Characterization of a segmented clover detector

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Introduction

The study of nuclear structure of exotic nuclei produced in fission and deep inelastic type reactions, requires to identify both the recoiling nucleus and the γ-rays emitted from the nucleus. As the γ-rays, in this case, are emitted from a source moving with a high velocity, the energy resolution is affected by Doppler broadening due to angular acceptance of the detector element. This problem is minimized by minimising the effective size of the detector and increasing the granularity. This can be achieved by using segmented clover configuration which can facilitate (a) high granularity (b) precise correction for Doppler broadening (c) polarization measurement (d) Add-back facility for enhanced photopeak efficiency. Such segmented clover type detectors are used at EXOGAM [1] and TIGRESS [2] arrays. In these detectors, the advantages of clover geometry [3] are retained along with the Doppler broadening correction. An EXOGAM-type segmented clover HPGe detector has been procured and characterized recently at VECC. The result of the initial characterization is presented here.

The CANBERA (France)- make segmented clover detector consists of 4 HPGe tapered crystals in a single cryostat having a 'four-leaf clover' shape. Each crystal is electrically divided into four segments, constituting a total of 16 segments. Size of each crystal is 90 mm (length) x 60 mm (dia). There are total 40 output signals from this detector. Both energy and timing signals are taken from the 4 high-resolution core contacts (4 crystals) and 16 low-resolution outer contacts (16 segments). The outer contacts are used for position and the inner contacts for energy measurements.

Characterization of the detector

The initial characterization of the detector was done by measuring energy resolution, absolute efficiency and add-back factor using ^{133}Ba, ^{152}Eu and ^{60}Co radioactive sources and the same has been compared with a normal clover detector (crystal size 70(l) x 50(d) mm^2). The data acquisition and analysis was done by using LAMPS. A typical γ-ray energy spectrum (^{152}Eu) of one of the four crystals of the segmented clover is shown in Fig.1. Typical energy resolutions were found to be around 2 keV for the four crystals and $2.5 - 3.0$ keV for the 16 segments at 1332 keV energy measured with 6μs shaping time. Add-back spectrum of four crystals were generated after gain matching of four crystals using list-mode data. The absolute efficiencies of the detector at a distance of 11 cm from the source for single crystal, normal sum of four crystals and add-back modes were measured and shown in Fig. 2. The ratio of efficiencies of the segmented-clover and the normal clover detector for the three modes are shown in Fig.3.

Measured add-back factors of the segmented and the normal clovers are compared in Fig.4. By definition, the add-back factor cannot be less than 1, but due to multi-hit probability of the highly intense low-energy γ-rays, the add-back factor becomes < 1 at low energies. The lowest add-back factor of unity is obtained when necessary corrections were incorporated from the single-hit events.

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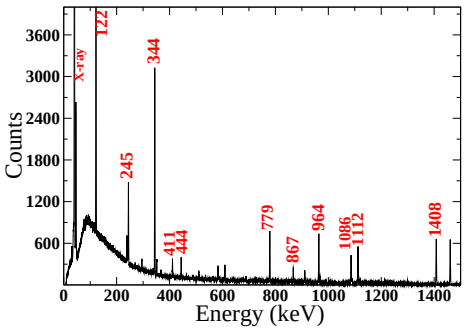

FIG. 1: γ-ray energy spectrum of one of the crystals of the segmented clover using a ^{152}Eu source.

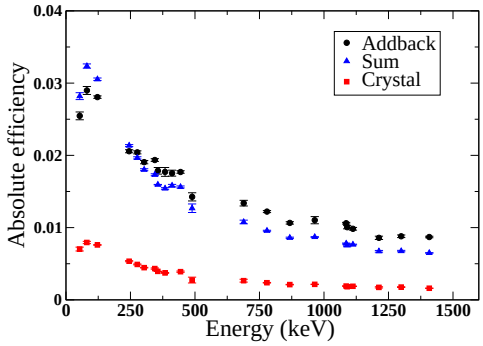

FIG. 2: Absolute efficiencies of crystal, sum-of-four crystal and add-back of the segmented clover detector placed at 11 cm away from the source.

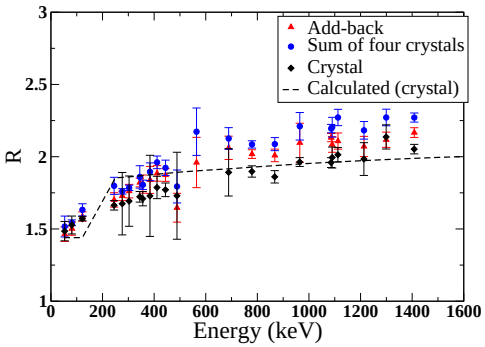

FIG. 3: The ratio (R) of the efficiencies of segmented clover and a normal clover as a function of γ-ray energy. The value of R calculated from a geometrical picture is shown by dashed line.

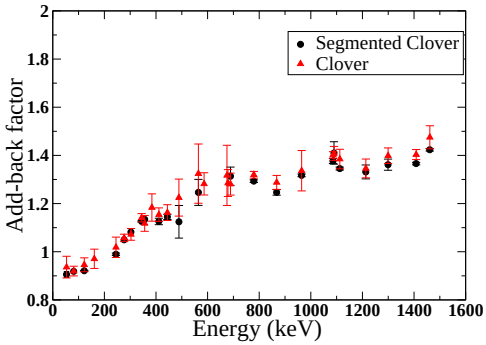

FIG. 4: Add-back factors of the segmented clover (circle) and normal clover (triangle) detectors.

Discussion

The add-back efficiency of the segmented clover becomes significantly higher than the normal sum-of-four crystals at energies > 250 keV (Fig. 2) so, the polarization threshold of this detector is also about the same energy. Higher efficiency of the segmented clover over a normal clover by a factor of ~ 2 (Fig.3) for $E_\gamma > 500$ keV is mainly due to its larger crystal volume. The measured ratio agrees well with the ones calculated using a simple geometrical picture (dashed line in Fig. 3). It can also be seen that add-back factors remain almost same with a value of about 1.4 at 1 MeV for both the detectors (Fig. 4), although there are large differences in their efficiencies.

Conclusion

For the first time an EXOGAM type segmented clover detector is tested and characterized in India. The energy resolution, efficiency and its comparison with a normal clover detector has been done. The position resolution, which can be obtained from the segments using induced charge, will be tested soon.

References

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