Which clover for CLODETTE ?

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1 Summary

Preliminary GEANT4 [1] simulations have been performed to compare several existing "Clover" [2] germanium detectors from CANBERRA. Using these simulations the optimal CLODETTE detector (ANR-12-BS05-0013) for the GABRIELA [3] array was determined.

2 Existing Clover detectors

To minimize costs only currently existing CANBERRA detectors will be considered. The CANBERRA nomenclature, 4YX, will be used to denote specific clover detectors. "4" means four crystals. "Y" represents the nominal diameter in cm of the crystal and X is the nominal length in cm. Additionally there are the abrieviations "T" for tapered, "S" for straight and "BC" for back-catcher. In figure 1 some of the options studied are presented. Other variants included a 477T BC and a 458S DC.

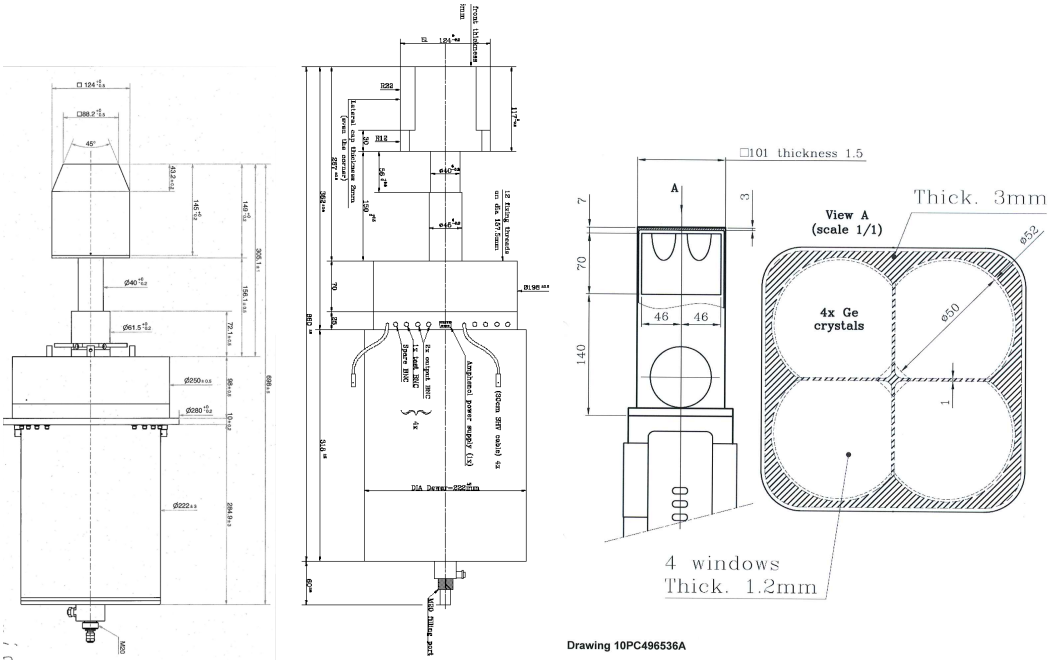


Figure 1: Schematic diagrams of some of the germanium detecors investigated. From left to right: a 469T BC (EXOGAM), a 466S BC, and a 457S.

3 Geant4 simulations

For the initial simulations a comparison of the absolute efficiency of the specific detector types is all that is required. Therefore an extended source (75 mm in diameter) placed 20 mm away from the end cap of the detector was used to approximately simulate the ditribution of the nuclei of interest implanted in the DSSD at the focal plane of SHELS. For each gamma-ray energy simulated 1x10^6 gamma rays were emitted into 4π and the energy deposited in each crystal on an even-by-event basis was recorded. In figure 2 are shown the absolute detection efficiencies as a function of incident gamma-ray energy for some of the detector variants studied. As to be expected - the detector with the largest cross-section has the highest low energy efficiency while the detector with the longest crystals has the largest efficiency for the higher energy gamma rays. Based on solely the absolute efficiency it would appear that the 466S would be the best choice. The cost of the detector is also a factor to consider and in the right hand panel of fig. 2 are shown the absolute efficiencies normalised by the cost of the detector. Using this metric the 457S looks very interesting. It should be noted that not only has the 469T the longest crstals but it is also segmented making it a very cost prohibative option for this particular physics case of decay spectroscopy.

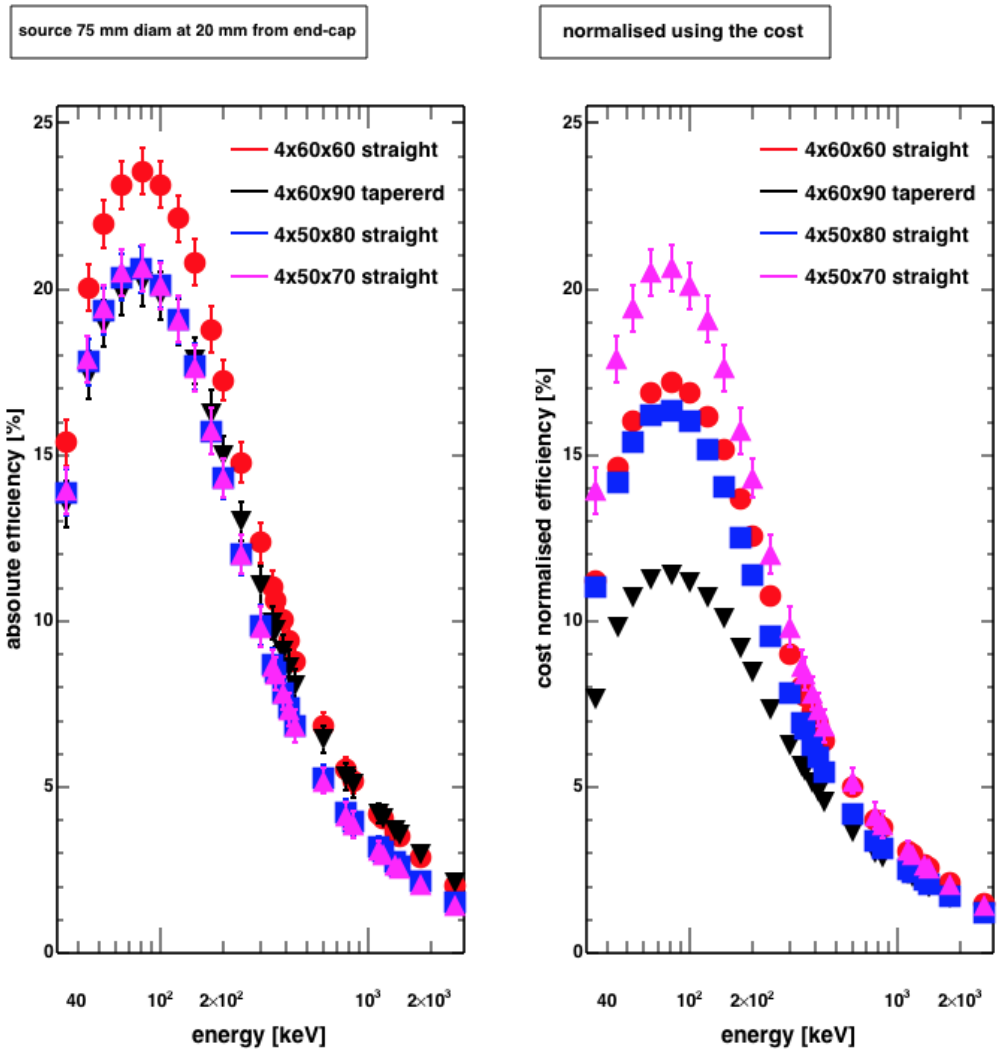
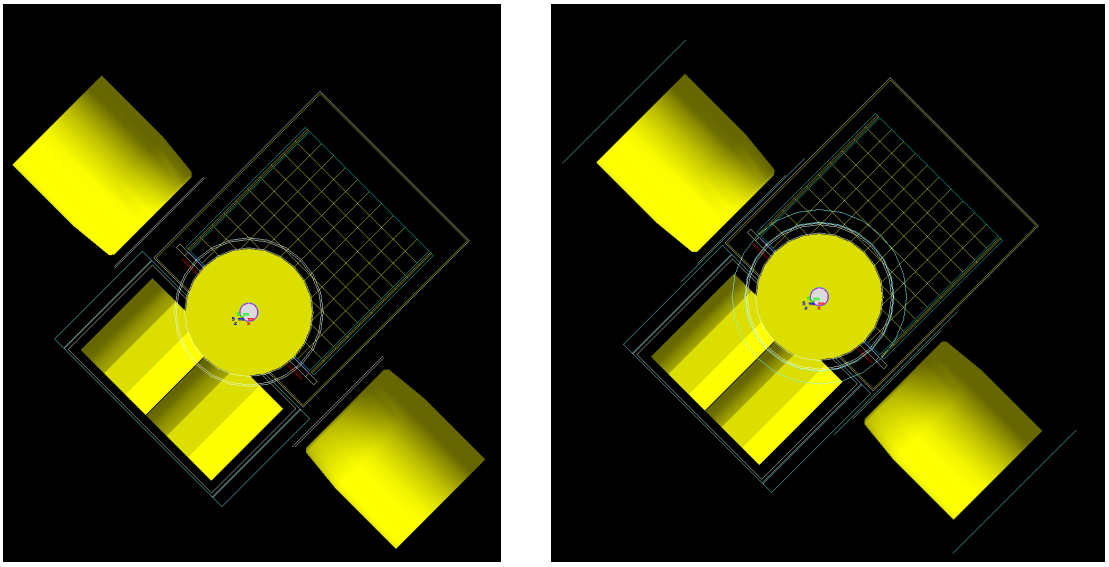


Figure 2: A comparison of the (left) absolute detection efficiencies and (right) cost-normalised absolute detection efficiencies for various clover detector geometries.

Another aspect that must be considered is how these specific clover detectors match and affect the overall geometry of the complete detection system. For example, the larger front face of the 466S (124x124 mm^2 □) compared to that of the 457S (101x101^2 □) would imply that germanium detectors placed orthogonal would be moved further apart. In order to investigate this a more complete geometry was constructed in Geant4, as shown in fig. 3, which includes one colinear clover, four single crystal detectors placed orthogonal to the clover and silicon detectors mounted on PCBs inside a vacuum chamber. The clover detector was placed 2 mm from the vacuum chamber. The upstream face of the VETO detector is 10 mm from the inside chamber wall and the distance between the VETO and the DSSD is 5 mm. The side detectors are of the same geometry as the detectors we have modified from the French-UK loan pool for use with GABRIELA[1] and are placed 2 mm from either the 466S or the vacuum chamber.



C466 + 4x'Shorty' C457 + 4x'Shorty'

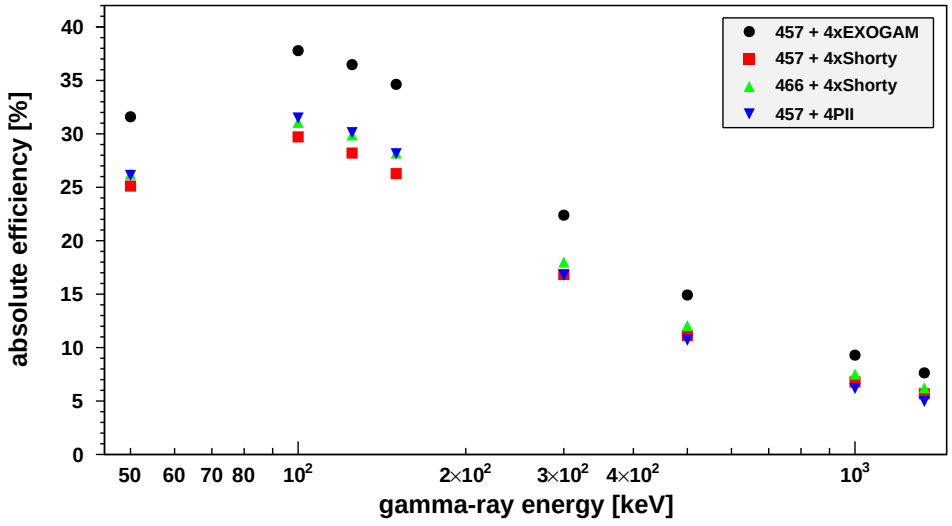


Figure 3: A comparison of the compact geometries possible with the (top-left) 466S and (top-right) 457S clover placed facing the DSSD. Bottom: absolute efficiency as a function of gamma-ray energy for various germanium detector combinations.

[1]since these detectors had a end-cap shortened in order to minimise the gap between the germanium crystal and the front-face of the end-cap they have been labeled "shorty"

To determine the absolute detection efficiency 1x10^6 gamma-rays were emitted into 4π from a Gaussian distribution with σ_x=σ_y=25 mm centred at x=y=0 mm on the upstream face of the DSSD. In addition to the two geometries discussed above the 457S was also simulated with four EUROGAM Phase-II clovers (PII) and four 469T clovers (EXOGAM). The efficiency curves for these four simulated set-ups are show in the bottom panel of fig. 3. From this plot it is immediately apparent that the total efficiency of the 466S+4xShorty and the 457S+4xShorty configurations are essentially identical: i.e. the gain in efficiency of the 466S compared to the 457S is compensated by the loss in efficiency of side detectors. It is also worth noting that using four EUROGAM Phase-II clovers does not significantly increase the detection efficiency.

4 Conclusion

Based on these Geant4 simulations the already existing 457S appears to be the optimal solution for CLODETTE with regards to absolute detection efficiency, cost and simplicity. To improve the quality of the measured gama-ray spectra BGO shields are needed. Therefore additional simulations are required to find the optimal compromise between detection efficiency (most compact geometry) and peak-to-total (thicker, longer and costlier BGO shields).

References

[1] S.Agostinelli et. al., Nucl. Instr. and Meth., **A506** 250 (2003).

[2] G. Duchêne et. al., Nucl. Instr. and Meth., **A432** 90 (1999).

[3] K. Hauschild et. al., Nucl. Instr. and Meth., **A560** 388 (2006).