ABSTRACTS

of the XXVII International Workshop on Nuclear Theory

Rila Mountains, Bulgaria, June 23-28, 2008

The Workshop is organized by the Nuclear Theory Laboratory, Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences. It is sponsored by the Bulgarian Nuclear Society.

Laboratory of Theoretical Nuclear Physics

PROGRAMME

Monday, June 23

Morning session

09:30 – 10:00 Opening of the Workshop and Talk of *Prof. Yordan Stamenov*

10:00 – 10:20 *Coffee*

10:20 – 11:05 *Werner Scheid*: Nuclear Effects by Electron Capture in Highly-Charged Heavy Ions

11:15 – 12:00 *Andrey Shirokov*: Novel Realistic NN Interaction JISP16 and Spectroscopy of Light Nuclei

12:10 – 12:55 *Alexander Volya*: Quantum Many-body Dynamics and Many-body Forces

17:00 – 17:30 *Coffee*

Afternoon session

17:30 – 18:15 *Eric Voutier*: Deeply Virtual Compton Scattering Off Nuclei

18:25 – 19:10 *Elena Zemlyanaya*: Calculations of the ^{6}He+p Elastic Scattering Cross Sections within the Folding Approach and High-Energy Approximation for the Optical Potential

Tuesday, June 24

Morning session

09:30 – 10:15 *Nicola Lo Iudice*: A Reformulation of an Equation of Motion Approach to Multiphonon Nuclear Spectra

10:15 – 10:35 *Coffee*

10:35 – 11:20 *Chavdar Stoyanov*: Fine Structure of Proton-Neutron Mixed Symmetry States in Some $N = 80$ Isotones

11:30 – 12:15 *Dimitar Tarpanov*: The Effects of a Tensor Force on the Single-Particle Evolution in $Z = 14$ and $N = 28$ Chains

12:25 – 13:10 *Stoyan Mishev*: Low-lying States in Odd-mass Nuclei and the Extended Random Phase Approximation

15:30 – 16:00 *Coffee*

Afternoon session

16:00 – 16:45 *Marek Płoszajczak*: Many-Body Calculations for Weakly Bound and Unbound States

16:55 – 17:40 *Mitko Gaidarov*: Neutron Skins in Exotic Nuclei from Skyrme Hartree-Fock Calculations

17:50 – 18:35 *Maria Garzelli*: Simulation of Heavy-Ion Reactions at Non Relativistic Bombarding Energies

18:45 – 19:15 *Kutsal Bozkurt*: Isovector Collective Excitations in Hot Nuclear Matter

Wednesday, June 25

Morning session

09:30 – 10:15 *Eric Suraud*: The Self Interaction Correction Revisited

10:15 – 10:35 *Coffee*

10:35 – 11:20 *Mariana Kirchbach*: Baryon Spectroscopy from the Exactly Solvable Extension to the Cornell Potential

11:30 – 12:15 *Maria Barbaro*: The Role of Pair Correlations in Quasielastic Lepton-Nucleus Scattering

12:25 – 13:10 *Martin Ivanov*: Superscaling Analyses of Lepton Scattering from Nuclei beyond the Relativistic Fermi Gas Model

15:30 – 16:00 *Coffee*

Afternoon session

16:00 – 16:45 *Krzysztof Graczyk*: Resonance Contribution in Single Pion Production in Neutrino-Nucleon Scattering

16:55 – 17:40 *Oscar Moreno*: Nuclear and Nucleon Contributions to the Parity-Violating Electron Scattering

17:50 – 18:35 *Raquel Álvarez-Rodríguez*: Energy Distributions from Three-Body Decaying ^{12}C Resonances

Thursday, June 26

EXCURSION

Friday, June 27

Morning session

09:30 – 10:15	*Gabriela Popa*: New $SU(3)$ Approach in Calculating the 0^+ States and Transitions in Heavy Deformed Nuclei
10:15 – 10:35	*Coffee*
10:35 – 11:20	*Ana Georgieva*: Systematics of the Behavior of the Ground and Octupole Bands of the Deformed Even-Even Lantanides
11:30 – 12:15	*Nikolay Minkov*: Coriolis Interaction in Quadrupole-Octupole Deformed Nuclei
12:25 – 12:55	*Huben Ganev*: Boson and Fermion Degrees of Freedom in Orthosymplectic Extension of the IVBM: Odd-Odd Nuclear Spectra

Nuclear Effects by Electron Capture in Highly-Charged Heavy Ions

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If a free electron of the continuum is captured into the $L-$ (or $K-$) shell of a heavy ion, several processes can proceed:

(a) The energy of the electron can be irradiated which is the radiative recombination (RR).

(b) The captured electron gives its energy to a second bound electron to excite it from the $K-$shell to the $L-$shell which is denoted as dielectronic recombination (DR). This is a resonating process at an energy depending on the charge distribution of the nucleus. It allows to measure isotope shifts of exotic nuclei and to determine nuclear radii. Experimental data on Nd-isotopes will be presented.

(c) The energy of the captured electron is given to the nucleus to excite it. This is the inverse process of internal conversion and denoted as NEEC-process (nuclear excitation by electron capture). The NEEC-process with the radiative decay of the nucleus is the analogue of the DR. Because of the relatively long lifetime of the excited nuclear state, the resonance is very small and not yet experimentally observed.

(d) There is the possibility that the nucleus is excited by an electron capture to the $L-$shell and that the electron makes a fast transition to the $K-$shell, so that certain nuclei have no more the chance to decay by internal conversion, but only by a radiative decay. This process, denoted as NEECX (NEEC with fast X-ray), leads to a longer lifetime of the excited nucleus and can serve for a measurement of the NEEC process with heavy ions as our calculations proved for $^{232}_{90}$Th and $^{238}_{92}$U.

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Novel Realistic NN Interaction JISP16 and Spectroscopy of Light Nuclei

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We present recent results of our systematic *ab initio* studies of the spectroscopy of s and p shell nuclei in the fully-microscopic large-scale (up to one billion basis functions) no-core shell model calculations.

A new high-quality realistic non-local NN interaction JISP16 is used. This interaction is obtained in the J-matrix inverse scattering approach (JISP stands for the J-matrix inverse scattering potential) and is of the form of a small-rank matrix in the oscillator basis in each of the NN partial waves. The interaction provides an excellent description of deuteron properties and NN scattering data together with a very fast convergence in the shell model studies [1–3]. We suggested an *ab exitu* approach [2–3] in which the nucleon-nucleon interaction is fitted to the binding energies and spectra of light nuclei by means of phase-equivalent transformations. The fit is based on the many-body calculations in relatively small model spaces of a limited number of nuclei. Next, we explore systematically various observables of a wide range of light nuclei with the obtained NN interaction in the *ab initio* large-scale calculations on supercomputers.

We discuss the properties and results of the many-body nuclear structure studies with the JISP16 interaction. The purely two-body JISP16 nucleon-nucleon interaction provides a better description of a wide range of observables (binding energies, spectra, r.m.s. radii, quadrupole moments, electromagnetic transition probabilities, *etc.*) in all s and p shell nuclei than the best modern interaction models combining realistic nucleon-nucleon and three-nucleon interactions.

The extension of the no-core shell model on the case of continuum spectrum is discussed. This extension is possible if the small-rank JISP-like NN interaction is used. The results of application to the $N\alpha$ scattering are discussed.

References

[1] A.M. Shirokov, A.I. Mazur, S.A. Zaytsev, J.P. Vary, T.A. Weber (2004) *Phys. Rev. C* **70** 044005.

[2] A.M. Shirokov, J.P.Vary, A.I.Mazur, S.A.Zaytsev, T.A.Weber (2005) *Phys. Lett. B* **621** 96.

[3] A.M. Shirokov, J.P. Vary, A.I. Mazur, T.A. Weber (2007) *Phys. Lett. B* **644** 33.

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Quantum Many-body Dynamics and Many-body Forces

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Microscopic quantum studies of many-body systems in different branches of physics indicate an important role played by the many-body forces. In this presentation we explore possible effects in level structure, electromagnetic transition rates, and particle-decay spectroscopic factors from three and four-body interactions within the nuclear shell model approach. Some realistic nuclear physics examples are used for this purpose.

Quantum chaos is another robust and at the same time sensitive tool to probe microscopic details of the Hamiltonian and symmetry. Elucidating the generic role of the many-body forces we explore n-body random ensembles in the presence of spin and isospin symmetries. A striking emergence of regularities in spectra and ground state quantum numbers is observed in both odd and even-particle systems [1]. Various types of correlations from pairing to spectral sequences and correlations across different masses are explored. A search for interpretation is presented.

References

[1] A.Volya, *Emergence of symmetry from random n-body interactions*, `arXiv:0712.3754` [nucl-th].

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Deeply Virtual Compton Scattering Off Nuclei

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The recent advent of the Generalized Parton Distributions (GPDs) has provided a powerful and appealing formalism for the description of the partonic structure and dynamics of the nucleon. GPDs represent the interference between amplitudes corresponding to different quantum states and describe the correlations between quarks, anti-quarks, and gluons. They can be interpreted as the transverse distribution of partons carrying a certain longitudinal momentum fraction of the nucleon, providing then a natural link with the transverse degrees of freedom in the nucleon. Consequently, GPDs unify in the same framework electromagnetic form factors, parton distributions, and the spin of the nucleon.

Deeply virtual Compton scattering (DVCS) is the simplest process to access GPDs. Similarly to the scattering of light by a material, DVCS provides information about the dynamics and the spatial structure of the nucleon encoded in GPDs. The real and imaginary parts of the DVCS amplitude are the quantities of interest that can be experimentally separated via beam or target polarization observables.

This talk will review the extension of the GPD framework to the description of the partonic structure of the nucleus and its benefit for the understanding of the nuclear structure. Particular emphasis will be put on the present experimental efforts to investigate nuclear GPDs with DVCS at the Jefferson Laboratory.

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Calculations of the ^{6}He+p Elastic Scattering Cross Sections within the Folding Approach and High-Energy Approximation for the Optical Potential

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Calculations of microscopic optical potentials (OP's) (the real and imaginary parts) are performed to analyze the ^{6}He+p elastic scattering data at tens of MeV/nucleon (MeV/N) [1]. The OP's were constructed on the basis of two microscopic models (the folding procedure [2] and the high-energy approximation [3]) using three model densities of ^{6}He [4–6]. Cross sections were calculated with a help of DWUCK4 code [7]. The effect on cross sections of the dependence of the NN-forces on nuclear matter density is investigated. The role of the spin-orbital terms and the non-linearity of the OP's and also the role of its renormalization are studied. The sensitivity of the cross sections to these effects is tested.

References

[1] K. V. Lukyanov, V. K. Lukyanov, E. V. Zemlyanaya, A. N. Antonov, M. K. Gaidarov (2007) *European Physical Journal A* **33** 389.

[2] D. T. Khoa, G. R. Satchler (2000) *Nucl. Phys. A* **668** 3.

[3] V. K. Lukyanov, E. V. Zemlyanaya, K. V. Lukyanov, (2006) *Physics of Atomic Nuclei* **69** 240.

[4] M. V. Zhukov, B. V. Danilin, D. V. Fedorov, J. M. Bang, I. J. Thompson, J. S. Vaagen (1993) *Phys. Rep.* **231** 151.

[5] I. Tanihata (1992) *Phys. Lett. B* **289** 261.

[6] S. Karataglidis, P. J. Dortmans, K. Amos, C. Bennhold (2000) *Phys. Rev. C* **61** 024319.

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A Reformulation of an Equation of Motion Approach to Multiphonon Nuclear Spectra

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Recently, we have developed an equation of motion phonon method (EMPM) for solving the nuclear eigenvalue problem in a space spanned by a basis of microscopic multiphonon states [1]. To generate such a basis we derived equations of simple structure, for each n-phonon subspace, and solved them by an iterative procedure which starts from the Hartree-Fock vacuum and can reach a space with an arbitrary number of phonons.

The Choleski decomposition method was adopted to extract from the above set of states, necessarily overcomplete, a subset of linear independent states. In such a multiphonon basis, the Hamiltonian matrix is extremely simplified and can be brought easily to diagonal form to yield exact eigenvalues and eigenvectors.

A new reformulation of the EMPM has been accomplished now. In this new version, all Fermionic degrees of freedom are hidden in the phonons. This new framework is more elegant and brings forth important simplifications in the procedures of removing the redundant states and the center of mass spuriosity. Moreover, it makes feasible a drastic reduction of the dimensions of each n-phonon subspace while monitoring the accuracy of the eigensolutions. In virtue of such a truncation, it is possible to operate in a space which, though of reduced dimensions, encompasses states with many phonons and incorporating a large number of configurations.

^{16}O is adopted as numerical test ground.

References

[1] F. Andreozzi, F. Knapp, N. Lo Iudice, A. Porrino, and J. Kvasil, (2007) *Phys. Rev. C* **75** 044312.

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Fine Structure of Proton-Neutron Mixed Symmetry States in Some $N = 80$ Isotones

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A microscopic multiphonon approach is adopted to investigate the structure of some low-lying states observed experimentally in the $N = 80$ isotones ^{134}Xe, ^{136}Ba, and ^{138}Ce. The calculation yields levels and electromagnetic transition strengths in good agreement with experiments and relates the observed selection rules to the neutronproton symmetry and phonon content of the observed states. Moreover, it ascribes the splitting of the M1 strength in ^{138}Ce to the proton subshell closure which magnifies the role of pairing in the excitation mechanism.

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The Effects of a Tensor Force on the Single-Particle Evolution in $Z = 14$ and $N = 28$ Chains

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In the present work, a self-consistent mean field approach was used to analyze two findings based on experimental data, complemented by a shell model analysis [1, 2]:

1. the shrinkage of the proton spin-orbit splitting $1d_{3/2} - 1d_{5/2}$ in the $Z = 14$ isotopes when going from $N = 20$ (^{34}Si) to $N = 28$ (^{42}Si);
2. the quenching of the neutron shell closure gap $2p_{3/2} - 1f_{7/2}$ when going along the isotonic chain $N = 28$ from $Z = 20$ (^{48}Ca) to $Z = 14$ (^{42}Si).

The analysis is based on non-relativistic Hartree-Fock-BCS (HFBCS) approach with Skyrme-type interactions, and a tensor term explicitly included in the interaction Hamiltonian. The aim is to discuss the effects, of the tensor component (of the two-body effective interaction) on the evolution of the shell structure when one goes towards the drip-lines. The HF-BCS model is well suited for that purpose with the several Skyrme-type tensor forces proposed recently.

It is found that the tensor force indeed, governs the reduction of the 1d proton spin-orbit splitting. On the other hand, the reduction of the neutron $1f_{7/2}$ subshell closure is not clearly related to the tensor force [3].

References

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[2] B. Bastin *et al.*, (2007) *Phys. Rev. Lett.* **99** 022503.

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Low-lying States in Odd-mass Nuclei and the Extended Random Phase Approximation

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The Random Phase Approximation (RPA) is known to be inadequate for describing the vibrational states in even-even nuclei far from the valley of stability. An extended version of this theory (ERPA) [1] has proved successful in removing some deficiencies of the RPA [2].

Within the ERPA we derived renormalized interaction strengths between an even-even core and a particle outside of that core in odd-mass nuclei. The problem of investigating the properties of odd-mass nuclei within this approach is essentially reduced to solving a large system of coupled non-linear equations which takes into account the pairing correlations, the multipole-multipole interaction and the core-particle coupling.

References

[1] K. Hara, (1964) *Progr. Theor. Phys.* **32** 88.

[2] D. Karadjov, V.V. Voronov, F. Catara, M. Grinberg and A.P. Severyukhin, (1998) *Nucl. Phys. A* **643** 497.

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Many-Body Calculations for Weakly Bound and Unbound States

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The continuum shell model provides the microscopic description of weakly bound or unbound states. Of particular interest is the threshold region between regimes of closed and open quantum systems which has generic transitional features. Various threshold effects, ranging from the cross section and associated overlap integral anomalies, to anomalies in the NN-correlations and spectroscopic factors can be studied in the continuum shell model framework.

In this talk, we shall discuss a modern view of these universal transitional phenomena which result from an interplay between many-body correlations and the continuum coupling effects.

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Neutron Skins in Exotic Nuclei from Skyrme Hartree-Fock Calculations

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The formation of neutron skin and its evolution with an increase of the neutron number is investigated within a self-consistent framework based on deformed Hartree-Fock calculations with density dependent Skyrme forces and pairing correlations in BCS approximation [1]. We study several isotopic chains of Ni, Kr, and Sn nuclei and consider all the experimentally observed isotopes from neutron-deficient to neutron-rich. Various definitions of the neutron skin thickness based on the differences between neutron and proton radii as well as on comparison of the tails of the neutron and proton density distributions have been tested [2,3]. The effects of deformation on the neutron skins in even-even deformed nuclei based on the example of Kr isotopes are discussed.

References

[1] P. Sarriguren, M.K. Gaidarov, E. Moya de Guerra, and A.N. Antonov, (2007) *Phys. Rev. C* **76** 044322.

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Simulation of Heavy-Ion Reactions at Non Relativistic Bombarding Energies

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In this talk a review of models available for the simulation of the overlapping stage of non-relativistic heavy-ion reactions is presented, up to a few hundred MeV/A bombarding energies. In particular, the capabilities of models and codes built on the basis of the Molecular Dynamics (MD) approaches are outlined and the present performances of the Quantum MD (QMD) code developed at the University of Milano [1, 2] are discussed, with emphasis on the link between nuclear EoS parameters and predictions concerning heavy-ion reaction peculiar observables.

References

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Isovector Collective Excitations in Hot Nuclear Matter

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We study the isovector collective excitations in nuclear matter by employing the linearized Landau–Vlasov equation at finite temperature using Skyrme and Gogny forces for infinite nuclear matter and Skyrme force, Gogny force and Landau–Migdal interaction for finite nuclei in semiclassical Thomas–Fermi approximation. We calculate the giant dipole resonance (GDR) strength function for these cases for ^{120}Sn and ^{208}Pb and compare our results.

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The Self Interaction Correction Revisited

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The Self Interaction Correction (SIC) is a long standing problem in Density Functional Theory (DFT). It causes several major difficulties especially with the universally used simple and efficient Local Density Approximation (LDA). The standard SIC approaches lead to the introduction of orbital dependent functional which exhibit several formal and technical problems. The Optimized Effectove Potential (OEP) methods allow to deal with such difficulties but in an approximate manner.

We propose a simplification of the Optimized Effective Potential (OEP) applied to the Self Interaction Correction (SIC) scheme of Density Functional Theory (DFT). The new scheme fulfills several key formal properties and turns out to be both simple and accurate. We show examples of applications on model molecules in terms of observables known to be especially sensitive to details of the SIC-OEP approach.

We also discuss an extension of time-dependent DFT including SIC. A strictly variational formulation is given taking care of the necessary constraints. A manageable and transparent propagation scheme using two sets of wavefunctions is proposed and applied to laser excitation with subsequent ionization of a dimer molecule.

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Baryon Spectroscopy from the Exactly Solvable Extension to the Cornell Potential

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We make the case that the Coulomb– plus linear quark confinement potential predicted by lattice QCD (so called Cornell potential) is an approximation to the exactly solvable trigonometric Rosen-Morse potential that has the property to interpolate between the Coulomb– and the infinite wells. We test the predictive power of this potential in the description of the nucleon (considered as a quark-diquark system) and provide analytic expressions for its mass spectrum and the proton electric form factor. We compare the results obtained in this fashion to data and find quite good agreement. We obtain an effective gluon propagator in closed form as the Fourier transform of the potential under investigation.

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The Role of Pair Correlations in Quasielastic Lepton-Nucleus Scattering

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The study of electron scattering off nuclei in the quasielastic peak domain has been recently the focus of renewed interest because it is closely related to neutrino scattering and the accurate theoretical knowledge of ν-nucleus cross sections is essential for the analysis of on-going and future neutrino oscillation experiments.

Indeed it has been proposed that the connection between electron and neutrino reactions is based on the superscaling properties of the inclusive data, namely the fact that the (e, e') cross sections, divided by the corresponding single nucleon factors, are to a large extent independent of both the momentum transfer q (scaling of the first kind) and the specific nuclear target (scaling of the second kind).

Owing to the complexity of nuclear dynamics it is not obvious that the nuclear response to an electroweak field superscales: indeed effects which go beyond the mean field description of nuclei, like correlations among nucleons and two-body (meson exchange) currents, are expected to break superscaling. Therefore in order to exploit the above mentioned connection it is important to understand these effects.

Here we present a simple model for describing pair correlations between nucleons, consisting in an extension of the Relativistic Fermi Gas model inspired by the BCS theory of condensed matter physics. We show results for the longitudinal superscaling function and explore its behaviour with respect to scaling of first and second kind.

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Superscaling Analyses of Lepton Scattering from Nuclei beyond the Relativistic Fermi Gas Model

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A scaling function for the description of the superscaling phenomenon in the inclusive electron scattering from nuclei has been constructed in [1, 2] within the Coherent Density Fluctuation Model (CDFM) [3]. This model is a natural extension to finite nuclei of the Relativistic Fermi Gas Model (RFG) within which the scaling variable ψ' has been introduced [4]. In this work we suggest a new modified CDFM approach to calculate the total, longitudinal and transverse scaling functions on the basis of the hadron tensor and the longitudinal and transverse response functions in the RFG [5]. A test of superscaling phenomena was performed by calculation of the cross sections of electron scattering (in QE- and Δ-region for nuclei with $12 \leq A \leq 194$ at different energies and angles) and the CDFM results are compared with those from other theoretical approaches and with available experimental data. The superscaling CDFM analysis is extended to calculate charge-changing neutrino and antineutrino scattering on ^{12}C at energies from 1 to 2 GeV not only in the quasielastic but also in the delta excitation region. The scaling function obtained within the CDFM is applied to neutral current neutrino and antineutrino scattering with energies of 1 GeV from ^{12}C with a proton and neutron knockout.

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Resonance Contribution in Single Pion Production in Neutrino-Nucleon Scattering

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The Rein and Sehgal (RS) model for single pion production in neutrino-nucleon scattering will be presented. In particular, I will focus on the resonance contribution to this process. This contribution is described in the framework of the relativistic harmonic oscillator quark model (by Feynman *et al.*). The new vector and axial form factors in the RS model will be introduced. It will be shown that the vector part agrees with the resonant contribution to electron-proton inclusive F2 data. The axial part is obtained by finding a simultaneous fit to ANL and BNL $\mathrm{d}\sigma/\mathrm{d}Q^2$ neutrino scattering data. Eventually, the relevance of the heavier than $\Delta(1232)$ resonances will be discussed.

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Nuclear and Nucleon Contributions to the Parity-Violating Electron Scattering

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The influence of the isospin mixing in nuclear states on the parity-violating (PV) asymmetry is studied for the even-even, $N = Z$ nuclei ^{12}C, ^{24}Mg, ^{28}Si, and ^{32}S. Their ground states have been calculated within a self-consistent axially symmetric mean field approximation with density-dependent effective two-body Skyrme interactions. Some differences from previous shell-model calculations appear for the isovector Coulomb form factors, from which the PV asymmetry is subsequently calculated. For the sake of the accuracy in the isovector and isoscalar form factor calculations, the full Coulomb multipole operator (charge and spin-orbit contributions) has been considered. A very suitable parametrization has been used for the electric and magnetic nucleon form factors, as well as for the form factor including strange content of the nucleon. The strangeness contribution to the PV asymmetry is also studied independently from the isospin mixing contribution. Total form factors have been decomposed into contributions from states of spherical harmonic oscillator basis to get an insight into the changes with respect to previous shell model calculation. Our results on PV asymmetry, calculated within the distorted-wave Born approximation, can be compared with experimental results from polarized electron scattering off the nuclei under study. To this end, we propose for each nucleus a set of kinematic ranges where the signal (PV asymmetry) and the signal to noise ratio are maximized.

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Energy Distributions from Three-Body Decaying ^{12}C Resonances

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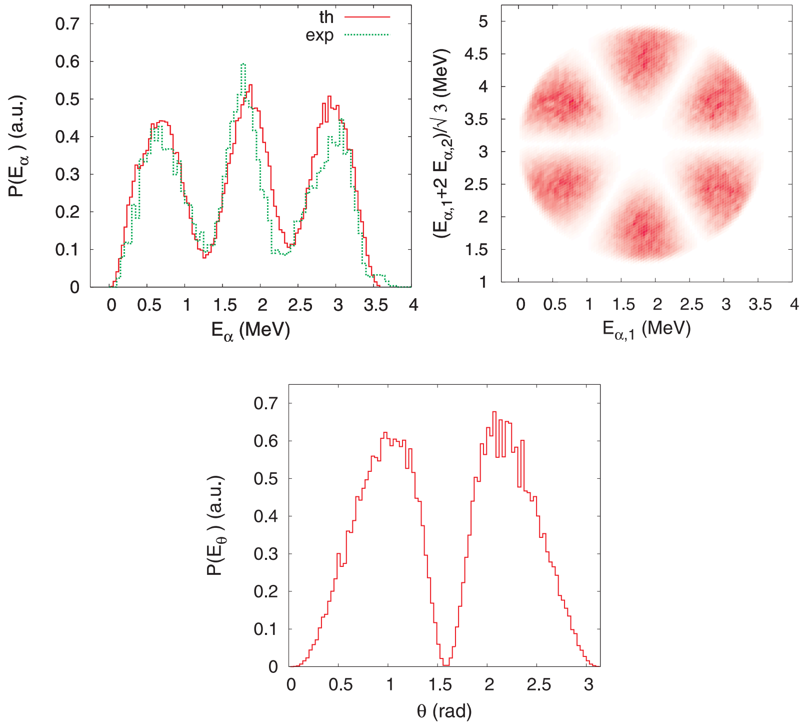
The breakup of a physical system in a three-body continuum with Coulomb interaction is not yet a well understood problem of few body physics, although it has been well studied over many years. The main difficulty lies in constructing correct asymptotic wave functions when no binary bound states exist. We investigate here the decay of low-lying continuum states into three particle final states for the case of ^{12}C, assuming that the decay mechanism is independent of how the initial state was formed. We describe the decay in analogy with α-decay, assuming that the three fragments are formed before entering the barrier at sufficiently small distances to allow the three-body treatment. The hyperradius ρ provides a measure of distances for our three-body problem.

The hyperspherical adiabatic expansion, combined with the complex rotation method, is an efficient technique to compute bound states and resonances. The wave functions in this approach are expanded on basis states related to adiabatic potentials calculated as a function of the hyperradius ρ. The asymptotic behaviour of the decaying resonance wave function determines the energy distribution in the observable final state. Both sequential and direct decays are treated.

The known experimental single α-particle energy distributions are reproduced rather well. We illustrate by the example of the 1^+ resonance of ^{12}C this good agreement (see figure). In conclusion, we provide a reliable method to deal with three-body decays.



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New $SU(3)$ Approach in Calculating the 0^+ States and Transitions in Heavy Deformed Nuclei

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We developed a new approach for calculating the excited 0^+ states in heavy deformed nuclei. In our model we employ the $SU(3)$ symmetry for truncating the model space, and also for building the Hamiltonian. We build the model space by including the proton and neutron valence particles [1]. In this new approach we allow one pair of particles from the lower intruder state to participate in building the basis states. In the previous model we have successfully described these properties for a series of even-even deformed nuclei [2]. With this model we investigate few nuclei from the deformed Gadolinium isotopes and their even-even neighboring nuclei.

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Systematics of the Behavior of the Ground and Octupole Bands of the Deformed Even-Even Lantanides

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We investigate systematically the behavior of the collective energies of states from the ground and octupole bands of the deformed even-even lantanides, described very accurately by the $U(6) \supset U(3) \otimes U(2) \supset SO(3)$ dynamical symmetry of the symplectic extension to $Sp(12, R)$ of the Interacting Vector Boson Model [1]. Our approach is based on the assumption, that the phenomenological parameters of the Hamiltonian, obtained for each individual nucleus should reflect the dependence of the energies on the nuclear characteristics, the number of valence neutrons N and protons Z. Hence we employ a two step fitting procedure. First we fit the parameters of the Hamiltonian as first or second order polynomials of the changing values of N for the isotopic chains (fixed Z) of the deformed Nd, Sm, Gd, Dy, Er, Yb and Hf nuclei. Next step is to approximate each of the obtained polynomial coefficients within their uncertainties by a linear regression in respect to the number of valence protons Z. As a result we obtain a unified expression for the energies of the ground and octupole bands for the deformed nuclei in the rare earth region. This allows us to relates the phenomenological parameters of the Hamiltonian to the fundamental nuclear structure and to interpret in this way the development of collectivity trough the vast region of nuclei that we explore.

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Coriolis Interaction in Quadrupole-Octupole Deformed Nuclei

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We develop an algorithm for calculating the Coriolis decoupling strength in deformed nuclei. It is realized within the reflection asymmetric deformed shell model which gives the single particle wave function decomposition in the axially deformed harmonic oscillator (ADHO) basis. To obtain the Coriolis interaction strength we transform the ADHO decomposition coefficients of the wave function into coefficients in the spherical oscillator basis. For this purpose the transformation brackets relating deformed and spherical oscillator basis functions are integrated numerically. Preliminary calculations were implemented in the nuclei ^{223}Ra, ^{237}U and ^{239}Pu which possess quadrupole and octupole deformations. The results show the applicability of the applied algorithm to study the effects of Coriolis interaction in complex deformed nuclei.

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Boson and Fermion Degrees of Freedom in Orthosymplectic Extension of the IVBM: Odd-Odd Nuclear Spectra

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The dynamical symmetry group $Sp(12, R)$ of the Interacting Vector Boson Model (IVBM) is extended to the orthosymplectic group $OSp(2\Omega/12, R)$ in order to incorporate fermion degrees of freedom. The structure of even-even nuclei is used as a core on which the collective excitations of the neighboring odd-mass and odd-odd nuclei are build on. Hence, the spectra of odd-mass and odd-odd nuclei arise as a result of the coupling of the fermion degrees of freedom, specified by the fermion sector $SO^F(2\Omega)$ to the boson core, whose states belong to an $Sp(12, R)$ irreducible representation.

The orthosymplectic dynamical symmetry is applied for the simultaneous description of the spectra of some neighboring nuclei from rare earth and actinide regions. The theoretical predictions for different low-lying collective bands with positive and negative parity are compared with the experiment. The obtained results reveal the applicability of the model and its boson-fermion extension.

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Multiply Charged Helium Isoelectronic Ions with Charge Z to 118: I.Ground State Energies, Masse Corrections, Mass Polarization

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Multiply charged Helium ions are strongly responsible for the properties and characteristics of high-temperature astrophysical and laboratory plasma, as well as for the processes within plasma.

Our previous works [1] present ground state electron energies, mass corrections and mass polrization effects of He isoelectronic ions, with charge from $Z = 2$ to $Z = 54$. Results were obtained by solving the two-electron Schrodinger equation. Explicitly correlated wave functions $(ECWF)$ of a generalized Hylleraas type were used as trial wave functions, in the expansion series with positive powers of the Hylleraas coordinates. The numerical procedure for determination of coefficients in this expansion brings to a solving of algebraic system of non-lineal integro-differential equations of 4^{th} order. The developed method allows to obtain numerical data up to the 6^{th} decimal accuracy comparing to the most precisely obtained [2,3] results for He isoelectronic ions, with charge from $Z = 2$ to $Z = 10$.

The proposed work presents ground state electron energies, mass corrections and mass polrization effects of He isoelectronic ions with nuclear charge for the main nuclides from $Z = 2$ to $Z = 118$. The same type $ECWF$ are used. The variational procedure for determination of the coefficients is discrete, leading to an eigenvalue problem. The developed analytical and numerical method allows to obtain numerical results, which are practically coinciding with those presented in [2, 3]. Using of the same method, we have the same accuracy for ions with charge $Z > 10$. The dependence of the obtained energies versus Z is investigated, as well as the relative and complex contributions of mass corrections and mass polarization effects in formation of the ground state electron energies.

The approach developed may be regarded as a base for investigation of the relativistic corrections and QED effects at next stage. The accuracy of the obtained results allows directly usage in precise theoretical approaches [4] for plasma diagnostics.

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