International Workshop “Infinite and Finite Nuclear Matter”(INFINUM-2025)

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BLTP

Book of Abstracts

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Holographic model for neutron star with color superconductivity in the inner core

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In this project, we use the Einstein Gauss Bonnet gravity for this holographic model. The crust contains baryon phase correspond the instanton gas in AdS soliton solution and the core color supeconductivity (CSC) phase correspond to the AdS black hole. We use this model to compute the equation of state of this type of compact star

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Introduction

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Active role of gluons in multiparticle production.

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Long-term studies of multiparticle processes indicate an ever-increasing role of the gluon component of hadrons and its active participation in the formation of secondary hadrons. The gluon dominance model, taking into account the stage of the quark-gluon cascade, based on PT QCD and hadronization, described by a phenomenological scheme is consistent with experimental data well.
The development of this model occurred with the appearance of data on multiplicity at different accelerators. According to this model, the creation of secondary particles is carried out by active gluons, while valence quarks remain in the leading particles. It is confirmed the fragmentation mechanism of hadronization in e^+e^- annihilation and recombination in hadron collisions, and also many other phenomena.

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Study of the properties of rotating quark-gluon matter by means of lattice QCD simulations на решетке

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The paper will present the results of the study of the influence of relativistic rotation on the properties of quark-gluon matter. To carry out this study, we switch to a reference frame that rotates together with the system we study. In this reference frame, the rotation leads to the appearance of an external gravitational field, and the problem is reduced to the study of the properties of QCD in the external gravitational field. The lattice modeling method is used to study the properties of the KCD. The paper will discuss the following results: the effect of rotation on confinement/deconfinement transitions, breaking/restoration of chiral symmetry, negative moment of inertia of quark-gluon matter, spatially inhomogeneous phase transitions in a rotating QCD.

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Chiral and deconfinement thermal transitions at finite quark spin density in lattice QCD

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We study the effect of finite spin quark density on the chiral and deconfinement thermal transitions using numerical simulations of lattice QCD with two dynamical light quarks. The finite spin density is introduced by the quark spin potential in the canonical formulation of the spin operator. We show that both chiral and deconfinement temperatures are decreasing functions of the spin potential. We determine the parabolic curvatures of transition temperatures in a limit of physical quark masses.

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Hypernuclear Properties and Hyperonic Interactions

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Hypernuclei remain for a long time the major source of information on hyperonic interactions in nuclear environments. This information is useful for neutron star and heavy ion fields.

We discuss some topics on the modern status and recent progress in hypernuclear studies. Particularly, we consider exotic Λ hypernuclei with nuclear cores close to the drip lines. In some cases, the hyperon can stabilize an unbound nuclear core. Specifically, we predict the existence of the bound

_Λ⁹C hypernucleus with unique *Z/N*=3. Exotic Λ hypernuclei can clarify, among others, the problem of the charge symmetry breaking ΛN interaction.

Data on ΛΛ and Ξ hypernuclei, being rather scarce now, nevertheless open the window into the *S* = −2 sector of baryonic interaction studies. We discuss current problems in this field, particularly, properties of the lightest ΛΛ hypernuclei and the ΛΛ-ΞN mixing.

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Many-body effects of hyperonic interactions in neutron stars

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Medium effects, which can be introduced in the Skyrme formalism as density-dependent or three-body forces, are an essential part of describing hyperonic interactions. In neutron stars, these effects are especially important due to the extremely high densities.

We study the influence of the different aspects of these medium effects on neutron stars characteristics. In particular, the role of γ in the dependence of ΛN-interaction on nucleon density ρ_N^γ in description of neutron stars is studied. Known Skyrme parametrizations of ΛN-interaction with $\gamma < 1$ provide softer equations of state and smaller masses of neutron stars than those with $\gamma = 1$. However, we show that it is not necessarily so and parametrizations with lower value of γ can provide stiffer equations of state. We also compare the density-dependent ΛN forces to the three-body ΛNN forces. The latter in neutron stars lead to a softer equation of state and can, in some cases, considerably affect the chemical composition of the star.
Finally, we include a density dependence to the ΛΛ potential and compare the obtained potential with known potentials of ΛΛ-interaction.

This work was supported by the Russian Science Foundation under Grant No 24-22-00077.

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Implications of dense matter properties on neutron-star thermal evolution on various time scales

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Interplay between recent progress in studies of thermal evolution of neutron stars and dense matter theory is discussed. Consideration is limited to the nucleonic composition of neutron-star interior. Passive cooling of isolated neutron stars is considered along with heating and cooling of accreting neutron stars in binary systems. Cases of practical interest are highlighted, where the usual concepts of quasi-stationary envelope and isothermal core of a neutron star are violated. The work is supported by the Russian Science Foundation Grant 24-12-00320.

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Transport properties of rotating quark matter

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Measurements of global spin polarization of hyperons and mesons in non-central heavy ion collisions reveal a promising signature of non-zero net angular momentum in the locally thermalized medium of quark-gluon plasma. This motivates a detailed understanding of the thermodynamic and transport properties of quark matter in a rotating frame. Rotation breaks translational symmetry in a system and anisotropies its thermodynamic quantities, potentially disrupting the thermalization requirement at high angular velocity. Along with thermodynamic variables, rotation disrupts the isotropy of transport coefficients in the same way as an external magnetic field does. In this work, we calculate anisotropic components of transport coefficients by considering angular velocity ($\vec{\Omega}$) as an independent degree of freedom in the rotating frame. As a result, shear and bulk viscosity breaks up into five independent components and electrical conductivity breaks up into three independent components. We calculate the transport coefficients by solving the Boltzmann transport equation (BTE) using kinetic theory formalism. With the modified equation of motion in the rotating frame, the force term in the BTE naturally gives rise to Coriolis, centrifugal, and many other fictitious forces. We solve the BTE for the leading order terms in $\vec{\Omega}$. We employ a two-flavor Nambu-Jona—Lasinio model to estimate the transport coefficients, with the modified Lagrangian taking care of the equation of motion in a rotating frame and including a spinorial connection. As a first estimate, we choose a fixed coupling constant, due to which chiral condensate melts down with rotation and the transportation increases.

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On the possibility of π^0 condensation and magnetization in freely interpenetrating nuclei

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Conditions are found, at which in the nuclear matter there may appear a spatially nonuniform p wave π^0 condensate supplemented by a spatially varying spontaneous magnetization. The pion-nucleon interaction and the anomaly contributions to the magnetization are taken into account. Response of the system on the external magnetic field is also considered. Then the model of nonoverlapped nucleon Fermi spheres is employed. Arguments are given in favor of the possibility of the occurrence of the π^0-condensation and a spatially varying magnetization as well as effects of pronounced anisotropic pion fluctuations at finite pion momentum in peripheral heavy-ion collisions. Relevant effects such as response on the rotation, charged pion condensation and other
are discussed.

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Thermal enhancement of nuclear (anti)neutrino emission during pre-supernova stage

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Accurate estimates of (anti)neutrino spectra and luminosities are essential for assessing the possibility of detecting neutrinos from pre-supernova stars. Using the thermal quasiparticle random-phase approximation (TQRPA) method, we studied the effects of nuclear temperature on pre-supernova (anti)neutrino emission. Comparing the ν_e and $\bar{\nu}_e$ spectra produced in neutral- and charged-current weak reactions involving cold and thermally excited (hot) nuclei, we conclude that energy transfer from hot nuclei not only enhances (anti)neutrino emission but also hardens the spectrum.

Using the MESA stellar evolution code, we generated density, temperature, and chemical composition profiles for a $14\,M_\odot$ pre-supernova model. From these results, we calculated the time evolution of luminosities and spectra for (anti)neutrinos emitted via thermal and nuclear processes. We find that the luminosity of ν_e from electron capture on hot nuclei exceeds that from e^+e^--pair annihilation by an order of magnitude even one day before collapse. Moreover, we show that for $\bar{\nu}_e$ production, neutrino-antineutrino pair emission via nuclear de-excitation (ND) is at least as significant as pair annihilation. We also demonstrate that flavor oscillations amplify the high-energy component of the ND process in the $\bar{\nu}_e$ flux. This effect could be crucial for the detection of pre-supernova $\bar{\nu}_e$ by terrestrial detectors.

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Dual QCD Quark hadron phase transition in presence of magnetic field

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To gain a deeper insight into the dynamics of the quark-hadron phase transition
under a magnetic field, the thermal characteristics of the non-perturbative
QCD vacuum have been studied. The dynamic arrangement of the resulting
dual QCD vacuum and its flux tube structure has been examined to investigate
the non-perturbative features of QCD. The partition function of quarks
and gluons in the QGP phase in the presence of a magnetic field in dual QCD
structures is used to deduce various thermodynamical parameters, such as
pressure, energy density, the square of speed of sound, specific heat and free energy using the grand-canonical partition
function.

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Directed flow in heavy-ion collisions at high baryon densities

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Results of simulations of directed flow of various hadrons in Au+Au collisions at collision energies $\sqrt{s_{NN}} =$ 3–4.5 GeV are presented. Simulations are performed within the model three-fluid dynamics and the event simulator based on it (THESEUS). The results are compared with available data. The directed flows of various particles provide information on dynamics in various parts and at various stages of the colliding system. However, the information on the equation of state is not always directly accessible because of strong influence of the afterburner stage or insufficient equilibration of the matter. It is found that the crossover scenario gives the best overall description of the data. The transition into QGP in Au+Au collisions occurs at collision energies between 3 and 4.5 GeV, at baryon densities $n_B \geq 4n_0$ and temperatures ≈ 150 MeV.

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Classical and quantum shear

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The structures of classical Energy-momentum tensor (EMT) are related to the ones appearing in the hadronic matrix elements of quantum EMT operator. The crossing properties of the latter allow one to establish relations between seemingly different processes.
The structures corresponding to shear viscosity contribution require (naive) T-violation in the hard exclusive hadron scattering channel described by Generalized Parton Distributions. At the same time, for annihilation channel described by Generalized Distribution Amplitudes the exotic quantum numbers are required. The perturbative estimates of the relevant objects lead to the smallness of viscosity, compatible to the holographic bound. The relation to equivalence principle and its generalization is also discussed.

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Recent Advances in the Physics of the Inner Crust

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The talk offers a concise overview of recent advancements in the study of the inner crust, focusing on refinements in trial functions for extended Thomas-Fermi (ETF) calculations and their impact on predictions regarding the structure of the pasta phase. We will also discuss the specifics of thermodynamically consistent calculations of pressure and chemical potential within ETF framework utilizing these trial functions. Additionally, we will present findings on the elasticity properties of the inner crust.

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Matrix kinetic equation approach to calculation of neutrino emission accompanying formation of Cooper pairs in superfluid neutron star matter.

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TBA

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Weakening of the deconfinement phase transition in an external gravitational field

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We have investigated the accelarating hot gluonic matter near the critical temperature of the deconfinement phase transition within the framework of lattice quantum field theory (QFT). We used the Tolman-Ehrenfest relation between the temperature gradient and the gravitational field to introduce acceleration into the lattice QFT formalism. We considered several lattice sizes along imaginary time and took the infinite-volume limit to make our results convincing. We have shown that even the weakest acceleration to ~4 MeV is sufficient to change the first-order deconfinment phase transition occurring in pure gluodynamics to a soft crossover for the accelerated medium.

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Structure of QCD string near Casimir Surface

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The confinement problem still remains an important topic in quantum chromodynamics (QCD). At the moment, there is no acceptable way to describe the low-energy limit of QCD, at which nonpertubative effects appear, except for lattice modeling. In my work, using lattice QCD methods, I considered flux tubes connecting a quark - antiquark pair, with additional boundary conditions in

the form of a Casimir plate. The behavior of the flux tube was studied near the plate, at different distances between quarks, and the components of the force tensor of the field were calculated. Based on the results of the work, one can conclude that the coupling between quarks weakens at close distances to the plate and its bending, which hypothetically may indicate the possibility of observing a quarkiton.

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Fluctuation-induced first-order superfluid transition in unitary $SU(n)$ Fermi gases

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We use the functional renormalization group to study the superfluid phase transition in unitary $SU(n)$-symmetric Fermi gases. For $n \geq 4$ critical fluctuations invalidate mean-field theory and drive the transition first-order. We calculate the critical temperature and the jumps in the superfluid gap and the entropy density as functions of spin multiplicity n. All discontinuities grow with n, indicating an increasingly pronounced phase transition.

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Directed flow of protons and deuterons in heavy-ion collisions at BM@N

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In heavy ion collisions at the beam energy of several GeV per projectile nuclei hot and dense strongly interacting matter being produced at high baryon densities. One of the observables sensitive to the properties of this matter is the azimuthal anisotropy of the created in the collision particles. We present the results on the measured directed flow of protons and deuterons from the recent physical data of Xe+CsI at $E_{kin} = 3.8A$ GeV from the BM@N experiment.

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Cluster production as a probe of EoS in HICs

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Spectral functions of the $O(N)$ model from the functional renormalization group approach

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We will discuss the computation of spectral functions of bound states using the real-time formulation of a functional renormalization group (FRG) approach on the example of the O(4) model. The computation is based on the Kallen-Lehmann spectral representation of dressed propagators used in the Wetterich equation – the flow equation of the effective action. We consider an approximation of momentum-independent vertices, the so called propagator approximation. Such an approach gives analytic access to the emergent singularities and brunch cuts, which opens the way for the numerical solution of a system of the FRG equations for the spectral functions corresponding to dressed retarded propagators.

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Systematic study of anisotropic flow in relativistic heavy-ion collisions

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Measurements of the anisotropic collective flow of particles produced in relativistic heavy ion collisions play an important role in the study of the transport properties of strongly interacting matter. In this work we present the results of the most complete systematic study of the dependence of the anisotropic collective flow on the collision energy from 2.4 GeV to 5.76 TeV based on the available experimental data and discuss them using different scaling relations for the azimuthal anisotropy and comparison with models.

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Light nuclei and hypernuclei production based on THESEUS event generator

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The thermodynamical approach to light (hyper)nuclei production in heavy-ion collisions and its implementation in the new version of the generator THESEUS (Three-fluid Hydrodynamics-based Event Simulator Extended by UrQMD final State interaction) are reviewed.
In this approach light (hyper)nuclei are treated on the equal basis with hadrons, i.e. using only thermodynamic quantities deduced from simulations within 3FD model (3-Fluid Dynamics).

Production of various species of light (hyper)nuclei (deuterons, tritons, ^{3}He, ^{4}He, $^3_\Lambda$H and $^4_\Lambda$He nuclei) is studied by means of the new version of THESEUS.
The performed modeling demonstrated the efficiency of the thermodynamical approach: it showed reasonable agreement of the obtained results with available experimental data of the NA49 and STAR collaborations in the energy range $\sqrt{s_{NN}}$ from 3 to 19.6 GeV. A good description of rapidity distributions, p_T- and m_T-spectra, and particle ratios (d/p, t/p, t/d and tp/d^2) is obtained. Collective flow of light (hyper)nuclei is also studied.
Modeling of the hypernuclei production also gives good description of experimental data.

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Spin polarization in heavy ion collisions and relativistic spin-hydrodynamics

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I present an overview of recent developments in the measurements of spin-polarization in heavy ion collisions and the formulation of spin-hydrodynamics.

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Description of nucleus-nucleus interaction using the Skyrme energy density functional

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The typical requirement for the energy density functional (EDF) is the accurate description of the binding energies of nuclei, the energy spectra of single-particle states, and the properties of collective excitations [1]. At present, the EDFs based on the effective Skyrme-type interaction serve as a powerful tool for studying the nuclear structure. However, a simultaneous description of nuclei properties and their interaction potential within the Skyrme EDF has yet to be realized. As known, the sub-barrier fusion cross sections, as well as astrophysical reaction rates, are very sensitive to the effective nucleus-nucleus potential [2]. The experimentally determined height of the Coulomb barrier will become an additional criteria for finding a new set of the EDF parameters. In the present report, we discuss a procedure aimed for improving the Coulomb barrier height while preserving the description of nuclear structure based on the new EDF set.

The research was supported within the framework of the scientific program of the National Center for Physics and Mathematics, topic No. 6 "Nuclear and Radiation Physics" (stage 2023-2025).

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Instability windows of relativistic r-modes in hyperonic stars

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R-modes are oscillations of rotating stars, restored primarily by Coriolis force. Of all oscillations, they are the most susceptible to the Chandrasekhar-Friedmann-Schutz instability with respect to emission of gravitational waves. This instability makes them particularly promising targets for current and future gravitational wave searches. In order to develop, the CFS instability should surpass the dissipative processes that accompany oscillations. As a result, r-modes become unstable only for specific combinations of stellar angular velocity Ω and its (redshifted) temperature T^{∞}, which define the so-called instability window on the (Ω, T^{∞}) plane. At high temperatures, bulk viscosity ζ (heat production sourced by out of equilibrium chemical reactions) is the primary dissipative agent that opposes the CFS instability. Dissipation due to ζ can be substantially enhanced by two physically indendent mechanisms: 1) the presence of hyperons (if permitted by the equation of state), which greatly amplifies bulk viscosity ζ, and 2) the recently discovered peculiar properties of relativistic r-modes in nonbarotropic matter, which lead to substantially higher dissipation through ζ compared to predictions from Newtonian theory. In this study, we investigate for the first time the combined effect of these amplification mechanisms on the r-mode instability windows. In our calculations, we take into account that, apart from generating bulk viscosity, chemical reactions also modify adiabatic index of the matter. We also provide the estimates on how the effects of nucleon superconductivity and superfluidity might influence the instability windows. We compare our predictions against the up-to-date observations of neutron stars in Low-Mass X-ray Binaries and find that bulk viscosity could be the long-sought dissipative mechanism capable of stabilizing r-modes in the fastest-spinning and moderately hot stars, even when accounting for nucleon superfluidity and superconductivity. The reported results are particularly important for interpreting observations and improve the overall understanding of relativistic r-mode physics.

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Percolation, polymers and square ice: exact formulas and finite size scaling

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Percolation models are widely recognized in statistical physics for providing the simplest example of a phase transition and critical phenomenon. Bonds of an infinite lattice chosen to be open at

random with probability p and closed otherwise form an infinite cluster when p exceeds a critical value. The statistics of open clusters show typical critical behavior at the critical point, like fat-tailed fluctuations of cluster sizes, universal long-range correlations between them, and conformal invariance of observables. When, on the other hand, there is an intrinsic finite scale in the system, like it is on a cylinder of finite circumference, the universality is still revealed in the finite-size scaling of cluster statistics. The latter brings information about the universal critical behavior of the model, as well as about the violation of scaling and conformal invariance. In the talk, I will give an overview of the recent exact results on the densities of critical percolation clusters on the cylinder. The technique based on the toolbox of the theory of integrable systems exploits the tight connection of the critical bond percolation on the square lattice with the dense loop model and with the exactly solvable six-vertex model of square ice.

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Low-energy spectra of nobelium isotopes

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The low-energy multipole spectra in isotopes 250-262No are investigated in the framework of fully self-consistent Quasiparticle-Random-Phase-Approximation (QRPA) method with Skyrme forces SLy4, SLy6, SkM* and SVbas [1] . The main attention is paid to nuclei 252No and 254No, where we have most of the experimental spectroscopic information [2,3]. The calculations confirm the prediction [4] of a significant shell gap in the neutron single-particle spectrum of these two isotopes. It is shown that, in the chain 250–260No, features of 252No and 254No exhibit essential irregularities caused by this neutron shell gap and corresponding drop of the neutron pairing.
The observed K-isomers (K⊠ = 2-,8-,3+) are reasonably described. We confirm the assignment of 8− state at 1.254 MeV in 252No as the neutron 2qp configuration nn[624↓,734↑]. The 2qp 8− isomer in 254No was earlier investigated within various models and alternative assignments nn[734↑, 613↑] and pp[514↓,624↑] were disputed. Our calculations support the neutron assignment based on the complete decay scheme proposed in the experimental paper [5].
We predict in 252No and 254No low-energy pairing vibrational Kπ = 0+ states with basically proton structure. The recently observed Kπ = 0+ state at 0.888 MeV in 254No [6, 7] was previously treated as a result of coexistence of the normal deformation and superdeformation or/and coexistence of axial and triaxial shapes. Instead, our calculations show that this state should be the pairing vibration. Such low-energy 0+ pairing vibrations are typical for rare-earth and actinide deformed nuclei. Note that low-energy 0+ states were earlier predicted in Fl and Cn (Z=112) isotopes.
The low-energy quadrupole, octupole and hexadecapole (lm=20,22,30,31,32,43,44) one-phonon states were also explored. The hexadecapole counterparts Kπ = 3+ and 4+ with a similar 2qp structure and close excitation energies were predicted. In general, the calculations predict rich multipole spectra below 2MeV in 252,254No. The Skyrme forces Sly6 and Sly4 demonstrate the best performance.
Further measurements of low-energy states in 252,254No are very desirable. Spectroscopy of nobelium isotopes could be a crucial test for the theory pretending for description of even heavier nuclei, first of all, of superheavy elements.

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Investigation of the structure of the lowest quadrupole excitations in Ge isotopes

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At present, a lot of experimental information has been accumulated on the structure of low-lying excited states in Ge isotopes. Interest in these nuclei is due to the fact that with an increase in the number of neutrons there is a transition between spherical and deformed forms of the nucleus that determine their structure. On the other hand, microscopic calculations show that Ge isotopes are soft in relation to triaxial deformation. In this report, we analyze the properties of low-lying 2+ states in isotopes of 70-88Ge. Calculations were carried out by constructing and diagonalization of the collective quadrupole Hamiltonian. The surfaces of potential energy and mass parameters were calculated in the relativistic mean field model with two parameterization of the energy density functional: PC-PK1 and NL3. The results of the calculations are compared with the experimental data and the results obtained within other approaches

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van der Waals droplets balancing between liquid and vapor

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Dynamics of heated droplets of particles interacting with Lennard-Jones potential are simulated by employing the classical molecular dynamics (CMD). Such large aggregates represent an example a finite system exhibiting the van der Waals equation of state in thermodynamic limit which properly characterizes the existence of spinodal region relevant for liquid-gas phase transition. We analyze an exact evolution of microcanonical ensemble of such droplets with statistically distributed deposited energy corresponding to a temperature T.
At small T the system displays liquid like behavior when droplets cool down by evaporation. While particles evaporate the expansion momentum on the droplet surface decreases. It gives rise to a loop like trajectory in (density, temperature) plane. The system never enters inside the instability region. At high excitation energy the droplets enter the instability region from the gas phase. The temperature never increases and no loop behavior shows up. At transitional temperatures the van der Waals droplets experience critical evolution resembling the second order liquid-gas phase transition. Such criticality occurs at a mixture of liquid- and gas-like events and leaves the signatures in properties multifragmentation. We analyze features of such critical events in statistics, correlations and fluctuations of fragment mass distribution. Possible effects of droplet magnetization are discussed.

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Cluster production as a probe of EoS in HICs

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We investigate the sensitivity of the light nuclei and hypernuclei production to the strongly interacting nuclei matter equation-of-state (EoS) within the Parton-Hadron-Quantum-Molecular Dynamics (PHQMD) microscopic transport approach.

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Reconstruction of Neutron Stars Mass Distribution from Cooling Evolution

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The influence of environmental effects and proton superconductivity in the matter of neutron stars on the evolution of stellar cooling is studied. It is shown that using cooling models and observational data on the temperature and age of pulsars, it is possible to extract the masses of the observed objects and the mass spectrum of neutron stars.

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Description of low energy fragmentation reactions in the transport-statistical approach

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Fragmentation reactions at energies from 35 to 140 MeV per nucleon are a powerful tool to obtain new isotopes far from stability line. To plan the future experiments model calculations should be performed. Usually models developed to describe relativistic heavy-ion collisions are used for this purpose, like the EPAX and the Abration-Ablation models. They perfectly predict the cross-sections of the isotopes on the stability-line, but it is known that these models underestimate the cross-sections of neutron-reach isotopes and also they can't explain the hyperbolic shape of target ratio of the nuclear reactions with the same projectile but two different targets. In this talk we explain the target ratio of reactions on two targets 181Ta and 9Be for projectiles 18O at energy 35 MeV per nucleon and 86Kr (64 MeV per nucleon) in the multi-step transport statistical approach. The first step of our calculations is solving the Boltzmann-Nordheim–Vlasov (BNV) equation with the test-particle method and the second - is using SMM code to find de-excited fragments to be able to compare to experimental data. We show that hyperbolic shape of target ratio can be explained by the impact-parameter dependence of final isotope distributions. The influence of mass and energy of the projectile on the parameters of this hyperbola is discussed.

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Possible phase transition in accelerated system

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Heavy ion collisions produce matter with extreme vorticity and acceleration, sparking strong theoretical and experimental interest. I will discuss theoretical results on the (acceleration-temperature) phase diagram for spin-1/2 particles, predicting a new phase transition below the Unruh temperature. This transition links to an effective black hole in an accelerated frame, namely, with the singularity of the lower Matsubara modes on the horizon and non-unitarity of the representations of the Poincaré group. Results of the PHSD model simulations of Au-Au collisions will also be presented, which predict early stage temperatures below the Unruh temperatures and support the hadronization mechanism based on the novel phase transition.

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Pion transition form-factor in the frameworks of the PNJL model and the quark model with separable interaction

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The study of the pion photodecay plays an important role in particle physics. The practical interest is explained by the fact that the neutral pion decays electromagnetically in two photons with branching ratio 99%. And a great percentage of photons in the background of heavy ion collision (HIC) is a result of π0 and η decays. The decay width can be considered in terms of the transition form factor (TFF) which encodes the effect of strong interaction of decaying mesons. We consider the pion photodecay and TFF in the frame of two models: we analyze the photon-pion transition form factor in the framework of Polyakov-loop extended NJL and use the quark model with separable interaction kernel.

To describe mesons in second model, we start from the Bethe-Salpeter equation chosing the interaction kernel as $D(q-p) = D_0\varphi(q^2)\varphi(p^2)$ and define the meson vertex function in Gaussian form $\varphi(q^2) = e^{-q^2/\Lambda_H^2}$. To describe the meson properties we fix the model parameters using the meson electromagnetic, leptonic decay constants. In the frame of this model we considered the $\gamma^*\pi^0 \longrightarrow \gamma$ transition formfactors and extended the work by calculating η_c and η_b transition formfactors.

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Applications of dual symmetries of QCD

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It has been shown in the framework of effective models that QCD phae diagram as in thee color cas as well as in two color one possesses dualities.
I means that various phenomena are dual with respect to each other. Then dualities were shown in a more and more general setings. And then finally dualities has been shown from first principles, three dualities as in two color QCD and one in three color one. The fact that dualities have been shown from first principles, i. e. in QCD itself, expanded their possible application much further.
In the talk I discuss two interesting applications. (i) studies of speed of sound at various chemical potentials (ii) studies of possible inhomogeneous phases of QCD phase diagram, including rather unexpected ones.

The talk is partly based on

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In detail about (i) and (ii):
(i) The equation of state of dense hadronic matter is not known yet, so the speed of sound at large baryon densities. The speed of sound at zero baryon density and non-zero temperature has been obtained in lattice QCD simulations. And the behavior is the following, it rises with increase of temperature but up to asymptotic value of 1/3, but never exceeds that value. It is called conformal bound. At non-zero baryon density, in the region of phase diagram interesting in the context of neutron stars lattice simulations are plagued by the sign problem and is not now possible. There was idea that maybe speed of sound should not exceed conformal bound at non-zero baryon density as well. Though observational data favor the scenario that speed of sound breaks the conformal limit at muB, it is still an open question.

Recently in [B.B.Brandt, F.Cuteriand G.Endrodi, JHEP 07, 055 (2023); R. Abbott et al. [NPLQCD], Phys. Rev. D 108, no.11, 114506 (2023)] it has been shown from first principles (lattice QCD) that the conformal bound is broken in quark matter with isospin density (isospin asymmetric quark matter). Then using duality mapping it is possible to get sound speed in quark matter with chiral imbalance mu_{I5} and show that conformal bound is also broken in this case.
And having shown duality from first principles it is also first principle robust result.
Then it was also found that there are additional weaker dual symmetries in phase diagram shown only in the framework of effective models. If one uses these dualities, though it would not be first principle results, one can show that conformal bound is also broken in quark matter with chiral imbalance mu5.
Then it was shown in two color QCD lattice calculations [E. Itou and K. Iida, PoS LATTICE2023, 111 (2024); PTEP 2022 (2022) no.11, 111B01] that conformal bound is exceeded in the case of two colors at non-zero baryon density. Then using first principle dualities one can show that conformal bound is broken at (i) isospin chemical potential (ii) chiral chemical potential mu_{I5}. Moreover, using additional dualities found in effective models one can show also that it does at (iii) chiral chemical potential mu5. So it is shown to be broken at all chemical potentials in two color case.

So one can see from all these results on two color and three color QCD that it is not very peculiar and uncommon to break conformal bound at non-zero chemical potentials.

(ii) Inhomogeneous phases has long history on research but it is still open question if there is inhomogeneous phases in QCD at finite baryon chemical potential. Some inhomogeneous phases have been predicted in various approaches. Dualities gives us opportunity to predict plethora of new inhomogeneous phases. The most interesting phase is the one at zero baryon chemical potential, as a rule one is used to the fact that inhomogeneous phases can be present at nno-zeroi mu_B and it is a first example of inhomogeneus phase at zero mu_B (some other chemical potentials are non-zero)

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Constraints on the nuclear Equation of State: From terrestrial experiments to neutron star observations

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The equation of state (EoS) of asymmetric nuclear matter and its isospin dependence play a fundamental role in nuclear structure, reactions, and decays, as well as in neutron star properties and formation. To constrain the EoS robustly, studies must span extreme densities and pressures across nuclear and astrophysical systems. A well-determined EoS would provide critical insights into ground-state properties of finite nuclei, stability of neutron-rich and superheavy nuclei, heavy-ion collision dynamics, giant monopole resonances and excitation energies, and nuclear surface diffuseness, as well as neutron star structure. Astrophysical observations of neutron stars, particularly their masses, radii, and tidal deformability, serve as key probes of the dense-matter EoS up to several times nuclear saturation density.

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Vorticity in Heavy-Ion Collisions

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One of the most common quantities discussed in connection with Quark-Gluon Plasma is vorticity: $\vec{w} = curl\,\vec{v}$, where $\vec{v}$ is velocity. However, as the coordinates are not observed in a real experiment, we will also investigate such observable: $\vec{w}_p = (p_y v_z - p_z v_y, p_z v_x - p_x v_z, p_x v_y - p_y v_x)$, which can be interpreted as handedness and to which we refer as pulse-vorticity, since $\vec{w}$ and $\vec{w_p}$ seem related trough the uncertainty principle. Modelling of the velocity space was done by creating a grid of set parameters and calculating for each cell: $\vec{v_i} = \frac{\sum \vec{p_i}}{\sum E_i}$, where E_i and $\vec{p_i}$ are energy and momentum of each particle in given cell. Doing so would automatically arrange particles with respect to their energies. The Parton-Hadron-String Dynamics (PHSD) model was used for calculations. Some basic properties of the two quantities match.

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Signature of strange star in SGR 0501+4516

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A strange star is a hypothesized compact star that is dense enough to literally break down ordinary neutrons into their constituent quarks. Furthermore, the up and down quarks are squeezed into an even rarer sort of quark known as a strange quark, which explains the name strange star. Technically, up, down, and strange quarks make up the "strange" matter of a strange star. This mixture of sub-hadronic particles may be even more stable than a typical neutron star.

Magnetars are a type of rare neutron star with a magnetic field that is the most powerful in the universe, approximately a thousand times stronger than that of a typical neutron star and a quadrillion times stronger than that of Earth. As a spinning magnetar can progressively collapse into an even more dense form through glitches of inside vortices, which would be something akin to a strange star with the requisite mix of quarks. It would undoubtedly cause gamma-ray and X-ray outbursts in near-infrared (NIR) imaging of soft gamma repeater (SRG) highly magnetized neutron stars. We found SGR 0501+4516 is a magnetar renowned for its gamma-ray and X-ray bursts and is a candidate for a strange quark star.

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Universalities in neutron star equations of state

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There are plenty of models for the neutron star (NS) equation of state (EoS) on the astrophysical market. While they are very diverse (nucleonic, hyperonic, or hybrid, based on different microphysics), it is widely known that some macroscopic NS properties show universal correlations which are largely independent of a specific EoS model. Such universalities have several astrophysical applications. First, they form a handful tool to constrain the EoS from observational data on masses and radii of NSs. Second, they give a hint of what future observations may be the most informative for strengthening EoS constraints. Third, they allow to construct semi-analytic methods to solve the inverse NS hydrostatics problem, i.e. to determine physical conditions in centers of individual NSs based on their observed properties. In this talk, we show how these applications work for existing observations of NS masses and radii, and briefly discuss origins of the considered universalities.