Surface event pulse shape studies

of Phase I semi-coaxial Ge-detector

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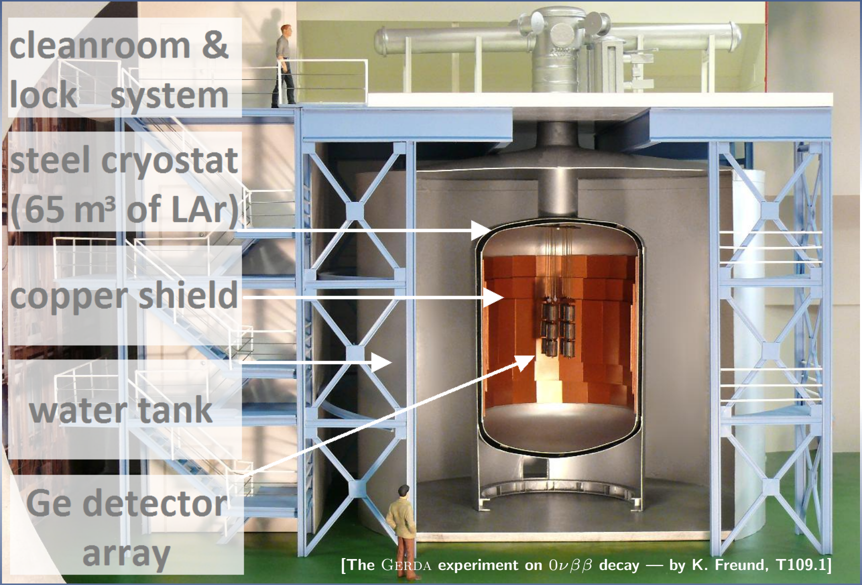
Outline

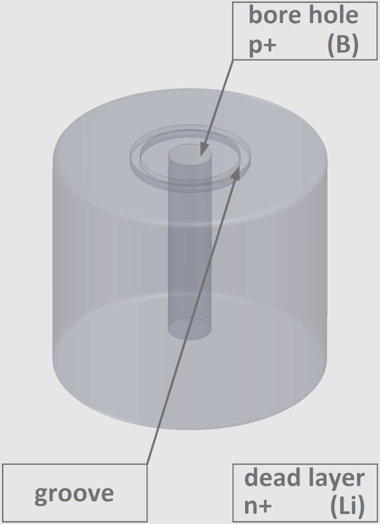
Motivation



[The GERDA experiment on $0\nu\beta\beta$ decay — by K. Freund, T109.1]

Motivation

semi-coaxial Ge-detector



under investigation

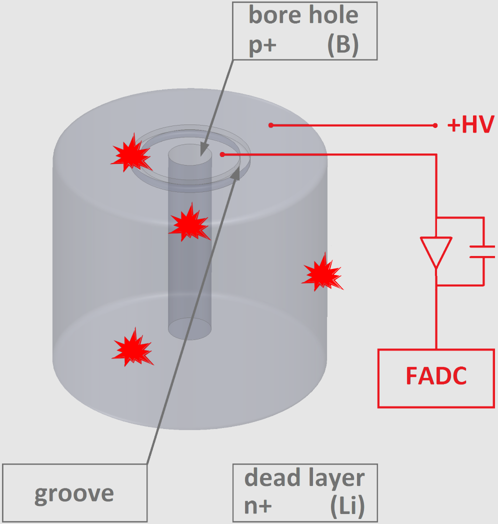
$^{76}\mathrm{Ge} \rightarrow {}^{76}\mathrm{Se} + 2\mathrm{e} + 0\nu$

background

1. γ events
   - compton scattering
   - photoelectric absorption
   - pair production
2. α/β surface events

Motivation

semi-coaxial Ge-detector



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background

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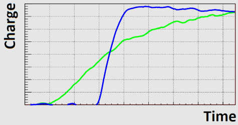
→ pulse shape



Strontium source

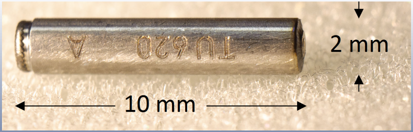
equation of physical decay

$$^{90}_{38}\mathrm{Sr} \rightarrow {}^{90}_{39}\mathrm{Y} + \mathrm{e} + \overline{\nu}_\mathrm{e}$$
$$\hookrightarrow {}^{90}_{40}\mathrm{Zr} + \mathrm{e} + \overline{\nu}_\mathrm{e}$$

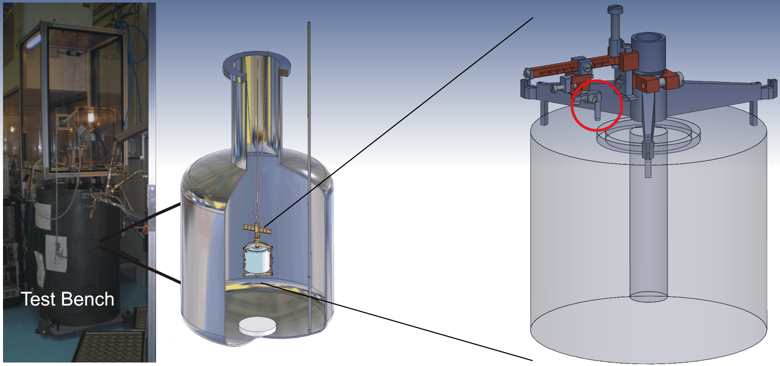
endpoint energies

$$E_{\mathrm{Sr}\rightarrow\mathrm{Y}} = 0.546\ M\mathrm{eV}$$
$$E_{\mathrm{Y}\rightarrow\mathrm{Zr}} = 2.273\ M\mathrm{eV}$$

- almost perfectly pure β source with activity of $7.0 \pm 1.4\ k$Bq
- ... interesting for studying signals related to surface events, e.g. α's
- totally encapsulated (welded stainless steel) with window of $50\ \mu$m
- ... allows localization for position sensitive data-taking



Experimental procedure



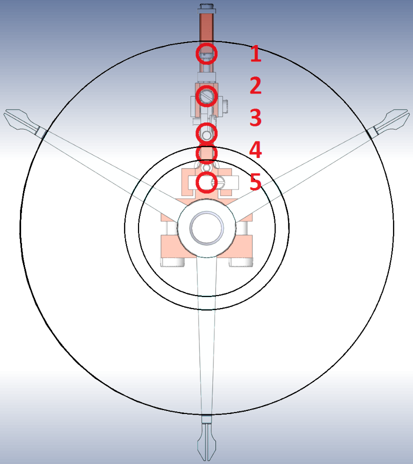
LAr test bench of GDL, consisting of a double-wall dewar and an attached glove box [M. Barnabé-Heider, 2009]

Schematic drawing of the used semi-coaxial HPGe detector with mounted source holder

^{90}Sr 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



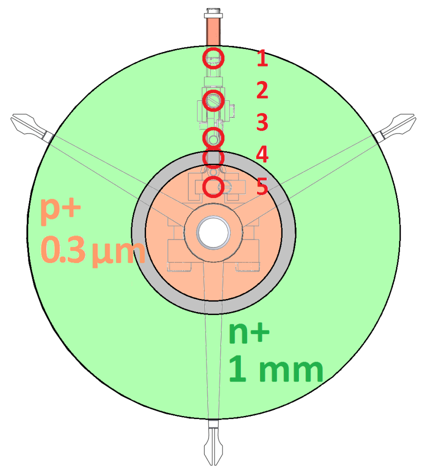
Schematic drawing of the positions locall
exposed to the ^{90}Sr source, view from bottom.

- data for 5 different positions

❶ outer edge of detector
❷ edge of detector – groove
❸ outer edge of groove
❹ in the groove
❺ inner contact of detector

- additional calibration source: ^{60}Co for energy calibration of the strontium spectrum (re-movable)
- 2 x data (event & event-calib)

Measured positions



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

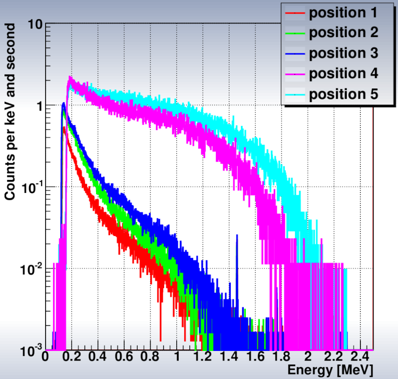
- data for 5 different positions

1. outer edge of detector
2. edge of detector – groove
3. outer edge of groove
4. in the groove
5. inner contact of detector

- additional calibration source: ^{60}Co for energy calibration of the strontium spectrum (removable)
- 2 x data (event & event-calib)

Energy spectrum of ^{90}Sr

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



- very different ^{90}Sr spectra shapes for positions ❶❷❸ and positions ❹❺!

Position	duration [sec]	number of events	count rate $[s^{-1}]$
1	1273.57	101998	80.1
2	1532.56	151054	98.6
3	1215.05	186477	153.5
4	87.31	94125	1678.0
5	193.68	148785	1441.8

1. higher count rates
2. proportionately more events in higher energy regions

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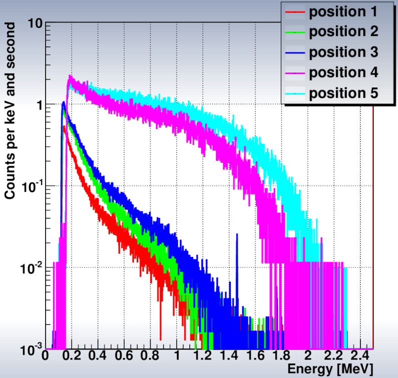

Because of (missing) dead layer?

MC simulations to check...

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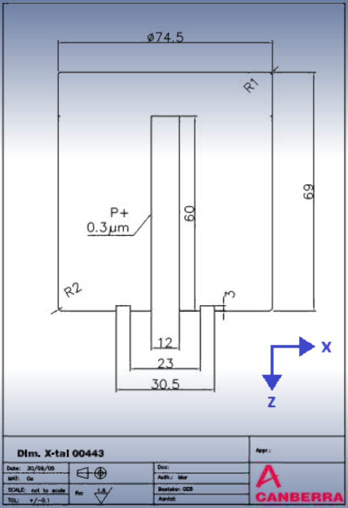
What was simulated?



Technical drawing with dimensions of the 'Prototype' detector, by CANBERRA

- implemented geometry of the 'Prototype' detector in MaGe (MC software based on geant4)
- decay chain ^{90}Sr→ ^{90}Y→ ^{90}Zr
- scan of several parameters:

radial (x-)direction:

-1.3375 cm ❹ -2.5 cm ❷

vertical (z-)direction:

0.5 mm 1.0 mm 1.5 mm

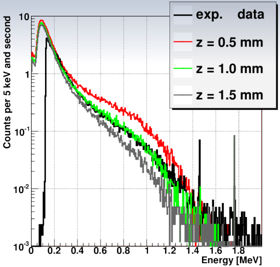
thickness of dead layer:

0.3 μm ❹ 0.8 mm 1.0 mm 1.2 mm ❷

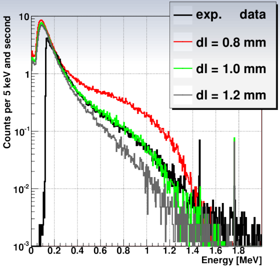
Spectral shapes

position ❷

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



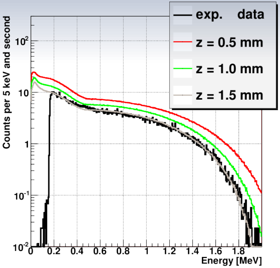
Measured and simulated spectrum for a fixed vertical source distance of 1.0 mm:



Match: dead layer thickness and source distance @ 1.0 mm

position ❹

Measured and simulated spectrum without dead layer → thickness of 0.3 μm:

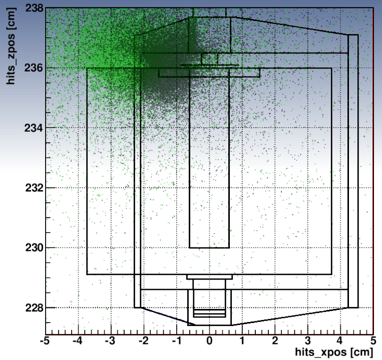


Match: source distance @ 1.5 mm

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

  ($A = 7.0 \pm 1.4$ kBq, datasheet by Eckert & Ziegler Nuclitec GmbH)

Energy deposition in active volume



Picture displays simulated interaction positions for ❷❹

thickness of active layer [mm]	deposited energy [%]	
	position 2	position 4
$\leqslant 1$	38.4	97.0
$\leqslant 2$	47.5	97.8
$\leqslant 5$	64.5	98.8
$\leqslant 10$	78.5	99.0
$\leqslant 20$	90.2	99.6
$\leqslant 50$	98.9	99.96
whole active vol.	100	100

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

- different distributions of energy deposition for ❷❹
- not only surface events for ❶❷❸ @ n_+ contact

position ❷

1.1% of total dep. energy within the active volume

position ❹

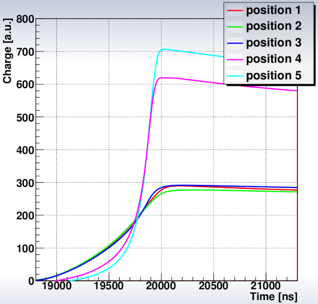
31.1% of total dep. energy within the active volume

Similar pulse shapes for different energy bins observed!

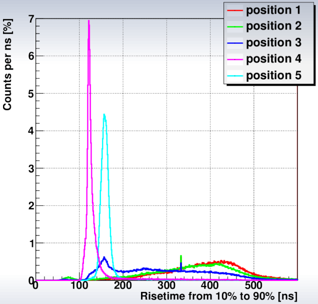
Average charge signal & risetime

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 ❹❺

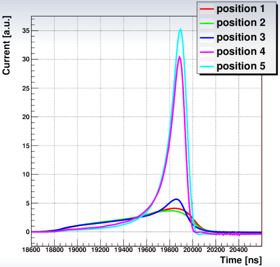
also: last two positions feature steeper slope → faster rise times

near read-out contact

Current signals

average

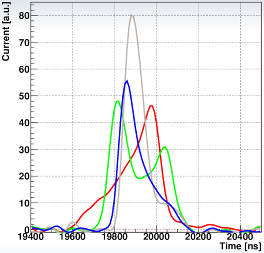
Current signal (can be obtained by differentiation of charge pulse):



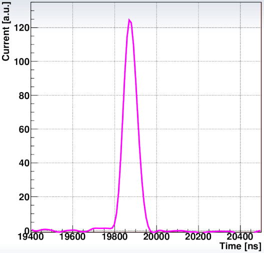
- simulation of pulse shapes → in process

"typical" signal / no average

Selection of exemplary current shapes of positions ❶❷ (smoothed):



Observed current shape of positions ❶❷ (smoothed):



position ❶❷

4 different shapes

position ❸

← mixture →

position ❹❺

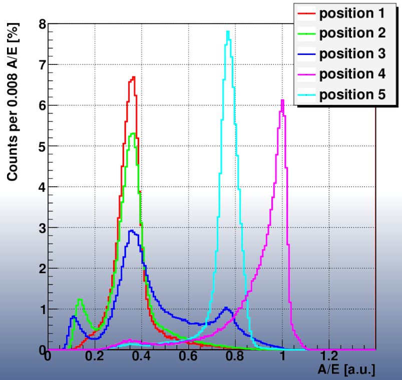
no variations

A/E for different positions

Definition: A/E

= maximum current amplitude ÷ energy

Distribution of Amplitude-to-Energy-Ratio:



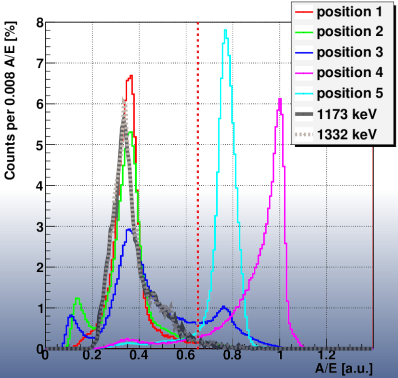
- allows discrimination of signals originated from ❶❷❸ and ❹❺

A/E for different positions and ^{60}Co

Definition: A/E

= maximum current amplitude ÷ energy

Distribution of Amplitude-to-Energy-Ratio:



- allows discrimination of signals originated from ❶❷❸ and ❹❺
- events from ^{60}Co peaks exhibit same A/E like first 3 positions
- separation sufficient for cutting procedure?

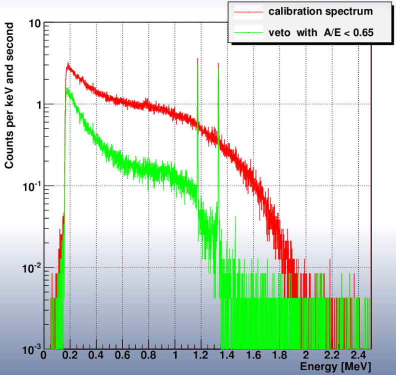
e.g.:

calibration measurement with additional ^{90}Sr source from position 4

Calibration spectrum with A/E-Cut

= events originated from ^{90}Sr and ^{60}Co source

Calibration spectrum for position ❹: original (red) and vetoed (green).



- applied veto cut: A/E < 0.65
- overview of cutting properties:

energy [keV]	number of events original	number of events vetoed	survival propability [%]
all	325408	83613	25.6
1173 ± 2.5	2092	2001	95.6
1332 ± 2.5	1701	1637	96.2

suppression of β's in calibration spectrum from position 4 works!

Outlook & Conclusion

- possible to distinguish/cut surface signals coming from the groove ❹ and near the inner contact ❺
- @ n_+ surface: several different pulse shapes, similar to ^{60}Co γ 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