Performance of custom designed prototype inverted coaxial HPGe detectors for GERDA and LEGEND

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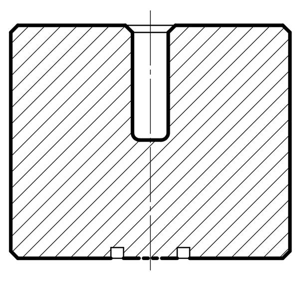
1. Introduction



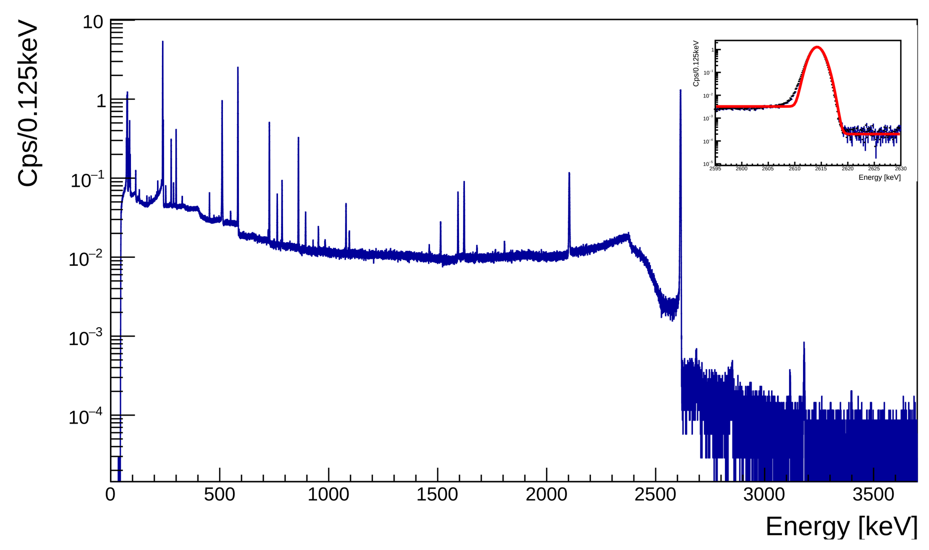
The newly formed LEGEND[1] collaboration plans to deploy up to 200 kg of enriched germanium detectors in its first phase in the upgraded GERDA[2] infrastructure at Laboratori Nazionali del Gran Sasso (LNGS), Italy.

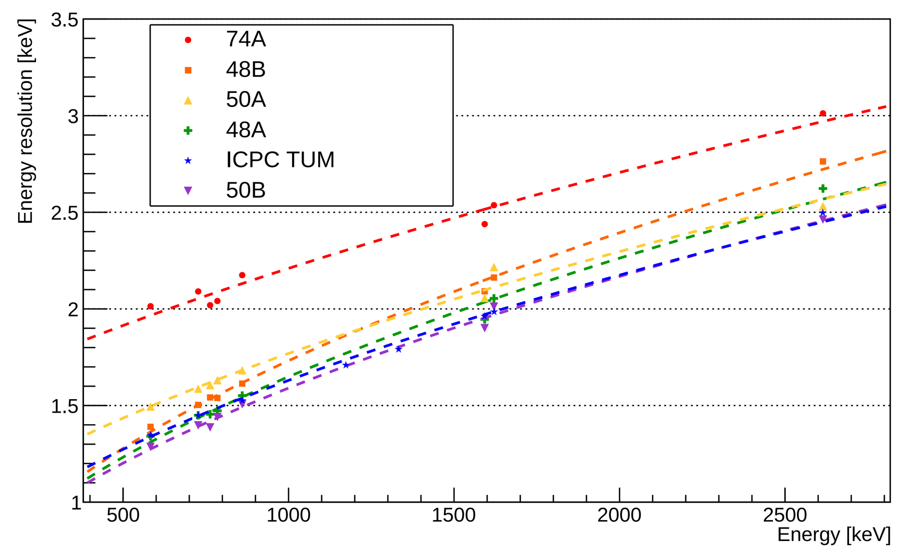
- **Science goal**: search for neutrinoless double beta ($0\nu\beta\beta$) decay of ^{76}Ge with a half-life sensitivity of $\sim 10^{27}$ yr
- **Prerequisite**: reduction of background by a factor of ~ 5 (w.r.t. GERDA); a factor of ~ 2 can be gained by increasing the detector mass by a similar factor, thereby reducing the background from nearby components as cables and holders
- **Focus on**: reach Pulse Shape Discrimination (PSD) performances comparable to detectors currently used in GERDA (the so called Broad Energy Germanium detectors (BEGe)) and Majorana Demonstrator experiments

A novel detector geometry, called inverted coaxial, has been proposed[3] and is now the baseline design of LEGEND HPGe detectors. Five enriched inverted coaxial detectors have been produced and characterized in the framework of GERDA latest upgrade.

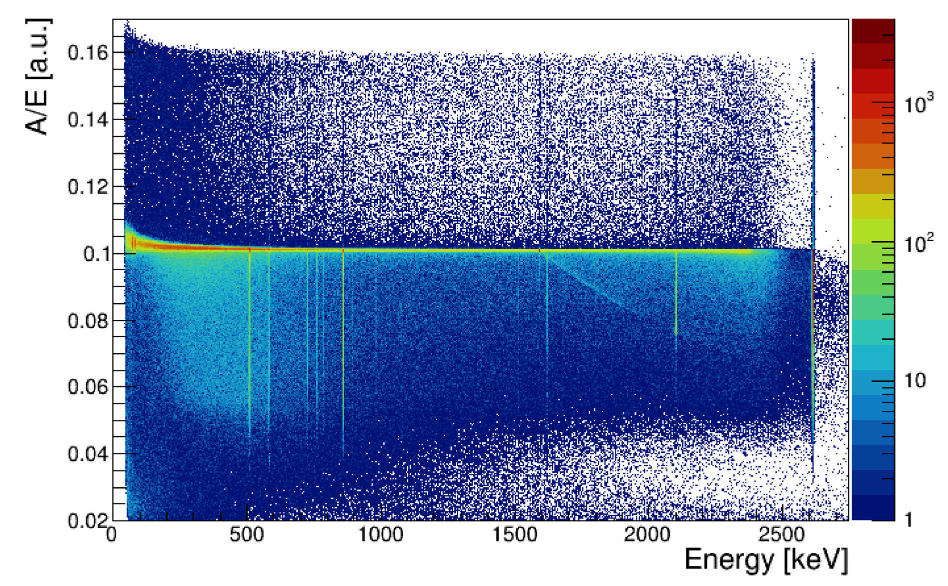
2. Energy Resolution

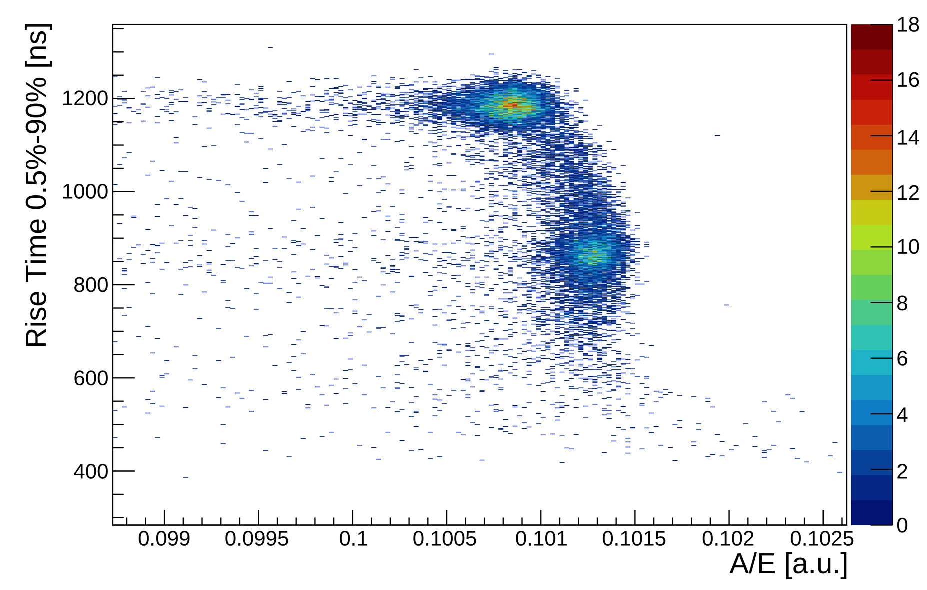
After energy calibration, resolution of the detectors for different peaks has been studied.





3. Pulse Shape Discrimination





The PSD method currently used in GERDA and Majorana Demonstrator is based on the A/E parameter, which is the ratio of:

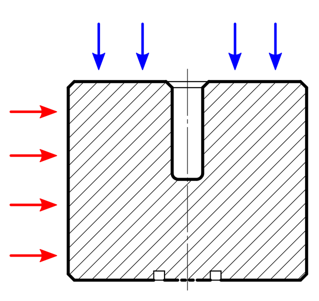
- **A**: maximum value of the current signal
  - Multi Site Events (MSE) → lower A
  - Single Site Events (SSE)→ higher A
- **E**: energy of the event, extracted from the charge signal

A new feature has been observed with these prototypes: a double peak in A/E, which is correlated with charges drift time.

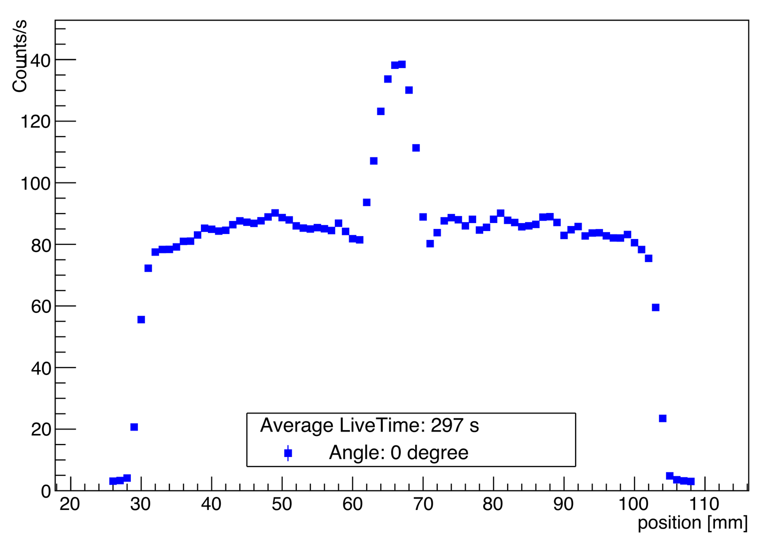
The efficiency of our PSD cut is given in terms of survival probability of events with different topologies.

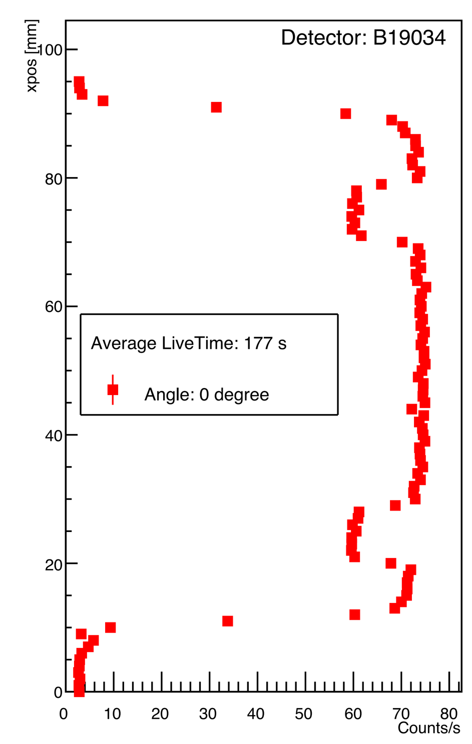
	Survival Probability (%)	
	Inv-Coaxs	BEGe[4]
^{208}Tl DEP	90.0(3)	88.9 (18)
^{208}Tl SEP	5.4(3)	7.6 (6)
^{212}Bi FEP	8.8(3)	10.4 (12)
^{208}Tl FEP	7.6(5)	9.6 (5)

4. Surface Scan



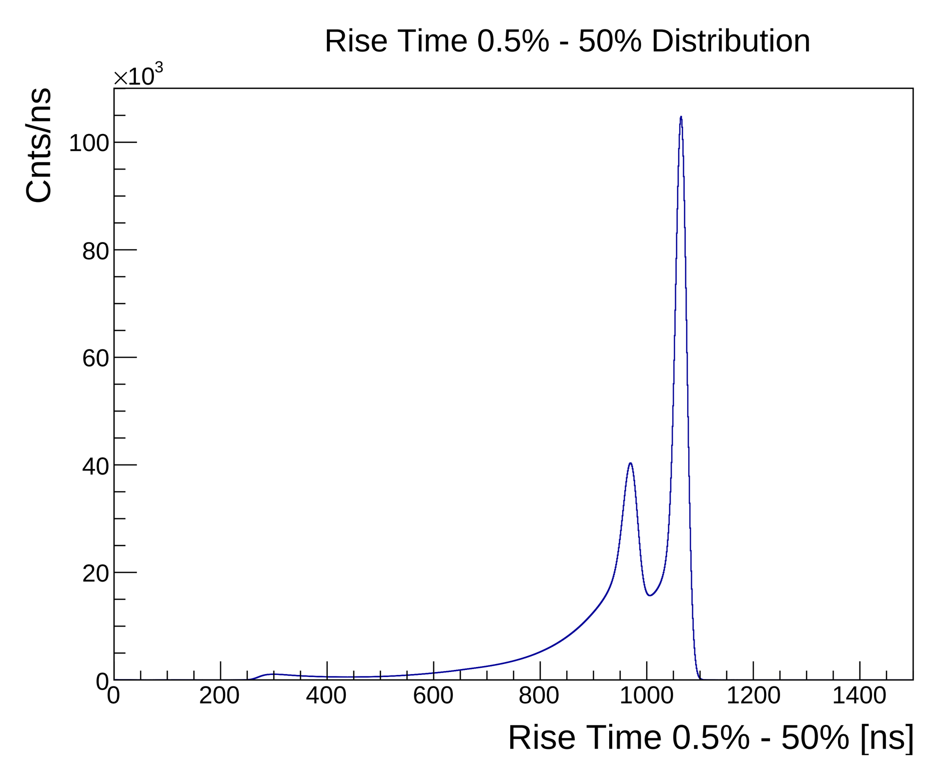
Detector surface has been studied using a collimated ^{241}Am source. For the only natural detector, a reduction of events in ^{241}Am peak for high Z positions has been observed, due to ≈ 0.2 mm thicker transition layer ($\approx 0.5\%$ volume). This issue has not been found in any of the enriched detectors.

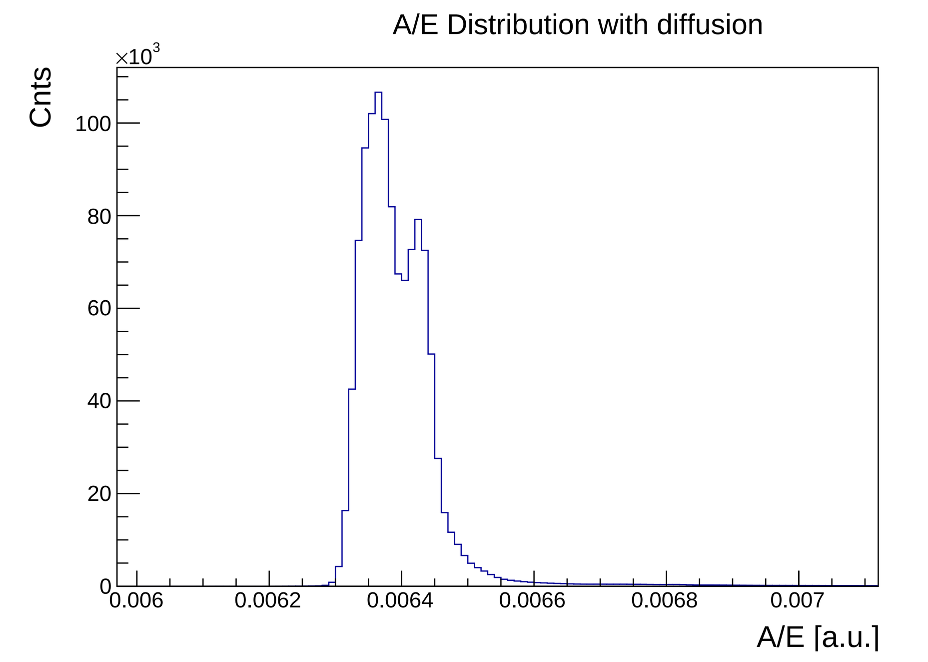




5. Pulse Shape Simulation

Pulse shapes have been simulated (SigGen) to study the new behaviour in A/E. Simulations are consistent with data when taking charge cloud diffusion into account.





6. Conclusions

Performance of these prototypes suffices the goals of LEGEND and GERDA in terms of energy resolution. Further studies on PSD are currently ongoing to crosscheck our PSD method.

7. References

[1] Abgrall et al. The large enriched germanium experiment for neutrinoless double beta decay. *arXiv:1709.01980v1*, 2017.

[2] M. Agostini et al. Background free search for neutrinoless double beta decay with gerda phase ii. 2017.

[3] Cooper et al. A novel hpge detector for gamma-ray tracking and imaging. *Nuclear Instruments and Methods in Physics Research Section A*, 665(Supplement C):25 – 32, 2011.

[4] D Budjas et al. Pulse shape discrimination studies with a broad-energy germanium detector for signal identification and background suppression in the gerda double beta decay experiment. *Journal of Instrumentation*, 4(10), 2009.

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