First Look at Background of the LEGEND-200 Experiment

LEGEND

Valerio D'Andrea valerio.dandrea@roma3.infn.it INFN Roma Tre Large Enriched Germanium Experiment for Neutrinoless ββ Decay



on behalf of the LEGEND Collaboration



XX International Workshop on Neutrino Telescopes (NeuTel 2023) 23–27 Oct 2023, Venice, Italy

LEGEND Collaboration





CIEMAT Comenius Univ. Czech Tech. Univ. Prague and IEAP Daresbury Lab. Duke Univ. and TUNL Gran Sasso Science Inst. Indiana Univ. Bloomington Inst. Nucl. Res. Rus. Acad. Sci. Jagiellonian Univ. Joint Inst. for Nucl. Res. Joint Res. Centre Geel Lab. Naz. Gran Sasso Lancaster Univ. Leibniz Inst. for Crystal Growth Leibniz Inst. for Polymer Research Los Alamos Natl. Lab. Max Planck Inst. for Nucl. Phy. Max Planck Inst. for Physics Natl. Res. Center Kurchatov Inst. Natl. Res. Nucl. Univ. MEPhl North Carolina State Univ. Oak Ridge Natl. Lab. Polytech. Univ. of Milan Princeton Univ. Queen's Univ. Roma Tre Univ. and INFN Simon Fraser Univ. SNOLAB

South Dakota Mines Tech. Univ. Dresden Tech. Univ. Munich Tennessee Tech. Univ. Univ. of California and LBNL Univ. of California and LBNL Univ. college London Univ. of Liverpe London Univ. of Cagliari and INFN Univ. of Cagliari and INFN Univ. of Cagliari and INFN Univ. of Houston Univ. of Liverpool Univ. of Milan and INFN Univ. of Milano Bicocca and INFN Univ. of New Mexico Univ. of North Carolina at Chapel Hill Univ. of Padova and INFN Univ. of Regina Univ. of South Carolina Univ. of South Dakota Univ. of Tennessee Univ. of Texas at Austin Univ. of Tuebingen Univ. of Warwick Univ. of Washington and CENPA Univ. of Zurich Williams College

> 12 countries 55 institutions ~270 members

LEGEND Program



LEGEND collaboration aims to develop a phased, ⁷⁶Ge based double-beta decay experimental program with discovery potential at a half-life beyond 10²⁸ years, using existing resources as appropriate to expedite physics results



First Stage LEGEND-200

- up to 200 kg of ⁷⁶Ge
- modification of existing GERDA infrastructure at INFN Gran Sasso Laboratory (Italy)
- background goal of 0.6 cts/(FWHM·t·yr)

Subsequent Stage LEGEND-1000

- 1000 kg of ⁷⁶Ge
- location to be selected
- background goal < 0.03 cts/(FWHM·t·yr)
- timeline connected to review process



LEGEND-200 Experiment





Installation & Commissioning









Tests of electronics and DAQ Installation of mechanics and glove box

Installation and commissioning of all available HPGe detectors

Post-GERDA Test



Status and Plan



COAX (GERDA)

Coax

PPC

BEGe

ICPC







- Successful installation of 142 kg of HPGe detectors, 101 detectors in 10 string
- 130 kg operational
- LAr instrumentation operational
- Focus on analysis of ICPC and BEGe detectors
- PSD development for other detectors ongoing

Next Steps

- Continue data taking, evaluate backgrounds
- Complete array and fix hardware failures in 2024

Energy Resolution and Stability



- Energy scale evaluated by weekly ²²⁸Th calibration between physics runs
- Most of the detectors fulfilling LEGEND-200 goal in terms of energy resolution
- Stable energy scale among calibrations
- Precise determination of energy scale confirmed by potassium lines in physics data



Background Spectra and Decomposition



- No unexpected background components
 - ²³⁸U and ²³²Th decay chains
 - Gamma lines from ⁴⁰K and ⁴²K
- Similar GERDA spectral shape
 - higher rate from ²⁰⁸Tl expected from more construction material
- Improved peak to Compton ratio
 - Reduces Compton continuum background
 - Higher detection efficiency due to larger mass detectors



Work in progress on background modeling before analysis cuts Well described by expected contributions with current statistics

Pulse Shape Discrimination



- PSD based on A/E parameter, rejects multi-site and alpha events effectively
- Double Escape Peak (DEP) of ²⁰⁸Tl used as single-site event proxy, cut tuned to 90% DEP survival
- Good rejection of multi-site events
- More powerful due to higher multi-site probability in larger ICPC detectors





survival

LAr Instrumentation



- Higher light yield and less shadowing improved background suppression of LAr instrumentation → 3x more light compared to GERDA
- Compton continuum more strongly suppressed
- LAr signal can be used for particle identification (e.g. BiPo tagging), LAr instrumentation now acts as a full-fledged detector



First look at LEGEND-200 Background



First 10.1 kg yr of LEGEND-200 physics data including ICPC and BEGe detectors





- Successfully upgraded GERDA infrastructure to accommodate LEGEND-200 array
 - Installed first 142 kg of HPGe detectors in LEGEND-200 in October 2022
 - Good performance of all detector systems
- First look at LEGEND-200 physics data
 - No unexpected background components (background decomposition in progress)
 - LAr instrumentation and PSD work as expected
 - Background after cuts evaluated on first 10.1 kg yr of physics data compatible with LEGEND-200 goal
- Data taking is currently ongoing & new detectors will be added in 2024

Thanks for your attention!



Backup slides

Bi-Po tagging with LAr instrumentation



$2\nu\beta\beta$ decay count uniformity



| 23-27 Oct 2023 First Results of LEGEND-200 Valerio D'Andrea

Comparing LEGEND-200 and GERDA spectrum





First Results of LEGEND-200 | 23-27 Oct 2023 Valerio D'Andrea





