R&D on novel Ge-detector geometries for ultimate position resolution and efficiency

Semiplanar Detector Studies

I. Kojouharov, GSI, Darmstadt

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DESPEC Phases and expected performance

Property	RISING	Phase I	Phase II	Phase III
Array type	Composite Ge detector array	Composite Ge detector array	Phase I complem. by γ-tracking dets.	γ-imaging array
Energy range (keV)	50-5000	50-5000	50-5000	50-5000
Noise threshold (keV)	24	15	15	**10**
Energy resolution (at 1.3 MeV)	2.3 keV	2.3 keV	2.3 keV	**2.0 keV**
Full energy γ-detection efficiency (at 1 MeV)	16%	16%	18%	**>20%**
Effective full energy efficiency after prompt flash blinding	13.9%	14%	16%	**>20%**
P/T-value	34%	34%	40%	**>50%**
Time resolution (at 1.3 MeV)	13 ns	10 ns	10 ns	< 10 ns
Overload recovery time	≤ 1ms	100 ns/MeV	100 ns/MeV	100 ns/MeV
Relative background suppression	1	5	10	**100**
Coverable implantation area	16 x 8 cm^2	24 x 8 cm^2	24 x 8 cm^2	24 x 8 cm^2
Max. acceptable event rate (kHz)	3.5	10	10	10

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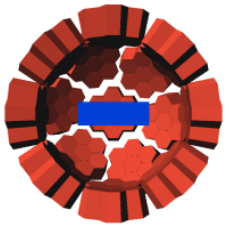
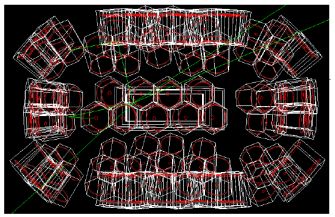
Setup limitations

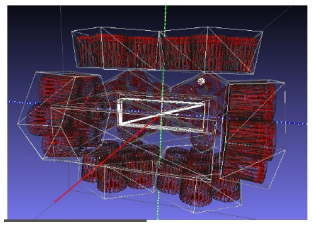
DESPEC-1 setup definition. Based on EB encapsulated HPGe crystals detectors.



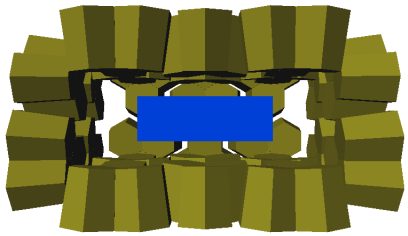
Half sphere
EB Clusters based

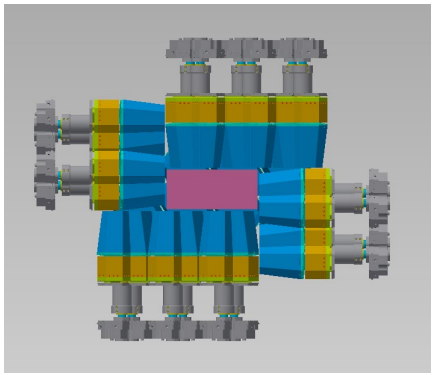


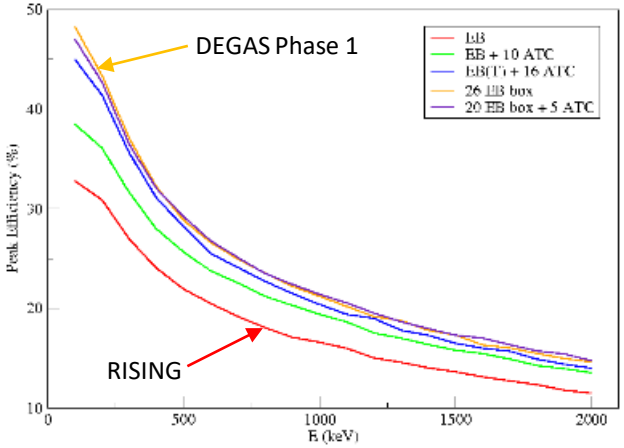
Shell
Triples based



Box
Triples based







The GEANT4 simulations have shown a substantial improvement of the efficiency when a box geometry adopted.

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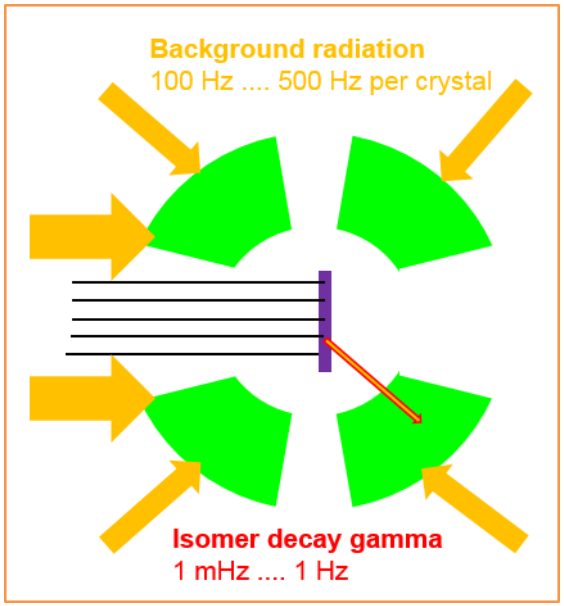
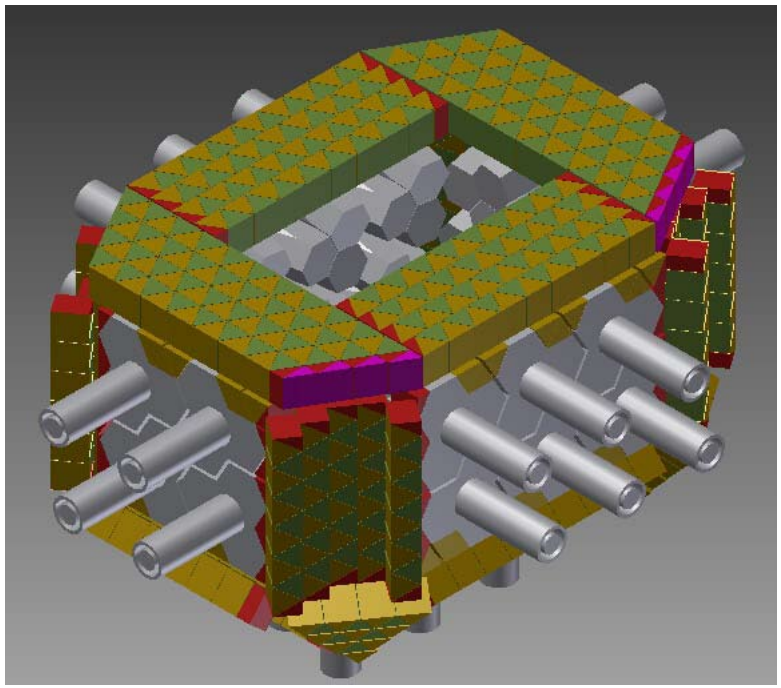
Setup limitations

The background problem



Side shielding fills up the gaps outside the DEGAS detectors and is based on passive-active elements. The element is comprised by 50 mm long CsI scintillator read out by SiPM and is protected for the outward radiation by 6 mm Densimet plate…

Side shielding



G.Li, GSI, 2016

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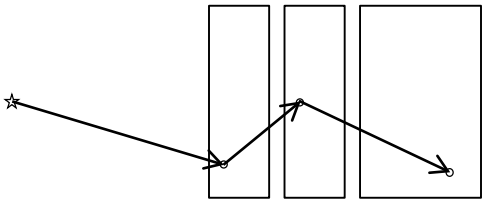
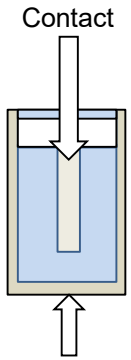
Setup limitations

The segmented planar detectors possess:
- Better position resolution
- Higher granularity

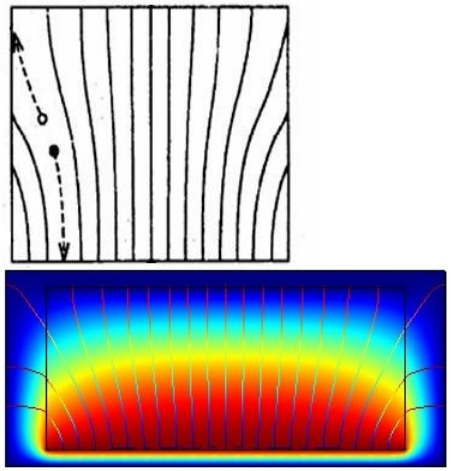
…
- Low efficiency limited by:
  - The thickness of the crystal => stack of detectors
  - Vast constructive dead space => new geometries
  - The Field Defect => new crystal structure



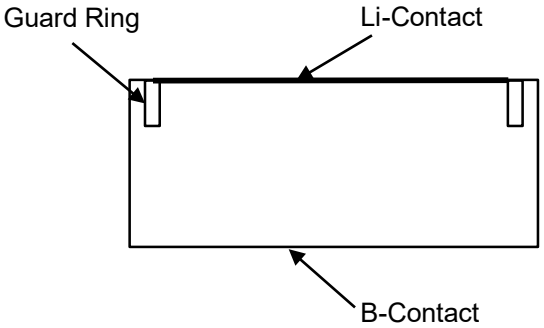
$$d = \left(\frac{2\varepsilon V}{\rho}\right)^{1/2}$$

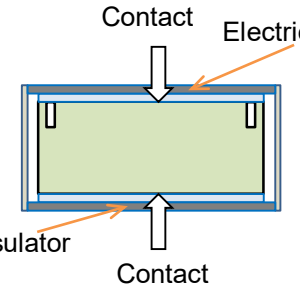


Coaxial crystal assembly



Enclosure effects on the internal field distribution in HPGe planar detector. *I.Kojouharov, J.Gerl, J.Kojouharova, NSS conference record, 206, IEEE*





Planar crystal assembly

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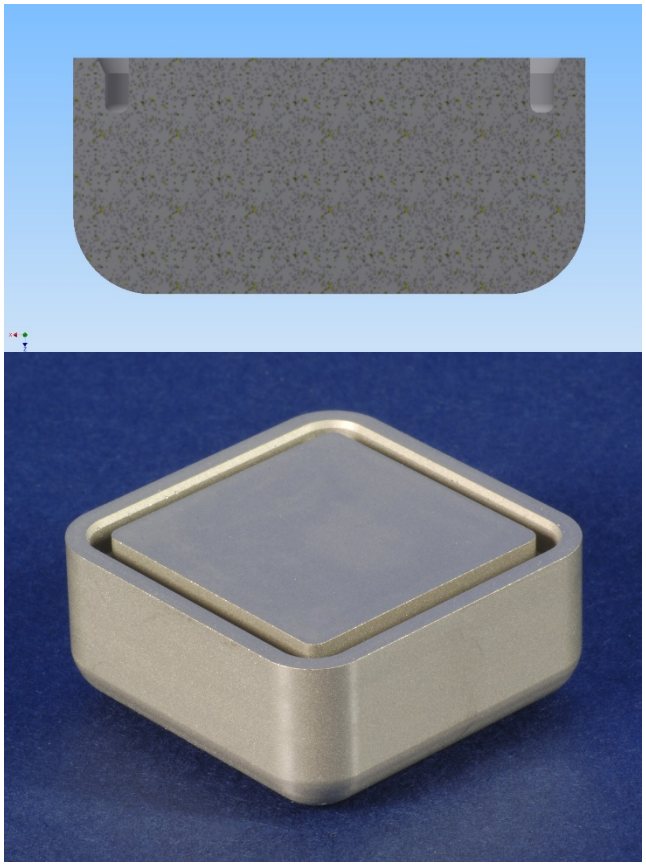
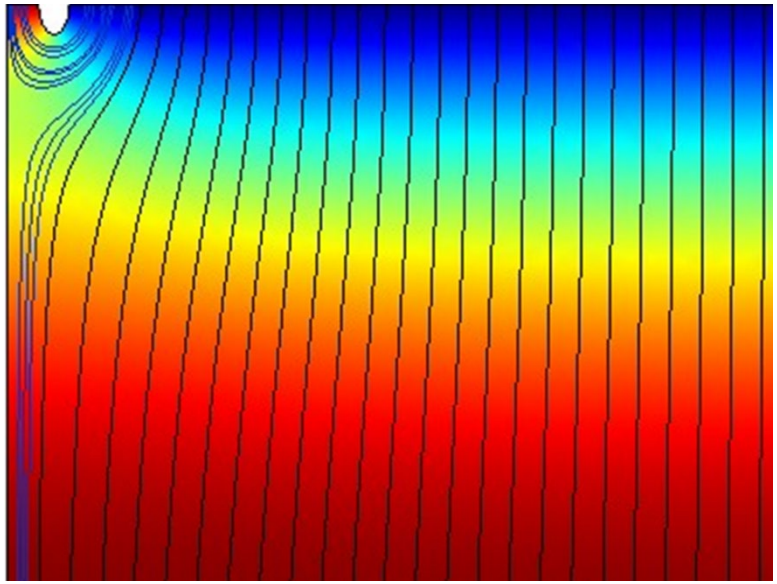
Setup limitations

The semiplanar detector - detailed





The semiplanar detector offers the advantages of the planar detector and the assembly convenience of the coaxial detectors:

- Minimized Field Defect
- Possibility for segmentation in any way similar to the planar one – pixel, strip, point contact
- Possibility for encapsulation
- Compact assembly

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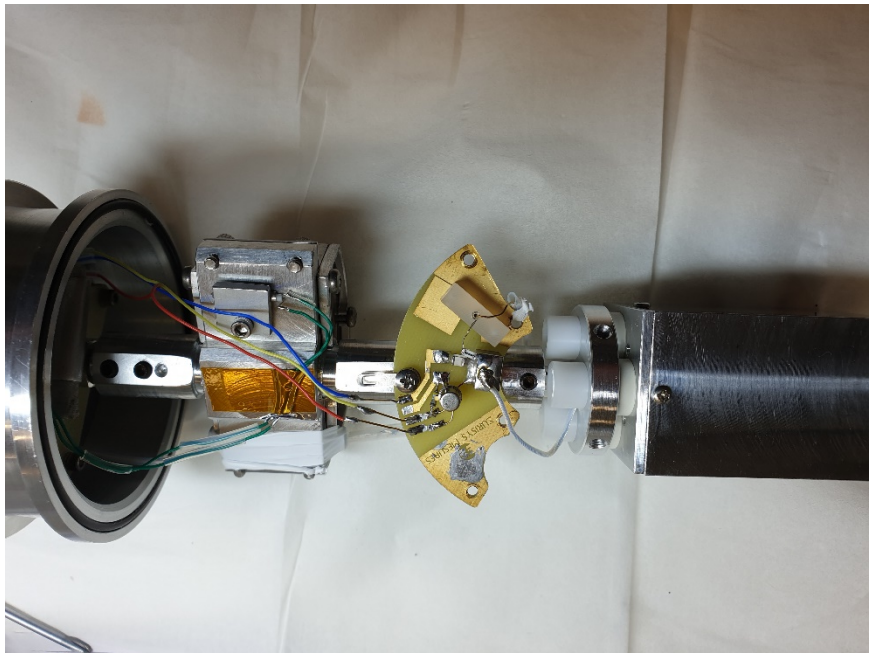
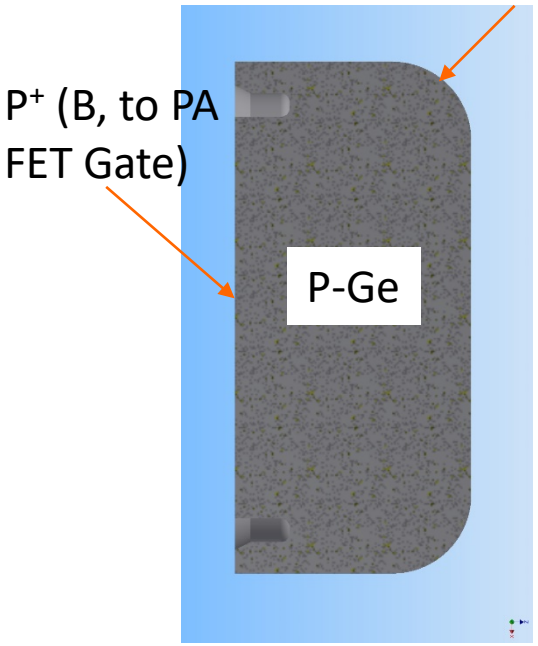
Detector studies





The detector assembly. The cold board is from EB capsules PA

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The following questions are to be cleared:

- Do we have substantially small Field Defect (FD) with the proposed geometry?

- Do we have substantially different pulse shapes from the middle and periphery?

- Do we have a reliable technology for contacting, segmentation and passivation?

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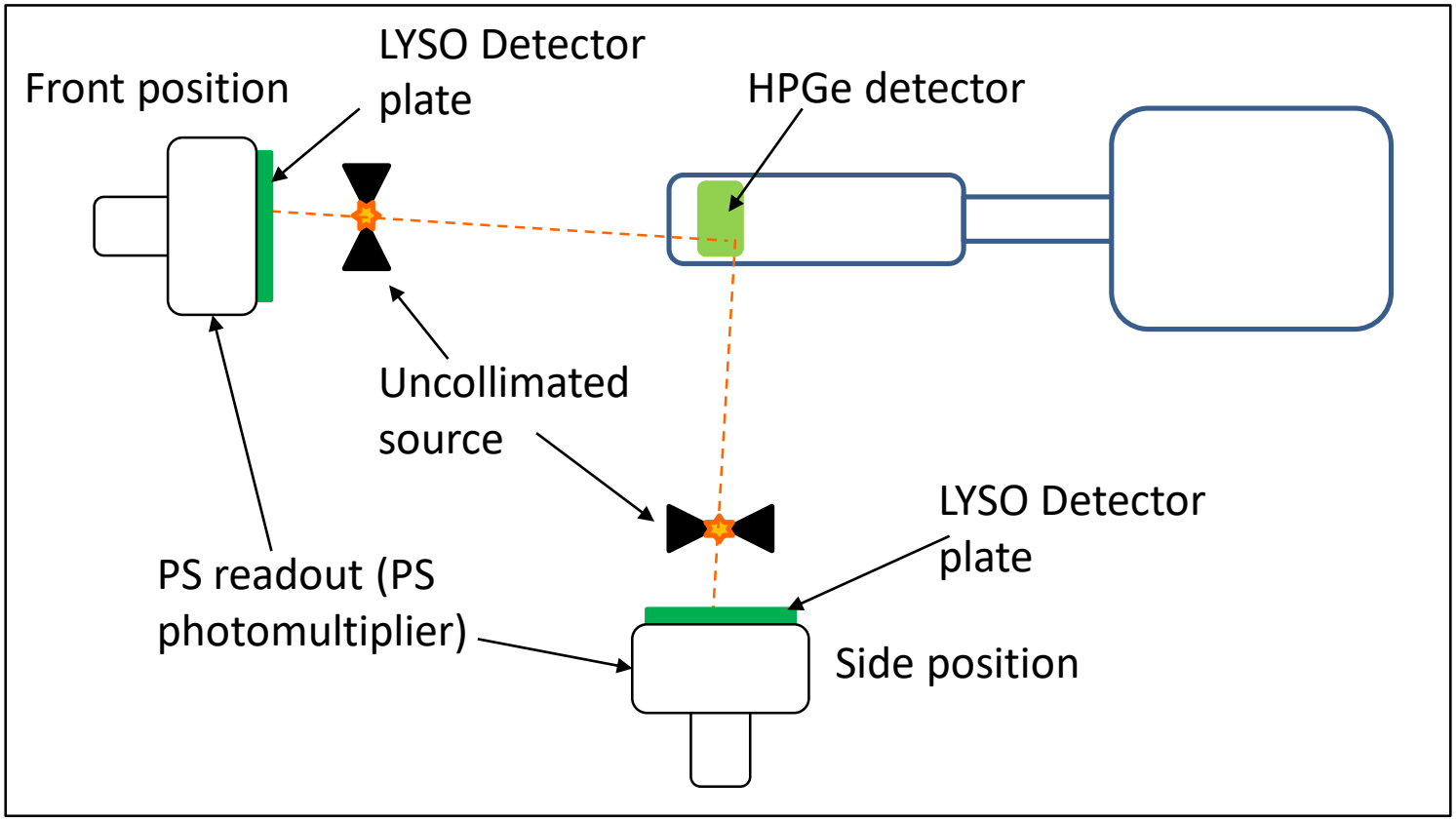
Detector studies

Probing of the position of the detector crystal, sizes, the depletion depth, the FD and the pulse shapes by the GSI scanning approach.



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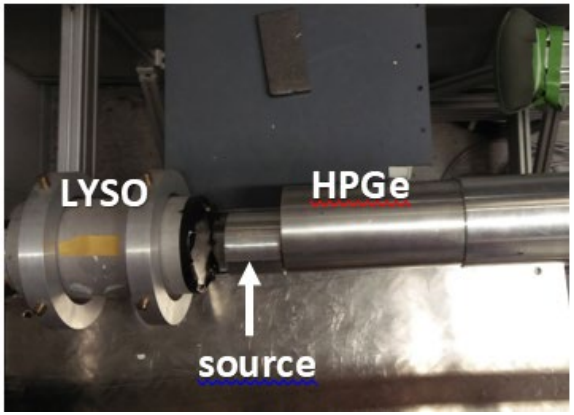
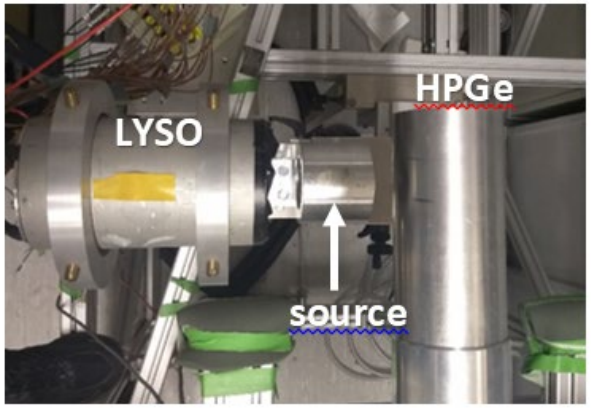
Detector studies





The experimental setup. The HPGe detector has been biased to 250 V, which is under the depletion voltage (approx,. 400 V), despite the AC-coupling of the preamplifier. High leak current does not allow successful work at higher HV. The shaping is kept at 3 µs.

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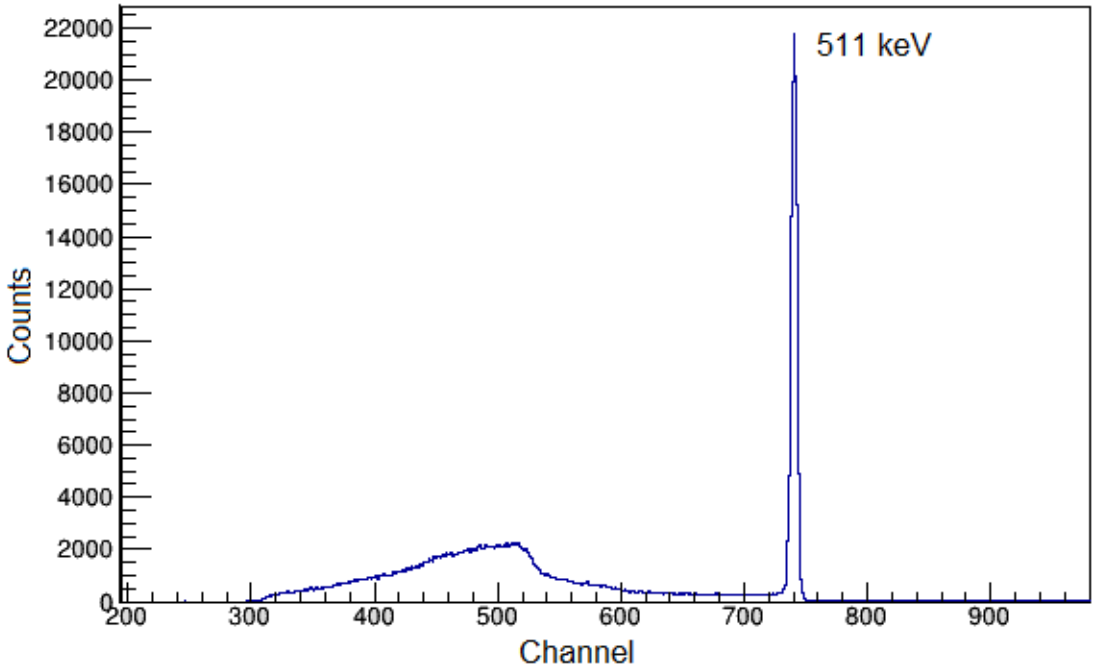

Germanium spectra in coincidence with the LYSO detector

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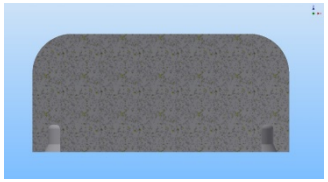

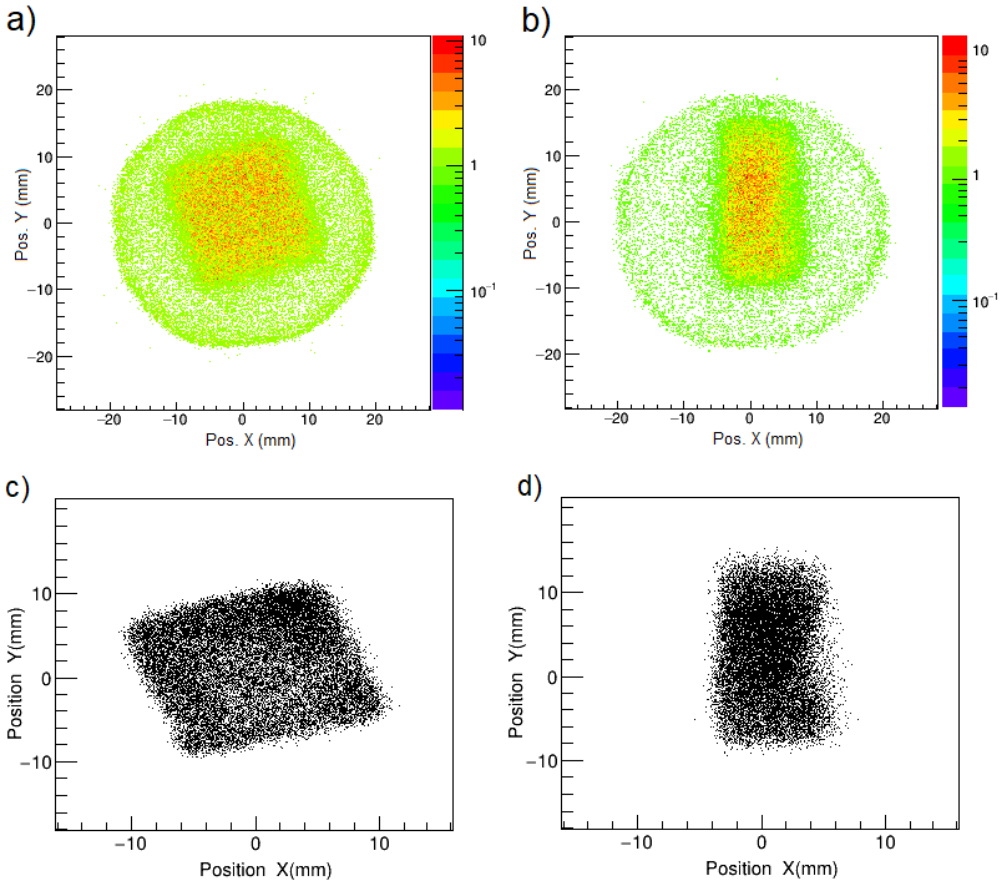

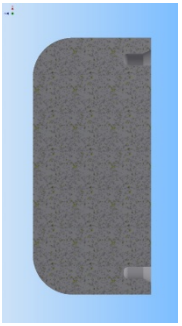

Images of the front a) and side b) view of the planar detector and the same images after background reduction for the front c) and the side d) view

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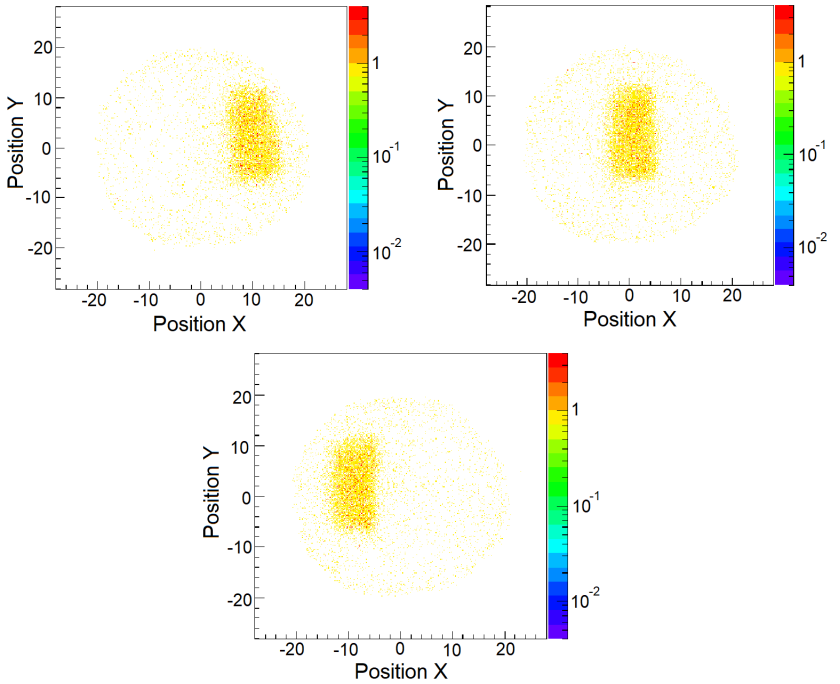

2D plots for lateral scanning of the germanium detector in steps of 1.5 cm used for space calibration. The rough estimation of the depleted thickness is approx. 10 mm, which corresponds to the calculated depletion depth. Based on the rather low position resolution (the gain matching was not sufficiently good) the FD cannot be determined. However, the rather regular shape of the image suggests that it must be small.

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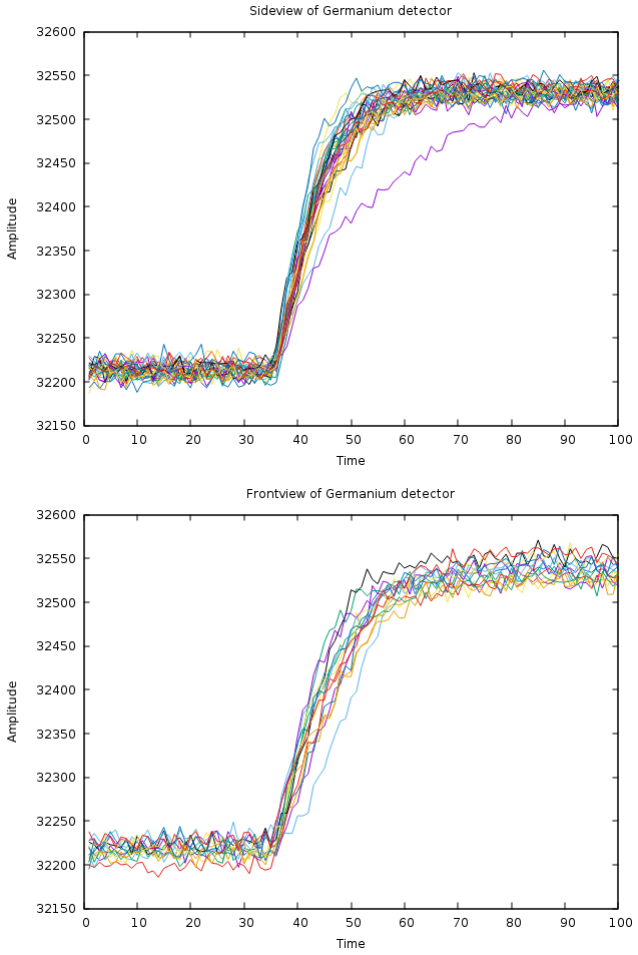

Pulse shapes sideview (upper) and frontview (lower).

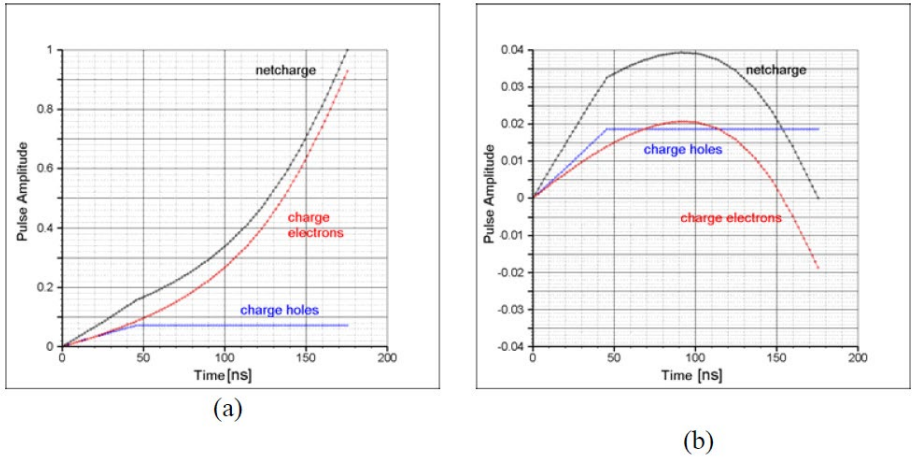

Fig. 5. Pulse shape: (a) net charge; (b) induced charge

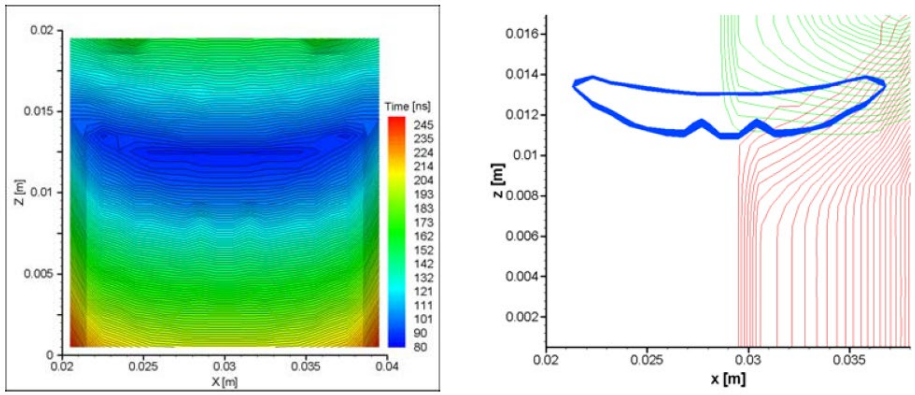

Fig. 6. Mapping plot: (a) T_{90} net charge; (b) T_{90} net charge band and amplitude ratio

Pulse shapes (upper)and T90 mapping (under) for 10 mm pixel size.

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Conclusive remarks

- The sizes of the active zone of the detector can be reliable measured, but requires a good position resolution of the scanner. The size and the depth of the FD should be scanned by 241-Am.
- The geometry most likely has to be slightly changed giving up the grove guard ring and leaving the open surface as a step. By this way the FD can be minimized, the reliability of the passivation enhanced and the active volume preserved.
- The evaluation of the wave forms acquired is still under processing, we hope even in underdepletted state to see significantly different wave forms from the various parts of the detector.
- The wave forms strongly depend on the preamplifier topology. It is a great field for optimization.
- The stability of α-Ge seems not sufficient. The detector did not have passivation of the open surface and after rebuilding exhibited higher leak current.
- Further investigations are to be done by reprocessing the contacts.

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Thank you