Calibration of the LEGEND-200 experiment

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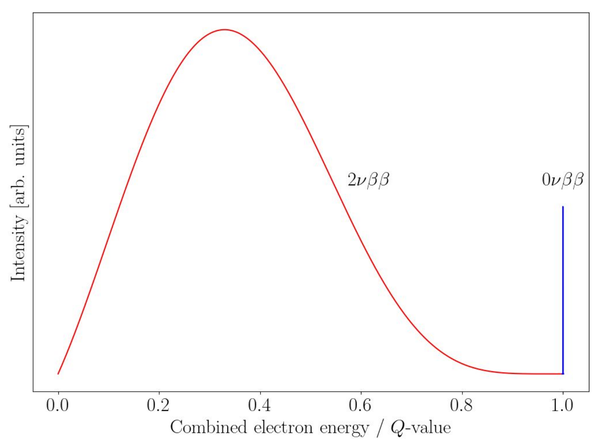
LEGEND
Large Enriched Germanium Experiment for Neutrinoless ββ Decay

1. Physics goal: search for neutrinoless double beta decay

- observation proves Majorana nature of neutrinos
- implies violation of lepton number (ΔL) conservation

- 2 neutrinos emitted (2νββ), observed in SM (e.g. in ^{76}Ge)
  - $^{76}Ge \rightarrow {}^{76}Se + 2e^- + 2\bar{\nu}_e$ (ΔL=0)
  - continuous spectrum
- no neutrinos emitted (0νββ), beyond SM
  - $^{76}Ge \rightarrow {}^{76}Se + 2e^-$ (ΔL=+2)
  - peak at Q-value



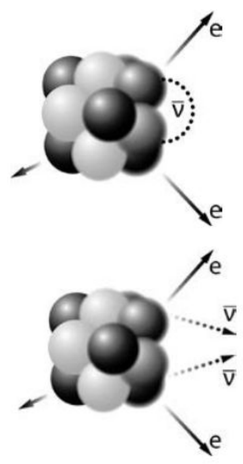
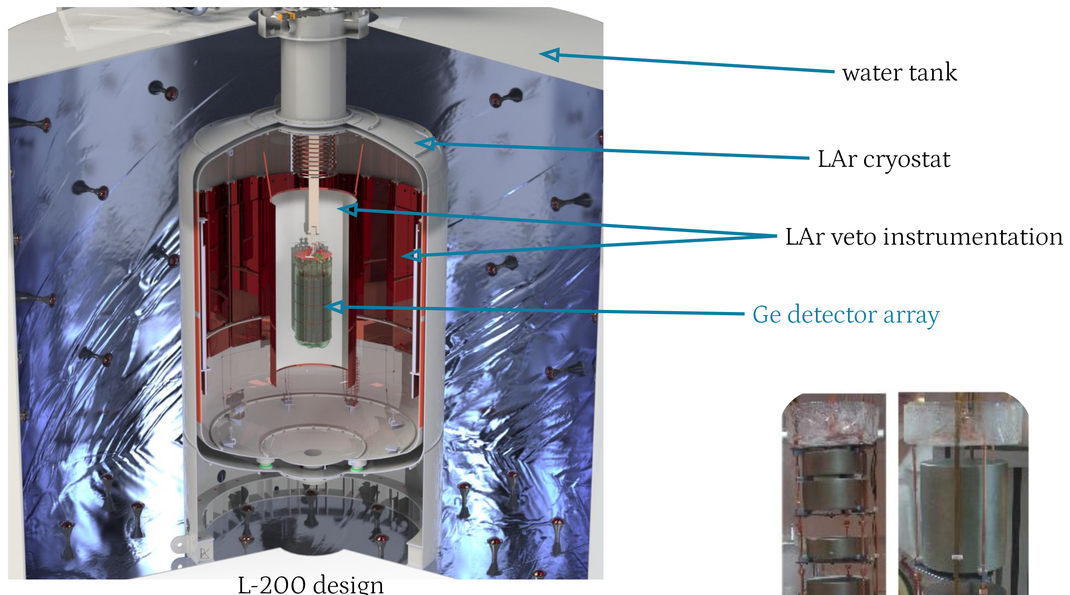


Image taken from European Astroparticle Physics Strategy, 2017-2026, APPEC (2017)

2. LEGEND experiment

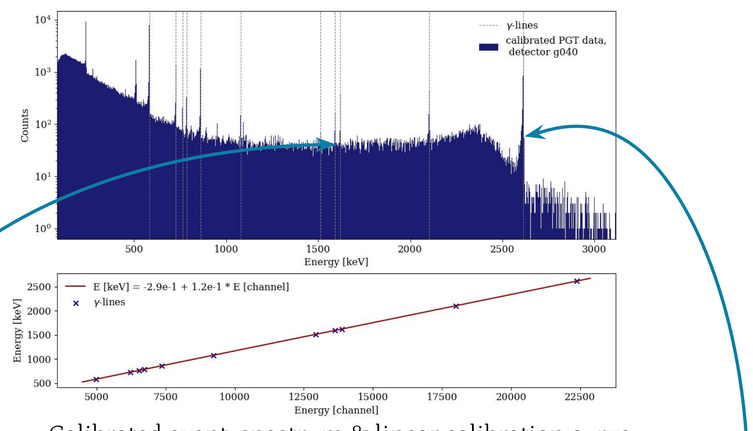
- dual phase program, LEGEND-200 (L-200) & LEGEND-1000 (L-1000)
- aiming to reach a half-life discovery sensitivity $T_{1/2}$ beyond 10^{28}yr
- L-200 is under commissioning at Laboratori Nazionali del Gran Sasso (LNGS)
- operates 200 kg of high-purity Ge crystals enriched in ^{76}Ge
- liquid Ar (LAr) at 87 K serves as coolant, passive shield & active veto



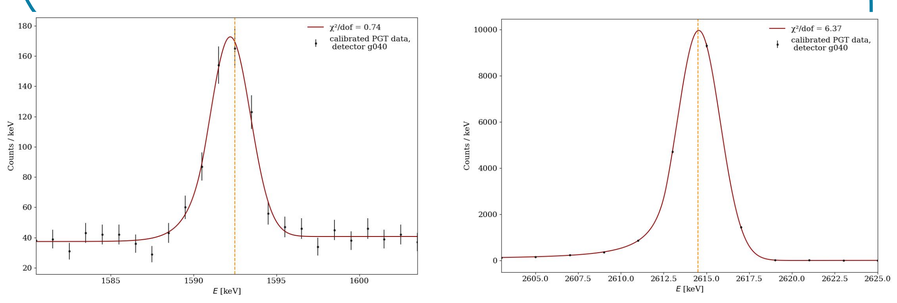
L-200 design

3. Detector calibration procedure

- regular deployment of radioactive ^{228}Th sources into cryostat
- identification of γ-ray lines from decay chain in ADC channel spectrum
- determine energy scale via fit of peak positions to convert ADC into physical energy *keV*
- determine energy resolution via fit of peak widths of γ-ray lines



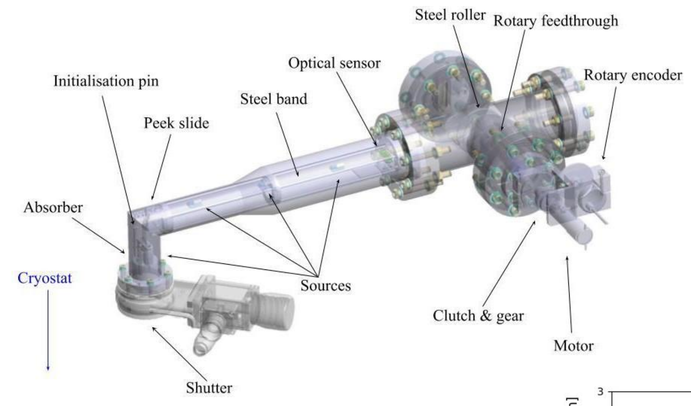
Calibrated event spectrum & linear calibration curve, Post-GERDA test data

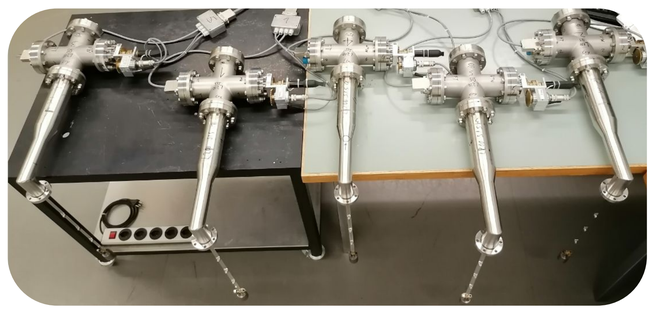


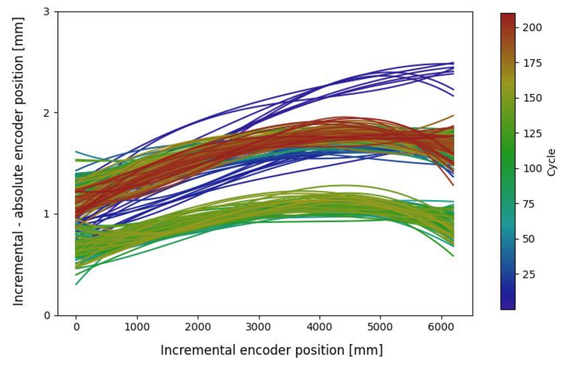
Fit of ^{208}Tl double escape (l.) & full energy peak (r.)

4. Calibration system

- 5 systems (1 is backup) equipped with 4 sources each, for homogeneous event distribution, as shown by simulations & during testings at LNGS
- source holders spot-welded onto 11.2 m long steel band with laser-drilled holes, steel band connected to a motor
- source position monitored by 2 systems, with accuracy of few mm
  - incremental encoder: optical sensor counting transition of passing holes
  - absolute encoder: turn counter storing multi- & single-turn angles of gears



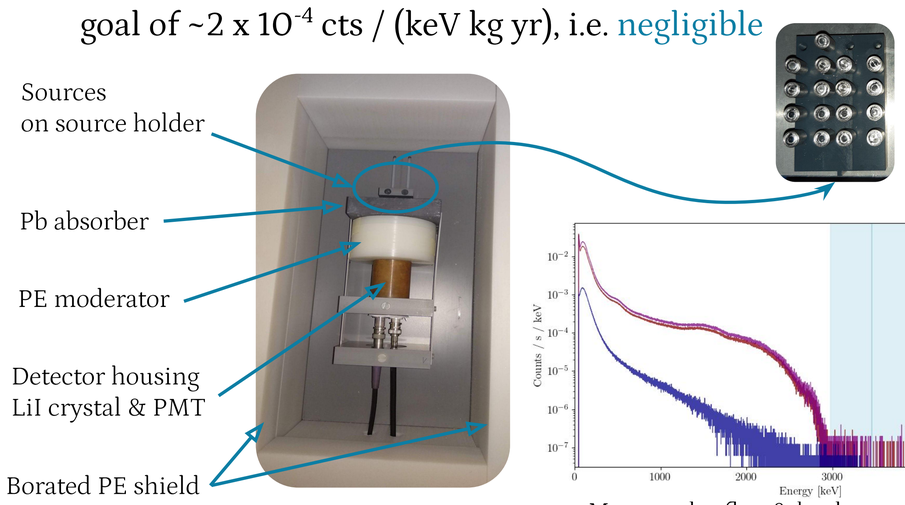




5 calibration systems (l.) & polynomial fits of position deviations monitored over >200 movement cycles of 1 prototype system on a 6.2 m test platform at UZH (r.)

5. Background considerations

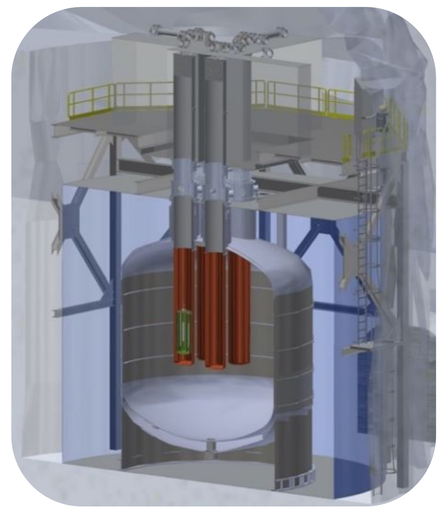
- neutron (n) flux emitted by sources measured with LiI detector underground at LNGS
- simulate n capture in Ge during calibrations, causing internal ^{77}Ge production
- simulate subsequent ^{77}Ge β decay in detectors
- contribution estimated to be ~3000x lower than L-200 bkgr. goal of ~2 x 10^{-4} cts / (keV kg yr), i.e. negligible



Measured n flux & background spectrum

6. Summary & outlook

- L-200, searching for 0νββ in ^{76}Ge, is under commissioning at LNGS
- operating Ge detectors are calibrated with multiple ^{228}Th sources
- energy scale & resolution of the detectors are measured with γ-ray line positions & widths
- measurement of n flux shows calibration induced background is negligible
- calibrations of L-200 will inform design of calibration system for L-1000, which will be deployed to calibrate 1000 kg of Ge detectors



Planned L-1000 design

The LEGEND collaboration
11 countries, ~50 institutions, >250 members,
visit us on https://legend-exp.org/