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Position sensitivity of the proposed segmented germanium detectors for the DESPEC project

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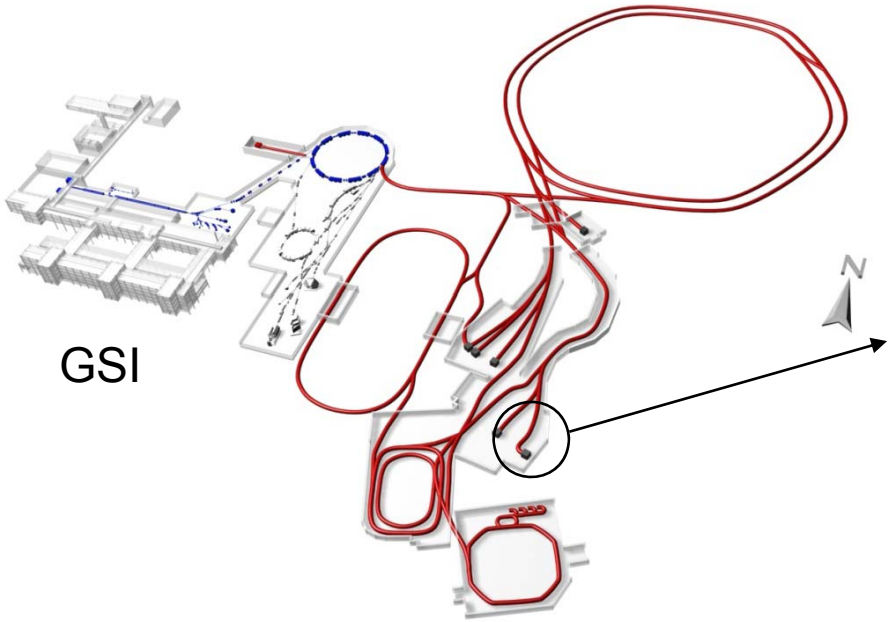
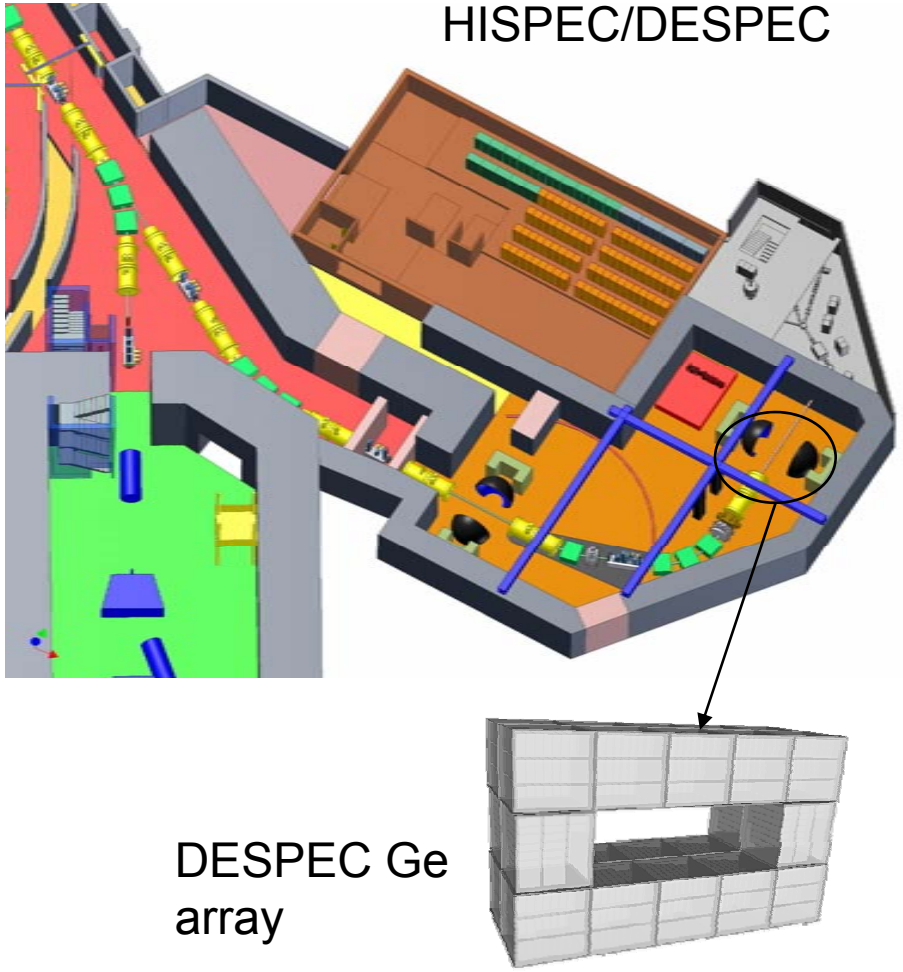
Glasgow, PSD8, 2008 09 02

DESPEC project at FAIR

Facility for Antiproton and Ion Research

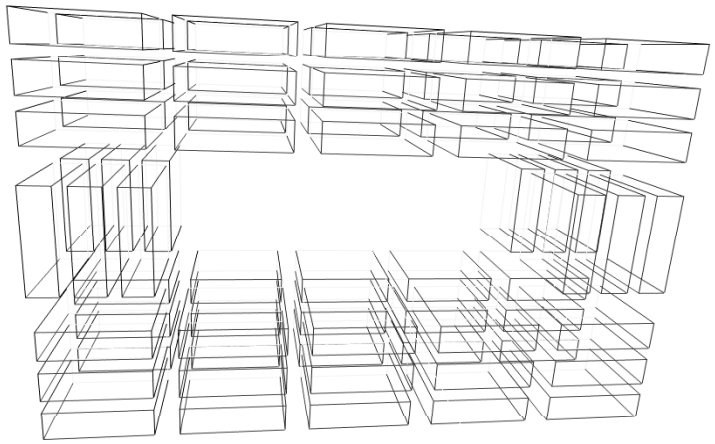


Low-energy branch of the SuperFRS

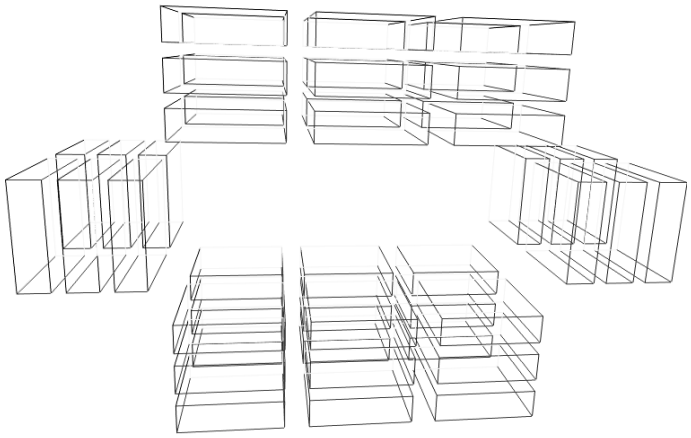


DESPEC Ge array

24 planar triple modules



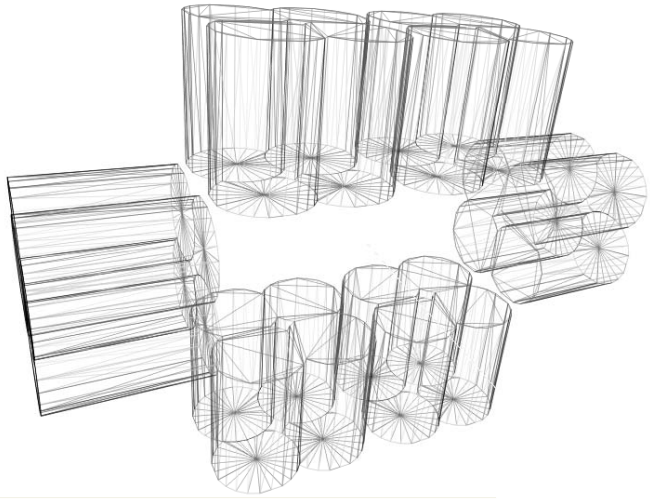
16 planar triple modules



γ-ray tracking spectrometer for experiments with stopped exotic beams.

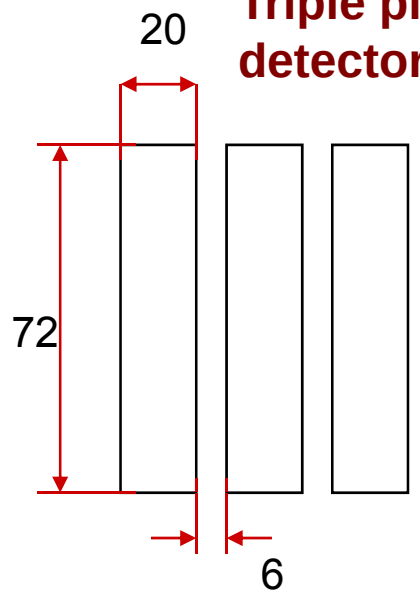
Nuclei implanted in a highly segmented silicon detector, AIDA at the center of Ge array

6 clovers

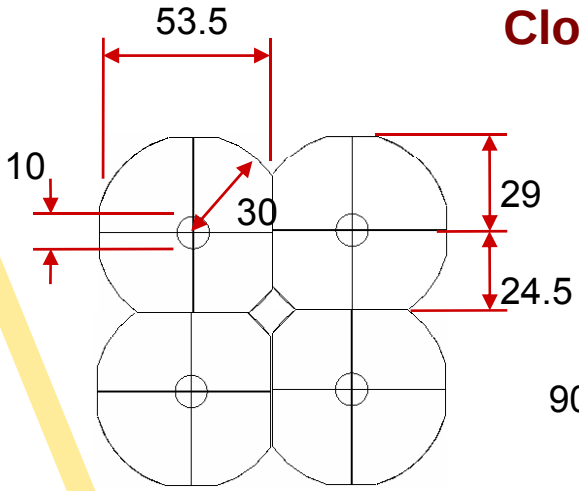


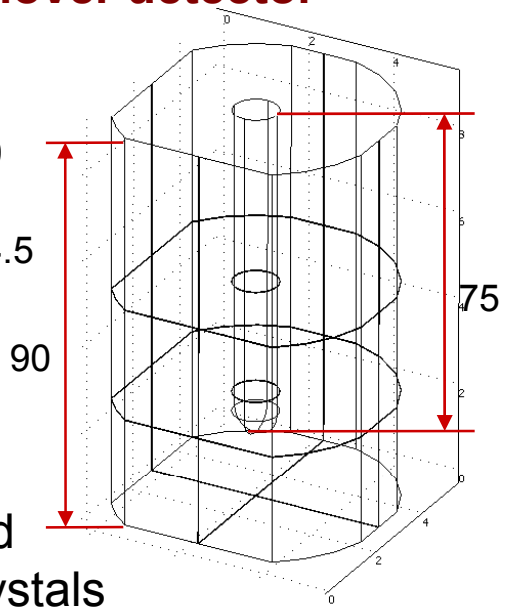
Proposed detectors

Triple planar detector module



Clover detector

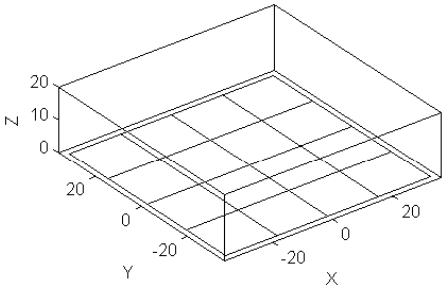




12- and 16-fold segmented crystals

depth segmentation of the outer contact, mm
25 – 25 – 40
20 – 40 – 30
20 – 25 – 25 – 20
15 – 25 – 30 – 20
15 – 25 – 25 – 25

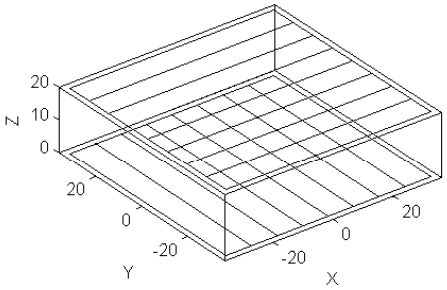
Pixel detector



16 pixels 17 x 17mm

2 mm guard ring

Strip detector



8+8 strips 68 x 8.5mm

Advantages of position sensitive detectors

Compton background suppression
energies of photons interacting in more than one crystals can be added back, while Compton-escape events can be identified and suppressed with no anti-coincidence shields required.

Recoil identification
in case of relatively long-lived nuclei or isomers, it is essential to correlate the γ -rays with an earlier implantation location in the silicon detector.

Background radiation suppression
using γ-ray imaging, background photons and those originating in other parts of the experiment and in the environment, can be rejected.

Monte Carlo events

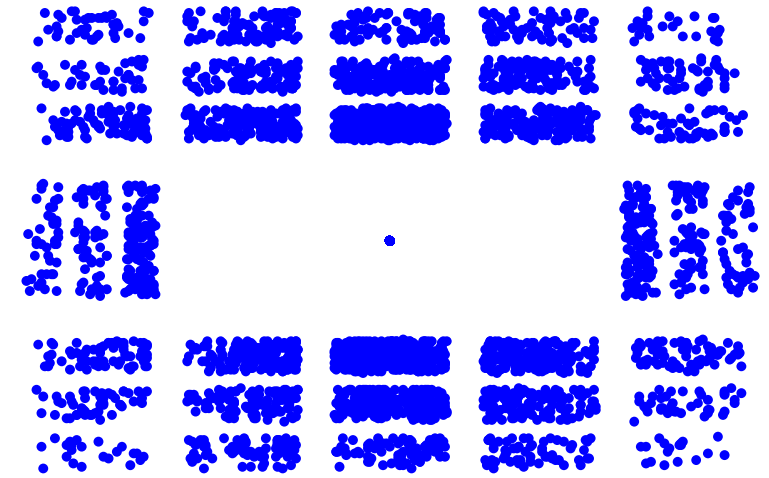
Position resolution for realistic interactions:

250, 662, 1332 keV photons simulated in GEANT4

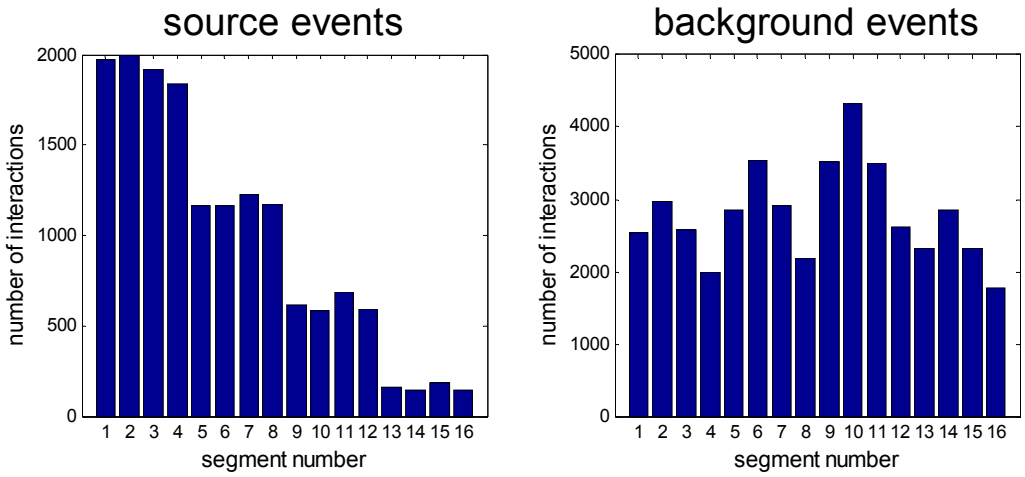
~3000 for each energy from the implantation point (source events)

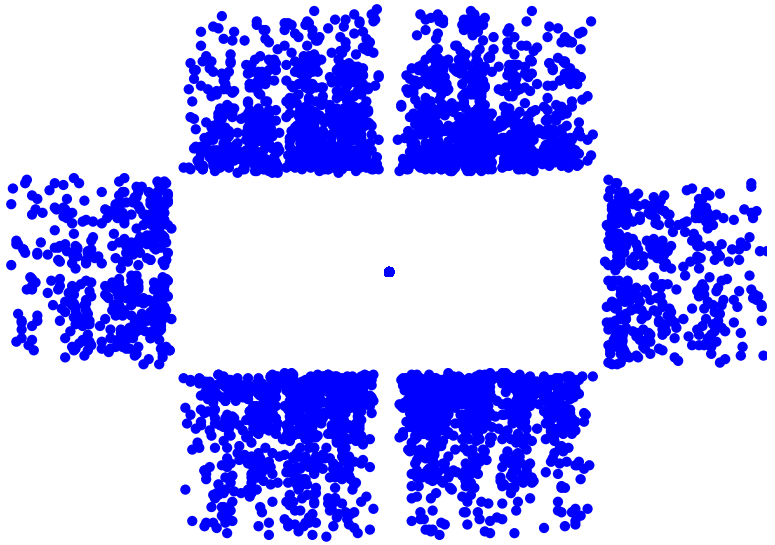
~10000 for each energy from all directions isotropically (background events)

Interaction points for source events:



Distribution of hits in clover detector segments

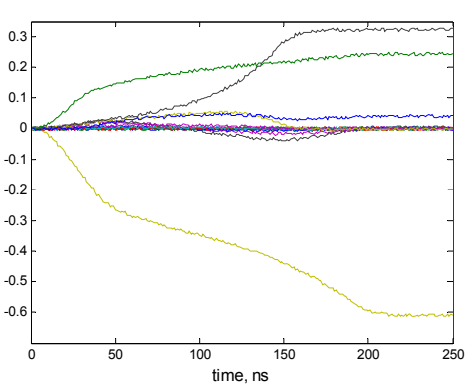


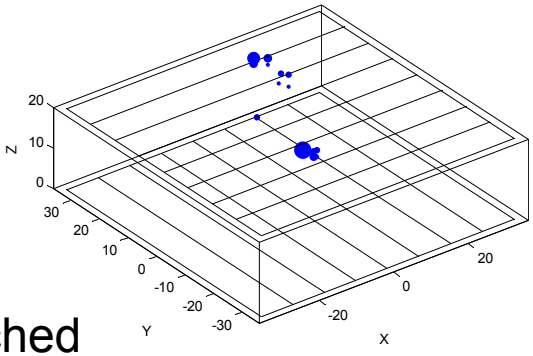


Pulse shape analysis

Position reconstruction:

- interactions generated in GEANT4
- pulses calculated for simulated interactions
- preamp response and noise added
- pulses used to reconstruct positions
- original and reconstructed positions compared
- mean position errors as function of energy, type and multiplicity of interaction

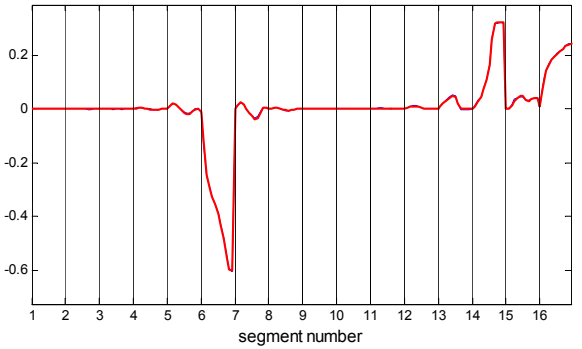




measured/ simulated signal

time-matched meta-signal

energy deposit distribution



Detector comparison

Single – one segment in crystal hit

Multiple – more than one segment hit

Mean position errors in mm

Detector (sensitive volume)	**16-strip planar** (68x68x20)	**16-pixel planar** (68x68x20)	**15 – 25 – 30 – 20 clover** (<53.5x53.5x90)
physical voxel size	8.5x8.5 mm	17x17 mm	different
basis grid	5x5x14x16	5x5x14x16	64x(14to17)x44
Single	1.14	2.13	3.41
Multiple	2.20	3.92	6.63
Single, merged	2.11	3.23	4.89
Multiple, merged	2.58	4.24	7.39
Single, non-merged	0.99	1.79	2.85
Multiple, non-merged	2.05	3.68	6.04

Multiple interactions in the same segment:

-- merged into 1 effective interaction

-- when resolved, both position and energy resolution are very poor.

This affects 20% (strip16) 30% (pixel16) 40% (clover16) 50% (clover12) of events.

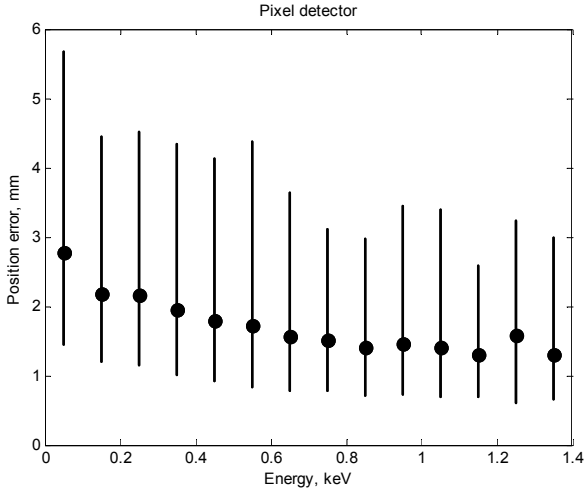
Error vs energy

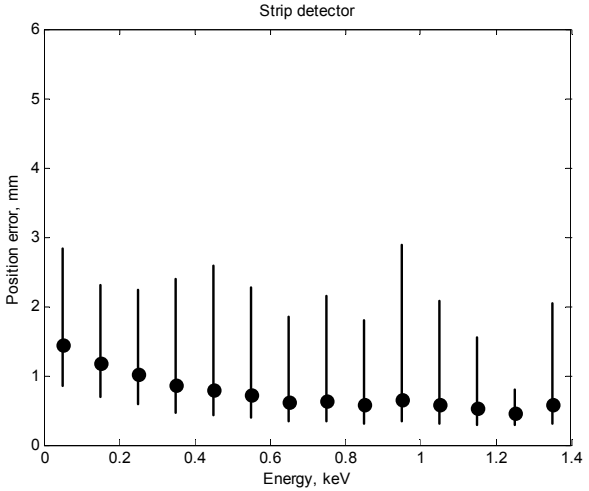
Pixel

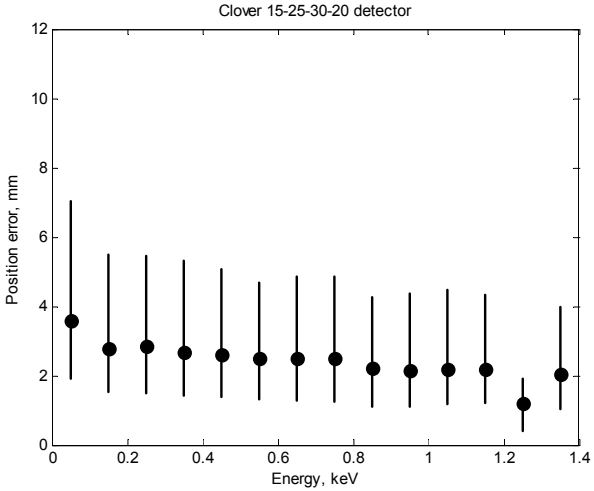
Strip

Clover

single interactions

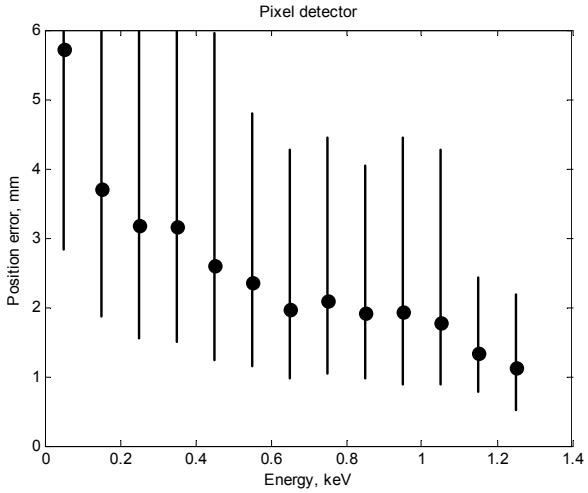


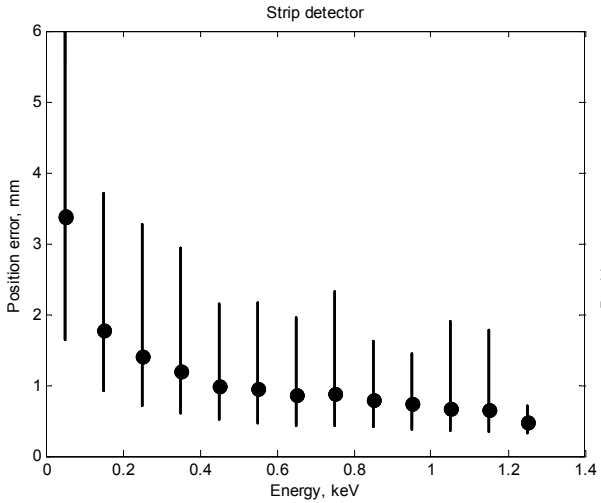


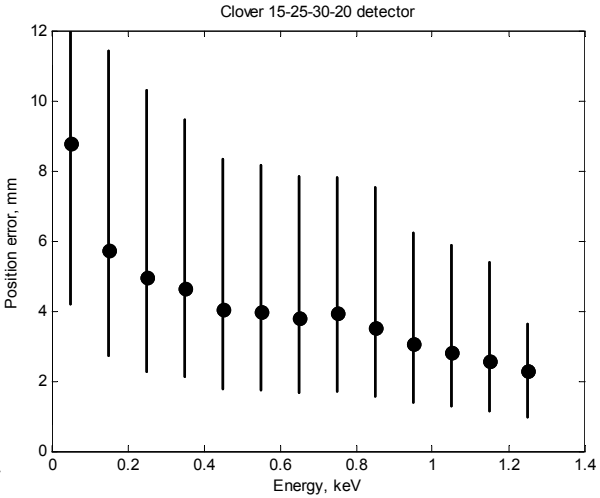


note – the scale is doubled

multiple interactions





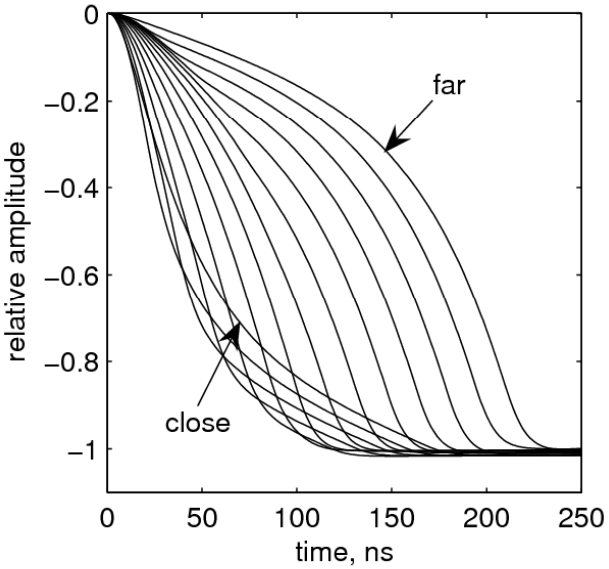


Conclusions

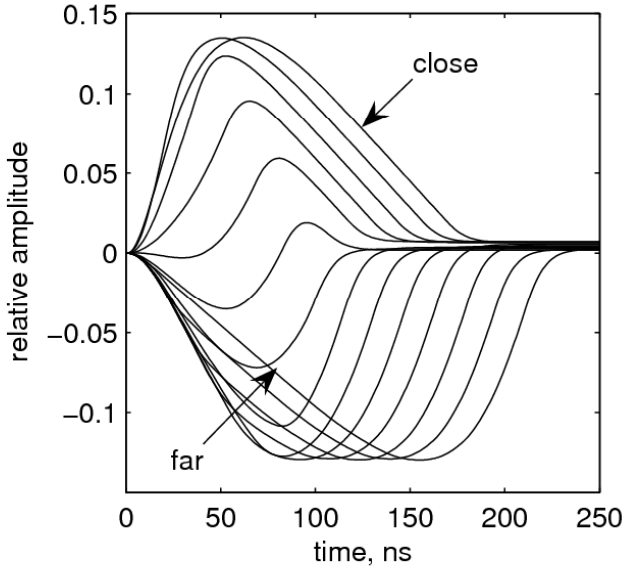
Planar strip	good position resolution, little merging	64 voxels readout through 16 signals – pile-up in a strip presents problems, both sides must be instrumented, guard rings (dead material)
Planar pixel	small contacts – little pile-up, one side needs to be readout, least data stored for PSA	lower position resolution, more merging, guard rings (dead material)
Clover	best raw (before tacking) efficiency, best active/passive material ratio, no guard rings, only 6 cryostats required	lowest position resolution, most merging, large segments – most PSA data required

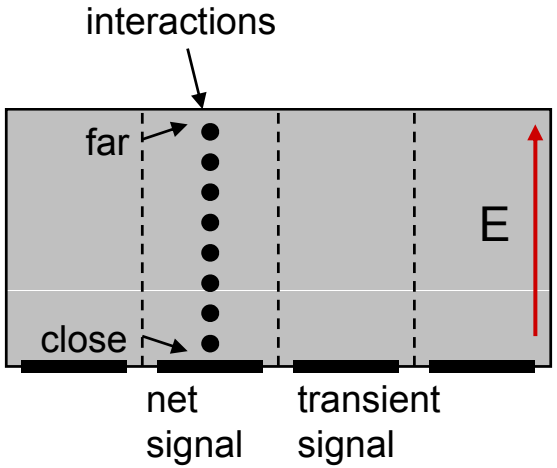
Pulse shapes

net signal



transient signal

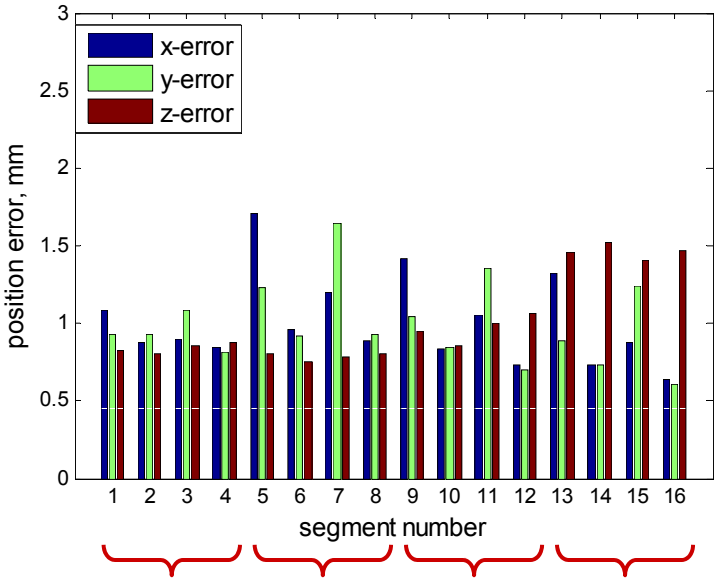




Net and transient signal pulse shape variation as a function of interaction depth in a planar detector.

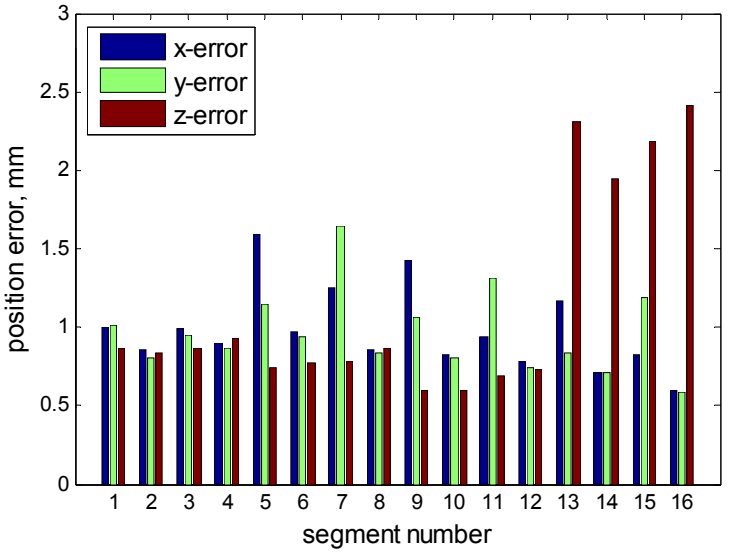
Position uniformity tests for Clovers

15-25-30-20



front middle 1 middle 2 back

15-25-25-25



Segment numbering