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LEGEND

The Large Enriched Germanium Experiment for Neutrinoless Double Beta Decay

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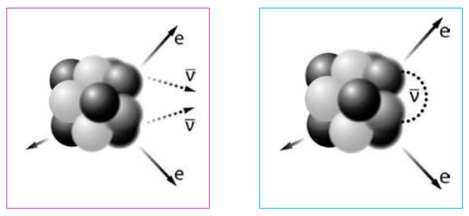
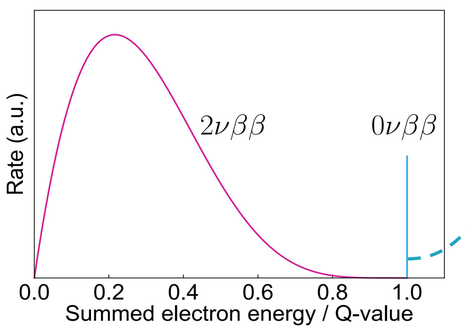
Physics goal: Search for neutrinoless double beta decay (**0νββ**) in ^{76}Ge





Two neutrinos emitted (**2νββ**), observed SM process:

- $^{76}Ge \rightarrow {}^{76}Se + 2e^- + 2\bar{\nu}_e$ ($\Delta L=0$)

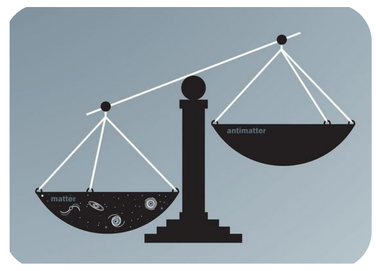
No neutrinos emitted (**0νββ**), physics beyond SM:

- $^{76}Ge \rightarrow {}^{76}Se + 2e^-$ ($\Delta L=+2$)

Ge detectors achieve the excellent energy resolution needed to resolve the 0νββ peak.

Physics motivation: An observation of **0νββ** would have important implications for particle physics & cosmology.

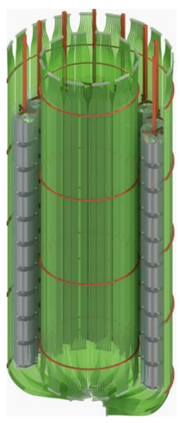
- Majorana nature of the neutrino (particle = antiparticle)
- Absolute neutrino mass scale & neutrino mass ordering (inverted vs normal)
- Violation of lepton number conservation
- Hint on the matter-antimatter asymmetry in our Universe

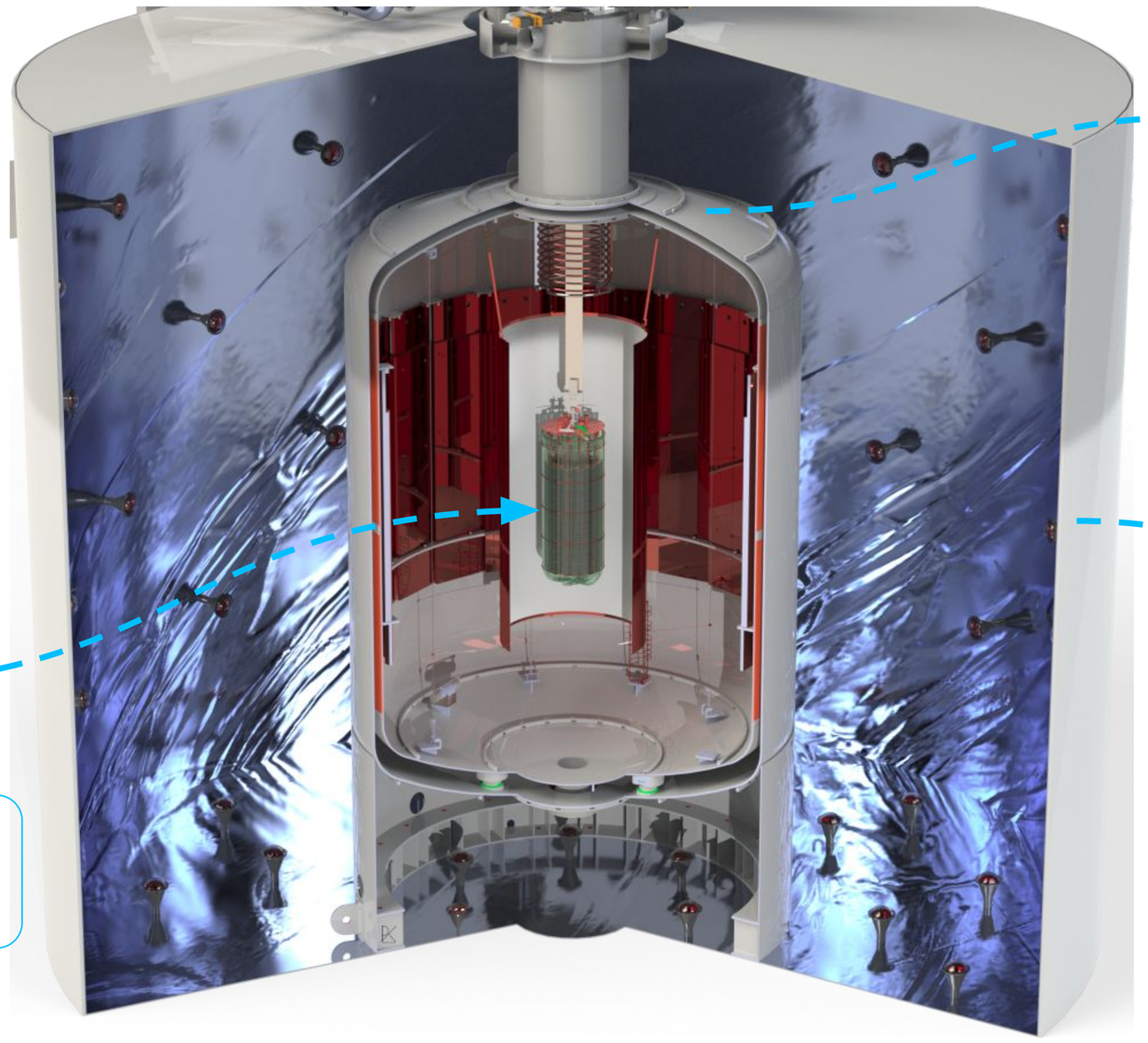


Credit: Symmetry Magazine / Sandbox Studio, Chicago

Experiment: LEGEND-200 is under construction at Laboratori Nazionali del Gran Sasso (LNGS), using the former infrastructure of GERDA. It will operate 200 kg of high-purity germanium crystals enriched in ^{76}Ge. Liquid argon (LAr) cools the detectors to 87 K, & serves as both passive shield & active veto.

1. The germanium detectors are surrounded by wavelength-shifting fibers coupled to photodetectors.





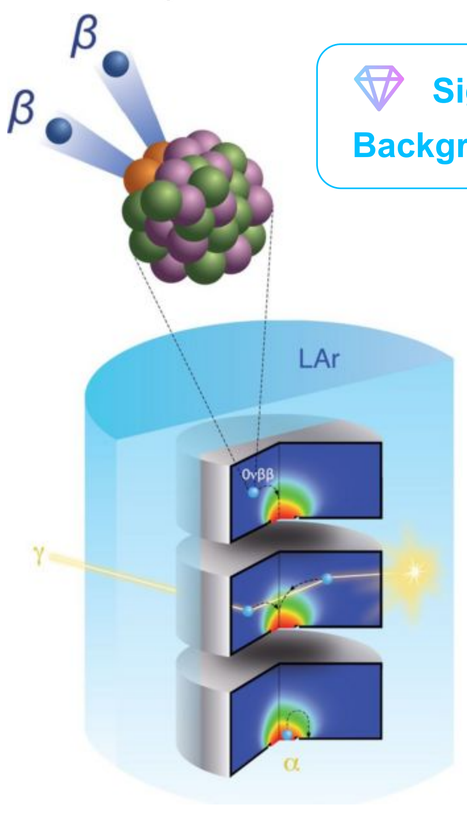
2. The detectors & the LAr veto instrumentation are inside a cryostat filled with 63 m^3 of LAr.

3. The cryostat is inside a water tank equipped with PMTs (muon veto).

4. The muon flux under 1.4 km of rock is suppressed by a factor of 10^6.

Sensitivity: The LEGEND-200 discovery sensitivity aim of $T_{1/2} > 10^{27}$yr is 10x better than the current world-leading $T_{1/2}$ constraint from GERDA.

Background reduction: LEGEND uses multiple techniques to reject background events to clearly identify the expected **0νββ** peak.

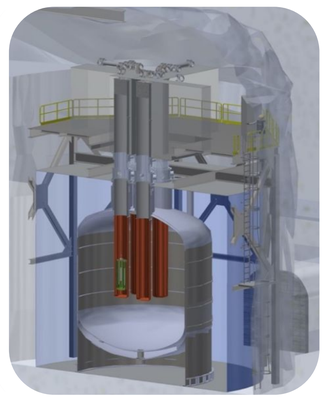


Signal: Single-site energy deposition, ββ
Background: multi-site γ, surface α & β, cosmic μ

- LAr instrumentation to veto γ, β
- Pulse shape discrimination for γ, α, β
- Detector anti-coincidence cut for γ
- Cherenkov water veto for cosmic μ

The Future: LEGEND-1000, aiming for an unambiguous discovery of **0νββ**, will probe $T_{1/2}$ beyond 10^{28}yr, meaning it will entirely cover the inverted neutrino mass ordering regime.

- Operation of 1000 kg of enriched germanium detectors, distributed over four modules
- Detector strings immersed in radiopure underground LAr, surrounded by natural LAr
- @SNOLab or LNGS, commissioning ~2030, 10 yr runtime
- Excellent resolution & background level, ⩽1 count around **0νββ** peak



[1] LEGEND collaboration: The Large Enriched Germanium Experiment for Neutrinoless Double Beta Decay, AIP CP 1894:020027 (2017)
[2] LEGEND collaboration: LEGEND-1000 Preconceptual Design Report, arxiv:2107.11462
[3] European Astroparticle Physics Strategy 2017-2026, APPEC (2017)
[4] GERDA collaboration: Probing Majorana neutrinos with double beta decay, Science 365, 1445 (2019)
[5] GERDA collaboration: Final Results of GERDA on the Search for Neutrinoless Double-β Decay Phys. Rev. Lett. 125, 252502 (2020)

The LEGEND collaboration:
11 countries, 48 institutions, 266 members