Understanding Pulse Shape Discrimination in Germanium Detectors: Diffusion Effects

DPG Würzburg 2018

Barbara Schweisshelm

Max Planck Institute for Physics, Munich

March 22, 2018

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

GERDA Experiment

- Outstanding background reduction
- But: some background always remains
- Signal and background discrimination is indispensible

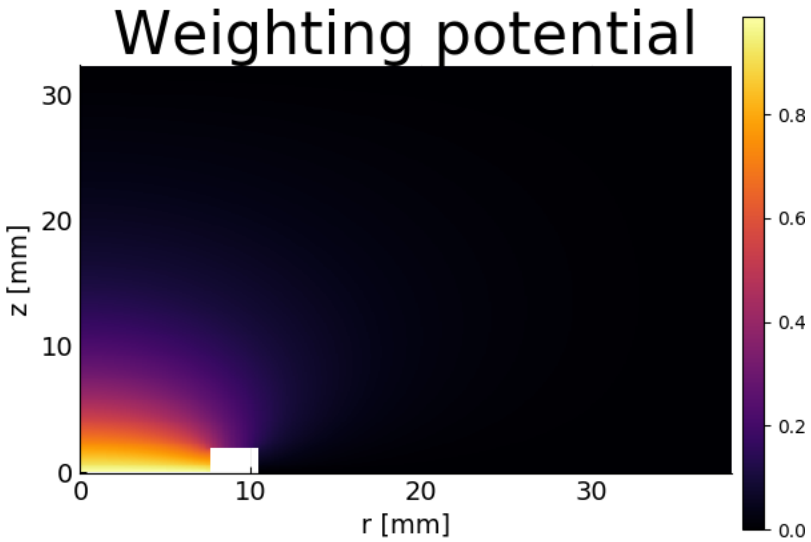
→ Pulse Shape Discrimination (PSD)

[GERDA Homepage]

30 Broad Energy Germanium (BEGe) detectors

- High energy resolution
- Pronounced weighting potential → simplifies PSD

Weighting Potential



Shockley - Ramo Theroem

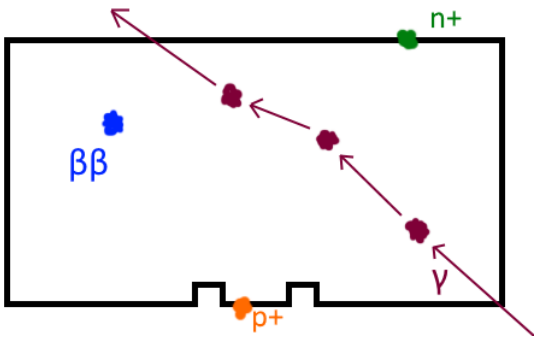
$$Q = -q\ \varphi_0(\vec{x})$$

Q = induced charge at electrode

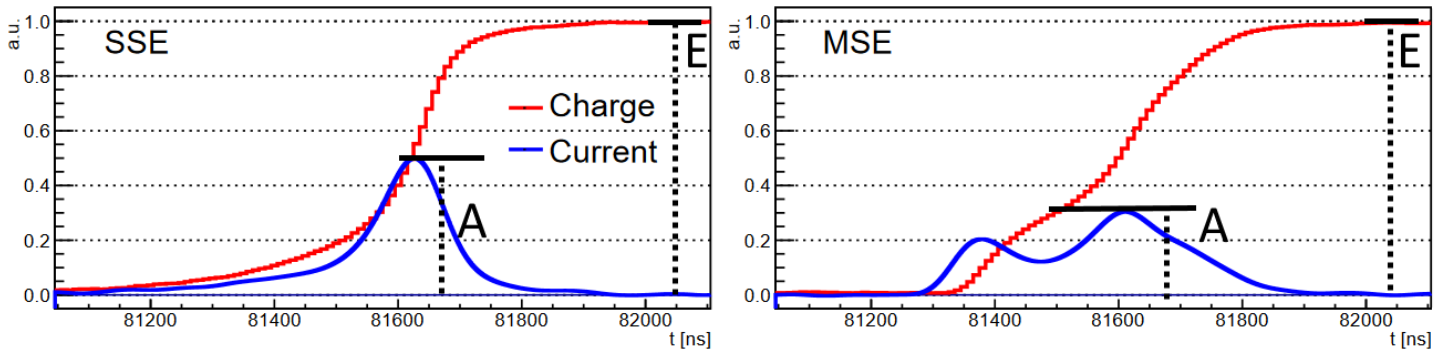
q = drifting charge

φ_0 = weighting potential

Pulse Shape Discrimination in GERDA BEGes



- Pronounced weighting potential at electrode
- Distinguish single site (SSE) and multi site events (MSE)
- Rejection of surface events

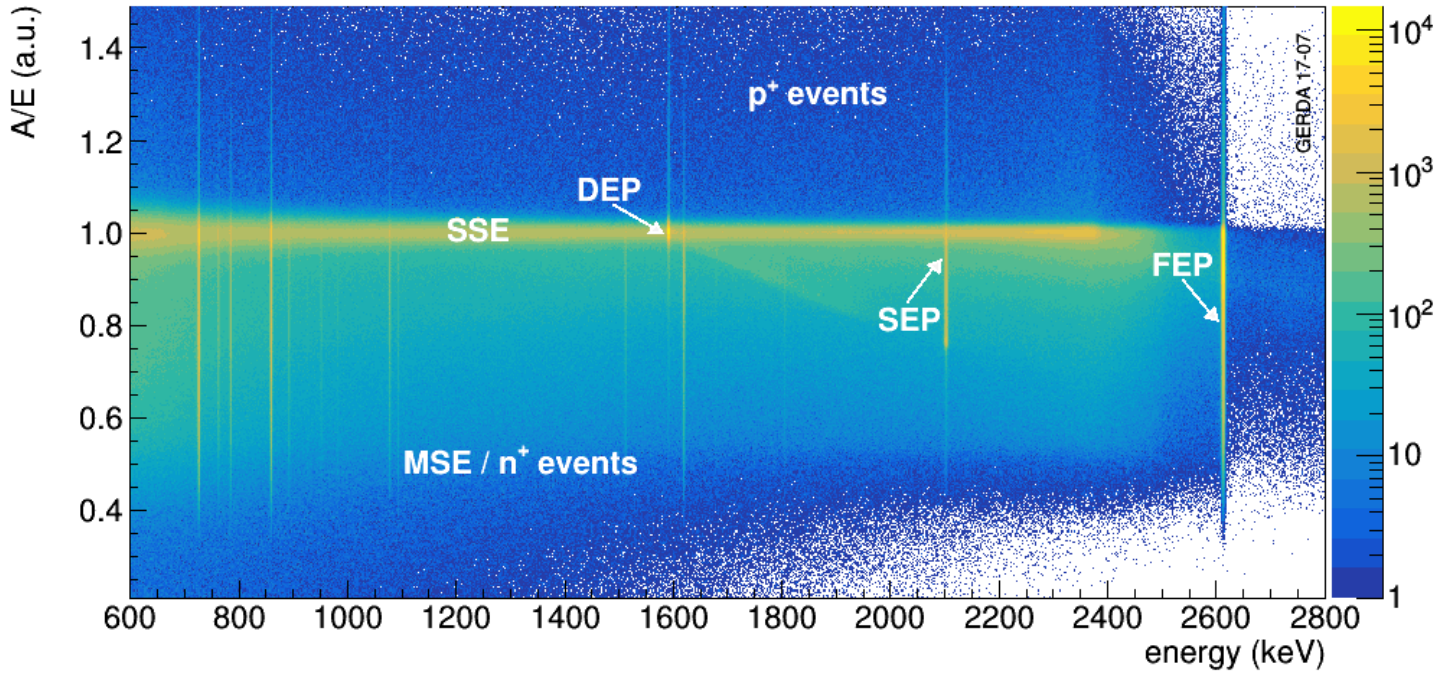


[adapted from arXiv: 1307.2610]

Amplitude / Energy (A/E) of current signal gives information over event topology → A/E used to classify events

2D Calibration Spectrum

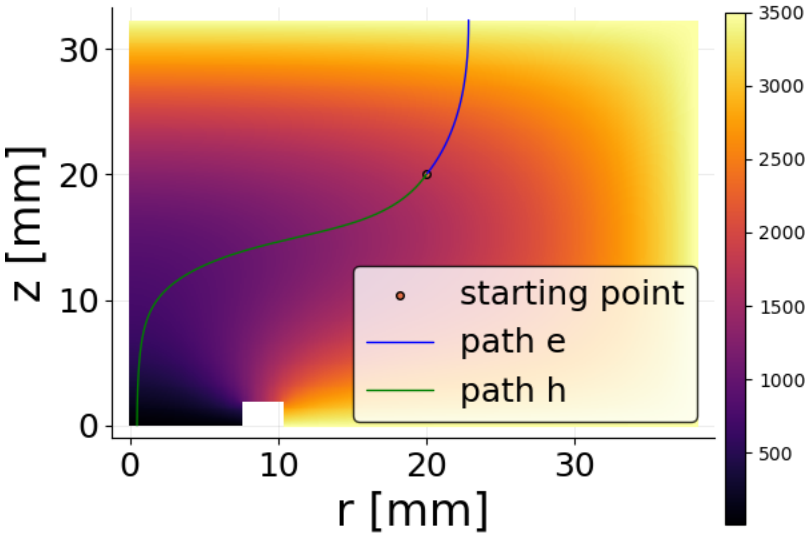
A/E spectrum for Th calibration data



Double escape peak (DEP), single escape peak (SEP) and full energy peak (FEP) of ^{208}Tl

What influence do diffusion effects have on this spectrum?
$\rightarrow$ Simulation

Charge Diffusion in SigGen Simulation



SigGen code by David Radford,
open source:
`https://radware.phy.ornl.gov/MJ/mjd_siggen/`

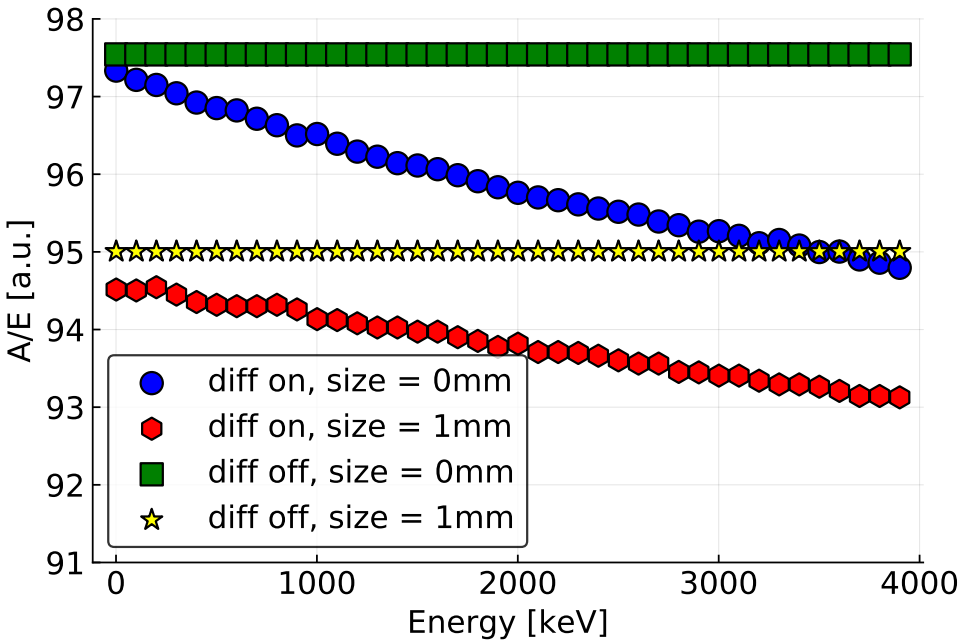
- Spherical charge clouds
- Holes and e^- separately
- Cloud is traveling through the detector
  $\rightarrow$ velocity depends on field strength at each point
- Charge cloud size affected by diffusion and self-repulsion
- Track drift of point charge and cloud dimensions separately $\rightarrow$ convolution

$\rightarrow$ How does the diffusion affect A/E?

Effect on Simulated Pulses

Energy deposition at **a specified position**

$\rightarrow$ Energy dependence of the current pulse amplitude (A)?

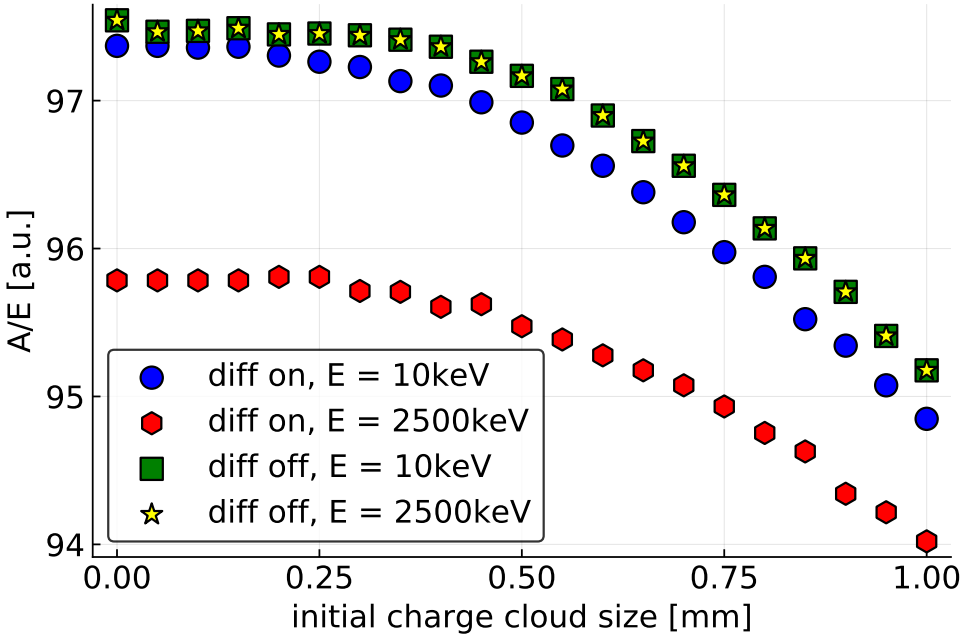


- Diffusion creates a slope
- Initial charge cloud size additionally decreases A/E

Effect on Simulated Pulses

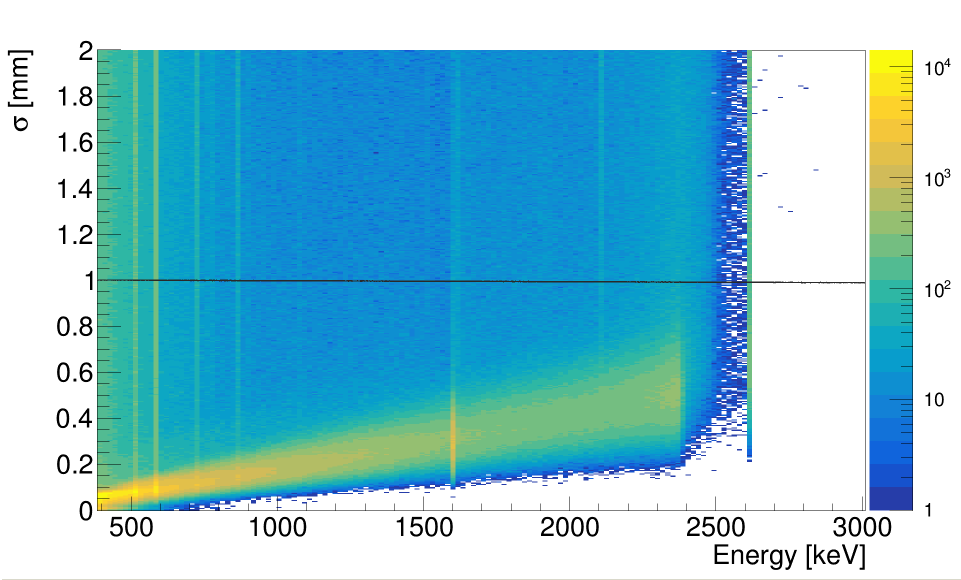
Energy deposition at **a specified position**

→ Initial charge cloud size dependence of pulse amplitude?



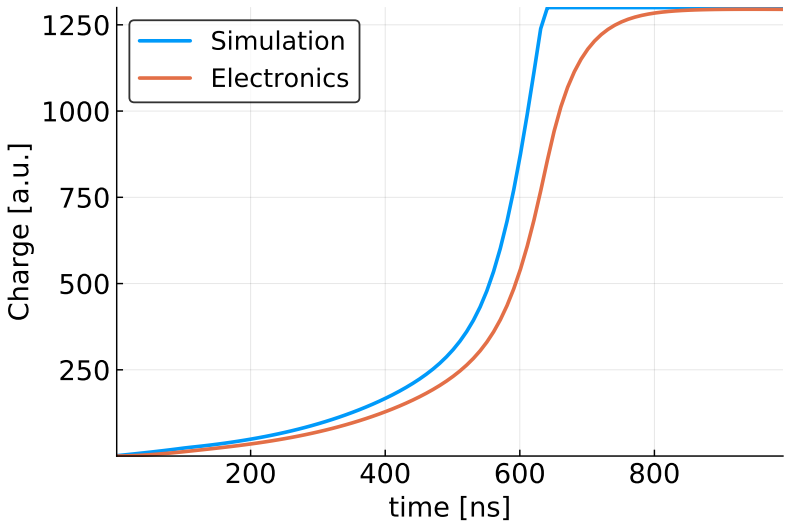
- A/E decreases with increasing charge cloud size
- Diffusion leads to an additional decrease with energy

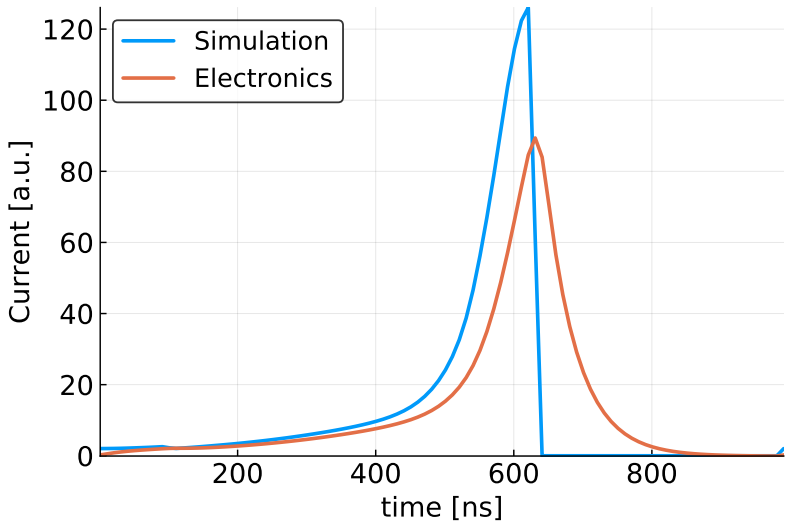
E dependence of initial single site cloud size



- σ of hits given by Geant4 Th calibration simulation
- Higher E $\rightarrow$ bigger charge cloud size $\rightarrow$ lower A/E
- Study effect of different clustering sizes

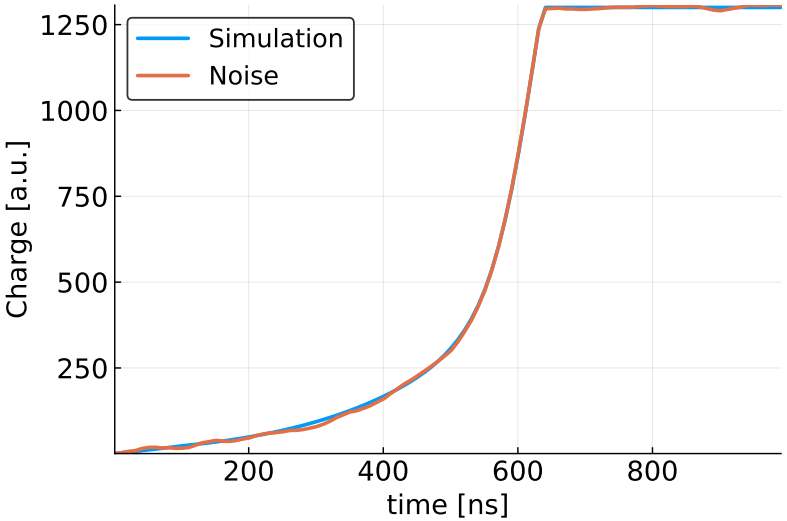
Electronics Model

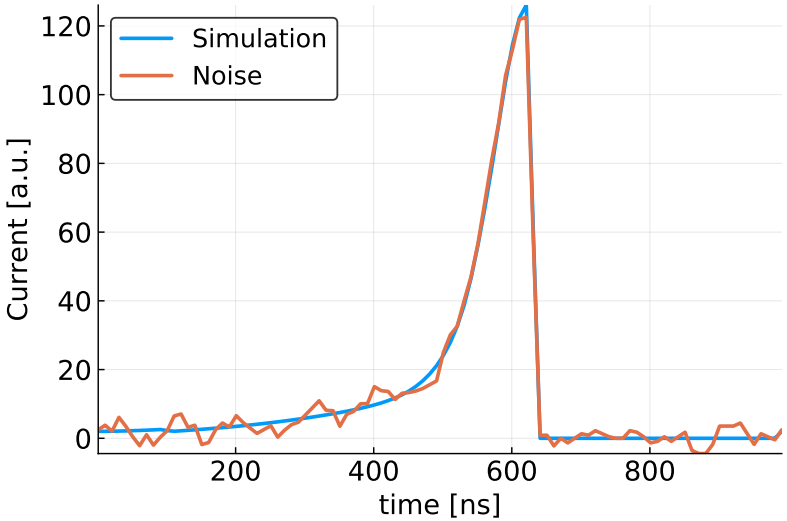




- Optimization of parameters using averaged DEP events from data
- Electronics smoothens the pulses

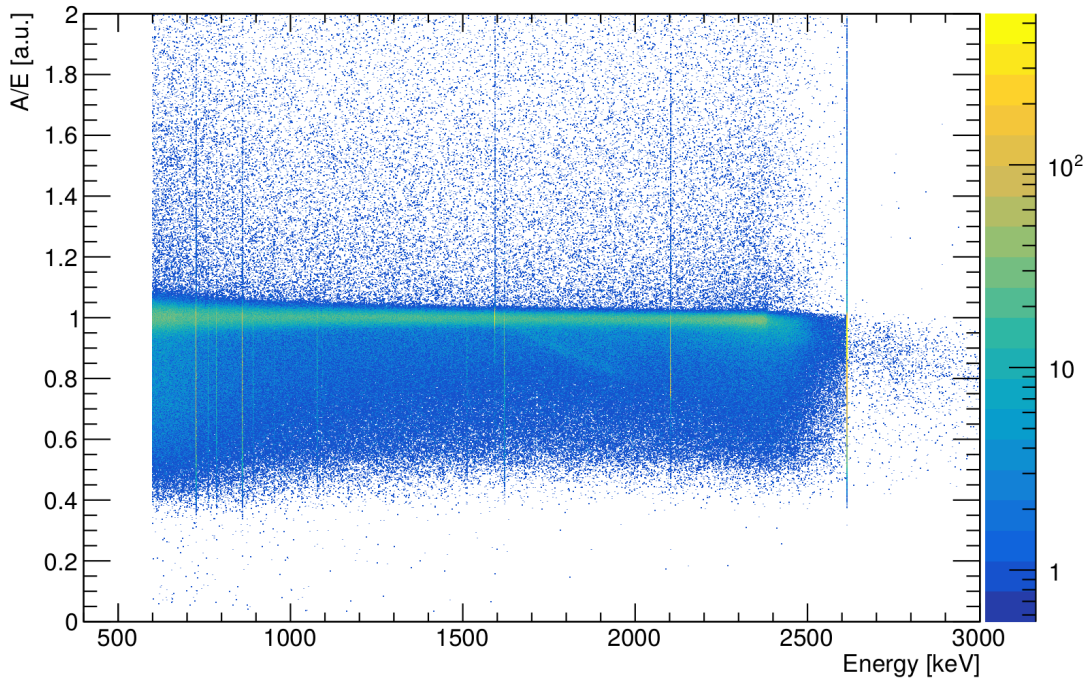
Realistic Noise





- Sharp A/E distribution from simulated pulses
- Extract noise from baseline events
- Add noise for a more realistic distribution

Energy Dependence of A/E



- A/E distribution with electronics and realistic noise
- A determined after 50 ns moving window average filter
- Slope of SSE band determined by fit

Results for one BEGe

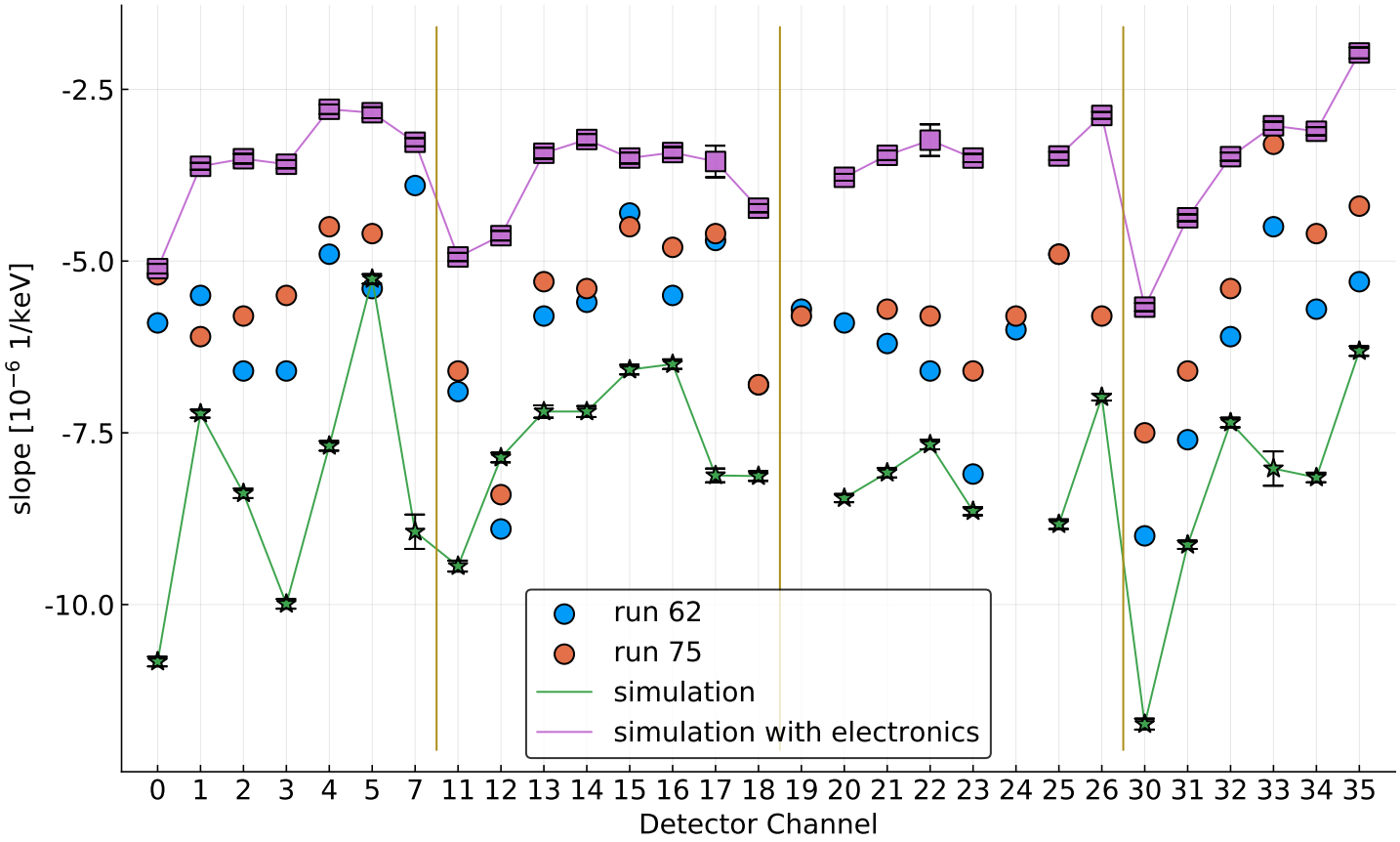
Simulated slopes [10^{-6} keV^{-1}]

	without electronics	
clustering size	diff on	diff off
0 mm	-8.03 ± 0.07	-8.18 ± 0.07
0.1 mm	-7.67 ± 0.07	-8.15 ± 0.08
0.3 mm	-7.09 ± 0.07	-7.58 ± 0.07
0.5 mm	-7.68 ± 0.06	-5.59 ± 0.21
	with electronics	
0 mm	-3.07 ± 0.07	-3.24 ± 0.06
0.1 mm	-3.24 ± 0.23	-2.83 ± 0.06
0.3 mm	-3.21 ± 0.07	-2.69 ± 0.06
0.5 mm	-3.14 ± 0.06	-2.11 ± 0.06

- Uncertainty given by fit
- Slope is already induced by event size (not diffusion)
- Electronics model reduces slope

Comparison of all Detectors

Slopes of SSE band for all detectors in data and simulation



- Simulated slope and data are same order of magnitude
- Simulation shows similar trends as data

Conclusion

- BEGe detectors $\rightarrow$ powerful event by event background identification
- Energy dependence of A/E seems to be mainly caused by event size
- Diffusion goes in the same direction but the effect is not significant if the event size is taken into account
- Electronics model has a larger influence than diffusion
- Electronics model can reproduce the trends within the strings
- Pulse shape simulations help GERDA to understand A/E better