Building and characterizing strings of Ge detectors for the MAJORANA DEMONSTRATOR

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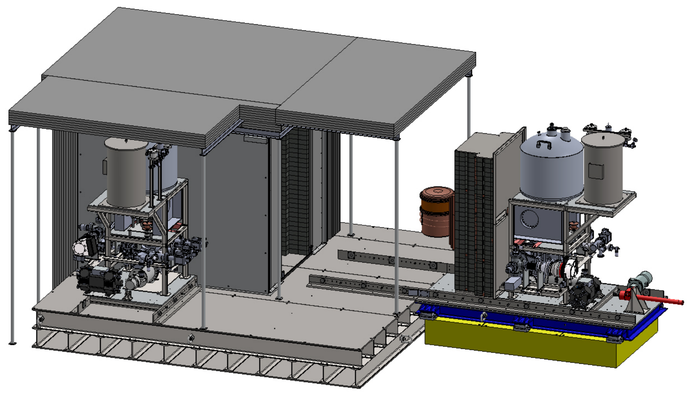
on behalf of the MAJORANA Collaboration

The MAJORANA DEMONSTRATOR

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

- 40 kg array of high purity Ge p-type point contact (PPC) detectors
- 30 kg of detectors enriched to 87% in ^{76}Ge
- Background goal of 3 counts/t/y in the 4 keV region of interest at 2039 keV, which scales to ~1 count/ROI/t/y for a tonne scale experiment
- Located on the 4850' level of the Sanford Underground Research Facility in Lead, SD



The goals for the DEMONSTRATOR are:

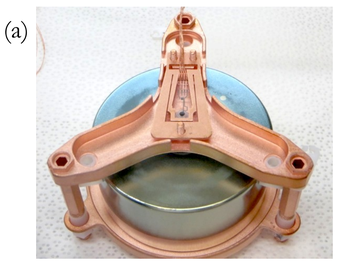
1. Demonstrate background levels low enough to justify building a tonne-scale experiment
2. Establish the feasibility of constructing & fielding modular arrays of Ge detectors
3. Search for additional physics beyond the Standard Model, such as solar axions and dark matter

Modular Approach: Detector, String, Cryostat

Construction of the DEMONSTRATOR follows a modular approach, which allows for scalability and rapid deployment.

a) The fundamental unit, a detector in its mount. Immediately above the detector is the front-end electronics board, which is custom made to be ultra-clean and low-mass. The high voltage contact is a ring of ultra-pure underground electroformed copper under the detector.
b) Detectors are stacked together into groups of four to five, called strings. Each detector in a string is electrically isolated, but all share a common thermal contact
c) A single module cryostat houses seven strings. Up to two modules can be simultaneously housed in the DEMONSTRATOR shield

(a)



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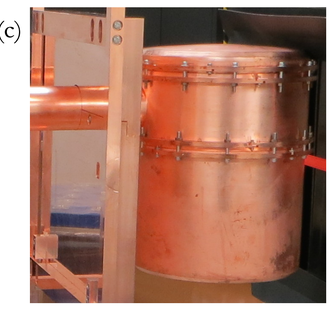

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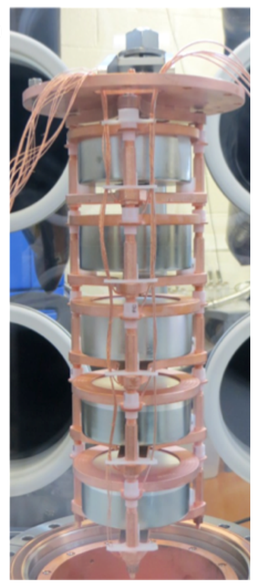


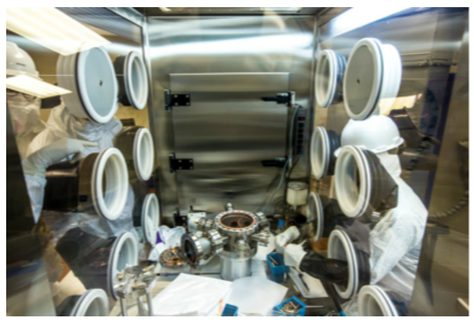
String Building

Cleanliness protocols

The low-background aim of the DEMONSTRATOR mandates that great care be taken to avoid introducing any radiocontaminants to the detectors. Of particular concern is radon, which is gaseous and present in the lab air. To address this concern, the DEMONSTRATOR follows strict cleanliness protocols. To mitigate cosmogenic activation in storage, detectors are kept underground in (a) a chamber purged with liquid nitrogen boil off. Detector unit and string construction is performed inside (b) a glovebox maintained as a class 10 cleanroom and purged with liquid nitrogren boil off.

(a)

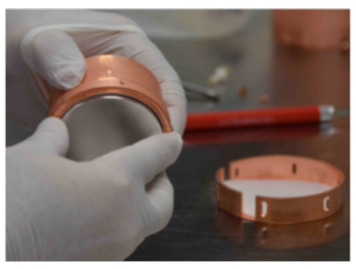
(b)



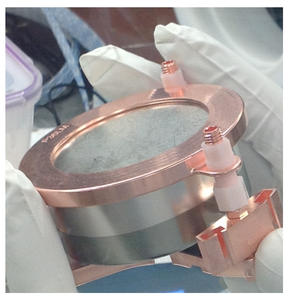
Detector unit construction

The collaboration receives detectors in a vendor cryostat. After acceptance measurements are made, the detector is (a) decryostated in the glovebox. The detector is then (b) mounted into a detector unit made of electroformed copper. Detector materials are chosen to be ultra-pure and minimal mass. Each detector has a unique HV connection and (c) signal read-out cable which is fed to a preamplifier outside of vacuum via a Vespel connector.

(a)



(b)



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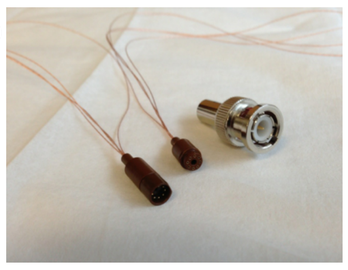
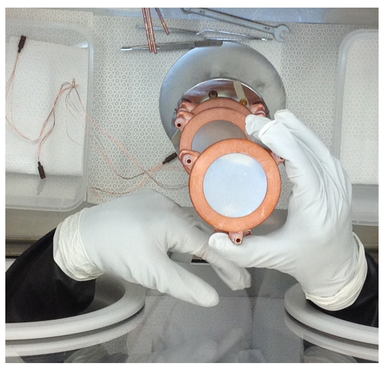


String construction and testing

Strings are built by (a) stacking detector units along three copper rods, threading HV and signal cables through copper guides. The string is then (b) inserted into a String Test Cryostat (STC), a vessel for operating and testing individual strings. The collaboration can operate up to seven STCs simultaneously. Once testing is complete, the string is mounted, along with six other strings, into a module cryostat, forming a full DEMONSTRATOR module.

(a)



(b)

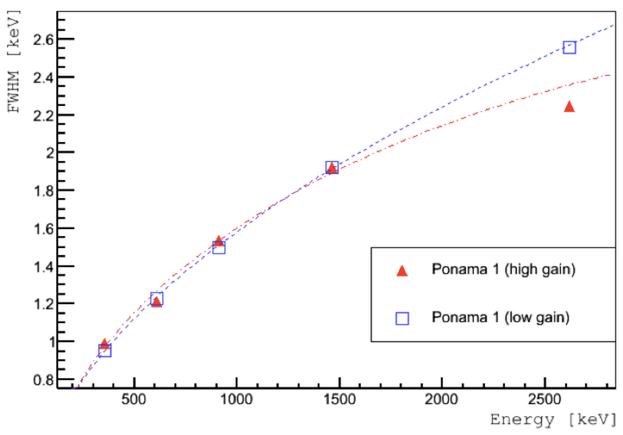
String characterization measurements

The STC is used to verify that the detectors & strings behave as expected before their insertion into a module cryostat. Characterization data taken in the STC includes:

- Source measurements to look for cross-talk between detectors
- Coincidence measurements to measure relative timing
- Noise and microphonics characterization, using random triggers
- Pulse shape analysis performance for background discrimination
- Threshold determination

String Characterization

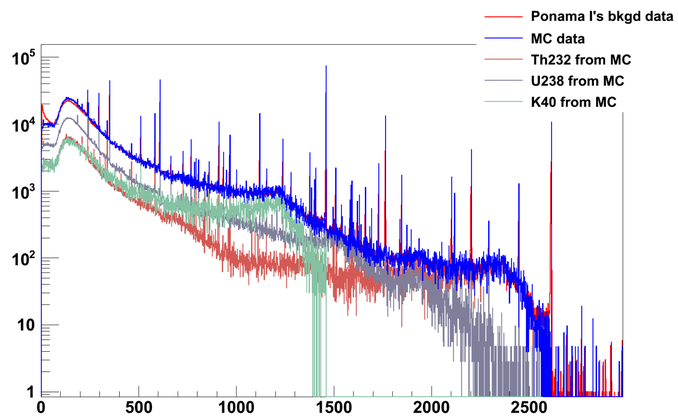
Energy resolution



A series of source measurements are taken in the STC to confirm the detector resolution matches values taken during acceptance testing, as well as to optimize the performance of the digitizer. Data shown at left are for a natural Ge detector manufactured by ORTEC.

Room background measurement & modeling (detector not in shield)

To ensure each string has been constructed without introducing contamination, background data were taken with the string in an unshielded String Test Cryostat. Monte Carlo simulations of the STC and surrounding rock provide an expected background spectrum for each detector. Simulation and can be compared to measured data to check for unexpected features.

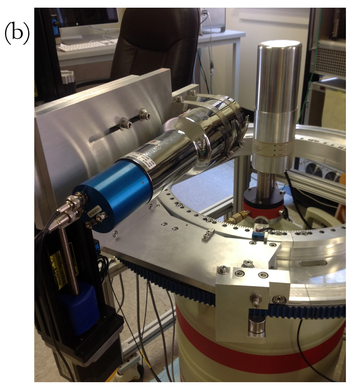


Source scanning measurements

An automated z-scanner (a) with a ^{133}Ba source is used to measure the insensitive dead layer at the outer surface of the detector. A rotating scanning table (b) will be used to determine crystal axes, which facilitates a solar axion program.

(a)

(b)



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