LEGEND: The Large Enriched Germanium Experiment for Neutrinoless Double Beta Decay

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JINR Young Scientists and Specialists Association Workshop "Alushta-2020"

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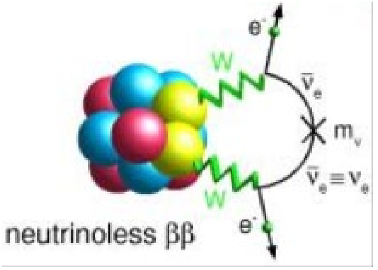
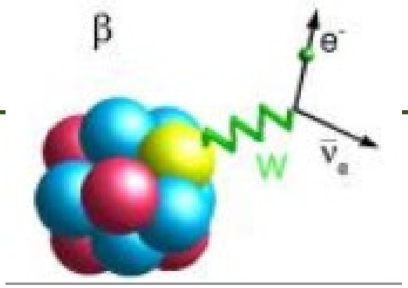


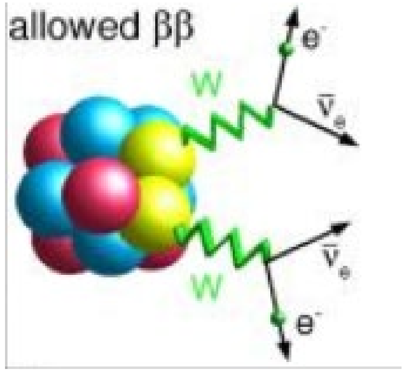
Neutrinoless Double-Beta Decay



If observed, 0νββ decay would:

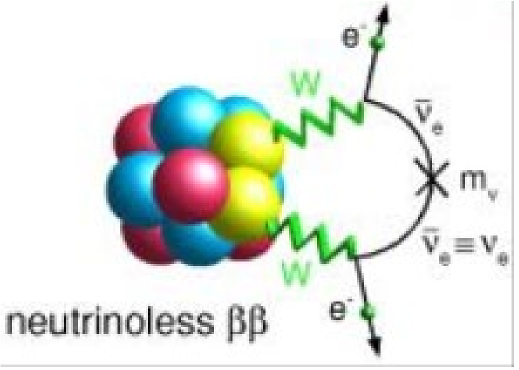
- Demonstrate that lepton number is not conserved
- Show that neutrinos are Majorana particles
- Provide plausible scenarios for the origin of the baryon asymmetry of the universe
- Offer a potential mechanism for the very light masses of neutrinos compared to that of the charged fermions
- Provide a model-dependent measurement of the absolute neutrino mass

All of this from a process that has no neutrinos in either the initial or the final state!

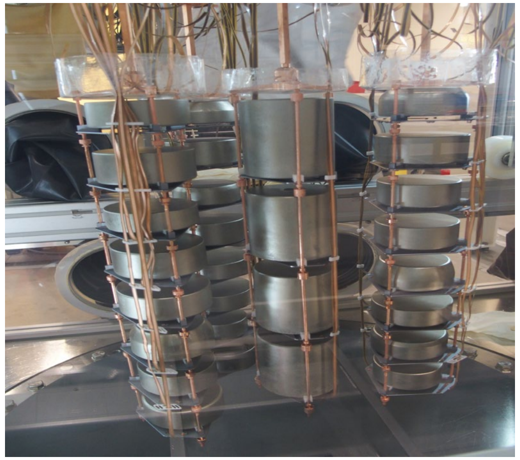


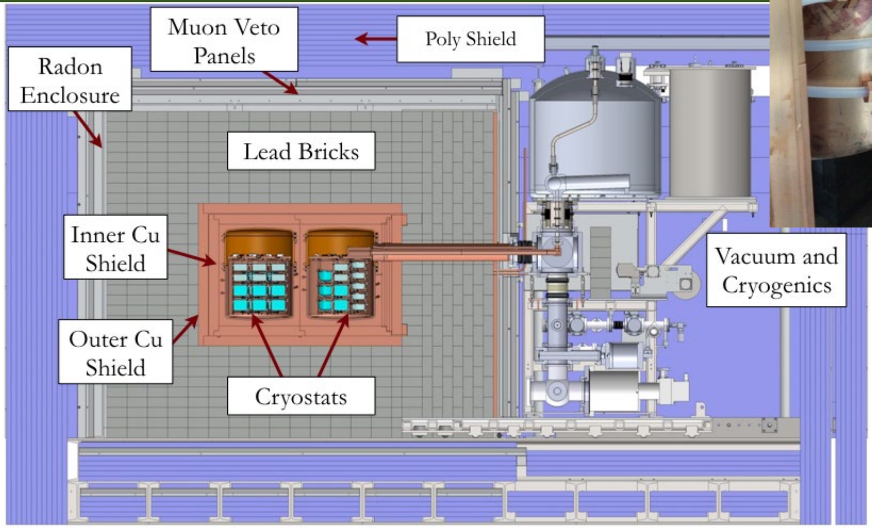
Major challenges:

- Exposure (detector mass)
- Background event rates

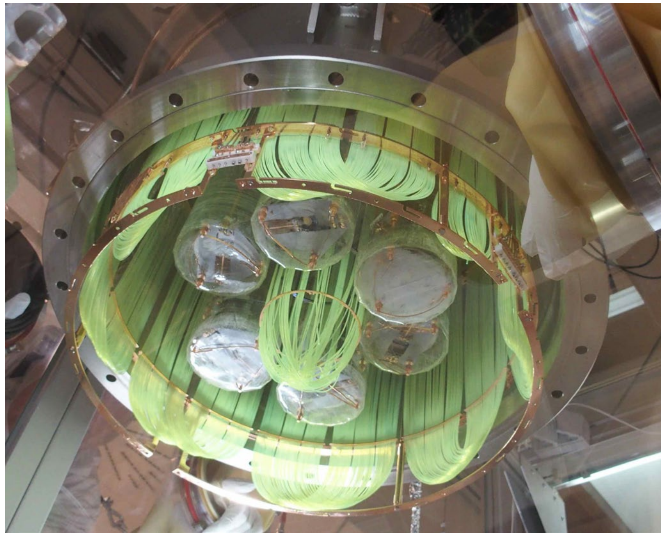


GERDA and MAJORANA

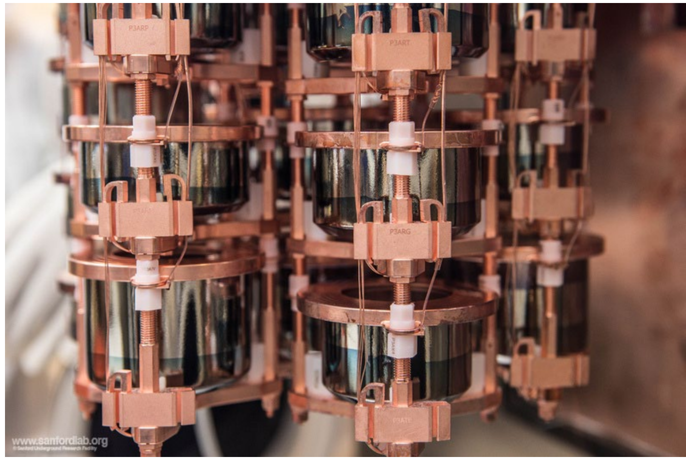




GERDA
- Novel configuration: bare crystals in LAr active veto



The MAJORANA DEMONSTRATOR
- Traditional approach: Vacuum cryostats in Passive shield, ultraclean materials



LEGEND Strategy: Best of Both Worlds

- Combine the best of **GERDA:**
  - LAr veto
  - Low-A shield, no Pb
  - GERDA infrastructure at LNGS

- … with the best of **MAJORANA DEMONSTRATOR (MJD):**
  - Radiopurity of parts near detectors (FETs, cables, Cu mounts, etc.)
  - Low noise electronics; helps improve background through better pulse-shape discrimination
  - Low energy threshold for improved cosmogenic background rejection

- and techniques developed in **Both** experiments:
  - Clean fabrication techniques
  - Control of time on surface to reduce cosmogenic backgrounds
  - Development of large point-contact detectors
  - Lowest background and best resolution of existing 0nbb experiments

Large Enriched Ge Experiment for Neutrinoless ββ Decay (LEGEND)

47 Institutions, 237 Scientists

Univ. New Mexico
L'Aquila Univ. and INFN
Gran Sasso Science Inst.
Lab. Naz. Gran Sasso
Univ. Texas
Tsinghua Univ.
Lawrence Berkeley Natl. Lab.
Leibniz Inst. Crystal Growth
Comenius Univ.
Lab. Naz. Sud
Univ. of North Carolina
Sichuan Univ.
Univ. of South Carolina
Jagiellonian Univ.
Banaras Hindu Univ.
Univ. of Dortmund
Tech.Univ. – Dresden
Joint Inst. Nucl. Res. Inst.
Nucl. Res. Russian Acad. Sci
Univ. South Dakota
Univ. Zurich

Joint Res. Centre, Geel
Chalmers Univ. Tech.
Max Planck Inst., Heidelberg
Dokuz Eylul Univ.
Queens Univ.
Academia Sinica
Univ. Tuebingen

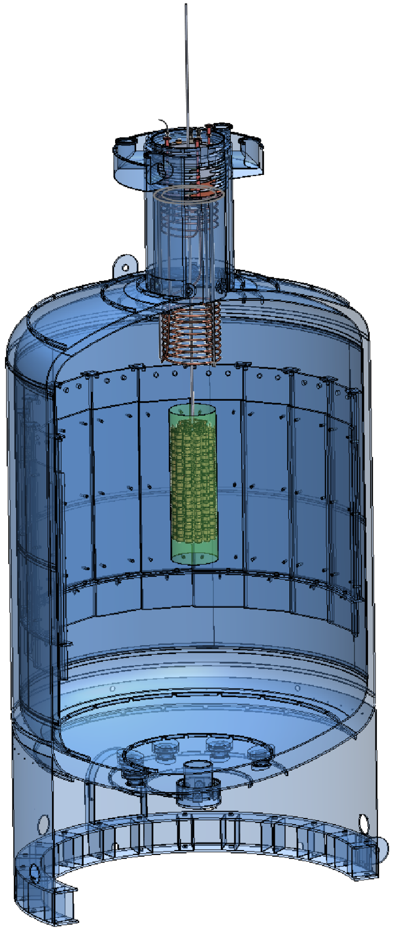
Univ. Tennessee
Argonne Natl. lab.
Univ. Liverpool
Univ. College London
Los Alamos Natl. Lab.
Univ. Washington
North Carolina State Univ.

Lund Univ.
INFN Milano Bicocca
Milano Univ. and Milano INFN
Natl. Res. Center Kurchatov Inst.
Lab. for Exper. Nucl. Phy.
South Dakota School Mines Tech.

MEPhI Max Planck Inst., Munich
Tech. Univ. Munich
Oak Ridge Natl. Lab.
Padova Univ. and Padova INFN
Czech Tech. Univ. Prague
Princeton Univ.

Two Phases: LEGEND-200 and LEGEND-1000

LEGEND mission: "The collaboration aims to develop a phased, 76Ge 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."

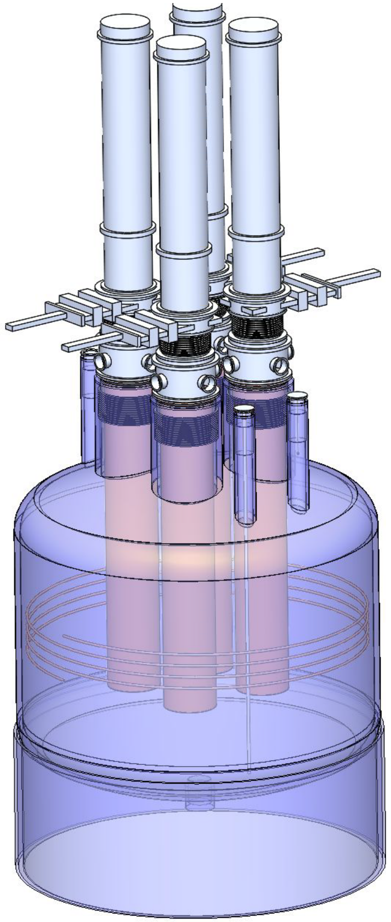


LEGEND-200:

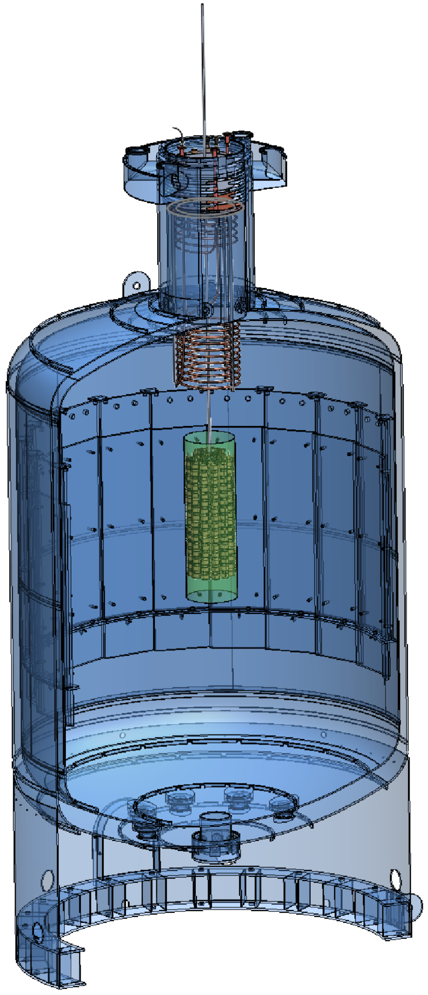
- Initial Phase
- Up to 200 kg in upgrade of existing GERDA infrastructure at LNGS
- Bkg goal: 0.6 counts/FWHM-t-yr (5x lower than GERDA)
- Sensitivity **10^{27}** yr
- Data-taking could start as early as 2021

LEGEND-1000:

- Ultimate goal
- 1000 kg (phased) required to cover neutrino-mass inverted ordering
- Timeline connected to US DOE down -select process
- Bkg goal: 0.1 counts/FWHM-t-yr
- Location TBD
- Sensitivity **10^{28}** yr
- Required depth under investigation

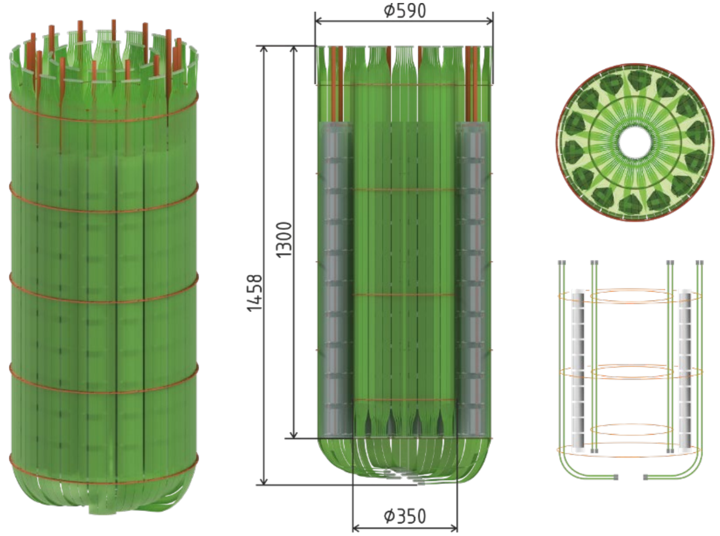


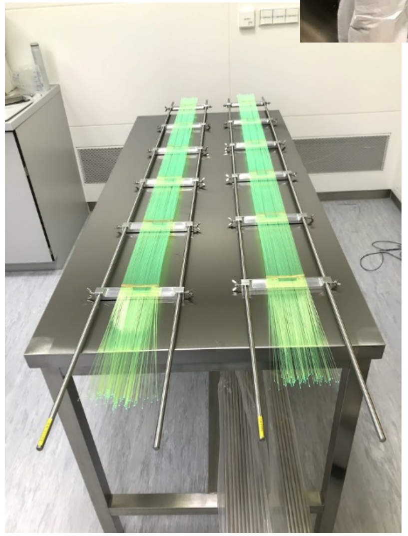
LEGEND-200: first stage



- ✓ Reuse existing GERDA infrastructure at LNGS
- ✓ Modifications of internal cryostat piping so can accommodate up to 200 kg of detectors (neck of cryostat 800 mm diameter)
- ✓ Improvements
  - use some larger Ge detectors
  - improve LAr scintillator light collection (LAr veto)
  - lower mass, cleaner cables
  - lower noise electronics
- ✓ Estimate background improvement by ~ x5 over GERDA/MAJORANA (goal 0.6 cnt /(FWMH t yr)):
  - intrinsic : including ^{68}Ge/^{60}Co all OK
  - external Th/U: cleaner materials based on those used in DEMONSTRATOR
  - surface events : α & β rejection via PSD
  - ^{42}Ar : better suppression & mitigation
  - muon induced : OK

Lar veto for LEGEND-200





February 2020

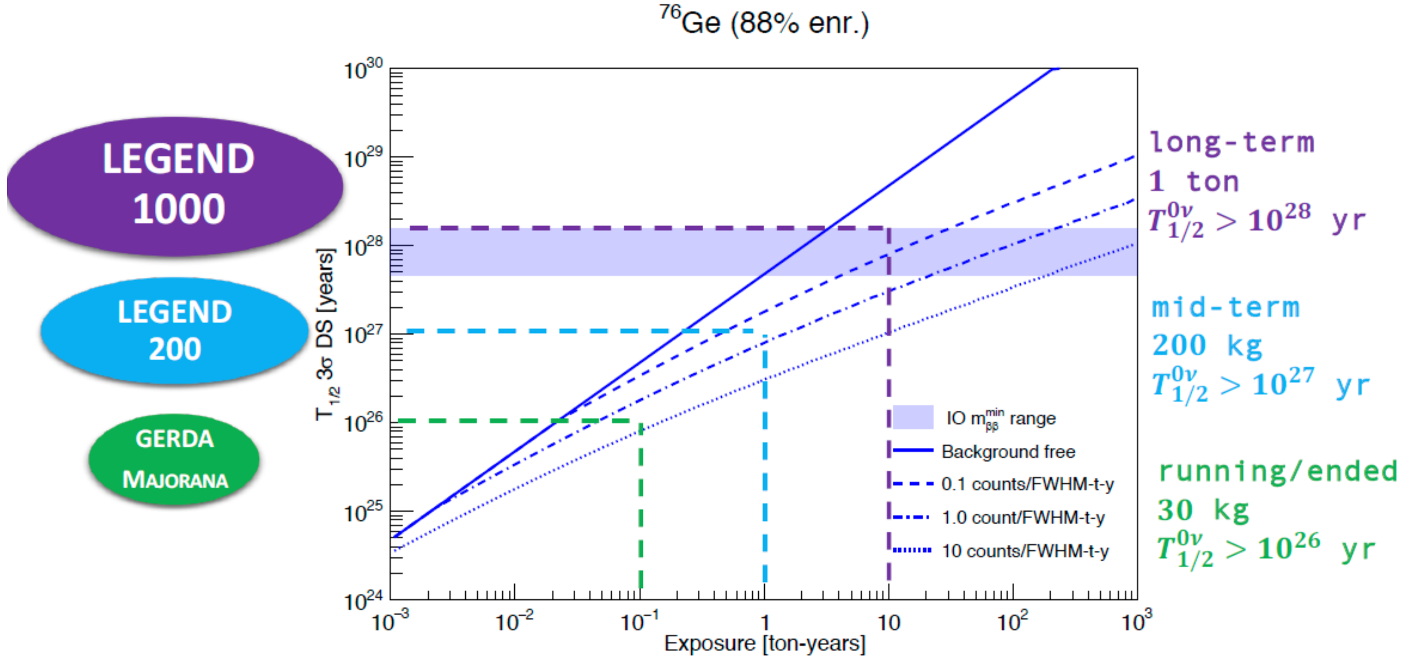
LEGEND-200 Fiber Shroud

— 60 channels (each with 9 SiPMs) in two concentrical fiber shrouds.
— Improved version of the GERDA fiber modules.
— Outer shroud is bended inwards at the bottom.
— Read out new fiber modules on both ends - minimize the light attenuation inside the fibers.
— Select materials thouroughly - minimal background.

Summary

LEGEND-200 already using GERDA infrastructure at LNGS

- Test of prototype electronics and DAQ started in existing cryostat,
- to be followed by infrastructure upgrade.
- Data-taking will begin in 2021



LEGEND-1000: ton-scale experiment achievable with modest evolution of LEGEND-200 design

- goal to reach the **10^{28}** yr discovery potential sensitivity

Thank you for attention