Preliminary simulations for the focal plane detection system of S3

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November 5, 2008

In this report preliminary Geant4 simulations for the focal plane detection system of S^3 using standard, off-the-shelf, germanium and silicon detectors are described and results for various proposed schemes are given.

1 Si detectors

1.1 Implantation detector

These preliminary simulations are based around using a 100×100 mm^2 double sided Silicon 128–strip detector of 300 μm thickness which is currently available from Micron. This detector is mounted on a 133×128 mm^2 board (apparently Micron is able to make these boards such that only two adjacent sides are significantly larger than the Si). The board is assumed to be 1.5 mm thick.

While the 100×100 mm^2 geometry does not quite match the 140×60 mm^2 focal plane from the ion-optics simulations of Manikonda et al, it is a simple starting point to get an idea of the γ–ray and conversion–electron efficiencies to be expected. Furthermore, for the case of the ^{292}116 ion-optics simulations a 100×100 mm^2 detector would result in a transmission efficiency of 48.7% (collecting 4 charge states) instead of 55.1% (5 charge states) for the 140×60 mm^2 detector. Additionally, for most spectroscopic runs a dispersive mass analysing mode is unnecessary. If there is no other mode of operation possible the effect of an asymmetric focal plane on the $\gamma-$ray detection efficiency needs to be investigated.

1.2 Veto detector

A veto detector of the same size has been placed 10 mm downstream from the implantation detector. This gap is a guestimate, but the fact that the support boards can be made with the connectors on two adjacent sides should allow the two detectors to be reasonably close. There is an additional 10 mm gap between the Veto support board and the vacuum chamber back-plate.

1.3 Si tunnel

Four 1 mm thick Si detectors of 100 mm width perpendicular to the beam axis and varying length along the beam axis have been simulated. The support board has also been assumed to be 1.5 mm thick, but, unlike the implant and veto boards, it has not been simulated with a central hole. The support board extends 20 mm upstream of the tunnel as an indication of the position of a support/cooling frame.

2 Ge detectors

Simulations have been performed with standard Ge detectors : Eurogam Phase-I's, a Phase-I detector modified by the GABRIELA collaboration, EXOGAM clovers and larger clovers similar in size to those at GREAT. This conservative approach has been taken for two reasons :

- Simplicity : these detectors are well known and do not complicate commissioning of S^3
- Cost : until money is actually allocated for a focal plane using existing detectors is the only option

3 Visualisation

Figure 1 shows a representation of these focal plane detectors using Geant4. In the left panel, the central dark blue object is the implantation detector, which is surrounded by the blue coloured silicon tunnel. The beige objects are the support boards for the silicon tunnel, implant and veto detectors. In this example a ring of ten Phase-I Ge detectors (yellow) has been placed around the vacuum chamber. The panel on the right of Figure 1 shows the same detector system, but this time looking along the beam-line axis directly at the implantation detector giving an indication of the space available either side of the support boards for cables, support frame, cooling lines etc. The inner radius of the vacuum chamber (coloured grey) is 103 mm and has a thickness of 2 mm. The ten Phase-I's are also visible : the germanium crystal is yellow and the end-cap is grey. (The green lines by the end-cap indicate the vacuum.) At this distance it would not be possible to use the BGO shields, nor would it be possible to use passive shielding.

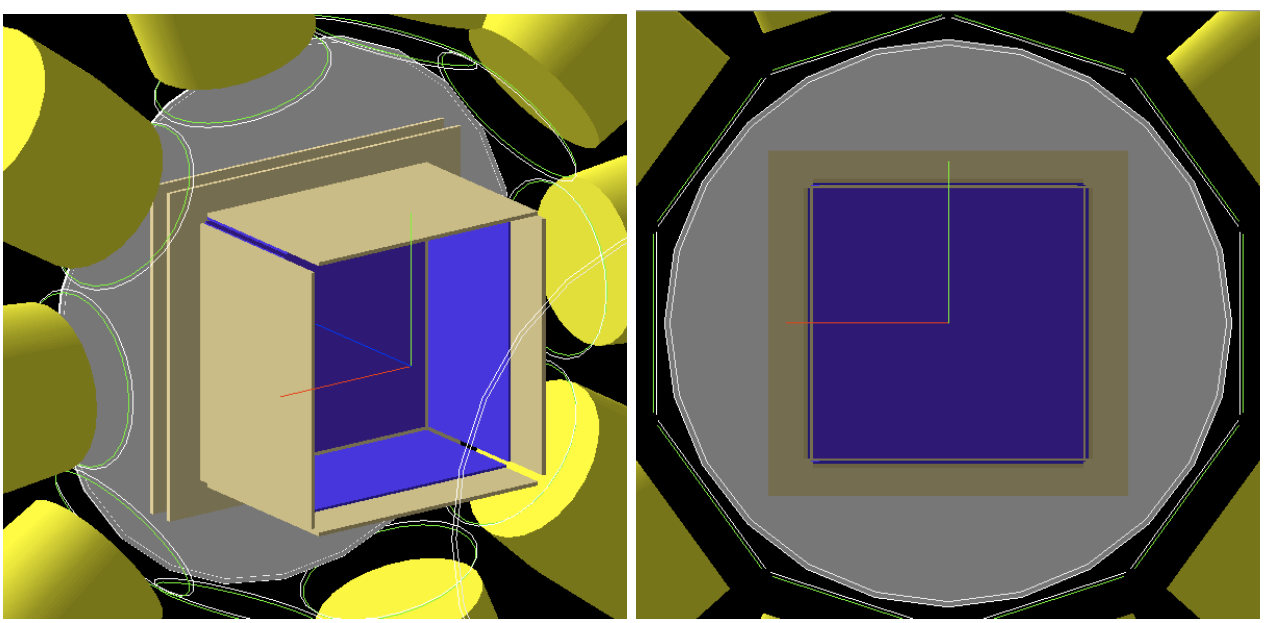

Figure 1: Geant4 view of a simple S^3 focal plane. The viewpoint is from up-stream.

In Figure 2 side views are shown with a modified (GABRIELA) Phase-I detector (left), an EXOGAM clover with 60 mm diameter by 70 mm long crystals (middle) and an EXOGAM detector scaled to a GREAT-like 70 mm diameter but keeping the length 70 mm (right) positioned axially aligned with the beam-line. The relative dimensions and distances from the Ge end-cap, chamber back-plate, veto detector and implantation detector can easily be compared.

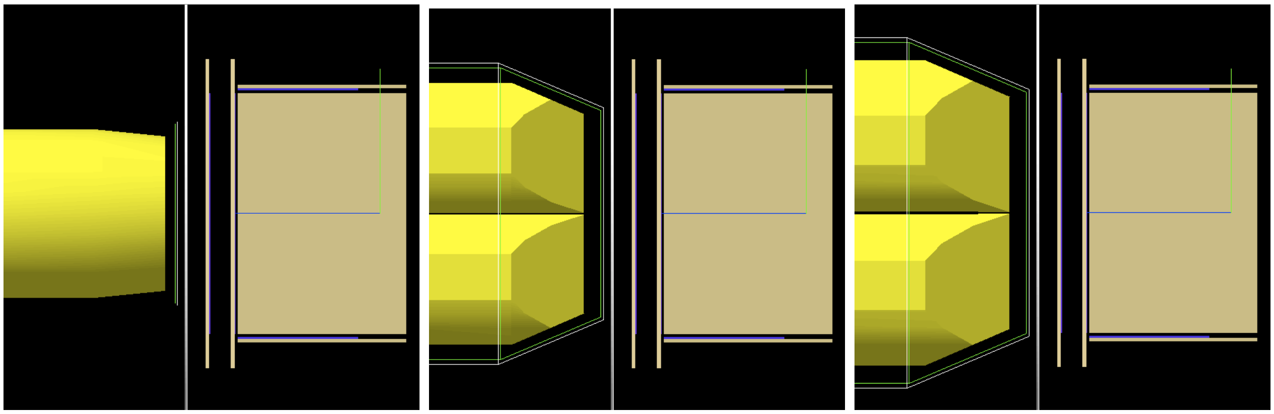

Figure 2: A comparison of a modified Phase-I (left), EXOGAM (middle) and GREAT-like Clover in close geometry to the focal plane Si detectors.

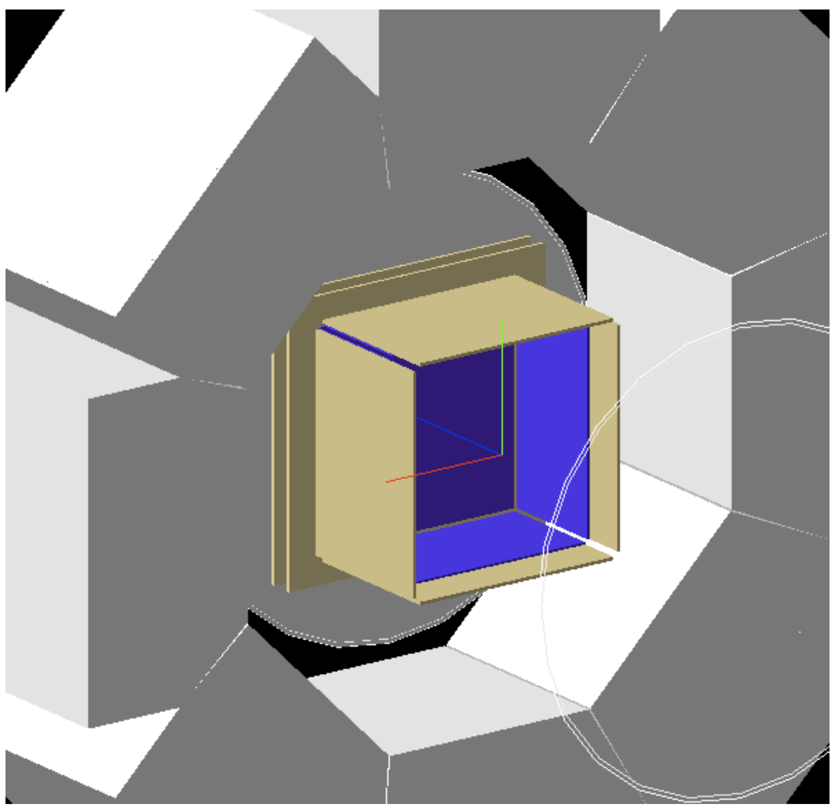

Figure 3: The “If I were a rich man” all Clover array.

4 Results

The simulated singles conversion–electron and gamma–ray detection efficiency using various detector arrangements are given in the following section. The electrons and gamma–rays were emitted from a distribution of points on the implantation detector using a recoil distribution calculated by Andrey Popeko for $^{22}Ne(E_{1/2} = 115$ MeV) on $^{238}U(0.2mg/cm^2$ U in $U_3O_8) \rightarrow {}^{255}No+5n$ transmitted through the upgraded VASSILISSA : a 2D gaussian distribution with $\sigma_x = \sigma_y = 46$ mm. For a specialised S^3 solution recoil distributions for S^3 are needed.

4.1 Conversion electrons

Simulations were performed with tunnel detectors of varying lengths along the beam-line axis. The width remained constant at 100 mm and thickness was 1 mm. Waely asked me to make an unrealistically long detector just to see what the asymptotic efficiency is. The results are shown in Fig. 4 for a 150–keV electron.

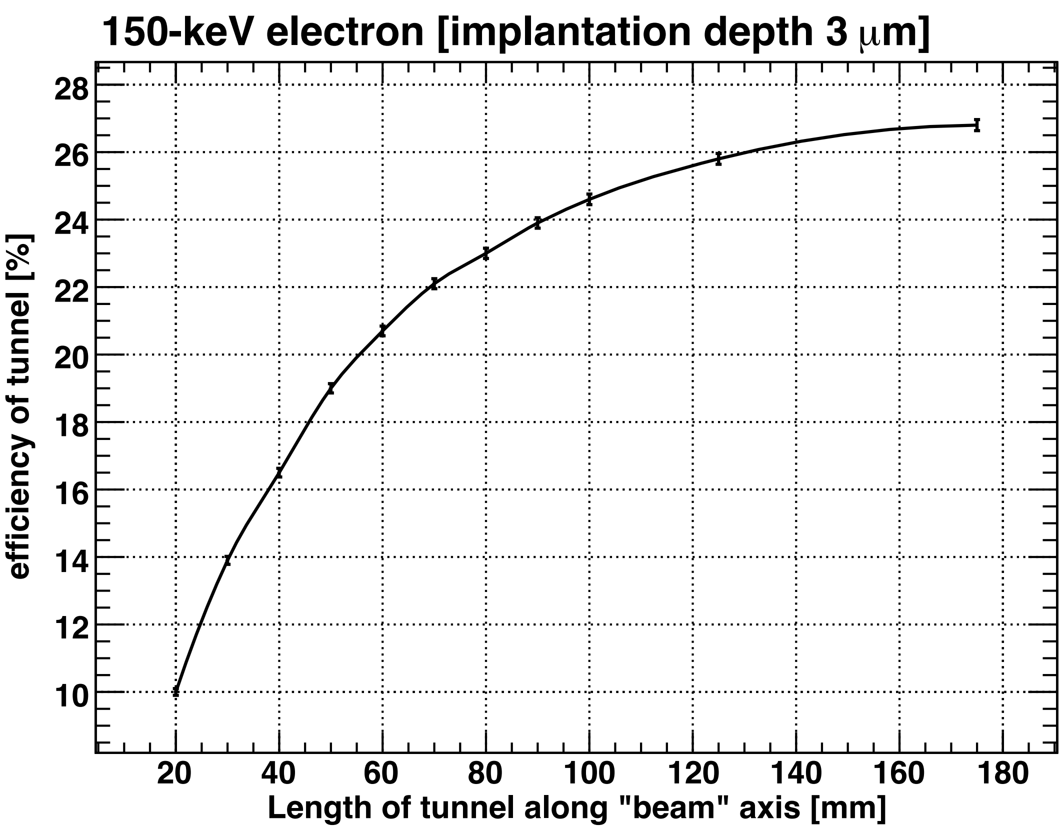

Figure 4: Simulated 150–keV electron detection efficiency for the tunnel as a function of tunnel length.

4.2 Gamma-rays : Phase-I's only

Ten standard Phase-I Eurogam detectors were placed in a ring around the implantation detector at a radius of ∼110 mm. A modified (shortened end-cap) Phase-I was placed 2 mm from the focal plane vacuum chamber back-plate axially aligned with the beam-line. The simulated γ–ray efficiency curve is given in Fig. 5.

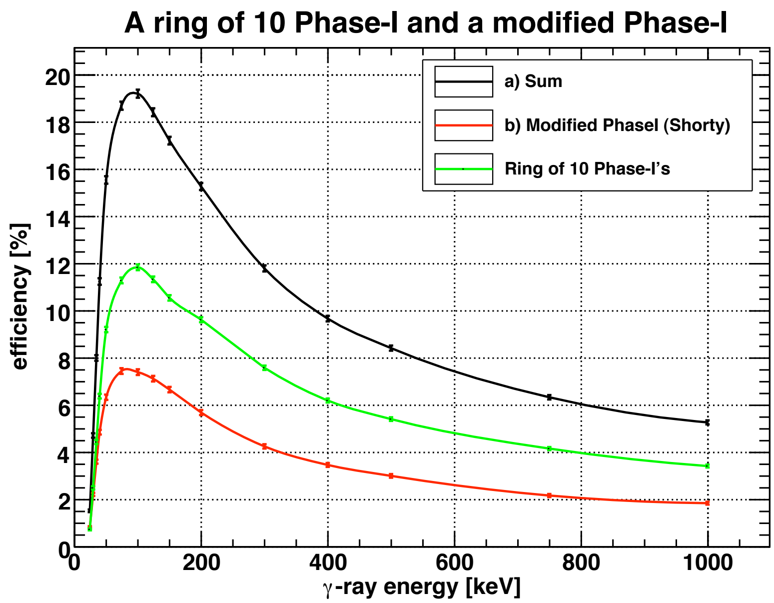

Figure 5: Simulated γ–ray singles detection efficiency for a Phase-I Ge array.

4.3 Gamma-rays : EXOGAM clovers

As above, but with 8 EXOGAM clovers (60 mm diam. crystals) in a ring (also at ∼110 mm) and a ninth EXOGAM clover facing upstream. The simulated γ–ray efficiency curve is given in Fig. 6.

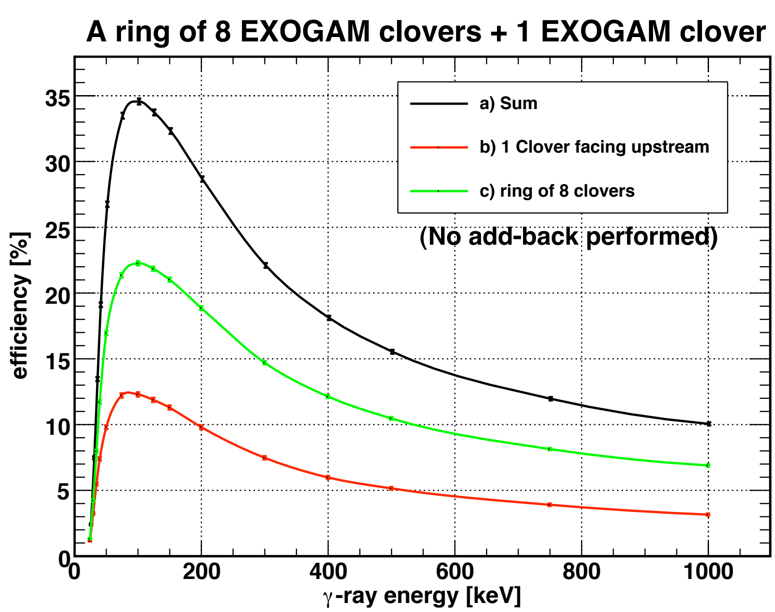

Figure 6: Simulated γ–ray singles detection efficiency for an EXOGAM clover array.

4.4 Gamma-rays : modified EXOGAM clovers

As above, but with 8 modified EXOGAM clovers (70 mm diam. crystals) in a ring (∼125 mm) and a ninth modified EXOGAM clover facing upstream. The simulated γ–ray efficiency curve is given in Fig. 7.

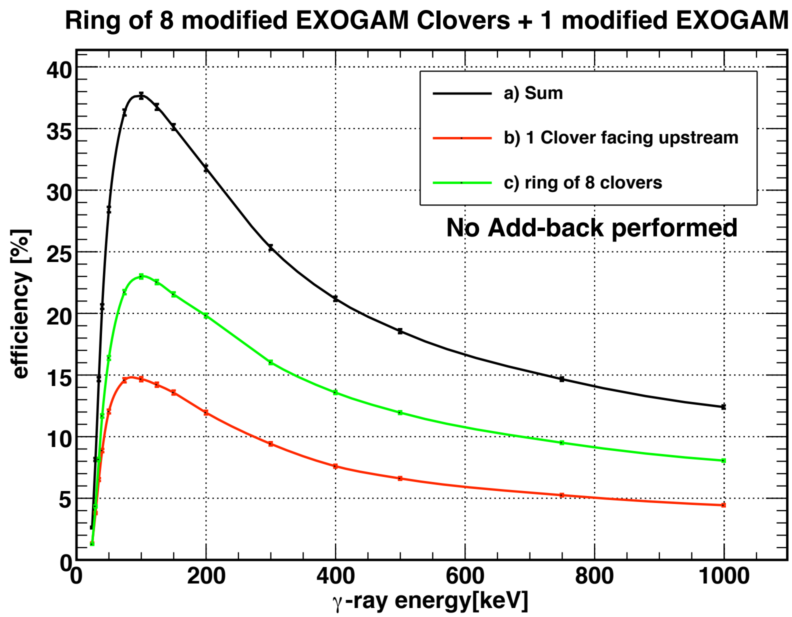

Figure 7: Simulated γ–ray singles detection efficiency for a modified EXOGAM clover array.

5 Comments

- With the recoil distribution used little conversion electron detection efficiency is gained by having a tunnel ≥80 mm.
- Even an array of tried, trusted, but aging Phase-I detectors provides a reasonably efficient fall-back option.
- Adding a modified (larger) EXOGAM clover in the up-stream position would increase the overall efficiency by ∼50% in relative terms.
- A close packed ring of 8 EXOGAM detectors provides the same efficiency as the modified (larger diameter crystal) EXOGAM detectors which have to be pushed further back (provides more space).
  - A ring of 8 clovers is almost twice as efficient as a ring of 10 phase-I's. Therefore a relative increase of ∼35% in efficiency would occur if the larger Clover+Phase-I ring array was replaced by the larger Clover+Clover ring.

6 Additional information

- Chamber back-plate thickness = 1 mm
- **NO** add-back has been performed for the clover detectors. It's use must be on a case-by-case basis.