Brunel University London

Determination of energy resolution for YSO:Ce detector modelled with FLUKA code

G. M. Nadeera Hemamali[1], P. R. Hobson[1,2], D. R. Smith[1]

[1] Brunel University London, College of Engineering, Design and Physical Sciences, Kingston Lane, Uxbridge, Middlesex, UB8 3PH, UK
[2] Queen Mary University of London, School of Physical and Chemical Sciences, Mile End Road, London, E1 4NS, UK

Introduction

The energy resolution of any detector is defined as the ability to distinguish between two peaks which is dependent on the FWHM (Full Width at Half Maximum) value. The lower the FWHM value, the greater the resolution. The calculation of resolution can also be done by using simulation techniques. A variety of simulation approaches are available in the literature [1-5]. For this purpose, Monte Carlo based programs such as FLUKA, GEANT4, MCNPX are beneficial. In this study, 5×5×5 mm^3 YSO:Ce detector is used. The presented study was done with FLUKA version 4.2.0 and FLAIR 3.1-15 version installed in Centos (Linux-based operating system).

Materials and Methods

A. Experimental Work

In this study, to measure the emission spectra, we coupled a YSO:Ce scintillator crystal from Epic crystals, China with a custom-designed SiPM MCA from Bridgeport Instruments (model no: SIPM 1K_BC36_H50) with peak spectral sensitivity at around 420 nm which matches closely with the peak emission of the scintillator crystal used in this study. The cerium content of YSO:Ce is 0.5 mol%.

B. FLUKA Simulation

FLUKA cards, BEAM, and BEAMPOS were used to introduce the energy type, position/direction, and energy spectrum of the chosen radiation sources, respectively. The DETECT card was used for acquiring the energy deposition spectrum. The EMF (electromagnetic interactions) card also was active. Radiation sources used for experimental activities are listed in Table 1.

Radiation Source	Expected γ-ray or X-ray energy (keV)	Current activity (μCi)
Cs-137	32.2, 661.7	0.445
Am-241	59.5	0.998
Ba-133	31, 81, 276.4, 302.9, 356	0.129

Conversion process of photons to pulse height spectrum in FLUKA

The DETECT card records the amount of deposited energy for each scintillation pulse. The photon pulse height distribution consists of the bins in which each of their energy is set to 1 keV, using the DETECT card in the FLUKA code.

Results

The spectrum obtained by the FLUKA code does not include the broadening effect of the photopeak and the detector's response functions (blue lines). The spectra obtained by simulation are converted to real detector responses using the sigma values calculated theoretically and presented by dotted red lines.

$\sigma = \sqrt{N}$ — N - mean number of scintillator events generated, σ - standard deviation

$\sigma(E) = \sqrt{E_m}.\sqrt{E_{avg}}$ — E_m - the smallest energy value measured by the FLUKA simulation (1 keV); E_{avg} - average energy deposited in the crystal after the scintillation pulse

The response function is approximately Gaussian in shape. The FWHM for a Gaussian distribution is given by: **$FWHM = 2\sqrt{2\ln 2}.\sigma$**

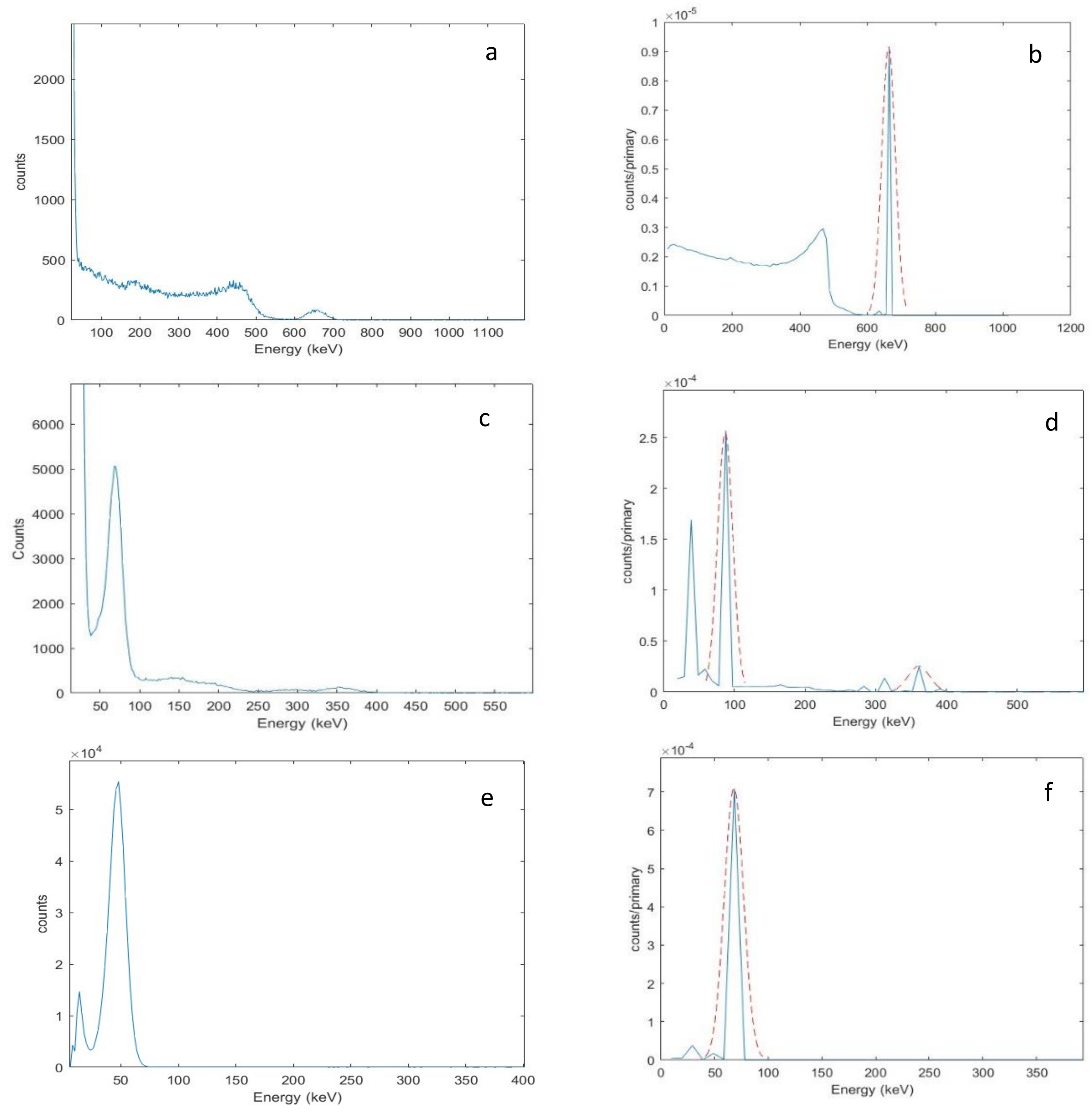

Figure 1: (a) Cs-137 spectrum, (b) simulated spectrum for Cs-137, (c) Ba-133 spectrum, (d) simulated spectrum for Ba-133, (e) Am-241 spectrum, (f) simulated spectrum for Am-241.

Energy (keV)	FLUKA		Experimental			Relative difference (RD%)
	FWHM (Calculated)	Energy resolution (R%)	Peak Energy (keV)	FWHM	Energy resolution (R%)	
59.5	19.04	32.0	48	15.3	31.8	0.6
81	21.6	26.7	70	18.6	26.5	0.7
356	31.02	8.7	354	33.9	9.5	8.4
661.7	43.7	6.7	660	48.8	7.4	9.4

Conclusion

In this study, a 5x5x5 mm^3 YSO:Ce detector was modelled using the FLUKA code. The pulse height distributions of the detector were obtained for each point gamma source in the energy range 59 keV-662 keV, and the energy resolution was calculated. It was observed that relative percentage differences between the experimental and simulation results are within 10%. This study showed that the FLUKA code also can be used to determine the energy resolution and can therefore be of benefit in terms of reducing financial cost and time in the development of new scintillators and radiation sensors.

Acknowledgments:

This work was performed as a part of Ph.D. project funded under EPSRC DTP grant EP/T518116/1. The authors would like to thank EPSRC for financial support, and Brunel University London for facilitating this research.

References:

[1] N. Demir, Z. Nur Kuluozturk, Determination of energy resolution for a NaI(Tl) detector modelled with FLUKA code, Nuclear Engineering and Technology 53 (2021) 3759-3768.

[2] I. Mouhti, A. Elanique, M.Y. Messous, A. Benahmed, J.E. McFee, Y. Elgoub, P. Griffith, Characterization of CsI(Tl) and LYSO(Ce) scintillator detectors by measurements and Monte Carlo simulations, Applied Radiation and Isotopes 154 (2019) 108878.

[3] H.X. Shi, B.X. Chen, T.Z. Li, D. Yun, Precise Monte Carlo simulation of gamma-ray response functions for an NaI(Tl) detector, Appl. Radiat. Isot. 57/4 (2002) 517-524.

[4] C.M. Salgado, L.E.B. Brand, R. Schirru, C.M.N.A. Pereira, C.C. Conti, Validation of a NaI(Tl) detector's model developed with MCNP-X code, Prog. Nucl. Energy 59 (2012) 19-25.

[5] H.Vincke et al. Nuclear Instruments and Methods in Physics Research A 484 (2002) 102–110.