Status of the LEGEND Neutrinoless ββ Decay Search

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LEGEND (arXiv:1709.01980)

The LEGEND Collaboration

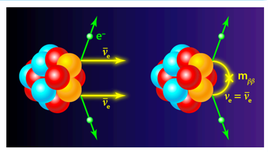
48 institutions, ~240 scientists

Mission: "To develop a **phased, ^{76}Ge based double-beta decay experimental program** with **discovery potential at a half-life beyond 10^{28} years,** using existing resources as appropriate to expedite physics results."


Seattle, WA, Dec. 2019

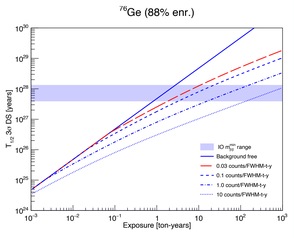
The Search for Neutrinoless ββ Decay

Observation of this phenomenon would be the **first evidence for lepton number violation in Nature**, and provide insight into the **matter-antimatter asymmetry** in our Universe.



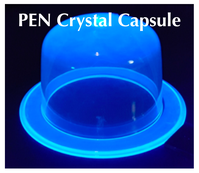
Advantages of ^{76}Ge:

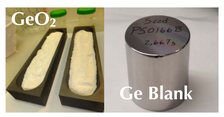
- Large & reliable world supply
- Able to enrich from 8% to ≥ 92%
- Excellent pulse shape discrimination
- Best E resolution: ~0.1%, 2039 keV
- Lowest background of any 0νββ experiment
- Negligible 2νββ background
- No strong background lines near $Q_{\beta\beta}$

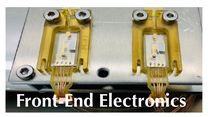


Ongoing Research & Development

- New HPGe detector geometries & larger sizes
- Scanning cryostats for surface event analysis
- Scintillating PEN (*JINST 14 (2019) 07006*)
- ASIC front-end (lower power, increased fidelity)
- Xe-doped LAr (substantially increases light yield)







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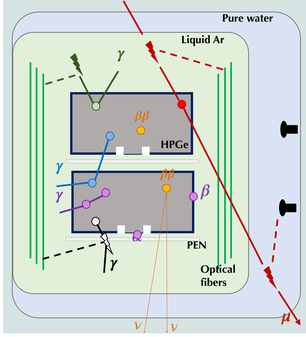
Realizing Ultra-Low Backgrounds

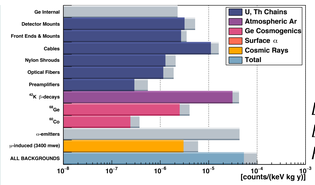
Strategy: Select best technologies based on what has been learned from GERDA and the MAJORANA DEMONSTRATOR, as well as contributions from other groups.

- **GERDA:**
  - LAr veto
  - Low-A shield, no Pb
- **MAJORANA:**
  - Radiopurity of nearby parts
  - Low noise, low-threshold electronics
- **Both:**
  - Lowest background and best resolution 0νββ experiments
  - Clean fabrication techniques
  - Controlling surface exposure time of components
  - Development of large point-contact detectors

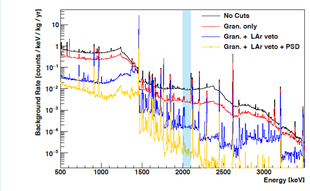
Active Background Rejection in LEGEND



- Pulse shape discrimination (PSD) for multi-site and surface α events
- Ge detector anti-coincidence veto
- Scintillating PEN plate
- LAr veto: Ar scintillation light read by fibers + PMT's
- Muon veto: Cherenkov light & plastic scintillator



L200 Background Projection

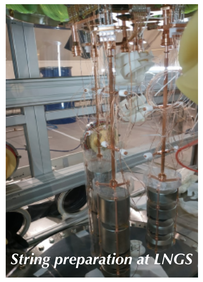


Simulated reduction after vetos,

UL total from U/Th/^{40}K, all components, assay-based

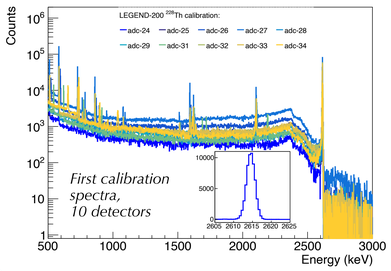
LEGEND-200: Current Status

- 200 kg ^{enr}Ge in upgrade of existing infrastructure at LNGS
- Resolution: 2.5 keV FWHM
- BG goal: < 0.6 cts/(FWHM t yr)
- Will use GERDA and MAJORANA DEMONSTRATOR enriched detectors
- Data start ~2021


String preparation at LNGS

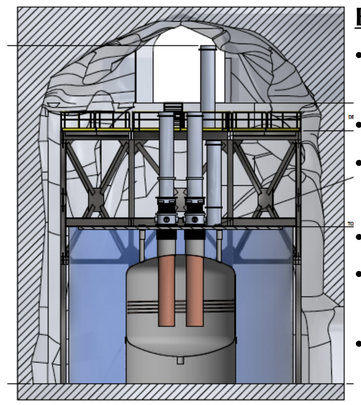
Recent Developments:

- GERDA infrastructure now operated by LEGEND collaboration
- Screening, assays, electroformed Cu all on schedule
- First calibration data taken (below)



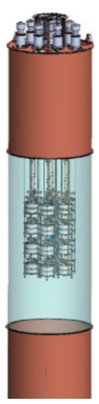
- 177 kg ^{enr}Ge material ordered, 162 kg delivered, 12.6 kg at LNGS
- Successful DAQ test with 20-channel FlashCam digitizer system
- PEN detector unit parts installed
- Multi-source calibration system is ready for deployment at LNGS
- Characterization, simulation, and analysis software is in development
- Production of fiber shroud and SiPM array is progressing
- **First 12 detectors installed & operating in LAr (February)**
- COVID-19: reduced lab access

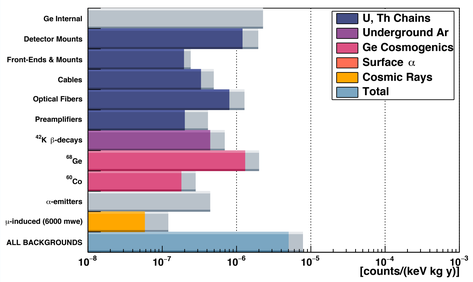
Towards LEGEND-1000



Baseline Design:

- 1000 kg ^{enr}Ge (staged approach, multiple payloads)
- Resolution: **2.5 keV FWHM**
- Background goal:
  < 0.03 cts/(FWHM t yr)
- UG Location to be selected
- Lab-specific infrastructure and cryostat design underway
- Documenting pre-conceptual design





L1000 Background Reduction

- **U/Th:** optimized array spacing, minimize opaque materials, larger detectors, better light collection, cleaner materials
- **^{42}Ar:** eliminate w/ UG-sourced Ar
- **μ-induced:** deeper labs and improved rejection techniques
- **Surface α:** improved process control, pulse shape discrimination

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