First Measurement of the response matrix of a large $LaBr_3$:Ce detector up to 30 MeV at the HIγS facility

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Introduction

The invention of Lanthanum Halide detectors, namely, Lanthanum Bromide ($LaBr_3$:Ce) and Lanthanum Chloride ($LaCl_3$:Ce) has been one of the most significant recent developments in the field of scintillator detectors. The production and marketing of the $LaCl_3$:Ce and $LaBr_3$:Ce crystals have resulted in a flurry of activities for their testings and characterisations [1, 2]. The excellent energy resolution of $LaBr_3$:Ce, $\sim$3% at 662 keV, is better than any other commercially available scintillator detector. The fast decay time of 35 ns, with no intense slow component and afterglow, leads to a time resolution of about a few hundred picoseconds [1]. The high density of $LaBr_3$:Ce (5.08 gm/cm^2) and the high Z of Lanthanum result in higher detection efficiency than NaI(Tl). These highly attractive properties of $LaBr_3$ make it suitable for both low and high energy gamma-rays spectroscopy.

The measurements

We have recently procured a rather large volume (946 cm^2) $LaBr_3$:Ce detector for high energy (up to 40 MeV) continuum gamma-rays spectroscopy. The large volume detector is an integral assembly of a cylindrical crystal coupled with a Photo Multiplier Tube (PMT) procured from M/S Saint Gobain Inc. The cylindrical crystal (commercially named B380) is 3.5" in diameter and 6" in length and is housed in an aluminium encasing packed with 5 mm thick reflector material. The crystal is viewed by a 3.5" diameter HAMAMATSU R10233 PMT. All the major properties of this integral assembly, namely, energy and timing resolutions, linearity of response, uniformity, internal activity etc. have been studied from 662 keV up to 22.5 MeV using gamma-ray sources and in-beam reactions [3]. Since the purpose of this detector is high energy continuum gamma-ray spectroscopy up to about 40 MeV it is absolutely essential to measure the response of this detector up to around 40 MeV at regular intervals. However, production of monochromatic high energy gamma-rays using light-ion induced capture reactions at low energies is highly restrictive, primarily because of the very limited number of such facilities. The Free Electron Laser laboratory at Duke University is an ideal place for complete characterisation of detectors up to 100 MeV using monochromatic γ-ray beams. Here we present the results of our measurements to determine the response matrix of our large volume detector up to 30 MeV using monochromatic photon beams from the High Intensity Gamma Source (HIγS) at Duke Free Electron Laser Facility. The cylindrical $LaBr_3$:Ce detector was placed in path of the highly collimated and attenuated monochromatic photon beam. The spectra were recorded for 5.5, 6.5, 7.5, 9.9, 15, 20, 25 and 30 MeV gamma-rays. The absolute photo peak efficiencies for the different energies were determined having estimated

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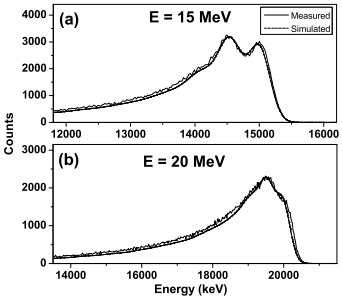

FIG. 1: The measured γ-rays spectra and their GEANT4 reproductions (solid lines).

the background subtracted counts under the photo-peaks and using the total flux of the gamma rays impinging upon the detector. The line shapes and the efficiencies were also simulated using the GEANT4 package. Figures 1 and 2 present the measured gamma-rays spectra and the GEANT4 reproductions (solid lines) for 15, 20 , 25 and 30 MeV γ-rays.

The energy resolution of the detector, at each energy, determined from the FWHM of the photo-peak is a convolution of the detector resolution and the spread in the beam energy. For the HIγS beam the intrinsic detector resolution gets masked by the beam resolution. We have made use of Nuclear Resonance Fluorescence (NRF) reaction off ^{12}C to measure the intrinsic resolution of the detector. This was achieved by bombarding a thick disk of Carbon with 15.1 MeV photons from the HIγS facility. The large volume $LaBr_3$:Ce detector was placed at 90^o to the beam direction and at a distance of 30 cm from the centre of the target. The 15.1 MeV NRF γ-rays spectrum was measured and the photo peak was fitted to find an excellent energy resolution of around 1.5%. The extracted absolute photo-peak efficiencies for all the eight beam energies were found to be in excellent agreement with the GEANT4 calculations. All the results will be presented in the meeting.

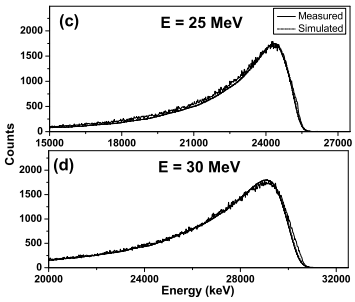

FIG. 2: The measured γ-rays spectra and their GEANT4 reproductions (solid lines).

Acknowledgments

We thank the DFEL staff for providing the photon beams and excellent support for the measurements.

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