T 46: Cosmic Rays II

Time: Tuesday 16:00–18:30 Location: Tu

T 46.1 Tue 16:00 Tu

Composition Measurements with AugerPrime using Deep Learning* — Sonja Schröder and •Julian Rautenberg for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal, Germany

The AugerPrime upgrade of the Pierre Auger Observatory in Argentina will enhance the precision of primary particle composition measurements made by the Surface Detector. This will be achieved using the different response of the Water Cherenkov Detector (WCD) and the Surface Scintillator Detector (SSD) to the electromagnetic and muonic component of the extensive air shower.

With the deployment of AugerPrime ongoing, the cosmic ray composition sensitivity of the upgrade can already be probed using simulations and modern machine learning techniques. In this presentation, a Deep Learning approach is shown to be able to reconstruct the depth of shower maximum, $X_{\max}$, a mass sensitive observable, on an event-by-event basis. For this, a combination of deep convolutional neural networks is used to process information simultaneously from both WCD and SSD signals, obtained from full AugerPrime detector simulations using a mixed composition of protons, helium, oxygen, and iron. The increase in sensitivity gained through the addition of the SSD, as well as the end estimated mass bias and resolution will be presented.

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T 46.2 Tue 16:15 Tu

Towards the Determination of the UHECR Composition using Deep Learning and the Surface Detector of the Pierre Auger Observatory — Martin Erdmann, •Jonas Glombitza, Berenika Idaszek, and Niklas Langner — III. Physikalisches Institut A, RWTH Aachen University

Ultra-high energy cosmic rays (UHECRs) are the most energetic particles found in nature. When propagating within the Earth's atmosphere, they induce extensive air showers which can be measured by cosmic-ray observatories. The Pierre Auger Observatory features a surface detector (SD) which is overlooked by 27 fluorescence telescopes. The reconstruction of event-by-event information sensitive to the cosmic-ray mass is a challenging task and so far, mainly based on fluorescence observations with a duty cycle of about 15%.

Recently, deep learning-based algorithms have shown to be extraordinary successful across many domains. Applying these algorithms to surface-detector data allows for an event-by-event estimation of the cosmic-ray mass, exploiting the 100% duty cycle of the SD [1].

In this contribution we present a deep neural network, designed to exploit the symmetries of the SD and suited to the real operation-conditions at the Pierre Auger Observatory. We evaluate the performance of the method and introduce a calibration of the algorithm using Auger hybrid data. Finally, we estimate the expected accuracy of the method to determine the UHECR composition at the highest energies with unprecedented statistics.

[1] arXiv:2101/02946

T 46.3 Tue 16:30 Tu

Paving the way to an event-by-event level estimation of the masses of UHECRs with AugerPrime and Air Shower Universality — •Max Stadelmaier, Markus Roth, Darko Veberic, and David Schmidt for the Pierre Auger-Collaboration — Institut für Astroteilchnphysik KIT, Karlsurhe, Germany

Reconstructing the primary masses of ultra high-energetic cosmic rays (UHECRs) on event level can give insight into a manifold of open questions in astrophysics, for instance identifying individual sources or source regions. A reconstruction based on Air Shower Universality allows the determination of the relative muon content, R_μ, and the atmospheric depth of the shower maximum, $X_{\max}$, of an extensive air shower with data collected only from a surface detector. Both these observables can be linked to the mass of the cosmic ray. The upgraded surface detector of the Pierre Auger Observatory, *AugerPrime*, will allow an accurate reconstruction of these mass sensitive observables on an event level. We present the principles of Air Shower Universality as well as first results based on simulations to reconstruct the relative muon content of extensive air showers produced by ultra high-energetic cosmic rays using AugerPrime.

T 46.4 Tue 16:45 Tu

Determination of the muon deficit in air shower simulations using SD-AERA hybrid events detected with the Pierre Auger Observatory* — •Marvin Gottowik and Julian Rautenberg for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal

The number of muons in extensive air showers is underpredicted by all current generation hadronic interaction models. For the first time, this muon deficit is determined using hybrid events that have been detected with the Auger Engineering Radio Array (AERA) and the Surface Detector (SD) of the Pierre Auger Observatory. Using a subset of 31 high quality events with primary energies between 6 EeV and 20 EeV and zenith angles between 60° and 80°, that have been detected in more than 6 years of operation, a muon deficit of up to 40 % is found assuming a pure proton composition. Assuming a mixed composition of protons and iron reduces the deficit to about 15 %. The analysis is limited by low statistics due to the small area of AERA of only 17 km^2 and by the high energy threshold originating from the SD reconstruction. Statistics will be increased by the Radio Upgrade of Auger which will measure thousands of events with energies up to 100 EeV. This will allow for the study of the mean number of muons, as well as their intrinsic spread, with vastly increased statistics and allowing for in-depth tests of hadronic interactions at energies much higher than those accessible with current accelerators.

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T 46.5 Tue 17:00 Tu

Analysis of photon-like air showers measured by the Pierre Auger Observatory — •Jannis Pawlowsky for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal

The Pierre Auger Observatory is the largest experiment measuring ultra high energy cosmic rays. It has sensitivity to the primary particle type from the differences in the way showers develop. This leads to the Pierre Auger Observatory presently being the most sensitive detector for photons and neutrinos at energies above the EeV range. For the search of photons, the 12 years of the Surface Detector data was used. The detectors are able to discriminate the electromagnetic and hadronic shower component by the shape of the measured time traces and by the lateral particle density distribution of the air shower. These observables are combined in a principal component analysis (PCA) resulting in a photon-like parameter. In this, the distributions for hadrons and photons are well separated. Photon candidates have been selected by applying a PCA threshold corresponding to a 50% photon detection efficiency. Applied to the full dataset, 13 candidates in the tail of the data-distribution were found.

To test a hadron hypothesis, events with highly energetic π^0 secondaries have been simulated and analysed. Results for the characterization of these photon-like hadronic showers and the probability to be misinterpreted as photon candidates are presented.

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T 46.6 Tue 17:15 Tu

Search for ultra-high energy photons with the AugerPrime upgrade of the Pierre Auger Observatory — •Paulo Ferreira, Thomas Bretz, and Thomas Hebbeker for the Pierre Auger-Collaboration — III. Physikalisches Institut A, RWTH Aachen University

The Pierre Auger Observatory, the world's largest experiment for the detection of ultra-high energy cosmic rays, consists of an array of 1660 water Cherenkov detectors and 27 fluorescence telescopes, allowing for a hybrid reconstruction of air showers. An air shower detected by the observatory can have its origin in nuclei, but also in very energetic photons. Analyzing the photon flux is crucial to understand the flux suppression of cosmic rays above 50 EeV. No photon-induced air shower has yet been detected by the Pierre Auger Collaboration. While recent studies allowed for better upper limits for the photon flux at ultra-high energies, they are constrained by the current discrimination power between different types of primary particles. AugerPrime, an on-going upgrade of the Pierre Auger Observatory, brings, among other improvements, an additional scintillator detector to be installed on top of each water Cherenkov detector station. Since the scintillator's signals are mostly dominated by the electromagnetic part of the shower and the water Cherenkov detectors by the muonic one, their combination offers a better characterization of the shower. Through this, new variables which increase the sensitivity to primary photons are aimed at. As such, a new analysis strategy exploiting the additional information obtained using AugerPrime has been developed.

T 46.7 Tue 17:30 Tu

Testing the Pierre Auger Observatory Starburst Galaxy and Active Galactic Nuclei Correlation Result with CRpropa Simulations — •Wilson Namasaka for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal, Germany.

Intermediate scale anisotropies in the distribution of UHECR arrival directions can be associated with two prominent classes of extragalactic gamma-ray sources detected by Fermi-LAT. In the most recent study, a correlation between the arrival directions of cosmic rays at energies above 38 EeV for starburst galaxies (SBG) and above 39 EeV for active galactic nuclei (AGN) was reported by the Pierre Auger Collaboration with a significance against isotropy at 4.5σ and 3.1σ, respectively. In the study, the observed gamma ray luminosity was used as a proxy for cosmic ray luminosity. The cosmic ray excess models for these sources used an angular smearing parameter to fit the observed arrival direction distribution in an optimization scan. The goal of this research is to investigate the viability of this angular smearing using CRPropa simulation and test whether the results of the Pierre Auger Observatory can be reproduced by the deflections expected due to galactic and extragalactic magnetic fields. For this test, the five strongest gamma-ray sources in both the Fermi-LAT AGN and SBG catalogs have been selected based on flux weight. Simulations of these sources including extragalactic and galactic magnetic fields are hereby discussed. The preliminary angular smearing found in these simulations are presented. *Supported by the DAAD Ref No. 91653888.

T 46.8 Tue 17:45 Tu

Fitting a model of the ultra-high-energy cosmic ray universe — •Teresa Bister, Martin Erdmann, Josina Schulte, and Marcus Wirtz for the Pierre Auger-Collaboration — III. Physikalisches Institut A, RWTH Aachen University

The Pierre Auger Collaboration performed a fit of the measured energy spectrum and shower depth distribution, using an astrophysical model of a homogeneous source distribution. Later, measurements showed that the arrival directions of ultra-high-energy cosmic rays are in better agreement with the positions and fluxes of catalogs of starburst galaxies and active galactic nuclei compared to isotropy.

Here, a combination of both analyses is presented, utilizing all three complementary measurements simultaneously. For that, a three-dimensional universe model containing a nearby source population as well as a homogeneous background is built and its parameters are adapted with a combined fit of energy spectrum, shower depth distribution and arrival directions using an MCMC method. A rigidity dependent symmetric magnetic field smearing is used and its size is adapted by the fit along with the magnitude of the anisotropic fraction induced by propagation effects. Additionally, the element fractions and spectral parameters of the cosmic ray sources are fitted. We use CRPropa3 to simulate data resembling measurements of the Pierre Auger Observatory to show that the fit is able to determine the correct best-fit parameters. Additionally, we use a likelihood ratio to demonstrate the method's ability to significantly discriminate between the catalogs of starburst galaxies and active galactic nuclei.

T 46.9 Tue 18:00 Tu

Studies of Lorentz Violation using Air Shower Data — •Fabian Duenkel, Marcus Niechciol und Markus Risse — Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen

Due to their extremely high energies, cosmic rays are ideally suited to search for new physics, for example violations of Lorentz invariance. Isotropic, nonbirefringent Lorentz violation is considered in the following, specializing to the case of a photon velocity which is larger than the maximum attainable velocity of standard Dirac fermions. Earth-based bounds on this type of Lorentz violation have been determined before by observations of TeV gamma rays. The approach to test Lorentz invariance presented here is based on the measurement of extensive air showers induced by cosmic-ray particles in the Earth's atmosphere. Lorentz-violating processes can have a large impact on the longitudinal shower development of air showers, for example reducing the average atmospheric depth of the shower maximum Xmax. For showers with high primary energies, this change is significantly larger than the average resolution of current air-shower experiments. This can be used to obtain new bounds on this type of Lorentz violation, which can be further improved by taking into account further shower observables.

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T 46.10 Tue 18:15 Tu

A Simulation study of the performance of the AugerPrime Radio Detector — •Felix Schlüter for the Pierre Auger-Collaboration — Institut für Astroteilchenphysik, Karlsruhe, Deutschland

The AugerPrime Radio Detector will pioneer the detection of ultra-high energy cosmic rays with energies of up to 10^{20} eV with the aid of the world's largest, 3000 km^2 array of radio antennas. The detection of highly inclined air showers with radio antennas in coincidence with the Auger water-Cherenkov detector array provides highly complementary information yielding a strong sensitivity to the mass of the primary cosmic rays. Measuring the mass of cosmic rays at the highest energies is the key challenge in the quest after their origin. I will present first results of an end-to-end simulation study of the performance of the Auger Radio Detector. The study features a newly developed reconstruction model for the radio-emission induced footprint of inclined air showers. Based on the achieved performance, the potential to discriminate between proton and iron primaries will be presented.