A $LaBr_3$:Ce-NaI(Tl) Phoswich for X- and low energy γ-rays

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Introduction

We present results of our measurements to study the performance of a Phoswich detector made of 3" diameter and 0.5" thick $LaBr_3$:Ce with 3" diameter and 1" thick NaI(Tl) [1]. A pulse shape analysis was used to separate the signals from the individual layers. A significant reduction in general background and in the internal activity in the low energy region was achieved. The results were well reproduced by GEANT4 simulation considering the phoswich geometry and the internal activity of the $LaBr_3$:Ce. This work, to the best of our knowledge, reports for the first time, the testings and performance of a Phoswich of $LaBr_3$:Ce and NaI(Tl). The results obtained from the measurements and simulations are expected to guide further work in this direction.

The $LaBr_3$:Ce-NaI(Tl) Phoswich

The phoswich detector, a combination of two layers of scintillators with widely different decay times and optically coupled to a single Photomultiplier Tube (PMT) has established itself as a very useful detection system for over three decades. The basic purpose of a phoswich continues to be efficient detection of low-energy and low-intensity X-rays, γ-rays, alpha and beta particles in presence of a high energy background. The very wide application of Phoswich detectors range from particle identification, X- and γ-ray astronomy to medical imaging in more recent times. The widely different decay times of the two scintillators in a typical phoswich detector allow efficient rejection of background using pulse shape discrimination. Over the years a variety of combinations of scintillators, namely, NaI(Tl)-CsI, BGO-CsI, CsI(Na)-GSO, BGO-GSO, Plastic-BaF_2, YSO-LSO, two different plastic scintillators etc. have been investigated and used. The selection of the primary photon detector in all such combinations is guided by the criteria of better detection efficiency, energy resolution and background rejection. The recent discovery of Lanthanum-halide (LaX_3:Ce) crystals seems to be a major step forward in the field of scintillation detectors. The highly attractive and superior properties of $LaBr_3$:Ce over other scintillators open up a very wide usage of these scintillators. We report, for the first time, the performance of a phoswich of $LaBr_3$:Ce and NaI(Tl). It is composed of a 3" Diameter and 0.5" thick $LaBr_3$:Ce coupled to a 3" diameter and 1" thick NaI(Tl) from Saint-Gobain Crystals. The front side of the phoswich is covered by a 0.3 mm thick Be window. The rear side is coupled to a 0.5" thick light guide. The whole assembly, is housed in an Aluminium casing without covering the front side. The best performance of a $LaBr_3$:Ce crystal crucially depends upon the selection of a suitable PMT and optimum operating conditions [2]. The detector is coupled to a 3" diameter BURLES83021E photo multiplier tube. The optimum operating voltage was determined to be around 1000 V and the signals were drawn from the anode.

Results and discussions

The energy spectrum recorded with the Phoswich for ^{137}Cs (661.6 keV) is shown in top part of Fig.1. Double peaks are recorded for the photo peaks corresponding to the full energy deposition in either $LaBr_3$:Ce or NaI(Tl).

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The peak at higher channel in the spectrum corresponds to the photopeak in $LaBr_3$ and the peak at the lower channel with much wider width (poorer energy resolution) corresponds to the photopeak in NaI(Tl). Similar double peaked spectra are seen for other sources also, namely, ^{60}Co, ^{22}Na, and ^{133}Ba. We set up a rise time discrimination circuit based upon the zero-crossover technique [3] to separate the signals originating from the two crystals.

The bottom panel of Fig.1. presents the Cs spectrum gated with the $LaBr_3$ time peak. Having obtained the spectrum purely from the $LaBr_3$ we checked the response of the detector using three different sources, namely, ^{137}Cs (661.6 keV), ^{22}Na (511 keV) and ^{60}Co (1173, 1332 keV). The energy resolution of the $LaBr_3$:Ce was found to be about 4.7% at Cs energy of 661.6 keV and 3.2% at Co energy of 1332 keV. The energy resolution of 4.7% is much worse than the expected value of around 3% and reported by us for a single $LaBr_3$:Ce crystal of 1" diameter and 1" length [2]. However, this poorer performance is most probably due to the loss (absorption) of the photons emitted by the $LaBr_3$:Ce in the thick NaI(Tl) layer and possibly at the optically coupled junction of the two crystals.

The primary application of this Phoswich will be detection of X-rays and low energy gamma rays. The Phoswich detector is required to reject the background generated by the partial energy deposition of the higher energy radiations in both the layers. In addition the internal radioactivity of $LaBr_3$:Ce poses background problem for low-intensity radiations of interest around 30 keV. We will present our measurements showing considerable reduction in the general background and in the internal activity while operating the phoswich in anticoincidence mode. A detailed simulation using GEANT4 has been carried out considering the realistic phoswich geometry and internal activity of the phoswich through out the volume of the $LaBr_3$:Ce. The simulation reproduces the experimentally obtained internal activity spectrum (see figure 2) and the background reduction satisfactorily.

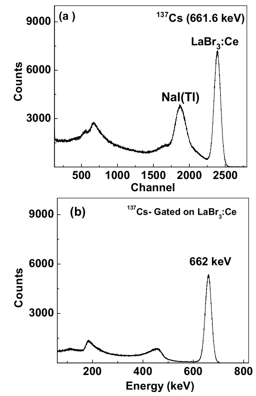

FIG. 1: The energy spectrum recorded in the phoswich detector for ^{137}Cs (661.6 keV). The lower figure shows the Cs spectrum gated with the time peak corresponding to the $LaBr_3$:Ce.

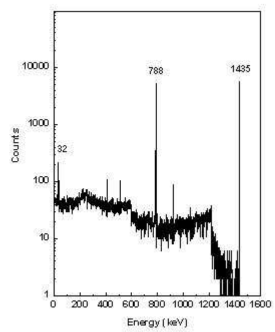

FIG. 2: The gamma-ray energy spectrum recorded in the NaI(Tl), as obtained from GEANT4 simulation, due to the internal radioactive decay of ^{138}La in the $LaBr_3$:Ce section of the phoswich.

References

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