Studying Pulse Shape Discrimination Performance for the LEGEND Experiment

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LEGEND

Large Enriched Germanium Experiment for Neutrino-less ββ Decay (LEGEND) [arXiv:1709.0198]

Located underground Italy's Gran Sasso mountain

First phase: LEGEND-200 with 200 kg of ^{76}Ge

Next phase: LEGEND-1000 with 1000 kg of ^{76}Ge

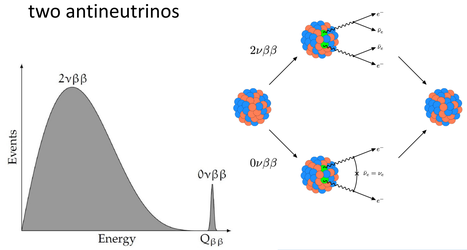
We want to see 0νββ!!

with a discovery sensitivity of a half life greater than 10^{28} years

GOAL

Double Beta Decay

Rare nuclear process where two neutrons decay into two protons, emitting two electrons and two antineutrinos



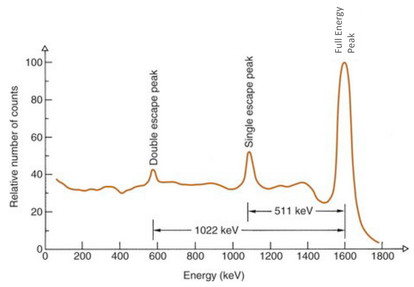
Neutrino-less Double Beta Decay Theory

Neutrino is a Majorana particle (its own antiparticle), meaning it will annihilate itself in 2νββ → could explain matter-antimatter asymmetry in universe

OUR MISSION: CUT BACKGROUND

Gamma Ray Spectral Features

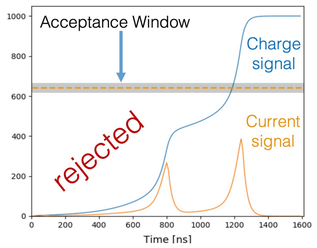
- *Double Escape Peak (DEP)*: gammas produced from pair production leave and the remaining energy is collected; **single-site, "fake signal"**
- *Single Escape Peak (SEP)*: one gamma from pair production escapes detector while remaining energy is collected; **multi-site, "fake background"**
- *Full Energy Peak (FEP)*: all energy from gammas is collected; **mix of single- and multi-site**
- *Compton Continuum*: background resulting from Compton scattering

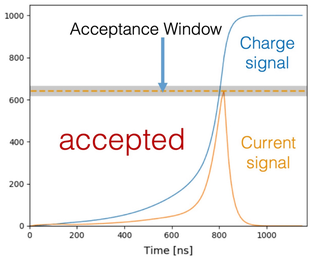


Waveform Analysis Cuts

Current Amplitude / Energy (A/E)

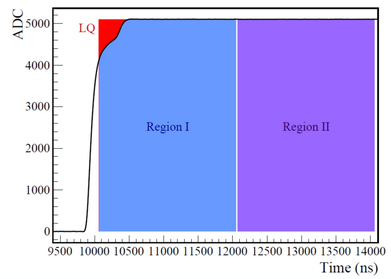
Derivative of voltage to get current amplitude of waveform



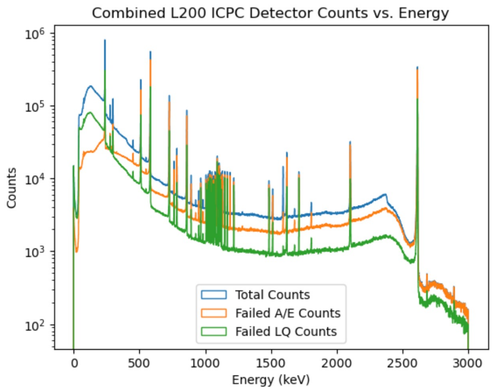


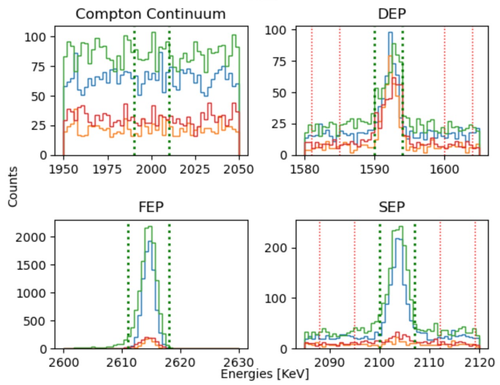
Late Charge (LQ)

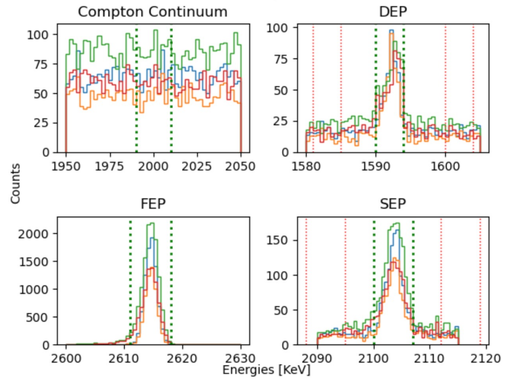
"Missing charge" from the integral after the waveform reaches 80% of its max



A/E and LQ Efficiencies: Comparing Two LEGEND Detectors





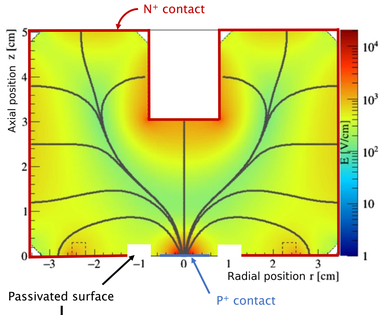


Channel:	1104001		1104002	
Technique:	A/E	LQ	A/E	LQ
DEP Eff.	0.93	0.99	0.85	0.96
SEP Eff.	0.04	0.77	.08	.68
FEP Eff.	0.10	0.72	0.10	0.64
CC Eff.	0.36	0.75	0.34	0.69

Side band subtraction is a method to estimate integral of a region by subtracting average underlying background

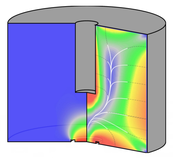
Detector Charge Collection

LEGEND-200 ICPC Detector Geometry

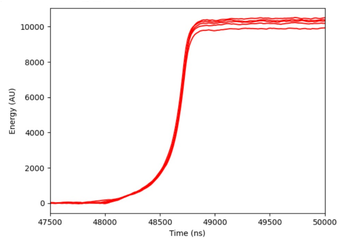


more vulnerable to alpha and beta background radiation due to thin material

- High-purity enriched ^{76}Ge detectors
- Signal is formed by charges drifting in electric field



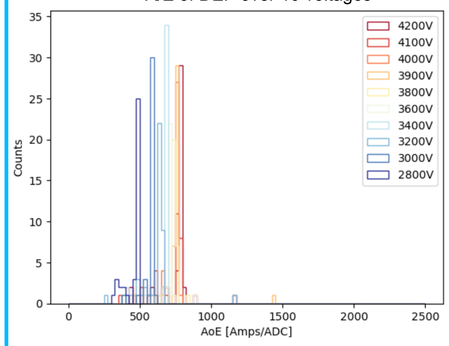
DEP Waveforms that Passed A/E



Each waveform is a series of discrete voltage values sampled over certain time intervals

Voltage Effects on Depletion

A/E of DEP over 10 voltages



- Insufficient voltage causes undepleted region of delayed charge collection
- Higher voltage = less drift time and faster charge collection

Conclusion + Next Steps

- A/E is more effective than LQ at identifying multi-site gamma events, as expected
- LQ has very high signal efficiency and is more consistent between detectors
- Higher voltage → fully depleted detectors, higher charge velocity, higher current amplitude
- Next steps: compare more detectors to continue checking consistency
- LEGEND could be key to explaining matter-antimatter asymmetry and new physics beyond the standard model

Acknowledgements

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