The MAJORANA DEMONSTRATOR Neutrinoless Double-Beta Decay Experiment

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on behalf of the MAJORANA Collaboration

MAJORANA Posters

- C. Cuesta, *Pulse shape analysis studies for the MAJORANA DEMONSTRATOR*
- S. Mertens, *Backgrounds in the MAJORANA DEMONSTRATOR experiment*
- B. Shanks, *Building and characterizing strings of Ge detectors for the MAJORANA DEMONSTRATOR*
- B. White, *Production and acceptance of enriched germanium crystals for the MAJORANA DEMONSTRATOR*

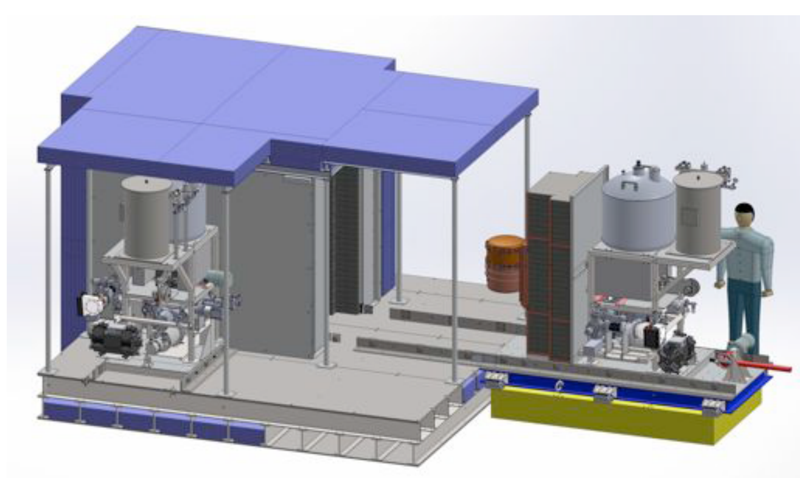
The MAJORANA DEMONSTRATOR

The DEMONSTRATOR is a neutrinoless double beta decay experiment using germanium as source and detector.

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

- Background Goal in the 0νββ peak region of interest (4 keV at 2039 keV)
  - 3 counts/ROI/t/y (after analysis cuts)
  - Scales to 1 count/ROI/t/y for a tonne experiment
- 40 kg of Ge detectors
  - 30 kg of 86% enriched ^{76}Ge crystals
  - 10 kg of ^{nat}Ge
  - Detector Technology: P-type, point-contact.
- Two 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 the 4850-foot level of the Sanford Underground Research Facility in Lead, SD



Status

- Commissioning prototype module with 3 strings of natural Ge
- 30 enriched Ge detectors underground (25.2 kg detector mass), all natural Ge detectors on hand
- Module 1 in operation by end of 2014 with 7 strings containing ^{76}Ge
- Module 2 in operation by end of 2015 with 7 strings of ^{76}Ge and ^{nat}Ge

^{76}Ge and Double-Beta Decay

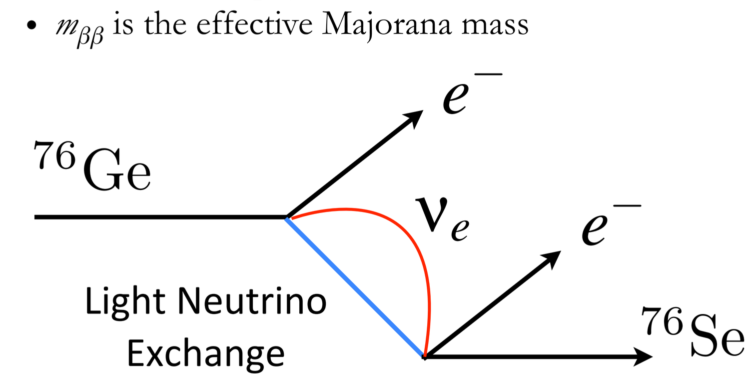
Discovery of the neutrinoless double decay provides

i. Neutrino is its own antiparticle
ii. Lepton number violating process
iii. Effective Majorana mass

Decay rate proportional to the effective majorana mass

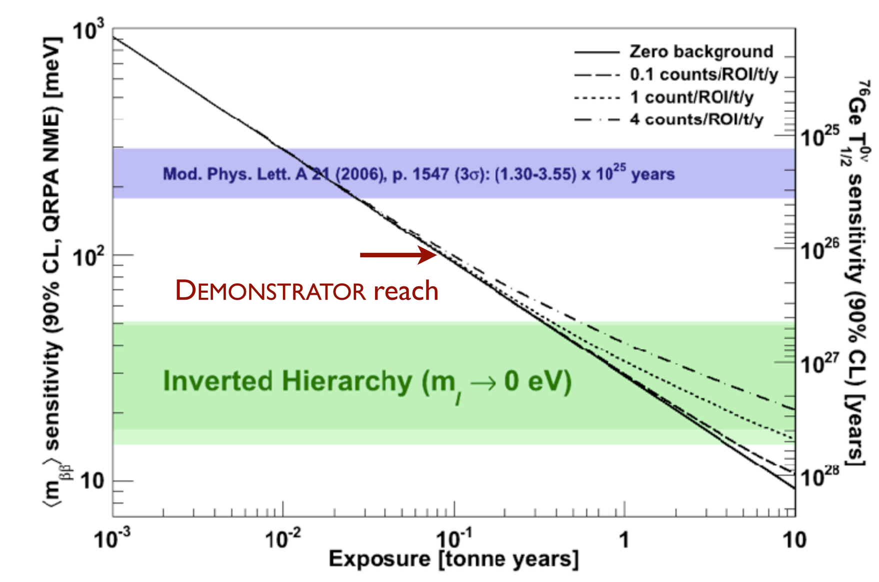
$$\Gamma_{0\nu} = G_{0\nu}|M_{0\nu}|^2 \langle m_{\beta\beta}\rangle^2$$

- G are calculable phase space factors
- M are nuclear physics matrix elements
- $m_{\beta\beta}$ is the effective Majorana mass

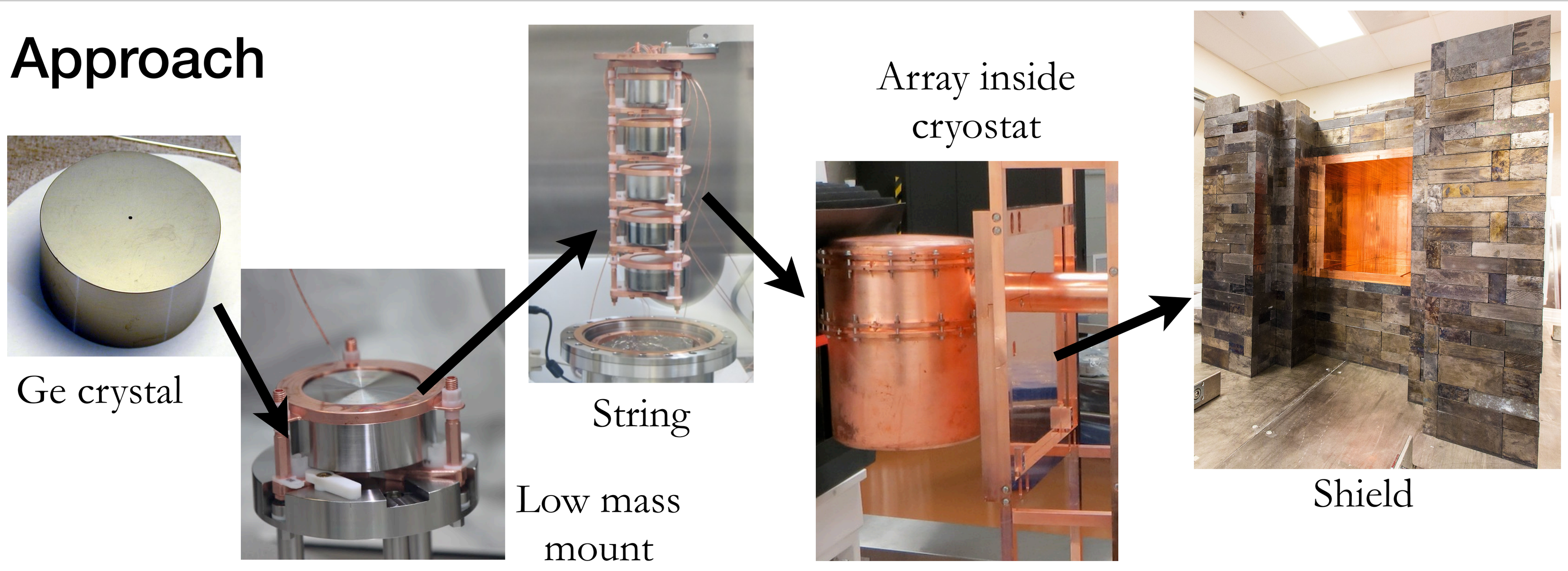


$$^{76}\mathrm{Ge} \Rightarrow {}^{76}\mathrm{Se} + 2e^-$$

- Ge is the source & detector
  - Maximizes source to total mass ratio
  - Well-understood technologies
  - Excellent energy resolution: 0.16% at 2.039 MeV, 4-keV ROI
    - Advantage for improving signal to background
  - Existing, well-characterized large Ge arrays
- Demonstrated ability to enrich 7.44% to 86%
- Favorable nuclear matrix element
- Slow 2νββ rate ($T_{1/2}$ = 1.4 x 10^{21} y)
- Powerful background rejection technologies
  - granularity, timing, pulse shape discrimination
- Past ^{76}Ge 0νββ searches gave highly competitive lifetime limits

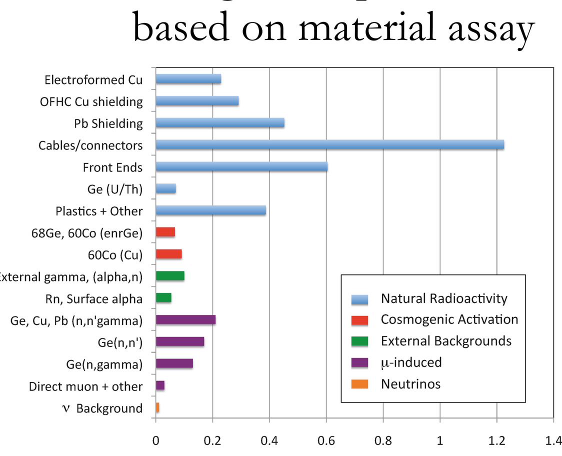


Approach



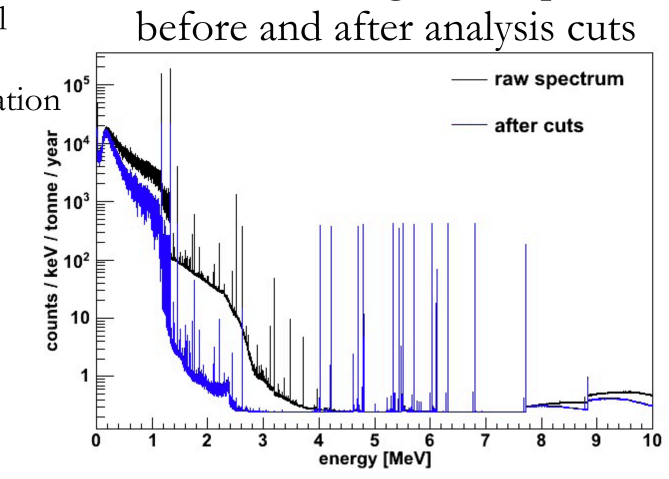
Material Purity and Backgrounds

Background prediction based on material assay



- The detector
  - Ge crystal zone refined and pulled into a crystal provides purification
  - Limit surface exposure to prevent cosmic activation
  - Deep underground operation
- Detector mounts
  - Ultra-pure plastic and electroformed Cu
  - Low mass design
  - Custom cable connectors and front-end boards
- Cryostat and inner shielding
  - Underground electro-formed Cu

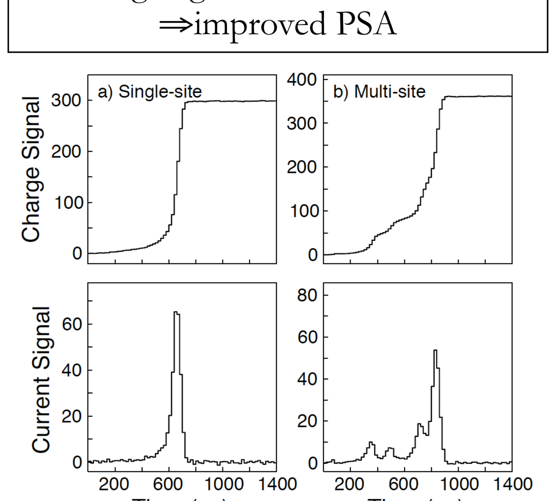
Simulated background spectra before and after analysis cuts



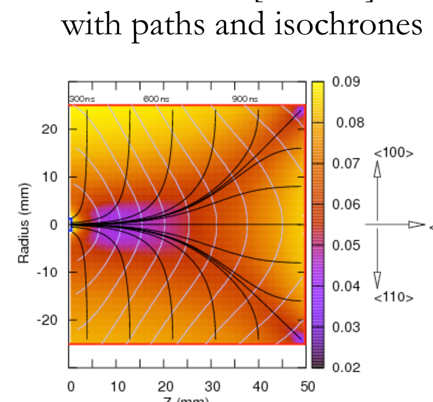
Detectors

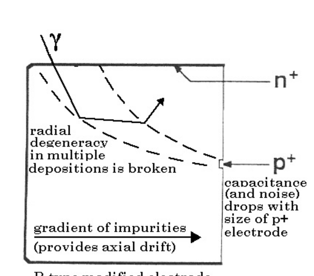
- Ultra-low background rate requires a pulse shape analysis (PSA) rejection of multi-site gamma events
- P-type Point-Contact (PPC) detectors
  - No deep hole; small point-like central contact
  - Simple, cost-effective, low intrinsic radioactivity
  - Localized weighting potential gives excellent rejection of events with multiple interaction sites
  - Low capacitance (~ 1 pF) gives superb resolution at low energies

Rising edge "stretched" in time ⇒improved PSA



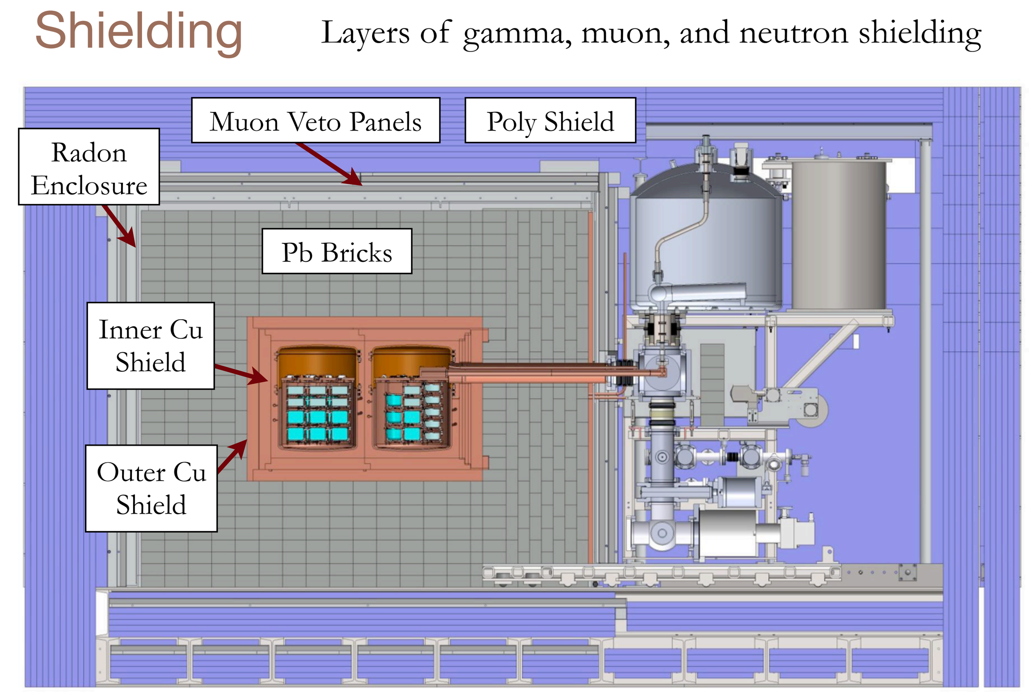
Hole v_{drift} [mm/ns] with paths and isochrones





Shielding

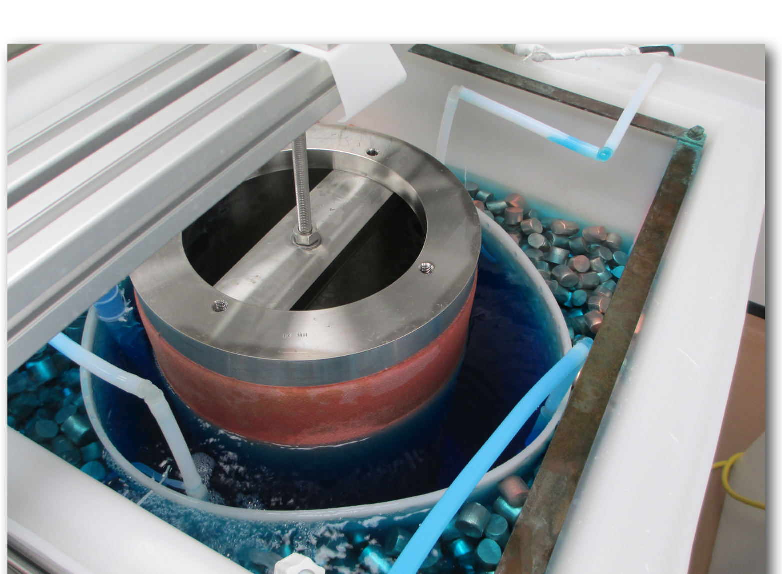
Layers of gamma, muon, and neutron shielding



Underground Facilities

Cu Electroforming

Underground Cu electro-forming laboratory produces all of the ultra-pure inner Cu.

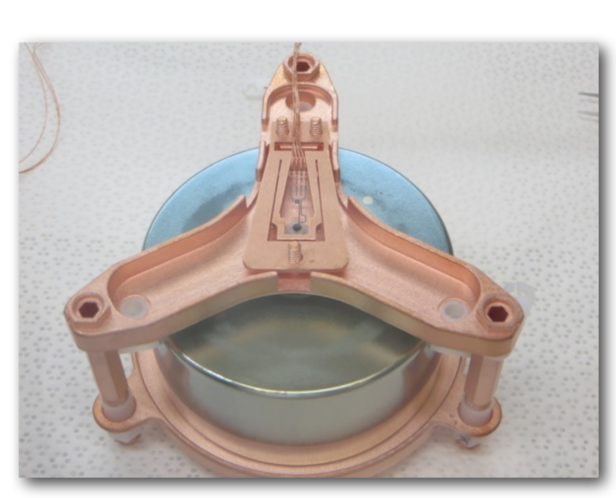


Cu Machining

Underground clean room machine shop directly adjacent to a chemical cleaning lab and detector hall.

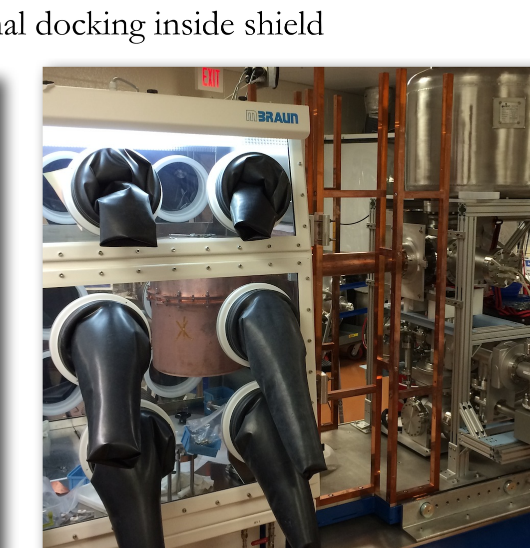
All parts are uniquely tracked through machining, cleaning, and assembly by a custom-built database.

Detector and Module Construction



Detector units and strings built inside a glovebox with a radon-reduced, dry N_2 environment

Cryostat loaded with string inside glovebox prior to final docking inside shield



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