Characterization of $CeBr_3$-NaI(Tl) phoswich detector for PARIS collaboration

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Introduction

For study of high energy γ-rays in reactions involving low intensity radioactive ion beams (RIB), a high efficiency detector array PARIS (Photon Array for the Studies with Radioactive Ion and Stable beams) is being developed [1, 2]. The PARIS array is based on the concept of phoswich detector, where a $LaBr_3$(Ce) crystal ($2'' \times 2'' \times 2''$) is optically coupled to a NaI(Tl) crystal ($2'' \times 2'' \times 6''$) and both detectors are read out by a single Photo Multiplier Tube (PMT). The phoswich detector design was developed by Saint-Gobain Crystals. Recenly, $CeBr_3$ detectors are also shown to be comparable to $LaBr_3$(Ce) detector, in terms of energy and time resolution [3]. Moreover, the $CeBr_3$ is free from internal activity which can be advantageous when low background levels are desired. With this motivation, the PARIS collaboration has also explored the $CeBr_3$-NaI(Tl) phoswich detector configuration. This paper reports the test results of the $CeBr_3$-NaI(Tl) phoswich detector. A comparison with the $LaBr_3$(Ce) -NaI(Tl) phoswich is also presented.

Experimental Details and Data analysis

Four $CeBr_3$-NaI(Tl) phoswich detectors manufactured by M/S Scionix, Netherlands, were tested at TIFR, Mumbai using different radioactive sources. Each detector was coupled to R13089-100 PMT, with a typical operating bias of -1 kV. Detectors were also tested with a R7723-100 PMT, which is a PARIS standard. Typical pulses in $CeBr_3$-NaI(Tl) phoswich detector for 662 keV γ-ray are shown in Fig. 1. It can be seen that pulses corresponding to $CeBr_3$ (rise time $\sim$12 ns) and NaI(Tl) are clearly separated. The data have been acquired using V1730 CAEN digitizer (2 Vpp, 14-bit, 500 MS/s) and digiTES-4.2.6 data aqusition software [5]. This digitizer, specially developed for the PARIS collaboration, has an in-built constant fraction discrimination (CFD) algorithim and gives the time stamp, pulse shape discrimination (PSD) and energy information [5]. The C++ based ROOT framework [6] is used for data analysis.

Data were taken with ^{137}Cs and ^{60}Co sources

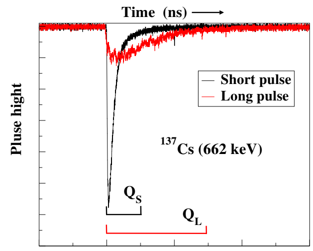

FIG. 1: Typical pulses, $CeBr_3$-NaI(Tl) phoswich detector.

for individual phoswich detectors, with source placed sideways at junction of the two crystals. The output pulse from the PMT was integrated and recorded for different gate widths of 300 and 900 ns, to get the integrated charge over the short gate (Q_S) and long gate (Q_L), respetivily. The energy deposited in $CeBr_3$ and NaI part of the detector is seperated using the pulse shape discrimination (PSD) parameter defined as,

$$PSD = \frac{Q_L - Q_S}{Q_L} \quad (1)$$

A 2-dim plot of PSD vs Q_L is shown in

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Fig. 2, where seperate band corresponding to full energy deposition in $CeBr_3$ and NaI(Tl) as well as mixed events are clearly visible.

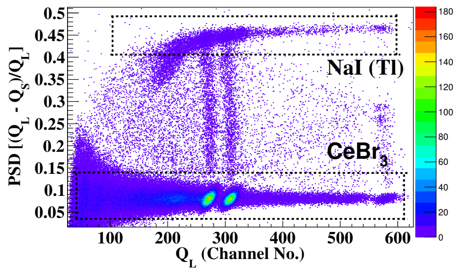

FIG. 2: A PSD spectrum with ^{60}Co source in Detector D.

Energy spectra for $CeBr_3$ and NaI(Tl) detectors are obtained by suitable gates on PSD and are shown in the Fig. 3. The measured resolution for all the detectors are tabulated in Table I. It also lists 'peak to valley ratio', defined as ratio of peak intensity of 1173 keV to intensity at valley point between two peaks in the ^{60}Co spectrum, which is an additional figure of merit.

TABLE I:

Resolution of $CeBr_3$ and NaI(Tl) crystals.

Detectors	Measured^a Resolution (%)		Peak to Valley ratio
	$CeBr_3$	NaI(Tl)	
A	4.9	7.6	29.3
B	5.1	8.4	28.9
C	5.9	8.2	23.6
D	4.7	8.0	30.3

^{a}Error in resolution is ~ 0.5%.

It is observed that one of the detector (C) has relatively poorer resolution. Similar resolution was obtained with Hammatsu R7723-100 PMT.

A comparison of γ-ray spectra using $LaBr_3$(Ce)-NaI(Tl) [4] and $CeBr_3$-NaI(Tl) phoswich detectors is shown in Fig. 4. The internal activity in $LaBr_3$ due to ^{138}La is clearly visible as peak at 1468 keV.

In summary, measurements of $CeBr_3$-NaI(Tl) phoswich detectors have been carried out with two different PMTs. On the average, the resoultion of $CeBr_3$ (~ 5% at 662 keV) is only slightly worse than that of $LaBr_3$ (~ 4.5% at 662 keV). In high energy experiments, where the recoil velocity is large and results in significant Doppler broadening, this difference in the intrinsic resolution may not be siginificant. Moreover, $CeBr_3$ being free of internal activity, has lower background. Thus, $CeBr_3$-NaI(Tl) phoswich detector is shown to be a viable option for the PARIS array.

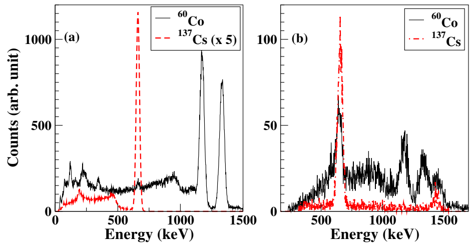

FIG. 3: PSD gated spectra of ^{60}Co and ^{137}Cs in individual crystals (a) $CeBr_3$ (b) NaI(Tl) for detector D.

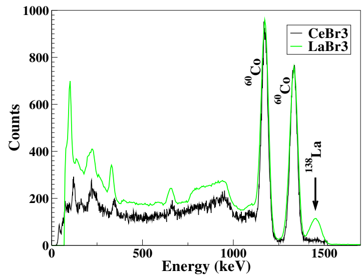

FIG. 4: A comparison of γ-ray spectra using $CeBr_3$-NaI(Tl) and $LaBr_3$(Ce)-NaI(Tl) detectors.

Acknowledgments

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References

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