Smooth band termination in odd mass La nuclei: ^{127,129,131}La

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High spin states in ^{127,129,131}La have been investigated using the ^{100}Mo(^{32}S,$p4n$), $E=160$ MeV, ^{100}Mo(^{34}S,$p4n$), $E=155$ MeV, and ^{100}Mo(^{36}S,$p4n$), $E=160$ MeV reactions, respectively. γ rays were detected using the EUROBALL IV (^{127,131}La) and EUROGAM II (^{129}La) arrays. The results have enabled the negative parity yrast band, built on the $\pi h_{11/2}$ orbital at low spin, and the lowest lying $(\pi,\alpha)=(+,\pm\frac{1}{2})$ bands to be extended to higher spins. The positive parity, $\alpha=-\frac{1}{2}$, bands in ^{127,129}La and the positive parity, $\alpha=\frac{1}{2}$, band in ^{127}La can be interpreted, with the aid of cranked Nilsson-Strutinsky calculations, as examples of smoothly terminating bands in valence space based on both signatures of the $\pi[(g_{7/2}d_{5/2})^5(h_{11/2})^2] \otimes \nu[(g_{7/2}d_{5/2})^x(h_{11/2})^6(d_{3/2}s_{1/2})^2]$ configuration, where $x=12,14$ for ^{127,129}La, respectively. The favored $\alpha=-\frac{1}{2}$ bands of these configurations are predicted to terminate at $\frac{95}{2}^+$ and $\frac{83}{2}^+$, respectively, and experimentally the bands are observed to within two transitions of these terminating states. The data for the positive parity, $\alpha=\frac{1}{2}$, band in ^{129}La do not allow any firm conclusions to be made regarding the high spin structure of this band. The positive parity bands in ^{131}La have a different structure at high spin compared with the lighter nuclei. In this case the bands may be interpreted in terms of a $\pi[(g_{7/2}d_{5/2})^5(h_{11/2})^2] \otimes \nu[(g_{7/2}d_{5/2})^{12}(h_{11/2})^8(d_{3/2}s_{1/2})^4]$ configuration relative to a ^{100}Sn core.

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I. INTRODUCTION

Although the phenomenon of smoothly terminating bands is now well established in the $A\sim110$ and 60 regions [1], the investigation of similar bands in other mass regions is important in order to obtain a more complete understanding of many-fermion quantum mechanical systems, since a continuous transition from collective rotation to a noncollective single particle state appears to be a unique feature of nuclei. In a smoothly terminating band a specific configuration possesses collective, rotational-like, features at low spin but gradually loses this collectivity as the spin increases and eventually terminates at the maximum spin in a fully aligned state of single particle character [1,2]. In this configuration, the nucleus slowly traces a path over many states through the triaxial plane from a near prolate to either a noncollective oblate ($\gamma=60°$) or noncollective prolate ($\gamma=-120°$) shape. Furthermore, in order to observe smooth band termination it is essential that a particular configuration can be followed up to or close to the terminating state. Structures of this type, based on proton two-particle–two-hole ($2p$-$2h$) excitations across the $Z=50$ shell gap, are well known in the $A\sim110$ region (e.g., see Refs. [1,3,4]).

As the mass number A, and hence the number of valence particles, increases there are two different scenarios for the continuation of these bands. First, there is the possibility of bands which are based on two $g_{9/2}$ proton holes in the $Z=50$ core, i.e., similar to the smooth terminating bands in the $Z=50$–53 nuclei [1]. However, as A increases the maximum spin for these structures will soon become greater than can be observed in experiment, because of the large number of valence particles and holes involved in the configurations. Indeed, the superdeformed bands around ^{132}Ce are interpreted to be of this type [5] and to terminate with spins of the order of $80\hbar$. Secondly, bands with no holes in the $Z=50$ core are possible. These are expected to have a maximum spin of $I\sim40$–$60\ \hbar$ in the $A\sim130$ region.

Recent work on the spectroscopy of ^{127}La has revealed the first evidence in the mass 130 region for smooth band termination [6]. The observed structure has been assigned a configuration which does not have holes in the $g_{9/2}$ orbital. Recent calculations [5] have provided some tentative evidence that the La nuclei near $A=130$ may be good cases for studies of structures which terminate smoothly at moderate spins, i.e., $\sim50\hbar$. Here the particles involved in the configurations occupy valence orbitals outside a ^{100}Sn core. In view

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of the results obtained in ^{127}La it is clearly of interest to pursue this work further, both in this nucleus and in the neighboring nuclei in order to investigate whether the same smoothly terminating configuration is favored in all three isotopes, and also, to see whether any of the bands can be followed to their terminating states.

In the present work the spectroscopy of ^{127,131}La has been investigated using data taken with the EUROBALL IV array. In addition, data previously obtained with Eurogam II have also been analyzed in order to study the high spin structure of ^{129}La. The results suggest that the lowest $(\pi,\alpha)=(+,-\frac{1}{2})$ configuration is favored at high spin in all three nuclei; however, there is a significant change in the behavior of the $(\pi,\alpha)=(+,\pm\frac{1}{2})$ bands in ^{131}La. This paper discusses these structures and the negative parity yrast bands in all three nuclei and the data are compared to the results of cranked Nilsson-Strutinsky calculations.

II. EXPERIMENTAL DETAILS AND DATA ANALYSIS

The nuclei ^{127,131}La were populated at high-spin using the ^{100}Mo(^{32}S,$p4n$) and ^{100}Mo(^{36}S,$p4n$) reactions, respectively, at beam energies of 160 MeV. γ rays were detected in the EUROBALL IV spectrometer [7] which contained a 161 element inner bismuth germanate (BGO) ball. In each case, the target consisted of a single 500 μg/cm^2 self-supporting, enriched, ^{100}Mo foil. A beam of approximately 30 enA was used in both experiments. In the ^{127}La experiment, approximately 1.2×10^9 events with fold four or higher and an inner BGO ball threshold of 14 or above were collected. For the ^{131}La experiment, the number of fold four and higher events obtained was about 1.5×10^9, but in this case with an inner BGO ball threshold of 18 or greater. The high spin states in ^{129}La were populated using the ^{100}Mo(^{34}S,$p4n$) reaction at a beam energy of 155 MeV. γ rays from this reaction were detected in the EUROGAM II spectrometer [8]. In this experiment the target consisted of two stacked self-supporting foils of ^{100}Mo with a nominal thickness of 600 μg/cm^2. Approximately 8×10^8 Compton suppressed events with fold 5 and above were collected to tape. The beams for all three experiments were provided by the Vivitron accelerator at CNRS, Strasbourg.

The data from each experiment were unpacked into either γ-γ-γ triples or γ-γ-γ-γ quadruples events and sorted into RADWARE cubes or hypercubes [9]. For the ^{127}La and ^{131}La data cubes were created both with and without gates on the sum energy signal from the inner BGO ball, the latter being used to try and enhance the selection of the high spin states in these nuclei. In addition to the cubes, the data were also sorted into 1-d spectra. These were generated directly from the high-fold data using certain γ-ray gating constraints, i.e., three or four simultaneous gates from a list of transitions. These spectra were again generated both with and without a gate on the sum energy signal from the inner BGO ball. The unfolding procedure of Ref. [10] was used to create these spectra.

III. RESULTS AND DISCUSSION

Partial decay schemes deduced from the present work for ^{129,131}La are shown in Fig. 1. The decay scheme for ^{127}La has changed only slightly from that published in Ref. [6] hence it has not been reproduced here. One of the prime aims of the ^{127}La experiment was to try and extend the known [6]

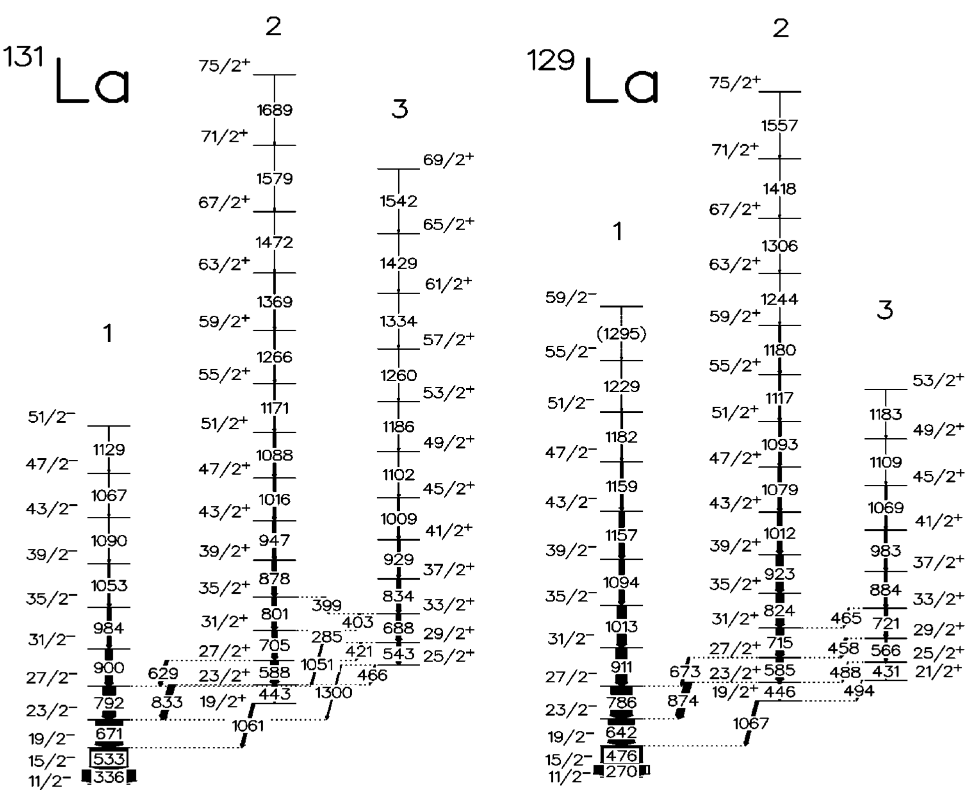

FIG. 1. Partial decay schemes for ^{129,131}La deduced from the present work. The thickness of the arrows is proportional to the intensity of the transitions.

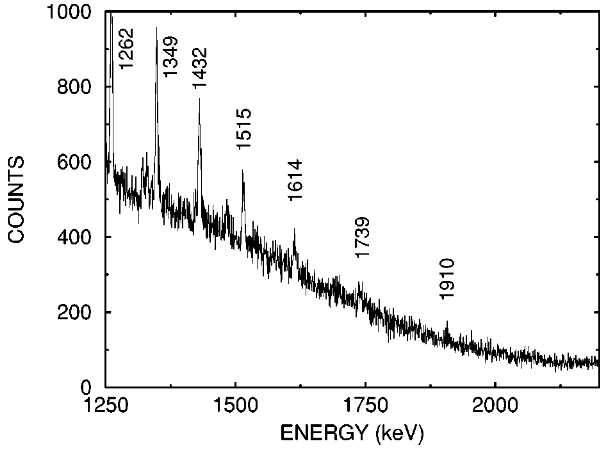

FIG. 2. Spectrum showing the high spin part of the $\pi,\alpha=(+,-\frac{1}{2})$ band (band 2) in ^{127}La. This spectrum was produced by unfolding the data and sorting into a 1-d histogram using the method given in the text. For this particular spectrum quintuple events were used, i.e., an event must have had four γ rays belonging to a gate list which contains all γ rays in this band up to the 1739 keV transition. A gate was also used on the BGO sum energy signal to create this spectrum. The limits for this gate were chosen by first gating on the γ rays in band 2 and creating a sum energy BGO spectrum in coincidence with these γ rays. Appropriate gates were then applied to the BGO sum energy signal. No background has been subtracted from the spectrum. γ rays in the band are labeled by their energies in keV.

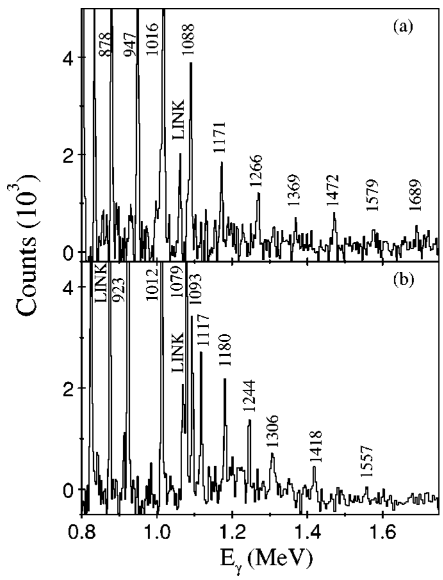

FIG. 3. Spectra showing the high-spin portion of the $(\pi,\alpha)=(+,-\frac{1}{2})$ bands (band 2 in each case) in (a) ^{131}La and (b) ^{129}La. In both cases the spectrum results from a sum of all double gates of transitions in the bands and is taken from a RADWARE cube. γ rays belonging to the bands of interest are labeled by their energies in keV.

$(\pi,\alpha)=(+,-\frac{1}{2})$ smooth terminating band up to the terminating state at $\frac{95}{2}^+$. Unfortunately, this did not prove to be possible and we were only able to confirm the presence of the previously tentatively assigned 1910 keV transition at the top of this band, band 2 of Ref. [6] (see Fig. 2). Two new transitions of energies 1431 and 1537 keV were identified in the $(\pi,\alpha)=(+,\frac{1}{2})$ signature partner band (band 3).

In previous work on ^{127}La [6] it was noted that the yrast negative parity band, built on the $\pi h_{11/2}$ proton orbital, could not be extended to very high spins. A possible reason for this was discussed in terms of the cranked Nilsson-Strutinsky calculations (see Fig. 4 of Ref. [6]) which predicted that at high spin $(I\sim\frac{65}{2}\hbar)$ the structure is crossed by a highly deformed $(\beta_2\sim0.35)$ negative-parity band whose configuration involves two $g_{9/2}$ proton holes. In this work it was speculated that the highly deformed band possibly took much of the population intensity from the normal deformed band at high spins. In the present work there is evidence for a very weakly populated $(<0.2\%)$ highly deformed structure which may belong to ^{127}La. However, we cannot rule out the possibility that the band belongs to ^{128}La, since low-spin transitions from both nuclei are observed with similar strength in spectra generated from a RADWARE cube with a sum of gates on the highly deformed band transitions. The energies of the transitions in this band, in keV, are (899), 964, 1034, 1102, 1174, 1250, 1324, 1399, 1475, 1549, 1625, 1706, 1788, 1867. The use of the inner BGO ball could not uniquely resolve the ambiguity in the assignment. Since there is no definitive proof that this structure belongs to ^{127}La, it will not be discussed further.

An analysis of the RADWARE hypercube containing the ^{129}La data has enabled us to extend the lowest $(\pi,\alpha)=(+,-\frac{1}{2})$ band (band 2) shown in Fig. 3(b) by five transitions up to a spin and parity of $\frac{75}{2}^+$. Its signature partner has been extended by four transitions compared to the data presented in Refs. [11,12]. The yrast negative parity band, built on the $\pi h_{11/2}$ orbital, has been extended by two transitions (1159 and 1229 keV) from that observed in previous work [11,12]. In the present work the previously known 1157 keV γ ray is observed to be a doublet, and from intensity considerations the new 1159 keV transition has been placed before the 1182 keV transition in the decay scheme. A tentative γ ray of energy 1295 keV has been placed at the top of this band.

For ^{131}La, eight and seven new transitions have been observed in the lowest $(\pi,\alpha)=(+,-\frac{1}{2})$ and $(\pi,\alpha)=(+,\frac{1}{2})$ bands (bands 2 and 3), respectively, compared to previous work [13]. Figure 3(a) shows the upper portion of the spectrum of transitions in band 2. Finally, the $\pi h_{11/2}$ structure has been extended by two transitions (1067 and 1129 keV) in the present work.

Figure 4 shows a plot of the energy minus a rigid rotor reference energy (E-E_{RLD}) against spin for bands 2 and 3 in ^{127,129,131}La. The rigid rotor reference is calculated using an $A^{5/3}$ mass scaled parameter based on the value of 0.007, which was used in ^{158}Er [14]. The figure clearly indicates that the $\alpha=-\frac{1}{2}$ structures in ^{127,129}La show evidence for a band crossing at spins of $\frac{47}{2}\hbar$ and $\frac{51}{2}\hbar$, respectively. Previous work on ^{127,129}La [6,11] has assigned this crossing to the alignment of a pair of $h_{11/2}$ neutrons. This same crossing is also clearly observed in the $\alpha=\frac{1}{2}$ band in ^{127}La at spin $\frac{45}{2}\hbar$. However, although there is a slight change in the slope of the E-E_{RLD} curve for the $\alpha=\frac{1}{2}$ band in ^{129}La at about the same

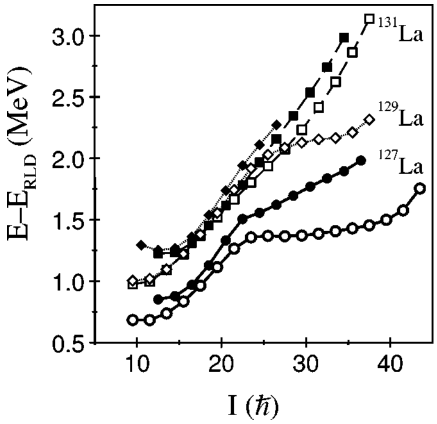

FIG. 4. Energy minus a rigid rotor reference energy (E-$E_{\rm RLD}$) as a function of spin for bands 2 and 3 in ^{127,129,131}La. The rigid rotor reference energy was calculated using the parameters shown in Fig. 5. Open (filled) symbols represent the $\alpha=-\frac{1}{2}(\frac{1}{2})$ signatures, respectively.

spin it is not so clear whether this results from the $(\nu h_{11/2})^2$ crossing. This structure clearly needs extending to higher spins in order to confirm the presence of the crossing. A further feature that is evident from Fig. 4 is that the $h_{11/2}$ neutron crossing is absent in the lowest $(\pi,\alpha)=(+,\pm\frac{1}{2})$ bands in ^{131}La. A possible reason for this difference in behavior between these bands and the equivalent bands in the lighter odd mass La isotopes will be discussed below.

A. Positive parity bands

Figure 5 shows a comparison of the experimental data for bands 2 and 3 in all three nuclei with cranked Nilsson-Strutinsky model calculations. These calculations were performed without pairing using the configuration dependent shell correction approach and a cranked Nilsson potential, with single-particle κ and μ parameters from Ref. [15], but with the modification that the μ value of the $N=6$ neutron shell being increased from 0.34 to 0.40 in order to get the $i_{13/2}$ neutron shell at a lower energy [15]. Note, since pairing is not included in the calculations they are not expected to show good agreement with the experimental data until spins in excess of 30$\hbar$. The nomenclature used to identify the structures in this figure is $[p_1p_2,n_1]$, which is equivalent to a configuration of $\pi(g_{9/2})^{-p_1}(h_{11/2})^{p_2}\otimes\nu(h_{11/2})^{n_1}$ relative to a ^{100}Sn closed core. The large circles indicate the terminating states for specific configurations, while the dotted lines mark the locus of the yrast states. These calculations indicate that bands which are predicted to terminate around spin $I\sim 40$–$50\,\hbar$, with configurations which do not involve $g_{9/2}$ proton holes, are yrast or very close to yrast. A discussion of the results for the various nuclei is given below.

Bands 2 and 3 in ^{127}La were previously identified as signature partners with a $\pi[(g_{7/2}d_{5/2})^5(h_{11/2})^2]\otimes\nu[(g_{7/2}d_{5/2})^{12}(h_{11/2})^6(d_{3/2}s_{1/2})^2]$ configuration [6] relative to a ^{100}Sn core. Such a configuration implies that the $g_{7/2},d_{5/2}$ subshells are almost fully occupied. For the $\alpha=-\frac{1}{2}$ signature (band 2) this structure is expected to terminate at a spin and parity of $\frac{95}{2}^+$. In the present work this band has been observed up to $\frac{87}{2}^+$, i.e., two transitions from termination. The weakness of the last transition (see Fig. 2) suggests that it will be extremely difficult to observe this structure up to the terminating state. The calculations also support this observation since it is clear from Fig. 5(b) that the final two states depart very rapidly from the yrast line, thus the intensity for populating these states may be expected to be extremely weak.

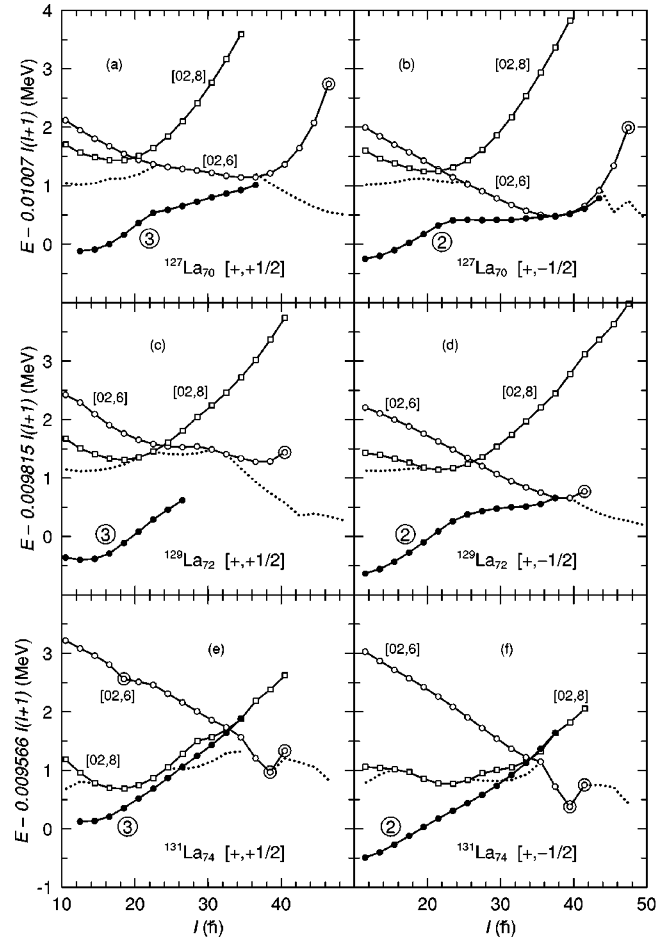

FIG. 5. Energy minus a rigid rotor reference energy (E-$E_{\rm RLD}$) versus spin plots for the $(\pi,\alpha)=(+,\pm\frac{1}{2})$ bands in (a),(b) ^{127}La, (c),(d) ^{129}La, and (e),(f) ^{131}La, respectively. The results of the cranked Nilsson-Strutinsky calculations are shown with open symbols whilst the experimental data are shown with filled symbols. (Note the calculations do not include pairing, hence they only become valid for spins in excess of 30$\hbar$.) The large open circles indicate terminating states. The experimental and theoretical energies are normalized for each nucleus at high spin for the $(\pi,\alpha)=(+,-\frac{1}{2})$ configuration.

Figure 5(b) shows that the $\alpha=-\frac{1}{2}$ signature of the [02,6] configuration is yrast over a large spin range and hence one may expect smooth band termination behavior for this band. Band 3 would also be expected to terminate smoothly, however, the calculations show that the $\alpha=\frac{1}{2}$ signature departs from the yrast line at a somewhat earlier spin than its signature partner, consequently, for this band it will be even more difficult to observe the terminating state. A further interesting feature of the calculations, as noted previously [6], is that

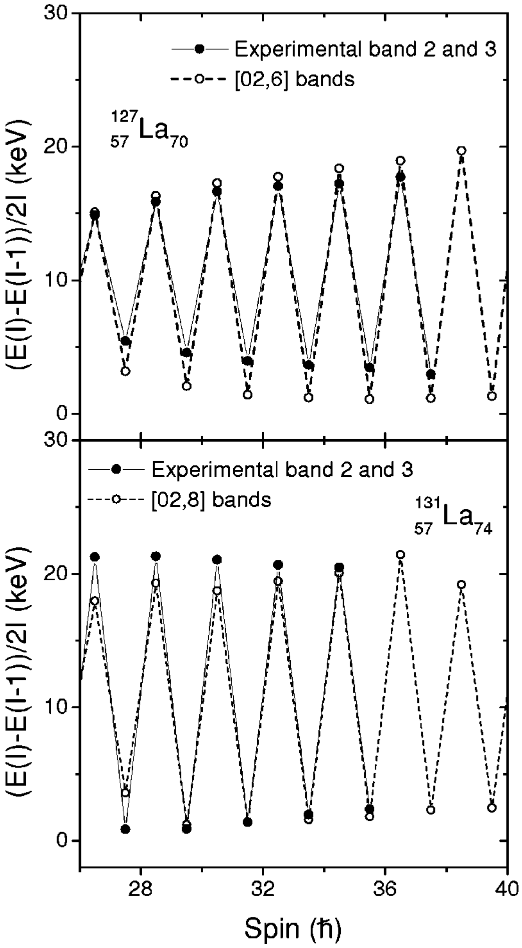

FIG. 6. Comparison of experimental and theoretical signature splitting at high spin for bands 2 and 3 in (a) ^{127}La and (b) ^{131}La. The theoretical values are taken from the assigned configurations for these bands.

the position of the $(\nu h_{11/2})^2$ crossing compares very well with the crossing in the unpaired calculations of the [02,8] and [02,6] configurations for both signatures. It is also interesting to note that the cranked Nilsson-Strutinsky calculations are able to reproduce the observed experimental signature splitting between the lowest $(\pi,\alpha)=(+,\pm\frac{1}{2})$ bands at high frequencies (see Fig. 6).

Bands 2 and 3 in ^{129}La have previously been assigned a $\pi(g_{7/2}\otimes h_{11/2}^2)$ configuration at low spin [11]. The present work agrees with this assignment. Figures 5(c) and 5(d) show the comparison between the lowest $(\pi,\alpha)=(+,\pm\frac{1}{2})$ configurations from the cranked Nilsson-Strutinsky calculations with the experimentally observed bands. At low spin both bands are expected to have a [02,8] configuration. The comparison of experimental data with calculations suggests that band 2 is based on the [02,6] configuration at high spin. One might also expect that band 3 will have the same configuration in this spin regime, however, the experimental data do not extend to sufficiently high spin for this to be confirmed. Indeed, Fig. 5(c) tentatively suggests that the [02,8] configuration may be more appropriate for this band. With the above assignment, band 2 has a $\pi[(g_{7/2}d_{5/2})^5(h_{11/2})^2]\otimes\nu[(g_{7/2}d_{5/2})^{14}(h_{11/2})^6(d_{3/2}s_{1/2})^2]$ configuration relative to a ^{100}Sn core, which terminates in a fully aligned $\frac{83}{2}^+$ state. In this case the neutron $g_{7/2},d_{5/2}$ subshells are completely full. The results therefore indicate that this band is observed up to two states below the terminating state. For the $\alpha=\frac{1}{2}$ signature partner band the experimental data only extend to the $\frac{53}{2}^+$ state, i.e., far below the terminating states for either the [02,6] or [02,8] configurations. It is clear from Fig. 5(c) that for this signature the [02,6] configuration departs from the yrast line somewhat earlier than its signature partner while the [02,8] configuration rapidly departs from the yrast line at spin $\sim\frac{47}{2}$, hence, one would expect there to be less chance of being able to populate this band to the terminating state for either of these configurations.

From Fig. 4 there is evidence in the $\alpha=-\frac{1}{2}$ band (band 2) of ^{129}La for the alignment of a pair of $h_{11/2}$ neutrons at a slightly higher spin than that observed for the equivalent band in ^{127}La. In Fig. 5 this crossing shows up as a crossing between the [02,8] and [02,6] configurations in the unpaired calculations. Theoretically, the spin at which the two configurations cross is indeed slightly higher in ^{129}La compared to ^{127}La and is in good agreement with the experimental observations. In the case of the $\alpha=\frac{1}{2}$ signature for ^{129}La the data do not quite extend far enough for the presence of this crossing to be confirmed.

Previous work on ^{131}La [13] assigned bands 2 and 3 in this nucleus to be signature partners based on a $\pi(g_{7/2}\otimes h_{11/2}^2)$ configuration at low spin. This is nominally the same configuration as bands 2 and 3 in both ^{127,129}La at low spin. The present work supports these assignments. However, it is evident from Fig. 4 that at high spin these structures do not show any experimental evidence for the $(\nu h_{11/2})^2$ crossing which is seen in structures based on the same configurations in ^{127,129}La. Thus, it would appear that the bands remain in the same configuration over the whole spin range in which they are observed. This can be understood in terms of the cranked Nilsson-Strutinsky calculations [see Figs. 5(e), 5(f)] where it can be seen that the crossing between the [02,8] and [02,6] configurations occurs at much higher spins (frequencies) than is observed in the lower mass nuclei. The irregularities seen in the calculations for the [02,8] and [02,6] bands at high spins in ^{131}La result from the jumps between different minima in the potential energy surface. Such a scenario should not be unexpected since this nucleus is known to be extremely γ soft [13]. Thus, we believe that in ^{131}La bands 2 and 3 are associated with the [02,8] rather than the [02,6] configuration at high spin. [Note, in the unpaired regime the bands under discussion simply differ in the number of $h_{11/2}$ neutrons present in the configuration. In standard cranking calculations, however, there is no attempt made to track the numbers of high-j particles ($h_{11/2}$ neutrons in this case) before and after the crossing. It is therefore possible that band 2 in ^{127,129}La, for example, could be closer to the [02,8] configuration before the $\nu(h_{11/2})^2$ crossing and [02,6] configuration after the crossing.] A possible configuration at high spin for the ^{131}La bands could be $\pi[(g_{7/2}d_{5/2})^5(h_{11/2})^2]_{21.5}\otimes\nu[(g_{7/2}d_{5/2})^{12}(h_{11/2})^8(d_{3/2}s_{1/2})^4]_{24}$, relative to the ^{100}Sn core, which would have terminating spins of $\frac{91}{2}\hbar$ and $\frac{89}{2}\hbar$ for the $\alpha=-\frac{1}{2}$ and $\alpha=\frac{1}{2}$ bands, respectively. However, these aligned states are very unfavored energetically so no clear termination is calculated. Once again, it is interesting to note that at high spins the calculations, based on a [02,8] configuration, can reproduce the experimentally observed signature splitting for bands 2 and 3 (see Fig. 6).

B. Negative parity yrast bands

In ^{127}La the yrast negative parity band has previously been associated with the [01,6] configuration at high spin [6]. Figure 7 shows a comparison of the energy minus a rigid rotor reference energy plot for the lowest $(\pi,\alpha)=(-,-\frac{1}{2})$ bands in ^{127,129,131}La from the cranked Nilsson-Strutinsky calculations with the experimental data. Clearly the crossing between the [01,6] and [01,8] configurations can reproduce the observed spins at which the $(\nu h_{11/2})^2$ alignment occurs in ^{127}La ($\sim\frac{35}{2}\hbar$) and ^{129}La ($\sim\frac{43}{2}\hbar$). In ^{131}La, however, Fig. 7 shows that the [01,6] configuration does not cross the [01,8] configuration until spin $\sim\frac{59}{2}\hbar$ but that there is a kink (i.e., a change of slope) in the [01,8] configuration at around spin $\frac{47}{2}\hbar$. This kink in the calculations results from the fact that the ^{131}La nucleus is very γ soft and hence the position of the minimum in the energy surface changes substantially from $\gamma\sim 25°$ to $\gamma\sim -25°$ where the kink occurs. Experimentally, the observed behavior of the band appears to agree nicely with the calculations. However, one cannot rule out the possibility that it is the alignment of an $h_{11/2}$ neutron pair that is responsible for the change of slope in the experimental data. If the latter is true, it certainly puts some doubts on our interpretation in terms of the cranked Nilsson-Strutinsky model for the observed crossings in the negative parity bands of ^{127,129}La. These results suggest that further experimental work is required in order to determine whether the disturbance in the negative parity yrast band in ^{131}La at around $\frac{47}{2}\hbar$ is due to the alignment of a pair of $h_{11/2}$ neutrons or to a change in the shape of the nucleus without a change in the overall structure of the band.

Finally, it is interesting to note that the negative parity yrast bands in all three nuclei are observed up to the spins where the cranked Nilsson-Strutinsky calculations predict that the structures begin to depart rapidly from the yrast line (see Fig. 7). This suggests that the calculations correctly predict the point at which these configurations become nonyrast.

C. Summary

In summary the γ-ray spectroscopy of the negative-parity yrast bands and the lowest $(\pi,\alpha)=(+,\pm\frac{1}{2})$ bands in ^{127,131}La and ^{129}La have been studied using the EUROBALL IV and EUROGAM II arrays, respectively. A comparison of the data for the positive parity structures in ^{127,129}La with cranked Nilsson-Strutinsky calculations suggests that the $\alpha=-\frac{1}{2}$ bands in these nuclei and the $\alpha=\frac{1}{2}$ band in ^{127}La are smoothly terminating structures based on $\pi[(g_{7/2}d_{5/2})^5(h_{11/2})^2]\otimes\nu[(g_{7/2}d_{5/2})^x(h_{11/2})^6(d_{3/2}s_{1/2})^2]$ ([02,6]) configurations at high spin with $x=12,14$ for ^{127,129}La, respectively. The data for the positive parity, $\alpha=\frac{1}{2}$, band in ^{129}La are inconclusive in that they do not extend to a sufficiently high spin to enable any firm conclusions to be made regarding the structure of this band at high spin. However, in ^{131}La the calculations suggest that the equivalent bands have a [02,8] configuration at high spin, since the alignment of a pair of $h_{11/2}$ neutrons is not observed experimentally in either signature. Overall the results indicate that

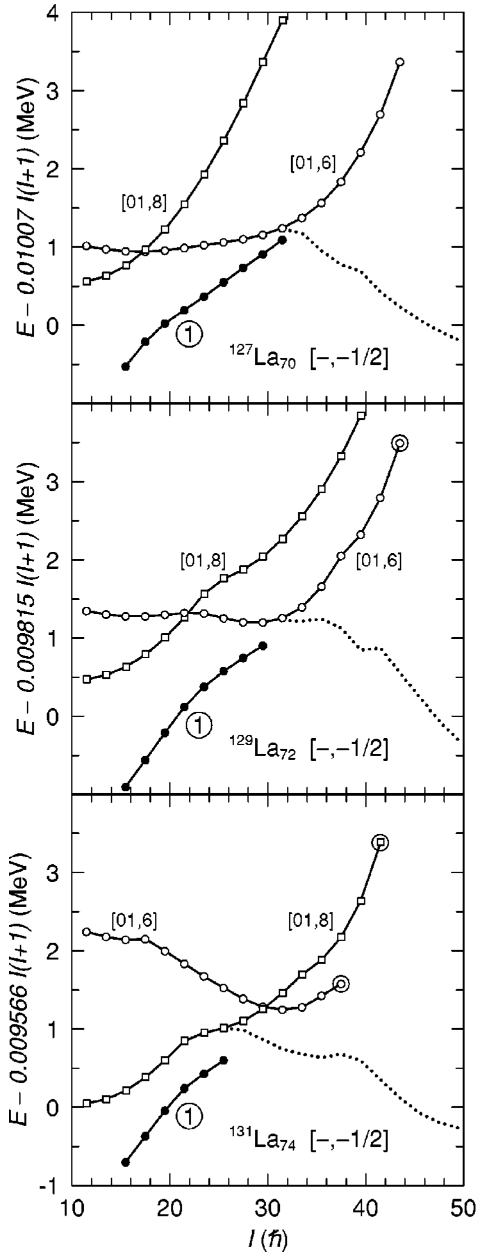

FIG. 7. Energy minus a rigid rotor reference energy (E-$E_{\rm RLD}$) versus spin plots for the $(\pi,\alpha)=(-,-\frac{1}{2})$ bands in (a) ^{127}La, (b) ^{129}La, and (c) ^{131}La, respectively. The results of the cranked Nilsson-Strutinsky calculations are shown with open symbols while the experimental data are shown with filled symbols. (Note the calculations do not include pairing, hence they only become valid for spins in excess of 30$\hbar$.) The large open circles indicate terminating states. The experimental and theoretical energies were normalized for each nucleus at high spin for the $(\pi,\alpha)=(+,-\frac{1}{2})$ configurations.

the lowest $(\pi,\alpha)=(+,\pm\frac{1}{2})$ bands in ^{127}La and the $(\pi,\alpha)=(+,-\frac{1}{2})$ band in ^{129}La do behave as smoothly terminating bands. It will be very difficult, however, to populate the actual terminating states in these isotopes since the calculations suggest that the terminating states for these configurations lie well above the yrast line. A similar situation is also found to be the case for the lighter odd mass La isotopes. Work on the odd-odd La isotopes is currently underway in order to see if the situation is different in these nuclei.

The negative-parity yrast bands in ^{129,131}La, which are built on a $\pi h_{11/2}$ orbital, have both been extended by two transitions. The $\pi h_{11/2}$ bands in all three nuclei show evidence for some form of band crossing or irregularity around spins of $\frac{35}{2}\hbar$, $\frac{51}{2}\hbar$, and $\frac{47}{2}\hbar$ in ^{127,129,131}La, respectively. In ^{127,129}La it is believed that this corresponds to the alignment of a pair of $h_{11/2}$ neutrons while in ^{131}La it is not clear whether it is $h_{11/2}$ neutrons that are responsible or the γ-soft nature of the nucleus. Further experimental work is required in ^{131}La in order to try and determine the nature of the change in slope of the E-E_{RLD} curve in the negative-parity yrast band of ^{131}La.

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