# T 16: Cosmic Rays V

Time: Monday 16:00–18:15 Location: Tp

T 16.1 Mon 16:00 Tp

**Turbulence level dependent investigation of the cosmic ray diffusion coefficient** — •Leander Schlegel[1,2], Patrick Reichherzer[1,2,3], Julia Becker Tjus[1,2], Lukas Merten[4], Antonius Frie[1,2], Björn Eichmann[1,2], Moritz Püschel[5], and Ellen Zweibel[6] — [1]RuhrUniversity Bochum, Theoretical Physics IV — [2]Ruhr Astroparticle and Plasma Physics (RAPP) Center — [3]Irfu, CEA Paris-Saclay — [4]Institute for Astro-& Particle Physics, University of Innsbruck — [5]Dutch Institute for Fundamental Energy Research, 5612 AJ Eindhoven, The Netherlands — [6]Department of Astronomy & Physics, University of WisconsinMadison

Understanding the transport of energetic cosmic rays belongs to the most challenging topics in astrophysics. The complicated evolution of the cosmic-ray distribution can be modeled mathematically by a diffusive process in the limit of large times. Consequently, diffusion is of fundamental importance in the transport of cosmic rays through turbulence. We show that at turbulence levels b/B above 5% of the total magnetic field, the approximation of an energy dependence E^(1/3) as predicted for a Kolmogorov spectrum within Quasi-Linear Theory does not hold. Different energy regimes also lead to specific diffusive behaviour, especially for low energies magnetic mirroring could have a relevant influence on the diffusion. Using a gridless synthetic turbulence model, we therefore investigate the diffusion coefficients behaviour in more detail dependent on E and b/B.

T 16.2 Mon 16:15 Tp

**Diffusion of cosmic rays in plasmoids of AGN jets - implications for multimessenger predictions** — •Marcel Schroller, Julia Becker-Tjus, Mario Hoerbe, Ilja Jaroschewski, and Patrick Reichherzer — Ruhr-University Bochum,44780 Bochum, Germany

Active Galactic Nuclei (AGN), and the accompanied AGN jets, are one of the most fascinating and luminous objects in the observable Universe. Both the active cores and their jets are candidates for the engine of cosmic rays and neutrinos with the highest energies measured at Earth. A deep understanding of the processes related to jets will not only fuel the field of high energy cosmic rays, it will give insights in fundamental plasma, astro, and particle physics. The physical and mathematical modelling of an AGN jet is challenging, with ambiguous signatures that need to be understand by numerical simulations of cosmic-ray transport and interaction. Based on the work of Hoerbe et al. (MNRAS 2020), a simulation framework for hadronic constituents and their interactions inside of a plasmoid, propagating along the AGN jet axis, was made. The final goal of the simulation is to give predictions in context of multimessenger astrophysics. This talk will answer one of the preceding questions, namely at which point the propagation of cosmic rays inside the plasmoid is diffusive or ballistic. The solution of the telegraph equation in this context will be presented and analysed, alongside a scheme for the classification of different astrophysical regions. A first excerpt of the results will be given, as well as a run time analysis of the full 24-dimensional parameter space of the setup.

T 16.3 Mon 16:30 Tp

**Propagation in the Galactic magnetic field: Effects on the spectrum, composition, and anisotropy of Galactic and extragalactic cosmic rays *** — •Alex Kääpä, Eric Mayotte, and Karl-Heinz Kampert — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal

In the energy range signifying the transition from Galactic to extragalactic cosmic rays (GCRs and EGCRs), current cosmic ray source and propagation models fail to describe the observed flux above PeV energies. This is partly due to the complicated effects the Galactic magnetic field (GMF) imposes on both GCRs and EGCRs, as the propagation regime of cosmic rays in the GMF transitions from diffusive to ballistic. At the lowest rigidities, near the end of the diffusive regime, GCRs are trapped in, and EGCRs are effectively shielded from the Galaxy. At intermediate rigidities, the EGCRs that reach the Galaxy and the GCRs are concentrated in the Galactic plane where they propagate diffusively. At highest rigidities, particles are hardly affected by the GMF. In this talk, we present the consequences of these propagation effects on the spectrum, composition, and anisotropy of both GCRs and EGCRs based on CRPropa simulation. Special focus will given on how these results may help elucidate the missing predicted flux in the transition region.

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T 16.4 Mon 16:45 Tp

**When heavy ions meet cosmic rays : potential impact of QGP formation on the muon puzzle** — •Tanguy Pierog[1], Sebastien Baur[2], Hans Dembinski[3], Matias Perlin[1], Ralf Ulrich[1], and Klaus Werner[4] — [1]KIT, IAP, Karlsruhe, Germany — [2]Université Libre de Bruxelles, Belgium — [3]Experimentelle Physik 5, TU Dortmund — [4]SUBATECH, Nantes, France

The deficit of muons in the simulation of extensive air showers is a long standing problem and the origin of large uncertainties in the reconstruction of the mass of the high energy primary cosmic rays. Hadronic interaction models, re-tuned after early LHC data, have a more consistent description of the muon content among them but still disagree with data. Collective hadronization due to the formation of a quark gluon plasma (QGP) has already been studied as a possible cause for a larger production of muons under extreme conditions (rare, very central nuclear interactions), but without real success. However, in the view of the most recent LHC data, a collective hadronization phase might not be limited to such extreme conditions. And because of its different ratio of electromagnetic to hadronic energy, a QGP may have the properties to solve the muon puzzle. It is demonstrated using a theoretical approach and tested in a realistic way by the modification of hadronic model spectra in CONEX to mimic the production of a QGP also in not so extreme conditions with a possible large impact on air shower physics.

T 16.5 Mon 17:00 Tp

**Status of air shower simulation for GRAND** — •Chao Zhang, Tim Huege, Tanguy Pierog, Markus Roth, Andreas Haungs, Frank Schroeder, and Ralph Engel for the GRAND-Collaboration — Institut fuer Astroteilchenphysik, Karlsruher Institut fuer Technologie-Campus Nord, Post-fach 3640, 76021 Karlsruhe, Germany

GRAND is a proposed project to measure ultra-high-energy air showers with a 200,000 km $^2$ array of radio antennas distributed in mountainous areas. It will be able to detect cosmic ray, gamma-ray, and neutrino primaries in the energy range beyond $10^{17}$ eV with unprecedented sensitivity and thereby opening a window to study the origin of the ultra-high-energy cosmic rays. Further more, it will play an important role in the multi-messenger era.

In this talk, we will present simulation work aimed at GRAND-Proto300, a prototype of GRAND, covering an area of 300 km $^2$, for which construction will start in 2021. This presentation will include a study of the atmospheric models applicable to different candidate sites, the methods we have implemented to prepare an air shower library, upgrades of CORSIKA for the simulation of upward going neutrinos for GRAND, and the investigation of a signal model derived from CoREAS simulations.

T 16.6 Mon 17:15 Tp

**Efficiency and aperture estimation of the Tunka-Rex array** — •Vladimir Lenok for the Tunka-Rex-Collaboration — Institute for Astroparticle Physics, Karlsruhe Institute of Technology, Germany

Sparse digital-antenna arrays are a promising technique for the future large-scale observatories of cosmic rays and neutrinos. However, estimation of the efficiency of these instruments is challenging. The efficiency depends on the zenith and azimuth angles. Monte-Carlo simulations of the radio emission of cosmic-ray air showers, which are usually the main tool in assessment of an instrument performance, are computationally intensive. We developed a phenomenological model for the estimation of the detection efficiency. The model is based on a parametrization of the air-shower radio footprint and includes a probabilistic treatment of both, the signal detection by an individual antenna and the shower detection. Currently, the model is under validation against Monte-Carlo simulations and the observational data of the Tunka-133 air-Cherenkov array. We use the model in application to the Tunka-Rex instrument — a radio-antenna array operated on the site of TAIGA (the Tunka Advanced Instrument for cosmic ray physics and Gamma Astronomy). However, the developed model can be applied to any radio antenna array. In the talk we will present the recent updates of the model development and the results of the validation.

T 16.7 Mon 17:30 Tp

**Towards the Energy Spectrum of Cosmic-Rays using Atmospheric Stopping Muons in IceCube** — •Janina Bolles for the IceCube-Collaboration — TU Dortmund, Germany

In the IceCube neutrino observatory the main type of detected events are muons being produced by cosmic-ray particles interacting with the earth's atmosphere. In the context of neutrino analyses these muons are the dominating background, though in case of cosmic-ray physics the energy losses of the muons within the detector can be used as an indicator to reconstruct the cosmic-ray energy spectrum.

In this work muon events stopping inside the detector are selected, due to the possibility to reconstruct the range to the muons stopping point as a proxy for its energy. This approach takes advantage of the high statistics of atmospheric muons, so strict cuts on the reconstruction can be applied to obtain an event sample of single muons with high resolution. The reconstructed range of the muons can later be used to estimate the cosmic ray energy spectrum. This talk covers the early stage of the analysis and an overview over the analysis methods and goals is given.

T 16.8 Mon 17:45 Tp

**Towards an Energy Spectrum Using the Depth Dependence of Stopping Atmospheric Muons in IceCube** — •Lucas Witthaus for the IceCube-Collaboration — Technische Universität Dortmund

The IceCube Neutrino Observatory, located in the Antarctic ice sheet near the geographic South Pole, is meant to detect neutrinos with energys up to a few PeV. However, the majority of recorded events in IceCube is caused by muons from atmospheric air showers. Those events pose as background for neutrino observations, but are particulary suitable to study the underlying cosmic ray spectrum.

This work aims to reconstruct the muon energy spectrum from the depth-dependence of the stopping muon events. The propagation length of these muons is a direct proxy to their surface energy. First steps towards such a data set using deep neural networks and machine learning techniques are presented.

T 16.9 Mon 18:00 Tp

**Calibration of the Data Acquisition System of the IceCube Surface Array Enhancement** — •Ömer Nuhoglu, Andreas Haungs, Bernd Hoffmann, Marie Oehler, and Andreas Weindl for the IceCube-Collaboration — KIT, Karlsruhe, Germany

IceTop, the surface array of the IceCube Neutrino Observatory, will be enhanced with hybrid stations within the current footprint, which will increase the detection sensitivity of cosmic rays significantly. Each station consists of eight scintillation detectors and three radio antennas, which are read out by a custom designed central hybrid data acquisition system (DAQ). The detectors consist of organic scintillators, wavelength shifting optical fibers and silicon photomultipliers (SiPM). The analog signals of the SiPM are integrated and digitized inside the detectors and then transferred to the central DAQ.

Since the signal of the SiPM depends on the applied voltage and the temperature, calibration measurements are needed to ensure the stability of the voltage and the reliability of the temperature sensor in the detector. Additionally, the integration of the SiPM signals needs to be characterized. In this contribution the methods and results of these calibration measurements will be presented.