EUROPEAN AI FOR FUNDAMENTAL PHYSICS CONFERENCE EuCAIFCon 2025

Contribution ID: **39** Type: **Poster + Flashtalk**

Estimation of Temporal Muon Signals in Water-Cherenkov Detectors of the Surface Detector of the Pierre Auger Observatory

The Pierre Auger Observatory is a cosmic-ray detector that uses multiple systems to simultaneously observe extensive air showers (EAS). EAS are particle cascades initiated by ultra-high-energy cosmic rays (UHECRs) interacting with the atmosphere of the Earth. Determining the sources of UHECRs requires precise knowledge of their mass composition. One key observable for estimating the mass of an impinging cosmic ray is the number of muons created in the shower cascade. The Surface Detector (SD) of the Observatory is a 3,000 km^2 array of independent detector stations. The main component of the SD stations is a water-Cherenkov detector, which records the signals of air shower particles reaching the ground. Since the particle cascade consists of many different elementary particles, such as muons, electrons, and photons, filtering the detected signals to isolate the muonic component is non-trivial. To estimate the contribution of muons in these signals, a recurrent neural network approach based on long short-term memory layers was developed. The model performs well on simulations, achieving a small muon signal bias on an unseen dataset and generalizing across different hadronic interaction models. In addition, the estimator can be calibrated using measurements from the Underground Muon Detector, a set of buried scintillator detectors that directly measure high-energy muons. Such a calibration is a key advantage due to limitations in shower and detector simulations.

AI keywords

recurrent neural networks, long short-term memory, simulation-based inference

Primary author: KUBÁTOVÁ, Margita (FZU - Institute of Physics of the Czech Academy of Sciences)

Presenter: KUBÁTOVÁ, Margita (FZU - Institute of Physics of the Czech Academy of Sciences)

Track Classification: Inference & Uncertainty