Efficiency and cross-talk estimation of $CeBr_3$ array through GEANT4 simulation

Saswata Roy[1,2], Saumanti Sadhukhan[1,2], Deepak Pandit[1,2 *], S. Manna[1], S. Mukhopadhyay[1,2], Debasish Mondal[1,2], Surajit Pal[1] and S. Bhattacharyya[1,2]

[1]*Variable Energy Cyclotron Centre, 1/AF-Bidhannagar, Kolkata 700 064, India.*

[2]*Homi Bhabha National Institute, Mumbai 400 094, India.*

Introduction

The study of giant dipole resonances (GDR), involves high energy gamma photon spectroscopy in the energy range, 8-30 MeV. Such high energy gamma rays mainly produce electromagnetic showers through pair production while interacting with detector. For efficient confinement of this shower, detectors with high efficiency is needed. Further, in study of GDR built on excited state, it is necessary for a detector to have good timing property to separate gamma and neutron events. Keeping these conditions in mind, Large Area Modular BaF_2 Detector Array, was constructed in VECC [1]. However, for Pygmy Dipole Resonances (PDR) studies which lies in the energy range 4-8 MeV, BaF_2 detectors are not suitable because of their poor energy resolution.

In such cases, detectors with high efficiency, good timing property and good energy resolution are needed. $CeBr_3$ detectors can reasonably fulfill all of these requirements. Table 1 presents a comparison of various properties between BaF_2 and $CeBr_3$ detectors.

Table - 1

Detector	Density (gm/cc)	Volume (cc)	E_{res}(%) (@662 keV)	T_{res} (ps)	References
BaF_2	4.89	428.75	~ 16	~960	[1]
$CeBr_3$	5.1	411.85	~ 4	~224	[2]

In present work, certain properties of a 3×3 array of $CeBr_3$ detectors, each having dimensions of 2″×2″ square faced and varying length (2″, 4″, 6″) is studied using GEANT4 simulation. The response of this 3×3 array is also compared with response of 7×7 LAMBDA.

GEANT4 simulation

The Geometry And Tracking 4 (GEANT4), version 10.7.3 [3] has been used for making the geometry and simulating the response of the $CeBr_3$ array. The array has been constructed using G4Box class. Each crystal of the array is placed inside an aluminum casing of 0.5 mm thickness. The array is placed at a distance of 50 cm from the source, covering ~ 0.74% of 4π solid angle. The set up for crystals of 6″ length, is shown in Fig.1.

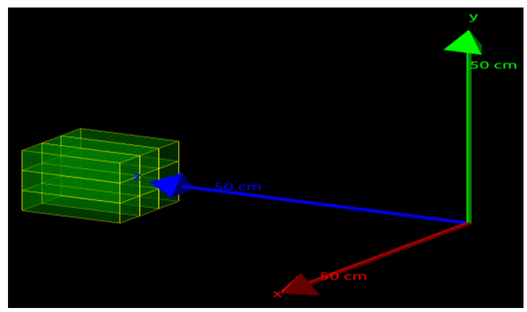

Fig. 1 $CeBr_3$ array of dimensions 2″×2″×6″ placed 50 cm from the origin (source).

In simulation we have incorporated all possible physics processes. The gamma ray interactions are covered by the classes G4ComptonScattering, G4PhotoElectricEffect, and G4GammaConversion. Since, for high energy gamma photons, electron-positron shower is produced, physics processes for them are incorporated using G4eMultipleScattering, G4eIonisation, G4eBremsstrahlung and G4eplusAnnihilation. For event reconstruction, total summing technique is used. The simulation is verified with experimental result for a cylindrical $CeBr_3$ detector having equal length and diameter (2 inch each), shown in Fig. 2. The response of 3×3 $CeBr_3$ array is also simulated for E_γ = 10 MeV. The response is compared with normalized response of 7×7 LAMBDA which is shown in Fig. 3. It is observed that the nature of the response is

*Electronic address: deepak.pandit@vecc.gov.in

different in both arrays as escape peaks at this energy range can be separated by $CeBr_3$ array. Thus for PDR research, this array is a suitable option.

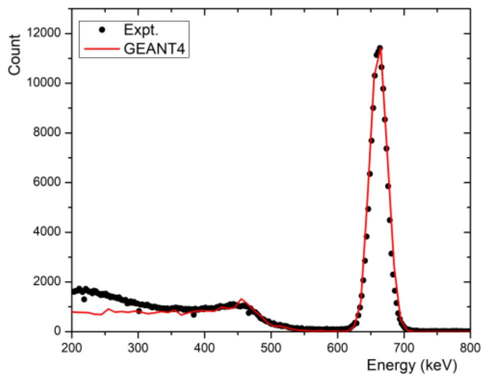

Fig. 2 Simulated and experimental spectrum of ^{137}Cs using cylindrical $CeBr_3$ detector.

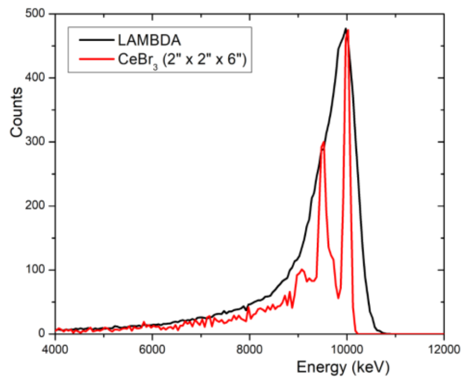

Fig. 3 Response for 10 MeV γ-ray from 7×7 LAMBDA and 3×3 $CeBr_3$ array.

Efficiency

The absolute efficiency of 3×3 $CeBr_3$ array is studied for different sizes of detectors, for gamma rays of energy range 1-30 MeV. The array is kept fixed at a distance of 50 cm from source, covering a solid angle of 0.092 sr. For each run, 10^6 monoenergetic gamma photons are generated in GEANT4, in uniform distribution. The observed result is shown in Fig.4.

Cross-talk probability

Cross-talk probability depends on the applied threshold and energy of gamma ray. Cross-talk probability in the array is studied for gamma photon of energies, 662 keV, 1 MeV, 5 MeV and 10 MeV. Table-2 displays the cross-talk probability for 6″ length detectors at various thresholds, and the corresponding plot is shown in Fig. 5.

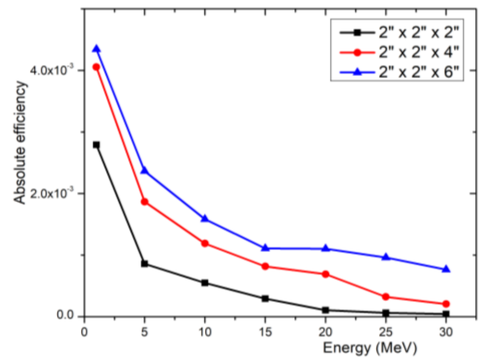

Fig. 4 Absolute efficiency for detectors of different dimensions.

Table - 2

Energy (MeV)	Cross-talk probability (%)	
	@Threshold 40 keV	@Threshold 320 keV
0.662	20.4	1.4
1	25.9	13.3
5	42.9	32.4
10	55.8	45.0

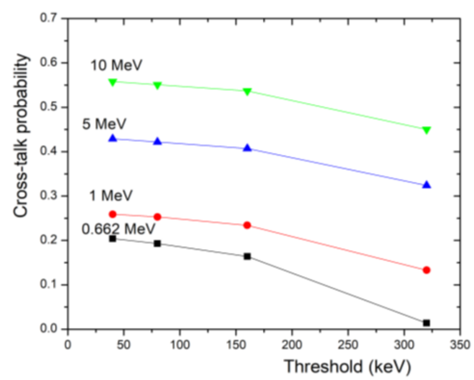

Fig. 5 Variation of cross-talk probability with variation in threshold.

References

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[3] Geant4 - A Simulation Toolkit., Nucl. Instr. Meth. A 506 (2003) 250.