ABSTRACTS

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List of Participants

Antonov, Anton: INRNE*, Sofia, Bulgaria,
`aantonov@inrne.bas.bg`

Bijker, Roelof: Universidad Nacional Autónoma de México,
`Bijker@nuclecu.unam.mx`

Bonatsos, Dennis: INP, N.C.S.R. "Demokritos", Athens, Greece,
`bonat@inp.demokritos.gr`

Brancus, Iliana–Magdalena: IFIN-HH Bucharest, Romania,
`iliana@ifin.nipne.ro, iliana@muon2.nipne.ro`

Caballero, Juan: Universidad de Sevilla, Spain `juan@nucle.us.es`

Cseh, Jozsef: Institute of Nuclear Research, Debrecen, Hungary,
`cseh@atomki.hu`

Cowley, Anthony: University of Stellenbosch, South Africa,
`aac@sun.ac.za`

Darai, Judit: University of Debrecen, Hungary,
`darai@tigris.klte.hu`

Deloncle, Isabelle: CSNSM, IN2P3/CNRS and Université Paris-Sud,
`deloncle@csnsm.in2p3.fr`

Demetriou, Vivian: Université Libre de Bruxelles, Belgium,
`vdemetri@astro.ulb.ac.be`

Dimitrova, Sevdalina: INRNE, Sofia, Bulgaria,
`sevdim@inrne.bas.bg`

Dukelsky, Jorge: Instituto de Estructura de la Materia, CSIC, Spain,
`dukelsky@iem.cfmac.csic.es`

Elenkov, Dancho: INRNE, Sofia, Bulgaria, `elenkov@inrne.bas.bg`

Gaidarov, Mitko: INRNE, Sofia, Bulgaria,
`gaidarov@inrne.bas.bg`

Ganev, Huben: INRNE, Sofia, Bulgaria
`huben@inrne.bas.bg`

Garistov, Vladimir: INRNE, Sofia, Bulgaria,
`garistov@inrne.bas.bg`

Georgieva, Ana: INRNE, Sofia, Bulgaria, `anageorg@inrne.bas.bg`

*Institute for Nuclear Research and Nuclear Energy

Giusti, Carlotta: Istituto Nazionale di Fisica Nucleare, Pavia, Italy, Carlotta.Giusti@pv.infn.it

Gómez, Jose: Phys. Fac., Complutense Univ., Madrid, Spain, decano@fis.ucm.es

Grabmayr, Peter: University of Tübingen, Germany, grabmayr@pit.physik.uni-tuebingen.de

Illarionov, Alexey: JINR, Dubna, Russia, Alexei.Illarionov@jinr.ru

Ivanov, Martin: INRNE, Sofia, Bulgaria, martin@inrne.bas.bg

Ivanovich, Maria: Institute of Solid State Physics, Sofia, Bulgaria, dimaria@pronto.bas.bg

Kadrev, Dimitre: INRNE, Sofia, Bulgaria, kadrev@inrne.bas.bg

Krumova, Galina: University of Rousse, Bulgaria, gal@ru.acad.bg

Kukulin, Vladimir: Moscow State University, Russia, kukulin@nucl-th.sinp.msu.ru

Laftchiev, Hristo INRNE, Sofia, Bulgaria, laftchiev@inrne.bas.bg

Lalkovski, Stefan: University of Sofia, Bulgaria, stl@phys.uni-sofia.bg

Lallena, Antonio: Universidad de Granada, Granada, Spain, lallena@ugr.es

Lenis, Dimitris: INP, N.C.S.R. “Demokritos”, Athens, Greece, lenis@inp.demokritos.gr

Libert, Jean: Institut de Physique Nucléaire, Orsay, France, libert@ipno.in2p3.fr

Minkova, Ani: University of Sofia, Bulgaria, animin@phys.uni-sofia.bg

Minkov, Nikolay: INRNE, Sofia, Bulgaria, nminkov@inrne.bas.bg

Matev, Mladen: INRNE, Sofia, Bulgaria, mmatev@inrne.bas.bg

Nikolaev, Vladimir: INRNE, Sofia, Bulgaria, sahralink@inrne.bas.bg

Pavlov, Rossen: INRNE, Sofia, Bulgaria, ropavlov@inrne.bas.bg

Pavlova, Katyusha: INRNE, Sofia, Bulgaria, kpavlova@inrne.bas.bg

Petrellis, Dimitris: INP, N.C.S.R. “Demokritos”, Athens, Greece

Pittel, Stuart: University of Delaware, USA,
`pittel@bartol.udel.edu`

Porquet, Marie–Geneviève: CSNSM, IN2P3/CNRS and Université Paris-Sud,
`porquet@csnsm.in2p3.fr`

Rebel, Heinigerd: Institut für Kernphysik, Germany,
`Heinrich.Rebel@ik.fzk.de`

Rombouts, Stefan: Ghent University Belgium,
`Stefan.Rombouts@Ugent.be`

Scheid, Werner: Institut für Theoretische Physik, Giessen, Germany,
`werner.scheid@theo.physik.uni-giessen.de`

Stamenov, Jordan: INRNE, Sofia, Bulgaria,
`jstamen@inrne.bas.bg`

Stoyanov, Chavdar: INRNE, Sofia, Bulgaria,
`stoyanov@inrne.bas.bg`

Tarpanov, Dimitre: Bulgaria

Terziev, Peter: INRNE, Sofia, Bulgaria, `terziev@inrne.bas.bg`

Tsvetkov, Boyan: Bulgaria

Udias, Jose: Phys. Fac., Complutense Univ., Madrid, Spain,
`jose@nuc2.fis.ucm.es`

Venkova, Tsanka: INRNE, Sofia, Bulgaria, `venkova@inrne.bas.bg`

Voutier, Eric: LPSC, Grenoble, France,
`Voutier@isn.in2p3.fr, Voutier@lpsc.in2p3.fr`

Yanev, Jordan: INRNE, Sofia, Bulgaria

Yotov, Plamen: INRNE, Sofia, Bulgaria, `pyotov@inrne.bas.bg`

Program

	14 June Monday	*15 June Tuesday*	*16 June Wednesday*	*17 June Thursday*	*18 June Friday*	*19 June Saturday*
8^{45}	*Breakfast*					
9^{30}-10^{15}	P. Grabmayr	J. Udías	W. Scheid	*EXCURSION*	D. Bonatsos	J. Gómez
10^{15}-10^{35}	*Coffee break*					
10^{35}-11^{20}	A. Lallena	J. Dukelsky	A. Cowley		D. Lenis	E. Voutier
11^{30}-12^{15}	J. Caballero	S. Pittel	H. Rebel		J. Cseh	I. Deloncle
12^{25}-13^{10}	A. Antonov	S. Rombouts	I. Brancus		R. Bijker	J. Libert
13^{30}	*Lunch*					
16^{00}	*Coffee break*					
16^{30}-17^{15}	C. Giusti	V. Kukulin	V. Demetriou		H. Laftchiev	
17^{25}-18^{10}	Ch. Stoyanov	J. Darai	V. Garistov		A. Georgieva	
18^{20}-19^{05}	N. Minkov	M. Gaidarov	H. Ganev			
19^{30}	*Dinner*		*Party*	*Dinner*		

References of Talks

Study of Short-Range Nucleon-Nucleon Correlations in Knockout Experiments

P. Grabmayr

Physikalisches Institut, University of Tübingen

The atomic nucleus is a rather complicated many-body system which still attracts a lot of attention. The nuclear shell model is well established as a model of atomic nuclei: many properties of their ground states and excited states are well described; a global understanding of nuclear interaction forming these many-body systems could be obtained by the plenty of experiments performed in the past and their theoretical interpretation. Most of this physics in the valence region takes place at low momenta. From the very beginning, on the other hand, the shell model had opponents using the strong repulsion of nucleons at short relative distances as counter-argument. The corresponding high momentum components became accessible only in more recent experiments.

The properties of the atomic nuclei can be studied very well by electromagnetically induced knockout of its constituents. Single nucleon knockout is well suited to determine the occupation of shell model orbitals. A reduced occupation is interpreted as the result of the existence of high momentum components; this is a cummulative measure of the short range and tensor nucleon-nucleon correlations. In this reactions the high momentum is connected to high excitation of the residual nucleus, where difficulties arise to separate the competing continuum contributions. In contrast, high nucleon momenta can be observed at low excitations for the two-body knockout reactions. If separated, the well resolved final states might serve as spin-isospin filters. In this case the theoretical interpretations are facilitated as only a few partial waves will contribute. The effects due to the correlations will be enhanced over competing mechanism.

In this lecture, the experimental methods developed in the past decade will be presented together with the results obtained for light nuclei (^{12}C and ^{16}O) and the fewbody systems ^{3}He and ^{4}He. Contributions from competing reactions and their suppression will be discussed. The experimental results are compared to state-of-the-art model calculations.

Short-Range Nucleon-Nucleon Correlation Effects in Photon- and Electron-Nucleus Reactions

A. M. Lallena

Departamento de Física Moderna, Universidad de Granada
E-18071 Granada, Spain

In the last years, and in framework of the Granada-Lecce collaboration, we have focused our attention on the problem of investigating the effects of the short-range nucleon-nucleon correlations (SRC) in the scattering of real and virtual photons by nuclei [1–8]. In this talk I present an overview of the work carried out.

First I describe the basic model we have built up in order to take into account SRC in the different processes of interest. The proper normalization of the many-body wave functions requires the evaluation of two- and three-point diagrams, the last ones usually neglected in the literature. The model developed has been applied to study the inclusive (e,e'), semi-exclusive $(e,e'N)$, photoemission (γ,N), and two-proton emission by both electron- and photon-nucleus reactions. Also the excitation of low-lying high-spin states has been investigated.

The results obtained for doubly-closed shell nuclei show that the (γ,pp) process appears to be the most adequate for identifying SRC tracks in the clearer way. In the case of the nucleus excitation to discrete states, SRC effects are very small. For all the other reactions, the effects due to other ingredients are dominant. In (e,e') and $(e,e'p)$ processes, final state interactions are much larger than SRC. (γ,p) shows a certain sensitivity to SRC, but meson-exchange current effects are bigger. Finally, in $(e,e'pp)$ SRC act on the size of the cross sections and a quantitative comparison between theoretical predictions and experimental data is needed, what will suffer from the uncertainties in the required theoretical input. Besides, the role of the two-body Δ currents is not at all negligible and only in particular kinematical conditions it can be minimized. A similar situation is found for (γ,pp) which appears to be a good tool to investigate SRC.

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Relativistic Nucleon Dynamics & Meson Exchange Currents in Electron Scattering

J. A. Caballero

Departamento de Física Atómica, Molecular y Nuclear Universidad de Sevilla, Apdo. 1065, E-41080 Sevilla, SPAIN

Most of the electron scattering experiments performed in the last decade have involved energies and momenta high enough to invalidate the non-relativistic approximations assumed within the standard non-relativistic distorted wave impulse approximation (DWIA). In the relativistic distorted wave impulse approximation (RDWIA), nucleon wave functions are described by solutions of the Dirac equation with scalar and vector (S-V) potentials, and the relativistic free nucleon current operator is used. Relativistic ingredients have been shown to play a crucial role in the description of the interference TL response and left-right asymmetry A_{TL}.

Moreover, meson exchange currents (MEC) and the Δ-isobar contribution have recently been analyzed within a fully relativistic calculation for inclusive processes and a semi-relativistic approach for exclusives ones, showing also very significant effects, particularly due to the Δ. We present a study of the role played by dynamical relativistic effects and meson exchange currents in a consistent description of electroweak responses.

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Superscaling in Nuclei: a Scaling Function beyond the Relativistic Fermi Gas Model

A. N. Antonov[1,2], M. K. Gaidarov[1], D. N. Kadrev[1], M. V. Ivanov[1], E. Moya de Guerra[3], J. M. Udias[2]

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

[2]Departamento de Fisica Atomica, Molecular y Nuclear, Facultad de Ciencias Fisicas, Universidad Complutense de Madrid, Madrid E-28040, Spain

[3]Instituto de Estructura de la Materia, CSIC, Serrano 123, 28006 Madrid, Spain

A scaling function for inclusive electron scattering was constructed [1] within the Coherent Density Fluctuation Model (CDFM) [2]. The latter is a natural extension to finite nuclei of the Relativistic Fermi Gas Model within which the scaling variable ψ' was introduced [3]. It was shown that the high-momentum components of the nucleon momentum distributions in the CDFM and their similarity for different nuclei explain quantitatively the superscaling in nuclei for negative values of ψ', including also those smaller than $\psi' < -1$.

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Green's Function Approach to (e,e′) Reactions

C. Giusti

Dipartimento di Fisica Nucleare e Teorica, Università di Pavia, and
Istituto Nazionale di Fisica Nucleare, Sezione di Pavia, Pavia, Italy

A Green function approach to the inclusive quasielastic (e, e') scattering is presented. The single particle Green function is expanded in terms of the biorthogonal eigenfunctions of the nonhermitian optical potential. This allows one to treat final state interactions consistently in the inclusive and in the exclusive reactions. Numerical results are presented and discussed in a nonrelativistic and in a relativistic approach. The effects of correlations is also considered including in the model a realistic one-body density.

High-Lying Single-Particle Modes, Chaos, Correlational Entropy, and Doubling Phase Transition

Ch. Stoyanov[1] **and V. Zelevinsky**[2]

[1]Institute for Nuclear Research and Nuclear Energy, Tzarigradsko Chaussee 72, 1784 Sofia, Bulgaria

[2]National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan 48824-1321

Highly-excited single-particle states in nuclei are coupled with the excitations of a more complex character, first of all with collective phonon-like modes of the core. In the framework of the quasiparticle-phonon model we consider the structure of resulting complex configurations using the $1k_{17/2}$ orbital in ^{209}Pb as an example. Although, on the level of one- and two-phonon admixtures, the fully chaotic GOE regime is not reached, the eigenstates of the model carry significant degree of complexity that can be quantified with the aid of correlational invariant entropy. With artificially enhanced particle-core coupling, the system undergoes the doubling phase transition with the quasiparticle strength concentrated in two repelling peaks. This phase transition is clearly detected by correlational entropy.

Description of the Parity Shift and the Fine Rotation Structure in the Spectra of Nuclei with Octupole Deformations

N. Minkov[1,2]**, P. Yotov**[1]**, S. Drenska**[1] **and W. Scheid**[2]

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

[2]Institut für Theoretische Physik der Justus-Liebig-Universität, Heinrich-Buff-Ring 16, D–35392 Giessen, Germany

We propose a collective model formalism which describes consistently the strong parity shift observed in the low-lying spectra of nuclei with octupole deformations together with the fine rotational band structure developed at the higher angular momenta. The parity effect is reproduced by solving numerically the Schrödinger equation for octupole vibrations in a double-well potential with an angular momentum dependent (centrifugal) term. The collective rotational structure of the spectrum is obtained through the point-symmetry based Quadrupole-Octupole Rotation Hamiltonian [1]. The developed algorithm is tested on the octupole bands of several light actinide nuclei.

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Chasing Modifications of the Nucleon Form Factor in the Nuclear Medium

J. M. Udías, J. R. Vignote

Departamento de Física Atómica, Molecular y Nuclear Universidad Complutense de Madrid, Avda. Complutense s/n, Madrid 28040, SPAIN

We review the experimental results on exclusive electron scattering from nucleus, and analyze them in the framework of the relativistic distorted wave impulse approximation. The ratio of polarized observables shows sensitivity to the nucleon form factors, and implications of the new experimental results for the behaviour of the form factors in the nuclear medium are inferred.

The Richardson-Gaudin Integrable Models

J. Dukelsky

Instituto de Estructura de la Materia, CSIC, Serrano 123,
28006 Madrid, SPAIN

Exactly solvable models have a long history in nuclear physics. In general they are related to a dynamical symmetry. In such cases the hamiltonian is written as a linear combination of the Casimir operators of a group decomposition chain, having analytic solutions for the eigenvalues and transition operators. The fundamental restriction common to all dynamical symmetry models is that they are only valid for degenerate single-particle levels. The concept of quantum integrability goes beyond the limitation of a dynamical symmetry. A particular example is the exact solution of the pairing model with non-degenerate single particle levels given by Richardson in the sixties. We will discuss this exactly solvable model based on the su(2) pair algebra and we will then introduce new families of integral models for fermion and boson systems as well as the generalization of the Richardson–Gaudin models to larger rank algebras. As an example, we will present the exact solution of the so(5) algebra corresponding to a proton-neutron pairing Hamiltonian with T=1 isospin and non-degenerate single particle levels.

Exactly-Solvable Generalization of the Jaynes-Cummings Model and Its Application to Atom-Molecule Systems

S. Pittel

Bartol Research Institute, University of Delaware, USA

The development of exactly-solvable models has provided important insight into the properties of a wide variety of strongly correlated many-body quantum systems. Typically this has been limited, however, to models that involve either interacting bosons or interacting fermions. There are several important physical phenomena, however, in which the interplay between fermion and boson degrees of freedom is critical. One of the most interesting concerns the formation of bosonic molecules from ultracold degenerate fermionic gases. This has recently been realized in two beautiful experiments, for 40K [1] and 6Li gases [2].

To help in the interpretation of these experiments and future experiments that build upon them, we have recently developed a new family of exactly-solvable models that involve a set of either fermions or bosons interacting via a pairing hamiltonian and coupled to a single bosonic field. The models are derived from the trigonometric family of exactly-solvable Richardson–Gaudin models [3] by replacing one of their SU(2) or SU(1,1) degrees of freedom by an ideal boson.

Following a review of earlier work on the Richardson–Gaudin exactly-solvable models and a description of the new models that we have derived for coupled systems, I will report a first application to a system of bosonic atoms and molecules.

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Exactly Solvable Models of Nuclear Structure and Bose-Einstein-Condensates

S. Rombouts†

Universiteit Gent, Vakgroep Subatomaire en Stralingsfysica,
Proeftuinstraat 86, B-9000 Gent, Belgium

The algebraically solvable pairing models, pioneered by Racah, Richardson and Gaudin, have only recently gained wider popularity. Recent advances in numerical methods now allow to actually solve the algebraic equations, for boson and fermion pairs. I have applied this method to the pairing model in atomic nuclei. The pairing Hamiltonian for several tens of particles distributed over several mayor shells can now be solved exactly in a matter of seconds. This makes these models truly 'exactly-solvable'. The models are relevant in other fields of physics too. For example, they can be used to quantify the influence of the Pauli principle on the Bose-Einstein condensation of bosons that are made up of fermionic atoms or particles. It turns out that these condensates have a maximal condensed fraction, solely determined by Pauli-exclusion effects and the structure of the order parameter.

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New Concept for 2N- and 3N-Short-Range Correlations in Nuclei

V. I. Kukulin

Institute of Nuclear Physics, Moscow State University, Russia

The traditional picture for short-range correlations in nuclei, which is based on meson-exchange nucleon-nucleon force, usually meets quite serious problems when trying to describe the transfer a hard initial momentum (*e.g.* in electromagnetic processes) from incident particles to other nucleons in the target. It is evident *e.g.* when comparing a consistent theoretical description with accurate experimental data for the processes like (γ,pp), (e,$e'pp$) etc. at high energy and momentum transfers where the MEC-contributions are significantly supressed. Moreover, the deficit of high-momentum components in nuclear wavefunctions is also seen in many other experiments where the large discrepancies between traditional theory (including MEC) and experimental data are usually "repeared" by invoking strong delta-isobar currents. The present situation with short-range many-body correlations looks even more ambiguous.

Some time ago we proposed a new concept for intermediate- and short-range nuclear forces. The concept assumes the following s-channel mechanism for intermediate and short-range nuclear force: $NN \rightarrow$ dressed six-quark bag (DB) $\rightarrow NN$ with dressing the intermediate bag with π, σ, ρ and ω fields. This mechanism leads inevitably to an appearance of strong rather short-range ($r \sim 0.7 - 1$ fm) many-nucleon forces when other nucleons interact with the strong meson fields surrounding this dressed bag, mainly of scalar nature, induced by sigma-exchange between the DB and third and other nucleons. We have demonstrated recently that such intermediate and short-range $3N$-forces offer roughly the same, or even larger, attractive contribution to the $3N$ nuclear binding as two-body force contribution, in sharp contrast to the traditional force models (of OBE-type). Moreover, the above new concept has been shown to lead to a strong density dependence of the two-and three-body forces, which is in a good qualitative agreement with the picture emerged from phenomenological Skirme model. Thus the novel picture of short-range nuclear substructures resulted from the above concept inplies some serious revision of the traditional view:

(i) quite remarkable admixture of the dressed dibaryon components (ca 10%) in nuclear wavefunctions, which should determinate sharing the initial high momentum (*e.g.* of virtual gamma-quantum) among other nucleons;

(ii) a significant portion of nuclear binding comes just from *many-nucleon* interactions between nucleons and DB-components rather than from two-body force, as in the conventional force models;

(iii) there appear new transition currents (*e.g.* in e.-m. processes accompanied with high momentum transfer) associated with these new degrees of freedom;

(iv) there appear automatically the contributions of multi-quark components (well known today from the recent experiments in JLab etc) which should be in agreement with quark-counting rules.

Also there appear in the model cumulative effects in interaction of high energy external probes with the dressed multi-quark bags inside nuclei etc. We plan to discuss in the talk many above-mentioned aspects of the novel physics and compare these comprehensively with the results of traditional approaches.

Modified Faddeev-Noble Equations for the Three-Body Coulombic Problem

J. Darai

Institute of Experimental Physics, University of Debrecen, Debrecen, Bemtér 18/a, H–4026, Hungary

The solution of the three-body Faddeev equations with Coulomb-like potentials is a long-standing problem. The Faddeev equations were originally derived for short range interactions, and if their potential is simply substituted by a Coulomb-like one, then the equations become singular. The first and formally exact approach to solve the three-body Coulomb problem was proposed by Noble. In his procedure the interactions were split into a short-range and a long-range parts, and the Faddeev procedure was applied only to the short-range potentials, while the long range parts were formally included in the "free" Green's operator. However, this Green's operator is not known, therefore this formalism, as presented in Ref. [1] is not suitable for practical calculations.

The approach proposed by Sasakawa and Sawada [2] gives Faddeev-type equations with calculable Green's operator. These equations are not of Noble-type, the source term is not really a short range potential.

Recently an improvement of the Noble approach has been introduced [3], in which the Coulomb Green's operator of the Faddeev–Noble equations are obtained from the solution of an independent Lippmann–Schwinger equation. The modified Faddeev–Noble equations has subsequently been applied to study various nuclear and atomic three-body systems with Coulomb interactions in bound and scattering state dynamics [4].

Here we compare the efficiency of the two approaches for nuclear three-body systems. Our numerical examples show, that the modified Faddeev–Noble equations provide better convergence in terms of partial waves.

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Studies of Charge Form Factors of Neutron-Rich Light Exotic Nuclei

A. N. Antonov[1,2], **M. K. Gaidarov**[1], **D. N. Kadrev**[1], **P. E. Hodgson**[3], **E. Moya de Guerra**[4]

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

[2]Departamento de Fisica Atomica, Molecular y Nuclear, Facultad de Ciencias Fisicas, Universidad Complutense de Madrid, Madrid E-28040, Spain

[3]Subdepartment of Particle Physics, Department of Physics, University of Oxford, Oxford OX1-3RH, United Kingdom

[4]Instituto de Estructura de la Materia, CSIC, Serrano 123, 28006 Madrid, Spain

Charge form factors corresponding to proton density distributions in exotic nuclei, such as ^{6,8}He, ^{11}Li, ^{17,19}B and ^{14}Be are calculated and compared [1]. Various theoretical models to obtain the charge densities are used, such as those proposed by Tanihata [2], the COSMA model [3], the model of Suzuki [4] and the Large–Scale Shell Model [5]. The form factor predictions and comparisons with future data can be used as tests of these theoretical models, and second, they can throw light on the effects of the neutron halo or skin on the proton distributions in exotic nuclei. Accurate information on the charge distributions of exotic nuclei can be obtained from future experiments on electron-nucleus scattering in inverse kinematics using a colliding electron-exotic nucleus storage ring [6, 7].

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Cluster Structure of Deformed Nuclei

T. Shneidman[1], G. G. Adamian[1], N. V. Antonenko[1], R. V. Jolos[1], Y. Palchikov[1], and W. Scheid[2]

[1]Joint Institute for Nuclear Research, 141980 Dubna, Russia

[2]Institut für Theoretische Physik der Justus-Liebig-Universität, Giessen, Germany

The nuclear structure of even-even and even-odd deformed nuclei is described with several important degrees of freedom: the rotation of the whole system, the fragmentation in a heavy and a very light cluster, like an α– or an ^{8}Be–cluster, the quadrupole and octupole oscillations of the heavy cluster and the single-particle motion of the odd particle. The clusterization is treated within the dinuclear system model by use of the mass (or charge) asymmetry coordinate [1]. The dinuclear system consists of two touching nuclei which exchange nucleons and/or clusters. This description is capable to explain a wide range of nuclear structure effects [2, 3]: positive and negative parity bands, parity splitting, super– and hyperdeformed bands and electromagnetic transition probabilities in and between the bands. Applications and comparison with experimental data are made for rare earth and actinide nuclei, *e.g.* ^{223,227}Th and ^{225}Ra.

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Cluster Structure of Nuclei

A. A. Cowley

University of Stellenbosch, South Africa

In studies of nuclear reactions, especially when the motivation is to investigate the reaction mechanism, it is sometimes convenient to assume a cluster structure for the target and projectile. It is realised that the assumption of cluster structure is often not more significant than a convenient method to simplify the complexity of a proper shell model theoretical formulation. Also, especially for heavier nuclei, it is not always clear whether cluster preformation probabilities which are implied by the extracted quantities are realistic. My review of the issues that are involved will be restricted mostly to how these are intervowen with the interpretation of experimental work that I have personally been involved with. Preliminary results of recent sophisticated breakup measurements will also be presented.

What May We Learn about High-Energy Hadronic Interaction Processes from Extensive Air Shower Observations?

H. Rebel

Institut für Kernphysik, Forschungszentrum Karlsruhe and Faculty of Physics and Astronomy, University of Heidelberg

Extensive air showers (EAS) induced by collisions of primary cosmic particles with atoms of the Earth's atmosphere are a playground for studies of the high-energy hadronic interaction. The hadronic interaction is subject of various uncertainties and debates, in particular in energy regimes which exceed the energies of man-made accelerators and the knowledge from collider experiments. The EAS development is dominantly governed by soft processes, which are not accessible to pertubative QCD. Thus one has to rely on QCD inspired phenomenological interaction models like string models based on the Gribov–Regge theory. In this lecture recent EAS results of the KASCADE experiment (Forschungszentrum Karlsruhe) are scrutinized with respect of their information about salient features and tests of various high-energy interaction models, being en vogue as generators for Monte Carlo EAS simulations.

Experimental Guided Monte Carlo Calculations of the Atmospheric Muon Flux for Interdisciplinary Applications

I. M. Brancus

IFIN-HH Bucharest, Romania

Atmospheric muons are produced by interactions of primary cosmic rays particles with the Earth's atmosphere, mainly by the decay of pions and kaons generated in hadronic interactions. They decay furtheron in electrons and positrons and electron and muon neutrinos with a half-life of 2.2 s. Due to the smaller electromagnetic interaction the muons pass less disburbed through the atmosphere and absorbers at the Earth's surface.

By interactions with the absorber material they produce longliving nuclear isotopes. This cosmogenic production provides information of astrophysical, environmental and material research interest. In order to evalute the information the local flux of the atmosperic muons has to be known.

Some semi-analytical approximations have been used to calculate the muon flux for estimating the cosmogenic isotope production for different applications. But these estimates imply various uncertainties and do usually no account for effects of the local magnetic field of the Earth. Our estimation of the atmospheric muon flux is based on a Monte Carlo simulations calculated with the program CORSIKA, which simulates the development of extensive air showers produced by primary cosmic particle in the atmospher. They use optionally different models for the description of the hadronic interaction and take into account the influence of the Earth's magnetic field. The simulations are controlled by the experimental results of the muon charge ratio, *i.e.* the ratio of positive to negative muon flux, being measured with WILLI rotatable detector in IFIN-HH Bucharest.

The advantages of our method arise from the fact that CORSIKA code allows a correct description of all secondary interactions in the Earth's atmosphere and follows all trajectories of the particles in the geomagnetic field. In addittion such simulations can be checked with experimental data of muon charge ratio measured with WILLI detector.

Microscopic Predictions of Fission Properties for Astrophysical Applications

V. Demetriou

Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, CP 226, Campus de la Plaine, Bd. du Triomphe, 1050 Brussels, Belgium

Nuclear fission could play a crucial role in the r-process nucleosynthesis under certain hydrodynamical conditions. For example, if the nucleosynthesis reaches the transuranium region, then fission will prohibit the synthesis of the superheavy elements. Neutron-induced and beta-delayed fission in particular, in astrophysical environments where the neutron densities are sufficiently large to produce fissile nuclei, may strongly influence the abundances in the lower mass region through the re-cycling of the r-process material, while spontaneous fission will affect the final abundance pattern, especially the production of long-lived radiocosmochronometers Th and U. Of course all of these fission processes involve extremely neutron-rich nuclei that are unable to be measured in the laboratory. It is therefore of paramount importance to be able to make reliable predictions of the relevant beta-delayed and neutron-induced fission rates, as well as the spontaneous fission half-lives, of all these unknown nuclides, starting from relatively close to the stability line and going out towards the drip line. In this respect, an attempt has been made to treat all aspects of fission on a microscopic basis, using a Skyrme-Hartree-Fock approach for the calculation of ground-state properties, fission barriers and fission level densities.

We present the results of the analysis of the potential energy surfaces obtained with a Skyrme–Hartree–Fock–Bogoliubov method in a multidimensional deformation space. We describe the approaches used to determine the relevant fission paths, barrier heights and widths. These quantities are subsequently used to calculate fission half-lives and neutron-induced fission cross sections. The results which are based entirely on microscopic input, are compared with existing experimental data and other macroscopic approaches. We discuss possible improvements and finally, give some perspectives.

Simplified IVBM Analysis of the Nuclear Structure

V. P. Garistov

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

The Interacting Vector Boson Model (IVBM) has been applied for the investigation of the collective structure of low lying excited states in even-even nuclei. The energies of the ground, β, octupole and γ bands with a good accuracy are reproduced within the framework of the simplified version of IVBM. Comparison of our calculations with experiment for large ammount of even-even nuclei is presented.

Symplectic Classification of Collective States with Fixed Angular Momentum in IVBM

H. Ganev[1], **V. P. Garistov**[1], **A. I. Georgieva**[1,2], **and J. P. Draayer**[2]

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

[2]Louisiana State University, Department of Physics and Astronomy, Baton Rouge, Louisiana, 70803-4001 USA

The symplectic symmetries prove to play an important role in nuclear structure physics. In particular, the symplectic extension of the Interacting Vector Boson Model (IVBM) has been used to describe with great accuracy the nuclear collective bands up to very high angular momenta.

We introduce a theoretical approach based on a new reduction of the model dynamical symmetry algebra $sp(12, R)$ to its non-compact subalgebra $sp(4, R) \times so(3)$ for description of the low-lying nuclear spectra. Hence the different irreps of $Sp(4, R)$ group are labelled by L, and so distinguish sets of collective states with fixed angular momenta. A basis of the irreps $Sp(4, R)$ is labelled by the quantum numbers of the total number of vector bosons N that build the IVBM states, and the pseudospin T with third projection T_0. The correspondence of this reduction of $sp(12, R)$ to the one through $u(6) \supset u_T(2) \otimes su(3)$, yields the possibility to study the energy distribution of the collective states with fixed L. We present results for the low-lying nuclear spectra from the rare-earth region, where the experimentally observed states are classified by the number of vector bosons N. The model confirms the empirical observation for the energy distributions of the collective states with $J^\pi = 0^+, 2^+, 4^+, ...$ on parabolic functions of N.

Variational Procedure Leading from Davidson Potentials to the E(5) and X(5) Critical Point Symmetries

D. Bonatsos[1], **D. Lenis**[1], **N. Minkov**[2], **D. Petrellis**[1], **P. P. Raychev**[2], **P. A. Terziev**[2]

[1]Institute of Nuclear Physics, N.C.S.R. "Demokritos", GR-15310 Aghia Paraskevi, Attiki, Greece

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

Davidson potentials of the form $\beta^2+\beta_0^4/\beta^2$, when used in the E(5) framework (i.e., in the original Bohr Hamiltonian after separating variables as in the E(5) model, describing the critical point of the U(5) to O(6) shape phase transition) bridge [1, 2] the U(5) and O(6) symmetries, while they bridge [1,2] the U(5) and SU(3) symmetries when used in the X(5) framework (*i.e.*, in the original Bohr Hamiltonian after separating variables as in the X(5) model, corresponding to the critical point of the U(5) to SU(3) transition). Using a variational procedure [1, 2], we determine for each value of angular momentum L the value of the parameter β_0 at which the rate of change of various physical quantities (energy ratios, intraband B(E2) ratios, quadrupole moment ratios) has a maximum, the collection of the values of the physical quantity formed in this way being a candidate for describing its behavior at the relevant critical point. Energy ratios lead [1] to the E(5) and X(5) results (which correspond to an infinite well potential in β), while intraband B(E2) ratios and quadrupole moments lead [2] to the E(5)-β^4 and X(5)-β^4 results, which correspond to the use of a β^4 potential in the relevant framework [3–5]. A new derivation of the Holmberg–Lipas formula for nuclear energy spectra is obtained as a by-product [1, 2].

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Z(5): Critical Point Symmetry for the Prolate to Oblate Shape Phase Transition

D. Bonatsos[1], **D. Lenis**[1], **D. Petrellis**[1], **P. A. Terziev**[2]

[1]Institute of Nuclear Physics, N.C.S.R. “Demokritos”, GR-15310 Aghia Paraskevi, Attiki, Greece

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

A critical point symmetry for the prolate to oblate shape phase transition is introduced, starting from the Bohr Hamiltonian and approximately separating variables for $\gamma = 30^o$ [1]. Parameter-free (up to overall scale factors) predictions for spectra and B(E2) transition rates are found [1] to be in good agreement with experimental data for ^{194}Pt, which is supposed [2] to be located very close to the prolate to oblate critical point, as well as for its neighbours (^{192}Pt, ^{196}Pt). Hallmarks of the model are the $R_4 = E(4)/E(2)$ ratio of 2.350, as well as the location of the γ_1- and β_1-bandheads (normalized to the 2^+ state of the ground state band) at 1.837 and 3.913 respectively [1], while the selection rules for B(E2) transition rates are similar to the ones of the O(6) limit of the Interacting Boson Model. Using the exactly soluble Davidson potentials $u(\beta) = \beta^2 + \beta_0^4/\beta^2$ in the Bohr equation treated as above, a triaxial vibrator with $R_4 = 2.150$ is obtained for $\beta_0 = 0$, while the triaxial rotator (with $R_4 = 2.667$) is obtained for $\beta_0 \to \infty$. Z(5) is then obtained through a variational procedure [3], by maximizing the rate of change of R_4 with respect to the parameter β_0 between these two limits.

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Cluster-Coexistence in Nuclei and Dynamical Symmetries

J. Cseh

MTA ATOMKI, Debrecen Pf.51. Hungary-4001

Clusterization is an important effect in atomic nuclei, at small and large mass numbers, in the ground-state and in the highly excited regions, for spherical and deformed shape, at small and high spins, etc. A particular atomic nucleus, and even a specific state of it may show evidence for different cluster configurations (they are not orthogonal to each other, their wavefunctions may have large overlap). In short: different cluster-configurations may coexist in nuclei.

The semimicroscopic algebraic cluster model [1] proved to be easily applicable for the description of the spectrum of a (single) cluster-configuration. Since this approach has a microscopically constructed model space, one can inquire within this framework about the overlap and coexistence of different cluster-configurations as well. In this presentation I plan to discuss how the concept of dynamical symmetry can be extended for the description of cluster-coexistence [2], and what kind of predictive power can be obtained from its application [3].

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Spectroscopy of Pentaquark States

R. Bijker[1], **M. M. Giannini**[2], **and E. Santopinto**[2]

[1]Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, A.P. 70-543, 04510 México, D.F., México

[2]Dipartimento di Fisica dell'Università di Genova, I.N.F.N., Sezione di Genova, via Dodecaneso 33, 16164 Genova, Italy

The building blocks of atomic nuclei, the nucleons, are very complicated objects, as is evident from the large anomalous magnetic moment and the charge distribution of both the proton and the neutron. To first approximation, the internal structure of the nucleon is made up of three constituent quarks q^3.

The discovery of the $\Theta(1540)$ with positive strangeness $S = +1$ by the LEPS Collaboration [1] as the first example of an exotic baryon (*i.e.* not q^3) has motivated an enormous amount of experimental and theoretical studies. The width of this state is observed to be very small < 20 MeV (or perhaps as small as a few MeV's). More recently, the NA49 Collaboration [2] reported evidence for the existence of another exotic baryon $\Xi(1862)$ with strangeness $S = -2$. The Θ^+ and Ξ^{--} resonances are interpreted as $q^4\bar{q}$ pentaquarks belonging to a flavor antidecuplet with quark structure $uudd\bar{s}$ and $ddss\bar{u}$, respectively. In addition, there is now the first evidence for a heavy pentaquark $\Theta_c(3099)$ from the H1 Collaboration [3] in which the antistrange quark in the Θ^+ is replaced by an anticharm quark. The spin and parity of these states have not yet been determined experimentally. Theoretical interpretations range from chiral soliton models which provided the motivation for the experimental searches, correlated quark or cluster models, and various constituent quark models.

In this contribution, we introduce a collective stringlike model of $q^4\bar{q}$ pentaquarks in which the four quarks are located at the corners of an equilateral tetrahedron and the antiquark in its center. This nonplanar equilibrium configuration is a consequence of the permutation symmetry of the four quarks. As an application, we discuss the spectrum of exotic Θ baryons, as well as the parity and magnetic moments of the ground state antidecuplet baryons [4]. The width is suppressed by a small spatial overlap with the decay products.

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The Higher Tamm–Dankov Approximation for superdeformed A=150 and A=190 bands

H. Laftchiev[1,3], **J. Libert**[2], **P. Quentin**[3]

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

[2]IPN-Osay, CNRS-IN2P3 and Univ. Paris Sud, 91406 Orsay France

[3]Centre d'Études Nucléaires de Bordeaux Gradignan, CNRS-IN2P3 and Université Bordeaux-I, BP 120, F-33175 Gradignan, France

The new approach gives the possibility to perform realistic models with direct diagonalization of the Schroedinger equation for heavy nuclei. The symmetry restrictions of the computing for these states become less important now. Some new results for calculations in these regions are presented in this talk.

Chaos and $1/f$ Noise in Nuclear Spectra

J. M. G. Gómez, E. Faleiro, R. A. Molina, A. Relaño, and J. Retamosa

Departamento de Física Atómica, Molecular y Nuclear Universidad Complutense de Madrid, E-28040 Madrid, Spain

A new approach to quantum chaos based on traditional methods of time series analysis has recently been proposed [1]. The essential feature of chaotic energy spectra in quantum systems is the existence of level repulsion and correlations. To study these correlations, we can consider the energy spectrum as a discrete signal, and the sequence of energy levels as a time series. In particular, spectral fluctuations can be characterized by the function $\delta_n = \sum_{i=1}^{n} s_i - n$, where s_i are the nearest level spacings of the unfolded energy spectrum. This function can be considered as a time series, where the level order index n plays the role of a discrete time.

The power spectrum $\langle S(k) \rangle$ of δ_n has been studied for representative energy spectra of regular and chaotic quantum systems. Neat power laws $\langle S(k) \rangle \sim 1/k^{\alpha}$ have been found in all cases. For several examples of chaotic quantum systems, like the sd shell nucleus ^{24}Mg, the $sd - pf$ shell nucleus ^{32}Na, and the Gaussian Orthogonal Ensemble, we obtain $\alpha = 1$. On the contrary, for Poisson spectra we get $\alpha = 2$, as expected, because the consecutive nearest level spacings are independent random variables. These results suggest the conjecture that *chaotic quantum systems are characterized by $1/f$ noise in the energy spectrum fluctuations*. This property is not a mere statistic to measure the chaoticity of the system. It provides an intrinsic characterization of quantum chaotic systems without any reference to the properties of Random Matrix Theory ensembles.

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Results and Prospects of Few Body System Structure Studies

E. Voutier

Laboratoire de Physique Subatomique et de Cosmologie, 53 avenue des Martyrs, 38026 Grenoble, France

Since the very first experiments at Frascati, Saclay, and NIKHEF the $(e, e'p)$ reaction has been proven a powerful tool for the investigation of nuclear structure. The advent of high energy electron beams with high intensity and duty cycle has opened access to the high momentum range, a region expected to reveal peculiar features of the nucleon substructure. Indeed, large virtual photon momentum q allows access to distances scales $\sim \hbar/q$ that are comparable or smaller than the nucleon radius. In addition, the $(e, e'p)$ Meson Exchange Current (MEC) mechanism at large q is expected to be less important due to the natural decrease built into the propagators and form factors. Therefore, one can expect to probe more reliably high initial momenta in the nucleus, that is small inter-nucleon distances, and learn about the origin of the short-range repulsion of the NN interaction from its standard representation up to the most exotic descriptions.

The general framework of nuclear structure studies has been evolving since the first generation of $(e, e'p)$ experiments at the Continuous Electron Beam Accelerator Facility (CEBAF) of the Jefferson Laboratory (JLab). This talk will review our present understanding of the dynamics of the $(e, e'p)$ reaction. Particularly, the dominance of the Final State Interactions (FSI) and its consequences for the study of the nucleon and nuclear structure will be discussed. Future prospects in this domain as well as more exotic use of the $(e, e'p)$ reaction in the study of the Color Transparency phenomenon will be also addressed.

New Clues for the B(E2: $0_1^+ \rightarrow 2_1^+$) Behavior Around ^{68}Ni: Seniority and p-n Interaction

I. Deloncle[1], **B. Roussière**[2]

[1] Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, CNRS/ IN2P3 -Université Paris-Sud XI, Orsay, F-91640, FRANCE

[2] Institut de Physique Nucléaire, CNRS/ IN2P3 -Université Paris-Sud XI, Orsay, F-91640, FRANCE

The B(E2: $0_1^+ \rightarrow 2_1^+$) (B(E2)↑) reduced transition probability is correlated to the possibilities to perform excitations leading, from the underlying single-particle level spectrum of the 0_1^+, to a 2_1^+ state. Its value is then very sensitive to the (sub-) shell structure. The noticeable difference of the B(E2)↑ behavior observed in the ^{66,68}Ni isotopes and the ^{68,70}Zn ones [1] is an important point to understand since it concerns the still discussed N=40 sub-shell closure.

Several experiments have been recenlty performed at Ganil [2] and at Isolde [3] in order to measure the B(E2)↑ values of heavier Ni and Zn isotopes for which the results are soon to be expected. Two recent theoretical papers [4, 5] discuss the B(E2)↑ values in the Ni isotopes only, in particular the decrease between ^{66}Ni and ^{68}Ni in relation with the presence or not of a N=40 sub-shell closure. Nevertheless, the Ni B(E2)↑ curve exhibits some features also observed in the Zn isotopes and in heavier nuclei of the region (N, Z around 40), that a N=40 gap does not allow to explain.

We have analysed the experimental curves using the calculated ones obtained when taking only into account these features. The calculations have been performed in an approximation of the generalized seniority – at the basis of the boson models describing collective states– which leads to a very simple expression of the B(E2)↑ .

We report on this analysis which casts a new light on the differences observed around N=40 in the evolution of the B(E2)↑ from the Ni up to the Se isotopes. It suggests a scenario in which a N=40 gap is not the main point. Indeed, the reproduction of the evolution of the experimental B(E2)↑ curves observed in the region implies a more complex sub-shell structure in which the p-n interaction plays an important role [6, 7].

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Microscopic Description of Shape Isomerism and SD Phenomena in the Actinide Region

J. Libert[1], **J. P. Delaroche**[2], **M. Girod**[2], **H. Goutte**[2]

[1]IPN-Osay, CNRS-IN2P3 and Univ. Paris Sud, 91406 Orsay France

[2]CEA-DPTA/SPN, BP12, 91680 Bruyères-le-Châtel, France

The D1S effective force is used in constrained Hartree-Fock-Bogoliubov (HFB) potential energy calculations to map superdeformed (SD) shapes in 55 even-even isotopes of the Th, U, Pu, Cm, Cf, Fm and No elements. Quadrupole collective excitations are predicted together at normal (ND) and super- (SD) déformation using configuration mixing calculations. These microscopic approach which takes into account the five quadrupole degrees of freedom ($\beta - \gamma$ and Euler angles) furnishes collective positive parity states with good angular momentum. Predicted sequences have been compared for SD shapes with experimental data when available. Their stability is discussed against octupole mode which is of some importance in this region of heavy nuclei at large déformation. Half-lives relevant to γ-decay of 0^+ SD states toward normally deformed (ND) levels have been also evaluated in the WKB approximation.

Systematics of Nuclei with Critical Point Symmetries

Tz. Venkova[1], **A. I. Georgieva**[1], **and A. Aprahamian**[2]

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

[2]The University of Notre Dame, Department of Physics, Notre Dame, IN46556, USA

An empirical investigation of the main properties of even-even nuclei with $E(5)$ and $X(5)$ critical point symmetries is realized in the framework of an $Sp(4,R)$ based classification scheme. As a result of the analysis of their specific nuclear characteristics in the shell, outlined in the classification of the already experimentally investigated nuclei, we are able to predict some possible new cases with these two types of phase transitions.