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Current status of LEGEND: Searching for Neutrinoless Double-Beta Decay in ^{76}Ge: Part II

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Neutrinoless double-beta decay($0\nu\beta\beta$) decay is a hypothetical process that violates lepton number, and whose observation would unambiguously indicate that neutrinos are Majorana fermions. In the standard inverted-ordering neutrino mass scenario, the minimum possible value of $m_{\beta\beta}$ corresponds to a half-life around 10^{28} yr for $0\nu\beta\beta$ decay in ^{76}Ge, which is the target of the next generation of experiments. The current limits of GERDA and MAJORANA DEMONSTRATOR indicate a half-life higher than 10^{26} yr. These experiments use high-purity germanium (HPGe) detectors that are highly enriched in ^{76}Ge. They have achieved the best intrinsic energy resolution and the lowest background rate in the signal search region among all $0\nu\beta\beta$ experiments.

Taking advantage of these successes, a new international collaboration - the Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay (LEGEND) - has been formed to build, following a phased approach, a ton-scale experiment with discovery potential covering the inverse-ordering neutrino mass range in a decade. The first part of LEGEND proceedings describes GERDA and MAJORANA DEMONSTRATOR capabilities and the general plan of LEGEND to reach the goal, while this second part is focused in the status of the first stage of LEGEND, LEGEND-200.

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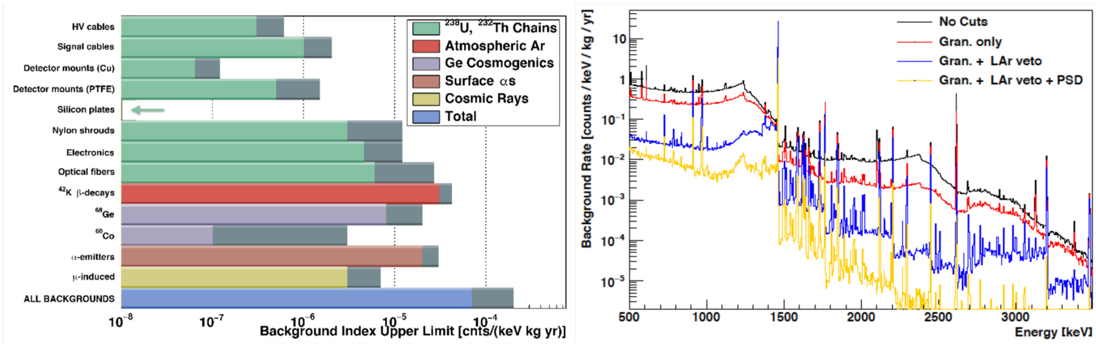

Figure 1: Monte Carlo simulations based on experimental data and material assays. Left: Background rates at 90% CL. The color bar indicates the type of background present in the element. The grey bar indicates the uncertainty in overall background rejection efficiency. Right: Energy spectrum before cuts (black), after granularity cut (red) after granularity and LAr veto (blue) and with all cuts applied (yellow) [9].

1. The LEGEND experiment

Combining the best technologies of GERDA [2][3] and MAJORANA DEMONSTRATOR [4][5], and including contributions of other groups that are not present in the previous experiments, the Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay (LEGEND) [6] aims to reach a sensitivity of 10^{28} yr for neutrinoless double beta ($0\nu\beta\beta$) decay half-life ($T^{0\nu}_{1/2}$) in ^{76}Ge. The requirement to reach that goal is at least 10 t-y of isotopic exposure in High Purity Germanium (HPGe) detectors, and a background level lower than 0.1 cts/(FWHM t y).

LEGEND will have 2 different phases; in the first phase (LEGEND-200), 200 kg of HPGe detectors will be deployed in the existing GERDA infrastructure with a background goal of $<$ 0.6 cts/(FWHM t yr). This will provide a half-life sensitivity of $\sim 10^{27}$ y after 5 years of data taking. LEGEND-200 is in its final stage of design and beginning construction stage, with data taking projected to begin in 2021. The second phase, LEGEND-1000, will operate 1000 kg of HPGe detectors. This last stage is in the early planning and R&D phase.

2. LEGEND-200

LEGEND-200 will implement several improvements for achieving further background reductions and assuring a good detector operation. For example, additional cables and electronics and a new vacuum feedthrough will be introduced to accommodate additional detectors in the GERDA infrastructure. Also, a mini-shroud covering the HPGe detector surfaces has been introduced and tested successfully to reduce the number of background events coming from the lithium-doped surface. Those events are produced by β decay of ^{42}K deposited in the crystal surface by the LAr [7].

LEGEND-200 will reuse 20 kg of enriched Broad Energy Germanium detectors, 15 kg of enriched semi-coaxial detectors and 10 kg of Inverted Coaxial Point-Contact detectors (ICPC) from GERDA, and 28 kg of enriched P-type Point-Contact detectors from the MAJORANA DEMONSTRATOR. In addition, around 150 kg of new ICPC enriched detectors are being manufactured

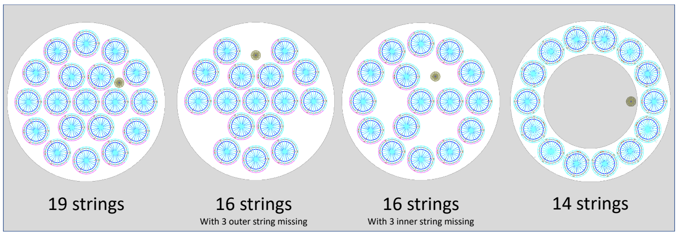

Figure 2: Top view of the four main array geometries considered. The blue circles represent detector strings and the small green circle the possible location of 1 calibration source (if more than 1 source is used, the other locations will be determined by symmetry) [1].

and characterized for use in LEGEND-200[8]. The expected background has been calculated from the experimental data and material assays, showing an expected reduction of a factor 5 in relation to GERDA and MAJORANA DEMONSTRATOR, as Figure 1 shows. Several geometries have been considered for the array geometry, as Figure 2 shows. Simulations also show that geometries with a high number of arrays inside the ring have a degradation in the liquid argon (LAr) rejection capabilities. For that reason, currently, the ring of 14 strings and variations with only a few string inside are the preferred by the collaboration [1]. The string arrangement further impacts the calibration system design, which must position a calibration source within the array to illuminate all detectors.

3. Conclusions

The expected background index for LEGEND-200 is estimated by simulations from the measured materials radio-purity. These simulations show a reduction in backgrounds by a factor 5 [9] in relation to GERDA and the MAJORANA DEMONSTRATOR. Based on simulations and the results of GERDA and the MAJORANA DEMONSTRATOR, LEGEND-200 will meet its background target of $<$ 0.6 cts/FWHM-t-y. Expected improvements from active R&D on LEGEND-1000 indicate that the accuracy on the energy determination and the effectiveness of background suppression techniques will reduce the background index to the levels required to achieve a sensitivity to the $0\nu\beta\beta$ half-life of 10^{28} yr at 90% CL.

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