Segmented Broad Energy Germanium Detector

Outline:

- Physics Goals
- BEGe detector
- First measurements on segmented BEGe detector
- Summary & outlook

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IMPRS @ Föhringer Ring 6, Munich, 13/02/2015

Motivation & Mission Statement

GEDET collaboration:

Germanium detector R&D for future application in fundamental physics

- ✓ **Neutrinoless double beta decay**
- ✓ **Dark matter searches**

Tasks:

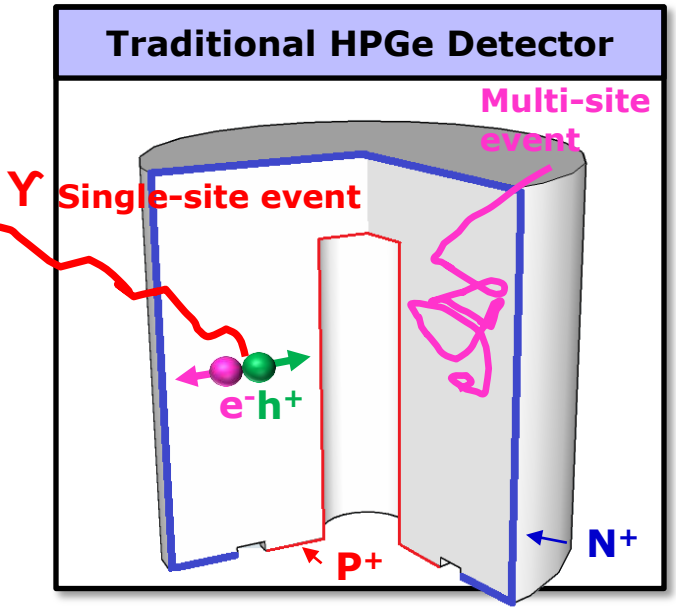
- ➢ **Reduce background**
- ➢ **Establish techniques to distinguish signal events from background events**

→ **Use intelligent detectors**

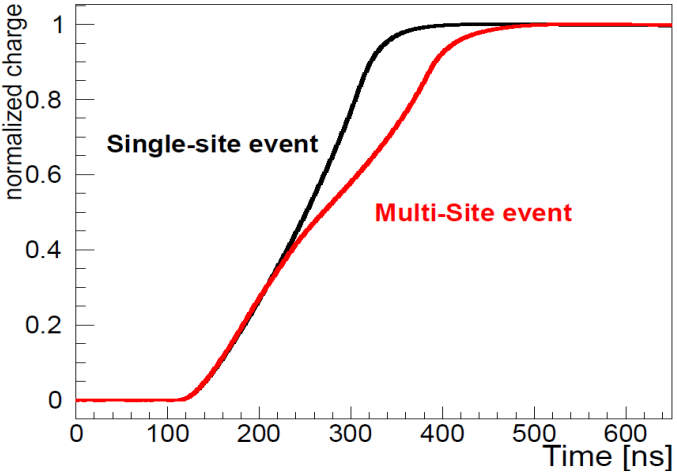
Key issue:

Good understanding of the detector response for signal and background events

High Purity Germanium Detector

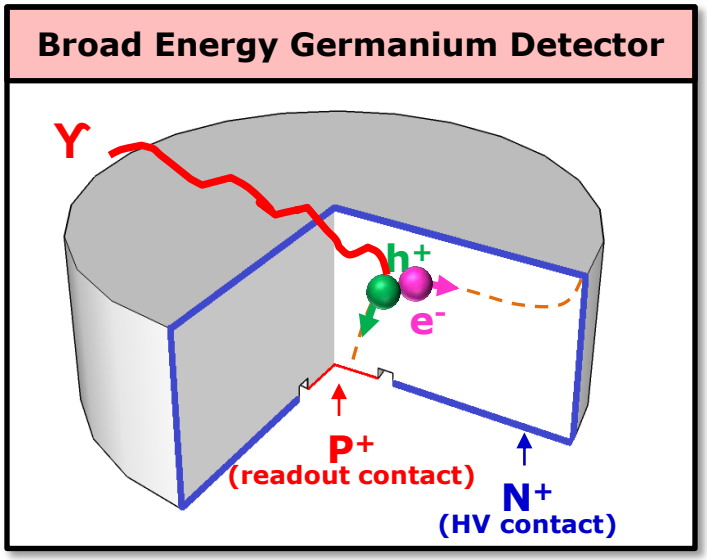


- **High Purity Germanium detector in general:**
  - ✓ **Excellent energy resolution**
  - ✓ **Intrinsically clean**

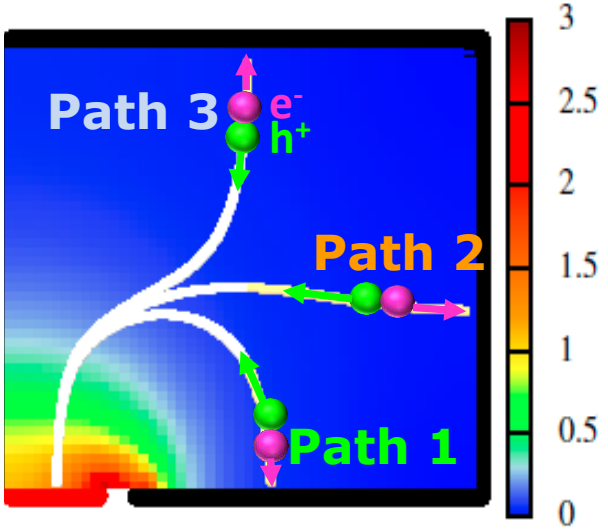


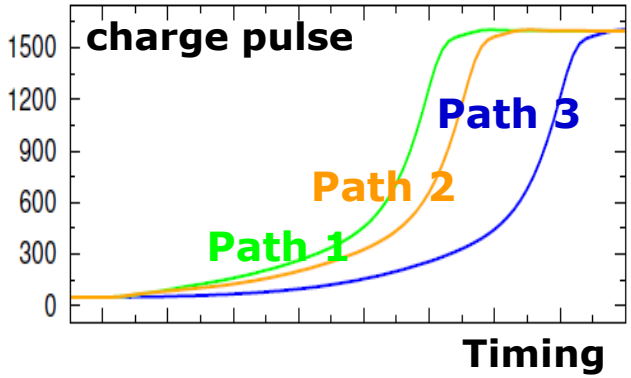
- **Disadvantages for traditional HPGe detector:**
  - ☐ **Big capacitance ⇨ Noisy**
  - ☐ **Limited pulse shape discrimination**

Broad Energy Germanium Detector

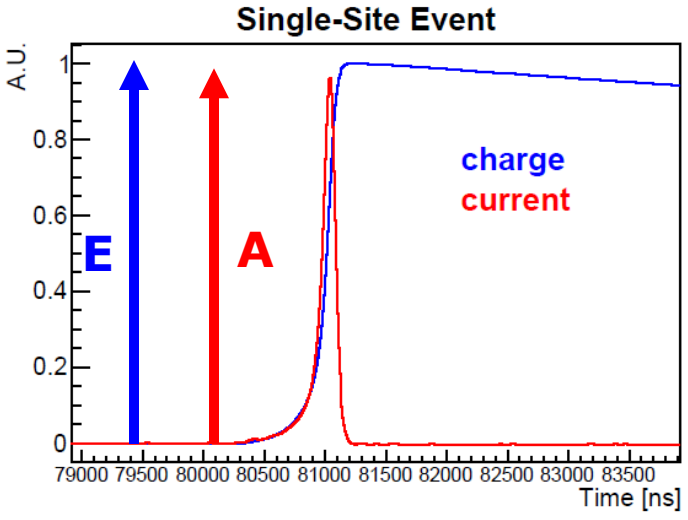


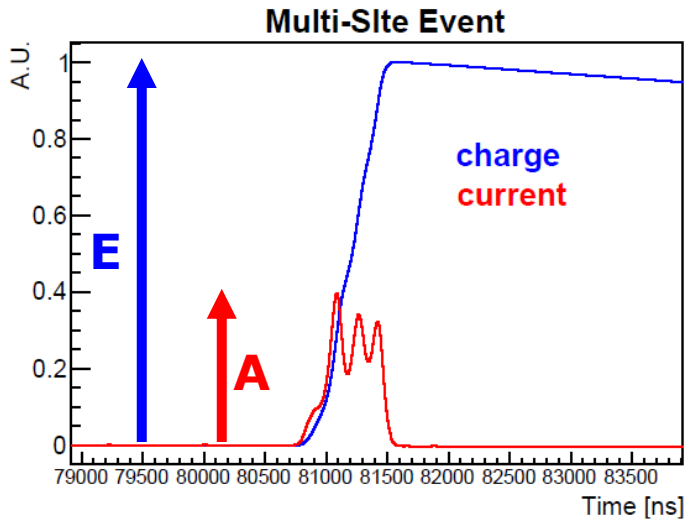
- **Broad Energy Germanium Detector**
- **Widely used for many experiments: GERDA/MAJORANA, CoGeNT, …**
- **Advantages for BEGe detector:**
  - ✓ **smaller p^+ contact ⇨ less noise**
  - ✓ **Strong located E-field**
    - ⇨ **Powerful PSD**





Broad Energy Germanium Detector





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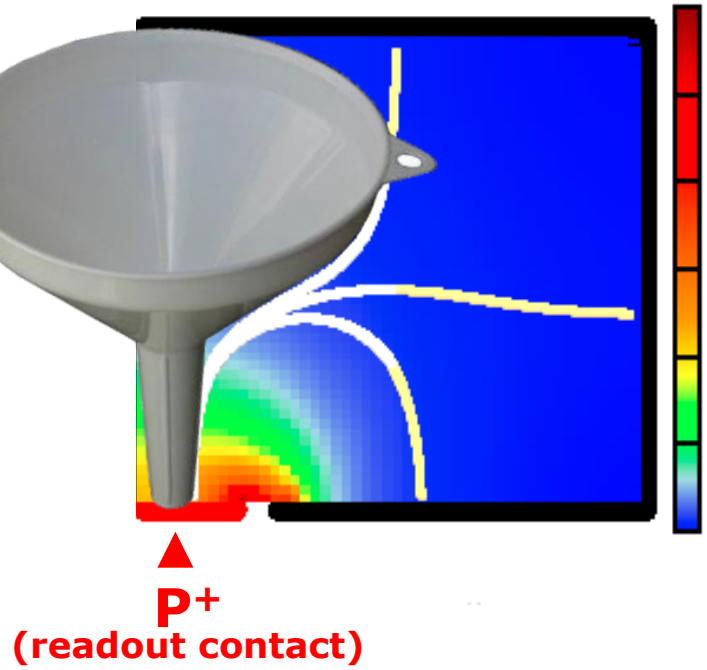
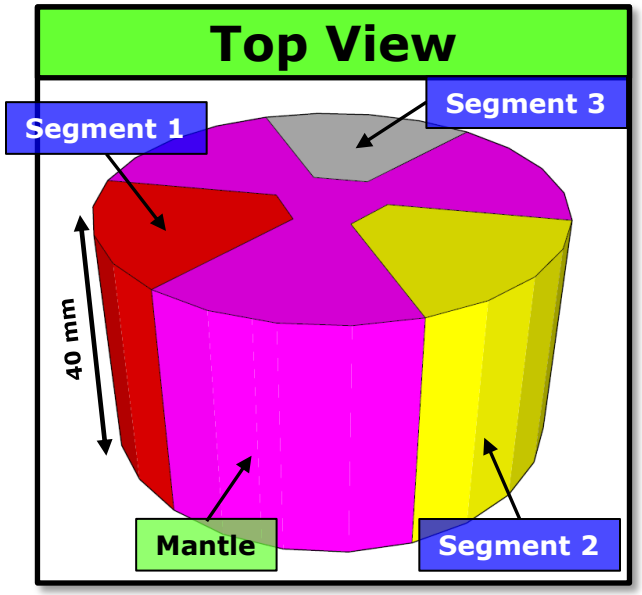
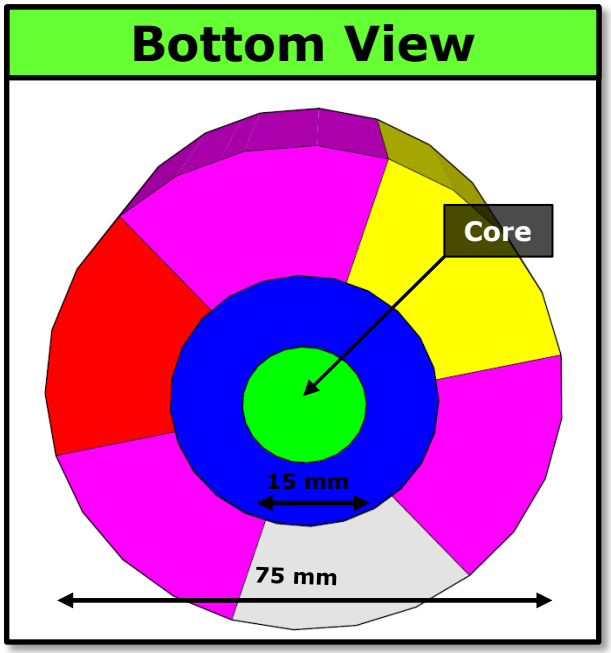
Broad Energy Germanium Detector



- **Broad Energy Germanium Detector**
- **Widely used for many experiments: GERDA/MAJORANA, CoGeNT, …**
- **Advantages for BEGe detector:**
  - ✓ **smaller p^+ contact ⇨ less noise**
  - ✓ **Strong located E-field ⇨ Powerful PSD**
- **Disadvantages for BEGes:**
  - **1D degeneracy in ϕ**
    - **extra segmentations to extract event topology information**

Segmented Broad Energy Germanium Detector

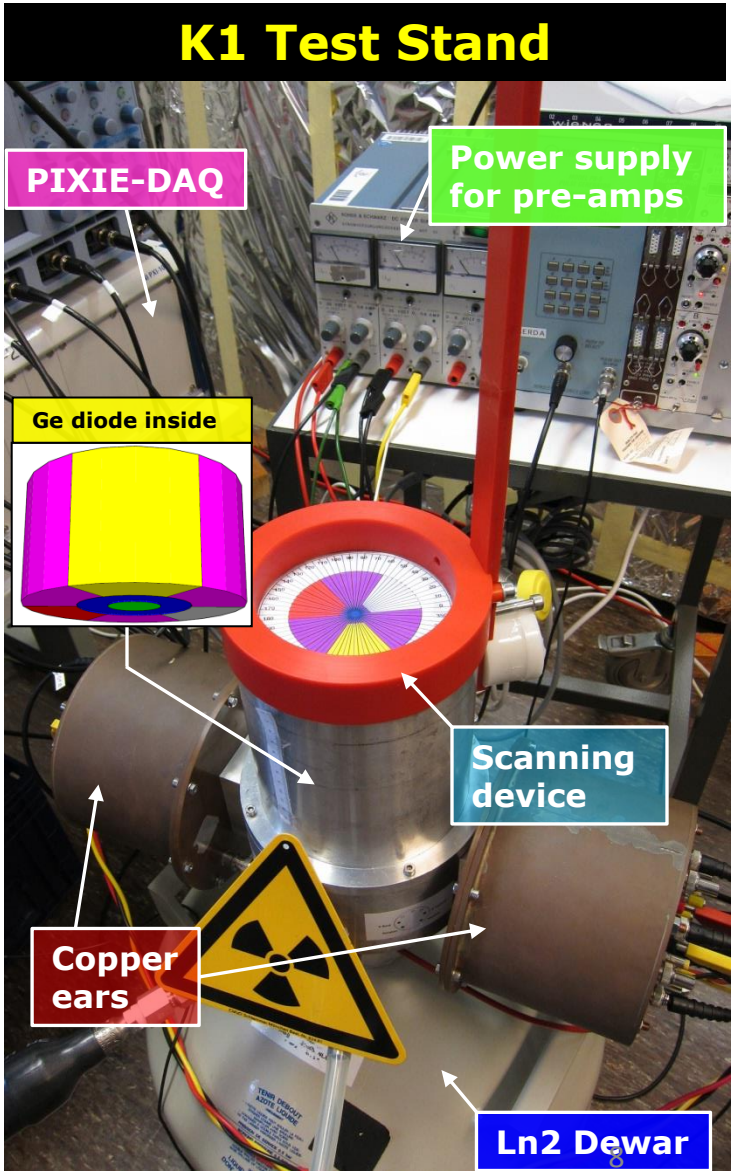




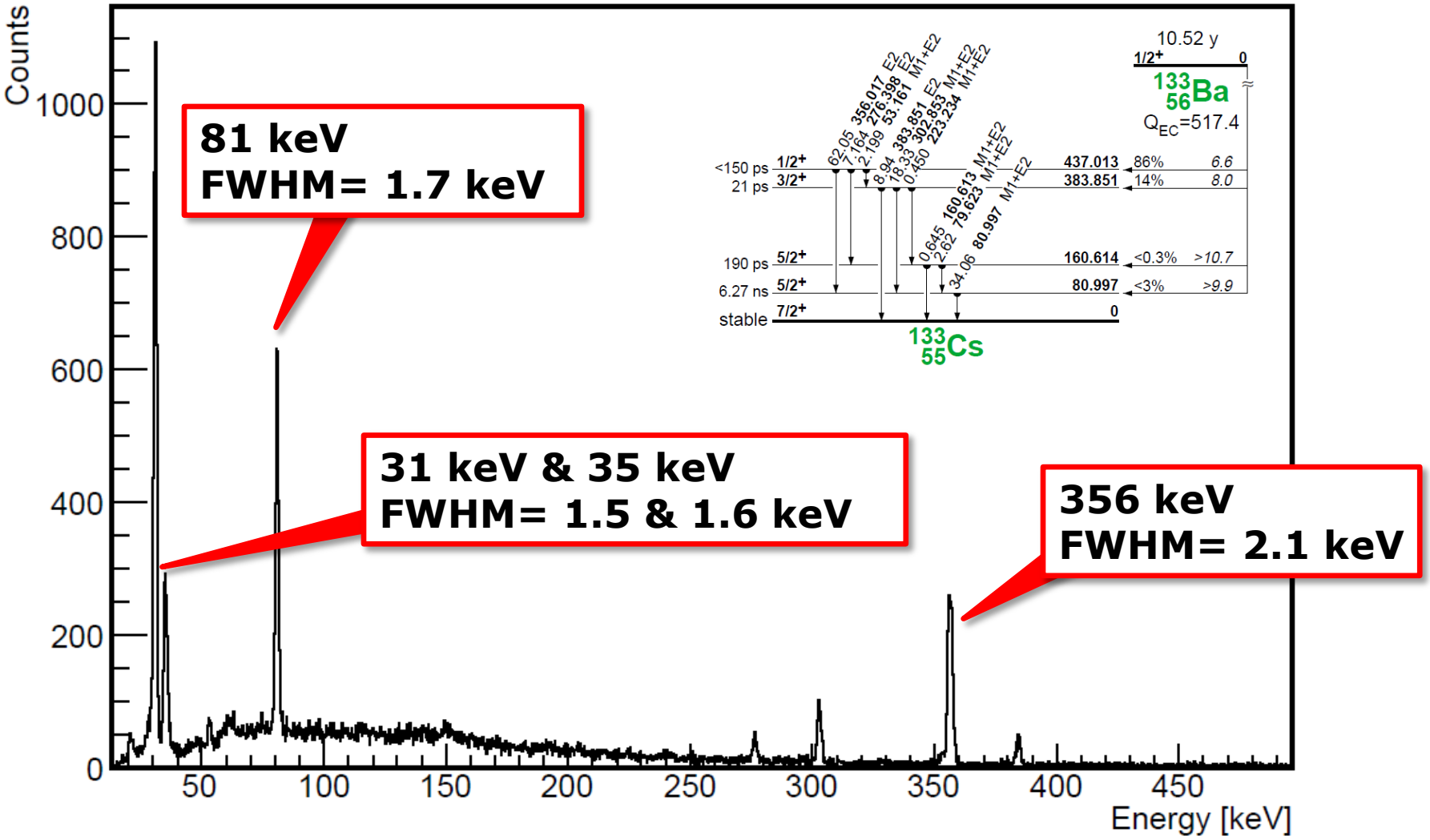
- **Designed by the GEDET group, made by Canberra France**
- **N-Type BEGe detector**
- **Point contact with 4-fold segmentation**
- **3D event reconstruction:**
  - ✓ **Break degeneracies on ϕ and pulse drift time**
- **Segmentation design:**
  - ✓ **Minimizing amount of contacts**
  - ✓ **Maximizing retrieval of information**
- **Configurations:**
  - **Dimension: ϕ 75mm x 40mm**
  - **Mass: 940 g**
  - **HV: +4500 Volt (on N^+ contact)**

Test Facility

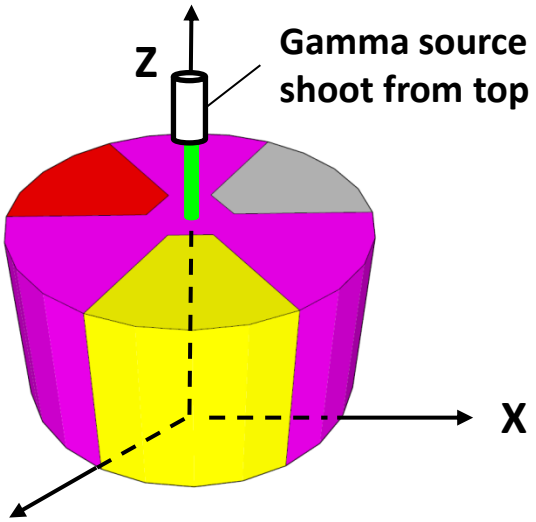
- K1 test stand:
  - Conventional vacuum cryostat
  - Single detector:
    cooling finger submerged in LN2
  - 2 Copper ears to house electronics
    - stand alone preamp for core
    - single preamp/segment
  - Built by Canberra France and modified at MPI
- Flexible device capable to scan through different (r, ϕ, z)



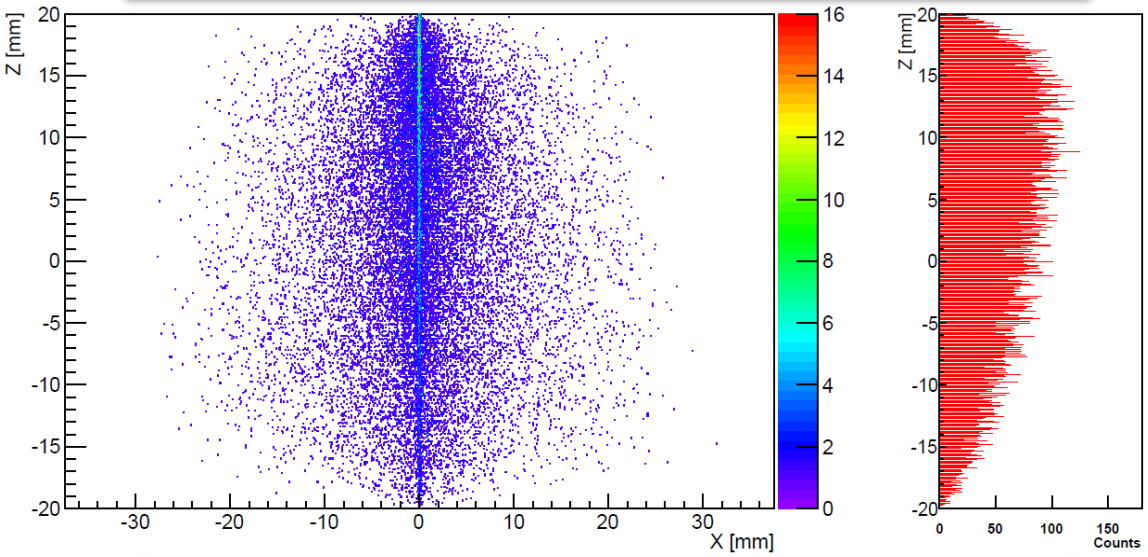
Characterization using ^{133}Barium source



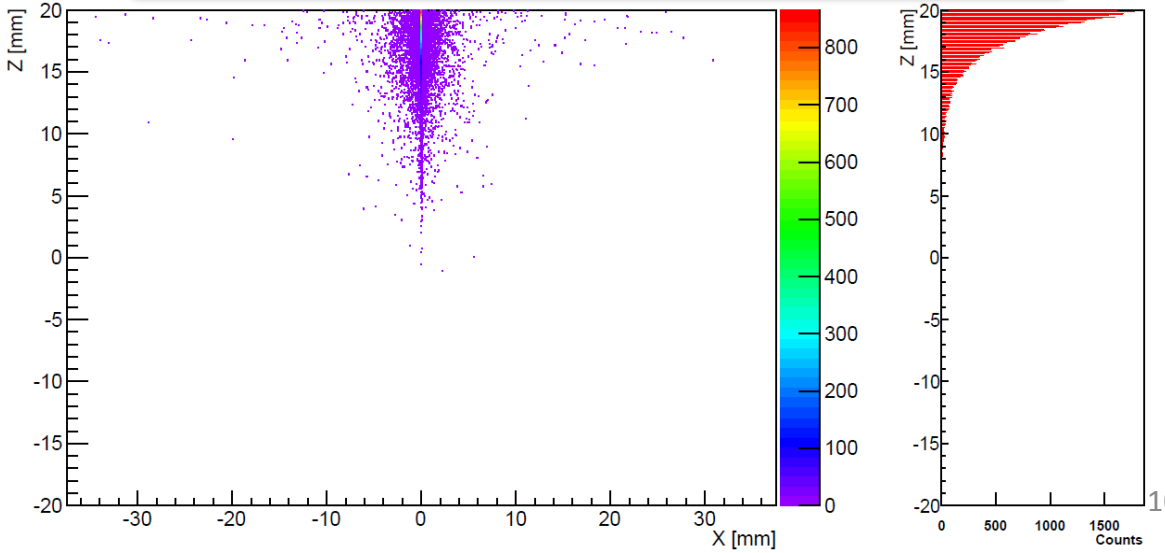
Hit Positions at X-Z plane from simulation



Hit Positions for 356 keV gammas

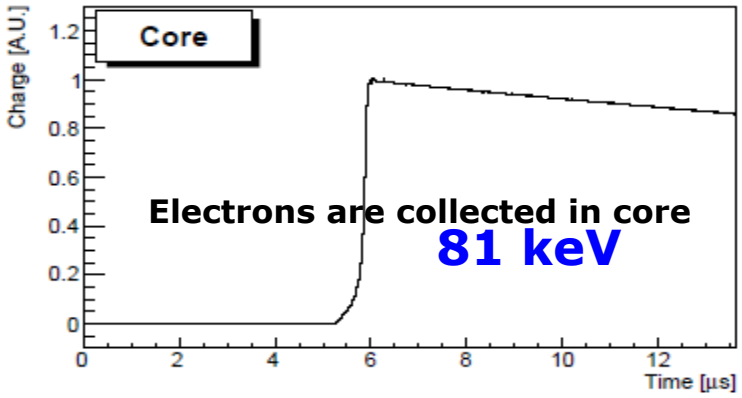


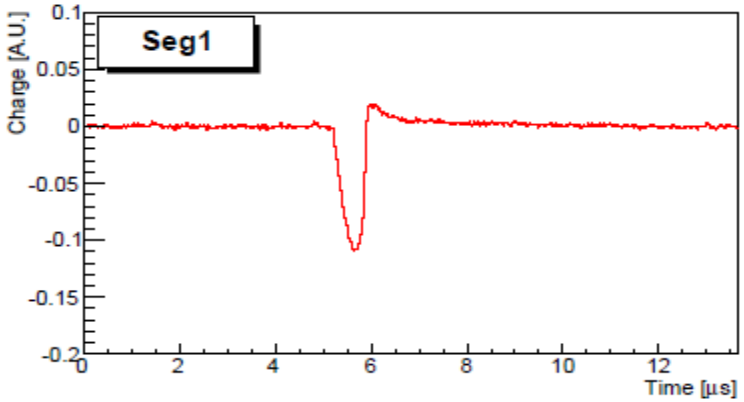
Hit Positions for 81 keV gammas

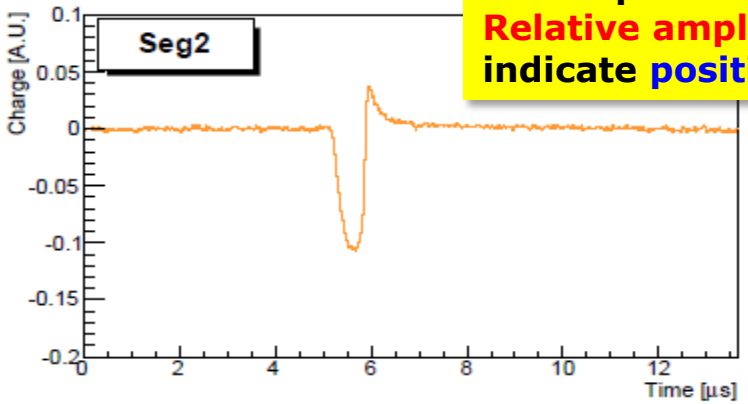


- **81 keV gammas:**
  KEEP characteristic feature of waveform

Mirror Pulse: sensitive to event topologies

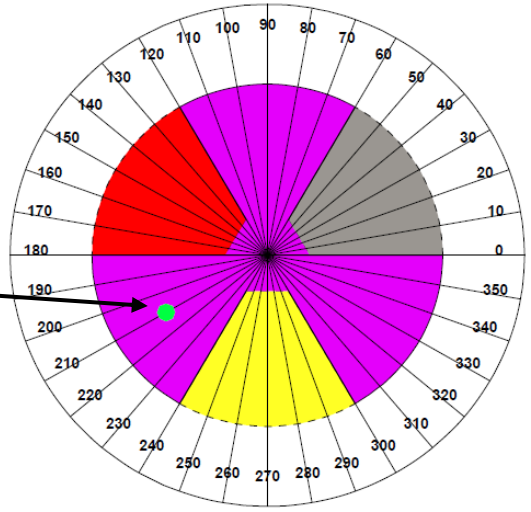


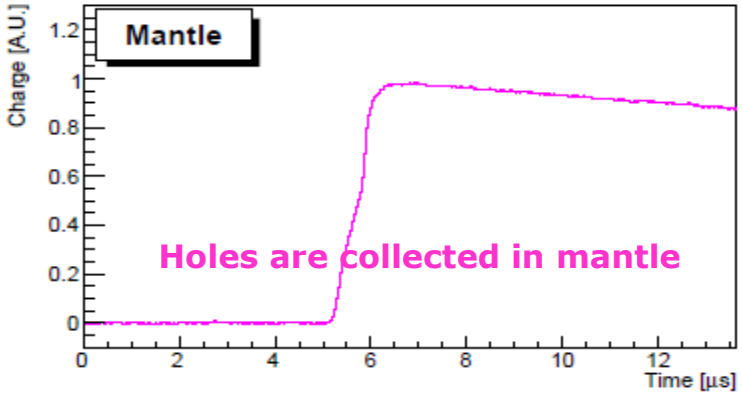


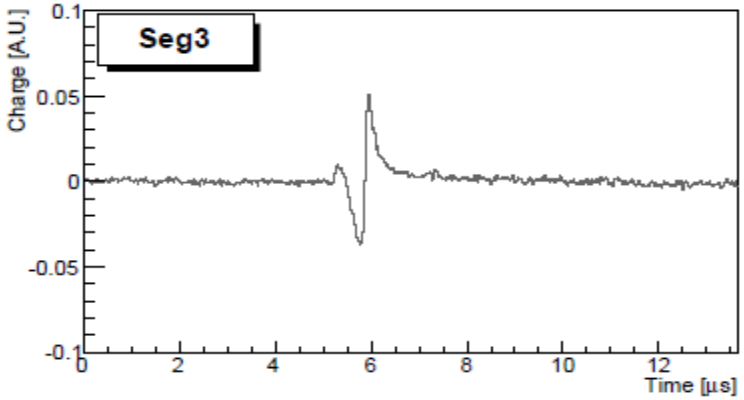


Mirror pulses:
Relative amplitude indicate position

Scanning point







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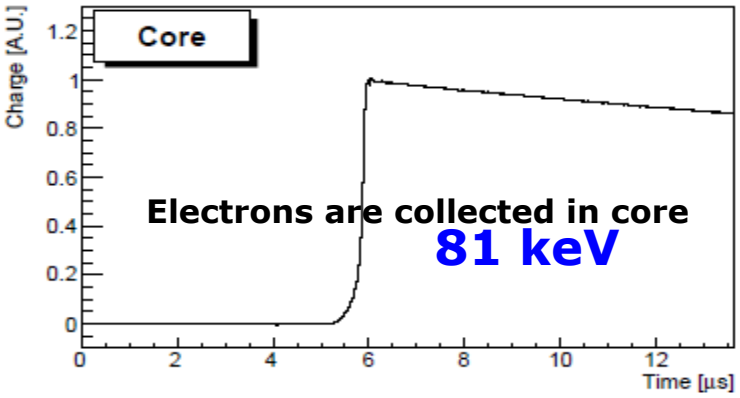

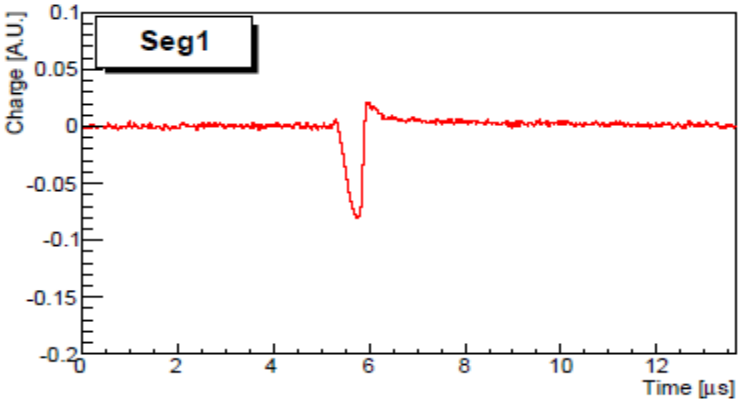

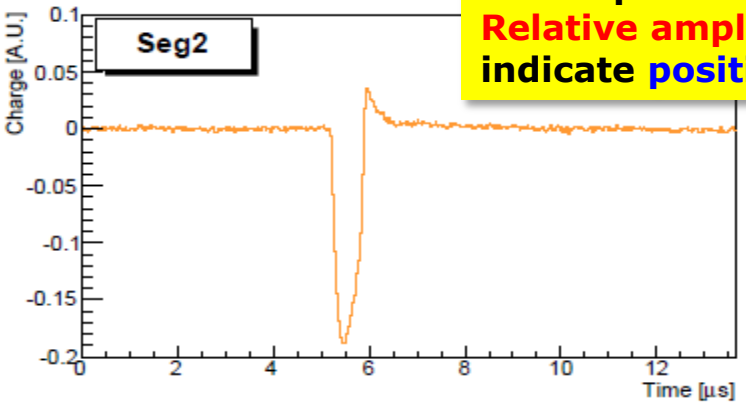

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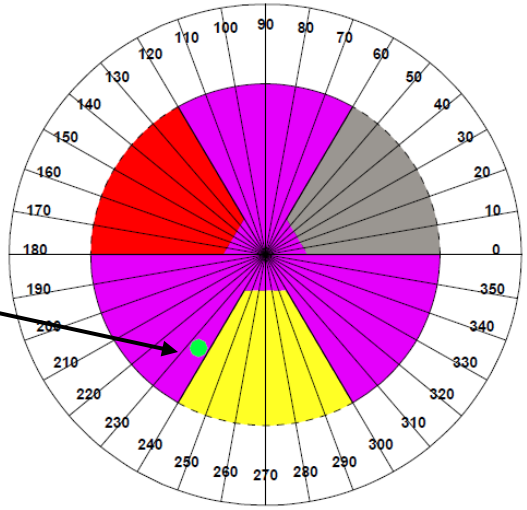

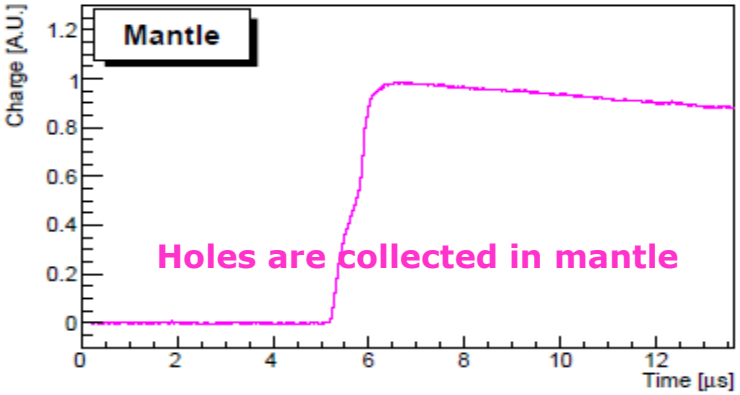

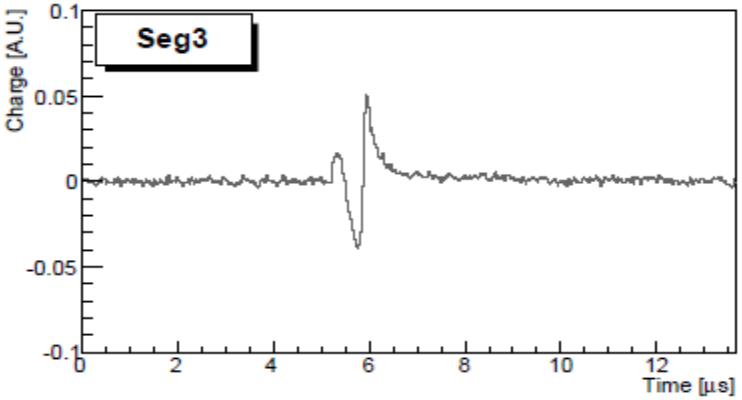

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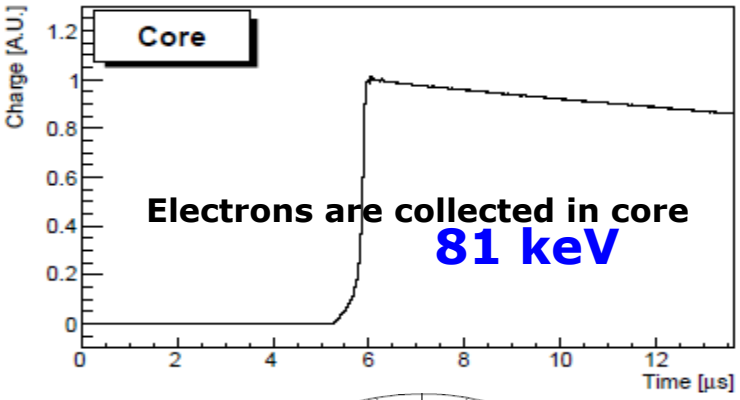

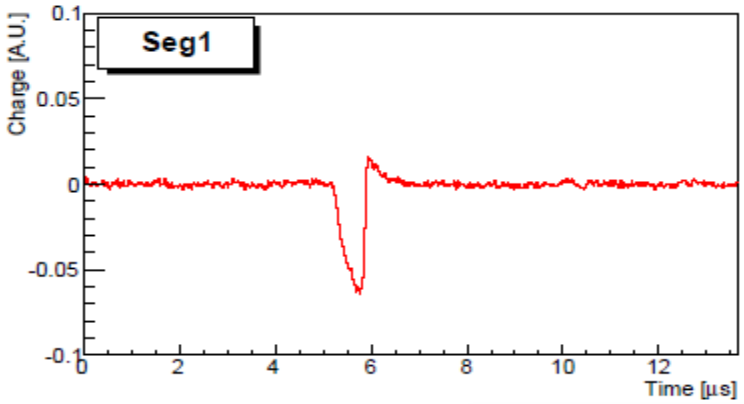

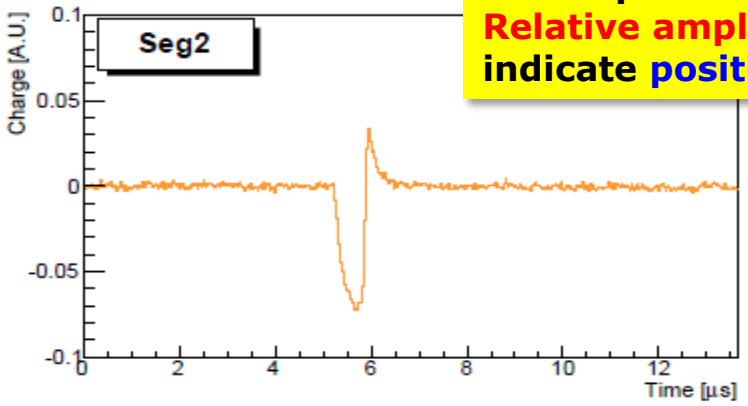

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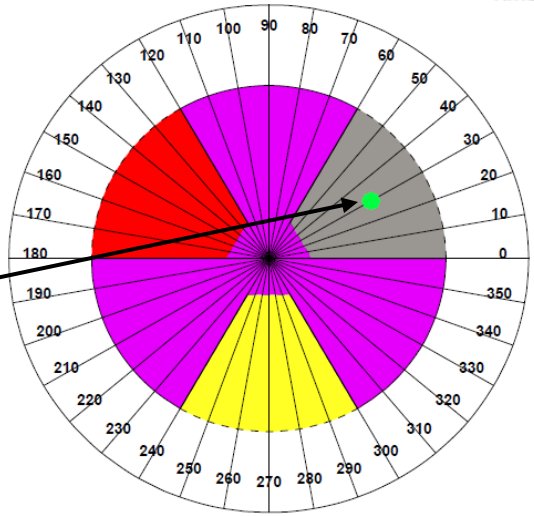

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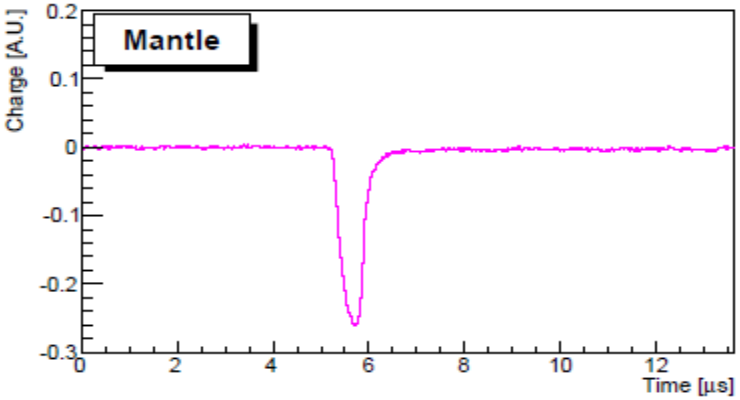

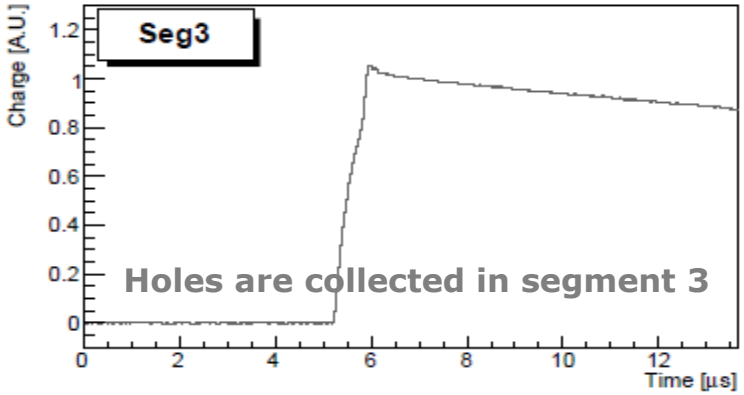

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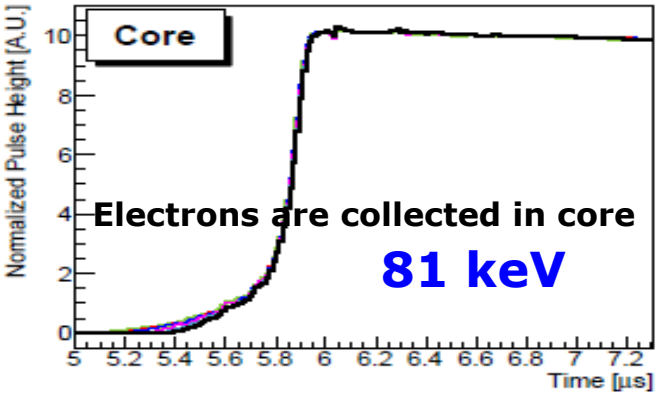
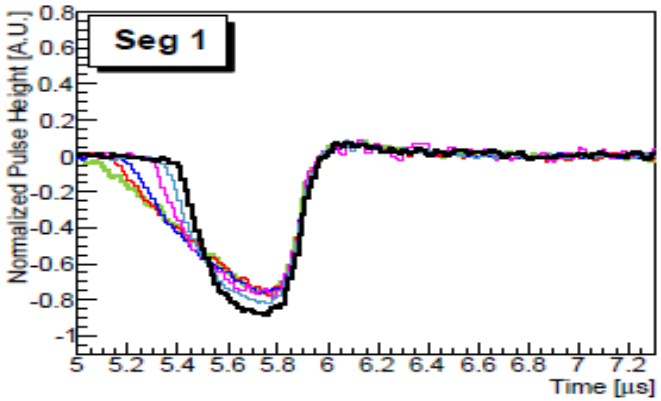
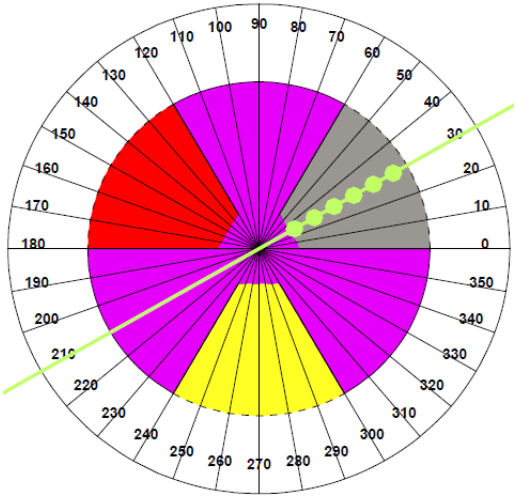
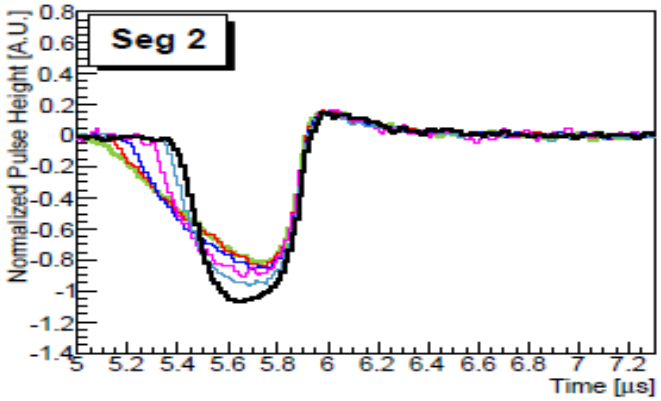
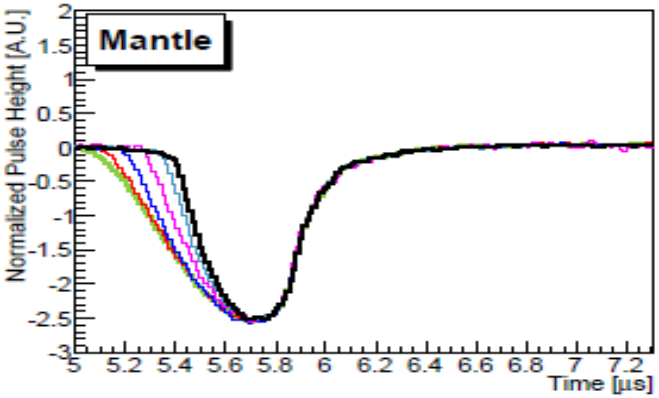


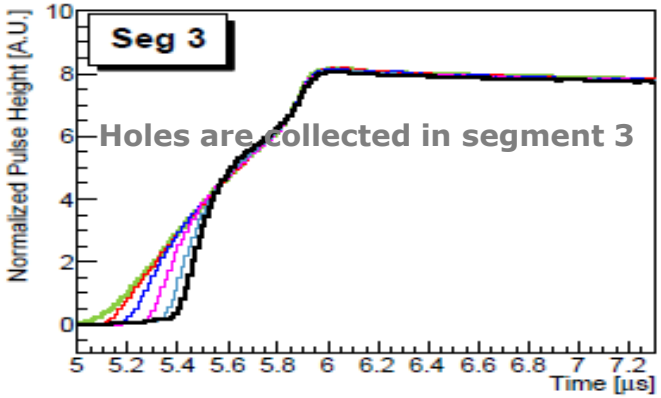


r=34 mm
r=29 mm
r=24 mm
r=19 mm
r=14 mm
r=9 mm









Pulse Shape Simulation

- **Why pulse shape simulation?**
  Improve the understanding of Germanium detector, like:
  - **impurity distribution**
  - **charge trapping**
  - **charge collection efficiency**
  - **Sensitivity of event topology**

- **Simulation tools:**

✓ **Geant4: physics process ⇨ hit info**

✓ **MaGe: Pulse shape simulation**

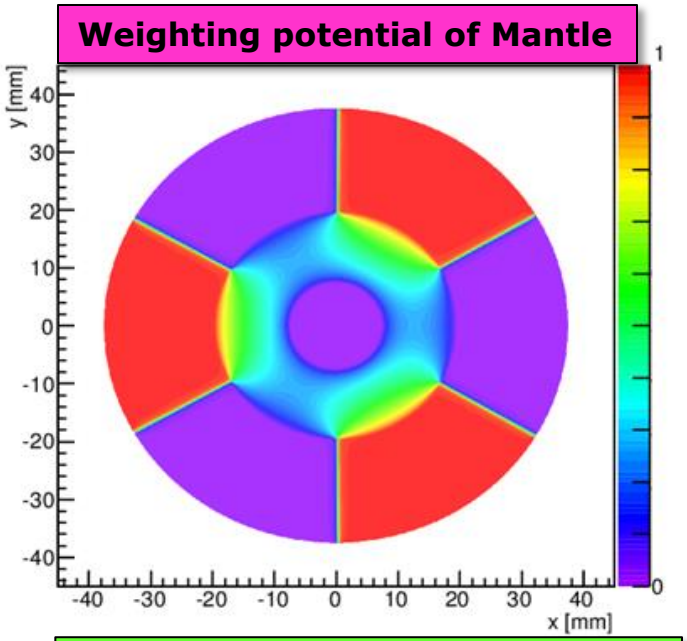
Field calculation

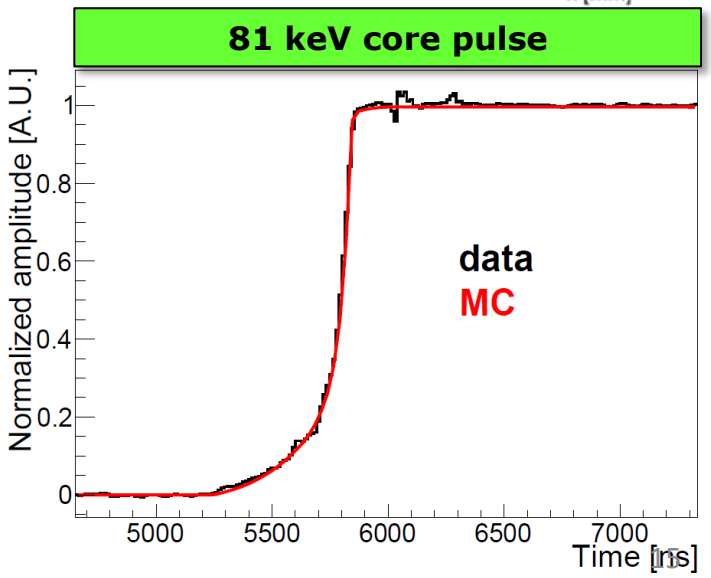
⇩

e/h drift in the bulk

⇩

induced charge on the electrode (waveform)





Summary & Outlook

Summary:

- **BEGe detector with extra segmentations useful to disentangle different event topologies**
- **The segmented BEGe detector is designed by GEDET group and built by Canberra France**
- **Commissioning since July, 2014**
- **Characterization using ^{133}Ba source**

Outlook:

- **Validate Monte Carlo**
- **Provide tools for detector design**
- **Write characterization paper**