LEGEND

David Hervas Aguilar

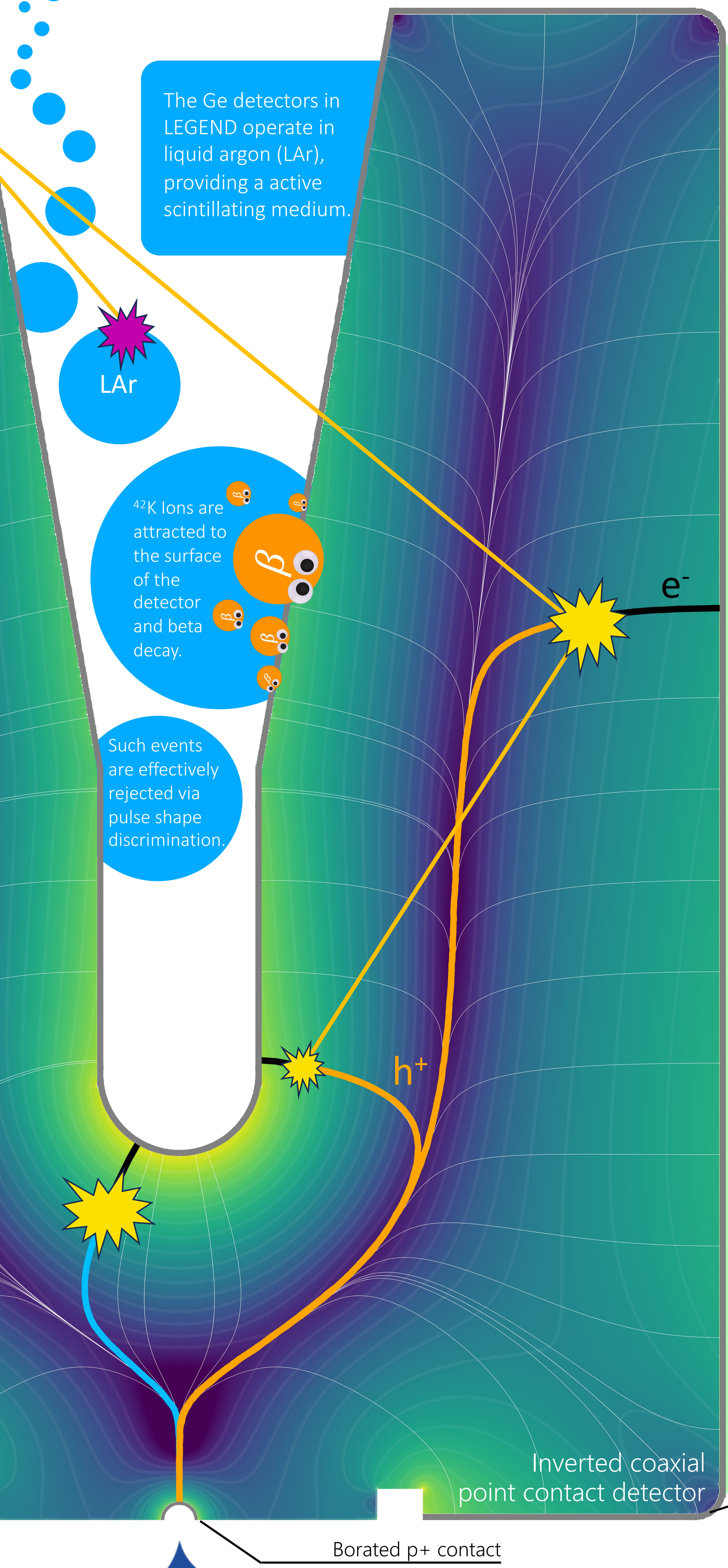
Towards a Tonne-Scale Germanium Neutrinoless Double-Beta Decay Experiment

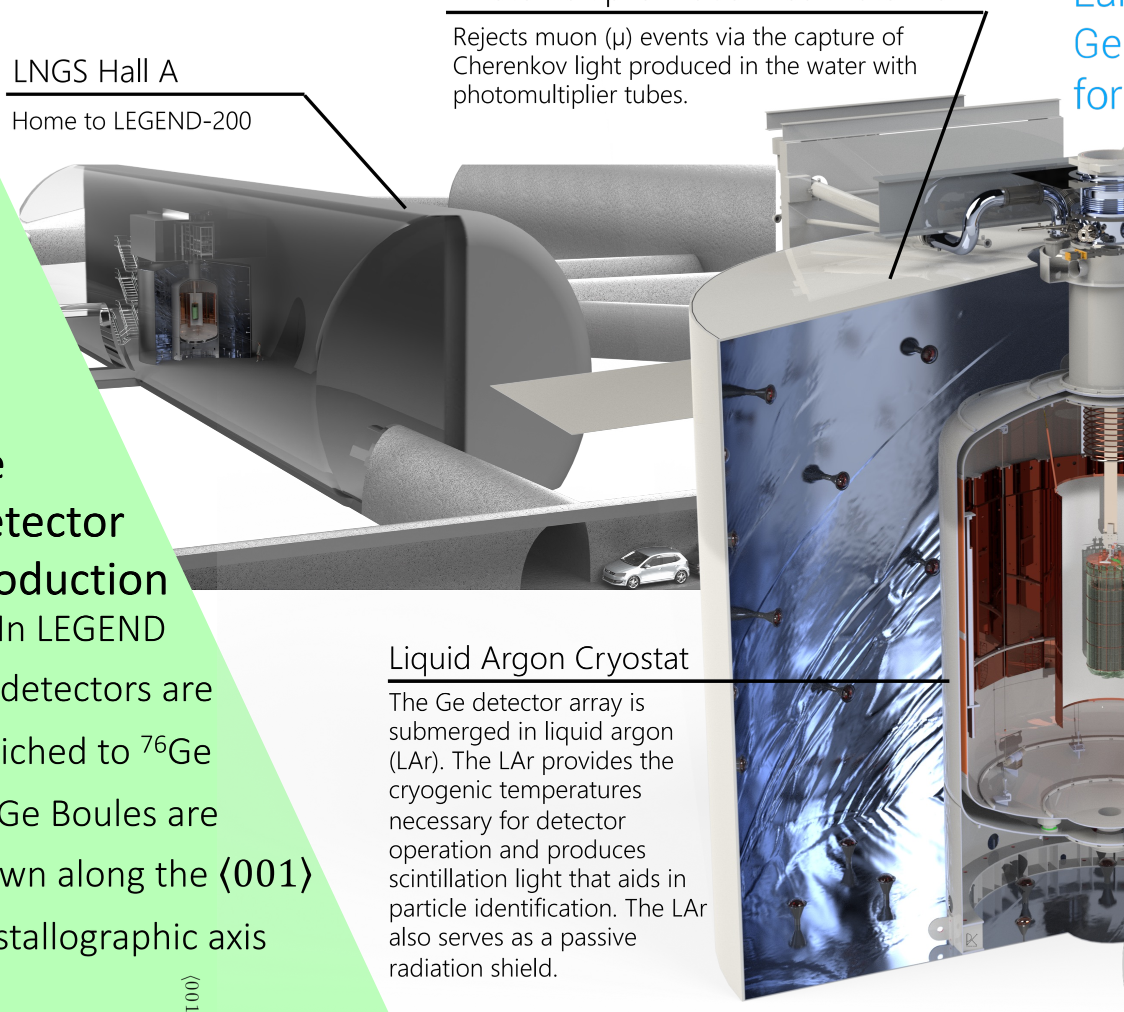
Large Enriched Germanium Experiment for Neutrinoless ββ Decay

The Ge detectors in LEGEND operate in liquid argon (LAr), providing a active scintillating medium.

^{42}K Ions are attracted to the surface of the detector and beta decay.

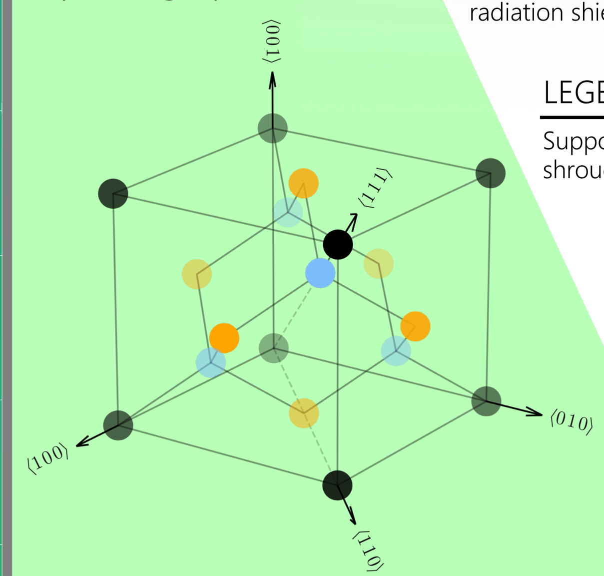
Such events are effectively rejected via pulse shape discrimination.



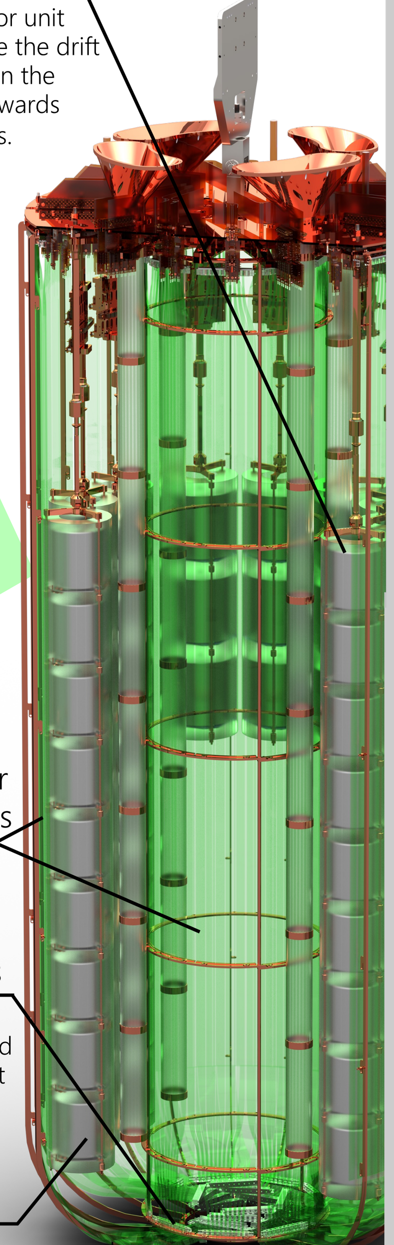


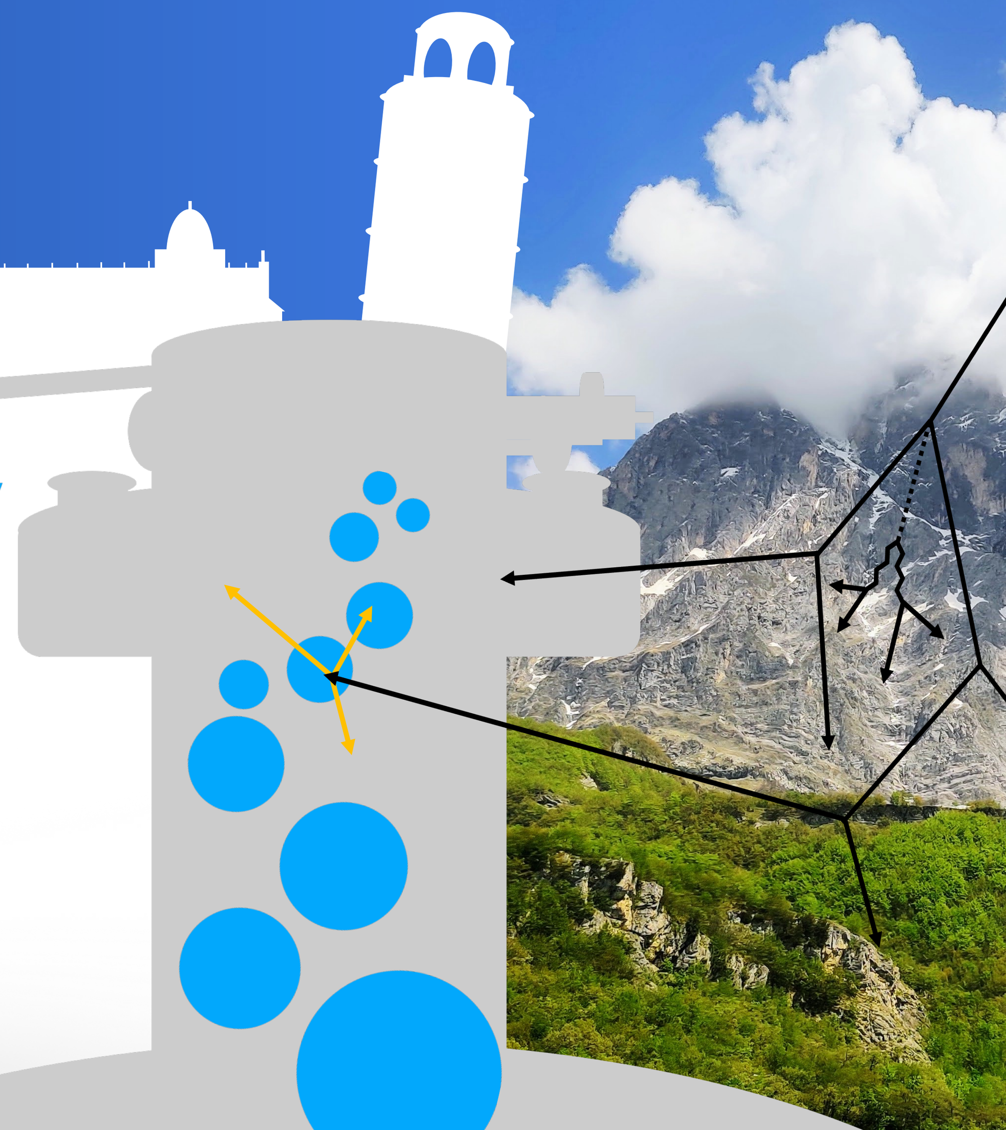
Ge Detector Production

- In LEGEND Ge detectors are enriched to ^{76}Ge
- Ge Boules are grown along the ⟨001⟩ crystallographic axis



- Ge detector blanks are cut from the boule
- Lithium is drifted into the surface (n+ contact) of the p-type detector blanks forming a PN-junction
- A point or spot p+ contact is created via boron implantation. This configuration minimizes capacitance.
- The detector is reverse biased such that the depleted region spans the entire bulk





LEGEND aims 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

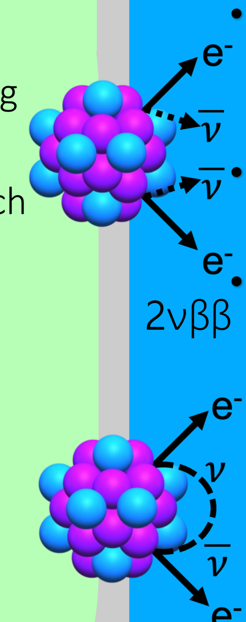
Are we the same?

LEGEND-200

- The first phase of the LEGEND experimental program
- 200 kg ^{76}Ge in modified existing GERDA infrastructure at LNGS
- Taking physics data since March 2023. 4-5 years to go.

Goals

- Match current best energy resolution: 2.5 keV FWHM
- Reduce current record background by a factor of 2-3: 2×10^{-4} cts/(keV kg yr)
- $T_{1/2}$ discovery sensitivity (3σ): 1×10^{27} yr

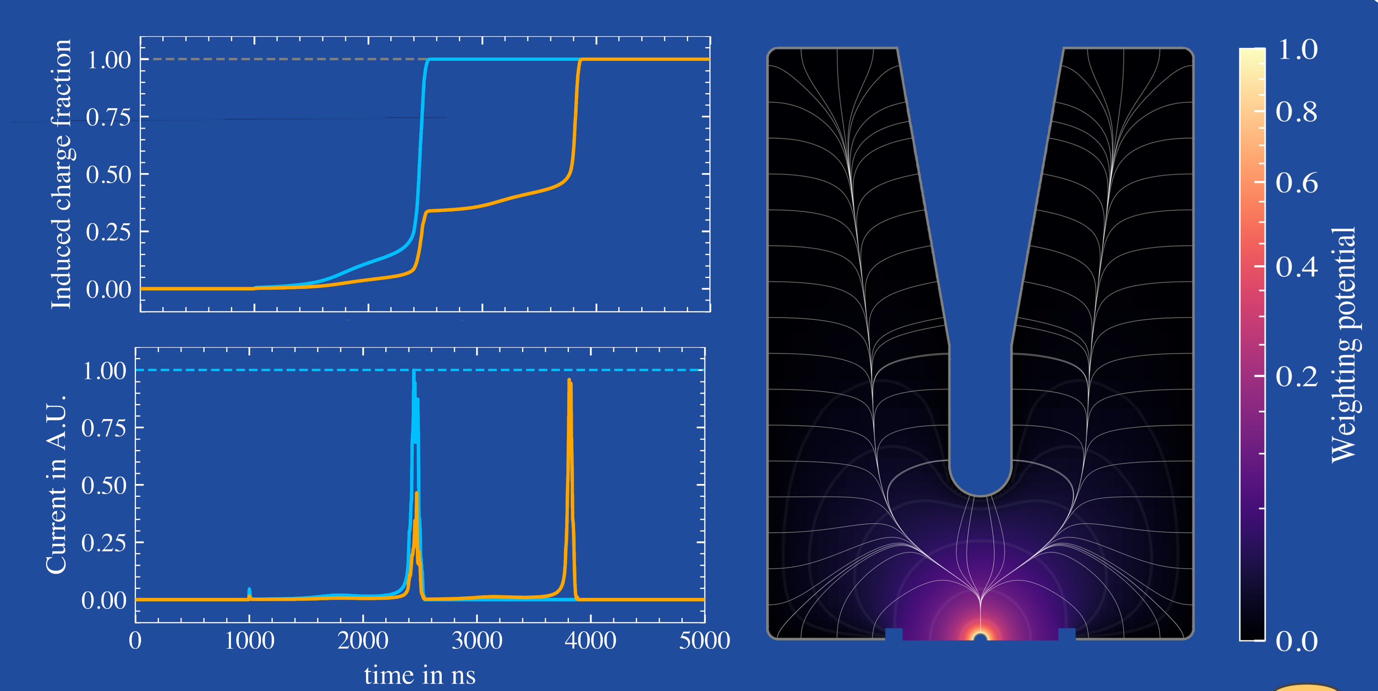


Neutrinoless Double-Beta Decay 0νββ

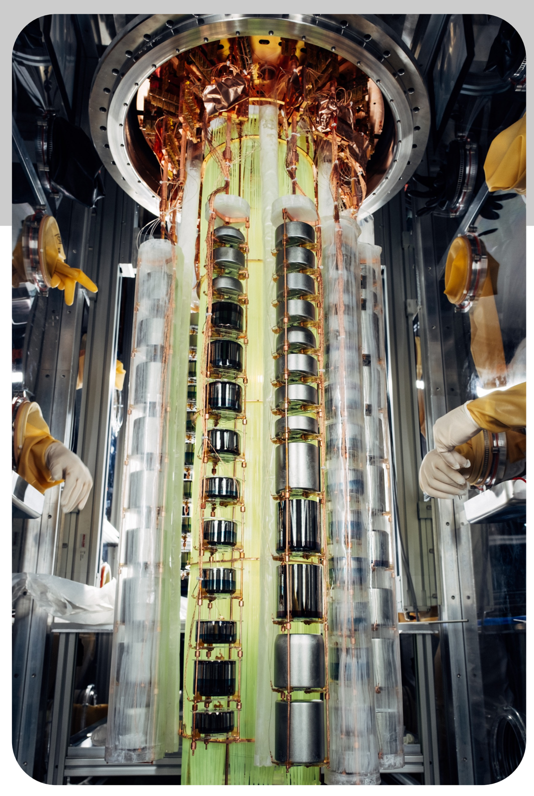
- Only allowed if neutrinos are Majorana particles
- Violates lepton number conservation (LNV)
- Observation would provide insight into
  - Matter-antimatter asymmetry
  - The nature of the neutrino
  - The absolute mass scale of the neutrino

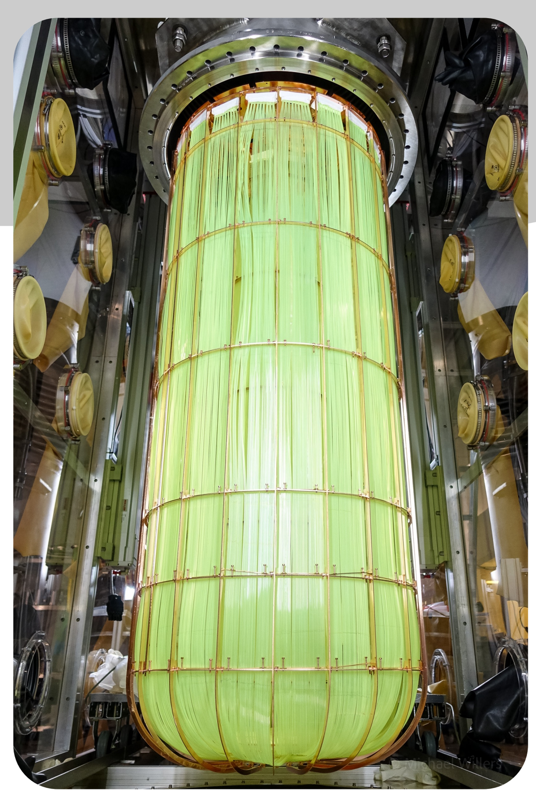
LEGEND-1000

- 1000 kg ^{76}Ge, payloads deployed in stages. 10 years of data
- Increase average detector mass to 3 kg
- Projected to start construction as early as 2025 with first data in 2030
- Background goal (20x lower): $<1 \times 10^{-5}$ cts/(keV kg yr)
- $T_{1/2}$ discovery sensitivity (3σ): 1.3×10^{28} yr



The detector is designed such that single-site events (such as 0νββ) throughout the bulk produce signals with similar current amplitudes. In this manner multi-site events (γ-like) can be effectively rejected.



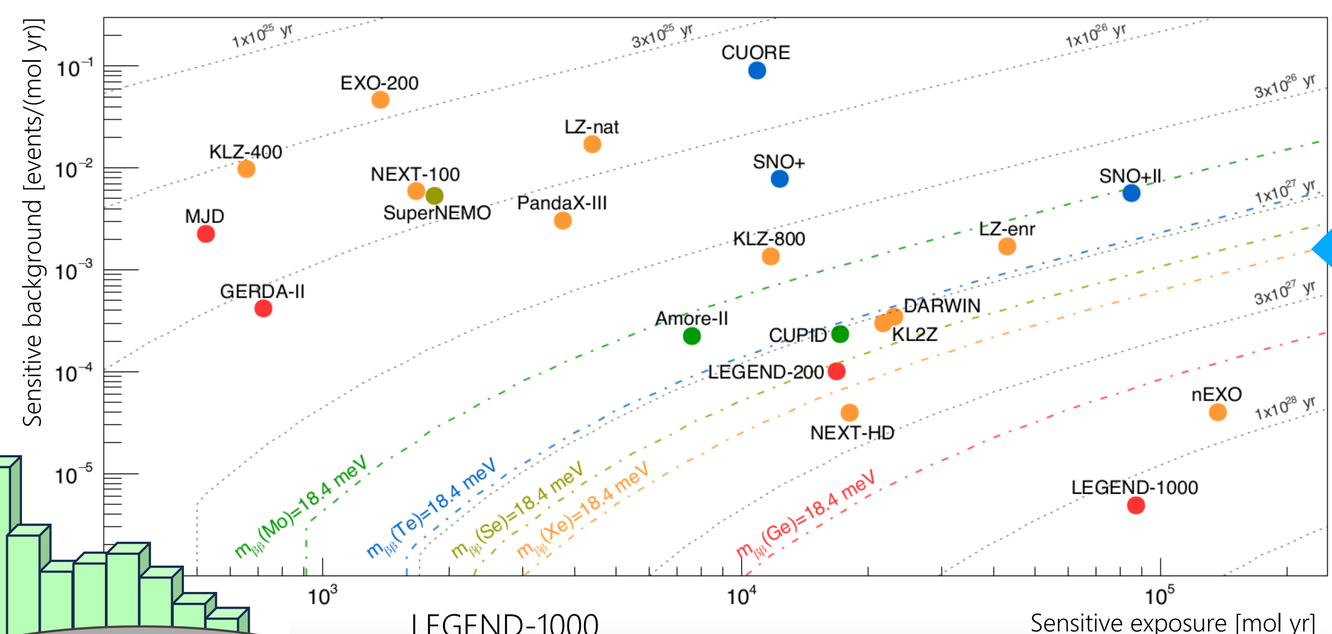


Larger detectors reduce the surface to volume ratio and reduce the mass of cables and supports near the detectors driving down the background.

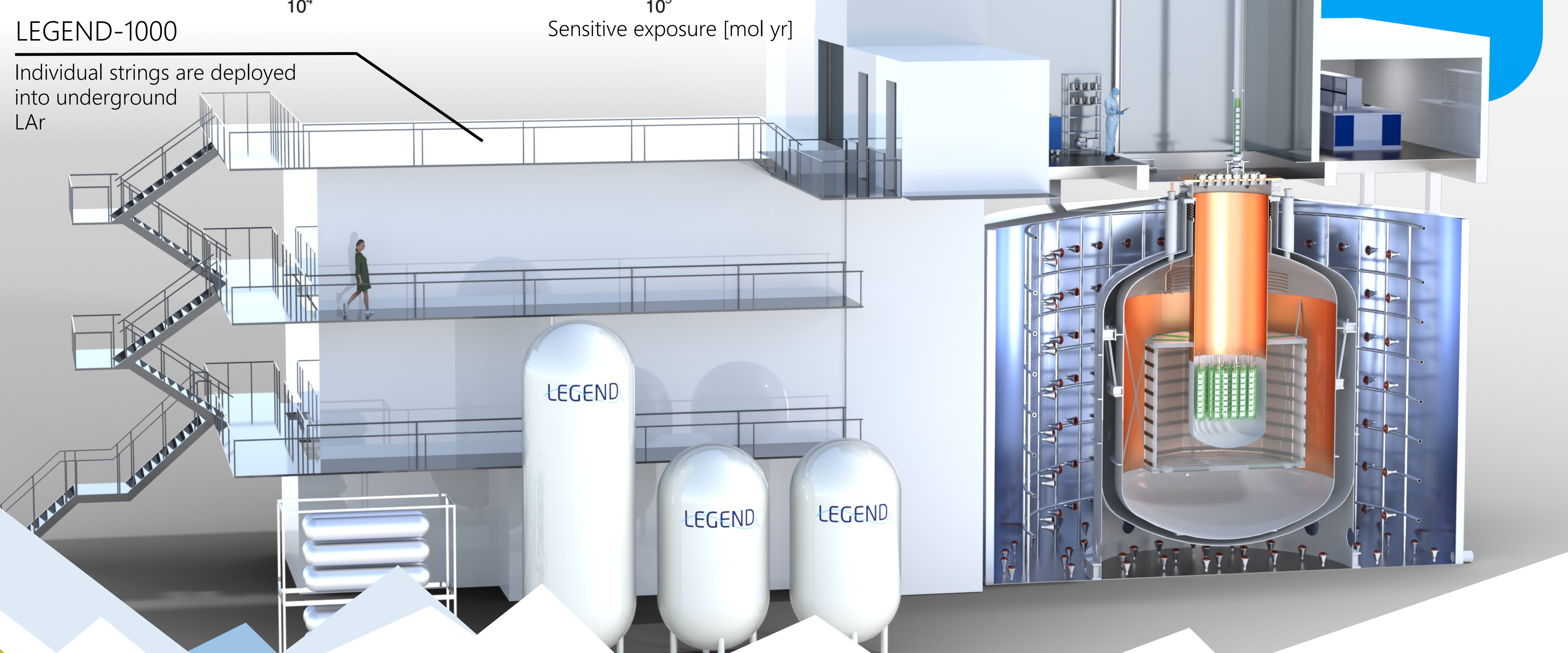
We work with commercial vendors to obtain crystals with the desired impurity profiles.

The electric fields of ~10^5 possible detector geometries are simulated. Geometries with viable electric fields are ranked based on depletion voltage, mass, surface area, and pulse shape discrimination performance.

We are exploring a larger detector geometry parameter space to push detector mass to unprecedented levels to achieve the goals of the LEGEND experimental program.



[Projected] Sensitive background and exposure for recent and [future] 0νββ experiments. The grey lines delimit specific discovery sensitivity values on the 0νββ-decay. Dashed colored lines indicate the half-life sensitivities required to fully probe the inverted ordering region. A lifetime of 10 years is assumed for future experiments. For all isotopes the largest QRPA nuclear matrix elements is assumed.



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