# Superdeformed bands in $^{153}$Ho

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(Received 7 July 1997)

In a recent experiment performed with the EUROGAM II $\gamma$-ray spectrometer three superdeformed (SD) bands have been established in $^{153}$Ho. The properties of these bands are discussed in terms of single-particle proton excitations and are compared with respect to the SD magic nucleus $^{152}$Dy. These results represent the first observation of SD structures in a holmium nucleus and provide further information on the proton orbitals lying above the $Z=66$ shell gap. [S0556-2813(97)04111-3]

PACS number(s): 21.10.Re, 23.20.En, 23.20.Lv, 27.70.+q

## I. INTRODUCTION

Nuclei in the neutron deficient mass $A \approx 150$ region of the Segré chart such as Gadolinium ($Z=64$), Terbium ($Z=65$), and Dysprosium ($Z=66$) have been extensively studied over the past 10 years. This is mainly due to the presence of shell gaps (at $Z=66$ and $N=86$) at a prolate quadrupole deformation of $\beta_2 \approx 0.6$, giving stability to superdeformed (SD) shapes, with a 2:1 axis ratio. The first evidence for a discrete line SD band originated in this mass region in $^{152}$Dy [1]. Following this discovery many other nuclei in this region of the Segré chart have been shown to possess SD bands [2].

Of the twenty-one SD nuclei in this region, there are only four with $N>86$ ($^{152}_{65}$Tb [3], $^{153}_{66}$Dy [4], $^{154}_{66}$Dy [5], and $^{155}_{66}$Dy [6]) and only one with $Z>66$ ($^{154}_{68}$Er [7]), thus lying above the SD shell gaps. Therefore, information on the character of the nuclear orbits, specifically above the SD shell gap at $Z=66$, is minimal and stems mainly from the behavior of the excited SD bands assigned to nuclei lying at or below this gap.

$^{152}$Dy ($Z=66$, $N=86$) can be defined as the doubly magic SD core nucleus in the $A \approx 150$ region, with the high-$N$ intruder configuration $\pi 6^4 \nu 7^2$. Six SD bands [8] are presently known in this nucleus, three based on neutron excitations from the core configuration (bands 4, 5, and 6) and two based on proton excitations (bands 2 and 3). The two proton excited bands are thought to be based on excitations from either the $\pi[301]1/2$ or the $\pi[651]3/2$ orbitals into the $\pi[770]1/2$ (band 2) or the $\pi[530]1/2$ (band 3) orbitals. Band 2 has a large dynamical moment of inertia $\mathcal{J}^{(2)}$ which shows evidence for an interaction occurring at a frequency of $\omega \approx 0.5$ MeV/$\hbar$, which has been attributed to the crossing of the $\pi[530]1/2$ and the $\pi[770]1/2$ orbitals. This interaction leads to a gain in alignment of $\approx 3\hbar$, which is consistent with that expected from theoretical calculations [9].

Superdeformed states in $^{153}$Ho ($Z=67$) (an isotone of $^{152}$Dy) are expected to be based on this $^{152}$Dy core plus one valence proton occupying one of the low-lying orbits above the shell gap. If the two proton excited bands in $^{152}$Dy originate from the [301]1/2 orbital then one might expect that the yrast SD band in $^{153}$Ho would be identical to one of these bands. This suggestion arises from the observed identicality between the first excited band and the yrast band in its $Z+1$ neighbor in the $N=86$ isotones [10], which is due to particle-hole excitations involving this [301]1/2 orbital.

Previous studies of $^{153}$Ho [11] provided evidence for ridgelike structures in an $E_\gamma$-$E_\gamma$ correlation matrix with a separation from the matrix diagonal of $\approx 52$ keV, however, no discrete $\gamma$-ray transitions were observed. In this paper we report on the first observation of three discrete-line superdeformed structures in $^{153}$Ho.

## II. EXPERIMENTAL DETAILS

The experiment was performed with the EUROGAM II $\gamma$-ray spectrometer [12] at CRN Strasbourg. High-spin states in $^{153}$Ho were populated via the $^{120}$Sn($^{37}$Cl,4$n$)$^{153}$Ho fusion-evaporation reaction at a bombarding energy of 177 MeV. The $^{37}$Cl beam was provided by the Vivitron electrostatic accelerator and was incident upon two stacked, self-supporting targets of $^{120}$Sn, each of nominal thickness 440 $\mu$g cm$^{-2}$. Approximately $7.7 \times 10^8$ events of suppressed fold $\geqslant 4$ were collected during the experiment. After unfolding these data, using the method described in Ref. [13], approximately $8.8 \times 10^9$ triplefold coincidences resulted. The 4$n$ exit channel to $^{153}$Ho was the most intensely populated,

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TABLE I. The $\gamma$-ray energies, relative in-band intensities, and the measured $R_{asym}$ angular correlation ratios for SD band 1. The unmarked transitions were unable to be measured due to contamination or low intensity. Tentative transitions are marked with an asterisk.

| $E_\gamma$ (keV) | Intensity | $R_{asym}$ |
|---|---|---|
| 651.3 (19) | 0.44 (5) | |
| 695.8 (11) | 0.75 (8) | 1.5 (4) |
| 740.0 (8) | 0.95 (8) | 1.3 (3) |
| 784.0 (2) | 0.99 (8) | 1.4 (4) |
| 830.6 (5) | | |
| 875.6 (3) | 0.97 (10) | 1.3 (2) |
| 922.3 (3) | 1.06 (9) | |
| 969.5 (5) | 0.89 (9) | 1.3 (3) |
| 1014.9 (5) | 0.92 (8) | 1.4 (3) |
| 1059.9 (3) | 0.60 (10) | 1.6 (6) |
| 1103.1 (3) | 0.71 (10) | |
| 1144.4 (3) | 0.41 (7) | |
| 1180.3 (3) | 0.52 (8) | |
| 1215.5 (3) | 0.27 (6) | |
| 1251.1 (3) | 0.27 (5) | |
| 1295.2 (6) | | |
| 1343* (1) | | |
| 1390* (1) | | |

Assigned spins for the lowest and highest observed transitions

$\frac{55}{2}^-\hbar \rightarrow \frac{51}{2}^-\hbar$ (651 keV)

$\frac{123}{2}^-\hbar \rightarrow \frac{119}{2}^-\hbar$ (1390 keV)

TABLE II. The $\gamma$-ray energies, proposed spins, and relative in-band intensities for SD bands 2 and 3. The unmarked transitions were unable to be measured due to contamination or low intensity. Tentative transitions are marked with an asterisk.

| Band 2 | | Band 3 | |
|---|---|---|---|
| $E_\gamma$ (keV) | Intensity | $E_\gamma$ (keV) | Intensity |
| 713* (2) | | 657* (2) | |
| 761* (2) | | 683.3 (7) | 0.95 (8) |
| 808.4 (3) | 0.41 (8) | 726.3 (5) | |
| 854.1 (3) | 0.74 (8) | 770.8 (3) | 0.83 (9) |
| 900.3 (3) | 1.26 (9) | 816.3 (3) | 0.98 (8) |
| 946.6 (3) | 0.96 (9) | 861.3 (3) | 1.00 (8) |
| 993.1 (5) | | 906.9 (5) | |
| 1041.3 (5) | | 953.3 (3) | 0.89 (8) |
| 1087.6 (3) | 1.04 (10) | 996.4 (5) | |
| 1133.7 (6) | 0.92 (9) | 1046.1 (4) | 0.67 (10) |
| 1182.3 (3) | 0.94 (9) | 1092.7 (3) | 0.71 (8) |
| 1229.6 (3) | 0.84 (8) | 1143.3 (5) | 0.64 (8) |
| 1278.4 (4) | 0.71 (8) | 1194.9 (5) | |
| 1326.2 (4) | 0.24 (8) | 1247.4 (10) | 0.51 (8) |
| 1377.0 (4) | | 1297.4 (10) | 0.32 (9) |
| 1425* (2) | | 1351* (2) | 0.32 (9) |

Measured band intensities (Band 1 = 100%)

| Band 2 | Band 3 |
|---|---|
| $30\pm5$ | $30\pm5$ |

Assigned spins and parities for the lowest and highest observed transitions

| Band 2 | Band 3 |
|---|---|
| $\frac{61}{2}^-\hbar \rightarrow \frac{57}{2}^-\hbar$ (713 keV) | $\frac{53}{2}^-\hbar \rightarrow \frac{49}{2}^-\hbar$ (657 keV) |
| $\frac{121}{2}^-\hbar \rightarrow \frac{117}{2}^-$ (1425 keV) | $\frac{117}{2}^-\hbar \rightarrow \frac{113}{2}^-\hbar$ (1351 keV) |

carrying $\approx$45% of the total evaporation cross section for the reaction. For comparison, the $^{154}$Ho $(3n)$, $^{152}$Ho $(5n)$, $^{153}$Dy $(p3n)$, $^{152}$Dy $(p4n)$, and $^{150}$Tb $(\alpha 3n)$ channels carried $\approx$2, 3, 8, 10, and 22% of the total reaction intensity, respectively.

## III. RESULTS

The data were sorted into an $E_\gamma$-$E_\gamma$-$E_\gamma$ three-dimensional coincidence cube [14], which was examined for rotational structures with a separation of $\approx$50 keV (the typical separation of SD transitions in this mass region) using the search algorithms of Wilson [15] and Hibbert [16]. Several structures were found that appeared to be good candidates for SD bands in $^{153}$Ho. On subsequent analysis, the majority of these bands were identified with the previously known yrast SD bands in $^{152,153}$Dy [8,4] and $^{150}$Tb [17]. However, three SD bands have been identified based on these searches, which have not been previously observed in any of the major reaction channels populated in this reaction. These three bands have all been assigned to $^{153}$Ho based on observed coincidences with low-lying normal-deformed (ND) transitions in $^{153}$Ho and on the population intensities of these bands measured with respect to ND channels.

The transition energies of these new SD bands are listed in Tables I and II, while coincidence spectra of the three bands are shown in Fig. 1. Band 1 was found to carry $\approx$0.4% of the decay intensity of $^{153}$Ho, relative to the 913 keV $\frac{35}{2}\hbar \rightarrow \frac{31}{2}\hbar$ normal-deformed transition [18] (the 913-keV transition directly feeds the 229-ns isomer in $^{153}$Ho). Bands 2 and 3 are weaker than band 1, having intensities which are $\approx$30% that of band 1.

The multipolarities of the in-band transitions for band 1 have been established from the angular correlation ratio, defined as

$$R_{asym} = \frac{I_\gamma(\text{forward}+\text{backward})}{I_\gamma(90°)}.$$

To extract the $R_{asym}$ ratio the data were sorted into two single-gated $E_\gamma$-$E_\gamma$ asymmetric matrices, with the requirement that at least one of the ''clean'' band members was present in any detector before the matrix event was incremented. The first matrix had detectors at the angles 22.4°, 46.4° (forward), 133.6°, and 157.6° (backward) on the one axis versus all detectors on the second axis, while the second matrix contained those detectors which were close to 90° (71.0°, 80.0°, 100.0°, and 109.0°) versus all detectors. The $R_{asym}$ ratio for a $\gamma$-ray transition was obtained from the ratio of the peak areas in both matrices when the same coincidence gates were placed on the ''all'' detector axis. The ratio was extracted for both the band members and some of the normal-deformed transitions in $^{153}$Ho [18] for calibration. Known stretched quadrupole transitions yielded a weighted average ratio, $R_{asym} = 1.49\pm0.15$, while stretched dipole

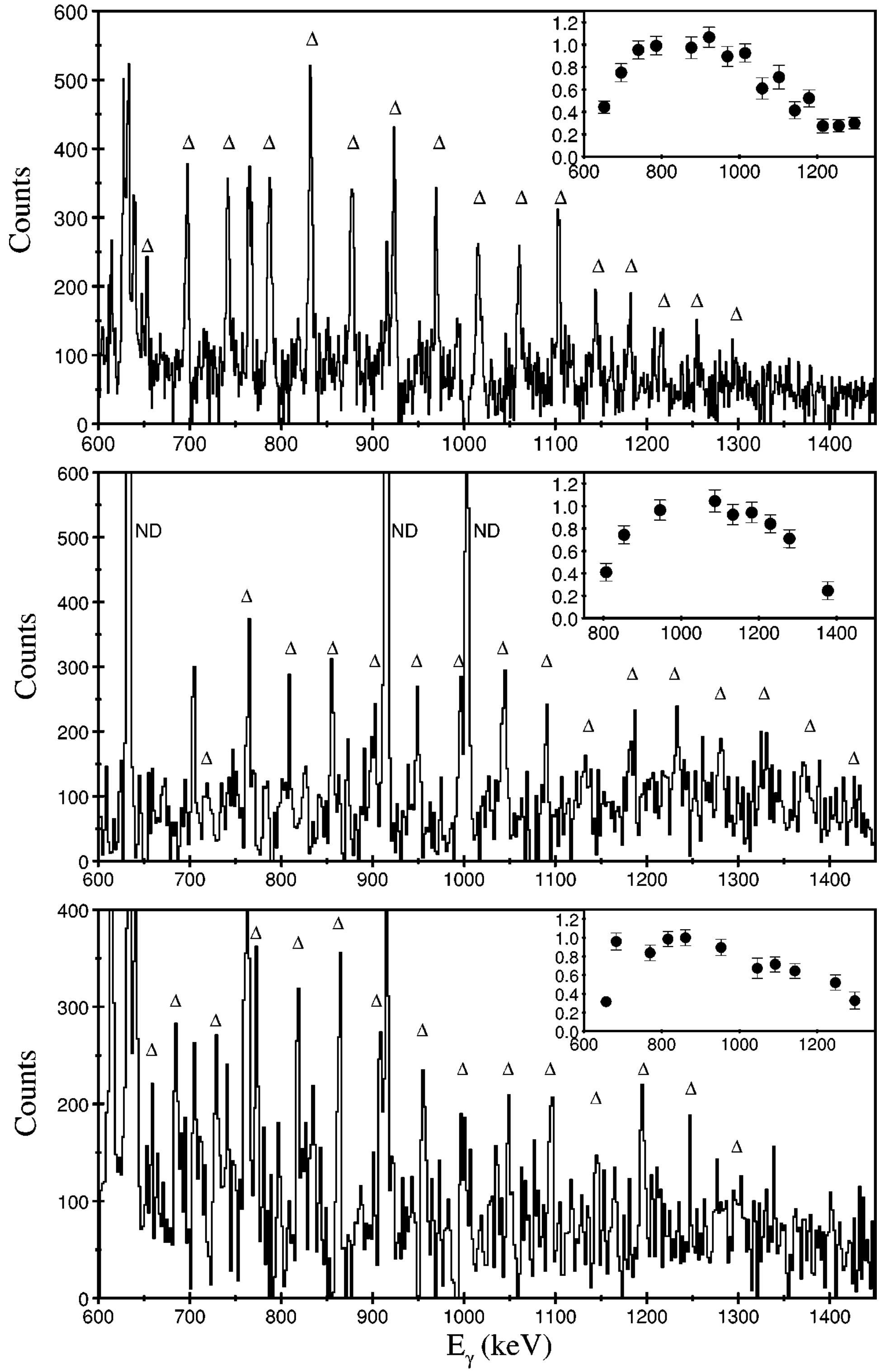


FIG. 1. Coincidence spectra (double gated) for SD bands 1–3 in $^{153}$Ho. Band 1 (top) is compressed to 1 keV/chan while bands 2 (middle) and 3 (bottom) are at 2 keV/chan. The insets show the relative in-band intensities. Band members are marked by a △.

transitions gave $R_{asym}=1.08\pm0.12$. The measured $R_{asym}$ values for the individual band members are presented in Table I. The weighted average value for band 1 is $R_{asym}=1.41\pm0.12$, which is consistent with the transitions being stretched quadrupole in nature.

The relative in-band intensity profile for band 1 is displayed in the inset of Fig. 1 (top) and is typical of those of other SD bands in this mass region; the band is fed over the seven to eight highest energy transitions until it reaches a plateau region (where there is no discernible feed-in or decay-out) and then decays over the lowest energy two to three transitions.

By using a series of double gates in an $E_\gamma$-$E_\gamma$-$E_\gamma$ coincidence cube, where one of the gates was on a ND transition, while the second was placed on a SD transition, the third $\gamma$ ray being projected, it was possible to determine what ND states were fed by band 1. It was found that band 1 fed ND states in $^{153}$Ho up to spin 49/2 $\hbar$, however, no transitions were observed linking the ND states to the SD states.

Band 2 consists of sixteen $\gamma$-ray transitions ranging in energy from 713 to 1425 keV. A triples coincidence spectrum of this band is presented in Fig. 1 (middle), while the energies and relative in-band intensities are given in Table II. Due to the weak intensity of this band the $R_{\rm asym}$ ratios could not be measured. The relative in-band intensity profile, Fig. 1 (middle, inset), shows that this band is fed over the two to three highest energy transitions, and depopulates over the lowest energy two to three transitions separated by a large plateau region.

The transition energies of band 2 lie at the half points, in energy, of those in band 1 (for energies below 1 MeV), indicating that these two bands may be signature partners. For energies $\geqslant 1$ MeV the relationship between the transition energies of bands 1 and 2 is no longer constant. No evidence has been observed experimentally that band 2 and band 1 ''talk'' to each other via interlinking dipole transitions. Due to the relatively weak population intensity of this band the ND states fed by this band were difficult to discern.

Band 3 consists of sixteen $\gamma$-ray transitions ranging in energy from 657 to 1351 keV. A triples coincidence spectrum of this band is presented in Fig. 1 (bottom), while the energies and relative in-band intensities are given in Table II. Again, due to the weak population intensity of this band the $R_{\rm asym}$ ratios could not be measured. The relative in-band intensity profile, Fig. 1 (bottom, inset), shows that the band decays over the lowest two to three energy transitions, while the band is fed over the highest energy seven to eight transitions until a relatively small plateau region is reached. Similarly to band 2, the ND states fed by this band were difficult to discern.

## IV. DISCUSSION

The dynamic moments of inertia ($\mathcal{J}^{(2)}$) of SD bands in the mass 150 region have been shown to be sensitive to the single-particle structure of the band, with the magnitude related to the number of high-$N$ intruder orbits that are occupied [9]. Theoretically, the $\mathcal{J}^{(2)}$ moment of inertia reflects the curvature of the single-particle orbitals, while experimentally it is simply extracted from the measured $\gamma$-ray energies. The experimental $\mathcal{J}^{(2)}$ moments of inertia of bands 1, 2, and 3 are plotted in Figs. 2(a)–2(c) as a function of rotational frequency where they are compared with the moment of inertia for the yrast SD band in $^{152}$Dy (open squares). As can be seen, at low frequencies, below $\approx 0.5$ MeV/$\hbar$, the moments of inertia of bands 1 and 2 are similar to each other and to that of $^{152}$Dy. However, band 1 appears to undergo a band crossing at a frequency of 0.6 MeV/$\hbar$, where a large increase in the $\mathcal{J}^{(2)}$ is observed. In contrast, the moment of inertia of band 2 continues smoothly up to its highest observed frequency $\omega \approx 0.7$ MeV/$\hbar$. The $\mathcal{J}^{(2)}$ for band 3 is different from that of bands 1 and 2 in that it exhibits a drop in magnitude at a frequency of $\omega \approx 0.55$ MeV/$\hbar$, indicative of a strong interaction taking place at this frequency.

Due to the large shell gap for neutrons ($\approx 1.7$ MeV) and the availability of an unpaired proton it is likely that the observed SD bands in $^{153}$Ho are based on valence proton configurations. (SD bands based on neutron excitations are expected; however, such bands would have a weak population intensity, as in $^{152}$Dy [8], compared with bands based on proton excitations.) Calculated single-particle proton Routhians are plotted in Fig. 3 as a function of rotational frequency for a deformation of $\beta_2 = 0.62$ (a similar deformation to that measured for the yrast SD band in $^{152}$Dy [19]). The low-lying proton [530]1/2 orbital is an obvious choice for the 67th proton for band 1 (the yrast band). The observed interaction in this band is well reproduced by the crossing of the [770]1/2 intruder orbital at $\omega \approx 0.6$ MeV/$\hbar$. The measured gain in alignment for band 1, $\approx 2.4\hbar$, compares well with the calculated change of 2.8 $\hbar$. Thus a likely configuration for band 1 is $\pi 6^4 \nu 7^2 \otimes \pi[770]1/2$ ($\alpha = -1/2$) at high frequencies and $\pi 6^4 \nu 7^2 \otimes \pi[530]1/2$ ($\alpha = -1/2$) at lower frequencies, below the crossing.

The transition energies of band 1 are almost identical to those of the yrast superdeformed band in $^{152}$Dy [8] below $\omega \approx 0.5$ MeV/$\hbar$, with a root mean square (r.m.s.) average energy difference of 2.08 keV. This is similar to the effect observed in $^{133}$Ce [20] when the extra neutron above the $^{132}$Ce core is placed in the *neutron* [530]1/2 orbital. In this case the observed r.m.s. deviation from identicality between the superdeformed core nucleus ($^{132}$Ce) and the $N+1$ nucleus was 1.0 keV over the frequency range $\omega \approx 0.55$ to 0.75 MeV/$\hbar$. Outside this range there was a small observed difference from identicality, attributed to the curvature of the $\nu[530]1/2$ orbital.

As a specific decay sequence has not been observed linking the SD states to the ND states in $^{153}$Ho it is not possible to determine the absolute spins of the SD states. Rather the spins of the observed SD states in $^{153}$Ho have been assigned relative to the spins of the yrast SD band in $^{152}$Dy [8]. In assigning the spins to the yrast SD band in $^{152}$Dy, Dagnall *et al.* [8] used the relative alignment method prescribed by Ragnarsson [21]. Ragnarsson suggested two possible spin assignments for the yrast SD band in $^{152}$Dy, differing by two units of spin. From the two possibilities calculated by Ragnarsson, Dagnall *et al.* [8] assigned the 602.4-keV transition, in the yrast band of $^{152}$Dy, to deexcite from the $26^+$ to the $24^+$ state. Assuming that these spins are correct, making use of the relationship between transition energy and spin shown by Stephens [22], and taking into account the signature of the orbital containing the extra proton, the 651-keV transition in band 1 has been assigned $\frac{55}{2}\hbar \rightarrow \frac{51}{2}\hbar$. As this band is built on an $N=5$ orbital, the in-band states are assigned to have negative parity.

The similarity of the $\mathcal{J}^{(2)}$ moments of inertia for band 2 and the yrast SD band in $^{152}$Dy implies that both of these bands are based on the same high-$N$ intruder configuration, i.e., $\pi 6^4 \nu 7^2$, with the 67th proton occupying a flat, natural parity orbital. Examples of such proton orbitals close to the Fermi surface for $^{153}$Ho are the $[530]1/2(\alpha=+1/2)$, $[523]7/2(\alpha=+1/2)$, and the $[532]3/2(\alpha=+1/2)$ orbitals. The transition energies for band 2 lie at the half-points of those of the yrast SD band in $^{152}$Dy. This requires an orbital having a decoupling parameter $a=-1$, where the decoupling parameter $a$ is defined in the strong coupling limit as

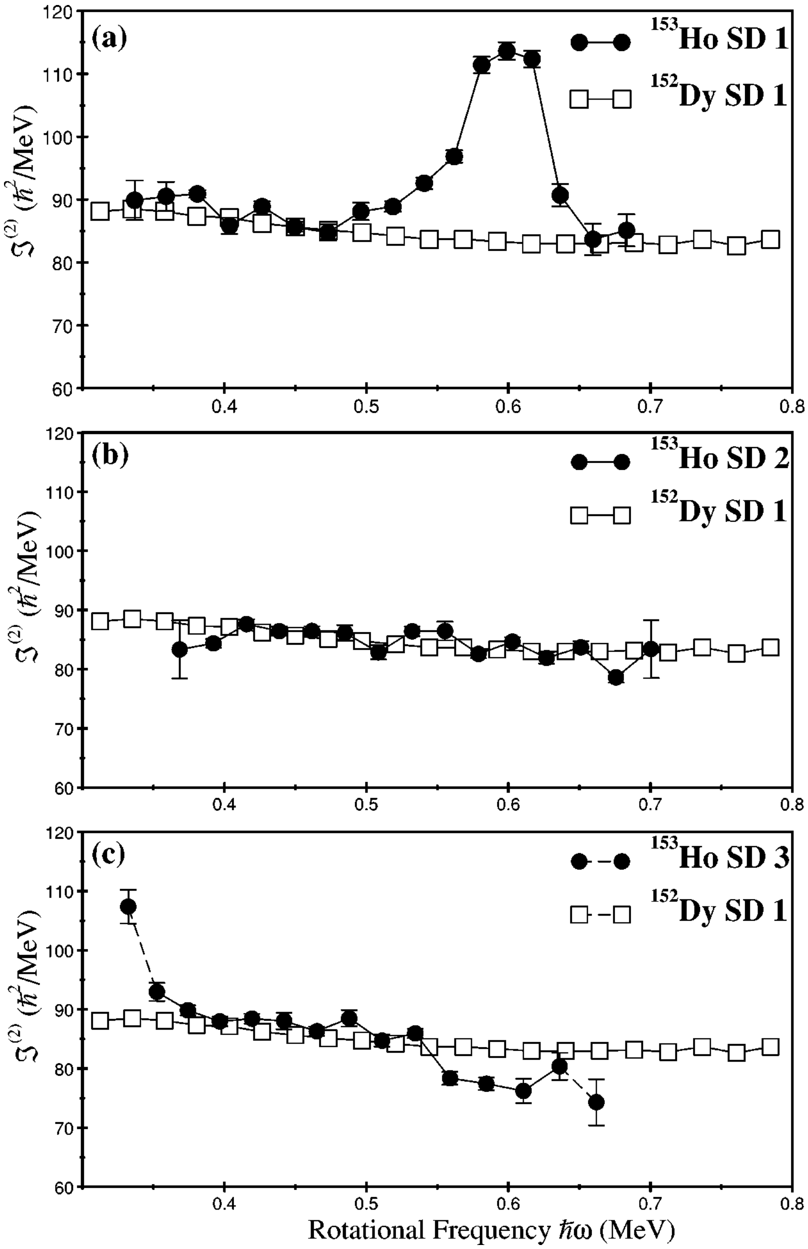


FIG. 2. A comparison of the dynamical moment of inertia $\mathcal{J}^2$ for bands 1 (a), 2 (b), and 3 (c) in $^{153}$Ho, and the yrast band of the doubly magic SD nucleus $^{152}$Dy.

$a=(-1)^N\delta_{\Lambda,0}$ [23]. The orbital closest to the Fermi surface in $^{153}$Ho which fulfills these conditions is the negative parity [530]1/2 orbital. Accordingly we have assigned band 2 as the signature partner to band 1 with the configuration $\pi 6^4 \nu 7^2 \otimes \pi[530]1/2(\alpha=+1/2)$. This is the first identical SD band in the $A\approx 150$ mass region which is observed at half-point energies where the concept of pseudospin is not required to explain.

An alternative configuration for bands 1 and 2 could involve the nearby $\pi[523]7/2$ orbital. A configuration based on the occupation of this orbital by the 67th proton also reproduces the observed features of these bands, the interaction and energy relationships although at a somewhat lower deformation of $\beta_2=0.58$ MeV. The predicted gain in alignment, however, due to the crossing of the $\pi[523]7/2$ and $\pi[770]1/2$ orbitals, is $5\hbar$ which does not agree well with the measured value for band 1. Furthermore at this lower deformation there is predicted to be a quasineutron crossing at a frequency of $\omega\approx 0.45$ MeV/$\hbar$ (see Fig. 8 in Ref. [17] and the associated discussion), evidence for such a crossing would be observed by a rise in the magnitude of the $\mathcal{J}^{(2)}$ for the band at this frequency. Such a rise in $\mathcal{J}^{(2)}$ at low frequencies is not observed for either bands 1 or 2, therefore, the former configuration is preferred.

The spins and parities for band 2 have been assigned in a similar way to band 1. As bands 1 and 2 are thought to be signature partners, the spins of the states in band 2 should have 1 $\hbar$ more spin (as the proton is excited from an $\alpha=-1/2$ state to an $\alpha=+1/2$ state). This implies that the spin of the 713-keV transition is $\frac{61}{2}\hbar\rightarrow\frac{57}{2}\hbar$. Again the states in

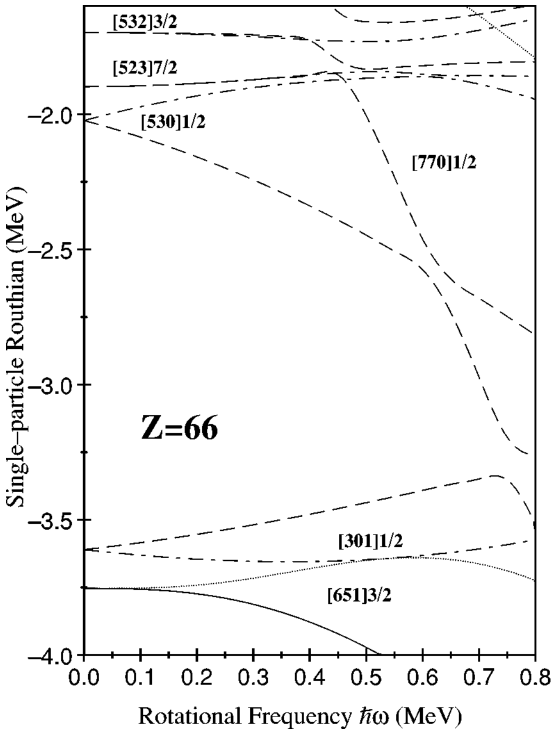


FIG. 3. Cranked shell model calculations for the proton single-particle orbits close to the Fermi surface of $^{153}$Ho. Calculated for $\beta_2=0.63$, $\beta_4=0.12$, $\gamma=0.0°$ [Dotted lines represent orbitals with $(\pi,\alpha)=(+,-1/2)$; dashed for $(\pi,\alpha)=(-,-1/2)$; solid for $(\pi,\alpha)=(+,+1/2)$; dot-dashed for $(\pi,\alpha)=(-,+1/2)$].

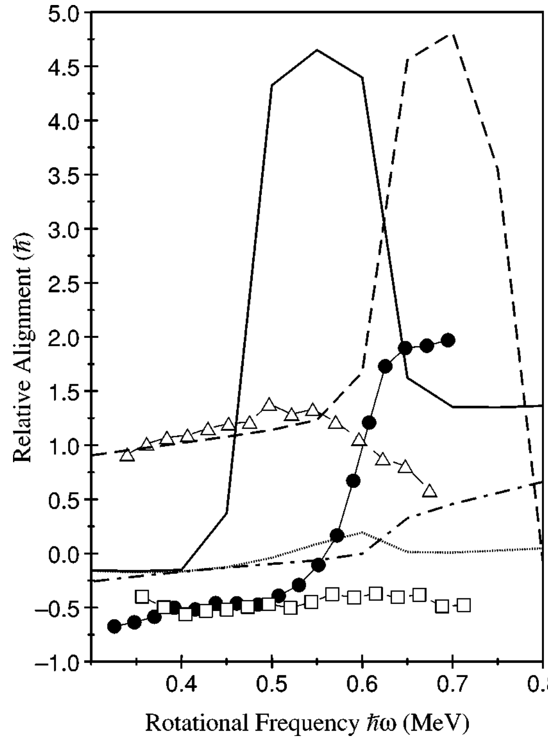


FIG. 4. A comparison of the experimental relative alignments of the three SD bands in $^{153}$Ho with respect to the $^{152}$Dy SD core, and the calculated contributions to the alignment of the nucleus from cranked shell model calculations (CSM). Filled circles: band 1; squares: band 2, triangles: band 3. Dashed line: CSM predicted alignment contribution from the $\pi[530]1/2(\alpha=-1/2)$. Dot-dashed line: CSM predicted alignment contribution from the $\pi[530]1/2(\alpha=+1/2)$. Solid line: CSM predicted alignment contribution from the $\pi[523]7/2(\alpha=-1/2)$. Dotted line: CSM predicted alignment contribution from the $\pi[523]7/2(\alpha=+1/2)$.

band 2 are assigned to be negative parity.

The $\mathcal{J}^{(2)}$ moment of inertia for band 3 between $\omega\approx0.45$ and 0.55 MeV/$\hbar$ is similar to that of band 1 in $^{152}$Dy. However at higher frequencies, it exhibits a small but measurable drop in the magnitude of its $\mathcal{J}^{(2)}$, this is accompanied by a loss in alignment of $\approx0.5\hbar$. As with band 1, this loss in alignment can be used to aid in the configuration assignment for this band. It is possible to extract, from cranked shell model calculations [24], the theoretical addition a specific orbital contributes to the alignment of the system. The calculated single-particle contributions to the alignment from the $\pi[530]1/2$ and $\pi[523]7/2$ orbitals are shown in Fig. 4. The experimentally measured relative alignment for band 3 (relative to the yrast SD band in $^{152}$Dy) shows a gradual increase from $\omega\approx0.4$ MeV/$\hbar$ to $\omega\approx0.55$ MeV/$\hbar$ where there occurs a sudden loss in alignment. Theoretically, calculations carried out for the [523]7/2 $(\alpha=+1/2)$ orbital, Fig. 4, show that this orbital mimics the experimentally observed behavior. However, the calculated loss in alignment is $\approx0.2\hbar$, which occurs at $\omega\approx0.6$ MeV/$\hbar$. From these observed characteristics, the most probable configuration for band 3 is the $^{152}$Dy SD core coupled to the positive signature of the $\pi[523]7/2$ orbital.

In order to assign the spins and parities for band 3, a similar procedure to that used for bands 1 and 2 has been employed. It is found that the transition energies for band 3 lie at the 3/4 points to the transition energies for the yrast SD band in $^{152}$Dy. Following this relationship, the spins of the two states connected by the 657-keV transition are assigned to be $\frac{53}{2}\hbar$ and $\frac{49}{2}\hbar$. As this band is thought to be based on an $N=5$ orbital, the individual states comprising the band are assigned to be of negative parity.

## V. CONCLUSIONS

Three superdeformed bands have been observed, and have been assigned to the nucleus $^{153}$Ho. The configurations of the three bands have been assigned based on single-proton excitations. The transition energies for band 2 lie at the half points of the corresponding transitions of the yrast SD band in $^{152}$Dy, this relationship is understood in the strong coupling limit without the need to invoke pseudospin. This is the first study of SD states in a $Z=67$ nucleus and the first observation of excited SD structures in a nucleus with $Z>66$.

## ACKNOWLEDGMENTS

We wish to thank the crew of the Vivitron for providing the beam, we also wish to thank D. C. Radford for his analysis software [14]. Two of us (D.E.A. and M.B.S.) acknowledge the support of EPSRC. EUROGAM is jointly funded by EPSRC (U.K.) and IN2P3 (France).

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