22nd International Symposium on Very High Energy Cosmic Ray Interactions (ISVHECRI 2024)

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Book of Abstracts

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The Cosmic Ray Extremely Distributed Observatory (CREDO) [Online]

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The Cosmic Ray Extremely Distributed Observatory (CREDO) is a recently formed, global collaboration dedicated to observing and studying cosmic ray ensembles (CRE): groups of minimum two cosmic rays with common primary interaction vertex or the same mother particle. The CREDO program embraces testing the known CRE scenarios, and getting ready to observe the unexpected physics, it is also suitable for multi-messenger and multi-mission applications. CRE could be formed both within classical models (e.g. as products of photon-photon interactions), and exotic scenarios (e.g. as results of decay of Super Heavy Dark Matter particles and subsequent interactions, Lorentz invariance violation), their fronts might be significantly extended in space and time, and they might include cosmic rays of energies spanning the whole cosmic ray energy spectrum. CRE are expected to be partially observable on Earth even if the initiating interaction or process occurs as far as ˜1 Gpc away, with a footprint composed of at least two extensive air showers with parallel arrival directions and correlated arrival times.
Since CRE are mostly expected to be spread over large areas over hundreds of kilometers or more, and because of the expected wide energy range of the contributing particles, CRE detection might only be feasible when using the available cosmic ray infrastructure collectively, i.e. as a globally extended network of detectors. CREDO is perfectly suited for probing the variation of fundamental constants in the aforementioned physical processes as well as for other applications like the search for signatures of Earthquake precursors within the flux of cosmic rays.

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Constraining astrophysical sources of intermediate-mass UHECR

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Constraining the astrophysical source populations of Ultra High Energy Cosmic Rays (UHECRs), CRs with energy higher than 10^{18}eV (1 Exa eV or EeV), is difficult because UHECRs deflect by the Galactic Magnetic Field (GMF).
Recent interpretations of cosmic-ray-produced air showers with hadronic interaction models suggest a gradual increase in the mean mass of UHECRs with energy. The decades-old view of UHECRs being a mix of hydrogen and iron (with relative composition varying with energy) also expands to consider intermediate nuclear compositions. Notably, while hydrogen and iron UHECRs have expected mean free paths of $\sim$ 100Mpc, intermediate composition UHECRs have mean free paths of only 10s of Mpc. %, further reducing the original source distances of UHECRs.

Sotomayor et al.2023 used Monte-Carlo simulations of H, O, and Fe composition UHECR tracks in 8 proposed GMF models to estimate deflections suffered by the UHECRs detected by the Pierre Auger Observatory and the Telescope Array. These deflections can identify sub-samples of 'least-deflected' UHECRs relatively independent of the assumed GMF model. The distribution of the GMF-deflection-corrected arrival directions of this 'least deflected' sample was correlated with astrophysical catalogs. There was a strong association between the (GMF-deflection-corrected) arrival directions of 'least deflected' UHECRs with nearby (D ≤ 20 Mpc) galaxies when considering an oxygen UHECR composition.
This work continues the analysis of Sotomayor et al. 2023, using O, a high-abundance intermediate mass species, H, and Fe samples. The correlation is replaced by a likelihood test approach. Instead

of a distance cutoff, a weight proportional to a property is attenuated following Allard et al. 2008 results. It is proposed to account for the effect of the magnification of the flux outside the Galaxy due to GMF.
Until now, the anisotropy of the out-of-Galaxy UHECR distribution of oxygen composition, under the GMF BSS model is consistent with the distribution of SM and SFR of the nearby universe.

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Hadronic origin TeV afterglow from GRB 221009A

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Gamma-ray burst (GRB), GRB 221009A, a long-duration GRB, was observed simultaneously by the Water Cherenkov Detector Array (WCDA) and the Kilometer Squared Array (KM2A) of the Large High Altitude Air Shower Observatory (LHAASO) during the prompt emission and the afterglow periods. Characteristic multi-TeV photons up to 13 TeV were observed in the afterglow phase. The observed very high-energy (VHE) gamma-ray spectra by WCDA and KM2A during different time intervals and in different energy ranges can be explained very well in the context of the photohadronic model with the inclusion of extragalactic background light models. In the photohadronic scenario, interaction of high-energy protons with the synchrotron self-Compton (SSC) photons in the forward shock region of the jet is assumed to be the source of these VHE photons. The observed VHE spectra from the afterglow of GRB 221009A are similar to the VHE gamma-ray spectra observed from the temporary extreme high-energy peaked BL Lac (EHBL), 1ES 2344+514 only during the August 11 and the August 12 of 2016 and are new, first among their kinds in the GRB context. In future, from the observations of many more GRBs in VHE at low redshifts, we expect to identify some of them with a two-zone VHE emission, features similar to the ones observed in the several nearby transient EHBL-like sources.

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Investigating Muon Content in Extensive Air Showers using Pythia 8

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The field of air shower physics dedicated to understanding the development of cosmic-ray interactions with the Earth’s atmosphere faces a significant challenge regarding the muon content of air showers observed by the Pierre Auger Observatory. Thorough comparisons between extensive air shower (EAS) measurements and simulations are imperative for determining the primary energy and mass of ultra-high energy cosmic rays. Current simulations employing state-of-the-art hadronic interaction models reveal a muon deficit compared to experimental measurements, commonly known

as the "Muon Puzzle". The primary cause of this deficit lies in the uncertainties surrounding high-energy hadronic interactions.

In this contribution, we propose the integration of a new hadronic interaction model, Pythia 8, into the effort to resolve the Muon Puzzle. While the Pythia 8 model is well-tailored in the context of Large Hadron Collider experiments, its application in air shower studies remained limited until now. However, recent advancements, particularly in the Angantyr model of Pythia 8, offer promising enhancements in describing hadron-nucleus interactions, thereby motivating its potential application in air shower simulations.

We present results from EAS simulations conducted using Corsika 8, wherein Pythia 8 is employed to model hadronic interactions.

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Neutrinos from muon-rich ultra high energy electromagnetic cascades: The MUNHECA code [Online]

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Unveiling the still unknown ultra high energy astrophysical sources in the sky greatly benefits of a multimessenger approach, combining information from charged cosmic rays with the one carried by photons and neutrinos. However, implementing this approach necessitates a thorough understanding of the microphysics processes shaping the spectra and energy distribution across these species. In this context, we have recently studied a purely leptonic channel for production of ultra high energy neutrinos, the electromagnetic cascade, linked to muon-producing QED processes.
In this presentation I will introduce a public python3 code, MUNHECA, to compute the neutrino spectrum by taking into account various QED processes, with the electromagnetic cascade developing either along the propagation in the cosmic microwave background in the high-redshift universe or in a predefined photon background surrounding the astrophysical source.

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Determination of Pseudo-redshifts to Long GRBs by the Guiriec Method [Online]

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Gamma Ray Burst (GRBs) are brief and highly energetic gamma ray explosions, which can be classified into short and long bursts based on their duration. Long GRBs last more than two seconds, and are believed to originate from the collapse of massive stars. Determining the distances to GRBs is challenging due to the current limitations of optical telescopes; only approximately 11% of the redshifts of known GRBs have been recorded. The Guiriec method for estimating pseudo-redshifts to GRBs is based on an empirical correlation between the spectral parameters within a fine time analysis and the total released energy in episodes of the burst. This work analyzes a sample of long GRBs using Guiriec's method to determine their pseudo-redshifts. This project was accomplished thanks to the support of the PAPIIT IG101323 project.

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Preliminary atmospheric effects through air showers at Agra using DEASA experiment [Online]

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Dayalbagh Educational Air Shower Array is the first detector array in Northern India (Uttar Pradesh) to study cosmic rays. Investigations of the physical behaviour of the cosmic ray variations in various time scales are an important aspect of cosmic ray astronomy. In other words, the modulation of cosmic rays is an important tool for investigating disturbed behaviour in the heliosphere. Longer time scales are related to solar activities of the solar cycle, while shorter time variations can be associated with Earth's atmospheric phenomena.

In this paper, the atmospheric temperature and pressure effect on count rates of DEASA detectors for 7 hours daily spanning 170 days. These detectors have been calibrated since January 2022 and are located at Agra, India (27.18O N, 78.02O E, 170 m above sea level) where the geomagnetic rigidity cut-off value is 22 GV. The barometric coefficient obtained from the graph of atmospheric pressure vs count rates is -1.14 /mbar and the temperature coefficient is 0.4/ degree C. The skewness and kurtosis for pressure distribution were -0.91 and -0.18, for temperature distribution were 0.40 and -1.05, and for count rates were -1.22 and 1.23.

Further, linear regression analysis has been performed, and a scatter plot between relative intensity vs time, relative pressure vs time, and relative temperature vs time. Added graphs between the relative intensity of cosmic ray flux and pressure and temperature respectively are shown and coefficients are compared with other experiments.

Air showers have been simulated by CORSIKA code at specifications of Agra with iron, proton, and alpha as the primary particles. The longitudinal profile of the showers at different atmospheric depths is studied. The Monte Carlo simulation code provides hadronic interaction models at higher energies. EPOS model with QGSJET and later DPMJET models have been selected for the studies. The lateral profile of the showers is also plotted. The muon charge ratio has been observed from the output generated in CORSIKA.

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Impact of the Magnetic Horizon on the Interpretation of the Pierre Auger Observatory Spectrum and Composition Data

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Ultra-high energy cosmic rays (UHECR) exceeding the ankle energy (5 EeV) can be described as a mixture of nuclei with very hard spectra and a low rigidity cutoff. Extragalactic magnetic fields are expected to affect the observed spectrum of cosmic rays by reducing the flux of low-rigidity particles reaching Earth. We present a combined fit to the UHECR spectrum and the distributions of the depth of the shower maximum measured by the Pierre Auger Observatory, incorporating the influence of the magnetic horizon effect. We find that a softer spectrum of accelerated particles at the sources with a shape closer to E^{-2} as expected from diffusive shock acceleration, can explain the observations above the ankle energy provided that the inter-source distances are large and the intergalactic magnetic fields between the closest sources and the Earth are strong. Additionally, a

distinct UHECR population with a softer spectrum and higher source density is required to reproduce the entire observed spectrum ($E > 0.6\,\mathrm{EeV}$) and composition data. This population is likely extragalactic and dominates the flux at EeV energies.

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Status and First Results from the KM3NeT neutrino telescope [Online]

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KM3NeT is a distributed research infrastructure under construction in abyssal sites of the Mediterranean Sea that hosts two underwater neutrino telescopes: ARCA, located offshore Portopalo di Capo Passero in Italy and ORCA, located offshore Toulon in France. Both telescopes employ the same photon detection technology, using spherical optical modules based on the innovative multi-PMT design. The optical modules are arranged in vertical string-like structures, the detection units which are anchored at the seabed. ARCA and ORCA configurations are opitmised according to different physics cases. ARCA is targeted to the detection of neutrinos with energies in the TeV-PeV range coming from astrophysical sources, while ORCA aims at studying the atmospheric neutrino oscillations at energies of a few GeV. In this talk, the status of ARCA and ORCA is presented and the results obtained using data taken with the first detection units are discussed.

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High-energy Hadronic Interaction Models: Insights from the Pierre Auger Observatory

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Our knowledge about the primary composition of ultra-high-energy cosmic rays (UHECRs) relies heavily on our understanding of extensive air showers and the hadronic interactions governing their development. The Pierre Auger Observatory, the world's largest facility for studying UHECRs, employs various techniques to analyze shower characteristics, which can be exploited to infer the composition of the primary particle. These multi-hybrid measurements have been instrumental in assessing the performance of post-LHC tuned models of hadronic interactions, revealing unexpected phenomena such as an apparent deficit of muons in simulations compared to observed data. In this presentation, I will review these experimental endeavors, discuss their findings, and outline the Observatory's potential to further refine the parameters of hadronic interaction models in the future.

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Investigating the hadron nature of high-energy photons with PeVatrons [Online]

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In high energy Gamma-Ray Astronomy with shower arrays the most discriminating signature of the photon-induced showers against hadron-induced cosmic-ray ones is the content of muons in the observed events.
In the electromagnetic γ-showers the muon production is due to the dominant channels: photo-production of pions followed by the decay $\pi \rightarrow \mu\nu$, prompt leptonic decay of charmed particles in the shower, and electromagnetic pair production $\gamma \rightarrow \mu^+\mu^-$.
The number of muons is typically a few percent of that in a hadron showers where muons are abundantly generated by charged pions decay.

In high energy photo-production process the photon exhibits an internal structure which is very similar to that of hadrons, with a small relative probability of order α ($\simeq$ 1/137).
Indeed, photon-hadron interactions can be understood if the physical photon is viewed as a superposition of a bare photon and an accompanying small hadronic component which feels conventional hadronic interactions.

Information on photo-production γp and $\gamma\gamma$ cross-sections are limited to $\sqrt{s} \leq$ 200 GeV from data collected at HERA. Starting from $E_{lab} \approx$ 100 TeV the difference between different extrapolations of the cross sections increases to more than 50\% at $E_{lab} \approx 10^{19}$ eV, with important impact in the observables used to select the photon-initiated air showers.

Recently, the LHAASO experiment opened the PeV-sky to observations detecting a number of PeVatrons in a background-free regime starting from about $E_{lab} \approx$ 100 TeV. This result provides a beam of pure high energy primary photons allowing to measure for the first time the photo-production cross section even at energies not explored yet.
The future air shower array SWGO in the Southern Hemisphere, where the existence of Super-Pevatrons emitting photons well above the PeV is expected, could extend the study of the hadron nature of the photons in the PeV region.

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High Energy Neutrinos studies in the forward direction with the FASER experiment at the LHC

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The LHC collides protons with a centre-of-mass energy of 13.6 TeV, which corresponding to about a 100 PeV proton irradiation onto a fixed target proton. In these collisions a huge number of hadrons are produced in the forward direction.
The FASER experiment studies the decay products of these hadrons, 480m away from the collision point. These could include beyond Standard Model particles such as dark photons or axion like particles, but also Standard Model particle, ie. high energy neutrinos from pion, kaon and charm hadron decays. The detected neutrinos can provide valuable information on high energy forward hadron production, which is currently poorly studied or in some cases unknown. The energy of the neutrino's is several hundred GeV to a few TeV, where no experimental results exist. The neutrino target of FASER is an Emulsion Cloud Chamber (FASERnu) with tungsten acting as the active target allowing all three neutrino flavours, electron-, muon-, tau-, to be measured with clear separation. The momenta of charged particle tracks from the neutrino interaction products and electro-magnetic shower energy can be measured in the FASERnu detector. The neutrino target is followed by a spectrometer with air core di-pole magnets providing muon charge and momentum measurements. Recently, FASER has made the first muon and electron neutrino cross-section measurements from the LHC collisions. Here, I will discuss the FASER experiment and present the results from the high energy neutrino analysis.

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POEMMA-Balloon with Radio: a balloon born Multi-Messenger Observatory

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The POEMMA-Balloon with Radio (PBR) mission has been designed to address several key questions in astrophysics. Specifically, PBR aims to observe the fluorescence emission of Extensive Air-Showers (EASs) produced by Ultra-High-Energy Cosmic Rays from sub-orbital altitudes. Additionally, PBR intends to observe a large number of high-altitude horizontal air-showers to measure the cosmic-ray spectrum around 0.5 PeV and above. Furthermore, PBR will search for astrophysical neutrinos following multi-messenger events by detecting upward-going EASs, potentially generated by tau-neutrino interactions inside the Earth.
The telescope design of PBR includes a Fluorescence Camera, a Cherenkov Camera, and a Radio Instrument optimized for EAS detection. PBR builds upon the conceptual design of the Probe Of Extreme Multi-Messenger Astrophysics (POEMMA) mission, which has been scaled and refined to serve as a payload on one of NASA's Super Pressure Balloons, circling over the Southern Ocean for up to 100 days after launching from Wanaka, New Zealand. Drawing from previous mission experiences, PBR aims to advance the technical readiness of future missions while exploring multi-messenger science from sub-orbital altitudes.
This contribution will provide an overview of the mission's science goals, instruments, and the current status of PBR.

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Hadronic Interactions in CRPropa with state-of-the-art generators

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CRPropa 3.2, released recently, is the latest update in a continued effort to maintain and extend this open-source code well known in the cosmic-ray community. Originally aimed at simulating the ballistic propagation and interactions of Ultra-High Energy Cosmic Rays (UHECRs), today it can handle diffusive propagation of cosmic rays in a variety of magnetic fields, deal with stochastic cosmic ray acceleration, model electromagnetic cascades for gamma ray emission and transport, among other capabilities. Of special interest is the introduction of hadronic interactions to facilitate the treatment of cosmic ray interactions in the galaxy and within the sources. This talk provides an up-to-date overview of the code and details the recently implemented hadronic interactions in the context of bursting sources of UHECRs.

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A new air shower array in the Southern Hemisphere looking for the origins of Cosmic rays: the ALPACA experiment

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In 2019 the Tibet ASγ collaboration reported the detection of sub-PeV γ-rays coming from the Crab nebula using a novel technique with a hybrid Surface Array and underground water Cherenkov muon detector to discriminate against hadrons. Using this technique, we are now building a new experiment to explore the gamma-ray sky in the Southern Hemisphere looking for the origins of cosmic rays in our Galaxy. The name of this new project is the Andes Large area PArticle detector for Cosmic ray physics and Astronomy (ALPACA).

Installed at an altitude of 4740 m in the Chacaltaya plateau, ALPACA will cover an area of 83 000 m^2 with 401 scintillation counters and 4 underground muon detectors of 900 m^2 each. A prototype array called ALPAQUITA, having 1/4 of the total area of the full ALPACA, started observations in September 2022. The first MD is expected to start operations this year.

In this presentation we will introduce the current status of ALPAQUITA and the plans to extend the array to reach the full operation of the experiment. We will also report the results of the analysis of the initial data, including the observation of the moon shadow in cosmic rays and search for bright gamma-ray sources.

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On the correlation between X-rays and TeV gamma-rays in HBL Blazars

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Correlations between the fluxes of X-rays and TeV gamma-rays in blazars have been reported by observational studies. These correlations are expected in the context of the leptonic Synchrotron Self-Compton (SSC) model. The high-frequency peaked BL Lac object (HBL) blazar Mrk 421 exhibits a linear correlation between these two energy ranges. However, this correlation breaks down at the highest gamma-ray fluxes, suggesting the involvement of additional mechanisms such as hadronic and lepto-hadronic contributions. Understanding the strength of the correlation between X-rays and gamma-rays can provide insights into the relative contributions of these mechanisms responsible for the gamma-ray emission in blazars. In this study, we extend the analysis to four HBL blazars: Mrk 501, 1ES 1959+650, PKS 2155-304, and 1ES 2344+514, utilizing gamma-ray data from ground-based Imaging Atmospheric Cherenkov Telescopes and X-ray data from satellite observations at different epochs and testing different correlation models. Our analysis reveals flux correlations described by a power law function with indices ranging from 1 to 2, similar to the observed correlation in Mrk 421. A deviation from the correlation is also observed at high-energy gamma-ray fluxes. This research was supported by the UNAM-PAPIIT project number IG101323 and the Gestiona I+D 02-2021 project of the Secretaría Nacional de Ciencia y Tecnología de Guatemala (SENACYT).

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Top-Down reconstruction of extensive air showers: a method to quantify the rescaling of the muon signal of hadronic interaction models

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Over the past twenty years, multiple astroparticle experiments have reported an excess of muons in the measurements of extensive air showers when compared to predictions derived from hadronic interaction models calibrated to LHC data. Such a discrepancy has deep implications regarding the interpretation of mass composition studies, and a better understanding of its origin would provide valuable insight into the physics of particle interactions at energies beyond the reach of human-made accelerators. At the Pierre Auger Observatory, the signal recorded by ground particle detectors consists of the electromagnetic and the muonic components. The detection of the fluorescence light emitted by air showers offers a precise characterization of the former through the measurement of the longitudinal profile. In this study, we propose a Monte Carlo simulation scheme where the longitudinal profile of a given shower is matched in order to identify the muons as the sole responsible for any discrepancy found in ground particle detectors' signal at 1000 m from the shower core. Performed for a given energy bin and for a given hadronic interaction model, such a procedure –also referred to as Top-Down reconstruction –allows us to estimate the amount by which the average muon signal of different simulated primaries must be rescaled in order to match the one of a dataset composed of observed or simulated air showers. Consequently, we can determine the quantity by which the Heitler-Matthews β coefficient of the selected hadronic model must be altered. Here, we consider a mock dataset composed of air showers simulated with the Sibyll* hadronic model, a variant of Sibyll 2.3d that produces ~35-40% more muons, and with proton and iron primaries of ~10 EeV. These showers are reconstructed with the Pierre Auger Observatory software, optimized for fluorescence and ground detectors. We test the Top-Down method by assuming the Sibyll 2.3d hadronic interaction model, and investigate how well the difference in the predicted muon signal is recovered.

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Recent Results of sub-PeV Gamma Ray Observation with the Tibet ASgamma Experiment

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The Tibet Air Shower (AS) array and the underground water-Cherenkov-type muon detector (MD) array have been operating successfully since 2014 at an altitude of 4,300 m in Tibet, China. The primary energy and arrival direction are determined by the surface AS array, while the MD array enables us to drastically reject background cosmic rays by counting the number of muons in an air shower. In 2019, using these Tibet AS+MD arrays, we succeeded for the first time in observing gamma rays above 100 TeV (sub-PeV) from the Crab Nebula [Amenomori et al. PRL, 123, 051101 (2019)]. On the other hand, it is believed that there are PeVatrons in our Galaxy, which accelerate PeV cosmic rays. PeV cosmic rays accelerated by the source interact with surrounding molecular clouds and emit sub-PeV gamma rays through neutral pion decay. Therefore, sub-PeV gamma-ray observations are crucial for PeVatron searches. In this presentation, we will review recent sub-PeV gamma-ray observations with the Tibet ASgamma experiment and discuss the most powerful cosmic-ray source, the "PeVatron," in our Galaxy.

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Estimation of the cosmic-ray mass composition and proton-proton interaction cross sections from air shower data measured by the Pierre Auger Observatory

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The atmospheric depth at which the number of particles in a shower reaches its maximum, $X_{\max}$, is an observable that is highly sensitive to the cosmic-ray mass composition and the characteristics of hadronic interactions throughout the development of the extensive air shower in the atmosphere. The shower maximum provides information about the type of nuclei that initiated the shower and is also directly related to the depth of the first interaction in the atmosphere, which provides a measure of the ultra-high energy hadronic cross sections.

In this contribution, we discuss the results of the measurements of the cosmic-ray mass composition and estimation of the proton-proton interaction cross sections at ultra-high energies from the $X_{\max}$ distributions as observed by the fluorescence detector of the Pierre Auger Observatory. The interpretation of the latest $X_{\max}$ data in terms of the evolution of the elemental fractions with energy is presented. The estimated proton-proton cross sections are compared with the predictions of existing hadronic interaction models and are in good agreement with extrapolations from lower energy accelerator data and the previous air shower measurements. Additionally, we explore further possible improvements to the analysis.

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Unveiling New Physics with Tau Leptons: Innovative Approaches at Belle II

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Abstract:

In the quest to explore new physics beyond the Standard Model of particles (BSM), the Belle II experiment at the SuperKEKB collider stands as a pivotal platform for investigating the frontiers of particle physics. With an unprecedented dataset of tau-lepton pairs, this study presents three distinct approaches aimed at unraveling the mysteries of BSM phenomena through tau-lepton decays.

Firstly, we introduce a search for lepton-flavor-violating decays of the tau lepton to a lepton and an invisible spin-0 boson. Utilizing a dataset with an integrated luminosity of 62.8 fb^{-1} at a center-of-mass energy of 10.58 GeV, we set stringent upper limits on the branching-fraction ratios for tau decays to an electron or muon plus an invisible boson, significantly improving upon previous bounds.

Secondly, we propose a new method to enhance the search for invisible BSM particles in tau decays. By meticulously analyzing the kinematics of tau pair decays, our approach offers a substantial improvement in the sensitivity to tau decays to a lepton and an undetected massive particle, expanding the potential to probe BSM physics in both 3×1 and 1×1 prong tau decays.

Lastly, we present the most precise measurement of the tau-lepton mass to date, achieved through the analysis of a large sample of electron-positron collisions producing tau pairs. The measurement is based on the kinematic edge of the tau pseudomass distribution in the decay to three pions and neutrinos, leveraging the full potential of the 190 fb^{-1} dataset used in this study.

Together, these studies exemplify the power of innovative analytical techniques in extracting the maximum information from the rich Belle II dataset, paving the way for new discoveries and a deeper understanding of the fundamental constituents of our universe.

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Design, manufacturing and installation of multi-PMT vessel for Hyper-Kamiokande

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Hyper-Kamiokande (Hyper-K) is a cutting-edge water Cherenkov detector 70 m tall and 70 m in diameter using 260,000 metric tons of ultra-pure water to detect neutrinos from accelerators, cosmic phenomena, and atmospheric activities. It aims to explore CP violation in neutrino oscillations, determine neutrino mass hierarchy, and investigate proton decay. As the far-detector in Japan's 300 km long-baseline neutrino experiment, it works in tandem with the proposed Intermediate Water Cherenkov Detector (IWCD), located 1-2 km from the J-PARC neutrino source, to address flux and cross-section uncertainties.

Innovations at Hyper-K include the development of multi-PMT (mPMT) optical modules, each containing 19 small (3-inch) photomultiplier tubes within a pressurized vessel, enhancing the detector's resolution and timing precision. Planned production includes around 2000 modules, enhancing the capabilities of the Hyper-K detector array. These mPMTs offer superior spatial and temporal resolution over traditional single large (20-inch) PMTs and are designed with unique orientations to improve photon directionality tracking, noise discrimination, and event reconstruction. This presentation will cover the mechanical design, assembly, and testing of these mPMT prototypes produced by the Hyper-K international community and the potential for large-scale production and installation.

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Results from the first 8.5 years of operation with CALET

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CALorimetric Electron Telescope, CALET, is an astroparticle physics experiment installed on the International Space Station. Its scientific objectives include searching for possible nearby sources of high-energy electrons and dark matter signatures, as well as studying the details of galactic cosmic-ray acceleration and propagation in the Galaxy. CALET measures cosmic-ray electron and positron spectrum up to 20 TeV, gamma-rays up to 10 TeV, and nuclei up to 1000 TeV. The instrument features a 30 radiation length thick calorimeter with fine shower imaging capability, providing excellent energy resolution of 2% for electrons and gamma-rays and outstanding electron identification capability from background protons. CALET is also capable of charge identification with single-element resolution and energy measurement, covering a wide energy range of six orders of magnitude from 1 GeV to 1 PeV. Since its start of operation in October 2015, CALET has been accumulating scientific data without any major interruptions. In this contribution, we present results from CALET's first 8.5 years of operation, including the electron + positron energy spectrum, proton and other nuclei spectra, gamma-ray observations, as well as on-orbit performance. Additionally, some results on the electromagnetic counterpart search for gravitational wave events and observations of solar modulation are included.

Contributed talks / 29

Mean number of TeV muons in air showers measured with IceTop and IceCube

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IceCube is a cubic kilometer detector buried in the Antarctic ice at the South Pole. Combined with its surface component, IceTop, it constitutes a unique detector for air-shower physics in the PeV to EeV primary energy regime. In this contribution, a recent measurement of the mean multiplicity of muons with energies above several 100 GeV (”TeV muons”) in near-vertical air showers seen in coincidence between IceTop and IceCube is reported. The results are found to be in agreement with expectations from simulations based on the hadronic interaction models used in the analysis: Sibyll 2.1, and the post-LHC models QGSJet-II.04 and EPOS-LHC. However, inconsistencies with other air-shower observables are found for all considered models. Notably, the observed density of GeV muons at large lateral distance in IceTop indicates a lighter cosmic-ray mass composition than the high-energy muon measurement.

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QGSJET-III: predictions for extensive air shower characteristics and the corresponding uncertainties

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Results of the QGSJET-III Monte Carlo generator, regarding calculated characteristics of extensive air showers (EAS) initiated by very high energy cosmic rays, are presented in comparison to the corresponding predictions of other cosmic ray interaction models. A quantitative analysis of uncertainties for such predictions is performed, notably, regarding possibilities to enhance the EAS muon content or to delay the air shower development.

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Calculation of Long Gamma-Ray Burst Pseudo-Redshifts using the Amati Correlation

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Gamma-ray bursts (GRBs) are high-energy events that release isotropic energy on the order of 10^{48} - 10^{55} erg. They are classified into long or short bursts depending on their observed duration. Long GRBs have a duration (t_{90}) greater than 2 seconds, and their progenitors are associated with the collapse of massive stars (collapsars).

Distances are only known for a small number of GRBs. Empirical correlations have led to various methods for obtaining pseudo-redshift calculations. One of the most well-studied correlation is the

$E_{peak} - E_{iso}$ correlation, also known as the Amati correlation, which relates the peak energy of the Band function of the $\nu F \nu$ spectrum in the GRB frame to the equivalent isotropic energy for long GRBs.

In this work, a sample of long GRBs from the Fermi telescope catalogue is analized, and the Amati correlation is used to infer pseudo-redshifts. This research was supported by the UNAM-PAPIIT project number IG101323.

Contributed talks / 33

Neutrino Classification Through Deep Learning

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Neutrinos are a kind of subatomic particle that has become widely studied in several experiments around the world because of its characteristics of only interacting via the so-called weak-interactions and presenting a special behavior called oscillation. It is expected that by analyzing them we could gather insight into some of the Universe's mightiest enigmas such as confronting elementary particle unification theories and the mysteries of the Universe's evolution. The way in which neutrinos are studied in some of such international experiments is by gathering the data of the Cherenkov radiation that neutrinos produce when they collide with the charged particles within the ultra-purified water contained in the detection tanks of the observatories developed to analyze them, this radiation commonly has the shape of a ring or a cone. The first step after gathering the data in the detector is to reconstruct the event, which implies the identification of particle types and the determination of properties of the detected particle such as energy levels and the position and direction of travel of the particle when its detected. Hence, we propose this project where the aim is to improve the identification of the type of neutrino involved in an event by employing deep learning architectures, which are VGG19, ResNet50, PointNet and Vision Transformer. These architectures are trained and tested using simulated data of single-ring neutrino events and corresponding to a detection tank called Intermediate Water Cherenkov Detector or IWCD which is currently being built in Japan as part of the Hyper-Kamiokande Collaboration, the simulated data are contained within h5 files and range from 9 thousand to 8 million events per type of particle. After training the models, different evaluation metrics were computed to properly compare the architectures among themselves and with the ones found in the state of art to determine which of all the models, if any, classified neutrinos the best.

Contributed talks / 34

Production and propagation of secondary antinuclei in the Galaxy

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The AMS-02 experiment, a multipurpose cosmic ray detector on board the International Space Station since 2011, has reported having detected 7 candidates for antideuterons, 6 antihelium-3, and 3 antihelium-4 during nearly 12 years of operation [1]. Their origin is an open question, on one side their production in cosmic ray interactions (secondary production) is predicted to follow a hierarchy from lighter to heavier antinuclei that measurements seem to avoid. On the other hand, theories beyond the Standard Model predict antinuclei production at low energies (<1GeV/n), orders

of magnitude above secondary production [2]. Studying the effects of production and absorption cross-sections for antinuclei and their uncertainties in the Galaxy is fundamental to understand the origin of these observations.
This work reviews the current state of the antinuclei production cross-sections in cosmic ray interactions and its uncertainties, considering the coalescence model and recent measurements in accelerator experiments. These cross-sections have been included in a simulation of antinuclei propagation in the Galaxy using GALPROP v57 [3], where an updated diffusive reacceleration model was taken into account. Estimations of the expected antinuclei fluxes at Earth are presented.

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Exploring the Cosmic Frontiers: IceCube's Update on Neutrinos and Cosmic Rays

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The IceCube Neutrino Observatory detects particles produced from cosmic rays and neutrinos to explore the high-energy universe. The deep in-ice array consists of 5160 light sensors instrumenting a cubic kilometer of South Pole ice at depths between 1.5 and 2.5 kilometers measuring high-energy neutrino interactions and PeV muon bundles from cosmic ray air showers. The deep detector is complemented by IceTop, a square kilometer surface detector directly above the in-ice array. IceTop enables a wide range of cosmic ray science and serves as a veto for identifying neutrino events. An overview of recent results from IceCube and IceTop will be presented, including recent results about high-energy neutrino sources as well as updates on the measurement of the high-energy cosmic ray flux, mass composition and anisotropy. Additionally, an outlook on the planned high-energy extension IceCube-Gen2 will be given as well.

Contributed talks / 37

Constraints from the Pierre Auger Observatory on BSM scenarios generating UHE nu_tau, tau, and tau-like particles

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The Fluorescence Detector (FD) of the Pierre Auger Observatory provides a large exposure for the detection of ultra-high-energy (UHE) upward-going showers (UGS) as suggested by the "anomalous" events reported by ANITA. Recently, strong limits on UGS were obtained using 14 years of FD data, which are in tension with the observations made by ANITA-I and III. Later, ANITA-IV has reported new UGS candidates. Both of these observations motivate the exploration of beyond standard model (BSM) scenarios. In this work, we explore the parameter space to test three classes of BSM models.

These unknown BSM particles can interact inside the Earth and produce ν_τ , τ, or τ-like particles which can further interact or decay. Some of their final products may escape the Earth and induce a UGS in the atmosphere. Due to the non-observation of the UGS by the FD, upper flux limits of these types of UHE BSM particles are obtained as a function of their possible cross-sections with matter. In addition, stronger constraints are achieved by combining the surface detector and FD data of the Pierre Auger Observatory.

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A measurement of the muon number of extensive air showers from cosmic ray collisions using the data from KASCADE-Grande

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Recent analyses of the muon content in extensive air showers produced by cosmic rays above 100 PeV reveal an excess in the data in comparison with Monte Carlo (MC) simulations. These differences point out problems of the high-energy hadronic interaction models, which are not yet understood. In this regard, measurements of different experiments are important, since they could provide some clues to find the origin of the anomaly. This way, the measurements of the muon data from KASCADE-Grande could be helpful. In this analysis, we provided measurements of the total muon number of hadronic air-showers as a function of the primary energy from 100 PeV to 1 EeV and for three zenith-angle intervals [0°, 21.78°], [21.78°, 31.66°] and [31.66°, 40°]. The data was measured with the KASCADE shielded array for threshold energies of 230 MeV (vertical incidence). For energy calibration, we used as a reference the predictions of the MC simulations for the Global Spline Model of cosmic rays, shifted in energy to match the spectrum of Pierre Auger observatory. The analysis was carried out using the expectations from the QGSJET-II-04, EPOS-LHC and SIBYLL 2.3d hadronic interaction models. When comparing with the model predictions for iron and hydrogen nuclei, we found no excess of the measurements on the muon number, on the contrary, a deficit in the data is observed for vertical showers, and a reasonable agreement with the data for inclined events. We also found that the measured muon content in air showers has a smaller effective attenuation in the atmosphere than predicted by MC simulations in agreement with a previous KASCADE-Grande result on the attenuation length of shower muons.

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EPOS LHC-R : up-to-date hadronic model for EAS simulations

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The hadron production in the simulation of extensive air showers is a long standing problem and the origin of large uncertainties in the reconstruction of the mass of the high energy primary cosmic rays. Hadronic interaction models re-tuned after early LHC data give more consistent results among each other compared to the first generation of models, but still can't reproduce extended air shower data (EAS) consistently. Ten years after the first LHC tuned model release, much more detailed data are available both from LHC, SPS and hybrid air shower measurements allowing to understand some deficiencies in the model. Properly taken into account in the new EPOS LHC-R, it leads to a change in both Xmax and the muon production by air showers. A careful study of the hadronization mechanism is important for the muon production while an update of diffraction and nuclear fragmentation is changing the Xmax distribution. The detailed changes introduced in EPOS LHC-R will be addressed and their consequences on EAS observable.

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Overview on ALICE highlights and synergy with cosmic rays

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This talk will explore key highlights from the ALICE experiment at CERN's Large Hadron Collider (LHC) and its connection to cosmic ray physics.

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Machine learing model for discrimination of simulated muonic traces in water cherenkov detectors

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This article presents a novel technique for discriminating the muonic component within extensive air showers (EAS) using water Cherenkov detectors (WCDs) situated at the surface detector array of the ALPACA experiment. The WCD used in this study boasts a capacity of 20,000 liters and is equipped with a photomultiplier tube (PMT) mounted on its top. With Monte Carlo simulations of both the EAS and the WCD, we obtain the temporal distribution of photons generated in the detector by the passage of particles, termed as "traces". These traces are subsequently parameterized and fed into a machine learning algorithm based on binary regression, which categorizes traces that include muons from those that lack muons. The accuracy rate obtained is 70%, which is comparable to the results of other studies that use similar techniques.

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The complex nature of the abnormally weak absorption of cosmic ray hadrons in lead calorimeters at superhigh energies [Online]

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In the course of further processing of data from two similar cosmic ray experiments, carried out in the Tien Shan and Pamir mountains using calorimeters, represented by 2-tier X-ray emulsion chambers (XRECs) with large air gaps (2.12 and 2.5 m, respectively), were obtained distributions of numbers of blackening spots, created by electron-photon cascades (EPCs) on X-ray films, according to the hadron observation depth in the chamber.

These distributions, in principle, are in good agreement with each other, taking into account other smaller differences in the design of the two XRECs, different sensitivities of the films used, as well as different depths of the XREC location in the Earth's atmosphere (3340 m and 4370 m, respectively).

On the other hand, the obtained experimental distributions are also well reproduced by model calculations performed within the framework of the phenomenological model of strong interactions FANSIY 1.0, which takes into account the production of charmed hadrons and the rapid increase in their production cross section with the energy of colliding particles, observed in the LHC experiments. Computer modeling of experiments also include detailed simulations of the response of XREC of a particular design.

In particular, taking into account the production of charmed hadrons, which effectively decay in the air gap between two lead blocks of the calorimeter through electromagnetic channels with the emission of electrons and gammas, makes it possible to qualitatively and quantitatively describe the experimentally observed peak in the distribution curves at a depth of t_0 = 9.0 c.u. The amplitude of this peak, sensitive to the cross section for the production of charmed particles, makes it possible to conclude that the cross section σ_{pp→cc̄} ˜ 8 mb at <E$_{Lab} > ˜75TeVandatx_\{Lab\}$ 0.1.

An unexpected result of both experiments was an excess of blackening spots, apparently formed by some unconventional hadrons (possibly strangelets), at great depths of the lower lead blocks (in particular, at t_0 = 29.0 c.u. and t_0 = 120.0 c.u., respectively). This result needs more careful study and analysis.

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Results from the telescope array

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The Telescope Array is the largest cosmic ray observatory in the northern hemisphere. Ultra high energy cosmic rays are observed indirectly via the extensive air shower they induce when they collide with a nucleus in the upper atmosphere. A large array of scintillator detectors is spread over ˜1800 sq km in the west desert of Utah, USA to sample the footprint of the showers when they arrive at the Earth's surface. Meanwhile, batteries of telescopes are employed to observe the longitudinal development of the showers via the nitrogen fluorescence light generated as the shower particles traverse the atmosphere. The data from the scintillators and telescopes is used to study the spectrum, composition, and anisotropy in arrival direction of cosmic rays. Recent results from the Telescope Array will be presented.

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Cost Effective Large Area Gaseous Detectors for Detection of Charged Particles [Online]

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Detection of charged particles especially cosmic muons is very crucial to study cosmic rays. There are several experiments dedicated to this purpose. Detection of cosmic rays needs detectors covering large areas. The cost of the detectors increases significantly with the increase in the detection area. Gaseous detectors like Resistive Plate Chambers (RPCs) offer a very cost-effective solution for the detection of charged particles, especially muons. These detectors can be fabricated over a large surface area (each of a few m^2). They have excellent detection efficiency ($>$ 98\%) and time resolution ($\sim$10 ps). These detectors are used by several High Energy Physics and Neutrino Physics experiments. These detectors are broadly classified into two categories - glass RPCs and bakelite RPCs, based on the nature of their electrodes. Developing bakelite RPC without any kind of oil treatment further reduces the cost significantly. The summary and overview of the development and performance of oil-free large-area bakelite RPCs and MRPCs for the detection of charged particles will be presented and discussed. The detector has been developed from indigenous materials in India. The feasibility of using these detectors to study cosmic ray interactions will also be discussed.

Contributed talks / **47**

Outreach Hyper-Kamiokande México

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Outreach Hyper-Kamiokande Mexico invites you to learn more about the contribution of Mexico in the international collaboration with Japan for the construction of the next big neutrino detector Hyper-Kamiokande, that it will be constructed underground at the Kamioka Mine in Hida City, Gifu Prefecture, Japan.

This conference will function as a pivotal point to highlight the importance of the dissemination of neutrino research in Mexico that Outreach Hyper-Kamiokande plays inside of the nation and the role Mexico contributes to this initiative. With this, we aim to inspire future generations of Mexican science researchers to participate in projects related to elemental particles.

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The Southern Wide-field Gamma Ray Observatory (SWGO)

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The Southern Wide-field Gamma Ray Observatory (SWGO) is a collaboration to develop and construct an air-shower array for ground-based gamma ray observatory in the Southern Hemisphere. The plan is to improve on or at least equal the performance of similar observatories, like LHAASO or HAWC.

The detector will be installed at an altitude above 4400m a.s.l. It will consist of Water-Cherenkov based detector units in an arrangement to allow the detection of gamma rays from a few hundred GeV up to a few PeV. The observatory will have a rich science program, which will allow it to complement IACTs and existing ground-based detectors in the Northern Hemisphere.

We will present the status and advances in the design of the Observatory, prototyping, and site selection for the project.

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Recent Results from the HAWC Gamma Ray Observatory

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The High-Altitude Water Cherenkov (HAWC) gamma-ray Observatory is an extensive air shower array consisting of 300 Water Cherenkov detectors located at 4100 m in Puebla, Mexico. With a wide field-of-view of ˜2 sr, operating 24 hrs/day with a high duty cycle (> 95%), it is the perfect instrument to perform all-sky monitoring. HAWC has been surveying the gamma-ray sky since 2015 and has improved its performance at background rejection and energy resolution with the recently developed PASS 5. In order to probe and understand the cosmic rays acceleration mechanisms, very-high energy gamma-ray observations are crucial. In this talk I will present the most recent results and highlights from the HAWC Observatory concerning cosmic rays studies and its implications for understanding the most powerful particle accelerators in our Galaxy.

Invited talks / **50**

The status and overview of LHAASO [Online]

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LHAASO is a hybrid detector experiment, its full array start operation in July 2021, becoming the leading Ultra-High-Energy (UHE) gamma-ray detection facilities with the highest detection sensitivity and all-sky monitoring capability in the world. The detector operates very stably and has collected a large amount of high-quality data sets. LHAASO has found more than 40 Ultra-High-Energy (UHE) cosmic accelerators within the Milky Way, with the highest energy photon reaching 1.4 quadrillion electron-volts, the highest energy photon ever observed. So many UHE gamma ray celestial body exit in our galaxy, prompting us to rethink the mechanism by which high-energy particles are generated and propagated in the Milky Way. It will also allow scientists to explore extreme astrophysical phenomena and their corresponding processes, thus enabling examination of the basic laws of physics under extreme conditions. Multi-parameter observation of showers allows LHAASO to measurement the single elements energy spectrum, elemental composition and anisotropy with high resolution, which give us an excellent opportunity to understand the origin, acceleration and propagation of high energy cosmic rays. In this presentation, I will introduce the current status of LHAASO's discoveries in UHE gamma ray sources and focus on introducing cosmic ray measurements. I will also introduce the future plans and prospects of LHAASO experiment.

Invited talks / **51**

Soft QCD review [Online]

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Probing Astroparticle and Particle physics at the Pierre Auger Observatory: highlights and perspective

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The complementary information carried by cosmic rays, photons, neutrinos, and gravitational waves provides extremely valuable insights about individual cosmic sources and source populations. The Pierre Auger Observatory plays a central role in multi-messenger astronomy, and its results provide a deeper view of the properties of ultra-high cosmic rays. In this talk, we will review some of the most relevant results, such as the information implied by the energy spectrum, composition and anisotropies of the UHCR, and the latest results on photons and neutrinos. The data collected at the Observatory allow us to study the characteristics of hadronic interactions at energies unreachable at accelerators, and to test the existence of possible effects beyond the Standard Model of particles, such as the decay of super-heavy dark matter, or the violation of the Lorentz invariance. The perspectives opened by the AugerPrime upgrade of the observatory and its future contributions will be discussed.

Contributed talks / 53

POEMMA-Balloon with Radio: a balloon born Multi-Messenger Observatory

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The Giant Radio Array for Neutrino Detection - experimental status and plans

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Strange Hadrons in Underlying- Events, Measured in Proton- Proton Collisions at □ = 13 TeV with the ATLAS Detector

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In this talk, recent measurements of distributions sensitive to the underlying event, the hadronic activity observed in relationship with the hard scattering in the event, by the ATLAS experiment are presented. Underlying event observables like the average particle multiplicity and the transverse momentum sum are measured for Kaons as Lambda baryons as a function of the leading track-jet and are compared to MC predictions which in general fail to describe the data. If ready in time,

a recent measurement of charged-particle multiplicities in diffractive pp collisions are presented. Events are classified using the ATLAS forward proton tagging.

Invited talks / 56

Status and Prospects of the LHCf experiment [Online]

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The LHCf experiment measures neutral particles, such as photons and neutrons, emitted in the very forward region of LHC collisions. These energetic particles play an important role in the air shower development induced by very high energy cosmic-rays. In September 2022, we performed data taking with proton-proton at \sqrt{s} = 13.6 TeV and 300 M events were recorded, which is about 10 times larger statistic than that of the operation in2015. This high statistics data allow us to address measurements of strange particles, K0s and lambda. Additionally, we will have an operation with proton-Oxygen collisions, which are ideal condition to simulate interactions between cosmic-rays and atmospheric nuclei. In this presentation, we reports about the recent results and future prospects.

Contributed talks / 57

Top-Down reconstruction of extensive air showers: a method to quantify the rescaling of the muon signal of hadronic interaction models

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Contributed talks / 58

Estimation of the cosmic-ray mass composition and proton-proton interaction cross sections from air shower data measured by the Pierre Auger Observatory [Online]

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Invited talks / 59

Astroparticle Physics with the Forward Physics Facility

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High-energy collisions at the high-luminosity Large Hadron Collider (HL-LHC) will produce an enormous flux of particles along the beam collision axis that is not accessible by existing LHC experiments. Multi-particle production in the far-forward region is of particular interest for astroparticle physics. High-energy cosmic rays produce extensive air showers (EAS) in the atmosphere which are driven by hadron-ion collisions under low momentum transfer in the non-perturbative regime of QCD. Thus, the understanding of high-energy hadronic interactions in the forward region is crucial for the interpretation of EAS data and for the estimation of backgrounds for searches of astrophysical neutrinos, for example. The Forward Physics Facility (FPF) is a proposal to build a new underground cavern at the HL-LHC which will host a variety of far-forward experiments to detect particles outside the acceptance of the existing LHC experiments. We will present the current status of plans for the FPF and highlight the synergies with astroparticle physics. In particular, we will discuss how measurements at the FPF will improve the modeling of high-energy hadronic interactions in the atmosphere and thereby reduce the associated uncertainties of measurements in the context of multi-messenger astrophysics.

Contributed talks / 60

Neutron Production in Extensive Air Showers

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Results from the first 8.5 years of operation with CALET

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Invited talks / 62

A combined analysis from the WHISP working group on the muon data from ten extensive air shower experiments [Online]

The muon content of extensive air showers is not only important for the study of the elemental composition of cosmic rays, but also serves as a test and validation of modern high-energy hadronic interaction models at laboratory energies well above 1 PeV. This line of research has led to the discovery of several discrepancies between the model predictions and the measurements on the muon content. The most impactful discrepancy is the deficit of muons in MC simulations in comparison to air shower data, a problem that has been called the muon puzzle. To study the characteristics of this anomaly, the WHISP working group has compiled the data from ten air shower experiments and has analyzed the behavior of the measurements in comparison with the predictions of different post-LHC hadronic interaction models and as a function of the primary energy. The study was done for energies between 10 PeV and 60 EeV. Differences in the energy scale among the experiments are corrected by applying a constant energy-scale shift per experiment. The combined analysis shows a muon deficit in the MC simulations in several experiments above 100 PeV, with the deficit in simulated muons increasing with the primary energy. However, it also reveals that this anomaly is not observed by all experiments. Some experiments are in agreement with the MC predictions and show an opposite trend as a function of energy. In consequence, the observation of the muon puzzle may depend on the experimental conditions.

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High Energy Neutrinos studies in the forward direction with the

FASER experiment at the LHC

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Machine learing model for discrimination of simulated muonic traces in water cherenkov detectors

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NA61/SHINE is a fixed target experiment designed to study hadron-hadron interactions at the CERN Super-Proton-Synchrotron

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In this contribution we will present final results on production spectra in pion-carbon interactions, which are of fundamental importance to improve the extensive air shower modeling, and hence the interpretation of ultra-high-energy-cosmic-rays measurements. In particular, our measurements of (anti)baryons and ρ^0 production in pion-carbon interactions will contribute to improve the predictions of muon production by air shower simulations using hadronic interaction models. Moreover, we will give an overview on available rich variety of measurements of hadronic interactions with NA61 at beam energies from 13 to 400 GeV, with proton, pion and kaon projectiles on proton and nuclear target, as well as nucleus-nucleus collisions. Furthermore, we will discuss future measurements of nuclear fragmentation with NA61/SHINE, mostly of interest for Galactic cosmic-ray studies, but with some relevance for modeling fluctuations in air showers.

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Recent results from GRAPES-3 [Online]

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Contributed talks / 67

Impact of the Magnetic Horizon on the Interpretation of the Pierre Auger Observatory Spectrum and Composition Data [Online]

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Invited talks / 68

Status of the Hyper-K Experiment, and Mexican contributions so far

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"The Hyper-Kamiokande (HK) experiment, a next-generation water-Cherenkov neutrino detector near Toyama, Japan, aims to significantly advance our understanding of neutrino physics. The specific physics goals include studying neutrino oscillations to refine their parameters, observing asymmetries between neutrino and antineutrino oscillations to investigate CP violation, probing Grand Unified Theories(GUTs) through the search for nucleon decay, investigating potential signals of dark matter through indirect detection methods, studying neutrinos produced by the Sun to understand solar processes, and observing neutrinos from astrophysical sources such as supernovas. With approximately eight times the fiducial volume of its predecessor, Super-Kamiokande (SK), HK is designed to house around 20,000 20-inch photomultiplier tubes (PMTs) and about 800 additional multi-PMTs (mPMTs) to improve event directionality and calibration accuracy, each mPMT with 19 3-inch PMTs in the inner detector region, along with up to 3,600 3-inch PMTs in the outer detector region, providing extensive photo-coverage for signal detection.

This talk focuses on the development and evaluation of deep learning models to classify neutrino type or detect background from Cherenkov light cone images within the HK framework. Specifically, it compares the performance of four state-of-the-art deep learning architectures—VGG19, ResNet50, PointNet, and Vision Transformer—using data simulated by the WCSim software for the Intermediate Water Cherenkov Detector (IWCD). This work contributes to the broader Hyper-K effort by proposing robust machine learning solutions for particle identification, aiming to enhance event reconstruction accuracy and reliability. Additionally, this talk also focuses on mPMT mechanical developments and testing to ensure the robustness of the sensor technology used in the experiment, which is crucial for maintaining detector reliability and precision to reach the experimental physics goals."

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SIBYLL

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Invited talks / 70

CORSIKA 8: particle cascades beyond air showers

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CORSIKA 8 is a completely rewritten Monte-Carlo simulation for cascades in cosmic-ray physics. The aim is to provide a flexible framework, written in modern C++, that can be adapted to applications beyond air-showers. This allows to use of the software in scenarios that were previously difficult or impossible to simulate in CORSIKA 7. This includes, for example, cascades that cross from air into ice or water. CORSIKA 8 is designed to benefit from modern computer architectures, such as parallel execution on multi-core CPUs or using GPU accelerators. CORSIKA 8 is now physics-complete and able to simulate realistic cascades. We will discuss the current status of the project and present some applications. We will also discuss briefly the validation of the software and plans for the future.

Invited talks / 71

Progress on modeling atmospheric leptons at the surface and underground using MCEq; and CHROMO [Online]

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Invited talks / 72

CMS highlights

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Invited talks / 73

EPOS4 What are the new concepts? [Online]

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Invited talks / 74

FLUKA [Online]

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Public lecture / 75

Encounters with Modern Physics

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Summary

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Summary

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