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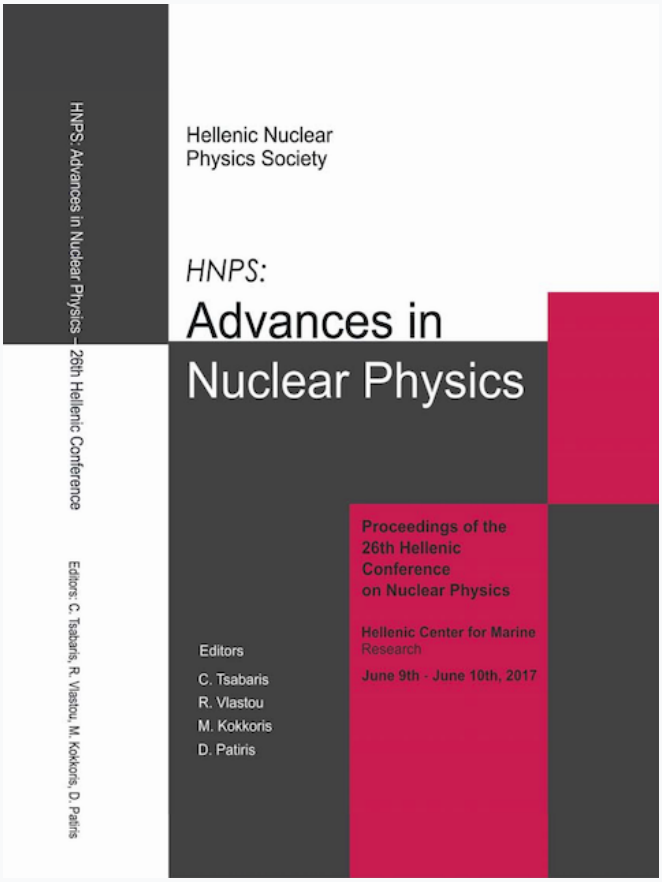

Efficiency calibration of a medium resolution subsea detection system for extended sediment samples

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Efficiency calibration of a medium resolution subsea detection system for extended sediment samples

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Abstract In this study, the efficiency calibration of the detection system GeoMAREA, consisting of a 2"x 2" CeBr3 crystal is presented. The efficiency calibration for laboratory measurements on marine sediment samples was performed both experimentally and theoretically using Monte Carlo (MC) simulations. The calibration was validated by corresponding measurements on a marine sediment sample using the system GeoMAREA and a HPGe detector (Canberra model GC5021, 50%).

Keywords $CeBr_3$, Expeimental Calibration, Monte Carlo, MCNP5, medium resolution detector

INTRODUCTION

The development of appropriate gamma ray detection systems for in situ and on site measurements in the marine environment is of great importance due to the great variety of their applications. In that regard, a detection system consisting of a 2"x 2" $CeBr_3$ crystal, the system GeoMAREA, was developed. The $CeBr_3$ crystal was selected due to its higher energy resolution compared to other scintillators like NaI (Tl). Moreover, the adequate energy resolution combined with the favorable cost of $CeBr_3$ detectors (compared to HPGe detectors), render these systems competitive candidates for laboratory measurements as well.

The efficiency calibration of the system GeoMAREA was performed experimentally and theoretically, in the energy range of 100 to 2000 keV. The MCNP5 Monte Carlo (MC) code was implemented for the theoretical efficiency calibration. The MC estimated results were compared with corresponding experimental data, obtained using a $^{152/154}$Eu source. For the validation of the calibration, a marine sediment sample was measured using both the GeoMAREA system and a HPGe detector (Canberra model GC5021).

EFFICIENCY CALIBRATION OF THE DETECTION SYSTEMS

A volumetric ^{152,154}Eu source was used for the experimental efficiency (ε) calibration of both detection Systems ($CeBr_3$, HPGe 50%). The experimental spectra were analyzed using the SPECTRW program [1]. The experimental efficiency ε was calculated using the following formula:

$$\varepsilon = \frac{Counts}{I\,t\,A} F_{tcs} \quad (1)$$

Where

- Counts = # detected events in a photopeak
- I = emission probability
- t = acquisition time
- A= ^{152}Eu activity
- F_{tcs} = True Coincidence Summing correction factor [2]

Convoluted peaks appear in the spectrum when two different photopeaks have a difference in energy smaller than the energy resolution of the detector. This results in them being recorded as one in the spectrum. The energy resolution of the detection systems in addition to the complex decay schemes of ^{152}Eu and ^{154}Eu in the volumetric source that was used for the experimental calibration resulted in the appearance of such convoluted peaks in the spectra. The convoluted photopeaks consisted of one or of both elements (^{152}Eu or ^{154}Eu). For the convoluted photopeaks consisting of both elements, the contributions of ^{154}Eu had to be subtracted prior to the analysis.

The MCNP5 [3] code was implemented to estimate the efficiency values for volumetric sources. For this purpose, a model of the detection system and the source (sediment sample) was developed (Fig. 1).

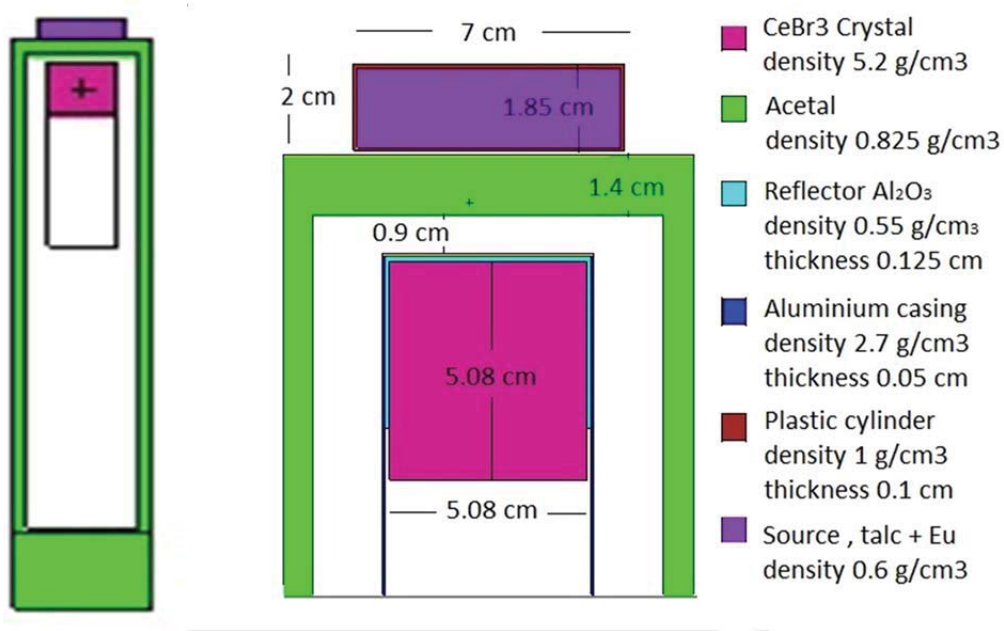

Fig. 1. The GeoMAREA detection system and a volumetric source, as implemented using the MCNP5 code.

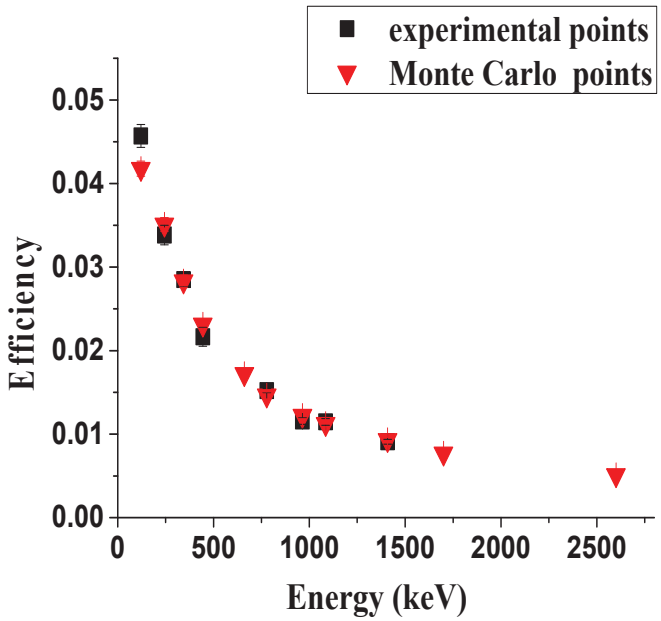

Fig. 2. Comparison of experimental and MC results of the efficiency calibration of the GeoMAREA system for volumetric source. Relative differences ranging from 1% to 9%.

CALIBRATION VALIDATION THROUGH COMPARISON WITH HPGE RESULTS

For the validation of the calibration, a marine sediment sample was measured using the GeoMAREA system and a calibrated laboratory HPGe detector. The sediment sample was collected from a deep basin near Samothraki Isle and was properly treated prior the measurement [4]. The acquired spectra were analyzed using the SPECTRW program [1]. The activity concentration results, A (Bq/kg), for the radionuclides ^{40}K, ^{214}Pb, ^{228}Ac and ^{208}Tl are presented and compared in Table 1. The calculated activity concentrations using the two different detectors were found to be in excellent agreement, as the relative differences did not exceed 3% for all the studied radionuclides.

Element	GeoMAREA	HPGe	GeoMAREA /HPGe
	A(Bq/kg)	A (Bq/kg)	
^{40}K	546.74 ± 54.77	538.88 ± 35.70	1.01 ± 0.12
^{214}Pb	19.82 ± 3.18	20.24 ± 1.45	0.98 ± 0.17
^{228}Ac	59.77 ± 7.48	58.11 ± 5.15	1.03 ± 0.16
^{208}Tl	20.09 ± 2.74	19.57 ± 1.53	1.03 ± 0.16

Table 1. Comparison between the measured activity concentrations for the radionuclides ^{40}K, ^{214}Pb, ^{228}Ac, ^{208}Tl as measured using the GeoMAREA system and the HPGe detector

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