Updates for the MAJORANA DEMONSTRATOR

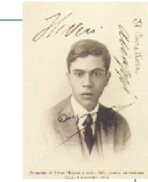
SAM MEIJER

UNIVERSITY OF NORTH CAROLINA, CHAPEL HILL

INVISIBLES17 WORKSHOP
ZÜRICH, SWITZERLAND

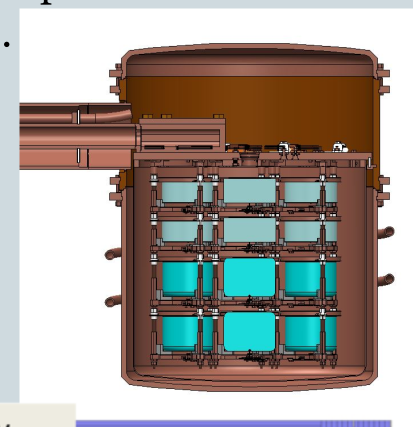
15 JUNE, 2017

The MAJORANA DEMONSTRATOR

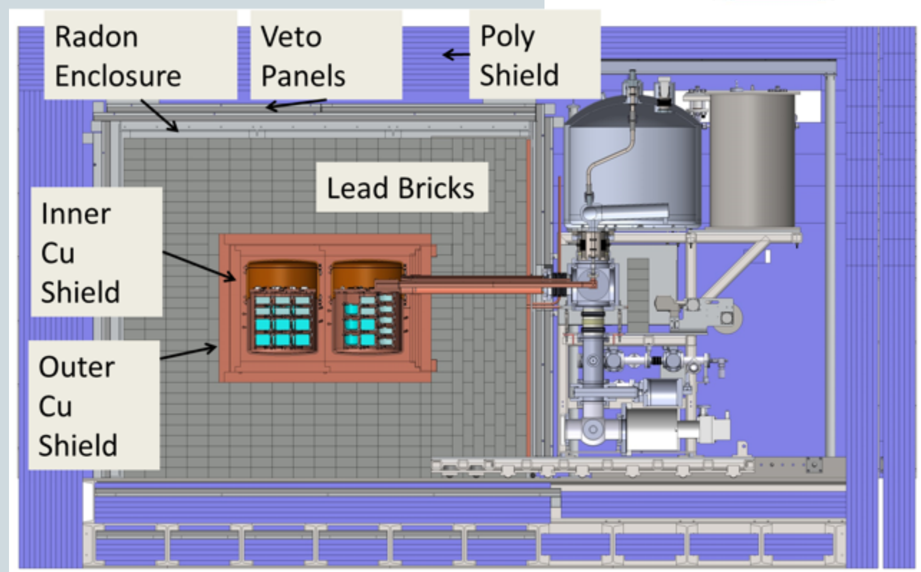


Funded by DOE Office of Nuclear Physics, NSF Particle Astrophysics, NSF Nuclear Physics
with additional contributions from international collaborators.

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
- 44.1-kg of Ge detectors
  - 29.7 kg of 88% enriched ^{76}Ge crystals
  - 14.4 kg of ^{nat}Ge
  - Detector Technology: P-type, point-contact.
- 2 independent cryostats
  - ultra-clean, electroformed Cu
  - 22 kg of detectors per cryostat
  - naturally scalable
- Compact Shield
  - low-background passive Cu and Pb
    shield with active muon veto



The MAJORANA Collaboration

Black Hills State University, Spearfish, SD
Kara Keeter

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

Joint Institute for Nuclear Research, Dubna, Russia
Viktor Brudanin, M. Shirchenko, Sergey Vasilyev, E. Yakushev, I. Zhitnikov

Lawrence Berkeley National Laboratory, Berkeley, California and the University of California - Berkeley
Nicolas Abgrall, Yuen-Dat Chan, Lukas Hehn, Jordan Myslik, Alan Poon, Kai Vetter

Los Alamos National Laboratory, Los Alamos, New Mexico
Pinghan Chu, Steven Elliott, Ralph Massarczyk, Keith Rielage, Larry Rodriguez, Harry Salazar, Brandon White, Brian Zhu

National Research Center '*Kurchatov Institute' Institute of Theoretical and Experimental Physics, Moscow, Russia*
Alexander Barabash, Sergey Konovalov, Vladimir Yumatov

North Carolina State University, and TUNL
Matthew P. Green

Oak Ridge National Laboratory
Fred Bertrand, Charlie Havener, Monty Middlebrook, David Radford, Robert Varner, Chang-Hong Yu

Osaka University, Osaka, Japan
Hiroyasu Ejiri

Pacific Northwest National Laboratory, Richland, Washington
Isaac Arnquist, Eric Hoppe, Richard T. Kouzes

Princeton University, Princeton, New Jersey
Graham K. Giovanetti

Queen's University, Kingston, Canada
Ryan Martin

South Dakota School of Mines and Technology, Rapid City, South Dakota
Colter Dunagan, Cabot-Ann Christofferson, Anne-Marie Suriano, Jared Thompson

Tennessee Tech University, Cookeville, Tennessee
Mary Kidd

Technische Universität München, and Max Planck Institute, Munich, Germany
Tobias Bode, Susanne Mertens

University of North Carolina, Chapel Hill, North Carolina, and TUNL
Thomas Caldwell, Thomas Gilliss, Chris Haufe, Reyco Henning, Mark Howe, Samuel J. Meijer, Christopher O' Shaughnessy, Gulden Othman, Jamin Rager, Anna Reine, Benjamin Shanks, Kris Vorren, John F. Wilkerson

University of South Carolina, Columbia, South Carolina
Frank Avignone, Vince Guiseppe, David Tedeschi, Clint Wiseman

University of South Dakota, Vermillion, South Dakota
CJ Barton, Wenqin Xu

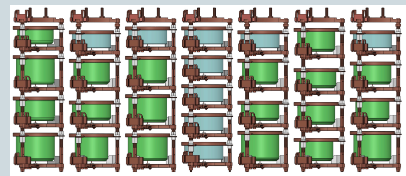
University of Tennessee, Knoxville, Tennessee
Yuri Efremenko, Andrew Lopez

University of Washington, Seattle, Washington
Sebastian Alvis, Tom Burritt, Micah Buuck, Clara Cuesta, Jason Detwiler, Julieta Gruszko, Ian Guinn, David Peterson, Walter Pettus, R. G. Hamish Robertson, Nick Rouf, Tim Van Wechel

Construction Status

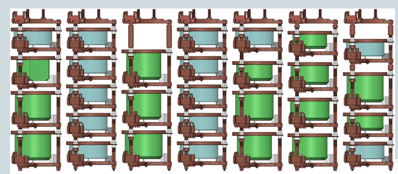
- Both modules are assembled, in shield, and taking data
- Blind data taking has commenced

Module 1: 16.9 kg (20) ^{enr}Ge
5.6 kg (9) ^{nat}Ge

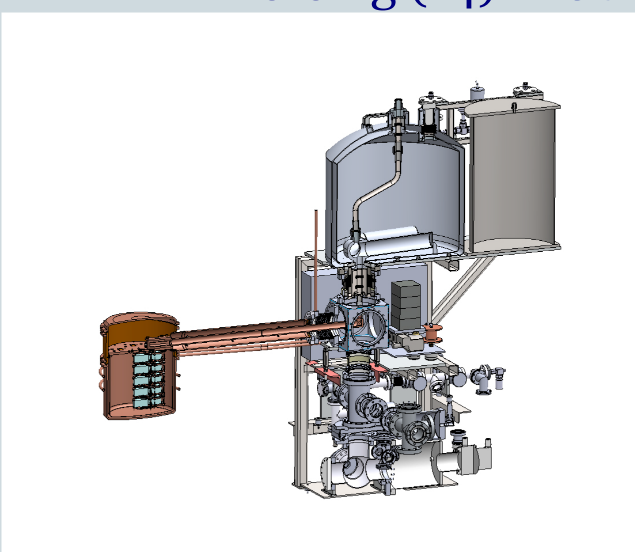


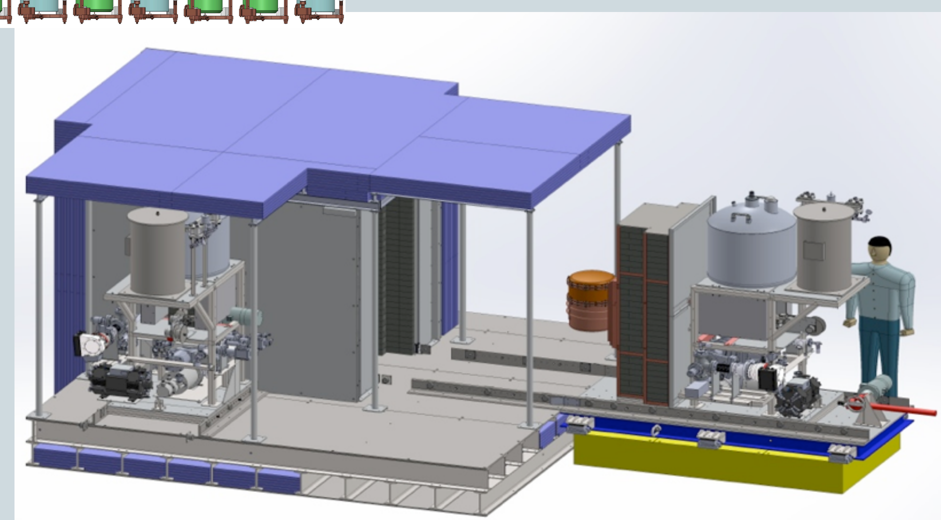
May–Oct. 2015,
Final Installations,
Dec. 2015 ongoing

Module 2: 12.9 kg (15) ^{enr}Ge
8.8 kg (14) ^{nat}Ge



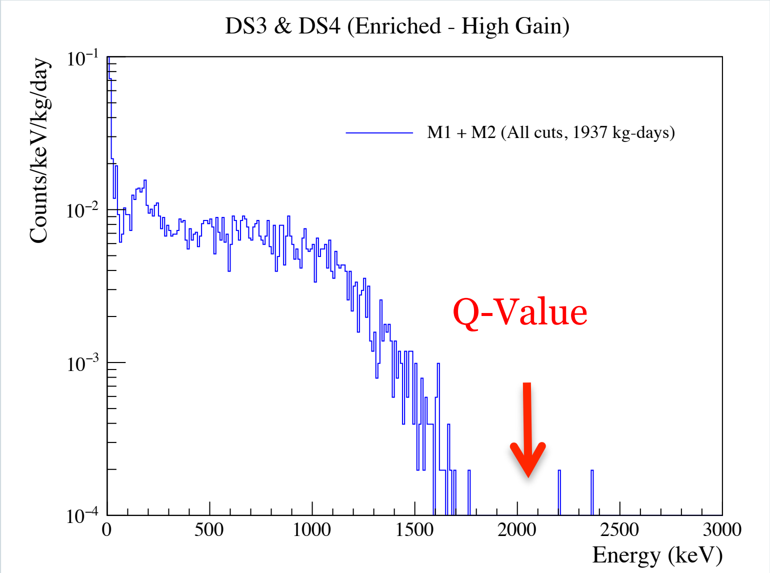
Mid 2016





Initial Results from Both Modules in-shield

- The ^{76}Ge enriched point contact detectors developed by Majorana
  - Have attained the best energy resolution of any ββ-decay experiment (2.4 keV FWHM at 2039 keV)
  - Provided excellent pulse shape discrimination based reduction of backgrounds
  - Have sub-keV energy thresholds and excellent resolution at low energies, allowing the DEMONSTRATOR to perform sensitive tests in this region for physics beyond the standard model (see PRL 118, 161801)
- The DEMONSTRATOR's initial backgrounds and the GERDA Phase II backgrounds are the lowest backgrounds in the region of interest (ROI) achieved to date of all current or previous 0νββ experiments by an order of magnitude.



- Exposure: 1.39 kg-yr
- After cuts, 1 count in the 400 keV window centered at 2039 keV (0νββ peak)
- Projected background rate is $5.1^{+8.9}_{-3.2}$ c/(ROI-t-yr) for a 2.9 keV (M1-DS3) and 2.6 keV (M2-DS4) ROI (68% CL).
- Background index of 1.8 x 10^{-3} c/(keV-kg-yr)
- Analysis cuts are still being optimized
- Through mid-May, have 10x more exposure in hand. Analysis is in progress

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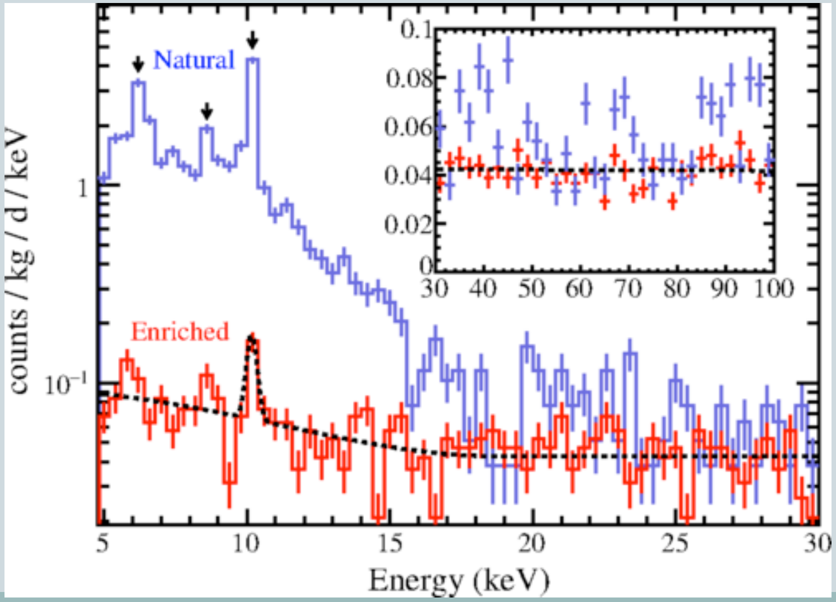

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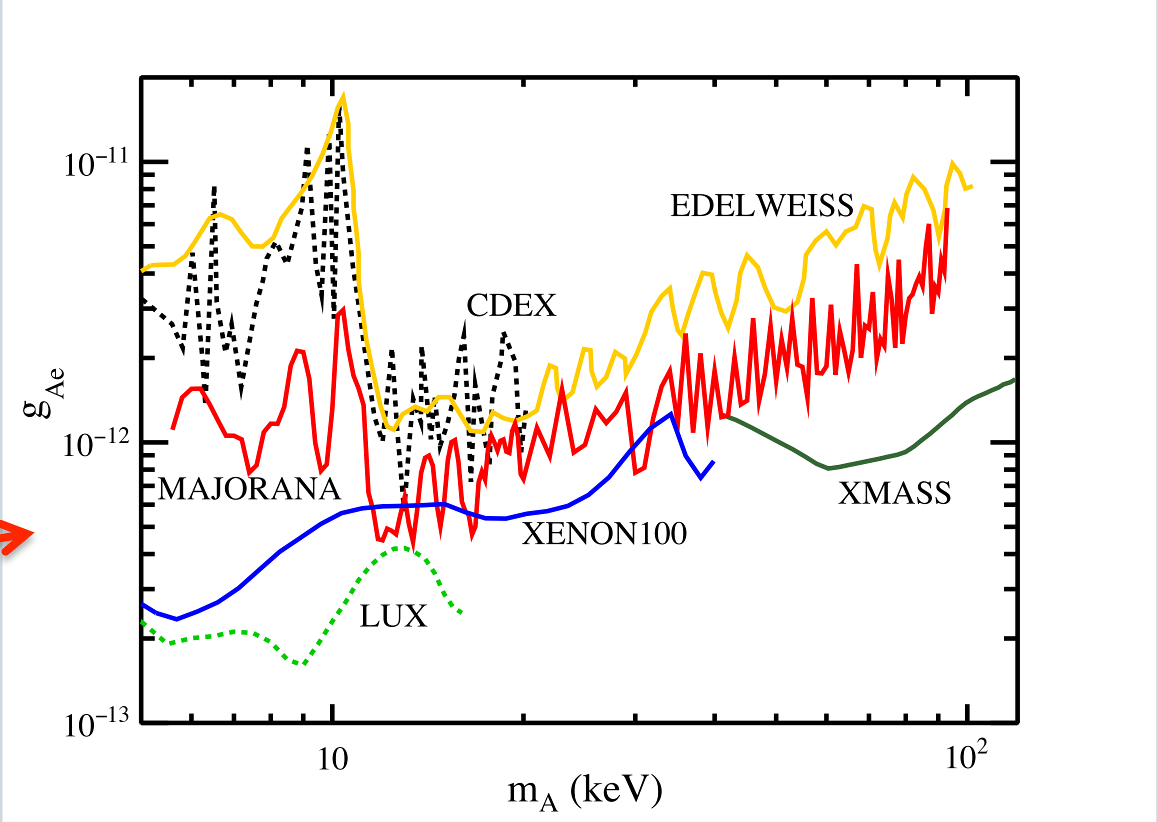
DS0: 4.1 kg Natural 10.06 kg Enriched

Recent Results

Arxiv: 1612.00886

- Recently published results (PRL 118, 161801) :
  - Pseudoscalar and vector dark matter
  - Solar Axions
  - PEPV
  - Electron Decay

Pseudoscalar limit



Summary

- Construction completed
- Taking blind data!
- Have some early results

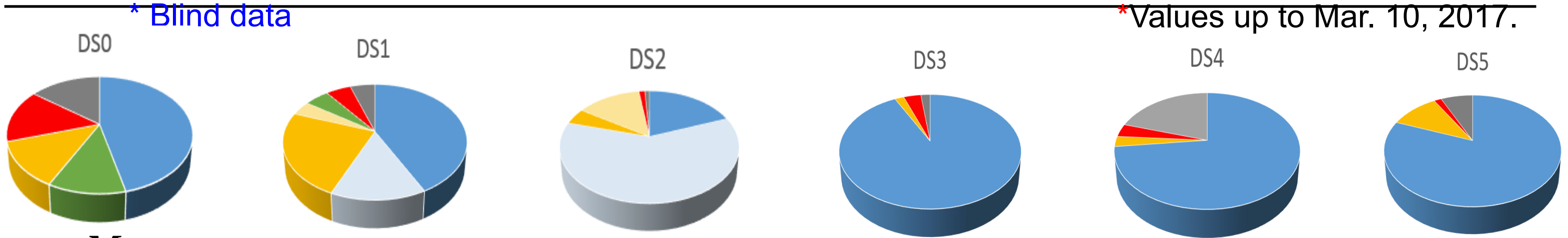
Thanks!

Data Sets and Duty cycles

	DS0 (days) Module1 June 26, – Oct. 7, 2015	DS1 (days) Module 1 Dec. 31, 2015 – May 24, 2016	DS2 (days) Module 1 May 24 – July 14, 2016	DS3 (days) Module 1 Aug. 25, – Sept. 27, 2016	DS4 (days) Module 2 Aug. 25, – Sept. 27, 2016	DS5 (days) Module 1 & 2 Oct. 13, 2016 – ongoing*
Total	103.15	144.50	50.97	32.37	32.36	147.68
Total acquired	87.93	136.98	50.47	31.73	25.80	137.42
Physics *	47.70	61.34 + 20.41*	9.82 + 30.56*	29.91	23.69	119.38
High radon	11.76	7.32	-	-	-	-
Disruptive Activities *	13.10	34.43+ 5.92*	2.41 + 7.03*	0.63	0.93	15.68
Calibration	15.44	7.32	0.65	1.18	1.17	2.36
Down time	15.21	7.51	0.50	0.64	6.56	10.25

* Blind data

*Values up to Mar. 10, 2017.



M1 Commissioning, no inner shield

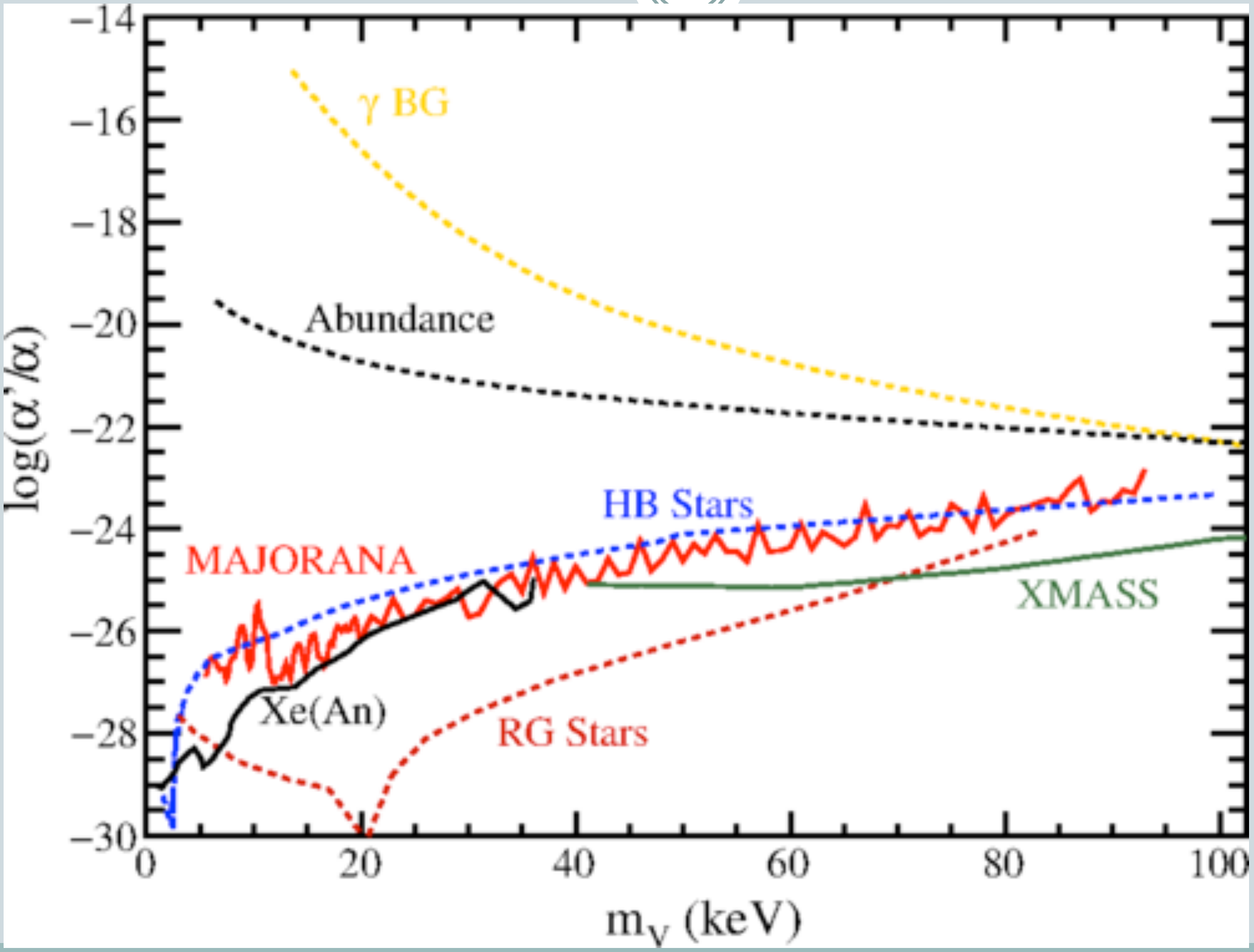
M1 inner shield

M1 Multi-sampling

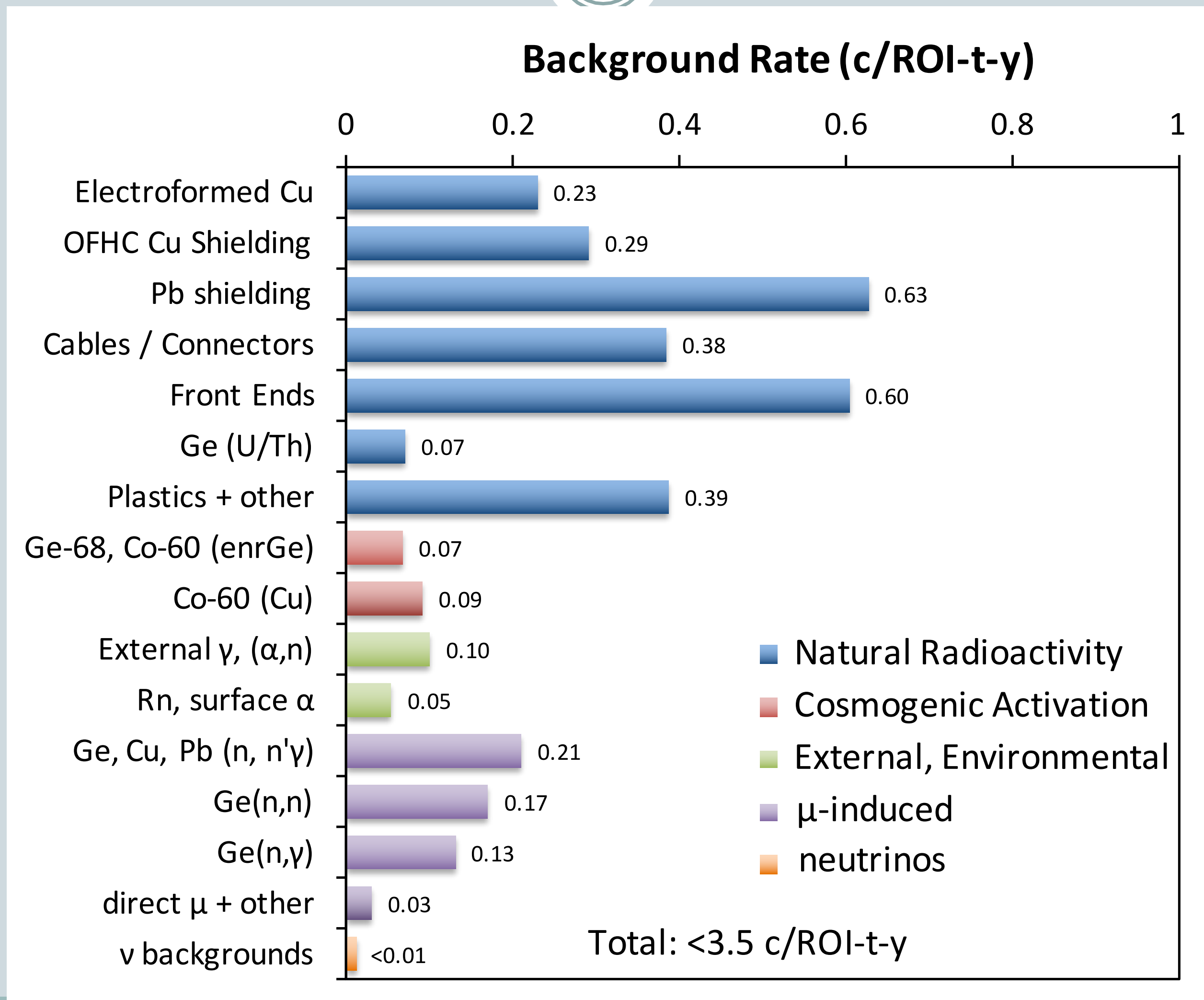
Modules 1 and 2 Together in-shield

Module 1 & 2 Integrated DAQ

Vector Dark Matter Limit

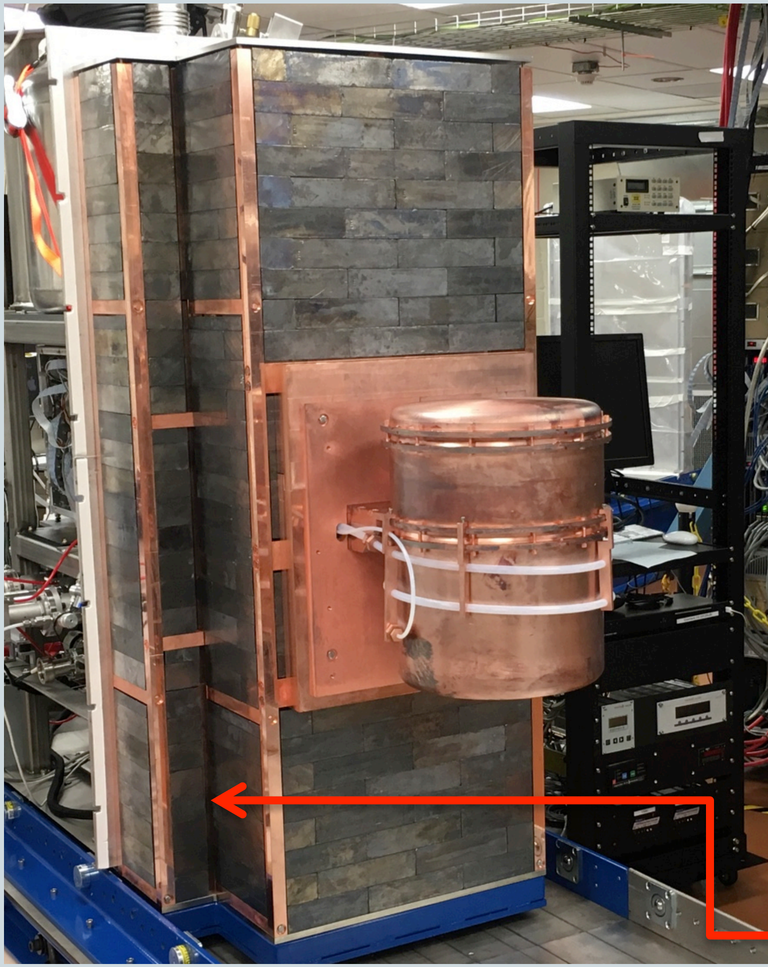


Background Budget



Background based on Assay Program (NIMA **828** (2016) 22)

Modular Cryostat and Shield

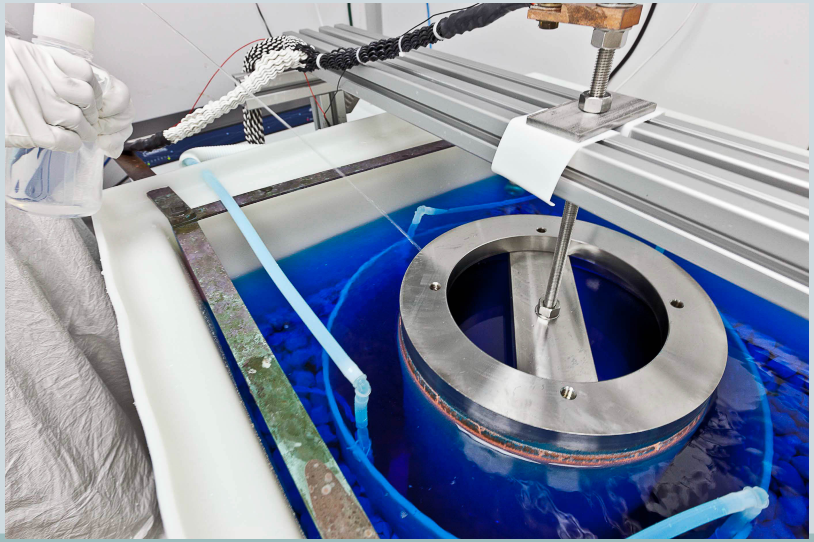


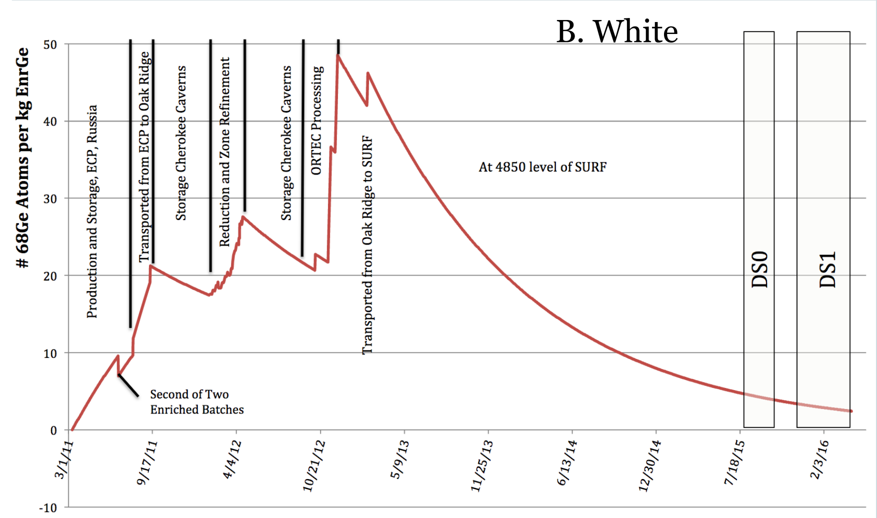
Keyed mating surface

MAJORANA Detectors

Cosmogenic Activation

- Cosmic rays can cause activation, particularly at high altitude (as in an airplane)
- Careful planning must be done to avoid this

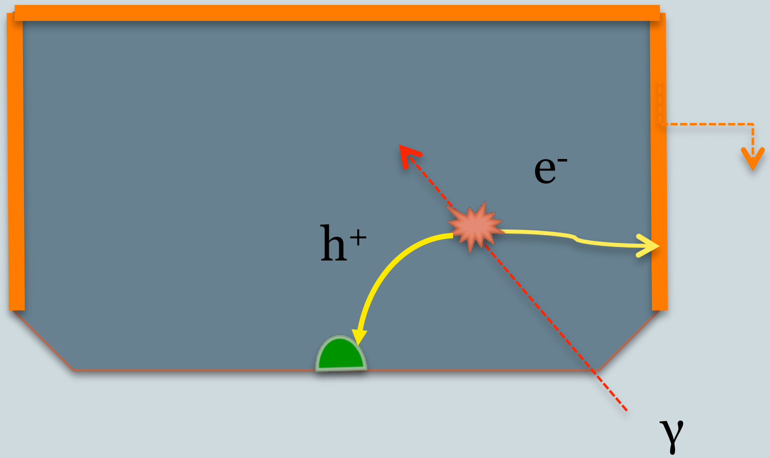


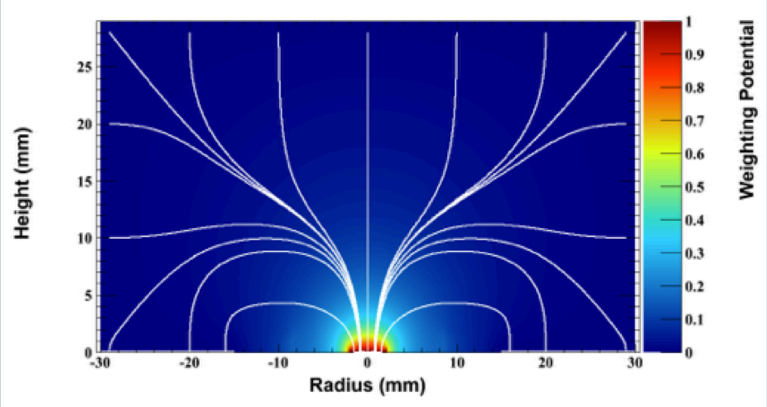


Signal Generation

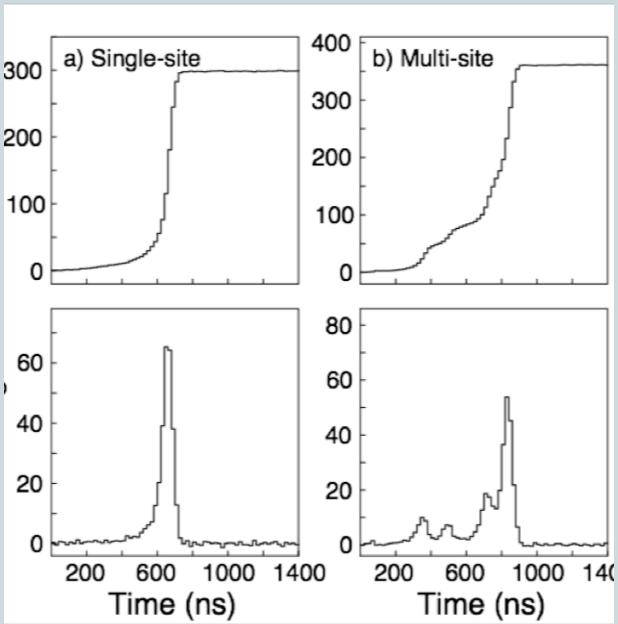
- Electron-hole pairs created
- Under influence of applied field, the charges drift towards contacts
- Motion of charges induces current into electrodes

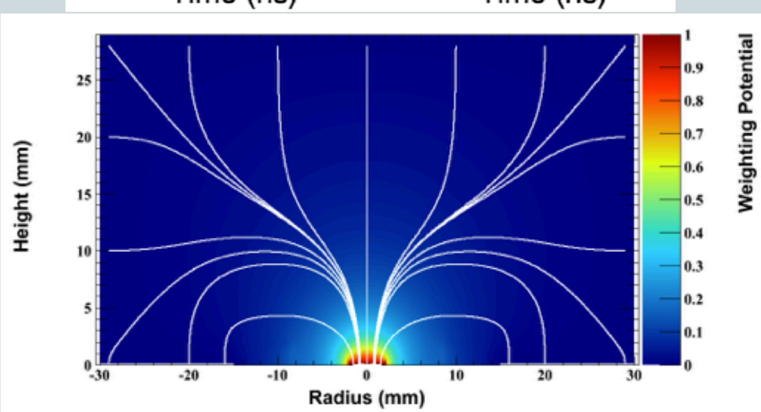
$$i = qv(\vec{E}) \cdot \Delta\vec{E}_0(r, \theta, \phi)$$





P-type Point Contact Detector





- P-type: Easier to fabricate and handle
- Low capacitance
  - <10 pF
- Long drift times
  - ~µs, not ns
- Low energy threshold