Characterization of the CeBr₃ scintillator detectors

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Introduction

The need of having better energy- as well as timing- resolution has resulted in an increased interest in the development of new scintillator detectors. The efforts have led to development of Lanthanum-halide detectors, such as lanthanum-bromide (LaBr₃) and lanthanum-chloride (LaCl₃). Out of these, the cerium doped LaBr₃ (Ce) are used in wide range of applications due to their excellent energy resolution (~3% @ 662 keV), fast rise time and decay constant which leads to excellent time resolution (~98 ps for 1in. X 1in. Crystal at energies from ⁶⁰Co source)[1]. Though being superior in energy and time characteristics, the expensive crystal technology and the presence of radioactive constituent ¹³⁸La in LaBr₃:Ce poses a serious challenge of their use in applications such as low intensity gamma measurements, homeland security applications etc. The Cerium Bromide (CeBr₃) as a low-cost viable alternative, with the possibility of substantially improved gamma-ray spectrometer because of their lower intrinsic internal activity, has become the area of interest in recent times.

This paper aims to present preliminary results of a study exploring the basic characteristics of two cylindrical CeBr₃ detectors of diameter 1.5-inch and height 1.5-inch.

Experimental Details

Two Scionix made CeBr₃ cylindrical detectors (hereinafter referred to as D1 & D2) with optically coupled with Hamamatsu 2” Type R6231-100 PMT, in conjunction with standard Gamma sources ¹³⁷Cs, ⁶⁰Co, ²²Na, Am-Be were used for characterization purpose. The VME based data acquisition system LAMPS[2] was used for recording the data which were further analyzed using a modular scientific software framework ROOT. Fig.1 depicts the schematic of electronic setup used to measure time response of each CeBr₃ detector in coincidence with the other CeBr₃.

![Fig. 1 A schematic of time response measurement of CeBr3 detectors.](image)

The coincidence energy spectra with ⁶⁰Co source for D1(E1) and D2(E2) is shown in fig.2, where distinct patches can be seen at 1173 keV and 1332 keV and their corresponding back scattered components.

![Fig. 2 D1 and D2 Coincidence spectra with ⁶⁰Co.](image)

The timing response between D1 and D2 with energy gating in the region around the peak lines...
of 1173 and 1332 keV for $^{60}$Co source, shown in fig. 3, was measured using a time-to-amplitude converter (TAC) unit with one of the detector (D1 or D2) as a START signal and the remaining detector with an adequate delay as a STOP signal.

![Energy gated time response](image1)

Fig. 3 Time response spectrum using TAC with energy gating.

Table 1 shows the individual time resolution (in picoseconds) of each detector at different voltages, including the manufacturer suggested operating voltage of -710 V and -740 for D1 and D2 respectively, assuming identical Gaussian time response for each detector. The error in measurement of ~10%, is mainly due to error in time calibration.

<table>
<thead>
<tr>
<th>Detector Bias</th>
<th>@511 keV</th>
<th>(1173-1332) keV</th>
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</thead>
<tbody>
<tr>
<td>D1=600V, D2=600V</td>
<td>930±93 ps</td>
<td>670±67 ps</td>
</tr>
<tr>
<td>D1=710V, D2=740V</td>
<td>610±51 ps</td>
<td>430±43 ps</td>
</tr>
<tr>
<td>D1=850V, D2=850V</td>
<td>530±53 ps</td>
<td>360±36 ps</td>
</tr>
</tbody>
</table>

Table 1. Time response of each detector with varying voltages.

Apart from measuring the time response, these detectors were also characterized for their energy resolution, linearity and stability. Fig. 4 shows the measured energy spectra for D1 with $^{22}$Na (511 & 1274KeV) and $^{137}$Cs (662KeV) at operating bias of -710V.

![D1 energy spectra with $^{22}$Na and $^{137}$Cs source.](image2)

Fig. 4 D1 energy spectra with $^{22}$Na and $^{137}$Cs source.

Energy resolution of one detector D2, as a function of energy(E), is shown in fig.6 with a fitting according to function A/E$^{1/3.506}$, where A is fitting parameter [3].

![Linearity of D2 with varying operating bias.](image3)

Fig. 5 Linearity of D2 with varying operating bias.

![Energy resolution as a function of energy with a power function fit for detector D2.](image4)

Fig. 6 Energy resolution as a function of energy with a power function fit for detector D2.

References