

# Searching for Beyond-Standard-Model Physics with LEGEND-1000



Large Enriched Germanium Experiment for Neutrinoless  $\beta\beta$  Decay



Samuel Watkins on behalf of the LEGEND collaboration  
Los Alamos National Laboratory, Los Alamos, NM 87545, USA



This work was supported by the U.S. Department of Energy through the Los Alamos National Laboratory. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218CNA000001). Research presented in this poster was supported by the Laboratory Directed Research and Development program of Los Alamos National Laboratory under project number 20230782PRD1.



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

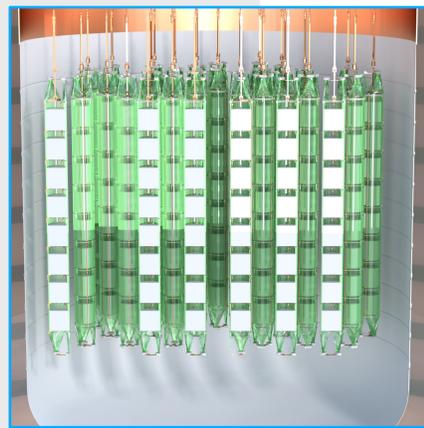
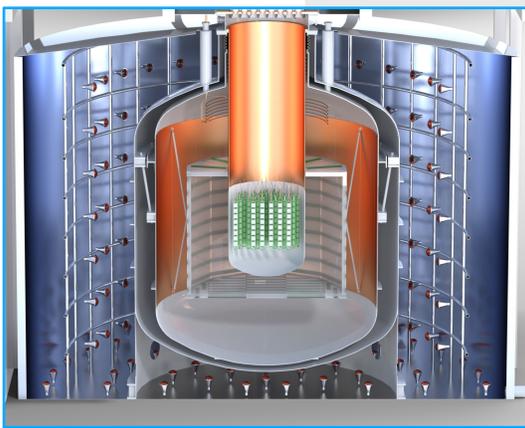
Leibniz Inst. for Polymer Research  
Los Alamos Natl. Lab.  
Max Planck Inst. for Nucl. Phys.  
Max Planck Inst. for Physics  
Natl. Res. Center Kurchatov Inst.  
Natl. Res. Nucl. Univ. MEPhI  
North Carolina State Univ.  
Oak Ridge Natl. Lab.  
Polytech. Univ. of Milan  
Princeton Univ.  
Queen's Univ.  
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. College London  
Univ. of L'Aquila 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

## LEGEND-1000 Design

- 1000 kg of HPGe detectors
- Operated in a bath of underground-sourced LAr



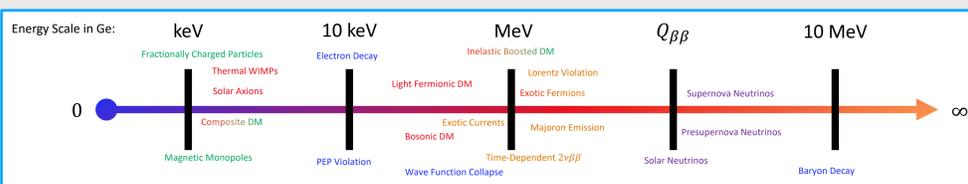
See V. E. Guiseppe's talk for more!

- Wed. Aug 30, 2:45pm in Audimax
- Neutrinos and Astrophysics session

## Beyond Standard Model Physics

Many physics topics beyond neutrinoless double beta decay

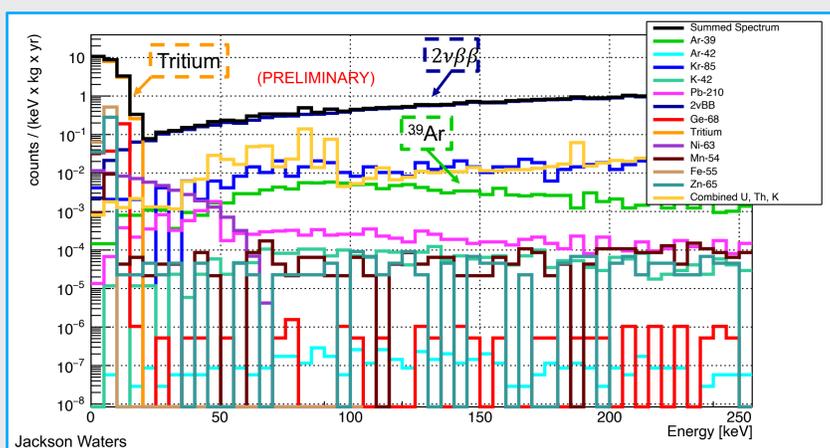
- Dark matter candidates
- $2\nu\beta\beta$  spectral effects
- Tracklike signatures
- Tests of fundamental physics
- Astrophysical neutrinos



## Low-Energy Background Model

Developing a low-energy background model to estimate sensitivities

- Assume underground-sourced liquid Ar
- Assume surface exposure of detectors limited to <40 days



## Composite Dark Matter

DM-nucleon recoils: exponential decay + nuclear form factor

- Ultraheavy dark matter with large interaction cross sections can interact multiple times in a line

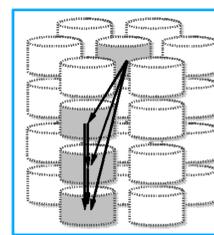
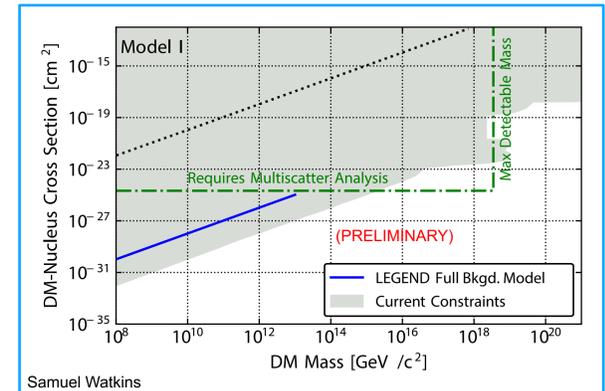


Diagram from:  
[arXiv:1801.10145](https://arxiv.org/abs/1801.10145)

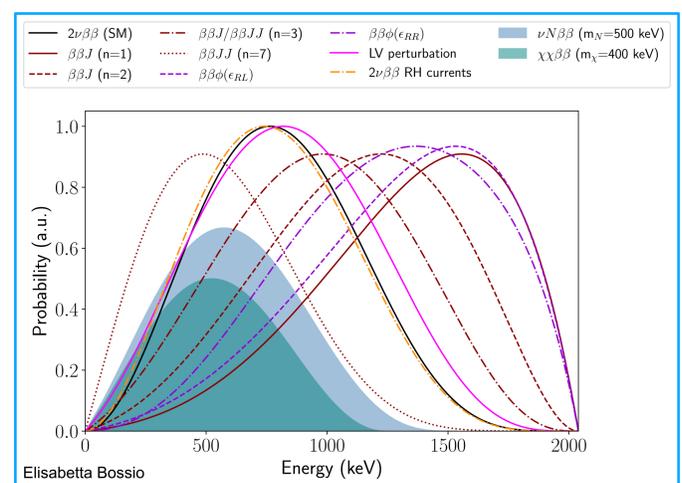


## $2\nu\beta\beta$ Spectral Effects

Indicated by a distortion of the  $2\nu\beta\beta$  decay spectrum

- Emission of new particles (e.g. Majorons, sterile neutrinos)
- Lorentz violation
- Exotic currents

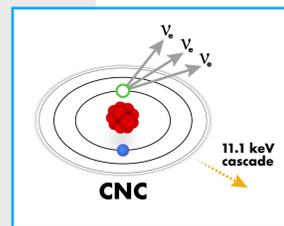
Latest GERDA result: [arXiv:2209.01671](https://arxiv.org/abs/2209.01671)



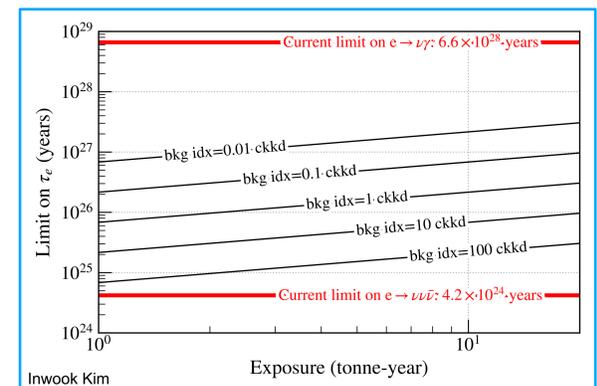
## Electron Decay

K-shell electron in Ge could decay, leaving a hole to be filled, producing a 11.1 keV X-ray (i.e. a Gaussian peak at 11.1 keV in the spectrum)

- Can set lifetime limits on  $e \rightarrow \nu\nu\bar{\nu}$  channel of charge nonconservation



Latest MAJORANA result:  
[arXiv:2203.02033](https://arxiv.org/abs/2203.02033)



## And More!

- White paper in development, to be published
- Includes sensitivities on all listed BSM topics

