UHECR2022

Report of Contributions

Contribution ID: **1** Type: **not specified**

Welcome

Session Classification: Session 6

Contribution ID: **2** Type: **not specified**

Welcome

Monday, 3 October 2022 09:00 (20 minutes)

Presenters: DE MITRI, Ivan (Gran Sasso Science Institute (GSSI) and INFN); ENGEL, Ralph

Contribution ID: **13** Type: **not specified**

Poster Rapporteur: Theory

Thursday, 6 October 2022 16:30 (25 minutes)

Presenter: Prof. OIKONOMOU, Foteini (Norwegian University of Science and Technology)

Contribution ID: **27** Type: **not specified**

Poster Rapporteur: Experiments

Thursday, 6 October 2022 16:55 (25 minutes)

Presenter: DI MATTEO, Armando

Contribution ID: **35** Type: **not specified**

Poster Prize announcement

Thursday, 6 October 2022 17:20 (10 minutes)

Contribution ID: **48** Type: **not specified**

Poster Rapporteur 4

Contribution ID: **59** Type: **not specified**

Opening Talk

Contribution ID: **60** Type: **not specified**

Summary Talk

Contribution ID: **62** Type: **not specified**

The underground Gran Sasso Laboratory

Contribution ID: **65** Type: **Talk**

Signatures of Cosmic-Rays Transports on Gamma-Ray Starburst Galaxies Observations

Thursday, 6 October 2022 12:10 (20 minutes)

Experimental observations have demonstrated a strong correlation between star-forming processes and gamma-ray luminosities, giving strong hints about the nature of the Cosmic-Rays (CRs) transport mechanisms inside Starburst Nuclei (SBNs). In this talk, I will discuss the imprints on nearby Starburst galaxies (SBGs) gamma-ray spectra left by different CR transport models, quantifying the potentiality of future measurements from CTA and SWGO telescopes to distinguish between them. I will also investigate the possibility of constraining the properties of light Dark Matter (DM) particles exploiting the peculiar nature of CR transport inside SBNs. I will show that the property of elastic scattering between high-energy CRs and DM particles leads to observable features, thereby posing stringent constraints on the DM parameter space.

Primary author: AMBROSONE, Antonio (University of Naples "Federico II" and Istituto Nazionale di Fisica Nucleare (INFN) sezione di Napoli)

Co-authors: Dr CHIANESE, Marco (University of Naples "Federico II" and Istituto nazionale di Fisica Nucleare (INFN) sezione di Napoli); Dr FIORILLO , Damiano F.G. (Niels Bohr International Academy, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark); Dr MARINELLI , Antonio (University of Naples "Federico II" and Istituto Nazionale di Fisica Nucleare (INFN) sezione di Napoli); Prof. MIELE, Gennaro (University of Naples "Federico II", Istituto Nazionale di Fisica Nucleare (INFN) sezione di Napoli and Scuola Superiore Meridionale (SSM))

Presenter: AMBROSONE, Antonio (University of Naples "Federico II" and Istituto Nazionale di Fisica Nucleare (INFN) sezione di Napoli)

Contribution ID: **66** Type: **Talk**

Multi-Messenger emission of Tidal Disruption Events

Thursday, 6 October 2022 11:30 (20 minutes)

Tidal Disruption Events (TDEs) of massive stars are potential candidates for neutrinos and cosmic rays at the highest energies. Three Tidal Disruption Event candidates (AT2019dsg, AT2019fdr, AT2019aalc) have been recently associated with astrophysical neutrinos; they have strong dust echoes (in the infrared range) in common, with time delays which seem to be correlated with the neutrino arrival times. We address the question where/how the neutrinos may be produced and what we can learn about the cosmic ray primaries. For example, if the IR photons from the dust echoes indeed serve as cosmic ray targets in photohadronic interactions, cosmic ray energies in the UHECR range are required, and the neutrino detections will be the smoking gun signature for the origin of the UHECRs.

Primary author: WINTER, Walter (DESY)

Presenter: WINTER, Walter (DESY)

Contribution ID: **67** Type: **Talk**

UHECR Reverberation from the Council of Giants

Tuesday, 4 October 2022 14:00 (20 minutes)

Recent observations by the PAO indicate a correlation between UHECRs and the local galactic structure. We explore the possibility that this correlation is brought about by UHECRs having a single origin, and subsequently ballistically propagating in extragalactic space before reverberating off the local galactic within the Council of Giants. Focusing effects within the reverberated wave structure observed are discussed. We demonstrate that such a scenario imprints itself on the composition of the direct wave from the primary source, and secondary reverberated waves from the local structure.

Primary authors: Dr TAYLOR, Andrew (DESY); Prof. BELL, Tony (University of Oxford); Dr MATTHEWS, James (University of Cambridge)

Presenter: Dr TAYLOR, Andrew (DESY)

Contribution ID: **68** Type: **Talk**

A Hierarchical Interpretation of the Observed Cosmic Ray Spectrum.

Thursday, 6 October 2022 10:00 (20 minutes)

Cosmic rays are observed at earth with energies from less than 100 MeV to more than 100 EeV. Undoubtedly, they have many sources but we explore the minimalist possibility that they mostly derive from diffusive shock acceleration over a range of scales assocaited successively with stellar winds, supernova remnants, galactic winds and intergalactic accretion onto filaments and clusters, with highest energy particles from one scale providing the injection for the next scale. Special attention will be paid to the contribution of the highest energy particles that escape ahead of strong shock fronts. Fairly robust and potentially refutable implications of this interpretation will be discussed.

Primary author: Prof. BLANDFORD, Roger (KIPAC Stanford)

Presenter: Prof. BLANDFORD, Roger (KIPAC Stanford)

Contribution ID: **69** Type: **Talk**

Evidence for a break in the Elongation Rate of Shower Maximum at ~3 EeV from four independent studies

Monday, 3 October 2022 15:50 (20 minutes)

During UHECR2018, it was pointed out that data from Fly's Eye, HiRes and the Telescope Array were suggestive of a break in the Elongation Rate above ~3EeV. Sokolsky and D'Avignon (2021) have recently rediscovered this observation. Additionally, they assert that cosmic rays arriving from the Northern Hemisphere have a different mass composition from those arriving from the Southern Hemisphere. Data from four independent measurements of the Elongation Rate will be reviewed. It will be shown that there is strong evidence for a break in the Elongation Rate above ~3EeV in each data set, so adding support to the long-held conclusion of the Auger Collaboration that the mean mass of cosmic rays increases with energy above ~3 EeV. However, the claim by Sokolsky and D'Avignon of a mass difference between cosmic rays arriving from the two hemispheres is not upheld. This talk is offered as, in the view of the joint TA/Auger Mass Working Group, it may help 'spice up the discussions' on mass composition at this meeting.

Primary author: Prof. WATSON, Alan (University of Leeds, UK)

Presenter: Prof. WATSON, Alan (University of Leeds, UK)

Contribution ID: **70** Type: **Review**

Astrophysics of cosmic ray accelerators

Monday, 3 October 2022 10:50 (30 minutes)

The Universe is capable of accelerating cosmic rays to energies beyond 10^20 eV. Due to deflection in magnetic fields during their propagation, it is difficult to trace them back to their origin. However, cosmic rays produce gamma-ray photons and neutrinos in interactions with matter and photon fields in or close to the source. Being neutral those secondary particles can travel undeflected and ultimately point back to the source.

Candidate sources include active galactic nuclei (AGN), Starburst Galaxies, Tidal Disruption Events (TDEs) and Gamma-ray Bursts (GRBs). I will put the potential acceleration sites in the context of recent observations of gamma-ray and neutrino emission.

Primary author: FRANCKOWIAK, Anna (Ruhr-University Bochum)

Presenter: FRANCKOWIAK, Anna (Ruhr-University Bochum)

Contribution ID: **71** Type: **Review**

Magnetic fields and UHECR propagation

Tuesday, 4 October 2022 09:30 (30 minutes)

In this talk, I will review the observational properties of magnetic fields in our Galaxy – in particular in the Galactic halo – and in the intergalactic medium.
I will lay the emphasis on the properties that are relevant to the propagation of UHECRs, namely, the strength and the overall topology of the magnetic field.
I will discuss how these properties fit in with the basic predictions of dynamo theory.

Primary author: FERRIÈRE, Katia (IRAP/OMP)

Presenter: FERRIÈRE, Katia (IRAP/OMP)

Contribution ID: **73** Type: **Talk-To-Poster**

Near-future discovery of point sources of ultra-high-energy neutrinos

Upcoming neutrino telescopes may discover ultra-high-energy (UHE) cosmic neutrinos, with energies beyond 100 PeV, in the next 10–20 years. Finding their sources would expose the long-sought origin of UHE cosmic rays. We search for sources by looking for multiplets of UHE neutrinos arriving from similar directions. Our forecasts are state-of-the-art, geared at neutrino radio-detection in IceCube-Gen2. They account for detector energy and angular response, and for critical, but uncertain backgrounds. We report powerful insight. Sources at declination of -45° to 0° will be easiest to discover. Discovering even one steady-state source in 10 years would disfavor most known steady-state source classes as dominant. Discovering no transient source would disfavor most known transient source classes as dominant. Our results aim to inform the design of upcoming detectors.

Primary author: FIORILLO, Damiano F. G. (Niels Bohr Institute, Copenhagen)

Co-authors: BUSTAMANTE, Mauricio (Niels Bohr Institute, Copenhagen); VALERA, Victor (Niels Bohr Institute, Copenhagen)

Presenter: FIORILLO, Damiano F. G. (Niels Bohr Institute, Copenhagen)

Contribution ID: **74** Type: **Review**

Results from high energy direct measurements and future prospects

Monday, 3 October 2022 11:20 (30 minutes)

In this talk I will review the recent results from high energy cosmic ray measurements, in the ‘above TeV’ energy region. I will also describe the future experiments that will be realised to significantly improve the current measurements, aiming to explore the PeV region with direct measurements.

Primary author: ADRIANI, Oscar (University of Florence and INFN Firenze)

Presenter: ADRIANI, Oscar (University of Florence and INFN Firenze)

Contribution ID: **75** Type: **Review**

Particle Acceleration via Magnetized Turbulence and Magnetic Reconnection

Thursday, 6 October 2022 09:00 (30 minutes)

Magnetized turbulence and magnetic reconnection are often invoked to explain the generation of high energy particles in astrophysics. Originally, these two routes for particle acceleration were treated as distinct plasma processes. However, with the rapid advances in computing power and theory, they are converging towards a unified domain. In this talk, I will outline recent developments in this fast-growing front exploiting the results of first-principles kinetic (PIC) simulations. I will also show how particles can be accelerated up to the highest energies in some astrophysical sources.

Primary author: COMISSO, Luca (Columbia University)

Presenter: COMISSO, Luca (Columbia University)

Contribution ID: **76** Type: **Talk**

Status of the LHCf experiment

Wednesday, 5 October 2022 14:00 (20 minutes)

A precise understanding of hadronic interactions is essential to interpreting the mass composition of ultra-high energy cosmic rays from the results of air shower experiments. The LHC-forward (LHCf) experiment aims to measure forward neutral particles to validate hadronic interaction models adopted in air shower simulations.
We already published the energy spectrum of forward photons and neutrons for proton-proton collisions at $\sqrt{s}$ = 13 TeV. Recently, we showed a preliminary result of the energy spectrum of forward η mesons for proton-proton collisions at $\sqrt{s}$ = 13 TeV. Moreover, in September 2022, we have another data-taking for proton-proton collisions at $\sqrt{s}$ =13.6 TeV. In the data-taking, we plan to obtain ten times larger π^0 and η candidates for precise measurements and have a joint operation with the ATLAS Roman pots and Zero-degree calorimeters. Thanks to the joint operation with the ATLAS Roman pots, we can measure diffractive mass and neutral particles from diffractive dissociation simultaneously. Furthermore, energy resolution for neutrons is expected to be improved from 40% to 20% by combining the LHCf and the ATLAS zero-degree calorimeters.
In this talk, we report the status and prospects of the LHCf experiment.

Primary author: OHASHI, Ken (Nagoya University)

Co-author: LHCF COLLABORATION

Presenter: OHASHI, Ken (Nagoya University)

Contribution ID: **77** Type: **Poster**

Performance evaluation of LHCf-ATLAS ZDC joint measurement using proton beam

The LHCf experiment measures neutral particles emmitted to the very forward region of pp collisions at the Large Hadron Collider (LHC) with a detectors located 140 m away from the ATLAS Interaction point (IP1).
Measurements of neutrons will allow us to investigate π-p cross-section via one-pion exchange process as well as inelasticity measurement, which are important for air shower development. However, the precision of these measurements is limited by the energy resolution of the LHCf detectors.
To improve it, a joint measurement with ATLAS-ZDC, which will be installed behind the LHCf detector, will be performed with pp collisions at $\sqrt{s}$ = 13.6 TeV in September 2022. In September 2021, a beam test was conducted at the H4 beam line of SPS to verify the performance of the joint measurement. This beam test used 350 GeV proton beams. Combining the LHCf data with the ZDC data, we confirmed that the energy resolution improved from about 40% to 21%.

Primary authors: KONDO, Moe; LHCF COLLABORATION; ATLAS-ZDC COLLABORATION

Presenter: KONDO, Moe

Contribution ID: **78** Type: **Talk-To-Poster**

Ultra-High Energy Proton-Proton Collision in the Laboratory System as the Source of Proton, Neutrino and Gamma Spectra in Astrophysics

This paper argues that production, collisions, and decays of matter in space
result in the form of particle spectra, which are measured in cosmic rays and astrophysics. Protons, nuclei, and dark matter are the known forms of matter in the Galaxy. If we understand how a high-energy proton produces protons in a collision with another proton (or antiproton), we can predict the form of the spectra of secondary particles. This is also the way to clarify the nature of Dark Matter (DM).
LHC experiments can provide us with the proton spectrum at the very high energy
(VHE) of collision. The suggested method means only to convert this spectrum into the laboratory system of coordinates and to compare it with the spectra of various CR particles. It has been shown that spectra of cosmic protons reproduce the form of proton production spectrum at the single collision of the initial
proton of ultra-high energy (UHE), which was predicted in the Quark-Gluon String
Model. The specifics of proton energy spectrum in c.m.s. are the following: the growing central-rapidity table due to the proton-antiproton pairs production and the triple-Pomeron peak at the end of spectrum because of diffraction dissociation of initial proton. This peak or bump in the neutrino spectra is expected in the recent measurements at the UH energies.
The gamma spectrum in the entire diapason of gamma energies has also the
distinct bump at the highest energy that is the signature of proton-proton collision.

Primary author: Dr PISKOUNOVA, Olga (P.N. Lebedev Institute for Physcs)

Presenter: Dr PISKOUNOVA, Olga (P.N. Lebedev Institute for Physcs)

Contribution ID: **80** Type: **Review**

Multi-messenger connections of UHECRs

Monday, 3 October 2022 09:50 (30 minutes)

The growing number of multi-messenger observations provides an unprecedented view on powerful cosmic fireworks. Recent developments on the modeling of the sources and the related multi-messenger signals will be reviewed together with the most exciting detection prospects.

Primary author: TAMBORRA, Irene

Presenter: TAMBORRA, Irene

Contribution ID: **82** Type: **Talk-To-Poster**

Probing Lorentz violation at ultra-high energies using air showers

In air showers initiated by ultra-high-energy cosmic rays in the Earth's atmosphere, even the secondary particles created in the start-up phase are produced at energies far above those accessible by other means. These high-energy particles can be used to search for New Physics, such as a violation of Lorentz invariance. We focus on isotropic, nonbirefringent Lorentz violation in the photon sector and and consider the two cases $\kappa < 0$ and $\kappa > 0$ (i.e., the velocity of photons is larger/smaller than the maximum attainable velocity of standard Dirac fermions). In both cases, processes that are forbidden in the standard, Lorentz-invariant theory ($\kappa = 0$) become allowed, in particular photon decay in the case $\kappa < 0$ and vacuum-Cherenkov radiation for $\kappa > 0$. Implementing these processes into air-shower simulations, we found that the development of an air shower at the highest energies can be significantly impacted, specifically the average atmospheric depth of the shower maximum $\langle X_{\mathrm{max}} \rangle$ and its shower-to-shower fluctuations $\sigma(X_{\mathrm{max}})$. Comparing these simulations to actual measurements, we were able to obtain much stricter bounds on this specific type of LV in the case $\kappa < 0$ than possible with previous methods. We discuss these limits and, in addition, present first results for the case $\kappa > 0$.

Primary authors: Dr NIECHCIOL, Marcus (University of Siegen); DUENKEL, Fabian; RISSE, Markus

Presenter: Dr NIECHCIOL, Marcus (University of Siegen)

Contribution ID: **83** Type: **Talk**

Production of high-energy neutrinos in binary-neutron-star merger events

Thursday, 6 October 2022 11:50 (20 minutes)

High-energy neutral astrophysical messengers, such as neutrinos and photons, can be produced by the interaction of ultra-high-energy cosmic rays (UH0ECRs) with radiation fields, either during extragalactic propagation or within source environments. Neutrinos and gamma-rays can play a crucial role in the study of acceleration mechanisms of cosmic rays. In particular, after being produced, neutrinos leave the source environment and propagate to the Earth without further interactions. They are only subject to energy redshift and flavour oscillation, which makes them bearers of information about their sources otherwise not accessible. We study high-energy environments of the type that are likely to be the end states of a binary-neutron-star (BNS) merger, and we model their local photon field as a black body at a given temperature. Using a modified version of the Monte Carlo code SimProp v2r4 we simulate the propagation and interaction of UHECRs through these environments. We consider several combinations for composition, spectral index and high-energy cutoff of the UHECR primaries, in order to obtain the escaped neutrino flux. We propagate these fluxes to the Earth and compare to the astrophysical IceCube neutrino flux to obtain constraints on the BNS merger spectra properties, emissivity and density rate.

Primary author: Mr ROSSONI, Simone (University of Hamburg)

Co-authors: Prof. BONCIOLI, Denise (University of L'Aquila); Prof. SIGL, Günter (University of Hamburg)

Presenter: Mr ROSSONI, Simone (University of Hamburg)

Contribution ID: **84** Type: **Talk-To-Poster**

CRPropa high statistic simulations for UHECR anisotropy studies

Despite the great progress made by modern cosmic ray observatories, the origin and acceleration mechanism of ultra-high-energy cosmic rays (UHECRs) remains an unsolved problem to this day. However, there is experimental evidence for an anisotropic component in the UHECR arrival direction greater then few EeV. The search for UHECR sources is further complicated by two main factors: during extragalactic propagation UHECRs interact with background photon fields (like the CMB and the EBL) and, since they are electrically charged, they are deflected by extragalactic and galactic magnetic fields (EGMF and GMF). Moreover, the strength, structure and origin of the EGMF are still not well known, causing reconstructing the deflection of UHECRs a non-trivial task. In this work we consider several EGMF models obtained from constrained MagnetoHydroDynamics (MHD) simulations of our local Universe to study the propagation of UHECRs through such a structured environment. We simulate propagation, interactions and observation of UHECRs by using the Monte Carlo code CRPropa3. We also take into account the effect of the GMF by adopting a lensing procedure of the arrival UHECR sky map. We explore several combination of source distribution, EGMF structure and mass composition. As a reference, we also simulate scenarios without the EGMF and with a statistically homogeneous field. We use our simulation results to compute UHECR observables, such as the energy spectrum, the angular power spectrum and the arrival direction map (before and after the GMF) in order to obtain constraints on possible combinations of source distributions and EGMF models.

Primary author: Mr ROSSONI, Simone (University of Hamburg)

Co-author: Prof. SIGL, Günter (University of Hamburg)

Presenter: Mr ROSSONI, Simone (University of Hamburg)

Contribution ID: **86** Type: **Talk-To-Poster**

MultI-messenger probe of Cosmic Ray Origins: the MICRO project

We present the milestones achieved by the MICRO (MultI-messenger probe of Cosmic Ray Origins) project. This multi-institute project consists of a study of bursting astrophysical sources as candidate sources for Ultra-High-Energy Cosmic Rays (UHECRs). We aim at identifying source classes that correlate best with existing observational data (direction, energy distribution, and primary mass) and to constrain the origin of UHECRs on the basis of the largest datasets acquired to this day. The study of the secondary fluxes of neutrinos and gamma rays will provide a powerful test of the most suitable astrophysical scenarios.
For these achievements, a public software enabling a joint fit of both composition and flux data as a function of energy and direction is being developed. In addition, a modelling of transient sources is foreseen, including the treatment of hadronic interactions within the sources, which represents a novelty for UHECR simulation codes.
This contribution will highlight the first results of the project and detail upcoming software releases, which will benefit the astroparticle community at large.

Primary author: CONDORELLI, Antonio (IJCLAB/CNRS)

Presenter: CONDORELLI, Antonio (IJCLAB/CNRS)

Contribution ID: **87** Type: **Talk**

Indication of a Local Source of Ultra-High-Energy Cosmic Rays in the Northern Hemisphere

Thursday, 6 October 2022 14:40 (20 minutes)

We present the first joint fit of an UHECR source population to Telescope Array (TA) and Pierre Auger Observatory (PAO) data. We simulate the propagation of UHECRs for a wide range of source parameters and fit this to the spectrum and composition observed by both experiments. The systematic differences between the two experiments are taken into account as additional parameters of the fit. To explain the differences between the measurements of TA and PAO above 30 EeV, we include an additional local source in the Northern Hemisphere. The presence of that local source is favored at the 5.6σ level compared to the scenario where both experiments observe the same isotropic UHECR flux. In the best-fit scenario, the local source lies at a distance of 14 Mpc and emits cosmic rays dominated by the silicon mass group. We discuss other possible parameter combinations and possible source candidates by comparing these results with recent TA anisotropy measurements.

Primary authors: Mr PLOTKO, Pavlo (DESY); Dr VAN VLIET, Arjen (Department of Physics, Khalifa University); Dr RODRIGUES, Xavier (DESY/Ruhr University Bochum); Dr WINTER, Walter (DESY)

Presenter: Mr PLOTKO, Pavlo (DESY)

Contribution ID: **88** Type: **Talk-To-Poster**

Energy-dependent flavor ratios, cascade/track spectrum tension and high-energy neutrinos from magnetospheres of supermassive black holes

The IceCube neutrino observatory measures the diffuse flux of high-energy astrophysical neutrinos by means of various techniques, and there exists a mild tension between spectra obtained in different analyses. The spectrum derived from reconstruction of muon tracks is harder than that from cascades, dominated by electron and tau neutrinos. If confirmed, this tension may provide a clue to the origin of these neutrinos, which remains uncertain. Here we investigate the possibility that this tension may be caused by the change of the flavor content of astrophysical neutrinos with energy. We assume that at higher energies, the flux contains more muon neutrinos than expected in the usually assumed flavor equipartition. This may happen if the neutrinos are produced in regions of the magnetic field so strong that muons, born in pi-meson decays, cool by synchrotron radiation faster than decay. The magnetic field of ~10^4G is required for this mechanism to be relevant for the IceCube results. We note that these field values are reachable in the immediate vicinity of supermassive black holes in active galactic nuclei and present a working toy model of the population of these potential neutrino sources. While this model predicts the required flavor ratios and describes the high-energy spectrum, it needs an additional component to explain the observed neutrino flux at lower energies.

Primary author: RIABTSEV, Kirill (Moscow State University)

Co-author: Mr TROITSKY, Sergey (Institute of Nuclear Research of the Russian Academy of Sciences)

Presenter: Mr TROITSKY, Sergey (Institute of Nuclear Research of the Russian Academy of Sciences)

Contribution ID: **89** Type: **Talk**

Testing hadronic and photo-hadronic interactions as responsible for UHECR and neutrino fluxes from Starburst Galaxies

Thursday, 6 October 2022 14:00 (20 minutes)

We test the hypothesis that starburst galaxies are the sources of ultra-high energy cosmic rays and high-energy neutrinos. The computation of interactions of ultra-high energy cosmic rays in the starburst environment as well as in the propagation to the Earth is made using a modified version of the Monte Carlo code *SimProp*, where hadronic processes are implemented for the first time. Taking into account a star-formation-rate distribution of sources, the fluxes of ultra-high energy cosmic rays and high-energy neutrinos are computed and compared with observations, and the explored parameter space for the source characteristics is discussed. We find that, depending on the density of the gas in the source environment, spallation reactions could hide the
outcome in neutrinos from photo-hadronic interactions in the source environment and in extra-galactic space. We confirm that source-propagation models constitute a promising way to improve the discrimination power of models considering only ultra-high energy cosmic rays, on the way to unveiling the source class responsible for ultra-high energy cosmic rays and high-energy neutrinos.

Primary authors: CONDORELLI, Antonio (IJCLAB/CNRS); Prof. BONCIOLI, Denise (University of L'Aquila); Dr PERETTI, Enrico (Niels Bohr International Academy, Niels Bohr Institute, University of Copenhagen); PETRERA, Sergio (GSSI, L'Aquila)

Presenter: CONDORELLI, Antonio (IJCLAB/CNRS)

Contribution ID: **90** Type: **Talk**

Diffuse flux of ultra-high energy photons from cosmic-ray interactions in the disk of the Galaxy and implications for the search for decaying super-heavy dark matter

Wednesday, 5 October 2022 15:00 (20 minutes)

When propagating to Earth, UHECRs can interact with the gas in our Milky Way and produce secondary particles including photons. This can impact the search for UHE photons as we face a diffuse flux of UHE photons resulting from their propagation. This flux, together with the photon flux expected from the GZK interactions, participates in the diffuse photon flux which is limiting the detection of UHE-gamma sources. We present an estimate of the diffuse flux resulting from the interactions of UHECRs in our galaxy above 10^{17}eV, using results from the Pierre Auger Collaboration concerning the flux and its composition, and two different interstellar gas density models. We also discuss the impact of the evaluated diffuse flux of UHE photons on SHDM searches, as the former can be considered as a floor below which other signals would be overwhelmed. Similarly, the neutrino flux produced during the same process can be evaluated, by accounting for the neutrino mixing.

Primary authors: TORRÈS, Zoé (LPSC Grenoble); Dr BÉRAT, Corinne (LPSC, Grenoble); Dr MONTANET, François (LPSC, Grenoble); Dr BLEVE, Carla (LPSC, Grenoble); Dr SAVINA, Pierpaolo (University of Wisconsin-Madison); Dr DELIGNY, Olivier (Laboratoire de Physique des 2 Infinis Irène Joliot-Curie, Orsay)

Presenter: TORRÈS, Zoé (LPSC Grenoble)

Contribution ID: **91** Type: **Talk-To-Poster**

Monocular Energy Spectrum using the TAx4 Fluorescence Detector

The Telescope Array (TA) Experiment is the largest cosmic ray detector in the northern hemisphere located in Utah, USA. Following the evidence for a hotspot in the arrival directions of the highest energy cosmic rays, TA expanded the area of the Surface Detectors (SDs) by a factor of four and added new Fluorescence Detectors (FDs) to view over the new SD arrays. Currently, TAx4 consists of 12 FDs and 257 SDs, of a planned 500, at a spacing of 2.08 km spread over two sites. TAx4 North (4 FDs), completed in 2018, views over the northern wing of the new SDs, and TAx4 South (8 FDs), completed in 2019, views over the southern wing of new SDs. Both FD sites are in routine observation, with data being taken remotely at the TAx4 South site. In this presentation, we show the performance of the TAx4 FDs, data/MC comparisons, and the TAx4 monocular energy spectrum as measured by the FDs.

Primary author: Dr POTTS, Mathew

Co-author: Dr JUI, Charles

Presenter: Dr POTTS, Mathew

Contribution ID: **92** Type: **Poster**

The Tunka-Grande array: preliminary results for the first 5 years of operation

The Tunka-Grande array is the part of the TAIGA (Tunka Advanced Instrument for cosmic ray physics and Gamma Astronomy) astrophysical complex. This complex is located in the Tunka Valley, 50 km from Lake Baikal. The scientific program of the array is devoted to the study of cosmic rays by the detection of charged particles (electrons and muons) of EAS.
In the report we present a description of the Tunka-Grande array, methods of EAS parameters reconstruction, scientific program and the main results: CR energy spectrum in the energy range 10 PeV - 1000 PeV and limit on the flux of the diffuse gamma rays in the same energy range.

Primary author: Mr MONKHOEV, Roman (API ISU)

Co-author: Mrs IVANOVA, Anna (API ISU)

Presenters: Mr MONKHOEV, Roman (API ISU); Mrs IVANOVA, Anna (API ISU)

Contribution ID: **93** Type: **Talk**

Progress and future prospect of the CRAFFT project for the next generation UHECR observatory

Friday, 7 October 2022 09:00 (20 minutes)

The next generation of ultra-high energy cosmic ray observations will require large detector arrays to achieve large statistics. In order to realize next-generation large-scale detector arrays, the Cosmic Ray Air Fluorescence Fresnel lens Telescope (CRAFFT) project is developing a low-cost simple fluorescence detector (FD) The simple structure of the CRAFFT detector will reduce the cost to about 1/10 of the current FD. We also aim to realize a fully automated observation system. A prototype of the CRAFFT detector has been successfully used to detect cosmic ray air showers. Since the spatial resolution of the simple FD is rougher than that of the current FD, we are developing a new air shower reconstruction method using the waveform fitting method. In this presentation, we will report the performance of the CRAFFT detector, detector optimization, and future prospect.

Primary author: Prof. TAMEDA, Yuichiro (Osaka Electro-Communication University)

Co-authors: Dr TOMIDA, Takayuki (Shinshu University); Dr IKEDA, Daisuke (Kanagawa University); Dr YAMAZAKI, Katsuya (Chubu University); Mr KUBOTA, Yuto (Shinshu University); Mr NAKAMURA, Yuya (Shinshu University); Mr ISHIMOTO, Yasuki (Osaka Electro-Communication University); Mr KATAYAMA, Tomoki (Osaka Electro-Communication University); Mr KOBAYASHI, Yuga (Osaka Electro-Communication University); Mr SHIBATA, Norimichi (Osaka Electro-Communication University); Mr NISHIO, Eiji (Osaka Electro-Communication University); Mr MURAKAMI, Miyato (Osaka Electro-Communication University)

Presenter: Prof. TAMEDA, Yuichiro (Osaka Electro-Communication University)

Contribution ID: **94** Type: **Talk-To-Poster**

Ultra-High-Energy Cosmic Rays from a Population of Non-identical Sources

Astrophysical candidates for the sources of ultra-high-energy cosmic rays (UHECRs) exhibit a large diversity in terms of their properties relevant for the acceleration of charged particles, such as luminosity, Lorentz factor, size and magnetic field. Yet, fits of the observed UHECR spectrum and composition often assume identical sources.
Here we investigate a population of sources with a power-law distribution of maximum energies. We show that the allowed source-to-source variance of the maximum energy must be small to describe the UHECR data. Even in the most extreme scenario, with a very sharp cutoff of individual source spectra and negative redshift evolution of the accelerators, the maximum energies of 90% of sources must be identical within a factor of three – in contrast to the variance expected for astrophysical sources.

Primary authors: EHLERT, Domenik (Norwegian University of Science and Technology); Prof. OIKONOMOU, Foteini (Norwegian University of Science and Technology); UNGER, Michael (KIT)

Presenter: EHLERT, Domenik (Norwegian University of Science and Technology)

Contribution ID: **95** Type: **Poster**

On the mystery of the multi-muon flux at the TeV cosmic-ray energy range

The muon component of air showers is not yet well described by actual Monte Carlo simulations. Many air shower experiments report discrepancies between data and Monte Carlo predictions, ranging from the TeV scale to the highest energies.
One example we address is the seasonal variation of multiple-muon events with energies above 50 GeV observed by the NOvA Near Detector (ND). For our studies, we use the general-purpose Monte Carlo code Fluka to treat the transport and interactions of the shower particles in several media. Our design considers a multi-layered atmosphere and a layered underground approximated to the NOvA Near Detector (ND) location and geometry. Our atmosphere model uses winter and summer air densities calculated from the temperatures and geopotential information for the pressure levels given by the European Center for Medium-Range Weather Forecasts (ECMWF) datasets *in situ*. Understanding the multi-muon flux in the High-Energy range may lead to a better description of Ultra-High-Energy muon production mechanisms in extensive air showers. In addition, it can help improve future Monte Carlo codes or hint at new physics processes or interactions.

Primary authors: TUNEU, Jordi; DOS SANTOS, Eva (FZU - Institute of Physics of the Czech Academy of Sciences); Dr FILIP, Peter (FZU - Institute of Physics of the Czech Academy of Sciences)

Presenter: TUNEU, Jordi

Contribution ID: **96** Type: **Talk**

2022 report from the Auger-TA working group on UHECR arrival directions

Tuesday, 4 October 2022 10:00 (20 minutes)

The origin of ultra-high-energy cosmic rays (UHECRs) remains a mystery. The interactions of UHECRs with background photons restricts their propagation length to at most a few hundred megaparsecs. Because the distribution of extra-Galactic matter at such distances is anisotropic, we expect the angular distribution of UHECR arrival directions to bear information about this anisotropy. However, because UHECRs are deflected by poorly-known Galactic and extra-Galactic magnetic fields, the anisotropy is distorted and suppressed. In previous works of the Auger-TA anisotropy working group we presented full-sky searches for dipole and quadrupole modulations, as well as correlations with classes of nearby galaxies. Full-sky searches, combining data from both detectors, allow us to significantly reduce certain uncertainties compared to single-hemisphere results. In this contribution we update on those results with the most recent available data. Moreover we offer an interpretation of these results by comparing the experimental data to a suite of simulated datasets with varying composition and propagation models.

Primary authors: DI MATTEO, Armando; URBAN, Federico (CEICO, FZU); GOLUP, Geraldina; FARRAR, Glennys; RUBTSOV, Grigory; MARIŞ, Ioana; KIM, Jihyun; ANCHORDOQUI, Luis; KUZNETSOV, Mikhail; DELIGNY, Olivier; TINYAKOV, Peter; HIGUCHI, Rio; DE ALMEIDA, Rogerio; BISTER, Teresa; GIACCARI, Ugo

Presenter: URBAN, Federico (CEICO, FZU)

Contribution ID: **97** Type: **Talk-To-Poster**

Performance of the TALE infill experiment as a TA-TALE extension down to the PeV region

The TALE-infill experiment is a further extension of TA-TALE detectors to observe low-energy cosmic rays down to the PeV region. TALE-infill utilizes the existing TALE-FD detectors, and newly developed “infill” surface detectors with 100m and 200m spacing. The new detectors will be deployed at the TALE site in early 2023. We’ll present the design and performance of the TALE-infill array in the hybrid mode, in terms of the resolutions and biases of arrival direction, energy, and Xmax.

Primary author: IWASAKI, Aoi

Co-authors: Prof. FUJII, Toshihiro; Prof. TSUNESADA, Yoshiki

Presenter: IWASAKI, Aoi

Contribution ID: **98** Type: **Talk**

Measurement of cosmic-ray energy spectrum with the TALE detector in hybrid mode

Monday, 3 October 2022 15:10 (20 minutes)

The TA Low-energy Extension (TALE) experiment extends the TA experiment on the low-energy side to below 10^{16} eV. We aim to study the transition from galactic to extragalactic cosmic rays. The TALE detector is a hybrid apparatus composed of fluorescence telescopes and surface detectors, and the surface detectors are arranged to be suitable for hybrid energy spectrum measurements in the low-energy region. In this presentation, we will show the energy spectrum measured with the TALE hybrid detector, which is important in understanding the transition from cosmic rays of galactic origin to those of extragalactic origin.

Primary author: Dr OSHIMA, Hitoshi (ICRR, the University of Tokyo)

Co-authors: Dr FUJITA, Keitaro (ICRR, the University of Tokyo); Prof. OGIO, Shoichi (ICRR, the University of Tokyo); Prof. SAKO, Takashi (ICRR, the University of Tokyo); TELESCOPE ARRAY COLLABORATION

Presenter: Dr OSHIMA, Hitoshi (ICRR, the University of Tokyo)

Contribution ID: **100** Type: **Talk**

Recent results from prototypes of the Fluorescence detector Array of Single-pixel Telescopes (FAST) in both hemispheres

Friday, 7 October 2022 09:20 (20 minutes)

The origin and nature of ultrahigh-energy cosmic rays (UHECRs) are of uppermost importance in astroparticle physics. Motivated by the need for an unprecedented aperture for further advancements, the Fluorescence detector Array of Single-pixel Telescopes (FAST) is a prospective next-generation, ground-based UHECR observatory that aims to cover an enormous area by deploying a large array of low-cost fluorescence telescopes. The full-scale FAST prototype consists of four 20 cm photomultiplier tubes at the focus of a seg- mented mirror 1.6 m in diameter. Three FAST prototypes have been installed at the Telescope Array Experiment in Utah, USA, and two prototypes at the Pierre Auger Observatory in Mendoza, Argentina, commencing remote observation of UHECRs in both hemispheres. We report on recent results of the full-scale FAST prototypes operated in both hemispheres, including telescope calibrations, atmospheric monitoring, ongoing electronics upgrades, development of sophisticated reconstruction methods and UHECR detections.

Primary author: FUJII, Toshihiro (Osaka Metropolitan University)

Presenter: FUJII, Toshihiro (Osaka Metropolitan University)

Contribution ID: **101** Type: **Poster**

Search for the large-scale cosmic-ray anisotropies using the TA and TALE surface detector arrays

Origins of ultra-high-energy cosmic rays (UHECRs) are still largely unknown. In particular, the "2nd knee" around 10^{17} eV could be related to a transition of origins from the galactic to extra-galactic sources. In this scenario, One would expect the large-scale anisotropies of UHECRs to change over the 2nd knee region. We search for large-scale anisotropies using data taken from surface detector (SD) arrays of the Telescope Array experiment (TA), the largest cosmic-ray detector in the northern hemisphere, and from its low energy extension, the Telescope Array Low energy Extension experiment (TALE). In this contribution, we will report on preliminary results in the search for the large-scale cosmic-ray anisotropies with 11-years TA SD and 2-years TALE SD data.

Primary authors: KIMURA, Yusuke (Osaka Metropolitan University); FUJII, Toshihiro (Osaka Metropolitan University); Prof. OGIO, Shoichi (ICRR, the University of Tokyo); Prof. TSUNESADA, Yoshiki

Presenter: FUJII, Toshihiro (Osaka Metropolitan University)

Contribution ID: **103** Type: **Talk**

POEMMA: Probe Of Extreme Multi-Messenger Astrophysics

Friday, 7 October 2022 14:00 (20 minutes)

The Probe Of Extreme Multi-Messenger Astrophysics (POEMMA) has been developed with the science goals of identifying the sources of ultra-high energy cosmic rays (UHECRs) and transient sources of cosmic neutrinos. The POEMMA observatory consists of two spacecraft flying in a loose formation in 525 km altitudes orbits, providing full-sky coverage for astrophysical sources. Each spacecraft hosts a large area, wide-FoV Schmidt telescope with a hybrid focal plane optimized to observe both the UV fluorescence signal from extensive air showers (EAS) and the beamed, optical Cherenkov signals from EAS. In UHECR stereo fluorescence mode, the POEMMA telescopes are oriented to view a common atmospheric volume to optimize the measurement of the UHECR spectrum, composition, and full-sky distribution of the UHECRs above 20 EeV, while having remarkable sensitivity to UHE neutrinos and photons. The POEMMA telescopes will slew to re-orientate to the direction of transient astrophysical sources in an Earth-limb viewing, Target-of-Opportunity (ToO) neutrino mode to observe cosmic tau neutrinos by using the upward-moving EAS induced from tau neutrinos interacting in the Earth. This ToO mode provides exceptional neutrino flux sensitivity to a variety of neutrino transient events, including short-gamma-ray bursts and binary neutron star mergers. Key technologies and experimental methodologies will be tested with the EUSO-SPB2 ULDB mission scheduled for 2023. POEMMA's science goals, instrument designs, and UHECR and neutrino measurement capabilities will be presented with context t0 EUSO-SPB2.

Primary author: KRIZMANIC, John (NASA/GSFC)

Presenter: KRIZMANIC, John (NASA/GSFC)

Contribution ID: **104** Type: **Talk**

New Constraints on the Global Structure of the Coherent Galactic Magnetic Field

Tuesday, 4 October 2022 12:20 (20 minutes)

We present a major revision of the widely used model of the coherent magnetic field of the Galaxy from Jannson&Farrar (JF12). For this purpose, we use new full-sky data of extragalactic rotation measures, final polarized intensity maps from WMAP and Planck and the rotation measures of Galactic pulsars. Furthermore, we tune auxiliary models for the thermal electron density to the dispersion measures of Galactic pulsars and employ a suite of state-of-the-art cosmic-ray electrons models to predict the synchrotron emission from the Galaxy. Finally, we developed new divergence-free parametric models of the global structure of the magnetic field and tune them to the data.

We will discuss the deflection of ultrahigh-energy cosmic rays implied by this new model and estimate a lower limit on their uncertainties from a variation of model assumptions.

Primary author: UNGER, Michael (KIT)

Co-author: Prof. FARRAR, Glennys

Presenter: UNGER, Michael (KIT)

Contribution ID: **106** Type: **Talk**

Updates on the Hotspot and the Perseus-Pisces supercluster Excess Observed by the Telescope Array Experiment

Tuesday, 4 October 2022 11:00 (20 minutes)

The Telescope Array (TA) experiment, the largest observatory studying ultra-high energy cosmic rays in the northern hemisphere, has reported evidence for two medium-scale anisotropies. The first, known as the TA hotspot, is an excess in the arrival direction distribution for events with energies greater than 5.7×10^{19} eV. More recently, an additional excess of events with energies greater than $10^{19.4}$ eV appearing in the direction of the Perseus-Pisces supercluster has been named the PPSC excess. In this presentation, we will update the status of the TA hotspot and the PPSC excess results using the most recent data measured by the TA surface detector array.

Primary authors: Dr KIM, Jihyun (University of Utah); Dr IVANOV, Dmitri (University of Utah); Dr KAWATA, Kazumasa (University of Tokyo); Prof. SAGAWA, Hiroyuki (University of Tokyo); Prof. THOMSON, Gordon (University of Utah)

Co-author: TELESCOPE ARRAY COLLABORATION

Presenter: Dr KIM, Jihyun (University of Utah)

Contribution ID: **107** Type: **Talk**

Energy spectrum measured by the Telescope Array Surface Detectors

Monday, 3 October 2022 14:50 (20 minutes)

Located in the west desert of Utah, USA, the Telescope Array experiment is the largest ultra-high energy cosmic ray observatory in the northern hemisphere. It consists of two types of detectors: scintillator surface detectors (SDs) and air fluorescence detectors (FDs). A total of 507 SDs consisting of two-layer plastic scintillation counters is deployed with 1.2 km spacing, making measurements over an area of approximately 700 km^2. There are 3 FD stations, having 38 fluorescence telescopes viewing 3°–31° in elevation, overlooking the SD array. In this presentation, we update the Telescope Array energy spectrum as measured by the SDs. We will discuss the measurement and features in the spectrum.

Primary authors: Dr KIM, Jihyun (University of Utah); Dr IVANOV, Dmitri (University of Utah); Prof. JUI, Charles (University of Utah); Prof. THOMSON, Gordon (University of Utah)

Co-author: TELESCOPE ARRAY COLLABORATION

Presenter: Prof. OGIO, Shoichi (ICRR, the University of Tokyo)

Contribution ID: **108** Type: **Talk**

EUSO-SPB2: A balloon experiment for UHECR and VHE neutrino observation

Friday, 7 October 2022 12:10 (20 minutes)

The Extreme Universe Space Observatory on a Super Pressure Balloon 2 (EUSO-SPB2) experiment will make new measurements from suborbital space as a precursor for future space missions that will address the challenge of the extremely low fluxes of ultra-high energy cosmic rays (UHECR) and very high energy (VHE) neutrinos.
The EUSO-SPB2 detector is comprised of two 1m diameter aperture telescopes. The Fluorescence Telescope (FT) will point in nadir and will record fluorescence light from cosmic ray EAS with energies above 1EeV in its field of view of 36 by 12 degrees. The Cherenkov Telescope (CT) features a silicon photomultiplier focal surface with a field of view of 12 by 6 degrees. The CT will switch between two observation modes: one which points the CT above the limb to measure the Cherenkov emission of cosmic ray EAS with energies above 1PeV and one which points the CT below the limb to record the Cherenkov emission produced by PeV scale EAS initiated by neutrino-sourced tau decay. As it is the first time such an instrument has been flown, one of the priorities of the CT will be the study of the optical backgrounds for observing neutrinos in this way.
EUSO-SPB2 is undergoing the final integration steps for launch on a NASA super pressure balloon payload in the spring of 2023 from Wanaka NZ. The CT was field-tested in March 2022 and the field tests for the FT are planned for later this year.
The data collected during the EUSO-SPB2 mission will be essential to advancing the development of a space-based multi-messenger observatory such as the Probe of Extreme Multi-Messenger Astrophysics (POEMMA). In this contribution, we discuss the EUSO-SPB2 science goals, the instruments, the expected performance and the current status.

Primary authors: ESER, Johannes (The University of Chicago); OLINTO, Angela (The University of Chicago); WIENCKE, Lawrence (Colorado School of Mines)

Presenter: CUMMINGS, Austin (Pennsylvania State University)

Contribution ID: **109** Type: **Talk-To-Poster**

Examination of Xmax anisotropy for the next generation Ultra-high energy cosmic rays observation

Estimation of the mass composition in ultra-high energy cosmic rays is essential to understand their origin and generation mechanism. Recent experiments are expected to discover anisotropy of the mass composition in ultra-high energy cosmic rays. Anisotropy analysis of mass composition using Xmax is currently being performed, but the problem is that the statistics of cosmic rays with Xmax information is limited. For the next generation experiments, it is important to know how much statistics should be accumulated to find Xmax anisotropy. Therefore, in this analysis, we examine of Xmax anisotropy search for ultra-high energy cosmic rays under various conditions for the case where there is a difference in Xmax in the reported anisotropy.

Primary author: Mr SAITO, Ryosuke (Graduate School of Science and Technology, Shinshu University)

Co-authors: Mr TOMIDA, Takayuki (Shinshu University); Mr IKEDA, Daisuke (Kanagawa University)

Presenter: Mr SAITO, Ryosuke (Graduate School of Science and Technology, Shinshu University)

Contribution ID: **110** Type: **Poster**

Measurement of fluorescent telescope optical properties in TA experiments using UAV

We have developed an “Opt-copter” as a calibration device for fluorescence detectors (FDs). opt-copter is a UAV equipped with a light source.
The Opt-copter is equipped with a high-precision RTK-GPS, which enables it to fly within the field of view (FOV) of the FD while accurately measuring the position of the light source.
This allows detailed measurement of the FD’s optical characteristics (FOV direction and spot size).
In this paper, we report the analysis method and results of the optical characteristics of the FD using data obtained with the 0pt-copter.

Primary author: TOMIDA, Takayuki (Shinshu University)

Co-authors: TAMEDA, Yuichiro (Osaka Electro-Communication University); Mr NAKAZAWA, Arata (Shinshu University); Mr HIBI, Ryosuke (Shinshu University); Mr SATO, Daiki (Shinshu University); Ms UENO, Airi (Osaka Electro-Communication University)

Presenter: TOMIDA, Takayuki (Shinshu University)

Contribution ID: **111** Type: **Talk-To-Poster**

An end-to-end in-flight calibration of the Mini-EUSO detector

Mini-EUSO is a wide Field-of-View (FoV, 44 deg) telescope currently in operation from a nadir-facing UV-transparent window in the Russian Zvezda module on the International Space Station (ISS).
It is the first detector of the JEM-EUSO program deployed on the ISS. Mini-EUSO is mainly sensitive in the 290 - 430 nm bandwidth. Light is focused by a system of two Fresnel lenses of 25 cm diameter each on an array of 36 Multi-Anode Photomultiplier Tubes (MAPMTs) for a total of 2304 pixels working in photon counting mode, in three different time resolutions of 2.5 μs, 320 μs and 40.96 ms at the same time. In the longest time scale, the data is continuously acquired without a trigger system, and allows a continuous monitoring of the UV emission of the Earth, which is best suited for the observation of ground sources.
For this reason, it has been used to observe the signal produced by two UV flasher systems assembled on ground and fired in two different observational campaigns in order to perform an end-to-end calibration of Mini-EUSO.
In this contribution, the assembling of the UV ground flasher, the operation of the field campaign and the analysis of the obtained data is presented. The result is compared with the overall efficiency computed from the expectations which take into account the atmospheric absorption and the parametrisation of different effects such as the optics efficiency, the MAPMT detection efficiency, BG3 filter transmittance and the transparency of the ISS window.

Primary authors: MIYAMOTO, Hiroko (GSSI/INFN Turin); Dr BATTISTI, Matteo (INFN Torino)

Presenter: MIYAMOTO, Hiroko (GSSI/INFN Turin)

Contribution ID: **112** Type: **Talk**

TAx4 surface detectors data analysis

Tuesday, 4 October 2022 16:50 (20 minutes)

The TAx4 experiment aims to understand UHECR by expanding the observation area of the TA experiment by a factor of 4 and increasing the statistics of UHECR events above 10^19 eV. TAx4 consists of newly installed Surface Detectors (SD) and Fluorescence Detectors (FD), and currently operates with an area 2.5 times TA including the original TA area. The TAx4 SD array has been collecting data since April 2019, and data analysis is underway. In this talk, I will report on the comparison between Monte Carlo simulation and real data acquired by the TAx4 SD array and the preliminary results of the data analysis.

Primary author: Mr FUJISUE, Kozo (ICRR, University of Tokyo)

Presenter: Mr FUJISUE, Kozo (ICRR, University of Tokyo)

Contribution ID: **114** Type: **Talk**

Implications of Mini-EUSO measurements for a space-based observation of UHECRs

Friday, 7 October 2022 11:50 (20 minutes)

Mini-EUSO is a telescope launched on board the International Space Station in 2019 and currently located in the Russian section of the station and viewing our planet from a nadir-facing UV-transparent window in the Zvezda module. The instrument is based on an optical system employing two Fresnel lenses and a focal surface composed of 36 Multi-Anode Photomultiplier tubes, 64 channels each, for a total of 2304 channels with single photon counting sensitivity and an overall field of view of 44°. Mini-EUSO can map the night-time Earth in the near UV range (predominantly between 290 – 430 nm), with a spatial resolution of about 6.3 km and different temporal resolutions of 2.5 μs, 320 μs and 41 ms. Mini-EUSO observations are extremely important to better assess the potential of a space-based detector of Ultra-High Energy Cosmic Rays (UHECRs) such as K-EUSO and POEMMA. In this contribution we focus the attention on the UV map measurements, the detection of clouds and of certain categories of events that Mini-EUSO triggers with the shortest temporal resolution and place them in the context of UHECR observations from space, namely estimation of exposure and sensitivity to EAS-like events.

Primary author: Prof. BERTAINA, Mario Edoardo (INFN & Univ. Torino)

Presenter: Prof. BERTAINA, Mario Edoardo (INFN & Univ. Torino)

Contribution ID: **115** Type: **not specified**

Special Lecture - Historical remarks on UHECR measurements with EAS surface detector arrays

Thursday, 6 October 2022 18:30 (30 minutes)

Presenter: WATSON, Alan (University of Leeds, UK)

Contribution ID: **116** Type: **not specified**

Special Lecture - Historical remarks on UHECR measurements with EAS fluorescence detectors

Thursday, 6 October 2022 19:00 (30 minutes)

Presenter: SOKOLSKY, Pierre

Contribution ID: **117** Type: **Talk**

Extreme energy cosmic rays: a quest for new physics?

Wednesday, 5 October 2022 14:40 (20 minutes)

I discuss problems regarding the origin, propagation, spectral shape and chemical composition of the ultra-high energy cosmic rays above the GZK cutoff, and show how one could alleviate these problems with a new physics presumably also related to dark matter.

Primary author: BEREZHIANI, Zurab (Univ. L'Aquila and INFN)

Presenter: BEREZHIANI, Zurab (Univ. L'Aquila and INFN)

Contribution ID: **118** Type: **Talk**

Current status of the TAx4 surface detectors

Tuesday, 4 October 2022 16:30 (20 minutes)

Telescope Array (TA) is the largest ultrahigh-energy cosmic-ray (UHECR) observatory in the northern hemisphere. It explores the origin of UHECRs using a surface detector (SD) array covering approximately 700 km^2 and fluorescence detector (FD) stations. TA has found evidence for a cluster of cosmic rays with energies greater than 57 EeV known as a hotspot. Recently, implications of anisotropy in the arrival directions in other energy ranges were obtained. Implications of spectrum anisotropy were also obtained. The new SD array of the TAx4 experiment was designed to increase the data collection rate at the highest energies to confirm the implications with more data. We constructed more than half SDs of the TAx4 experiment and have stably operated the SDs. We present TAx4 SD's current status and the data that have already been collected.

Primary author: Dr KIDO, Eiji (RIKEN, Cluster for Pioneering Research)

Presenter: Dr KIDO, Eiji (RIKEN, Cluster for Pioneering Research)

Contribution ID: **119** Type: **Review**

Opening: The Snowmass UHECR White Paper

Monday, 3 October 2022 09:20 (30 minutes)

This talk will provide an overview on the whitepaper 'Ultra-High-Energy Cosmic Rays: The Intersection of the Cosmic and Energy Frontiers' [arXiv:2205.05845] that has been prepared for the Snowmass survey in the USA. The paper discusses recent progress and open questions regarding the particle physics and astrophysics related to ulra-high-energy cosmic rays. The upgraded Pierre Auger Observatory and Telescope Array will be the workhorses at the highest energies in the curent decade. A possible timeline for a few next-generation UHECR experiments is presented that will complement each other in the next decade. GRAND and POEMMA will provide maximum exposure for UHECR; IceCube-Gen2 with its surface array and GCOS aim at increased statistics with high accuracy for particle physics and rigidity-based galactic and extra-galactic astrophysics.

Primary author: SCHRÖDER, Frank (University of Delaware / Karlsruhe Institute of Technology)

Presenter: SCHRÖDER, Frank (University of Delaware / Karlsruhe Institute of Technology)

Contribution ID: **120** Type: **Talk**

A machine learning approach for mass composition analysis with TALE-SD data

Monday, 3 October 2022 17:00 (20 minutes)

The TALE experiment is a TA low-energy extension to observe cosmic rays with energies down to 1016.5 to clarify the origin of the second knee and the energy of a galatic-to-extragalactic transition. TALE consists of 10 high-elevation fluorescence detectors and 80 scintillation counters in an area of 21km . The key of data interpretation is the mass composition of cosmic rays, and we will report on a machine learning approach of mass composition analysis that usilizes waveform data of TALE scintillation counters.

Primary author: ARIMURA, Ryuhei (Osaka Metropolitan University and Telescope Array Group)

Co-authors: Prof. YOSHIKI, Tsunesada; Prof. FUJII, Toshihiro

Presenter: ARIMURA, Ryuhei (Osaka Metropolitan University and Telescope Array Group)

Contribution ID: **121** Type: **Talk**

Unresolved sources naturally contribute to PeV γ-ray diffuse emission observed by Tibet ASγ

Thursday, 6 October 2022 15:00 (20 minutes)

The Tibet ASγ experiment provided the first measurement of the total diffuse gamma-ray emission from the Galactic disk in the sub-PeV energy range.
Based on analysis of the TeV sources included in the HGPS catalogue, we predict the expected contribution of unresolved pulsar-powered sources in the two angular windows of the Galactic plane observed by Tibet ASγ.
We show that the sum of this additional diffuse component due to unresolved sources and the truly diffuse emission, produced by the interaction of Cosmic Rays (CRs) with the interstellar medium, well saturates the Tibet data, without the need to introduce a progressive hardening of the cosmic-ray spectrum toward the Galactic centre.

Primary authors: VECCHIOTTI, Vittoria (GSSI); VILLANTE, Francesco L (Università degli studi dell'Aquila); PAGLIAROLI, Giulia (LNGS); ZUCCARINI, Flavio (Università degli studi dell'Aquila)

Presenter: VECCHIOTTI, Vittoria (GSSI)

Contribution ID: **122** Type: **Talk**

UHECR anisotropy and extragalactic magnetic fields with the Telescope Array

Tuesday, 4 October 2022 11:40 (20 minutes)

We study the energy-dependent distribution of ultra-high energy cosmic ray arrival directions with respect to luminous matter in the local Universe. We use a specially designed test statistic (TS) that is robust to uncertainties of the galactic magnetic field. We generate realistic mock UHECR sets assuming various injected compositions, and different strengths of the extragalactic magnetic field (EGMF). Applying the TS to both mock sets and the Telescope Array Surface Detector data we constrain, for a given EGMF strength, the UHECR injected mass composition at energies above 10 EeV. We then compare the obtained results with the direct Telescope Array fluorescence measurements of the UHECR mass composition. Requiring that the TA composition measurements are compatible with the arrival direction distribution allows us to constrain the parameters of the EGMF.

Primary authors: KUZNETSOV, Mikhail (ULB & INR RAS); TINYAKOV, Petr (Universite Libre de Bruxelles (ULB))

Presenter: TINYAKOV, Petr (Universite Libre de Bruxelles (ULB))

Contribution ID: **123** Type: **Talk**

Searching for neutral particles at the highest energies at the Pierre Auger Observatory

Tuesday, 4 October 2022 15:00 (20 minutes)

The Pierre Auger Observatory, being the largest air-shower experiment in the world, offers an unprecedented exposure to neutral particles at the highest energies. Since the beginning of data collection more than 18 years ago, several searches for ultra-high-energy (UHE, $E > 10^{17}$ eV) photons and neutrinos have been performed. The upper limits on the diffuse flux of UHE photons and neutrinos derived from Auger data are among the most stringent in the world, severely constraining current models for the origin of UHE cosmic rays. In addition, the Pierre Auger Observatory contributes to current efforts in multimessenger astrophysics through follow-up searches for UHE photons and neutrinos in association with transient events, such as gravitational wave events.

In this contribution, the various activities concerning searches for UHE photons and neutrinos in the data from the Pierre Auger Observatory are presented and the current results are summarized. In addition, future perspectives will be discussed.

Primary author: Dr NIECHCIOL, Marcus (University of Siegen)

Presenter: Dr NIECHCIOL, Marcus (University of Siegen)

Contribution ID: **124** Type: **Talk**

Diffusive shock acceleration in galactic wind bubbles

Thursday, 6 October 2022 10:50 (20 minutes)

Starburst Galaxies (SBGs) and Active Galactic Nuclei (AGNi) can launch and sustain powerful outflows of very high velocity and large opening angle.
Such winds develop a bubble structure characterized by an inner wind shock and an outer forward shock.
During the time the forward shock expands in the surrounding medium, the inner wind shock quickly decelerates while remaining strong, thereby creating ideal conditions for stationary particle acceleration.
We model the diffusive shock acceleration process at the wind shock of such winds and we explore the multimessenger implications in terms of high energy photons, neutrinos and escaping cosmic rays.

Primary author: Dr PERETTI, Enrico (Niels Bohr Institute)

Presenter: Dr PERETTI, Enrico (Niels Bohr Institute)

Contribution ID: **126** Type: **Talk-To-Poster**

Sensitivity of the combined fit of energy spectrum, shower depth distributions, and arrival directions at the Pierre Auger Observatory

The Pierre Auger Observatory measures several characteristics of ultra-high-energy cosmic rays (UHECRs), most importantly the energy spectrum, the distribution of maximum shower depths and the arrival directions. We use all three observables for a combined fit, in which the parameters of possible UHECR sources can be constrained.
The astrophysical model used in the fit consists of homogeneously distributed background sources as well as an adaptable contribution from a nearby source population. For this, the catalogs of starburst galaxies and active galactic nuclei are used which show an indication for a correlation with the UHECR arrival directions.
The signal fraction, as well as the size of a rigidity-dependent magnetic field blurring, are part of the fit parameters, along with the parameters describing the source emission.
In this work, we present an astrophysical simulation containing an energy-dependent contribution from starburst galaxies, which simultaneously describes the energy spectrum, shower depth distributions and arrival directions measured by the Pierre Auger Observatory.
On this simulation, the discrimination power of the method regarding the differentiation of source catalogs is demonstrated, and the expected statistical significance of the result is investigated.

Primary author: BISTER, Teresa (RWTH Aachen University)

Presenter: BISTER, Teresa (RWTH Aachen University)

Contribution ID: **127** Type: **Talk**

Pulsars as cosmic-ray sources

Pulsars have been proposed as candidate sources of high-energy cosmic rays, due to their large magnetic fields and rotational energy, and gamma-ray observations demonstrating their ability to accelerate electrons and positrons. However, a precise description of the acceleration processes at play is still to be established.

Numerical experiments, such as particle-in-cell (PIC) simulations of pulsars magnetospheres and winds, can provide us with a deeper understanding of physical processes influencing cosmic-ray injection, propagation and acceleration in the vicinity of these objects.

I will describe our series of PIC simulations of aligned pulsar magnetospheres, that aim to assess from first principles the mechanisms for the injection of cosmic rays from the neutron star surface, and their acceleration in the magnetosphere and the wind, and eventually to strengthen multi-wavelength and multi-messenger predictions for both individual pulsars and populations of pulsars.

Primary author: GUEPIN, Claire (The University of Chicago)

Presenter: GUEPIN, Claire (The University of Chicago)

Contribution ID: **128** Type: **Talk**

Interpreting the cosmic ray spectrum and composition measurements across the ankle and up to the highest energies with the data of the Pierre Auger Observatory

Thursday, 6 October 2022 14:20 (20 minutes)

In this work we investigate the astrophysical interpretation of the energy spectrum and mass composition data above 6×10^{17} eV as measured at the Pierre Auger Observatory.
Aiming at including the "ankle" feature observed at 5×10^{18} eV, we propose two simple scenarios in which it is generated as the superposition of different components. In both of them the flux above the ankle is dominated by the contribution of an extragalactic source population with a mixed mass composition; as for the below-ankle flux, we add either an extragalactic component of pure protons plus the high-energy tail of a Galactic component or a single additional extragalactic component with a mixed mass composition.
We discuss our capability to constrain the astrophysical models by studying the impact on the fit results of the main experimental systematic uncertainties and of the assumptions on the uncertain quantities affecting the cosmological source evolution, the propagation through the intergalactic medium and the air-shower development in atmosphere.
Our fit results show that the energy spectrum and mass composition data are reasonably reproduced if the mixed above-ankle component has a very hard spectrum with a low rigidity cutoff; while, as concerns the region below the ankle, a heavy mass composition is excluded in this energy range and a very soft spectrum with a scarcely constrained rigidity cutoff is estimated for the low-energy extragalactic component in both scenarios.
The consequences of the fit results on cosmogenic neutrinos and gamma-rays expectations are also evaluated and the constraining power of the corresponding current upper limits and expected future sensitivities on our astrophysical model are discussed.

Primary author: Dr GUIDO, Eleonora (Universität Siegen)

Co-author: ON BEHALF OF THE PIERRE AUGER COLLABORATION

Presenter: Dr GUIDO, Eleonora (Universität Siegen)

Contribution ID: **129** Type: **Talk**

Cosmic ray mass composition measurement with the TALE hybrid detector

Monday, 3 October 2022 17:20 (20 minutes)

The Telescope Array (TA) located in the State of Utah in the US is the largest ultra-high energy cosmic rays observatory in the northern hemisphere. The Telescope Array Low-energy Extension (TALE) detector was constructed to study the transition of cosmic rays from Galactic to extra-galactic origin. The TALE detector consists of a Fluorescence Detector (FD) station with 10 high elevation telescopes located at the TA Middle Drum FD Station (itself made up of 14 FD telescopes), and a Surface Detector (SD) array made up of 80 scintillation counters, including 40 with 400 m spacing and 40 with 600 m spacing. We have continued stable observation with hybrid mode since 2017. In this contribution, we present the latest result of the cosmic ray mass composition measurement using almost 4 years of TALE hybrid data.

Primary author: Dr FUJITA, Keitaro (Institute for Cosmic Ray Research, University of Tokyo)

Co-author: TELESCOPE ARRAY COLLABORATION

Presenter: Dr FUJITA, Keitaro (Institute for Cosmic Ray Research, University of Tokyo)

Contribution ID: **130** Type: **Talk-To-Poster**

Estimation and reduction of the biases by the galactic magnetic field on the UHECR correlation studies

We estimate the biases caused by the coherent deflection due to the galactic magnetic field (GMF) in the previous maximum-likelihood analysis for searching the UHECR sources (Aab et al. 2018, Abbasi et al. 2018). We generate the mock event datasets with a set of assumptions for the starburst galaxy (SBG) source model, coherent deflection by a GMF model , and the mixed-mass composition, then conducted a maximum-likelihood analysis with ignorance of the GMF in the same manner as previous studies. We find that the anisotropic fraction $f_{\rm ani}$ is estimated systematically lower than the true value when we ignore the effect caused by the GMF. We estimate the true parameters which reproduce the best-fit parameters reported in Aab et al. (2018). We also develop the maximum-likelihood method with consideration of the GMF model and confirm that the estimated parameters would be improved. In this talk we also discuss about the apprication of the method to the observational datasets obtained from the Telescope Array and Auger experiments.

Primary author: HIGUCHI, Ryo (RIKEN)

Presenter: HIGUCHI, Ryo (RIKEN)

Contribution ID: **131** Type: **Talk**

Anisotropies in the arrival direction of ultra-high-energy cosmic rays measured by the Pierre Auger Observatory

Tuesday, 4 October 2022 11:20 (20 minutes)

The Pierre Auger Observatory, in continuous operation since 2004, provides the largest statistics in the world on ultra-high-energy cosmic rays (UHECRs). The Observatory employs a hybrid technique: a surface detector (SD) consisting of 1660 water-Cherenkov detectors and covering an area of 3000 km² and 27 fluorescence telescopes. The distribution of UHECR arrival directions is expected to provide essential clues to understanding their origin despite the difficulties that arise from the deflection they suffer due to galactic and extragalactic magnetic fields. We show here the latest results of searches for anisotropies in the arrival directions of the UHECRs detected by the Pierre Auger Observatory over more than three decades in energy. We present analyses of the equatorial dipole component above 0.03 EeV. At energies above 4 EeV, where the SD is fully efficient, we obtain the dipolar and quadrupolar amplitudes. The most significant equatorial dipole amplitude obtained is that in the cumulative bin above 8 EeV, which is inconsistent with isotropy at the 6σ level. Above 4 EeV we find that the amplitude of the dipole increases with energy, and the direction of the dipole is consistent with an extragalactic origin of these anisotropies. The quadrupolar components are not statistically significant. At energies below 1 EeV, even though the equatorial dipole amplitudes are not significant, the phases determined in most of the bins are not far from the the Galactic Center suggesting a predominantly Galactic origin for anisotropies at these energies. Finally, we investigate the most energetic events, where flux excesses associated with individual UHECR sources could possibly be detected. We give the latest results for a search for localized excess and a correlation with different populations of nearby extragalactic objects above 32 EeV. We have found evidence for a deviation from isotropy at an intermediate angular scale of ~25 degrees at a 4σ significance level, for energies above ~40 EeV.

Primary authors: Mr GIACCARI, Ugo (IMAPP, Radboud University, Nijmegen); OBSERVATORIO PIERRE AUGER

Presenter: Mr GIACCARI, Ugo (IMAPP, Radboud University, Nijmegen)

Contribution ID: **132** Type: **Talk**

The Radio Detector of the Pierre Auger Observatory – status and expected performance

Friday, 7 October 2022 09:40 (20 minutes)

As part of the ongoing AugerPrime upgrade of the Pierre Auger Observatory, we are deploying short aperiodic loaded loop antennas (SALLAs) measuring radio signals from extensive air showers in the 30-80 MHz band on each of the 1660 surface detector stations. This new Radio Detector of the Observatory allow us to measure the energy in the electromagnetic cascade of inclined air showers with zenith angles larger than 65°. The water-Cherenkov detectors, in turn, perform a virtually pure measurement of the muon component of inclined air showers. The combination of both thus extends the mass sensitivity of the upgraded Observatory to high zenith angles and therefore enlarges the sky coverage of mass-sensitive measurements at the highest energies while at the same time allowing us to cross-check the performance of the established detectors with an additional measurement technique. In this contribution, we will outline the design and capabilities of the Radio Detector, report on its current status and initial results from the first deployed stations, and illustrate its expected performance with a detailed, end-to-end simulation study.

Primary authors: HUEGE, Tim (Karlsruhe Institute of Technology); FOR THE PIERRE AUGER COLLABORATION

Presenter: HUEGE, Tim (Karlsruhe Institute of Technology)

Contribution ID: **133** Type: **Talk**

Recent achievements and scientific results of KM3NeT

Thursday, 6 October 2022 15:20 (20 minutes)

KM3NeT is a multidisciplinary observatory, for the detection and study of cosmic neutrinos and their sources in the Universe, as well as the measurement of neutrino properties such as the mass hierarchy and oscillation parameters.
Two underwater detectors are under construction in the Mediterranean Sea. The configuration of the ARCA detector, located off-shore Sicily, Italy, is optimised for the detection of neutrinos in the energy range of 1 TeV-100 PeV. The ORCA detector off-shore Toulon, France is configured for the measurement of neutrinos of a few GeV-10 TeV. At present, 19 and 10 detection units are taking data at the ARCA and the ORCA sites, respectively. Installation of additional detection units is foreseen in the next few years.
In this contribution the main physics results obtained with ARCA and ORCA, still in their partial configuration, will be reported. In the context of the multi-messenger scenario, the KM3NeT on-line alert system will be presented. Finally, an overview of the expected performances of the full detectors will be reviewed.

Primary author: CHIARUSI, Tommaso (INFN - Sezione di Bologna)

Presenter: CHIARUSI, Tommaso (INFN - Sezione di Bologna)

Contribution ID: **134** Type: **Talk**

Searches for Lorentz Invariance Violation at the Pierre Auger Observatory

Wednesday, 5 October 2022 14:20 (20 minutes)

Lorentz symmetry requires the space-time structure to be the same for all observers, but, on the other hand, various quantum gravity theories suggest that it may be violated when approaching the Planck scale. Even a small violation of Lorentz Invariance (LI) could easily affect the Ultra High Energy Cosmic Rays (UHECRs) propagation on a cosmological scale. Moreover, at the extreme energies, like those available in the collisions of UHECRs in the atmosphere, one should also expect a change in the interactions and, therefore, in the development of extensive air showers. In this work, Lorentz Invariance Violation (LIV) has been introduced as a perturbation term in the single particle dispersion relation considering a phenomenological approach. As a result, the kinematics of the interactions in the extragalactic propagation and in the shower development in the atmosphere is affected. The unprecedented statistics and data quality collected by the Pierre Auger Observatory in the EeV range are used to explore LIV scenarios. In particular, LIV effects have been tested by comparing the energy spectrum and the composition of cosmic rays determined with the Pierre Auger Observatory with the predictions from simulations including LIV. Also the impact of LIV on the resulting upper limits on the photon flux has been studied. Finally, the effects on the development of extensive air-showers in the atmosphere are studied. In particular, the change in the energy-momentum relation leads to a modification of the energy threshold of particle decays, which allows for hadronic interactions of neutral pions that contribute to the growth of the hadronic cascade. As a consequence, an increase in the number of muons and a decrease in their intrinsic fluctuations are expected. In this contribution, limits on LIV parameters have been derived and presented considering the muon fluctuation measurements from the Pierre Auger Observatory.

Primary author: TRIMARELLI, Caterina (Università dell'Aquila)

Co-author: ON BEHALF OF THE PIERRE AUGER OBSERVATORY

Presenter: TRIMARELLI, Caterina (Università dell'Aquila)

Contribution ID: **135** Type: **Talk**

The depth of the shower maximum of air showers measured with AERA

Monday, 3 October 2022 17:40 (20 minutes)

The Auger Engineering Radio Array (AERA), as part of the Pierre Auger Observatory, is an array of radio antennas probing the nature of ultra-high energy cosmic rays at energies around the transition from Galactic to extra-galactic origin. It measures the MHz radio emission of extensive air showers produced by cosmic rays hitting our atmosphere. The elemental composition of cosmic rays is a crucial piece of information in determining what the sources of cosmic rays are and how cosmic rays are accelerated. This composition can be obtained from the mass-sensitive parameter X_{max}, the depth of the shower maximum. We reconstruct X_{max} with a likelihood analysis, by comparing the measured radio footprint on the ground to an ensemble of footprints from Monte-Carlo CORSIKA/CoREAS air shower simulations. We compare our X_{max} reconstruction with fluorescence X_{max} measurements on a per-event basis, a setup unique to the Pierre Auger Observatory, and show the methods to be fully compatible. Furthermore, we extensively validate our reconstruction by identifying and correcting for systematic uncertainties. We determine the resolution of our method as a function of energy and reach a precision better than $15\ \mathrm{g\,cm^{-2}}$ at the highest energies. With a bias-free set of around 600 showers, we find a light to light-mixed composition at energies between $10^{17.5}$ to $10^{18.8}$ eV, also in agreement with the Auger fluorescence measurements.

Primary authors: PONT, Bjarni (Radboud University Nijmegen); ON BEHALF OF THE PIERRE AUGER COLLABORATION

Presenter: PONT, Bjarni (Radboud University Nijmegen)

Contribution ID: **136** Type: **Talk**

Results and perspectives of the Mini-EUSO mission on board the International Space Station

Friday, 7 October 2022 11:30 (20 minutes)

Mini-EUSO is a telescope observing the Earth from the International Space Station since 2019. The instrument employs a Fresnel-lens optical system and a focal surface composed of 36 Multi-Anode Photomultiplier tubes, 64 channels each, for a total of 2304 channels with single photon counting sensitivity. Mini-EUSO also contains two ancillary cameras to complement measurements in the near infrared and visible ranges. The scientific objectives of the mission span from the search for extensive air showers (EAS) generated by Ultra-High Energy Cosmic Rays (UHECR) with a energies above 1021 eV, the search for nuclearites and Strange Quark Matter to the study of atmospheric phenomena such as Transient Luminous Events, meteors and meteoroids. Mini-EUSO can map the night-time Earth in the near UV range (predominantly between 290 - 430 nm), with a spatial resolution of about 6.3 km (full field of view equal to 44◦) and a maximum temporal resolution of 2.5 µs, observing our planet through a nadir-facing UV-transparent window in the Russian Zvezda module. The detector saves triggered transient phenomena with a sampling rate of 2.5 µs and 320 µs, as well as continuous acquisition at 40.96 µs scale. In this talk we discuss the detector response, and the first results of the mission.

Primary authors: Dr MARCELLI, Laura (INFN, Sezione di Roma Tor Vergata - Rome, Italy); Prof. BERTAINA, Mario (INFN, Sezione di Torino - Torino, Italy, Dipartimento di Fisica, Universitá di Torino, Italy); Prof. PARIZOT, Etienne (Université de Paris, CNRS, Astroparticule et Cosmologie, F-75006 Paris, France); Prof. RICCI, Marco (INFN-LNF - Frascati, Italy); CASOLINO, Marco (INFN and RIken)

Presenter: CASOLINO, Marco (INFN and RIken)

Contribution ID: **137** Type: **Poster**

Reconstruction of the muon production longitudinal profiles in extensive air showers

Muons produced in extensive air showers have large decay lengths and small radiative energy losses, enabling a large fraction of them to reach surface and underground detector arrays while keeping relevant information about the hadronic interactions that occurred high in the atmosphere. We can relate a muon's arrival time and position at the detector to its production distance/depth. The total delay of muons with respect to the shower plane is primarily due to their geometric path and energy, which we call the geometric and kinematic delays, respectively. We are currently working on improving the current kinematic delay parameterizations using Deep Neural Networks for muons arriving at surface and underground detector arrays. We aim to reconstruct the longitudinal profile of muons for future arrays of buried scintillator detectors at energies from around the second knee to the ankle of the cosmic ray spectrum, where there is an overlap with the nominal energies at the LHC. Given the low zenith angle acceptance of scintillator detectors and the richness of the forward physics near the shower core, we aim at applying a radial cut of 200 m instead of the usual 1000 m used in previous works.

Primary authors: Dr DOS SANTOS, Eva (FZU - Institute of Physics of the Czech Academy of Sciences); Mr KRAVKA, Antonín (Czech Technical University - Faculty of Nuclear Sciences and Physical Engineering)

Co-author: Dr YUSHKOV, Alexey (FZU - Institute of Physics of the Czech Academy of Sciences)

Presenter: Dr DOS SANTOS, Eva (FZU - Institute of Physics of the Czech Academy of Sciences)

Contribution ID: **138** Type: **Talk-To-Poster**

Single source scenario describing the very end of the cosmic-ray energy spectrum

The energy spectrum of cosmic rays is steeply falling with a suppression of the flux at the highest energies caused by energy losses during propagation or by reaching the maximum power of cosmic accelerators. The energy spectrum at the highest energies is currently measured with high precision by two experiments, Telescope Array in the Northern hemisphere and Pierre Auger Observatory in the Southern hemisphere. However, the measured shapes of the two energy spectra differ at the highest energies. One possible explanation of such discrepancy between the two spectra might be the fact that both experiments observe different cosmic-ray sources at the highest energies. In our work, we study the possibility of explaining the shape of the energy spectrum above $10^{19.5}$ eV measured by the Pierre Auger Observatory with a single (dominant) source. Using numerical simulations in CRPropa3 of cosmic ray propagation in the Universe we show possible features of such a single source that would be able to create a shape of the energy spectrum compatible with the measurement including limitations on the source distance, spectral index and mass composition. In case of a low-mixed heavy mass composition on the Earth, we find that a single dominant source can produce the shape of the energy spectrum compatible with the observed one only for lower rigidity cutoffs $\log_{10}$(R/V) < 19.2 and spectral indices $\gamma \geq 2$ of the source distant within ≈10 Mpc from the Earth.

Primary author: BAKALOVÁ, Alena (FZU - Institute of Physics of the Czech Academy of Sciences)

Co-authors: VÍCHA, Jakub (FZU - Institute of Physics of the Czech Academy of Sciences); TRÁVNÍČEK, Petr (FZU - Institute of Physics of the Czech Academy of Sciences)

Presenter: BAKALOVÁ, Alena (FZU - Institute of Physics of the Czech Academy of Sciences)

Contribution ID: **139** Type: **Talk**

Next-Generation UHECR Research with GCOS

Friday, 7 October 2022 10:00 (20 minutes)

The Global Cosmic Ray Observatory (GCOS) is a proposal for a ground-based detector to measure the properties of the highest-energy particles in the Universe with unprecedented precision after the year 2030. In this contribution we will report on the results from the GCOS 2022 workshop, in which basic parameters for a the detector design were defined and we will discuss preliminary estimates of the physics reach of such a next-generation cosmic-ray facility.

Primary author: MARIS, Ioana (Université Libre de Bruxelles)

Presenter: MARIS, Ioana (Université Libre de Bruxelles)

Contribution ID: **140** Type: **Talk**

Muon enhancement ad extremum in Sibyll

Wednesday, 5 October 2022 12:20 (20 minutes)

In recent years it has become more and more clear that simulations of air showers of ultra-high energy cosmic rays do not agree with measurements when it comes to observables related to muons. The usual explanation is that hadronic interactions are miss represented in the models that enter the simulations. Several mechanisms within standard hadronic interaction physics have been identified in the past that are capable of enhancing the number of muons in EAS. However with none of these extensions it was so far possible to increase the number of muons by a sufficient amount to describe the experimental data.
Using the example of Sibyll, one of the models for hadron interactions used in air shower simulations, we introduce ad-hoc enhancements of baryon, rho0 and strangeness production to test whether it is at all possible to reach the number of muons observed in experiments.

Primary authors: RIEHN, felix (lip); ENGEL, Ralph; FEDYNITCH, Anatoli

Presenter: ENGEL, Ralph

Contribution ID: **141** Type: **Talk**

The JEM-EUSO program for UHECR studies from space

Friday, 7 October 2022 11:10 (20 minutes)

Despite intense observational efforts and a series of important results in the last two decades, the study of ultra-high-energy cosmic rays (UHECRs) remains one of the most challenging in astronomy, both because their flux is extremely low (one particle per m^2 per billion year at the highest known energies) and because their macroscopic energies (tens of Joules) still remain insufficiently large to allow quasi-rectilinear propagation in the Galactic (and extragalactic) magnetic fields. As a consequence, no direct detection of their sources has been possible thus far, and their astrophysical origin as well as their acceleration mechanism remain a mystery. To take up the challenge, new UHECR observational means appear necessary. The JEM-EUSO Collaboration has undertaken to open the space road to UHECR studies. For more than a decade, it has been developing a realistic program to measure the UHECRs from space with unprecedented aperture. Several intermediate missions have already been completed (on the ground: EUSO-TA; under stratospheric ballons: EUSO-Balloon and EUSO-SPB1; in space: TUS, and on-board the ISS: MINI-EUSO), and others are in preparation for flight (EUSO-SPB2), under review (K-EUSO), or proposed for the next decade (POEMMA). We will report on the general status of the JEM-EUSO program, based on the demonstrated performance of its now mature technology.

Primary authors: PARIZOT, Etienne (Université Paris Cité); ON BEHALF OF THE JEM-EUSO COLLABORATION

Presenter: PARIZOT, Etienne (Université Paris Cité)

Contribution ID: **142** Type: **Talk**

A detailed presentation of the highest-energy cosmic rays recorded at the Pierre Auger Observatory

Monday, 3 October 2022 18:00 (20 minutes)

A catalog that contains details of the highest-energy cosmic rays, recorded by the Pierre Auger Collaboration between 1 January 2004 and 31 December 2020, is presented. Data from 100 air showers, generated by particles having energies in the range 78 EeV to 166 EeV, are described, together with nine other very energetic events used in the energy calibration. The catalog has been created to demonstrate the quality of the data that underlie measurements reported by the Collaboration, and to make the details of these events available for scrutiny. After a brief description of the techniques used for data acquisition and reconstruction, the contents of the catalog will be described: some events within it will be discussed in detail.

Primary author: BUSCEMI, Mario (INFN Catania)

Presenter: BUSCEMI, Mario (INFN Catania)

Contribution ID: **143** Type: **Talk-To-Poster**

Absolute calibration of the photodetection modules for the JEM-EUSO missions

The JEM-EUSO (Joint Experiment Missions for Extreme Universe Space Observatory) collaboration constructs a series of balloon and orbital telescopes to detect fluorescent UV emission from the Earth atmosphere, with the primary aim to study ultrahigh energy cosmic rays (UHECRs) from space.
The detectors have wide field-of-view (more than 20 degrees FOV), high temporal resolution (1-2.5 μs) and sensitivity provided by a large aperture. Currently one of these detectors is operating onboard the ISS (Mini-EUSO). The next one is planned to be launched in the spring of 2023 (EUSO-SPB2) and the other one is in preparation stage (K-EUSO). These projects use the same photo-detection modules (PDMs) composed of 36 multi-anode photomultiplier tubes (MAPMTs) with 2304 channels in total. Mini-EUSO uses one PDM, EUSO-SPB2 uses three and K-EUSO will use more than 40 PDMs.
In the process of preparing and testing of PDMs, a unique technique for absolute calibration was developed, a comprehensive study of the efficiency of the multi-anode PMTs used in the projects, including the structure of the photocathode of both the MAPMT as a whole and individual pixels, was carried out. Efficiency measurements were carried out at different supply voltages and input near UV photon flux intensity.
The methods of absolute calibration and its application to EUSO-SPB2 PDMs in different modes of operation and internal PDM structure studies will be presented.

Primary authors: Mr DANIIL, Trofimov (APC and MSU); Prof. PARIZOT, Etienne (Université Paris Cité APC); Dr KLIMOV, Pavel (MSU); FOR THE JEM-EUSO COLLABORATION

Presenter: Mr DANIIL, Trofimov (APC and MSU)

Contribution ID: **144** Type: **Talk**

AugerPrime status and prospects

Tuesday, 4 October 2022 17:30 (20 minutes)

The Pierre Auger Collaboration started a few years ago the AugerPrime project to increase the Surface Detector (SD) performance of the Pierre Auger Observatory. It aims to address the still open questions on the origin and composition of the highest energy cosmic rays by allowing better identification of the nature of the primaries. The key element of this major upgrade is the capability of measuring the different components of extensive air showers, which will be significantly improved by the addition of a Surface Scintillator Detector (SSD) on each water Cherenkov detector (WCD) constituting the SD. Moreover, the dynamic range of measurement is extended through an additional small photomultiplier tube inside the WCD. New electronics is processing the signals from the WCD and the SSD with higher sampling frequency and enhanced resolution. The scintillator module deployment started in 2019, and the new electronics in December 2020. The collected data allow for the evaluation of the first performances of the upgraded array and to adapt the whole data acquisition chain necessary for an efficient and sustainable operation of the Observatory.
After the recall of the motivations for the upgrade, the main characteristics of the new detection setup are reviewed, as well as the status of its deployment and commissioning. The expected prospects are also discussed.

Primary authors: Dr BÉRAT, Corinne (LPSC, Grenoble); ON BEHALF OF THE PIERRE AUGER COLLABORATION

Presenter: Dr BÉRAT, Corinne (LPSC, Grenoble)

Contribution ID: **145** Type: **Talk-To-Poster**

A Bayesian source association analysis of UHECRs: Impact of the Galactic magnetic field and composition

We present a statistical analysis of the association between UHECRs and proposed astrophysical sources. Our approach is based on the Bayesian hierarchical framework presented in Capel & Mortlock 2019, but with notable extensions. Using CRPropa3, we now include the lensing effect of the Galactic magnetic field and explore the impact of heavier compositions. This analysis directly connects to the physics of UHECR propagation so that each detected event is allowed different possible deflections and energy-loss horizons based on its measured energy, arrival direction and the corresponding uncertainties. In this way, we can easily interpret the connection to proposed sources in a physical way. We verify our approach using simulated data and then present our results with views of the Northern and Southern skies thanks to publicly available data from both the Telescope Array experiment and Pierre Auger Observatory.

Primary authors: Mr WATANABE, Keito (University of Bonn); FEDYNITCH, Anatoli; CAPEL, Francesca (Max Planck Institute for Physics); Prof. SAGAWA, Hiroyuki (University of Tokyo)

Presenter: CAPEL, Francesca (Max Planck Institute for Physics)

Contribution ID: **146** Type: **Talk**

Flux predictions in the transition region incorporating the effects from propagation of cosmic rays in the Galactic magnetic field

Tuesday, 4 October 2022 14:40 (20 minutes)

Galactic cosmic rays (GCRs) and (anisotropically injected) extragalactic cosmic rays (EGCRs) are both affected by the Galactic magentic field (GMF) on their voyage to Earth at energies pertaining to the transition from GCRs to EGCRs, such that their flux, composition and arrival directions are modified. GCRs increasingly leak from the Galaxy with rising energy, leading to a flux suppression. The flux modification imposed on EGCRs is more complex, but may exhibit (subtle) spectral breaks depending on the direction and nature of the injected anisotropy.
Using a full Monte Carlo approach with CRPropa and making realistic and minimal assumptions about the injected GCR and EGCR fluxes, we make predictions of the total all-particle flux in the transition region. We find that it cannot account for the flux measured by various cosmic ray experiments in this energy range. This calls for the need of an additional component to the flux in the transition region.

Primary authors: Dr KÄÄPÄ, Alex (Ruhr Universität Bochum); Prof. KAMPERT, Karl-Heinz (Bergische Universität Wuppertal); Dr BECKER TJUS, Julia (Ruhr-Universität Bochum)

Presenter: Dr KÄÄPÄ, Alex (Ruhr Universität Bochum)

Contribution ID: **147** Type: **Poster**

The CORSIKA 8 project and Pythia 8 as hadronic interaction model in air shower simulations

The CORSIKA 8 project aims to provide a modular, flexible, and comprehensive framework for the simulation of particle cascades in air and other media. Recent developments include the integration of the PROPOSAL code as electromagnetic interaction model, implementations of the Zas-Halzen-Stanev (ZHS) and CoREAS algorithms for simulations of radio emission, and the introduction of thinning. In this contribution, we give a status report of the project, present an overview of the current capabilities, and give an outlook to future developments.

As a highlight, we show first results using Pythia 8 as hadronic interaction model in UHECR air shower simulations, which since its latest version 8.307 offers a number of features that make it usable as such. Among them are the ability to produce events with arbitrary energies and projectiles without a time-consuming re-initialization as well as a simplified treatment of nuclear targets. Additionally, the extended energy range of usability down to 200 MeV (lab) eliminates the need of a supplementary low-energy interaction model.

Primary author: REININGHAUS, Maximilian (Karlsruher Institut für Technologie)

Presenter: REININGHAUS, Maximilian (Karlsruher Institut für Technologie)

Contribution ID: **148** Type: **Talk**

Measurements of Cosmic Ray Mass Composition with the IceCube Neutrino Observatory

Monday, 3 October 2022 12:10 (20 minutes)

The IceCube Neutrino Observatory is a multi-component detector at the South Pole capable of measuring high-energy cosmic rays from PeV to EeV. This energy region is typically thought to cover the transition from galactic to extragalactic sources of cosmic rays. The observatory consists of the IceTop surface array, which is sensitive to the electromagnetic and low-energy muonic part of an air shower, and the deep in-ice IceCube array, which measures the high-energy (≥ 500 GeV) muonic component. One of the recent cosmic ray detector enhancements at the South Pole consists of the IceAct prototype array, which is measuring the Cherenkov light produced by low-energy extensive air showers directly in the atmosphere, extending the energy range to below 100 TeV.

The primary energy and the mass composition can be measured simultaneously by applying modern machine-learning techniques and statistical methods to reconstruct cosmic ray air showers. In this contribution, we will discuss recent improvements to the reconstruction techniques, the mass composition sensitivity, and an outlook on future improved measurements with the full surface scintillator/radio array and improved air Cherenkov telescopes.

Primary author: PLUM, Matthias (South Dakota School of Mines and Technology)

Presenter: PLUM, Matthias (South Dakota School of Mines and Technology)

Contribution ID: **149** Type: **Talk-To-Poster**

Modeling Neutrino and Background Signals for the Payload for Ultrahigh Energy Observations (PUEO) Experiment

In the current age of multimessenger astronomy, Very High Energy (VHE) cosmic neutrinos (E>1PeV) represent a unique observation window into the most extreme astrophysical events in the universe. Measurements of the neutrino flux in this high energy regime provide information regarding the distribution and composition of Ultra-High Energy Cosmic Rays (UHECR), details of source acceleration mechanics, and definitive tests of physics beyond the standard model. Observations in multiple different detection channels (e.g. optical, radio, direct particle counting) are being explored to extend the sensitivity to neutrinos above PeV energies.

The Payload for Ultrahigh Energy Observations (PUEO) is a long duration balloon experiment that builds on the successes of the Antarctic Impulsive Transient Antenna (ANITA) experiment to probe the cosmic neutrino flux above EeV energies. PUEO, like ANITA, seeks to measure coherent radio emission in the form of Askaryan emission from in-ice neutrino interactions and both geomagnetic and Askaryan emission from Extensive Air Showers (EAS) produced by the decays of Earth-emergent τ-leptons sourced from τ neutrinos.

To evaluate the sensitivity of PUEO (and other detectors) to a given flux of neutrinos, it is necessary to accurately model i) the propagation of neutrinos through the Earth ii) the emission generated from the neutrino-sourced particle shower iii) the detector performance to a generated signal and iv) relevant backgrounds. Numerous software frameworks exist to model these different mechanisms independently, but can often require significant work to use together.

nuSpaceSim is an open source, end-to-end neutrino simulation package that models these described mechanisms for an arbitrary detector geometry in both the optical and radio emission channels. For a given experimental design, nuSpaceSim is designed to model the sensitivity to both the cosmogenic neutrino flux and to astrophysical neutrino transient events. The highly modular design of nuSpaceSim allows for comparison and exploration of different physics models within the same code base.

In this contribution, we detail the state of the nuSpaceSim code as it pertains to modeling the sensitivity of the PUEO experiment, and highlight the mechanisms necessary to perform this calculation. We also describe the near-term improvements to the radio emission calculation in nuSpaceSim and the modeling of the most relevant backgrounds for PUEO: the direct (above-the-limb) cosmic rays, and the indirect (ice-reflected) cosmic ray signals.

Primary author: CUMMINGS, Austin (Pennsylvania State University)

Co-authors: KRIZMANIC, John (NASA/GSFC); WISSEL, Stephanie (Pennsylvania State University)

Presenter: CUMMINGS, Austin (Pennsylvania State University)

Contribution ID: **150** Type: **Talk**

Muon lateral distribution from Telescope Array Surface Detector data

We present a method for muon density reconstruction for extensive air showers detected by the Telescope Array Surface Detector (TA SD). The method uses machine learning to predict the muon density at each triggered SD station of the event based on both station-local and shower-wide information. We discuss the sensitivity and systematics of the method. We report the reconstructed muon lateral distribution function from TA SD data and compare it with the predictions of Monte-Carlo simulations.

Primary authors: VAIMAN, Igor (INR RAS, Moscow); RUBTSOV, Grigory

Presenter: Dr JUI, Charles

Contribution ID: **151** Type: **Talk**

Testing the Compatibility of the Depth of the Shower Maximum Measurements performed at Telescope Array and the Pierre Auger Observatory

Monday, 3 October 2022 15:30 (20 minutes)

The Telescope Array and the Pierre Auger Observatory estimate the composition of ultra-high-energy cosmic rays by observing the distribution of depths of air shower maximum, $X_{\rm max}$. Both experiments directly observe the longitudinal development of air showers using fluorescence telescopes with surface particle detectors used in conjunction to provide precision in determining air shower geometry. The two experiments differ in the details of the analysis of events, so a direct comparison of $X_{\rm max}$ distributions is not possible. The Auger – Telescope Array Composition Working Group presents their results from a technique to compare $X_{\rm max}$ measurements from Auger with those of Telescope Array. In particular, the compatibility of the first two moments of the $X_{\rm max}$ distributions of Auger with the data from the Black Rock Mesa and Long Ridge detectors of the Telescope Array is tested for energies above $10^{18.2}$ eV. Quantitative comparisons are obtained using air shower simulations of four representative species made using the Sybill 2.3d high energy interaction model. These are weighted to fit the fractional composition seen in Auger data and reconstructed using the Telescope Array detector response and analysis methods.

Primary authors: BERGMAN, Douglas (University of Utah); BELLIDO, Jose (University of Adelaide); ENGEL, Ralph; KIM, Jihyun (University of Utah); Dr MAYOTTE, Eric (Colorado School of Mines); TKACHENKO, Olena (Karlsruhe Institute of Technology); UNGER, Michael (KIT); Dr YUSHKOV, Alexey (FZU - Institute of Physics of the Czech Academy of Sciences)

Presenter: BERGMAN, Douglas (University of Utah)

Contribution ID: **152** Type: **Talk**

A Study of Modified Characeristics of Hadronic Interactions

Wednesday, 5 October 2022 13:40 (20 minutes)

We have implemented ad-hoc modifications to the CORSIKA Monte-Carlo generator which allow us to simultaneously adjust the multiplicity, elasticity and cross-section of hadronic interactions with respect to the predictions of the Sibyll 2.3d interaction model, in order to assess whether a reasonable combination of changes (that is not excluded by current experimental data) could alleviate the observed tension between the model predictions and observed features of extensive air showers induced by ultra-high energy cosmic rays (UHECR). Previously, we have studied the effects of such changes on proton-initiated showers. Because a multitude of experimental data suggest that the primary composition of the UHECR is mixed, we have expanded the modification procedure to include nuclear projectiles in a consistent way based on the superposition model, in a similar manner as was used in the previous studies carried out using one-dimensional simulation methods. As we are using a fully three-dimensional approach, we can quantify the effects of the changes on both longitudinal and lateral features of the showers. With the inclusion of nuclear projectiles, we can study the impact of the changes on observable quantities for realistic primary beams as well as on the determination of the primary composition from data under the assumption of the modified hadronic interactions.

Primary authors: BLAZEK, Jiri (FZU Prague); VÍCHA, Jakub (FZU - Institute of Physics of the Czech Academy of Sciences); EBR, Jan (FZU); PIEROG, Tanguy (KIT, IAP); TRÁVNÍČEK, Petr (FZU - Institute of Physics of the Czech Academy of Sciences)

Presenter: BLAZEK, Jiri (FZU Prague)

Contribution ID: **153** Type: **Talk-To-Poster**

The XY-Scanner for Absolute End-to-End Calibration of Fluorescence Detectors

The precise determination of the energy scale is a key part of experiments in astroparticle physics. At the Pierre Auger Observatory, the energy scale is set by the calorimetric measurement of extensive air showers with fluorescence detectors. Thus, the absolute end-to-end calibration of the fluorescence detectors is of utmost importance. In the past, this calibration was performed by illuminating the whole optical system of a fluorescence telescope with a large-scale extended uniform light source of the same diameter as the telescope aperture. However, handling difficulties, excessive manpower requirements, and degradation of such a source led to the need for a different approach for the absolute end-to-end calibration. The fundamental idea of the novel approach is to significantly reduce the geometrical size of the calibration light source, which is a near-UV LED source implemented in a portable integrating sphere with specifically designed interior. This light source is moved over the aperture by a rail mechanism with two independent linear stages named the XY-Scanner. Calibration data are evaluated from a series of light source positions instead of illuminating the entire aperture at once. The absolute photometric determination of the light source emission intensity is performed in a dedicated laboratory setup with a measurement uncertainty of 3.5 %. The XY-Scanner mechanics installed at the aperture gives also the opportunity to install other, devices for instance a narrow, collimated beam source to investigate local impurities of the telescopes. This contribution gives an overview of this novel XY-Scanner calibration method and presents preliminary results and discusses plans for the future.

Primary author: VACULA, Martin (Palacky University Olomouc, Faculty of Science)

Presenter: VACULA, Martin (Palacky University Olomouc, Faculty of Science)

Contribution ID: **154** Type: **Talk**

Multi-messenger studies with the Pierre Auger Observatory

Tuesday, 4 October 2022 15:20 (20 minutes)

The combination of data from observatories measuring ultra-high energy cosmic rays, photons, neutrinos and gravitational waves has provided new insights into the most extreme phenomena in the Universe. Sharing information within a broad community is the foundation of the multi-messenger approach.
The Pierre Auger Observatory, the world's largest cosmic ray detector, provides sensitivity to photons and neutrinos above 10^{17} eV, thus contributing efficiently to this joint effort.
The latest results from diffuse and targeted searches will be reviewed here, along with results from follow-up analyses and future perspectives.
In particular, preliminary limits on photon fluence from a selection of gravitational wave sources detected by LIGO/Virgo and results of the search for ultra-high energy neutrinos from binary black hole mergers will be presented.

Primary authors: PERRONE, Lorenzo (Università del Salento and INFN Sezione di Lecce); ON BEHALF OF THE PIERRE AUGER COLLABORATION

Presenter: PERRONE, Lorenzo (Università del Salento and INFN Sezione di Lecce)

Contribution ID: **155** Type: **Talk**

The energy spectrum of cosmic rays above 6 PeV as measured at the Pierre Auger Observatory

Monday, 3 October 2022 14:30 (20 minutes)

Since 2004, the Pierre Auger Collaboration has measured one of the most important features of ultra-high-energy cosmic rays, the energy spectrum, with unprecedented precision. Located in the Southern hemisphere, the Observatory comprises an array of 1,660 water-Cherenkov detectors covering ~3,000 km² overlooked by 27 fluorescence telescopes. Five sets of measurements have been used to reconstruct the spectrum from 6 PeV to beyond 100 EeV. The highest-energy events, recorded by surface detectors on a 1,500 m triangular grid, are reconstructed differently depending on their inclination (vertical events below 60° and inclined ones above 60°). A cross-check of these measurements is made using 'hybrid events', in which there are simultaneous detections at both the fluorescence detectors and at least one surface detector. Events with energies below 3 EeV have been studied using a nested array with a spacing of 750 m and using the Cherenkov light recorded with three high-elevation telescopes. In this contribution, updated methods for the reconstruction of all events are discussed, together with their associated uncertainties. A combination of all data sets is reported to construct a spectrum above 6 PeV to the highest energies. A detailed discussion of the spectral features will be presented.

Primary author: THE PIERRE AUGER COLLABORATION

Presenter: LUCE, Quentin

Contribution ID: **156** Type: **Talk-To-Poster**

Search for upward-going showers with the Pierre Auger Observatory

Motivated by the ANITA report of pulses compatible with upward-going extensive air showers, we present a recent search for such showers with the Pierre Auger Observatory. The data set registered using the fluorescence detector of the Observatory is scanned to identify showers ascending from the ground. Consistently with the exit angles reported from the first and third ANITA flights, we focus on shower geometries that are not compatible with the Standard Model interactions of neutrinos in the Earth. We provide the effective area of the Observatory to generic upward-going showers as a function of shower energy and altitude that can be used to constrain predictions based on physics beyond Standard Model and the upgoing-shower interpretation of the ANITA results. To demonstrate this method, we calculate limits on the production rate of tau leptons near the ground emerging under the investigated exit angles.

Primary author: NOVOTNÝ, Vladimír (IPNP, Charles University)

Presenter: NOVOTNÝ, Vladimír (IPNP, Charles University)

Contribution ID: **157** Type: **Talk**

Testing Model Predictions of Depth of Air-Shower Maximum and Signals in Surface Detectors using Hybrid Data of the Pierre Auger Observatory

Wednesday, 5 October 2022 12:00 (20 minutes)

We present a new method for testing the predictions of hadronic interaction models and improving their consistency with observed two-dimensional distributions of the depth of shower maximum, X_{max}, and signal at the ground level as a function of zenith angle. The method relies on the assumption that the mass composition is the same at all zenith angles, while the atmospheric shower development and attenuation depend on composition in a correlated way. In the present work, for each of the three leading LHC-tuned hadronic interaction models, we allow a global shift ΔX_{max} of the predicted shower maximum, which is the same for every mass and energy, and a rescaling R_{Had} of the hadronic component at the ground level which depends on the zenith angle.

We apply the analysis to 2297 events reconstructed with both the fluorescence and surface detectors of the Pierre Auger Observatory with energies $10^{18.5-19.0}$ eV and zenith angles below 60°. Given the modeling assumptions made in this analysis, the best fit reaches its optimum value when shifting the X_{max} predictions of hadronic interaction models to deeper values and increasing the hadronic signal at both extreme zenith angles. This change in the predicted X_{max} scale alleviates the previously identified model deficit in the hadronic signal (commonly called the muon puzzle) but does not remove it. Because of the size of the adjustments ΔX_{max} and R_{Had} and the large number of events in the sample, the statistical significance of these assumed adjustments is large, greater than $5\sigma_{\mathrm{stat}}$, even for the combination of the systematic experimental shifts within $1\sigma_{\mathrm{sys}}$ that are the most favorable for the models.

Primary author: VÍCHA, Jakub (FZU - Institute of Physics of the Czech Academy of Sciences)

Presenter: VÍCHA, Jakub (FZU - Institute of Physics of the Czech Academy of Sciences)

Contribution ID: **158** Type: **Talk**

Auger@TA: Deploying an independent Pierre Auger Observatory SD array at the Telecope Array Project

Tuesday, 4 October 2022 17:10 (20 minutes)

The Pierre Auger Observatory and the Telescope Array (TA) are the two largest ultra-high-energy cosmic ray observatories in the world. They operate in the Southern and Northern hemispheres, respectively, at similar latitudes, but with different surface detector (SD) designs. This difference in detector design changes their sensitivity to the various components of extensive air showers. The over-arching goal of the Auger@TA working group is to cross-calibrate the SD arrays of the two observatories in order to identify or rule out systematic causes for the apparent differences in the flux measured at Auger and TA.
The project itself is divided into two phases. Phase-I finished in 2020, and consisted of a station-level comparison facilitated by the deployment of two Auger stations, one prototype station with a single central PMT and a standard Auger station, in the middle of the TA SD near the Central Laser Facility along with a modified TA station to provide external triggers from the TA SD. This provided the opportunity to observe the same extensive air showers with both Auger and TA detectors to directly compare their measurements. Results from the analysis of Auger@TA phase-I data will be shown. Phase-II of Auger@TA is currently underway, and aims at building a self-triggering micro-Auger-array inside the TA array. This micro-array will consist of eight Auger stations, seven of which use the prototype configuration and form a single hexagon with a traditional 1.5 km Auger spacing. The 8^{th} station is of the standard Auger configuration and is placed at the center of the hexagon, along with a TA station to form a triplet. Each Auger station will also be outfitted with an AugerPrime Surface Scintillator Detector. A custom made communication system using readily available components will be used to provide access to the stations directly via the internet. The deployment of the micro-array via helicopter skycrane is currently scheduled for the end of September 2022 and will also be reported on in this talk. A simulation study was carried out to gauge the expected performance of the Auger@TA micro-array; trigger efficiencies and event rates derived from this study will be reported.

Primary author: Dr MAYOTTE, Sonja (Colorado School of Mines)

Co-authors: THE PIERRE AUGER COLLABORATION; THE TELESCOPE ARRAY COLLABORATION

Presenter: Dr MAYOTTE, Sonja (Colorado School of Mines)

Contribution ID: **159** Type: **Talk**

Update on the indication of a mass-dependent anisotropy above 1e18.7 eV in the hybrid data of the Pierre Auger Observatory

Tuesday, 4 October 2022 12:00 (20 minutes)

We test for a large-scale anisotropy in the mass of arriving cosmic-ray primaries as a function of galactic latitude. The sensitivity to primary mass is obtained through the depth of shower maximum, $X_{\rm max}$, extracted from hybrid events measured over a 14-year period at the Pierre Auger Observatory. The sky is split into distinct on- and off-plane regions using the galactic latitude of each arriving cosmic ray to form two distributions of $X_{\rm max}$ which are compared using an Anderson-Darling 2-samples test. A scan over roughly half of the data is used to select a lower threshold energy of $10^{18.7}$ eV and a galactic latitude splitting at $|b| = 30^{\circ}$, which are set as a prescription for the remaining data. With these thresholds, the distribution of $X_{\rm max}$ from the on-plane region is found to have a $9.1 \pm 1.6^{+2.1}_{-2.2}$ g/cm^2 shallower mean and a $5.9 \pm 2.1^{+3.5}_{-2.5}$ g/cm^2 narrower width than that of the off-plane region and is observed in all telescope sites independently. These differences indicate that the mean mass of primary particles arriving from the on-plane region is greater than that of those from the off-plane region. Monte Carlo studies yield a 5.9×10^{-6} random chance probability for the result in the independent data, lowering to a 6.0×10^{-7} post-penalization random chance probability when the scanned data is included. Accounting for systematic uncertainties leads to an indication for anisotropy in mass composition above $10^{18.7}$ eV with a $3.3\,\sigma$ significance. Furthermore, the result has been newly tested using additional independent FD data recovered from the quality selection process. This test disfavors the null hypothesis of the on- and off-plane regions being uniform in composition at $2.2\,\sigma$ which is in good agreement with the expected sensitivity of the dataset used for this test. Possible interpretations, accompanying results and plans for further tests will be presented.

Primary authors: Dr MAYOTTE, Eric (Colorado School of Mines, University of Wuppertal); Dr FITOUSSI, Thomas (Karlsruhe Institute of Technology)

Co-author: THE PIERRE AUGER COLLABORATION

Presenter: Dr MAYOTTE, Eric (Colorado School of Mines, University of Wuppertal)

Contribution ID: **160** Type: **Talk**

The energy spectrum of ultra-high energy cosmic rays measured at the Pierre Auger Observatory and the Telescope Array

Monday, 3 October 2022 14:10 (20 minutes)

In the study of cosmic rays, the measurement of the energy spectrum of the primaries is one of the main issues and provides fundamental information on the most energetic phenomena in the Universe. At ultra-high energies, beyond 10^18 eV, the cosmic rays are studied by the two largest observatories built so far, the Pierre Auger Observatory and the Telescope Array. Both observatories are based on an hybrid design and reported a measurement of the energy spectrum using the high duty cycle of the surface detector and the calorimetric estimation of the energy scale provided by the fluorescence detector.

The differences among the reported spectra are scrutinized by a working group made by members of the Auger and Telescope Array Collaborations. The two measurements have been found well in agreement below 10^19 eV while, at higher energies, they show an energy-dependent difference that is beyond the systematic uncertainties associated to the energy scale.

In this contribution we review the status and perspectives of the working group activities including new studies aiming at addressing the impact on the flux measurement at the highest energies of potential biases in the estimation of the shower size.

Primary author: Dr VERZI, Valerio (INFN, Roma Tor Vergata)

Presenter: Dr VERZI, Valerio (INFN, Roma Tor Vergata)

Contribution ID: **161** Type: **Talk-To-Poster**

Muon counting with the Underground Muon Detector of The Pierre Auger Observatory

The Pierre Auger Observatory was designed to answer the key questions about the origin and composition of ultra-high energy cosmic rays. As part of the Observatory's upgrade, AugerPrime, a new detection system has been conceived to have direct access to the muon component of the air showers above $10^{16.5}$ eV up to the ankle-region of the energy spectrum. The Underground Muon Detector (UMD) consists of 30 m^2 buried devices based on plastic-scintillators that measure muons with energy greater than ~ 1 GeV and are deployed in a triangular array over an area of 23.5 km^2. To estimate the number of particles the UMD works in two complementary ways dubbed as counting and integrated modes. The first, relying on the amplitude of the signals in the detector, is optimized for low particle densities while the latter, based on the signal charge, is better suited for high densities close to the shower core.

In this work, we will present an overview of the final design of the Underground Muon Detector and its reconstruction techniques alongside the observations obtained during the engineering array phase. First results are compatible with a muon deficit that current hadronic interaction models have at energies between 2 x 10^{17} eV and 2 x 10^{18} eV.

Primary authors: Ms SCORNAVACCHE, Marina (UNSAM - KIT); ON BEHALF OF THE PIERRE AUGER COLLABORATION

Presenter: Ms SCORNAVACCHE, Marina (UNSAM - KIT)

Contribution ID: **163** Type: **Talk-To-Poster**

Neutron production in simulations of extensive air showers

We study neutrons produced in simulations of extensive air showers. By using the Monte Carlo simulation package FLUKA, our examination is able to extend from the highest energy neutrons down to thermal energies. Their longitudinal profiles as well as lateral distributions and arrival times at different atmospheric depths are juxtaposed for different primary species and are interpreted in the context of the distinct production mechanisms. Direct comparisons are also drawn with the analogous distributions for muons.

Primary authors: ENGEL, Ralph (Karlsruhe Institute of Technology (KIT)); FERRARI, Alfredo (Karlsruhe Institute of Technology (KIT)); ROTH, Markus (Karlsruhe Institute of Technology (KIT)); SCHIMASSEK, Martin (Karlsruhe Institute of Technology (KIT)); SCHMIDT, David (Karlsruhe Institute of Technology (KIT)); VEBERIC, Darko (Karlsruhe Institute of Technology (KIT))

Presenter: SCHMIDT, David (Karlsruhe Institute of Technology (KIT))

Contribution ID: **164** Type: **Talk-To-Poster**

The Pierre Auger Observatory: Studying atmospheric electricity with cosmic-ray detectors

The Pierre Auger Observatory, designed to detect extensive air showers (EAS) generated by ultra high energy cosmic rays, proved to be a unique instrument to study phenomena associated with atmospheric electricity as Terrestrial Gamma-ray Flashes (TGFs) and ELVES. TGFs are the most explosive events emitted by thunderstorms and have been usually observed by spacecraft, but the Auger surface detector have collected events with a morphology very different from that proper of EAS, that are likely downward TGFs. Ground observations are a crucial addition to detection in space, as detectors are closer to TGF sources, and a single event can be observed with several instruments which are complementary one to another. In this talk, I will discuss the comparison of the already collected data with simulations as well as the on-going work to adapt the data-taking system to detect TGFs. I will also discuss the status of the study of ELVES, upper atmospheric optical phenomena associated with thunderstorms, which we have detected since 2013 with the fluorescence detectors. We have recorded with unprecedented time and space resolution both single and double ELVES, the latter being classified using radial variation of the time gap and the photon flux ratio between flashes. The detection and classification algorithms were improved by detecting ELVES from closer lightning thanks to the three High Elevation Auger Telescopes, which observe the night sky with an enhanced time resolution at elevation angles between 30 and 60 degrees.

Primary authors: COLALILLO, Roberta; FOR THE PIERRE AUGER COLLABORATION

Presenter: COLALILLO, Roberta

Contribution ID: **165** Type: **Talk**

UHECR production in AGN jets

Thursday, 6 October 2022 11:10 (20 minutes)

Active galactic nuclei (AGNs) are one of the most promising sources for accelerating particles up to the highest energies. In this talk, we present a scenario in which cosmic rays are accelerated in multiple shocks created by the interaction of relativistic AGN jets with embedded massive stars. We solve the Fokker-Planck equation considering the spatial and radiative losses as well as the collective effect of the shocks and the reacceleration of the particles. Finally, we calculate the maximum energies that the particles can achieve and discuss the possibility of producing ultra-high energy cosmic rays in this astrophysical situation.

Primary authors: Ms MÜLLER, Ana Laura (ELI Beamlines, Institute of Physics of the Czech Academy of Sciences); Ms ARAUDO, Anabella (Montpellier Universe and Particles Laboratory, CNRS, and Institute of Physics of the Czech Academy of Sciences)

Presenter: Ms MÜLLER, Ana Laura (ELI Beamlines, Institute of Physics of the Czech Academy of Sciences)

Contribution ID: **166** Type: **Talk**

TERZINA on-board NUSES: a pathfinder for EAS Cherenkov Light Detection from space

Friday, 7 October 2022 10:50 (20 minutes)

UHECRs above 100 PeV might be detected from space by a mission pointing to the Earth limb when optical emission from extensive air showers is produced. Space-born detection might also play a relevant role in the multi-messenger field if detection of Earth skimming neutrinos will be ensured. The validation process for this detection of rare UHE events goes through precursors as the NUSES space mission, designed to be operated in a Sun synchronous, quasi-polar, low Earth orbit. On board the satellite platform, developed by TAS-I, there will be two payloads: TERZINA, discussed in this contribution, and ZIRE', devoted to low energy cosmic and gamma rays, space weather, and study of the magnetosphere-ionosphere-lithosphere coupling.

TERZINA is essential for the technological space validation of SiPM with their associated electronics, with a few ns resolution, thus enabling discrimination from the background night glow. It will also validate the optical system and provide background characterization, as well as measuring, for the first time, UHECRs from space, with a rate of hundreds events per year above 100 PeV.

Both scientific and technological outcomes will be very important in the design and optimization of future and bigger missions in the field.

Presenter: BURMISTROV, Leonid (UNIGE)

Contribution ID: **167** Type: **Review**

Transition from galactic to extragalactic CRs

Thursday, 6 October 2022 09:30 (30 minutes)

Understanding the transition from Galactic to extragalactic cosmic rays (CRs) is essential to make sense of the Local cosmic ray spectrum. Several models have been proposed to account for this transition in the 0.1 - 10 $\times 10^{18}$ eV range. For instance: *ankle models*, where the transition from a steep Galactic component to a hard extragalactic spectrum occurs in the $4 - 10 \times 10^{18}$ eV region, *dip models*, where the interactions of CR protons with the CMB producing electron-positron pairs shapes the ankle, or *mixed composition* models, in which extragalactic cosmic rays are composed of nuclei of various types.

In all these scenarios, the low-energy part of the transition involves the high-energy part of the Galactic component. Therefore, any information on the Galactic component, such as maximum energy, chemical composition, and spectrum after propagation, is crucial to understanding the Galactic-extragalactic transition.
We will briefly review the high-energy part of the CR spectrum expected from the best potential sources of Galactic CRs.

Primary author: CRISTOFARI, Pierre (Observatoire de Paris - IJCLab)

Presenter: CRISTOFARI, Pierre (Observatoire de Paris - IJCLab)

Contribution ID: **168** Type: **Review**

UHECR sources

Tuesday, 4 October 2022 09:00 (30 minutes)

This is an invited review talk.
Abstract text to be added.

Primary author: GLOBUS, Noemie (University of California Santa Cruz)

Presenter: GLOBUS, Noemie (University of California Santa Cruz)

Contribution ID: **169** Type: **Talk**

Cosmic Ray Knee Measurements with LHAASO

Monday, 3 October 2022 11:50 (20 minutes)

LHAASO as a complex of detector arrays has been built and operated for cosmic ray (CR) measurements in the energy range from 100 TeV to 100 PeV. The goals are measuring knees of individual species such as protons, helium and iron nuclei. Two key issues are the energy scale determination and separation of specific species from others in the air shower detection. Using the moon shadow in galactic CRs as a negative beam of charged particles that are deflected in geo-magnetic field, we have measured the energy scale at 21 TeV, the highest energy scale of CR measurements ever reached. We have studied multiple variables of air showers that characterize the development of cascades of particles in the atmosphere, such as the atmospheric depth of shower maximum using Cherenkov telescopes, muon content of showers and some lateral distribution parameters using ground arrays of detectors, thus, we develop the primary CR identification based on a multi-variable-analysis procedure. Some preliminary results are presented in this talk together with the status of the LHAASO experiment in the CR detection.

Primary author: CAO, Zhen (Institute of High Energy Physics)

Presenter: CAO, Zhen (Institute of High Energy Physics)

Contribution ID: **170** Type: **Talk**

Powerful Indirect Constraints on the Origins of UHECRs

Tuesday, 4 October 2022 14:20 (20 minutes)

As is now painfully evident, finding the sources of UHECRs is very challenging due to the combination of most UHECRs having intermediate masses, the precision of charge assignments being still crude, and deflections in the Galactic magnetic generally being large. These effects not only smear the images of individual UHECR sources but also lead to a non-trivial and poorly-constrained mapping between a source's direction and the arrival direction distribution of its UHECRs. In the face of this challenge, indirect information on the sources which is imprinted on the spectrum and composition of UHECRs as they emerge from the source surroundings, provides valuable additional information on the nature of the sources. This talk will discuss the resulting constraints on the physical properties of the environment surrounding the source, and a possible picture that emerges when also considering evidence on the number density and diversity of source types.

Primary authors: FARRAR, Glennys (NYU); MUZIO, Marco (NYU)

Presenter: FARRAR, Glennys (NYU)

Contribution ID: **194** Type: **Review**

Hadronic interactions studies at LHC

Wednesday, 5 October 2022 10:10 (30 minutes)

LHC results/projects with relevance for (UHE)CR physics will be covered, including some comparisons with hadronic interaction model/simulation predictions and recent progress in the field.

Primary author: PIEROG, Tanguy (KIT, IAP)

Presenter: PIEROG, Tanguy (KIT, IAP)

Contribution ID: **195** Type: **Review**

Beyond Standard Model physics with UHECRs

Wednesday, 5 October 2022 10:40 (30 minutes)

BSM physics with UHECRs

Primary author: KACHELRIESS, Michael (NTNU)

Presenter: KACHELRIESS, Michael (NTNU)

Contribution ID: **196** Type: **Talk**

Report from the WHISP group

Wednesday, 5 October 2022 11:40 (20 minutes)

Report from the WHISP group

Primary author: SOLDIN, Dennis (Karlsruhe Institute of Technology)

Presenter: SOLDIN, Dennis (Karlsruhe Institute of Technology)

Contribution ID: **197** Type: **Review**

Special Lecture - Cosmic Ray Physics at LNGS: a historical journey

Wednesday, 5 October 2022 09:40 (30 minutes)

Cosmic ray physics at LNGS, starting from late 80's

Primary author: PETRERA, Sergio (GSSI, L'Aquila)

Presenter: PETRERA, Sergio (GSSI, L'Aquila)

Contribution ID: **198** Type: **Poster**

UHECR Signatures and Sources

Presenter: Prof. DANIELE , Fargion