Testing of $LaBr_3$(Ce)-NaI(TI) Phoswich detector at VECC

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Introduction

For the study of γ-rays with high efficiency and good energy resolution, the PARIS (*Photon Array for studies with Radioactive Ion and Stable beams*) collaboration has developed a new type of detector, consisting of $LaBr_3$(Ce)-NaI(TI) in a phoswich geometry [1,2]. Each phoswich consists of a front $LaBr_3$(Ce) crystal (2"×2"×2") optically coupled to NaI(TI) crystal (2"×2"×6") at the back, sealed in a single aluminium can with a glass window and viewed by a photomultiplier tube (PMT). The light outputs generated from both phoswich components are collected by the single PMT. The phoswich detector can measure high-energy gamma rays as well as low energy discrete gamma rays associated with a reaction. VECC has three phoswich detectors and this paper reports the testing of one such element. The linearity and energy resolution properties of the same have been studied upto 4.44 MeV. Using pulse shape discrimination (PSD) technique, add-back of energy deposited in both the scintillators has been tested. Detector simulation has been studied to compare the experimental results.

Experimental Details

The phoswich detector was coupled with a Hamamatsu 6231 photomultiplier tube using optical grease and a bias voltage of -1000 V was applied. The measurements were carried out with different lab standard γ-sources (^{22}Na, ^{137}Cs, ^{60}Co, ^{241}Am-^{9}Be). The testing has been done in two ways. In the first case, sources were placed only in front of each crystal to find out the properties of $LaBr_3$(Ce) and NaI(TI) crystals separately. In the other, pulse shape discrimination technique (PSD) has been used to find out the energy deposition in each crystal. An analog electronic setup was made to register energies in an event. The setup consisted of two VME QDCs (CEAN V792) with short and long gate of widths 160 ns and 600 ns respectively. The signal coming from PMT was first fed to a fixed gain 8-channel fast amplifier (CAEN N412), which simply amplifies the output pulses. Then the signal was divided into two parts. The logic part was sent to the CFD for setting the thresholds and finally sent to GDG to generate two gates of different widths for the charge integration. The analog part was fed to a linear fan-in fan-out module to produce two identical signals and finally sent to the QDC inputs for long and short integrations. The circuit diagram is shown in Fig. 1.

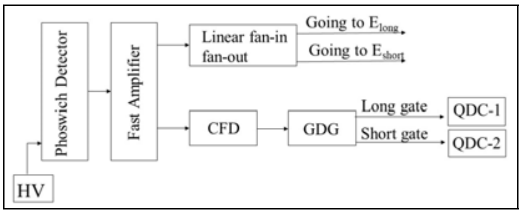

Fig 1: The block diagram of analog electronic setup.

Results and Discussion

An analysis program has been developed to convert the recorded data into ROOT [5] format for further processing. A typical 2D spectrum is shown in Fig. 2 for E_γ = 4.44 MeV, where two semi diagonal bands are observed which signify the clear separation of energy deposition in different phoswich elements. Here, the band around 45^0 with respect to long gate axis corresponds to the energy deposition in the $LaBr_3$(Ce) crystal and another band around 75^0 is due to energy deposition in the NaI(TI) crystal. In between $LaBr_3$(Ce) and NaI(TI) bands, the events correspond the energies which are shared by both the crystals. To find out the total amount of energy deposition in the phoswich detector an algorithm is used as described in detail in ref. [3,4]. To select events from individual detector two graphical cuts are made.

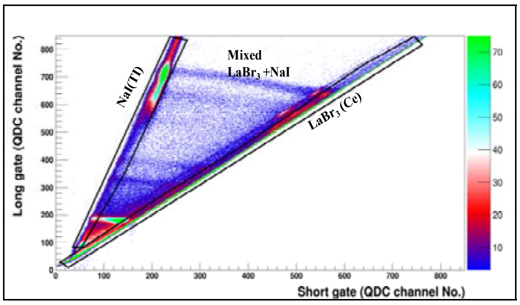

Fig 2: The 2-dimensional plot of the charges collected in long and short gates from phoswich detector for 4.44 MeV γ-ray using pulse shape discrimination technique.

Individual spectra of each crystal for different radioactive sources are obtained by taking appropriate projections (along both the axes) of the corresponding 2-D plot within these graphical cuts. The energy calibration has been performed from the projected spectra. For each event let E_1 and E_2 be the energies deposited in $LaBr_3$(Ce) and NaI(Tl) crystals respectively, then total energy deposited in a single event in the phoswich detector is $E_{tot} = E_1 + E_2$. The total energy (E_{tot}) spectrum in the phoswich element is reconstructed by internal add-back mode which is shown in Fig. 3.

The linearity and energy resolution of both the crystals are studied separately. Energy responses of both the scintillators are found to be linear at least upto 4.44 MeV. The energy resolution of $LaBr_3$(Ce) at 1.13 MeV placing the source close to the crystal is found to be 3.3% whereas from PSD technique it is about 4%. From the PSD technique it is found that the energy resolution of $LaBr_3$(Ce) and NaI(TI) crystals in the phoswich element are 2.7% and 5.1% respectively at 4.44 MeV γ-ray.

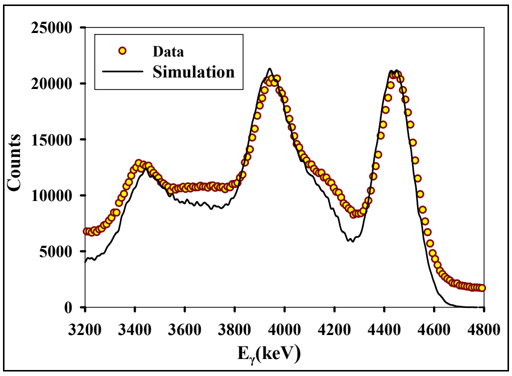

Fig 3: Add-back spectrum at 4.44 MeV gamma rays in comparison to simulated spectrum.

The response function of the phoswich detector at 4.44 MeV is simulated in order to compare experimentally measured γ-energy spectrum. The simulation study has been performed using Monte Carlo code GEANT3 [6] considering the realistic phoswich geometry. The energy resolution and experimental discriminator threshold values are embedded properly in the simulation analysis. The γ-energy source is placed at a distance of 10 cm from the detector to generate the line-shape of the γ-energy at 4.44 MeV. The simulated spectrum is shown in Fig. 3 which matches very well to the experimental spectrum. The test results will be presented in the symposium.

References

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