Fourteenth International Workshop on Nuclear Theory

Rila Mountains,
Bulgaria
June 14-19, 1995

(Abstracts)

The Workshop was partly supported by the Bulgarian National Science Foundation under contracts Φ – 406 and Φ – 415, the Bulgarian Committee of Atomic Energy and the Foundation "St.St. Cyril and Methodius".

Fourteenth International Workshop on Nuclear Theory
Rila Mountains, Bulgaria

From 14^{th} to 19^{th} June, 1995, the 14^{th} International Workshop on Nuclear Theory was held at the Scientific House of the Sofia University "St.Kliment Ohridsky" in the Rila Mountains for about 30 participants. The Workshop takes place every year and is organized by the Nuclear Theory Group in the Institute of Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences (Sofia, Bulgaria). The sponsors of the Workshop this year were the Bulgarian National Science Foundation, the Bulgarian National Committee for Peaceful Use of the Atomic Energy and the Foundation "St.St. Cyril and Methodius".

The topics of the nuclear physics treated in the lectures and contributions were short-range nucleon-nucleon correlations in nuclei (Prof. A.N. Antonov, Dr. S.S. Dimitrova, Dr. S. Massen, M.K. Gaidarov), relativistic scaling in nuclear matter and finite nuclei (Dr. M.V. Stoitsov, G. Stoicheva), hadron structure in chiral quark-meson theory (Dr. Chr.V. Christov), residual interaction strength and surface effects in the multistep reaction calculations (Dr. M. Avrigeanu), theoretical and experimental studies of heavy ion collisions (Prof. V.K. Lukyanov, Prof. E. Gadioli, Prof. K.A. Griduev), quantum algebraic approach to nuclear collective properties (N. Minkov), description of low-lying states in even-even nuclei (Dr. A.I. Georgieva), deformed oscillator potentials (Dr. D. Bonatsos), studies of solar neutrinos by I-127 detectors (Prof. S. Pittel) and gamma-ray astronomy of ultra-high energies (Prof. J. Stamenov).

The wonderful places for mountaineering in the Malyovitza region of the Rila Mountains enable the participants in the Workshop to have good rest hours after the lectures and discussions.

It is supposed that the next Workshop on Nuclear Theory will be held in June 1996.

A.N.Antonov and M.V.Stoitsov
Nuclear Theory Group,
Institute of Nuclear Research and
Nuclear Energy,
Bulgarian Academy of Sciences,
Sofia 1784, Bulgaria

List of Participants

Antonov A.N.	INRNE*, Sofia
Andrejtscheff W.	INRNE, Sofia
Avrigeanu M.	IPNE, Bucharest, Romania
Bonatsos D.	NCSR "Demokritos", Athens, Greece
Botchev B.	INRNE, Sofia
Christov Chr.V.	INRNE, Sofia
Delchev Ya.	INRNE, Sofia
Dimitrov V.	University of Sofia
Dimitrova S.S.	INRNE, Sofia
Elenkov D.	INRNE, Sofia
Gadioli E.	Università di Milano, Italy
Gaidarov M.K.	INRNE, Sofia
Georgiev V.G.	INRNE, Sofia
Georgieva A.I.	INRNE, Sofia
Gridnev K.	St. Petersburg University, Russia
Kadrev D.N.	INRNE, Sofia
Karadjov D.	INRNE, Sofia
Kutsarova T.	INRNE, Sofia
Lukyanov V.K.	Joint Institute for Nuclear Research, Dubna, Russia
Massen S.	University of Thessaloniki, Greece
Minkov N.	INRNE, Sofia
Pavlova K.A.	INRNE, Sofia
Pavlov R.	INRNE, Sofia
Pittel S.	Bartol Research Institute, U.S.A.
Roussev R.P.	INRNE, Sofia
Spasova K.	University of Shoumen, Bulgaria
Stamenov J.	INRNE, Sofia
Stoicheva G.	University of Sofia
Stoitsov M.V.	INRNE, Sofia
Terziev P.A	INRNE, Sofia
Tzoneva N.	University of Plovdiv, Bulgaria
Vankov Chr.	INRNE, Sofia

*Institute for Nuclear Research and Nuclear Energy

References of Talks

V.K. Lukyanov: "The High-energy Approximation Method for Description of Heavy Ion Collisions"

S.E. Massen: "Effects of Short Range Correlations on the Ca and O isotopes"

Chr.V. Christov and K. Goeke: "Hadron structure in a chiral quark-meson theory"

A.N. Antonov, S.S. Dimitrova, M.K. Gaidarov, M.V. Stoitsov, M.E. Grypeos, S.E. Massen and K.N. Ypsilantis: "Realistic One-body Density Matrix in Nuclei"

M.K. Gaidarov, A.N. Antonov, G.S. Anagnostatos,S.E. Massen, M.V. Stoitsov and P.E. Hodgson: "Proton Momentum Distribution in Nuclei beyond Helium-4"

N. Minkov, P.P. Raychev and R.P. Roussev: "Nuclear Deformation in the $su_q(2)$-rotor Model"

Stuart Pittel: "What's SNU with Iodine?"

D. Bonatsos, C. Daskaloyannis and H.A. Mavromatis: "Quasi-Exactly Soluble Potentials and Deformed Oscillators"

M.V. Stoitsov, G. Stoicheva, P. Ring and M. Sharma: "Relativistic Scaling in Symmetric Nuclear Matter"

M.V. Stoitsov, G. Stoicheva, P. Ring and M. Sharma: "Relativistic Scaling in Finite Nuclei"

E. Gadioli: "Complete and incomplete fusion reactions and pre-equilibrium emission in the interaction of ^{12}C and ^{16}O with nuclei below 10 MeV/Amu"

M. Avrigeanu, A. Harangozo, V. Avrigeanu and A.N. Antonov: "Residual Interaction Strength and Surface Effects in Multistep Reactions Calculations"

S. Drenska, A. Georgieva, V. Gueorguiev, R. Roussev and P. Raychev: "Unified Description of the Low Lying States of the Ground Bands of the Even-Even Nuclei"

A.N. Antonov, M.V. Stoitsov, M.K. Gaidarov, S.S. Dimitrova and P.E. Hodgson: "The Hole Spectral Function and the Relationship between Overlap Functions, Natural Orbitals and the One-body Density Matrix in Nuclei"

M.V. Stoitsov, S.S. Dimitrova and A.N. Antonov: "Restoration of Overlap Functions and Spectroscopic Factors in Nuclei"

D.N. Kadrev, A.N. Antonov, M.V. Stoitsov and S.S. Dimitrova: "Natural Orbitals and Electron Elastic Magnetic Scattering by Nuclei"

K.A. Gridnev: "Nonlinear Schroedinger Equation and Elastic Scattering of Heavy Ions"

J. Stamenov: "Recent problems of the astrophysics and gamma-ray astronomy of ultra high energies"

BG9600231

Complete and incomplete fusion reactions and pre-equilibrium emission in the interaction of ^{12}C and ^{16}O with nuclei below 10 MeV/Amu

E. Gadioli

Dipartimento di Fisica, Università di Milano, Istituto Nazionale di Fisica Nucleare, Sezione di Milano

A great deal of information on nuclear reaction mechanisms is obtained by the comprehensive study of all or a large number of the reactions which may occur when two nuclei interact. This is possible with the activation technique which may provide accurate measurements of cross-sections and of the energy and the angular distribution of the heavy radioactive residues. A great number of experiments of this type was made in case of light particle induced reactions, while few measurements of this type are reported in literature for heavy ions. This is perhaps due to the fact that in this case many different mechanism may contribute to the formation of a given residue including decay of precursors which in many instances are created with much higher cross-sections. However, an accurate set of measurements of a large number of cross-sections and recoil range and angular distributions of heavy fragments may allow one to separate the contribution of independent production from precursor decay and disentangle the mechanisms which contribute to a given reaction. A systematic study of this type, has been made in the case of the reactions induced by ^{12}C and ^{16}O on heavy nuclei at incident energies below 10 MeV/nucleon and has provided interesting information, including the accurate measurement of fusion and incomplete fusion reaction cross sections, and the evidence for pre-equilibrium nucleon emission. This study has been recently carried out at higher incident energies using as a target a medium heavy nucleus such as ^{103}Rh, to reduce as much as possible the contribution of fission which, in the case of heavy nuclei, is expected to become dominant with increasing incident energy.

The analysis of these data shows that an accurate reproduction of the amount of pre-equilibrium decay in complete fusion events is possible also at the lowest considered energies using the *Boltzmann Master Equation* theory. The results of the calculation critically depend on the initial energy distribution of the nucleons of the composite nucleus. This is evaluated assuming that at the lowest energies the projectile and the target, slowed down by their Coulomb field, form a long lasting di-nuclear system while nucleons migrate from the projectile to the target and *viceversa* through the window which forms as soon as the two nuclei overlap and start a cascade of nucleon-nucleon interactions.

The incomplete fusion reactions are reproduced with a reasonable accuracy by assuming that the incomplete fusion occurs by a break-up-fusion mechanism, that is the quasi-elastic break-up of the projectile followed by the fusion of one of the fragments with the target nucleus.

* * *

What's SNU with Iodine?

Stuart Pittel

Bartol Research Institute, University of Delaware, Newark, DE 19716 USA

In 1988, Haxton proposed the use of ^{127}I as the active element in a new solar neutrino detector. He estimated that a tank filled with 1000 tons of iodine would detect roughly 20-30 times as many ^{8}B neutrinos as the existing chlorine detector in the Homestake mine. If true, an iodine detector could achieve the high statistics required to study temporal variations in the solar neutrino signal, a characteristic feature of several of the proposed solutions to the solar neutrino puzzle. Equally important, he suggested that such a detector might be especially sensitive to ^{7}Be neutrinos. A ^{7}Be-sensitive detector would be very attractive since pinning down the ^{7}Be flux now seems to be a crucial step to resolving the solar neutrino puzzle.

Several important questions remained following Haxton's proposal. How good was his original estimate of the ^{8}B response? And, would such a detector indeed be highly sensitive to ^{7}Be neutrinos? To address these questions, we have carried out a series of calculations, aimed at an optimum description of the response of ^{127}I to solar neutrinos. The results of this analysis have been reported in refs. 2 and 3.

The key conclusions of the analysis are as follows:

- For comparably sized tanks, an iodine detector would be roughly an order of magnitude more sensitive to ^{8}B neutrinos than a chlorine detector, somewhat less of an enhancement than estimated by Haxton, but still sufficient to make it attractive as a high-statistics detector.
- For an iodine detector, the relative response of ^{7}Be to ^{8}B neutrinos is roughly a factor of 4 larger than for chlorine, supporting the idea that it could provide a uniquely ^{7}Be-sensitive detector of solar neutrinos.

Based in large part on these calculations, an iodine detector is now under development. A prototype tank has been built and is being tested at the University of Pennsylvania. Later this year, the experiment will be placed in the same Homestake mine as the existing chlorine experiment.

1. W.C. Haxton, Phys. Rev. Lett. **60** (1988) 768.
2. J. Engel, S. Pittel and P. Vogel, Phys. Rev. Lett. **67** (1991) 426.
3. J. Engel, S. Pittel and P. Vogel, Phys. Rev. **C50** (1994) 1702.

* * *

ZY 9600133

Residual Interaction Strength and Surface Effects in Multistep Reactions Calculations

M. Avrigeanu[1], A. Harangozo[1], V. Avrigeanu[1] and A.N. Antonov[2]
[1]*Institute of Physics and Nuclear Engineering, P.O. Box MG-6, 76900 Bucharest, Romania*
[2]*Institute for Nuclear Research and Nuclear Energy, Sofia 1784, Bulgaria*

The successful application of the quantum-mechanical theory of Feshbach, Kerman and Koonin (FKK) [1] to multistep direct (MSD) and multistep compound (MSC) preequilibrium nucleon emission from nucleon-induced reactions up to 200 MeV (e.g. [2]) has been followed by recent improvements of the physics modelling and analyses of the sensitivity to input parameters. On the other hand, it has been underlined that the specific experimental data do not impose sufficient constraints on the theoretical preequilibrium emission (PE) models, so that most of them could be equally well reproduced in terms of different approaches (by adjustment of parameters always involved even in the "parameter free" models) [3]. Things are explained by the different treatment of the *special* PE parameters and the *external* ones which describe general nuclear quantities [4].

Particle-hole state densities are among the main *external* parameters of the FKK theory, although the equidistant spacing model (ESM) state density of Williams [5] is still widely used. However, an increased criticism has recently been expressed on the phenomenological single-particle state (s.p.s.) density $g = A/14$ MeV^{-1} which is inconsistent with the number of A nucleons in the nucleus [6, 7]. Further indication for s.p.s. energy dependence of Fermi gas model (FGM) type below the Fermi level, and linear above this level was obtained by Herman *et al.* [6], while the assumption of equal s.p.s. densities for excited particles and holes was also shown to be a crude approximation even at low excitation energies. A realistic particle-hole state density including different energy-dependencies of the hole- and excited particle state densities has recently been used [8] in the geometry-dependent hybrid (GDH) semiclassical PE model [9]. A similar attempt has been done for the MSD and MSC processes in the framework of the FKK theory [10]. Additional analysis concerning the PE surface effects, which are taken into account by decreasing the Fermi energy for interactions at the nuclear surface [11], is the aim of the present work.

First, the main points of the FKK formalism and implemented particle-hole state densities with energy-dependent s.p.s., and corrections for the finite nuclear potential depth, Pauli, pairing and shell effects are presented. Next, the criteria concerned in setting the statistical input parameters which are also involved within the quantum-mechanical theory, as well as their test by means of semiclassical calculations of reaction cross sections are described. Results of the FKK theory and comparison with experimental data are given including parallel analysis of surface effects, linking of the MSD and MSC processes, and shell effects. Finally, following previous assumption of the dependence of effective N-N interaction strength V_0 (treated as the only free parameter of the FKK theory) by the nuclear matter density, possible connection between V_0 and the Fermi energy at the nuclear surface is analyzed.

References

[1] H. Feshbach, A. Kerman, S. Koonin, Ann. Phys. (NY) **125**, 429 (1980).

[2] E. Gadioli and P.E. Hodgson, *Pre-Equilibrium Nuclear Reactions* (Oxford University Press, Oxford, 1992).

[3] M. Herman and G. Reffo, in I.A.E.A. Report INDC(NDS)-247/L, Vienna, 1991, p. 225.

[4] P.E. Hodgson, in *Nuclear Data for Science and Technology*, edited by S. Igarasi (Saikon, Tokyo, 1988), p. 655.

[5] F.C. Williams, Nucl. Phys. **A166**, 231 (1971).

[6] M. Herman, G. Reffo, M. Rosetti, G. Giardina, and A. Italiano, Phys. Rev. C **40**, 2870 (1989).

[7] M.B. Chadwick and G. Reffo, Phys. Rev. C **44**, 919 (1991).

[8] M. Avrigeanu and V. Avrigeanu, J. Phys. G **20**, 613 (1994).

[9] M. Blann and H.K. Vonach, Phys. Rev. C **28**, 1475 (1983).

[10] M. Avrigeanu, A. Harangozo, and V. Avrigeanu, in *Proceedings of the 7th International Conference on Nuclear Reaction Mechanisms*, Varenna, 1994, edited by E. Gadioli (Ricerca Scientifica ed Educazione Permanente, Milano, 1994), p. 165.

[11] C. Kalbach, Phys. Rev. C **32**, 1157 (1985).

* * *

The High-energy Approximation Method for Description of Heavy Ion Collisions

V.K. Lukyanov

Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, 141980 Dubna (Moscow region), Russia

For calculating the heavy ion scattering and transfer reactions, DWBA is used with relative-motion quasiclassical functions whose phases are computed within the high-energy approximation developed in [1,2]:

$$\Psi^{(\pm)} = \exp\{i(\vec{k} \mp \frac{\vec{q}_c}{2})\vec{r} - \frac{i}{\hbar v}\int_{\mp\infty}^{z} V(\sqrt{\rho^2+\lambda^2})d\lambda \pm \frac{1}{\hbar v}\int_{\mp\infty}^{z} W(\sqrt{\rho^2+\lambda^2})d\lambda\}, \qquad (1)$$

where $q_c = 2k\alpha_c = 2k\sin(\theta_c/2)$ is the momentum of a deflection of the classical path from the asymptotic direction $\vec{k}$, while the classical limited angle of scattering is $\theta_c \simeq V(R_t)/E$. The corresponding amplitudes are as follows:

$$T = -\frac{m}{2\pi\hbar}\int d\vec{r}\Psi_f^{(-)*}\hat{O}\Psi_i^{(+)}, \qquad (2)$$

$$\hat{O}_{el} = V(r,R), \quad \hat{O}_{inel} \sim \frac{dV(r,R)}{dR}Y^*_{\lambda\mu}(\hat{r}), \quad \hat{O}_{tr} \sim u_\lambda(r)Y^*_{\lambda\mu}(\hat{r}). \qquad (3)$$

It has been shown that each of them is determined by the poles $r_n = R \pm ia\pi(2n+1), n = 0,1,2...$ in the complex r-plane, where R and a are the radius and "thickness" of the interaction potential. Thus, the amplitudes can be obtained in an analytic form, which have the typical behaviour:

$$T_{fi} \sim e^{-a\pi(\theta-\theta_c)}F(\theta,\theta_c,R). \qquad (4)$$

One can see that the slope of an angular distribution is very sensitive to the "thickness" of the corresponding surface of a nuclear collision which depends on a mechanism of a process. Then, the absolute value of a cross section is proportional to the corresponding structure factor, e.g. to $B(E_\lambda)$ for inelastic scattering, and to the spectroscopic factor S_λ for transfer reactions. A good comparison was obtained with the data from GANIL for the HI collisions at $E \approx 100MeV/N$ and $\theta > V/E$ [3,4].

References

1. Lukyanov V.K., Bull. of Russ.Acad.of Sc., Physics, 58 (1994) 8;

2. Lukyanov V.K., Preprint JINR (Dubna), E4-314-94; Proc. 7th Int. Conf.on Nucl. React. Mechanisms (Varenna, 1994), ed. by E.Gadioli, Ed. curata da CittaStudi Edizioni, Milano, P.207.

3. Lukyanov V.K., Gridnev K.A., Embulaev A.V., Bull. of Russ.Acad.of Sc., Physics, 58 (1994) 19. Lukyanov V.K., Embulaev A.V., Permyakov V.P., JINR Rapid Comm., 4[67]-94, p.12, Dubna, 1994.

4. 4 Fedotov S.I. and Lukyanov V.K., JINR Rapid Comm., 4[67]-94, p.5, Dubna, 1994. S.I. Fedotov, K.A. Gridnev, V.K. Lukyanov, Preprint E4-94-35, Dubna, 1994.

* * *

Nonlinear Schroedinger Equation and Elastic Scattering of Heavy Ions

K.A. Gridnev
St. Petersburg University, Institute of Physics, 198904, St. Petersburg, Ul'anovskaia 1, Russia
E-mail: Gridnev@Phim.niif.spb.su

The physics leading from hydrodynamics to a nonlinear Schroedinger equation $\sim \psi^3$ is recalled. The final expression given previously is re-written in terms of a partial-wave expansion and the equation is solved numerically. Applications to the elastic scattering of heavy ions lead to a nice correspondence of the differential cross-sections to experiment and to consistent values of the nuclear compressibility modulus, K = 230 MeV. Besides it, anomalous large angular scattering was described rather well.

* * *

Effects of Short Range Correlations on the Ca and O isotopes

S.E. Massen
Department of Theoretical Physics
Aristotle University of Thessaloniki
GR-54006 Thessaloniki, Greece

The effect of short range correlations on the *Ca* and *O* isotopes has been studied by using an isospin dependence of the harmonic oscillator spacing, $\hbar\omega$ and of the correlation parameter. The analysis indicates that short range correlations as well as the isospin dependence of the parameters are important to explain the behavior of the differences of the MS charge radii and the differences of the charge densities between the *Ca* and the *O* isotopes.

* * *

BY9600237

Quasi-Exactly Soluble Potentials and Deformed Oscillators

Dennis Bonatsos [1,2*], C. Daskaloyannis[3†] and Harry A. Mavromatis[4‡]

[1] European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*) Strada delle Tabarelle 286, I-38050 Villazzano (Trento), Italy

[2] Institute of Nuclear Physics, NCSR "Demokritos" GR-15310 Aghia Paraskevi, Attiki, Greece

[3] Department of Physics, Aristotle University of Thessaloniki GR-54006 Thessaloniki, Greece

[4] Physics Department, King Fahd University of Petroleum and Minerals Dhahran 31261, Saudi Arabia

It is proved [1] that quasi-exactly soluble potentials (QESPs) corresponding to an oscillator with harmonic, quartic and sextic terms,

$$V(x) = 8a^2x^6 + 8abx^4 + 2[b^2 - (2k+3)a]x^2,$$

where $k = 2n + r$, $n = 0, 1, 2, \ldots$ and $r = 0, 1$ for which the $n + 1$ lowest levels of a given parity $(-1)^r$ can be determined exactly, may be approximated by WKB equivalent potentials [2] corresponding to deformed anharmonic oscillators of $SU_q(1,1)$ symmetry, which have been used for the description of vibrational spectra of diatomic molecules [3]. This connection allows for the immediate approximate determination of all levels of the QESPs.

Furthermore, a new class of quasi-exactly soluble potentials with

$$V(x) = 2a^6x^4 + 4a^4bx^3 + a^2cx^2/b + (c - 2b^3 - 2a^3(n+1))x$$

is determined. It is shown that for given n the first $n+1$ eigenvalues and eigenfunctions can be found analytically. The relation of these potentials to vibrational molecular spectra, to double-well potentials with linear symmetry breaking, and to the spherically symmetric anharmonic oscillator is discussed. In addition, isolated exact solutions for potentials of the form $V(x) = \sum_{i=1}^{2n} a_i x^i$ are obtained.

[1] D. Bonatsos, C. Daskaloyannis and H.A. Mavromatis, Phys. Lett. A 199 (1995) 1.
[2] D. Bonatsos, C. Daskaloyannis and K. Kokkotas, J. Math. Phys. 33 (1992) 2958.
[3] D. Bonatsos, E.N. Argyres and P.P. Raychev, J. Phys. A 24 (1991) L403.

* * *

*e-mail: bonat@ectstar.ect.unitn.it
†e-mail: daskaloyanni@olymp.ccf.auth.gr
‡e-mail: facm007@sanpm00.bitnet

Realistic One-body Density Matrix in Nuclei

A.N. Antonov[a], S.S. Dimitrova[a], M.K. Gaidarov[a], M.V. Stoitsov[a], M.E. Grypeos[b], S.E. Massen[b], K.N. Ypsilantis[b]
[a]*Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia 1784, Bulgaria*
[b]*Department of Theoretical Physics, Aristotle University of Thessaloniki, Thessaloniki 54006, Greece*

A phenomenological method based on the natural orbital representation is applied to construct the ground state one-body density matrix which describes correctly both density and momentum distributions in ^{16}O and ^{40}Ca nuclei. The parameters of the matrix are fixed by a best fit to the experimental density distribution and to the correlated nucleon momentum distribution. The method allows the natural orbitals, the occupation probabilities and the depletion of the Fermi sea to be obtained. Ground-state characteristics of ^{16}O and ^{40}Ca nuclei, such as rms radii and mean kinetic energies are calculated, as well.

* * *

Proton Momentum Distribution in Nuclei beyond Helium-4

M.K. Gaidarov[1], A.N. Antonov[1], G.S. Anagnostatos[2], S.E. Massen[3], M.V. Stoitsov[1], P.E. Hodgson[4]
[1]*Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia 1784, Bulgaria*
[2]*Institute of Nuclear Physics, NCSR "Demokritos", Aghia Paraskevi-Attiki, 15310 Greece*
[3]*Department of Theoretical Physics, University of Thessaloniki, GR-54006 Thessaloniki, Greece*
[4]*Nuclear Physics Laboratory, Department of Physics, University of Oxford, Oxford OX1-3RH, U.K.*

Proton momentum distributions of the ^{12}C, ^{16}O, ^{40}Ca, ^{56}Fe and ^{208}Pb nuclei are calculated by a model using the natural orbital representation and the experimental data for the momentum distribution of the ^4He nucleus. The model allows realistic momentum distributions to be obtained using only hole-state natural orbitals (or mean-field single-particle wave functions as a good approximation to them). To demonstrate the model two different sets of wave functions were employed and the predictions were compared with the experimental data.

* * *

The Hole Spectral Function and the Relationship between Overlap Functions, Natural Orbitals and the One-body Density Matrix in Nuclei

A.N. Antonov[1], M.V. Stoitsov[1], M.K. Gaidarov[1], S.S. Dimitrova[1], P.E. Hodgson[2]

[1]*Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia 1784, Bulgaria*

[2]*Nuclear Physics Laboratory, Department of Physics, University of Oxford, Oxford OX1-3RH, U.K.*

A new theoretical method to obtain the hole spectral function in the discrete part of the spectrum is suggested. The method is based on the natural orbital representation in nuclear theory and uses essentially both the natural orbitals and overlap functions as well as their relationship with the one-body density matrix (OBDM). The theoretical point of the method consists in the possibility of using the OBDM which is related to the properties of the A-nucleon system to calculate the hole spectral function which determines the cross-section of the nucleon removal processes and gives information on the structure of the $(A-1)$-nucleon system. The applications of the method can serve also as a test of the predictions of the correlated methods concerning the OBDM of the correlated ground state of the A-nucleon system.

* * *

Natural Orbitals and Electron Elastic Magnetic Scattering by Nuclei

D.N. Kadrev, A.N. Antonov, M.V. Stoitsov and S.S. Dimitrova

Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia 1784, Bulgaria

Natural orbitals obtained within the coherent density fluctuation model and containing nucleon correlation effects are used to calculate characteristics of the A–nucleon system, such as the electron elastic magnetic scattering form factors. The calculations are performed for nuclei with a doubly–closed core and a valence nucleon in a stretched configuration ($j = l + 1/2$), such as the ^{17}O and ^{41}Ca nuclei. It is shown that the calculations of the transverse form factor using natural orbitals improve the agreement with the experimental data in comparison with the case when shell–model single–particle wave functions are used.

* * *

Unified Description of the Low Lying States of the Ground Bands of the Even-Even Nuclei

S. Drenska, A. Georgieva, V. Gueorguiev, R. Roussev, P. Raychev
Institute of Nuclear Research and Nuclear Energy,
Bulg. Acad. of Sci., Tzarigradsko shosse 72, 1784 Sofia, Bulgaria

An unified description of the low-lying excited states of the ground bands of the even-even nuclei throughout the periodic table is obtained.

A new variable ω in the geometrical part of the interaction

$$E_L = \alpha L(L+\omega)$$

, characterizing the different types of collective modes -rotational $\omega = 1$, vibrational $\omega > 15$ and transitional $1 < \omega < 15$ is evaluated and analyzed for each of the considered nuclei.

We unify the description of collective levels of all even-even nuclei by evaluating the dynamical coefficient α of the interaction, as a quadratic function of the nuclear shell quantum numbers:

$$\begin{array}{rclcl} A_p & = & N_p^{(1)} + N_p^{(2)}, & & A_n = N_n^{(1)} + N_n^{(2)}, \\ N & = & \frac{1}{2}(N_p + N_n), & & F_0 = \frac{1}{4}(N_p - N_n), \\ \bar{N} & = & \frac{1}{2}(\bar{N}_p + \bar{N}_n), & & \bar{F}_0 = \frac{1}{4}(\bar{N}_p - \bar{N}_n). \end{array} \quad (1)$$

where the labels $N_p^{(1)}$, $N_n^{(1)}$ and $N_p^{(2)}$, $N_n^{(2)}$ denote the proton and neutron magic numbers at the beginning and at the end of the shell, respectively; $(N_p^{(2)} > N_p^{(1)}, N_n^{(2)} > N_n^{(1)})$. N_p and N_n are the valence proton and neutron numbers, while $\bar{N}_p$ and $\bar{N}_n$ are the corresponding hole numbers. Finally, N $(\bar{N})$ is the total number of valence bosons (boson holes) and F_0 and $\bar{F}_0$ are the third projections of the F-spin and $\bar{F}$-spin, respectively. The unified description of all the even-even nuclei, with shapes changing from spherical to well-deformed is a result of the so obtained single phenomenological formulae for the coefficient in front of the interaction. This permits the investigation of the generality of nuclear phenomena in respect to vast nuclear regions or types of collectivity.

A good agreement between the so-obtained theoretical ground band energies and the experimental ones is obtained for 928 low lying states of 272 nuclei from 5 major shells.

This approach can lead in future to establishing a connection between the phenomenological collective modes and their microscopic description.

* * *

Relativistic Scaling in Symmetric Nuclear Matter

M.V. Stoitsov[a], G. Stoicheva[a], P. Ring[b], M. Sharma[c]
[a]*Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia-1784, Bulgaria*
[b]*Physik Department, Technische Universität, München, D-85748 Garching, Germany*
[c]*Physics Department, Kuwait University, Kuwait 13060*

Failure of the standard coordinate scaling, usually applied in the nonrelativistic physics, is observed within the relativistic Walecka model of infinite symmetric nuclear matter. New relativistic scaling is proposed preserving the relation $m' = m + g_\sigma \sigma'$ which connects the effective mass m' and the σ-field σ' when one-loop vacuum fluctuations are taken into account. The influence of the vacuum polarization effects on both constrained and scaling equations of state and the associated constrained K^C_{NM} and scaling K^S_{NM} nuclear matter incompressibilities is analyzed for various set of parameters. The application of the relativistic scaling to finite nuclei is discussed.

* * *

Relativistic Scaling in Finite Nuclei

M.V. Stoitsov[a], G. Stoicheva[a], P. Ring[b], M. Sharma[c]
[a]*Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia-1784, Bulgaria*
[b]*Physik Department, Technische Universität, München, D-85748 Garching, Germany*
[c]*Physics Department, Kuwait University, Kuwait 13060*

Failure of the standard coordinate scaling largely exploited within the nonrelativistic physics is observed in the mean-field treatment based on the relativistic Walecka model. New relativistic scaling procedure is applied to the σ-field σ_α which preserves the well-known expression for the effective mass $m_\alpha = m + g_\sigma \sigma_\alpha$. Both constrained K^C_A and scaling K^S_A incompressibilities as well as the associated excitation energies of the isoscalar giant monopole resonance in nuclei are analyzed for a reference set of spherical nuclei using various parameters of the lagrangian. Comparison is made with nonrelativistic results and available experimental data.

* * *

Nuclear Deformation in the $su_q(2)$-rotor Model

N. Minkov, P.P. Raychev and R.P. Roussev
Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia 1784, Bulgaria

Based on the previously established theoretical correlation [1] between the $SU_q(2)$-parameter τ and the number of nucleon pairs in the valence shells N and using the expectation value of the deformation parameter β calculated in [2], it is found that β is connected with τ trough the equation:

$$\beta(\tau) = \alpha\left(\frac{B}{3(2B+60.25)^{1/2}-22.5}\right)^{1/2} \quad (1)$$

where

$$B = \frac{1}{1-\tau\cot\tau} \quad (2)$$

and α is an overall normalization constant for a given region of deformed nuclei. It is shown that $\beta(\tau)$ which is defined in (1) decreases with the increase of τ. The above theoretical result is supported by the experimentally established deformations and the corresponding τ-values fitted empirically in the energy spectra of rotational nuclei. It follows that the deterioration of the nuclear rotational properties which is characterized by τ is relevantly connected with the corresponding decrease of nuclear deformation. This result is a consequence of the increase of τ with the decrease of the number of valence pairs which are responsible for the polarization of the core. As a consequence, it is obtained that the $B(E2;2_1^+\to 0_1^+)$-transition probabilities of deformed nuclei should decrease with the increase of τ. This theoretical result is supported by the experimental $B(E2;2_1^+\to 0_1^+)$-values measured in rare earth nuclei and actinides. The obtained decrease of β and $B(E2)$ with the increase of τ allows one to consider τ as a relevant measure of decrease of deformation and rotational collectivity respectively in the limits of a given rotational region or group of isotopes. So, the present results indicate that the application of the quantum algebra $SU_q(2)$ in deformed nuclei leads in a very natural way to a more general treatment of nuclear coherent properties, which are only roughly subordinated to the symmetry imposed by the usual Lie algebra $SU(2)$.

[1] Minkov N., Roussev R.P. and Raychev P.P. 1994 J. Phys. G **20** L67
[2] Partensky A. and Quesne C. 1981 *Ann. Phys.*, NY **136** 340

* * *

Restoration of Overlap Functions and Spectroscopic Factors in Nuclei

M.V. Stoitsov, S.S. Dimitrova and A.N. Antonov
Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia-1784, Bulgaria

An asymptotic restoration procedure is applied for analyzing overlap functions, separation energies and single-nucleon spectroscopic factors for bound $(A-1)$ - particle eigenstates by means of a model one-body density matrix emerging from the Jastrow correlation method in its Low order approximation for nuclei ^{16}O and ^{40}Ca. Comparison is made with available experimental data and mean-field and natural orbital representation results. The calculated separation energies are in acceptable agreement with the self-consistent Hartree-Fock (HF) results and available experimental data. The calculated spectroscopic factors S_α, however, differ significantly from their mean-field values. Due to the short-range correlations a depletion of the states below and a filling of the states above the Fermi level results. At the same time the calculated values of S_α are consistent with experimentally deduced spectroscopic factors. It is shown, that all the three functions, namely the overlap, mean-field and natural orbital wave functions, are quite similar for the hole states in nuclei. This justifies the use of shell-model orbitals instead of overlap functions within DWBA calculations for such kind of nuclear states. This approximation, however, is no longer valid for the particle nuclear states where the mean-field wave-functions significantly differ from the overlap functions. The latter take some intermediate position between the natural orbitals and the HF wave-functions. The instructive conclusion is that neither natural orbitals nor shell-model wave-function can be used as particle-state overlap functions within the DWBA analysis of experimental data. The present restoration procedure gives a possible solution of the problem if it is applied to some realistic ground-state one-body density matrices.

* * *

BG9600247

Hadron structure in a chiral quark-meson theory

Chr.V. Christov[1,2] and K. Goeke[1]
[1]*Institut für Theoretische Physik II, RUB, 44780 Bochum, Germany*
[2]*Institut für Nuclear Research and Energy, Sofia 1784, Bulgaria*

The talk will be devoted to the hadron structure as it is described in the semibosonized SU(2) Nambu – Jona-Lasinio lagrangean where the boson fields are treated in large N_c limit as classical ones. In the model the mesons are generated dynamically as quark-antiquark pairs whereas the baryons appear as a bound state of N_c (number of colors) valence quarks coupled to the polarized Dirac sea. Since the model lacks confinement the proper way to describe the hadron (meson and baryons) is to study the correlation functions of currents with corresponding quantum numbers. As it is expected in the pseudoscalar channel pions appear as Goldstone bosons, and after fixing the cutoff to reproduce the physical pion decay constant, we obtain well-known current-algebra results. In the case of baryons the solution is obtained in two steps. In the first step, motivated by the large N_c limit, a static localized solution (soliton) is found by solving the corresponding equations of motion in an iterative self-consistent procedure, assuming that the meson fields have hedgehog structure. Since this hedgehog soliton does not preserve the spin and isospin, in order to get nucleon states with proper spin and isospin numbers, in the second step the soliton is quantized. Making use of the rotational zero modes, we follow a semiclassical quantization scheme, in which any observable can be evaluated as perturbation series in Ω which is actually an expansion in $\frac{1}{N_c}$. The nucleon form factors are obtained form the matrix elements of the corresponding currents using the projected soliton solution. Other observables, namely the nucleon mean squared radii, the magnetic moments, the axial vector coupling constant, the pion-nucleon coupling constant and the nucleon–Δ splitting are calculated as well. The parameters of the model are fixed in the mesonic sector to reproduce the physical pion mass m_π and the pion decay constant f_π. The constituent quark mass is the only free parameter. The final results, including rotational $1/N_c$ corrections, are compared with the existing experimental data, and they are found to be in a good agreement for the constituent quark mass of about 420 MeV. The experimental q–dependence of the nucleon electromagnetic, axial and pseudoscalar form factors are very well reproduced up to momentum transfer of 1 GeV. The only exception is the neutron electric form factor which is overestimated at intermediate momentum transfer. The axial form factor is in an absolute good agreement with the experiment. For the pion nucleon form factor a monopole mass of about 850 MeV is predicted.

* * *

On some recent problems of ultra high energy astrophysics and gamma-ray astronomy

J.N. Stamenov

Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia-1784, Bulgaria

The energies of primary cosmic particles are distributed over an extremely wide interval 10^9–10^{20} eV and the corresponding energy spectrum decreases rapidly with particle energy. Therefore, the flux intensities for energies $E_0 > 10^5$ GeV become relatively low. The possibilities for observations, carried out with the help of spectrometrical apparatuses on satellites and balloons, become limited. In this context, the role of indirect methods, the extensive air showers (EAS), in studying the energy spectrum and mass composition of the primary cosmic flux at energies $E_0 > 10^6$ GeV becomes the main information source.

A new selection method is developed for observation levels 10^4–10^7 GeV. This gives the possibility to obtain a practically unbiased energy spectrum and mass composition estimations.

Specific EAS experiments placed at observation levels 500–600 $g.cm^2$ are necessary in order to calibrate the indirect methods for obtaining the parameters of the primary cosmic flux at energies higher than 10^6 GeV.

Following this logic, the Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences develops extensive experimental investigations in the field of ultra high energy gamma-ray astronomy.

A wide-angle telescope was set up for registration of Cerenkov light, generated in the atmosphere by electron-photon cascades initiated by primary cosmic particles and gamma-quanta of energies higher than 10^{12} eV. The telescope is placed near the town of Melnik (φ=41°, λ=23°, h=231 *m.a.s.l.* 250 cloudless nights per year), close to the Bulgarian-Greek boundary, and its purpose is to search for astrophysical objects emitting gamma-fluxes with energies in the interval (1-10) TeV.

* * *