Angular Correlation Measurements in ^{155}Eu Nuclei

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A method of analysis for gamma angular correlation experiments was developed for the case of a multi-detector setup, tested with several known sources of radiation, and applied in the decay of the ^{155}Eu nucleus. The method has shown good reliability. This method was applied for five cascades for the transitional nucleus ^{155}Eu and produced the following results: $\delta(65 \text{ keV}) = 0.09(11)$, $\delta(203 \text{ keV}) = -0.44(17)$, $\delta(246 \text{ keV}) = 0.281(22)$, $\delta(664 \text{ keV}) = -0.231(21)$, $\delta(1002 \text{ keV}) = -0.35(6)$.

1 Introduction

The Eu nuclei are in the transitional deformation region and, therefore, it is of great theoretical interest to study their deformation changes as a function of the mass number and excitation energy, as well as investigate the structure of their excited states. A recent bibliographic research shows that levels of the ^{155}Eu nucleus were studied via β^- decay first by Ungrin et al.[1] in 1969 using Ge(Li) and NaI(Tl) detectors, determining the most part of the levels of this nucleus. Only two studies that performed angular correlation measurements were found, the most recent was done in 1974, by Begzhanov et al.[2]. This indicated the need for further measurements.

2 Measurements

The samples were composed of 5 mg of samarium oxide, enriched to 98.7% of ^{154}Sm. They were submitted to a thermal neutron flux of 10^{13} n/cm^{2}s in the IEA-R1m reactor of IPEN/CNEN-SP during one minute. The angular correlation measurements were performed with a system installed at the Linear Accelerator Laboratory of the Instituto de Física da Universidade de São Paulo, which is composed of four Ge detectors with active volumes ranging from 50 to 190 cm^3. The detectors were arranged with their axes on a horizontal plane, with angles of $90°$, $120°$, $150°$ and $180°$. They were mounted inside lead collimators, to define their solid angles for photon acceptance and to prevent coincidence events of photon scattering from one detector into another.

The signals from these detectors were inserted into a usual fast-slow electronics, where the decisory functions were performed by a home-made CAMAC module. If all logic conditions were met, a CAMAC controller, directly coupled to the bus of an IBM-compatible personal computer (PC), managed the data transfer to the PC, through an ISA bus lengthener [3]. Both devices, the controller and the lengthener, were designed and built in-house, and allow a high data throughput. The data were recorded on event-by-event mode on hard disk.

A total of 103 sources was produced. Those were counted for a period of 1.3 hours each, totalling 137 hours of measurement.

3 Fit of the function $W(\theta)$

Differences among the efficiencies of detector pairs must be taken into account, and this causes the raw coincidence data not to match to a continuous model function, $W(\theta)$. The coincidence efficiencies must be introduced into the model function to be used for the fits. The structure of the angular correlation function represents a model to be fitted to the experimental data, with the help of the least squares method. Calling this function $W_{\rm theo}(\theta)$, it may be put into matrix form as follows: the column vector containing the model estimates is written as

$$\boldsymbol{W}_{\rm theo} = C_0 \cdot \boldsymbol{\epsilon} \cdot \mathbf{R} \cdot \mathbf{X} \tag{1}$$

where C_0 is a constant which will be one of the quantities to be fitted, and $\boldsymbol{\epsilon}$ represents the efficiency matrix, diagonal. The length N of this vector is the number of independent detector pairs. Matrix $\mathbf{R}$ is given by the product of the Legendre polynomials by the corresponding solid angle corrections. The column vector $\mathbf{X}$ contains the correlation coefficients expressed as functions of the deltas.

The minimization procedure involves the fit of correlated data, the covariances being due to the detection efficiencies. The quantity to be minimized is

$$\chi^2 = \boldsymbol{\Delta}^t \mathbf{M}^{-1} \boldsymbol{\Delta} \,, \tag{2}$$

done by varying C_0, and the multipole mixtures δ_1 (of the first transition) and δ_2 (of the second transition). In Eqn.(2), $\boldsymbol{\Delta}$ is the column vector containing the differences

$$\boldsymbol{\Delta} = \boldsymbol{W}_{\rm exp} - \boldsymbol{W}_{\rm theo} \,, \tag{3}$$

$\boldsymbol{W}_{\rm exp}$ contains the experimental coincidence counts obtained and $\mathbf{M}$ is the complete covariance matrix of $\boldsymbol{W}_{\rm exp}$.

TABLE 1. Multipole mixing ratios values obtained in the fits of multi-detector data, together with δ values from Ref.4.

Decaying Nuclide (Gamma Cascade)	δ (this work)	δ (Ref. 4)
^{60}Co (1173-1333 keV)	0.016 (15)	-0.0025 (22)
^{133}Ba (81-356 keV)	-0.137 (7)	-0.151 (2)
^{152}Eu (344-778 keV)	0.03(4)	0.002 (6)
^{152}Eu (344-1089 keV)	29 (29)	29^{+42}_{-11}

TABLE 2. Multipole mixing ratios for transitions in ^{155}Eu. Values are compared to those in Ref.4.

Transition (keV)	δ (this work)	δ (Ref. 4)
64.7	0.09(11)	0.12^{+3}_{-4}
203.1	-0.44(17)	E1
245.8	0.281(22)	0.31(3)
664.1	$-0.231(21)$	M1
1002.4	$-0.35(6)$	M1

4 Results

Application of the fitting method was performed for four γ-cascades from calibration sources and to five gamma cascades from ^{155}Eu. The results are shown in table 1 and table 2, respectively.

5 Discussion

Reliability tests of the method were successfully performed for four γ-cascades, belonging to three different radioisotopes usually employed as calibration sources for γ-ray spectroscopy: one cascade from the decay of ^{60}Co, one from ^{133}Ba and two from ^{152}Eu . These fits, shown good agreement, compared to the accepted values, as shown in table 1. We can also view in table 2 the good results for the ^{155}Eu.

The method used was tested on its statistical correctness and comparison was made of its results with those accepted in the literature, measured with other techniques.

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