High Spin Physics 2001, Warsaw, February 6-10, 2001

Abstract No: 001
Submitted on: 2 Nov 2000, 9:15 GMT

Title: **The structure of high-Z nuclei from studies with GAMMASPHERE at ATLAS**

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This presentation will review one of the main research programs carried out with the Gammasphere array at ATLAS. Taking advantage of the availability of very heavy beams on the one hand, and of the coupling of Gammasphere with the Fragment Mass Analyzer on the other, it was possible to gain new insights into the properties of actinide and transfermium nuclei.

Coulomb excitation measurements with ^{207,208}Pb beams at energies $\sim$15% above the barrier have been carried out on ^{232}Th and on long-lived Pu targets with A = 239, 240, 242, and 244. In addition to the target excitations, transfer channels leading to ^{238,241,243}Pu were studied as well. With a ^{209}Bi beam, the level structures of ^{237}Np, ^{241}Am and of the one-proton transfer channel leading to ^{242}Cm were investigated. Several surprising results concerning the behavior of the negative parity bands and of band structures built on the first excited 0^+ states will be discussed.

The recoil decay tagging technique was used to study not only the yrast structure of Z=102 isotopes ^{253}No and ^{254}No, but also the entry distributions using ^{48}Ca + ^{207,208}Pb fusion-evaporation reactions. The results confirm that the shell-correction energy responsible for the stability of No is partly derived from deformation. Based on a novel approach to determine a lower bound of the barrier height, the measured entry distributions provide direct information on the reaction mechanism(s), the fission barrier and the shell-correction energy. The results will be compared with theoretical expectations.

Finally, several single-particle and vibrational states above the N = 152 subshell gap were investigated by combining the results from α-γ spectroscopy following the decay of ^{255}Fm to ^{251}Cf with cross section data for the ^{250}Cf(d,p) reaction.

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Invited talk

Abstract No: 002
Submitted on: 5 Dec 2000, 10:52 GMT
Title: **Effects of neutron-proton interaction in doubly odd deformed nuclei.**
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The two most important effects associated with the residual n-p interaction in doubly odd deformed nuclei are the Gallagher-Moszkowski splitting and the odd-even or Newby shift. Further information on the neutron-proton interaction may be obtained by studying the odd-even staggering in $K \neq 0$ bands; in fact, the main mechanism responsible for this effect is the mixing, through the Coriolis interaction, of $K \neq 0$ bands with one or more Newby-shifted $K = 0$ bands.

We have investigated the effects of the neutron-proton interaction in doubly odd deformed nuclei, with particular attention focused on the role of the tensor force, by studying the doubly odd Lu isotopes within the framework of the particle-rotor model. The results of our calculations lead to the conclusion that the tensor force as well as the space-exchange and spin-spin space-exchange forces play an important role in the description of $K = 0$ bands and of some $K \neq 0$ bands. [1, 2].

We are currently extending our study to other doubly odd deformed nuclei. In this presentation we shall report on results for Ta isotopes.

References

[1] A. Covello, A. Gargano, and N. Itaco, Phys. Rev. **C56**, 3092 (1997).

[2] N. Itaco, A. Covello, and A. Gargano, *6th International Spring Seminar on Nuclear Physics, Sant'Agata sui Due Golfi, 1998*, ed: A. Covello, (World Scientific, Singapore, 1999), p.451.

Preferred presentation of the contribution: in the oral session.

Abstract No: 003
Submitted on: 9 Dec 2000, 19:56 GMT
Title: **Development of Gamma-Ray Tracking Detectors**
Author(s): R.M. Lieder,[1] for the Gamma-Ray Tracking Detector Collaboration,[2–13]
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The investigation of new phenomena in atomic nuclei requires the study of their structure under extreme conditions at the boundary of stability, where the excitation energy, the spin or isospin take extreme values. The most powerful means for such studies is the high-precision γ-ray spectroscopy with highly efficient and highly granulated γ-detector arrays. The array should for a maximum coverage of the total solid angle consist only of Ge detectors. A new concept is required to build such a Ge shell since with present-day Ge detectors the performance would be poor due to the large probability to detect several γ-rays in one detector and the scattering of γ-radiation between them due to the Compton effect. However, if one could follow the tracks of the γ-rays in the Ge shell an unprecedented performance could be obtained. Such a Ge shell will have a sensitivity which is about two orders of magnitude larger than that of present-day γ-detector arrays. The prerequisite for the construction of such a γ-ray tracking array is the development of γ-ray tracking detectors. They consist of high-fold segmented Ge detectors and front-end electronics, based on digital signal processing techniques, which allows to extract energy, timing and spatial information for a γ-ray by pulse shape analysis of the Ge detector signals. Utilizing the information on the positions of the interaction points and the energies released at each point the tracks of the γ-rays in a Ge shell can be reconstructed in three dimensions on the basis of the Compton scattering formula.

To design γ-ray tracking detectors for a 4π γ-detector array research and technical development is carried out in the following areas: (i) Development of segmented Ge detectors, (ii) Development of digital signal-processing electronics, (iii) Development of pulse shape analysis methods, (iv) Development of tracking algorithms and (v) Simulation of tracking arrays.

The research and development work is carried out in the framework of a TMR (Training and Mobility in Research) network project of the European Commission under contract no. ERBFM-RXCT970123.

Preferred presentation of the contribution: in the oral session.

Abstract No: 004
Submitted on: 18 Dec 2000, 1:30 GMT

Title: **Collective Rotational Motion in the $N = Z$ Nucleus ^{36}Ar**

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High-spin states in the $N = Z$ nucleus ^{36}Ar have been studied via the ^{28}Si(^{16}O,2α)^{36}Ar and ^{24}Mg(^{20}Ne,2α)^{36}Ar reactions in two experiments conducted at Argonne National Laboratory with the Gammasphere array and the Microball charged-particle detector. These experiments resulted in the identification of a "super"-deformed ($\beta_2 \approx 0.46$) rotational band in ^{36}Ar. At low spin the band is firmly linked to previously known states, while at high spin it is observed to its termination at $I^\pi = 16^+$. Spins, parities, excitation energies, and in-band, as well as decay-out, transition matrix elements have been established throughout the band, providing essentially complete spectroscopic information.

This highly-deformed band in ^{36}Ar arguably represents the best known example of well-developed collective rotational motion in a light nucleus. In analogy with rotational motion in heavier nuclei, two major shells are active for both protons and neutrons, yet, in ^{36}Ar, the valence space dimension remains small enough to be meaningfully approached from the shell model perspective. This band thus provides an ideal case in which to study the microscopic origins of collective rotation through a comparison of the experimental data with both deformed mean-field models of the nuclear intrinsic state and the laboratory-frame description of rotational motion achieved in large-scale spherical shell-model calculations.

We have initiated this program of studies by performing both configuration-dependent cranked Nilsson-Strutinsky (CNS) and $(s_{1/2}d_{3/2})$-pf shell-model (SM) calculations for ^{36}Ar. These calculations have provided a consistent description of the band based on a highly-deformed configuration in which four pf-shell orbitals are occupied. While an excellent description of the energetic properties of the band has been achieved, detailed comparisons with the $B(E2)$ values deduced from experimental lifetime measurements indicate the need for a more refined treatment of transition matrix elements close to termination in the CNS calculations, and the inclusion of the complete *sd*-pf model space in the shell-model diagonalization. In this presentation, I will discuss the experimental results for ^{36}Ar, the successes, and limitations, of current theoretical models, and possible directions toward a more complete microscopic description of this highly-collective rotational band.

Invited talk.

Abstract No: 005
Submitted on: 18 Dec 2000, 11:31 GMT

Title: **Search for the Jacobi instability in rapidly rotating ^{46}Ti***

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Hot and rotating nuclei are expected to develop many different shapes with increasing rotational frequency. At low angular momentum, if their thermal energy is low, shell effects are dominant and nuclei are either spherical or prolate with rather small deformations. When the thermal energy is sufficiently large, the role of shell effects becomes smaller and according to the liquid drop model [1] the nucleus, under the influence of rotation, undergoes a prolate(spherical)-oblate shape phase transition. The size of the oblate deformation increases with the rotational frequency. When the rotational frequency is sufficiently large, the nucleus might undergo another shape phase transition, in which the nucleus becomes triaxially elongated. This transition called Jacobi transition (Jacobi instability) is expected to be rather better seen in light nuclei, where high rotational frequencies can be reached before the fission competition dominates. For example for nuclei with mass A$\approx$45 the critical angular momentum for the Jacobi transition is expected to be at $\approx$30 $\hbar$.

The first experimental evidence for the Jacobi shape transition was obtained for the ^{45}Sc compound nuclei based on inclusive spectra [2]. In the photon absorption cross-section, apart from the lorentzian shape centered at 18 MeV corresponding to the GDR of nuclei with small deformation, a shoulder at $E_\gamma \approx 25$ MeV was found. This has suggested large effective deformation of the compound system at high rotational frequencies. However, the corresponding A_2 coefficient of the angular distributions did not show the correct expected behaviour.

To verify the existence of Jacobi shapes and to understand the unexpected behaviour of the measured angular anisotropy another experiment was made for the neighbouring ^{46}Ti nucleus. It allowed to obtaine more exclusive data corresponding to better selected regions of the angular momentum. For this experiment the HECTOR array [3] and the accelerator facility of the Niels Bohr Institute in Risø (Denmark) were employed. The reaction used was 98 MeV ^{18}O on ^{28}Si target, producing the compound nucleus ^{46}Ti at the excitation energy of 81 MeV, and with angular momentum distribution having $l_{max} \approx 32$ $\hbar$. The high-energy spectra, measured in the BaF_2 detectors at different angles, were obtained as a function of the multiplicity filter's folds. The results of this experiment, confirming the existence of Jacobi shapes, will be presented and the comparison to the theoretical prediction will be discussed.

References

[1] S. Cohen, F. Plasil, W.J. Świątecki, Ann. Phys. (N.Y.) 82 (1974) 557.

[2] M. Kicińska-Habior et al., Phys. Lett. B308 (1993) 225.

[3] A. Maj et al., Nucl. Phys. A571 (1994) 185.

Preferred presentation of the contribution: in the oral session.

High Spin Physics 2001, Warsaw, February 6-10, 2001

Abstract No: 006
Submitted on: 19 Dec 2000, 17:37 GMT

Title: **Measurements of spectroscopic quadrupole moments at high spins: test of the Tilted Axis Cranking (TAC) model**

Author(s): D.L. Balabanski,[1,2] K. Vyvey,[1] G. Neyens,[1] D. Boremans,[1] N. Coulier,[1] W. De Clercq,[1] R. Coussement,[1], G. Georgiev,[1,2] A. Lèpine-Szily,[1,3] S. Ternier,[1] S. Teughels,[1] M. Mineva,[4] P.M. Walker,[5] H. Hubel,[6] S. Chmel,[6] N. Nenoff,[6] D. Rossbach,[6] R.Schwengener,[7] P. Blaha,[8] D. Almehed[7] and S. Frauendorf[7,9]

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Several measurements of spectroscopic quadrupole moments of high-spin isomers ware carried out recently at the CYCLONE facility at Louvain-la-Neuve, using the *Le*vel *M*ixing *S*pectroscopy (LEMS) technique [1]. All of them aimed to test the predictions of the *T*ilted *A*xis *C*ranking (TAC) model [2]

The spectroscopic quadrupole moment of the high-spin, high-K five-quasiparticle isomer ($K^\pi = \frac{35}{2}^-$, $T_{1/2} = 750 \pm 80$ ns, $E_i = 3349$ keV) in ^{179}W was found to be $Q_s = 4.00(^{+0.83}_{-1.06})$ eb, which corresponds to an intrinsic quadrupole moment $Q_0 = 4.73(^{+0.98}_{-1.25})$ eb and to a quadrupole deformation $\beta_2 = 0.185(^{+0.038}_{-0.049})$. These values differ significantly from the deduced ground-state quadrupole moments and deformations and are in disagreement with the current theoretical predictions in this mass region [3].

In another experiment we have measured the spectroscopic quadrupole moment of the $I^\pi = 11^-$ isomer in ^{196}Pb. This isomer has the same proton $\pi(s_{1/2}^{-2}h_{9/2}i_{13/2})$ configuration as the $I^\pi = 16^{(-)}$ bandhead of the magnetic band in ^{196}Pb, which allows to deduce the quadrupole moment of the $16^{(-)}$ state as $Q_s = -0.316(97)$ eb. This is the first experimental determination of the quadrupole moment of a magnetic rotational bandhead. Its small value proves the nearly sphericity of the magnetic bandhead [4].

References

[1] F. Hardeman *et al.*, Phys. Rev. **C43**, 130 (1991).

[2] S. Frauendorf, Nucl. Phys. **A557**, 259c (1993).

[3] D.L. Balabanski *et al.*, Phys. Rev. Lett. (in print).

[4] K. Vyvey *et al.*, in preparation for Phys. Rev. Lett.

Preferred presentation of the contribution: in the oral session.

Abstract No: 007
Submitted on: 19 Dec 2000, 19:19 GMT
Title: **Wobbling motion in $^{163}_{71}\mathrm{Lu}_{92}$ - Understanding of observed properties**
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Affiliation(s): Division of Mathematical Physics, LTH, University of Lund, P.O.Box 118, S-22100 Lund, Sweden

Though nuclear wobbling motion, which is a unique feature of the rotation of a triaxial nuclear shape, has been theoretically discussed for years (for example, see ref. [1]), it has never been experimentally identified with conclusive evidence. For nuclei with N$\sim$94 and Z$\sim$71-72, the total energy surface calculations [2] predict stable triaxial shapes with large quadrupole deformation ($\varepsilon\sim0.38$ and $\gamma\sim\pm20°$) for all parity and signature in a certain region of angular momentum. Using the fusion evaporation reaction ^{139}La(^{29}Si,5n)^{163}Lu with a beam energy of 152 MeV, two presumably triaxial super deformed (TSD) bands have been observed. The possible assignment of the excited TSD band as a wobbling mode built on the yrast TSD band is reported [3].

A careful analysis of all observed quantities (the level scheme, spin-alignments, electromagnetic properties, etc.) of those TSD bands is now available [4]. I plan to explain our understanding of the result of the analysis in terms of a wobbling mode built on the aligned $i_{13/2}$ proton, which is suggested using particle-rotor model calculations in ref. [5]. We believe that we have now a convincing evidence for the observation of nuclear wobbling motion.

References

[1] A. Bohr and B. R. Mottelson, *Nuclear Structure*, Vol.II, (Benjamin, New York, 1975), Chap. 4, p. 190.

[2] H. Schnack-Petersen et al., Nucl. Phys. **A594**, 175 (1995).

[3] S. W. Odegaard, G.B.Hagemann et al., Proc. of International Conference at MSU, Aug., 2000 ; to be published in a special issue of Nucl. Phys. **A**.

[4] S. W. Odegaard, G.B.Hagemann et al., contribution to this conference.

[5] I. Hamamoto, Phys. Lett. **B193**, 399 (1987).

Invited talk.

Abstract No: 008
Submitted on: 20 Dec 2000, 12:59 GMT

Title: **High-Spin Nuclear Properties within the Dirac Mean-field Approach with a Woods-Saxon Potential**

Author(s): N. Schunck,[1] J. Dudek,[1] and Z. Lojewski[2]

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It was found in recent years that Relativistic Mean Field theory (RMF) leads to a very efficient description of ground state properties of nuclei as well as those of selected rotational bands. So far, many interesting results were obtained when solving the RMF equations (Dirac equation with "vector" and "scalar" potentials originating from the exchange mechanisms of vector and scalar mesons respectively, coupled self-consistently to the corresponding Klein-Gordon equations)[1].

We adopted a non self-consistent method, in which the low-energy limit of the Dirac equation was studied by parametrising the potentials and the effective-mass with the help of Woods-Saxon functions. The main purpose of this study was to find the best parameter fit that could next give the message about an overall limitation of the possible maximum quality of the Dirac mean-field in nuclei in terms of the single-particle description. In this approach, the main difficulty consisted in finding a suitable set of parameters for the nuclear potentials. For that purpose, we selected a certain number of criteria that gave us a measure of the agreement between theory and experiment. We automatized the research of the best set of parameters via a minimisation process. This procedure was successfully applied to several doubly magic nuclei and enabled us to reproduce many of the ground state properties such as the experimental single particle spectra, the r.m.s. radii and the nucleonic binding energies with an accuracy comparable to or better than that of the best approaches known in the literature. Calculations performed for deformed nuclei also reproduced well the spin and parity band-head assignments. A presentation of the method has been given elsewhere [2].

The results obtained for the ground states of nuclei beeing very satisfactory, we applied the method to the study of rotational bands. As an intermediate step, microscopic-macroscopic calculations of the nuclear equilibrium deformations were performed, and will be briefly presented. Several quantities like the moments of inertia or the effective alignment for various bands have been calculated using the Dirac cranked mean-field and show a very good agreement with experiment.

References

[1] Y. K. Gambhir, P. Ring and A. Thimet, Annals of Physics **198** 132. (1990).

[2] N. Schunck and J. Dudek, Proceedings of the XXXIV Zakopane School of Physics, Acta Phys. Polonica, to be published.

Preferred presentation of the contribution: in the oral session.

Abstract No: 009
Submitted on: 21 Dec 2000, 12:07 GMT

Title: **Population of high spin states in fragmentation reactions**

Author(s): M. Pfützner[1], P.H. Regan[2], P. Walker[2], Zs. Podolyak[2], M. Caamaño[2], J. Gerl[3], M. Hellström[3], P. Mayet[3], and M. Mineva[4] for the GSI ISOMER Collaboration
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The use of projectile fragmentation reactions at intermediate and relativistic energies, combined with unambiguous channel selection afforded by state of the art magnetic separators, has proved to be a very sensitive technique in the study of exotic nuclei which are often inaccessible by other, more standard high-spin methods. As recently demonstrated by results from both GANIL and GSI, the application of this technique for the spectroscopy of μs isomer decays, allows the first identification of excited states in nuclei very far from stability, even with secondary beam production rates as low as a few ions per minute [1, 2]. However, rather surprisingly, one of the key variables in this method, namely the population of high-spin states in fragmentation reactions, has, until now, not been systematically studied. The current work reports on measurements of the population of more than twenty isomers produced by fragmentation of 1 GeV/nucleon ^{208}Pb at SIS/FRS facility at GSI Darmstadt. The isomers observed range from low spin example up to decays of $K = \frac{35}{2}\,\hbar$ states in ^{179}W and ^{181}Re. The dependence of measured isomeric ratios on the number of abraded nucleons, spin and excitation energy above the yrast line will be discussed and compared with predictions from a simple, 'sharp cut-off' model based on the abrasion-ablation description of the fragmentation process [3].

References

[1] J.M. Daugas et al., Phys. Lett. **B 476**, 213 (2000).

[2] Zs. Podolyák et al., Phys. Lett. **B 491**, 225 (2000).

[3] M. de Jong, A.V. Ignatyuk and K.-H. Schmidt, Nucl. Phys. **A 613**, 435 (1997).

$\boxed{\text{Invited talk.}}$

Abstract No: 010
Submitted on: 21 Dec 2000, 16:48 GMT GMT

Title: **Evidence for the wobbling mode in ^{163}Lu**

Author(s): S.W. Ødegård[1,2], G.B. Hagemann[1], D.R. Jensen[1], M. Bergström[1], B. Herskind[1], G. Sletten[1], S. Törmänen[1], J. Wilson[1], P.O. Tjøm[2], K. Spohr[3], H. Hübel[4], A. Görgen[4], G. Schönwasser[4], A. Bracco[5], S. Leoni[5], A. Maj[6], C. Petrache[7], P. Bednarczyk[8], D. Curien[8]

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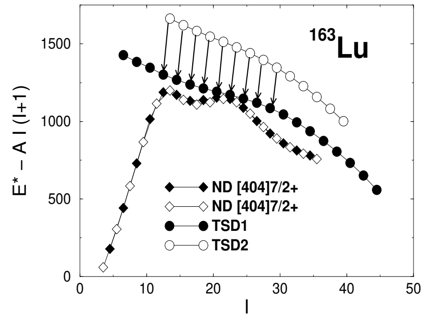
The wobbling mode is a direct consequence of rotational motion of a triaxial body. The wobbling degree of freedom introduces sequences of bands with increasing number of wobbling quanta [1], and a characteristic $\Delta I = 1$ decay pattern between the bands in competition with the in-band decay.

Favourable candidates for establishing for the first time this exotic excitation mode may be found in Lu-isotopes for which stable triaxial superdeformed shapes are expected. Several, presumably triaxial, superdeformed bands (TSD's) involving an aligned $i_{13/2}$ proton, which would strongly influence the decays from a wobbling excitation [2], are reported in recent years [3].

In a search for the wobbling mode built on TSD1 in ^{163}Lu an experiment using the fusion evaporation reaction ^{139}La(^{29}Si,5n) with a beam energy of 152 MeV was performed at the Euroball IV setup in Strasbourg. Several crossband transitions between a new band, TSD2, and TSD1 have been established, see the figure. From angular distribution, DCO ratio, and linear polarization measurements the mixed E2/M1 multipolarity could be deduced. Thereby firm spin and parity are assigned to TSD2. The relative excitation energy (200-300 keV) of TSD2 compared to TSD1 and in particular the EM properties with $B(E2)_{out}/B(E2)_{in} \sim 0.2$ and $B(M1)/B(E2)_{in} \sim 0.006\mu_N^2/e^2b^2$, are in severe disagreement with expectations for the signature partner. Furthermore, no three-quasiparticle excitations of the correct spin and parity is expected this low in excitation energy from cranking calculations. In contrast, a comparison to calculations [2] for the wobbling excitation shows reasonable agreement, thereby giving experimental evidence for observation of the long sought wobbling mode for the first time.



References

[1] Å. Bohr and B.R. Mottelson, *Nuclear Structure*, Vol. II, (Benjamin, New York, 1975).

[2] I. Hamamoto, Phys. Lett. B193 (1987) 399 and invited talk at this conference.

[3] G.B. Hagemann, Phys. Scripta T88 (2000) 77 and refs. therein.

Preferred presentation of the contribution: in the oral session.

Abstract No: 011
Submitted on: 21 Dec 2000, 17:36 GMT
Title: **Wobbling motion in multi-bands crossing region**
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Affiliation(s): [1]*Department of Physics, University of Surrey, Guildford, U.K.,* [2]*Department of Applied Physics, Fukui University, Fukui, Japan,* [3]*Institute of Physics, Bhubaneswar, India,* [4]*Department of Engineering, Aomori University, Aomori, Japan,* [5]*Department of Engineering, Yamanashi University, Kohu, Japan.*

The backbending in the $A \simeq 180$ mass region is expected to be caused by multi-bands crossing between low-K (g- and s-bands) and high-K bands (t-bands) [1].

We analyze a mechanism of coupling of these bands in terms of a dynamical treatment for nuclear rotations, i.e.,wobbling motion [2]. The wobbling states are produced through the generator coordinate method after angular momentum projection (*GCM-after-AMP*), in which the intrinsic states are constructed through fully self-consistent calculations by the 2d-cranked (or tilted-axis-cranked) HFB method [3]. In particular, the phenomena of "signature inversion" and "signature splitting" in the t-band (tilted rotational band) are explained in terms of the wobbling model. We also discuss the wobbling motion in terms of a dynamical symmetry breaking and restoration, of the signature symmetry. Our calculations will be compared with new data for in-band E2 transition rates in ^{182}Os [4], which may shed light on the mechanism of the anomalous $K = 25$ isomer decay, directly to the yrast band.

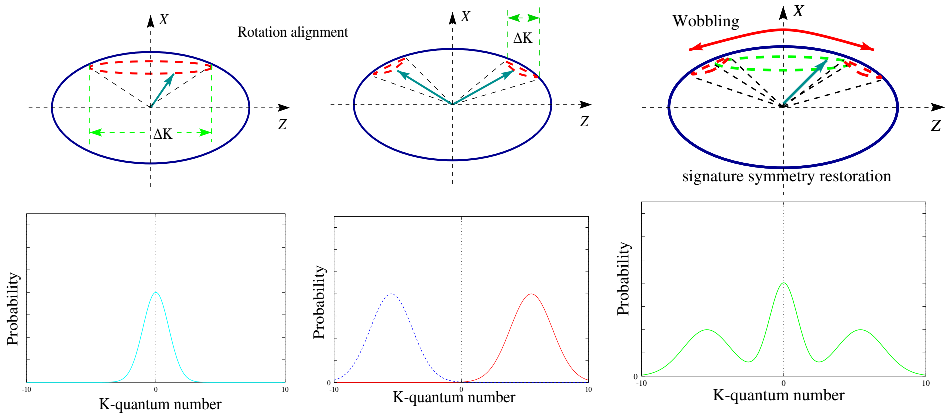

Figure: (from left to right) rotational alingment in s-band; in high-K band; and wobbling motion.

References

[1] P.M.Walker *Int. Conf. on the future of nuclear spectroscopy*, Crete, 1993.

[2] M.Oi et al, Phys. Lett. **B480**, 53 (2000).

[3] T. Horibata and N. Onishi, Nucl. Phys. **A596**, 251 (1996).

[4] Zs. Podolyák (University of Surrey), et al., *Private Communication* .

Preferred presentation of the contribution: in the oral session.

Abstract No: 012
Submitted on: 22 Dec 2000, 9:39 GMT

Title: **The structure of heavy octupole and superheavy quadrupole deformed nuclei.**

Author(s): P.A. Butler[1]
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This contribution will be divided into two parts. In the first part I will describe experimental attempts to determine the sign of the electric dipole moment (relative to the electric octupole moment) in the octupole deformed nucleus ^{226}Ra. Sensitivity to this quantity is observed in the measured yields of γ-ray transitions following very low energy Coulomb excitation.

In the second part I will report on recent progress in the development of new spectroscopic techniques that promise to elucidate the structure of deformed superheavy nuclei in the region of ^{254}No. The $4^+ \rightarrow 2^+$ transition in ^{254}No has been identified using recoil-tagged conversion electron spectroscopy. This technique has been applied to the measurement of the strongly converted rotational bands in ^{253}No.

Both experimental projects have been carried out by a collaboration between the University of Liverpool and the University of Jyväskylä at the Jyväskylä cyclotron laboratory.

$\boxed{\text{Invited talk.}}$

Abstract No: 013
Submitted on: 22 Dec 2000, 12:32 GMT

Title: **Magnetic Rotation in ^{196}Pb***

Author(s): A.K. Singh[1], N. Nenoff[1], D. Rossbach[1], A. Görgen[1], F.Azaiez[2], A. Astier[3], D. Bazzacco[4], M. Bergström[5], C. Bourgeois[2], N. Buforn[3], K. Hauschild[6], A. Korichi[7], W. Korten[6], A. Lopez-Martens[7], R. Lucas[6], H.J. Maier[8], H. Hübel[1], T. Kröll[4], E. Mergel[1], N. Redon[3], P. Reiter[8], C. Rossi-Alvarez[4], G. Schönwasser[1], O. Stezowski[3], P. Thirolf[8], A. N. Wilson[9]

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Since the first discovery of regular bands of enhanced magnetic dipole transitions in the Pb isotopes [1] a large number of such bands has been found. From their properties it soon became clear that they represent a new mode of nuclear excitation [2], for which the name "Magnetic Rotation" was suggested [3]. The magnetic rotational bands are built on states which result from a coupling of high-spin particle to high-spin hole excitations. In the Pb region, high-spin particle states can be formed by proton excitations into the $h_{9/2}$ and $i_{13/2}$ orbitals and high-spin hole states are available by neutron excitations in the $i_{13/2}$ subshell. Such proton-particle/neutron-hole states have large components of the magnetic moments perpendicular to the total angular momentum. The magnetic moments rotate about the total angular momentum axis giving rise to the enhanced M1 radiation.

We have investigated magnetic rotational bands and their linking transitions to lower-lying states in ^{196}Pb. High spin states in this nucleus have been populated in the ^{170}Er(^{30}Si,4n) reaction and γ-ray coincidences were measured using the Euroball IV spectrometer array. The analysis revealed several new M1 bands in addition to the previously known ones [4] and showed that some transitions within the bands have to be reordered. Most of the bands are now linked to lower levels. On the basis of spins, parities and excitation energies configuration assignments can be made. The results are compared to neighbouring Pb isotopes and to tilted-axis cranking calculations.

$*$ Supported by BMBF (contract no. 06 BN 907) and by the European Community - Access to Research Infrastructure. A.K.S acknowledges financial support from the AVH foundation.

References

[1] G. Baldsiefen *et al.*, Proc. X International School of Nucl. Phys., Neutron Phys. and Nucl. Energy, Varna (1991).

[2] H. Hübel, Nuovo Cim. **111A**, 709 (1998).

[3] S. Frauendorf, Z. Phys. A**358**, 163 (1997).

[4] G. Baldsiefen *et al.*, Z. Phys. A**355**, 337 (1996).

Preferred presentation of the contribution: in the poster session.

High Spin Physics 2001, Warsaw, February 6-10, 2001

Abstract No: 014
Submitted on: 23 Dec 2000, 5:02 GMT
Title: Symmetries of the rotating mean field
Author(s): S. Frauendorf
Affiliation(s): University of Notre Dame, USA and FZR Rossendorf, Germany

The cranking model, which provides uniformly rotating mean field solutions, is the standard microscopic description of high spin states. The existence and structure of rotational bands reflects the symmetries of these solutions. The relation between angular momentum $\vec{J}$ and velocity $\vec{\omega}$ is much more complex than for molecules or liquids, because nuclei are composed of nucleons on orbits with an angular momentum, which is largely controlled by quantization.

The currents of these orbitals are the elements of anisotropy, which break the symmetry of the mean field with respect to $\vec{J}$, thus giving rise to rotational bands. The existence of magnetic rotation demonstrates that substantial anisotropy of the current distribution may occur for a nearly isotropic density distribution.

The nucleonic currents combine to a flow pattern that is different from rigid body flow when the pair correlations are quenched. This is clearly the case for bands in weakly deformed nuclei, but the moments of inertia of well deformed nuclei deviate from the rigid body value too, which is only approached in superdeformed nuclei.

The combination of $\vec{J}$ with the density distribution gives rise to a variety of discrete symmetries. A new possibility is the breaking of chiral symmetry in triaxial reflection symmetric nuclei. It shows up as a pair of identical $\Delta I = 1$ bands of the same parity. Mean field solutions of this type have been found in nuclides around $A = 134$, where there is experimental evidence for a small island of chirality

There are 15 different discrete symmetries of the rotating mean field if time odd components are considered and no reflection asymmetry is demanded. Some of them have a spin parity sequence that is distinctly different from the familiar ones, which would be a clear experimental signature of the symmetry. So far there is only evidence for the symmetries leading to the spin parity sequences: $I^+, (I+2)^+, (I+4)^+, ...$, $I^+, (I+1)^+, (I+2)^+, ...$, $2I^+, 2(I+1)^+, 2(I+2)^+, ...$ (chiral doubling), $I^+, (I+1)^-, (I+2)^+, ...$, and $I^\pm, (I+1)^\pm, (I+2)^\pm, ...$ (parity doubling).

Invited talk.

Abstract No: 015
Submitted on: 27 Dec 2000, 10:12 GMT

Title: **Search for magnetic rotation in the A ≈140 region.**

Author(s): T. Rząca-Urban[1] in collaboration with research groups from IKP Jülich, LNL Legnaro, Universities of Warsaw, Padova and Bonn.
Affiliation(s): [1]*Institute of Experimental Physics, University of Warsaw, Poland*

In the early 1990's, a new type of rotation, represented by the rotation of a large magnetic dipole around the nuclear spin, has been discovered in Pb nuclei with A≈200. To date, such bands have been found in different nuclei in several mass regions [1]. Magnetic rotation (MR) is expected in weakly deformed nuclei close to magic numbers, if high-j particle orbitals and high-j hole orbitals are active [2]. In this work we will present recent data for several nuclei from the Z≈64 and N≤82 region obtained with γ-ray arrays EUROBALL and GASP at the Legnaro National Laboratory. Dipole magnetic bands, with strong M1 and weak or unobserved E2 crossover transitions, have been identified in ^{142,143,144}Gd and ^{141}Eu nuclei. In general, a reasonable agreement between the experimental data and the predictions of the tilted axis cranking (TAC) model has been obtained supporting the interpretation of the dipole bands in this region as MR bands. Information about the strength of the effective interaction between constituent nucleons has been deduced using a semiclassical scheme of the coupling of two angular momentum vectors. A transition from regular to irregular MR bands has been found in Gd nuclei with N approaching 82. This can be explained as a decrease of quadrupole polarizability close to the magic shell, where short range residual interactions between valence particles dominate, which do not favour the formation of stable "shears blades".

References

[1] R.M. Clark and A.O. Macchiavelli, Annu. Rev. Nucl. Part. Sci., **50**, 1 (2000).

[2] S. Frauendorf, Rev. Mod. Phys. In press (2000).

Invited talk.

Abstract No: 016
Submitted on: 28 Dec 2000, 10:37 GMT
Title: **Spectroscopy of Superdeformed Pb Isotopes***
Author(s): H. Hübel
Affiliation(s): Institut für Strahlen- und Kernphysik, Universität Bonn, Nussallee 14-16, D-53115 Bonn, Germany

In our recent work we have concentrated on an investigation of superdeformed (SD) Pb isotopes in an attempt to make configuration assignments to the observed bands. Comparison to theoretical calculations shows how well the mean-field approach can reproduce energy levels at extreme deformation. It is also of great interest that theory predicts octupole vibrations in the A = 190 region which may be responsible for the lowest excited states in the even-even isotopes.

Information that can lead to configuration assignments has to come from the following observables: The spin-fitting method can help to make spin assignments. The relative intensities of the bands indicate the ordering in excitation energy. If M1 transitions between signature-partner bands are observed, g factors can be derived and compared to theoretical values for various configurations. The dynamical moments of inertia contain information about alignment effects and possible blocking of intruder orbitals. The quadrupole moments depend also on the intruder configurations. Furthermore, quasiparticle routhians and their signature splittings can be compared to calculations. Finally, in cases where enhanced E1 transitions between bands exist, the excited bands may be built on octupole vibrations.

We have investigated an odd-A nucleus, ^{193}Pb, and an even-even nucleus, ^{196}Pb, using the Gammasphere and Euroball spectrometer arrays, respectively [1, 2]. High-spin states in ^{193}Pb have been populated in the ^{168}Er(^{30}Si,5n) reaction at the 88-Inch Cyclotron, Berkeley. In addition to the previously known six SD bands three new bands have been found [1]. From the properties of the bands, quasiparticle configuration assignments are made and compared to cranked shell model calculations. More than half of the predicted routhians near the Fermi surface have now been identified experimentally. SD bands in ^{196}Pb have been populated in the ^{170}Er(^{30}Si,4n) reaction at the Vivitron, Strasbourg. In this nucleus, where four bands are known [3], the E1 multipolarity of a group of transitions around 945 keV connecting an excited to the yrast SD band has been determined from a linear polarisation measurement using the Clover Ge detectors of the Euroball spectrometer. These transitions, which compete with the highly collective in-band E2 transitions, are strongly enhanced (B(E1) $\simeq 10^{-4}$ Wu). This supports calculations [4] which predict low-lying octupole vibrations in the A = 190 region.

*Supported by BMBF, Germany, under contract no. 06 BN 907 and by the European Community - Access to Research Infrastructure.

References

[1] D. Rossbach et al., Nucl. Phys. **A 660**, 393 (1999)

[2] D. Rossbach et al., to be publ.

[3] S. Bouneau et al., Z. Phys. **A 358**, 179 (1997)

[4] T. Nakatsukasa et al., Phys. Rev. **C 53**, 2213 (1996)

Preferred presentation of the contribution: in the oral session.

High Spin Physics 2001, Warsaw, February 6-10, 2001

Abstract No: 017
Submitted on: 28 Dec 2000, 18:19 GMT

Title: **Gamma-ray Strength Functions in Thermally Excited Rotating Nuclei**

Author(s): T Døssing[1] and B. Herskind[1]
Affiliation: [1]*The Niels Bohr Institute, Blegdamsvej 17, DK-2100 Copenhagen Ø, Denmark*

The study of γ-ray cascades in rotating nuclei probes to investigate the gradual transition with increasing temperature from ordered rotational bands of specific structure to chaotic rotation with fragmented quadrupole transition strength.

Recent data collected by the Gammasphere and Euroball multi-detector arrays provide spectra with enough counts to allow for a detailed study of interactions between excited bands in various temperature ranges. The data are sorted into three-dimensional $E_{\gamma_1} \times E_{\gamma_2} \times E_{\gamma_3}$ spectra, or two-dimensional spectra with specific gates. For the nuclei ^{168}Hf and ^{163}Lu, typically 10^6 triplet consecutive transitions are recorded, such as for example the three steps of cascades connecting angular momenta $34 \rightarrow 32 \rightarrow 30 \rightarrow 28\,\hbar$. The coincidences arising from such sequences are located at specific places, close to the "central valley" at $E_{\gamma_1} = E_{\gamma_2} = E_{\gamma_3}$.

The most intense and most strongly fluctuating regions in the spectra are the the "ridges" in three dimensions, carrying strong transitions emitted from ordered rotational bands. Somewhat wider and more smooth ridges are formed by transitions from interacting bands with fragmented quadrupole strength, still carrying significant rotational energy correlations. The width of such ridges is related to the compound damping width, that is the spreading width of the basis bands. Equivalent wide ridges in two dimensional gated spectra are displayed below. Finally, the most smooth regions of the spectra, the "valleys", contain transitions from highly fragmented rotational decay, emitted from states of temperature up to around 0.5 MeV in rare earth nuclei.

Current studies of fluctuations of such spectra and covariances between gated spectra will be presented. The aim is to obtain clear information about the energy scales characterising the rotational motion of warm nuclei: (*i*) the energy for onset of fragmentation of the rotational transitions, (*ii*) the compound damping width, (*iii*) the rotational damping width.

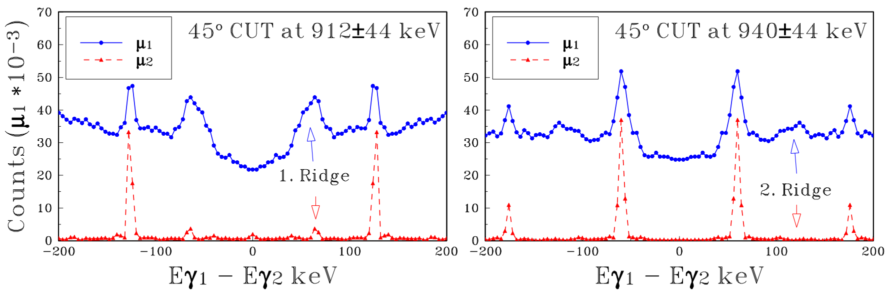

Figure 1: Two "perpendicular cuts" of a two-dimensional spectrum and its second moment, measuring the fluctuations of the spectrum, gated by the S-band in ^{168}Hf. The cut centred at 940 keV contains a coincidence on the S-band on the first ridge. At 912 keV, the cut contains a coincidence on the second ridge, and the first ridge becomes wide and smooth, containing about 100 different coincidences.

Invited talk.

High Spin Physics 2001, Warsaw, February 6-10, 2001

Abstract No: 018
Submitted on: 14 Nov 2000, 14:42 GMT

Title: **Is the collective IBM space exhausted only by the valence shell?**

Author(s): A. D. Efimov, and V.M. Mikhajlov
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During last two decades the Interacting Boson Model (IBM) serves as one of the most useful tools for analysis properties of nuclear collective states [1]. The feature of IBM is the finite number of bosons Ω which is adopted to be equal to the half of the valence particle or hole number ($\Omega_{\text{canonical}}$). Such statement is based on the assumption that IBM bosons are formed only by valence shell nucleons. The most sensible function of Ω is B(E2) along the ground state band. In accordance with these probabilities increase with spin I up to a maximum value at I Ω and then decrease. In many nuclei experiments confirm this prediction. However there are data (e.g. ^{100}Mo [2], ^{128}Xe [3]) showing that the growth of B(E2) is not stopped after I$\sim$ $\Omega_{\text{canonical}}$.

Moreover the decrease of B(E2) frequently occurs at those energies and spins in the band-crossing region that causes decreasing B(E2) independently of Ω. The theoretical description of this phenomenon requires the detail consideration of different mechanisms for mixing the collective and high-spin two quasiparticle bands, that was implemented for ^{126}Ba [4], ^{120}Xe [5] and ^{118}Te [6]. The analysis of B(E2) values in these nuclei indicates that the description of experiments demands increasing Ω by comparison with $\Omega_{\text{canonical}}$. Such values of Ω are evidence that the nuclear quadrupole collectivity is created by not only valence shell nucleons. It can be conditioned firstly by the action of the residual interacting leading to the appearance of two quasiparticle components from adjacent shells in the microscopical structure of the quadrupole boson and secondly by the decrease of energy gaps between shells which can be aroused by the impact of the presence of many quadrupole bosons (effective deformation).

References

[1] F. Iachello, and P. Van Iasaker, *The Interacting Boson-Fermion Model* (Cambrige University Press, Cambrige, 1991).

[2] D. Hook, J.L. Dunell, W. Gelletly et al., J. Phys. G.: Nucl.Phys. **12**, 1277 (1986).

[3] J. Srebrny, T. Czosnyka, P. Napiorkowski et al., Nucl. Phys. **A557**, 663 (1993).

[4] A.D. Efimov, and V.M. Mikhajlov, Phys. Rev. **C59**, 3153 (1999).

[5] A.A. Pasternak, Y. Sasaki, A.D. Efimov and et al., submitted to Eur.Phys.J. **A**.

[6] A.A. Pasternak, J. Srebrny, A.D.Efimov and et al., submitted to Eur.Phys.J. **A**.

Preferred presentation of the contribution: in the oral session.

Abstract No: 019
Submitted on: 29 Dec 2000, 12:57 GMT

Title: **New superdeformed and "high spin" structures in the A=80-100 and A=150 regions.**

Author(s): A. Johnson,[1]
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New, highly effective arrays for γ-ray spectroscopy like EUROBALL and Gammasphere, combined with state of the art ancillary detectors and/or recoil mass separators for channel selection, have during recent years allowed identification and in-beam γ-spectroscopic studies of very neutron deficient nuclei in the $A \approx 80 - 100$ mass region. These nuclei have so far been produced in heavy-ion induced fusion evaporation reactions utilizing stable beams and targets. This mass region shows a richness of phenomena. Here the heaviest $N = Z$ nuclei are identified and enhanced neutron-proton correlations are expected when protons and neutrons occupy identical orbitals. At the same time the vicinity to the proton drip line may influence the stability and structure of the most neutron deficient nuclei. The nucleus ^{100}Sn is the heaviest $N = Z$ doubly magic nucleus believed to be bound. ^{100}Sn and its neighbours are key nuclei for understanding the nuclear shell model. New "high spin" results on some neighbours of ^{100}Sn will be presented.

The A=80-90 region was early predicted to be a favoured region for observation of superdeformed (SD) structures. A number of SD-bands have been reported for nuclei with A=80-91. Large energy gaps at SD-shapes for especially N=Z=38,42,44,46 stabilize the structures. The $N = Z$ nucleus ^{88}Ru is predicted to have a "doubly magic" SD structure with two protons and two neutrons in the lowest N=5 intruder orbitals. Recently SD structures have been reported for ^{88}Mo [1], ^{89}Tc [2] and ^{91}Tc [3] which are the heaviest nuclei in this region with known SD-structures. The SD-band in ^{91}Tc shows unexpected features. The SD-structures of these nuclei will be discussed.

In ^{154}Er a new SD-band has been observed in an experiment at EUROBALL [4]. The structure of this new band and the previously observed SD-band in ^{154}Er will be discussed.

References

[1] T.Bäck et al., Eur. Phys. J.**A6**, 391 (1999).

[2] B.Cederwall et al., Eur. Phys. J.**A6**, 251 (1999).

[3] E.Ideguchi et al. Phys. Lett. **B492**, 245 (2000).

[4] K.Lagergren et al. , to be published.

Invited talk.

High Spin Physics 2001, Warsaw, February 6-10, 2001

Abstract No: 020
Submitted on: 29 Dec 2000, 14:14 GMT

Title: **Terminating rotational bands in nuclei - detailed configuration assignment at very high spin**

Author: Ingemar Ragnarsson
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The description of nuclear high spin bands in terms of the configuration constrained cranked Nilsson-Strutinsky (CNS) approach will be discussed. Pairing is neglected in these calculations, making it possible to get a simple understanding of the different configurations. Examples from different mass regions show very good agreement between calculations and experiment in many cases, making it possible to assign detailed configurations. In this assignment, the fact that the configurations have well-defined maximum spin values is very important, independently of if the bands really terminate or not [1].

Special emphasis will be put on the $Z = 66$ Dy isotopes where the rotational bands show very different properties depending on the number of proton holes in the $(g_{7/2}d_{5/2})$ subshells of the $Z = 64$ proton core. Thus, bands terminating smoothly at $I \approx 60$ have been identified in ^{156}Dy [2, 3] while a teminating 'magnetic band' has been observed in ^{154}Dy [4].

References

[1] A. V. Afanasjev, D. B. Fossan, G. J. Lane and I. Ragnarsson, Phys. Rep. 322 (1999) 1.

[2] F. G. Kondev *et al.*, Phys. Lett. B 437 (1998) 35.

[3] I. Ragnarsson and F. Saric, to be publ.

[4] Wenchao Ma *et al.*, to be publ.

$\boxed{\text{Invited talk.}}$

Abstract No: 021
Submitted on: 29 Dec 2000, 15:58 GMT
Title: **Structure of N=Z nuclei from studies with GASP and Euroball**
Author(s): S. Lunardi
Affiliation(s): Dipartimento di Fisica and INFN Sezione di Padova, Padova, Italy

The nuclei close to the N=Z line up to mass 90 constitute one of the regions of actual interest and a continuos effort is being devoted to study their structure in a systematic manner. With increasing Z such nuclei are very close to the proton drip line, being therefore hardly accessible with the available (stable) target-projectile combinations. The lighter ones are close to the stability line but the study of their high spin states has become feasible, due to variuos reasons, only with the advent of large γ-detector arrays coupled with powerful ancillary detectors.

A major research program in the last 3-4 years both at GASP and Euroball has been the study of N=Z nuclei in their low and high spin behaviour. Experiments, making use of 4π charge particle detectors and neutron detectors, have been performed for a series of nuclei ranging from mass 30 (^{32}S and neighbours) to mass 90. The most recent result is the first identification of excited states (up to 8^+) in ^{88}Ru making it the heaviest N=Z nucleus where such states are known [1]. Unlike the neighbouring nuclei, showing an alignment in their ground state rotational bands at $I^{\pi}=8^+$, ^{88}Ru does not, which confirm a trend of lighter N=Z nuclei. Results will also be presented on $1f_{7/2}$ and A$\approx$60 nuclei related to isospin mixing and isospin symmetry in nuclei. [2, 3].

The most recent experiment performed at GASP in the more "classical" high spin field had the goal to search for highly-deformed, superdeformed and stable triaxial structures in ^{138,139}Nd. The status of the analysis of this experiment will also be presented.

References

[1] N. Marginean et al., Phys. Rev. **C**, Rapid Communication, in press.

[2] S. Lenzi et al., Proceedings of the international workshop on N=Z nuclei, Lund 2000.

[3] E. Farnea et al., Proceedings of the international workshop on N=Z nuclei, Lund 2000.

Invited talk.

Abstract No: 022
Submitted on: 30 Dec 2000, 16:18 GMT

Title: **Total Routhian surface calculations for ^{149}Ce**

Author(s): R. Kaczarowski,[1] W. A. Płóciennik,[1]
A. Syntfeld,[2] H. Mach,[3] W. Kurcewicz,[2] W. Urban,[2] B. Fogelberg[3] and P. Hoff[4]

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Rotational states in ^{149}Ce were calculated using TRS model. Configurations at β_2 =0.23, γ=1° and β_4 =0.08 were assigned to these states. Good agreement was found beetwen experimental [1] and calculated angular momenta.

References

[1] A. Syntfeld, H. Mach, R. Kaczarowski, W. Kurcewicz, W. Urban, B. Fogelberg and P. Hoff,*to be published* .

Preferred presentation of the contribution: in the oral session.

Abstract No: 023
Submitted on: 30 Dec 2000, 16:22 GMT

Title: **Fast nuclear rotation and octupole deformation**

Author(s): W. Urban[1], W.R. Phillips[2], M.K. Khan[2], J.C Bacelar[3], J. Jongman[3], N. Schulz[4], I. Ahmad[5] and J. Nyberg[6]

Affiliation(s): [1]*Institute of Experimental Physics, Warsaw University, Warsaw, Poland*
[2]*Dep. of Physics and Astronomy, Manchester University, Manchester, UK*
[3]*KVI, University of Groningen, Groningen, The Netherlands*
[4]*Inst. de Recherches Subatomiques, Univ. Louis Pasteur, Strasbourg, France*
[5]*Argonne National Laboratory, Argonne, USA*
[6] *NBI Riso, Roskilde, Denmark*

Enhanced octupole interactions, which may cause octupole deformation, are expected in nuclei, in which *opposite-parity* orbitals, satisfying $\Delta j = \Delta l = 3$ relation, are placed close to the Fermi level. One member of the $\Delta j = \Delta l = 3$ pair is the high-j *intruder orbital.* Such orbital plays an important role in generating spin of a fast rotating nucleus and is a source of a characteristic *backbending* phenomenon. An octupole interaction provides an extra force binding the intruder orbital to the so called *normal-parity* orbitals, changing thus its response to fast nuclear rotation. Observation of spin alignment as a function of rotational frequency in nuclei with strong octupole interactions provides, therefore, a convenient tool to study octupole correlations in nuclei[1].

Standard example of such behaviour is that reported for the ^{222}Th nucleus [2], where instead of a sharp backbanding, expected for the proton $i_{13/2}$ intruder orbital, a gradual increase of alignment is observed. Calculations assuming the presence of octupole deformation in ^{222}Th are in excellent agreement with the experiment [3] up to the highest observed spin, I=22. The same calculations predict that at still higher rotational frequency, the neutron $j_{15/2}$ intruder orbital will allign, displaying a sharp backbending, since the alignment of *two* intruder orbitals should be enough to restore reflection symmetry in a nucleus.

Rotational frequencies observed in ^{222}Th are too low to observe the predicted transition from octupole to reflection-symmetric shape. Higher rotational frequencies are observed in another region of strong octupole correlations, in the neutron-rich Lanthanides [4]. The ^{150}Sm nucleus [5] displays a behaviour similar to that observed for ^{222}Th, yet here seen to higher rotational frequencies. Studies of the neighbouring odd-A nuclei provide a unique identification of the observed alignment process in ^{150}Sm, where after the second, sharp backbanding a reflection-symmetric shape is restored.

References

[1] P.A. Butler and W. Nazarewicz, Rev. Mod. Phys. 68, 349 (1996)

[2] M. Dahlinger et al, Nucl. Phys. A 484, 337 (1988)

[3] W. Nazarewicz, *Nuclear Structure Through Static and Dynamic Moments*, ed. H.H. Bolotin (Conference Proceedings Press, Melbourne, 1987), p. 180.

[4] W.R. Phillips et al, Phys. Rev. Lett. 57, 3257 (1986)

[5] W. Urban et al, Phys. Lett. B 185, 331 (1987)

Invited talk.

Abstract No: 024
Submitted on: 30 Dec 2000, 16:54 GMT

Title: **Fermionic Bubbles and Foam**

Author(s): A. Bulgac,[1] and P. Magierski,[2]
Affiliation(s): [1] *Department of Physics, University of Washington, Seattle, USA,*
[2] *Institute of Physics, Warsaw University of Technology, Warsaw, Poland*

The positioning of one or more bubbles inside a many fermion does not affect the volume, surface or curvature terms in the liquid drop expansion of the total energy. If Coulomb effects are irrelevant, the only contribution to the ground state energy of a system with one or more voids arises from quantum effects, which is similar to the Casimir effect in vacuum or in critical phenomena. We discuss the characteristics of such systems, the interplay among various effects, such as shell corrections and chaotic behavior, and briefly mention the role of the temperature and pairing [1]. As an example we consider the neutron matter at subnuclear densities in the neutron star crust which is unstable towards the formation of inhomogeneities. Depending on the average value of the neutron density one can observe the appearance of either bubbles, rods, tubes or plates embeded in a neutron gas. We estimate the quantum corrections to the ground state energy (which could be termed either shell correction or Casimir energy) of such phases of neutron matter. The calculations are performed by evaluating the contribution of the shortest periodic orbits in the Gutzwiller trace formula for the density of states. The magnitude of the quantum corrections to the ground state energy of neutron matter are of the same order as the energy differences between various phases [2].

References

[1] Y. Yu, A. Bulgac, and P. Magierski, Phys. Rev. Lett. **84** (2000) 412.

[2] A. Bulgac, P. Magierski, Nucl. Phys. **A** (2001) (in press), Los Alamos preprint library: astro-ph/0002377; Phys. Rev. **E** (2001) (submitted), Los Alamos preprint library: physics/9902057; Physica Scripta **T** (2001) (in press), Los Alamos preprint library: astro-ph/0007423; Acta Phys. Pol. **B** (2001) (in press), Los Alamos preprint library: nucl-th/0011006;

Preferred presentation of the contribution: in the oral session.

Abstract No: 025
Submitted on: 3 Jan 2001, 11:00 GMT
Title: **Symmetry restorations in Skyrme mean-field calculations**
Author(s): P.-H. Heenen,
Affiliation(s): PNTPM, Université Libre de Bruxelles, B1050, Bruxelles, Belgium

The general framework of a method which permits to restore the rotational and particle number symmetries of wave functions obtained in Skyrme HF+BCS calculations has been presented recently[1]. This restoration is nothing but a projection of mean-field intrinsic wave functions onto good particle number and good angular momentum. The method allows also to *mix* projected wave functions. Such a configuration mixing is discussed for sets of HF+BCS intrinsic states generated in constrained calculations with suitable collective variables. This procedure gives collective states which are eigenstates of the particle number and the angular momentum operators and between which transition probabilities can be calculated. An application to ^{24}Mg will first be presented, to test the method. The mean-field wave functions are generated by axial quadrupole constraints. Theoretical spectra and transition probabilities are compared to the experiment.

An application to several neutron rich isotopes between oxygen and titan will then be presented. The effect of symmetry restoration on the shell closure at N=20 will be discussed in details. The ability of the method to describe excited states with large quadrupole deformations will be illustrated by a study of the excited 0^+ states in ^{16}O.

References

[1] A. Valor, P.-H. Heenen and P. Bonche, Nucl. Phys **A671** 145 (2000)

$\boxed{\text{Invited talk.}}$

Abstract No: 026
Submitted on: 3 Jan 2001, 11:25 GMT

Title: **Lifetimes and transition probabilities of low-lying positive parity states in ^{120}Xe and ^{118}Te**

Author(s): A.A Pasternak,[1] J. Srebrny,[2] T. Morek,[2] Ch.Droste,[2] Y.Sasaki,[3] M.Oshima,[3] A.D. Efimov,[1] V.M. Mikhailov,[1] E.O. Podsvirova,[1] S. Juutinen,[4] and G.B. Hagemann[5]

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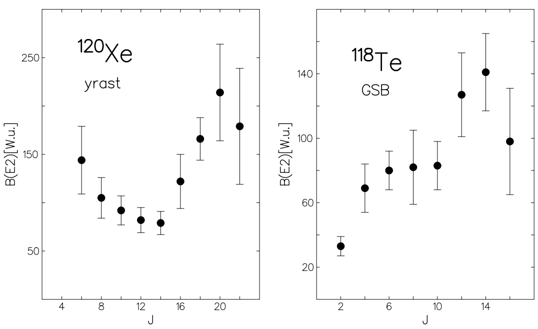

Lifetimes of 22 positive parity states in ^{120}Xe have been measured by the Doppler Shift Attenuation Method(DSAM) using the ^{111}Cd(^{12}C,3n) reaction at a beam energy of 56 MeV. The experiment was performed at the JAERI Tandem Accelerator (Japan). The γ-γ coincidences were collected by the GEMINI array. Lifetimes of the 8 ground state band levels of ^{118}Te up to I=16$^+$ and 2 other levels have been measured by DSA and Recoil Distance (RD) methods using the ^{109}Ag(^{13}C,p3n) reaction at a beam energy of 54 MeV. The experiment was performed at TAL NBI (Danmark). The γ-γ coincidences were colected by the NORDBAL array.
New methodical approache of lifetime determination based on the lineshape analysis of coincidence spectra has been applied for both nuclei in the case of the DSA and RD methods. In the case of RDM, lifetime was determined by analysis of the shape of full line (unshifted and shifted components together) - Recoil Distance Doppler Shift Attenuation method [1]. The B(E2) values which have been measured in ^{118}Te give us the unique possibility to analyse E2 transition probabilities in the ground state collective band above the band crossing (see right panel of figure). In case of ^{120}Xe the B(E2) values along the yrast band are presented in the left panel of figure. The energies of the levels and E2 transition probabilities are interpreted in the framework of a new version of IBFM(IBM + 2q.p.) [2]. In this approache it was assumed, that the boson number increases with angular momentum. A satisfactory description of the level structure and B(E2) behaviour along the ground state, γ and 2-qp bands is achieved for ^{120}Xe and ^{118}Te isotones.

References

[1] J. Srebrny et. al, Nuclear Physics A (2001), in print.

[2] A.D.Efimov et. al, contribution to this conference.

Preferred presentation of the contribution: in the poster session.

Abstract No: 027
Submitted on: 3 Jan 2001, 14:45 GMT
Title: **Cranking in isospace – towards consistent mean-field description of $N = Z$ nuclei**
Author(s): Wojciech Satuła
Affiliation(s): *Institute of Theoretical Physics, University of Warsaw, Warsaw, Poland*

Cranked mean-field model has proven to be one of the most successful tools used to describe high-spin states of atomic nuclei in a microscopic way. Since the concept of cranking can be viewed as the lowest order projection onto good angular momentum it can be easily and rather naturally extended to project out good isospin by introducing auxiliary routhian $\hat{H}^\omega = \hat{H} - \omega \hat{t}_x$ with a constraint $\langle \hat{t}_x \rangle = \sqrt{T(T+1)}$ in complete analogy to a case of spatial rotations.

The aim of this paper is to present applications of isospin-cranked mean-field model to isobaric excitations in even-even [T=0,1,2 states] and odd-odd [T=0,1] $N = Z$ nuclei. The microscopic structure of these states nicely reflects various aspects related to a response of nuclear pairing against iso-rotations and $2qp$ excitations showing, in many cases, beautiful analogies to the well known high-spin phenomena. The character [calculation scheme] of these fundamental excitations in $N = Z$ nuclei is schematically depicted in left part of Fig. 1. Right hand side of Fig. 1 shows calculated and empirical excitation energies, see Ref. [1] for more details.

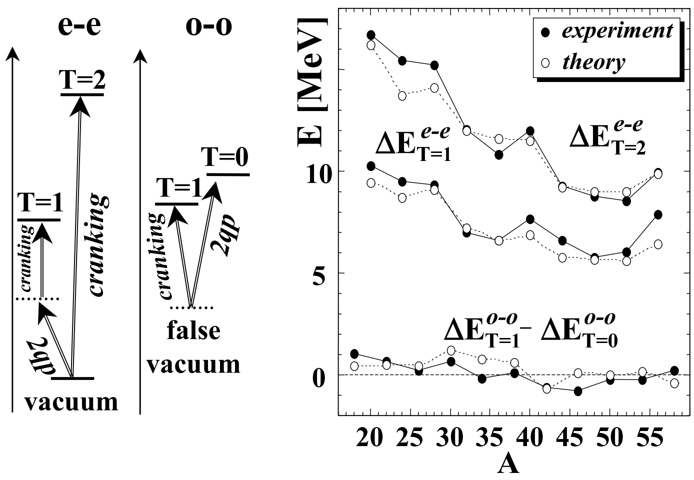

Figure 2: Schematic illustration of the calculation scheme [left] applied to compute excitation energies of T=0,1, and 2 isobaric excitations in N=Z nuclei [right].

References

[1] W. Satuła and R. Wyss, nucl-th/0010041; nucl-th/0011056

Invited talk.

Abstract No: 028
Submitted on: 3 Jan 2001, 11:20 GMT

Title: **Investigation of the $K^\pi = 8^-$ isomers in N=74 isotones on beam of the Warsaw Cyclotron**

Author(s): T. Morek,[1] J. Srebrny,[1] Ch.Droste,[1] M. Kowalczyk,[1] T. Rząca-Urban,[1] K. Starosta,[1] W. Urban,[1] R. Kaczarowski,[2] E. Ruchowska,[2] M. Kisieliński,[3] A. Kordyasz,[3] J. Kownacki,[3] M. Palacz,[3] E. Wesołowski,[3] M. Wolińska,[3] W. Gast,[4] R.M. Lieder,[4] P. Bednarczyk,[5] W. Męczyński,[5] J. Styczeń,[5]

Affiliation(s): [1]*Nuclear Physics Division, IEP, Warsaw University, Poland,* [2]*The Andrzej Sołtan Institute for Nuclear Studies, Świerk, Poland,* [3]*Heavy Ion Laboratory, Warsaw University, Poland,* [4]*Institut für Kernphysik, Forschungszentrum Jülich, Germany,* [5]*The Niewodniczański Institute of Nuclear Physics, Kraków, Poland*

The decay of the $K^\pi = 8^-$ isomers in ^{132}Ce and ^{134}Nd have been investigated on the beam of the Warsaw Cyclotron using OSIRIS array. Reactions ^{120}Sn(^{16}O,4n)^{132}Ce and ^{118}Sn(^{20}Ne,4n)^{134}Nd were used.

For ^{132m}Ce a half-life of 9.4±0.3 ms was determined. Two new decay paths have been found in the deexcitation of this isomer. The hindrance factors for the $E1$, $M2$ and $E3$ transitions deexciting the isomer have been determined [1]. The decay properties of the 8^- isomers in the N=74 isotones are discussed. A band mixing mechanism involving the ground state band and s-band seems to be responsible for the behaviour of the reduced hindrance factors of the $E1$ transitions deexciting the $K^\pi=8^-$ isomers in these isotones.

A K-mixing, characteristic for the axially asymmetric nuclei, may account for the reduced hindrance factors $f_3 \approx 6.5$ of the $E3$ transition to the 5^+_γ states in ^{130}Ba and ^{132}Ce. Similar E3 decay of the 410 μs isomeric state in ^{134m}Nd has not been observed. However, we were able to determine that in this case the reduced hindrance factor $f_3 \geq 9$.

References

[1] T. Morek et. al, Phys.Rev **C63 (2001), in print.**

Preferred presentation of the contribution: in the oral session.

Abstract No: 029
Submitted on: 6 Jan 2001, 19:48 GMT

Title: **Shell-model applications to deformed nuclei**

Author(s): Gabriel Martínez-Pinedo
Affiliation(s): Department für Physik und Astronomie, Universität Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

Large scale shell-model calculations have been very successful in the description of medium-light nuclei. I will review the current status of shell model studies of deformed pf-shell nuclei. A good treatment of the proton-neutron pairing correlations will be shown necessary to obtain the correct moment of inertia of $N = Z$ nuclei. The coulomb energy differences for several mirror pairs will be presented and their relationship with alignment discussed. Finally, I will consider the effect of cross-shell correlations (from the sd-shell to the pf-shell) and his effect on the isotope shifts of calcium and the appearance of rotational bands in ^{36}Ar and ^{44}Ti.

Invited talk.

High Spin Physics 2001, Warsaw, February 6-10, 2001

Abstract No: 030
Submitted on: 7 Jan 2001, 23:00 GMT
Title: **Discrete Line Spectroscopy at $\sim 60\hbar$ in the Light Er Isotopes, and Global Lifetime Measurements of Highly-Deformed and Other Rotational Structures in the A$\sim$135 Light Rare-Earth Region.**
Author(s): M.A.Riley[1], J.Simpson[2], A.P.Bagshaw[3], J.C.Lisle[3], A.Pipidis[1,4], R.W.Laird[3], F.G. Kondev[1,5], D. Applebe[2], M.A.Bentley[6], D. Campbell[1], D.M.Cullen[3], P.J.Dagnall[3], C. Fox[7], G.B.Hagemann[8], S.L.King[7], V. Putnel[2], S.L. Shepherd[7], A.G.Smith[3], J. Smith[3], S.Törmänen[8], A. Afanasjev[9,10,11], I. Ragnarsson[11], and D.E. Archer[13], T.B. Brown[1], R.M. Clark[12], M. Devlin[14], P. Fallon[12], D.J.Hartley[16], I.M. Hibbert[7], D.T. Joss[15], D.R. LaFosse[14], P.J. Nolan[7],N.J. O'Brien[15], J. Pfohl[1], E.S. Paul[7], D.G. Sarantites[14], R.K.Sheline[1], R. Wadsworth[15], M.T. Matev [16,18], J. Dobaczewski[17,18], G.A. Lalazissis[9], W. Nazarewicz[16,18,19], W. Satuła[18]
Affiliation(s): [1]*Florida State U.,USA.* [2]*Daresbury Lab., UK.* [3]*U. of Manchester, UK.* [4]*U. of Surrey, UK.* [5]*ANL, USA.* [6]*Staffordshire U., UK.* [7]*U. of Liverpool, UK.* [8]*NBI, Denmark.* [9]*Tech. Universität München, Germany.* [10]*U. of Latvia, Latvia.* [11]*Lund Inst. of Tech., Sweden.* [12]*LBNL, USA.* [13]*LLNL, USA.* [14]*Washington U., USA.* [15]*U. of York, UK.* [16]*U. of Tennessee, USA.* [17]*CNRS-IN2P3, France.* [18]*Warsaw U., Poland.* [19]*ORNL, USA.*

The quest to observe increasingly high angular momentum states in atomic nuclei has driven the field of high spin nuclear spectroscopy for many years. It is in the light mass A $\sim$ 160 Dy and Er nuclei that the highest spin states in normal deformed nuclei have been observed (spin I $\sim 60\hbar$ and $E_{excit} \sim 30$ MeV) [1, 2]. Aside from the question of the limiting spin at which discrete states in nuclei exist, other fundamental issues concern the effect of rotation on the nuclear equilibrium shape, on the nuclear pairing correlations and charting the correct single-particle spectrum of states at ultra-high spins. We have performed two recent experiments using the Euroball γ-ray spectrometer to explore the $N = 91$ - 94 erbium isotopes ($^{159-162}$Er) in order to shed light on these important questions. Several key systematic trends have been identified and will be discussed.

GAMMASPHERE coupled with the Microball charged-particle detector has made possible a new class of nuclear lifetime measurements. For the first time, it has been possible to extract differential lifetime measurements free from common systematic errors for over 15 different nuclei (various isotopes of Ce, Pr, Nd, Pm, and Sm) at high spin from a single experiment [3]. This comprehensive study establishes Z, N, and configuration dependent quadrupole moment trends in the A$\sim$135 light rare-earth region. Detailed comparisons are made with theoretical calculations using the Cranked Skyrme Hartree-Fock framework which lead to theoretical estimates for the effective deformation parameters of the single-particle orbitals in this region.

References

[1] J. Simpson *et al.*, Phys. Rev. **C62** (2000) 024321.

[2] F.G. Kondev *et al.*, Phys. Lett. **B437** (1998) 35.

[3] R.W. Laird *et al.*, to be published.

Invited talk.

Abstract No: 031
Submitted on: 8 Jan 2001, 04:57 GMT
Title: **E2 and M1 strengths in heavy deformed nuclei**
Author(s): J. P. Draayer,[1] G. Popa,[1] and J. G. Hirsch[2]
Affiliation(s): [1]*Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803, USA*
[2]*Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Apartado Postal 70-543 México 04510 DF, México*

Energy levels of the four lowest bands in ^{160,162,164}Dy, B(E2) transition strengths between these levels, and the B(M1) strength distribution of the ground state, all calculated within the framework of pseudo-SU(3) model, are presented [1]. Realistic single-particle energies and quadrupole-quadrupole and pairing interaction strengths fixed from systematics were used in the calculations [2]. The strengths of four rotor-like terms, all small relative to the other terms in the interaction, were adjusted to give an overall best fit to the energy spectra. The procedure yielded consistent parameter sets for the four nuclei.

References

[1] R. F. Casten, J. P. Draayer, K. Heyde, P. Lipas, T. Otsuka, and D. Warner, *Algebraic Approaches to Nuclear Structure: Interacting Boson and Fermion Models* (Harcourt, Brace, and Jovanovich, New York, 1993).

[2] G. Popa, J. G. Hirsch, and J. P. Draayer, Phys. Rev. **C62**, 064313 (2000).

Invited talk.

Abstract No: 032
Submitted on: 8 Jan 2001, 09:02 GMT
Title: **Structure studies of heavy nuclei using recoil decay tagging at JYFL**
Author: M. Leino
Affiliation: *Department of Physics, University of Jyvskyl, Finland*

The structure of heavy nuclei has been studied in several extensive campaigns at JYFL using the Recoil Decay Tagging (RDT) method. In most experiments, different versions of the Jurosphere array were used for detection of prompt gamma-rays. Jurosphere consists of 25 Compton-suppressed Ge-detectors and has an efficiency of 1.5–1.8 % at at 1.3 MeV. The produced evaporation residues were separated and identified using the gas-filled recoil separator RITU.

In a series of experiments using ^{48}Ca beams, the main results were the observation of the ground state bands of ^{252,254}No [1]. These studies have very recently been extended through the measurement of recoil-tagged conversion electrons from ^{254,253}No [2].

Another field of interest has been the study of shape coexistence in very neutron deficient isotopes in the Pb-Po region. Here, the closed proton shell favours spherical shapes while close to the neutron mid-shell, prolate structures intrude to low excitation energies. These have been associated with more than two protons being excited across the Z = 82 gap [3]. In our experiments, prolate inruder bands have been observed in ^{176}Hg and in ^{182,184}Pb. In Pb isotopes, low-lying oblate states have been associated with *2p-2h* excitations. The ground states of Po isotopes in this region have also been found to have a strong *4p-2h* component [4]. These basic observations are strongly supported by (and partly arise from) alpha decay studies in this region [5]. Some new results from our studies concerning neutron-deficient Hg, Pb, and Po isotopes will be discussed. Generally speaking, the observations concerning shape coexistence in this region are well described by theoretical mean field calculations [3, 6]

This work is supported by the Academy of Finland under the Finnish Centre of Excellence Programme 2000–2005 (Project No. 44875, Nuclear and Condensed Matter Physics Programme at JYFL).

References

[1] M. Leino *et al.*, Eur. Phys. J. A **6**, 63 (1999); R.-D. Herzberg *et al.*, to be published.

[2] P. A. Butler, *This conference.*

[3] W. Nazarewicz, Phys. Lett. B **305**, 195 (1993).

[4] K. Helariutta *et al.*, Eur. Phys. J. A **6**, 289 (1999).

[5] A. N. Andreyev *et al.*, Nature **405**, 430 (2000).

[6] A. Oros *et al.*, Nucl. Phys. A **645**, 107 (1999).

Invited talk.

Abstract No: 033
Submitted on: 8 Jan 2001, 13:45 GMT

Title: **Quantum Rotor - A Powerful Tool in Studying Nuclear Symmetries**

Author(s): J. Dudek,[1] A. Góźdź,[1,2] and D. Rosły[2]
Affiliation(s): [1]*Institut de Recherches Subatomiques, IN2P3-CNRS/Université Louis Pasteur F-67037 Strasbourg Cedex 2, France*
[2]*Institute of Physics, Marie Curie-Skłodowska University Pl-20031 Lublin, Poland*

Many nuclear physicists would most likely say that quantum rotors in nuclear structure physics are very well known objects. The knowledge usually quoted would concern first of all the properties of the hamiltonians that resemble those of a triaxial rotating ellipsoid, possibly coupled to one or some (quasi-) particles and/or to collective vibrations. The symmetry aspects other than those of an ellipsoid, the latter nicknamed with the keyword D_{2h}-symmetry, are nearly absent in the nuclear structure literature, with the notable exception of Ref. [1] where the authors analyze a particular symmetry hypothesis related to nuclear superdefomation. But even the 'elementary' D_{2h}-symmetry is not really exploited in nuclear structure physics. It seems that a part of the reason for such a 'neglect' consists in some specific experimental difficulties encountered when studying the rotors down to sufficiently sophisticated level - but only a part. We believe that with the contemporary level of experimental/instrumental sensitivity much more can be done in this domain as the example of the experimental analyses of the so-called ($\Delta I = 2$)-staggering demonstrates. Despite the existence of positive examples like those quoted, a comparison to what one can find in the literature of other domains of physics, in particular in molecular physics, shows the nuclear structure field as rather underdeveloped.

In the present article we address the problem of studying symmetries through characteristic features of the underlying rotor spectra focusing on the normal-deformed (as opposed to super-deformed) nuclei.

We are going to introduce what we call a generalized rotor hamiltonian that allows to express any point-group nuclear symmetry. This is done through an expression of the rotor hamiltonian with the help of a suitably constructed tensor-operator expansion. We illustrate briefly microscopic results concerning shape isomerism with a particular focus on the normally-deformed nuclei that manifest symmetries *other than* D_{2h}. To introduce the discussion of symmetries we do begin by illustrating the relatively less known (or unknown) properties of the D_{2h} rotors. We mention the problems related to the experimental verifications of the theoretical predictions as well as the problem of possible non-unique manifestations of the rotor symmetries: usually, the manifestations of rotor symmetries through the energy spectra can only be formulated in terms of necessary- but not necessary-and-sufficient conditions. Analogies related to some specific molecular phenomena will be used in parallel to the discussion of purely nuclear physics phenomena together with the simulations of the electromagnetic feeding and deexcitation patterns for rotational bands.

References

[1] I. Hamamoto and B. Mottelson, Phys. Lett. **33**, 294 (1994); Phys. Scripta **T56** 27 (1955).

Invited talk.

Abstract No: 034
Submitted on: 8 Jan 2001, 14:31 GMT

Title: **High-Spin States in and around Doubly-Magic Nuclei**

Author(s): R. Broda[1] *et al.*
Affiliation(s): [1]*H. Niewodniczanski Institute of Nuclear Physics, Krakow, Poland*

The experimental study of high-spin states in the well established doubly-magic nuclei were for long time severely hampered by difficulties in accessing these nuclei in nuclear reactions suitable for the gamma spectroscopy. The situation changed when the development of large multi-detector gamma arrays offered resolving powers satisfactory to exploit very complex nuclear reactions, as deep-inelastic heavy-ion reactions or spontaneous fission, for spectroscopic studies. The progress achieved in such studies in recent years will be illustrated by reviewing the following results obtained in regions of doubly-magic nuclei:

1. High-spin states in the ^{48}Ca core and lowest yrast excitations in its 1 particle (hole) neighbors.
2. Valence proton structures in N=82 isotones of the ^{132}Sn region studied in spontaneous fission and in deep-inelastic heavy-ion reactions.
3. New high-spin states in the ^{208}Pb core and in the two-proton hole ^{206}Hg nucleus.

The shell model interpretation of observed states will be discussed and future prospects will be outlined.

$\boxed{\text{Invited talk.}}$

Abstract No: 035
Submitted on: 8 Jan 2001, 18:48 GMT

Title: **Rotational Properties of Neutron Drip-Line Nuclei**

Author(s): Witold Nazarewicz[1–3]
Affiliation(s): [1]*Department of Physics, University of Tennessee, Knoxville, Tennessee 37996,* [2]*Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831,* [3]*Institute of Theoretical Physics, Warsaw University, ul. Hoża 69, PL-00681, Warsaw, Poland*

Moving away from stable nuclei by adding either protons or neutrons, one finally reaches the particle drip lines. The neutron-rich, weakly-bound nuclei close to the neutron drip line have very unusual properties: they are large, diffused, and superfluid [1]. The main objective of this talk is to discuss some of the theoretical challenges and opportunities for high-spin studies of neutron-rich nuclei provided by radioactive nuclear beams.

The systematic behavior of rotational bands in deformed neutron-rich nuclei is investigated with the cranked Skyrme-Hartree-Fock approach and the deformed shell model. In particular, rotational properties and isovector deformations of heavy Ne and Mg isotopes are studied together with quasi-particle spectra of heavy Er isotopes. The effect of the increased surface diffuseness gives rise to the change in the position of the high-j intruder shell, and this has a significant effect on nuclear rotation.

This work has been carried out in collaboration with Jacek Dobaczewski, Mladen Matev, Shoujirou Mizutori, Rafał Nowakowski, and Wojtek Satuła. It was supported by the U.S. Department of Energy under Contract Nos. DE-FG02-96ER40963 (University of Tennessee), DE-AC05-00OR22725 with UT-Battelle, LLC (Oak Ridge National Laboratory), and by the Polish Committee for Scientific Research (KBN) under contract No. 2 P03B 040 14

References

[1] J. Dobaczewski and W. Nazarewicz, Phil. Trans. R. Soc. Lond. A **356**, 2007 (1998).

Invited talk.

Abstract No: 036
Submitted on: 9 Jan 2001, 21:28 GMT

Title: **Fingerprints of Neutron Proton Pairing at High Angular Momenta**

Author(s): R. Wyss[1]
Affiliation(s): [1]*KTH-Karnfysik, Frescativ. 24, S-104 05 Stockholm, Sweden*

The study of high spin states has since long been one of the most powerful tools in the study of nuclear structure. The recent advance in nuclear spectroscopy has paved the way to access heavy N=Z nuclei. Since the neutron and proton wave functions are essentially degenerate in these nuclei, one may expect proton-neutron correlations to become important. The quest for proton-neutron pairing has been a long standing issue in nuclear structure. The importance of proton-neutron correlations for the backbending frequencies, the moments of inertia as well as the structure of two quasi-particle states in heavy N=Z nuclei will be reviewed. Analogies with the superfluid phases in He3 are discussed.

Invited talk.

Abstract No: 037
Submitted on: 11 Jan 2001, 15:00 GMT

Title: **Signature Inversion in Odd-odd Pr Nuclei**

Author(s): L.L. Riedinger,[1,2] D.J. Hartley,[1] A. Galindo-Uribarri,[2] B.H. Smith,[1] C. Baktash,[2] M.P. Carpenter,[3] M. Danchev,[1] M. Devlin,[4] C.J. Gross,[2] R.V.F. Janssens,[2] M. Lipoglavsek,[2] S.D. Paul,[2] D.C. Radford,[2] W. Reviol,[1,4] D.G. Sarantites,[4] D. Seweryniak,[3] C.-H. Yu,[2] and O. Zeidan[1]

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A series of experiments have been performed to populate high-spin states in neutron-deficient odd-odd ^{126,128,130}Pr. The ^{40}Ca + ^{92,94}Mo reactions were used to produce these $Z = 59$ isotopes. Rotational structures in ^{126,128}Pr were identified in an experiment utilizing the new Clarion Ge clover and HyBall CsI charged-particle arrays, along with the Recoil Mass Spectrometer, at Oak Ridge National Laboratory. In fact, excited states in ^{126}Pr were observed for the first time, which makes it the lightest known odd-odd Pr isotope. The other experiments used Gammasphere, in conjunction with the Washington University Microball, to extend the sequences to high spins ($\sim$40 $\hbar$).

While many rotational bands were observed in each nucleus, the yrast $\pi h_{11/2}\nu h_{11/2}$ sequences are of particular interest due to the observation of signature inversion [1] at lower spins. Although several attempts have been made to describe signature inversion, an adequate explanation for this behavior is still elusive. The validity of the theories is often tested by how well the model reproduces systematic trends; therefore, establishing these experimental trends is crucial for understanding the mechanism(s) behind signature inversion. With the present work, it is now possible to examine the systematics in the praseodymium nuclei. A trend of increasing initial energy staggering with N is observed in the Pr isotopes. This result is compatible with the idea of triaxial deformation causing the inversion [1], as γ likely increases with N. However, this trend is *opposite* to that found in the nearby Cs ($Z = 55$) nuclei [2], where the initial energy staggering decreases with N. These differing systematics pose a substantial challenge for any model that attempts to describe the signature inversion phenomenon in the mass 130 region.

References

[1] R. Bengtsson *et al.*, Nucl. Phys. **A415**, 189 (1984).

[2] J.F. Smith *et al.*, Phys. Lett. B **406**, 7 (1997).

Invited talk.

High Spin Physics 2001, Warsaw, February 6-10, 2001

Abstract No: 038
Submitted on: 12 Jan 2001, 10:02 GMT

Title: **Quadrupole collectivity in neutron-rich light nuclei.**

Author(s): R.R. Rodriguez-Guzman, J.L. Egido and L.M. Robledo
Affiliation(s): Dep. Física Teórica C-XI, Facultad de Ciencias, Universidad Autónoma de Madrid, 28049 Madrid, Spain

Nowadays, many experimental and theoretical studies are focusing on the understanding of how quadrupole collectivity develops in neutron-rich light nuclei. The main reason being that, for those nuclei, the $N = 20$ and $N = 28$ shell closures seem to be weakened opening up the possibility of quadrupole deformed ground states. The best example, up to know, of the erosion of the $N = 20$ shell closure corresponds to the first excited 2^+ state in ^{32}Mg [1]. Both its excitation energy and its $B(E2)$ transition probability indicate [2] that this state is the member of a strongly deformed rotational band. From a theoretical point of view, this nucleus has been studied with the shell model (SM) and with the mean field method. In the later method the key ingredient to obtain a deformed ground state in ^{32}Mg is the rotational energy correction [3] which is usually disregarded in mean field calculations for heavier nuclei. In order to study the properties of the neutron rich nuclei around $N = 20$ and $N = 28$ we have used the Gogny interaction (D1S parameterization) to perform, as an initial step, HFB calculations constrained in their quadrupole moment for several nuclei. To evaluate the effect of the restoration of the rotational symmetry we have computed [4] the angular momentum projected (AMP) energy curves for the quadrupole constrained HFB intrinsic states. The main conclusion of those calculations is that the AMP dramatically changes the HFB energy landscape. For instance, the ground state of the nucleus ^{32}Mg is spherical in the HFB calculation but it becomes deformed in the AMP one. We have also found that in many cases two coexisting minima appear after the AMP has been carried out. Therefore, for a proper description of the ground and excited states of the nuclei considered we have performed configuration mixing calculations (GCM) with the angular momentum projected wave functions (AMP-GCM).

In my talk I will present the results of such AMP-GCM calculations for several neutron rich and light nuclei. To be more precise, I will discuss the isotopes $^{30-34}Mg$ [5], $^{32-36}$Si and $^{28-32}$Ne to illustrate the erosion of the $N = 20$ core and the isotonic chain $^{40}Mg -^{48} Ca$ [6] to illustrate the erosion of the $N = 28$ core. The theoretical results for two neutron and two proton separation energies, excitation energies and $B(E2)$ transition probabilities agree well with both experimental results and the calculations carried out with other interactions and/or methods.

References

[1] D. Guillemaud-Müller et al. Nucl. Phys. **A426**, 37 (1984).

[2] T. Motobayashi et al. Phys. Lett. **B346**, 9 (1995).

[3] X. Campi, H. Flocard, A.K. Kerman and S. Koonin, Nucl. Phys. **A251** (1975) 193.

[4] R. Rodríguez-Guzmán, J.L. Egido and L.M. Robledo, Phys. Lett. **B274** (2000) 15.

[5] R. Rodríguez-Guzmán, J.L. Egido and L.M. Robledo, Phys. Rev. **C62** (2000) 054319.

[6] R. Rodríguez-Guzmán, J.L. Egido and L.M. Robledo, *To be published*

Invited talk.

Abstract No: 039
Submitted on: 15 Jan 2001, 20:33 GMT
Title: **Violation of the K-selection rules in ^{178}Hf observed via Coulomb excitation.**
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The study of the K-isomer properties with Coulomb excitation attracts recently a great interest. Experiments performed to explain the nature of the well-known long-lived isomer in ^{180}Ta indicate the existence of the intermediate state or states, making possible to depopulate the collective structures built on the isomeric level. Despite the large difference of K quantum number between the ground state and the isomeric state such depopulation has been observed [1, 2]. But intermediate states have not been identified yet.

The other approach to test the K-selection rules is to populate states in an isomeric band starting from a ground state band [3, 4]. Coulomb excitation offers an unique way to search for the intermediate states because, unlike any other nuclear reaction, selectively populates the levels strongly connected to the ground state.

The Coulomb excitation experiment on the ^{178}Hf was performed using the Gammasphere equipped with the particle detector Chico.[5] For the first time discrete transitions in the $K^{\pi}=8^{-}$ isomeric band excited from $K^{\pi}=0^{+}$ ground state were observed. The mechanism of the excitation of the isomeric band is still an open question. It can be explained either by assuming direct E3 excitation or E1 decay from higher lying states of ground state band. The conclusions from the analysis of recent experiments are presented.

References

[1] C.Schlegel *et al.*, Phys.Rev. **C50**, 2198 (1994)

[2] M.Loewe *et al.*, Acta Physica Polonica **B30**, 1319 (1999)

[3] J.H.Hamilton *et al.*, Phys.Lett. **112B**, 327 (1982)

[4] H.Xie *et al.*, Phys.Rev. **C48**, 2517 (1993)

[5] M.W.Simon *et al.*, *Proc. of the Int. Conf. of Fission and Properties of Neutron-rich Nuclei*, (Sanibel Island, FL World Scientific Publishing Co., December 1997)
D.Cline, Acta Physica Polonica **B30**, 1291 (1999)

Preferred presentation of the contribution: in the poster session.

Abstract No: 040
Submitted on: 16 Jan 2001, 16:21 GMT

Title: **Effective Field Theory for Rotational Bands in Deformed and Superdeformed Nuclei**

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An overview is given on the description of rotational bands in normally deformed and superdeformed nuclei in the framework of effective field theories such as the Relativistic Mean Field (RMF) theory or the Relativistic Hartree-Bogoliubov (RHB) theory. In particular we discuss recent investigations for the description of superdeformed bands in the $A \sim 30$, $A \sim 60$, $140-150$ and 190 mass regions and compare them briefly with the results obtained in non-relativistic mean field theories.

Invited talk.

Abstract No: 041
Submitted on: 16 Jan 2001, 17:43 GMT

Title: **Spin ordering of nuclear spectra from random interactions**

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Recent developments in many-body quantum chaos have raised the issue of correlations between different families of levels in the spectra of random fermionic systems. It seems that rotational invariance is sufficient to force an otherwise random system to have statistically ordered spectra where the ground state can have the maximum spin allowed or zero spin a huge portion of the time. We have tackled this question and have characterized the role of "geometric chaoticity" and pairing in random systems. We have shown how the geometry gives rise to such a distribution of ground state spins and examined the coexistence of these regularities with chaotic wave functions.

Preferred presentation of the contribution: in the oral session.

Abstract No: 042
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Title: **Determination of quadrupole deformation parameters of the ^{165}Ho nucleus in excited states**

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The ground state level of the ^{165}Ho nucleus may be understood as built by a single proton occupying the Nilsson orbital [523] around a ^{164}Dy core which gives the spin of 7/2 and negative parity.

The nucleus may undergo a γ vibration and the spin of a phonon may be subtracted or added to the ground state spin and these two possibilities give two other rotational γ bands starting from the states 3/2- and 11/2-, respectively.

A remarkable change of quadrupole moment in one of the γ-vibrational bands was found.

Coulomb Excitation experiments, using O, Ne and Ar beams, were performed at the Heavy Ion Laboratory of Warsaw University using the CUDAC and Osiris set-ups.

A model–independent analysis using the GOSIA code yielded a set of reduced matrix elements values coupling the low–lying collective excited states. A quadrupole sum rules approach was used to determine the deformation of the states.

Preferred presentation of the contribution: in the poster session.