ABSTRACTS

of the XXVI International Workshop on Nuclear Theory

Rila Mountains, Bulgaria, June 25-30, 2007

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 25

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 *Rick Casten*: Exotic Nuclei and the Evolution of Structure Across the Nuclear Chart

11:15 – 12:00 *Kobus Lawrie*: Recent Results from the Experimental Nuclear Structure Program at iThemba LABS

12:10 – 12:55 *Stephane Platchkov*: Spin Structure of the Nucleon: Recent Results from the COMPASS Experiment at CERN

16:30 – 17:00 *Coffee*

Afternoon session

17:00 – 17:45 *Mario Stoitsov*: Continuum Hartree-Fock-Bogoliubov Calculations

17:55 – 18:40 *Valentin Nesterenko*: TDDFT for Skyrme Forces: Basic Points and Recent Advances

18:50 – 19:35 *Andrej Vdovin*: Gamow-Teller Transitions in Hot Nuclei

Tuesday, June 26

Morning session

09:30 – 10:15 *Juan Caballero*: A Study of Electroweak Processes in the Relativistic Impulse Approximation: Does a "Universal" Scaling Function Emerge?

10:15 – 10:35 *Coffee*

10:35 – 11:20 *Maria Barbaro*: Electron and Neutrino Scattering Off Nuclei in the Δ-Resonance Region and Beyond

11:30 – 12:15 *Anton Antonov*: Superscaling in a Dilute Fermi Gas and the Nucleon Momentum Distribution in Nuclei

12:25 – 12:55 *Cristina Martínez*: Superscaling Analysis of Neutral-Current Neutrino Quasielastic Cross Sections within the Relativistic Impulse Approximation

12:55 – 13:25 *Martin Ivanov*: Superscaling and Neutral Current Quasielastic Neutrino–Nucleus Scattering beyond the Relativistic Fermi Gas Model

15:30 – 16:00 *Coffee*

Afternoon session

16:00 – 16:45 *Pedro Sarriguren*: Signatures of Nuclear Deformation in Single and Double Beta Decay

16:55 – 17:40 *Nicholas Keeley*: Transfer Coupling Effects on Elastic Scattering and Fusion for Weakly Bound Exotic Nuclei

17:50 – 18:35 *Planem Krastev*: Effective Interactions in Neutron-Rich Matter

18:45 – 19:30 *Panagiota Papakonstantinou*: Nuclear Collective Excitations Using Correlated Realistic Interactions: Beyond Standard RPA

Wednesday, June 27

Morning session

09:30 – 10:15 *Werner Scheid*: Evolution of the Dinuclear System in Fission, Quasifission, Incomplete and Complete Fusion

10:15 – 10:35 *Coffee*

10:35 – 11:20 *Dennis Bonatsos*: Exactly Separable Version of X(5) and Related Models

11:30 – 12:15 *Eric Suraud*: Small Fermionic Systems, the Common Methods and Challenges

12:25 – 12:55 *Stoyan Mishev*: Description of the Low-Lying States of Odd-Even Nuclei within the Extended Random Phase Approximation

12:55 – 13:25 *Nikolay Minkov*: Collective and Single Particle Motion of Nuclei with Reflection Asymmetry

15:30 – 16:00 *Coffee*

Afternoon session

16:00 – 16:45 *Javier Rodriguez Vignote*: Ratio of the Electric to Magnetic Form Factors in Nuclei

16:55 – 17:40 *Elena Georgieva-Lawrie*: Possible Chirality in the Oblate Doubly-Odd ^{198}Tl Nucleus

17:50 – 18:35 *Simon Mullins*: Probing a Variety of Nuclear Phenomena with DIAMANT and AFRODITE

18:45 – 19:15 *R. Burcu Cakirli*: Comparison of Empirical Proton-Neutron Interactions with Growth Rates of Collectivity and Recent DFT Calculations

19:15 – 19:45 *Galina Krumova*: Charge Form Factor and Cluster Structure of ^{6}Li Nucleus

Thursday, June 28

E X C U R S I O N

Friday, June 29

Morning session

09:30 – 10:15 *Makito Oi*: Anharmonic Wobbling Motion

10:15 – 10:35 *Coffee*

10:35 – 11:05 *Vladimir Garistov*: On E0 Transitions in Even-Even Nuclei

11:05 – 11:35 *Huben Ganev*: A New Look at Nuclear Supersymmetry

11:45 – 12:15 *Michail Ivanov*: sp(4,R)-Systematics of Atomic Nuclei. F-multiplets and Shell Structure

12:15 – 12:45 *Nikolay Kostov*: Computer Algebraic Methods in the Theory of Nuclei

Exotic Nuclei and the Evolution of Structure Across the Nuclear Chart

R.F. Casten

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Nuclear Structure physics is entering a new era, associated with three major technological developments and the physics they enable: facilities that give access to large numbers of exotic nuclei far from the valley of stability, new generations of detector systems and particle separators, and advanced computing capabilities both for data acquisition and analysis, and for theory. This talk will discuss the physics of exotic nuclei, focusing on new phenomena in the weakly bound, strongly interacting, quantal systems that nuclei near the drip lines provide, and on the opportunities to study the evolution of structure, shell structure, collective modes, many-body symmetries, and quantum phase transitional behavior and critical point symmetries across long chains of nuclei. A brief worldwide perspective on next generation exotic beam facilities will also be presented. Work supported in part by the USDOE under grant number DE-FG02-91ER-40609.

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Recent Results from the Experimental Nuclear Structure Program at iThemba LABS

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The nuclear structure research program at iThemba LABS is based on the use of both light and heavy ion beams from a k=200 separated sector cyclotron. Charged particle spectroscopy is done with a k=600 magnetic spectrometer, and gamma spectroscopy with the AFRODITE array, which consists of up to 9 clovers and 7 planar Ge detectors. A charge particle array or a recoil filter can be used with AFRODITE in certain experiments. An overview of recent results will be presented, with emphasis on γ-spectroscopy studies. These include studies of dipole bands in the mass 190 region, signature inversion phenomena in Tl isotopes and results on ^{152,154}Gd. In addition results from an investigation of the barrier-distribution in the ^{86}Kr + ^{208}Pb system, which are obtained from large-angle quasi-elastic scattering, will be presented.

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Spin Structure of the Nucleon: Recent Results from the COMPASS Experiment at CERN

St. Platchkov

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Where is the nucleon spin coming from? After more than 15 years of both experimental and theoretical efforts, the answer to this question is still unsatisfactory. It is now firmly established that the quarks alone account for only about 30% of the nucleon spin. The remaining 70% are expected to come from partly from the gluons, and partly from the parton orbital momentum. The contribution of the gluons ΔG to the nucleon spin is one of the major goals of the COMPASS collaboration. The COMPASS experiment makes use of the high-energy muon beam delivered by the CERN SPS accelerator and of a large-size polarized target. The determination of ΔG is based on the measurement of longitudinal double-spin asymmetries in which the photon-gluon fusion process is isolated. It is also deduced from our QCD fit to the world data for the polarized structure function $g_1(x)$. Using transverse orientation of the target spin, COMPASS is also able to access, through Collins and Sivers asymmetries, the less well known transverse spin distributions in the nucleon. In this talk I will present the most recent results of COMPASS for both longitudinal and transverse spin asymmetries. I will then discuss the impact of our measurements on the understanding of the nucleon spin puzzle.

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Continuum Hartree-Fock-Bogoliubov Calculations

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A method for continuum Hartree-Fock-Bogoliubov calculations is suggested for spherical and axially deformed nuclei by expanding the Hartree-Fock-Bogoliubov solution in the complete set of analytical Pöschl-Teller-Ginocchio wave functions. The method combines the technics of diagonalization in the configurational space with the matching of the solution to its true outgoing boundary conditions in coordinate space. Good agreement is obtained with Hartree-Fock-Bogoliubov results using box boundary conditions for a set of benchmark spherical and deformed nuclei.

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TDDFT for Skyrme Forces: Basic Points and Recent Advances

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Time-dependent density functional theory (TDDFT) is one of the main tools for description of dynamics of diverse quantum systems, from nuclear to electronic ones. In particular, TDDFT with Skyrme forces is successfully exploited for decades to investigate nuclear structure and collective dynamics [1]. In this lecture, we review the present status of the Skyrme TDDFT, its recent achievements and some open problems. Besides the theory is compared with its counterpart for electronic systems (based on the Kohn-Sham functional).

The main points of the discussion are illustrated using the formalism and numerical results of the self-consistent separable RPA (SRPA) model for Skyrme forces, recently developed by our group [2,3]. SRPA can be applied to both spherical [2] and deformed [3] nuclei. It is fully self-consistent and does not need additional parameters. The model takes care of the full residual interaction including both time-even and time-odd coupling terms, the Coulomb contribution and the pairing particle-particle channel. Due to factorization of the residual interaction, SRPA drastically reduces the computational effort while keeping accuracy of full RPA methods. This feature becomes crucial in the case of heavy and deformed nuclei when we deal with a huge configuration space.

We analyze ability of the Skyrme TDDFT to describe various giant resonances (GR), first of all isovector ones. In particular we explore the isovector E1 GR which, in spite of intensive investigation, still demonstrates some unclear and puzzling properties. In this study we try to establish reliable trends and relations between GR properties and specific terms of Skyrme forces (alias nuclear matter properties).

The dominant contributions to the collective response from the principle terms of the Skyrme functional have different signs and thus, in a large extent, compensate each other [3]. As a result, the smaller contributions (time-odd, Coulomb, ...) become important [3]. We analyze these contributions for rare-earth, actinide and superheavy deformed nuclei. Besides, the low-energy vibrational states in superheavy nuclei are scrutinized in connection with actual and planned experiments in Dubna and Darmstadt.

Finally, the basic points of nuclear Skyrme and electronic Kohn-Sham TDDFT are compared. Gauge invariance and necessity in contributions of time-odd currents and densities are discussed.

References

[1] M. Bender, P.-H. Heenen, and P.-G. Reinhard, "Self-consistent mean-field models for nuclear structure", *Rev. Mod. Phys.* **75**, 121 (2003).

[2] V.O. Nesterenko J. Kvasil, and P.-G. Reinhard, *Phys. Rev. C* **66**, 044307 (2002).

[3] V.O. Nesterenko, W. Kleinig, J. Kvasil, P. Vesely, P.-G. Reinhard, and D.S. Dolci, to be published in *PRC*; ArXiv: `nucl-th/0609018`.
V.O. Nesterenko, W. Kleinig, J. Kvasil, P. Vesely, and P.-G. Reinhard, to be published in *Int. J. Mod. Phys. (E)*; ArXiv: `nucl-th/0610040`.

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Gamow-Teller Transitions in Hot Nuclei

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A temperature dependence of collective nuclear excitations (giant resonances (GR) in particular) is a subject of theoretical and experimental investigations for many years. One of the reasons of this interest is that the GR properties at finite temperatures are quite important in understanding various astrophysical processes. For example, electron or neutrino capture on nuclei plays an essential role in the early presupernova collapse. In that context, it is important to know the dependence of the charge-exchange and/or magnetic resonance strength distribution from stellar media temperature.

To study the problem, we apply the formalism based on the quasiparticle-phonon model [1] extended to finite temperature using the thermo field dynamics [2]. Following the TFD prescriptions we have constructed a microscopic thermal Hamiltonian which describes collective vibrations in a hot nucleus [3,4]. In this approach, the fragmentation of the giant vibrations at $T \neq 0$ is due to the coupling with thermal two-phonon configurations.

The calculations are performed for selected nuclei from the Fe region. The Gamow-Teller strength distributions are calculated within the thermal RPA at different temperatures. Then they are used to study a temperature dependence of β-decay rates for these nuclei in stellar media.

References

[1] V.G. Soloviev *Theory of atomic nuclei: quasiparticles and phonons*, (Institute of Physics Publishing, Bristol and Philadelphia, 1992).

[2] Y. Takahashi, H. Umezawa, *Collective Phenomena* **2**, 55 (1975).

[3] D.S. Kosov, A.I. Vdovin, *Mod. Phys. Lett. A* **9**, 1735 (1994).

[4] A. Dzhioev, A. Vdovin, to be published.

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A Study of Electroweak Processes in the Relativistic Impulsez Approximation: Does a “Universal” Scaling Function Emerge?

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The phenomenon of superscaling for quasielastic lepton induced reactions at energies of a few GeV is investigated in the relativistic impulse approximation. Scaling is shown to emerge from the analysis of electron and charged-current neutrino reactions on nuclei. The experimental scaling function presents an asymmetric shape which is reproduced by the model when final state interactions are accounted for through the relativistic mean field approach. Electromagnetic and weak processes lead to a similar superscaling function which supports the universality property of scaling phenomenon.

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Electron and Neutrino Scattering Off Nuclei in the Δ-Resonance Region and Beyond

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It is shown that electron scattering data in the Delta-resonance excitation region exhibit a superscaling behavior analogous to the one observed in the quasielastic domain, if analyzed in terms of an appropriate scaling variable. The resulting scaling function can be used to predict charge-changing neutrino and antineutrino scattering cross sections off nuclei, relevant for the interpretation of oscillation experiments. The microscopic origin of the Delta scaling function is discussed and the extension of the analysis to the complete inelastic spectrum is presented within the context of a unified relativistic approach.

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Superscaling in a Dilute Fermi Gas and the Nucleon Momentum Distribution in Nuclei

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The superscaling observed in inclusive electron scattering is described within the dilute Fermi gas model with interaction between the particles [1]. The comparison with the relativistic Fermi gas (RFG) model without interaction shows an improvement in the explanation of the scaling function $f(\psi')$ in the region $\psi' < -1$, where the RFG result is $f(\psi') = 0$. It is found that the behavior of $f(\psi')$ for $\psi' < -1$ depends on the particular form of the general power-law asymptotics of the momentum distribution $n(k) \sim 1/k^{4+m}$ at large k [2]. The best agreement with the empirical scaling function is found for $m \simeq 4.5$ in agreement with the asymptotics of $n(k)$ in the coherent density fluctuation model where $m = 4$, the latter model being applied successfully to describe the superscaling phenomenon [3]. Thus, superscaling gives information about the asymptotics of $n(k)$ and the NN forces.

References

[1] A.N. Antonov, M.V. Ivanov, M.K. Gaidarov, and E. Moya de Guerra, *Phys. Rev. C* **75**, 034319 (2007).

[2] R.D. Amado, *Phys. Rev. C* **14**, 1264 (1976); R.D. Amado and R.M. Woloshin, *Phys. Lett. B* **62**, 253 (1976); *Phys. Rev. C* **15**, 2200 (1977).

[3] A.N. Antonov, M.K. Gaidarov, D.N. Kadrev *et al.*, *Phys. Rev. C* **69**, 044321 (2004); A.N. Antonov, M.K. Gaidarov, M.V. Ivanov *et al.*, *Phys. Rev. C* **71**, 014317 (2005); A.N. Antonov, M.V. Ivanov, M.K. Gaidarov *et al.*, *Phys. Rev. C* **73**, 047302 (2006); *Phys. Rev. C* **74**, 054603 (2006).

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Superscaling Analysis of Neutral-Current Neutrino Quasielastic Cross Sections within the Relativistic Impulse Approximation

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The scaling properties of the Relativistic Impulse Approximation when applied to neutral-current neutrino-nucleus quasielastic scattering are investigated for the first time. Both scaling of first kind (independence on the transferred momentum) and second kind (independence on the particular nucleus) are analyzed for neutrino beam energies ranging from 1 to 3 GeV. Several approaches are used to compute the outgoing nucleon wave function, including the relativistic plane-wave impulse approximation (RPWIA). Results within RPWIA exhibit superscaling (simultaneous scaling of first and second kinds) at all considered energies and angles. In contrast, when final-state interactions are accounted for, scaling violation to some degree is observed for certain angles at which the ejected nucleon is detected. In order to study the universality of scaling, a comparison of the neutral-current neutrino superscaling function here obtained and the experimental superscaling function extracted from quasielastic (e, e') data is performed.

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Superscaling and Neutral Current Quasielastic Neutrino-Nucleus Scattering beyond the Relativistic Fermi Gas Model

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The superscaling analysis is extended to include quasielastic scattering via the weak neutral current of neutrinos and antineutrinos from nuclei. The scaling function obtained within the coherent density fluctuation model (used previously in calculations of quasielastic inclusive electron and charge-changing neutrino scattering) is applied to neutral current neutrino and antineutrino scattering with energies of 1 GeV from ^{12}C with a proton and neutron knockout (u-channel inclusive processes). The results are compared with those obtained using the scaling function from the relativistic Fermi gas model and the scaling function as determined from the superscaling analysis of quasielastic electron scattering.

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Signatures of Nuclear Deformation in Single and Double Beta Decay

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We study Gamow-Teller transitions in deformed nuclei within a microscopic formalism based on a selfconsistent deformed Hartree-Fock calculation with density-dependent Skyrme forces. Pairing correlations between like nucleons are treated in BCS approximation. Residual spin-isospin interactions in both particle-hole and particle-particle channels are included and treated in the proton-neutron Quasiparticle Random Phase Approximation (QRPA).

We study the sensitivity of the calculated Gamow-Teller strength distributions to the various ingredients in the formalism, such as the two-body force, the deformation, and the pairing and residual interactions. We compare our results with the experimental information available on Gamow-Teller strength distributions, summed strengths and half-lives.

This approach is used to address different problems of interest in nuclear structure, nuclear astrophysics, and particle physics. In particular, we study the $\beta-$decay properties of neutron-deficient isotopic chains in medium-mass (Kr-Sr) and heavy (Hg-Pb) nuclei, as well as their dependence on the nuclear deformation. We find that the shape of the parent nucleus might lead to sizable differences in the Gamow-Teller strength distributions [1]. We have identified the best candidates to look for deformation signatures in their decay patterns.

The deformed QRPA formalism is also used to describe simultaneously the two-neutrino double beta decay matrix elements and the Gamow-Teller distributions of the two single beta branches in the double process [2]. The half-lives for the $2\nu\beta\beta$ process are evaluated and compared to experiment, using the same set of parameters that reproduce the single beta decay properties. This is done for all the cases where the two-neutrino double-beta decay half-lives have been measured: ^{48}Ca, ^{76}Ge, ^{82}Se, ^{96}Zr, ^{100}Mo, ^{116}Cd,

^{128}Te, ^{130}Te, and ^{150}Nd. It is found that the double-beta decay half-lives are particularly sensitive to the difference between initial and final nuclear deformations. This is a suppression mechanism of the double beta decay nuclear matrix elements, which is absent in spherical formalisms.

References

[1] P. Sarriguren *et al.*, *Nucl. Phys. A* **A 691**, 631 (2001);
E. Nacher *et al.*, *Phys. Rev. Lett.* **92**, 232501 (2004);
O. Moreno *et al.*, *Phys. Rev. C* **73**, 054302 (2006).

[2] F. Simkovic *et al.*, *Nucl. Phys. A* **A 733**, 321 (2004);
R. Alvarez-Rodriguez *et al.*, *Phys. Rev. C* **70**, 064309 (2004).

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Transfer Coupling Effects on Elastic Scattering and Fusion for Weakly Bound Exotic Nuclei

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When studying coupling effects on fusion and elastic scattering induced by beams of weakly bound exotic nuclei such as ^{6,8}He, ^{11}Be *etc.* attention has thus far been focussed on breakup. However, recent exclusive measurements for ^{6}He + ^{209}Bi found that at near-barrier energies the large total reaction cross sections observed for this system are dominated by one and two neutron stripping reactions [1,2]. Although a large cross section is no guarantee of an important coupling effect, we have found that coupling to single neutron stripping reactions has an important effect on the total fusion cross section for exotic nuclei such as ^{6,8}He and ^{11}Be [3] which appears to be unique to those nuclei classed as "halo" systems. We shall present additional examples of this coupling effect on the total fusion cross section and further show that the coupling effects on the elastic scattering are equally important for these nuclei and should not be neglected.

References

[1] J. P. Bychowski *et al.*, *Phys. Lett. B* **596**, 26 (2004).

[2] P. A. DeYoung *et al.*, *Phys. Rev. C* **71**, 051601(R) (2005).

[3] N. Keeley, R. Raabe, N. Alamanos, and J.-L. Sida, Progress in Particle and Nuclear Physics, to be published.

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Effective Interactions in Neutron-Rich Matter

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A study of effective interactions in the nuclear medium will be presented with a particular emphasis on dense and neutron-rich matter. The properties of in-medium interactions are reflected in what is known as the nuclear equation of state (EOS), which plays an important role in the physics of various nuclear and astrophysical systems. Isospin and spin asymmetries can have a dramatic impact on the EOS and possibly alter its stability conditions. After briefly reviewing our previous work concerning the isospin asymmetries of the EOS, we will concentrate on our most recent results and their relevance toward a better understanding of the nuclear force in dense neutron-rich matter.

Concerning astrophysical applications, we calculate the total gravitational masses and radii of non-rotating (static) neutron stars. The implications will be discussed. Finally, we will outline an effort to constrain possible time variations of the gravitational constant G through terrestrial nuclear laboratory data.

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Nuclear Collective Excitations Using Correlated Realistic Interactions: Beyond Standard RPA*

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The Unitary Correlation Operator Method (UCOM) provides a way to derive a universal, phase-shift equivalent effective interaction starting from a realistic nucleon-nucleon (NN) potential. The short-range central and tensor correlations induced by the NN interaction are imprinted in the correlated interaction, which can then be used within standard many-body methods and tractable Hilbert spaces. Starting from the Argonne V18 potential, a correlated two-body Hamiltonian has been derived and applied recently in nuclear structure and response calculations [1–4]. In this work we focus on nuclear collective excitations.

By employing the UCOM Hamiltonian in standard, first-order Random-Phase Approximation (RPA), a reasonable description of the properties of the Giant Monopole Resonance is achieved, whereas the energies of the Giant Dipole and Quadrupole Resonances are overestimated by several MeV [3]. The effect of explicit RPA correlations built in the ground state is examined in detail within a renormalized RPA version and is found to be rather small [5]. By contrast, the coupling to second-order configurations, as described within Second RPA, produces sizable corrections, which are found essential for the description of giant resonances using the UCOM Hamiltonian. Some discrepancies remain, probably due to residual three-body effects. Such effects can be included by means of a phenomenological three-body term supplementing the UCOM Hamiltonian.

References

[1] R. Roth *et al.*, *Phys. Rev. C* **72**, 034002 (2005).

[2] R. Roth *et al.*, *Phys. Rev. C* **73**, 044312 (2006).

[3] N. Paar *et al.*, *Phys. Rev. C* **74**, 014318 (2006).

[4] C. Barbieri *et al.*, submited to *Phys. Rev. C* (2006); `nucl-th/0608011`.

[5] P. Papakonstantinou *et al.*, *Phys. Rev. C* **75**, 014310 (2007).

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Evolution of the Dinuclear System in Fission, Quasifission, Incomplete and Complete Fusion

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The dinuclear system concept [1] can be used for the description of various physical processes: fission, quasifission, incomplete and complete fusion. Whereas in fission [2] the distribution of the dinuclear configurations is formed by starting from the compound nucleus, colliding heavier nuclei get captured into a touching or dinuclear configuration where a repulsive potential originating from the antisymmetrization (Pauli) principle prohibits the nuclei to approach closer and to fuse. The time evolution of the excited dinuclear system in the mass and charge asymmetry degrees of freedom can be treated with master equations for the proton and neutron numbers [3]. The basic process is the transfer of a single nucleon between the clusters leading to a change in their proton and neutron numbers. The decay of the dinuclear system contributes to quasifission (no compound nucleus is formed in contrast to fission) and to incomplete fusion originating from a very asymmetric cluster configuration before the system crosses the inner fusion barrier in the mass and charge asymmetry coordinates. If this barrier is overcome, the system fuses. Incomplete fusion gives the possibility to produce new isotopes of superheavy nuclei with charge numbers in the range of 104–108 [4].

References

[1] V.V. Volkov, *Izv. AN SSSR ser. fiz.* **50**, 1879 (1986).

[2] A.V. Andreev, G.G. Adamian, N.V. Antonenko, S.P. Ivanova, *Eur. Phys. J. A* **26**, 327 (2005).

[3] G.G. Adamian, N.V. Antonenko, W. Scheid, *Phys. Rev. C* **68**, 034601 (2003).

[4] G.G. Adamian, N.V. Antonenko, A.S. Zubov, *Phys. Rev. C* **71**, 034603 (2005).

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Exactly Separable Version of X(5) and Related Models

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One-parameter exactly separable versions of the X(5) and X(5)-β^2 models, labelled as ES-X(5) and ES-X(5)-β^2 respectively, are derived [1] by using in the Bohr Hamiltonian potentials of the form $u(\beta) + u(\gamma)/\beta^2$. Unlike X(5), in these models the β_1 and γ_1 bands are treated on equal footing. Spacings within the γ_1 band are well reproduced by both models, while spacings within the β_1 band are well reproduced only by ES-X(5)-β^2, for which several nuclei with $R_{4/2} = E(4_1^+)/E(2_1^+)$ ratios and [normalized to $E(2_1^+)$] β_1 and γ_1 bandheads corresponding to the model predictions have been found.

References

[1] D. Bonatsos, D. Lenis, E. A. McCutchan, D. Petrellis, and I. Yigitoglu, *Phys. Lett. B*, in press. nucl-th/0612101.

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Small Fermionic Systems, the Common Methods and Challenges

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We present recent results on structure pnd dynamical roperties of simple metal clusters. We focus on properties which have well known counterparts in nuclear physics, such as single particle energies and collective properties, and to the extent that these opbservables indeed give clues on the underlying structure of the clusters. We discuss in particular single electron properties (photo electron spectoscopy) and optical response (Mie surface plasmon). The latter is corresponding to the nuclear giant dipole resonance. It provides a bunch of relevant structure information, especially on structure details and shape. We also analyze the impact of temperature on this quantity, as temperature plays a central role in the physics of simple metal clusters.

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Description of the Low-Lying States of Odd-Even Nuclei within the Extended Random Phase Approximation

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The Random Phase Approximation (RPA) is often used for describing the properties of the excited states of even-even nuclei near the magic numbers. However this theory, based on the quasiboson approximation, is not applicable for nuclei far away from the valley of stability, because the ground states of these nuclei cannot be approximated by the Bogoliubov quasiparticles vacuum state.

To remove the above mentioned drawback, a theory which explicitly takes into account the distribution of the quasiparticles in the ground state (referred to as Extended Random Phase Approximation (ERPA)) was proposed by *K. Hara* [1] and later developed by *D. Karadjov et al.* [2].

In the present work, we develop a model, in which the states of the odd-even nuclei are obtained as a result of the interaction between an even-even core, described within the ERPA, and a particle outside of the core. The interaction strengths depend on the number of the quasiparticles in the ground state and therefore the core+particle equations cannot be solved independently but become a part of a larger non-linear system of equations including also generalized equations describing the pairing correlations and the excited vibrational states of the core. In the limit case, where the number of the quasiparticles in the ground state is set to zero, this system of equations decouples to reduce to the model obtained in *S. Mishev et al.* [3].

The proposed model does not have any additional free parameters.

References

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

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

[3] S. Mishev, V.V. Voronov, *Proceedings of the XXV International Workshop on Nuclear Theory*, (Rila Mountains, Bulgaria, June 26–July 1) 2006.

Collective and Single Particle Motion of Nuclei with Reflection Asymmetry

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The collective motion of nuclei with reflection-asymmetry shape instability can be described through the analytic solution of two-dimensional Schrödinger equation under the assumption of coherent interplay between quadrupole and octupole axial degrees of freedom. The model formalism reproduces parity split spectra with the attendant electric transition probabilities in both even-even and odd-A nuclei. The experimental data, especially in odd-A nuclei, show variety of indictions for the influence of the single particle motion on the collective behavior of the system. The connection between the collective shape characteristics of the nucleus and the intrinsic reflection-asymmetric shell structure is discussed. The possibility to study the Coriolis coupling between core and single particle through deformed reflection-asymmetric shell-model calculations is examined. The possible extension of the quadrupole-octupole formalism beyond the assumption of coherence is also discussed.

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Ratio of the Electric to Magnetic Form Factors in Nuclei

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A long standing question in nuclear physics is the effect of the nuclear medium on the properties of the nucleon. In this talk, we present a review of past and present efforts in the search for evidence of possible modifications of the nucleon form factors inside the nuclear medium, using the $(e, e'p)$ reaction. Particularly, we discuss the E89-044 experiment, which studied the quasi-elastic $^3\text{He}(e, e'p)^2\text{H}$ reaction at a transfer momentum $Q^2 = 1.5$ (GeV/c)^2 and three different beam energies of 1255, 1954 and 4807 MeV in the Hall A of Jefferson Laboratory. The extraction of the $^3\text{He}(e, e'p)^2\text{H}$ cross section has been performed with a fitting procedure method, using the simulation program MCEEP (Monte Carlo for Electro-Nuclear Coincidence Experiments), taking into account the effects of internal and external radiation and spectrometer resolutions. Unpolarized nuclear response functions have been separated for three different values of the longitudinal polarization of the exchanged photon ϵ. Possible changes in the structure of nucleons embedded in a nucleus are studied indirectly, via the ratio of Longitudinal and Transverse nuclear response functions. A comparison of extracted data with the predictions of the Relativistic Distorted Wave Impulse Approximation Madrid code is showed.

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Possible Chirality in the Oblate Doubly-Odd ^{198}Tl Nucleus

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In order to expand the present level scheme of ^{198}Tl [1] two complementary experiments both using the ^{197}Au(α,3n) reaction at a beam energy of 40 MeV were carried out. The first one was performed at iThemba LABS and was a γ-spectroscopy study with the AFRODITE array.The second experiment was performed with the Orsay electron spectrometer, consisting of two magnetic lenses positioned at 90° and 180° with respect to the beam direction, which directed the internal conversion electrons towards two large surface Si detectors, each one vertically segmented. Eight large (Eurogam phase one) Ge detectors were placed in the hemisphere opposite to the 90° lens. The γ-spectroscopy data from the first experiment was used to expand the level scheme of ^{198}Tl by studying γ coincidences, and carrying out DCO ratio and linear polarization measurements. The electron spectroscopy data were essential in searching for low-energy transitions and for multipolarity assignments through internal conversion measurements.

The known yrast band built on a $\pi h_{9/2} \times \nu\, i_{13/2}$ configuration was extended up to a bandcrossing region. A new 72 keV transition was placed at the bottom of this band using electron spectroscopy, and signature inversion was established. A partner band developing above a 10^- level was found. Strong M1 and sometimes E2 transitions link most of the levels of this band to levels of the yrast band. No configuration different from $\pi h_{9/2} \times \nu\, i_{13/2}$ seems to fit the observed spins, parities and excitation energies. These two bands look similar to the pairs of doublet bands identified in the mass 130 region. Possible interpretation in terms of chiral symmetry will be discussed.

References

[1] A.J. Kreiner, *et al.*, *Nucl. Phys. A* **282**, 243 (1977).

Probing a Variety of Nuclear Phenomena with DIAMANT and AFRODITE

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The DIAMANT light-charged-particle detector [1] has been coupled with the AFRODITE γ-ray spectrometer [2] through a project funded under an ongoing bilateral agreement between Hungary and South Africa. A number of measurements have been carried out at iThemba LABS with a variety of beams supplied by Separated Sector Cyclotron accelerator. These include studies of incomplete fusion reactions, high-K metastable states in stable hafnium nuclei, chiral structures in silver nuclei and superdeformation in ^{32}S. The analysis of these data-sets is at various stages of completion and the latest results will be presented. Plans for future measurements will also be discussed.

References

[1] J. N. Scheurer *et al.*, *Nucl .Instr. and Meth. A* **385**, 501 (1997).
[2] R. T. Newman *et al.*, *Balkan Phys. Lett.* Special Issue, p. 182 (1998).

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Comparison of Empirical Proton-Neutron Interactions with Growth Rates of Collectivity and Recent DFT Calculations

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Proton-neutron interactions give information about configuration mixing, collectivity and deformation in nuclei. Empirical p-n interactions in terms between the last proton(s) and last neutron(s) can be obtained from double differences of binding energies. We will discuss an interpretation with a simple shell model for both closed shell and deformed nuclei, as well as a relation between p-n interaction strengths and the growth rates of collectivity. We will also present results of recent calculations using the nuclear density functional theory.

Work was supported by the U.S. DOE Grant No. DE-F602-91-ER-40609.

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Charge Form Factor and Cluster Structure of ^{6}Li Nucleus

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The charge form factor of ^{6}Li is considered on the basis of the cluster structure of this nucleus. The charge density of ^{6}Li is presented as a superposition of two terms. One of them is a folded density and the second one is a sum of the charge densities of ^{4}He and the deuteron. Using the available experimental data for ^{4}He and the deuteron charge form factors, a good agreement of the calculations with the data for the charge form factor of ^{6}Li is obtained, including those in the region of large transferred momenta.

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Anharmonic Wobbling Motion

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The original model for the nuclear wobbling motion was presented by Bohr and Mottelson in 1970s. Despite its beauty in the theoretical framework, the wobbling phenomenon had not been observed until recently. However, as the experimental investigations go on, there appear many problems in the observed wobbling spectrum. One of them is a strong anharmonicity seen in the two wobbling phonon states. The energy spacing between the one- and two-phonon states are only half the spacing between the zero and one-phonon states. With macroscopic and microscopic approaches, we try to investigate the origin of this strong anharmonicity in the wobbling motion.

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On E0 Transitions in Even-Even Nuclei

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The energies and electromagnetic decay properties of the excited 0^+ states are important in determining the applicability of the models. (Shell model, Claster-vibrational model, Quasi-particle – phonon model, a deformed configuration mixing shell model, Interacting boson approximation, pairing quadrupole correlations)

We want to analyze and feel the gross-behavior of the E0 transition probabilities between different excited 0^+ states in the same nucleus coming from the transition charge density distribution and our approach parameters. For this purpose we calculate the transition matrix elements and compare our results with experiment.

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A New Look at Nuclear Supersymmetry

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A new approach to nuclear supersymmetry based on the non-compact orthosymplectic supergroup $OSp(4/12, R)$ is proposed. The latter is a supersymmetric extension of the dynamical symmetry group $Sp^B(12, R)$ of the symplectic Interacting Vector Boson Model (IVBM) used to describe energy spectra of the even-even nuclei. The even sector of the group $OSp(4/12, R)$ is used to describe energy spectra of the odd-mass nuclei. The energy levels of the neighboring even and odd nuclei are unified within a common unitary irreducible representation of $OSp(4/12, R)$. The correlations of the spectroscopic properties of the even and odd mass systems are examined through the odd generators of the supersymmetric group.

The theoretical predictions for some pairs of nuclei from the actinide and rare earth region are compared with the experimental data. The obtained results reveal the applicability of the models extension.

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sp(4,R)-Systematics of Atomic Nuclei. F-multiplets and Shell Structure

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Along with the well known systematics of the atomic nuclei in terms of proton number Z and neutron number N, it is considered a systematics, according to which the chart of the nuclei is situated in the frame given by the nucleon number $A = Z + N$ and $F = Z - N$ ($F = 2T_0$), where T_0 is the third projection of the isotopic spin. In this case the multitude of the nuclei splits in a natural way into two parts - the first one is given when A (and the corresponding F) is even, and the second one is consisted of nuclei for which A (and the corresponding F) is odd. It makes possible to map the nuclei into spaces of the two irreducible infinite oscillator representations of the non-compact algebra $sp(4, R)$. One can systematize the even-even and odd-odd nuclei (A - even) in the first one and the even-odd and odd-even nuclei (A - odd) in the other. In this context A and F are the first order Casimir operators of the compact subalgebra $u(2)$ and the non-compact subalgebra $u(1,1)$ respectively. According to this interpretation the nuclei are classified in isobaric multiplets corresponding to the irreducible representations of $u(2)$. On the other hand the nuclei are classified into multiplets corresponding to the irreducible representations of $u(1,1)$. These multiplets are called F-multiplets ($F = fix$).

The proposed systematics is suitable to study the behavior of nuclear mass excess Δ and half-life $T_{1/2}$. In particular, the behavior of Δ as a function of F at $A = fix$ has the known parabolic form in a very wide interval (up to $A = 260$). In the case of isobaric multiplets with even A, the mass excess Δ and its first and second discrete derivatives, considered as functions of F exhibit a staggering behavior, corresponding to the alternation of even-even and odd-odd nuclei. For even-A isobaric multiplets, with $A \leq 208$, and odd-A isobaric multiplets, with $A \leq 209$ and $229 \leq A \leq 253$, both, the minimum of the mass excess Δ and the maximum of the half-life $T_{1/2}$ are at the same value of F. For the odd $211 \leq A \leq 227$ this rule is not fulfilled, while for the even $A \geq 210$ and the odd $A \geq 255$ the situation is ambiguous.

The behavior of Δ as a function of the discrete argument A for a given F-multiplet ($F = fix$) is of a special interest. The corresponding curves

$\Delta = \Delta(A)|_{F=fix}$ are examined together with their first and second discrete derivatives. The absolute values of the derivatives and a specially constructed (in terms of discrete differences) function are also analyzed. All considered curves show periodically repeating properties.

As a main result many clear indications for the existence of the shell structure of the nuclei are established. All Z and N magic numbers giving the major shells are displayed by distinct changes in the behavior of the analyzed curves. Also, a set of sub-magic numbers (giving sub-shells) as 6, 16, 40, 162, etc. is well seen. Noticeable changes in the behavior of the curves are observed at other values of Z and N such as 18, 60, 76, etc. They can be interpreted as a sign of other possible substructures. The common impression is that the curves $\Delta A = |\Delta(A)|_{F=fix}$ together with their discrete derivatives contain a lot of information about the nuclei that is coming to be decoded and explained.

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Computer Algebraic Methods in the Theory of Nuclei

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Development and application of a software complex for mathematical simulation of transport of particles and nuclei in media from 10 MeV up to several TeV. Development of advanced models of statistic theory of equilibrium and non-equilibrium fissions of strongly excited post-cascade nuclei. Development of algorithms and software for modelling:

- in condensed matter physics
- interaction of pulsed beams with metal samples taking phase transitions into account;
- behaviour of atoms in magnetic trap;
- nonlinear effects in frames of continuous and lattice field models of nonlinear optics and condensed matter;
- in nuclear physics.

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Relativistic Corrections on the Ground State Energies of Helium Isoelectronic Series from Helium to Xenon for Main Nuclides and Their Isotopes

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Relativistic spinless corrections of the order of α^2 on the Ground State for Helium Isoelectronic Series with atomic number from $Z = 2$ to $Z = 54$, as well as for main nuclides and for the isotopes existing, are investigated. Calculations of non-relativistic Ground State Energies are performed using explicitly correlated trial wave-functions of the generalized Hylleraas type. Calculations are made without, and as well as with taking into account the mass correlations operator to the main Hamiltonian. Variational procedure is used, which allows a solving of the two-particle non-relativistic Schrodinger equation for a practically unlimited number of parameters in a series of trial wave functions along the positive degrees of Hylleraas coordinates. Non-conventional optimization methods are developed and particularly nonlinear programming is applied to solve the problem. The expectation values of the operators of relativistic corrections are given in analytical form, which is convenient to calculate the wave functions of the generalized Hylleraas type. Velocity corrections of the kinetic energy, the contact correction to the potential energy, the correction of Darwin and the orbit-orbit corrections, are calculated. Behavior of these corrections upon the atomic number Z, the dependence of the mass number A versus Z, as well as the influence of the mass polarization effects on their forming, are studied.

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