PREFACE

The XXII International Workshop on Nuclear Theory was held at Gjuletchitsa resort in Rila Mountains, Bulgaria, from 16-th to 22-nd June, 2003. It was attended by about 50 participants from 11 countries: Bulgaria, Brazil, Czech Republic, France, Germany, Greece, Hungary, Italy, Japan, Russia, USA. The workshop is an annual event organized by the Laboratory of Nuclear Theory of the Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences (INRNE, Sofia). The workshop was partly sponsored by the Nuclear Regulatory Agency and the Bulgarian Nuclear Society.

The main topics were:

- nucleon-nucleon correlation effects on nuclear structure and reactions;
- algebraic and field theory methods in nuclear theory;
- density functional theory for many-fermion systems.

The first working session was opened by Prof. L. Masperi In his talk, "Transition from Nuclear to Quark Matter", he discussed extremely large density and low temperature conditions where the stable phase of QCD is colour-superconducting and quarks of different flavours are paired. Prof. Masperi concludes that such a quark matter might be formed inside neutron stars. Further analysis of physics at higher temperatures could indicate whether the observed today strangelets can be interpreted as remnants of the primordial confinement transition. The lecture of Prof. H. von Geramb was devoted to relativistic nucleon-nucleon potentials. The formalism of coupled two-body Dirac equations within constraint instant form dynamics is used to study the nucleon-nucleon interaction. This particular approach for two spin 1/2 particles defines a Poincaré invariant interaction in terms of scalar, pseudo scalar, vector, and so on potentials. Prof. H. von Geramb presented numerical procedures for np and pp scattering phase shifts for energies in the range of 0-3 GeV. The adjustment of coupling constants and short range form factors yield high quality fits to the Arndt SP2003 phase shifts. Above $T_{Lab} = 300$ MeV an optical model term is added. *PP* data and their partial wave phase shifts suggest a transition from a repulsive core scattering to a short range attraction (barrier penetration scattering mechanism). The effect appears more clearly for $^1S_0$,$^3P_0$ and the $^3P_1$ channels at $1 < T_{Lab} < 3$ GeV. They lend support to a fusion/fission interpretation in which the two nucleons first fuse into a dibaryon then a fission is followed. The relativistic mean field (RMF) theory treating the meson degrees of freedom was discussed in talk given by Dr. S. Sugimoto. Authors formulate a model based on the RMF theory which treats the pion explicitly by breaking the parity symmetry of single-particle states. By applying the new model to N=Z nuclei, they demonstrate that the pion affects at large the nuclear mean field. A relativistic model of electromagnetic knockout emission applied to $(e, e'N)$ and (γ, N) cross-sections and polarizations was presented in the talk given by Prof. F. Pacati. The results for nonrelativistic energies are compared to those obtained within the distorted wave impulse approximation approach. The effect of two-body currents, like meson exchange contributions or isobar excitations, is discussed both in relativistic and nonrelativistic frame. Relativistic quantum field theory works well for the point-like particles such as electrons, but conceptual and technical problems arise for nucleons (protons and neutrons) which have a spatial extent. Chiral field soliton model (Skyrme model) is the model which leads to the localizable solitons with a finite size. The topological chiral solitons (skyrmions) are classical configurations presented by unitary matrix – $SU(2)$ or $SU(3)$ – and are characterized by topological or winding number identified with baryon number B. The classical energy (mass) of these configurations is found usually by minimization of energy functional depending on chiral fields. As other extended object skyrmions possess also moments of inertia, mean square radii of mass and baryon number distribution, etc. The variational approach to the problem of seeking axially symmetric solitons with $B = 12$ was presented in the lecture of Prof. V. Nikolaev. The numerically obtained local minima of the skyrmion mass functional and baryon charge distributions suggest a possible existence of shape isomers in C^{12} spectra in the the framework of the original Skyrme model.

Nucleon knockout reactions by using incident nucleons, $(p, 2p)$ and other (N, NN) reactions, provide useful means to study properties of the nucleon-nucleon (NN) interaction in nuclear field and nucleon bound-state wave functions. Within these reactions spin observables play essential role cancelling considerable parts of spin-independent ambiguities in nuclear structure and reaction mechanism. Prof. T. Noro reviewed present status of the experiments with special attention given to the analyzing powers and polarizations. He discussed their measurements at incident energies of 392 MeV taken at RCNP, Osaka, and at 1 GeV at PNPI, Gatchina, respectively. Dr. M. Gaidarov presented a semiclassical distorted wave (SCDW) model for multistep direct $(p, p'x)$ reactions. The model is based on use of Wigner distribution functions. They are constructed in two cases: where nucleon-nucleon correlations are accounted to a some extent; and where Woods–Saxon single-particle wave function are used. He stressed the crucial role of the higher momentum components of target nucleons in reproducing the high-energy part of the backward proton spectra. This SCDW model is applied to analysis of multistep direct processes in ^{12}C$(p, p'x)$, ^{40}Ca$(p, p'x)$ and ^{90}Zr$(p, p'x)$ in the energy range of 150–392 MeV. It was concluded that the results obtained with the Wigner distribution function derived on the basis of the coherent density fluctuation model provide in general a better agreement with the experimental data over the whole emission energies. Dr. K. Ogata talked about determination of S_{17} by systematic analysis on ^{8}B Coulomb breakup with the Eikonal-CDCC method. This method involves eikonal approximation of the center-of-mass motion of the projectile, which leads to easy to solve first-order differential coupled equations. Nucleon–nucleon correlations and final-state-interactions in electromagnetic knockout reactions are reviewed in the talk given by Prof. C. Giusti. In particular, the role of different types of correlations in the initial state and the influence of the mutual interaction between the two outgoing nucleons are considered. Numerical results were presented and discussed for different situations and kinematics. Dr. S. Dimitrova presented both infinite and finite system procedures of the Density Matrix Renormalization Group Method applied to realistic large shell-model calculations in the sd- and pf-shells. Results about ^{24}Mg and ^{48}Cr were reported. Prof. J. Libert presented Cranked Higher Tamm-Dancoff Approximation as a way to describe pairing correlations in Super Deformed sequences without spreading on the number of particles. After a brief survey of static problems for which this method has shown to be efficient and numerically tractable, recent progresses involving rotational Cranking constraints and, therefore, time reversal breaking and triaxiality have been produced. In context of the weak pairing which arises on increasing angular momentum, quasi-particle approximations lead to spurious phase transitions driving catastrophic accidents in the behaviour of the moment of inertia. The preliminary results obtained for the first Super Deformed (SD) band of ^{192}Hg (moments of inertia, evolution of correlations with angular momentum) have been compared with Cranked Hartree Fock Bogoliubov values (with and without Lipkin-Nogami approximate projection on the good particle number of particle) and discussed in view of the related experimental information. Quenching of pairing correlations as a simple model for rotating nuclei was discussed in Dr. H. Lafchiev's talk. Adding a Kelvin momentum constraint to the Routhian HF equations one can generate intrinsic vortical currents in the HF solution. It was found that one may simply reproduce in such a way the HFB dynamical properties of rotating nuclei especially in cases where the evolution of rotational properties is only governed by the coupling between the global rotation and the pairing-induced intrinsic vortical currents. Prof. S. E. Massen presented an application of the information entropy to nuclear theory. He calculates Shannon's information entropies in position- and momentum-space and their sum S for various s-p and s-d shell nuclei. It was found that the information entropy sum for a nucleus depends only on the correlation parameter through a simple relation.

Prof. D. Bonatsos presented new results about the X(5) symmetry, derived from the original Bohr collective Hamiltonian. He described nuclei related to the U(5)–SU(3) phase transition characterized by ratio $R_4 = E(4)/E(2)$ equal to 2.904. Using the same separation of variables as in X(5), an exactly soluble model with $R_4 = 2.646$ was constructed and its parameter independent predictions are compared to existing spectra and $B(E2)$ values. In addition, a chain of potentials interpolating between this new model and the X(5) symmetry is considered. Parameter independent predictions for the spectra and $B(E2)$ values of nuclei with R_4 ratios of 2.769, 2.824, and 2.852 were derived numerically and compared to existing experimental data, suggesting several new experiments. Prof. J. Cseh discussed in his talk the hidden symmetry and nuclear clusterization. The case of the effective symmetry based on the mathematical notion of embedded representation is not known in the classical mechanics, where the representations of the (symmetry) group usually do not play any essential role. In the talk presented it was shown that an effective SU(3) symmetry appears in heavy nuclei, and it can be useful in studying their (extremely) exotic cluster configurations. Dr. D. Lennis talked about chain of potentials interpolating between the U(5) symmetry of the 5-dimensional harmonic oscillator and the E(5) symmetry, corresponding to the U(5)–SO(6) phase transition. Dr. K. Sviracheva considered a q-deformed extension of a fermion realization of the compact symplectic $sp(4)$ algebra. The approach is used to describe pairing correlations and higher-order interactions in atomic nuclei. The obtained results suggest that the q-deformation has physical significance beyond what can be achieved by simply tweaking the parameters of a two-body interaction and the q-parameter. The additional degree of freedom was found to be closely related to isovector pairing correlations between nucleons. The q-deformation also plays a significant role in understanding the 'phase transitions' between regions of dominant and negligible higher-order interactions in finite nuclear systems. The talk given by Dr. A. Georgieva was devoted to the behavior of the first excited $K^\pi = 0^+, 2^+$ bands in deformed nuclei and its microscopic interpretation with the pseudo $SU(3)$-model. The energy spectra of these bands in the deformed nuclei are reproduced and interpreted microscopically, by an application of the proton-neutron version of the algebraic shell model with pseudo $SU(3)$ symmetry. Dr. Minkov presented results on evolution of octupole collectivity in the structure of nuclear rotational bands in the framework of a Quadrupole-Octupole Rotation Model. The developed formalism includes the lowest states of the spectrum in which the octupole degrees of freedom are not well pronounced. This model describes well the angular momentum region where the separate sequences of negative and positive parity levels merge into a single octuple rotational band. Isotope effects on the staggering patterns of light and heavy diatomic molecules were presented by Dr. A. Kuleff. In order to clarify the conditions under which the staggering phenomenon occurs and get some hints on its physical origin, the behaviour of the fourth-order finite difference $E^{(iv)}$

of rotational energies as a function of rotational quantum number J for different bands of heteronuclear diatomics involving nuclear isotopes was investigated. For upper and lower bands of both ^{197}AuH and ^{63}CuH the $\Delta J = 1$ sign alternation in the staggering pattern appears clearly larger than the errors induced by the measurement and calculation process. Dr. H. Ganev presented the description of the ground and octupole bands as yrast bands in the symplectic extension of the Interacting Vector Boson Model. In the framework of the IVBM, a good description of not only the positive, but also of the negative parity bands of the nuclei in the rare earth and the actinide region was achieved. With the recent advance of the experimental technique, the bands investigated in the model were extended to very high angular momenta. This motivated a new approach in the framework of the model aiming at the description of the first positive and negative bands, up to very high values of spin. In this new application, authors made use of the symplectic extension of the IVBM. This allows them to consider these bands as yrast bands. The $\Delta L = 1$ staggering effect between states from the two bands was also reproduced by the theoretical calculations.

Prof. W. Scheid described in his talk the quasifission within a microscopical transport model by using a system of master equations for the evolution of the dinuclear system in charge and mass asymmetry and its decay along the internuclear distance. He reported the calculated charge, mass and kinetic energy distributions of quasifission products. Prof. Scheid showed that the theoretically obtained yields of quasifission products and their distributions in kinetic energy are in agreement with recent experimental data of hot fusion reactions leading to superheavy nuclei. One of the main challenges in nuclear physics is to understand how nuclear structure arises from the interactions among the main "constituents" of the nucleus, the protons and the neutrons. Microscopic studies in neutron-rich matter were presented by Prof. F. Sammarruca. She demonstrated the calculated equation of state (EOS) in asymmetric nuclear matter using realistic nucleon-nucleon forces and the Dirac-Brueckner-Hartree-Fock framework. The approach is self-consistent and parameter-free. Predictions, as well as on-going and future applications such as calculations of neutron r.m.s. radii and neutron skins were discussed too. Microscopic predictions of these EOS-sensitive observables are crucial, especially in view of the possibility of measuring neutron distributions with unprecedented accuracy. This theme was continued by the talk given by Dr. G. Thiamova devoted to the systematic analysis of neutron-rich Carbon isotopes. The authors applied an improved version of the Antisymmetrized Molecular Dynamics (AMD) approach and re-analyzed the systematics of the C isotopes. In this approach the value of the r.m.s. radius is constrained during the cooling process and afterwards a lot of Slater determinants with different intrinsic structure (corresponding to different constrained r.m.s. radii) are superimposed. Binding energies, the excitation energies of the 2^+ states for the even-even C isotopes and the r.m.s. radii are calculated and compared with the experimental data. The behaviour of these quantities suggests the appearance of the N=16 magic number for the C isotopes. Furthermore, the calculated 2^+ energies of the even-even isotopes indicate the change from spherical to deformed structure at N=8.

In his talk Dr. V. Garistov presented a new glance at the collective spectra in even-even deformed nuclei. The available experimental data for the energies of the excited states with the J^π up to 8^+ for ^{176,178}Hf, ^{168}Yb, ^{156,160,162}Dy, ^{162,168}Er, ^{154}Gd isotopes can be presented as a parabolic distribution with integer classification parameter. This distribution of the low lying excited states energies turns to be appropriate for all nuclei under investigation. He pointed out that the Interacting Vector Boson Model is able to explain such a behavior with a very good accuracy. Dr. S. Lalkovski in his talk formulated an extended phenomenological approach for description and analysis of the ground-γ band mixing interaction in collective spectra beyond the regions of well deformed nuclei. It is based on the band coupling mechanism developed in the Vector Boson Model with SU(3) dynamical symmetry. The used approach could provide a relevant test of newly obtained experimental data and their interpretation in terms of the exact symmetry limits as SU(3), O(6) and U(5) as well as in terms of some phase transition symmetries as E(5) and X(5). The nuclear chirality has both dynamical and geometrical nature. The last is based on the distinction between left and right-handed coordinate systems fixed to the triaxial nucleus. The chirality is suggested to occur in triaxial doubly-odd nuclei with substantial asymmetry (γ=30^0), for which the Fermi surface of the valence proton (neutron) is near the bottom of high-j shell, while the neutron is at the top of a high-j shell. New experimental results on searching of chiral doublet bands at ^{186,188}Ir were presented in the talk by Dr. N. Nikolov. The experiments were performed at the WNSL of Yale University using of the YRASTBALL spectrometer. Chiral twin ΔI=1 bands with negative parity have been suggested in ^{188}Ir, having the $\pi h_{9/2} \otimes \nu i_{13/2}$ configuration. Mixed M1/E2 links, as well as similar ratios for the reduced transitions probabilities in the both bands have been observed, which reflects their common underlying structure.

The participants had opportunities to conquer attractive high mountain spots in the Rila Mountains. They also visited the famous Rila Monastery – a symbol of the Bulgarian Christianity – situated in the heart of the mountains.

The next XXIII Workshop on Nuclear Theory is planned to be held in June 2004.

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