Active Volume studies of depleted and enriched BEGe detectors

Katharina von Sturm

for the GERDA Collaboration

Università degli Studi di Padova
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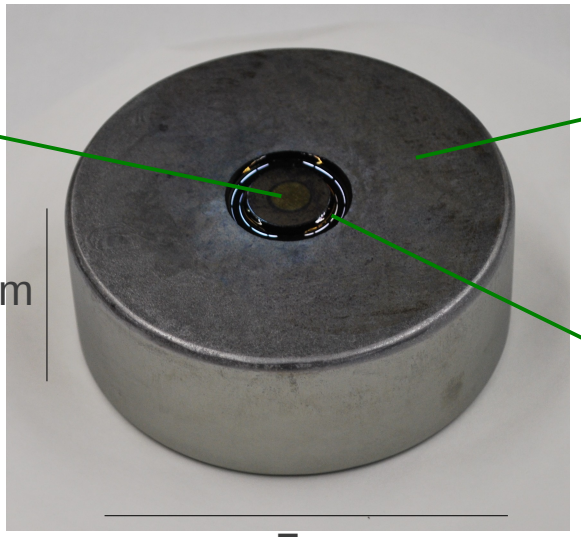
Broad Energy Germanium detectors

- GERDA is aiming to prove the existence of the 0νββ decay
- BEGe chosen as Phase II detector geometry for GERDA
- Point contact diodes → improved pulse shape discrimination performance
- Made of ultra pure Germanium (Ge) enriched in ^{76}Ge
- Detectors fabricated from depleted material for testing purposes
- Of special importance for GERDA is their Active Volume (AV)

Active Mass
~ Active Volume

$$T_{1/2}^{0\nu} > a\,\epsilon\,\sqrt{\frac{M \cdot t}{B \cdot \Delta E}}$$

p+ contact
B implanted
does not contribute
to DL

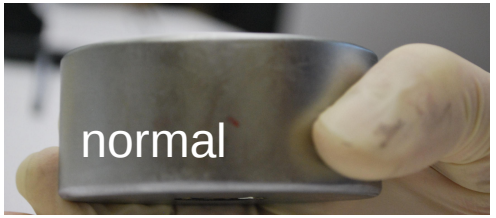


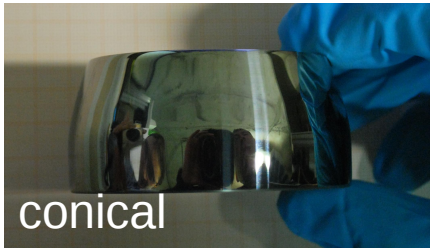
outer surface
Li drifted
Dead Layer (DL)

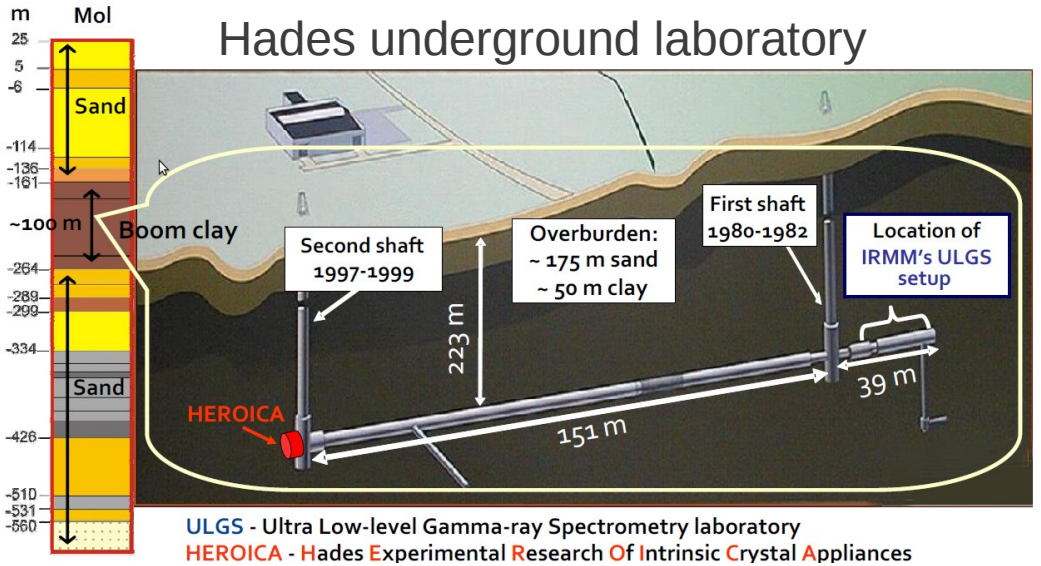
Groove
separating
n+ and p+ contact

Measurements

- 30 diodes were characterized in the Hades underground laboratory in Belgium
- Diodes have rather different shapes as the aim was to keep as much material as possible

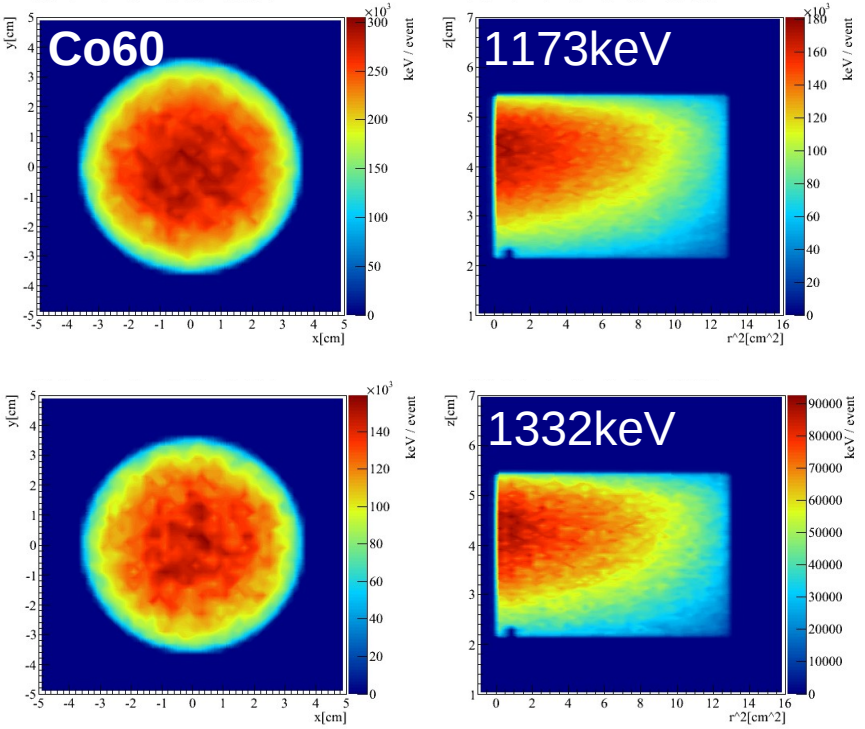


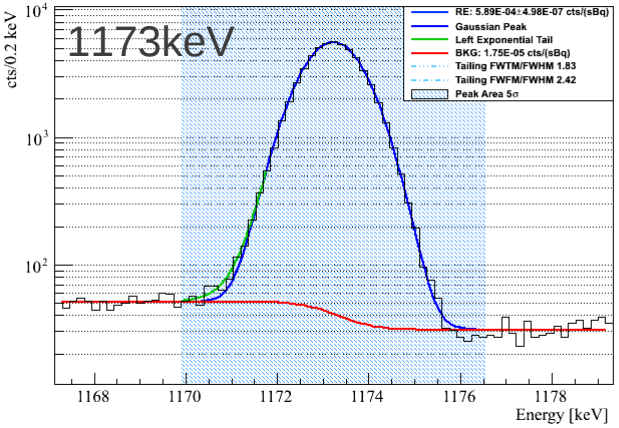


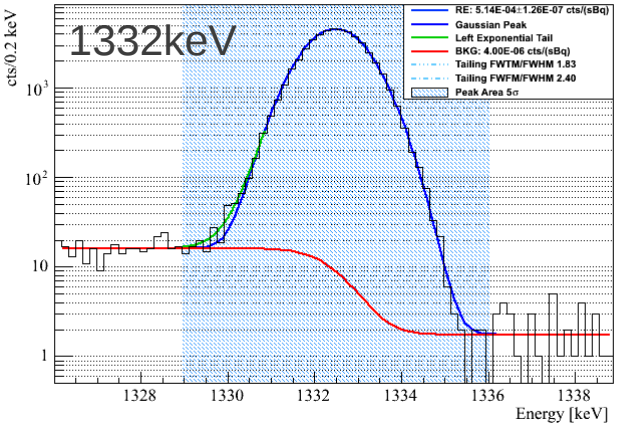


^{60}Co AV determination

- AV determination with ^{60}Co
- Total count rate at 1173keV and 1333keV is compared to MC
- Peaks are fitted with a Gaussian and an exponential low energy tail
- Depends on gamma attenuation
- Sensitive to the whole detector volume







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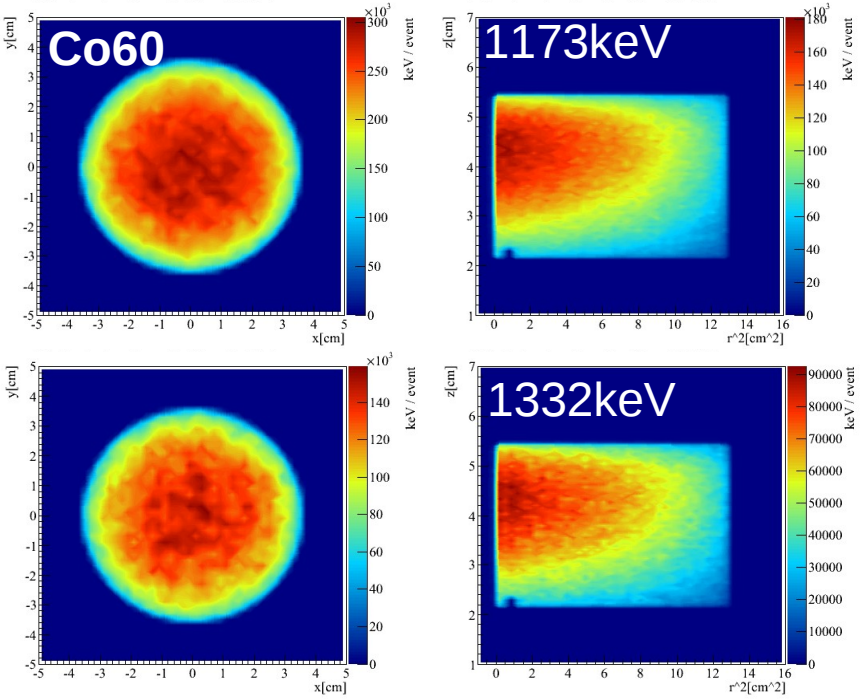
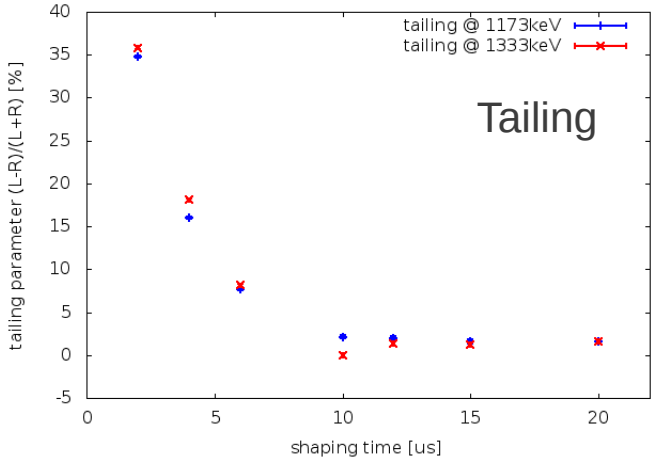
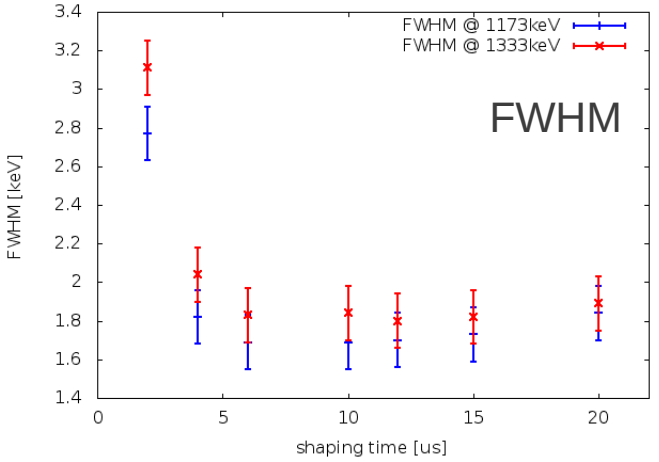
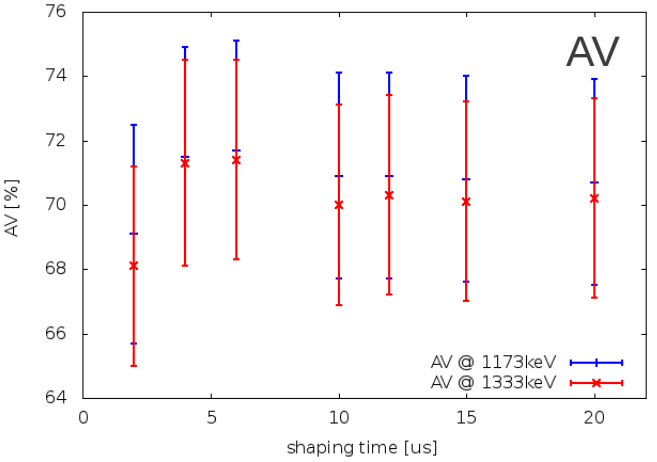


AV independent if the fit contains the tail

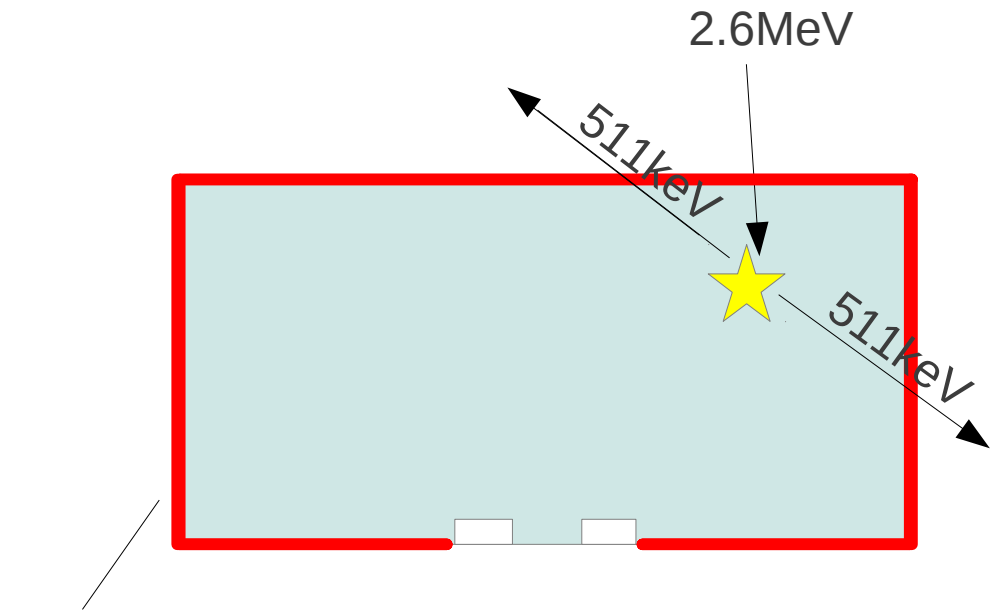




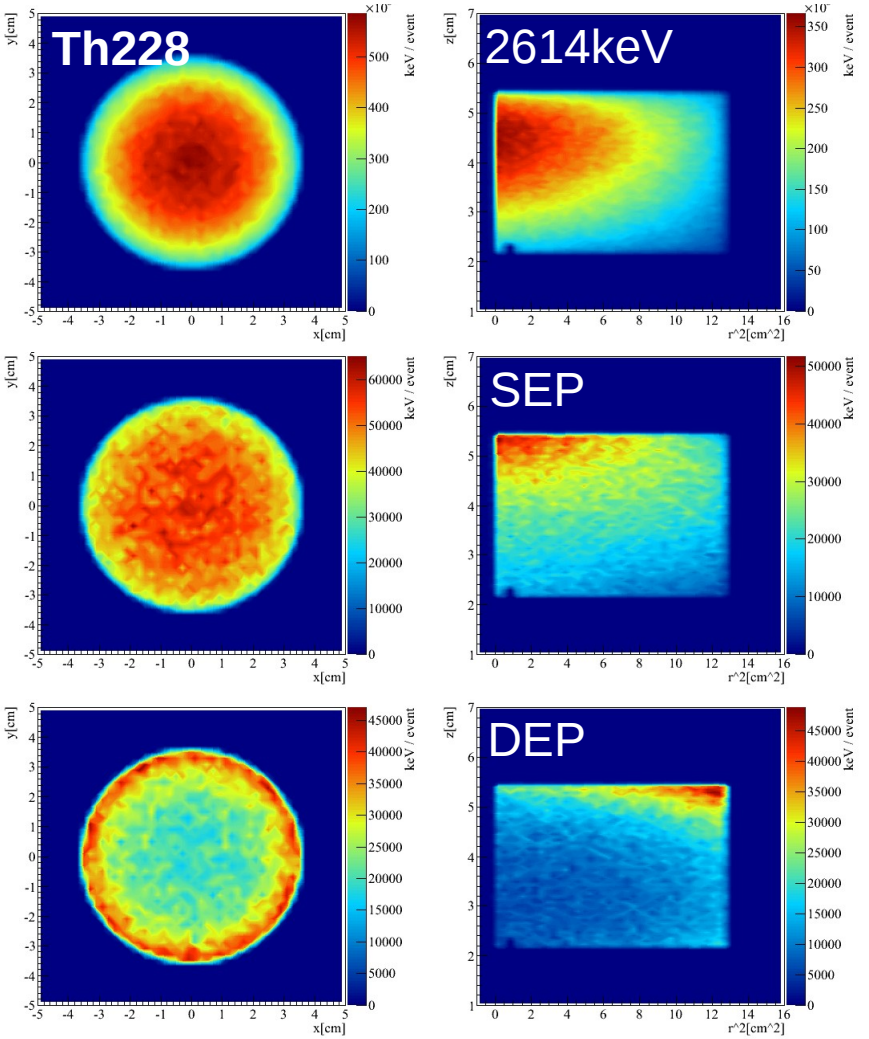


^{228}Th AV determination

- AV determination with ^{228}Th
- Ratios FEP/DEP and SEP/DEP are compared to MC simulation
- Sensitivity smaller than ^{60}Co
- Depends only on geometry



Dead Layer on outer surface Li drifted



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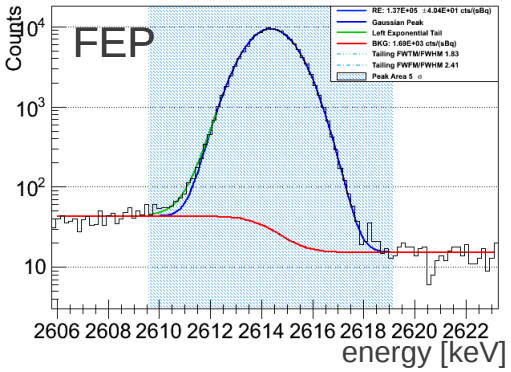
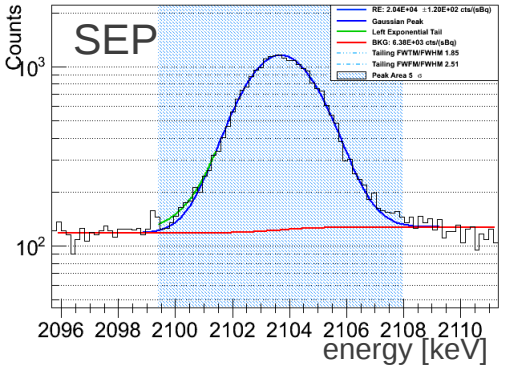
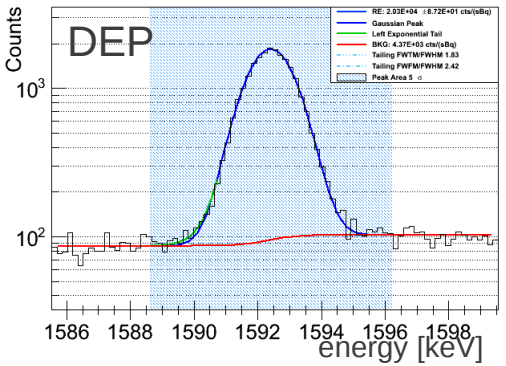
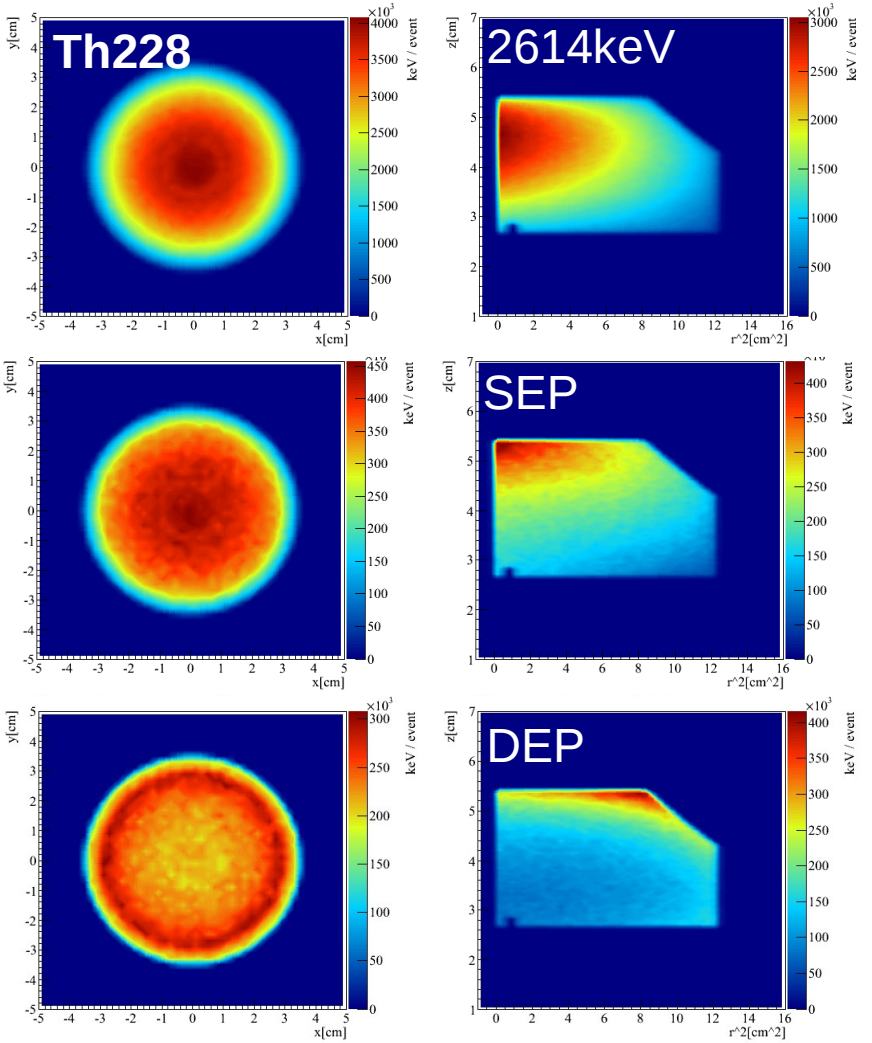


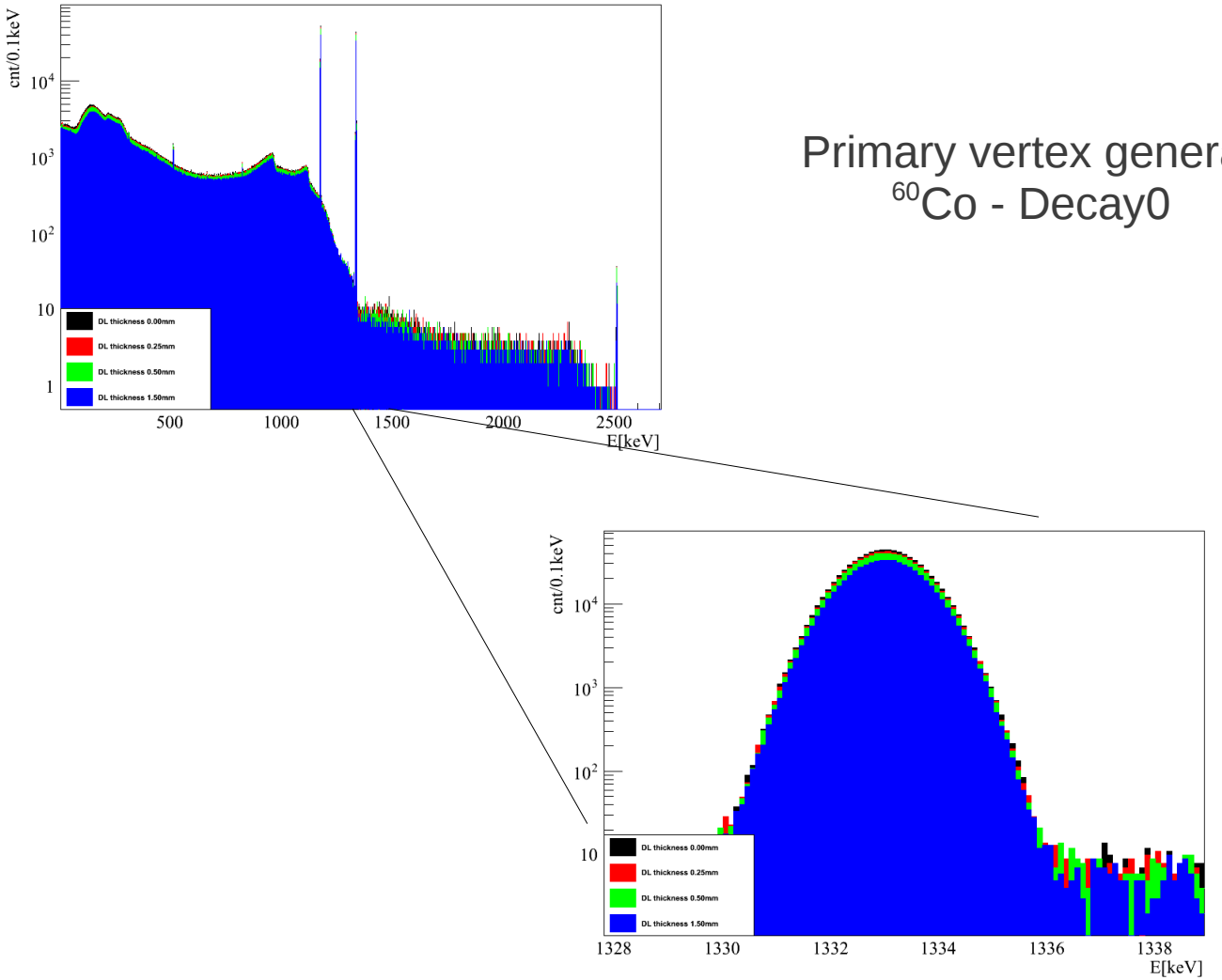






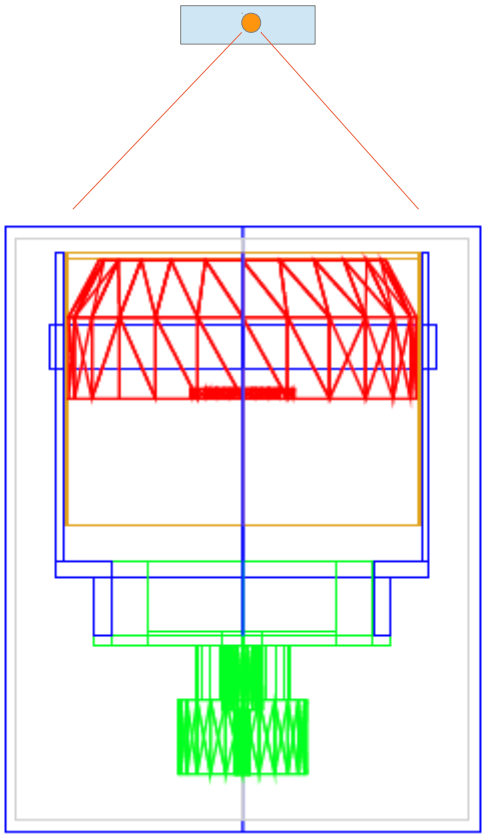
Simulations

- Precise implementation of detector dimensions is crucial for ^{60}Co
- Data is post processed for different DL thicknesses



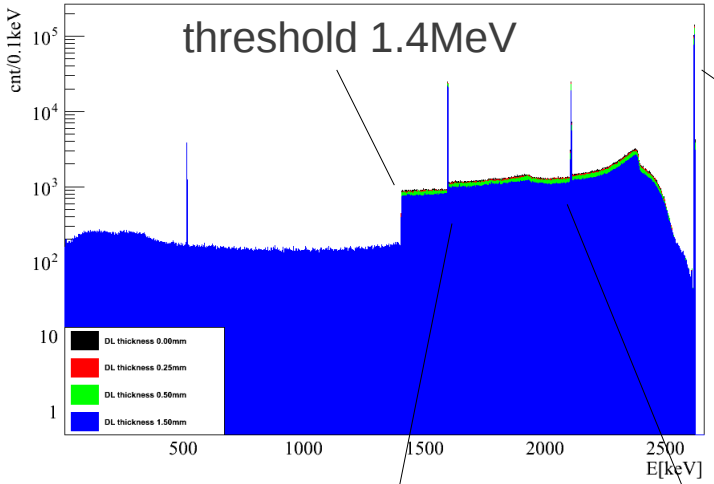
Primary vertex generator
^{60}Co - Decay0

^{60}Co source

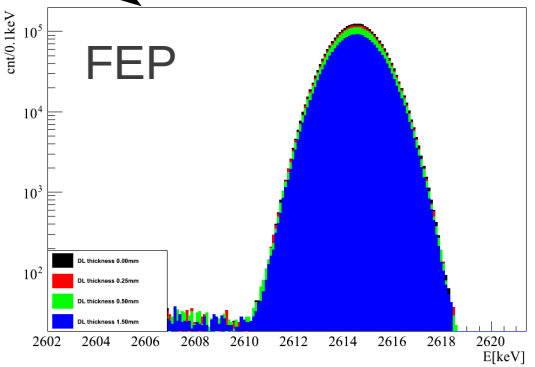


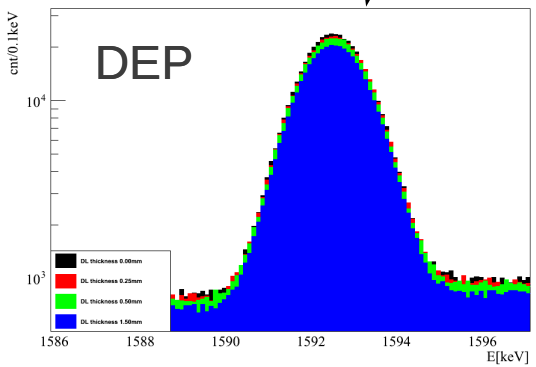
Simulations

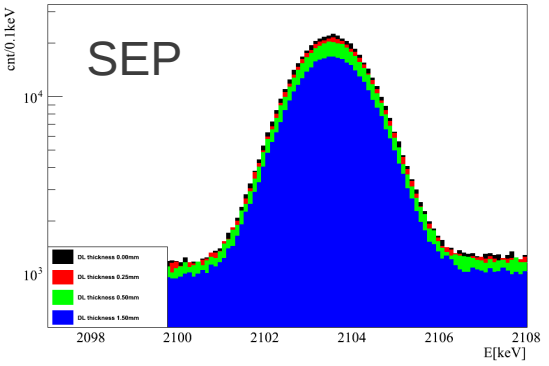
- Source distance is a crucial parameter for ^{228}Th



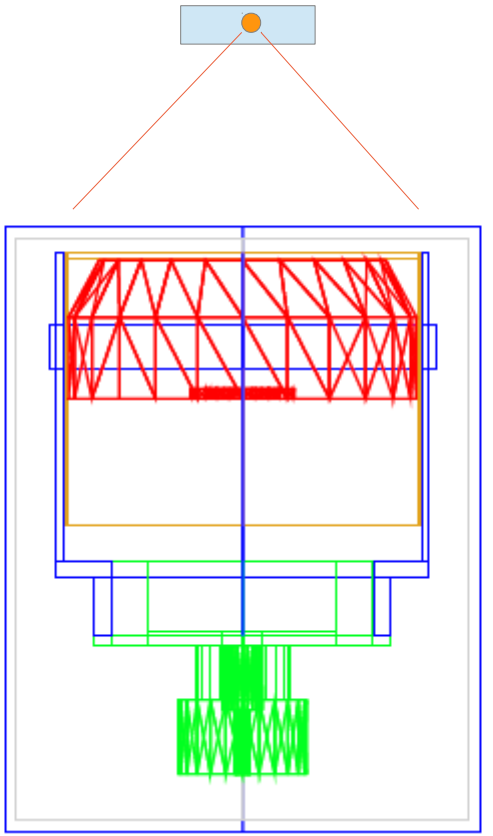
Primary vertex generator
^{228}Th - G4gun





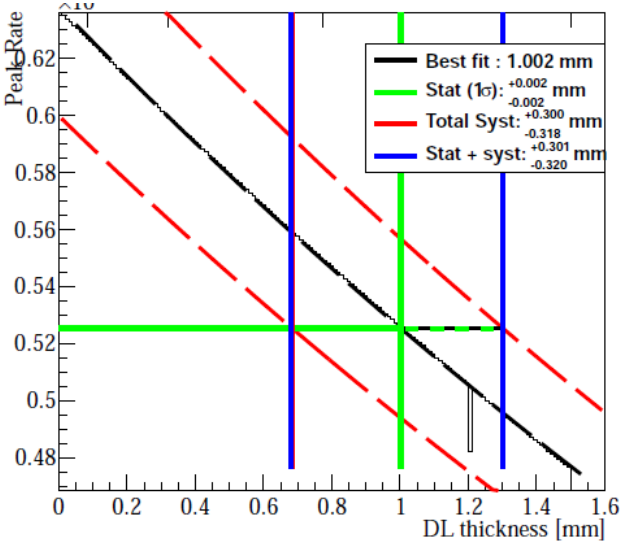


^{228}Th source

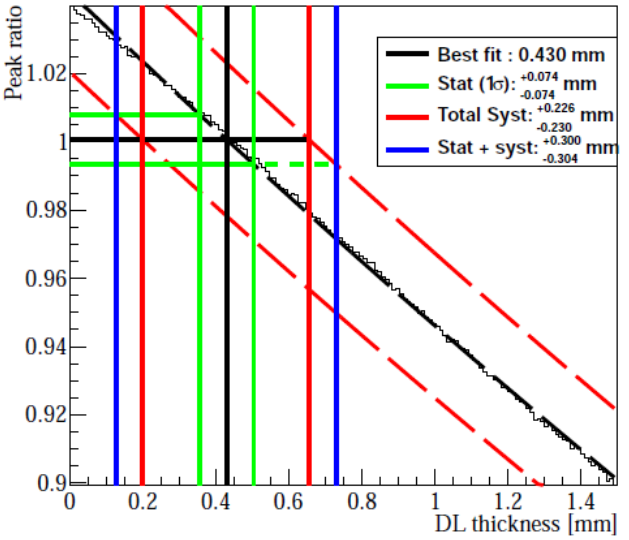


Results and Uncertainties

- Systematic uncertainties propagate from observable (rate or ratio) to the AV
- Although sensitivity is much smaller ^{228}Th is a useful additional method due to reduced systematic uncertainties
- ^{60}Co results: DL~1(+-0.3)mm → AV~90(+-4)%
- ^{228}Th results sometimes significantly smaller which is a hint for a larger dead layer in the corners



systematic uncertainty	^{60}Co rate	^{228}Th ratio
Geant4 physics	4%	2%
detector dimensions	3%	1%
source activity	3%	-
source distance	1.2%	-
detector placement	0.6%	-



Summary

- ^{60}Co and ^{228}Th provide independent methods to probe different volumes inside the detector
- Methods are limited by the model of the Dead Layer on the outer surface → Dead Volume inside the detector will be modeled as Dead Layer on the outer surface
- Large batch of different diodes creates the possibility to look for correlations
- Uncertainty on the AV is already smaller than for the Phase I detectors of about +-5% which is the main systematic uncertainty for the analysis of the 0νββ half-life

- See also: R. Falkeinstein T, B. Lehnert T110, V. Wagner T