Searching for Neutrinoless Double Beta Decay with the LEGEND Experiment

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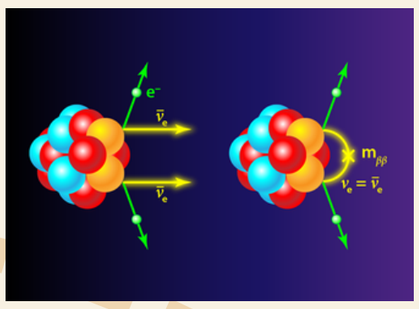
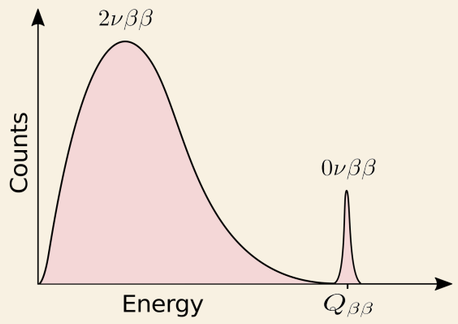
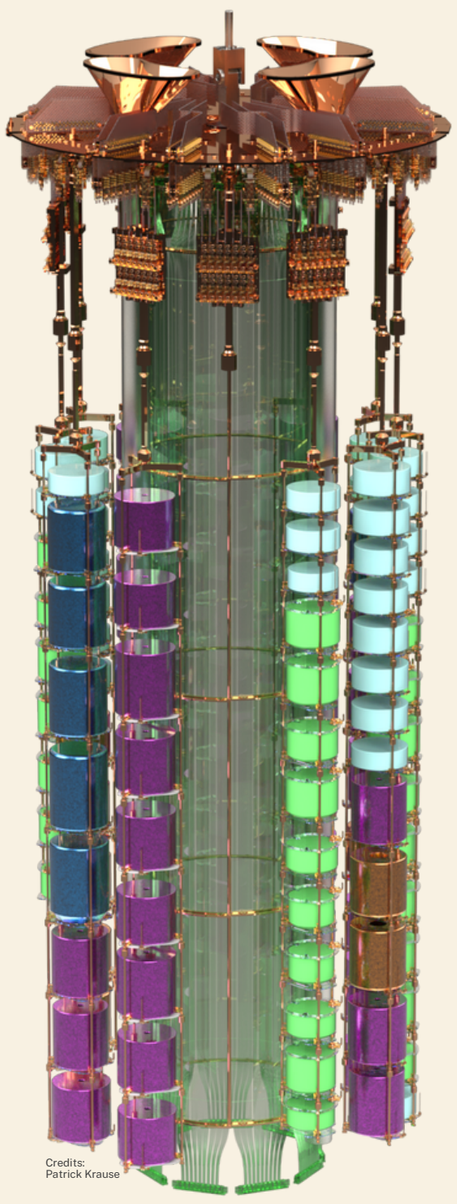
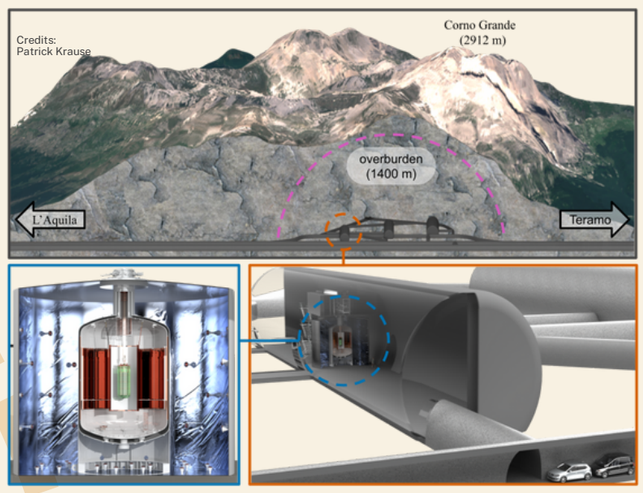




The Physics

Neutrinos' nature is still unknown: they could be Dirac or Majorana fermions. The most sensitive probe which could prove them to be Majorana is neutrinoless double beta (0νββ) decay, a hypothetical Beyond Standard Model process which violates the lepton number conservation by two units. Its experimental signature is a sharp peak at the endpoint of the double beta spectrum (Qββ): the strategy is therefore to acquire the sum energy spectrum of the two electrons and to minimize the background in the Qββ region, so that even a few counts at Qββ would be a significant 0νββ signal.

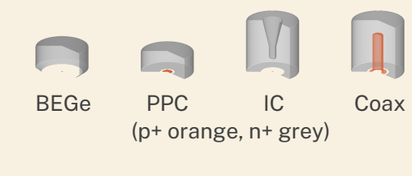




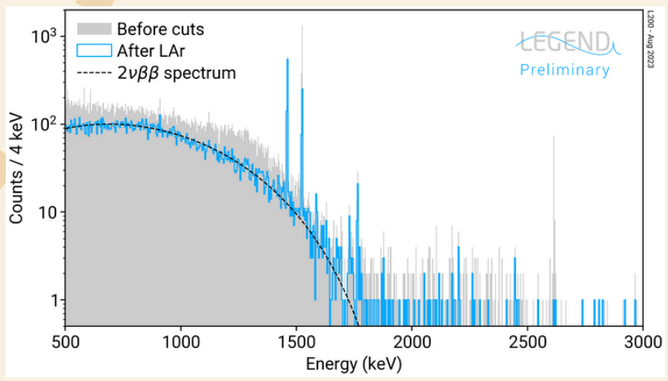
The Experimental site

The LEGEND experiment (Large Enriched Germanium Experiment for Neutrinoless double beta Decay) is located in Gran Sasso National laboratories (LNGS), in Italy. The experimental area is surmounted by a 1400 m rock overburden which acts as a shielding from cosmic rays. LEGEND-200, the first phase of the LEGEND project, is currently operated in the pre-existing GERDA facility, and combines the best technologies from GERDA and MAJORANA Demonstrator.

The Experiment



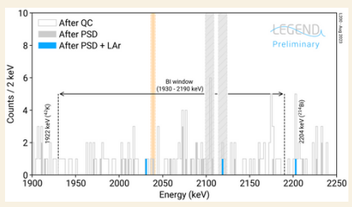
LEGEND searches for 0νββ decay in ^{76}Ge. It uses active HPGe detectors, serving both as source of the decaying isotope and as detectors for the emitted electrons. To improve the efficiency of the experiment, the Ge crystals are enriched in ^{76}Ge to a fraction above 90% (natural abundance ~8%). The Q-value for double beta decay in ^{76}Ge is Qββ = 2039 keV and Ge detectors provide a superior energy resolution, going below 3 keV FWHM at Qββ.
The topology of the energy release in ββ events is crucial for the experiment: the energy deposit in the detector is highly localized, with all the energy deposited in about 1 mm^3. This plays a crucial role when coming to event selection, since it makes it possible to perform Pulse Shape Discrimination (PSD) to identify good 0νββ candidates. In addition, two active vetoes based on anticoincidences are deployed to identify and discard background signals: the liquid Argon (LAr) veto and the muon veto.



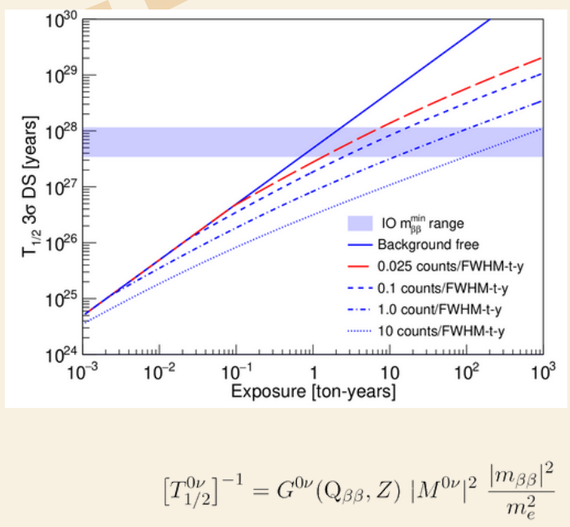
Preliminary results

First data release in August 2023 .

- Exposure: 10.1 kg yr
- Detector types: ICPC and BEGe
- Background Index achieved in a 260 keV analysis window around Qββ:
  B. I. = 4.1 [1.5, 11.4] x 10^{-4} cts/(keV kg yr), at 68% CL
  Compatible with background goal!



Perspectives



$$[T^{0\nu}_{1/2}]^{-1} = G^{0\nu}(Q_{\beta\beta}, Z)\ |M^{0\nu}|^2\ \frac{|m_{\beta\beta}|^2}{m_e^2}$$

Two-phase experiment	**LEGEND-200**	**LEGEND-1000**
Ge mass	200 kg	1000 kg
Status	Data taking from March 2023	Planned (first data in ~2030)
Background goal	B.I. $\leqslant$ 2 x 10^{-4} cts/(keV kg yr)	B. I. $\leqslant$ 1 x 10^{-5} cts/(keV kg yr)
Half life discovery sensitivity goal	1.5 x 10^{27} yr (3σ) within 10^3 kg yr of exposure	1.3 x 10^{28} yr (3σ) within 10^4 kg yr of exposure
Effective Majorana mass upper limit	27 - 63 meV	9 - 21 meV