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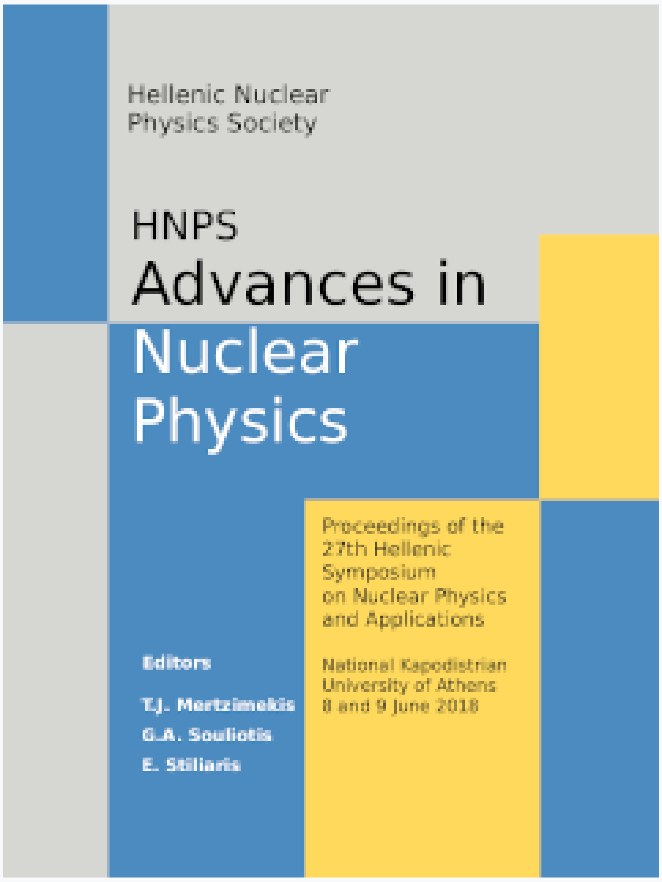

Energy, Resolution and Efficiency Calibration of a LaBr3(Ce) Scintillator

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Energy, Resolution and Efficiency Calibration of a $LaBr_3$(Ce) Scintillator

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Abstract The last decade $LaBr_3$(Ce) scintillation detectors have become commercially available and have better scintillation properties (energy resolution, temperature performance, decay time, light yield and material density) when compared with NaI(Tl) scintillators. The aim of this work is the full calibration (energy, resolution and efficiency) of a 1.5x1.5 in $LaBr_3$(Ce) Canberra scintillator. Energy and resolution calibration were performed experimentally with the use of point sources with a source-detector distance at 22 cm. MCNPX simulations were performed in order to evaluate the efficiency calibration for three different source-detector geometries and then they were validated by the experimental efficiencies estimation.

Keywords gamma spectrometry, $LaBr_3$(Ce), calibration, MCNPX

INTRODUCTION

LaBr3(Ce) scintillation detectors are very promising due to their high light yield (>65000 photons/MeV) that results in a better energy resolution compared to NaI(Tl) detector (<3% FWHM at ^{137}Cs), their decay time of 35 ns and their material density (5.29 g/cm^3) [1, 2]. Due to their better scintillation properties, when compared with NaI(Tl) scintillators, they can substitute them in many applications. The main disadvantages of a $LaBr_3$(Ce) detector are the internal backgrounds of ^{138}La decaying to stable ^{138}Ba by electron capture and the ^{138}Ce decay by beta emission, which affect the background spectrum up to 1500 keV [3].

In this study, the full calibration (energy, resolution and efficiency) of a 1.5x1.5 in $LaBr_3$(Ce) Canberra scintillation detector is performed. For this purpose, two multiple gamma ray emitting sources (a large volume source and a large area source) as well as three point sources (^{241}Am, ^{60}Co and ^{152}Eu) were used.

Energy and resolution calibration were performed experimentally with the use of the point sources with a source–detector distance at 22 cm, by fitting several functions in both calibrations. MCNPX simulations were performed in order to evaluate the efficiency calibration for three different source-detector geometries and then validated by the experimental efficiencies estimation.

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MATERIALS AND METHODS

Experimental Setup

The gamma spectrometry system is consisted of the following main parts:

- Detector unit: a Canberra scintillation detector $LaBr_3(Ce)$ (Model LABR-1.5x1.5) with a 1.5x1.5 in crystal in a hermetically sealed aluminum housing, including a photomultiplier tube, an internal magnetic/light shield and a 14-pin connector (Fig.1)
- Electronics and acquisition unit: a digital signal processing unit (Osprey Digital Tube Base MCA) and a high voltage supply system (670 V).
- Lead shielding structure with thickness 5 cm

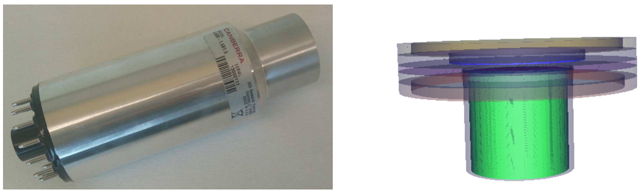

Fig. 1 The LaBr3(Ce) detector (left) and MCNPX simulation of the gamma area source (right)

SPECTRW software [4] was used for spectrum analysis and MCNPX Monte Carlo code for efficiency evaluation by simulations (Fig.1).

The experimental data were obtained from two multiple gamma ray emitting sources (a large volume source and a large area source) and three point sources (^{241}Am, ^{60}Co and ^{152}Eu) (Table 1).

Isotope	T½ (d)	Reference Activity (Bq)			Source Uncertainty (%)		
		VS	AS	PS	VS	AS	PS
^{210}Pb	8139.5	12300	12400	-	11.4	11.4	-
^{241}Am	157753	1230	1180	351000	3.6	3.6	3
^{137}Cs	11001.1	2600	1870	-	2.9	2.9	-
^{60}Co	1923.55	3250	2190	384700	2.9	2.9	3

Table 1 Characteristics of radioactive sources used for the $LaBr_3(Ce)$ detector calibration. The reference date for Volume Source (VS) and Area Source (AS) is 01/03/2007. The reference date for ^{241}Am and ^{60}Co point sources (PS) is 01/10/1995 and the reference date for ^{152}Eu point source (PS) is 01/03/2004

Each of the multiple ray emitting sources was adapted on an acetal holder that was attached on the detector surface (Fig.2).

Fig. 2 The acetal holder: the source side (left) and the detector side (right)

Internal Background of $LaBr_3(Ce)$

The internal background of $LaBr_3(Ce)$ (Fig.3) was taken into account in all measurements and subtracted in all spectra.

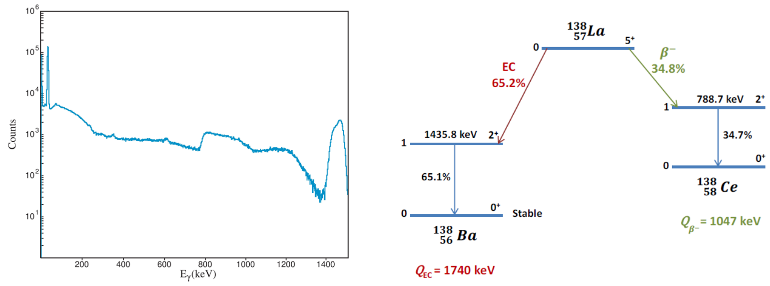

Fig. 3 Background spectra of $LaBr_3(Ce)$: Internal activity of ^{138}La (T½ = 1011 y) and ^{227}Ac (T½ = 21.77 y) in the energy range 0 – 1500 keV (acquisition time 54000 sec) and ^{138}La decay diagram

Energy and Resolution Calibration

The three point sources (^{241}Am, ^{60}Co and ^{152}Eu) were used in order to establish the relationship between the channel number and the photon energy (keV) (energy calibration) and the dependence of the Full Width Half Maximum (FWHM) (%) on the photon energy (keV) (resolution calibration) (Fig.4).

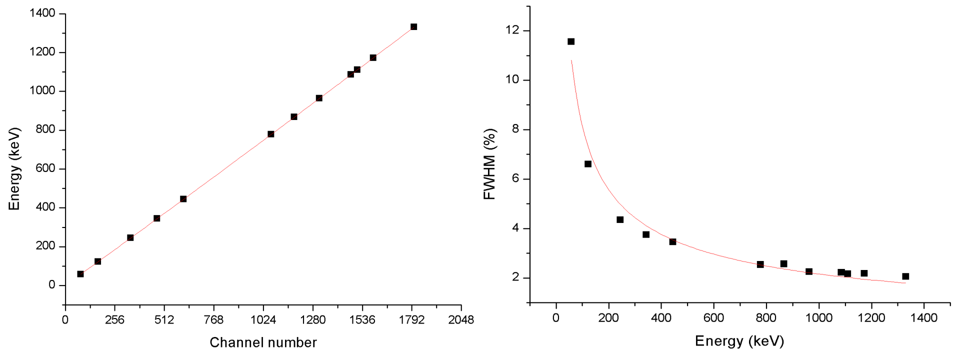

Fig. 4 Energy calibration (left) and resolution calibration (right) of the $LaBr_3(Ce)$ scintillator

A 2nd order polynomial proved to be the best option for the energy calibration:

$y = 1.047*10^{-5}\ x^2 + 0.7194\ x + 0.64$, with adjusted $R^2 = 1$

and a power curve for the resolution calibration: $y = 87.28\ x^{-1/2} - 0.6$, with adjusted $R^2 = 0.98$.

Efficiency Calibration

For efficiency calibrations, the Absolute Full Energy Peak Efficiency (AFEPE) was evaluated for three different source-detector geometries. AFEPE relates the peak area to the number of gamma rays emitted by the source and depends upon the geometrical arrangement of source and detector [5].

The following source-detector geometries were studied:

1) Points sources (PS) at 22 cm from detector surface
2) Multiple gamma volume source (VS) adapted on the acetal holder

3) Multiple gamma area source (AS) adapted on the acetal holder

MCNPX simulations were performed for the above geometries and validated by the experimental efficiency calibrations (Fig.5-6). The black dots represent the MCNPX data and red dots the experimental data.

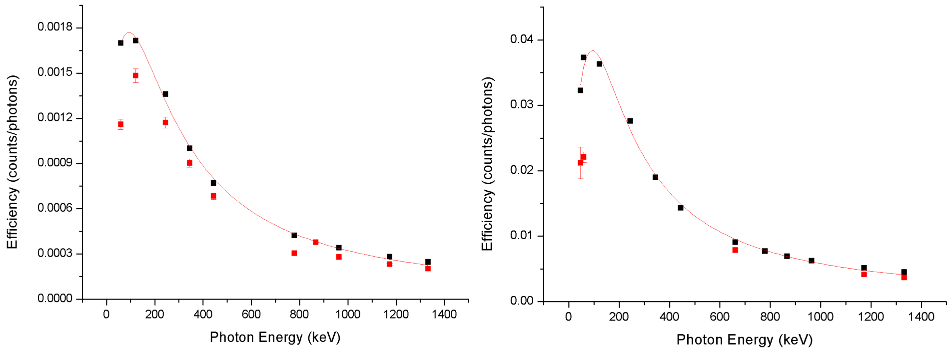

Fig. 5 Efficiency calibration curves for the geometries (PS) (left) and (VS) (right) with the corresponding selected fitting functions for the MCNPX data: $y = (2.874\ x^{0.394})/\ (7444 + x^{1.703})$, $R^2 = 0.998$ and $y = (38.413\ x^{0.587})/\ (9800 + x^{1.857})$, $R^2 = 0.995$

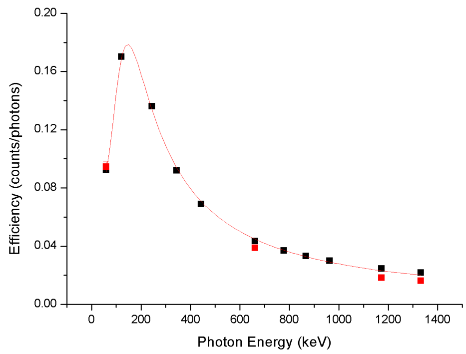

Fig. 6 Efficiency calibration curve for the geometry (AS) with the selected fitting function for the MCNPX data $y = (81.122\ x^{2.780})/\ (18*10^7 + x^{3.953}) + 3.318/x$, with $R^2 = 0.999$

CONCLUSIONS

In this study, a complete calibration of a Canberra 1.5x1.5 in $LaBr_3(Ce)$ scintillator is presented. The bias observed between MCNPX simulations and experimental data can be attributed to the lack of the specific characteristics of the detector; only the generic characteristics were given from the manufacturer. Future work will be focused on the efficiency calibration optimization.

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