

The GALATEA Test Facility

First HPGe Detector Surface Scans with Alpha Particles

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for the GeDet Group

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MAX-PLANCK-GESELLSCHAFT

Outline

- ① What are we interested in?
- ② Segmented n-type HPGe Detectors
- ③ Pulses and Mirror Pulses
- ④ What information can we obtain?
- ⑤ Surface Effects
- ⑥ Surface Scans - Experimental Implementation
- ⑦ ^{241}Am Spectrum
- ⑧ Energy Balance and Pulse Shapes
- ⑨ Summary and Conclusion

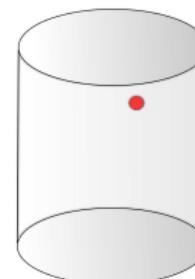


Characterisation of HPGe Detectors

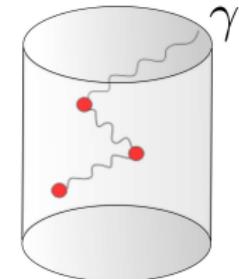
...for low-BG experiments

- BG reduction through event recognition
 - $0\nu\beta\beta$: localized event
 - γ : multiside event
- Segmentation of HPGe detectors

Signal Event

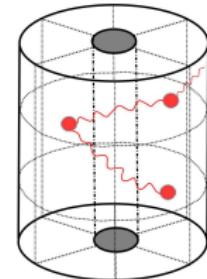
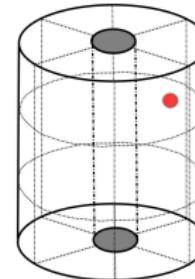


Background Event



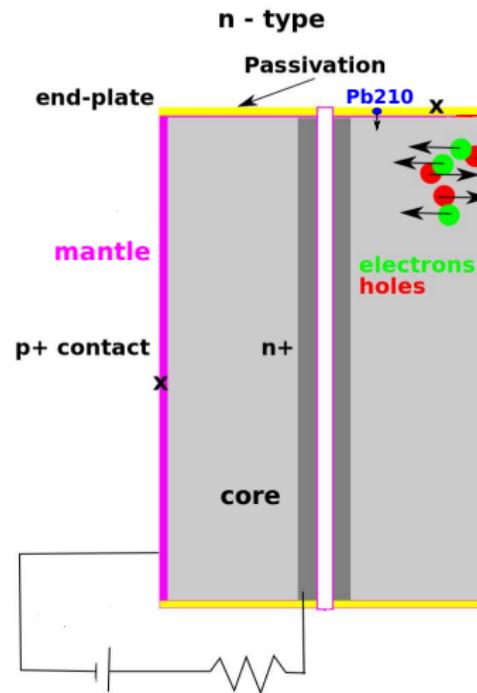
...for further detector development

- Charge trapping
- Surface channel effect



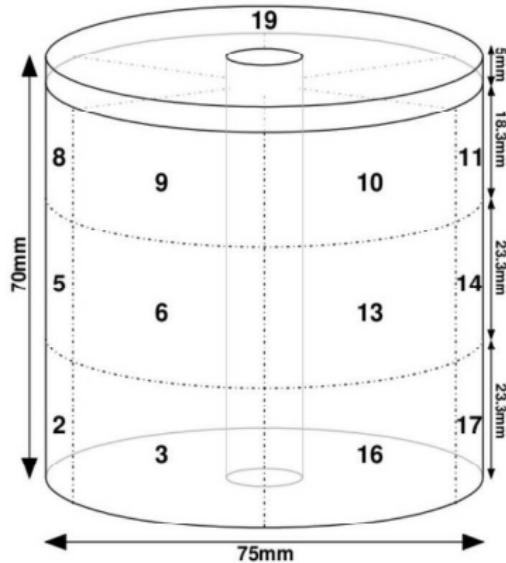
n-type coaxial Detectors

- electron-hole pair creation
- **n-type**: the electric field pulls the **electrons** to the **core** and the **holes** to the **mantle**
- resulting pulses are sampled and digitized at a given frequency
- passivation layers
- end plates → **contamination** → creates BG if part of energy is seen

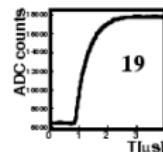
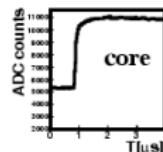


"Supersiegfried"

- Cylindrical true-coaxial n-type HPGe Detector
- 18 + 1 fold Segmentation (3z and 3 ϕ)
- Additional top Segment
- Dimensions:
 - $h = 70 \text{ mm}$
 - $r_{\text{inner}} \approx 5 \text{ mm}$
 - $r_{\text{outer}} \approx 38 \text{ mm}$



Example pulse seen by "SuSie" - one Event



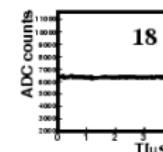
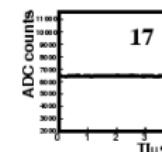
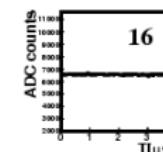
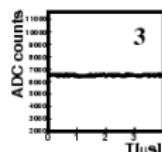
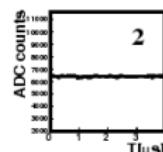
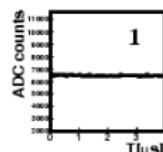
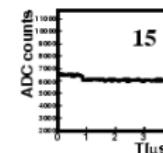
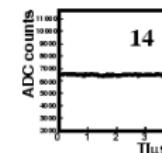
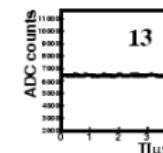
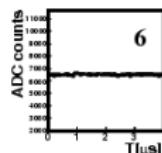
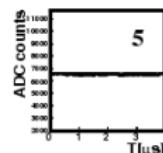
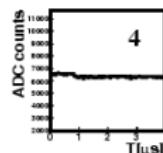
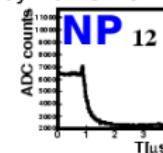
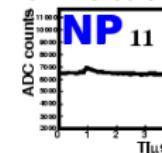
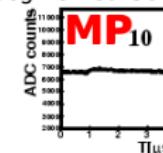
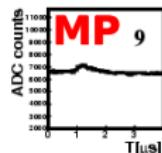
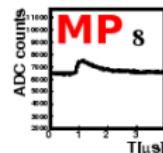
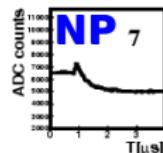
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 $E_{19} = 1575.2 \text{ keV}$

Ref.: from the Ph.D. Thesis: "Pulse Shape and Surface Effects
in Segmented Germanium Detectors" by Daniel Lenz

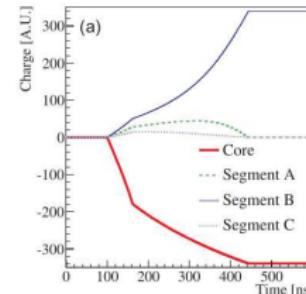
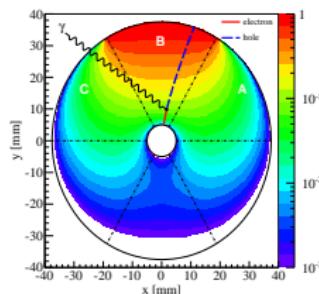


NP = Negative Pulse MP = Mirror Pulse



Pulses and Mirror Pulses

Drift of charge carriers in a hitted segment induces mirror pulses in neighbouring segments



Real Pulse: charge "trajectory" ends at considered segment electrode

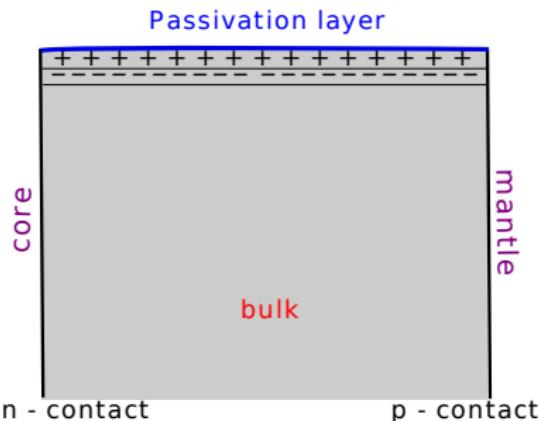
Mirror Pulse: charge "trajectory" does not end at considered segment electrode

Ref: Publication: "Pulse shape simulation for segmented true-coaxial HPGe detectors" by I. Abt, A. Caldwell, D. Lenz, J. Liu, B. Majorovits



Surface Channel Effect

Perfect



Imperfect

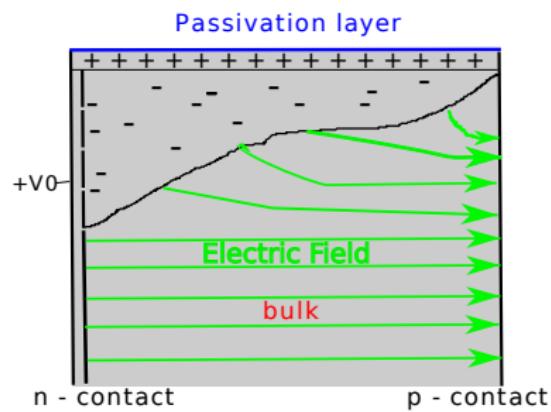


Figure adapted from: Ph.D. thesis by D. Lenz

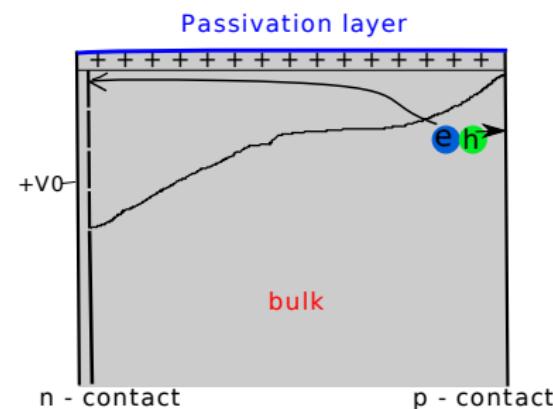
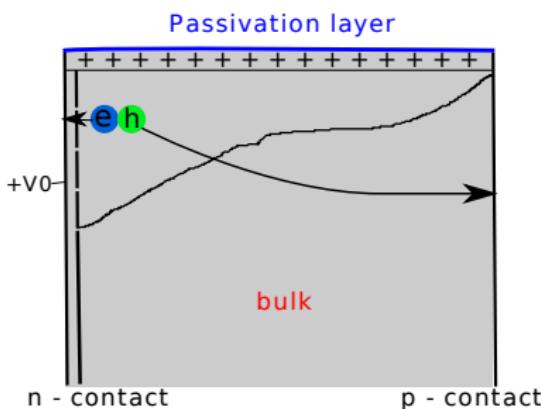


Path of electrons and holes in a detector with an n-type surface channel

Electron-hole pairs created in the surface channel region

(a) close to the n-contact

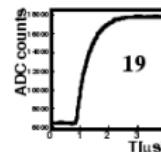
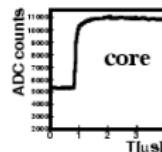
(b) close to the p-contact



(not to scale) Figure adapted from: Ph.D. thesis by D. Lenz



Example pulse seen by "SuSie" - one Event



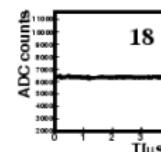
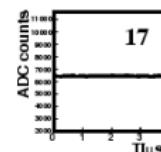
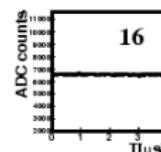
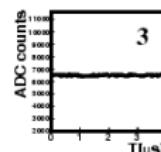
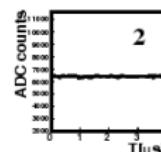
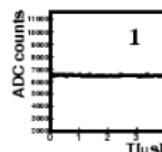
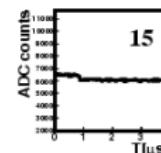
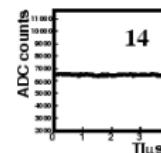
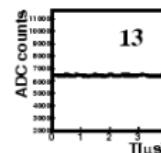
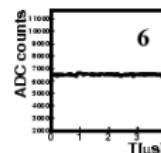
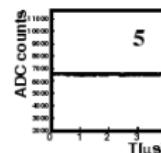
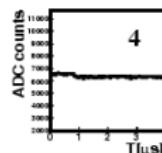
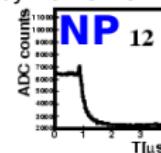
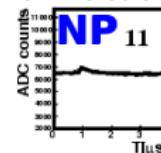
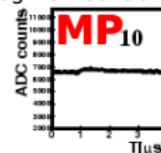
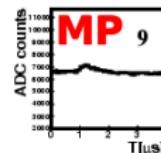
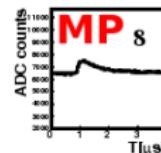
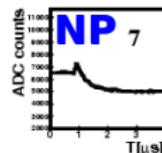
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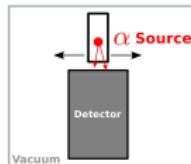


What Information can we obtain?

- Segmentation for inference of event topologies and event positions
- Pulse shapes including mirror pulses give information about
 - ① The energy deposited
 - ② The position of an event
 - RT plus polarity of mirror pulses → position in r
 - Relative strength of mirror pulses → position in ϕ
 - ③ Proximity to end plates: long pulses → surface channel effect



Experimental Implementation - The Test Facility GALATEA



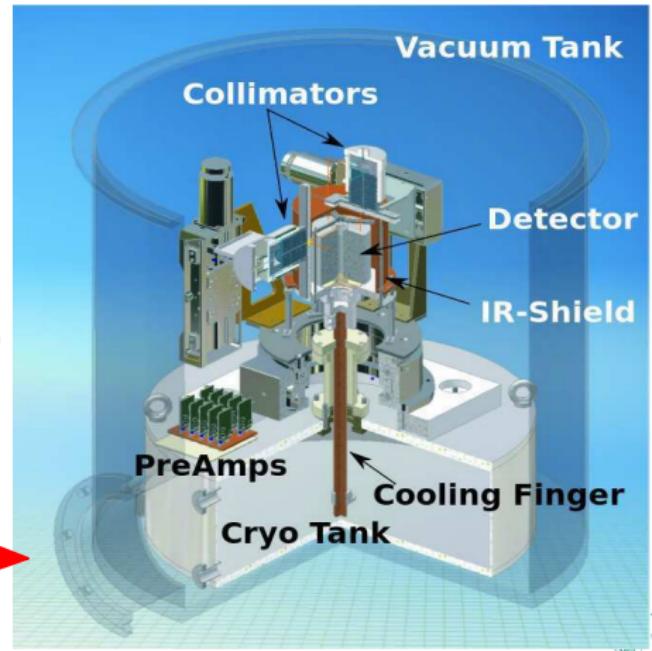
Scan of the Detector Surface
with an ^{241}Am source (α - particles)
inside the tank

- Studying Surface Effects
- effective inactive layers
can be measured very
precisely

Technical
Implementation

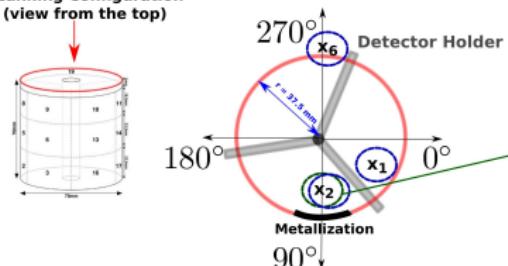
- Vacuum Tank
- LN₂ Cooling
- Adjustable Source (UHV Stage)
- Electronics inside the Vacuum
Tank

Mount Detector
in a Test Facility

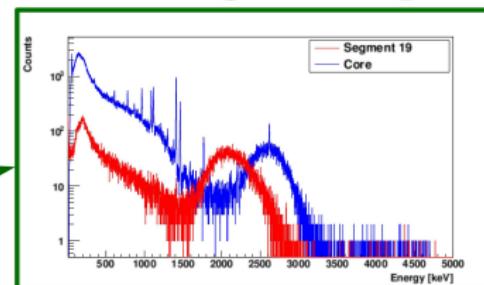


Alpha Spectrum

Scanning Configuration
(view from the top)

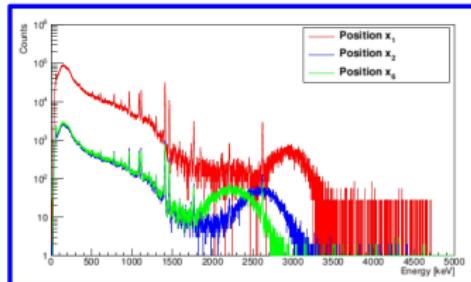


Scanning Position x_2

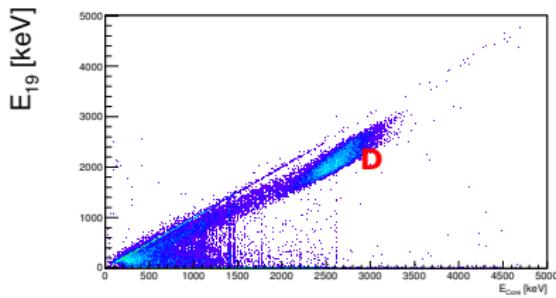
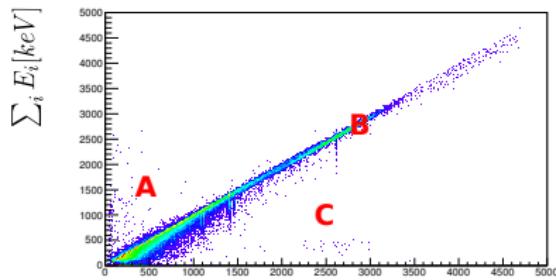


Scanning Positions x_1 , x_2 and x_6

Core Spectra



Energy Balance



A Events above 45°

$$\sum_i E_i > E_{Core}$$

B Events in the 45° band

$$\sum_i E_i = E_{Core}$$

C Events below 45°

$$\sum_i E_i < E_{Core}$$

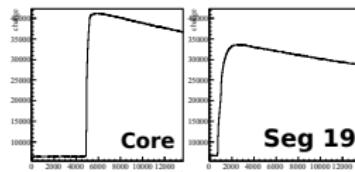
D Surface Events

→ event cloud

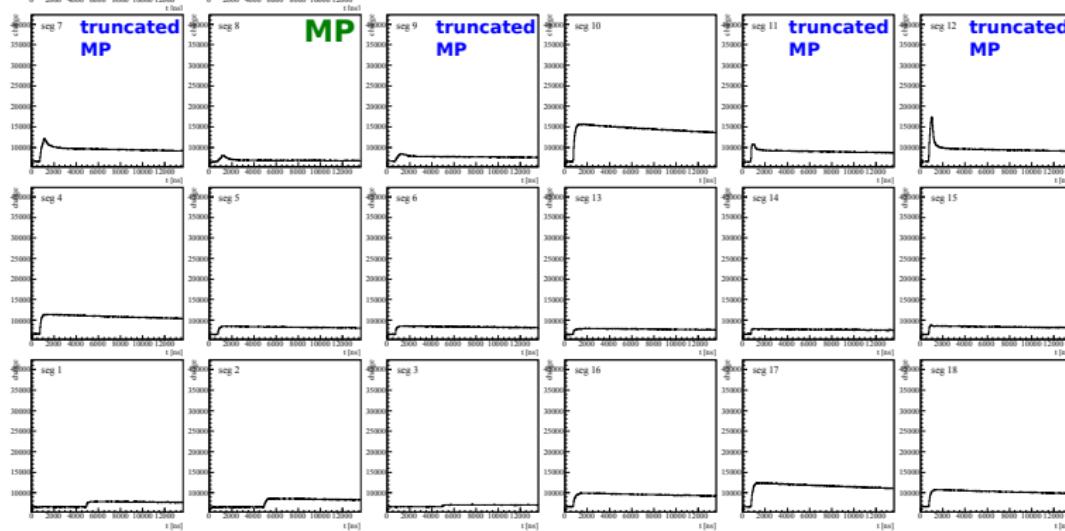
→ α -particles depositing energies on the detector
→ charge trapping



Pulse Shape Event



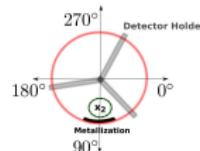
- higher signal recorded in the core than in the 19th segment
- positive **mirror pulse** in segment 8
- truncated positive **mirror pulse** in segment 7, 9, 11 and 12
→ **HOLE TRAPPING**



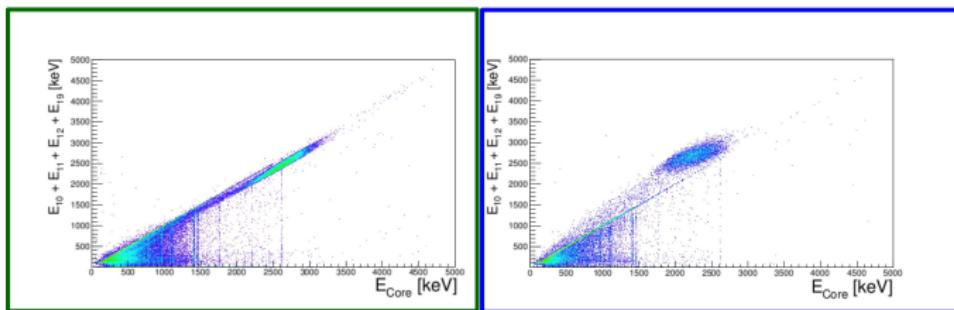
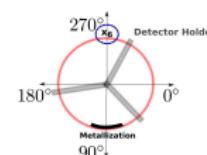
Charge Trapping

Segment Energy Sums of the top layer plus Segment 19

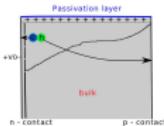
Position right on top of the detector



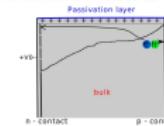
Position on the detector edge



HOLE TRAPPING



ELECTRON TRAPPING



Summary and Outlook

- ➊ What are we interested in?



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- Study surface effects in a segmented true-coaxial HPGe detector
- Identify and characterize surface events



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- Pulse shapes and mirror pulses



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 - ① Energy deposition
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③ What do we need for a surface scan?

- A special 19-fold segmented HPGe detector
- α -source
- A test stand which allows a full scan of the detector



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- ③ What do we need for a surface scan?
 - A special 19-fold segmented HPGe detector
 - α -source
 - A test stand which allows a fully scan of the detector
- ④ Where are we?



Summary and Outlook

① What are we interested in?

- Study surface effects in a segmented true-coaxial HPGe detector
- Identify and characterize surface events

② What information can we obtain?

- Pulse shapes and mirror pulses
 - ① Energy deposition
 - ② Event position
- Long Pulses → surface channel effect

③ What do we need for a surface scan?

- A special 19-fold segmented HPGe detector
- α -source
- A test stand which allows a full scan of the detector

④ Where are we?

- First results of a surface scan with a ^{241}Am source were shown
- Charge trapping effects were seen
- → **Looking forward to full detector surface scans!**

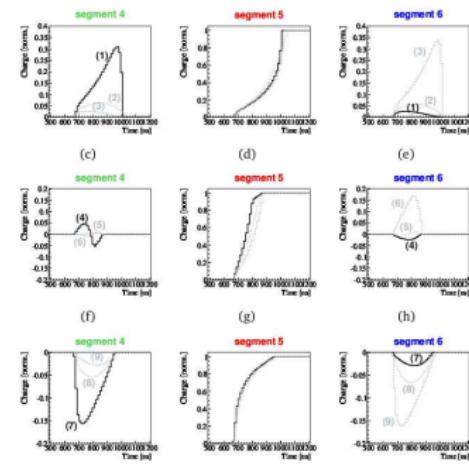
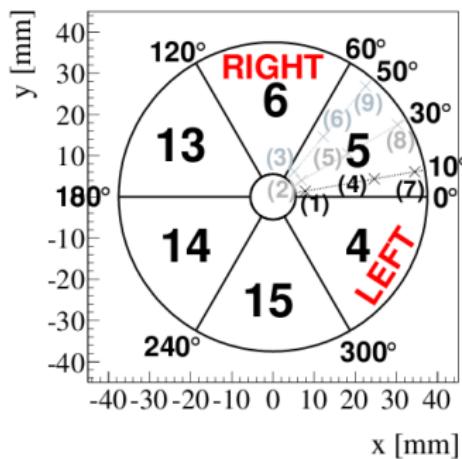


Back-Up Slides

Back-Up Slides



Characteristics of Mirror Pulses

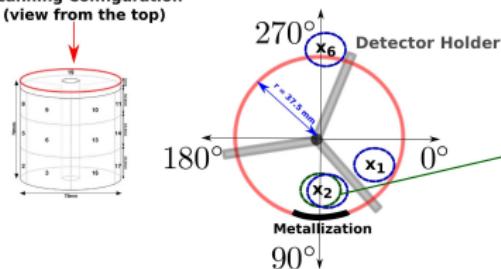


Ref: Diploma Thesis: "Mirror pulses and position reconstruction in segmented HPGe detectors" by S.Hemmer

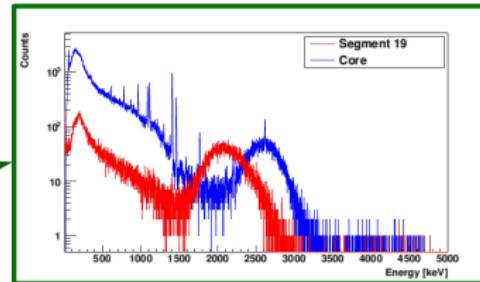


Alpha Spectrum

Scanning Configuration
(view from the top)

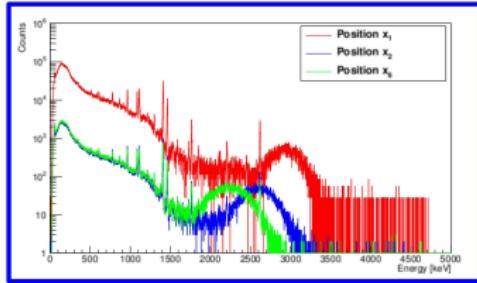


Scanning Position x_2



Scanning Positions x_1 , x_2 and x_6

Core Spectra



19th Segment Spectra

