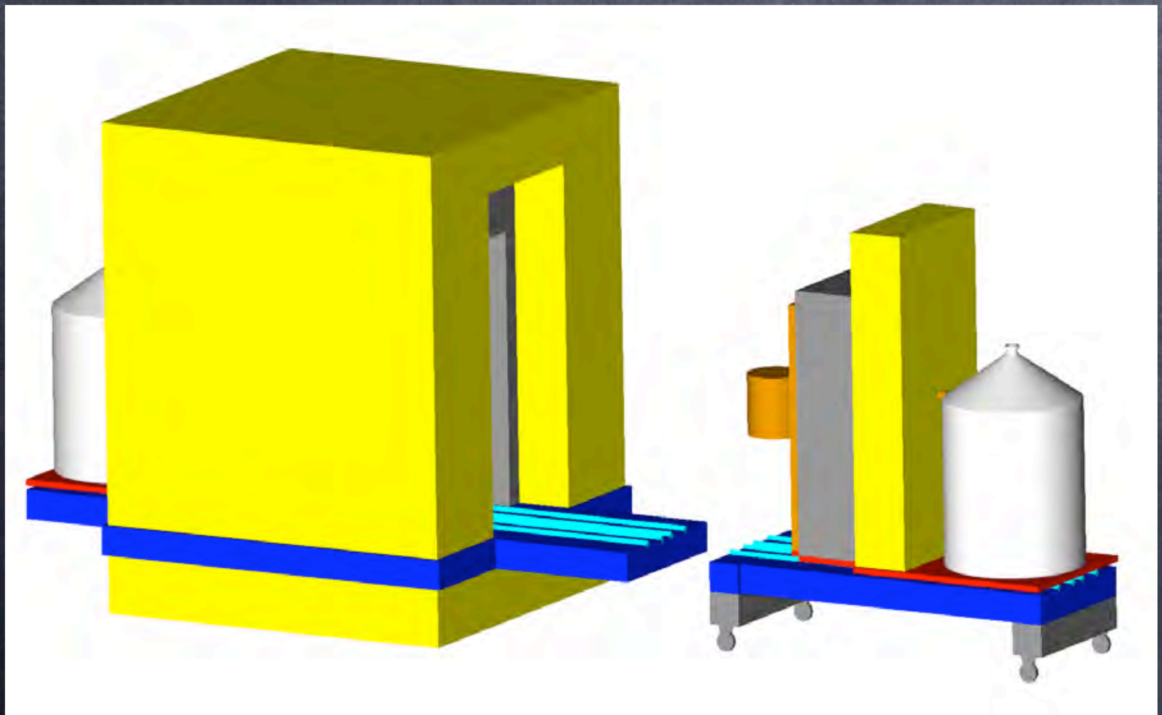
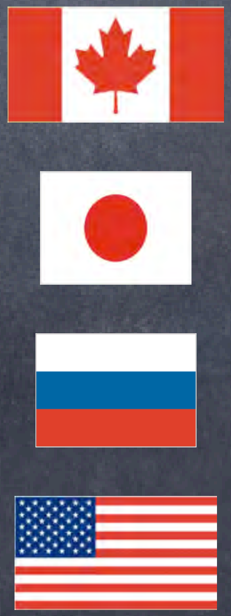
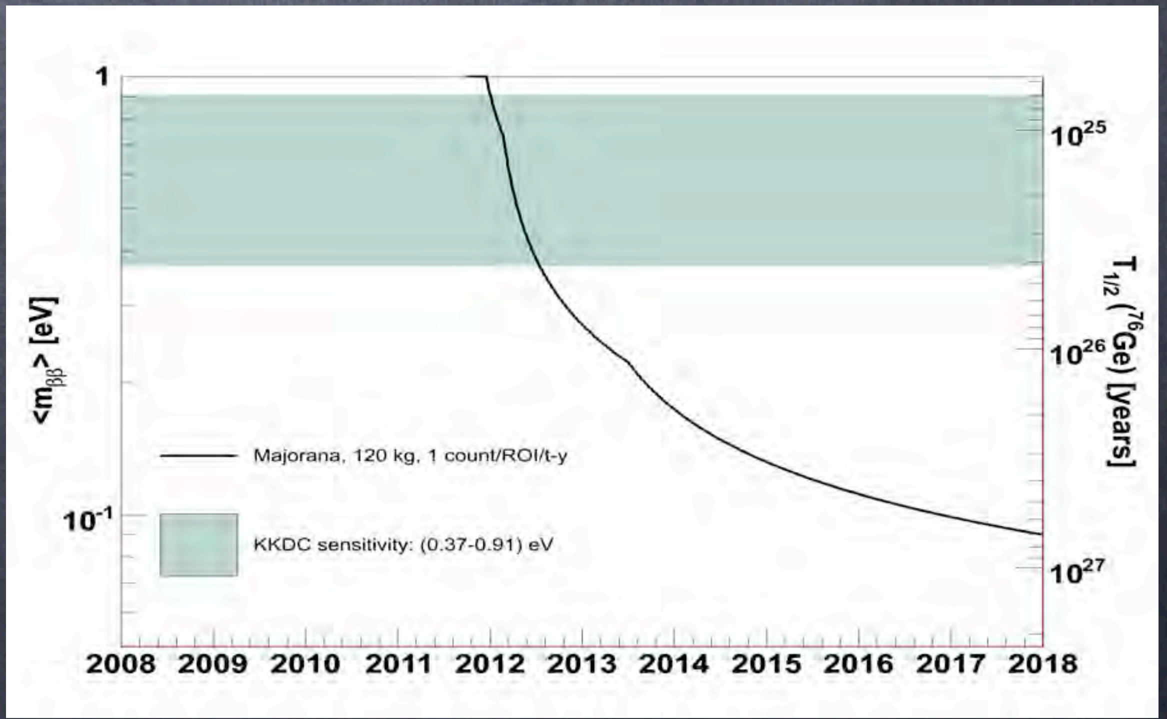
Majorana Status and Overview

Victor M. Gehman
Los Alamos National Laboratory
University of Washington







Majorana in One Sentence...

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"Our collaboration proposes to construct an array of 86%-enriched ^{76}Ge crystals contained in an ultra-low-background structure"*

* quoted from November 2006 Majorana proposal

MAJORANA in One Sentence...

"Our collaboration proposes to construct an array of 86%-enriched ^{76}Ge crystals contained in an ultra-low-background structure"*

Outline:

- Why ^{76}Ge?
- MAJORANA design
- MAJORANA backgrounds and mitigation
- MAJORANA status

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Why ^{76}Ge?

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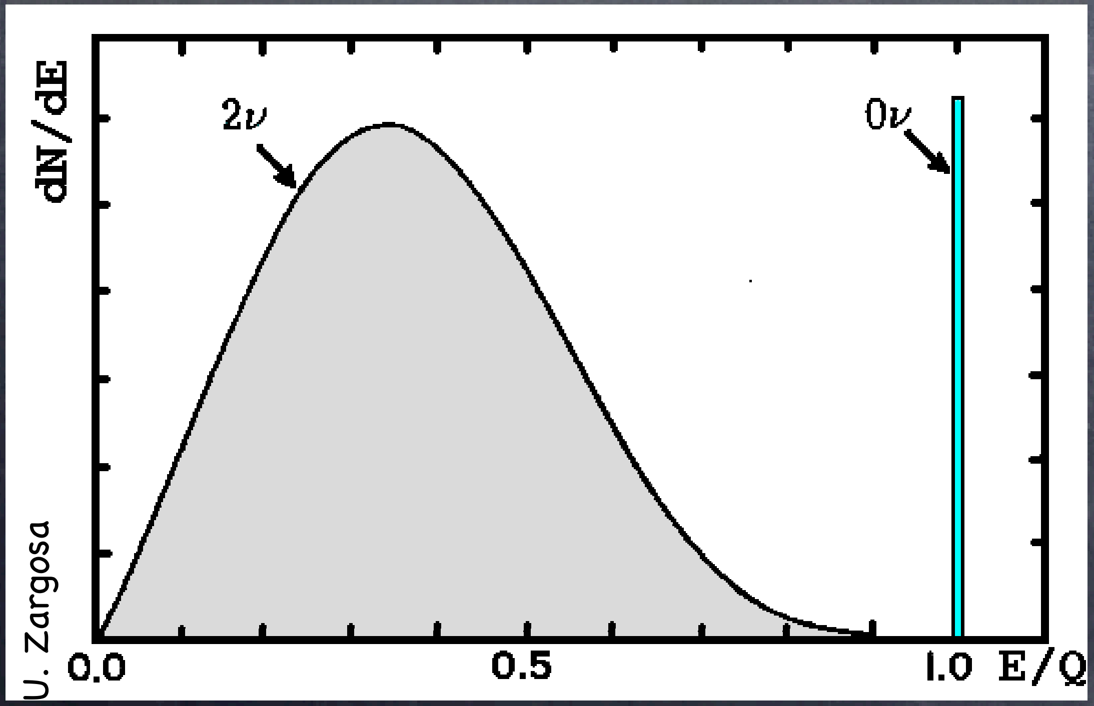

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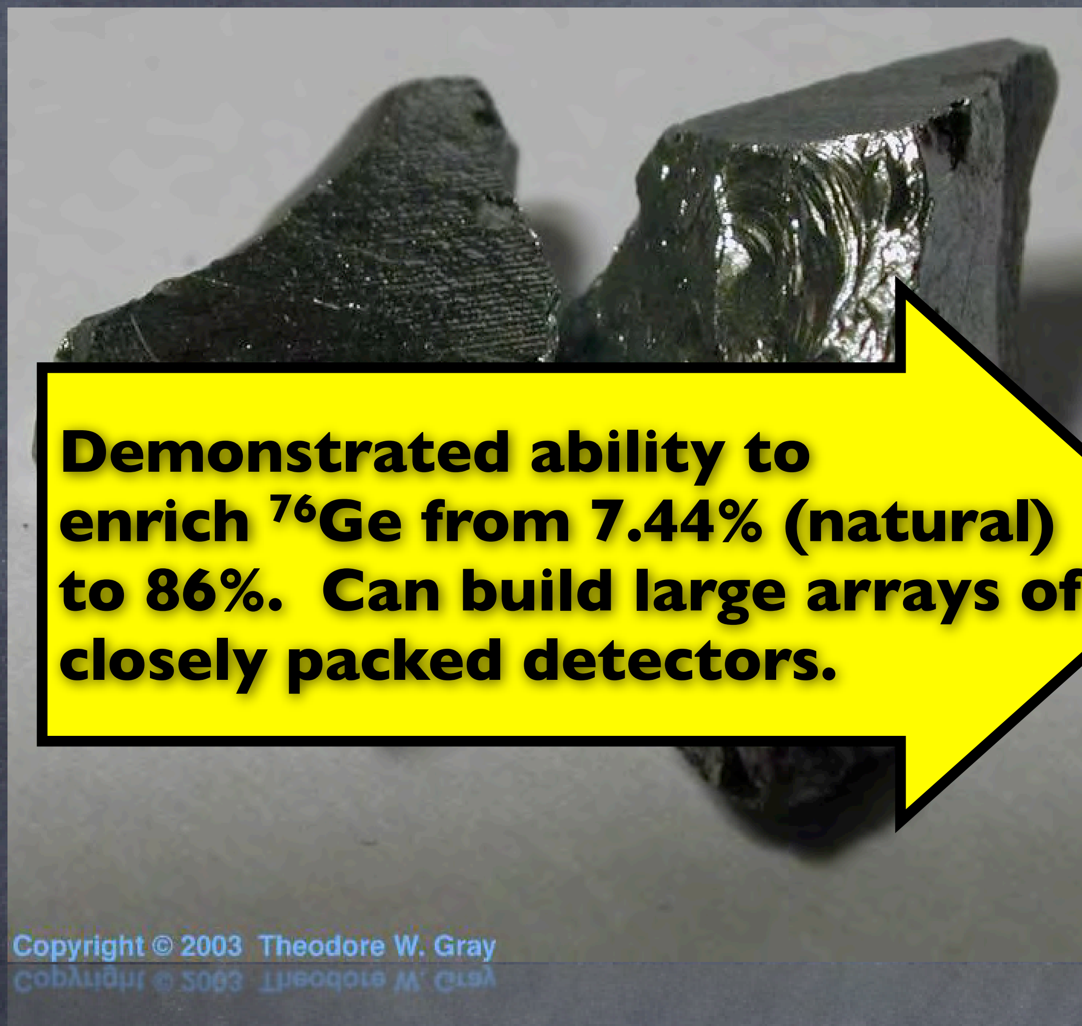
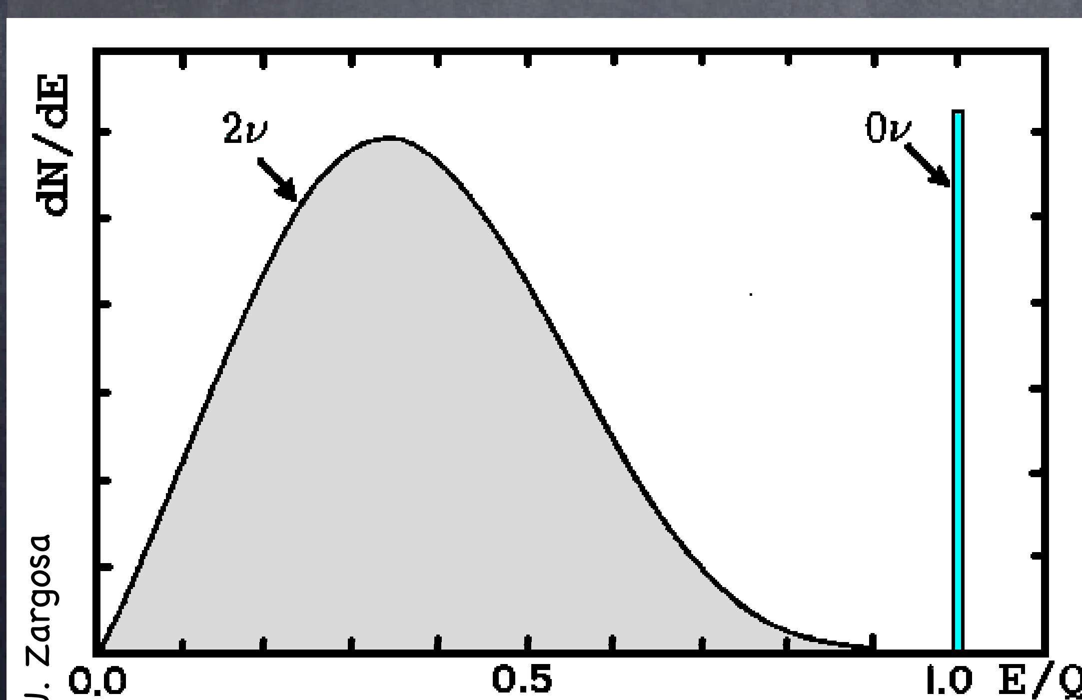


Demonstrated ability to enrich ^{76}Ge from 7.44% (natural) to 86%. Can build large arrays of closely packed detectors.



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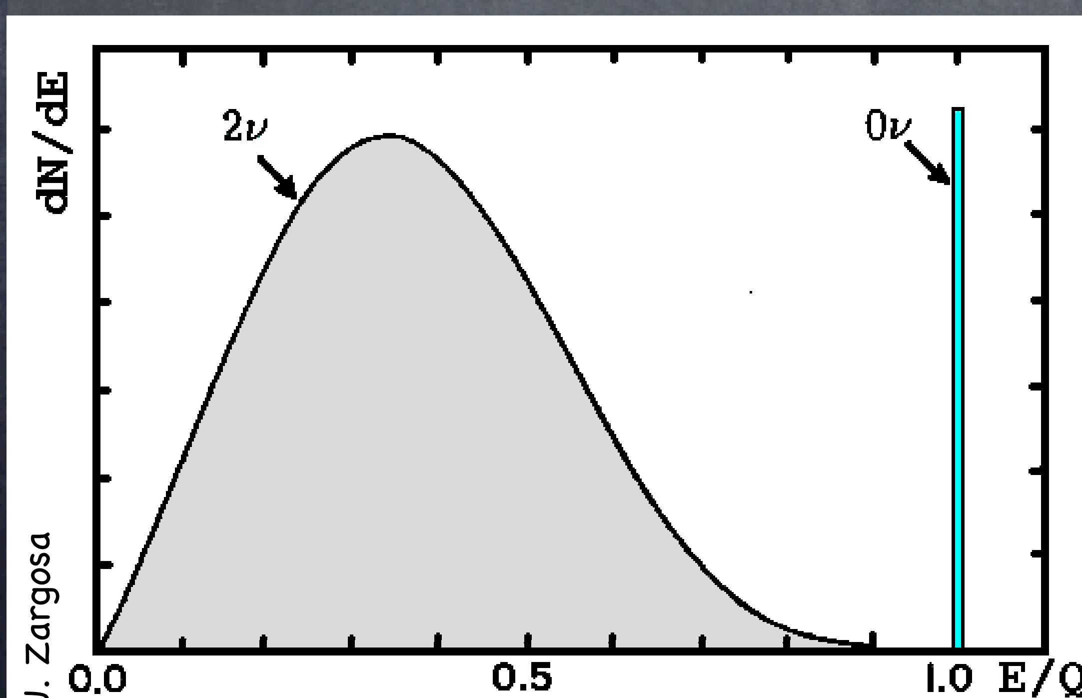

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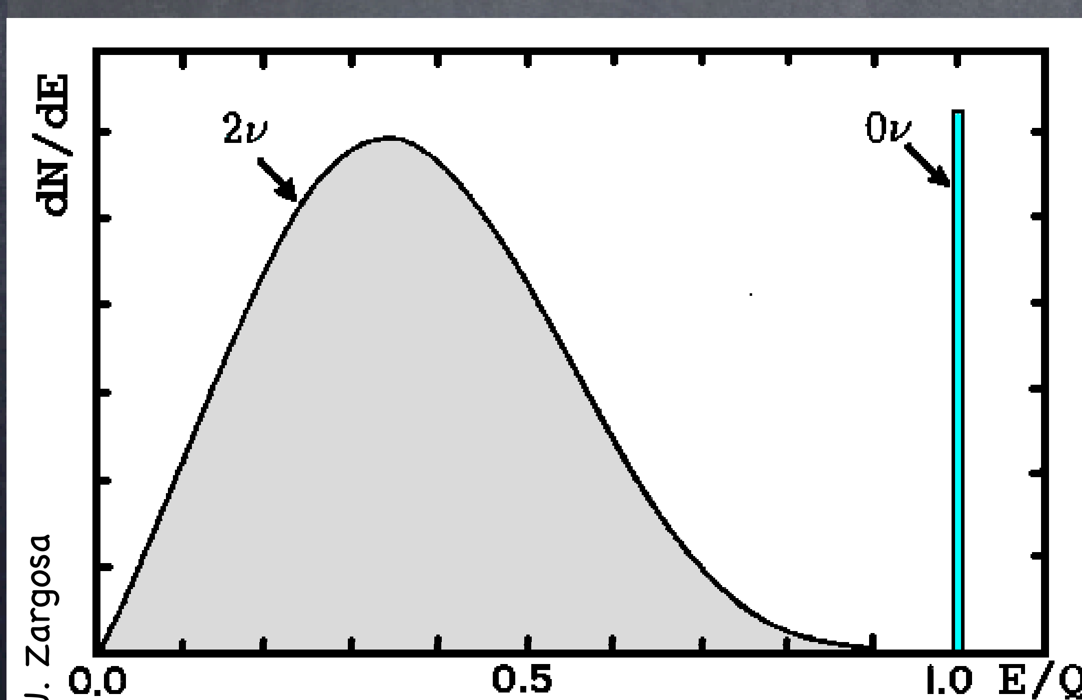
Ge diodes are intrinsically clean! Very few non-active materials in the array!



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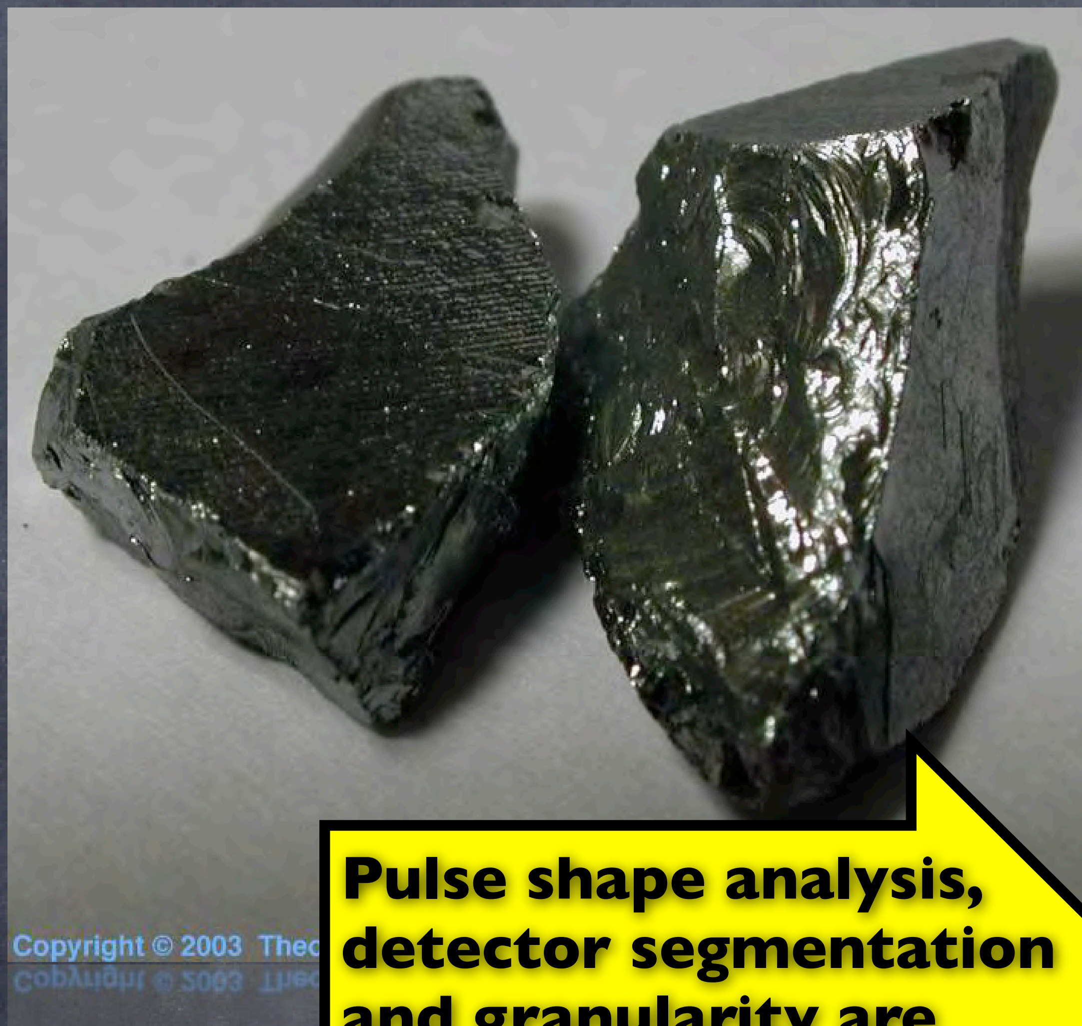

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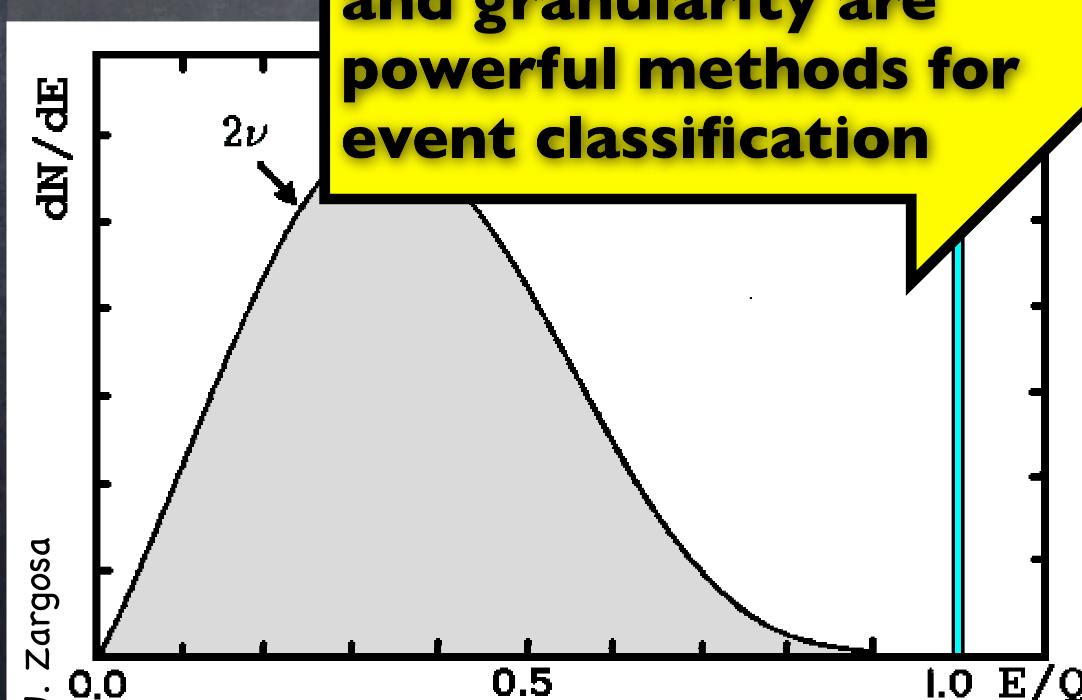
Pulse shape analysis, detector segmentation and granularity are powerful methods for event classification



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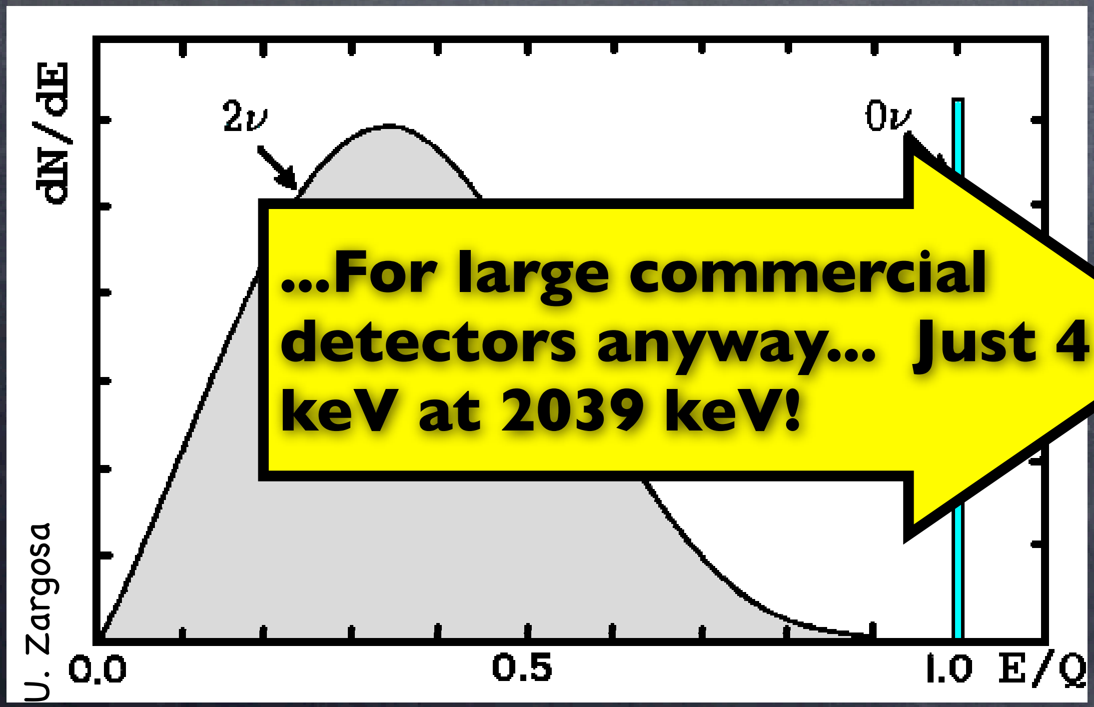

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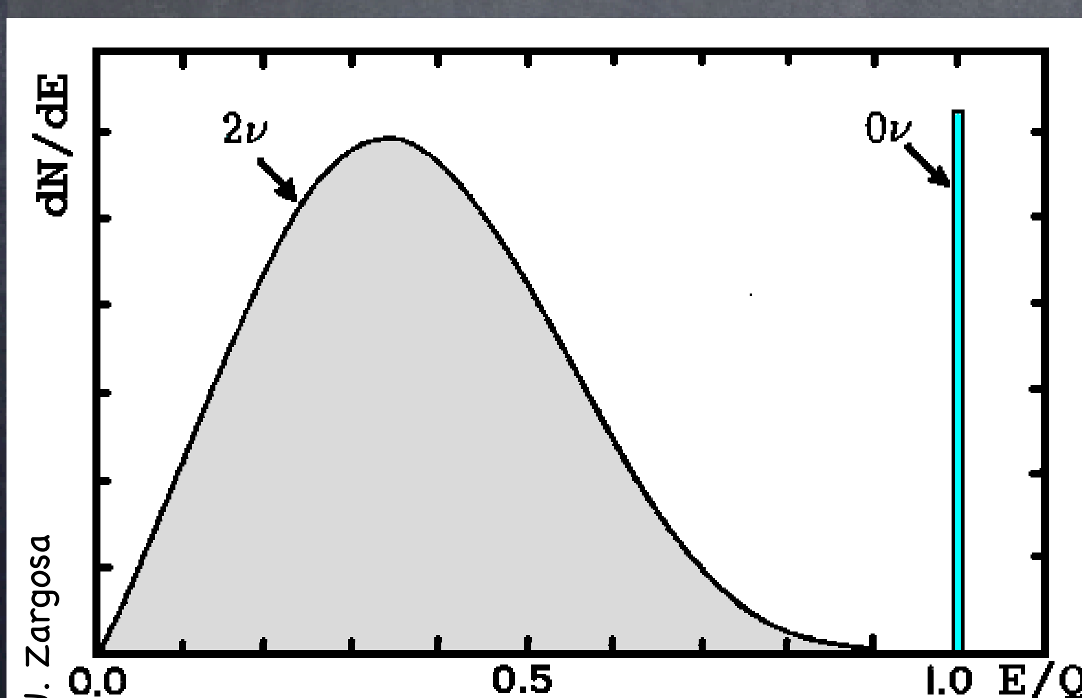

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^{76}Ge also has a reasonably slow $2\nu\beta\beta$ rate!

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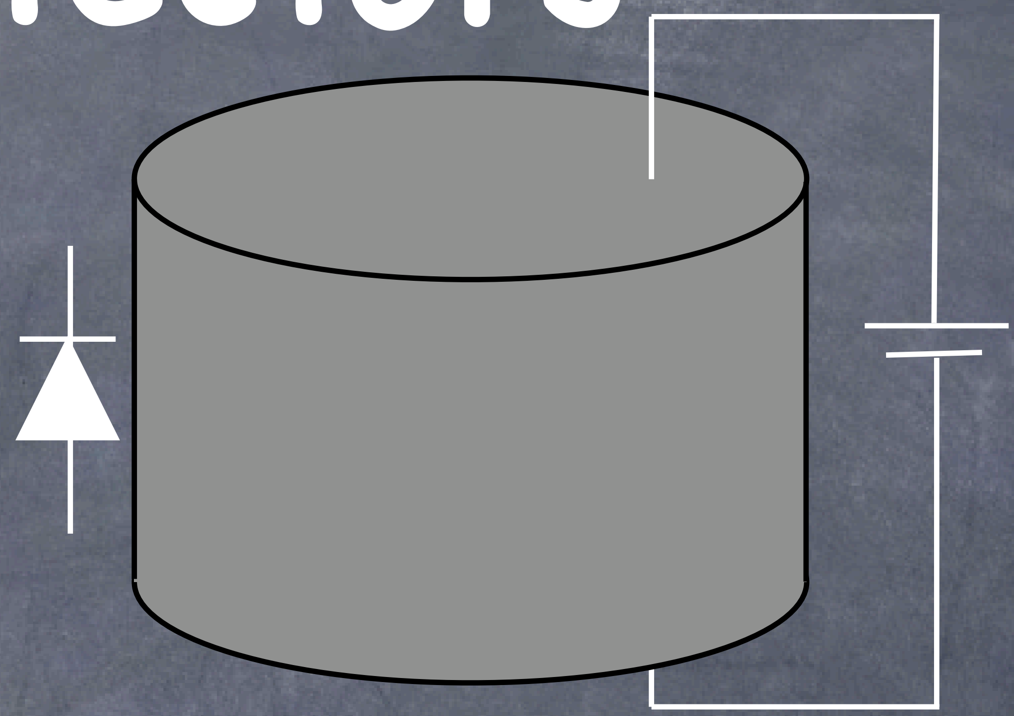

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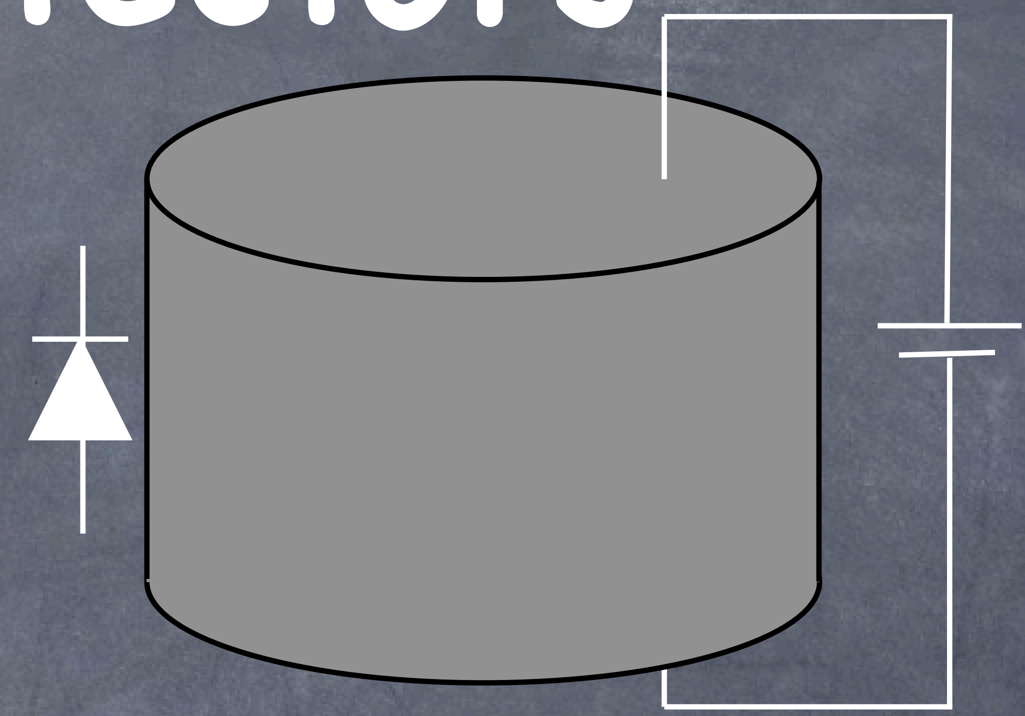

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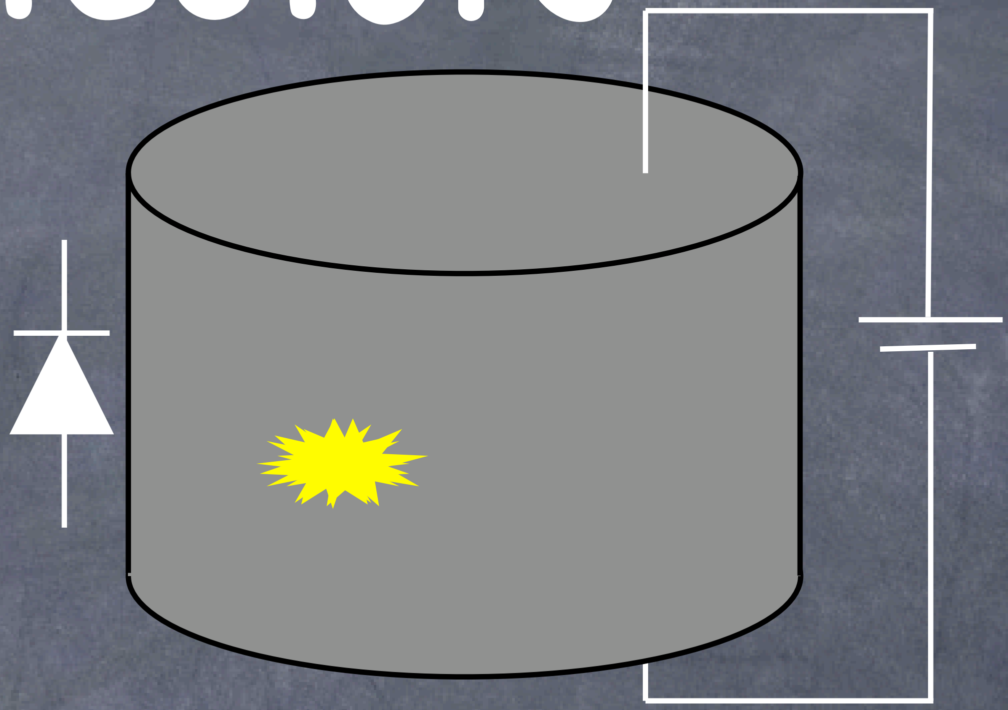

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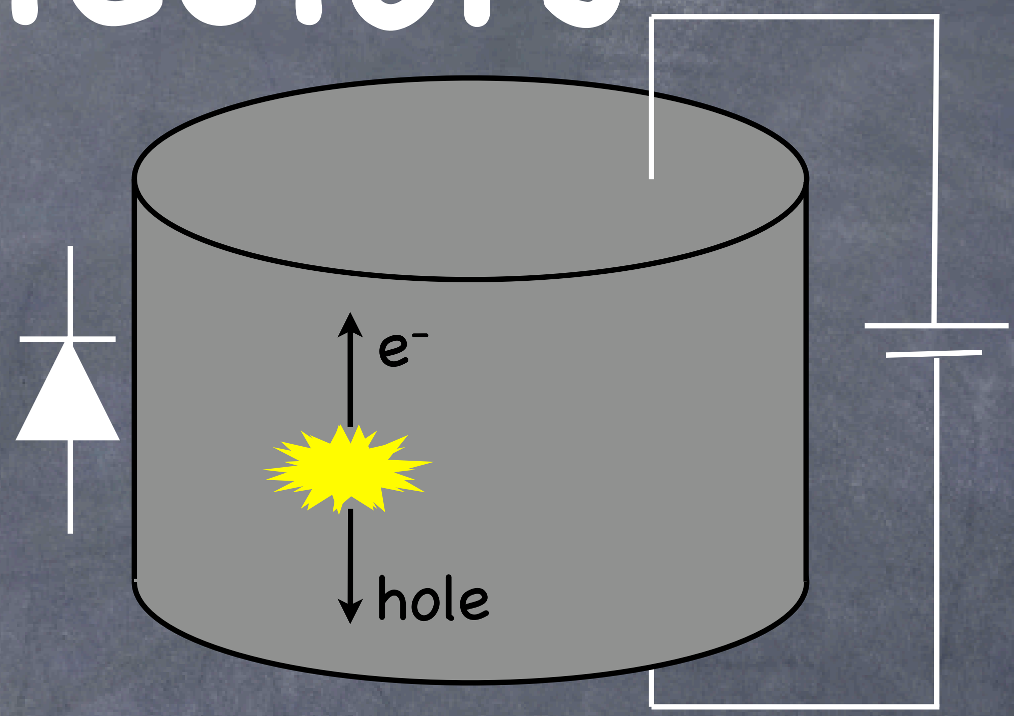

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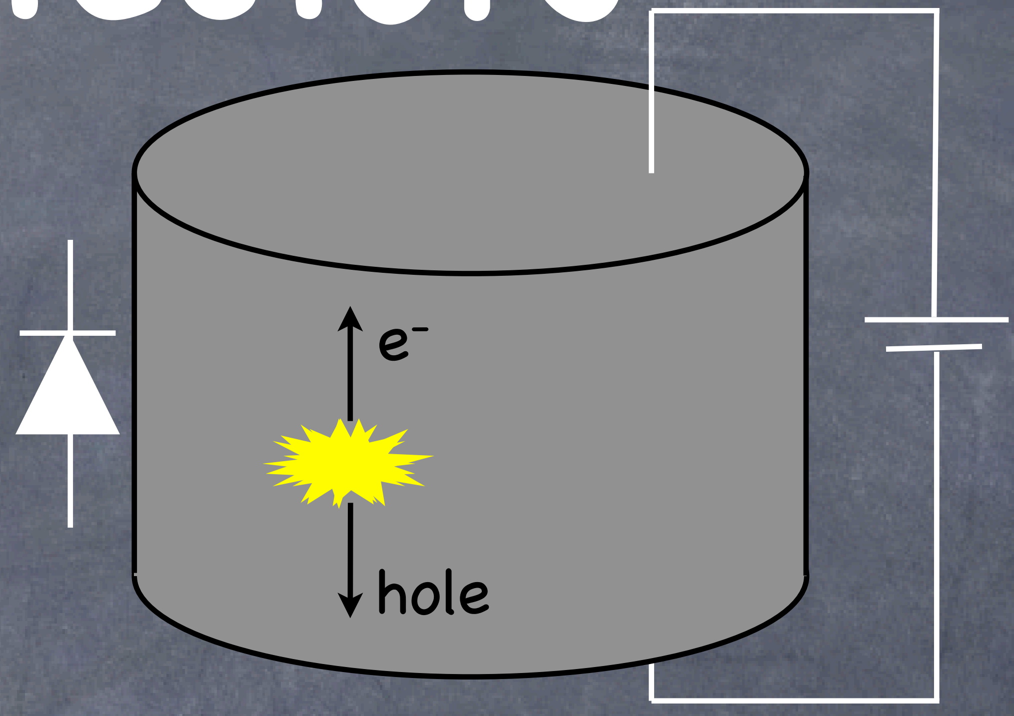

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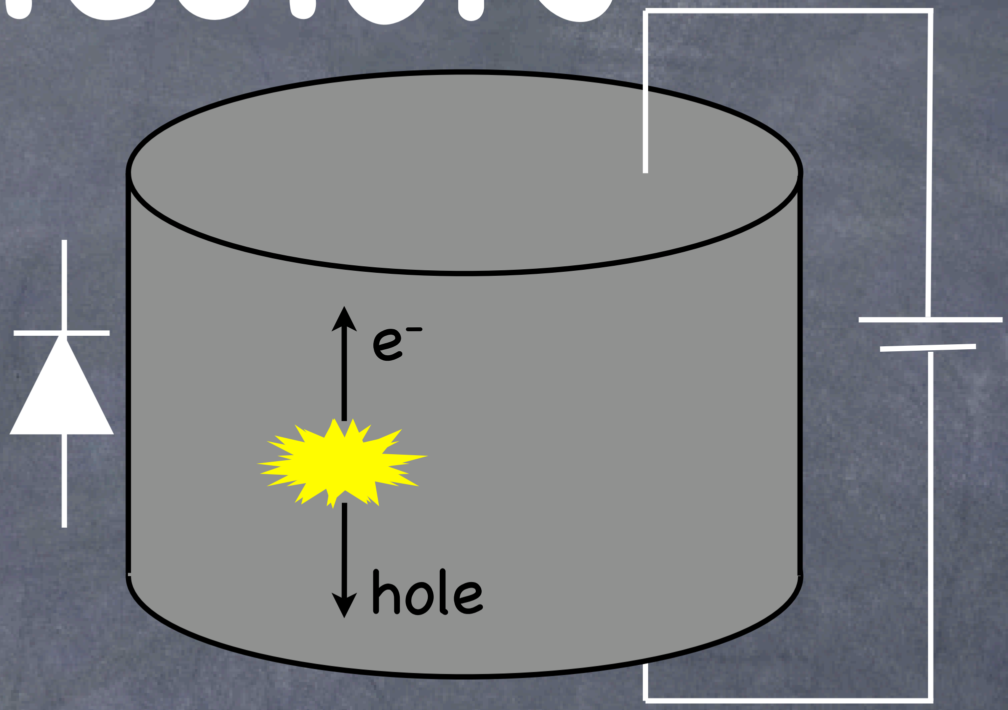

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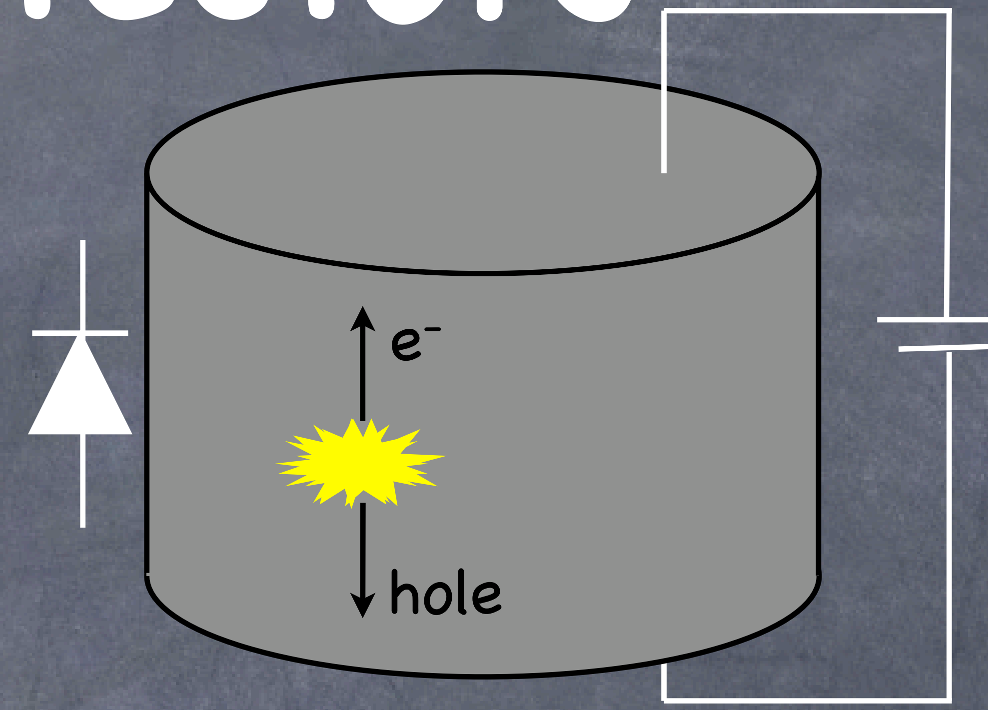

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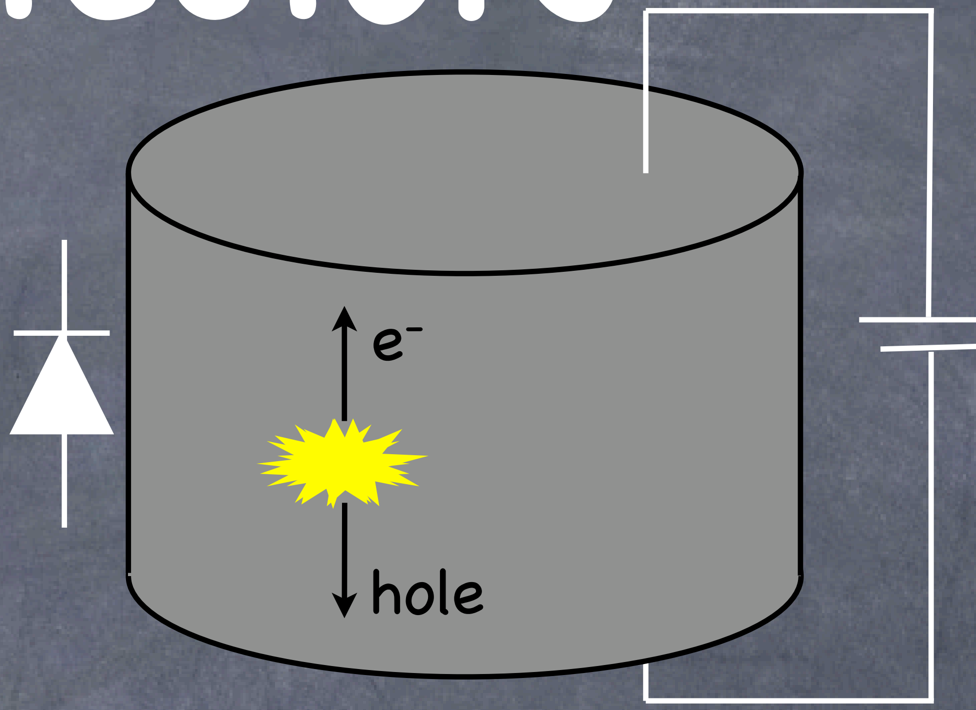

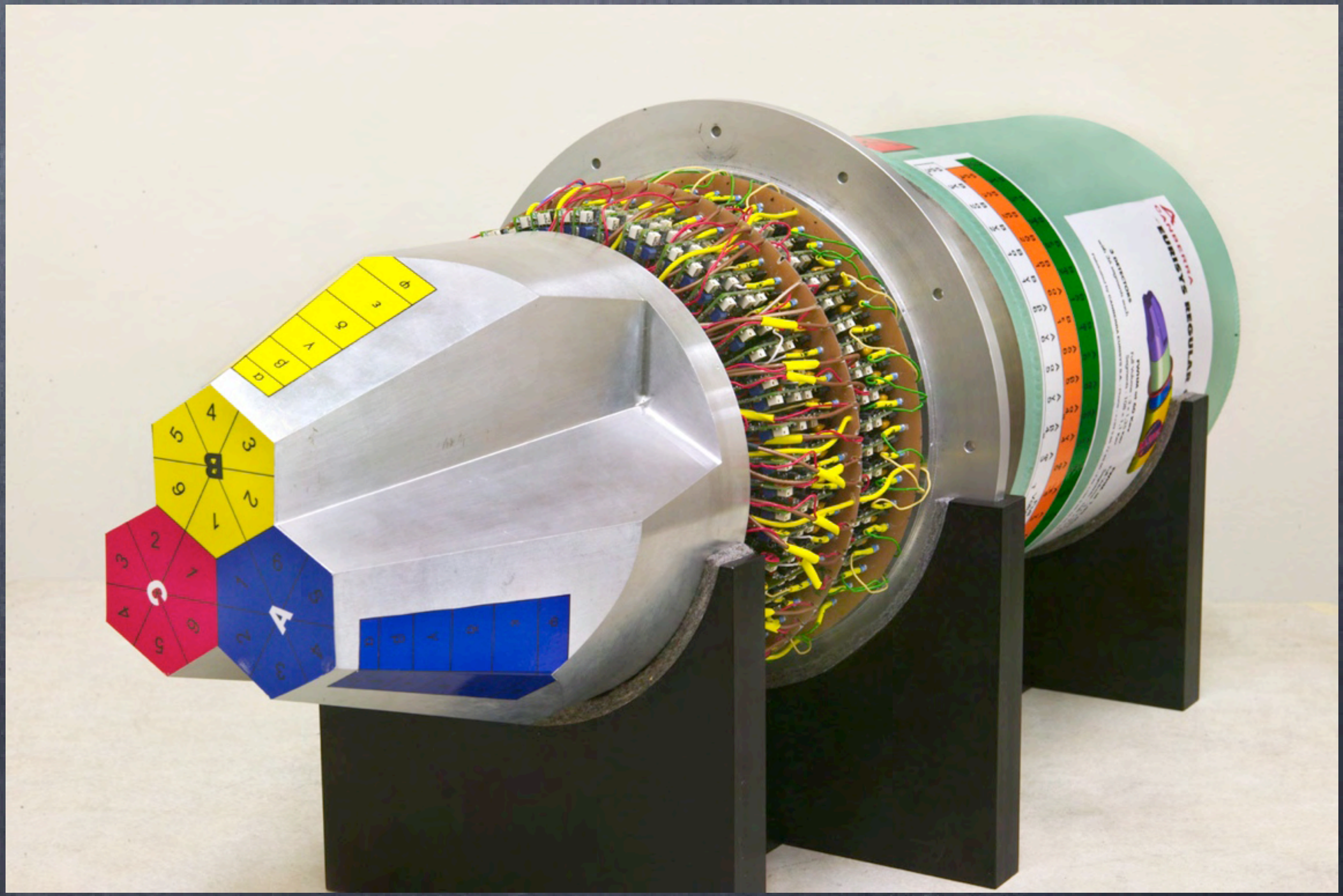

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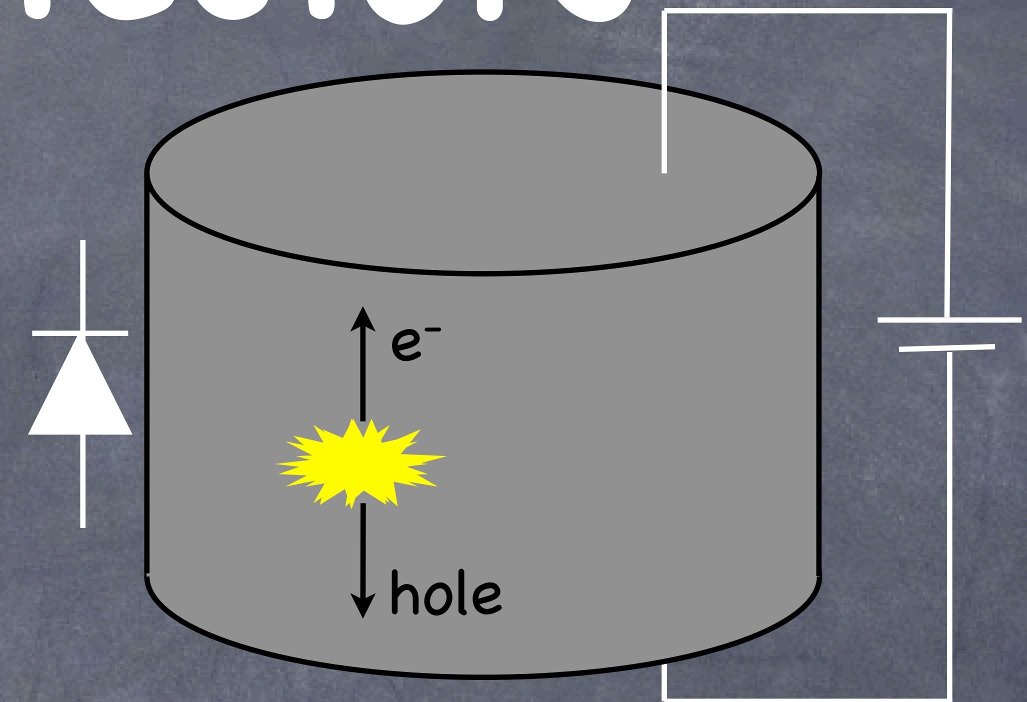

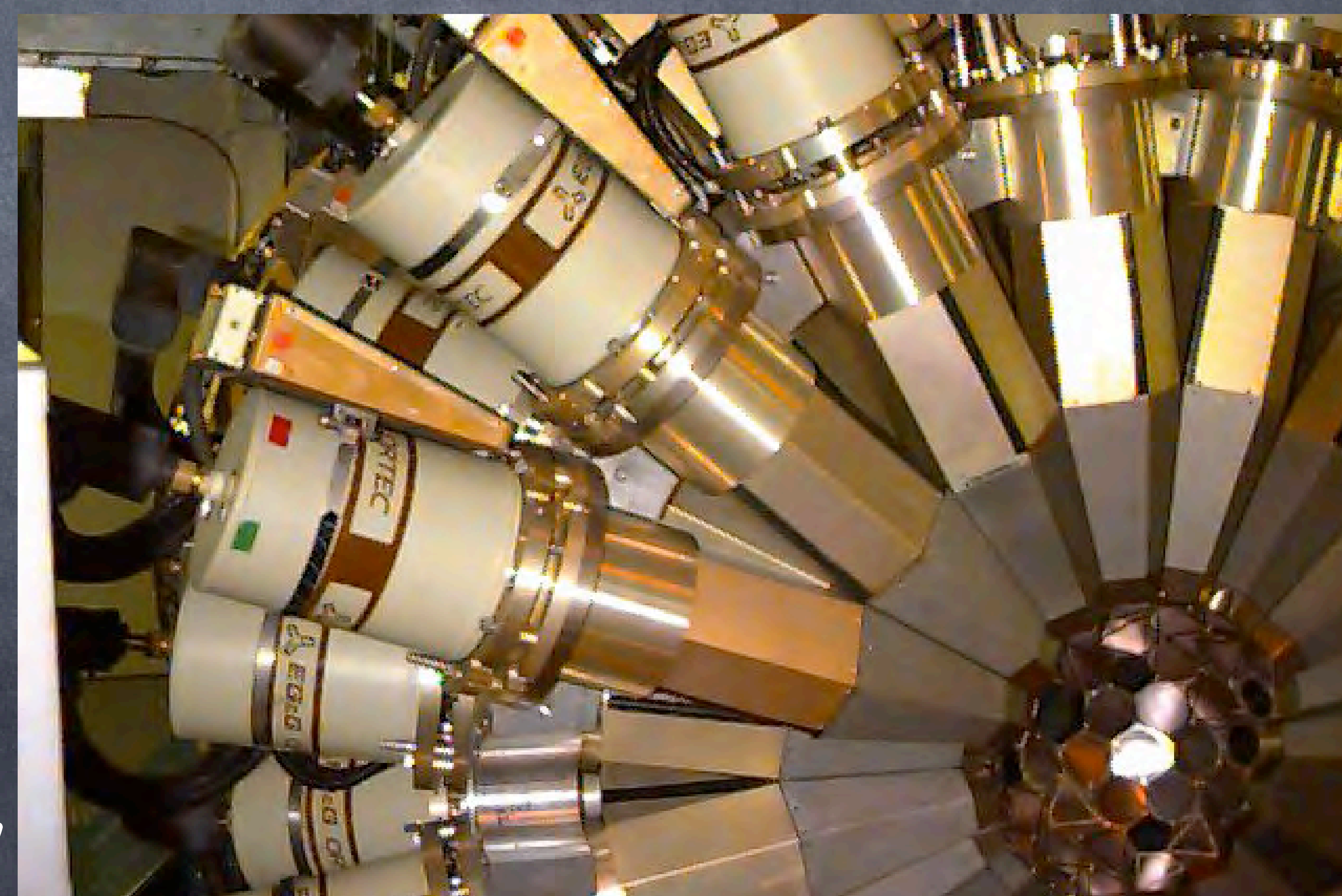

The Majorana Collaboration

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Joint Institute for Nuclear Research, Dubna, Russia
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Los Alamos National Laboratory, Los Alamos, New Mexico
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Osaka University, Osaka, Japan
Hiroyasu Ejiri, Ryuta Hazama, Masaharu Nomachi, Shima Tatsuji

Note: Red text indicates students

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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
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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

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Our plan has been guided by advice from NuSAG, an independent external panel review (March 06), and a DOE ββ-decay Pre-conceptual design review panel (Nov. 06)

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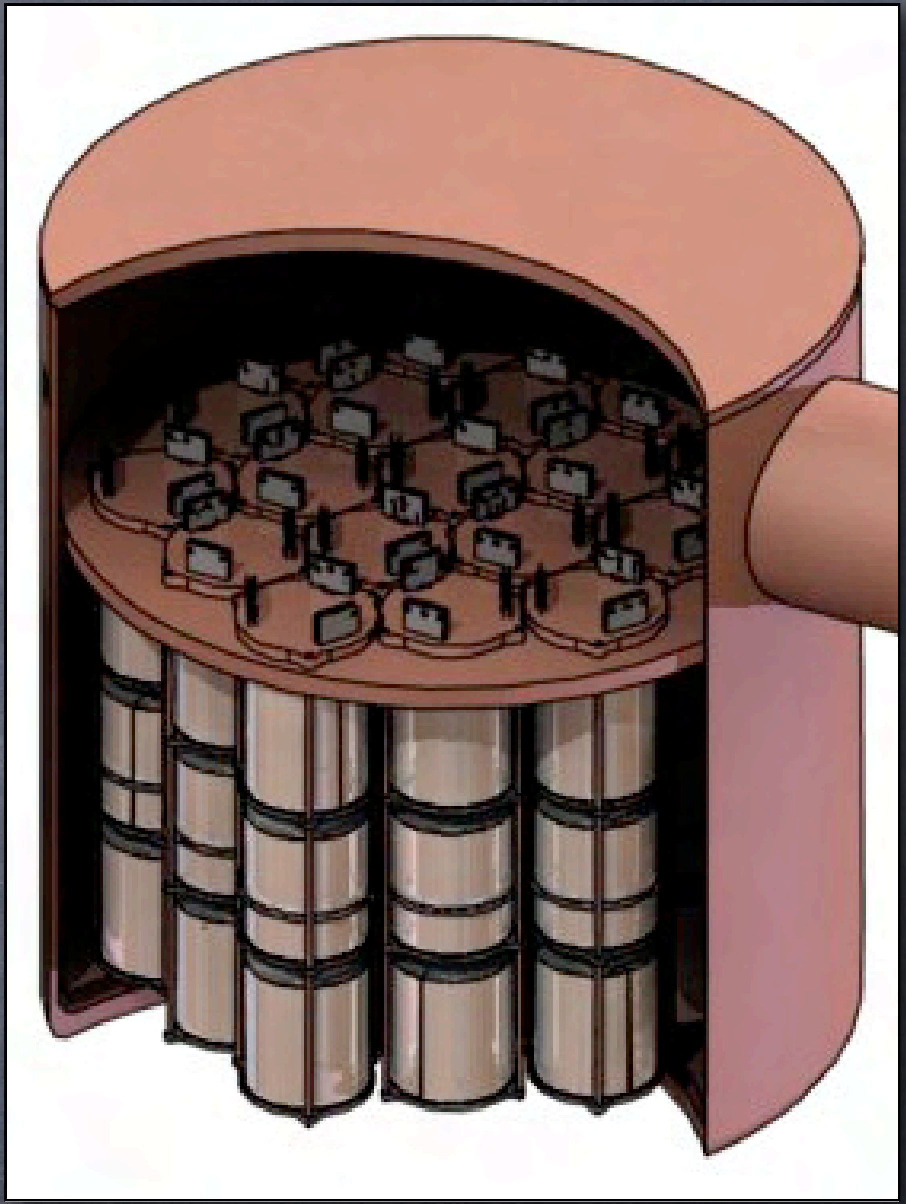
- Close-packed structure is to decrease non-active mass and increase crystal-to-crystal background rejection
- 57 1.1 kg detectors per module:
  - Conventional vacuum cryostat made from electroformed copper
  - Each three-crystal stack is individually removable
  - Investigating several segmentation schemes



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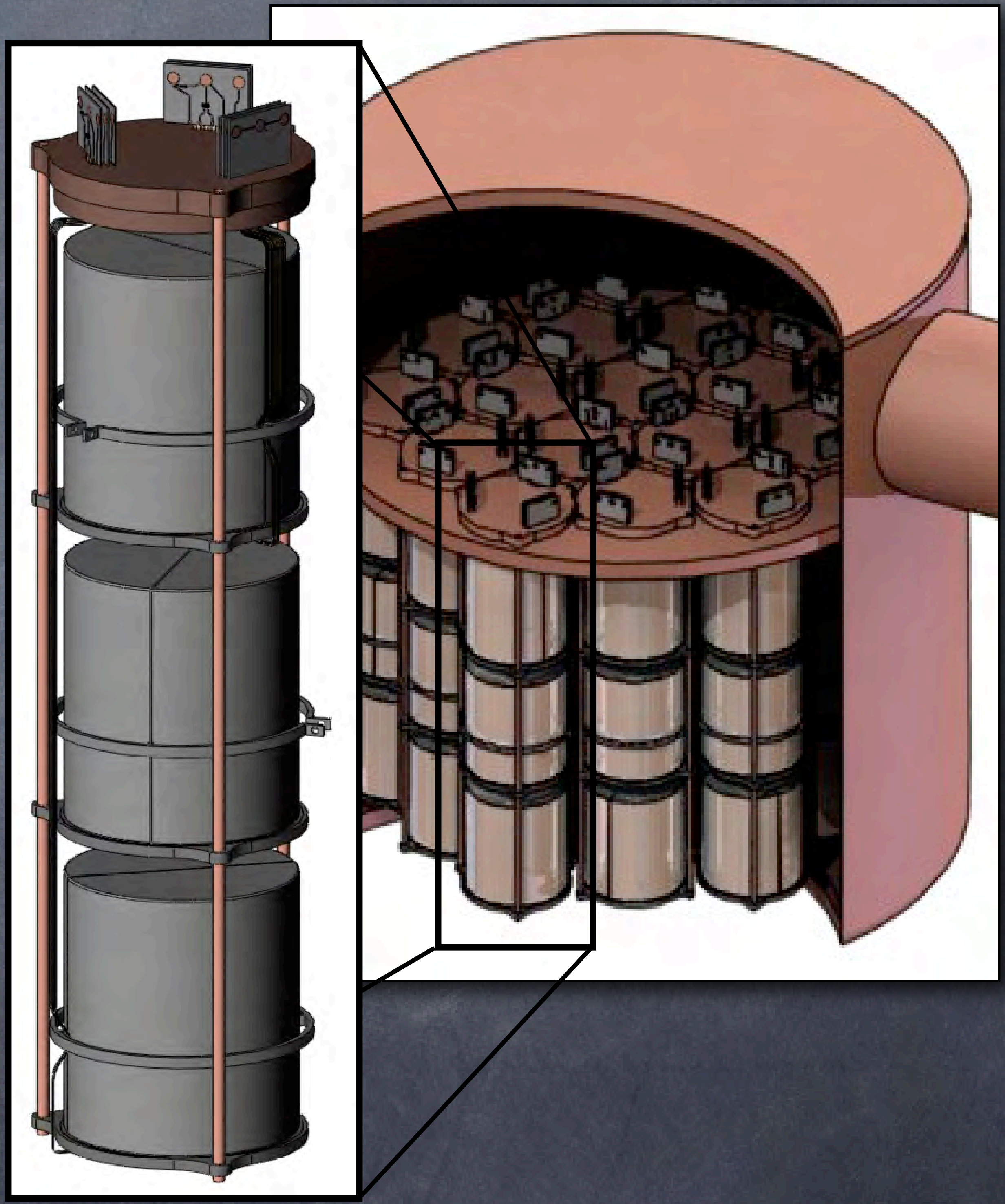

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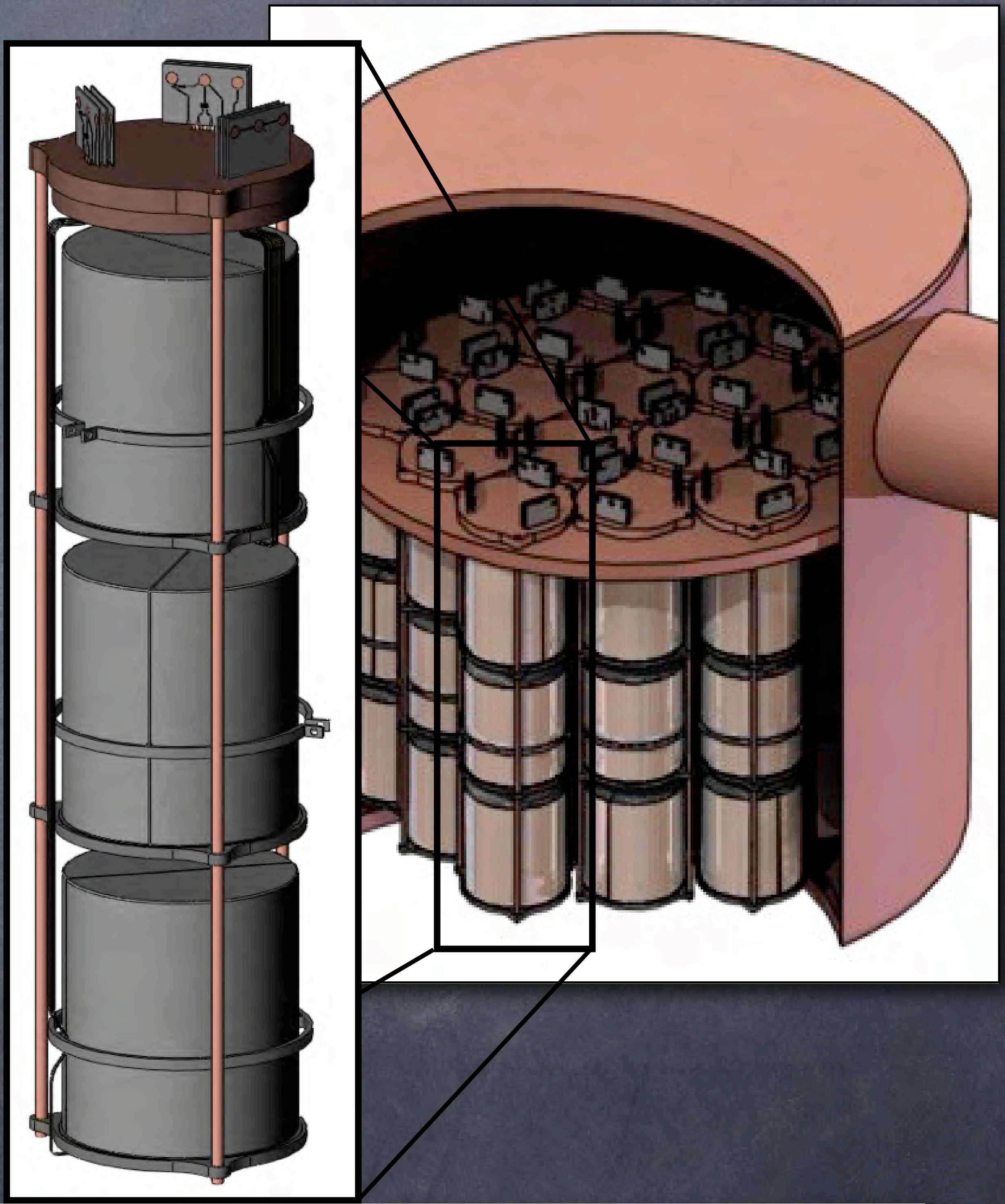

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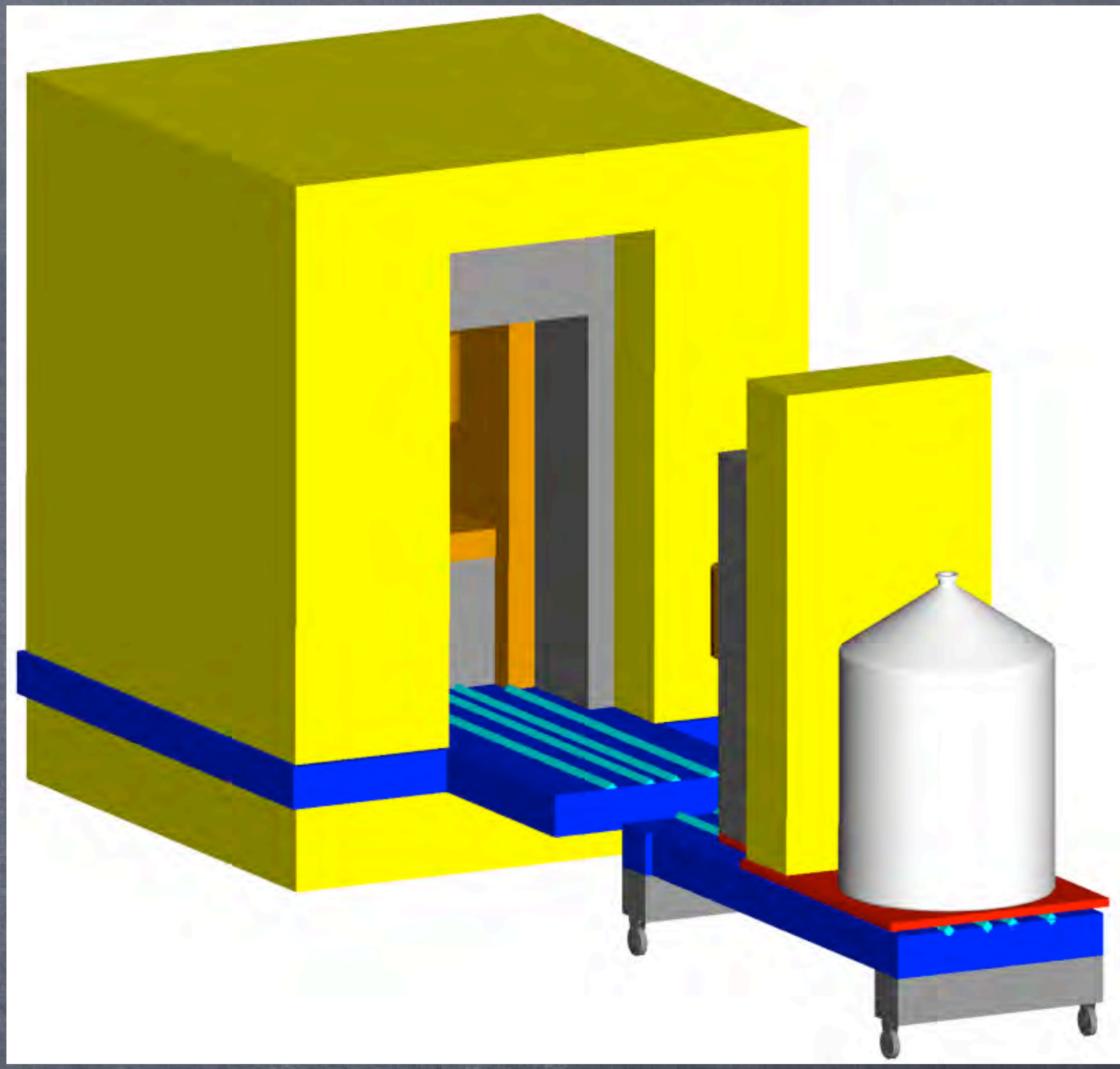

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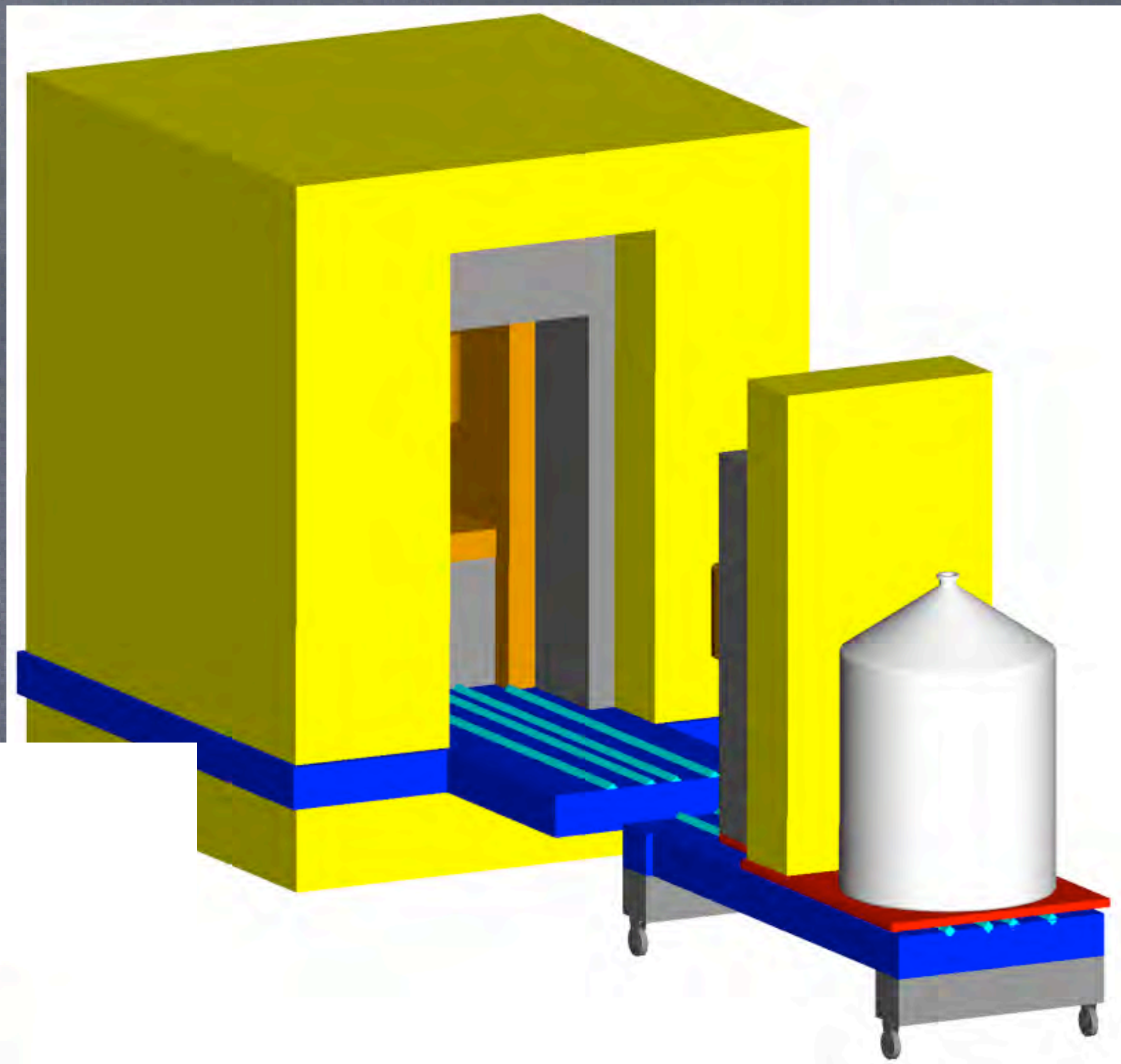

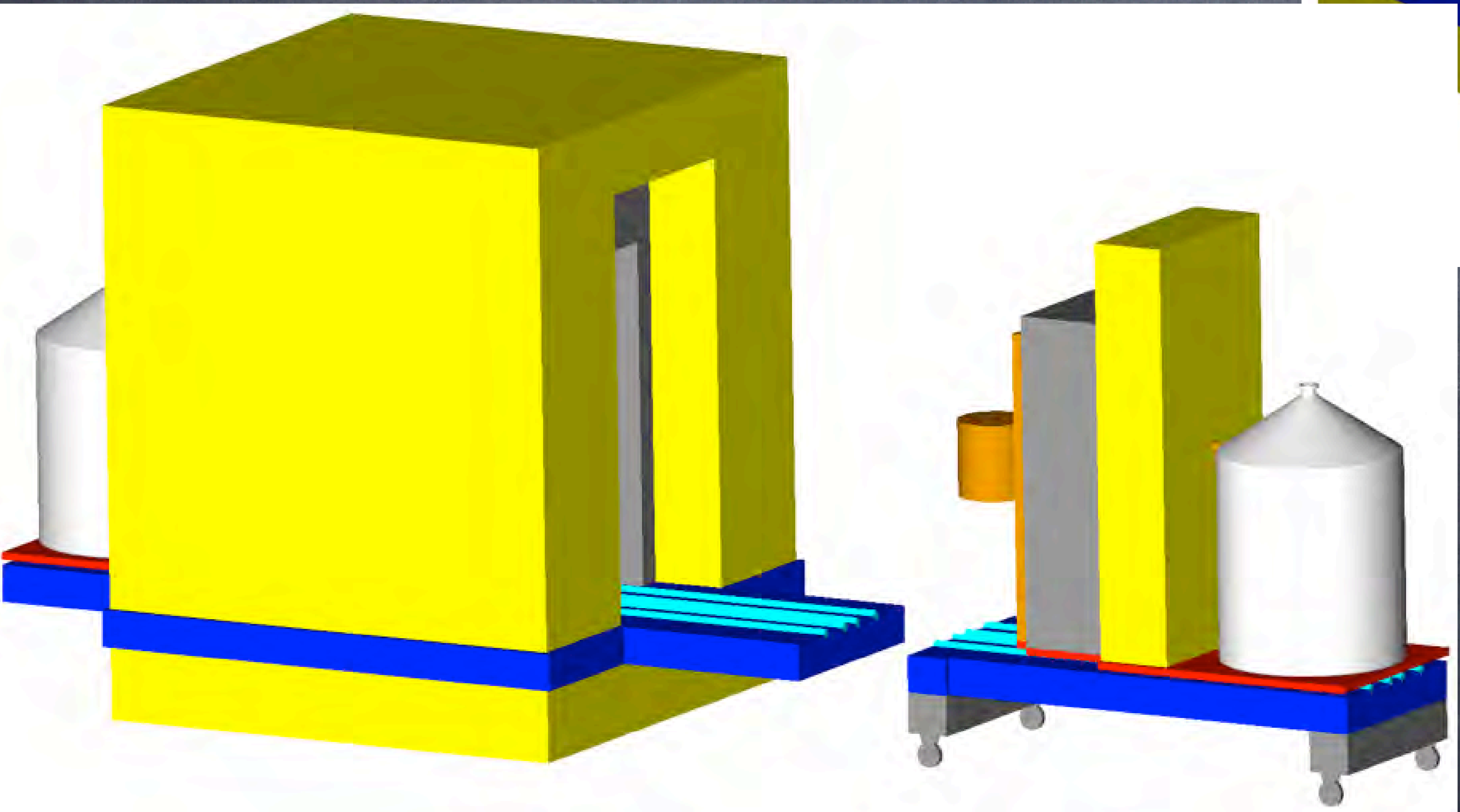

Crystal Production

From raw
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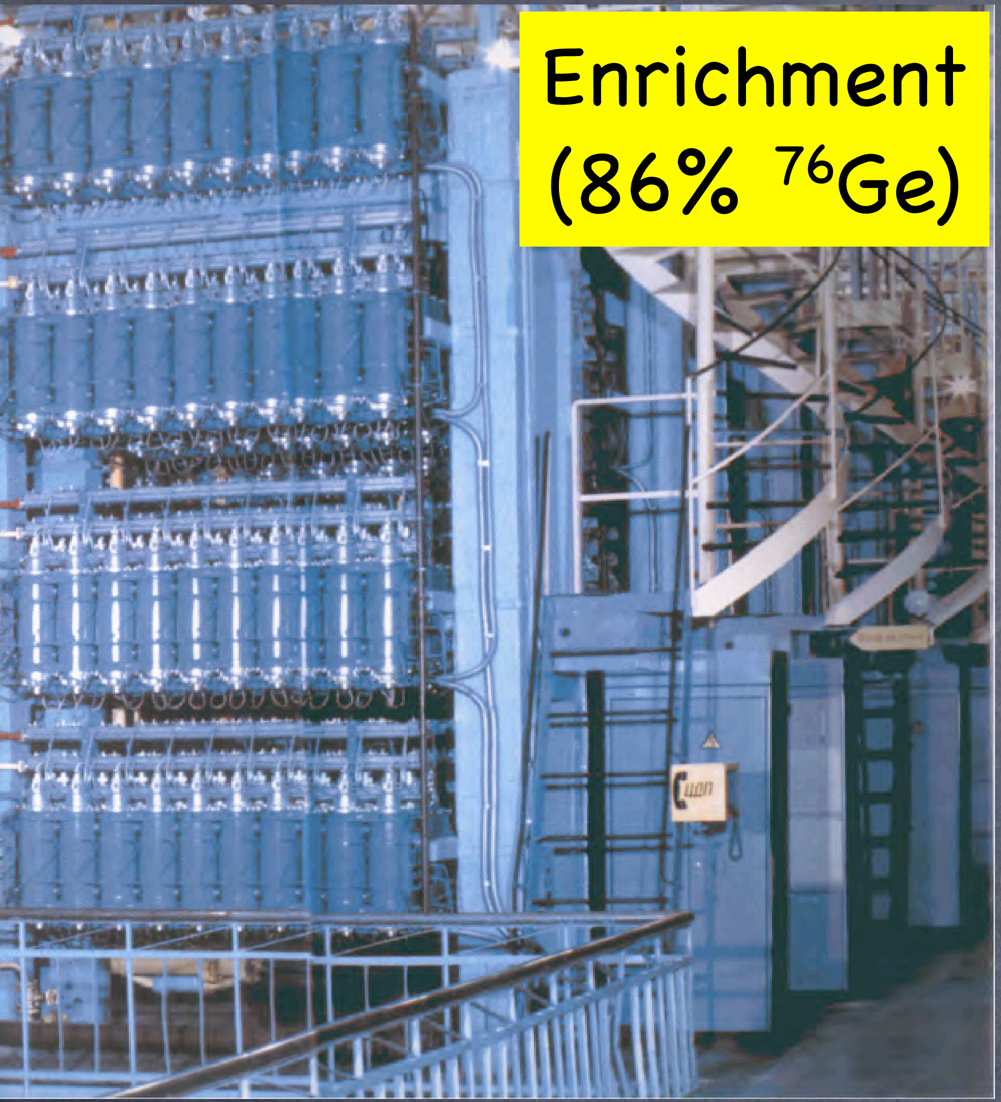

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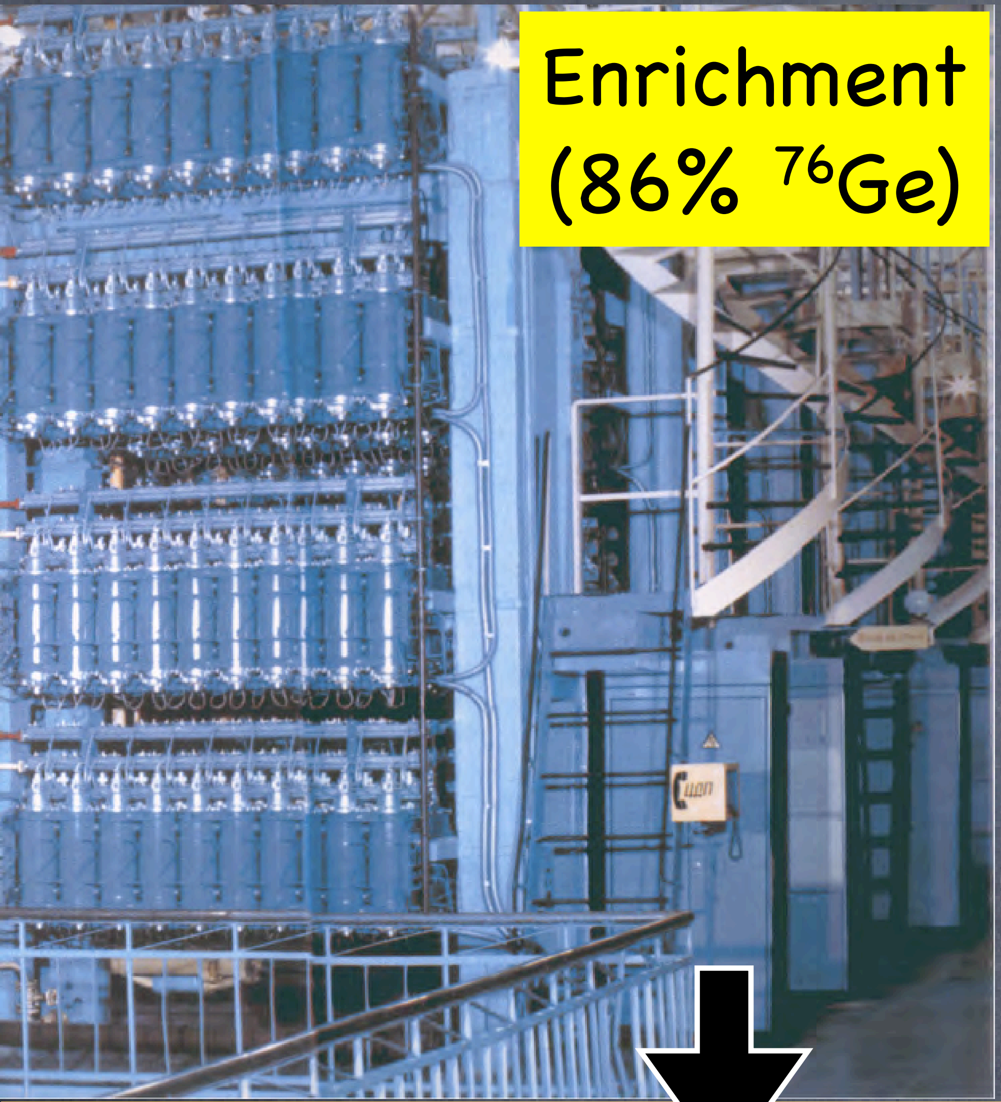

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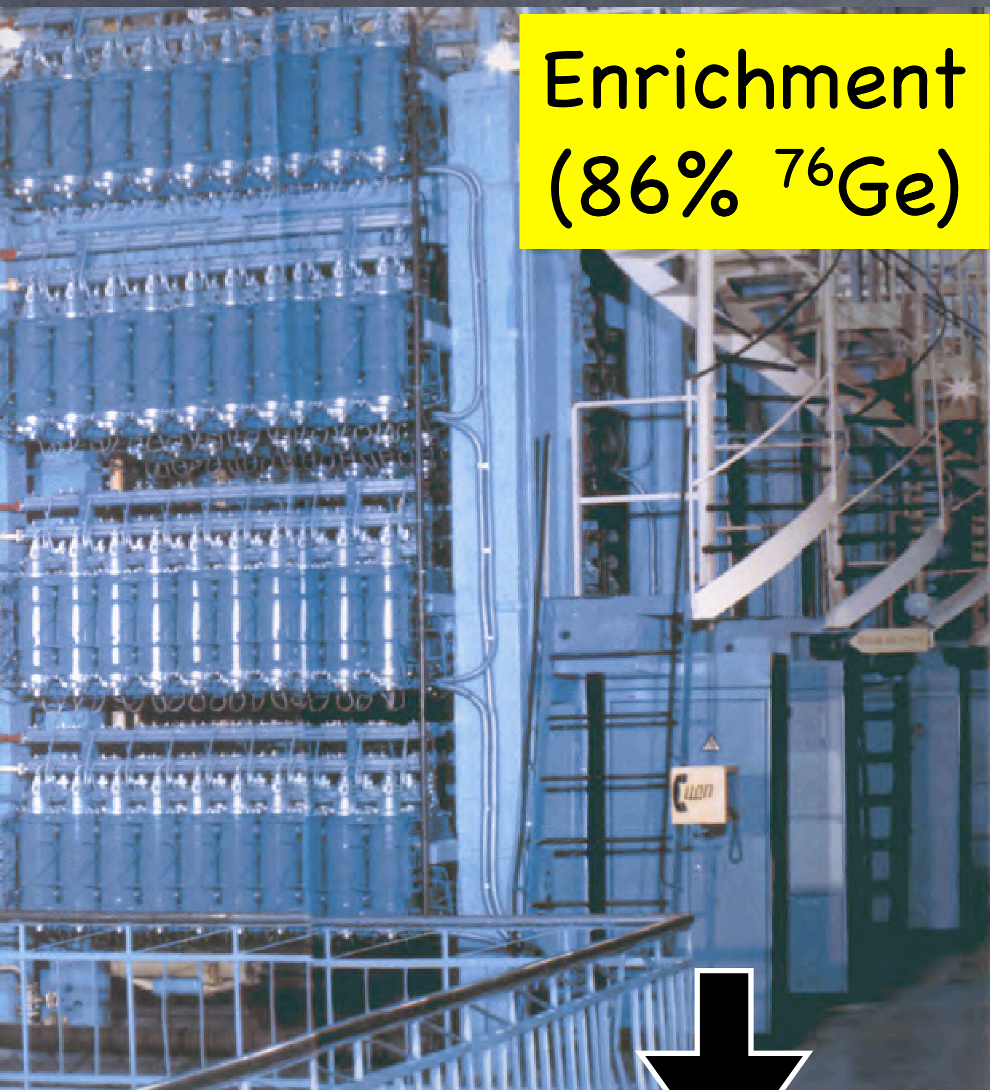

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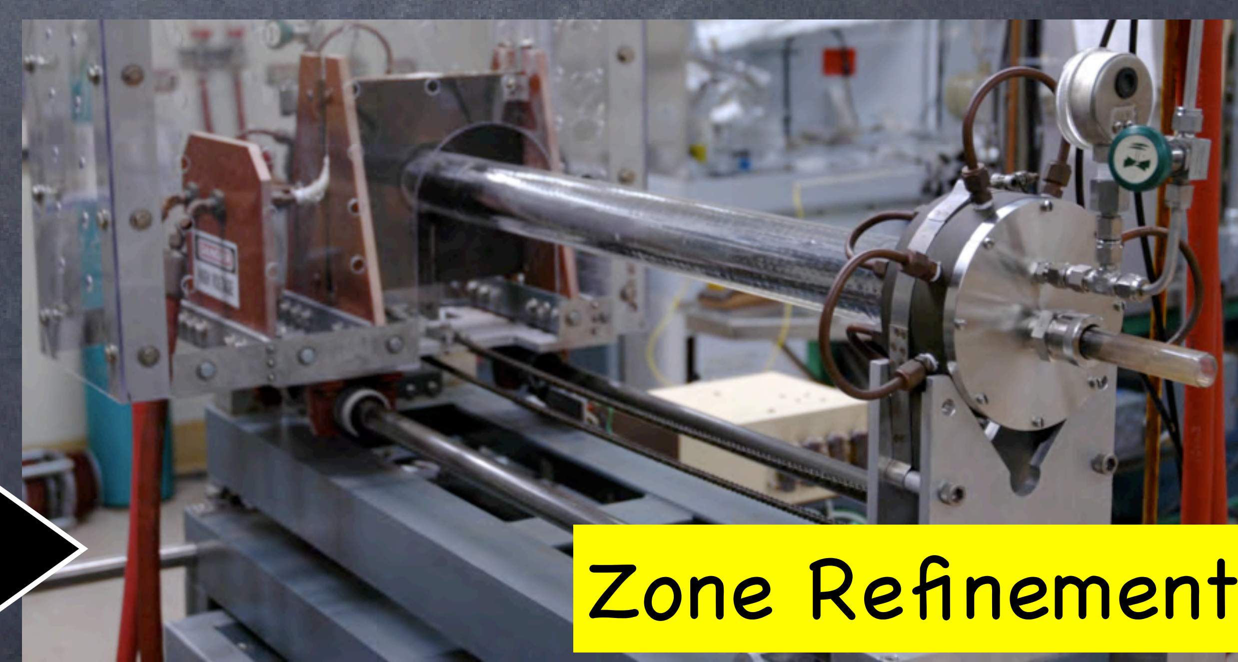

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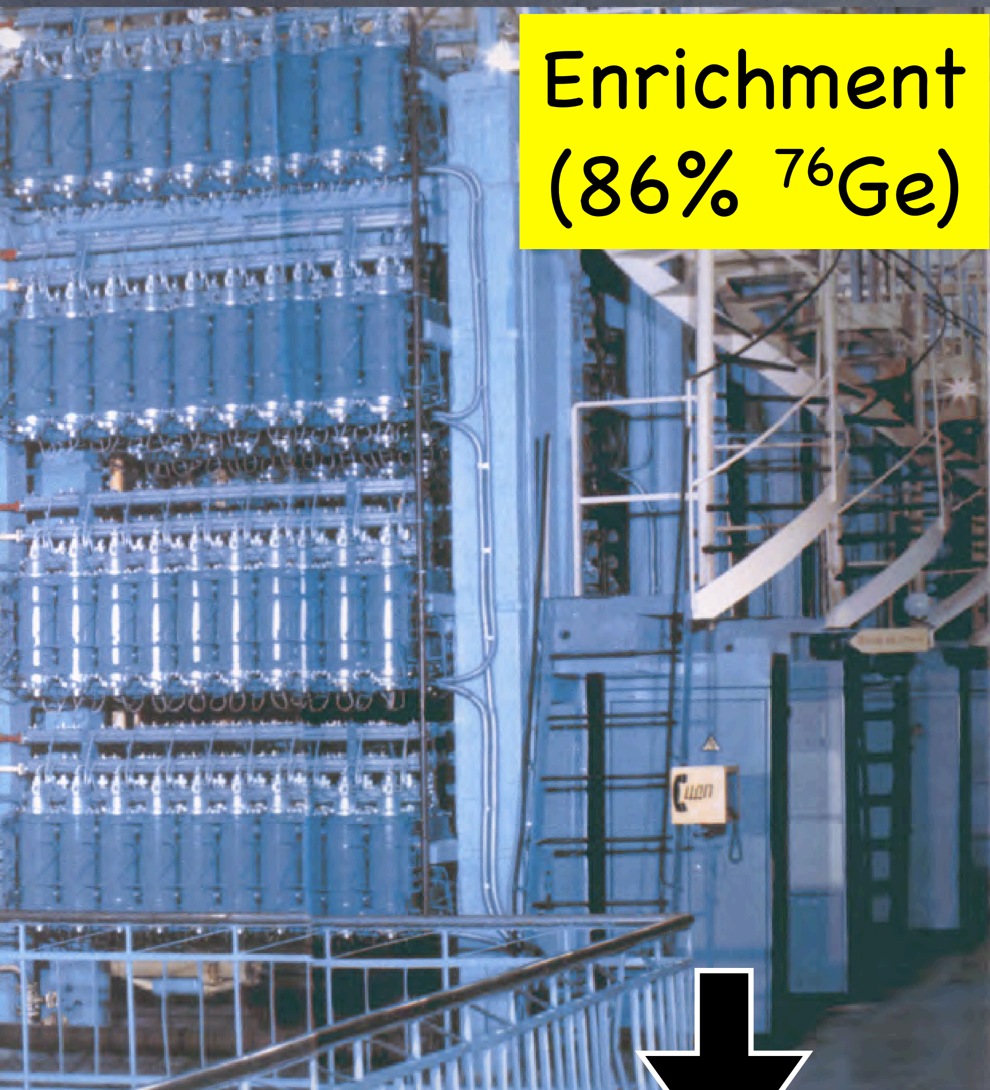

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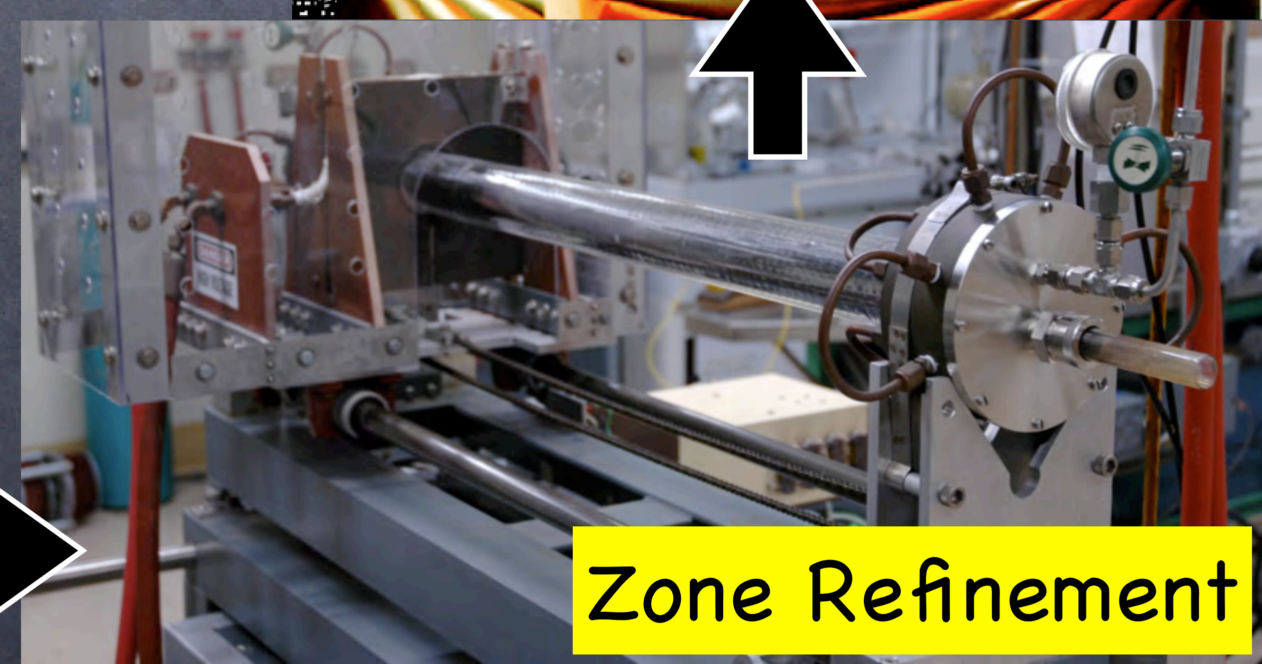

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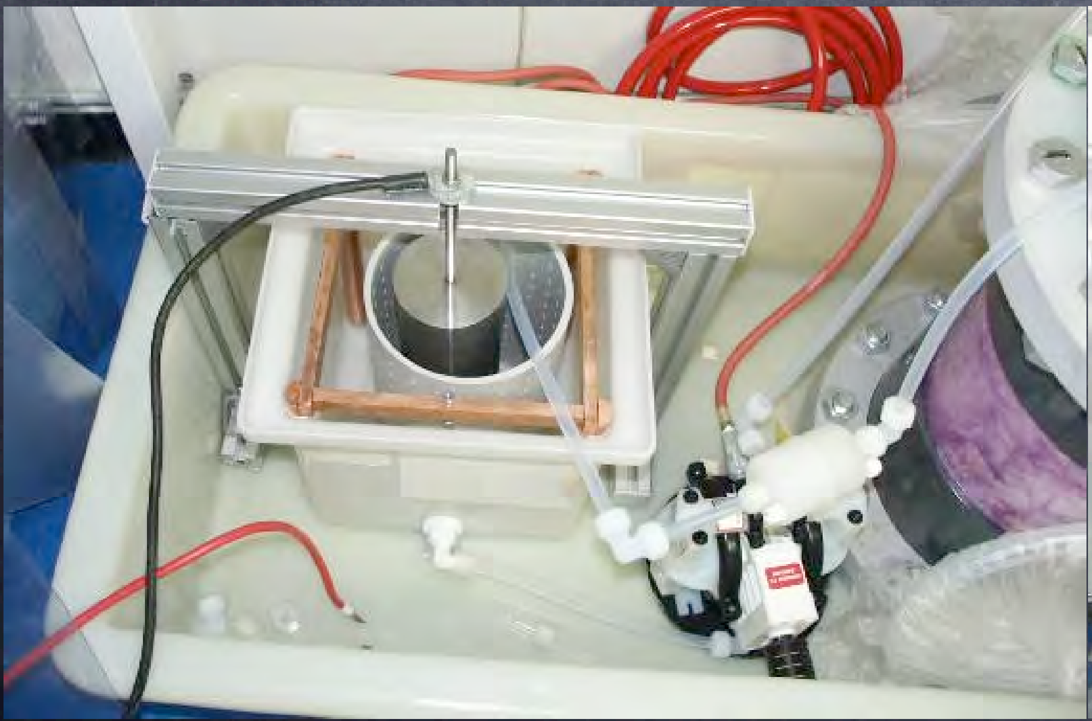
  - continuously filtering the bath

Electroformed Copper

- Copper is nice because it has no relatively long-lived radioisotopes (worst background is ^{60}Co from (n,α) reactions on ^{63}Cu)
- AND YOU CAN MAKE STUFF OUT OF IT!!!
- Made by dissolving Cu in sulfuric acid and applying a small potential across the bath, causing Cu metal to plate out onto a cathode
- Parts grown this way are kept clean by:
  - carefully controlling the plating potential
  - continuously filtering the bath



MAJORANA Backgrounds

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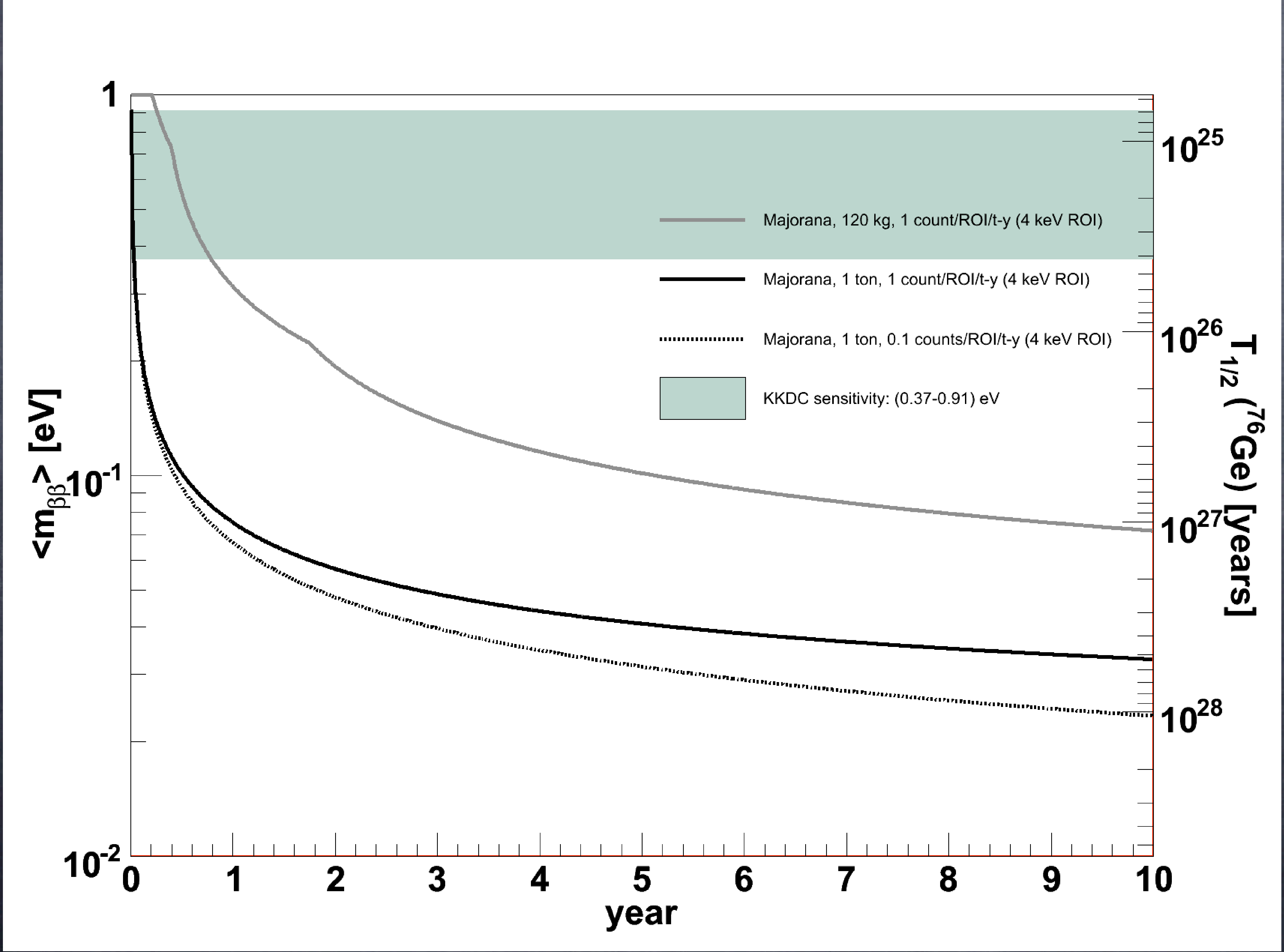
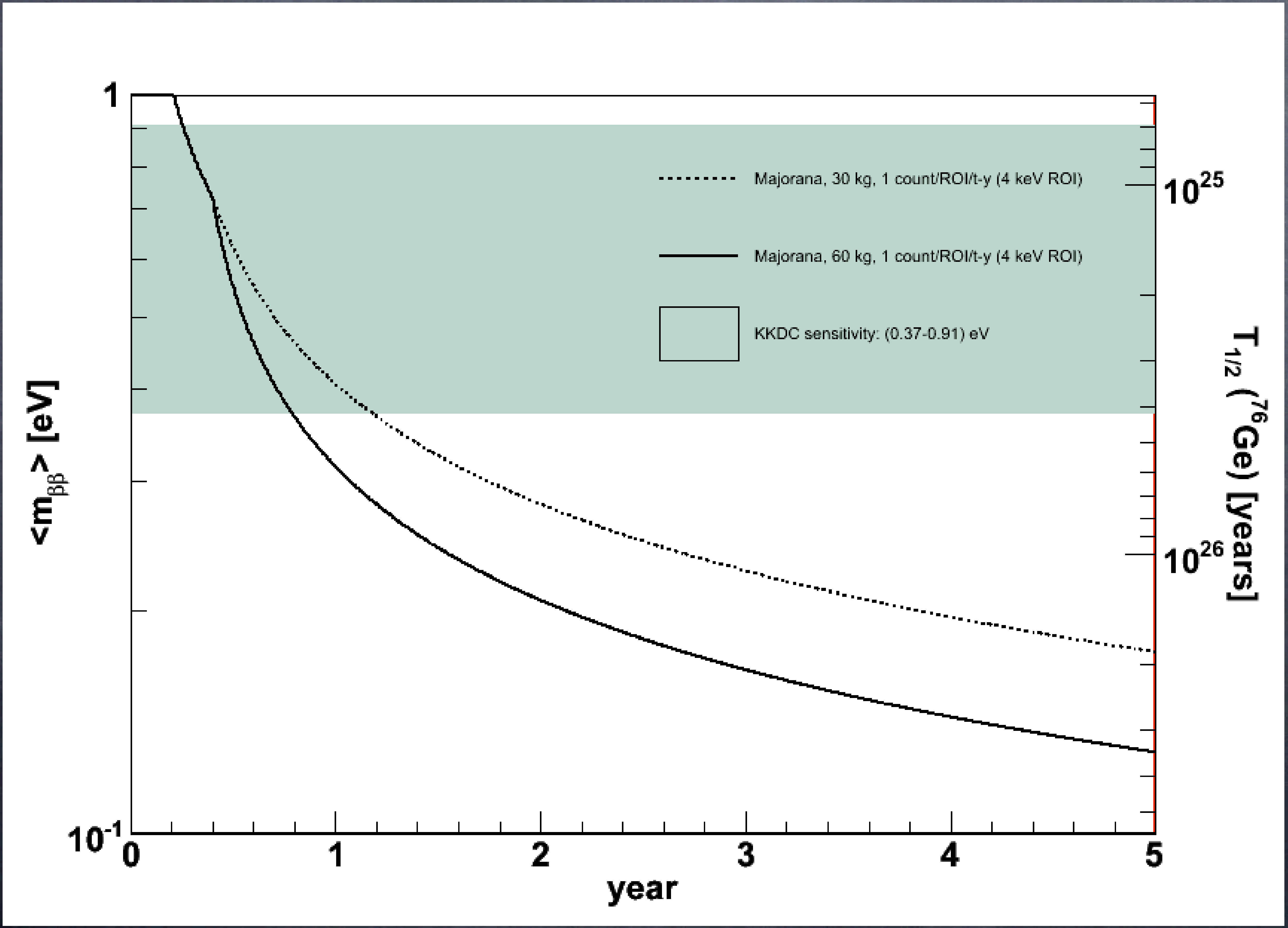
Backgrounds: tonne-scale sensitivity



Backgrounds: Prototype Sensitivity



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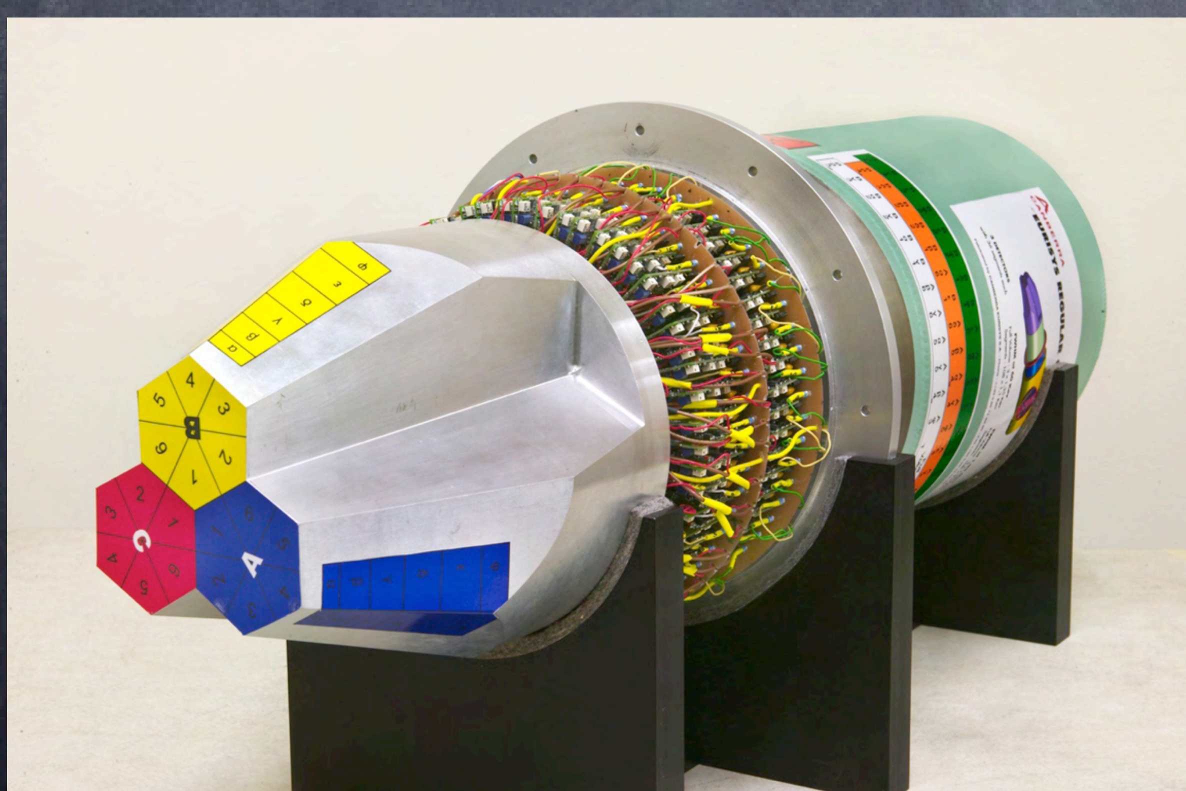

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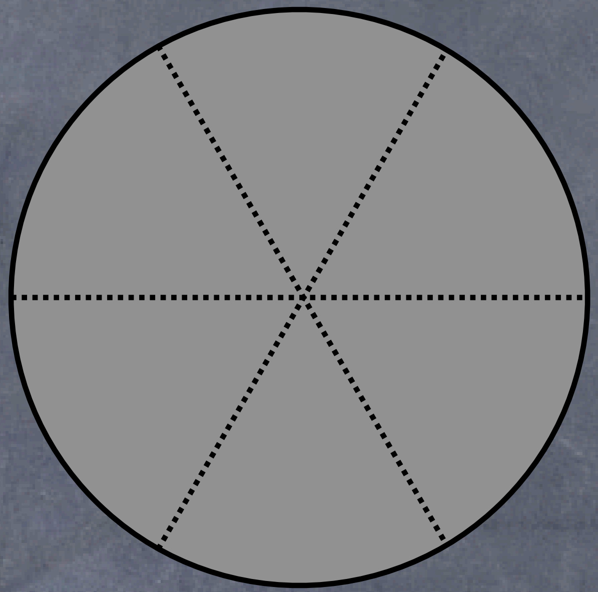

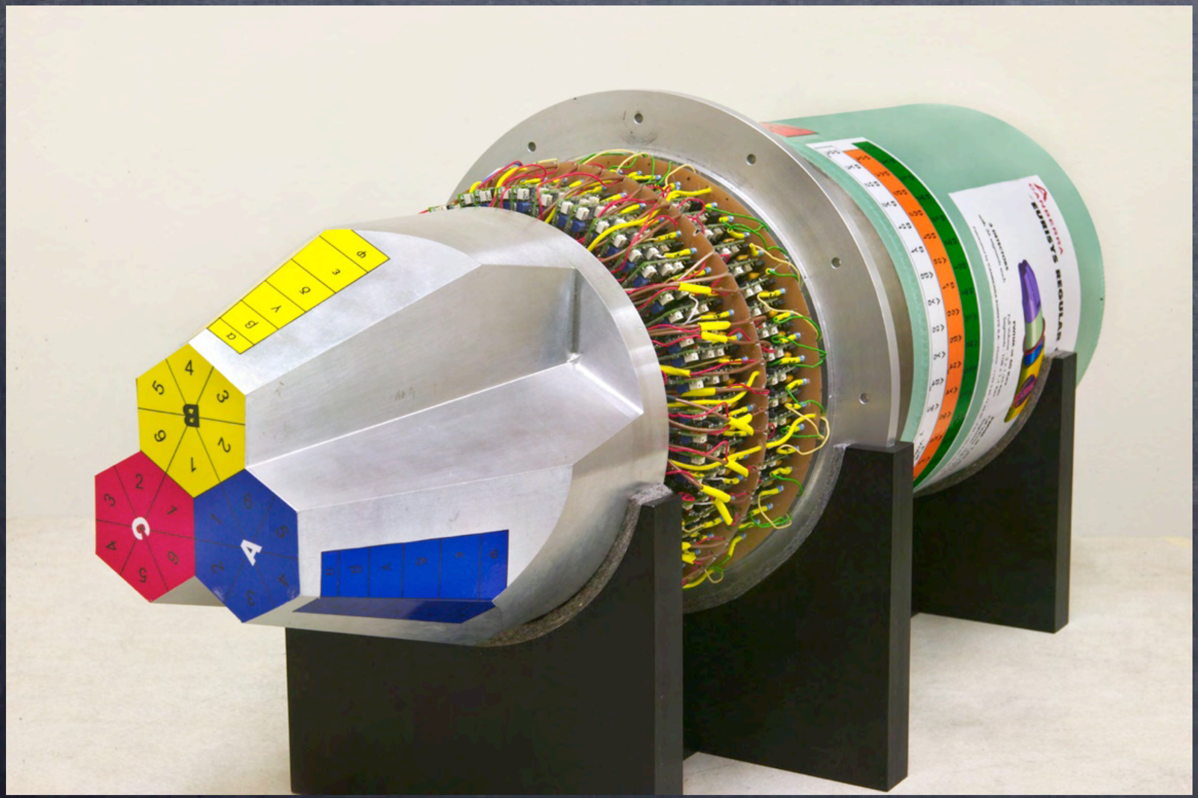

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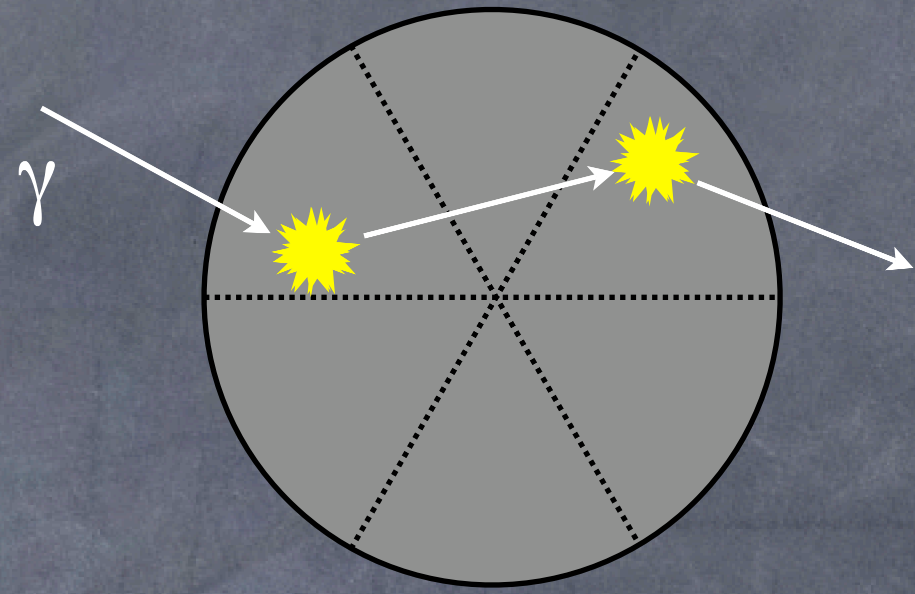

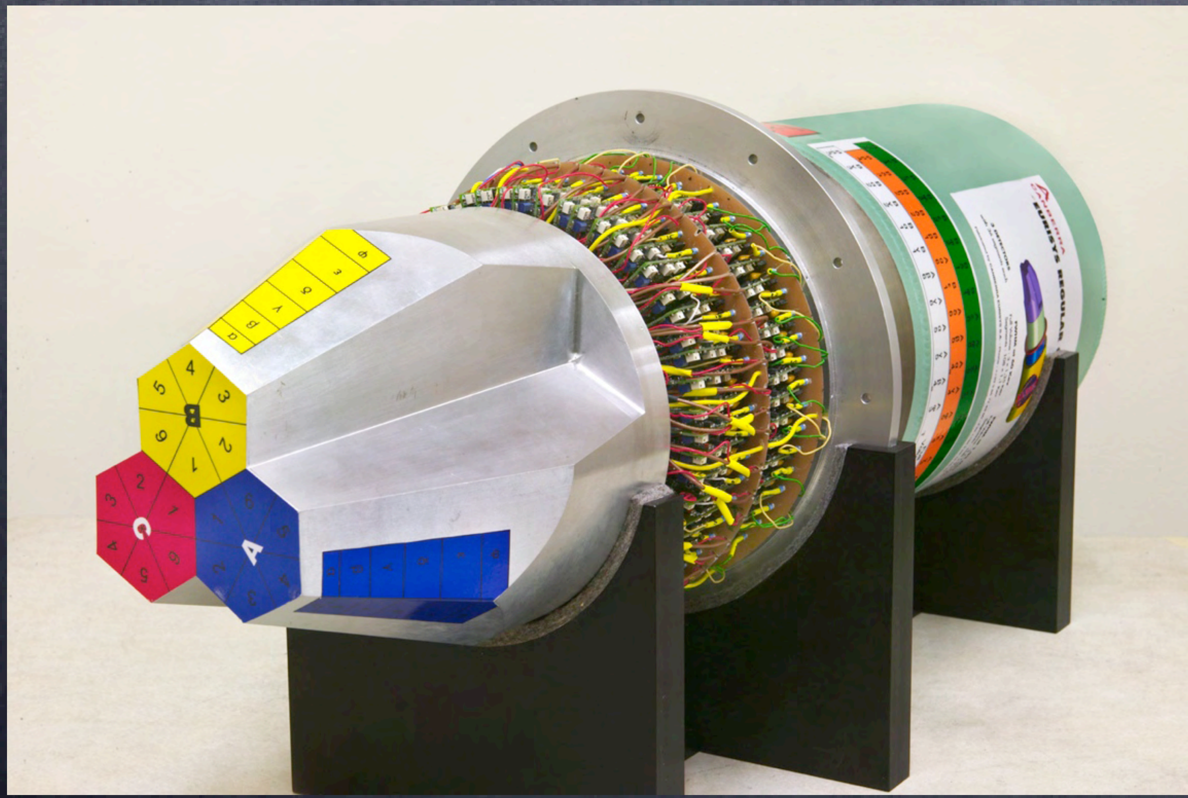

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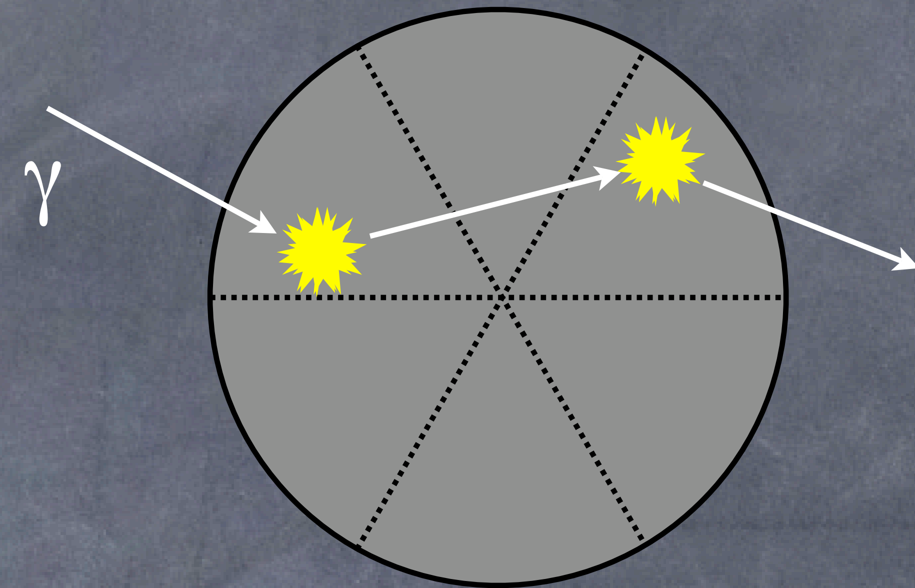

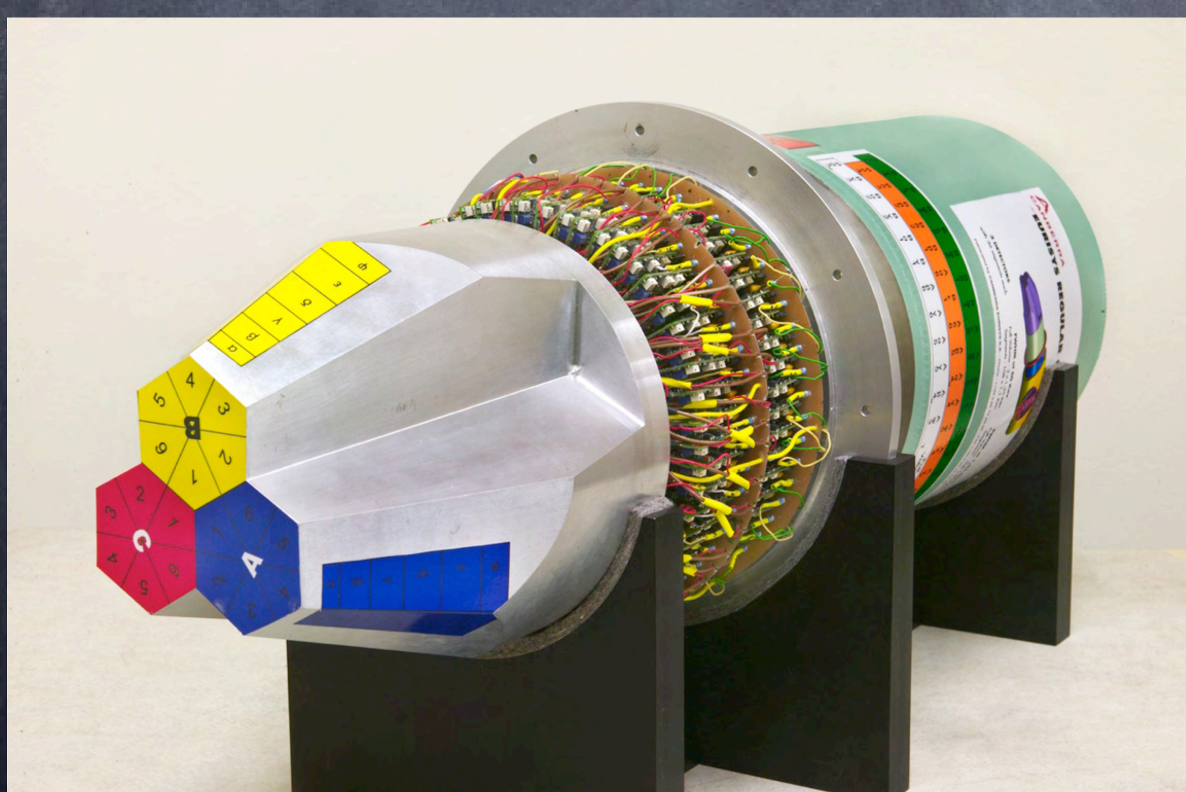

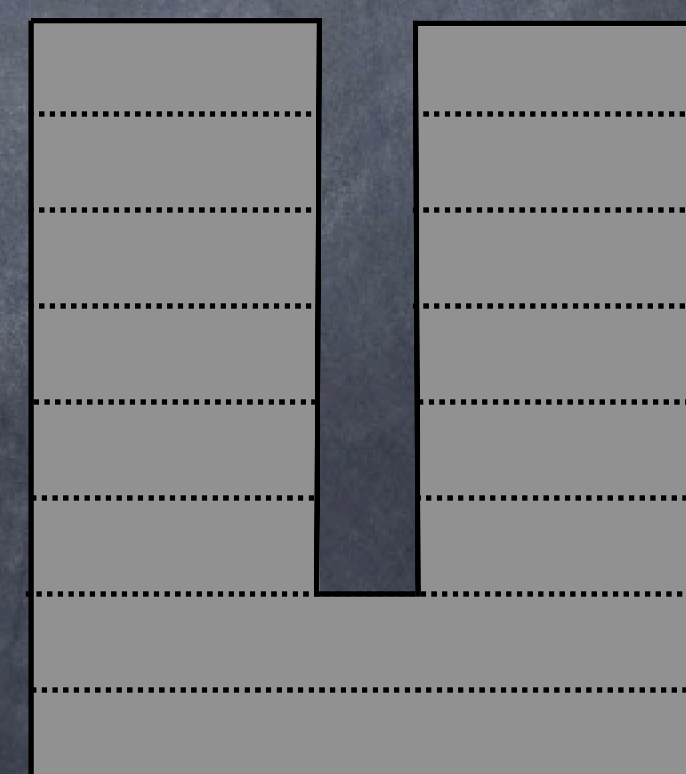

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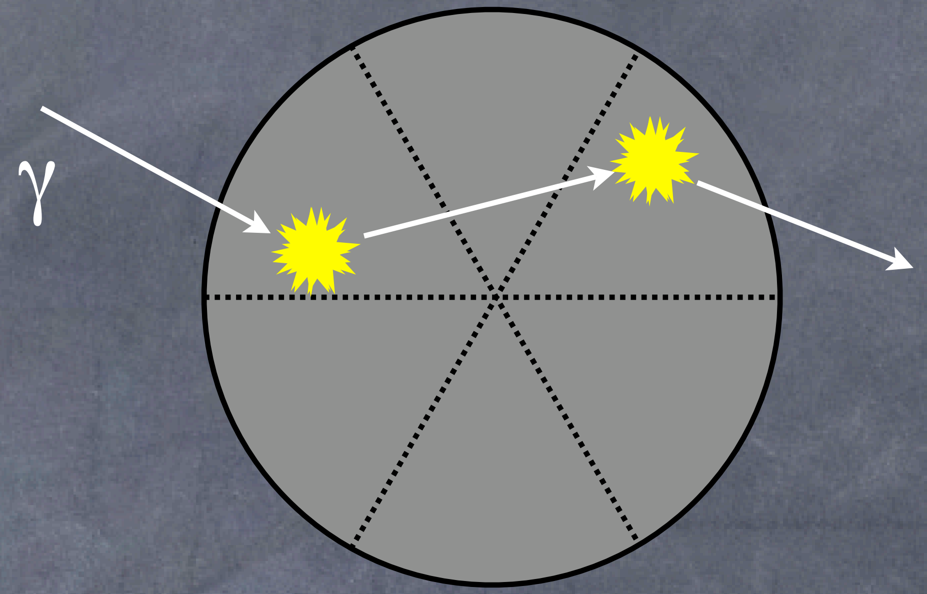

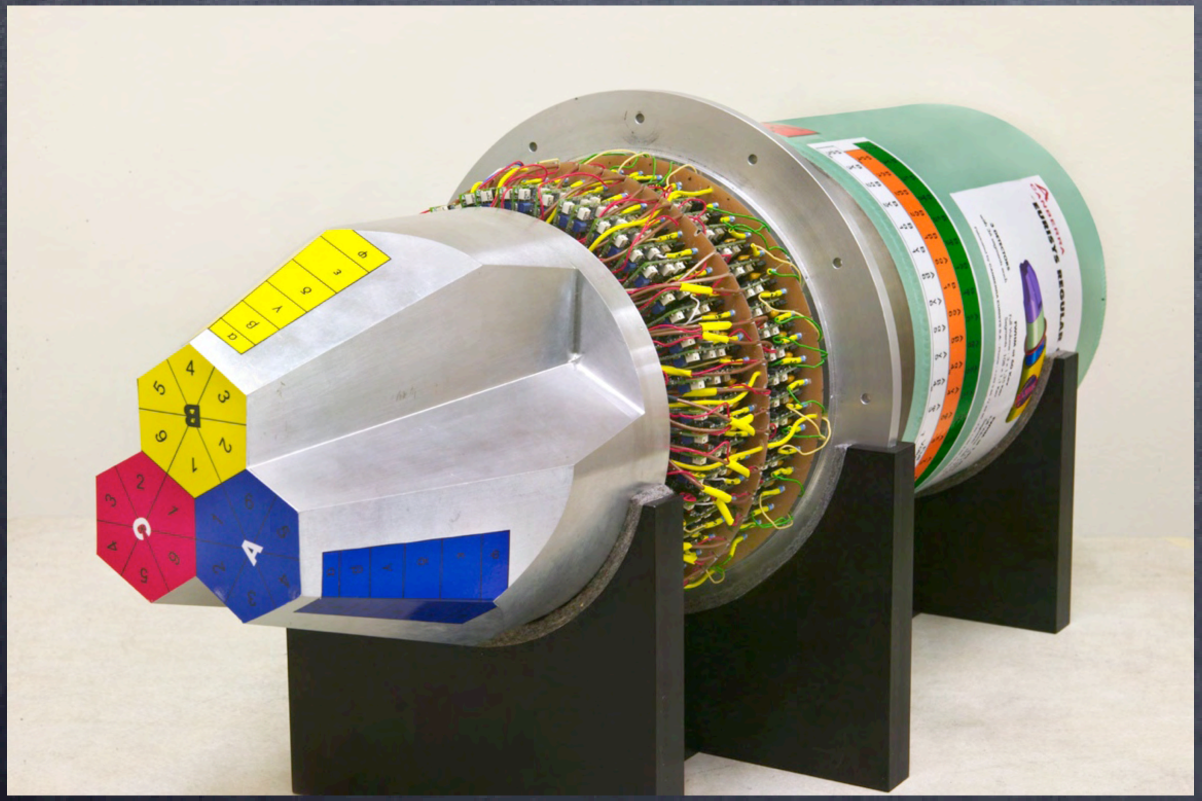

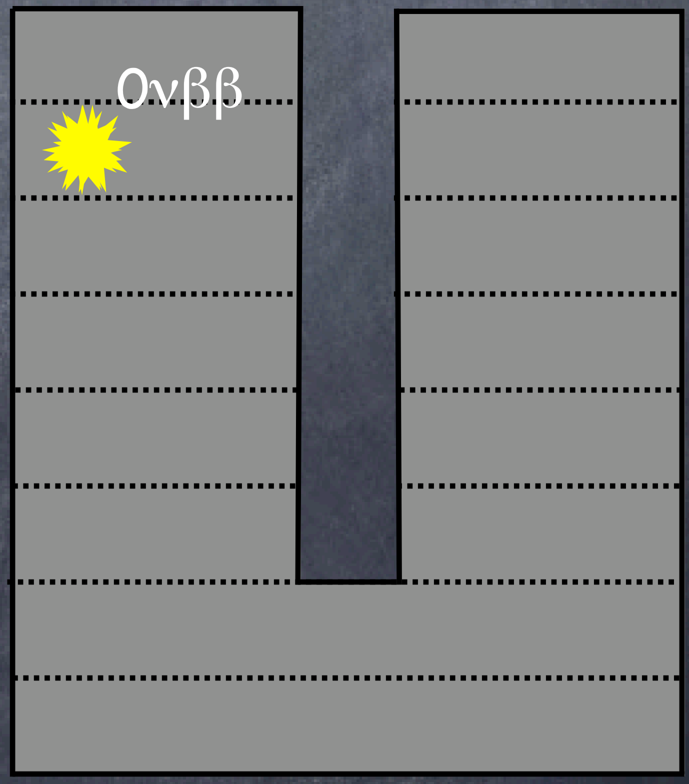

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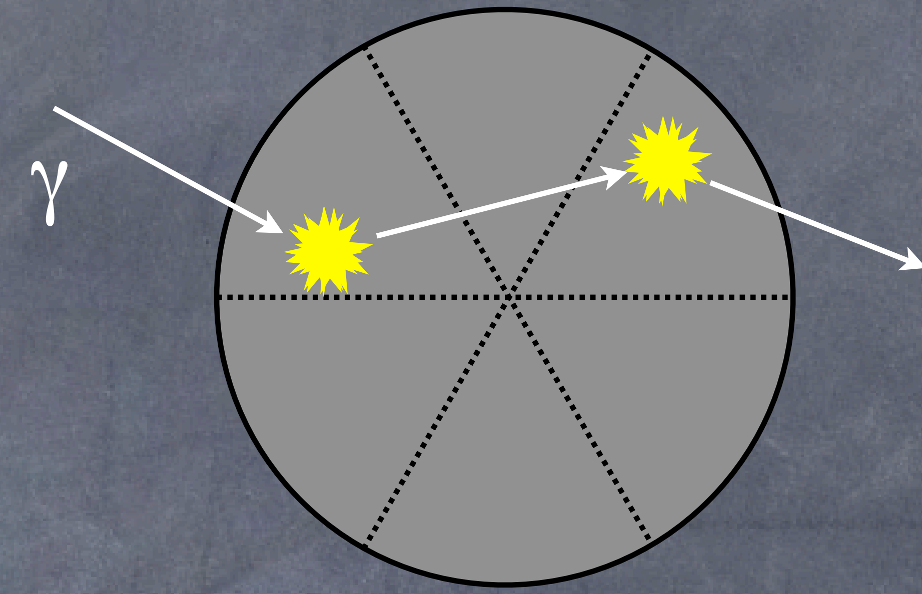

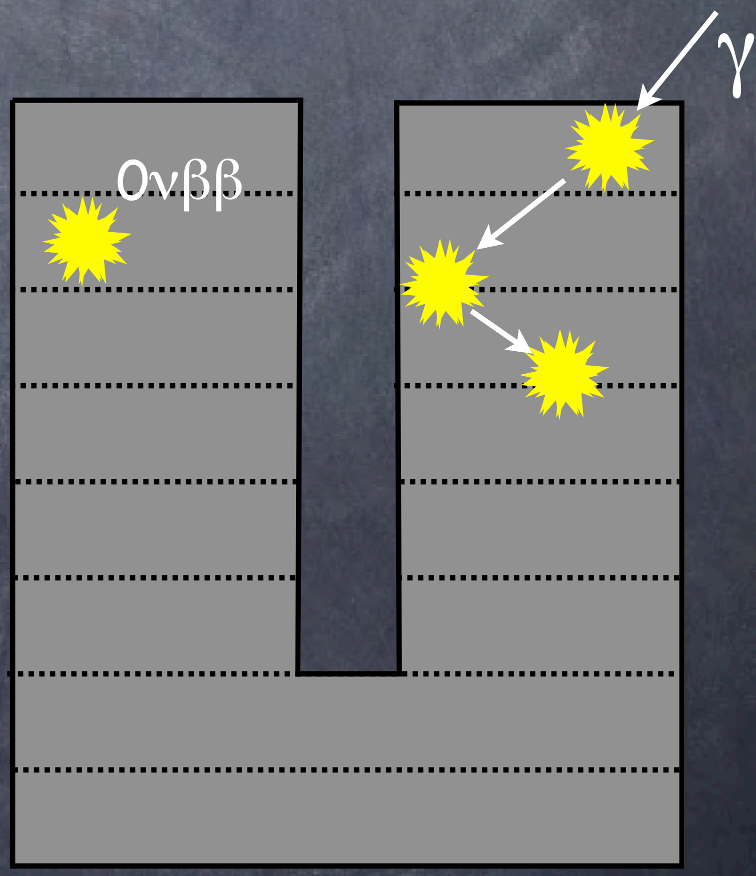

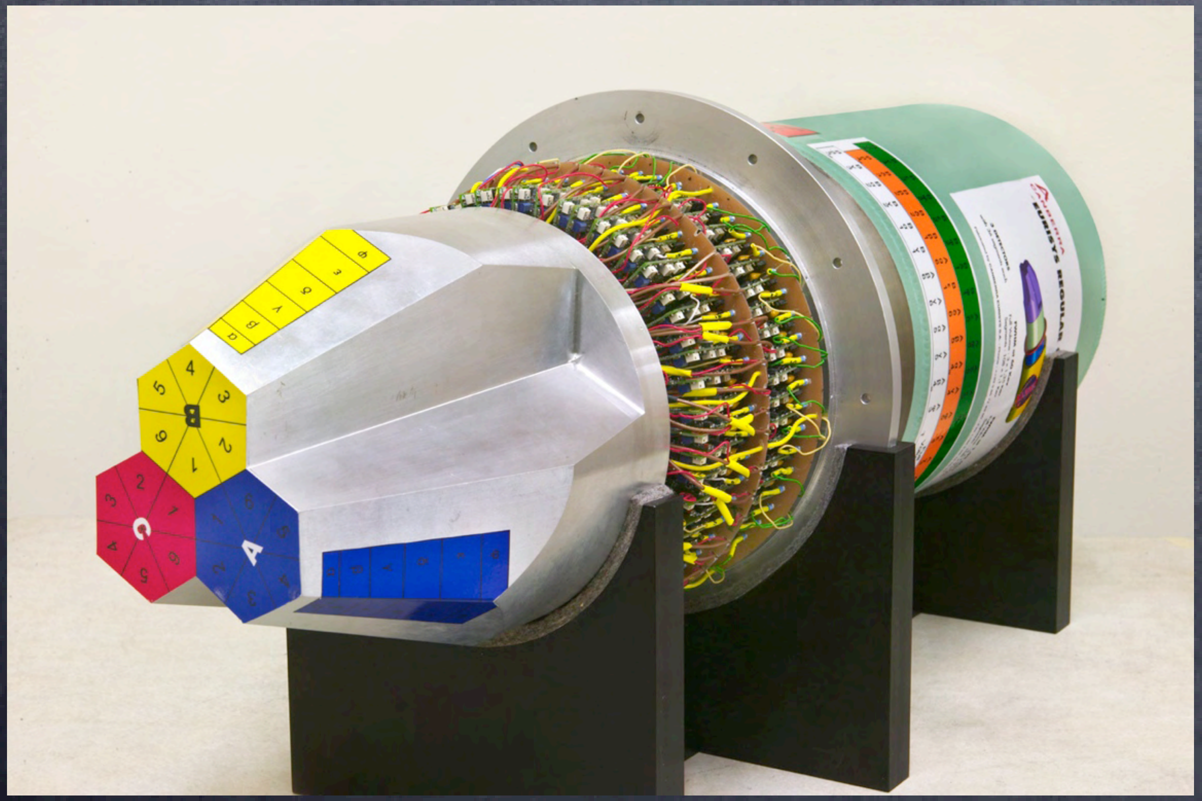

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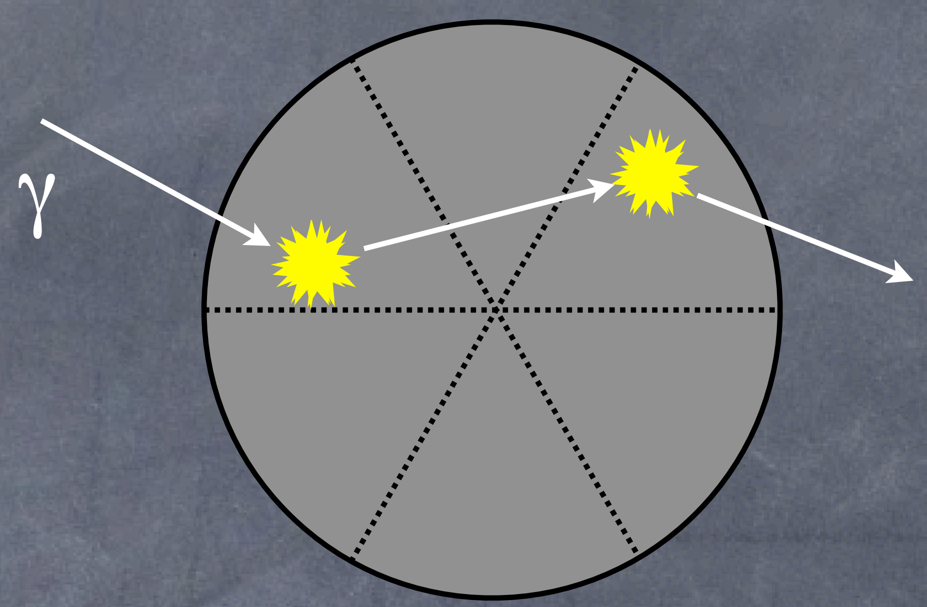

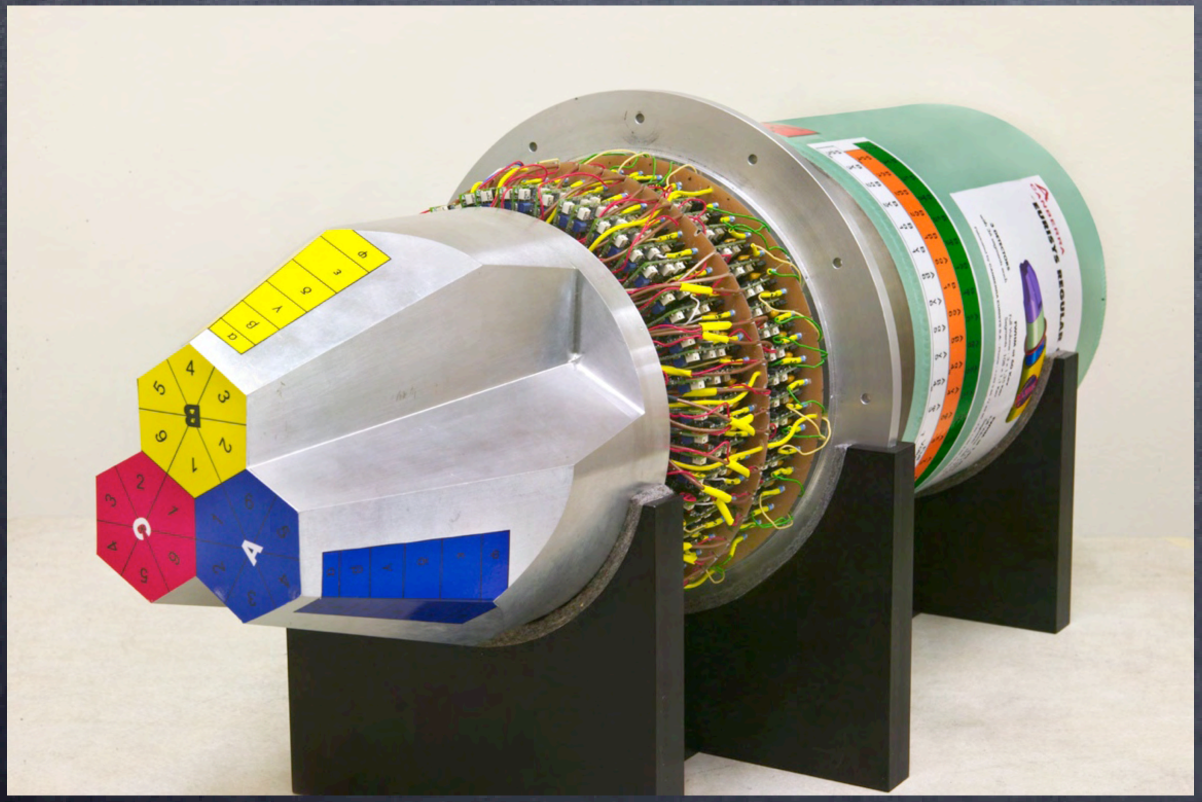

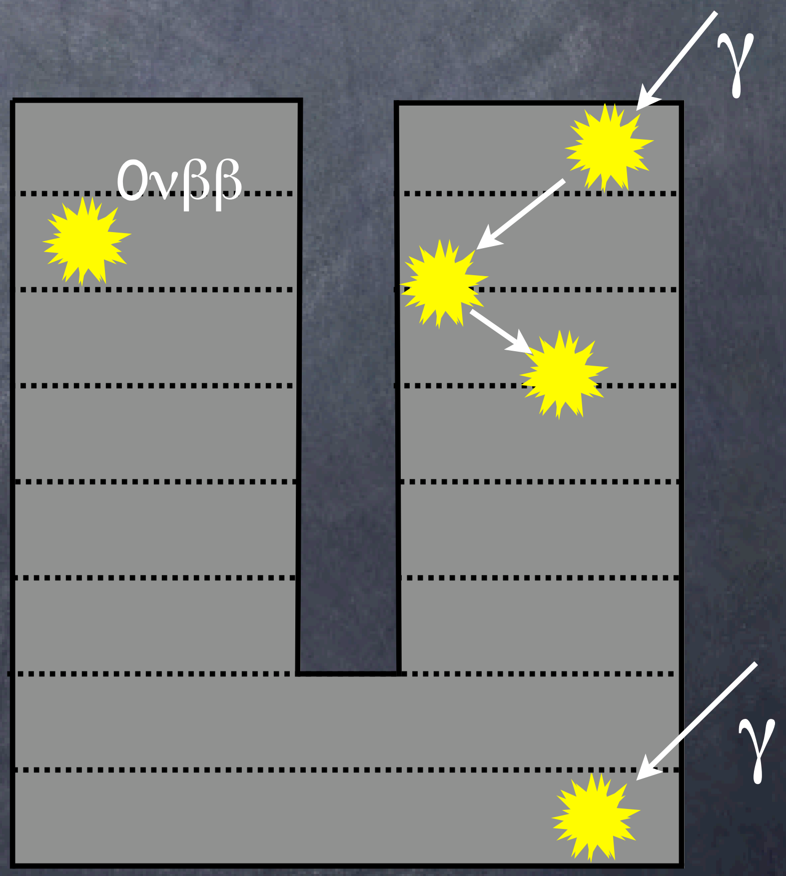

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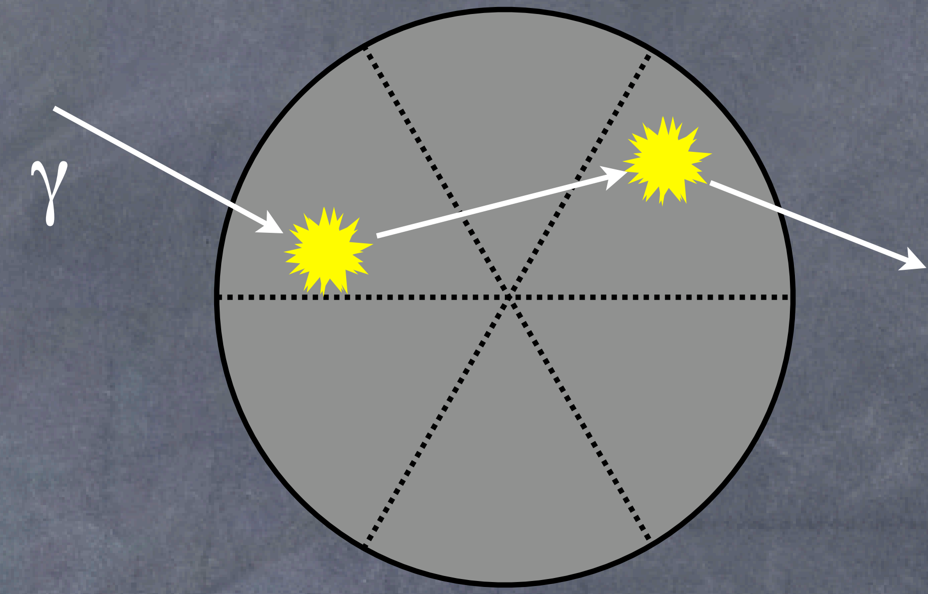

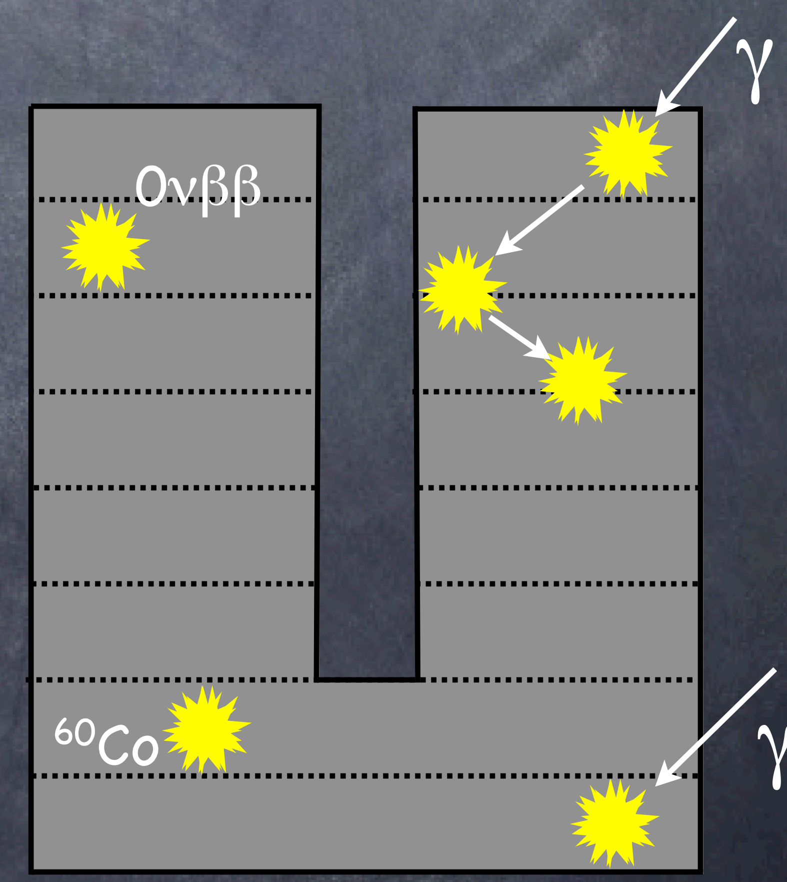

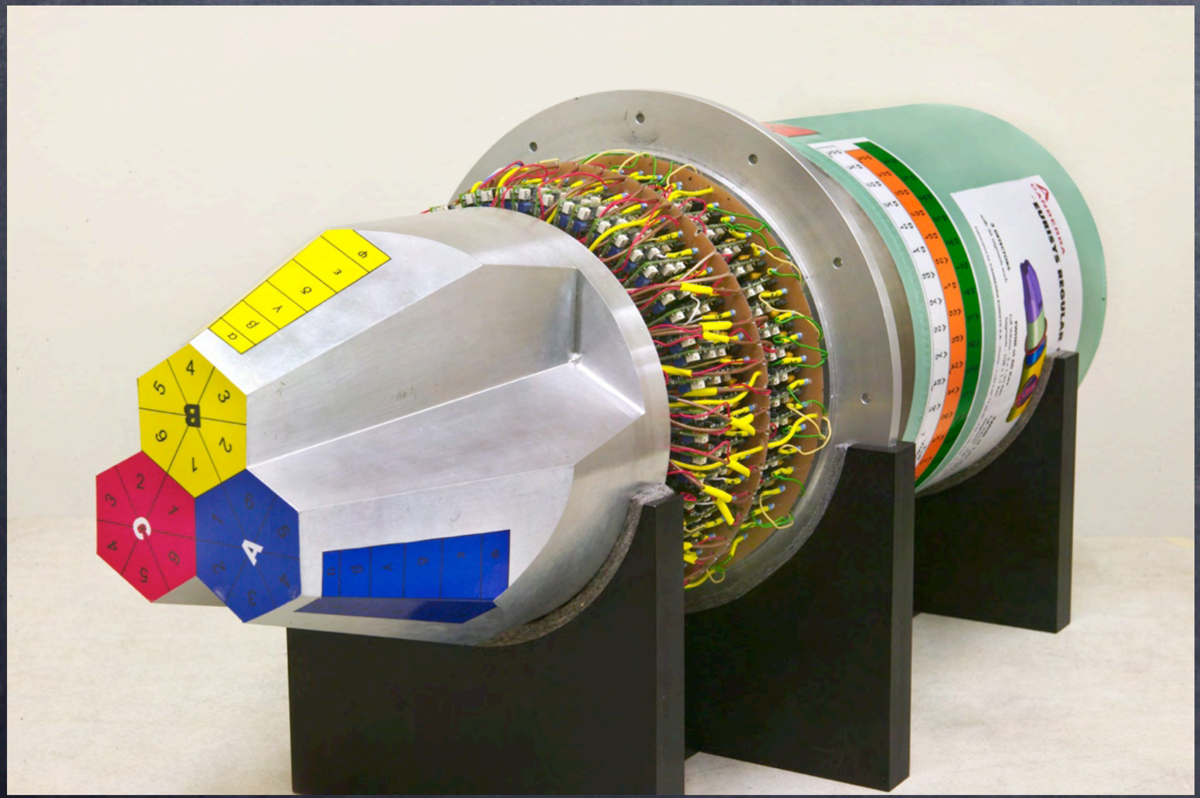

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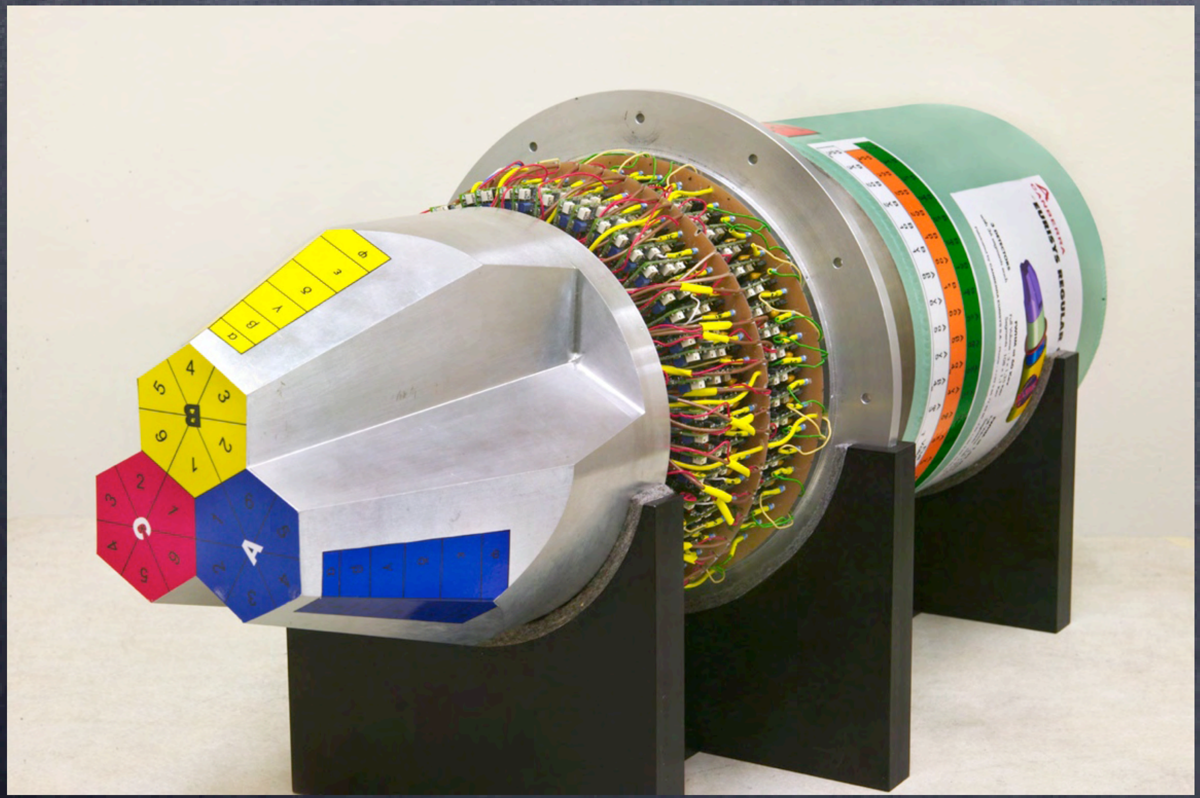
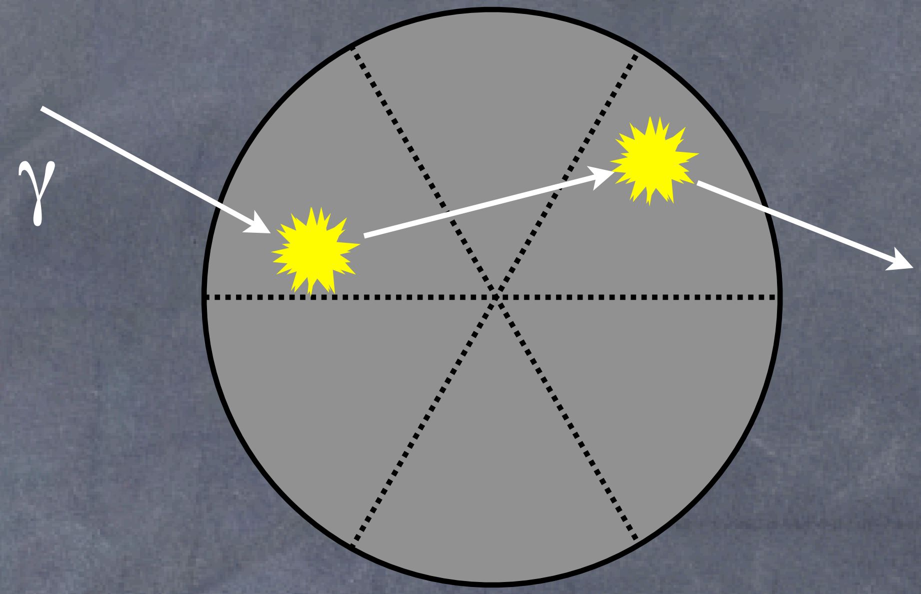
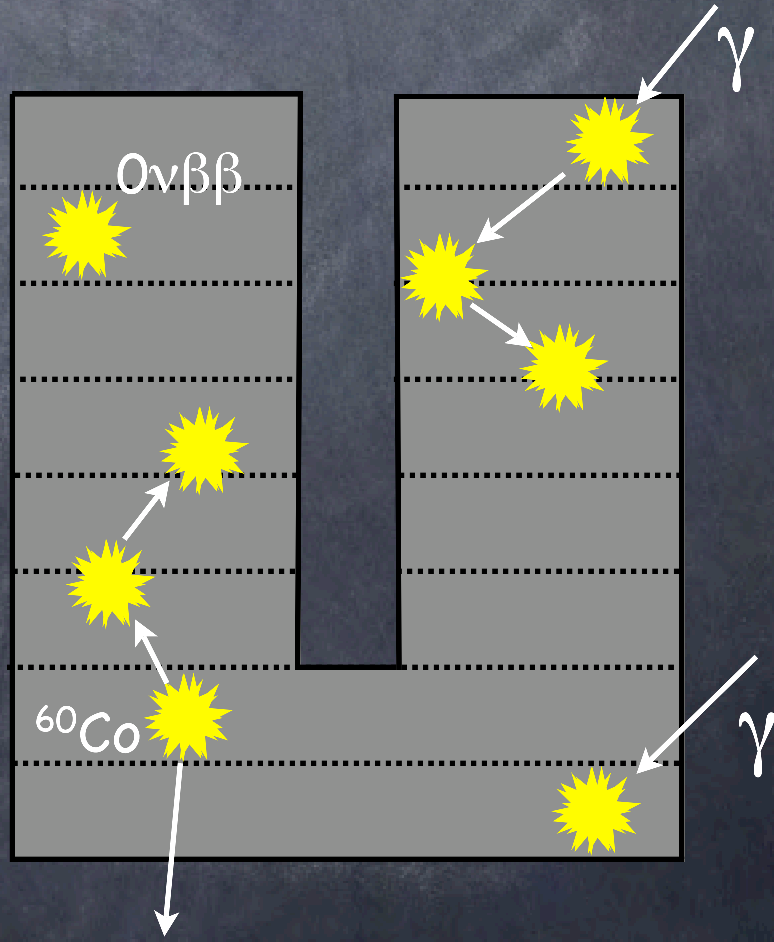
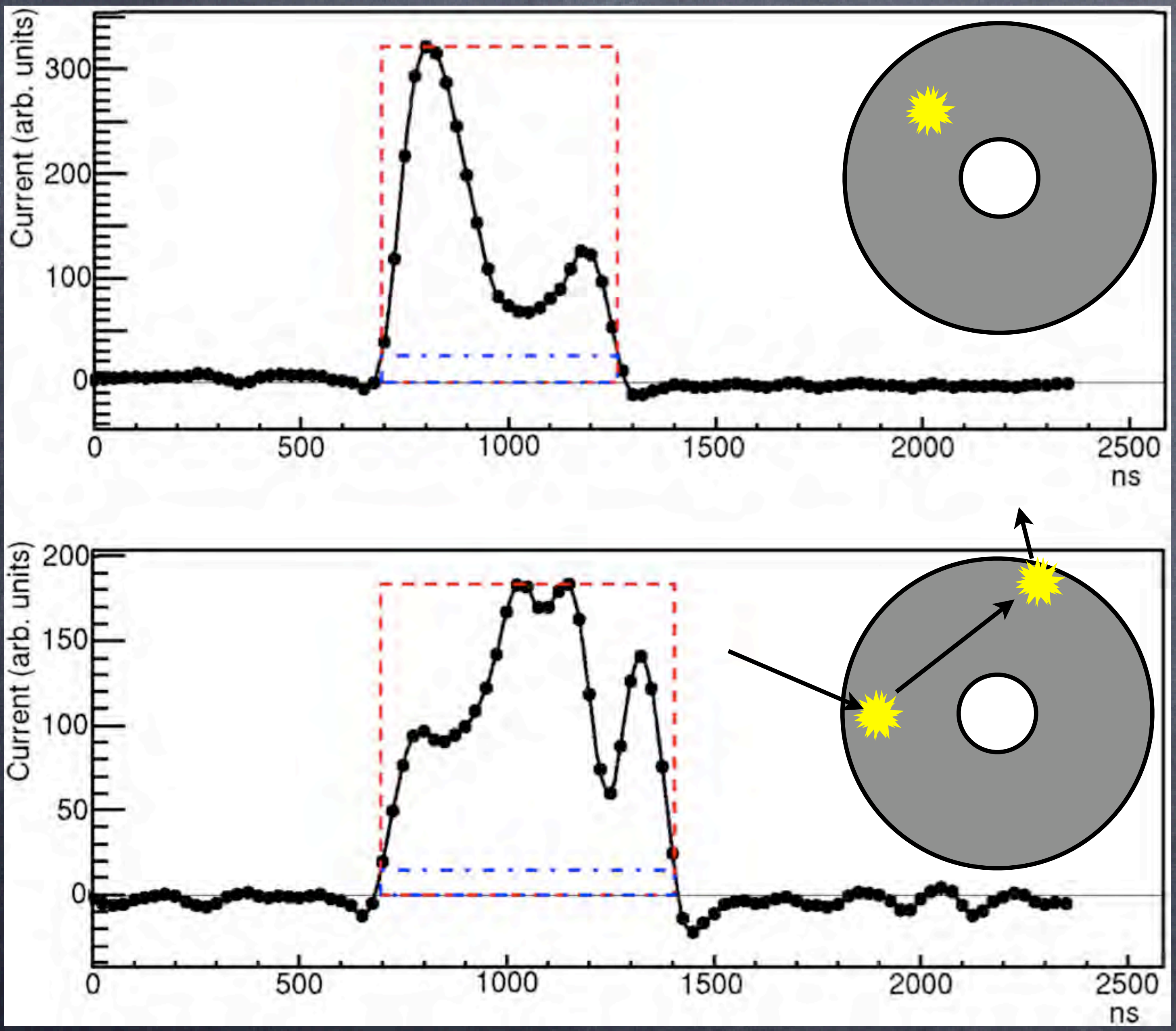






Pulse Shape Analysis (PSA)

Helps separate radially extended evetns



- Excellent for rejecting internal ^{68}Ge and ^{60}Co
- Works well with segmentation and allows sophisticated techniques

Other Cuts

Also plan to use:

- Detector to detector anti-coincidence
- Time coincidence
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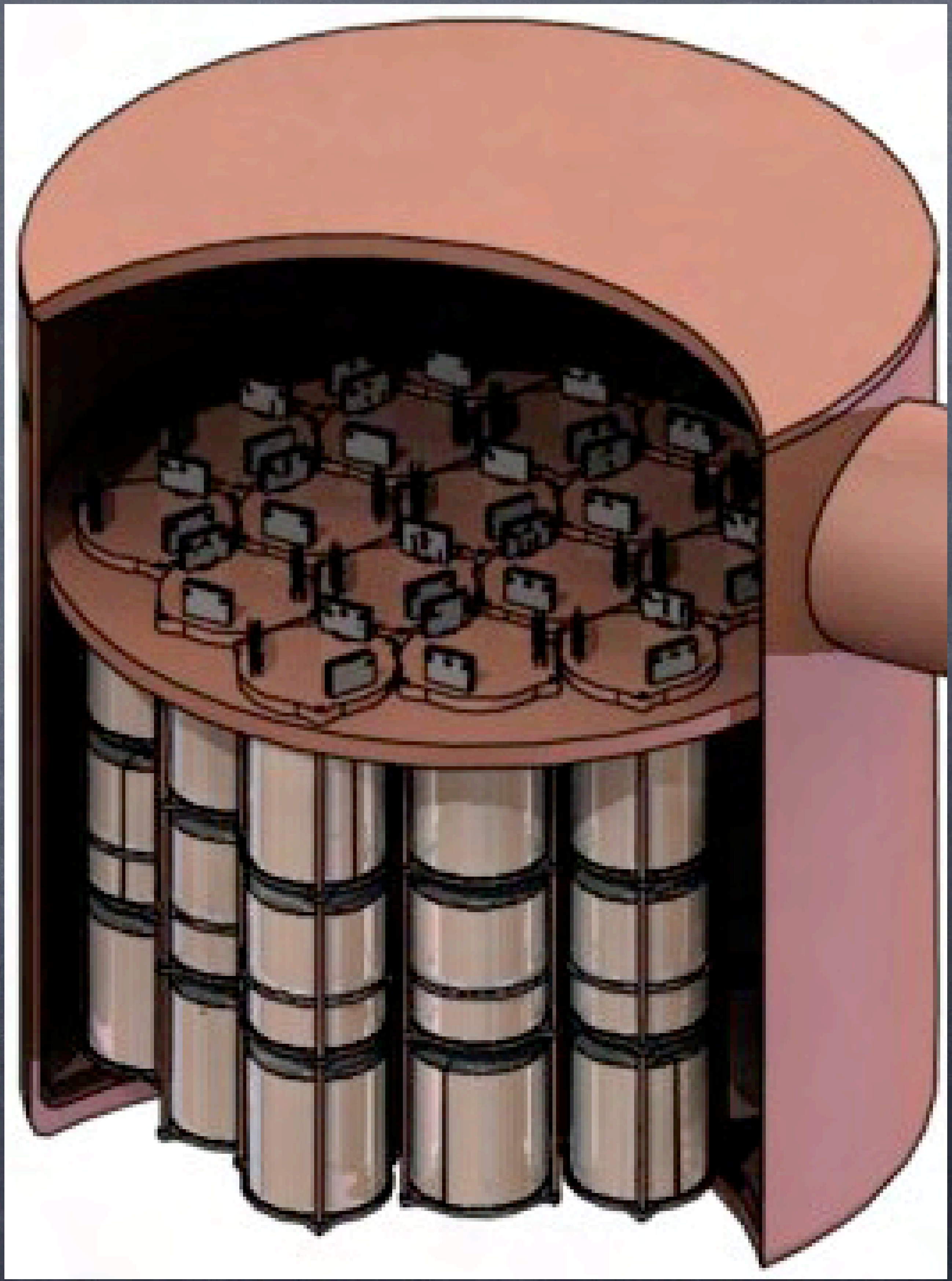

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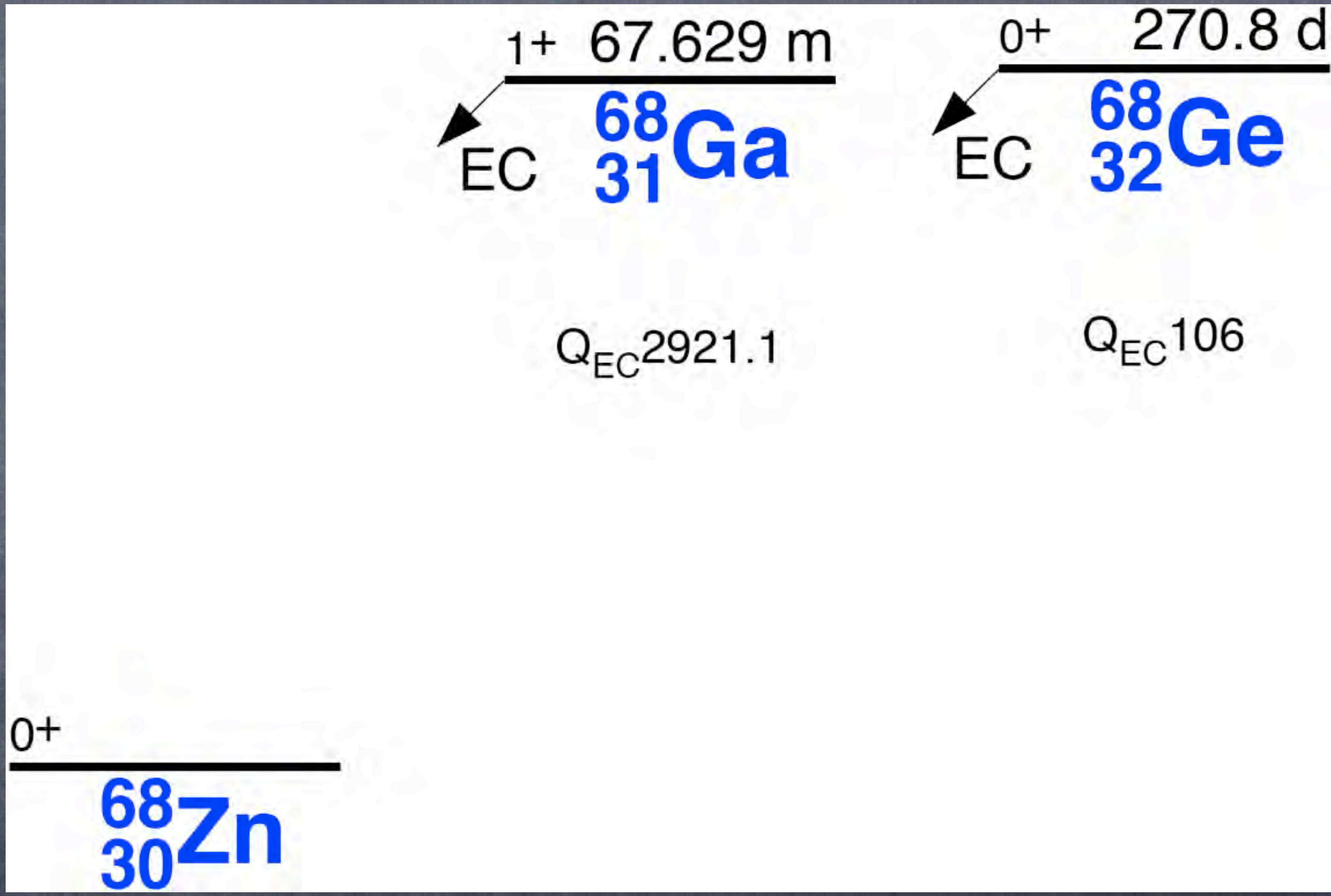

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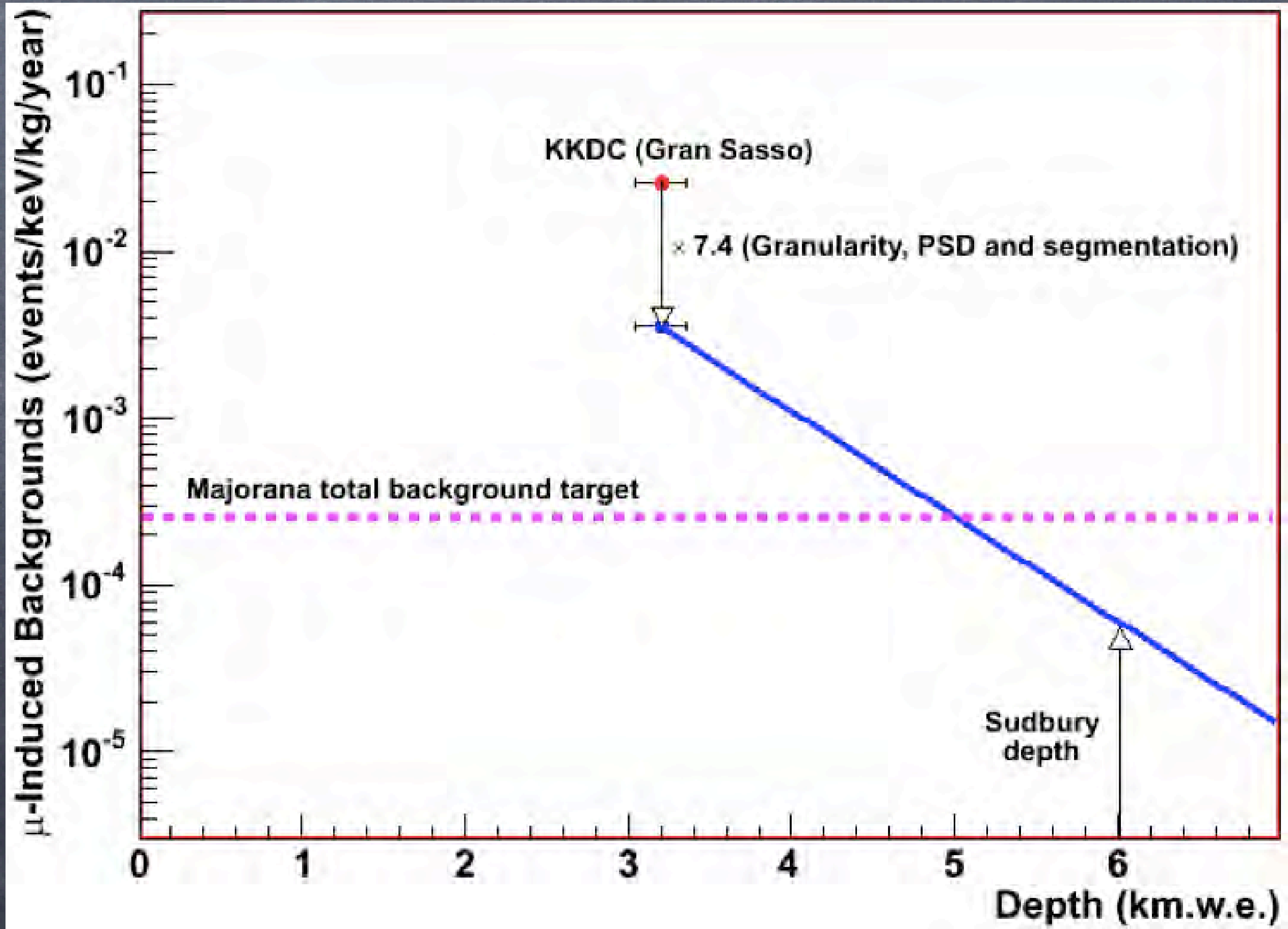
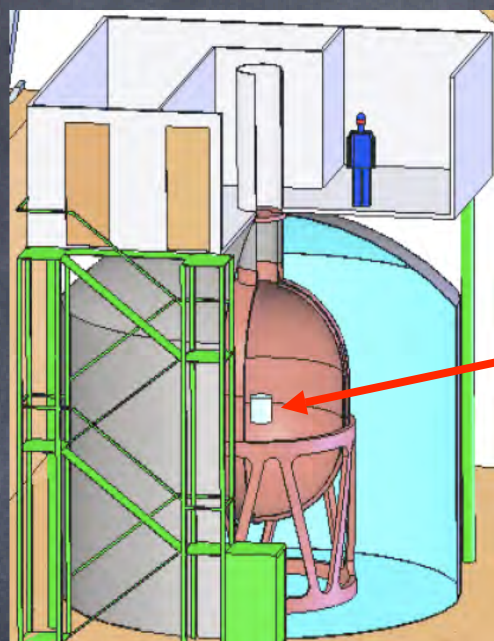
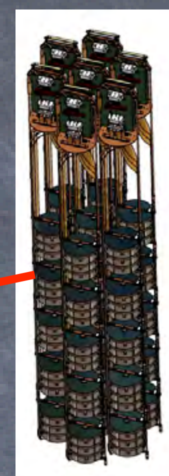


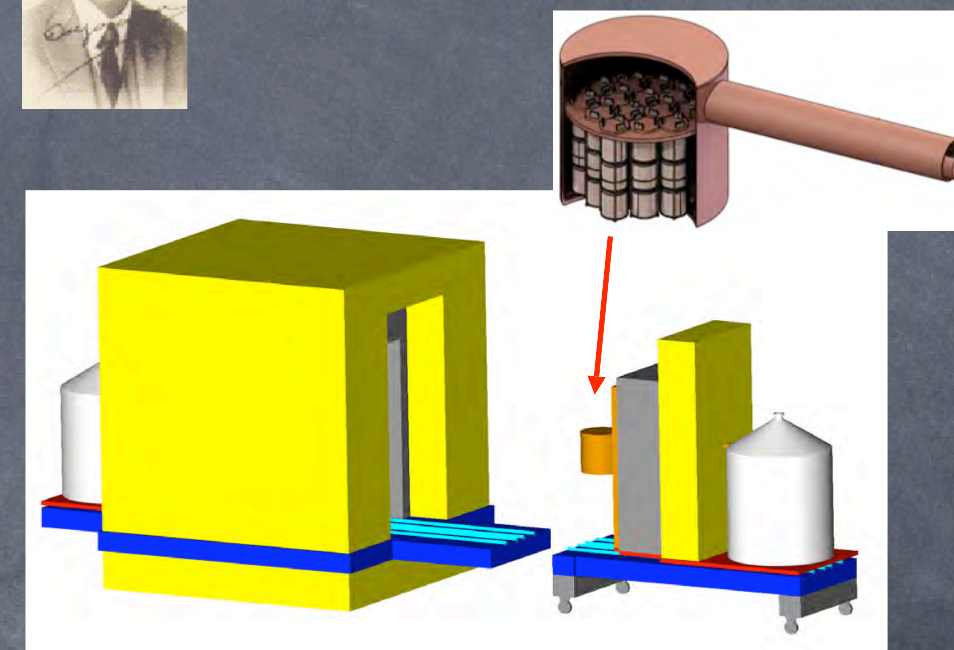
GERDA-MAJORANA Cooperation

GERDA





MAJORANA

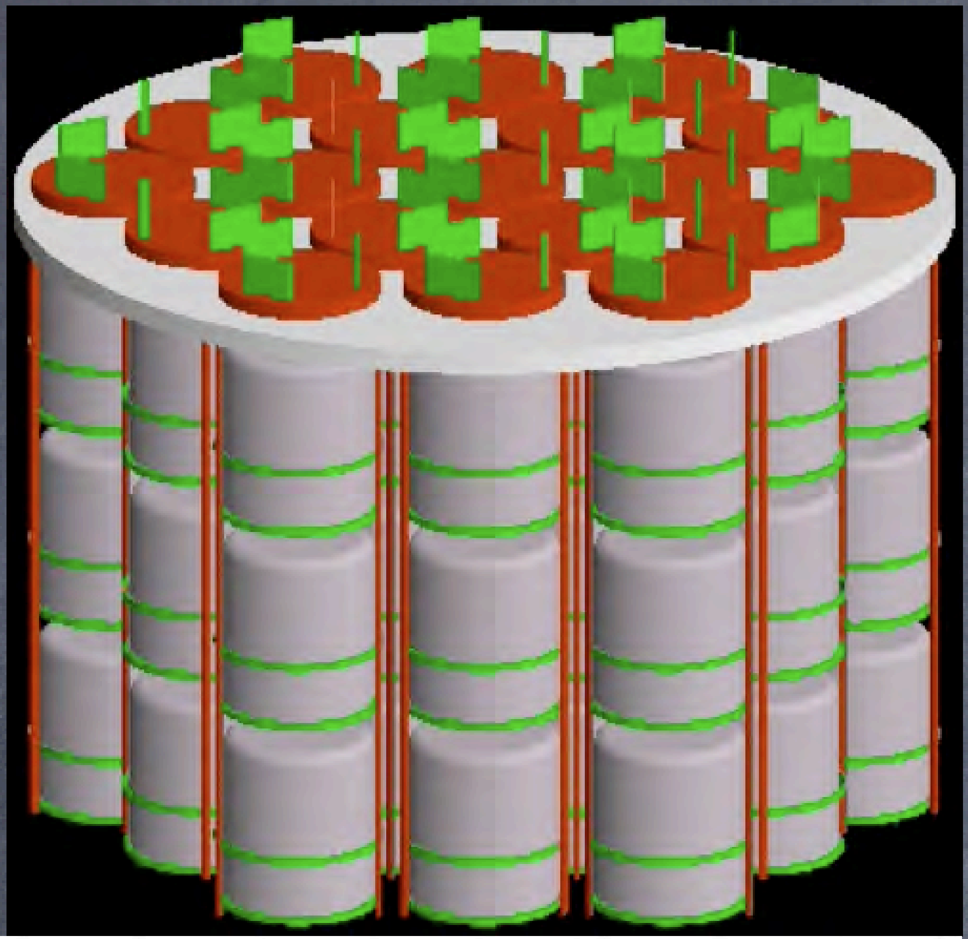


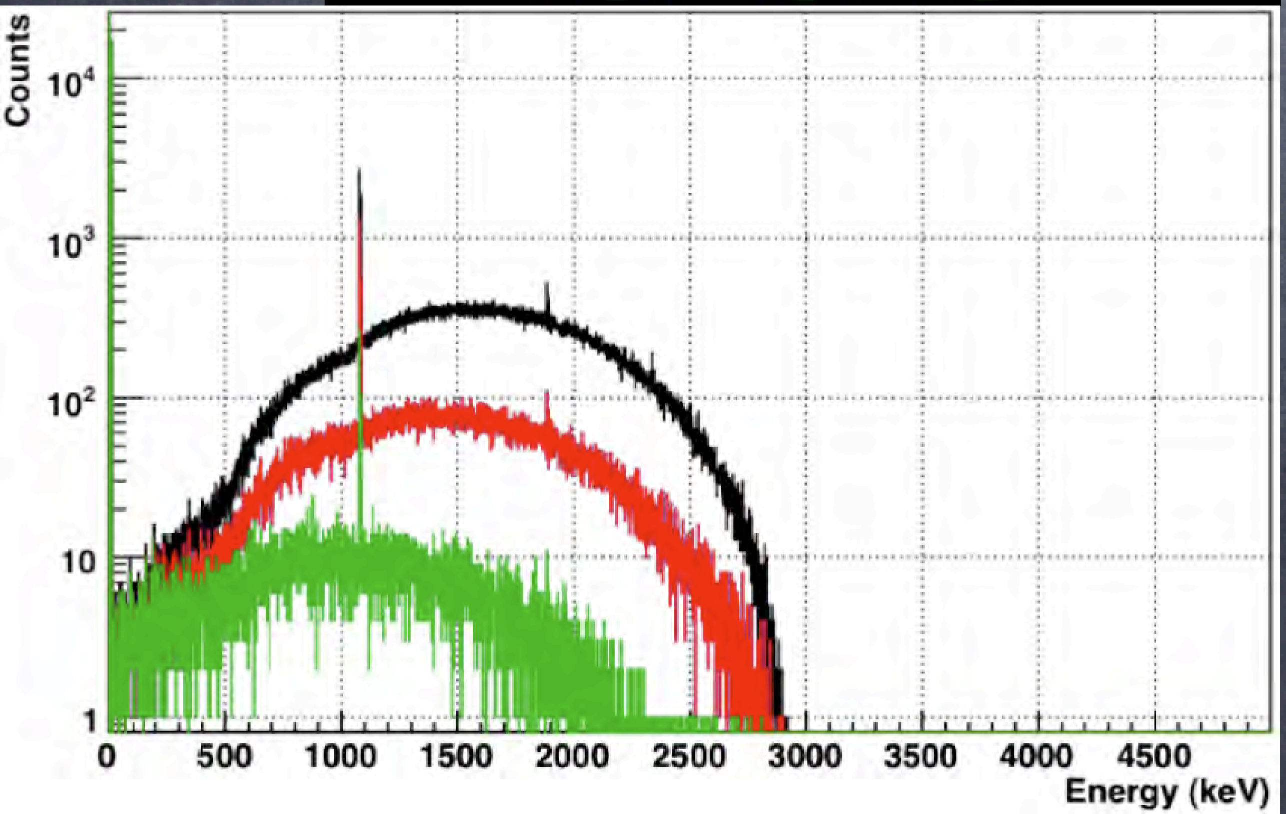
- 'Bare' enrGe array in liquid argon
- Shield: high-purity liquid Argon / H2O
- Phase I (mid 2008): ~18 kg (HdM/ IGEX diodes)
- Phase II (mid 2009): add ~20 kg new detectors (Total ~40 kg)

- Modules of enrGe housed in high-purity electroformed copper cryostat
- Shield: electroformed copper/lead
- Initial phase: R&D prototype module (Total 60 kg)

Joint Cooperative Agreement:
Open exchange of knowledge & technologies (e.g. MaGe, R&D)
Intention to merge for 1 ton exp. Select best techniques developed and tested in GERDA and Majorana

MAJORANA Simulation





Simulation Includes:

- 57 Enriched crystal w/ dead layers
- 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

R&D Detectors/Facilities

Detectors:

- CLOVER - LANL
- Canary Cage - LANL
- SEGA - TUNL
- WIPP-n - WIPP
- MEGA - WIPP
- 8x5 Detector - Oroville

Facilities:

- ICPMS - PNNL
- Electroforming - PNNL, Soudan, WIPP
- Screening - LOMO, Oroville, WIPP, Soudan, Homestake, SNOLab

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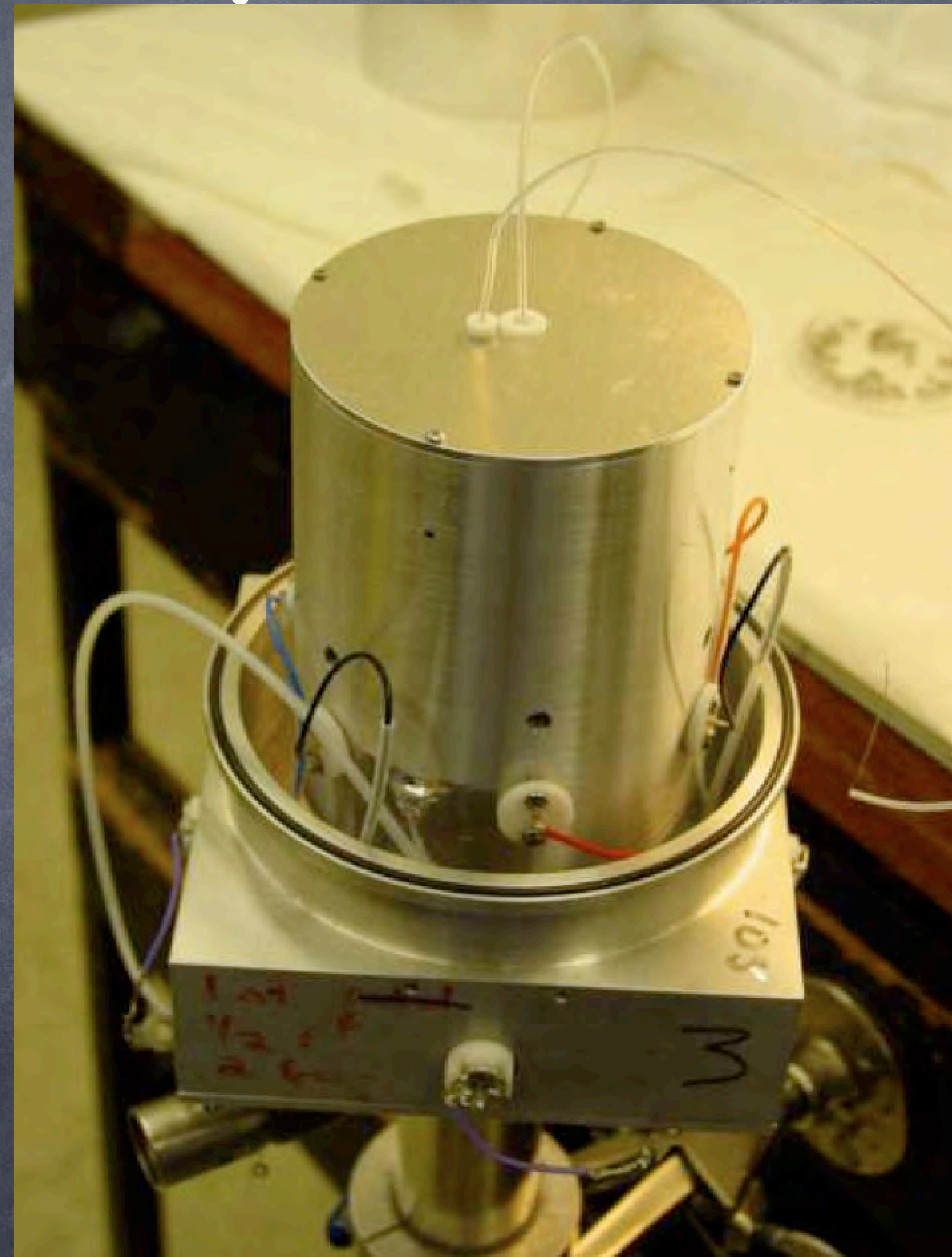

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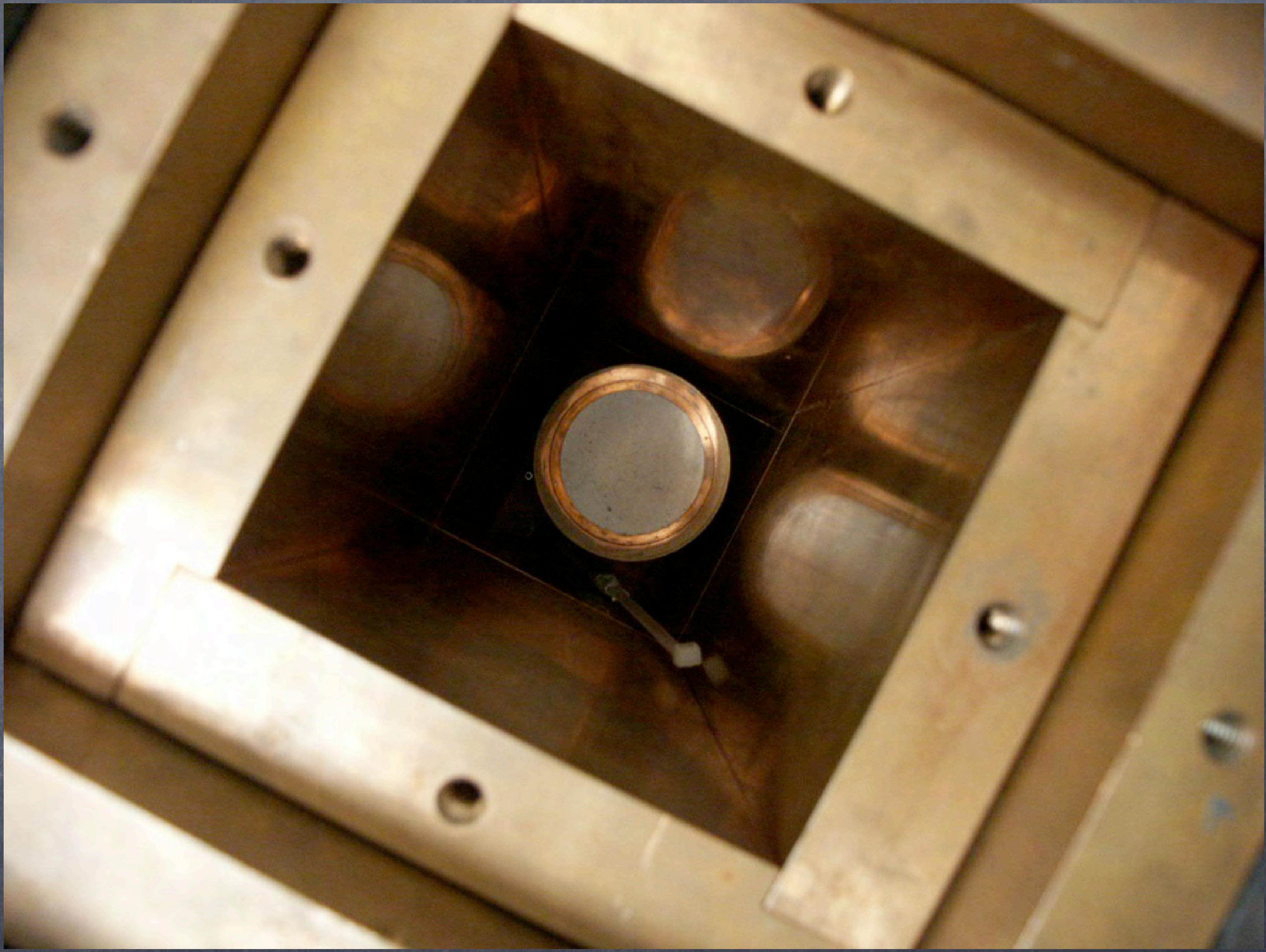

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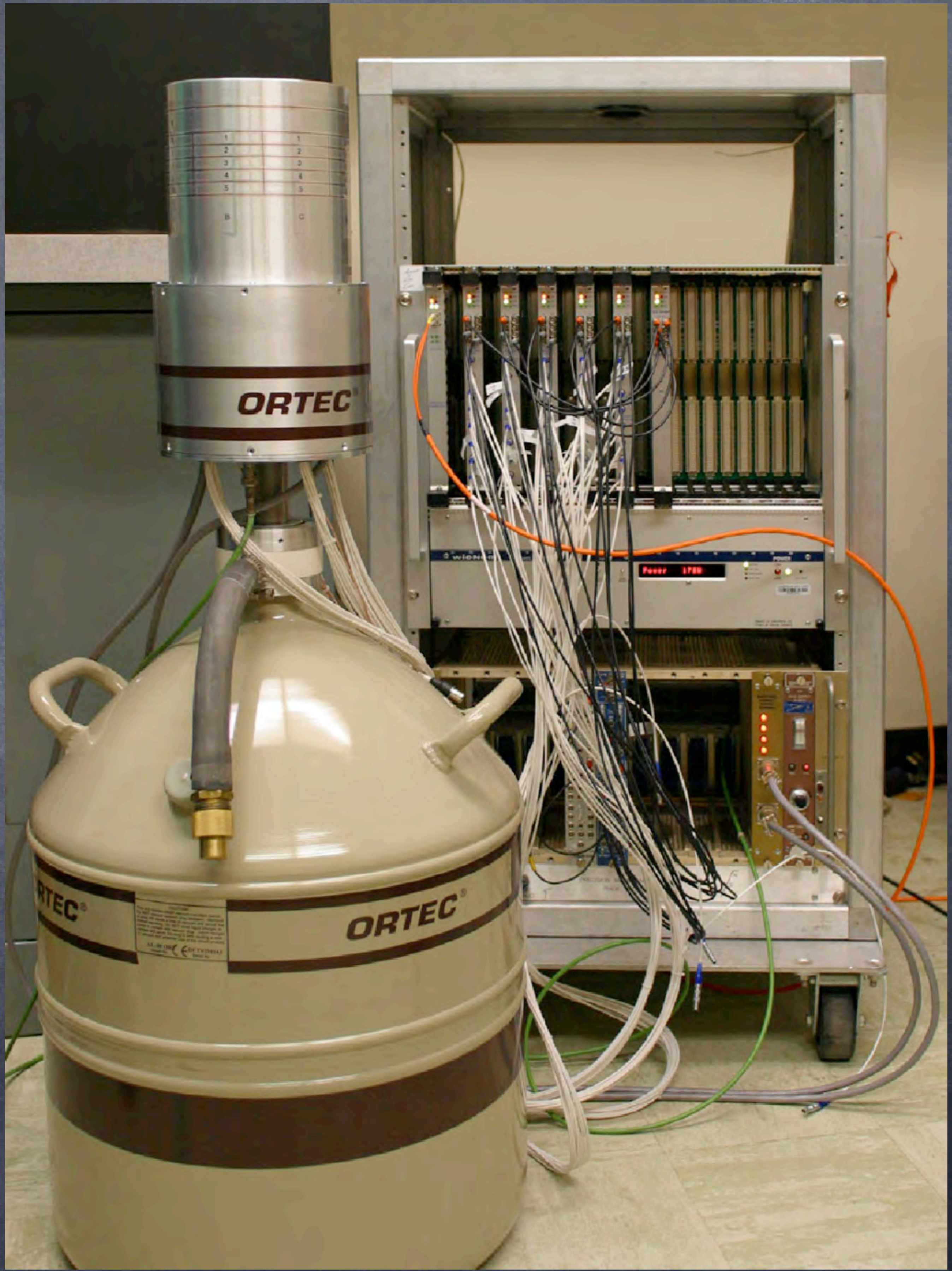

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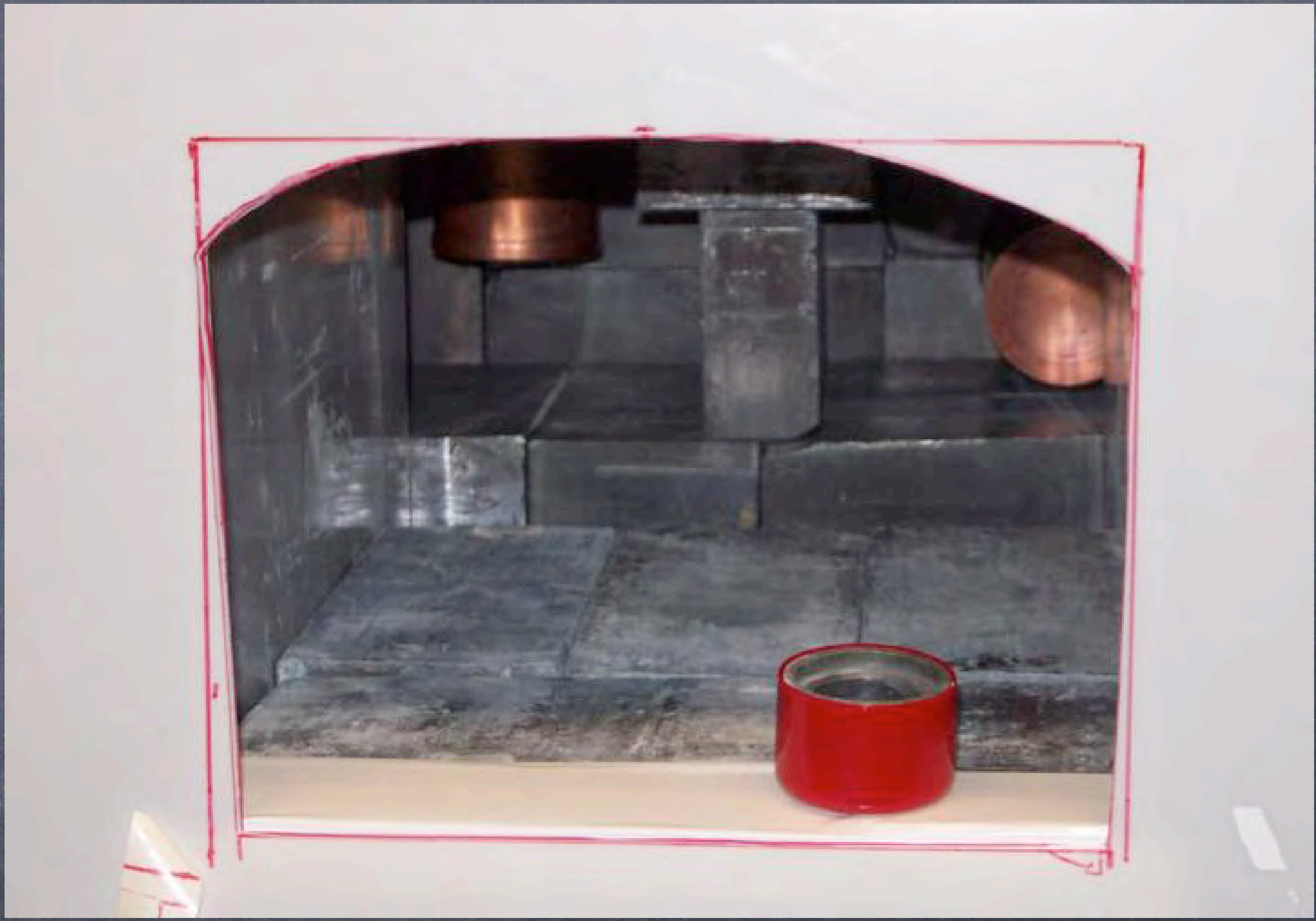

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Recent MAJORANA Technical Progress

- 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 neutrons 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.)
- Background reduction using 36 and 40-fold segmented detectors (paper in preparation)
- Background reduction using SEGA and the TUNL HIGs facility (paper in preparation)
- Quantitatively comparing sensitivities for different detector configurations and segmentations
- Large prototype electroformed cryostat (MEGA) and operated with multiple crystals
- 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)
- Sensitivity of $2\nu\beta\beta$ and $0\nu\beta\beta$ to excited states in ^{76}Ge (Kazkaz thesis, paper in preparation)
- Development of an improved Geant4 surface sampling routine (paper in preparation)
- Support of Gretina digitizing card in ORCA

Summary

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An initial prototype ^{76}Ge module with 30-60 kg of 86% enriched ^{76}Ge and backgrounds on the order of or less than 1 count/ROI/t-y will allow us to demonstrate the feasibility of Ge for a 1-ton scale experiment capable of reaching a sensitivity to the "inverted hierarchy" neutrino mass scale (30-40 meV)

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  - Demonstrating electroformed Cu that meets the low-activity requirements
  - Producing low-background, low-mass cables
  - Examining options to avoid potential detector fabrication & schedule delays
- We have to continue to explore ways to "aggressively pursue the construction of the first 60 kg module"
  - Prototype module using existing ^{nat}Ge modules and realistic cryostat, small parts and strings
  - Alternative detector technologies
  - Mixed deployment of different detector technologies
  - Early deployment of smaller numbers of crystals

Any Questions?