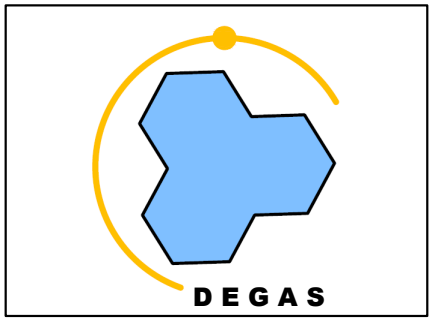


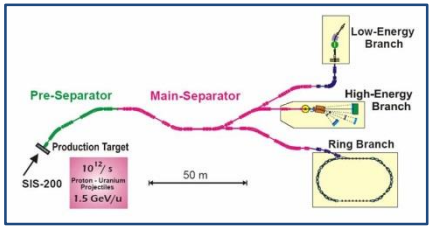
Ge-detector geometry with imaging capability for DEGAS

I. Kojouharov, GSI, Darmstadt

Ge-detector geometry with imaging capability for DEGAS

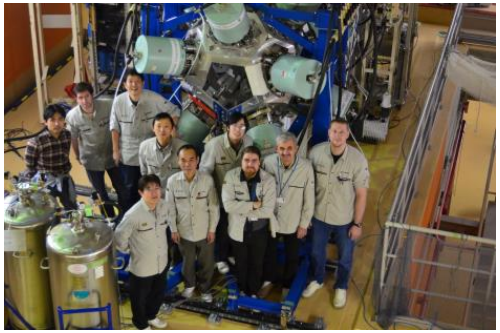
I. Kojouharov, *GSI, Darmstadt*

Super FRS

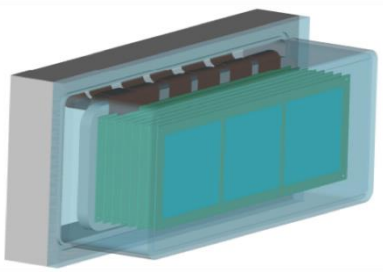


DESPEC (DEcay SPECtroscopy) project is aimed at experiments with exotic nuclei implanted in an active target (AIDA). The gamma spectroscopy based on HPGe detector is in the core of the project. The HPGe detector array is to operate at SFRS (FAIR). It follows the successful decay spectroscopy experiments of RISING (GSI) and EURICA (RIKEN).

RISING 2003 - 2009



EURICA 2012 - 2016



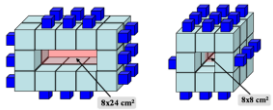
The model of the AIDA implantation detector with its Al housing as considered in the simulations

Ge-detector geometry with imaging capability for DEGAS

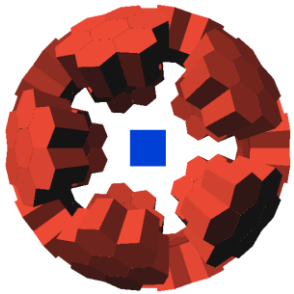
I. Kojouharov, *GSI, Darmstadt*

Extensive simulations have been done over the years in order to evaluate the efficiency and the overall performance of the HPGe detector array. Starting from a planar detector array…

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



The planar array (2004) and the peak efficiency (2008)

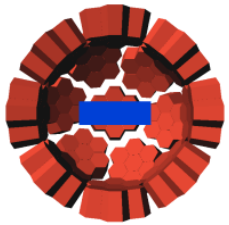


RISING “stopped beam” configuration coupled with the short AIDA implantation detector.

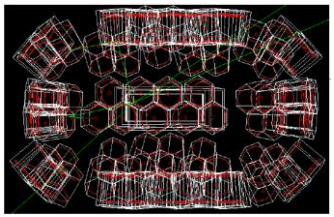
Ge-detector geometry with imaging capability for DEGAS

I. Kojouharov, *GSI, Darmstadt*

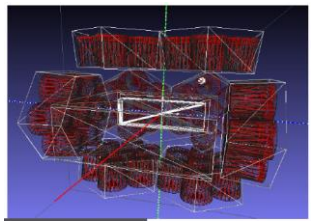
DESPEC-1 setup definition. Based on EB encapsulated HPGe crystals detectors.



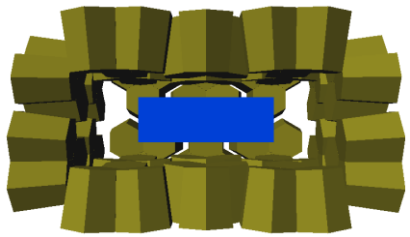
Half sphere
EB Clusters based

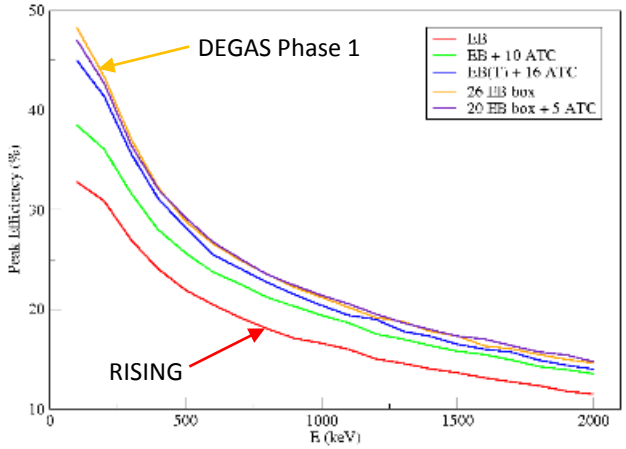


Shell
Triples based



Box
Triples based





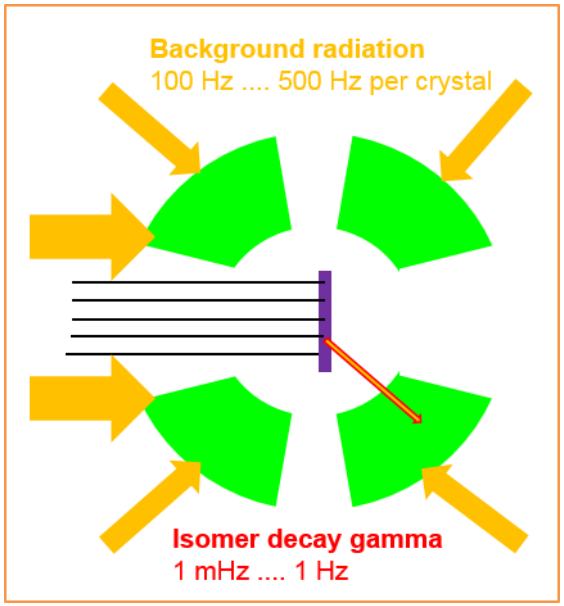
The GEANT4 simulations have shown a substantial improvement of the efficiency when a box geometry adopted.

Ge-detector geometry with imaging capability for DEGAS

I. Kojouharov, *GSI, Darmstadt*

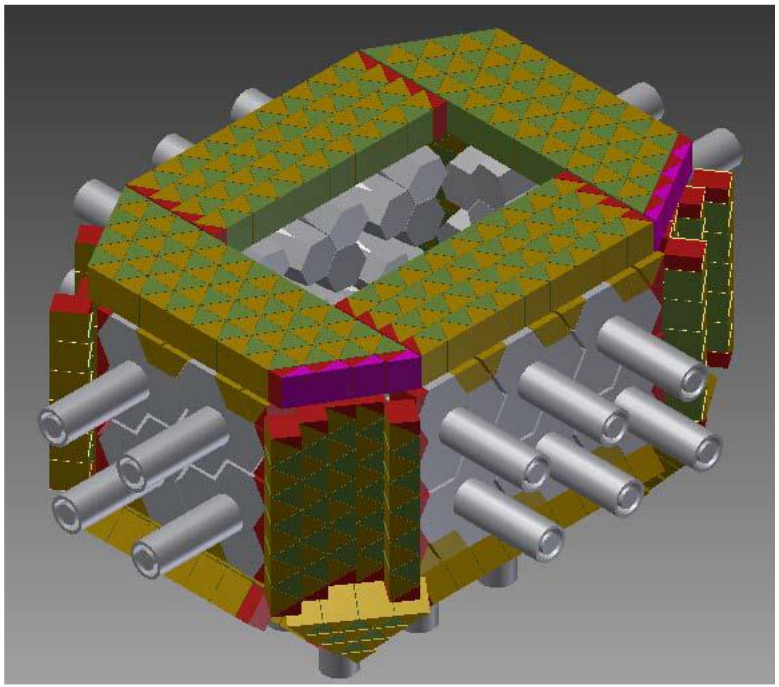
2. DESPEC setup

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



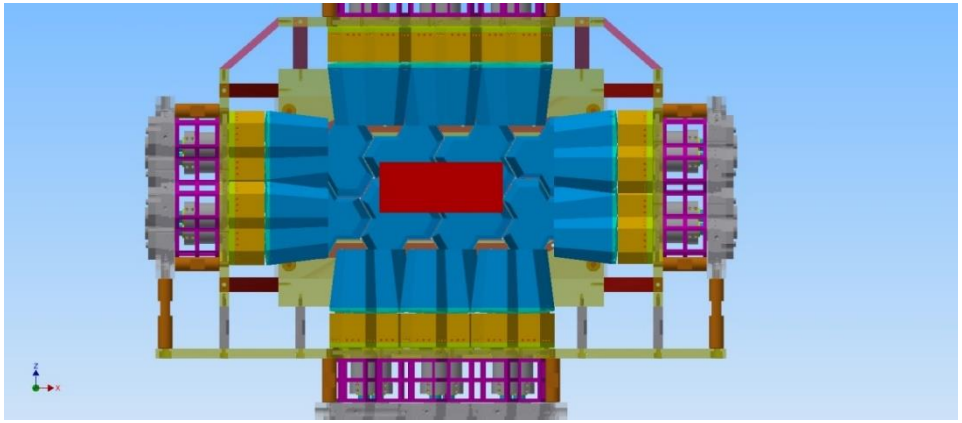
G.Li, GSI, 2016

Ge-detector geometry with imaging capability for DEGAS

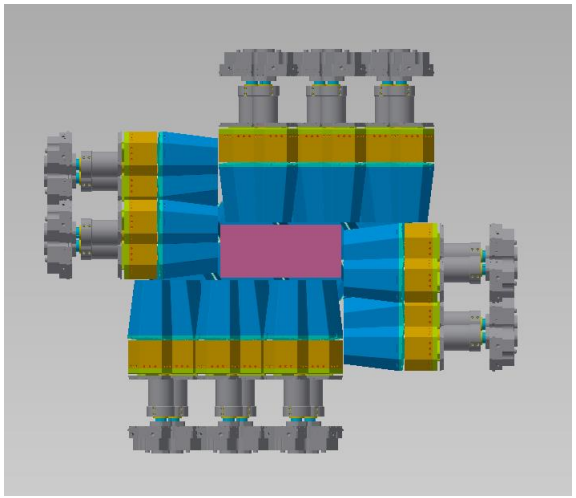
I. Kojouharov, *GSI, Darmstadt*

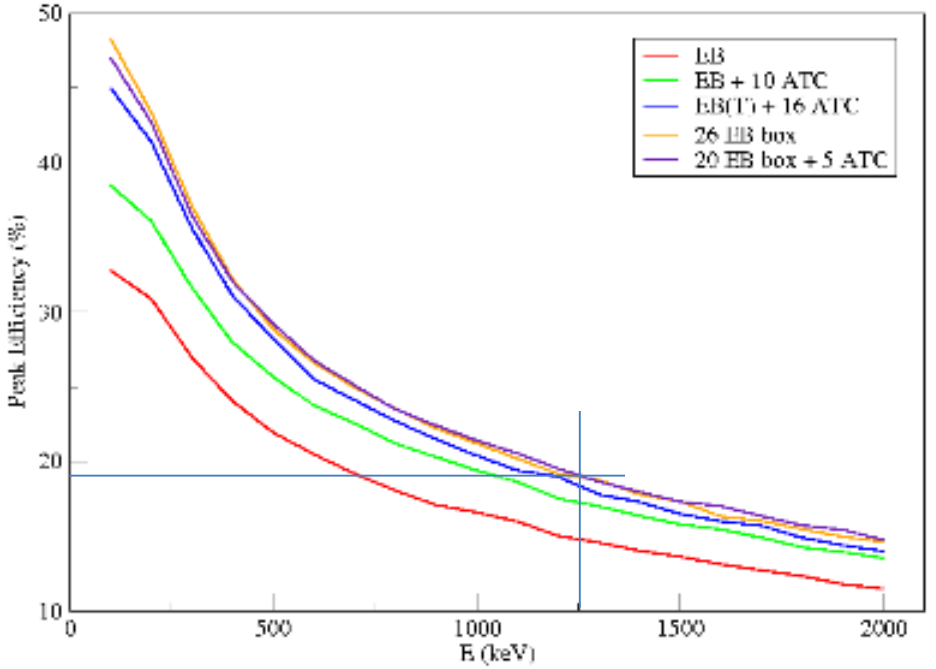
Can we increase further the efficiency:

"Box" geometry of the setup



"Box+" geometry





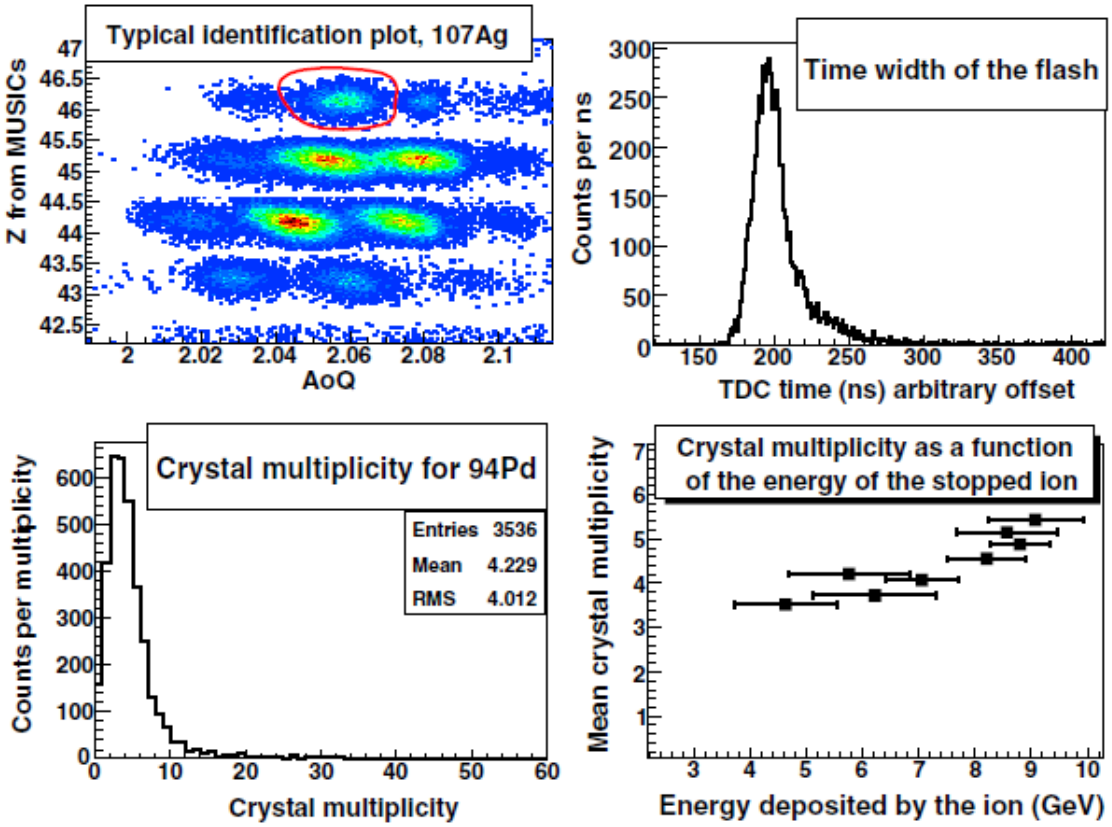
Transition from mirror symmetry to swirl symmetry increases the efficiency with some 25%.

- Less shielding in the corners
- Less veto
- More germanium

- … but stronger prompt flash effect.

Ge-detector geometry with imaging capability for DEGAS

I. Kojouharov, *GSI, Darmstadt*



Experimental details of the Stopped Beam RISING campaign., S. Pietri, P.H. Regan, Zs. Podolyak et al., *Eur. Phys. J. Special Topics 150, 319–320 (2007)*

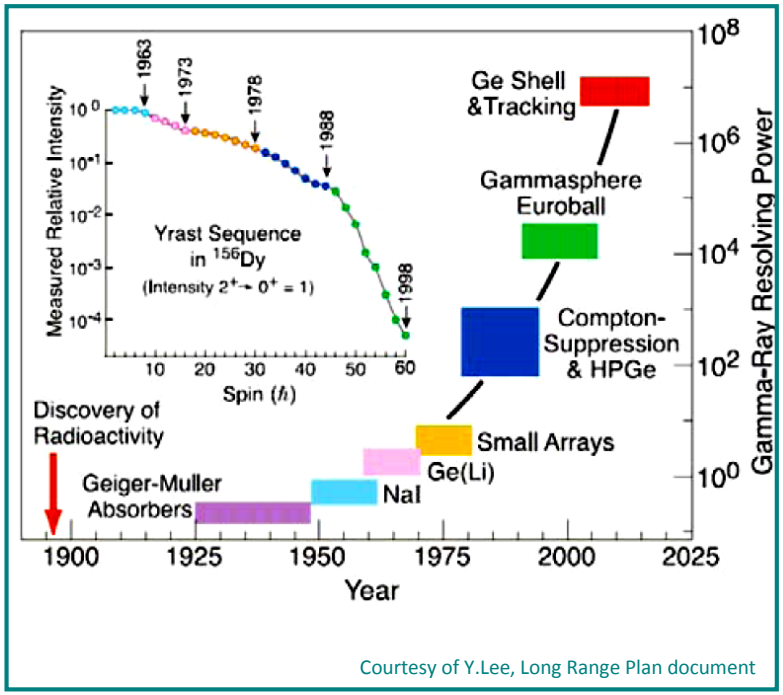
The Prompt Flash problem arises due to the:
- Atomic interaction with the target (active or passive) atoms
- Blinds for a certain time a number of detectors, thus reducing the efficiency

- The multiplicity of the photons and their energy depends on the energy of the implanted ions at the entrance surface of the target
- The duration of the Prompt Flash is some 100 ns.
- The saturation of the preamplifier may reach (upon the energy of the ions) 1 s.

To reduce the impact of the Prompt Flash:
- Fast reset preamplifiers – typically few µs blind time
- Apply absorbers – high multiplicity photons do have low energy
- DEGAS-3 based on segmented planars must perform outstandingly due to high granularity.

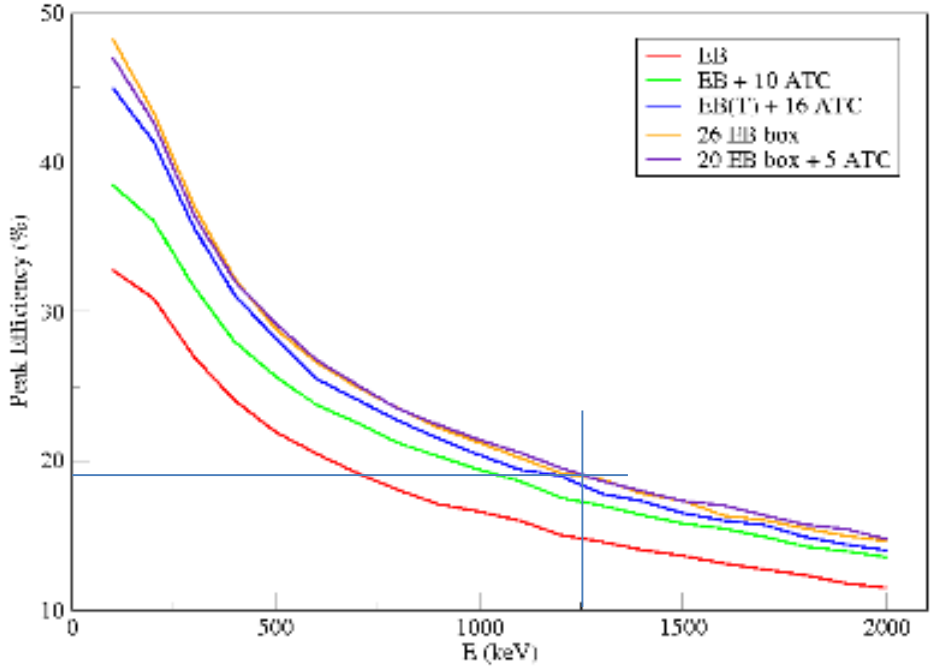
Ge-detector geometry with imaging capability for DEGAS

I. Kojouharov, *GSI, Darmstadt*



Courtesy of Y.Lee, Long Range Plan document

$R = 0.76(SE\gamma/\Delta E\gamma)PT$



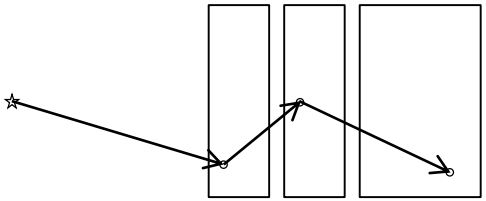
The efficiency of the array cannot be substantially increased. However, the quality of the spectrum must…

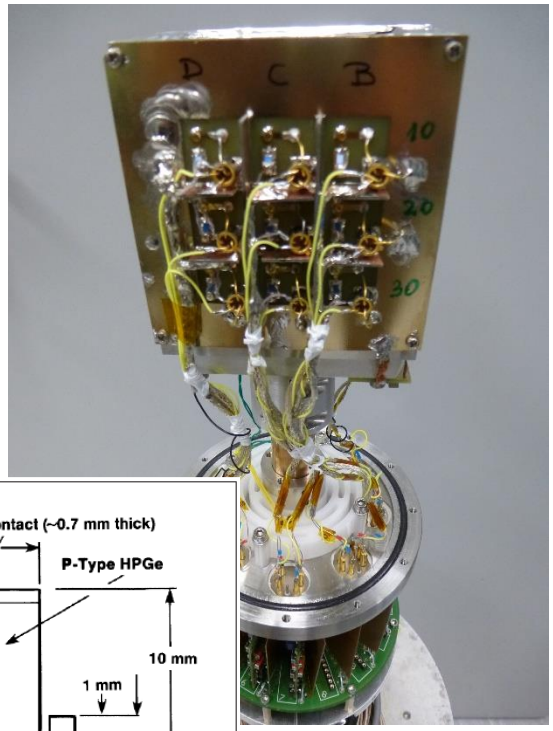
Ge-detector geometry with imaging capability for DEGAS

I. Kojouharov, *GSI, Darmstadt*

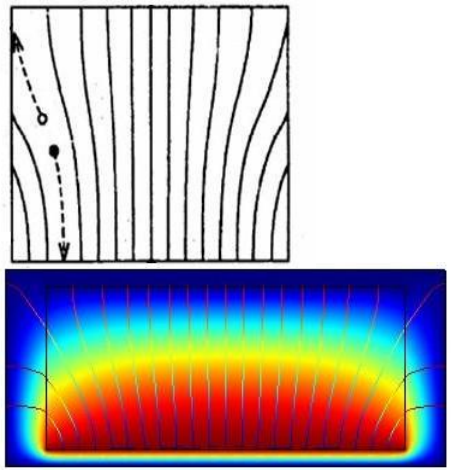
The segmented planar detectors possess:
- Better position resolution
- Higher granularity

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

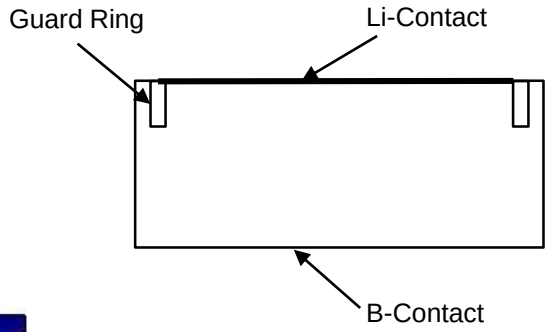


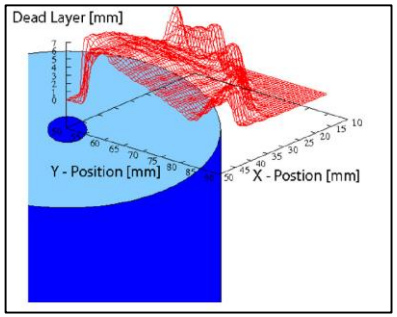


$$d = \left(\frac{2\varepsilon V}{\rho}\right)^{1/2}$$



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





Measured thickness of the dead layer caused by passivation of the intrinsic surface of an n-type HPGe detector. *J. Eberth, J. Simpson / Progress in Particle and Nuclear Physics 60 (2008) 283–337*

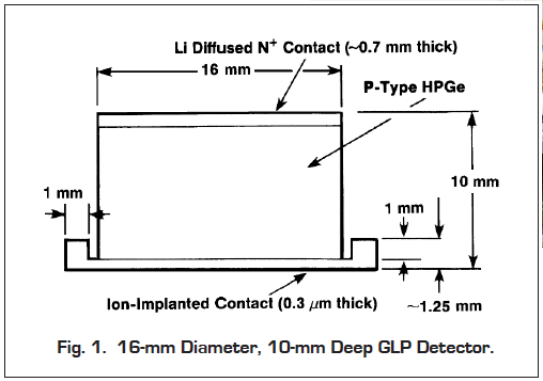
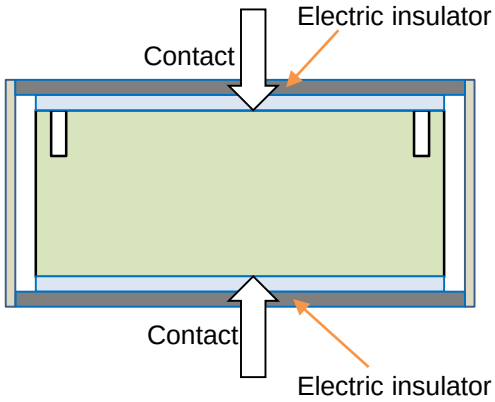


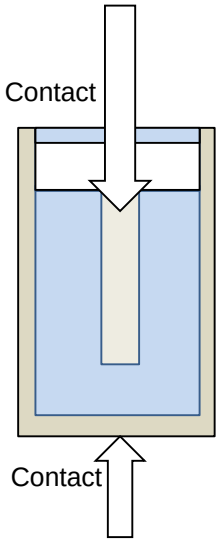
Fig. 1. 16-mm Diameter, 10-mm Deep GLP Detector.

Ge-detector geometry with imaging capability for DEGAS

I. Kojouharov, *GSI, Darmstadt*



Planar crystal assembly



Coaxial crystal assembly

Ge-detector geometry with imaging capability for DEGAS

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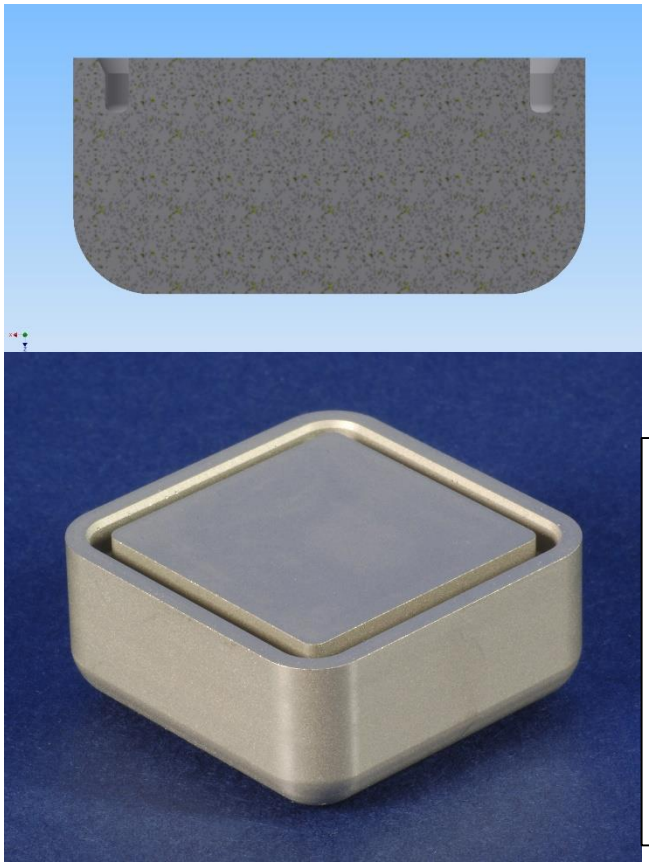
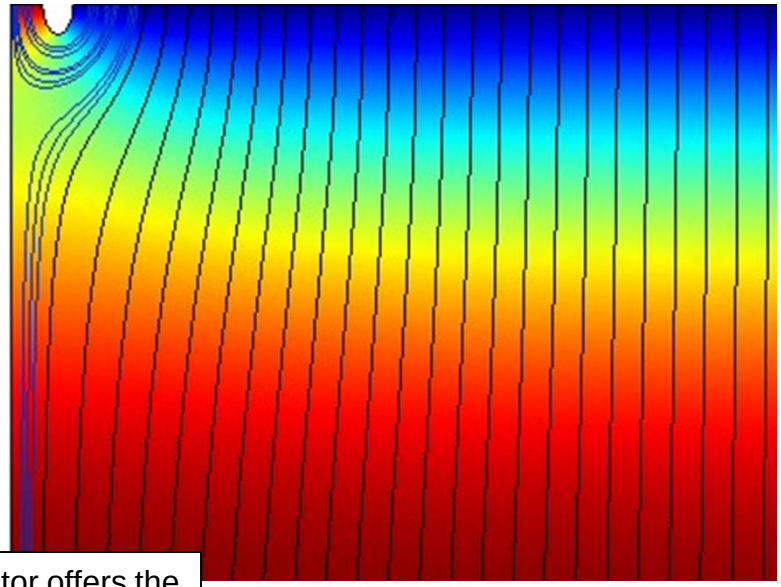
The semiplanar detector - detailed





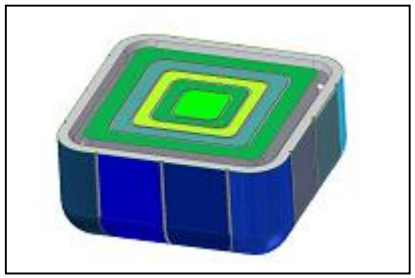
The semiplanar detector offers the advantages of the planar detector and the assembly convenience of the coaxial detectors:

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

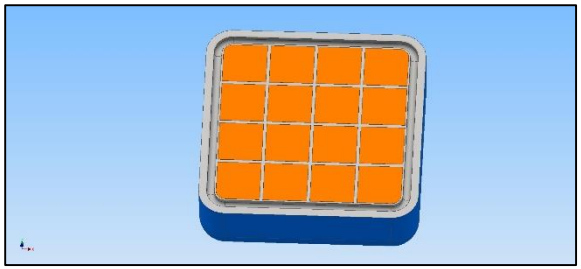
Ge-detector geometry with imaging capability for DEGAS

I. Kojouharov, *GSI, Darmstadt*

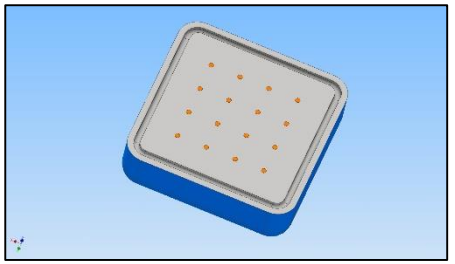
Segmentation modes of the semiplanar detector allow DSSD type, pixel type and small contact (in pixel or DSSD geometry) to be implemented



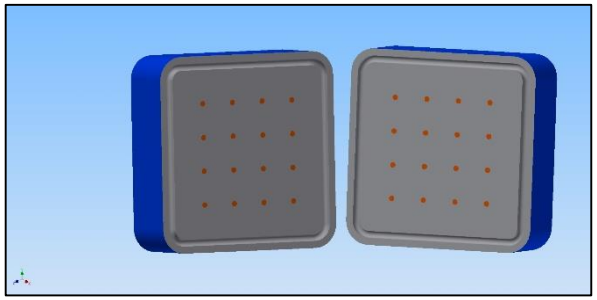
Concentric-angular DSSD



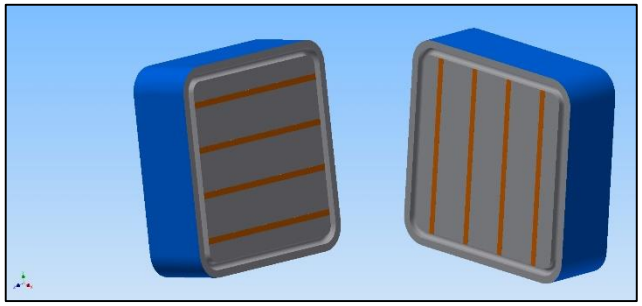
Pixelated



Small pixel contact



Double side small pixel



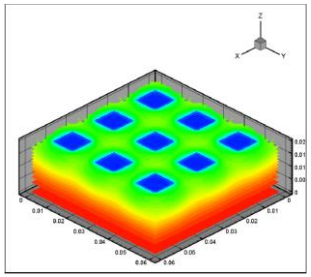
DSSD

All these modes of segmentation need a careful evaluation.

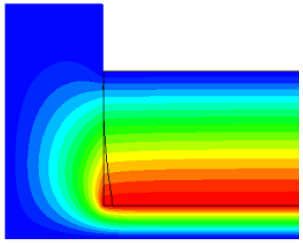
Ge-detector geometry with imaging capability for DEGAS

I. Kojouharov, *GSI, Darmstadt*

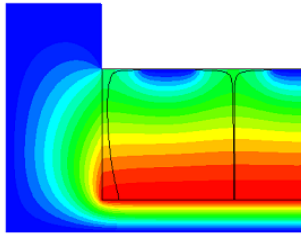
The electric field in the planar detector



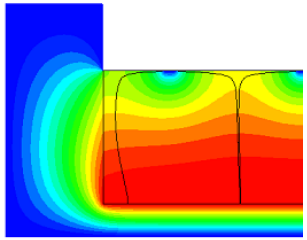
a)



b)



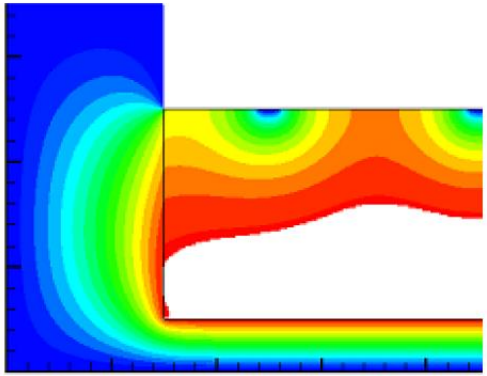
c)



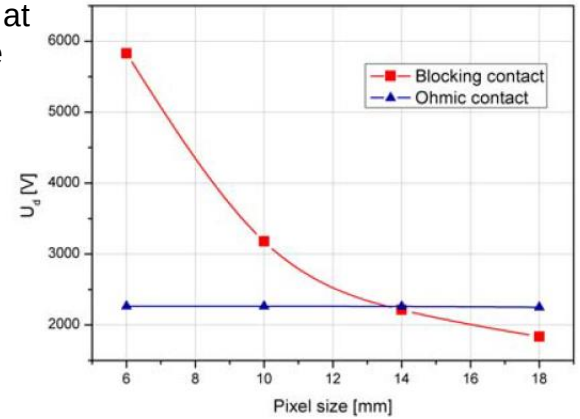
d)

Electric potential at applied voltage of 5000 V and a pixel size: (b) 20 mm; (c) 8 mm; (d) 2 mm. It is well distinguishable that a decrease of the pixel size tends to result in a distortion of the electric potential and thus better position resolution resulting in better imaging capability is anticipated.

Electric field of none fully depleted detector at pixel size of 2 mm and applied voltage of 3000 V.



Depletion voltage at different pixel size



Ge-detector geometry with imaging capability for DEGAS

I. Kojouharov, *GSI, Darmstadt*

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

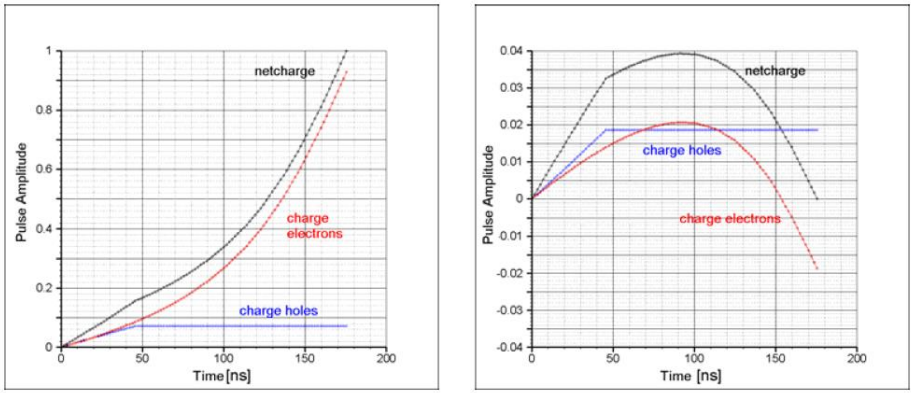


Fig. 5. Pulse shape: (a) net charge; (b) induced charge

The evaluation of 30 % of the rise time (T30) and 90 % of it (T90) respectively provides us with additional information and the position sensitivity might be enhanced. In our approach a mapping technique has been proposed. To that end T90 has been calculated and plotted over a midplane of the fired segment (s. Fig. 6 a). The typical rise time for the detector of interest reaches hundreds of ns and the measurements precision is within a range of 2 – 5 ns which assures 2-3 mm accuracy in z-direction. Accuracy in x-y play remains in order of the pixel size.

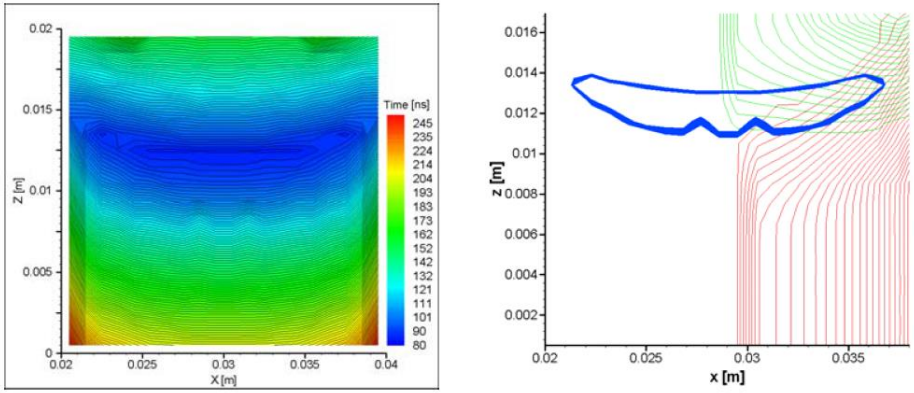


Fig. 6. Mapping plot: (a) T_{90} net charge; (b) T_{90} net charge band and amplitude ratio

Ge-detector geometry with imaging capability for DEGAS

I. Kojouharov, *GSI, Darmstadt*

Conclusion:

1. Planar or semiplanar detector with a specific guard ring geometry can reduce substantially the Field defect thus improving the efficiency.
2. This geometry is very beneficial for compact enclosure/encapsulation thus dramatically reducing the dead/empty/insensitive layers of the detector assembly.
3. A certain geometry of the contacts may enable a good position resolution combining the net charge and the induced charge signals.
4. A further analysis and experimental verification is needed to determine the optimal geometry of the detector.
5. Combining of two planar position highly sensitive detectors in a telescope configuration with coaxial crystal may substantially increase the efficiency and improve the quality of the spectrum. A Clover configuration is to be sought.

Thank you Jasmina and Samuel for the great job done for the simulation of the pixel detector charge collection and position resolution analysis.