MAJORANA
An Ultra-Low Background Enriched-Germanium Detector Array for Fundamental Physics Measurements

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GERDA Collaboration Meeting
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MAJORANA Collaboration Goals

Actively pursuing R&D aimed at a ton-scale $^{76}$Ge $0\nu\beta\beta$-decay experiment

- Technical Goal: Demonstrate background low enough to justify building a ton-scale experiment
- Science Goal: Build a prototype module to test the recent claim of an observation of $0\nu\beta\beta$
- Work cooperatively with the GERDA Collaboration to prepare for a single international ton-scale Ge experiment that combines the best technical features of MAJORANA and GERDA
- Pursue longer term R&D to minimize costs and optimize the schedule for a ton-scale experiment
The **Majorana Demonstrator**

- 60-kg of Ge detectors required for sensitivity to background goal: 1 c/ROI/t/y
- 30-kg of 86% enriched $^{76}\text{Ge}$ crystals required for science goal: test HDKK claim
- Examine detector technology options: p- and n-type, segmentation, point-contact
- Low-background cryostats & shield: ultra-clean, electroformed Cu
- Initial module will have 3 cryostats
- Compact low-background passive Cu and Pb shield with active muon veto
- Located underground 4850’ level at Sanford Lab / DUSEL.
DEMONSTRATOR Sensitivity

\[ \langle m_{\beta\beta} \rangle \text{ sensitivity (90\% CL) [eV]} \]

- **MAJORANA Prototype Module (30 kg, 1 count/ROI/t/y)**
- **MAJORANA Prototype Module (30 kg, 10 counts/ROI/t/y)**
- **KKDC (3\sigma): (0.69-4.18) \times 10^{25} \text{ years}**
Recent Baseline Updates

• Concentrate on PPC Detectors. Advantages of cost and simplicity, with no loss of physics reach. Will continue NSC R&D utilizing SEGA crystal.

• Considering additional physics one can do with low-energy-threshold PPC detectors. Exploits low-energy sensitivity (~100 eV threshold) of PPC detectors.

• In joint partnership with agencies and institutions, plan early implementation of natural-Ge PPC sub-module.
Point Contact Detectors

Hole $v_{\text{drift}}$ (mm/ns) w/ paths, isochrones

Point Contact Detectors

- CνNS (Reactor, SN ν...)
- DM (light/slow WIMPs, Q-balls)
- Axions (see recent CDMS results)
- e⁻ decay

Point Contact Detectors

Detectors in hand:

<table>
<thead>
<tr>
<th>Owner</th>
<th>Dimensions</th>
<th>Mass</th>
<th>Resolution (1.33 MeV)</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>U. Chicago</td>
<td>50 mm $\Theta$ x 44 mm</td>
<td>460 g</td>
<td>1.82 keV</td>
<td>Canberra</td>
</tr>
<tr>
<td>PNNL</td>
<td>50 mm $\Theta$ x 50 mm</td>
<td>527 g</td>
<td>2.15 keV</td>
<td>Canberra</td>
</tr>
<tr>
<td>LBNL</td>
<td>62 mm $\Theta$ x 44 mm</td>
<td>800 g</td>
<td>2.11 keV</td>
<td>LBNL</td>
</tr>
<tr>
<td>LANL</td>
<td>72 mm $\Theta$ x 37 mm</td>
<td>800 g</td>
<td>2.15 keV</td>
<td>PHD’s</td>
</tr>
<tr>
<td>ORNL</td>
<td>62 mm $\Theta$ x 46 mm</td>
<td>740 g</td>
<td>4. – 4.5 keV</td>
<td>PHD’s</td>
</tr>
</tbody>
</table>

Further planned PPCs for R&D

- ORTEC PPC prototype: $>500$ g
- Canberra BEGe for low-BG low-E studies
- Inverted-coax PPC
- Mini-PPCs for surface preparation studies
Incomplete Charge Collection

• $^{57}$Co scan shows rapidly dropping efficiency near the detector back
• Consistent with drift trajectories being “blocked” by ditches
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Hole Drift on Open Surface

- Kinked slow-roll pulses consistent with charged open surface with slower hole mobility
- Can convert the waveform to radius via weighting potential
- Under investigation
Surface Passivation R&D

- Mini-PPCs in T-variable cryostat
- Surface passivation that didn’t work for SPPC works for mini PPC
- Spectral variations consistent with charge trapping on passivated surface
- Investigate as a function of passivation recipe
First Module

- 18 natural-Ge Canberra BEGe’s on order
  - $\varnothing = 70\pm2.5$ mm, $h = 30\pm2.5$ mm
  - 579 g active mass
  - contact $r < 6.5$ mm (5 mm nom.)
  - Front surface metalized for HV
- 4 to 6 crystals per string
- Front-ends mounted next to the crystal
- Closed cold plate and beefier Cu in detector mounts for added strength
Detector Mounts

- Single detector units that attach to form strings
- HV on outer contact
- Mostly EFCu with minimal amount of plastics
- Front ends integrated into contact pin; encapsulate in EFCu for $\alpha, \beta$ shielding
- Currently iterating design and prototyping
Detector Readout

- Parallel development of resistive feedback (LANL) and pulse reset (UW) designs: trade off between noise and thermal / radioactivity challenges
- Integrated detector contact pin: currently under design
- Investigating multiple cable options: “pico”-coax, CuFlon-based flex cables, PEN flex cables, twisted pairs of parylene-coated extruded EFCu
- Cable connection options: wire bond, dimpled pressure connection, conducting adhesive, e-beam welding
Front Ends: Resistive Feedback

- Trace proximity provides \(~1\) pF capacitance
- Silica or sapphire substrate provides thermal control
- Amorphous Ge resistor: deposit in H environment gives proper R at low T
- MX-120 FET
- Possibility to add decoupling C inside feedback loop (substrate stands off HV)
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COGENT front ends → UW “Hybrid” Design

- Front-end and first stage “hybrid” design: close the loop near the detector
- Power dissipation and radioactivity levels may be challenging
- Currently prototyping
Site Facilities

- Current layout: EFCu and detector facilities in one campus at 4850’ level in new drift to Davis cavity (LUX)
- Water removal proceeding faster than anticipated; may get to go UG at June collaboration meeting at Sanford Lab
- Beneficial occupancy by year’s end
Simulations and Analysis

- Design simulations
- Internal front-ends
- Increased internal Cu
- $^{40}$K in plastics
- Backgrounds from new structural components
- Background Simulation Campaign: Spring 2009
  - **DEMONSTRATOR** geometry
  - Full-spectrum background model
  - Low-E modeling and verification
  - DAQ / event building / analysis software under active development

Energy Spectra after granularity

$^{40}$K in plastic detector supports continuum: ~100 mBq/kg $\leftrightarrow$ ~1 c/keV/y
Materials Purity

• 2009 campaign to further reduce limits on backgrounds in EFCu (previous best: \(~0.7 \text{ \(\mu\)Bq/kg}, addressing bath purity\))

• Procuring enough “EXO” plastic for detector supports, with NAA to follow

• Staged Pb procurement with ICPMS program for shield

• Cables and electronics materials screening
Other First Module Preparations

- Detector acceptance / characterization lab
- Designing tools, jigs, glove boxes for detector / string / cryostat assembly
- Thermal / mechanical / electrical testing in Canary Cage
- Construction procedure document drafts
- Preparing to procure GRETINA 10ch 100 MHz digitizers; extensive test stand usage and debugging well underway
UMICORE not interested in processing enriched Ge

Fully costed plan to establish a small processing facility in Oak Ridge

USD received SD funding for a UG crystal pulling lab

Continue to monitor alternative enrichment methods, but not much promise at this point
• 4x2 segmented n-type $n^{enr}\text{Ge}$ detector

• Currently electroforming detector mount components

• Install in WIPP this Spring, Summer
Other R&D

• Neutron interaction simulations
• Cross-beam characterization
• Rn deposition on crystal surfaces
• Surface alpha background characterization
• Spectral shape as a function of source position (see arxiv:0902.4370)
DEMONSTRATOR Schedule

- **2009**: Create Lab
- **2010**: Purchase natGe PPCs, Purchase PPCs
- **2011**: Assemble 1st cryostat of PPCs
- **2012**: Purchase enrGe
- **2013**: Fabricate enrGe dets, Assembly of enrGe sub-modules
S4 Proposal Status

- Requested funding for
  - Design of UG facilities and potential MJ-like aspects of design (cryostats, shields)
  - Ge detector production / acquisition issues
  - MJ-GERDA down-select studies in the later years
- Project planning
- Submitted Jan 2009
- Response / funding scheduled for Summer 2009
Summary

• Primary focus is on first module, 18 BEGe’s

• Much design work and prototyping in progress.

• Final detector mount / cryostat design and readout down-select for first module in the summer

• Homestake preparations are proceeding rapidly, hope to begin installation late 2009

• Next collaboration meeting: June 2-4 at Sanford Lab in South Dakota