Meeting of the Division of Particles and Fields of the American Physical Society

August 9-13, 2011

Brown University, Providence, Rhode Island

The MAJORANA Demonstrator Project

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(For the MAJORANA COLLABORATION)

DPF-2011, BROWN UNIVERSITY AUGUST 9-13, 2011

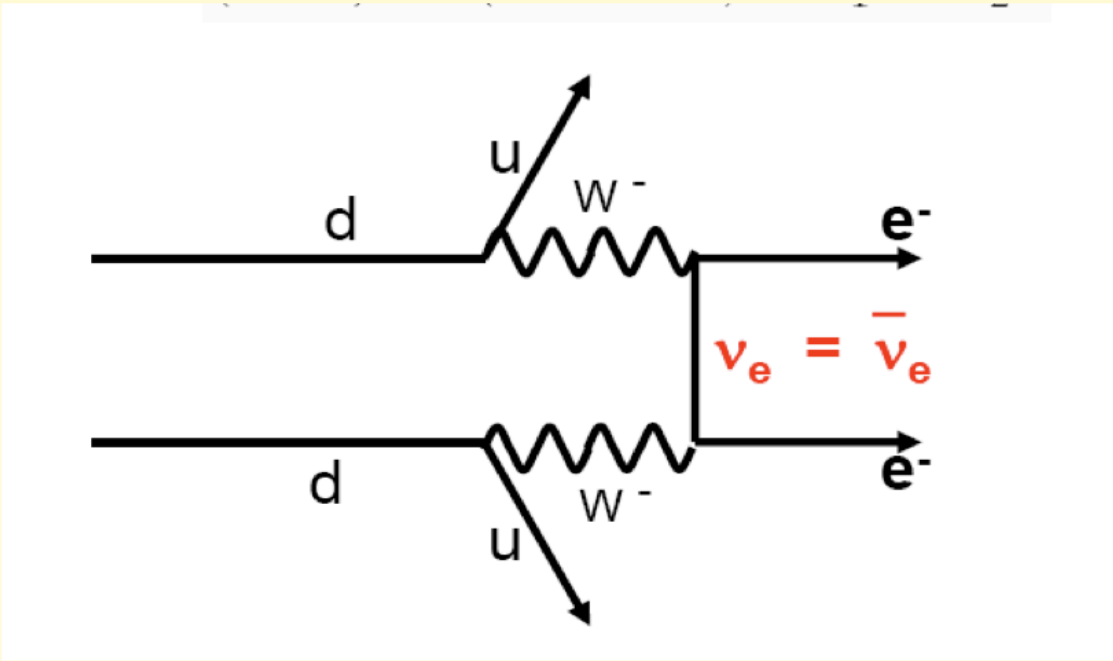
Modes of Double-Beta Decay

$(A,) \rightarrow (A,Z+2) + 2e^- + 2\bar{\nu}_e$

2ν Double Beta Decay allowed by the Standard Model observed : $T_{1/2} = 10^{19} - 10^{21}$y

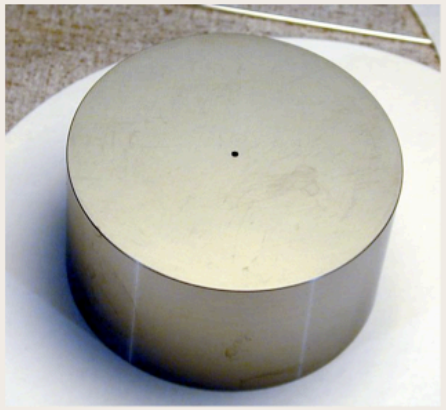
$(A,Z) \rightarrow (A,Z+2) + 2e^-$

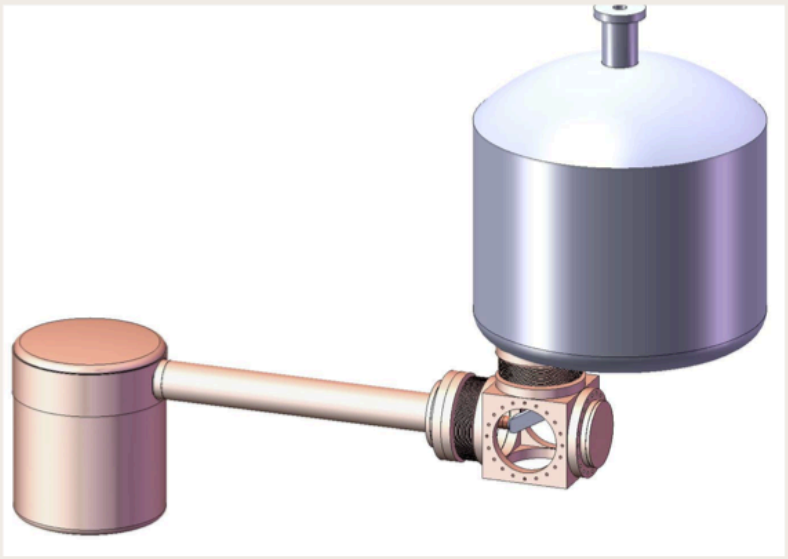
Neutrinoless Double Beta Decay (0ν-DBD) never observed (except KKDK claim) $T_{1/2} > 10^{25}$ y

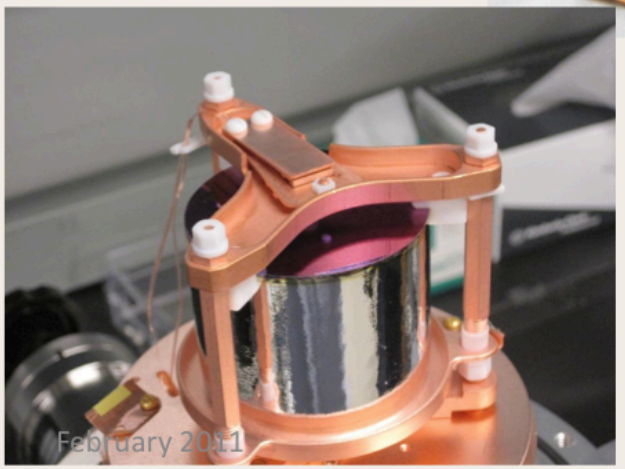


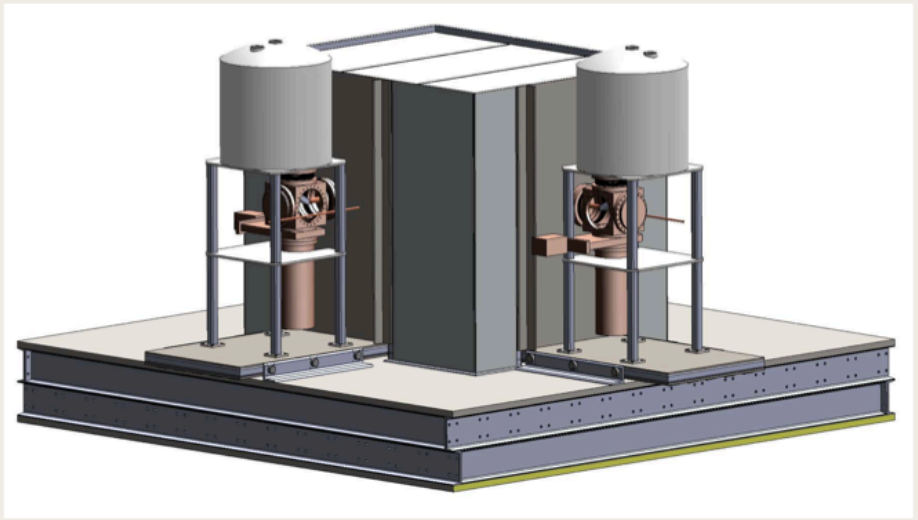
Lepton-Number Violation? Dirac or Majorana Character? Neutrino Mass Scale?

Towards a Ton-scale Experiment: the MAJORANA Demonstrator





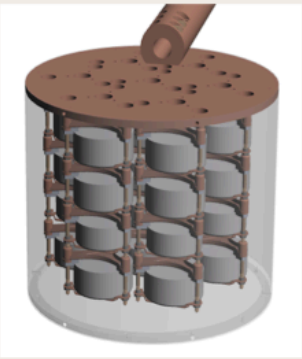




The MAJORANA Demonstrator Module

^{76}Ge offers an excellent combination of capabilities & sensitivities.

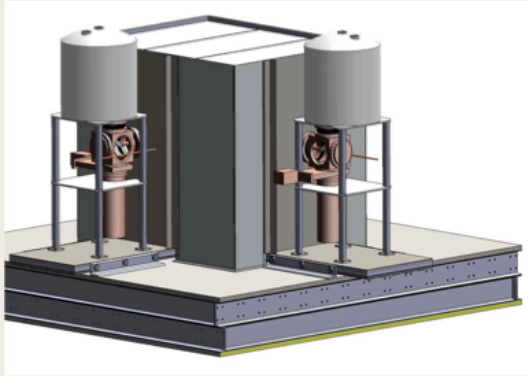
(Excellent energy resolution, intrinsically clean detectors, commercial technologies)



- ***40-kg of Ge detectors***

  Up to 30-kg of 86% enriched ^{76}Ge crystals required for science and background goals
  focus on point-contact detectors for DEMONSTRATOR

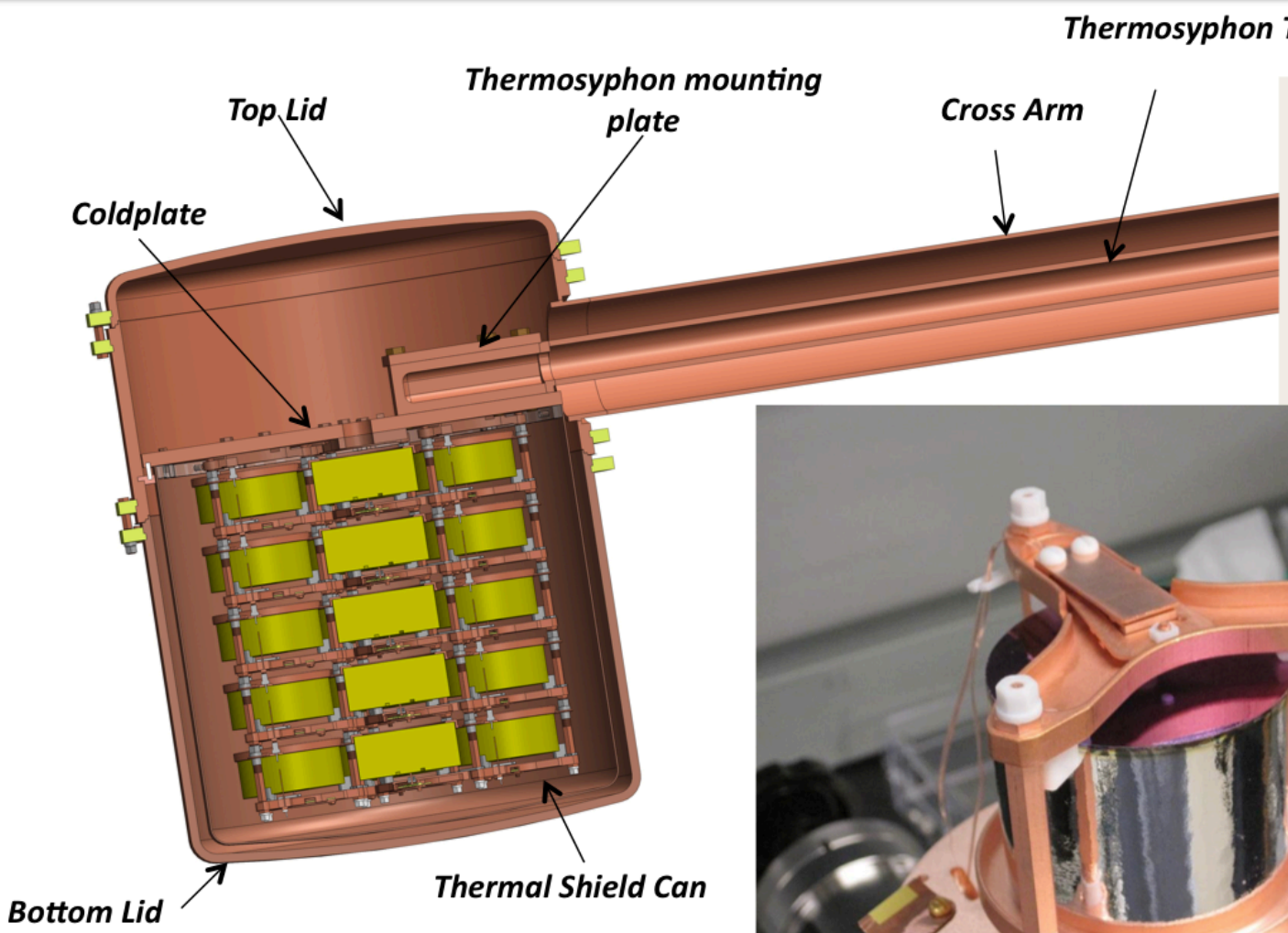
- ***Low-background Cryostats & Shield***
  - ***ultra-clean, electroformed Cu***
  - ***naturally scalable***
  - ***Compact low-background passive Cu and Pb shield with active muon veto***



- ***Background Goal in the $0\nu\beta\beta$ peak ROI(4 keV at 2039 keV)***

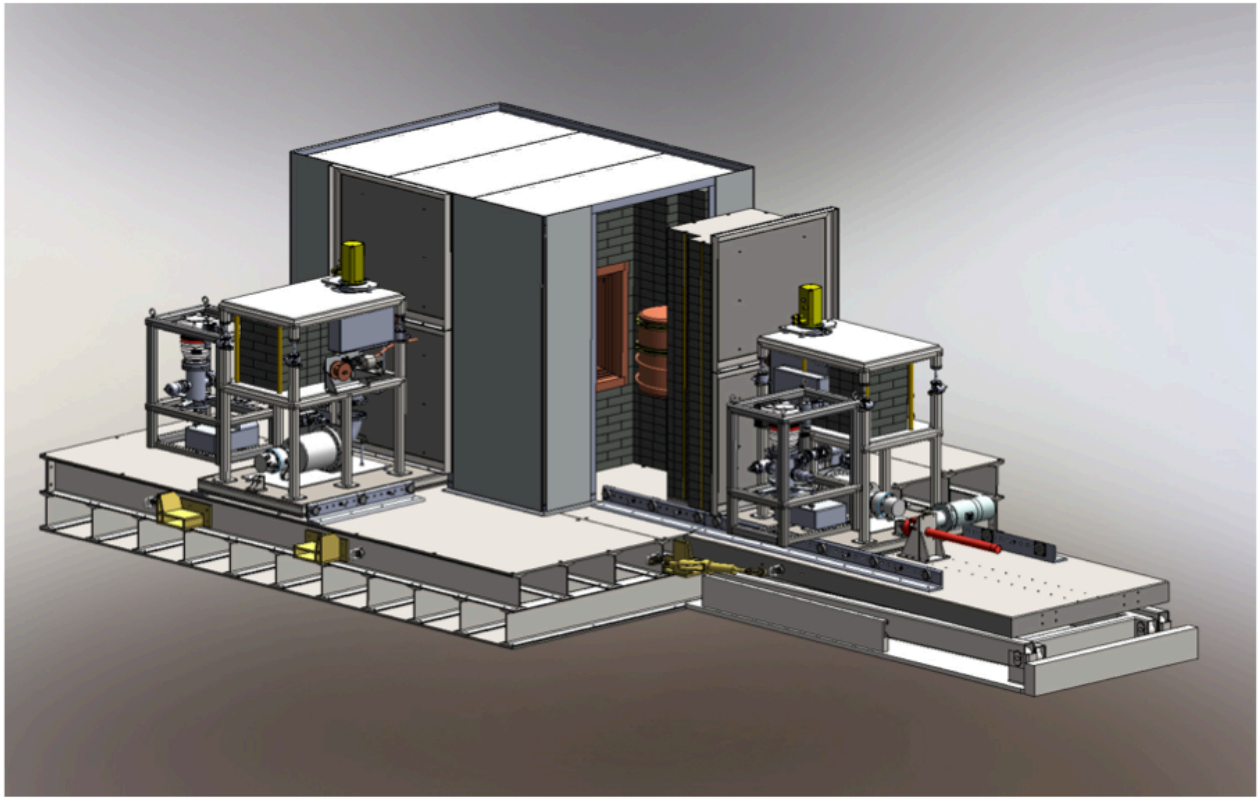
~ 4 count/ROI/t-y (after analysis cuts) (scales to 1 count/ROI/t-y for tonne expt.)

Electroformed Copper Cryostat

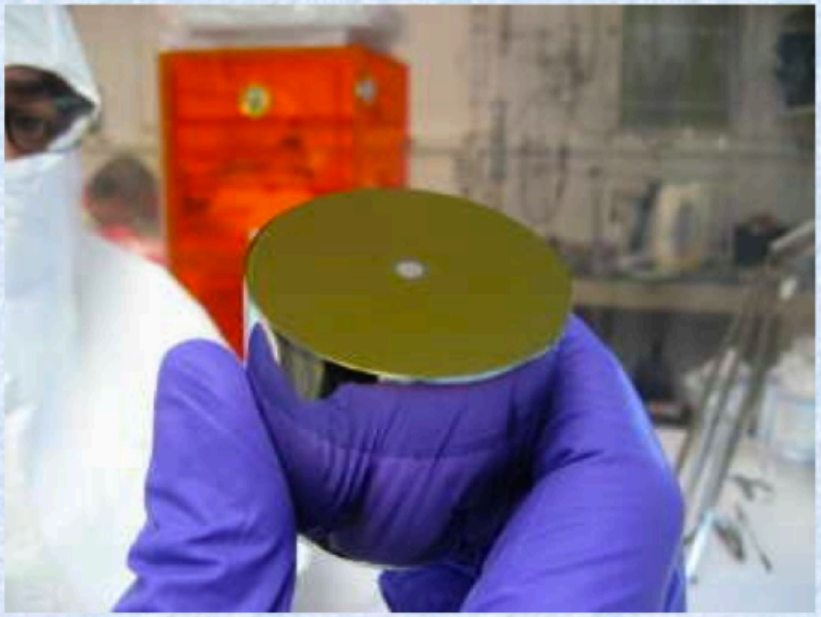


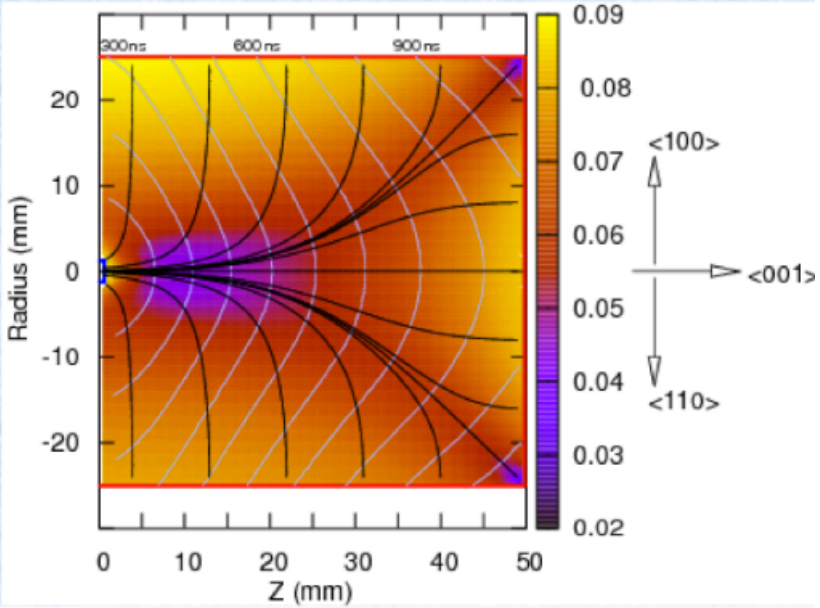
The Dual Module Shield

- *Three Phases*
  - *Prototype cryostat (3 strings, ^{nat}Ge)* *(Sept. 2012)*
  - *Cryostat 1 (3 strings ^{enr}Ge & 4 strings ^{nat}Ge)* *(Mar. 2013)*
  - *Cryostat 2 (up to 7 strings ^{enr}Ge)* *(Sept. 2014)*

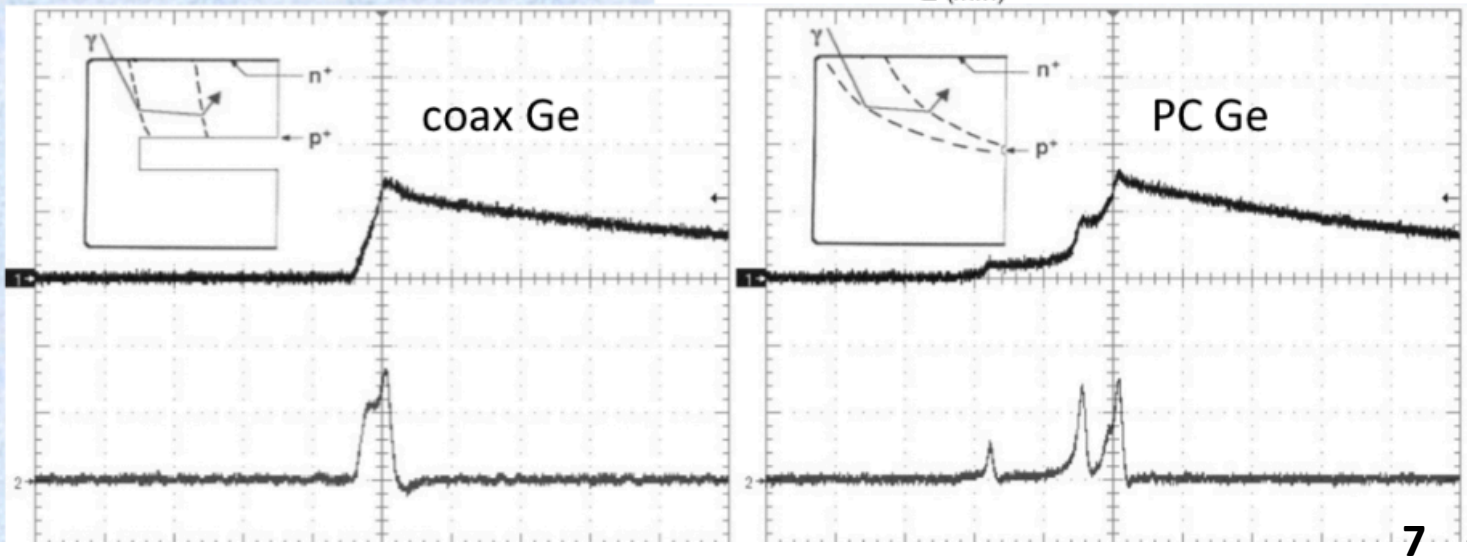


Point Contact Detectors for Pulse Shape Analysis





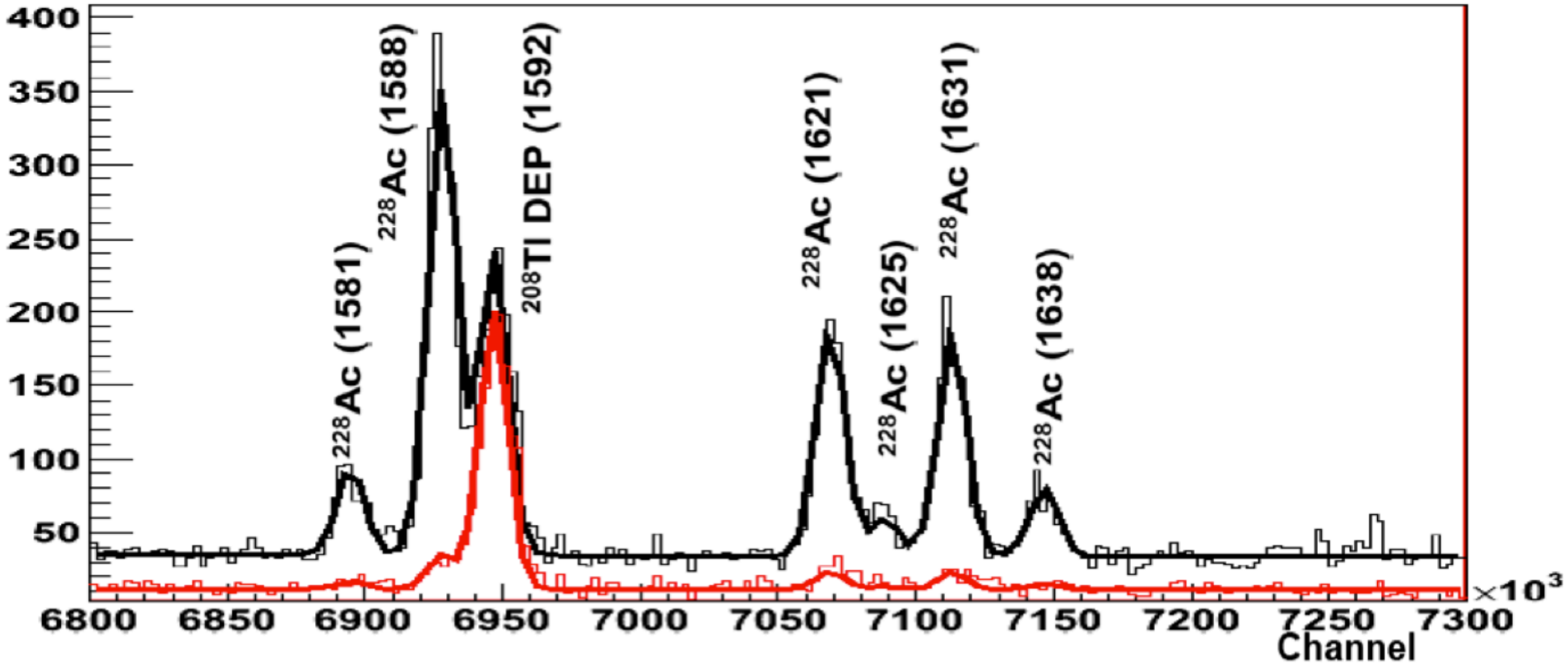
Point contact Ge detectors allow multi-site events to be identified- invented by Paul Luke (LBNL), Developed by Juan Collar for MAJORANA



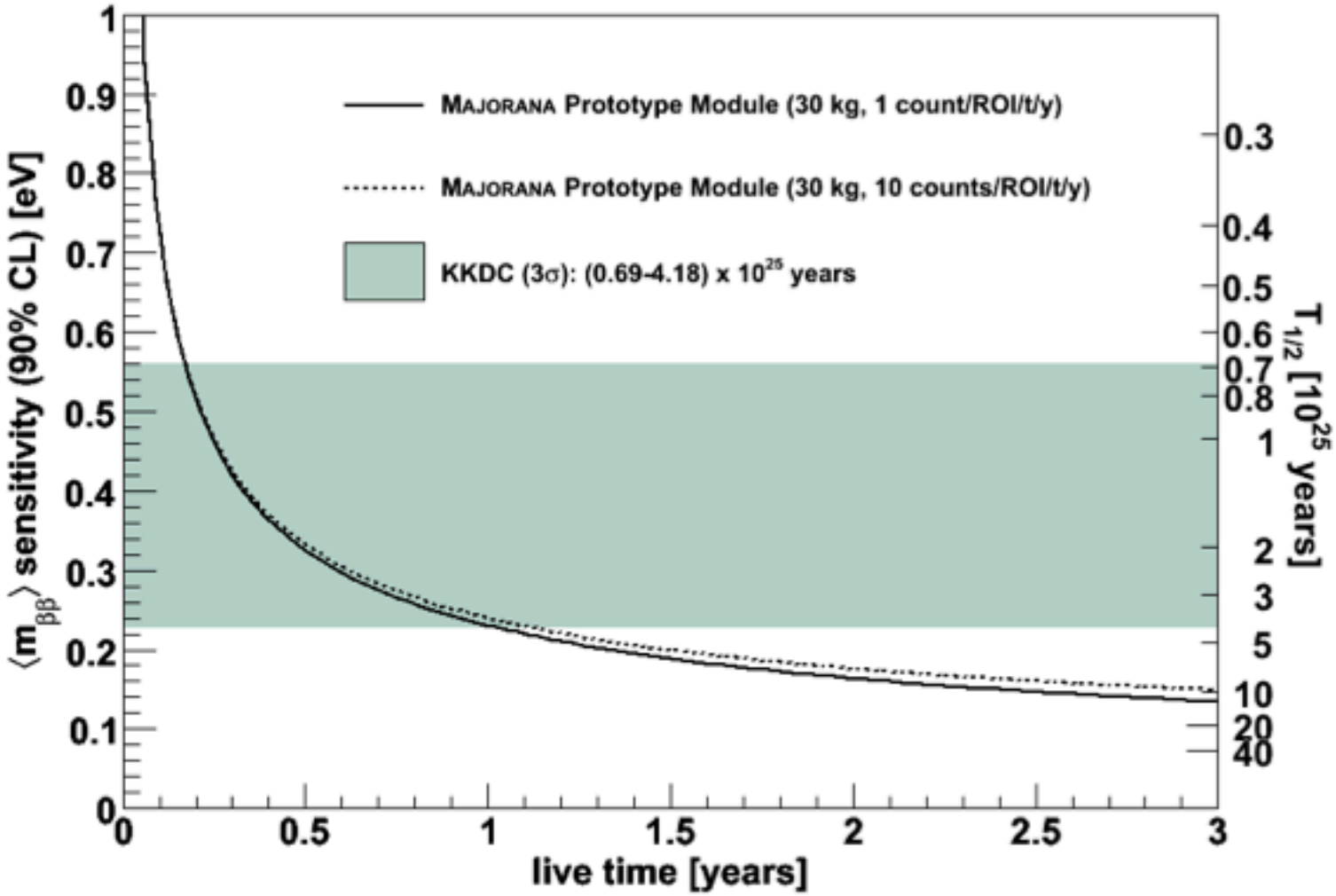
Effectiveness of Pulse-Shape Discrimination With MAJORANA POINT Contact Detectors

Single-site versus multi-site event discrimination

Example of DUPPC ^{232}Th spectrum:



MAJORANA Demonstrator Sensitivity



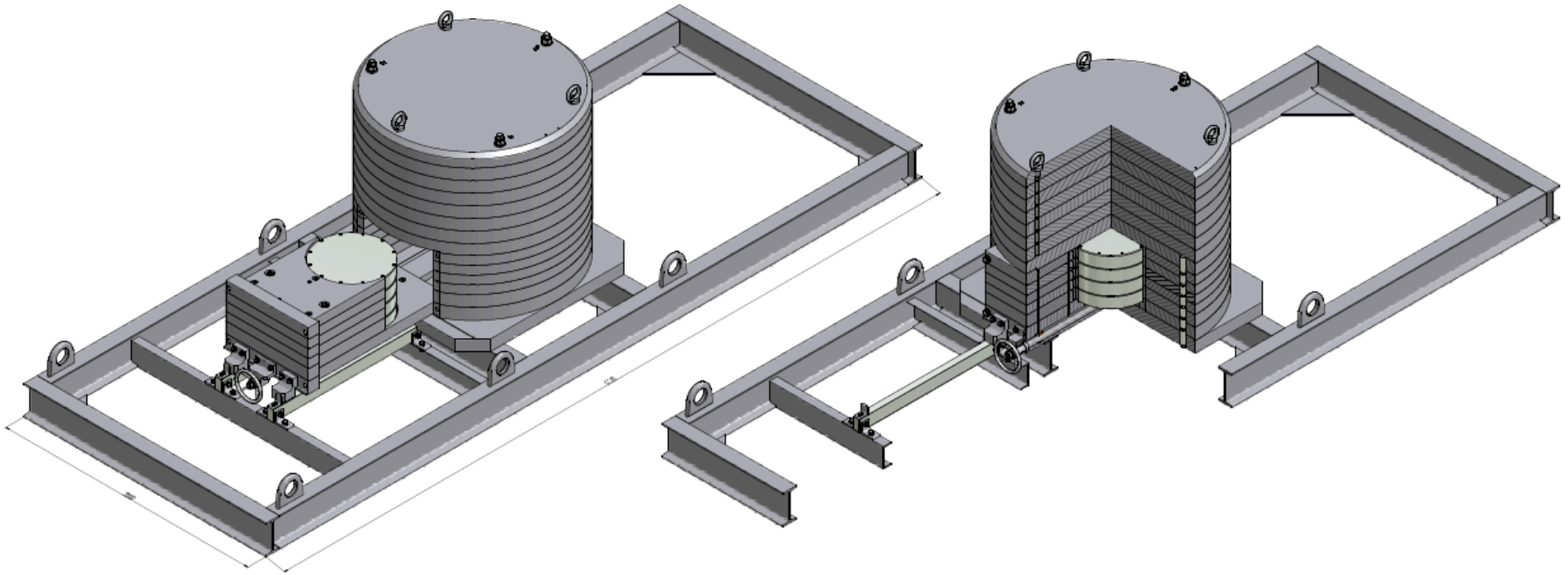
Acquisition of Enriched ^{76}Ge

- *The first 29 kg of GeO_2 of Ge enriched to >86% in ^{76}Ge has been processed and is already on its way to Oak Ridge (20 kg of Ge metal)*

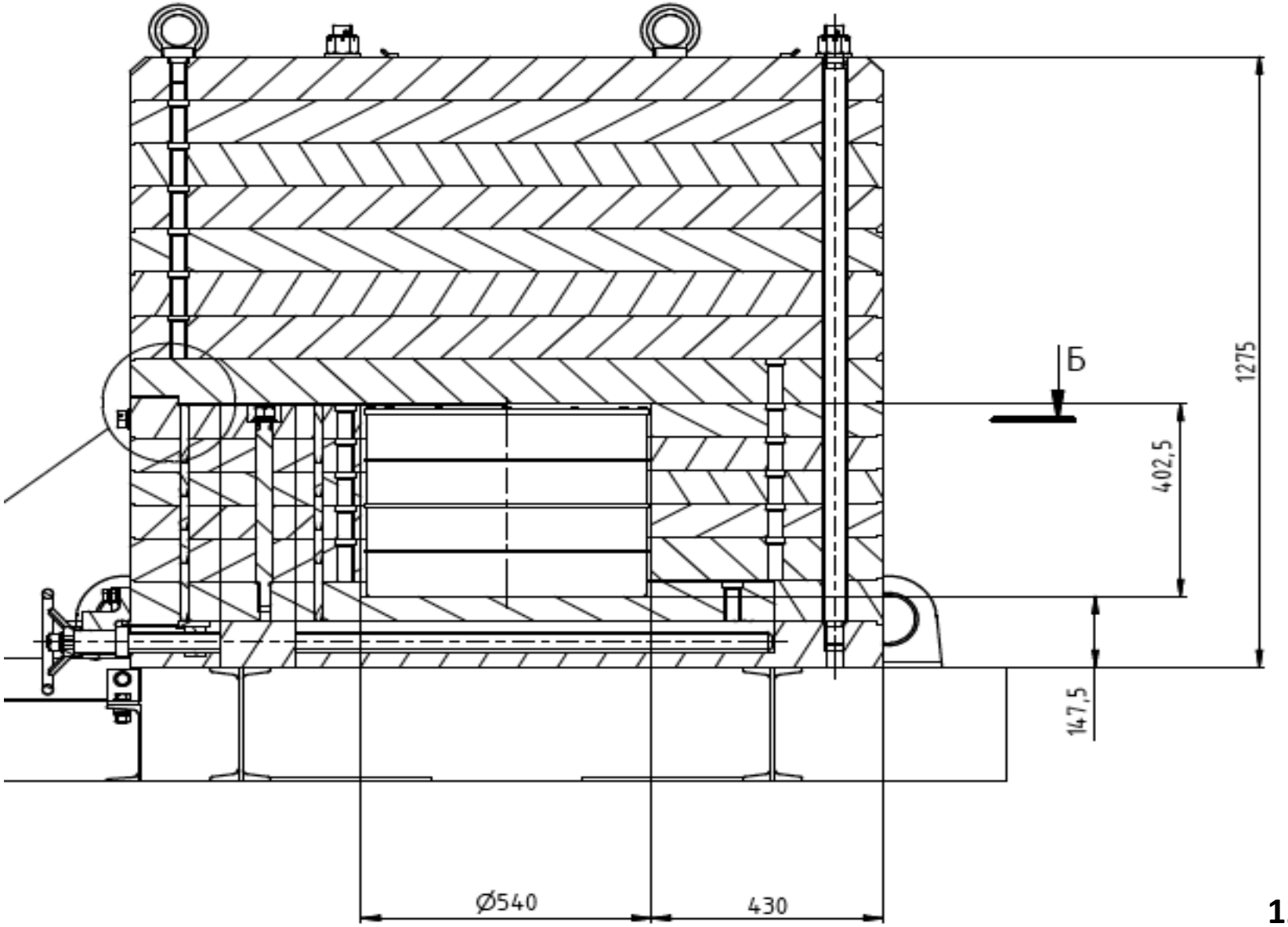
- *It is proceeding by truck from the Electrochemical Plant in Zelenogorsk, Russia to the Port of St. Petersburg, then by ship to a U.S. port, then by truck to Oak Ridge.*

- *It is being shipped in a steel shipping shield to reduce exposure to cosmic ray neutrons that generate ^{56,57,60}Co, ^{68}Ge, ^{65}Zn, etc., by spallation reactions.*

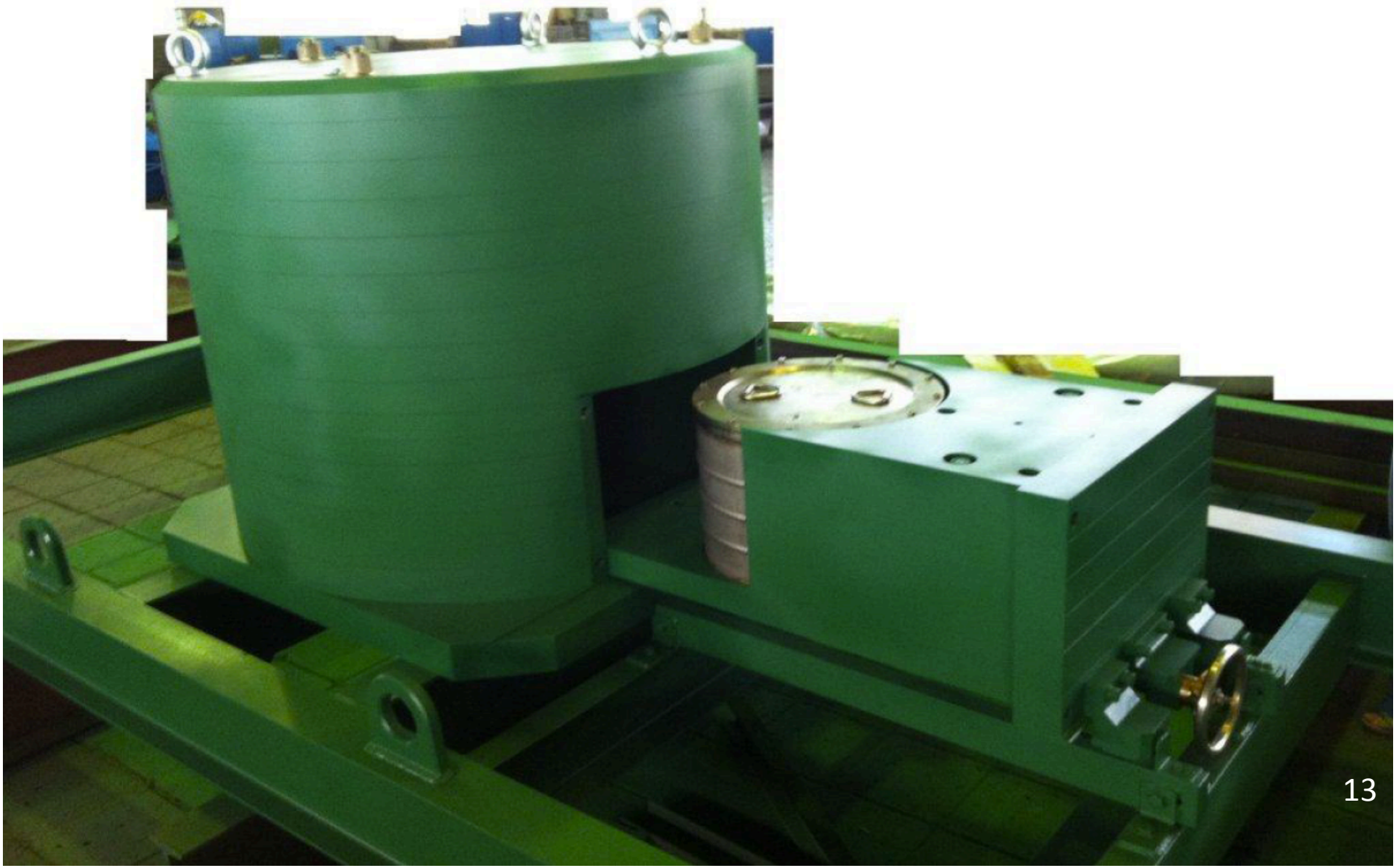
The Shipping Shield (GERDA design, built in Russia)



Shield Dimensions



A Photo of the MAJORANA SHIPPING SHIELD



Reduction of the GeO_2 and Zone Refining the Ge

- ***Unfortunately, no experienced commercial company in the U.S. would agree to reduce the oxide and zone-refine the enriched Ge.***

- ***This required the setting up of a complete facility to do this.***

- ***A building was rented, experts, some from the Ge industry, were hired, and all necessary equipment was purchased and installed.***

- ***The process is being tuned using 29 kg of $^{nat}GeO_2$.***

Reduction of the $^{nat}GeO_2$ to ^{nat}Ge Metal

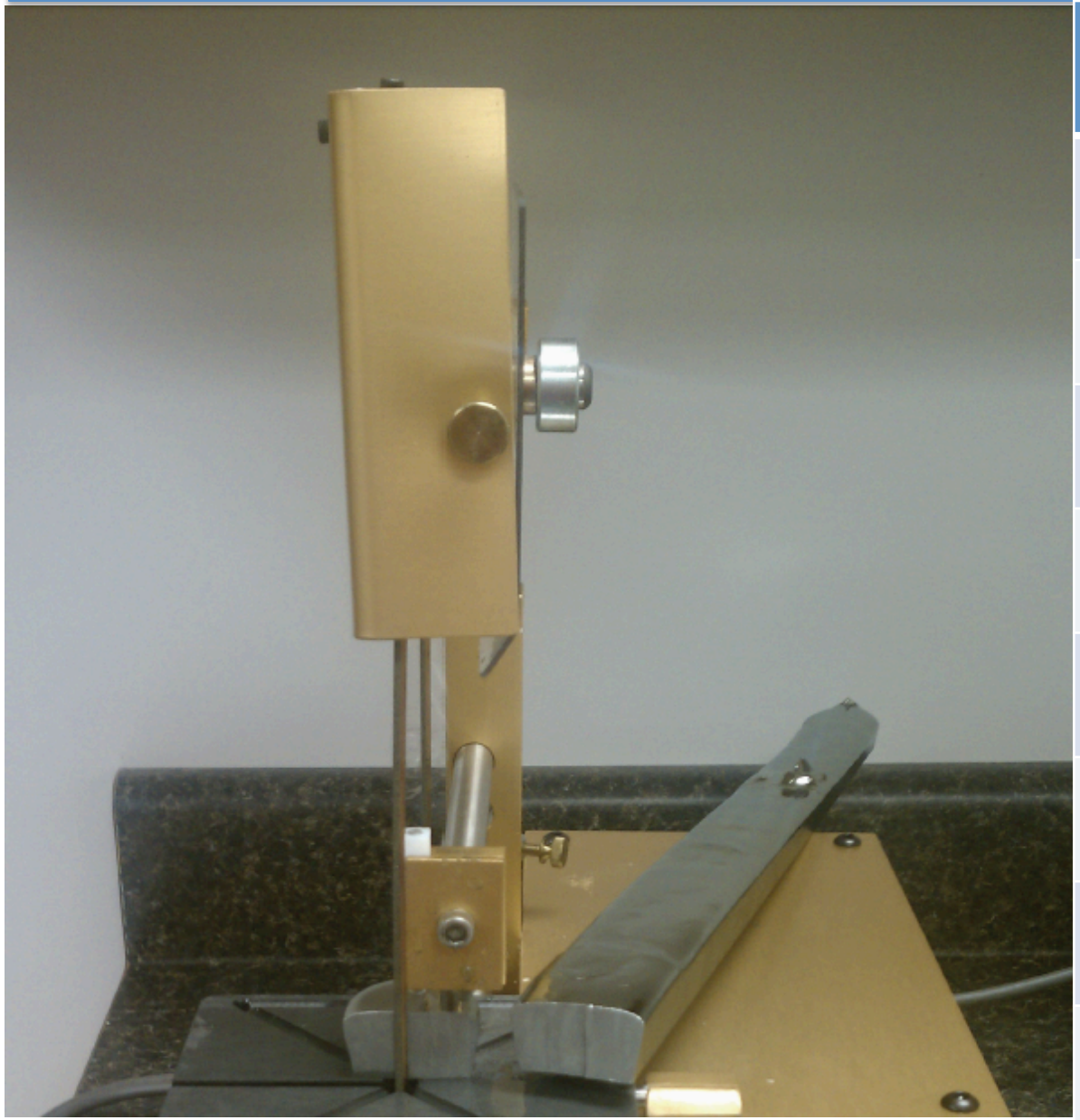
Reduction Furnace at 650 °C, Then Melt at 1030 °C.

The First 12 of 29 Bars from Reduction. Each is ~0.75 kg

Zone Refining the ^{nat}Ge

50 KW LEPEL RF Generator and Zone Refiner coils (left) Above is shown the graphite boat with about 2.5 kg of Ge moving through the RF coils.

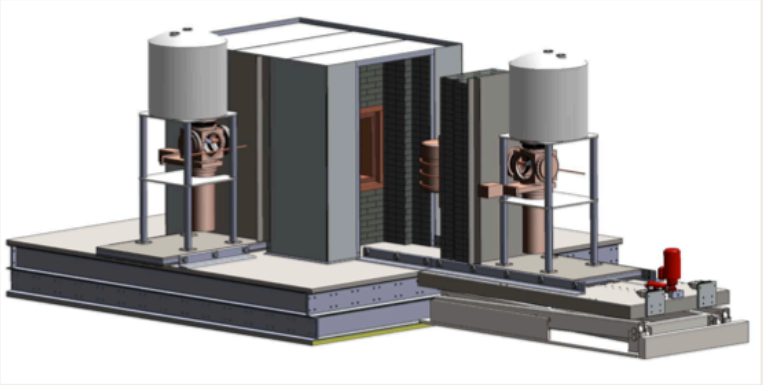
Cutting Zone-Bar I, Reduction Bars 27-29 (2155.6 g)



Zone Bar	Reduction Bars	Total Mass (g)
A	2-6	2634.0
B	7-9	1658.0
C	10-12	1694.4
D	13-15	1952.5
E	16-18	2223.2
F	19-21	2257.2
G	22-24	2251.3
H	25-26	2155.6

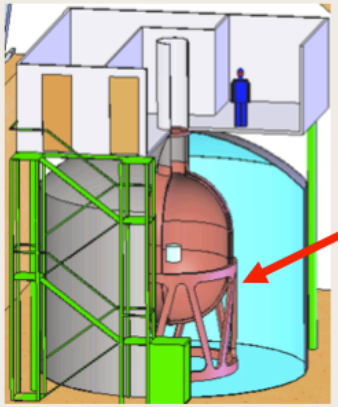
MAJORANA and GERDA for the Ton Scale Effort

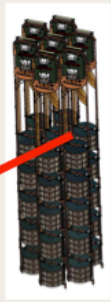
MAJORANA



- *Modules of ^{enr}Ge housed in high-purity electroformed copper cryostat*
- *Shield: electroformed copper / lead*
- *Initial phase: R&D demonstrator module: Total ~40 kg (up to 30 kg enr.)*

GERDA



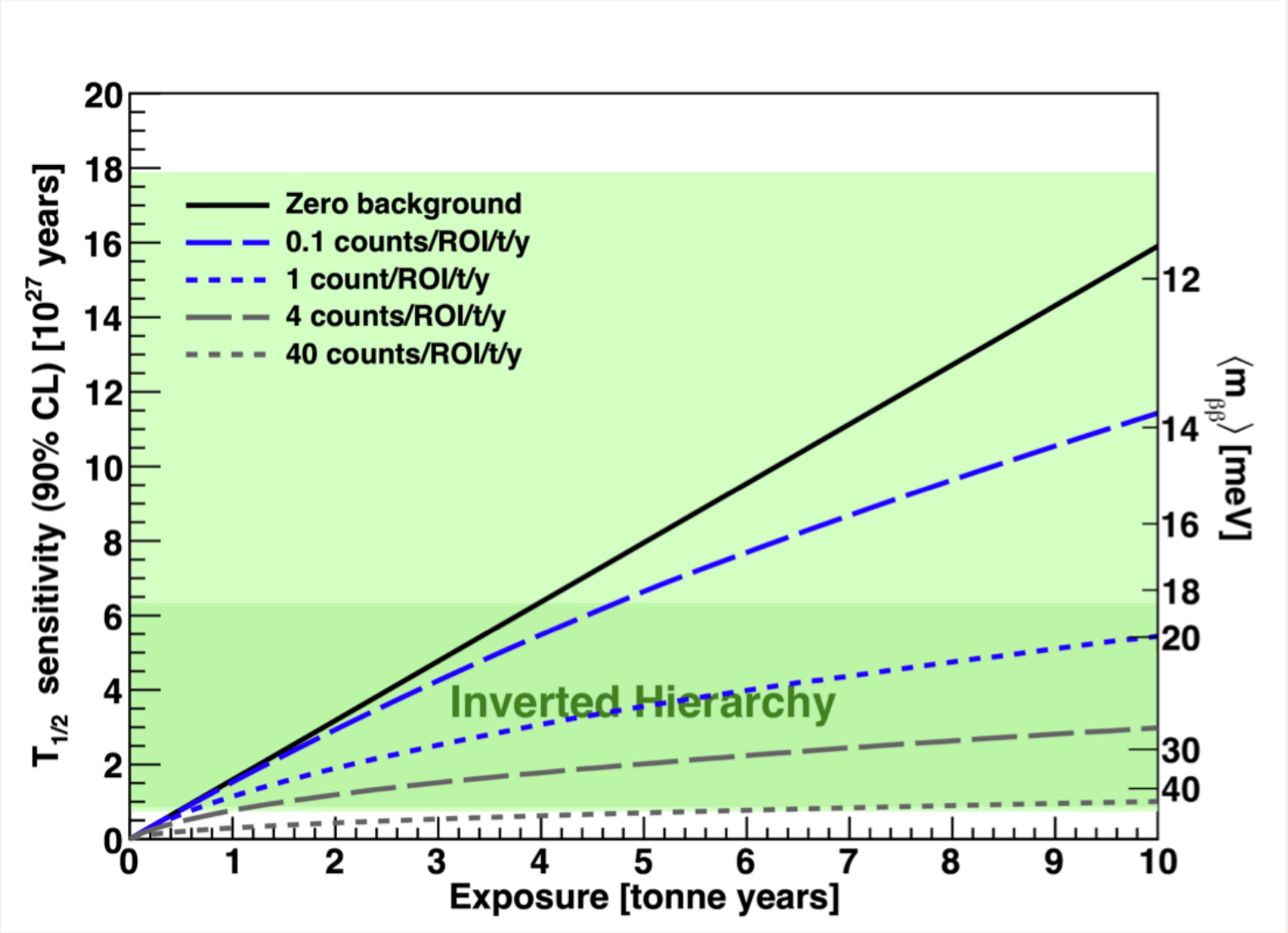


- *'Bare' ^{enr}Ge array in liquid argon*
- *Shield: high-purity liquid Argon / H_2O*
- *Phase I (2011): ~18 kg (HdM/IGEX diodes)*
- *Phase II (2012): add ~20 kg new detectors - Total ~40 kg*

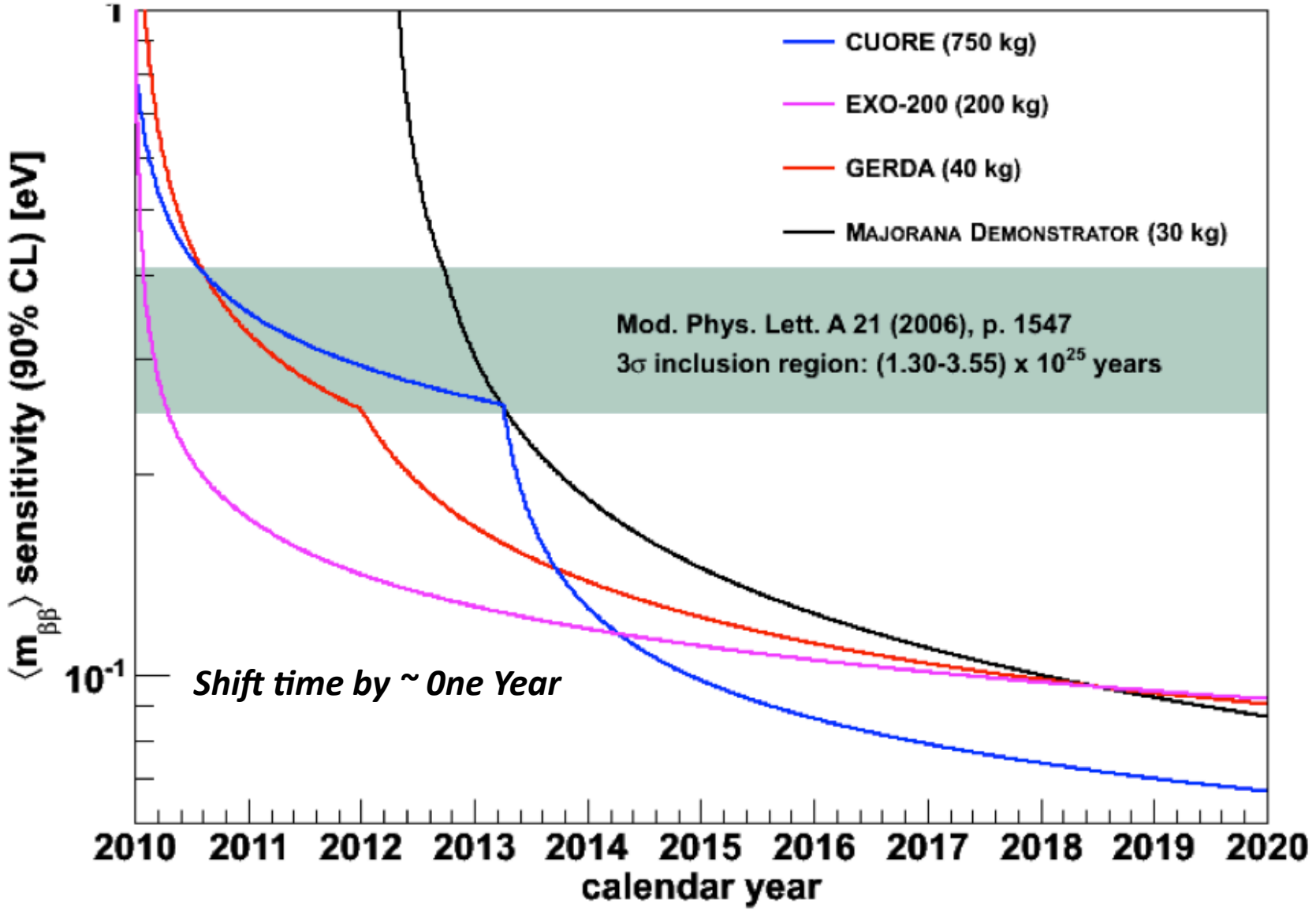
Joint Cooperative Agreement:

- *Open exchange of knowledge & technologies (e.g. MaGe, R&D)*
- *Intention is to merge for 1 ton exp. Select best techniques developed and tested in GERDA and MAJORANA*

Predictions for the Ton-Scale Experiment

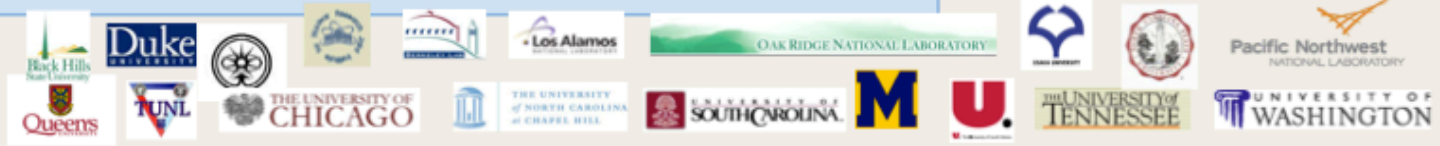


Estimated Schedules



The MAJORANA Collaboration (Feb. 2011)

Note: Red text indicates students



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