Simulation study of clover detector performance in INGA at IUAC

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Introduction

Clover detectors are composite hyper-pure germanium detectors used in high resolution gamma ray spectroscopy [1]. Clover detectors used in INGA array at IUAC consists of four crystals arranged like leaves of a clover. INGA array at IUAC [2] is an array of 24 clover detectors, each housed inside a BGO Anti-Compton Shield (ACS) detectors. In our earlier study detailed characteristics of clover detectors, such as, efficiency as a function of gamma ray energy, fold distribution, add-back etc. has been studied [3,4,5]. With time we have observed for a number of detectors that one of the crystal develops problem and stops giving signal. In this abstract we report our present simulation study on 1) the basic characteristics of the clover detectors with one or two non-working crystals, 2) the clover array efficiency and peak-to-total at different energies and 3) the effect of variation of source position on the photo-peak efficiency (ε_p) and peak-to-total ratio of clover detectors for gamma rays from a ^{60}Co radioactive source.

Geometry of the detectors and simulation conditions:

We have performed this simulation study using the Geant4 simulation tool kit [6]. We have defined the geometry of detectors and their positions according to the INGA array at IUAC [2]. There are 4 detectors at spherical polar angles (θ, ϕ), $\theta = 148^o$ with $\phi = 0^o$, 90°, 180°, 270° , 4 at $\theta = 123^o$ with $\phi = 45^o$, 135°, 225°, 315°, 8 at $\theta = 90^o$ with $\phi = 0^o$, 45°, 90°, 135°, 180° , 225°, 270°, 315° , 4 at 4 at $\theta = 57^o$ with $\phi = 45^o$, 135°, 225°, 315°, and 4 at $\theta = 32^o$ with $\phi = 0^o$, 90°, 180°, 270° with respect to the beam direction. The setup parameters for simulation are given in Table 1. The collimators mounted on ACS are assumed to be made up of lead (Pb) material. The configuration of detectors used in simulation is shown in Fig.1. For clarity only 16 (ACS+Clover) detectors are shown, however, the simulation was carried out for 24 detectors.
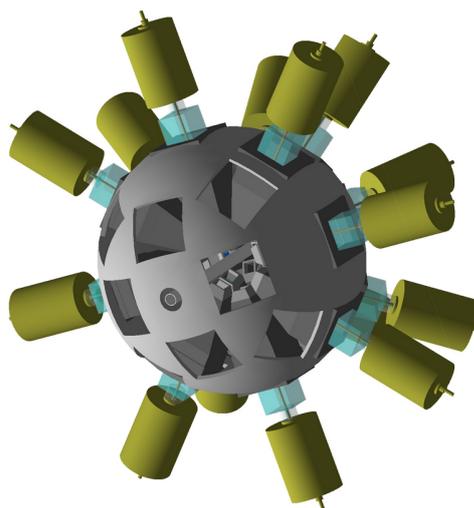
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Fig.1: Configuration of detectors used in the simulation (only 16 of 24 shown for clarity)

Table-1 : Simulation parameters

Detector Distance	234.00 mm
Source Angle	29.00 deg
Structure Thickness	20.00 mm
Glass Tube OD	50.80 mm
Glass Tube ID	46.80 mm
Crystal Length	70.00 mm
Crystal Diameter	50.00 mm
Inter Crystal Gap	0.20 mm
Volume of 1 crystal	117.68 cm3
Volume of 4 crystals	470.72 cm3
Density	5.32 g/cm3
Collimator Length	40.0 mm
Collimator front opening	47.0 mm
Collimator back opening	64.0 mm

Simulation results:

The results of clover detectors has been shown in Fig.2, in *2a* & Table 2 *for* full array with 4, 3, 2 crystals, in *2b* & Table 3 for individual crystals of a clover and in *2c* & Table 4 for single clover with 4, 3, 2 crystals with add back factor.

In Fig. 3 photo peak efficiency and peak-to-total ratio as a function of γ ray energy is shown for the full array. During the in-beam experiments it is known that the beam spot may wander during the experiment within the target boundary. We have thus also simulated the variation of source position to see the effect on peak-to-total and the detector photo-peak efficiency.

Table-2 : P/T ratio & PP (ε_p) efficiency for array

SPEC	Peak AREA	Peak to total (%)	ε_p % (1173 + 1332)	ARRAY ε_p % @1252 keV	Single Clover ε_p %
ALL4_24	794352	46.404	7.944	3.972	0.165
ALL3_24	519114	30.326	5.191	2.596	0.108
ALL2_24	315155	18.411	3.152	1.576	0.066

Table 3: P/T ratio & PP (ε_p) efficiency for each crystal

SPEC	Peak AREA	Peak to total (%)	ε_p % (1173 + 1332)	ε_p % @1252 keV
Crystal-1	5516	30.934	0.055	0.028
Crystal-2	5490	30.789	0.055	0.027
Crystal-3	5399	30.278	0.054	0.027
Crystal-4	5458	30.609	0.055	0.027

Table 4: P/T ratio & PP (ε_p) efficiency for a clover with add back factor.

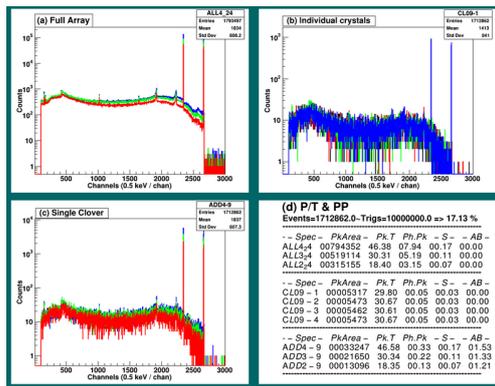| No. of Crystals in the clover	Peak AREA	Peak to total (%)	ε_p % (1173 + 1332)	ε_p % @1252 keV	Add back factor
4	33354	46.763	0.334	0.167	1.526
3	21868	30.660	0.220	0.110	1.333
2	13414	18.807	0.130	0.065	1.219

Fig. 2 Compton suppressed add back spectrum of ^{60}Co for a) full array, b) individual crystals c) single clover d) P/T, PP and add back factor.

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In Fig. 4 the maximum difference (asymmetry) observed between the detectors in the peak-to-total ratio is plotted for different positions of the source. the variation of source position to see the effect on peak-to-total and the detector photo-peak efficiency. In Fig. 4 the maximum difference (asymmetry) observed between the detectors in the peak-to-total ratio is plotted for different positions of the source.
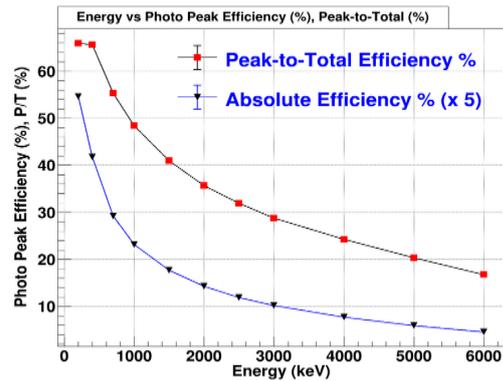

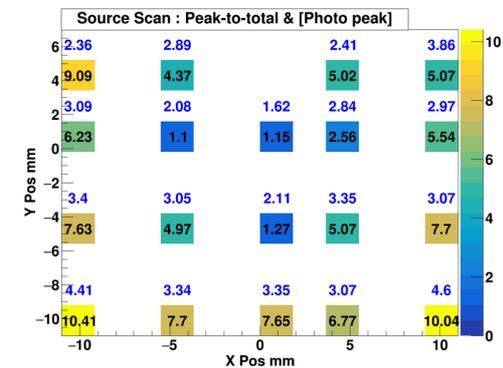**Fig. 3** Photo-peak efficiency and peak-to-total ratio vs γ ray energy for the array.

Fig. 4 Max. difference in photo peak efficiency and peak to total at different source positions.

References

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[4] R.P. Singh et al., DAE-BRNS Symp. On Nucl. Phys. Proc. 46B (2003) 562.
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