24th Indian-Summer School of Physics - Prague

Identification and Characterization of Signal and Background Events with Segmented Germanium Detectors

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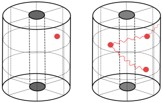
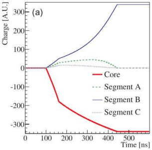
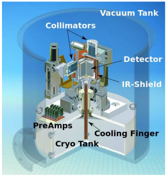
MAX-PLANCK-GESELLSCHAFT

Outline

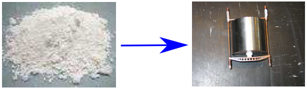
1. Why Germanium Detectors?
2. Characterisation of Signal and BG Events
3. n-type coaxial Detectors
4. Segmented Detectors
5. Pulses and Mirror Pulses
6. Experimental Scanning of the Detector
7. Summary and Outlook







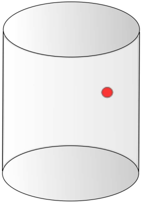
Why Germanium Detectors?



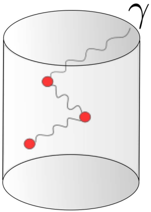
1. Detection of low levels of γ-radiation
2. Very good energy resolution $\rightarrow$ allows precision spectroscopy
3. Large active volume due to high purity
4. Detector $=$ Source (for some physics application like: search for the $0\nu\beta\beta$ decay; dark matter search)

Characterisation of Signal and Background Events

Background reduction through event recognition in low-background experiments (e.g. Gerda).



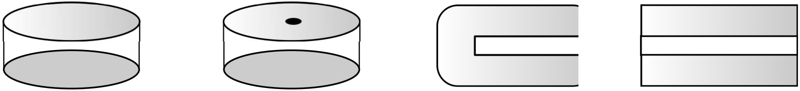
Signal (e.g. $0\nu\beta\beta$): localized event



Background (γ): multiside events

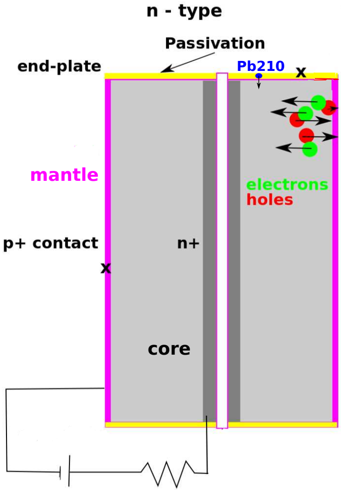
Germanium detector properties are important for further analysis, like charge trapping or surface effects.

Configurations of Germanium Detectors



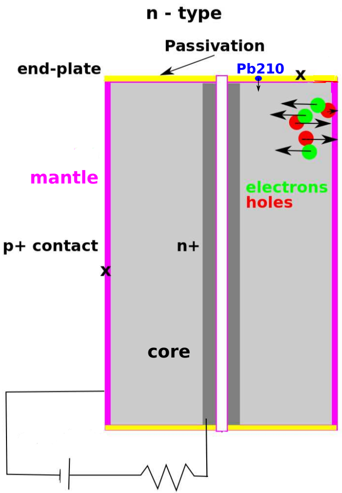
Planar **Point-contact** **Closed-ended coaxial (bulletized)** **True-coaxial**

n-type coaxial Detectors



n-type coaxial Detectors

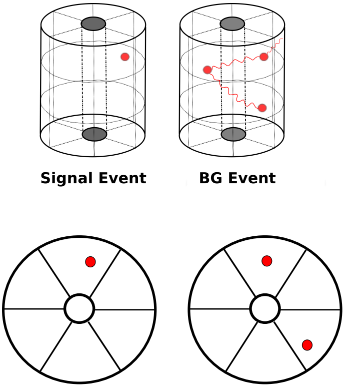
- electron-hole pair creation
- **n-type**: the electric field pulls the **electrons to the core** and the **holes to the mantle**
- resulting pulses are sampled and digitized at a given frequency
- passivation layers
- end plates → **contamination** → creates BG if part of energy is seen



Segmented Germanium Detectors

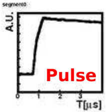
- Cylindrical true coaxial high purity germanium detector
- 18 fold segmentation (3z and 6ϕ) $\rightarrow$ segmentation for inference of
  - Event topologies
  - Event positions

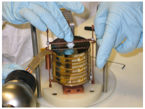
$\rightarrow$ Signal and BG discrimination



Example pulse seen by "Siegfried" - one Event

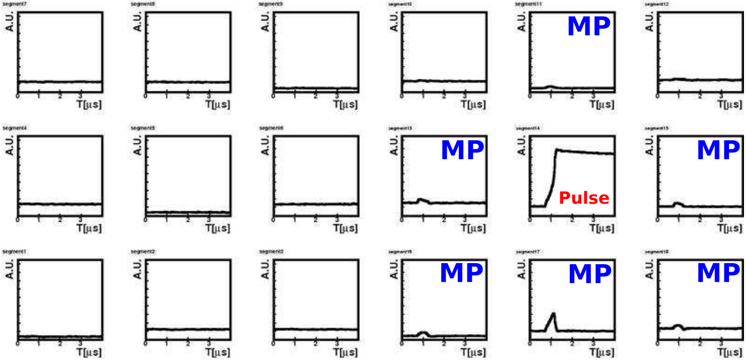
"Siegfried-II" Detector (n-type) Height: 70 mm
Inner radius: 5 mm
Outer radius: 37.5 mm





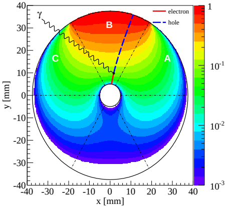
Eseg0=	1330.2	Eseg5=	0.0	Eseg10=	0.0	Eseg15=	0.0
Eseg1=	0.0	Eseg6=	0.0	Eseg11=	0.0	Eseg16=	0.0
Eseg2=	0.0	Eseg7=	0.0	Eseg12=	0.0	Eseg17=	1.1
Eseg3=	0.0	Eseg8=	0.0	Eseg13=	0.0	Eseg18=	0.4
Eseg4=	0.0	Eseg9=	0.0	Eseg14=	1327.6		

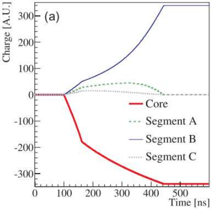
MP = Mirror Pulse



Pulses and Mirror Pulses

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



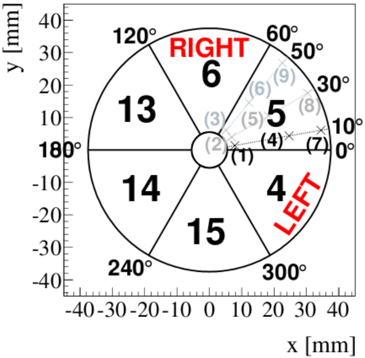


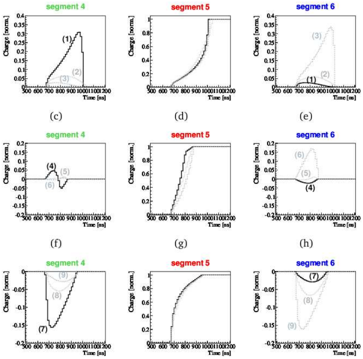
Real Pulse: charge "trajectory" ends at considered segment electrode

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

Characteristics of Mirror Pulses

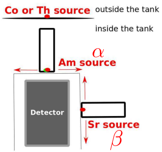




Ref: Diploma Thesis: "Mirror pulses and position reconstruction in segmented HPGe detectors" by S.Hemmer

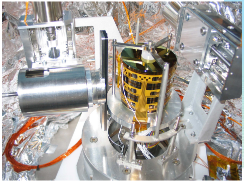
Experimental Scanning of the Detector: Teststand "Galatea"

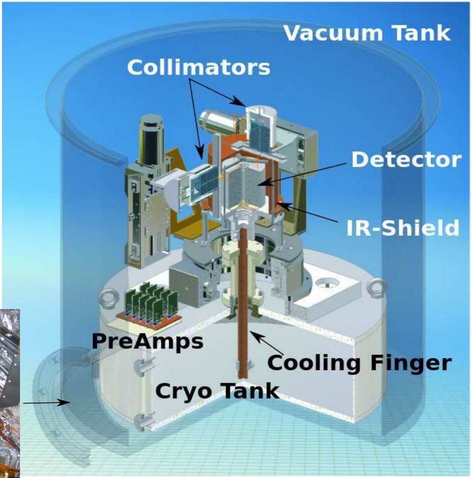
Detector Scanning



Scan of the detector with sources inside the tank (α, β- particles)

→ **studying surface effects**
→ **effective inactive layers can be measured very precisely**





Summary and outlook

- Segmented true-coaxial high-purity Germanium detectors $\rightarrow$ help to disentangle event topologies
- Pulses and Mirror Pulses give Information about
  1. The energy deposited
  2. 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
- Detector scans with high precision teststand for further detector studies $\rightarrow$ identify and characterize surface events

BackUp Slides

Surface Channel Effect

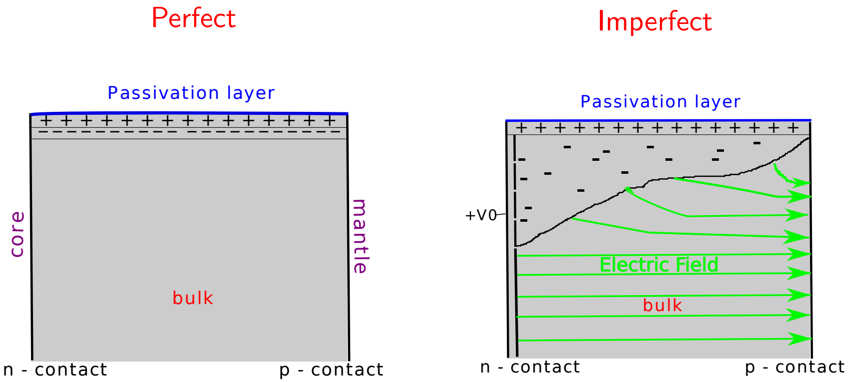


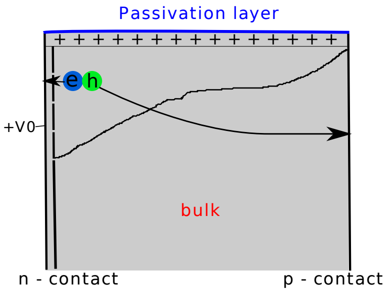
Figure adapted from: Ph.D. thesis by D. Lenz

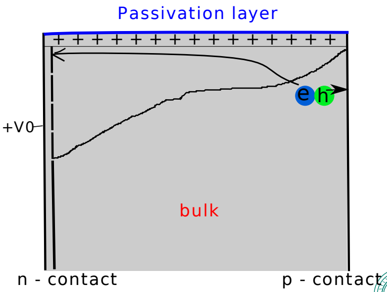
Path of electrons and holes in a detector with an n-type surface channel

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