JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN VOL. 34, SUPPLEMENT, 1973
PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON NUCLEAR MOMENTS AND NUCLEAR STRUCTURE, 1972

VII-5 Nuclear Spectroscopic Quadrupole Moments of ^{175}Lu and ^{235}U: A New Approach

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The methods presently used to determine nuclear spectroscopic quadrupole moment, such as hfs measurements in electronic atoms,[1] measurements of the reorientation effect in Coulomb excitation[2] etc. are all subject to considerable uncertainties.[1] In addition there are model-dependent ways to obtain nuclear quadrupole moments, for example from the crosssection for Coulomb excitation or from an analysis of the splittings of the 3d − 2p and 2p − 1s X-ray transitions in muonic atoms.[3]

We propose to measure spectroscopic (model-independent) quadrupole moments from the quadrupole splittings of excited states of muonic atoms for which the mean muon radius is large compared to the nuclear radius but a quadrupole splitting still can be observed experimentally. The dominant part of the quadrupole coupling constant may then be evaluated in the point nucleus approximation. The nuclear finite size effect, nuclear polarization and also effects of the dynamic quadrupole interaction[6] are then small corrections. The splitting can thus be calculated from the spectroscopic quadrupole moment Q and the eigenfunction of the bound muon. In contrast to the situation in electronic atoms this latter quantity can be exactly calculated since we are dealing with a simple hydrogenlike system.

In an experiment performed at the muon channel of the CERN Synchrocyclotron we have observed the quadrupole splittings on the 5g − 4f and the 4f − 3d X-ray transitions in muonic ^{175}Lu and ^{235}U.[4] The energy spectra are shown in Figs. 1, 2, 3 and 4.

For a preliminary analysis we have used the following procedure: The energies of the quadrupole hyperfine components were calculated with point nuclear relativistic muonic eigenfunctions by diagonalization of the energy matrices for each value F, but neglecting nuclear excitation, nuclear polarization and the magnetic hyperfine splitting. For the 3d levels finite size corrections have been included. For the intensities a statistical population of the initial hyperfine levels was assumed. The relative intensities of the two dominant fine structure lines were taken from the cascade program of Hüfner.[5] The weak

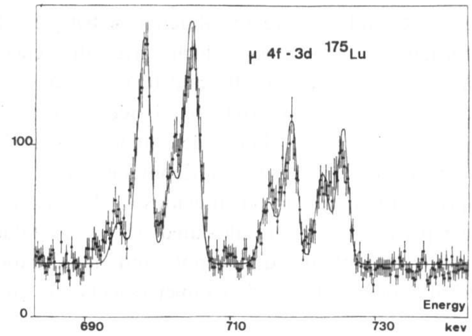

Fig. 1. Energy spectrum of 4f − 3d transitions in μ^{175}Lu, obtained with a 2.4 cc planar Ge(Li) detector. The total number of counts is given as a function of the energy.

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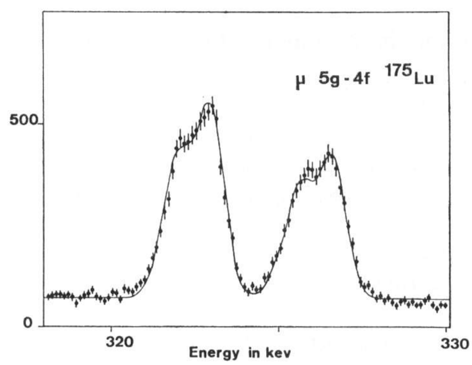

Fig. 2. Energy spectrum of 5g — 4f transitions in μ^{175}Lu, obtained with a 1 cc planar Ge(Li) detector. The total number of counts is given as a function of the energy.

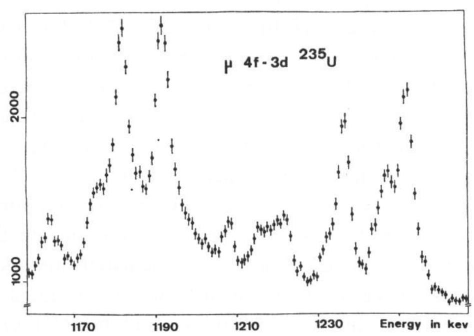

Fig. 3. Energy spectrum of 4f — 3d transitions in μ^{235}U, obtained with a 40 cc coaxial Ge(Li) detector. The total number of counts is given as a function of the energy.

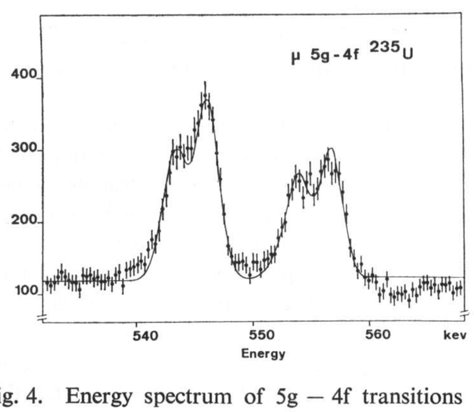

Fig. 4. Energy spectrum of 5g — 4f transitions in μ^{235}U, obtained with a 2.4 cc planar Ge(Li) detector. The total number of counts is given as a function of the energy.

Table I. Preliminary spectroscopic quadrupole moments Q[b] from 5g — 4f and 4f — 3d transitions in ^{175}Lu and ^{235}U. The errors quoted are those obtained from the fit.

	^{175}Lu	^{235}U
5g — 4f	3.74 ± 0.05	4.55 ± 0.09
4f — 3d	3.35 ± 0.02*	—

* A finite size correction of 4% has been applied.

fine structure transition $4d_{3/2} - 3p_{1/2}$ is neglected in the fit to the 4f — 3d X-ray transition and the $5f_{7/2} - 4d_{5/2}$ component in the 5g — 4f transition. For all components Gaussian line profiles were assumed with a width taken from calibration lines. Thus the only important parameters in the fit are the spectroscopic quadrupole moment Q and the (fine structure) splitting between the two main groups of lines.

The solid line in Figs. 1, 2 and 4 is a fit to the data. The results are shown in Table I. The spectrum of the 4f — 3d transition in ^{235}U could not be well reproduced by a fit. This is due to the dynamical nuclear excitation which was neglected in the present treatment. The deviations between 5g — 4f and 4f — 3d values for ^{175}Lu are believed to be due to the approximate nature of the procedure used in analyzing the data. An evaluation of all the corrections is in progress. Therefore, the deduced quadrupole moments (Table I) will change in an improved analysis.

References

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2) B. Povh: in *Angular correlations in nuclear disintegration,* ed. H. van Krugten and V. van Nooijen (Rotterdam University Press, The Netherlands, 1971) p. 327.
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4) The ^{235}U metal target (enriched to 93.16%) was obtained from the Oak Ridge National Laboratory through the kind offices of Dr. E. Ritter of the US Atomic Energy Commission.
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