EPS-HEP 2025

Contribution ID: **520** Type: **Parallel**

Inference of the Mass Composition of Cosmic Rays with energies between 3 and 100 EeV using the data of the Pierre Auger Observatory and Deep Learning

Monday 7 July 2025 10:10 (20 minutes)

One of the open questions of astrophysics is the mass composition of ultra-high-energy cosmic rays (UHECRs). The flux of UHECRs is extremely low, demanding large observatories for indirect measurements of cosmic-ray air showers, cascades of secondary particles created by interactions of the cosmic ray with the atmosphere.
Located in Argentina, the Pierre Auger Observatory is the largest cosmic-ray observatory on Earth. The Observatory is a hybrid detector employing different detection principles to observe multiple components of air showers. The core part of the detector is the Surface Detector (SD), which comprises 1 600 water-Cherenkov detectors with $1.5\,\mathrm{km}$ spacing in an area of $3000\,\mathrm{km}^2$. The highly sensitive Fluorescence Detector (FD) overlooks the area above the SD. Since the FD can only operate on moonless nights, its duty cycle is limited to approximately 15%.
The indirect nature of measurements of the Pierre Auger Observatory poses several challenges. For example, estimating the mass of a primary cosmic ray. The atmospheric depth of the shower maximum X_{max} is a mass-sensitive observable. The FD observes the X_{max} directly but can measure only a subset of the detected events due to its duty cycle.
On the contrary, the SD of the Pierre Auger Observatory, operating almost at 100% duty cycle, allows for a significant increase in the data. In this contribution, we present the X_{max} reconstruction based on deep neural networks that extend the energy range and statistics. We probe the energy evolution of the mean and standard deviation of the reconstructed X_{max}, which reflect the changes in the mass composition. The features found in the average X_{max} rate suggest a heavier and purer mass composition with increasing energy.

Secondary track

Author: ČERMÁKOVÁ, Berenika (Karlsruhe Institute for Technology)

Presenter: ČERMÁKOVÁ, Berenika (Karlsruhe Institute for Technology)

Session Classification: T01 (Astroparticles, Gravitation and Cosmology)

Track Classification: T01 - Astroparticles, Gravitation and Cosmology