The dotted curves in Fig. 2 show the cross sections which result when the *magnitude* of M_{d2}^0 is decreased by 7.5% by adding a constant Δ_1 (corresponding to a decrease of 15% in $|M_{d2}^0|^2$). The dashed curves in Fig. 2 show the cross sections which result when the *phase* of M_{d2}^0 is changed by -15% by adding Δ_2. (The Kloet and Tjon calculation predicts a value for $^2\delta_0$ which is 15° less than the prediction of the YY model; we have taken this difference in the elastic phase shift as a rough estimate of the expected defect in the phase of M_{d2}^0.)

Except in the vicinity of the minimum, the changes in the cross section produced by these "reasonable" choices of Δ are in the range ± 0–12%. These variations are of the same order as the typical differences between model calculations and data.[1,9] Therefore it is possible that the discrepancy between data and model calculations can be largely explained as a defect in the $l=0$ part of the M_{d2} amplitude. To test this hypothesis, data should be acquired along loci such as those of Fig. 1 and compared with calculations which include a variation of Δ to obtain the best fit. ^{2}H$(n, 2n)p$ data at lower bombarding energies would be especially valuable, because the separable s-wave approximation to the NN force is more realistic in this case and the model cross section depends more sensitively on the s-wave part of M_{d2} at the lower energies. It is expected that the comparison of data with calculations in the vicinity of the interference minimum such as those of Fig. 2 will provide a sensitive test of three-body calculations.

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Test of Backbending Models Using Odd-*A* Nuclei*

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We have studied the properties of decoupled bands in particular odd-A nuclei, and the results provide information on the origin of backbending in even-even nuclei. Our data are in agreement with the rotation-alignment model and in apparent disagreement with the pairing-collapse model. This proposed test also provides a means to determine which particles are involved in the two-quasiparticle band that intersects the ground band in the rotation-alignment picutre of backbending.

A process known as "backbending" has recently been discovered[1] to occur at high spins in the ground-state rotational bands of some even-even rare-earth nuclei. The name refers to the fact that a plot of moment of inertia $\mathcal{J}$ versus the square of the rotational frequency, $(\hbar\omega)^2$, for the various spin states of these nuclei has an s-shaped form. That is, $\hbar\omega$ becomes temporarily smaller around $I \approx 16$, while $\mathcal{J}$ increases rather sharply with I. Since $\hbar\omega$ is very nearly half the rotational transition energy, the above shape results from several transition energies around the critical spin value being lower than those for spins just below or above this value. It is by now quite clear that this occurs for many rare-earth nuclei, but it does not occur (at least in the same spin region) for others. The change in $\mathscr{I}$ is typically from about half the rigid-rotor value to nearly the full value.

A number of explanations for backbending have been given. One of these predated the experimental observations by some ten years, and is known as the Mottelson-Valatin effect.[2] This refers to a coherent collapse of the pairing correlations in the nucleus (probably only for the neutrons) due to the increasing Coriolis force as the system rotates more rapidly. An alternative explanation was proposed shortly after the experiments by Stephens and Simon,[3] in which it is suggested that only one pair of $i_{13/2}$ neutrons is broken by the Coriolis force. The angular momentum from this pair (up to $12\hbar$) is then aligned with that of the rotating core to produce a band which crosses the ground-state band at the backbend, and for larger spin values becomes the yrast band (rotation-alignment model). Other models involving centrifugal shape changes[4] or generalized "moment of inertia" changes[5] have been proposed, but the two types of Coriolis effects mentioned above have thus far received the most serious consideration. It is a challenge at the present time to find ways to distinguish between these models. A number of such tests have been suggested,[6-8] but these are for the most part difficult experimentally, and so far not conclusive,[9] since both models predict much the same result. It is the purpose of this Letter to propose and apply a new test to differentiate between these two explanations of backbending.

This test involves the properties of a particular type of band in odd-A nuclei. It has been shown[10,11] that under the proper conditions an odd nucleon in a high-j orbital "decouples." This term refers to the alignment by the Coriolis force of the particle angular momentum j with that of the rotor. The result is a band with spin values $j, j+2, j+4, \ldots$, and energy spacings like the levels having spins 0, 2, 3, ... in the adjacent even-even nuclei. Many odd-A nuclei have been shown to possess such decoupled bands. It is of importance here that the agreement between the odd-A and even-even spacings is expected to get better the larger I becomes. The decoupling described here is closely related to the rotation-alignment explanation of backbending in the even-even nuclei; the band which intersects the ground band at the backbend is, in this model, essentially composed of two decoupled $i_{13/2}$ neutrons. However, the Pauli principle prevents the second neutron from being fully aligned with the rotation axis.

Consideration of the above properties leads to the following proposed test of the backbending models. If one considers the effect on backbending of the presence of a decoupled $i_{13/2}$ neutron, then opposite behavior is predicted by the two models. An odd neutron, because of blocking effects, will weaken the pairing correlations, so that they should collapse sooner (at lower $\hbar\omega$ or I) with rotation. On the other hand, such a decoupled $i_{13/2}$ neutron interferes with the formation of the band which intersects the ground band in the rotation-alignment model, resulting in a later (higher $\hbar\omega$ or I) intersection. Provided the decoupled odd-A bands are correctly interpreted, a comparison of their properties in the backbending region with those of the adjacent even-even nuclei should indicate which explanation is correct.

We chose ^{157}Er and ^{159}Er as the odd-A nuclei to be studied for this test since the decoupled bands had previously been observed[12] in these nuclei and the backbends in ^{156,158,160}Er were all known[13-16] It seemed likely that the observation of just one or two more levels in each odd-A nucleus would suffice for the test. We bombarded metallic targets of ^{150,152}Sm about 10 mg/cm^2 thick with ^{12}C ions of 92 and 88 MeV, respectively, from the Lawrence Berkeley Laboratory 88-in. cyclotron. Singles γ-ray spectra were taken with a coaxial Ge(Li) detector of ~30 cm^3, and with a 9-cm^3 planar intrinsic-Ge detector. The γ-γ coincidences between these detectors were also taken, as was a two-point angular distribution of the γ rays relative to the beam direction. Table I contains a summary of the lines assigned to the decoupled bands in ^{157,159}Er. The bands up to spin $\frac{37}{2}$ are considered certain since the transitions (1) had stretched $E2$ angular distributions, (2) could be shown to belong to the band (summed coincidences), and (3) were further shown to be in coincidence with each lower band member. Only (1) and (2) could be clearly established for the $\frac{41}{2}$ states because of poorer statistics, but the intensities are reasonable and we believe that these assignments are very likely correct. The $\frac{45}{2}$ state in ^{159}Er was so weak that only (1) could be established, and we consider this state tentative.

In Fig. 1, the plot of $2\mathscr{I}/\hbar^2$ versus $(\hbar\omega)^2$ is shown for the ground band of ^{156,158}Er and for the decoupled band of ^{157}Er (beginning at $I = j = \frac{13}{2}$). The ^{157}Er band appears to be completely decoupled in the beginning (lies midway between ^{156}Er and

TABLE I. Energies, intensities, and A_2 coefficients of the transitions observed in ^{157}Er [^{150}Sm + ^{12}C(92 MeV)] and ^{159}Er [^{152}Sm + ^{12}C(88 MeV)].

	^{157}Er			^{159}Er		
$I_i \to I_f$	E_γ (keV)	I_γ	A_2	E_γ (keV)	I_γ	A_2
17/2 → 13/2	266.1 ± 0.3	(100)	0.23 ± 0.02	208.3 ± 0.3	(100)	0.37 ± 0.02
21/2 → 17/2	415.1 ± 0.3	79 ± 4	0.24 ± 0.03	350.0 ± 0.3	83 ± 4	0.38 ± 0.03
25/2 → 21/2	527.2 ± 0.3	68 ± 4	0.35 ± 0.04	464.5 ± 0.3	77 ± 4	0.36 ± 0.04
29/2 → 25/2	622.4 ± 0.3	47 ± 3	0.31 ± 0.05	555.9 ± 0.3	56 ± 4	0.38 ± 0.05
33/2 → 29/2	702.2 ± 0.4	29 ± 3	0.39 ± 0.09	625.9 ± 0.3	49 ± 3	0.33 ± 0.08
37/2 → 33/2	765.0 ± 0.5	17 ± 2	0.34 ± 0.12	675.7 ± 0.4	25 ± 2	0.38 ± 0.09
41/2 → 37/2	802.9 ± 0.6	7 ± 1	0.5 ± 0.3	708.7 ± 0.5	12 ± 1	0.24 ± 0.11
(45/2 → 41/2)				(738.4 ± 0.8)	(8 ± 2)	(0.13 ± 0.20)

^{158}Er), but clearly does not backbend at the same $\hbar\omega$ (or I) as the adjacent even-even nuclei. The plot for ^{158,159,160}Er is shown in Fig. 2. and is very similar, except that the ^{159}Er band is not quite completely decoupled at the lowest spins. These plots show that the decoupled bands in both ^{157}Er and ^{159}Er backbend only at values of $\hbar\omega$ (and I) *higher* than the adjacent even-even nuclei, if they backbend at all. This is in accordance with the rotation-alignment model and in apparent contradiction to the expectations of the pairing-collapse model.

A more sensitive way to present these same data is shown in Fig. 3. Here we have plotted I *versus* the ratio of transition energy in the odd-A nucleus $(E_{I+j} - E_{I+j-2})$ to that in the even-even nucleus $(E_I - E_{I-2})$. Prior to the backbend region $(I \lesssim 12)$, both odd-A nuclei seem to be converging to a value of about 1.1. As the even-even backbend occurs $(I = 14)$, however, the ratio rises sharply since the odd-A bands do not experience the same drop in transition energy. This sharp rise at $I = 14$ is very clear in both cases. A smaller but suggestive rise in this ratio has also been seen[17] in ^{165}Yb.

We have proposed that the backbending properties of a decoupled $i_{13/2}$ band can distinguish between the two currently favored models of backbending. The expectations of the models seem to be reasonably clear and opposite. The experimental data are quite clear and go in the direction of the rotation-alignment model. Probably the greatest uncertainty in this test arises from the possibility that an entirely unforeseen effect is causing the odd-A bands not to backbend. This can be checked by looking at the $h_{11/2}$ decoupled

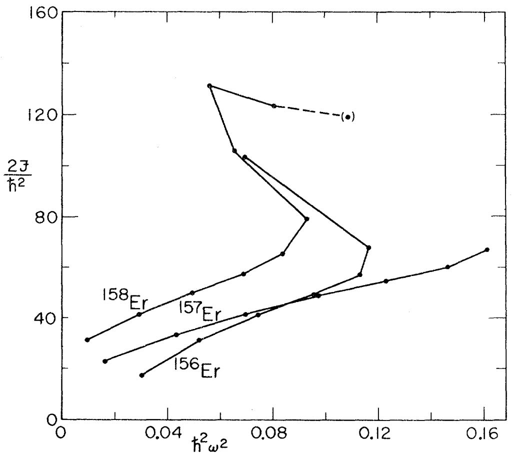

FIG. 1. $2\mathcal{J}/\hbar^2$ [$= 4I' - 2/(E_I - E_{I-2})$] versus $\hbar^2\omega^2$ [$= \frac{1}{4}(E_I - E_{I-2})^2$] for ^{156,157,158}Er. For the even-even nuclei $I' = I$, and for the odd-A nuclei $I' = I - j$.

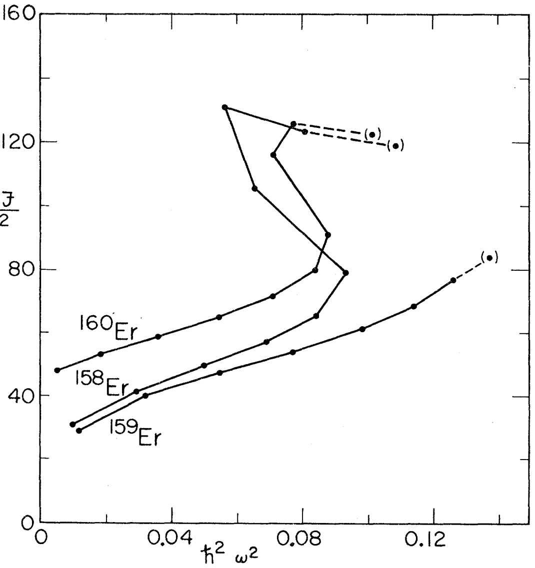

FIG. 2. $2\mathcal{J}/\hbar^2$ versus $\hbar^2\omega^2$ for ^{158,159,160}Er.

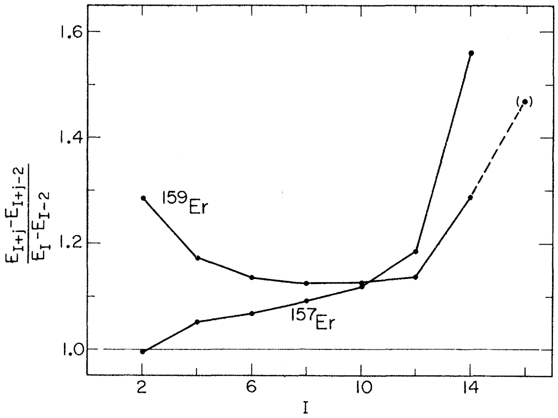

FIG. 3. Decoupled-band transition energy divided by the corresponding even-even energy versus I for ^{157,159}Er. The even-even value used is the average of the two adjacent nuclei.

bands in ^{157}Ho and ^{159}Ho. Since the rotation-alignment picture describes the crossing band as composed mainly of $i_{13/2}$ neutrons, the blocking of a proton orbital should have much less, if any, effect on the backbending. Thus, the decoupled bands in ^{157,159}Ho should backbend like the even-even nuclei, and preliminary data[18] indicate that they do. If this proves to be the case, it will not only confirm the present test, but also provide a means to analyze which configurations are important in the band intersecting the ground band.

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