DPG Frühjahrstagung Göttingen 2012

The GALATEA Test Facility

Analysis of Surface Effects for coaxial n-type Germanium Detectors

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MAX-PLANCK-GESELLSCHAFT

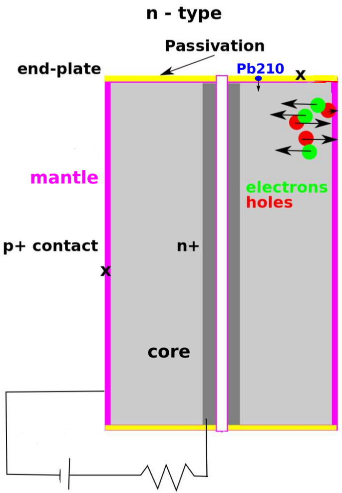
Outline

Germanium Detectors

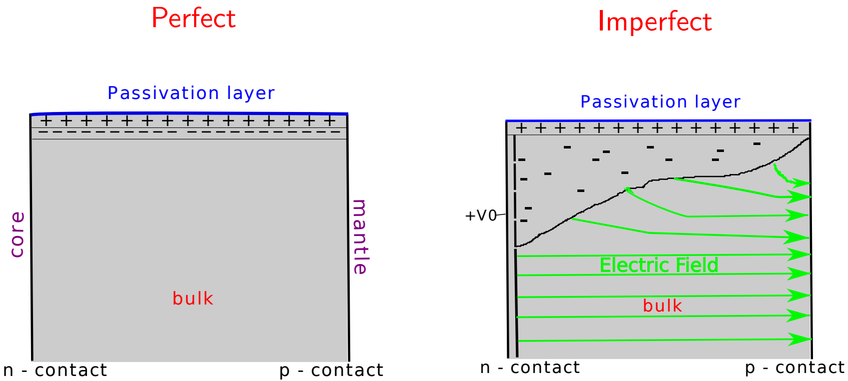
- Why Germanium Detectors?
  - Widely used in nuclear physics experiments and dark matter searches
  - Measurement of low levels of radioactivity
  - Gamma ray tracking
  - Very sensitive devices with a high resolution
- Segmentation of Germanium Detectors
  - Position reconstruction
  - Discrimination of signal and background events
- Further Germanium detector properties
  - Charge trapping
  - Surface effects

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



Surface Channel Effect



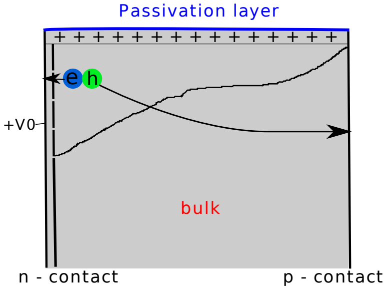
(not to scale) Figure adapted from: Ph.D. thesis by D. Lenz

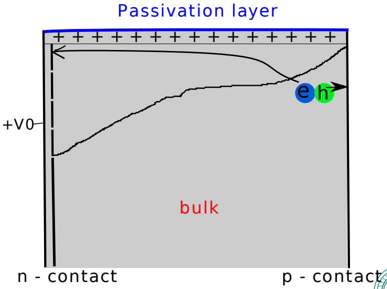
Path of electrons and holes in a detector with an n-type surface channel

Electron-hole pairs created in the surface channel region

(a) close to the n-contact

(b) close to the p-contact

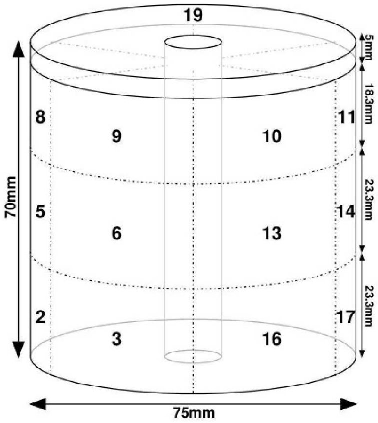




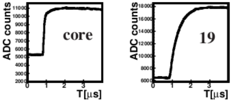
(not to scale) Figure adapted from: Ph.D. thesis by D. Lenz

"Supersiegfried"

- Cylindrical true coaxial n-type high purity germanium detector
- h = 70 mm
- Inner bore hole r = 5.05 mm
- Outer radius r = 37.5 mm
- 18 **+ 1** fold segmentation (3z and 6ϕ) $\rightarrow$ segmentation for inference of
  - Event topologies
  - Event positions
- Single segment on one side of the detector

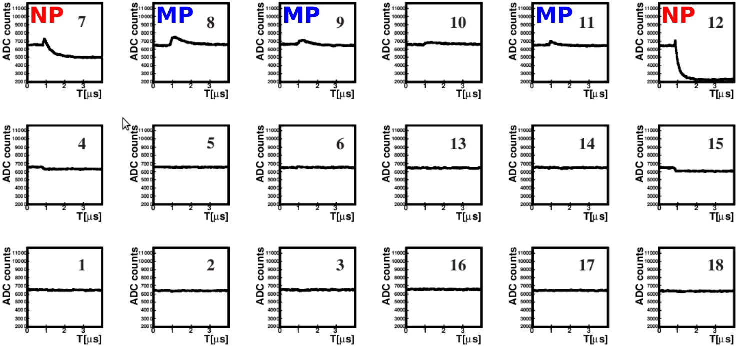


Example pulse seen by "SuSie" - one Event



E_{Core}=	455.8 keV	E_5=	0.0 keV	E_{10}=	0.0 keV	E_{15}=	0.0 keV
E_1=	0.0 keV	E_6=	0.0 keV	E_{11}=	0.0 keV	E_{16}=	0.0 keV
E_2=	0.0 keV	E_7=	0.0 keV	E_{12}=	0.0 keV	E_{17}=	0.0 keV
E_3=	0.0 keV	E_8=	0.0 keV	E_{13}=	0.0 keV	E_{18}=	0.0 keV
E_4=	0.0 keV	E_9=	0.0 keV	E_{14}=	0.0 keV	E_{19}=	1575.2 keV

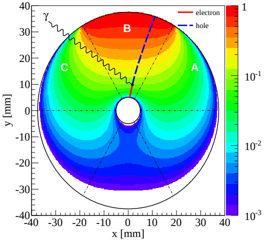
Ref.: from the Ph.D. Thesis: "Pulse Shape and Surface Effects in Segmented Germanium Detectors" by Daniel Lenz



NP = **Negative Pulse** **MP** = **Mirror Pulse**

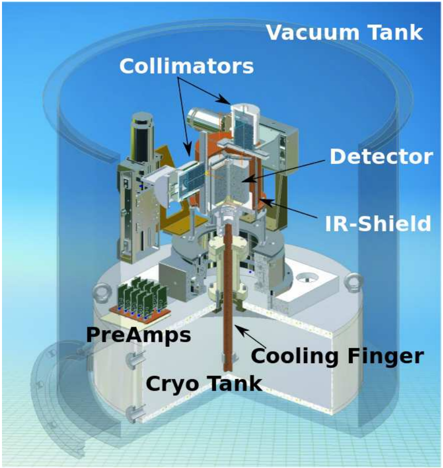
Pulse Shapes including Mirror Pulses

- Mirror Pulses in general
  - Information about the position of an event
    - Position in r $\rightarrow$ rise time plus polarity of mirror pulses
    - position in ϕ $\rightarrow$ relative strength of mirror pulses



- Proximity to end plates $\rightarrow$ we see long and strange pulses plus truncated mirror pulses
- How can we study this?

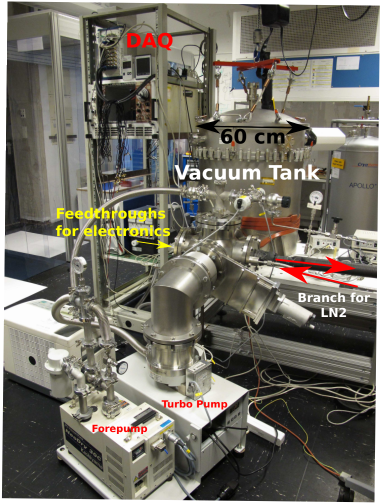
The Test Stand "Galatea"



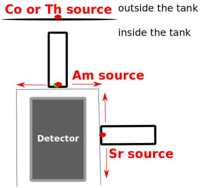
Technical Requirements

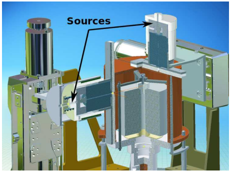
- Cooling System
- Vacuum
- Adjustable Sources
- Readout Electronics

The GALATEA setup



Experimental Scanning of the Detector



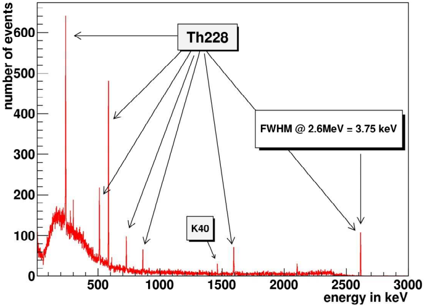


- Sources inside the tank: looking for events which relate to α and β
- Using α and β particles to study the surface $\rightarrow$ they do not penetrate deeply (penetration depth of an electron: $\approx$ 1mm at 1 MeV in Ge)
- Effective inactive layers can be measured very precisely

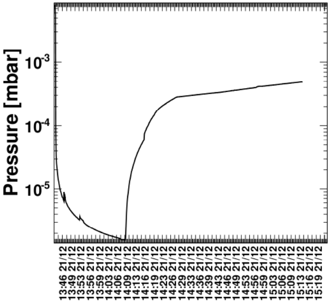
^{228}Th Spectrum seen by the "SuSie" Detector in one representive Segment

Resolution (in all measurements)

- 19th segment: $\approx$ 3 keV
- Core: $\approx$ 15 keV
- Segments: 3-4 keV



Status Report and Open Issues



Commissioning phase of Galatea

- Calibration spectra with a ^{60}Co and a ^{228}Th source have been taken
- Vacuum, cooling, grounding, cable shielding need to be improved
- Improvement of the core resolution

Summary and Outlook

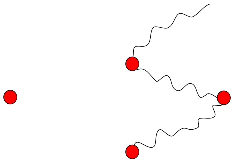
1. What is our plan?
   - Study surface effects in a segmented true-coaxial HPGe detector
   - Identify and characterize surface events
2. What do we need?
   - Scan of a special 19-fold segmented Ge detector with α and β sources
   - A test stand which allows a fully scan of the detector
3. Where are we?
   - Commissioning phase
   - First calibration spectra have been taken
4. **Looking forward to full detector scans!**

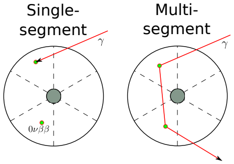
Backup Slides

Backup Slides

Characterisation of HPGe Detectors

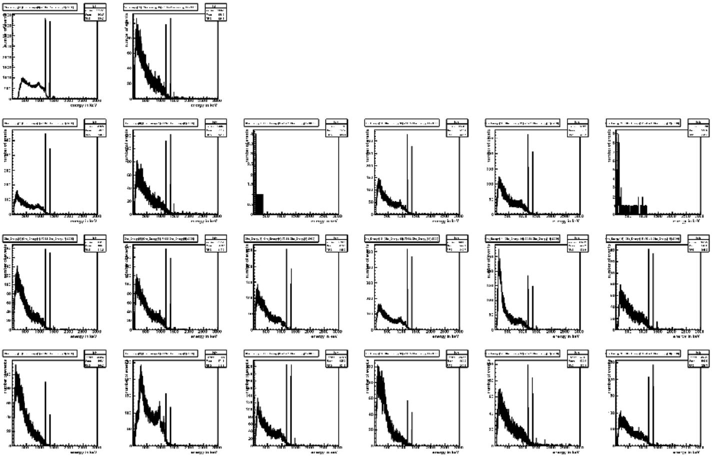
- Background reduction through event recognition in low-background experiments
  - $0\nu\beta\beta$: localized event
  - γ: multiside events





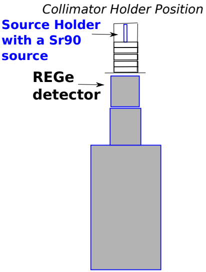
- Germanium detector properties are important for further analysis, like
  - Charge trapping
  - Surface effects

^{60} Co Spectra seen by the "SuSie" detector in all segments



^{90}Sr Spectrum seen by a ReGe detector

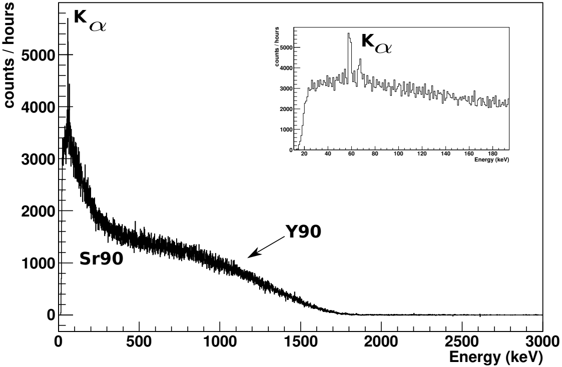
REGe = Reverse-Electrode Coaxial Ge Detector



Calibration Measurements

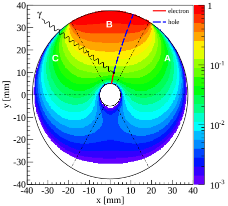
1. **The REGe Detector**
   - Geometry is related to cylindrical Ge detectors
   - mantle: p-contact, core: n-contact
   - 3 keV - 10 MeV
2. **Galatea Collimator holder**
   - W collimator segments
3. β **source: ^{90}Sr**
   - $^{90}\mathrm{Sr} \rightarrow {}^{90}\mathrm{Y} + e^{-} + \bar{\nu}$

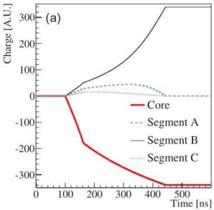
^{90}Sr Spectrum seen by a REGe Detector



Pulses and Mirror Pulses

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



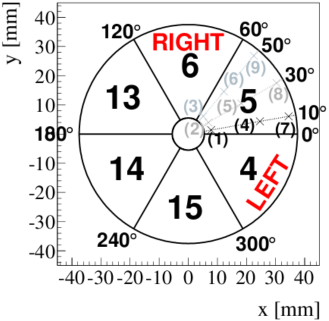


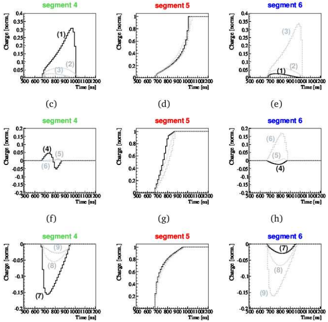
Real Pulse: charge "trajectory" <u>ends</u> at considered segment electrode

Mirror Pulse: charge "trajectory" <u>does not end</u> 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

Characteristics of Mirror Pulses





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