ABSTRACTS

of the XXVIII International Workshop on Nuclear Theory

Rila Mountains, Bulgaria, June 22-27, 2009

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

Laboratory of Theoretical Nuclear Physics

PROGRAMME

Monday, June 22

Morning session

09:30 – 10:15 *R.J. Peterson*: Comparison of y-scaling for Electrons and Hadrons

10:15 – 10:35 *Coffee*

10:35 – 11:20 *C. Giusti*: Relativistic Models of Quasielastic Electron and Neutrino-Nucleus Scattering

11:30 – 12:15 *A. Cowley*: Mechanism of Proton-induced α-particle and Helion Emission into the Continuum of Outgoing Energies

12:25 – 13:10 *Yo. Ilieva*: Probing Nuclear Dynamics in Exclusive Meson Photoproduction

17:10 – 17:30 *Coffee*

Afternoon session

17:30 – 18:15 *F. Sammarruca*: Recent Progress with ab initio Calculations of Nuclear Matter

18:20 – 18:50 *Ch. Moustakidis*: Equation of State for Dense Supernova Matter

18:55 – 19:15 *Tz. Apostolova*: Nonlocal Electron Dynamics in the Presence of Pulsed Laser Irradiation

Tuesday, June 23

Morning session

09:30 – 10:15 *R. Machleidt*: The Missing Three-nucleon Forces: Where are they?

10:15 – 10:35 *Coffee*

10:35 – 11:20 *A.F. Krutov*: Instant Form of Relativistic Quantum Mechanics and the Electromagnetic Structure of Composite Systems

11:30 – 12:15 *M. Avrigeanu*: On the Alpha-particle Optical Potential for Astrophysical Studies

12:25 – 13:10 *K.V. Lukyanov*: The K^+-Nucleus Microscopic Optical Potential of Scattering and Calculations of the Corresponding Differential Elastic and Total Reaction Cross Sections

16:00 – 16:20 *Coffee*

Afternoon session

16:20 – 17:05 *S. Strauch*: Medium Modifications from ^{4}He($\vec{e}, e'\vec{p}$)^{3}H

17:10 – 17:55 *G. Rainovski*: Evolution and Shell Stabilization of Proton-Neutron Mixed Symmetry States in the Mass $A \approx 130$ Region

18:00 – 18:30 *M. Gaidarov*: A Microscopic Optical Potential Approach to ^{6,8}He+p Elastic Scattering

18:35 – 19:05 *S. Dimitrova*: Two Approximate Approaches for Solving the Large-scale Shell-model Problem

Wednesday, June 24

Morning session

09:30 – 10:15 *D. Bonatsos*: The Bohr Hamiltonian with the Morse Potential: Analytical Solutions through the Asymptotic Iteration Method

10:15 – 10:35 *Coffee*

10:35 – 11:05 *N. Minkov*: Coriolis Interaction in Nuclear Single-Particle States with Mixed Parity

11:10 – 11:40 *H. Ganev*: Structure of the Doublet Bands in Doubly Odd Nuclei with Mass Around 130

11:45 – 12:15 *V. Garistov*: Unified Description of the Yrast Lines

12:20 – 12:50 *S. Lalkovski*: The Nucleus ^{106}Zr and the Structural Evolution bellow ^{132}Sn

16:00 – 16:20 *Coffee*

Afternoon session

16:20 – 16:50 *V. De Donno*: Nuclear Excited States within Random Phase Approximation Theory

16:55 – 17:15 *G. Deyanova*: Systematic Study of Signature Inversion in $\pi h_{11/2} \times \nu h_{11/2}$ Structure in ^{136}La and $A = 130 \sim 140$ Mass Region

17:20 – 17:40 *P. Detistov*: Simulations of the AGATA Response to Relativistic Heavy Ions Beams

17:45 – 18:15 *S. Mishev*: An Extended Approximation for the Low-lying States in Odd-mass Nuclei

Thursday, June 25

E X C U R S I O N

Friday, June 26

Morning session

09:30 – 10:15 *H. Wolter*: Equation-of-State of Nuclear Matter with Light Cluster Correlations

10:15 – 10:35 *Coffee*

10:35 – 11:20 *L. Bonneau*: Time-odd Effects on Single-particle Spectra of Odd-mass Nuclei within a Skyrme–Hartree–Fock Approach

11:30 – 12:15 *N. Chamel*: Hartree-Fock-Bogoliubov Mass Models and the Description of Neutron-star Crusts

12:25 – 13:10 *E. Suraud*: Towards the Microscopic Description of the Irradiation of Biomolecules

Comparison of y-scaling for Electrons and Hadrons

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Over many years, a large body of inclusive (e, ex) spectra on complex nuclei has been analyzed through y-scaling, in which the observed momentum and energy loss of the projectile are combined into one variable y, related to the internal motion of the one struck nucleon within the complex nucleus. A similar analysis for inclusive hadron spectra has many advantages, since in-medium hadron-nucleon cross sections are of interest and the range of spin/isospin couplings available for hadrons is complete, not just the two interactions available to electrons. If scaling is found, a complete range of nuyclear single nucleon spin/isospin responses can be obtained. However, the strength of hadronic interactions is such that the assumption of incoherent single-nucleon scattering that lies behind behind the y-scaling idea are in doubt. An extensive review of global (h, hx) spectra for beams of protons, pions and K^+ on nuclei from ^{6}Li to U has been completed in a fashion closely following the electron analyses. For light nuclei, scaling of the first kind is noted, and scaling of the second kind is found only with smaller in-medium hadron-nucleon total cross sections. A new scaling of the third kind, including all hadron species, is noted for light nuclei. A practical advantage of successful scaling for hadrons is to unify the difficult-to-measure high energy neutron data needed for an understanding of spallation sources.

Relativistic Models of Quasielastic Electron and Neutrino-Nucleus Scattering

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Relativistic models of electron and neutrino-nucleus scattering in the quasielastic region are presented and compared. For inclusive processes the numerical results obtained with different approaches to describe final-state interactions are compared. The scaling properties of different models are also investigated. The scaling functions obtained in the different models are compared with the experimental scaling function extracted from the analysis of (e, e') data.

Mechanism of Proton-induced α-particle and Helion Emission into the Continuum of Outgoing Energies

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The mechanism that determines the emission of light complex projectiles with energies in the continuum, has been studied extensively over many years. Cross sections, and especially analyzing power of ejectiles, display angular and energy distributions which are typical of an intranuclear nucleon-nucleon multistep statistical reaction mechanism.

For the formation of a complex ejectile in the final stage of the reaction, pickup of a correlated neutron-proton pair from an atomic nucleus would seem to be a most likely process in a (p,^{3}He) reaction. However, for (p,α) either pickup of a triton-like grouping, or α-cluster knockout are possible processes, with the latter preferred on dynamical grounds. The theory reproduces experimental distributions well under these assumptions.

An overview of results for the reactions (p,^{3}He) and (p,α) on ^{59}Co and ^{93}Nb at incident energies between 100 and 160 MeV will be presented. The trend of cross section and analyzing power distributions as a function of incident energy and emission energy will be discussed, and remaining issues that still need to be explored will be described.

Probing Nuclear Dynamics in Exclusive Meson Photoproduction

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Understanding hadron interactions and nuclear structure has been a long standing problem in nuclear physics. The theory of the strong interaction, the Quantum Chromodynamics (QCD), has proved to be very successful in the description of high-energy nuclear phenomena where perturbative methods can be used. However, presently there is no direct low-energy solution of QCD and nuclear models have been used to understand nuclear properties and dynamics. The success of these models essentially depends on the knowledge of the effective degrees of freedom in nuclear processes and those have been the subject of rigorous studies. In this talk I will present results of experiments with real photon beams on deuterium from Jefferson Lab Hall-B. The invariant cross sections of coherent pion photoproduction exhibit scaling properties already at moderate momentum transfer, where perturbative QCD does not apply. This empirical observation opens the venue to probe the transition between hadron and quark-gluon degrees of freedom in the nuclear system.

Rescattering mechanisms dominate meson photoproduction at specific kinematics and can be a viable tool to search for the onset of color transparency. I will also present preliminary results on polarization observables of incoherent pion photoproduction on deuterium obtained with circularly and linearly polarized photons and discuss future perspectives.

Recent Progress with *ab initio* Calculations of Nuclear Matter

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This talk will review a broad spectrum of studies aimed at improving our knowledge of nuclear matter, including its extreme states with respect to density and/or spin and isospin asymmetry. Our *ab initio* approach is microscopic and relativistic. The calculated nuclear matter proprties are derived self-consistently from realistic nuclear forces and have relevance for the physics of rare, short-lived nuclei and, on a dramatically different scale, the physics of neutron stars. The "common denominator" is the symmetry energy, which plays a crucial role in the formation of the neutron skin in neutron-rich nuclei *and* the radius of a neutron star (a system 18 orders of magnitude larger and 55 orders of magnitudes heavier). The details of the density dependence of the symmetry energy are still poorly understood.

Our recent progress also includes predictions of the energy per particle in hyperonic matter. We find that the presence of strange baryons in nuclear matter can alter the equation of state considerably.

Equation of State for Dense Supernova Matter

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We provide an equation of state for high density supernova matter by applying a momentum-dependent effective interaction. We focus on the study of the equation of state of high-density and high-temperature nuclear matter containing leptons (electrons and neutrinos) under the chemical equilibrium condition. The conditions of charge neutrality and equilibrium under β-decay process lead first to the evaluation of the lepton fractions and afterwards the evaluation of internal energy, pressure, entropy and in total to the equation of state of hot nuclear matter for various isothermal cases. Thermal effects on the properties and equation of state of nuclear matter are evaluated and analyzed in the framework of the proposed effective interaction model. Since supernova matter is characterized by a constant entropy we also present the thermodynamic properties for isentropic case. Special attention is dedicated to the study of the contribution of the components of β-stable nuclear matter to the entropy per particle, a quantity of great interest for the study of structure and collapse of supernova.

Nonlocal Electron Dynamics in the Presence of Pulsed Laser Irradiation

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A generalized non-local Fokker-Planck equation derived on the basis of quantum-mechanical formalism is established for studying the conduction electron dynamics in a solid excited by spatially inhomogeneous pulsed laser irradiation. In this approach the electrons are envisioned as undergoing a drift- diffusion motion in the energy-position manifold.

The Missing Three-nucleon Forces: Where are they?

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In recent years, there has been substantial progress in the derivation of nuclear forces from chiral effective field theory. Accurate two-nucleon forces (2NF) have been constructed up to next-to-next-to-next-to-leading order (N^3LO) [1–3] of chiral perturbation theory and applied in microscopic nuclear structure calculations with a good degree of success. However, chiral three-nucleon forces (3NF) have been used only at N^2LO, improving some miscroscopic predictions [4], but leaving also several issues, like the "A_y puzzle" of nucleon-deuteron scattering [5], unresolved. Thus, the 3NF at N^3LO is needed for essentially two reasons:

- For consistency with the 2NF, and
- to (hopefully) improve some critical predictions of nuclear structure and reactions.

However, there are indications that the 3NF at N^3LO (in the so-called Δ-less version of the theory) is rather weak and may not solve any of the outstanding problems. If this suspicion is confirmed, we have to go beyond, which may be similar to opening Pandora's Box. In this talk, I will discuss the various possible scenarios and how to deal with them.

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Instant Form of Relativistic Quantum Mechanics and the Electromagnetic Structure of Composite Systems

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The objective of this talk is the description of one of the possible relativistic invariant models of the electroweak structure of a two-particle composite systems. The method in the relativistic theory of composite systems which is used here is based on the direct realization of the Poincaré algebra on the set of dynamics observables of systems. This approach is called the theory of direct interaction, relativistic Hamiltonian dynamics (RHD) and the relativistic quantum mechanics. From the point of view of the principle underlying it, the relativistic quantum mechanics occupies the intermediate position between the local quantum field theory and nonrelativistic quantum mechanics.

The main problem in construction of these models is known to be the problem of construction of operators of transition currents. Generally speaking, the complexity of the construction of, for example, the operator of electromagnetic current of the composite system satisfying the Lorentz-covariance and conservation conditions appears in all approaches, including the perturbative quantum field theory. This problem has been discussed in literature widely. The approach to describing the electroweak structure of two-particle composite systems presented in this talk has the following characteristical features [1, 2].

1. The matrix element of the electroweak current of the composite system automatically satisfies the relativistic covariance conditions.

2. The matrix element of the electromagnetic current satisfies the conservation law.

3. The relativistic impulse approximation is formulated in a relativistically invariant way with account of the conservation law for the electromagnetic current.

4. The described approach gives the natural nonrelativistic limit, i.e., the correspondence principle is fulfilled.

5. In description of composite systems with nonzero spin this approach yields an unambiguous description of electromagnetic form factors and does not use the concept of "good" and "bad" currents components.

6. Calculation in this approach yield a good description of electromagnetic properties of composite quarks and nucleon systems.

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On the Alpha-particle Optical Potential for Astrophysical Studies

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The recent high precision measurements of α-particle elastic-scattering as well as of the (α, x) reaction cross sections [1–3] make possible further improvement of global OMPs. We have looked in this respect for an extension of the previous semi-microscopic analysis [4] of the α-particle elastic-scattering, based on the Double Folding Model, to the mass region $50 < A < 120$ nuclei and energies from ~ 13 to 50 MeV [5] and finally to heavy nuclei up to ^{209}Bi.

The energy-dependent phenomenological imaginary part for this semi-microscopic optical potential was obtained including the dispersive correction to the microscopic real potential, and used within a concurrent phenomenological analysis of the same data basis [4, 5]. A global parameter set for low-energy -particles entirely based on elastic-scattering data analysis was thus obtained for the nuclei within the above-mentioned mass and energy ranges, and next involved in the reaction data analysis.

The (α, γ), (α, n) and (α, p) reaction cross sections analysis for target nuclei from ^{45}Sc to ^{118}Sn, and incident energies below 10-12 MeV completed the parameterization of the alpha-particle OMP. The statistical–model parameters used for the cross section calculations were established by analyzing various independent experimental data for all stable isotopes of V, Mn, Co, Ni, Cu, Mo, Pd, Sn and Te [6], allowing us to focus on the uncertainties of the α-particle OMP. Therefore the former diffuseness of the real part of optical potential as well as the surface imaginary–potential depth have been found responsible for the description of the reaction cross section data under Coulomb barrier. They were modified in order to obtain an optical potential which describe equally well both the low energy elastic–scattering and induced–reaction data of α-particles.

Finally, better results were provided in comparison with either the well-known four-parameter global potential [7] of McFadden-Satchler or the global α-nucleus OMP is proposed by the BARC group [8] for A $\sim$ 12-209 and energies from Coulomb barrier up to about 140 MeV, based on a systematics of the real and imaginary potential volume integrals.

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The K^+-Nucleus Microscopic Optical Potential of Scattering and Calculations of the Corresponding Differential Elastic and Total Reaction Cross Sections

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The microscopic optical potential (OP) is calculated for the K^+-meson scattering on the ^{12}C and ^{40}Ca nuclei at intermediate energies. The distinctive respect of this OP is that it has no free parameters and based on the known kaon-nucleon amplitude and point-like density distributions of nuclei. Then, the respective relativistic Shrödinger equation is adapted to the considered task and solved numerically using the standard code DWUCK4. The effect of different methods of relativization is studied and shown to play an important role. A good agreement with the experimental data on differential elastic cross sections is obtained. Besides, to explain the data on total reaction cross sections the contribution is studied of the additional surface term of OP introduced to account for the peripheral collective nuclear excitations and nucleon removal reactions.

Medium Modifications from ^{4}He$(\vec{e}, e'\vec{p})^3$H

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One of the most exciting topics in nuclear physics is to study how the hadron properties are modified by the nuclear environment and how such modifications affect the properties of nuclei. Since nucleons and mesons are made of quarks, anti-quarks and gluons, one expects their internal structure to change when placed inside nuclear matter or atomic nuclei. Polarization transfer in quasi-elastic nucleon knockout is sensitive to the properties of the nucleon in the nuclear medium. In our recently completed experiment E03-104 at Jefferson Lab in Hall A we measured the proton recoil polarization in the ^{4}He$(\vec{e}, e'\vec{p}\,)\,^3$H reaction at a Q^2 of 0.8 (GeV/c)^2 and 1.3 (GeV/c)^2 with unprecedented precision. These data complement earlier data between 0.4 and 2.6 (GeV/c)^2 from both Mainz and Jefferson Lab. The measured ratio of polarization-transfer coefficients differs from a fully relativistic calculation, and is well described by the inclusion of a medium modification of the proton form factors as predicted by the quark-meson coupling or chiral quark-soliton models. However, these polarization-transfer data are also well described by strong charge-exchange final-state interactions. The measured induced polarizations agree well with the fully relativistic calculation and indicate that these strong final-state interactions may not be applicable.

Evolution and Shell Stabilization of Proton-neutron Mixed Symmetry States in the Mass $A \approx 130$ Region

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Considerable progress has been achieved recently in the experimental investigation of quadrupole-collective isovector excitations in the valence shell, the so called mixed-symmetry states (MSSs), in the mass $A \approx 130$ region. This is due to a new experimental technique for study MSSs which is based on the observation of low-multiplicity γ-ray events from inverse kinematics Coulomb excitation with the large 4π spectrometer Gammasphere. Using this technique we have studied all stable cerium and xenon isotopes with $N < 82$. The obtained experimental information show that for low-collective vibrational nuclei the underlying single-particle structure can be the most important factor for preserving or fragmenting the MSSs. The observed fragmentation of MSSs in ^{138}Ce and ^{136}Ce is attributed to the lack of **shell stabilization** at the proton $1g_{7/2}$ sub-shell closure.

The evolution of the MSSs from ^{134}Xe to ^{138}Ce shows that the separation in energy between the fully-symmetric 2^+_1 state and the $2^+_{1,\mathrm{ms}}$ level increases as a function of the number of proton pairs outside the $Z = 50$ shell closure. This behavior can be understood as resulting from the mixing of the basic proton and neutron one-quadrupole phonon excitations of the nuclear two-fluid quantum system. It provides the first experimental estimate of the strength of the proton-neutron interaction derived from states with symmetric and antisymmetric nature.

The method, the experimental results, and their consequences will be discussed together with future perspercitves for the investigation of MSSs in the mass $A \approx$ 130 region.

A Microscopic Optical Potential Approach to ^{6,8}He+p Elastic Scattering

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A microscopic approach to calculate the optical potential (OP) with the real part obtained by a folding procedure and with the imaginary part inherent in the high-energy approximation is applied to study the ^{6,8}He+p elastic scattering data at energies of tens of MeV/nucleon (MeV/N) [1, 2]. The OP's and the cross sections are calculated using different models for the neutron and proton densities of ^{6,8}He [3–6]. The role of the spin-orbit potential and effects of the energy and density dependence of the effective NN forces are studied. Comparison of the calculations with the available experimental data on the elastic scattering differential cross sections at beam energies < 100 MeV/N is performed and conclusions on the role of the aforesaid effects are made. It is shown that the present approach, which uses only parameters that renormalize the depths of the OP, can be applied along with other methods like that from the microscopic g-matrix description [7] of the complex proton optical potential.

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Two Approximate Approaches for Solving the Large-scale Shell-model Problem

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The nuclear shell model with full configuration mixing is the most adequate tool for describing the low–energy structure of light and medium mass nuclei. The method requires a diagonalization of the hamiltonian of the system. The size of the hamiltonian matrix increases drastically when a large number of valence shells and/or valence nucleons are considered. Thus a massive truncation of the configuration space is inevitable.

In what follows two different approaches for sampling the configuration space will be discussed - the Density Matrix Renormalization Method [1, 2] and the Importance Sampling Algorithm [3]. Recent results obtained by both methods for the low laying states of ^{48}Cr in the $fp-$ shell will be compared.

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The Bohr Hamiltonian with the Morse Potential: Analytical Solutions through the Asymptotic Iteration Method

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The Asymptotic Iteration Method (AIM) for solving differential equations is used in order to obtain closed analytical expressions for the energy eigenvalues and B(E2) rates of the Bohr Hamiltonian in the γ-unstable case, as well as in an exactly separable rotational case with $\gamma \approx 0$, called the exactly separable Morse (ES-M) solution [1]. The effectiveness of the AIM is demonstrated by solving in addition the relevant Bohr equations for the Davidson and Kratzer potentials [1]. All medium mass and heavy nuclei with known β_1 and γ_1 bandheads have been fitted by using the two-parameter γ-unstable solution for transitional nuclei and the three-parameter ES-M for rotational ones. It is shown that bandheads and energy spacings within the bands are well reproduced for more than 50 nuclei in each case. Comparisons to the fits provided by the Davidson [2] and Kratzer potentials are made.

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Coriolis Interaction in Nuclear Single Particle States with Mixed Parity

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We examine the Coriolis decoupling strength in nuclear single particle states with mixed parity. Different schemes of coupling between the particle and the core in an odd-A nucleus are considered in dependence on the parity mixing. We show that in the different cases the decoupling factor should be specifically defined. Then it is evaluated by using a deformed shell model with reflection asymmetry for which the single particle wave function is decomposed in the basis of an axially deformed harmonic oscillator. In this framework we examine the behaviour of the Coriolis interaction in the limits of strong and weak parity mixing. The approach allows one to investigate the dependence of the decoupling factor on nuclear quadrupole and octupole deformations. The implemented study suggests a possibility for a consistent collective and microscopic model description of quadrupole-octupole vibrations and rotations coupled to the single particle motion in odd-mass nuclei.

Structure of the Doublet Bands in Doubly Odd Nuclei with Mass Around 130

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The structure of the $\Delta I = 1$ doublet bands in doubly odd nuclei from the $A \sim 130$ mass region is investigated within the orthosymplectic extension [1] of the Interacting Vector Boson Model (IVBM). A new, purely collective interpretation of these bands is given on the basis of the obtained boson-fermion dynamical symmetry of the model. The model calculations are performed for three odd-odd nuclei, namely ^{126}Pr, ^{134}Pr and ^{132}La [2]. The theoretical predictions for the energy levels of the doublet bands as well as the E2 and M1 transition probabilities between the states of the yrast and yrare bands are compared with experiment and the results of other theoretical approaches. The obtained results reveal the applicability of the used orthosymplectic dynamical symmetry of IVBM.

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Unified Description of the Yrast Lines

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The description and the classification of the vast amount of experimental data on the low-lying collective spectra of even-even nuclei in the rare-earth and actinide regions is still a problem of particular interest in the nuclear structure physics. In sequences of nuclei where the investigated nuclear characteristics are empirically studied, the energies of the yrast lines and E2 transition probabilities have been analyzed using different phenomenological models. Among them the Interacting Vector Bosons Model /IVBM/ provides the most precise description of the BE2 transition probabilities between the states within the yrast line which is due to the symplectic extension of the model. Analysis of the model parameters as functions of the nuclear characteristics, that aims at their unified description, is presented.

The Nucleus ^{106}Zr and the Structural Evolution below ^{132}Sn

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The talk focuses on the spectroscopy of neutron-rich ^{106}Zr, which is situated in a region that displays a variety of nuclear shapes and collective phenomena. It is often claimed that the filling of the $h_{11/2}$ intruder orbital is responsible for the increase in deformation of the zirconium isotopes as the neutron number increases. The occurrence of intruder orbits is, however, dependent on the nucleonic spin-orbit interaction, which is conjectured to weaken or even disappear close to the neutron drip-line. This weakening would alter the valence-shell structure in this region and in particular modify the collective properties of nuclei that are traditionally at mid-shell. The nucleus ^{106}Zr with 66 neutrons, in between the traditional magic numbers 50 and 82, is therefore of particular interest.

Basic spectroscopic observables such as level energies and transition probabilities were calculated in the framework of the Interaction Boson Model for the neighboring known nuclei and subsequently extrapolated to ^{106}Zr, assuming the traditional shell structure to be valid. The comparison of the model prediction with future experimental studies of ^{106}Zr might help to indicate whether the magic number 82 persists in the heavy zirconium isotopes, long before the nucleus ^{122}Zr itself becomes experimentally accessible.

Nuclear Excited States within Random Phase Approximation Theory

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Calculation of low-lying excitation spectra and electromagnetic responses of doubly closed shell nuclei within Random Phase Approximation theory using four phenomenological effective interactions was made [1–3]. Particular attention has been paid to observe the sensitivity of the quantities studied to different interactions. Then self-consistent RPA calculations were made to test the validity of the finite-range D1 Gogny interaction. For all the nuclei investigated was found that this interaction inverts the energies of all the magnetic states forming isospin doublets. Then an improvement of discrete RPA was illustrated that treats the continuum particle space correctly using an expansion on Sturmian functions basis. [1]

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Systematic Study of Signature Inversion in $\pi h_{11/2} \times \nu h_{11/2}$ Structure in ^{136}La and $A = 130 \sim 140$ Mass Region

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The inversion of the two signatures of a rotational band is considered as an indicator of the nuclear shape [1]. This phenomenon is studied systematically in the odd-odd ^{136}La and its neighbours, where a positive parity $\pi h_{11/2} \otimes \nu h_{11/2}$ yrast band are known. These nuclei are soft with respect to the triaxiality parameter γ and take a variety of shapes due to the competition of the shape driving forces of the valence $h_{11/2}$ quasineutron and $h_{11/2}$ quasiproton.

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Simulations of the AGATA Response to Relativistic Heavy Ions Beams

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Based on the developed Bremsstrahlung GEANT4 simulation model [PDet] an estimation of two possible configurations of the future AGATA array [agataCode] performances at GSI will be presented. The first one for the case of fast beams, when one-step Coulex is studied and the second one for the case of stopped beams, when the fragments are implanted in the catcher and the isomeric decay is studied. Comparison with experimental data from such RISING campaigns [risNim,Pietri] will be made.

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An Extended Approximation for the Low-lying States in Odd-mass Nuclei

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We present an enhanced theory for the lowest-lying states in odd-mass nuclei. Our approach has built on the Quasi-particle Phonon Model extending it to take into account the ground state correlations due to the action of the Pauli principle more accurately than in the conventional theory. Physically, the derived interaction strengths between the quasi-particles and the phonons depend on the quasi-particle occupation numbers explicitly coupling the odd-mass nucleus equations with those of the even-even core. Further, we performed calculations on a number of nuclei where the developed corrections turn out to be significant.

Equation-of-State of Nuclear Matter with Light Cluster Correlations

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The equation-of-state (EoS) of nuclear matter as a function of density and temperature, its composition and the possible occurrence of phase transitions or condensates are widely discussed topics not only in nuclear physics, but are also of great interest in astrophysics and cosmology. Since many of the systems of interest, e.g. exotic nuclei, neutron stars, and supernovae, have large charge asymmetries and exist at very different densities, the density dependence of the symmetry energy is of particular interest. We therefore aim at formulating an EoS which is valid from very low to several times nuclear saturation density and for temperatures up to several tenth of MeV. A particular emphasis is put on the inclusion of light clusters, which are of importance at low densities. The medium dependence of the clusters of mass 2 to 4 is included in a thermodynamical Green function approach and transitions between clusterized and unclusterized phases are discussed. Heavier clusters become important at higher densities and form the transition to homogeneous matter at high density. These are not yet fully included in the approach, limiting its applicability at higher densities. The model is formulated in the generalized relativistic mean field (RMF) approach. Light clusters are treated as independent degrees of freedom with a medium dependent self energy which gives rise to the coupling to the nucleon and meson degrees of freedom. Since nuclear matter is discussed for various asymmetries we also extract the symmetry energy, which is considerably modified at low density due to appearance of correlations. The EoS constructed should be of relevance to a wide range of problems, in particular to supernovae simulations. We also compare to other theoretical approaches used in this field.

Time-odd Effects on Single-particle Spectra of Odd-mass Nuclei within a Skyrme–Hartree–Fock Approach

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A time-reversal symmetry breaking Skyrme–Hartree–Fock approach is applied to the calculations of single-particle states in odd-mass nuclei. As a first step of a more complete treatment, the pairing correlations are not taken into account. The effects on single-particle spectra of the time-odd Hartree–Fock fields resulting from the current and spin-vector densities are studied. The associated removal of the Kramers degeneracy is interpreted in terms of diamagnetic/paramagnetic types of polarization of the even-even core generated by the presence of an odd particle.

Hartree-Fock-Bogoliubov Mass Models and the Description of Neutron-star Crusts

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We review our recent achievements in the construction of microscopic mass tables based on the Hartree-Fock-Bogoliubov method with Skyrme effective interactions. In the latest of our series of HFB-mass models, we have obtained our best fit ever to essentially all the available mass data, by treating the pairing more realistically than in any of our earlier models [1]. With the additional constraint on the neutron-matter equation of state, this new force is thus very well-suited for the study of neutron-rich nuclei and for the description of astrophysical environments like supernova cores and neutron-star crusts [2].

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Towards the Microscopic Description of the Irradiation of Biomolecules

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The irradiation of biomolecular nanosystems in the gas phase represents a significant opening in radiation science. We make a general presentation of the field and of its numerous applications to motivate the theoretical developments to be performed. We then focus on microscopic mechanisms of irradiation of biological molecules with the aim to analyze the effects of the water environment on such processes, ultimately by considering molecules coated with a well defined (tunable) number of water molecules. The path towards such an ambitious goal is long and due to the many elementary processes involved one needs to validate step by step the various experimental and theoretical ingredients. We consider here simple organic molecules as test cases, in particular single water molecules collided by a projectile. The step towards an assembly of molecules raises no major theoretical difficulty and we show as first examples of application examples of irradiation of small water clusters.

The microscopic description of irradiation processes requires an explicit dynamical account of electronic degrees of freedom which are primarily responding in such situations. Moreover, it is necessary to treat electrons in a non-adiabatic way and to allow for ionization and/or electron transport. This invalidates most calculations based on the Born-Oppenheimer (BO) approximation except in some specific situations. Indeed, depending on the characteristics of the ionizing projectile (charge, velocity), one can treat the problem in a simplified manner by decoupling electronic and ionic dynamics. A typical example is the case of high velocity charged projectiles in which ions can be safely considered as frozen and the dynamics reduced to the electronic one, at least on short times. Another example is the case of low velocity neutral projectiles for which a ground state (Born-Oppenheimer, BO) treatment is acceptable. To the best of our knowledge low velocity charged and high velocity neutral projectiles can nevertheless not be treated by usual available calculations, and certainly not in the framework of a unique theoretical approach.

In the present work we have adapted the non adiabatic approach of Calvayrac et al. [1] to the case of organic molecule and we apply it to realistic irradiation scenarios. This method contains as limiting cases pure electron dynamics and BO dynamics (Car-Parinello dynamics) and can thus describe collisions with high-velocity charged or low-velocity neutral projectiles. Moreover, at variance with currently available approaches, it enables complementing cases to be described such as low-velocity charged and high-velocity neutral projectiles. Indeed such a non adiabatic approach places no restriction on the velocity or charge state of the projectile and thus offers an unified picture of many possible irradiation scenarios. Furthermore this approach can be extended to account for environment effects in a hierarchical picture, which will be extremely useful to treat large water environments [2]. We illustrate the capabilities of the method on irradiation of ethylene [3], and water molecules [4] and clusters.

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Contributions of Mass Correlations in Nonrelativistic and Relativistic Ground State Energies of Multiply Charged Helium Like Ions in High-Temperature Plasma

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Multiply charged isoelectron Helium ions in high-temperature astrophysics and laboratory plasma possesses specific properties and characteristics caused by the non-compensated by electrons long-range Coloumb field of the nuclei.

When the ion charge z increases, the relativistic effects role rapidly rises. The LS coupling turns into $j - j$ coupling through area where these two couplings are equally probable - complex coupling. The mass polarization effects become less, but the role of the mass corrections is the same, ensuring the accuracy of the numerical results.

The strong Coloumb field determines possibility one or two electrons to occupy highly excited quasidiscrete (autoionized) states, outside the ionization limit. There are two decomposition channels of the excited ion: autoionization and radiation. In that case one can observe several resonance processes, for example electron transition in bound (excited or ground) state with photon emission - radiative recombination (RR) and the opposite process - photoionization.

In the case of electron capture the decomposition channels of double excited ion are two also: autoionization and radiation. Radiation decomposition is also possible to realize several resonance processes, depending on the energy electron capture. In the case of electron ”observer” the transition of ion's electron from free to bound (excited or ground) state is accompanied by so called satellite lines in the spectrum. In the case of interaction with electron having the appropriate resonance energy, there is electron capture and simultaneous ion excitation. The radiative decomposition of double excited ion realizes by photon emission and electron transition into bound (excited or ground) state - dielectronic recombination (DR).

In order to investigate the multiply charged ions in high-temperature plasma, theoretical calculations should account relativistic effects, but studying the scattering effects are solved applying non-relativistic approaches: the deformed waves method, strong coupling method, which at $Z \to \infty$ are leading to the classical Born-Coloumb approximation with exchange. The applying of these methods in the approaches for plasma diagnostic requires using of precise values for the energetic quantities of the final non-relativistic bound electron states. Then the resonance energy of the interacting electron is possible to be estimated.

The proposed work presents ground state electron energies, mass corrections and mass polarization effects of He isoelectronic ions with nuclear charge for the main nuclides from $Z = 2$ to $Z = 118$. The developed analytical and numerical method in the Explicitly Correlated Wave Functions approach gives high accuracy of the numerical results, which allows direct application in precise approaches for plasma diagnostics.

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 nonrelativistic and relativistic ground state electron energies. The role of the mass polarization effects is investigated for transition from LS coupling, though complex coupling, to $j - j$ coupling.

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