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Thirteenth International Workshop on Nuclear Theory

Riia Mountains,
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(Abstracts)

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Thirteenth International Workshop on Nuclear Theory
Rila, Bulgaria

From 13^{th} to 18^{th} June, 1994, the 13^{th} International Workshop on Nuclear Theory was held at the Scientific House of the Sofia University "St. Kliment Ohridski" in the Rila Mountains for about 40 participants. The Workshop was organized by the Nuclear Theory group in the Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences (Sofia, Bulgaria). The sponsors of the Workshop were the Bulgarian National Science Foundation, the Bulgarian Committee of Atomic Energy, the Bulgarian National Academic Foundation ("Credit for Education") and Dr. Lilia Marinova (Chicago, U.S.A.).

The main topics of the nuclear theory treated in the lectures were nucleon correlation effects in nuclei (Prof. C. Ciofi degli Atti, Prof. A.N. Antonov, Dr. V. Garistov, Dr. D. Karadjov, Prof. M. Grypeos, M.K. Gaidarov), collective nuclear motions (Prof. R. Hilton), applications of group theory methods in nuclear physics (Prof. J.P. Draayer, Prof. G. Rosensteel, Dr. C. Daskaloyannis, Dr. D. Bonatsos, Dr. R. Asherova, N. Minkov, Tz. Dankova), Wigner quantum systems (Prof. T. Palev), pre-equilibrium neutron and proton emission from nuclei (Dr. M. Avrigeanu), particle–nuclei collision processes at high energies (Prof. V.K. Lukyanov, Prof. Yu.A. Berezhnoy), few–body states (Dr. A.D. Polozov), optical potential for neutron–nucleus scattering (Dr. J. Engel), relativistic generator coordinate calculations (Dr. M. Stoitsov) and variational nuclear structure calculations (Dr. V. Dimitrov).

In the rest hours the participants visited the beautiful lakes of the Malyovitza region of the Rila Mountains situated over 2000 m above sea–level as well as the complex for mountaineering "Malyovitza".

The Organizing Committee President was Professor I.Zh. Petkov. It is supposed that the next Workshop on nuclear theory will be held in June 1995.

A.N. Antonov and M.V. Stoitsov
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References of Talks

J.P. Draayer: "Algebraic Description of Deformed Nuclei."

R. Hilton: "Some Aspects of Descriptions of the Nuclear System in Rotation."

G. Rosensteel: "Casimirs of Collective Models."

Tz. Dankova: "Bifurcations of Rapidly Rotating Charged Ellipsoids."

N. Minkov, S.B. Drenska, P.P. Raychev and R.P. Roussev: "Description of Nuclear β- and γ-rotational Bands in the $SU_q(2)$-rotor Model."

M. Grypeos: "Nuclear Momentum Distribution in Light Nuclei."

D. Bonatsos, C. Daskaloyannis, D. Ellinas and A. Faessler: "Discretization of the Phase Space for a q-deformed Harmonic Oscillator with q a Root of Unity."

D. Bonatsos, C. Daskaloyannis, P. Kolokotronis and D. Lenis: "Symmetry Algebra of the Three-dimensional Anisotropic Quantum Harmonic Oscillator with Rational Ratio of Frequencies."

T. Palev: "Wigner Quantum Systems."

V. Garistov: "Large Range Correlations in Nuclei."

D. Karadjov, V. Voronov and F. Catara: "Effects of the Ground State Correlations Beyond the RPA on the Properties of Vibrational States."

C. Ciofi degli Atti: "N-N Correlations in Quasi-elastic and Deep-inelastic Lepton Scattering."

M. Avrigeanu, V. Avrigeanu, A. Harangozo and P.E. Hodgson: "Pre-equilibrium Neutron and Proton Emission in the Frame of Feshbach-Kerman-Koonin Theory."

M. Avrigeanu, V. Avrigeanu, A. Antonov, M.B. Chadwick, P.E. Hodgson and M.V. Stoitsov: "Pauli-Blocking Effects in Neutron-Alpha Reactions."

M. Gaidarov, A.N. Antonov, S.S. Dimitrova and M.V. Stoitsov: "Nucleon Correlation Effects on Y-scaling Quantities in Nuclei."

Yu.A. Berezhnoy: "The Mechanism of Intermediate Energy Deuteron-nucleus Interaction."

P. Quentin: "A Semiclassical Description of Large Amplitude Collective Motion and its Generalization to Other Models."

V. Lukyanov: "Three-dimensional Quasiclassics for Description of the Nuclear Collision Processes at High Energies."

V. Dimitrov: "Hybrid Symmetry-conserving Variational Procedure for Nuclear Structure Calculations."

M. Stoitsov, P. Ring and M. Sharma "Generator Coordinate Calculations for Giant Monopole Resonances in the Relativistic Mean-Field Theory."

A.D. Polozov: "Few-body Bound and Quasi-bound States in the Yukawa Model."

J. Engel: "Calculation of a T-violating Optical Potential for Neutron-nucleus Scattering."

R. Asherova, Yu. Smirnov and V. Tolstoy: "Wigner-Racah Algebras for Quantum Groups $SU_q(2)$ and $SU_q(3)$ and q-analyses."

BG96CC209

Nucleon–nucleon Correlations in Electron Scattering

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The concept of nucleon momentum distributions, $n(k)$, and spectral function, $P(k, E)$, are reviewed and the way short range and tensor correlations generate high momentum and high removal energy components is illustrated. The experimental information on both $n(k)$ and $P(k, E)$ obtained from exclusive and inclusive (y–scaling) electron scattering is reviewed and the evidence of NN correlation effects on these quantities are pointed out. Starting from some general assumptions about the nature of NN correlations in nuclei, a nucleon spectral function, valid for any value of A, is obtained in terms of a convolution formula involving the relative and center–of–mass momentum distributions of a correlated NN pair. This spectral function is applied to the calculation of inclusive electron scattering in the quasi–elastic, inelastic and deep–inelastic regions. It is demonstrated that quasi-elastic scattering at $x > 1$ can provide fundamental information about NN correlations and that, provided these are consistently taken into account both in initial and final nuclear states, a satisfactory explanation of the experimental data can be achieved in terms of nucleon degrees of freedom only.

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BG9600210

Pauli-blocking Effects in Neutron-alpha Reactions

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A model of (n, α) knockout reactions, in which restrictions on the available phase space for the four nucleons of the α-particle after the knockout is imposed by the Pauli-blocking function, is developed in analogy with the analysis of the quasideuteron photoabsorption. The results of the model are in agreement with the data for the excitation functions of (n, α) reactions on ^{48}Ti, ^{51}V, ^{52}Cr, ^{54}Fe, ^{55}Mn and ^{59}Co nuclei for the neutron energies between 13 and 20 MeV. It is shown that Pauli-blocking effects are important for describing (n, α) processes. A sensitivity study of the results to the values of the model parameters, namely the local Fermi energy at the nuclear surface from where knockout occurs and the α-particle preformation factor, shows that the ranges of their variations are quite limited. A consistent analysis of the same experimental data within the semi-classical Geometry-Dependent Hybrid and statistical Hauser-Feshbach models supports this conclusion.

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BG9600111

Effect of Ground State Correlations on the Properties of the Low-lying Vibrational States

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The problem of the ground state correlations (GSC) beyond the RPA leads [1,2] to a non-linear system of equations, which is solved numerically [3]. The influence of the GSC on the pairing is considered too [4]. Such a self-consistent calculation takes into account both: the mixing of different multipolarities and the Pauli blocking, due to the GCS. The inclusion of the GSC results in an essential suppression of the unphysical oscillations of the quadrupole charge transition density in nuclear interior as compared to the RPA calculations and enable one to reproduce the experimental data. The energies of the first quadrupole vibrational states are shifted down, coming closer to their experimental values. An example of these calculations is shown in the Table. An average nuclear field in Woods-Saxon form is used with a residual interaction in separable form with Bohr-Mottelson radial dependence in the isoscalar $p-h$ channel. The strengths of the residual force is fixed so as to reproduce the experimental value of the $B(E2)$-factors.

Table. Energies and $B(E2)$-factor of first 2^+ states in Zn-isotopes

Nucleus	Experiment		Calculations		
A	ω (MeV)	$B(E2)$ (e^2fm^4)	ω_{RPA} (MeV)	ω_{GSC} (MeV)	$B(E2)_{GSC}$ (e^2fm^4)
64	0.992	1597	1.16	0.90	1597
66	1.039	1426	1.33	1.02	1426
68	1.077	1360	1.39	1.25	1360
70	0.885	2050	1.32	1.05	2050

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BG9600212

Large Range Correlations in Nuclei.

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We apply the Nuclear Surface Oscillation (NSO) model in investigating nuclear structure, nuclear reactions and other processes in which the nuclear surface plays an important role is discussed. To understand quasi-elastic electron scattering on nuclei the scaling function can play an important role. We present scaling functions for all nuclei treated in the present paper. Our numerical results are compared with the results extracted from the quasi-elastic electron scattering data and the Hartree-Fock calculations. A large part of our investigation is dedicated to ^{4}He form factor and momentum distribution using the infinite well mean field with the oscillation of potential radius. We have a good agreement with the experimental data for all the characteristics under investigation.

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BG9600213

The Nucleon Momentum Distribution in Light Nuclei

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The nucleon momentum distribution in light nuclei is studied by means of a single particle potential model which consists of an attractive harmonic oscillator potential $V_a = 1/2m\omega^2r^2$ and also of a repulsive one of the form $V_r = B/r^2$, $B > 0$. The main advantage of this model is that it leads to fairly simple analytic expressions for the nucleon momentum distribution of light nuclei and also for the density distributions and the elastic form factor which in many cases give improved results, in comparison with those obtained with the harmonic oscillator potential. These expressions are quite useful in obtaining, for example, the asymptotic form of $\eta(k)$ for large k from which it is seen that the steep decrease of the nucleon momentum distribution observed with the harmonic oscillator model in this region is improved. Numerical results using various least squares fittings are obtained and discussed for a number of nuclei of the $1s$, $1p$ shell.

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BG9600214

Nucleon Correlation Effects on Y-scaling Quantities in Nuclei

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The asymptotic scaling function $F(y)$ and the binding correction $B(y)$ as well as the mean kinetic and removal energies are calculated in the cases of the ^{4}He, ^{12}C, ^{16}O and ^{40}Ca nuclei using the nucleon momentum distributions obtained within the Jastrow correlation method and the phenomenological model accounted for short-range and tensor nucleon-nucleon correlations. The scaling functions $F(y)$ differ from those obtained in the mean-field approximation and are in qualitative agreement with the available experimental data. It is shown that the binding correction $B(y)$ can be explicitly evaluated using a realistic nuclear spectral function. The account for the nucleon-nucleon correlations gives increased values of the mean kinetic $\langle T \rangle$ and mean removal $\langle E \rangle$ energy (in comparison with their values in the mean-field approximation) and leads to correct values of the binding energy per nucleon in the nuclei considered.

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BG9600215

Casimirs of Collective Models

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Collective models of rotating systems correspond to various subalgebras of the noncompact symplectic Lie algebra $Sp(3, R)$. The $ROT(3)$ subalgebra is the adiabatic rotational model in quantum mechanics and the Euler rigid body model in classical physics. The Casimirs of this algebra measure the shape of the rigid body and are given by the angular momentum scalars in the $ROT(3)$ algebra, namely, $Q.Q$ and $Q.(Q \times Q)$, where Q denotes the mass quadrupole operator. If the motion group is enlarged from the rotation group to the special linear group, then $ROT(3)$ is enlarged to $SCM(3)$, the special collective motion group. It has two Casimirs, one measures the nuclear volume and the other measures the nuclear circulation. Using the circulation Casimir enables the character of nuclear rotation to be determined. The symplectic Lie algebra has three Casimirs that relate shell structure to the geometrical observables. Methods of computing the values of these Casimirs are reviewed. The experimental measurement of the circulation is achieved in electron scattering from the $E2$ transverse form factor. The relationship between the subalgebra representations and the full symplectic shell model representation is reported. The analogous relationship in classical mechanics is also investigated.

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BY 9600116

Algebraic Description of Deformed Nuclei — Recent Applications and Future Directions —

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The purpose of this talk is to give a status report on the Symplectic Shell Model and its extension to heavy nuclei, the Pseudo Symplectic Scheme. These two algebraic theories are extensions of the Elliott $SU(3)$ Model and the Pseudo $SU(3)$ Scheme, respectively. They includes multiple $2\hbar\omega$ couplings as generated by the quadrupole-quadrupole interaction $(Q_\mu \approx r^2 Y_{2\mu})$ in a very natural way. It is for this reason that these two theories can be used to study phenomena that are sensitive to the momentum distribution of nucleons in the nuclear medium as measured through (e,e') scattering experiments (elastic as well as inelastic), for example, and as revealed through the one-body and higher order density matrices. The story begins with a straightforward demonstration that the $SU(3)$ symmetry of the isotropic harmonic oscillator leads directly to a microscopic foundation for rotational motion as realized via an asymmetric rotor description of even-even nuclei. The formal equivalence of these two is established by showing that upon contraction $SU(3)$ reduces to $T_5 \wedge SO(3)$, the symmetry group of the rotor. A discussion of vibrational degrees of freedom is then shown to lead to a paradox: the kinetic energy part of the collective model Hamiltonian transforms straight-away, but the potential energy appears to have no simple microscopic counterpart. The resolution of this paradox is shown to lie in a deeper appreciation for the role the Pauli Principle plays in determining the structure of atomic nuclei: it curtails deformation within a major shell by ruling out many-particle configurations that violate fermion statistics; it forces vertical mixing as allowed by the symplectic extension of the $SU(3)$ scheme to saturate the deformation requirements of the long range part of the nucleon-nucleon interaction. The extension of principles that apply for light nuclei ($A < 40$) to heavy ones ($A > 100$) is then shown to come about because of the occurrence of good pseudo-spin symmetry the heavier species. Progress on the search for the origin of good pseudo-spin symmetry in heavy nuclei is also discussed. A new interpretation for the role of pairing as a generator of asymmetric shapes is suggested and model results which demonstrate that for low-lying levels the nucleons in the intruder levels of heavy nuclei behave adiabatically relative to those in the complementary normal parity space are given. The latter can be used to simplify applications of the symplectic scheme as one can focus on the normal parity nucleons only, relegating effects from nucleons in the unique parity orbitals to renormalization status. A combination of horizontal and vertical mixing as generated, for example by pairing and the quadrupole-quadrupole interaction, is then put forward as the microscopic theory of choice, one that can be used to address questions that cannot be considered using theories like a $0\hbar\omega$ shell model or a mean field approximation, even though the latter normally includes vertical mixing.

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DQ 9600217

Some Aspects of Descriptions of the Nuclear System in Rotation

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The study of the rotating nuclear many-body system, even after some forty years of investigation, still attracts considerable attention in present day literature. In the first part of these lectures, the behaviour of the giant dipole resonance width recently observed in some heavy and light nuclei in states of high angular momentum and temperature will be considered. We discuss a novel interpretation of these observations as evidence for an effect, the nuclear analogue of a Foucault Pendulum. The ramifications, as a potential tool to probe the nuclear shape at high spins or establish absolute nuclear orientations will be discussed within the framework of a mathematically transparent model. In the second part of these lectures, we reconsider one of the most popular descriptions of the rotating nuclear system, the cranking model, and take a second and more critical look at the orthodox interpretation of its formulation.

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DQ 9600218

Discretization of the Phase Space for a q-deformed Harmonic Oscillator with q a Root of Unity

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The "position" and "momentum" operators for the q-deformed oscillator with q being a root of unity are proved to have discrete eigenvalues which are roots of deformed Hermite polinomials. The Fourier transform connecting the "position" and "momentum" representation is also found. The phase space of this oscillator has a lattice structure, which is a non-uniformly distributed grid. Non-equidistant lattice structures also occur in the cases of the truncated harmonic oscillator and of the q-deformed parafermionic oscillator, while the parafermionic oscillator corresponds to a uniformly distributed grid.

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BY9600119

Symmetry Algebra of the Three–dimensional Anisotropic Quantum Harmonic Oscillator with Rational Ratios of Frequencies

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The symmetry algebra of the three-dimensional quantum harmonic oscillator with rational ratios of frequencies is identified as a non-linear extension of the $u(3)$ algebra. The finite dimensional representation modules of this algebra are studied and the energy eigenvalues are determined using algebraic methods of general applicability to quantum superintegrable systems. The usefulness of these results in identifying the underlying symmetry of superdeformed and hyperdeformed nuclei is discussed.

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BY9600120

Wigner-Racah Algebra of $SU_q(2)$ and $SU_q(3)$ Quantum Groups and q-analysis

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We are continuing the constructing Wigner-Racah calculus of $SU_q(2)$ and $SU_q(3)$ algebras using the projection operators (PO) approach. Many elements of Wigner-Racah calculus such as Clebsch-Gordan coefficients, Racah coefficients, transformation matrices of the transition between different basises of irreducible representations of quantum algebras (similar to the case of usual nondeformed algebras) can be represented as matrix elements of PO for vectors of corresponding basises. For calculations these matrix elements of PO any explicit realization of generators and basis vectors of representations of algebra are unnecessary. Only commutation rules for generators, their Hermitian properties and the existence of the highest vector are enough. The calculating of matrix elements of PO brings to the sums of q-factorials. In addition to method of PO we used the some elements of q-analysis, namely, the summation formulae of q-factorial expressions.

Thus the method of the projection operators and the summation formulae of q-factorial expressions were being applied to :

i) the obtaining of different representation of Clebsch-Gordan coefficients for the $SU_q(2)$ quantum algebra (q-analogues of Van der Waerden, Wigner, Racah, Majumdar and others formulae);

ii) the constructing of $U-$, $V-$, $T-$ canonical basises of irreducible representation of $SU_q(3)$ algebra;

iii)the obtaining of the transformation matrices (so-called Weyl coefficients) of the transitions between these basises, which can be used for solution of multiplicity problem in calculating of the normalization Clebsch-Gordan coefficients of $SU_q(3)$ algebra.

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BG9600221

Description of Nuclear β- and γ-rotational Bands in the $SU_q(2)$-rotor Model

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The $SU_q(2)$-rotor Model, which was previously used for the description of the ground-state bands of deformed even-even nuclei, is applied to the cases of excited bands. The results of the $SU_q(2)$-calculations for β_1- and γ_1-rotational bands of rare earth and actinide nuclei are presented. It is pointed out that the model gives successful results in this extension. Also, it is obtained that the quantum algebraic parameter τ, fitted for γ_1-bands of Er- and Yb-isotopes, decrease significantly with increasing of the number of valence nucleon pairs N. This result confirms the previously proposed physical interpretation of the parameter τ in connection to the nuclear "softness". Further, using the q-generalized form of the Clebsh-Gordan coefficients of the $SU_q(2)$ algebra, q-deformed expressions for $B(E2)$-intraband transitional probabilities in γ_1-rotational bands are derived. In the case of β_1-bands $B_q(E2)$ is exactly the same as that previously obtained for the ground-state bands. It is shown that $B_q(E2; I+2 \rightarrow I)$-reduced probabilities increase with increasing of the angular momentum I for the both β_1- and γ_1-bands, while the corresponding rigid rotor values exhibit saturation. Moreover, in the case of $\triangle I = 1$-transitions in γ_1-bands, $B_q(E2; I+1 \rightarrow I)$-reduced probabilities increase with increasing of I, while in the rigid rotor limit one obtains well pronounced decrease. So obtained q-expressions for $B(E2)$ transitional probabilities have predictive character because of the insufficient experimental data, which due to the short life times and strong $M1$ mixing observed in the intraband transitions of the excited bands.

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BG9600222

Bifurcations in Rapidly Rotating Charged Ellipsoids

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Rapidly rotating nuclei are studied in the classical domain for which the potential energy is modeled by the sum of repulsive Coulomb and attractive surface energies. A very accurate approximation, valid for both small and large deformations, is reported for this potential. With the help of this approximation analytic formulae for angular momentum and circulation as functions of axis lengths are given. Bifurcation to triaxial shapes is investigated as a function of the nuclear fissility, circulation, and angular momentum. The bifurcation point for a given fissility depends sensitively upon the ratio of the circulation to angular momentum.

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BY9600223

Pre-Equilibrium Neutron and Proton Emission in the Frame of Feshbach-Kerman-Koonin Theory

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The energy and angular distributions of pre-equilibrium neutrons and protons from 15 MeV neutron induced reactions on ^{46}Ti, ^{48}Ti and ^{56}Fe are analyzed in the frame of the multistep compound (MSC) and multistep direct (MSD) theory formalism of Feshbach-Kerman-Koonin (FKK) [1].

Different energy dependences of the single-hole and excited particle state densities, of Fermi-gas model type and a linear dependence respectively are introduced in the exciton state density formula. The formalism is extended to take into account the surface effects [2] in the exciton state density in both MSC and MSD mechanism components of FKK formalism. Special attention is paid to obtain the Y functions for the MSC theory with these surface effects.

Furthermore, an advanced energy and exciton dependent pairing correction has added to the Pauli correction as already described in the semi-classical Geometry-Dependent-Hybrid Model [2],as well as shell correction exciton configuration dependence. The MSC and MSD codes : GAMME [3] and MUDIR [4] respectively were modified in this respect. The same parameter sets were used for both MSC and MSD calculations, the only free parameter being V_0 (the strength of the interaction) used only in MSD calculations. The value found in the best agreement with experimental data is V_0=35 MeV. For MSC calculations the entrance channel strength function has been obtained from the optical model transmission coefficients corrected for the direct inelastic scattering to discrete target levels.

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BY 9600224

Three-dimensional Quasiclassics for the High Energy Nuclear Collisions

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The method is presented for calculating the distorted waves in the case of the realistic nuclear potential with the Coulomb forces included. The method can be applied under the conditions $kR \ll 1$ and $E \ll V$ (the high energy approximation). Thus, one can avoid the traditional partial wave decompositions, for which in this case a very large number of terms is to be included. Using this method the amplitudes of elastic and inelastic scattering and nucleon transfer reactions are obtained in an analytical form. Applications are done for the GANIL data for the heavy ion collisions at energy of projectiles of several dozen MeV per nucleon.

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BY 9600225

The Mechanism of Intermediate Energy Deuteron-nucleus Interaction

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The intermediate energy deuteron-nucleus interaction is studied on the basis of diffraction theory. The differential cross sections of elastic scattering, inelastic scattering with excitation of the vibrational states of nuclei, dissociation, inclusive stripping reaction of deuterons are analyzed. The integrated cross sections of different processes of deuteron-nucleus interaction are also studied. The importance of the S-matrix approach is shown. It is noted that taking account of the nuclear surface diffuseness is important. The largest effect from the surface diffuseness is observed in the stripping cross section, where the Serber opaque and transparent models are combined. It is shown that the diffraction theory enables one to solve all main problems of deuteron-nucleus interaction.

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BY9600126

Few-body Bound and Quasi-bound States in the Yukawa Model

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The variational method, within the Hamiltonian formalism of quantum field theory, is used to derive relativistic fermion-antifermion wave equations with interactions mediated by a neutral scalar or pseudo-scalar meson fields. Approximate numerical solution of the obtained system of the coupled integral equations is presented for purely bound and decaying states in a wide range of masses and coupling constant.

The momentum space wave equations for any number of fermions interacting via a massive scalar field are obtained. These coupled equations are shown to be exactly solvable in the limit of fixed fermions. Approximate solutions are given in the two- and three-particle bound state case for various masses and strength of the coupling of the fermion and scalar fields.

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Generator Coordinate Calculations for Breathing-Mode Giant Monopole Resonance in the Relativistic Mean-Field Theory

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The breathing-mode giant monopole resonance is studied within the framework of the relativistic mean-field theory using the Generator Coordinate Method (GCM). The constrained incompressibility and the excitation energy of isoscalar monopole states are obtained for finite nuclei with various sets of Lagrangian parameters. A comparison is made with the results of nonrelativistic constrained Skyrme Hartree-Fock calculations and with those from Skyrme RPA calculations. In the RMF theory the GCM calculations give a transition density for the breathing mode, which resembles much that obtained from the Skyrme HF+RPA approach and also that from the scaling mode of the GMR. From the systematic study of the breathing-mode as a function of the incompressibility in GCM, it is shown that the GCM succeeds in describing the GMR energies in nuclei and that the empirical breathing-mode energies of heavy nuclei can be reproduced by forces with an incompressibility close to $K = 300$ MeV in the RMF theory.

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Calculation of a T-violating Optical Potential for Neutron-Nucleus Scattering

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I show how to calculate a T-violating optical potential for neutrons starting from a T-violating P-conserving NN interaction due to ρ or $A1$ exchange. The results are applied to a measurement of the T-violating "5-fold correlation" $(I \times \sigma.p)$ $(I.p)$ in the amplitude for neutron forward scattering from an aligned holmium target. The limits on P-conserving nuclear T-violation from this kind of experiment are approaching the level obtained in measurements of electric dipole moments in nucleons and atoms.

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Wigner Quantum oscillators

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We present three groups of noncanonical oscillators. By definition these are oscillators, for which the Hamiltonian and the Heisenberg equations are identical. The position and the momentum operators of each of the groups generate basic Lie superalgebras, namely $sl(1/3)$, $osp(1/6)$ and $osp(3/2)$. The $sl(1/3)$-oscillators have finite energy spectrum and finite-dimensions. The $osp(1/6)$-oscillators are related to the para-Bose statistics. The angular momentum s of the $osp(3/2)$-oscillators takes no more than three (half)integer values. In a particular representation $s=1/2$.

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