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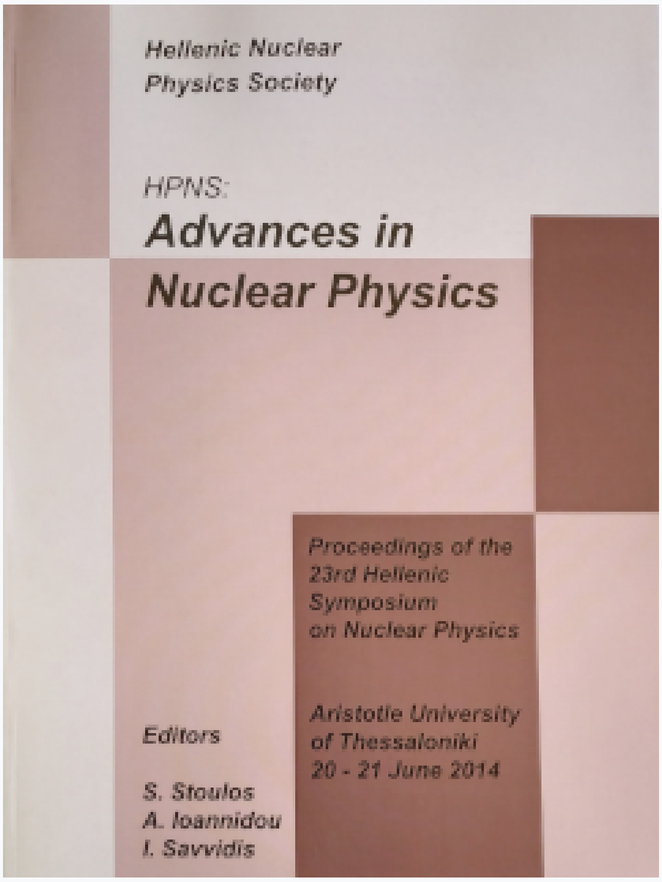

A new γ-spectroscopy station at the University of Athens

V. Lagaki, E. Kouvaris, T. J. Mertzimekis

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A new γ-spectroscopy station at the University of Athens

Varvara Lagaki, Efthimios Koubaris and Theo J. Mertzimekis

Faculty of Physics, University of Athens, Zografou Campus, GR-15784, Athens, Greece

Abstract A new γ-spectroscopy station at the University of Athens has been recently deployed. The station is built around a 25% HPGe detector and aims at supporting the environmental radioactivity studies program of the NuSTRAP group at UoA. The detector needs detailed characterization of its efficiency and calibration over a rather wide range of energies. Besides standard calibration point sources (^{60}Co, ^{137}Cs, ^{152}Eu and ^{226}Ra), detector simulations using the Monte Carlo N-particle transport code (MCNP) were performed. Results of the MCNP calculations are shown and compared with real spectra showing satisfactory agreement

Keywords γ-ray spectroscopy, HPGe detector, efficiency calibration, MCNP

THE NEW γ-SPECTROSCOPY STATION

The use of γ-ray spectroscopy can benefit a wide range of scientific fields, from fundamental nuclear research to radiation applications. Typically, high-resolution γ spectroscopy employs a high-purity Ge detector (HPGe) that offers good-to-exceptional energy resolution accompanied by appropriate shielding to reduce background.

A new γ-spectroscopy station has been recently developed (Fig. 1) at the University of Athens in an effort to support the environmental applications of the NuSTRAP group. A 25% relative efficiency HPGe has been recently acquired, coupled by matching electronics, while also shielded with lead to reduce background and cosmic radiation. Prior to carrying out real measurements, characterization of the setup is of fundamental importance. In this paper, detailed calibration and efficiency measurements, as well as detector simulations using the MCNP5 [1] code are reported.

MEASUREMENTS

Calibration and efficiency measurements were performed with four point sources (^{60}Co, ^{137}Cs, ^{152}Eu and ^{226}Ra) placed along the axis of the HPGe cylinder at distances 10, 15 and 20 cm from the detector entrance window. Typically run time was 15 min for each distance and source. In addition, a few long runs without sources (~24 hr) were recorded to estimate the average background levels. Spectra analysis was carried out with SPECTRW [2]. The variety of sources allowed few accurate determination of the system linearity, as well as possible summing effects (checked comfortably with the 1173 and 1332 keV lines of the ^{60}Co), up to about 3000 keV range.

The detailed energy efficiency curves were obtained by analyzing the well-known ^{152}Eu photopeaks and some of the data are illustrated in Figs. 2 and 3.

Figure 1: The γ-spectroscopy station with Pb shielding

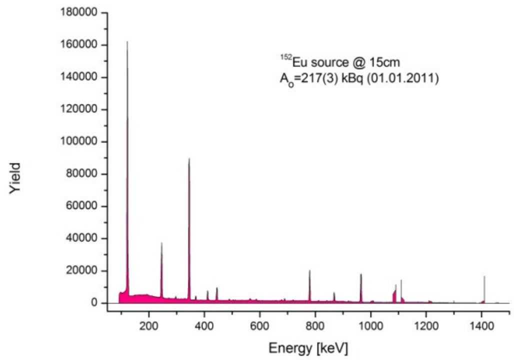

Figure 2: Experimental spectra of ^{152}Eu point source at 15 cm from the detector

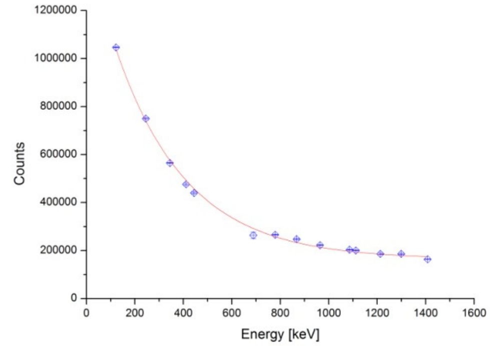

Figure 3: The energy efficiency obtained with ^{152}Eu source placed at 10 cm away from the crystal

For the efficiency curve the equation

$$\varepsilon = A \cdot \frac{E^B}{1000 \cdot C + E^D}$$

was used, where ε is the detector and the E is the energy in keV. A, B, C and D are parameters deduced by fitting the experimental data. The final values are given as:

A= (2.783±0.318)·10^7, B= 3.200±31.288, C=(1.381±8.314)·10^5, D= 4.088±1.274

MCNP SIMULATIONS

In addition to experimental measurements, the Monte Carlo N-particle transport code (MCNP v.5) was used to simulate and estimate the energy efficiency parameters.

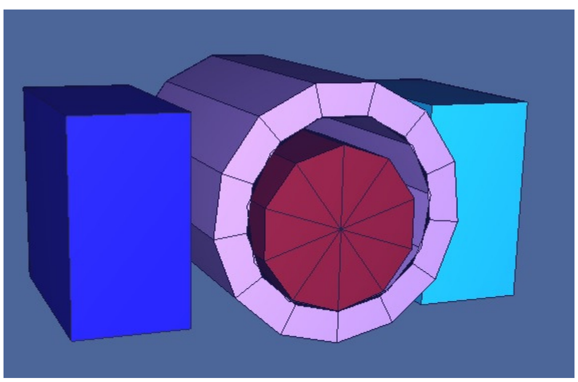

Figure 4: A 3D model of the experimental setup in MCNP. Color code: red for the Ge crystal enclosed in aluminum casing; violet, blue, light blue for Pb shielding.

MCNP is for modeling the interaction of radiation with materials based on composition and density and utilizes the latest nuclear cross section libraries and physics models for particle types and energies. In the experimental spectra, as shown in Fig. 2, the energy lines have Gaussian shape. The MCNP code did not simulate the effect; it rather matches the peak width obtained experimentally to the calculation, using the Gaussian Energy Broadening (GEB) option. GEB is a special treatment for tallies, to better simulate a physical radiation detector in which an energy peak exhibits Gaussian energy broadening. The obtained agreement suggests that GEB is a good option for the present case, as well. For that purpose, the FWHM values from the ^{152}Eu photo peaks were measured and fitted with the formula:

$$FWHM = a + b\sqrt{E + cE^2}$$

E is the γ-ray energy measured in keV and a, b, and c are parameters obtained from a least-square approach based on the present FWHM formula and experimental FWHM ^{152}Eu peaks. The deduced values are:

$$a=2.989\ \text{keV},\ b=1.5\cdot10^{-3}\ \text{keV}^{1/2},\ c=0.0992\ \text{keV}^{-1}$$

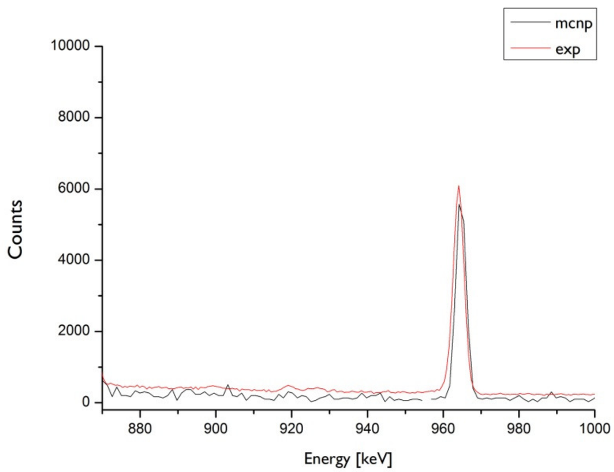

Figure 5: Comparison of experimental data and simulation of the ^{152}Eu at a distance of 10 cm from the detector for a randomly selected photopeak, after GEB was applied. The geometry resembles the real setup accurately as it is also evident by the off center placement of the hollow cylindrical Pb shield around the crystal.

CONCLUSIONS

The new UoA γ-spectroscopy station has been fully characterized using standard point calibration sources. Energy efficiency and resolution were modeled using MCNP. Overall simulations are in very good agreement with experimental measurements. Further characterization using IAEA reference materials are underway.

Acknowledgments

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References

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[2] C.A. Kalfas, "SpectrW: a spectra analysis program" (2012), private communication