



The Majorana Neutrinoless Double-beta Decay Experiment

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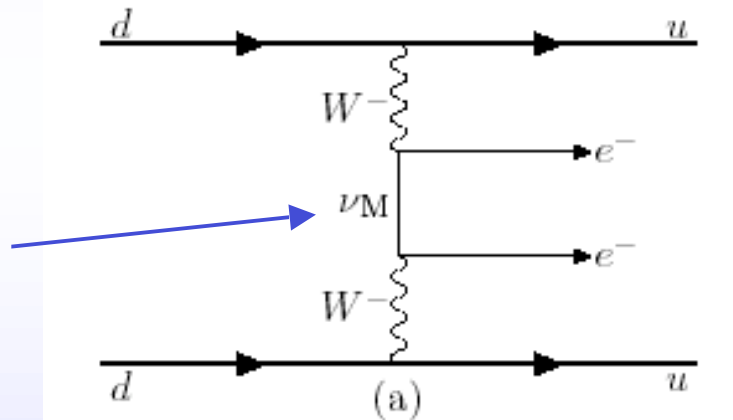
Neutrinoless Double Beta-decay

T4.00003 : Henry Primakoff Lecture: Neutrinoless Double-Beta Decay, J. Wilkerson



- Immediate Implications of Discovery:
 - Neutrino is Majorana (own antiparticle)
 - Total Lepton Number is not conserved
 - Neutrino has mass (known)
- Well-studied example: Exchange of virtual neutrino.
- Could probe absolute Mass-scale of Neutrino:

$${}^Z A \Rightarrow {}^{Z+2} A + 2e^{-}$$



$$\left[T_{1/2}^{0\nu} \right]^{-1} = (\text{Matrix Element}) \times (\text{Phase Space}) \times \langle m_{\nu} \rangle$$

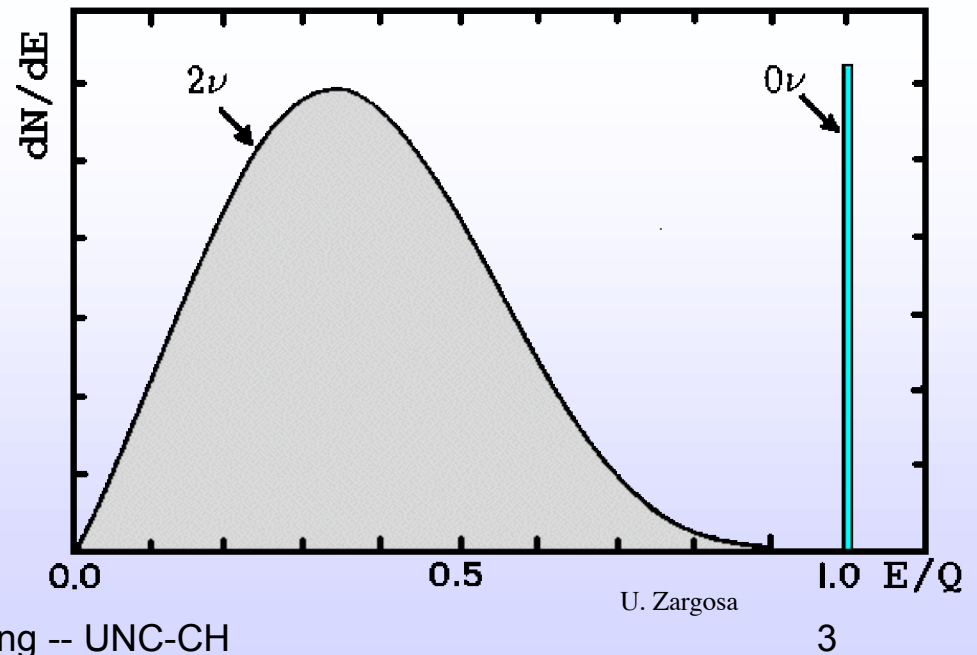


Experimental Considerations



- Measure *extremely* rare decay rates :
 $T_{1/2} \sim 10^{26} - 10^{27}$ years ($\sim 10^{13}$ x age of universe!)
- Large, highly efficient source mass.
- Extremely low (near-zero) backgrounds in the $0\nu\beta\beta$ peak region-of-interest (ROI) (1 count/t-y)

1. High Q value
2. Best possible energy resolution
 - Minimize $0\nu\beta\beta$ peak ROI to maximize S/B
 - Separate $2\nu\beta\beta/0\nu\beta\beta$

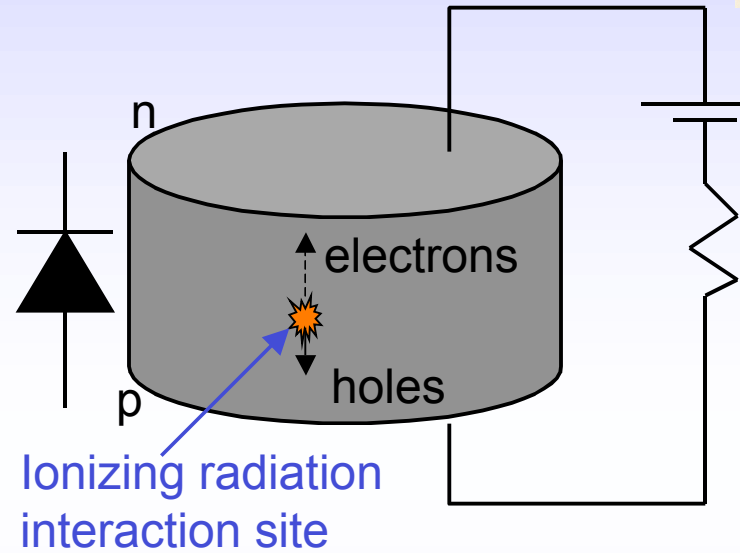




Ge Detection Principle



- Majorana uses ^{76}Ge
- Enriched HPGe Diodes -- Detector is Source.
- Excess at $Q = 2039 \text{ keV}$
- Demonstrated in IGEX, Heidelberg Moscow.
- Intrinsically clean



- ➡ **HPGe Detectors have excellent energy resolution**
- ➡ **0.16% at ROI for Majorana**



Majorana R&D

Towards a 1-tonne experiment



- Phase I: Construct 30-60 kg R&D Module
- Mixed detectors, enrichment levels
- Goals:
 - Selection of optimal detector design:
 - Highly/modestly segmented
 - Modified electrode
 - Unsegmented p-type
 - Verification of background simulation.
 - Materials, in particular cable and copper shielding.
- Continued cooperation with GERDA collaboration (MaGe, materials, Lar Shield)



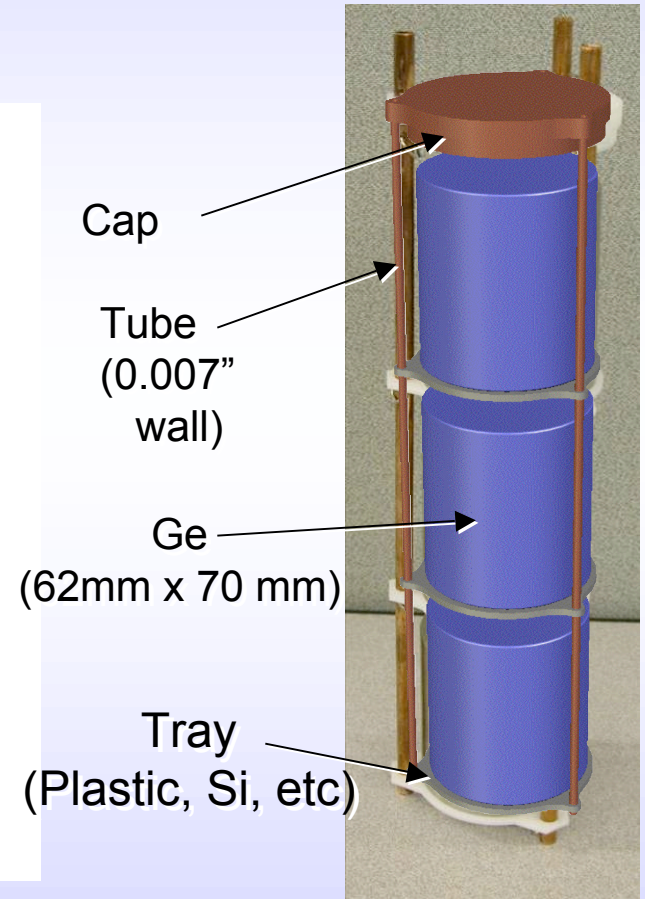
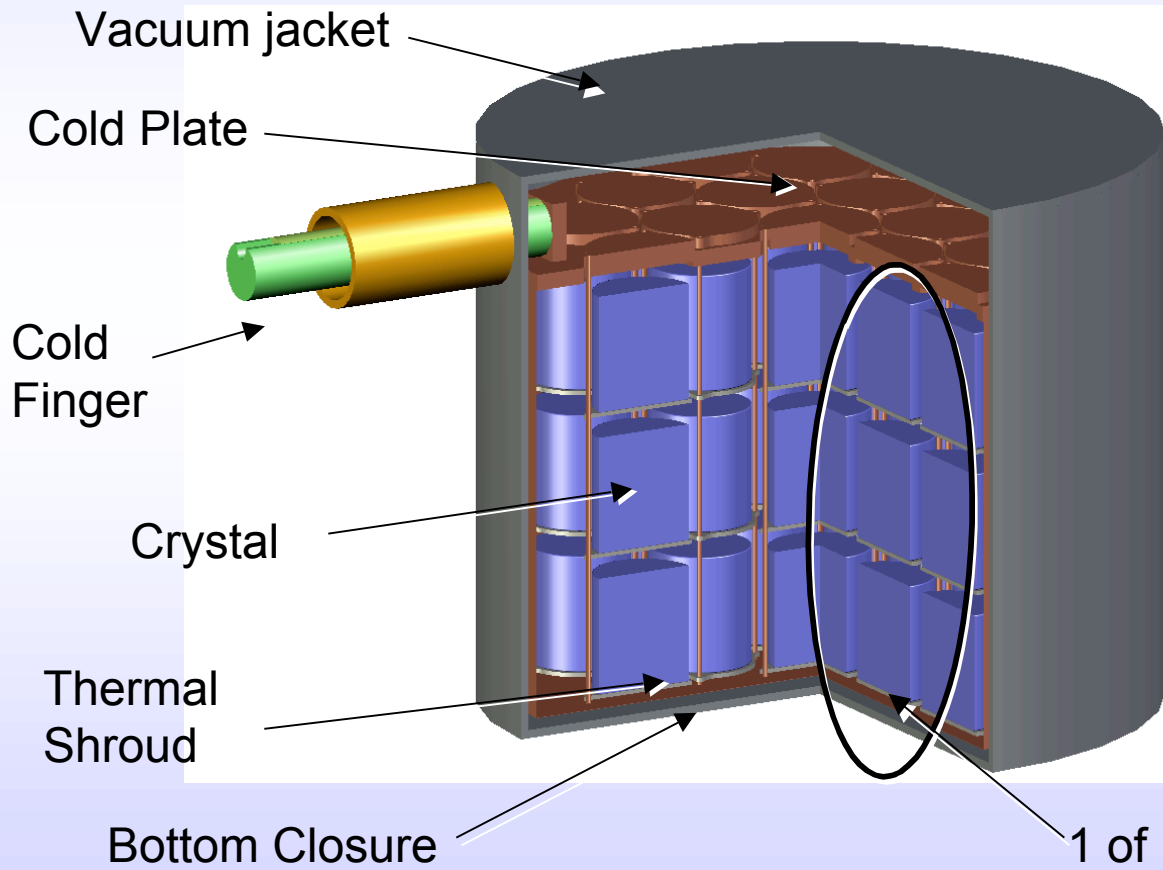
The Majorana Modular Approach



1 Concept: 57 crystal modules

Conventional vacuum cryostat made with electroformed Cu.

Scalable to 1-tonne





Background Identification



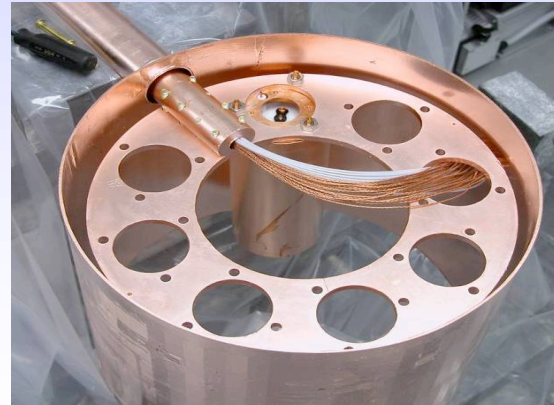
- Majorana is background limited.
- Goal: 1 event / ton-year in 4 keV ROI
- Backgrounds:
 - Natural isotope chains: ^{232}Th , ^{235}U , ^{238}U , Rn
 - Cosmic Rays:
 - Activation at surface creates ^{68}Ge , ^{60}Co .
 - Hard neutrons from cosmic rays in rock and shield.
 - $2\nu\beta\beta$ -decays.
- Need factor ~ 100 reduction over what has been demonstrated.
- Monte Carlo estimates of acceptable levels
- **Most backgrounds are multi-site. Signal is single-site**



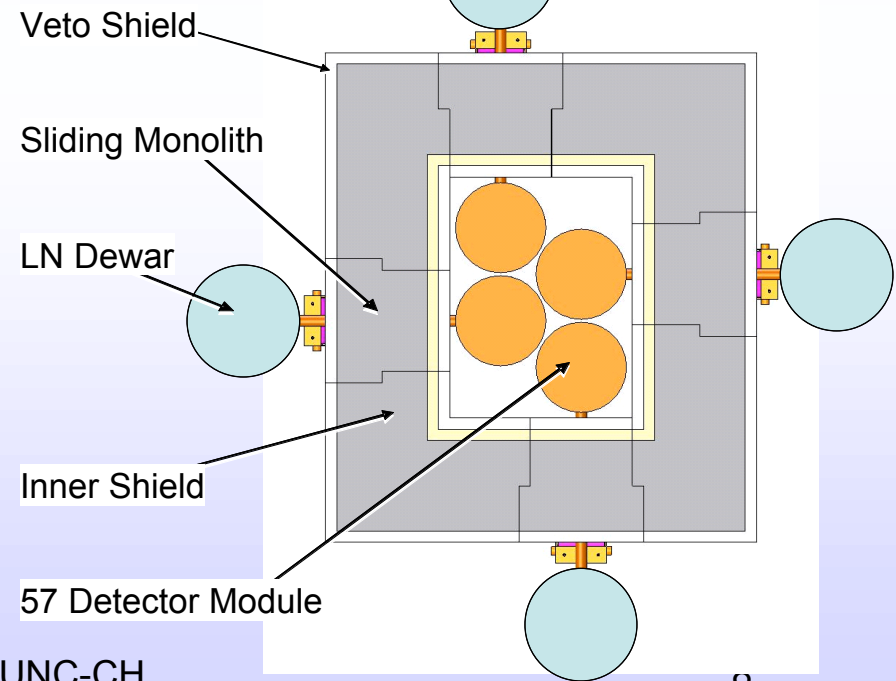
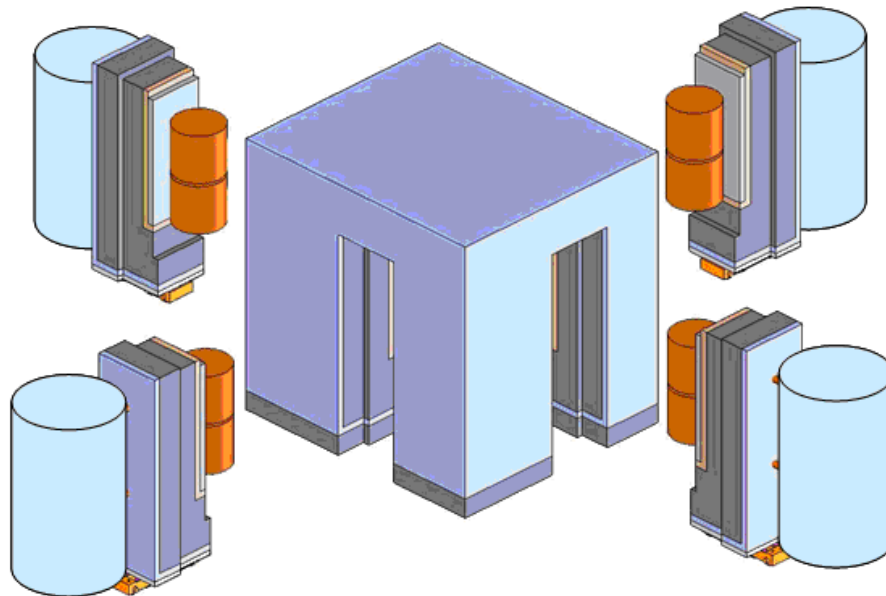
Materials and Shielding



- Ultra-radiopure materials
- Deep underground: >5000'
- Modular deployment.
- 40 cm bulk Pb, 10 cm ultra-low background shield
- Active 4π veto detector



Top view

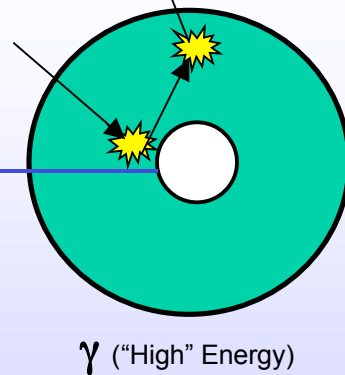
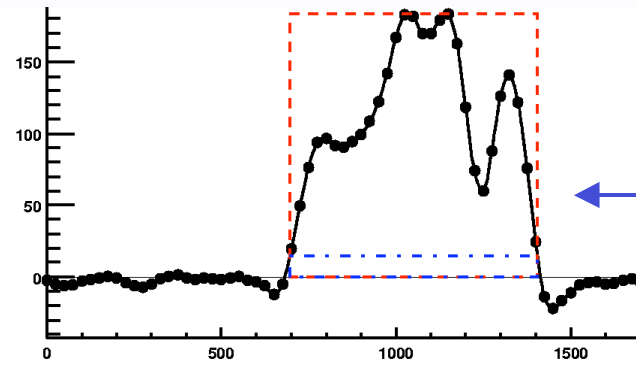
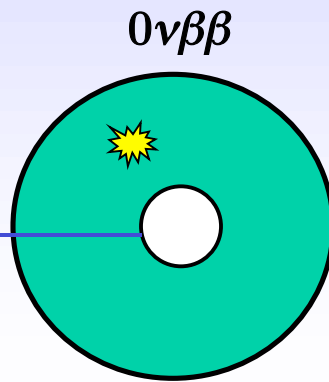
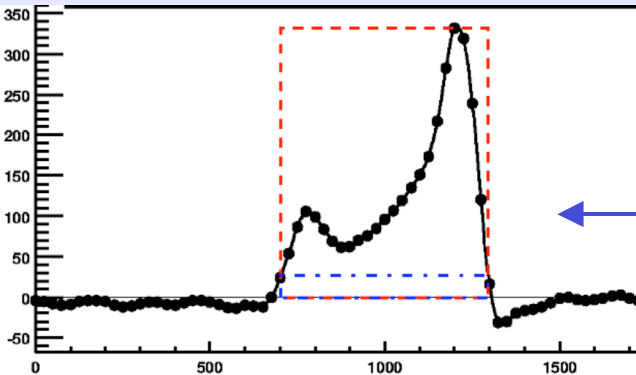


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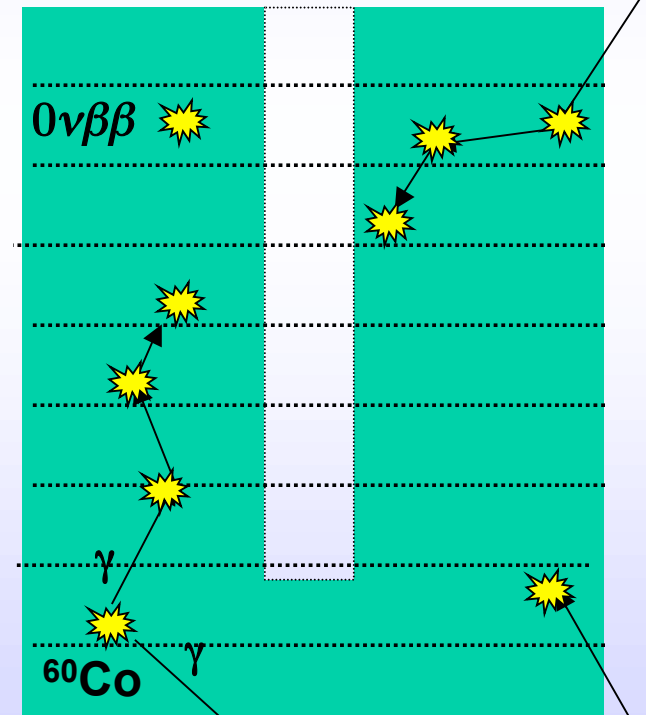
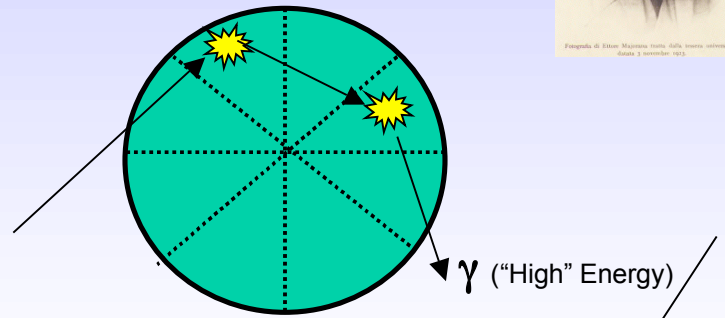
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Pulse-shape discrimination



Segmentation



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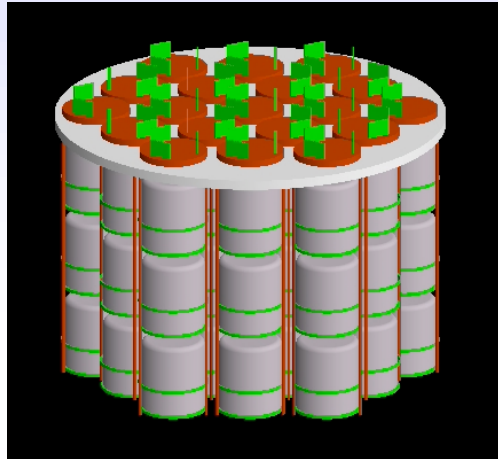
γ ('Low' Energy)
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Majorana Simulation

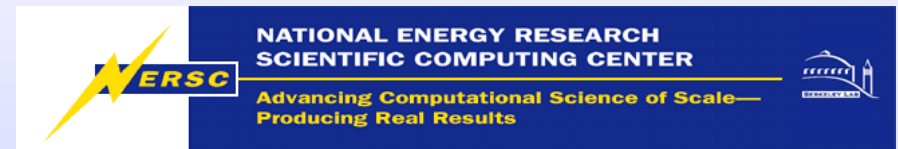
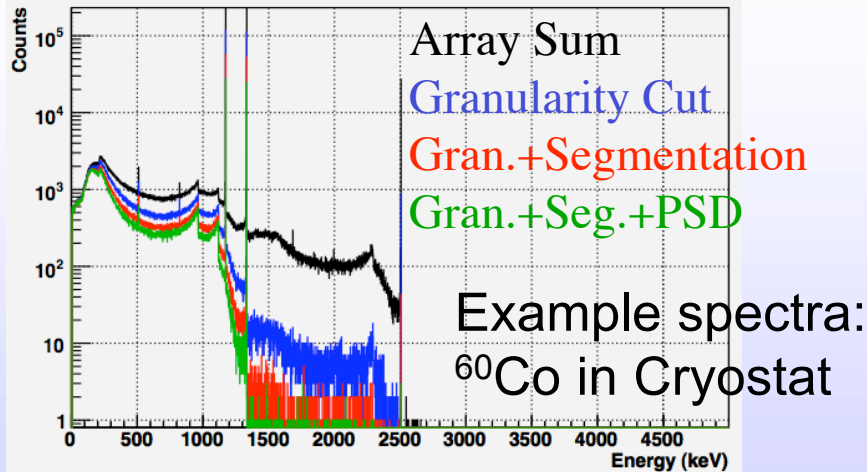


Simulated Geometry
Shields & Cryostat Removed



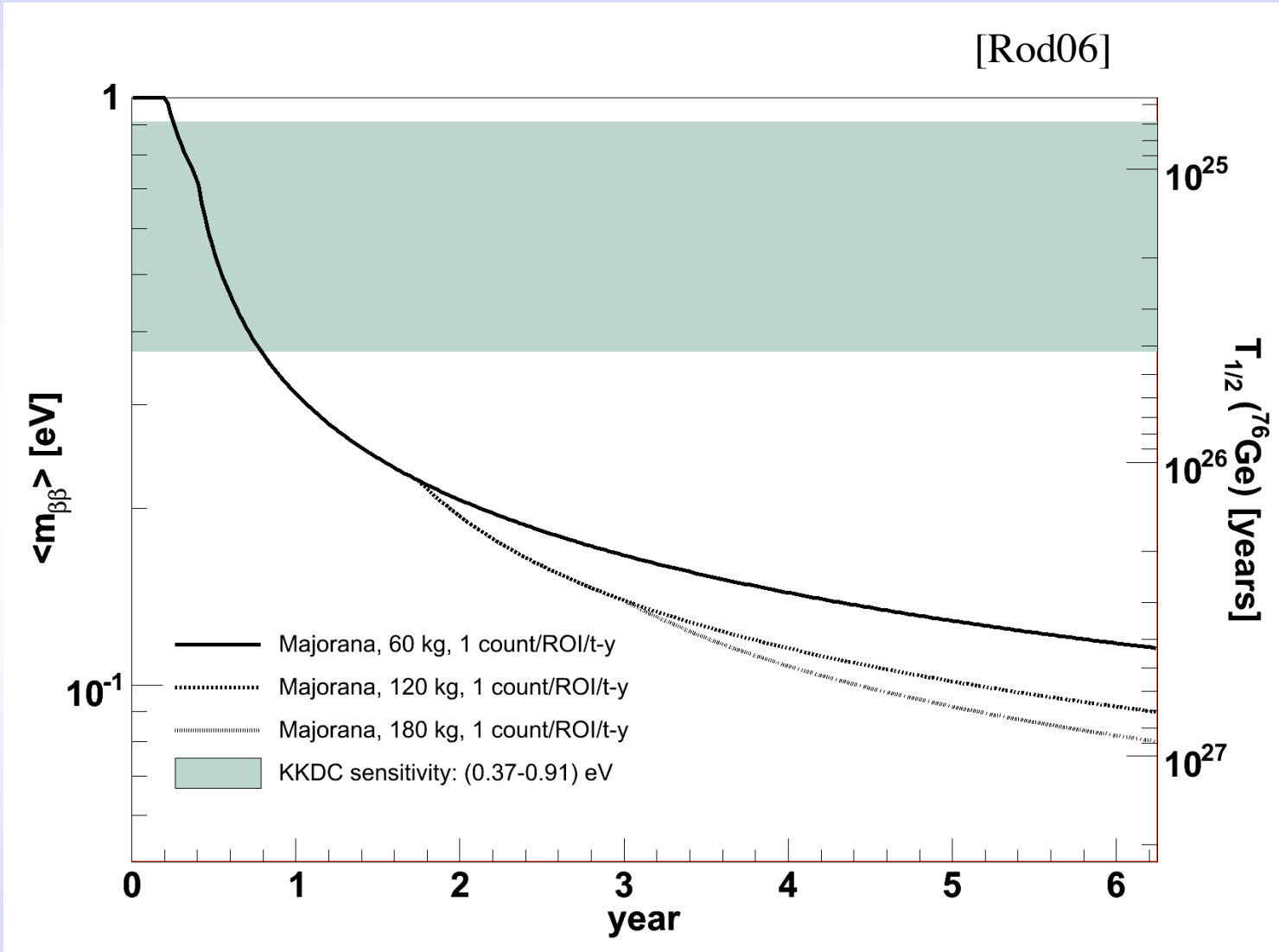
Simulation Includes:

- 57 Enriched crystal w/ deadlayers.
- LFEPs
- Support Rods
- Ge Trays
- Contact Rings
- Cryostat
- Surface Alphas
- Shields:
 - Inner, Outer Cu
 - Inner, Outer Pb
 - Neutron shield.
 - Room, rock wall.
- 45,000 CPU hours, 12,000 jobs.





Majorana Sensitivity



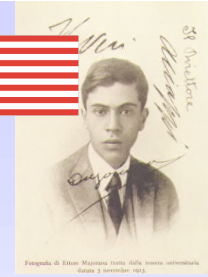


Schedule

- Submit R&D proposal this summer for prototype for 1-tonne.
- Construction in FY09.
- Collect data FY11. 30-60 kg. of enriched material.



Majorana Collaboration



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