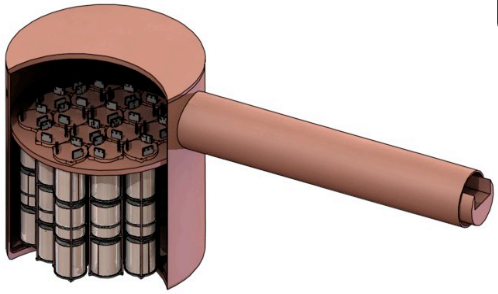
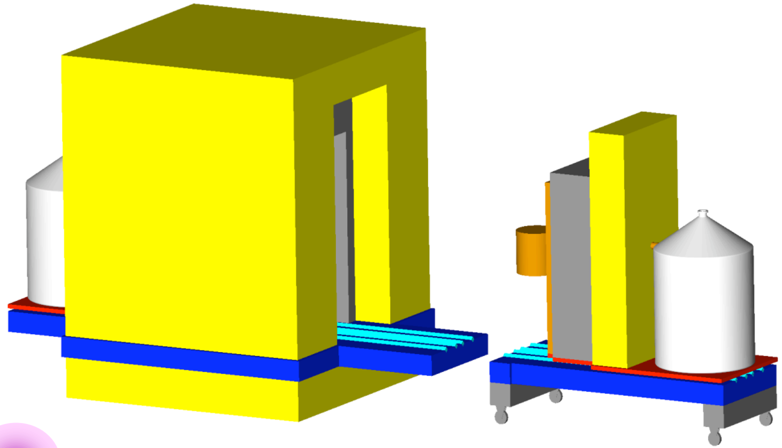
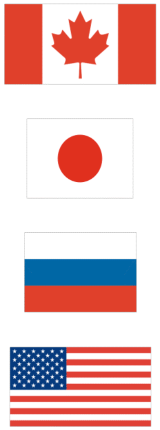
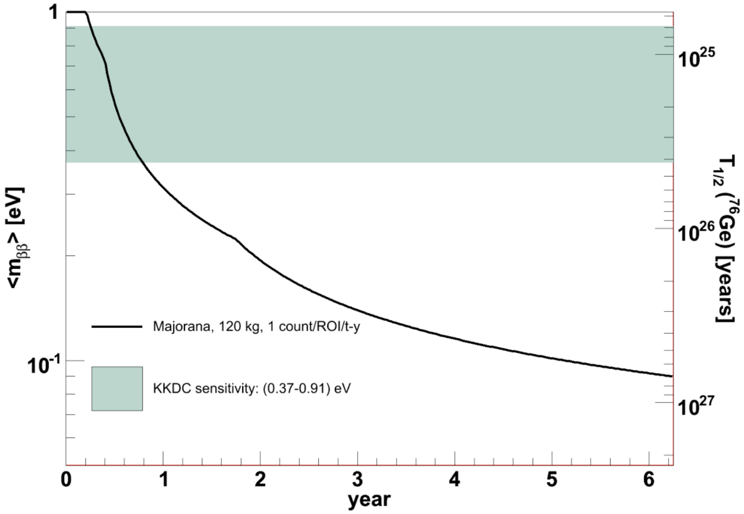
Majorana Status

J. F. Wilkerson
University of Washington









CENPA
Center for Experimental Nuclear Physics and Astrophysics
University of Washington

GERDA Collaboration Meeting
February 13, 2007

The Majorana Collaboration

Institute for Theoretical and Experimental Physics, Moscow, Russia
Alexander Barabash, Sergey Konovalov, Igor Vanushin, Vladimir Yumatov

Joint Institute for Nuclear Research, Dubna, Russia
Viktor Brudanin, Slava Egorov, K. Gusey, S. Katulina, Oleg Kochetov, M. Shirchenko, Yu. Shitov, V. Timkin, T. Vvlov, E. Yakushev, Yu. Yurkowski

Lawrence Berkeley National Laboratory, Berkeley, California
Yuen-Dat Chan, Mario Cromaz, Brian Fujikawa, Reyco Henning, Donna Hurley, Kevin Lesko, Paul Luke, Akbar Mokhtarani, Alan Poon, Gersende Prior, Nikolai Tolich, Craig Tull

Lawrence Livermore National Laboratory, Livermore, California
Dave Campbell, Kai Vetter

Los Alamos National Laboratory, Los Alamos, New Mexico
Steven Elliott, Gerry Garvey, Victor M. Gehman, Vincente Guiseppe, Andrew Hime, Bill Louis, Geoffrey Mills, Kieth Rielage, Larry Rodriguez, Richard Schirato, Laura Stonehill, Richard Van de Water, Hywel White, Jan Wouters

Oak Ridge National Laboratory, Oak Ridge, Tennessee
Cyrus Baktash, Jim Beene, Fred Bertrand, Thomas V. Cianciolo, David Radford, Krzysztof Rykaczewski, Chang-Hong Yu

Osaka University, Osaka, Japan
Hiroyasu Ejiri, Ryuta Hazama, Masaharu Nomachi, Shima Tatsuji

Note: Red text indicates students

Pacific Northwest National Laboratory, Richland, Washington
Craig Aalseth, Ronald Brodzinski, James Ely, Tom Farmer, Jim Fast, Eric Hoppe, Brian Hyronimus, David Jordan, Jeremy Kephart, Richard T. Kouzes, Harry Miley, John Orrell, Jim Reeves, Robert Runkle, Bob Schenter, John Smart, Bob Thompson, Ray Warner, Glen Warren

Queen's University, Kingston, Ontario
Fraser Duncan, Aksel Hallin, Art McDonald

Triangle Universities Nuclear Laboratory, Durham, North Carolina and Physics Departments at Duke University and North Carolina State University
Henning Back, James Esterline, Mary Kidd, Werner Tornow, Albert Young

University of Chicago, Chicago, Illinois
Phil Barbeau, Juan Collar, Keith Crum, Smritri Mishra, Brian Odom, Nathan Riley

University of South Carolina, Columbia, South Carolina
Frank Avignone, Richard Creswick, Horatio A. Farach, Todd Hossbach, George King

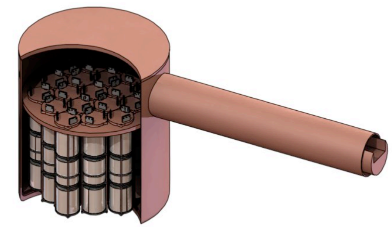
University of South Dakolta, Vermillion, South Dakota
Tina Keller, Dongming Mei

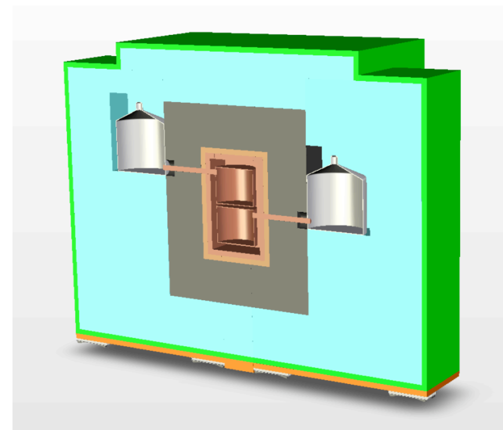
University of Tennessee, Knoxville, Tennessee
William Bugg, Tom Handler, Yuri Efremenko, Brandon White

University of Washington, Seattle, Washington
John Amsbaugh, Tom Burritt, Jason Detwiler, Peter J. Doe, Alejandro Garcia, Mark Howe, Rob Johnson, Michael Marino, Sean McGee,R. G. Hamish Robertson, Alexis Schubert, Brent VanDevender, John F. Wilkerson

The Majorana Experiment Overview

- Reference Design
  - Based on 60 kg modules, each containing 57 segmented, n-type, 86% enriched ^{76}Ge crystals
  - Scalable, with independent, ultra-clean, electroformed Cu cryostat modules
  - Enclosed in a low-background passive shield and active veto
  - Located deep underground (≥ 4500 mwe)





- Background Specification in the $0\nu\beta\beta$ peak region of interest (4 keV at 2039 keV)

  ~ **1 count/ROI/t-y** (after analysis cuts)

- Expected Sensitivity to $0\nu\beta\beta$

  (for two modules and 5 years, or 0.5 t-y of ^{76}Ge exposure)

  $T_{1/2} \geq 7 \times 10^{26}$ y (90% CL)

  Sensitivity to $\langle m_\nu \rangle$ ~ 90 meV (90% CL) ([Rod06] RQRPA NME)

  or a 20% measurement assuming a 400 meV value.

The Majorana Scientific Goals

Perform a “near background-free” search for neutrinoless double-beta decay in ^{76}Ge

- Probe the quasi-degenerate neutrino mass region above 100 meV.
- Demonstrate background levels that would justify scaling up to a 1-ton or larger experiment.
- If the Klapdor-Kleingrothaus claim of an observation of $0\nu\beta\beta$ in ^{76}Ge is confirmed, do a precision measurement (20%).

Recent Majorana technical progress

- Progress in investigating potential backgrounds that can become relevant at the 1 ton scale :
  - Development of MaGe simulation framework (paper in preparation with GERDA)
  - Extensive study of backgrounds for the Majorana reference design (paper in preparation)
  - Understanding sensitivity to neutron induced backgrounds underground (Mei and Hime)
  - Geant4 validity for simulations of muon-induced neutrons (paper in preparation).
  - Studies of sensitivity to surface contaminations (paper in preparation).
  - Sensitivity of Ge detectors to neutron backgrounds using an AmBe source (paper in preparation).
  - Studies on potential (n, n'γ) backgrounds at TUNL and LANSCE.
- Effectiveness of background cuts using a Clover detector (Elliott *et al.*)
- Studies of segmented detectors and background reduction methods using the MSU detector (36) and the LLNL (40) Ge detector (paper in preparation).
- Studies of effectiveness of background reduction using SEGA and the TUNL HIGs facility (paper in preparation).
- Quantitative study comparing sensitivities for different detector configurations and segmentation schemes.
- Constructed large prototype electroformed cryostat (MEGA) and operated with multiple crystals.
- Development of improved techniques to electroform large, ultra-clean Cu cryostats (Hoppe *et al.*).
- Progress on pushing ICP-MS assay sensitivities to the sub μBq/kg level (Hoppe et al. paper).
- Exploration of an improved modified electrode Ge detector (Collar *et al.* papers submitted).
- Study of sensitivity of two neutrino and neutrinoless double-beta decay to excited states in ^{76}Ge (Kazkaz dissertation and paper in preparation)
- Development of an improved Geant4 surface sampling routine (paper in preparation).

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Evaluation of Detector Configurations and Segmentation Schemes

Quantitative analysis of reference design and alternatives considering all aspects potentially impacting performance, cost, and schedule.

- Evaluation of detector configuration and segmentation schemes for the MAJORANA experiment
- Quantitatively compare possible detector implementations
- Redefine reference design if needed
- Identify and quantify critical risk to performance, cost, and schedule
- Provide guidance for R&D to minimize risk

- Status of evaluation:
  - Made significant progress…

… more work needs to be done …

Approach - Details

Identify/ Select Configurations

Identify all issues potentially impacting performance, cost, and schedule

Manufacturer
Production & Delivery schedule

Mont-Carlo simulations

Determine impact of these issues

Engineering
•Mechanical (cryostat)
•Electrical

Statistical analysis

R&D

Systematic analysis:
Signal and background consistency
Signal robustness
Unforeseen backgrounds

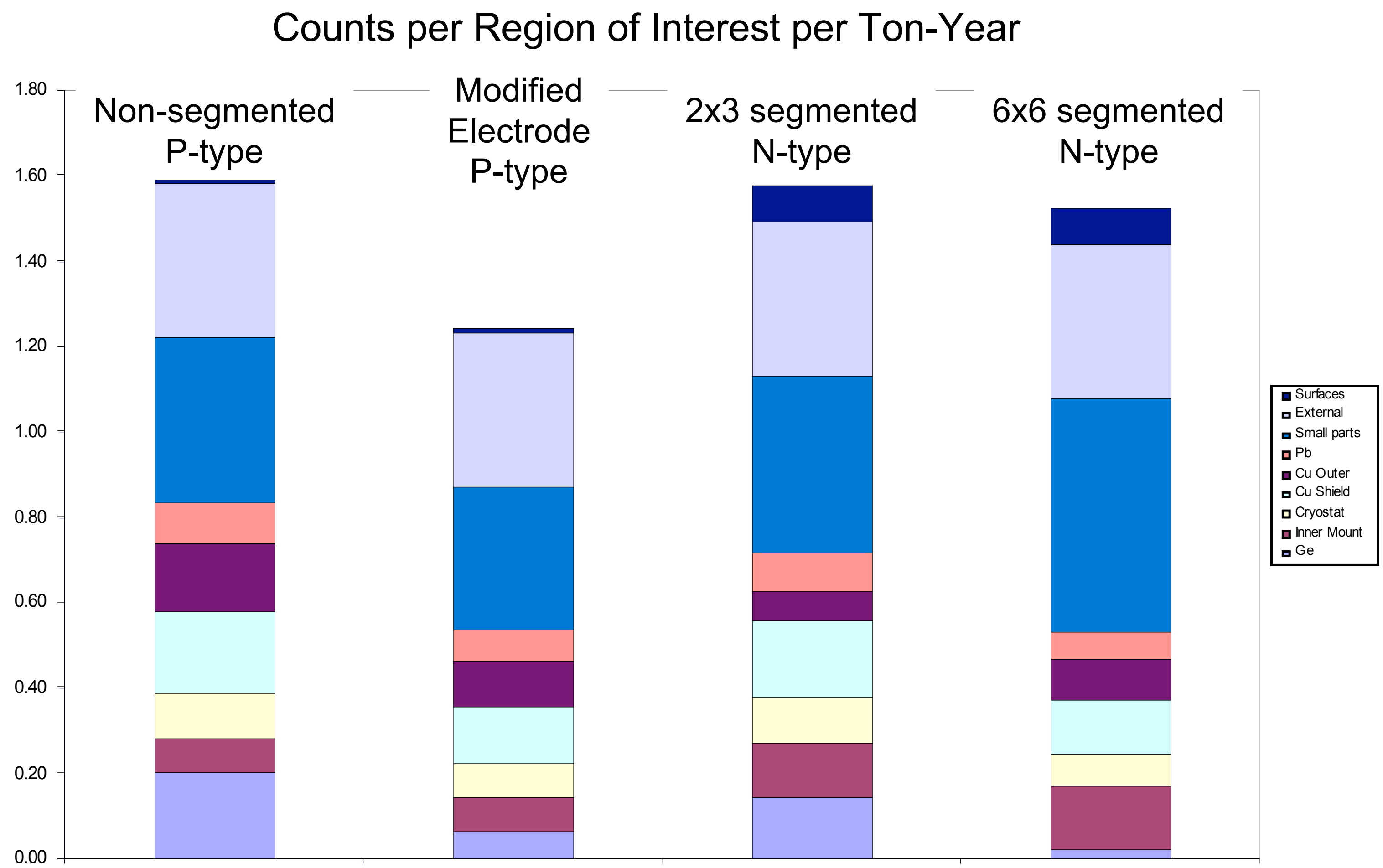
Decision

Identify Detector Configurations

- Detector configurations
  1. Non-segmented p-type detectors (0.55 kg or 1.1 kg)
  2. Modestly segmented n-type detectors (4-8 one-dimensional segments)
  3. Highly segmented n-type detectors (up to 36 segments)
  4. Ge-drift or modified electrode, non-segmented p-type detector

- Assume reference design (57 crystals, 1.1 kg)

Results: Anticipated background rates



Background rates are comparable !

⇨ Background suppression compensates the increased background level for segmented and more complex implementations

Approach - Details

Identify/ Select Configurations

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•Mechanical (cryostat)
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Statistical analysis

R&D

Systematic analysis:
Signal and background consistency
Signal robustness
Unforeseen backgrounds

Decision

Not quantitatively explored, yet

Where is Majorana in the process?

- Sept. 2003 - Majorana White Paper
- Nov. 2003 - DOE Office of Science 20 year Future Facilities
- Nov. 2004 - APS Multidivisional Neutrino Study
  - $0\nu\beta\beta$ program one of three top recommendations
- Sept. 2005 - NuSAG Review of U.S. $0\nu\beta\beta$ program
  - *"CUORE, EXO, and Majorana have the highest funding priority"*
- Nov. 2005 DOE NP Mission Need for "generic" bb-decay
  - Permission to redirect DOE funds to R&D
- Oct. 2006 - Particle Physics Project Prioritization Panel (P5) Physics Roadmap
  - *"The three techniques to measure neutrino-less beta decay, CUORE, EXO, and Majorana should be investigated vigorously"*
- 2006-2007 - U.S. Nuclear Physics Community Long-range planning process
  - Jan. 07 - Town Meeting on Neutrinos - top priority sustained $0\nu\beta\beta$ **program** aimed at 1 ton experient
  - May 07 - Resolution meeting

Majorana Status - Feb. 2007

- Nov. 2006 - DOE NP ββ-decay Panel Review

  The overall plan of assessing and reducing background seems sound. The projected factor of 100 background reduction is impressive, aggressive but achievable. The technical risks associated with this approach appear to be low.

  Cooperation between Majorana and GERDA is strong. The projects have the documented intent to combine into one international collaboration and Ge experiment in the long term. Efforts would be merged and the superior technology would be the focus for add-on detector capability

  Technical: The level of development of the Germanium detector production model is beyond what is typical for this stage of the project.

  Cost and Schedule: A significant effort has been put into the preparation of cost and schedule information for a project at a pre-conceptual stage of development. The project team is highly commended for their efforts in this regard. The level of detail is on-par with several projects already in construction.

- Current Status

  FY 07 federal budget NOT enacted. -> "Continuing Resolution" (CR)

  Current CR(expires Feb. 15) - Gov. operates on FY06 budget, no new project starts.

  Revised CR with improved funding for science has passed House

  FY08 Budget released (Feb. 5), but will be impacted by final FY07 CR

  FY08 includes support for R&D on double-beta decay.

  Verbal encouragement from DOE NP, but need to wait until final CR

  Initiating discussions with NSF (possible strong interest because of DUSEL).

Spare slides

Majorana Projected Schedule

- Assumes a realistic, but DOE "constrained" schedule.
- Assumes DOE CD-1 approval in early FY08

Critical Decision	**DOE Parlance**	**Date in FY quarter**
Mission Need	CD-0	Q1, FY06
Design Selection and Cost range	CD-1	Q1, FY09
Project Baseline	CD-2	Q3, FY09
Long Lead Items	CD-3a (module 1)	Q3, FY09
Construction	CD-3 (module 1)	Q1, FY10
Long Lead Items	CD-3a (module 2)	Q2, FY10
Construction	CD-3 (module 2)	Q1, FY11
Deliverables (finish)	CD-4	Q4, FY14

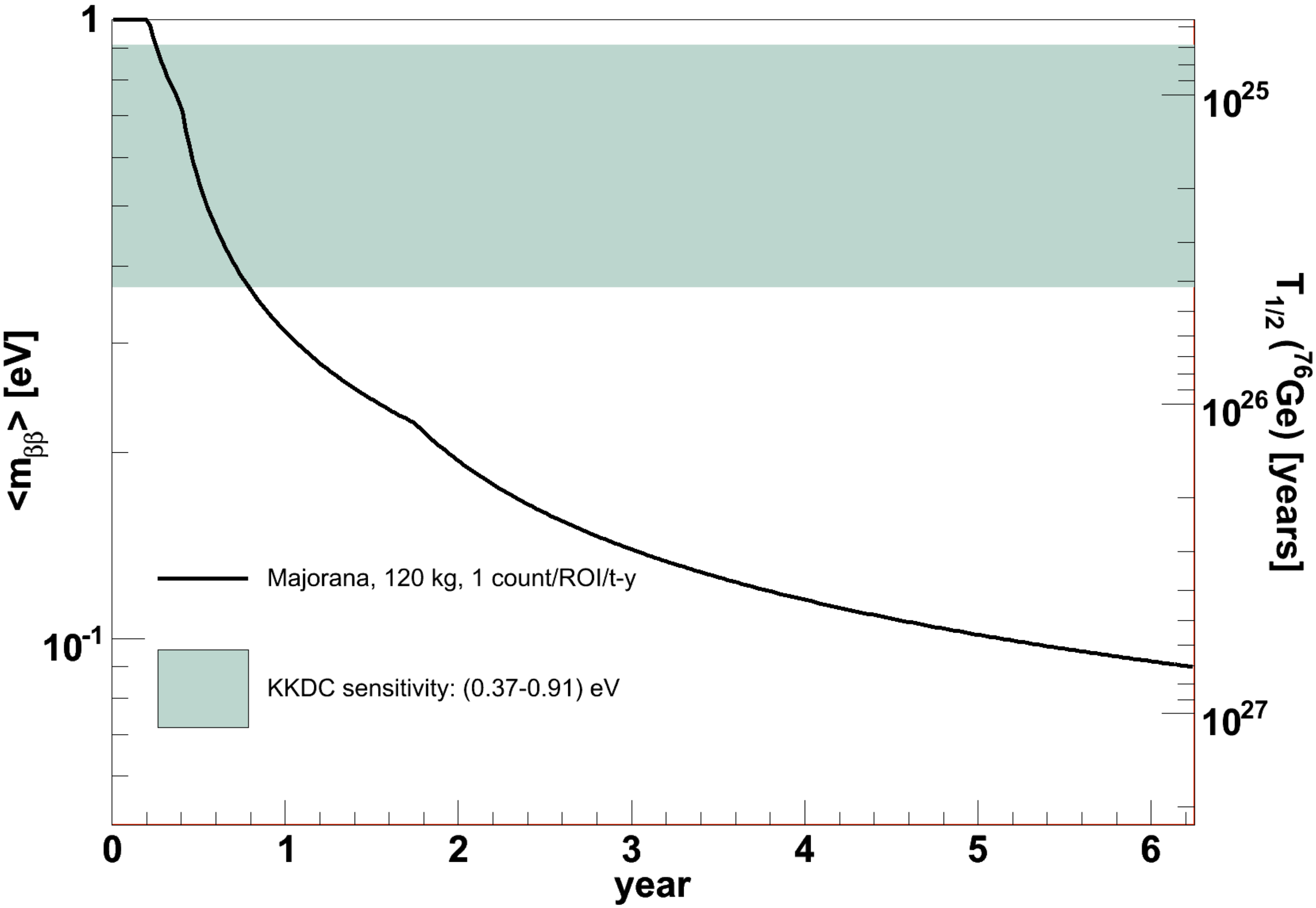
U.S. Deep Underground Science & Engineering Laboratory (DUSEL)

- NSF DUSEL Envisioned Process as of May 2004
  - S-1: site-independent science case for DUSEL
    - Sadoulet leading this effort, nearly complete.
  - S-2: site dependent projection on different sites
    - 6 sites submitted proposals
    - Homestake and Henderson selected and funded
  - S-3: Technical Design Report solicitation by invitation
- *NSF Guidelines for Planning and Managing the Major Research Equipment and Facilities Construction* (MREFC) (Nov. 2005) A response to National Academy Review (Brinkman Report)
  - The Process
    - Conceptual Design Stage (open process, down select at completion)
    - Readiness Stage (Preliminary Design)
    - National Science Board (NSB) Approved Stage (Final Design)
    - Construction Stage
    - Commissioning Stage
    - Operation Stage

DUSEL Status - Feb. 2007

- September 06 S-3 “open” solicitation announced
  - corresponds to community being asked to submit conceptual designs, with the intent to select a single proposal to move forward into the “Preliminary Design” stage.
- Fall 06 NSF and DOE announce call for proposals for DUSEL R&D (Jointly reviewed between DOE and NSF)
  - ~ 50 responses
- January 07 - Four sites submit proposals to S-3 Solicitation
  - Cascades, Henderson, Homestake, Soudan
  - ~March site visits by a panel subcommittee
  - ~April reverse site visits to Washington
  - May-June - Selection of proposal to proceed to “Readiness Stage” (Preliminary Design)
- NSB Approved Stage Starts (Final Design) ~2008
- FY10 or 11 MREFC Construction Funding

Majorana M120 Sensitivity



Majorana M120 Sensitivity