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Publication Date
1974-12-01

Submitted to Physics Letters B

LBL-3446
Preprint c.2

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December 1974

Prepared for the U. S. Atomic Energy Commission
under Contract W-7405-ENG-48

DISCLAIMER

HIGH-SPIN STATES IN ^{127,129}La; A TEST OF BACKBENDING IN THE EVEN Ba AND Ce NUCLEI*

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ABSTRACT: The $h_{11/2}$ band in ^{127,129}La has been identified to spin $35/2^-$, and it does not backbend. This suggests that rotation-aligned $h_{11/2}$ protons are a major component of high-spin states in neighboring Ba and Ce nuclei which do exhibit backbending.

*Work done under the auspices of the U. S. Atomic Energy Commission.

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The rotation-aligned coupling scheme [1] has had considerable success in describing the collective bands in a number of weakly deformed odd-mass nuclei. It has also been pointed out that the presence of backbending in an odd-mass rare-earth nucleus is an important clue as to the cause of backbending in the adjacent doubly-even nuclei. If a particular rotation-aligned particle delays or prevents the occurrence of backbending in the odd-mass case, it is likely that this particle is involved in the structure of the band whose intersection with the ground band causes the backbending in the doubly-even nucleus [2]. Conversely, if the odd-particle band does backbend, this particle must not be such an important component [3]. Application of this idea has shown the importance of $i_{13/2}$ neutrons in the backbending behavior observed in the lighter deformed nuclei Dy [4], Er [2], and Yb [5]. Very recently the importance of rotation-aligned $h_{9/2}$ protons in the backbending of the heavier deformed Hf, W, and Os nuclei has been demonstrated by studying ^{167}Lu [6] and ^{181}Re, ^{181,183}Os [7]. It may be that in some of these cases both the $i_{13/2}$ neutrons and the $h_{9/2}$ protons are important, presumably as a mixed band, but this is not yet established.

In this letter we report a study of the high-spin decoupled states of ^{127,129}La from which we can draw conclusions concerning the causes of the backbending observed in the neighboring Ba and Ce nuclei. To our knowledge, this is the first time this method has been applied outside the rare-earth deformed region.

Previous studies of high-spin states in ^{126,128}Ba [8] and ^{130}Ce [9] have shown that the ground bands backbend around spin 10^+. This corresponds to a spin of $31/2^-$ in the $11/2^-$ band in La, but the earlier work on $^{127,129}La$ [10] only assigned levels as high as $27/2^-$. In the present work we have identified levels to spin $35/2^-$, just beyond the critical region. To obtain as complete a comparison as possible, we have also studied the ground band in ^{128}Ce, since it was previously known [11] only to spin 8^+.

The experiments were performed at the LBL 88" Cyclotron, using the reactions $^{117}Sn(^{14}N,4n\gamma)^{127}La$ with 75 MeV ^{14}N, $^{119}Sn(^{14}N,4n\gamma)^{129}La$ with 67 and 75 MeV ^{14}N, and $^{116}Sn(^{16}O,4n\gamma)^{128}Ce$ with 88 MeV ^{16}O. The targets were made by evaporating the tin isotope to $\sim$ 1 mg/cm^2 thickness on backings of $\sim$ 50 mg/cm^2 of lead. Gamma rays were detected both in singles and in coincidence mode using two 45 cc coaxial Ge(Li) detectors. The 0° to 90° anisotropy of the γ-rays was measured to test that the main cascade sequences were indeed stretched E2 transitions.

To reduce the number of magnetic tapes collected in the γ-γ coincidence runs, whilst retaining high statistics, only events were stored which corresponded to restricted regions of the pulse height spectrum from one of the γ-detectors. Four S.C.A.'s were used to define the regions of interest. For example, in ^{129}La, windows about 20 keV wide were set on the three lowest transitions of the decoupled band and the last window was set from just below the fourth transition (786 keV) up to about 1200 keV. It was estimated that this procedure increases the useful data on a magnetic tape by about a factor of eight compared with storing all coincident events. Furthermore, the effective count-rate could be increased considerably, since the dead time involved in writing events on magnetic tape was the limiting factor with our apparatus.

Typical coincidence spectra for ^{129}La are shown in fig. 1, and the cascade sequences deduced from individual gates set on the known ground-band transitions are summarized in table 1. The A_2 values derived from the anisotropy measurements assuming A_4 = -0.05 ± 0.05 are consistent with stretched E2 assignments, (table 1). However, in several cases the γ-ray lines in the direct (singles) spectra were not pure and it was rather difficult to extract reliable values for their A_2 coefficients.

The coincidence data also enabled us to identify side-bands in both ^{127}La and ^{129}La. These are shown in fig. 2. The angular anisotropy of the γ-cascades within the La side-bands indicates that they are probably stretched E2 transitions. Spin and parity assignments can be proposed for these levels, but they are rather uncertain and not relevant to the main point of this letter.

To compare the systematics of the core states in ^{127,129}La with those of the corresponding Ba and Ce nuclei we have calculated the moments of inertia, $\mathcal{J}$ and the rotational frequencies, ω, according to the formulae given in [3]. Plots of $\mathcal{J}$ vs. ω^2 are shown in fig. 3. It can be seen that the $11/2^-$ decoupled band in La does not backbend, even for rotational frequencies appreciably higher than those for which the Ba and Ce nuclei do backbend. This fact suggests that a rotation alignment of two such $h_{11/2}$ protons is involved in the backbending in the even barium and cerium nuclei. In fact it seems likely that the backbending is caused by an intersection of the ground band with a band composed of two $h_{11/2}$ protons maximally aligned with the rotation axis. It is of interest not only that the backbending is caused by protons rather than neutrons in this region, but also that it is most likely due to a rotation-alignment effect like that observed in the rare-earth region, rather than to a shape change as is the case for the neutron-deficient Hg nuclei. It appears that the technique of studying an even-even case by observing its behavior with various particle orbits blocked, is applicable to this Ba-Ce region, as well as to the deformed rare-earth region, and can probably be applied rather generally.

ACKNOWLEDGMENTS

One of us (P.A.B.) gratefully acknowledges the receipt of a U.K. S.R.C./N.A.T.O. fellowship.

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Table 1. Summary of the rotational cascades in $^{127,129}La$ and ^{128}Ce observed in this experiment. Assignments in La nuclei to spin $27/2^-$ (8^+) have been made previously [10]. Values for $^{126,128}Ba$ and ^{130}Ce are from previous work; ^{128}Ce assignments [8,9] to spin 8^+ have been made previously [11]. Uncertainties in the relative intensities and A_2 coefficients are shown in parentheses.

Spin	^{128}Ba [8]	^{129}La (75 MeV)			^{130}Ce[9]
I (or I - 11/2)	E_γ (keV)	E_γ	Int	A_2	E_γ
2	284	269.3	100	0.35(3)	254.1
4	479	474.8	81(8)	0.32(3)	456.7
6	644	641.9	55*(16)	0.35(3)	614.2
8	782	785.6	29(3)	0.31(4)	729.6
10	894	910.5	11*(2)	0.26(15)	757.0
12	906	1013.5	8*(2)	0.02(30)	503.3
14					549.0
16					693.5

Spin	^{126}Ba[8]	^{127}La (76 MeV)			^{128}Ce (88 MeV)		
I (or I - 11/2)	E_γ (keV)	E_γ	Int	A_2	E_γ	Int	A_2
2	256	252.4	100	0.19(3)	207.3	100	0.26(3)
4	455	458.6	73(7)	0.28(3)	399.6	88(9)	0.23(3)
6	621	630.8	48(5)	0.23(3)	550.6	88(9)	0.32(3)
8	757	780.3	31*(4)	0.13(4)	662.6	50(5)	0.26(4)
10	852	908	8(2)	0.10(15)	711.1	33(3)	0.31(6)
12	805	1003	5*(1)	0.16(30)	576.5	28(3)	0.25(6)
14	672				560.6	22*(2)	0.24(6)
16	825				689.9	14*(2)	0.38(10)

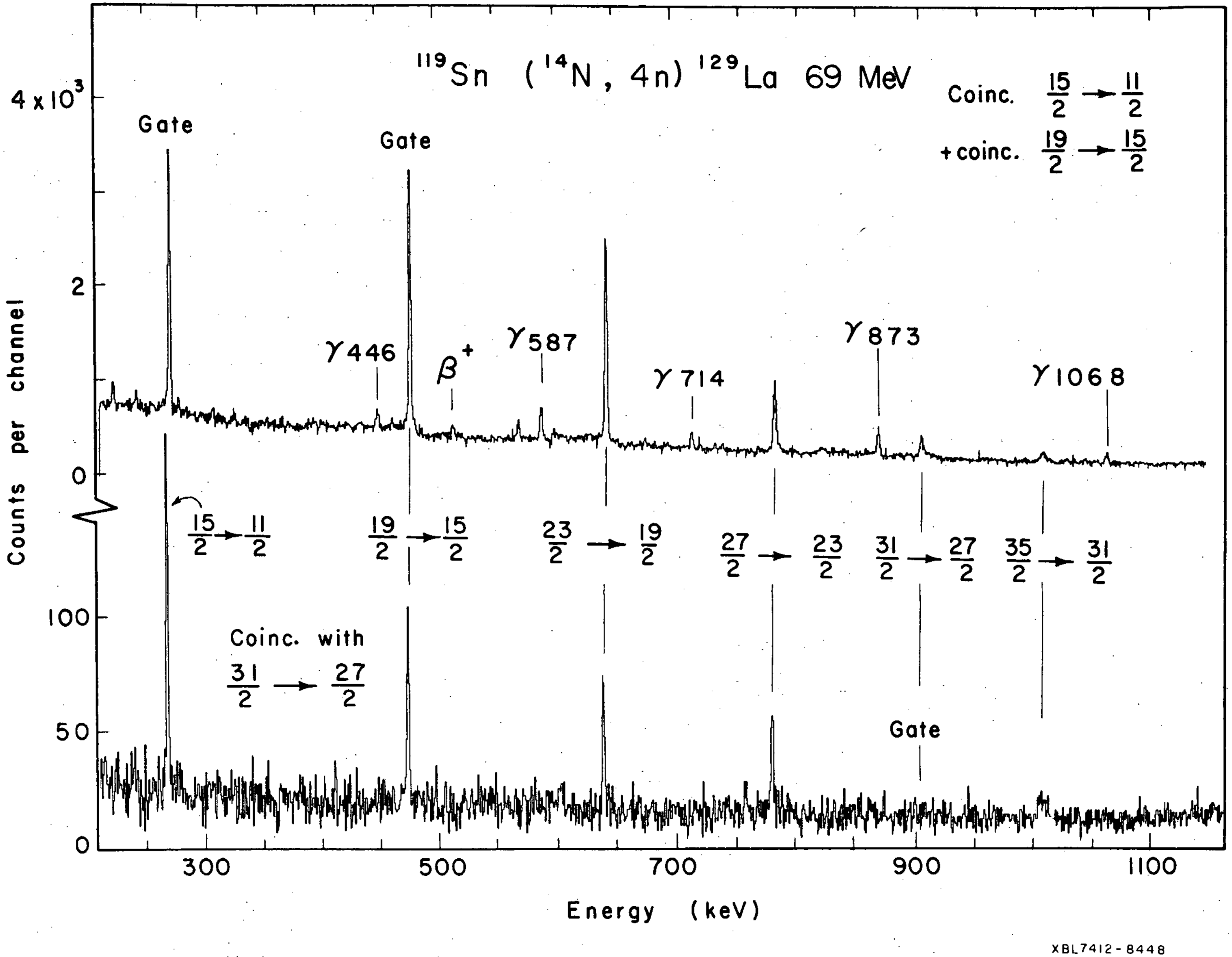
*Not single lines in the direct spectra. Relative intensities taken from spectra in coincidence with the $2^+ \rightarrow 0^+$ ($15/2^- \rightarrow 11/2^-$) transitions.

FIGURE CAPTIONS

Figure 1. Coincidence spectra for ^{129}La, spectrum (a) is for the sum of gates set on the lowest two rotational transitions, (b) is for the 31/2 → 27/2 transition. Spectra corresponding to background events have been subtracted in an appropriate way.

Figure 2. Level schemes for ^{127,129}La and ^{128}Ce.

Figure 3. Comparison of backbending plots for *core states* in ^{127,129}La with adjacent even nuclei.



^{119}Sn (^{14}N, 4n) ^{129}La 69 MeV
Coinc. 15/2 → 11/2
+coinc. 19/2 → 15/2
Gate
Gate
γ446
β+
γ587
γ714
γ873
γ1068
15/2 → 11/2
19/2 → 15/2
23/2 → 19/2
27/2 → 23/2
31/2 → 27/2
35/2 → 31/2
Coinc. with
31/2 → 27/2
Gate
4 x 10³
2
0
100
50
0
Counts per channel
300
500
700
900
1100
Energy (keV)
XBL7412-8448

Fig. 1

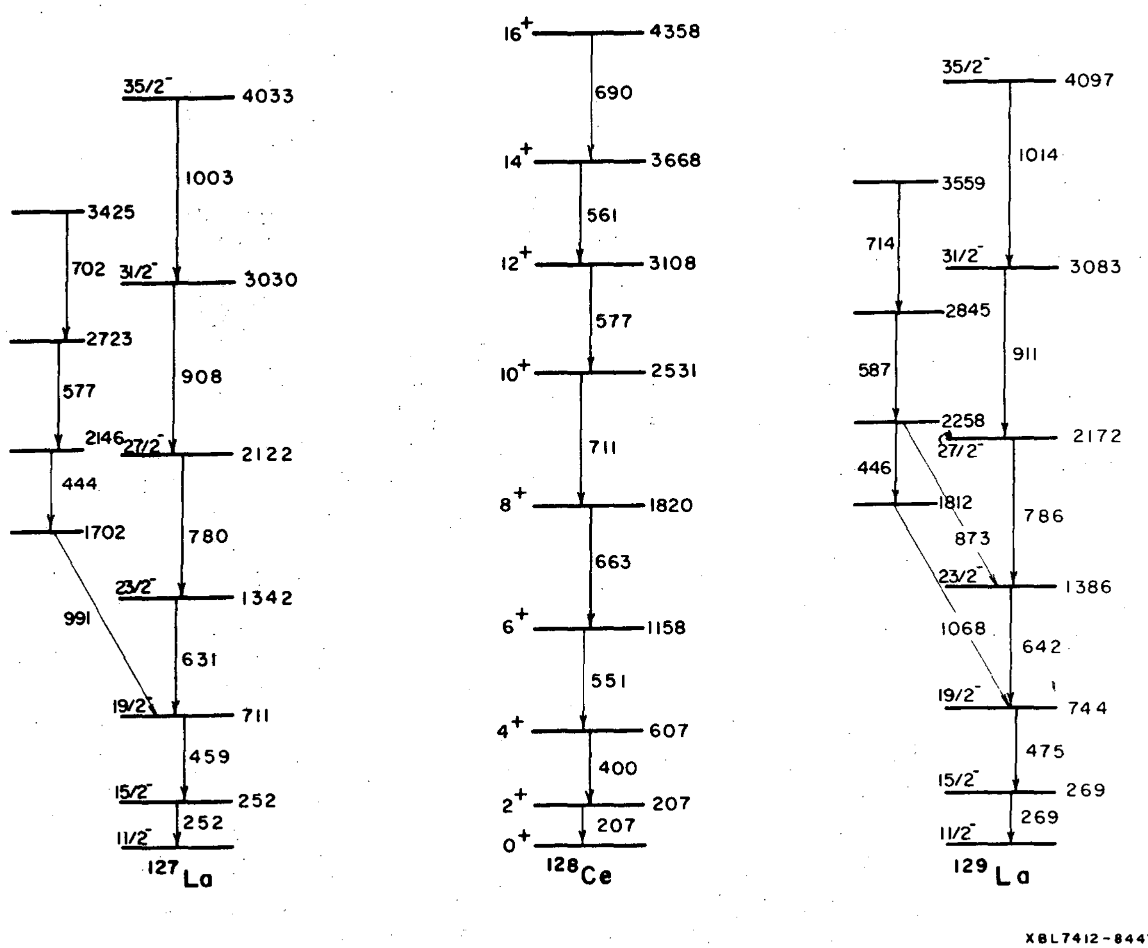

35/2⁻ 4033
1003
3425
702
31/2⁻ 3030
2723
577
908
2146
27/2⁻ 2122
444
1702
780
23/2⁻ 1342
991
631
19/2⁻ 711
459
15/2⁻ 252
252
11/2⁻
127 La
16+ 4358
690
14+ 3668
561
12+ 3108
577
10+ 2531
711
8+ 1820
663
6+ 1158
551
4+ 607
400
2+ 207
207
0+
128 Ce
35/2⁻ 4097
1014
3559
714
31/2⁻ 3083
2845
911
587
2258
2172
27/2⁻
446
1812
786
873
23/2⁻ 1386
1068
642
19/2⁻ 744
475
15/2⁻ 269
269
11/2⁻
129 La
XBL7412-8447

Fig. 2

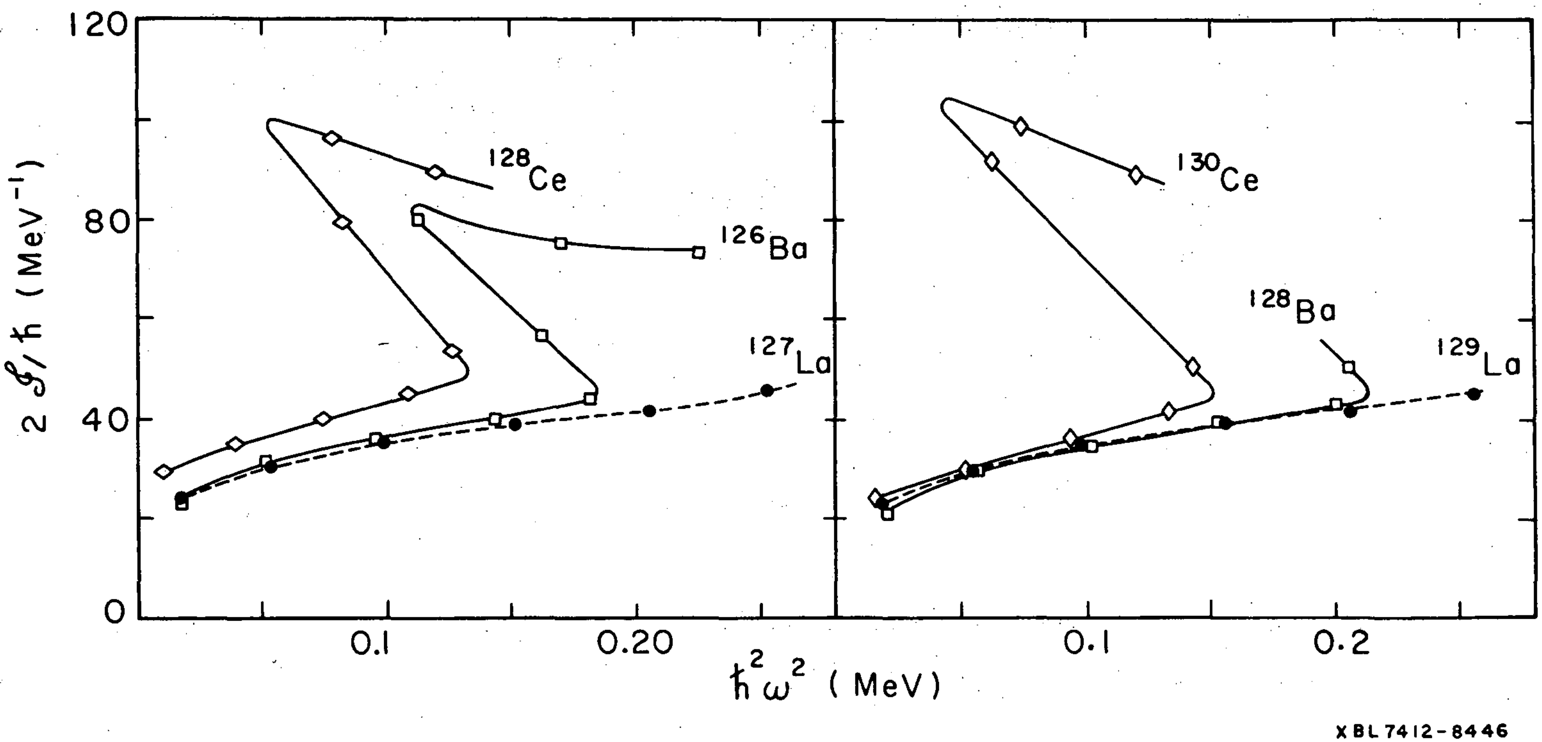

120
80
40
0
$2\mathcal{J}/\hbar$ (MeV^{-1})
^{128}Ce
^{126}Ba
^{127}La
^{130}Ce
^{128}Ba
^{129}La
0.1
0.20
0.2
$\hbar^2\omega^2$ (MeV)
XBL 7412-8446

Fig. 3

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