# T 40: Cosmic Rays II

Time: Tuesday 16:15–18:30 Location: KS 00.006

T 40.1 Tue 16:15 KS 00.006

**The triboelectric effect at the Pierre Auger Observatory** — •Julian Rautenberg for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal, Germany

With the AugerPrime extension of the Pierre Auger Observatory all surface detector stations have been equipped with radio antennas to measure extensive air showers in the 30-80 MHz region. For the data acquisition using a trigger based on radio pulses, the triboelectric effect has been reported to be responsible for an increased background rate at high wind-speeds for ice-based radio experiments. With the self-triggered data of the Auger Engineering Radio Array (AERA) we estimate the correlation between trigger rate and wind speed.

T 40.2 Tue 16:30 KS 00.006

**Transferability of 3D-Wave Reconstruction with ML Models*** — •Sven Querchfeld for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal, Germany

Within the ErUM-Wave project, a Machine Learning (ML) model is developed to reconstruct three-dimensional wave fields. The goal is to predict the propagation of seismic waves on the basis of only a few measurements. To test the transferability of this 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 extensive air showers and are measured by the Pierre Auger Observatory. First events have already been recorded by its radio detector, which finished deployment on the full array in November 2024. Training and validation are based on CORSIKA 7 simulations using the CoREAS extension. To obtain more realistic traces, a noise library was created using in-field measurements, utilising the small radio footprint of vertical showers to supplement the simulated events. Due to the CPU-intensive simulations, a preliminary test of the developed ML models for reconstructing 3D wave propagation is presented, using a limited set of showers.

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T 40.3 Tue 16:45 KS 00.006

**Measurement of air-showers by the radio antennas of the IceCube Surface Array Enhancement** — •Megha Venugopal for the IceCube-Collaboration — Institute of Astroparticle Physics (IAP), Karlsruhe Institute of Technology, Germany

In a cubic km of ice at the South Pole, strings of Digital Optical Modules of the IceCube observatory measure neutrinos from astrophysical phenomena. IceTop, located on the surface of this detector, comprising 81 pairs of ice Cherenkov detectors measure the electromagnetic and muonic parts of air showers induced by cosmic rays. Challenges arising from the accumulation of snow over these detectors over time led to a planned enhancement of these detectors. Since early 2025, the Surface Array Enhancement has three stations each equipped with 3 antennas and 8 scintillators deployed on the IceTop footprint. The data from the new stations were checked and the first radio data triggered by scintillators measured in all three stations have been reconstructed and verified. Estimation of Xmax with the previous dataset with a single station is also discussed.

T 40.4 Tue 17:00 KS 00.006

**Absolute Energy Calibration of the Auger Engineering Radio Array** — •Asil Meidow for the Pierre Auger-Collaboration — Karlsruhe Institute of Technology

The Pierre Auger Observatory detects ultra-high-energy cosmic rays over a surface area of more than 3000 km$^2$, requiring a precise and stable energy-scale calibration. Traditionally, this calibration relied solely on fluorescence detectors (FD). In recent years, radio detection has become an increasingly valuable technique, offering complementary insights through an independent reconstruction. Previous comparisons revealed that the energy scales determined with the FD and the Auger Engineering Array (AERA) are consistent within systematic uncertainties, with energies reconstructed with AERA being 12% higher. We present how the AERA standard event reconstruction has been adapted to provide electromagnetic and cosmic-ray energies consistent with the energy scale determined with AERA. We also outline how this approach will be extended to inclined air showers in future work.

T 40.5 Tue 17:15 KS 00.006

**A bayesian method for radio-based air shower reconstruction** — •Karen Terveer[1] and Anna Nelles[1,2] — [1]ECAP, FAU Erlangen-Nürnberg, Germany — [2]Deutsches Elektronen-Synchroton (DESY) Zeuthen, Germany

Over the past decade, radio detection of cosmic-ray air showers has established itself as a standalone technique. Observatories such as the Low-Frequency Array (LOFAR) have successfully constrained the mass composition in the $10^{16.5}$ - $10^{18}$ eV range, capturing the transition region from galactic to extragalactic sources. Although standard reconstruction methods based on CoREAS simulations achieve a state-of-the-art $X_{\max}$ precision of 19 g/cm$^2$, they are computationally expensive and do not use all available signal information. We present a new reconstruction method based on Information Field Theory (IFT) that simultaneously uses particle and radio data. The Bayesian framework of IFT ensures rigorous uncertainty quantification and reconstruction of the full posterior distribution. Using JAX for automatic differentiation, the method enables efficient gradient-based inference in high-dimensional parameter spaces. We present the first results of this technique applied to LOFAR data, representing the first approach to exploit a more complete information content of these datasets.

T 40.6 Tue 17:30 KS 00.006

**Bayesian Inference to Reconstruct Current Densities from Radio Emission of Extensive Air Showers** — •Stefanie Girod, Maximilian Straub, and Martin Erdmann — RWTH Aachen University, Physics Institute 3A, Otto-Blumenthal-Str., 52074 Aachen, Germany

We are developing an approach to image extensive air showers based on Bayesian Inference. This approach aims to reconstruct the atmospheric current densities that induce radio emissions. The reconstruction requires a forward model with a generator capable of producing current densities in extensive air showers. To ensure differentiability and computational efficiency, we employ Gaussian processes to generate the current densities. We extract the current densities from air showers simulated by the Monte Carlo code CORSIKA to tune the generator's hyperparameters. With a tuned generator capable of sampling the parameter space of realistic air showers, we can apply the reconstruction on realistic scenarios.

T 40.7 Tue 17:45 KS 00.006

**The Auger Radio Infill SKALA Extension (ARISE)** — •Carmen Merx[1], Ben Flaggs[2], Alexander Novikov[2], Frederik Schmitt[1], Megha Venugopal[1], Stef Verpoest[2], Andreas Weindl[1], and Frank Schröder[1,2] — [1]Institute for Astroparticle Physics, Karlsruhe Institute of Technology — [2]Bartol Research Institute, Department of Physics and Astronomy, University of Delaware

Radio detection of extensive air showers has become a powerful technique for studying high-energy cosmic rays. To further enhance the measurement of ultra-high-energy cosmic rays, the Pierre Auger Observatory in Argentina, the world's largest cosmic-ray experiment, has been upgraded with radio antennas for inclined air showers. In 2025, we have installed an additional pathfinder radio array, ARISE ("Auger Radio Infill SKALA Extension"), aiming at the demonstration of full detection efficiency for vertical air showers in the energy range of 100 PeV and above.

The ARISE setup is based on the radio component of the IceCube Surface Array Enhancement. It consists of six stations, each comprising three SKALA antennas installed around a surface detector in the denser infill region of the Pierre Auger Observatory.

This talk will give an overview of ARISE and present first radio measurements triggered by the Auger surface detector.

T 40.8 Tue 18:00 KS 00.006

**A Near-Field Interferometry of Cosmic Ray Air Showers with the Square Kilometre Array** — •Keito Watanabe[1], Tim Huege[1,2], Torsten Ensslin[3,4,5], and Vincent Eberle[3,4] for the SKA HECP SWG-Collaboration — [1]Institute for Astroparticle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Inter-University Institute For High Energies, Vrije Universiteit Brussel, Brussels, Belgium — [3]Max-Planck Institut für Astrophysik, Garching, Germany — [4]Ludwig-Maximilians-Universität München,

München, Germany — [5]Deutsches Zentrum für Astrophysik, Görlitz, Germany

With the advent of the low-frequency component of the Square Kilometre Array (SKA-Low), its high antenna density and large frequency bandwidth will allow radio measurements of cosmic ray air showers to be performed with unprecedented accuracy. Current analysis techniques can already reconstruct shower properties with high precision, but are limited by their high computational cost and limited use of the information within the signal. In this work, we showcase that SKA-Low has the potential to perform near-field interferometry by reconstructing the spatial and temporal evolution of the shower with Information Field Theory, a novel Bayesian reconstruction framework that retrieves distributions of field-like quantities from observed signals. We validate our approach with realistic simulated datasets, showing that, through the reconstruction of the shower evolution, we can not only improve our understanding of the mass composition of cosmic rays but also probe the underlying hadronic physics within the shower.

T 40.9 Tue 18:15 KS 00.006

**Development of Radio-Interferometric Lightning Reconstruction for BOLT Using AERA Measurements*** — •Melanie Joan Weitz for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal

The Pierre Auger Observatory has detected downward terrestrial gamma-ray flashes (TGFs) with its water-Cherenkov detectors. A key to understanding this high-energy radiation in thunderstorms is to combine such measurements with those of lightning processes in their earliest stages. The Broadband Observatory of Lightning and TGFs (BOLT) is a detector currently under construction for imaging lightning propagation in three dimensions using radio interferometry. With eleven modified Auger Engineering Radio Array (AERA) stations and their bandwidth range from 30-80 MHz, the necessary spatial and temporal resolution can be provided.

To prepare for BOLT measurements, we characterize lightning signals in existing AERA data to validate the instrument design, particularly concerning the signal amplitude and dynamic range. We will present the reconstructed location and emission time of lightning candidates observed with AERA stations using external lightning information. Furthermore, we present the development of a radio-interferometric analysis suitable for application to the first BOLT signal traces.

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