

# MULTIPARAMETRIC COINCIDENCE MEASUREMENTS OF $^{155}\text{Sm}$ $\beta^-$ DECAY

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## ABSTRACT

Recently, the  $^{155}\text{Sm}$  decay was studied in the Nuclear Structure Laboratory (LEN-IPEN/SP) by single spectroscopy measurements and two new transitions were proposed. In order to confirm and possibly enhance these results, in this work gamma-gamma coincidence spectroscopy measurements were performed using a multiparametric data acquisition system. These measurements were performed using 4 high-resolution HPGe detectors with active volumes ranging from 50 to 190 cm<sup>3</sup>. The multiparametric data acquisition system used, installed in the Linear Accelerator Laboratory of the Physics Institute (LAL/IFUSP). The six bidimensional spectra produced were relocated and summed up, so that two “all-in-one” bidimensional spectra, one for the total coincidences and the other for accidental coincidences, were then used in the analysis. From these results, ten new transitions were added to this decay scheme, and a level at 1310 keV could also be proposed.

## 1. INTRODUCTION

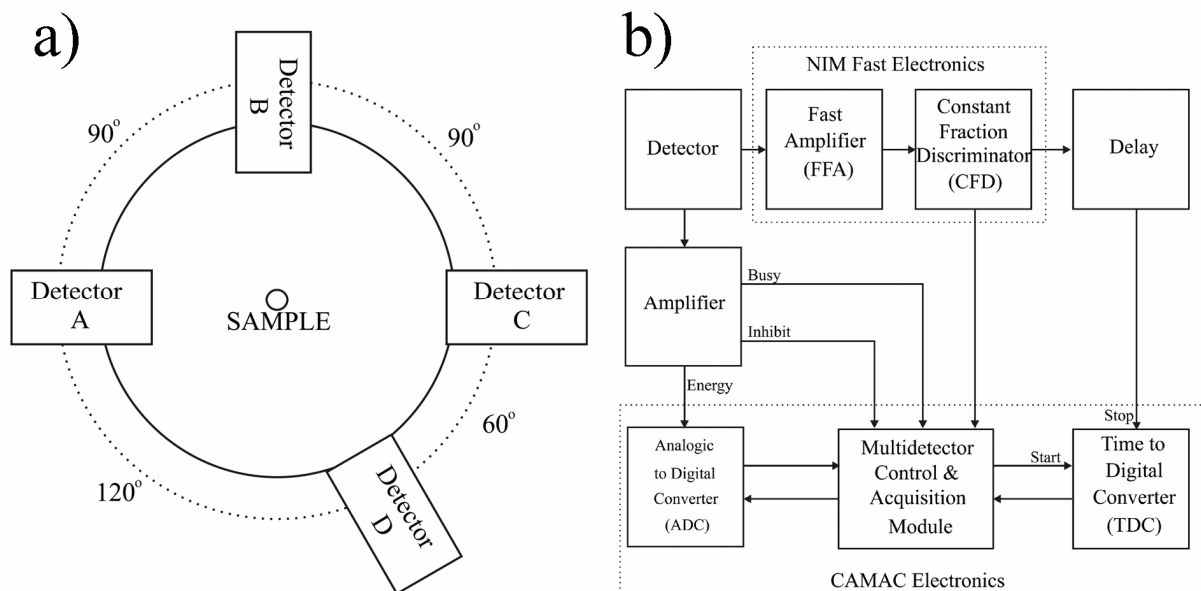
Some investigations have been made in the past to determine the decay scheme of  $^{155}\text{Sm}$  through the  $\beta^-$  decay studies, but almost all the features of the low-lying excited levels in it have been established by the measurement performed by *Ungrin et al.*[1] in 1969, using NaI(Tl), Si(Li) and Ge(Li) detectors, with much lower statistics than what can be obtained with present-day equipment.

Recently, the  $^{155}\text{Sm}$  decay scheme was studied in the Nuclear Structure Laboratory (LEN-IPEN/SP) by single spectroscopy measurements, and two new transitions were proposed on this decay scheme and indications of new transitions have been observed. Other aim of this work was study angular correlation parameters in order to determined the multipole signature of the transitions [2]. These measurements were performed using 4 high-resolution HPGe detectors and a multiparametric coincidence system. In these cases, the use of a multiparametric system, where  $n$  detectors are associated as  $L=n.(n-1)/2$  independent pairs,

represents an improvement, due to the reduction of the acquisition time, when compared to setups with only two detectors. Due to great amount of data in this measurement, methods to use this data in non-angular coincidence analysis, as in the verification of gamma-gamma coincidence relations and the determination of transition intensities, were developed [2]. In order to check for new information obtained in single measurements and deepen this study, angular gamma-gamma coincidence spectroscopy measurements were analyzed.

## 2. MEASUREMENTS

In these measurements the sources of  $^{155}\text{Sm}$  were produced by thermal neutron irradiation of Samarium oxide (98.69% enriched  $^{154}\text{Sm}$ ). About 1-3mg of  $^{154}\text{Sm}$  were irradiated for 60 seconds in the IEA-R1 nuclear reactor at IPEN in a neutron flux of  $10^{12} n.cm^{-2}.s^{-1}$ . A total of 103 sources were produced. Those were counted for a period of 1.3 hours each, totaling about 137 hours of measurement.



**Figure 1. The experimental setup:**

- a) Detector setup used in the present measurements;**
- b) Electronic setup used in the present experiment; everything except for the CAMAC Electronics is independent for each of the 4 detectors used.**

## 2.1. Data Acquisition

The multiparametric system used in this test, located at the Linear Accelerator Laboratory of the Instituto de Física da Universidade de São Paulo, is composed of four Ge detectors with active volumes ranging from 50 to 190 cm<sup>3</sup>. The signals from these detectors are inserted into a usual fast-slow electronics, where the decisory functions are performed by a custom CAMAC module. If all logic conditions are met, a CAMAC controller, directly coupled to the bus of an IBM-compatible personal computer (PC) through an ISA-bus lengthener, manages the data transfer to the PC. Both devices, the controller and the lengthener, were designed and built in-house [3], and allow a high data throughput. The data were recorded on an event-by-event mode on hard disk. The whole system can be seen in Figure 1

## 2.2. Data Reduction

In order to increase the statistics all the six bidimensional spectra, due to the six detector pair combination, were summed. The summation procedure must be carefully done, and two steps are required. In the first step, the data set taken with a particular detector pair is time-gated in order to produce a pair of two-dimensional spectra, one containing accidental coincidences only (AC) and other, with the total (true + accidental) coincidences (TC). In the second step, the six bidimensional spectra produced were relocated and summed up, so that two “all-in-one” bidimensional spectra, one for the total coincidences and the other for accidental coincidences, were then used in the analysis. As the difference of time spectra has a dependence on the energy of the photons and the pair of the detectors, before summing the six bidimensional spectra it was necessary make the selection of accidental events by off line digital gating. Thus, the bidimensional spectra were sliced in 100 smaller spectra and the energy limits of these spectra was determined by the ranges in which the difference of time spectra are similar. After the selection of accidental and total events for the smaller spectra in each one of the pairs, the six were then summed, and each one of these 100 spectra produced one spectrum for total events of the six pairs and one for the accidental events.

## 2.3. Data Analysis

As explained above, 200 spectra were produced. To perform the analysis of these spectra, the BIDIM software [4] was used; this software makes the fit of bidimensional Gaussian photopeaks, with corrections considering the Compton influence.

## 3. RESULTS

To help the visualization of the position of the gamma-rays in the decay scheme and the respective coincidence relations with other transitions, a partial decay scheme is shown in figure 2. From these results, nine gamma transitions without confirmed positioning in the Firestone compilation decay scheme [5] were confirmed, as shown in Table 1. Ten new transitions were added to this decay scheme, and one new excited level presented in Table 2 could also be proposed.

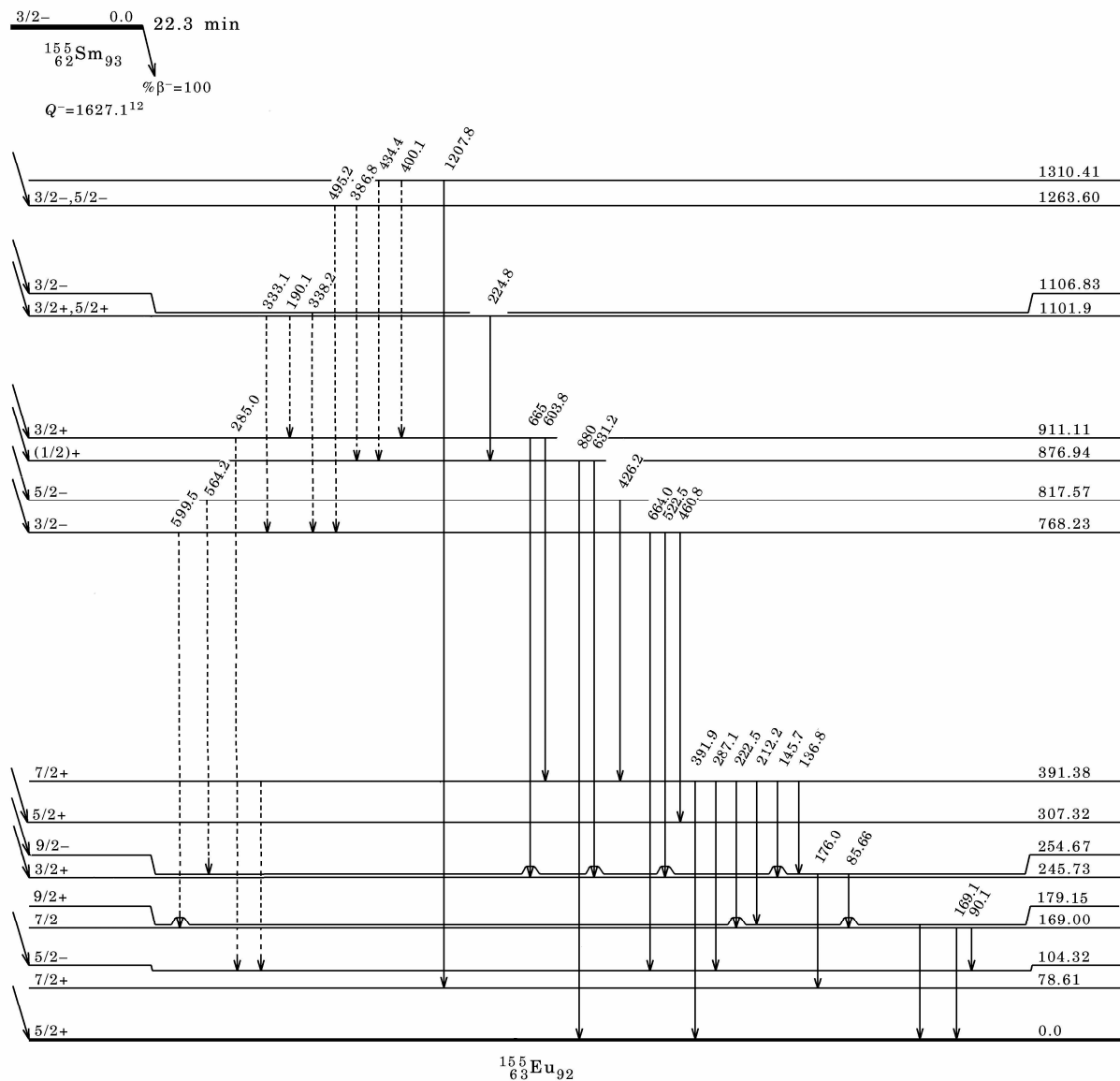


Figure 2. Partial decay scheme for the  $^{155}\text{Sm} \beta^-$  decay.

The new level at 1310 keV permits to propose that the 1207 keV transition, at the moment unplaced in the decay scheme, depopulates this level. The coincidence relation with this transitions cannot be measured by the techniques used in this work, because the level that is fed by the 1207 keV transitions have a large half-life. The placement of the 1095.04 keV transitions has also been changed in this work; it was originally placed between 1096 – 0 keV levels, therefore having no coincidence relations, but the coincidence relation with the 169 keV transition, observed in this work, suggested a new placement of this transition as depopulating the level at 1264 keV.

**Table 1. Gamma-ray transitions confirmed in the  $^{155}\text{Sm}$  decay scheme**

Energy (keV)	Coincidence relations (keV)
136.8172 (11)	426
142.814 (4)	523, 461
145.7083 (21)	426
176.0262 (5)	137
179.1570 (6)	213
212.284 (3)	426, 179
222.4732 (24)	426, 169
224.8323 (25)	880, 631
391.34 (3)	426

**Table 2. New gamma-ray transitions in the  $^{155}\text{Sm}$  decay scheme**

Energy (keV)	Initial level (keV)	Final level (keV)	Coincidence relations (keV)
190.05 (8)	1102	911	665, 604
285.04 (7)	911	104	604
333.11 (18)	1102	768	523, 461
338.24 (7)	1107	768	664, 523, 461
386.80 (16)	1264	877	631
400.05 (7)	1310 (new)	911	665, 604
434.42 (5)	1310 (new)	877	631
495.17 (10)	1264	768	522, 461
564.20 (5)	818	255	85
599.54 (13)	768	169	90, 169

#### 4. CONCLUSIONS

In this work, multiparametric coincidence measurements were performed using four detectors, with the bidimensional spectra from all six detector pairs being summed producing one “all-in-one” bidimensional spectrum. From this data, nine gamma transitions without confirmed positioning the in the Firestone compilation decay scheme were confirmed, ten new transitions were added to this decay scheme, and one new excited level at 1310 keV was proposed. The next step in this analysis is to determine intensities for these transitions, and then to use the IAEA computer codes to aggregate this new information to the decay scheme, thus recalculating parameters of this scheme as the energy of new transitions, energies of all levels and beta feeding.

## REFERENCES

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