Office of Nuclear Physics

Majorana Needs

AARM collaboration meeting

Nov 2010

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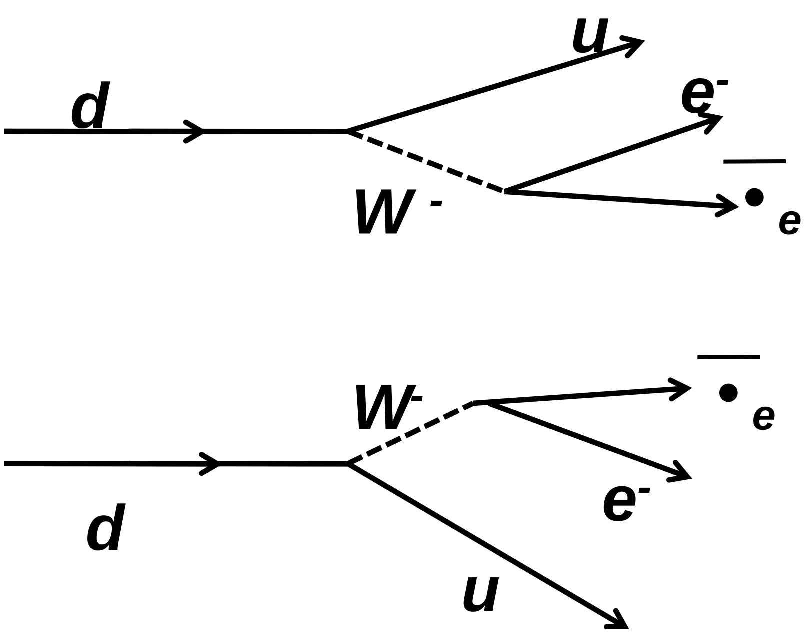
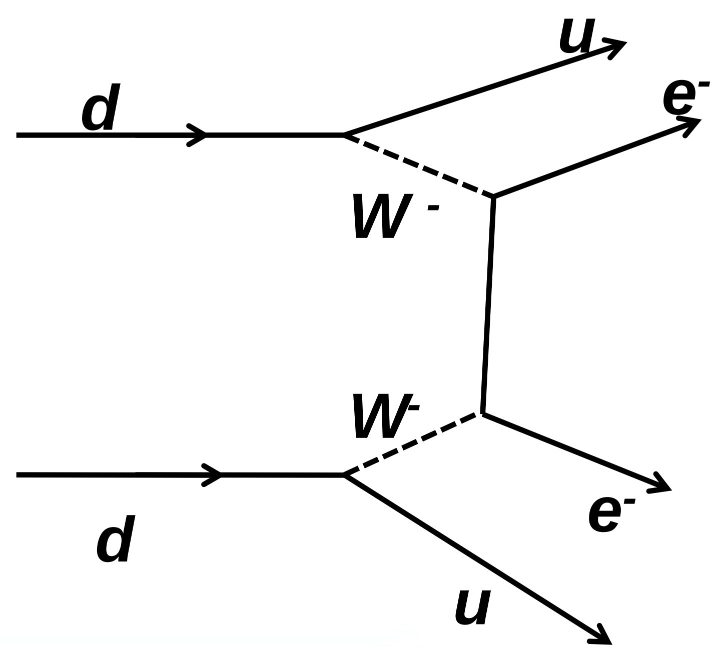
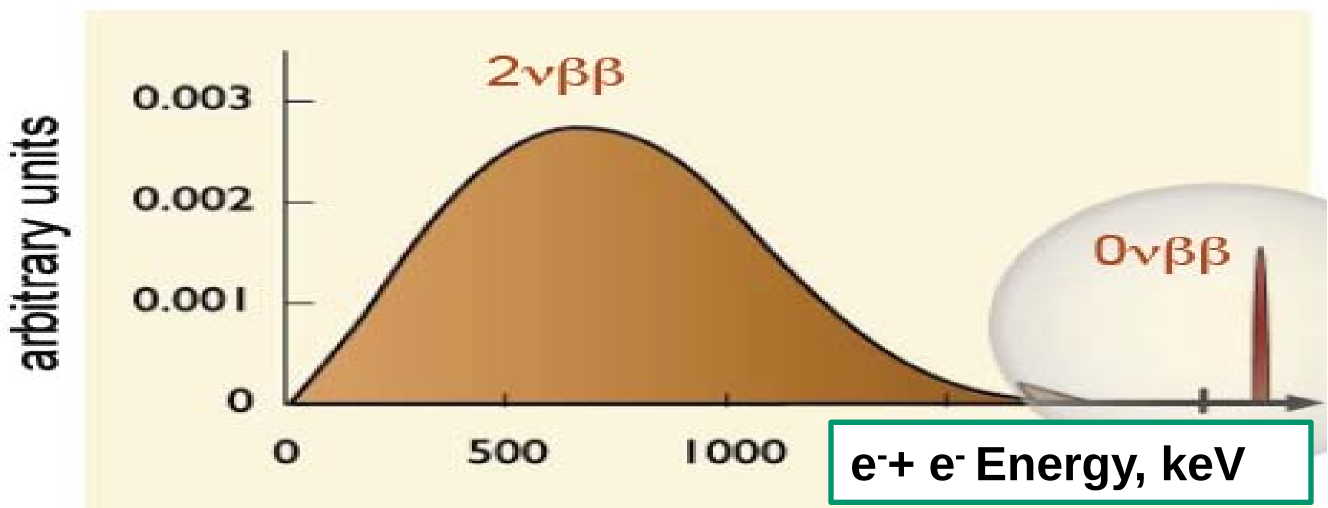
UTK / ORNL

Two neutrinos or zero neutrinos?

$$^{Z}A \Rightarrow {}^{Z+2}A + 2e^{-} + 2\bar{\nu}_e \qquad\qquad ^{Z}A \Rightarrow {}^{Z+2}A + 2e^{-}$$



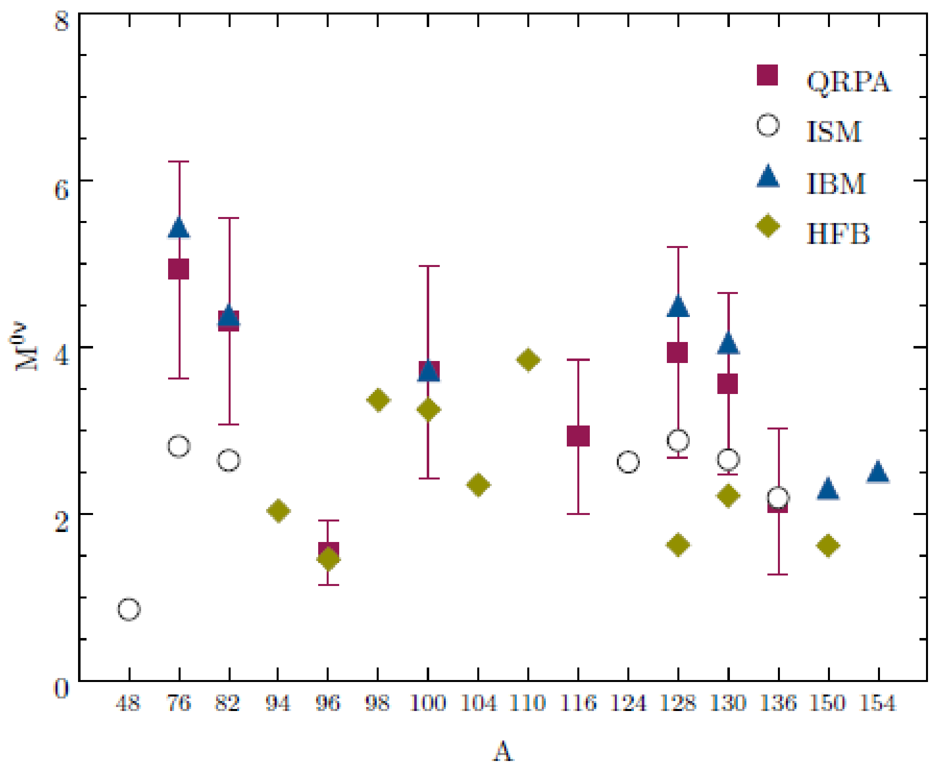




Neutrino-less Double Beta Decay

2β0ν-mode:

$$\left(T_{1/2}^{0\nu}\right)^{-1} = G_{0\nu}(Q_{\beta\beta}, Z)\,|M^{0\nu}|^2 < m_\nu >^2$$



$$\langle m_\nu \rangle = \left|\sum_{i=1}^{3} U_{ei}^2 \cdot m_i\right| \approx \left|(0.87)^2 \cdot m_1 + (0.5)^2 \cdot \sqrt{m_1^2 + \Delta m_{21}^2} \cdot e^{2i\beta} \;\; + s_{13}^2 \cdot m_3 \cdot e^{-2i(\gamma-\delta)}\right|$$

Region of Interest

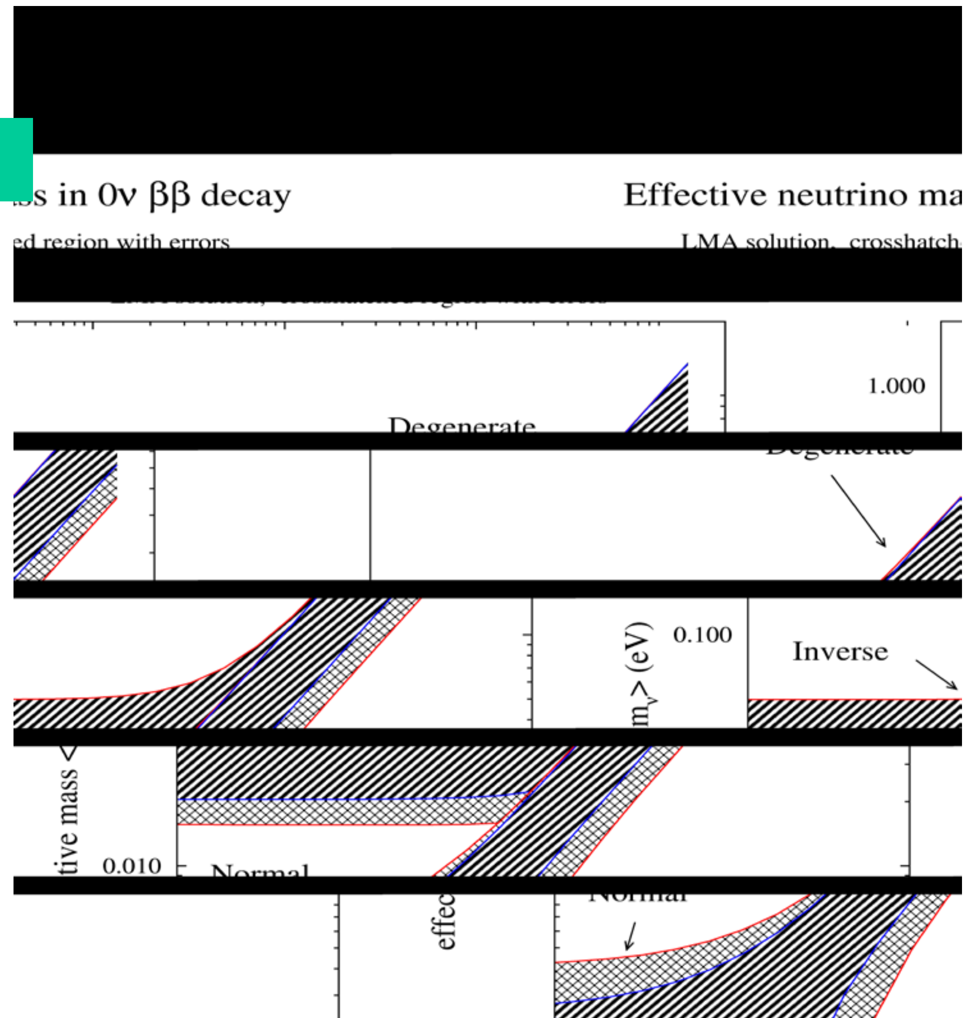
$$\langle m_\nu \rangle = \left| \sum_{i=1}^{3} U_{ei}^2 \cdot m_i \right| \approx \left| (0.87)^2 \cdot m_1 + (0.5)^2 \cdot \sqrt{m_1^2 + \Delta m_{21}^2} \cdot e^{2i\beta} + s_{13}^2 \cdot m_3 \cdot e^{-2i(\gamma-\delta)} \right|$$

Hierarchical

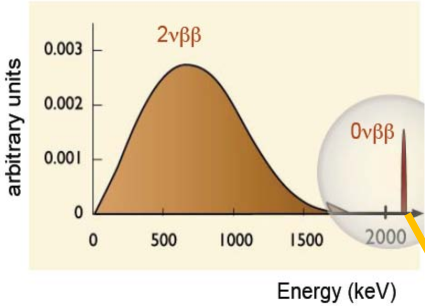
- m_{atm}
- m_{solar}

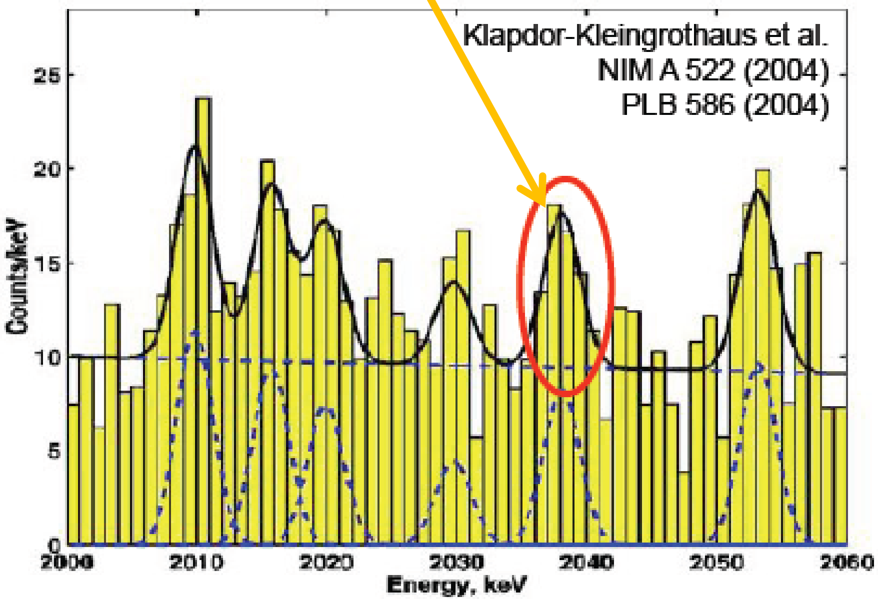
Inverse hierarchical

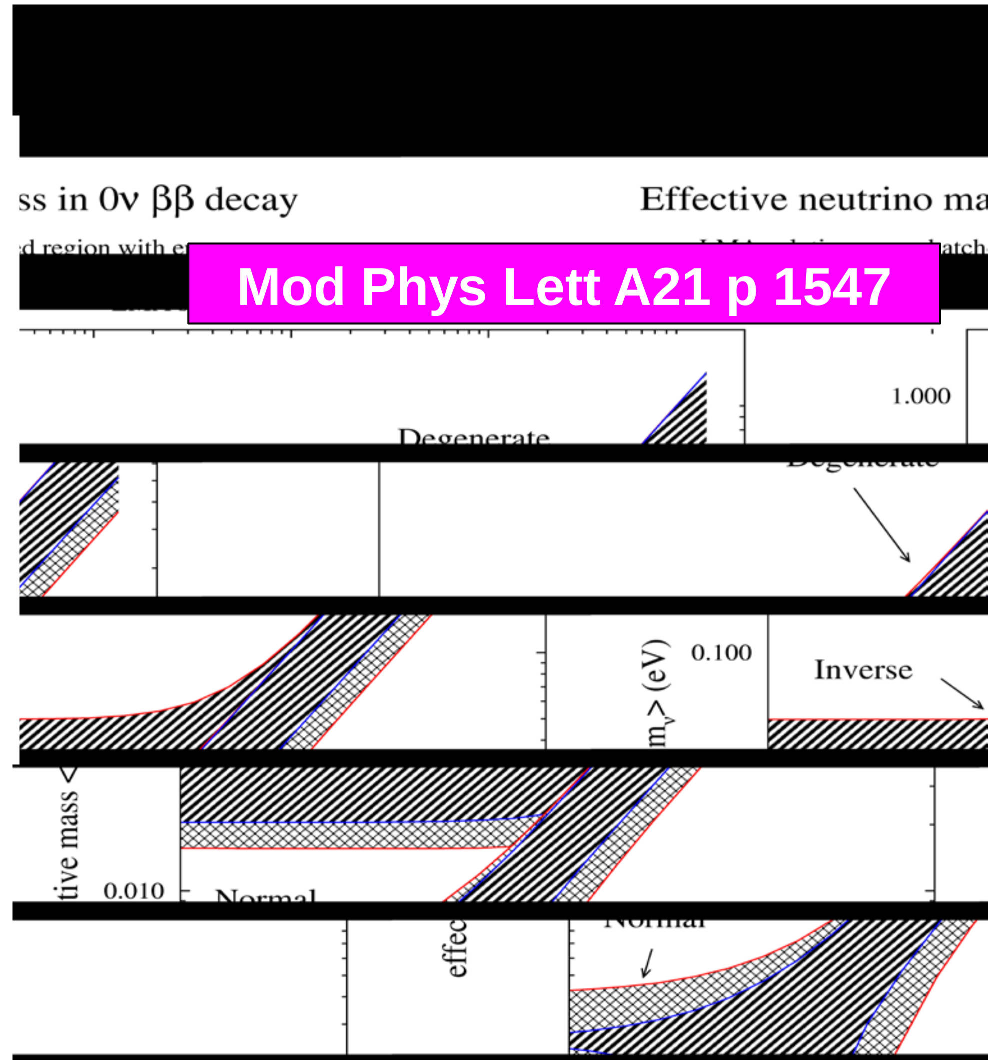
- m_{solar}
- m_{atm}



Claim of Discovery by 4 people from H-M collaboration (KKDC analysis)







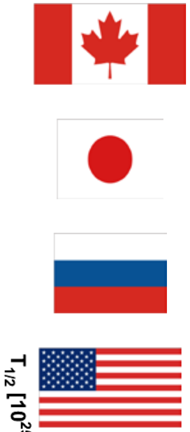
Mod Phys Lett A21 p 1547

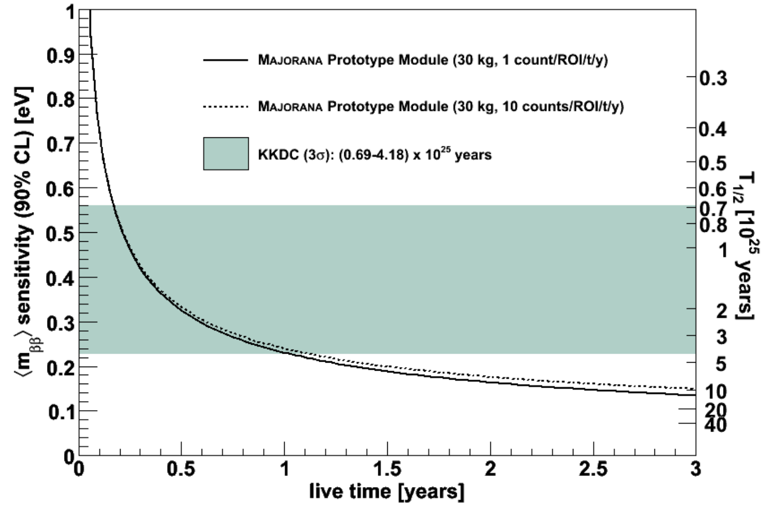
10 years of efforts
~10 kg of detectors build out of isotopicaly enriched Germanium
Located at the ultrapure environment

Claim of 4 sigma effect. Corresponds to 170-450 meV effective neutrino mass

Background level is about ~ 0.1 event/kg/y/keV

Majorana Demonstrator



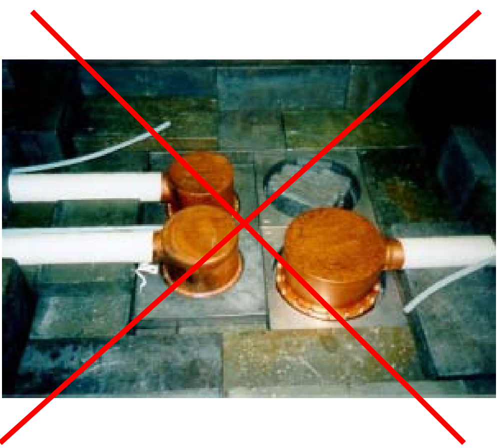


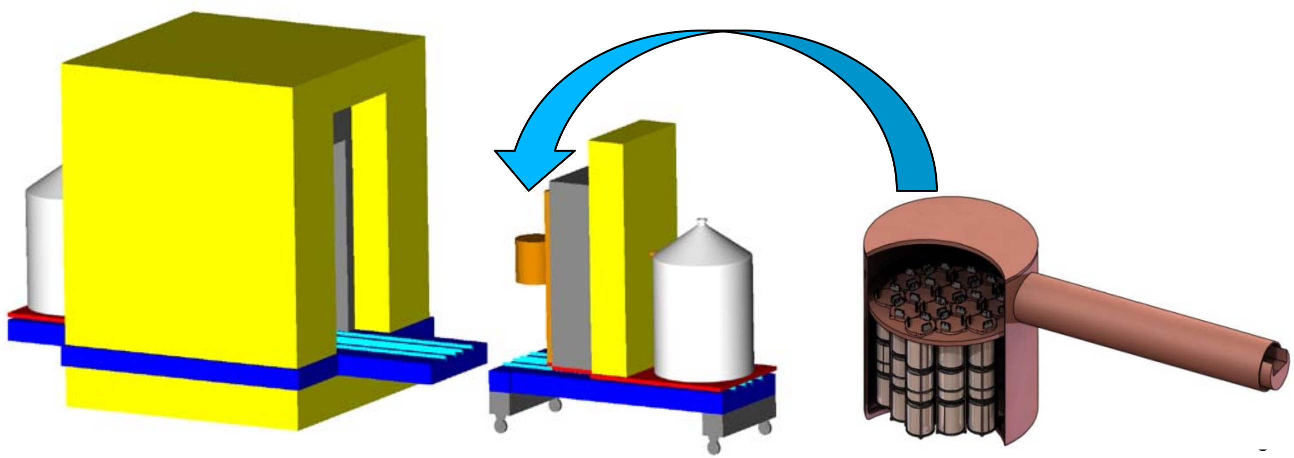
Objectives

- *Test KKDC claim after one year of operation*
- *Demonstrate path toward one ton experiment (achieve background level of 1 event per keV R.O.I. per ton per years*

Concept:

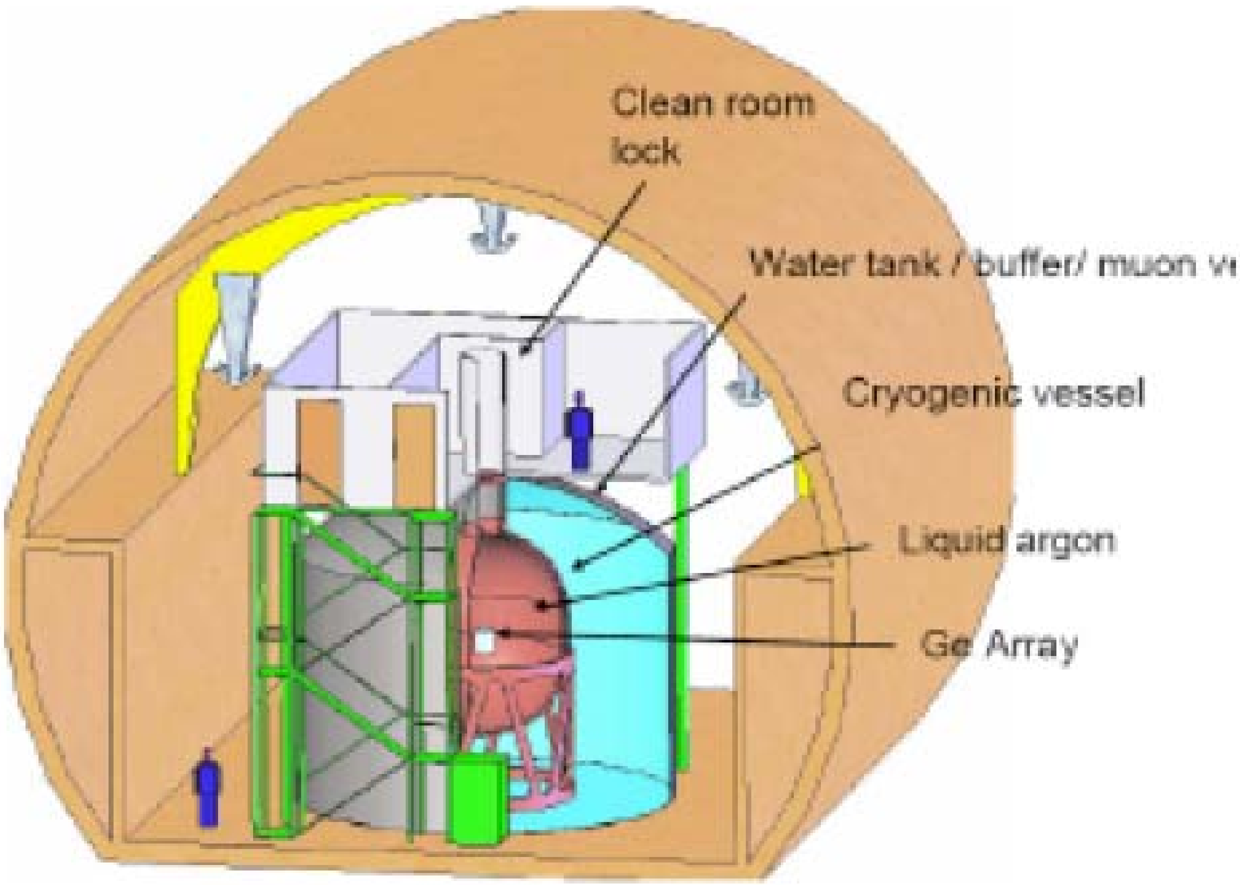
- *Multiple Ge detectors inside single large cryostat.*
- *Multiple layers of shielding outside*
- *Compact Structure*



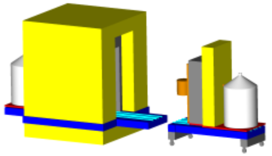


Gerda - Alternative Approach to Ge 2Beta

GERDA design



Majorana Demonstrator design



Two different approaches how to achieve best background suppression

Two collaboration are planning to merge together toward one ton experiment

Assay

For Majorana Demonstrator central task is to demonstrate low background in detectors

Goal is 1 event per keV per year to one ton of detectors !!!

One detector is ~ 1kg.Therefore background should be less than 1 count in ROI per detector after 1000 years of operation

All Components in Majorana Demonstrator should be extremely radio pure!!!

Gamma Counting

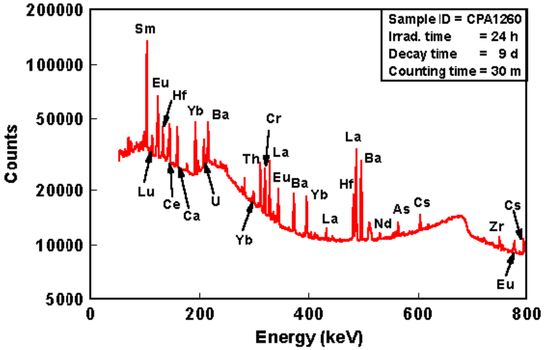
Neutron Activation Analysis

Inductively Coupled Plasma Mass Spectrometry

Gamma Counting

Samples are placed inside shielding next to the sensitive Germanium detector

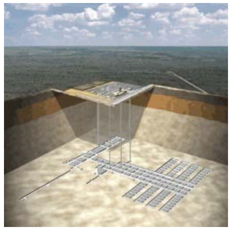
Direct counting of radioactivity



Facilities Used by Majorana Collaboration

Oroville (LBNL)
180 m.w.e.
available ~30%,

KURF (NC./VA.)
1400 m.w.e.
available ~100%



WIPP (LANL)
1600 m.w.e
available 100%

Gran Sasso
3800 m.w.e
available for unique measurements

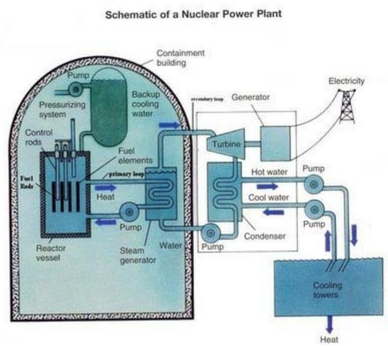
PNNL
Surface facility
Used as pre screening

Best of those facilities are just a micro “Majorana Demonstrator”

New, very low background Gamma counting facility at SUSEL/DUSEL will be of a great benefit for Majorana and especially for 1 ton experiment

Neutron Activation Analysis

Samples irradiated in a strong neutron field
Activated sample counted with Germanium detector



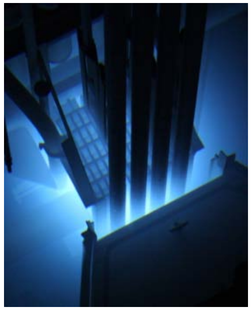
Element	Isotope	Decay chain	$t_{1/2}$
U	^{238}U	$^{239}U \rightarrow {}^{239}Np$	2.35 d
Th	^{232}Th	$^{233}Th \rightarrow {}^{239}Pa$	27 d

Facilities Used by Majorana Collaboration

MNRC (U.C. Davis) 2 MW
$1.5 \cdot 10^{13}$ n/cm^2 sec^{-1}

HFIR (ORNL) 85 MW
$2 \cdot 10^{14}$ n/cm^2 sec^{-1}

Pulstar (NCSU) 1 MW
$4\text{-}8 \cdot 10^{12}$ n/cm^2 sec^{-1}



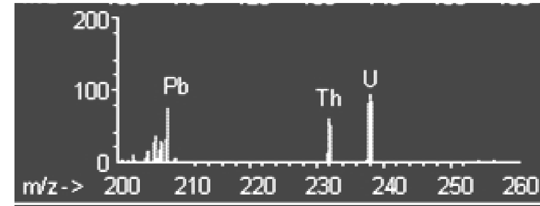
Sensitivity is 100-1000 times better that for direct Gamma Counting
A few gram sample is enough   Can be used only for light elements → plastics

Counting of irradiated samples at underground facility will bring better sensitivity for ultra clean samples.

Inductively Coupled Plasma Mass Spectrometry

ICP-MS

Samples ionized in high temperature plasma and then subject to mass spec analysis



Only a few gram sample is required, destructive

Facilities Used by Majorana Collaboration

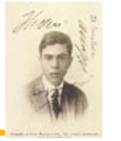
PNNL – State of the art, Sensitivity <0.001 mBg/kg

ORNL – good Sensitivity ~0.01 mBg/kg

IPTM, Russia Inexpensive, Sensitivity ~0.5 mBg/kg

New high sensitivity ICP-MS facility at DUSEL/SUSEL coupled to sample preparation lab. will be of a great benefit for Majorana

Witness preparation



One of the challenges for Majorana and future one ton experiment is accurately trace activation of samples during transportation

One of the ideas is to let witness materials travel with components of interest.

For this to be effective such witnesses should be free from activants at the beginning.

We have interest in accumulation and storage underground for cooling-off different materials which we canuse as witnesses later.

Liq Scintillator, Ge, Al, Copper,……

Witness protection - program

Radon

We like to see

Support for Rd emanation studies at Sanford Lab

Need Ultra sensitive Rd detectors, Rd tight chambers

Commercial 3.7 Bq/m^3

Specially build = 1 mBq/m^3

Large Scintillator detector(KamLAND) = 0.002 mBq/m^3

Conclusion (Needs for Majorana, 1 ton)

•Gamma counting with specially build ultrapure detectors

•ICP-MS with sample preparation laboratory

•Facility to study radon emanation

•Accumulation of pure samples for tracing

•Alpha counting

I did not mention:

•Underground copper electroforming facility → being build by Majorana collaboration
•Underground clean machine shop →being build by Majorana collaboration

•Environment monitoring
•Sites characterization
•Clean cryogens

→ Is it part of AARM or Sanford Lab?