The 5th International Symposium on Cosmic Rays and Astrophysics (ISCRA-2025)

Report of Contributions

https://indico.nevod.mephi.ru/e/iscra-2025

Contribution ID: **1** Type: **Original Talk**

Solar-diurnal anisotropy of cosmic rays for 71 years of observations

Daily vectors of solar-diurnal anisotropy of cosmic rays (CRs) are obtained based on the Climax neutron monitor (NM) data for 1953-2006. These results are compared with similar anisotropy vectors obtained with the Moscow NM data for 1966-2006 and by the global survey method for 1957-2006. During quiet periods, there is a good agreement between the results obtained with different datasets and by different methods. A homogeneous reliable series of annual average vectors of solar-diurnal anisotropy for CRs with a rigidity of 10 GV at quiet periods is formed.

Primary author: SHLYK, Nataly (IZMIRAN)

Co-authors: Dr BELOV, Anatoly (IZMIRAN); ABUNINA, Maria (IZMIRAN)

Presenter: SHLYK, Nataly (IZMIRAN)

Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **2** Type: **Poster**

Carpet-3 EAS array efficiency estimates

Carpet-3 of BNO INR RAS is an array of scintillation detectors situated in Neutrino Village, Kabardino-Balkarain Republic, Russian Federation. It is meant to observe extensive air showers (EAS) with energies above 100 TeV.

We generated more than 200,000 EAS using CORSIKA 7.8000 with QGSJETIII and FLUKA2024 models from different primary particles: γ-quanta, protons, helium and iron nuclei. Chosen energy range: 10-300 TeV with a discrete uniform distribution, θ distribution is uniform by $\cos^2\theta$ in $[0°, 40°]$ range. The height of observation is 1700 m above sea level.

We created a Geant4 model of the Carpet-3 facility to estimate the efficiency of the array. The simulation program includes 1251 scintillation detectors and passive geometry (buildings and granite embankment). The main result is the energy dependencies of the EAS detection and reconstruction efficiencies.

Primary author: VASILIEV, Nikita (MSU & INR RAS)

Presenter: VASILIEV, Nikita (MSU & INR RAS)

Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **3** Type: **Poster**

Development of method for determining the heavy ion characteristics using solid-state detectors (glasses, minerals)

The report presents the results of development of an algorithm for determining the charge and energy of heavy ions based on the characteristics of the etched tracks in optically transparent solid-state detectors. Initially, the procedure was developed for the experiment to search for and identifying primary cosmic radiation nuclei registered in meteorite olivines, and their charge determination. Currently, the algorithm is being upgraded for simultaneous determination of charge and energy. The ability of the tested materials to preserve ion tracks at high temperatures is being tested. These materials are promising, in particular, for registration by method of gas thermochromatography of fission products of superheavy nuclei synthesized on accelerators.

Primary author: STARKOVA, Elena

Presenter: STARKOVA, Elena

Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **4** Type: **Original Talk**

Ultra high energy cosmic rays from the Galactic center

It is shown that Eddington-like accretion event in the Galactic center several
million years ago and particle acceleration at accompanying shocks and jets could explain the the observed cosmic ray spectrum at energies above 1 PeV. Cosmic ray particles are confined in extended
(several hundred kiloparsec in size) galactic halo. It is shown that the halo magnetic field could be as small as
2×10^{-7} G for the effective confinement.

Primary authors: ZIRAKASHVILI, Vladimir (Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radiowave Propagation, Moscow, Russia); ROGOVAYA, Svetlana (IZMIRAN)

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **5** Type: **Original Talk**

A New Approach to Ground Level Enhancement analysis

Ground Level Enhancement (GLE) refers to a rapid increase in the intensity of cosmic particles reaching the Earth's surface, typically associated with solar flares and coronal mass ejections. This phenomenon is of significant interest due to the high energy of solar particles required to initiate secondary particles in the atmosphere that can reach sea level, subsequently increasing the counting rate in neutron monitors. This study proposes a novel approach by focusing on the enhancements observed in the neutron monitors. The signals of 76 events were analyzed and classified based on their morphological features. Four distinct classes of GLE were identified. Further examination of their temporal and amplitude characteristics revealed patterns that suggest varying underlying processes. This research provides valuable insights into the nature of GLEs and may contribute to a better understanding of space weather phenomena.

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Presenter: CHELIDZE, Ksenia (MEPhI)

Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **6** Type: **Original Talk**

Dynamo&oscillation effects in supernova neutrino spectra

The neutrino transport in magnetized stellar plasma of type II supernovae is considered paying particular attention for fluctuations in neutrino-nuclear scattering. These effects can be described by the Fokker-Planck equation for the neutrino phase space distribution function [1]. The respective kinetic coefficients are determined by energy transfer and straggling cross sections in neutrino collisions with a magnetized nucleon gas caused by the neutral current Gamow-Teller interaction. Such scattering leads to neutrino acceleration at realistic parameters of stellar environment. As is shown the high-energy component of the electron antineutrino flux is enhanced in addition due to neutrino oscillations. Such a strengthening of the spectrum hardness is particularly pronounced in the case of the inverted mass ordering and makes the signal more registrable by ground-based detectors. The possibilities of supernova neutrino observations by Cherenkov underwater telescopes and sensitivity to mass ordering are discussed.
1. V. N. Kondratyev, IJMPE 33 (2024) 2441024

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Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **7** Type: **Original Talk**

PROTON ACCELERATION RATE REQUIRED FOR THE GLE EVENTS OF THE 24th AND 25th SOLAR CYCLES

The AntiCoincidence Shield of the SPectrometer on the INTEGRAL (ACS SPI) records primary and secondary HXR with energies E >100 keV. The secondary HXR is due to galactic and solar CR protons. The ACS SPI is a perfect instrument for studies of temporal relation between solar HXR flares and associated solar proton enhancements. The onset of a significant increase in the ACS SPI count rate of concurrently or after a solar HXR burst might be considered as a moment of the first solar protons arrival to the Earth's orbit with energy less than 430 MeV — the atmospheric cutoff. In some GLEs, the increases in the count rate of the ACS SPI detector are observed earlier than the GLE onset registered by NMs, (GLE71) but in some other GLEs the situation is opposite (GLE72). The delayed response of NM's may indicate the reversal velocity dispersion due to the small acceleration rate. The proton acceleration rate (effective electric field) was estimated from a time difference between the onset of >100 keV electron emission and the SEP onset observed by ACS SPI as well as neutron monitors network in cases of GLEs. The earlier onset of GLEs in comparison with ACS SPI proton enhancement corresponds to acceleration of observable by NMs amount of protons in the flare impulsive phase. In these cases the ACS SPI solar proton enhancement is visible later due to high solar HXR background. The later onset of GLEs in comparison with ACS SPI proton enhancement correspond to acceleration of very small amount of protons above their atmospheric cutoff during the flare impulsive phase. The ACS SPI solar proton enhancement is visible earlier due to better sensitivity to protons of energies below the atmospheric cutoff. The majority of solar protons responsible for the 73rd, 74th, 75th and 76th GLE events (the GLE events of the 25th cycle up to May 2025 have been accelerated in rather weak electric fields and as a result look like subGLE events of the 24th cycle.

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Presenter: STRUMINSKY, Alexei (Space Research Institute, Moscow, Russia)

Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **8** Type: **Poster**

On the usability of small-scale scintillation muon telescopes

Perspectives and difficulties of using small (<1 mˆ2) particle detectors made with scintillating materials for measuring muon component of galactic cosmic rays will be discussed using the example of an experiment carried out at IZMIRAN in last 3 years.

Parameters of the instrument will be shown. Special attention will be given to methods of correcting the data for environmental effects, which play the bigger role when working with muon component.

Scientific potential of using similar instruments for building networks distributed worldwide will be assessed.

Primary authors: BELOV, Semyon (IZMIRAN); YANKE, Victor (IZMIRAN)

Presenter: BELOV, Semyon (IZMIRAN)

Session Classification: Poster Session

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **9** Type: **Poster**

March 24th, 2024 Forbush effect: cosmic ray variations spectra, anisotropy and magnetospheric current system parameters

Using data of ground-level cosmic ray observations at the worldwide network of neutron monitors, Yakutsk muon telescope and URAGAN muon hodoscope (Moscow) and the spectrographic global survey method, we calculated cosmic ray variations spectra and anisotropy, as well as changes in the planetary system of rigidities of geomagnetic cutoff during the Forbush effect of March 24th, 2024. At the sites of muon component observations, mass-average air temperature was also obtained. We demonstrate that cosmic ray variations spectra can't be described by a power law function in a wide range of rigidities, We established, that during the aforementioned event, a "magnetic loop"-like structure of the interplanetary magnetic field was present at Earth's orbit. Based on the data on changes in the planetary system of rigidities of geomagnetic cutoff, we estimated parameters of the primary current systems of the magnetosphere during the March 24th, 2024 geomagnetic storm within an axisymmetric magnetosphere model.

Primary authors: Dr OLEMSKOY, Sergei (ISTP SB RAS); КОВАЛЕВ, Иван (ИСЗФ СО РАН); Dr SDOBNOV, Valery (ISTP SB RAS); Dr KRAVTSOVA, Marina (ISTP SB RAS)

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Session Classification: Poster Session

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **10** Type: **Poster**

РАЗДЕЛЕНИЕ ИЗОТОПОВ ВОДОРОДА В ЭКСПЕРИМЕНТЕ ОЛВЭ ПО ФОРМЕ АДРОННОГО КАСКАДА

Проблема исследования спектров ядер дейтерия и трития является частью более общей проблемы изучения процессов ускорения и распространения космических лучей. В последние годы разные эксперименты показали заметные отличия в спектрах различных компонент, а также наличие дополнительного “колена” в спектре по магнитной жесткости. Эти эффекты требуют объяснения. Для решения проблемы необходима информация о спектрах дейтронов высоких энергий и, возможно, тритонов. Эти частицы являются вторичными, и анализ их спектров может помочь сделать выбор между различными гипотезами. Предлагается метод разделения изотопов водорода в области высоких энергий, основанный на анализе формы адронного каскада в глубоком ионизационном калориметре, который будет использоваться в планируемом эксперименте ОЛВЭ. Возможность такого разделения ранее была показана при обработке результатов эксперимента СОКОЛ-2.

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Presenter: RAKHIMCHANOVA, Karina

Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **11** Type: **Original Talk**

Analysis of the time structure of extensive air showers with E<=10^16 eV based on data from the Horizont-T facility at the Tien Shan high-mountain scientific station of the Lebedev Physical Institute

The Horizont-T installation at the Tian Shan High-Mountain Scientific Station of the Lebedev Physical Institute (LPI/FIAN), located at an altitude of 3350 meters above sea level, is designed for the detection of extensive air showers (EAS) of ultra-high energies with axis inclinations up to 70^o. The capabilities of the equipment allow for digitization of signals recorded by scintillation detector stations with a resolution of 2 ns, enabling studies of the time structure of EAS, including so-called multimodal events or events with delayed particles—signals that appear as multiple pulses separated in time.

In the first stage, a simplified simulation of EAS signals with energies of 10^{16}–5×10^{18} eV in the detectors of the Horizont-T prototype was performed using the classical Corsika-77500 code with the commonly used QGSJETII-04 hadronic interaction model. It was shown that the occurrence of multimodal events can be explained without invoking exotic particles or interactions, but rather by the arrival of several particles or groups of particles from a single EAS within the detector's time gate.

The second stage of the study was based on the analysis of specially collected experimental data from Horizont-T, consisting of random low-energy background events. The potential contribution of low-energy ($E \leq 10^{12}$ eV) showers to the recorded signals from high-energy EAS was investigated. Low-energy events simulated using Corsika-77500 were analyzed, and conclusions were drawn regarding the optimal parameters for simulations and the contribution of random low-energy showers to the time profiles registered from high-energy EAS events.

In the third stage of the work, the developed event processing algorithms for Horizont-T were applied to analyze a dataset of EAS events with energies near the detection threshold of the installation—approximately 5×10^{16} eV. This experimental dataset is used to study the phenomenology of multimodal events in comparison with artificial EAS events generated using Corsika-77500.

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Presenters: Mr SAMOILOV, Mikhail (Lebedev Physical Institute); ANOKHINA, Anna (M.V.Lomonosov MSU, SINP MSU)

Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **12** Type: **Poster**

Studying the relationship between cosmic rays and atmospheric electricity at the Tunka-Grande scintillation array: status and prospects

Research on thunderstorm phenomena has been conducted for centuries, however, some fundamental questions remain unresolved. One of these is the mechanism of occurrence and propagation of lightning discharges. Initiated by high-energy (E > 10ˆ15 eV) cosmic rays (CR) extensive air showers (EAS) can be one of the factors influencing the mechanism of lightning development. At the same time, the thunderstorm cloud itself probably plays the role of an active medium that modifies the processes of EAS propagation.
In 2016, the Tunka-Grande array was commissioned and included in the TAIGA astrophysical complex (Tunka Advanced Instrument for cosmic rays and Gamma Astronomy). It consists of an array of scintillation detectors grouped into 19 stations on an area of 0.5 km2. The main objectives of the experiment are to study the energy spectrum and mass composition of CR, as well as to search for diffuse gamma radiation in the energy range of 10-1000 PeV by detecting the electron-photon and muon components of EAS. In the summer of 2024, in order to study the relationship between CR and atmospheric electricity, the hardware and software of three stations was upgraded, and the EFM-100 surface electric field strength sensor was included in the dataset.
The report provides a description of the Tunka-Grande array, the results of joint measurements of the flow of single atmospheric particles (electrons and muons) and the electric field strength for the 2024 season. It is shown that lightning discharges with a range of more than 15 kilometers have no effect on the flow of charged particles. Additionally, plans for further modernization of the facility and research prospects are being discussed.

Primary authors: MALAKHOV, Stanislav (API ISU); MONKHOEV, Roman (API ISU)

Presenter: MALAKHOV, Stanislav (API ISU)

Session Classification: Poster Session

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **13** Type: **Overview**

Proposal for a next generation astronomy neutrino telescope

In 2021, LHAASO observed a large number of Pevatrons in the Milky Way, which pointed out the direction for the sensitivity design of the next generation astronomy neutrino telescope, and it is expected to observe the precious neutrino celestial point source in the Milky Way only by designing a telescope with at least 30 times the sensitive volume of the IceCube detector. Therefore, we proposed the High-energy Underwater Neutrino Telescope project (HUNT). In order to realize this project, we innovatively put forward the scheme of an optical module based on a 20-in PMT. Relying on the Baikal-GVD experiment, we have deployed optical modules into Lake Baikal. Then, it is planned to set up a small array in the near future to observe the atmospheric neutrino signal in the South China Sea. At the same time, we built a detector simulation program based on GEANT4 and GPU parallel algorithm, and the performance expectations will be presented.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **14** Type: **Poster**

MODELING OF EXTENSIVE AIR SHOWERS IN PYTHIA 8.3 WITH MODIFIED HADRONIC INTERACTION CHARACTERISTICS

One of the most relevant difficulties in the ultra-high energy cosmic ray (UHECR) physics is the so-called “muon puzzle”. It refers to the observed excess of muons in extensive air showers (EAS) induced by UHECR compared to the results of simulations. It is assumed that one possible solution of the “muon puzzle” could be the modification of hadronic interaction models. Some studies suggest an idea of the excess of ρ^0-mesons compared to $\rho^{\pm}$-mesons. Other possible solutions may include an increased yield of baryons or strange particles in hadronic interactions. However, performing numerical calculations using standard EAS simulation tools within the framework of the abovementioned modifications is a serious challenge.

In this study, the methods for modeling muon and hadronic components of the EAS induced by UHECR are investigated using the PYTHIA 8.3 event generator which allows modification of hadronic interaction parameters. In particular, the influence of hadronization parameters, such as the probability of s-quark production relative to u- and d-quarks and the probability of vector meson production relative to pseudoscalar mesons, on the EAS characteristics is studied.

It is found that the increase in the strange particle yield leads to a noticeable increase in the number of muons in the EAS. In addition, the simulations, including partial replacement of π-mesons by heavier mesons, also indicate an increase in the number of muons in the EAS and a shift in the muon component energy spectrum. These results may support the hypothesis that changing of the hadronization parameters may play a role in solving the “muon puzzle”.

Primary authors: ABDUNAZAROV, Mardon; NIKOLAENKO, Roman

Presenter: ABDUNAZAROV, Mardon

Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **15** Type: **Original Talk**

PRIMARY COSMIC RAYS ENERGY SPECTRUM BY THE 3 YEARS DATA OF THE TAIGA-HiSCORE ARRAY

The TAIGA-HiSCORE EAS Cherenkov light array with total area of about 1 kmˆ2 has collected data during the 3 seasons of observation (2021 – 2024). Reconstruction of the primary energy with Cherenkov light fluxes at the distances 100 and 200 m from the core with the adequate zenith angle corrections let us obtain the energy spectrum in the range from 300 TeV to 10 PeV. Our spectrum is in extreamely good agreement with the data of HAWC and LHAASO experiments.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **16** Type: **Overview**

Hybrid complex of TAIGA-1 - current status and development prospects.

Currently, the TAIGA-1 complex includes 4 Imaging Atmospheric Cherenkov Telescopes (IACT) of the TAIGA-IACT facility, 295 wide-angle Cherenkov detectors of the TAIGA-HiSCORE and Tunka-133 arrays, distributed over an area of 3 kmˆ2, and 19 scintillation stations of the Tunka-Grande installation. With their help, a large volume of experimental data has already been obtained on the cosmic rays flux with energies from 200 TeV to several EeV and gamma quanta with energies above 3 TeV, including, for the first time, gamma quanta with energies above 100 TeV were detected by the Cherenkov method, both within the framework of the hybrid and stereo modes. While the TAIGA-1 complex continues to develop methods and technologies that are planned to be used to create the TAIGA-100 complex with an area of about 100 kmˆ2, the potential of the TAIGA-1 complex for solving a wide range of physical problems is far from exhausted. In the coming years, it is planned to commission the fifth IACT to significantly increase the sensitivity for detecting the charged component of EAS by deploying new detectors of the TAIGA-Muon scintillation setup. In addition, it is planned to begin studying atmospheric electricity, including thunderstorm phenomena. The report presents plans for the development of the TAIGA-1 complex and a program of physical research for the next 5 years.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **17** Type: **Original Talk**

Is Lorentz Invariance Violation the Key to the Muon Puzzle?

Recent experimental results have shown an excess of muons in extensive air showers produced by cosmic rays with energies above 10^{17} eV. In this work, I discuss how even small deviations from Lorentz-invariant physics could influence the interpretation of the current state of the so-called "muon puzzle."

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **19** Type: **Overview**

Highlights of Recent Progress in UHE Gamma-Ray Astronomy with LHAASO

In this talk, I will overview the recent studies of LHAASO in TeV-PeV gamma-ray astronomy, including our measurements on supernova remnants, pulsar wind nebulae, massive star clusters, microquasars, and diffuse emission from the Galactic Plane.

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Presenter: LIU, Ruoyu (Nanjing University)

Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **20** Type: **Original Talk**

High-energy photonuclear reactions contribution to the ground-level muon content of extensive air showers

In the extensive air showers (EASs), photonuclear reactions transfer energy from the electromagnetic to the hadronic cascade and thus contribute to the muon production rate. However, the high-energy (center-of-momentum frame energy > 100 GeV) photonuclear cross-section is poorly constrained by laboratory experiments. This implies a systematic uncertainty in the Monte-Carlo (MC) simulations of EASs. In this work, we develop a simple analytic approach to estimate this uncertainty over a vast range of high-energy photonuclear cross-section models. We derive a parametric formula that estimates the expected number of muons at the ground level as a functional of the assumed photonuclear cross-section. We fit the parameters using MC simulations and discuss the physical implications in the context of the so-called 'muon puzzle'.

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Presenter: Mr MARTYNENKO, Nickolay (MSU, Physical Faculty / INR RAS)

Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **21** Type: **Overview**

Исследование астрофизических источников космического излучения сверхвысоких энергий на комплексе установок “Ковер-3”

В докладе рассматривается современное состояние и перспективы развития уникального комплекса установок Баксанской нейтринной обсерватории ИЯИ РАН, состоящего из ливневых установок “Ковер-3” и “Андырчи”, и Баксанского подземного сцинтилляционного телескопа (БПСТ), для проведения исследований астрофизических источников космического излучения сверхвысоких энергий.
Одной из основных задач установки “Ковер-3” является измерение характеристик высокоэнергичного гамма-излучения космического происхождения, для чего необходимо с высокой эффективностью отделять ливни, рожденные первичными гамма-квантами сверхвысоких энергий, от обычных ШАЛ, образованных первичными протонами и ядрами. Для проведения исследований в области гамма-астрономии планируется увеличение эффективной площади регистрации ШАЛ установкой “Ковер-3” до 104 м2 и увеличение площади подземного мюонного детектора до 615 м2.
В целом комплекс установок позволяет проводить изучение спектра, состава и анизотропии космических лучей в широком диапазоне первичных энергий: 1013 – 1018 эВ. Рассматривается возможность решения “мюонной загадки” по результатам одновременного изучения мюонов высокой (200 ГэВ) и низкой энергии (1 ГэВ) в ШАЛ с первичными энергиями в диапазоне 1016 — 1018 эВ при одновременной регистрации ливней разнесенными установками комплекса.

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Presenter: PETKOV, Valeriy (INR RAS)

Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **22** Type: **Original Talk**

Mass Composition of Cosmic Rays in the 0.8–2 EeV Energy Range: Muon Measurements from the Upgraded Yakutsk EAS Array

We present the results of a study on the mass composition of cosmic rays (CRs) in individual air shower events with energies of 0.8–2 EeV and arrival zenith angles less than 60°. The analysis utilizes extensive air showers (EAS) recorded over three observation seasons (2021–2024) by the Yakutsk EAS array following its major upgrade in 2019–2021. The CR composition was estimated by comparing the measured muon content in EAS with simulated predictions based on the QGSJET-II.04 model. Our findings confirm the previously reported detection at the Yakutsk array (for energies above 10 EeV) of four distinct groups of primary particles with different origins. These results are potentially significant for understanding the nature of cosmic rays in this primary energy range.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **23** Type: **Overview**

The Yakutsk EAS Array: Advancing Cosmic Ray Research Through Modernization and Future Development

The Yakutsk EAS Array, one of the world's longest-running cosmic ray observatories, has undergone major modernization (2019–2021) to enhance its detection capabilities. Currently operating an upgraded hybrid system of scintillation and muon detectors, it provides precise measurements of extensive air showers in the 10^{16}–10^{20} eV range. Recent results include mass composition studies and anisotropy analyses of ultra-high-energy cosmic rays. Future development focuses on increasing the muon detector number, improving composition sensitivity, and participating in multi-messenger astrophysics. The array's unique capabilities continue to contribute to understanding cosmic ray origins and testing fundamental physics at extreme energies.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **24** Type: **Original Talk**

On solar sources of interplanetary disturbances leading to high-energy magnetospheric electron enhancements in geostationary orbit

Based on measurements of magnetospheric electron fluxes with energies >2 MeV in geostationary orbits, solar wind (SW) velocity, and geomagnetic activity for the period 1995-2023, a catalog of electron flux enhancements has been compiled. For the events of this catalog, interplanetary disturbances have been determined, after which high-energy electron fluxes (HEEF) begin to increase, and their solar sources have been established. It is found that in 97.2% of cases, one of the solar sources of interplanetary disturbances that led to electron flux increases were high-speed streams from coronal holes (HSSs from CHs), in particular only HSSs from CHs were observed in 52.5% of events, and in the remaining cases, HSSs from CHs were observed together with coronal mass ejections (CMEs) after solar flares and/or filaments disappearance. The average behavior of the HEEF, SW velocity and geomagnetic activity indices for events associated with the arrival of an HSS from CH to the Earth is obtained. It is shown that electron flux enhancements events associated with interplanetary disturbances from HSSs from CHs and from CMEs differ in duration and maximum electron fluence.
This research is funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. AP19678078 and Grant No. BR21881941).

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Presenter: KRYAKUNOVA, Olga (Institute of Ionosphere)

Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **25** Type: **Original Talk**

The LVD Experiment: 1992 to present

The Large Volume Detector (LVD) located at the Gran Sasso Laboratory is designed to continuously search for neutrinos from stellar core collapses in our galaxy. The detector has been collecting data since 1992 from the cosmic ray, neutrino astrophysics, and background research programs in the underground laboratory. This talk presents a short overview of the previously obtained muon results and the promising experimental tasks that can be solved using the underground scintillation detector LVD.

Primary author: Dr AGAFONOVA, Natalia (Institute for Nuclear Research of RAS)

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Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **26** Type: **Overview**

TIen Shan Experimental Complex: Current Status, New Results, and Development Prospects

The report reviews the current state of research at the multifunctional detector complex of the Tien Shan high-mountain scientific station of the Lebedev Physical Institute. The results of the search for new phenomena in the field of cosmic ray astrophysics, high-energy atmospheric physics, and geophysics are presented. In the field of cosmic ray astrophysics, the main results include the study of EAS with a non-standard time structure, the detection of scaling violation in cosmic rays, the detection of an excess of the muon component and an anomalous increase in the fluxes of thermal neutrons and gamma quanta accompanying the passage of EAS in the energy region of the "knee" in the cosmic ray spectrum, as well as the results of the development of a cosmic ray spectrum model taking into account the existence of particles of strange quark matter. In the field of high-energy atmospheric physics, experimental evidence on the relationship between cosmic rays and processes in the thunderstorm atmosphere are presented, and the results of studying the features of increasing the intensity of hard radiation at the moments of lightning discharges inside thunderstorm clouds are considered. In the field of geophysics, the results of multichannel monitoring of the radiation background in the TSHVNS area and the search for signals-precursors of seismic activity are presented. Prospects for upgrading the complex and new research areas are considered.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **27** Type: **Original Talk**

Energy spectrum and mass composition of the primary cosmic rays based on the intensity of muon bundles detected in the NEVOD-DECOR experiment

The results of the analysis of the NEVOD-DECOR data on the study of inclined muon bundles of cosmic rays for the period from 2012 to 2023 are presented. An original method for studying the muon component of extensive air showers, local muon density spectra, was used. The data are compared with the calculations based on the simulation of air showers using the CORSIKA program for different models of hadronic interactions. The estimates of the energy spectrum and the behavior of the mass composition of primary cosmic rays in a wide energy range from *2ˆ15 to 3*10ˆ18 eV were obtained. They are compared with the data of other experiments.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **28** Type: **Poster**

EAS arrival direction reconstruction in the ENDA-INR experiment

The prototype of the ENDA (Electron Neutron Detector Array) cluster was created on the territory of the INR RAS in Moscow (ENDA-INR). It consists of 16 electron-neutron detectors (en-detectors) and using to study EAS (Extensive Air Showers) with energy above 1 PeV. Its purpose is testing the registration methods and methods for signal processing. The paper describes the detectors calibration method, the array fast timing estimation, an algorithm for reconstruction the shower arrival direction and some preliminary results obtained from experimental series.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **29** Type: **Poster**

ENDA-INR extensive air shower experiment

The prototype of the ENDA (Electron Neutron Detector Array) cluster was created on the territory of the INR RAS in Moscow (ENDA-INR). The concept of the ENDA consists in simultaneous registration of the electromagnetic and thermal neutron components (being a part of hadronic component) of the EAS. The report is devoted to the first experimental data of the prototype together with the simulation data.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **30** Type: **Original Talk**

EAS Maximum Depth from the Space-Time Structure of Cherenkov Light Based on the TAIGA-HiSCORE Data

A new simulation using the CORSIKA code without accelerating coarsening of the results was performed for the energy range of 1-100 PeV, taking into account pulse formation at the input of the optical station of the TAIGA-HiSCORE array. Refined relationships between the steepness parameter of the lateral distribution function (LDF) and the light pulse FWHM at distances of 200-400 m and the relative position of the EAS maximum have been obtained. The application of the new simulated relationships to measure the EAS maximum depth (X_{max}) by the data of the 3 seasons of the TAIGA-HiSCORE observations (2021 – 2024) are shown.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **31** Type: **Poster**

Симуляция регистрации сигнала от гамма-всплеска на наземных телескопах TAIGA-IACT

В послесвечении гамма-всплесков (GRB) могут встречаться гамма-кванты с энергией $E =$ 1 и более. Присутствие в спектре гамма-квантов высокой энергии можно обнаружить с помощью наземных установок, например, распределённых черенковских детекторов (HAWC, LHAASO), или же с помощью атмосферных черенковских телескопов (H.E.S.S, TAIGA-IACT).

При наличии автоматической системы быстрого наведения по координатам из оповещений о гамма-всплесках можно провести сеанс наблюдения за участком неба и провести выделение гамма-сигнала. Поток гамма-квантов при GRB на короткое время может превышать поток от Крабовидной туманности на несколько порядков, что существенно упрощает задачу подавления фоновых адронных событий.

В настоящей работе приведена симуляция регистрации высокоэнергичного гамма-излучения с помощью черенковского телескопа TAIGA-IACT на примере события GRB221009A.

[1] LHAASO Collaboration*† et al., A tera–electron volt afterglow from a narrow jet in an extremely bright gamma-ray burst.Science380, 1390-1396(2023). DOI:10.1126/science.adg9328

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **32** Type: **Poster**

Potential sites for deployment of the TAIGA-100 project

The TAIGA-100 astrophysical complex is a project of a large-scale facility designed to solve a wide range of fundamental problems in gamma ray astronomy, cosmic ray physics and particle astrophysics. It will include several types of detectors to record various components of extensive atmospheric showers over an area of 100 square kilometers.
A key aspect of the successful implementation of the TAIGA-100 project is choosing an optimal site for its location. The report examines potential sites and analyzes their astroclimate by satellite data. The importance of in-situ measurements is emphasized. A prototype of the astroclimate station deployed on the area of the Tunka Astrophysical Center for Collective Use, where the operating TAIGA-1 complex is located, is described. The results of the comparison of the predictions of the Era5 model based on satellite data with the measured soil temperature profile at a depth of up to 3 m are presented, which allows assessing the accuracy of climate models and their applicability for planning future studies.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **33** Type: **Overview**

The orbital telescope system ERA: Extreme Relativistic Astrophysics

One of the most challenging tasks in modern astrophysics is determining the nature and origin of cosmic rays with energies exceeding the Greisen-Zatsepin-Kuzmin (GZK) cutoff (˜50 EeV), known as ultra-high-energy cosmic rays (UHECRs). The primary difficulty lies in their extremely low flux, necessitating experiments with vast exposure areas. The two largest ground-based observatories– the Pierre Auger Observatory (Auger) in Argentina and the Telescope Array (TA) in the USA – cover areas of approximately 3000 km² and 1800 km², respectively. However, neither Auger nor TA can achieve uniform exposure across the entire celestial sphere, a crucial requirement for identifying UHECR sources. Moreover, discrepancies exist between their results concerning the energy spectrum and composition of UHECRs.

An alternative approach to measuring UHECRs from low-Earth orbit (LEO) via extensive air shower (EAS) fluorescence emission was first proposed by J. Linsley in the early 1980s and later developed through projects such as TUS, JEM-EUSO, OWL, and POEMMA. This method offers the advantages of a large observational area and uniform exposure over the celestial sphere. However, designing instruments that combine large aperture, wide field of view, and high temporal resolution presents significant technological challenges.

The ERA (Extreme Relativistic Astrophysics) project proposes a novel solution: deploying a constellation of small spacecraft in LEO, each equipped with identical compact telescopes. Each telescope has a relatively narrow field of view (˜10°) but is capable of detecting at least 10 particles with energies above the GZK limit. The telescopes are launched in pairs to enable stereoscopic observation of EAS tracks, substantially improving the reconstruction accuracy of primary particle parameters, particularly the depth of the shower maximum.

The initial phase involves launching two spacecraft to validate the technique and achieve the first reliable detection of about a dozen UHECR events from space within one year of operation. Ultimately, a fleet of 5 pairs of satellites will provide sufficient statistics to measure the UHECR spectrum across the entire celestial sphere, helping to resolve discrepancies between ground-based experiments. This advancement will mark a critical step toward identifying the sources and acceleration mechanisms of UHECRs and testing hypotheses about the existence of a nearby source (within ˜10 Mpc), potentially enabling its identification.

This report presents the current status of detector development, including the optical system design, photodetectors, spacecraft subsystems, and organizational aspects of preparing and conducting the space-based experiment.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **34** Type: **Original Talk**

Метод определения энергии гамма квантов по данным АЧТ в эксперименте TAIGA на основе анализа существенных признаков, выделяемых с помощью автоэнкодеров.

Одной из основных задач исследования гамма источников с помощью атмосферных черенковских телескопов (АЧТ) является восстановление энергетического спектра испускаемых гамма квантов. В традиционном методе определения энергии гамма квантов физические характеристики восстанавливаются путем анализа параметров Хилласа, полученных из изображений ШАЛ на АЧТ и которые являются следствием статистических моментов изображения. Их число конечно и определяется эмпирическими соображениями. Мы представляем альтернативный метод обработки данных АЧТ, основанный на формировании другого набора существенных признаков с помощью нейронных сетей - автоэнкодеров. В качестве альтенативного набора существенных признаков предлагается использовать параметры скрытого пространства автоэнкодеров, которые, как и параметры Хилласа, содержат информацию об изображении в сжатой форме, но, в отличие от традиционного подхода, размерность скрытого пространства не фиксирована и может быть оптимизирована так, чтобы наилучшим образом восстанавливать исходные физические параметры гамма квантов.
Использование скрытого пространства атоэнкодер для выделения существенных признаков представляет особый интерес в случае анализа мультимодальных данных. В частности, мы предполагаем распространить предложенный метод для совместного анализа мальтимодальных данных, полученных с АЧТ и массива черенковских детекторов HiSCORE в эксперименте TAIGA.
В данной работе рассматривается метод восстановления энергии гамма квантов на примере Монте-Карло данных АЧТ для установки TAIGA путем выделения существенных признаков с помощью нейронных сетей типа автоэнкодер, исследуется зависимость качества восстановления энергии гамма квантов от размерности скрытого пространства и проводится сравнение с традиционным подходом восстановления энергии.

Работа выполнена при финансовой поддержке РНФ, грант № 24-11-00136

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **35** Type: **Poster**

Влияние методов предобработки данных атмосферных черенковских телескопов на точность восстановления параметров ШАЛ

Атмосферные черенковские телескопы (АЧТ) сегодня активно используются в гамма-астрономии. С их помощью регистрируют угловое распределение черенковского света широких атмосферных ливней (ШАЛ), инициированных первичными частицами высоких энергий. Наблюдения осложняются наличием постоянного фонового шума, например, свечение ночного неба, антропогенная засветка. Это приводит к снижении точности восстановления физических параметров ШАЛ, а иногда и к регистрации ложных событий. Для выделения областей с изображением ШАЛ от фонового шума, в процессе предварительной обработки данных применяется процедуры очистки изображений (см., например, [1]). Несмотря на то, что такие процедуры эффективно удаляют значительную часть шумовых пикселей, они все же вносят искажения в изображения ШАЛ, что ухудшает качество последующего анализа данных. Особое значение влияния на качество восстановления параметров ШАЛ это вопрос приобретает при построении нейросетевых моделей анализа данных для подготовки обучающих выборок на основе Монте-Карло данных.

В данной работе исследуется степень вносимых искажения параметров Хилласа при использовании различных процедур предобработки изображений, а также возможность уменьшения таких искажений путём модификации процедуры tail-cut cleaning. Предложенный подход апробирован на данных АЧТ астрофизического комплекса TAIGA [2]. Он может быть адаптирован и для других АЧТ установок.

Работа выполнена при финансовой поддержке РНФ, грант № 24-11-00136

[1] Daum A. et al. First results on the performance of the HEGRA IACT array //Astroparticle Physics. – 1997. – Т. 8. – №. 1-2. – С. 1-11.

[2] Kuzmichev L. A. et al. TAIGA gamma observatory: status and prospects //Physics of Atomic Nuclei. – 2018. – Т. 81. – С. 497-507.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **36** Type: **Original Talk**

Hybrid detection of Cosmic Rays with ENDA-64

The Electron-Thermal Neutron Detector Array (ENDA) is located at Haizishan, Daocheng, Sichuan Province, China, at an altitude of 4410 meters. The scientific goal of ENDA is to measure the composition-resolved energy spectrum of cosmic rays, particularly in the knee region, through joint observations with LHAASO. Currently, 64 detectors, so called ENDA-64, have been deployed at the LHAASO site and have been operational for over a year. This report presents the current status and results of ENDA-64, including the detector's operational performance, measurements of secondary particle distributions and event reconstruction. Efforts have been made to explore the potential for cosmic ray energy determination and composition separation by combining ENDA's neutron and electron detection with LHAASO-KM2A's electron and muon detection. This report also outlines ongoing work and anticipated directions for further studies with ENDA and its collaboration with LHAASO.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **37** Type: **Original Talk**

The results of the development of the setup of SPHERE-3 for studying the composition of the PCR in the field of 1-1000 PEV. The status of 2025.

The SPHERE-3 setup is destined to register the EAS Cherenkov light, both the direct and the reflected from the snow surface. A set of methods and new approaches in the measurement technique enable substantial progress in the study of the primary cosmic ray composition in the energy range 1-1000 PeV. The present work reveals the current status of the project development and detector performance modeling.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **38** Type: **Poster**

Development of the method for the assessment of EAS primary particle mass by the data of both the direct Cherenkov light detector and the snow-reflected light telescope of the SPHERE-3 setup

The SPHERE-2 telescope constructed for the registration of EAS by the Cherenkov light reflected from the snowed surface used a method for the shower classification by the primary mass based on the steepness of the light lateral distribution function on the telescope's mosaic. The simulation shows that the classification errors for a criterion by the characteristics of the direct Cherenkov light are lower. For this reason the next generation setup SPHERE-3 will be equipped with an extra detector of the direct light. As the two detectors will see different aspects of an event, the development of the criterion using the data of both can improve the classification quality.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **39** Type: **Original Talk**

The project of a ground-based wide-angle EAS Cherenkov light imaging detector for PCR mass composition study in the 1-1000 PeV energy range

This report presents a draft of a new detector designed to determine the chemical composition of primary cosmic rays based on the characteristics of the angular distribution of Cherenkov light from EAS. The installation, consisting of several such detectors, will be able to register individual EAS events in the energy range from 1 to 1000 PeV with high angular resolution of up to 0.3 degrees. The proposed detector's distinctive feature is its simple design and wide viewing angle of up to ±30 degrees.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **40** Type: **Poster**

Modernization of database and algorithms for processing events in the Yakutsk EAS array

In December 2024, an upgraded data recording and processing system was put into operation at the Yakutsk extensive air shower (EAS) array, and an additional detector grid with a step of 250 m was deployed, which covers the central part of the array with an area of 0.16 km².
In this report we will describe the upgraded software package for event processing and present the first results of its operation. As part of this work, a unified server database was created, combining data with different formats accumulated over the entire period of operation of the array since 1973. Event processing algorithms were updated and an analysis of the accuracy of reconstructing shower parameters was carried out based on Monte Carlo modeling. The first scientific results obtained on the new data collection and processing system are presented.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **41** Type: **Poster**

Yakutsk EAS array. Current status

The Yakutsk EAS array is designed to study ultra-high-energy cosmic rays reaching the Earth's atmosphere. For more than 50 years, the Yakutsk array has maintained continuous operation. It is the longest-running experiment in the world to register ultra-high-energy cosmic rays. The current state, development prospects of the array, and the latest scientific results are presented.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **42** Type: **Poster**

Elaboration of the method for the primary energy estimation by the EAS image in the telescope of snow-reflected Cherenkov light of the SPHERE-3 setup

The energy estimation method is based on the inverse interpolation of the dependence of the integral over the axially symmetric function approximating the EAS image on the distance from the
detector axis to the shower axis on the snow. For the approximation and the parameters derived from it to be authentic the shower axis should hit the snow within the field of view of the telescope. Due to the fluctuations of the reflected photon flow a random local maximum can be mistaken for the absolute one, corresponding to the shower axis, while the true axis is not visible. A method was
developed to filter out such situations which decreases the mean uncertainty of the primary energy estimate.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **43** Type: **Poster**

Selection of the cosmic rays light component from data of the TAIGA-IACT facility in the stereo observing mode

The TAIGA astrophysical complex [1], located in the Tunka Valley (Republic of Buryatia), covers an area of about 1.1 km² and is designed to study gamma rays with energies above 3-4 TeV and cosmic rays with energies above 200 TeV. The complex includes the TAIGA-IACT facility, which currently consists of four atmospheric Cherenkov telescopes.

TAIGA-IACT makes it possible to distinguish extensive air showers (EAS) induced by primary gamma rays from hadronic EAS with high accuracy, and therefore TAIGA-IACT data are used to solve gamma-ray astronomy problems. In this work, we propose a technique for using TAIGA-IACT data in stereo mode to extract the light component of cosmic rays. The methods for the reconstruction of the main parameters of EAS are presented: the EAS axis, the direction of arrival of the primary particle, the depth of the maximum of the shower development, and the particle energy.

1. L. A. Kuzmichev et al. Cosmic ray study at the astrophysical complex taiga: Results and plans // Physics of Atomic Nuclei. — 2021. — Vol. 84, no. 6. — P. 966–974.

Primary authors: VOLCHUGOV, Pavel (SINP MSU); TAIGA COLLABORATION

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **44** Type: **Original Talk**

Estimation of the capabilities of the SPHERE-3 Cherenkov telescope by determining the parameters of the primary cosmic particles.

New results of modelling the operation of the new Cherenkov telescope SPHERE-3 are presented. The telescope will be able to detect cosmic particles by direct and reflected Cherenkov light of EAS. Dual detection improves the accuracy of determining the parameters of the primary particle. The study is based on the data bank of distributions of the EAS Cherenkov light obtained on the Lomonosov-2 supercomputer. The accuracy of determining the energy and type of the primary particle from the reflected and direct flux of Cherenkov light is estimated.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **45** Type: **Original Talk**

Investigations of extensive air showers in the Experimental complex NEVOD

The main information about high-energy cosmic rays (above 10^15 eV) is provided by the extensive air showers (EAS), which are formed as a result of interaction of primary cosmic rays (PCR) with nuclei of atmospheric atoms. In the energy range from 10^15 to 10^17 eV, the PCR energy spectrum reconstructed by the data of EAS experiments has features which cannot be explained within the frameworks of existing models of cosmic ray origin.

Studies of air-showers in the energy range of 10^15–10^17 eV are carried out in the Experimental complex NEVOD. The NEVOD-EAS array allows detection of the electron-photon component, the Calibration Telescope System ensures selection of the EAS muon component, and the URAN array measures the air-showers hadronic component.

The lateral distributions of the electron-photon, muon, and hadronic components of the air-showers obtained by the data from these facilities are presented. The technique for reconstructing EAS parameters and PCR energy spectrum based on the NEVOD-EAS array response is described.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **46** Type: **Original Talk**

Поиск совпадений нейтрино на БПСТ с сигналами гравитационно-волновых детекторов LIGO, Virgo и KAGRA во время их 4-го наблюдательного периода

Гравитационно-волновые детекторы LIGO, Virgo и KAGRA в настоящее время находятся в стадии 4-го наблюдательного периода (до октября 2025 г.). Информация о кандидатах в гравитационно-волновые события появляется на портале The General Coordinates Network (GCN). На Баксанском подземном сцинтилляционном телескопе (БПСТ) осуществляется своевременная сверка зарегистрированных мюонных нейтрино с кандидатами в гравитационные волны. Поиск совпадений осуществляется для всех типов оповещений на портале GCN, включая автоматические («предварительные»). Рассматриваются различные подходы к сверке событий и способам определения результатов. Проведена предварительная обработка имеющихся на данный момент данных.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **47** Type: **Poster**

Optimization of the model of the direct and snow-reflected Cherenkov light detector SPHERE-3

The description of the model and its construction blocks, i.e. EAS event processor, physical model of the reflected light telescope in Geant4 and the image handling procedure, is presented. The process of the optimization of the model and the processing conveyor is explained.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **48** Type: **Overview**

Проект астрофизического комплекса TAIGA-100

Астрофизический комплекс TAIGA-100, площадью 100 км2 , создается для проведения исследований в области гамма-астрономии ПэВных энергий и космических лучей сверхвысоких энергий.
В докладе будет представлена научная программа проекта, базовые детекторы и программа развертывания астрофизического комплекса.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **49** Type: **Original Talk**

Studying of the muon energy spectrum in the Baikal-GVD neutrino telescope

The muon component of extensive air showers (EAS) is widely used in the High-energy Physics as a tool for studying the processes of nucleus-nucleus interactions and secondary particle decays. Muons with energies above 100 TeV (very-high energy muons, VHE-muons) can provide information about new processes of muon generation. So the task of measuring the energy spectrum of such muons is promising. Nowadays, the only instrument for measuring the energy of VHE-muons in the range of above 10 TeV are the gigaton neutrino telescopes, such as IceCube and Baikal-GVD.

VHE-muons lose their energy stochastically, producing high-energy cascades, which could be used for the muon energy spectrum estimation. High-energy cascades selection technique is based on reconstructing longitudinal energy loss profile of muons with Cherenkov light and on determining the ratio of it's maximum and medium values (the peak-to-median ratio p/m). In this work, the abovementioned technique was tested for the Baikal-GVD detector, and the spectrum of cascades from EAS muon bundles was analyzed.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **50** Type: **Poster**

Multicomponent EAS studies involving the hardware and software system for storing and analyzing large volumes of the Experimental complex NEVOD data

The Experimental Complex (EC) NEVOD includes a set of scientific facilities for studying extensive air showers (EAS): the Cherenkov water detector NEVOD, the calibration telescope system CTS, the coordinate detectors DECOR and TREK, the arrays of scintillation detectors URAN, PRISMA, NEVOD-EAS which measure different EAS components. In order to develop multicomponent EAS studies, the hardware and software system (HSS) for storing and analyzing large amount of the EC NEVOD facilities data is being created.
The HSS hardware part is a set of network attached storages and high-performance servers for storing and analyzing data. The software part is based on the database management system MongoDB, as well as on the specialized software developed with the Python programming language.
The report presents the results of the analysis joint events obtained with HSS, which demonstrates the possibility of the multicomponent EAS studies with the EC NEVOD facilities. The results of EAS parameters reconstruction for modeled and experimental joint events in the NEVOD-EAS, CTS, DECOR are shown. The lateral distribution function of the EAS muon component is measured based on the CTS data in joint events with the NEVOD-EAS. The possibility of reconstructing the number of EAS muons based on the CTS data is experimentally assessed. The PCR energies, reconstructed with the LMDS method and with the traditional methods by the EAS electron-photon component, in joint events of the DECOR and NEVOD-EAS facilities are compared.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **51** Type: **Poster**

Characteristics of the extensive air showers detected with the URAN array

The URAN array was constructed at the Experimental Complex NEVOD to study extensive air showers (EAS) in the energy range of 10^{15}–10^{17} eV. The URAN array consists of 72 detectors combined into 6 clusters of 12 detectors and installed on the roofs of two buildings of the experimental complex. The array simultaneously detects both the electron-photon and hadronic (via thermal neutrons) EAS components.
The technique for calibrating the URAN array detectors by means of the joint EAS events, recorded also by the existing NEVOD-EAS array, is considered. The main characteristics of the reconstructed EAS are presented: the lateral distribution functions of the electron-photon and hadronic components, the size spectrum, and other distributions of air-shower parameters.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **52** Type: **Poster**

Track reconstruction in the Cherenkov water calorimeter NEVOD

Cherenkov water calorimeter (CWC) NEVOD is the main part of the Experimental complex (EC) NEVOD designed to detect cosmic rays on the Earth's surface. The CWC detection system represents a spatial lattice of the quasi-spherical modules (QSM), located at its nodes. The QSM is able to measure Cherenkov radiation practically in the entire solid angle of 4π. Due to the modernization of the EC NEVOD and the increase of the QSM spatial lattice volume from 800 m^3 to 1200 m^3, the development of new and adaptation of old reconstruction methods are required.
Track determination in the CWC NEVOD was carried out by the "simple" method, in which the particle direction was reconstructed by summing the amplitudes from the photomultiplier tubes directed along one axis. The analysis shows that for particles passing through the center of the QSM array, the "simple" method gives errors in track reconstructing by angle from 2° to 20° and by distance to the center of gravity of about 1 m.
The maximum likelihood method was used to increase the reconstruction accuracy. The dependence of the photomultiplier response on the distance to the track and on the incidence angle of Cherenkov light to the photocathode was obtained for calculating and analyzing the likelihood function.
In the talk, the results of single particle track reconstruction by the "simple" method are presented. The dependence of the PMT response on the distance to the track and on the incidence angle of Cherenkov light to the photocathode is obtained. The features of the likelihood function, taking into account the obtained dependence, is discussed.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **53** Type: **Original Talk**

The systematics of the theoretical studies of the muon excess in UHECR

The problem of the excess of muons in extensive air showers (EAS) from ultra-high energy cosmic rays (UHECR) in comparison to the simulation predictions, also known as the "muon puzzle", stands as a bright signal of the incompleteness of our knowledge of high-energy cosmic ray physics. In principle, there are several ways to explain this phenomenon. One can suggest changes in the cosmic ray mass composition and energy spectrum, including the scenarios with exotic nature of the incoming particle. Another approach is to consider the modification of the hadronic interaction models for taking into account new effects, states of matter, and physics. Some studies investigate the possibilities of the non-hadronic origin of the muon excess.

This report presents a systematized review of the theoretical approaches and hypotheses aiming to solve the "muon puzzle". A review for the important EAS properties, that should be considered when studying the muon production, is given. A brief examination of the proposed ways to explain the deficit of muons in the simulations is done. The main focus is placed on the modifications of hadronic interaction models, including those that attempt to consider the exotic states of matter.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **54** Type: **Poster**

Analysis of the energy deposit of EAS cores in the Cherenkov water calorimeter NEVOD

The Experimental complex NEVOD includes a set of facilities for the investigation of extensive air showers (EAS). Two of them are: the Cherenkov water calorimeter (CWC) NEVOD and the NEVOD-EAS air-shower array. The CWC measures energy deposit of EAS cores. The NEVOD-EAS detects the EAS electron-photon component in the primary energy range of 1015-1017 eV and allows reconstructing the main air-shower parameters: the size, the arrival direction and the core position.
According to the NEVOD-EAS data, it is possible to select EAS events, in which the air-shower core falls within the CWC NEVOD boundaries. The CWC response to these events can be observed within the time gate of up to 1 ⊠s starting from the NEVOD-EAS event timestamp. In such joint events, it is possible to measure the energy deposit of EAS core in the CWC NEVOD by the number of detected charged particles.
In the talk, the estimates of the CWC NEVOD counting rate, taking into account the muon flux integral intensity, obtained by simulation are discussed. Also, the spectrum of energy deposit in the CWC NEVOD in joint events with the NEVOD-EAS array are presented.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **55** Type: **Original Talk**

Nonmonotonic change with energy of the mean logarithmic mass of cosmic rays in the knee region: the mechanism of formation of this feature and sources of particles

Recently, the Large High Altitude Air Shower Observatory (LHAASO) published measurements of the all-particle CR energy spectrum and the mean logarithmic mass of CRs with unprecedented accuracy in 0.3 - 30 PeV. The mean logarithmic mass shows a nonmonotonic change with energy, a feature observed for the first time.

Phenomenological studies of the cosmic-ray flux and its mass composition in the knee region have been conducted in many papers utilizing the most up-to-date data available at different times. However, this technology is not a model in the usual sense since it does not try to explain the data.

In this work, we present a new approach to describe the mechanisms of formation of this feature. The key elements of this approach are the non-classical diffusion model of cosmic rays developed by the authors in which the knee in the observed spectrum occurs naturally without the use of additional assumptions, as well as power-law asymptotics before and after the knee, and a soft spectrum of particle generation in cosmic ray source.

To obtain a more complete picture of the spectrum formation in the region of the knee and the sources that form it, we carried out calculations of the spectra of the main groups of nuclei in the energy range of 1 TeV - 100 PeV. It is shown that the behavior of the all-particle spectrum and mass composition in the knee region is determined by local pevatrons located at a distance of 750-900 pc from the Earth. The position of the knee practically coincides with the break in the spectrum of helium nuclei. The contribution of the light components p + He is about 70%, the CNO group provides $\sim$ 13%. The energy spectrum index of the light components is -2.61 before the knee. The nonmonotonic change in the mean logarithmic mass is due mainly to a decrease in the contribution of the CNO group in the energy range of 0.3 - 3 PeV.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **56** Type: **Poster**

Development of silicone rubber-based scintillators for different particles recording

In our work we investigate specialized scintillators based on locally produced powdered phosphors immersed in an optically transparent silicone rubber. Scintillators of this type can be optimized for recording different types of particles. We present the results of studies of silicone rubber-based scintillators response to atmospheric muons, fast neutrons and radioactive background, mainly represented by the radon decay chain.

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Session Classification: Poster Session

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **57** Type: **Poster**

The project of the hybrid detector for the multicomponent studies of extensive air showers

At the present time, the studies of ultra-high energy cosmic rays can be carried out only at the ground-based facilities recording extensive air showers (EAS). The existing facilities for the cosmic ray research measure various components of extensive air showers using different detecting systems. Simultaneous detection of several EAS components using hybrid detectors will provide additional information on the energy spectrum and mass composition of cosmic rays, as well as the opportunities to test cosmic ray interaction models and, subsequently, to interpret the features of the experimental spectra of the measured EAS components.
The report considers various design options for the planned hybrid detector and presents the preliminary results of its detecting part simulation.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **58** Type: **Original Talk**

Forbush-decreases in 2024 according to the data of the PRISMA-36 and “Neutron” facilities

At the Experimental complex NEVOD (MEPhI, Moscow), the PRISMA-36 and “Neutron” facilities are used to study variations in the neutron background. In these facilities, a detector with a thin (˜30 mg/cmˆ2) inorganic scintillator ZnS(Ag) with LiF, where Li is enriched to 90% of 6ˆLi, is used to measure neutrons.
In 2024, there was a peak of solar activity, and the most powerful flares in the last decade were observed. The neutron background near the Earth’s surface is predominantly caused by the interaction of cosmic rays with matter, and therefore its variations are directly related to the flux of cosmic rays. The results of measuring and analyzing the Forbush-decreases of 2024 based on the data from two facilities with unshielded neutron detectors are presented.

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Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **59** Type: **Overview**

Prospects of the development of the Experimental Complex NEVOD

The accumulated problems of the high- and ultra-high energy cosmic ray physics and the tasks of the multichannel astronomy require the development of new experimental methods ensuring reliable identification of both primary and secondary cosmic ray particles.
To conduct breakthrough research in this area, the complex installations containing detectors of various types for multicomponent analysis of recorded events are needed. Such an installation is the Experimental Complex NEVOD, which combines a set of unique detectors and methods for measuring the electron-photon, hadron and muon components of cosmic rays.
In the coming years, it is planned to expand the complex by adding a new multi-cluster installation with dimensions of 450×450 m2. The cluster will include 12-16 hybrid detectors containing both a plastic scintillator for recording the EAS electron-photon component and a ZnS(Ag) scintillator with addition of 10B for recording thermal neutrons generated by the hadronic component of the air-shower. It is also planned to equip the clusters with shielded muon tracking detectors. Thus, in each event the number of particles of the three main EAS components will be measured separately.
The report discusses the prospects of the Experimental Complex NEVOD in solving problems of ultra-high energy particle astrophysics, gamma-astronomy, and in testing models of hadronic interactions.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **60** Type: **Poster**

Feasibility study of an onshore detector system for joint registration of EAS with Baikal-GVD.

We present a study of the possibility of registering EAS simultaneously by the onshore detector facility and the Baikal Neutrino Telescope. Such a setup would allow obtaining experimental information on the number of muons in EAS with ultra-high energy. This, subsequently, would make it possible to examine EAS modeling programs and additionally to verify the atmospheric neutrino flux calculations.
For an installation of this type on Baikal, the angle of incidence of the EAS is approximately 76 degrees. This causes a high energy threshold for the registration of primary cosmic rays. An additional factor determining the possible number of registered events is the limited solid angle of the installation.
The CORSIKA program was used to simulate the registration of EAS close to the Baikal-GVD. The energy threshold of registered inclined EAS was determined, and estimates of the required total area of detectors were obtained. The propagation of ultra-high energy muons produced by EAS through 3.5 km of water and their registration by Baikal-GVD was simulated using the PROPOSAL package.
The report presents the estimates of the number of events jointly registered by the onshore installation and the Baikal-GVD for various total areas of EAS registration detector systems.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **61** Type: **Original Talk**

COMPARISON OF GLE EVENT OF 11 MAY 2024 AND MAGNETOSPHERIC EFFECT 5 NOVEMBER 20-23

Relativistic Runaway Electron Avalanches (RREA) are central to understanding a spectrum of high-energy atmospheric phenomena, including Terrestrial Gamma-ray Flashes (TGFs), Thunderstorm Ground Enhancements (TGEs), and gamma-ray glows. Despite their common physical origin, these events are often treated separately due to differences in detection methods, duration, and altitude. In this work, we present a unified conceptual and observational framework that reinterprets these radiation bursts as manifestations of the same runaway processes occurring in distinct atmospheric depths. Integrating recent results from satellite (ASIM), aircraft (ALOFT), balloon (HELEN), and ground-based (SEVAN) experiments, we demonstrate consistent spectral and temporal behavior across scales. We propose a rational revision of current terminology and challenge longstanding models that attribute TGFs to lightning leader dynamics. This study resolves key contradictions in the field, establishes new classification criteria based on physics rather than detector location, and reshapes our understanding of particle acceleration in thunderstorms.

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Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **62** Type: **Overview**

SEVAN particle detector network for Solar, Atmospheric physics, and Space Weather research

The SEVAN network (Space Environment Viewing and Analysis Network), as part of the United Nations Basic Space Science (UNBSS) activities, was supported
by the International Heliophysical Year 2007 and the U Office for Outer Space Affairs. CD experts developed a new class of hybrid particle detectors capable
of measuring both neutral and charged particles. The network's initial rollout included installations in Croatia, Bulgaria, and India. Expansion continued with
the installation of SEVAN detectors in Slovakia, Germany (Hamburg and Berlin), the Czech Republic, and atop Zugspitze, Germany's highest peak, in 2023.
Local SEVAN groups foster a community for research in solar physics and high-energy atmospheric physics by analyzing neutrons and muons modulated
during solar violent events and recording increased fluxes of electrons and gamma rays during thunderstorms, RREA/TE events.

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Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **63** Type: **Overview**

The Baikal-GVD Neutrino Telescope: Current Status and Selected Results

The Baikal-GVD Neutrino Telescope is a cubic-kilometer scale detector being constructed in Lake Baikal. As of summer 2025, the telescope array consists of 14 clusters, including in total more than 4000 optical modules. The achievement by Baikal-GVD of the nominal sensitive volume for high-energy cascade detection of 1 km3 is expected by 2028. In this report we present the status of the detector and selected physics results obtained using the data collected in 2018 – 2024.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **64** Type: **Original Talk**

A network of muon hodoscopes for monitoring of the processes of ”space” and atmospheric weather

Igor Yashin

At present, in addition to direct observations of the Sun using space born apparatus, ground-based equipment that registers cosmic rays is widely used to monitor solar activity - neutron monitors, muon telescopes (hodoscopes) and other detectors. Neutron monitors detect neutrons from primary cosmic particles of GeV energies (˜ 10 GeV), while the muon component is generated by primary particles with energies from tens to hundreds of GeV. Muons retain the direction of primary particle motion with good accuracy, which allows us to study the anisotropy of cosmic rays caused by solar and magnetosphere activity. The capabilities of muon diagnostics of near- terrestrial space were demonstrated by means of precision muon hodoscopes created at MEPhI, for which methods of muonography were developed, allowing real-time observation of processes in the heliosphere, magnetosphere and atmosphere of the Earth. An important advantage of muon hodoscopes is the ability to monitor the state of the atmosphere over an area of about 10ˆ4 sq. km. However, despite the fact that a wide-aperture muon hodoscope allows one to detect and analyze variations in the muon flux over a wide range of zenith angles, a limitation for ground-based studies of near-Earth space is the rotation of the Earth, as a result of which the disturbed region in the heliosphere leaves the aperture of the ground-based detector after 2–3 hours. The report considers the project of creating a network of ground-based hodoscopes placed in different geographical locations. To solve this problem, it is proposed to create the first segment of the future network of three muon hodoscopes, which will be placed in Kaliningrad (branch of IZMIRAN), in the Moscow region (MEPhI - IZMIRAN) and in Irkutsk (ISTP SB RAS).

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Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

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

Carpet-3 detection of a photon-like air shower with estimated primary energy above 100 TeV in a spatial and temporal coincidence with GRB 221009A

The brightest cosmic gamma-ray burst (GRB) ever detected, GRB˜221009A, was accompanied by photons of very high energies. These gamma rays may be used to test both the astrophysical models of the burst and our understanding of long-distance propagation of energetic photons, including potential new-physics effects. Here we present the observation of a photon-like air shower with the estimated primary energy of 300^{+43}_{-38} TeV, coincident (with the chance probability of $\sim 9 \cdot 10^{-3}$) with the GRB in its arrival direction and time. Making use of the upgraded Carpet-3 muon detector and new machine learning analysis, we estimate the probability that the primary was hadronic as $\sim 3 \cdot 10^{-4}$. This is the highest-energy event possibly associated with any GRB.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

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

Potassium influence on Earth's mantle convection and Borexino data

We provide the indication of high flux of ^{40}K geo-antineutrino and geo-neutrino (^{40}K-geo-($\bar{\nu}+\nu$)) with Borexino Phase III data. Simultaneously we obtained the count rates of events from ^{7}Be, pep and CNO solar neutrinos. MC pseudo-experiments showed that the case of high metallicity Sun and absence of ^{40}K-geo-($\bar{\nu}+\nu$) can not imitate the result of multivariate fit analysis of Borexino Phase III data with introducing ^{40}K-geo-($\bar{\nu}+\nu$) events. We also provide arguments for the high abundance of potassium in the Earth. Large amounts of ^{40}K should produce a significant heat flow that should affect the Earth's internal processes. We present the results of modeling mantle convection taking into account excess heat from ^{40}K.

Primary authors: KARPIKOV, Ivan (INR RAS); SINEV, Valery (INR RAS)

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Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **67** Type: **Overview**

Expansion Possibilities of the Baikal-GVD Neutrino Telescope

The Baikal-GVD Neutrino Telescope is a cubic-kilometer scale detector being constructed in Lake Baikal. The achievement by Baikal-GVD of the nominal sensitive volume for high-energy cascade detection of 1 km3 is expected by 2028. Currently, the Baikal collaboration is working on the development of a conceptual project of neutrino telescope in Lake Baikal with a volume about an order of magnitude larger than the volume of Baikal-GVD: the GVD+ project. In this report we discuss the possibilities of the telescope expansion up to 10 km3 scale after completion of the Baikal-GVD deployment.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

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

Cosmic ray acceleration up to hundreds of TeV in young massive star clusters: 3D MHD simulations

Young compact clusters of massive stars contain dozens of O-, B and WR-type stars with fast powerful winds in a small ~ pc radius. The particle acceleration by ensembles of shocks and waves of compression and rarefaction in the turbulent environment of young massive star clusters (YMSCs) is an alternative to the standard paradigm of Galactic cosmic rays acceleration on supernova shocks. In recent years, the topic is of great interest due to the fact that modern gamma- and X-ray observatories are detecting the radiation from YMSCs (e.g. Westerlund 1, 2), which indicates particle acceleration processes in these objects. We study particle propagation and acceleration in a YMSC with the help of 3D magnetohydrodynamic (MHD) modeling using PLUTO, an open source code based on the numerical solution of MHD equations with the Godunov scheme [1]. The code allows modeling of the turbulent environment of YMSCs and obtaining crucial for particle acceleration values of velocity, density and magnetic field inside the cluster core [2]. The particle module implemented in PLUTO allows solving the equations of motion for test charged particles together with MHD equations for the medium. We obtained that protons acceleration up to hundreds of TeV takes place in the cluster core near the termination shocks of O-stars, which are surrounded by shocks of their neighbour stars. We also modeled an interesting case of a young supernova remnant expanding inside the cluster core. In this case a very fast acceleration takes place: particle energies >100 TeV can be obtained in <100 years. The particle spectra and spatial distribution are discussed.

[1] Mignone A, Bodo G, Massaglia S, Matsakos T, Tesileanu O, Zanni C and Ferrari A 2007 ApJS 170 228–242 (Preprint astro-ph/0701854)
[2] Badmaev D V, Bykov A M and Kalyashova M E 2022 MNRAS 517 2818 2830 (Preprint 2209.11465)

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

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

Diffusive shock acceleration: nonclassical model of cosmic ray transport

Galactic cosmic rays up to about 100 PeV are believed to be accelerated by shock waves at supernova remnants by a Fermi process called diffusive shock acceleration (DSA). In this process, a test particle undergo a number of encounters with both inhomogeneities in the interstellar space and with shock and gain an energy.

All collisionless shock calculations should approximate particle transport, and most models assume that fast particles obey standard diffusion in homogeneous medium where the mean-square displacement is proportional to time. It is known that for highly relativistic particles, this DSA gives rise to a power-law energy distribution with spectral index $\gamma = (r + 2)/(r - 1)$, where r is the compression ratio of the shock. The standard cosmic rays spectral index for a maximal compression ratio of four equals to $\gamma = 2$.

However, during last few decades many evidences of the existence of multiscale structures in the Galaxy have been found. Filaments, ribbons, clouds and voids are entities widely spread in the interstellar medium. A rich variety of structures can be related to the fundamental property of turbulence called intermittency. The fluctuation (or small-scale) turbulent dynamo mechanism, and random shock waves produce highly intermittent magnetic fields with random magnetic structures surrounded by weaker fluctuations.

Non-homogeneous character of matter distribution and associated magnetic field should be adequately incorporated into the cosmic ray diffusion model. A physically reasonable way for the generalization of the normal diffusion model is to abandon the assumption about statistical homogeneity of irregularities' distribution in favor of its fractal-like distribution and nonclassical diffusion.

In this work the theory of diffusive shock acceleration is extended to the case of nonclassical transport with Lévy flights and Lévy traps, when the mean square displacement grows nonlinearly with time. In this approach the Green function is not a Gaussian but it exhibits power-law tails. By using the propagator appropriate for nonclassical diffusion, it is found that energy spectral index of particles accelerated at shock fronts is $\gamma = [\alpha (r + 5) - 6 \beta]/[\alpha(r - 1)]$, where α ($0 < \alpha < 2$, $r \longrightarrow \infty$) and β ($0 < \beta < 1$, $t \longrightarrow \infty$) are the exponents of power-law behavior of Lévy flights and Lévy traps, respectively.

We note that this result coincides with standard slope at $\alpha=2$, $\beta=1$ (normal diffusion), and also includes those obtained earlier for the subdiffusion ($\alpha=2$, $\beta<1$; Kirk J.G et al., AA. 1996) and superdiffusion regimes ($\alpha<2$, $\beta=1$; Perri S. et al., ApJ. 2012).

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **70** Type: **Poster**

Чувствительность атмосферных черенковских телескопов TAIGA при обработке в стереорежиме для регистрации протяженного гамма-источника

При регистрации гамма-источников атмосферными черенковскими телескопами большое количество наблюдаемых источников имеет не точечный характер, а протяженную форму. Это ухудшает точность их наблюдения одиночными телескопами или делает его полностью невозможным. Для решения этой задачи в астрофизическом комплексе TAIGA (51.813129°‘с.ш., 103.071849° в.д.), где работают уже три телескопа, будет использован анализ данных в стереорежиме работы телескопов. В докладе описана обработка такого источника на данных моделирования методом Монте-Карло. Определены оптимальные параметры обработки и оценена чувствительность систем телескопов для регистрации таких источников. Показано, что для ряда хорошо наблюдаемых телескопами TAIGA протяженных гамма-источников чувствительность достаточна для эффективной их регистрации за срок порядка 2-3 лет.

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Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **71** Type: **Original Talk**

Finding strangelets in cosmic rays from HESS J1731-347, a possible strange quark star

The idea that supernova remnants are a significant source of Galactic cosmic rays is supported by the fact that HESS J1731-347 would be one of the few Galactic sources to accelerate hadronic cosmic rays to TeV energy. The radius (4.2-5.5 km) and estimated mass (˜ 0.77 M) are both much less than the usual range for neutron stars. Because of its compactness and short radius, we investigate a different explanation for the low-mass ultra-compact star in this supernova remnant. Our findings support the idea that the compact object in HESS J1731-347 could be a strange quark star rather than a regular neutron star, which produces hadronic cosmic rays when 2SC transforms into the Color-Flavor-Locking (CFL) phase. This strange quark matter star estimates the strangelet flux in cosmic rays, which is important for strangelet detection in planned cosmic ray space studies.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **72** Type: **Original Talk**

Low-energy cosmic ray flux reconstruction using ground-based neutron monitors

Many attempts have been made to develop accurate techniques for calibrating ground-based detectors using data from satellite instruments. Those will allow to reconstruct the actual cosmic ray fluxes, which are not distorted by interactions with the Earth's atmosphere. Such methods will significantly enhance the capabilities of ground-based detectors for monitoring and forecasting space weather events and conditions, especially for stations located in polar regions. Unfortunately, there are currently no known techniques that have been proven effective in solving this problem and producing reliable results in practical applications. This is due to a variety of physical processes that occur during the interaction of cosmic rays with the Earth's atmosphere. Accurate accounting of all these effects is a difficult task, especially during turbulent events in a short period of time. We have used machine learning approach to overcome this challenges. Each selected neutron monitor was calibrated using a neural network that was trained using various optimization techniques. Several feature preprocessing algorithms were used to enhance the accuracy of the developed models. Data from the AMS-02, GOES-16, -17, and -18 satellite missions were used to train and test the models. After the training phase, these networks are able to calculate the low-energy cosmic ray flux based on individual count rates measured by ground-based detectors. The results of this study are presented and discussed.

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Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **73** Type: **Original Talk**

On primary cosmic ray energy spectrum beyond 10 PeV measured with ENDA-INR

ENDA-INR is a sea level prototype of the running now at high altitude in China ENDA (Electron-Neutron Detector array), being a part of the LHAASO experiment. The main task of the ENDA is measuring of primary cosmic ray energy spectrum using hadronic EAS component. The latter is a principal point because only hadrons form the EAS "skeleton" which defined all its properties at observation level. Preliminary experimental results obtained after 3 years of measurements are presented and analyzed.

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Presenter: STENKIN, Yuri (INR RAS)

Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **74** Type: **Original Talk**

Geomagnetic cutoff rigidity in neutron monitors locations

One of the detectors for long-term observations of cosmic rays are neutron monitors (NM) which are located at different points on the planet, allowing for studies of the time, energy and angular characteristics of galactic and solar particle fluxes. Since NMs are located inside the Earth's magnetosphere, their response depends on their location on the planet's surface which can be characterized by the geomagnetic cutoff rigidity. Its calculation depends on the magnetic field model used, the date, and even the numerical methods used. The paper presents calculated values of geomagnetic cutoff rigidities at the locations of some neutron monitors, and compares the cutoff values with the results of other calculations, including a comparison of the time dynamics over the past decade. We show that the geomagnetic cutoff values obtained for 2020 using the IGRF-14 model differ from those in IGRF-13, however, for 2015 the difference between the models is negligible. We demonstrate the geomagnetic cutoff tendency to decrease the over time, especially at mid-latitudes. As a result of comparing the obtained cutoff rigidity values with the results of other authors, it is shown that in most cases the difference does not exceed 0.2 GV. Such discrepancies are significant only in the circumpolar region, where particles are mostly shielded not by the geomagnetic field, but by the Earth's atmosphere instead. We show that the accuracy of the algorithm used is comparable to that of other existing instruments and is sufficient for correct operation with ground-based cosmic ray detectors.

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Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **75** Type: **Overview**

Recent results from the GRAPES-3 experiment

The GRAPES-3 experiment, located in Ooty, India, uses an array of 400 plastic scintillator detectors deployed over 25,000 mˆ2, and a 560 mˆ2 tracking muon telescope to record extensive air showers in the TeV–PeV energy range and angular muon flux above a GeV, respectively. The energy spectrum and nuclear mass composition of primary cosmic rays, solar and heliospheric phenomena, and atmospheric acceleration are among the broad subjects that may be studied using these two equipments and the observations that go along with them. The GRAPES-3 instrumentation and important scientific findings from the past few years will be discussed in this talk. These include (i) the measurement of 1.3 GV thundercloud potential in a massive thundercloud, (ii) the use of a geomagnetic storm to probe a crack in the geomagnetic shield, (iii) the hardening of the proton energy spectrum at 166 TeV, and (iv) small-scale cosmic ray anisotropy at TeV energies, observed with the GRAPES-3 experiment.

Ref: https://www.tifr.res.in/grapes3/publications.html

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Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **76** Type: **Overview**

Instrumentation of the GRAPES-3 Muon Telescope

The proportional counters developed and operated by the GRAPES-3 experiment (Gamma Ray Astronomy PeV EnergieS Phase-3), Ooty, are gas-based detectors designed using mild steel rectangular tubes. The existing muon telescope of GRAPES-3, consisting of 3712 PRCs, has been in operation for the past few decades and data gathered by it has ensured the study of solar, atmospheric and cosmic muons. Another muon telescope is under construction using 3776 more PRCs. Instrumentation is being upgraded using in-house developed front-end readout and FPGA-based back-end data acquisition systems to enhance sensitivity and performance. This talk provides insights into the existing instrumentation techniques and advancements included in the ongoing upgrade, along with an account of the current status of the GRAPES-3 muon telescope.

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Session Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **77** Type: **Original Talk**

The positioning system for Baikal-GVD

In large-scale underwater neutrino telescopes, the geometry of the photomultiplier array constantly changes due to water currents, with individual optical modules drifting tens of meters from their initial positions. Accurate monitoring of the photomultiplier positions is indispensable to ensure stable telescope performance and maintain its angular resolution. In Baikal-GVD, the positioning of individual photomultipliers is achieved using a hybrid system comprising a hydroacoustic network of acoustic modems installed sparsely along the vertical detector structures (strings) and an independently operated inertial positioning system, relying on integrated inertial sensors installed near the photomultipliers. We present the current state of the Baikal-GVD positioning system and demonstrate a positioning accuracy of 20 cm.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **78** Type: **Poster**

Manufacturing of mirrors for atmospheric Cherenkov telescopes

The poster presents materials on the production of mirrors for atmospheric Cherenkov telescopes of the TAIGA project.
Due to the increase in the diameter of the telescope, the issue of reducing the mass of mirrors as a whole is becoming relevant, so much attention is now being paid to the development of technology for the production of composite mirrors.
The parameters of monolithic and composite mirrors, both of our own production and available analogues, are compared.

Primary authors: SHAIKOVSKII, Andrei (Joint Institute for Nuclear Research (RU)); BORODIN, Artur; BLINOV, Aleksandr; Mr DZHAKUPOV, Mark (JINR); Mr MOROZ, Vladimir (Dubna State University); Mrs BAULINA, Ludmila (Dubna State University)

Presenter: BLINOV, Aleksandr

Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **79** Type: **Original Talk**

Acceleration of Protons to Very High Energies in Double-Torus Pulsar Wind Nebulae

Based on direct numerical modeling, it is shown that pulsar wind nebulae (PWN) with a double X-ray torus are capable of accelerating very high energy protons. These objects (with well known Vela nebula as the prototype) are distinguished by a special structure of MHD flows of strongly magnetized plasma. This special structure of the nebula allows for longtime confinement of high-energy particles which are the subject of combined acceleration mechanisms. The mechanisms include acceleration on shear and counter-streaming MHD flows, as well as Type I Fermi acceleration. The injected CR particle trajectories were directly followed in the simulated PWN structure. The maximum energies that protons can gain in the body of a compact double-torus nebula exceeds 100 TeV. The acceleration process allows 5-6% of protons (in terms of the total number of particles involved) to increase their Lorentz factor from 10^4 to $\sim 5 \times 10^5$ in just 10-30 years. This efficiency can be maintained as long as the nebula retains its double-torus X-ray morphology, which can lasts from a few thousand to several hundred thousand years, depending on parameters of the pulsar and the external environment in which the pulsar moves.

Primary authors: BYKOV, Andrey (Ioffe Institute); FURSOV, Aleksandr (Ioffe Institute); LEVENFISH, Kseniya (Ioffe Institute); PETROV, Aleksei (Ioffe Institute)

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **80** Type: **Poster**

Numerical simulation of atmospheric neutrino production

This work presents a numerical simulation of the energy spectrum of atmospheric neutrinos. We model the propagation of Galactic Cosmic Ray (GCR) protons from the magnetosphere boundary to near-Earth space, followed by their subsequent interactions with the Earth's atmosphere, leading to the production of secondary particles. The simulation is performed using the GT software package [1], developed within our research group.

A comparison with similar studies [2] demonstrates good agreement and confirms the reliability of the performed calculations. Thanks to its modular structure, the GT package allows for easy replacement of the used magnetospheric models, atmospheric models, and nuclear interaction models (Geant4 physics lists) with others. This flexibility enables a comprehensive investigation of systematic uncertainties attributed to these factors. Such an analysis is of significant interest for the interpretation and processing of measurements from both current and future neutrino observatories.

[1] Golubkov, V. S., and A. G. Mayorov. "Software for numerical calculations of particle trajectories in the Earth's magnetosphere and its use in processing PAMELA experimental data." Bulletin of the Russian Academy of Sciences: Physics 85.4 (2021): 383-385.
[2] Honda, M., et al. "Atmospheric neutrino flux calculation using the NRLMSISE-00 atmospheric model." Physical Review D 92.2 (2015): 023004.

Primary author: YULBARISOV, Rustam (NRNU MEPhI)

Co-author: MAYOROV, Andrey (NRNU MEPhI)

Presenter: YULBARISOV, Rustam (NRNU MEPhI)

Session Classification: Poster Session

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **81** Type: **Original Talk**

Поиск источников гама - излучения высокой энергии по данным установки TAIGA-HiSCORE

В статье развивается метод поиска гамма- излучения от неизвестных источников над сложным астрофизическом фоном по данным установки HiSCORE в эксперименте TAIGA. Такая задача распадается на три этапа: разработка критериев выделения гамма-квантов от частиц, составляющих основной фон; выбор метода оценки и сглаживание фона; анализ статистической значимости сигнала на сложном фоне. Представлены первые результаты применения этого метода по данным HiSCORE за один сезон наблюдения и анализ достоверности зарегистрированного излучения с энергией более 70 ТэВ.

Primary authors: СВЕШНИКОВА , Любовь (НИИЯФ МГУ); TAIGA КОЛЛАБОРАЦИЯ

Presenter: СВЕШНИКОВА , Любовь (НИИЯФ МГУ)

Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **82** Type: **Original Talk**

Modeling of the production of the observed primary positrons by the nearest bow shock pulsar PSR J0437-4715

The origin of antiparticles – positrons and antiprotons – as detected by the observatories PAMELA and AMS-02 is a topical issue due to their discussed relation to the dark matter annihilations/decays. On the other hand, the observed excess of positrons can be explained by a contribution from the near-Earth pulsars once these are driving a bow shock into the interstellar medium. In this case both the positrons injected by the pulsar and the background cosmic ray (CR) nuclei are re-accelerated by the bow shock which forms the spectra of both leptons and nuclei. The nearest pulsar PSR J0437-4715 located at distance ˜160 pc has a bow shock detected by the Hubble Space Telescope. It can be considered as a natural source of positrons and re-accelerate primary and secondary CRs including antiprotons. The re-acceleration model may help to explain the observed similarities in their spectra. The moderate spin-down power of PSR J0437-4715 ˜6x10(33) erg/s allows it to produce very high energy (VHE) leptons. This was confirmed by an accurate kinetic modeling of lepton acceleration in between its pulsar wind termination shock and bow shock that allowed us to reproduce both the multiwavelength spectra and observed structure of its pulsar wind nebula in the far ultraviolet and X-ray bands. Using the results of this simulation for accurate normalization of the produced lepton flux and the modern models of particles transport in the local interstellar medium, we calculate the spectra of positrons and electrons produced by PSR J0437-4715 at the Earth and confront them to the near-Earth fluxes of positrons and electrons detected by PAMELA and AMS-02. We discuss a possible contribution into the observed near-Earth CR from some other nearby sources.
(The work was supported by the Foundation for the Advancement of Theoretical Physics and Mathematics “BASIS” – grant No. 24-1-3-28-1)

Primary authors: PETROV, Aleksei (Ioffe Institute); BYKOV, Andrey (Ioffe Institute)

Presenter: PETROV, Aleksei (Ioffe Institute)

Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

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

Investigating the properties of the EAS simulated with LIV pair production cross-sections

One of the intriguing possibilities in the search for the new physics in ultra-high energy cosmic rays (UHECR) is the discovery of the Lorentz invariance violation (LIV). Several studies have investigated the consequences of the different LIV scenarios for cosmic ray physics and their influence on the measured properties of the extensive air showers (EAS). Yet, only recently, a new approach was considered: the suppression of the Bethe-Heitler e^+e^- pair production cross-sections for gammas of ultra-high energy. A deviation from the standard e/m physics adopted in the existing simulation codes can significantly affect the interpretation of the UHECR experimental data.

In this study, we investigate, how reducing the pair production cross-sections for very energetic gammas changes the measured EAS properties. The most essential of them are: the form of the cascade curve (CC), the shower maximum position ($X_{\max}$) and the number of particles recorded at the ground level (N_μ, N_e). A special attention is payed to the case of the inclined air-showers (with large zenith angle), as it is vital to consider the zenith-angle dynamics of the introduced changes in order to estimate the scale and validity of the proposed hypothesis.

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Presenter: NIKOLAENKO, Roman

Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **84** Type: **Poster**

Mobile muon hodoscope for investigating the structure of objects using the muonography method

Nowadays, the muonography method (by the analogy with the X-Ray radiography) has become widely used for studying various natural and industrial objects: the atmosphere and heliosphere, the mountains and volcanoes, the blast furnaces and nuclear reactors, the historical heritage sites, and others. The method is based on the "scanning" of thick layers of matter using the penetrating flux of cosmic-ray muons. Implementation of this technique requires the development of the easy-to-use high-precision mobile muon hodoscopes.

At the Scientific and Educational Center NEVOD (National Research Nuclear University MEPhI), a mobile muon hodoscope (MMH) has been developed. It represents a multi-channel detection system consisting of single-projection coordinate planes (SPCP). Each plane has an area of about 1 m^2 and includes 192 long polystyrene-based scintillator strips doped with p-terphenyl and POPOP. The scintillators are arranged in two layers. One layer of the plane is offset by a half of the strip width relative to another layer. The light collection is performed using the wavelength-shifting optical fibers (Kuraray Y-11) coupled to the silicon photomultipliers (SiPM, Joinbon TN-3050 SMT). The signals from each SiPM are read out using 32-channel boards based on the ASIC Petiroc2A (6 boards per plane).

Six planes are assembled into three pairs with orthogonal strip orientation and are mounted on a common frame ensuring the adjustment for different zenith angles.

In the report, the detector design is presented. The results of testing the detecting elements and the first detection plane of the hodoscope, which were obtained using the specialized test benches developed at the Scientific and Educational Center NEVOD, are discussed.

The work is carried out with the support of the Program of Strategic Academic Leadership "Priority-2030".

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Presenter: TSELINENKO, Maxim (Национальный исследовательский ядерный университет «МИФИ»)

Session Classification: Poster Session

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **85** Type: **Poster**

Cherenkov water detector of the TAIGA-100 observatory

TAIGA (Tunka Advanced Instrument for Cosmic Rays and Gamma-Astronomy) is the largest gamma-ray observatory in Russia, designed for detection of the high-energy gammas in the range from several TeV to several PeV, as well as of the high-energy cosmic rays (CR) in range from 102 TeV to 103 PeV. A new EAS complex TAIGA-100 is based on the experience of the TAIGA observatory and is planned to be deployed in the next 10-15 years. The complex will include an array of approximately 3000 Cherenkov water detectors at the area of 100 km2. The experimental setup will allow detection of muons from extensive air showers and effective separation of gamma- and hadron-initiated air-showers.
The Cherenkov water detector (CWD) of TAIGA-100 represents a cylindrical concrete tank, filled with purified water, with wall thickness of 10 cm and inner dimensions of
360 cm x 120 cm. The tank is buried in soil and has a soil overburden with a thickness of 250 cm. The inner surface of the tank is covered with diffuse reflective liner with reflection index of 0.98. The tank includes one Hamamatsu R7081 PMT mounted in the center of the upper face.
To study the characteristics and to determine the optimal design of the CWD for the TAIGA-100 observatory, its simulation using the Geant4 software package was performed. In the report, the detector design and the properties of used material and optical surfaces are described. The results of calculating Cherenkov photons lifetime in the CWD are presented. The results of simulation of the PMT responses to muons passing through the detector in different directions and of the influence of soil overburden thickness on the detector response to muons, gammas and hadrons are discussed.

Primary authors: GUDELEV, Max (NRNU MEPhI); YASHIN, Igor (National Research Nuclear University MEPhI); BOGDANOV, Aleksei (MEPhI); DMITRIEVA, Anna (National Research Nuclear University MEPhI (Moscow Engineering Physics Institute))

Presenter: GUDELEV, Max (NRNU MEPhI)

Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **86** Type: **Original Talk**

Search for ultrahigh-energy gamma rays from gamma-ray bursts using the Carpet-3 EAS array

The paper presents the first results of the search for ultra-high-energy gamma radiation from cosmic gamma-ray bursts based on the data from the Carpet-3 EAS array of the BNO INR RAS. The facility is located in the Baksan gorge at an altitude of 1700 m above sea level and consists of a ground-based array of and an underground muon detector with an area of 410 sq. m., which allows for the highly efficient selection of EAS initiated by primary photons with energies above 300 TeV. This work is of particular interest in connection with the observation of a photon-like event from the GRB221009A gamma-ray burst at the Carpet-3 EAS array.

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Presenter: ROMANENKO, Viktor (INR RAS)

Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

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

Ultra-high-energy event KM3-230213A constraints on Lorentz Invariance Violation in neutrino sector

We discuss the constraints on superluminal neutrino Lorentz Invariance Violation (LIV) parameters from the observation of the ultra-high-energy event KM3-230213A by the KM3NeT collaboration in cases of linear n=1 and quadratic n=2 LIV scenarios. Assuming extragalactic origin of the event, we obtain the constraints on LIV mass scale Λ_1=1.1×10ˆ30 GeV and Λ_2=1.1×1019 GeV from the absence of neutrino splitting.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **88** Type: **Original Talk**

Mean shower depth and interaction characteristics

The mean depth of shower is used for studying interconnection between shower longitudinal profile and hadronic interaction characteristics. The equations for the shower originated by high energy proton in the atmosphere are written and, within certain simplifications, solved for the case of logarithmically decreasing interaction length of hadrons in air.
The obtained expression explicitely splits into center of gravity of the purely electromagnetic cascade at the primary proton energy and modification of that by hadronic cascading and provides transparent view of the way in which hadronic interaction characteristics determine the longitudinal shower development.
Results of calculations for two hadronic generators QGSJETII-04 and EPOS-LHC
are compared with values obtained from shower simulations with use of CORSIKA.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **89** Type: **Poster**

Forbush effect of magnetic storm 10-12 May 2025

Forbush effect of magnetic storm 10-12 May 2025

Primary author: RIABOVA, Svetlana (IPE RAS, IDG RAS)

Presenter: RIABOVA, Svetlana (IPE RAS, IDG RAS)

Session Classification: Poster Session

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

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

The blazar origin of the KM3-230213A ultra high energy neutrino event

The source of the remarkable ultra high energy neutrino event KM3-230213A detected with the KM3-ARCA array is still not established. A persistent isotropic source hypothesis is disfavored due to the non-observation of a similar event by the larger IceCube detector that benefits from $\sim$ an order-of-magnitude larger observation time compared to the KM3-ARCA array as well.

We consider two possible sources of the KM3-230213A event, namely, the blazars PKS 0605-085 and MRC 0614-083. PKS 0605-085 is a powerful flat-spectrum radio quasar (FSRQ) at the redshift z = 0.87 located at 2.4° from the reconstructed direction of the KM3-230213A event. In particular, we consider a scenario where the neutrino is produced on the external photon field provided by the outer layer (the "sheath") of the "spine-sheath" jet structure. In this case, the blazar PKS 0605-085 appears to be among the most probable sources of the KM3-230213A event.

The blazar MRC 0614-083 is located at 0.6° from the reconstructed direction of the KM3-230213A event. We consider a hypothesis that MRC 0614-083 is actually an extreme TeV blazar. In this case, MRC 0614-083 is a viable candidate source of the KM3-230213A event.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **91** Type: **Poster**

The atmospheric ionization rate estimation during solar proton events

A cosmic ray flux, predominantly protons, is continuously present at the boundary of both the Earth's magnetosphere and atmosphere, and can be divided into galactic cosmic rays (GCR) and solar cosmic rays (SCR). While the GCR flux is isotropic and its proton spectrum has a wide energy range, the characteristics of SCR depend on solar activity, and their energies rarely exceed a few GeV. Nevertheless, the absolute flux unit of SCR can significantly surpass that of GCR (by several orders). Both GCR and SCR primary protons, depending on their energy, can reach the upper boundary of the Earth's atmosphere (conventionally set at 100 km in this study) and interact with atmospheric nuclei (mainly oxygen and nitrogen). In this work, the propagation of cosmic ray protons through the Earth's atmosphere is modeled using a own program based on the GEANT4 SDK. Examples of altitude ionization profiles are presented for various values of vertical geomagnetic cutoff rigidity and for different primary cosmic ray proton spectra.

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Presenter: MAURCHEV, Evgenii (IZMIRAN)

Session Classification: Poster Session

Track Classification: Cosmo- and geophysical aspects of cosmic rays at the ground level

Contribution ID: **93** Type: **Poster**

Separation of Muon Component of Extensive Air Showers in Multipurpose Detector of Muons

The Multipurpose Detector of Muons (MDM) is now under development at the National Research Nuclear University MEPhI. It is an array of multiwire drift chambers shielded with the layers of steel absorber. Such configuration enables the detection and analysis of both single-particle and multiparticle events across a zenith angle range from 0° to 60°.
The detector is designed for investigation of muon bundle flux, both in standalone operation and in conjunction with other facilities of the Experimental complex NEVOD, as well as for studying single muon flux in a hodoscopic mode. Additionally, the MDM can be used as a precise test bench for measuring spatial characteristics of charged particle detectors.
It is necessary to determine the energy range in which the muon detector is able to record and reconstruct events, as well as to cut off other particles. The detector model was developed using the Geant4. The events for muons, electrons, photons, neutrons, protons and pions were modeled, and the possibility of isolating only muon events was tested using the reconstruction methods.

Primary author: TROSHIN, Ivan (Yurievich)

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Presenter: TROSHIN, Ivan (Yurievich)

Session Classification: Poster Session

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **94** Type: **Original Talk**

Status of the large-scale coordinate detector TREK for investigation of muon bundles in inclined extensive air showers

An excess of extensive air showers (EAS) muons was found in several experiments at energies above 10ˆ17 eV compared to estimates assuming even heavy composition of primary cosmic rays (PCR). Presently, the explanations for this excess are being explored, including both the potentially new physical phenomena and states of matter in EAS development, along with the efforts to modify existing models of nuclear-physical interactions. Among these experiments, the NEVOD-DECOR covers the record energy interval from 10ˆ15 to 10ˆ18 eV and has possibility to measure not only the local density of muons but also their energy deposit, that should clearly separate different reasons of muon excess.

However, the existing coordinate detector DECOR does not cover the entire aperture of the Cherenkov water detector (CWD) and does not exclude the possibility of passing of the part of muons through the gaps between the individual modules of the detector; besides, its granularity limits the ability to separate two or more particle tracks with a distance of less than 3 cm.

The new large-scale coordinate detector TREK is developed in MEPhI to increase the possibilities of the experimental complex in investigation of inclined muon bundles. The detector allows to increase the resolution of close tracks by the order of magnitude and provides the possibility of muon track recording with a resolution of 3 mm. It is based on 264 multiwire drift chambers, developed in IHEP for experiments at the neutrino channel of the U-70 accelerator, and has 250 mˆ2 of continuous effective area.

The detector's inner plane was launched into operation in 2023, and in 2025 the full configuration of the detector was ready for measurements in conjunction with the Cherenkov water detector and the DECOR coordinate detector. The talk describes the design of the TREK and its data acquisition system, the principle of synchronization and selection of joint events with other installations of the Experimental complex NEVOD, as well as the examples of recorded muon bundles of inclined EAS initiated by the ultra-high energy primary cosmic rays.

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Contribution ID: **95** Type: **Overview**

Progress of Giant Radio Array for Neutrino Detection (GRAND)

some text

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Session Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)

Track Classification: Cosmic rays (nuclei, gammas, neutrinos) of very high energies (> 100 TeV)