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# VII-6 Search for Strong Interaction Quadrupole Effect in the Pionic Atom of $^{175}$Lu

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The level splittings of highly excited states in pionic atoms due to the electromagnetic interaction are treated in much the same way as for muonic atoms.[1,4] For nuclei with angular momentum $I > 1/2$ the electric quadrupole interaction dominates and splits each fine structure level into $(2l+1)(2I+1)$ components, where $l$ is the orbital angular momentum of the pion. For each component characterized by the total angular momentum $F$, the angular momentum of the bound pion has a well-defined orientation with respect to the nuclear spin axis. Hence the amount of overlap between the pion and the nucleus is different for different $F$ levels.

Therefore the shift and width due to the strong interaction between the pion and the nucleus are also different for different $F$ components.[2] The theory of this phenomenon has recently been developed by Scheck.[3] The strong interaction effect may be described by the following equations:

$$\varepsilon_F = \varepsilon_0 + \frac{3C(C+1) - 4I(I+1)l(l+1)}{2I(2I-1)l(2l-1)}\varepsilon_2 \quad (1)$$

$$\Gamma_F = \Gamma_0 + \frac{3C(C+1) - 4I(I+1)l(l+1)}{2I(2I-1)l(2l-1)}\Gamma_2, \quad (2)$$

where $\varepsilon_F$ and $\Gamma_F$ are the shift and the width of the $F$ level, $\varepsilon_0$, $\varepsilon_2$, $\Gamma_0$ and $\Gamma_2$ are constants within a fine structure multiplet, and $C$ is given by

$$C = F(F+1) - I(I+1) - l(l+1)\ . \quad (3)$$

Equations (1) and (2) are derived on the basis on an equivalent optical potential for the pion nucleus interaction. The nucleus is assumed to be of quadrupole shape only. In the case where $R_n \ll \langle r_\pi \rangle$ the ratio $\varepsilon_2/\varepsilon_0$, where $\varepsilon_0$ is the overall shift of the hyperfine multiplet due to the strong interaction, and also the ratio $\Gamma_2/\Gamma_0$ are independent of the parameters of the optical potential. They thus represent new model-independent nuclear quantities which probe the mass distribution near the nuclear surface for the high angular momentum states under consideration. Based on a Fermi-type charge distribution and the rotational model, Scheck[3] has calculated numerical values for the strong interaction quadrupole coupling constant $\varepsilon_2$. In the case of the 4f level in $\pi$ $^{175}$Lu the quantity $\varepsilon_2/A_2$ is predicted to be $-0.032$ and $\Gamma_2/\Gamma_0 = -0.21$, assuming a spectroscopic quadrupole moment $Q = 3.75$ barns.

The splitting due to both the electromagnetic and the strong interaction is thus described by a total quadrupole coupling constant $A_2 - \varepsilon_2$, where $A_2$ is the usual quadrupole coupling constant of the electromagnetic interaction between pion and nucleus.

The parameter $\varepsilon_2$ of the strong interaction quadrupole effect experimentally can be determined by comparing a measured effective quadrupole moment in pionic atoms with the spectroscopic quadrupole moment determined in muonic atoms.[1]

In an experiment performed at the muon channel of the CERN Synchrocyclotron we have observed the quadrupole splitting on the 5g — 4f X-ray transition in pionic $^{175}$Lu (see Fig. 1). The intensities of the hfs lines have been calculated assuming a statistical distribution of the initial states. For all components Gaussian line profiles were assumed with the width as a free parameter. The only other important

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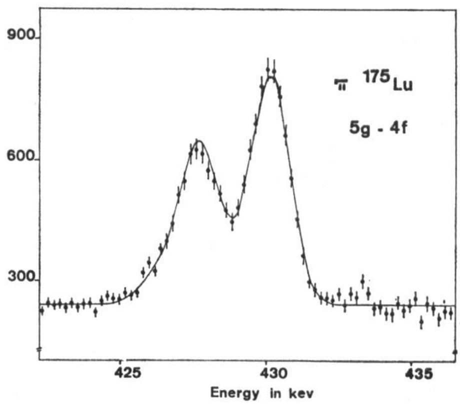


Fig. 1. Energy spectrum of 5g − 4f transition in $\pi^{175}$Lu, obtained with a 1 cc planar Ge(Li) detector. The total number of counts is given as a function of the energy.

parameter in the fit is the effective quadrupole moment, defined by

$$Q_{\text{eff}}A_2 = Q(A_2 - \varepsilon_2) , \qquad (4)$$

where $Q$ is the nuclear spectroscopic quadrupole moment. As a result of this analysis we obtain

$$Q_{\text{eff}} = 3.70 \pm 0.04\text{b} . \qquad (5)$$

This value may be compared to $Q$ as deduced from muonic $^{175}$Lu.[1] Until the muonic data are fully evaluated, however, no definite conclusion can be reached concerning the strong interaction quadrupole effect.

## References

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