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 π^- 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.

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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.