^{76}Ge Detectors of the LEGEND experiment: Production, Characterization, Performance

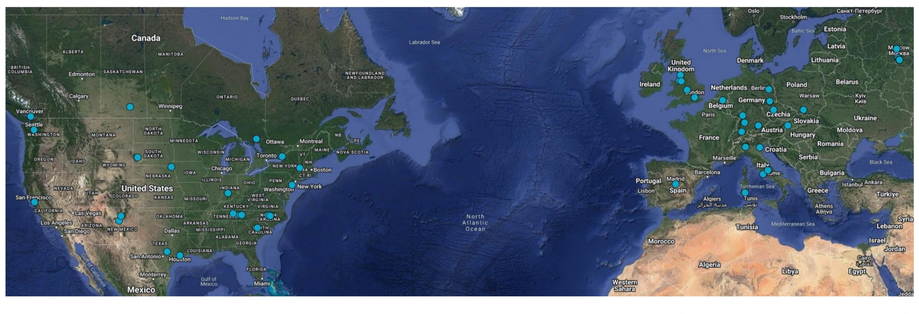
LEGEND

Large Enriched Germanium Experiment for Neutrinoless ββ Decay

TAUP VIENNA 2023

V. Biancacci on behalf of the **LEGEND collaboration**

Gran Sasso Science Institute, L'Aquila, Italy; INFN Laboratori Nazionali del Gran Sasso, Italy



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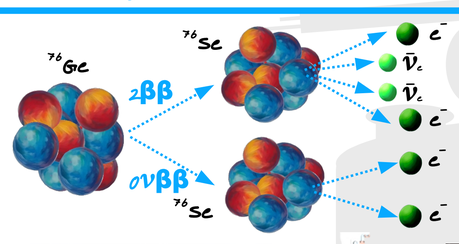
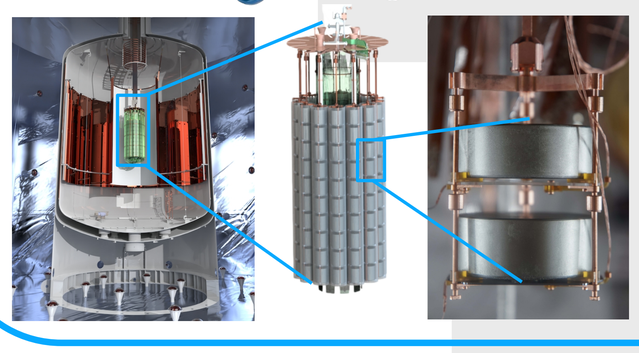
Why ^{76}Ge for double beta decay search?



SM allowed $2\nu\beta\beta$: $T_{1/2} = 2.0 \times 10^{21}$ yr

$Q_{\beta\beta} = 2039$ keV

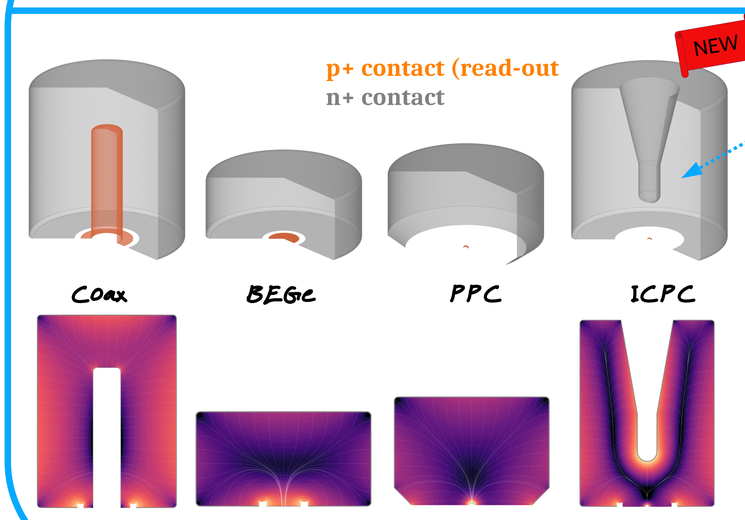
Beyond SM $0\beta\beta$: $T_{1/2} > 2.3 \times 10^{26}$ yr



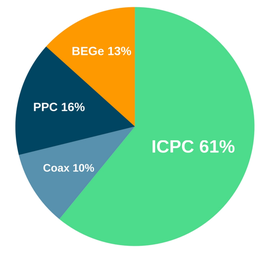
- The LEGEND experiment will search for $0\nu\beta\beta$ decay in the candidate isotope ^{76}Ge
- The first stage, LEGEND-200, comprises ~200 kg of HPGe detectors arranged in array submerged into liquid argon

- Detector=source (high detection efficiency)
- Suited for γ-rays measurements (MeV)
- Superior energy resolution (0.1% at $Q_{\beta\beta}$)
- Low internal radioactivity
- Well-established technology

HPGe detectors in LEGEND-200



- Enriched up to 92% in ^{76}Ge
- Excellent energy resolution and pulse shape discrimination (PSD)
- Significantly larger w.r.t. BEGe or PPC (up to 3 kg)
- Less channels, less background
- Better surface to volume-ratio

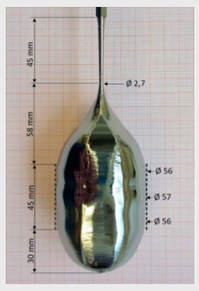


composition by mass

Detector Electric Fields

HPGe detector production

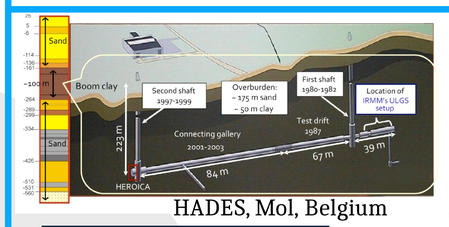
- Enriched Ge (~92%) delivered in GeO_2 form by Isotope JSC in Russia and Urenco in Netherlands
- Reduction of the oxide to metallic germanium until 6N purity by PPM Pure Metals, IKZ



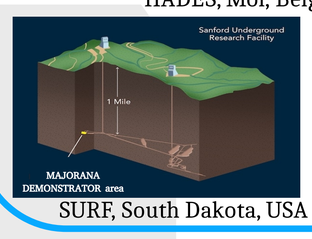
- Ingot

- Crystals grown using the Czochralski process and converted into diodes by MIRION, ORTEC

HPGe detector characterization

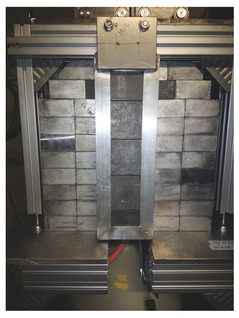


HADES, Mol, Belgium

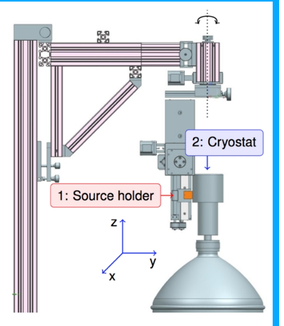


SURF, South Dakota, USA

- Two underground sites in Europe and US for the HPGe detector characterization
- Determination of standard parameters and optimal operational conditions
- Determination of dead layer and active volume



- Static measurements with ^{232}Th, ^{60}Co, ^{136}Ba, ^{241}Am

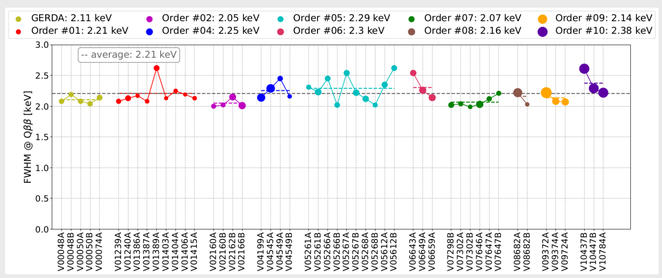


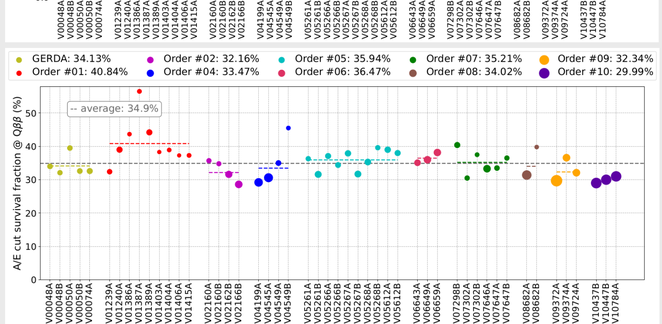
- Surface scans with collimated and uncollimated ^{241}Am

HPGe detector performance in vacuum

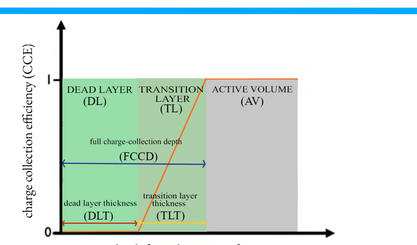
- Interpolated energy resolution in terms of FWHM at $Q_{\beta\beta}$
- The resolution curves is retrieved from γ-rays peaks from lateral ^{228}Th source spectrum

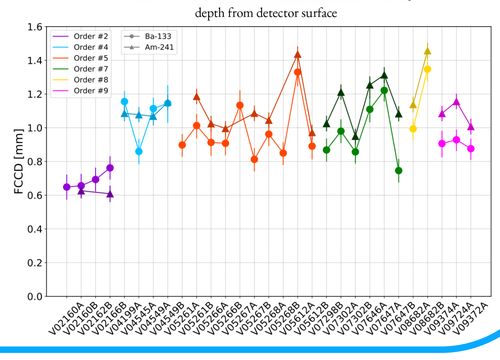
- Pulse shape discrimination at $Q_{\beta\beta}$
- PSD performance diagnostic relies on the acceptance of multi-site events sample upon the low A/E cut when accepting 90% of the single-site events from ^{208}Tl DEP.





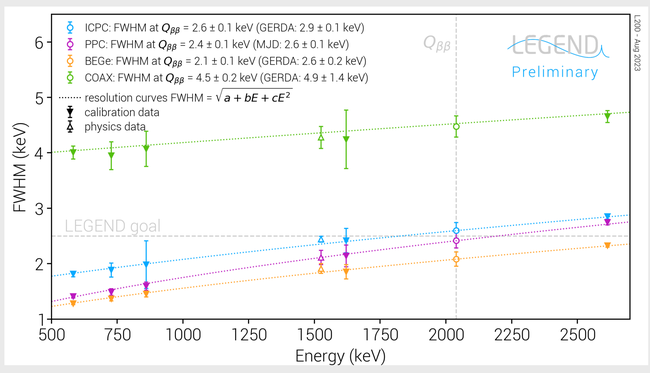
- Active volume (AV) ≠ total volume → presence of a conductive surface layer where charges are not fully collected
- Full charge-collection depth (FCCD) = depth at which the charge-collection efficiency reaches unity
- FCCD obtained with ^{241}Am and ^{133}Ba sources for most of the ICPCs characterized in the HADES laboratory
- AV is necessary for a precise detector efficiency calculation which is required for all analyses in LEGEND



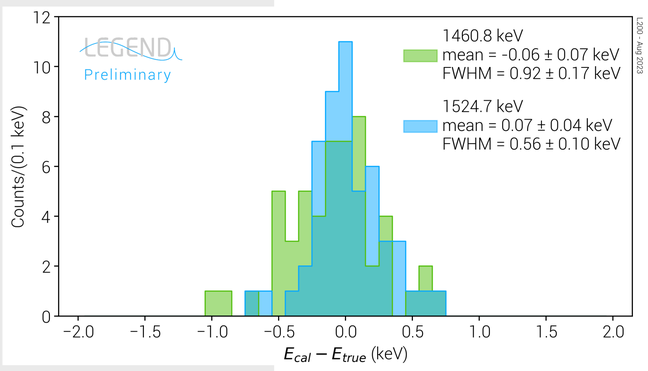


HPGe detector performance in LEGEND-200

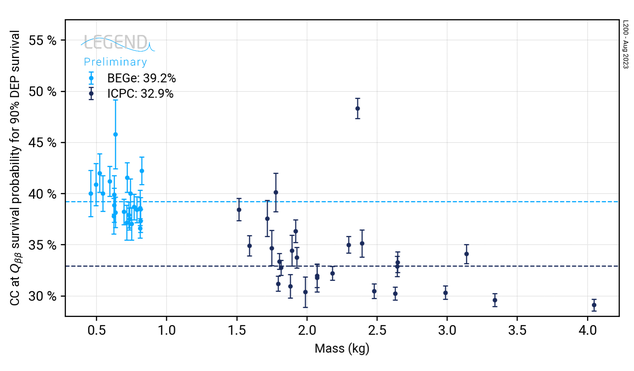
- LEGEND-200 preliminary performance is very good
- Most of the detectors already fulfilling LEGEND-200 goals in terms of energy resolution
- The energy scale is very stable between calibrations
- Good rejection of multi-site events thanks to the PSD



- Resolution curves per detector type calculated as weighted average over the detectors
- The plot shows the FWHM from the calibration peaks and from the ^{42}K line in physics data



- Residual on the mean value of potassium lines in physics data
- The residual distribution around 0 confirms the precise determination of the energy scale



- Survival fraction in the Compton continuum around $Q_{\beta\beta}$ for 90% DEP survival
- Larger detectors, like ICPC, present a lower survival fraction as more events are multi-site