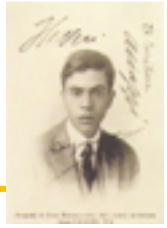
Status of the MAJORANA DEMONSTRATOR

Benjamin Shanks

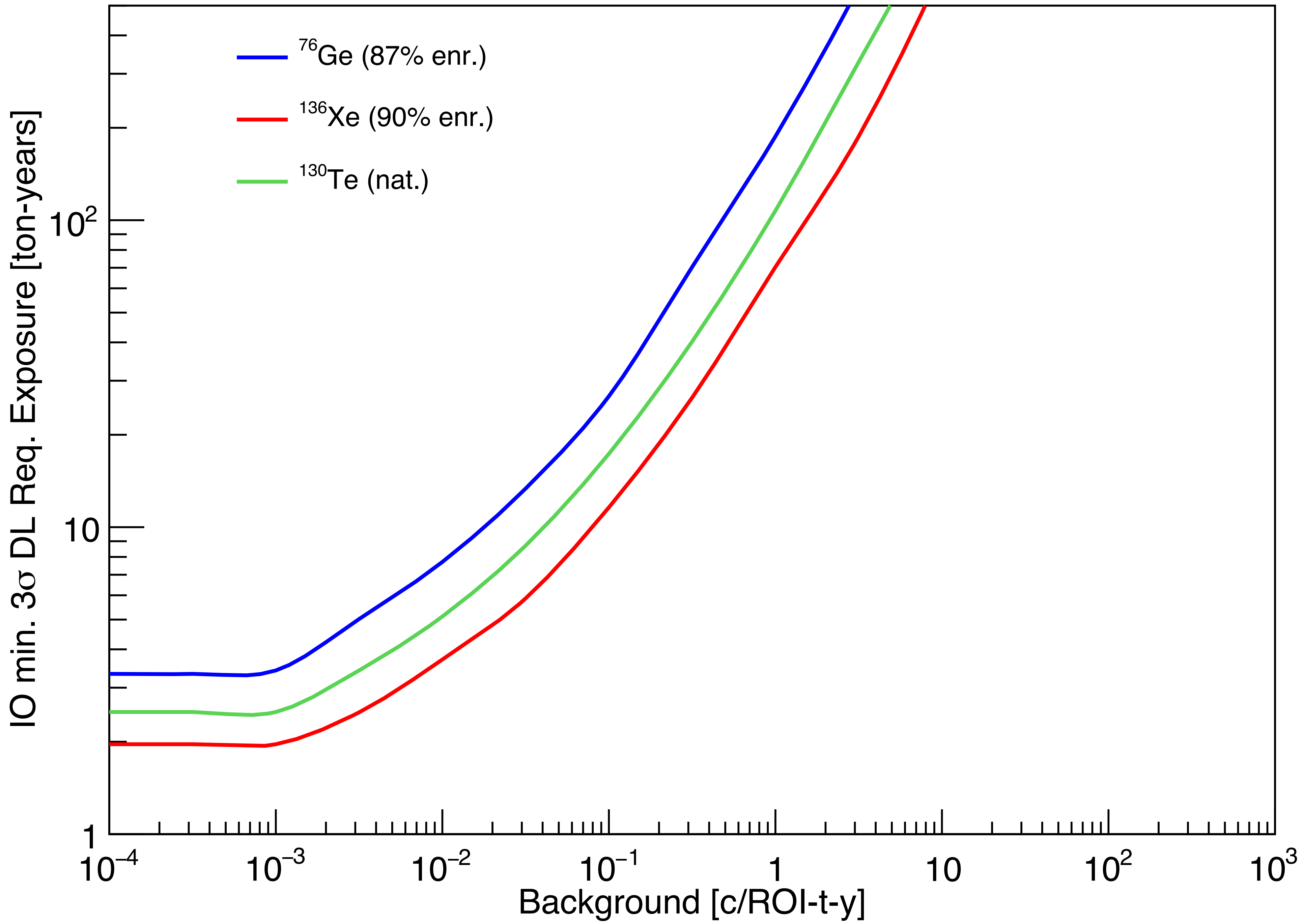
Univ. of North Carolina / TUNL

On behalf of the MAJORANA Collaboration

Required 3σ Exposure vs. Background

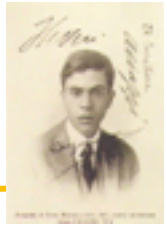


J. Detwiler



"Required" exposure assuming minimum IO $m_{\beta\beta}$=18.3 meV, taken from using the PDG2013 central values of the oscillation parameters, and the most pessimistic NME for the corresponding isotope among QRPA, SM, IBM, PHFB, and EDF

Required 3σ Exposure vs. Background



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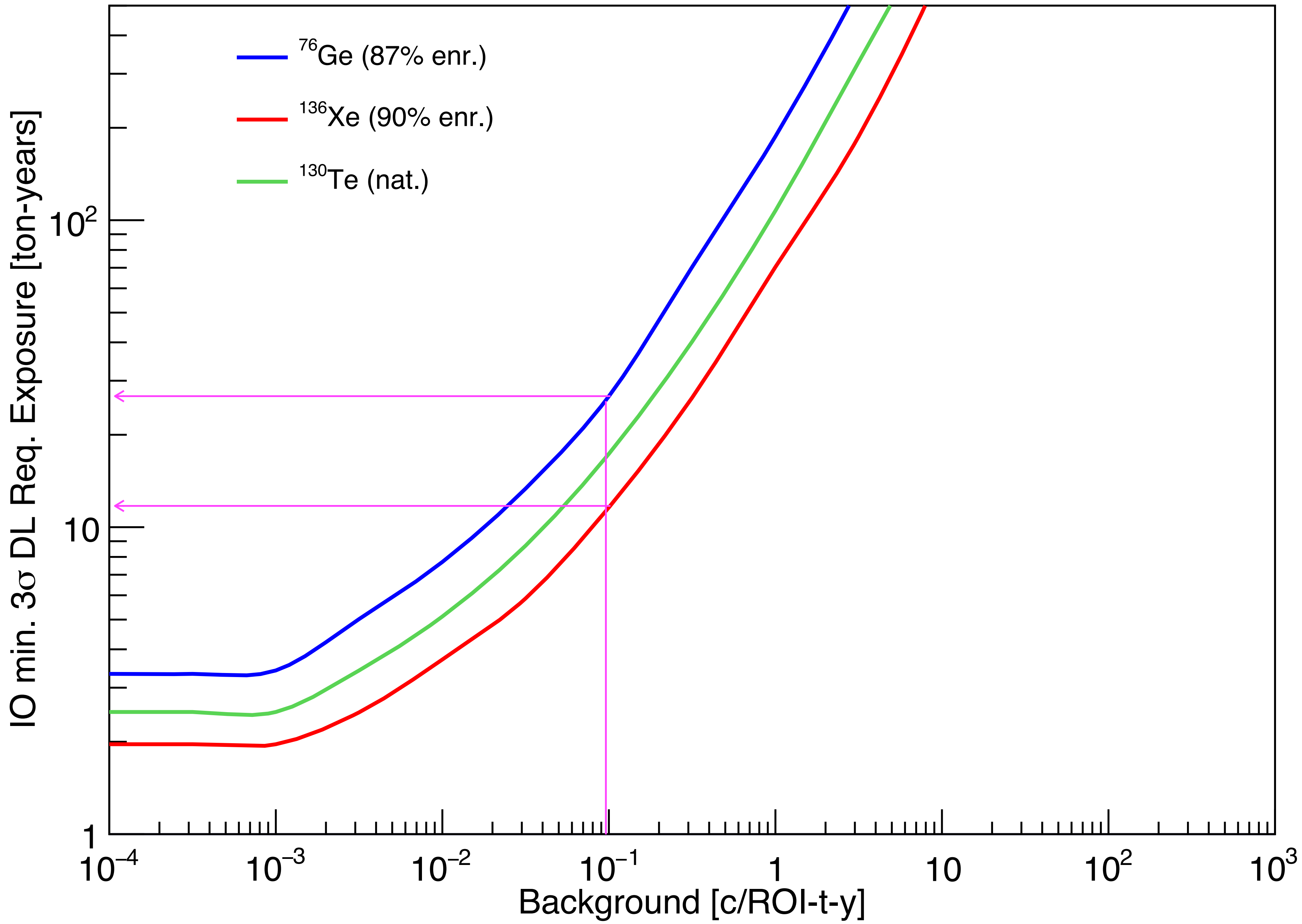
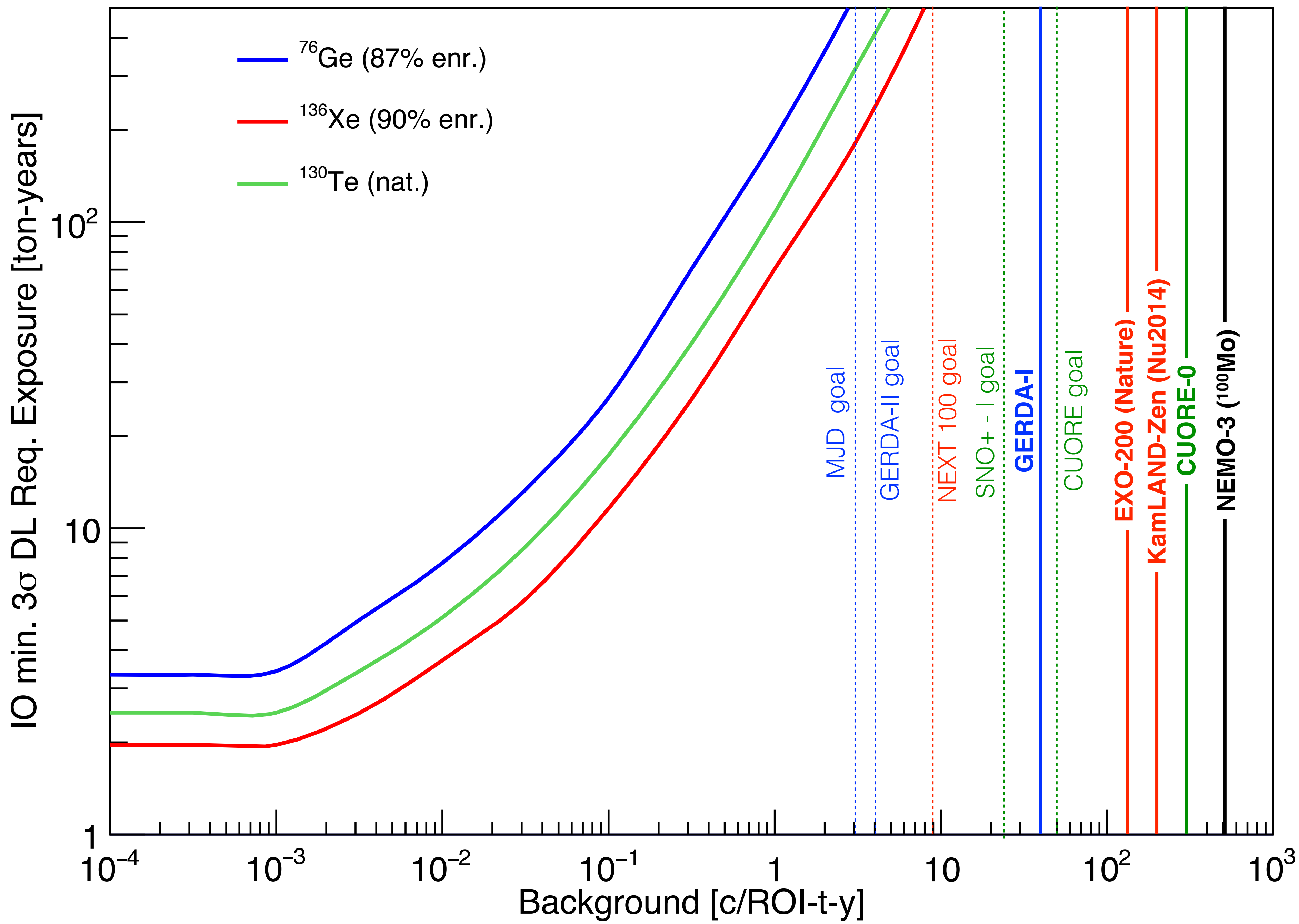


"Required" exposure assuming minimum IO $m_{\beta\beta}$=18.3 meV, taken from using the PDG2013 central values of the oscillation parameters, and the most pessimistic NME for the corresponding isotope among QRPA, SM, IBM, PHFB, and EDF

3σ Discovery vs. Background

J. Detwiler

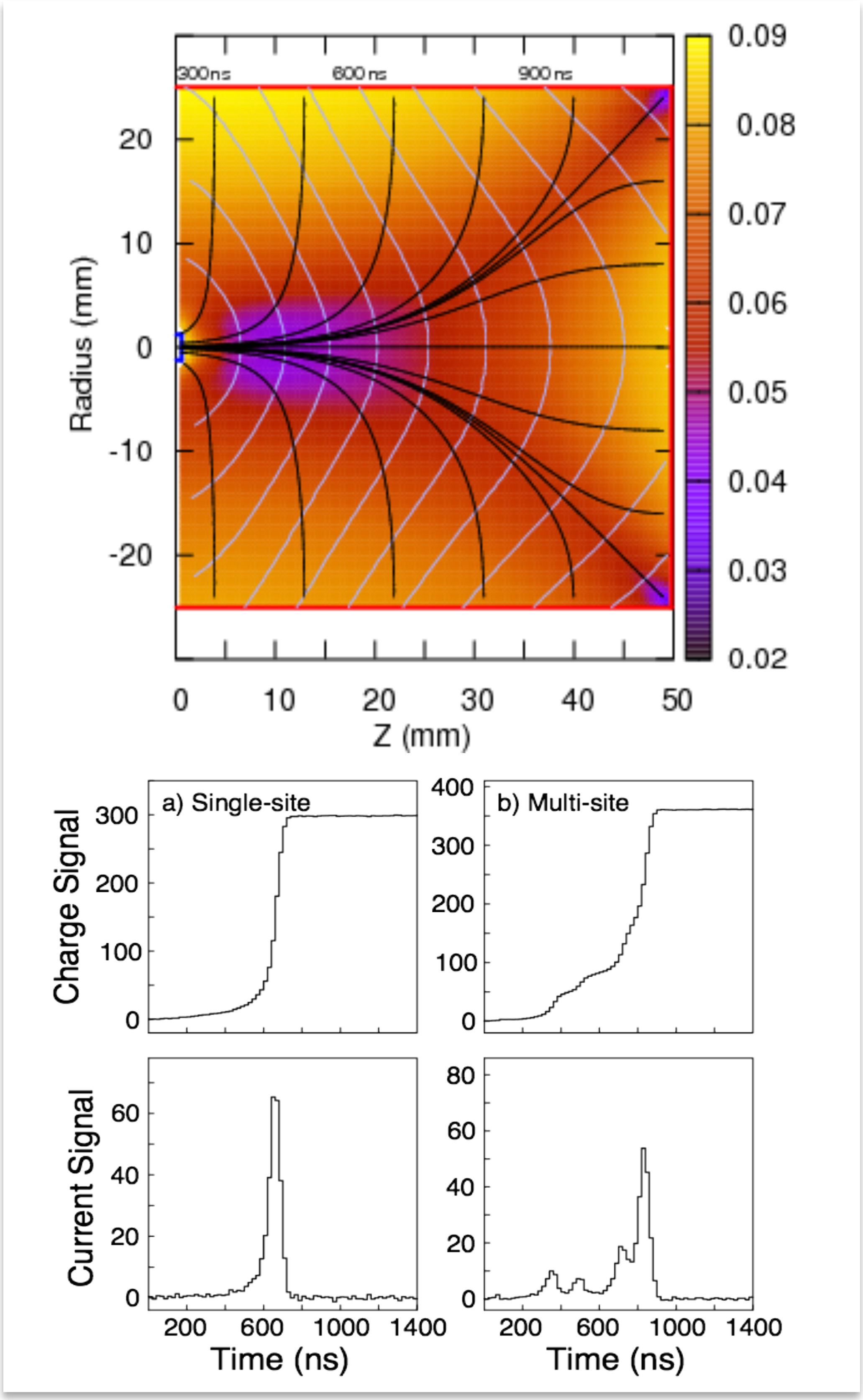


Take away:

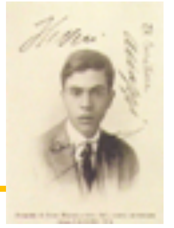
Realistically, a next generation experiment should aim for backgrounds at or below 0.1 c/ROI-t-y

Germanium for 0νββ

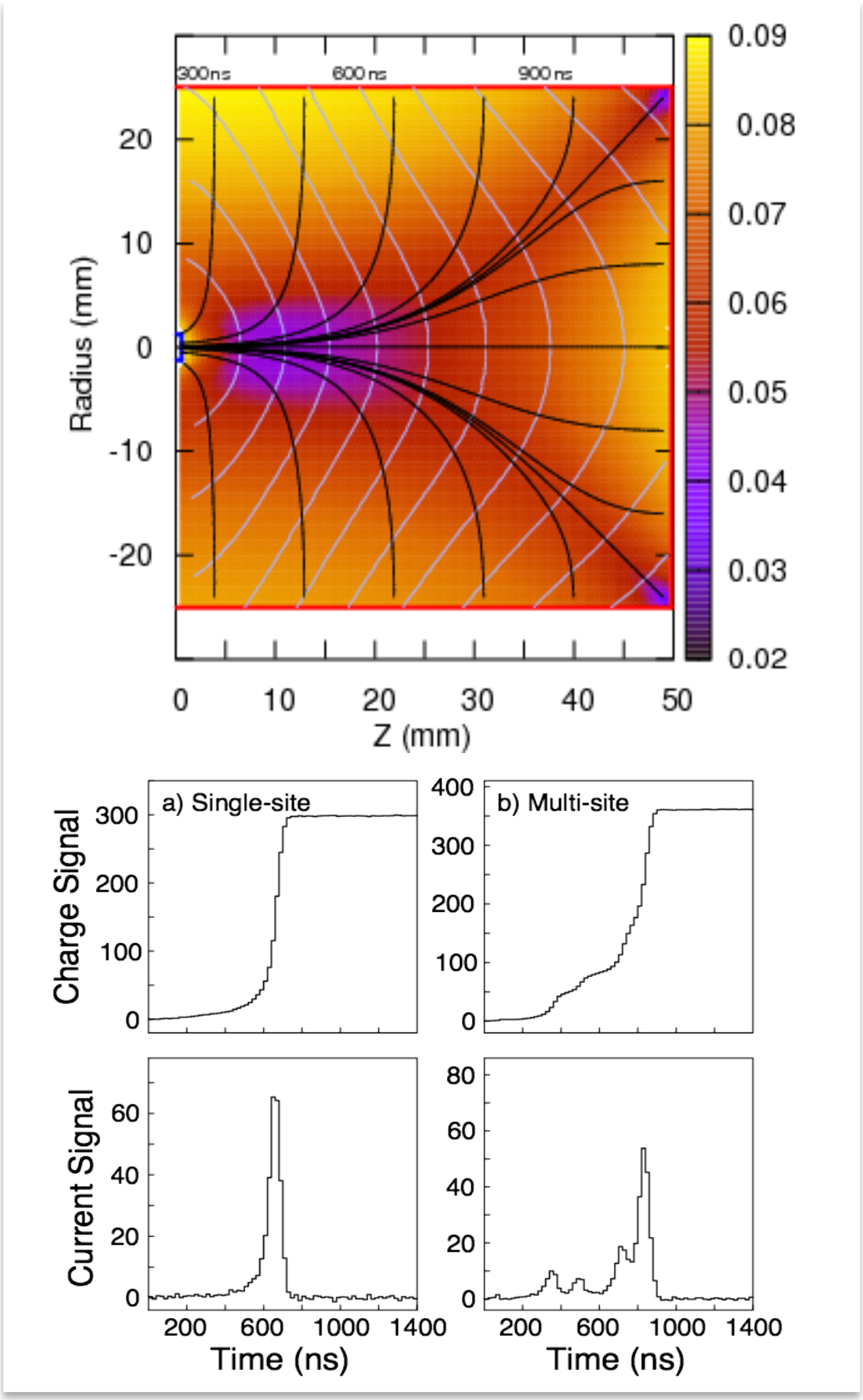
- Q_{val} = 2039keV
- Best energy resolution: <3keV FWHM @2039



Germanium for 0νββ

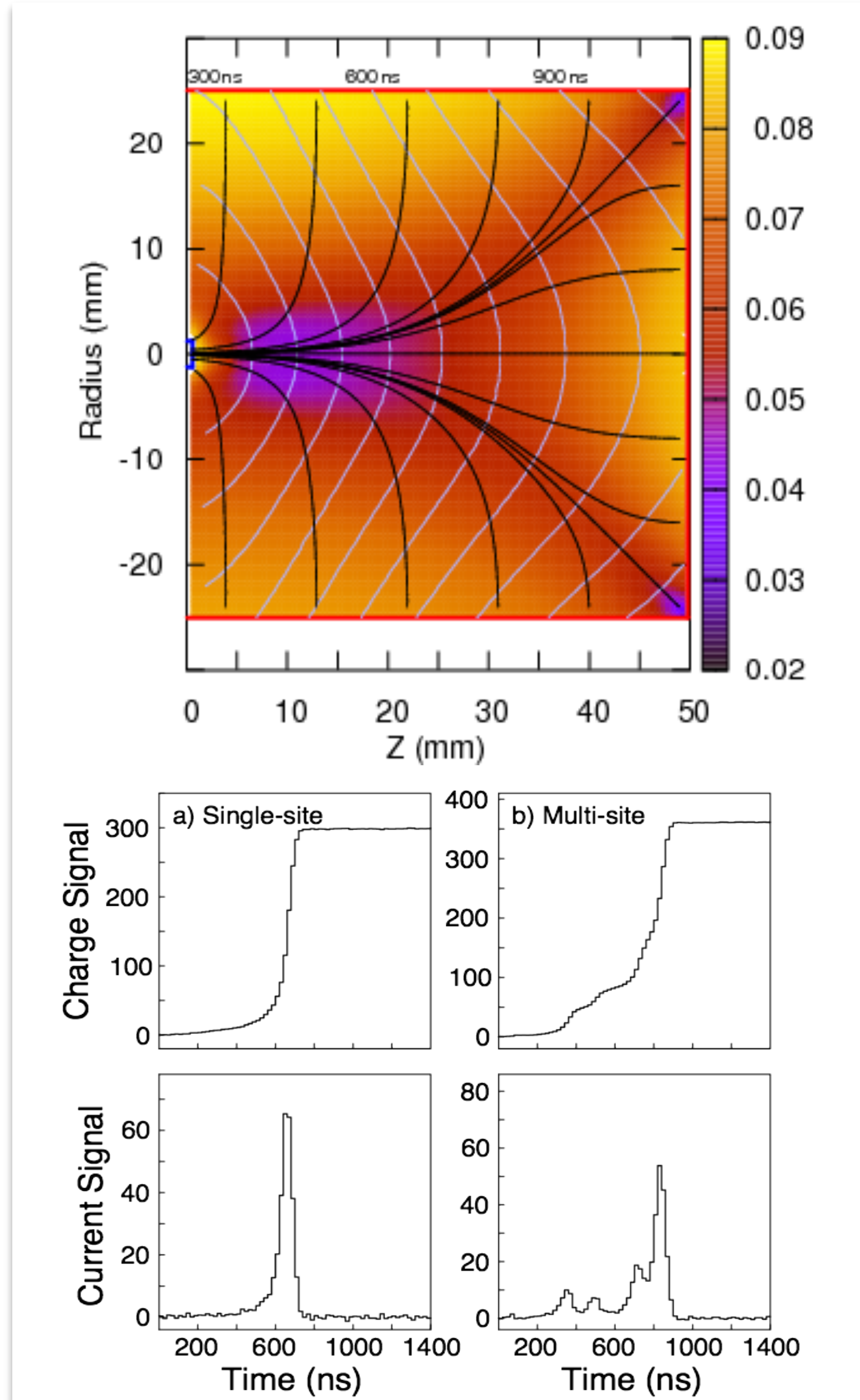


- Q_{val} = 2039keV
- Best energy resolution: <3keV FWHM @2039
- HPGe detectors inherently low-background

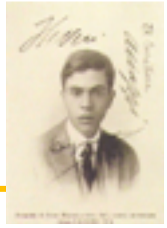


Germanium for 0νββ

- Q_{val} = 2039keV
- Best energy resolution: <3keV FWHM @2039
- HPGe detectors inherently low-background
- Powerful background rejection techniques:
  - Granularity rejects compton scatters in multiple detectors
  - PPC timing response enables PSD of multi-site events
  - Low energy thresholds allow rejection of ^{68}Ge events

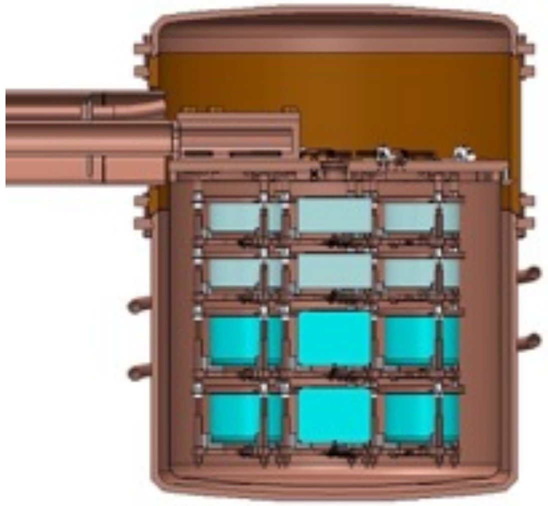


The MAJORANA DEMONSTRATOR

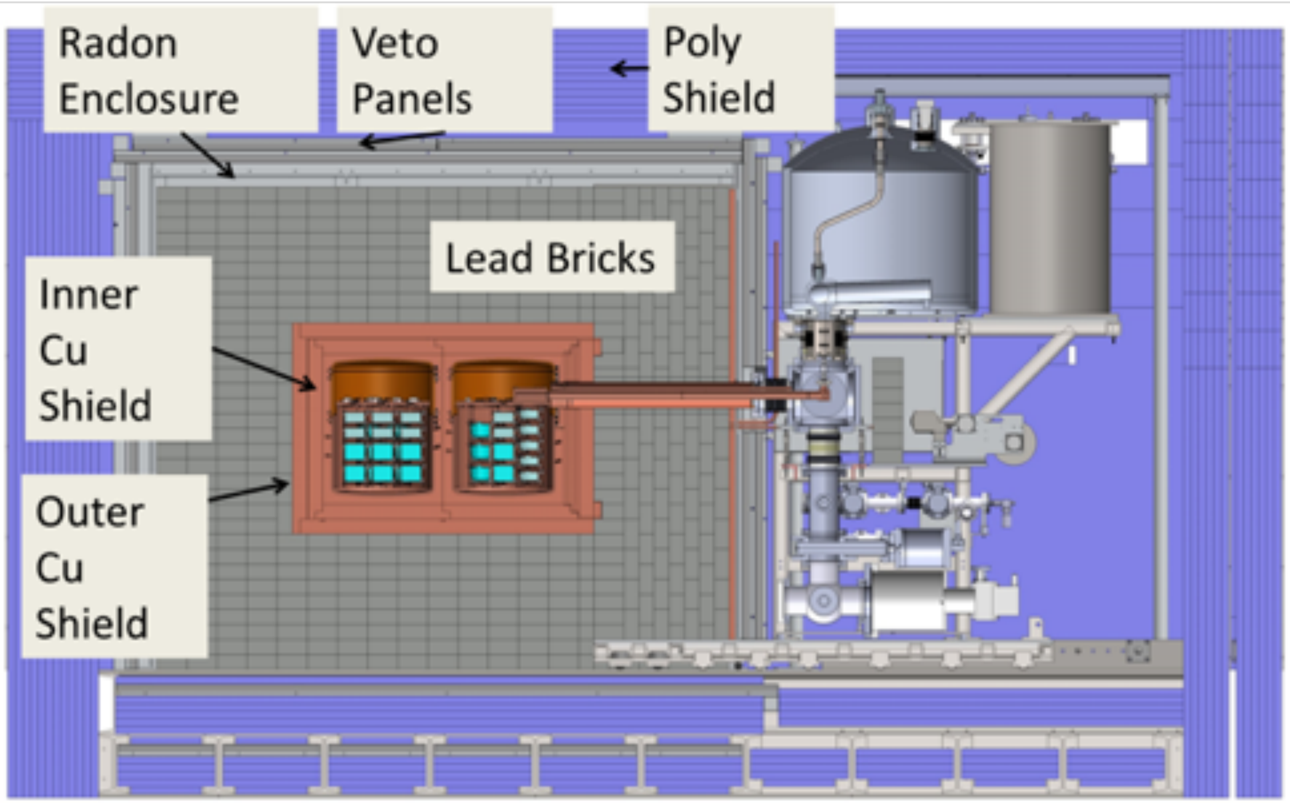


Funded by DOE Office of Nuclear Physics and NSF Particle Astrophysics, with additional contributions from international collaborators.

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.

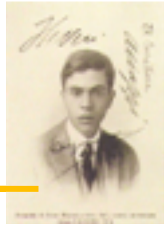


- **Located underground at 4850' Sanford Underground Research Facility**
- **Background Goal in the 0νββ peak region of interest (4 keV at 2039 keV)**
  3 counts/ROI/t/y (after analysis cuts) — Assay U.L. currently ≤ 3.5
  scales to 1 count/ROI/t/y for a tonne experiment
- **44-kg of Ge detectors**
  - 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



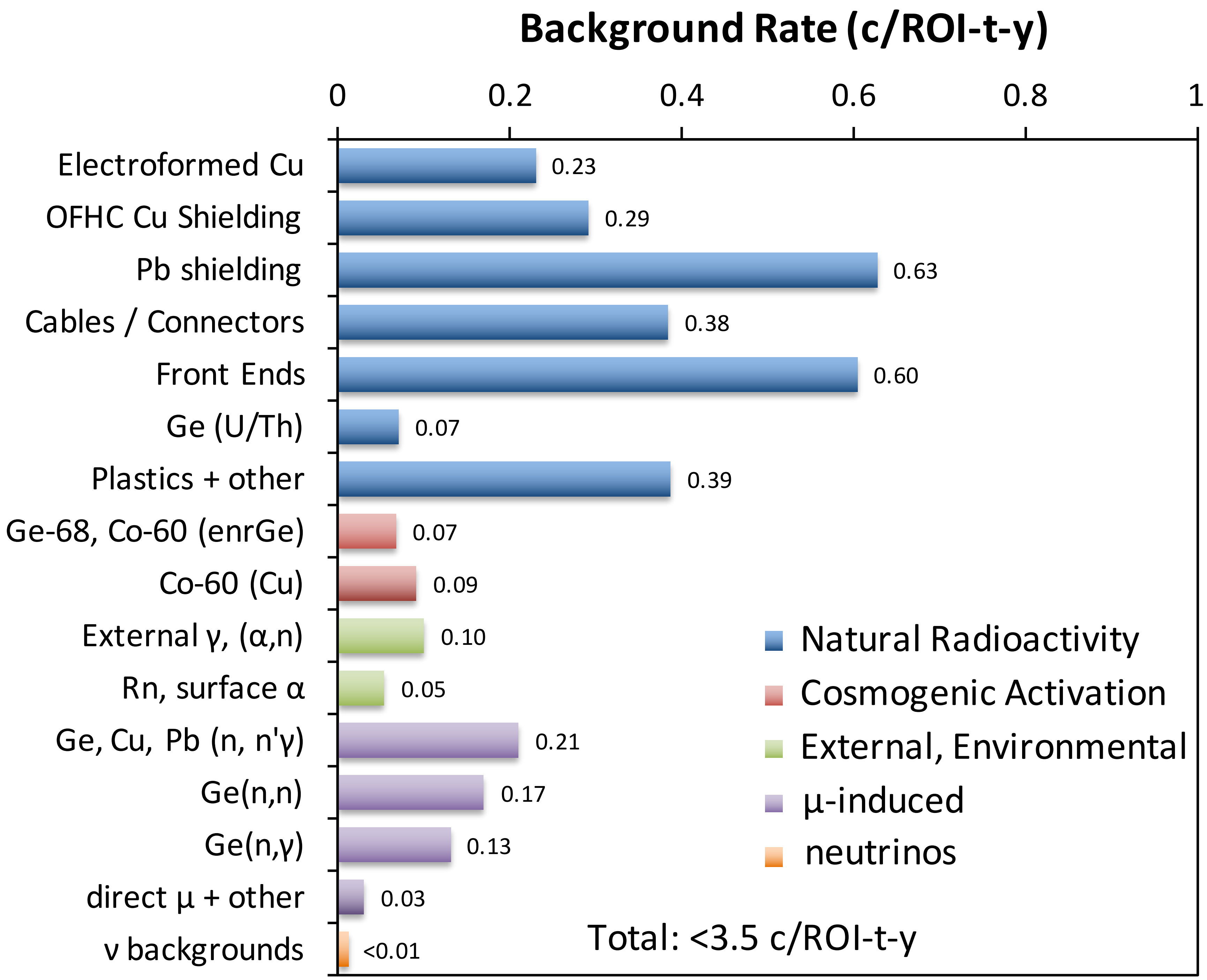
Low Background Construction

DEMONSTRATOR Background Budget

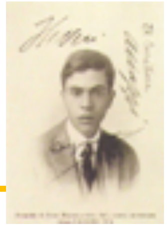


Based on achieved assays of materials
When UL, use UL as the contribution

MJD Goal: 3.0 cts / 4 keV / t-y



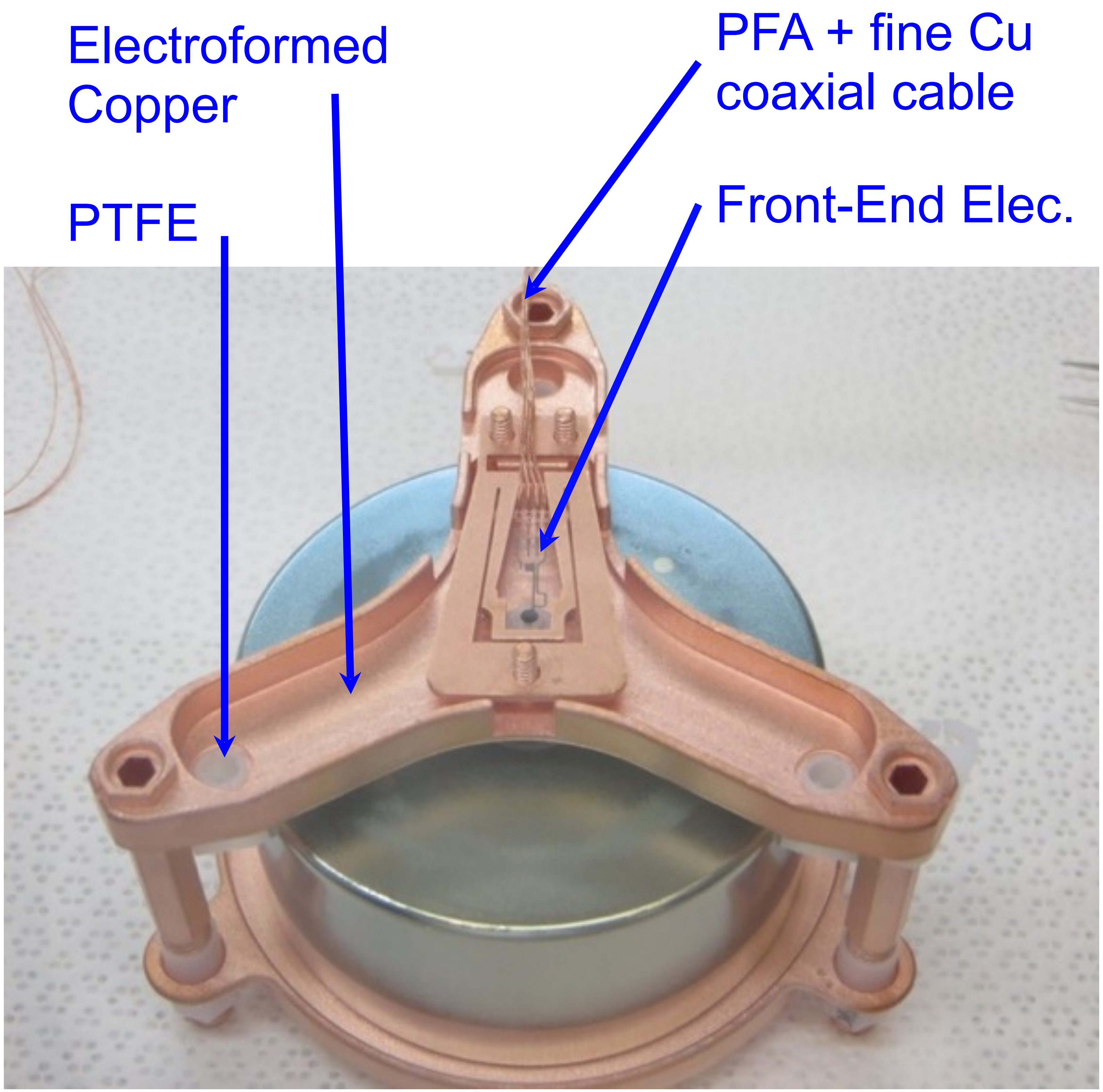
Low Background Construction

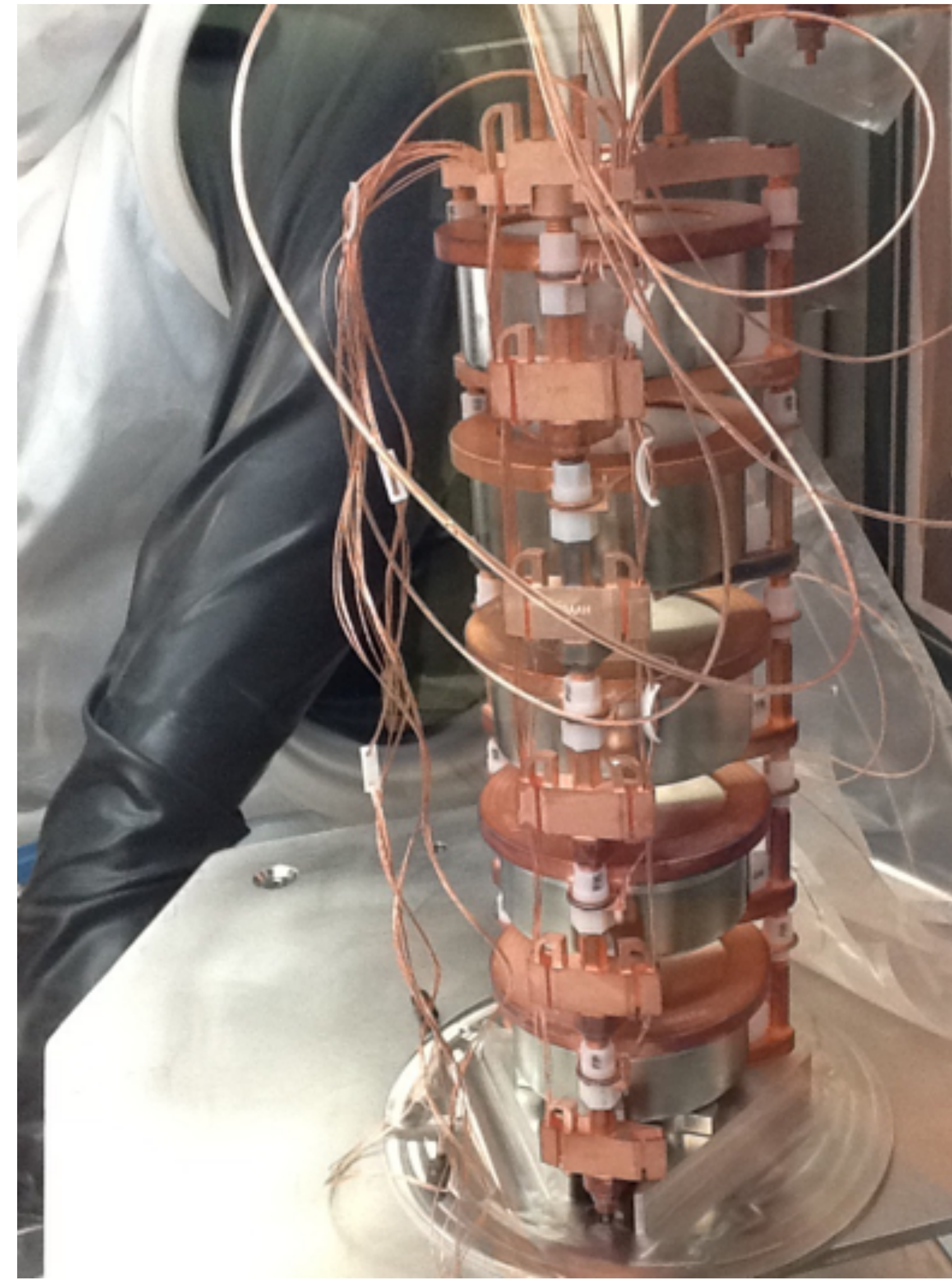


Low Background Construction

Low Background Construction

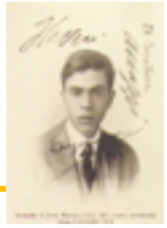
Assembled Detector Unit and String



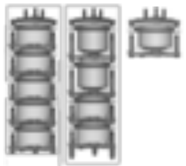


String Assembly

MJD Implementation

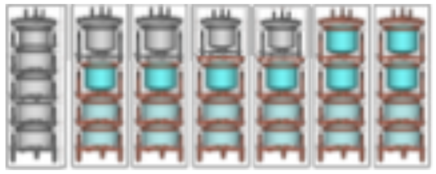


- Three Steps
  - **Prototype Module*** : 7.0 kg (10) ^{nat}Ge
    3 strings



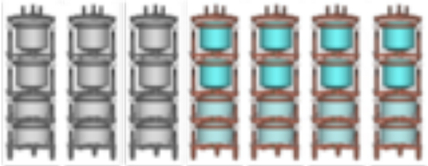
June 2014 - June 2015

  - **Module 1** : 16.8 kg (20) ^{enr}Ge,
    7 strings 5.7 kg (9) ^{nat}Ge

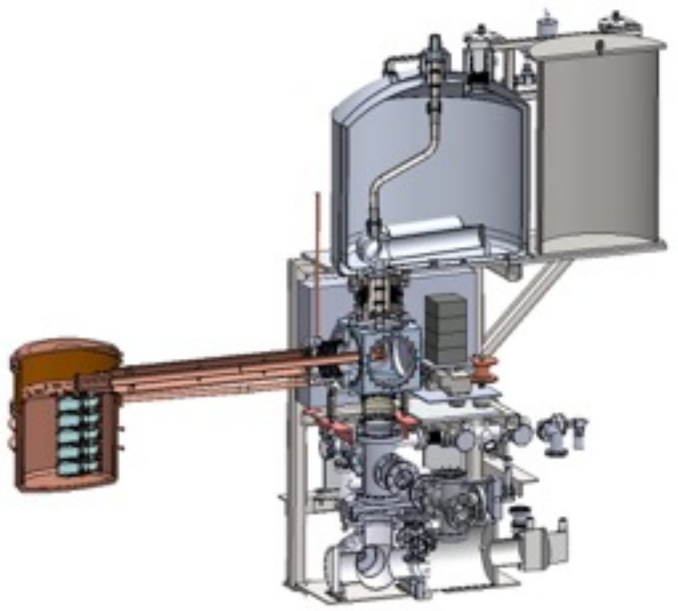


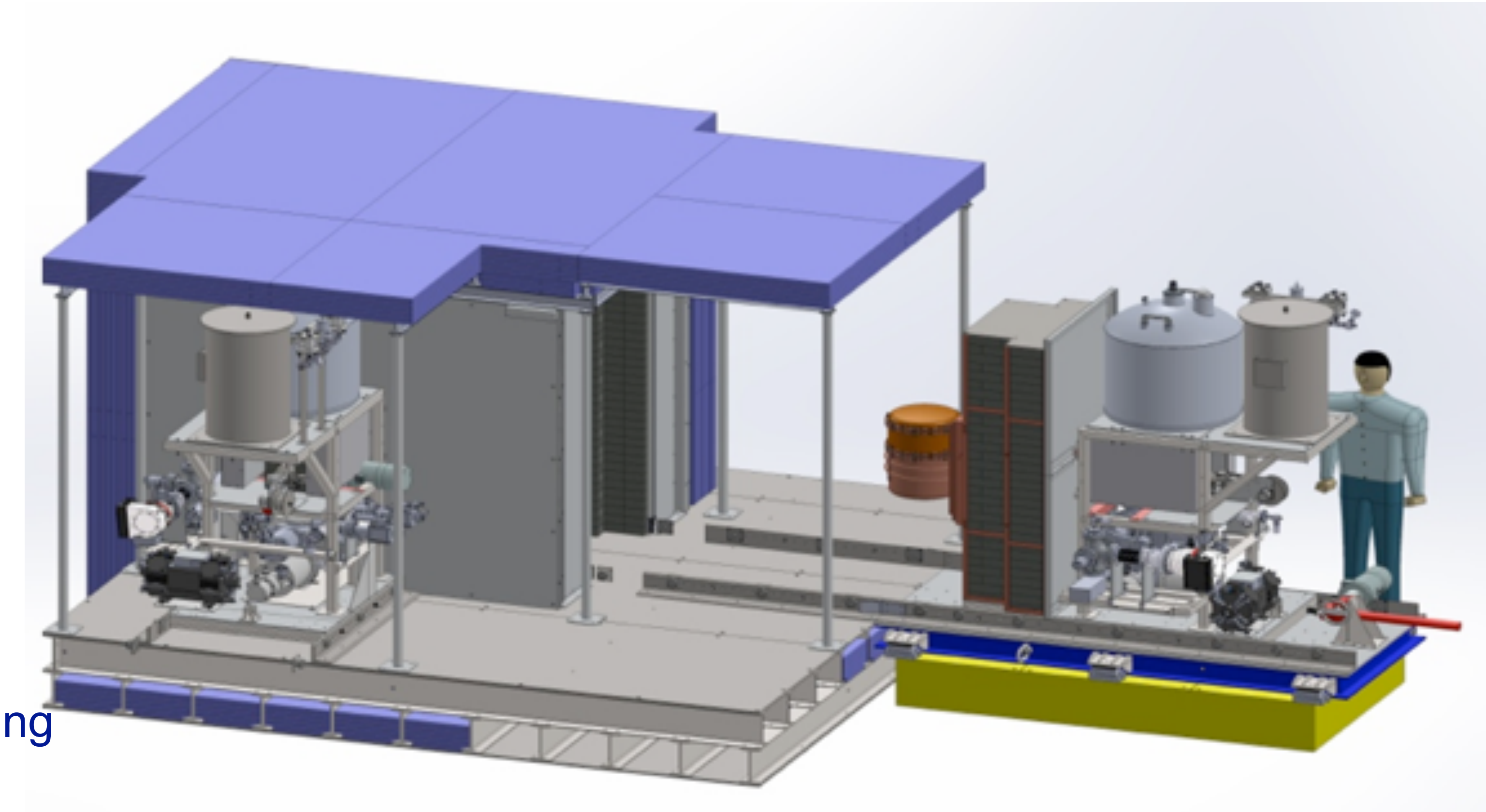
In-shield June - Oct. 2015
Upgrades Fall 2015
In-shield January 2016-

  - **Module 2** : 12.8 kg (14) ^{enr}Ge,
    7 strings 9.4 kg (15) ^{nat}Ge



Commissioning summer 2016





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

Module One Status

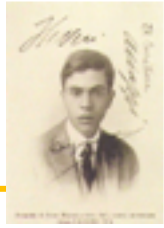
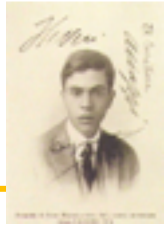



Photo: M. Kapust

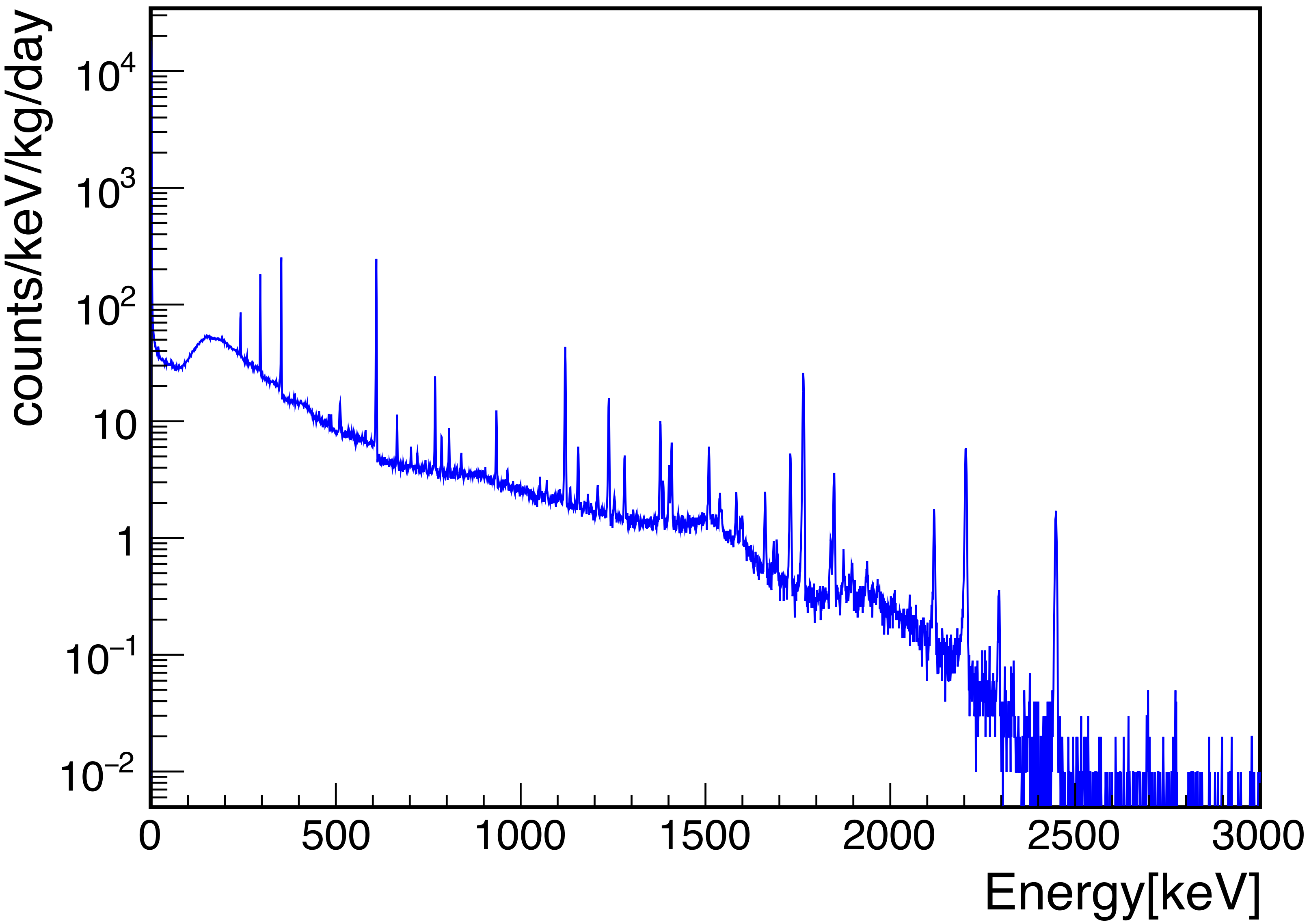
Module One Commissioning Run



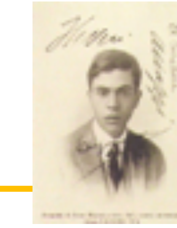
Operated in-shield from July-Oct. 2015

- 23 of 29 detectors operational (14 kg enriched, 3.7 kg natural)
- Partial shielding, some temporary “high” background components
- Removed for planned improvements

Run without Radon Purge



Module One Improvements

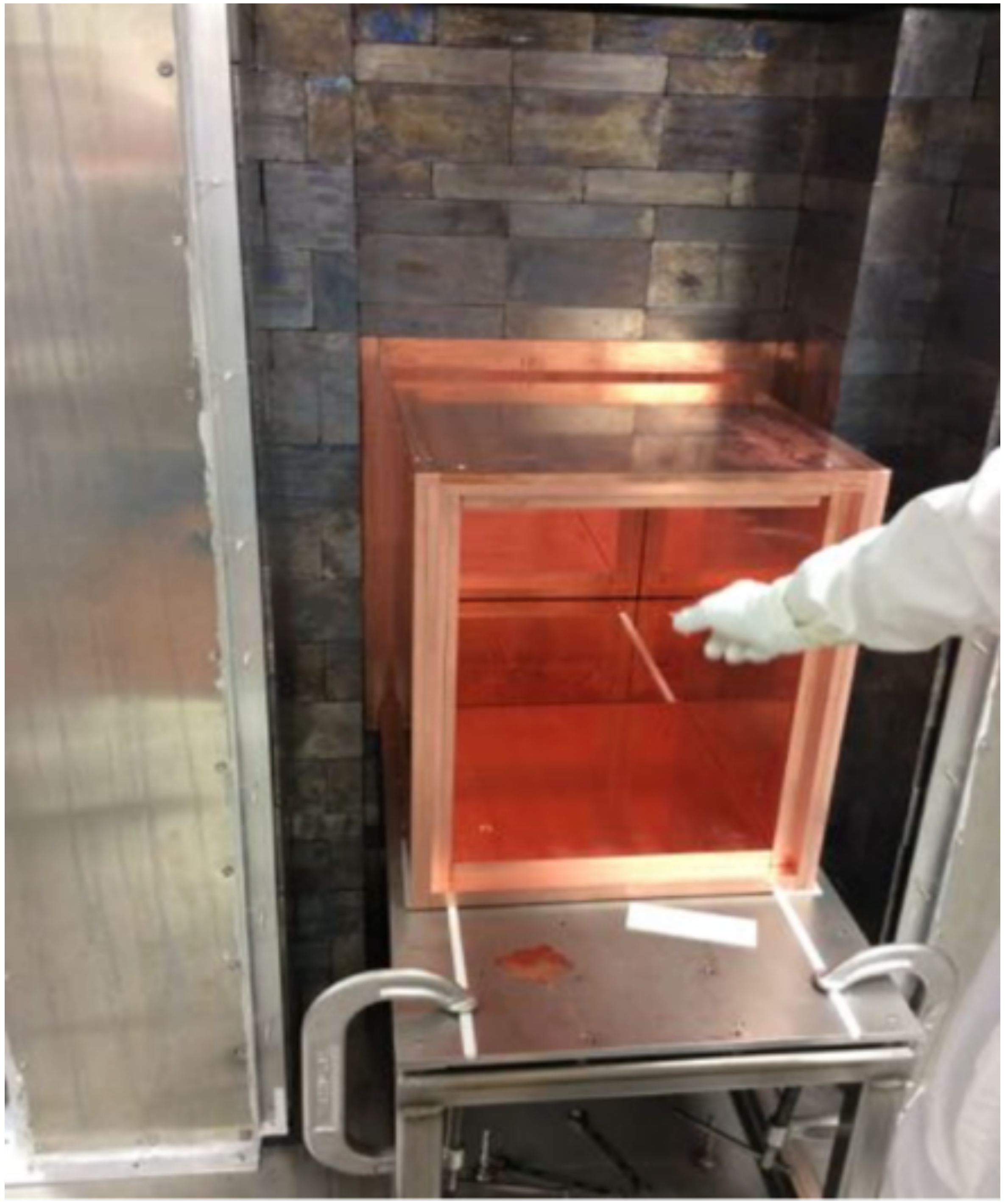


Removed in Oct. 2015 for planned improvements

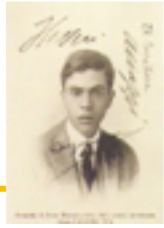
1. Installed inner electroformed copper shield
2. Added crossarm shielding
3. Replaced cryostat seals with low radioactivity versions
4. Repaired non-operating channels (6 out of 29)
   - Cable connection, HV connection, LMFE replacement…
   - Improved D-sub vacuum feedthrough connector

Inner copper shield

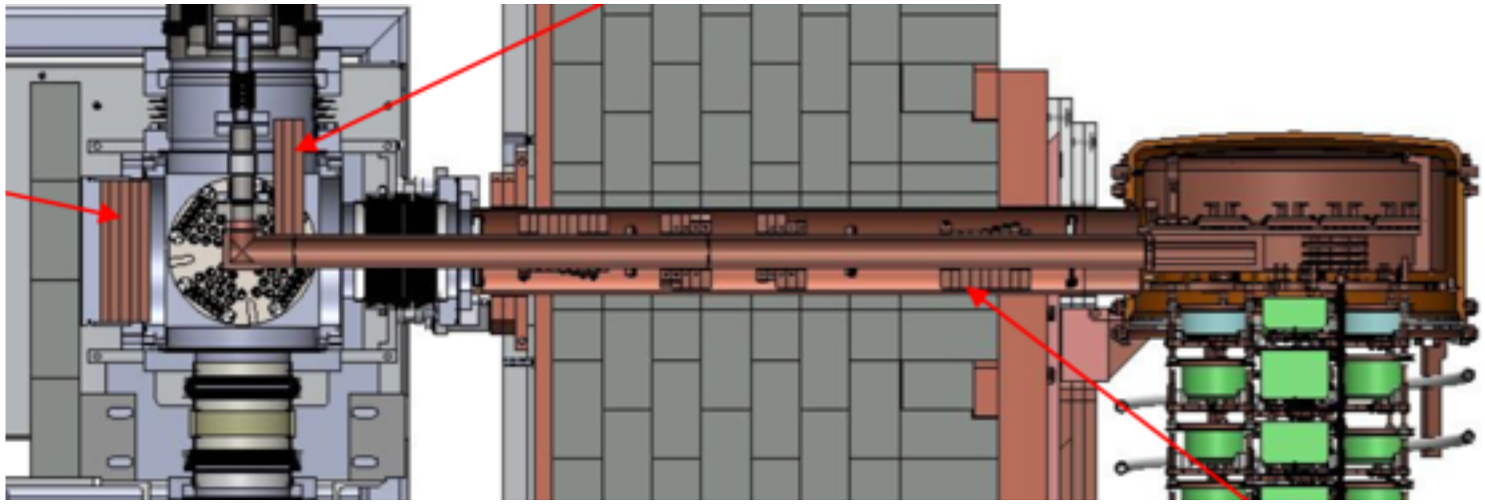
- Will decrease background contribution from outer Cu shield and Pb by factor of ~10

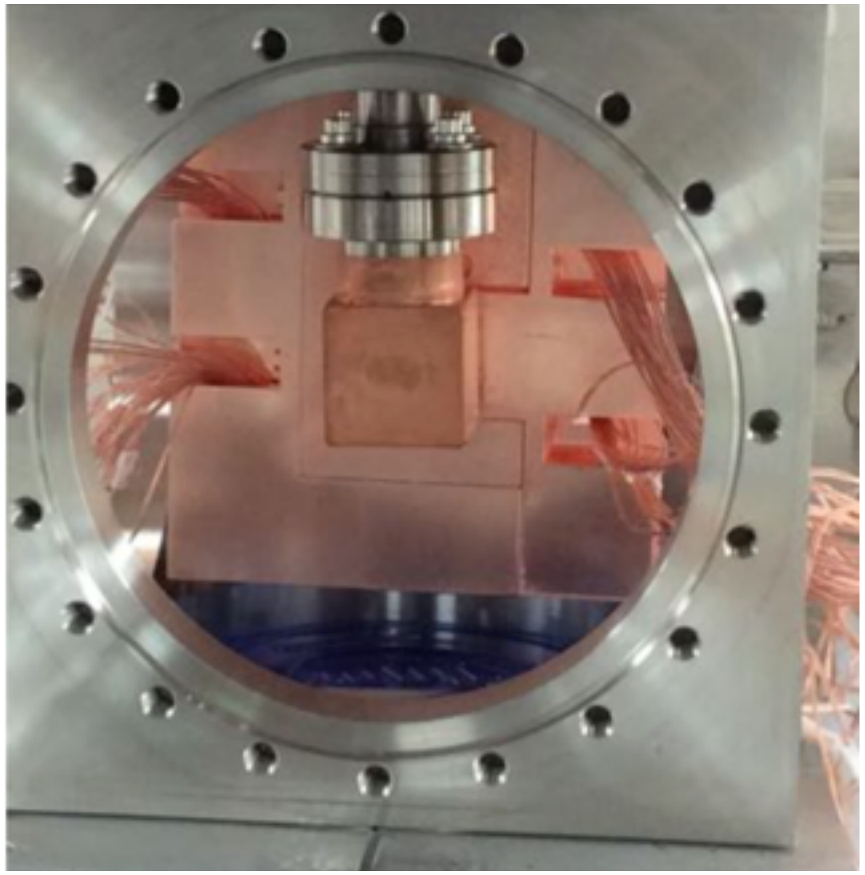


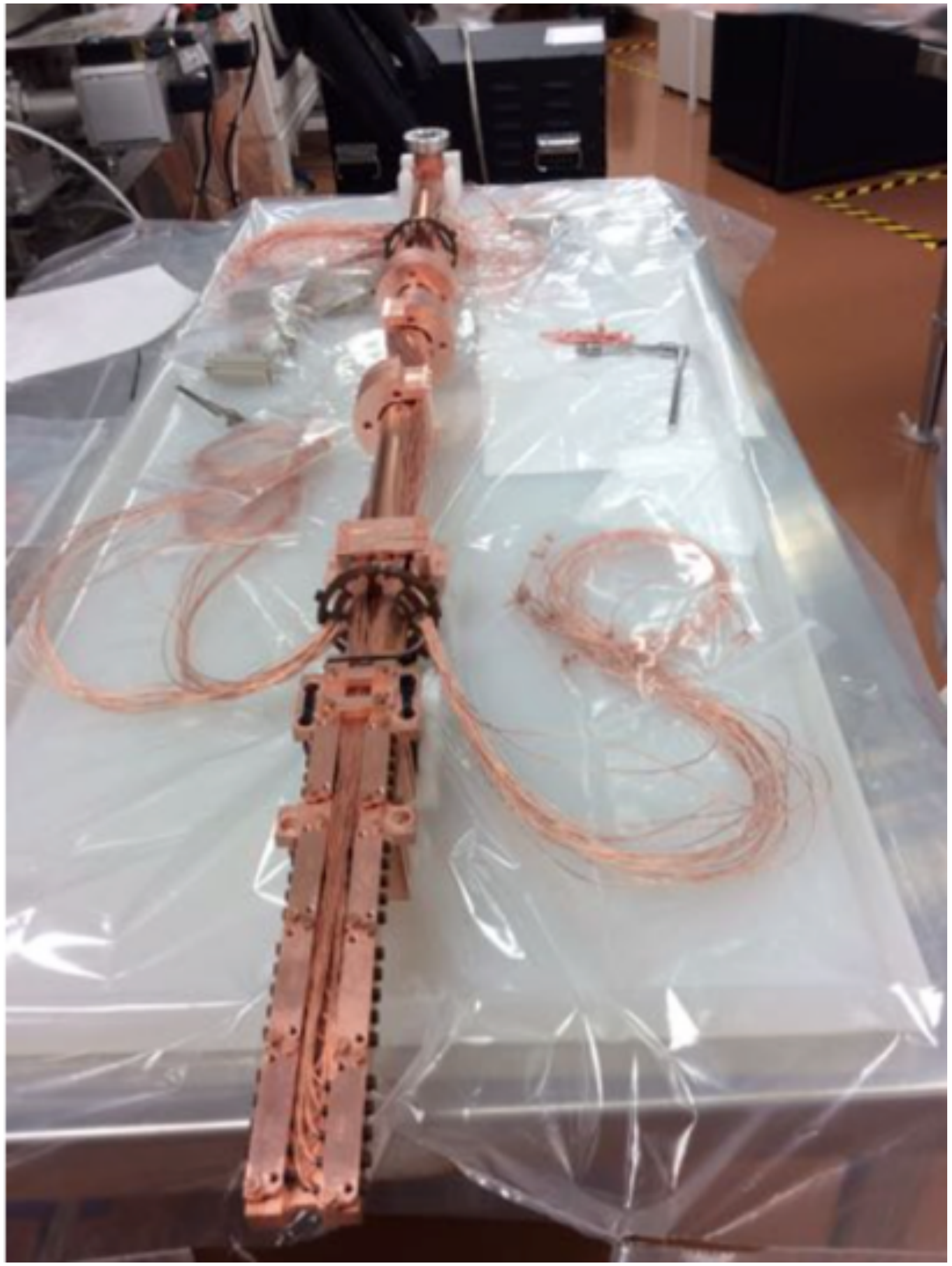

Crossarm shielding



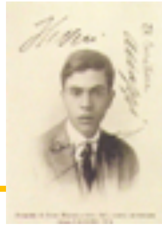
- Decreases background contributions from electronics breakout-box region
- Replaced welded bellows (high uranium activity) with formed bellows







Cryostat gaskets



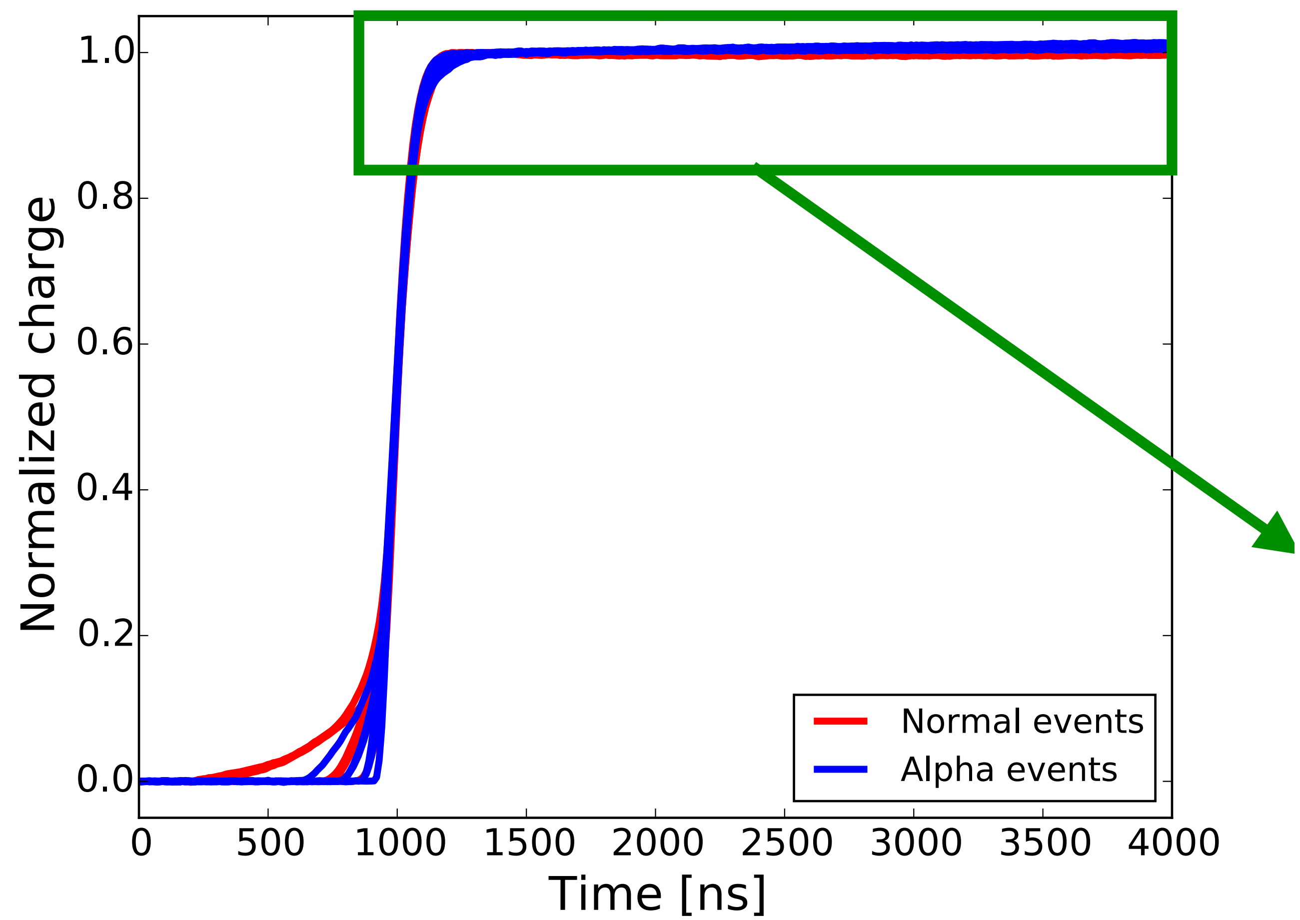
- Replaced reusable Kalrez gasket with low activity, low mass single-use 0.002” PTFE gasket.

Kalrez: **27.8** counts/ROI/tonne/yr
PTFE: **0.013** counts/ROI/tonne/yr

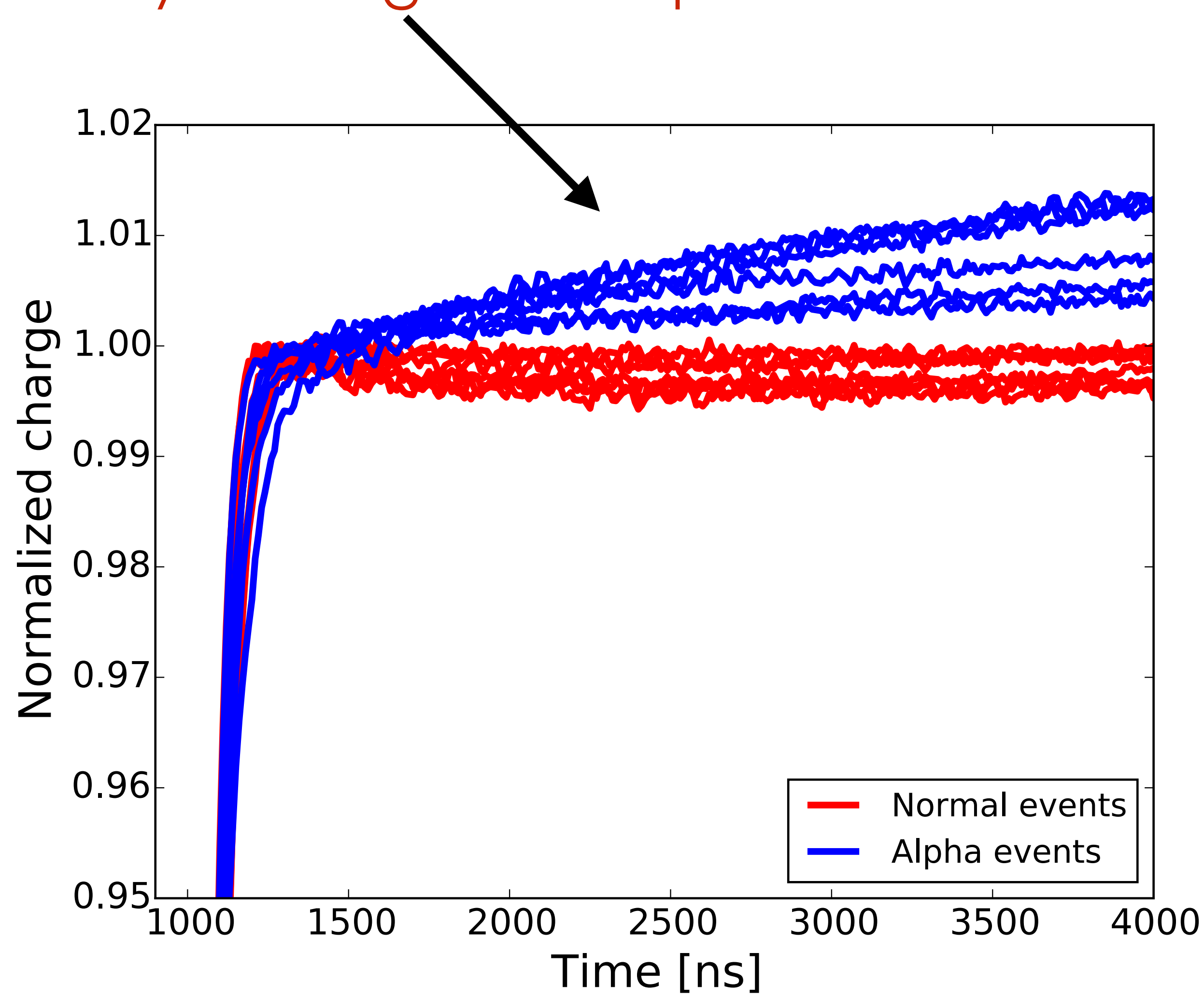
Alpha Background

- Unexpected background found in commissioning run (1700-3500 keV)
- Identified as arising from alphas events incident on passivated surface

Sample of events from 2-3 MeV

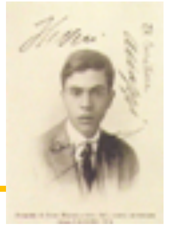


For alpha events, slow drift of charges along passivated surface results in very slow signal component

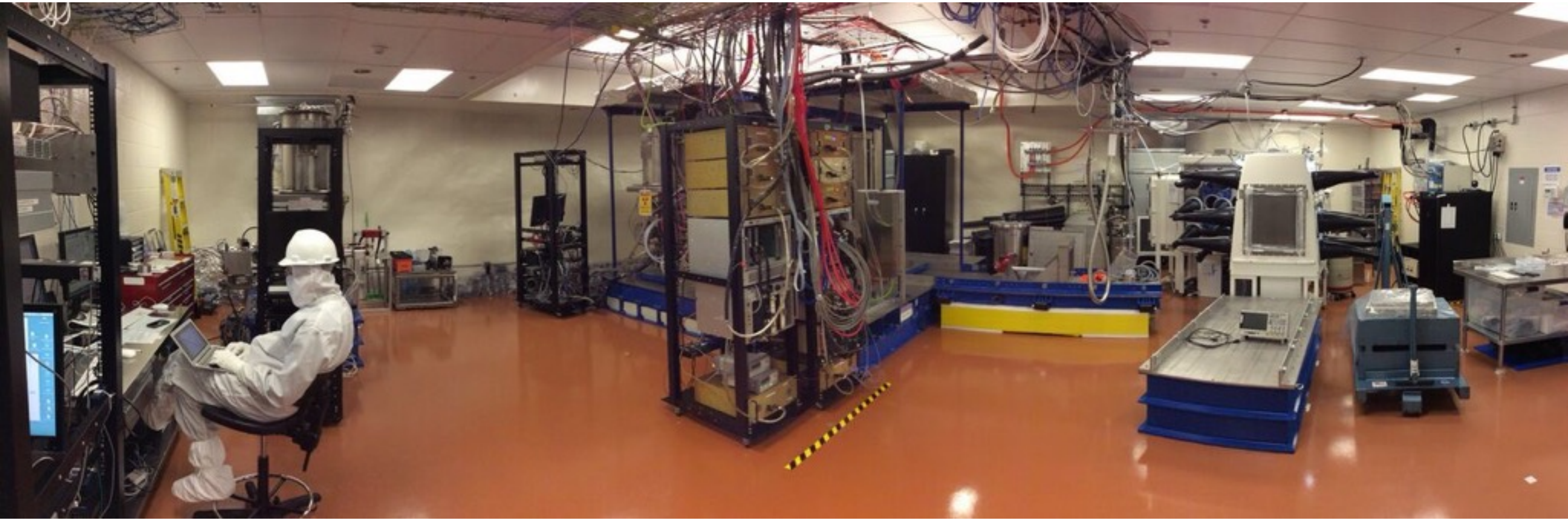


High-efficiency cut of alpha events based on waveform slope in flat-top region

Current Status Summary



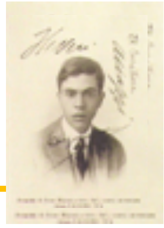
- Module One:
  - Reinserted into shield Dec. 2015. Currently commissioning.
  - Aim to have first background information in the spring
- Module Two:
  - Cryo-Vacuum system constructed and being tested. 2 of 7 strings built
  - Data taking scheduled to begin in May 2016



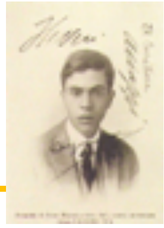
The MAJORANA Collaboration

Black Hills State University
Duke University
ITEP
Joint Institute for Nuclear Research
Berkeley Lab
Los Alamos National Laboratory
Oak Ridge National Laboratory
TUNL
The University of North Carolina at Chapel Hill
University of South Carolina
Tennessee Tech University
M
NC State University
The University of Tennessee
Osaka University
Pacific Northwest National Laboratory
Queen's University

Acknowledgements



- This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, the Particle Astrophysics and Nuclear Physics Programs of the National Science Foundation, and the Sanford Underground Research Facility.



Backup

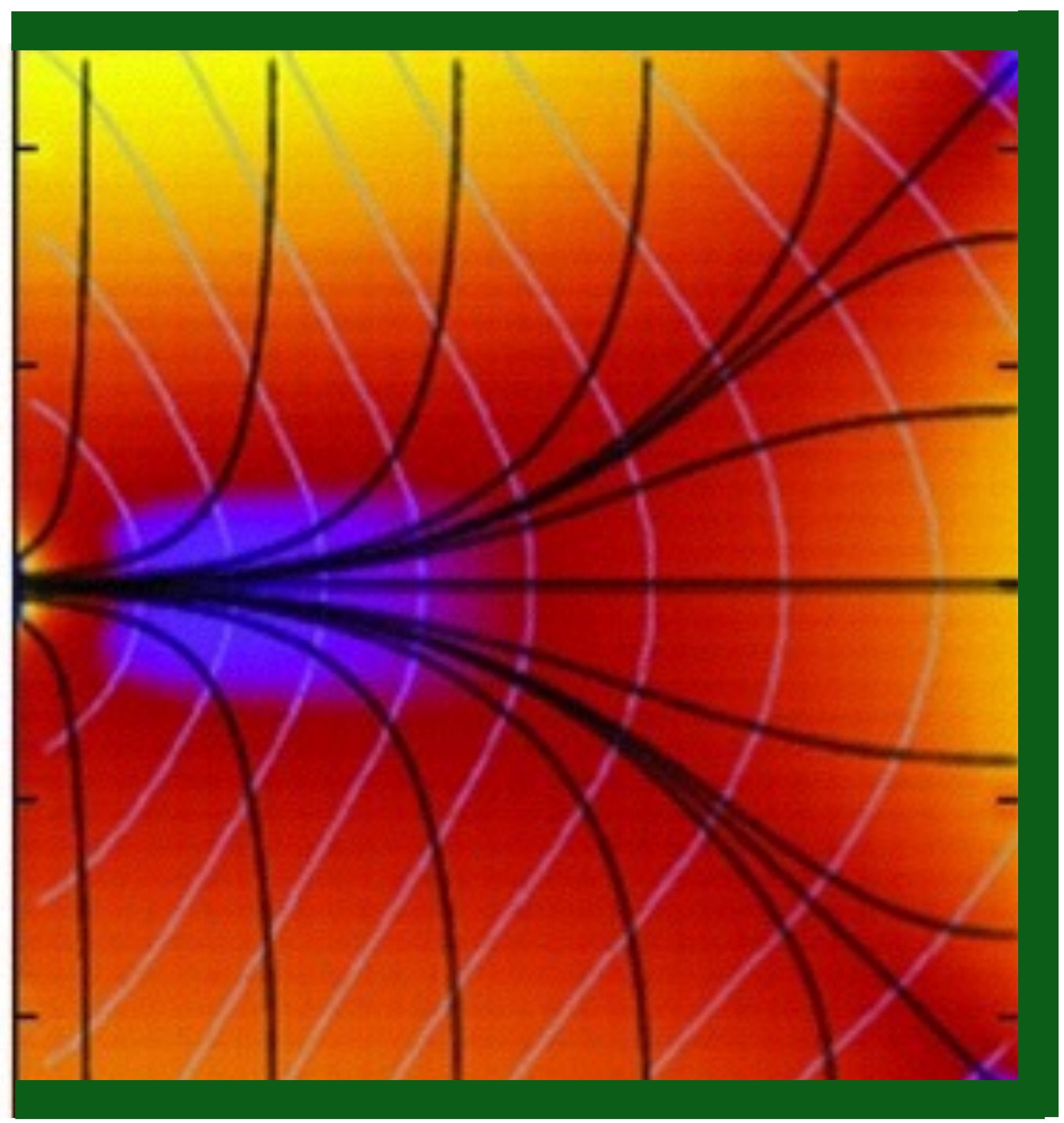
Alpha Background: Pulse Shape

- Alpha background on passivated surface

HV Contact (+2-3 kV):
electron collection surface

Point Contact (0V):
hole collection

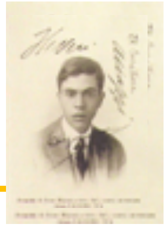
Passivated
Surface



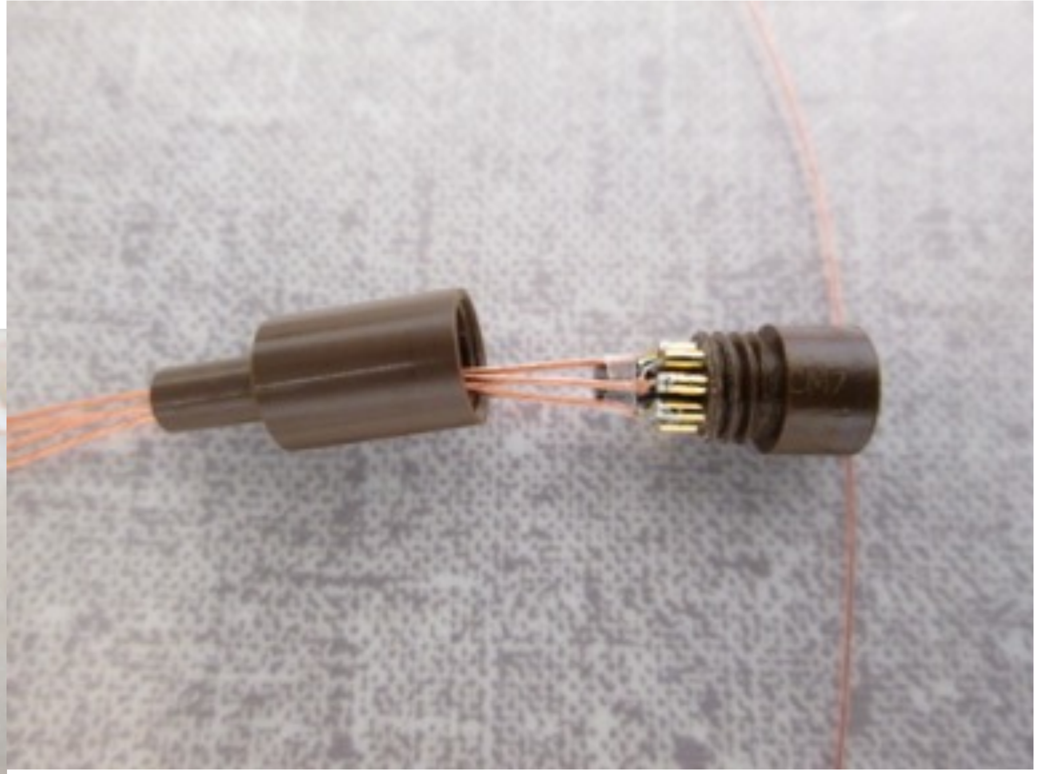
Black lines are charge drift paths

White lines are isochrones

Signal and HV Connections



- Signal connectors reside on top of cold plate.
  - In-house machined from vespel. Axon’ pico co-ax cable.
  - Low background solder and flux.
- HV connection done at detector unit.
  - Small `fork’ is clamped to HV ring.
- Tension between radio-purity constraints and connection robustness.
  - Ongoing R&D to improve performance.



The search for 0vBB