Lawrence Berkeley National Laboratory

Title
MULTIPOLE DEFORMATION OP 238U

Permalink
https://escholarship.org/uc/item/7308d2xr

Author
Hendrie, D.L.

Publication Date
1972-04-01

MULTIPOLE DEFORMATION OF ^{238}U

D. L. Hendrie, B. G. Harvey, J. R. Meriwether,
J. Mahoney, J-C. Faivre, and D. G. Kovar

April 1972

DISCLAIMER

MULTIPOLE DEFORMATION OF ^{238}U[*]

D. L. Hendrie, B. G. Harvey, J. R. Meriwether[†], J. Mahoney,
J-C. Faivre[††], and D. G. Kovar

Lawrence Berkeley Laboratory
University of California
Berkeley, California   94720

April 1972

Abstract:

Elastic and inelastic scattering of 50 MeV helium ions from ^{238}U was studied with a high-resolution magnetic spectrometer. Angular distributions for members of the ground state rotational band up to the 8^+ level were measured. Coupled channels calculations yield 0.022, 0.060, and -0.012 for the deformation parameters β_2, β_4, and β_6 for an optical radius of 1.44 $A^{1/3}$ fm. These values are compared with other experimental results.

The ability to measure details of nuclear shapes by means of alpha-particle inelastic scattering has been first demonstrated for permanently deformed rare earth nuclei.[1] Attempts to extend these measurements to the interesting actinide region of permanent deformations have been thwarted by experimental difficulties, mainly the inability of solid state detectors to resolve the more closely spaced energy levels in these nuclei. Meanwhile, several theoretical predictions for the hexadecapole moments of actinide nuclei and a few experimental results using other techniques have been published. The interest in the problem is intensified, however, because both the theoretical

predictions[2,3,4] and the experimental results[5,6] show large variations for

the Y_{40} moment of uranium. These experiments determine rather large values

for the deformation parameters, β_L, when the nuclear radius R is expanded from

an optical radius, R_o

$$R = R_o(1 + \beta_2 \ Y_{20} + \beta_4 \ Y_{40} + \beta_6 \ Y_{60}) \ , \qquad (1)$$

where Y_{LO} are the spherical harmonics.

Our experiment measured the angular distributions in elastic and

inelastic scattering of 50 MeV alpha particles by ^{238}U, utilizing a new

magnetic spectrometer[7] for detection of the scattered alphas. Differential

cross sections were measured for levels in the ground state rotational band up

to the 8^+. The target was made by evaporating 75 $\mu g/cm^2$ of uranium metal on to

a 50 $\mu g/cm^2$ carbon backing. Beams of up to 1μa were prepared by the high

resolution magnetic analysis system, delivered on to the target, and collected

and measured in a Faraday cup. The quantity of beam on target was also

monitored by a solid state detector placed at 20° with respect to the incident

beam. Detection of scattered alphas at the focal plane of the spectrometer was

made by a 1 cm high by 5 cm long position sensitive silicon detector obtained

from Nuclear Diodes, Inc. The energy resolution of the entire system was 16

keV at forward angles, changing slowly to 20 keV at the most backward angles,

where target thickness effects become more important. The data were taken in

two independent runs. Scattering from a target contaminant of about 10% ^{182}W

obscured the ^{238}U levels for several angles in the first run. This problem did

not repeat in the second run; the results from the two runs reproduced well

where they could be checked. A sample spectrum from the second run is shown in

Fig. 1.

Because of the limited height (1 cm) of the position sensitive detector
and the large vertical magnification of the spectrometer, we were able to
detect only about 80% of the scattered particles accepted by our solid angle
of 0.7×10^{-3} sr. Relative normalization was made by utilizing a special
target made by evaporating 200 $\mu g/cm^2$ of ^{238}U on to a carbon foil in the form
of a strip 1 mm in height. This produced a 5 mm high image at the focal
surface centered vertically in the detector aperture. A short run on this
target was made at every data angle; the data were normalized by comparison
of the sum of the elastic and 2^+ levels with the equivalent sum from the
special target. Counting statistics limited the accuracy of the relative
normalizations to 2-3% for angles less than 54°, and ±4-5% for angles greater
than that, other sources of error were negligible. Absolute normalization
was made by comparing the measured elastic cross sections at small angles,
where the scattering is nearly pure Coulomb and insensitive to optical model
parameters, to coupled-channels calculations of small angle scattering. This
proceedure yields an estimated ±1-2% accuracy in the absolute normalizations.
In this case, as with the estimations of the errors for the deformation
parameters, the errors were determined by visually ascertaining misfits between
the data and the calculations.

The resulting angular distributions are shown in Fig. 2. Also shown
in Fig. 2 are the results of coupled-channels calculation using the program of
Glendenning.[8] The transition amplitude between the various rotational levels
are determined by the pure rotational model treatment of the deformed optical
potential. Improvements to the fits to the 6^+ and 8^+ state were achieved by
including a β_8 term, but it is not included here because we feel it has no

real significance. Expansions and numerical sums were carried to convergence,
so that the only approximations involved in the calculation are those inherent
in the model itself. The optical parameters chosen were the same as were used
in the rare earth work.[9] Varying them by 10-20% in such a way as to preserve
the fits did not change the values extracted for the deformation parameters.
Estimates of the errors were made by making several independent calculations
with altered deformation parameters.

Table I lists the value of the deformation parameters obtained from
our work and from other recent theoretical and experimental results. Not
listed in the table are the results of Huber[11] from α-decay and the theoretical
results of Chasman,[4] both of whom seem to obtain small negative values of β_4,
nor the theoretical results from Ref. 3, who predict positive values of β_4
ranging from 0.039 to 0.075. Our results are in fair agreement with the
theories of Refs. 2 and 3, but do not agree within the quoted errors with the
two other experimental values, for β_4. One should not underestimate the
difficulty of extracting precise values of higher-order deformations in Coulomb
excitation work,[6] especially since the β_4 values depend sensitively on very
precise values of β_2. On the other hand, the relationship between the
deformation of the nuclear potential that we measure, and the deformation of
the mass distribution is not well understood at present.[12] Surely this problem
must be solved before differences between proton and neutron deformations can
be extracted from the comparison of the two types of data. The discrepancy
between the proton[5] and alpha results is not easy to understand, but the lack
of an independently derived optical potential and the possibility of exchange
effects[13] are potential sources of error for the former, effects that are not
expected to contribute to uncertainties in the present experiment.

FOOTNOTES AND REFERENCES

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

† Permanent address: University of Southwestern Louisiana, Lafayette, La.

†† Permanent address: CEN Saclay, France.

1. D. L. Hendrie, N. K. Glendenning, B. G. Harvey, O. N. Jarvis, H. H. Duhm, J. Saudinos, and J. Mahoney, Phys. Letters 26B, 127 (1968).

2. S. G. Nilsson, C. F. Tsang, A. Sobiczewski, Z. Szymanski, S. Wycech, C. Gustafson, I. L. Lamm, P. Möller, and B. Nilsson, Nucl. Phys. A131, 1 (1969); P. Möller, B. Nilsson, S. G. Nilsson, A. Sobiczewski, Z. Szymanski, and S. Wycech, Phys. Letters 26B, 418 (1968).

3. F. A. Gareev, S. P. Ivanova, and V. V. Pashkevich, Yad. Fiz. 11, 1200 (1970); [Sov. J. Nucl. Phys. 11, 667 (1969)]; K. Harada, Phys. Letters 10, 80 (1964); K. Kjällquist, Nucl. Phys. 9, 163 (1958).

4. R. R. Chasman, Phys. Rev. C1, 2144 (1970).

5. J. M. Moss, Y. D. Terrien, R. M. Lombard, C. Brassard, J. M. Loiseaux, and F. Resmini, Phys. Rev. Letters 26, 1488 (1971).

6. F. K. McGowan, C. E. Bemis, J. L. C. Ford, Jr., W. T. Milner, R. L. Robinson, and P. H. Stelson, Phys. Rev. Letters 27, 1741 (1971).

7. D. L. Hendrie, J. R. Meriwether, F. Selph, D. Morris, and C. Glashausser, BAPS 15, 650 (1970); J. R. Meriwether, D. L. Hendrie, F. Selph, and D. Morris, Proc. of the Louisiana Academy of Science, April 1971, p. 18.

8. N. K. Glendenning, Proceeding of the International School of Physics "Enrico Fermi", Course XL (Academic Press, 1967).

9. N. K. Glendenning, D. L. Hendrie, and O. N. Jarvis, Phys. Letters 26B, 131 (1968).

10. D. L. Hendrie (to be published).

11. M. G. Huber, Phys. Letters $\underline{13}$, 242 (1964).

12. G. H. Rawitscher and R. A. Spicuzza, Phys. Letters $\underline{37B}$, 221 (1971); A. M.
     Bernstein, Advances in Nuclear Physics, eds. M. Baranger and E. Vogt
     (Plenum Press, 1969) Vol. 3, p. 325.

13. L. W. Owen and G. R. Satchler, Phys. Rev. Letters $\underline{25}$, 1720 (1970).

Table I. Table of deformation parameters for this and other work. The parameters are defined by describing the nuclear surface as in Eq. (1). The radius common to all values in the table is $R_0 = 1.2 \ A^{1/3}$ fm. The values for this experiment are obtained by a second order treatment for radius scaling.[10]

β_2	β_4	β_6	Method
0.22 ±0.01	0.06±0.01	−0.012±0.01	This Work
0.23 ±0.01	$0.017 \begin{Bmatrix} +0.015 \\ -0.030 \end{Bmatrix}$	−0.015	$(p,p')^a$
0.235±0.006	0.100±0.028	—	Coulomb Excitation[b]
0.220	0.071	—	Theory[c]

Notes: a. Ref. 5
        b. Ref. 6
        c. Ref. 2

FIGURE CAPTIONS

Fig. 1.   Sample spectrum of the ^{238}U (α,α') reaction at 48 °(lab).

Fig. 2.   Differential cross sections and coupled-channels calculation for

^{238}U (α,α') at 50 MeV.   The optical parameters for the calculation are the

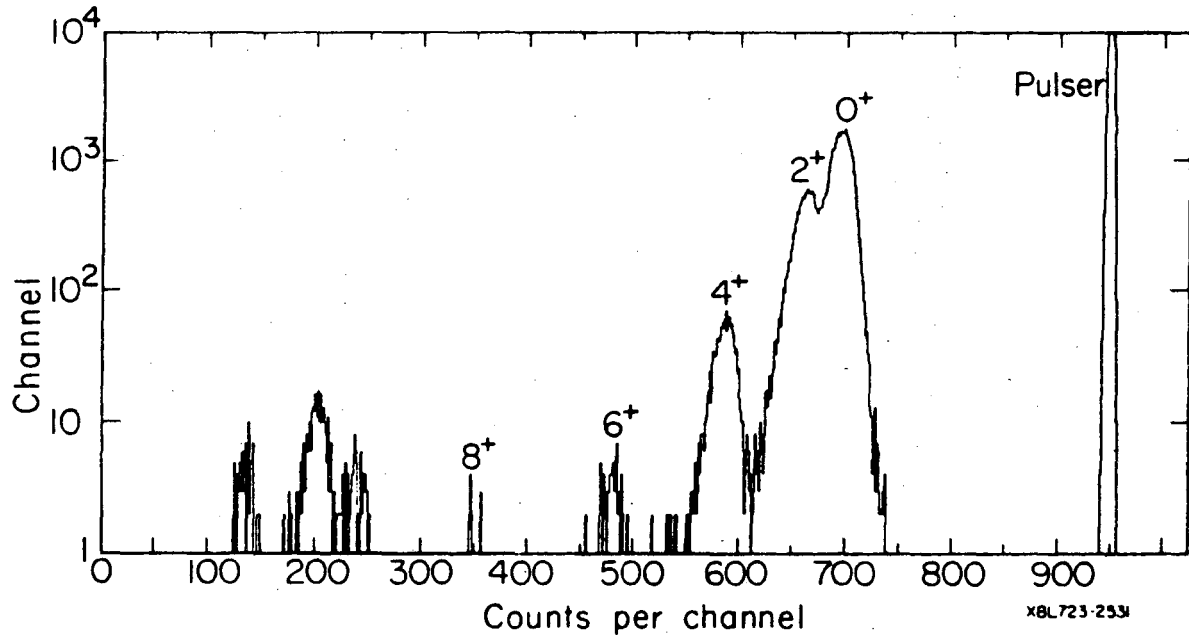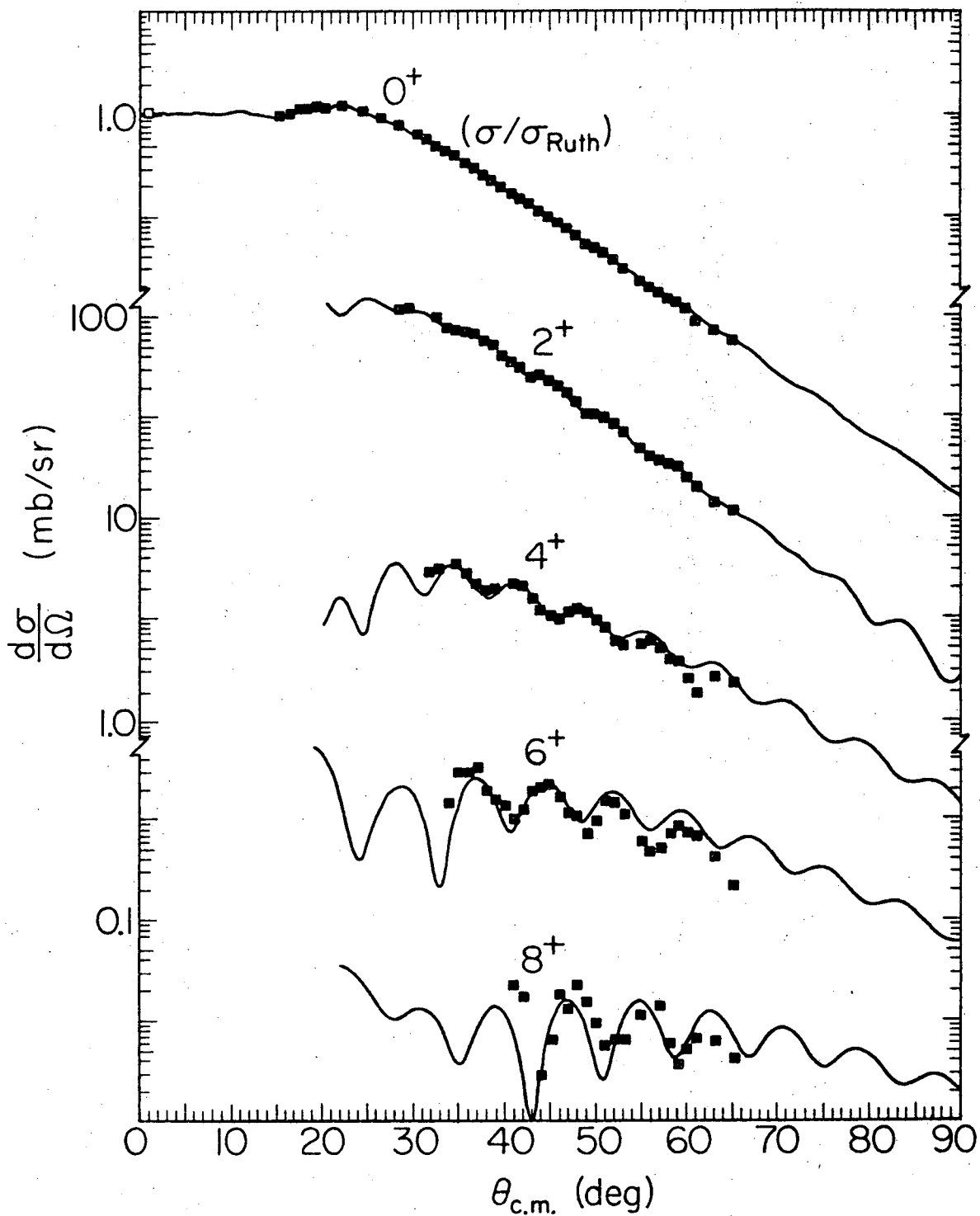same as in Ref. 9.   The deformation parameters are given in the text.

XBL723-253I

Fig. 1

XBL723-2530

Fig. 2