Characterization of the $CeBr_3$ 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 ($LaBr_3$) and lanthanum-chloride ($LaCl_3$). Out of these, the cerium doped $LaBr_3$ (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 ^{60}Co source)[1]. Though being superior in energy and time characteristics, the expensive crystal technology and the presence of radioactive constituent ^{138}La in $LaBr_3$:Ce poses a serious challenge of their use in applications such as low intensity gamma measurements, homeland security applications etc. The Cerium Bromide ($CeBr_3$) 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 $CeBr_3$ detectors of diameter 1.5-inch and height 1.5-inch .

Experimental Details

Two Scionix made $CeBr_3$ cylindrical detectors (hereinafter referred to as D1 & D2) with optically coupled with Hamamatsu 2" Type R6231-100 PMT, in conjunction with standard Gamma sources ^{137}Cs, ^{60}Co, ^{22}Na, 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 $CeBr_3$ detector in coincidence with the other $CeBr_3$.

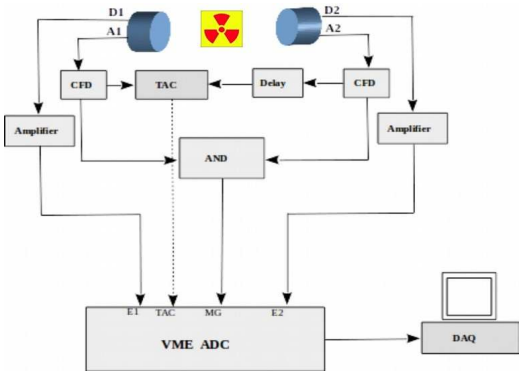

Fig. 1 A schematic of time response measurement of CeBr3 detectors.

The coincidence energy spectra with ^{60}Co 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.

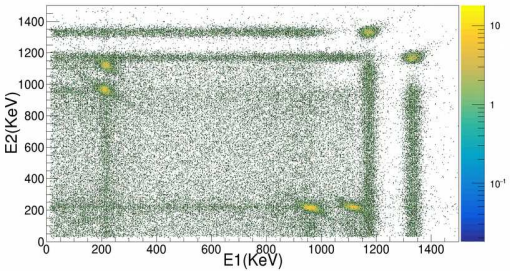

Fig. 2 D1 and D2 Coincidence spectra with ^{60}Co.

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.

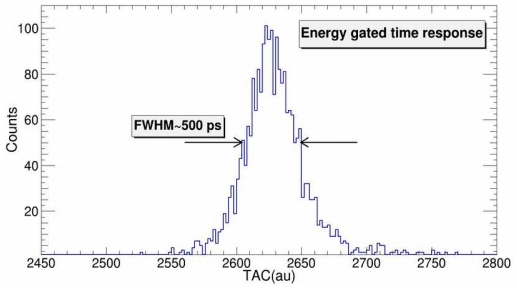

Fig. 3 Time response spectrum using TAC with energy gating.

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.

Detector Bias	@511 keV	@(1173-1332) keV
D1=-600V D2=-600V	930±93 ps	670±67 ps
D1=-710V D2=-740V	610±61 ps	430±43 ps
D1=-850V D2=-850V	530±53 ps	360±36 ps

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.

Linearity of one such detector D2 is shown in fig.5, in the energy region spanning from 511 keV to 4439 keV, at different operating bias starting from -600V to -900V. It has been observed (inset in fig.5) that the non-linearity tends to set in when the absolute operating voltage is kept at ~900V.

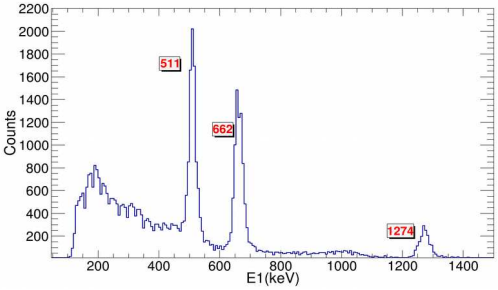

Fig. 4 D1 energy spectra with ^{22}Na and ^{137}Cs source.

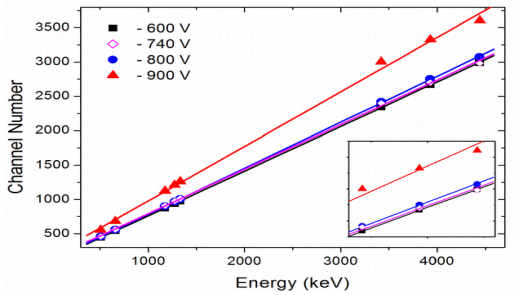

Fig. 5 Linearity of D2 with varying operating bias.

Energy resolution of one detector D2, as a function of energy(E), is shown in fig.6 with a fitting according to function $A/E^{0.5008}$,' where A is fitting parameter [3].

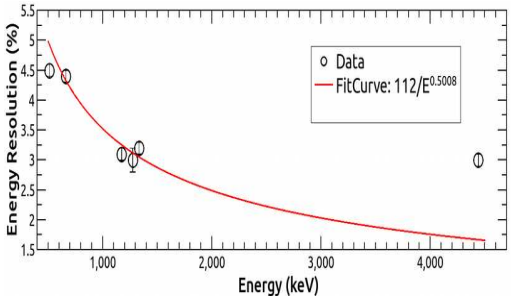

Fig. 6 Energy resolution as a function of energy with a power function fit for detector D2.

References

[1] V.Vedia et al., NIM **A**795, 144 (2015).
[2] www.tifr.res.in/∼pell/lamps.html
[3] R. Billnert et al., Phy. Procedia 31,29(2012).