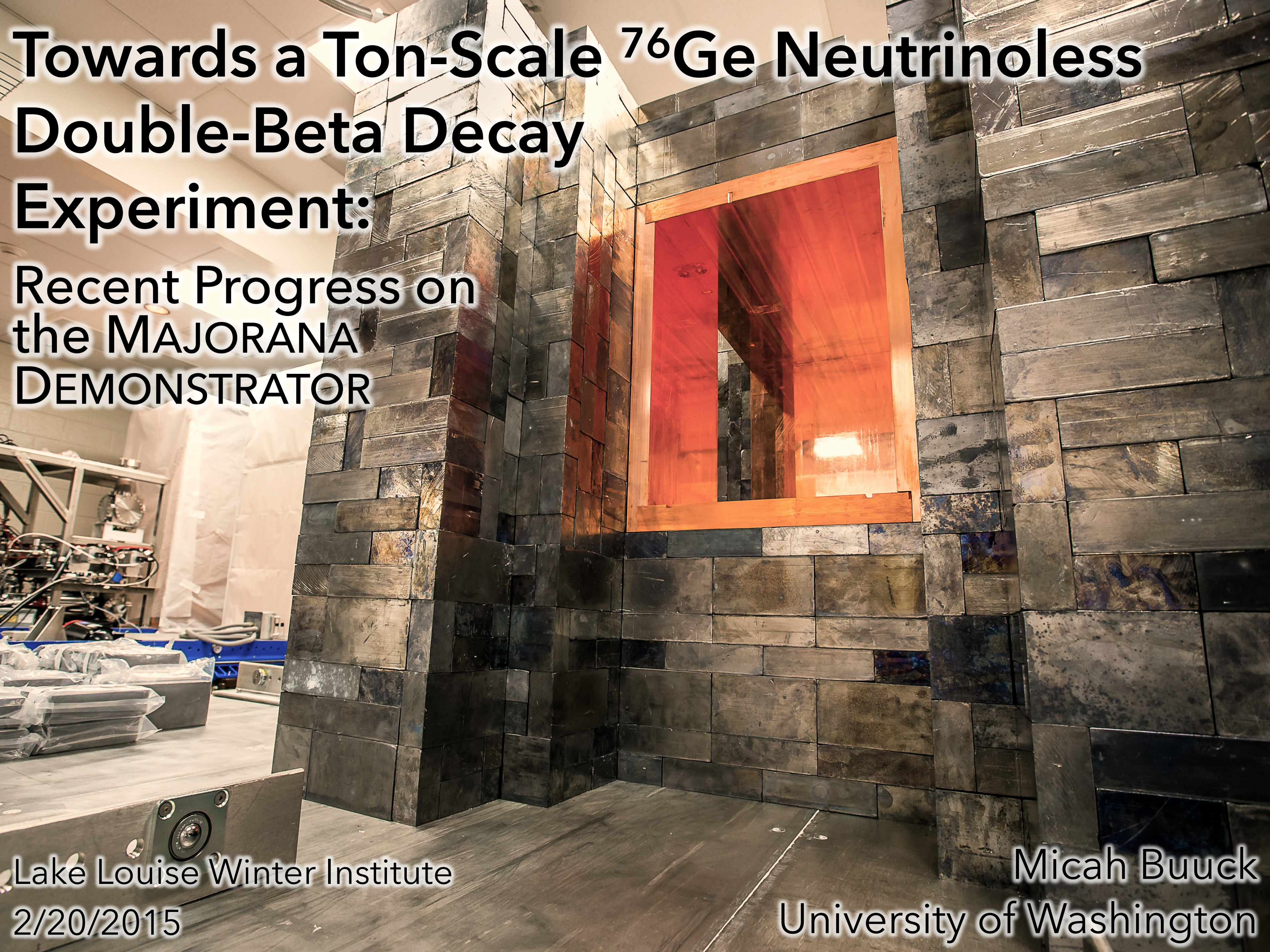
Towards a Ton-Scale ^{76}Ge Neutrinoless Double-Beta Decay Experiment:

Recent Progress on the MAJORANA DEMONSTRATOR



Lake Louise Winter Institute
2/20/2015

Micah Buuck
University of Washington

Prospects for 0νββ Discovery

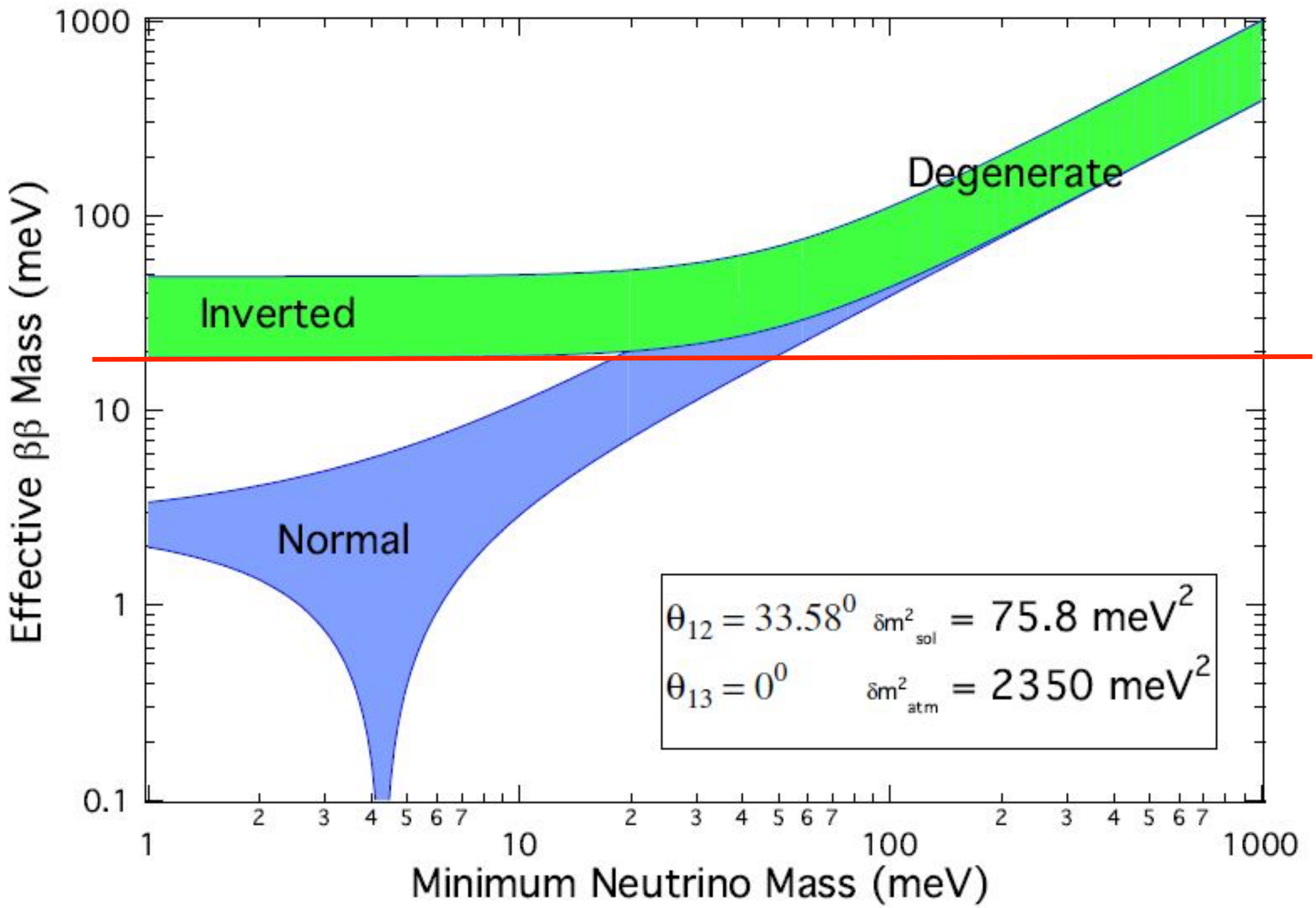
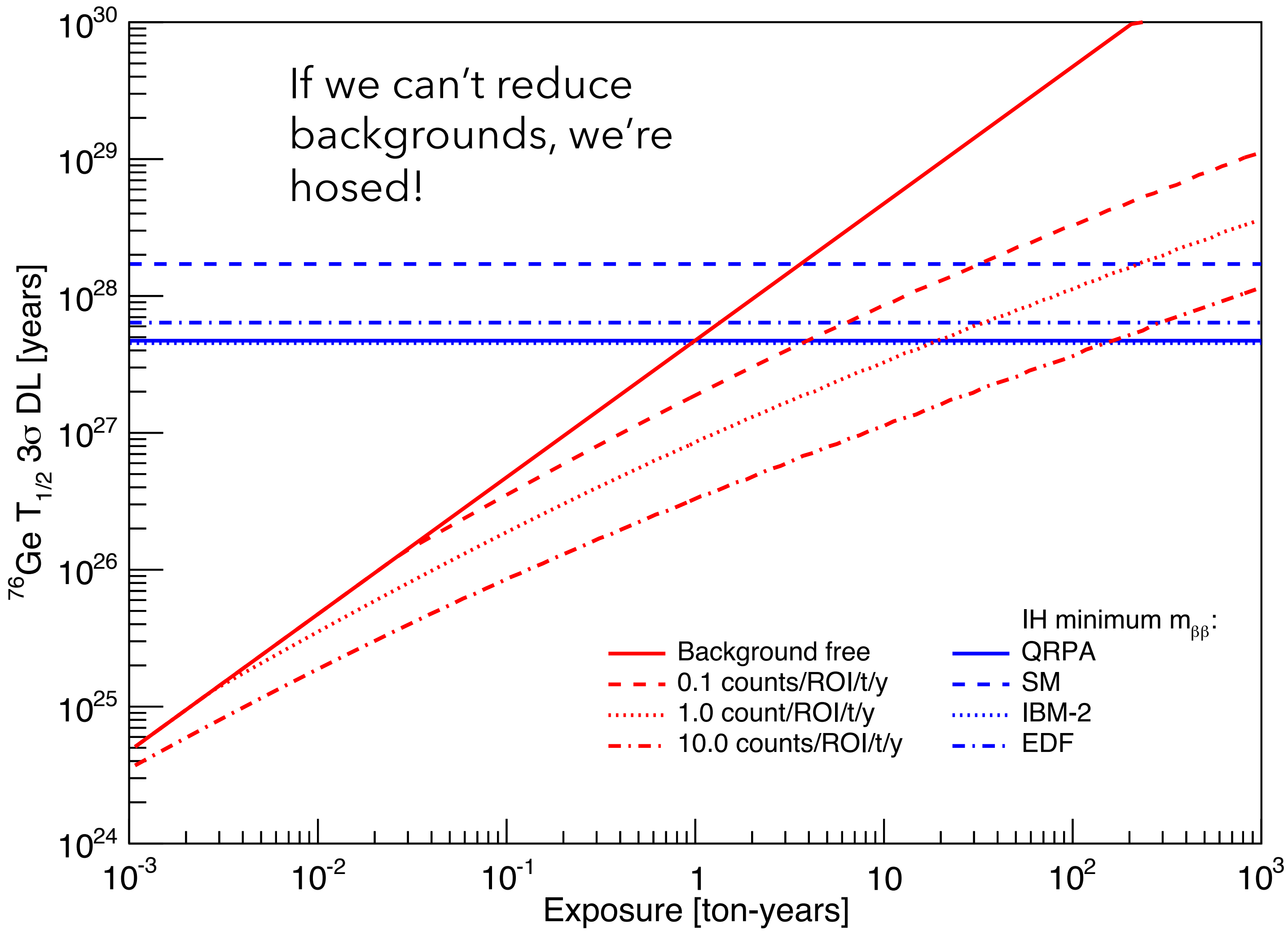


*Figure by Steve Elliott

Prospects for 0νββ Discovery



The MAJORANA Collaboration

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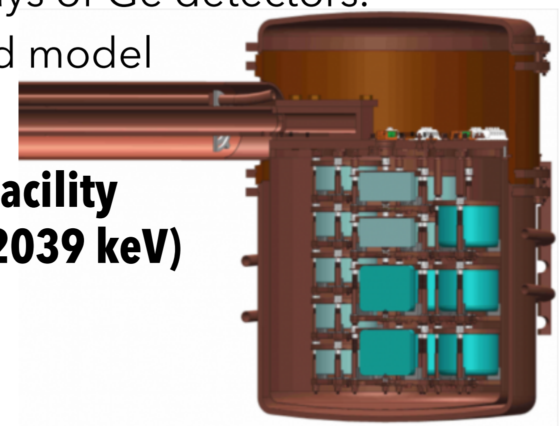
Students in red

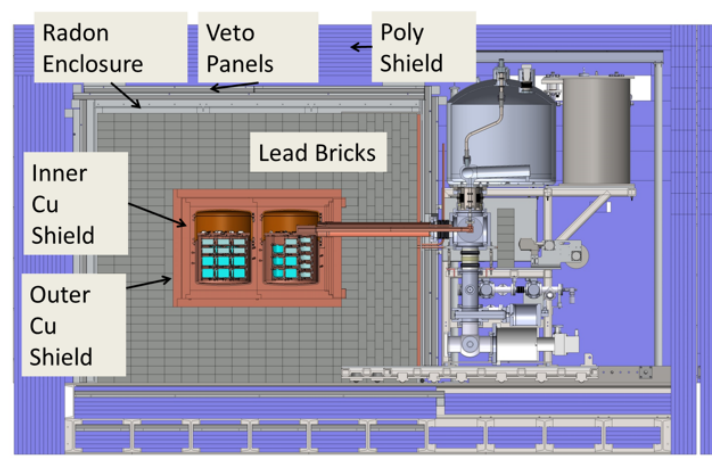
The MAJORANA DEMONSTRATOR

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 ton-scale ^{76}Ge experiment.
- Establish feasibility to construct & field modular arrays of Ge detectors.
- Searches for additional physics beyond the standard model



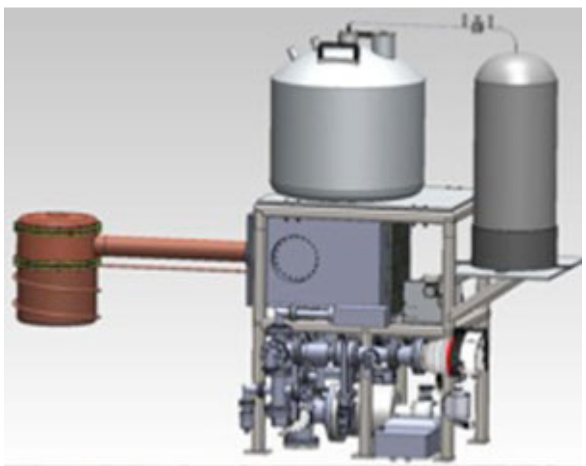
- **Located underground at 4850′ Sanford Underground Research Facility**
- **Background Goal in the 0νββ peak region of interest (4 keV at 2039 keV)**
  3 counts/ROI/t/y (after analysis cuts)
  scales to 1 count/ROI/t/y for a ton-scale experiment
- **40-kg of Ge detectors**
  - 30-kg of 87% enriched ^{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

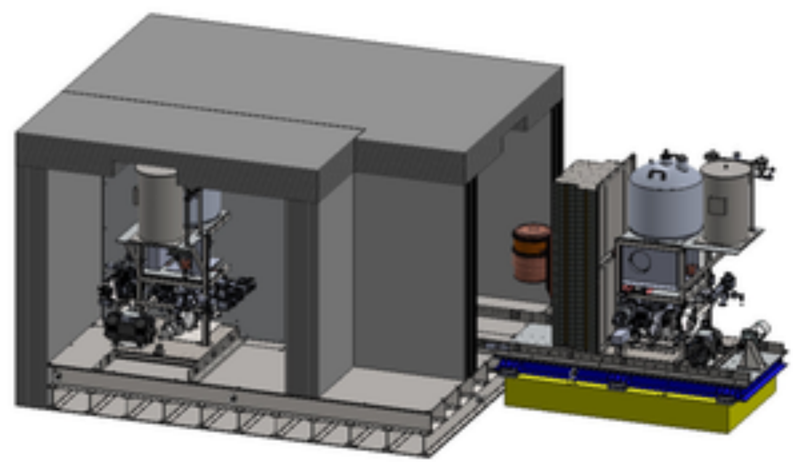


MJD Implementation

- **Three Steps**
  - Prototype Cryostat* (2 strings, ^{nat}Ge)
  - Cryostat 1 (7 strings ^{enr}Ge)
  - Cryostat 2 (3 strings ^{enr}Ge & 4 strings ^{nat}Ge)

Commissioning Dates
- November 2013
- September 2014
- (Late 2015)





✶ Same design as Cryos 1 & 2, but fabricated using OFHC Cu (non-electroformed) components.

Background Minimization Campaign

3 counts/ ROI/ton/ year

Pulse Shape Analysis

Active Shielding

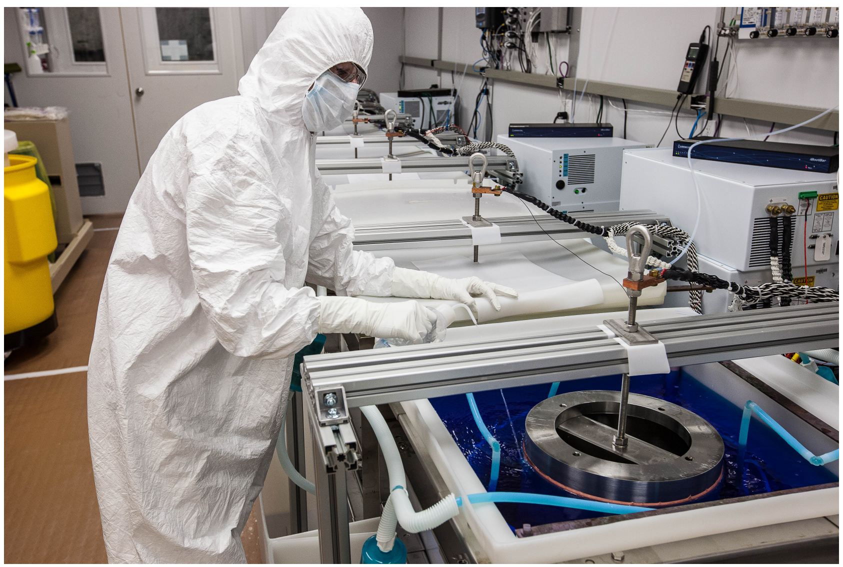
Passive Shielding

HPGe Detector Technology

Low-Background Materials

Low-Background Materials

	Th (µBq/kg)	U (µBq/kg)
OFHC Copper	1.1	1.25
E-formed Copper	0.06	0.17

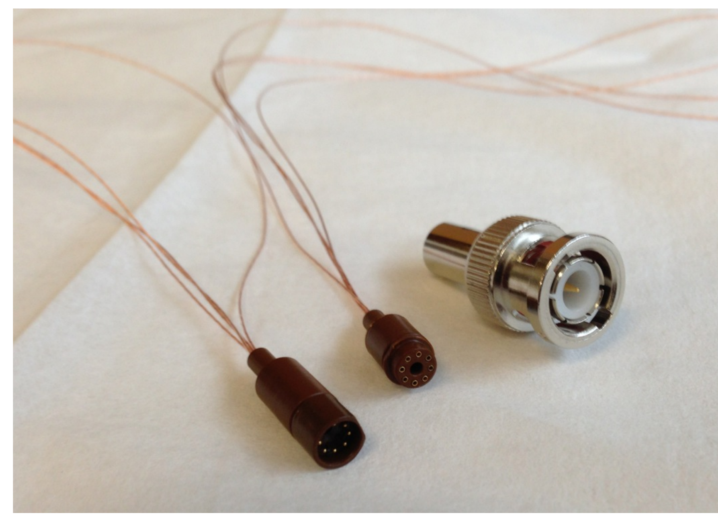


Underground copper electroforming

Low-Background Materials

	U and Th (µBq/ connector)	U and Th (counts/(ROI-t-y))
Connectors w/BeCu Springs	> 40	> 10
Connectors w/o BeCu Springs	1.45	0.28

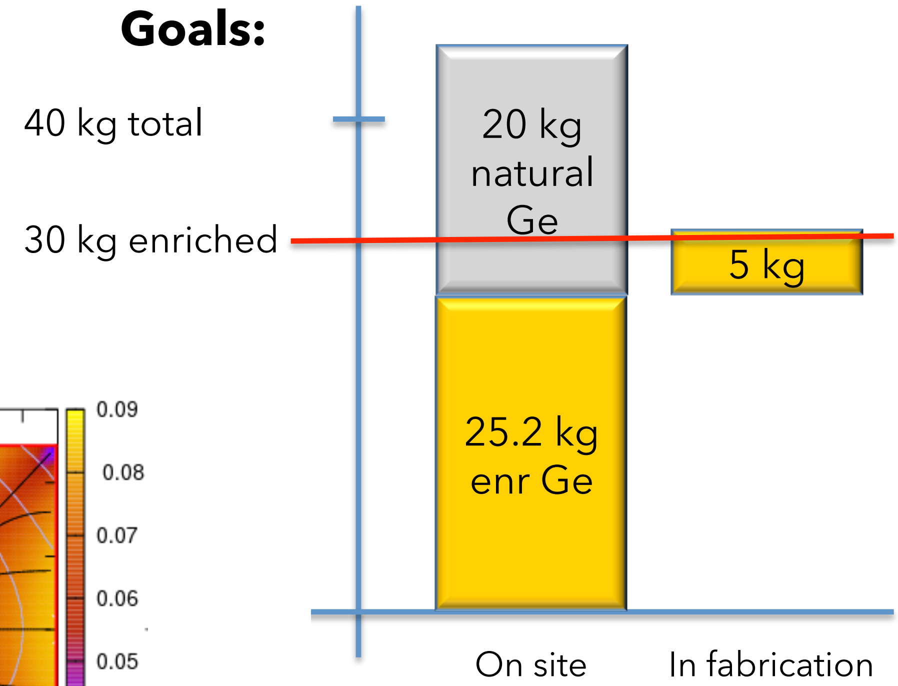
- No beryllium-copper
- Central conductor 80 µm diameter (40 gauge)
- Hand-soldered to connector pins in cleanroom

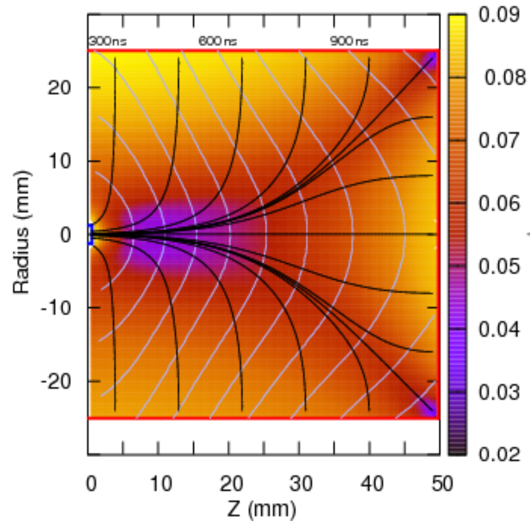


Signal Cables and Connectors

HPGe Detector Technology

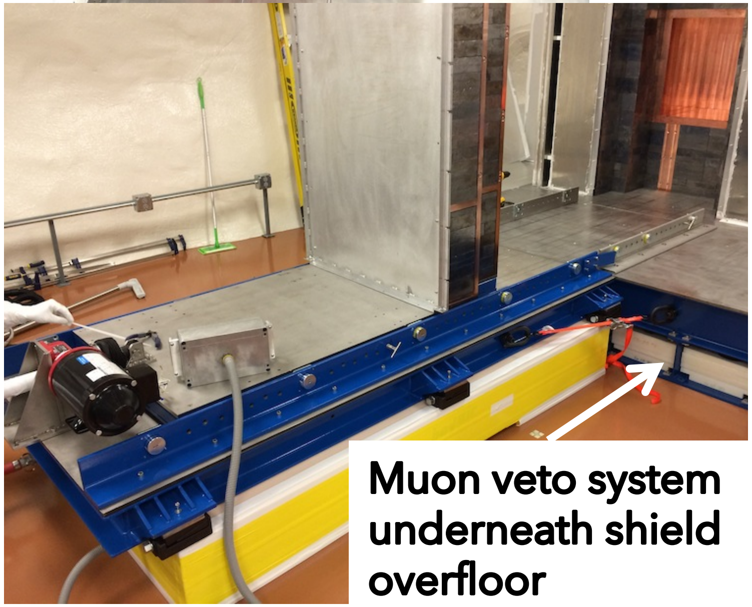
- P-type Point-Contact (PPC) detectors
  - Localized weighting potential → multi-site rejection
  - Low capacitance (~ 1 pF) → good low energy resolution
  - Small point-like central contact
  - Cost effective, low background



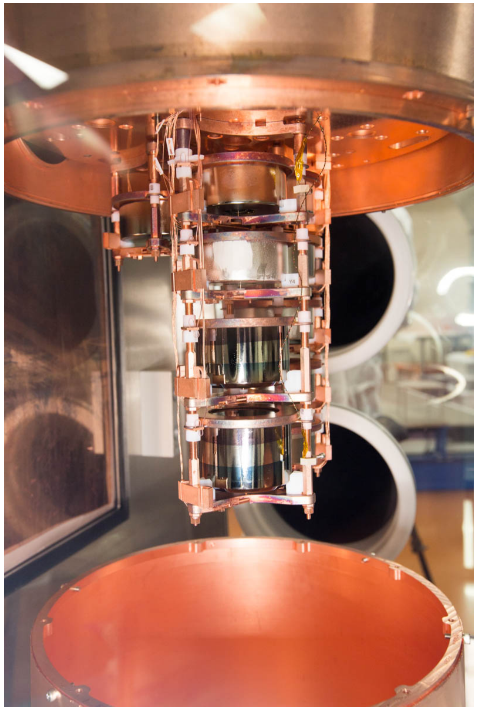


Shielding

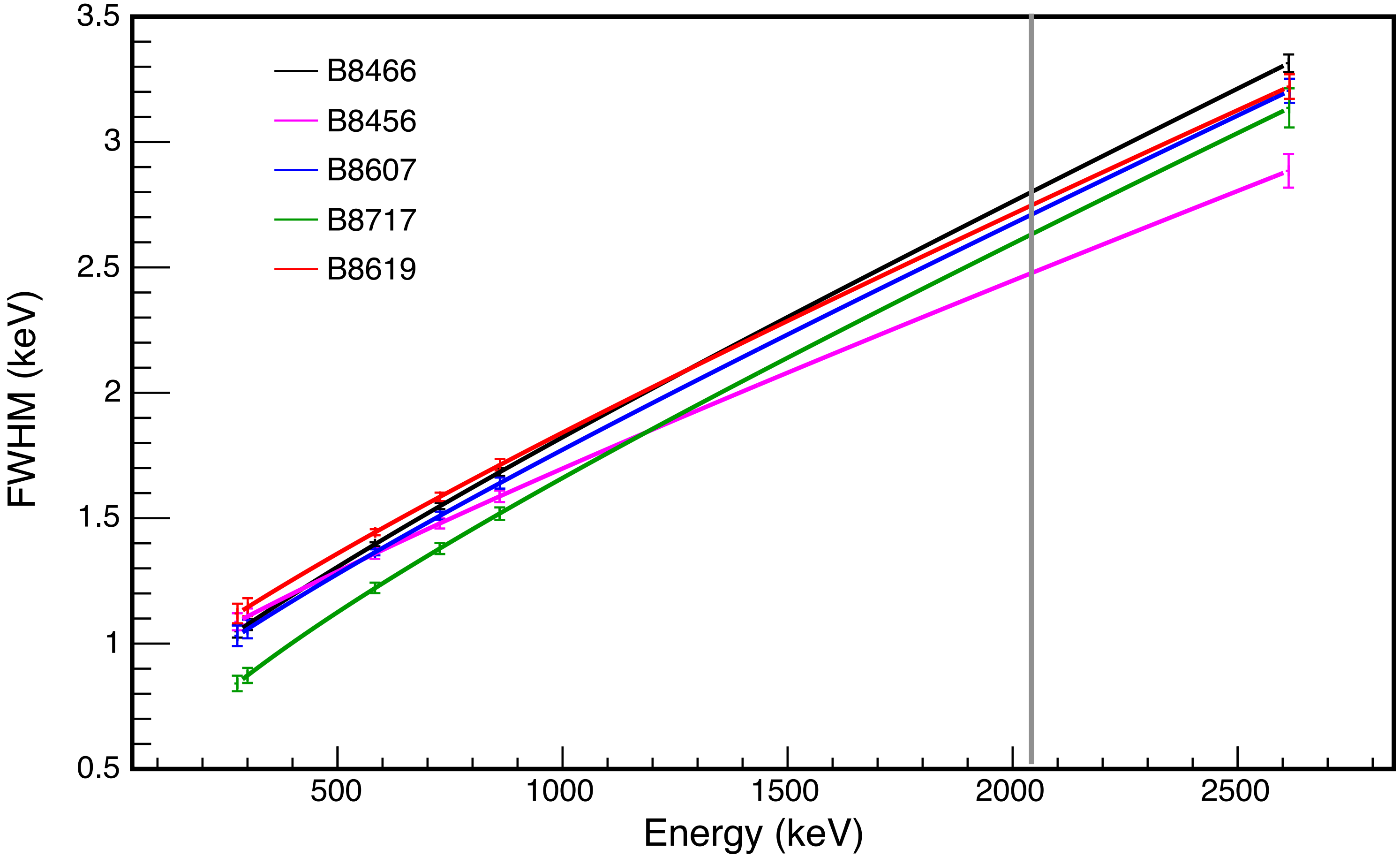
- Passive Cu and Pb
- Muon veto
- Coincident event rejection



Muon veto system underneath shield overfloor

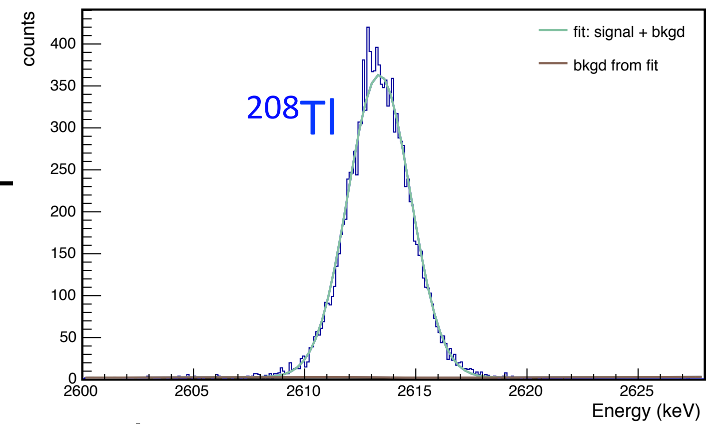


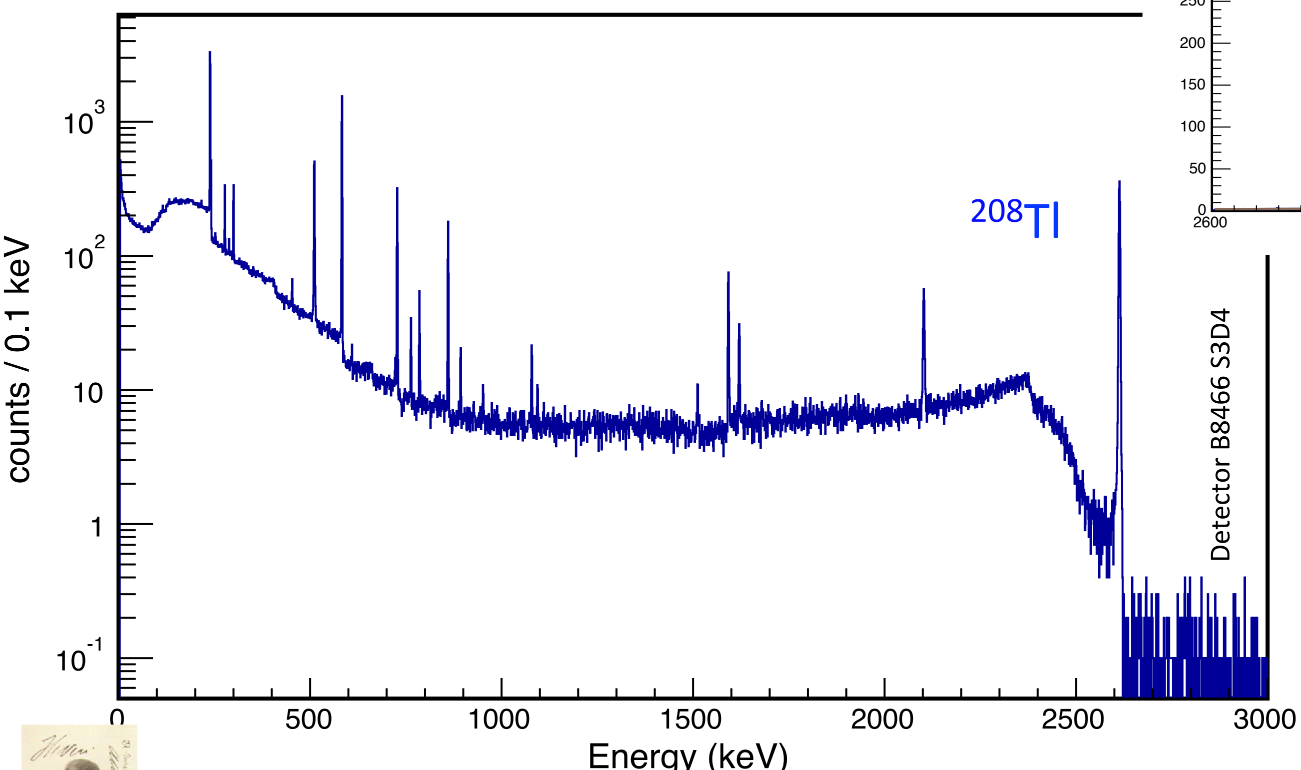
Energy Resolution of BEGe Detectors within Prototype Cryostat



^{228}Th Calibration Spectrum in Prototype Cryostat

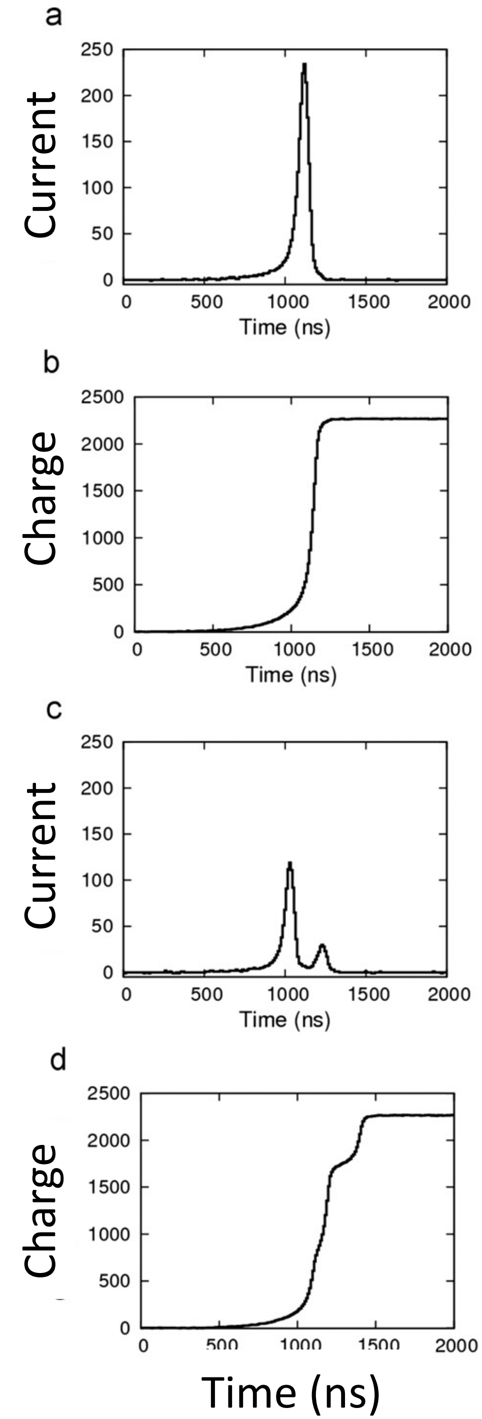
One detector in prototype cryostat and shield. FWHM 3.2 keV at 2.6 MeV



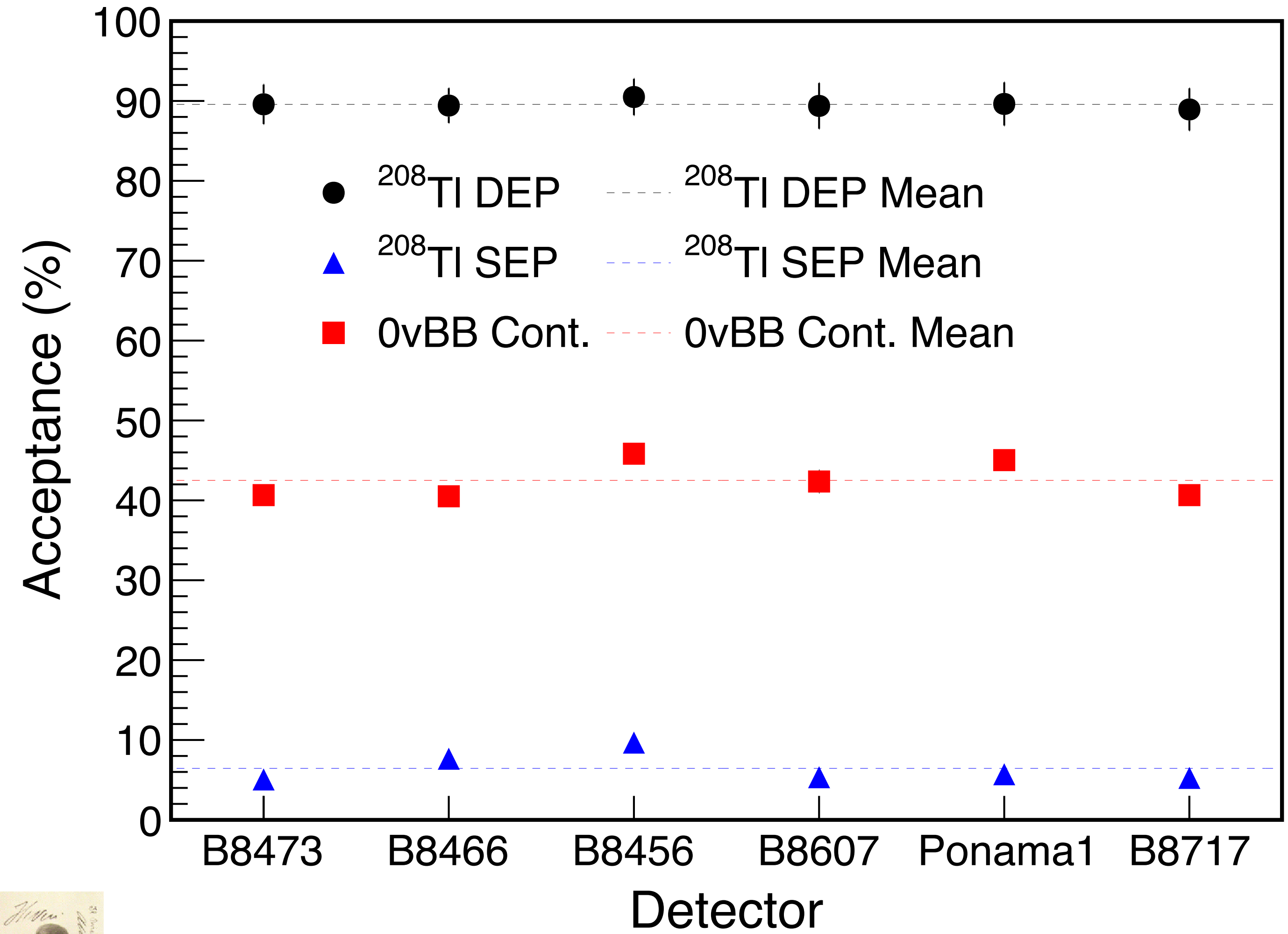


Pulse-Shape Analysis

- Pulse-basis library
  - Build single-site pulse library
  - Fit data to basis using sample-by-sample χ^2 minimization
- A/E
  - Max current over energy
  - GERDA technique



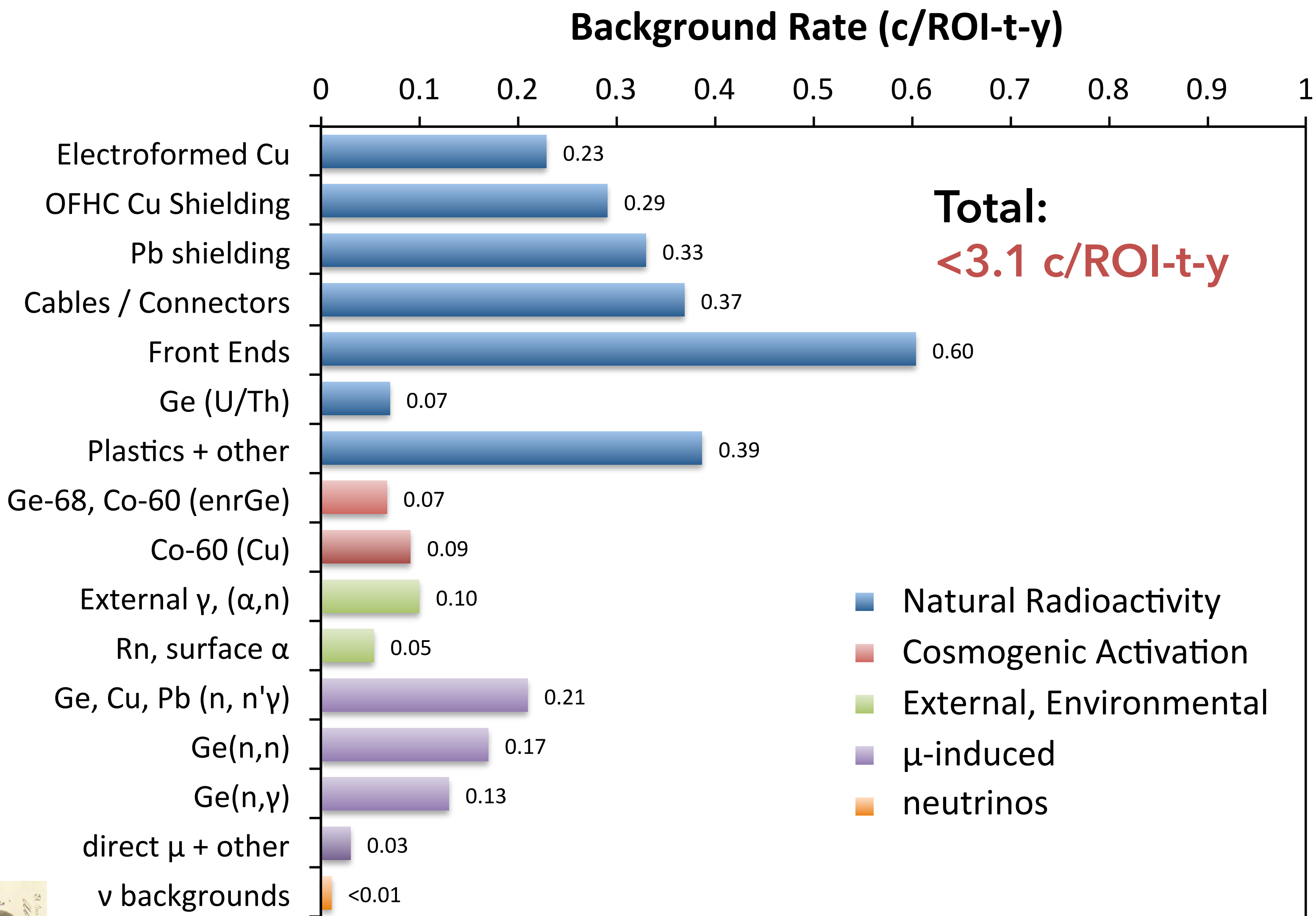
A/E Results in Prototype Cryostat



^{208}Tl DEP (single site events) fixed to 90%

^{208}Tl SEP (multi-site events) reduced to <10%

Background Status



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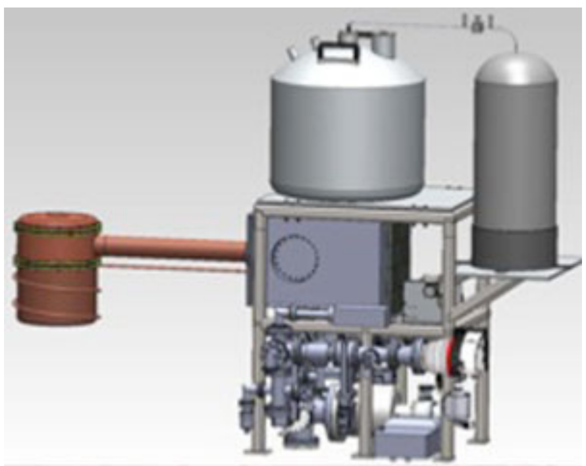

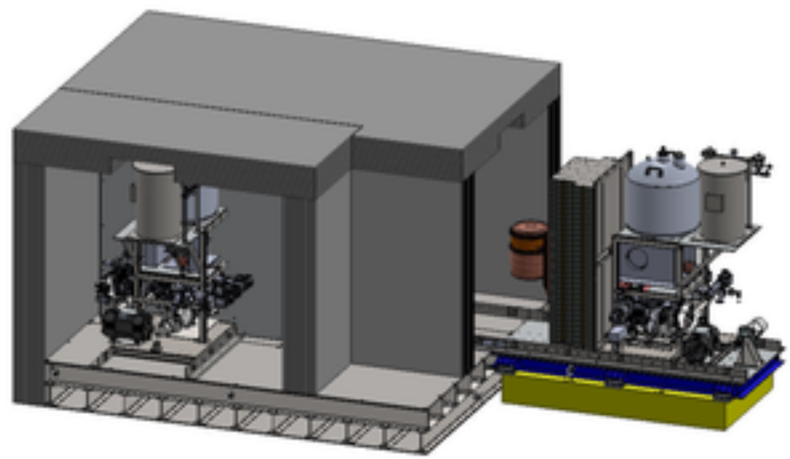

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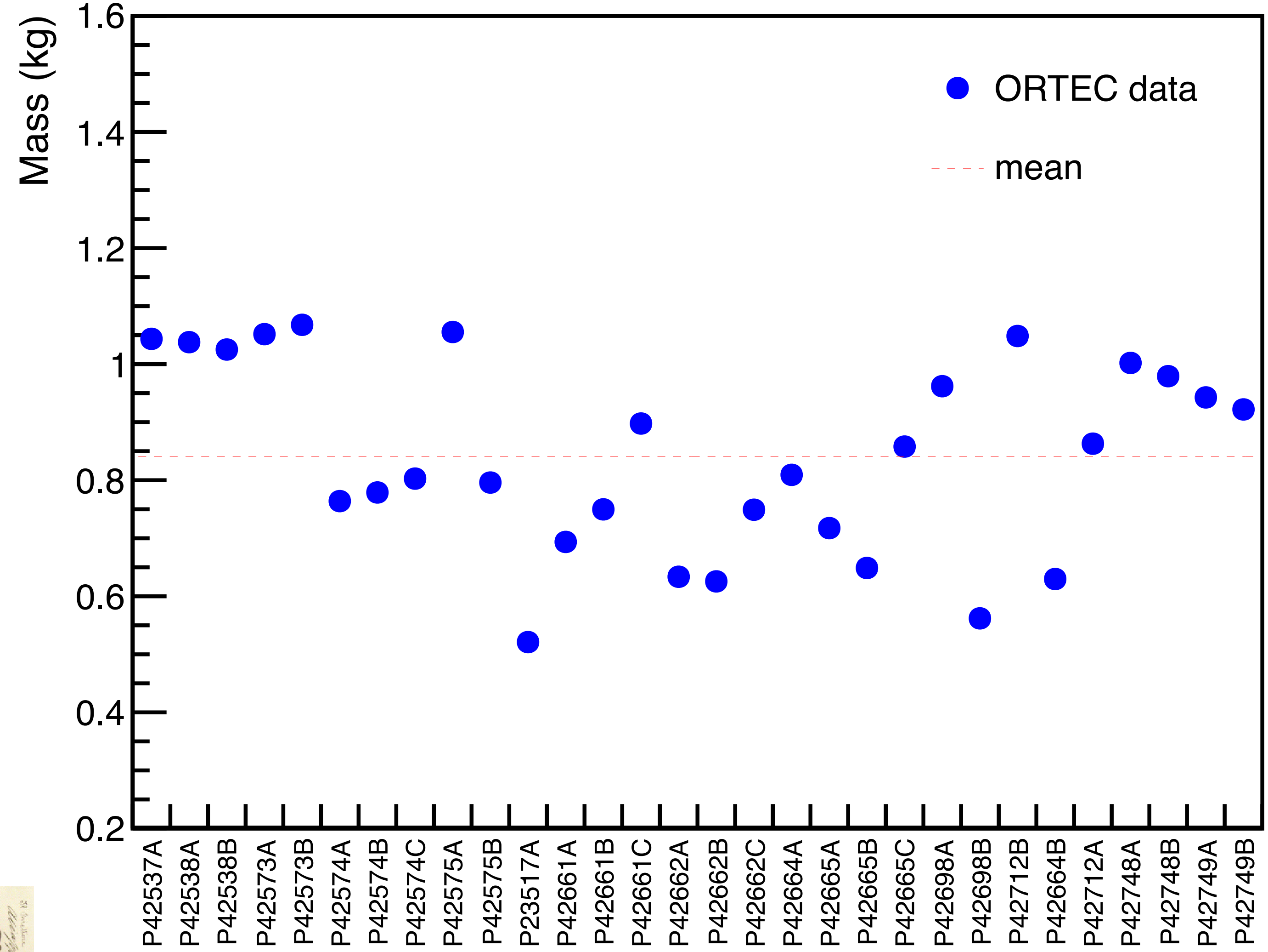
Thank you!
LLWI 2015
Summer snow at Sanford Lab

DETECTOR CHARACTERIZATION

^{enr}Ge Detector Mass

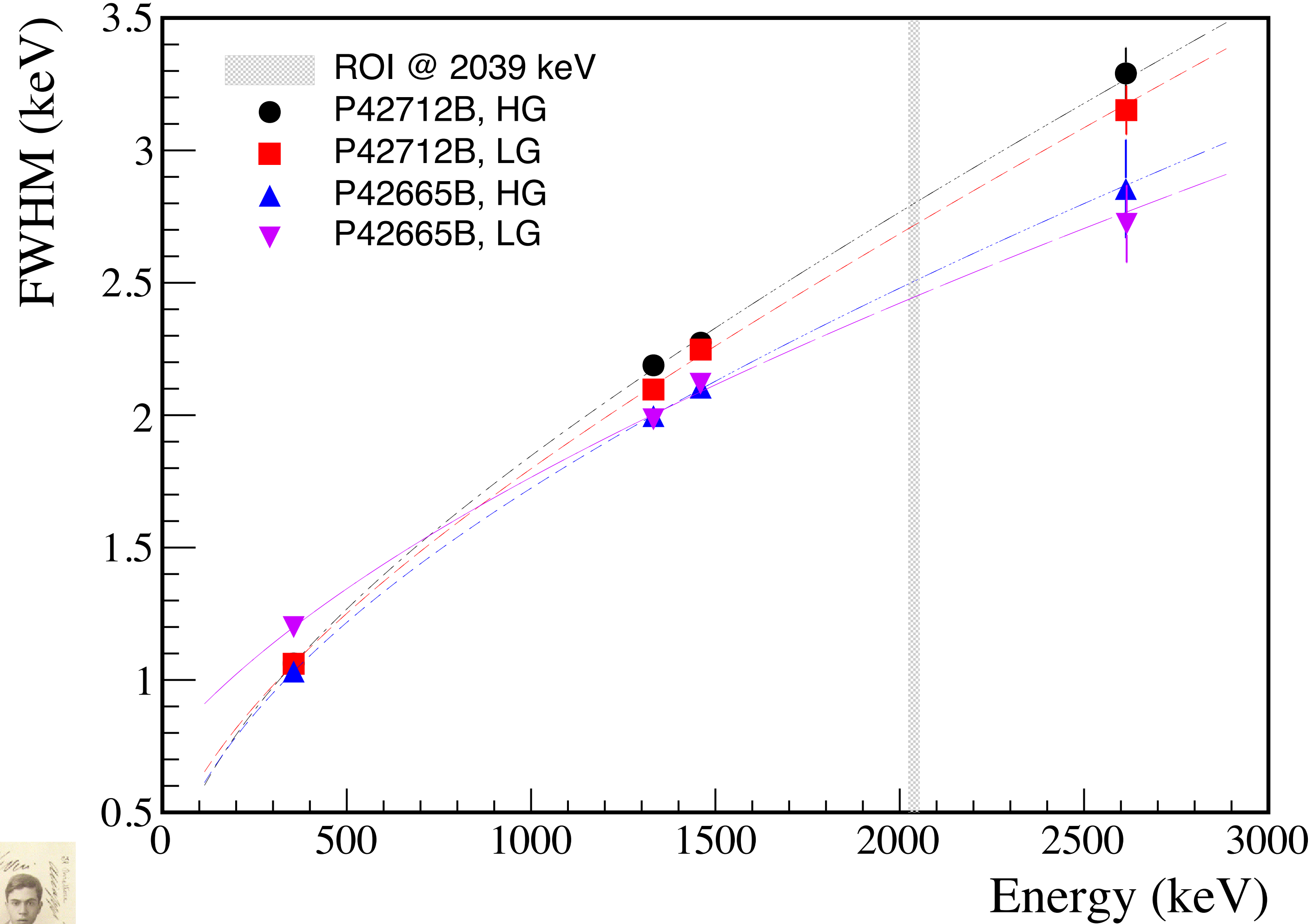
Mean mass of 840 g (Presently: 25.2 kg of detectors UG)



ENERGY RESOLUTION

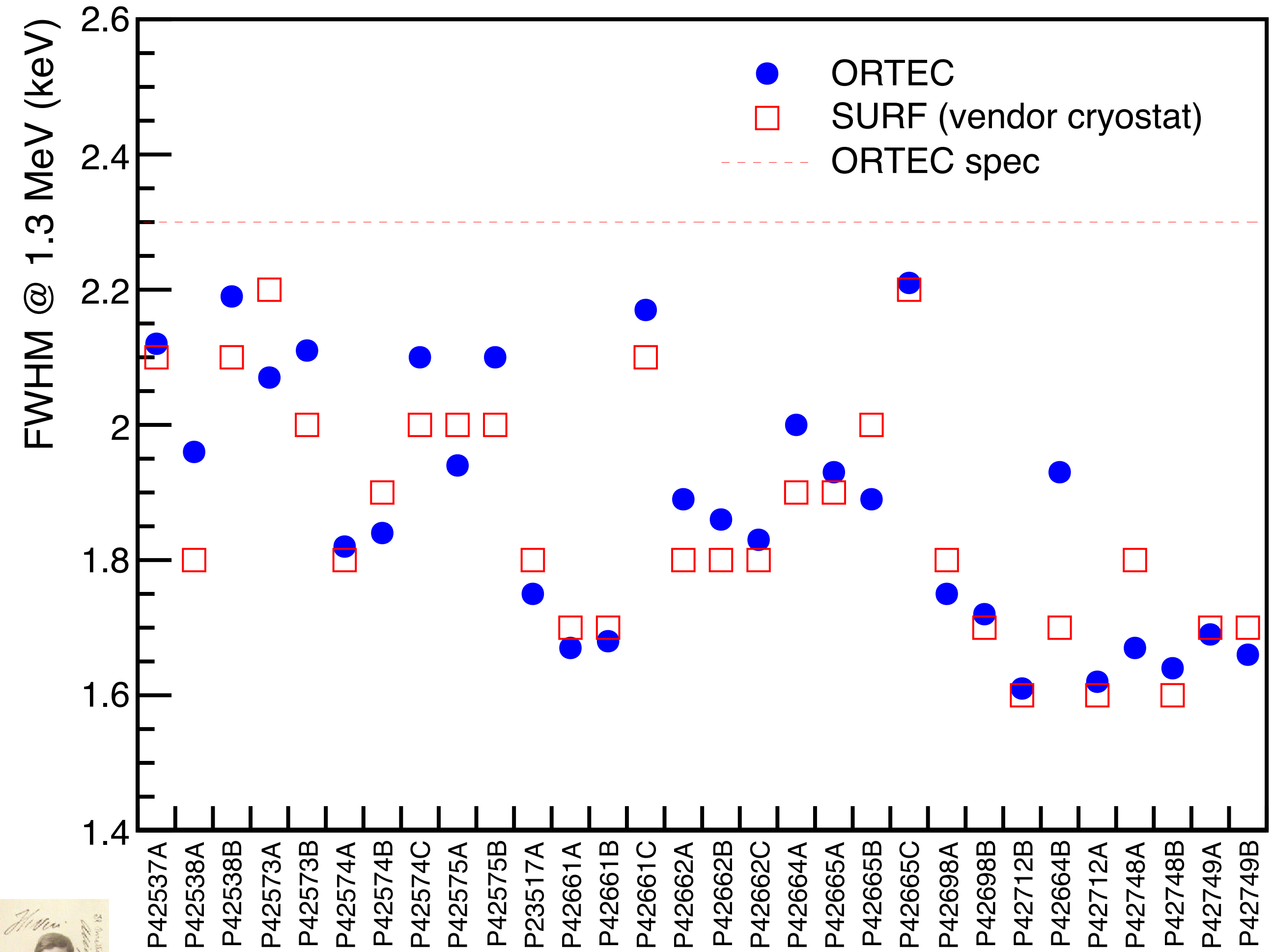
Resolution of ^{enr}Ge Detectors within a String Test Cryostat

Resolution in both high/low gain channels for two detectors



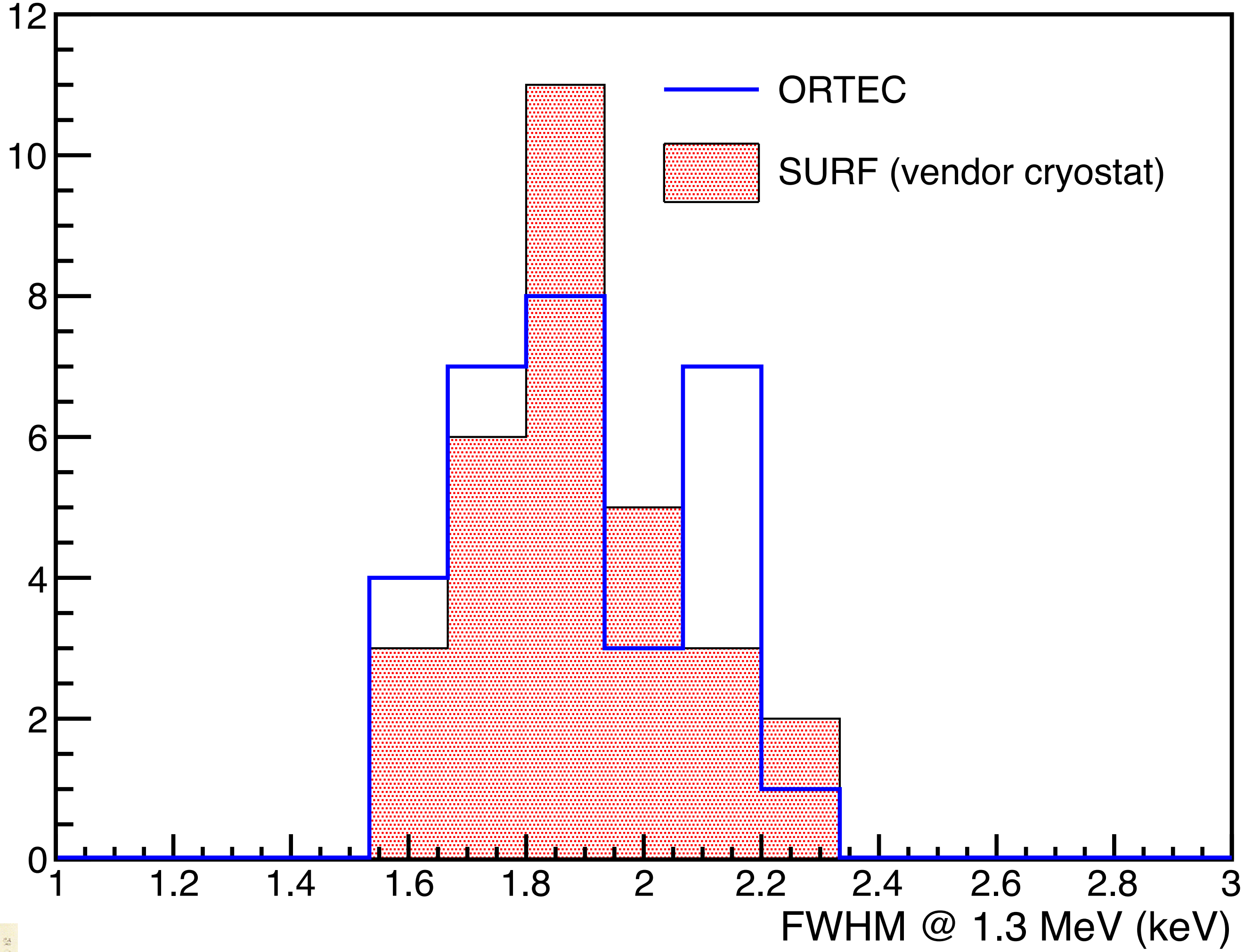
^{enr}Ge Detector Energy Resolution

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

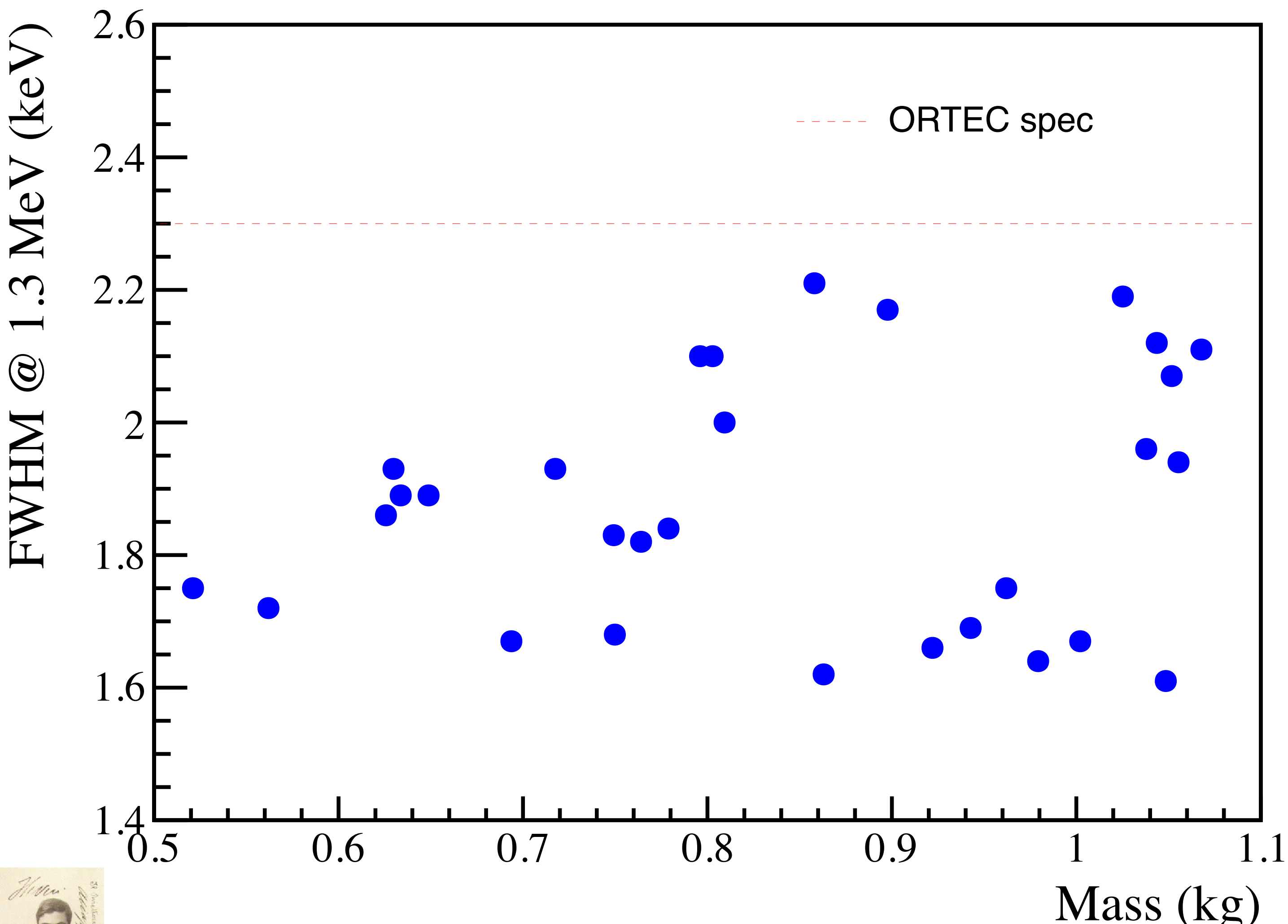


^{enr}Ge Detector Energy Resolution

Resolution measurements in vendor cryostat



^{enr}Ge Detector Energy Resolution Vs. Detector Mass

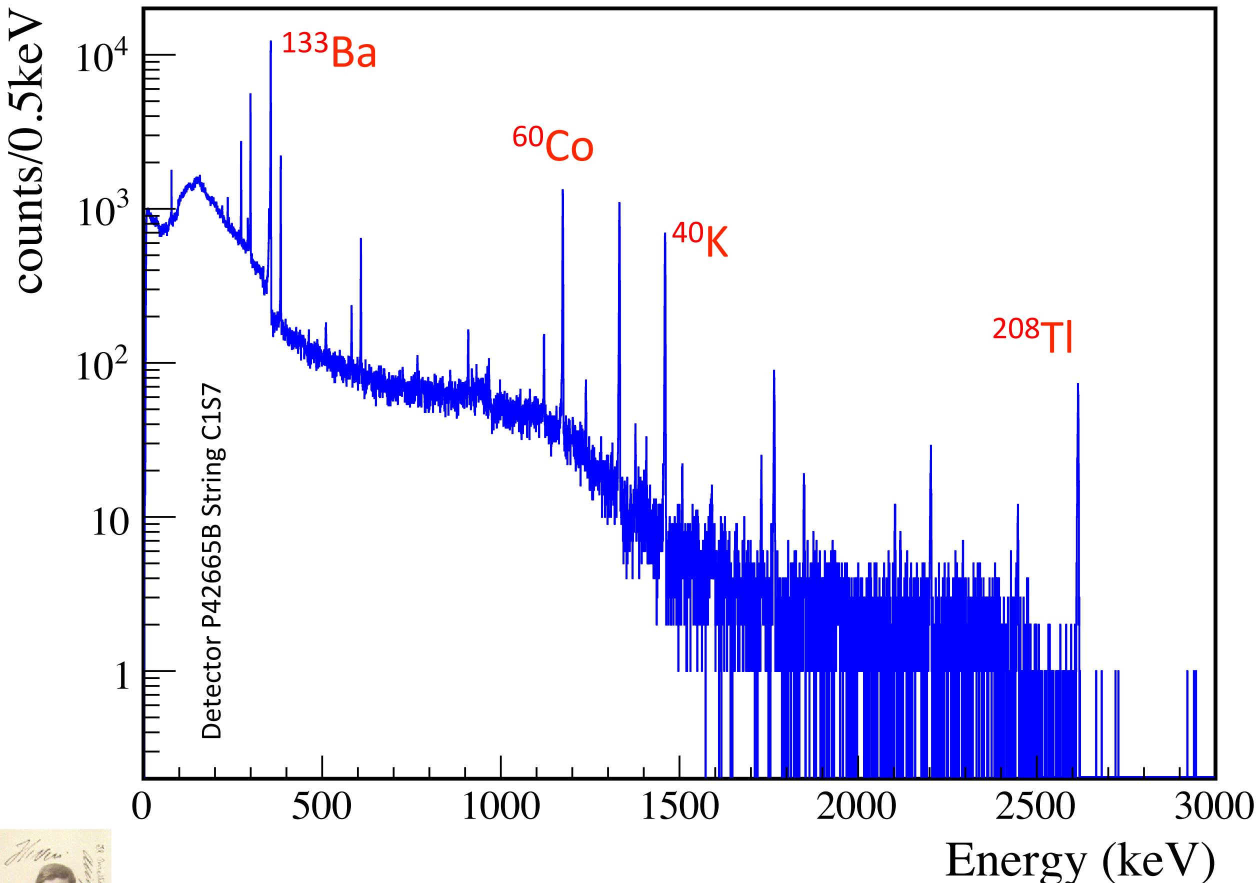


Measured at vendor

CALIBRATION

Multiple Source Calibration within a String Test Cryostat

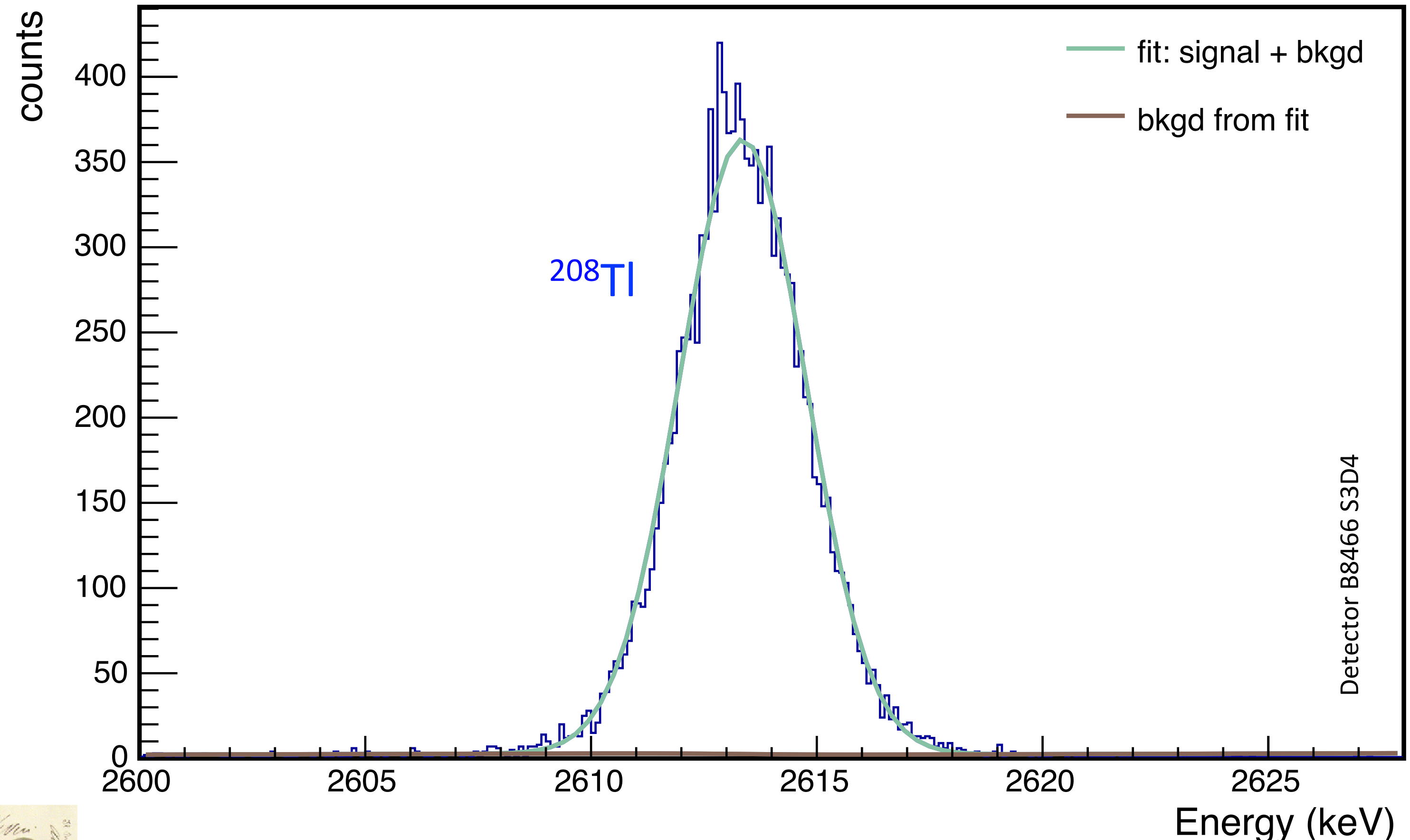
At 1332 keV, FWHM = 1.98 keV +/- 0.024 keV
At 2614 keV, FWHM = 2.72 keV +/- 0.15 keV



Remounted enriched detector in string test cryostat

^{228}Th Calibration Spectrum in Prototype Cryostat

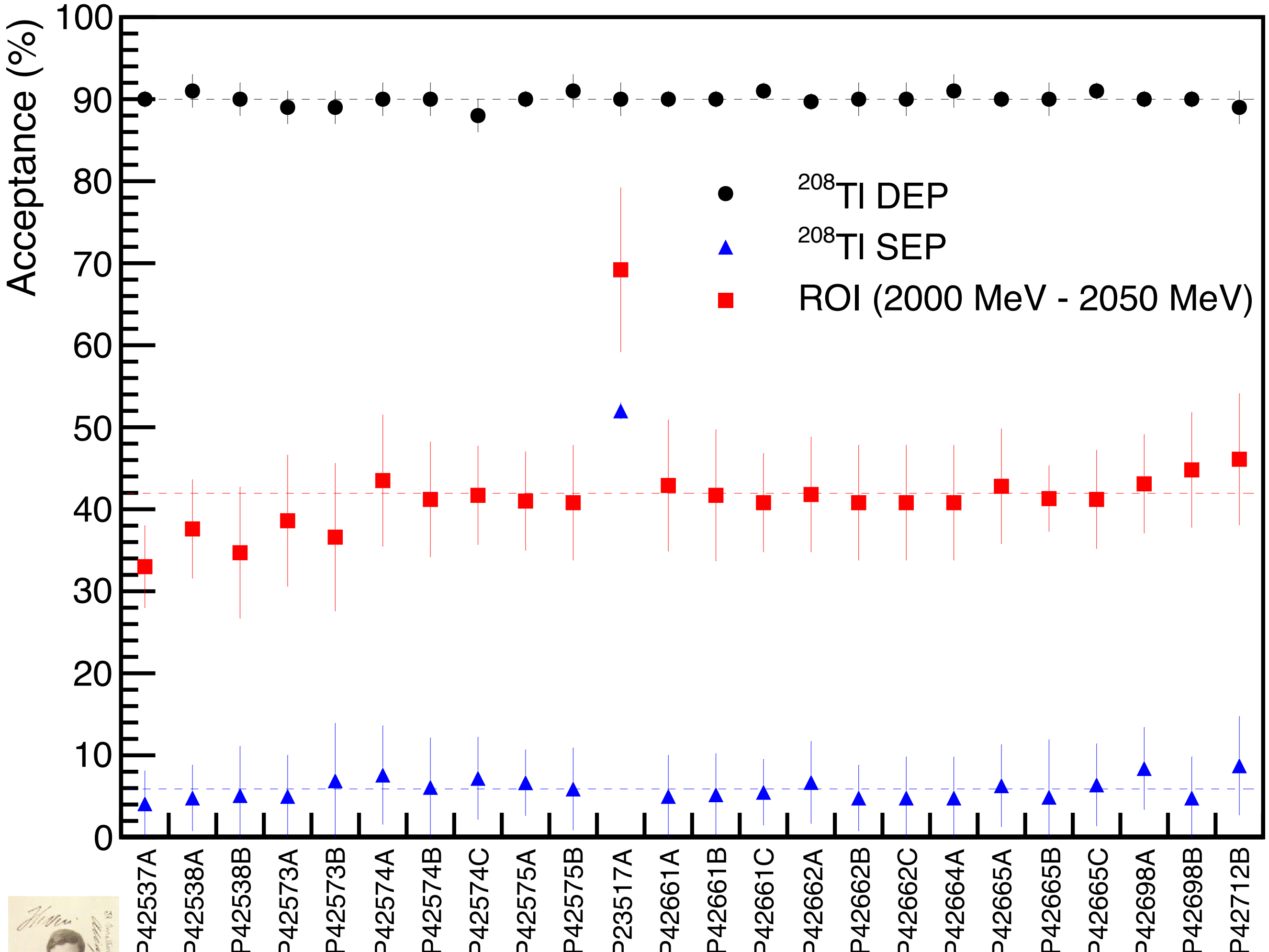
One detector spectrum within a string mounted in the prototype cryostat and inside shield. FWHM 3.2 keV at 2.6 MeV



PULSE SHAPE DISCRIMINATION

^{enr}Ge Detector PSD Performance in Vendor Cryostats

One detector has degraded PSD



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