The MAJORANA DEMONSTRATOR

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on behalf of the MAJORANA COLLABORATION

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The MAJORANA DEMONSTRATOR

- The MAJORANA DEMONSTRATOR (MJD) is an array of enriched and natural germanium detectors that will search for the $0\nu\beta\beta$-decay of $^{76}\text{Ge}$.

- The specific **goals** of the MAJORANA DEMONSTRATOR are:
  1. Demonstrate background levels low enough to justify building a tonne-scale experiment.
  2. Establish feasibility of modular Ge detector array construction and deployment.
  3. Searches for other physics beyond the standard model, such as dark matter and axions.

Ge enrichment

Ge crystal

Modular Ge detector array

C. Cuesta
MJD Configuration

- **Background goal** in the $0\nu\beta\beta$-decay ROI (4 keV at 2039 keV):
  - 3 cnts/(ROI-t-y) (after analysis cuts).
  - Scales to 1 cnt/(ROI-t-y) for a tonne experiment.

- **40-kg of Ge detectors:**
  - 30 kg of 87% enriched $^{76}$Ge crystals.
  - 10 kg of $^{nat}$Ge.
  - Detector Technology: P-type point-contact.

- **2 independent cryostats:**
  - Ultra-clean electroformed Cu.
  - 20 kg of detectors per cryostat.
  - Naturally scalable.

- **Compact shield:**
  - Low-background passive Cu and Pb shield with active muon veto.

- Located underground at 4850’ **Sanford Underground Research Facility**, Lead, SD.
Point Contact Detectors (PPC)

- Small point-like central contact; no deep hole.
- Length is typically shorter than standard coaxial detector.
- Simple, cost-effective, low-background.
- Localized weighting potential gives excellent multi-site rejection, required for 0νββ.
- Low capacitance (~1pF) gives superb resolution at low energies, low threshold.

Enriched Ge detectors

- 61 kg GeO$_2$ (42.5 kg Ge) produced at ECP, Zelenogorsk, Krasnoyarsk, Russia.
- Transported shielded by sea.
- Reduction and Refinement: ESI, Oak Ridge, TN.
- Detector fabrication: Ortec, Oak Ridge, TN.
- Hand – transported to SURF.
- 30 enriched PPC detectors, 25.2 kg mass produced by ORTEC are at SURF characterized and ready for installation in Modules 1 & 2.
- Ge recovery plan to produce another ~4 kg of detectors.
Background Considerations

- Background reduction:
  - Large detectors arrays.
  - Shielding.
  - Reduction of radioactive impurities.
    - Extensive campaigns to qualify, procure and produce clean materials.
    - UG manufacturing for reduction of cosmogenic activation.
    - Material assay (NAA, ICPMS, γ-counting)

![Shielding](image1)

![UG machine shop](image2)

\[ \leq 4.1 \ \text{cnts}/(\text{ROI-t-y}) \]
Background Considerations

- **Background rejection:**
  - **Energy resolution:**
    Excellent in HPGe detectors (<0.2% at $Q_{\beta\beta}$)
    → narrow ROI (4 keV)
    → irreducible 2νββ-decay bkg negligible.
  - **Analysis cuts:** multi-site events, hit multiplicity, time correlations.
  - **Background model.**
    Monte Carlo simulations with MaGe.

![Energy Spectrum](image1)

$^{228}$Th calibration (BEGe at Prototype Module)

![Energy Spectrum](image2)

$^{76}$Ge $Q_{\beta\beta}$ (2.039 MeV)
MJD Implementation

Modular approach:

- **Prototype Module:** 3 strings, nat\text{Ge}.
  → Taking data inside the shielding

- **Module 1:** 7 strings enr\text{Ge} (20 kg).
  → Commissioning 2014.

- **Module 2:** 3 strings enr\text{Ge} (10 kg) & 4 strings nat\text{Ge}.
  → Commissioning 2015.
MJD Prototype Module

- Commercial Copper Cryostat.
- Testbed for MJD:
  - Mechanical systems.
  - Fabrication processes.
  - Assembly procedures.
- Vacuum and cryogenic systems operational.
- 3 strings of detectors with $^{\text{nat}}\text{Ge}$ are taking data inside the shielding.
- Provided valuable information in preparation for Module 1 deployment.
Module 1 Commissioning

- 1 backup string $^{\text{nat}}\text{Ge}$ built and tested.
- 2 strings $^{\text{enr}}\text{Ge}$ built and under testing.
- Ultraclean cryostat fabricated with electroformed copper.
- Vacuum system assembled.
- We aim to start putting strings into the cryostat in the coming month.
MAJORANA DEMONSTRATOR Prospects

• Construction of MJD underway:
  – Prototype Module: Taking data inside the shielding.
  – Module 1: Begin data taking in 2014 with $^{enr}\text{Ge}$ (20 kg).
  – Module 2: 2015 with $^{enr}\text{Ge}$ (10 kg).

• Working cooperatively with GERDA towards the establishment of a single $^{76}\text{Ge}$ 0νββ-decay collaboration to built a large experiment to explore the inverted hierarchy region.

![3σ Discovery Level](image)
Backup
Sensitivity

Inverted Hierarchy ($\eta \rightarrow 0$ eV) (QRPA, $q=1.25$)

- Background free
- 0.1 counts/ROI/t/y
- 1.0 count/ROI/t/y
- 10.0 counts/ROI/t/y