Title

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Publication Date

1987-08-01

LBL-23869
Preprint

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August 1987

NUCLEAR SCIENCE DIVISION

Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

Search for Entrance-Channel Effects in the Production of Superdeformed Nuclei

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Abstract: In order to test whether entrance channel effects influence the production of superdeformed nuclei, the yields of the discrete superdeformed band in ^{152}Dy are compared for three projectile-target combinations. No evidence for entrance channel effects is found. Rather, the population of this band seems to be determined by the excitation energy and maximum angular momentum brought in by each reaction.

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Long after the discovery of superdeformation (SD) in fission isomers of the actinide region[1], such shapes have been found at high spins in both the heavy and the light rare-earth regions. These are due mainly to a shell effect for shapes having axes with length in the ratio 2:1. While the reduced Coulomb repulsion further stabilizes the SD shape in the former case, it is the centrifugal force which is playing that role at high spins in the latter. In the heavy rare-earth region, a discrete SD band was first discovered[2] at Daresbury in ^{152}Dy. Moment of inertia, as well as lifetime measurements, are consistent with a 2:1 ratio of axes (as in the actinides). This band is observed up to spin $60\hbar$ compared with maximum spins around $40\hbar$ for bands of normal deformation.

The population of these SD bands is not well understood at present. It was proposed[3] several years ago that entrance channel effects might favor the superdeformed shapes since a symmetric target and projectile in contact have a shape with axis ratio close to 2:1. This is an interesting possibility because it would contradict the idea of a compound nucleus. However, such effects may not be necessary to explain the population of SD bands. Herskind et al[4]. have shown recently that statistical decay calculations (including effects of the tail of the giant dipole resonance) can account for the higher population of discrete SD states relative to states of normal deformation for the highest spins. Neverthless, this does not exclude entrance channel effects. In the present study, we search for such effects by comparing yields of the ^{152}Dy SD band for different projectile-target combinations.

In order to look for the influence of the entrance channel in the feeding of the SD band in ^{152}Dy, we have studied the nearly symmetric reaction

^{74}Ge+^{82}Se $\rightarrow$^{152}Dy+4n and compared it with the two other reactions that have produced this SD band. The ^{74}Ge beam was provided by the SuperHILAC accelerator at the Lawrence Berkeley Laboratory at an energy of 4.6 MeV/nucleon. We used a 500 μg/cm^2 target with a Au backing of 250 μg/cm^2 that faced the beam in order to avoid any slowing down of the recoils. Fourteen Compton-suppressed Ge detectors from the HERA array were used[5]. These Ge detectors were placed at 18 cm from the target in a close-packed arrangement near 0° and 180°. This geometry was chosen to minimize Doppler broadening while maintaining reasonable efficiency. A lead catcher, placed 20 cm behind the target, was surrounded by an annular BGO detector covering 80% of 4π. Thus, γ-rays deexciting the 17^+, 60 ns isomer[6] at ~5 MeV were detected in the BGO annulus, providing both an isomer sum energy and a time relative to the prompt γ-rays. The isomer trigger was particularly effective in cleaning up the spectra, perhaps because there were γ-rays associated with fission. Approximately 14 million two- and higher-fold events were recorded on tape.

A spectrum showing the lines of the superdeformed band is shown in Fig.1. It is gated by the 692 and 738 keV lines which are the only ones sufficiently clean. Although this spectrum is not so impressive, the existence of the SD band is unmistakeable, and its yield can be reasonably well established. The yields of the SD band from this reaction and those from the two other reactions previously published are shown in Table 1. These reactions were: ^{48}Ca+^{108}Pd at 205 MeV (Ref.2) and ^{40}Ar+^{116}Cd at 180 MeV (Ref.7). To understand these results, we need to consider how the maximum angular momentum (l_{max}) and the excitation energy (E^*) are related to these yields.

In Fig.2, a plot of excitation energy vs angular momentum, we have drawn the known SD band and the normally deformed prolate band and have extrapolated them with appropriate moments of inertia. For each reaction, we have also plotted E* and the I_{max} calculated with the Bass model[8]. The angular momentum at which the liquid-drop-model fission barrier is equal to the neutron binding energy is also indicated. A schematic feeding pattern of the SD band, as a function of spin, derived from the intensity of the observed transitions[2], is also shown. This spin region can be taken as a lower limit to the angular momentum required to produce this band, and it appears to coincide with the spin range where this band is yrast.

In order to provide good yields of this SD band, the I_{max} from the reaction needs to be well above this lower limit. It is apparent that the ^{48}Ca- and ^{74}Ge-induced reactions produce an I_{max} close to or above the angular momentum for fission, and satisfy the above criterion . However, the ^{40}Ar reaction did not bring in enough angular momentum to meet this requirement. To get the necessary angular momentum with an ^{40}Ar reaction, the energy would have to be higher, leading to a 5n rather than a 4n main product. For this case, ^{48}Ca is a better projectile than ^{40}Ar due largely to its more favorable Q-value. Also, for this case, the lower Q-value and increased Coulomb barrier for the ^{74}Ge + ^{82}Se system make it rather similar to the ^{48}Ca + ^{108}Pd system although the I_{max} is somewhat larger. From this comparison of the three reactions we can conclude that, in order to maximize the population of the SD band, it is necessary to use the reaction that will bring in an I_{max} near the fission limit at an excitation energy which produces a reasonable yield of the desired nucleus.

A comparison of the SD ridge structure (generated by unresolved SD bands) for the three reactions, suggests that excitation energy may also influence the population of SD bands. Although the intensity of the discrete SD band in the Ar-induced reaction is smaller than that of the other reactions, the intensity of the unresolved SD ridge appears to be at least as high (Table 1). In the ^{40}Ar-induced reaction, the I_{max} is slightly above the required lower angular momentum limit, and it appears that (unresolved) SD states are populated. However, it seems that this population does not reach the yrast line in the spin range where the discrete SD band is strongly populated. This suggests that the excitation energy of the product may also be an important parameter for the population of discrete SD bands.

In conclusion, we have not observed evidence for entrance channel effects in the yields of these three reactions. It appears that all the yields can be explained by the expected I_{max} and E^* behavior; the lower yield for the ^{40}Ar reaction being due to insufficient angular momentum (and/or too high excitation energy), and the similar yield for the ^{48}Ca and ^{74}Ge reactions resulting from the similar excitation energies and I_{max} values at (or above) the fission limit.

This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the US Department of Energy under Contract DE-AC03-76SF00098.

References:

[1] S. M. Polikanov et al., Soviet Phys. JETP 15 1016 (1962).

[2] P. J. Twin et al., Phys. Rev. Lett. 57 811 (1986).

[3] W. Kuhn et al., Phys. Rev. Lett. 51 1858 (1983).

[4] B. Herskind et al., NBI preprint (1987).

[5] R. M. Diamond " The Berkeley High-Resolution Ball" in Instrumentation for Heavy-Ion Research, ed. D. Shapira (Harwood Acad. Pub. New York, 1985) p.259.

[6] T. L. Khoo et al., Phys. Rev. Lett. 41 1027 (1978).

[7] M. J. A. de Voigt et al., Phys. Rev. Lett. 59 270 (1987).

[8] R. Bass, Phys. Lett. B47 139 (1973).

Figure Captions:

Fig.1: A section of the coincidence spectrum gated by the lines at 692 and 738 keV in the SD band of ^{152}Dy. The proposed[2] spins of the initial SD states generating the transitions are indicated.

Fig.2: Excitation energy vs angular momentum plot for the normal prolate (thin solid line) and SD (thick solid line) bands in ^{152}Dy. The dashed parts of these curves are extrapolations of these two bands. The Gaussian is a schematic feeding curve of the discrete SD band (see text), whose vertical scale and location are arbitrary. The angular momentum at which the fission barrier is equal to the neutron binding energy is indicated by the dotted line. Also shown are E^* and I_{max} for the ^{40}Ar+^{116}Cd (o), ^{48}Ca+^{108}Pd (□) and ^{74}Ge+^{82}Se (Δ) reactions.

TABLE 1

Reaction	E_{Lab}[a]	E^*	l_{Max}	I_{SD}	I_{ridge}
	(MeV)	(MeV)	$\hbar$	(%)	(%)
$^{48}\mathrm{Ca} + {}^{108}\mathrm{Pd}$[2]	200	75.5	70	~2.2	~2
$^{40}\mathrm{Ar} + {}^{116}\mathrm{Cd}$[7]	173	75.4	60	~0.5	5±2
$^{74}\mathrm{Ge} + {}^{82}\mathrm{Se}$	299	76.6	75	2.0 ±0.4	6±3

[a] Taking into account target thickness

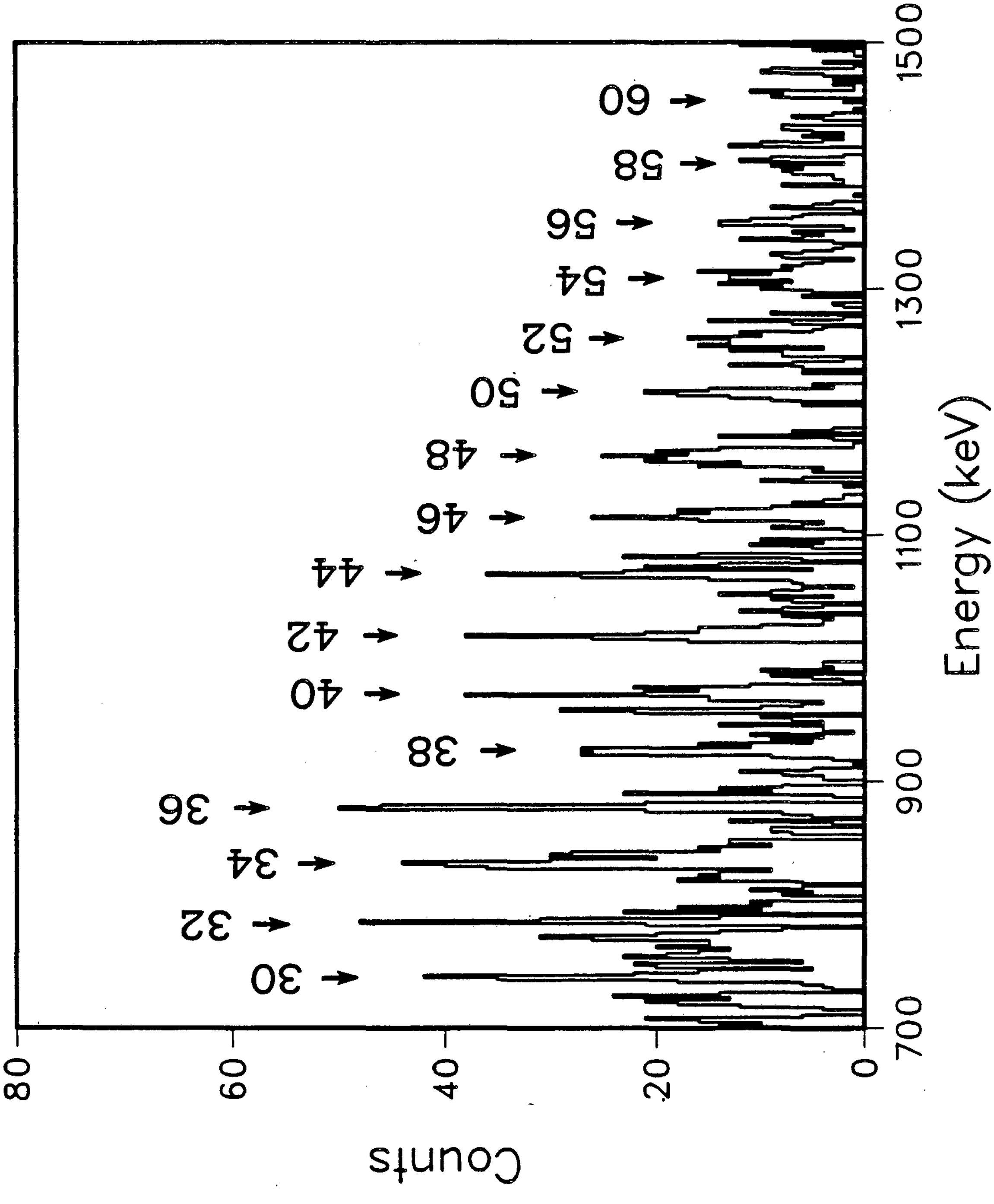

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Fig. 1

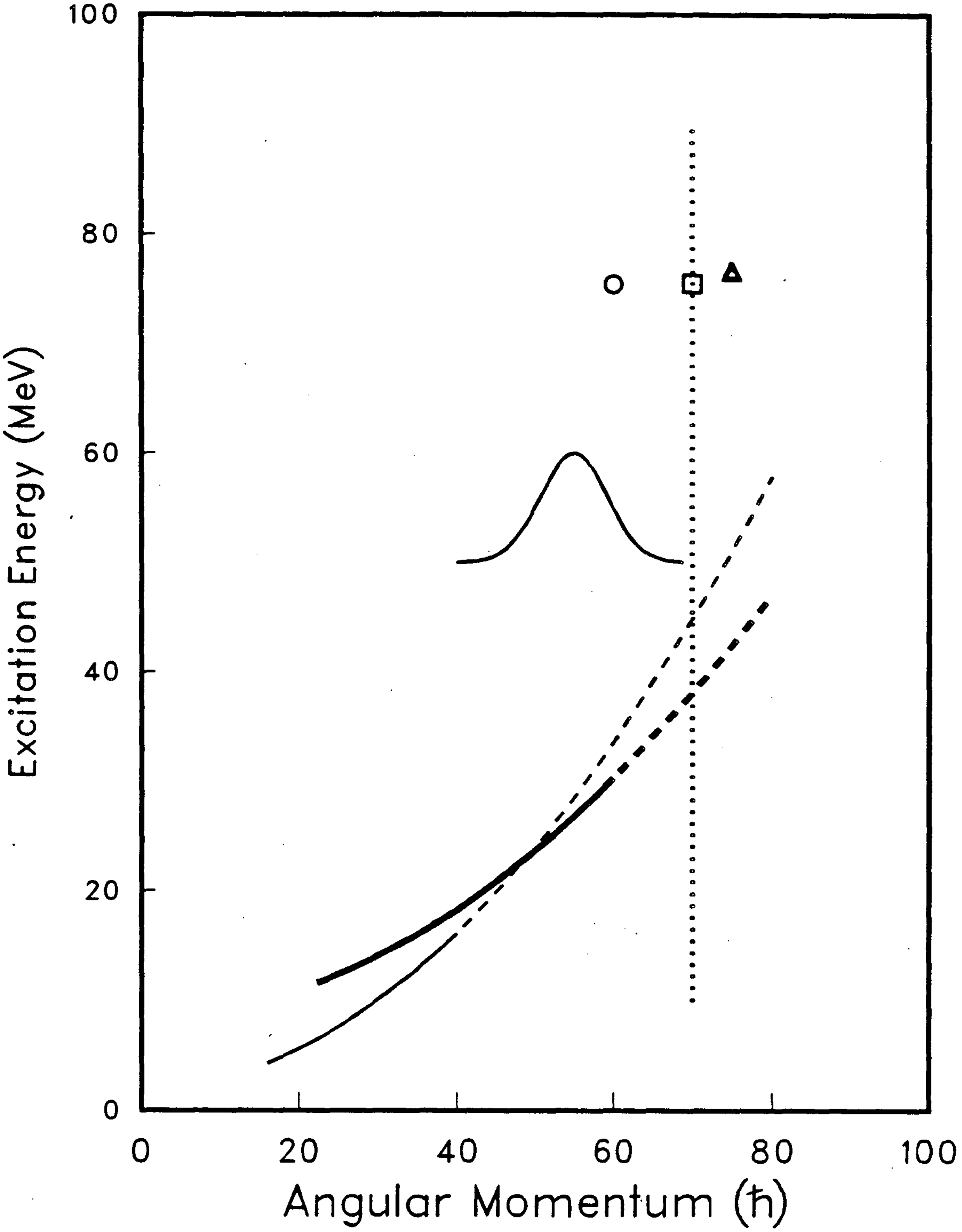

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Fig. 2