The Majorana Neutrinoless Double-beta Decay Experiment

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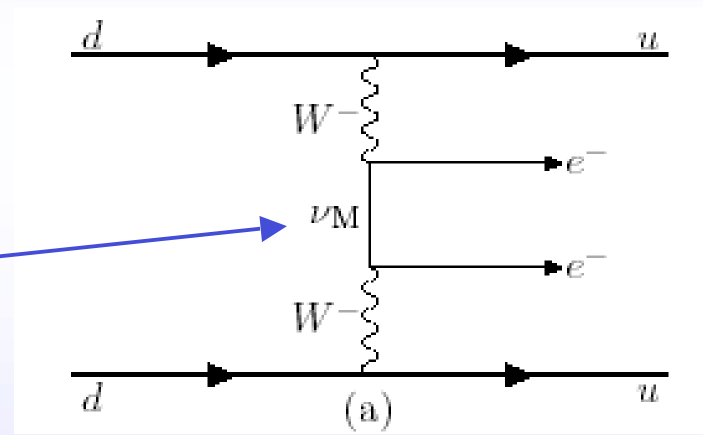
Neutrinoless Double Beta-decay

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:

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



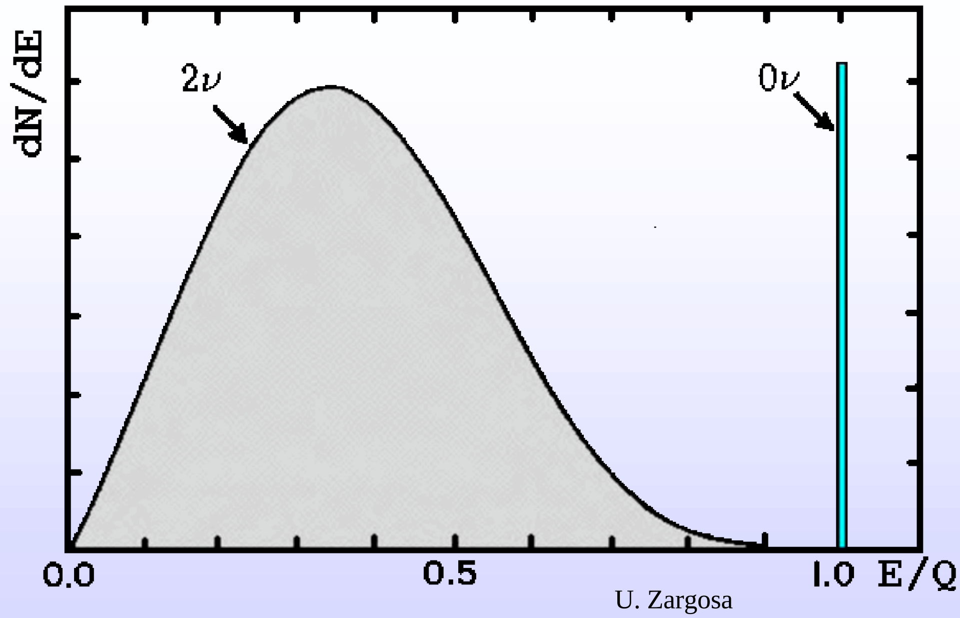
$$\left[T_{1/2}^{0\nu}\right]^{-1} = (\text{Matrix Element}) \times (\text{Phase Space}) \times \left|\langle m_{\nu} \rangle\right|$$

Experimental Considerations

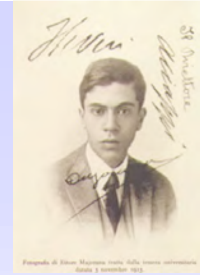
- Measure ***extremely*** rare decay rates :

  $T_{1/2}$ ~ 10^{26} -10^{27} years (~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)

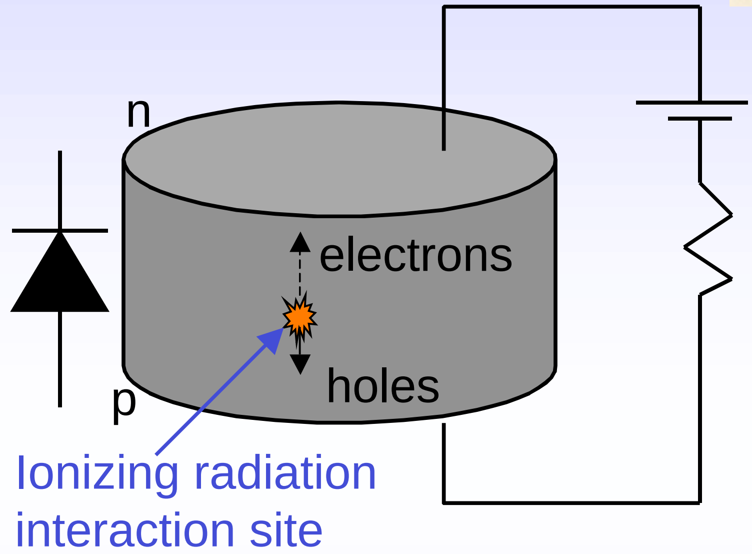
1. High *Q* value
2. Best possible energy resolution
   - Minimize 0νββ peak ROI to maximize S/B
   - Separate 2νββ/0νββ



Ge Detection Principle



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



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

Majorana R&D

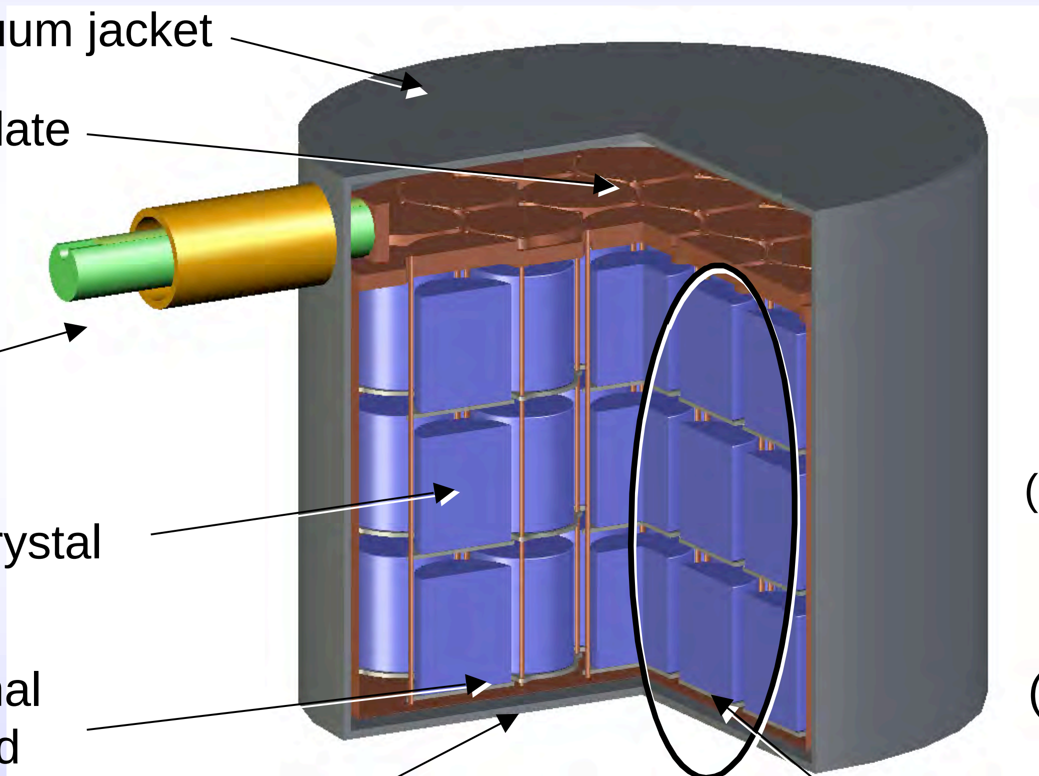
Towards a 1-tonne experiment

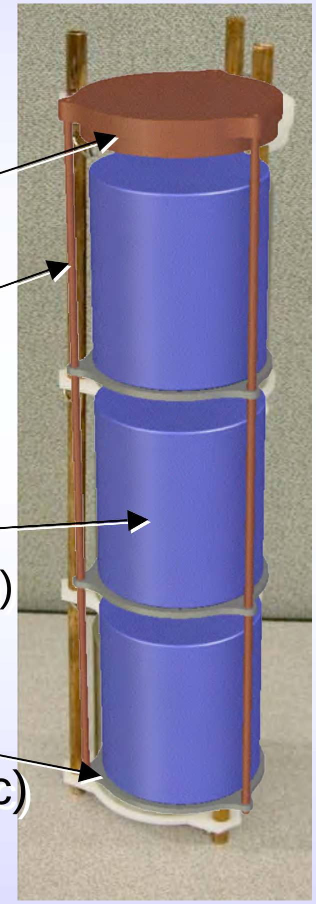
- Phase I: Construct 30-60 kg R&D Module
- Mixed detectors, enrichment levels
- Goals:
  - Selection of optimal detector design:
    - Highly/modestly segmented
    - Modified electrode
    - Unsegmented p-type
  - Verification of background simulation.
  - Materials, in particular cable and copper shielding.
- 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



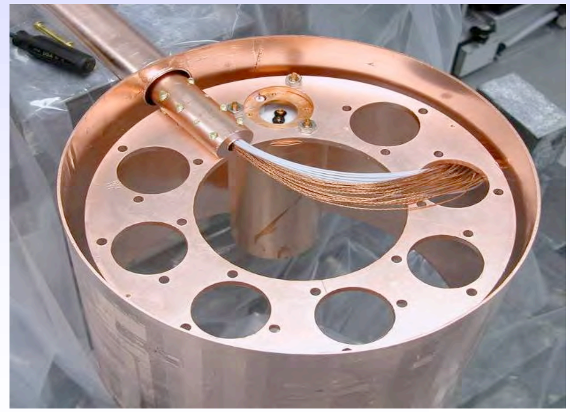


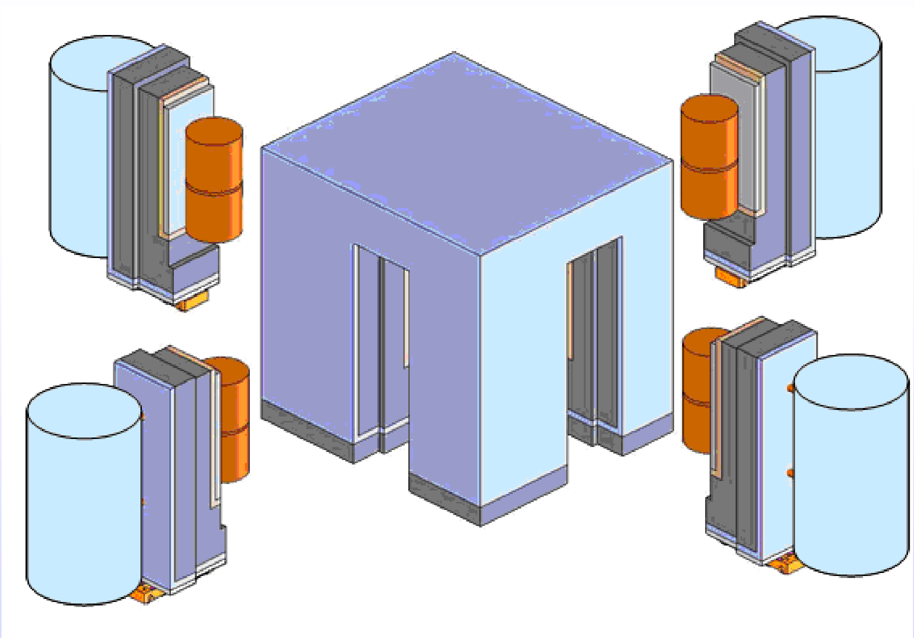
Background Identification

- 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

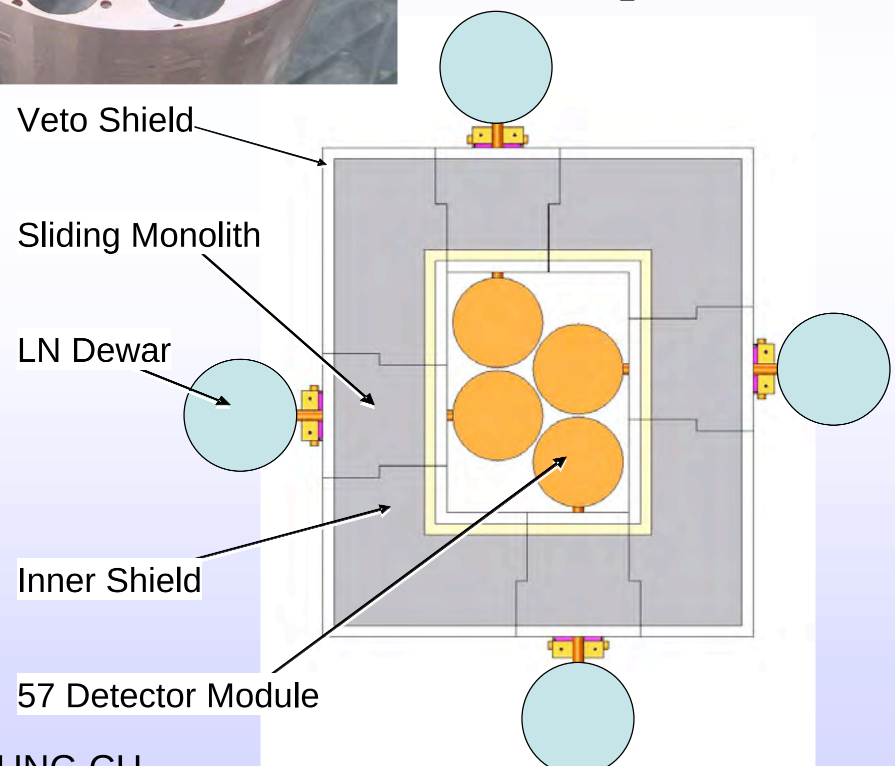
Materials and Shielding

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



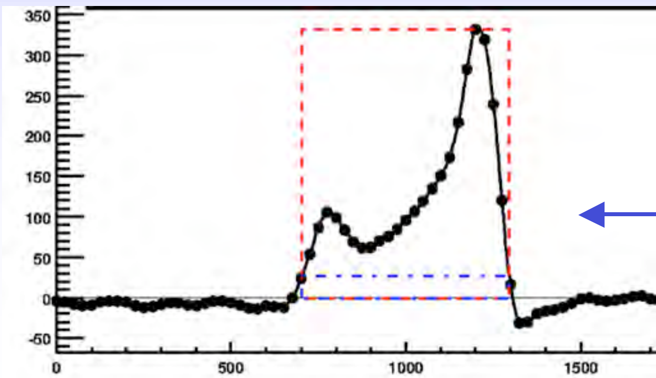


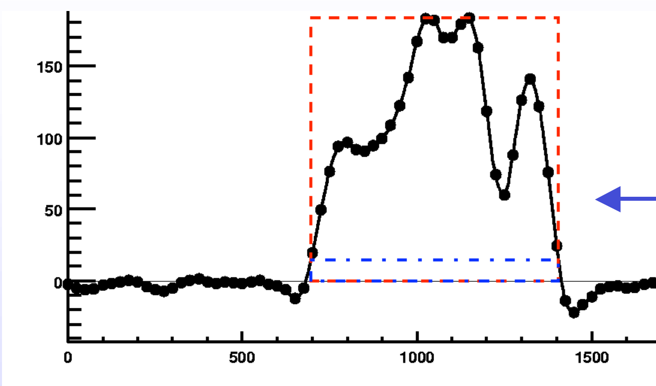
Top view

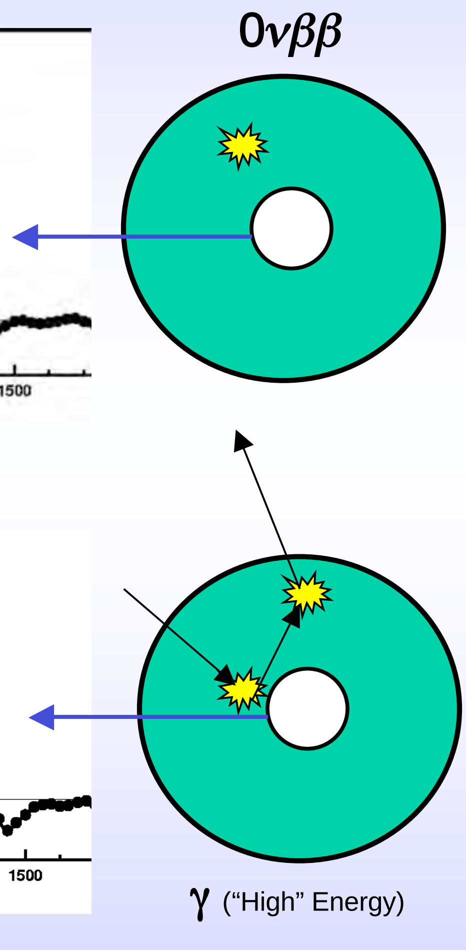


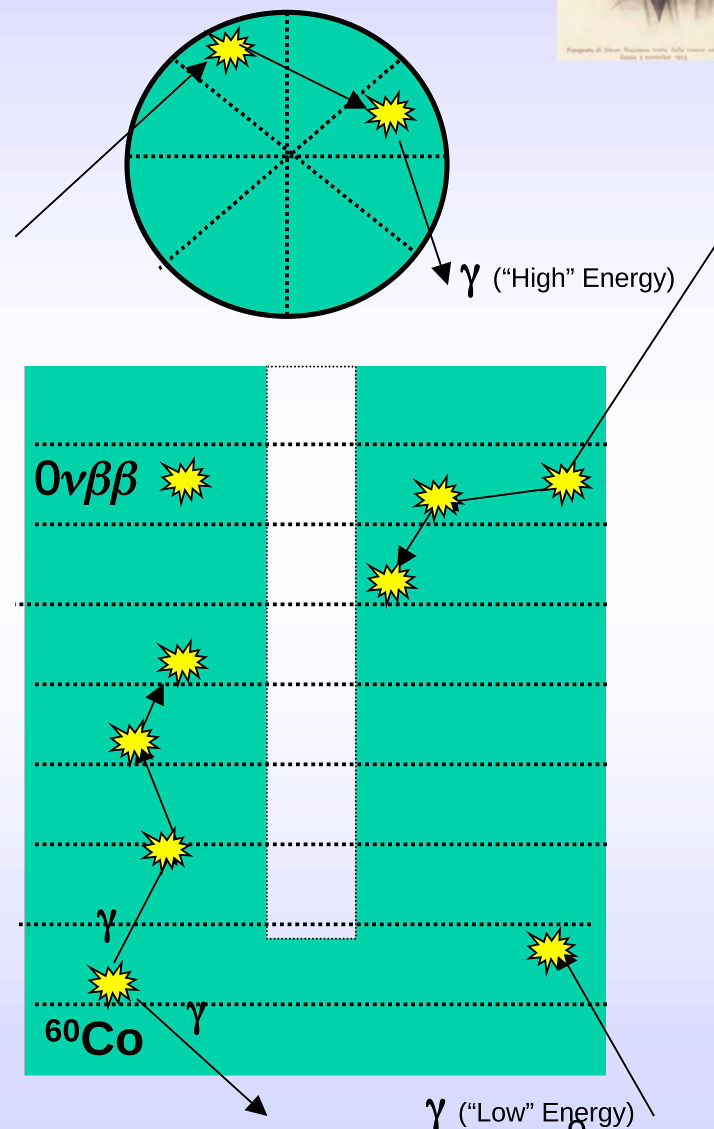
Pulse-shape discrimination

Segmentation

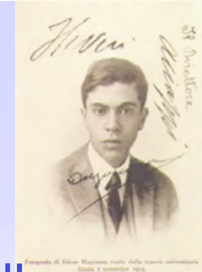




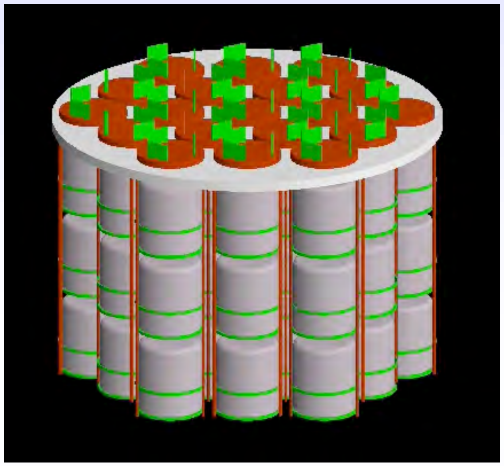


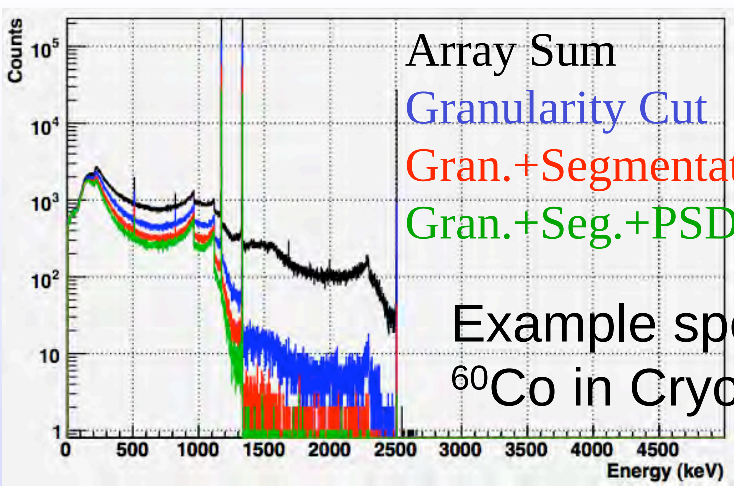


Majorana Simulation



Simulated Geometry
Shields & Cryostat Removed





Example spectra:
^{60}Co in Cryostat

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.

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Majorana Sensitivity

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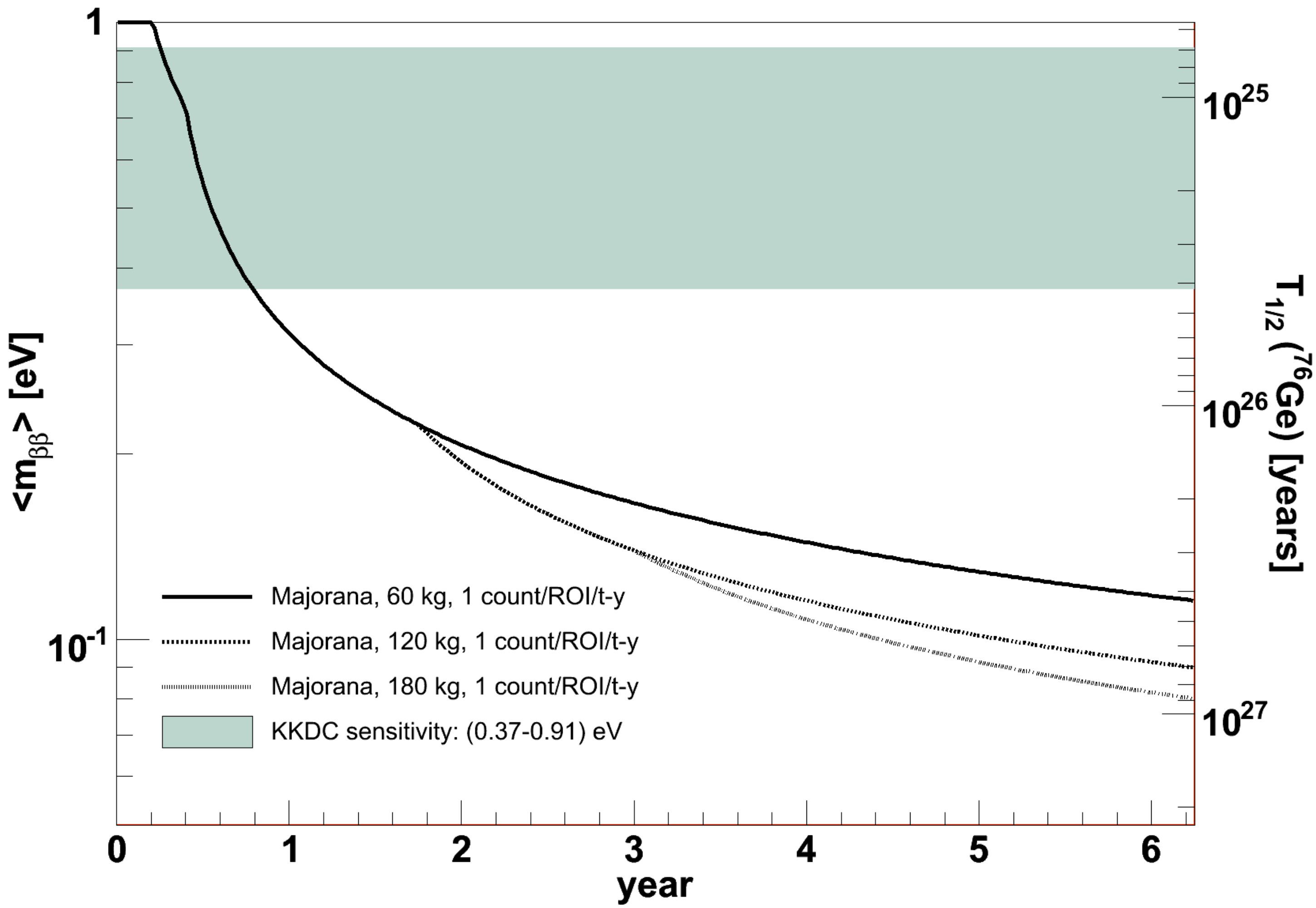

Schedule

- 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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