Surface event pulse shape studies
of Phase I semi-coaxial Ge-detector

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Outline
1 Experimental Setup
2 Energy Spectrum
3 Monte Carlo
4 Pulse Shapes
5 A/E Properties
Motivation

- cleanroom & lock system
- steel cryostat (65 m³ of LAr)
- copper shield
- water tank
- Ge detector array

[The Gerda experiment on 0νββ decay — by K. Freund, T109.1]
Motivation

**semi-coaxial Ge-detector**

- bore hole (B)
- groove
- dead layer (Li)

**under investigation**

\[ ^{76}\text{Ge} \rightarrow ^{76}\text{Se} + 2e + 0\nu \]

**background**

1. \(\gamma\) events
   - compton scattering
   - photoelectric absorption
   - pair production

2. \(\alpha/\beta\) surface events

Surface event pulse shape studies
Motivation

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- +HV
- FADC
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**→ pulse shape**

Surface event pulse shape studies
Strontium source

**equation of physical decay**

\[ ^{90}\text{Sr} \rightarrow ^{90}\text{Y} + e + \bar{\nu}_e \]
\[ \rightarrow ^{90}\text{Zr} + e + \bar{\nu}_e \]

**endpoint energies**

\[ E_{\text{Sr\rightarrow Y}} = 0.546 \text{ MeV} \]
\[ E_{\text{Y\rightarrow Zr}} = 2.273 \text{ MeV} \]

- almost perfectly pure \( \beta \) source with activity of \( 7.0 \pm 1.4 \text{ kBq} \)
- ... interesting for studying signals related to surface events, e.g. \( \alpha \)'s
- totally encapsulated (welded stainless steel) with window of 50 \( \mu \text{m} \)
- ... allows localization for position sensitive data-taking
Experimental procedure

LAr test bench of GDL, consisting of a double-wall dewar and an attached glove box [M. Barnabé-Heider, 2009]

90Sr source (red circle), bare detector and preamplifier were submerged in LAr during data-taking

experiment was performed in GDL - a GERDA test facility @ LNGS
Measured positions

Schematic drawing of the positions locally exposed to the $^{90}$Sr source, view from bottom.

- data for 5 different positions
  - outer edge of detector
  - edge of detector — groove
  - outer edge of groove
  - in the groove
  - inner contact of detector

- additional calibration source: $^{60}$Co for energy calibration of the strontium spectrum (removable)
- $2 \times$ data (event & event-cali)
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  4. In the groove
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Experimental Setup

Energy spectrum

Monte Carlo

Pulse Shapes

A/E properties

Energy spectrum of $^{90}\text{Sr}$

Spectra measured with 'Prototype' detector exposed to the $^{90}\text{Sr}$ source.

- very different $^{90}\text{Sr}$ spectra shapes for positions 1, 2, 3 and positions 4, 5!

<table>
<thead>
<tr>
<th>Position</th>
<th>duration [sec]</th>
<th>number of events</th>
<th>count rate [s$^{-1}$]</th>
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<tbody>
<tr>
<td>1</td>
<td>1273.57</td>
<td>101998</td>
<td>80.1</td>
</tr>
<tr>
<td>2</td>
<td>1532.56</td>
<td>151054</td>
<td>98.6</td>
</tr>
<tr>
<td>3</td>
<td>1215.05</td>
<td>186477</td>
<td>153.5</td>
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<tr>
<td>4</td>
<td>87.31</td>
<td>94125</td>
<td>1678.0</td>
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<tr>
<td>5</td>
<td>193.68</td>
<td>148785</td>
<td>1441.8</td>
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1. higher count rates
2. proportionately more events in higher energy regions

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Because of (missing) dead layer?

MC simulations to check...
What was simulated?

- Implemented geometry of the 'Prototype' detector in MaGe (MC software based on Geant4)
- Decay chain $^{90}$Sr $\rightarrow ^{90}$Y $\rightarrow ^{90}$Zr
- Scan of several parameters:

  **Radial (x-)direction:**
  - $-1.3375 \text{ cm} \quad 4$
  - $-2.5 \text{ cm} \quad 2$

  **Vertical (z-)direction:**
  - $0.5 \text{ mm} \quad 0.8 \text{ mm} \quad 1.0 \text{ mm} \quad 1.2 \text{ mm} \quad 2$

  **Thickness of dead layer:**
  - $0.3 \mu\text{m} \quad 4$
  - $0.8 \text{ mm} \quad 1.0 \text{ mm} \quad 1.2 \text{ mm} \quad 2$
**Spectral shapes**

**position ②**
Measured and simulated spectrum for a fixed dead layer of 1.0 mm thickness:

**position ④**
Measured and simulated spectrum for a fixed vertical source distance of 1.0 mm:

**Match: dead layer thickness and source distance @ 1.0 mm**

**Match: source distance @ 1.5 mm**

- MC to determine dead layer thickness and distance of source to detector surface
- Very nice agreement between simulated and measured activity

\( A = 7.0 \pm 1.4 \text{ kBq}, \text{ datasheet by Eckert & Ziegler Nuclitec GmbH} \)
Energy deposition in active volume

Picture displays simulated interaction positions for different distributions of energy deposition for not only surface events for @ n+ contact

<table>
<thead>
<tr>
<th>thickness of active layer [mm]</th>
<th>deposited energy [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>position 2</td>
<td>position 4</td>
</tr>
<tr>
<td>≤ 1</td>
<td>38.4</td>
</tr>
<tr>
<td>≤ 2</td>
<td>47.5</td>
</tr>
<tr>
<td>≤ 5</td>
<td>64.5</td>
</tr>
<tr>
<td>≤ 10</td>
<td>78.5</td>
</tr>
<tr>
<td>≤ 20</td>
<td>90.2</td>
</tr>
<tr>
<td>≤ 50</td>
<td>98.9</td>
</tr>
<tr>
<td>whole active vol.</td>
<td>100</td>
</tr>
</tbody>
</table>

Table shows fraction of simulated dep. energy in regions of different layer thickness, starting from the surface.

- different distributions of energy deposition for
- not only surface events for @ n+ contact

**position 2**
1.1% of total dep. energy within the active volume

**position 4**
31.1% of total dep. energy within the active volume
Similar pulse shapes for different energy bins observed!
Average charge signal & risetime

Similar pulse shapes for different energy bins observed!

Charge pulses coming from the preamplifier.

Distribution of risetimes from 10% to 90%.

average of energy higher for 4 5
also: last two positions feature steeper slope → faster rise times
near read-out contact
Current signals

average

Current signal (can be obtained by differentiation of charge pulse):

"typical" signal / no average

Selection of exemplary current shapes of positions 1\(\oplus\)2 (smoothed):

Observed current shape of positions 1\(\oplus\)2 (smoothed):

- simulation of pulse shapes → in process

<table>
<thead>
<tr>
<th>position 1(\oplus)2</th>
<th>position 3</th>
<th>position 4(\oplus)5</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 different shapes</td>
<td>← mixture →</td>
<td>no variations</td>
</tr>
</tbody>
</table>
Definition: A/E

\[ \text{A/E} = \frac{\text{maximum current amplitude}}{\text{energy}} \]

- allows discrimination of signals originated from positions 1, 2, 3, and 4, 5.
**A/E for different positions and \(^{60}\text{Co}\)**

**Definition: A/E**

\[ A/E = \frac{\text{maximum current amplitude}}{\text{energy}} \]

Distribution of Amplitude-to-Energy-Ratio:

- allows discrimination of signals originated from \(1, 2, 3\) and \(4, 5\)
- events from \(^{60}\text{Co}\) peaks exhibit same A/E like first 3 positions
- separation sufficient for cutting procedure?

**e.g.:**

calibration measurement with additional \(^{90}\text{Sr}\) source from position 4
Calibration spectrum with A/E-Cut

= events originated from \( ^{90}\text{Sr} \) and \( ^{60}\text{Co} \) source

Calibration spectrum for position 

- original (red) and vetoed (green).

- applied veto cut: A/E < 0.65

- overview of cutting properties:

<table>
<thead>
<tr>
<th>energy [keV]</th>
<th>number of events</th>
<th>survival probability [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>all</td>
<td>325408</td>
<td>83613</td>
</tr>
<tr>
<td>1173 ± 2.5</td>
<td>2092</td>
<td>2001</td>
</tr>
<tr>
<td>1332 ± 2.5</td>
<td>1701</td>
<td>1637</td>
</tr>
</tbody>
</table>

suppression of \( \beta \)'s in calibration spectrum from position 4 works!
Outlook & Conclusion

- possible to distinguish/cut surface signals coming from the groove and near the inner contact.
- n+ surface: several different pulse shapes, similar to $^{60}$Co $\gamma$ lines
- p+ surface: no pulse shape variations observed
- drawback: no exp. measurements for borehole

[α background characterization for the GERDA experiment — by N. Becerici-Schmidt, T109.3]

To do / work in process:

- MC simulations of pulse shapes (using detector dimensions, applied depletion voltage, impurity concentration, etc.)
- attempt to understand / reproduce measured pulse shapes
- expand MC efforts to detector dimensions of GERDA Phase I for comparison with GERDA data