CONF-890406--1

Received OCT 1 2 1988

NUCLEAR SHAPES FROM SPECTROSCOPIC STUDIES OF FISSION FRAGMENTS+

I. Ahmad, H. Emling*, R. Holzmann*, R.V.F. Janssens and T.L. Khoo

Argonne National Laboratory, Argonne, Illinois 60439

W.R. Phillips

Department of Physics, University of Manchester, Manchester, England

and

M.W. Drigert**

University of Notre Dame, Notre Dame, Indiana 46556

CONF-890406--1

DE89 000597

Abstract

Partial level schemes for several neutron-rich Ba and Ce nuclei have been determined from the study of gamma-gamma coincidences in ^{252}Cf fission fragments. The experiment was performed with the Argonne-Notre Dame gamma ray facility, which consisted of 7 Compton-suppressed Ge detectors, a low-energy photon spectrometer and an inner ball of fourteen hexagonal BGO detectors. Gamma-gamma coincidence events between the Ge detectors, which were accompanied by a gamma in BGO detectors, were accepted. The triple coincidence requirement eliminated most of the beta-decay background. Transitions in individual Ba and Ce nuclei were identified by gating on the known $2^+ \rightarrow 0^+$ gamma rays. Level schemes deduced from these studies indicate interleaved negative and positive parity levels in ^{144}Ba, ^{146}Ba and ^{146}Ce which are connected by fast E1 transitions. Both these features are signature of octupole deformation (reflection asymmetric shape) and are reproduced by recent theoretical calculations.

+This work was supported by the U.S. Department of Energy, Nuclear Physics Division, under contract No. W-31-109-ENG-38, by the Science and Engineering Research Council of the U.K. and by the National Science Foundation Grant No. PHY-84-16025.

*Permanent address: GSI, Planckstrasse 1, D-6100, Darmstadt, West Germany.
**Present address: INEL, EG&G Idaho Inc., Idaho Falls, Idaho 83415.

NUCLEAR SHAPES FROM SPECTROSCOPIC STUDIES OF FISSION FRAGMENTS+

I. Ahmad, H. Emling*, R. Holzmann*, R.V.F. Janssens and T.L. Khoo
Argonne National Laboratory, Argonne, Illinois 60439
W.R. Phillips
Department of Physics, University of Manchester, Manchester, England
and
M.W. Drigert**
University of Notre Dame, Notre Dame, Indiana 46556

Strong octupole correlations between valence nucleons are expected in some regions of the nuclear table. They arise from the occurrence of closely spaced, opposite parity single-particle orbits with $\Delta\ell=3$ and $\Delta j=3$. These correlations may induce stable octupole deformation (reflection asymmetric shape) either in the ground state or in excited states of moderately high spin. Specifically, cranked mean field calculations [1,2] predict octupole deformation in limited sets of nuclei near Z=56, N=88 and Z=88, N=132. The signature of the reflection asymmetric shape is the occurrence of interleaved negative and positive parity rotational bands connected by fast electric dipole transitions. Such band structures have been observed in many even-even Ra and Th nuclei. Until recently very little information was available on the neutron-rich nuclei near Z=56, N=88. These nuclei are not accessible by commonly used (HI,xn) reaction spectroscopy. These neutron-rich nuclei are available as fission fragments. The present article reviews our recent studies [3,4] of the structure of Ba and Ce nuclei, which were produced in the fission of ^{252}Cf.

In the fission process, hundreds of nuclei are produced and they generate a complex gamma ray spectrum. Also, unlike in-beam gamma-ray spectroscopy, the average spin in the fission fragment is quite low (~5 $\hbar$). Higher spin states (I~12) in these nuclei are populated with intensity of only ~1%. To observe such weak transitions, a high sensitivity spectrometer is required. These kinds of measurements became possible with the availability of arrays of Compton-suppressed germanium detectors. The experiment described here was performed at the Argonne-Notre Dame BGO gamma-ray facility. A 60-microcurie ^{252}Cf source embedded in a beryllium cylinder was used in the experiment. The spectrometer consisted of 7 Compton-suppressed germanium detectors, a low-energy photon spectrometer (LEPS) and an inner ball of fourteen hexagon BGO detectors. The LEPS was placed at a close distance to detect x-rays and low-energy gamma rays. Gamma-gamma coincidence events, with the additional constraint that at least one hexagon fired, were recorded. The triple coincidence requirement eliminated most beta-decay backgrounds and emphasized prompt events of high multiplicity. The events were later sorted by placing gates on the known $2^+ \rightarrow 0^+$ transitions. In this way, transitions in individual nuclei were identified.

Spin-parity of levels were deduced on the basis of angular correlations and, in one case, on the basis of the conversion coefficient deduced from the K x-ray intensity. From these analyses, the level schemes of ^{142}Ba, ^{144}Ba, ^{146}Ba, ^{146}Ce, ^{148}Ce, and ^{150}Ce were deduced. The level schemes of ^{144}Ba and ^{146}Ce are shown in Fig. 1. In these two nuclei and in ^{146}Ba, the levels above 6 $\hbar$ deexcite by competing E1 and E2 transitions. Also, the negative and positive parity levels are intertwined forming a single rotational band. The energy spacings between levels with spins grater than 6 $\hbar$ approaches the value expected for a single rotational band as the spin increases. This indicates that octupole deformation is increasing with increasing spin. Other Ba and Ce isotopes do not exhibit properties characteristic of reflection asymmetric shape.

From the observed E1/E2 branching ratios, and assuming that the quadrupole moment deduced from the lifetime of the $2^+ \rightarrow 0^+$ level remains constant throughout the rotational band, one can deduce the electric dipole moment. The electric dipole moment D_o is related to the B(E1) value by the following expression

$$B(E1;I_i \rightarrow I_f) = 3D_o \langle I_i 010 | I_f 0 \rangle^2 / 4\pi,$$

where the term in the angular bracket is the appropriate Clebsch-Gordon coefficient. The dipole moments deduced from our measurements are compared with those calculated from theory in Table 1.

In summary, structure of Ba and Ce isotopes, studied from measurements of fission fragments, indicate that ^{144}Ba, ^{146}Ba and ^{146}Ce develop octupole deformation above 7 $\hbar$. In contrast, other Ba and Ce isotopes do not exhibit these properties. These findings are in full agreement with the recent cranked mean field calculations.

+This work was supported by the U.S. Department of Energy, Nuclear Physics Division, under contract No. W-31-109-ENG-38, by the Science and Engineering Research Council of the U.K. and by the National Science Foundation Grant No. PHY-84-16025.

*Permanent address: GSI, Planckstrasse 1, D-6100, Darmstadt, West Germany.
**Present address: INEL, EG&G Idaho Inc., Idaho Falls, Idaho 83415.

References

[1] G.A. Leander et al., Nucl. Phys. A388, 452 (1983).
[2] W. Nazarewicz and P. Olanders, Nucl. Phys. A441, 420 (1985).
[3] W.R. Phillips et al., Phys. Rev. Lett. 57, 3257 (1986).
[4] W.R. Phillips et al., submitted to Phys. Lett.

Table 1

Experimental and Predicted Intrinsic Dipole Moments

Nucleus	D_o (exp) (efm)	D_o (theory) (efm)
^{144}Ba	0.13	0.09
^{146}Ba	0.04	0.03
^{146}Ce	0.20	0.18
^{146}Nd	0.18	0.20
^{148}Nd	0.23	0.22
^{150}Sm	0.20	0.25

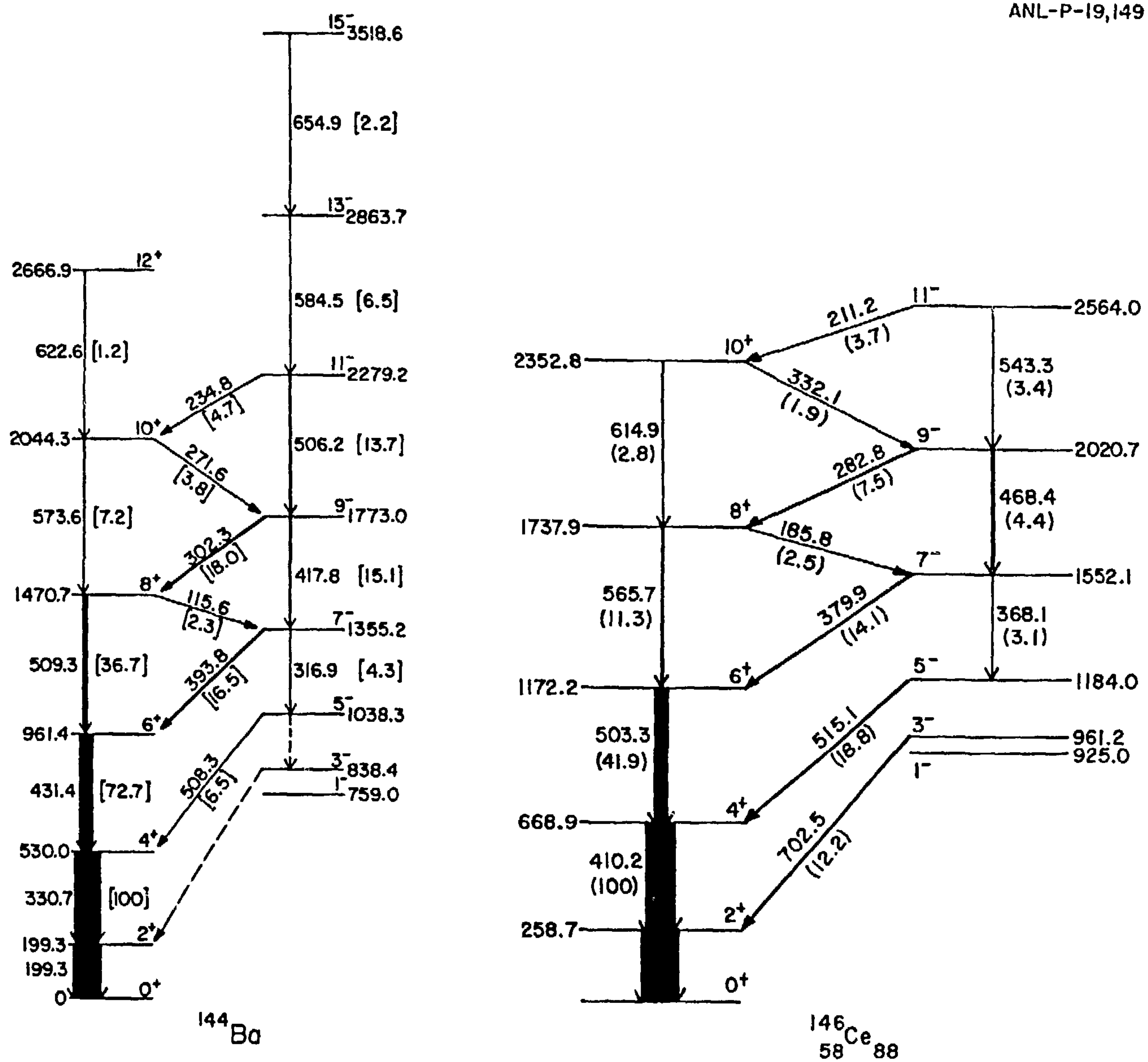

Fig. 1. Partial level schemes of ^{144}Ba and ^{146}Ce.