Design of VENTURE-2.0: $\gamma - \gamma$ fast timing array at VECC

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Introduction

The initial stage of the VENTURE (VECC Nuclear Fast Timing and Angular Correlation) array [1] which is known to be the first $\gamma - \gamma$ fast timing array in India and the first $CeBr_3$ array in the world, was assembled at VECC with eight $1^{''} \times 1^{''}$ $CeBr_3$ detectors, each equipped with Hammamatsu 9779 PMT. The current VENTURE array predominantly employs the Generalized Centroid Difference (GCD) Method [2] to measure lifetimes down to a few picoseconds.

The upcoming array, referred to as VENTURE-2.0, is intended to incorporate more number of $CeBr_3$ detectors compared to its first phase along with few clover HPGe detectors in the median plane. This phase aims to be established for conducting in-beam fast timing and perturbed angular correlation experiments utilizing the K-130 cyclotron and other available facilities at VECC. The effectiveness of a $\gamma - \gamma$ fast timing array, like any other time measuring instrument, is determined by its level of 'precision'. Timing precision of a $\gamma - \gamma$ fast timing array depends on several key parameters, such as detector efficiency, time resolution, and the total number of detector pairs used in the measurement. Furthermore, fast timing measurements can be influenced by inter-detector Compton scattering, in addition to the previously mentioned factors [3]. The ultimate choice of detectors for VENTURE-2.0 was made by aiming to achieve the best time precision while optimizing the inter-detector scattering.

Simulation of Array Using Geant4

The design of VENTURE-2.0 was made using Geant4 (Geant4.10.7.3 version) [5]. $CeBr_3$ crystals of different diameter (ϕ) and thickness (t), varied as $1^{''}$, $1.5^{''}$ and $2^{''}$, were used for this purposes. For all sizes, a cylindrical PMT of $2^{''}$ diameter was considered. Various parts of the setup were constructed using classes such as G4Tubs, G4Trd, G4Sphere, G4Polyhedra, G4Polycone, G4UnionSolid, G4SubtractionSolid etc. Three different configurations were considered in all of which the distance of eight BGO suppressed Clover HPGe detectors, placed in the median plane, was 22.6 cm from the target. Maximum possible number of $CeBr_3$ detectors were placed in a compact geometry for all the three configurations where $CeBr_3$ crystals were placed at 10 cm (27 no.), 12.5 cm (41 no.) and 15 cm (53 no.) from the target and at non zero ϕ angles. Total number of detectors was independent of crystal sizes and the most θ and ϕ symmetric configuration with target detector distance as 12.5 cm is shown in Fig. 1.

Simulation Results

The absolute efficiency, time precision and total number of inter-detector Compton scattering events were calculated for all the three configurations of the array, placing nine different sizes of $CeBr_3$ detectors varying the thickness and diameter as $1^{''}$ $1.5^{''}$ and $2^{''}$. The time resolution of the detectors were estimated through simulations and existing ex-

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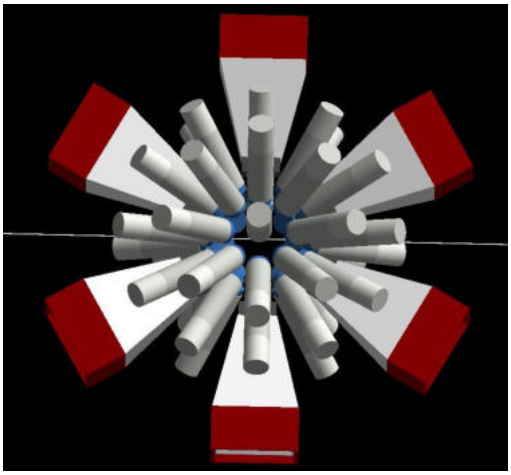

FIG. 1: Configuration of VENTURE 2.0 with 41 no. of $2^{''} \times 1^{''}$ CeBr3 detector are placed at 12.5 cm from the target.

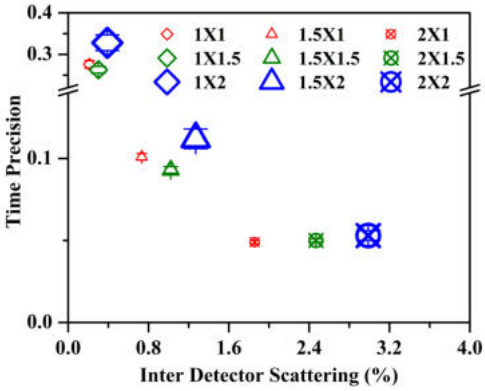

FIG. 2: The time precision and inter-detector scattering of the VENTURE-2.0 array, varying with different sizes of $CeBr_3$ detectors. The symbol sizes represents the time resolution of the detectors.

perimental data [4]. The inter-detector scattering was estimated with $1{\times}10^6$ number of 1.3 MeV photons distributed uniformly in 4π. The time precision values are normalized with that from a pair of $2^{''} \times 2^{''}$ $CeBr_3$ detectors placed at 10 cm from the target. The Fig. 2 illustrate the time precision and cross-talk characteristics of the VENTURE-2.0 array. Notably, it is apparent that the array equipped

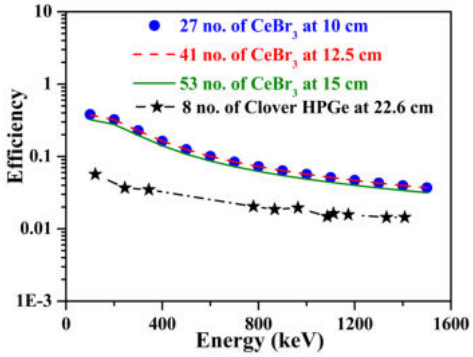

FIG. 3: Simulated efficiency of VENTURE-2.0 array with $2^{''} \times 1^{''}$ $CeBr_3$ detectors placed at different distances from the target are shown in comparison to the efficiency of the Clover HPGe detectors.

with $2^{''} \times 1^{''}$ detectors exhibits the best time precision, along with reduced cross-talk and superior time resolution.

In Fig. 3, we compare the absolute efficiencies of the array with $2^{''} \times 1^{''}$ $CeBr_3$ detectors placed in in three different configuration along with the absolute efficiency of the clover detectors in the array.

It is observed that all the configurations provide similar efficiency, time precision and cross-talk but the configuration with target detector distance at 12.5 cm provides the best θ symmetric design favourable for perturbed angular correlation measurements.

References

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