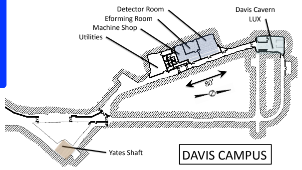
The MAJORANA Project
a status report

Los Alamos
Steve Elliott

Outline

ββ

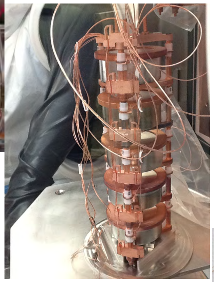
Science



Underground Laboratory

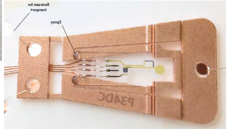
Shield

Monoliths

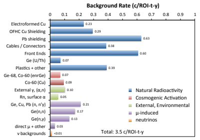


Strings

Detectors



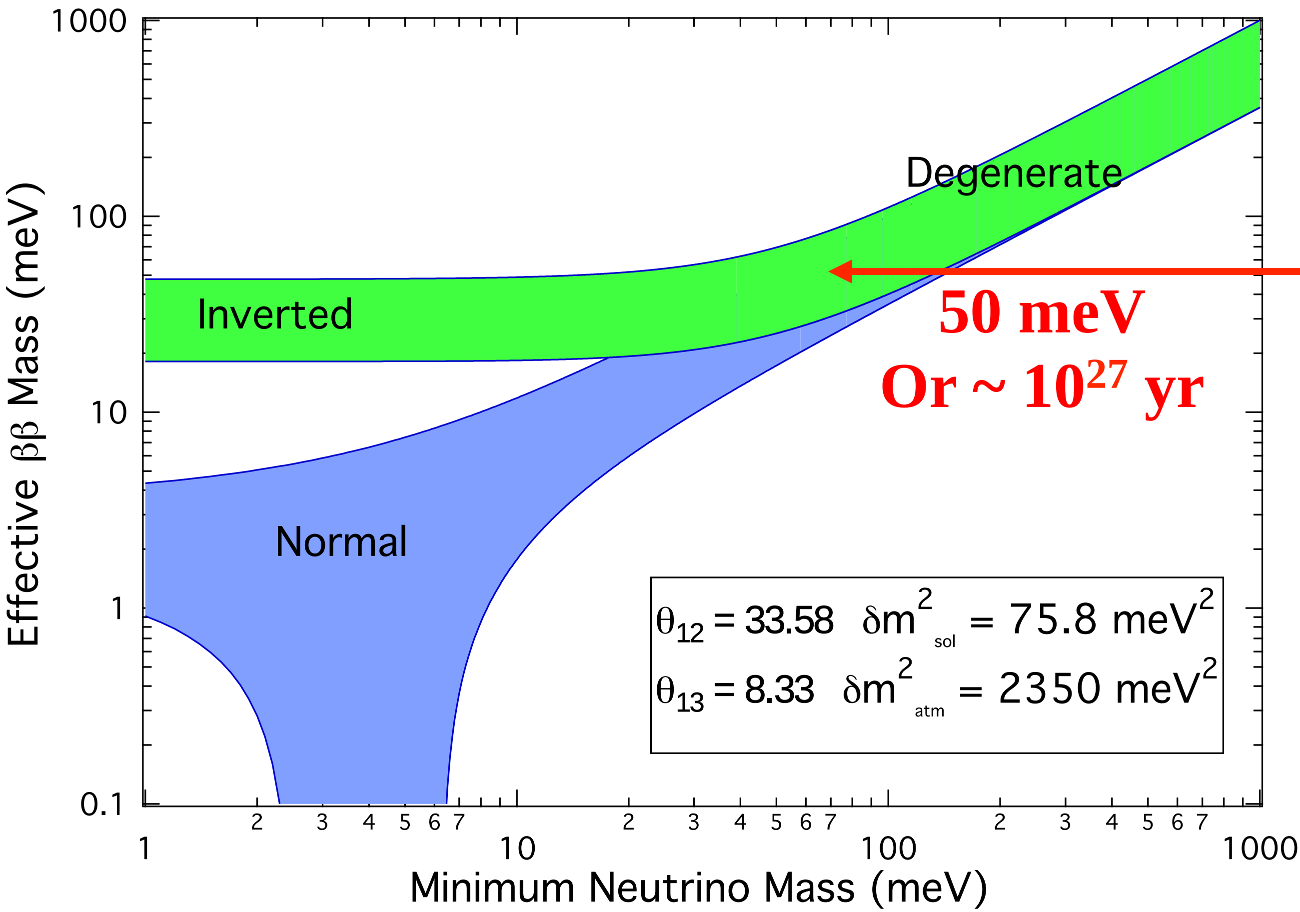
Small Parts



Background

ββ Sensitivity

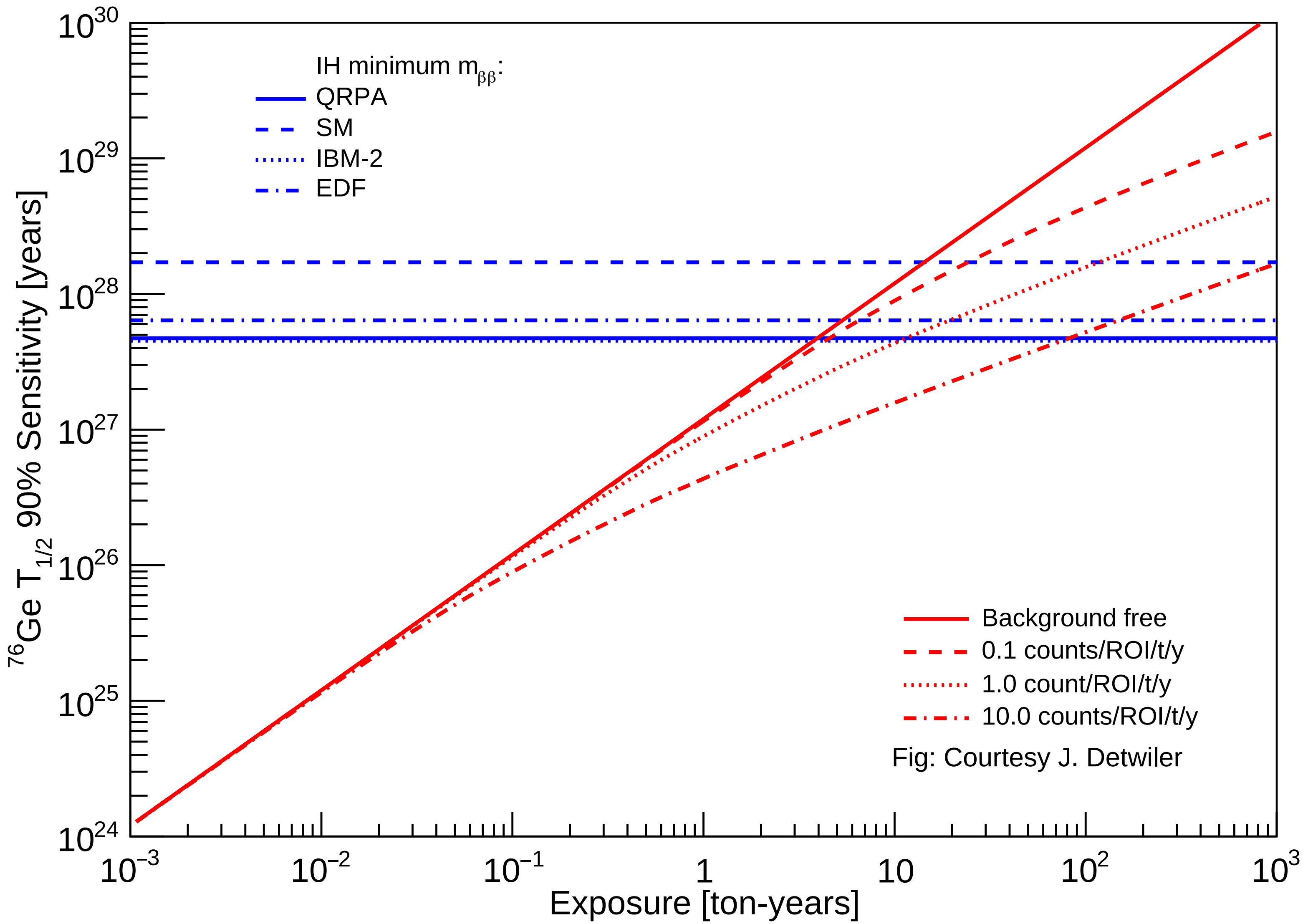
(mixing parameters from arXiv:1106.6028)



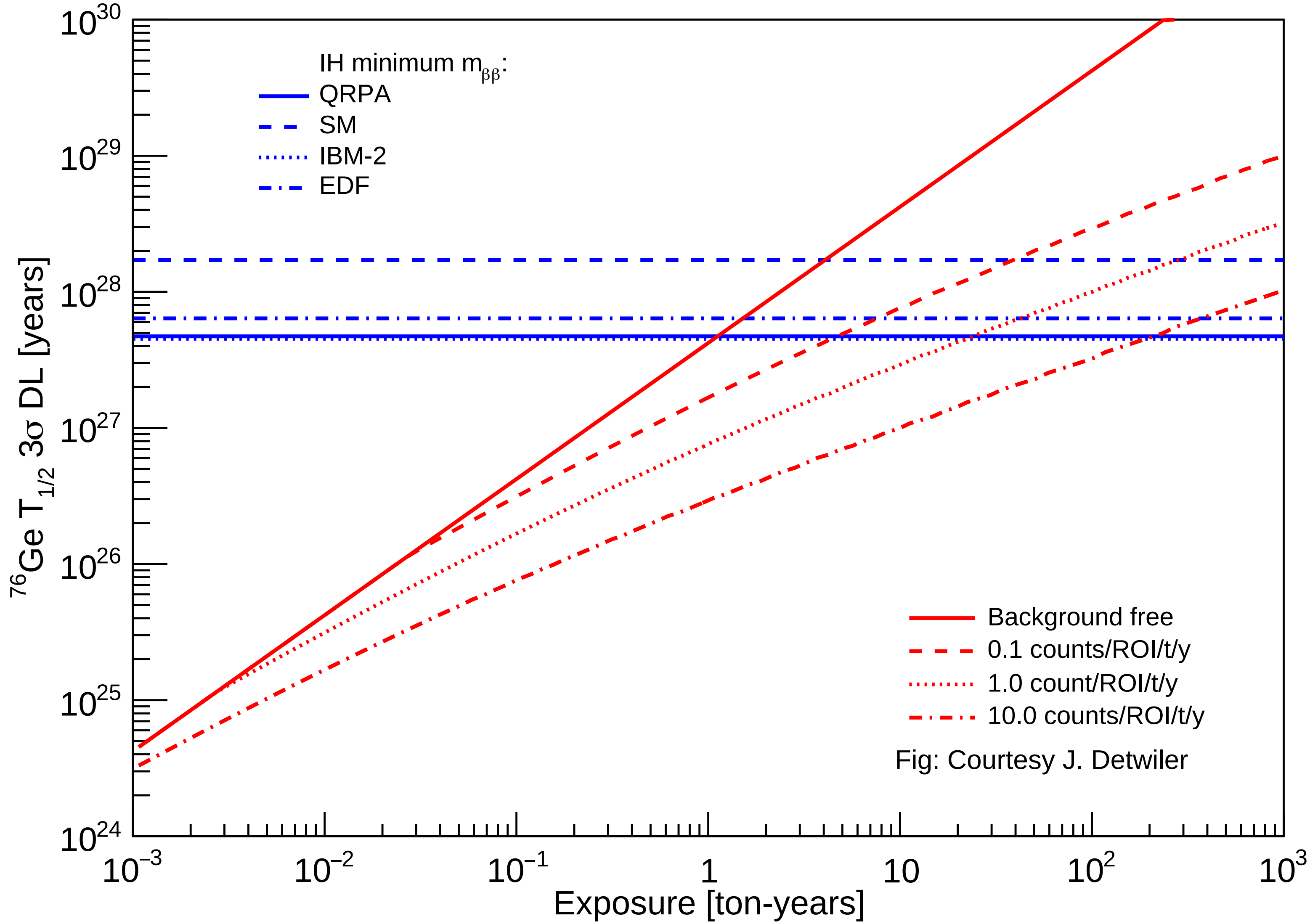
Even a null result will constrain the possible mass spectrum possibilities!

A $m_{\beta\beta}$ limit of ~15 meV would disfavor Majorana neutrinos in an inverted hierarchy.

Sensitivity, Background and Exposure



Discovery, Background and Exposure



NSAC Subcommittee (highlights added)

The Subcommittee recommends the following guidelines be used in the development and consideration of future proposals for the next generation experiments:

1.) Discovery potential: Favor approaches that have a credible path toward reaching 3σ sensitivity to the effective Majorana neutrino mass parameter $m_{\beta\beta}$=15 meV within 10 years of counting, assuming the lower matrix element values among viable nuclear structure model calculations.

2.) Staging: Given the risks and level of resources required, support for one or more intermediate stages along the maximum discovery potential path may be the optimal approach.

3.) Standard of proof: Each next-generation experiment worldwide must be capable of providing, on its own, compelling evidence of the validity of a possible non-null signal.

4.) Continuing R&D: The demands on background reduction are so stringent that modest scope demonstration projects for promising new approaches to background suppression or sensitivity enhancement should be pursued with high priority, in parallel with or in combination with ongoing NLDBD searches.

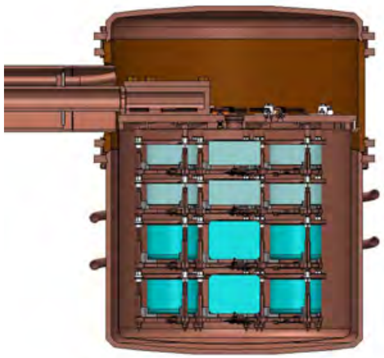
5.) International Collaboration: Given the desirability of establishing a signal in multiple isotopes and the likely cost of these experiments, it is important to coordinate with other countries and funding agencies to develop an international approach.

6.) Timeliness: It is desirable to push for results from at least the first stage of a next-generation effort on time scales competitive with other international double beta decay efforts and with independent experiments aiming to pin down the neutrino mass hierarchy.

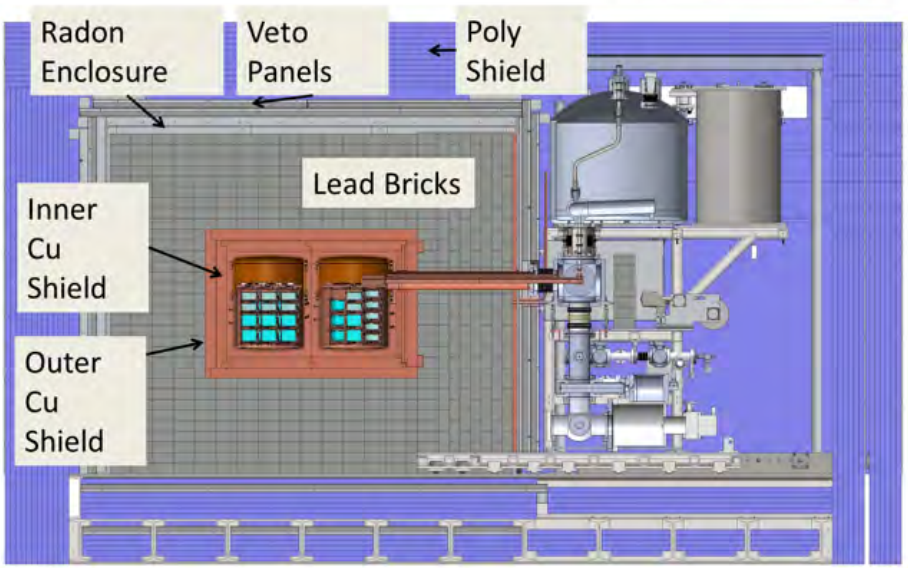
The MAJORANA DEMONSTRATOR

Funded by DOE Office of Nuclear Physics and NSF Particle Astrophysics,
with additional contributions from international collaborators.

Goals:
- Demonstrate backgrounds low enough to justify building a tonne scale experiment.
- Establish feasibility to construct & field modular arrays of Ge detectors.
- Searches for additional physics beyond the standard model.



- **Located underground at 4850' Sanford Underground Research Facility**
- **Background Goal in the $0\nu\beta\beta$ peak region of interest (4 keV at 2039 keV)**
  3 counts/ROI/t/y (after analysis cuts) Assay U.L. currently ≤ 3.5
  scales to 1 count/ROI/t/y for a tonne experiment
- **44-kg of Ge detectors**
  - **29 kg of 87% enriched ^{76}Ge crystals**
  - **15 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**

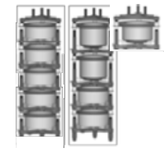


MAJORANA DEMONSTRATOR Implementation

Three Steps

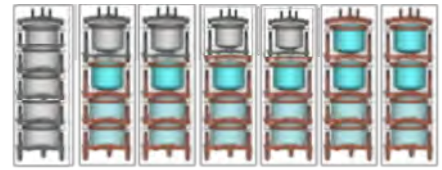
Prototype cryostat: 7.0 kg (10) ^{nat}Ge

Same design as Modules 1 and 2, but fabricated using OFHC Cu Components



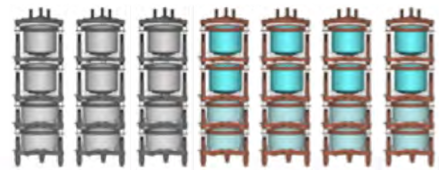
June 2014

Module 1: 16.8 kg (20) ^{enr}Ge
5.7 kg (9) ^{nat}Ge

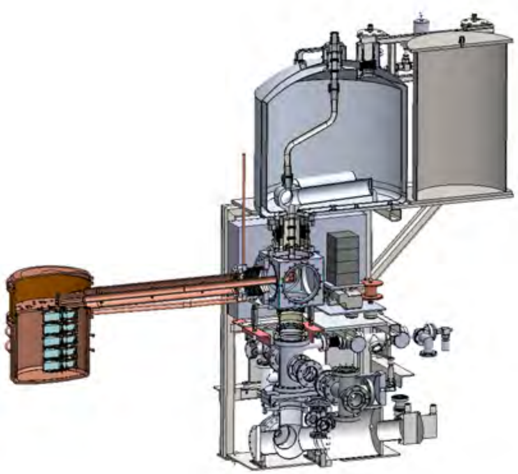


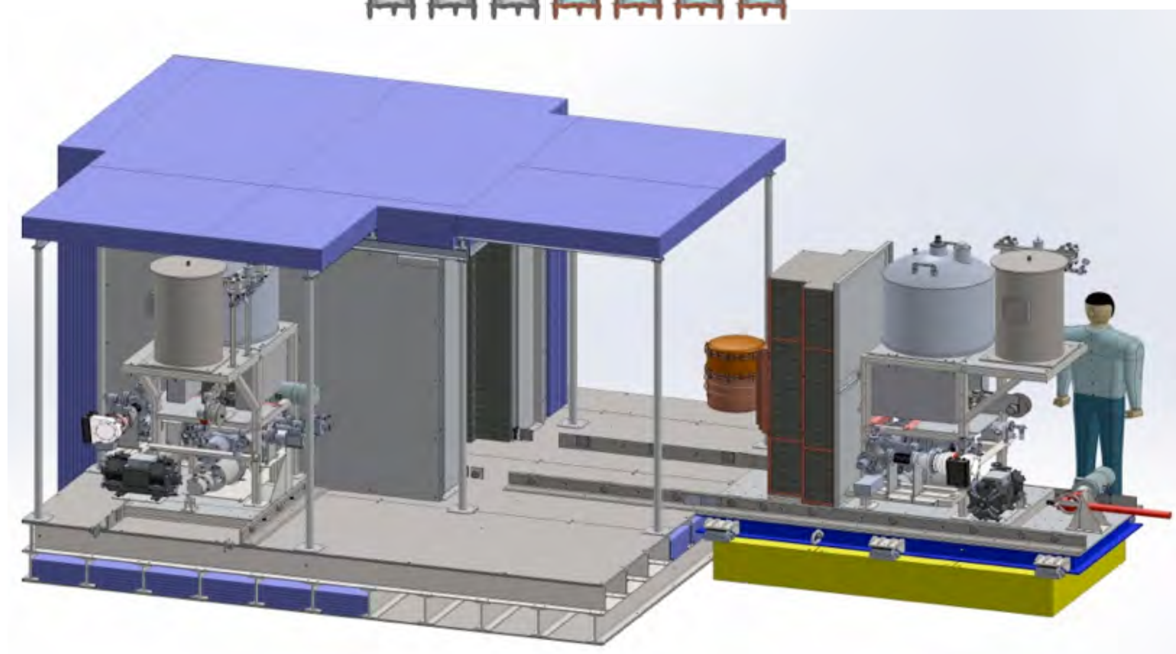
May 2015

Module 2: 12.6 kg (14) ^{enr}Ge
9.4 kg (15) ^{nat}Ge

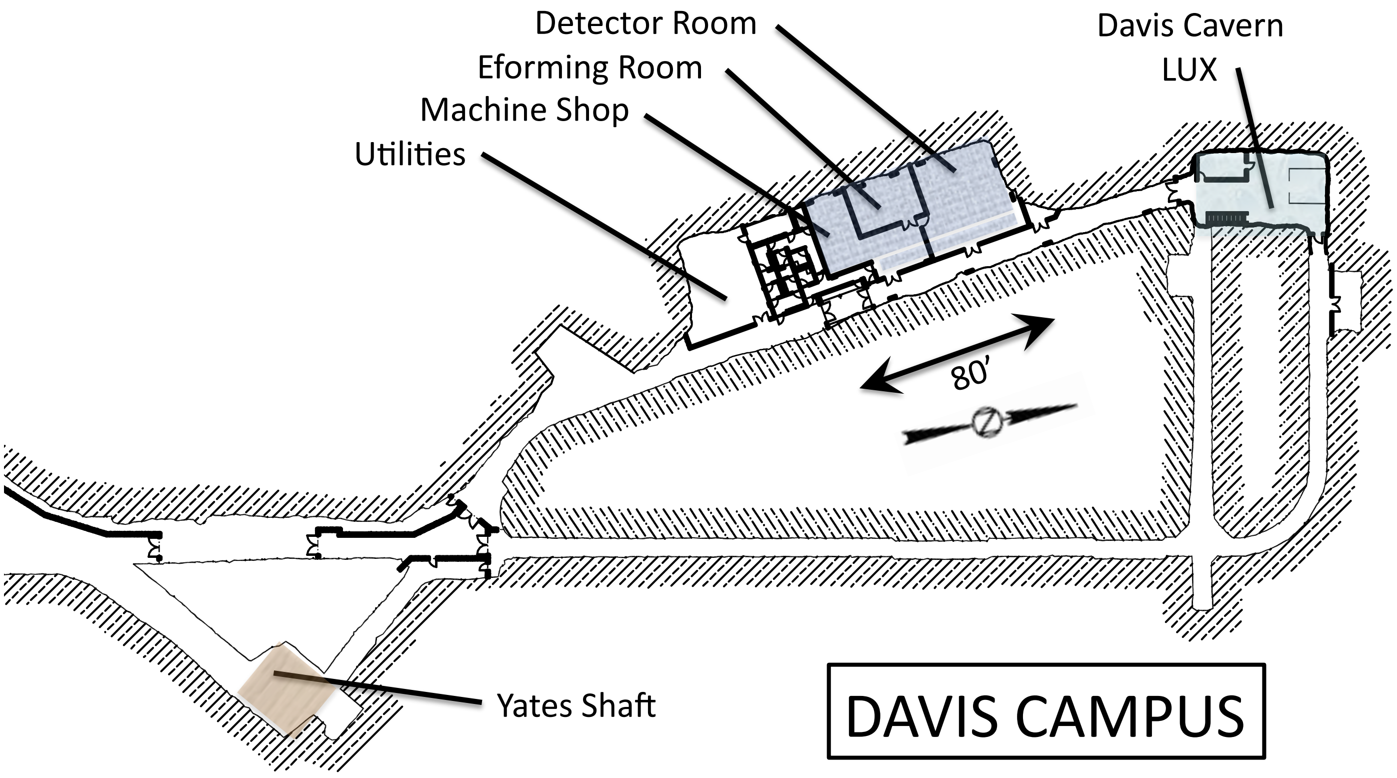


End 2015

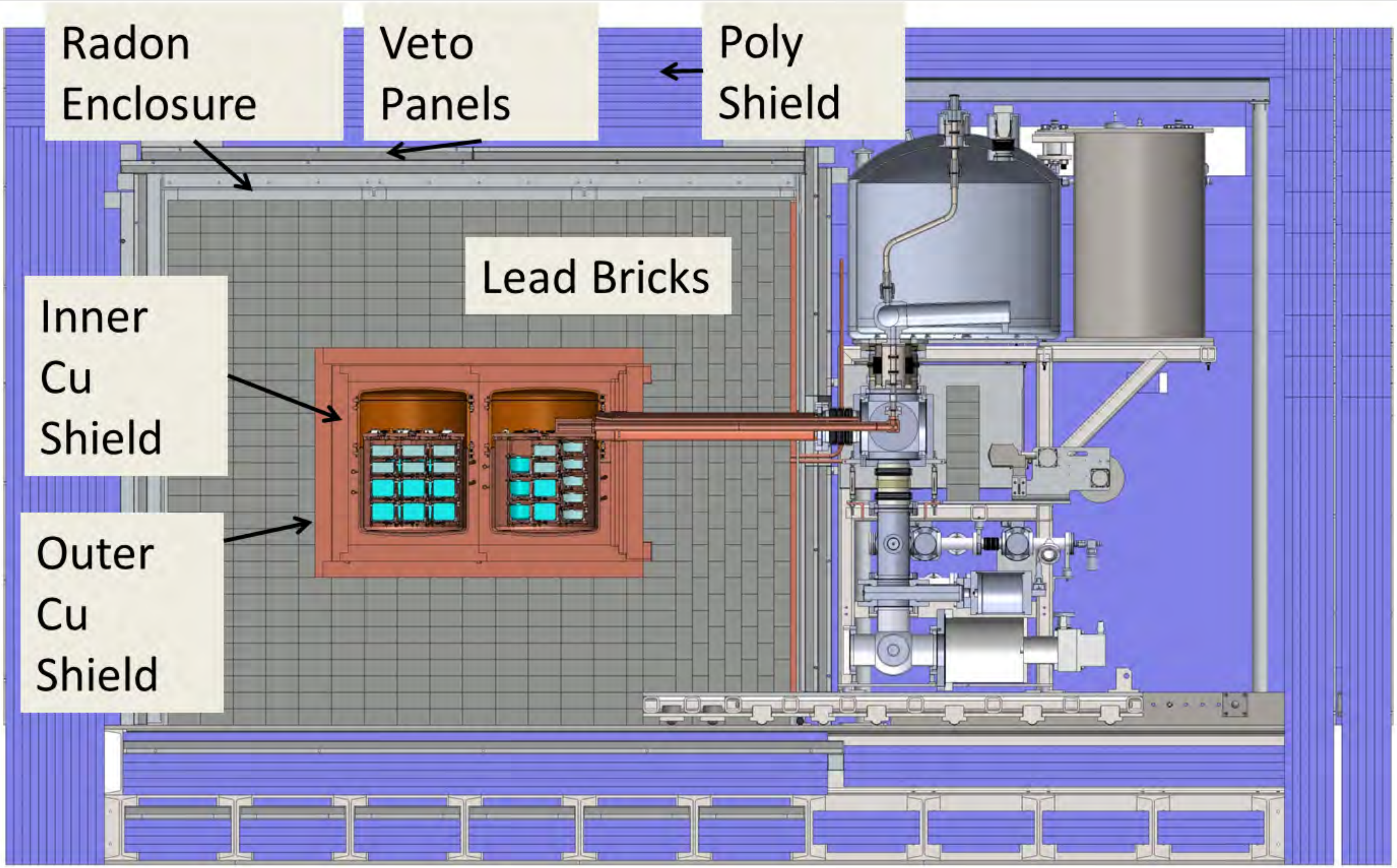




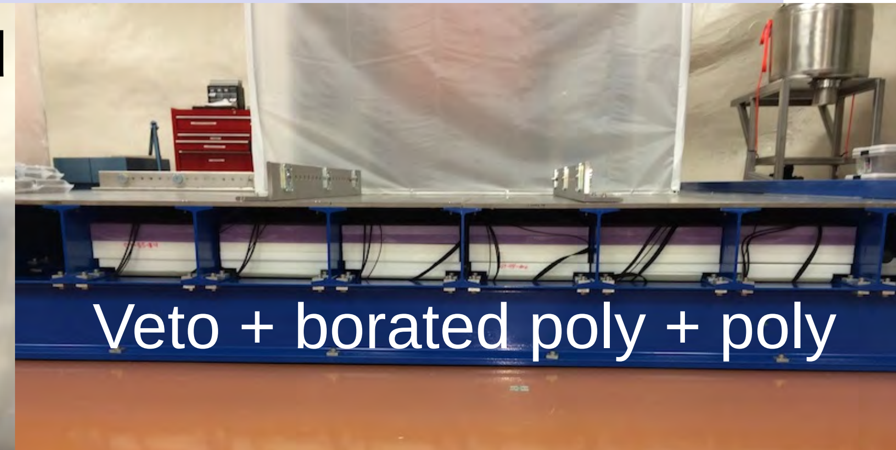
Underground Laboratory



Apparatus Overview

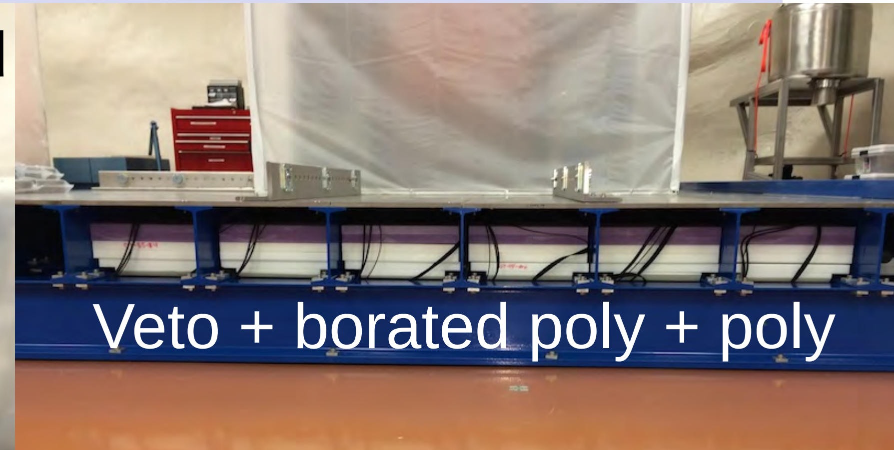


The Shield



- **Pb shield constructed**
- **Outer Cu shield layer installed**
- **Rn exclusion box installed**
- **Poly layers being installed**
- **Hovair in-use underground**
- **Most veto panels operational**
- **Calibration system demonstrated**

The Shield



- Pb shield constructed
- Outer Cu shield layer installed
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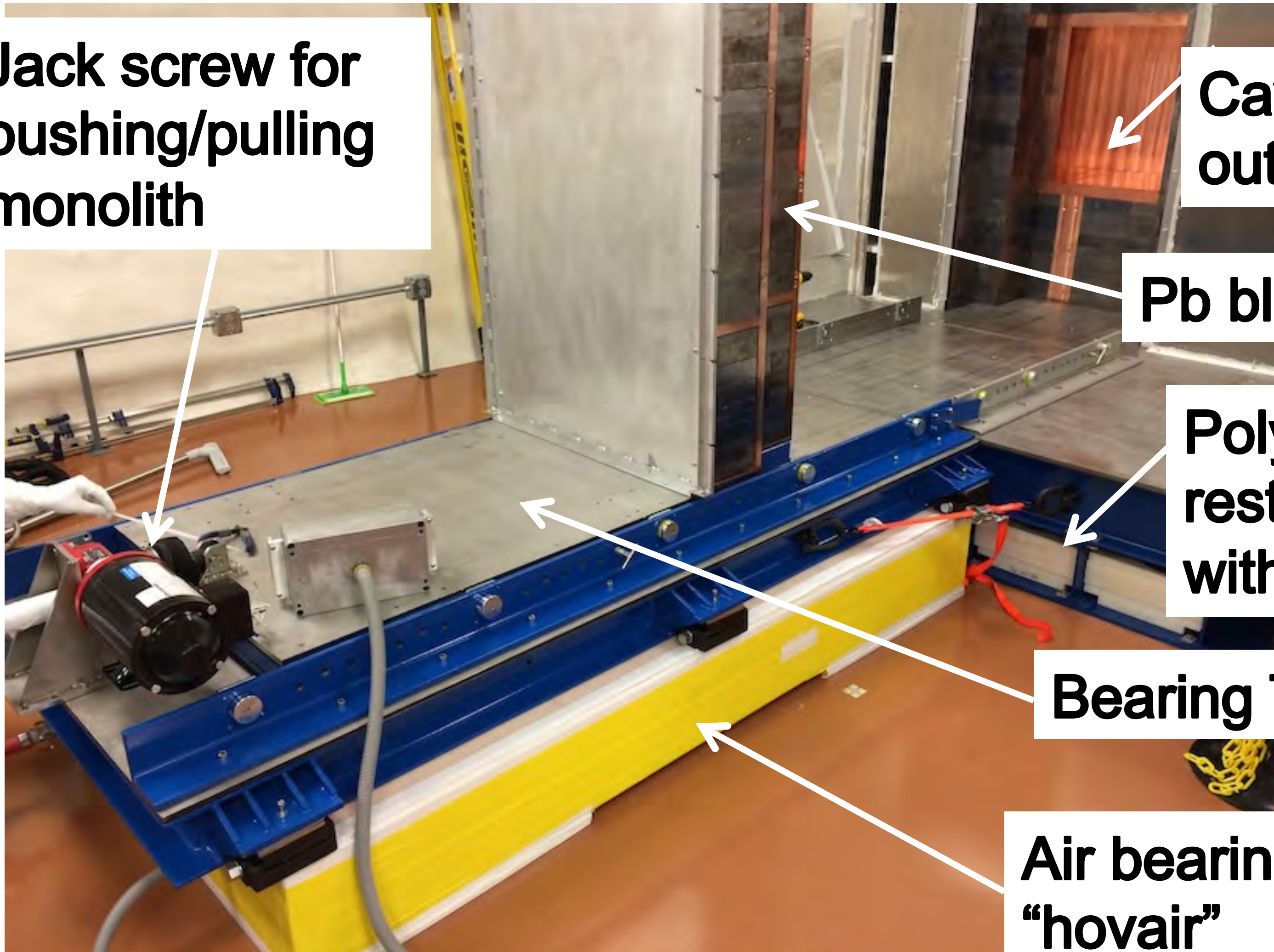
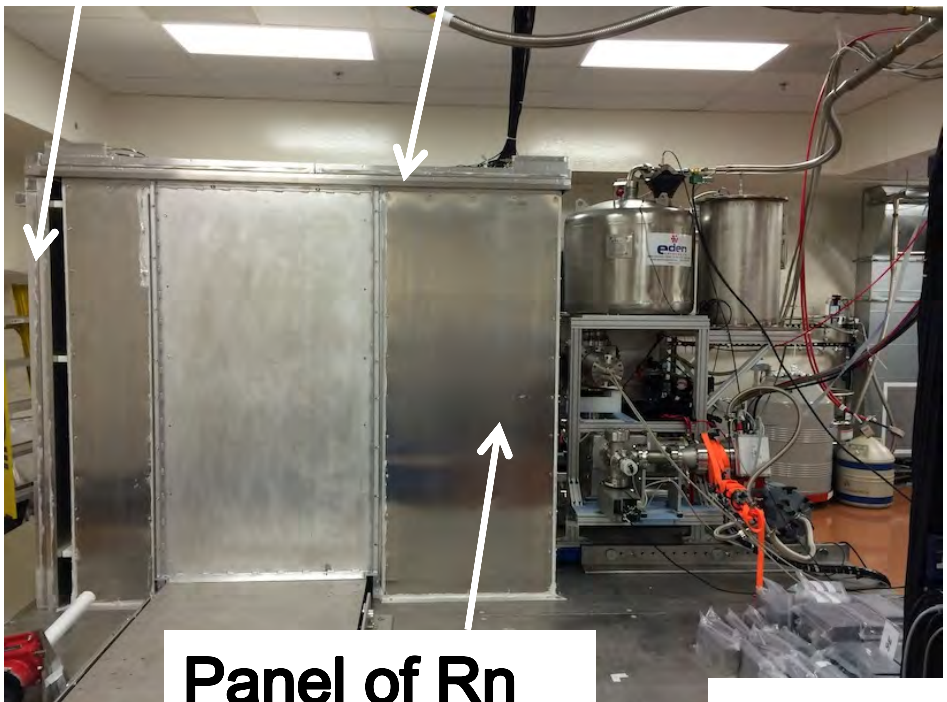
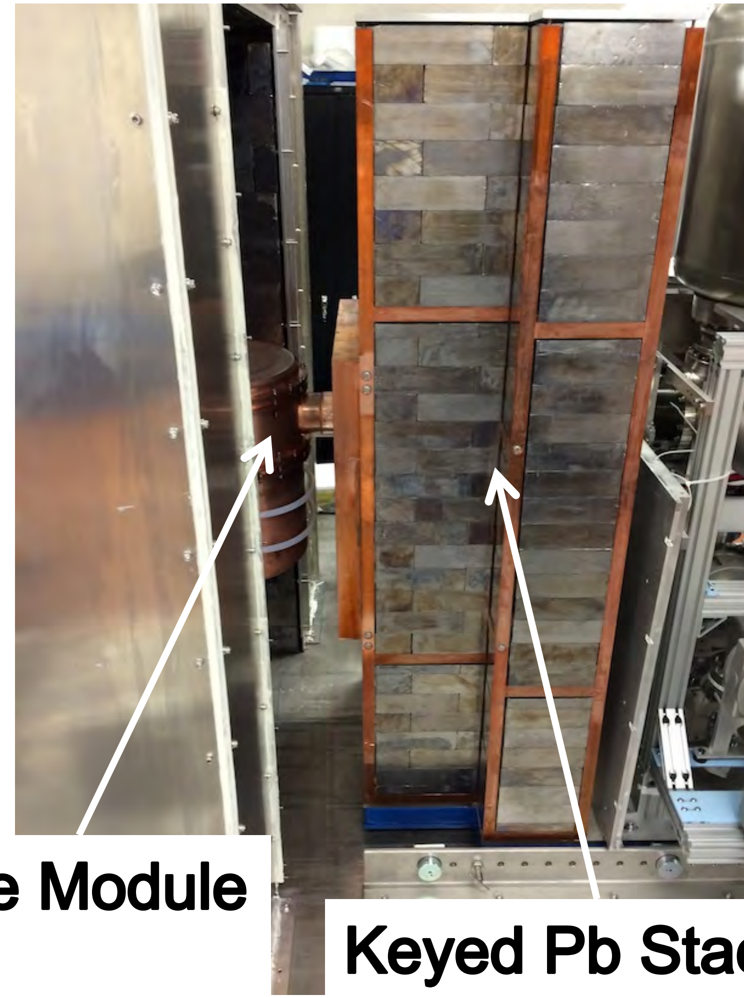
Blank Monolith, when running only one cryostat of detectors



Shield Details

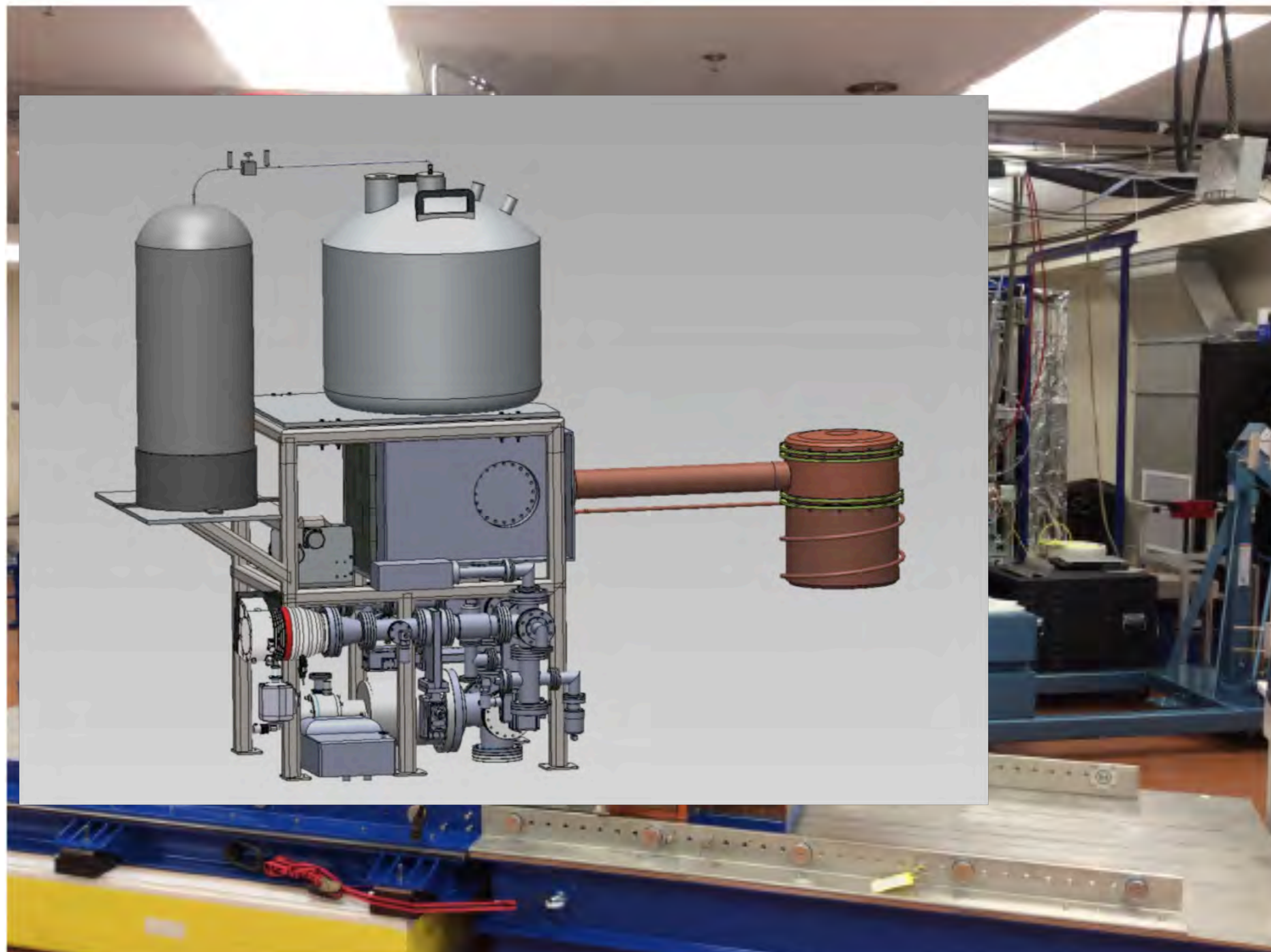




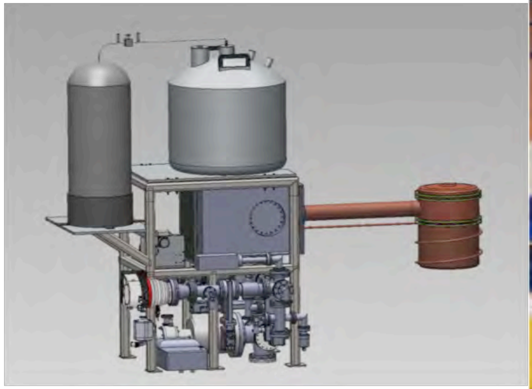
Modules

A Module is:

- Cryostat
- thermosyphon,
- Vacuum
- Shield Section
- All resting on a movable bearing table



Modules

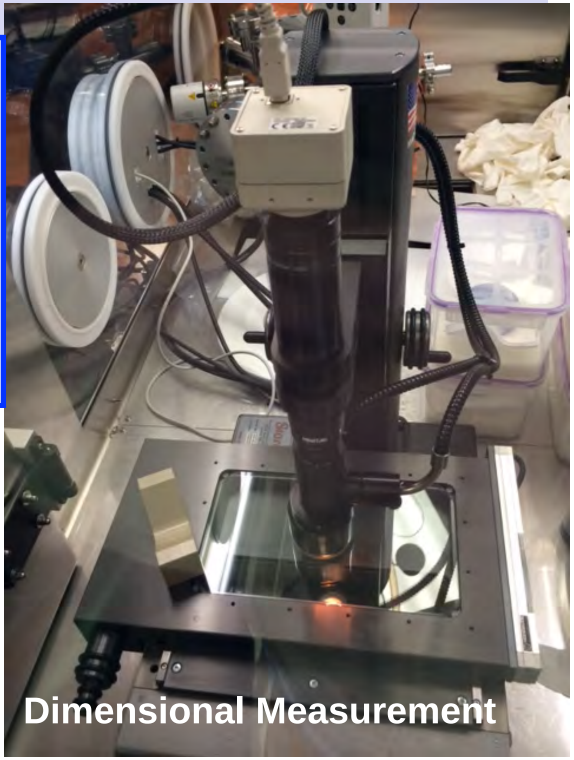


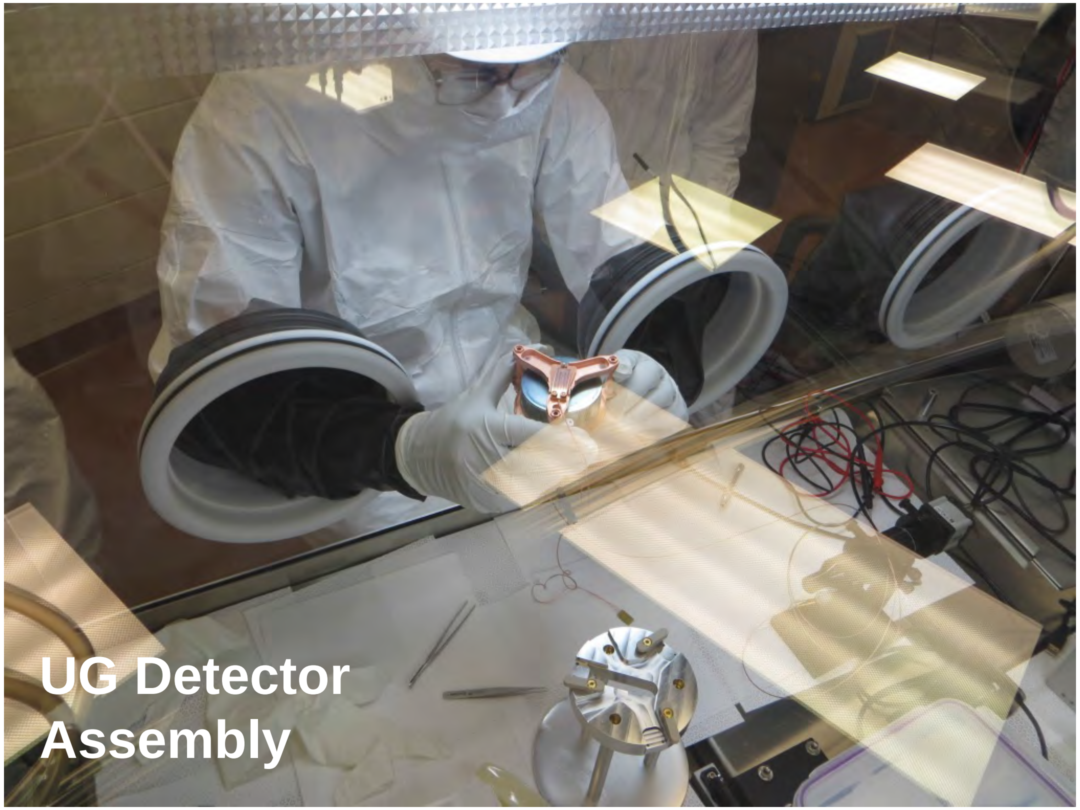
Modules

- **Prototype cryostat operating, over 140 d live.**
- **Thermosyphon, vacuum system operating.**
- **Pictured cryostat with enriched detectors will be sited inside shield during May 2015.**
    - **Started cooling May 26.**
- **Parts and material tracking in place.**
- **Clean machining implemented underground.**

Detectors

- ORTEC selected for enriched detectors.
- 30 Enriched detectors at SURF 25.2 kg, 87% ^{76}Ge
- Up to an additional 5 kg of enriched detector expected during June 2015. 2 kg UG at ORNL
- 20 kg of modified natural-Ge BEGe (Canberra) detectors in hand (33 detectors UG).

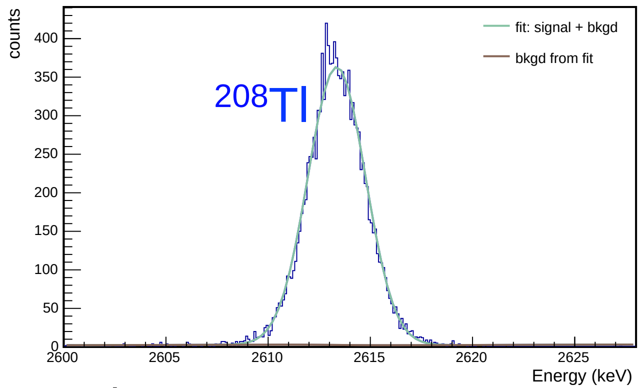


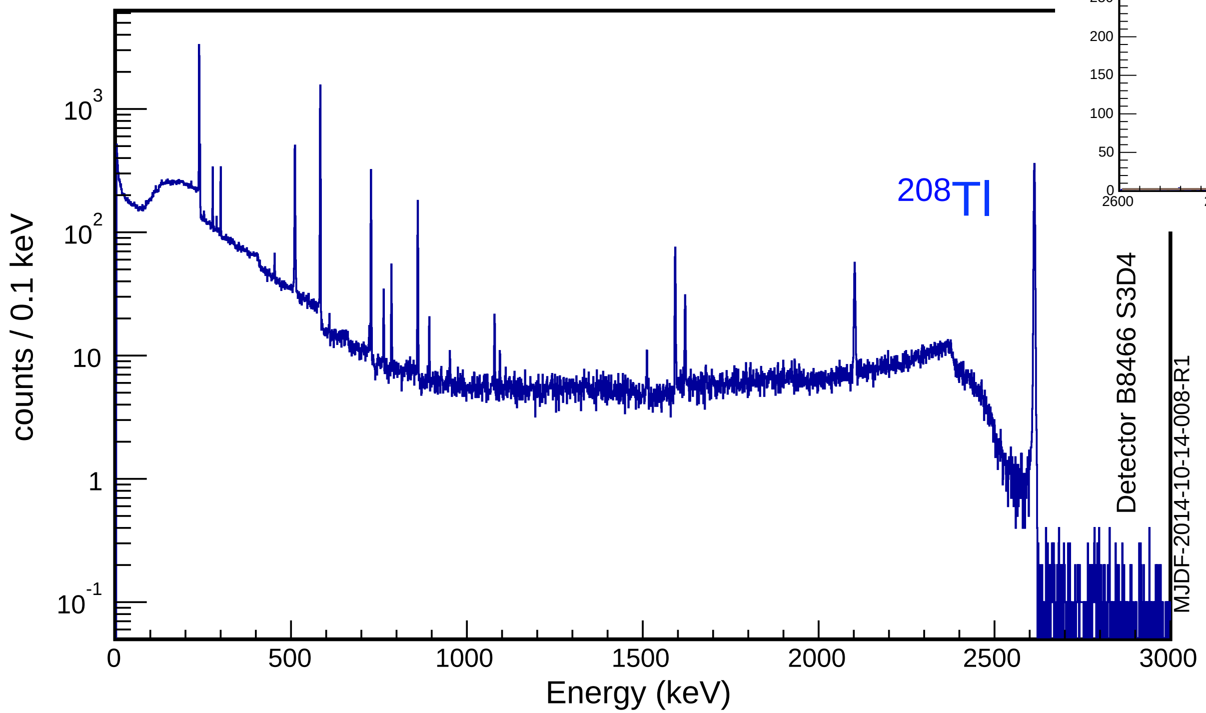


- All detector related assembly performed in N_2 purged gloveboxes.
- All detectors' dimensions recorded by optical reader.

^{228}Th Calibration Spectrum of Prototype Module Detector

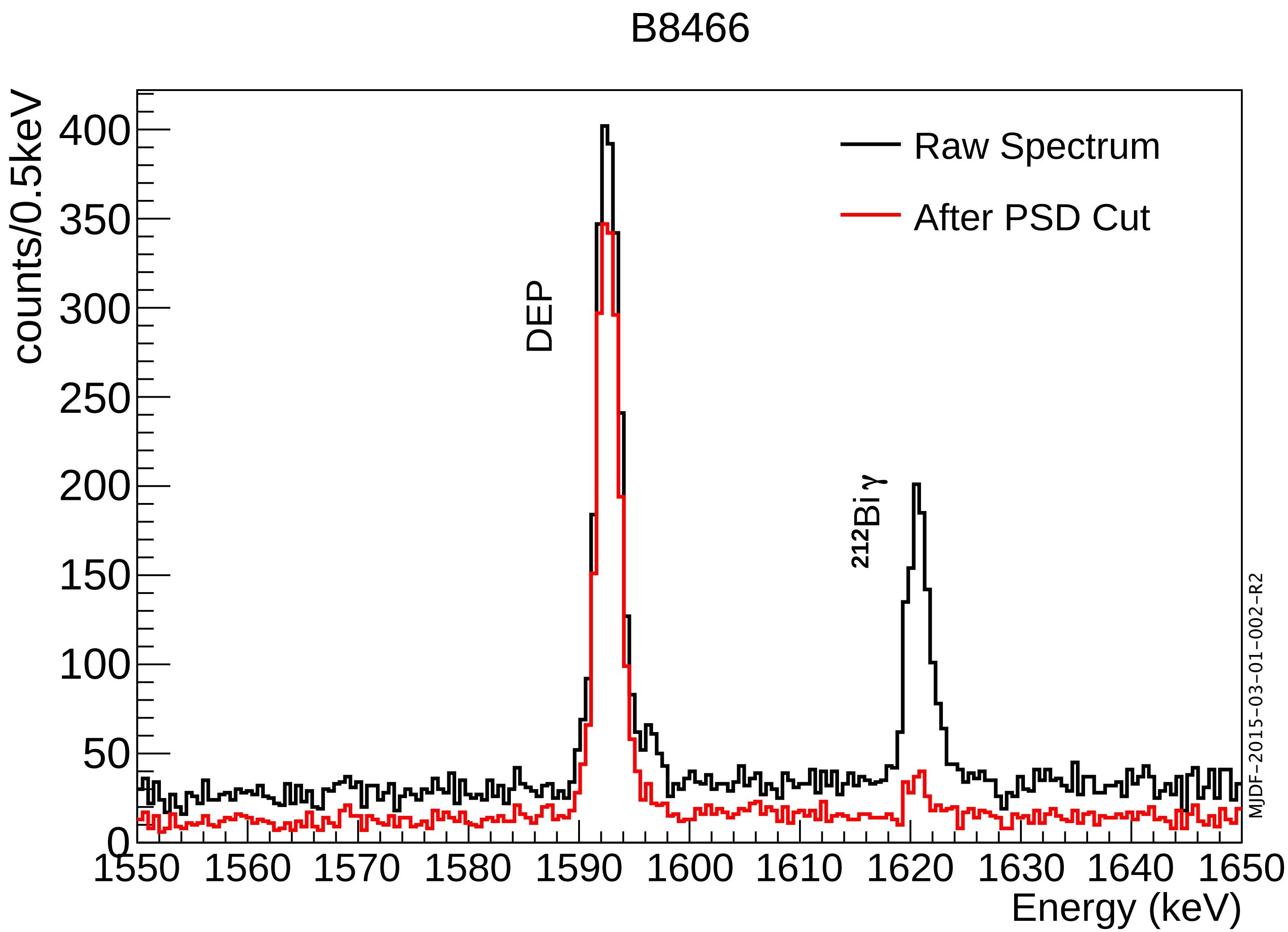
One detector spectrum within a string mounted in the prototype cryostat and inside shield. FWHM 3.2 keV at 2.6 MeV.





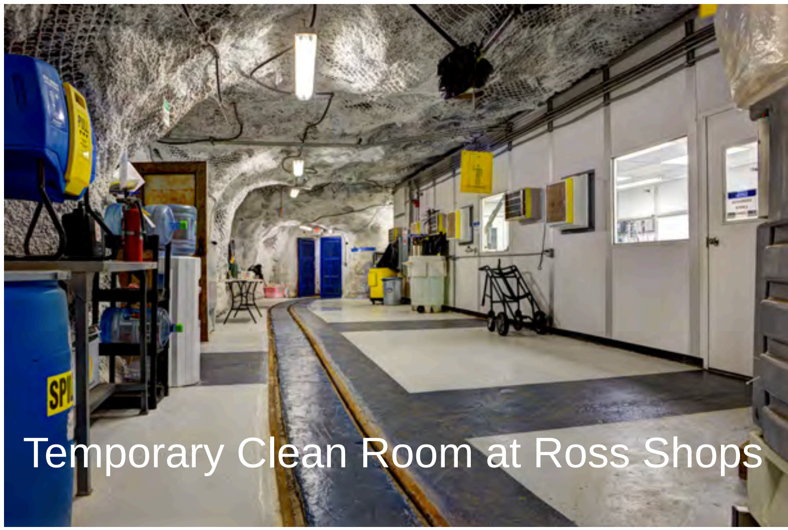
Pulse Shape Discrimination: A/E

Natural BEGe detector in Prototype Cryostat



Electroforming

- Eforming at PNNL and at 4850’ at SURF
- Eforming complete in May 2015
- Machine shop operational



Temporary Clean Room at Ross Shops

Copper ready to cut

Flattened Plate

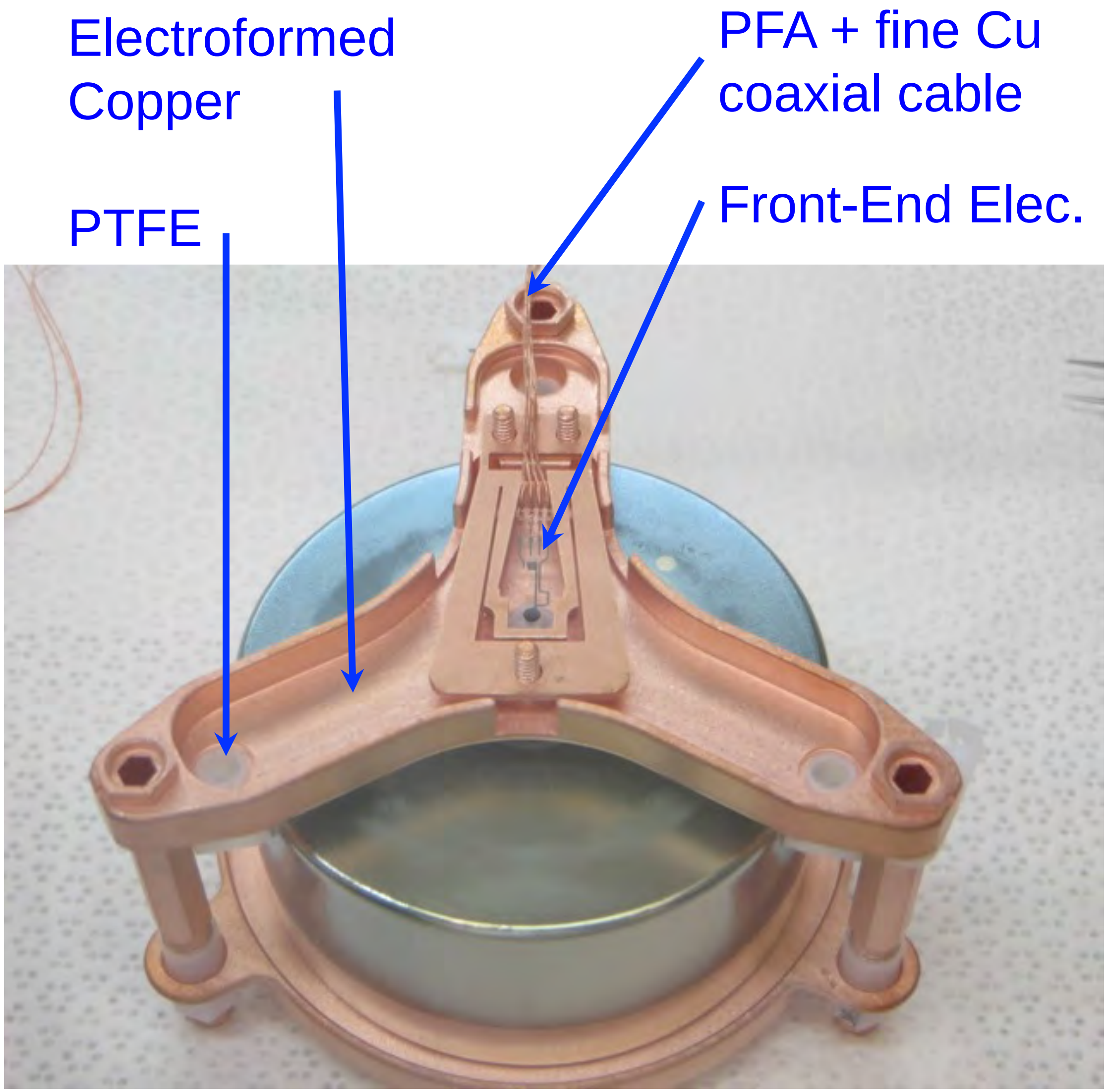
Installation of mandrel in bath

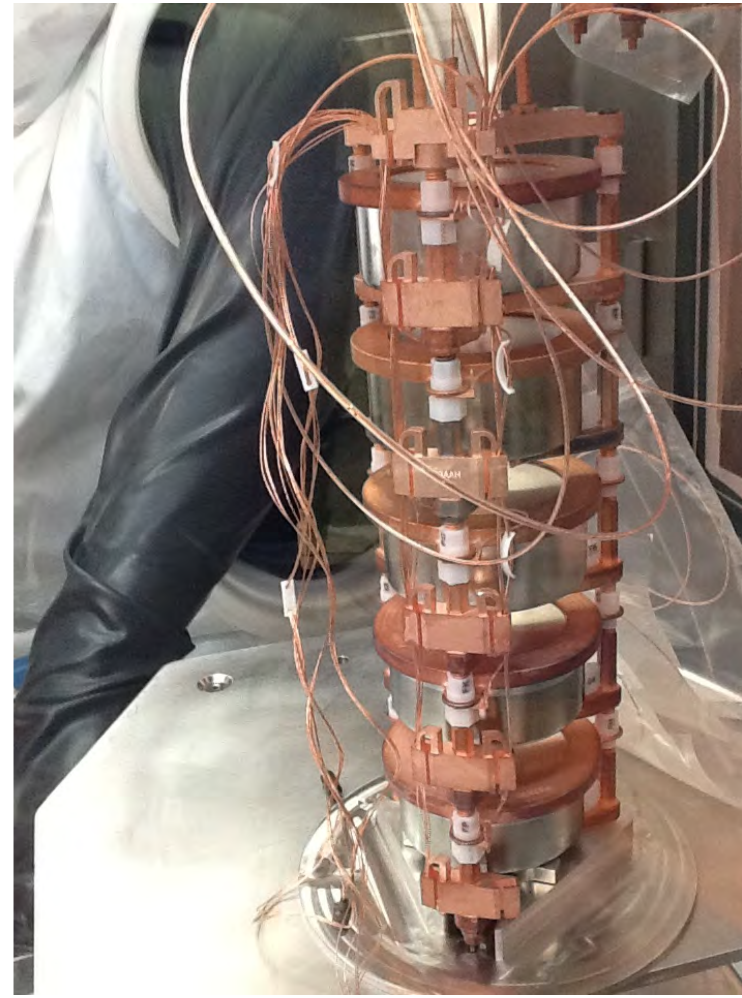
Bake/Quench

Lathe installed UG

Electroformed Parts Stored in Nitrogen

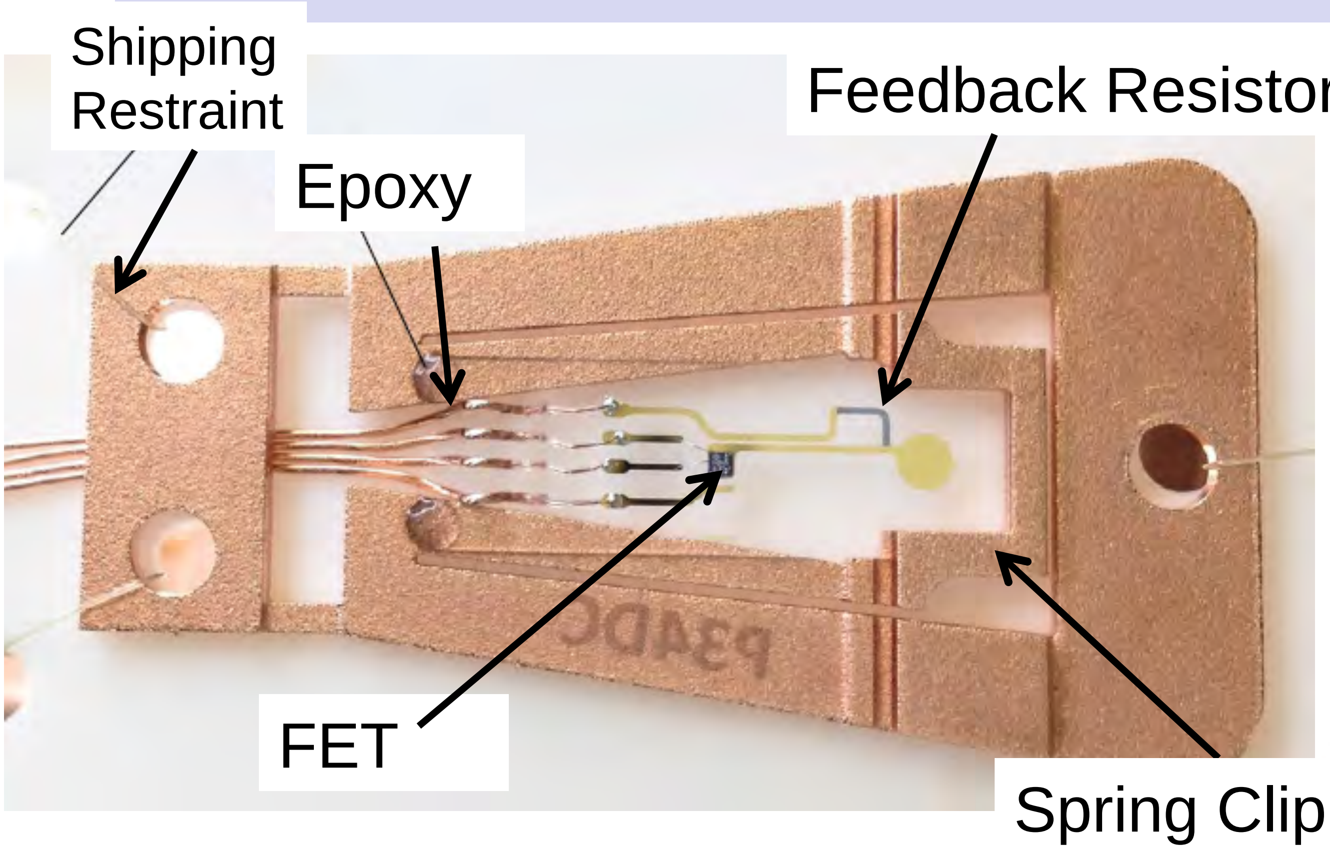
Assembled Detector Unit and String



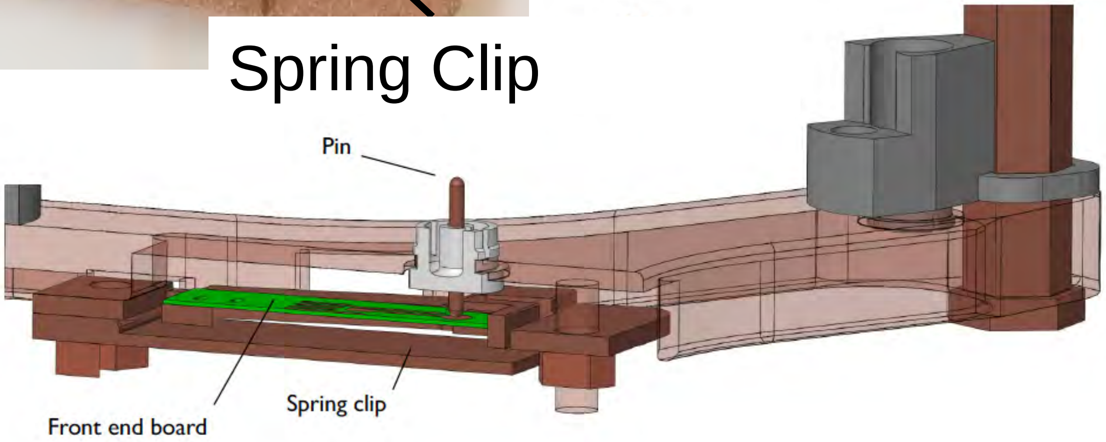


String Assembly

Front-End Board

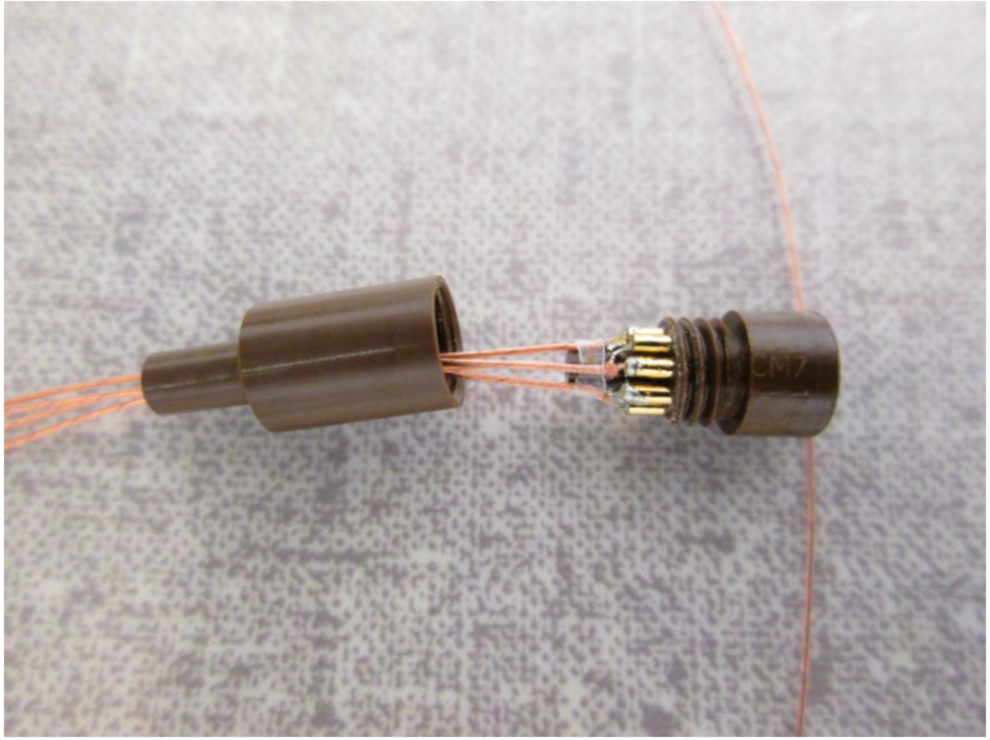


Clean Au+Ti traces on fused silica, amorphous Ge resistor, FET mounted with silver epoxy, EFCu + low-BG Sn contact pin

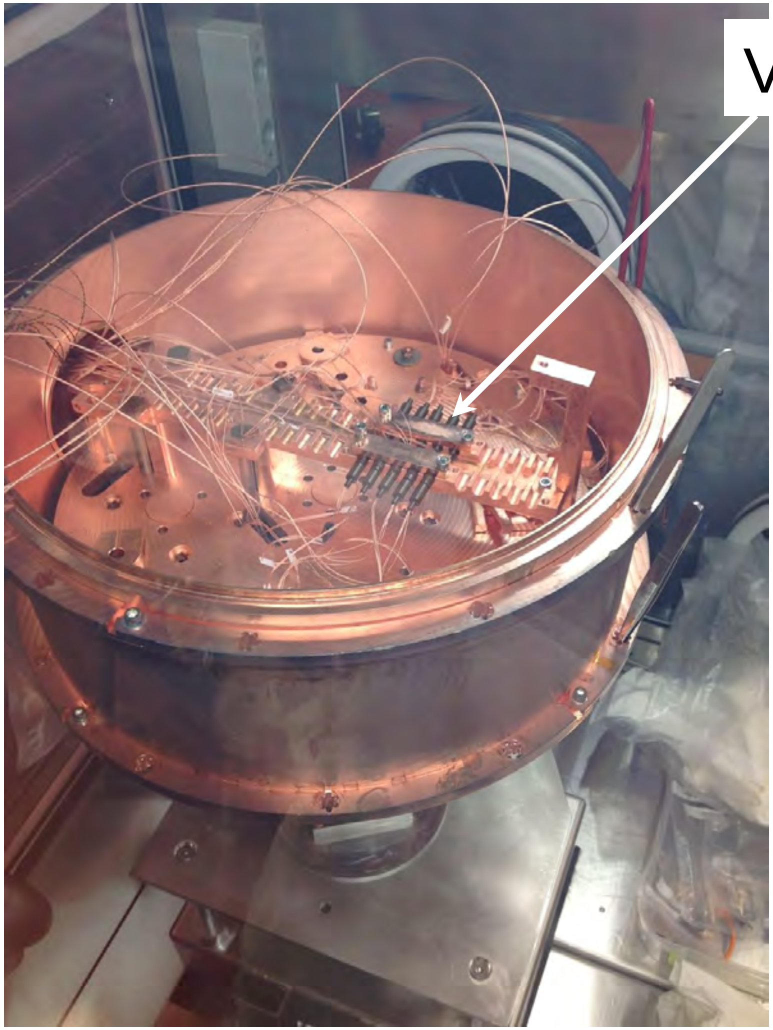


Signal Connectors

Connectors reside on top of cold plate.
In-house machined from vespel. Axon pico co-ax cable.
Low background solder and flux.

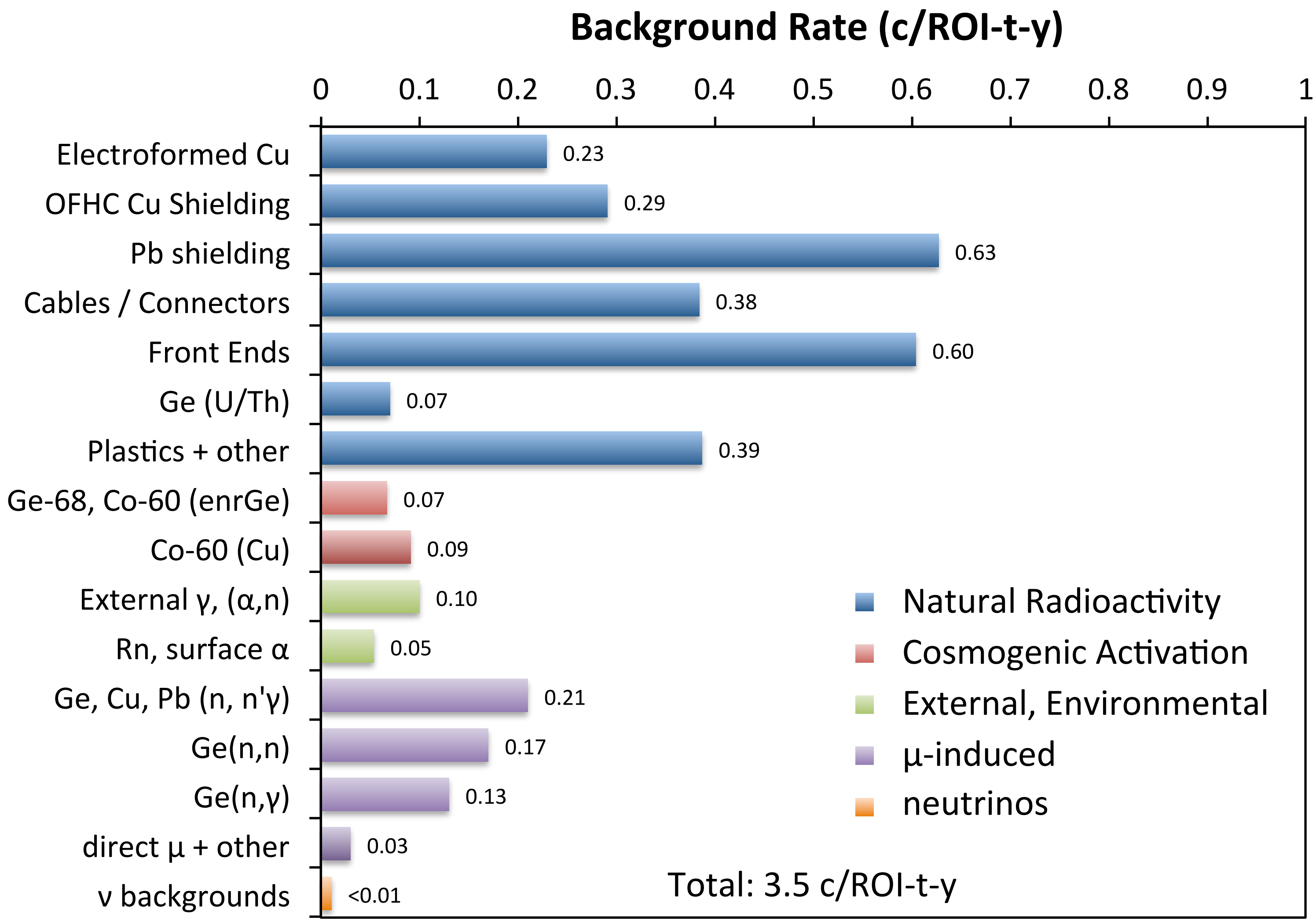


Top of the Cold Plate



HV cables are run from vacuum feed-through to detector.

DEMONSTRATOR Background Model



MJD Overview

- Assembly and construction proceeding at Sanford Davis Campus laboratory.
- Based on assays, material backgrounds projected to meet cleanliness goals.
- Module 1 complete.
- EF copper just completed at SURF and PNNL.
- Shield nearly complete.
- Successful reduction and refinement of ^{enr}Ge with 98% yield.
- AMTEK (ORTEC) has produced 27 kg within 32 detectors from the reduced/refined ^{enr}Ge. 30 of these are underground at SURF being assembled into strings.

Commissioning Schedule
– Prototype Cryostat – In use
– Module 1 – May 2015
– Module 2 – Late 2015

The MAJORANA Collaboration

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Duke University, Durham, North Carolina , and TUNL
Matthew Busch

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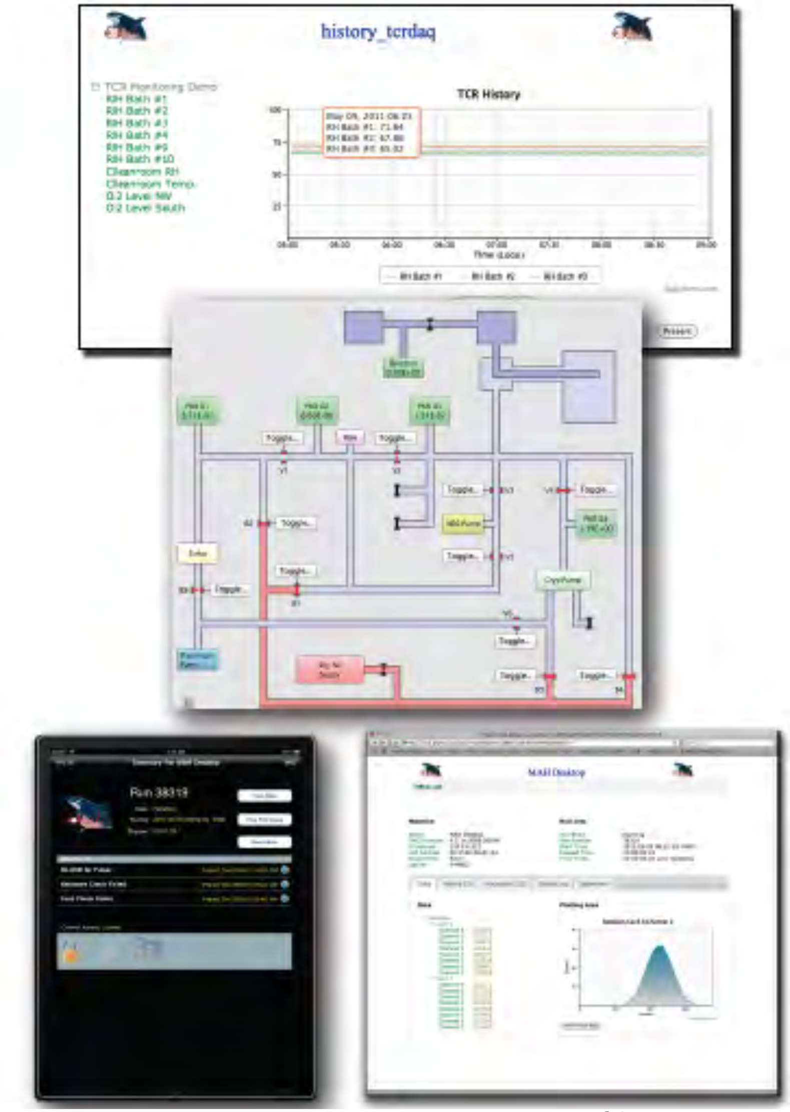
EXTRAS

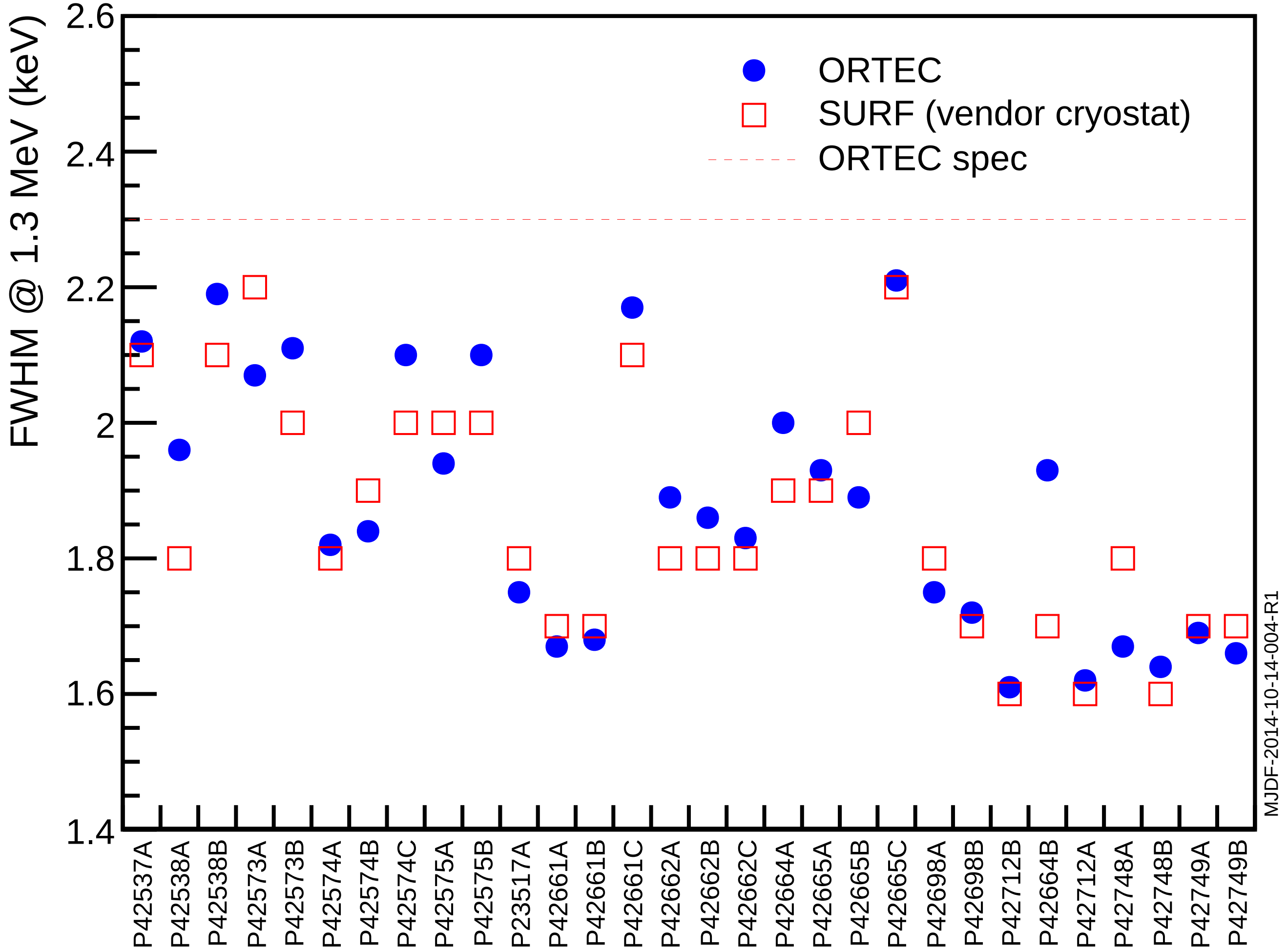
Data Acquisition

- Slow controls fielded and in operation. Vacuum systems in operation.
- Low sub-keV threshold digital system operating for MALBEK.
- The DAQ software and hardware is up and running and in continuous use for Prototype, test cryostats and detector acceptance testing.
- Tablet and smart phone support.



Enriched Detector Performance

Comparison of measurements done at ORTEC and SURF within the vendor cryostat. All are better than specification.

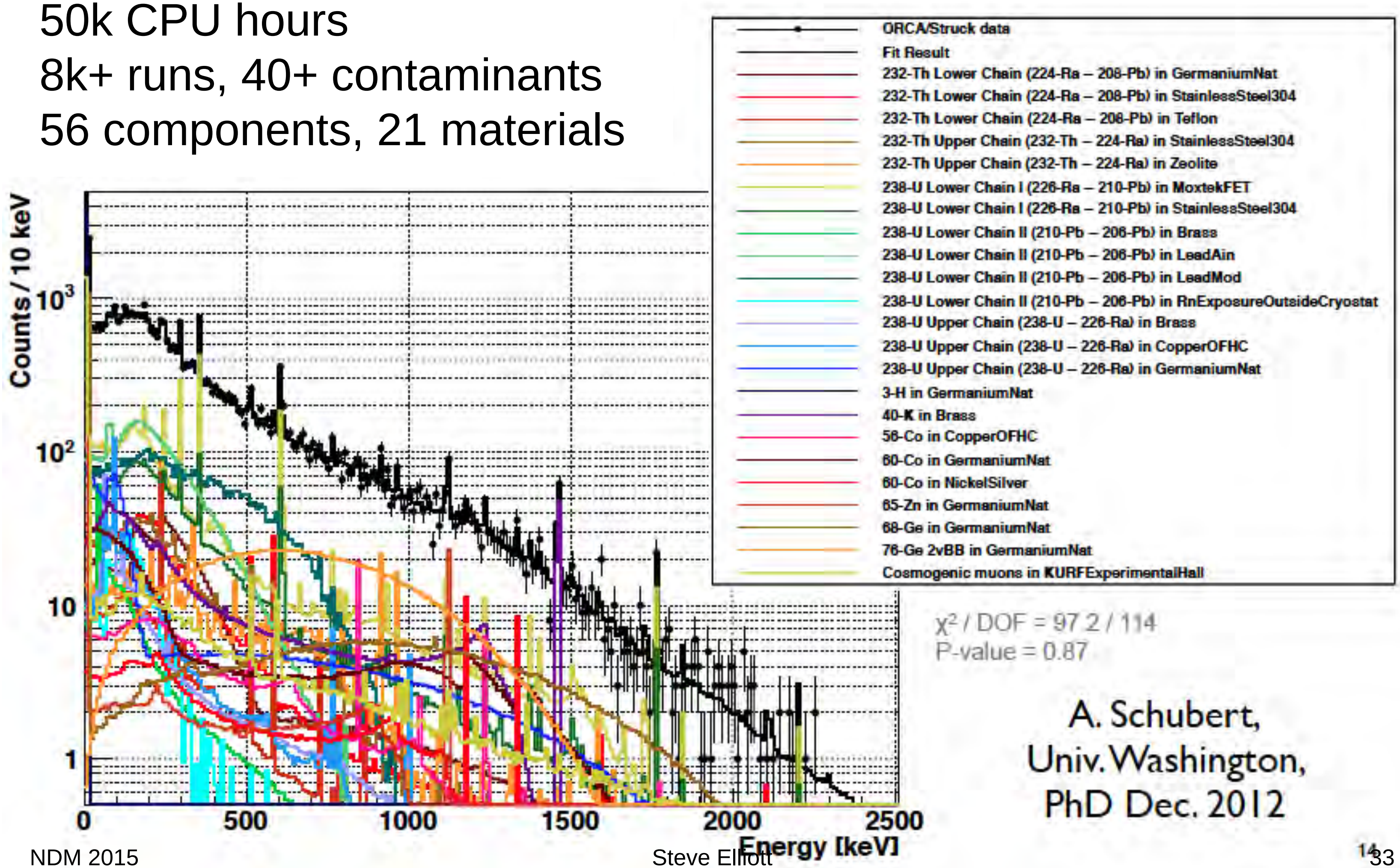


A full background model has been successfully built for MALBEK using MaGe. Our simulations of MJD produce the entire spectrum.

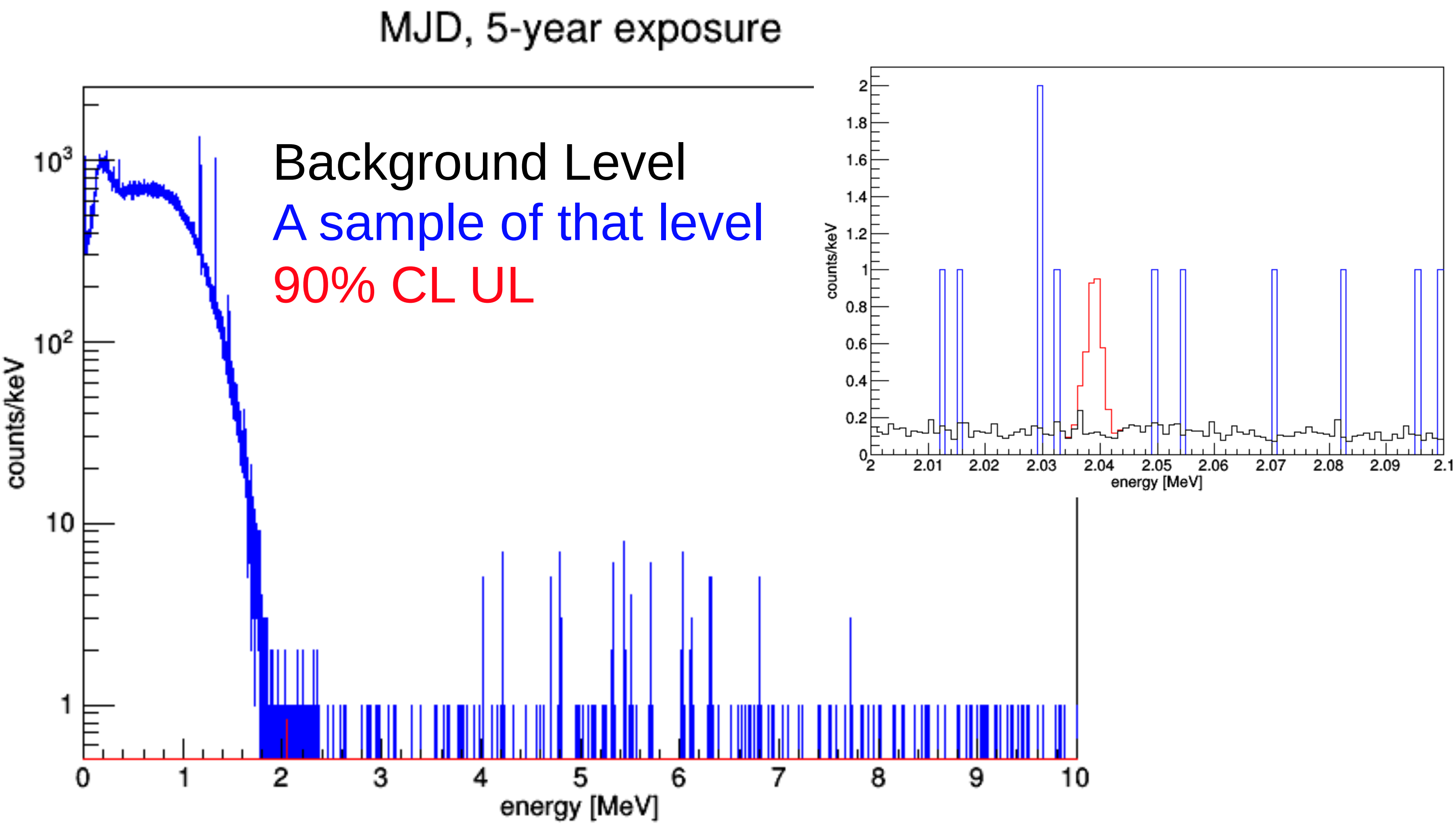
50k CPU hours

8k+ runs, 40+ contaminants

56 components, 21 materials



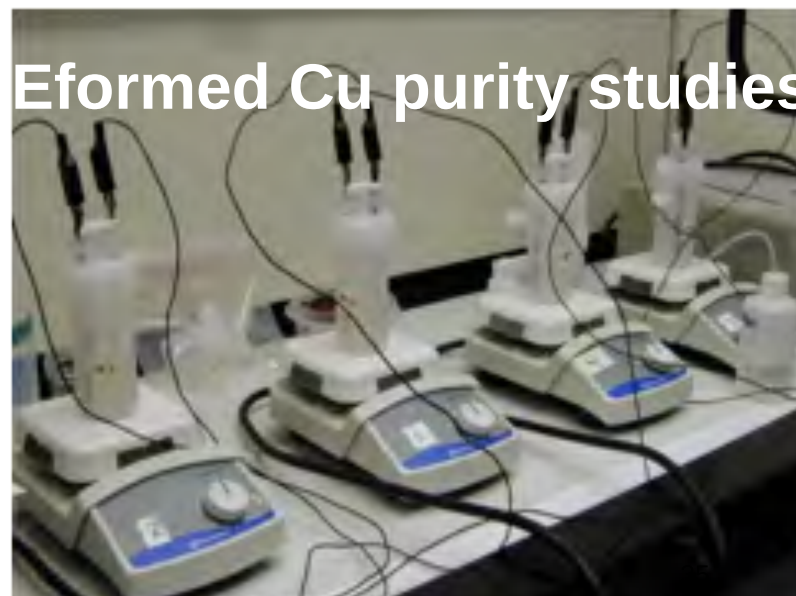
Simulation: MJD 0-10 MeV



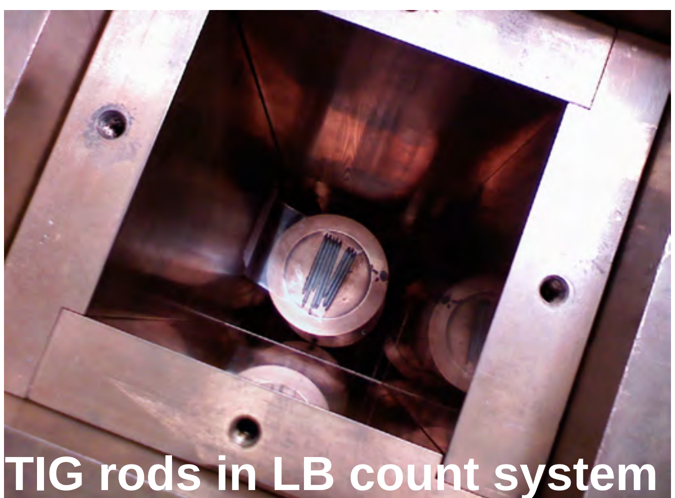
Materials and Assay

- Significant R&D and advances made in improvement of ICP-MS sensitivity for U and Th in copper near 0.1 µBq/kg level.
- Monitoring U and Th in copper baths electrolyte.
- All plastic materials selected after high sensitivity NAA analysis. Assay complete.
- Significant progress made in development of low background front-end electronics.

Plastics for NAA analysis

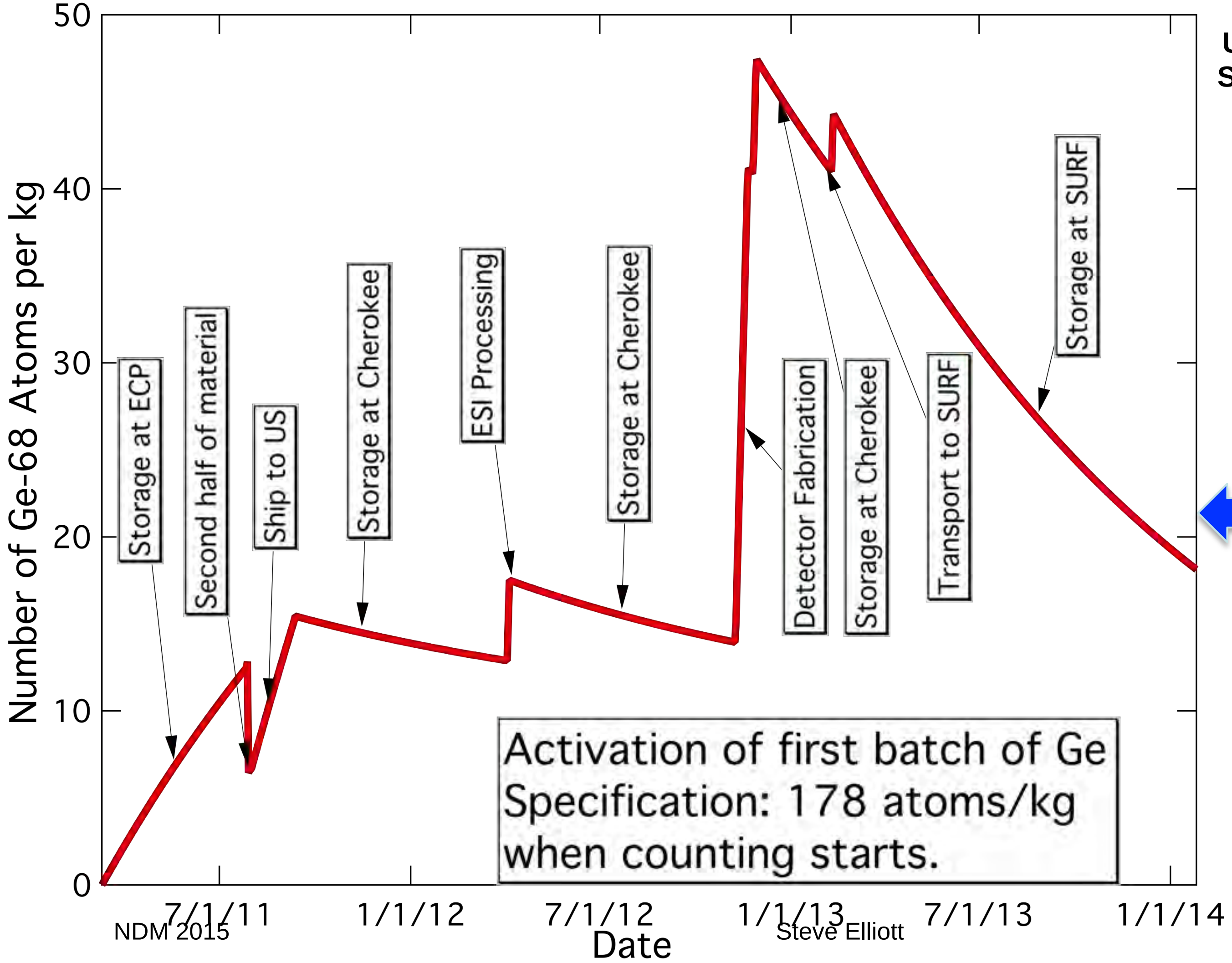


Eformed Cu purity studies



TIG rods in LB count system

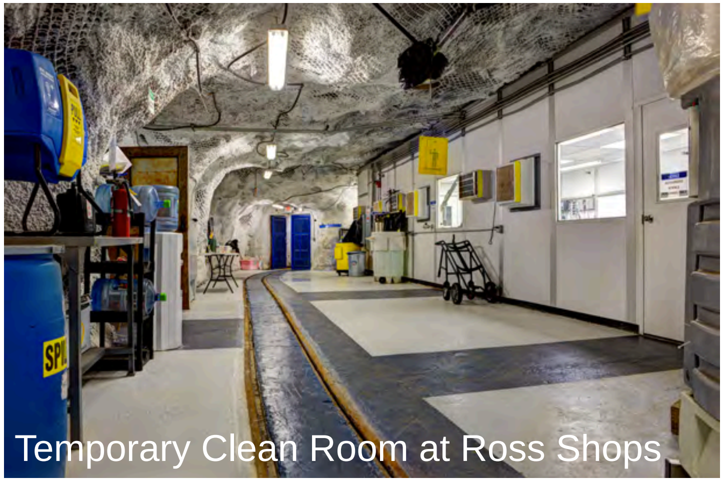
Enriched Ge Typical Effective Surface Exposure



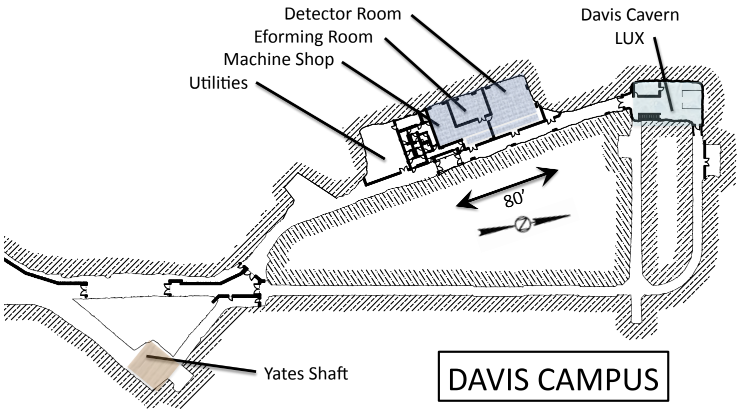
UG storage at ECP x22 reduction
Shipping container x10 reduction
UG at Cherokee x100 reduction

10 days equivalent sea level exposure

Underground Lab - Status



- Eforming lab operational since 2011
- Davis Campus lab occupied, March 2012
- Shield floor, LN system, assembly table, air bearing system, glove boxes, localized clean space all installed



Enriched Ge

- 42.5 kg ^{enr}Ge received as oxide and stored UG in Oak Ridge.
- Processed to metal with >98% conversion.

	Specs	ECP	ORNL Physics (Sample 1)	ORNL CSD (sample 2)	PNNL (Sample 3)
^{76}Ge	≥86.0	87.67	86.9 (2)	87.9 (9)	88.2 (3)
^{74}Ge		12.16	12.5 (1)	12.0 (1)	11.8 (3)
^{73}Ge		0.07	< 0.2	0.052 (1)	0.04 (2)
^{72}Ge		0.05	<0.2	0.0058 (3)	0.02 (1)
^{70}Ge	≤0.07	0.05	<0.2	0.0157 (3)	0.005 (4)