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HIGH-SPIN STRUCTURE OF ^{163}Lu

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Abstract

The $\pi 1/2^+[411]$ ground band structure of ^{163}Lu shows a large signature splitting with inversion above the backbend suggesting a shape change associated with the triaxiality degree of freedom. The $\pi 1/2^-[541]$ band shows no backbending up to $\hbar\omega$ = 0.4 MeV indicating a more deformed structure.

Recently, the cranked shell model has been very successful in interpreting the spectra of the deformed nuclei at high spins. In this picture, the nucleus is assumed to have an intrinsic nonspherical shape and to rotate adiabatically around a space fixed axis.[BEN79] Traditionally, most experimental and theoretical efforts were focused on the asphericity parameter ε_2 and its influence on the rotational spectra. In contrast, only very recently attention has been directed to the triaxiality parameter γ, which plays an important role on the evolution of shapes as a function of spin. More thorough investigations are needed to provide a detailed understanding of the behavior of nuclei at high spins as a function of γ.

It has been pointed out by several authors that the population of rotationally aligning high-j orbitals may provide a sensitive probe of the triaxiality parameter γ, and could be used to trace the evolution of γ with angular momentum [BEN83], [FRA83], [LEA83]. These observations are based on the fact that a particle (hole) in a high-j orbital polarizes the core toward

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oblate (prolate) shape, whereas, a quasi-particle in a half-filled high-j orbital shell generates the intermediate situation leading to a triaxial shape. These expectations where confirmed in a cranked shell-model calculation by Leander [LEA83], who concluded that in a γ-soft nucleus the presence of a high-j quasi-particle with favored signature will stabilize the shape of the nucleus at a γ value that depends initially on the position of the Fermi level in the shell. For non γ-soft nuclei that have a potential-energy minimum at some other γ value the quasi-particle exerts a driving force toward positive γ values when the shell is less than half full or toward negative γ values when it is more than half full. In contrast the unfavored signature states are much less sensitive to variations of γ and λ, the position of the Fermi level in the shell. This results in signature splittings that become a sensitive measure of the variation of γ-deformation with spin and λ. Inversion of signature splitting above the backbend in ${}^{157}_{67}Ho_{90}$ [HAG82] and in ${}^{159}_{69}Tm_{90}$ [RIE83] in the $\pi 7/2^-$[523] band was explained by the positive driving influence of the two $i_{13/2}$ neutrons above the backbend which results in a change from negative to slightly positive γ above the backbend.

In order to explore the possibility of such effects in the γ plane as a function of the proton number we have studied the high spin structure of ${}^{163}_{71}Lu_{92}$ which has two protons and two neutrons more than ${}^{159}Tm$. In this case the $\pi 1/2^+$[411] and $\pi 7/2^+$[404] orbitals would be predominantly populated. The former of these may be a new candidate for such a signature inversion.

The high spin states in ${}^{163}Lu$ were populated via the ${}^{122}Sn({}^{45}Sc,4n)$ reaction at 192 MeV with the tandem accelerator at the Holifield Heavy-Ion Facility. A stack of four (250 mg/cm^2 each) ${}^{122}Sn$ self-supporting foils were used as a target. A short run with a thicker (1.2 mg/cm^2) target gave similar energy resolution in the Ge γ-ray energy spectra.

The γ-ray spectroscopic information was obtained using an array of five Ge detectors with pentagonal NaI anti-Compton shields located at 63° to the beam and three additional Ge detectors at 24°. Two-fold or higher coincident events from these detectors were used to trigger the 72 NaI detectors of the Spin Spectrometer (SS) at ORNL. [JAA83] An average Compton suppression factor of 3.5 for the ${}^{60}Co$ spectrum was obtained. The Ge detectors were placed at 20.8 cm from the target.

The event tapes were processed in order to (1) linearize and match the gains of the NaI detectors, (2) separate the neutron from the γ pulses in the SS, and (3) construct the total pulse height, H, and the coincidence fold k. The processed events were then sorted by placing 2-dimensional gates in (H,k) space in order to separate the cascades associated with the 4n from the 5n channel. This procedure reduces the background from the competing channels by a factor of 2 or more. The gated events were sorted into an $E\gamma$-$E\gamma$ matrix, which was corrected for Ge detector efficiency. A two-dimensional background subtraction procedure was developed to subtract the Compton-Compton and peak-Compton backgrounds from each gate on the observed peaks. Angular correlation information was obtained from a matrix with the 24° and 63° detectors on separate axes.

In Fig. 1 are shown three band structures believed to be associated with ^{163}Lu. Energy systematics in the heavier odd A Lu isotopes show that the $1/2^+$[411] state decreases rapidly in energy with decreasing A relative to the $7/2^+$[404] state and in the ^{165}Lu and ^{163}Lu may become the ground state configuration. In ^{165}Lu [JON84] the $1/2^+$[411] is not strongly populated in the (^{16}O,4n) reaction, but in ^{163}Lu it is the strongest band populated in the present work. The decay scheme shown in Fig. 1 is preliminary and further analysis is in progress to connect the different structures based on observed coincident γ-rays. The transitions from all these structures have yields associated with (H,k) distributions characteristic of the (^{45}Sc,4n) reaction and thus were assigned to ^{163}Lu.

There is a striking similarity between some of the bands in ^{163}Lu and ^{165}Lu. In ^{165}Lu the $1/2^+$[411] band was seen up to I = $27/2^+$ and it has a very large signature splitting [JON84]. Based on systematics from the odd-A Lu isotopes, we have assigned this yrast band as the $\pi 1/2^+$[411]. The backbending in this region is due to breaking and alignment of an $i_{13/2}$ neutron pair, which places the backbending at about 12 units of rotational angular momentum. From this information the lowest state was assigned as $5/2^+$ although a $1/2^+$ is not excluded. A second band was assigned as $\pi 1/2^-$[541] based on systematics and in analogy with ^{165}Lu. A third band structure shown in Fig. 1 is most likely a part of the $7/2^+$[404] band.

The favored and unfavored bands ($\alpha = -\frac{1}{2}$ and $\frac{1}{2}$) gain 7.0 and 8.6 units of angular momentum above the backbend, respectively (Fig. 2a). This is con-

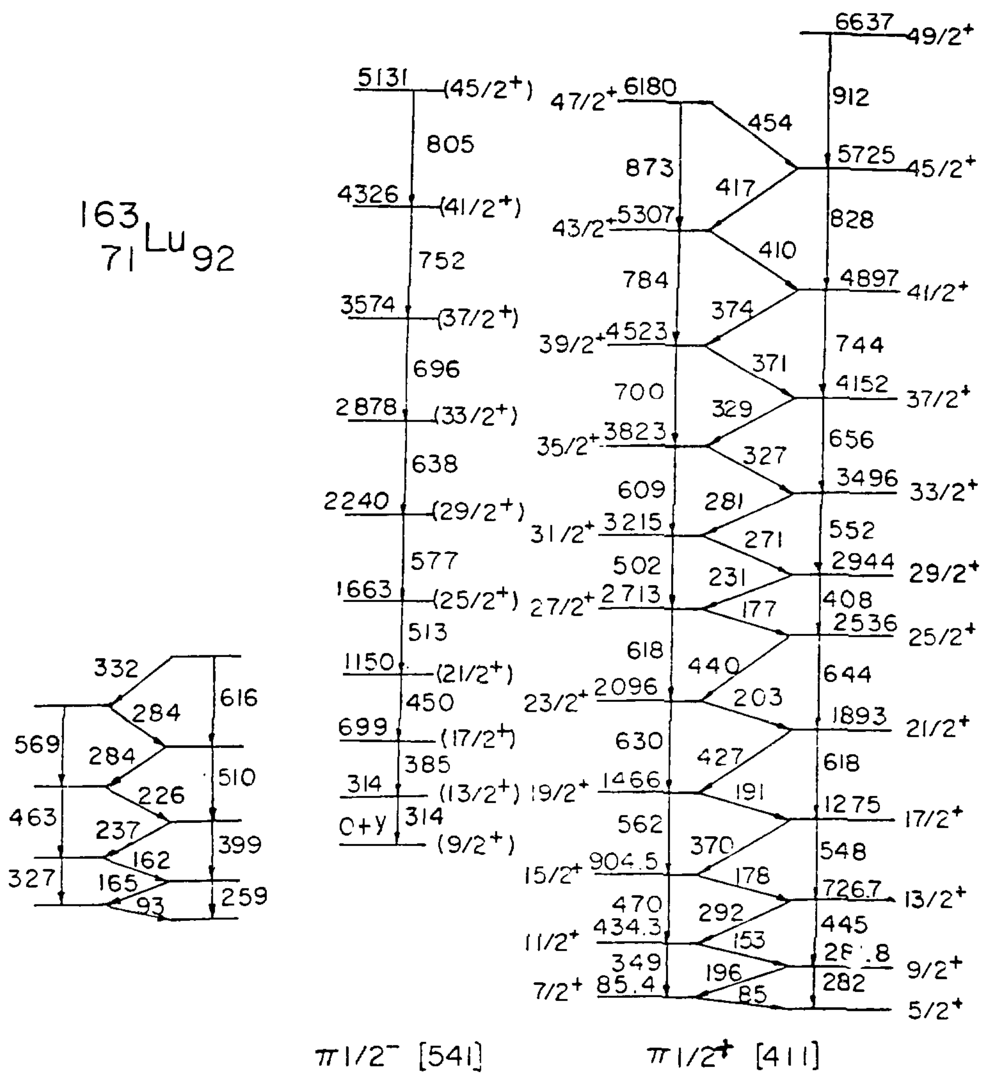

Fig. 1 Tentative decay scheme for the three band structures assigned to ^{163}Lu.

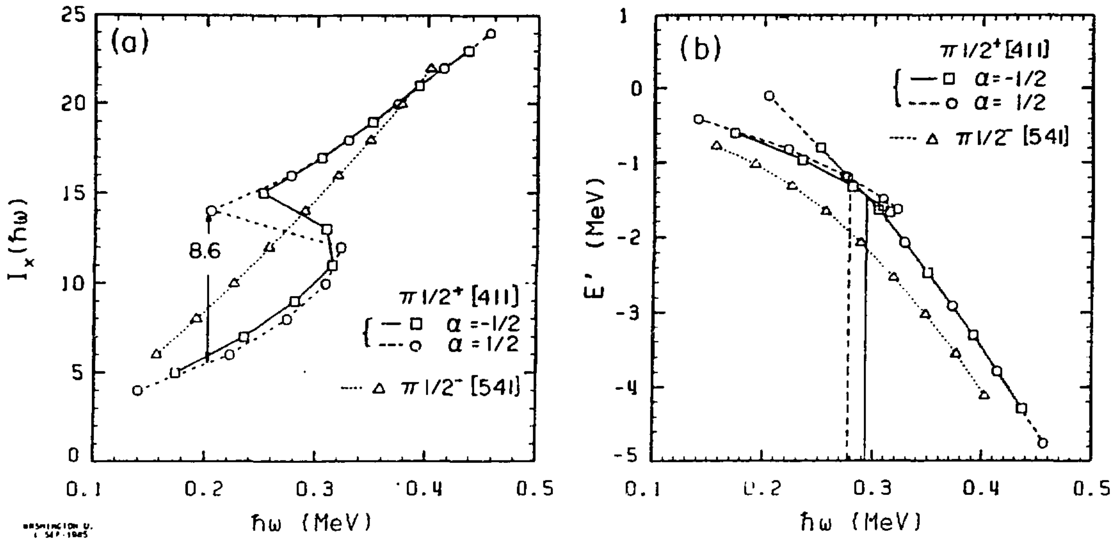

Fig. 2. Panels a and b show the aligned angular momentum and the energy in the rotating frame ($E' = E_{Level} - \hbar\omega I_x$) for the bands indicated.

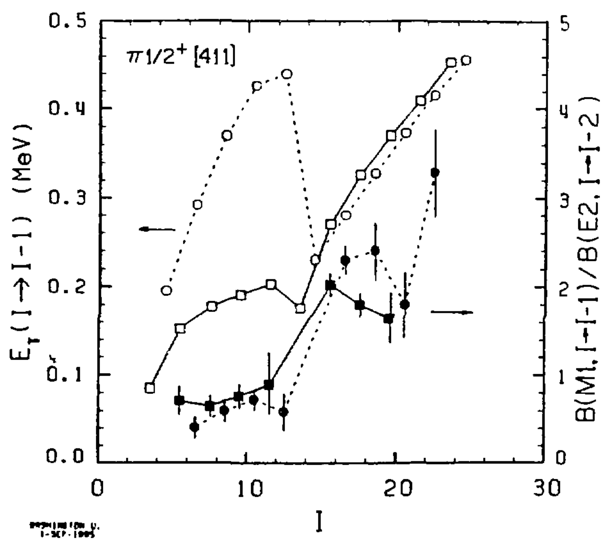

Fig. 3 Signature splitting indicated by the differences in Eγ (I→I-1) values for transitions starting from the $\alpha=-\frac{1}{2}$ levels (open squares) and the $\alpha=\frac{1}{2}$ levels (open circles). The corresponding full points give the B(M1,I→I-1)/B(E2, I→I-2) ratios obtained from branching ratios assuming $\delta=0$.

sistent with the decoupling and alignment of an $i_{13/2}$ neutron pair. The crossing frequencies for the $\alpha=-\frac{1}{2}$ and $\alpha=\frac{1}{2}$ bands are 0.278 and 0.293 MeV, respectively, as is seen from Fig. 2b. Below the backbend the $\pi 1/2^+$[411] band shows a large negative signature splitting which increases with ω from ~ 55 to 120 keV (Fig. 2b), but above the backbend a signature inversion occurs with a splitting of 10 keV which remains constant with increasing ω. This is seen in detail in Fig. 3.

A cranked shell-model calculation for ^{163}Lu gave a constant ~ 80 keV negative signature spitting for the quasi-protons for γ values between -60° and 20°. A signature inversion is predicted for the quasi-proton configuration at $\gamma \simeq 30^\circ$. Above the backbend the two $i_{13/2}$ quasi-neutrons are driving toward positive γ values. When the routhians for this 3-quasiparticles are added and the effect of the core is included, a γ value for this configuration can be obtained. Qualitatively, it appears that a significant shape change from negative to positive γ values is present in this case. Thus, the signature inversion in the $\pi 1/2^+[411]$ band is quite similar to that observed in ^{155}Ho on ^{159}Tm where the $7/2^-[523]$ quasi-proton configuration was pushed toward slightly positive γ values by the positive driving influence of the two strongly aligning $i_{13/2}$ quasi-neutrons.

Finally, the presence of the non-backbending $\pi 1/2^-[541]$ band in ^{163}Lu suggests that as in ^{165}Lu this band involves a substantially large ε_2 value of ~ 0.3 compared to the ε_2 = 0.2 value for the $\pi 1/2^+[411]$ configuration.

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References

[BEN79] R. Bengtsson and S. Frauendorf, Nucl. Phys. A 314, 27 (1979); A314, 139 (1979).

[BEN83] R. Bengtsson, et al. Bormio, 1982 p. 144; and in "High Angular Momentum Properties of Nuclei", Ed. N. R. Johnson (Harwood, New York, 1983) p. 161.

[FRA83] S. Frauendorf and F. R. May, Phys. Lett. 125B, 245 (1983).

[LEA83] G. A. Leander, et al. in "High Angular Momentum Properties of Nuclei", Ed. N. R. Johnson (Harwood, New York, 1983), p. 281.

[HAG82] G. B. Hagemann, et al. Phys. Rev. 25C, 3324 (1982).

[JÄÄ83] M. Jääskeläinen et al., Nucl. Instr. 204, 385 (1983).

[JON84] S. Jonsson et al. Nucl. Phys. A422, 397 (1984).