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BOOK OF ABSTRACTS

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CONTENTS

ABSTRACTS

Performance of SuperFGD in the T2K neutrino beam

Angelina Chvirova

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The T2K long-baseline neutrino oscillation experiment is designed to probe CP violation in the neutrino sector and to perform precise measurements of neutrino oscillation parameters. The T2K neutrino beam, produced at J-PARC, is detected by the near detector ND280, located 280 meters downstream from the proton target. The recent upgrade of the ND280 was accomplished to reduce systematic uncertainties and to improve measurements of the neutrino beam as the oscillations become more significant. A core element of the upgrade is the Super Fine-Grained Detector (SuperFGD) that consists of 2 million scintillator cubes. Signals from each cube are read out by three orthogonal wavelength-shifting (WLS) fibers and detected by micropixel photodetectors (MPPCs). SuperFGD provides enhanced detection capabilities, allowing it to efficiently select high-angle and low-momentum particles, accumulate a larger sample of neutrino interactions, and detect neutrons. The detector has a high light yield for charged particles, high time resolution, and a low detection threshold. SuperFGD was installed in the ND280 pit at J-PARC in October 2023 and began full data taking in June 2024. The detection of muon neutrinos in SuperFGD via charged current in the T2K neutrino beam and reconstruction of stopped protons, long particle tracks, and multi-track events in SuperFGD will be presented. Key parameters such as time resolution and attenuation length will be discussed in detail. Supported by the RSF grant No. 24-12-00271

Emission of gravitational waves by cosmic domain walls with constant tension

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Employing the publicly available CosmoLattice code, we conduct numerical simulations of a domain wall network and the resulting gravitational waves (GWs) in a radiation-dominated Universe in the Z_2-symmetric scalar field model. In particular, the domain wall evolution is investigated in detail both before and after reaching the scaling regime, using the combination of numerical and theoretical methods. We demonstrate that the total area of closed walls is negligible compared to that of a single long wall stretching throughout the simulation box. Therefore, the closed walls are unlikely to have a significant impact on the overall network evolution. This is in contrast with the case of cosmic strings, where formation of loops is crucial for maintaining the system in the scaling regime. To obtain the GW spectrum, we develop a technique that separates physical effects from numerical artefacts arising due to finite box size and non-zero lattice spacing. Notably, we observe a peak at the Hubble scale, an exponential falloff at scales shorter than the wall width, and a plateau/bump at intermediate scales. We also study sensitivity of obtained results on the choice of initial conditions. We find that different types of initial conditions lead to qualitatively similar domain wall evolution in the scaling regime, but with important variations translating into different intensities of GWs.

Axion-like particle emission from type Ia supernovae

Daniil Davydov

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Axion-like particles (ALPs) are a class of hypothetical bosons beyond the standard model of particle physis, which are very weakly-interacting and long- lived. Since many ALPs may be produced in hot plasma in supernovae (SNe), a nearby SNe Ia can be used as a probe of ALPs. It is desirable to predict the ALP emission from SNe Ia to discuss a possible constraint that can be obtained from the event. ALPs may convert into photons and back in the magnetic field in the intergalactic space and galaxies. It is hence possible to constrain the ALP parameters by γ-ray observations of a nearby astronomical object which emits a lot of ALPs. Here, we calculate the ALP emission from type Ia SNe and take into the account the light range of ALPs mass. Using the SN Ia model, we consider the issue of detection a photon flash from SNe Ia.

Application of the amplitude analysis method to the study of mass and angular spectra of heavy tetraquarks in di-J/ψ and J/ψ-$\psi(2S)$ decay channels

Alisa Didenko, L. Gladilin, and I. Yeletskikh

JINR

The experimental discovery of resonant-like states in the di-J/psi mass spectra in pp-collisions near the production threshold suggests the existence of fully-charmed tetraquarks (broad structure at 6600 MeV and narrow structures at 6900 and 7200 MeV). Numerous theoretical models following this discovery provide descriptions of the observed data, propose mechanisms underlying formation of this new states, and predict additional phenomena. Further investigations require precision experimental measurements. In this work, the amplitude analysis method is applied to describe mass and angular spectra of the observed signals in ATLAS experimental data simultaneously in J/psi-J/psi and J/psi-psi(2S) decay channels. Mass and width of the resonances are measured accounting for interference effects between signals and background.

Development of 10 m^2 hodoscope made of drift tubes for cosmic rays muon registration

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Development of a mobile cosmic ray muon tomograph using drift tube chambers

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Charged pion momentum reconstruction in the 3D-segmented neutrino detector SuperFGD

Daria Fedorova

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To achieve enhanced precision in neutrino analysis, it is crucial to consider the kinematic distributions of reaction products. This poster will showcase methods for reconstructing the momentum of charged pions within the novel neutrino detector SuperFGD of the T2K experiment. Additionally, comparisons will be presented between the developed statistical and machine learning approaches.

Cosmological constant due to quantum corrections to the effective potential

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JINR BLTP

In this work, we show that quantum corrections to some cosmological models[1] can lead to a significant modification of the behaviour of the initial potential and the appearance of a non-zero ground state energy of the Universe which

[1]D. I. Kazakov, R. M. Iakhibbaev, and D. M. Tolkachev. "Leading all-loop quantum contribution to the effective potential in the inflationary cosmology". In: *JCAP* 09 (2023), p. 049. DOI: 10.1088/1475-7516/2023/09/049. arXiv: 2308.03872 [hep-th].

[2]Renata Kallosh, Andrei Linde, and Diederik Roest. "Superconformal Inflationary α-Attractors". In: *JHEP* 11 (2013), p. 198. DOI: 10.1007/JHEP11(2013)198. arXiv: 1311.0472 [hep-th].

can be interpreted as a cosmological constant. We apply the formalism of the effective potential to the simplest forms of α-attractors which can be represented by the so-called T-models and E-models[2]. We derived the generalised renormalisation group (RG) equations that sum up the whole sequence of leading logarithmic contributions to the effective potential. As a result, the accounting of quantum corrections leads to a change of character and a lift of the effective potential[3],[4]. We interpreted this uplift as the appearance of the cosmological constant Λ for the T^2 and E^2 models. Thus, we have found out that the cosmological constant Λ may exist as a consequence of quantum corrections to the effective potential with some value of the scale transmutation parameter μ even in non-renormalizable models of inflation. And the value of the cosmological constant Λ allows one to fix the parameter μ which is a free parameter in the non-renormalizable theory.

Exploring Exotic and Non-Standard Phenomena in the NOVA Experiment

A. Antoshkin, O. Geitota, Aleksandra Ivanova, and A. Morozova

JINR & ISU

The NOvA experiment, primarily focused on neutrino oscillation studies, also provides a unique platform to search for exotic and non-standard physics phenomena. In this poster, we present the ongoing analyses in the following topics: atmospheric and cosmogenic neutrinos, slow magnetic monopoles, high-energy muons, low-ionizing particles, neutron-antineutron oscillation. We will outline the current status of each analysis, highlight the methods and techniques, and discuss the preliminary results. We also highlight the importance of these searches for our scientific knowledge.

Inflation after Curvature Bounce

Rinat Kagirov

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We present a stable cosmological model of a closed universe in the presence of conventional scalar field. The stability of the model and the absence of singularity is ensured by spatial curvature without the need for additional peculiar matter. We reconstruct the Lagrangian and numerically compute observational predictions, including the number of e-folds, the spectral index n_s, and the tensor-to-scalar ratio. We present several sets of parameters that satisfy the current observational data.

Event selection for the NOvA 3 flavor analysis

Anastasiia Kalitkina

JINR

NOvA is a long-baseline accelerator-based neutrino oscillation experiment designed to measure electron (anti-)neutrino appearance and muon (anti-)neutrino disappearance. The experiment employs a 297t near detector at Fermilab and a larger 14kt far detector in Minnesota, both are tracking calorimeters filled with liquid scintillator. Event selection in NOvA is crucial for distinguishing neutrino interactions from background events. The experiment utilizes advanced techniques, including a Convolutional Visual Network algorithm, for event identification, categorization, and reconstruction. In 2024 the latest results of the 3-flavor oscillation analysis were obtained. They based on 10 years of data collecting, equivalent to 26.6×10^{20} protons-on-target (POT) statistics with neutrino beam and 12.5×10^{20} POT with antineutrino. In this poster, an improved event selection method will be presented. The main focus is on enhancing the statistic by low-energy electron neutrino events, which is useful for increasing the sensitivity to neutrino mass ordering.

Modeling of particle acceleration in star clusters with 3D-MHD simulations

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Young compact clusters of massive stars contain dozens of O-, B- and WR-type stars with fast powerful winds in a small $\sim$ pc radius. The acceleration of particles by ensembles of

[3]D. M. Tolkachev et al. "Quantum corrections to effective potentials of simplest α-attractors". In: *PoS* ICPPCRubakov2023 (2024), p. 022. DOI: 10.22323/1.455.0022.

[4]V. A. Filippov et al. "Cosmological constant due to quantum corrections to the effective potential". In: *Natural Sci. Rev.* 1 (2024), p. 3. URL: https://nsr-jinr.ru/index.php/nsr/article/view/16.

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 on particle acceleration processes in these objects. We study propagation and acceleration of particles 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[5]. 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[6]. 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. The particle spectra and spatial distribution are discussed.

Neutrino production in the central dark-matter spikes of active galaxies

Polina Kivokurtseva

MSU & INR RAS

Recent multi-messenger observations suggest that high-energy neutrinos may be produced close to central black holes in active galaxies. These regions may host dark-matter (DM) spikes, where the concentration of DM particles is very high. Here we explore the contribution of the DM annihilation to the target photons for the neutrino production, proton-photon interactions, estimate the associated neutrino spectrum and figure out possible future tests of this scenario.

Anomalous cosmic-ray correlations of the TA arrival directions with BL Lacs

Maria Kudenko

MSU & INR RAS

Stereoscopic fluorescent observations by the High Resolution Fly's Eye detector revealed correlations between arrival directions of ultra-high-energy cosmic rays and positions of distant BL Lac type objects (Gorbunov et al. 2004, Abbasi et al. 2005). They implied the existence of non-deflected particles travelling for cosmological distances, hard to explain within standard physics and astrophysics. These correlations have not been conclusively tested with independent data. Here, we present the results of such testing performed with the Telescope Array data set.

Search for two-neutrino double electron capture on Ar-36 with DarkSide-50 detector

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JINR

Two-neutrino double electron capture is a rare nuclear decay where two electrons are simultaneously captured from the atomic shells and two neutrinos are carried away. The measurements of the energies of the emitted particles and the half-life of the 2EC2ν decay to the ground state are of great interest to nuclear physics. The model predictions for 2EC2ν half-life are based on the evaluation of form the main source of NME. The NME calculations are complicated and have large uncertainties. Therefore, if retrieved from experiment, half-life values can serve as a test for nuclear theory. In the one model framework some constraints on the 2EC0ν NME can be derived using supposed values of the 2EC2ν NME, so the estimation of 2EC2ν half-life could help to study physics beyond the Standard Model. The novelty of this work is in the fact that such processes have not previously been studied on the argon isotope ^{36}Ar. In this work, a search is made for two-neutrino double electron capture in the KK and KL shells of ^{36}Ar, using exposition of about 12 ton-day of data from the

[5]A. Mignone et al. "PLUTO: A Numerical Code for Computational Astrophysics". In: *The Astrophysical Journal Supplement Series* 170.1 (May 2007), pp. 228–242. ISSN: 1538-4365. DOI: 10.1086/513316. URL: http://dx.doi.org/10.1086/513316.

[6]D V Badmaev, A M Bykov, and M E Kalyashova. "Inside the core of a young massive star cluster: 3D MHD simulations". In: *Monthly Notices of the Royal Astronomical Society* 517.2 (Sept. 2022), pp. 2818–2830. ISSN: 1365-2966. DOI: 10.1093/mnras/stac2738. URL: http://dx.doi.org/10.1093/mnras/stac2738.

DarkSide-50 dark matter detector. As a preliminary result of the analysis, no significant excess above background was found, which allowed us to estimate that the half-life limits with CL=90%. An estimate of the sensitivity of the DarkSide-20k experiment, which will be launched in the next few years, is also given.

Search for photon-induced air showers at the Carpet-3 experiment

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INR RAS

We report our results on the new technique for searching for photon-induced EAS events at the Carpet-3 experiment. To search for photon-like events, we employ a neural network, trained on Monte-Carlo simulations of the experiment. On Monte-Carlo simulations our method achieves considerably higher background rejection efficiency than traditional methods, particularly for EAS events with high muon content. We also report on the 300 TeV gamma ray event associated with GRB 221009A.

Application of machine learning in lattice quantum theory

V. Chistiakov and Dmitry Salnikov

INR RAS

The numerical calculation of observables in quantum theory is reduced to the sampling from a set of random variables with a joint distribution density defined analytically on the basis of physical theory. This problem is solved by various modifications of the Metropolis method, but it requires significant computational costs with a large sample size and the number of random variables describing the physical system. An alternative approach based on generative machine learning models is being considered. The features of the problem, such as translational symmetry, are analyzed in the context of building the most optimal architecture.

Hypothetical Lorentz invariance violation and the muon content of EASs

Andrey Sharofeev

MSU & INR RAS

Extensive air showers (EASs), produced by cosmic rays in the atmosphere, serve as probes of particle interactions, providing access to energies and kinematical regimes beyond the reach of laboratory experiments. Measurements from multiple cosmic-ray detectors indicate a significant, yet unexplained, discrepancy between the observed muon content in EAS and that predicted by state-of-the-art interaction models, suggesting a need for refinements in our understanding of fundamental physics. Here we show that a tiny, experimentally allowed, violation of the Lorentz invariance (LIV) may result in the suppression of the number of electrons in EAS, leaving the muon number intact and explaining both the "muon excess" and its energy dependence. On the other hand, we use the lack of a much stronger discrepancy between EAS data and simulations to obtain strict constraints on the LIV scale.

Absorption of a twisted photon by an electron in strong magnetic field

Alexander Shchepkin

ITMO University

The work investigates absorption of a twisted photon, which possesses quantized total angular momentum (AM), by an electron in a strong magnetic field up to the Schwinger limit, $H_c = 4.4 \cdot 10^{13}$ G. The absorption cross sections (CSs) and their dependence on the parameters of the incident photon and the initial Landau electron are examined. It is found that the total absorption CSs decrease as AM of the incident photon increases and increase as AM of the initial electron grows. It is also found that the processes without an electron spin flip dominate and, on top of that, the asymmetry in the "spin-down" $\rightarrow$ "spin-up" and the "spin-up" $\rightarrow$ "spin-down" transitions is observed. Specifically, the CSs for the "spin-down" $\rightarrow$ "spin-up" transition are larger, which can be interpreted as an analogy of the Sokolov-Ternov effect for photon emission. Our findings can help to improve the understanding of the QED processes in critical fields, typical for astrophysical environments such as neutron stars. The work was carried out with the support of the Russian Science Foundation Grant No. 23-62-10026.

SuperNova Early Warning System status and plans

Andrey Sheshukov

JINR

SuperNova Early Warning System (SNEWS) is an international network of neutrino experiments, aiming at the real-time search and analysis of neutrino signals for providing the early warning of galactic supernova. This system has been operating since 1998 in a simple coincidence mode. In this work we present the current status and plans of an ongoing major upgrade of the SNEWS system, which includes studying theoretical predictions of supernova neutrino signals and expected observable effects in various neutrino detectors, applying more advanced coincidence techniques, accounting for directional information and a search for pre-supernova neutrino signal.

TeV-PeV neutrinos from AGN coronae

Simon Sotirov

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In this paper, we attempt to explain the TeV-PeV neutrinos observed by IceCube by assuming that they originate from active galactic nuclei. The results are obtained in the model where the accretion disk emits in the UV-optical range inside the electron plasma cloud. Using a Monte-Carlo approach to simulate photopion interactions in the jets and then taking into account the cosmological evolution, we generalize the results of previous researchers within this approach by taking into account the coronal emission.

Modifying EAS parameters reconstruction algorithms for Carpet-3 detector array

Nikita Vasiliev

MSU

Carpet-3 is a detector array for high-energy ($E \geq 100$ TeV) extensive atmospheric shower (EAS) detection. It is situated at geographical coordinates: $43.273°N$, $42.685°E$, 1700 m above sea level. It consists of a central part 196 m^2 in area, an underground muon detector 410 m^2 in area and 30+ remote registration points. We have created a model of Carpet-3 using Geant4 package. It takes the geometry of the detectors and facility buildings, the scintillation processes and light collection nuances into account. We created a dataset of $\approx$ 85 000 low-energy EAS with the help of CORSIKA. By simulating the response of the detector array to these showers, we were able to calculate the precision of different reconstruction techniques used to estimate such EAS parameters as $E, \theta, \varphi, N_e, s$.

Measurement of the CNO solar neutrino flux in Borexino

Alina Vishneva

JINR

About 1% of solar neutrinos are produced in the CNO cycle. Despite their subdominant role in the energy production, CNO neutrinos provide important information on the abundance of heavy elements in the solar core. In this work we present the details of the final analysis of Borexino data for measuring the flux of solar CNO neutrinos. This analysis features the fit of the electron recoil spectrum alongside with the directional information of neutrino events.

Detection of Gamma Rays from the Crab Nebula with TAIGA-IACT Telescopes in Stereo Mode Based on 2020–2023 Data

Pavel Volchugov

SINP MSU

The TAIGA astrophysical complex[7], located in the Tunka Valley, 50 km from Lake Baikal, was developed for research in the field of ultra-high-energy gamma-ray astronomy and cosmic ray physics. This report provides a detailed description of the methodology for detecting gamma rays using the TAIGA-IACT atmospheric Cherenkov telescopes in stereo mode[8] and presents the results obtained from observations of the gamma-ray source in the Crab Nebula. The report includes:

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[7]L. A. Kuzmichev et al. “Cosmic Ray Study at the Astrophysical Complex TAIGA: Results and Plans”. In: *Physics of Atomic Nuclei* 84.6 (Nov. 2021), pp. 966–974. DOI: 10.1134/S1063778821130172.

[8]P. A. Volchugov et al. “γ-Ray Detection with the TAIGA-IACT Installation in the Stereo Mode of Observation”. In: *Instruments and Experimental Techniques* 67.1 (Feb. 2024), pp. 143–152. ISSN: 0020-4412. DOI: 10.1134/S0020441224700106.

- The methodology for reconstructing the parameters of extensive air showers detected in stereo observation mode;
- The procedure for gamma-hadron separation;
- The calculation of the effective area for the facility with two and three TAIGA-IACT telescopes;
- The energy spectrum of gamma rays from the Crab Nebula.

Energy spectrum of primary cosmic rays according to the NEVOD-EAS array datao

M. Amelchakov, A. Bogdanov, S. Khokhlov, E. Khomchuk, C. Nugaeva, I. Shulzhenko, and Elena Yuzhakova

MEPhI

The main source of information about high-energy cosmic rays (above 10^{15} eV) are extensive air showers (EAS), which are formed as a result of interaction of primary cosmic rays (PCR) with nuclei of atmospheric atom. 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. To study air-shower in the energy range 10^{15}–10^{17} eV, the NEVOD-EAS array was constructed at the MEPhI (Moscow). It consists of 9 clusters deployed around the Experimental Complex NEVOD. The cluster includes 4 detector stations measuring energy deposit and arrival time of secondary EAS particles. The technique for reconstructing air-shower parameters and PCR energy spectrum based on the response of the NEVOD-EAS array is described. It has been tested using the simulation in the CORSIKA program and the QGSJET-II-04 + FLUKA hadronic interaction model. In total 3 000 000 air-showers from primary protons and iron nuclei have been analyzed in the energy range 10^{14}–10^{17} eV. The results of reconstruction of the primary particles energy based on the developed technique are presented.