13th APCTP - BLTP JINR Joint Workshop ”Modern Problems in Nuclear and Elementary Particle Physics”

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Book of Abstracts

13th APCTP - BLTP JINR Joint Workshop "Modern problems in nuclear and elementary particle physics" The APCTP - BLTP JINR Joint Workshop was initiated to promote cooperation between the Asia Pacific Center for Theoretical Physics (APCTP) and the Bogoliubov Laboratory of Theoretical Physics (BLTP) of the Joint Institute for Nuclear Research (JINR).

The first Joint Workshop was organized by BLTP JINR and was held in Dubna on June 18-23, 2007. After a series of very successful Joint Workshops in the JINR and APCTP member countries the 13th APCTP - BLTP JINR Joint Workshop will take place in JINR, Dubna, Russia, 14-20 July 2019.

The main organizers of the 13th Joint Workshop are BLTP JINR and APCTP.

Therefore, one of the goals of the Workshop is to promote the close cooperation in the field of the nuclear and elementary particle physics between Asian countries and Russian leading scientific centers. In particular, we will focus on the subjects where the interests of the researchers of the two sides overlap and thus the collaboration is highly expected.

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Radiative symmetry breaking in the Standard Model

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Breaking of the conformal symmetry in the Standard Model is realized with the help of the Coleman-Weinberg mechanism. The emergence of the electroweak scale is shown. The naturalness problem and vacuum stability of the Standard Model are discussed. The energy scale of new physics is estimated.

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Revival of supersymmetric dark matter

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The lightest supersymmetric particles (LSPs) are natural candidates for the constituents of dark matter. However, the constraints obtained at LHC exclude such particles with masses below roughly 1TeV. In conventional cosmology heavier LSPs would have too high energy density and overclose the Universe. In modified gravity the expansion regime is different and the density of LSPs can be considerably smaller. We have shown that in $R + R^2$ theory particle kinetics is noticeably modified and the frozen density of heavy LSPs would be strongly diminished. They become viable candidates for dark matter if their mass is about 1000 TeV.

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Pygmy and giant dipole resonances in ^{48,50}Ca and ^{68,70}Ni

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The structure of exotic neutron-rich nuclei is one of the main science drivers in contemporary nuclear physics research. An attention has been devoted to effects of varying the ratio between the proton Z and neutron N numbers on different nuclear structure characteristics of nuclei deviated from their valley of β-stability. One of the phenomena associated with the change in N/Z ratios is the pygmy dipole resonance (PDR) [1]. One of the successful tools for describing the PDR is the quasiparticle random phase approximation (QRPA) with the self-consistent mean-field derived from Skyrme energy density functionals (EDF) [2]. Such an approach can describe the properties of the low-lying states reasonably well by using existing Skyrme interactions. Due to the anharmonicity of the vibrations there is a coupling between one-phonon and more complex states [3]. The main

difficulty is that the complexity of calculations beyond standard QRPA increases rapidly with the size of the configuration space, and one has to work within limited spaces. Using a finite rank separable approximation for the residual particle-hole interaction derived from the Skyrme forces one can overcome this numerical problem [4-6].

In the present report, we analyze the effects of phonon-phonon coupling (PPC) on the $E1$ strength distributions of neutron-rich calcium and nickel isotopes. Using the same set of the EDF parameters we describe available experimental data for ^{48}Ca, ^{68}Ni and give prediction for ^{50}Ca, ^{70}Ni. The inclusion of the PPC results in the formation of low energy 1^{-} states of ^{48}Ca. There is an impact of the PPC effect on low-energy $E1$ strength of ^{48}Ca [7]. The effect of the low-energy $E1$ strength on the electric dipole polarizability is discussed. We predict a strong increase of the summed $E1$ strength below 10 MeV (12 MeV), with increasing neutron number from ^{48}Ca (^{68}Ni) till ^{50}Ca (^{70}Ni) [8].

This work is partly supported by CNRS-RFBR agreement No. 16-52-150003.

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The central cusps in dark matter halos: fact or fiction?

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We investigate the reliability of standard N-body simulations by modelling of the well-known Hernquist halo with the help of GADGET-2 code (which uses the tree algorithm to calculate the gravitational force) and ph4 code (which uses the direct summation). Comparing the results, we find that the core formation in the halo center (which is conventionally considered as the first sign of numerical effects, to be specific, of the collisional relaxation) has nothing to do with the collisional relaxation, being defined by the properties of the tree algorithm. This result casts doubts on the universally adopted criteria of the simulation reliability in the halo center. Though we use a halo model, which is theoretically proved to be stationary and stable, a sort of numerical 'violent relaxation' occurs. Its properties suggest that this effect is highly likely responsible for the central cusp formation in cosmological modelling of the large-scale structure, and then the 'core-cusp problem' is no more than a technical problem of N-body simulations.

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Investigation of level density parameters of superheavy nuclei

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In our work we defined level density of heavy nuclei with the single-particle spectra using the saddle-point method and based on a superconducting formalism. Calculated energy dependent level density parameter of superheavy nuclei, by fitting the Fermi gas expression with BCS calculations at the ground state and at saddle point, compared with the phenomenological model are presented. The role of the shell and pairing effects on the level density are studied. The extracted level density parameter is represented as a function of mass number and ground-state shell correction.

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Self-consistent study of isobaric analog resonances in nuclei with pairing

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Fully self-consistent calculation of the IAR resonances is performed for the long chain of Ni isotopes with Tz ≠0. The recently established DF3-f parametrization [1] of the Fayans energy density functional [2] is used. Its performance in “reference”neutron-rich Sn and Pb isotopes with developed pairing correlations is also studied. The main aim is to figure out the influence of T=1 pn-pairing on IAR characteristics and to check how the self-consistency is preserved in the calculations for long isotopic chains. Comparison with the available calculations using relativistic Hartree-Bogolubov plus D3C* functional [3] and the HF+BCS with SAMi functional [4] is performed,

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Stochastic hydrodynamics and long time tails under the effect of multiplicative noise

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We investigate hydrodynamic fluctuations on correlation functions in a conserved U(1) charge fluid beyond the white noise approximation. We introduce two additional nonlinear mode coupling constants to study the effect of multiplicative noise due to the position dependent transport coefficients. The behaviors of two vertexes are constrained by the disappearance while averaging the noise term due to the conservation law and the fluctuation-dissipation theorem in the near equilibrium system. We generalize the kinetic equations for the two-point functions of pressure, momentum and heat energy densities within the context of the path integral formalism. We reproduce the long time tails which have obtained from other approaches.

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Electron Ion Collider Plan in China (EicC)

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Recently, an Electron-Ion Collider is proposed in China based on the High-Intensity Heavy Ion Accelerator Facility (HIAF) which is under construction. The EIC in China (EicC) consists of different phases with the capability of an upgrade for both beam energy and luminosity. The phase-I will start with e-p(nucleus) collision with 3.5 GeV (e) $\times$ 20 GeV (p) beam energy configuration. The baseline design for the luminosity is around 5 $\times$
10^{33} cm$^{-2}s^{-1}$. Both electron and proton (nucleus) beams will be polarized. In this talk, I will present a preliminary design for the project and some selected physics topics at the EicC. The current status and the proceeding plan will also be discussed.

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Neutrino-Process for Core Collapse Supernova Explosion

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We investigate the neutrino oscillation effects by the neutrino self-interaction near to the neutrino sphere and the MSW effect far from the sphere on the element abundances. The representative synthesized elements by neutrino from supernova explosion are known as 7Li, 11B, 92Nb, 98Tc, 138La, and 180Ta. Near to the neutrino sphere, the neutrino density is about 1032 / cm3, whose number is high enough to consider the neutrino self-interaction.

Their effects on the neutrino flux are estimated in the Boltzmann equation with a collision term for the neutrino density under the mean field approximation. Due to the propagation of the shock wave we also have to take the neutrino propagation in matter, i.e. MSW effects. One of the important MSW regions is the O/Ne/Mg layer given by the progenitor and the hydrodynamics models.

In this work, we discuss how the neutrino self-interaction and the MSW effects influence on the element production by using the modified neutrino spectra and the neutrino-nucleus interactions

calculated by QRPA. Our results show that the neutrino-process element abundances are increased by the self-interaction rather than the MSW effect. 11B/138La ratio is shown to be sensitive on the self-interaction. Dependence on the mass hierarchy is also discussed.

Recent calculations about the non-adiabatic shock effects on the neutrino propagation and the effects by sterile neutrinos will also be discussed with the nuclear abundances by the neutrino process.

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Beyond the Standard Model and neutrino precision test

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On ρ meson generalized parton distributions

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We study ρ meson unpolarized and polarized generalized parton distribution functions (GPDs) based on a light-front constituent quark model[1,2]. The electromagnetic form factors as well as other low-energy observables of
the ρ meson are calculated and our results are compared to other calculations and possible experimental data. In our calculation, the contributions both from the valence and non-valence regimes are analyzed in detail. Moreover, we also
give the structure functions in the forward limit. Our numerical results show that the present phenomenological model is reasonable to describe the general properties of the ρ meson.

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The proton size puzzle: latest news

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Current status of the proton size puzzle from experimental and theoretical points of view is briefly discussed.
The interest to these studies is primarily related to experiments conducted by the CREMA collaboration (Charge Radius Experiments with Muonic Atoms) with muonic hydrogen and deuterium by methods of laser spectroscopy. As a result a more accurate value of the proton charge radius was found to be $r_p = 0.84184(67)$ fm, which is different from the value recommended by CODATA for 7σ.

Then, we discuss recent calculations of the contribution of light pseudoscalar (PS) and axial-vector (AV) mesons to the interaction operator of a muon and a proton in muonic hydrogen atom, with the coupling of mesons to the muon being via two-photon intermediate state. Numerical estimates of the contributions to the hyperfine structure of the spectrum of the S and P levels are presented. It is shown that such contribution to the hyperfine splitting in muonic hydrogen is rather important for a comparison with precise experimental data.

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Effects of RPA correlations on charged-current neutrino opacities in supernova neutrino-sphere

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The study of neutrino interaction processes with core-collapse supernova matter is crucial to our understanding of the explosion mechanism. The charged-current processes $\nu_e + n \to p + e^-$ and $\bar{\nu}_e + p \to n + e^+$ are mainly responsible for heating behind the stalled shock front and thus for reviving the explosion. Neutrino transport to the shock region is sensitive to the physics of hot and dense nuclear matter, which is a complex problem due to the strong correlations induced by nuclear forces.

We have analyzed the combined effect of mean-field potentials and RPA correlations on the ν_e and $\bar{\nu}_e$ opacity in the neutrino-sphere. The RPA response function for the hot and dense nuclear matter is computed by a self-consistent approach based on the solution of the Bethe-Solpiter equation with the Skyrme forces. Using different Skyrme parametrizations, we have shown that the joint effect of mean-field potentials and RPA correlations makes the neutrino-sphere more opaque (transparent) for (anti) neutrino radiation as compared to the noninteracting Fermi gas model.

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B-splines and Bernstein basis polynomials

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Computational methods based on a B-spline decomposition have found numerous applications in different fields of physics. The Cox - de Boor recurrence relation is a main tool for numerical calculations with B-splines. Here we derive the analytic representation of B-splines for an arbitrary knot sequence and order using decomposition on Bernstein basis polynomials. This representation allows to perform analytically many calculations with B-splines. Few examples of applications are presented.

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DK interaction as a doorway to manifestly exotic mesons

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In recent years, it is found that many of the newly discovered states cannot easily fit into the naïve quark model. Because some of them are located close to two body thresholds, they have been conjectured as molecular states. We propose that one way to unambitiously test such a picture is going to few body (greater than two) systems while the building blocks are the two body subsystems. The DK/DDK/DDDK systems provide one of the be best playground for testing our proposal.

The Ds0*(2317) is widely accepted as a DK molecule. Its existence indicates that the DK interaction is attractive and strong enough to form a bound state. A natural question is then whether the system will still bind with one or more D mesons added. In a series of recent works, we explored such possibilities and showed that the DDK three-body molecular state exists, with a mass around 4140 MeV and a width of about 10 MeV. Due to the doubly charmed and doubly charged nature, such a state is explicitly exotic. We have also performed a preliminary study of the strong decay of the DDK state and the existence of a DDDK molecule. In this talk, I will report on these studies.

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Phase transition between the isovector to isoscalar pairing correlations in deformed N=Z nuclei

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We demonstrated that the enhanced IS pairing brings about the IS condensation with the deformation. In fact, the relationship between the IS pairing in the tensor force and the deformation is not clear because of the shell evolution along the deformation. In particular, the completion of the pairing interaction in the residual interaction and the deformation in the mean field remains to be discussed.

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Nuclear experiments at KoBRA and Y2L in Korea

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Korea is currently constructing the radioactive ion (RI) beam accelerator facility called RAON. One of the experimental facilities called KoBRA, located in the low energy experimental hall, is expected to carry out nuclear astrophysics and nuclear structure experiments in the early phase of RAON. Several experiments using both stable and RI beams of tens of MeV/nucleon are considered for carrying out nuclear structure and nuclea astrophysics experiments. There is an underground laboratory called the Yangyang laboratory (Y2L) in Korea. Several rare decay measurements such as the half-life of 180mTa and the gamma ray transitions of E > 3 MeV in 208Pb were conducted at Y2L. The half-life of 180mTa is considered to be an important parameter for nuclear synthesis models for heavy elements. 208Pb is one of the most interesting nuclei because it is the doubly magic nucleus and its structure has been studied. However, some branching ratios of gamma transitions with Eg > 3 MeV were never been identified. Current activities and prospects of nuclear astrophysics using RI beams at KoBRA and rare decay measurements at Y2L will be discussed.

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CMS upgrade plan for high-luminosity era and prospect on heavy-ion physics

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The CMS Collaboration has a major detector upgrade plan during the long shutdown 3 (LS3) to prepare the high-luminosity runs. It includes the new tracking system, the muon system, the electromagnetic and hadronic calorimeters, and the trigger system. This upgrade will significantly enhance the physics performance of the CMS detector not only for proton-proton collisions, but also heavy-ion collisions in high-luminosity environment. In this presentation we, firstly, give an overview of the CMS upgrade plan during LS3. Then, we present the impact of the detector upgrade to the various physics observables for heavy-ion physics to better understand the interaction of quarks and gluons in hot, dense medium.

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Calculation of fission fragment mass distributions by using a semi-empirical method

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Fission product yield data are important for applications of nuclear technology such as the estimation of decay heat, operation of nuclear reactors and handling of spent fuels. However, due to the

short life-time, a large part of fission fragment yield data cannot be obtained from measurements. Therefore, models of fission fragment yields are needed for such unmeasured cases. Though many theoretical fission models are developed, the calculation results are not necessarily accurate enough to reproduce the fission observables quantitatively. On the other hand, semi-empirical models may be useful in describing fission product yields in a simple way but with a relatively good accuracy.
We developed a semi-empirical fission model based on the saddle point fission model of Itkis [1] and Schmidt [2]. It is assumed that fission product yields are determined by the fission barrier to some extent whereas values of the effects of detailed nuclear dynamics from saddle to scission are included in our model parameters. The parameters for our empirical model are deduced by fitting the evaluated fission yields to the ENDF data, and we found that the parameters can be expressed in simple forms. The calculated fission product yields from our model which has 10 parameters can reproduce the yields nearly as well as GEF.

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Decay $B_s \to K^{*0}\mu^+\mu^-$ in covariant confined quark model

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We evaluate $B_s \to K^{*0}$ transition form factors in the full kinematical region within the covariant confined quark model. The calculated form factors used to calculate the $B_s \to K^{*0}\mu^+\mu^-$ rare decay branching ratio, which was recently measured by LHCb collaboration.

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Shape coexistance in nuclei

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Transfer products accompanying complete fusion

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The product yields of multinucleon transfer reaction is analyzed in low-energy collisions of ^{48}Ca+^{nat}Cm at Elab=5.63 MeV/nucleon. The transfer products accompany the complete fusion. While the collisions with low angular momenta contribute to the production of very neutron-deficient isotopes, the collisions with high (near and above critical angular momentum) angular momenta result in the production of heavier isotopes. The model describes rather well the yields of isotopes with N>126. The possible reasons of discrepancy for the lighter isotopes are suggested.

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Modeling the gluon and ghost propagators in Landau gauge by truncated Dyson-Schwinger equations

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We suggest a framework based on the rainbow approximation with effective parameters adjusted to lattice data. The analyticstructure of the gluon and ghost propagators of QCD in Landau gauge is analyzed by means of numerical solutions of the coupled system of truncated Dyson-Schwinger equations. We find that the gluon and ghost dressing functions are singular in complex Euclidean space with singularities as isolated pairwise conjugated poles. These poles hamper solving numerically the Bethe-Salpeter equation for glueballs as bound states of two interacting dressed gluons. Nevertheless, we argue that, by knowing the position of the poles and their residues, a reliable algorithm for numerical solving the Bethe-Salpeter equation can be established.

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Tetraquark mixing framework for the two light-meson nonets

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We propose a tetraquark mixing framework for the two light-meson nonets in the $J^P = 0^+$ channel, the light nonet $f_0(500)$, $f_0(980)$, $a_0(980)$, K_0^*(800), and the heavy nonet $f_0(1370)$, $f_0(1500)$, $a_0(1450)$, $K_0^*(1430)$. According to this framework, one can introduce two types of tetraquark with different spin configuration, $|J, J_{12}, J_{34} = |000>, |011>$, where J is the spin of the tetraquark, J_{12} the diquark spin, J_{34} the antidiquark spin. They differ by the color configuration also but both have the same flavor structure. The two tetraquark types seem to have interesting correspondence with the two nonets in PDG. Indeed, the two tetraquarks mix strongly through the hyperfine color-spin interaction and the eigenstates that diagonalize the hyperfine masses can be identified with the two nonets in PDG. We report that their hyperfine mass splitting can generate the mass gap between the two nonets qualitatively. We also discuss interesting signatures in the decays of these tetraquarks.

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The Pomeron, Odderon, and nucleon resonances in φ-meson photoproduction

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We suggest a possible explanation for the φ(1020) photoproduction mechanism in the W = 2.0–2.8 GeV region covering the full scattering angles. We have found that, with the universally accepted Pomeron exchange, the Odderon and three PDG N^* resonances play a crucial to describe the cross sections and spin-density matrix elements data from the CLAS collaboration.

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BFKL evolution manifestations in jet production at colliders

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Approach by Brodsky-Fadin-Kim-Lipatov-Pivovarov (BFKLP) for next-to-leading approximation (NLA) of Balitsky-Fadin-Lipatov-Kuraev (BFKL) evolution with generalized Brodsky-Lepage-McKenzie (BLM) resummation of QCD coupling constant effects is reviewed. Applications of NLA BFKL evolution within BFKLP approach for virtual gamma-gamma scattering and dijet productions with large rapidity separation in hadron collisions are discussed.

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Deeply Virtual Meson Production with CLAS and Impact on chiral-odd GPD models

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Deeply virtual compton scattering and deeply virtual meson production are useful tooo to study the Generalized Parton distributions. We have measured cross sections and asymmetry from pi0 and eta production with CLAS at Jefferson Lab. The results will be compared with two theoretical models which describe the chiral-odd GPDs. We also discuss our future plan with upgraded 12 GeV electron beams and CLAS12.

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QCD vacuum in nuclear matter?

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A possible role of QCD vacuum in dense matter is an interesting topic to be pursued.
We first present some reults from studies based on a parity doublet model and then discuss a possibility to tackle the problem in terms of chiral quarks and classical gluon fields.

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A Froissart-bounded longitudinal structure function

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We present a method to extract, in the leading and next-to-leading order approximations, the longitudinal deep-inelastic scattering structure function $F_L(x,Q^2)$ from the experimental data by relying on a Froissart-bounded parametrization of the transversal structure function $F_2(x,Q^2)$ and, partially, on the Dokshitzer-Gribov-Lipatov-Altarelli-Parisi equations. Particular attention is paid on kinematics of low and ultra low values of the Bjorken variable x. Analytical expressions for F_L(x,Q2) in terms of the effective parameters of the parametrization of F_2(x,Q2) are presented explicitly. We argue that the obtained structure functions FL(x,Q2) within both, the leading and next-to-leading order approximations, manifestly obey the Froissart boundary conditions. Numerical calculations and comparison with available data from ZEUS and H1-Collaborations at HERA demonstrate that the suggested method provides reliable structure functions $F_L(x,Q^2)$ at low x in a wide range of the momentum transfer ($1\ GeV^2 < Q^2 < 3000\ GeV^2$) and can be applied as well in analyses of ultra-high energy processes with cosmic neutrinos.

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Tidal deformability of neutron stars and gravitational waves

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Gravitational waves (GW170817) produced in a binary neutron star inspiral have been observed followed by gamma-ray burst (GRB 170817A) and afterglows from X-ray to radio. By combining the distance obtained by gravitational waves and red shift obtained by electromagnetic waves, even Hubble constant has been estimated. This indicates the start of new era of multimessenger astronomy. In addition to the masses of inspiralling neutron stars, the tidal deformability which depends on the inner structure of neutron stars has been estimated from gravitational waves. This confirms that even strong interactions can be tested by gravitational waves. In this talk, I review the effect of tidal deformability of neutron stars to the gravitational waves produced in the inspiral process, and

discuss the implications of detected tidal deformability to the neutron star equations of state.

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Scalar meson a_0(980) as the mixed tetraquark within QCD sum rules

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Recently the tetraquark mixing framework has been proposed for the two light-meson nonets in the $J^{PC} = 0^{++}$ channel, namely the light nonet composed by $a_0(980)$, $K_0^*(800)$, $f_0(500)$, $f_0(980)$, and the heavy nonet by $a_0(1450)$, $K_0^*(1430)$, $f_0(1370)$, $f_0(1500)$. According to this mixing framework, these two nonets are represented by the linear combination of the two tetraquark types, one type containing the spin-0 diquark and the other with the spin-1 diquark. One interesting result from the mixing framework is that the second tetraquark with the spin-1 diquark configuration is more important to explain the light nonet. For the light nonet, the second tetraquark with the spin-1 diquark is found to be more dominant configuration.
In this work, we report that this result is consistent with the QCD sum rule calculations. In particular, we construct QCD sum rules for the isovector resonance $a_0(980)$ using both type of tetraquark currents by performing the operator product expansion up to dimension 10 operators. We perform the operator product expansion
is performed up to dimension 10 operators and see if the we investigate whether this result is consistent with QCD sum rules by constructing a QCD sum rule for the isovector resonance, $a_0(980)$.

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Role of ρ-tensor coupling in describing nuclear structure

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Towards an ab initio covariant density functional for nuclear structure

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Nuclear structure models built from phenomenological mean fields, the effective nucleonnucleon interactions (or Lagrangians), and the realistic bare nucleon-nucleon interactions are

reviewed. The success of covariant density functional theory, which starts from effective Lagrangians, to describe nuclear ground-state and excited-state properties and its influence on Brueckner theory within the relativistic framework are focused upon. The challenges and ambiguities of predictions for unstable nuclei without data or for high-density nuclear matter, arising from covariant density functionals, are discussed. The basic ideas in building an ab initio covariant density functional for nuclear structure from ab initio calculations with realistic nucleon-nucleon interactions for both nuclear matter and finite nuclei are presented. The current status of fully self-consistent relativistic Brueckner-Hartree-Fock (RBHF) calculations for finite nuclei or neutron drops (ideal systems composed of a finite number of neutrons and confined within an external field) is reviewed. The guidance and perspectives towards an ab initio covariant density functional for nuclear structure derived from the RBHF results are provided.

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Studies on Λ_c^+ hadronic decays

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In this talk, we would like to report our recent theoretical studies on the Λ_c^+ hadronic decays, i.e., $\Lambda_c^+ \to \pi^+ K^- p$ (charged) and $\Lambda_c^+ \to \pi^+ \bar{K}^0 n$ (neutral), using the effective Lagrangian approach. Considering the strong ud-diquark correlation inside the Λ_c^+ baryon, we confine our model to that with the I=0 hyperon resonances and other meosonic contributions. The Belle experiment data are reproduced qualitatively well for the charged channel, and we provide theoretical predictions for the neutral channel as well. It tuns out that the $\eta\Lambda$-channel opening effect makes a peculiar peak-like structure at $M_{K^-p} \approx 1670$ MeV and nontrivial interference effects on the Dalitz plot for the charged channel.

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Spreading widths of giant dipole resonance in the lead region

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The statistical properties of the 1^- spectrum in energy interval 9.5-18.5 MeV for ^{206}Hg, ^{204,206,208}Pb and ^{210}Po nuclei are analysed thoroughly within the microscopic approach and the Random Matrix Theory. The microscopic approach is based on the mean field, simulated by means of the Skyrme interaction SLy4 and the volume pairing interaction, treated in the BCS approximation. The quasiparticle random phase approximation and the coupling between one- and two-phonon states are used to generate excited states. The comparison of the results, obtained with the aid of the coupling calculated microscopically and by means of the Gaussian random distribution, demonstrates a close similarity in the description of the spreading widths of the Isovector Dipole Giant Resonanse of the

considered nuclei. Furthermore, a good agreement is obtained with the microscopic description of the decay widths if the random distribution is used for the coupling between microscopic one-phonon states and two-phonon states that are also generated by the Gaussian Orthogonal Ensembles distribution.

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Vortical toroidal mode in nuclei: recent progress

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The vortical dipole toroidal mode (TM) attracts a high attention last decades [1]. The squeezed TM produces the pygmy dipole resonance [2,3] and forms the low-energy part of the isoscalar giant dipole resonance. TM can also occur as the lowest dipole state in light deformed nuclei [4-6]. TM is the only intrinsic electric vortical mode in nuclei. It can exist as a vortex ring [2,7] or vortex-antivortex pair [4].
In the present talk, we review a recent progress in exploration of TM and various interesting aspects related to this vortical mode.

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Study of nuclear structure with a generalized Skyrme functional

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In the framework of the KIDS generalized energy density functional (EDF), the nuclear equation of state (EoS) is expressed as an expansion in powers of the Fermi momentum or the cubic root of the density. Although an optimal number of converging terms was obtained in specific cases of fits to empirical data and pseudodata, the degree of convergence remains to be examined not only for homogeneous matter but also for finite nuclei. One goal of the present work is to validate the minimal and optimal number of EoS parameters required for the description of homogeneous nuclear matter over a wide range of densities relevant for astrophysical applications. The major goal is to examine the validity of the adopted expansion scheme for an accurate description of finite nuclei. To this end we vary the values of the high-order derivatives of the EoS, namely the skewness of the energy of symmetric nuclear matter and the kurtosis of the symmetry energy, at saturation and examine the relative importance of each term in density expansion for homogeneous matter. For given sets of EoS parameters determined in this way, we define equivalent Skyrme-type functionals and examine the convergence in the description of finite nuclei focusing on the masses and charge radii of closed-shell nuclei. The EoS of symmetric nuclear matter is found to be efficiently parameterized with only 3 parameters and the symmetry energy (or the energy of pure neutron matter) with 4 parameters when the EoS is expanded in the power series of the Fermi momentum. Higher-order EoS parameters do not produce any improvement, in practice, in the description of nuclear ground-state energies and charge radii, which means that they cannot be constrained by bulk properties of nuclei.

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Closing

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Transverse momentum distributions of hadrons in the Tsallis nonextensive statistics

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The exact analytical formulas for the transverse momentum distributions of the Bose-Einstein, Fermi-Dirac and Maxwell-Boltzmann statistics of particles with a nonzero mass in the framework of the Tsallis normalized and Tsallis unnormalized statistics were consistently derived. We have revealed that the phenomenological classical Tsallis distribution (widely used in high energy physics) is equal to the distribution of the Tsallis unnormalized statistics in the zeroth term approximation. The exact ultrarelativistic transverse momentum distribution of the Tsallis normalized statistics was applied to describe the experimental data on the transverse momentum distributions for the charged pions produced in proton-proton collisions at high energies.

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Modeling of Physical Phenomena in Superconducting Nanostructures

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We study the resonance phenomena in the intrinsic Josephson junctions shunted by LC-elements (L-inductance, C-capacitance). A realization of parametric resonance through the excitation of a longitudinal plasma wave, within the bias current interval corresponding to the resonance circuit branch, is demonstrated. It is found that the temporal dependence of the total voltage of the stack, and the voltage measured across the shunt capacitor, reflect the charging of superconducting layers, a phenomenon which might be useful as a means of detecting such charging experimentally. Thus, based on the voltage dynamics, a novel method for the determination of charging in the superconducting layers of coupled Josephson junctions is proposed. A demonstration of the influence of external electromagnetic radiation on the IV-characteristics and charge-time dependence is given. Over certain parameter ranges, the radiation causes an interesting new type of temporal splitting in the charge-time oscillations within the superconducting layers. We show that the amplitude dependence of the Shapiro step width crucially changes when the Shapiro step is on the resonant circuit branch.
When a barrier in the Josephson junction is a noncentosymmetric, then unusual current-phase relation with a phase shift proportional to the magnetic moment perpendicular to the gradient of the asymmetric spin-orbit potential is realized. Such Phi_0 Josephson junctions demonstrate a number of unique features important for superconducting spintronics and modern informational technologies. Here we show that a current sweep along IV-characteristic may lead to both regular and chaotic magnetization dynamics with a series of specific phase trajectories. We demonstrate an appearance of DC component of superconducting current and clarify its role in the transformation of IV-characteristics in resonance region. The presented results might be used for developing novel resonance methods of determination of spin-orbit coupling parameter in the noncentrosymmetric materials.

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Interaction of a twisted Dirac particle with a magnetic field in high energy physics

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Interaction of a twisted Dirac particle with a magnetic field in high energy physics

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A relativistic quantum-mechanical description of a twisted (vortex) Dirac particle in a magnetic field (in general, nonuniform) is presented [1-3]. Twisted particles can possess giant intrinsic orbital

angular momenta and magnetic moments. Methods for the extraction of a twisted beam with a given orbital polarization and for the beam manipulation [1] are discussed. For twisted electron beams in magnetic storage rings, the effect a radiative orbital polarization (similar to that of a radiative spin polarization for untwisted electrons) takes place [2]. A twisted spin-1/2 particle possesses a tensor magnetic polarizability [3]. We suppose that twisted particles can be created at collision of heavy ions. In this case, the presence of a strong nonuniform magnetic field leads to the Stern-Gerlach-like force which depends on the intrinsic orbital angular momentum and influences a particle motion [2].

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Matrix elements for neutrinoless double beta decay

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The present-day results of the calculation of the 0νββ-decay nuclear matrix elements (NMEs) are discussed. The progress in the calculation of the double beta decay NMEs within the QRPA is presented in the context of the restoration of the SU(4) symmetry. A connection between the 2νββ-decay and 0νββ-decay matrix elements is analyzed. An impact of the quenching of the axial-vector coupling constant on double-beta decay processes is investigated and a novel approach to determine quenched value of gA is proposed. The question is addressed whether light and heavy neutrino contributions to 0νββ-decay are experimentally distinguishable. Several simplified benchmark scenarios within left-right symmetric models are considered and the conditions for the dominance of the light or heavy neutrino mass mechanisms are analyzed.

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Triton binding energy and neutron-deuteron scattering up to next-to-leading order in chiral effective field theory

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Determination of the proper power-counting scheme is an important issue for the systematic application of Chiral Effective Field Theory in nuclear physics. We analyze the cutoff dependence of three-nucleon observables (the neutron-deuteron scattering lengths and the triton binding energy) at the leading and next-to-leading orders of a power counting that ensures order-by-order renormalization in the two-nucleon system. Our results confirm that, as usually assumed in the literature, three-body forces are not needed for renormalization of the three-nucleon system up to next-to-leading order. The error correction to the previous reported result is discussed.

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The structure of low-energy excited states in even-even spherical nuclei within a multiphonon approach

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The low-lying spectra of heavy spherical nuclei are investigated within the microscopic Quasiparticle–Phonon model. The approach goes beyond the quasiparticle random-phase approximation by treating a Hamiltonian of separable form in a multiphonon basis. It is therefore able to describe the anharmonic effects of collective modes as well as the multiphonon states. By associating the microscopic isoscalar and isovector quadrupole and octupole phonons with proton–neutron symmetric and mixed-symmetry bosons, respectively. The microscopic states can be classified to their phonon content and their symmetry. Due to its flexibility, the method can be implemented numerically for systematic studies of spectroscopic properties throughout entire regions of vibrational nuclei. The spectra and multipole transition strengths are in overall reasonable agreement with the experimental data.

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Scaling properties of azimuthal anisotropy at RHIC

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A central goal of current experiments at RHIC is to study the properties of the hot and dense QCD matter produced in energetic heavy-ion collisions. Such studies can give provide on the QCD phase diagram, as well as the transport coefficients of the strongly-coupled Quark Gluon Plasma (sQGP). Anisotropic flow measurements of identified particles play an essential role in such studies. We report on the results of the recent measurements of elliptic and triangular flow at RHIC energies and discuss them using different scaling relations for azimuthal anisotropy.

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Baryon Polarization in heavy-Ion Collisions

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The anomalous mechanism of transformation of orbital angular momentum to baryons' polarization is discussed. The comparison with thermodynamical mechaniam is outlined.

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Multi-photon dynamics of non-linear quantum processes in short polarized electromagnetic pulses

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We have performed a simultaneous analysis of two essentially non-linear QED processes in circular and linear polarized short and intensive e.m. (laser) pulses: (i) non-linear Breit-Wheeler e^+e^- pair creation in the interaction of probe photon with such a pulse and (ii) the photon emission or the non-linear Compton scattering when an initial electron interacts with the short and intensive e.m. (laser) pulse. Both processes are analyzed in the multi-photon region, where several photons at the same time participate in the process. In case of non-linear Breit-Wheeler e^+e^- pair emission, the multi-photon region is determined uniquely by the variable $\zeta > 1$ or $s < s_{\rm sthr} = 4m^2$. For the non-linear Compton scattering we use the partially integrated cross section where the integration starts from the dynamical parameter $\kappa > 1$ which selects the multi-photon events and is an analog of the variable ζ in the Breit-Wheeler process.

Our analysis shows the step like ζ (κ) behavior of the total cross sections for Breit-Wheeler (Compton) process in the case of relatively long pulses with the number of oscillations in a pulse $N \geq 2$, similar to the prediction for the infinitely long pulse. In case of sub-cycle pulse ($N = 1/2$), the cross sections exhibit an exponential dependence $\exp[-b_\zeta\zeta]$ ($\exp -[b_\kappa\kappa]$). The slopes b_ζ, b_κ depend on the field intensity and the pulse duration.

The azimuthal angle distributions are very sensible and, in particularly, depend on the carrier envelope phase ϕ_{CEP}. In addition to the processes occurring in the circularly polarized e.m.\ pulses considered earlier, the case of linear polarization leads to the qualitative modification of the azimuthal distributions of outgoing electrons. These distributions are

non-monotonic functions %of the azimuthal angle of outgoing electrons with peculiar maxima and minima.
Their positions, heights, and depths are determined by the structure of the phase factor $P^{(L)}$ of the basis functions $\widetilde{A}_m$, and they depend on the reduced field intensity ξ^2, dynamic variables ζ, κ, and ϕ_{CEP} and the pulse width ($\Delta = \pi N$) as well.
In the case of non-linear Compton scattering, the angular distributions are determined by a nontrivial destructive interference of the terms in the partial probability $w^{(L)}(\ell)$.

Our results may be used as a unique and powerful method for studying the multi-photon dynamics of elementary non-linear QED processes.

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Resonance mechanism of the reaction $pd \to pd\pi\pi$ in the GeV region

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At present as one of the most realistic candidate to dibaryon resonance is considered the resonance $D_{IJ} = D_{03}$ observed by the WASA@COSY [1] in the total cross section of the reaction of two-pion production $pn \to d\pi^0\pi^0$, here I is the isospin and J is the total angular momentum of this resonance.
Very similar resonance structure was observed by ANKE@COSY in the differential cross section of the two-pion production reaction $pd \to pd\pi\pi$ at beam energies 0.8-2.0~GeV with high transferred momentum to the deuteron at small scattering angles of the final proton and deuteron [2].
In the distribution over the invariant mass $M_{d\pi\pi}$ of the final $d\pi\pi$ system the resonance peaks were observed at $M_{d\pi\pi} \approx 2.38$~GeV [2] that is the mass of the isoscalar two-baryon resonance $D_{IJ} = D_{03}$, while the kinematic conditions differ considerably from that in Ref. [1].
This data we analyzed in Ref. [3] assuming excitation of the D_{03} resonance via t-channel σ-meson exchange between the proton and deuteron and using the two-resonance mechanism of the D_{03} resonance decay [4].
The shapes of the distributions over the invariant masses of the final $d\pi\pi$ and $\pi\pi$ systems were explained qualitatively in [3] assuming the lowest values of the orbital angular momenta in the vertices $\sigma d \to D_{03}$ ($L = 2$), $D_{03} \to D_{12} + \pi$ ($l_1 = 1$), $D_{12} \to d + \pi$ ($l_2 = 1$).
In this work we study the role of higher orbital momenta in those vertices ($L = 2, 4,\ l_1 = 1, 3, 5,\ l_2 = 1, 3$).
Furthermore, a possible contribution of the D_{03} excitation to the pd-backward elastic scattering is studied in the 1 GeV region.

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Electron capture rates on neutron-rich nuclei in core-collapse supernova

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The rates of electronic captures (EC) on nuclei largely determine the dynamics of the late-stage evolution and collapse of massive star which is a prelude
to the explosion of type II supernova.

To simulate this astrophysical phenomenon one needs a large-scale set of data on the EC probabilities. The
data are needed for a large number of nuclides most of which are unstable and, possibly, have rather short lifetime. Besides, the EC's occur in a
stellar matter which affects their probabilities since it is extremely hot and dense. The most reliable and systematic calculations of ECs in stellar environment
have been performed for nuclei of sd and pf shells within the Large Scale Shell Model approach [1]. However, the approach has some restrictions, in particular, it cannot be applied to nuclei with mass number $A > 65$ and
to first-forbidden transitions involved high-lying spin-dipole nuclear resonances.

In [2], the thermodynamically consistent method which overcome the above shortcomings of the LSSM approach has been elaborated.
Essentially, the method is the quasiparticle RPA extended to finite temperatures (TQRPA) in the framework of the
thermo field dynamics [3]. The method allows to calculate temperature-dependent strength
functions of the process taking into account both the exo- and endo-energetic nuclear transitions.
In [4], the TQRPA has been combined with self-consistent microscopic Hamiltonian based on the Skyrme energy density functional.

Here, we compute the EC rates on even-even neutron-rich nuclides ^{78}Ni and $^{76-80}$Ge in hot and dense pre-supernova
matter. The contributions of allowed 0^+, 1^+ and first-forbidden $0^-, 1^-, 2^-$ transitions are considered.
Three different Skyrme parameterizations are used: SLy4, SGII, SkM*. In agreement with our earlier study [2] we observe that unblocking
effect for the Gamow-Teller transitions is quite sensitive to increasing temperature. For ^{78}Ni the EC cross sections were computed within
the Donnelly-Walecka multipole expansion method. It is found that not only thermally unblocked allowed
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Opening

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Role of the h1(1800) and f1(1285) states in the J/psi decays

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A state around 1800 MeV was generated from the interaction of the KstarKstar-bar within the local hidden gauge approach. We show that the peak observed in J/psi->eta Kstar Kstar-bar naturally comes from the creation of this h1 state. A second analysis, model independent, corroborates the first result, confirming the relationship of the enhancement in the invariant mass spectrum with the h1 resonance. On the other hand, we study the role of the f1(1285)resonance in the decays of J/psi->phi Kbar Kstar and J/psi->phi f1(1285). The theoretical approach is based on the results of chiral unitary theory where the f1(1285)resonance is dynamically generated from the Kbar Kstar interaction. The results can be tested in future experiments and therefore offer new clues on the nature of the f1(1285)state.

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Open quantum systems of atomic nuclei

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Weakly bound and unbound nuclei are complex open quantum systems (OQS) in which the coupling to the scattering continuum is crucial and should be properly treated. A small uncertainty in

modeling would change the conclusions of physics. The nuclei around driplines can simultaneously undergo gamma-ray transitions, beta decays and particle emissions. An important feature of the loosely bound and unbound nuclei is that their excitation spectra contain low-lying resonant levels. Recently, we have made a plenty of investigations on the resonant excitation spectra of nuclei in the region of the neutron dripline. The calculations were performed using two types of ab-initio methods: Gamow shell model and Gamow in-medium similarity renormalization group, which were developed recently by our group. The resonance and continuum are treated in a self-consistent manner by using the Gamow-Berggren complex-momentum space. The ab-initio calculations start from the chiral effective field theory (chiral EFT). We can well reproduce and explain the experimentally observed resonant states, and as well predict many interesting resonant levels and decays.

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Implementation of polarized $e^+e^- \to \gamma\gamma$ process in MCSANC

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We present implementation of $e^+e^- \to \gamma\gamma$ process in **MCSANC** project.

The dominant processes in the e^+e^- experiments are the processes of annihilation.
Possible alternative lumiprocess Bhabha is large angle photon-pair production and
annihilation to muon pair because the cross section value of the photon-pair production estimated for large angles is of the same order as that of Bhabha scattering.

We calculate full one-loop electroweak radiative correction with respect of all masses and taking into account polarization of initial beams. The results of the calculation are integrated in the Monte Carlo generator **MCSANC**.

We reached good agreement and present a comprehensive comparison
with results existing in the world literature, i.e.
at tree level with **CalcHEP**, **WHIZARD** and
at one-loop level without polarization effect with **BabaYaga@NLO**.

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Meson-baryon scattering in the Regge realm

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We present a model for the Regge phenomenology of meson-baryon scattering at high energies. Diffraction features of pi-N and KN elastic scatterings are described by the Pomeron trajectory which we newly formulated to apply for high energy data.
On the basis of the Reggeized meson exchanges in the t-channel we also discuss N* resonances in the pi-N scatterings by using the parameterization of the Breit-Wigner type for a fit of data. The s-wave phase shift is applied to describe the low energy data on KN scattering. Summary and conclusions are given for the respective features of elastic and inelastic processes from threshold to tens of GeV with a stress on the applicability of the present model.

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Relativistic description of novel nuclear structure towards extremes of spin and isospin

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The development of worldwide rare isotope beam facilities has brought many new insights in nuclear physics. In particular, novel structure in nuclei towards extreme isospin and spin has acquired great interest over the years for the challenges and implications it involves. Theoretically, covariant density functional theory (CDFT) has achieved great success in describing many nuclear phenomena over the past several decades. In particular, a new covariant functional PC-PK1 has been developed recently in Ref. [1]. It considerably improves the isospin dependence of nuclear properties, and is more reliable for the description of neutron-rich nuclei [2,3]. Based on this density functional, CDFT has also been extended for nuclear spectroscopic properties within the tilted-axis-cranking approach [4,5].

The extended CDFT has provided successful description of many novel rotational structure in nuclei towards high spin, such as the magnetic rotation [4], antimagnetic rotation [6], reorientation for nuclear spin [5], chiral rotation [7] etc. These successes have also stimulated a number of new measurements, and the interactive research between theorists and experimentalists has presented many novel rotational phenomena; several examples associated with the novel spin modes in triaxial nuclei can be seen in Refs. [8-11].

The success of CDFT in nuclear spectroscopic properties with high spin is not the only accomplishment recently achieved. Going to both the extreme isospin and spin, in Ref. [12], the anomalous rod shape in carbon isotopes has been investigated in cranking covariant density functional theory, and the coherent effects between the high spin and isospin have been discussed for the first time in the stabilization of such a novel shape. By adding valence neutrons and rotating the system, it is found that the spin and isospin effects enhance the stability of the rod-shaped configuration. This provides a strong hint that a rod shape could be realized in nuclei towards extreme spin and isospin.

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Ordinary muon capture studies by means of gamma-spectroscopy

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HPGe detectors were used to make a precise measurement of the γ-ray spectrum produced following ordinary (non-radiative) capture of negative muons by isotopically-enriched
(48Ti, 76Se, 82Kr, 106Cd and 150Sm) and natural tartegets (Se, Kr, Cd and Sm). By investigating energy and time distributions, the lifetime of negative muons in the different isotopes was deduced. A detailed analysis of the intensity of the γ-lines enabled the extraction of the relative yields of several daughter nuclei. The partial rates of muon capture to numerous excited levels of the 48Sc, 76As and 106Ag isotopes (considered to be virtual states of the intermediate odd-odd nuclei in the ββ decay of 48Ca, 76Ge and 106Cd respectively) were also extracted. These rates are important as an experimental input for the theoretical calculation of the nuclear matrix elements in ββ decay.

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The Isoscalar Mesons and Exotic States in Light Front Holographic QCD

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In this talk a quantitative analysis of the isoscalar bosonic states will be shown in the framework of supersymmetric light front holographic QCD. The spectroscopy of the η and h mesons can be well described if one additional mass parameter – which corresponds to the hard breaking of chiral $U(1)$ symmetry in standard QCD – is introduced. The mass difference of the η and η' isoscalar mesons is then determined by the strange quark mass content of the η'. The theory also predicts the existence of isoscalar tetraquarks which are bound states of diquarks and anti-diquarks. The candidates for these exotic isoscalar tetraquarks are identified. In particular, the $f_0(1500)$ is identified as isoscalar tetraquark; the predicted mass value 1.52 GeV agrees with the measured experimental value within the model uncertainties.