Rare Low-Energy Event Searches with the MAJORANA DEMONSTRATOR

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The MAJORANA DEMONSTRATOR

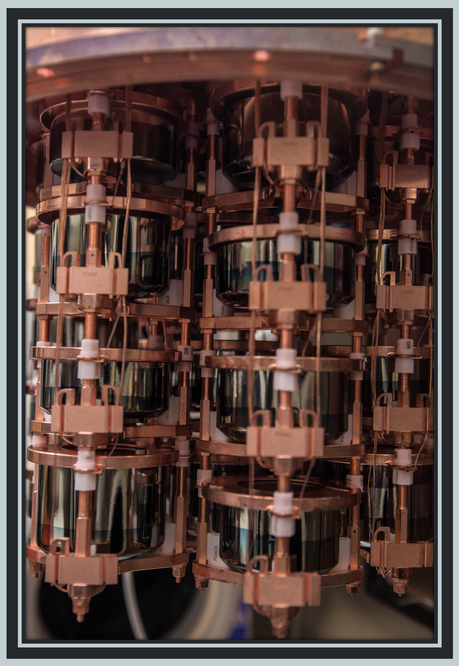


Figure 1: Assembled detector strings before closing of the underground electroformed copper cryostat. Photo Credit: Matthew Kapust, Sanford Underground Research Facility

The MAJORANA DEMONSTRATOR is a neutrinoless double-beta decay experiment using enriched germanium as source and detector. The DEMONSTRATOR is currently operating underground at the 4850' level of the Sanford Underground Research Facility.[1,2]

The goals for the DEMONSTRATOR are:

1) Demonstrate background levels low enough to justify building a tonne scale experiment.
2) Establish the feasibility of constructing & fielding modular arrays of Ge detectors.
3) **Search for additional physics beyond the Standard Model, such as solar axions and dark matter.**

Energy resolution of 2.5 keV FWHM @ 2039 keV is the best of any ββ–decay experiment [2]

❖ Background Goal in the 0νββ peak after analysis cuts with the achieved resolution: 2.5 counts/(FWHM t yr)
- **Projected backgrounds based on assay results ≤ 2.2 counts/(FWHM t yr)**

❖ 44.1-kg of Ge detectors
- 29.7 kg of 88% enriched ^{76}Ge crystals
- 14.4 kg of ^{nat}Ge
- Detector Technology: P-type, point-contact.

❖ 2 independent cryostats
- Ultra-clean, electroformed Cu
- 22 kg of detectors per cryostat
- Naturally scalable

❖ Ultra-low-activity components and construction

❖ Compact Shield
- Low-background passive Cu and Pb shield with active muon veto

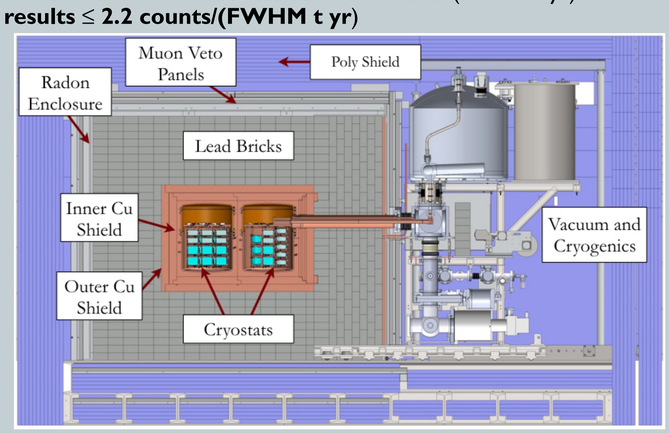


Figure 2: View of Module 1 in the compact lead and copper shielding (background), with Module 2 waiting to be inserted into the shield (foreground).

MAJORANA PPC HPGe Detector Advantages

- ❖ Sub-keV energy thresholds possible (< 500 eV) (Data for results shown has 5 keV analysis threshold)
- ❖ Excellent energy resolution (0.4 keV FWHM at 10.4 keV)
- ❖ Excellent pulse shape discrimination
- ❖ Ultra-low background components, including underground electroformed Cu
- ❖ Reduced cosmogenic activation in our enriched detectors from surface exposure control

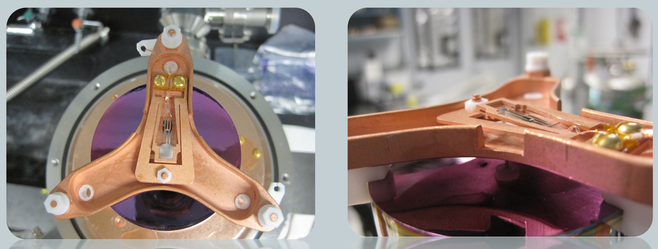


Figure 3: Bottom (left) and side (right) view of an enriched PPC HPGe detector unit with low noise, radiopure low-mass front end (LMFE) board[3]

The MAJORANA Low-Energy Program

- ❖ The Low-Energy program is interested in analysis of events in the energy region 1 keV - 100 keV. ($Q_{\beta\beta}$ for ^{76}Ge is 2039 keV)
- ❖ Ongoing searches for bosonic dark matter, low-mass WIMPs, Pauli Exclusion Principle violation, solar axions, and electron decay

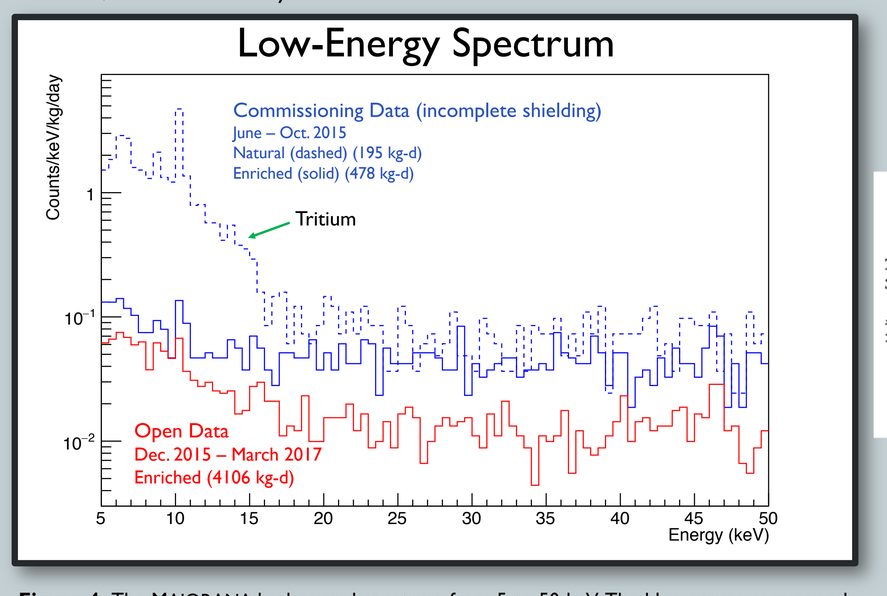
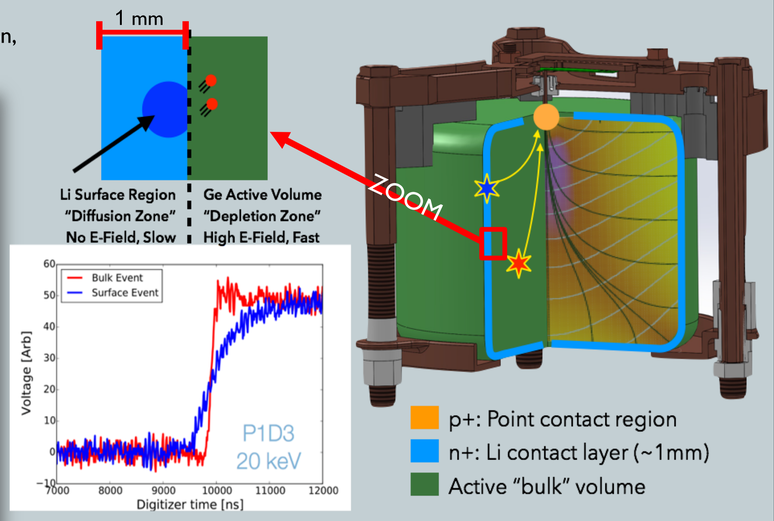


Figure 4: The MAJORANA background spectrum from 5 to 50 keV. The blue curves correspond to commissioning data with incomplete shielding, which was used to set the current limits[4] shown in Figures 5 and 6. The red curve correspond to data taken after shielding was complete.

Slow Pulse Discrimination



- ❖ "Surface" (Li layer) signals are from the *fraction* of charge that slowly diffuses into the active region.
- ❖ Slow pulses are energy degraded events and contribute a significant background at energies below 30 keV [5]
- ❖ Slow pulses are effectively removed by pulse shape discrimination cuts

Current Limits and Sensitivity Projections for Selected Rare Event Searches

- ❖ Projections for vector and pseudoscalar bosonic dark matter based on previous results, which correspond to data in blue in the energy spectrum in Figure 4, and current background levels.
- ❖ 4106 kg-d enriched exposure corresponds to all open data up to March 2017, 12208 kg-d corresponds to the estimated exposure of all low-background open and blind data through December 2017, including natural detectors.

Vector Dark Matter

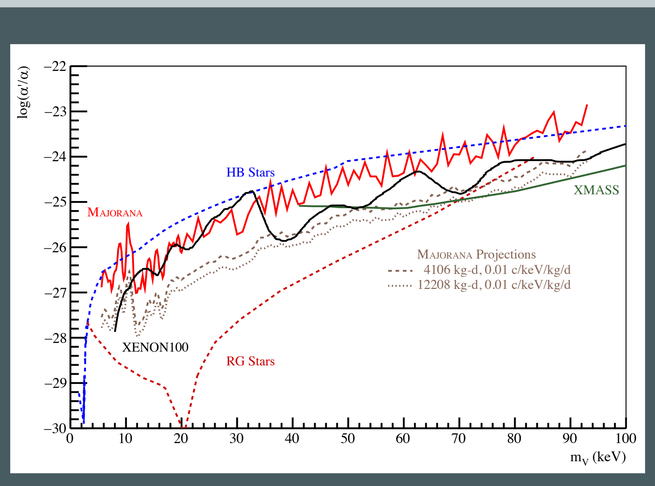


Figure 5: Current MAJORANA limits[4] (red) and projected sensitivities (gold) for vector dark matter.

Pseudoscalar Bosonic Dark Matter

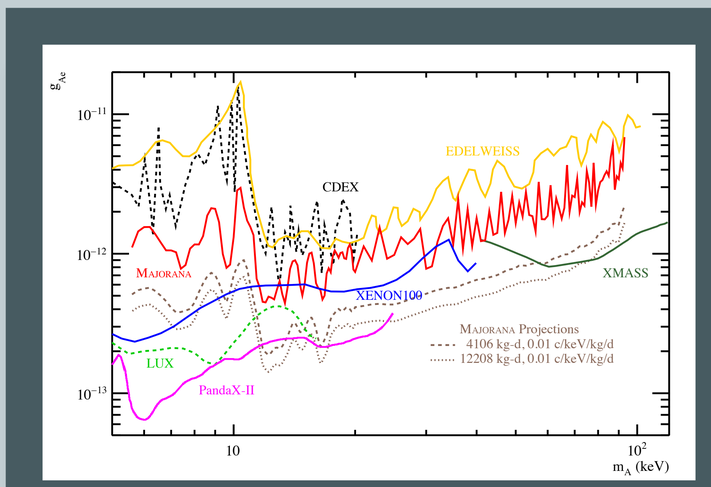


Figure 6: Current MAJORANA limits[4] (red) and projected sensitivities (gold) for pseudoscalar bosonic dark matter.

Low-Mass WIMPs

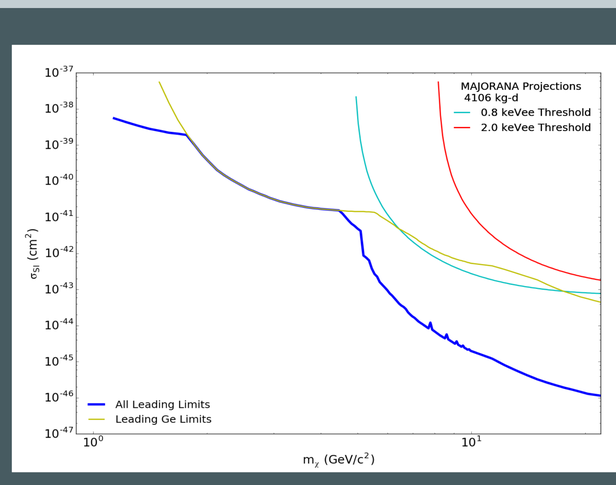


Figure 7: Projected sensitivity for low-mass WIMP search assuming 4106 kg-d exposure and various analysis thresholds.

References

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2. C. E. Aalseth et al. Search for Neutrinoless Double- Decay in 76Ge with the Majorana Demonstrator. Phys. Rev. Lett., 120(13):132502, 2018.
3. P. Barton et al. Low-noise low-mass front end electronics for low-background physics experiments using germanium detectors. In 2011 IEEE Nuclear Science Symposium Conference Record, pages 1976–1979, Oct 2011.
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5. G. Giovanetti et al., Phys. Proc., 61, 77 (2015), ISSN 1875-3892.

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