at wafer level. For the hybrid modules, 131 readout chips on approx. 700 wafers have to be tested for their functionality.

This talk provides an overview of the fully automated testing procedures developed for the ATLAS ITk pixel detector modules at the Forschungs- und Technologiezentrum Detektorphysik (FTD) in Bonn. It focuses on the wafer probing setup and the module-level thermocycling setup, which are crucial for ensuring the functionality and quality of the detector modules.

T 61.3 Wed 16:30 Geb. 30.22: kl. HS B

**TID Irradiation of the ATLAS ITkPix readout chip** — Patrick Ahlburg, Yannick Dieter, Fabian Hügging, Hans Krüger, •Konstantin Mauer, Maximilian Mucha, Marco Vogt, and Jochen Dingfelder — Physikalisches Institut, University of Bonn, Germany

The upcoming High-Luminosity upgrade of the Large Hadron Collider (HL-LHC) will significantly increase the instantaneous luminosity. This will lead to a higher track density, a higher hit rate and thus an increased amount of radiation damage in the experiments.

For this reason, the ATLAS experiment will be upgraded and a new all-silicon inner tracking (ITk) detector has been designed, consisting of strip and pixel modules. The pixel modules are used in the innermost layers of the detector and have a hybrid design where a sensor is read out with a dedicated readout chip called ITkPix. Both components are designed to be radiation hard. The readout chip itself has to withstand up to 700 Mrad TID damage in $SiO_2$.

In this talk an X-ray irradiation campaign to verify the radiation hardness and characterize the performance of the production version of the ITkPix will be presented.

T 61.4 Wed 16:45 Geb. 30.22: kl. HS B

**Integration Tests with Module Prototypes for the Phase- 2 Upgrade of the CMS Outer Tracker** — •Lea Stockmeier, Alexander Dierlamm, Ulrich Husemann, and Stefan Maier — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

To deal with the increased luminosity of the HL-LHC, the CMS experiment will be upgraded until 2028. During this Phase-2 Upgrade, the CMS Outer Tracker will be equipped with modules each assembled with two silicon sensors. Depending on the position in the tracker, these silicon sensors are pixel or strip sensors. The modules with two strip sensors are called 2S modules while those assembled of one macro-pixel and one strip sensor are called PS modules. In the endcap region these modules are mounted on structures called "dees". Four dees will be combined to one "double-disc" which provides the hermetic coverage of one detector plane.

During the prototyping phase of the modules, integration tests are performed with the purpose of testing the integration procedure itself as well as the module functionality on the final detector structures. For example, the electronic noise of the modules can be taken to check the performance of the modules on the supporting structures.

This talk summarizes an integration test performed at DESY (Hamburg) with six PS and seven 2S modules on a prototype dee in cooperation with other CMS working groups.

T 61.5 Wed 17:00 Geb. 30.22: kl. HS B

**Database and test procedures for the production of CMS 2S modules at RWTH Aachen** — •Max Beckers[2], Christian Dziwok[2], Lutz Feld[1], Nina Höflich[2], Katja Klein[1], Alexander Pauls[1], Oliver Pooth[2], Nicolas Röwert[1], Martin Lipinski[1], Vanessa Oppenländer[1], and Tim Ziemons[2] — [1]I. Physikalisches Institut B, RWTH Aachen University, D-52056 Aachen — [2]III. Physikalisches Institut B, RWTH Aachen University

For the CMS Phase-2 Outer Tracker upgrade, new silicon strip detector modules consisting of two silicon strip sensors, so-called 2S modules, are developed and produced. This process is distributed along multiple assembly centers worldwide. To ensure consistent module quality, many specifications need to be respected. This includes different kinds of tests and measurement results.

RWTH Aachen University will build around 800 2S modules. The production requires well-organised procedures. To guarantee the transparency and traceability of the production conditions and module quality many data are recorded and analysed.

This talk presents the latest results from the assembly process, with a focus on the quality control measurements that are taken on different test stands. The measurement results are compared with specifications. Details about the data handling with the local and central CMS construction database are given.

T 61.6 Wed 17:15 Geb. 30.22: kl. HS B

**Thermal Cycling of ATLAS ITk Modules with the DESY Coldbox** — Sören Ahrens[1], •Lukas Bayer[1], Ben Bruers[2], Sergio Díez-Cornell[1], Torsten Kuelper[1], Jonas Neundorf[1], and Elizaveta Sitnikova[1] — [1]DESY, Hamburg, Germany — [2]DESY, Zeuthen, Germany

In the course of the upcoming High Luminosity upgrade for the LHC, also the Inner Detector of the ATLAS experiment will receive an upgrade to the new Inner Tracker (ITk). Its two endcaps, one of which will be assembled at DESY, consist of individual modules with silicon strip sensors, hybrid read-out chips and power boards. Prior to the integration of these modules into the larger detector structures, they have to run through a series of quality control steps, including thermal cycling and electrical tests, to ensure full functionality at operation temperature. For this purpose, DESY has developed controlled testing environments, so-called coldboxes, and also provided them to other institutions in the ITk community. Each coldbox features electromagnetic shielding, low humidity conditions and temperature control for up to four modules at the same time, and can be paired with high-voltage power-supplies. In this talk the functionality of the coldbox will be discussed, as well as the thermal cycling procedure and its importance for the ITk production chain.

T 61.7 Wed 17:30 Geb. 30.22: kl. HS B

**Simulation and measurement of humidity-induced breakdown in silicon sensors** — Ingo Bloch[2], Ben Brüers[2], Heiko Lacker[1], Peilin Li[1], Ilona Stefana Ninca[2], and •Christian Scharf[1] — [1]Humboldt-Universität zu Berlin — [2]Deutsches Elektronen-Synchrotron (DESY)

Humidity exposure of silicon sensors, which do not have a special treatment of the top oxide/nitride layer, can lead to early electrical breakdown. The cause has been long known to be the humidity-dependent mobility of impurity ions on the outer oxide/nitride surface, which can alter the potential at the surface. However, the exact mechanisms that lead to electrical breakdown are poorly studied.

This work focuses on TCAD simulations of the guard ring region of planar silicon diodes, where breakdown can be located by hot-electron emission microscopy. The effect of humidity is simulated by adding a resistive layer on top of the oxide/nitride and adjusting the mobilities of the charge carriers in the layer. To verify the results of the TCAD simulations, TCT measurements in the guard ring region and accompanying Allpix Squared simulations have been performed.

The simulations together with the measurements are targeted to contribute to a better understanding of the mechanism and the relevant parameters driving the humidity-induced early breakdown.

T 61.8 Wed 17:45 Geb. 30.22: kl. HS B

**Simulation and measurement of charge transport near the Si-SiO$_2$ interface of silicon sensors** — Ingo Bloch[1], Ben Brüers[1], Heiko Lacker[2], •Peilin Li[2], Ilona Stefana Ninca[1], and Christian Scharf[2] — [1]Deutsches Elektronen-Synchrotron (DESY) — [2]Humboldt Universität zu Berlin

Some of the n-in-p silicon sensors for the ATLAS Inner Tracker (ITK) strip detector show signs of early breakdown at high humidity. To investigate the breakdown mechanism, Transient Current Technique (TCT) measurements are conducted in the region between the sensor's guard ring and edge ring, where the breakdown has been observed through hot-electron emission microscopy. Picosecond laser pulses of 660 nm photons are focused on the sensor surface, generating free electrons and holes near the surface. These free charges drift in the local electric field and induce transient currents, which are measured as a function of the laser position and the applied bias voltage. To reproduce the measurements, charge transport at the Si-SiO$_2$ interface has been implemented in the simulation framework Allpix Squared. The electric and weighting fields have been simulated with Synopsys Sentaurus TCAD. By comparing the measurements to the simulations, a qualitative estimation of the discrepancy between the TCAD-simulated and actual electric fields can be achieved. The results of this analysis help to validate the TCAD simulation against measurements and to gain understanding of surface TCT measurements in the guard ring region of sensors, enabling further exploration of the humidity dependence of surface breakdown.

# T 62: Standard model 2 (electroweak/bosons)

Time: Wednesday 16:00–18:00 Location: Geb. 30.23: 2/0

T 62.1 Wed 16:00 Geb. 30.23: 2/0

**Measurement of the differential $W \to \ell\nu$ cross section at high transverse masses at $\sqrt{s} = 13$ TeV with the ATLAS detector** — Frank Ellinghaus, Johanna Wanda Kraus, and •Tim Frederik Beumker — Bergische Universität Wuppertal

A measurement of the differential cross section of the process $W \to \ell\nu$ is shown. The data set analyzed is based on data from pp-collisions at a center-of-mass energy of $\sqrt{s} = 13$ TeV, corresponding to an integrated luminosity of $\mathscr{L} = 140\,\mathrm{fb}^{-1}$. It is taken with the ATLAS detector during LHC Run-2. The measurement is done double-differentially in the transverse mass of the W boson and the absolute of the pseudorapidity of the lepton. It focuses on the region of high transverse masses between 200 GeV and 2000 GeV. The results will allow for constraints on effective field theories and parton distribution functions of the proton. An overview of the complete analysis will be presented.

T 62.2 Wed 16:15 Geb. 30.23: 2/0

**$W\gamma\gamma$ analysis in Run 3 with the ATLAS detector at the LHC** — •Isabel Sainz Saenz-Diez — Kirchhoff Institute for Physics, Heidelberg University

The production of a $W$ boson in association with two photons from proton-proton collisions, among other triboson final states, is predicted by the Standard Model of Particle Physics (SM). The observation of this process was possible with the data collected by the ATLAS detector during the Run 2 of the LHC. This opened the possibility for testing the SM predictions, in particular the quartic gauge couplings. The focus of this talk is the analysis of $W\gamma\gamma$ final states in Run 3. Due to the higher centre of mass energy and the large dataset, more events are expected with respect to the previous observation and dedicated triggers are now used. A study of the efficiencies of these triggers is presented, followed by the background estimation of some processes that can be misreconstructed as signal. The most relevant backgrounds come from misidentified photons, for which a data-driven estimation method is used. Additionally, results of the estimation through Monte Carlo simulations of other backgrounds are shown.

T 62.3 Wed 16:30 Geb. 30.23: 2/0

**Measurement of $\gamma\gamma jj$ final states from Vector Boson Scattering at the ATLAS experiment** — •Orcun Kolay and Frank Siegert — Technische Universität Dresden, Germany

Vector boson scattering (VBS) offers an opportunity to study triple and quartic gauge couplings, which are relatively uncommon occurrences. This provides us with a means to examine the Standard Model (SM), the electroweak (EW) symmetry-breaking mechanism, and to explore potential new physics phenomena.

This study focuses on the final state involving two photons and two jets, denoted as $\gamma\gamma jj$. The $\gamma\gamma jj$ process has a crucial role not only for new physics anomalies such as the coupling of four neutral gauge bosons but also for understanding the background of the two-photon final state of the Higgs boson produced via vector boson fusion.

The measurement of the VBS $\gamma\gamma jj$ process comes along with two main challenges: The background coming from QCD induced $\gamma\gamma jj$ and misidentified jets as photons. This presentation covers an ongoing work focusing on the phase space strategy discriminating EW $\gamma\gamma jj$ processes from the background, the estimation of backgrounds from misidentified jets, and the treatment of the systematics.

T 62.4 Wed 16:45 Geb. 30.23: 2/0

**Measurement of $ZZ\gamma$ final states with the ATLAS detector at the LHC** — •Anke Ackermann — Kirchhoff-Institute for Physics, Heidelberg University

The Standard Model of Particle Physics (SM) predicts the rare production of triboson final states. Although suffering from small cross sections and hence a limited amount of signal events, such triboson states can be studied with the vast amount of data collected by the ATLAS detector in Run 2. In addition to validating the predictions of the SM for rare processes, sensitivity to New Physics is given via anomalous quartic couplings of e.g. four neutral gauge bosons. This talk will focus on the analysis of the simultaneous production of $ZZ\gamma$. In order to determine the cross sections of this process, it is crucial to separate signal events from events arising through background processes mimicking the signal topology. The most dominant background process contains fake photons, which are non-prompt photons within jets. Due to the limited statistics a new approach with jet ratios is applied to estimate the amount of fake photons in the signal region. Additionally, processes with misidentified leptons contribute to the background. Their contribution is estimated with the likelihood matrix method. After giving a general introduction about the triboson production of the $ZZ\gamma$ process, a summary of the analysis, including the event selection and the background estimation, is presented.

T 62.5 Wed 17:00 Geb. 30.23: 2/0

**Estimation of the photon contribution from mis-identified electrons to the differential cross-section measurements of single-top quark production in association with a photon with the ATLAS experiment at $\sqrt{s} = 13$ TeV** — •Lucas Cremer, Nils Julius Abicht, Tomas Dado, and Andrea Helen Knue — TU Dortmund, Experimentelle Physik

Measuring the differential production cross-sections of single top quarks in association with a photon provides a unique opportunity to probe the electroweak interaction of the top quark with the photon.

An important background to this process arises from events with an electron that is mis-identified as a photon. Due to the difficulty to model this process from Monte Carlo simulations, a data-driven method is used to estimate the contribution of this background to the selected events. Corrections are derived from two control regions enriched with $Z \to ee$ and $Z \to e\gamma$ events, respectively. Distributions of the invarivant-mass of the electron pair $m_{ee}$ and the electron and the photon $m_{e\gamma}$ obtained from Monte Carlo simulations are fitted to the data in bins of the pseudorapidity of the photon as well as its conversion type to extract the corrections. The results estimated on the complete ATLAS Run-2 dataset, corresponding to an integrated luminosity of 140 fb$^{-1}$, are presented.

T 62.6 Wed 17:15 Geb. 30.23: 2/0

**Fake photon background estimate with the template fit method at ATLAS** — •Tobias Heintz — Kirchhoff Institute for Physics, Heidelberg University

Photons are an important signature in the final state of proton-proton collisions at the Large Hadron Collider. A background contribution to these final states are so-called fake photons, which are not promptly produced in the $pp$ collision, but arise within the fragmentation of jets, mainly via $\pi^0 \to \gamma\gamma$. This study deals with a template fit method to estimate the background contribution of fake photons. As established in various multi-boson analyses at ATLAS, templates for the isolation energy distribution are extracted using Monte Carlo simulations. The templates are currently extracted for each final state separately, so this study aims to extract generic templates that can be used for photons in different final states. Therefore, the dependence of the isolation templates on the transverse momentum of the photon, $p_\mathrm{T}$, is investigated. Considering the correlations between the isolation energy and $p_T$ and taking into account the $p_T$ distribution of the investigated phase space, the same templates can be used for photons in the $Z\gamma$ and $Z\gamma\gamma$ process.

T 62.7 Wed 17:30 Geb. 30.23: 2/0

**Towards a measurement of the Z boson mass in proton-proton collisions with the ATLAS experiment** — •Dionysios Fakoudis[1,2], Stefan Tapprogge[1], and Emilien Chapon[2] — [1]Institute of Physics, Johannes Gutenberg University, Mainz, Germany — [2]CEA,Paris,France

The precise measurement of the Z boson mass is an important foundation of the Standard Model. This talk presents an analysis of the challenges encountered in the Z boson mass measurement using ATLAS data having recorded about $10^8$ Z boson decays to $\mu^+\mu^-$ in proton - proton collisions at 13 TeV centre-of-mass energy. Di-muon final states are considered and specific emphasis is given to the associated uncertainties. To allow a precision determination of Z boson mass an excellent understanding of the detection and the measurement of the muon kinematics is required, therefore the focus is on the crucial aspect of calibration. The presentation delves into the intricacies of calibration techniques, exploring the methods employed, their efficacy, and the challenges associated with achieving the desired precision.

T 62.8 Wed 17:45 Geb. 30.23: 2/0

**Electroweak Parameters from Yang-Mills Thermodynamics** — Ralf Hofmann[1] and •Janning Meinert[1,2] — [1]ITP Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [2]Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal, Germany

Based on the thermal phase structure of pure SU(2) quantum Yang-Mills theory, we describe the electron at rest as an extended particle, a so-called blob. Utilizing a mirror-charge construction, we compute the mixing angle $\theta_W$ for the bulk thermodynamics and the charge of the blob as seen by a soft external probe field. It is shown that the blob does not exhibit an electric dipole or quadrupole moment. Within this model, we calculate the Weinberg angle to be $\theta_W \sim 30^\circ$ and the fine-structure constant to be $\alpha^{-1} \sim 134$, which is close to the experimental values. The ratio of blob radius $r_0$ and the reduced Compton radius $r_c$ is computed from a quantum-thermodynamical mass formula and coincides with $\alpha_{\mathrm{exp}}^{-1}$. This identifies $r_0$ with the Bohr radius $a_0$. In this talk, I will briefly review Yang-Mills thermodynamics and sketch the calculation of the Weinberg angle within this model.

*Supported by SFB 1491 and the Vector Foundation

# T 63: Detectors 6 (calorimeters)

Time: Wednesday 16:00–17:45 Location: Geb. 30.23: 2/1

T 63.1 Wed 16:00 Geb. 30.23: 2/1

**The SHADOWS calorimeter** — •Claudia Caterina Delogu for the SHADOWS-Collaboration — Johannes Gutenberg Universität Mainz

The SHADOWS experiment, proposed for the 400 GeV/c proton beam at CERN SPS, is dedicated to exploring feebly interacting particles (FIPs) generated during proton interactions. This contribution specifically focuses on advancements related to the electromagnetic calorimeter of SHADOWS. In addressing the challenge of reconstructing particles that decay into photons, we present a conceptual design study of a plastic scintillator-based calorimeter designed to provide energy and direction measurements. As part of the ongoing experimental development, efforts are underway to study the SHADOWS electromagnetic calorimeter technology, including activities related to calorimeter and module design, scintillator-SiPM coupling, readout concept, prototyping, and test measurements. The pointing capability is essential for FIP detection and has been validated through GEANT4 simulations.

T 63.2 Wed 16:15 Geb. 30.23: 2/1

**Development of a SplitCAL Prototype** — •Matei Climescu and Rainer Wanke — Johannes Gutenberg Universität Mainz

The SplitCAL is a mixed electromagnetic calorimeter designed to provide both energy reconstruction through layers of scintillating strips read out by wavelength shifting fibres and shower direction information through high-precision layers. This enables particular precision in the reconstruction of photon final states e.g. arising from Dark Matter decays in fixed target experiments. The development accounts for low rates but a large dynamic range to allow for reconstruction of both electromagnetic showers and MIPs. The focus of this presentation will be the design and building of the SplitCAL calorimeter as well as the evaluation of its readout electronics.

T 63.3 Wed 16:30 Geb. 30.23: 2/1

**Time response of a position-sensitive wavelength-shifting fibre structured plastic scintillator detector (CheapCal)** — Alessia Brignoli[1], Valery Dormenev[2], Karl Eichhorn[3], Jan Friedrich[3], Heiko Markus Lacker[1], Martin J. Losekamm[3], Anupama Reghunath[1], Christian Scharf[1], Ben Skodda[1], Valerian von Nicolai[1], •Ida Wöstheinrich[1], and Hans-Georg Zaunick[2] — [1]Humboldt-Universität zu Berlin — [2]Justus-Liebig-Universität Gießen — [3]Technische Universität München

The goal of the CheapCal project is to build a low-cost and easy-to-build detector for charged-particle detection with a spatial resolution of about 1 cm or better. The detector is made from an extruded plastic scintillator plate of short light attenuation length, with wavelength-shifting fibres embedded into it at a fibre-to-fibre distance of 1.5 cm. The fibres on the front side and the backside of the plate are oriented perpendicular to each other and are optically coupled at each end to silicon photomultipliers. We report on the timing performance of the detector measured with a Sr-90 beta source. We acknowledge the support from BMBF via the High-D consortium.

T 63.4 Wed 16:45 Geb. 30.23: 2/1

**First test beam measurements of a position-sensitive wavelength-shifting fibre structured plastic scintillator detector (CheapCal)** — Alessia Brignoli[1], Andrew Picot Conaboy[1], Valery Dormenev[2], Christian Dreisbach[3], Karl Eichhorn[3], Jan Friedrich[3], Heiko Markus Lacker[1], Martin J. Losekamm[3], Anupama Reghunath[1], Christian Scharf[1], Ben Skodda[1], •Valerian von Nicolai[1], Ida Wöstheinrich[1], and Hans-Georg Zaunick[2] — [1]Humboldt-Universität zu Berlin — [2]Justus-Liebig-Universität Gießen — [3]Technische Universität München

The CheapCal project aims to develop a low-cost and easy-to-build detector for charged particle detection with a spatial resolution of about a centimetre or better. The detector is based on a $(25 \times 25)\,\mathrm{cm}^2$ extruded plastic scintillator with a short light attenuation length, which is structured with wavelength-shifting fibres embedded into the material at a fibre-to-fibre distance of 1.5 cm. The fibres are read-out at each end by a silicon photomultiplier (SiPM). After proof-of-principle measurements in the laboratory with a Sr-90 source, we constructed a first detector with fibres in orthogonal orientation on the front and back of the scintillator. We successfully tested this prototype with a 100 GeV muon beam at the AMBER experiment at CERN, using a beam telescope consisting of silicon-strip detectors for tracking. The initial results of this test campaign will be presented. We acknowledge the support from BMBF via the High-D consortium.

T 63.5 Wed 17:00 Geb. 30.23: 2/1

**Fast Hadron Shower Simulation using Generative Adversarial Networks with the CALICE AHCAL Prototype** — •André Wilhahn, Julian Utehs, and Stan Lai for the CALICE-D-Collaboration — II. Physikalisches Institut, Georg-August-Universität Göttingen, Deutschland

Extensive simulations of particle showers are crucial for high energy physics experiments, since they allow for a sensible interpretation of recorded calorimeter data. As many calorimeters are designed with increasing granularity, while having to cope with higher energy deposits and higher luminosity conditions, the accurate simulation of particle showers in a computationally efficient manner is of utmost importance. This talk describes preliminary investigations into a data-driven fast calorimeter simulation, based on machine learning techniques, that is meant to describe particle showers accurately.

We start by investigating pion showers in the CALICE AHCAL (Analog Hadron Calorimeter) prototype, which is a highly granular hadronic calorimeter comprising a total of 38 active layers embedded in a stainless-steel absorber structure. Each active layer contains a grid of $24 \times 24$ scintillator tiles that are read out individually via silicon photomultipliers. Based on energy distributions, Generative Adversarial Networks have been trained on testbeam data, aiming at creating a neural network that is able to generate and recreate energy distributions from random input noise, while also preserving correlation factors between individual detector layers.

T 63.6 Wed 17:15 Geb. 30.23: 2/1

**Results of the Megatile prototype for the CALICE AHCAL** — •Anna Rosmanitz for the CALICE-D-Collaboration — Johannes-Gutenberg Universität Mainz

The CALICE collaboration develops several highly granular calorimeter concepts for a future $e^+e^-$ collider, that are designed for Particle Flow Algorithms. The current design for the Analog Hadronic Calorimeter (AHCAL) consists of 3x3 $\mathrm{cm}^2$ scintillator tiles read out by silicon photomultipliers (SiPM). Each tile is individually wrapped in reflective foil and glued to the boards. The final AHCAL detector would contain 8 million channels.

To facilitate the assembly process, the Megatile design is developed at the University of Mainz. It is made from a large scintillator plate which houses 12x12

channels at once. The channels are separated by tilted trenches filled with a mixture of glue and $TiO_2$ for reflectivity and optical insulation. Optical tightness is achieved by gluing reflective foil on both faces and varnishing the edges. Until now, ten prototypes have successfully been built, continuously monitored in a cosmic test-stand in Mainz and tested in several test beam campaigns at DESY and CERN. This talk presents the latest technical developments and preliminary results from electron test beam measurements.
This includes a high-resolution scan of the megatile performance in the inter-channel region across the tilted $TiO_2$ trenches, utilizing a beam telescope to study MIP-like energy depositions without any absorber material.

T 63.7 Wed 17:30 Geb. 30.23: 2/1

**Quality control of the pre-series scintillator tiles of the High Granularity Calorimeter upgrade of the CMS experiment** — •Daria Selivanova — Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany

As the High Luminosity era of LHC approaches, it is important to finalise production techniques for the components of the upgrades of the collider experiments and CMS is no exception. The CMS endcap calorimeters are getting a high granularity upgrade (HGCAL), which promises to improve energy resolution by reducing background via pileup rejection. This is done through use of both intrinsic timing capabilities of the sensors and front-end electronics design as well as unprecedented transverse and longitudinal segmentation. HGCAL consists of electromagnetic and hadronic compartments, the latter of which is divided into two by the different technologies used in its construction. One of them, SiPM-on-tile, will make up ~250 000 channels: scintillator tiles optically coupled to SiPMs soldered onto a PCB with readout electronics. All of such channels will need to withstand harsh radiation conditions of HL-LHC to be able to continue with physics searches until the end of life (integrated luminosity ~ 3000 fb-1) and even beyond. Assurance of that is tackled by the Tile Assembly Center (TAC) at DESY performing quality control (QC) checks for all components of the SiPM-on-tile section of the HGCAL. Results of QC of scintillator tiles are discussed. Tiles under investigation are pre-series tiles the study of which aids the finalising of the production techniques. This part is essential for start and ease of the final production phase.

## T 64: Detectors 7 (gas detectors)

Time: Wednesday 16:00–17:45 Location: Geb. 30.23: 2/17

T 64.1 Wed 16:00 Geb. 30.23: 2/17

**Test of ATLAS Micromegas detectors with a ternary gas mixture at the CERN GIF++ facility** — •Fabian Vogel, Otmar Biebel, Valerio D'Amico, Stefanie Götz, Ralf Hertenberger, Roman Lorenz, Eshita Kumar, Katrin Penski, Nick Schneider, and Chrysostomos Valderanis — LMU München

The ATLAS collaboration at LHC has chosen the resistive Micromegas technology, along with the small-strip Thin Gap Chambers (sTGC), for the high luminosity upgrade of the first muon station in the high-rapidity region, the New Small Wheel (NSW) project. Achieving the requirements for these Micromegas detectors revealed to be even more challenging than expected. One of the main features being studied is the HV stability of the detectors. Several approaches have been tested in order to enhance the stability, among them the use of different gas mixtures. A ternary Argon-$CO_2$-$iC_4H_{10}$ mixture has shown to be effective in dumping discharges and dark currents. It allows the operation of the Micromegas detectors at safe working points with high cosmic muon detection efficiency. The presence of Isobutane in the mixture required a set of aging studies, ongoing at the GIF++ radiation facility at CERN, where the expected HL-LHC background rate is created by a $^{137}$Cs 14 TBq source of 662 keV photons. Preliminary aging results and muon reconstruction efficiencies under photon background of the ternary mixture will be shown.

T 64.2 Wed 16:15 Geb. 30.23: 2/17

**Performance of new generation of Resistive Plate Chambers operating with alternative gas mixtures** — •giorgia proto, hubert kroha, oliver kortner, Daniel soyk, nayana bangaru, and timur turkovic — Max-Planck-Institut fur Physik

The Resistive Plate Chambers (RPC) are gaseous detectors with excellent timing performance and are used for triggering on muons in the ATLAS experiment. They operate with the standard gas mixture, composed of $C_2H_2F_4$/i-$C_4H_{10}$/$SF_6$, because it allows the detector operation in avalanche mode, as required by the high-luminosity collider experiments. The $C_2H_2F_4$ and the $SF_6$ are now considered to be non-eco-friendly gases for their high Global Warming Potential (GWP). This gases are not recommended for industrial uses anymore, thus their availability will be increasingly difficult over time and the search for an alternative gas mixture is then of absolute priority within the RPC community. There are several studies on going which use different approach to find an alternative gas mixture suitable for experiment which work in high-radiation environment, as those operating at the Large Hadron Collider (LHC). One approach is to replace the standard gas with a mixture of HFO1234ze/$CO_2$/i-$C_4H_{10}$/$SF_6$. The second approach, currently under study by ATLAS and CMS collaborations, is to introduce a small fraction of $CO_2$ in the standard gas mixture and by reducing the amount of $SF_6$. In this presentation the results on the performance achieved using a 1 mm gas gap RPC with both types of gas mixtures are reported.

T 64.3 Wed 16:30 Geb. 30.23: 2/17

**Performance Evaluation of the Newly Developed TPC Gas Monitoring Chambers for the T2K Near Detector Upgrade** — Stefan Roth, •Keitlin Sejdarasi, David Smyczek, Jochen Steinmann, and Nick Thamm — RWTH Aachen University, Physics Institute III B, Aachen, Germany

In order to ensure the stable operation of time projection chambers (TPCs), the gas parameters are continuously monitored over time. For the upgrade of the T2K near detector ND280, this task will be accomplished by gas monitoring chambers (GMCs), which are essentially a miniature version of a TPC. In this talk, first results from the measurements of the gas gain and drift velocity for different gas mixtures for the newly developed GMCs are presented. These results are compared to simulations, as well as to measurements with the predecessor model of the GMC.

T 64.4 Wed 16:45 Geb. 30.23: 2/17

**Studying Effects of Temperature and Pressure on Measurements of the TPC Gas Monitoring Chambers for the T2K Near Detector Upgrade** — Stefan Roth, Keitlin Sejdarasi, •David Smyczek, Jochen Steinmann, and Nick Thamm — RWTH Aachen University - Physics Institute III B, Aachen, Germany

A new pair of Time Projection Chambers for high angle measurements (HATs) are part of the T2K near detector upgrade. For their calibration, the gas parameters will be continuously monitored using newly developed Gas Monitoring Chambers (GMCs). Besides the gas mixture itself, temperature and pressure have a large effect on the monitored gas parameters. Only by measuring these environmental variables, and including them inside the analysis of the gas, significant statements about the gas parameters and quality can be made. Furthermore, the surrounding temperature influences the GMC setup, affecting the measurement process. The status of these investigations is presented.

T 64.5 Wed 17:00 Geb. 30.23: 2/17

**Study of different operating gases for Micromegas detectors at the International Axion Observatory** — •Christian Stoss, Elisa Ruiz Chóliz, and Matthias Schott — Johannes Gutenberg Universität Mainz

The purpose of this work is to determine the optimal operating gas for micromegas detectors that fulfils the requirement of the IAXO collaboration for the search for axions. In order to measure the few photons created by the Primakoff effect in the magnetic field of (Baby)IAXO, high-precision measurements with extremely low background rates are required. However, argon, which is the main component of the operating gas used, has an escape peak at around 2.9 keV. This can strongly overlap the expected signal in the range of 3-4 keV. To avoid this problem, a different gas mixture is required, so the performance of a micromegas detector with a Iron-55 source using several gas mixtures was analysed. However, as xenon in particular is a cost-intensive gas and the pressure, which has a major influence on the performance of the gas, could not yet be controlled in this setup, a gas-tight chamber was developed. In this chamber, a micromegas prototype within the same technical specifications as the BabyIAXO ones, can be characterized with different gases and different pressures with a comparatively small amount of gas. The development of the entire chamber and the development of a bash script for an automated measurement are the main components of this work. The first test measurements were also taken.

T 64.6 Wed 17:15 Geb. 30.23: 2/17

**The Influence of Combined Oxygen and Water Impurities on Measurements with a MicroMegas Detector filled with an Ar-$CO_2$ Gas Mixture** — •Burkhard Böhm and Raimund Ströhmer — Universität Würzburg, Germany

In particle physics, Micro-Pattern Gaseous Detectors (MPGD) find high usage in different experiments like ATLAS, CMS or ALICE. In this study MicroMegas Detectors (MM) - a special type of MPGDs - are researched in terms of combined contamination from $H_2O$ and $O_2$. These detectors are well known for their simple single-stage amplification, high and stable gain and excellent spatial and temporal resolutions. Gas systems are rarely perfectly tight and can be contaminated by $H_2O$ or $O_2$ from ambient air. The effect of $H_2O$ impurities on measurement results was researched to be very small while $O_2$ concentration can significantly effect the results. As processes in 3 or more component gases are complex, studying the behaviour of the combination $O_2$ and $H_2O$ in an Argon atmosphere experimentally is very useful. By precisely controlled inflowing of $O_2$ and humid Ar-$CO_2$ inside a resistive MM chamber, the effect on the gas-gain, mainly due to attachment in the drift region, and the amplification of the number of primary electrons are studied. In parallel to the experimental study numerical investigations were done to explore the parameter space of the amplification gap of the MM detector.

T 64.7 Wed 17:30 Geb. 30.23: 2/17

**Development of a flexible gas supply system for gaseous detectors** — •Jan Glowacz, Jochen Kaminski, and Klaus Desch — Physikalisches Institut, University of Bonn

For testing and operation of gaseous detectors a well controlled supply of gas mixtures is of high importance. We have developed a compact and mobile gas system for operation both in the laboratory as well as in test beam environments. Its small dimensions and light weight facilitate transportation and setup at different locations. It is laid out to control the gas flow and gas pressure in the detector for premixed gases or gas mixtures with two components. The system can be controlled via web browser interface and includes recording of important environmental parameters such as temperatures, gas pressure inside and outside the detector and flow rates. First tests with a detector have shown that the gas system can operate at a wide range of gas pressures of 0.3-1.5 bar.

# T 65: Trigger+DAQ 2

Time: Wednesday 16:00–18:00 Location: Geb. 30.23: 3/1

T 65.1 Wed 16:00 Geb. 30.23: 3/1

**Optimization of the Level-1 Tau Trigger at ATLAS for Run 3** — •Philipp Rincke[1,2], Stan Lai[1], and Arnaud Ferrari[2] — [1]II. Physikalisches Institut, Georg-August-Universität Göttingen, Deutschland — [2]Department of Physics and Astronomy, Uppsala University, Sweden

The Level-1 calorimeter trigger system of the ATLAS detector was updated for Run 3 of the LHC, including the introduction of the electron feature extractor (eFEX) and jet feature extractor (jFEX). For tau signatures, both the eFEX and jFEX reconstruct tau objects, which are referred to as eTAUs and jTAUs respectively.

By geometrically matching the eTAUs and jTAUs in a topological processor, combined tau objects (cTAU) are reconstructed in the Level-1 Trigger. This allows to combine the better energy resolution of eTAUs with the larger isolation area of jTAUs. So far the tau isolation criterion has not been optimized for cTAUs and the proposed cTAU trigger items have not been commissioned. In this talk, the current status of the investigations to optimize the isolation criterion for cTAUs are presented.

T 65.2 Wed 16:15 Geb. 30.23: 3/1

**Commissioning of the Upgraded ATLAS Level-1 Jet Trigger** — •Moritz Hesping, Anamika Aggarwal, Volker Büscher, Ralf Gugel, Christian Kahra, Emanuel Meuser, Niklas Schmitt, and Duc Bao Ta — Johannes Gutenberg Universität Mainz

For Run 3 of the LHC, the ATLAS level-1 calorimeter trigger (L1Calo) has received a major upgrade. An important part of this is the Jet Feature Extractor (jFEX). This system is responsible for the measurement of jets, tau leptons and forward electrons at level 1, and the calculation of the missing transverse energy and total energy of the event. It receives input from the calorimeters at a finer granularity than the Run 2 systems.

In this talk, results from the physics commissioning of the jFEX jet triggers are presented. This includes measurements of trigger efficiencies and rates, as well as optimization studies for the tuning of the system's parameters such as trigger thresholds and energy calibrations.

T 65.3 Wed 16:30 Geb. 30.23: 3/1

**Commissioning and Validation of the jFEX $E_T^{miss}$ Algorithm for the ATLAS Level-1 Trigger** — Anamika Aggarwal, Volker Büscher, Ralf Gugel, Moritz Hesping, Christian Kahra, Emanuel Meuser, •Niklas Schmitt, and Duc Bao Ta — Johannes Gutenberg-University, Mainz

During the last long shutdown of the LHC, the ATLAS level-1 calorimeter trigger underwent a major upgrade to cope with increased event rates when running at higher energies and instantaneous luminosity during Run 3 and beyond. As part of this phase-1 upgrade, a new system of feature extractor modules was implemented. These modules receive inputs from the calorimeters with finer granularity and execute more advanced algorithms. The new **J**et **F**eature **EX**tractor (jFEX) reconstructs jets, tau-leptons, forward electrons and energy sums, including $E_T^{miss}$ . A big improvement compared to the Run 2 trigger is a new event-by-event pile-up correction. The latter provides a real-time correction for in-time pile-up that leads to additional energy deposits in the calorimeters. The commissioning of the new system, along with the performance validation using early Run 3 data, is crucial to assure optimal data-taking conditions.

This talk will give an overview about the calibration of the new jFEX $E_T^{miss}$ trigger as well as the parameter optimization for the pile-up correction algorithm. Furthermore, efficiency- and rate measurements based on 2023 proton-proton data are presented.

T 65.4 Wed 16:45 Geb. 30.23: 3/1

**Implementation of a two-level AI-enhanced trigger on a single chip for live reconstruction** — •Patrick Schwäbig for the Lohengrin-Collaboration — Physikalisches Institut, Universität Bonn, Deutschland

For years, data rates generated by modern detectors and the corresponding readout electronics exceeded by far the limits of data storage space and bandwidth available in many experiments. The solution of using fast triggers to discard uninteresting and irrelevant data is a solution used to this day. Using FPGAs, ASICs or directly the readout chip, a fixed set of rules based on low level parameters is applied as a pre-selection. Only a few years ago, live track reconstruction for triggering was rarely possible. With the emergence of highly parallelized processors for AI inference, attempts to sufficiently accelerate tracking algorithms become viable. The Xilinx Versal Adaptive Compute Acceleration Platform (ACAP) is one such technology and combines FPGA and CPU resources with dedicated AI cores. Our approach is to implement a two-level trigger on a single chip by utilizing the tightly integrated combination of FPGA and AI cores to profit from their individual strengths. In this talk our concept for a two-level trigger setup, implemented on a Xilinx VC1902, including AI algorithms and Timepix3 readout, will be shown. They will be used in an envisioned mid-size ultra-high rate fixed-target dark matter experiment (Lohengrin) at the ELSA accelerator at the University of Bonn.

T 65.5 Wed 17:00 Geb. 30.23: 3/1

**Implementation of Graph Neural Networks for online track reconstruction at the ATLAS experiment** — •Poppy Hicks, Sebastian Dittmeier, and André Schöning — Physikalisches Institut, Universität Heidelberg, Heidelberg

The upcoming High Luminosity upgrade to the LHC poses several challenges, most notably the huge increase in data to process. This necessitates improvements to the Trigger and Data Acquisition systems at the ATLAS experiment, including to its final stage, the Event Filter. Significant effort is being invested into computing R&D for the Event Filter, to keep resources within capacity; one promising avenue is the use of algorithms based on graph neural networks (GNNs) for track reconstruction in the Inner Tracker detector. GNNs demonstrate exceptional capability at modelling complex relationships within graph-structured data. Here, a graph represents detector hits as nodes; edges connecting these nodes represent the possibility the hits belong to the same particle. A GNN is used to score these edges to quantify that probability. In this talk, an overview of the use of GNNs for track reconstruction will be summarized; the focus will be on optimizing graphs for subsets of the data, in the pursuit of minimizing GPU memory requirements and maximising throughput.

T 65.6 Wed 17:15 Geb. 30.23: 3/1

**ML Pile-up Rejection at the ATLAS High Level Trigger (HLT) based on Hit-level Information** — •Mathias Backes — Kirchhoff-Institut für Physik Heidelberg

The rejection of pile-up in proton collisions at the LHC is crucial for analyses like the Di-Higgs. One possibility to reject pile-up is by reconstructing the primary vertex position of several jets in the same event, which is implemented offline as well as in the trigger. In the case of the ATLAS experiment, this is implemented in the High Level Trigger (HLT). The main bottleneck of the HLT is the CPU usage, which is significantly increased by performing a track reconstruction.

Here we study a possibility to save computing resources by extracting the primary vertex position directly from the position of the hits in the inner detector, without performing a track reconstruction algorithm. Using ideas that have already been applied in trackless flavour tagging algorithms, we aim to construct a DeepSet neural network which is trained to predict the primary vertex z position as well as its uncertainty on a jet-by-jet basis. Events can consequently be rejected if not all required jets originate in the same vertex.

T 65.7 Wed 17:30 Geb. 30.23: 3/1

**Testing of the ATLAS MDT Trigger Processor board** — •Davide Cieri, Markus Fras, Oliver Kortner, and Sandra Kortner — Max-Planck-Institut für Physik, Munich, Germany

The MDT Trigger Processor (MDTTP) is a fundamental part of the upgrade of the first-level (L0) muon trigger of the ATLAS experiment at the HL-LHC. The new system will be responsible for improving the muon momentum resolution and thus refining the muon selectivity, using for the first time at L0 the precision tracking information from Monitored Drift Tube (MDT) chambers in addition to the trigger chamber information. The system will also transmit the MDT hit data to the data acquisition (DAQ) system in the event of a trigger accept.

We present here the results of the testing done on the produced prototype board. In particular, the results of the thermal tests and the connection tests with the other system within the ATLAS L0Muon are shown.

T 65.8 Wed 17:45 Geb. 30.23: 3/1

**The TARGET module calibration procedure and performance for the SST Camera** — •Benjamin Schwab for the CTA-Collaboration — ECAP, FAU Erlangen-Nürnberg

The SST Camera is part of the Small Sized Telescope (SST) which will probe the TeV gamma-ray universe as part of the Cherenkov Telescope Array Observatory (CTAO). The basis of this camera builds the TeV Array Read-out with GSa/s sampling and Event Trigger (TARGET) module with its ASICs (Application Specific Integrated Circuit) CTC and CT5TEA. The tasks of the TARGET module range from supplying the silicon photomultiplier pixel with the needed high voltage to the shaping, sampling, triggering and digitisation of events. A total of 64 pixel can be handled with one module, resulting in a total number of 32 modules per camera. The required calibration routines for the module commissioning and the performance of the signal and trigger path shall be discussed in detail.

## T 66: Neutrino astronomy 3

Time: Wednesday 16:00–18:00 Location: Geb. 30.23: 6/1

T 66.1 Wed 16:00 Geb. 30.23: 6/1

**The Galactic Diffuse Neutrino Emission in a Combined Fit of Muon Tracks and Cascades with IceCube*** — •Jonas Hellrung[1,2], Philipp Fürst[3], Niclas Krieger[1,2], Lukas Merten[1,2], and Julia Becker Tjus[1,2,4] for the IceCube-Collaboration — [1]Theoretical Physics IV, Plasma Astroparticle Physics, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — [3]III. Physikalisches Institut B, RWTH Aachen University, 52062 Aachen, Germany — [4]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

The measurement of diffuse neutrino emission from the Galactic plane provides unique information on the distribution of cosmic rays in our Galaxy. The IceCube collaboration has published a first measurement of this neutrino flux in 2023. IceCube can measure neutrinos through two main experimental signatures: The so called cascades arise from neutral current interactions of all flavors or charged current interactions from electron and tau neutrinos while tracks are produced in charged current interactions from muon neutrinos. The first measurement of the Galactic plane used the cascade channel, but since then hints for the Galactic plane where also found in a track sample. A combined measurement of both detection channels can help to understand the properties of the Galactic diffuse neutrino emission better. Sensitivities and model discrimination power of such a combined measurement are discussed here. *Supported by BMBF and SFB 1491

T 66.2 Wed 16:15 Geb. 30.23: 6/1

**A model-independent measurement of the Galactic neutrino flux with IceCube** — •Mirco Hünnefeld[1] and Ludwig Neste[2] for the IceCube-Collaboration — [1]TU Dortmund University, AG Rhode, Dortmund, Germany — [2]Oskar Klein Centre, Stockholm University, Stockholm, Sweden

The IceCube Neutrino Observatory recently published results on the observation of high-energy neutrinos from the Galactic Plane. These neutrinos can be produced when cosmic rays interact at their acceleration sites and during their propagation through the interstellar medium. The observed neutrino signal appears consistent with diffuse emission from the Galactic Plane, potentially in combination with emission by a population of unresolved sources. Additional follow-up studies are required to further investigate the production mechanisms of the Galactic neutrino flux and to adequately correlate this observation with measurements by gamma-ray experiments. In this contribution, the development of such a follow-up analysis with IceCube is presented. The goal of the analysis is to provide a spatially-resolved, model-independent measurement of the Galactic neutrino flux.

T 66.3 Wed 16:30 Geb. 30.23: 6/1

**Numerical Investigation of Bursting Sources as Potential Accelerators of Ultra-High-Energy Cosmic Rays*** — •Leander Schlegel[1,2], Julia Becker Tjus[1,2,3], and Marcel Schroller[1,2] — [1]Theoretical Physics IV, Plasma Astroparticle Physics, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — [3]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

Since their discovery over a century ago, the origin of cosmic rays (CR) of the highest energies is still widely uncertain. A promising class of source candidates are Active Galactic Nuclei (AGN), whose subclass of blazars shows strong temporal variability as they appear in quiescent and flaring states. The goal of this work is trying to understand the detailed behaviour of these bursting sources and their possible contribution to the ultra-high-energy CR flux, by numerically simulating the time resolved propagation of a relativistic plasmoid inside the jet of an AGN. In foregoing work, a tool for cosmic-ray propagation and interaction in these local environments was implemented into the open-source code CRPropa, that is now further improved and applied. During this work, contributions could also be made to the development of CRPropa 3.2. With our framework, we apply the model to observed data of bursting sources, aiming to fit both their spectrum and light curve and try to predict their multi-messenger signatures, in order to get a more detailed understanding of this source class. *Supported by DFG (MICRO and SFB 1491)

T 66.4 Wed 16:45 Geb. 30.23: 6/1

**Stacking Analysis of Extreme Blazars as Neutrino Source Candidates** — •Juan Manuel Cano Vila[1,2], Chiara Bellenghi[1], Paolo Padovani[3], and Elisa Resconi[1] — [1]Technical University of Munich, TUM School of Natural Sciences, Department of Physics, James-Franck-Straße 1, D-85748 Garching bei München, Germany — [2]Arnold Sommerfeld Center, Ludwig-Maximilians University, 80333 Munich, Germany — [3]European Southern Observatory, Karl-Schwarzschild-Straße 2, D-85748 Garching bei München, Germany

Since IceCube Neutrino Observatory confirmed the existence of high-energy astrophysical neutrinos, enormous efforts have been made to determine which kind of objects emit them. Blazars constitute one of the most promising candidates as astrophysical neutrino sources, with evidence of emission from TXS 0506+056. Although it has been shown that blazars can only account for a fraction of the astrophysical diffuse flux, it remains open whether they can be identified as sources of high-energy neutrinos, especially the most energetic ones. One way to tackle this problem is to study the joint signal from multiple selected sources through an unbinned stacking log-likelihood analysis, enhancing the statistics by a population-wide study in this way. In this work, we perform such analysis with the IceCube 10 yr public data sample to a catalog of these extreme blazars.

T 66.5 Wed 17:00 Geb. 30.23: 6/1

**Search for neutrinos from AGN using a data-driven source selection** — •Sebastian Schindler[1] and Thorsten Glüsenkamp[1,2] for the IceCube-Collaboration — [1]ECAP, FAU Erlangen-Nürnberg, Germany — [2]Uppsala University, Sweden

The IceCube Neutrino Observatory is a gigaton-volume high-energy neutrino detector. One of the main goals is the association of the previously discovered astrophysical neutrino flux with specific source classes. A few sources have been found (NGC 1068 and TXS 0506+056), which belong to certain classes of Active Galactic Nuclei (AGN). However, the underlying physical processes of neutrino production remain poorly understood. One problem for neutrino-source searches comes from the use of historically-driven class definitions of AGN, which are based on specific spectral properties that are not necessarily optimal for the selection of potential neutrino sources.

Using multi-wavelength data in a data-driven approach, we aim to define a source selection in a way that emphasizes intrinsic physical properties and mostly disregards the general AGN classification. This will allow to identify potential neutrino sources similar in physical properties to those associated with the currently detected sources. Later, a statistical analysis will be performed to test the correlation of neutrinos with these previously defined source selections.

This talk will present the recent progress in this study consisting of exploratory data analysis of some multi-wavelength data. Cross-matched x-ray (2RXS) and infrared (AllWISE) catalogs are analyzed using the clustering algorithm HDBScan in a high-dimensional space.

T 66.6 Wed 17:15 Geb. 30.23: 6/1

**Investigating the contribution of Seyfert galaxies to astrophysical neutrino observations using source population simulations** — •Lena Saurenhaus and Francesca Capel — Max-Planck-Institut für Physik, Boltzmannstr. 8, 85748 Garching b. München, Germany

Active galactic nuclei (AGNs) are among the most powerful objects in the Universe and are suspected to be sources of astrophysical neutrinos. Recently, the IceCube Collaboration reported an excess of neutrino events with energies between 1.5 and 15 TeV associated with NGC 1068, a nearby Seyfert galaxy with an extraordinarily high intrinsic X-ray flux. The lack of observable gamma rays in this energy range indicates that these neutrinos are likely to be produced in the AGN corona, which is opaque to high-energy gamma rays. Motivated by these findings, we explore the prospects of observing other hidden neutrino sources with similar neutrino production mechanisms. Assuming a correlation between the intrinsic X-ray luminosity and the neutrino luminosity of a source, we build a simple neutrino emission model that accounts for both photohadronic and hadronuclear interactions. Using this model in combination with publicly available detector information, we then make predictions about the detectability of the neutrino emission from a selection of other nearby Seyfert galaxies with IceCube and its planned extension IceCube-Gen2. In addition, we simulate an entire population of Seyfert galaxies and estimate the resulting diffuse neutrino emission to draw a coherent picture of the contribution of these sources to astrophysical neutrino observations.

T 66.7 Wed 17:30 Geb. 30.23: 6/1

**Modelling an Orphan Flare from Blazar 1ES 1959+650 on 4th of July 2002 using CRPropa*** — •Vladimir Kiselev[1,2], Marcel Schroller[1,2], and Julia Becker Tjus[1,2,3] — [1]Theoretical Physics IV, Ruhr University Bochum — [2]RAPP Center, Ruhr University Bochum — [3]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

1ES 1959+650 is a blazar, which is known to emit high-energy gamma rays. On the 4th of July 2002, a so-called orphan flare occurred, where a high-energy signal was detected by several Cherenkov observatories with no corresponding X-ray counterpart. Additionally, in later analysis, several neutrinos consistent with the direction of the blazar have been reported by the AMANDA collaboration. Both peculiar signatures could hint at a hadronic origin of the flare, instead of a synchrotron self-Compton scenario often used to model SEDs of blazars. Although not statistically significant, this flare has long been discussed as an early hint of the correlation between gamma rays and neutrinos. Here, we want to pick up on this source and use today's possibilities of 3D theoretical modelling to test how the orphan flare and the neutrino signal, unmasked by the AMANDA collaboration, can be explained. For this purpose, we utilise a modified version of CRPropa with a hadronic model with propagation in a 3D magnetic field. We present the first results of how this flare and the neutrino signal can be explained within the model of emission from a magnetized, relativistic plasmoid travelling along the AGN jet. *Supported by DFG (SFB 1491)

T 66.8 Wed 17:45 Geb. 30.23: 6/1

**Extending Hadronic Test Particle Simulations by Non-Linear Leptonic Processes** — •Marcel Schroller[1,2], Julia Becker Tjus[1,2,3], and Lukas Merten[1,2] — [1]Theroretical Physics IV, Ruhr University Bochum, 44780 Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — [3]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

Active galactic nuclei (AGN) and the accompanying jets are candidates for the engine of ultra-high-energy cosmic rays, gamma rays, and neutrinos. In 2017, IceCube observed an extragalactic high-energy neutrino event with a strong hint of a directional coincidence with the position of a known jetted AGN TXS0506+056. A deep understanding of the processes related to jets will fuel the field of high-energy cosmic rays, fundamental plasma, astro, and particle physics. However, an AGN jet's physical and mathematical modelling is challenging, with ambiguous signatures that need to be understood by numerical simulations of cosmic-ray transport and interactions. In this context, we present a simulation framework based on CRPropa 3.2 for hadronic constituents and their interactions inside a plasmoid boosted along the AGN jet axis. Consequently, the framework was utilised to investigate the impact of spacetime-dependent photonic and hadronic target fields on hadronic interactions. Furthermore, we will present the results of our simulations and discuss how to implement non-linear leptonic radiation processes into our test particle simulation framework, enabling us to construct an improved physical description of AGN jets.

# T 67: Data, AI, Computing 5 (normalising flows)

Time: Wednesday 16:00–17:45 Location: Geb. 30.33: MTI

T 67.1 Wed 16:00 Geb. 30.33: MTI

**Applications of Normalizing Flows in High-Energy Particle Physics** — •Lars Sowa, Roger Wolf, Markus Klute, and Günter Quast — Institute of Experimental Particle Physics (ETP), Karlsuhe Institute of Technology (KIT)

Normalizing flows (NFs) are neural networks that preserve probability when mapping probability density distributions from a given input to an arbitrary output space. They exhibit promising capabilities both, as surrogates for the fast generation of new samples as approximators of arbitrary probability density functions. These properties make them compelling in high-energy physics (HEP) applications. This work focuses on the application of NFs for recoil calibration, specifically with LHC Run-3 data taken with the CMS detector. Additionally, an NF-based b-jet regression is introduced, enabling the estimation of the per-jet energy resolution. The proposed methods showcase the versatility of NFs in HEP, serving as effective tools.

T 67.2 Wed 16:15 Geb. 30.33: MTI

**Parameter reconstruction for gravitational wave signals at the Einstein Telescope using conditional normalizing flows** — Johannes Erdmann and •Tobias Reike — III. Physikalisches Institut A, RWTH Aachen University

The proposed Einstein Telescope will be a gravitational wave detector of the third generation. It will improve the sensitivity compared to the current interferometers LIGO and VIRGO by an order of magnitude, resulting in a substantial additional volume for observation. The sensitive frequency range of the Einstein Telescope will also be much larger, allowing it to observe signals earlier and for longer durations. These improvements will significantly increase the amount of incoming data compared to current experiments, so that more efficient ways of processing data are needed.

Deep learning presents a promising option for fast analysis of incoming data, handling event detection as well as reconstruction. This talk will focus on simultaneous detection and parameter estimation of gravitational wave signals from Binary Black Hole Mergers using conditional normalizing flows.

T 67.3 Wed 16:30 Geb. 30.33: MTI

**Normalizing Flows to Infer Ultra-High-Energy Cosmic-Ray Source Properties from Surface Detector Measurements at the Pierre Auger Observatory** — •Frederik Krieger[1], Teresa Bister[2], Martin Erdmann[1], and Josina Schulte[1] — [1]III. Physikalisches Institut A, RWTH Aachen University — [2]Institute for Mathematics, Astrophysics and Particle Physics, Radboud Universiteit Nijmegen

The energy spectrum and the depth of shower maximum $X_{\text{max}}$ distributions of ultra-high-energy cosmic rays (UHECRs) are measured at the Pierre Auger Observatory. Since $X_{\text{max}}$ is correlated to the mass of the primary cosmic ray, these measurements are used to constrain the astrophysical parameters of UHECR source models. These parameters include the spectral index and the maximum energy of the injected spectrum, and the initial mass composition. Owing to the stochastic nature of interactions during propagation, simple inversion of the process from source to Earth is not possible.

For parameter inference, we apply conditional invertible neural networks, a method based on normalizing flows. In comparison to the frequently used Markov Chain Monte Carlo method, they act as likelihood-free estimators. We investigate the influence of higher event statistics of the $X_{\text{max}}$ distributions, which can now be extracted from the surface detector data of the Pierre Auger Observatory using deep learning. Our results indicate that the increased statistics lead to stronger constraints on the astrophysical parameters and to enhanced sensitivity to experimental systematic effects.

T 67.4 Wed 16:45 Geb. 30.33: MTI

**Using neural networks to calculate bounce actions** — •Fabio Campello[1], Georg Weiglein[2], and Thomas Biekötter[3] — [1]UHH, Hamburg, Deutschland — [2]DESY, Hamburg, Deutschland — [3]KIT, Karlsruhe, Deutschland

Computing the decay rate of a meta-stable state is a well-known problem with relevance in various areas of physics. The decay rate is dominated by an exponential factor B, called the bounce action. Determining the bounce action for a given potential and meta-stable vacuum involves solving a set of partial differential equations. Numerically solving these equations can be challenging, especially in instances where the meta-stable vacuum is nearly degenerate to the deeper vacuum, referred to as the thin-wall limit. There are several dedicated solvers available for this problem, however finding bounce actions in potentials of many variables still remains a challenge.

It is also established that neural networks can be used to solve any differential equation with fixed boundary conditions, as neural networks are general function approximators. We use a neural network to solve the partial differential equation for finding the tunneling path. Using a custom tensorflow operation for the loss function enables us to make use of the full capabilities of modern GPUs.

Subsequently, we apply this approach to analyze vacuum stability in both the Minimal Supersymmetric extension of the Standard Model (MSSM) and Next-to-MSSM (NMSSM), where we successfully determine bounce actions for the tree-level potential including all Higgs fields and 3rd generation sfermions, for a total of 22 scalar fields.

T 67.5 Wed 17:00 Geb. 30.33: MTI

**Generating Accurate Showers in Highly Granular Calorimeters Using Convolutional Normalizing Flows** — •Thorsten Buss — Institut für Experimentalphysik, Universität Hamburg, Germany

Monte Carlo MC simulations are vital for collider experiments. They allow us to compare experimental findings with theory predictions. These simulations have a high computational demand, and future developments, such as higher event rates, are expected to push the computation needs beyond availability. Generative neuronal networks can alter MC simulations, speeding them up and mitigating the problem.

Last year, we presented a masked auto-regressive flow (MAF) based generation of particle showers. While generating highly accurate showers in highly granular calorimeters is possible, the generation on CPUs is slower than MC simulations. Also, the architecture does not scale well with input dimensions. Therefore, we change the MAF to a coupling-based flow with convolutional sub-networks. This speeds up the model by a significant factor and improves the model's accuracy further.

Lately, point-cloud-based generative models have become popular. These models represent showers as unordered sets of energy depositions characterized by their position in the detector and the amount of energy. Since fixed grid models, such as our flow, are usually trained on the irregular detector geometry, point-cloud-based models are expected to generalize better to different detector geometries. We conduct a systematic comparison between point cloud and fixed gride models.

T 67.6 Wed 17:15 Geb. 30.33: MTI

**Improving MCMC sampling efficiency with normalizing flows** — Michael Dudkowiak[1], Cornelius Grunwald[2], Oliver Schulz[1], and •Willy Weber[2] — [1]Max Planck Institute for Physics, Munich — [2]TU Dortmund University, Department of Physics

The Bayesian data analysis approach combines prior knowledge and observed data to derive information about the parameters of a model. Typically, numerical sampling methods are required for performing Bayesian inference due to the complexity of the models and the high-dimensional parameter spaces involved, as is usually also the case in particle physics applications. Markov Chain Monte Carlo (MCMC) methods are commonly used to generate samples that approximate the posterior distribution. Machine learning techniques have the potential to enhance MCMC methods by improving the exploration of complex parameter spaces, leading to more accurate results. This talk focuses on normalizing flow models, which allow to transform a complex distribution into a simpler one, thereby improving the sampling efficiency of MCMC algorithms. This presentation introduces an implementation of a normalizing flow enhanced MCMC ensemble algorithm currently being integrated into the Bayesian Analysis Toolkit (BAT.jl). Initial studies on the performance of this new algorithm are presented.

T 67.7 Wed 17:30 Geb. 30.33: MTI

**Conditional normalizing flows for correcting simulations** — •Caio Cesar Daumann[1], Mauro Donega[2], Johannes Erdmann[1], Massimiliano Galli[2], Jan Lukas Späh[1], and Davide Valsecchi[2] — [1]III. Physikalisches Institut A, RWTH Aachen University — [2]ETH Zurich

Simulated events are key ingredients for almost all high-energy physics analyses. However, imperfections in the configuration of the simulation often result in mis-modelling and lead to discrepancies between data and simulation. Such mis-modelling often must be taken into account by correction factors accompanied by systematical uncertainties, which can compromise the sensitivity of measurements and searches. To address this issue, we propose to use normalizing flows, a powerful technique for learning the underlying distributions of input data. Where the flow is trained with both simulation and data, and is able to map betwenn the distributions.

We demonstrate that the proposed architecture can accurately correct simulation marginal distributions results in better closure with data. Additionally, we show that the flow can correct the correlations of variables, leading to significantly reduced differences in correlation matrices compared to the data.

# T 68: Data, AI, Computing 6 (ML utilities)

Time: Wednesday 16:00–18:00 Location: Geb. 30.34: LTI

T 68.1 Wed 16:00 Geb. 30.34: LTI

**b-hive: a Model-Independent Machine Learning Training Framework for the CMS Experiment** — •Mate Farkas[1], Niclas Eich[2], and Martin Erdmann[3] — [1]mate.farkas@rwth-aachen.de — [2]niclas.eich@rwth-aachen.de — [3]martin.erdmann@physik.rwth-aachen.de

In high-energy physics (HEP), neural-network (NN) based algorithms have found many applications, such as quark-flavor identification of jets in experiments like the Compact Muon Solenoid (CMS) at the Large Hadron Collider (LHC) at CERN. Unfortunately, complete training pipelines often finds application-specific obstacles like the processing of many and large root files, the data provisioning to the model, and a correct evaluation. We have developed a framework called "b-hive" that combines state-of-the-art tools for HEP data processing and training in a Python-based ecosystem. The framework uses common Python packages like law, coffea and pytorch bundled in a conda-environment, aimed for an uncomplicated setup. Different subtasks like dataset conversion, training, and evaluation are implemented as law tasks, making the reproduction of trainings through built-in versioning and parametrization straightforward. The framework is designed in a modular structure so that single components can be exchanged and used through parameters, making b-hive not only suited for production tasks but also network development and optimization. Further, fundamental HEP requirements as the configuration of different physics processes, event-level information, and kinematic cuts can be specified and steered in a single configuration without touching the code itself.

T 68.2 Wed 16:15 Geb. 30.34: LTI

**Checkpointing of long running machine learning trainings on GPUs** — •Jonas Eppelt, Matthias Schnepf, Giacomo De Pietro, and Günter Quast — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

The rise of Machine Learning (ML) applications in High Energy Physics (HEP) analysis and reconstruction pushes for the use of GPUs in such workflows. The training of neural networks can have long runtimes, making them more susceptible to runtime constraints and failures. Checkpoints contain information about the current state of the training and therefore allow continuing the training from this state to another time and another place. This will provide resistance to failures and will allow for long runtimes while abiding to time constraints. Additionally, checkpointing will enable efforts in sustainable computing. For example, trainings can be run at times when renewable energies are available and haltet during times with limited energy supply. This talk presents a Python interface that bundles common tools from the HEP community to provide storing, transferring and restoring checkpoints for ML training.

T 68.3 Wed 16:30 Geb. 30.34: LTI

**MLProf: Automated resource profiling of machine learning models in CMS production** — •Nathan Prouvost, Marcel Rieger, and Peter Schleper — University Hamburg, Hamburg, Germany

With the increasing amount of data recorded by LHC experiments and collaborations, the efficient handling of computing resources is a topic of growing importance. In this regard, machine learning models, with their increasing number of applications and increasing specialization, can be difficult to include in central reconstruction workflows of an experiment.

For the CMS experiment at CERN, the awareness of this situation concerning time and memory budget has been growing in the last years. On top of these challenges, the integration of machine learning models into the CMS core software can be a very laborious task to begin with, impeding a fast feedback loop from performance measurements back to the model development. Therefore, a new tool for automating the extraction of resource consumption metrics of machine learning models within the CMS software environment, called MLProf, has been created.

This presentation introduces MLProf and its main features, including automated runtime measurements on different batch sizes, different versions of the CMS software environment and for different inference engines.

T 68.4 Wed 16:45 Geb. 30.34: LTI

**Ahead-of-time (AOT) compilation of Tensorflow models** — •Bogdan Wiederspan, Marcel Rieger, and Peter Schleper — Universität Hamburg

In a wide range of high-energy particle physics analyses, machine learning methods have proven as powerful tools to enhance analysis sensitivity. In the past years, various machine learning applications were also integrated in central CMS workflows, leading to great improvements in reconstruction and object identification efficiencies.

However, the continuation of successful deployments might be limited in the future due to memory and processing time constraints of more advanced models evaluated on central infrastructure.

A novel inference approach for models trained with TensorFlow, based on Ahead-of-time (AOT) compilation is presented. This approach offers a substantial reduction in memory footprints while preserving or even improving computational performance.

This talk outlines strategies and limitations of this novel approach, and presents integration workflow for deploying AOT models in production.

T 68.5 Wed 17:00 Geb. 30.34: LTI

**Hog: handling HDL repositories on git** — •Davide Cieri — Max-Planck-Institut für Physik, Munich, Germany

Handling HDL project development within large collaborations presents many challenges in terms of maintenance and versioning, due to the lack of standardized procedures. Hog (HDL on git) is a tcl-based open-source management tool, created to simplify HDL project development and management by exploiting git and GitLab/GitHub Continuous Integration (CI).

Hog is compatible with the major HDL IDEs from Xilinx, Intel, and Microsemi, and guarantees synthesis and placing reproducibility and binary file traceability, by linking each binary file to a specific git commit. Hog-CI validates any changes to the code, handles automatic versioning and can automatically simulate, synthesise and build the design.

T 68.6 Wed 17:15 Geb. 30.34: LTI

**Improved Clustering with Graph Neural Networks on FPGAs for the Electromagnetic Calorimeter Trigger at Belle II** — •Isabel Haide[1], Torben Ferber[1], and Marc Neu[2] — [1]Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT) — [2]Institut fuer Technik der Informationsverarbeitung (ITIV), Karlsruhe Institute of Technology (KIT)

For the Belle II experiment, beam background plays a very impactful role, especially on the hardware trigger level. Due to the maximum latency of 1.3 $\mu$s the current trigger algorithm for the Belle II electromagnetic calorimeter uses a simple clustering mechanism that, especially in high beam background, identifies a high number of fake clusters and is additionally unable to separate overlapping clusters. As Belle II plans to increase its luminosity by a factor of 40, an update of the trigger algorithm will be necessary. In this talk, we will show the application of a Graph Neural Network in the form of the object condensation algorithm applied on the hardware trigger level of the electromagnetic calorimeter at Belle II. We will show an implementation of the machine learning algorithm on FPGA level, which is necessary to guarantee a fast execution time, and the evaluation on possible Dark Sector models which would be inaccessible with the current trigger algorithm.

T 68.7 Wed 17:30 Geb. 30.34: LTI

**Dealing with negatively weighted Events in DNN-based LHC Analyses** — •Jörn Bach[1,2,3], Christian Schwanenberger[1,2], Peer Stelldinger[3], and Alexander Grohsjean[2] — [1]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [2]Universität Hamburg, Hamburg, Germany — [3]HAW Hamburg, Hamburg, Germany

The recent decade has seen a growth of machine learning algorithms across all disciplines. In LHC physics, a multitude of applications have been tested and - in particular Deep Neural Networks (DNNs) - have been proven to be very effective in various usecases, for example in particle tagging or for separating signal from background in analyses. Since training data is primarily generated through Monte-Carlo (MC) simulation, specific challenges can emerge during DNN training due to partly negatively weighted samples. MC simulations produce negative event weights in the presence of destructive interference in the process or in the case of next-to-leading order simulations with an additive matching scheme. The negatively weighted training data impair the DNN convergence. Therefore, the current state of the art is to use reweighting methods that lead to consistently positive weights. However this alters the input distribution. We propose an alternative technique that is interpretable, computationally efficient and does not affect the input distribution. Furthermore, we show the method employed on a hypothetical search for a beyond the standard model heavy Higgs boson and discuss implications of negative weights throughout DNN based analyses.

T 68.8 Wed 17:45 Geb. 30.34: LTI

**Automated Hyperparameter Optimization and Input Variable Selection for Neural Networks** — •Erik Bachmann, Frank Siegert, Max Stange, and José Antolín Neumann — Technische Universität Dresden

Recent years have seen the widespread adoption of artificial neural networks in many high energy physics analyses to increase the sensitivity of measurements, largely replacing other multivariate techniques. The hyperparameters of the neural network, e.g. the number of hidden layers in a multilayer perceptron, are however often still chosen based on intuition and experience without any optimization.

Presented in this talk is a framework to perform automated hyperparameter optimization and input variable selection. During development, a special focus was put on generality and a flexible definition of metrics, allowing the framework to be configured for any supervised learning task. Being built on the Ray computing platform, the optimization can be scaled from a single computer to a multi-node HPC cluster.

## T 69: Search for Dark Matter 3

Time: Wednesday 16:00–17:45 Location: Geb. 30.35: HSI

T 69.1 Wed 16:00 Geb. 30.35: HSI

**Improved modeling of charge trapping and impact ionization in phonon-based crystal detectors used for dark matter searches** — •Matthew Wilson[1], Alexander Zaytsev[1], and Belina von Krosigk[2] — [1]Karlsruhe Institute of Technology, Institute for Astroparticle Physics, Karlsruhe, Germany — [2]University of Heidelberg, Kirchhoff Institute for Physics, Heidelberg, Germany

Various dark matter search experiments employ phonon-based crystal detectors operated at cryogenic temperatures. Some of these detectors, including HVeV detectors used by the SuperCDMS collaboration, are able to achieve single-charge sensitivity when a voltage bias is applied across the detector. The total amount of phonon energy measured by such a detector is proportional to the number of electron-hole pairs created by an interaction. However, crystal imperfections and surface effects can cause propagating charges to either trap inside the crystal or ionize additional charges, producing non-quantized measured energy as a result. Modeling these detector-response effects continues to be important for understanding and distinguishing between different sources of events, as well as for modeling the detector response of potential signals for dark matter searches. This presentation showcases an improved, more robust model of these detector-response effects that has fewer limitations and is capable of modeling more effects compared to previous models. This model allows for more accurate characterization of phonon-based crystal detectors and may facilitate discrimination between potential dark matter signals and background sources.

T 69.2 Wed 16:15 Geb. 30.35: HSI

**Signal formation in superfluid helium-4 for the DELight experiment** — •Francesco Toschi for the DELight-Collaboration — Karlsruhe Institute of Technology, Institute for Astroparticle Physics — Kirchhoff-Institut für Physik (KIP), Ruprecht-Karls-Universität Heidelberg

As xenon- and argon-based experiments dominate the search for direct interaction of dark matter particles with nuclei for weakly interacting massive particles (WIMPs) with masses above few GeV/$c^2$, the parameter space for light dark matter (LDM) remains mostly unexplored. Indeed, the low energy threshold needed to be sensitive to sub-GeV/$c^2$ LDM could be achieved so far only by solid state semiconductor detector coupled to low-temperature phonon sensors, with the disadvantage of a limited scalability. The DELight experiment will use a target of superfluid helium-4: this technology recovers the scalability of noble liquid experiments, while reaching low thresholds typical of cryogenic semiconductors thanks to its phonon channel. In addition, the light nuclear mass of helium makes it an ideal candidate for LDM searches, allowing DELight to probe LDM masses down to 100 MeV/$c^2$ already during its first phase which will deploy an helium-4 target of about 1 kg. This talk will present the principle of particle detection in superfluid helium-4, focusing on the signal formation processes and expected final observables for the DELight experiment.

T 69.3 Wed 16:30 Geb. 30.35: HSI

**XENONnT Optical Model** — •Kai Böse for XENONnT — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

XENONnT is one of the world leading direct detection experiments aiming to find or exclude dark matter candidates, especially the WIMP. The experiment is located at the Gran Sasso Underground Lab, where 8.5 tons of the target material xenon are shielded from cosmic radiation.

Particles (potentially including dark matter) recoil in the target with the xenon atoms, resulting in scintillation light. Before being detected by photomultipliers at the top and bottom of the setup, the light scatters with the xenon, can be absorbed by impurities or reflected on surfaces. This talk covers our optical model which describes how light behaves in the detector and how it is used to simulate our signals.

T 69.4 Wed 16:45 Geb. 30.35: HSI

**Realistic event simulations in XENONnT** — •Henning Schulze Eissing for the XENON-Collaboration — Institut für Kernphysik, Münster, Germany

The XENON Dark Matter Project uses a dual phase time projection chamber filled with liquid xenon to search for dark matter in the form of weakly interacting massive particles (WIMPs). Detailed simulations are essential for our understanding of the detector and in the various physics searches.

This talk presents the key components of the XENONnT simulation chain. Based on the geometry and particle tracking simulations in Geant4, xenon microphysics effects are simulated. The detector response is modeled, including the simulation of a proper PMT and electronics response resulting in realistic waveforms which are processed with the same analysis software as for real data.

The new XENONnT simulation software fuse will be presented. fuse is build on top of the strax(en) framework, which is the core of the XENONnT analysis software. It has a modular structure where simulation steps are placed into standalone plugins. It provides a better simulation speed, easy access to intermediate simulation steps and a higher level of configurability.

This work is supported by BMBF under contract 05A23PM1 und by DFG within the Research Training Group GRK-2149.

T 69.5 Wed 17:00 Geb. 30.35: HSI

**Development of a standardized analysis chain for the full COSINUS detector array** — •Maximilian Gapp for the COSINUS-Collaboration — Max-Planck-Institut für Physik, Garching, Deutschland

The DAMA/LIBRA experiment located in the LNGS underground laboratory claims to detect an annual modulation in the rate of interactions in sodium iodide (NaI) crystals, which is consistent with the expected dark matter signal. The COSINUS (Cryogenic Observatory for SIgnals seen in Next-generation Underground Searches) experiment is designed to check the persistent results of the DAMA/LIBRA experiment through the use of cryogenic NaI calorimeters, by leveraging their low energy thresholds and introducing particle identification techniques through the use of an additional channel.To accomplish this, various prototypes for the detectors must be tested, which requires careful analysis of the raw data. By separating noise and real events, and removing artifacts by applying quality cuts a standard event and an optimum filter are created to enable reconstruction of the pulse height to subsequently calibrate the prototypes and determine their performance. Since the COSINUS experiment plans to operate 16 channels in the initial run and 48 in the next one the analysis process must be automated as much as possible. In this contribution, the analysis workflow to characterize new prototypes is shown and possible approaches for the automation are highlighted.

T 69.6 Wed 17:15 Geb. 30.35: HSI

**ELOISE - Electronic stopping power in $CaWO_4$ and $Al_2O_3$ for background simulations** — •Holger Kluck[1], Jens Burkhart[1], and Michael Stoeger-Pollach[2] — [1]Institut für Hochenergiephysik der Österreichischen Akademie der Wissenschaften, 1050 Wien, Österreich — [2]Technische Universität Wien, University Servicecentre for TEM, 1040 Wien, Österreich

$CaWO_4$ and $Al_2O_3$ are well-known target materials for experiments searching for rare events like CE$\nu$NS with NUCLEUS or hypothetical dark matter-nucleus scattering with CRESST. Pushing the detection threshold down to sub-keV energies, experiments require verified and reliable simulations of radioactive background components at sub-keV energies, such as those based on the widely used Geant4 toolkit.

The ELOISE project aims to tackle this issue for electromagnetic particle interactions in both materials. Currently, we are preparing an evaluation of Geant4's current accuracy by conducting benchmark simulations and comparing them with data from extended literature research and dedicated measurements. As sub-keV data on the electronic stopping power is rare or totally missing, ELOISE conducted dedicated measurements for $CaWO_4$ and $Al_2O_3$. Currently, we are deducing electronic stopping powers from our measurements.

In this contribution, I will shortly motivate the problem and outline the scope of ELOISE. Afterwards, I will report the results of ELOISE's reference measurements. Finally, I will discuss our preliminary findings for the electronic stopping power in $CaWO_4$ and $Al_2O_3$ at sub-keV energies.

T 69.7 Wed 17:30 Geb. 30.35: HSI

**Calibration of a closed MADMAX prototype** — •David Leppla-Weber for the MADMAX-Collaboration — Deutsches Elektronen-Synchrotron DESY, Germany

The **MA**gnetized **D**isk and **M**irror **A**xion e**X**periment is a dielectric haloscope aiming to detect axions from the galactic halo by resonant conversion to photons in a strong magnetic field. It uses a stack of dielectric disks, called booster, to enhance the axion-photon conversion probability over a significant mass range. In 2022, a prototype system called Closed Booster 100 (CB100) with three sapphire disks of 100 mm diameter, encased in an aluminum cylinder, was used for datataking at CERN. To be able to set limits on the axion-photon coupling, the enhancement provided by the system has to be understood precisely. This requires a noise model of the booster itself as well as the Low Noise Amplifier (LNA) connected to it, which is used to amplify the signal to detectable levels. The calibration procedure together with the resulting signal enhancement is presented, showing the potential of such a dielectric haloscope setup.

## T 70: Di-Higgs 2 (4b & other)

Time: Wednesday 16:00–17:45 Location: Geb. 30.41: HS 1

T 70.1 Wed 16:00 Geb. 30.41: HS 1

**Search for non-resonant Higgs Boson Pair Production in the $b\bar{b}b\bar{b}$ Final State using a Neural-Network based Background Estimation with the CMS Experiment** — Martin Erdmann, Peter Fackeldey, •Benjamin Fischer, and Dennis Noll — III. Physikalisches Institut A, RWTH Aachen University

The non-resonant Higgs boson pair production provides direct access to the triple Higgs coupling. With a branching fraction of about 1/3, the four-$b$-quark final state is a significant contributor to the overall sensitivity for a combined measurement.

However, this decay channel is dominated by Multijet-processes which are challenging to model. This is overcome through the use of a data-driven estimation of the entire background.

In this work, the viability of an alternative approach using Neural Network based reweighting is examined in detail using CMS experiment Data of Run II. Additionally, the performance of the signal extraction facilitated by a Neural-Network based multiclass classification is studied.

T 70.2 Wed 16:15 Geb. 30.41: HS 1

**Search for Higgs boson pair production via vector-boson fusion in final states with four b-quarks in the boosted regime using data collected by the ATLAS detector at $\sqrt{s}$ = 13 TeV** — •Marcus Vinicius Gonzalez Rodrigues, Katharina Behr, and Kunlin Ran — Deutsches Elektronen-Synchrotron

Searches for Higgs boson pair production provide unique access to the Higgs trilinear coupling, and allow to set constraints on theories that predict Beyond Standard Model resonant production of heavy particles that interact directly with the Higgs boson. Searches targeting Higgs pair production via vector-boson fusion (VBF) additionally allow an examination of the coupling of a Higgs boson pair to a vector boson pair $\kappa_{2V}$ in great detail. The ultimate goal of this analysis is to improve the constraints on $\kappa_{2V}$ and search for heavy particles produced via VBF. For this purpose we consider the VBF di-Higgs pair production with final states containing four bottom quarks in the boosted regime, where a pair of particle showers initiated by bottom quarks from the decay of a high transverse momentum Higgs boson produces one single merged large-radius jet. Event reconstruction in this topology significantly benefits from a dedicated $X \rightarrow b\bar{b}$ tagger to identify jets from Higgs boson decays to a pair of b-quarks.

This analysis relies on data collected by the ATLAS detector at $\sqrt{s}$ = 13 TeV with an integrated luminosity of 140 fb$^{-1}$. The results shown in this presentation for $\kappa_{2V}$ are the most stringent from the ATLAS collaboration and the resonant search is extended for masses up to 5 TeV for the first time.

T 70.3 Wed 16:30 Geb. 30.41: HS 1

**PAIReD jet: A multi-pronged resonance tagging strategy across all Lorentz boost regimes** — Gaetano Barone[1], Alexander Jung[2], Ming-Yan Lee[2], Spandan Mondal[1], Uttiya Sarkar[2], Alexander Schmidt[2], Jan Schulz[2], and •Ulrich Willemsen[2] — [1]Brown University, Providence, USA — [2]III. Physikalisches Institut A, RWTH Aachen University, Germany

Jet flavor tagging is still a major challenge in the search for the Higgs Boson decay into charm quarks. Although, there are several machine learning approaches for distinguishing between c-, b-, and light-flavor jets, for multi-pronged jets, many of them neglect crucial information on the correlations between the jets that can substantially enhance the reconstruction efficiencies of signal events containing heavy-flavor jets. Therefore, we introduce a new approach of jet-based event reconstruction that aims to optimally exploit correlations between the products of a hadronic multi-pronged decay across all Lorentz boost regimes. The new approach utilizes clustered small-radius jets as seeds to define unconventional jets, referred to as PAIReD jets. This results in light-flavor jet rejections at low Lorentz boosts that exceed conventional strategies, while maintaining similar rejection rates for high Lorentz-boost regimes based on large-radius multipronged jet classifiers.

T 70.4 Wed 16:45 Geb. 30.41: HS 1

**Sensitivity study on the Higgs trilinear coupling with the ssWWhjj signal at ATLAS** — •Lisa Marie Lehmann[1,2], Joany Manjarres[2], Frank Siegert[1], and Maren Bühring[1] — [1]TU Dresden, Institut für Kern- und Teilchenphysik — [2]Université Paul Sabatier Toulouse, Laboratoire des 2 Infinis

The exact value of the Higgs boson's trilinear coupling is of particular interest since it is a central but unknown parameter of the Standard Model (SM) and fundamental to many Beyond SM scenarios. This study probes the sensitivity of Higgs boson production associated with the scattering of same-sign W bosons as a complementary approach to studies of Di-Higgs production to further constrain the value of the trilinear coupling parameter. This project presents the first detector-level study of ssWWhjj in final states with the W bosons decaying leptonically and the Higgs boson decaying into b quarks, using the full simulation of the ATLAS detector corresponding to $\sqrt{s} = 13$ TeV and an integrated luminosity of 140 fb$^{-1}$. This offers valuable insights into the prospects and potential challenges of this channel.

T 70.5 Wed 17:00 Geb. 30.41: HS 1

**Prospects for the search for Higgs boson pair production in the $WW\gamma\gamma$ channel at future hadron colliders** — Johannes Erdmann, Jan Lukas Späh, and •Jialiang Sun — III. Physikalisches Institut A, RWTH Aachen University

Measuring Higgs boson pair production is important because it allows for direct access to the Higgs trilinear coupling. In LHC run 3 and the HL-LHC, the most sensitive final states are $bb\gamma\gamma$, $bb\tau\tau$, and $bbbb$, since the decay $H \to bb$ has the largest branching fraction. However, for higher center-of-mass energies and integrated luminosities at future hadron colliders, it may be beneficial to explore not only these prominent channels but also consider rarer but cleaner decay channels that comprise leptons, photons, and missing transverse energy.

In this talk, we present a sensitivity study for Higgs boson pair production in the $WW(\to e^{\pm}\mu^{\mp}\nu_e\nu_\mu)\gamma\gamma$ final state, in which both gluon fusion and vector boson fusion production channels are considered. The primary background for this final state arises from the associated Higgs boson production with a top quark pair. We train a classifier to distinguish the signal from the main backgrounds. A preliminary estimate for the expected sensitivity will be given.

T 70.6 Wed 17:15 Geb. 30.41: HS 1

**Study of di-Higgs couplings in the multi-lepton channel with the ATLAS detector** — •Janek Both, Volker Büscher, Christian Schmitt, and Duc Bao Ta — Johannes Gutenberg-University, Mainz

While numerous predictions about the Higgs boson have been tested after its discovery at the LHC, the functional form of the Higgs potential remains largely undetermined. After electroweak symmetry breaking, the Higgs potential gives rise to cubic and quartic terms in the Higgs field, inducing a self-coupling that can be probed experimentally in Higgs pair production. Due to the small cross-section, di-Higgs processes have mainly been studied in decay channels with high branching ratio in the past. However, with increasing data size, multi-lepton channels will become more important, as they are less affected by background processes than the established analyses. In view of small signal rates, refined and sophisticated analysis strategies are required to increase the sensitivity of these channels.

In this talk, an analysis of the $HH \to WWWW \to 3\ell + X$ process with the ATLAS detector is presented. By taking into account the distribution of the invariant di-Higgs mass, the event selection can be optimized depending on the assumption about the trilinear self-coupling and di-Higgs couplings in the Higgs Effective Field Theory. The expected sensitivity to di-Higgs couplings after Run 3 and at the HL-LHC are presented.

T 70.7 Wed 17:30 Geb. 30.41: HS 1

**NLO Yukawa and self-coupling corrections to $gg \to HH$** — Gudrun Heinrich[1], Stephen Jones[2], Matthias Kerner[1], Thomas Stone[2], and •Augustin Vestner[1] — [1]KIT ITP, Karlsruhe, Germany — [2]IPPP, Durham, United Kingdom

Higgs boson pair production is the prime process to constrain the trilinear Higgs boson self-coupling at the LHC, hereby testing whether the Higgs potential is Standard-Model-like. While full NLO QCD corrections to this process are available since some time already, calculations of NLO electroweak corrections have only emerged very recently and are not yet available in a public Monte Carlo program. Working towards this goal, we present the status of the calculation of the Yukawa-type and Higgs self-coupling corrections to Higgs boson pair production in gluon fusion.

# T 71: Higgs 3 (coupling to b and c quarks)

Time: Wednesday 16:00–18:00 Location: Geb. 30.41: HS 2

T 71.1 Wed 16:00 Geb. 30.41: HS 2

**Progress of the ATLAS Run 2 t$\bar{t}$H(H→b$\bar{b}$) Legacy Analysis at 13 TeV** — Arnulf Quadt, •Chris Scheulen, and Elizaveta Shabalina — II. Physikalisches Institut, Georg-August-Universität Göttingen

The bottom anti-bottom Higgs decay channel of Higgs-associated top quark pair production offers direct access to measurements of the top Yukawa coupling and Higgs-$p_{\mathrm{T}}$ differential cross-section, which are sensitive to potential new physics. To incorporate improvements such as developments in $b$-tagging and Monte Carlo simulation of the dominant $t\bar{t} + b\bar{b}$ background, a legacy analysis of the $t\bar{t}H(H \to b\bar{b})$ process with the full ATLAS Run 2 dataset of $\mathscr{L} = 140$ fb$^{-1}$ is currently ongoing.

This talk will outline the analysis strategy and provide an insight into the expected sensitivity. A special focus will be placed on ongoing studies, such as recent improvements and validation of the transformers – an advanced deep learning architecture – developed in the analysis for event classification and Higgs-$p_{\mathrm{T}}$ reconstruction. Among others, developments herein consist of the inclusion of missing transverse energy in the model inputs, performance comparisons of competing reconstruction methods, and the optimisation of the region definitions obtained from the event classification networks.

T 71.2 Wed 16:15 Geb. 30.41: HS 2

**Background Modelling using ML in $t\bar{t}H(bb)$ Final States** — Steffen Korn, Arnulf Quadt, Chris Scheulen, and •Paul Wollenhaupt — II. Physikalisches Institut, Georg-August- Universität Göttingen, Germany

Systematic differences between simulated samples and measured data are challenging for many high-energy physics analyses. The machine learning field of domain translation provides a powerful framework for learning mappings that systematically correct the distribution of simulated samples. Analogous to the ABCD method, which extrapolates the absolute number of events in a signal region (SR) from the translations of yields in control regions (CRs), mappings from sample to data distributions are first learned in the CRs and then extrapolated to the blinded SR. This domain translation approach is used to improve the background modelling of $t\bar{t}H(\to b\bar{b})$. Specifically, regions are defined based on the number of jets and b-tagged jets. The distributions of the jet kinematic variables, which are systematically mis-modelled due to the NLO approximation of the top quark, are then extrapolated for events with at least six hadronic jets, three of which are $b$-tagged.

T 71.3 Wed 16:30 Geb. 30.41: HS 2

**Extracting the Gluon Fusion Component of the Higgs Production in Association with a Z Boson through the ZH-WH Symmetry at the CMS Experiment** — •Svenja Diekmann, Niclas Eich, and Martin Erdmann — III. Physikalisches Institut A, RWTH Aachen University

The gluon fusion production mechanism of the associated ZH production ($gg \to ZH$) is a yet unmeasured Standard Model process, sensitive to various new physics scenarios. The considered final state of the invisible Z boson decay and two b-jets is not only populated by large backgrounds arising from other processes, but also by the dominant quark initiated ZH production ($qq \to ZH$). In order to separate these two production mechanisms, the total ZH production can be utilised in combination with the WH production to extract the gluon fusion component by analysing the ratio of their cross sections. The strategy and first expected results of this analysis to extract the gluon fusion component of the ZH production are shown using the 2017 dataset of the CMS experiment.

T 71.4 Wed 16:45 Geb. 30.41: HS 2

**Transfomer based Search for the Gluon-Fusion induced ZH Production in the $H \to b\bar{b}$, $Z \to e^+e^-/\mu^+\mu^-$ Final States with the CMS Experiment** — •Niclas Eich, Svenja Diekmann, and Martin Erdmann — RWTH Aachen University

The gluon fusion induced ZH production is yet to be measured. Its estimated cross section in the Standard Model is relatively small with only 0.12 pb, making a search difficult over the vast number of background events. We present the blinded results of our analysis in the $H \to b\bar{b}$, $Z \to e^+e^-/\mu^+\mu^-$ final states, at the CMS experiment for the Run 2 data taking period.

In this, we leverage Machine Learning methods, employing a transformer-based process classifier to differentiate between signal and various background processes. Subsequently, we enhance the analysis sensitivity by subjecting the classifier's predictions to K-Means clustering. This two-step approach allows us to create bins for a statistical evaluation in a multi-dimensional space. The final results are presented as sensitivity analysis, including systematic and statistical uncertainties.

T 71.5 Wed 17:00 Geb. 30.41: HS 2

**Flavour Sensitive Observables in Hadronic Higgs Decays at NLO QCD** — •Benjamin Campillo Aveleira[1,2], Aude Gehrmann-De Ridder[2,4], and Christian Tobias Preuss[2,3] — [1]Institute for Theoretical Physics, KIT, 76128 Karlsruhe — [2]Institute for Theoretical Physics, ETH, CH-8093 Zürich, Switzerland — [3]Department of Physics, University of Wuppertal, 42119 Wuppertal — [4]Department of Physics, University of Zürich, CH-8057 Zürich,

We study flavour sensitive observables in hadronic Higgs decays up to next-to-leading-order in QCD. In a first step we look at an infrared safe definition of jet flavour. The two algorithms that will accomplish this and that will be discussed in this talk are the flavour dressing and flavour $k_T$ algorithm. Having an infrared flavour safe algorithm, we apply it to flavour-sensitive observables. The main observables of interest are the energy of the (sub-)leading flavoured jet and the angle between the leading $b\bar{b}$ pair as well as its invariant mass. It will be shown: The distributions look quite different in the two categories and thus they can be used as a discriminator. Furthermore, we also discuss that the flavour dressing algorithm is better suited to make theoretical predictions, which can be used to compare to experiments.

T 71.6 Wed 17:15 Geb. 30.41: HS 2

**PAIReD jet tagging in CMS: Testing and developing a new approach of Hcc and Hbb classification in the CMS experiment** — Gaetano Barone[1], Alexander Jung[2], Ming-Yan Lee[2], Spandan Mondal[1], Uttiya Sarkar[2], Alexander Schmidt[2], •Jan Schulz[2], and Ulrich Willemsen[2] — [1]Brown University, Providence, USA — [2]III. Physikalisches Institut A, RWTH Aachen University, Germany

Machine learning, for example in the form of jet flavor tagging, can provide indispensable help in analyzing the rare Higgs decay into two charm quarks. In a recent tagging approach, a new unconventional type of jet is defined, the so-called PAIReD jet. It has been shown that classifiers for PAIReD jets have a higher background rejection compared to the traditional jet definitions in CMS analyses (AK4, AK8, AK15). However, so far these studies have only been carried out with CMS-independent simulations. Therefore, the testing of the approach with official CMS simulations as well as the concrete implementation in CMS are essential steps towards a more advanced physics analysis and will be presented in this talk. Furthermore, possible further developments and improvements of the originally proposed PAIReD tagger will be discussed.

T 71.7 Wed 17:30 Geb. 30.41: HS 2

**Analysis strategies for the search for the Higgs boson decay to a charm-anticharm pair at CMS** — •Valentyn Vaulin[1], Alena Dodonova[1], Ming-Yan Lee[1], Spandan Mondal[2], Andrzej Novak[1], Andrey Pozdnyakov[1], and Alexander Schmidt[1] — [1]III. Physikalisches Institut A, RWTH Aachen University, Germany — [2]Brown University, Providence, USA

During the recent years substantial progress has been made in constraining the Higgs boson coupling to charm quarks. In this talk the search for the Higgs boson decay into a charm-anticharm pair, where the Higgs boson is produced in association with the W or Z boson, will be presented. A general overview of the analysis strategies as well as the implementation of the columnar analysis framework with the intention to reproduce the Run 2 results of the VHcc analysis will be shown.

T 71.8 Wed 17:45 Geb. 30.41: HS 2

**Charge-asymmetry measurement in WH($\tau\tau$) and WH(WW) events** — Sebastian Brommer, Nils Faltermann, Markus Klute, •Ralf Schmieder, Nicolo Trevisani, Roger Wolf, and Xunwu Zuo — Karlsruhe Institute for Technology, Karlsruhe, Germany

At the LHC, an asymmetry in $W^+$ H and $W^-$ H production is expected as the parton distribution functions (PDFs) favour the production of positively-charged W bosons in proton-proton collisions. The measurement of the WH charge asymmetry provides a consistency test for the Standard Model (SM), as it is sensitive to enhanced Yukawa couplings to the first and more so to second generation quarks like the c quark. The production of an H in association with a W boson can happen through the exchange of a c quark in the t channel. Experimentally, the WH charge asymmetry measurement is independent of any challenging c jet tagging algorithms. This talk reports the status of this measurement in the channels in which the Higgs boson decays into a pair of $\tau$ leptons and into a pair of W bosons respectively.

# T 72: BSM Higgs 3 (extended Higgs sectors)

Time: Wednesday 16:00–17:45 Location: Geb. 30.41: HS 3

T 72.1 Wed 16:00 Geb. 30.41: HS 3

**Domain Walls in the N2HDM: Exploring Vacuum Trapping and Scalar Potential Evolution** — •Rohan Gupta[1], Gudrid Moortgat-Pick[1,2], and Mohamed Younes Sassi[1,2] — [1]Universität Hamburg, Germany — [2]DESY, Hamburg, Germany

In various Beyond the Standard Model (BSM) theories, the scalar sector is extended with additional scalar doublets and singlets. Consequently, the scalar potential of the theory becomes significantly more intricate than that of the Standard Model and leads to the possibility of having new phenomena such as Vacuum Trapping, where the vacuum expectation values (VEV) of the doublet scalar fields remain zero, despite the non-zero VEVs at the global minimum of the theory. The universe is then trapped in the symmetric phase and electroweak symmetry breaking does not occur, rendering the parameter points, that exhibit this phenomenon, as unphysical. This study specifically explores the occurrence of vacuum trapping in the N2HDM, an extension of the Standard Model's scalar sector that includes an additional doublet and a singlet scalar. Due to the breaking of a discrete symmetry related to the singlet, this model leads to the formation of domain walls in the early universe. We discuss the possibility of preventing vacuum trapping, particularly in cases where tunneling to the electroweak vacuum occurs within the domain wall structure.

T 72.2 Wed 16:15 Geb. 30.41: HS 3

**Electroweak symmetry restoration in the N2HDM via domain walls** — •Mohamed Younes Sassi and Gudrid Moortgat-Pick — II. Institut für Theoretische Physik, Hamburg, Germany

Domain walls are a type of topological defects that can arise in the early universe after the spontaneous breaking of a discrete symmetry. This occurs in several beyond Standard Model theories with an extended Higgs sector such as the Next-to-Two-Higgs-Doublet model (N2HDM). In this talk I will discuss the domain wall solution related to the singlet scalar of the N2HDM as well as demonstrate the possibility of restoring the electroweak symmetry in the vicinity of the domain wall. Such symmetry restoration can have profound implications on the early universe cosmology as the sphaleron rate inside the domain wall would, in principle, be unsuppressed compared with the rate outside the wall.

T 72.3 Wed 16:30 Geb. 30.41: HS 3

**Precision Calculations of Effective Potentials and Electroweak Phase Transitions in the Early Universe** — Thomas Biekötter[1], •Andrii Dashko[2], Maximilian Löschner[2], and Georg Weiglein[2,3] — [1]Institute for Theoretical Physics, Karlsruhe Institute of Technology, Wolfgang-Gaede-Str. 1, 76131 Karlsruhe, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany — [3]II. Institut für Theoretische Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We present a detailed study of the precision calculations of higher-order contributions to effective potential with the application of three-dimensional effective field theories (3D EFTs). Our work focuses on the thermodynamic quantification and description of electroweak phase transitions in the early Universe for the complex singlet extended Standard Model (cxSM). In particular, we address the issue of gauge and scale dependences associated with the effective potential, which can lead to ambiguities when calculating thermodynamical quantities from the effective potential. To overcome this issue, we employ the high temperature 3D EFT framework, which provides a robust approach for consistently taking into account the relevant contributions in physical predictions. In addition, we study the ambiguities in commonly used renormalization schemes of the effective potential. The phenomenological implications of our results are discussed.

T 72.4 Wed 16:45 Geb. 30.41: HS 3

**Phenomenology of inflation inspired two Higgs doublet models with extensions** — •Hannah Bürgel and Gudrid Moortgat-Pick — Universität Hamburg, Deutschland

In my master thesis I study the phenomenology of inflation inspired (i.e. via inclusion of a non-minimal coupling to gravity) two Higgs doublet models with extensions particularly the two Higgs doublet model with singlet. For this purpose, an inflation term is inserted in the potential. I investigate the effects on the parameter space including masses and mixing angles under several theoretical and experimental constrains and compare them to collider results.

T 72.5 Wed 17:00 Geb. 30.41: HS 3

**In search for heavy and light scalars with the Higgs boson in the hadronic final state with the ATLAS experiment** — •Daariimaa Battulga, Arely Cortes Gonzalez, and Cigdem Issever — Institut für Physik, Humboldt-Universität zu Berlin

One of the most successful theories, the Standard Model (SM) of particle physics, describes the fundamental interactions amongst the subatomic particles. Yet, there are many unexplored areas in new physics beyond the SM. With the Higgs boson discovery, many open questions in particle physics can be explored further, such as searches for an extended Higgs sector, including additional heavy scalars. In this search, a heavy scalar $X$ in a mass range of $1-6$ TeV decays into a Higgs boson, and the light scalar $S$, in a mass range of $70-500$ GeV. Here, with a sufficiently high mass of the scalar $X$, the scalar $S$ and the Higgs boson are Lorentz-boosted. When it comes to where both the scalar $S$ and the Higgs boson decay into a pair of bottom quarks, they can be reconstructed and identified inside a large-radius jet. This talk presents the status of this search, which employs a new graph neural network to identify jets containing two bottom quarks. This study uses the proton-proton collision data collected by the ATLAS detector with the center of mass energy of $\sqrt{s} = 13$ TeV with an integrated luminosity of $\mathscr{L} = 140\,\mathrm{fb}^{-1}$.

T 72.6 Wed 17:15 Geb. 30.41: HS 3

**A novel machine learning-based background estimation for the X → SH → 4b analysis at the ATLAS experiment** — •Malin Horstmann, Nicole Hartman, and Lukas Heinrich — Technical University Munich, Germany

The search for additional scalar particles has been part of the ATLAS physics program since the Higgs discovery. The work presented has been done within the X → SH → 4b analysis at the ATLAS experiment, which searches for two additional scalars in the dominant decay mode of the Higgs. In order to interpret the data, an estimation of the expected background is necessary. We present a novel machine learning-based background estimation technique that uses a normalising flow and a Gaussian process. A particular focus will be on the propagation of the systematic uncertainties related to the neural network model.

T 72.7 Wed 17:30 Geb. 30.41: HS 3

**Probing new frontiers: Unveiling Dark Matter with novel collider signatures in Type-I 2HDM+*a*** — •Ilia Kalaitzidou[1], Spyridon Argyropoulos[1], and Ulrich Haisch[2] — [1]Physikalisches Institut, Universität Freiburg, Hermann-Herder Str. 3a, 79104 Freiburg, Germany Freiburg, Germany — [2]Max Planck Institute for Physics, Föhringer Ring 6, 80805 München, Germany

One of the biggest unresolved mysteries in particle physics is the nature of dark matter (DM). It has long been suggested that the Standard Model (SM) Higgs sector, or extensions of it, could be a portal to DM. The Two Higgs Doublet Model with an additional pseudoscalar singlet acting as a mediator between the SM and DM particles (2HDM+$a$) is a promising model to explore the dark sector at the Large Hadron Collider (LHC). The present work studies a 2HDM+$a$ with a moderately fermiophobic Type-I Yukawa sector and non-degenerate Higgs bosons. This model features a large region of parameter space that accommodates signatures poorly explored at the LHC. A sensitivity study for new experimental signatures is presented, extending to Higgs masses below the SM Higgs mass.

# T 73: Flavour physics 3

Time: Wednesday 16:00–18:00 Location: Geb. 30.41: HS 4

T 73.1 Wed 16:00 Geb. 30.41: HS 4

**Testing Lepton Flavour Universality with $B_s^0 \to \phi\ell^+\ell^-$ decays using LHCb data** — •Sebastian Schmitt[1], Christoph Langenbruch[2], Stefan Schael[1], and Eluned Smith[3] — [1]RWTH Aachen — [2]Universität Heidelberg — [3]Massachusetts Institute of Technology

In the Standard Model of Particle Physics (SM), $b \to s\ell^+\ell^-$ transitions are forbidden at tree-level and may only occur at the loop-level. The branching fractions of these so-called flavour changing neutral currents can thus be significantly affected by New Physics (NP) beyond the SM. While in the SM, the coupling of the electro-weak gauge-bosons is lepton flavour universal, this universality can be broken in NP scenarios. Thus, ratios of branching fractions of semileptonic rare decays with muons and electrons in the final state constitute clean SM tests.

The LHCb detector is located at the LHC at CERN and is optimised to study rare $b$-hadron decays. For this purpose, LHCb features high trigger efficiencies, excellent track reconstruction, and particle identification.

This talk gives an overview of the current status of the measurement of $R_\phi = \mathscr{B}(B_s^0 \to \phi\mu^+\mu^-)/\mathscr{B}(B_s^0 \to \phi e^+e^-)$, which benefits from the experimentally clean $B_s^0 \to \phi\ell^+\ell^-$ environment. The analysis uses the full Run 1 and Run 2 dataset collected by LHCb which corresponds to $9\,\mathrm{fb}^{-1}$ of integrated luminosity.

T 73.2 Wed 16:15 Geb. 30.41: HS 4

**Search for $B^+ \to K^{*+}\nu\bar{\nu}$ using Lorentz Equivariant Neural Networks at the Belle II Experiment** — •Caspar Schmitt, Nikolai Hartmann, Sviatoslav Bilokin, and Thomas Kuhr — Ludwig-Maximilians-Universität München

Searches for rare B meson decays allow precision standard model tests owing to particularly precise theory predictions. At the Belle II experiment, B meson pairs are produced exclusively at a known center of mass energy. This allows searches for decays with invisible final state particles, by fully reconstructing one B meson and thereby kinematically constraining the other.

Current precision of searches for $B \to K^{*+}\nu\bar{\nu}$ is statistically limited, therefore, reconstruction efficiency and background suppression are key figures. In a novel method, the accompanying B meson decay is inclusively reconstructed and neural networks are used to suppress background contaminations. We demonstrate the feasibility of Lorentz-equivariant graph neural nets in inclusive reconstruction, which respect the physical symmetries of the input features and improve the experimental upper limit on the branching fraction.

T 73.3 Wed 16:30 Geb. 30.41: HS 4

**A model-independent likelihood method and its application to the Belle II $B^+ \to K^+\nu\bar{\nu}$ analysis** — •Lorenz Gärtner[1], Thomas Kuhr[1], Slavomira Stefkova[2], Danny van Dyk[4], Méril Reboud[5], Lukas Heinrich[3], Nikolai Hartmann[1], and Malin Horstmann[3] — [1]LMU, Munich, DE — [2]KIT, Karlsruhe, DE — [3]TU, Munich, DE — [4]IPPP, Durham, UK — [5]Siegen University, Siegen, DE

$B^+ \to K^+\nu\bar{\nu}$ decays offer a window into physics beyond Standard Model. The Belle II collaboration found the first evidence for this decay. In order to search for this decay, assumptions on its kinematic distribution were made. Consequently, the results feature a model dependency arising from both Standard Model assumptions and from the description of the pertinent hadronic matrix element, making reinterpretation complicated without reanalysing the underlying data.

We develop a novel reweighting method in order to perform reinterpretations and combinations of particle physics results. The generality of this method allows for statistical inference in the space of theoretical parameters, assuming different kinematic distributions, according to any beyond Standard model prediction.

We implement our method as an extension to the `pyhf` software for statistical inference and interface it with the `EOS` software for flavor physics phenomenology.

Furthermore, we present an easily publishable format of the resulting likelihood function and argue why publishing such likelihoods is crucial for a full exploitation of experimental results.

T 73.4 Wed 16:45 Geb. 30.41: HS 4

**Testing of lepton universality with $\Lambda_b^0 \to pK^-\ell^+\ell^-$ decays at LHCb** — Johannes Albrecht[1], Vitalii Lisovskyi[2], and •Jannis Speer[1] — [1]TU Dortmund University, Dortmund, Germany — [2]EPFL, Lausanne, Switzerland

Rare decays involving $b \to s\ell^+\ell^-$ transitions offer a wide variety of probes for the Standard Model. This includes null tests of fundamental properties of the Standard Model, such as lepton flavour universality (LFU), which states that the couplings of the gauge boson to the three lepton generations are identical.

The LHCb experiment has performed several measurements of LFU in rare $b$-meson decays, most recently the ratio of branching fractions of the electron and muon mode in the decay channels $B^+ \to K^+\ell^+\ell^-$ and $B^0 \to K^{*0}\ell^+\ell^-$. However, LFU can also be tested in rare $b$-baryon decays, which are subject to partly orthogonal experimental and theoretical uncertainties. The first measurement of the ratio of branching fractions of the decays $\Lambda_b^0 \to pK^-e^+e^-$ and $\Lambda_b^0 \to pK^-\mu^+\mu^-$, $R_{pK}^{-1}$, was performed by the LHCb Collaboration using proton-proton collision data corresponding to an integrated luminosity of $4.7\,\mathrm{fb}^{-1}$. The ratio was measured to be $R_{pK}^{-1} = 1.17^{+0.18}_{-0.16} \pm 0.07$ in the dilepton mass-squared range $0.1 < q^2 < 6.0\,\mathrm{GeV}^2/\mathrm{c}^4$ and the $pK$ mass range $m(pK) < 2600\,\mathrm{MeV}/\mathrm{c}^2$. The updated measurement of $R_{pK}^{-1}$ seeks to reduce the uncertainties by analysing the full $9\,\mathrm{fb}^{-1}$ dataset of LHCb experiment and implementing new selection techniques.

This contribution presents the current status of the ongoing analysis.

T 73.5 Wed 17:00 Geb. 30.41: HS 4

**Inclusive analysis of untagged $B \to X\ell^+\ell^-$ decays at Belle II** — •Arul Prakash Sivagurunathan, Sviatoslav Bilokin, and Thomas Kuhr — Ludwig-Maximilians-Universität München

In recent years various deviations from the standard model expectation were observed in $b \to s\ell^+\ell^-$ measurements, dominated by exclusive studies. The combined deviations, while being large, are still not above the $5\sigma$ discovery threshold, partially owing to theoretical uncertainties. Precision measurements of inclusive $B \to X\ell^+\ell^-$ decays can provide invaluable complementary information to scrutinize anomalies observed in their exclusive decay counterparts. However, limited tagging efficiency, small Standard Model signal and very high background rate make these measurements extremely challenging, with no results being published so far.

In our work, we will evaluate the chances of a $5\sigma$ result with data from the Belle and Belle II experiments. We will apply machine learning algorithms to tackle background rejection. We will finally compute the lepton flavour universality ratio $R(X) = \mathscr{B}(B \to X\mu^+\mu^-)/\mathscr{B}(B \to Xe^+e^-)$ which will be key to constrain potential New Physics contributions.

T 73.6 Wed 17:15 Geb. 30.41: HS 4

**Measurement of $D^+$ and $D_s^+$ production asymmetries on $pp$ collisions at the LHCb experiment with data from Run 3** — •Paula Herrero Gascon — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

The production asymmetry of charm hadrons and anti-hadrons in $pp$ collisions at the LHC is an important input to many CP violation measurements in the charm system. Thus their measurement is one of the first analyses carried out with the upgraded LHCb experiment. In this talk, we focus on the production asymmetries, $A_P$, of the $D^+_{(s)}$ mesons exploiting their decay to $\phi\pi^+$. The raw asymmetries must be corrected for the different detection efficiencies of $\pi^+$ and $\pi^-$. These are determined in a data-driven approach via a tag-and-probe method applied in the abundant decay $K^0_S \to \pi^+\pi^-$. These results represent the first measurement of $D^+$ and $D_s^+$ production asymmetries at a center-of-mass energy of 13.6 TeV.

T 73.7 Wed 17:30 Geb. 30.41: HS 4

**Early measurement of charm meson production asymmetries at LHCb in Run 3** — •Luca Balzani[1], Laurent Dufour[2], Paula Herrero Gascon[3], Serena Maccolini[1], Dominik Stefan Mitzel[1], Sascha Stahl[2], Giulia Tuci[3], and Francesco Zenesini[4] — [1]TU Dortmund University, Dortmund, Germany — [2]CERN, Geneva, Switzerland — [3]Heidelberg University, Heidelberg, Germany — [4]University of Bologna, Bologna, Italy

Ahead of Run 3 of the LHC, the LHCb detector was profoundly upgraded to leverage the programmed increase in luminosity. Studying the features of the upgraded detector is of paramount importance in order to reliably perform measurements.

Production asymmetries, of charm mesons in particular, are observables which depend on the colliding system characteristics but shall not be influenced by experimental effects, having these latter contributions under control is essential to perform a consistent measurement. This makes production asymmetries ideal candidates to investigate the characteristics of the new LHCb detector. Being this measurements one of the firsts done with the new data, it will also provide useful insights for their validation. Precise measurements of production asymmetries also allow for a better understanding of QCD models used in Monte Carlo generators, especially in the high-rapidity region. Finally, this analysis will lead to the first measurement of neutral charm meson production asymmetry for proton-proton collisions at the LHC energies. This contribution will discuss the general strategy and the techniques used for the extraction procedure.

T 73.8 Wed 17:45 Geb. 30.41: HS 4

**Measurements of prompt-charm-production-cross-sections in pp collisions at LHCb for Run 3** — Rowina Caspary, Giulia Frau, Paul André Günther, Stephanie Hansmann-Menzemer, and •Maurice Pierre Morgenthaler — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

The LHCb experiment at CERN plays a leading role in the study of bottom and charm quark physics. The experiment was heavily upgraded for Run 3, necessitating studies to validate its performance. In this talk, we will present one of the initial Run 3 analysis which delivers interesting first physics results and provide a detailed understanding of the upgraded experiment simultaneously. The data used to measure the prompt-charm-production-cross-sections is taken in pp-collisions in 2023 at a center-of-mass energy of 13.6 TeV corresponding to an integrated luminosity of 47 $pb^{-1}$. Using bins of charm-hadron transverse-momentum and rapidity, the cross-sections of $D^0$, $D^+$, $D_s^+$ and $D^{*+}$ mesons are measured.

# T 74: Top physics 3 (single top)

Time: Wednesday 16:00–17:45 Location: Geb. 30.95: Audimax

T 74.1 Wed 16:00 Geb. 30.95: Audimax

**Measurement of total and differential t-channel production cross-sections of single top quarks and top antiquarks in proton-proton collisions at 13 TeV using the full Run 2 dataset recorded with the ATLAS detector** — Benedikt Gocke[2], Dominic Hirschbühl[1], Lukas Kretschmann[1], Adrian Miemczyk[1], Olaf Nackenhorst[2], Joshua Reidelstürz[1], •Maren Stratmann[1], and Wolfgang Wagner[1] — [1]Bergische Universität Wuppertal, Wuppertal, Deutschland — [2]Technische Universität Dortmund, Dortmund, Deutschland

The t-channel production is the dominant process for single top quark and single top antiquark production at the LHC. The presented analysis measures the total cross-sections for top-quark and top-antiquark production $\sigma(tq)$ and $\sigma(\bar{t}q)$ as well as the combined cross-section $\sigma(tq + \bar{t}q)$ and the cross-section ratio $R_t = \sigma(tq)/\sigma(\bar{t}q)$. The differential production cross-sections are measured as a function of the transverse momentum $p_{\mathrm{T}}$ and rapidity |Y| of the top-quark and top-antiquark respectively. The full Run 2 dataset recorded with the ATLAS detector in the years 2015-2018 is used.

T 74.2 Wed 16:15 Geb. 30.95: Audimax

**Measurement of differential cross-sections of associated production of a top-quark and a Z-boson** — •Nilima Akolkar and Ian Brock — Physikalisches Institut, Universität Bonn

The associated production of a single top-quark with a Z-boson (tZq) is a rare process at the LHC. This process is of special interest, as it allows one to probe the couplings of the Z-boson to the quark sector and to the W-boson simultaneously.

This talk will focus on the differential cross-section measurement of the tZq process, analyzed in the trilepton decay channel. The data used were collected with the ATLAS detector during Run 2 of the LHC, corresponding to an integrated luminosity of 140 fb$^{-1}$ . The tZq differential cross-section is measured using profile likelihood unfolding. The presentation will include the outcomes of tests conducted to assess the method's robustness in addition to Asimov fit results.

T 74.3 Wed 16:30 Geb. 30.95: Audimax

**Measurement of top quark involved CKM matrix elements in single top-quark t-channel processes** — Tomas Dado, •Benedikt Gocke, and Kevin Kröninger — Technische Universität Dortmund, AG Kröninger

Measuring top quark properties is one of the main purposes of the ATLAS experiment at the LHC. Since the top quark is the heaviest quark and thus decays before it hadronises, it can be seen as a quasi free quark. Therefore, its properties and especially its couplings are crucial to test the Standard model.

In general, all flavour-changing quark couplings are described by the Cabbibo-Kobayashi-Maskawa (CKM) matrix. There are no theoretical predictions for any CKM matrix elements. Thus, these need to be measured. For the small CKM matrix-elements Vts and Vtd, a measurement is especially challenging.

Single top-quark t-channel cross section measurements can be used to extract $V_{tb}$. In this talk, the CKM interpretation of the single top-quark t-channel cross-section measurement at $\sqrt{s}$ = 13 TeV with the ATLAS experiment is presented. For this purpose, all possible top quark production and decay vertices are considered. The measurement exploits the full Run2 dataset corresponding to an integrated luminosity of 140 fb$^{-1}$. For the first time, two-dimensional profile-likelihood scans are used to also set limits on $V_{td}$ and $V_{ts}$.

T 74.4 Wed 16:45 Geb. 30.95: Audimax

**Search for the $tW\gamma$ process with the CMS experiment** — •Michele Mormile[1], Ulrich Husemann[1], Abideh Jafari[1], and Michael Wassmer[2] — [1]Karlsruhe Institute of Technology — [2]Deutsches Elektronen-Synchrotron (DESY)

We present an ongoing search for the production of a top quark in association with a W boson and a photon ($tW\gamma$). The analysis is based on proton-proton collision data at a center-of-mass energy of 13 TeV recorded by the CMS experiment at the CERN LHC. $tW\gamma$ is a rare process, with cross section in the order of 100 fb and it poses the experimental challenge of discriminating the signal from the large background of top quark pair production in association with a photon ($t\bar{t}\gamma$). The analysis is performed in the double lepton channel, where both the top quark and the W boson decay leptonically. This talk will focus on the difficulties in reliably modeling the signal, due to the overlap of Feynman diagrams contributing to the production amplitudes of $tW\gamma$ and $t\bar{t}\gamma$, and on the Machine Learning algorithms used for the discrimination of the signal from the background.

T 74.5 Wed 17:00 Geb. 30.95: Audimax

**EFT interpretations of single top quark and Z boson production at the ATLAS experiment with run-2 data** — Ian Brock, Nilima Nilesh Akolkar, and •Can Süslü — University of Bonn, Bonn, Germany

Although the Standard model (SM) of particle physics has been successful to explain the observed phenomena, there are indications of new physics beyond the SM, such as dark matter and neutrino oscillations and masses. The Standard Model Effective Field Theory (SMEFT) is a framework for parametrizing the phenomena occuring at the high energies, and contains additional operators in the Lagrangian with dimensions larger than the SM. These operators from a basis, describing all possible interactions and couplings where the new physics can hide.

Single top quark and Z boson production is a convenient channel for EFT interpretations as it contains the couplings of the top quark and W and Z boson, and is thus quite sensitive to many SMEFT operators. In this analysis, using a kinematic distribution, the Wilson coefficients of the dimension six operators sensitive to the tZq channel have been constrained at the detector level via profile likelihood fits. The constraints obtained via the detector-level approach and the further plans for optimizing the EFT-sensitive regions will be presented in this talk.

T 74.6 Wed 17:15 Geb. 30.95: Audimax

**Estimation of the background contributions of non-prompt or misidentified photons from hadronic activity to the differential cross-section measurements of single-top quark production in association with a photon with the ATLAS experiment at $\sqrt{s} = 13\,\mathrm{TeV}$** — •Nils J. Abicht, Lucas Cremer, Tomas Dado, and Andrea H. Knue — TU Dortmund, Experimentelle Physik

The differential cross-section measurements of single-top quark production in association with a photon represent a test of the standard model, particularly of the coupling between the top quark and the photon.

A significant background for the process arises from non-prompt or misidentified photons from hadronic activity. Since this background contribution is not necessarily well-modeled in Monte Carlo simulations, a data-driven approach is employed. Four orthogonal selections are constructed in order to exploit the weak correlation between certain photon identification variables and photon track isolation. One of these selections matches the requirements of the photons used in the differential cross-section measurements and the other three selections are enriched with non-prompt or misidentified photons. The data contributions in the latter selections are used to extrapolate to the misidentification efficiency in the former selection. A description of the data-driven method, systematic uncertainties as well as an estimation obtained using the complete ATLAS LHC Run-2 dataset, corresponding to an integrated luminosity of 140 $\mathrm{fb}^{-1}$, are presented.

T 74.7 Wed 17:30 Geb. 30.95: Audimax

**Event classification of t-channel single top-quark production in proton-proton collisions at a centre-of-mass energy of 13 TeV with the ATLAS detector using Graph Neural Networks.** — •Lukas Kretschmann, Joshua Reidelstürz, Dominic Hirschbühl, and Wolfgang Wagner — Bergische Universität Wuppertal, Wuppertal, Germany

For the differential cross section of single top-quark t-channel production, a high-purity signal region with high statistics in single top t-channel production events and low statistics in background processes is necessary. The definition of the signal region for the total t-channel cross section analysis is used as a starting point for defining the high-purity signal region. An additional cut on the NN distribution produced by the neural network trained for the total cross section analysis is applied to define the high-purity signal region.

To improve the separation between signal and background events, we investigate the use of Graph Neural Networks (GNNs) as an alternative to traditional feed forward networks for constructing a final discriminant. Studies on the separation power and signal over background ratios for various cuts on the output values will be presented using simulated data.

## T 75: Annual Meeting of Young Scientists in High Energy Physics (yHEP)

Time: Wednesday 19:45–21:30 Location: Geb. 30.22: Gaede-HS

T 75.1 Wed 19:45 Geb. 30.22: Gaede-HS

**Annual Meeting of Young Scientists in High Energy Physics (yHEP)** — Dima El Khecken[1], Farah Afzal[2], Felipe Peña[3,4], Leonel Morejon[5], Meike Küssner[6], •Michael Lupberger[2], Ruth Jacobs[3], and Srijan Sehgal[5] — [1]Karlsruhe Institute of Technology — [2]University of Bonn — [3]DESY — [4]University of Hamburg — [5]University of Wuppertal — [6]University of Bochum

We will present our activities from the last year, would like to discuss plans for the coming year with you and hear your ideas and thoughts. Topics are current and future developments in high and low energy physics, i.e. particle, astroparticle, hadron and nuclear physics, as well as accelerator physics, including topics of the situation of early-career researchers, environmental sustainability, networking and shaping the future of our fields.

All doctoral candidates, post-docs and scientists on temporary contracts are cordially invited.

Please register to our mailing list which can be found from yhep.desy.de to receive details on the meeting.

## T 76: Invited Overview Talks 5

Time: Thursday 9:00–10:30 Location: Geb. 30.95: Audimax

**Invited Overview Talk** T 76.1 Thu 9:00 Geb. 30.95: Audimax

**Origin of heavy elements: r-process in neutron star mergers and core-collapse supernovae** — •Almudena Arcones — Institut für Kernphysik, Technische Universität Darmstadt, Schlossgartenstr. 2, Darmstadt 64289, Germany — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstr. 1, Darmstadt 64291, Germany

Our understanding of the origin of heavy elements by the r-process has made great progress in the last years. In addition to the gravitational wave and kilonova observations for GW170817, there have been major advances in the hydrodynamical simulations of neutron star mergers and core-collapse supernovae, in the microphysics included in those simulations (neutrinos and high density equation of state), in galactic chemical evolution models, in observations of old stars in our galaxy and in dwarf galaxies. This talk will report on recent breakthroughs in understanding the extreme environments in which the formation of the heavy elements occurs, as well as open questions regarding the astrophysics and nuclear physics involved.

**Invited Overview Talk** T 76.2 Thu 9:30 Geb. 30.95: Audimax

**Radio Detection of Neutrinos** — •Anna Nelles — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, 15738 Zeuthen, Germany

Optical neutrino telescopes, in particular IceCube, have truly started the field of neutrino astronomy. However, in order to pursue higher neutrino energies, those that are expected to be directly related to ultra-high energy cosmic rays, other methods are needed. This talk will introduce radio detection as promising route to discovery of EeV neutrinos. I will highlight the global experimental landscape, but focus on the Radio Neutrino Observatory Greenland (RNO-G) that is currently under construction.

**Invited Overview Talk** T 76.3 Thu 10:00 Geb. 30.95: Audimax

**High precision gravitational wave physics from quantum field theory** — •Jan Plefka — Humboldt-Universität zu Berlin, Berlin, Germany

Predicting the outcome of scattering processes of elementary particles in colliders is the central achievement of relativistic quantum field theory applied to the fundamental (non-gravitational) interactions of nature. While the gravitational interactions are too minuscule to be observed in the microcosm, they dominate the interactions at large scales. As such the inspiral and merger of black holes and neutron stars in our universe are now routinely observed by gravitational wave detectors. The need for high precision theory predictions of the emitted gravitational waveforms has opened a new window for the application of perturbative quantum field theory techniques to the domain of classical gravity. In this talk I will show how observables in the classical scattering of black holes and neutron stars can be efficiently computed in a perturbative expansion using a world-line quantum field theory; thereby combining state-of-the-art Feynman integration technology with perturbative quantum gravity. Here, the black holes or neutron stars are modelled as point particles in an effective field theory sense. Fascinatingly, the intrinsic spin of the black holes may be captured by a supersymmetric extension of the world-line theory, enabling the computation of the far field wave-form including spin and tidal effects to highest precision.

## T 77: Invited Topical Talks 3

Time: Thursday 11:00–12:30 Location: Geb. 30.21: Gerthsen-HS

**Invited Topical Talk** T 77.1 Thu 11:00 Geb. 30.21: Gerthsen-HS
**Track reconstruction for the ATLAS Phase-II Event Filter using GNNs on FPGAs** — •Sebastian Dittmeier — Physikalisches Institut, Universität Heidelberg, Heidelberg, Germany
The High-Luminosity LHC poses new challenges for the trigger and data acquisition system of the ATLAS experiment. The reconstruction of charged particle tracks is already now the computationally most intensive task of the trigger. It becomes even more expensive once the new tracking detector, called the Inner Tracker, is installed and the luminosity reaches HL-LHC target levels. To keep the computing resources within their given power, space and cost constraints, a heterogeneous server farm is proposed for the Event Filter, and novel algorithms are investigated.

Over the last years, it has been shown that Graph Neural Networks have great potential to efficiently solve the combinatorial challenge of finding track candidates in dense environments with hundreds of thousands of hits per event. Recent studies conducted for the ATLAS experiment come close to the physics performance of current tracking methods, while offering potential speed-ups. GNNs are well-suited to be implemented on FPGAs because of their intrinsic message passing algorithms, which lead to highly irregular computations and memory access patterns. This talk summarizes the development of the ATLAS Event Filter for HL-LHC, the most recent results of tracking with GNNs for ATLAS, and the translation of these models to FPGAs.

**Invited Topical Talk** T 77.2 Thu 11:30 Geb. 30.21: Gerthsen-HS
**Searches for Long-Lived Particles at LHC** — •Lisa Benato — Hamburg University
An overview of the most recent results in searches for long-lived particles at the LHC experiments is presented, with an emphasis on very long lifetimes, producing peculiar signatures in the outer layers of the detectors (calorimeters and muon systems). Future perspectives, along with new ideas for algorithmic developments, are briefly discussed.

**Invited Topical Talk** T 77.3 Thu 12:00 Geb. 30.21: Gerthsen-HS
**Searches for long-lived particles at accelerators** — •Maksym Ovchynnikov for the SHiP-Collaboration — Karlsruhe Institute of Technology, Karlsruhe, Germany
The scientific community's interest in discovering long-lived new physics particles has intensified in recent years. These particles, elusive due to their tiny interactions, represent a significant area of inquiry in particle physics. This talk will focus on recent progress in this field, highlighted by two case studies: the Downstream algorithm at LHCb and the SHiP experiment, representing searches at the LHC and utilizing extracted beamlines. The discussion will cover the capacity of these experiments to exclude a range of particle signatures, a vital step in the search process. Furthermore, in the event of a positive detection, the talk will address the methodologies employed by these experiments to determine the properties of these long-lived particles. Such discoveries could provide essential insights into phenomena that extend beyond the standard model of particle physics.

## T 78: Invited Topical Talks 4

Time: Thursday 11:00–12:30 Location: Geb. 30.22: Gaede-HS

**Invited Topical Talk** T 78.1 Thu 11:00 Geb. 30.22: Gaede-HS
**Signatures of quantum gravity in neutrino telescopes** — •Alba Domi for the ANTARES-KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
The Standard Model of particle physics and General Relativity are expected to merge into a new theory of Quantum Gravity (QG) at energies approaching the Planck scale. However, none of the proposed QG approaches has been validated to date. In an effort to gain insights into this unifying theory, the existence of "Windows on Quantum Gravity" has been postulated: observable signatures of QG effects at energy scales that are accessible to current experiments. Two such signatures are quantum decoherence (QD) and violation of Lorentz invariance (LIV). In the neutrino sector, these effects could cause modifications in neutrino oscillations, that can be measured by neutrino telescopes such as IceCube, ANTARES, and KM3NeT.

The goal of the QGRANT project is to analyse the huge amount of data collected by these telescopes via a global and novel fit in order to search for evidence of QG effects. This talk will discuss the current progress and future prospects of quantum gravity searches using neutrino telescopes.

**Invited Topical Talk** T 78.2 Thu 11:30 Geb. 30.22: Gaede-HS
**Development, characterization, and integration of the Silicon Drift Detector array TRISTAN for KATRIN** — •Frank Edzards for the KATRIN-Collaboration — Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — Max Planck Institute for Physics, 85748 Garching, Germany
Sterile neutrinos are a natural extension of the Standard Model of particle physics. If their mass is in the keV range, they are a viable dark matter candidate. One way to search for sterile neutrinos in a laboratory-based experiment is via tritium beta decay. A sterile neutrino with a mass up to 18.6 keV would manifest itself in the decay spectrum as a kink-like distortion. The objective of the TRISTAN project is to extend the KATRIN experiment with a novel multi-pixel silicon drift detector and readout system to search for a keV-scale sterile neutrino signal. This talk will give an overview on the current status of the project. Characterization measurement results obtained with a 166-pixel system will be shown.

This work is supported by BMBF (05A17PM3, 05A17PX3, 05A17VK2, 05A17WO3), KSETA, the Max Planck society, and the Helmholtz Association. This project has received funding from the European Research Council (ERC) under the European Union Horizon 2020 research and innovation programme (grant agreement No. 852845).

**Invited Topical Talk** T 78.3 Thu 12:00 Geb. 30.22: Gaede-HS
**New Chapter in Neutrino Physics with JUNO** — •Yury Malyshkin — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291, Darmstadt, Germany — Forschungszentrum Jülich GmbH, Wilhelm-Johnen-Straße, 52428, Jülich, Germany
The phenomenon of neutrino oscillations is being studied by various experiments around the world, leading to a more precise understanding of the neutrino properties and enabling to use these particles as a tool to investigate natural objects, either via their neutrino emission or via their transparency to neutrinos. However, several basic neutrino characteristics are still to be clarified. In JUNO (Jiangmen Underground Neutrino Observatory, South China) electron antineutrinos produced in two powerful nuclear power plants will be observed in a spherical target, 35.4 m in diameter, filled with 20 kton of liquid scintillator. The light produced after neutrino interaction will be collected by 17,612 20-inch and 25,600 3-inch photo-multiplier tubes covering 78% of the target surface, enabling measuring neutrino energy with unprecedented resolution. The talk will explain how this apparatus is going to resolve the neutrino mass ordering, measure three out of the six independent parameters driving the neutrino oscillations with a sub-percent precision, and how JUNO can serve as an observatory for neutrinos coming from the atmosphere and the interior of the Earth, from the Sun, and from the supernova explosions. The talk will also cover the status of JUNO construction which is planned to be accomplished already in the second half of 2024.

# T 79: Invited Topical Talks 5

Time: Thursday 14:00–15:30 Location: Geb. 30.21: Gerthsen-HS

**Invited Topical Talk** T 79.1 Thu 14:00 Geb. 30.21: Gerthsen-HS
**Construction, Commissioning, and Performance of the new ATLAS Level1-Trigger System for Run 3** — •Ralf Gugel — JGU Mainz
Already before the formal transition from LHC to HL-LHC various improvements on the accelerator side provide opportunities and challenges alike: higher instantaneous luminosity as well as increased pileup. In order to maximally benefit from this during the LHC Run 3 and as a first step towards HL-LHC, the ATLAS Level1-Trigger System has been upgraded in order to improve the accuracy of selecting the most interesting collisions. Following a brief introduction to requirements and resulting design choices for such a system the additions and modifications to the ATLAS Level1-Trigger System are presented with a focus on the calorimeter based trigger path. Further more selected aspects of the integration of the new subsystems among each other and into ATLAS, and achieved/anticipated physics performance are discussed.

**Invited Topical Talk** T 79.2 Thu 14:30 Geb. 30.21: Gerthsen-HS
**Hadronic signals at the LHC: timing as a handle to face the challenges of higher luminosity** — •Margherita Spalla — Max-Planck-Institut für Physik, München
The physics programme at the Large Hadron Collider (LHC) relies on measuring increasingly rare processes with high precision, while coping with the busier environment driven by increased luminosity. An efficient signal reconstruction is the first step towards this goal. During the LHC Run 1 and 2, the ATLAS experiment has mostly relied on measured energy and momentum, as well as fine detector segmentation. Even though this method has proven highly performant, it is sensitive to the piling-up effect of hadrons from additional soft collisions (*pile-up*). Integrating a precise measurement of signal timing into the existing reconstruction is gaining interest as a way to improve pile-up suppression. While a dedicated High-Granularity Timing Detector is expected to provide timing information for tracking at the High-Luminosity LHC, a measurement of signal timing is already provided in the current detector by the ATLAS calorimeters. Calorimeter signals are reconstructed based on energy signal-to-noise ratio, they provide the basis for the reconstruction of jets, electrons, photons and $\tau$-leptons. The introduction of a timing criterion in the topological clustering algorithm is shown to suppress pile-up originated jets by $\sim$ 50% or more, with no reduction in signal reconstruction efficiency. Such large pile-up suppression also reduces the average ATLAS event size by 6%, improving resource consumption. This method has been adopted as the Run 3 default.

**Invited Topical Talk** T 79.3 Thu 15:00 Geb. 30.21: Gerthsen-HS
**The LHCb Mighty Tracker - Getting ready for flavour physics at the HL-LHC** — •Klaas Padeken — HISKP University Bonn
With Upgrade II of the LHCb Experiment (LS4 of the LHC 2033/2034) the instantaneous luminosity at Point 8 will be increased by an factor 10 to $1.5 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. This requires a redesign of the LHCb tracking system. For the downstream tracker a hybrid system of monolithic pixel sensors in the central part and scintillating fibers in the outer part is foreseen. The detector will cover a $\eta$ region of 2 to 5, while keeping a triggerless streaming readout (at 40MHz) and improving the momentum resolution to $\sigma_p/p \approx 0.3\%$. The challenge is to keep the material budget for the pixel part, including all services, below 1 % $X/X_0$ per layer, and to read out the fibres with an increased hit rate of up to 20 MHz/cm$^2$. While the material budget can be reduced using monolithic sensors and a cooling solution, the latter part can only be solved by cooling the readout SiPMs to cryogenic temperatures.
This talk will give an overview of the LHCb Upgrade II plans and motivate the construction of a large scale state of the art hybrid detector, which will continue to add flavour to the physics program of the LHC.

# T 80: Invited Topical Talks 6

Time: Thursday 14:00–15:30 Location: Geb. 30.22: Gaede-HS

**Invited Topical Talk** T 80.1 Thu 14:00 Geb. 30.22: Gaede-HS
**The advent of TeV gamma-ray astronomy with gamma-ray bursts** — •Alessio Berti — Max Planck Institute for Physics, Garching, Germany
Gamma-ray bursts (GRBs) are the prototypical transient sources and the most energetic ones in the electromagnetic domain. After their first discovery more than 50 years ago, they have been the subject of searches across all wavelengths. Since then, the understanding of these enigmatic sources has greatly improved, especially in the recent years in the context of multi-messenger astrophysics. One of the most intriguing bands is the very-high-energy range (VHE, E$\gtrsim$100 GeV), through which one can probe the presence of new emission components and better understand the properties of particle acceleration and energy dissipation within GRBs. At these energies and above, Cherenkov telescopes and extensive air shower arrays have been hunting for GRBs for decades. All previous VHE observations did not result in any detection. This changed suddenly in 2019, when the MAGIC and H.E.S.S. collaborations announced the detection of VHE emission from two distinct GRBs, followed by two additional events within the following two years. More recently, in October 2022 the LHAASO collaboration announced the detection of another event. These detections provide unique datasets to improve our understanding of GRB physics, but they can be used also for fundamental physics studies. In this contribution I will present the journey which has led to these discoveries, what the GRB community has learned from them and what are the perspectives for future searches.

**Invited Topical Talk** T 80.2 Thu 14:30 Geb. 30.22: Gaede-HS
**Multi-messenger models of active galaxies: achievements and future directions** — •Xavier Rodrigues — European Southern Observatory, Garching bei München
The IceCube neutrino experiment has now accumulated over a decade of observations, and a suite of next-generation experiments is on the horizon. Theorists try to keep pace by developing increasingly refined astrophysical neutrino source models. In this talk I give an overview of some of the most recent advancements in these models, with emphasis on active black holes. I discuss the state of the art of numerical cosmic-ray simulation methods, the predicted multi-wavelength signatures of neutrino production, and the most promising source classes. I illustrate the significance of utilizing public multi-wavelength catalogs and open-source simulation software in developing the next generation of multi-messenger models.

**Invited Topical Talk** T 80.3 Thu 15:00 Geb. 30.22: Gaede-HS
**Acceleration and transport of relativistic electrons in the parsec-scale jets of the microquasar SS 433** — •Laura Olivera-Nieto — Max-Planck-Institut für Kernphysik, Heidelberg, Germany
The microquasar SS 433 provides a unique opportunity to study relativistic collimated jets. In contrast to the precessing inner jets, the larger-scale jet dynamics remain poorly understood. Here I will present results from the High Energy Stereoscopic System (H.E.S.S.), which reveal an energy-dependent shift in the position of the gamma-ray emission of the outer SS 433 jets. These observations, which trace the energetic electron population, confirm an inverse-Compton origin of the gamma rays. Our analysis of the energy-dependent gamma-ray morphology establishes the location of particle acceleration and requires an abrupt deceleration of the jet flow. We find strong evidence for the presence of shocks 25-30 pc either side of the binary system. That the self-collimation of the precessing jets forms such efficiently accelerating shocks strengthens claims that a similar process takes place in other sources hosting powerful relativistic jets.

# T 81: Search for new particles 5 (SUSY)

Time: Thursday 16:00–17:45 Location: Geb. 20.30: 1.067

T 81.1 Thu 16:00 Geb. 20.30: 1.067
**Search for Dark Matter in association with a hadronically decaying top quark at the CMS experiment** — •Michael Wassmer, Ulrich Husemann, Moritz Molch, and Sebastian Wieland — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)
In this talk a search for the production of Dark Matter in association with a single highly-energetic top quark is presented. In the standard model of particle physics such a final state can only be generated by higher-order effects and is, in addition, CKM and GIM suppressed, making it a prime candidate to search

for new physics. The search is based on the total Run-2 dataset collected by the CMS collaboration. The mono-top signature is characterized by large missing transverse momentum and the well-known top quark decay. This talk is focused on the hadronic decay of the top quark. Large-radius jets are used to reconstruct the decay products and multivariate methods are employed to distinguish these jets from purely QCD-initiated jets. The results of the search are interpreted in the context of a simplified model introducing a flavor-changing neutral current at tree level by a spin-1 mediator and a Dirac Dark Matter particle.

T 81.2 Thu 16:15 Geb. 20.30: 1.067

**Searches for new physics with MUSiC in pp collisions at $\sqrt{s} = 13$ TeV in 2018 CMS Data** — Thomas Hebbeker, •Yannik Kaiser, Lucas Karwatzki, Arnd Meyer, Chinmay Seth, and Felipe Torres da Silva de Araujo — III. Physikalisches Institut A, RWTH Aachen University

Despite the large effort of the LHC collaborations, no direct evidence for physics beyond the Standard Model has been found. Considering several theory models available, which address the inadequacies of the Standard Model, many model-specific searches have been employed. Complementary to this approach is MUSiC - Model Unspecific Search in CMS - a model-independent search procedure in which data collected by the CMS experiment are classified according to their final state multiplicities of well-reconstructed objects. For each class a search algorithm is applied to identify regions where the CMS measurements deviate from the theoretical prediction. The algorithm is based on a well-defined p-value and a complete simulation of the Standard Model. The procedure also takes into account systematic and statistical effects. As an extension of the already published result using 2016 data, we report preliminary results of the MUSiC search on data collected by CMS during 2018, corresponding to 58.83 $fb^{-1}$ of integrated luminosity.

T 81.3 Thu 16:30 Geb. 20.30: 1.067

**Combination and Reinterpretation of LHC SUSY Searches** — •Alexander Feike[1], Juri Fiaschi[2,3], Benjamin Fuks[4], Michael Klasen[1], and Alexander Neuwirth[1] — [1]Institut für Theoretische Physik, Universität Münster, Wilhelm-Klemm-Straße 9, 48149 Münster, Germany — [2]Department of Mathematical Sciences, University of Liverpool, Liverpool L69 3BX, United Kingdom — [3]Dipartimento di Fisica, Università degli Studi di Milano-Bicocca, Piazza della Scienza 3, I-20126 Milano, Italy — [4]Laboratoire de Physique Theorique et Hautes Energies (LPTHE), UMR 7589, Sorbonne Universite et CNRS, 4 place Jussieu, 75252 Paris Cedex 05, France

To maximise the information obtained from various BSM searches conducted at the LHC, it is imperative to contemplate the combination of multiple analyses. We consider a simplified SUSY scenario with all particles but one squark flavor and a bino like neutralino decoupled to showcase the exclusion power gained by combining uncorrelated signal regions of different analyses. This study includes the purely strong squark pair, the associated squark neutralino and the purely weak neutralino pair production, individually and their combination. We find that considering associated and strong production together significantly impacts the mass limit, while the contribution from the weak production is insignificant. In addition, we demonstrate that the combination of uncorrelated signal regions substantially pushes the exclusion limit towards higher masses, compared to the most sensitive individual analysis.

T 81.4 Thu 16:45 Geb. 20.30: 1.067

**Automatic combinations of signal regions for pMSSM scans at the ATLAS detector** — •Leon Renn, Jonas Würzinger, and Lukas Heinrich — Technical University Munich Data Science in Physics, Munich, Germany

The Large Hadron Collider (LHC) at CERN discovered the Higgs particle, concluding the search for elementary particles in the Standard Model (SM). However, the Higgs particle's mass challenges SM principles, suggesting physics beyond the SM (BSM). Supersymmetry (SUSY) elegantly addresses this issue by introducing supersymmetric partners. Despite extensive LHC analyses, no SUSY particles have been found. My thesis presents an automated method to combine numerous analyses, enhancing sensitivity to the phenomenological Minimal Super Symmetric Model (pMSSM). By identifying statistically uncorrelated analyses using an overlap matrix and a longest path algorithm, we efficiently determine the most sensitive combination. This novel approach significantly improves SUSY particle mass exclusion limits compared to individual analyses, with integration into the ATLAS collaboration's standard software.

T 81.5 Thu 17:00 Geb. 20.30: 1.067

**Search for Dark Matter Using Two Soft Opposite-Sign Displaced Muons at the CMS Experiment** — •Alexandra Tews — Universität Hamburg, Hamburg, Deutschland

A search for the decay of heavy neutral particles into a dark matter candidate and a pair of displaced, low-energetic muons is presented. The search targets supersymmetric extensions of the Standard Model of particle physics predicting light electroweakinos with compressed mass spectra in the selected parameter space with electroweakino mass differences ranging from 0.3 to 3.0 GeV. A bino or higgsino-like lightest supersymmetric particle (LSP) is considered, offering a dark matter candidate. The heavier neutralino ($\tilde{\chi}^0_2$) has a decay length of up to a few centimeters and the decay can lead to a pair of opposite-sign muons. The analysis concentrates on identifying displaced tracks of muon pairs, employing a specialized reconstruction and identification method for the displaced secondary decay vertex of the $\tilde{\chi}^0_2$. The background is estimated from a control region in the data.

Data corresponding to an integrated luminosity of 36.4 fb$^{-1}$ collected by the CMS experiment in proton-proton collisions at $\sqrt{s} = 13$ TeV are analyzed.

T 81.6 Thu 17:15 Geb. 20.30: 1.067

**Search for compressed electroweakinos in events with a low-momentum, displaced track at the CMS experiment** — Samuel Bein, Peter Schleper, Alexandra Tews, and •Moritz Wolf — Universität Hamburg

Many supersymmetric extensions to the Standard Model predict the three lightest electroweakinos, $\chi^0_2$, $\chi^\pm_1$, and $\chi^0_1$, to be Higgsino-like with nearly degenerate masses around the electroweak scale. The lightest chargino and the second-lightest neutralino can be produced alongside another electroweakino and then decay to the lightest neutralino. To search for these particles, the best strategy depends on the differences between the various masses. For $\Delta m(\chi^0_2, \chi^0_1) > \mathcal{O}(1\,\mathrm{GeV})$ lepton pairs from the decay of the second-lightest neutralino leave an experimentally distinct signature, whereas $\Delta m(\chi^\pm_1, \chi^0_1) \lesssim 0.3\,\mathrm{GeV}$ can lead to the chargino giving rise to a disappearing track. However, for mass splittings in the range of $\Delta m(\chi^\pm_1, \chi^0_1) = 0.3 - 1.0\,\mathrm{GeV}$, searches carried out so far at the LHC are lacking in sensitivity.

In this analysis, a slightly displaced track with small transverse momentum, corresponding to a pion originating from the chargino decay, is used to gain sensitivity to this challenging range of mass splittings.

T 81.7 Thu 17:30 Geb. 20.30: 1.067

**Not so inelastic Dark Matter** — •Giovani Dalla Valle Garcia[1], Felix Kahlhoefer[2], Thomas Schwetz[1], and Maksym Ovchynnikov[1,3] — [1]Institut für Astroteilchen Physik, Karlsruher Institut für Technologie (KIT), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany — [2]Institute for Theoretical Particle Physics (TTP), Karlsruhe Institute of Technology (KIT), D-76131 Karlsruhe, Germany — [3]Instituut-Lorentz, Leiden University, Niels Bohrweg 2, 2333 CA Leiden, The Netherlands

Models of inelastic (or pseudo-Dirac) dark matter commonly assume an accidental symmetry between the left-handed and right-handed mass terms in order to suppress diagonal couplings. Here we point out that this symmetry is unnecessary, because for Majorana fermions the diagonal couplings are in fact not strongly constrained. Removing the requirement of such an accidental symmetry in fact relaxes the relic density constraint, because additional annihilation modes can contribute, leading to larger viable parameter space. We discuss how the sensitivity of searches for both long-lived particles and missing energy signatures is modified in such a set-up, and explore the relevance of events with two long-lived particles.

# T 82: Neutrino physics 9

Time: Thursday 16:00–18:00 Location: Geb. 20.30: 2.058

T 82.1 Thu 16:00 Geb. 20.30: 2.058

**Final CEvNS result of the CONUS experiment at the Brokdorf reactor** — •Nicola Ackermann for the CONUS-Collaboration — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The CONUS experiment (COherent elastic NeUtrino nucleus Scattering) aimed to detect coherent elastic neutrino-nucleus scattering (CEvNS) of reactor antineutrinos on germanium nuclei by measuring their recoil after such an interaction. It operated from 2017 to 2022 at 17m distance from the 3.9 GWth core of the Brokdorf nuclear power plant (Germany). The experiment employed four 1 kg point-contact high-purity germanium (HPGe) detectors, which provided an energy threshold of 210 eV and background rates in the order of 10 events per kg, day and keV.

The analysis of the final CONUS data set allows to establish the current best limit on CEvNS from a nuclear reactor with a germanium target, improving the previous CONUS result by an order of magnitude. Moreover, this new result refutes other measurements where quenching factors deviating significantly from Lindhard theory were considered. The results from the last physics run together with the quenching measurements performed by CONUS will be discussed in this talk.

T 82.2 Thu 16:15 Geb. 20.30: 2.058

CE$\nu$NS **at reactor site with CONUS+** — •Janine Hempfling, Nicola Ackermann, Sophie Armbruster, Aurelie Bonhomme, Hannes Bonet, Christian Buck, Janina Hakenmueller, Gerd Heusser, Manfred Lindner, Werner Maneschg, Kaixiang Ni, Thomas Rink, Edgar Sanchez-Garcia, and Herbert Strecker for the CONUS-Collaboration — Max-Planck Institut fuer Kernphysik, Heidelberg, Germany

As a successor of the CONUS (COherent elastic NeUtrino nucleus Scattering) experiment CONUS+ aims for the detection of coherent elastic neutrino nucleus scattering with antineutrinos on a germanium target at a nuclear reactor. After the shut down of the Brokdorf nuclear reactor in 2021 the upgraded CONUS setup was moved successfully to a new site, the nuclear power plant in Leibstadt (Switzerland). CONUS+ is located at 21m distance from the 3.6 $GW_{th}$ reactor core and is equipped with the four former 1kg point-contact high-purity germanium detectors of CONUS which were optimized to achieve a significantly improved performance. Additionally, a second active muon-veto system is installed to improve the tagging of cosmogenic background. This talk will focus on the background characterization campaign at the new reactor site, the improvements of the detectors and the whole setup, the final installation and the first data-taking run of CONUS+.

T 82.3 Thu 16:30 Geb. 20.30: 2.058

**Simulation of CLOUD, the first LiquidO reactor anti-neutrino experiment** — •Cloé Girard-Carillo for the CLOUD-Collaboration — Johannes Gutenberg University, Mainz, Germany

LiquidO is an innovative particle detection paradigm using opaque liquid scintillators. The emitted light is confined near its creation point and captured by a lattice of wavelength-shifting fibers. This enables high-resolution imaging for particle identification down to the MeV scale, giving LiquidO the potential for various practical applications in particle physics.

After the successful development of two prototypes and with a third currently under construction, the next step is to build a 5 to 10-ton detector at the ultra-near site of the Chooz nuclear power plant in France. This is part of an Innovation program (EIC-Pathfinder project - AntiMatter-OTech) for monitoring nuclear reactor activity. The CLOUD collaboration, composed of 18 institutions over 11 countries, plans to exploit the fundamental science programme associated to this project.

Constructing the detector at the ultra-near site poses challenges, as being at the surface implies a high cosmic background rate. It also imposes strict constraints on design elements such as materials and maximum building size. The external background simulations presented in this talk are essential for guiding the detector design, taking into account these challenges. They play a crucial role in understanding the capabilities of a LiquidO-based detector operated at a nuclear power plant.

T 82.4 Thu 16:45 Geb. 20.30: 2.058

**Reconstruction of atmospheric neutrino events for NMO analysis in JUNO using GCNs** — •Rosmarie Wirth, Caren Hagner, Daniel Bick, and Vidhya Thara Hariharan — Universitaet Hamburg, Hamburg, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a large liquid scintillation detector, currently under construction in Jiangmen, China. With its 20 kt volume, high energy resolution of 3 %/$\sqrt{E[MeV]}$ and great optical coverage of 78 %, JUNO is aiming to unveil the Neutrino Mass Ordering (NMO) with a 3 $\sigma$ significance within 6 years of data taking, by observing reactor electron anti-neutrinos.

Additionally, JUNO will be sensitive to atmospheric neutrinos in lower energy ranges than today's Cherenkov detectors. Upward-going atmospheric neutrinos in the low GeV energy range show a different oscillation pattern for the normal and inverse ordering hypothesis, due to experiencing the matter effect when passing earth's core. Thereby, they could contribute to JUNOs NMO analysis as an independent secondary channel. To do so, the atmospheric neutrino events need to be reconstructed precisely.

This talk shows methods to reconstruct low GeV atmospheric neutrino events in JUNO using Graph Convolutional Networks (GCNs).

T 82.5 Thu 17:00 Geb. 20.30: 2.058

**EoS: A Pathfinder Experiment for Low Energy Neutrino Physics with the Hybrid Detector THEIA** — •Hans Theodor Josef Steiger — Physik-Department, Technische Universität München, James-Franck-Str. 1, 85748 Garching, Germany — Johannes Gutenberg University Mainz, Cluster of Excellence PRISMA+, Staudingerweg 9, 55128 Mainz, Germany

Future ktonne-scale, scintillation-based neutrino detectors, such as THEIA, plan to exploit new and yet to be developed technologies to simultaneously measure Cherenkov and scintillation signals in order to provide a rich and broad physics program. These hybrid detectors will be based on fast timing photodetectors, novel target materials, such as water-based liquid scintillator (WbLS), and spectral sorting. Besides a brief overview on THEIA*s program for low energy astroparticle and particle physics this talk focuses on a currently realized demonstrator experiment, called EOS. This novel detector with an approximately 4-tonne target fiducial volume is under construction at the UC Berkeley and LBNL (Lawrence Berkeley National Laboratory). The detector will provide a test bed for these emerging technologies required for hybrid Cherenkov/Scintillation detectors. Furthermore, EOS will deploy calibration sources to verify the optical models of WbLS and other liquid scintillators with slow light emission, to enable an extrapolation to ktonne-scale detectors. After achieving these goals, EOS can be moved near a nuclear reactor or in a particle test-beam to demonstrate neutrino event reconstruction or detailed event characterization within these novel detectors.

T 82.6 Thu 17:15 Geb. 20.30: 2.058

**Observables of the Electrical Potential of the KATRIN Tritium Source from Calibration with a High-Intensity Krypton-83m Source** — •Moritz Machatschek — Institute for Astroparticle Physics, Karlsruhe Institute of Technology

The KArlsruhe TRItium Neutrino experiment currently provides the best neutrino-mass upper limit of 0.8 eV/c$^2$ (90 % C.L.) in the field of direct neutrino-mass measurements. After a total measurement time of 1000 days in 2025, a final sensitivity better than 0.3 eV/c$^2$ (90 % C.L.) is expected, which at the same time requires a detailed study of systematic measurement uncertainties.

One major uncertainty is linked to the electric potential inside the tritium source. Inhomogeneities of the potential lead to a distortion of the $\beta$-spectrum, which needs to be characterized in order to reduce the systematic bias in the neutrino-mass measurement.

To this end we use conversion electrons from $^{83m}$Kr as nuclear standard. Traces of gaseous $^{83m}$Kr are circulated alongside tritium in the 10 m long source, such that inhomogeneities of the potential are observable as a broadening of the selected mono-energetic $^{83m}$Kr lines. In this talk we describe the results of $^{83m}$Kr campaigns carried out in 2021 and 2023 and their impact on the neutrino-mass determination.

*This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6).*

T 82.7 Thu 17:30 Geb. 20.30: 2.058

**First glance at the latest science runs of the KATRIN neutrino mass experiment using the KaFit analysis package** — •Richard Salomon[1] and Jaroslav Storek[2] for the KATRIN-Collaboration — [1]Institute for Nuclear Physics, University of Münster — [2]Institute for Astroparticle Physics, Karlsruhe Institute of Technology

Performing a precision measurement of the endpoint region of the tritium $\beta$-decay spectrum, the Karlsruhe Tritium Neutrino (KATRIN) experiment aims at measuring the neutrino mass with a sensitivity of better than 0.3 eV/c$^2$ (90% C.L.). The current world-leading upper limit of $m_\nu \leq 0.8$ eV/c$^2$ (90% C.L.) was determined from combined analysis of the first two measurement campaigns and a publication including the three subsequent measurement campaigns is currently in preparation.

The focus of this presentation is on the most recent measurement phases, which feature a significant increase of statistics in the region of interest. Following KATRIN's model blinding strategy, studies on Asimov data using the *KaFit/SSC* model within the *Kasper* framework will be presented to provide an initial overview of this dataset.

This work is supported by the Deutsche Forschungsgemeinschaft (DFG) through the Research Training Group "GRK 2149: Strong and Weak Interactions - from Hadrons to Dark Matter", the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6).

T 82.8 Thu 17:45 Geb. 20.30: 2.058

**Exploring eV-Scale Sterile Neutrinos with the KATRIN Experiment** — •Shailaja Mohanty for the KATRIN-Collaboration — Institute of Astroparticle Physics, KIT, Karlsruhe, Germany

Sterile neutrinos, though not part of the standard three-neutrino framework, are a crucial component of various physics models. They have the potential to address anomalies observed in short-baseline neutrino oscillations, backed by some theoretical support for their existence. The Karlsruhe Tritium Neutrino (KATRIN) experiment, aiming at 0.3 eV/$c^2$ (90% C.L.) sensitivity to the neutrino mass, measures the tritium $\beta$-decay endpoint spectrum with a high precision. The same spectrum is sensitive to sterile neutrino admixture. This presentation provides the current status of sterile neutrino search in the first five measurement campaigns of KATRIN using the analysis framework "KaFit". The analysis procedure and sensitivity are discussed, along with assumptions about constraining active neutrino mass and their influence on sterile neutrino sensitivity.

*This work is supported by the Helmholtz Association, the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6) and the Doctoral School "Karlsruhe School of Elementary and Astroparticle Physics: Science and Technology (KSETA)" through the GSSP program of the German Academic Exchange Service (DAAD).*

# T 83: Cosmic rays 6

Time: Thursday 16:00–18:15 Location: Geb. 20.30: 2.059

T 83.1 Thu 16:00 Geb. 20.30: 2.059

**Sensitivity of IceCube-Gen2 for Cosmic-Ray Anisotropy Studies** — •Wenjie Hou for the IceCube-Collaboration — Institute for Astroparticle Physics, Karlsruhe Institute of Technology (KIT)

One of the major unresolved issues in cosmic-ray physics is the transition from galactic to extra-galactic origin of high-energy particles. Pinpointing the exact energy of this transition remains a challenge, as the trajectories of CRs are significantly influenced by the magnetic fields present in the Galaxy, making it difficult to trace individual CRs back to their specific origins. However, constraints can be obtained by studying the large-scale cosmic-ray anisotropy in the energy range from PeV to EeV where the transition is expected to occur. The sensitivity to cosmic-ray anisotropy is in particular a matter of statistics. With the upcoming IceCube-Gen2 surface array, which will cover 8 times more area than the existing IceTop surface array and increase in aperture by factor 28.9. Therefore, there will be an increase in statistics and capability to investigate cosmic-ray anisotropy with higher sensitivity. We will present performed simulation studies of the sensitivity to the cosmic-ray anisotropy signal expected with the IceCube-Gen2 surface array.

T 83.2 Thu 16:15 Geb. 20.30: 2.059

**Effects of the galactic magnetic fields on anisotropies in a catalog based research** — •Luca Deval, Ralph Engel, Thomas Fitoussi, and Michael Unger — Karlsruhe Institute of Technology, Karlsruhe, Germany

Cosmic rays (CRs) are charged particles which, throughout their propagation in the Galaxy, undergo the effect of the galactic magnetic field (GMF). Due to these deflections, the arrival directions of CRs do not point in the direction of their sources. The Pierre Auger Observatory observes a hotspot in the Centaurus region which has been correlated with starburst galaxies at significance of $4\sigma$ but this result has been obtained assuming that the coherent deflections of the arrival directions of CRs can be neglected.

In this work, we investigate the effect of the GMF deflections on this analysis, by constructing 9 different realizations of the turbulent galactic magnetic field. We created a set of 10.000 simulated data sets for every GMF configurations to witch we apply the analysis reported by the Pierre Auger Collaboration with the intention of recovering compatible scenarios. We show that even in the presence of significance coherent deflections, the reported results can be recovered for a large fraction of realizations. However, when studying the local significance (LiMa) of the brightest and second brightest hotpost, we find agreement in only $< 1e^{-3}$ of the considered simulations indicating a discrepancy between the data and the model assumptions.

T 83.3 Thu 16:30 Geb. 20.30: 2.059

**The Effects of the Galactic Magnetic Field on the Transition from Galactic to Extragalactic Cosmic Rays** — •Veronika Vašíčková and Leonel Morejon for the Pierre-Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal, Germany

Identifying the sources of ultra-high-energy cosmic rays (UHECRs) has been a long-standing task of Astroparticle Physics. Understanding the influence of propagation on the energy spectrum and arrival direction is crucial to identifying UHECR sources and their properties. It has been shown that the Galactic Magnetic Field (GMF) affects UHECRs up to the highest energies.

This contribution highlights how the GMF influences the arrival direction and energy composition of cosmic rays in the rigidity range from 10 PV to 100 EV, whether they originated in the galactic plane or outside the Galaxy. This is accomplished through simulations utilising the CRPropa3 software which includes models of the GMF. A variety of potential sources in the Milky Way as well as starburst galaxies and active galactic nuclei is explored. In addition, the fractions of cosmic rays escaping from the Galaxy due to diffusion is calculated and the residence times of the cosmic rays within the Galaxy are computed. Finally, possible injection spectra which fit the observations of the Pierre Auger Observatory are extracted, given the effects of the GMF.

*Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)*

T 83.4 Thu 16:45 Geb. 20.30: 2.059

**Probabilistic modelling of discrete cosmic ray sources** — •Anton Stall[1], Leonard Kaiser[2,1], Chun Khai Loo[1], and Philipp Mertsch[1] — [1]Institute for Theoretical Particle Physics and Cosmology (TTK), RWTH Aachen University, Aachen, Germany — [2]1. Physikalisches Institut, University of Cologne, Cologne, Germany

Cosmic rays can be probed via direct detection at the Earth's position or indirectly through diffuse emissions of gamma-rays and neutrinos produced by the interaction of cosmic rays with the interstellar medium in other parts of the Galaxy. It is commonly assumed in the modelling of galactic cosmic rays that the source density is smooth and steady. However, supernova remnants, the likely sources of cosmic rays, have a point-like and burst-like nature. This renders our predictions very sensitive to the precise positions and times of the sources. Yet observationally, those parameters are not accessible such that the source modelling must be done probabilistically. Fluctuations in locally observed cosmic rays can constrain the energy dependence of escape from the accelerators. Concerning the diffuse emissions, we find that the diffuse sky at GeV energies has a different morphology compared to the one at hundreds of TeV, relevant for observations with LHAASO, Tibet AS-gamma, IceCube and the upcoming SWGO, indicating that extrapolations from lower energies must fail.

T 83.5 Thu 17:00 Geb. 20.30: 2.059

**Improvement of the Cosmic Ray Fit in the Galactic Diffuse Emissions Model CRINGE** — •Lasse Ausborm[1,2], Jakob Böttcher[2], Philipp Fürst[2], Sven Günther[1], Hanno Jacobs[1], Philipp Mertsch[1], Anton Stall[1], and Christopher Wiebusch[2] — [1]Institute for Theoretical Particle Physics and Cosmology (TTK), RWTH Aachen University, 52056 Aachen, Germany — [2]III. Physikalisches Institut B, RWTH Aachen University, 52056 Aachen, Germany

CRINGE (Cosmic Ray-fitted Intensities of Galactic Emission) is a model used to calculate the galactic diffuse emission of gamma-rays and high-energy neutrinos. These emissions are the result of Cosmic Ray (CR) interactions, mostly proton and helium, with the interstellar medium. The distribution of these CRs in the Galaxy is calculated by fitting the source and transport parameters to the local proton and helium flux measured by AMS-02, DAMPE, KASCADE and IceTop, along with electron, positron, carbon, and B/C-ratio data from AMS-02. In this talk, we focus on improvements of the CR modeling of CRINGE by including new data from DAMPE and HAWC, as well as modifiying the model parameterization. Additionally, we discuss the uncertainty estimation in the high-energy CR data. We present these improvements and their significance.

T 83.6 Thu 17:15 Geb. 20.30: 2.059

**Studying effects of Lorentz violation in the photon sector using extensive air shower simulations** — •Nico Spornhauer, Fabian Duenkel, Marcus Niechciol, and Markus Risse — Center for Particle Physics Siegen, Experimentelle Astroteilchenphysik, Universität Siegen

Ultra-high-energy cosmic rays induce extensive air showers involving secondary particles, which can exceed the energies reached by today's accelerators. The effects of isotropic, non-birefringent Lorentz violation in the photon sector can be studied at these high energies. Using the 1-dimensional air shower simulation program CONEX, bounds on the studied Lorentz violation were set based on the significant reduction of the average atmospheric depth of the shower maximum $\langle X_{\max} \rangle$ and its shower-to-shower fluctuations $\sigma(X_{\max})$. We implemented modifications achieving Lorentz violation into the 3-dimensional air shower simulation program CORSIKA. The aim is an improved search for Lorentz violation by including observables unavailable to a 1-dimensional simulation such as those connected to the lateral particle distribution. We present preliminary results for the 3-dimensional shower simulations.

This work is supported by the Deutsche Forschungsgemeinschaft (DFG).

T 83.7 Thu 17:30 Geb. 20.30: 2.059

**Micromirror confinement of sub-TeV cosmic rays in galaxy clusters** — •Patrick Reichherzer[1], Archie F. A. Bott[1], Robert J. Ewart[1], Gianluca Gregori[1], Philipp Kempski[2], Matthew W. Kunz[2], and Alexander A. Schekochihin[1] — [1]University of Oxford, UK — [2]Princeton University, US

Recent observations reveal that cosmic rays (CRs) are more tightly confined in various astrophysical systems than current theories predict. We propose that microscale magnetic fluctuations, particularly from the mirror instability, significantly influence CR transport. Our theory is supported by simulations of CRs in the intracluster medium (ICM) of galaxy clusters. Our results indicate that sub-TeV CR confinement in the ICM is much more efficient than previously thought based on extrapolating existing Galactic-transport theories.

T 83.8 Thu 17:45 Geb. 20.30: 2.059

**Modelling hadronic interactions of Galactic Cosmic rays in Giant Local Molecular Clouds with CRPropa*** — •Julien Dörner[1,2], Leonel Morejon[2,3], Julia Becker Tjus[1,2,4], and Karl-Heinz Kampert[2,3] — [1]Theoretical Physics IV, Plasma Astroparticle Physics, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — [3]Bergische Universität Wuppertal, Department of PhysicsGaußstraße 20, 42103 Wuppertal, Germany — [4]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

For Galactic Cosmic rays (GCRs) the hadronic interaction with the ambient gas are the most relevant energy loss channel. These interactions produce gamma-rays in the very high energy band as well as neutrinos, electrons and positrons. One tracer of the interactions of the GCRs of the local interstellar spectrum are gamma-ray observations of local giant molecular clouds (GMCs).

In this talk the implementation of hadronic interactions for primary protons on a proton target, based on different parametrisations of the production cross-section, is presented. We apply different interaction models to simulate the interactions of GCRs with the GMC Rho-Oph. The results of the parametrised models are compared to directly interfaced event generators and current observations.

* *Financial support by the DFG (SFB 1941) is gratefully acknowledged*

T 83.9 Thu 18:00 Geb. 20.30: 2.059

**Hybrid modeling of particle acceleration in MHD-jet simulations using stochastic differential equations** — •Patrick Günther, Karl Mannheim, and Sarah Wagner — Julius-Maximilians-Universität Würzburg

Fluid-dynamical simulations of jets generated by accreting supermassive black holes have made great progress in recent years showing the evolution of the thermal particle parameters along the jets. The observed jets, however, show non-thermal emission from particles accelerated in situ at shock waves and magnetic reconnection sites. To connect the non-thermal particles with the simulated bulk of the thermal particles, we study the diffusive propagation and energy losses of energetic particles in the test-particle approximation. We use the equivalence to a set of stochastic differential equations to solve the underlying Fokker-Planck equation and apply the code to the case of both Fermi-type acceleration mechanisms (diffusive shock acceleration and stochastic acceleration). Integrating the stochastic differential equation with a basic Euler scheme does not lead to the analytically expected power-law indizes in the case of shock acceleration, but accuracy can be improved by applying a semi-implicit second-order scheme. This method enables us to calculate particle distributions emerging from arbitrary shock szenarios efficiently. We show first results and develop a perspective on the potential of hybrid simulations.

# T 84: Methods in particle physics 5 (tagging)

Time: Thursday 16:00–18:00 Location: Geb. 20.30: 2.066

T 84.1 Thu 16:00 Geb. 20.30: 2.066

**Development of flavour-tagging algorithms for the LHCb in Run 3** — •Jonas Rönsch, Johannes Albrecht, Quentin Führing, and Vukan Jectić — TU Dortmund University, Dortmund, Germany

The Standard Model allows the oscillation of the flavour from neutral $B$ mesons, which can lead to a change in flavour between production and decay. For studies in the field of heavy flavour physics, e.g. analyses of $CP$ violation in the decay of neutral $B$ mesons, knowledge of the initial flavour is necessary. This information can be retrieved through the process of flavour-tagging. At the LHCb experiment, a flavour-tagging technique involving the charge of particles which are connected to the production flavour of the $B$ meson. For Run 3 of the LHC, most components of the LHCb detector were upgraded. Consequently, the existing flavour-tagging algorithms must be revisited and adapted according to the Run 3 detector conditions. The reimplementation and optimization of the flavour tagging algorithms based on simulated Run 3 data samples will be presented in this contribution.

T 84.2 Thu 16:15 Geb. 20.30: 2.066

**Recent results in Heavy-Flavor Jet Tagging algorithms in the CMS Experiment** — Alexander Jung, Ming-Yan Lee, Andrey Pozdnyakov, •Uttiya Sarkar, Alexander Schmidt, Jan Schulz, and Ulrich Willemsen — III. Physikalisches Institut A, RWTH Aachen University

Identification of heavy-flavor jets plays an important role in many physics data analyses in the CMS Experiment. The method is implemented in the CMS physics reconstruction chain and relies primarily on charged particle tracks and secondary vertices within the jets. There has been a continuous evolution of heavy-flavor tagging algorithms, with each new algorithm consistently outperforming its predecessor. This presentation gives an overview of jet flavor tagging in CMS and discusses the comparison between data and simulation for various input variables, tagging discriminants, and other relevant kinematic observables. These comparisons are made across different phase space regions that are enriched in b, c, and light (udsg) quark jets, respectively. Studies are performed using the proton-proton collision data recorded by the CMS detector during the early part of the LHC Run 3.

T 84.3 Thu 16:30 Geb. 20.30: 2.066

**Calibration of b-jet taggers at the ATLAS experiment** — •Johannes Hessler, Daniel Britzger, and Stefan Kluth — Max-Planck-Institut für Physik

Flavor tagging describes the identification of jets originating from heavy quarks in high energy physics. It plays an important role in many analyses at the ATLAS experiment.

This talk will discuss the calibration of the most recent machine learning based ATLAS b-jet taggers. The focus will be on the c-jet mistag rate. It accounts for the misidentification of c-jets as b-jets.

T 84.4 Thu 16:45 Geb. 20.30: 2.066

**Calibration of boosted vector boson tagging algorithms in ATLAS using diboson events** — •Simone Ruscelli and Chris M. Delitzsch — TU Dortmund

The unprecedented centre-of-mass energy of the $pp$ collisions at the Large Hadron Collider enables vector bosons production with a transverse momentum much larger than their rest mass, resulting in the collimation (or boost) of their decay products. The hadronic decay products of the vector bosons are captured within a large-radius ($R = 1.0$) jet. To distinguish such a jet from a quark/gluon-initiated jet, boosted object identification (tagging) algorithms are developed that exploit the radiation pattern within the large-radius jet, also known as jet substructure. The state-of-the-art tagging algorithms are based on machine learning techniques and significantly outperform simple cut-based taggers using a few jet substructure variables. Before such tagging algorithms can be used in analyses, they must be calibrated to match the efficiency obtained in Monte Carlo Simulation to that in data. To calibrate boosted W/Z boson tagging algorithms, $t\bar{t}$ events and V+jets events are used. While V+jets events cover the $p_T > 500$ GeV range, W bosons from top-quark decays are only available up to $p_T \approx 350$ GeV. In these feasibility studies, diboson events (WZ and ZZ) in which the Z-boson decays into a pair of charged leptons are explored to fill the gap in $p_T$ between the $t\bar{t}$ and V+jets selections, but also to provide a cross-check to the current analyses in regions of overlap. The studies use $\sqrt{s} = 13$ TeV $pp$ collisions recorded by the ATLAS detector at the Large Hadron Collider between 2015 and 2018.

T 84.5 Thu 17:00 Geb. 20.30: 2.066

**Overview of adversarial studies for heavy flavour tagging** — •Alexander Jung, Ming-Yan Lee, Uttiya Sarkar, Alexander Schmidt, Hendrik Schönen, Jan Schulz, and Ulrich Willemsen — III. Physikalisches Institut A, RWTH Aachen University, Germany

Neural networks have become indispensable in jet tagging algorithms. The ever-increasing performance in classifying jets comes with the disadvantage that these algorithms are susceptible to mismodeled input data. Networks are trained on simulated samples with a fixed detector setup. The real setup is not always constant, e.g. misalignment can occur or parts of the detector can fail. However, it would not be feasible to take these variations into account in the simulation, which means that mismodeling occurs "by design". In this contribution, we will look at how neural networks react to mismodeling, i.e. how robust they are against them and how their robustness can be improved.

T 84.6 Thu 17:15 Geb. 20.30: 2.066

**b-tagging with Graph Neural Networks and additional Hit information** — •Roman Kuesters and Spyros Argyropoulos — University of Freiburg, Freiburg im Breisgau, Germany

With a large region of the parameter space of new physics models already excluded by ATLAS and CMS, searches for new physics increasingly focus on the hunt for heavy resonances that often produce high-momentum B-hadrons.

B-hadrons with a high momentum are likely to decay after the first instrumented detector layers, thereby leaving fewer hits in the detector. This leads to a reduced track reconstruction efficiency and, consequently, a reduced b-jet identification efficiency.

Using hit information directly in the b-jet identification algorithms has been proposed to circumvent this problem. The talk will present how hit information can improve the b-jet identification at high momenta.

T 84.7 Thu 17:30 Geb. 20.30: 2.066

**A study of ML based heavy flavour tagging** — •Pradyun Hebbar, Stefan Kluth, and Daniel Britzger — Max Planck Institute for Physics, Munich, Germany

Heavy Flavour tagging, the identification of jets originating from t, b and c quarks, is a critical component of the physics programme of the ATLAS experiment at the Large Hadron Collider (LHC). Flavour tagging is of particular importance for the study of the Standard Model (SM) Higgs boson and the top quark, which preferentially decay to b quarks through the channels H to bb, and t to bW+. In recent years, with the advent of machine learning, many deep learning algorithms have shown drastically improved performance for flavour tagging compared to the traditional taggers. One such algorithm - PELICAN, the permutation equivariant and Lorentz invariant or covariant aggregator network, has achieved state-of-the-art performance for top tagging with fewer learnable parameters (as low as 11k) than the previous highest-performing networks. The goal of my study is to extend the PELICAN architecture for the objective of flavor tagging (specifically, b tagging) and compare its performance with other state-of-the-art b-tagging algorithms like ParticleNet and GN2!

T 84.8 Thu 17:45 Geb. 20.30: 2.066

**Soft Secondary Vertex tools for the ATLAS experiment** — Diptaparna Biswas[1], •Beatrice Cervato[1], Markus Cristinziani[1], Carmen Diez Pardos[1], Ivor Fleck[1], Arpan Ghosal[1], Gabriel Gomes[1], Jan Joachim Hahn[1], Vadim Kostyukhin[1], Nils Krengel[1], Buddhadeb Mondal[1], Stefanie Müller[1], Katharina Voss[1], Wolfgang Walkowiak[1], Adam Warnerbring[1], and Tongbin Zhao[1,2] — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Shandong University, China

Several interesting physics processes lead to the production of low-energy (soft) $b$-quarks in the final state, that may fragment into $b$-hadrons without the creation of a reconstructable jet. Moreover, $b$-hadrons in jets are sometimes so soft that their decay products are distributed wider than the standard jet cone (the typical cone $\Delta R$ is about 0.4). The tools described in this contribution are targeting secondary vertices which are not detectable by standard Flavour Tagging algorithms. It is important to develop and optimize such $b$-tagging tools in order to extend the overall capability to identify $b$-quarks. In particular, we will describe the performance and the calibration of the tools.

# T 85: Methods in astroparticle physics 4

Time: Thursday 16:00–18:00 Location: Geb. 20.30: 2.067

T 85.1 Thu 16:00 Geb. 20.30: 2.067

**Intensity interferometry with Fresnel lens telescopes** — •Christopher Ingenhütt, Naomi Vogel, Andreas Zmija, Pedro Silva Batista, Stefan Funk, Gisela Anton, Alison Mitchell, and Adrian Zink — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

Intensity interferometry (II) correlates the photon streams of at least two telescopes with varying baselines to determine the angular diameter of stars with high (~milliarcsecond) resolution. This method is less sensitive to atmospheric effects than similar methods and doesn't set high requirements on the optical imaging capabilities of the individual telescopes. Limiting factors that determine the observable objects are light collection area and possible baselines. We built two telescopes, each using a 1m diameter Fresnel lens focusing the starlight onto a photomultiplier tube. By using widely available standardized aluminium and carbon fiber parts and complementing them with self-designed 3D-printed components, the telescope setup was kept both cheap and lightweight (~10kg). The lightweight design also enables the telescopes to be repositioned, allowing data acquisition with multiple telescope baselines. We present an overview of the design and assembly process, characterize the telescopes with respect to photon rates from stars as well as from the night sky, and give an outline of potential observation targets.

T 85.2 Thu 16:15 Geb. 20.30: 2.067

**Simultaneous two color intensity interferometry measurements at H.E.S.S.** — •Naomi Vogel, Andreas Zmija, Gisela Anton, Stefan Funk, Alison Mitchell, and Adrian Zink — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

Intensity interferometry (II) is a method that can achieve high angular resolution astronomical observations in the optical band by correlating photon streams from at least two telescopes with varying baselines. Imaging Atmospheric Cherenkov Telescopes are used for this technique because of their large light collection areas. Our II setup was designed to be mounted to the lid of the Phase I H.E.S.S. telescopes in Namibia. The light beam reflected from the telescope is split into two 10nm interference filters with central wavelengths at 375nm and 470nm. It is detected by photomultiplier tubes whose photo currents are transferred to our workstation via optical fibers for further analysis. Following our first measurement campaign in April 2022, we give a review and an update on the changes of the optical setup and show new results from our measurement campaign in April 2023.

T 85.3 Thu 16:30 Geb. 20.30: 2.067

**Interpolating Antenna Calibration Data from Sparse Measurements with Information Field Theory** — •Maximilian Straub, Martin Erdmann, and Alex Reuzki for the Pierre-Auger-Collaboration — Physics Institute III A RWTH Aachen

In order to measure radio emissions from cosmic-ray induced air showers, Short Aperiodic Loaded Loop Antennas (SALLAs) are being installed at the Pierre Auger Observatory. The antennas' directional response is being determined using a drone carrying a reference signal. Information Field Theory, a Bayesian method, is used to interpolate the point measurements into a full pattern in both the direction and frequency domain. This allows to incorporate all knowledge on the measurement and learn local correlation structures to fill in the unseen directions and frequencies. Given the Bayesian nature, the resulting map provides a good estimate of the resulting pattern's uncertainties. We apply the approach to simulation data and to measurements conducted in situ at the Pierre Auger Observatory.

T 85.4 Thu 16:45 Geb. 20.30: 2.067

**Intrinsic Resolution Limits in Low-Energy Event Reconstruction with IceCube** — •Kaustav Dutta and Sebastian Böser — JGU Mainz, Germany

The IceCube Observatory is a cubic-kilometer neutrino telescope built into the deep glacial ice at the South Pole. Low energy extensions to the detector include the existing DeepCore subarray and the upcoming IceCube Upgrade, which will be constructed in the 2025/26 Antarctic Summer season. The IceCube Upgrade will consist of seven new strings of photosensors, characterized by a denser instrumentation than the existing array. The setup will allow us to study neutrino oscillations with greater sensitivity compared to the existing instrumentation, improve neutrino mass hierarchy studies, and test for the PMNS mixing matrix unitarity with high precision. The reconstruction of event information, in particular the direction of an incoming neutrino, is a crucial ingredient to all of these low-energy physics analyses. Here, we focus on identifying the theoretically achievable resolution in directional reconstruction. The factors that limit the physics information in the events, specifically the transverse spread of hadronic shower, in-ice photon scattering, module resolutions and module noise, have been analyzed. These limitations subsequently impose constraints on the achievable resolution. The resolution limits are finally compared with the performances of the state-of-the-art reconstruction algorithms used by the IceCube Collaboration.

T 85.5 Thu 17:00 Geb. 20.30: 2.067

**Use of Moyal and Lambert functions for reconstruction and simulation of PMT signals** — •Oleg Kalekin for the ANTARES-KM3NET-ERLANGEN-Collaboration — ECAP, FAU Erlangen-Nürnberg

Photomultiplier Tubes (PMTs) are widely used in astrophysical experiments as photodetectors. Signals from PMTs have Gaussian like rising edge and exponential like falling edge. Such signals can be fitted with a modified Moyal function with decoupled parameters for rising and falling edges. The solution for the inverse modified Moyal function can be found using a Lambert function. A method for the fast calculation of the Lambert function has been proposed recently by Darko Veberic. Therefore, the analytical Moyal and its inverse functions can be used for simulations of PMT signals including deriving of trigger time or Time-over-Threshold parameters.

T 85.6 Thu 17:15 Geb. 20.30: 2.067

**Improving the Signal Extraction and Gain Calibration for the IceAct Telescopes** — •Lukas Brusa, Jonas Häussler, Johanna Hermannsgabner, Lars Heuermann, Lea Schlickmann, and Christopher Wiebusch for the IceCube-Collaboration — RWTH Aachen, Aachen, Germany

IceAct is a surface detector array of Imaging Air Cherenkov Telescopes located at the South Pole as part of the IceCube Neutrino Observatory. The telescopes feature a camera with 61 SiPM-based pixels and are optimized for air-shower measurements in harsh environments. Physics goals are improved cosmic ray studies, the cross calibration of IceCube and IceTop by a hybrid measurement of air-showers, and an improved atmospheric neutrino veto. First step in the analysis of the recorded data is the gain calibration of the pixels and the signal extraction. When extracting photon hit information for a single pixel, the measured signal (waveform) is cross-correlated with the noise-free signal expectation. This increases the signal-to-noise ratio leading to an improved gain calibration. This talk will give an overview of the new signal extraction algorithm, present an updated gain calibration and compare the data between experiment and simulation.

T 85.7 Thu 17:30 Geb. 20.30: 2.067

**Status of the IceAct Telescopes above the IceCube Neutrino Observatory** — •Lars Heuermann, Lukas Brusa, Jonas Häussler, Andreas Nöll, Lea Schlickmann, Rosa van Monsjou, and Christopher Wiebusch for the IceCube-Collaboration — RWTH Aachen - III. physikalisches Institut B, Aachen, Germany

IceAct is an array of Imaging Air Cherenkov Telescopes on the ice surface above the IceCube Neutrino Observatory. Each telescope features a SiPM-based 61-

pixel camera and Fresnel lens-based optics, resulting in a 12-degree field of view. The design is optimized to be operated in harsh environments, particularly at the South Pole. Since 2019, two telescopes have been taking data in a stereoscopic setup, 200m apart. In the future, this setup will be expanded to a station comprising seven of these telescopes in a so-called flys eye configuration, increasing the field of view to 36 degrees. For this purpose, the first additional telescope was shipped to the South Pole in October 2023. In this talk we will review the status of the installation, recent analysis results, and report on the ongoing upgrade.

T 85.8 Thu 17:45 Geb. 20.30: 2.067

**Measurement-based performance comparison of SiPM and PMT pixels in the MAGIC IACT camera** — •Alexander Hahn[1], Razmik Mirzoyan[1], Antonios Dettlaff[1], David Fink[1], Daniel Mazin[1,2] und Masahiro Teshima[1,2] — [1]Max Planck Institute for Physics, Garching, Germany — [2]Institute for Cosmic Ray Research, The University of Tokyo, Kashiwa City, Japan

All the major Imaging Atmospheric Cherenkov Telescopes (IACTs) in operation, including MAGIC, H.E.S.S., VERITAS, and CTA's LSTs and MSTs, utilize photomultiplier tubes (PMTs) as low light level (LLL) detectors. It has been shown that smaller IACTs, such as FACT and ASTRI, can utilize Silicon photomultipliers (SiPMs) instead. However, whether SiPMs can effectively replace PMTs as light detectors in larger-scale IACTs remains an unresolved question primarily investigated through simulations. We have built several SiPM-based prototype detector modules at the Max Planck Institute for Physics to address this question. Our SiPM detector modules have been installed for several years in one of the two MAGIC cameras and were operated in parallel. This allows us to directly compare the performances of SiPM and PMT-based pixels without added assumptions. Here, we present a multi-year in situ study that covers detector calibration, long-term stability, detection efficiencies, and signal-to-noise ratio comparisons between the two detector types.

# T 86: Neutrino physics 10

Time: Thursday 16:00–18:00 Location: Geb. 30.21: Gerthsen-HS

T 86.1 Thu 16:00 Geb. 30.21: Gerthsen-HS

**Sensitivity Studies on the Implementation of New Detector and Source Concepts at KATRIN** — •Svenja Heyns for the KATRIN-Collaboration — KIT, IAP

The Karlsruhe Tritium Neutrino experiment (KATRIN) is leading the direct kinematic neutrino mass measurement with an upper limit on the effective neutrino mass $m_\nu$ of 0.8 eV/c$^2$ (90% CL) based on the initial two measurement campaigns, and a final sensitivity of below 0.3 eV/c$^2$.

Making further steps towards an ultimate sensitivity to the neutrino mass below the level of 0.1 eV/c$^2$ may require significant conceptual modifications in the future neutrino mass determination with KATRIN. In this talk we present sensitivity studies on the impact of a high-resolution electron detector for a neutrino mass measurement which implies the measurement of a differential electron spectrum in comparison to the present integral measurement. The use of atomic tritium is explored as a replacement for the current molecular source to avoid the limitation posed by molecular final states. The results presented in this talk show that with these modifications a KATRIN-like experiment can potentially reach the inverted hierarchy, and indicate what is necessary to increase even further in sensitivity.

*This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6)*

T 86.2 Thu 16:15 Geb. 30.21: Gerthsen-HS

**ELECTRON - Development of High Resolution Metallic Microcalorimeters for a Future Neutrino Mass Experiment** — •Neven Kovac[1], Fabienne Bauer[2], Tamara App[1], Beate Bornschein[1], Daniel de Vincenz[1], Ferench Glück[1], Svenja Heyns[1], Sebastian Kempf[2], Marie-Christin Langer[2], Michael Müller[2], Rudolf Sack[1], Magnus Schlösser[1], Markus Steidl[1], and Kathrin Valerius[1] — [1]Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology — [2]Institute of Micro- and Nanoelectronic Systems (IMS), Karlsruhe Institute of Technology

Metallic Magnetic Calorimeters (MMCs) are low temperature single particle detectors, whose working principle is based on quantum technology. Due to their excellent energy resolution, near linear detector response, fast signal rise time and close to 100% quantum efficiency, MMCs outperform conventional detectors by several orders of magnitude, making them interesting for a wide range of different applications. The aim of the ELECTRON project is to demonstrate, for the first time, that MMC based detectors can be employed for a high resolution spectroscopy of external electron sources, namely electron-gun, krypton-83m and tritium. Technology and methods developed within the context of the ELECTRON project will pave a way for the next generation neutrino experiments with tritium, employing a differential detector based on quantum technology. We present the first measurements of the $^{83m}$Kr spectrum performed with an MMC-based detector, as well as the efforts put towards the first ever measurements of the tritium $\beta$-decay spectrum using a novel compact tritium source.

T 86.3 Thu 16:30 Geb. 30.21: Gerthsen-HS

**KATRIN like MINI MAC-E Filter with a tritium source for the advanced physics lab course** — •Sarah Untereiner for the KATRIN-Collaboration — Karlsruhe Institute of Technology (KIT), Wolfgang-Gaede-Str. 1, 76131 Karlsruhe, Germany

The KATRIN experiment aims to determine the effective neutrino mass using the kinematics of electrons from the tritium $\beta$-decay. The integral energy spectrum of the electrons is measured by an electro-static high-pass filter, using the MAC-E filter principle (Magnetic Adiabatic Collimation and Electrostatic filter). Only electrons with energies above the retarding potential of the filter are counted at the detector at the end of the MAC-E spectrometer. In order to give students the opportunity to learn more about the experimental principles behind KATRIN, a smaller version of the MAC-E filter setup, called MiniMACE, has been built, which will be used in the advanced physics lab course at KIT. With a scale of approximately 1:20 the MiniMACE experiment includes all the major components of KATRIN: a tritium source, the spectrometer with adjustable high voltage, a high resolution detector and the magnetic guiding field. Other than KATRIN, the source uses two implanted disks with tritium and $^{83m}Kr$ that can be exchanged inside the ultra-high vacuum source chamber. This talk is about the design of the physics lab setup and reports on first results. This project has been supported by RIRO (Research Infrastructure in Research-Oriented teaching), which is part of the ExU project at KIT.

T 86.4 Thu 16:45 Geb. 30.21: Gerthsen-HS

**LEGEND-200 Calibration Performance with the LEGEND Julia Software Stack** — •Florian Henkes[1], Oliver Schulz[2], and Felix Hagemann[2] for the LEGEND-Collaboration — [1]Physik-Department, Technische Universität München, Germany — [2]Max-Planck Institut für Physik, Garching, Germany

The **L**arge **E**nriched **G**ermanium **E**xperiment for **N**eutrinoless $\beta\beta$ **D**ecay (LEGEND) is a ton-scale, $^{76}$Ge-based, neutrinoless double-beta ($0\nu\beta\beta$) decay experimental program with discovery potential at half-lifes greater than $10^{28}$ years. The first 200 kg stage of the experiment, LEGEND-200, is currently taking data at Gran Sasso underground laboratory in Italy. We present the first analysis results on LEGEND-200 calibration data gained using the LEGEND Julia Software Stack. We will focus specifically on the performance of the energy reconstruction and pulse-shape discrimination algorithms. We acknowledge support by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany*s Excellence Strategy * EXC 2094 * 390783311, the support by the BMBF Verbundprojekt 05A2023 - LEGEND: Suche nach dem neutrinolosen doppelten Beta-Zerfall in Ge-76 mit LEGEND and the Max-Planck Society.

T 86.5 Thu 17:00 Geb. 30.21: Gerthsen-HS

**Towards a Better Liquid Argon Anti-Coincidence Classifier for LEGEND-200** — Elisabetta Bossio[2], •Rosanna Deckert[1], Nils Doll[1], Patrick Krause[1], Luigi Pertoldi[1], Stefan Schönert[1], and Mario Schwarz[1] for the LEGEND-Collaboration — [1]Technical University of Munich, Garching, Germany — [2]IRFU, CEA, Université Paris-Saclay, Paris, France

LEGEND-200 is an experiment designed to search for neutrinoless double beta decay of Ge-76. Located deep underground at LNGS, it operates up to 200 kg of enriched high-purity germanium (Ge) detectors in a liquid argon (LAr) cryostat. To achieve ultra-low backgrounds, the LAr is instrumented as an active detector to detect scintillation light emitted upon interactions with ionizing radiation, thus tagging and rejecting backgrounds. The current rejection condition of the LAr anti-coincidence cut uses the LAr detector's light intensity information. In this talk, we will present a test statistic-based approach that exploits the time information of the LAr signals relative to the Ge signals. This new classifier can be used in a multivariate analysis to exploit the full potential of the LAr instrumentation's rejection power.

This research is supported by the BMBF through the Verbundforschung 05A20WO2 and by the DFG through the Excellence Cluster ORIGINS and the SFB1258.

T 86.6 Thu 17:15 Geb. 30.21: Gerthsen-HS

**The LEGEND Experiment DAQ** — •Simon Sailer for the LEGEND-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The LEGEND experiment searches for the neutrino-less double beta decay of the germanium isotope 76Ge which would reveal the Majorana nature of neutrinos and prove lepton number non-conservation. The first stage of experiment (LEGEND-200) is built at the underground facility of LNGS in Italy and is successfully taking data since beginning of 2023.

The DAQ hardware is based on the FlashCam readout system and operating at two sampling frequencies: 250/62.5 MSamples/s with 12/16-bit dynamic range respectively. The individual digitizer boards perform continous fully-digital trigger formation and are interconnected with a hierarchical clock- and trigger distribution system. In addition, the development for a 2nd stage software trigger is finished, enabling real-time reconstruction of the detected photo-electrons from the liquid Argon active veto and >millisecond time-windows on coincidence requirements.

For LEGEND-1000, R&D is ongoing for a possible upgrade of the system using new generations of FPGAs providing higher sampling frequencies with a higher on-board channel density.

T 86.7 Thu 17:30 Geb. 30.21: Gerthsen-HS

**Design of a Drift Tube Spectrometer for AdvSND@LHC** — •Wei-Chieh Lee, Daniel Bick, and Caren Hagner — Institut für Experimentalphysik, Universität Hamburg

The Advanced Scattering and Neutrino Detector at the Large Hadron Collider (AdvSND@LHC) is proposed as a possible upgrade to the existing SND@LHC. In the design of this upgraded detector, stations of trackers are included to measure the charge and momentum of muons emerging from neutrino interactions in the target with a required track resolution better than 100 $\mu$m.

A first design of drift tube trackers has been developed for this purpose at the Universität Hamburg, and prototyping is currently ongoing. In this talk, the foreseen setup will be presented, including the mechanical design as well es the front end electronics. First measurements with a test tube and plans for a larger prototype module will be shown.

T 86.8 Thu 17:45 Geb. 30.21: Gerthsen-HS

**North Area Neutrino Experiment at SPS collider CERN** — Chen Wang, •Dhruv Chouhan, Matthias Schott, and Rainer Wanke — Johannes Gutenberg University, Mainz, Germany

The North Area Neutrino is a new beam-bump experiment proposed to study the neutrino sector of the Standard Model in the energy realm of 10GeV - 60GeV. The main goal of NaNu is a first discovery of anti-tau neutrinos.

# T 87: Neutrino physics 11

Time: Thursday 16:00–18:00 Location: Geb. 30.22: Gaede-HS

T 87.1 Thu 16:00 Geb. 30.22: Gaede-HS

**Search for the leptonic CP violation with the ESSnuSB(+) project** — •Tamer Tolba — Universität Hamburg, Hamburg, Germany

The measurement of the unexpectedly high value of the third neutrino mixing angle, $\theta_{13}$, opened the possibility of measuring the Dirac leptonic CP violating angle, $\delta_{CP}$, using intense neutrino beams. The European Spallation Source neutrino Super Beam (ESS$\nu$SB) is a long-baseline neutrino project that aims in measuring CPV in the leptonic sector at the second, rather than the first, of the $\nu_\mu$ to $\nu_e$ oscillation maximum, where the sensitivity is ~ 3 times higher. The use of the 5 MW proton beam of the ESS linac combined to a ~ cubic-km Water Cherenkov detector located at the second oscillation maximum paves the way to a precise measurement of $\delta_{CP}$. The ESS$\nu$SB CDR showed that after 10 years of data taking, more than 70% of the $\delta_{CP}$ range will be covered with 5$\sigma$ C.L. to reject the no-CP-violation hypothesis. The expected value of $\delta_{CP}$ precision is smaller than 8$^\circ$ for all $\delta_{CP}$ values, making it the most precise proposed experiment by a large margin. The next phase of the project, the ESS$\nu$SB+, which started in 2023, aims in using the intense muon flux produced together with neutrinos to measure the neutrino-nucleus cross-section (the dominant term of the systematic uncertainty) in the energy range of 0.2 to 0.6 GeV, using a LEnuSTORM and a LEMNB facilities.

In this talk, an overview of the concluded phase and an update on the first-year design-study of the current phase of the project will be presented.

T 87.2 Thu 16:15 Geb. 30.22: Gaede-HS

**The Low Energy Excess in ANNIE** — •Daniel Tobias Schmid, Johann Martyn, David Maksimović, Amala Augusthy, Noah Goehlke, Dorina Zundel, and Michael Wurm for the ANNIE-Collaboration — Johannes Gutenberg-Universität Mainz, Germany

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a 26-ton Gadolinium-doped water Čerenkov detector located on the Booster Neutrino Beamline (BNB) at Fermilab. The scientific aim of ANNIE is the study of the cross-section and the neutron multiplicity of GeV neutrinos in the BNB.

The MiniBooNE experiment, a mineral oil Čerenkov detector that was also served by the BNB, previously measured an unexpected excess of $e^\pm$-type events at neutrino energies below 500 MeV. This is referred to as the Low Energy Excess (LEE). An excess solely due to $\nu_e$ interactions is disfavoured by findings of the MicroBooNE experiment within the same beamline. A yet unprobed explanation for the LEE in the BNB is that the excess could be constituted by an abundance of interacting $\bar{\nu}_e$.

The suppressed $\bar{\nu}_e$ interaction cross-section in Argon makes this measurement difficult within MicroBooNE and other LArTPC-based experiments. As a water Čerenkov detector with a high neutron detection efficiency, ANNIE is well-suited to directly measure and constrain the $\bar{\nu}_e$ flux via inverse-beta-decay (IBD) events.

In this talk, we inform about the ongoing efforts in measuring IBD-type events within ANNIE.

This work is supported by the DFG Project 490717455.

T 87.3 Thu 16:30 Geb. 30.22: Gaede-HS

**Characterization and deployment of LAPPDs for ANNIE** — •Noah Goehlke, Amala Augusthy, David Maksimovic, Johann Martyn, Daniel Tobias Schmid, Michael Wurm, and Dorina Zundel for the ANNIE-Collaboration — JGU Mainz, Institute of Physics and EC PRISMA+

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a neutrino detector at the Booster Neutrino Beam at Fermilab. It is designed for a measurement of the neutron multiplicity in neutrino-nucleus interactions, improving the systematics of neutrino detectors. In addition, ANNIE has a strong focus on testing new detector technologies, in specific Water-based liquid scintillators (WbLS) and Large Area Picosecond Photodetectors (LAPPD). WbLS is a novel detector medium, combining the low energy threshold of a scintillator with the good directional resolution of a Cherenkov detector. LAPPDs are micro channel plate-based photon detectors with an active area of 20×20 cm$^2$. Their high spacial (< 1 cm$^2$) and timing (< 60 ps) resolution promise a more precise reconstruction than conventional PMTs. In combination with WbLS, the high timing resolution can be used for a time separation of the Cherenkov and scintillation emission from WbLS. ANNIE aims to upgrade from three to five LAPPDs. In preparation, those LAPPDs have to be tested, characterized and assembled with their electronics in a waterproof housing. This talk presents ANNIE and the LAPPDs, as well as the recent progress towards the use of five LAPPDs. This work is supported by the DFG Project 490717455 and the DFG Graduate School GRK 2796: Particle Detectors.

T 87.4 Thu 16:45 Geb. 30.22: Gaede-HS

**Deployment of water-based liquid scintillator in ANNIE** — •Johann Martyn, Amala Augusthy, Noah Goehlke, David Maksimovic, Daniel Tobias Schmid, Michael Wurm, and Dorina Zundel for the ANNIE-Collaboration — JGU Mainz, Institute of Physics and EC PRISMA+

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a 26-ton water Cherenkov neutrino detector installed on the Booster Neutrino Beam (BNB) at Fermilab. As its main physics goals the experiments aims to perform a measurement of the neutron yield from neutrino-nucleus interactions, as well as a measurement of the charged-current cross section of muon neutrinos. Additionally, ANNIE has an equally important focus on the research and development of new detector technologies and target media. Here water-based liquid scintillator (WbLS) is of special interest, as it allows for the simultaneous detection of scintillation and Cherenkov light of the events. This talk presents the deployment and first data of a 366 L WbLS vessel in ANNIE in March 2023. The successful observation of both scintillation and Cherenkov light in ANNIE corresponds to a proof-of-concept for the hybrid event detection concept in ANNIE. This allows for the future development of reconstruction and particle identification algorithms, as well as dedicated analyses in ANNIE, that make use of both the Cherenkov and scintillation component. This work is supported by the DFG Project 490717455.

T 87.5 Thu 17:00 Geb. 30.22: Gaede-HS

**Status of the KM3NeT experiment and contributions from ECAP** — •Tamas Gal for the ANTARES-KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

The KM3NeT neutrino telescope is continuously growing at two detector sites. The ORCA detector designed to detect neutrinos with energies from a few GeV up to several tens of GeV located off the coast of France and the ARCA detector with a much larger instrumentation volume but the same technology optimised for the detection of high-energetic neutrino events above 100 GeV located off the shore of Sicily. Both detectors are installed in the deep seas of the Mediterranean. ORCA currently consists of more than 10000 photomultiplier tubes and already provides valuable data for roughly 1200 kt-years while ARCA operates with nearly 16000 photomultiplier tubes. Both detectors are continuously extended with additional detection units and presumably double their size by the end of 2024. We will report on the status of the KM3NeT experiments and the contributions from the ECAP team to these scientific endeavours.

T 87.6 Thu 17:15 Geb. 30.22: Gaede-HS

**First measurement of tau appearance with KM3NeT/ORCA** — •Nicole Geisselbrecht for the ANTARES-KM3NET-ERLANGEN-Collaboration — ECAP, FAU Erlangen-Nürnberg

KM3NeT/ORCA is a water Cherenkov detector currently under construction in the Mediterranean Sea, aiming for the determination of the neutrino mass ordering. It is optimised for the study of atmospheric neutrinos.

Upon production, the atmospheric neutrino flux at GeV energies is dominated by electron and muon neutrinos. However, the tau neutrino component of the atmospheric neutrino flux at the Earth is considerably increased due to neutrino oscillations. This phenomenon is also known as tau appearance and can, among other things, be used to probe neutrino oscillations and test the unitarity of the PMNS matrix. This is one of the main goals of the KM3NeT/ORCA detector that can already be addressed during the ongoing construction. A first measurement has been performed with an early sub-array of the final detector configuration. In this talk, the first results and prospects for the future will be presented.

T 87.7 Thu 17:30 Geb. 30.22: Gaede-HS

**Neutrino Generator Comparisons GiBUU/GENIE in KM3NeT** — •Johannes Schumann for the ANTARES-KM3NET-ERLANGEN-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg

KM3NeT/ORCA is currently under construction in the Mediterranean Sea. It has been designed to detect atmospheric neutrinos with energies lower than 100 GeV. For this, a three dimensional grid of photomultiplier tubes (PMTs) detects the Cherenkov radiation emitted by particles that result from neutrino interactions with matter. The assessment of the data recorded by the detector is performed by comparisons to Monte Carlo simulations, which include the state of the art knowledge about all the physical processes involved in the production of the detected signals. The so-called neutrino generators employ different approximations to simulate the distribution of final state particles produced in neutrino interactions. KM3BUU is an implementation of the GIBUU generator for the KM3NeT detector, which is currently under development. In this talk, the status of KM3BUU is presented, as well as a comparison to an implementation of the GENIE generator in KM3NeT.

T 87.8 Thu 17:45 Geb. 30.22: Gaede-HS

**Measuring Cherenkov light in liquid scintillator neutrino detectors using Wavelength-Shifting Optical Modules** — •Florian Rehbein[1], Thomas Hebbeker[1], Heiko Lacker[2], and Michael Wurm[3] — [1]Physics Institute III A, RWTH Aachen University — [2]Humboldt-Universität zu Berlin — [3]Johannes Gutenberg-Universität Mainz

Wavelength-Shifting Optical Modules (WOMs) are photo sensors consisting of a PMMA tube coated with wavelength-shifting paint. The coating absorbs photons and re-emits wavelength-shifted photons, which are guided toward the ends of the tube and are then detected using an array of attached SiPMs. This simple design of a WOM presents a novel optical sensor for various applications, as the size of the module and the type of coating can be adjusted to the specific requirements of the detector. One future application of WOMs will be the Surrounding Background Tagger (SBT) of the proposed SHiP (Search for Hidden Particles) experiment at the CERN facility.

This contribution will present the first study of WOMs in liquid scintillator-based low-energy neutrino detectors. Instrumenting such a detector with two types of WOMs with different wavelength-shifting coatings provides spectral sensitivity for the incident photons. Since the two WOM types are sensitive to different wavelength ranges, one can discriminate long-wavelength Cherenkov from short-wavelength scintillation photons. This hybrid detection technique is especially advantageous to achieve both low-energy threshold (scintillation) and directional reconstruction (Cherenkov) for background reduction.

# T 88: Outreach 2

Time: Thursday 16:00–17:30 Location: Geb. 30.22: Lehmann-HS

T 88.1 Thu 16:00 Geb. 30.22: Lehmann-HS

**Workshop zur Konstruktion eines Myonendetektors** — •Sebastian Laudage, Florian Bernlochner, Maike Hanse und Barbara Valeriani-Kaminski — Universität Bonn

Das Projekt "Cosmic Watch" von Spencer N. Axani beschreibt die Entwicklung eines vergleichbar kostengünstigen, zuverlässigen und mobilen Myonendetektors für experimentelle Zwecke. Der kompakte Detektor ermöglicht eine einfache Handhabung und kann eigenständig die lokale Rate, Energie und Richtung von durchdringenden Myonen messen. Diese Eigenschaften machen ihn zu einem idealen Werkzeug, um Schüler:innen sowie Fachfremden einen Einblick in die faszinierende Welt der Astroteilchenphysik zu gewähren.

An der Universität Bonn haben wir einen Workshop zur Konstruktion des Detektors entwickelt und im Rahmen des Mint-EC Camps Detektorphysik 2023 erfolgreich getestet. Dieser Vortrag präsentiert den Detektor, erläutert den Ablauf des Workshops und teilt die Erfahrungen, die wir während der Durchführung des Projekts gesammelt haben.

T 88.2 Thu 16:15 Geb. 30.22: Lehmann-HS

**Als Schüler:in am CERN forschen - Die Projektwochen von Netzwerk Teilchenwelt** — •Tobias Patrick Treczoks[1,2], Uta Bilow[1], Michael Kobel[1], Niklas Herff[2] und Sascha Schmeling[2] für die Netzwerk Teilchenwelt-Kollaboration — [1]TU Dresden, Institut für Kern- und Teilchenphysik — [2]CERN

Einen direkten Einblick in die aktuelle Forschung am CERN erlangen und dabei zwei Wochen an einem eigenen Projekt arbeiten: Diese einmalige Gelegenheit bieten die Projektwochen von Netzwerk Teilchenwelt jährlich rund zehn Jugendlichen, die ihr besonderes Interesse und Engagement im Rahmen des Stufenprogramms gezeigt haben.

Die Teilnehmenden erleben so bereits zu Schulzeiten hautnah, wie sich aktuelle Forschung im Bereich der Kern- und Teilchenphysik anfühlt. Individuell betreut durch ein Team aus internationalen Forschenden werden die Jugendlichen motiviert, auf ihrem zukünftigen Weg der "Physik der kleinsten Teilchen" treu zu bleiben. Darüber hinaus entsteht ein Kompetenzgewinn durch das Anfertigen einer Forschungsarbeit, die von schulischer Seite mit Unterstützung durch das Netzwerk Teilchenwelt betreut wird. Die jeweiligen Projekte sind dabei so vielfältig wie einzigartig: Von der Produktion von Radioisotopen für die medizinische Forschung über die Analyse von Daten der LHC-Experimente bis hin zu Qualitätstests von neuen Detektorkomponenten wird eine Vielfalt an Themen bearbeitet.

Zusammen mit einem Überblick über das Konzept der Projektwochen stellt dieser Vortrag die Erfahrungen der Teilnehmenden der Projektwochen 2023 in den Vordergrund.

T 88.3 Thu 16:30 Geb. 30.22: Lehmann-HS

**Bilingual Masterclasses for German High School Students** — •Maike Hansen, Barbara Valeriani-Kaminski, Laura Rodriguez Gomez, Sebastian Laudage, and Florian Bernlochner — Uni Bonn

Masterclasses are one-day workshops for (high) school students aiming to make (astro-)particle physics and the applied data analysis methods accessible. Within a masterclass the students become researchers for a day, allowing them for an authentic experience on how fundamental research works. Bilingual masterclasses are offered fully or partially in English language. This represents a great opportunity for students to experience the internationality of research. Furthermore, they acquire language practice in English in the direct communication with the facilitators. The playful introduction of English as a basis for communication between people of different mother tongues creates a common ground and removes potential language barriers for the students. The communication with the facilitators about exciting topics from physics enables them to apply their English skills in a relaxed atmosphere. At the same time, bilingual masterclasses offer international students the opportunity to actively participate in events for pupils and the public, to pass on their enthusiasm for their research and to be a role model for the young students.

Over the past year, we have conducted and evaluated a few masterclasses in English. This presentation will introduce the general concept and the experiences made so far. Also, Benefits and challenges of the bilingual format are going to be discussed

T 88.4 Thu 16:45 Geb. 30.22: Lehmann-HS

**Förderung weiblicher Physik-Talente durch Netzwerk Teilchenwelt** — •Uta Bilow und Michael Kobel für die Netzwerk Teilchenwelt-Kollaboration — Institut für Kern- und Teilchenphysik, Technische Universität Dresden

Netzwerk Teilchenwelt ist ein Zusammenschluss von Wissenschaftler:innen aus 34 Forschungeinrichtungen in Deutschland und dem CERN. Die Programm-angebote leisten bundesweit Breiten- und Spitzenförderung von Jugendlichen. Über ein Stufenprogramm mit direktem Kontakt zur Forschung auf dem Gebiet der Physik der kleinsten Teilchen werden pro Jahr ca. 3500 Jugendliche erreicht. Die Basisstufen werden in der Regel im Klassen- oder Kursverband wahrgenommen, während auf den höheren Stufen individuelle Angebote bestehen. Darauf aufbauend fördert ein sogenanntes Fellow-Programm junge Menschen beim Übergang von der Schule zum Physik-Studium.

Besonders auf den höheren Stufen bei den Jugendlichen und weiter im Fellow-Programm gibt es erstaunlich hohe Frauenanteile: etwa die Hälfte der Teilnehmenden ist weiblich. Dies steht in großem Kontrast zum sonstigen Bild im Physikstudium, wo die Anteile der Absolventinnen nur bei etwas über 20 Prozent liegen. Offenbar sprechen die Angebote im Netzwerk Teilchenwelt in besonderem Ausmaß Mädchen und junge Frauen an und tragen dazu bei, den Weg ins und durch das Physikstudium zu ebnen. Der Vortrag zeichnet diese Wege nach, benennt ausschlaggebende Faktoren und stellt junge Frauen vor, die an Angeboten von Netzwerk Teilchenwelt teilnahmen und nun erfolgreich Physik studieren oder im MINT-Bereich arbeiten.

T 88.5 Thu 17:00 Geb. 30.22: Lehmann-HS

**Science Camp Teilchen- und Astroteilchenphysik: Konzept und Erfahrungen** — Michael Gauss, •Michelle Gensmann, Artur Monsch, Carolin Quast, Günter Quast und Linus Schlee für die Netzwerk Teilchenwelt-Kollaboration — Karlsruher Institut für Technologie

Science Camps sind Angebote der außerschulischen Jugendbildung. Zielgruppe für das Science Camp Astro- und Teilchenphysik waren interessierte Schülerinnen und Schüler ab 16 Jahren. Vorgestellt wird das Konzept als zielgerechte Maßnahme zur Nachwuchsgewinnung, das Wissenschaft, forschendes Lernen und soziale Eingebundenheit in der Gruppe vereint. Beim im Jahr 2023 erstmals am KIT angebotenen Camp erhielten 16 Jugendliche die Möglichkeit, neben einführenden Vorträgen und Führungen durch Forschungseinrichtungen auch an Masterclasses des Netzwerks Teilchenwelt zu den lokalen Experimenten mit KIT-Beteiligung (Belle II und CMS) sowie zum Thema Astroteilchenphysik teilzunehmen. Weiterhin bearbeiteten die Teilnehmenden in Kleingruppen im Laufe der Woche ein mehrtägiges Projekt ihrer Wahl mit Nebelkammern, Myon-Detektoren, Halbleitersensoren oder zur Auswertung von CERN openData. Über ihre Ergebnisse berichteten die Jugendlichen dann in einer Abschlussveranstaltung in einem Vortrag im Hörsaal, zu dem auch Eltern und Freunde eingeladen waren.

T 88.6 Thu 17:15 Geb. 30.22: Lehmann-HS

**Dortmund Celebration of Charm: celebrating 50 years of experimental charm physics** — Johannes Albrecht, •James Andrew Gooding, Dominik Mitzel, Donata Osthues, and Luca Toscano — TU Dortmund University, Dortmund, Germany

In 2024 the particle physics community celebrates 50 years of experimental charm physics, culminating in the 50th anniversary of the $J/\psi$ meson discovery. At TU Dortmund, this takes the form of the Dortmund Celebration of Charm, a year-long outreach programme celebrating the rich history of charm physics and the charm research taking place in Dortmund within the LHCb experiment. This programme consists of two components: a wider social media campaign throughout the year to highlight key moments in charm over the last 50 years, and local in-person events. Both components aim to reach a broad range of audiences including university students, school children and the general public.

This contribution discusses the ongoing and upcoming charm outreach activities at TU Dortmund. Additionally, this contribution serves as a forum to discuss best practices for such activities with the German particle physics community.

## T 89: Gamma astronomy 4

Time: Thursday 16:00–18:00 Location: Geb. 30.22: kl. HS A

T 89.1 Thu 16:00 Geb. 30.22: kl. HS A

**Group report: the future has more MAGIC! Highlights and prospects from the MAGIC Collaboration** — •Giovanni Ceribella for the MAGIC-Collaboration — Max-Planck-Institut für Physik, Blotzmannstr. 8, 85748 Garching

Even more than twenty years after its first light, MAGIC keeps delivering cutting-edge science in the multifaceted field of very-high-energy gamma-ray astronomy (VHE). Located at the observatory of the Roque de Los Muchachos, at 2200m above sea level on the Canary island of La Palma (Spain), the two 17m-diameter imaging atmospheric Cherenkov telescopes have decisively contributed to the development of VHE astrophysics in the last two decades. While future perspectives are focusing more and more on the next generation telescopes of CTAO, the MAGIC telescopes still have compelling science cases, that motivated its participating institutions to extend the collaboration for five additional years (2029). In the talk I will review recent scientific highlights from MAGIC in galactic, extragalactic, and fundamental physics, present its novel technical developments, and discuss its future.

T 89.2 Thu 16:15 Geb. 30.22: kl. HS A

**Status of the CTA Large-Sized Telescopes** — •Martin Will for the CTA-Collaboration — Max-Planck-Institut für Physik

The Cherenkov Telescope Array (CTA) is the next-generation observatory for ground-based gamma-ray astronomy at very high energies. CTA will consist of two arrays, one in the northern hemisphere at the Roque de Los Muchachos Observatory on La Palma (Canary Islands, Spain) and one in the southern hemisphere at the Paranal Observatory in the Atacama Desert (Chile).

The Large-Sized Telescope (LST) is one of the three types of telescope in CTA. With a reflective surface diameter of 23 meter, LSTs are optimized to detect low-energy gamma rays in the range 20 GeV to 3 TeV. LST-1 in La Palma is close to finishing its commissioning phase, while construction has begun on the next three LSTs.

In this presentation, the status of the LSTs in the North and plans for the LSTs in the South will be shown.

T 89.3 Thu 16:30 Geb. 30.22: kl. HS A

**LST Condition Monitor** — •Felix Pfeifle, Karl Mannheim, and Marcel Vorbrugg for the CTA-Collaboration — Lehrstuhl für Astronomie, Universität Würzburg

The Large-Sized Telescope (LST) with a mirror diameter of 23 m is the largest of the telescope designs for the Cherenkov Telescope Array (CTA). While LST-1 is finishing commissioning, LST 2-4 are currently under construction for a timely completion of the full LST subarray in the Roque de los Muchachos Observatory (ORM) in La Palma.

The LSTs will be exposed to rapid pointing maneuvers during follow-up observations of gamma-ray bursts and gravitational wave events. The piezo-electrical acceleration sensors have been mounted on LST1 bogies, delivering data on mechanical accelerations used as a diagnostic tool to predict the bogies' health and safety. We analyzed data from the sensors searching for eigenfrequencies to set thresholds alerting in case of pathological responses. We outline the plan to implement a condition monitor system for the predictive maintenance of the LSTs and present preliminary results of our analyses.

T 89.4 Thu 16:45 Geb. 30.22: kl. HS A

**Asimov Datasets for Gamma-ray Astronomy** — •Stefan Fröse and Jan Lukas Schubert — TU Dortmund University, Dortmund, Germany

The hunt for dark matter is a very long-existing and still ongoing quest since the first evidence of its existence was uncovered by Fritz Zwicky and later by Vera Rubin investigating the rotation curves of galaxies. Today one of the most promising candidates for dark matter are weakly interacting massive particles (WIMPs). These particles can be detected indirectly by searching for their annihilation and decay products. Among other things, these products can cre- ate high-energy gamma rays detectable by Imaging Atmospheric Cherenkove Telescopes like MAGIC or CTA.

For the exclusion of different WIMP masses and annihilation or decay channels, the sensitivity of the telescopes has to be known to sufficient precision. New methods for the calculation of upper limits based on the concept of the Asimov dataset[1], as already used by other high-energy experiments, are introduced and implemented in a new Python package called TITRATE. This package works as an extension to the already existing open-source analysis tool gammapy[2] and therefore will support any science products based on the Gamma Astro Data Formats (GADF)[3].

[1] https://doi.org/10.48550/arXiv.1007.1727
[2] https://doi.org/10.48550/arXiv.1709.01751
[3] https://doi.org/10.3390/universe7100374

T 89.5 Thu 17:00 Geb. 30.22: kl. HS A

**Cherenkov Telescope Array SST Camera Status Update** — •Frederik Wohlleben for the CTA-Collaboration — Max-Planck- Institut für Kernphysik, P.O. Box 103980, D 69029 Heidelberg, Germany

The Cherenkov Telescope Array (CTA) is a next generation instrument for gamma ray astronomy. Within CTA initially an alpha configuration of 42 small sized telescopes (SST) will cover the highest energy range of 5 to 300 TeV. The design of the SST camera is currently being finalized and its performance verified in lab tests. This talk will give a comprehensive overview over the current status and the most recent developments.

T 89.6 Thu 17:15 Geb. 30.22: kl. HS A

**Finding the optimal trigger strategy for the SWGO** — •Johannes Bennemann for the SWGO-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The Southern Wide-field Gamma-ray Observatory (SWGO) will be the first water-Cherenkov gamma-ray instrument in the Southern Hemisphere. It will consist of over 6000 water-Cherenkov detector units at an altitude of at least 4.4 km. An instrument of this size will be subject to constant bombardment with cosmic rays and thus produce a huge amount of data. This makes a sophisticated trigger strategy necessary to achieve the highest possible sensitivity whilst reducing the readout bandwidth. This talk will cover the simulation and optimization of trigger strategies for the SWGO.

T 89.7 Thu 17:30 Geb. 30.22: kl. HS A

**Updates on the Lake Design for SWGO** — •Hazal Goksu — Saupfercheckweg 1, 69117 Heidelberg

The lake concept is one of the detector design options considered for the Southern Wide-field Gamma-ray Observatory (SWGO), a next-generation high altitude gamma-ray observatory in the southern hemisphere that is made of an array of water Cherenkov detectors. SWGO, with its wide energy range, broad field of view, and large duty cycle, positioned in the southern hemisphere, will complement other planned and existing gamma-ray observatories. In the lake design, light-tight bladders, each housing one or more photosensors, filled with clean water, are deployed near the surface of a natural or artificial lake. Prototyping and testing for over two years have led to the first dual-layer prototype detector for SWGO that is currently in operation. In this contribution, we will give an update on the prototyping studies and simulations for the lake design option.

T 89.8 Thu 17:45 Geb. 30.22: kl. HS A

**The Compton Spectrometer and Imager (COSI)** — •Savitri Gallego — Johannes Gutenberg-Universität, Mainz,Germany

The Compton Spectrometer and Imager (COSI) is a gamma-ray telescope, selected by NASA as a Small Explorer satellite mission to be launched in 2027. COSI employs a novel Compton telescope, consisting of a compact array of cross-strip germanium detectors. Owing to its wide field-of-view and excellent energy resolution, COSI will achieve an unprecedented sensitivity in the 0.2-5 MeV energy band. In particular, it will improve narrow-line sensitivity by about one order of magnitude over existing searches, mapping the full sky uniformly with an energy-dependent angular resolution on the degree scale. The mission requirements enable four key science goals: the origin of Galactic positrons, nucleosynthesis in the Galaxy, polarization studies of accreting black holes, and multi-messenger astrophysics. In this talk, I will provide an overview of the instrumental design and science of COSI. I will present the current status of the project and the publicly-available data challenges released every year.

# T 90: Silicon trackers 4

Time: Thursday 16:00–18:00 Location: Geb. 30.22: kl. HS B

T 90.1 Thu 16:00 Geb. 30.22: kl. HS B

**Test beam characterization of the H2M chip designed in a 65 nm CMOS imaging process** — •Sara Ruiz Daza[1,3], Rafael Ballabriga[2], Eric Buschmann[2], Michael Campbell[2], Raimon Casanova Mohr[2], Dominik Dannheim[2], Ana Dorda[2], Finn Feindt[1], Philipp Gadow[2], Ingrid-Maria Gregor[1,3], Karsten Hansen[2], Lennart Huth[1], Iraklis Kremastiotis[2], Stefano Maffessanti[1], Younes Otarid[2], Christian Reckleben[1], Judith Schlaadt[1], Simon Spannagel[1], Tomas Vanat[1], Gianpiero Vignola[1,3], and Håkan Wennlöf[1] — [1]DESY, Hamburg, Germany — [2]CERN, Geneva, Switzerland — [3]University of Bonn, Bonn, Germany

The Tangerine project is studying monolithic active pixel sensors (MAPS) that are manufactured using a 65 nm CMOS imaging process. To investigate this technology and explore the design challenges of porting a hybrid pixel de- tector architecture into a monolithic chip, the H2M (Hybrid-to-Monolithic) test chip has been developed. The chip matrix consists of 64x16 square pixels with a size of 35x35 $\mu$m2. The sensor is designed in the so-called n-gap layout to enhance fast charge collection. The H2M chip can operate in four different acquisition modes: ToT, ToA, Photon Counting, and Triggered mode. The characterization of these modes provides a fundamental understanding of the analog/digital front-end designs. This contribution presents the validation and characterization of all four readout modes in the laboratory. It also presents first results on detection efficiency, spatial resolution, and time resolution obtained in test beam campaigns.

T 90.2 Thu 16:15 Geb. 30.22: kl. HS B

**Laboratory Characterization of an H2M Monolithic Pixel Detector Prototype** — Rafael Ballabriga[3], Eric Buschmann[3], Michael Campbell[3], Raimon Casanova Mohr[3], Dominik Dannheim[3], Ana Dorda[3], Finn Feindt[2], Philipp Gadow[3], Ingrid-Maria Gregor[2], Karsten Hansen[2], Lennart Huth[2], Iraklis Kremastiotis[3], Stefano Maffessanti[3], Lucia Masetti[1], Younes Otarid[3], Christian Reckleben[2], Sara Ruiz Daza[2], •Judith Schlaadt[1,2], Simon Spannagel[2], Tomas Vanat[2], Gianpiero Vignola[2], and Haakan Wennloef[2] — [1]JGU, Mainz, Germany — [2]DESY, Hamburg, Germany — [3]CERN, Meyrin, Schweiz

In the context of developing monolithic active pixel sensors (MAPS), the H2M (hybrid-to-monolithic) project represents the joint effort of CERN, DESY and IFAE to design and test a monolithic chip with an integrated hybrid pixel detector architecture. This pixel sensor was designed and fabricated in a 65nm CMOS imaging process and consists of 64 x 16 square pixels with a 35um pitch. It makes use of the so-called n-gap layout which improves the charge collection from pixel edges and corners. The laboratory characterization of the first prototypes started in August 2023 with a particular focus on the trimming DAC as it allows for threshold adjustment for each individual pixel with a 4-bit resolution. On this basis, a procedure was implemented to determine the optimal setting for each pixel and eventually minimize the threshold dispersion for the whole matrix. This contribution presents preliminary results of the described measurements.

T 90.3 Thu 16:30 Geb. 30.22: kl. HS B

**Charge Collection Studies for HV-MAPS** — •Ruben Kolb for the HD-HVMAPS-Collaboration — Physikalisches Institut Universität Heidelberg

High-Voltage Monolithic Active Pixel Sensor (HV-MAPS) technology, developed for high-rate applications, unites precise spatial and time resolution. It combines active detector volume and readout on one chip. The TelePix1 is an HV-MAPS test chip that realizes amplifier and comparator as in-pixel electronics.

The charge deposition and charge collection process in this sensor is investigated to inform further designs of HV-MAPS. In particular, this talk focuses on disentangling the contribution of drift and diffusion to the signal. To achieve this goal, the Time-over-Threshold (ToT) and cluster size of sensors with varying thicknesses are studied, exploring their dependence on the applied high voltage. Pixel-to-pixel variations necessitate a calibration of the sensors before comparison. The calibrated signal was studied for a 4 GeV electron beam and electrons from a $^{90}$Sr source. For both sources, a significant contribution of diffusion to the signal size is observed, especially in the low signal region.

T 90.4 Thu 16:45 Geb. 30.22: kl. HS B

**Temperature dependence study of data link stability of MuPix11** — •Florian Schlötzer for the HD-HVMAPS-Collaboration — Physikalisches Institut Universität Heidelberg, Germany

For the Mu3e experiment the need for detectors with the ability to handle a high rate of muon decays is crucial. High-Voltage Monolithic Active Pixel Sensor (HV-MAPS) achieves an accurate time and spatial resolution combined with a high readout capability, fitting this requirement. It combines sensor and readout-electronics in one ultra-thin chip. The MuPix11 is a fully developed HV-MAPS chip used for the construction of the tracking detector for the Mu3e experiment.

In the Mu3e experiment the sensors will be operated in a large temperature range, which will influence their performance. This talk focuses on the data integrity and the stability of data links for a temperature range from -20°C to 80°C. The signal quality is studied with the help of eye diagrams and the adjustable parameter space of the data transmitter is checked for stable ranges. A linear decrease of the signal amplitude is observed with increasing temperature, yet a stable operation without transmission errors can be achieved in all cases.

T 90.5 Thu 17:00 Geb. 30.22: kl. HS B

**In-pixel charge collection study with an epitaxial MALTA2 sensor, a depleted monolithic active pixel sensor** — •Lucian Raphael Fasselt — Deutsches Elektronen Synchrotron (DESY), Zeuthen, Germany — Humboldt Universität zu Berlin, Berlin, Germany

MALTA2 is a depleted monolithic active pixel sensor (DMAPS) designed for radiation-hard future tracking application and is produced in the modified Tower Semiconductor 180 nm CMOS technology. The sensing layer of the $36.4 \times 36.4\ \mu m^2$ pixels consists of either high resistivity epitaxial or Czochralski silicon. The small collection electrode features a small pixel capacitance and offers low noise. A MALTA beam telescope consisting of multiple sensor planes is used to track minimum ionizing particles with 4.1 $\mu m$ spatial and 2.1 ns timing resolution.

In this contribution an epitaxial sensor is characterised with in-pixel resolution in terms of hit detection efficiency and cluster size at fine threshold steps. Data was taken at the CERN SPS test beam campaign in 2023. A reconstruction of the signal amplitude from binary hit data is performed. From there, a two dimensional map of the collected charge is obtained and quantifies the effect of charge sharing at the pixel boundaries. The presented method provides an in-beam alternative to grazing angle studies or Edge-TCT for also determining the depletion depth.

T 90.6 Thu 17:15 Geb. 30.22: kl. HS B

**Irradiation studies of HV-CMOS MAPS for the LHCb Mighty Tracker** — •Hannah Schmitz, Klaas Padeken, Niclas Sommerfeld, and Sebastian Neubert — University of Bonn

The upgraded LHCb downstream tracker (Mighty Tracker), foreseen to be installed during LS4 of the LHC, will consist of six layers HV-CMOS MAPS with a total size of $18\text{m}^2$ covering the central part of the acceptance close to the beampipe. For the pixel (MightyPix) a commercial 180nm process and a chip size of 2cm × 2cm with a pixel size of $55\mu$m × $165\mu$m is foreseen. Characterization of a first version and other engineering prototypes are ongoing. HV-CMOS MAPS are optimal sensors to fulfill the requirements that encounter the Mighty Tracker. Due to the increased instantaneous luminosity from $2 \times 10^{33}\text{cm}^{-2}\text{s}^{-1}$ to $1.5 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$ the downstream tracker has to withstand an irradiation of $3{\times}10^{14}\text{MeVn}_{\text{eq}}\text{cm}^{-2}$ and a high occupancy. Additionally, a time resolution ≤ 3ns is required to operate the trigger-less 40MHz DAQ implying up to 5Gbit output rate per chip. Furthermore, a low power consumption of ≤ 150mW and a low material budget is needed. Fulfilling these requirements is necessary to ensure a precise tracking. In this presentation irradiation studies of HV-CMOS MAPS are presented. An irradiation campaign with a 14MeV proton beam at the Bonn cyclotron was performed. The operation and further analysis of the sensor was done with the newly developed readout system MARS.

T 90.7 Thu 17:30 Geb. 30.22: kl. HS B

**Exploring Thermal Neutron Detection Capabilities with HV-MAPS** — •Damini Suresh Babu for the HD-HVMAPS-Collaboration — Physikalisches Institut Universität Heidelberg

$^{10}$B coated silicon sensors allow to construct incredibly compact thermal neutron detectors, as per the following neutron capture reaction, $^{10}B{+}n \rightarrow {}^{4}He{+}^{7}Li$. For the first time the usage of High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) is studied for this purpose. HV-MAPS offer the combination of readout and detection on a common silicon die and are produced in a commercially available 180 nm HV-CMOS process. Preliminary research is underway with the MuPix11 chip with an active size of 20 × 20 mm.

Feasibility tests include a study of the sensor response to large energy depositions with the help of $\alpha$ particles. The $\alpha$ and $\gamma$ particles are also discriminated based on the observable cluster size and measured deposited charge. In this talk, the first results obtained with an $^{241}$Am source are presented.

T 90.8 Thu 17:45 Geb. 30.22: kl. HS B

**The role of the overhang structure at the guard rings before and after X-ray irradiation** — •Sinuo Zhang, Tomasz Hemperek, and Jochen Dingfelder — Physikalisches Institut,Universität Bonn, Bonn, Deutschland

In high energy physics, the silicon pixel sensors manufactured in commercial CMOS chip fabrication lines have been proven to have a good radiation hardness and spatial resolution. Along with the mature manufacturing techniques and the potential of large throughput provided by the foundries, the so-called "passive CMOS" sensor has become an interesting alternative to standard planar sensors, in particular for large-area applications.

The overhang structure consists of polysilicon and metal layers, which are implemented on the guard rings. As a part of the guard-ring design, it plays an important role in shaping the potential and the electric field distribution at the surface of the silicon sensor, and influences the IV characteristics and the breakdown performance. In this presentation, the effect of the overhang structure will be discussed based on the measurements of the test structures and the corresponding TCAD simulations, for irradiated and unirradiated cases.

# T 91: Standard model 3 (strong/QCD)

Time: Thursday 16:00–18:00 Location: Geb. 30.23: 2/0

T 91.1 Thu 16:00 Geb. 30.23: 2/0

**Recent updates in the Sherpa event generator** — •Mareen Hoppe[1], Stefan Höche[2], Marek Schönherr[3], and Frank Siegert[1] — [1]Institute of Nuclear and Particle Physics, TUD Dresden University of Technology, Germany — [2]Fermi National Accelerator Laboratory, Batavia, USA — [3]Institute for Particle Physics Phenomenology, Durham University, UK

Sherpa is a general-purpose Monte-Carlo event-generator for particle collisions in high-energy collider experiments. It is able to provide complete hadronic final states for various processes with hard scattering process calculation up to NLO QCD and approximate NLO EW. During this talk, some recent updates in the Sherpa matrix element generation are presented including progress in the simulation of polarized cross sections of intermediate particle states at higher orders.

T 91.2 Thu 16:15 Geb. 30.23: 2/0

**Workflow and performance optimization for fast NNLO pQCD Calculations** — •Johannes Gäßler — Karlsruhe Institute of Technology, Germany

fastNLO is a library that allows for fast NNLO pQCD calculations by interpolating parton distribution functions. This makes it possible to reuse the results of an expensive Monte Carlo integration for arbitrary a posteriori choices of the PDFs, the strong coupling constant, and the energy scales. A new procedure for determining momentum fraction nodes for the interpolation has been implemented. New nodes are added dynamically as needed. This obsoletes one of the steps in the previous workflow in which the interpolation nodes were first determined in a so-called ”warmup” run.

T 91.3 Thu 16:30 Geb. 30.23: 2/0

**Fast simulations with NNLO QCD accuracy - new developments in the APPLfast project** — •Lucas Kunz — Karlsruhe Institute of Technology, Karlsruhe, Germany

The calculation of theoretical predictions for hadron colliders at higher orders in perturbation theory involves computing time expensive iterative procedures. The same is true for the extraction of parton distribution functions (PDFs) from measured data. Hence, to produce results in reasonable time, a very efficient and flexible setup is needed. The APPLfast project fulfills these requirements by linking the parton-level Monte Carlo program NNLOJET with both the APPLgrid and fastNLO grid libraries, thereby allowing for an a posteriori choice of a set of PDFs or value of the strong coupling constant. This talk will give an overview of the project, focusing on an explanation of the general logic and on possible applications rather than technical details. It will further present some results for NNLO dijet production at the LHC, both at leading and full color, as well as corresponding new determinations of the strong coupling.

T 91.4 Thu 16:45 Geb. 30.23: 2/0

**Deep Inelastic Scattering events for photon and heavy boson TMDs in the Parton Branching Method** — •Keila Moral Figueroa — Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg

Deep Inelastic Scattering (DIS) events at HERA are the most precise DIS measurement to date, which constitutes an important tool to study transverse momentum dependent (TMD) parton distribution functions. In this study, we introduce standard DIS Monte Carlo events recreating HERA conditions, and apply their cross section as a constraint for both photon and heavy boson TMDs in the Parton Branching Method.

T 91.5 Thu 17:00 Geb. 30.23: 2/0

**Two-loop matching of the chromo-magnetic dipole operator with the gradient flow** — •Janosch Borgulat[1], Robert Harlander[1], Matthew D. Rizik[2], and Andrea Shindler[1,3,4] — [1]TTK, RWTH Aachen University, 52056 Aachen, Germany — [2]Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA — [3]NSD, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA — [4]Department of Physics, University of California, Berkeley, CA 94720, USA

The baryon asymmetry of the universe requires sources of CP-violation beyond those predicted by the standard model. On the other hand, experimental constraints on the neutron electric dipole moment leave a large window for CP-violating contributions beyond the standard model. Such contributions can be described by CP-violating effective interactions at hadronic energies in QCD. Because of confinement, these contributions cannot be computed perturbatively. However, they are accessible to lattice simulations. These, on the other hand, suffer from power divergences in the inverse lattice spacing.

A useful tool to circumvent these inconveniences is the gradient flow which acts on the fields similar to the heat equation, smoothing them along an auxiliary fifth dimension, the flow time. This removes all ultraviolet divergences and leads to well-behaved flowed operators on the lattice. The mixing matrix translating between regular and flowed operators is accessible to perturbative calculations. In our work, we compute the renormalized mixing matrix for the chromomagnetic dipole operator through next-to-next-to-leading order.

T 91.6 Thu 17:15 Geb. 30.23: 2/0

**Diagrammatic resummation of QCD double logarithms in $B_c \to \eta_c$ form factors** — Guido Bell[1], Philipp Böer[2], Thorsten Feldmann[1], •Dennis Horstmann[1], and Vladyslav Shtabovenko[1] — [1]Theoretische Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]PRISMA+ Cluser of Excellence & Mainz Institute for Theoretical Physics, JGU Mainz

Soft-Collinear Effective Theory is an important tool used for setting up factorisation theorems and achieving resummations for collider and flavour observables. While most conceptual problems appearing in calculations at leading power have been understood, at subleading power endpoint divergent convolution integrals appear in the factorisation theorems preventing the use of renormalization group equations for resummations. While this problem has recently been solved for several collider observables, it persists in exclusive $B$-decays. We therefore resort to diagrammatic resummation techniques to derive the double-logarithmic series of the "soft-overlap" contribution to $B_c \to \eta_c$ transition form factors at large hadronic recoil, assuming the scale hierarchy $m_b \gg m_c \gg \Lambda_{\rm QCD}$. In this case, the relevant hadronic matrix elements can be computed perturbatively. We find that the leading double logarithms arise from a peculiar interplay of soft-quark "endpoint logarithms" from ladder diagrams with energy-ordered spectator-quark propagators, as well as standard Sudakov-type soft-gluon corrections. We elucidate the all-order systematics, and show that their resummation proceeds via a novel type of integral equations.

T 91.7 Thu 17:30 Geb. 30.23: 2/0

**Three-loop heavy-to-light form factors in QCD** — Robin Brüser[2], Tobias Huber[1], •Jakob Müller[1], and Maximilian Stahlhofen[2] — [1]Theoretische Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]University of Freiburg

Precision calculations require the evaluation of higher orders in the perturbative expansion of quantum field theory. In this talk, we discuss the computation of form factors for decays of heavy into light quarks at third order in QCD for various currents. We describe the generation and simplification of the corresponding Feynman diagrams and the integration-by-parts reduction to a finite basis of master integrals. Further, we report on the status of the calculation of the master integrals and give an outlook on the phenomenological applications of the results.

T 91.8 Thu 17:45 Geb. 30.23: 2/0

**Short-flow-time expansion of quark bilinears through next-to-next-to-leading order QCD** — Janosch Borgulat[1], Robert Harlander[1], •Jonas Kohnen[1], and Fabian Lange[2,3,4,5] — [1]TTK, RWTH Aachen University, 52056 Aachen, Germany — [2]Physik-Institut, Universität Zürich, Winterthurerstrasse 190, 8057 Zürich, Switzerland — [3]Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [4]Institut für Theoretische Teilchenphysik, Karlsruhe Institute of Technology (KIT), Wolfgang-Gaede-Straße 1, 76128 Karlsruhe, Germany — [5]Institut für Astroteilchenphysik, Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

The gradient-flow formalism has proven to be a valuable tool for calculations in lattice gauge theory. It extends the fields of QCD by the flow time $t$. Matrix elements of flowed composite operators do not mix under renormalization and can be calculated efficiently on the lattice. In order to match the flowed operators to regular QCD, one can perform an operator-product expansion at short flow times. The coefficients of this short-flow-time expansion can be calculated perturbatively. The topic of this talk is the calculation of the coefficients of the short-flow-time expansion for the scalar, pseudoscalar, vector, axialvector and tensor currents at next-to-next-to leading order.

# T 92: Detectors 8 (semiconductors)

Time: Thursday 16:00–17:45 Location: Geb. 30.23: 2/1

T 92.1 Thu 16:00 Geb. 30.23: 2/1

**A double arm spectrometer for the measurement of energy loss in silicon sensors** — •Laura Bees, Tamasi Kar, and André Schöning — Physikalisches Institut, Ruprecht Karl University, Heidelberg

The aim of the double arm spectrometer is to precisely measure the energy loss of low energy electrons < 50MeV in silicon sensors with a resolution of ≪ 1%. It is designed such that a charged particle is deflected in two 180° turns in strong magnetic fields with opposite polarity. The detector arms, which each comprise two thin (monolithic) pixel layers, detect the particle's position and direction before entering and after leaving the magnetic field. Located between the two spectrometer arms is the position sensitive device under test (DUT). The energy loss in the DUT can be deduced from the particle's momentum difference measured between the first and second arm. In the talk, results obtained from a Geant4 simulation are presented. Of particular interest is the maximum achievable energy loss resolution and the study of systematic uncertainties from magnetic stray fields and misalignment.

The double arm spectrometer will serve as a high precision instrument to calibrate the energy loss in tracking detectors and for measuring the energy resolution in $\frac{dE}{dx}$ measurements. It can also be used for studying the energy resolution of converted photons in the Mu3e-Gamma experiment, which has been proposed to search for the lepton flavor violating decay $\mu^+ \to e^+ + \gamma(e^+e^-)$ and employs an active silicon converter.

T 92.2 Thu 16:15 Geb. 30.23: 2/1

**Non-linear Response of Silicon Photomultipliers** — •Lukas Brinkmann — University of Hamburg, 22761, Luruper Chaussee 149, Hamburg, Germany

In this talk, a method and novel setup are presented that study the non-linear response of SiPMs under different conditions.

The response function of the SiPM to increasing light intensity was measured. From this response function both the on-set of non-linearity can be determined as well as a correction that expands the dynamic range. An essential part of the correction is that it only depends on the measured SiPM response and does not require a linear light source.

The response function shows no dependence on operating voltage and minor dependence on the temporal distribution of light. For the given Hamamatsu SiPM investigated (S14160-1315PS, pixel pitch 15 $\mu$m, number of pixels 7296), the on-set of linearity was found to be at 15% of the total number of pixels fired, highlighting the limited dynamic range. With the correction function deviation from linearity by 5% occurs once the measured charge is equal to approximately 80% of the total number of pixels having fired.

The method and setup can be used to reliably measure the response function of the studied SiPM and increase the dynamic range by a factor of five.

T 92.3 Thu 16:30 Geb. 30.23: 2/1

**Ultrafast timestamping of charged particles using a digital SiPM** — •Stephan Lachnit[1,2], Inge Diehl[1], Finn Feindt[1], Erika Garutti[2], Karsten Hansen[1], Frauke Poblotzki[1], Daniil Rastorguev[1,3], Simon Spannagel[1], Tomas Vanat[1], and Gianpiero Vignola[1,4] — [1]DESY, Hamburg, Germany — [2]Universität Hamburg, Germany — [3]Bergische Universität Wuppertal, Germany — [4]Universität Bonn, Germany

Silicon Photo-Multipliers (SiPMs) have emerged as crucial semiconductor detectors in the realm of single-photon detection and timing. Traditionally analog devices, SiPMs are now evolving with the integration of digital readout techniques akin to monolithic active pixel sensors. This brings forth new possibilities such as full hitmap readout, pixel masking, and on-chip timestamping. In the context of High Energy Physics, the ultrafast $\mathcal{O}(10\,\mathrm{ps})$ timestamping capabilities of digital SiPMs position them as compelling contenders for 4D tracking applications. However, this requires evaluating the performance of SiPMs in charge particle detection.

At DESY, a digital SiPM has been developed using LFoundry's 150 nm CMOS process. In this contribution, the analysis of data from a testbeam at DESY-II using 4 GeV electrons is shown. A time resolution of $(46 \pm 5)$ ps for the direct detection of electrons at the center of the Single-Photon Avalanche Diode (SPAD) cells has been measured. Variations in response times were observed at the periphery of the SPAD cells.

T 92.4 Thu 16:45 Geb. 30.23: 2/1

**Characterisation and Performance of a Digital SiPM in an 150 nm CMOS Imaging Technology** — •Gianpiero Vignola[1,2], Inge Diehl[1], Karsten Hansen[1], Tomas Vanat[1], Finn Feindt[1], Daniil Rastorguev[1,3], Simon Spannagel[1], and Stephan Lachnit[1,4] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg — [2]University of Bonn, Germany — [3]University of Wuppertal, Germany — [4]University of Hamburg, Germany

Silicon Photomultipliers are arrays of Single Photon Avalanche Diodes (SPADs) and represent the most widely used technology in the field of solid state single photon detection nowadays. They are extensively employed in high-energy physics, medical and various commercial applications. Commercial CMOS processes have recently implemented SPADs in process design kits, allowing a low-cost implementation of monolithic SiPMs with customised electronics. Digital SiPMs allow for reduced readout system complexity, because digitization and processing are done on chip. Furthermore, it is possible to implement new features such as single pixel masking and full hit map readout. These features make dSiPMs an attractive technology for applications like optical fibre readout, calorimetry and 4D-tracking of charged particles.

A prototype digital SiPM was developed by DESY using LFoundry 150 nm CMOS imaging technology. In this contribution, the design and functionality of the dSiPM will be presented together with the results of the characterisations performed. Particular attention will be paid to spatial and temporal resolution in MIP detection.

T 92.5 Thu 17:00 Geb. 30.23: 2/1

**Active Transverse Energy Filter Development for KATRIN** — •Kevin Gauda, Sonja Schneidewind, Kyrill Blümer, Christian Gönner, Volker Hannen, Hans-Werner Ortjohann, Sebastian Wein, and Christian Weinheimer for the KATRIN-Collaboration — University of Münster, Institute of Nuclear Physics

The KATRIN experiment aims to measure the neutrino mass via tritium $\beta$-decay spectroscopy. An upper limit of 0.8 eV/c$^2$ (90% C.L.) was published in 2022 (Nat. Phys. 18, 160-166 (2022)). Despite implementation of efficient countermeasures, we still observe an elevated experimental background (150 mcps instead of 10 mcps), which needs to be reduced to reach the targeted sensitivity of 0.2 eV/c$^2$. Radioactive decays in the stainless steel vessel of the main spectrometer produce highly-excited Rydberg or autoionizing atomic states in the volume. These release low-energetic electrons, which are energetically indistinguishable from $\beta$-electrons at the detector. Their angular distribution, however, is significantly sharper. The "active Transverse Energy Filter" (aTEF) concept was invented to reduce this background by discrimination of electrons in a large magnetic field based on their pitch angle (EPJ-C 82, 922 (2022)).

This talk will introduce the "Si-aTEF" as a concept based on Si-PIN diodes. The fabrication process, prototype performance, and measures against leakage current from surface damage will be presented. The implementation of the Si-aTEF in KATRIN – success supposed – and the expected sensitivity improvement will be shown. This work is supported by BMBF under contract number 05A23PMA.

T 92.6 Thu 17:15 Geb. 30.23: 2/1

**Determination of the impurity density profile of a large-volume germanium detector** — •Felix Hagemann[1], Iris Abt[1], Arthur Butorev[2], David Hervas Aguilar[1], Johanna Lührs[1], Julia Penner[1], and Oliver Schulz[1] — [1]Max-Planck-Institut für Physik, Garching — [2]Technische Universität München

Over the past four years, a novel experimental setup has been built, commissioned and operated at the Max-Planck-Institute for Physics in Munich to characterize the bulk of germanium detectors via Compton scattering. In this fully automated setup, a detector is irradiated with a collimated beam of 661.66 keV gammas from a $^{137}$Cs source. A part of these gammas Compton scatter in the germanium detector and are detected by pixelated cameras placed nearby, allowing to reconstruct their interaction point in the detector.

Compton imaging the undepleted volume when operated below its depletion voltage gives access to the real impurity density profile of the detector. The obtained impurity density profile is reproduced independently using capacitance measurements. The results shows that only impurity density profiles with a radial dependence can realistically capture the observations.

T 92.7 Thu 17:30 Geb. 30.23: 2/1

**A HV-CMOS sensor based beam monitoring system for therapeutic ion beams** — •Bogdan Topko[1], Matthias Balzer[2], Alexander Dierlamm[1,2], Felix Ehrler[2], Ulrich Husemann[1], Pietro Marchesi[1], Ivan Perić[2], and Hui Zhang[2] — [1]Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Institute for Data Processing and Electronics (IPE), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Therapeutic ion beams for cancer treatment have significant benefits over photon irradiation. The Bragg peak of ion energy deposition and accurate control of the beam position and size via the beam delivery system enable the largest amount of energy to be deposited into the tumor with the least amount of damage to healthy tissue. In this approach the beam monitoring system is needed to deliver doses to the tumor in an efficient and safe manner. The presented studies are focused on the development of a beam monitoring system based on HV-CMOS sensors. The beam position, shape and fluence should be provided by the system in real time. The system should be tolerant to the magnetic fields and vibrations for the MRI-guided ion beam therapy application. The HV-CMOS HitPix sensor family with counting electronics and frame based readout has been developed at the ASIC and Detector Lab (IPE, KIT) to fulfill these requirements. Recent results of ion beam measurements and a beam monitor demonstrator are presented.

# T 93: Detectors 9 (gas detectors)

Time: Thursday 16:00–17:45 Location: Geb. 30.23: 2/17

T 93.1 Thu 16:00 Geb. 30.23: 2/17

**Photon Position Reconstruction using Structured Converter Layers in Micro-Pattern Gaseous Detectors** — •Katrin Penski, Otmar Biebel, Valerio D'Amico, Stefanie Götz, Roman Lorenz, Ralf Hertenberger, Eshita Kumar, Nick Schneider, Chrysostomos Valderanis, and Fabian Vogel — LMU München

Micro-Pattern Gaseous Detectors are high-rate capable with excellent spatial and temporal resolution. Developed for the detection of charged particles, the low density in the active gas volume of these detectors exhibit only a poor detection efficiency for electrically neutral particles. For photons the detection via the photoelectric effect can be increased using a solid converter cathode, which is made of high-Z materials. With our novel approach, the detection efficiency can be optimized by incorporating multiple converter plates quasi perpendicularly on top of the first GEM foil. Moreover, this technique aims to provide a full two-dimensional position reconstruction of the particle with a resolution of less than 100 $\mu$m within a converter plate. Using the two coordinates of the readout anode of the GEM detector enables this by mounting the converter layers at a specific angle that allows geometric position reconstruction. An optimized electric field, where the electric field lines are parallel to the amplification field, guides the electrons from the converter layers to the GEM foils. Simulations were performed to optimize the design and understand the underlying physical processes. These and measurement results are presented, which aim to image an object in order to verify the functionality of this method.

T 93.2 Thu 16:15 Geb. 30.23: 2/17

**Development of a GridPix-based X-ray Polarimeter** — Klaus Desch, •Markus Gruber, Jochen Kaminski, and Vladislavs Plesanovs — Physikalisches Institut Uni Bonn, Nussallee 12, 53115 Bonn

In astrophysics with X-ray telescopes and material science at synchrotron light sources the measurement of X-ray polarisation can be a valuable tool. It can be directly measured by tracking photoelectrons created in photoelectric interactions. This is possible because their emission angle depends on the direction of the electric field vector of the photons. Within a gaseous detector these electrons have a sufficiently long mean free path such that tracking is possible - if the granularity of the readout is high enough to resolve the tracks and scattering. Also resolving the charge and time distribution of secondary ionisations is needed to differentiate the start and the end of the track. For this a GridPix - a combination of a Timepix(3) ASIC with 55 $\mu$m pixel pitch and a photolithographically postprocessed gas amplification stage (integrated grid) can be used. Perfect alignment of the holes in the grid to the pixels enables the possibility to detect avalanches of individual primary electrons.

In this talk, I will present new results on the performance of a GridPix-based X-ray polarimeter. Based on data taken at PETRA III and at a polarised X-ray source at INAF-IAPS the dependence on different detector parameters like gas choice and geometry will be discussed and compared to simulations. Additionally challenges and possible improvements of such a detector will be presented.

T 93.3 Thu 16:30 Geb. 30.23: 2/17

**Status of new GridPix production in Bonn** — •Sabine Hartung, Yevgen Bilevych, Jochen Kaminski, and Klaus Desch — Physikalisches Institut Universität Bonn

GridPixes are Micropattern Gaseous Detectors optimized for highest resolution and single primary electron detection. It uses a highly pixelized readout ASIC, such as the Timepix and Timepix3, which have a pixel pitch of 55×55$\mu$m. To protect the ASIC an additional protection layer is built on the surface of the chip. On top a Micromegas gas amplification stage is built by photolithographic postprocessing. So far, this process has been done at the Fraunhofer Institute IZM in Berlin but is now being transfered to the Forschungs- und Technologiezentrum Detektorphysik (FTD) in Bonn. Here, besides the standard process developed before, more flexible production techniques without masks are available, allowing for a wider range of optimization.

This talk will explain both the general production steps as well as the status of the production in Bonn.

T 93.4 Thu 16:45 Geb. 30.23: 2/17

**Studies on GEM amplification and time resolution** — •Tim Fabisch, Thomas Hebbeker, Kerstin Hoepfner, Shawn Zaleski, and Francesco Ivone — III. Physikalisches Institut A, RWTH Aachen University

The GEM (Gas Electron Multiplier) technology is being adopted for muon detection in high energy physics experiments, for both tracking and triggering, as well as in other application areas. Two key detector performance figures are the amplification factor and the time resolution.

The electron amplification in GEM detectors depends on the gas mixture, GEM foil's structure, environmental conditions and high voltage settings. The foil's structure is affected by the manufacturing technique which can be based on either single or double mask etching. The time resolution strongly depends on the gas mixture and applied voltage.

In this contribution, we describe the influence of the aforementioned parameters on the amplification factor and the time resolution of a GEM detector. The study complements experimental measurements with numerical simulations.

T 93.5 Thu 17:00 Geb. 30.23: 2/17

**Efficiency Increase of Photon Detection of Micro-Pattern Gaseous GEM Detectors via Material Optimisation of Strucured Converter Layers** — •Nick Schneider, Otmar Biebel, Valerio D'Amico, Stefanie Götz, Ralf Hertenberger, Eshita Kumar, Katrin Penski, Chrysostomos Valderanis, Fabian Vogel, and Roman Lorenz — LMU München

Micro-Pattern Gaseous Detectors (MPGDs) are heavily used for the detection of charged particles with excellent temporal and spatial resolution. Electrically neutral particles like photons are detected with poor efficiency due to the low density in the active gas volume. By inserting solid converter layers of high-Z material this disadvantage can be mitigated. In our desgin multiple converter layers are placed perpendicular to the amplification region. In order to further increase the photon detection efficiency the material and structure of the converter layers need to be optimised to find the balance between creation and extraction rate. For photon conversion copper plated layers are used with relatively thin FR4 or Kapton as carrier material. Different converter layer geometries are tested in order to achieve high photon detection efficiencies. These results are compared to simulations for better understanding of the physical processes. The best performing converter layer type increases the photon detection efficiency by a factor of $\approx 5$ compared to the non-optimised layers.

T 93.6 Thu 17:15 Geb. 30.23: 2/17

**Electron swarm parameter measurements at subatmospheric pressures** — Stefan Roth, Keitlin Sejdarasi, David Smyczek, Jochen Steinmann, and •Nick Thamm — RWTH Aachen University - Physics Institute III B, Aachen, Germany

Tissue Equivalent Gas mixtures (TEGs) were created to mimic the interactions of ionizing particles in human tissue for precise dose measurements. Filling Time Projection Chambers (TPCs) with TEGs enables measurements which resolve the spacial development of particles passing through tissue. By lowering the operating pressure inside a TPC, it is possible to fine-tune these detectors towards improved track resolution for low energies. For the correct interpretation of the low-pressure TPC data, various electron swarm parameters need to be precisely determined at these low pressures. Existing drift parameter simulations can be verified by utilizing a specialized Gas Monitoring Chamber (GMC). In this talk the hardware modification of a GMC towards low pressure operation is addressed, the associated challenges are explained and first measurement results of TEGs are shown.

T 93.7 Thu 17:30 Geb. 30.23: 2/17

**High-rate electron detectors to study Compton scattering in strong-field QED** — •Antonios Athanassiadis[1,2], Louis Helary[1], Luke Hendriks[1,3], Ruth Magdalena Jacobs[1], Jenny List[1], Gudrid Moortgat-Pick[2], Evan Ranken[1], Stefan Schmitt[1], Ivo Schulthess[1], and Matthew Wing[1,3] — [1]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [2]Universität Hamburg, Hamburg, Germany — [3]University College London (UCL), London, UK

In the field of non-perturbative quantum electrodynamics (QED), advances in high-intensity lasers allow the generation of strong fields in collisions between laser pulses and relativistic electron beams. This enables phenomena such as non-linear Compton scattering and Breit-Wheeler pair production to be probed in the laboratory.

The study of Compton energy spectra in these collisions is challenging due to the large number and wide range of outgoing particles per collision ($10^3$ to $10^9$). Our study introduces a new detector concept combining a segmented gas-filled Cherenkov detector with scintillator screens and a camera system. Integrated into experiments such as E320 at SLAC and LUXE at DESY, these detectors allow to resolve the electron energy spectrum within the required wide dynamic range.

This talk presents the results of first beam tests with a prototype and discusses techniques to reconstruct the non-linear Compton electron energy spectrum.

# T 94: Trigger+DAQ 3

Time: Thursday 16:00–17:45 Location: Geb. 30.23: 3/1

T 94.1 Thu 16:00 Geb. 30.23: 3/1

**Hypothesis Firmware on L0Global** — •Emanuel Meuser — Institut der Physik, Johannes Gutenberg Universität Mainz

During the LHC's upgrade to higher luminosity, the ATLAS trigger system will also be upgraded. The L0Global Trigger System will be added as a time-multiplexed trigger system, combining, for the first time in ATLAS, cell data from the calorimeters and Trigger Objects from upstream systems of an event onto a singular FPGA. The L0Global will also replace the L1Topo in its current functionality. Since L0Global will host a large number of algorithms, the FPGA resources for the individual algorithms are rather slim. Thus, the current parallel implementation of the L1Topo algorithmic firmware has to be adapted for usage on the L0Global.

The individual components of the firmware are serialized to take advantage of the L0Global's highly increased latency budget (from new event data every 25 ns on L1Topo to new event data every 1200 ns on L0Global) and to reduce the algorithms resource cost (from 2.5M LUTs on L1Topo to 100k LUTs on L1Topo). The overall structure of the firmware will also be adapted to fit the L0Global*s framework. These Phase-II related firmware adaptations will be discussed in detail.

T 94.2 Thu 16:15 Geb. 30.23: 3/1

**Development of machine-learning based topological algorithms for the CMS level-1 trigger** — Johannes Haller, Gregor Kasieczka, Karla Kleinbölting, •Finn Labe, Artur Lobanov, Matthias Schröder, and Shahin Sepanlou — Institut für Experimentalphysik, Universität Hamburg

Using a HH process as an example, the possibility of using machine learning to construct trigger selections using full event topologies is studied. Targeting the CMS level-1 trigger, it is shown that simple neural networks can provide increased sensitivity at low rate costs and that these neural networks can be deployed in the FPGA-based electronics of the trigger system.

T 94.3 Thu 16:30 Geb. 30.23: 3/1

**The Forward Feature Extractor for the HL-LHC ATLAS Calorimeter Trigger** — •Adrian Alvarez Fernandez, Bruno Bauss, Dennis Layh, Ulrich Schaefer, Stefan Tapprogge, and Christian Kahra — Johannes Gutenberg University (Mainz)

The ATLAS detector will undergo many upgrades to account for the more challenging running conditions of the High Luminosity LHC (HL-LHC). Some of these Phase-II upgrades will be focused on improving the trigger system, a crucial part to deal with the higher data rates and increased pile-up. Phase-I upgrades for Run 3 introduced the Feature EXtractors for a more refined processing of the calorimeter information and to better discriminate between jets, photons, electrons and taus. A Forward Feature EXtractor (fFEX) is being developed for the HL-LHC, which will make use of the full detailed calorimeter granularity in the forward region. It will complement the existing Phase-I systems by providing more flexible algorithms in the regions of |eta|>2.5 for electrons and taus and |eta|>3.2 for jets. The hardware design of the fFEX has been finalized and will be discussed in this presentation, as well as the current state of firmware and algorithmic design.

T 94.4 Thu 16:45 Geb. 30.23: 3/1

**Forward Electron Identification at the ATLAS First Level Trigger for the High Luminosity LHC** — •Maximilian Linkert, Dennis Layh, and Stefan Tapprogge — Institut für Physik, Johannes Gutenberg-Universität, Mainz

As part of the high luminosity LHC the challenge is to properly trigger events in the forward region of ATLAS covering a pseudo rapidity of $2.5 < |\eta| < 4.9$. New first level trigger modules (being under development) based on FPGAs will be used the first time to access the full granularity of the calorimeters in this region to efficiently identify electrons and positrons. The aim is to use machine learning to gain efficiency compared to classical algorithms. The algorithms need to be optimized to run on the FPGAs, thus dealing with a simultaneous optimization of the signal efficiency, background rejection, resource consumption and latency. Moreover, the algorithm implementation needs to address non trivial changes in the geometrical calorimeter segmentation within the region under consideration. The present status of the investigations and next steps will be presented.

T 94.5 Thu 17:00 Geb. 30.23: 3/1

**Elevating LHCb's beauty selection for Run 3: A neural network approach** — Johannes Albrecht[1], Gregory Max Ciezarek[2], Blaise Delaney[3], Niklas Nolte[4], and •Nicole Schulte[1] — [1]TU Dortmund University, Dortmund, Germany — [2]CERN, Geneva, Switzerland — [3]Massachusetts Institute of Technology, Cambridge, USA — [4]META AI (FAIR)

The performance of LHCb's beauty physics program relies significantly on *b*-hadron triggers, specifically topological triggers. These triggers are designed for the comprehensive identification of *b*-hadron candidates, leveraging the distinct decay topology of beauty particles and their anticipated kinematic properties. Constituting the predominant component on the trigger selection output, topological triggers play a crucial role in the success of numerous physics analyses within LHCb.

In this contribution, we present the Run 3 implementation of the topological trigger, seamlessly integrating Lipschitz monotonic neural networks. This architecture ensures resilience in the face of varying detector conditions and enhances sensitivity to long-lived candidates. This framework can potentially open avenues for the discovery of new physics at LHCb. The primary focus is on synergizing a comprehensive physics selection with state-of-the-art machine learning approaches, all within the constraints of available computational resources.

T 94.6 Thu 17:15 Geb. 30.23: 3/1

**Online Track Reconstruction for the Mu3e Experiment** — •Haris Avudaiyappan Murugan — Institute of Nuclear Physics, Johannes Gutenberg University of Mainz, Germany

The Mu3e experiment aims to find or exclude the lepton flavour violating decay of a positive muon to two positrons and an electron with a branching fraction sensitivity of $10^{-16}$. To observe such a rare event, we require a tracking detector from custom-designed High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) together with timing detectors made from scintillating fibre and tiles for the experiment. The detector will be streaming up to 1 TBit/s of data to the filter farm composed of the graphics processing unit (GPU), in which the data rate is reduced to less than 100 MB/s and this filtered data is stored for later analysis. This reduction can be achieved by selecting potential signal events with two positrons and one electron originating from a single vertex through online track and vertex reconstruction on the GPU. The misalignment of thin pixel tracking detectors can affect the precision of track reconstruction. Track-based alignment algorithm requires constraints from global parameters of the actual position of the pixels which can be measured using a camera alignment system. By calibrating the track reconstruction and histogramming the momentum of tracks on the GPU, the searches can be extended to observe potential two-body decays of the muon.

T 94.7 Thu 17:30 Geb. 30.23: 3/1

**A New Track Fit for the ATLAS Event Filter** — •Abhirikshma Nandi, André Schöning, Sebastian Dittmeier, and Christof Sauer — Physikalisches Institut, Universität Heidelberg, Heidelberg, Germany

The ATLAS experiment is going through a comprehensive set of upgrades in preparation for data taking at the High-Luminosity Large Hadron Collider. The Trigger and Data Acquisition (TDAQ) systems are being upgraded to handle an increased trigger rate and run even more sophisticated algorithms online to retain performance in the face of increased event complexity. The ATLAS Event Filter (EF) has to provide the second level of filtering, reducing the Level-0 trigger rate of 1 MHz to 10 KHz for storage. To this end, it is required to perform track reconstruction (EF Tracking) for the entire Inner Tracker (ITk) at a maximum rate of 150 kHz. A new, parallelizable track fit, based on hit triplets, is being developed for EF Tracking. The general triplet fit is a generalization of the Multiple Scattering-only triplet fit, developed originally for the Mu3e experiment, and includes hit uncertainties. Results from the general triplet track fit will be summarized along with an overview of the work in the broader context of the EF Tracking project.

# T 95: Gravitational waves 1

Time: Thursday 16:00–18:00 Location: Geb. 30.23: 6/1

T 95.1 Thu 16:00 Geb. 30.23: 6/1

**A superconducting cavity for the SUPAX experiment** — •Tim Schneemann, Kristof Schmieden, and Matthias Schott — Johannes Gutenberg-Universität Mainz

The SUPAX experiment is one of the first RF cavity based haloscope experiments in Germany to search for axions and dark photons as well as high frequency gravitational waves. A proof-of-concept analysis was presented in summer 2023. Our ongoing effort, within the RADES collaboration, is now focused on developing a tuning mechanism of the RF cavity's resonance frequency without the need of tuning rods as well as improving the quality factor $Q_0$ within a magnetic field of up to 14 T. The quality factor of a resonant system like an RF cavity is a measure of the energy losses, determining the resonance amplification of a signal. Since it mainly depends on the surface resistance of the cavity material superconducting surfaces should yield a boost in $Q_0$, directly resulting in an increased sensitivity.

Currently superconducting REBCO or YBCO tapes yield the best results. These layered tapes have a very high critical magnetic field, making them suitable for axion searches where the cavity is inside a strong magnetic field. However, they are very sensitive to any kind of curvature in the surface they are applied to. We are presenting a different approach, using a cavity coated with NbN, a superconductor with a high critical magnetic field of $\mathcal{O}(10\text{ T})$ which does not have any constraints on surface curvature. In this talk the production and coating process, characterization of the coated cavity and expected improvement on sensitivity will be presented.

T 95.2 Thu 16:15 Geb. 30.23: 6/1

**Ultra high-frequency Gravitational Waves as Messengers of New Physics** — •Lars Fischer[1], Tom Krokotsch[1], Gudrid Moortgat-Pick[1,2], Michel Paulsen[1], Krisztian Peters[2], and Marc Wenskat[1] — [1]Universität Hamburg, Hamburg, Germany — [2]Deutsches Elektronen Synchrotron DESY, Hamburg, Germany

Gravitational wave searches have been strongly motivated for frequencies below $\mathcal{O}(10\text{ kHz})$. However, Standard Model and beyond Standard Model sources for gravitational waves (GW) could also emit at high (kHz-MHz) and ultra high-frequencies (MHz-GHz). But current state of the art GW detector technologies are not capable of pushing their sensitivities to frequencies above $\mathcal{O}(10\text{ kHz})$. New detection concepts are thus needed to set upper limits for cosmological models or to find evidence for sources beyond the Standard Model.

Superconducting radio frequency (SRF) cavities as precise quantized electromagnetic systems are well suited to probe interactions between GW and photons in the MHz to GHz regime. Although sources at ultra high-frequencies impose new challenges on this detector concept, observed signals would provide evidence for physics beyond the Standard Model or for a cosmic gravitational microwave background. A search strategy in this regime could aim for exotic compact objects or be optimized for the detection of cosmological GW backgrounds, from e.g. additional scalar fields.

This talk will emphasise the opportunities of GW search at ultra high-frequencies for particle physics and make a connection between GW-photon interactions and SRF cavity detectors.

T 95.3 Thu 16:30 Geb. 30.23: 6/1

**Gravitational Wave Detection with SRF-Cavities** — •Michel Paulsen[1], Tom Krokotsch[1], Lars Fischer[1], Gudrid Moortgat-Pick[1,2], Krisztian Peters[2], and Marc Wenskat[1] — [1]Universität Hamburg, Hamburg, Germany — [2]Deutsches Elektronen Synchrotron DESY, Hamburg, Germany

Superconducting radio frequency (SRF) cavities, initially developed for particle accelerators, have recently (re-)emerged as some of the most promising tools for high precision measurements. In particular, they can be used to search for axion-like particles but also for gravitational waves (GWs) in previously uncharted frequency ranges.

Even before the first measurements of GWs by VIRGO and LIGO, there were already concepts for measuring GWs with SRF cavities in the so called MAGO project.

In addition to its compactness compared to laser interferometers, this concept is motivated by particularly high sensitivity to GWs in the kHz range up to the GHz range. This could lead to the confirmation of predictions from particle physics and cosmology.

The focus of this talk will be on the concept of 'heterodyne GW detection' with SRF cavities and presenting the work we have done so far on an existing prototype. I will also take a look at the future direction of the project.

T 95.4 Thu 16:45 Geb. 30.23: 6/1

**Particle Physics Prospects of High Frequency Gravitational Wave Detection** — •Tom Krokotsch[1], Lars Fischer[1], Gudrid Moortgat-Pick[1,2], Michel Paulsen[1], Krisztian Peters[2], and Marc Wenskat[1] — [1]Universität Hamburg, Hamburg, Germany — [2]Deutsches Elektronen Synchrotron DESY, Hamburg, Germany

Gravitational wave searches so far have mainly focused on frequencies lower than kHz. However, expanding the search to higher frequencies will open an entirely new window for physics beyond the standard model and dark matter research.

Electromagnetic cavities are particularly sensitive to mechanical deformations caused by gravitational waves in the kHz to MHz regime. A detector based on this concept could search for primordial black holes as dark matter candidates or for novel scalar bosons like axions through the effect of black hole superradiance. Additionally, new exclusion limits could be set on further non-coherent gravitational wave sources.

The aim of this talk is to make a case for high frequency gravitational wave detection with superconducting radio frequency cavities and highlight the opportunities it brings for future particle physics.

T 95.5 Thu 17:00 Geb. 30.23: 6/1

**Composite Vacuum Tubes and Distributed Pumping for the Einstein Telescope** — •Charlotte Benning[1], Robert Joppe[1], Tim Kuhlbusch[1], Oliver Pooth[1], Purnalingam Revathi[1], Ralf Schleichert[2], and Achim Stahl[1] — [1]III. Physikalisches Institut B, RWTH Aachen — [2]Institut für Kernphysik, Forschungszentrum Jülich GmbH

The Einstein Telescope will be the first gravitational wave detector of the third generation. It requires about 120 km of vacuum tubes with a diameter of 1 m to achieve the design sensitivity and reduce scattered light. The pressure inside the tubes needs to be $10^{-11}$ mbar to minimize the residual gas noise. Stainless steel tubes are currently the standard for ultra-high vacuum applications due to the vacuum requirements and mechanical integrity. Reducing the thickness of stainless steel would reduce vacuum firing costs and also help in logistics and assembly underground. Therefore, the concept of composite tubes with an outer glass fiber-reinforced epoxy shell is explored. The distributed pumping system needed to achieve the design vacuum levels will be a significant cost factor. Integrating getter surfaces into the inside of the tubes promises a cheaper and more homogeneous distribution of pumping power. This talk gives an overview of the development and testing of composite tubes and provides an introduction to distributed pumping.

T 95.6 Thu 17:15 Geb. 30.23: 6/1

**Methods to reduce Low-Frequency Noise of Wind Turbines for the Einstein Telescope** — Marc Boxberg[2], •Tom Niggemann[1], Niklas Nippe[1], Achim Stahl[1], and Florian Wagner[2] — [1]III. Physikalisches Institut B RWTH Aachen — [2]Geophysical Imaging and Monitoring RWTH Aachen

Seismic vibrations from nearby wind turbines are expected to be a significant noise source in the Einstein Telescope, a future third-generation gravitational wave detector in Europe. Direct and gravitational couplings are a limiting factor for detection of gravitational waves in the low-frequency range. This talk will discuss and evaluate methods to produce less vibrations in the first place and to reduce their coupling to the ground. Measurements of the vibrations from different types of wind turbines will be explicated.

T 95.7 Thu 17:30 Geb. 30.23: 6/1

**Characterizing the Seismic Impact of Wind Turbines on the Einstein Telescope** — Marc Boxberg[2], Tom Niggemann[1], •Niklas Nippe[1], Achim Stahl[1], and Florian Wagner[2] — [1]III. Physikalisches Institut B, RWTH Aachen — [2]Geophysical Imaging and Monitoring, RWTH Aachen

Knowing the seismic impact of nearby wind turbines is crucial for future gravitational wave detectors like the Einstein Telescope. In the low frequency regime, seismic and gravity gradient noise are the dominant effects impacting the sensitivity. Vibrations of nearby wind turbines are expected to be significant contributions. A deep understanding of these vibrations and the coupling into the ground are necessary to define buffer zones around the detector. I will present measurements of seismic noise at the Einstein Telescope candidate site close to Aachen and their impact on the definition of buffer zones.

T 95.8 Thu 17:45 Geb. 30.23: 6/1

**Seismometer Position Optimization for Newtonian Noise Mitigation in the Einstein Telescope** — •Patrick Schillings and Johannes Erdmann — III. Physikalisches Institut A, RWTH Aachen University

The Einstein Telescope is a third-generation gravitational wave detector that will allow us to measure gravitational waves with significantly improved precision. Its 'xylophone' arrangement is designed to extend the frequency range down to a few Hertz. To improve the sensitivity of the low-frequency interferometer, one needs to mitigate the effect of density fluctuations in the surrounding rock caused by seismic activity, which result in so-called Newtonian noise in the detector. To achieve that, an array of seismometers will be installed around the mirrors. Expensive boreholes will have to be drilled in order to place these seismometers, which will limit the total number of seismometers that can be placed for a given budget. Therefore, the available resources should be used optimally in terms of predicting the Newtonain noise from the seismometer data. In this talk, I will focus on methods for the optimization of such an array.

## T 96: Data, AI, Computing 7 (uncertainties, likelihoods)

Time: Thursday 16:00–18:15 Location: Geb. 30.33: MTI

T 96.1 Thu 16:00 Geb. 30.33: MTI

**Effects of adversarial attacks and defenses on generic neural network applications in high energy physics** — •Timo Saala and Matthias Schott — Johannes Gutenberg-Universtität Mainz

Neural networks have emerged as pivotal tools within high-energy physics (HEP). A field that has recently gained a lot of traction in general deep learning is adversarial learning, which concerns itself with generating adversaries that can be leveraged in order to fool neural networks. Adversaries, intentionally crafted for maximal classification or regression errors with minimal visible input perturbation have spurred the development of techniques for both generating, as well as defending against them. A subset of defense techniques can additionally be applied in order to improve the robustness, and sometimes even the generalization capabilities of deep neural networks. Moreover, adversarial attacks and defenses could potentially offer a means to define the systematic uncertainties in neural networks.

In this study, we employ adversarial learning techniques on multiple neural networks from the HEP environment, reconstructed using exclusively CMS Open Data in order to ensure replicable findings. Through the deployment of adversaries, we not only assess the robustness of these networks but also apply adversarial defenses aiming for the construction of HEP networks displaying larger robustness and better generalization.

T 96.2 Thu 16:15 Geb. 30.33: MTI

**Using Adversarial Attacks to Fool IceCube's Deep Neural Networks** — •Oliver Janik[1], Philipp Soldin[2], and Christopher Wiebusch[2] — [1]FAU Erlangen-Nürnberg, Germany — [2]RWTH Aachen, Germany

Deep neural networks (DNNs) find more and more use in the data analysis of physics experiments. In the context of adversarial attacks, it has been observed that imperceptible changes to the input of DNNs can alter the output drastically. These adversarial attacks are utilized to investigate DNNs used in particle and astroparticle physics within the AI Safety project. While existing algorithms, like DeepFool, can successfully attack those networks, they produce physically improbable changes. A new method has been developed to vary the inputs only within their uncertainties. The algorithm is applied to an exemplary DNN from the IceCube Neutrino Observatory for particle identification. This network's robustness and unique evaluation prospects are presented using the developed fooling algorithm.

T 96.3 Thu 16:30 Geb. 30.33: MTI

**Sharing AI-based Searches with Classifier Surrogates** — •Sebastian Bieringer[1], Gregor Kasieczka[1], Jan Kieseler[2], and Mathias Trabs[3] — [1]Universität Hamburg, Institut für Experimentalphysik, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Karlsruhe Institute of Technology, Institute of Experimental Particle Physics, 76131 Karlsruhe, Germany — [3]Karlsruhe Institute of Technology, Institute of Stochastics, 76131 Karlsruhe, Germany

In recent years, Neural Network-based classification has been used to improve evaluations at collider experiments. While this strategy proofs to be hugely successful, the underlying models are not commonly shared with the public as they are based on experiment-internal simulation. We propose to cater a generative model, a Classifier Surrogate, sampling the classification output from high-level jet information, with every Neural Network-based evaluation to enable further tests on the evaluation. Continuous Normalizing Flows are one suitable generative architecture that can be efficiently trained using Conditional Flow Matching and easily extended by Bayesian uncertainties to indicate the unknown inputs to the user. For a top-tagging example, we demonstrate the application of Flows in combination with uncertainty estimation through either inference of a mean-field Gaussian weight posterior, or Monte Carlo sampling network weights.

T 96.4 Thu 16:45 Geb. 30.33: MTI

**Combining data with unknown correlations** — •Lukas Koch — JGU Mainz

The combination of data points is a regular necessity in particle physics: be it to calculate an "average" of multiple measurements of the same thing, or to do model tests and fits to one or more data sets with multiple data points each. Under ideal circumstances, the uncertainties and correlations between all data points – i.e. the joint likelihood function – is known. In that case, it is trivially possible to do "the right thing" and, e.g., use the Mahalanobis distance – or "chi-squared" – calculated with the known covariance matrix in order to do statistical tests with the expected properties. In reality, at least some of that information is missing, e.g. when there is no information about the correlation between the results from two separate experiments which share some systematics, or – especially for older publications – when there is no publicly available covariance matrices for an experimental result. Applying the M-distance under the assumption of no correlation can lead to undercoverage in this case. In this talk, I will present the use of alternative test statistics that behave conservative in these circumstances, and thus could be a more robust choice when faced with this issue.

T 96.5 Thu 17:00 Geb. 30.33: MTI

**Binary Black Hole Parameter Estimation using a Conditioned Normalizing Flow** — •Markus Bachlechner, Oliver Pooth, and Achim Stahl — III. Physikalisches Institut B, RWTH Aachen University

The proposed Einstein Telescope is the first of the third-generation gravitational wave detectors. It is expected to reach a noise level at least an order of magnitude lower than current interferometers like LIGO and Virgo. The thus improved sensitivity increases the observable volume and extends the time window in which the inspiral phase of binary systems is measurable. To analyze the resulting vast amounts of data efficiently, Neural Networks (NNs) can be utilized. This talk presents a fast Binary Black Hole parameter reconstruction by applying a conventional convolutional NN which conditions a subsequent Normalizing Flow (NF). Using the NF, an approximated posterior parameter distribution on an event-by-event basis is obtained, and thus uncertainties can be estimated.

T 96.6 Thu 17:15 Geb. 30.33: MTI

**Probabilistic Machine Learning for the XENONnT position reconstruction** — •Sebastian Vetter — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

The XENONnT detector is a dual-phase Xenon time projection chamber to search for Dark Matter. To fully exploit background reduction, it is important to know the exact position of events in the detector. The event position reconstruction is commonly performed by a combination of different neural networks (NNs). These NNs, like most machine learning models used in modern experiments, output a singular point in the parameter space. The parameter space in this example is the horizontal plane of the detector.

In this talk I will present and compare two ways of modifying NNs to change their output from a singular point to a probability density.

The resulting probability density functions provide information about the uncertainty of the predictions. The numerical value of the uncertainty can be used to filter for potentially incorrectly reconstructed events. The shape of the uncertainty distribution can be analyzed to learn about trends and biases in the position reconstruction, ultimately leading to an improved signal to background discrimination.

This work is supported in part through the Helmholtz Initiative and Networking Fund (grant agreement no. W2/W3-118). In addition, support by the graduate school KSETA at KIT is gratefully acknowledged.

T 96.7 Thu 17:30 Geb. 30.33: MTI

`dilax`**: Differentiable Binned Likelihoods in JAX** — •Peter Fackeldey, Benjamin Fischer, Felix Zinn, and Martin Erdmann — III. Physikalisches Institut A, RWTH Aachen University

`dilax` is a software package for statistical inference using likelihood functions of binned data. It fulfils three key concepts: performance, differentiability, and object-oriented statistical model building.

`dilax` is build on JAX - a powerful autodifferentiation Python framework. By making every component in `dilax` a "PyTree", each component can be jit-compiled (`jax.jit`), vectorized (`jax.vmap`) and differentiated (`jax.grad`). This enables additionally novel computational concepts, such as running thousands of fits simultaneously on a GPU.

We present the key concepts of `dilax`, show its features, and discuss performance benchmarks with toy datasets.

T 96.8 Thu 17:45 Geb. 30.33: MTI

**Building and Evaluation of Likelihood Functions with** `dilax` **– Differentiable Likelihoods in** `JAX` — Peter Fackeldey, Benjamin Fischer, •Felix Zinn, and Martin Erdmann — III. Physikalisches Institut A, RWTH Aachen University

A common task in high energy phsics (HEP) is the measurement of physical quantities, such as the cross section of a physics process, using likelihood functions of binned data.

The python software package `dilax` allows to define these likelihood functions. It is purely based on `JAX` and thus enables novel computing concepts such as automatic differentiation and vectorization in the context of likelihood fitting.

In this talk we show how to build and evaluate a likelihood function in `dilax`. We present how to perform a likelihood fit including systematic uncertainties in the context of HEP analyses. The results will be validated with existing fitting libraries commonly used in HEP.

T 96.9 Thu 18:00 Geb. 30.33: MTI

**Refining Fast Simulations using Machine Learning Techniques** — Samuel Bein[2], Patrick Connor[2], Sebastian Götschel[1], Daniel Ruprecht[1], Peter Schleper[2], •Lars Stietz[1,2], and Moritz Wolf[2] — [1]Technische Universität Hamburg — [2]Universität Hamburg

In the realm of particle physics, a large amount of data are produced in particle collision experiments such as the CERN Large Hadron Collider (LHC) to explore the subatomic structure of matter. Simulations of the particle collisions are needed to analyse the data recorded at the LHC. These simulations rely on Monte Carlo techniques to handle the high dimensionality of the data. Fast simulation methods (FastSim) have been developed to cope with the significant increase of data that will be produced in the coming years, providing simulated data 10 times faster than the conventional simulation methods (FullSim) at the cost of reduced accuracy. The currently achieved accuracy of FastSim prevents it from replacing FullSim. We propose a machine learning approach to refine high level observables reconstructed from FastSim with a regression network inspired from the ResNet approach. We combine the mean squared error (MSE) loss and the maximum mean discrepancy (MMD) loss. The MSE (MMD) compares pairs (ensembles) of data samples. We examine the strengths and weaknesses of each individual loss function and combine them as a Lagrangian optimization problem.

# T 97: Future colliders

Time: Thursday 16:00–18:00 Location: Geb. 30.34: LTI

T 97.1 Thu 16:00 Geb. 30.34: LTI

**Heavy-quark precision measurements at FCC-ee** — Kevin Kröninger[1], Romain Madar[2], Stéphane Monteil[2], and •Lars Röhrig[1,2] — [1]TU Dortmund University, Department of Physics, Dortmund — [2]Université Clermont-Auvergne, Laboratoire de Physique de Clermont, Clermont-Ferrand

The FCC-ee, proposed as the successor to the Large Hadron Collider, aims at electron-positron collisions in order to achieve unprecedented precision in the electroweak sectors, producing in particular about $\mathcal{O}(10^{12})$ $Z \to q\bar{q}$ events. This makes it possible to measure electroweak observables related to the $Z \to b\bar{b}$ coupling with a very high accurary. However, the accuracy of these measurements is expected to be limited by systematic uncertainties, primarily originating from events related to light-quark physics.

To enhance overall measurement precision, we introduce an ultra-pure $b$-flavour tagger. This tagger relies on exclusive $b$-hadron reconstruction to effectively eliminate background contributions. We evaluate its performance and discuss the remaining systematic uncertainties in the measurement of $R_b = \frac{\Gamma(Z\to b\bar{b})}{\Gamma(Z\to q\bar{q})}$ and the $b$-quark forward-backward asymmetry $A^b_{\text{FB}}$.

These results are put in context alongside top-quark measurements at FCC-ee, allowing us to establish stringent constraints on dimension-6 operators within the SMEFT framework.

T 97.2 Thu 16:15 Geb. 30.34: LTI

**Unique physics probes at FCC-ee for both Standard Model and beyond** — Simon Keilbach, Jan Kieseler, Markus Klute, Matteo Presilla, and •Xunwu Zuo — KIT, Karlsruhe, Germany

The Future Circular Collider (FCC) is a post-LHC project aiming to provide unprecedented insights into both Standard Model physics and beyond. The first stage of FCC features electron-positron collisions (FCC-ee) at center-of-mass energies ranging from 91 GeV for Z boson production to around 365 GeV for top-quark pair production. The FCC-ee, benefiting from low experimental backgrounds, precisely determined collision energy, and outstanding luminosity, offers various novel ways to probe physics, which are unfavorable in current experiments. This talk selects a few recent physics studies that are unique to the FCC-ee dataset and discusses the preliminary results as well as physics outlooks.

T 97.3 Thu 16:30 Geb. 30.34: LTI

**Discrimination of models with additional Z-bosons at muon colliders** — •Kateryna Korshynska[1], Maximilian Löschner[1], Mariia Marinichenko[1], Krzysztof Mekala[2], and Jürgen Reuter[1] — [1]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany — [2]Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warszawa, Poland

We study the discovery reach and discrimination power of future muon colliders for a variety of Z'-models, such as the Left-Right Symmetric Model or the Sequential Standard Model. The study is carried out by combining a set of observables for leptonic and hadronic channels, together with the respective estimated systematic and statistical uncertainties. We discuss the influence of polarized initial or final state partons on the discrimination power of the models in terms of the expected resolution of axial and vector couplings. We will show that even for unpolarized partons, there is a noteworthy potential for distinguishing Z'-models and a high discovery reach in terms of the Z'-mass range.

T 97.4 Thu 16:45 Geb. 30.34: LTI

**Towards a No-Lose Theorem for New Physics at Future Colliders** — Philip Bechtle, Klaus Desch, Christian Grefe, and •Murillo Vellasco — Rheinische Friedrich-Wilhelms-Universität Bonn, Germany

For over half a century, the Standard Model of particle physics (SM) has stood as the current best description of matter and its interactions, despite recent experimental results, such as the muon $g-2$ and the $B$-anomalies, providing hints at an underlying, more fundamental theory. Whereas the proposal of the Large Hadron Collider was supported by the "No-Lose Theorem", which guaranteed the discovery of either the Higgs or some other New Physics (NP) process, no such analogous result can be stated at the moment for potential future collider experiments. This is due to the UV-complete nature of the Standard Model including the Higgs Boson.

In this talk, I will outline the steps towards a potential new "No-Lose Theorem" for future colliders, based on a parametrization of recent experimental deviations using the reasonably model-independent framework of the Standard Model Effective Field Theory (SMEFT). Under the assumption that these deviations are true NP effects, they can be parametrized using SMEFT in order to study their measurability in future experiments, since SMEFT operators can directly affect kinematic distributions and precision observables. The results of these studies could eventually point to a set of optimal future experiments, which, under these assumptions, are guaranteed to lead to fundamental discoveries.

T 97.5 Thu 17:00 Geb. 30.34: LTI

**Multiple boson production at high-energy muon colliders to probe the Higgs-muon coupling** — Eugenia Celada[1,2], Tao Han[3], Wolfgang Kilian[4], •Nils Kreher[4], Yang Ma[5], Fabio Maltoni[1,5,6], Davide Pagani[5], Jürgen Reuter[7], Tobias Striegl[4], and Keping Xie[3,8] — [1]Università di Bologna, Bologna, Italy — [2]University of Manchester, Manchester , United Kingdom — [3]University of Pittsburgh, Pittsburgh, USA — [4]University of Siegen, Siegen, Germany — [5]INFN, Sezione di Bologna, Bologna, Italy — [6]Université catholique de Louvain, Louvain-la-Neuve, Belgium — [7]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [8]Michigan State University, East Lansing, USA

I will present a phenomenological study of the sensitivity of the muon-Yukawa sector at a high-energy muon collider. While this sector is described by a single parameter in the Standard Model, effects of new physics that are not aligned with the Yukawa interactions of the Standard Model can introduce a more sophisticated parameter dependence that can be understood in the framework of either SMEFT or HEFT. Exploiting the coincident small value of the muon-Yukawa coupling and its subtle role in the high-energy production of multiple bosons (vector and Higgs bosons), I will discuss the possibility of constraining the muon-Higgs couplings through a combined analysis of the production cross sections of multiple bosons at both 3-TeV and 10-TeV muon collider levels. Furthermore, I will discuss the implications of an extended Higgs sector on the same processes in both frameworks.

T 97.6 Thu 17:15 Geb. 30.34: LTI

**Physics Performance and Detector Requirements at an Asymmetric Higgs Factory** — •Antoine Laudrain, Ties Behnke, Mikael Berggren, Karsten Büsser, Frank Gaede, Christophe Grojean, Benno List, Jenny List, Jürgen Reuter, and Christian Schwanenberger — DESY, Notkestraße 85, 22607 Hamburg

The Hybrid Asymmetric Linear Higgs Factory (HALHF) proposes a shorter and cheaper alternative for a future Higgs factory. The design includes a 500 GeV electron beam accelerated by an electron-driven plasma wake-field, and a conventionally-accelerated 31 GeV positron beam. Assuming plasma acceleration R&D challenges are solved in a timely manner, the asymmetry of the collisions brings additional issues regarding the detector and the physics analyses, from forward boosted topologies and beam backgrounds. This contribution will detail the impact of beam parameters on beam-induced backgrounds, and provide a first look at what modification to e.g. the ILD can improve the physics performance at such a facility. The studies are benchmarked against some flagship Higgs Factory analyses for comparison.

T 97.7 Thu 17:30 Geb. 30.34: LTI

**Trilinear Higgs Couplings in N2HDM and 2HDMS Type 2 at e+e- Colliders** — •Daniel Schieber[1], Gudrid Moortgat-Pick[1], Sven Heinemeyer[2], and Cheng Li[3] — [1]Universität Hamburg — [2]Cantabria Inst. of Phys. — [3]SYSU, ShenZhen

The Next to two Higgs Doublet Model (N2HDM) and Two Higgs Doublet Model plus complex Singlet (2HDMS) are promising model candidates, for physics beyond the Standard Model (SM). Both can embed the 95 GeV excesses at LEP, CMS and ATLAS. We consider the N2HDM as a limiting case of the 2HDMS when the $\mathcal{CP}$-odd singlet decouples from SM particles. Close to this limit, the models differ mainly by the additional trilinear terms in the 2HDMS, which arise due to its $\mathbb{Z}_3$ symmetry. This difference may lead to phenomenological effects in the di-Higgs production at collider experiments. We study the di-Higgs production at $e^+e^-$ colliders, such as the $ILC_{500}$, and identify the parameter regions where we expect these differences to exceed the experimental uncertainties.

T 97.8 Thu 17:45 Geb. 30.34: LTI

**Probe of top-quark electroweak couplings at the FCC-ee** — •Simon Keilbach, Jan Kieseler, Markus Klute, Matteo Presilla, and Xunwu Zuo — KIT, Karlsruhe, Germany

The Future Circular Collider (FCC) is a post-LHC project aiming to provide unprecedented insights on both Standard Model physics and beyond, featuring electron-positron collisions (FCC-ee) as the first stage of the program. The FCC-ee operation includes a dataset with a collision energy of around 365 GeV, containing roughly 2 million instances of top-quark pair production. With such a clean collection of top quarks, we expect to enter a new era of top precision measurements, among which the top electroweak coupling parameters, especially the ttZ and ttgamma couplings, are of crucial importance. Traditional proposals for such measurements rely on beam polarization to disentangle the ttZ and ttgamma contributions. This talk reports a recent study at FCC-ee on the possibility of ttZ and ttgamma measurements with unpolarized incoming beams.

## T 98: Search for Dark Matter 4

Time: Thursday 16:00–17:30 Location: Geb. 30.35: HSI

T 98.1 Thu 16:00 Geb. 30.35: HSI

**Design and Commissioning of the MainzTPC2** — •Constantin Szyszka, Uwe Oberlack, Alexander Deisting, Christopher Hils, and Jan Lommler — Institut für Physik & Exzellenzcluster PRISMA+, Johannes Gutenberg-Universität Mainz

The MainzTPC is an experimental dual-phase xenon time projection chamber (TPC) dedicated to the study of scintillation and ionization processes of liquid xenon for low-energy electronic and nuclear recoils. It features a signal readout with two PMTs and eight APDs, enabling 3D position reconstruction. The TPC also allows to study the influence of the drift field's strength on the scintillation process. Its design has been optimized for the use as primary target in Compton scattering experiments to measure recoil energies in liquid xenon down to 1 keV.

The MainzTPC is being redesigned to accommodate a SiPM array instead of the top PMT and APDs to improve position resolution in $x$ and $y$. To address known instabilities in the liquid level of the MainzTPC, we observed the liquid-gas interface using commercially available cameras and aim to improve the level meters and level control based on these observations. We report on the status of this work.

T 98.2 Thu 16:15 Geb. 30.35: HSI

**A new test stand for detector tests at Bonn University** — •Gerrit Schmieden, Johanna von Oy, Tobias Schiffer, Klaus Desch, and Jochen Kaminski — Universität Bonn, Bonn

The search for the axion particle using helioscopes, like IAXO, requires detectors sensitive to low-energy X-rays (~1 keV). Due to the low probability of axion-to-X-ray conversion via the inverse Primakoff effect only very few events are expected. This results in the need for ultra-low background detectors. A GridPix detector, constructed from radio-pure materials, is a suitable candidate.

In order to estimate the background behaviour of the detector a dedicated test stand, is essential. This setup consists of two subsystems: a passive lead shielding to block external radiation and an active muon veto based on scintillators. The muon veto is consisting of 14 scintillators and will cover a $4\pi$ solid angle. In order to loose as few events as possible fast timing information, synchronised with the detector, is needed. Therefore a new readout system is developed using a Teensy 4.1 microcontroller.

The talk will offer insights into the construction of the test stand, with a special focus on the scintillator readout.

T 98.3 Thu 16:30 Geb. 30.35: HSI

**Results of the pure-water phase of the XENONnT neutron veto: The world's first water Cherenkov neutron veto** — •Daniel Wenz for the XENON-Collaboration — Institut for Nuclear Physics University of Muenster

Liquid xenon time projection chambers (TPCs) play a key role in the direct search for dark matter such as Weakly Interacting Massive Particles (WIMPs). Neutrons emitted by traces of radioactive isotopes in the detector materials pose a great risk for the search of WIMPs as they can undergo single-scatter nuclear recoils and escape the TPC mimicking WIMP signals. To mitigate this background XENONnT was augmented with a new neutron veto (NV), designed as a Gadolinium water Cherenkov detector, which tags neutrons through their capture on gadolinium and hydrogen. In the first phase of XENONnT the neutron veto was operated using pure water only.

In this talk we will present results of the performance of the NV in this first phase, its calibration using coincident gammas and neutrons from an Americium-Beryllium source, and its impact on the first science search data of XENONnT.

The presented work is supported by the BMBF through the project numbers 05A20UM1 and 05A23PM1.

T 98.4 Thu 16:45 Geb. 30.35: HSI

**Muon Shielding Simulations for an Above Ground Cryostat** — •Maximilian Hughes for the COSINUS-Collaboration — Max Plank Institute for Physics, Munich, Germany

Cryogenic detectors are highly susceptible to pile-up due to their long signals. Reducing signals from backgrounds, such as muons, can be done by running detectors in underground labs, but space in underground cryostats is limited and in high demand. Detector performance in above ground cryostats can be improved with radiation shielding. Different configurations of shielding for the COSINUS group's above ground cryostat at the Max Plank Institute for Physics (MPP) has been investigated with GEANT4 simulations. The addition of a muon veto made out of plastic scintillator has also been simulated. Using the results of the simulation, the optimal shielding configuration will be designed and built.

T 98.5 Thu 17:00 Geb. 30.35: HSI

**Water Cherenkov muon veto for the COSINUS experiment** — •Kumrie Shera for the COSINUS-Collaboration — Max-Planck Institue for Physics, Munich, Germany

The Cryogenic Observatory for Signals seen in Next Underground Searches (COSINUS) is a direct dark matter search utilizing sodium iodide (NaI) as a cryogenic calorimeter. The cryogenic facility is located in the hall B at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy. The NaI cryogenic detectors will be housed in a dry dilution refrigerator positioned at the center of a water tank with dimensions of 7 meters in diameter and height. The water serves as passive shielding against ambient radiation. High-energy muons can reach the detector surroundings, generating muon-induced neutrons that can cause nuclear recoils and potentially mimic a dark matter signal. To actively identify and veto against these events, the water tank will be equipped with 28 photo-multiplier tubes (PMTs), enabling the operation of the tank as a Cherenkov detector. This contribution introduces the water Cherenkov muon veto for the COSINUS experiment.

T 98.6 Thu 17:15 Geb. 30.35: HSI

**Large scale liquid xenon test platform PANCAKE for future dark matter detectors** — •Julia Müller — University of Freiburg

The PANCAKE facility is a large-scale cryogenic platform with a diameter of 2.8m allowing to test detector components such as electrodes for future liquid xenon detectors e.g. DARWIN. As over the past decades these detectors continuously grew in size and sensitivity their technical realization becomes more and more challenging, with the electrodes among the most crucial components. These can be tested in PANCAKE in cryogenic conditions and on full scale. The PANCAKE facility was operated successfully with an entire of 300kg of xenon and preparations for an electrodes testing campaign are currently taken.

# T 99: Di-Higgs 3 (bbWW)

Time: Thursday 16:00–17:30 Location: Geb. 30.41: HS 1

T 99.1 Thu 16:00 Geb. 30.41: HS 1

**Search for non-resonant Higgs boson pair production in dilep- ton final states of the bbWW decay mode at CMS** — Matteo Bonanomi, Mathis Frahm, Johannes Haller, Viacheslav Kosterin, •Lara Markus, Janek Möls, Alexander Paasch, and Matthias Schröder — Insitut für Experimentalphysik, Universität Hamburg

The trilinear coupling of the Higgs boson is related to the shape of the Higgs potential, which makes it a crucial parameter of the Standard Model. The shape can be directly probed by measuring the cross-section of Higgs boson pair production.

In this talk, studies towards a search are presented for non-resonant pair production of Higgs bosons decaying into a b quark anti-quark pair and two W bosons, with subsequent decays of the W bosons into leptons and neutrinos. The analysis strategy is developed using simulated proton-proton collision data at 13 TeV center-of-mass energy at the CMS experiment. The analysis is implemented in a columnar-based framework 'columnflow'.

T 99.2 Thu 16:15 Geb. 30.41: HS 1

**Conceptualization and Development of a Boosted Analysis for Run-3 for Higgs boson pair production in the 1-lepton $bbWW^*$ final state** — •Lina Buschmann, Kira Abeling, and Stan Lai — II. Physikalisches Institut, Georg-August-Universität Göttingen

Since the discovery of the Higgs boson in 2012, many studies have been performed to test its properties against Standard Model (SM) predictions. In particular, a direct measurement of the Higgs self-coupling is important to characterise the Higgs potential.

Furthermore, it is known that there must be physics beyond the SM (BSM). Many BSM theories predict additional, highly massive narrow-width scalars, $X$, which can resonantly decay to two Higgs bosons, $H$, enhancing the di-Higgs cross section. Since the mass of $X$ is not predicted by theory in this approach, a wide range of masses, $m_X$, is considered, resulting in various decay topologies.

In this talk, the development of a Run-3 analysis, based on the Run-2 analysis, for $HH$ production in the boosted $bbWW^*$ decay channel with the one lepton final state is discussed. Since only large resonant masses are considered, the jets from the $W$ boson decay and the $bb$ decay cannot be resolved completely. This yields a boosted topology and the decay products being collected in two back-to-back large-$R$ jets, where the lepton overlaps with the $W_{\text{had}}$ jet. This channel offers a fairly high branching ratio with a moderate amount of background, dominated by $tt$ events with at least one leptonic top decay.

T 99.3 Thu 16:30 Geb. 30.41: HS 1

**Search for non-resonant Higgs boson pair production in the boosted lepton+jets final state of the bbWW decay mode at CMS** — Matteo Bonanomi, Mathis Frahm, Johannes Haller, Viacheslav Kosterin, Lara Markus, •Janek Möls, Alexander Paasch, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

The Higgs potential is a largely unexplored area of the Higgs mechanism. One important parameter for this potential is the Higgs boson self-coupling, since it is related to the shape of the potential. Measuring the cross section of Higgs boson pair production (HH) allows probing this parameter directly. The small HH production cross section in the Standard Model of just 33 fb at 13 TeV center-of-mass energy makes the experimental observation challenging. Analyzing the Run 3 data of the LHC detectors promises a further leap in sensitivity.

In this talk, preparatory studies towards a search for non-resonant HH production in the lepton+jets final states of the bbWW decay mode with Run 3 data of the CMS detector at the LHC are presented. Particular emphasis is placed on the impact of a separation between the resolved and boosted phase space for the Higgs boson candidates decaying into two bottom quarks.

T 99.4 Thu 16:45 Geb. 30.41: HS 1

**Employing Matrix Elements with Neural Networks to Search for Higgs Self-coupling** — •Christoph Ames, Otmar Biebel, Lars Linden, Celine Stauch, Edis Hrustanbegovic, Stefanie Götz, Lukas Von Stumpfeldt, and Youn Jun Cho — Ludwigs-Maximilians-Universität, München

The Higgs boson was discovered in 2012 as predicted by the Standard Model (SM); however not all of its predicted couplings have been measured. One such coupling is the Higgs self-coupling, in which a Higgs boson decays into two further Higgs bosons. By integrating over all possible initial states and by using the details of the end state, the matrix element method evaluates the weight (likelihood) of an event for the specific production cross section. In this work, machine learning is combined with the matrix element method to search for $HH \to b\bar{b}W^+W^-$ using simulated data. A neural network is trained to calculate the matrix element weight of an event and to use this to determine whether the event contains a signal or a background decay.

T 99.5 Thu 17:00 Geb. 30.41: HS 1

**Employing Matrix Elements in the Search for Higgs Self-coupling** — Christoph Ames, Otmar Biebel, Lars Linden, Celine Stauch, and •Edis Hrustanbegovic — Ludwigs-Maximilians-Universität, München

The Higgs boson is one of the most complex and least understood parts of the Standard Model. Even though it cleared up a lot of the questions this model posed, some of the predictions that came with it have yet to be proven by measurement. One of these predictions being the Higgs self-coupling. This coupling is especially difficult to measure, since it has a very small cross section along with background reactions that are far more common. Using the C++ software package MoMEMta the probability of a measurement aligning with the process $H \to HH \to (b\bar{b})(W^+W^-) \to (b\bar{b})((l\nu)(q'\bar{q}))$ can be calculated to determine if this decay took place, or if it is a background process. This is done by using the matrix element method, in which for the wave functions the measured particles and jets are being used to compute the cross section of the investigated process. Since the momenta of the initial partons are unknown, MoMEMta employs energy and momentum conservation to substitute the momenta of the initial partons and up to two more particles. However, the necessary Jacobian is not available for the considered $HH$ process which, therefore, needs to be constructed from the available processes in the MoMEMta package. The challenges and the result of this implementation will be presented in this talk.

T 99.6 Thu 17:15 Geb. 30.41: HS 1

**Separating $tt$ and $HH$ end states using neural networks** — •Youn Jun Cho, Christoph Ames, Stephanie Goetz, Edis Hrustanbegovic, Lars Linden, Celine Stauch, Lukas von Stumpfeldt, and Otmar Biebel — Ludwig-Maximilian University of Munich

Immense research has been conducted on the Higgs Boson since its discovery. However, the sheer amount of background events in high energy particle colliders complicate the study of its physical properties. Research on the Higgs self interactions is no exception. The corresponding cross section is small compared to many competing processes with similar final states. For example, the Higgs self interactions and the top anti-top quark pair decays can have equivalent final states, e.g. $b\bar{b}W^+W^-$, but the cross sections are roughly 30 femtobarns and 1 microbarns, respectively, such that the top anti-top quark distributions reach into those of the Higgs pair production. To separate these two, Pytorch neural networks were applied onto the data simulated with the MCatNLO+Herwig event generator. Given a reasonable computation time, MCatNLO+Herwig could not generate enough top background events to train the neural network. Therefore, certain features of these data beyond kinematics were modified in order to generate sufficient training data. Overall, the neural network was effective in separating the two end states.

# T 100: Higgs 4 (coupling to taus, CP, rare decays)

Time: Thursday 16:00–18:00 Location: Geb. 30.41: HS 2

T 100.1 Thu 16:00 Geb. 30.41: HS 2

**H→ $\tau\tau$ cross-section measurement in the VBF production mode with focus on the non-$\tau$ background** — •Lena Herrmann, Christian Grefe, Philip Bechtle, and Klaus Desch — Physikalisches Institut, University of Bonn

Precision measurements of the Higgs boson properties are promising to show evidence of physics beyond the Standard Model. One aspect of interest is the Yukawa-interaction which can be directly investigated by a cross-section measurement in the di-$\tau$ final state.

Differential measurements in the vector-boson fusion production mode are performed in a binned maximum-likelihood fit of the di-$\tau$ mass in various $p_T^H$ and $m_{jj}$ bins using the *"Simplified Template Cross Section"* framework (STXS). The main backgrounds of this analysis are, besides Z→ $\tau\tau$ events, misidentified $\tau$ leptons – so called *Fakes*. This background has a non-negligible impact on the final sensitivity and is therefore a central topic in developing strategies to improve the measurement. Apart from introducing a more accurate reconstruction of misidentified tau leptons, effort has been made to define fake reduced signal regions and to stabilize the fit setup by decreasing statistical uncertainties on the shape of the background in question.

This presentation will discuss several studies related to the fake estimate. These include strategies applied in the current analysis as well as promising ideas for future fit setups which are already validated in preparatory studies. In addition, fit results will be presented to probe the Standard Model prediction in the vector-boson fusion production mode.

T 100.2 Thu 16:15 Geb. 30.41: HS 2

**The $\tau\tau$ background estimation with the $\tau$-embedding method of CMS** — •Christian Winter, Sebastian Brommer, Artur Gottmann, Roger Wolf, and Günter Quast — ETP, Karlsruhe Institute of Technology, Karlsruhe, Germany

In $H \to \tau\tau$ analyses a major source of background are genuine tau leptons, mostly originating from $Z \to \tau\tau$ decays. The $\tau$-embedding method is a method to estimate this background from data, by replacing muons in a selected-event in data with simulated $\tau$-decays. This talk will explain this method and gives an outlook of how this method will be improved further.

T 100.3 Thu 16:30 Geb. 30.41: HS 2

**Test of CP invariance in Higgs boson production via vector boson fusion exploiting the $H \to \tau_{\mathrm{had}}\tau_{\mathrm{had}}$ decay mode** — •Daniel Bahner, Ö. Oğul Öncel, and Markus Schumacher — Physikalisches Institut, Freiburg, Deutschland

Violation of CP invariance is one of the Sakharov conditions to explain the observed baryon asymmetry in our universe (BAU). While CP violation is already realized in the Standard Model via CKM matrix, it is not sufficient to explain the observed magnitude of BAU. The discovery of the Higgs boson has opened a new window to search for additional sources of CP violation. The vector-boson fusion (VBF) production of the Higgs boson is one of them. Here, it is possible to probe CP-violating contributions to the $HVV$ vertex.

In this talk, the subsequent Higgs boson decay into two hadronically decaying tau leptons is considered. The dominant background process in this decay channel is the irreducible $Z \to \tau\tau$ process. A data-driven Fake Factor method is used to estimate the sizeable contribution from events in which jets are misidentified as hadronically decaying tau leptons. A neural network is exploited to discriminate signal from background processes.

CP-odd observables are used in a profile-likelihood fit to perform a test of CP invariance and to constrain the strength of new CP-violating interactions. The talk will discuss the analysis strategy, CP-odd observables, and first results including systematic uncertainties based on $\sqrt{s} = 13$ TeV proton-proton collision data collected by the ATLAS detector corresponding to $\mathscr{L}_{\mathrm{int}} = 140\,\mathrm{fb}^{-1}$.

T 100.4 Thu 16:45 Geb. 30.41: HS 2

**Measurement of the CP properties of the Higgs boson in the decay into tau leptons with the Run 3 data of the CMS experiment** — •Stepan Zakharov, Alexei Raspereza, Elisabetta Gallo, and Andrea Cardini — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

The Standard Model (SM) Higgs boson is predicted to be CP-even. Measurements from Run 2 data at the LHC have excluded a purely CP-odd state at 3 standard deviations. However, experimental results up to now do not exclude the possibility for the Higgs boson to be a mixture of a CP-even and a CP-odd state. The analysis of the Run 3 combined with the Run 2 data collected by the CMS experiment will allow to elucidate the CP nature of the SM Higgs boson. The Run 3 analysis is developed by exploiting observables sensitive to CP in the decay of the Higgs boson to a pair of tau leptons using the Columnflow approach. This talk will cover the strategy of the analysis: starting from the theoretical motivation, discussing the main steps, and presenting the first data and Monte Carlo comparisons for some observables with the 2022 dataset.

T 100.5 Thu 17:00 Geb. 30.41: HS 2

**Comparison of the sensitivity of different CP-odd observables for testing CP-invariance in the Vector-Boson-Fusion production of the Higgs-Boson** — •Lea Kuttler, Lorenzo Rossini, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

The observed baryon asymmetry in our universe (BAU) can be explained if the three Sakharov conditions, including the violation of CP-invariance, are met. However, the amount of CP-violation predicted by the Standard Model, via the CKM-matrix, is insufficient to explain the BAU. Hence, it is instructive to search for new sources of CP-violation in the Higgs sector. The vector-boson fusion production allows to investigate the CP-structure of the Higgs-boson coupling to electroweak gauge bosons HVV and to test its CP invariance.

The strength of the new CP-violating interactions can be constrained by maximum-likelihood fits to the distribution of CP-odd-observables. In this talk, the sensitivity of different CP-odd observables exploiting the $H \to \tau_{\mathrm{had}}\tau_{\mathrm{had}}$ decay mode are compared by determining the expected length of the confidence intervals for the CP-violating coupling strength. The comparison includes both, newly constructed machine learning observables and traditional ones, such as the azimuthal angle difference of the tagging jets and the optimal observable.

The sensitivities are derived from simulated events corresponding to the data set collected with the ATLAS detector during Run-2 of the LHC at a center of mass energy of 13 TeV.

T 100.6 Thu 17:15 Geb. 30.41: HS 2

**Classifying the CP properties of the ggH coupling in H+2j production** — Henning Bahl[1], Elina Fuchs[2,3], Marc Hannig[2], and •Marco Menen[2,3] — [1]Ruprecht Karls Universität, Heidelberg, Deutschland — [2]Leibniz Universität, Hannover, Deutschland — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland

The Higgs-gluon interaction is crucial for LHC phenomenology. To improve the constraints on the CP structure of this coupling, in this talk I will investigate

Higgs production with two jets using machine learning. In particular, the CP sensitivity of the so far neglected phase space region that differs from the typical vector boson fusion-like kinematics is exploited. The presented results suggest that significant improvements in current experimental limits are possible. In the talk I also discuss the most relevant observables and how CP violation in the Higgs-gluon interaction can be disentangled from CP violation in the interaction between the Higgs boson and massive vector bosons. Assuming the absence of CP-violating Higgs interactions with coloured beyond-the-Standard-Model states, the projected limits on a CP-violating top-Yukawa coupling are stronger than more direct probes like top-associated Higgs production and limits from a global fit.

T 100.7 Thu 17:30 Geb. 30.41: HS 2

**Steering towards an H → $\mu\mu$ analysis of the LHC Run III Data with the CMS Experiment** — •Erik Hettwer Benitez — Karlsruhe Institute of Technology

Measuring the coupling of the Higgs Boson (H) to the second generation fermions is an important milestone of the LHC physics program. Evidence for H → $\mu\mu$ has been established by CMS in 2021 analysing LHC Run II data from 2016, 2017 and 2018, resulting in a signal significance of 3.0 standard deviations. This talk gives an overview of our first steps towards an H → $\mu\mu$ analysis with LHC Run III data.

T 100.8 Thu 17:45 Geb. 30.41: HS 2

**Searches for Exclusive Higgs and Vector Boson Decays to a Meson and a Photon at ATLAS** — •Robert Ward — Universität Hamburg

In the Standard Model (SM) the mass generation of fermions is implemented through Yukawa couplings to the Higgs boson. Experimental evidence exists for the Higgs boson couplings to second and third generation leptons through its decay to muon and tau pairs, but for quarks direct evidence exists only for the third-generation couplings. Direct searches for inclusive decays of the Higgs boson to lighter quarks are challenging due to large QCD backgrounds at the LHC.

With their distinct experimental signature, radiative decays of the Higgs boson to a meson and a photon may offer an alternative probe of quark Yukawa couplings. Moreover, these decays provide an opportunity to investigate physics beyond-the-SM, where significantly modified branching fractions from the SM expectation are predicted, as well as the existence of potential quark-flavour-violating couplings of the Higgs and $Z$ bosons. This talk will summarise searches for rare exclusive Higgs boson decays to a meson and a photon performed by the ATLAS experiment using the $\sqrt{s}$ = 13 TeV dataset, along with searches for related decays of the massive vector bosons. These searches use dedicated triggers which were in operation throughout Run 2 of the LHC, as well as novel non-parametric data-driven techniques to model the backgrounds.

# T 101: BSM Higgs 4

Time: Thursday 16:00–18:00 Location: Geb. 30.41: HS 3

T 101.1 Thu 16:00 Geb. 30.41: HS 3

**Analysis of interference effects in the di-top final state for CP-mixed scalars in extended Higgs sectors** — Henning Bahl[1], •Romal Kumar[2], and Georg Weiglein[2,3] — [1]Institut für Theoretische Physik, Philosophenweg 16, 69120 Heidelberg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany — [3]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Various extensions of the Standard Model predict the existence of additional Higgs bosons. If these additional Higgs bosons are sufficiently heavy, an important search channel is the di-top final state. In this channel, interference contributions between the signal and the corresponding QCD background process are expected to be important. If more than one heavy scalar is present, besides the signal-background interference effects associated with each Higgs boson also important signal-signal interference effects are possible. We perform a comprehensive model-independent analysis of the various interference contributions within a simplified model framework considering two heavy scalars that can mix with each other, taking into account large resonance-type effects arising from loop-level mixing between the scalars. The interference effects are studied with Monte Carlo simulations for the di-top production process at the LHC. We demonstrate that signatures can emerge from these searches that may be unexpected or difficult to interpret.

T 101.2 Thu 16:15 Geb. 30.41: HS 3

**Search for heavy Higgs bosons and Axion-Like Particles in the $t\bar{t}$ final state at CMS** — •Jörn Bach[1,2,3], Christian Schwanenberger[1,2], Alexander Grohsjean[2], Laurids Jeppe[1], Samuel Baxter[1], and Afiq Anuar[4] — [1]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [2]Universität Hamburg, Hamburg, Germany — [3]HAW Hamburg, Hamburg, Germany — [4]CERN, Geneva, Switzerland

The Standard Model of particle physics is very successful in predicting the processes we observe at modern colliders such as the Large Hadron Collider (LHC). It is however incomplete and remaining questions, such as the nature of dark matter, are motivating searches for new particles.

A CMS search for a heavy Higgs boson in the $t\bar{t}$ final state in 2016 data has observed a local excess of 3.5$\sigma$ (1.9$\sigma$ global) for a pseudoscalar with a mass of 400 GeV and a width of 4%. Motivated by this result, we present a search for a scalar and pseudoscalar heavy Higgs boson decaying to $t\bar{t}$ with the full Run 2 CMS dataset. We exploit spin correlation information and the invariant mass of the $t\bar{t}$ system. Additionally to the scalar and pseudoscalar heavy Higgs bosons, we interpret the search in terms of a more general pseudoscalar Axion-like particle (ALP) by also allowing for direct couplings to the gluon.

T 101.3 Thu 16:30 Geb. 30.41: HS 3

**Distinguishing Axion-Like Particles from Extended Higgs Sector Models in $t\bar{t}$ production at the LHC** — Anke Biekötter[1], Thomas Biekötter[2], Alexander Grohsjean[3], Sven Heinemeyer[4], •Laurids Jeppe[5], Christian Schwanenberger[5,3], and Georg Weiglein[5,3] — [1]PRISMA+ Cluster of Excellence & Institute of Physics (THEP) & Mainz Institute for Theoretical Physics, Johannes Gutenberg University, Mainz, Germany — [2]Institute for Theoretical Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — [3]Universität Hamburg, Hamburg, Germany — [4]Instituto de Física Teórica UAM-CSIC, Madrid, Spain — [5]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

We present an analysis of the sensitivity of LHC searches for new spin-0 particles produced via gluon-fusion and decaying into top quark-antiquark ($t\bar{t}$) final states to generic axion-like particles (ALPs) coupled to top-quarks and gluons. We derive new limits on the effective ALP Lagrangian in the linear representation in terms of the Wilson coefficients $c_t$ and $c_G$ based on the existing CMS search using 35 fb$^{-1}$ collected at $\sqrt{s}$ = 13 TeV. We further investigate posssible distinctions between ALPs and pseudoscalar Higgs bosons as predicted by the two-Higgs-doublet model (2HDM), and find that distinction is possible with data anticipated to be collected during the high-luminosity of the LHC for a significant range of the effective ALP-gluon coupling.

T 101.4 Thu 16:45 Geb. 30.41: HS 3

**Search for long-lived axion-like particles produced in Higgs boson decays at the ATLAS Experiment** — •Lukas Bauckhage — Physikalisches Institut, Universität Bonn, Bonn; Germany

Preliminary results of a search for long-lived axion-like particles produced in a Higgs decay in association with a Z boson and decaying into a pair of photons are presented. Exotic Higgs decays to long-lived particles are featured in theories beyond the standard model related to hidden sectors, while (long-lived) axion-like particles are not only a prime candidate to dark matter but also part of hidden and dark sector theories. This analysis uses Run 2 and 3 data collected with the ATLAS detector and follows a previous search for promptly decaying axion-like particles. The ALP decay's displacement challenge the standard photon reconstruction and call for new techniques, such as machine learning and a new tagger utilising shower shape information. Detailed studies of the ALP identification and reconstruction efficiency as a function of its radial and longitudinal displacement will be discussed.

T 101.5 Thu 17:00 Geb. 30.41: HS 3

**Search for long-lived particles produced in Higgs boson decays with b-quark like signature** — Lisa Benato, •Karim El Morabit, Mascha Hackmann, Gregor Kasieczka, and Sriya Madarapu — Institut für Experimentalphysik, Universität Hamburg

New particles predicted by theories of physics beyond the standard model (BSM) can have relatively long lifetimes and decay after macroscopic flight distances. Such long-lived particles (LLPs) can occur, for example, in Higgs-portal models in which a dark sector of particles, that are neutral under the SM gauge groups, is accessible via mixing of the standard model and dark sector Higgs bosons. With this, a SM Higgs boson could then decay to a pair of dark sector particles $\pi$ which could then decay back to SM particles. In case these new particles $\pi$ are long-lived particles, it would result in experimental signatures of displaced tracks or jets.

This talk discusses a search for LLPs with data recorded at the CMS experiment. It targets LLPs with comparably short lifetimes $c\tau$ on the order of cm and decays into bottom quark-antiquark pairs. The decays of the LLPs result in b-jets with displacements only slightly larger than those of SM b-jets, leading to challenges regarding the background suppression and modeling. Machine learning methods are used to address those challenges.

T 101.6 Thu 17:15 Geb. 30.41: HS 3

**Search for Higgs boson decays into long-lived particles with displaced vertices** — Lisa Benato, Karim El Morabit, Gregor Kasieczka, and •Karla Peña — Institut für Experimentalphysik, Universität Hamburg

Higgs-portal models propose the existence of a dark sector, neutral under all Standard Model (SM) gauge groups. Interaction between the dark sector and the SM is mediated solely by the Higgs boson, which mixes with its dark partner. As a consequence of this, the Higgs boson is predicted to decay also in the dark sector. Scenarios are considered where the Higgs boson decays into a pair of dark long-lived particles (LLPs), each of which travels a macroscopic distance before decaying back to a pair of SM particles—predominantly b quarks.

Decays occurring within the CMS tracking system result on displaced-vertex signatures, which can be observed with almost no background from the SM. However, as conventional tracking and vertex finding algorithms are optimized for prompt decays, these signatures are challenging to find and advanced reconstruction techniques are required. This talk presents a search for LLPs using data collected by the CMS detector in pp collisions at a center-of-mass energy of 13 GeV.

T 101.7 Thu 17:30 Geb. 30.41: HS 3

**Search for flavour-changing neutral current couplings between the top quark and the Higgs boson in multilepton final states** — •Marvin Emin Geyik and Wolfgang Wagner — University of Wuppertal

Flavour-changing neutral current interactions are strongly suppressed in the Standard Model. Still, some extensions of the Standard Model predict tree-level FCNC couplings between the top quark, other up-type quarks and neutral bosons, including the Higgs boson. These anomalous couplings can be parametrised in the framework of effective field theories (EFT). The presented analysis searches for the production of a single top-quark in association with a Higgs boson and for top-quark-antiquark production with one of the top quarks decaying to an up quark or a charm quark and a Higgs boson. Higgs decays to $WW^*$, $ZZ^*$ and two taus leading to leptonic final states are considered in the event selection. Two analysis channels are defined: one with two leptons (electrons or muons) of the same electric charge and a second channel with three leptons. The results obtained by the analysis will be presented in the form of upper exclusion limits on the relevant coefficients of EFT operators and the ensuing branching ratios.

T 101.8 Thu 17:45 Geb. 30.41: HS 3

**Double Sliced Event Generation: A novel method for multijet background generation for forward jet sensitive Physics searches** — •Gediminas Glemža and Christian Sander — DESY, Notkestr. 85, 22607 Hamburg, Germany

Beyond Standard Model searches with significant reliance on forward jets, such as invisible Higgs decay in vector boson fusion topology, are sensitive to various effects stemming from multijet background events. These forward jets can be faked by pile-up jets. Conventionally generated multijet background events may have a leading jet stemming from pileup interaction resulting in unphysically large event weights. Typical selection cuts can negate these effects to some extent at the cost of aggressively reducing the statistics of multijet samples. Hence, a new method of generating multijet background events enriched in a particular region of interest, called Double Sliced Event Generation, is presented.

The method generates hard scatter and leading pileup interactions in sliced kinematic phase-space, employs full truth jet smearing, considers all possible pile-up tagged jet combinations, and repeatedly samples jet responses and invisible jet energy fractions. The produced backgrounds are enriched in signal regions with correctly calculated physical event weights, hence able to survive the selection cuts and are resistant to the aforementioned negative effects. For the validation of the method, a generated double-sliced event generation multijet background is compared to its conventional MC counterpart for invisible Higgs decay in vector boson fusion topology.

# T 102: Flavour physics 4

Time: Thursday 16:00–18:00 Location: Geb. 30.41: HS 4

T 102.1 Thu 16:00 Geb. 30.41: HS 4

**Isospin asymmetry in $B \to K\mu^+\mu^-$ decays** — Johannes Albrecht[1], •Fabio De Vellis[1], Cristoph Langenbruch[2], Vitalii Lisovskyi[3], Biljana Mitreska[1], Thomas Oeser[4], and Stefan Schael[4] — [1]TU Dortmund University, Dortmund, Germany — [2]Heidelberg University, Heidelberg, Germany — [3]EPFL, Lausanne, Switzerland — [4]RWTH Aachen University, Aachen, Germany

Symmetries in the Standard Model come from very fundamental aspects of the theory, and tests of them play a determinant role in the understanding of the whole picture of elementary particles. Isospin symmetry predicts a branching fraction that is almost the same for decays which differ only by one spectator quark, like $B^0 \to K^0\mu^+\mu^-$ and $B^+ \to K^+\mu^+\mu^-$. For these decays, a quantity which describes differences in branching fraction, namely the asymmetry, can be defined. This is particularly convenient since it is theoretically clean and it allows canceling some experimental uncertainties.

Previous measurements on these decays from LHCb and Belle, despite being compatible with Standard Model expectations, suggested coherent deviations that could be interpreted as statistical fluctuations, or unaccounted theoretical uncertainties, or as a sign of New Physics.

In this talk an update of the asymmetry measurement on data collected at LHCb and corresponding to an integrated luminosity of 9 $\text{fb}^{-1}$ is presented.

T 102.2 Thu 16:15 Geb. 30.41: HS 4

**Measurement of the isospin asymmetry in $B \to K^*\mu^+\mu^-$ decays with LHCb** — Johannes Albrecht[1], Fabio De Vellis[1], Christoph Langenbruch[2], Vitalii Lisovskyi[3], Biljana Mitreska[1], •Thomas Oeser[4], and Stefan Schael[4] — [1]Technische Universität Dortmund — [2]Universität Heidelberg — [3]EPFL — [4]RWTH Aachen

Precision measurements of rare $b \to s\ell\ell$ transitions, which are forbidden at tree level in the Standard Model (SM) and can only occur via loop-level and higher-order processes, constitute clean tests of the SM, sensitive to various potential New Physics contributions.

The isospin asymmetry $\mathscr{A}_I$ between $B^0 \to K^{*0}\mu^+\mu^-$ and $B^+ \to K^{*+}\mu^+\mu^-$ has a very clean SM prediction as many hadronic uncertainties cancel in the calculation. Previous measurements are in agreement with this prediction, within still large uncertainties.

This talk presents an overview of the analysis of the isospin asymmetry in $B \to K^*\mu^+\mu^-$ and the differential branching fraction of $B^+ \to K^{*+}\mu^+\mu^-$ using the full LHCb Run 1 and Run 2 dataset, recorded between 2011 and 2018 and corresponding to an integrated luminosity of approximately $9\text{fb}^{-1}$.

T 102.3 Thu 16:30 Geb. 30.41: HS 4

**Search for $B^+ \to K^{*+}\tau\tau$ with Hadronic Tagging at Belle II** — •Lennard Damer, Torben Ferber, and Pablo Goldenzweig — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

In recent years, intriguing hints for violation of lepton flavor universality have been accumulated in semileptonic $B$ decays with the help of multiple experiments.

The flavor-changing neutral current process $b \to s\,\tau^+\tau^-$ is particularly sensitive to New Physics models which only couple to the third generation, or with couplings proportional to the particle mass. Some theoretical models allow for an increase in the branching fraction of up to three orders of magnitude compared to the Standard Model prediction, which is within the observable experimental range of the Belle II experiment.

This talk presents the status of the first search for $B^+ \to K^{*+}\tau\tau$ decays, where hadronic tagging is employed. By this, the corresponding $B$ meson partner in $\Upsilon(4S)$ decays is reconstructed in a variety of hadronic decay chains to increase the selection purity.

T 102.4 Thu 16:45 Geb. 30.41: HS 4

**Studies of angular and CP asymmetries in $D^+_{(s)} \to h^+\mu^+\mu^-$ decays at LHCb** — Dominik Mitzel, Serena Maccolini, and •Luca Toscano — TU Dortmund University, Dortmund, Germany

The LHCb experiment has recorded the world's largest sample of charm hadron decays and takes a leading role in measurements of rare decays and searches for CP violation.

Rare semi-leptonic charm decays such as $D^+ \to \pi^+\mu^+\mu^-$ and $D^+_s \to K^+\mu^+\mu^-$ are sensitive to beyond-standard-model effects in flavour-changing neutral current $c \to u\mu^+\mu^-$ transitions. Observables such as angular and CP asymmetries, can be defined to test the Standard Model. Null tests on these observables are performed in the vicinity of intermediate hadronic resonances, where new physics signals can be enhanced.

In this talk, the first study of angular distributions and CP asymmetries in $D^+_{(s)} \to h^+\mu^+\mu^-$ decays is presented. The analysis uses data collected by the LHCb detector from 2015 to 2018 at a centre-of-mass energy of 13 TeV, corresponding to an integrated luminosity of $6\text{fb}^{-1}$. The preliminary results are showed.

T 102.5 Thu 17:00 Geb. 30.41: HS 4

**Studies of resonance-enhanced angular and CP asymmetries in $\Lambda^+_c \to p\mu^+\mu^-$ decays** — •Marco Colonna, Serena Maccolini, and Dominik Mitzel — TU Dortmund University, Dortmund, Germany

The LHCb experiment has collected the largest sample of charm hadron decays, being a leader experiment in studying rare decays and investigating CP violation.

Suppressed semi-leptonic decays of charm baryons, like $\Lambda_c^+ \to p\mu^+\mu^-$, may shed a light on beyond-standard-model effects appearing in $c \to u\mu^+\mu^-$ transitions. Performing measurements of null test observables, like angular and CP asymmetries in the phase space regions where the physics signal is enhanced by the contribution of intermediate hadronic resonaces, allows to scrutinize the prediction of the Standard Model.

The talk presents the analysis and the methods applied to measure for the first time the CP and angular asymmetries of the $\Lambda_c^+ \to p\mu^+\mu^-$ decay in the phase space region dominated by the $\phi$ resonance contribution. The analysis uses data collected by the LHCb detector from 2016 to 2018 at a centre-of-mass energy of 13 TeV, corresponding to an integrated luminosity of 6fb$^{-1}$.

T 102.6 Thu 17:15 Geb. 30.41: HS 4

**Measurement of $\mathscr{R}(D)$ and $\mathscr{R}(D^*)$ with semileptonic tagging at Belle II** — Florian Bernlochner, Jochen Dingfelder, Peter Lewis, and •Alina Manthei — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

The Belle II experiment at the SuperKEKB asymmetric-energy collider, where electrons and positrons are collided at the $\Upsilon(4S)$ resonance, is able to collect a large number of events with $B\overline{B}$ pairs. The analysis of semitauonic decays of these $B$ mesons allows for tests of lepton flavour universality.Existing experimental results on the ratios of the branching fractions $\mathscr{R}(D) = \mathscr{B}(\overline{B} \to D\tau^-\overline{\nu})/\mathscr{B}(\overline{B} \to D\ell^-\overline{\nu})$ and $\mathscr{R}(D^*) = \mathscr{B}(\overline{B} \to D^*\tau^-\overline{\nu})/\mathscr{B}(B^* \to D\ell^-\nu^-)$, where $\ell$ denotes an electron or muon, are in tension with the Standard Model (SM) predictions, which might hint at physics beyond the SM, such as the presence of charged Higgs bosons or leptoquarks. A combined analysis of $\mathscr{R}(D)$ and $\mathscr{R}(D^*)$ with measurements from Belle, BaBar and LHCb yields a divergence from the SM prediction by $> 3\sigma$, where $\sigma$ indicates the standard deviation. Thus, further investigations of these decays with the recently collected data by Belle II are necessary. In order to measure the semitauonic $B$ decay as exact as possible, a reconstruction of the respective other $B$ meson in the event in semileptonic modes is performed, a technique known as tagging. In this talk, a signal extraction strategy for such a measurement of $\mathscr{R}(D^{(*)})$ using these data will be outlined and its results will be presented.

T 102.7 Thu 17:30 Geb. 30.41: HS 4

**Improving $\mathrm{R}(\mathrm{D}^{(*)})$ with hadronic FEI and leptonic tau decays with Belle II Run 1 data.** — •Agrim Aggarwal, Florian Bernlochner, Jochen Dingfelder, and Markus Prim — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

In the Standard Model (SM) of particle physics, the W boson couples identically to the three lepton flavors. This concept is known as Lepton Flavor Universality (LFU). In extensions of the SM, additional particles, which couple to the $b-c-\tau-\nu_\tau$ vertex, are able to modify the coupling to the three lepton flavors. At Belle II, this can be studied using $B \to D^{(*)}\tau\bar{\nu}_\tau$ decays and by probing ratios of the form $\mathrm{R}(D^*) = \mathscr{B}(B \to D^{(*)}\tau\bar{\nu}_\tau)/\mathscr{B}(B \to D^{(*)}\ell\bar{\nu}_\ell)$. We present the current status of an improved analysis strategy to determine $\mathrm{R}(D^*)$ using 364 fb$^{-1}$ of integrated luminosity of Run 1 collision data of the Belle II experiment.

T 102.8 Thu 17:45 Geb. 30.41: HS 4

**Measurement of the branching ratio and $q^2$-spectrum of $B \to D^{**}\ell\nu$ decays at Belle II** — •Eylül Ünlü, Thomas Lück, and Thomas Kuhr — Ludwig-Maximilians-Universität München

There is currently some tension between the measured value of $R(D^*) = \mathscr{B}(B \to D^*\tau\nu_\tau)/\mathscr{B}(B \to D^*\ell\nu_\ell)$ and the Standard Model prediction, hinting at lepton universality violation. Semileptonic $B$ meson decays to $D^{**}$ mesons are background to the $R(D^*)$ measurement, where $D^{**}$ denotes the orbitally excited P-wave charm mesons: $D_1(2420)$, $D_2^*(2460)$, $D_0^*(2300)$, and $D_1^{'}(2430)$. These decays are not well understood, and there are discrepancies between past measurements of their yields by BaBar and Belle. Hence, improved understanding of these decays would reduce the systematic uncertainty on $R(D^*)$ measurements.

The aim of the present study is to use simulation and data from the Belle II experiment to study these decays, in particular to determine the $q^2$ spectrum, which is a key input for theory.

We reconstruct one of the $B$ mesons from the $\Upsilon(4S) \to BB$ decay in the signal channel, $B \to D^{**}(D^*\pi)\ell\nu$. The other $B$ meson is reconstructed in hadronic decay channels using the Full Event Interpretation algorithm, which provides a tag $B$ sample with well determined kinematics. The signal yield is obtained by a fit to the mass difference $M(D^*\pi) - M(D^*)$. The resulting $q^2$ spectrum is fitted by a differential decay rate model after correcting for detector resolution effects.

The current status of the analysis will be presented including results on simulation and some sources of systematic uncertainty.

# T 103: Top physics 4 (tt+X)

Time: Thursday 16:00–18:00 Location: Geb. 30.95: Audimax

T 103.1 Thu 16:00 Geb. 30.95: Audimax

**Separation of events with three top quarks from events with four top quarks** — Steffen Korn, •Sophia Pennuttis, Arnulf Quadt, and Sreelakshmi Sindhu — Georg-August-Universität Göttingen

The production of three top quarks in the Standard Model is only possible in association with a W boson or a quark, making it challenging to separate the process from the four top production process. Both of these processes are sensitive to the top-Higgs Yukawa coupling, the precise measurement of which is important to identify evidence for physics beyond the Standard model (BSM). Furthermore, their cross-sections could be enhanced by various BSM effects, like flavour-changing neutral currents. While the production process of four top quarks has already been observed by ATLAS and CMS, the measurement of the much rarer three top production has not been possible yet. The ability to separate the two processes is a prerequisite to the observation of three top production in a combined measurement. To achieve this, neural networks are trained on various kinematic variables considering final states with two same sign leptons and those with at least three leptons, using the LHC Run2 and Run3 datasets.

T 103.2 Thu 16:15 Geb. 30.95: Audimax

**Classification of $t\bar{t}$+X (heavy flavour) processes at the CMS experiment** — •Rufa Kunnilan Muhammed Rafeek[1], Ulrich Husemann[1], Emanuel Pfeffer[1], Jan van der Linden[2], and Michael Wassmer[1] — [1]Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT) — [2]Institute of Experimental Particle Physics and Gravity, Ghent University (BE)

Top quark - antiquark pairs ($t\bar{t}$) produced in association with other particles (X) where X can be the Higgs boson, Z/W boson or QCD-initiated heavy flavour jets ($b\bar{b}/c\bar{c}$), plays a significant role in experimental studies at the LHC.

The analysis is challenging as these processes, particularly when the bosons decay into heavy flavour quarks, like for example, $t\bar{t} + H(H \to b\bar{b})$ and $t\bar{t} + b\bar{b}$ or $t\bar{t} + Z(Z \to b\bar{b})$, share the same signature and kinematic features. These high jet multiplicity final states create ambiguities in the reconstruction and identification of these processes and thus, it is hard to differentiate them from each other. The complex task of simultaneously measuring these $t\bar{t} + X$ processes is made by exploring advanced machine learning techniques such as Graph Neural Networks. The primary objective is to distinguish the additional heavy flavour jets, treated as a binary classification task, from the one originating in the $t\bar{t}$-system. This differentiation is crucial for subsequent multi-class event classification, encompassing categories such as $t\bar{t} + b\bar{b}$, $t\bar{t} + H(b\bar{b})$, $t\bar{t} + Z(b\bar{b})$ and $t\bar{t} + c\bar{c}$.

In this talk the current status of such a measurement for the separation of these events, using the $t\bar{t}$ single lepton channel is presented.

T 103.3 Thu 16:30 Geb. 30.95: Audimax

**t$\bar{\text{t}}$+heavy flavor event classification with graph neural networks at the CMS experiment** — •Emanuel Pfeffer[1], Ulrich Husemann[1], Rufa Rafeek[1], Jan van der Linden[2], and Michael Wassmer[1] — [1]Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT) — [2]Institute of Experimental Particle Physics and Gravity, Ghent University (BE)

Processes in which a top quark-antiquark pair is produced in association with additional heavy flavor jets are difficult to separate from each other. Such processes include $\mathrm{t\bar{t}+b\bar{b}}$ and $\mathrm{t\bar{t}+c\bar{c}}$, where the additional heavy flavor quark-antiquark pair stems from gluon splitting, as well as $\mathrm{t\bar{t}+H}$ with $\mathrm{H \to b\bar{b}}$ and $\mathrm{t\bar{t}+Z}$ with $\mathrm{Z \to b\bar{b}}$. Machine learning methods based on graph neural networks are promising techniques for enhancing the classification accuracy of these events in the t$\bar{\text{t}}$+heavy flavor phase space. In this talk the latest status of a simultaneous measurement of the production cross section of a top quark-antiquark pair in association with heavy flavor jets in the dileptonic decay channel at the CMS experiment is presented.

T 103.4 Thu 16:45 Geb. 30.95: Audimax

**Inclusive cross-section measurements of top-quark pair production in association with charm quarks with the ATLAS experiment** — •Matthew Kingston, Arnulf Quadt, and Elizaveta Shabalina — II. Physikalisches Institut, Georg-August-Universität Göttingen

The production of top-quark pairs in association with charm quarks is an irreducible background to rare final states such as $t\bar{t}H$ and $t\bar{t}t\bar{t}$, as well as being a particular challenge for QCD modelling due to the uncertainties in the choice of factorisation and renormalisation scales. The first ATLAS measurement of the inclusive total and fiducial cross-section of this process is performed using data corresponding to an integrated luminosity of 140 fb$^{-1}$, collected by the ATLAS experiment at the LHC between 2015 and 2018 at a centre-of-mass energy of

13 TeV. Measurements are performed in both the dileptonic and semi-leptonic channels, and their combination. A custom heavy-flavour tagging algorithm is used to distinguish jets originating from $b$ and $c$ quarks, based on the standard ATLAS DL1r tagger. This presentation will focus on the work done to understand systematic uncertainties. The measurements of the cross-section as well as of the ratio of $t\bar{t}+ \geq 2c$ and $t\bar{t} + 1c$ production over inclusive production of $t\bar{t}$+jets are compared with predictions of the state-of-the-art NLO+PS Monte Carlo simulations of $t\bar{t}$ production.

T 103.5 Thu 17:00 Geb. 30.95: Audimax

**joint $ttZ$ and $tZq$ measurement** — Steffen Korn, •Sebastian Preuth, Arnulf Quadt, Baptiste Ravina, and Elizaveta Shabalina — II. Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen, Germany

Single top ($tZq$) and top pair production ($ttZ$) in association with a $Z$ boson are important channels for studying the electroweak sector and potential deviations from Standard Model predictions. The two signals are measured jointly in the reprocessed Run 2 dataset, using an analysis model compatible with a future Run 3 measurement. The dataset, corresponding to a centre-of-mass energy of 13 TeV and an integrated luminosity of 140 fb$^{-1}$, is used to extract the $ttZ$ and $tZq$ production cross sections and set constraints on the top-$Z$ couplings. The analysis targets final states with three leptons and additional $b$-jets. To improve the background estimation, which is dominated by diboson production, neural networks are used.

T 103.6 Thu 17:15 Geb. 30.95: Audimax

**Prospects for ttW in Run3** — Steffen Korn, •Tobias Moritz, and Arnulf Quadt — II. Physikalisches Institut, Georg-August-Universität Göttingen

The process, where a top-quark anti-top pair is produced in association with a $W$-boson ($t\bar{t}W$), was first observed by ATLAS and CMS in Run 1 of the LHC. First differential cross-section measurements and precision inclusive measurements only became available with Run 2 of the LHC and show some friction between the theory prediction and the measured cross-section.

$t\bar{t}W$ is one of the heaviest final state that is accessible at the LHC and produced via quark-antiquark annihlation at leading order. The $W$-boson is emitted by either particle in the initial state. $t\bar{t}W$ has a relatively small cross-section. Nonetheless, it is an important background for other searches at the LHC, as it is one of the few irreducible sources of same-sign lepton pairs.

In order to prepare for a Run 3 analysis of $t\bar{t}W$ new MC samples need to be produced corresponding to the higher center-of-mass energy of $\sqrt{s} = 13.6$ TeV and the upgrades to the ATLAS detector. This talk will present ongoing efforts concerned towards a Run 3 analysis.

T 103.7 Thu 17:30 Geb. 30.95: Audimax

**Reinterpretation of the recent ATLAS $t\bar{t}W$ measurement in the framework of the SMEFT** — Marcel Niemeyer, Arnulf Quadt, Baptiste Ravina, Elizaveta Shabalina, and •Sreelakshmi Sindhu — II. Physikalisches Institut, Georg-August-Universität Göttingen, Germany

The Standard Model Effective Field Theory (SMEFT) provides a model independent approach to study beyond the Standard Model effects. A search for new physics using the framework of the SMEFT is performed using events with one or two top quarks in association with a boson ($t\bar{t}W$, $t\bar{t}Z$, $tZ$, $t\bar{t}H$, $tH$). The simultaneous analysis of these processes gives the opportunity to constrain a large number of dimension six SMEFT operators.

In this analysis, final states with two same sign or three isolated leptons are selected and classified into various regions based on the number of leptons, jets, b-jets and the total charge of the leptons. Using the event yields in these regions, limits are extracted on the SMEFT operators. This measurement is performed using the proton-proton collision data at $\sqrt{s} = 13$ TeV with an integrated luminosity of 139 fb$^{-1}$, recorded from 2015 to 2018 with the ATLAS experiment at the Large Hadron Collider at CERN.

T 103.8 Thu 17:45 Geb. 30.95: Audimax

**Fitting SMEFT with a CLEW** — •Tom Tong — Universität Siegen

Semileptonic charged-current interactions are crucial for exploring the nuances of the Standard Model and its possible extensions. Recent examinations have underscored discrepancies with the SM predictions, particularly in the Cabibbo Angle Anomaly (CAA), which demonstrates a 3 sigma deviation from zero. In this paper, we undertake a rigorous analysis using the SMEFT framework to shed light on potential BSM sources of the CAA. By integrating insights from collider processes (C), low-energy processes (L), and electroweak precision observables (EW), we introduce a holistic CLEW approach. Our analysis underscores the significance of a global CLEW perspective in vetting BSM propositions that align with observations across scales, from the weak to the TeV range. While our initial impetus revolves around the CAA, our findings naturally establish a foundational CLEW framework, poised to significantly influence future SMEFT investigations, especially those sidelining severe phenomenological constraints, including FCNCs and CP violations. We will touch upon preliminary results within the ambit of the U(3)^5 flavor assumption, followed by an in-depth exploration of a flavor-assumption-independent analysis. In this broader analysis, we have incorporated the Akaike Information Criterion (AIC). When combined with the chi-square method, the AIC promotes a model that not only aligns well with experimental data but also circumvents unnecessary complexities, accentuating the challenges and prospective avenues for model-independent global analyses.

## T 104: Members' Assembly

Time: Thursday 19:00–20:00 Location: Geb. 30.22: Lehmann-HS

**All members of the Particle Physics Division are invited to participate. Pretzels and drinks will be provided.**

## T 105: Search for new particles 6

Time: Friday 9:00–10:30 Location: Geb. 20.30: 1.067

T 105.1 Fri 9:00 Geb. 20.30: 1.067

**The Search for Electric Dipole Moments of Charged Particles in Storage Rings** — •Achim Andres for the JEDI-Collaboration — IKP, Jülich, Germany

The matter-antimatter asymmetry in the universe, unexplained by the Standard Model of elementary particle physics, requires CP-violating phenomena, as proposed by A. Sakharov. Subatomic elementary particles with Permanent Electric Dipole Moments (EDMs) violate time reversal and parity asymmetries, implicating CP violation if the CPT theorem holds. In addition, the axion or axion like particles (ALPs), initially proposed to explain CP violation in quantum chromodynamics and potentially constituting dark matter, induce an oscillating Electric Dipole Moment (EDM) along the spin direction when coupled with gluons.

The Cooler Synchrotron COSY at Forschungszentrum Jülich provides polarized and unpolarized protons and deuterons up to a momentum of 3.7 GeV/c and serves as an ideal platform for the JEDI - Collaboration (Jülich Electric Dipole moment Investigations) to conduct the first direct measurement of the permanent deuteron EDM by observing its influence on spin motion. In addition to this measurement of the static EDM, upper limits of the oscillating deuteron EDM due to Axions or ALPs have been measured. Both effects result in a build-up of a vertical polarization component which can be measured with a polarimeter. This presentation will describe both the permanent EDM and the oscillating axion-induced EDM experiments.

T 105.2 Fri 9:15 Geb. 20.30: 1.067

**King Plots: Constraining New Physics using Isotope Shift Spectroscopy** — •Agnese Mariotti[1], Erik Benkler[2], Julian Berengut[8], Shuying Chen[2], Jose R. Crespo Lopez-Urrutia[3], Melina Filzinger[2], Elina Fuchs[1,2,4], Nils Huntemann[2], Steven A. King[2], Fiona Kirk[2], Nils H. Rehbehn[3], Jan Richter[2], Matteo Robbiati[4,6,7], Micheal K. Rosner[3], Piet O. Schmidt[2,5], Lucas J. Spiess[2], Andrey Surzyhkov[2], Anna Viatkina[2], Malte Wehrheim[2], Alexander Wilzewski[2], Diana A. Craik[9], Jeremy Flannery[9], Jonathan Home[9], Luca Huber[9], Roland Roland[9], Menno Door[3], Klaus Blaum[3], and Martin R. Steinel[2] — [1]LUH-ITP — [2]PTB — [3]MPI — [4]CERN — [5]LUH-IQ — [6]TIF Lab — [7]TII — [8]UNSW — [9]ETH/TBD

With 95% of the universe's content still unexplained by modern physics, the motivations for new physics searches are becoming more and more evident. The approach used in our work exploits the high precision of low-energy experiments to identify deviations from the theoretical predictions of the Standard Model. We utilize a combination of isotope shift measurements and King plots, which allows to minimize the required theoretical input and is sensitive to a new interaction that couples electrons and neutrons. A wise combination of experimental data enables us to set strong constraints on such coupling. Here, we show how we improve the previous bounds by building King plots with the recent measurement of isotope shift in Ca14+, carried out at PTB. Additionally, we present two ways of utilizing the available data: a geometrical approach and a fitting method.

T 105.3 Fri 9:30 Geb. 20.30: 1.067

**Search for new light bosons with the KATRIN experiment** — •Joscha Lauer for the KATRIN-Collaboration — Karlsruhe Institute of Technology (KIT)

The Karlsruhe Tritium Neutrino (KATRIN) experiment is designed to measure the effective electron antineutrino mass with a sensitivity better than $m_\nu c^2$ = 0.3 eV (90% C.L.) in a kinematic approach by applying precision electron spectroscopy to the beta decay of molecular tritium. This determination occurs in the spectral endpoint ($E_0$) region, i.e. up to some tens of eV below $E_0 \approx 18.6$ keV.

Light neutral pseudoscalars and vector bosons arise in many theories beyond the Standard Model (BSM). Constraints on the couplings of such particles to neutrinos or electrons can be derived from cosmological, astrophysical and laboratory observations. High-statistics beta spectroscopy with KATRIN is a complementary probe for these new physics theories; with light bosons emitted in tritium beta decay, the spectrum is altered as described in JHEP 01 (2019) 206. This talk introduces possible interactions of light BSM bosons with their imprint on the observed electron spectrum. We estimate the sensitivity of the second KATRIN measurement campaign to the light boson couplings.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 105.4 Fri 9:45 Geb. 20.30: 1.067

**New physics searches with the precision spectroscopy of highly charged ions** — •Matteo Moretti, Zoltan Harman, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

High-precision spectroscopy of bound-electron systems enables searches for new physics. The comparison of precisely measured observables such as transition energies or $g$ factors with sufficiently accurate quantum electrodynamic (QED) calculations allows in principle the isolation of effects due to physics beyond the Standard Model. Recently, such a procedure was applied to set a bound on the coupling constant of a massive scalar boson exchanged between an electron and a nucleon [1,2]. Here we develop a one-particle exchange interaction among two bound electrons in a highly charged ion. The simplest way to treat this interaction is through the involvement of a massive scalar particle among electrons in the $1s$–$2s$ states. The correction due to this effect to $g$ factor is evaluated for three-electron ions, i.e. for the simplest electronic systems possessing net electron spin. For such ions, both QED theory and experiment are on a high level of sophistication, therefore, we anticipate competitive bounds for the coupling constant. Further studies are being performed for pseudo-scalar, vector and axial-vector exchange bosons. – [1] V. Debierre, C. H. Keitel, Z. Harman, Phys. Lett. B **807**, 135527 (2020); [2] T. Sailer, V. Debierre, Z. Harman, *et al.,* Nature **606**, 479 (2022).

T 105.5 Fri 10:00 Geb. 20.30: 1.067

**Fifth-force searches with the bound-electron $g$ factor** — •Zoltan Harman, Vincent Debierre, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

The use of high-precision measurements of the $g$ factor of one- and few-electron ions and its isotope shifts is put forward as a probe for beyond Standard Model (BSM) physics [1]. The contribution of a hypothetical new force to the $g$ factor can be calculated for H-like, Li-like and B-like ions, and employed to derive bounds on the parameters of such a force. This procedure makes use of the high level of sophistication reached in the evaluation of QED contributions to the $g$ factor of highly charged ions [2]. The weighted difference, and, particularly, the isotope shift of $g$ factors are used to increase the experimental sensitivity to the new physics contribution. We have found that a recent Penning-trap measurement of the isotopic shift of the $g$ factor of the isotopes $^{20}Ne^{9+}$ and $^{22}Ne^{9+}$ to sub-parts-per-trillion precision relative to their $g$ factors offers a promising alternative approach to set bounds on BSM interactions [3]. Furthermore, it is found that, combining measurements from different isotopes of H-like, Li-like and B-like ions [1] at accuracy levels projected to be accessible in the near future, experimental results would constrain the new physics coupling constant further than the best current atomic data and theory. – [1] V. Debierre, C. H. Keitel, Z. Harman, Phys. Lett. B **807**, 135527 (2020); [2] J. Morgner, B. Tu, C. M. König, *et al.,* Nature **622**, 53 (2023); [3] T. Sailer, V. Debierre, Z. Harman, *et al.,* Nature **606**, 479 (2022).

T 105.6 Fri 10:15 Geb. 20.30: 1.067

**Sensitivity of magnetic monopole detection at the Belle II PXD** — •Matthäus Krein, Katharina Dort, and Sören Lange — Justus-Liebig-University, Gießen, Germany

Particles with isolated magnetic charge, so-called magnetic monopoles, are of high experimental and theoretical interest. As most theories predict a high energy loss of these particles in matter, magnetic monopoles, which could be produced in collider experiments, would only reach the inner detectors close to the interaction point. The Belle II pixel detector, which has a minimum radial distance of only 1.4 cm from the interaction point, is therefore well suited for detection. In this contribution, we focus on light monopoles of below 1 GeV and present the sensitivity to these particles at Belle II. Our analysis uses so-called autoencoder neural networks for background suppression. Our study predicts exclusion limits on the order of $10^{-39}$ cm$^2$, which are competitive to established limits.

This research is supported by BMBF (05H21RGKB1) and Horizon2020 European Union Marie Slodowska Curie Action in the RISE program (n.822070).

## T 106: Search for new particles 7

Time: Friday 9:00–10:15 Location: Geb. 20.30: 2.058

T 106.1 Fri 9:00 Geb. 20.30: 2.058

**The Lohengrin Experiment at the ELSA Accelerator** — •Matthias Hamer for the Lohengrin-Collaboration — Physikalisches Institut der Universität Bonn, Nussallee 12, 53115 Bonn

The particle nature of dark matter remains one of the great mysteries in elementary particle physics. The dark matter relic density constrains the masses of weakly interacting massive particles (WIMPs) to values larger than a few GeV (Lee-Weinberg bound). With the negative results from collider and direct searches for WIMPs, so-called dark sector models with significantly lighter dark matter candidates have received increasing interest in the past years.

In some minimal models, the dark sector contains a new vector boson that mediates a new U(1) gauge interaction. This new vector boson couples to the dark matter particles, which are either scalars or fermions. In addition, it can mix with the SM electroweak gauge bosons, enabling a very weak coupling to electrically charged particles. The new mass eigenstate is called dark photon and it can, if the mixing is strong enough, be produced through a SM bremsstrahlung like process, e.g. by scattering electrons off a nuclear target.

In this talk I will present the layout and potential physics reach of a new experiment that we propose to set up at the ELSA accelerator in Bonn - the Lohengrin experiment. The discovery reach of the Lohengrin experiment will cover dark photon masses of up to 50 MeV and couplings that can fully explain the relic density for scalar and fermionic dark matter particles, exceeding current limits and projections for other experiments.

T 106.2 Fri 9:15 Geb. 20.30: 2.058

**Tracking with `Acts` for Lohengrin - A fixed target dark photon search experiment** — •Jan-Eric Heinrichs for the Lohengrin-Collaboration — Universität Bonn

The true nature of dark matter (DM) has long been of interest for scientists worldwide. Previous searches have so far been unsuccessful in finding proposed DM particles. A promising and not well explored family of DM models contains dark matter particles with masses below ≈1 GeV connected through a portal interaction to the standard model (SM). This portal can be realized via a new vector boson mediating a U(1) gauge interaction, the dark photon. One possible search strategy is looking for the production of dark photons in a process similar to SM bremsstrahlung in a fixed target experiment.

This talk highlights some aspects of Lohengrin, a proposed fixed target experiment at the ELSA accelerator in Bonn. One of the key factors for the discovery potential of the experiment is the precise tracking of low momentum electrons. Electrons mainly loose energy via bremsstrahlung, which is notoriously difficult to correctly parametrize in tracking algorithms due to its non-gaussian nature. I will show first results of using `Acts` (A Common Tracking Software) to tackle this problem. `Acts` is a generalized tracking framework currently under development in international collaboration. The key element to enhance electron tracking is a gaussian sum filter. I will show necessary steps to adapt the framework to telescope like detector geometries. First preliminary results for the implementation and performance will be shown.

T 106.3 Fri 9:30 Geb. 20.30: 2.058

**Search for single Vector-Like Quarks with the Run 2 data of the CMS experiment** — •Di Wang — Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg

As an extension of the standard model, Vector Like Quarks provide a possible solution to various unsolved issues, such as the hierarchy problem. This analysis focuses on the single production of the vector-like top quark $T'$, in the decay channel $T' \rightarrow tH$ ($H \rightarrow WW$), in the final state with two opposite sign leptons. The analysis is based on data collected by CMS Run 2, corresponding to an integrated luminosity of 137 fb$^{-1}$. The di-lepton final state includes the di-electron channel, the di-muon channel, and the electron-muon channel. A cut-based event selection strategy was designed, followed by a mass reconstruction method based on the $\chi^2$ sorting algorithm and neutrino kinematic approximations. A preliminary data-MC comparison and limits based on MC data will be presented.

T 106.4 Fri 9:45 Geb. 20.30: 2.058

**Dark Showers with the Herwig Generator** — Suchita Kulkarni[1], Simon Plätzer[1], and •Dominic Stafford[2] — [1]University of Graz, Graz, Austria — [2]DESY, Hamburg, Germany

Most dark matter searches at the LHC focus on models where dark matter is a single stable particle, leading to traditional "MET+X" type searches. However recent years have shown a growing interest in "dark sector" which have a more complex internal structure. One such model is "dark showers", in which the particles in the dark sector interact with each other via a strong force similar to QCD in the Standard Model, which leads to the formation of "dark hadrons", some of which are stable DM candidates, and others of which decay to SM particles. This can give rise to unconventional experimental signatures, such as semi-visible and emerging jets.

Accurately simulating these dark showers is challenging since the hadronisation step is non-perturbative, and described by semi-empirical models, which require tuning to Standard Model data. However so far no extensive studies have been performed to determine the impact of hadronisation uncertainties on these types of models. In this talk I will describe the implementation of this dark shower model into the Herwig 7 Monte Carlo generator, where this can improve on the predictions in the existing Pythia hadronisation model, and how one can use variations of the Herwig hadronisation parameters to obtain an estimate of the hadronisation uncertainties for these dark shower models.

T 106.5 Fri 10:00 Geb. 20.30: 2.058

**Validating Sherpa for New Physics Simulations in Diboson Processes** — •Maren Bühring[1], Frank Siegert[2], Lisa Marie Lehmann[3], Diana Mareen Hoppe[4], and Erik Bachmann[5] — [1]IKTP Dresden — [2]IKTP Dresden — [3]IKTP Dresden — [4]IKTP Dresden — [5]IKTP Dresden

The Monte Carlo event generator Sherpa enables the simulation of high-energy particle collisions, like the ones recorded by the ATLAS detector at the Large Hadron Collider. One of Sherpa's features is its compatibility with models formulated in the Universal FeynRules Output (UFO) format. These UFO models make simulations based on physics beyond the Standard Model possible. Presented here are the results of validation tests performed using two seperate UFO models: Sherpa's use of the SMEFTsim model was tested in the context of a Vector Boson Scattering process, and the inclusion of the HHVBF_UFO model was tested using a process involving a triple Higgs coupling. The tests are based on consistency within Sherpa, as well as comparisons with events generated with the MadGraph5_aMC@NLO event generator.

# T 107: Cosmic rays 7

Time: Friday 9:00–10:30 Location: Geb. 20.30: 2.059

T 107.1 Fri 9:00 Geb. 20.30: 2.059

**Towards the measurement of seasonal variations in the atmospheric muon spectrum** — •Samuel Haefs and Karolin Hymon for the IceCube-Collaboration — Astroparticle Physics WG Rhode, TU Dortmund University, Germany

Atmospheric muons are produced when cosmic rays interact with nuclei in the Earth's atmosphere. These interactions produce secondary particles, mainly pions and kaons. These secondary particles either interact with other nuclei or decay into muons and neutrinos, forming an air shower. The muons can be detected by the IceCube Neutrino Observatory. This observatory is located at the South Pole, 1450m to 2450m deep in the Antarctic ice. High-energy muons passing through the ice produce Cherenkov light, which is then detected by the optical modules of the detector. Seasonal variations in atmospheric muon flux are influenced by changes in atmospheric temperature and pressure. This work addresses these fluctuations using a deconvolution technique called funfolding, which employs Markov Chain Monte Carlo (MCMC) methods for unfolding.

Supported by BMBF (ErUM) and DFG (SFB 1491)

T 107.2 Fri 9:15 Geb. 20.30: 2.059

**Enhanced photon triggers using the underground muon detector of AugerPrime** — Linda Hofmann and •David Schmidt for the Pierre-Auger-Collaboration — Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

We present a method for increasing the aperture of the Pierre Auger Observatory for ultra-high-energy photons with energies exceeding a couple dozen PeV. The method involves lowering the trigger thresholds of individual water-Cherenkov detector stations when their partner underground muon detectors measure below a certain number of muons. This increases the detection efficiency for muon-poor photon primaries while mitigating otherwise significant increases in the total rate of event-level triggers due to the steep fall off of the cosmic ray energy spectrum. A detailed evaluation of the method is presented for the $23.5\,\mathrm{km}^2$ dense sector of the observatory's surface detector array, where the spacing between individual 12-ton water-Cherenkov detectors is 750 m, and where each detector position is currently also being equipped with a $30\,\mathrm{m}^2$ buried muon counter.

T 107.3 Fri 9:30 Geb. 20.30: 2.059

**Adding interferometric lightning detection to the Pierre Auger Observatory** — •Melanie Joan Weitz for the Pierre-Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal, Germany

The Pierre Auger Observatory has detected high-energy events with its Surface Detector in times of thunderstorms. The observed events indicate a connection to terrestrial gamma ray flashes (TGFs). A key to understanding this high-energy radiation in thunderstorms is to combine such measurements with measurements of lightning processes in their earliest stages. With small modifications of Auger Engineering Radio Array (AERA) stations we can build an interferometric detector to precisely measure the lightning stepped leaders in 3D. This will allow us to decipher atmospheric high-energy models and clarify the reason for the observed high-energy particles in thunderstorms. We will demonstrate the capabilities of the current stations for lightning measurements and show the status of the current detection plans.

*Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)*

T 107.4 Fri 9:45 Geb. 20.30: 2.059

**Measurement of the composition of cosmic rays and proton-proton interaction cross section at ultrahigh energies with the Pierre Auger Observatory** — •Olena Tkachenko for the Pierre-Auger-Collaboration — Karlsruhe Institute of Technology, Karlsruhe, Germany

We present a combined estimate of the cosmic-ray mass composition and particle interaction cross sections from the distributions of shower maximum ($X_{\mathrm{max}}$), measured with the fluorescence detector of the Pierre Auger Observatory. For this purpose, we adjust fractions of cosmic-ray mass groups to fit the data with $X_{\mathrm{max}}$-distributions from air shower simulations. In addition to the fractions, we fit for the proton-proton cross section at ultrahigh energies, from which simulations with modified nucleus-air cross sections are obtained via Glauber theory. Whereas previous analyses either fit the composition assuming the validity of hadronic interaction models or derived the cross sections assuming a particular composition, the combined fit presented in this contribution is the first self-consistent analysis of both quantities. We will present the resulting energy-dependent composition fractions and the ultrahigh-energy proton-proton interaction cross section and compare them to previous analyses and model extrapolations of low-energy accelerator data.

T 107.5 Fri 10:00 Geb. 20.30: 2.059

**The paleo-detectors technique applied to cosmic rays** — •Lorenzo Apollonio[1], Lorenzo Caccianiga[2], Claudio Galelli[3], Alessandro Veutro[4], and Paolo Magnani[1] — [1]Universita degli Studi di Milano — [2]Istituto Nazionale di Fisica Nucleare — [3]Laboratoire Univers et Théories, Observatoire de Paris, Université PSL, Université Paris Cité — [4]Universita di Roma La Sapienza

The paleo-detector technique proposes to use long-age minerals, which have been exposed to an enormous flux of particles, as astroparticle detectors. Some of these particles should have interacted with mineral nuclei, generating linear defects in the crystalline structure in the form of tracks. The paleo-detectors have been proposed to detect dark matter and neutrinos, using minerals found well deep in the ground, shielded by the cosmic rays. These studies take advantage of the enormous exposure, even to these rare events, that can be acquired through age with a small amount of material. By contrast, we propose to use the paleo-detectors as cosmic rays detectors. Since the cosmic rays can be shielded, we can find optimal exposure windows during which the minerals were exposed to the flux and then shielded. We take as example the dessication of the Mediterranea Sea during the Messinian (~ 6 Myr ago). After the dessication, several evaporites were formed, exposed to the flux of cosmic rays (for ~ 300 kyr) and then submerged again. The large amounts of tracks expected is enough to measure the variation of 1% of the flux, making this technique optimal to identify a potential transient events happened during the exposure window.

T 107.6 Fri 10:15 Geb. 20.30: 2.059

**Cosmic-ray tomography for a safe & secure harbor** — •Maximilian Perez Prada, Angel Bueno Rodriguez, Maurice Stephan, and Sarah Barnes — German Aerospace Center (DLR), Institute for the Protection of Maritime Infrastructures, Fischkai 1, 27572 Bremerhaven, Germany

Cosmic-ray tomography (CRT) is emerging as a promising non-destructive testing technology for a rising number of potential applications: study of archaeological or geological sites, additional tool in safeguards and border protection, new forms of inspection in civil engineering, and many more. Muon scattering tomography is one technique within the domain of CRT to infer target material properties by utilizing the path deflection of cosmic muons resulting from Coulomb scattering processes.

The Institute for the Protection on Maritime Infrastructures of the German Aerospace Center (DLR) contributes to the development of this technology to enhance safety and security in the maritime domain. Currently two promising methods within the application of muon scattering tomography for shipping container scanning are studied: the analysis of secondary particles for the reconstruction of the container content on top of the results from muon scattering measurements, and the usage of automized anomaly detection algorithms for more efficient container processing. The methods themselves, as well as their current status and results will be explained and presented. Furthermore, an outlook into future applications in the maritime domain, as well as in the scope of safety and security will be given.

# T 108: Methods in particle physics 6

Time: Friday 9:00–10:30 Location: Geb. 20.30: 2.066

T 108.1 Fri 9:00 Geb. 20.30: 2.066

**The current status of the Mu2e experiment at Fermilab** — •Stefan E. Müller, Anna Ferrari, Oliver Knodel, and Reuven Rachamin for the Mu2e-Collaboration — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

The Mu2e experiment, which is currently under construction at the Fermi National Accelerator Laboratory near Chicago, will search for the neutrinoless conversion of muons to electrons in the field of an aluminum nucleus. This process, which violates charged lepton flavor, is highly suppressed in the Standard Model and therefore undetectable. However, scenarios for physics beyond the Standard Model predict small but observable rates. The Mu2e experiment aims for a sensitivity four orders of magnitude better than previous experiments. This is achieved by a rigorous control of all backgrounds that could mimic the monoenergetic conversion electron signal.

In the presentation, the design and status of the Mu2e experiment and its detector subsystems will be presented.

T 108.2 Fri 9:15 Geb. 20.30: 2.066

**The Camera Alignment System for the Mu3e Experiment** — •Sophie Gagneur — Johannes Gutenberg-Universität Mainz

The Mu3e experiment under construction at the Paul Scherrer Institute, Switzerland, aims to search for the lepton flavour violating decay of a muon into one electron and two positrons with an ultimate sensitivity of one in $10^{16}$ muon decays. The Mu3e detector consists of High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) for an accurate track and vertex reconstruction complemented with scintillating tiles and fibres for precise timing measurements. In order to achieve the high sensitivity goal, special attention must be paid to the exact alignment of the detector elements. Misalignment may occur not only due to the construction or integration of the different detector parts but may also be caused by environmental influences during the operation of the experiment. To reduce the effects of misalignment and to achieve the best possible momentum resolution, a track-based alignment program is used. With the help of this tool, however, certain deformations of the detector that produce the same track quality, the so-called weak modes, cannot be resolved. To compensate for this, an optical system based on 18 camera modules is also being developed. In combination with high contrast optical fiducials, the cameras determine their positions among each other and to the different detector elements. At the moment several combinations of camera settings and different fiducials are being tested in order to achieve a sufficient precision to fulfil the experimental objectives.

T 108.3 Fri 9:30 Geb. 20.30: 2.066

**Status of the Mu3e Tile detector** — •Elizaveta Nazarova, Konrad Briggl, Hans-Christian Schultz-Coulon, Jan Küpperbusch, Erik Steinkamp, and Anna Dunz for the Mu3e-Collaboration — Kirchhoff Institut für Physik, Universität Heidelberg, Heidelberg, Germany

The future Mu3e experiment at the Paul Scherrer Institute (PSI, Switzerland) will search for the decay $\mu^+ \rightarrow e^+e^+e^-$ down to a branching ratio sensitivity of $10^{-16}$. Observation of such a lepton-flavour violating decay will test the Standard Model, where it is highly suppressed. The first phase of the experiment aims to reach the sensitivity of $2 \times 10^{-15}$ using the availible at PSI muon beam with rates up to $1 \times 10^8$ Hz. In order to suppress possible background and perform the search with the proposed sensitivity, the experiment needs precise tracking and time measurements. The Mu3e tile detector is one the dedicated timing systems, providing precise detection of electrons with the time resolution below 100 ps. The detector consists of plastic scintillator tiles that are read out by silicon photomultipliers (SiPMs), while the analog signals of SiPMs are read by the MuTRiG ASICs.

This talk presents an overview of the current status of the Mu3e tile detector, including the development and production of individual components, as well as quality assurance measurements. The production of the full detector and its subsequent integration into the Mu3e experiment will be discussed.

T 108.4 Fri 9:45 Geb. 20.30: 2.066

**Detector system and simulation of the 155 MeV Møller polarimeter at MESA** — •Michail Kravchenko — Institute of Nuclear Physics, Johannes Gutenberg University Mainz — PRISMA+ Cluster of Excellence, Johannes Gutenberg University Mainz

The Mainz Energy-Recovering Superconducting Accelerator (MESA) is an electron accelerator that is currently under construction at Johannes Gutenberg University Mainz. One of the primary goals of MESA is to precisely measure the weak mixing angle $sin^2\theta_w$, an important parameter of the Standard Model, with a relative uncertainty of 0.14%. This measurement will be carried out by the P2 experiment by examining the parity-violating asymmetry in elastic electron-proton scattering at low momentum transfer $Q^2$. MESA will provide a 150 $\mu A$ beam of alternatingly polarized 150 MeV electrons with very good beam stability. To fulfill the objectives of the P2 experiment, the beam polarization must be monitored online with a very low systematic error ($<$ 0.5% relative). The 155 MeV Møller polarimeter using a polarized atomic hydrogen target, known as the Hydro-Møller polarimeter, as proposed by V. Luppov and E. Chudakov, offers the prospect of achieving these requirements. The updated design of the detector system for the Hydro-Møller polarimeter and the current results of the simulation with Geant4 are presented.

T 108.5 Fri 10:00 Geb. 20.30: 2.066

**A novel approach to radon source production: $^{226}$Ra implantation at ISOLDE facility at CERN** — •giovanni volta, hardy simgen, and florian jörg — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Reliable radon sources are a key ingredient for calibrating and developing detectors for the radioactive noble gas $^{222}$Rn. A novel approach to producing such sources is the implantation of $^{226}$Ra into a carrier substrate at the ISOLDE facility at CERN. In light of the results of the first implantation tests of $^{226}$Ra in a stainless steel sample, performed in 2017, in November 2023, a new implantation campaign has been performed. The aim was the implantation of at most 5 Bq of $^{226}$Ra into different materials: Not only stainless steel but also other metals (copper, titanium, lead) as well as insulators (PTFE, acrylic, glass) and semiconductors (germanium and silicon). Eleven samples were implanted with the desired $^{226}$Ra activity. The ISOLDE facility, operation, and preliminary characterization of these samples will be presented in this talk.

T 108.6 Fri 10:15 Geb. 20.30: 2.066

**Measurement of Cross-sections of Intermediate Mass Nuclei with NA61/SHINE at CERN** — •Neeraj Amin for the NA61/SHINE-Collaboration — Karlsruhe Insitute of Technology, Institute for Astroparticle Physics, Karlsruhe, Germany

The current understanding of cosmic-ray propagation in the Galaxy primarily depends on the secondary-to-primary flux ratios and the nuclear fragmentation cross-sections. Space-based detectors like AMS-02 and CALET have measured the fluxes with high precision ($<$ 5%). Yet, the large uncertainties on the fragmentation cross-section values considerably hamper the study. While the B/C and Li/C flux ratios are used to infer quantities like the ratio of diffusion coefficient to the size of the galactic halo $D_0/L$, this degeneracy can be broken by estimating the galactic halo size ($L$) by measuring the $^{10}$Be/$^9$Be flux ratio. Therefore precise fragmentation cross-section measurements are crucial for modelling galactic cosmic-ray propagation. The fixed-target experimental facility NA61/SHINE at CERN can be utilized to remedy this situation. Pilot data on fragmentation was taken in 2018 to probe the feasibility of performing fragmentation studies at SPS energies using two fixed targets, polyethylene ($C_2H_4$) and graphite. In this contribution, we will present the production of beryllium ($^7$Be, $^9$Be & $^{10}$Be) and lithium isotopes ($^6$Li & $^7$Li) in $^{12}$C+p interactions at 13.5$A$ GeV/$c$. Finally, we discuss the tailored framework for a specialized, high-statistics data initiative set for October 2024, focusing on investigating the fragmentation of primary nuclei from C to Si.

# T 109: Neutrino physics 12

Time: Friday 9:00–10:30 Location: Geb. 30.21: Gerthsen-HS

T 109.1 Fri 9:00 Geb. 30.21: Gerthsen-HS

**Characteristics of electron gun to investigate the energy loss function in KATRIN** — •Rudolf Sack[1], Sonja Schneidewind[2], Volker Hannen[2], and Sascha Wüstling[1] for the KATRIN-Collaboration — [1]Karlsruhe Institute of Technology — [2]University of Münster

The KATRIN experiment aims to determine the mass of the neutrino by scanning the electron energy spectrum near the endpoint. Electrons can however scatter with tritium molecules in the source of the experiment and lose energy in the process. This energy loss function needs to be measured with high precision. At the back end of the KATRIN beam line a mono energetic and mono angular photo-electron source, the so called e-gun, is in place to perform this measurement in situ with high precision. This talk will focus on our new beam pulsing method for measurements using time of flight information in addition to energy scanning with the KATRIN main spectrometer. The combination of time of flight analysis with beam pulsing greatly reduces the background contribution in the measurement. With the much improved signal to noise ratio we performed a direct measurement of the function at 18.6 keV for energy losses of up to 200 eV.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6)

T 109.2 Fri 9:15 Geb. 30.21: Gerthsen-HS

**Improved analysis methods for the determination of the energy-loss function of electrons in high-purity tritium gas at KATRIN** — •Sonja Schneidewind[1], Volker Hannen[1], Rudolf Sack[2], Richard Salomon[1], and Christian Weinheimer[1] for the KATRIN-Collaboration — [1]Institute for Nuclear Physics, University of Münster — [2]Karlsruhe Institute of Technology (KIT)

The Karlsruhe Tritium Neutrino Experiment (KATRIN) aims to directly assess the absolute neutrino-mass scale via precision spectroscopy of the tritium beta-decay spectrum in its endpoint region. Energy-losses of electrons scattering with gas molecules while travelling through the high-density gaseous tritium source lead to distortions of the measured energy spectrum and therefore need to be known with high precision. In 2022 and 2023, new measurements of the energy-loss of electrons in tritium gas at different electron energies have been performed with a newly installed high-rate photoelectron source with narrow energy and angular distribution. Those measurements extend earlier measurements at KATRIN which were published in EPJC 81, 579 (2021). In this talk, improved analysis methods developed for the analysis of the new energy-loss data will be presented. This work is supported by the Helmholtz Association, by the Ministry for Education and Research BMBF, by Deutsche Forschungsgemeinschaft DFG (Research Training Group GRK 2149) and other agencies (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6).

T 109.3 Fri 9:30 Geb. 30.21: Gerthsen-HS

**Preliminary Results from the LAPPD Integration in the ANNIE Experiment** — •Marc Breisch, Tanjina Anannya, Lukas Bieger, Jessica Eck, Tobias Heinz, Benedict Kaiser, Florian Kirsch, Tobias Lachenmaier, Dhanushka Bandara, and Tobias Sterr — Physikalisches Institut, Eberhard Karls Universität Tübingen

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a 26-ton gadolinium-doped water Cherenkov detector on-axis of the Booster Neutrino Beam (BNB) at Fermilab. The main physics goal is to measure the final state neutron multiplicity of neutrino-nucleus interactions as well as the neutrino cross-section in water which will improve the systematic uncertainties of next-generation long-baseline neutrino experiments. ANNIE is also the first large scale neutrino experiment to deploy multiple Large Area Picosecond Photodetectors (LAPPD), a novel photo sensor with a timing resolution of <100 ps and a sub-centimeter spatial resolution. Three LAPPDs have been successfully commissioned in ANNIE and neutrino induced events were detected. This talk will give an update on the status of the LAPPD beam data analysis as well as the first results from neutrino induced events recorded by the LAPPD.

T 109.4 Fri 9:45 Geb. 30.21: Gerthsen-HS

**Particle Identification with the Cherenkov to Scintillation Ratio in an idealised Water-based Liquid Scintillator Detector** — Daniel Bick, Caren Hagner, and •Malte Stender — Universität Hamburg, Institut für Experimentalphysik

The Diffuse Supernova Neutrino Background (DSNB) is of great interest for the star formation rate and understanding of supernovae. However, DSNB neutrinos were not detected yet due to the presence of strong backgrounds. For water Cherenkov detectors, a relevant background are muons below Cherenkov threshold. Mixing liquid scintillator into the water gives the opportunity to suppress invisible muons via the Cherenkov to scintillation ratio (C/S ratio). Such a Water-based Liquid Scintillator (WbLS) detector has also access to advantages like direction and enhanced energy reconstruction, if a light separation algorithm is in place. This algorithm uses the difference between Cherenkov and scintillation photons - the first is emitted instantenous in a cone, the latter isotropic and delayed - to sort the hits.

For this sorting the photodetector of choice has to be able to resolve the difference in time and space from the hits of both light types. The Large Area Picosecond Detector (LAPPD) is a novel photosensor reaching a spatial resolution of about 1 mm and a time resolution of ~ 0.1 ns and is therefore well-suited to do exactly that.

At the example of a simulated and idealised WbLS detector completely covered with LAPPDs, a feasibility study is conducted.

This contribution presents the simulation and a light separation algorithm showing the suppression of invisible muons in a WbLS detector.

T 109.5 Fri 10:00 Geb. 30.21: Gerthsen-HS

**Simulating LiquidO detectors for prototype research and development** — •Ben Cattermole for the CLOUD-Collaboration — University of Sussex, Brighton, United Kingdom

LiquidO is a novel detector technology that makes use of the stochastic confinement of scintillator light around its origin in an opaque medium. To collect this light a lattice of wavelength-shifting fibers runs through the medium, with each fiber end leading to a SiPM. By analysing event topology LiquidO style detectors have strong particle identification down to the MeV scale. Subsequent background rejection capabilities of the LiquidO technology make it ideal for neutrino detection. LiquidO will be used in the Chooz LiquidO Ultra near Detector, CLOUD, planned to be a 5 to 10 ton above ground detector for reactor anti neutrinos.

I will report on my work which involves simulations of LiquidO based detectors for research and development purposes. These simulations are built in Geant4 and include the geometries of prototypes, the scintillator material itself, the reflectivity of the vessel, fiber position and simulations of light in the fibers themselves. Alongside prototyping, these simulations are used to generate machine learning datasets. The main machine-learning technique being considered is a convolutional neural network due to the lattice of fibers used by LiquidO detectors being easily mapped to a pixel grid image format.

T 109.6 Fri 10:15 Geb. 30.21: Gerthsen-HS

**LiquidO: Simulations for Cloud Inner Detector** — •Susanna Wakely for the CLOUD-Collaboration — Johannes Gutenberg Universität Mainz

LiquidO is an innovative technology that uses opaque liquid scintillators for particle detection. A LiquidO scintillator combines a short scattering length and a long absorption length to confine optical photons close to their creation point. A fine array of wavelength-shifting fibres is used to collect and transport the scintillation light for readout. A LiquidO detector will have unprecedented position resolution compared to current transparent scintillators and be capable of particle identification via event topology. Proof of principle has been demonstrated by two prototypes with a third currently under construction.

The Cloud collaboration is designing a 5-10 ton LiquidO anti-neutrino detector. This will be an above-ground ultra-near reactor anti-neutrino detector located in the Chooz nuclear power plant, France.

This talk will discuss simulations of the inner detector including particle identification via event topology and fibre array design. Two broad fibre array designs are considered: parallel and stereo shells. A parallel array achieves mm resolution in x and y, with z-position obtained at lower resolution from signal timing differences. A stereo shell array would improve the resolution in z but presents challenges for the design and construction of the detector.

# T 110: Search for Dark Matter 5

Time: Friday 9:00–10:30 Location: Geb. 30.22: Gaede-HS

T 110.1 Fri 9:00 Geb. 30.22: Gaede-HS

**Boosting the production of sterile neutrino dark matter with self-interactions** — •Maria Dias and Stefan Vogl — Institute of Physics, University of Freiburg, Herrmann-Herder-Str. 3, 79104 Freiburg, Germany

Sterile neutrinos are well-motivated and simple dark matter (DM) candidates. However, sterile neutrino DM produced through oscillations by the Dodelson-Widrow mechanism is excluded by current X-ray observations and bounds from structure formation. One minimal extension, that preserves the attractive features of this scenario, is self-interactions among sterile neutrinos. In this work, we analyze how sterile neutrino self-interactions mediated by a scalar affect the production of keV sterile neutrinos for a wide range of mediator masses. We find four distinct regimes of production characterized by different phenomena, including partial thermalization for low and intermediate masses and resonant production for heavier mediators. We show that significant new regions of parameter space become available which provide a target for future observations.

T 110.2 Fri 9:15 Geb. 30.22: Gaede-HS

**MHz to TeV expectations from scotogenic WIMP dark matter** — •Laura Eisenberger, Thomas Siegert, Karl Mannheim, and Werner Porod — University of Würzburg

Most efforts on the indirect search for dark matter (DM) focus on the high-energy photons directly produced by DM annihilation. However, such prompt signals alone are too weak to be measurable in large astrophysical fore- and backgrounds. Following a multiwavelength approach, the secondary emission from charged annihilation products should be also taken into account.

In our study, we investigate scotogenic DM with a mass around 1 TeV which is consistent with various experimental limits. Scotogenic WIMPs arise in models where an additional symmetry ensures both the existence of a stable DM candidate and the generation of neutrinos masses through couplings to the dark sector.

We present our calculations of the DM photon spectrum in 27 dwarf galaxies of the Milky Way reaching from synchrotron emission in the MHz range to the Inverse Compton peak at MeV energies and to the prompt signature in the GeV up to TeV regime. This unique "triple hump" structure will be easily distinguishable from any other source. We estimate the fore- and background emission from the Milky Way and AGN along the line-of-sight. We find signal-to-background ratios on the order of 1e-3 between 1 keV and 100 GeV. In the light of upcoming observatories like COSI-SMEX and CTA, the detection of faint DM signals is within reach if a coherent analysis across the MeV to GeV range is applied.

T 110.3 Fri 9:30 Geb. 30.22: Gaede-HS

**Riding the dark matter wave: Novel limits on general dark photons from LISA Pathfinder** — •Jonas Frerick — DESY Theory, Hamburg, Germany

We note the possibility to perform a parametrically improved search for gauged baryon ($B$) and baryon minus lepton ($B-L$) Dark Photon Dark Matter (DPDM) using auxiliary channel data from LISA Pathfinder. In particular we use the measurement of the differential movement between the test masses (TMs) and the space craft (SC) which is nearly as sensitive as the tracking between the two TMs. TMs and SC are made from different materials and therefore have different charge-to-mass ratios for both $B-L$ and $B$. Thus, the surrounding DPDM field induces a relative acceleration of nearly constant frequency. For the case of $B-L$, we find that LISA Pathfinder can constrain previously unexplored parameter space, providing the world leading limits in the mass range $4 \cdot 10^{-19}$ eV $< m < 3 \cdot 10^{-17}$ eV. This limit can easily be recast also for dark photons that arise from gauging other global symmetries of the SM.

T 110.4 Fri 9:45 Geb. 30.22: Gaede-HS

**Cavity response to time dependent dark matter signals** — •Althea Cappelli[1] and Elina Fuchs[2] — [1]Leibniz Universität Hannover, Hannover — [2]Leibniz Universität Hannover, Hannover

The search for Dark Matter remains a prominent focus in particle physics. There are already good Dark Matter candidates, one positive example being the Goldstone bosons axions, which also offer a resolution to the strong CP problem. However, axions have not been experimentally found yet, compounded by the challenge of determining their mass, a free variable. While some experiments target specific mass ranges, the range to scan is still very broad. For putting more bounds, cavities emerge as a helpful tool, as they can probe different masses using their resonance frequency. Although much progress has been done in the past couple of years, further optimizations can be done, using for instance different and/or entangled cavities. Moreover, such cavity experiments offer a dual-purpose platform, expanding their probing also to gravitational waves from primordial black holes, an additional Dark Matter candidate. Using the Heisenberg equations for a two cavity experiment derived in "Cavity entanglement and state swapping to accelerate the search for axion dark matter" by K. Wurtz et al, it is interesting to look at the response of the output cavity signal when putting different time dependent signals for different Dark Matter candidates in the equations. Evaluating the cavity's susceptibility to the signal given a certain noise could lead, together with parameter estimation of the constants, to predictions for experimental optimizations, enhancing the sensitivity to Dark Matter signals.

T 110.5 Fri 10:00 Geb. 30.22: Gaede-HS

**Modeling of self-interacting dark matter signatures in dwarf galaxies** — •Athithya Aravinthan[1,2], Julia Becker Tjus[1,2,3], and Lukas Merten[1,2] — [1]Theoretische Physik IV, Ruhr-Universität Bochum, Bochum, Germany — [2]RAPP-Center, Ruhr-Universität Bochum, Bochum, Germany — [3]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

Dwarf galaxies are a convenient testing ground in the search for Dark Matter (DM), due to their low, astrophysical background of electromagnetic emission in radio and gamma rays. While multi-messenger signatures of dwarf galaxies can lead to a more precise estimation of the astrophysical background, the modelling of the expected DM annihilation signals, and therefore the DM foreground, is necessary to derive constraints on DM parameters.

In this work, based on the J-factor, which describes the distribution of DM, the gamma-ray fluxes from DM annihilation in several dwarf spheroidal galaxies are determined. This is done using varying DM masses, distributions, and J-factor models, such as the canonical case for cold DM and the generalized case for self-interacting DM. *Supported by DFG (SFB 1491).

T 110.6 Fri 10:15 Geb. 30.22: Gaede-HS

**Einstein's basement - A model of dark matter and dark energy?** — •Fritz Riehle and Sebastian Ulbricht — Physikalisch-Technische Bundesanstalt, Braunschweig

The energy-momentum relationship (EMR) of a free particle in special relativity is regarded as the upper branch of an avoided crossing between the mass of the particle and its momentum. The corresponding EMR for the lower branch - a regime dubbed as Einstein's basement - is derived. From the associated Lagrangian and the conventional gravitational interaction a new kinematics in Einstein's basement is determined. It is shown that this can lead to a repulsion of the basement particles and a modified interaction with regular matter. The model suggests the identification of the basement particles with dark matter accompanied with a missing interaction with light. The expansion of the basement particles and the regular mass that is carried along could be interpreted as an expansion of the universe. Tests of the model by astronomical observations are suggested.

# T 111: Outreach 3

Time: Friday 9:00–10:30 Location: Geb. 30.22: Lehmann-HS

T 111.1 Fri 9:00 Geb. 30.22: Lehmann-HS

**The Astroparticle Immersive Synthesizer AIS$^3$** — •Lasse Halve[1], Jan Audehm[1], Charlotte Benning[1], Jonas Häussler[1], Johanna Hermannsgabner[1], Adam Rifaie[1], Tim Otto Roth[2], Lea Schlickmann[1], Miriam Seidler[2], Christopher Wiebusch[1], and Simon Zierke[1] — [1]III. Physikalisches Institut B, RWTH Aachen, Sommerfeldstr. 16, 52074 Aachen — [2]Imachination Projects, Bahnhofstr. 1, 77728 Oppenau i. Schw.

The Astroparticle Immersive Synthesizer (AIS$^3$) is a sound laboratory created by conceptual artist and composer Tim Otto Roth in cooperation with the IceCube Neutrino Observatory. The data from large-volume neutrino telescopes like IceCube, ANTARES, and KM3NeT are interpreted in sound and light. The installation consists of 444 spherical loudspeakers, each equipped with LEDs and a synthesizer. The loudspeakers, representing the photosensors of the neutrino detectors, are hanging on thin wire ropes allowing the visitors to move freely through the installation. The photosensor data are encoded by sound frequencies and additionally visualized by colored illumination of the loudspeakers, which allows the visitors to experience the time sequence of neutrino events in the 3D environment. The project creates a fundamental experiment in psychoacoustics for everyone by immersing the visitor in the sound generator. We describe the design and construction of the installation, the interpretation of the physics data as a natural source by Tim Otto Roth, and the exhibitions in Berlin, Munich, Aachen, and Paris.

T 111.2 Fri 9:15 Geb. 30.22: Lehmann-HS

**Belle II - Development of an interactive 3D detector representation** — •Johanna Häusler and Thomas Kuhr — Ludwig-Maximilians-Universität München

Public outreach is an essential part of modern science. This includes not just raising public awareness for physics questions themselves * and especially for particle physics questions * but also providing novel tools to reinforce learning and understanding of basic physics principles and of the technology required for studying those principles.

The general progress in the field of 3D technologies allows for entirely novel learning strategies that enable pupils to interact with the educational object, thereby increasing both learning and interest. 3D printing and displaying technologies are especially suitable for presentation of complex experimental arrangements * so as particle physics detectors to convey relatively simple cognitive access to the most basic principles behind those setups. The talk presents a 3D educational project of the Belle II Detector in its early stages of development.

T 111.3 Fri 9:30 Geb. 30.22: Lehmann-HS

**Citizen Science in Data-Intensive Physics: PUNCH4NFDI Perspective** — •Victoria Tokareva[1], Michael Kramer[2], Andreas Haungs[1], and Ramesh Karuppusamy[2] — [1]Karlsruhe Institute of Technology, Institute for Astroparticle Physics, 76021 Karlsruhe, Germany — [2]Max-Planck-Institut für Radioastronomie, 53121 Bonn, Germany

In recent years, citizen science projects have garnered widespread participation globally, fostering collaboration between enthusiastic individuals and professional researchers. Recent studies indicate that such collaborations yield a positive impact on social well-being by promoting continuous education, rational thinking, and active engagement in local and international social initiatives.

This contribution delves into the realm of citizen science projects within the data-intensive physics domain, specifically focusing on initiatives related to research within PUNCH4NFDI (Particles, Universe, NuClei and Hadrons for Nationale Forschungs-Daten Infrastruktur) scientific communities, such as astrophysics, astroparticle and particle physics, nuclear physics, and related fields. Our analysis aims to explore the experiences gained from citizen science projects across diverse research domains. This exploration aims to uncover the transformative potential of such collaborations, both within the realm of scientific inquiry and in the broader societal context.

This work is supported by the DFG fund "NFDI 39/1" for the PUNCH4NFDI consortium.

T 111.4 Fri 9:45 Geb. 30.22: Lehmann-HS

**Outreach modules for new particle Ssarches using the ATLAS Forward Proton detector, Higgs boson physics, and portals for Higgs bosons and SUSY particles** — •Peter Zacik and Andre Sopczak — Czech Technical University in Prague

We present two modules as part of the Czech Particle Physics Project (CPPP). These modules are intended as learning tools in masterclasses aimed at high-school students (aged 15 to 18). The first module is dedicated to the detection of an Axion-Like-Particle (ALP) using the ATLAS Forward Proton (AFP) detector. The second module focuses on the reconstruction of the Higgs boson mass using the Higgs boson golden channel with four leptons in the final state. Two further modules are educational aid and source for expert information, web portals dedicated to Higgs boson and Supersymmetry research. The modules are accessed at the following link: http://cern.ch/cppp.

T 111.5 Fri 10:00 Geb. 30.22: Lehmann-HS

**Designing a Time Projection Chamber for Schools** — •Annika Hoverath, Laura Rodríguez Gómez, Jochen Kaminski, Klaus Desch, Johannes Streun, Malte Koch, and Maximilian Meiss — Physikalisches Institut, University of Bonn

The CLEOPATRA project - CLassroom Experiment On PArticle TRAcking - is aimed to develop a new experiment in portable size for physics lessons in German high schools. Since there are only a few experiments, which focus on modern particle physics and which can be shown in lessons, CLEOPATRA visualizes how particles, especially cosmic muons and electrons from radioactive sources, can be detected in modern research. The idea is that pupils get an adequate insight into the research process and how knowledge about nature is obtained in science. The heart of this experiment is a time projection chamber. This detector type is often used in fundamental research. In this setup a so-called GridPix is used to measure the charge signals and to identify the particle track. The track projection on the anode yields two-dimensional information. With the usage of scintillators around the gas volume, the system is triggered and records the timing for three-dimensional information. With this detector particle tracks can be reconstructed digitally in three dimensions and almost in real-time.

In this talk, the CLEOPATRA detector and the corresponding physics will be presented and current developments and challenges will be explained. Currently, the detector will be improved by a magnetic field for track bending to distinguish particles and a scintillator will be developed around the whole gas volume for full track reconstruction.

T 111.6 Fri 10:15 Geb. 30.22: Lehmann-HS

**A new release of ATLAS open data for education** — •David Koch — LMU, Munich, Germany

The ATLAS Open Data project aims to provide data and tools to high-school, undergraduate and master students, as well as teachers and lecturers, to help educate them in physics analysis techniques used in experimental particle physics. Sharing data collected by the ATLAS experiment aims to generate excitement and enthusiasm for fundamental research, inspiring physicists of the future. The approach followed by the ATLAS Open Data & Tools Group is to not only publish recorded and simulated datasets but to also accompany the release of open data with high quality documentation in the form of tutorials, Jupyter Notebooks and interactive webpages to explore the data. The provided material is aimed at people with a wide variety of expertise, ranging from high-school students to teachers and the interested general public, to undergraduate and even master students of particle physics.

In the past, ATLAS has already released proton-proton collision data and associated simulated data at center-of-mass energies at 8TeV and 13TeV. These releases were eagerly received by the community and public.

In this talk I will present the status and plans of the ALTAS Open Data & Tools Group to publish a new release of ATLAS Open Data. The new release will include new, larger datasets that will allow for more advanced analysis techniques such as machine learning, as well as a revised web appearance and educational software and tools.

## T 112: Silicon trackers 5

Time: Friday 9:00–10:30 Location: Geb. 30.22: kl. HS A

T 112.1 Fri 9:00 Geb. 30.22: kl. HS A

**Timing studies of a depleted monolithic pixel sensor in 180 nm technology** — •Christian Bespin, Ivan Caicedo, Jochen Dingfelder, Hans Krüger, Lars Schall, and Norbert Wermes — Physikalisches Institut, Universität Bonn, Deutschland

The increasing availability of commercial CMOS processes with high-resistivity wafers has fueled the R&D of depleted monolithic active pixel sensors (DMAPS) for usage in high energy physics experiments. One of these developments is a series of monolithic pixel detectors with column-drain readout architecture aiming to meet ATLAS ITk outer pixel layer requirements. The TJ-Monopix series features a small collection electrode and is fabricated in a 180 nm CMOS imaging process.

The latest iteration, TJ-Monopix2, features a pixel size of 33 um x 33 um and 25 ns time-stamping capabilities. The front-end aims at a low power consumption (1 uW per pixel) while maintaining high signal-to-noise ratio and time resolution. This talk presents recent results of timing studies on non-irradiated devices in the laboratory and in particle beams, evaluating their time efficiency and resolution.

T 112.2 Fri 9:15 Geb. 30.22: kl. HS A

**Timing studies of MAPS in 65 nm imaging process** — •Manuel Alejandro Del Rio Viera — Deutsches Elektronen-Synchrotron (DESY) — Rhenish Friedrich Wilhelm University of Bonn

The goal of the TANGERINE project is to develop the next generation of monolithic silicon pixel detectors using a 65 nm CMOS imaging process, which offers a higher logic density and overall lower power consumption compared to currently utilized feature sizes. The Analogue Pixel Test Structure (APTS) are sensors designed and developed by ALICE with readout boards developed by CERN EP R&D using a 65 nm imaging process to study the capabilities of this technology. In order to study the timing capabilities, the sensor is tested at the DESY-II test beam facility. For each hit produced by an incident particle, the analogue signal output is recorded using an oscilloscope for offline analysis and track reconstruction. From this analysis, relevant timing parameters are compared with studies obtained through Technology Computer-Aided Design (TCAD) and Monte Carlo (MC) simulations. In this contribution, the sensor and setup, results obtained at the DESY-II Test Beam facility, laboratory characterization measurements using Fe-55, and a comparison with simulations will be presented.

T 112.3 Fri 9:30 Geb. 30.22: kl. HS A

**Laboratory and Beam-Test Measurements for proton-irradiated, large-scale depleted MAPS in 150nm CMOS technology** — •Lars Schall, Jochen Dingfelder, Christian Bespin, Ivan Caicedo, Fabian Hügging, Hans Krüger, Norbert Wermes, and Sinuo Zhang — University of Bonn

The increasing availability of high-resistivity silicon substrate with high-biasing capabilities in commercial CMOS processes facilitates the use of monolithic active pixel sensors (MAPS) in modern high-energy physics experiments. An improvement in radiation hardness is achieved by fully depleting the sensitive volume, as done for depleted MAPS (DMAPS), increasing the initial input signal and providing fast charge collection by drift. This makes DMAPS a promising alternative to conventional hybrid pixel detectors for use in high-rate, high-radiation environments, such as for the ATLAS Inner Tracker upgrade.

LF-Monopix2 is a large-scale 1x2cm$^2$ DMAPS with a 150x50$\mu$m$^2$ pixel pitch designed in 150nm LFoundry CMOS technology. The placement of the in-pixel electronics inside the large charge-collection electrode relative to the pixel pitch facilitates a homogeneous electric field with short drift distances across the sensitive sensor volume. Sensors have successfully been thinned down to 100$\mu$m thickness and backside processed. Laboratory measurements have proven the general functionality of proton-irradiated samples up to fluences of 2e15neq/cm$^2$. In this contribution, the latest beam-test studies of irradiated LF-Monopix2 sensors are presented. Special emphasis is put on hit-detection and in-time efficiencies after irradiation.

T 112.4 Fri 9:45 Geb. 30.22: kl. HS A

**Quality Control for MuPix11 for the Mu3e Pixel Detector** — •Anna Lelia Fuchs for the Mu3e-Collaboration — Physikalisches Institut Universität Heidelberg

The Mu3e experiment will search for the charged lepton flavour violating $\mu^+ \to e^+e^-e^+$ decay with an unprecedented single event sensitivity of $2 \cdot 10^{-15}$ in phase I. To achieve the necessary precision in the spatial and timing resolutions, the Mu3e experiment will feature the first tracking detector composed solely of ultra-thin High-Voltage Monolithic Active Pixel Sensors (HV-MAPS). HV-MAPS integrate readout electronics on the same sensor as the active detector volume, which allows the thinning of wafers to a minimum of 50 $\mu$m. The Mu3e detector will be composed of MuPix11 HV-MAPS at thicknesses of 50 $\mu$m and 70 $\mu$m. A quality control procedure is necessary to ensure the functionality of each sensor before its installation.

This talk will outline the quality control procedure developed for the MuPix11 sensors in the context of pre-production for the Mu3e vertex detector. The quality control evaluates key functions such as HV biasing, powering, global configuration and data readout. First tests were carried out on both 50 $\mu$m and 70 $\mu$m MuPix11 sensors, and the acquired information used to further develop the quality control procedure. This talk will present the quality control yield and failure profiles for both sensor thicknesses.

T 112.5 Fri 10:00 Geb. 30.22: kl. HS A

**Two layers simulations for a modified Phase I of the Mu3e experiment** — •Eloy Huidobro Rodriguez for the Mu3e-Collaboration — Physikalisches Institut, Heidelberg, Germany — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The Mu3e experiment at the PSI aims to observe the decay $\mu^+ \to e^+e^-e^+$ with a single event sensitivity of $2 \cdot 10^{-15}$ on the branching fraction in phase I. Measuring this decay, which violates lepton flavour conservation, would be a clear sign of new physics, as it is suppressed to unobservable orders in the SM.

Since the two outer pixel tracking layers of the experiment will not be ready for the beamtime in 2024, the performance of a setup consisting of only two inner pixel layers surrounding the stopping target is studied. The absence of the outer tracking layers causes an increase in fake rate due to a loss of redundancy in the track reconstruction, as well as a loss of acceptance and momentum resolution. To overcome these negative effects, it is necessary to reduce the muon stopping rate and increase the magnetic field for this setup. The lower muon stopping rate reduces the hit occupancy and thus the fake rate, while the larger magnetic field increases the rate of recurling tracks in the inner layers and increases the momentum resolution. Results from a simulation study are presented for different magnetic field strengths and a tailored track reconstruction based on recurling tracks measured in only two tracking layers. The achievable sensitivities for different magnetic field configurations are compared.

T 112.6 Fri 10:15 Geb. 30.22: kl. HS A

**Multiple Coulomb Scattering Monte Carlo Simulation Model Comparison** — •Kevin Dojan[1], Ingrid-Maria Gregor[1,2], Simon Spannagel[2], Paul Schütze[2], and Hakan Wennlöf[2] — [1]Rheinische Friedrich-Wilhelms Universität Bonn — [2]Deutsches Elektronen-Synchrotron (DESY)

Monte-Carlo simulations are a powerful tool in high-energy physics to simulate particle interactions, among others for simulating the traversal of particles through matter. This is particularly important when simulating particle detectors where the dominant factor for the momentum resolution is multiple Coulomb scattering. The standard toolkit for particle-matter interactions is GEANT4. It offers different models to simulate multiple scattering behaviours in numerous applications. The characteristics of multiple Coulomb scattering will be compared for these models.

## T 113: Silicon trackers 6

Time: Friday 9:00–10:30 Location: Geb. 30.22: kl. HS B

T 113.1 Fri 9:00 Geb. 30.22: kl. HS B

**Slow pion identification at the Belle II PXD with machine learning** — •Johannes Bilk and Sören Lange — II. Physikalisches Institut (Subatomare Physik), Justus-Liebig- Universität Giessen

The identification of slow pions in Belle II experiments presents a notable challenge, arising from their high dE/dx energy loss and their short flight path in the tracking detectors. This study introduces a method employing advanced machine learning algorithms to accurately detect pions with momentum p<100 MeV/c exclusively with the Belle II pixeldetector (PXD). By analyzing detector signals (in particular a 9x9 pixel matrix) with image processing and pattern recognition methods, this approach significantly boosts the efficiency and accuracy. Offline and online (FPGA) implemenation will be discussed.

T 113.2 Fri 9:15 Geb. 30.22: kl. HS B

**Characterization of Sensor Properties of Large DEPFET Modules for the Belle II Pixel Detector** — Patrick Ahlburg, Florian Bernlochner, Jochen Dingfelder, Georgios Giakoustidis, Munira Khan, Hans Krüger, •Botho Paschen, Jannes Schmitz, and Paula Scholz — University of Bonn

The Belle II PiXel Detector (PXD) is composed of large ($1.5 \times 8.5$ cm$^2$) all-silicon modules with integrated sensor and bump-bonded Application Specific Integrated Circuits (ASICs). Pixel matrices of DEpleted P-channel Field Effect Transistors (DEPFETs) with pixel pitches down to $55 \times 50$ $\mu$m$^2$ constitute their active area. The DEPFET technology is employed for the first time in High Energy Physics in the Belle II experiment that has recorded data from $e^+ - e^-$ collisions since 2019.

Variations in the DEPFET drain currents form the detection signal for ionizing radiation. To achieve a high resolution, an online dark current subtraction is implemented in the digitizer ASIC. Process and wafer bulk property fluctuations lead to variations of the FET properties and their dark currents over the sensor area.

The PXD pixel design and results of sensor current characterizations will be presented in this talk.

T 113.3 Fri 9:30 Geb. 30.22: kl. HS B

**Investigation of high backside currents in DePFET pixel sensors for the Belle II experiment using dedicated test-structures** — Florian Bernlochner, Jochen Dingfelder, •Georgios Giakoustidis, and Botho Paschen — University of Bonn, Germany

For the Belle II experiment at KEK (Tsukuba, Japan) the KEKB accelerator was upgraded to deliver $e^+e^-$ collisions at a center of mass energy of $E_{CM}$ = 10.58 $GeV$ and it has reached a record-breaking instantaneous luminosity of $4.7 \cdot 10^{34}$ $cm^{-2}s^{-1}$. During the so-called Long Shutdown 1 (LS1) the innermost part of the Belle II detector, the initially descoped PiXel Detector (PXD1) with 20 modules, based on Depleted P-channel Field Effect Transistor (DePFET) technology, was replaced by a fully-populated, two-layer PXD with 40 modules. As the detector closest to the experiment's interaction region, PXD is most exposed to radiation from the accelerator. Throughout the operation of the PXD1 a steady increase of backside current with irradiation was observed in several modules. Doping profile measurements and electric field simulations show that this is a consequence of (partially) shorted guard-rings at the backside leading to high electric fields and avalanche current multiplication. Irradiation results of dedicated test-structures to further investigate the mechanism will be presented.

T 113.4 Fri 9:45 Geb. 30.22: kl. HS B

**Upgrade of Belle II Vertex Detector with CMOS Pixel Technology** — •Marike Schwickardi[1], Ariane Frey[1], Yannik Buch[1], Benjamin Schwenker[1], Maximilian Babeluk[2], Ajit Kumar[4], Ludovico Massaccesi[3], Christian Finck[4], Jerome Baudot[4], Bernhard Pilsl[2], and Christian Irmler[2] — [1]Georg-August Universität, 37077 Göttingen, Germany — [2]Institute of High Energy Physics, Austrian Academy of Sciences, 1050 Vienna, Austria — [3]Dipartimento di Fisica, Università di Pisa, I-56127 Pisa, Italy — [4]Université de Strasbourg, CNRS, IPHC, UMR 7178, 67037 Strasbourg, France

The Belle II experiment at KEK in Japan considers upgrading its vertex detector system to address the challenges posed by high back-ground levels caused by the increased luminosity of the SuperKEKB collider. One proposal for upgrading the vertex detector aims to install a 5-layer all monolithic pixel vertex detector based on fully depleted CMOS sensors in 2027. The new system will use the OBELIX MAPS chips to improve background robustness and reduce occupancy levels through small and fast pixels. This causes better track finding, especially for low transverse momenta tracks elow 100 MeV. During the summer of 2023, electron-beam tests at DESY were conducted on the TJ-Monopix2, which served as the precursor to the OBELIX sensor. Initial measurements on irradiated modules, subjected to Protons at $5 \times 10^{14}$ $n_{eq}/cm^2$, were performed. Results from the laboratory and test beam evaluations, focusing on pixel response, efficiency, and spatial resolution, will be presented.

T 113.5 Fri 10:00 Geb. 30.22: kl. HS B

**Comissioning and Characterization of the Belle II PXD Power System** — •Jannes Schmitz, Florian Bernlochner, Jochen Dingfelder, and Botho Paschen — University of Bonn

The Belle II experiment at the SuperKEKB collider in Tsukuba, Japan, collected $e^+e^-$ collision data between 2019 and 2022, and after reaching a record-breaking instantaneous luminosity of $4.7 * 10^{34} cm^{-2}s^{-1}$ and a dataset corresponding to $424 fb^{-1}$ , it is currently in its first planned long shutdown phase (LS1) until December 2023. Aside from upgrades of the collider, the shutdown is used for the installation of the new two-layer Pixel Vertex Detector (PXD), which together with four layers of double-sided silicon strips (SVD) forms the Belle II Vertex Detector (VXD). The previous single-layer PXD was replaced by the new fully-populated PXD2, doubling the amount of required detector services. One key component are the custom-made power supplies (PS). For each of the 40 modules a dedicated PS provides voltages for 24 channels. Due to the 14m-long power lines, remote sensing is needed and electronic components need to be calibrated for accurate supply and monitoring of voltages and currents. This talk will cover the commissioning of the PXD power system as well as studies of calibration data to examine aging effects of the electronics.

T 113.6 Fri 10:15 Geb. 30.22: kl. HS B

**Pixel Vertex Detector background generation using Generative Adversarial Networks** — •Fabio Novissimo, Thomas Kuhr, and Nikolai Hartmann — Ludwig-Maximilians-Universität München

The Pixel Vertex Detector (PXD) is the innermost detector of the Belle II experiment. Information from the PXD, together with data from other detectors, allows to have a very precise vertex reconstruction. The effect of beam background on reconstruction is studied by adding measured or simulated background hit patterns to hits produced by simulated signal particles. This requires a huge sample of statistically independent PXD background noise hit patterns to avoid systematic biases, resulting in a huge amount of storage due to the high granularity of the PXD sensors. As an efficient way of producing background noise, we explore the idea of an on-demand PXD background generator realised using Generative Adversarial Networks (GANs). In order to evaluate the quality of generated background we measure physical quantities which are sensitive to the background in the PXD.

# T 114: Standard model 4 (strong/QCD)

Time: Friday 9:00–10:30 Location: Geb. 30.23: 2/0

T 114.1 Fri 9:00 Geb. 30.23: 2/0

**QCD cross-section measurements for astroparticle physics with the LHCb experiment** — Johannes Albrecht, Hans Dembinski, and •Lars Kolk — TU Dortmund University, Dortmund, Germany

A long-standing issue in the field of cosmic-ray research is the discrepancy between the observed and simulated numbers of muons in cosmic-ray-induced hadronic showers in the Earth's atmosphere, which are called air showers. This discrepancy is referred to as the Muon Puzzle, as the required changes to existing models in simulation would either violate data constraints or the consistency between air shower simulations and other air shower features.

One explanation for this inconsistency lies in universal strangeness enhancement, which measurements from the ALICE and LHCb experiments show first evidence off. To further study the impact on forward-produced hadrons and to test this universality, proton-ion data from the LHCb fixed target mode are analysed. Of particular interest are proton-oxygen collisions, as they are a good proxy for air showers. Since proton-oxygen data are not yet available, the first step is to bracket oxygen with helium and neon. The current status of this analysis is presented.

*Supported by DFG (SFB 1491)*

T 114.2 Fri 9:15 Geb. 30.23: 2/0

**Observation of antihelium and antihypertriton in $pp$ collisions with LHCb** — •Hendrik Jage, Dan Moise, Valery Zhukov, and Stefan Schael — I. Physikalisches Institut B, RWTH Aachen

The first observation at the LHCb experiment of hypertritons and antihypertritons is reported. The used dataset consists of $pp$ collisions at $\sqrt{s} = 13$ TeV, collected between 2016 and 2018, and corresponds to an integrated luminosity of 5.5 $fb^{-1}$. The hypertriton candidates are reconstructed via the two-body decay into helium-3 and a charged pion. The corresponding helium nuclei are identified with a technique that is innovative at the LHCb experiment and mainly exploits ionisation losses in the LHCb silicon sensors. A total of $1.1 \times 10^5$ prompt helium and antihelium candidates are identified with negligible background contamination and $107 \pm 11$ hypertriton candidates are found, paving the way for a rich programme of precise measurements of QCD and astrophysical interest to be performed on the available data.

T 114.3 Fri 9:30 Geb. 30.23: 2/0

**Triple differential Z+Jet cross section measurement** — •Cedric Verstege, Maximilian Horzela, Klaus Rabbertz, and Günter Quast — Karlsruhe Institute of Technology, Karlsruhe, Germany

The differential cross-sections of Z($\mu\mu$)+jet events is presented using the data recorded at 13 TeV center-of-mass energy by the CMS detector during Run 2. The cross-sections are measured as a function of the Z boson transverse momentum $p_T^Z$, the rapidity separation $y^*$ of the Z boson and the leading jet, and the boost in rapidity $y_b$ of their center-of-mass system in the lab frame. The observables $y^*$ and $y_b$ enhance the sensitivity to different parton initial-state and momentum contributions, and thus to the parton distribution functions.

The measured cross-sections are unfolded for detector effects in all three dimensions simultaneously. The resulting cross-sections at stable particle level are compared to precise theory predictions calculated at next-to-next-to-leading order in perturbative QCD corrected for electroweak and non-perturbative effects.

T 114.4 Fri 9:45 Geb. 30.23: 2/0

**Measurement of jet substructure observables on Z+bb events with the ATLAS Experiment** — •Alberto Lorenzo Rescia — Dipartimento di Fisica, Università di Genova, Genova, Italy — Deutsches Elektronen-Synchrotron, Hamburg, Germany

The study of jet substructure provides valuable insight into the underlying physics of particle interactions. In particular, through the study of the radiation pattern surrounding heavy flavour quarks, jet substructure studies can clarify the nature of strong interactions. In this work, we present a measurement of jet substructure observables on b-jets produced in Z+bb events at a center-of-mass energy of 13 TeV utilising data collected by the ATLAS experiment at the Large Hadron Collider (LHC). Our analysis focuses on the primary Lund Jet Plane as well as other jet substructure observables which aim to discriminate colour singlet decays, such as those of the Higgs boson, from colour octect decays.

T 114.5 Fri 10:00 Geb. 30.23: 2/0

**Measurement of differential $\phi$ production cross-sections in 13 TeV proton-proton collisions at the LHCb experiment** — •Donata Osthues, Johannes Albrecht, and Hans Dembinski — TU Dortmund University, Dortmund, Germany

Traditional models of hadronization in proton-proton and proton-ion collisions are based on effective non-perturbative theories and successfully describe many phenomena. However, their predictions have recently been challenged by the observation of multiplicity-dependent strangeness production at mid-rapidity by the ALICE collaboration. Since this discovery, enhanced strangeness production was also found in the forward rapidity region. Enhanced strangeness production is a key observable to understand the Muon Puzzle, which is a phenomenon seen in high-energy air-showers. The LHCb experiment is ideally suited for studies on strangeness production at the LHC in the forward region, thanks to its particle identification capabilities and low $p_T$ threshold. We studied $\phi$ mesons via the decay $\phi \to K^+K^-$, which consist of a strange-anti-strange quark pair and are abundantly produced. This makes $\phi$ mesons perfect candidates for these kind of studies. Thus, a measurement of their production cross-section in bins of transverse momentum and rapidity is performed. The data used for this analysis was collected during proton-proton collisions by the LHCb detector in 2015 and corresponds to an integrated luminosity of 4.6 n/b. This contribution presents the current status of the measurement.

T 114.6 Fri 10:15 Geb. 30.23: 2/0

**Early measurement of strange-hadron production ratios at LHCb in Run 3** — Johannes Albrecht[1], •Noah Behling[1], Lukas Calefice[2], Hans Dembinski[1], and Biljana Mitreska[1] — [1]TU Dortmund University, Dortmund, Germany — [2]Universitat de Barcelona, Barcelona, Spain

Hadron production ratios are a useful probe to test and improve hadronisation models. In this work, the production ratios of $K_S^0$, $\Lambda^0$, and $\bar{\Lambda}^0$ are studied with the upgraded LHCb experiment using early data recorded in 2022. These studies are also essential to calibrate and validate the performance of the upgraded detector. The proper operation of all subsystems needs to be validated step-by-step to carry on precise measurements with data recorded recently and in the future. The performance of the tracking system can be validated with the measured ratios.

The meson-to-baryon ratios and strangeness production in general contribute to the understanding of hadronic processes in cosmic-ray-induced extensive air showers, which are dominated by soft-QCD effects in the forward region. In air-shower data, an excess of muons produced with respect to Monte Carlo event generators has been observed, which could originate from mismodelling of the hadronisation process. The LHCb experiment offers a unique environment to test hadronic models in the forward region.

The current status of the analysis pipeline and recent studies on detector performance will be presented. Additionally, a bridge between collider and air-shower experiments will be built.

# T 115: Detectors 10 (semiconductors)

Time: Friday 9:00–10:30 Location: Geb. 30.23: 2/1

T 115.1 Fri 9:00 Geb. 30.23: 2/1

**Simulation of HV-CMOS sensor arrays intended for beam monitoring at ion beam therapy facilities** — •Pietro Marchesi[1], Alexander Dierlamm[1,2], Ulrich Husemann[1], Markus Klute[1], and Bogdan Topko[1] — [1]Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT) — [2]Institute for Data Processing and Electronics (IPE), KIT

The use of ion beams for cancer therapy has been proven to be an advantageous alternative to conventional photon therapy due to the ability to deliver the dose more precisely to the malignant tumor and spare healthy tissue thanks to the depth control that the Bragg peak of ions allows.

To operate such a therapeutic system safely, precise monitoring of the beam characteristics (specially position and width) is required. To this end, KIT has been developing HV-CMOS detectors intended for the Heidelberg Ion-Beam Therapy Center consisting of an array of individual sensor chips.

To assist in the development efforts, simulations using the Allpix Squared software have been made. The use of individual chips arranged into an array implies the presence of gaps between them, which can induce biases in the reconstruction of the beam characteristics. An interpolation algorithm is presented that bridges these gaps to avoid such effects. Simulated data and real data from beam tests are compared.

T 115.2 Fri 9:15 Geb. 30.23: 2/1

**Simulation of Hexagonal Pixel Configurations in Monolithic Active Pixel Sensors** — •Larissa Mendes[1], Simon Spannagel[1], Manuel Alejandro del Rio Viera[1], Lennart Huth[1], Ingrid-Maria Gregor[1,2], Håkan Wennlöf[1], Anastasiia Velyka[1], and Adriana Simancas[1] — [1]Deutsches Elektronen-Synchrotron DESY, Germany — [2]Universität Bonn, Germany

The Tangerine Project is investigating monolithic active pixel sensors (MAPS) fabricated using the 65 nm CMOS imaging process with a small collection electrode. The complex interplay between different doping regions in the silicon sensor and the resulting non-linear electric field configuration makes it challenging to predict sensor behavior accurately. Therefore, precise simulations are essential for describing and predicting the key performance parameters of the sensor, thereby contributing to an optimized performance.

A simulation approach for achieving this type of characterization may involve a combination of electrostatic field simulations and Monte Carlo techniques. This study explores a hexagonal pixel grid to enhance sensor performance as an alternative to conventional square or rectangular pixel layouts. The layouts are evaluated based on efficiency, cluster size, and spatial resolution, and a comparison is made between square and hexagonal pixel geometries. Transient simulations in detectors were also executed to model the time-dependent behavior of detectors in response to incident particles of hexagonal pixels. These investigations underscore the potential of the hexagonal pixel grid to improve the performance of MAPS in high-energy physics experiments.

T 115.3 Fri 9:30 Geb. 30.23: 2/1

**Developing a simulation chain for synthetic single and polycrystalline diamonds using Allpix-squared** — •faiz ur rahman ishaqzai[1,2], Tobias Bisanz[1], and Jens Weingarten[1] — [1]TU Dortmund, Germany — [2]DEU Izmir Turkey

Diamond, known for its exceptional properties, such as radiation hardness and a larger radiation length, stands out as a promising material for tracking detectors in high-energy physics experiments. A simulation chain has been developed to assess the validity of implementing diamond as a sensor material in Allpix-squared, a widely used software framework in the high-energy physics community, based on GEANT4. It was started to simulate testbeam setups with silicon detectors but has garnered interest from a wider community by now. It is shown that the currently implemented physics models for charge career drift are ineffective when applied to diamond. The charge carrier drift properties of diamond are influenced by very low acceptor concentrations, which resulted in the implementation of diamond-specific parameter values for mobility models in Allpix-squared. Additionally, a model representing the polycrystalline nature of diamond was introduced. I will present the simulation results of charge carrier properties of single-crystal chemical vapor deposition (scCVD) and polycrystalline chemical vapor deposition (pcCVD). These results are systematically compared with experimental and literature data to further validate the effectiveness of the implemented models in Allpix-squared.

T 115.4 Fri 9:45 Geb. 30.23: 2/1

**Sensor Performance of the ATLAS High Granularity Timing Detector** — •Theodoros Manoussos[1,2], Xiao Yang[1], Guilherme Saito[3], Xiangxuan Zheng[4], Dominik Dannheim[1], Gregor Kramberger[5], Stefan Guindon[1], Stefano Manzoni[1], Giulia Di Gregorio[1], and Lucia Masetti[2] — [1]CERN — [2]Johannes Gutenberg-Universität Mainz, Deutschland — [3]Universitade de São Paulo, Brasil — [4]University of Science and Technology of China, Hefei, China — [5]Institut Jožef Stefan, Ljubljana, Slovenia

The increase of the instantaneous luminosity at the HL-LHC will be a challenge for the ATLAS detector. The pile-up is expected to increase on average to 200 interactions per bunch crossing. To mitigate these effects a High Granularity Timing Detector (HGTD) will be integrated in the end-cap regions of ATLAS, covering a pseudo-rapidity range of $2.4 < |\eta| < 4.0$. HGTD, which also serves as a luminosity monitor, aims for a single track time resolution for MIPs of 30 ps at the beginning of the lifetime, up to 50 ps after a maximum fluence of $2.5 \times 10^{15}\ \frac{\text{neq}}{\text{cm}^2}$. The high precision timing information improves the assignment of tracks the correct vertex. HGTD sensors are based on the Low Gain Avalanche Detector (LGAD) technology. Each sensor is a $15 \times 15$ array of $1.3 \times 1.3$ mm LGAD pads. Along with the sensors, an equal amount of Quality Control-Test Structures is produced, to monitor the quality and uniformity of the sensors and extract technology parameters during the production. This contribution presents the status of the sensor quality control and the non-irradiated and irradiated LGAD performance obtained in a series of test-beam campaigns.

T 115.5 Fri 10:00 Geb. 30.23: 2/1

**Timing Performance of a Digital SiPM Prototype with a Fast Laser** — Inge Diehl[1], Finn Feindt[1], Karsten Hansen[1], Stephan Lachnit[1,2], Frauke Poblotzki[1], •Daniil Rastorguev[1,3], Tomas Vanat[1], and Gianpiero Vignola[1,4] — [1]Deutsches Elektronen-Synchrotron, Hamburg, Germany — [2]Universität Hamburg, Germany — [3]Bergische Universität Wuppertal, Germany — [4]Universität Bonn, Germany

Recent advances in CMOS technologies open up possibilities for new types of monolithic silicon detectors. DESY has designed a prototype of a silicon photomultipier integrated with a digital readout ASIC. This device, combining features of a pixelated chip, such as a high granularity readout, with an intrinsically high temporal resolution of a SiPM, is an interesting candidate for 4D tracking in future particle physics experiments. This work presents the characterization of the timing performance of the dSiPM by means of a fast pulsed laser, as well as comparison with the results, obtained via direct detection of charged particles at the DESY II testbeam facility. The study showcases temporal resolution of the device as a function of charge injection position. The results can be correlated to intrinsic properties of the single photon avalanche diodes and to the design of the digital circuitry.

T 115.6 Fri 10:15 Geb. 30.23: 2/1

**Module assembly for the ATLAS High Granularity timing detector** — •Hendrik Smitmanns[1], Maria Soledad Robles Manzano[1], Doğa Elitez[1], Jan Ehrecke[1], Theodorus Manoussos[1], Lucia Masetti[1], Andrea Brogna[2], Atila Kurt[2], Fabian Piermaier[2], Steffen Schoenfelder[2], Antonin Zeeman[2], and Quirin Weitzel[2] — [1]Institut für Physik, Johannes-Gutenberg Universität Mainz — [2]PRISMA+ Detector Lab, Johannes-Gutenberg Universität Mainz

To meet the challenges of the High Luminosity Large Hadron Collider (HL-LHC), especially the increase of pile-up interactions, the ATLAS detector will need to be upgraded. One of the foreseen upgrades will be the installation of the High-Granularity Timing Detector (HGTD). The HGTD will mitigate the effects of pile-up in the ATLAS forward region, providing a time resolution of about 30-50 ps per track. The active area consists of 2-double-sided disks per end-cap. Two 2x2 cm* Low Gain Avalanche Detectors bump-bonded to two ASICs and glued to a flexible PCB form the HGTD basic unit, the so-called module. Multiple modules are then glued onto a support unit to form a detector unit. Each module is tested before and after being glued to a support unit. Prototype modules and detector units are being assembled at Johannes Gutenberg University Mainz in preparation for the production of around 1000 modules for the final detector over the next few years. The assembly procedure, performance and test results are presented.

## T 116: Detectors 11 (gas detectors)

Time: Friday 9:00–10:30 Location: Geb. 30.23: 2/17

T 116.1 Fri 9:00 Geb. 30.23: 2/17

**BODELAIRE: A TPC for Neutron Science** — Klaus Desch[1], Jochen Kaminski[1], •Thomas Block[1], Michael Lupberger[1,2], Markus Köhli[3], Saime Gürbuz[1], Markus Gruber[1], and Laura Rodriguez Gómez[1] — [1]Physikalisches Institut, Univeristät Bonn — [2]HISKP, Universität Bonn — [3]Physikalisches Institut, Univeristät Heidelberg

An increase in demand and the resulting price increase of Helium-3 has sparked the development of alternative kinds of neutron detectors for various applications in neutron science.

The Boron Detector with Light and Ionisation Reconstruction (BODELAIRE) is a detector, which combines the concept of a time projection chamber (TPC) with a highly granular readout with high time resolution and a boronated glass window for neutron conversion. Boron absorbs incoming neutrons and decays into an alpha particle and a Lithium ion. One of the ions enters the drift volume of the TPC and creates a trace of electron-ion pairs, which the readout detects. The other ion emitted in opposite direction is used to start the readout with the help of a scintillator inside the glass vessel. The light created in the scintillator is coupled to a trigger board via wavelength shifting fibers to generate a start signal in silicon photomultiplier-based electronics. The trigger system is FPGA-controlled, which the user can interface with to set signal thresholds.

In this talk I will present the detector concept and its current status of development.

T 116.2 Fri 9:15 Geb. 30.23: 2/17

**Cosmic Muon Tracking with Micromegas Detectors and Neutron Source Characterisation** — •Eshita Kumar, Otmar Biebel, Valerio D'Amico, Stefanie Götz, Ralf Hertenberger, Roman Lorenz, Katrin Penski, Nick Schneider, Chrysostomos Valderanis, and Fabian Vogel — LMU München

MICRO MEsh GAseous Structure (Micromegas) detectors are Micro-Pattern Gaseous Detectors (MPGDs) that have high rate capability due to the fast evacuation of positive ions and excellent spatial resolution due to a small-scale readout strip pitch. To test the performance and resilience of such detectors in detecting cosmic muons under high background, a 2 $m^2$ Micromegas detector with four layers was irradiated by a 10 GBq Americium-Beryllium neutron source for a period of three years. The analysis performed on these measurements without background radiation and the final results obtained on the efficiency of the detectors in tracking cosmic muons after long-term irradiation will be discussed. Furthermore, an intensive study on the characteristics of the neutron source used was carried out: measurements with a shielding material of varying thicknesses placed in front of the source were used to disentangle the detector response for gamma and neutron radiation. A Germanium detector was used in order to determine the intensity of gammas produced by the source. Following this, a Geant4 simulation was performed to determine the interaction probability from the background radiation. A comparison of the analysis of the detector output to the simulation results for the final charge obtained from the gammas and the neutrons will be shown.

T 116.3 Fri 9:30 Geb. 30.23: 2/17

**Long term irradiation studies of ATLAS Micromegas detectors at the CERN GIF++ facility** — •Valerio D'Amico, Stefanie Goetz, Ralf Hertenberger, Eshita Kumar, Roman Lorentz, Katrin Penski, Nick Schneider, Chysostomos Valderanis, Fabian Vogel, and Otmar Biebel — Ludwig-Maximilians-Universität München

The ATLAS muon spectrometer will face an increase of particle rate consequently of the larger instantaneous luminosity for the HL-LHC phase, expected to reach $7.5\times10^{34}$ $cm^{-2}s^{-1}$. The New Small Wheel of the ATLAS muon spectrometer end-cap is equipped with small-strip Thin Gap Chambers and Micromegas (MM), able to provide good tracking and trigger performances in this dense environment. MM detectors are operated with $Ar : CO_2 : iC_4H_{10}$ 93:5:2 vol% ternary gas mixture, providing a good HV stability and a large pulse height, useful for inclined track reconstruction. Due to the hydrocarbon content in the mixture, an extensive aging campaign is ongoing at the Gamma Irradiation Facility (GIF++) at CERN on MM production detectors, where they are long term exposed to a 11.6 TBq $^{137}Cs$ $\gamma$-source, accumulating so far a charge equivalent to several years of HL-LHC operations. Amplification gain, tracking position and time resolution using 80 GeV muon beam were studied to test the detector stability during irradiation. This contribution will describe the results obtained from the above studies, showing the good response of the detector after several 'HL-LHC equivalent' years of irradiation, demonstrating the robustness of ATLAS MM detectors under intense particle rates.

T 116.4 Fri 9:45 Geb. 30.23: 2/17

**Upgrading the CMS muon end cap for the high luminosity LHC using GEM chambers** — •Shawn Zaleski, Thomas Hebbeker, Kerstin Hoepfner, and Francesco Ivone — III. Physikalisches Institut, RWTH University, Aachen

The first set of gas electron multiplier (GEM) chambers was installed in the Compact Muon Solenoid (CMS) end cap of the muon system during long shutdown 2 (LS2) in 2021 and 2022. These GEM chambers comprise the so-called GE1/1 subsystem. The GE1/1 system compliments the cathode strip chamber (CSC) system in an effort to improve the transverse momentum measurement of muons traversing the CMS end caps. The GE1/1 system has been participating in data taking within CMS since the start of Run 3 in 2022. Several performance studies have been performed in this time and a procedure for certifying GEM data has been developed. Additional extensions to the GEM system are foreseen. These extensions will extend the measurement acceptance of the muon system in pseudorapidity from 2.4 to 2.8.

T 116.5 Fri 10:00 Geb. 30.23: 2/17

**Production of thin-gap Resistive Plate Chambers for the Phase-2 Upgrade of the ATLAS muon spectrometer** — Nayana Bangaru, •Francesco Fallavollita, Oliver Kortner, Hubert Kroha, Giorgia Proto, Daniel Soyk, Timur Turkovic, and Elena Voevodina — Max Planck Institut für Physik - Werner Heisenberg Institute, München, Germany

The present ATLAS RPC system will undergo a major upgrade for the HL-LHC program, consisting in three additional full coverage layers of new generation thin-gap RPC trigger chambers, to be installed in the inner barrel region of the Atlas Muon Spectrometer. The Max Planck Institute for Physics (MPI) has established RPC production procedures compliant with industrial requirements and is in the process of certifying several companies for the future RPC series production for the ATLAS upgrade for HL-LHC and beyond. In order to certify the new manufacturers, several $40 \times 50$ $cm^2$ small-size detector prototypes have been built by them. Their performance have been studied in laboratory tests and at CERN Gamma Irradiation Facility (GIF++). Several full-scale prototypes are currently under construction and qualification at the external manufacturers and at MPI. The prototypes will undergo long-term irradiation for half a year in the CERN GIF++ facility in order to qualify the components and production procedures with respect to longevity. The core of the project is presented, together with a description about the technology transfer, the RPC prototype production and certification at the selected companies, as well as their performance and stability measurements at CERN GIF++ facility.

T 116.6 Fri 10:15 Geb. 30.23: 2/17

**Cosmic test stand studies with a small-strip Thin Gap Chamber quadruplet** — •Ksenia Solovieva, Jose Antonio Fernandez Pretel, Patrick Scholer, Vladislavs Plesanovs, and Ulrich Landgraf — Albert-Ludwigs University, Freiburg

The small-strip Thin Gap Chamber (sTGC) technology has been implemented in the New Small Wheel upgrade of ATLAS for improved triggering and tracking in a higher particle rate environment. For the purpose of investigating analog signal shapes and gas parameters, a quadruplet was set up in a cosmic muon test stand in Freiburg and read out with the final ATLAS NSW readout system and the final gas mixture. With the unique opportunity of this setup to study analog signals before digitisation and to closely monitor various properties of the gas and HV, it lends itself to studies of the properties of the sTGC gas mixture and analog signal shapes. This presentation discusses the goals and challenges of the dedicated setup, as well as comparing results to simulation in Garfield++.

# T 117: Trigger+DAQ 4

Time: Friday 9:00–10:30 Location: Geb. 30.23: 3/1

T 117.1 Fri 9:00 Geb. 30.23: 3/1

**Reconstruction of faint non-standard model particles in IceCube** — •Nick Jannis Schmeisser, Timo Stürwald, and Alexander Sandrock — Bergische Universität Wuppertal

The new Faint Particle Trigger (FPT) in IceCube was developed with the intention of reaching a higher sensitivity for faint signals in the IceCube detector. Instead of customary triggers, which are based on local coincidences between two optical modules in the detector, it also uses isolated hits. Therefore, it is especially suited for the search for faint signals in the detector. Examples are fractionally charged particles, which produce less Cherenkov light in comparison to muons because of their smaller charge, or other non-standard model particles.

This presentation shows studies on multiple cleaning and reconstruction approaches in order to develop a reconstruction algorithm for events triggered by the FPT. The discussed algorithms include customary reconstruction techniques used in IceCube, which were adapted to the newly recorded signals, as well as new approaches that use additional information provided by the trigger. Furthermore, reconstruction methods based on machine learning using Graph Neural Networks are applied to the resulting triggered events.

T 117.2 Fri 9:15 Geb. 30.23: 3/1

**Development and characterization of a new time reference plane and trigger system for a MIMOSA26 test beam telescope** — •Rasmus Partzsch, Christian Bespin, Yannick Dieter, Fabian Hügging, Lars Schall, and Jochen Dingfelder — Physikalisches Institut, University Bonn, Germany

Test beam telescopes facilitate a characterization of different detector parameters and consist of multiple detector planes with high spatial resolution. ANEMONE is a beam telescope, comprising 6 MIMOSA26 planes. Because of the MIMOSA26 readout cycle, multiple hits are included in a single readout frame. To resolve individual tracks within the readout cycle, a reference detector with high precision time-stamping capabilities is required. Currently, the ATLAS FE-I4 chip is utilized as such. For the ATLAS inner tracker upgrade, the ITkPix readout chip was developed, featuring a smaller pixel size and the same time resolution as the FE-I4. A replacement with the new ITkPix chip enables a more efficient track reconstruction. Additionally, it can be utilized to provide a region-of-interest trigger in conjunction with the new AIDA TLU. It provides clock and time-stamp synchronization with the DUT and a more complex triggering logic compared to the previously used EUDET TLU. A new Python-based control software for the AIDA TLU has been developed for usage with the ANEMONE beam telescope.

In this talk, the integration of the AIDA TLU into the ANEMONE telescope is demonstrated. In addition, results with the upgraded time reference plane in terms of track reconstruction efficiency are shown.

T 117.3 Fri 9:30 Geb. 30.23: 3/1

**ATLAS ITk-Pixel Read-out Chain Stress Test** — •Matthias Drescher, Jörn Grosse-Knetter, Arnulf Quadt, and Ali Skaf — II. Physikalisches Institut, Georg-August-Universität Göttingen, Germany

The current ATLAS Inner Detector will be upgraded to an all-silicon Inner Tracker (ITk) for the Phase 2 upgrade of the experiment. The ATLAS ITk readout system uses the FELIX hardware/software system to connect the fibre-optic cables of the on-detector components to the higher-level infrastructure. Each FELIX card has 24 bidirectional high-speed fibre links. In the Pixel subdetector configuration, each uplink fibre is connected to an lpGBT aggregator chip, which in turn bundles 7 Aurora 64b/66b data lanes at 1.28 Gbps. These data are the outputs of the connected front-end chips (RD53A or ITkPix). To ensure stable operation under full load before moving to the final large-scale readout system, a stress test is being prepared populating all 24 FELIX fibres.

Due to limited hardware availability, a stress test setup was prepared using lpGBT and RD53A emulators implemented on several Xilinx FPGA development boards, to be used in place of the respective ASICs. The hit data sent by the RD53A emulators are stored in fast local memory, which can be written from a central controller computer connected to the FPGA boards via Gigabit Ethernet. To implement this Ethernet connection, a processing system is implemented on the FPGA boards, making the design a System-on-Chip (SoC). The project is therefore threefold, consisting of the FPGA design, the SoC processor code and the offline code to control the boards.

T 117.4 Fri 9:45 Geb. 30.23: 3/1

**Microservices framework and configuration database for ATLAS ITk** — •Jonas Schmeing, Gerhard Brandt, Marvin Geyik, Maren Stratmann, and Wolfgang Wagner — Bergische Universität Wuppertal

For the LHC Phase-2 upgrade, a new inner tracker (ITk) will be installed in the ATLAS experiment. It will allow for even higher data rates and will be thoroughly tested in the ATLAS ITk system tests. To operate these tests and later the final detector, a GUI and configuration system is needed. For this a flexible and scalable framework based on distributed microservices has been introduced. Different microservices are responsible for configuration or operation of all the parts in the readout chain.

The configuration database microservice provides the configuration files needed to configure the hardware components of the readout chain and perform scans. It saves all the connectivity information and configuration files needed to operate the system in so called runkeys, who are saved in a flexible, tree-based data structure. This flexible structure the runkeys allows the storage of specialized runkeys made up of different objects for the ITk subdetectors.

To efficiently serve these files to the subdetectors, a distributed system of ConfigDB caches is introduced. The master instance of the ConfigDB provides these caches with subsets of the runkeys depending on the elements of the readout chain that the specific cache serves.

T 117.5 Fri 10:00 Geb. 30.23: 3/1

**OSIRIS DAQ: Design and Commissioning** — •Arshak Jafar, Michael Wurm, Oliver Pilarczyk, Tim Charisse, Marcel Buchner, and George Parker — JGU Mainz, Institute of Physics and EC PRISMA+

The Jiangmen Underground Neutrino Observatory (JUNO), under construction in southern China, will determine the neutrino mass hierarchy (MH) by observing neutrinos from nuclear reactors at a distance of 53 km. To reach the desired sensitivity ($> 3\sigma$) for MH, the radiopurity of the different detector components plays a crucial role. To ensure the purity of the 20 kt liquid scintillator (LS) target of JUNO, the Online Scintillator Internal Radioactivity Investigation System (OSIRIS) is being constructed. The 20-ton pre-detector will monitor the radiopurity of the LS during its production and the filling phase of the central detector of JUNO.

This talk will focus on the design principles and working of the data acquisition system (DAQ) of the OSIRIS pre-detector as well as the details on commissioning that has been done over the past year leading to the first data.

This work is supported by DFG, Research Unit FOR 5519.

T 117.6 Fri 10:15 Geb. 30.23: 3/1

**The build system for the *Mu3e* DAQ firmware** — •Alexandr Kozlinskiy — Institut für Kernphysik, JGU Mainz

The *Mu3e* experiment is designed to search for the lepton flavor violating decay $\mu^+ \to e^+ e^- e^+$ with the aim of reaching a branching ratio sensitivity of $10^{-16}$. The experiment is located at the Paul Scherrer Institute (Switzerland). The existing beam line will provide $10^8$ muons per second and at first will allow to reach a sensitivity of a few $10^{-15}$.

The readout system of *Mu3e* utilizes Intel FPGA chips for which the firmware and IP components are compiled with the Quartus software package. To streamline the development and testing of the *Mu3e* DAQ firmware, custom scripts and tools were developed to allow for building and testing of the firmware directly from the command line and on the continuous integration server where firmware for all subsystems is built on each commit. This allowes for faster iteration on firmware designs and better tracking of regressions during development.

The talk will present the scripts and tools, and the overall design of the build system for the *Mu3e* DAQ firmware.

# T 118: Gravitational waves 2

Time: Friday 9:00–10:00 Location: Geb. 30.23: 6/1

T 118.1 Fri 9:00 Geb. 30.23: 6/1

**Correlating dark matter and gravitational waves from a dark Higgs mechanism** — Torsten Bringmann[1], Tomás Gonzalo[2], Felix Kahlhoefer[2], •Jonas Matuszak[2,3], and Carlo Tasillo[4] — [1]Department of Physics, University of Oslo, Box 1048, N-0316 Oslo, Norway — [2]Institute for Theoretical Particle Physics (TTP), Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — [3]Institute for Theoretical Particle Physics and Cosmology (TTK), RWTH Aachen University, D-52056 Aachen, Germany — [4]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

The next generation of gravitational wave (GW) detectors open up a new window to probe physics beyond the Standard Model in the early universe. An intriguing possibility are first order phase transitions in a dark sector giving rise to a stochastic GW background. In this talk I will discuss GW signals from a dark sector with a spontaneously broken gauge symmetry and a stable dark fermion. Requiring the freeze-out mechanism to reproduce the observed relic abundance of dark matter constrains the GW signal frequency to lie within the LISA sensitivity range. Finally I will consider a scenario with feeble coupling between the dark and Standard Model sector, allowing the temperatures of the two sectors to evolve independently during the phase transition.

T 118.2 Fri 9:15 Geb. 30.23: 6/1

**Detectability of Gravitational Waves from Core-Collapse Supernovae for the Einstein Telescope** — Markus Bachlechner, Thilo Birkenfeld, •Timo Butz, and Achim Stahl — III. Physikalisches Institut B, RWTH Aachen

Core-collapse supernovae are interesting source candidates for gravitational wave detectors. Measurements of gravitational waves from such events can provide information on the physical processes occurring during the core-collapse of massive stars, especially with multi-messenger detections. The proposed Einstein Telescope, as the first of the third generation of gravitational wave detectors, is predicted to be an order of magnitude more sensitive in the whole frequency band compared to the previous generation. Therefore, an increased event rate due to the enlarged observable volume and the ability to study details of the underlying mechanism are expected.

This talk presents an analysis of the capability to detect core-collapse supernovae with the Einstein Telescope and prospects to extract information on the progenitor star.

T 118.3 Fri 9:30 Geb. 30.23: 6/1

**Test setup for cryogenic sensors and actuators working towards the Einstein Telescope** — Charlotte Benning[2], Thomas Hebbeker[1], •Robert Joppe[1], Tim Kuhlbusch[2], Oliver Pooth[2], Achim Stahl[2], and Franz-Peter Zantis[1] — [1]III. Physikalisches Institut A, RWTH Aachen — [2]III. Physikalisches Institut B, RWTH Aachen

The Einstein Telescope will be the first gravitational wave detector of the third generation. The sensitivity goal, especially in the low frequency region, will be achieved in particular by cooling the main parts of the interferometer. The required electronic components, sensors and actuators needed for mirror alignment and active damping of suspension resonances have to perform at cryogenic temperatures. The talk presents the progress on the development of electronics, optics and mechanics within the E-TEST project. Furthermore, the performance of our cryogenic UHV test setup and the characterization of light emitting diodes at low temperatures will be explicated.

T 118.4 Fri 9:45 Geb. 30.23: 6/1

**A Cryogenic Actuator and Position Sensor for the Einstein Telescope** — Charlotte Benning[2], Thomas Hebbeker[1], Robert Joppe[1], •Tim Kuhlbusch[2], Oliver Pooth[2], Achim Stahl[2], and Franz-Peter Zantis[1] — [1]III. Physikalisches Institut A, RWTH Aachen University — [2]III. Physikalisches Institut B, RWTH Aachen University

Thermal noise at room temperature would limit the sensitivity of future gravitational wave detectors in the lower frequency region. Cooling the optical components of the interferometric detector reduces the thermal noise but adds constraints for their suspension system. The Einstein Telescope, a foreseen next-generation European gravitational wave detector, requires an operating temperature below 20 Kelvin.

This talk will present the development of an actuator with an integrated absolute displacement sensor optimized for these temperatures. The sensitivity of the sensor and range of the actuator must be maintained at low temperatures while reducing produced heat. Measurements of all optical components of the sensor were performed to optimize the cryogenic performance. The produced heat was analysed and options to reduce the thermal load will be discussed.

# T 119: Data, AI, Computing 8 (foundational & transformer models)

Time: Friday 9:00–10:15 Location: Geb. 30.33: MTI

T 119.1 Fri 9:00 Geb. 30.33: MTI

**Finetuning Foundation Models for Joint Analysis Optimization** — •Matthias Vigl, Nicole Hartman, and Lukas Heinrich — TUM

Most searches at the LHC employ an analysis pipeline consisting of various discrete components, each individually optimized and later combined to provide relevant features used to discriminate SM background from potential signal. These are typically high-level features constructed from particle four-momenta. However, the combination of individually optimized tasks doesn't guarantee an optimal performance on the final analysis objective. In this study, we show how an analysis would benefit from adopting an end-to-end ML optimization approach. Specifically, we investigate the impact of jointly optimizing particle identification and signal vs background discrimination exploiting the transformer-based ParT architecture [arXiv:2202.03772] as foundation model, showing the effectiveness of finetuning in the case of multi jets final states with CMS open data [DOI:10.7483/OPENDATA.CMS.JGJX.MS7Q].

T 119.2 Fri 9:15 Geb. 30.33: MTI

**adaptive generative modeling for High-Granularity Calorimeters** — •Lorenzo Valente — Institut für Experimentalphysik, University of Hamburg, Germany

Simulating particle colliders in their entirety presents a substantial computational challenge for researchers. Detector simulations are among the most resource-intensive phases of this process. Deep generative models could be a potential solution since they have already been proven to speed up simulations.

The growing volume of data from upcoming high-energy physics experiments, including higher collider luminosities and highly granular calorimeters, requires the development of artificial intelligence algorithms capable of combining knowledge across different domains. Unfortunately, conventional deep learning algorithms struggle with handling multiple datasets. Research in domain adaptation involves creating methodologies to bridge the divide between datasets, enabling the construction of models that exhibit high performance across diverse domains simultaneously.

In this contribution, we illustrate how a more universal domain adaptation approach, utilizing the transfer learning method, enhances the flexibility of the model. Specifically, we showcase its effectiveness in data generation for different calorimeter geometries.

T 119.3 Fri 9:30 Geb. 30.33: MTI

**Leveraging Transformer Models for Gamma-Hadron Separation in SWGO** — •Markus Pirke, Jonas Glombitza, Martin Schneider, and Christopher van Eldik for the SWGO-Collaboration — ECAP, FAU Erlangen-Nürnberg

The Southern Wide-field Gamma-ray Observatory (SWGO) is a proposed next-generation water-Cherenkov gamma-ray observatory in the Southern Hemisphere, thus being complementary to other water-Cherenkov detectors like HAWC (Mexico) and LHAASO (China), which are both located in the Northern Hemisphere. One of the primary challenges of the water-Cherenkov technique, is the effective discrimination of gamma-ray signals from the prevalent hadronic background. Several techniques have been developed in the past, primarily relying on human-designed discrimination variables.

In other scientific areas, recent advancements in deep learning have revealed that employing an end-to-end learning approach, which involves using raw data without the inclusion of handcrafted designed features, frequently improves the performance. One specific deep learning architecture is the Transformer. The self-attention mechanism of the Transformer, initially developed for tasks in natural language processing, offers a promising approach to efficiently handle the complex and variable-sized data in a ground-based observatory with high multiplicities. In this work, this approach will be investigated specifically for Gamma-Hadron separation in SWGO. Performance will be evaluated and additionally the inner workings, meaning the individual building blocks and their functions, of the Transformer will be explained.

T 119.4 Fri 9:45 Geb. 30.33: MTI

**Point-Clouds based Diffusion Model on Hadronic Shower** — •Martina Mozzanica[1], Erik Buhmann[1], Frank Gaede[2,3], Gregor Kasieczka[1,3], Anatolii Korol[2], William Korcari[1], Katja Krüger[2], and Peter McKeown[2] — [1]Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany — [3]Center for Data and Computing in Natural Sciences CDCS, Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

Simulating showers of particles in highly-granular detectors is a key frontier in the application of machine learning to particle physics. Achieving high accuracy and speed with generative machine learning models can enable them to augment traditional simulations and alleviate a major computing constraint.

Recent developments have shown how diffusion based generative shower simulation approach that do not rely on a fixed structure, but instead generates geometry-independent point clouds are very efficient. We present an extension to a point-cloud based diffusion model, i.e. CaloClouds, previously applied only to electromagnetic showers of the International Large Calorimeter (ILD).

The works focuses on the more challenging hadronic showers, namely pion showers, and introduces a more advanced architecture that successfully deals with the increasing complexity of the data, i.e. the attention mechanism.

T 119.5 Fri 10:00 Geb. 30.33: MTI

**Photon Energy Reconstruction using Machine Learning at the Pierre Auger Observatory** — •Daniel Rech — Karlsruhe Institute of Technology (IAP), Karlsruhe, Germany

An energy reconstruction for photon-induced air showers at ultra-high energies ($\geq 10^{18}$ eV) is presented for the surface detector of the Pierre Auger Observatory. Photon showers have a signature that differs from that of hadron-induced showers: the photon shower composition is almost exclusively electromagnetic and they show a steeper lateral distribution function as well as a larger depth of the shower maximum. In order to improve the resolution of the energy prediction, a reconstruction method based on ML is taken into consideration and compared to the classical hadron shower reconstruction applied to photon-induced extensive air showers. Due to the high success rate in other areas of machine learning, the encoder stack of the so-called transformer architecture is explored as an alternative to the more traditional approach of convolutional networks. So far, no photon events in the Pierre Auger dataset have been unequivocally identified as photons, but the advances in ML could play a key role in detecting them in the future.

## T 120: Data, AI, Computing 9 (generative models & simulation)

Time: Friday 9:00–10:30 Location: Geb. 30.34: LTI

T 120.1 Fri 9:00 Geb. 30.34: LTI

**Faster Simulations of Instrument Response Functions for Imaging Air Cherenkov Telescopes through Methods of Adaptive Sampling** — •Tristan Gradetzke and Stefan Fröse — TU Dortmund University, Germany

Monte Carlo simulations of particle induced extensive air showers are of crucial importance to the analysis chain of data taken by Imaging Air Cherenkov Telescopes (IACTs). Besides for the training of particle classifiers and energy estimators, they are necessary to calculate the instrument response in the form of the Instrument Response Functions (IRFs). There usage however, comes at the extensive cost of computational resources. Therefore much effort has been made to this day, to make these simulations more efficient. This work, aims at investigating how to use them more efficiently for IRF calculations, thus reducing the amount needed. This is sought to be achieved by simulating only discrete points in energy and field of view, instead of continuous distributions currently used. The goal is to only sample the regions improving uncertainty and event statistics. The achieved uncertainties and event statistics are then compared to the standard approach. An outlook is given, on how methods of machine learning can be used to fasten the process even further.

T 120.2 Fri 9:15 Geb. 30.34: LTI

**Accelerating event generation in Sherpa with deep learning with matrix element weight surrogates** — •Tim Herrmann[1], Timo Janssen[2], Steffen Schumann[2], and Frank Siegert[1] — [1]Technische Universität Dresden, Germany — [2]Universität Göttingen, Germany

To calculate theory predictions for high energy physics (HEP) experiments, Monte Carlo (MC) methods are needed. Accelerating MC generation is needed to fulfil the future needs of HEP experiments. Unit-weight events are generated on particle level to make the most use of the following computationally expensive detector simulation. But making unit-weight events can also be time-consuming.

One way to save computation time during unit-weight event generation is to use a fast full matrix element weight surrogate. The surrogate is estimated via a deep neural network, which can be calculated much faster than the full matrix element. The estimate is corrected in a second step to get an unbiased prediction. This approach has already been shown to be effective. This work focuses on further optimizing it and working towards an implementation in an official Sherpa release.

T 120.3 Fri 9:30 Geb. 30.34: LTI

**Neural Networks for simulating Air-Shower Radio Emission** — •Pranav Sampathkumar[1] and Tim Huege[1,2] — [1]Karlsruher Institut für Technologie, Institut für Astroteilchenphysik, Karlsruhe, Germany — [2]Astrophysical Institute, Vrije Universiteit, Brussel, Belgium

Radio Measurements of Extensive Air Showers are gaining importance as a technique for high energy cosmic ray measurements since they have been reliable in the estimation of energy and Xmax. As the array of antennas grows bigger, the need for simulations in-order to fit the data and estimate shower parameters grows larger. The current way of microscopically calculating the pulses individually for every antenna is very time intensive and scales with the number of antennas. Novel methods are needed for interpolation and generation of radio simulations.

This work, presents a neural network model which is trained to provide radio pulses taking shower parameters and antenna positions as input. Preliminary results on the generated pulses are presented and the underlying physics potentially learned by the network is discussed along with the limitations and future possibilities of the current training methodology.

T 120.4 Fri 9:45 Geb. 30.34: LTI

**Equivariant Point Cloud GAN for 4-dimensional Calorimeter Clouds.** — •william korcari[1], erik buhmann[1], frank gaede[2], gregor kasieczka[1,3], anatolii korol[2], katja krüger[2], and peter mckeown[2] — [1]Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany — [3]Center for Data and Computing in Natural Sciences CDCS, Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

Fast simulation of the energy depositions in high-granular detectors is crucial for future collider experiments with increasing luminosity. Many proofs of concepts show how generative machine learning models can speed up and augment the traditional simulation chain in physics analysis. EPiC GAN has already shown promising results with very high-fidelity simulation of the physics of top jets with cardinality going as high as 150 particles and characterized by 3 dimensions. We show an extension of such a model, capable of conditional generation of photon calorimeter showers with even higher cardinality and an extra dimension.

T 120.5 Fri 10:00 Geb. 30.34: LTI

**Study of data-augmentation for simulated ATLAS data sets using machine learning** — •Lukas Vicenik, Boris Flach, and Andre Sopczak — Czech Technical University in Prague

Limitations on available simulated data sets have a strong impact on the uncertainty in searches for new particles and in precision measurements. This also applies to machine learning algorithms that aim to separate signal from background events. We propose to use Variational autoencoders (VAE) for augmenting and enriching simulated data sets. We consider two variants for training VAEs - the standard ELBO learning and a novel Nash equilibrium learning approach. The resulting generated data are validated and compared by studying their agreement with the original data sets.

T 120.6 Fri 10:15 Geb. 30.34: LTI

**Exploring tomorrow's Monte-Carlo generators: MC Validation in ATLAS with PAVER** — Frank Ellinghaus, Dominic Hirschbühl, •Johanna Wanda Kraus, Joshua Reidelstürz, Mustafa Schmidt, and Anna Vorländer — Bergische Universität Wuppertal

Monte-Carlo (MC) simulations play a key role in high energy physics, for example at the ATLAS experiment. MC generators are constantly evolved, where a periodic validation is indispensable for obtaining reliable physics simulations.

For that purpose, an automated and central validation system was developed: PMG Architecture for Validating Evgen with Rivet (PAVER). It provides an MC event generator validation procedure that allows a regular evaluation of new revisions and updates for commonly used MC generators in ATLAS as well as comparisons to measured data. The result is a robust, fast, and easily accessible MC validation setup that is constantly developed further. This way, issues in simulated samples can be detected before generating large samples for the collaboration, which is crucial for a sustainable and low-cost MC production procedure in ATLAS.

# T 121: Search for Dark Matter 6

Time: Friday 9:00–10:30 Location: Geb. 30.35: HSI

T 121.1 Fri 9:00 Geb. 30.35: HSI

**Position Dependent Corrections for the Electroluminescence Signal of the XENONnT Time Projection Chamber** — •Peter Gyorgy — JGU Mainz

The XENONnT experiment is a dual-phase liquid xenon time projection chamber (TPC) for the direct search of Dark Matter. The electroluminescence signal (S2) is created when electrons emitted from energy deposits are extracted from the liquid into the gas phase of the TPC. Various physical effects result in a position-dependent S2 distribution, which must be corrected using calibrations. Krypton 83m provides a uniform distribution of S2 signals, which allow for the creation of a 2D correction map. This presentation discusses the S2 correction map for Science Run 1 (SR1) of XENONnT, and compares them to those of Science Run 0.

T 121.2 Fri 9:15 Geb. 30.35: HSI

**Nuclear recoil response calibration for the XENONnT experiment** — •Johanna Jakob for the XENON-Collaboration — Institut für Kernphysik, Universität Münster, Germany

XENONnT is currently taking science data with the science goals to detect weakly interacting massive particles (WIMPs) and other rare event signals. The detector is a dual-phase time projection chamber filled with 8.5 tons of liquid xenon surrounded by an active water Cherenkov neutron and muon veto. Just like WIMPs, neutrons scatter off xenon nuclei elastically, producing a nuclear recoil (NR), and tend to leave the TPC cryostat after a single backscatter. As these signals are indistinguishable from WIMPs, they provide an excellent calibration source. This talk discusses a background-free NR response calibration of the XENONnT TPC, using neutrons from an americium beryllium source which are tagged by coincidentally emitted $\gamma$s detected in the neutron veto. This work is supported by BMBF under contract 05A23PM1 und by DFG within the Research Training Group GRK-2149.

T 121.3 Fri 9:30 Geb. 30.35: HSI

**Power Calibration of a Dielectric Haloscope** — •Bernardo Ary dos Santos for the MADMAX-Collaboration — RWTH, Aachen, Germany

The MADMAX collaboration intends to build a dielectric haloscope targeted to detect galactic axion dark matter, in the mass range from 40 to 400 $\mu$eV . This experiment consists of a series of dielectric discs and a mirror placed inside a strong homogeneous magnetic field that would produce the emission of coherent electromagnetic radiation with a frequency related to the mass of the axion. A prototype has recently been tested at CERN inside a 1.6T dipole magnet. In this talk I will explain the Power calibration procedure used during the data taking that allows us to estimate the sensitivity of the experiment.

T 121.4 Fri 9:45 Geb. 30.35: HSI

**Vibration decoupling in the COSINUS dry dilution refrigerator** — •Moritz Kellermann for the COSINUS-Collaboration — Max-Planck-Institut für Physik, 85748 Garching

Cryogenic detectors are a valuable class of detectors for rare event searches. Currently, energy resolutions and thresholds on the order of O(eV) are reached using Transition Edge Sensors (TES). However, besides detector effects, one of the dominating backgrounds limiting the sensitivity and operation stability of cryogenic detectors are microphonics which originate from vibrations produced by the refrigerator itself.

The COSINUS experiment will use a custom-made dry dilution refrigerator with a pulse tube cooler (PT) to cool down particle detectors with TES for dark matter research. To mitigate vibrations, a spring-based passive decoupling system inside of the refrigerator is currently under development in a test facility at the Max-Planck Institute for Physics (MPP) in Munich. This contribution shows the current status of the vibration system and presents first measurements of the vibration level at the lowest temperature stages.

T 121.5 Fri 10:00 Geb. 30.35: HSI

**Antenna alignment of the MADMAX booster system using Machine Learning techniques** — •Nabil Salama for the MADMAX-Collaboration — Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee149, 22761 Hamburg

The axion is a promising hypothetical dark matter candidate that would also solve the strong CP problem. The MADMAX experiment aims at detecting the axion in a large mass range corresponding to a frequency between 10 and 100 GHz using an array of dielectric disks in a high magnetic field of 9 T which are individually moveable to tune the resonance frequency. I present a method to spatially align the antenna that picks up a potential axion signal as well as the disks in order to compensate for a possible antenna misalignment. This is necessary to maximize the signal power of the system. The possibility of electric field measurements using the so-called bead-pull method for an objective function is investigated. The alignment procedure of antenna and disks involves many degrees of freedom which makes the problem complex, therefore it is approached using Machine Learning techniques. Results yielded by the algorithm are compared to a non-learning algorithm and theoretical expectations from Gaussian beam optics.

T 121.6 Fri 10:15 Geb. 30.35: HSI

**Coating based radon barriers for future liquid xenon detectors** — •Florian Jörg, Giovanni Volta, and Hardy Simgen — Max-Planck-Institut für Kernphysik Heidelberg, Germany

Dual-phase liquid xenon time projection chambers have become a leading technology in the search for dark matter. These detectors must be operated under extremely low radioactive background conditions. Especially, the radioactive noble gas $^{222}$Rn, that is constantly released from material surfaces, must be suppressed to the level of only a few atoms.

We have been investigating techniques to suppress its release by sealing surfaces with thin coating layers. A thousandfold reduction of the radon release has been demonstrated on a 2×2 cm$^2$-small stainless steel sample, that has been implanted with $^{226}$Ra at the ISOLDE facility at CERN. Following on the successful small-scale tests, the setup underwent an upgrade which allows coating of larger vessel-like samples. Besides the radon tightness of the coating layers, also their intrinsic radiopurity is now being assessed and first results will be shown.

# T 122: Miscellaneous

Time: Friday 9:00–10:15 Location: Geb. 30.41: HS 1

T 122.1 Fri 9:00 Geb. 30.41: HS 1

**Do we Need a New Particle Collider?** — •Alexander Unzicker — Pestalozzi-Gymnasium München

The goals of current collider projects are evaluated under a historical perspective, taking into account the development of particle physics since the 1960s and past predictions for physics beyond the standard model.

T 122.2 Fri 9:15 Geb. 30.41: HS 1

**Kaluza mit Spin** — •Thomas Schindelbeck — thomas.schindelbeck@iraeph.de

Theodor Kaluzas Modell für eine einheitliche Beschreibung von Gravitation und Elektrodynamik liefert völlig falsche Größenordnungen für Teilcheneigenschaften, ein Problem, das sich auch durch eine Kombination mit Konzepten der Quantenmechanik, erstmals vorgeschlagen von Oskar Klein, nicht zufriedenstellend lösen lässt. Ein modifiziertes Kaluza-Modell, mit Priorität auf Elektrodynamik sowie halbzahligem Spin als Randbedingung, ist dagegen in der Lage, zahlreiche Teilcheneigenschaften ab initio mit einer Genauigkeit in der Größenordnung von QED-Korrekturen zu beschreiben. U.a. liefert der Ansatz:

- a priori 12 elementare Objekte mit den Ladungen der 12 elementaren Fermionen;

- eine konvergierende Reihe von Teilchenenergien mit Energie des Elektrons und des Higgs-VEV als oberem und unteren Grenzwert;

- magnetische Momente der Baryonen, elektroschwache Kopplungskonstanten etc.

T 122.3 Fri 9:30 Geb. 30.41: HS 1

**An emergent model for wavefunctions that explains gauge interactions and particle physics** — •Christoph Schiller — Motion Moutain Research

It is shown that the approach by Dirac and by Battey-Pratt and Racey describing fermions as tethered objects yields spinor wave functions, the Dirac equation, the gauge groups, the gauge interactions, and the elementary particle spectrum. Thus, a single principle explains the standard model of particle physics, including quantum electrodynamics and quantum chromodynamics. The conclusions deduced from the principle agree with all experiments so far, both in particle physics and in general relativity. Testable experimental predictions are deduced.

C. Schiller, Testing a conjecture on quantum chromodynamics, International Journal of Geometric Methods in Modern Physics, 20 (2023) 2350095.

C. Schiller, Testing a conjecture on quantum electrodynamics, Journal of Geometry and Physics 178 (2022) 104551.

C. Schiller, Testing a conjecture on the origin of the standard model, European Physical Journal Plus 136 (2021) 79.

Details at https://www.motionmountain.net/research.html

T 122.4 Fri 9:45 Geb. 30.41: HS 1

**Particle models established in cylindrical eigenspaces with D = 6, 10 and 26 dimensions** — •Hans-Dieter Herrmann — Berlin

Particles observable in space-time are assumed to exist also in cylindrical eigenspaces. The building stones are rotons (entities consisting of masses and charges circulating with the velocity of light) with 4 dimensions. A two-dimensional noncommutative circulation plane, a spin axis and time give D = 4. Two rotons with common spin axis and time (called biroton) make up a lepton model with D = 6 dimensions. The small mass of the electron appears as the mass difference of a roton with positive and an antiroton with negative energy.

N coupled rotons or antirotons have eigenspaces with D = 2N + 2 dimensions. Models of mesons have two rotons and two antirotons with N = 4; D = 10, models of baryons have 12 rotons or 12 antirotons and D = 26. The dimensions of the models are known from little string theories (D = 6), superstring theories (D = 10) and bosonic string theories (D = 26).

Masses and magnetic moment anomalies of lepton and baryon models as well as masses of meson models are presented. Neutrino oscillation and weak parity violation are discussed within the framework of the models. Single rotons of positive and negative energy are suspected of representing dark matter and dark energy. They cannot exist in space-time, but interact by gravitation.

T 122.5 Fri 10:00 Geb. 30.41: HS 1

**Modified theory of elementary particles.** — •Albrecht Giese — Taxusweg 15, 22605 Hamburg

For decades, it has been the viewpoint of physics that elementary particles can only be understood and treated using quantum mechanics. However, another way is possible.

If Louis de Broglie's approach at the time is taken up and developed further, a number of particle parameters can be determined in the classical way. And this with a greatly simplified mathematical formalism and with results that are not only on a par with QM, but even superior. A striking example is the classical derivation of inertia/mass, which provides very precise and easily comprehensible results. It should be noted that the resulting formula for mass does not contain any adaptable parameters. Apart from the size of the particle, it only uses known physical constants. And the result for e.g. the electron deviates from the measurement by less than 10^-5. I think that's something!

These are results which the quantum mechanical Higgs model cannot compete with in any way, as it provides NO results.

As a supplement, we will show a list of (still existing) particle properties that cannot (yet) be determined independently of QM.

Further info: ag-physics.org/rmass

# T 123: Flavour physics 5

Time: Friday 9:00–10:30 Location: Geb. 30.41: HS 2

T 123.1 Fri 9:00 Geb. 30.41: HS 2

**Measurement of $R(D^*)$ with Inclusive $B$ Tagging at Belle II** — •Thomas Ametsbichler, Thomas Lück, and Thomas Kuhr — Ludwig-Maximilians-Universität München

A fundamental axiom of the Standard Model (SM) of particle physics is the universality of the lepton coupling, $g_l(l = e, \mu, \tau)$, to the electroweak gauge bosons. The average of measurements from the BaBar, Belle and LHCb experiments have shown a 2.3$\sigma$ discrepancy of $R(D^*) = \frac{\mathscr{B}(B\to D^*\tau\nu_\tau)}{\mathscr{B}(B\to D^*\ell\nu_\ell)}$, a ratio of branching fractions sensitive to the lepton coupling, with respect to the SM prediction. This discrepancy may be an indication of New Physics beyond the SM.

The goal of the presented analysis is an independent measurement of $R(D^*)$ with data from the Belle II experiment. Belle II is a so-called $B$ Factory, which produces $B$ meson pairs in $e^+e^- \to \Upsilon(4S) \to B\overline{B}$ reactions. While one $B$ meson is reconstructed in $B \to D^*\tau\nu$ or $B \to D^*\ell\nu$ to measure $R(D^*)$, there are multiple ways to reconstruct the second $B$ meson (referred to as the tag $B$).

In this analysis the tag $B$ is reconstructed inclusively instead of using a hadronic or semileptonic tag as previous measurements, which improves the reconstruction efficiency at the cost of more background. It is anticipated that this approach will reduce the statistical uncertainties of the $R(D^*)$ measurement.

T 123.2 Fri 9:15 Geb. 30.41: HS 2

**Inclusive Semileptonic $b \to c\ell\bar{\nu}$ Decays to Order $1/m_b^5$** — •Ilija S. Milutin[1], Thomas Mannel[1], and Keri Vos[2,3] — [1]Theoretical Particle Physics, Center for Particle Physics Siegen, University of Siegen, Germany — [2]Gravitational Waves and Fundamental Physics (GWFP), Maastricht University, The Netherlands — [3]Nikhef, Amsterdam, The Netherlands

Inclusive semileptonic $B \to X_c\ell\bar{\nu}$ decays can be described in the Heavy Quark Expansion (HQE) and allow for a precision determination of the CKM element $|V_{cb}|$. We calculate the terms of $1/m_b^5$ and derive a "trace formula" which allows for the computation of the decay rate and kinematic moments of the spectrum up to this order in the HQE. We focus specifically on the reparametrization invariant (RPI) dilepton invariant mass $q^2$ moments of the spectrum, which depend on a reduced set of HQE parameters. We find 10 RPI HQE parameters at $1/m_b^5$. At this order, "intrinsic charm" (IC) contributions proportional to $1/(m_b^3 m_c^2)$ enter, which are numerically expected to be sizeable. Using the "lowest-lying state saturation ansatz" (LLSA), we estimate the size of these contributions. Within this approximation, we observe a partial cancellation between the IC and the "genuine" $1/m_b^5$ contributions, resulting in a small overall contribution.

T 123.3 Fri 9:30 Geb. 30.41: HS 2

**Angular analysis of $B^0 \to D^*\mu\nu$ decay at LHCb** — •Biljana Mitreska[1], Johannes Albrecht[1], Lucia Grillo[2], Gregory Ciezarek[3], Marco Gersabeck[4], Derek Yeung[4], Hasret Nur[2], Tobias Knospe[1], and Manuel Schiller[2] — [1]TU Dortmund University, Dortmund, Germany — [2]University of Glasgow, Glasgow, UK — [3]CERN, Geneva, Switzerland — [4]The University of Manchester, Manchester, UK

Semileptonic $b \to c\ell\nu$ decays are excellent probe for testing Lepton Flavour Universality and New Physics (NP) effects. A search for NP is performed with an angular analysis of $B^0 \to D^*\mu\nu$ decays in pp collision data collected by LHCb with an integrated luminosity of 3 fb$^{-1}$. The signal is extracted using a multidimensional fit to data using templated distributions derived from simulation and from control samples in collision data. New Physics contributions are measured via their corresponding Wilson coefficients and in several fit configurations that allow for different New Physics operators. Form factor parameters using three parametrizations (BLPR, CLN and BGL) are measured in a Standard Model scenario.

T 123.4 Fri 9:45 Geb. 30.41: HS 2

**Measuring R($D^*$) in hadronic one-prong $\tau$ decays at Belle II** — Florian Bernlochner, Jochen Dingfelder, Markus Prim, and •Ilias Tsaklidis — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

Over the last decade, several experimental results hint at the existence of lepton universality violating processes. In this work we probe such a process by measuring the R($D^*$) = $\mathscr{B}(B \to D^*\tau\bar{\nu}_\ell)/\mathscr{B}(B \to D^*\ell\bar{\nu}_\ell)$ ratio using hadronically decaying $\tau$ leptons as a signature. The Belle II experiment provides an excellent laboratory to study these processes within the clean experimental environment of $e^+$ e− collisions. We present the current status of this measurement using the full Belle II Run 1 data set and by employing a hadronic reconstruction algorithm to fully reconstruct the accompanying $B$ meson using a dedicated machine learning algorithm. This allows us to reconstruct the entire collision event, assigning each final state particle to a signal and tag side. We target B → $D^*\tau\nu$ decays with a single charged hadron originating from the $\tau$ decay and two missing neutrinos in the event. This allows us to measure not only the rate, but also the polarization of the $\tau$ lepton, which has increased sensitivity to New Physics contributions.

T 123.5 Fri 10:00 Geb. 30.41: HS 2

**Measurement of the full set of kinematic moments of semileptonic $B$-meson decays with the Run 1 data set of Belle II** — •Munira Khan, Florian Bernlochner, Jochen Dingfelder, and Markus Prim — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

The determination of the Cabibbo-Kobayashi-Maskawa matrix element $|V_{cb}|$ relies on $b \to c\ell\nu_\ell$ transitions. The inclusive semileptonic process can be described with the Heavy Quark Expansion (HQE) and using the operator product expansion the total decay rate can be parameterized with a small number of non-perturbative parameters. These parameters cannot be determined from first principles, but their values are encoded into kinematic moments of the decay rate. In this talk we present the current status of measuring the full set of kinematic moments ($q^2, M_X, E_\ell, n_X$) within a single analysis, which characterize the semileptonic $b \to c\ell\nu_\ell$ and $b \to q\ell\nu_\ell$ transitions using the Run 1 data of the Belle II experiment. This allows for the first time to properly correlate experimental uncertainties. In addition, we present preliminary fits for $|V_{cb}|$ to simulated samples to illustrate the increase in sensitivity of this approach.

T 123.6 Fri 10:15 Geb. 30.41: HS 2

**Systematic Parametrization of the $B$-meson Light-Cone Distribution Amplitude** — •Philip Carlo Lüghausen[1], Thorsten Feldmann[1], and Danny van Dyk[2] — [1]Theoretische Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Institute for Particle Physics Phenomenology, Durham University

This talk presents a novel approach to understanding B meson decays through the lens of the light-cone distribution amplitude (LCDA). Our methodology diverges from traditional model-based analyses, focusing instead on a parametrization technique that allows for direct extraction of LCDA information using both experimental and theoretical input. This approach facilitates analytical and numerical computations, aiming to provide unbiased observable estimates while managing theoretical uncertainties. The discussion includes the application to decay amplitudes, notably in the context of the $B \to \gamma \ell \nu$ decay.

# T 124: BSM Higgs 5 (charged Higgs bosons)

Time: Friday 9:00–10:15 Location: Geb. 30.41: HS 3

T 124.1 Fri 9:00 Geb. 30.41: HS 3

**Searches for charged Higgs bosons in $H^\pm \to W^\pm h$ decays with the ATLAS detector** — Dominik Duda[2], •Simon Grewe[1], Sandra Kortner[1], and Hubert Kroha[1] — [1]Max Planck Institut for Physics — [2]University of Edinburgh

Many theories beyond the Standard Model predict the existence of charged Higgs bosons. The main production mode of these new particles depends on their mass. For large masses ($m(H^\pm) > m(t) + m(b)$), the dominant mode of production is in association with a top quark and a bottom quark ($tbH^\pm$). In the alignment limit of the Two-Higgs-Doublet Model (2HDM), heavy charged Higgs bosons decay almost exclusively via $H^\pm \to tb$. In other models such as the Georgi-Machacek model, however, significant branching ratios for $H^\pm \to W^\pm h$ are possible. This decay has so far not been studied by ATLAS or CMS.

A search for charged Higgs bosons in $H^\pm \to W^\pm h$ decays produced in association with a top and bottom quark is presented, based on the full Run-2 dataset of the ATLAS experiment. The analysis targets boosted $h \to bb$ decays in final states with at least one large-radius jet and a charged lepton. The decay of the neutral Higgs boson h is reconstructed via a large-radius jet, the W boson is reconstructed either from an additional large-radius jet or the lepton and missing transverse momentum. A neutral network is trained to distinguish between signal and backgrounds. Selection criteria based on the neutral network output are used to define signal and control regions. Upper limits on $\sigma(pp \to tbH^\pm) \times BR(H^\pm \to W^\pm h)$ are obtained by a maximum likelihood fit of the reconstructed H+ mass spectrum.

T 124.2 Fri 9:15 Geb. 30.41: HS 3

**Search for the charged Higgs production at high transverse momenta in the $H^\pm \to Wh(h \to b\bar{b})$ channel** — •Leila Hamdan, Jochen Dingfelder, and Tatjana Lenz — Bonn University

The discovery of the Higgs boson in 2012 at the LHC triggered large interest in searches for additional Higgs bosons beyond the SM. Several BSM theories, for example the two-Higgs doublet model and the next-to-two-Higgs doublet model, predict an existence of a charged Higgs boson. This talk focuses on the charged Higgs boson search in the $H^+ \to Wh$, $h \to b\bar{b}$ decay channel, where h is the SM-like Higgs boson with the mass of 125 GeV. The search focuses on charged Higgs boson masses above 800 GeV, resulting in highly boosted decay products. The analysis strategy is developed using the simulated samples for signal with charged Higgs boson masses between 800-3000 GeV and the main $t\bar{t}$ background. The analysis strategy is introduced and preliminary results will be presented.

T 124.3 Fri 9:30 Geb. 30.41: HS 3

**Search for a charged Higgs boson decaying to $cs$ in the low mass region with the ATLAS detector at $\sqrt{s} = 13$ TeV** — Jochen Dingfelder, Tatjana Lenz, and •Christian Nass — Physikalisches Institut, Universität Bonn, Deutschland

In the Standard Model (SM) electroweak symmetry breaking (EWSB) is introduced by a single complex scalar field. The consequence is the prediction of a scalar, neutrally charged particle, the Higgs boson, which was discovered in 2012 at the LHC. A simple extension of the SM is to introduce EWSB through two complex scalar fields. Such two-Higgs doublet models (2HDM) are attractive because they offer the opportunity to include additional CP violation to the SM, which is needed for explaining baryogenesis. 2HDMs feature 3 neutral and 2 charged Higgs bosons. An observation of such a charged scalar particle would be a striking signal of physics beyond the SM.

In the low mass region, $m_H^\pm < m_t$, the dominant production mode is by a $t\bar{t}$ pair with one $t$-quark decaying to $H^\pm b$ and the search for $H^\pm \to cs$ decays is suggested in several theory papers. This talk presents the search of $H^\pm \to cs$ decays in the full Run-2 ATLAS pp-collision dataset. That includes background estimation, signal extraction, and expected as well as observed sensitivities.

T 124.4 Fri 9:45 Geb. 30.41: HS 3

**$tbH^+$ analysis with multileptons with Run-2 ATLAS data** — •Martin Rames and Andre Sopczak — Czech Technical University in Prague

The latest results with Run-2 ATLAS data are presented for the search $tbH^+$ in the multilepton channel.

T 124.5 Fri 10:00 Geb. 30.41: HS 3

**Exploring Higgs Triplet Models - Georgi-Machacek Model's Unique Dynamics** — •Saurav Bania[1], Sara Chopra[2], Gudrid Moortgart Pick[3], and Sven Heinemeyer Heinemeyer[4] — [1]Universität Hamburg — [2]Universität Hamburg — [3]Universität Hamburg — [4]Consejo Superior de Investigaciones Científicas (CSIC)

In our focused research, we navigate the intricate realm of sum rules within the Higgs Triplet Model, specifically spotlighting the Georgi-Machacek Model. Our analysis hones in on the distinctive dynamics of doubly charged Higgs particles, unraveling nuanced alterations in unitarity sum rules induced by their intriguing presence.

Beyond mere exploration, our investigation aims to provide profound insights into the existence and potential energy ranges associated with these doubly charged Higgs particles. This work contributes valuable implications for theories extending Beyond the Standard Model, representing a significant stride in unraveling the complex behavior of Higgs Triplet Models, particularly at high energies.

As we traverse this scientific terrain, our research not only advances our understanding of the intricacies within the Georgi-Machacek Model but also marks a crucial contribution to the evolving landscape of particle physics. Each revelation in our study lays the groundwork for future discoveries, emphasizing the transformative potential within the study of Higgs Triplet Models and their unique features.

# T 125: Flavour physics 6

Time: Friday 9:00–10:30 Location: Geb. 30.41: HS 4

T 125.1 Fri 9:00 Geb. 30.41: HS 4

**Search for $B \to \mu\nu$ at Belle and Belle II** — Florian Bernlochner, Jochen Dingfelder, •Daniel Jacobi, and Markus Prim — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

The leptonic $B$ meson decay of $B \to \mu\nu$ is highly CKM- and helicity-suppressed and represents a challenging signature to identify. Its decay rate is extremely sensitive to new physics contributions from leptoquarks or thus far unidentified charged scalar mediators. Within the context of the Standard Model, its discovery also allows for another avenue to determine the Cabibbo-Kobayashi-Matrix element $V_{ub}$. Due to the two-body nature of the leptonic decay, however, the muon momentum is fixed in the rest frame of the decaying $B$ meson. By boosting muon candidates into this rest frame frame, a better signal resolution and improved sensitivity can be achieved. For this, however, the full $e^+e^- \to B\bar{B}$ event needs to be analyzed and the kinematic properties of the accompanying $B$ meson need to be reconstructed. This can be achieved with high efficiency using an inclusive reconstruction approach. We present the current status of a search for $B \to \mu\nu$ using the full Belle and Run 1 Belle II data set of 1.07 ab$^{-1}$. Control studies, using $B^- \to D^0[\to K^-\pi^+]\pi^-$ decays illustrate the accuracy of the employed inclusive reconstruction technique of the accompanying $B$ meson information. The signal extraction relies on a full likelihood combination of both data sets, resulting in improved sensitivity.

T 125.2 Fri 9:15 Geb. 30.41: HS 4

**Branching fraction measurement of the rare decays $B^0_{(s)} \to \pi^+\pi^-\mu^+\mu^-$ at LHCb** — Johannes Albrecht[1], Thomas Blake[2], •Jan Peter Herdieckerhoff[1], and Biljana Mitreska[1] — [1]TU Dortmund University, Dortmund, Germany — [2]University of Warwick, Coventry, United Kingdom

Rare flavour-changing neutral current decays with $b \to q\ell^+\ell^-$ quark transitions ($q = s, d$) are sensitive probes of the Standard Model and thus among the measurements of interest to the LHCb experiment. Due to smaller CKM factors the $b \to d\ell^+\ell^-$ transition is even more suppressed than the $b \to s\ell^+\ell^-$ transition and therefore, less frequently detected at LHCb. With Run 1 data LHCb measured the decay $B^0_s \to \pi^+\pi^-\mu^+\mu^-$ with a significance of 7.2 $\sigma$. The decay $B^0 \to \pi^+\pi^-\mu^+\mu^-$ was not yet observed, it was measured with a statistical significance of 4.8 $\sigma$. The main contributions to the studied channels are believed to proceed via the resonant decays $B^0_s \to f_0(980)(\to \pi^+\pi^-)\mu^+\mu^-$ and $B^0 \to \rho^0(770)(\to \pi^+\pi^-)\mu^+\mu^-$.

In this talk the current status of the branching fraction measurements of the $B^0_{(s)} \to \pi^+\pi^-\mu^+\mu^-$ decays using 8.9 $\text{fb}^{-1}$ of combined Run 1 and Run 2 data is presented. The possibility of performing a differential branching fraction measurement is explored.

T 125.3 Fri 9:30 Geb. 30.41: HS 4

**Search for CP violation in hadronic charm decays** — •Serena Maccolini — TU Dortmund University, Dortmund, Germany

A search for the violation of the *CP* symmetry $A_{CP}(h^-h^+)$ in the Cabibbo-suppressed $D^0 \to h^-h^+$ decays with $h = K, \pi$ is performed at the LHCb detector using proton-proton collisions recorded from 2015 to 2018 at the centre of mass energy of 13 TeV. The data used corresponds to an integrated luminosity of 5.7 $\text{fb}^{-1}$. The flavour of the charm mesons is defined from the charge of the pion in $D^{*+} \to D^0\pi^+$ and $D^{*-} \to D^0\pi^-$ decays. Instrumental effects are evaluated through the calibration of high-statistics control samples (with negligible *CP* violation) in order to emulate the detector response for the signal candidates. The precision of the measurements is limited by the size of the control samples after the calibration procedure. An overview on alternative techinques and future measurements is also reported.

T 125.4 Fri 9:45 Geb. 30.41: HS 4

**Charm-Quark Mass in the Heavy Quark Expansion** — •Anastasia Boushmelev[1], Thomas Mannel[1], and K. Keri Vos[2] — [1]Theoretical Particle Physics, Center for Particle Physics Siegen, University of Siegen — [2]Gravitational Waves and Fundamental Physics (GWFP), Maastricht University, Duboisdomein 30, NL-6229 GT Maastricht, the Netherlands and Nikhef, Science Park 105, NL-1098 XG Amsterdam, the Netherlands

The Heavy Quark Expansion is a powerful framework for making predictions for inclusive heavy hadron decays. It is well established for $b$-decays and for increasing precision several short-distance mass schemes have been invented in the case of the $b$ quark. Though, considering the charm sector, the treatment of the quark mass has to be further investigated as these mass schemes are not suitable in this case. Here we suggest to replace the charm mass, as well as further non-perturbative quantities, directly by $q^2$ moments based on a similar strategy applied on $b$-decays using $e^+e^-$ inverse moments [1]. Following this strategy we study the impact on the perturbative series.

[1] A. Boushmelev, T. Mannel and K. K. Vos, JHEP 07 (2023), 175 doi:10.1007/JHEP07(2023)175 [arXiv:2301.05607 [hep-ph]]

T 125.5 Fri 10:00 Geb. 30.41: HS 4

**Revisiting $D \to \pi\ell^+\ell^-$ in the Standard Model using LCSR** — •Anshika Bansal, Alexander Khodjamirian, and Thomas Mannel — Theoretical Particle Physics, Center for Particle Physics Siegen, University of Siegen

Recently, LHCb has significantly updated the upper bound on the flavour changing neutral current (FCNC) semi-leptonic charm decay ($D^+ \to \pi^+\mu^+\mu^-$). With these updates, it is important to re-analyse the theoretical predictions for this mode as, unlike for the down quark sector, the FCNC for the up-sector are very challenging due to strong GIM suppression of short distance contributions. This leads the branching fraction to be dominated by the long distance effects. In this talk, I will discuss $D \to \pi\ell^+\ell^-$ decays in the U-spin symmetry limit. I will further discuss the use of the method of Light Cone Sum Rules to compute these long distance contributions and the associated challenges. Lastly, I will provide some estimates for the branching ratio.

T 125.6 Fri 10:15 Geb. 30.41: HS 4

**Statistical Methods in the Search for Electric Dipole Moments at COSY** — •Valentin Tempel for the JEDI-Collaboration — Institute for Nuclear Physics II, FZ Jülich, Germany — III. Physikalisches Institut B, RWTH Aachen University, Germany — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

The observed matter-antimatter asymmetry in the Universe, which the Standard Model cannot explain, points to the necessity of additional CP-violating phenomena (Sakarov conditions). Particles with Electric Dipole Moments (EDMs) violate both T-symmetry and P-symmetry, implicating CP-violation as well, provided the CPT theorem holds true.

Charged particle EDMs can be measured in storage rings by observing the spin precession of a polarized particle beam. The Cooler Synchrotron (COSY) at Forschungszentrum Jülich provides polarized protons and deuterons up to a momentum of 3.7 GeV/c and offers the possibility to manipulate and measure the beam polarization. The JEDI-Collaboration (Jülich Electric Dipole moment Investigations) is working on the first measurement of the deuteron EDM by observing its influence on spin motion. This presentation will delve into the details of the statistical analysis and fitting methods used to obtain observables, such as the amplitude of the polarization, its corresponding confidence intervals and the spin coherence time.

# T 126: Top physics 5 (top mass)

Time: Friday 9:00–10:15 Location: Geb. 30.95: Audimax

T 126.1 Fri 9:00 Geb. 30.95: Audimax

**Measurement of the top quark mass and width from $t\bar{t}$ events with Run2 data at CMS** — •Valentina Guglielmi, Jiwon Park, Katerina Lipka, and Simone Amoroso — Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg

A measurement is presented of the top quark mass and width using $t\bar{t}$ events produced in proton-proton collisions at 13 TeV, recorded by the CMS experiment. In the context of the Standard Model (SM), the relationship between the top-quark mass and width has been precisely calculated. The strategy employed to determine the top quark mass and width consists in performing template fits to invariant mass spectra centered around the top-quark mass. Due to their cleaner event signatures, dilepton decays from $t\bar{t}$ production are considered. The minimax pairing of lepton-bjet invariant masses $m_{lb}$ is used in the fit, since it is the most sensitive observable. While the position of the $m_{lb}$ peak exhibits linear sensitivity to the top-quark mass, the tails of $m_{lb}$ distribution are sensitive to the top quark width. A comparison between the newest NLO bb4l MC generator, accounting for $t\bar{t}$ and tW interference and top off-shell contributions, with the standard Powheg+Pythia MC generator will be undertaken. In this talk, an overview of the current status of the measurement will be given.

T 126.2 Fri 9:15 Geb. 30.95: Audimax

**Measurement of the top quark mass with the template method in the $t\bar{t} \to$ lepton + jets channel using the full Run 2 dataset in ATLAS** — •Dimbiniaina Rafanoharana[1] and Andrea Knue[2] — [1]Albert-Ludwigs-Universität Freiburg — [2]TU Dortmund

The top-quark mass is a free parameter of the Standard Model (SM) and is playing a key role in the test of the consistency of the SM. Its precise determination is therefore of paramount importance. Several measurements of the top-quark mass in different final states using various methods were performed at the Tevatron and the Large Hadron Collider.

The combined measurement of the top-quark mass using fifteen measurements performed by ATLAS and CMS at Run 1 achieved a precision of 2 per mill. The combination is limited by the systematic effect as the relative statistical and systematic uncertainties are 0.8 per mill and 1.7 per mill, respectively.

The measurement of the top-quark mass with the template method in the $t\bar{t} \to$ lepton + jets channel using the full Run 2 dataset in ATLAS will be shown. Given the large amount of data collected during Run 2, the measurement is limited by systematic effects. The investigation of various methods aimed at reducing the dominant systematic uncertainty on the top-quark mass will be presented, where the latest ATLAS uncertainty prescriptions are used.

T 126.3 Fri 9:30 Geb. 30.95: Audimax

**Towards the simultaneous extraction of the top-quark mass and decay width using $bb4\ell$ predictions** — Diptaparna Biswas[1], Beatrice Cervato[1], Markus Cristinziani[1], Carmen Diez Pardos[1], Ivor Fleck[1], Arpan Ghosal[1], Gabriel Gomes[1], Jan Joachim Hahn[1], Vadim Kostyukhin[1], Nils Krengel[1], Buddhadeb Mondal[1], Stefanie Müller[1], •Katharina Voss[1], Wolfgang Walkowiak[1], Adam Warnerbring[1], and Tongbin Zhao[1,2] — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Shandong University, China

We present the first dedicated measurement aimed at the simultaneous extraction of the top-quark mass and decay width, which are two closely related input parameters in high-precision theoretical predictions. Previous top-quark decay width measurements were performed for a fixed top-quark mass value and a dependence of the decay width on the assumed mass value in the extraction was observed.

The sensitive observable used in the measurement is the $m_{\ell b}$ distribution obtained from top-quark pair production events in the dileptonic $e\mu$ decay channel of the full Run-2 $\sqrt{s}$ = 13 TeV ATLAS dataset. Since especially in the $t\bar{t}/tW$ interference region a high sensitivity to the top-quark decay width was observed, an accurate description of this phase space region is essential for the parameter extraction. This can be achieved with the $bb4\ell$ POWHEG generator. Studies of the systematic uncertainties related to the use of the $bb4\ell$ generator will be presented, which is of central importance to have a reliable estimate of the modelling uncertainties influencing the measurement.

T 126.4 Fri 9:45 Geb. 30.95: Audimax

**Mass-Decorrelated Classification of Unlabeled Data for $t\bar{t}$ Identification** — •Sofia Brozzo, Patrick Connor, Johannes Lange, Peter Schleper, and Hartmut Stadie — Institut für Experimentalphysik, Universität Hamburg

Precision measurements of the top quark mass are an important tool to test the Standard Model. Although the fully hadronic decay channel provides the largest branching fraction, the large QCD multijet background leads to a challenging event selection. To improve on the mass resolution and reduce combinatorical $t\bar{t}$ and QCD background, a kinematic fit is applied before the top quark mass is extracted.

Here, a neural network trained on unlabeled CMS data is employed to further improve the selection of $t\bar{t}$ events and to reject QCD background.

To further ensure that the neural network is not biased on the top mass, the aim of this analysis is to decorrelate the neural network output from the input mass via distance correlation.

T 126.5 Fri 10:00 Geb. 30.95: Audimax

**Improvements of the matching uncertainty definition in top-quark processes simulated with Powheg+Pythia8** — •Dominic Hirschbühl, Wolfgang Wagner, and Joshua Reidelstürz — Bergische Universität Wuppertal

Top-quark processes are modelled by the ATLAS Collaboration by matching the hard-scatter matrix element calculations of next-to-leading order Monte-Carlo generators with a parton shower generator. This talk presents a comprehensive study of the uncertainty related to the matching procedure and a new strategy to evaluate this uncertainty. The new approach is based on the Pythia 8 parton-shower matching parameter $p_{\mathrm{T}}^{\mathrm{hard}}$. It is designed to surpass the previous method, which involved comparing two generator setups to cover the uncertainty. The old method entangled all differences between the two setups in a single uncertainty while the new prescription implements a focused uncertainty that avoids double-counting with other uncertainties on the modelling of the top processes. Additionally first matching studies of a NNLO matrix element generator matched to parton shower are presented.

## T 127: Invited Overview Talks 6

Time: Friday 11:45–12:45 Location: Geb. 30.95: Audimax

**Invited Overview Talk** T 127.1 Fri 11:45 Geb. 30.95: Audimax

**Status and Highlights of Higgs Boson Measurements and Searches at the LHC** — •Marcel Rieger — Institute of Experimental Physics, Hamburg University, Germany

The Higgs boson, a cornerstone in our understanding of the Standard Model of particle physics, plays a pivotal role in imparting mass to elementary particles. 12 years after its discovery by the ATLAS and CMS collaborations at the LHC, and 60 years after the initial postulation of electroweak symmetry breaking, we can now reflect on a comprehensive set of findings in the Higgs sector. Years of data taking and meticulous analysis have provided deep insight into its properties and interactions, hitherto indicating, within experimental and theoretical uncertainties, agreement with SM predictions. Enhanced sensitivity resulting from continued collision data taking, along with advancements in theory, instrumentation, and analysis techniques, will ultimately pave the way for even more precise measurements and searches for new postulated phenomena, such as Higgs boson self-coupling. Focusing on the run 2 dataset, this talk aims to offer a broad overview of the latest results released by the ATLAS and CMS experiments, and provides a glimpse into the future of Higgs physics at the LHC.

**Invited Overview Talk** T 127.2 Fri 12:15 Geb. 30.95: Audimax

**Charting the unknown: results from recent searches for new phenomena at the LHC** — •Katharina Behr — Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg

A wide variety of searches at the LHC target new particles and interactions not described in the Standard Model of Particle Physics (SM). These are postulated to address the open questions of particle physics, such as the hierarchy problem, the origin of the baryon asymmetry in the universe, or the nature of dark matter, which the SM fails to answer. In the absence of evidence for new phenomena in the data analysed to date, new analysis strategies are needed to explore previously inaccessible kinematic regimes and provide sensitivity to signatures too subtle or exotic to have been picked up by previous searches.

In this talk, I will review results of recent searches for new phenomena conducted by the ATLAS and CMS Collaborations on their full LHC Run-2 datasets, highlighting new experimental techniques that allow us to explore previously uncharted regions in the vast landscape of new signatures and models beyond the SM. I will also give a brief outlook on the potential of searches on data from the on-going LHC Run 3.

# Working Group on Equal Opportunities
# Arbeitskreis Chancengleichheit (AKC)

Agnes Sandner
Sprecherin des AKC
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## Overview of Invited Talks and Sessions

(Lecture hall Geb. 30.22: Lehmann-HS)

### Invited Talks

| | | | | |
|---|---|---|---|---|
| AKC 1.1 | Tue | 11:45–12:45 | Geb. 30.22: Lehmann-HS | **The tragic destiny of Mileva Marić Einstein** — •Pauline Gagnon |

### Sessions

| | | | | |
|---|---|---|---|---|
| AKC 1.1–1.1 | Tue | 11:45–12:45 | Geb. 30.22: Lehmann-HS | **AKC** |
| AKC 2 | Tue | 12:45–13:45 | Geb. 30.22: Lehmann-HS | **Women in Physics Lunch** |

# Sessions

– Invited Talks –

## AKC 1: AKC

Time: Tuesday 11:45–12:45 Location: Geb. 30.22: Lehmann-HS

**Invited Talk** AKC 1.1 Tue 11:45 Geb. 30.22: Lehmann-HS

**The tragic destiny of Mileva Marić Einstein** — •Pauline Gagnon — CERN, Geneva

What were Albert Einstein's first wife's contributions to his extraordinary productivity in the first years of his career? A first biography of Mileva Marić Einstein was published in Serbian in 1969 but remained largely unknown despite being translated first in German, then in French in the 1990's. The publication of Mileva and Albert's love letters in 1987 revealed how they lived together while two recent publications shed more light on Mileva Marić's life and work. I will review this evidence in its social and historical context to give a better idea of her contributions. In this presentation, I avoid all type of speculation and do not attack Albert Einstein personally, but rather strictly stick to facts. The audience will be able to appreciate why such a talented physicist has been so unkindly treated by history.

## AKC 2: Women in Physics Lunch

Time: Tuesday 12:45–13:45 Location: Geb. 30.22: Lehmann-HS

**Female physicists of all career stages are cordially invited to join our meet-and-greet networking lunch. Diverse and all kinds of interested colleagues are also welcome!**

# Working Group "Young DPG"
# Arbeitsgruppe junge DPG (AKjDPG)

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## Overview of Invited Talks and Sessions

(Lecture halls Geb. 30.23: 3/1 and Geb. 30.22: Lehmann-HS)

### Invited Talks

| | | | | |
|---|---|---|---|---|
| AKjDPG 2.1 | Tue | 19:00–19:25 | Geb. 30.22: Lehmann-HS | **"I could *Never* work for Industry!" - How life ignores your resolutions.** — •Isabel Braun |
| AKjDPG 2.2 | Tue | 19:25–19:50 | Geb. 30.22: Lehmann-HS | **Als Physiker*in Krankenhäuser digitalisieren? Klar doch!** — •Charles Majer |
| AKjDPG 2.3 | Tue | 19:50–20:15 | Geb. 30.22: Lehmann-HS | **From giant particle physics experiment to giant corporation** — •Florian Herrmann |

### Sessions

| | | | | |
|---|---|---|---|---|
| AKjDPG 1.1–1.2 | Mon | 9:00–12:15 | Geb. 30.23: 3/1 | **Tutorials** |
| AKjDPG 2.1–2.3 | Tue | 19:00–22:00 | Geb. 30.22: Lehmann-HS | **Physicists beyond Academia** |

# Sessions

– Invited and Contributed Talks –

## AKjDPG 1: Tutorials

Time: Monday 9:00–12:15 Location: Geb. 30.23: 3/1

**Tutorial** AKjDPG 1.1 Mon 9:00 Geb. 30.23: 3/1
**Meet the Higgs boson** — •Sarah Heim — DESY
The Higgs boson was discovered in 2012 as the last missing piece of the Standard Model of Particle Physics. It is often seen as a key particle in our search for the origins of dark matter and the matter-antimatter asymmetry. In this tutorial, I will cover basic Higgs theory, the discovery of the Higgs boson, and our state-of-the-art knowledge of the Higgs boson properties, as well as possible connections to physics beyond the Standard Model.

**15 min. break**

**Tutorial** AKjDPG 1.2 Mon 10:45 Geb. 30.23: 3/1
**Introduction to particle physics detectors** — •Michael Lupberger — Research and Technology Center for Detector Physics, Bonn, Germany — Helmholtz-Institut für Strahlen- und Kernphysik, Bonn, Germany — Physikalisches Institut, Bonn, Germany
Advancing humankind by gaining fundamental knowledge of what holds together the world at its core is the subject of particle physics. This knowledge gain requires efforts in several domains, such as theory, experiment design, detector development and construction, electronics, big data computing and data analysis and interpretation. In all of these domains, cutting-edge methods and concepts are required. For example, due to the exceptional and demanding requirements, the majority of our experimental setups to probe nature are not available off-the-shelf.

Detector physics, R&D, construction, and instrumentation hence are one domain of particle physics equally relevant as the others.

In this tutorial, I will briefly introduce the basic concepts of the physics of particle detectors. Taking the ATLAS and other experiments as examples, we will walk through the different technologies, their strengths and weaknesses as well as recent developments. We will also look at "services" for the detectors and how information is transferred out of the detector.

## AKjDPG 2: Physicists beyond Academia

Time: Tuesday 19:00–22:00 Location: Geb. 30.22: Lehmann-HS

**Invited Talk** AKjDPG 2.1 Tue 19:00 Geb. 30.22: Lehmann-HS
**"I could *Never* work for Industry!" - How life ignores your resolutions.** — •Isabel Braun — Vector Academy, Vector Informatik GmbH, Stuttgart, Germany
Working as a scientist is amazing and few things are as satisfying as studying nature to a depth where you are creating new knowledge. Picking physics was the best decision I could make at the time - and so was leaving it eventually. When I left astro-particle physics, I had noticed that conferences and lectures are closer to my heart than writing grant proposals and even coding analysis tools. Hence, I studied the science of teaching, which happened to include business leadership - which turned out not as evil as I had imagined. I tried to leave academia *just a little*, hoping to return to a university for applied sciences after 3 years. Within weeks I realized I never would, because a job *found me* that simply covers those points that I enjoy most (in my case digging into complex topics, search for patterns, explain them as if they were simple and see others master them) - with an unlimited contract, paid travel and a good family income. And you know what? An actual 40h week leaves time for whatever you miss doing! When life happens (and it will), keep those elements of your work that empower you and let go of others. In presenting some of my choices, failures and sheer luck and a cool job (technical trainer) in a wonderful company, I hope to inspire you to master your own career jumping puzzle: hang on to whatever you are struggling with for as long as necessary, and jump off to the next platform if it takes you closer to yourself and who you want to become.

**Invited Talk** AKjDPG 2.2 Tue 19:25 Geb. 30.22: Lehmann-HS
**Als Physiker*in Krankenhäuser digitalisieren? Klar doch!** — •Charles Majer — Siemens Healthineers AG, Weissacher Str. 11, 70499 Stuttgart, Deutschland
Als Physiker*in ist man bestens vorbereitet neue, komplexe und vielfältige Themenfelder zu erfassen und sich diese zu Eigen zu machen. In diesem Sinne sind auch der Gesundheitssektor und im Besonderen Krankenhäuser ein spannendes Entwicklungsfeld für Physiker*innen * und das nicht nur als Medizinphysiker*in. Als Digital Portfolio Expert bin ich vertrieblich verantwortlich für das gesamte digitale Portfolio von Siemens Healthineers. Zu meinen Aufgaben gehört es, dieses bei Kund*innen vorzustellen und vor allem zu erklären.

Da digitale Systeme hochspezialisiert sind und individuell an jeden Einzelfall und die bereits vorhandene IT-Infrastruktur angepasst werden müssen, ist ein konzeptionelles Arbeiten ein Muss. Aber nicht nur die IT-technischen Voraussetzungen müssen Berücksichtigung finden, sondern auch die individuellen Bedürfnisse der Anwender*innen und gegebenenfalls der Patient*innen. Bereits aus diesen beiden Anforderungen können sehr komplexe Projekte entstehen.

Zudem ergibt sich durch sich immer schneller entwickelnde Trends und Änderungen im Gesundheitswesen, der Geschäftsmodelle unserer Kund*innen und der gesetzlichen Rahmenbedingungen ein hoch spannendes klinisches Ökosystem. Sich in diesem komplexen System tagtäglich zu bewegen ist eine meiner vielen spannenden Aufgaben als Physiker bei Siemens Healthineers.

**Invited Talk** AKjDPG 2.3 Tue 19:50 Geb. 30.22: Lehmann-HS
**From giant particle physics experiment to giant corporation** — •Florian Herrmann — Stryker Leibinger GmbH, Freiburg, Germany
Can I Make the move from academia to industry? What will be the main difference between my familiar academic environment and the world of industrial R&D and business?

Let me try to share with you my personal experience as an educated particle physicist over the last 10 years in the medical device industry at Stryker Corporation.

**Discussion with beer and prezels**

## Index of Exhibitors

**Exhibition venue**
Karlsruher Institut für Technologie (KIT)
Campus Süd – Audimax, Geb. 30.95
Straße am Forum 1, 76131 Karlsruhe

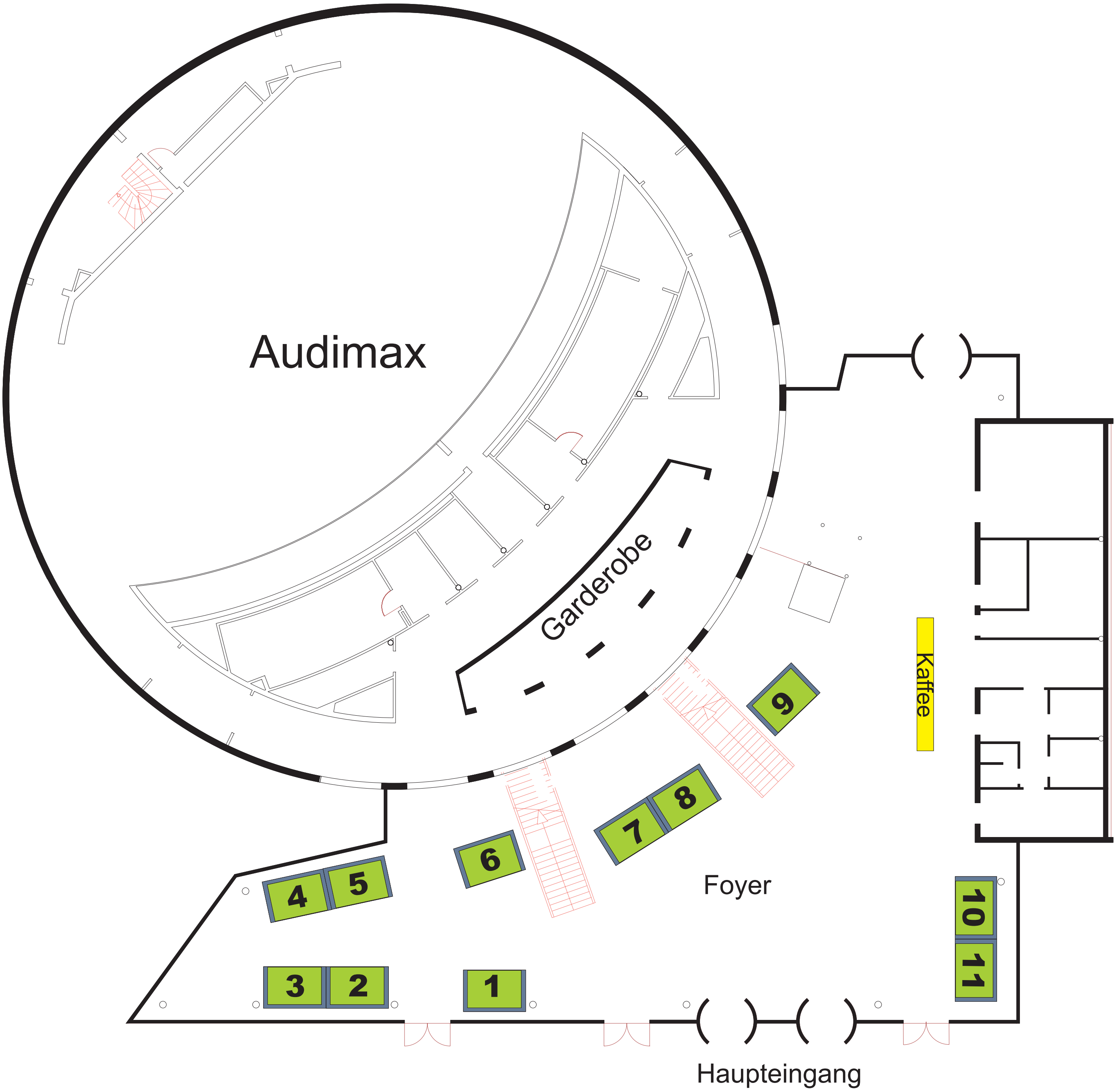
**Exhibition opening hours**

| | |
|---|---|
| Tuesday, March 05 | 10:30 – 19:00 |
| Wednesday, March 06 | 10:30 – 19:00 |
| Thursday, March 07 | 10:30 – 19:00 |

The entrance is free!

| Company | Booth No. |
|---|---|
| **Hamamatsu Photonics Deutschland GmbH**<br>Arzbergerstraße 10, 82211 Herrsching<br>*Our mission is to benefit society through the development of technologies that capture, measure, and generate various types of light.* | **08** |
| **Kashiyama Europe GmbH**<br>Leopoldstraße 244, 80807 München<br>*Kashiyama is a manufacturer of reliable and low-maintenance dry Multi-Stage Roots Pumps offering a wide range of pumping speed options.* | **09** |
| **LHC-ErUM-FSP-Büro**<br>Notkestraße 85, 22607 Hamburg<br>*Das LHC ErUM-FSP-Büro ist das gemeinsame Projektbüro für Öffentlichkeitsarbeit, Transfer und Nachwuchsförderung der deutschen Community an den LHC Experimenten.* | **10** |
| **Nationales Institut für Wissenschaftskommunikation (NaWik) gGmbH**<br>Englerstraße 2, 4. OG, 76131 Karlsruhe<br>*Das NaWik vermittelt Wissenschaftler:innen, Studierenden und professionellen Öffentlichkeitsarbeiter:innen die Grundlagen guter Wissenschaftskommunikation.* | **07** |

**Exhibition Map**



## DPG 2024 Karlsruhe: Timetable

| Start | Monday, March 04 | | Tuesday, March 05 | | Wednesday, March 06 | Thursday, March 07 | Friday, March 08 |
|---|---|---|---|---|---|---|---|
| 8:30 | | | | | | | |
| 8:45 | | | | | | | |
| **9:00** | | jDPG Tutorials (30.23 3/1) | Invited Overview Talks (30.95 Audimax) | | Invited Overview Talks (30.95 Audimax) | Invited Overview Talks (30.95 Audimax) | Parallel Sessions |
| 9:15 | | | | | | | |
| 9:30 | | | | | | | |
| 9:45 | | | | | | | |
| **10:00** | | | | | | | |
| 10:15 | | | | | | | |
| 10:30 | | | | | | | |
| 10:45 | | | | | | | |
| **11:00** | Registration | | Plenary Talk (30.95 Audimax) | | Ceremony Herwig Schopper (Audimax) | Invited Topical Talks (30.21 Gerthsen, 30.22 Gaede) | Plenary Talk (30.95 Audimax) |
| 11:15 | | | | | | | |
| 11:30 | | | | | | | |
| 11:45 | | | Invited Overview Talks (30.95 Audimax) | | | | Invited Overview Talks (30.95 Audimax) |
| **12:00** | | | | AKC Women in Physics (30.22 Lehmann) | | | |
| 12:15 | | | | | | | |
| 12:30 | | | | | | | |
| 12:45 | | | | | | | Closing Session (30.95 Audimax) |
| **13:00** | | | | | | | |
| 13:15 | | | | | | | |
| 13:30 | | Opening Session (30.95 Audimax) | | | | | |
| 13:45 | | | | | | | |
| **14:00** | | Plenary Talk (30.95 Audimax) | Invited Topical Talks (30.21 Gerthsen, 30.22 Gaede) | | Symposium: Future (30.95 Audimax) | Invited Topical Talks (30.21 Gerthsen, 30.22 Gaede) | |
| 14:15 | | | | | | | |
| 14:30 | | | | | | | |
| 14:45 | | Invited Overview Talks (30.95 Audimax) | | | | | |
| **15:00** | | | | | | | |
| 15:15 | | | | | | | |
| 15:30 | | | | | | | |
| 15:45 | | | | | | | |
| **16:00** | | Parallel Sessions | Parallel Sessions | | Parallel Sessions | Parallel Sessions | |
| 16:15 | | | | | | | |
| 16:30 | | | | | | | |
| 16:45 | | | | | | | |
| **17:00** | | | | | | | |
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| **18:00** | | | | | | | |
| 18:15 | | | | | | | |
| 18:30 | | | | | | | |
| 18:45 | | | | | Physikertheater (30.22 Gaede) | | |
| **19:00** | Welcome Evening (20.30 Mathematics Foyer) | | | jDPG Physics in Industry (30.22 Lehmann) | | Members' Assembly Division Particle Physics (30.22 Lehmann) | |
| 19:15 | | | Public Evening Lecture (30.95 Audimax) | | | | |
| 19:30 | | | | | | | |
| 19:45 | | | | | yHEP Annual Meeting (30.22 Gaede) | | |
| **20:00** | | | | | | | |
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| **21:00** | | | | | | | |
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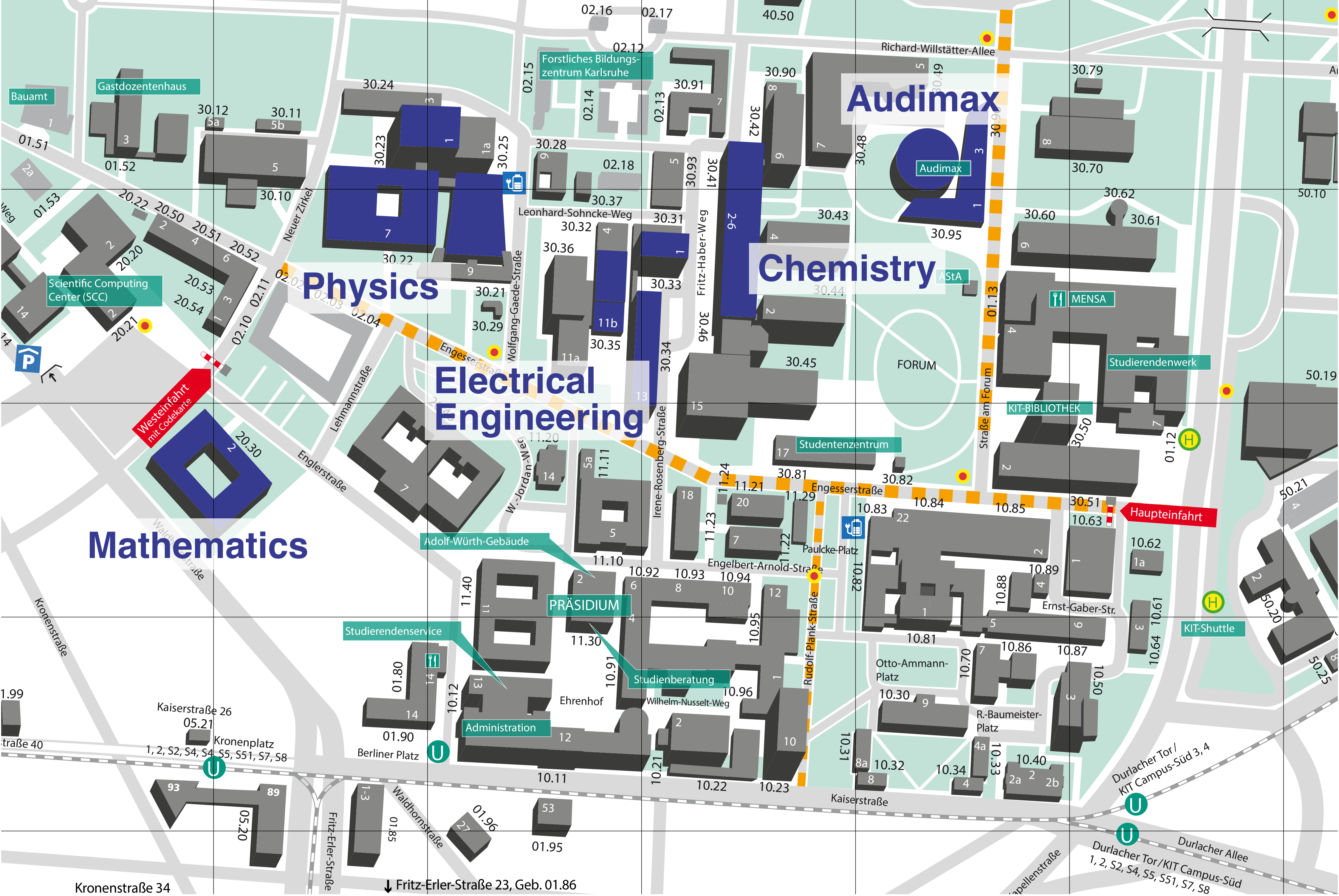
| 21:45 | | | | | | | |
| **22:00** | | | | | | | |
| 22:15 | | | | | | | |


Audimax
Chemistry
Physics
Electrical Engineering
Mathematics
Audimax
AStA
MENSA
Studierendenwerk
KIT-BIBLIOTHEK
FORUM
Studentenzentrum
Haupteinfahrt
Westeinfahrt mit Codekarte
KIT-Shuttle
Adolf-Würth-Gebäude
PRÄSIDIUM
Studierendenservice
Studienberatung
Administration
Ehrenhof
Scientific Computing Center (SCC)
Gastdozentenhaus
Bauamt
Forstliches Bildungszentrum Karlsruhe
Richard-Willstätter-Allee
Straße am Forum
Engesserstraße
Fritz-Haber-Weg
Leonhard-Sohncke-Weg
Wolfgang-Gaede-Straße
Irene-Rosenberg-Straße
W.-Jordan-Weg
Lehmannstraße
Englerstraße
Neuer Zirkel
Kronenstraße
Kaiserstraße
Rudolf-Plank-Straße
Engelbert-Arnold-Straße
Paulcke-Platz
Ernst-Gaber-Str.
Otto-Ammann-Platz
R.-Baumeister-Platz
Wilhelm-Nusselt-Weg
Berliner Platz
Kronenplatz
1, 2, S2, S4, S4, S5, S51, S7, S8
Kaiserstraße 26
Durlacher Tor / KIT Campus-Süd 3, 4
Durlacher Tor / KIT Campus-Süd 1, 2, S2, S4, S5, S51, S7, S8
Durlacher Allee
Waldhornstraße
Fritz-Erler-Straße
Fritz-Erler-Straße 23, Geb. 01.86
Kronenstraße 34