2016 International Conference on Ultra-High Energy Cosmic Rays

Monday, October 10, 2016 - Friday, October 14, 2016

Kyoto Research Park

Book of Abstracts

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Mini-EUSO: a precursor mission on the International Space Station for the observation of Atmosphere and Earth in the UV light

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For any experiment aiming at the observation of Ultra High Energy Cosmic Rays (UHECR's) from space, one key measurement is related to the UV emissions produced in the Earth's atmosphere. In view of planned missions under study (KLYPVE/K-EUSO, JEM-EUSO, EUSO-FF) at the International Space Station (ISS) and on board of free-flyer satellites, a small, compact UV telescope, Mini-EUSO, is being developed by the JEM-EUSO International Collaboration to be placed – in the second half of 2017 - at the UV-transparent, nadir looking window of the Russian module of the ISS. In addition to the main purpose of studying the UV background, Mini-EUSO will also perform studies of atmospheric phenomena, observation of meteors, strange quark matter search and space debris tracking. It will as well enhance the technological readiness level of the EUSO concept and instruments. Mini-EUSO is a mission approved and selected by the Italian Space Agency (ASI) and, under the name "UV atmosphere", by the Russian Space Agency Roscosmos. Scientific, technical and programmatic aspects of this project will be discussed.

Presentation type:

poster

Poster session / 3

Development of a UAV-mounted light source for fluorescence detector calibration of the Telescope Array experiment

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We are developing a unmanned aerial vehicle (UAV), which is called "Opt-copter", carrying a calibrated light source for fluorescence detector (FD) calibration of the Telescope Array (TA) experiment. The "Opt-copter" is equipped with a high accuracy GPS device and a LED light source in the shape of a dodecahedron. A positioning accuracy of the GPS mounted on the UAV is 0.1 m, which meets the requirement for the calibration of the FDs at distances of 100 m.
The light source consists of 12 UV LEDs attached on each side of the dodecahedron, and it is covered with a spherical diffuser to improve the spatial uniformity of the light intensity.
We will report the status of the "Opt-copter" development and the results of its test at the TA site.

Presentation type:

poster

Oct.12PM2 / **4**

Monte Carlo Bayesian search for the plausible source of the Telescope Array hotspot

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The Telescope Array (TA) collaboration has reported a hotspot of 19 ultrahigh-energy cosmic rays (UHECRs). Using a universal model with one source and energy-dependent magnetic deflections, we show that the distribution of the TA hotspot events is consistent with a single source hypothesis, although multiple sources cannot be ruled out. The chance probability of this distribution arising from a homogeneous distribution is 0.2%. We describe a Monte Carlo Bayesian (MCB) inference approach, which can be used to derive parameters of the magnetic fields as well as the source coordinates, and we
apply this method to the TA hotspot data, inferring the location of the likely source. We discuss possible applications of the same approach to future data.

Presentation type:

oral

Oct.14AM2 / **5**

The JEM-EUSO Program to study UHECRs from Space

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The JEM-EUSO program aims to study Ultra High Energy Cosmic Rays (UHECRs) from space with a potential for a significant increase in exposure and a uniform coverage of the sky. To achieve this goal within the strong constraints of power, mass, size and bandwidth of space detectors, a number of novel technologies, from optics to sensors, front-end and read-out electronics have been developed over the years and used in several precursor telescopes: 1) in August of 2014 a balloon flight (EUSO-BALLOON) was successfully performed from Timmins (Canada); 2) since February of 2015 a ground-based detector (EUSO-TA) has been operating at the Telescope Array site in Utah. Future steps of the JEM-EUSO program include: 3) EUSO-SPB a NASA Super Pressure Balloon (SPB) scheduled to fly from New Zealand in March 2017; 4) MINI-EUSO/UV Atmosphere - a detector to be placed inside the International Space Station in 2017; 5) K-EUSO, the first reflector detector to perform UHECR science from space (scheduled for 2020); 6) EUSO-FF, a free-flyer large field of view detector.
In this work we will present the results from the first detectors and address the current status of research and future plans of the JEM-EUSO program.

Presentation type:

oral

Oct.11AM2 / **6**

Can ultrahigh energy protons come from steady astrophysical sources?

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Among other questions, there are two long-standing mysteries about cosmic rays at the highest energies: are they mostly composed by protons or nuclei? Are their sources steady or transient? In this work, we aim to exam one out of the four scenarios led by these questions, namely, the possibility that the highest-energy particles are protons from steady sources. We start out by discussing the bolometric luminosity and the local number density of the sources required by observed events above 60-80 EeV. The requirements are then contrasted with the luminosity functions of the known steady sources in the local universe, including radio galaxies, blazars, and clusters of galaxies. Our results show that unless the intergalactic magnetic field is extremely strong, there are insufficient powerful steady sources in the nearby universe to account for the observed highest-energy cosmic rays if they have a proton composition.

Presentation type:

oral

Poster session / 7

Monte Carlo study of diffraction in proton-proton collisions at 13TeV with the very forward detector

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Diffractive and non-diffractive collisions are totally different hadronic interaction processes, the diffractive processes are hardly predicted theoretically. This leads to the significant differences in the treatments of diffraction in the hadronic interaction model. Due to the very forward detector has unique sensitivity to the diffractive processes, it can be a powerful detector for the detection of diffractive dissociation by combining with the central detector. Central detector can give the information to help the forward detector to identify diffractive and non-diffractive events, especially, for the low mass diffractions which are not measured precisely. Several Monte Carlo simulation samples in p-p collisions at 13TeV are analyzed. the central information is able to classify the forward productions into diffraction and non-diffraction, in particular, most of the survived events from the selection of diffraction are belong to the low mass diffractions at log10 (ξx) < -5.5. Therefore, the combined method can uniquely access to the low mass diffraction, experimentally.

Presentation type:

poster

Poster session / 8

Phenomenology of the invisible energy: revisiting the Heitler-Matthews cascade model.

Author: Analisa Gabriela Mariazzi[1]

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The estimation of invisible energy is central for experiments where only the electromagnetic component of the air shower is measured. This estimation is based on complex Monte Carlo simulations where the influence of the parameters describing the high energy hadronic interactions is difficult to unravel.
The Heitler-Matthews cascade model has been shown to be a powerful tool to understand the phenomenology of particle cascades.
Despite its simplicity the model gives accurate predictions for many shower observables.
In this work, we use this model to study the invisible energy of the cascade and its relationship with the primary particle mass and energy.
The expressions derived from the Heitler-Matthews model were used to describe the results from full Monte Carlo simulations, gaining insight on how the pion critical energy, pion multiplicity and inelasticity affects the amount of the invisible energy in the particle cascade.

Presentation type:

poster

Oct.11PM1 / 9

Estimation of the invisible energy with the data collected by the Pierre Auger Observatory

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The determination of the primary energy of extensive air showers using the fluorescence technique requires an estimation of the energy carried away by particles that do not deposit all their energy in the atmosphere.
This estimation is typically made using Monte Carlo simulations and thus depends on the assumed primary particle mass and on model predictions for neutrino and muon production.

In this work we review the method that the Pierre Auger Collaboration uses to obtain the invisible energy directly from hybrid events measured simultaneously with the fluorescence and the surface detectors of the Pierre Auger Observatory. As a corroboration of these results, a new method for the determination of the invisible energy using an independent dataset is also presented.
Both methods are based on the correlation of the invisible energy with the muon content of air showers and agree within systematic uncertainties, giving an estimation of the invisible energy that removes possible systematic uncertainties related to differences between the available high energy hadronic interaction models and data.

Presentation type:

oral

Oct.13AM2 / 10

Extra-galactic sources and propagation including constraints on Extragalactic magnetic fields

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With the newest version of our Monte Carlo code, CRPropa 3, the propagation of ultra-high-energy cosmic rays (UHECRs) from their sources to Earth, including all relevant interactions, deflections in galactic and extragalactic magnetic fields (EGMFs) as well as secondary neutrino and electromagnetic cascade production and propagation can be simulated. The modular structure of the code allows for flexibility while also facilitating high-performance computing. In this way predictions for arrival directions, anisotropy measures and expected average deflections for specific source distributions, EGMF
and GMF models have been obtained. Additionally will be shown that the expected composition at Earth can also be influenced by magnetic field effects.

Presentation type:

oral

Poster session / 11

Development of the Cosmic Ray Air Fluorescence Fresnel lens Telescope for a next generation UHECR observatory

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In near future, it is expected that sources of ultra-high-energy cosmic rays (UHECRs) can be identified, because the Telescope Array experiment reported that there is a Hotspot in the UHECR arrival direction. However, it is required to observe UHECRs with higher statistics. Moreover, the mass composition should be determined, which is important information for anisotropy study. Then, we should extend the scale of observatory with fluorescence telescopes which can observe $X_{\max}$, but they cost more than particle detectors at the ground.
In order to reduce the cost, we are developing the Cosmic Ray Air Fluorescence Fresnel lens Telescope (CRAFFT) which is a simple structure fluorescence telescope consisting of a plastic Fresnel lens of 1 m^2 and a 8 inch PMT.
In this presentation, we will report the current status of development and test observation.

Presentation type:

poster

Oct.14AM2 / 12

The first results of the TUS orbital detector of ultra high energy cosmic rays and transient events in the atmosphere

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TUS (Tracking Ultraviolet Set-up) is the first orbital detector of extreme energy cosmic rays (EECRs), which works as a part of the scientific payload of the Lomonosov satellite. The main aim of the mission is to test the technique of registering fluorescent and Cherenkov radiation of the secondaries born by EECRs in the atmosphere with a space telescope, and to collect information necessary for constructing the next generation instruments such as KLYPVE (K-EUSO) and JEM-EUSO. We briefly review the technical parameters of TUS and present preliminary results of its operation on orbit since May 2016.

Presentation type:

oral

Oct.14AM2 / 13

Prospects of silicon photomultipliers for ground-based cosmic ray experiments

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An established technique to study ultra-high-energy cosmic rays is the detection of extensive air showers induced in the atmosphere of the earth. Thereby cascades of secondary particles are produced consisting of a hadronic, an electromagnetic and a muonic component. Especially the determination of the number of muons and the amount of fluorescence light produced during the shower development allows us to infer the mass composition and energy of the primary particle. Thus, these are important observables for air shower experiments like the Pierre Auger Observatory in Argentina.

The steady development of semiconductor devices the last years resulted in highly improved photon sensors, e.g. silicon photomultipliers (SiPMs). The small package and moderate bias voltage (< 100 Volts) of these silicon devices allows for compact and robust designs.
Detailed detector simulations, the development of dedicated front-end electronics as well as construction and investigation of detector prototypes are needed to study the applicability of SiPMs for cosmic ray experiments.

We present our findings for two different detector techniques: First, we present the fluorescence telescope prototype, FAMOUS. Its basic principle is based on a Fresnel lens focusing the incoming light onto a camera instrumented with 64 SiPMs. Secondly, scintillator detectors designed for an improved determination of the muonic component in air showers of current experiments and their benefit from the high photon detection efficiency of SiPMs are presented. An SiPM adaption is also studied in the scope of AugerPrime, the upgrade of the Pierre Auger Observatory.

Presentation type:

oral

Poster session / 14

The full-scale prototype for the Fluorescence detector Array of Single-pixel Telescopes

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The Fluorescence detector Array of Single-pixel Telescopes (FAST) is a design concept for the next generation of ultra-high energy cosmic ray (UHECR) observatories, addressing the requirements for a large-area, low-cost detector suitable for measuring the properties of the low flux of cosmic rays at the highest energies. In the FAST design, a large field of view is covered by a few pixels at the focal plane of a mirror or Fresnel lens. Motivated by the successful detection of UHECRs using a prototype comprised of a single 200 mm photomultiplier-tube and a 1 m^2 Fresnel lens system, we have developed a new "full-scale" prototype consisting of four 200 mm photomultiplier-tubes at the focus of a segmented mirror of 1.6 m in diameter. We report on the status of the full-scale prototype, including test measurements made during first light operation at the Telescope Array site.

Presentation type:

poster

Poster session / 15

Energy dependence of the very-forward particle production in pp collisions by the LHCf experiment

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An important and remained problem for the observation of UHECRs by air shower experiments is the uncertainty arising from the hadronic interaction models.
Since we rely on particle production, namely air shower development of UHECRs described by the interaction models, it is necessary to verify these interaction models at accelerators as high energy as possible.
Large Hadron Collider forward experiment (LHCf) has measured forward particle production of proton-proton scattering from collision energy of 900 GeV to 13 TeV at the LHC.
We took two different approaches to understand the energy dependence of the particle production

using obtained data.
One is that the pseudorapidity dependence of the energy density of forward gamma-rays.
We are able to measure the differential energy density close to the peak of the energy flow, in which contribution to a shower development is maximized, especially in case of 7 and 13 TeV.
We also tested the scaling hypothesis for the collision energy of the particle production, Feynman scaling, from the point of view of forward gamma-rays.
Obtained data results were compared to the predictions of the post-LHC interaction models, such as QGSJETII-04 and EPOS-LHC.

Presentation type:

oral

Poster session / **16**

Measurement of forward eta/pi0 production ratio at LHC √s=13TeV p-p collision.

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The Large Hadron Collider forward (LHCf) experiment aim to verify
the hadron interaction model by using LHC. In this experiment, p-p collision was carried out at √s = 13TeV in Jun 2015.
Here we report the initial result of forward eta meson measurement. Very forward production of eta meson is highly unknown and has large discrepancy among the cosmic ray interaction models. Firstly, we verified the energy scale of the calorimeter detectors in the wide energy range by using the reconstructed mass peaks of pi0 and eta mesons. The second, we show the eta/pi0 ratio detected by the LHCf-Arm1 detector and compare with the results of QGSJETII-4 and EPOS-LHC.

Presentation type:

poster

Oct.12PM2 / **17**

A Close Correlation of TA Hotspot Events with Filaments of Galaxies Connected to the Virgo Cluster

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The hotspot feature of ultra-high-energy cosmic rays (UHECRs) was reported by the Telescope Array (TA) experiment in 2014. To study the nature and origin of the TA hotspot, we search structures in the local universe, within 50 Mpc. We identify filaments of galaxies around the TA hotspot area, which are connected to the Virgo cluster. By the anisotropy test, we find a close correlation of the arrival direction distribution of TA hotspot events with the filaments of galaxies. We discuss our finding and its implications.

Presentation type:

oral

Oct.12PM2 / **18**

Influence of the galactic magnetic field on the trajectory of ultra-high energy cosmic rays

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The trajectory of ultra-high-energy cosmic rays (UHECRs) is affected by the galactic magnetic field (GMF). The GMF has been extensively studied, but the GMF toward the high galactic latitude is yet uncertain. Assuming the deflection of UHECR trajectory by the GMF is mainly dependent on the galactic latitude, b, we analyze the correlation between the arrival direction distribution of UHECRs and the large-scale structure of the universe in regions of sky divided by the galactic latitude to explore the influences of the GMF. Through the Bayesian parameter inference of the deflection angle in the Monte-Carlo simulation, we estimate the strength of GMF in regions. We discuss the implications of our results.

Presentation type:

oral

Oct.14AM1 / **19**

The TAx4 Experiment

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The Telescope Array (TA) experiment consists of a surface detector (SD) array covering 700 km^2 in area and three fluorescence detector (FD) stations and explores the origin of ultra-high-energy cosmic rays. We found the evidence of a hotspot in the arrival directions of cosmic rays with energies above 57 EeV (Abbasi *et al.* 2014). New SDs and FDs are planned to be constructed for the TA$\times$4 experiment to cover 4 times larger area than TA to observe cosmic rays especially with the highest energies using high statistics. This project is expected to clarify not only the source of the hotspot but also the energy spectrum and the composition at the highest energies. The five-year proposal for TA$\times$4 SD was accepted in the spring of 2015. The proposal for constructing 2 FD stations was also accepted in 2016. In this talk, the current status and the future prospects of the TA$\times$4 experiment are shown.

Presentation type:

oral

Poster session / 20

Study of the microwave radiation from the electron beam at the Telescope Array site

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The Telescope Array experiment installed the electron accelerator in order to calibrate the fluorescence detector by shooting 40 MeV electrons into the atmosphere. This accelerator is also useful to investigate the radio detection techniques for the cosmic ray observation. Using this accelerator, four experimental groups have studied individual radio detection method at different frequency bands ranging from 50 MHz to 12 GHz. All of these experiments have observed the microwave radiation from the electron beam itself. We have studied the radiation by combining all the measured results and constructed a model of this phenomena. Details of the experiments, observation results and the comparisons with the model expectations will be presented.

Presentation type:

poster

Poster session / 21

Latest Results of the Cosmic-Ray Anisotropy with Energy >57 EeV Observed by the Surface Detector of the Telescope Array Experiment

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The Telescope Array Experiment has observed a cluster of the UHECRs, called the Hotspot, with $E > 57$ EeV around Ursa Major (Abbasi et al., ApJ, 790, L21) using the first five years of data by the TA surface detectors. In this work, we will report on an update of this result using the latest data collected by the TA surface detectors.

Presentation type:

poster

Poster session / 22

Air shower development and hadron production at very forward region

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Since cosmic ray was discovered about 100 years ago, the mechanism which generates huge energy has been always the subject of interest.
In order to study the origin of the extremely high energy cosmic ray, highly precise data of extended air shower has been acquired by two huge detectors
(Telescope Array and Pierre Auger Observatory) which have started observation from the beginning of the 21st century.
The knowledge of the hadron interaction is essential to estimate the primary composition and the energy of primary cosmic rays from the air shower phenomenon.
But the recent air shower observation results which show the clear excess of muons on the ground suggest that the hadronic interaction models at extremely high energy region is not perfect.
To improve the hadronic interaction models for cosmic ray study, Large Hadron Collider forward (LHCf) group measures the hadron production at the very forward region where the energy flux is large.
Their results show that the energy flux of neutron component at the very forward region is much larger than the expectations of recent hadron interaction models.
In this paper, the hadronic interaction model is modified to reproduce the LHCf results. The influence of the model modifications in the shower development will be presented.

Presentation type:

poster

Poster session / 23

The performance of the new LHCf detector for hadronic showers

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The Large Hadron Collider forward (LHCf) experiment is designed for verification of hadronic interaction models used in cosmic ray physics. We have measured neutral particles, especially neutrons, in very forward region of $\sqrt{s}$ = 13TeV proton-proton collision at CERN-LHC in order to measure inelasticity. For the purpose, the LHCf detector was updated in 2014 by using GSO scintillator to improve radiation-hardness of the detector. In this poster, we present the performance of the new LHCf detector for hadronic showers evaluated by a beam test at CERN-SPS and MC simulations. The energy resolution and position resolution are found to be 43% and 0.6mm at the center of detector for a 300 GeV proton beam. We confirmed the new detector performance is consistent with the performance of the old detector used in the 2010 operation.

Presentation type:

poster

Oct.12AM2 / 24

The resent results from the LHCf experiment

Author: Hiroaki Menjo[1]

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The LHCf experiment is one of the LHC forward experiment. The LHCf aims to provide critical data for evaluation of hadronic interaction models which are used in MC simulations of air shower developments induced by high energy cosmic-rays. The LHCf detectors measures neutral particles, photons, neutrons and neutral pions, emitted in the very forward region of a LHC interaction point. The psudorapidity coverage is $\eta > 8.4$.
In 2015, the LHCf had successfully completed an operation with proton-proton collisions at the collision energy of $\sqrt{s}$=13TeV. We present resent results from the new data, especially forward photon production spectra. We also mention about future plans, an operation with LHC p-Pb and an operation at RHIC p-p collisions (the RHICf experiment.)

Presentation type:

oral

Poster session / 25

The DAQ system and the operation condition of the RHICf experiment

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The purpose of the RHICf(Relativistic Hadron Ion Collider forward) experiment is the verification of hadronic interaction models, which is necessary to precisly understand air-shower developments induced by high energy cosmic-rays.We measure the forward neutral particles by using a calorimeter detector installed near the STAR detector. The RHICf detector is the LHCf - Arm1 detector brought from CERN, which is composed of scintillator layers, position sensitive layers and tungsten layers.

We measure the forward neutral particles by using a calorimeter detector installed near the STAR detector. The RHICf detector is the LHCf - Arm1 detector brought from CERN, which is composed of scintillator layers, position sensitive layers and tungsten layers.RHICf trigger signals are issued for detection of electromagnetic or hadronic showers induced by photons and neutrons. The trigger condition is set as that dE in any three successive layers are over a certain threshold.The RHICf experiment is going to be cooperated with the STAR experiment . So, we developed the DAQ system to fit the operation condition. In this presentation, the DAQ system and the operation condition are introduced.

Presentation type:

poster

Oct.14AM1 / **26**

Telescope Array Low energy Extension: TALE

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TALE, the Telescope Array Low Energy extension is designed to lower the energy threshold to about 10^16.5 eV. TALE has a surface detector(SD) array made up of 103 scintillation counters (40 with 400 m spacing, 36 with 600 m spacing and 27 with 1.2 km spacing) and a Fluorescence Detector (FD) station consisting of ten FD telescopes working with the Telescope Array Middle Drum FD station, which is made up of 14 telescopes. TALE-FD full operation started in 2013 and the SD array was partially-completed with 16 SDs and continues the operation from 2014. We will describe the history and the current status of the detectors and will make a brief report about the FD and the hybrid analysis results.TALE detector will be completed as a hybrid air shower detector near future. We will report the technical details of the detectors, the schedule and the expected performances.

Presentation type:

oral

Poster session / **27**

Wide-field optics and electronics for UHECR orbital detector: from prototype to pathfinder

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Two types of orbital detectors of ultra high energy cosmic rays are being developed nowadays: telescope with reflecting optical systems (TUS/KLYPVE and OWL mission with Schmidt optics) and complex lens system (EUSO/JEM-EUSO mission). They will cover much larger areas than existing ground-based arrays and almost uniformly monitor the celestial sphere. The TUS detector is the pioneering mission developed in MSU in cooperation with several Russian and foreign institutions and launched on board of Lomonosov satellite in 2016. It is a prototype for the next SINP MSU project, KLYPVE, UHECR telescope on board of Russian segment of the ISS with large mirror-concentrator, which allows decreasing the energy threshold. Finally, JEM-EUSO is a wide field of view (+/-30 deg) detector on ISS. The optics is composed of two curved double-sided Fresnel lenses with 2.65 m external diameter, a precision diffractive middle lens and a pupil. The ultraviolet photons are focused onto the focal surface, which consists of nearly 5000 multi-anode photomultipliers. It is developed by a large international collaboration. All orbital detectors have multi-purpose character due to continuous monitoring of various atmospheric phenomena.
To design of such ambitious experiment like OWL or JEM-EUSO prototypes development and pathfinder mission is very important issue. It allows to solve a number of complex technology challenges and to assess the real possibility of obtaining scientific information (first of all, the selection of events tracks and its reconstruction, real background and exposure estimations). Electronics and algorithms for on-line event selection will be tested within the project Mini-EUSO (lens detector of UV-flashes with

25 cm diameter on ISS illuminator, planned launch at 2018?). Recently to experimentally approve possibility of wide-angle optics on orbit international collaboration JEM-EUSO proposed K-EUSO mission, which is a mirror-lens telescope system on the outside of the Russian Segment of ISS. The project manages to combine technological solutions JEM-EUSO and TUS: the lightweight mirror-concentrator of 10 m2 area allows to registered UHECRs with energies above 50 EeV, and optical aberrations correction using a Fresnel-type lens lets design a photodetector with high angular resolution (in this case, photosensors and analog electronics of the JEM-EUSO can be used). In this work we provide a comparative overview of the optical systems (JEM-EUSO lens system, Schmidt optics, two option of K-EUSO optics), report first results of the lightweight segmented carbon-fiber mirror manufacturing and testing and new suggestion about electronic system for K-EUSO.

Presentation type:

poster

Poster session / 28

Night sky weather monitoring system using Fish-eye CCD

Author: Takayuki Tomida[1]

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Telescope Array (TA) is international joint experiment observing ultra-high energy cosmic rays. TA employs fluorescence detection technique to observe cosmic rays. In this technique, the existence of cloud significantly affects quality of data. Therefore, cloud monitoring provides important information. We are developing two new methods for evaluating night sky weather with pictures taken by charge-coupled device (CCD) camera. One is evaluating the amount of cloud with pixels brightness. The other is counting the number of stars with contour detection technique. The results of these methods show clear correlation, and we concluded both the analyses are reasonable methods for weather monitoring. We discuss reliability of the star counting method. In order to verify the reliability, we compared the result with man counting number of stars. We found reasonable correlation between these two numbers. It shows usability of this method for night sky weather monitoring.

Presentation type:

poster

Oct.12PM1 / 29

TA anisotropy summary

Author: Peter Tinyakov[1]

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We will summarize the search for anisotropy of the ultra-high-energy cosmic rays with the Telescope Array (TA), making use of the surface detector data that have been collected during full 8 years of the TA operation. We will present the global event distribution, the auto-correlation function, the correlation with the matter distribution in the local Universe, a blind search for localized excesses of

events anywhere on the sky (the “hot spot”), as well as a search for a possible directional dependence of the energy spectrum.

Presentation type:

oral

Poster session / 30

Studies of muons in extensive air showers from ultra-high energy cosmic rays observed with the Telescope Array surface detector

Author: Ryuji Takeishi[1]

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The number of muons from the ultra-high energy cosmic rays (UHECRs) is measured with the surface detectors (SDs) on the ground. Its MC prediction depends on hadronic interaction models and the composition. By comparing the measured number of muons with the MC prediction, hadronic models can be tested.
The Pierre Auger Observatory reported that the number of muons measured by water Cherenkov detectors is about 1.8 times larger than the MC prediction for proton, QGSJETII-03 model. The number of muons in the Auger data is also larger than the MC prediction for iron. The Telescope Array (TA) experiment uses the SD made of plastic scintillator. It is sensitive to the electromagnetic component that is the major part of secondary cosmic rays from UHECR air showers. An analysis approach to increasing muon purity is necessary to calculate the number of muons in the TA SD data. In this presentation, we report the method and the result of the comparison of charge density of muon-enriched sample in the data with that in the MC simulation.

Presentation type:

poster

Oct.11PM1 / 31

Cosmic Rays Energy Spectrum observed by the TALE detector

Author: Tareq AbuZayyad[1]

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We report on a cosmic ray energy spectrum measurement by the Telescope Array Low-Energy extension (TALE) fluorescence detector (FD). The TALE FD is an air fluorescence detector which is also sensitive to the Cerenkov light produced by shower particles. Low energy cosmic rays, in the PeV energy range, are detectable by TALE as “Cerenkov Events”. Using these events, we measure the energy spectrum from a low energy of ~ 4 PeV to an energy greater than 100 PeV. Starting at around 100 PeV, TALE also observes showers by their fluorescence light; and above this energy fluorescence becomes the dominant light production mechanism by which most showers are observed. The event processing and reconstruction procedures are identical for both low and high energy regions. This

allows for treating the Cherenkov events and Fluorescence events as a single data set and thus calculating a single cosmic rays energy spectrum based on this data set, which extends from an energy of ~ 4 PeV to above 1 EeV. In this talk, we will describe the detector, explain the technique, and present results from the measurement of the spectrum in this energy range by the Telescope Array experiment.

Presentation type:

oral

Poster session / 32

NICHE: Non-Imaging Cherenkov observation at the Telescope Array

Author: Yoshiki Tsunesada[1]

Co-authors: Douglas Bergman [2]; Tareq AbuZayyad [2]

[1] *Osaka City University*

[2] *University of Utah*

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The Non-Imaging CHErenkov Array (NICHE) is a low energy extension to Telescope Array and TALE using an array of closely spaced (70–100 m) light collectors covering an area of up to 1/4 square km. The target is cosmic rays with energies above the "knee", including the "transition region" above which Galactic cosmic rays are no more confined by the galactic magnetic field. It will be deployed in the field of view of TALE and will overlap it in energy range. TALE can observe events in the energy range 3–30 PeV by imaging air-Cherenkov, so NICHE and TALE will observe imaging/non-imaging Cherenkov hybrid events. NICHE itself will use both the Cherenkov Lateral Distribution and the Cherenkov time-width Lateral Distribution in measuring cosmic-ray air showers. These two methods will allow shower energy and Xmax to be determined. A prototype of the array with 15 counters, called j-NICHE, is currently being built and will be deployed within the coming year. We will present the design and plans of the experiment, performances, and the status of the prototype development.

Presentation type:

poster

Oct.12AM2 / 33

Xmax Uncertainty from Extrapolation of Cosmic Ray Air Shower Parameters.

Author: Gordon Thomson[1]

Co-author: Rasha Abbasi [2]

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Recent measurements at the LHC of the p-p total cross section have reduced the uncertainty in simulations of cosmic ray air showers, in particular of the depth of shower maximum. However, there is a remaining uncertainty due to the total cross section, multiplicity, and elasticity. Uncertainties due to extrapolations from accelerator data in the p-p center of mass, to 250 TeV (3×10^{19} eV in a cosmic ray proton's lab frame) introduce significant uncertainties in predictions of the depth of shower maximum. In this paper we estimate a lower limit on these uncertainties. At the full energy of the LHC, which is equivalent to $\sim 1 \times 10^{17}$ eV in the cosmic ray lab frame, our calculation of the extrapolation is less than the difference among the models. On the other hand, at 3×10^{19} eV in the cosmic ray lab frame, our calculation of the uncertainty in Xmax is approximately equal to the difference among the modern models being used in the field.

Presentation type:

oral

Oct.11PM2 / 34

Anisotropy Search in Energy Distribution in the Northern Hemisphere Using the Telescope Array Surface Detector Data

Author: Toshiyuki Nonaka[1]

Co-authors: Dmitri Ivanov [2]; Eiji Kido [3]; Hiroyuki Sagawa [4]; Kazumasa Kawata [5]; Robert Cady [6]

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The Telescope Array (TA) experiment is located in the western desert of Utah, USA, and observes ultra high energy cosmic rays in the northern hemisphere. In the region of highest energies, the shape of cosmic ray energy spectrum may contain information on the source density distribution and chemical composition. In this study, using observed events with the Telescope Array surface detector, we search for directional differences in the shape of energy spectrum. Observed cosmic ray energy spectra are compared between two sky areas: one is the area near the super-galactic plane that has larger density of nearby objects, and other is the remainder. We report the result of those studies.

Presentation type:

oral

Oct.12PM2 / 35

UHECR anisotropies and the Large-Scale matter distribution

Author: Peter Tinyakov[1]

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We will discuss the expectations for the UHECR anisotropy under the assumption that the UHECR sources trace the matter distribution in the Universe. The effect of cosmic magnetic fields and charge composition of UHECR will be considered. The experimental signatures and their possible discovery strategies will be discussed.

Presentation type:

oral

Oct.12PM1 / 36

Arrival Directions at Ultra-High Energies: A Review

Authors: Armando di Matteo[1]; Hiroyuki Sagawa[2]; Igor Tkachev[3]; Peter Tinyakov[4]; Toshiyuki Nonaka[5]

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In the same way as for previous series of international symposia on future directions in UHECR physics, an inter-collaborative anisotropy working group has been established with membership from the Pierre Auger Observatory (Auger) and the Telescope Array experiment (TA) with the task to compile a balanced view about the current status of anisotropy searches in the arrival directions of UHECRs. In addition to the review work, another pursued goal has been to produce a common full-sky map of UHECR arrival directions above 57 EeV to search for anisotropies through correlations with local extragalactic matter. The full-sky coverage allows eventual structures to stand out from the isotropic background with minimal exposure distortions. Special attention is given to the relative normalization of the respective exposures of the experiments by cross-calibrating the fluxes measured in declination ranges where the exposures overlap as a function of the energy. From the produced sky map, a comprehensive series of anisotropy searches is presented, and astrophysical implications are discussed.

Presentation type:

oral

Oct.11AM1 / 37

Auger-TA energy spectrum working group report

Author: Valerio Verzi[1]

Co-authors: Alexander Schulz [2]; Daisuke Ikeda [3]; Dmitri Ivanov [4]; Francesco Salamida [5]; Gordon Thomson [4]; Hiroyuki Sagawa [6]; Ines Valino [7]; Ioana Maris [8]; Isabelle Lhenry-Yvon [9]; Markus Roth [10]; Olivier Deligny [11]; Tareq AbuZayyad [4]; Toshiyuki Nonaka [12]; Yoshiki Tsunesada [13]

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The energy spectrum joint working group was re-established with membership from the Pierre Auger Observatory (Auger) and the Telescope Array experiment (TA). In-depth discussions on the energy determination and systematic uncertainties in the two experiments were made, resulting in a detailed comparison of the UHECR energy spectra observed in the southern and the northern hemispheres. The flux measured in the "overlapping region" in declination is of special interest to infer the differences of experimental origin. In this review, a special attention is given to i) the energy scale and the systematic uncertainties of the experiments, ii) the shape of the energy spectrum and the corresponding best fits, iii) the energy spectra in different declination bands, iv) a comparison of the Auger-TA spectra in the overlapping region, and v) the astrophysical interpretation of the results and possible links to anisotropy studies.

Presentation type:

oral

Poster session / 38

Development of the new DAQ system for the SD array of TA×4 and TALE

Author: Yuichi Takahashi[1]

[1] *Osaka City University*

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The data acquisition (DAQ) system of the surface detectors (SDs) of the TAx4 and the TALE experiment will be presented. Each SD records signals with 50MHz FADCs and sends the data to a central communication center (or the "communication tower") via a wireless network system. The techniques employed here are based on the currently-running DAQ system of the Telescope Array, and there are some improvements including the replacement of i) the wireless-LAN module with a custom protocol to another one with TCP/IP, and ii) the "tower electronics" to a generic Linux board (Raspberry Pi Type II B). The details and performace of the new DAQ system will be presented at the conference.

Presentation type:

poster

Oct.11AM1 / **39**

Measurement of the energy spectrum of cosmic rays with the Pierre Auger Observatory

Author: Markus Roth[1]

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The flux of cosmic rays has been measured with unprecedented precision at the Pierre Auger Observatory. We report on the recent update of the all-sky flux of cosmic rays above 3×10^{17}eV obtained by combining four independent high-quality data sets collected for more than 10 years, with a total exposure exceeding 50,000 km^{2}sr yr. These measurements are based on data from the surface detector arrays (divided into two sets according to the shower zenith angle), from a nested, denser, detector array, and hybrid events measured simultaneously with both the fluorescence detector and the surface detector. The spectral features are presented in detail and the systematic uncertainties are addressed.

Presentation type:

oral

Oct.14PM1 / **40**

Progress in Development of High Energy Neutrino Detectors in Antarctica using Coherent Radio Techniques

Author: Steven Barwick[1]

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Evidence is growing for the existence of a diffuse flux of astrophysical neutrinos with energies up to a few x 10^{15} eV. This has spurred considerable interest in developing new techniques that can extend the search to even higher neutrino energies. Promising new efforts over the past half-decade focus on the radio-Cherenkov technique in polar regions with cold, highly transparent ice. I will describe the broad, complementary physics goals of these telescopes with design sensitivities as least a factor 10 better than current limits for energies >$10^{17.5}$ eV. One important goal centers on a measurement of the cosmological neutrino flux, whose existence is relatively secure but also expected to be quite small even under the best of circumstances. The inherent cost efficiencies of radio-Cherenkov techniques suggest far greater boosts in sensitivity are possible. After briefly reviewing the progress by ANITA, ARA, and GNO collaborations, I will report on the new results from the Hexagonal Radio Array, a pilot array of the ARIANNA project. It was completed in December 2014 and located on surface of the Ross Ice Shelf at a site about 110 km from McMurdo Station, Antarctica. ARIANNA is designed to measure astrophysical neutrinos with energies greater than 10^{16} eV, with sufficient sensitivity to overlap with high energy tail of neutrino events detected by IceCube. The technique relies on the detection of nanosecond radio pulses produced by the particle cascade induced by the neutrino interaction in Antarctic ice. The RF emission was first observed during beam tests at SLAC about a decade ago. Interestingly, the air showers induced by cosmic rays generate a similar RF signal - though the dominant generation mechanism is distinct- which are used to validate the sensitivity of the neutrino detector expected from simulation studies. In this talk, I will discuss the first observation of cosmic rays by HRA and discuss the implications for neutrino detectors.

Presentation type:

oral

Poster session / **41**

Extracting a semi-model independent composition from Xmax distributions

Author: Simon Blaess[1]

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The uncertainty when inferring the mass composition from Xmax distributions comes mainly from unknown uncertainties on <Xmax> predictions. Different hadronic models have different <Xmax> predictions for proton showers (the separation between proton and Iron <Xmax> is similar in all models). Therefore, the estimated mass composition has a strong dependence on the hadronic model used for interpreting Xmax distributions. In this work we will show that it is possible to fit at the same time for the cosmic ray composition and for the expected <Xmax> for protons (the <Xmax> for other elements is parametrized in terms of the proton one), reducing drastically the model dependence of the mass composition interpretation. This global fit is only possible if there is a rich enough mix of elements in the fitted cosmic ray composition. It will work even if we had a nearly pure composition within an energy range, as long as we have other elements in other energy ranges.

Presentation type:

poster

Oct.14PM1 / **42**

Radio detection of cosmic rays - achievements and future potential

Author: Tim Huege[1]

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When modern efforts for radio detection of cosmic rays started about a decade ago, hopes were high but the true potential was unknown. Since then, we have achieved a detailed understanding of the radio emission physics and have consequently succeeded in developing sophisticated detection schemes and analysis approaches. In particular, we have demonstrated that the important air-shower parameters arrival direction, particle energy and depth of shower maximum can be reconstructed reliably from radio measurements, with a precision that is comparable with that of other detection techniques. In this talk I will review the achievements of the radio detection technique made with various experiments over the past decade, and discuss the potential for future application in existing and new experiments for cosmic-ray detection.

Presentation type:

oral

Oct.11PM1 / **43**

Results of CR energy spectrum and mass composition study with EAS Arrays in the Tunka Valley

Author: Vasily Prosin[1]

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There are three extensive air showers (EAS) arrays aimed to the study of Cosmic Rays (CR) in the different energy ranges in the Tunka Valley. The first of them is Atmospheric Cherenkov Light Array Tunka-133, containing 175 single PMT detectors at the area of about 3 km2. It ‘s operating since 2009 and has the energy range 5•1015 – 1018 eV. The second one is a low threshold observatory TAIGA-HiSCORE. It currently comprises 28 wide-angle stations (at the area of about 0.25 km2) for registration of Cherenkov light from EAS in the range of 2•1014 – 5•1016 eV. The most energetic CR are planned to be studied with the scintillation array Tunka-Grande. It consists of 19 stations now, recording electromagnetic and muon components of EAS at the area of about 1 km2. The differential energy spectrum collected by Tunka-133 during 5 winter seasons from 2009 to 2014 as well as the very preliminary spectra of two new arrays are presented. The methods of mass composition analysis for different arrays and some results of the analysis are presented.

Presentation type:

oral

Oct.14AM1 / **44**

The status of the TAIGA project

Author: Leonid Tkachev[1]

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Gamma-ray astronomy has had a major breakthrough in the last years with the impressive results obtained using ground- and space-based gamma-ray detectors. While it was not possible to pinpoint the highest energy accelerators within our Galaxy, cosmic rays must be accelerated up to energies of 1 PeV or higher. The new TAIGA project is proposed to solve a number of fundamental problems of high energy gamma-astronomy, cosmic ray and particle physics. The array will be located in the Tunka valley at the site of the Tunka-133 array. The array will consist of wide-angle (~0.6 sr Field of View) non-imaging Cherenkov optical detectors (HiSCORE station) covering an area of up to 5 km^2, and few (4 -16) IACT (Imaging Atmospheric Cherenkov Telescope) detectors based on ~9 m^2 mirrors and muon detectors with total area 1000 m^2. The information of the shower-front sampling array, e.g., the impact point of the shower axis will be combined with the imaging analysis to improve the sensitivity of the detector. This hybrid event reconstruction is a new approach that can be tested in the proposed setup. With such detectors the high angle resolution will be kept down to 30 TeV that allows essentially to improve the sensitivity at this energy range.

The aims of TAIGA are grouped into three main themes:
- Gamma-ray astronomy - one of the most intriguing questions in high-energy astroparticle physics is a search for objects for acceleration of particles up to PeV-energies

- Charged cosmic ray physics – the energy spectrum and mass composition measurements from 10^{14} to 10^{18} eV.
- Particle physics - axion/photon conversion; pp cross-section measurement; search for quark-gluon plasma phenomena.

Main TAIGA array parameters: area will be increased step by step from currently 0.25 to 5 km^2, energy threshold ~20 TeV, general FOV ~ 1 sr . According to preliminary timetable, a 0.6 km^2 stage is planned for 2017, subsequently increasing the area to the aimed 5 km^2 in the following years.
The status of the TAIGA experiment in 2016 will be presented.

Presentation type:

oral

Oct.11AM2 / **45**

The sFLASH experiment: Measuring air fluorescence from Laboratory EAS at SLAC.

Author: Pierre Sokolsky[1]

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We report on an experiment to measure the air-fluorescence from artificial air showers produced at the SLAC National Accelerator Laboratory. The showers have an energy of ~ 10^18 eV and are the result of a superposition of 10^9 10 GeV electons in a picosecond wide pulse. This electron pulse is pre-showered in 1, 2 or 3 radiation lengths of alumina (Al2O3) and then allowed to develop in ambient sea-level air over a distance of 3 meters. A set of phototubes with appropriate filters detects the fluorescence light from this shower at a distance of 10 m perpendicular to the shower axis. The electron beam intensity is monitored by an induction coil. An additional monitor is provided by a rf horn antenna that picks up transition radiation from the last vacuum window before the beam impacts the alumina target. The pmt's gains and spectral responses are carefully calibrated using the CRAYS system developed for the TA experiment at the ICRR in Tokyo. The total systematic error of the air fluorescence measurement is to be held to 10% or better. Preliminary data was taken in July to establish backgrounds and signal to noise levels. Based on this encouraging data the sFLASH experiment is scheduled for the end of September.

Presentation type:

oral

Oct.11PM2 / **46**

Lightest Nuclei UHECR from nearby galactic and nearest AGN sources

Author: Daniele Fargion[1]

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The absence of UHECR clustering toward largest cluster of galaxy, Virgo, the presence of a smeared hot spot toward Cen A and M82, the presence of rarest nearest size multiplet along our galactic

plane, all stand in favor of a very light UHECR composition. Their propagation from 20 Mpc Virgo is forbidden by photo-nuclear dissociation opacity, while it is allowed from few nearby AGN around 2-4 Mpc. Their smeared bending angle is consistent with the lightest nuclei of a few charges.
The very recent composition test by AUGER and TA by air showering models converged to light and Lightest nuclei that we did suggest several times since early 2008. Rare clustering multiplet at twenty EeV around Cen A and Magellanic Cloud, somehow hidden into the other UHECR noises, are also suggesting this interpretation.

Presentation type:

oral

Poster session / 47

Calibration of Photo-multiplier tubes in Fluorescence Detectors of the Telescope Array.

Author: Bokkyun Shin[1]

[1] *Osaka City University*

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For long-term UHECR observations, the gain calibration of photo-multiplier tubes (PMTs) in the Fluorescence Detector (FD) of the Telescope Array (TA) is crucially important to determine UHECR energies. Current uncertainty of PMT gain in TA FD is estimated to be 11% by adding 8% uncertainty of gain calibration using CRAYS in 2008 and 8% uncertainty of on-site monitoring using YAP pulser in quadrature. Here CRAYS is the system of Calibration using RAYleigh Scattering. We calibrate FD PMT using CRAYS again with more accurate laser and probe to achieve 3~4% calibration accuracy. And we have three application plans, the first is to provide calibrated PMTs to fluorescence measurement using electron beams in SLAC, named sFLASH, the second is to crosscheck with the end-to-end calibration result by ELS (on-site Electron Light Source) with calibrated PMTs, and the last plan is the calibration of PMTs of NICHE using CRAYS. Here NICHE is a low energy extension of TA and TALE using Cherenkov light. We will report the status and plan of the calibration.

Presentation type:

poster

Oct.11AM2 / 48

Energy spectrum and composition constraints on the transition from Galactic to extragalactic cosmic rays

Author: Etienne Parizot[1]

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Current data on the cosmic ray spectrum and composition from the knee to the GZK range provide important information and reveal interesting features, which shed new light about the transition from Galactic to extragalactic cosmic rays. A general description and understanding of this transition it shown to be possible within a simple framework involving only two components, a Galactic one with protons accelerated up to $\sim 10^{17}$ eV, and an extragalactic one, with a maximum energy of

the protons rarely exceeding 10^19 eV at the source, and a softer spectrum for protons compared to all heavier nuclei. This latter feature is shown to be expected if the acceleration occurs in an environment with high photon density. We review the main features of this model and show its quantitative agreement with the available data.

Presentation type:

oral

Poster session / 49

Composition studies with the Telescope Array surface detector

Author: Sergey Troitsky[1]

[1] *Institute for Nuclear Research, Russian Academy of Sciences (RU)*

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The method of composition studies with the Telescope Array surface detector (SD) data is presented. The method is based on the multivariate decision tree analysis of SD observables. Preliminary results of the study will be reported at the conference.

Presentation type:

poster

Poster session / 51

Possible implications of the differences between the Auger and TA data

Author: Etienne Parizot[1]

Co-author: Noemie Globus [2]

[1] *Université Paris Diderot / APC*

[2] *Hebrew University of Jerusalem*

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The UHECR data collected by the TA and Auger collaborations show some interesting differences in the spectrum as well as in possible anisotropies. Assuming that they do not simply reflect some statistical and/or systematic uncertainties, but on the contrary capture distinct features associated with different regions in the sky, it is interesting to investigate the implications of such differences to set constraints on the underlying astrophysical scenarios. We show the results of a series of detailed Monte-Carlo simulations, which allowed us to explore the cosmic variance and build a large number of possible sky maps corresponding to different astrophysical models. We find that the presence of a hotspot potentially compatible with the TA data is obtained with an occurence probability of the order of a few percent for some scenarios, and identify the associated constraints on the model parameters.

Presentation type:

poster

Oct.12PM2 / 52

Nonlinear Diffusive Shock Acceleration in GRB Afterglows

Author: Don Warren[1]

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The standard synchrotron afterglow model has been applied to enormous success since its original formulation. In spite of the variety of extensions and refinements made to the basic model, virtually all work on GRB afterglows has ignored two critical aspects of shock acceleration. First, it ignores the significant population of thermal particles that must be present downstream but are not part of a power law distribution. Second, particle-in-cell simulations show that relativistic shocks are efficient enough accelerators that the accelerated cosmic rays modify the shock structure away from the test-particle limit.

We will discuss a new model for GRB afterglows using Monte Carlo simulations. Our model takes into account the highly nonlinear interaction between efficient shocks and the cosmic rays they accelerate. It additionally includes all particles, and not just cosmic rays, in the calculations of photon production. Each of these enhancements makes an observable difference to the spectra and light curves expected.

We will also discuss how a more realistic magnetic field structure, which reaches near-equipartition levels near the shock itself, affects the ability of GRB forward shocks to accelerate protons up to – or even beyond – the ankle of the cosmic ray spectrum observed at Earth.

Presentation type:

oral

Poster session / 53

Auger at Telscope Array: Recent Progress Toward a Direct Cross Calibration of Surface Detectors Stations

Author: Sean Quinn[None]

Co-authors: Hiroyuki Sagawa [1]; Ryuji Takeishi [2]; Toshihiro FUJII [1]; Toshiyuki Nonaka [3]; corbin covault

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Since 2007 the Telescope Array Project (TA) and Pierre Auger Observatory (Auger) have collected extensive data sets spanning several orders of magnitude of the cosmic ray spectrum. In both experiments the bulk of data is generated from the surface detector (SD) array which are energetically calibrated with fluorescence detectors using a hybrid approach. However, each experiment has implemented a different SD station design, resulting in different sensitivities of extensive air shower

channels. Understanding these differences and any potential unforeseen systematic errors are essential for future joint analyses. In this paper we present an update on the progress of this in situ cross calibration program. We focus on recent hardware installations which enable the readout of co-located Auger and TA SD stations at the TA Central Laser Facility. We present a preliminary analysis of TA reconstructed showers also detected by Auger SDs. Finally, we briefly share some details of plans for the second phase of the program: installation of a functional micro array of prototype Auger North SD stations.

Presentation type:

poster

Oct.13AM2 / **54**

High-Energy Particle Showers Observed at Ground Level in Coincidence With Downward Lightning Leaders at the Telescope Array Observatory

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Terrestrial Gamma Ray Flashes (TGFs) detected by satellite observations have been shown to be generated by upward propagating negative leaders at altitudes of about 10 to 12 km MSL, and have durations ranging between a few hundred microseconds and a few milliseconds. The Telescope Array Cosmic Ray observatory, designed to observe air showers induced by ultra high energy cosmic rays, includes a surface scintillator detector (SD) covering approximately 750 square kilometers on a 1.2 km grid. Following the observation of anomalous SD triggers correlated with local lightning activity, a Lightning Mapping Array (LMA) and slow electric field antenna were installed at the TA site in order to characterize the lightning associated with these anomalous triggers. In this talk, we present evidence that the anomalous triggers are produced during the initial breakdown phase of fast, downward propagating, negative leaders above the detectors which produced the triggers. The durations of the high energy radiation are a few hundred microseconds, similar to satellite observations of TGFs. The triggers were produced within a few hundred microseconds of the initiation of the leaders, when the leaders were at an altitude of about 3 to 4 km MSL. The TA scintillation detectors are not optimized for gamma ray detection, however we present the results of simulations demonstrating that the fluxes observed are consistent with this picture. We conclude that the anomalous triggers observed by TA are clearly due to high energy radiation produced by the fast downward propagating negative leaders, and are probably downwarddirected TGFs.

Presentation type:

oral

Oct.12AM1 / **55**

Composition Measurements via Depth of Airshower Maximum at the Telescope Array

Author: John Belz[1]

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The chemical composition of ultrahigh energy cosmic rays (UHECR) is studied primarily through observations of the depth of airshower maximum (Xmax), as seen by nitrogen fluorescence telescopes. The Telescope Array (TA) observatory measures Xmax using both stereo fluorescence detectors and fluorescence/ground array hybrid detection to accurately determine extensive air shower geometry. We compare the resulting Xmax distributions to those predicted by air shower Monte Carlo simulations, by generating events and analyzing them with the same reconstruction program and event quality cuts as used in the data. In this talk, we present a summary of all TA Xmax measurements and discuss their implications for the chemical composition of UHECR.

Presentation type:

oral

Oct.13AM1 / **56**

Constraints on UHECR sources from IceCube

Author: Aya Ishihara[1]

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IceCube is a cubic kilometer scale, deep-ice Cherenkov neutrino detector at the South Pole. IceCube's cosmic neutrino searches cover an energy region all the way from below TeV to EeV and higher. In the EeV energy region, a flux of 'cosmogenic' neutrinos generated by interactions of ultra-high energy cosmic rays on intervening radiatio backgrounds is expected. We have analysed 7 years of IceCube data with the highest sensitivity to date to neutrinos of energy between 10 PeV and 10 EeV. This provides insights into the sources and nature of UHECRs since the "guaranteed" cosmogenic neutrino flux depends in fact on parameters such as the redshift evolution of the UHECR sources, the energy at which UHECRs transit from Galactic to extragalactic, and most importantly, the mass composition of UHECRs. In this talk, results from the cosmogenic neutrino search with IceCube will be presented and their implications discussed.

Presentation type:

oral

Oct.11PM1 / **57**

Cosmic ray physics with the KASCADE-Grande observatory

Author: Juan Carlos Arteaga-Velazquez[1]

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The existence of a knee at a few PeV in the all-particle cosmic ray energy spectrum has been well established by several experiments but its physical origin has eluded researches for a long time. It is

believed that keys to disentangle the mystery could be found in the spectrum and the composition of cosmic rays between 1 PeV and 1 EeV. A first detailed look into the elemental chemical abundances of cosmic rays in this energy regime was provided by both the KASCADE and the KASCADE-Grande experiments. Their measurements opened the door to a wealth of new data on the subject, which led to the discovery of new structures in the all-particle energy spectrum and the confirmation of knee-like features in the spectra of individual mass groups, as well as the observation of an unexpected ankle-like structure at around 100 PeV in the flux of the light component of cosmic rays. In this talk, I will review these early findings, then I will present an update on the spectrum and composition analyses currently performed with KASCADE-Grande and finally I will provide a short summary of further cosmic ray studies that have been carried out with the air-shower data of the observatory.

Presentation type:

oral

Poster session / **58**

Search for EeV Protons of Galactic Origin

Author: Dmitri Ivanov[1]

[1] *University of Utah*

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Three fluorescence detector experiments, HiRes, Telescope Array, and Pierre Auger, agree that the cosmic ray composition is light, probably protonic in 10^18.0 to 10^18.5 eV range. This energy range is well above the critical energy of the galactic magnetic field (GMF). Our simulations of the GMF field show that if these cosmic rays were of galactic origin, there would be an anisotropy in their arrival directions at the Earth. We will present a calculation of how this anisotropy should appear, show that the effect is absent in the Telescope Array surface detector data, and calculate the upper limit on the flux from the galactic protons in 10^18.0 to 10^18.5 eV range.

Presentation type:

oral

Oct.11AM1 / **59**

TA Spectrum Summary

Author: Dmitri Ivanov[1]

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This work summarizes the cosmic ray energy spectrum measurement by the Telescope Array Experiment (TA) in the energy range from 4 PeV to over 100 EeV. The TA is a hybrid detector that uses 3 air fluorescence detectors (FDs) overlooking a ground array of scintillation counters of 1200 m spacing. In May 2016, TA has collected 8 years of data. The TA low energy extension (TALE) extends the energy range of TA to 4 PeV, TALE consists of additional fluorescence telescopes at one of the TA FD stations, in combination with an infill array of 400m spaced counters. The TALE infill array is currently under construction and will become fully operational in 2017. TALE has collected

2 years of data. We will present (1) the energy spectrum measured by TA surface detector, which provides the largest statistics measurement at the highest energies; (2) the TA FD mono and hybrid spectra which cover intermediate energies; and (3) we will show the results of TALE, which include TALE monocular fluorescence and Cherenkov measurements and cover the lowest energies in the experiment.

Presentation type:

oral

Oct.13AM1 / **62**

Multi-messengers from transient candidates of UHECRs

Author: Kumiko Kotera[1]

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In the transient sky are found the most violent phenomena in the universe. These phenomena are the best known spots to supply enough energy and flux to ultrahigh energy astroparticles at the observed level. In this talk, we will focus on some of these powerful objects (e.g., gamma-ray bursts, young pulsars, magnetars, superluminous supernovae, black hole mergers) and estimate their expected signatures in terms of multi-messengers (cosmic rays, neutrinos, photons et gravitational waves). We will compare these predictions to the latest multi-messenger data and the new time-domain information, in order to assess the likelihood of these objects to be sources of ultrahigh energy cosmic rays.

Presentation type:

oral

Oct.14AM2 / **63**

IceCube-Gen2: The next generation neutrino observatory in Antarctica

Author: Lu Lu[1]

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The IceCube observatory, located at the Southpole has been taking high quality data in full operation since 2011. The observation of astrophysical neutrinos at IceCube led to a new era of multi-messenger astronomy. The next generation of IceCube (Gen2) is currently under design aiming at searching for point sources and understanding the production mechanisms at the source. The upgrade will also greatly increase the discovery potential for PeV tau neutrinos, GZK neutrinos and the Glashow resonance. It could in addition allow hybrid measurements at the surface and in-ice at a wider zenith angle range, which provides information on the mass composition of cosmic-rays and gives access to a unique energy range for studying hadronic interaction models.

In this talk, I will discuss current efforts for the upgrade including new sensor proposals for the in-ice and surface detectors. Simulations of the sensitivities to the physics cases will be shown.

Presentation type:

oral

Oct.12AM1 / **64**

Hadronic interaction studies at the Pierre Auger Observatory

Author: Darko Veberic[1]

[1] *Karlsruhe Institute of Technology (DE)*

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The muon content of extensive air showers produced by the ultra-high energy cosmic rays is an observable sensitive to the composition of the primary particle and to the properties of hadronic interactions driving the air-shower cascade. We present different methods to estimate the muon number at the ground and the muon production depth using measurements of the longitudinal, lateral, and temporal distribution of particles in the air showers recorded by the Pierre Auger Observatory. The results, obtained at ~140 TeV c.m. energy for proton primaries, are compared to the predictions of LHC-tuned hadronic interaction models for different primary masses. The models exhibit a deficit in the predicted muon content and the combination of these results with other independent mass composition analyses (such as Xmax) provides them with additional constraints. With the hybrid data it is possible to measure the cross section of proton-air collisions at energies far beyond the reach of the LHC. The proton-air cross section is estimated in two energy bins around ~10^18 eV, chosen for maximal statistics and significant primary proton fraction. In this intervals only the 20% of the most proton-like events are considered to eliminate contamination from higher nuclei. We discuss the model-dependent uncertainties of the measurements.

Presentation type:

oral

Oct.12PM1 / **65**

Search for Anisotropies in the measured Arrival Directions of Ultra-High Energy Cosmic Rays at the Pierre Auger Observatory

Author: Markus Lauscher[1]

[1] *RWTH Aachen University*

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The study of anisotropies in the arrival directions of ultra-high energy cosmic rays can give vital clues to understand their origin.
Here we report the recent results related to the search of anisotropies in the arrival directions of ultra-high energy cosmic rays
measured at the Pierre Auger Observatory.

We focus on the search for large scale patterns.
Prominent is a search within events with energies above 4 EeV using showers with a maximum zenith angle of 80 degrees.
Among the results, we report on the hint of a dipolar pattern for energies above 8 EeV.

Finally, we present an update on the search for correlations between events and nearby extragalactic objects.

Presentation type:

oral

Oct.13AM1 / **66**

UHECR and cosmogenic neutrinos

Author: Venya Berezinsky[1]

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Corresponding Author: venya.berezinsky@lngs.infn.it

Cosmogenic UHE neutrino fluxes are discussed. These fluxes can be detectable by Ice- Cube and future big neutrino detectors only in case the primary UHECR flux is proton dominated. The strong upper limit on proton component of UHECR is given by diffuse flux of HE photons measured recently by Fermi LAT detector up to energy 1 TeV. We argue that this limit still allows the proton-dominated composition of UHECR. The pro- ton and neutrino sources are discussed. The PeV neutrinos detected by IceCube can be produced by sources at large redshifts. This possibility is discussed in general terms and in particular model of neutrino generation at reionization epoch.

Presentation type:

oral

Oct.11PM2 / **67**

The physics of ultra-high energy cosmic rays: spectra, composition and the transition between galactic and extra-galactic cosmic rays.

Author: Roberto Aloisio[None]

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We will review the physics of ultra high energy cosmic rays discussing spectra and chemical composition. The expectations of different theoretical models will be compared with the latest experimental results. A particular emphasis will be given to the discussion of the transition between galactic and extra-galactic cosmic rays.

Presentation type:

oral

Oct.13AM2 / **69**

A novel study connecting UHECRs, neutrinos, and gamma-rays with the objective to identify common counterparts of the three astrophysical messenger

Author: Stefan Coenders[1]

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We present a novel study connecting UHECRs, neutrinos, and gamma-rays with the objective to identify common counterparts of the three astrophysical messengers. In the test presented here, we first identify potential hadronic sources by selecting gamma-ray emitters that are in spatial coincidence with IceCube neutrinos. Subsequently, these objects are correlated against UHECRs detected by the Pierre Auger Observatory and the Telescope array, scanning in gamma-ray flux and angular separation between sources and cosmic rays. A maximal excess of 80 cosmic rays (41.9 expected) is observed for the second catalog of hard {\it Fermi}-LAT (2FHL) objects of blazars of the high synchroton peak type. This corresponds to a deviation from the null-hypothesis of 3.26σ. No excess is observed for objects not in spatial connection with neutrinos. The gamma-ray sources that make up the excess are blazars of the high synchrotron peak type, which we propose here as ultra high energy cosmic ray and neutrino emitters.

Presentation type:

oral

Oct.12AM1 / **70**

Measurements of the mass composition of UHECRs with the Pierre Auger Observatory

Author: Matthias Plum[None]

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As a hybrid cosmic ray detector, the Pierre Auger Observatory can measure the longitudinal air shower
development with the fluorescence detector, and the lateral distribution of particles reaching the ground
with the surface detector. We report on the measurements of the first two moments of the Xmax
distributions measured as a function of energy with the fluorescence detector and convert them to
\<\lnA\> and sigma(lnA). This conversion depends on the adopted hadronic interaction model. To obtain
almost model-independent estimation of dispersion of primary masses sigma(lnA) near the 'ankle' we
use the correlation between Xmax and the signal in the water-Cherenkov stations at 1000 m from the
shower core S(1000). The correlation analysis is robust with respect to uncertainties in hadronic models
and to experimental systematic uncertainties. The observed correlation between Xmax and S(1000)
differs significantly from expectations for pure primary compositions and is well described by a mixed
composition with sigma(lnA) >1.0.

Presentation type:

oral

Oct.12AM2 / **71**

Review of accelerator experiments relevant to air shower development

Author: Takashi Sako[1]

[1] *Nagoya University (JP)*

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Hadronic cross sections relevant to the air shower development are difficult to calculate from the first principle. Instead, phenomenological models are developed, and they are tested using the accelerator data. Because the Large Hadron Collider provides the highest collision energy, 13TeV in the center-of-momentum system and 10^{17} eV cosmic-ray equivalent energy, it is the best tool to tune the models. Intensive studies and tunings of the cosmic-ray models are carried out since the beginning of the LHC. The status of model verifications and tuning using the LHC data will be reviewed in this talk after a general introduction to the collider experiments. Results from non-LHC accelerator experiments and future possibilities relevant to air shower will be also discussed.

Presentation type:

oral

Oct.11PM2 / **72**

Summary of low energy (E < 1 EeV) spectrum and composition

Author: Andrea Chiavassa[None]

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I will present the more recent results obtained in the study of the cosmic ray spectrum and composition from 0.1 PeV to 1 EeV. Recent measurements of the primary spectrum show that, even above the knee, it cannot be described by a single power law. The measured structures have been detected by different experiments and the results agree inside the systematic error due to the energy calibration. The cosmic ray chemical composition is studied using different experimental techniques and following different analysis approaches. I will try to discuss the qualities and the limits of these different approaches.

Presentation type:

oral

Oct.13AM2 / **73**

Multi-messenger signals from UHECR propagation

Author: Alexander Kusenko[None]

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Recent studies of gamma-ray spectra of distant blazars show evidence that cosmic rays are accelerated in their jets at least to 0.1-1 EeV. Secondary gamma rays from UHECR propagation can be used to understand extragalactic background light and to measure magnetic fields in deep intergalactic voids, where two independent techniques point to values of the order of a femtogauss. Secondary neutrinos produced in UHECR propagation may be responsible for PeV neutrino events reported by IceCube.

Presentation type:

oral

Oct.12AM2 / **74**

Review of model predictions for extensive air sowers

Author: Tanguy Pierog[1]

[1] *KIT*

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In detailed air shower simulations, the uncertainty in the prediction of shower observable for different primary particles and energies is currently dominated by differences between hadronic interaction models. With the results of the first run of the LHC, the difference between post-LHC model predictions has been reduced at the same level than experimental uncertainties of cosmic ray experiments. At the same time new type of air shower observable, like the muon production depth, has been measured adding new constraints on hadronic models. Currently no model is able to reproduce consistently all mass composition measurement possible within the Pierre Auger Observatory for instance. We will review the current model prediction for various particle production observables and their link with air shower observables and discuss the future possible improvments.

Presentation type:

oral

Oct.11AM2 / **75**

Particle acceleration to ultra-high rigidities

Author: Martin Lemoine[1]

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It will be argued that the detection of anisotropies at ultra-high energies brings important constraints on the composition of ultra-high energy cosmic rays. In particular, the pattern of anisotropies seen by the Telescope Array experiment suggests that protons are present at these energies. This, in turn, puts strong constraints on the sources.
These constraints as well as the physics of acceleration will be discussed in the second half of this presentation.

Presentation type:

oral

Oct.12AM1 / **76**

Auger-TA composition working group report

Corresponding Author: william.hanlon@gmail.com

Presentation type:

Oct.11PM2 / **77**

(Galactic Cosmic Ray Acceleration)(TBD)

Oct.14AM1 / **79**

AugerPrime, the Upgrade of the Pierre Auger Observatory

Author: Ralph Engel[1]

[1] *Institute for Nuclear Physics Karlsruhe Institute of Technology*

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The data collected with the Pierre Auger Observatory have led to a number of unexpected discoveries. While a strong suppression of the particle flux at the highest energies has been established unambiguously, the dominant physics processes related to this suppression cannot yet be identified. Within the energy range covered by fluorescence detector observations with sufficient statistics, an unexpected energy evolution of the distribution of depth of shower maximum is found. Using LHC tuned interaction models these observations can be understood as a correlated change of the fluxes of different mass groups. On the other hand, they could also indicate a change in hadronic interactions above the energy of the ankle. Complementing the water-Cherenkov detectors of the surface array with scintillator detectors will, mainly through the determination of the muonic shower component, extend the composition sensitivity of the Auger Observatory into the flux suppression region. The upgrade of the Auger Observatory, called AugerPrime, will allow us to estimate the primary mass of the highest energy cosmic rays on a shower-by-shower basis. In addition to measuring the mass composition, AugerPrime will open the possibility to search for light primaries at the highest energies, to perform composition-selected anisotropy studies, and to search for new phenomena including unexpected changes in hadronic interactions. After introducing the physics motivation for upgrading the Auger Observatory, the planned detector upgrade and the deployed engineering array are presented. In the second part of the contribution, the expected performance and improved physics sensitivity of the upgraded Auger Observatory are discussed.

Presentation type:

oral

Oct.13AM2 / **80**

Elves, Forbush decreases and solar activity studies at the Pierre Auger Observatory

Author: Roberta Colalillo[1]

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The Pierre Auger Observatory, designed to observe cosmic rays at the highest energies, can be also a valid ground based instrument for the observation of transient luminous events and for studying modulation of galactic cosmic rays due to solar activity. In more detail, the Fluorescence Detector can observe elves. They are transient luminous emissions from altitudes between 80 and 95 km above sea level, with timescales of tens of microseconds, which are triggered by lightning activity. A dedicated trigger and an extended readout scheme were introduced to enhance detection efficiency on these events and to improve the knowledge of some peculiar characteristics. The low energy mode of the Surface Detector, instead, records variations in the flux of low energy secondary particles with extreme detail. With the Scaler mode, it is possible to register the rate of signals for energies between 15 MeV - 100 MeV; the Histogram mode, using the calibration charge histograms of the individual pulses detected by each water-Cherenkov stations, covers different energy ranges up to 1 GeV. The variations in the flux of galactic cosmic rays has been studied on short and intermediate time scales (Forbush decreases), but also a long-term analysis, which shows the sensitivity of the Observatory to the solar cycle variation, is in progress.

Presentation type:

oral

Conference Summary and Discussion / 81

”conference summary”

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