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NUCLEAR SHAPES AND NUCLEAR STRUCTURE AT LOW EXCITATION ENERGIES

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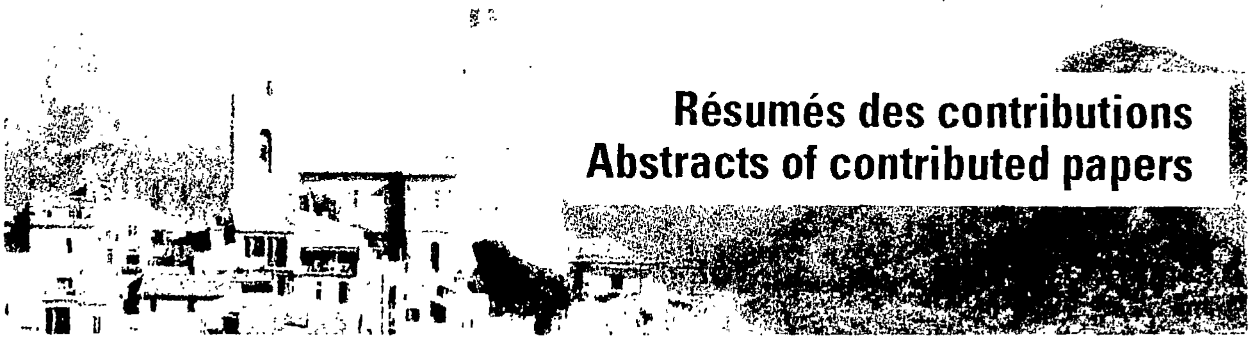

Résumés des contributions
Abstracts of contributed papers

ANTIBES, France
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NUCLEAR SHAPES AND NUCLEAR STRUCTURE AT LOW EXCITATION ENERGIES

Abstracts of contributed papers

Résumés des contributions

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CONTENTS

ON THE EXISTENCE OF INTRINSIC REFLECTION ASYMMETRY IN Z ~ 62, N ~ 90 REGION.

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The structure of odd- and odd-odd nuclei of the Z ~ 62, N ~ 90 region attracts great attention at present time, mainly, in connection with the problem of the existence of intrinsic reflection asymmetry (IRA) [1-3].

However, as follow from results of our investigation, the magnetic moments of low-lying states and decoupling parameters of K=1/2 rotational bands in odd-proton ^{151}Pm, $^{153,155}Eu$ and odd-neutron nuclei ^{153}Sm, ^{155}Gd, previously suggested as octupole deformed [1,2], can be explained without introducing intrinsic reflection asymmetry. This result agrees with the calculation of polarisation energies of octupole-driving orbitals, since there is not any octupole-driving orbital which has a polarisation energy being sufficient for stabilization of octupole deformed shapes. The calculation of polarization energies of unpaired nucleons in two-quasiparticle states of odd-odd $^{152,154,156}Eu$ nuclei also do not support the existence of IRA shapes for experimentally observed states. As a result, the small energy splitting between the levels of different bands with equal K but opposite parity might instead be understood as an accidental near-degeneracy of the two Nilsson orbitals.

While the low-spin experimental data can be explained assuming reflection symmetric shapes of nuclei under study, middle-spin spectra show some features inherent to octupole deformed nuclear system [3]. At present, it is not clear are these features connected with static octupole deformation or can be explained by dynamical octupole deformation. The study of this problem is in progress.

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SYMMETRY-BREAKING
IN SIMPLE ONE AND TWO LEVEL MODELS.

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Simple models, especially if they can be exactly solved, serve as meaningful tools for the testing of various many-body approximations. We present here results obtained in the framework of (i) the pairing-plus-quadrupole model including in addition the octupole-octupole interaction (Extended Baranger-Kumar model - EBKM) and (ii) the Lipkin model (LM).

The EBKM is applied to two opposite-parity j-orbitals. In the HF(HFB)-treatment in the Baranger-Kumar approximation, [1),2)] a phase transition from the spherical or quadrupole-deformed to the octupole-deformed mean field is found. The broken parity symmetry is restored by the variation-before-projection method (VBP). For two nucleons in the j-orbitals, the energy splittings of the lowest positive and negative parity states obtained (i) by the VBP and (ii) from the exact eigenvalues of the model Hamiltonian are compared.

For the octupole-octupole interaction only, namely $Y_{30}Y_{30}$, more detailed analysis was performed. For degenerate orbitals, the value of the octupole moment obtained in the HF-treatment does not depend on the interaction strength and is non-zero. The VBP energy splitting is zero, in spite of the non-zero exact value. For non degenerate orbitals, the phase transition occurs for a defined value of the interaction strength. For infinitely strong interaction, the results are the same as in the degenerate case.

The LM[3),4),5),6)] for both degenerate and non-degenerate cases gives similar results as the EBKM. For both the models, the VBP gives more advantageous results with respect to those effects which are expected to stem from the symmetry-breaking ansatz (the VBP energy splitting is lower than the exact value).

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ELASTIC PROTON SCATTERING ON NEUTRON RICH He ISOTOPES IN GLAUBER APPROACH

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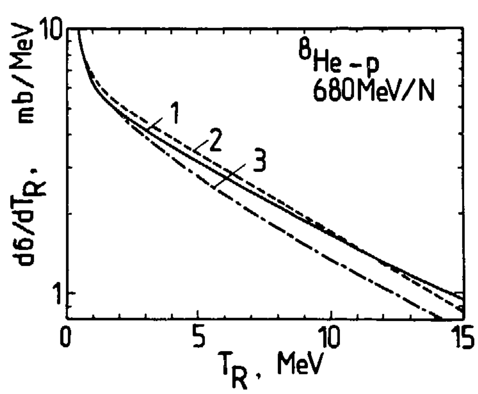
Recently nuclei with a neutron halo have been discovered. An outstanding example is 11-Li. Heavy He isotopes have also some neutron halos. Experimental study of these exotic nuclei is of particular interest. As we have shown in our previous paper 1), the sizes of the core and the halo in 11-Li may be determined rather accurately making use of intermediate energy proton elastic scattering in inverse kinematics. Since the halos in 6-He and 8-He are not so extended as that in 11-Li, it is not clear apriori whether the sensitivity of the method is enough to tell between the sizes of the core and the halo in these isotopes. To answer this question, we have performed calculations of differential cross sections for proton elastic scattering on 6-He and 8-He at 0.7 GeV using the Glauber multiple scattering theory.

Fig.1 presents calculated cross sections for the models with the neutron halo (curve 1) and without the halo in 8-He (curve 2), the root mean square matter radii of 8-He nucleus being the same in both cases. Curve 3 demonstrates the sensitivity of the cross sections to the size of the halo. It is seen that the difference between curves 1 and 2 is not very significant, nevertheless it may be concluded that accurate measurements of the cross sections at relatively small momentum transfers would allow to tell between these two situations and would permit to determine the size of the halo as well as that of the core.



Curve 1 - $\langle r^2\rangle^{1/2}_{core}$ = 1.7 fm; $\langle r^2\rangle^{1/2}_{halo}$ = 3.3 fm.
Curve 2 - $\langle r^2\rangle^{1/2}_{core}$ = 2.6 fm; $\langle r^2\rangle^{1/2}_{halo}$ = 2.6 fm.
Curve 3 - $\langle r^2\rangle^{1/2}_{core}$ = 1.7 fm; $\langle r^2\rangle^{1/2}_{halo}$ = 4.0 fm.

Fig.1. Calculated differential ^{8}He-p elastic cross sections as a function of the proton recoil energy.

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THE TRIAXIAL ASYMMETRY OF THE GROUND STATES OF EVEN-EVEN NUCLEI WITH $A \leq 192$

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The basic nuclear shape parameters are the symmetric quadrupole deformation β and the angle of triaxial asymmetry γ. Values of the parameter γ have been derived so far mainly using model assumptions, e.g. the validity of the asymmetric-rotor model for low-lying states. An approach for a model-independent determination of β_{rms} and δ_{eff} (closely related to β and γ) is offered[1,2] by the sum-rule method. However, the latter has been applied so far to a limited number of nuclei where a large amount of E2 matrix elements was extracted[1] by advanced CE studies. We have found that with reasonable approximations[3] the shape parameters of 0^+ ground states can be determined using only four widely known E2 matrix elements. In this way, we have estimated β_{rms} and δ_{eff} for nearly seventy nuclei with $A \leq 192$.

In the studied cases, a correlation between both shape parameters emerges: the asymmetry is generally increasing from $\delta_{eff} < 15^o$ in strongly deformed nuclei ($\beta_{rms} > 0.3$) to $\delta_{eff} \approx 30^o$ at weak deformation. As a measure of the deviation from axial symmetry at arbitrary values of β_{rms} and δ_{eff} we propose to consider the eccentricity $e=(15/\pi)^{1/2}\beta_{rms} sin\delta_{eff}$ at $\delta_{eff} \leq 30^o$. Surprisingly, the eccentricity of the overhelming majority of investigated nuclei turns out to fluctuate only weakly around 0.16. Observed deviations to larger values can be considered as strong candidates for pronounced triaxiality.

The new results can be compared to model calculations of potential-energy surfaces in the (β,γ) plane, e.g. according to Hartree-Fock and Nilsson-Strutinsky methods as well as to the Generalized Collective Model.

Shapes of isotopic chains (e.g. Ba, Ru) are discussed.

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STRONGLY ENHANCED E1 TRANSITIONS IN THE ^{232}U NUCLEUS

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Since 15 years, a renewed interest was focused on the study of nuclei belonging to the mass region 220<A<230, because the prediction, by Chasman [1], of a static octupolar deformation related to the occurence of alternating parity bands connected by enhanced E1 transitions.The present study of ^{232}U low-energy levels fed in ^{236}Pu α-decay ($T_{1/2}$= 2 .87 y), although placed on the borderline, comes up to this interest.

A strong ^{236}Pu source has been prepared by several irradiations of uranium targets with the proton beam of the Orléans cyclotron.The reaction ^{238}U(p,3n) led to ^{236}Np^m which decays to ^{236}Pu with a 50% branching ratio. The radiochemical isolation of ^{236}Pu, from uranium, neptunium and fission products, has been performed from ten uranium targets by ion exchange chromatographic techniques[2], over a period of one year.

The ^{236}Pu electroplated source (2.1 mCi) was measured with a 40% coaxial HPGe detector; γ-γ-t coincidences were also performed with three HPGe coaxial detectors of 17% and a 20 cm^2 area planar detector.

We report the energy and intensity (10^{-6}-10^{-8} %) of 26 γ-lines, which are unambiguously attributed to ^{236}Pu decay, among them 20 are new with respect to the previous study of Lederer [3].

A revised ^{232}U level scheme was built from our γ-γ-t coincidence results and sum relationships, as well as from ^{232}Pa β-decay data [4] and heavy ion reactions data [5].This level scheme allows the interpretation of 25 γ-transitions between 13 excited levels, of which 8 are reported for the first time. α-hindrance factors (HF) were calculated from the one-body spin-independant model of Preston [6].

The KI^π= 08$^+$ member of the g.s. rotational band is observed at 540.7 keV. The K^π= 0$^-$ band is found to be fed up to I= 5. In the so-called β-band, the I^π= 2$^+$ and 4$^+$ states were observed at respective energies of 734.6 and 833.6 keV. The KI^π= 22$^+$ state, at 867.1 keV, is also fed in this decay.

Moreover, two levels, never observed earlier, are evidenced at 927.3 and 967.7 keV, and interpreted as the two lower states of a new second excited $K^\pi = 0^+_2$ band. From B(E1)/B(E2) ratios of the γ-transitions deexciting these levels to states of the $K^\pi = 0^-$ and $K^\pi = 0^+$ bands, we deduced a mean E1 transition strength of $\approx 10^{-3}$ W.u.. These strongly enhanced E1 transitions compare well to the rates of the one-phonon → zero-phonon octupole-band transitions in lighter thorium nuclei and faster than the rates in nuclei heavier than ^{228}Th [7].

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ANALYSIS OF THE (n,e⁻) SPECTRUM OF ^{184}W

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ABSTRACT

The internal coeffecient spectrum of ^{184}W was obtained from a thermal neutron capture experiment carried out at the high flux reactor at the Insitut Laue-Langevin. This spectrum was studied and a very strong, previously unknown, E0 transition from the $0_2^+ \rightarrow 0^+$ was seen.

A comparision is made with predictions from the Interacting Boson Model.

TWO PROTON HIGH-SPIN EXCITATIONS AND OBLATE DIPOLE BANDS IN ^{192}HG

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The ^{192}Hg nucleus has been populated via the ^{36}S(^{160}Gd, 4n) reaction at 159 MeV with the beam being provided by the MP Tamdem of the Daresbury Nuclear Structure Facility. The γ - rays have been detected with the 45 Ge multi-detector array EUROGAM phase 1. A total of 6.5×10^8 events have been written to tape with an unsuppressed fold ≥ 5. These data have been sorted into γ-γ correlation matrices, some of them gated on the $2^+ \rightarrow 0^+$ or $4^+ \rightarrow 2^+$ γ - ray transitions select unambiguously the ^{192}Hg nucleus and angular distribution informations have been extracted from coincidence data.

The level scheme of ^{192}Hg, known previously [1], has been extended up to 10.4 MeV excitation energy and spin $34\,\hbar$ [2]. Two new structures, composed of competing $\Delta\,\mathrm{I} = 1$ and $\Delta\,\mathrm{I} = 2$ transitions, have been observed and their links with the known low-lying levels established. These two bands are based on states located at 6.305 MeV ($\mathrm{I} = 22^+$) and 6.879 MeV ($\mathrm{I} = 23^-$) excitation energy. The second band is more regular than the first one and shows a regular behaviour for the transition probabilities B(M1)/B(E2) ratios with a mean value of $5.5\,(\mu_N/eb)^2$.

This experimental result has been discussed in terms of mean-field Hartree-Fock calculations [3,4]. The two bands could be interpreted as two high-K quasi-proton excitations, $\pi(i_{13/2} * h_{9/2})_{K=11}$ and $\pi(h_{9/2})^2_{K=8}$ coupled to rotation-aligned $\nu(i_{13/2})^n$ quasi-neutron and $\pi(h_{11/2})^2$ quasi-proton excitations.

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Alpha-decay of $^{180}T\ell$ studied with the SARA/IGISOL facility

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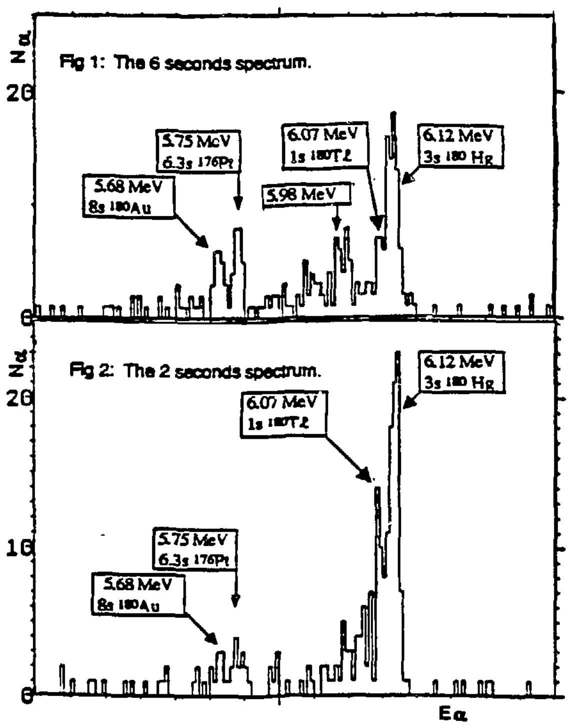
EC-delayed fission was observed and assigned to $^{180}T\ell$ precursor by Lasarev et al.[1)] but until now, very scarce data exist on the g.s. decay properties of the lightest $T\ell$ isotopes (A < 184). The aim of the present work was to extend our knowledge on the structure and decay modes of very n-deficient nuclei in the $Hg-Pb$ region. By using a new version of the ISIGOL technique[2)] we have mass-separated at SARA products of the $^{144}Sm+^{40}Ca$ (215 MeV) reaction. To avoid the plasma effect in the ion guide He-pressurized chamber, we took advantage of the huge difference between the angular distribution of ^{40}Ca beam and that of evaporation residues after passing a 2-3 mg/cm^2 thick target and thus applied the shadow method. The overall efficiency of the system was determined to be 1.4 10^{-3} with a mass-resolving power $M/\Delta M \simeq 375$ for stable $^{202}Hg^+$.



The α-particle energy spectra obtained at $A = 180$ are shown in fig.1 and 2.

Fig. 1 presents a 6 seconds collection, followed by a rapid tape-transportation of the activity in front of a Si surface-barrier detector and 6 seconds counting. This timing is adapted for the detection of the 6.12 MeV α-line of $^{180}Hg(T_{1/2} = 2.56\ s)$[3)] and daughters. In this figure we can notice the presence of a very weak α-line at 6.07 MeV which has not been observed in previous works on ^{180}Hg and isobars of lower Z.

In fig. 2 is presented a $2s$ collection and $2s$ counting spectrum. This timing is adapted for a better observation of shorter half-life α-activities. The 6.07 MeV α-line is clearly seen, its area is $\simeq 30\%$ that of the 6.12 MeV α-line of ^{180}Hg.

By comparing the relative intensities of these two lines in the two timings, the half-life of the 6.07 MeV can be estimated to : $T_{1/2} = 1.0 \pm 0.2\ s$.

We can ascribe this 6.07 MeV α-line to the decay of $^{180}T\ell$ on the basis of following considerations :

1/ A careful verification on the neighbouring masses indicates that this line is not seen in another mass-chain.

2/ This line was not observed in the $^{144}Sm+^{40}Ar$ reaction[3,4)] where ^{180}Hg is produced, indicating that it arises from a nuclide with $Z > 80$ and $Z \leq 82$.

3/ For a variety of reasons it cannot be associated to the decay of ^{180}Pb and its daughters :

i) The yield of ^{180}Pb produced via the $4n$-evaporation channel is severely decreased as compared to that of $^{180}T\ell$ produced via the $p3n$-channel.

ii) From systematics of the decay properties of the lightest Pb isotopes, the still unknown ^{180}Pb is expected to be a very short-lived α-decaying nucleus with a half-life certainly well below 100 ms and α-energy above 7 MeV.

iii) The decay products of ^{180}Pb are well-known and there is no possibility to indicate among these a 6.07 MeV α activity except for the very improbable $2p$ decay.

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STRONG DEPENDENCE OF A NUCLEAR LIFETIME ON THE IONIC CHARGE STATE

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For a long time, the electronic environment of a nucleus, has been regarded as having little influence on the nuclear decay processes[1,2]. Using a ^{125}Te beam, accelerated at 27 MeV/amu by the GANIL facility, we show for the first time that the K-shell internal conversion coefficient can strongly depends on the number of electrons in the outer shells. As a direct consequence, the lifetime of some nuclear excited states presents a large variation with the ionic charge state when the energy of the nuclear transition is slightly larger than the binding energy of the K-shell electrons in the neutral atom. Due to the changes in the mean electric field viewed by the inner electrons for different outer shells electronic configurations, the binding energy of the K-shell electron (E_K) increases as the charge state increases. Hence for a specific charge Q_c, E_K becomes larger than the available transition energy. The K-shell internal conversion becomes energetically forbidden in spite of the presence of the two K-shell electrons and the nuclear lifetime increases by a factor of the order of $(1 - \Gamma_K/\Gamma_T)$ where Γ_K and Γ_T are respectively the K conversion partial width and the total level width in the neutral atom. For a charge state larger than Q_c, the nucleus can only decay by gamma emission or by internal conversion on the remaining L-shell electrons. The experimental technique is based on the detection of the change of the trajectory of the ions inside a magnetic spectrometer when the charge state changes after a decay by internal conversion. The ^{125}Te beam extracted from the CSS in the 38^+ charge state is sent on a 1 mg/cm^2 ^{232}Th target and scattered at 2°5. When exiting the target, the charge state distribution follows a distribution caracterized by a mean charge state value Q = 47^+ (fwhm = 2). A fraction of the ^{125}Te nuclei are excited in the first $3/2^+$ state by Coulomb interaction with the target. The actual detection of the ion in the detection system plane depends on the location where the decay has taken place and consequently on the mean lifetime of the nuclear excited state. Based on the code Turtle a simulation program has been developped to achieve a quantitative interpretation of the data. In a neutral atom of ^{125}Te the half-life of the excited state is equal to 1.5 ns.

Up to Q = 45, the half-life of the first $3/2^+$ excited state of the ^{125}Te nucleus do not show, as expected, significant variations when compared to that of the neutral atom. Beyond the 46^+ charge state, the lifetime of the level is found to be strongly enhanced and for the 48^+ charge state the lifetime is already increased up to a factor 15.

The implication of the present effect to astrophysical processes[3] and to fundamental physics will be discussed.

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Low-energy band structures in light odd-A La and Pr isotopes

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Low-spin states were studied in ^{127,129}La and in ^{129,131}Pr by radioactive β^+/EC decays. Cerium and neodymium isotope precursors were produced using 5-6 MeV/nucleon ^{40}Ca or ^{35}Cl beams from the SARA accelerator in Grenoble on thin enriched targets of ^{94}Mo and ^{96}Mo. The mass identifications in a given A chain were insured with the SARA on-line isotope separator working with a coupled He-jet ion source system[1)] or with an ion-guide[2)]. The He-jet system was used to thermalize and transport the radioactive recoiling products to a low background detection station. Prompt and delayed γ-x, γ-γ and γ-e measurements, in addition to multipolarity assignments deduced from experimental internal conversion electron coefficients have allowed to built low energy odd-A La and Pr level schemes.

In addition to the large amount of data previously established in the odd-A prolate isotopes ($\beta_2 \sim 0.22$-0.25) of this A ~130 region, new low lying positive parity states were identified in the present results. By comparing these new informations with the in-beam data [3,4,5)] which contain a few band connections and with the predicted quasiparticle configurations, systematics of the low members of both positive and negative parity bands can be extended for odd-A La and Pr isotopes. The application of the IBFM-1 model for these odd-Z nuclei, as previously made for odd-A even-Z isotopes[6)], will be presented and discussed.

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REALISTIC EFFECTIVE INTERACTIONS FOR SHELL-MODEL CALCULATIONS

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In the usual theory the perturbation expansion for the shell-model effective interaction suffers from the difficulty that it diverges in the model space due to intruder states[1)]. This problem might be overcome by performing the shell-model calculation in a large no-core model space[2,3)], in which all A nucleons are active, so all core-polarization processes are eliminated[4)]. The effective interaction for $A=2$ is simply the Brueckner G-matrix[5)]. For $A > 2$, exact results for the eigenvalues are obtained, if the generalized, A-nucleon G-matrix and associated folded diagrams[4,6,7)] can be constructed. For sufficiently large model spaces the perturbation expansion for the effective interaction may be reasonably expressed in terms of only the Brueckner reaction matrix G in the no-core space plus all folded diagrams computed from it[8)].

We have developed a simple relationship for determining the starting energy of the two-nucleon G-matrix, so as to yield a good approximation to the starting-energy-independent G-matrix (i.e., the G-matrix plus the sum of all folded diagrams). This approach has been applied to the calculation of the properties of light nuclei ($A=2$ to 6).

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LIFETIMES FROM (n,n'γ) REACTION

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In recent years at the University of Kentucky, the (n,n'γ) reaction with accelerator-produced monoenergetic neutrons has been coupled with the Doppler-shift attenuation method (DSAM) to measure nuclear lifetimes. At extremely low ($v/c < 0.001$) initial velocities, a number of tests of the DSAM are required because of the various uncertainties [1]) associated with the stopping theory required to convert shifts into lifetimes. We have shown that the influence of kinematics of the scattering process on the DSA is minimal at neutron energies near the threshold for population of a level. While the large size of the scattering samples used is also important, the effect is in the opposite direction.

Here we present results for ^{48}Ti that has been chosen as a test case. In addition to the metallic target, TiC was also used to test the influence of chemical composition on the deduced lifetimes. A through comparison is made with the literature data [2]).

The DSAM has also been used to study heavier nuclei, e.g., the stable Sm nuclei. Transition rates obtained for γ-rays de-exciting low-energy negative-parity states in the even Sm nuclei have been compared with GRID and (γ,γ') results. The reduced transition probabilities have been successfully described by sdf-IBM calculations using an effective E1 operator [3]).

A final example is provided by ^{146}Nd nucleus, where mixed-symmetry states has been sought. In this nucleus, a number of observed 1^+ and 2^+ states seem to share mixed-symmetry character. The low-energy negative-parity states exhibit similar to that observed in even Sm nuclei [4]).

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THE STRUCTURE OF EXOTIC OR HIGHLY ROTATING NUCLEI AND THE SPIN-ISOSPIN DEPENDENCE OF LDM PARAMETERS

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In recent years important progresses have been made in the investigation of nuclear structure at very high spin as well as at the limits of stability by particle emission. The related most currently developped theoretical descriptions are the so-called macroscopic-microscopic approaches using the Liquid Drop Model (LDM) with quantal shell corrections *à la Strutinsky*[1]. More microscopic approaches on the other hand are now available which are both more theoretically grounded and numerically heavier. The aim of this contribution is to take stock of the basic ingredients of the latter approaches to assess the validity of the Strutinsky type calculations in such extreme context. More specifically, we calculate self-consistently average energies and densities within the semi-classical Extended Thomas Fermi approach[2] at zero and finite ω values. These quantities are then used as a database to check the validity of LDM assumptions.

Indeed in relation with the problems of high spin nuclear states and near drip line Nuclear Structure, we aim to answer two types of questions :

i) is the LDM parametrization totally adequate at finite angular velocity ω and if yes, are its parameters ω-independent ?

ii) is the LDM parametrization with respect to the isospin parameter $I = (N - Z)/A$ adequate ?

To the first question, the answer is qualitatively yes for slow rotations[3]. For higher ω values, systematic discrepancies show up reflected by the variation of microscopic nuclear liquid drop energies with ω as shown in Table 1.

As for the second question the current LDM parametrization is badly deficient far from the drip line due to the lack of any I-dependence of the Coulomb energy. A simple yet accurate approximate parametrization of the latter will be given[4].

Table 1: Semiclassical nuclear energies (in MeV) for various nuclei as functions of the angular velocity given by the energy $\hbar\omega$.

$\hbar\omega$ [MeV]	0.0	0.4	0.8	1.2
^{40}Ca	−419.93	−419.94	−419.99	−420.04
^{90}Zr	−1029.11	−1029.40	−1029.42	−1029.80
^{140}Ce	−1623.39	−1623.60	−1624.09	−1624.84
^{208}Pb	−2421.71	−2422.13	−2423.36	−2425.15

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Shape coexistence in neutron-deficient even-even Po isotopes, studied by β^+/EC decay.

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Low-lying 0^+ states in even-even nuclei near closed shells can be a manifestation of coexistence of different shapes in the same nucleus. Deformed band structures, coexisting with the groundstate band, have been observed in several regions of the nuclear chart. Such structures have been found in the neutron-deficient Pt, Hg and Pb isotopes [1]. Evidence for a deformed band at low energy has been found in ^{196}Po en ^{198}Po using in-beam studies [2]. Furthermore the α decay of ^{202,200}Rn studied at ISOLDE revealed feeding to 0^+ states at 816 keV in ^{198}Po [3] and at 558 keV in ^{196}Po. These 0^+ states are interpreted as the bandhead of the deformed band of which the 2^+ and 4^+ members were already observed [2].

Measurements have been performed on low-lying 0^+ states in ^{200,202}Po via the β^+/EC decay of ^{200,202}At at LISOL. The energy positions of the 0^+ states in function of neutron number seem to fit the parabolic behavior as expected for intruder states. Intruder states in the Pb region are often characterized by a strong E0 component in their decay to normal states [1]. Therefore we concentrate the analysis to the search of strong electron lines. Using coincidence data, we obtain more detailed level schemes at low energy for ^{200}Po and ^{202}Po.

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STUDY OF NUCLEAR ISOMERISM BY HEAVY IONS TRANSFER REACTION

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We have undertaken in 1990, at SACLAY an experimental program aiming to observe and study nuclear isomerism taking advantage of the high selectivity of the transfer reactions associated with high resolution gamma detection.
The experimental procedure consist in bombarding a target with a heavy ion beam delivered by the Saclay Superconducting Postaccelerated Tandem, detect and identify the ejectile in a QDDD spectrometer and observe the gamma decays in a Germanium array composed of six triple-telescopes BGO Compton suppressed surrounding the target.

The measure of the particle-gamma delay allows a very precise determination of the isomers half lives in a range of 10 to 500 ns.
This technique was used to characterize new isomeric states. In ^{65}Ni for instance, the transition from the known $9/2^+$ state at 1013 keV to the ground state was seen for the first time. This state is an 26.5 +/- 0.5 ns half live isomer.

Search for so-called shape isomer was also addressed. Both, light nuclei (^{66}Ni) and heavier systems like ^{194}Hg or ^{210}Po were studied.
All the middle and high spin super deformed states observed up to now in non fissile nuclei, have been populated by HI fusion-evaporation reactions, which means that the nucleus is formed at high excitation energy, typically 50 MeV, and at high spin (>30 $\hbar$). The idea is here to use few nucleons transfer reactions to feed the SD band at much lower spin and lower excitation energy to reach the shape isomer.

In Ni isotopes, no firm experimental evidence for shape isomerism was observed even if a good candidate was found in ^{68}Ni.
In our study of the ^{64}Ni(^{18}O,^{16}O)^{66}Ni reaction a delayed 1020 keV gamma ray was observed which could correspond to the transition from the O^+ predicted shape isomer to the first excited 2^+ state. The lack of statistics does not allow any firm conclusion about the existence of this isomer in this Ni isotope. Additional data taking is planned before summer.
The ^{192}Pt(^{16}O,^{14}C)^{194}Hg reaction has been used to populate the lowest transitions of the well known SD band and to reach so the shape isomer. Two transitions of this band seem to show up in our results.
For ^{210}Po we used a slightly different technique namely the measurement of a high energy (6 to 8 MeV) delayed gamma ray between second and first well. Here also some possible candidates were observed.

Results on these three different regions will be presented.

NUCLEAR MOMENTS AND CHARGE RADIUS OF THE HIGH-SPIN ISOMER ^{178m2}Hf FROM LASER SPECTROSCOPY

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Among all spin isomers found between the rare earth and the refractory elements the isotope ^{178}Hf is very interesting because it possesses the four quasi-particle yrast trap state ^{178m2}Hf, which has high spin ($I^{\pi}=16^{+}$), large half-life ($T_{1/2}=31\,y$) and a moderate excitation energy of E=2446 keV.

The complete hyperfine spectrum of ^{178m2}Hf has been recorded in the optical transition $5d^2 6s^2\,{}^3P_2 \rightarrow 5d6s^2 6p\,{}^1P_1$ by high-resolution collinear laser spectroscopy. The experiment was performed at the P.A.R.I.S.-separator of the CSNSM at Orsay using two samples containing about $2{\cdot}10^{13}$ (or 6ng) atoms of ^{178m2}Hf and –as deduced from the optical signals– a roughly 30 times larger amount of ^{178g}Hf. The production of the isomer was achieved by irradiation of highly enriched ^{176}Yb with a 36 MeV α-beam provided by the U-200 cyclotron at Dubna [1].

The magnetic moment of $\mu_I = +8.16(4)\,n.m.$, which is extracted from the hyperfine A-factor can be explained from the contributions of the four valence nucleons, the collective motion of the core and the application of additivity rules for these moments. From the hyperfine B-factor a spectroscopic quadrupole moment of $Q_s = +6.00(7)\,b$ has been evaluated. Assuming a strong coupling of the four quasi-particles to the core, we obtain an intrinsic quadrupole moment of $Q_0 = +7.2(1)\,b$ which is slightly higher than the corresponding value for the ground state as derived from B(E2)-values [2]. Moreover, the moment $Q_0(^{178m2}\mathrm{Hf})$ obtained in the present work is in agreement with self-consistent calculations [3]. The isomer shift $\delta\langle r^2\rangle^{178g,178m2} = -0.059(9)\,fm^2$ is large compared to the (normal) odd-even effect of $-0.014(5)\,fm^2$ for the stable odd mass nuclei ^{177}Hf and ^{179}Hf which is obtained from a parabolic fit procedure [4].

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g-factor of the low-lying SD band in ^{133}Nd

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A mean g-factor has been measured in the superdeformed (SD) band in ^{133}Nd. This nucleus has been selected since it has been studied extensively very recently, using GASP [1] and SD band spins, decay scheme and lifetimes [2] are well known; the lowest observed member is the $17/2^+$ at 2024 keV. Owing to the short lifetime the Transient Field (TF) technique has been used. The excited states in ^{133}Nd have been populated by the ^{104}Pd(^{32}S,2pn)^{133}Nd reaction at 135 MeV bombarding energy, with about 9% intensity of the entire exit channel. The target consisted of a 0.8 mg/cm^2 layer of enriched ^{104}Pd sticked onto a 2.3 mg/cm^2 natural Gd foil and then to a gold stopper. The target was kept at liquid nitrogen temperature and the polarizing field was periodically reversed. The experiment was carried out with the GASP detector array at the Legnaro National Laboratory XTU Tandem accelerator, employing 40 Compton suppressed HPGe detectors. About one giga two-fold events were collected. The GASP geometry has twelve detectors sensitive to small angular distribution precession: four in the plane perpendicular to the the field direction and four in each plane $\theta = 120^o$ and $\theta = 60^\circ$. These detectors are placed at $\phi \approx \pm 70^\circ$ and $\phi \approx \pm 110^\circ$. The $\gamma - \gamma$ coincidences between each of these twelve detectors and all the others have been analysed gating on the SD band γ transitions. The accumulated precession occurred during the transit time in the ferromagnetic foil was deduced using two SD probe states ($25/2^+$ and $29/2^+$). In order to extract the mean g-factor of the SD band the experimental sidefeeding has been taken into account. The preliminary experimental value $\bar{g}$= 0.28(8) agrees with a band based on a $\nu[660]1/2^+$ Nilsson intruder orbital. The result obtained so far give us confidence to apply the same technique to measure less intense SD bands.

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Gamow-Teller Beta Decay near ^{100}Sn

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The doubly-magic nucleus ^{100}Sn is far off the beta stability line. It has not been reach yet experimentally (January 1994) – but the identification experiments based on the fragmentation of the relativistic heavy ions are already scheduled at GSI Darmstadt and GANIL Caen for March/April 1994.

In the last years the region of nuclei near ^{100}Sn has attracted the interest of many experimental and theoretical groups. The studies were mostly focused on the nuclear structure of the systems close to the magic numbers N=Z=50 and on the related decay modes of these nuclei. The latter are governed by the Gamow-Teller (GT) transformation $\pi g_{9/2} \rightarrow \nu g_{7/2}$.

Complex shell-model model calculations describing the beta decay properties of nuclei near ^{100}Sn have recently been performed [1]. The resulting GT-strength distributions for the decays of even-even nuclei are in a good agreement with the available experimental data. For the decay of ^{100}Sn, a dominant feeding (over 98% of the total strength) to one level at 1.8 MeV excitation energy in ^{100}In has been predicted. This means that according to this calculations proton emission following beta decay of ^{100}Sn has negligible probability - in contrast to the previous predictions [2].

For the first time the GT-distribution for the decays of the "non even-even" nuclei close to ^{100}Sn have been obtained. The resulting predictions for the beta half-lives and beta-delayed proton branching ratios are in remarkable agreement with experiment [3] when the calculated decay energies are slightly corrected to fit measured values [4].

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Laser Spectroscopy of Neutron Deficient Bismuth Isotopes in a Gas Cell

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Ground state moments and changes in charge distributions of the neutron deficient A=202, 203 and 204 bismuth isotopes have been measured by laser-induced fluorescence spectroscopy in a gas cell (a description of the spectroscopy and dimensions of the cell used are given in ref [1]). The accuracy of the isotope shift measurements exceeds by an order of magnitude those reported for 205, 206 and 208 [2]. These measurements have for the first time enabled a detailed comparison of isotonic behaviour in the Pb, Po and the odd-Z Bi systems. The near-identical behaviour of the charge-radii and quadrupole moments of isotones just beyond the Z=82 closure (this includes the Q_s of high spin isomers) clearly resolves the roles of differing proton and neutron configurations in driving the deformation.

Property	202	203	204
IS ^{A,209}Bi(MHz)	10267(58)	8303(54)	7681(85)
μ(n.m.)	+4.259(14)	+4.017(13)	+4.322(15)
Q_s(barns)	-0.720(77)	-0.568(49)	-0.486(150)

Isotope shifts (306.7nm $^4S_{3/2}$–$^4P_{1/2}$) and nuclear moments.

The measurements have been made with samples of 10^{9-10} atoms. The bismuth samples, daughter products of the $^{197}Au(^{11}B,xn)^{208-x}Po$ reaction, were produced at the tandem-linac accelerator at SUNY, Stony Brook, and studied off-line in a cooled cell filled with 2–6 Torr of argon. The bismuth was released from the gold targets by baking in vacuum at ~900°C and the vaporized products were allowed to condense on the inner surface of a cold tantalum tube. Surface evaporation from this tube could be achieved at far lower temperatures (~500°C) and it formed the primary element of the sample oven inside the gas cell. The increased laser–atom interaction time in the buffer gas resulted in a high fluorescence yield (photons per atom) being observed on resonance. The 306.7nm $6p^3$–$6p^27s$ transition was pumped using 1-2mW of frequency doubled light from a Spectra Physics 380D dye laser (intra-cavity harmonic generation using AR coated $LiIO_3$). The resonance was observed on a 6% intercombination branch (472nm) allowing the otherwise crippling Rayleigh scattered background to be filtered out.

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NUCLEAR SHAPES AND SHAPE CHANGES: MAGNETIC DIPOLE SUM RULES AS A NEW SIGNATURE

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Nuclear sum rules provide a useful tool in order to measure in a quantitative way the degree of collectiveness for a given nuclear state, in particular, since only the ground-state expectation value for certain operators needs to be evaluated [1]. For the non-energy weighted M1 sum rule (NEWSR), this operator is the square of the M1 operator; for the linear energy-weighted M1 sum rule (EWSR), the operator turns out to be the double commutator of the M1 operator with the nuclear Hamiltonian.

Quite some controversy has occurred about the nature of low-lying 1^+ excitations in deformed nuclei and, in particular, of the degree of collectivity as a consequence of the observed 1^+ fragmentation in (e,e') and (γ,γ') reactions. The above magnetic sum rules can give new insight in some of these questions.

We have studied both the NEWSR and the EWSR for the M1 operator and this for rare-earth nuclei ranging from almost spherical, over vibrational and transitional into the region of strong deformation. It could be shown that, even for rather realistic Hamiltonians and using the Interacting Boson model framework, the NEWSR is related to the nuclear monopole (E0) properties and thus is connected to the nuclear radius [2]. Thereby, the NEWSR can act as a probe for nuclear shapes and shape changes. This is illustrated in particular for the rare-earth region. In evaluating the linear EWSR for the M1 transition strength, a relation to the summed E2 strength shows up and so connects to nuclear deformation properties in a slightly different way compared with the results as obtained using the NEWSR. Similar results have been obtained recently using a deformed harmonic oscillator potential and even using the spherical shell model [3,4].

Finally, we shortly discuss some new results concerning sum rules as derived for the E0,E2 and M3 operators as well as the sum rule results in the limiting situation that good F-spin holds and this for the U(5), O(6) and SU(3) dynamical symmetries.

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Mean field description of the $I^{\pi}=16^{+}$ isomer in ^{178}Hf

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The structure properties of the long-life ^{178m2}Hf ($I^{\pi}=16^{+}$, $T_{1/2}$=31y) spin isomer are studied through Hartree-Fock-Bogoliubov (HFB) calculations based on the Gogny force. In this description, the isomeric state is treated as a four quasiparticle (4qp) excitation built upon the qp vacuum. Radius and multipole moments of the radial charge distribution are calculated using a blocking procedure in which time reversal symmetry is either preserved or broken. These predictions are compared with the radius and moments for the ground state.

Cranking HFB calculations are also performed to predict the moment of inertia of the rotational band built upon the $I^{\pi}=16^{+}$ isomeric state. Comparisons with measurements are discussed.

Self-consistent cranking HFB calculations with the Gogny force for superdeformed bands in nuclei of the A=150 and 190 mass regions

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The Gogny force is used in self-consistent cranking Hartree-Fock-Bogoliubov calculations of superdeformed (SD) rotational states in various nuclei of the A=150 and 190 mass regions. Several properties including moments of inertia, antistretching effects and pairing correlations are presented and discussed for yrast bands. The good overall agreement found between present predictions and available experimental results shows that Gogny force is well behaved when time reversal symmetry is broken.

Our predictions are also extended to excited bands built on quasiparticle excitations, and compared with the results obtained from configuration mixing calculations. A discussion is made on the nature of these excited SD bands.

Hartree-Fock-Bogoliubov and configuration mixing calculations of isotope shifts for Kr, Sr, Zr and Hg isotopes

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Isotope shift measurements have been a powerful tool in the investigation of ground state properties of many nuclei in the vicinity of, and far away from the β - stability line. Such measurements have played a key role in the discovery of snape coexistence phenomena (for instance in the neutron-deficient Hg isotopes). They have often been interpreted within the droplet model and Hartree-Fock theory, that is ignoring ground state correlations.

In this work, charge radii are calculated using correlated wave functions. These wave functions are deduced from configuration mixing as follows. In the first step, potential energy surfaces and tensors of inertia are calculated within the Hartree-Fock-Bogoliubov theory including constraints on quadrupole moments. Then, the Hill and Wheeler equation is solved in the Gaussian Overlap Approximation to obtain the collective wave functions. These calculations are performed using Gogny force. Comparisons are made with measurements available for various Kr,Sr, Zr and Hg isotopes in which shape coexistence phenomena have been observed.

Production of a pure $^{42}Sc^m$ isomeric beam*

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Abstract

The availability of the last generation of heavy ion accelerators and their sophisticated equipments opens new ways to produce and study Radioactive Nuclear Beams (RNBs). In particular, secondary beams of nuclei in metastable states can be produced. Such isomeric beams are of great interest in order to investigate the nuclear structure of nuclei in an excited state.The most classical method to produce RNBs is the projectile fragmentation. Recent investigations at RIKEN and MSU using this mechanism have been performed to obtain secondary isomeric beams. We present an alternate method based on transfer reactions, to produce isomeric heavy ion beams. The selectivity of transfer reactions should lead to extremely pure isomeric beams and using one or two nucleon transfer reactions, one can expect reasonable RNB intensities.

A $^{42}Sc^m$ isomeric beam was produced for the first time at GANIL. In its ground state, ^{42}Sc has a lifetime of 681ms and $J^\pi = 0^+$, whereas its isomeric state has a high spin $J^\pi = 7^+$, a longer lifetime of $\tau = 61.8$ s and an excitation energy E_x=0.617 MeV. The $^{12}C(^{40}Ca,^{42}Sc^m)^{10}B$ transfer reaction at 30 MeV/A was used and yielded an isomeric purity of 98 ±5%. The secondary beam, separated with the LISE3 on line spectrometer, was however contaminated by 30 % of residual ^{40}Ca nuclei. A $^{42}Sc^m$ secondary beam intensity of 114 pps was obtained with a 5 pnA ^{40}Ca incident beam bombarding a 5 mg/cm^2 ^{12}C target.

*Experiment performed at GANIL,Caen,France

A microscopic description of the deformation properties in even-A platinum isotopes

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Résumé : *Les états collectifs de basse énergie liés à la dynamique quadrupolaire ont été étudiés pour les isotopes de platine dans un modèle purement microscopique. L'évolution des rayons moyens de charge statique et dynamique est comparée aux résultats expérimentaux.*

In the framework of a purely microscopic approach, using a Nucleon-Nucleon effective interaction of the Skyrme type (the SK* parametrization) and with a seniority force for the pairing correlations taken into account at the BCS approximation, we determine in the quadrupole deformation space (five independant collective degrees of freedom) the seven scalar functions defining the most general Bohr Hamiltonian (i.e. without any *a priori* dynamical restriction) for adiabatic dynamics.
Starting from a semi-classical expansion of the nuclear density matrix and using the so-called Expectation Value Method of ref [1], we yield Potential Energy Surfaces, individual energies and associated wave functions. The latter are then used to compute in the Inglis Cranking limit the inertia tensor at each point of the deformation space and then, the Bohr Hamiltonian obtained is requantized and diagonalized (by projection on an *ad hoc* basis).
It has been shown (ref [2]) that PES and the collective dynamics so-obtained are very much affected (in particular the static and dynamic deformation) by the global pairing strength. The study of the collective excitation modes provides therefore a very stringent constraint in the evaluation of the latter. In this present work a unique set of G_p and G_n has been used for the calculation of all the platinum isotopes.
The evolutions of the calculated root mean square static and dynamic charge radii are compared with data extracted from isotopic shift measurements performed using resonant ionization spectroscopy of laser desorbed radioactive atoms (ref [3]).

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Collective States and Transitions in Nuclei with Quadrupole and Octupole Deformations

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A transparent macroscopic model for description of energy levels belonging to even and odd rotational bands as well as reduced probabilities of dipole crossband and quadrupole interbands transitions in the soft even-even [1] and odd [2] nuclei with quadrupole and octupole is proposed. This model is generalization of the Davydov-Chaban model [3], which described rotational spectra of soft nuclei with the quadrupole deformation only. on the case of nuclei with both the quadrupole and the octupole deformations.

Three parameters expression for energy levels with angular momentum I of even and odd rotational bands is obtained in [1]

$$E_I^{\pm} = \frac{\hbar\omega_\sigma}{2}[(1+4(\Delta_0^{\pm}+I(I+1)/3))^{1/2} - (1+4\Delta_0^{+})^{1/2}].$$

Here parameter $\hbar\omega_\sigma$ is energetic parameter of spectra. This parameter in our theory has the same sense as $\hbar\omega_0$ in the Davydov-Chaban model [3]. The parameters are $\Delta_0^{\pm} = \mu^{-4} \mp \epsilon$ determined the relative position of levels in main even and odd parities rotational bands correspondingly, where μ is generalized quadrupole and octupole nuclear softness and ϵ is connected with the split energy, arisen as result of tunneling transitions between nuclear shape with opposite value of octupole deformations, with μ and with other parameters of potential surface in the space β_2 and β_3, see in detail in [1,2,4]. Note that the quadrupole softness of nucleus μ was introduced in the Davydov-Chaban model also. The influence of shape variations due to rotation of nucleus with different rotational velocities on ratio of reduced probabilities is described with the help of these parameters. The similar expressions for energy levels and transition probabilities are obtained for odd nuclei in Ref. [2].

Different macroscopic calculations of polarized electric dipole moment are discussed in detail. It is shown that this dipole moment depends on the position of the center of mass of nuclear shape with quadrupole and octupole deformations [4]. The conditions of consistency of the radii of the proton and neutron surfaces, respectively, are discussed. These conditions must be incorporated in a shell-correction of this dipole moment. The correct shell correction calculation of dipole moment has been presented [4].

The strong dependence of polarized electric dipole moment from angular dependence of neutron skin thickness is discussed.

The agreement between calculated and experimental values of the energy levels and the reduced probabilities are good.

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Simple Model of Giant Isoscalar Resonances in Nucleus with Neutron Halo

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We propose that the radial dependence of density distribution in nucleus with neutron halo is similar to two sharp steps. The inner part is connected with core of nucleus and the outer part is corresponded to halo.

The density vibrations of two steps system are considered in hydrodynamic approach. The density vibration in the core volume is dynamically connected both with the oscillation of core surface and with the density vibration in the volume of halo. The vibration in halo volume is connected with the oscillation of inner and outer surfaces of halo. The nucleon motions in the core and halo volumes are described by hydrodynamic equations with the different compressibility modulus. The density oscillations in the volume of both core and halo are satisfied special boundary conditions of the core and halo surfaces.

The expressions for excitation energies, transition densities, reduced probabilities of transitions, mass and stiffness parameters, contributions to sum rules of monopole and dipole resonances are obtained in framework of this simple model [1]. The excitations can be roughly classified on volume (core) and halo types. The first halo excitation has low energy, but the energy of the first core excitation is close to the energy of ordinary giant resonances on nucleus without halo. The reduced probabilities of transitions have comparable values for both excitations. The dependencies of excitation energies from halo compressibility modulus, thickness of halo and surface tensions are discussed.

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SEARCH FOR SHAPE ISOMERIC STATES IN EVEN EVEN NUCLEI WITH MASSES A < 100

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Open questions about low spin states in superdeformed bands and agreement between the several theoritical predictions[1-4]) for low spin shape isomers make worthwhile experimental investigations in that field.

The capability of the cluster and particles transfert mechanisms to populate such states has been explored with the help of a large angular acceptance supraconducting solenoid SOLENO, coupled to a set of 80% efficiency germanium detectors at the MP Tandem Orsay laboratory. The spectrometer with its associated focal plane detection offers an unambigous identification of the ejectile and a determination of the excitation energy in the residual nucleus.

Search for well deformed states in ^{48}Cr and ^{52}Fe has been carried out with the (^{12}C, α) and (^{16}O, α) reactions on a ^{40}Ca target. The two protons stripping reaction induced by ^{16}O beam on ^{58}Ni target is nowadays studied to search for isomeric state in the N=Z nucleus ^{60}Zn. For this isotope a second minimum in the calculated potential energy curve occurs at β=0.5 around 5 MeV excitation energy [3]). In our experimental conditions several nuclei with 59 <A <65 are formed in an excitation energy range of 10 MeV. The cross section leading to the population of levels in the second well is estimated from our data.

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SHAPE COEXISTENCE IN Z = 65 NUCLEI EVOLUTION OF THE DEFORMATION ALONG THE HIGH SPIN STATES OF $^{146-149}$Tb

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The high spin levels of $^{146-149}$Tb have been extensively studied with two complementary experimental devices : the Château de Cristal and the e^--γ spectrometer (operating with the MP Tandem accelerators at Strasbourg and Orsay). In all different experiments, the reactions ^{120,122}Sn(^{31}P,4n-5n) have been used at beam energies varying between 140 and 150 MeV. The magnetic lens was oriented in the forward geometry (0°) relative to the beam direction in order to minimize the Doppler broadening.

These nuclei are in the vicinity of the $^{146}_{64}Gd_{82}$ semi-magic core. Therefore, as expected, a competition between different shapes is observed through the interplay between collective and individual modes for carrying angular momentum, involving at higher spins the breaking of proton and neutron cores.

Most excited levels have been interpeted in the frame of a Deformed Independant Particle Model [1] with a Nilsson Hamiltonian and including the Strutinsky prescription. The calculated quadrupole deformation evolves from quasi-spherical at the lower states to sizeable oblate deformation ($\beta_2 \sim -0.2$) at the highest spins.

There is a close analogy between the high excited levels of the odd-A Tb and the corresponding levels of the even-even Gd and Dy cores which differ essentially by an $h_{11/2}$ proton. In particular, there is evidence in ^{147}Tb for a new octupole multiplet built upon the $\pi h^2_{11/2}\, g^{-1}_{7/2}$ $27/2^+$ two-particle one hole state which can be directly related to the $10^+ \times 3^-$ multiplet in ^{148}Dy[2]. The highest member ($I^\pi = (33/2^-)$, E = 5.718 MeV) of the ^{147}Tb multiplet is assigned as the maximally aligned state and would therefore be the first such a fully aligned octupole state observed to date.

A new level sequence, decaying through cascades of prompt transitions, has been assigned to $^{146}_{68}Tb_{81}$. This sequence is probably built on the 10^+ ($T_{1/2}$ = 1.18 ms) isomer[3].

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MAGNETIC PROPERTIES OF SUPERDEFORMED NUCLEI AROUND ^{192}HG AND THEIR NEUTRON AND PROTON SINGLE PARTICLE CONFIGURATIONS

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One of the more intriguing aspects to come out of the study of superdeformed SD nuclei is the observation of rotational bands with identical or related transition energies in neighbouring nuclei. For the A = 190 region, it has been shown [1] that many SD bands can be related to the one of the "doubly magic" SD nucleus ^{192}Hg. In order to understand the mecanism underlying the occurence of identical bands, it is of great importance to identify and caracterize as fully as possible the active single-particle orbitals in SD nuclei.

For this purpose detailed properties of the SD bands in ^{193}Hg, ^{194}Tl and ^{195}Tl have been measured using EUROGAM spectrometer. Dipole transitions linking signature partner SD bands have been observed for the three different nuclei. Measurements of the photon decay branching ratios, together with the average SD quadrupole moment measured in neighbouring nuclei , enable the M1 strength to be determined. Using this branching ratio method, it has been shown that the two of the three pairs of SD bands in ^{193}Hg involve a single neutron in the $[512]5/2^-$ and the $[624]9/2^+$ orbitals [2], and the pair of SD bands in ^{195}Tl correspond to a configuration where the single proton is occupying the intruder $[642]5/2^+$ orbital[3]. Theoretical calculations based on the mean field approximation (Woods-Saxon or self-consistent-Hartree -Fock) give the mentionned neutron and proton orbitals as being the first available configuration above the N=112 and Z=80 shell gaps. The three pairs of SD bands in ^{194}Tl (odd-odd nucleus) were found to exhibit a small M1 strength, in agreement with a configuration where the neutron-proton interaction is favoring the triplet spin state (Gallagher-Moskowski rule)

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High-spin yrast isomers in the odd-odd, N=85, ^{152}Ho nucleus

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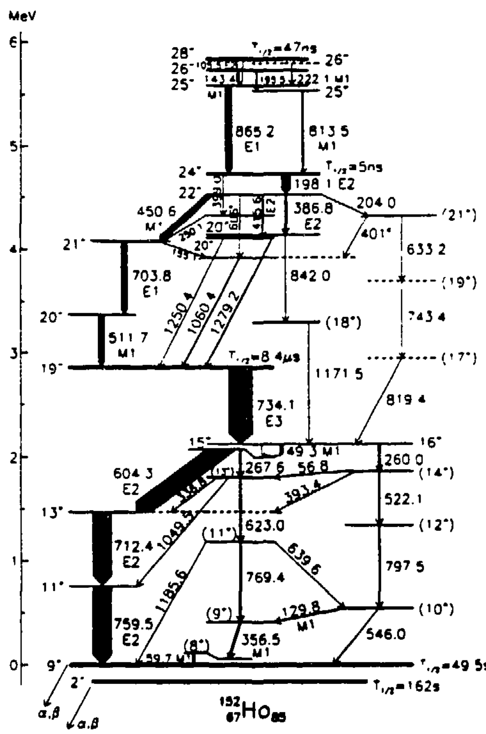
Several isomers have been identified in the ^{152}Ho nucleus using the catcher recoil method. The level structure below a 47 ns isomer located at 5.84 MeV has been established.



Proposed level scheme for ^{152}Ho below the 47 ns isomer. The transition intensities shown are measured on the catcher after recoil following the $^{120}Sn+^{37}Cl$ reaction at 178 MeV.

The gamma ray experiments were carried out at Grenoble with the beams of the cyclotron of SARA, while the electron measurements were performed on the MP tandem at Orsay. The ^{152}Ho nucleus was produced in the $^{120}Sn(^{37}Cl,5n)$ and $^{144}Sm(^{11}B,3n)$ reactions for the gamma-ray studies, and in the $^{141}Pr(^{16}O,5n)$ reaction for the electron measurements.

Prompt and delayed $\gamma-\gamma$, $\gamma-X$ coincidence experiments and half-lives measurements have allowed to locate three yrast isomers at 2.86 MeV ($I^{\pi}=19^{-}$), 4.72 MeV ($24^{+}, 5ns$) and 5.84 MeV ($28^{-}, 47ns$). The conversion electron measurements lead to reliable spin and parity assignments for the yrast levels.

The B(E3) value of 0.92 ± 0.03 W.U., obtained for the 734 keV, E3 transition deexciting the 19^{-} isomer is typical of a single particle transition. Its interpretation involves the j-1 state ($9/2^{-}$) of the ($\pi h^{3}_{11/2}$) multiplet coupled to the aligned state of the three valence neutrons.

The 47 ns isomer appears as the expected fully aligned state of the six valence particles.

The third isomer of 5 ns can be interpreted as due to the coupling of the aligned state of the three protons $(\pi h^{3}_{11/2})_{27/2^{-}}$ with the $h_{9/2}f^{2}_{7/2}$ neutron component of maximum spin $21/2^{-}$.

Finally, configurations are proposed for most of observed structures.

SEARCH FOR DEFORMATION EFFECTS IN HEAVY NUCLEI, N<126, Z>82.

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In the N<126, Z>82 region there have been many long standing calculations indicating the presence of deformation effects in nuclei away from stability (for example, [1-3]). One striking prediction is the calculation of an extended region of deformed nuclei lying "north west" of ^{208}Pb, in isotopes with Z>86 and N<116. Certain models indicate the possiblity of oblate ground-state shapes and, if verified, it would be unusual in constituting an extended region of oblate rotors. In addition, shape-coexisting minima are predicted, including superdeformation, at low spin and excitation, in the nuclei at the periphery of the predicted deformed region. There has been little experimental evidence with which to substantiate these calculations [4], and most translead nuclei remain relatively unstudied.

Experimental investigations using γ-ray spectroscopy is hampered by severe fission competition resulting in small cross sections and high γ-ray backgrounds. The Fragment Mass Analyser (FMA) at Argonne National Laboratory has been use to separate heavy residues from beam particles and used to tag γ-rays in ten Compton-suppressed germanium detectors surrounding the target. Preliminary studies were undertaken to assess the performance of the system, using the light Rn isotopes prepared by bombarding a thin ^{nat}Ta target with ^{27}Al beams. The FMA enabled excellent rejection of backgrounds and achieved a mass resolution approaching 1 in 300. Low-lying transitions were observed in ^{204}Rn, confirming results of a previous study with a lighter beam [5]. Transitions were seen for the first time in ^{203,202}Rn, for which, the latter is consistent with systematics for the heavier Rn isotopes. No evidence for charged-particle evaporation from the compound system was observed.

A beam of ^{28}Si was used to bombard a thin target of ^{182}W and ^{nat}Ta to produce isotopes of Ra and Fr. In both cases a range of masses was observed, from 4 to 8 mass units below the compound nucleus. Analysis of the coincident radiation indicated that, in contrast to previous experience with radon isotopes, charged-particle channels predominate (at levels of tens of μbarns in the ^{nat}Ta reaction and a few μbarns with the ^{182}W target). The results for the neutron evaporation channels remain inconclusive due to lack of statistics.

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Beta decay study of the very neutron-deficient ^{127}Pr nucleus
Systematics of low-energy states of odd-A Ce

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A detailed level scheme of the extremely neutron deficient ^{127}Ce isotope has been obtained from the radioactive decay study of ^{127}Pr. Rotational band structures and their connections at very low-energy have been observed and the systematics of the quasiparticle configuration energies in odd-A Ce nuclei extended.

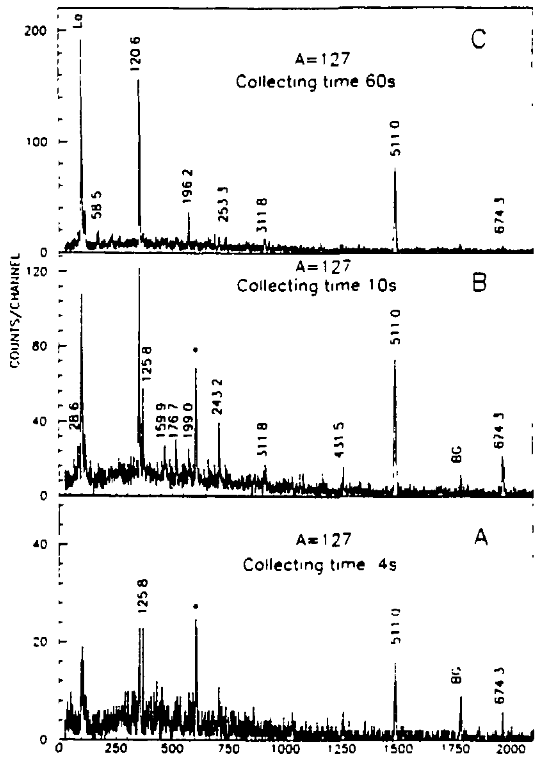

Fig.1 - β-gated spectra measured at A=127 with various collection times to select γ-lines in ^{127}Ce (A,B) and in ^{127}La (C).

The ^{127}Pr nuclei were produced using 240 MeV ^{40}Ca beams from the SARA facility at Grenoble on thin enriched targets of ^{94}Mo. The SARA/IGISOL technique[1] newly developed for heavy-ion induced fusion-evaporation reactions has been successfully applied. From the spectra recorded with various collecting times and presented in fig.1, the main γ-lines have been assigned to ^{127}Ce and ^{127}La. After on-line mass identifications, measurements have been undertaken, at high collection efficiency, by using the He-jet system to transport the recoiling products. Gamma-ray, X-ray and conversion electron spectroscopy in singles, multiscaling and coincidence modes were used to study the radioactive decays of the A = 127 chain.

From these measurements, the half-lives previously reported[2] for ^{127}Pr (4±1s) and ^{127}Ce (31±2s) have been confirmed. The ^{127}Ce level scheme established in the β^+/EC decay of ^{127}Pr exhibits clearly the bottom of the two collective structures observed by in-beam spectroscopy[3], namely the νh11/2 negative parity band based on a 7/2$^-$ state and the positive parity band very likely built on a d5/2 neutron-hole configuration. In addition, a new set of levels which receives ~60% of the beta strength is established. By analogy with similar band structures already identified by beta decay in light odd-A Xe and Ba nuclei, a 1/2+, 3/2$^+$, 5/2$^+$, 7/2$^+$ spin sequence can be very likely assigned to this set of levels. As a 5/2$^+$ spin assignment to the ^{127}Ce ground state agrees with the ^{127}Ce →^{127}La decay, the low-energy level systematics in odd-A Ce can be extended down to A = 127 and compared with multishell Interacting Boson-Fermion model calculations, as previously done for odd-A Ba nuclei[4].

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Gamma-ray and electron spectroscopy of vibrational states in even-even cerium isotopes

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Low-spin states of ^{128}Ce, ^{130}Ce and ^{132}Ce were investigated from both the β-decay of isomeric and ground states in odd-odd Pr nuclei. The radioactive isotopes were produced at the Grenoble SARA facility with the ^{94,96}Mo (^{40}Ca, αpxn) reactions, transported and collected using a He-jet plus tape driver system. X-γ-t and γ-γ-t coincidences were recorded with three Ge detectors. In addition, conversion electron and gamma singles spectra have been simultaneously measured, using a mini-orange magnetic filter or an electron magnetic spectrometer[1)] equipped with a Si (Li) detector.

The present investigations complement the preliminary level scheme previously reported on ^{130}Ce[2)]. Several new low-spin states are found in the A = 128,130,132 even-even Ce isotopes, up to a maximum spin of 6 or 8 ħ. Here, among the states fed by β-decay, we want to underline the new low lying states, not observed in extensive in-beam high spin experiments, and their γ-decay modes. Indeed, in addition to the ground state bands and to the even-spin members of the γ-bands, the analysis of the data reveals new "K = 0" bands in both ^{128}Ce and ^{130}Ce. The 0_2^+ bandheads at 1053 keV in ^{128}Ce and at 1025 keV in ^{130}Ce deexcite to the ground-band levels and very weak $0_2^+ \rightarrow 0_1^+$ E0 transitions were observed by conversion electrons. These "K = 0" bands exhibit characteristics similar to the one previously observed in ^{124}Ba[1)] for a band based upon a 0_2^+ state at 828 keV. In contrary, they desagree with the "K = 0" band populated by (α,n) in ^{126}Xe[3)] or by β-decay in ^{130}Ba[4)] and interpreted with the 0(6) symmetry of the Interacting Boson Model. In addition to several unfavored states in even-even Ce γ-bands, we have also identified two new states at 1671.7 and 2115 keV in ^{130}Ce. These levels, strongly fed by β-decay (5-6%), deexcite mainly to the γ-band. They have been compared with the "K = 4" anharmonic vibrational levels predicted in the multiphonon model[5)]. Experimental level energies and γ-branching ratios are well reproduced in the framework of the IBA-1 model.

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STATUS OF HIGH-SPIN ISOMER BEAM AT RIKEN

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A high-spin isomer beam was developed by using heavy ion beams such as ^{136}Xe of 7 - 10 MeV/u which were provided by RIKEN Ring Cyclotron. The high-spin isomer of ^{145}Sm [1)] of which a spin and parity is $(49/2^{+})$ was produced by the ^{16}O(^{136}Xe, 7n)^{145}Sm reaction. A SiO_2 foil of about 2 - 3 mg/cm^2 was used as a primary target. The primary beam intensity was 20 - 100 nA which corresponds to 6 - 30 x 10^9 particles per second. The isomer yields was obtained to be about 5 x 10^4 sec^{-1} by measuring the known γ-ray yields. The isomer ratio in this case is estimated to be 0.6 by using the calculated cross section of 300 mb. The kinetic energies of the recoiled ^{145}Sm of isomeric states range from 4.72 to 5.68 MeV/u depending on the position in the target where the fusion reactions take place. The isomer beam produced in such a way has to be separated from the primary beam whose energy is 6.35 MeV after passing through the target.

In the first step of developments, a dipole and a air of quadrupole magnets were used to separate them. A helium or nitrogen gas of a few Torr was filled in the beam line to equilibrate the charge state distribution. However the secondary beam spot obtained was so large as 3 x 4 cm. This was caused by the scattering of beams by the filled gas and the foil used to separate the beam line vacuum. The transmission of the system was 10%.

In the improved version, another pair of quadrupole magnets was added to have additional focus point. Much improvement of the secondary beam spot size was attained to less than 1 cmϕ by using the system without the filling gas. Although charge state distributions are broad for both of the primary and the secondary beams, three charge states of the reaction products could be selected at the first focus point stopping most of the primary beam. By setting the magnetic fields to select the charge states of 47,48 and 49 of ^{145}Sm ions, nearly 30% of the ^{145}Sm produced in the primary target could be focussed at the secondary target position by a pair of quadrupole magnets. This magnetic rigidity corresponds to a higher value than that of the 54+ state of the primary beam ^{136}Xe.

Coulomb excitation and fusion reaction experiments using the high-spin isomer beams are planned.

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THE DECAYS OF THE T_z=-1 NUCLEI ^{44}V AND ^{52}Co.

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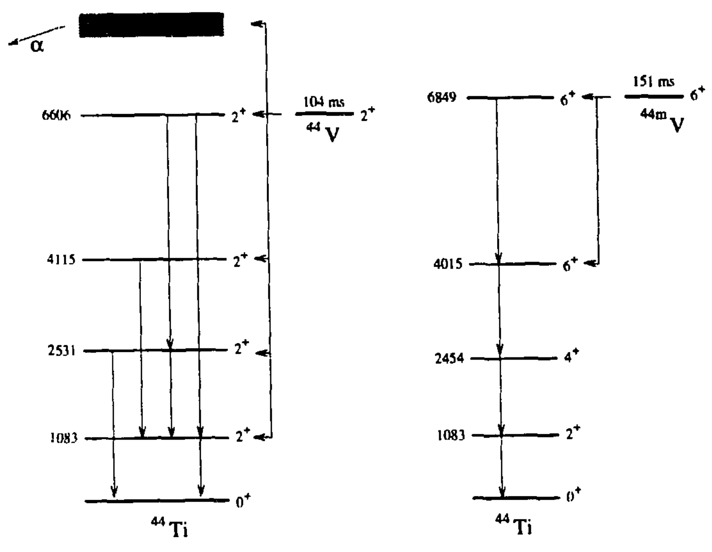
Weak beta-delayed particle branches are all that is currently known about the decays of ^{44}V and ^{52}Co. The observed particles originate from levels at very high excitation energies in the beta-decay daughters, ^{44}Ti and ^{52}Fe. However, large, but as yet unobserved, beta branches are expected to populate lower lying levels, including the isobaric analogue states (IAS). The allowed Gamow Teller (GT) branches as well as the superallowed branches result in beta-delayed γ rays.

We have produced ^{44}V and ^{52}Co by bombarding a stack of calcium targets with ^{6}Li and ^{14}N beams, respectively, from the TASCC facility. The reaction products were transported with a helium-jet transfer system and deposited on the tape of a fast tape-transport system. The samples were moved periodically to a counting location where the decays were recorded with plastic scintillator (β) and HPGe (γ) detectors. We also coupled the helium-jet system to our on-line isotope separator (ISOL) ion source and were thus able to observe the decays of mass-separated samples.

In the case of ^{44}V, four strong γ rays were observed in the ISOL experiment and unambiguously assigned to the decay of this nuclide. The gas-jet, γ-γ coincidence experiment revealed additional γ rays and also showed that our decay data originate from both the 2^+ ground state of ^{44}V and a 6^+ isomeric state (see figure; spin assignments based on the mirror nuclide ^{44}Sc). For both cases, we identified the superallowed beta-decay branch and obtained a precise value for the excitation energy of the isobaric analogue state. Three allowed GT branches were observed from ^{44}V and one from ^{44m}V.

In the case of ^{52}Co, our data are more sparse. Our decay scheme of ^{52}Co is similar to that of ^{44m}V (6^+). The mirror nucleus of ^{52}Co, ^{52}Mn, has a 6^+ ground state and a 2^+ isomeric state. We do not see any evidence for the latter state in ^{52}Co.

The experiments, the results and some theoretical comparisons will be described.



Decay schemes of ^{44}V and ^{44m}V. In both cases the parent state has been lined up with the corresponding IAS in the daughter.

PROJECTED MEAN FIELD DESCRIPTION OF NUCLEAR SHAPES, MOMENTS AND COMPLEX SPECTRA

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We will present an overview of the nuclear structure calculations and predictions performed during recent years with the projected mean-field MONSTER–VAMPIR model-family [1]. Results obtained with models related to the all four levels of approximations dicdated by the general theory will be compared to experiment. Possible future experiments related especially to the predictions of electromagnetic moments will be discussed.

In particular we will demonstrate the flexibility of the models to be able to describe the richness in structure of nuclei at various mass regions with close to spherical, stably deformed or coexisting shapes.

Examples of predictions for nuclei witht stable deformation will be taken from the rare earths. We will compare calculated excitation spectra to experiment for doubly even, odd–even and odd-odd nuclei.

Predictions [2] for transitional and near to spherical nuclei will be shown at mass A=130 region. Among other results the origin of the highly anharmonic behaviour of the moment of inertias is shown not to be related to an increase of the static quadrupole moment (deformation) but rather to the amount of microscopic quasiparticle correlations. Predicted quadrupole moments furthermore correlate with the effective K-quantum numbers of exited bands in a manner which allowes an experimental method to determine the K–values of the band heads.

While the calculations in the above mass regions were done with models built on projected mean fields with real transformations only, the examples discussed for the mass A=70 region are predicted [3] solely with models using essentially complex transformations. The complex mean fields are crucial for a proper description of proton neutron correlations and states with unnatural parity. In addition to this we will demonstrate that coexisting shapes are needed to explain the complex level structures obtained in this mass region.

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ROTATIONAL BANDS IN ^{77}Rb AT VERY HIGH SPINS*

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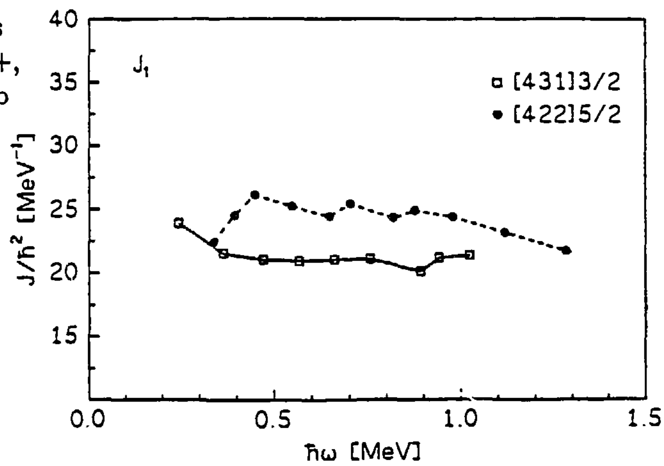
The neutron deficient A=80 region is unique in the chart of the nuclides. Due to large deformed shell gaps in the single particle spectrum [1], nuclei in this area show a high ground-state deformation up to $|\beta_2| \approx 0.4$ in the lightest known Sr [2] and Zr [3] isotopes. High spin states of ^{77}Rb were populated with the reaction ^{40}Ca(^{40}Ca,3p) at a beam energy of 128 MeV. The EUROGAM array consisting of 45 Compton-suppressed Ge detectors was coupled with the Daresbury recoil separator: Recoil-γ, $\gamma\gamma$ and $\gamma\gamma\gamma$ coincidence events were taken. The previously known level scheme [4] was extended to twice the excitation energy and spin ($E_x \approx 18.4$ MeV, $I^\pi = (\frac{57}{2}^+, \frac{55}{2}^-)$) and four new bands were identified. Both the yrast $[431]\frac{3}{2}$ *and* the $[422]\frac{5}{2}$ yrare ($\pi = +$, $\alpha = +\frac{1}{2}$)-bands show nearly constant moments of inertia over the full frequency range (see fig. 1). In the reaction ^{40}Ca(^{40}Ca,2pn)^{77}Sr also studied in this experiment by Gross et al. [5] states up to $I^\pi = (\frac{49}{2}^+)$ were observed. These are the hitherto highest spins in a $T_z = \frac{1}{2}$ nucleus. The level scheme of ^{78}Sr was extended to $I^\pi = (22^+)$. The ^{77,78}Sr data show a property which is new in this mass region: The $\alpha = \frac{1}{2}, g_{\frac{9}{2}}$ band and both signature partners of the negative parity band in ^{77}Sr were found to be identical to the yrast band in ^{78}Sr.

Fig. 1: Kinematic moments of inertia of the ($\pi = +$, $\alpha = +\frac{1}{2}$) bands in ^{77}Rb



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Anomaly in O(6) ^{196}Pt

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A strong E0 transition linking the first and second excited 0^+ states in ^{196}Pt has been found using the (n,e-) reaction. This transition is forbidden in the O(6) limit of the IBM, yet is over 20 times stronger than an allowed E0 transition depopulating the same level. This clean test of the wavefunctions of these 0^+ states indicates that one or both may not fall within an O(6) description. It appears that: a) the 0+(1402keV) state lies outside the IBM space, or b) the IBM cannot predict E0 transitions well, or c) core interactions have affected the predicted E0 transition strength predicted by the IBM from this level or d) ^{196}Pt is not an O(6), or SU(5) nucleus.

This is an interesting case where a nucleus has been shown to have many clear characteristics of O(6) symmetry, yet the apparently clean test of the wavefunctions using the E0 operator gives anomolous results. The question of whether the IBM, based on quadrupole interactions, can be expected to predict E0 transitions is explored.

Decay Characteristics of Mixed-Symmetry States in ^{158}Gd

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ABSTRACT

The conversion electrons from the 157Gd(n,e-)158Gd reaction were detected with the high-resolution spectrometer BILL at the Institute Laue-Langevin (ILL), Grenoble. Multiscans were performed to try to resolve the subshells of transitions from the 1+ mixed-symmetry states at 3192 and 3201keV to the ground state and the first three 2+ states.

The ratio of the subshell intensities in the electron spectrum could yield mixing ratios of these decays, but the high density of states at these energies made positive identification difficult. More work has now been done with (n,g) studies at the ILL to identify the secondary gamma-transitions in the previously unmapped region of 2.7-3.8MeV. This gamma work is now completed and several new levels and placings have been made. These will be summarised at the conference.

Attention can now be turned back to the complex electron spectrum. With the gamma-transitions now known, it is expected that we will be able to present results of the mixing ratios of transitions depopulating the 1+ mixed-symmetry states. The predicted ratios for these transitions vary with different nuclear models. The preliminary results will be discussed.

"SHEARS BANDS" IN Pb NUCLEI - A NEW NUCLEAR STRUCTURE EFFECT

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Regular sequences of strong M1 transitions with week E2 crossovers have recently been found in several Pb isotopes (see e.g. 1-5). They have been interpreted as rotational bands built on oblate high-spin proton and neutron excitations. Several of the observed features, however, differ from those of normal collective bands. In order to investigate their structure, we have performed a detailed experimental and theoretical investigation of the dipole sequences in $^{197-201}$Pb.

For the regular dipole bands we propose a structure which contains high-K proton $h_{9/2}$ and/or $i_{13/2}$ particle excitations that are aligned along the symmetry axis of the oblate nucleus and low-K neutron $i_{13/2}$ holes that are aligned perpendicular to that axis. The resulting total angular momentum does not coincide with one of the principal axes of the nucleus. This is the typical situation for the application of the tilted-axis (TAC) cranking model[6)]. Within the framework of that model we calculate that the proton and neutron spins gradually align with the total spin for increasing rotational frequency. The continuous alignment of the proton and neutron spins may be viewed as the closing of the two blades of a pair of shears and we suggest to call these structures "shears bands". This mechanism is a new way to generate angular momentum with increasing frequency and to build regular bands in nuclei with small quadrupole collectivity.

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IS A SHAPE COEXISTENCE PRESENT IN ^{184}Au ?

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The existence, in ^{184}Au, of a ground state with spin value 5 or 6 and an isomer with spin value 2 or 3 linked by an M3 isomeric transition is very puzzling[1,2)]. From results known in this mass region, the configuration of the ground state of an odd-odd nucleus usually corresponds to the coupling of the proton state with the neutron state observed respectively in the neighbouring odd-p and odd-n nuclei. Thus, a π h9/2 $\otimes$ ν 1/2$^-$ [521] configuration is expected for the ^{184}Au ground state but the level lying at the lowest energy for such a configuration cannot have a spin value 5 or 6. At this stage, one can wonder whether shape coexistence phenomenon could explain this mystery since a shape coexistence is present in three of the neighbouring odd-A nuclei, namely ^{183,185}Au and ^{185}Hg. In order to answer the question "Is the mystery of ^{184}Au due to shape coexistence phenomenon ?", low-spin states have been investigated from the β^+/EC decay of ^{184}Hg using the He jet facility at SARA. A level scheme has been established allowing us to determine unambiguously the spin and parity values as 2^+ and 5^+ for the isomeric and ground states respectively. Moreover, the decay-mode of a second isomer ($I^\pi = 3^-$) located at 228.6 keV has been defined.

The levels obtained will be compared to those calculated for a prolate and an oblate shape in the framework of the rotor + two quasiparticle model[3)]. Furthermore, the reduced transition probabilities B (E1) and B (M3) values obtained from the decay of the two isomers will be compared firstly with those known for the neighbouring odd-A and doubly-odd nuclei and secondly with the values calculated using the Nilsson model.

From these results added to those previously obtained from in-beam experiments[2)] we can answer the question that the ^{184}Au isomeric and ground states very likely correspond to a prolate nuclear shape.

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NON-STATISTICAL EFFECTS IN NUCLEI

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The non-statistical effects connected with the proton -particle and neutron-hole coupled to angular momentum 1^+ $(p,\bar{n})_{1^+}$ and $(n,\bar{p})_{1^+}$ configurations can be manifested in Gamow-Teller β-decays [1], in (p,γ) reactions [2], in charge-exchange reactions, ect.

From the phenomenological point of view, the non-statistical effects at the excitation energy E>5-10 MeV in the medium and heavy nuclei indicate conservation of some symmetry [1].

In present paper , questions associated with the investigation of the non-statistical effects for β-decay are considered. We plan to apply the total-absorption gamma -spectrometer [3] in the investigation of the spin-isospin SU(4) symmetry in nuclei.

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RESIDUAL INTERACTIONS AND BLOCKED PAIRING IN NORMAL HIGH-K STATES AND IN t-BANDS

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Recently we have shown that spin-dependent residual interactions play an important role in the study of high-K multi-quasiparticle (MQP) states [1]. Their explicit inclusion in ^{176}Hf removed a long-standing anomoly in the ordering of the three observed 6-quasiparticle states in that nucleus. The excitation of MQP states also provides useful information on the blocking of pairing correlations [2]. Pairing has been treated in a self-consistent manner using the blocked BCS theory and shows significant quenching of the pair gap for MQP states in this mass region.

Residual interactions and blocking are also important in the understanding of t-bands, *i.e.* high-K bands that can cause backbending [3]. Exact calculations for many particles in a single-j shell and also for the two-quasiparticle-plus-rotor model give complementary descriptions of these bands and show how the high-K coupling of two $i_{13/2}$ neutrons can become energetically favoured.

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ASYMPTOTIC PROPERTIES AND EFIMOV STATES OF HALO NUCLEI.

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Loosely bound halo nuclei are often described as two- or three-body systems consisting of the core nucleus and one or two nucleons [1]). All radial moments of the system remain finite for all energies, when the particles are charged. The non-normalized n'th radial moment of a neutron-core two-body system diverges as $(-E)^{(2l-1-n)/2}$ with vanishing energy for $n > 2l - 1$ (l is the angular momentum) and diverges logarithmically for $n = 2l - 1$. For two neutrons around a core, where no binary subsystem is bound, the n'th radial moment diverges as $(-E)^{(2K+2-n)/2}$ for $n > 2K + 2$ (K is the quantum number called the hypermoment) and diverges logarithmically for $n = 2K + 2$. Thus the second radial moment diverges logarithmically with energy when the neutrons are in s-states around the core and remains finite otherwise. Divergencies in two-body systems are stronger and more abundant than in three-body systems.

When binary subsystems are bound the two-body asymptotics (two particles in the bound state and the third particle far away) will dominate at very low binding energy. The actual transition and the proper mixture of two and three-body behaviour has not been studied in detail before. This is, however, necessary for real halo nuclei as for example demonstrated by the astrophysically interesting nucleus ^8B ($^4He +^3 He + p$). A practical three-body method are developed to treat such cases and numerical examples will be shown.

A special halo structure, called an Efimov state, occurs when at least two of the binary subsystems have a bound state at (or close to) zero energy [2]). We shall discuss the possibility of occurrence in two-neutron halo nuclei. When the neutron-core potential leads to a ground state binding energy in an interval of width around 200 keV at about 1 MeV, then the first excited (Efimov) state appears at an energy of up to about 10 keV. Its spatial extention is typically about 100 times the radius of the core nucleus and is divergent at thresholds. For realistic cases, where the core nuclear degrees of freedom including the Pauli principle is taken into account, the ground state binding energy is presumably reduced whereas the excited and spatially extended state is less sensitive. One could therefore hope to find Efimov states in halo nuclei.

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BETA DECAY OF MEDIUM-HEAVY NEUTRON-RICH NUCLEI*

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The gross properties of allowed Gamow Teller decay in the neutron-rich Zr-to-Pd-region have been studied by applying IGISOL-technique and proton induced fission of ^{238}U [1]). Results on Pd [2,3]) and Ru-isotopes [4,5]) have been published and the analysis of the decay properties of even-even $^{106-110}Mo$ and $^{102,104}Zr$ is in progress.

Region of interest provides decay data from soft Pd-isotopes to deformed Zr-region region, where quadrupole deformation reaches a value of $\beta \approx 0.4$. In the single particle picture this means transformation from the shell model states to the Nilsson states characterized by the asymptotic quantum numbers $[NN_z\Lambda\Sigma]$. Selection rules for the asymptotic quantum numbers in allowed unhindered transitions were derived by Alaga [6]) and for allowed fast transitions by Fujita et al. [7]). Due to the selectivity of beta decay it provides strong basis for the identification of participating single-particle states. Experimental beta decay properties and underlying nuclear structure will be discussed in the framework of the macroscopic-microscopic model [8]).

We have extended the half-life systematics to very neutron-rich nuclei by measuring over twenty new or improved half-lives. Recent r-process calculations have underproduced the abundance of isotopes [9]). This is related to poor half-life and atomic mass predictions. The failures of the half-life predictions are related to uncertainties in mass predictions. With this in mind we have done a series of decay energy measurements for n-rich even-even Pd, Ru, Mo and Zr isotopes. First results for Ru-isotopes showed that the recent mass models underestimate decay energies of Ru-isotopes [4,5]). In the case of $^{106,108}Mo$ situation seems to be opposite. When this is taken into account, the excellent agreement between half-life predictions and experiment can be achieved. Comparison of the experimental and predicted half-lives and decay energies will be presented.

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A Silicon Array for Conversion Electron Detection

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Abstract

A 25 element multi-detector array has been designed and constructed. Final tests are undergoing at Liverpool. This device will be used in conjunction with a superconducting solenoid for low energy conversion electron studies at the University of Jyväskylä, Finland. Electron-electron coincidences will be of main interest.

The array, manufactured by Hamamatsu Photonics, consists of 25 individual PiN diode elements, each of 5mm pitch. Tests have been carried out using the array with photons and conversion electrons for resolution measurements, and to study the effects of electron multiplicity and the efficiency of the array. Studies of the behaviour of the detectors under cooled conditions have been performed and results will be presented.

The performance of the multi-element array for in-beam experiments has been simulated by Monte Carlo techniques.

LEVELS IN ^{168}Er ABOVE 2 MeV AND THE ONSET OF CHAOS*

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Abstract: ^{168}Er is probably the best studied heavy deformed nucleus. On the basis of γ and electron spectroscopy using the neutron capture reaction together with particle transfer and decay data a complex level scheme of this nucleus up to an excitation energy of $\approx$ 2.2 MeV has been established[1]. This richness of spectroscopic knowledge made ^{168}Er an ideal experimentally-based testing ground for the predicting power of different competing theoretical descriptions of its collective behaviour (e.g. the geometrical model of Bohr and Mottelson[2], the IBM[3] and the quasiparticle-phonon nuclear model (QPNM)[4]). In a recent publication[5] an attempt has been made to extend the level scheme to even higher excitation energies. 17 additional rotational bands have been proposed in the region of rapidly increasing level density above 2.1 MeV where the increase of both the number of random energy combinations and the line density in ARC and thermal primary spectra make definite level assignments more and more difficult. Additional $\gamma-\gamma$-coincidence data, on the other hand, could give direct evidence for the existence of states proposed by the Ritz combination method.

We performed a 3 detector $\gamma-\gamma$-coincidence experiment at the HFBR of the BNL using thermal neutron capture to populate ^{168}Er. Altogether $\approx$ 1.6 10^9 coincidence events were recorded event by event on magnetic tape and in an off-line analysis $\approx$ 4.6 10^8 of them were sorted into coincidence matrices. The many γ-rays with $E_\gamma \geq 1.2$ MeV observed in the gates on transitions depopulating the 2^+- 5^+ members of the γ band allowed us to check some of the assignments made in ref.5. We use these new data to illustrate the danger in defining states above 2 MeV essentially based on energy combinations by means of some detailed examples. Furthermore, we will present evidence for the existence of many additional states supported by the coincidence data which question at least some of the arguments used to arrange levels into bands in ref.5. Since the complete level scheme proposed in ref.5 has recently played an important role in the discussion of chaos in nuclei and especially the goodness of the K quantum number[6] these results may have a wider interest beyond the detailed level assignments of a particular nucleus.

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Electromagnetic moments of seniority v=4,6 states in ^{90}Mo*

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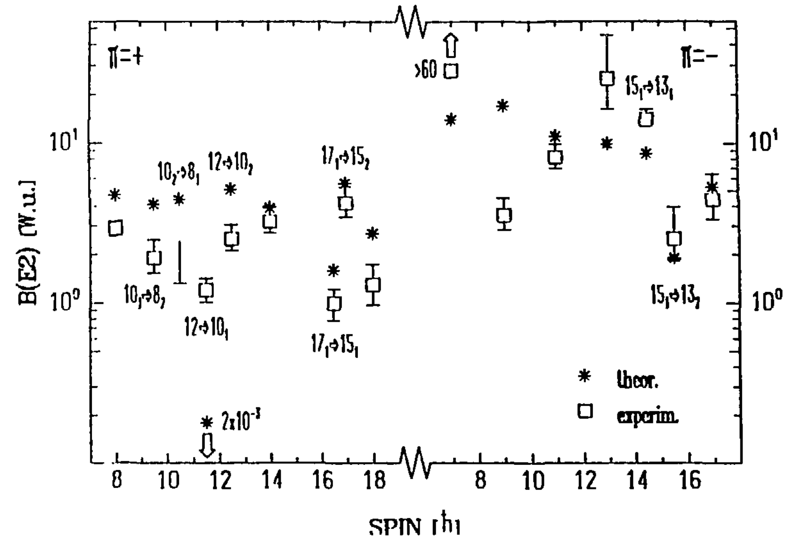
The recently identified high spin states in ^{90}Mo [1,2] have been interpreted with the spherical shell model in a truncated $(2p,1g_{9/2})$ single-particle space. A 1:1 correspondence between all experimental levels and the theoretical ones within a simple seniority classification was established. We report here on the measurement of lifetimes and magnetic moments of the presumed seniority v=4,6 states in the spin ranges $I^{\pi}=10^{+}-20^{+}$ and $7^{-}-17^{-}$ which sensitively test the calculated wavefunctions.- The reactions studied were $^{58}Ni(^{36}Ar,4p)$ at 140-149 MeV beam energy (VICKSI accelerator/Berlin) and $^{58}Ni(^{35}Cl,3p)$ at 110-120 MeV (Cologne tandem accelerator). Lifetimes in the $10^{-13}-10^{-9}$ s range were obtained via the DSA and RDDS techniques. The g-factors of the 4556 keV 12^{+} state, g=+0.50(6), and of the 4842 keV 11^{-} state, g=+0.42(13), were deduced from the integral rotations of these states in polarized Fe and Ni foils, by means of the IMPAD method; for details see [3,4]. E2/M1 mixing ratios of the $\Delta I=0,1$ transitions were deduced from singles' angular distributions and DCO ratios, the latter values measured with the OSIRIS array [4,5]. Fig. 1 compares experimental B(E2) values with shell model predictions obtained with the code RITSSCHIL within the $(g_{9/2}, p_{1/2})$ space, the Gross Frenkel parameters and $e_{\pi}=1.72$ e and $e_{\nu}=1.44$ e [7].



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NEET REVISITED IN CONNECTION WITH THE RESONANCE RADIATIVE PUMPING OF TH-229m

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Revival of interest in the process of non-radiative nuclear excitation by electronic transition (NEET) is noted for the last years (e.g. [1,2]). The process should have a relatively large probability if the nuclear and electronic transitions have nearly equal energies. Such cases were studied both theoretically and experimentally in the atoms of Os-189, Au-197, Np-237 and others. A possibility to use the resonance interaction for laser studies of the 3.5-eV isomeric state in nuclei of Th-229 is of great interest [1,2]. In spite of apparent simplicity and well over two decades research, no satisfactory description of the process has been achieved.

We consecutively treat the process in terms of internal conversion theory [1]. Main results which develop or correct the previous researches are as follows.

(1) Multiple interactions are brought to a factor which is the same for the NEET and the radiative widths, and therefore cancells out in the branching ratio for the NEET probability.

(2) Our results go over the corresponding formulae for the non-radiative nuclear excitation in muonic atoms.

(3) No isomers can be produced by NEET, except in the subsequent deexcitation cascade, like in Os-189. This is because the nuclear state excited by NEET decays with the total width of the atomic and nuclear levels, and not only the nuclear one. This is in obvious accordance with the general principle, namely, that in every channel the decay width is the same, being the sum of the partial widths. Specifically, for this reason the experiment as proposed in ref. [2] for the resonance radiative pumping of the 3.5-eV isomeric state in Th-229 is not correct. This result also has to be taken into account when considering the Heitler chain of equations for the NEET probability.

(4) We used term-dependent Hartree-Fock-Dirac method with a definite angular momentum of the atomic states. Accuracy of the method used is espetially important in the case of Th-229 where outer shells are involved.

(5) We propose three possible schemes of radiative pumping of the 3.5-eV level in Th-229 via resonance interaction with the electron shell: (i) By a laser tuned at the frequency of the nuclear transition. (ii) By populating the resonant atomic level in a cascade, like in muonic atoms, induced by excitation of higher electronic states. (iii) By a laser tuned at the frequency of the electronic transition, whilst compensating the detuning between the atomic and nuclear transitions by means of a second laser, as proposed in ref. [1].

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HEXADECAPOLE MOMENTS OF THE NUCLEI AND TERNARY FISSION AT LOW ENERGIES

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Low-lying collective multipole vibrations can be used as a basis for description of fission at low excitation energies. This possibility is of great interest. It was specifically shown in ref. [1] that overcoming the fission barrier can be viewed as step-by-step excitation of many-phonon quadrupole vibrational states, with the number of phonons $n \doteq 8 - 10$. Such low-lying quadrupole collective states with the energy of about 0.8 MeV are known in heavy nuclei. A superposition of n phonons assures that the vibration will occure with sufficiently large amplitude and close to the barrier total collective energy of about 6 MeV. Such n-phonon states serve as doorway states for fission.

In the case of ternary fission the hexadecapole vibrations are relevant (e.g. [2]). However, there is no evidence of existence of strong collective hexadecapole states at low excitation energies, in contrast with the quadrupole vibrations (e.g. [3]). This has a simple physical explanation that the number of possible combinations of quasiparticle-quasihole states with the total momentum $I = 4$ is less than in the case of $I = 2$. A relative suppression of the low-lying collective hexadecapole states is also reflected in smallness of the hexadecapole moments in the equilibrium states, which are several times lower than the quadrupole ones.

The reason may be qualitatively explained by the liquid-drop model which results for the nuclei in the uranium region in the values $\omega_2 \doteq 1.2$ and $\omega_4 \doteq 6$ MeV for the quadrupole and hexadecapole phonons, respectively. Therefore, creation of the hexadecapole vibrations is statistically suppressed due to much smaller level density. Concerning fission, this leads in turn to the structural suppression of ternary fission into comparable fragments. Analysis of the experimental data affirms this suggestion.

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NANOSECOND ISOMERS IN ^{89}Nb, ^{89}Mo AND ^{91}Tc*

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High spin states in many light Nb, Mo, Tc and Ru isotopes have been explained by the spherical shell model making use of the effective parameters derived by Gross and Frenkel [1]. The fact that a large number of proton particles and neutron holes in the $g_{9/2}$ shell can be angular momentum aligned leads to high spin values, without the need of collective rotations. In order to test our previous shell model calculations in ^{89}Nb, ^{89}Mo and ^{91}Tc [2-4], we measured the lifetimes of the $21/2^+$ and $17/2^-$ yrast states in these nuclei. Previous RDDS experiments had indicated some lifetimes to be in the range 0.7-2.7 ns [2,4].

The experiment was performed at the VICKSI accelarator by bombarding a 19.8 mg/cm^2 ^{58}Ni foil with the 149 MeV pulsed ^{36}Ar beam. The residual nuclei of interest are formed in the reactions ^{58}Ni+^{36}Ar → ^{89}Nb+5p, ^{89}Mo+4pn and ^{91}Tc+3p, respectively. The γ-radiation was recorded in 11 Compton suppressed Ge detectors of the OSIRIS spectrometer, while neutrons were registered in seven segments of the HMI NE213 neutron array. Three energy-time matrices were sorted from the data: one with only the Ge-detector having the best time resolution, one with the full OSIRIS array and a third one with neutron triggers set in the NE213 detectors. A consistent set of lifetimes for all γ-ray decay branches was found (see Table 1). Note the good agreement between the electronic timing and RDDS results. Also listed are the experimental and theoretical $\Delta I = -2$ E2 strengths, based on the Gross Frenkel TBME [1] and effective E2 charges of e_π=1.72 e, e_ν=1.44 e previously used throughout this mass region [5].

Table 1: Lifetimes and B(E2) values in ^{89}Nb, ^{89}Mo und ^{91}Tc

Nucleus	State E_x(keV), I^π	Lifetime τ (ns) Electronic	RDDS	B(E2,ΔI=-2) (WU) Experim.	Shell model
^{89}Nb	2193, $21/2^+$	19.9(5)	---	1.47(4)	2.3
	2152, $17/2^-$	< 1.0	0.74(7)[2]	---	---
^{89}Mo	2584, $21/2^+$	13.9(5)	---	0.050(2)	2.2 a)
				6.8(3)	5.1 b)
	2271, $17/2^-$	1.4(4)	---	7(2)	10.7
^{91}Tc	2137, $21/2^+$	2.7(1)	2.67(6)[4]	3.9(1)	6.4
	2153, $17/2^-$	1.5(4)	1.57(9)[4]	22(1)	16

a) 487 keV $21/2 \rightarrow 17/2_1$ yrast b) 168 keV $21/2 \rightarrow 17/2_2$ yrare

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New Experimental Beta Decay Studies in the Region of ^{100}Sn

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The nucleus ^{100}Sn is an exotic nucleus of great experimental and theoretical interest because of its double-magic shell-closures, its isospin symmetry and since it is close to the proton drip-line. ^{100}Sn itself has yet not been reached experimentally. However, the β-decay of nuclei near N=Z=50, which is goverened by a fast Gamow-Teller-transition between $\pi g_{9/2} \rightarrow \nu g_{7/2}$ spin-orbit partners, has been extensively studied. At the on-line mass separator of GSI Darmstadt the β-delayed proton and γ emission following the decays of neutron-deficient isotopes in the vicinity of ^{100}Sn was investigated. These isotopes were produced in fusions-evaporation reactions like ^{58}Ni+^{50}Cr. Chemical selectivity of short-lived tin isotopes was achieved by stepwise resonant ionization in a LASER ion source [1] or FEBIAD ion sources operated partly in the bunched-beam release mode [2]. ^{101}Sn was identified for the first time due to its β-delayed proton emission, and decay properties of the new isotopes ^{94}Ag ($T_{1/2} \approx 0.6$ s) and ^{95}Ag ($T_{1/2} \approx 2$ s) were measured, ^{94}Ag being the heaviest N=Z nucleus identified until now. These results, together with the decay properties measured for neighbouring nuclei, are compared to shell-model predictions [3]. Besides the results of high-resolution spectroscopy experiments for the decay of even-odd nuclei (^{101}Sn, ^{103}Sn, ^{105}Sn) and odd-odd nuclei (^{100}In, ^{102}In, ^{104}In), data from measurements with a total-absorption gamma spectrometer (TAGS) were obtained for ^{100}Ag and ^{104}In [4]. The latter are showing clearly for the first time that the major part of the beta strength is located at 5 to 6 MeV excitation energy. Finally, we present an outlook on future measurements using an improved TAGS setup and on experiments that are planned for unambigiously identifying the decay of ^{101}Sn and for searching for proton and cluster radioactivity near ^{100}Sn.

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DO THERE EXIST "TRUE" SU(5) NUCLEI ?

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Some of the difficulties in evincing the existence of good SU(5) nuclei are anharmonicities, configuration mixing, mainly with intruder states, and similarities between the SU(5) and O(6) spectra. In their review on IBM-1, Casten and Warner[1)] write (p.434): "It is therefore a little difficult to discuss whether or not true U(5) nuclei have indeed been observed". It is thus necessary to identify first distinctive features of SU(5) nuclei and to develop a method of selection. Our analysis is performed in the framework of IBM-1 and is an extension of a work[2)] performed on ^{112}Cd. It requires the knowledge of rather extended level schemes and the identification of particular states. A review of possible good candidates will be presented. All the necessary information is not always available for the possibly interesting nuclei. This points to isotopes for which there is a need for more extensive investigations.

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Seniority-inverted Yrast States in N=84 Nuclei above Gadolinium

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In in-beam experiments using the γ-spectrometers Nordball at the Niels Bohr Institute and OSIRIS at the Hahn-Meitner-Institute we populated the four N=84 isotones ^{151}Ho, ^{152}Er, ^{153}Tm and ^{154}Yb through compound evaporation reactions induced with medium HI beams of masses ranging from 28 to 56. All observed γ-transitions with intensities above 1% (5% in ^{154}Yb) of the respective exit channel were placed in the level schemes, with spins established up to 10 MeV (8 MeV for ^{154}Yb) and parities up to between 5 and 7 MeV.

We have found that in these N=84 nuclei the multi-valenceparticle configurations $\pi h^n_{11/2} \nu f^n_{7/2}$ and $\pi h^n_{11/2} \nu f_{7/2} h_{9/2}$ are strongly populated in the yrast cascades, and we have observed them up to their maximum aligned spins of 43/2$^-$ in Ho (at 4.8 MeV), 24$^+$ in Er (7.5 MeV), 51/2$^-$ in Tm (6.9 MeV), and only up to 24$^+$ in Yb, 0.5 MeV below the fully aligned 26$^+$ state expected at 9.1 MeV. The $\pi h^n_{11/2} \nu f^2_{7/2}$ configuration forms smooth sections of the yrast line, while the more irregular yrast line of $\pi h^n_{11/2} \nu f_{7/2} h_{9/2}$ character reflects the strong $(\nu f_{7/2} h_{9/2})_{8+}$ two-body attraction which gives rise to pronounced yrast line dips.

We have also carried out full shell model calculations of these yrast lines, which are in excellent agreement with the experimental data. Since we take all dynamic input values, i.e. the two-body matrix elements and the single particle energies, from experiment, these calculations are parameter-free, where the theory exculsively employs the symmetry of angular-momentum-coupled multiparticle configurations.

An interesting new result is the systematic identification in the $\pi h^n_{11/2} \nu f_{7/2} h_{9/2}$ configuration of yrast states formed by specific proton couplings, where the strongly attractive $(\pi h_{11/2} \nu h_{9/2})_{1+}$ interaction is selectively activated. As a consequence these states drop down to the yrast line and occur in energy below the maximum aligned state of the next lower proton seniotity. These seniority inverted yrast states were systematically identified in the four N=84 nuclei, including two such states in ^{153}Tm, the first N=84 nucleus where a second seniority inverted yrast state can be formed.

RDDS lifetime measurement for the lowest SD-levels in ^{194}Pb

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In the A=190 region many superdeformed (SD) bands have been observed in the last years. In this region the SD bands feed the normal deformed states at spins of about 10 $\hbar$. Lifetime measurements employing the DSAM technique give quite constant Q_t^2 values within the SD bands in this region of nuclei e.g. for ^{192}Hg $Q_t^2 \approx 20eb^2$. Due to the relatively low transition energies inside the SD-band the lifetimes of the lower levels are in the picosecond range and can be measured with the RDDS method. Recently we could measure the lifetimes of the two lowest levels of the SD band in ^{192}Hg with a coincidence RDDS experiment [1)] using the GASP spectrometer[2)] at Legnaro. These lifetimes helped considerably to obtain a better understanding of the decay out of the SD-bands. Later they were measured also with the EUROGAM spectrometer at Daresbury [3)].

We want to report on a RDDS experiment for ^{194}Pb employing the GASP spectrometer. In total we collected about $3 \cdot 10^9$ events at 5 different target to stopper distances. We used the ^{162}Dy(^{36}S,4n)^{194}Pb reaction at a beam energy of 168 MeV. The target consisted of a 0.9 mg/cm^2 ^{162}Dy layer evaporated onto a 1.4 mg/cm^2 thick tantalum foil. The recoils were stopped in a 10 mg/cm^2 gold foil. The plunger apparatus used was especially constructed for $\gamma\gamma$-coincidence measurements and was adapted to fit into the GASP spectrometer. It was possible to measure the lifetimes of the three lowest SD levels. The results obtained allow a detailed discussion of quantities like mixing amplitudes and statistical E1 transition probabilities which determine the decay out of the SD band.

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SHAPE TRANSITIONS IN PROTON-NEUTRON SYSTEMS

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Studies of shape transitions at low excitation energies have mostly been based on coexistence of different shell model configurations [1]). There is another possibility which results from the competition between two shape variables, and thus has purely collective origins. An example of such a shape transition, arising from the competition between the quadrupole and hexadecapole shapes, was recently given in the sdg boson model [2]).

Recent measurements of neutron deformation using pion beams [3]) indicate that there could be sizable differences between the proton and neutron deformations. There are also indirect evidence from g-factor measurements [4]) that the quadrupole operators for protons and neutrons could be rather different, especially in transitional nuclei [5]). In this contribution, we investigate, in the framework of the proton-neutron inteacting boson model (IBM-2), whether such differences could also drive a shape transition in proton-neutron systems. For this purpose, we employ the angular momentum projected mean field theory which leads to analytic expressions [6]), hence allowing a global study of the parameter space without much effort. We study the general conditions for shape transitions to occur in proton-neutron systems and show that the transitional region is the most favorable. For the Os isotopes, the calculations predict a prolate to oblate shape transition around spin 10. An opposite (oblate to prolate) shape transition is predicted for the Pt isotopes.

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CONSTANTS OF USUAL PAIRING FORCE FOR NUCLEI FAR REMOVED FROM VALLEY OF BETA-STABILITY.

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Two ways of finding the constant G_τ (τ=n,p) of the usual pairing force as a function of the nucleon numbers N,Z have been considered. First, we have calculated G_τ from empirical pairing energies P_τ for nuclei with 60<A<240 on the basis of the well known expression for P_τ

$$P_\tau=2S\exp(-1/G_\tau\rho_\tau)$$

where ρ_τ is the single-particle level density inside of a range of 2S centered about the Fermi energy ($\varepsilon_F \pm S$). $\rho_\tau(\varepsilon_F)$ has been obtained by the Strutinsky method with Saxon-Woods single-particle spectra. The parameter of averaging S is taken to be equal to $h\omega_0$. Experimentally unknown values of masses of nuclei far removed from the valley of β-stability have been calculated by the Garvey-Kelson method. Results of the calculations of G_τ can be represented as

$$G_\tau=g_\tau A^{-1}+\alpha_\tau+\beta_\tau(I-I_{st})$$

where $I=(N-Z)/A$, $I_{st}=(N_{st}-Z_{st})/A$ and N_{st},Z_{st} are the nucleon numbers of the most stable nuclei. Parameters (g_n=26.3 MeV, g_p=26.9 MeV, α_n=-0.019 MeV, α_p=0.024 MeV, β_n=-0.375 MeV, β_p=0.346 MeV) have been determined by a least-squares adjustment to empirical pairing energies.

The second way consists of the calculation of G_τ as the averages over the matrix elements of the particle-particle density dependent interaction[1]. The values G_τ calculated in this way give g_τ, α_τ and β_τ closed to the ones obtained by the first way.

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ANOMALOUS ISOTOPE SHIFTS IN Pb NUCLEI IN RELATIVISTIC MEAN FIELD THEORY

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Relativistic mean field (RMF) theory has recently achieved considerable success in describing the ground-state properties of nuclei at and far away from stability. It has been received as a viable alternative to the phenomenological density dependent Skyrme forces. In the latter, however, the spin-orbit interaction is added only phenomenologically. In the RMF theory the saturation and the density dependence of the nuclear interaction is provided by a balance between large attractive scalar σ meson and large repulsive vector ω meson. The asymetry component is provided by the isovector ρ meson. Recently, the important role played by ρ-meson strength for the correct description of the asymmetry energy was demonstrated and a new force (NL-SH) was proposed which reproduces nuclear ground state properties at and away from stability[1)] very well.

The anomalous kink in the empirical isotope shifts of the Pb nuclei[2)] about shell closure has remained a long-standing problem hitherto. This kink in the experimental data implies that placement of extra neutrons in a new shell brings about major changes in the mean field of protons. Attempts to reproduce this kink within the density-dependent Skyrme forces have been discussed recently. However, all the known Skyrme forces fail to reproduce the observed kink[3)]. RMF theory, on the other hand, has now been able to provide an excellent description[4)] of the anomalous kink in isotopic shifts about ^{208}Pb. It has been shown that the kink originates from the collective contribution of many single-particle orbitals to the proton rms radius. The contrasting feature of the RMF theory is the density-dependence of the spin-orbit interaction as compared to the Skyrme theory. The spin-orbit splitting is responsible for putting various orbitals in space and thus determining the structure of a nucleus. Thus, a difference in the spin-orbit splitting in the two methods lies partly at the origin of difference in the isotope shifts of the two approaches.

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Measurement of the Isotope Shift of the ^{242f}Am Fission Isomer*)

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The optical hyperfine spectroscopy of fission isomers has been a challenge since Bemis et al.[1] measured the isomer shift on ^{240f}Am. An ultrasensitive laser spectroscopic method is required for such experiments because the production rates of fission isomers are very low (a few per second), and the half-lives are very short ($\leq$ 14 ms). We have developed such a method which is based on resonance ionization spectroscopy (RIS) in a buffer gas cell and radioactive decay detection of the ionization process (RADRIS)[2,3].

In this contribution we report on RADRIS measurements at ^{242f}Am fission isomers. The ^{242f}Am fission isomers with a half-life of 14 ms have been produced via the ^{242}Pu(d,2n)^{242f}Am reaction (σ=8 $\pm$ 3μb) at the MP tandem accelerator of the MPI für Kernphysik in Heidelberg. The recoil ions are transported into a buffer gas cell filled with 35 mbar argon. About 13 % of the ions neutralize during the slowing down process. The resulting atoms are resonantly ionized using an excimer dye laser combination with a repetition rate of 100 Hz and transported with a suitable electric field in front of a fission fragment detector. The first resonant step proceeds through terms which correspond to wavelengths of 468 nm, 499 nm, or 500 nm. The second non resonant step is achieved with the 351 nm radiation of the excimer laser itself, running with XeF. Fig. 1 shows the frequency scan of the tuneable dye laser at 500 nm. The resonance ionization signal exhibit a large isotope shift between ^{242f}Am and ^{243}Am of $\delta\nu_{500nm}^{242f-243}$ = (10.14 $\pm$ 0.20) cm^{-1}. For the purpose of a precise normalization with respect to the isotope shift $\delta\nu^{243-241}$ between the ^{243,241}Am isotopes, we performed measurements in a reference cell yielding $\delta\nu_{500nm}^{243-241}$ = (0.248 $\pm$ 0.005) cm^{-1}. The ratio of the isotope shift $X_{500nm} = \delta\nu^{242f-241}/\delta\nu^{243-241}$ amounts to X_{500nm} = (41.9 $\pm$ 1.0). A preliminary model analysis based on the deformed Fermi-charge distribution yields Q_{20}^{242f} = (33.7 $\pm$ 0.2$_{Exp.}$ $\pm$ 4.6$_{model}$) eb.

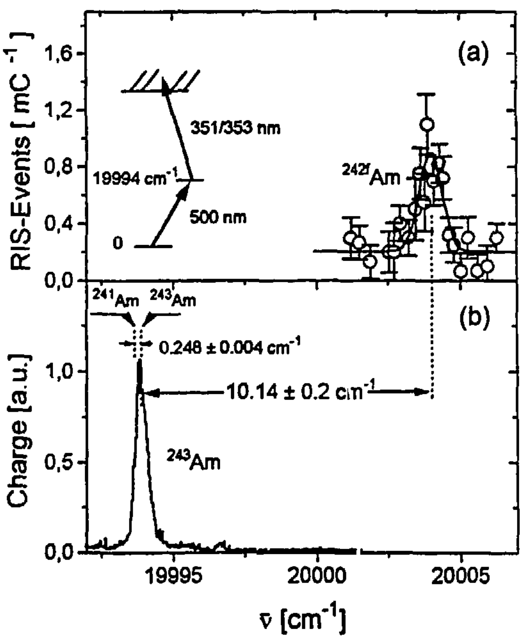

Fig.1: Resonance ionization signal for the ^{242f}Am fission isomer (a) and for ^{243}Am (b). The background of the ^{242f}Am fission isomer signal originates exclusively from a quasi resonant ionization with the excimer laser alone through a level at 28481 cm^{-1}.

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NEW NUCLIDES NEAR THE DEFORMED SHELLS N=162 AND Z=108

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Recent experiments [1] performed in the framework of the Dubna-Livermore collaboration have led us to the discovery of the three new heaviest nuclides, $^{266}106$, $^{265}106$, and $^{262}104$, that were produced in the $^{248}Cm+^{22}Ne$ reaction by employing the Dubna gas-filled recoil separator [2]. The identification of the new species was based on establishing genetic links between α decays of the mother nuclides and subsequent α or spontaneous-fission (SF) decays of their descendants.

Nuclide	Principal decay mode	Alpha-particle energy *MeV*	Half-life *s*
$^{266}106$	α	8.63±0.05	10–30
$^{265}106$	α	8.71 to 8.91	2–30
$^{262}104$	SF		$1.2^{+1.0}_{-0.5}$

The ground-state decay properties that we established for the new nuclides (see the Table and Ref.[1]) indicate a large enhancement in their SF stability and thus confirm the existence of the predicted deformed shells N=162 and Z=108 [3,4]. Our data clearly show that the SF stability at Z=106 and N=160 is not reduced by the destabilizing effect of the new fission valley which was predicted by theory to develop close to the fragment magic numbers N=2×82 and Z=2×50, to present up to Z=110, and to lead, with a low collective inertia, to very compact scission shapes and very short SF half-lives in the sub-*ms* range [5]. The discovery of the significant nuclear stability near N=162 and Z=108 creates new opportunities for many further explorations at the edge of the nuclear domain.

During February, March, and April of 1994 we are performing further experiments to explore properties of unusually stable nuclei near N=162 and Z=108. In this series of experiments, targets of ^{238}U are bombarded with high-intensity beams of ^{34}S accelerated by the Dubna U400 cyclotron. The aim of these long-term bombardments is to produce $^{267}108$ and $^{268}108$. The experiments will be finished by April 30 with an expected total beam dose of about 2×10^{19} particles ^{34}S. Findings of these experiments will be presented.

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PRODUCTION OF NUCLEI CLOSE TO ^{100}Sn IN THE FRAGMENTATION OF ^{112}Sn AT 58 MeV/nucleon

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Studies of doubly-closed-shell and neighboring nuclei are obviously important for testing and further development of nuclear models . Such studies on nuclei far from stability[1)] have additionally an astrophysical context. Reliable predictions of nuclear structure and disintegration rates, especially for the Gamow-Teller (GT) beta decay, are crucial for understanding the nucleosynthesis scenarios under stellar conditions.

These remarks may be considered as a general motivation for our interest in the ^{100}Sn region. We proposed studies of the nuclei near ^{100}Sn using the fragmentation reactions and LISE3 projectile fragment separator at the GANIL facility. It was expected that, relative to earlier experiments, production yields of the most neutron deficient nuclides will be increased, and the limit for detectable half-lives will be essentially improved. These two improvements offer an opportunity to reach ^{100}Sn. The expected increase of the production yields is mainly due to the use of ^{112}Sn as a projectile.

In the experiment performed recently at GANIL we used ^{112}Sn beam at 58 MeV/nucleon impinging on a ^{nat}Ni target. The mean intensity of the primary beam was about 130enA. Fragmentation reactions analyzed by means of the projectile fragment separator LISE3[2)] were exploited to enable the nuclei in the closest neighborhood of ^{100}Sn to be identified by means of the time-of-flight and ΔE-E measurements. Preliminary results of the data analysis confirm the first identification of ^{102}Sn and the recent observation of ^{101}Sn[3)] and ^{105}Sb[4)]. These results and further technical improvements open new possibilities in the study of nuclei close to ^{100}Sn.

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Interplay between rotation and vibrations in shape transition and coexistence phenomena

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It is generally accepted that rotational states and bands may exist depending upon the existence of secondary minima in the collective potential energy surface at various deformations. Such a picture is often adopted for nuclei showing shape coexistence phenomena.

In this work we discuss the coexistence and shape transition phenomena as follows. First, we address the question of the influence that have vibrational modes on the formation or demize of rotational bands and, second, we investigate the possibility that secondary potential minima take place under the influence of rotation. These studies are performed using Gogny force within i) the Generator Coordinate Method (GCM) treated in the Gaussian Overlap Approximation and, ii) the cranking Hartree-Fock-Bogoliubov formalism. Illustrations are given at low and moderate spins for ^{152}Dy, nucleus for which it is shown that i) the yrast superdeformed band does not exist at angular momentum I$\leq$18, and ii) a prolate band appears at intermediate deformation for I$\geq$10 giving rise to shape backbending in its yrast, normally deformed collective band.

Examples of strong rotation-vibration interplay are also presented for other medium mass nuclei.

STUDIES OF OCTUPOLE DEFORMATION IN ^{227}Ra; LIFETIME MEASUREMENT OF THE 90-KEV 3/2[761] LEVEL.

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Previous experiments have demonstrated clear evidence for stable octupole deformation in several Ra and Fr nuclei. It is of particular importance to study the transitional region and to demonstrate experimentally the sudden disappearance of the octupole deformation in the presence of a well developed quadrupole field. We have studied the β^- decays of ^{227}Rn$\rightarrow^{227}$Fr and of ^{227}Fr$\rightarrow^{227}$Ra at PSB ISOLDE/CERN. We report results on the transitional ^{227}Ra.

Two-fold γ-coincidence events were accumulated in the TARDIS array, which consists of 12 Compton-suppressed Ge detectors and a LEPS detector: this is the first time such an array has been used at ISOLDE. The main features of the previous coincidence results in ^{227}Fr decay [1]) are confirmed. Two-dimensional peak fitting has been carried out on the coincidence matrix, allowing many additional weak cascades to be identified even from the rather weak source of $\approx 10^3$ atoms/s.

The lifetime of the 90-keV 3/2[761] level has been measured using the fast timing $\beta\gamma\gamma(t)$ method [2]). It represents the first use of this complex technique at ISOLDE and requires specialized procedures to combine ISOLDE results with prompt calibrations of timing detectors at the OSIRIS separator at Studsvik. The measured $T_{1/2}$ of 262 $\pm$ 50 ps indicated a slow B(E1) rate of $5.7(12)\times10^{-4}$ W.u. for the 3/2[761] to 3/2[631] transition between parity doublet bands. The deduced dipole moment of D_o=0.098(11) efm is consistent with the transitional character of ^{227}Ra, although its value is higher than expected [3]). This could be attributed to the influence of octupole vibrations.

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Theoretical calculation of B(E3) transition probabilities in the Lead region.

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Recent measurements of the B(E3) transition probabilities in several Mercury isotopes [1] have opened a new problem in nuclear structure. The B(E3) transition probabilities of the $^{204-208}Pb$, $^{198-204}Hg$ and $^{192-198}Pt$ nuclei are roughly constant within each isotope chain changing rather abruptly from chain to chain - 35 W.u for Pb, 22 W.u. for Hg and 8 W.u. for Pt.

There have been several attempts to explain this behavior using the IBM model [2] without success. On the other hand we calculated the B(E3) transition probabilities using the collective hamiltonian method for the octupole degree of freedom with collective parameters extracted from a mean field calculation using the Gogny force. The B(E3) obtained were roughly constant for all the nuclei considered with a mean value of around 7 W.u. The strong disagreement was associated with the use of the rotational formula to relate intrinsic octupole deformations with B(E3) values. The rotational formula is based on the assumption that the intrinsic state is well deformed and this is not precisely the case in the nuclei considered here because we are too close to the double shell closure in Z=82 and N=126. To overcome this deficiency we carried out calculations in which the intrinsic wave functions for each parity were projected onto the proper angular momentum in order to compute transition probabilities. This procedure was applied to the nuclei $^{14-16}O$ and ^{14}C with great success [3].

In this paper we report on the results we have obtained by using the angular momentum projected transition probabilities in the Pb, Hg and Pt isotopes mentioned before. In our calculations we are able to reproduce satisfactory the jump in B(E3) in going from the Pt chain to the Hg one. However, some problems with the values obtained for the Pb chain still remain but they are probably associated to the proton shell closure.

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DYNASP : A NEW METHOD TO MEASURE ELECTROMAGNETIC MOMENTS OF UNSTABLE NUCLEI BY POLARIZING AFTER IMPLANTATION INTO A SEMICONDUCTOR InP

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Determination of electromagnetic moments of the low-lying states in unstable nuclei is a crucial issue for the study of the nuclear structure of unstable nuclei far from the stability line. Various techniques to polarize unstable nuclei for measuring electromagnetic moments have been proposed and used before[1,2)], yet no universal and versatile method to polarize short-lived nuclei with appreciable degree of polarization (say, larger than 10 %) has been developed.

We propose here to utilize a dynamic nuclear self-polarization phenomenon (DYNASP) for getting appreciable nuclear polarization of implanted unstable nuclei in InP semiconductors: in compound semiconductors like GaAs, InSb and InP, the magnetic field produced by polarized lattice nuclei is so profound that the electrons in conduction band and also in donor sites are appreciably polarized by this internal field and the polarized electrons can affect in turn strongly the lattice nuclei, resulting thus a kind of positive feedback in polarizations between the lattice nuclei and the conduction (and also donor) electrons. When the conduction electrons are depolarized artificially by exciting electrons from the valence band to the conduction band (Overhauser effect), for example, the electron polarization they have in thermal equilibrium is transferred to the lattice nuclei via the contact hyperfine interactions, so that by cooling the crystal down to some critical temperature (Tc), all the lattice nuclei (at least the nuclei near the donor sites) are fully polarized via a first or second order phase transition. This phenomenon, originally proposed by Dyakonov and Perel[3)] already some 20 years ago, has never been observed before, but recently we have confirmed the onset of this DYNASP phenomenon in InP by cooling the bulk material down to about 2K while irradiating the crystal with linearly polarized laser light. Appreciable nuclear polarizations of both the lattice ^{115}In nuclei (about 25 % with pulsed NMR technique) and unstable ^{114}In (about 7 % with beta-ray asymmetry measurements) produced by neutron irradiations were found to be produced by the DYNASP effect at about 2K, thus indicating profound applicability of the method for the measurement of electromagnetic moments of short-lived unstable nuclei: the unstable nuclei are polarized shortly after implanted into a polarized InP crystal due to the spin-spin interactions between the polarized lattice nuclei and the implanted nuclei. Implications of the obtained results on DYNASP and possible ways to apply the method for the study of unstable nuclei are presented and discussed.

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THE DELAYED PROTON EMISSION IN THE A = 65 - 77 MASS REGION STATISTICAL ASPECTS AND STRUCTURE EFFECTS

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The process of β^+–EC delayed proton emission, that becomes part of the radioactive decay mode when going far off stability, offers an unparalleled access to the low spin states characterization in proton rich nuclei, in the 3 - 10 MeV excitation energy range. Particularly it allows the level density and the proton widths to be estimated in the N = Z region close to the proton drip-line.

In the nuclei under study[1-3]), well resolved proton spectroscopy has been explored, and proton- X coincidence measurements have been performed. The aim of these investigations is to obtain information on level density, to determine the statistical behaviour of this decay mode, and to search for the well deformed low spin states predicted in the Q_{EC} - S_p window[4]). To this purpose, experimental data are compared to calculations carried out in order to establish the influence of the different parameters involved in the delayed particle emission. These calculations include the beta strength function and the analytical expressions for gamma and proton width. They take into account fluctuation phenomena on the level spacing and on the beta and particle transition matrix elements.This type of analysis, when developped for several nuclei presenting similar features in their decay, requires a consistent adjustement of the physical quantities involved in the process ie density parameter, pairing energy and penetrability.

A survey of the experimental data obtained from the decay of ^{65}Ge, ^{69}Se, ^{73}Kr and ^{77}Sr T_z=1/2 precursors is presented and discussed in the light of the computed results.

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NUCLEAR PHYSICS AT BUDAPEST NEUTRON CENTRE

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After major reconstruction and upgrading the 10 MW nuclear research reactor at KFKI Budapest was opened to users on 15 November 1993. Based on the research reactor, the new Budapest Neutron Centre (BNC) is intended to become a national and international centre for neutron-based research in the fields of physics, chemistry, biology and engineering. Thermal neutron fluxes averaging over 10^{14} n $cm^{-2}s^{-1}$ in the core and $2x10^{9}$ n $cm^{-2}s^{-1}$ at the exterior of radial beam ports, as well as the neutron guide system and planned cold neutron source will provide unique possibilities also for nuclear physics and applications.

The nuclear physics research program will focus on neutron capture physics, with special emphasis on measurements of nuclear level lifetimes using novel fast $\gamma_n\gamma\gamma(t)$ coincidence and Doppler-shift timing techniques. The (n,γ) station and the Compton-suppression/pair spectrometer will alternatively be used for neutron-capture prompt-gamma activation analysis (PGAA). Joint development of an ultra-fast rabbit tube system for activation analysis on very short-lived nuclides is also envisaged.

For nuclear astrophysics, s-process capture cross section measurements are planned using a filtered beam, to be constructed at one of the radial beam ports. A fundamental physics programme, such as tests of fundamental symmetries with polarized neutrons, as well as activities in nuclear solid state physics are also envisaged as soon as a polarized neutron guide becomes available.

0_2^+ STATES IN ^{76,78}Kr

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The interpretation of the nature of low-lying 0^+ states in even-even nuclei in the $A \sim 80$ region is still a matter of debate [1]. The investigations carried out in the framework of the IBM model on krypton isotopes offer a clear example of different theoretical interpretations of such states. On one hand the 0_2^+ states have been considered as "intruder" states, i.e. as lying outside the IBM–2 model space[2], on the other hand their properties have been reasonably reproduced in the frame of the IBM–1 model [3].

In a recent paper [4], based on our experimental study of the $E0$ and $E2$ decay of the 0_2^+ state in ^{80}Kr, we performed a new analysis of the low–lying levels in ^{78,80,82}Kr by applying the IBM-2 model. Quite satisfactory agreement was found between theory and experiment, also for the 0_2^+ states in ^{80,82}Kr, the only ones experimentally investigated in detail at that time.

In the present work we extend to ^{76,78}Kr isotopes the study of the 0_2^+ decay. For the investigation of the electric monopole transitions low–lying levels were populated via the β^+ decay of ^{76,78}Rb isotopes collected at the ISOLDE separator (CERN). The conversion electrons were analysed by means of a compact magnetic spectrometer coupled to a $5\,\mathrm{cm}^2 \times 6\,\mathrm{mm}$ silicon detector cooled down to liquid nitrogen temperature.

From the experimental value of the ratio $I_K(0_2^+ \to 0_1^+)/I_K(0_2^+ \to 2_1^+)$ of the K–conversion electron intensities we deduced the ratio X of the corresponding $E0$ to $E2$ reduced transition probability in ^{76,78}Kr.

The lifetime τ of the 0_2^+ state in ^{78}Kr has been determined by means of the Doppler shift attenuation method in gases. The measurements have been performed at Laboratori Nazionali di Legnaro (Padova), exciting the 0_2^+ level via inelastic scattering of 6 MeV protons on an 90% enriched gas sample of ^{78}Kr.

From the values of X and τ we deduced the electric monopole strength $\rho^2(0_2^+ \to 0_1^+) = 0.047 \pm 0.013$ which is in good agreement with the prediction of the IBM–2 calculations. It is to be stressed that the value of $\rho^2(0_2^+ \to 0_1^+)$ increases by about a factor 6 in going from ^{82}Kr to ^{78}Kr.

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GENERALIZED VIBRATING POTENTIAL MODEL FOR COLLECTIVE EXCITATIONS IN DEFORMED NUCLEI

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The vibrating potential model (VPM) [1-3] has recently been generalized [4] for description of $E\lambda$ collective excitations in atomic nuclei with practically any kind of deformation. The model is convenient for the qualitative analysis and provides the RPA accuracy of numerical calculations (the dispersion equation of the model is of the same form as in the case of the RPA with schematic separable forces). The expressions for the residual interaction and the strength constant are derived in a self-consistent way. Any single-particle potentials and ground state densities, for which the coefficients of the multipole expansion are known, can be used within this model. As a result, the model has much wider field of application as compared to the "stretched" coordinate method (see, for example [5]) and many others which are effective for systems with quadrupole deformation only.

The numerical calculations to check the generalized VPM [4] for the case of axial quadrupole and hexadecapole deformations are presented. The RPA equations for collective excitations in nuclei with quadrupole and octupole deformations are considered as a particular case of the model. The estimations for the splitting of $E\lambda$ giant resonances in these nuclei are proposed.

The new versions of the VPM for collective excitations of magnetic (orbital) type are discussed.

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Nuclear Shapes and Nuclear Structure at Low Exitation Energies,
Antibes, France, 20-25 june 1994

THE STATIC QUADRUPOLE MOMENT OF HIGH-SPIN ISOMERS IN ^{211}RN AND ^{214}FR MEASURED WITH LEMS.

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The Level Mixing Spectroscopy (LEMS) method [1,2] is an in-beam, time integrated perturbed angular distribution technique. A nuclear reaction, for example (HI,xn), is used to produce isomers in an oriented way. Perturbation of the initial orientation is due to a combined electric quadrupole and magnetic dipole interaction. From a LEMS-curve (anisotropy as a function of the external magnetic field strenght) the ratio of the nuclear quadrupole interaction frequency to the g-factor can be extracted. Other parameters involved are the initial orientation (alignment in our case), the radiation parameter characterising the investigated γ-transition and the relative efficiency of the Ge-detectors.

In a recent paper by Byrne et al. [3] the level scheme of ^{214}Fr has been extended up to very high spin states. Isomers with spins up to 33h have been discovered. We have been able to extract the quadrupole moment of one of these high spin isomers from a former LEMS - measurement that had been optimised to measure the quadrupole moment of high-spin isomers in ^{213}Fr [4]. In a heavy-ion reaction on a thick Tl target both ^{213}Fr and ^{214}Fr are produced Analysis of the ^{214}Fr γ-transitions is still in progress, but we have already a strong indication that we will be able to extract the quadrupole moment of the 33^+ isomer.

Another series of experiments has been performed to determine the quadrupole moment of high-spin isomers in neutron-deficient Rn isotopes. The Rn nuclei are produced in a Tl(^{11}B,xn) reaction at the CYCLONE cyclotron at Louvain-la-Neuve. As in the Fr(Tl)-experiments [4] a defect quadrupole interaction frequency is found in the data. This defect frequency indicates that not all Rn-nuclei are produced on a substitutional lattice position A LEMS-measurement on a Tl single crystal with its c-axis parallel to the initial orientation axis shows the effect of the defect-associated nuclei. By using the known quadrupole moment [5] of the 17^+ isomer in ^{210}Rn, the defect field gradient as well as the substitutional electric field gradient of Rn in Tl can be determined. With this result, the quadrupole moment of the $49/2^-$ isomer [6] in ^{211}Rn can be derived from the data. Analysis is also still in progress

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Nuclear Shapes and Nuclear Structure at Low Exitation Energies,
Antibes, France, 20-25 june 1994

EXTENTION OF THE LEVEL MIXING RESONANCE METHOD TO STUDY β-DECAYING LIGHT EXOTIC NUCLEI.

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The Level Mixing Resonance (LMR) method is proposed as a tool to study some features such as the initial alignment and the static quadrupole moment of light exotic nuclei produced in a projectile fragmentation reaction. Especially the quadrupole moment of neutron rich nuclei is of particular interest because it gives direct information on the deformation of these "neutron-halo" nuclei.

The LMR (and the LEMS) method have both proven to be very useful methods to determine the quadrupole moment of long lived isomeric states[1,2]. Until now, the methods have been applied in the study of gamma-decaying isomeric states produced in a fusion-evaporation reaction at low beam energies (5 MeV/amu). In this type of nuclear reaction the produced isomers are aligned with the beam axis as a symmetry axis. The initial alignment of the nuclear spin system is perturbed by a combined magnetic dipole and electric quadrupole interaction which is reflected in the angular distribution of the gamma rays. The time integrated angular distribution displays a resonant change of the alignment as a function of the magnetic field strength B. The position of the resonance (as a function of B) gives information on the quadrupole interaction strength while the amplitude of the resonance gives information on the initial alignment of the reaction.

For the study of β-decaying neutron-rich nuclei, β-radiation instead of γ-radiation is detected. Therefore, the angular distribution reflects the transfer of initial alignment to polarization as the magnetic field goes trough a resonance. Simulations about this transfer of alignment to polarization have been made and effects as large as 5% for even small initial alignments are expected[3].

However, not much is known about the initial alignment of the reaction products in a high-energy projectile fragmentation reaction[4]. A way to study this initial alignment is by the application of the LMR-method to a well-known nuclear system. The amplitude of the level mixing resonance is determined by the initial alignment, the β-radiation parameter A_1 and the angle between the static interaction axes. If the secondary fragments of a fragmentation reaction show an appreciable amount of initial orientation the LMR method can be applied to extract the quadrupole interaction frequency and hence the quadrupole moment of a nuclear state.

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EMPIRICAL PARAMETERS OF THE RESIDUAL P-N INTERACTION IN ODD-ODD DEFORMED NUCLEI

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The residual p-n interaction between the valence proton and neutron in doubly odd deformed nuclei is examined in the framework of the unified model.[1] Extensive experimental information about the Gallagher-Moszkowski (GM) splitting energies and the Newby (N) shifts in the rare-earth and actinide regions is used to deduced empirical parameters of the residual p-n interaction.

Experimental information about doubly odd nuclei is critically analyzed and empirical values of 164 GM splitting energies and 48 N shifts are extracted. Empirical parameters of the residual p-n interaction are deduced for two radial potentials, the contact (δ) and Gaussian-like potentials, in the framework of the two-particle-rotor model. For the first time, attention is given to significances of individual parameters. It turns out that both GM splitting energies and N shifts are well described by two empirical parameters. As expected, the GM splitting energies are well described by spin-spin ($\vec{\sigma}_p\vec{\sigma}_n$) and space-exchange-tensor forces ($P_M S_{12}$). The space-exchange (P_M) and spin-spin-space-exchange ($\vec{\sigma}_p\vec{\sigma}_n P_M$) forces are well determined by our experimental set of the N shifts. Also intrinsic spin polarization effects[2] are found to be significant for both GM splitting energies and N shifts. Deduced parameters are compared to those parameters obtained in previous fits.[2,3,4] Our results argue against a commonly accepted opinion[2,3] that the tensor forces give the most significant contributions to the N shifts. Finally, it is shown that, in some cases, the GM splitting energies as well as N shifts are strongly dependent on the shape of the average nuclear field.

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MICROSCOPIC DESCRIPTION OF OCTUPOLE DEGREES OF FREEDOM IN ODD-ODD DEFORMED NUCLEI

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The microscopic approach for the description of low-lying intrinsic states in deformed odd-odd nuclei is formulated as a generalization of the Quasiparticle-Phonon Model.[1,2,3] The model treats vibrational quadrupole and octupole degrees of freedom of deformed doubly even core, their coupling to quasiparticle degrees of freedom and the p-n interaction between the valence proton and neutron on the same microscopical footing.

In this approach both the quadrupole and the octupole degrees of freedom are treated as dynamical variables. The quadrupole and/or octupole correlations between intrinsic states, if they exist, are interpreted as dynamical deformations. We focus our attention on revealing the microscopic composition of, and particularly the contribution of octupole correlations in, the intrinsic states for the nucleus.[2,3] Our treatments aims at the validity of its description as an octupole deformed structure by seeking connections between intrinsic states, and also in evaluating the E3 transition strengths the same K states with opposite parities, to justify their pairing as parity doublets.

Microscopic structures of the low-lying non-rotational (intrinsic) states in the doubly odd $_{63}$Eu isotopes with A=152-156 are investigated.[2,3] Parity doublets suggested in earlier phenomological studies[4,5] as signatures of octupole deformed shapes are examined to conclude that, contrary to some recent suggestions,[5] the low-energy ^{156}Eu spectrum does not contain parity doublets characteristic of reflection asymmetric shapes, in contrast with the structures seen in ^{152}Eu and ^{154}Eu.

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ISOMERIC TARGETS AND BEAMS

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One of the main topics of modern nuclear physics is the investigation of exotic nuclei including hyper-nuclei, transfermium elements, proton and neutron rich isotopes near drip lines as well as high-spin excited states and states with anomalous deformation. The isomerism of nuclei is closely related with such phenomena as the alignment of single-particle orbitals, the coexistence of various deformations and the manifestation of intruder-levels from neighboring shells. The investigation of electromagnetic and nuclear interactions of isomers could give important information on their shell structure and its role in the mechanism of nuclear reactions. For such experiments with sufficiently long-lived isomers ($T_{1/2}$ >10 days) one can either make isomeric targets or use the method of direct acceleration of isomeric nuclei.

During the last few years there was developed at the FLNR JINR a highly efficient method of producing the isomer $^{178}Hf^{m2}$ ($T_{1/2}$=31 year) on the beam of the U-200 cyclotron in the reaction $^{176}Yb(^{4}He,2n)$. To date there have been produced over 1.5×10^{15} nuclei of the isomer and have been developed precision methods of chemical extraction, purification, mass separation and implantation of hafnium. An international collaboration was established with the aim of investigating the structure and interactions of this exotic nuclear state of an aligned four-quasi particle configuration with quantum numbers I, K^{π}=16,16^{+}. By using our isomeric targets there have been observed the reactions (n,γ), (p,p$'$), (d,d$'$), (p,t) and the Coulomb excitation on the isomer $^{178}Hf^{m2}$. The direct acceleration of $^{178}Hf^{m2}$ nuclei has not been performed, since it would have required to spend practically the whole stock of accumulated material during a 24 hour run of acceleration. This problem can be solved by using an up-dated ECR ion source with low consumption of the working material. The specific difficulty of work with isomers is the presence of both ground state and isomeric nuclei in the isomeric material.

The production of secondary beams of isomeric nuclei (including short-lived ones) will allow to approach the solution of the problem of separating the isomer from the ground state. Modern accelerator facilities such as the SIS-FRS-ESR complex built in Darmstadt and the K4–K10 heavy ion storage facility being designed presently at the FLNR JINR make it possible to produce the radioactive nuclide, separate and accumulate it in the storage ring. After cooling the beam to a higher momentum resolution it is possible to separate a pure isomeric beam by using the difference in the masses of the isomer and the ground state. The table presents some examples of isomers and gives the mass difference $\Delta M = M_i - M_g$ to M_g. It is evident that for certain nuclei the $\Delta M/M_g$ value exceeds 2×10^{-5} and thus they are most promising for separation in the storage ring. Besides, isomers with a high ΔM being structurally exotic nuclei are of the greatest interest.

Isomer	$^{24}Na^{m}$	$^{38}Cl^{m}$	$^{42}Sc^{m}$	$^{90}Zr^{m}$	$^{93}Mo^{m}$	$^{177}Hf^{m2}$	$^{178}Hf^{m2}$	$^{212}Po^{m}$
$T_{1/2}$	0.02s	0.72s	62s	0.81s	6.9h	0.85h	31y	45s
I^{π}	1^{+}	5^{-}	7^{+}	5^{-}	$21/2^{+}$	$37/2^{-}$	16^{+}	18^{+}
$\Delta M/M_g$, 10^{-5}	2.1	1.9	1.6	2.8	2.8	1.7	1.5	1.5

The studies with $^{178}Hf^{m2}$ target completed, some new proposals of future experiments and possibilities to produce isomeric beams are described in this talk.

ROTATIONAL MOTION
IN SPHERICAL SHELL MODEL CONFIGURATIONS

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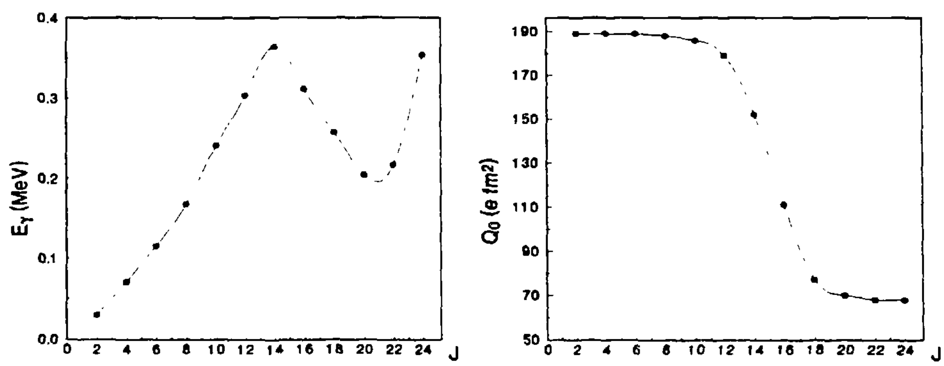
We discuss a class of shell model configurations that give rise to rotational spectra using realistic interactions. They are made up of spherical shell model orbits, belonging to the same major oscillator shell, and following a $\Delta j = 2$ sequence based upon the largest j orbit, for instance $1g_{9/2}, 2d_{5/2}, 3s_{1/2}$. The $\Delta j = 2$ scheme favours prolate shapes via the quadrupole interaction which is a very important component of any realistic effective interaction. Using the interaction of Lee Kahanna and Scott with single particle energies $\epsilon(j) = -\frac{1}{2}j$ (in MeV), we obtain very convincing rotors. We present here some results for the $(1g_{9/2}, 2d_{5/2}, 3s_{1/2})^8$ T=0 configuration. These states may be important to understand the deformation region around ^{80}Zr and may also describe superdeformed excited bands in ^{48}Cr. In the table below, we list the ratios of the excitation energies of the Yrast states to the 2^+ excitation energy and the ratios of the intrinsic quadrupole moments to that of the 2^+ and compare them to the rigid rotor predictions.

	$(1g_{9/2}, 2d_{5/2}, 3s_{1/2})^8$		Rigid Rotor	
J	$\frac{E(J)}{E(2^+)}$	$\frac{Q_0(J)}{Q_0(2^+)}$	$\frac{E(J)}{E(2^+)}$	$\frac{Q_0(J)}{Q_0(2^+)}$
4	3.32	1	3.33	1
6	7.13	1	7	1
8	12.66	0.995	12	1
10	20.56	0.984	18.33	1
12	30.57	0.947	26	1

The agreement is extremely good. Notice especially the neat signature of an intrinsic structure given by the almost constant value of the intrinsic quadrupole moment. What happens at higher spins in shown in the figures below. In the left side we have represented the gamma energies of the Yrast cascade versus the spin of the initial state. Backbending is evident for $J > 14$. In the right side we represent the intrinsic quadrupole moment as a function of J. In coincidence with the region of backbending we can see how the large, constant, prolate quadrupole moment changes to another constant but smaller prolate value. Looking to the wave functions -in the laboratory frame- we conclude that the second region corresponds to the mixing of prolate and oblate shapes. This behaviour is common to all the $\Delta j = 2$ blocks that we have studied.



Prolate Collectivity in ^{187}Tl and ^{189}Tl.

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Light mercury nuclei exhibit a variety of shapes, ranging from a slightly oblate ground state ($|\epsilon_2| \approx 0.14$) to a prolate intruder band of rotational states with rather strong deformation ($|\epsilon_2| \approx 0.22$), and even to a superdeformed prolate structure ($|\epsilon_2| \approx 0.45$) [1]. Understanding this variety of shapes in nuclei with an almost closed proton shell ($Z = 80$ for Hg) has been a challenge for some years. Recently, coexisting prolate bands have even been found at $Z = 82$, in *e.g.* ^{186}Pb and ^{188}Pb [2,3]. The purpose of our recent experiments has been to explore the microscopic structure of this low-lying prolate minimum (*e.g.* $E(0_2^+) = 523$ keV in ^{186}Hg [1] and $E(0_2^+) \approx 720$ keV in ^{188}Pb [2,3]) by searching for the occurrence of prolate $h_{9/2}$ and $i_{13/2}$ rotational bands in an odd-Z neighbor, ^{187}Tl, an isotone of both ^{186}Hg and ^{188}Pb, and in the heavier isotope, ^{189}Tl.

Both the $h_{9/2}$ and $i_{13/2}$ proton orbitals are strongly downsloping in energy with increasing deformation. Thus, they are expected to play a major role in the formation of the excited prolate minimum in light Hg and Pb nuclei. In fact, based on the observation of a prolate $\pi i_{13/2}$ band in ^{189}Tl, and the apparent lack of feeding of a prolate $\pi h_{9/2}$ structure, Porquet *et al.* [4] argued that the prolate Hg core could be largely of $(\pi h_{9/2})^2$ character. Our measurement and calculations on ^{187}Tl further test this "blocking" hypothesis in a case where the prolate minimum is even lower in energy in the core nuclei, ^{186}Hg and ^{188}Pb. We find that prolate bands based on both $\pi h_{9/2}$ and $\pi i_{13/2}$ orbitals are present in ^{187}Tl, as a result of an experiment performed at the ATLAS accelerator with the ^{156}Gd(^{35}Cl,4n) reaction.

These new bands are assigned to $\pi i_{13/2}$, $K = 1/2$ and $\pi h_{9/2}$, $K = 3/2$ configurations, both associated with similarly deformed prolate shapes of $\epsilon_2 \approx 0.23$. This is the first time that a prolate $h_{9/2}$ level structure has been found in an odd-A Tl nucleus. Bandhead calculations of the Nilsson-Strutinsky type have been performed supporting these assignments. The lack of evidence for a prolate $h_{9/2}$ configuration in ^{189}Tl is explained, alternatively to ref. 4, by the fact that the deformation of the expected $h_{9/2}$ band is small compared to that for the $i_{13/2}$ structure, so that the latter will be populated much more strongly at high spins. To test this idea, we have also performed a recent measurement on ^{189}Tl at GAMMASPHERE, utilizing the ^{156}Gd(^{37}Cl,4n) reaction. Preliminary results from the analysis of this large data set (3×10^8 triple coincidences) will provide information on the prolate bands in ^{189}Tl.

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NUCLEAR HALOS AND THEIR EXCITATION MODES

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Nuclear halo states appear when the last one or two added nucleons have a separation energy so small that they have an appreciable probability of tunneling out from the nuclear potential. This can happen if there are no confining barriers, i.e. if the angular momenta (and the charges in case of proton halos) involved are sufficiently small.

There are several existing reviews of halos, their structure and how they are probed in experiments [1,2,3,4]). I shall here not dwell on the structural detailes, but rather give a brief overview of what the characteristic features are of halos. The main part of the talk will concentrate on the interpretation of the various experiments used for probing halo states. An important group of experiments is the nuclear reactions made at high beam energy. Both nuclear and Coulomb break-up occur, the latter one being closely related to the electric dipole strength function. Beta decay experiments can also give valuable information on the halo structure and will also be treated in some detail.

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QUADRUPOLE-OCTUPOLE COUPLED STATES IN ^{144}Nd AND THE INFLUENCE OF THE $\nu(1i_{13/2})$ ORBITAL.

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The N = 84 isotones have long been a testing ground for the description of collective vibrations in spherical nuclei. In particular, ^{144}Nd has been studied extensively because it can be accessed in a number of different reactions. Attempts have been made to describe the low lying positive parity states in these nuclei in terms of purely collective models, such as the Interacting Boson Model. However, it has been shown, using particle-core coupling models [1,2] that the restricted neutron configuration space hinders the development of multi-phonon quadrupole collectivity and introduces significant (and in some cases dominant) neutron single-particle components into the wave functions of the low lying positive parity states.

Much less attention has been paid to the study of states arising from the possible coupling of the collective quadrupole and octupole phonon excitations, which (in a weak coupling picture) produces a quintuplet of negative parity states (1^- to 5^-). Though 1^- (2185 keV) and 5^- (2093 keV) states have been interpreted as members of this quadrupole-octupole coupled (QOC) quintuplet [3,4,5] no other members have been identified. However, the results of a recent a (p,p') study [6] of the 5^- state in ^{144}Nd showed it to have an enhanced ground-state transition, which was interpreted as evidence for significant single-particle influence.

In order to further examine these excitations detailed studies of levels in ^{144}Nd have been carried out at the Institut Laue-Langevin (ILL) in Grenoble, France using the neutron capture reaction. This paper reports on the identification of a 4^- level at 2204 keV and lifetime measurements of the $3_1^-, 5_1^-$ and 1_1^- states in ^{144}Nd. The lifetimes were measured using the Gamma-Ray Induced Doppler Broadening (GRID) technique [7].

The structure of these states can be explained based on an anharmonic splitting of the quadrupole-octupole quintuplet [8], together with significant neutron single-particle components of the form $\nu(2f_{7/2}, 1i_{13/2})^J$ in the QOC quintuplet states with $J^\pi \geq 3^-$. This picture also explains the absence of 2^- and 3^- states in this energy region.

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Study of the properties of shape isomers as a function of spin with the Gogny force.

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Since the discovery in 1985 of a superdeformed band in ^{152}Dy the interest on exotic shapes at high spins has increased enormously due to the striking properties associated with them. The properties observed involve different aspects of nuclear structure, such as the behavior of the nucleus with increasing angular velocity (responsible for the evolution of the moment of inertia) and with deformation (the unexpectedly strong population of superdeformed bands at high spins and the lack of a link between the superdeformed states and the yrast levels up to very low spins is strongly related to the energy landscape as a function of deformation and spin) [1]

There have been many calculations of energy surfaces as a function of deformation and for different spins focussing on superdeformed states. At high spins all of them have been carried out using the Strutinsky shell correction method [2] while for low spins there are also some calculations with realistic forces mainly in the Mercury region[3].

The purpose of this paper is to analyze the results of the energy surface calculations we have carried out at low and high spins in the superdeformed nuclei ^{192}Hg, ^{152}Dy and ^{88}Ru using the cranking mean field approximation with the Gogny force. A careful analysis allows us to determine the role played by different orbitals in different deformation regions. The evolution with spin of the energy barrier between the normal deformed and superdeformed states is also analyzed. Comparison of our results for the superdeformed barrier height at high spin with the available experimental data [4] shows a remarkable agreement.

Predictions on the behavior of the superdeformed band in ^{88}Ru as a function of angular momentum are also made.

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QUASI-MOLECULAR STATES IN ^{48}Cr AT HIGH SPINS

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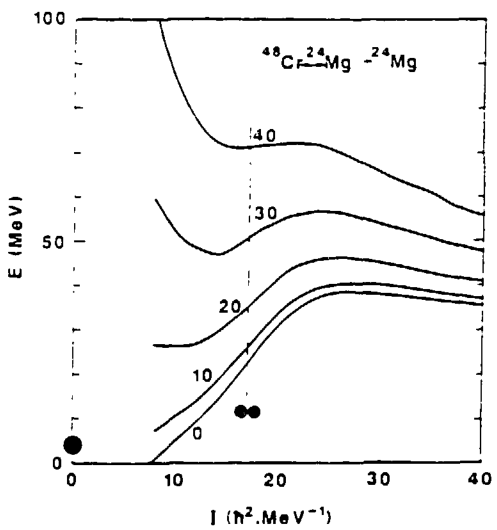
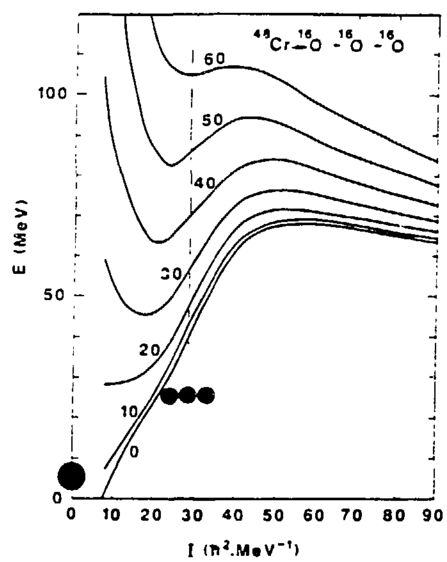
The binary and ternary l-dependent fission of the ^{48}Cr nucleus has been investigated within the finite-range liquid drop model and compact and creviced shape sequences leading rapidly to two or three touching spherical fragments. In the two figures the deformation barriers for the binary and ternary symmetric fission are displayed as a function of the angular momentum. The dashed and dotted curves correspond to the rupture of the neck between the nascent spherical fragments. With increasing angular momenta the minimum moves and for high spins large deformed and stable configurations appear at the foot of the external scission barrier. Their shapes correspond to two or three spherical fragments still connected by a small bridge of matter. These quasi-molecular states in ^{48}Cr might explain the existence of some structures recently observed[1]. Let us recall that such hyperdeformed configurations seem compatible[2] with the first data on hyperdeformed ^{152}Dy nucleus at very high spins.

Such hyperdeformed states have been also predicted[3] within the cranked cluster model of alpha particles for the ^{36}Ar and ^{48}Cr nuclei.





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Superallowed $0^+ \rightarrow 0^+$ branching ratio in the decay of ^{10}C using the 8π spectrometer

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The nucleus is a valuable laboratory to test fundamental physics to high precision. A particularly successful example is the test of the CVC hypothesis from precision measurements of a series of superallowed $0^+ \rightarrow 0^+$ β-decay emitters. Such measurements also provide the most precise value of V_{ud}, the up quark-down quark matrix element of the Kobayashi-Maskawa matrix, which dominates the unitarity tests that a three-generation standard model must satisfy. While the experimental results available are now in very good agreement, they suggest a small systematic Z-dependent shift whose existence could be best ascertained (or constrained) by a precision measurement on the lighest of the superallowed $0^+ \rightarrow 0^+$ emitters, ^{10}C. This measurement is particularly difficult since the superallowed branch involves only 1.5% of the ^{10}C decays. In addition, the superallowed branch feeds a level which is deexcited by emission of a 1022 keV gamma ray, a signature easily contaminated by piling up of annihilation gamma rays. Hence we selected to perform this measurement using a large gamma-ray detector array (the 8π spectrometer) where the total efficiency is obtained from many detectors, each with small solid angle. The relative contamination of the 1022 keV gamma ray peak by summed annihilation quanta is therefore much reduced.

In the simple decay scheme of ^{10}C a 718 keV gamma ray is emitted in all decays while a 1022 keV gamma ray is emitted only in the superallowed decay to the isobaric analogue state. The branching ratio can therefore be obtained from the ratio of the number of 1022 keV to 718 keV gamma rays emitted in the decay of ^{10}C. The experiment contains two parts: first a measurement of the relative yield of the two characteristic gamma rays in the decay of ^{10}C, followed by a measurement of the relative efficiency of the detector array for these two energies. This second part is performed by populating the state at 2.154 MeV excitation energy in ^{10}B by (p,p') reactions, and looking in-beam at γ-γ coincidences. Since a deexcitation pattern of this state is 3 consecutive γ-rays (414,1022 and 718 keV), the ratio of 414-718 coincidences to 414-1022 coincidences is the sought efficiency ratio.

Preliminary results of an experiment performed on the 8π spectrometer using this novel approach will be presented. The implications of finally adding ^{10}C to the set of precisely known superallowed $0^+ \rightarrow 0^+$ β-emitters for the CVC test and the additional constraints it brings to the unitarity test will be discussed.

SEARCH FOR OCTUPOLE DEFORMATION IN NEUTRON RICH Xe ISOTOPES.

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The knowledge of the properties at high angular momentum in the neutron-rich nuclei in the Z $\sim$ 58 region is limited since the high-spin states in such nuclei cannot be produced by the usual in-beam reactions. They are however accessible through the spontaneous fission of several nuclei and the advent of large and high-resolution γ-ray multidetector arrays made possible the study of high-spin states in primary fragments. A special interest in that region arises from the prediction that octupole correlations may occur in some nuclei and indeed level patterns consistent with octupole deformation have been observed in the neutron-rich Ba isotopes [1]). But there is no experimental indication of octupole deformation so far in the even-even heavy Xe isotopes [2]).

The present contribution reports on the study of neutron-rich Xe isotopes. Of particular interest is the investigation of odd-A isotopes since their asymmetry energy is predicted to be larger than in the neighbouring even-even cores [3]).

Xe isotopes with masses ranging from 136 to 143 were obtained as primary fragments in the spontaneous fission of ^{248}Cm. The source was placed in the center of the Eurogam spectrometer which in its phase 1 was located at the Daresbury Nuclear Structure Laboratory. In the present experiment the Eurogam array, constituted of 43 Compton-suppressed large volume Germanium detectors, was supplemented by the addition of 4 LEPS detectors.

The analysis of the extremely complex γ-spectra required the employment of double-, triple- or even quadruple-coincidence techniques. Spin values were inferred from γ-γ angular correlation data. The new experimental results consist mainly in yrast structures (up to J $\sim$ 16) and weakly populated yrare bands. For two odd-mass nuclei, the level schemes follow from the first observation of their excited states. These results will be compared to the data from heavier isotones and will be discussed in the framework of nuclear models which assume octupole deformations.

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Anisotropic alpha emission from deformed Pa nuclei.

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A study of the angular distributions of alpha particles from the favoured transitions in the decay of the deformed nuclei ^{227}Pa ($t_{1/2}$=38.3 m) and ^{229}Pa ($t_{1/2}$=1.50 d). is presented. The ^{227}Pa experiment was performed on-line in the KOOL dilution refrigerator that is coupled to the LISOL separator in Louvain-la-neuve. The ^{229}PaFe source was made at the Bonn isotope separator and subsequently oriented in the KOOL refrigerator. In these experiments, ion implantation and high-resolution detection of alpha particles at low temperatures were combined for the first time in an anisotropy measurement on deformed nuclei. The experimentally found alpha anisotropies from these Pa nuclei are the largest ever observed in a nuclear orientation experiment with W(0)/W(90) exceeding a value of 3. The results are discussed in the framework of different models. One is a microscopic model in which tunnelling through the deformed Coulomb barrier plays an important role[1]. The data are also compared with calculations from alpha-core models in which the quadrupole interaction between a structureless alpha particle and the core is diagonalised[2,3].

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Alpha anisotropy measurements on on-line separated At and Rn isotopes.

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We report on a systematic study of the alpha anisotropies from favoured transitions in the decay of nearly spherical At and Rn isotopes by means of on-line nuclear orientation. The experiments were performed in the NICOLE refrigerator on-line to the ISOLDE separator at CERN. The anisotropies from the decay of ^{205,207,209,211}At and of ^{205,207,209}Rn were observed. For the At isotopes a very profound increase of the anisotropy with increasing neutron number is found, the largest value being observed at the N=126 shell closure. This trend follows that observed earlier in experiments with ^{199,201,203}At[1)]. The results for the whole series of At isotopes are compared to theoretical calculations in different models[2,3,4)]. The fully quantum mechanical calculations by Berggren reproduce the observed trend but not the magnitude of the anisotropies[2)]. However, this model is still being improved. Shell model calculations including the p-n interaction between the valence neutron holes and the core protons as well as the pairing interaction were performed to reproduce the trend of the experimental data. Furthermore, a pure configuration calculation on ^{211}At yielded an anisotropy W(0)/W(90) of 2.0 for this nucleus which is within 10% of the experimental value. In the microscopic model of Delion et al. it is concluded that the alpha anisotropy is mainly due to the deformation of the decaying nucleus and that a prolate deformation gives rise to a positive anisotropy. Combined with our experimental data, this conclusion would imply that the deformation of the At isotopes increases when going towards the N=126 shell closure which seems rather unlikely. For the Rn isotopes, the variations of the anisotropies are much less pronounced. The results are compared with theoretical calculations[2,4)].

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SYMMETRY BREAKING IN THE SPECTRA OF THE ODD-A Ac NUCLIDES

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The remarkable features of the spectra of the odd-A Ac isotopes from ^{215}Ac (with 126 neutrons) through ^{231}Ac (with 142 neutrons) serve as a sequence of examples for the application of a variety of nuclear models. As the shapes vary in this sequence from spherical to spherical with strong octupole correlations to octupole deformed, the corresponding symmetry breaking leads to increasingly complex spectra. The spectrum of ^{215}Ac can be described in terms of the shell model configurations $\pi(h_{9/2})^{-3}$, $\pi(h_{9/2})^{-4}f_{7/2}$ and $\pi(h_{9/2})^{-4}i_{13/2}$. However, even in this 126 neutron nucleus there is already a strongly enhanced E3 transition.(1) The spectra of ^{217}Ac and ^{219}Ac can be interpreted in terms of the weak coupling of the $h_{9/2}$ proton to the ^{216}Ra and ^{218}Ra cores, respectively. However, the existence of parity doublet bands (same spins but opposite parities) in ^{219}At and the interleaving of positive and negative states in ^{218}Ra clearly demonstrate the increasing importance of octupole deformation. Parity doublet bands are also present in the spectra of ^{221}Ac. However in both ^{219}Ac and ^{221}Ac the positive parity members of the parity doublets appear to cut off before reaching the low spin values expected from the negative parity bands.(2) In ^{223}Ac, ^{225}Ac and ^{227}Ac the experimental spectra clearly show the existence of parity doublet bands built on the parity mixed configurations $5/2^{\pm}(0.0;-0.2)$ and $3/2^{\pm}(0.0;-0.3)$.(3) The fact that the ordering of these two configurations changes for ^{223}Ac results from decreasing quadrupole deformation. Other spectroscopic properties also confirm octupole deformation in these three isotopes. In ^{229}Ac and ^{231}Ac the only detailed but limited spectroscopic information comes from the (t, α) reaction on ^{230}Th and ^{232}Th.(4) While it is consistent with the presence of parity doublets, much more detailed spectroscopic studies could give information about the possible coexistence of reflection asymmetry and reflection symmetry in these nuclei.

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DEFORMATION ALIGNED YRAST STATES IN ^{182}W

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High spin states in ^{182}W have been populated by the reaction $^{176}Yb(^{13}C,\alpha 3n)$ at a beam energy of 65 MeV using a 4π array of Silicon detectors mounted inside the NORDBALL escape-suppression spectrometer. Only events in coincidence with a PID signal from the SiBall were recorded on tape for off-line sorting. About 13 million such events were collected. This is about 3% of the total fusion cross section.

Six new bands at high spins are characterized as quasi-particle configurations with K^π values of 11^+, 12^+, 15^+, 16^+, 17^- and 18^-. The first five have seniority 4 while the 18^- state probably has a 6 q.p. configuration. Near I=16$\hbar$ the deformation aligned 4 q.p. states become yrast with the K^π=17^- band at 4039.7 keV below the g.s.b. yrare line. The ground state band which is measured up to the 20^+ level backbends strongly at $\hbar\omega$=0.4 MeV and gains more than 6 units of angular momentum, probably caused by a $i_{13/2}$ quasi-neutron crossing.

Half lives of the K^π=15^+ and 17^- levels at excitation energies of 3754.0 and 4039.7 keV were determined to be 37(2) and 20(1) ns, respectively. Transitions of the 15^+ state into the K^π=10^+ band are hindered by factors of 13(1) and 19(1) per degree of K-forbiddenness for the E2 and M1 transitions. These values lie on the systematics of K-forbiddenness in deformed nuclei, but larger than those of the K-forbidden transition of the 10^+ state into the ground state band, which have been measured as f_ν=5(1) and 6(1) for the 1086 keV E2 and the 519 keV M1 transitions[1]). The ratio of the intensity of the E2 crossover to the M1+E2 cascade transition within the band can be used in the asymptotic limit to deduce the $|g_K$-$g_R|/Q_0$ values[2]). Compared with the expected values of g_K, quasi-particle configurations were assigned to the bands, considering the two-quasi-particle states[3]) previously found in ^{182}W and the Nilsson orbitals near the Fermi surface in this nuclei.

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PROLATE-OBLATE SHAPE COEXISTENCE AT Z,N $\approx$ 36,38 +

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Stabilized by the large gap between the single particle energies at large prolate deformation for Z,N=38 many nuclei in the mass region A≈70-80 show bands on prolate deformed intrinsic states with $\beta_2 > 0.3$. In recent years we studied the N=Z-region at A≈70 with respect to oblate deformation induced by the gap for Z,N=36. But no stable oblate deformation reaching up to high spins of about $10\hbar$ has been found until now. We discuss the systematics obtained in the data of the four even-odd Se and Kr isotopes with respect to the competing influence of the magic nucleon numbers Z,N=36 for oblate and Z,N=38 for the favoured prolate deformation.

For ^{69,71}Se positive sign of mixing ratio and strongly coupled band pattern of the $g_{9/2}$ band could be reproduced by model calculations only with oblate deformation [1]. From ^{69}Se (Z=34, N=35) to ^{71}Se (N=37) triaxiality rises and oblate deformation decreases due to the rising influence of the N=38 prolate single particle energy gap.

We were able to identify ^{73}Kr (Z=36, N=37) by crossbombardement, neutron coincidence and population characteristics [2]. The strongly coupled negative parity band starts at an excited state with a spin compatible only with prolate deformation. The weakly deformed band in ^{73}Kr might be built on an oblate deformed $g_{9/2}$ state.

In comparison, ^{75}Kr (N=39) has two strongly coupled major bands ($g_{9/2}$, K=5/2 ground state and $p_{3/2}$, K=3/2 excited state) of very large prolate deformation ($\beta_2 \approx 0.4$ derived from lifetimes) [3]. Each major band is accompanied by sidebands unexplainable by triaxiality. ΔI=0-transitions from side to major band point at a change in deformation. The sidebands are interpreted to be built on oblate states in agreement with Cranking Model calculations showing a second minimum in the Total Routhian Surface at oblate deformation and appropriate excitation energy.

Compared to the strong influence of the Z,N=38 single particle energy gap the Z,N=36 magic number is easily obstructed by rotation. In ^{71}Br (Z=35, N=36) no clear evidence for oblate deformation has been found. Thus, in this mass region as a last candidate for an undisturbed strongly coupled rotational band on an oblate state remains ^{71}Kr, which can be investigated only with radioactive beam or large detector arrays as EUROBALL.

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A SIMPLIFIED $\alpha + 4n$ MODEL FOR ^{8}He NUCLEUS

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In studies of light nuclei far from the stability line, besides the famous example of the ^{11}Li neutron halo nucleus [1], the neutron rich ^{6}He and ^{8}He isotopes are known to have extended valence neutron distributions, called neutron halos or "thick neutron skins" [2]. For the cases of ^{11}Li and ^{6}He, microscopic calculations in different three-body (core + 2n) approaches predict exotic correlations in the neutron halos (see [3] and references therein). The ^{8}He nucleus is a complex five body (α+4n) quantum system. Still it is possible to construct a simple theoretical model, which provides the opportunity to calculate the correlations and particle momentum distribution for this nucleus.
A simple five-body cluster orbital shell model approximation (COSMA), based on ref. [4], will be presented in order to describe the ground state wave function of the ^{8}He neutron halo nucleus. The COSMA use translationally invariant coordinates, it treats the Pauli principle between valence neutrons strictly and it combines the advantages of the shell and cluster models. A single free parameter of the model is fitted to reproduce the experimental r.m.s. matter radius of ^{8}He. The spatial angular correlations and the geometry of the system together with one-particle density distribution will be presented. Also the α-particle and the valence neutron momentum distributions have been calculated analytically. Comparison with ^{6}He [5] shows that halo correlations give an essential contribution to the shape and the width of the α-particle momentum distribution.

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IDENTIFICATION OF THREE- AND FOUR-PARTICLE STRUCTURES IN DEFORMED NUCLEI FROM BETA TRASITION RATES

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Over the past few years we have extensively investigated [1-3] the use of fast beta transition rates as a viable tool for deducing the configurational assignments of beta connected states in deformed nuclei. Using the data base of 122 identified decays in nuclei with $147 \lesssim A \lesssim 190$, we established [1] the 'strong' rule that all beta transitions with log ft $\lesssim$ 5.2 in the rare earth region connect an up-spin proton and a down-spin neutron, both having the same asymptotic quantum numbers ($Nn_3\Lambda$) with $N=n_3+\Lambda=5$. This rule was used [2] to deduce the two-quasiparticle (2qp) configurations for 42 levels in odd-odd, and 32 connected levels in even-even nuclei. Recently we extended [3] this approach to the actinide region wherein no confirmed instance of allowed unhindered transition had been reported so far; a modified asymptotic quantum number selection rule was suggested [3] for fast beta transitions of this region. Now this approach is further extended to systematically search for 3qp and 4qp structures in deformed nuclei by scanning the domain of fast beta transitions over the excitation energy range upto 4 MeV. In view of the expected configuration admixtures, and consequently of the distribution of multi-quasiparticle strength over a number of states, we analyse all transitions with log ft $\lesssim$ 6.0 to look for the dominant 3qp and 4qp components. In particular,it is shown that this procedure offers the only means for identifying the 4qp structures of high-energy low-spin states in even mass deformed nuclei.

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β-decay studies of far from stability nuclei near N = 28.

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Beta-decay half-lives and β-delayed neutron-emission probabilities of the very neutron-rich nuclei ^{43}P, $^{44,45}S$, $^{45-48}Cl$, $^{48-50}Ar$ have been recently measured. Some of them have been studied in a previous experiment [1]. These isotopes, which lie at or close to the N = 28 magic shell were produced at reasonable rates (betwen 0.1 and 10/sec) in interactions of a 63 MeV/u ^{48}Ca beam from GANIL accelerator with a ^{64}Ni target. They were separated by the doubly achromatic spectrometer LISE3 [2] which drastically reduced the number of contaminants. The nuclei then transmitted have been identified on-line in a telescope composed with three silicon detectors. The two first detectors gave a redundant determination of energy-loss and time-of-flight, whereas the third one served for the implantation of the nuclei and for the determination of their total energy. Beta-decay events, correlated with each precursor nucleus were also detected in this implantation detector. A neutron counter, composed with 36 ^{3}He gas filled tubes surrounded the telescope and allowed to determine the number of β-neutron coïncidences. With this triple coïncidence between the nuclei implanted and their corresponding β-neutron decay, the determination of half-lives and P_n have been performed with a very low background. The results, compared to recent model predictions, seems to indicate a rapid weakening of the N = 28 shell effect below $^{48}_{20}Ca_{28}$. These nuclear structure effects reflected in the decay properties of these exotic nuclei, may furthermore be the clue for the understanding of the striking $^{48}Ca/^{46}Ca$ abundance ratio measured in the solar system as well as correlated Ca-Ti-Cr anomalies observed in inclusions of the Allende meteorite.

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Half-lives for two neutrino double-beta decay transitions to first 2^+ excited states

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Abstract

Two neutrino double-beta decay half-lives for transitions to the first 2_1^+ excited states have been calculated in the framework of a second-QRPA procedure for the following nuclei: ^{76}Ge, ^{82}Se, ^{110}Pd, ^{116}Cd, $^{128,130}Te$ and ^{136}Xe. It was found that the corresponding decay rates are only weakly dependent on the g_{pp} parameter. Our calculations indicate as the most favorable cases ^{82}Se, ^{116}Cd and ^{136}Xe for which these half-lives are of the order of 10^{23} years.

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DOUBLE BETA DECAY TO EXCITED FINAL STATES

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A method for the calculation of beta-decay transitions of odd-odd nuclei to the ground state or excited states of an even-even daughter nucleus has been developed in [1]. In this framework the even-even daughter nucleus is treated using the spherical QRPA (quasi-particle random phase approximation) model in its pp+nn mode and the states of the odd-odd parent nucleus are described by using the proton-neutron QRPA model (pnQRPA).

An intriguing application of the above-described formalism concerns nuclei decaying through two-neutrino double-beta-decay ($2\nu\beta\beta$) transitions. The $2\nu\beta\beta$ mode can occur in the standard theory of electro-weak interactions and a considerable amount of experimental data on the decay half lives of the ground-state-to-ground-state (g.s.→g.s.) transitions is available. Contrary to this, only in recent years more and more experimental effort has been dedicated to searches for decays to excited states.

Experimental studies of $2\nu\beta\beta$ transitions are complemented by theoretical studies using the QRPA approach or the nuclear shell model (for light nuclei). Very recently the first theoretical attempts were made to describe the $2\nu\beta\beta$ transitions to the first excited 2^+ state [2] or the two-phonon 0^+ state [3]. In ref. [4] a complete description of the $2\nu\beta\beta$ transitions to one- and two-QRPA-phonon states is devised and applied to the decays of ^{76}Ge and ^{136}Xe. An interesting feature of the excited-state transitions is that they seem not to depend upon fine-tuning of the nucleon-nucleon interaction in the particle-particle channel contrary to the behaviour found in the calculations [5-7] of the g.s.→g.s. transitions. This feature enables a more direct comparison with experimental data, like in the case of ^{100}Mo [3,8]. In the light of this the experimentalists are urged to study these decays, especially in the promising cases of ^{96}Zr, ^{116}Cd and ^{150}Nd.

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FREEZING-OUT OF NUCLEAR POLARIZATION IN CORE IONS OF MICRO-CLUSTERS "SNOWBALLS" IN SUPERFLUID HELIUM

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An alien ion introduced in liquid helium exerts an electric field around itself and attracts helium atoms in the surrounding by means of electro-striction. A micro-cluster is thus formed and as such is called "snowball".

Polarization in the product nuclei ^{12}B in the heavy-ion reaction $^{9}Be(^{14}N, ^{12}B)$ was measured quite recently at 40 Mev/u by incorporating the beta-NMR method[1] and the polarization P attained a maximal value -35 ± 3 % for the highest momentum of ^{12}B at an reaction angle of 5 degrees[2], the sign of polarization being in accord with the Basel convention.

Such polarized ^{12}B were electromagnetically separated and shaped a polarized nuclear beam through the exotic nuclear beam course of the RCNP at Osaka University. A ^{12}B beam sustaining an average polarization of -25 % was implanted into superfluid helium at 1.4 K.

After transportation through a static electric field, asymmetry in beta decay of ^{12}B was measured and the polarization obtained after its lifetime ($T_{1/2}$ = 20.4 ms) for ^{12}B trapped as a core of snowball was -21 ± 1.6 %. Application of rf magnetic field at off-resonance produced asymmetry zero within 2 %. Further it was found that the beta-ray counting rate was suppressed appreciably at zero electric field. As the electric field was increased, the beta-ray counting rate increased and polarization saturated. If the electric field exceeded certain value, the polarization was destroyed, as most of the snowballs ended onto the chamber wall.

This fact consolidates that the nuclear spin polarization is frozen-out in snowballs and the mechanism is independent of atomic species.

The results of this experiment shed lights on the physics of nuclear moments of exotic nuclei and further structure of micro-clusters e.g., by observing the resonance width of beta-NMR processes.

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A DEVELOPMENT OF THE DECAY SCHEME OF ^{158}Gd FROM (n,γ) DATA

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ABSTRACT

The ^{157}Gd$(n_{th},\gamma)^{158}$Gd reaction was used to obtain a γ-ray spectrum and to build upon the existing decay scheme. γ-γ coincidences were taken at the Institut Laue-Langevin to cover the energy range of roughly 511 keV to 5.5 MeV.

The extremely high cross-section of the capture nucleus ^{157}Gd of 2.55×10^5 barns presented many difficulties. Although a full matrix of coincidences was recorded a double-escape spectrum was also obtained from the Pair Spectrometer[1]. This instrument took a singles spectrum of γ-rays right up to the neutron binding energy of 7.9 MeV. As it only records triple coincident events, an improved peak-to-background ratio was obtained. The high resolution of the Pair Spectrometer allows the use of the Ritz Combination principle to extend the decay scheme of ^{158}Gd.

The experimental data is compared with the predictions of the Interacting Boson Model.

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FAST RELEASES AND OTHER NEW FEATURES AT THE PS BOOSTER ISOLDE.

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The first 18 months of ISOLDE running at the PS Booster have seen great success, surprises and disappointment. One of the attractive features of the new ISOLDE is the fast release of the radioactivity produced in the target by the 1 GeV pulsed proton beam delivered by the Booster. Once the proton beam has smashed its way into the target nuclei, and as a result of spallation, fragmentation or fission has produced a diversity of exotic nuclei, these nuclei must escape from the target matrix. The further from stability we do our experiments the shorter half lives we have to work with. If such an exotic nucleus dwell around in the target ion-source system too-long it will decay and we have lost the oportunity of doing spectroscopy on it. In this way, the fast release of the PSB ISOLDE[1]) facility has paid dividens with, for example, the release of the celebrated halo-nucleus ^{11}Li from a Ta target of several thousands atoms per proton pulse: The half-life of ^{11}Li is 8.7 ms.

The performance of the Thorium-Carbide and Uranium-Carbide targets is particularily gratifying. The production of exotic-Radon nuclei was extended to mass 198, which is one mass further away than had earlier been achieved at ISOLDE2/3. The yields for Rn, Xe, Kr are in some cases as much as two orders of magnitude above their earlier results. The same applies for Na, Fr, Ra and K from the UC target.

These gains in yield are due to several factors: Firstly the increase from 600 MeV to the 1 GeV protons delivered from the Booster, leading to higher production far from stability. Secondly the pulsed beam of the booster imparts a rather fierce shock to the targets. This shock is both thermal and mechanical combined with a radiation shower. Although we do not claim to fully understand the processes involved, they do give rise to an extraordinarily fast release from the targets. In the case of the light K from the Titanium target in the presence of CF_4 gas the release time is in the order of 30 ms. The use of molecular side-bands from the very same target made possible the first observation of pure ^{38}Ca activity (IS308). In the case of ^{37}CaF the beam contained 50% of the total amount of ^{37}Ca produced with essentially no impurities (IS326).

The pulsed beam together with the "spiked" release has other advantages; in the case of short lived nuclei (≤ 200 ms) the instantaneous activity can be orders of magnitude over that produced by a DC proton beam, producing the same total yield, but in a much shorter time improving the peak to background ratio tremendously (IS316). With the 1.2 s repetion rate of the p-beam the background is also conveniently measured before next proton pulse hits the target.

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Gamow–Teller Strength in the β^+–Decay of ^{37}Ca and its Implications for the Detection of the Solar Neutrino Flux

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For the measurement of the solar neutrino flux by means of the Homestake mine ^{37}Cl detector[1] the Gamow-Teller strength function B(GT) of the ^{37}Cl(ν_e,e^-)^{37}Ar-reaction is needed. This distribution can be extracted from ^{37}Cl(p,n)^{37}Ar charge-exchange reactions[2] or, assuming good isospin symmetry, by measuring the B(GT) function for the β-decay of ^{37}Ca. The β-delayed proton- and the β-delayed γ-emission of ^{37}Ca was studied at the projectile fragment separator FRS[3] at GSI. A preliminary analysis of the experimental results, especially concerning the deduced B(GT) function, is discussed and compared to previous ^{37}Ca β-decay experiments and to ^{37}Cl(p,n)^{37}Ar reaction data. The γ-deexcitation of the first three excited states of ^{37}K fed by allowed β-decay of ^{37}Ca with excitation energies of 1370.9, 2750.4 and 3239.3 keV has been observed for the first time. Taking into account the measured γ-intensities, a value of Γ_γ/Γ_p=0.64 for the state at 2750.4 keV and the remarkably high value Γ_γ/Γ_p=25 for the 3239.3 keV state was obtained. With the new results, the B(GT) function extracted from the β-decay of ^{37}Ca agrees fairly well with the one obtained from ^{37}Cl(p,n)^{37}Ar reactions.

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PARITY NONCONSERVATION MEASUREMENTS IN RADIOACTIVE ATOMS: AN EXPERIMENTAL PERSPECTIVE*

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Progress towards making high precision measurements of parity nonconserving (PNC) atomic transition rates in Cs (and possibly Fr) isotopes are highlighted here as an important test of electroweak interactions in nuclei. By taking a suitable ratio of these PNC transition rates for several isotopes, the atomic structure uncertainties associated with extracting the weak interaction part of this process can be effectively eliminated. However, these ratios are sensitive to small changes in the neutron and proton radial distributions that occur from isotope to isotope. Although the rms charge radii have been measured in several isotopes of Cs [1] and Fr [2], the neutron radial distributions remain undetermined. Recent theoretical calculations by Chen and Vogel [3] indicate that, at least in the case of Cs isotopes, the influence of changing neutron radial distributions should not be a major problem in interpreting future PNC results.

To date such PNC experiments have been limited to measurements in ^{133}Cs [4], the only stable isotope of cesium. However, plans to use magnetic optical traps to concentrate, polarize, and cool radioactive species are seen as a way of undertaking such measurements. Several preparatory steps in undertaking such a PNC experiment with radioactive atoms have recently been made. The first is the high-intensity demonstration of a thin-target He-jet gas transport system operating at 700 μA of incident protons as a durable source of short-lived radioactive Cs isotopes. The second is the high efficiency trapping of Cs atoms directly out of the vapor state [5]. And third is the first trapping of radioactive species in a magnetic optical trap [6,7]. These and other developments related to undertaking PNC measurements with radioactive atoms will be discussed.

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DECAY MODES OF LIGHT NEUTRON-RICH NUCLEI: AN EXPERIMENTAL SURVEY USING THE TOFI SPECTROMETER*

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A survey exploring the β-delayed neutron and charged particle decay modes of light neutron-rich nuclei has been performed using the time-of-flight isochronous (TOFI) spectrometer. Beyond the initial experiment [1] where the power of this recoil tagging, time-correlated decay method was demonstrated, extensive new half-life, delayed-neutron emission probability, average delayed-neutron energy, and delayed-charged-particle emission probability measurements have been obtained for some 30 nuclei including such exotic nuclides as ^{11}Li, ^{14}Be, ^{17}B, ^{20}C, ... up to ^{28}Ne. A comparison of delayed-neutron emission probabilities measured in this work that uses a moderated ^{3}He neutron counter array to other measurements using scintillators suggests, in several cases, a sizable fraction of low-energy delayed neutrons that were not registered in scintillator-based experiments. These data are contrasted with improved gross theory, macroscopic-microscopic, QRPA, and shell model calculations where possible.

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Oral presentation requested

SHAPE COEXISTENCE AND DEFORMATIONS ABOVE Z=50: THE STUDY OF THE DECAY OF $^{120g+m}Cs$ TO LEVELS OF ^{120}Xe.*

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The regions of the chart of the nuclides where the proton number is nearly at a closed shell, and the neutron number approaches the middle of a major shell have proven to be rich in structures having coexisting shapes. This is most evident in the region Z ~ 82 and N ~ 104 (mid-shell neutron number), where, for example, the level structures of the Hg isotopes exhibit coexistence bands having quite different shape, with the deformed configuration minimized in energy near $^{184}Hg_{104}$. In this region it is the odd-parity $\pi h_{9/2}$ orbital, which crosses the Fermi surface at a deformation value $\beta_2 \sim 0.25$, that strongly influences [1]) the low-energy level structure of the Hg isotopes at mid-shell. In the region around Z = 50, shape coexisting structures have also been observed at and around mid-shell in the Sn nuclei, along with the closed-shell $\pm$ 2 nucleon mid-shell isotopes of Cd and Te. These cases of shape coexistence, as well as other documented cases of coexistence in even mass nuclei, including the Hg isotopes described above, have recently been reviewed by Wood et al. [2])

For the odd-Z nuclides above the Z = 50 closed shell there are well established bands [3]) associated with the $\pi g_{9/2}$ hole intruder structure, whereas the features of the intruder configurations in the even-even Te and Xe nuclides are less well defined. We have undertaken a study of the level structure of the mid-shell nucleus ^{120}Xe following the decay of $^{120g+m}Cs$ at the UNISOR isotope separator facility, for the purpose of investigating the role intruding 2p-4h states may play in determining the low energy structure of the Xe isotopes around N = 66. The collection of γ-ray and conversion electron singles, along with γ-γ and γ-e coincidence data has resulted in the identification of a number of new levels in ^{120}Xe, including several levels which depopulate by transitions having E0 multipolarity components. Lifetime measurements in the picosecond range have been made for several of the lower-spin states, and a new value for the B(E2; $0^+_1 \rightarrow 2^+_1$) has been extracted, which indicates that there is a large increase in B(E2) strength in the even-even Xe isotopes as mid-shell is approached. The appearance of E0 transitions in the low-energy portion of the level structure of ^{120}Xe and the jump observed in the B(E2) value for the transition between the first 2^+ state and the ground state both suggest that the low energy level structure of ^{120}Xe may be influenced by the crossing of the $\pi g_{9/2}$ orbital over the Z=50 shell closure and/or a change in the occupancy of the odd-parity $\pi h_{11/2}$ orbital.

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Fine structure in the α decay of neutron-deficient even-even nuclei in the Z=82 region: Study of low-lying 0^+ states in even-even Pt, Hg, Pb and Po isotopes

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The observation of fine structure in the α decay of several nuclei in the lead region has led to the identification and characterization of low-lying 0^+ states in the daughter nuclei [1-4]. These 0^+ excited states can be a manifestation of the coexistence of different shapes in the nucleus [5]. Due to its high selectivity in spin and parity change, α decay on mass-separated sources is very well suited to study low-lying 0^+ states in even-even nuclei far from stability. Using α-e-t coincidence techniques results in essentially backgroundfree spectra. Furthermore, it enables to extract the half life of the intermediate (0^+) state, giving information about the degree of mixing between intruder and normal state. This mixing can also very often be determined from the energy-level systematics of an isotopic chain combined with the low-spin behaviour of the rotationallike band built on top of the excited 0^+ state. A third way to determine the mixing is by comparing the reduced width of the s-wave α decay of the parent nucleus to the groundstate with the reduced width of the s-wave α decay to the excited 0^+ state.

Alpha-decay studies of $^{200,202}Rn$, $^{194,196,198}Po$, $^{186,188}Pb$ and $^{180,182,184}Hg$ to the excited 0^+ state in $^{196,198}Po$, $^{190,192,194}Pb$, $^{182,184}Hg$ and $^{176,178,180}Pt$ have been performed at the LISOL, GSI and ISOLDE mass separators. The observation of large variations in the hindrance factor of the α decay to the excited state, relative to the groundstate decay [1-4], is a proof of the persistence of the Z=82 shell closure at the neutron-deficient side. The hindrance of the α decay to the excited 0^+ state compared to the α decay to the groundstate can be used to probe the proton particle-hole character of the 0^+ states in the lead region

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SELF-CONSISTENT CALCULATION OF NUCLEAR SHAPES AND RADII IN SPHERICAL AND NONSPHERICAL NUCLEI

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The odd-even staggering of nuclear charge radii has long been an unsolved puzzle for nuclear structure theory. After some hints in that direction [1,2]) it has been demonstrated that this effect is connected with effective three-body forces (or more-body forces, in general) [3,4]). Proper inclusion of these not only allowed to calculate the odd-even effect of charge radii, but also an other feature could be qualitatively reproduced which hitherto had not been well described, namely the kinks in the general trend of charge radii at magic neutron numbers.

The calculations of refs. [3,4]) have been performed in the spirit of the Landau-Migdal theory of finite Fermi systems: only differences with respect to a reference nucleus have been computed employing the HFB method with effective forces.

In the meantime the feasibility of fully selfconsistent calculations with the so-called density functional method has been demonstrated [5-7]). This method is an alternative to HF calculations and can be considered as an extension of the Landau-Migdal theory. In order to apply it to nonmagic nuclei, pairing has to be included, and the ansatz for the pairing part of the energy functional must be such as to include three- or more-body forces. Then, for spherical nuclei, results very similar to the previous ones are obtained, but including also the absolute values.

With some changes in the numerical procedures, we have implemented the method also for nonspherical nuclei, making use of an existing code which had been developped by Damgaard et al. [8,9]) and has originally been used in connection with the Strutinski method. Deformation effects are very important in a complete discussion of isotopic shifts, particularly when dealing with long chains of isotopes which in recent years have been measured. First results obtained in the Pb region will be presented.

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INVESTIGATION OF COLLECTIVE EXCITATIONS IN PHOTON SCATTERING EXPERIMENTS

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In photon scattering or Nuclear Resonance Fluorescence (NRF) experiments using a bremsstrahlung source, the examined isotope is irraditated with an intense, continuous photon beam. The detection of the scatterered γ-rays with Ge-detectors results in a very high energy resolution. Due to the well known electromagnetic excitation mechanism, it is possible to determine the absolute transition strengths of the populated states independent of a model. The spin and strength selectivity of the method makes it an outstanding tool for the investigation of collective excitations, even in an energy region where the level density is already very high.

One of the most exciting findings in nuclear physics in the last decade was the observation of a new isovector collective magnetic dipole mode called "Scissors Mode" in electron scattering experiments by A. Richter and coworkers [1)]. Subsequent studies on a number of rare earth and actinides nuclei using electron [2)] and photon [3)] scattering yielded systematic information on the energetic position, fragmentation and strength of the M1 excitations. Very recently the coupling of an additional neutron to the "Scissors Mode" has been observed in the nucleus ^{163}Dy [4)]. A report on the latest photon scattering experiments on other odd nuclei will be given.

Another very rich field of interest studied in photon scattering experiments are electric dipole excitations. It was possible to show that the lowest 1^--states are octupole excitations both in spherical and in deformed nuclei. In the spherical nuclei the octupole vibration couples to the quadrupole vibration leading to two phonon states. Recently a multiplet of the structure $(2^+ \otimes 3^- \otimes j)$ has been identified in different N=82 and N=83 nuclei [5)]. In the well deformed nuclei the octupole vibration can couple to the quadrupole deformed core leading to octupole vibrational bands. These excitations are well understood, whereas the structure of strongly populated 1^--states at higher energies needs to be clarified [6)].

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