$CeBr_3$ detector array for measurement of lifetime and transition moment at VECC, Kolkata

S. S. Alam[1*], T. Bhattacharjee[1], D. Banerjee[2], S. Mukhopadhyay[1], D. Mondal[1], A. Saha[1], D. Pandit[1], S. Pal[1], P. Bhaskar[1], S. K. Das[2] and S. R. Banerjee[1]
[1]*Experimental Physics Group, Variable Energy Cyclotron Centre, 1/AF Salt Lake, Kolkata – 700 064, INDIA*
[2]*Accelerator Chemistry Section, RCD-VECC, 1/AF Salt Lake, Kolkata – 700 064, INDIA*
* email: safikul.alam@vecc.gov.in

Introduction:

Measurement of lifetime and transition moments for excited nuclear levels carries utmost importance in experimental nuclear physics as it provides direct insight into structure of a nucleus. Timing measurement techniques have been explored in different ranges from nanoseconds to picoseconds involving different detectors, viz., high resolution Ge as well as fast timing BaF_2 [1-3]. With the availability of detectors having moderate energy resolution along with very good time resolution in recent times, viz., $LaBr_3$(Ce) and $CeBr_3$, improved timing measurement techniques in picoseconds range have been proposed [3,4]. These measurements have been performed with $LaBr_3$(Ce) detectors and have also been explored at VECC, Kolkata during last few years in nuclei of different mass region [5,6]. $CeBr_3$ scintillator detectors, having slightly poor energy resolution compared to $LaBr_3$(Ce) and an improved time resolution [7] could be considered as another possible alternative to $LaBr_3$(Ce) which are limited by their higher hygroscopic nature and self-activity. Such initiative has been taken at VECC, Kolkata to explore the lifetime measurement with $CeBr_3$ and to develop a fast timing array with these detectors. Several such detectors, made up of 1″ ϕ X 1″ thick $CeBr_3$ scintillators coupled to Hamamatsu 9779 Photo multiplier tubes, have been procured. An ancillary timing array, made up of these detectors, has been developed, tested and used in a few in-beam and off-beam experiments [8, 9]. The array can be used in stand-alone mode as well as with the VENUS array made up of six Clover HPGe detectors [10]. In the present abstract we report the characterization of these $CeBr_3$ detectors and the exploration of generalized centroid difference (GCD) technique using the combination of these detectors, as shown in Fig. 1, for measurement of lifetime in picoseconds range. Combination of these detectors will also be used for the measurement of quadrupole moments using Perturbed Angular Correlation techniques.

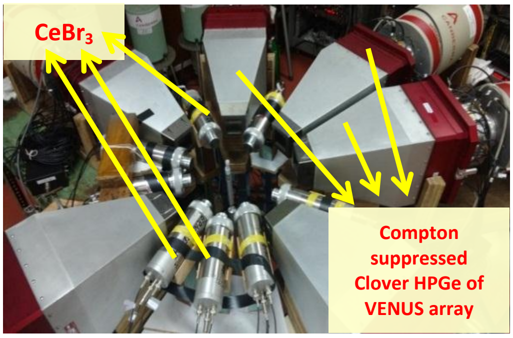

Fig. 1: The $CeBr_3$ detectors in the configuration of an ancillary array coupled to the VENUS array. This array was used for the off-beam decay spectroscopy experiments at VECC, Kolkata.

Characterization:

The detectors have been characterized with the measurement of their energy response, energy resolution and timing properties at different high voltages applied to the photomultiplier tube. The anode signals have been used for timing measurements whereas the dynode signals were used for the measurement of energy. A charge sensitive preamplifier has been developed at VECC, Kolkata in order to process the dynode signal. This development provides the possibility of operating the detectors at highest possible bias of the PM tube without compromising the linear energy response from the detector and thus to achieve the best possible time resolution. The pulse processing has been done with discrete NIM electronics and data have been acquired with VME based system using high resolution Mesytec ADCs. An energy resolution of ~4.5% has been achieved with the detectors, at 662 keV, as shown in Fig. 2. The time resolution obtained with two such detectors for 1173-1332 keV coincidence from ^{60}Co source has also been shown in Fig. 2 and this comes out to be ~230ps. The absolute efficiency of the detectors have been measured and compared with Geant3 simulation. It has been observed that the efficiency of one detector is nearly equal to the efficiency of one single crystal of a clover detector used in the VENUS array.

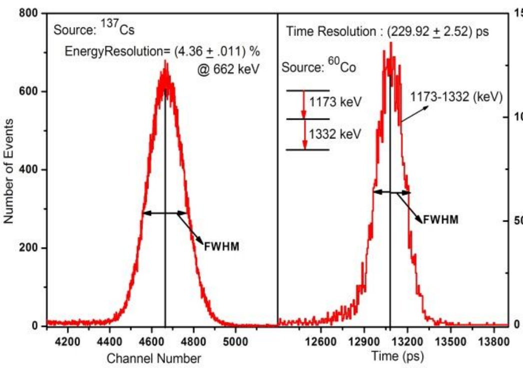

Fig.2: Energy and Time Spectrum obtained by using standard ^{137}Cs and ^{60}Co sources respectively.

Fast timing measurement with the $CeBr_3$ detectors:

The GCD technique has been explored to measure lifetimes in picosecond range. The measurements have been performed by using γ–γ coincidence obtained with combinations of two, four and eight such detectors. In the latter case, the eight detectors were kept in the configuration of an ancillary array coupled to the VENUS array, as shown in Fig. 1. The ORTEC 584 Constant Fraction discriminator has been used with different Constant Fraction Delay for exploring the measurements in CFD as well as ARC mode of timing signal generation. The ORTEC 567 Time to Amplitude converter modules, set in the range of 50ns, were used for gathering the time difference spectra. ^{152}Eu source was used for calibration of prompt time response. At the same time, data have been gathered with ^{133}Ba and ^{106}Ru sources for verifying the known level lifetimes and also measuring the new lifetimes. Prompt time curves have been generated during offline sorting of the data by applying the appropriate corrections to the various centroid differences obtained with each detector pair. The prompt time curve obtained with the eight detector setup has been shown in Fig. 3 with the centroid difference plot for 244-444 keV cascade of ^{152}Sm.

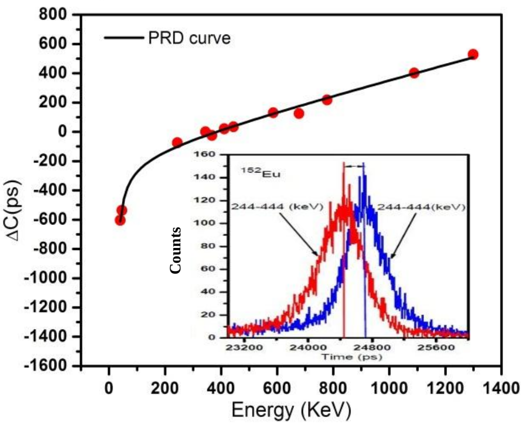

Fig. 3: The prompt time calibration curve obtained with ^{152}Eu source, following generalized centroid difference method. Inset shows the obtained centroid difference with 244-444 keV cascade.

References:

[1] H. Mach et. al., NIM A280, 49 (1989).
[2] H. Xie et al., NP **A599** 560(1996).
[3] J. M. Regis et al., NIM **A726**, 191 (2013).
[4] J. M. Regis et al., NIM **A622** (2010).
[5] T. Bhattacharjee et al., Phys. Rev. **C88**, 014313 (2013).
[6] S. S. Alam et al. DAE Symp. Nucl. Phys. **60**, 270 (2015).
[7] L. M. Fraile et al., NIM **A701,** 235 (2013).
[8]S. S. Alam et al., submitted to DAE symp. Nucl. Phys. 2016.
[9]A. Saha et al., submitted to DAE symp. Nucl. Phys. 2016.
[10]Soumik Bhattacharya et al., submitted to DAE symp. Nucl. Phys. 2016.