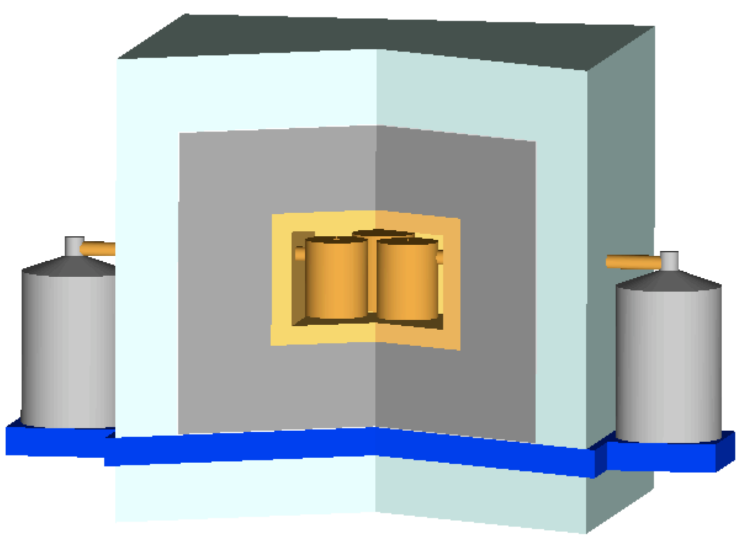
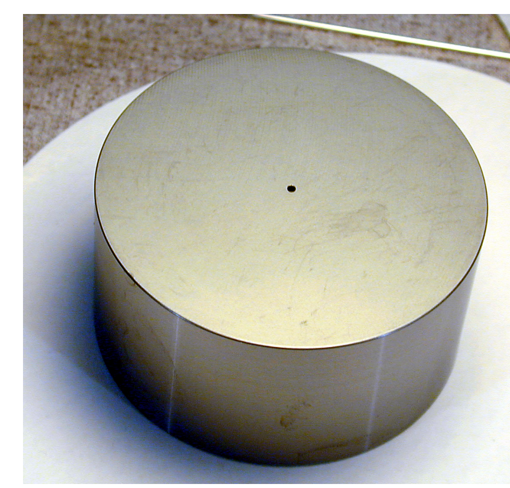
MAJORANA

An Ultra-Low Background Enriched-Germanium Detector Array for Fundamental Physics Measurements

Jason Detwiler
Lawrence Berkeley National Laboratory



GERDA Collaboration Meeting
March 2009
Padova, Italy



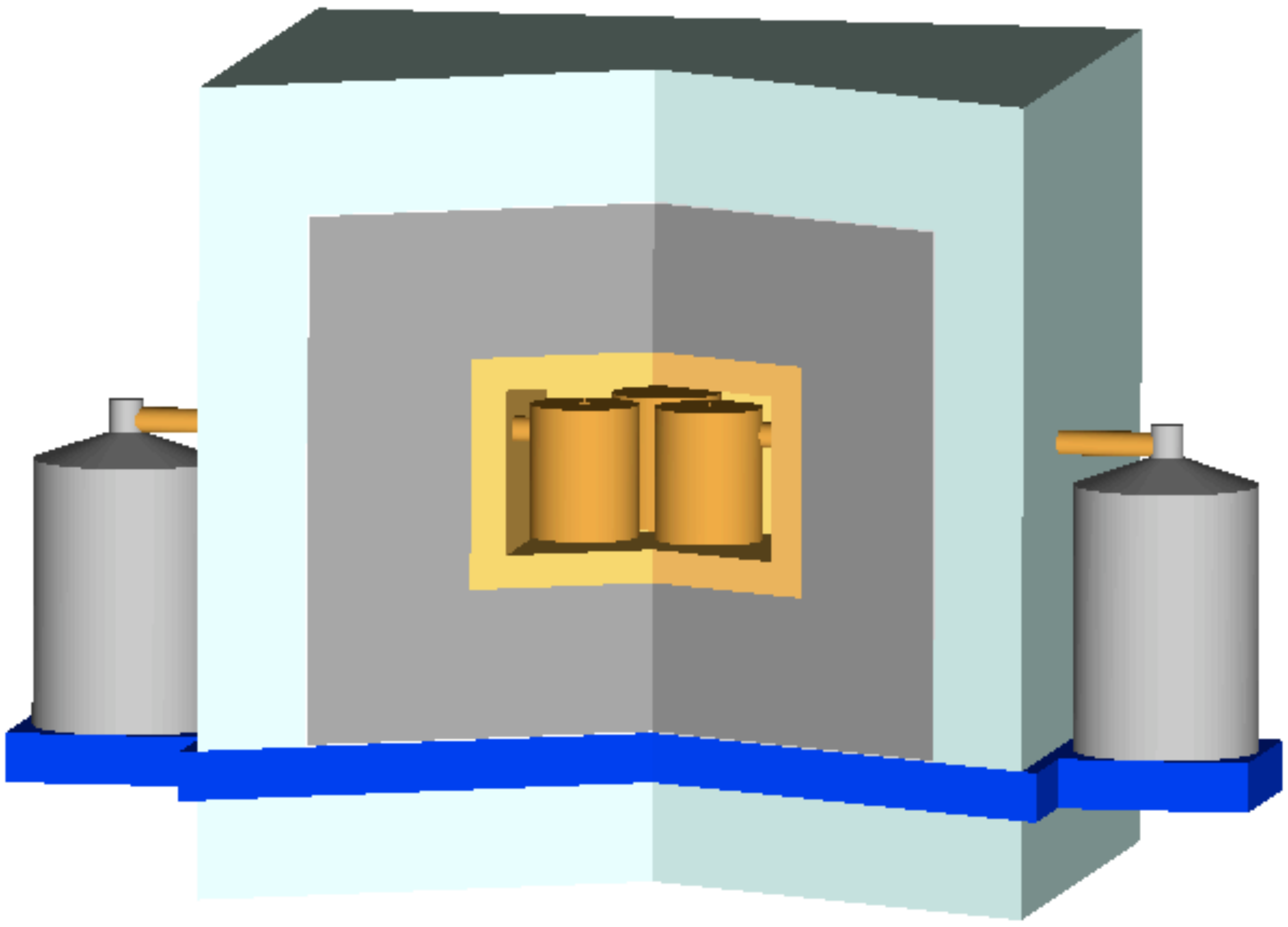
MAJORANA Collaboration Goals

Actively pursuing R&D aimed at a ton-scale ^{76}Ge 0νββ-decay experiment

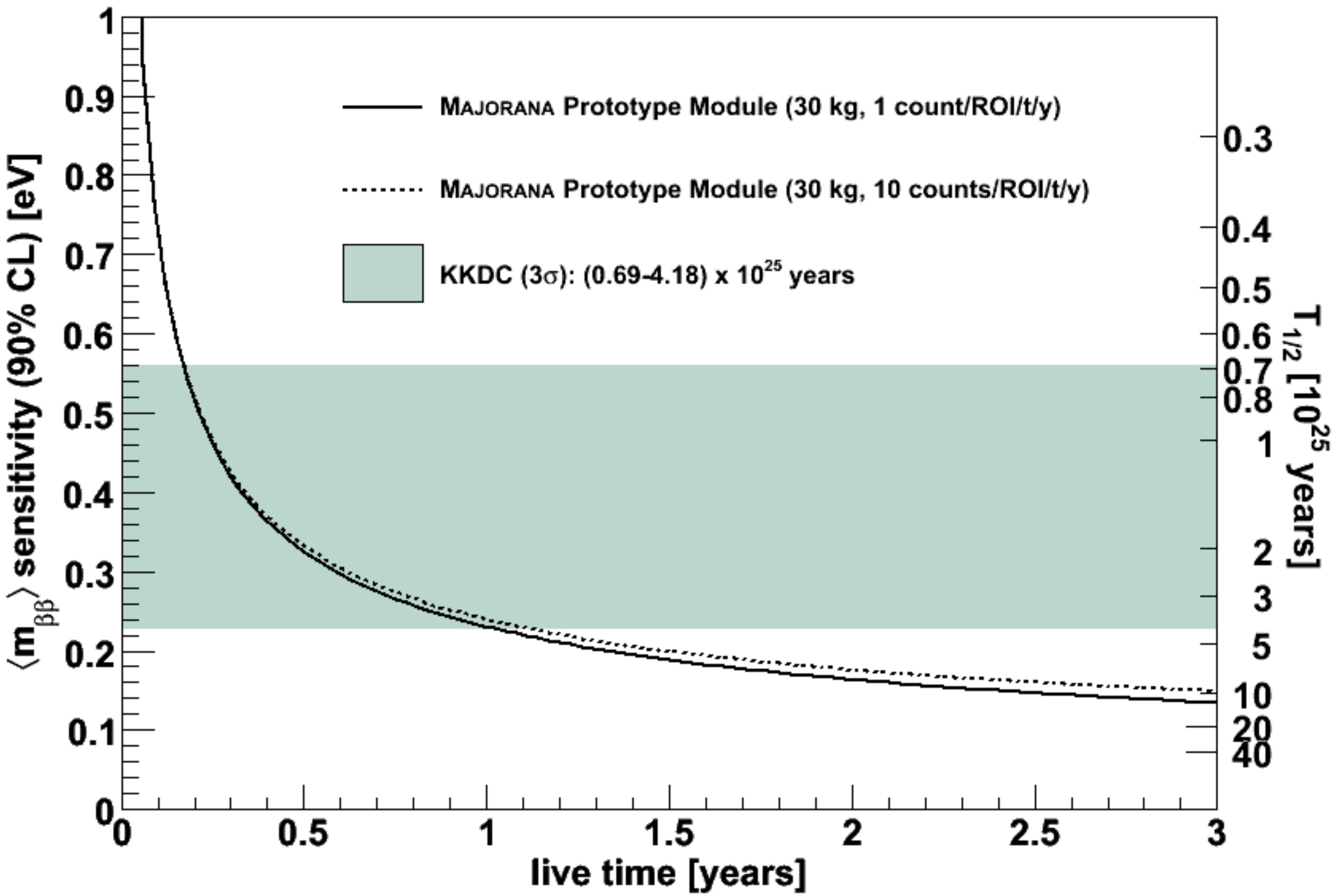
- Technical Goal: Demonstrate background low enough to justify building a ton-scale experiment
- Science Goal: Build a prototype module to test the recent claim of an observation of 0νββ
- Work cooperatively with the GERDA Collaboration to prepare for a single international ton-scale Ge experiment that combines the best technical features of MAJORANA and GERDA
- Pursue longer term R&D to minimize costs and optimize the schedule for a ton-scale experiment

The MAJORANA DEMONSTRATOR

- 60-kg of Ge detectors required for sensitivity to background goal: 1 c/ROI/t/y
- 30-kg of 86% enriched ^{76}Ge crystals required for science goal: test HDKK claim
- Examine detector technology options: p- and n-type, segmentation, point-contact
- Low-background cryostats & shield: ultra-clean, electroformed Cu
- Initial module will have 3 cryostats
- Compact low-background passive Cu and Pb shield with active muon veto
- Located underground 4850' level at Sanford Lab / DUSEL.



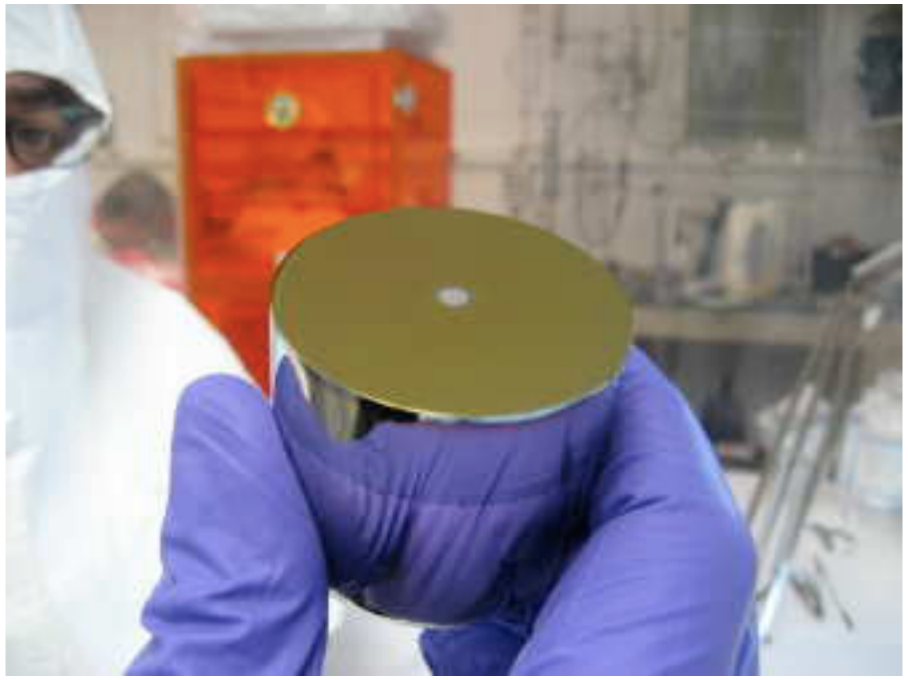
DEMONSTRATOR Sensitivity

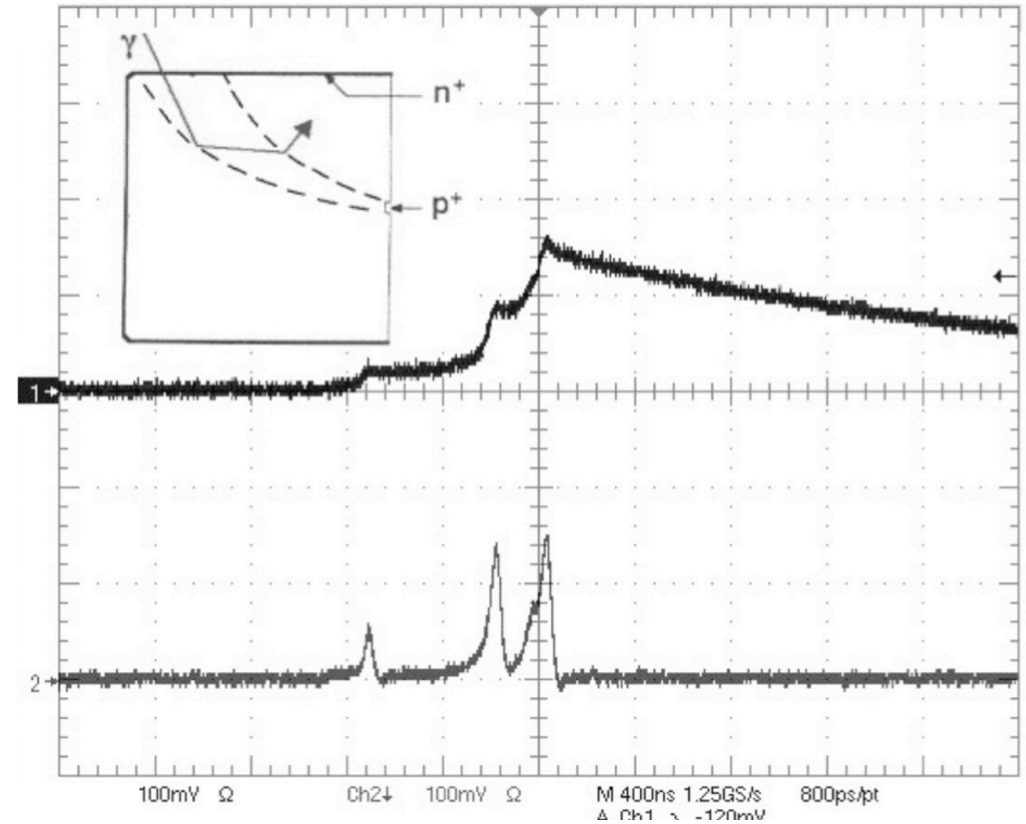


Recent Baseline Updates

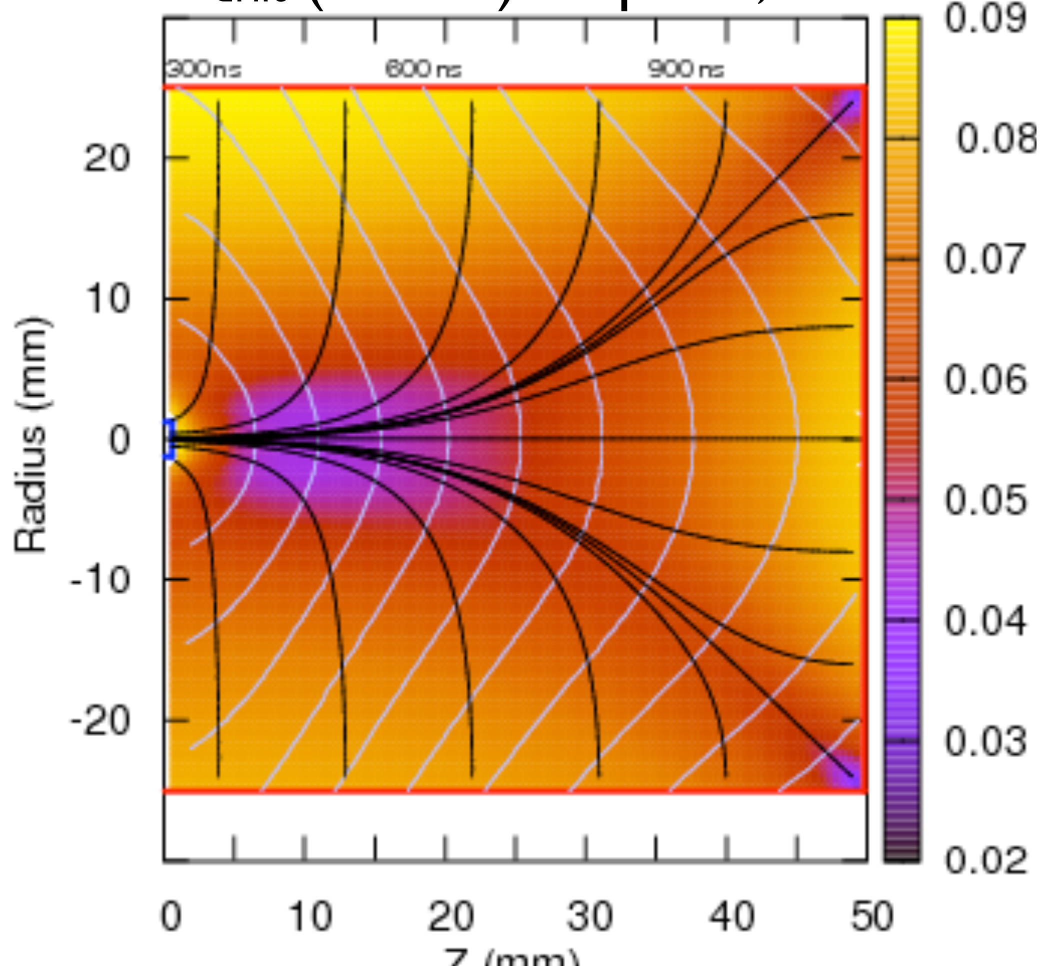
- Concentrate on PPC Detectors.
  Advantages of cost and simplicity, with no loss of physics reach.
  Will continue NSC R&D utilizing SEGA crystal.
- Considering additional physics one can do with low-energy-threshold PPC detectors.
  Exploits low-energy sensitivity (~100 eV threshold) of PPC detectors.
- In joint partnership with agencies and institutions, plan early implementation of natural-Ge PPC sub-module.

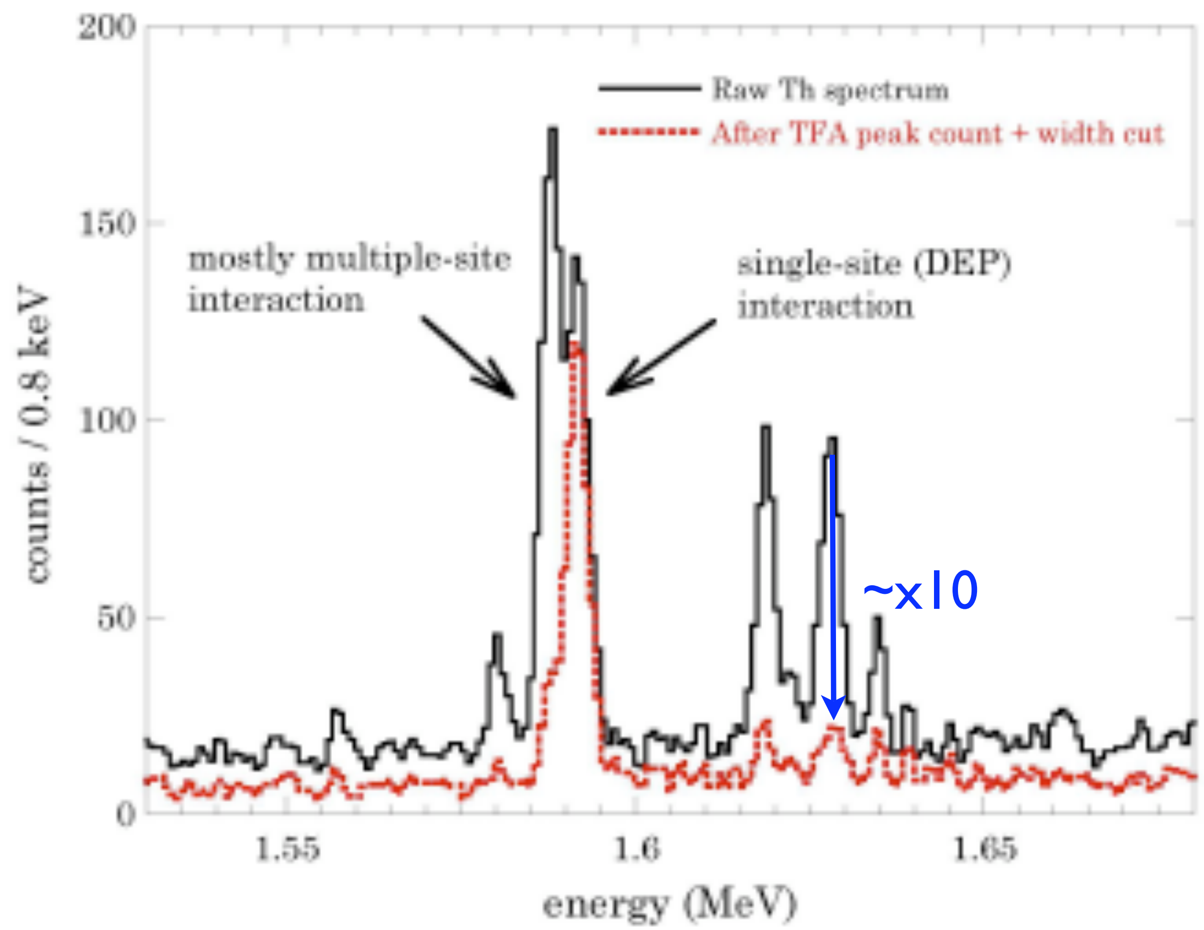
Point Contact Detectors





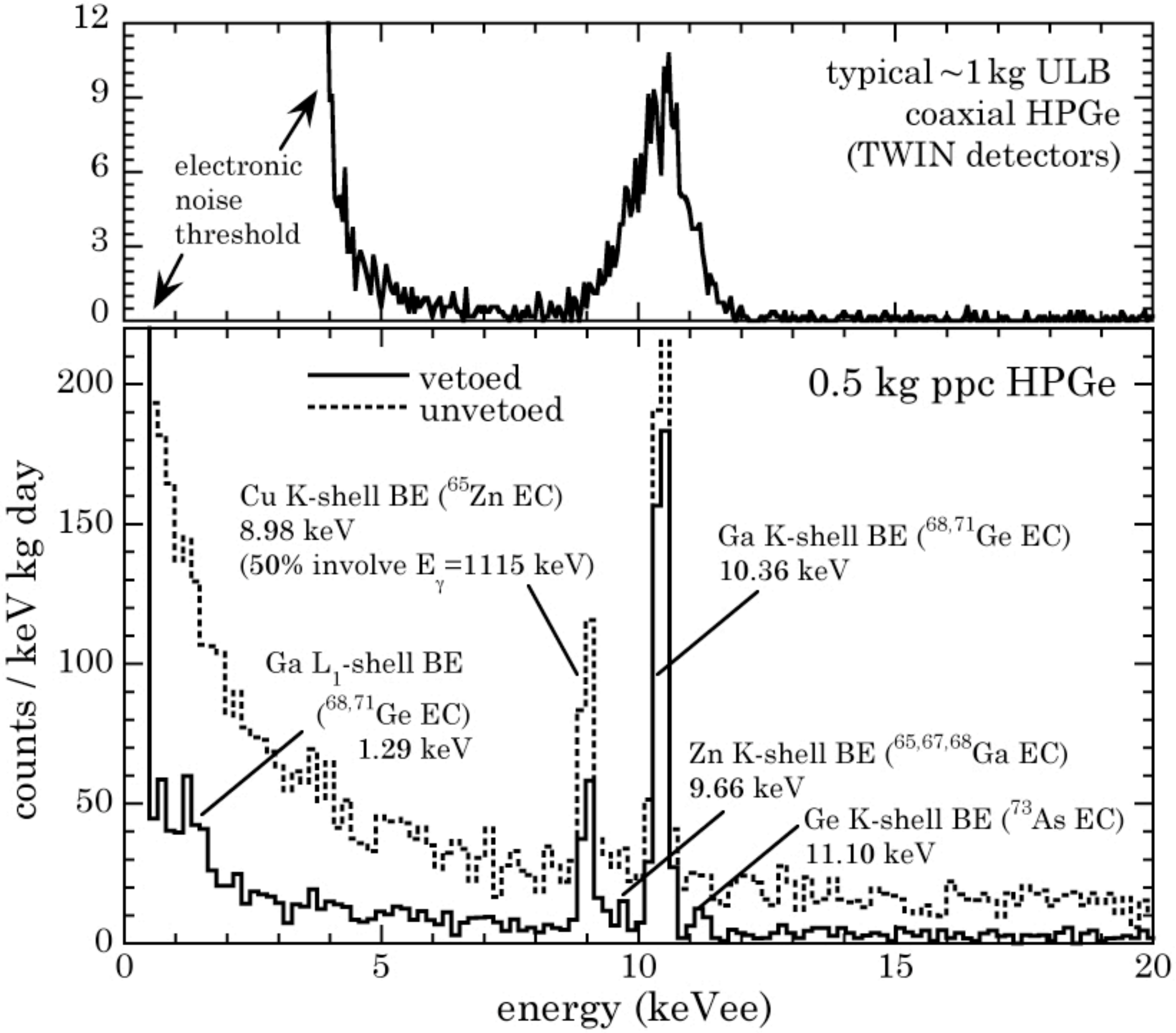
Hole v_{drift} (mm/ns) w/ paths, isochrones

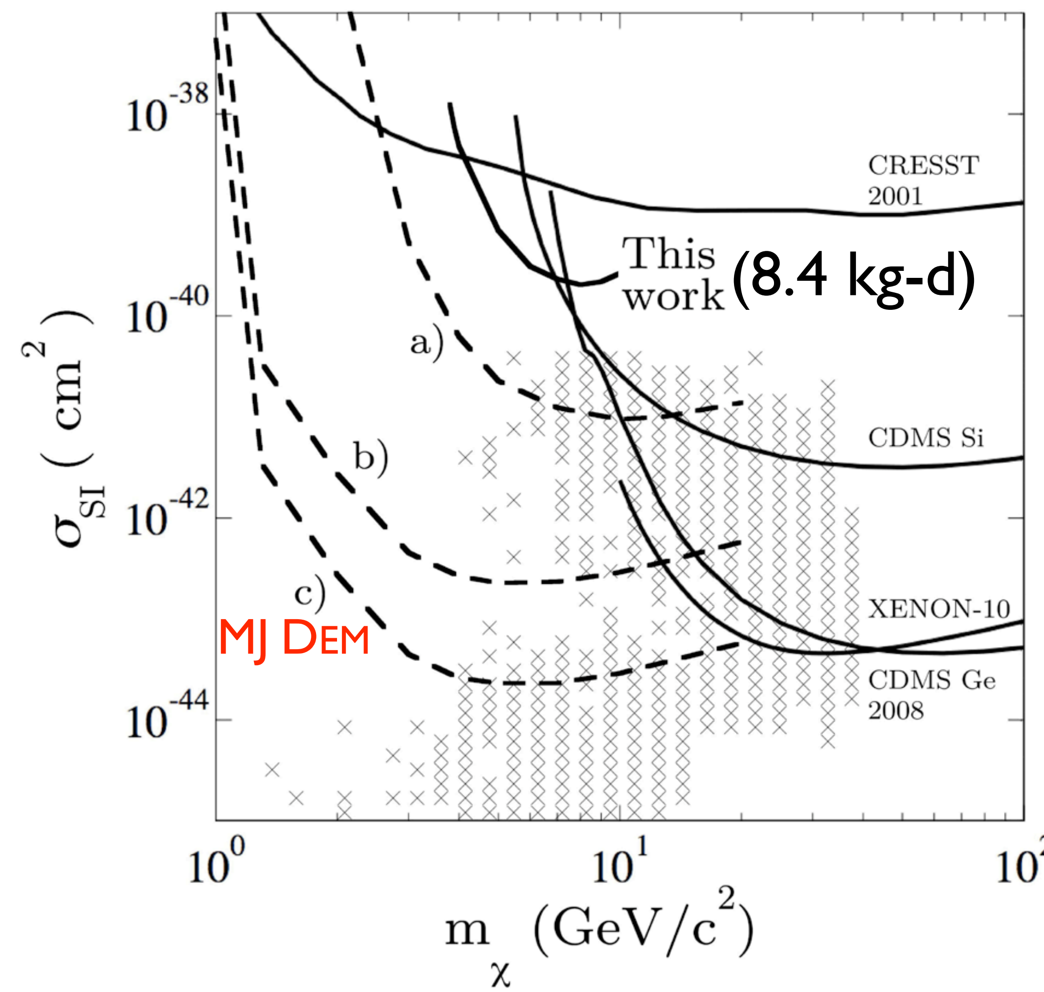




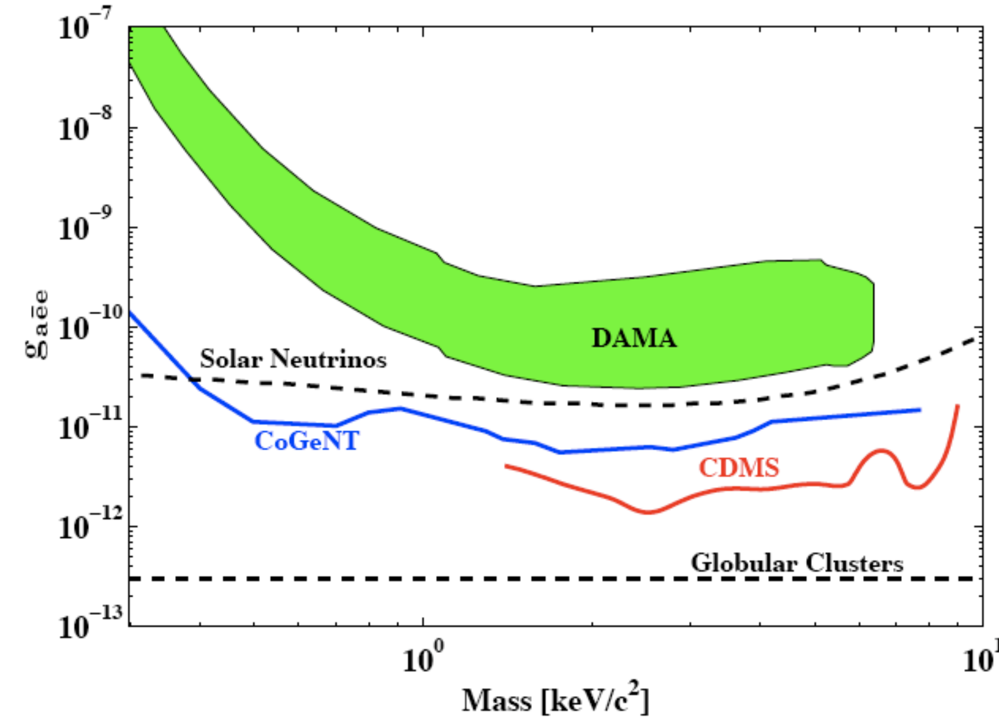
Barbeau et al., JCAP 09 (2007) 009; Luke et al., IEEE trans. Nucl. Sci. 36 , 926(1989).

Point Contact Detectors





- CνNS (Reactor, SN ν...)
- DM (light/slow WIMPs, Q-balls)
- Axions (see recent CDMS results)
- e^- decay



C. E. Aalseth *et al.*, Phys. Rev. Lett. **101**, 251301 (2008); Z. Ahmed *et al.*, arXiv:0902.4693 [hep-ex]

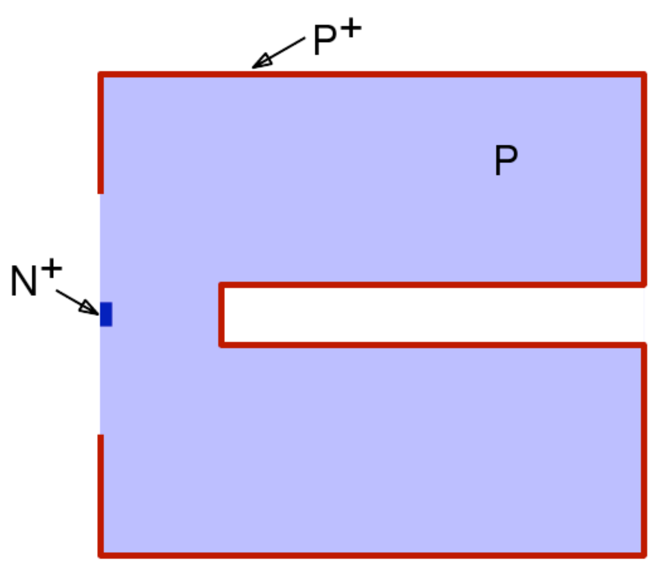
Point Contact Detectors

Detectors in hand:

Owner	Dimensions	Mass	Resolution (1.33 MeV)	Manfacturer
U. Chicago	50 mm ⃠ x 44 mm	460 g	1.82 keV	Canberra
PNNL	50 mm ⃠ x 50 mm	527 g	2.15 keV	Canberra
LBNL	62 mm ⃠ x 44 mm	800 g	2.11 keV	LBNL
LANL	72 mm ⃠ x 37 mm	800 g	2.15 keV	PHD's
ORNL	62 mm ⃠ x 46 mm	740 g	4. – 4.5 keV	PHD's

Further planned PPCs for R&D

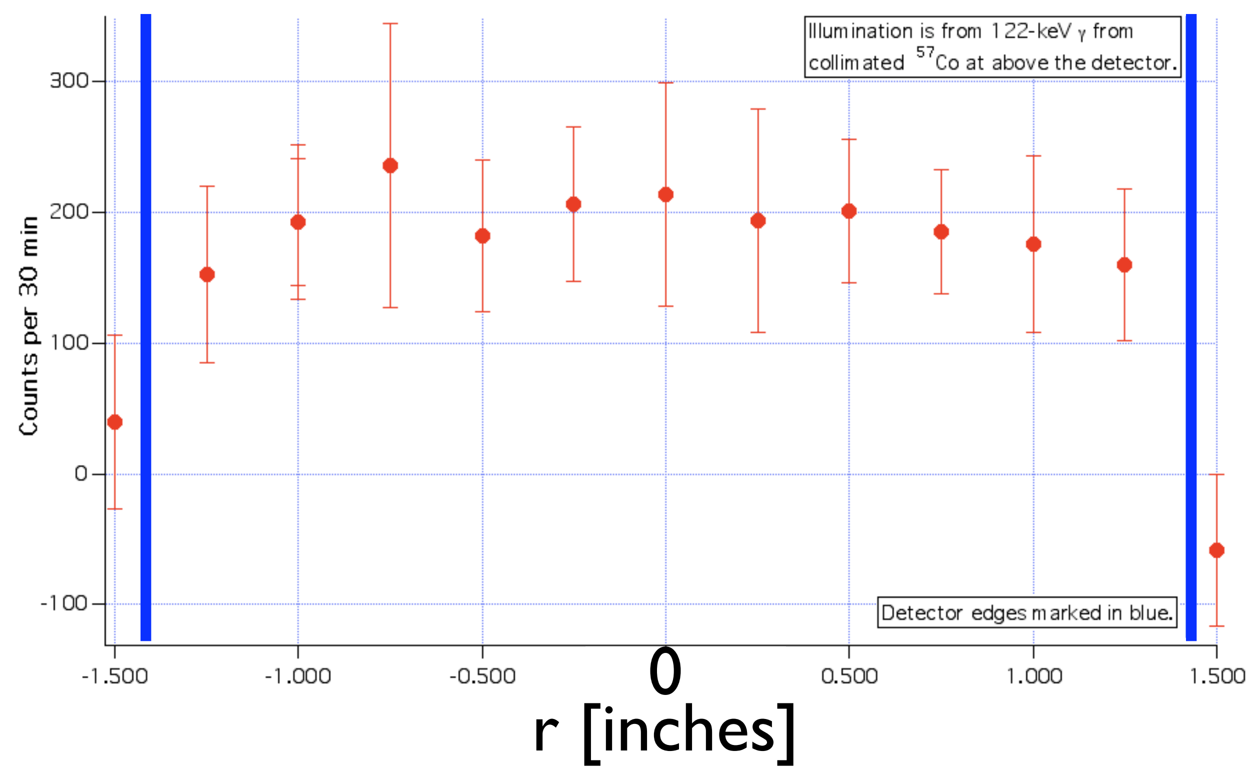
- ORTEC PPC prototype: >500 g
- Canberra BEGe for low-BG low-E studies
- Inverted-coax PPC ⟶
- Mini-PPCs for surface preparation studies

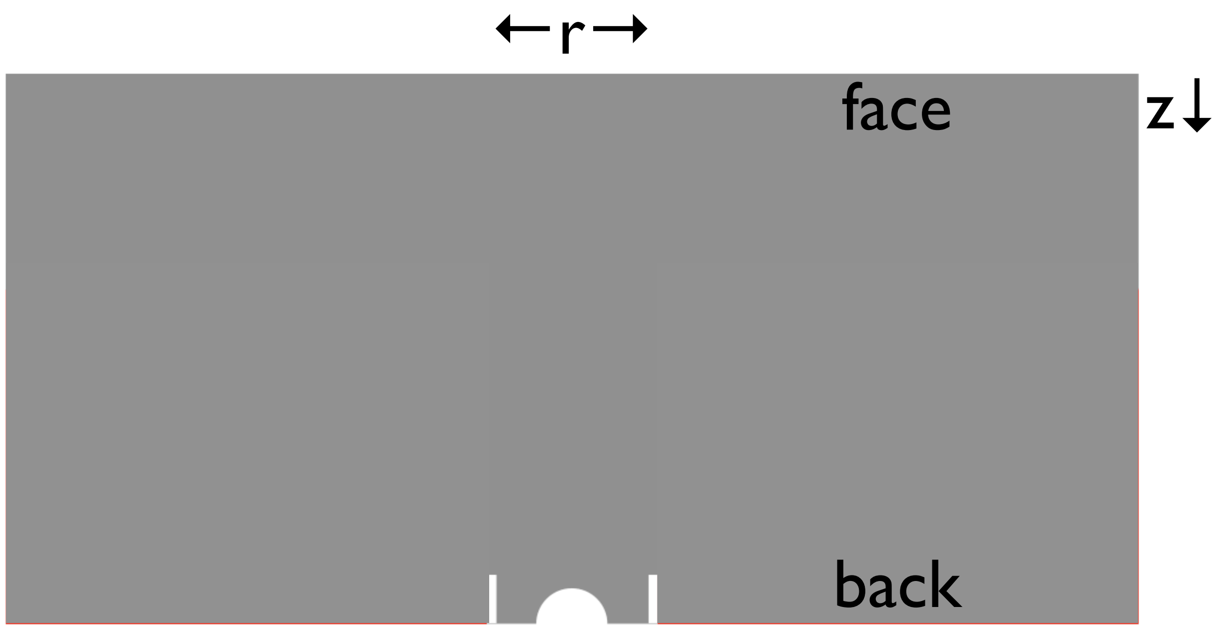


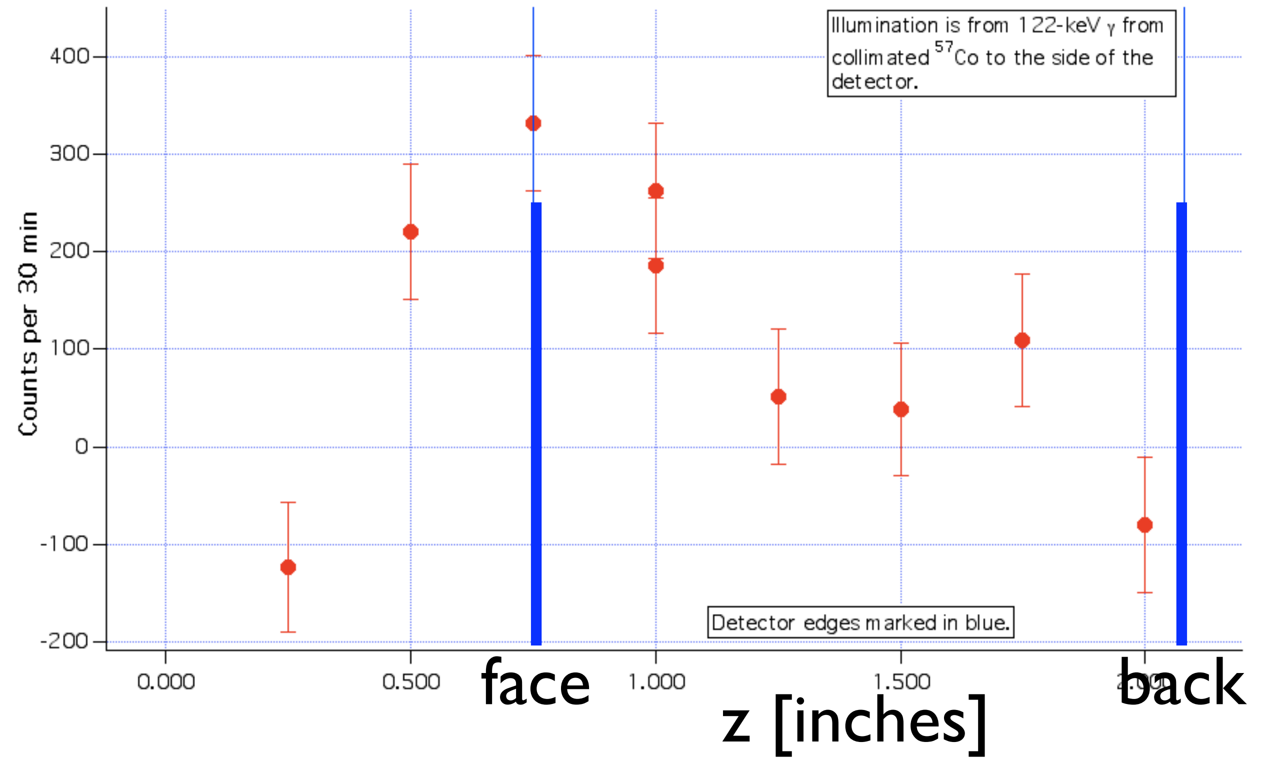
PPC R&D

Incomplete Charge Collection

- ^{57}Co scan shows rapidly dropping efficiency near the detector back
- Consistent with drift trajectories being "blocked" by ditches







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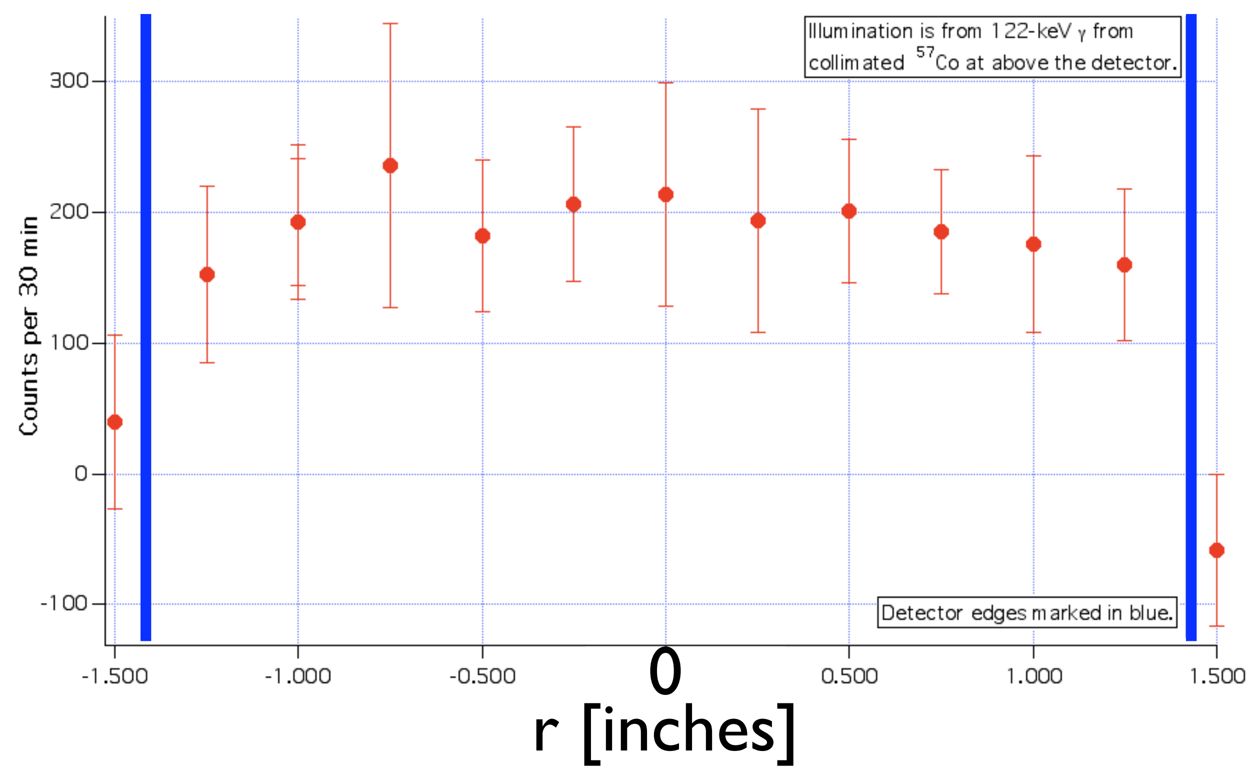
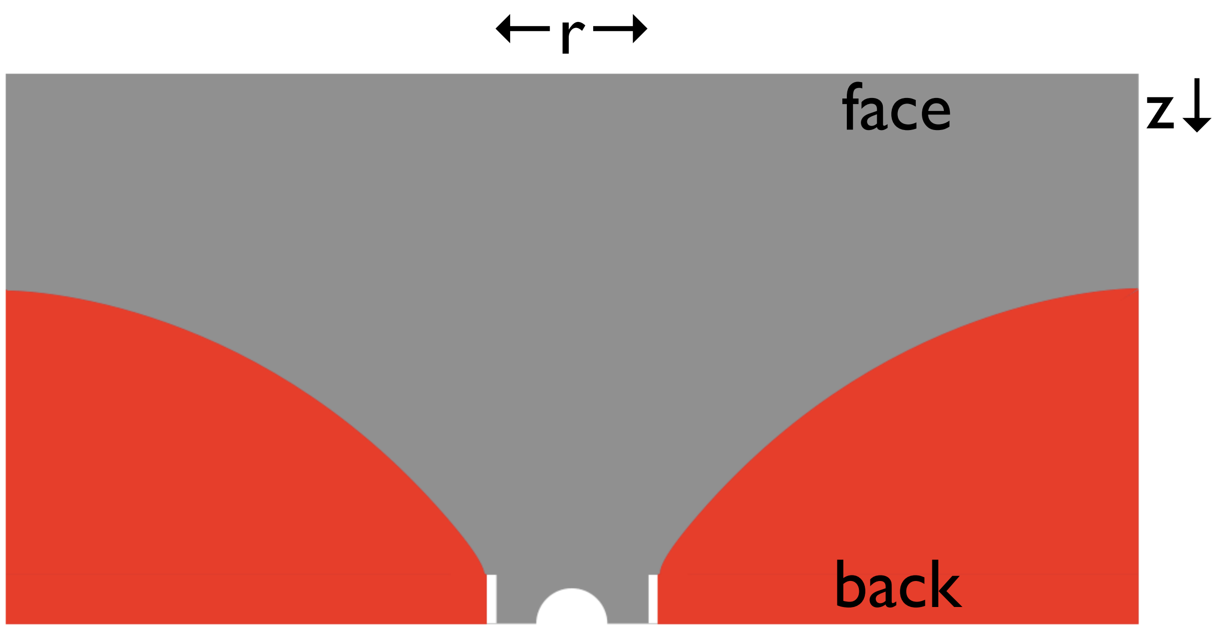
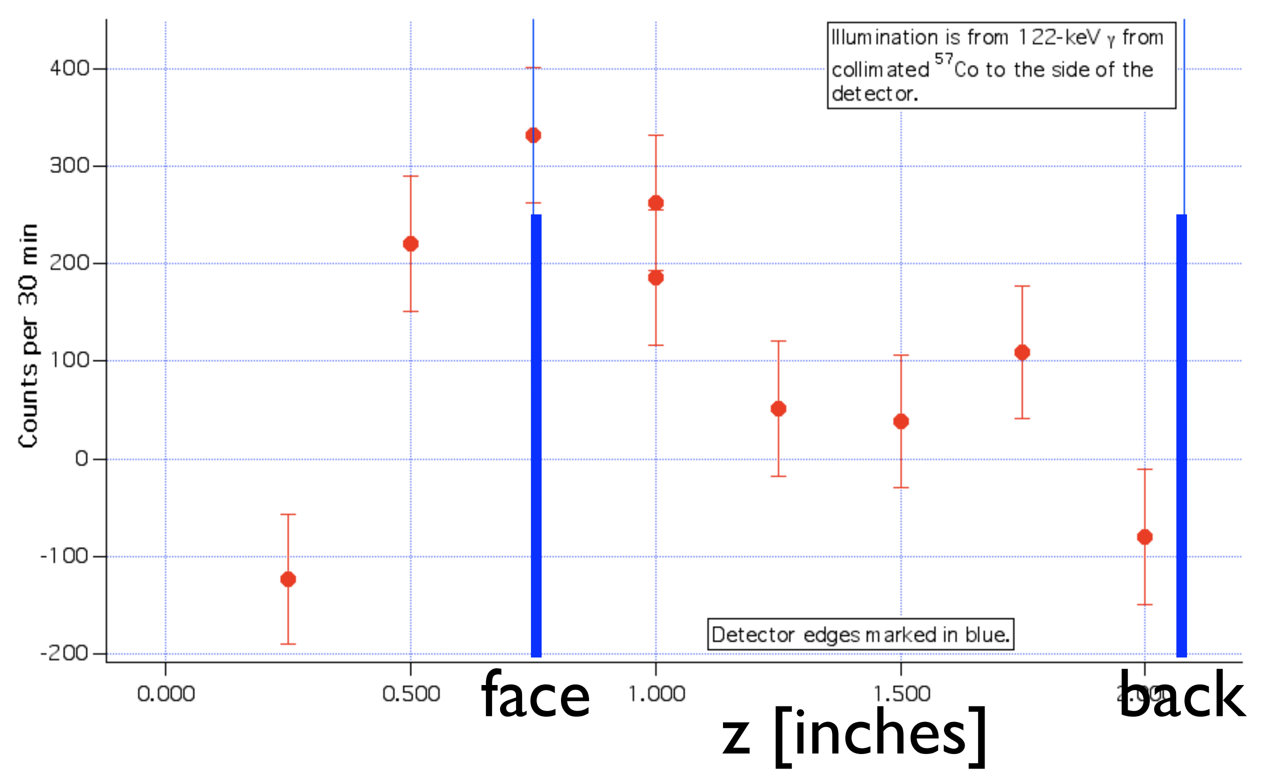


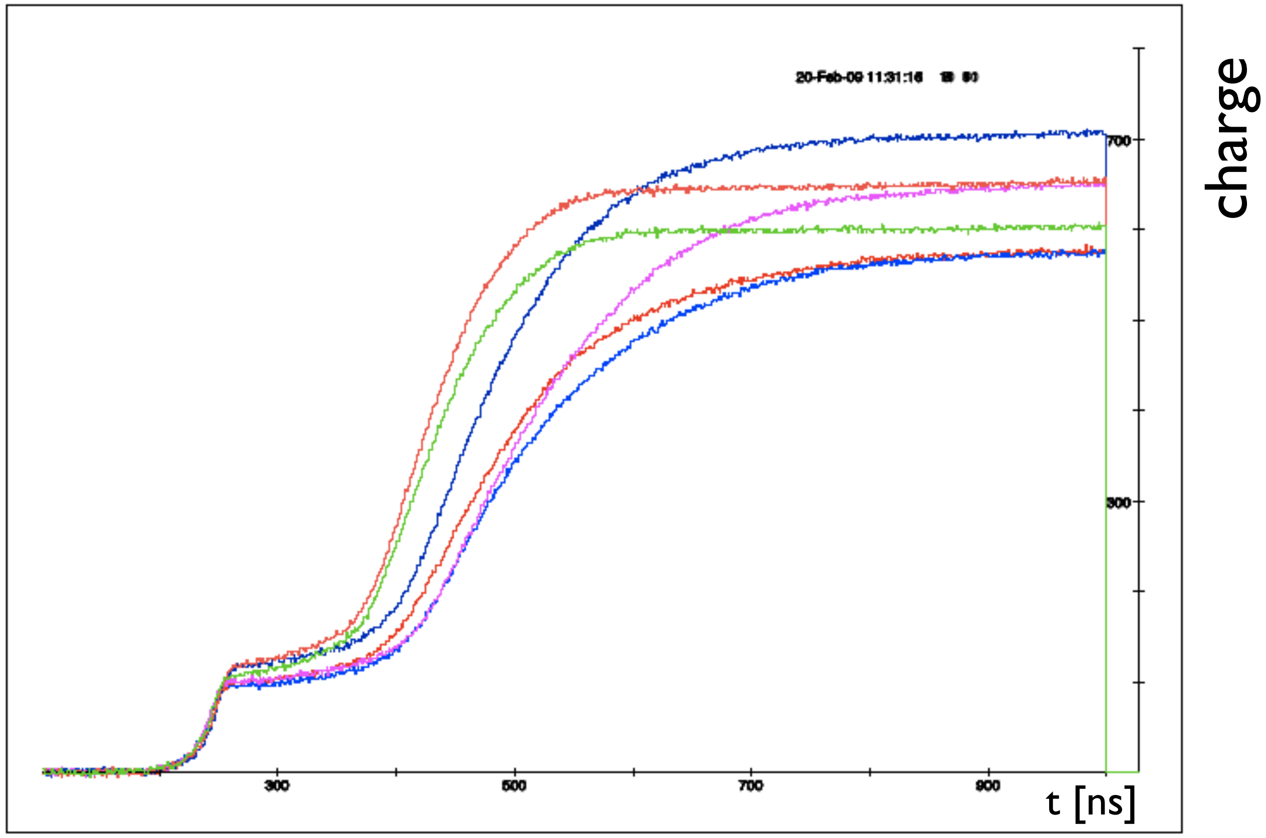


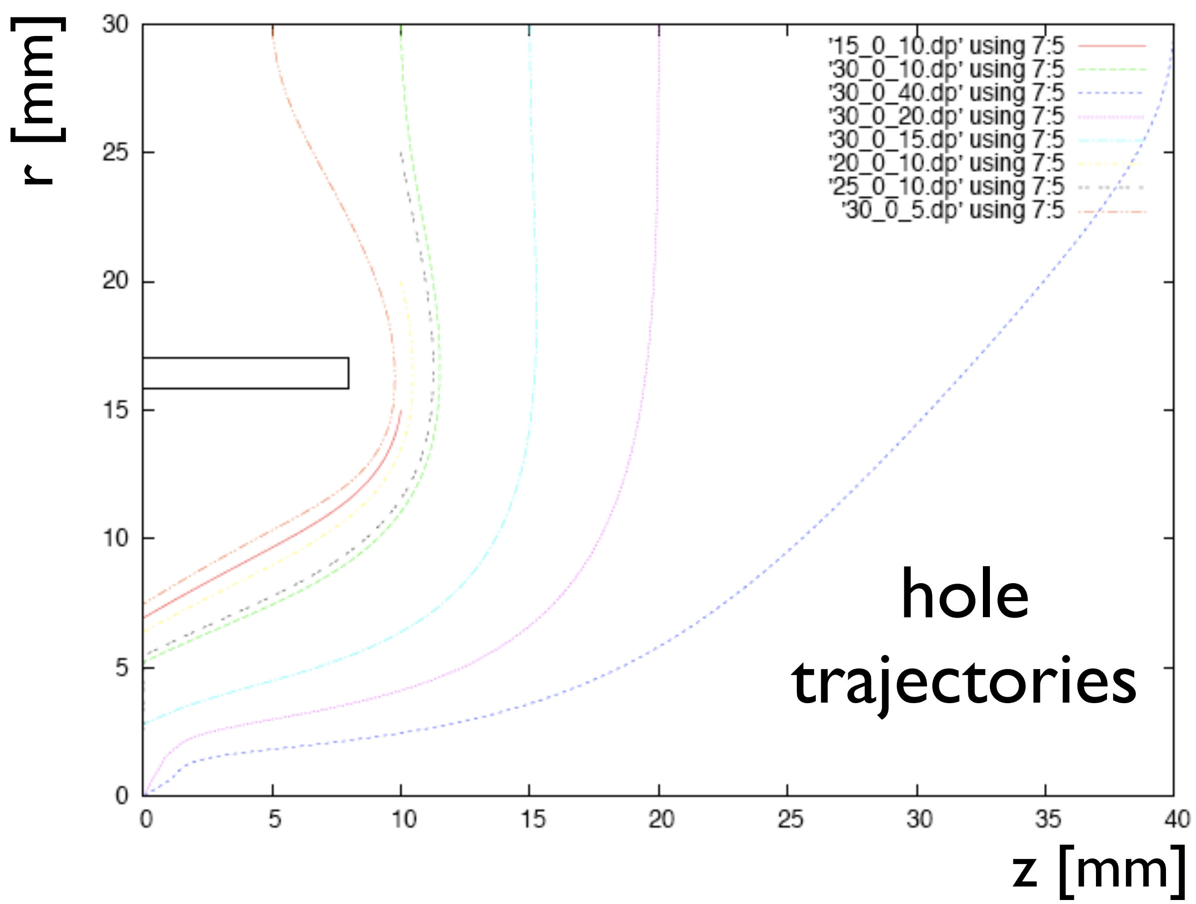


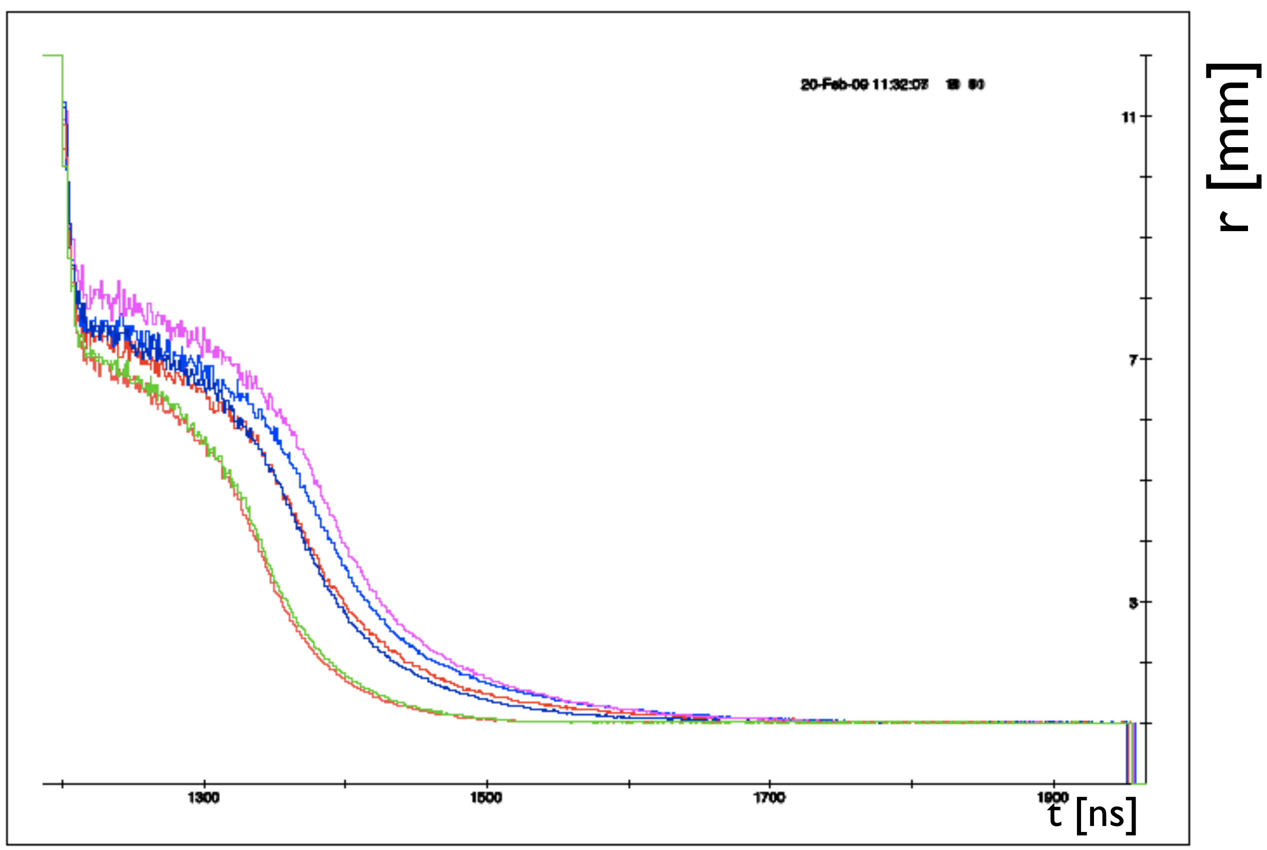
PPC R&D

Hole Drift on Open Surface

- Kinked slow-roll pulses consistent with charged open surface with slower hole mobility
- Can convert the waveform to radius via weighting potential
- Under investigation

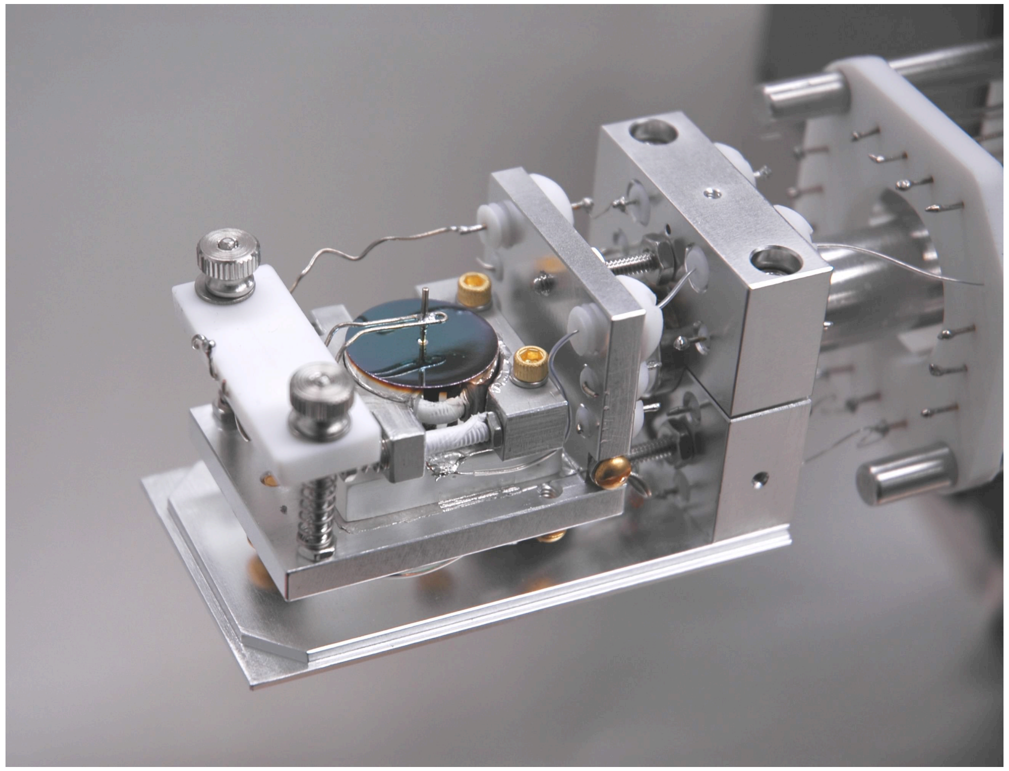


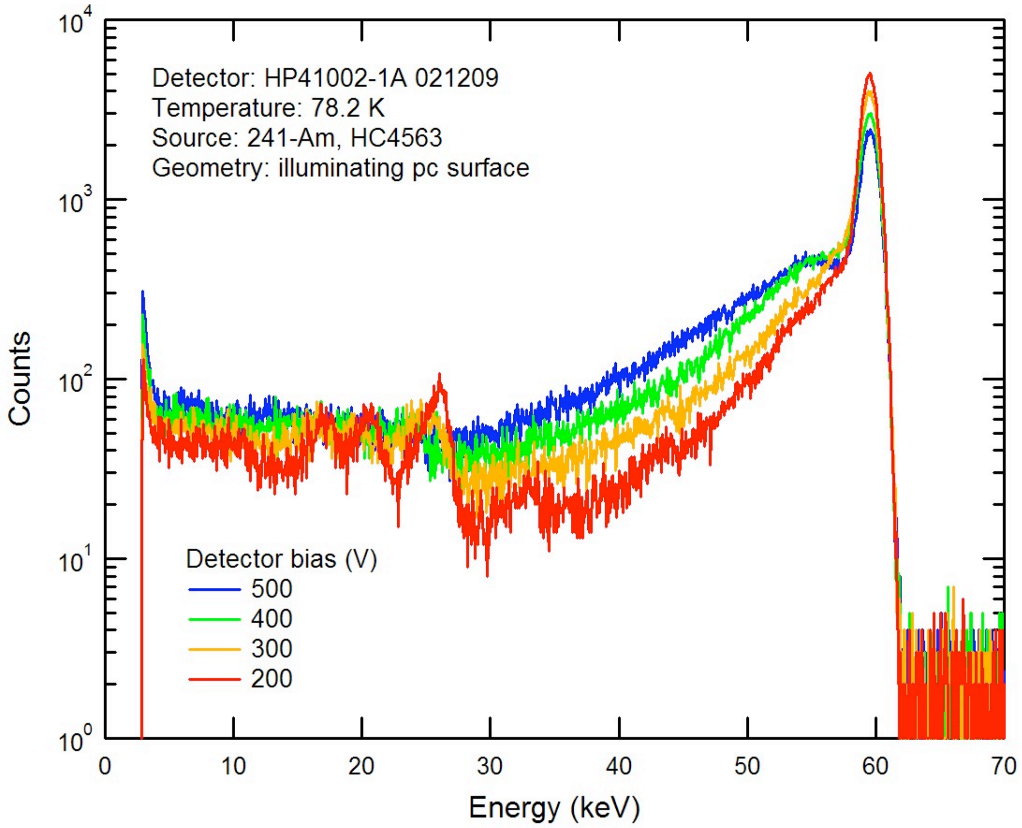


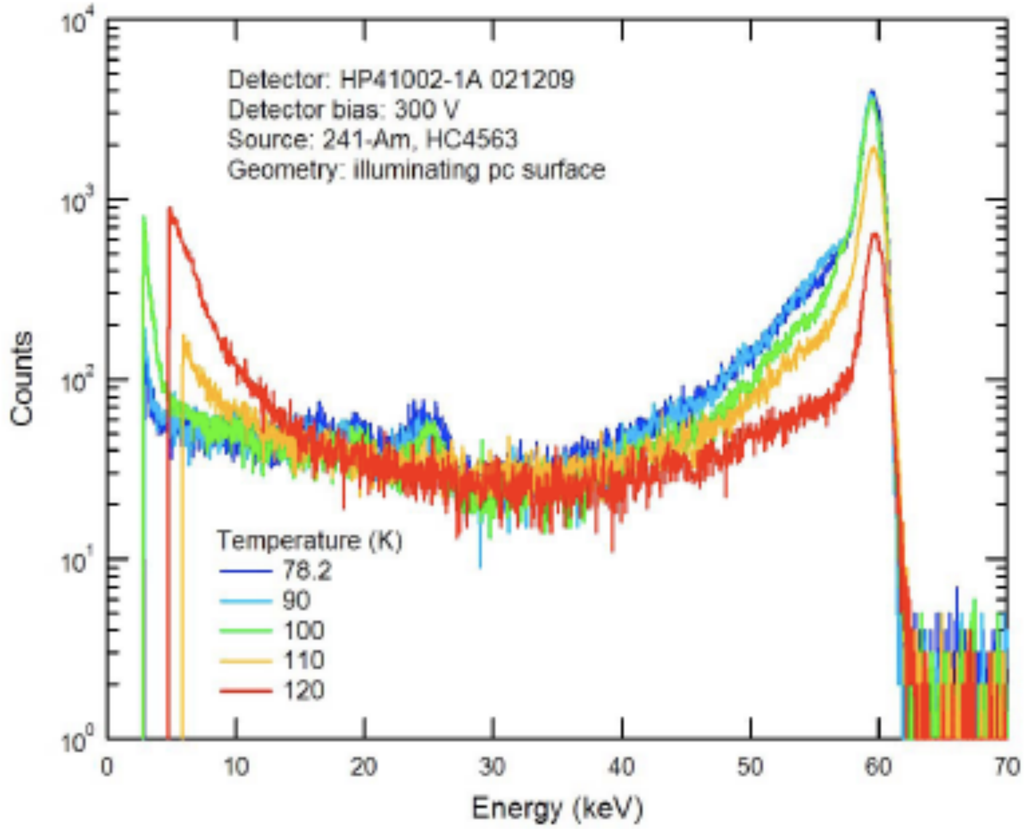


PPC R&D

Surface Passivation R&D



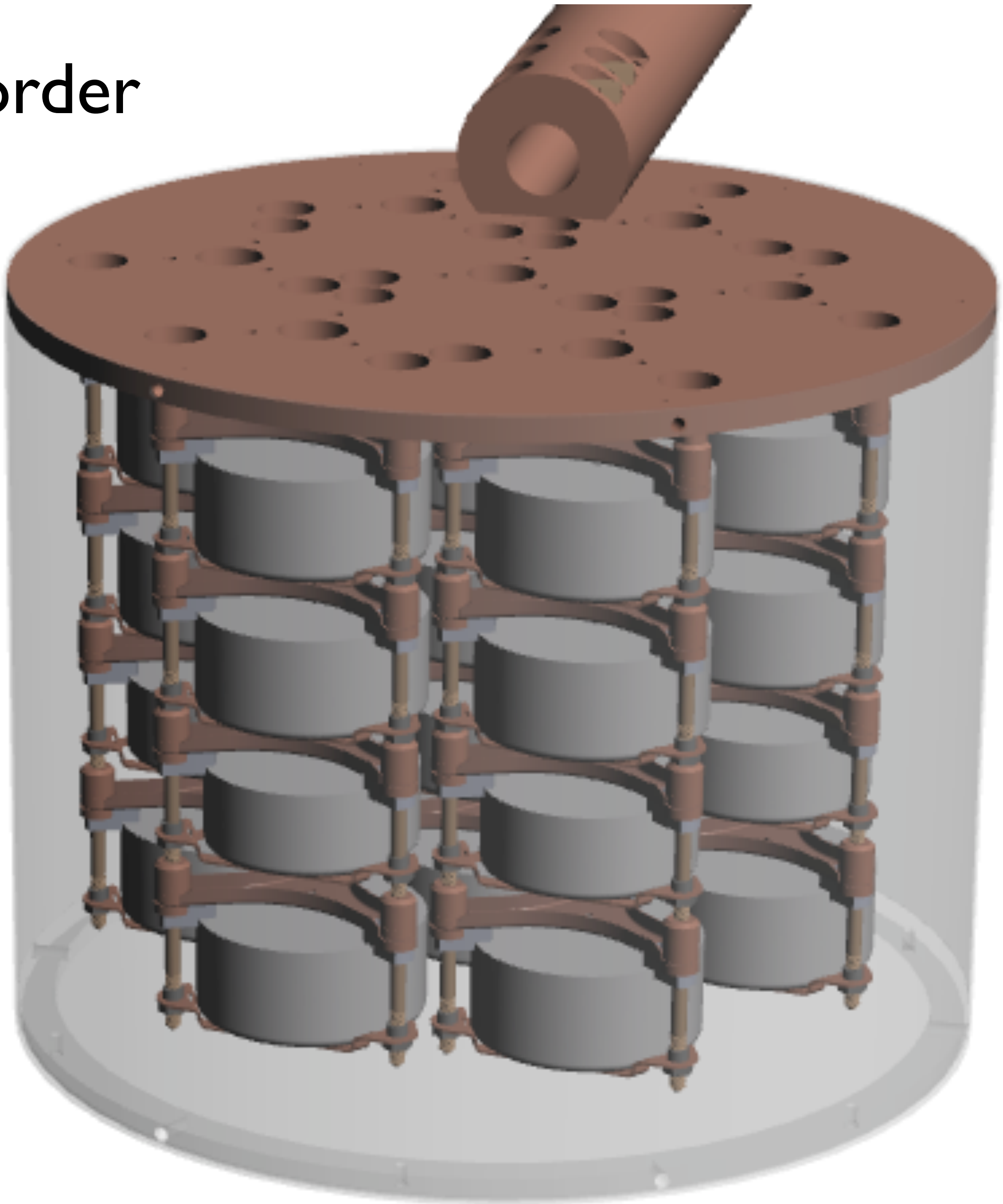




- Mini-PPCs in T-variable cryostat
- Surface passivation that didn't work for SPPC works for mini PPC
- Spectral variations consistent with charge trapping on passivated surface
- Investigate as a function of passivation recipe

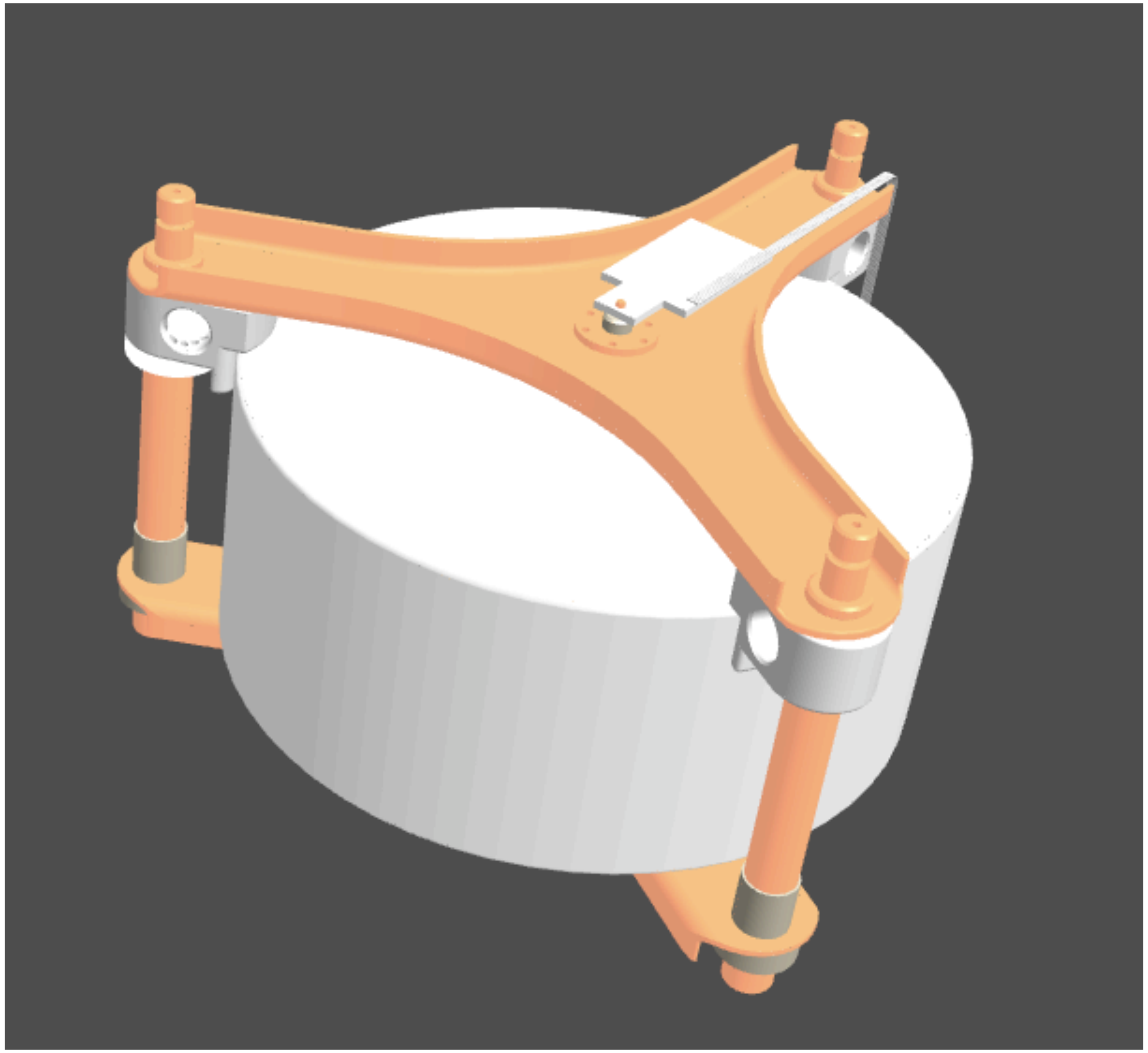
First Module

- 18 natural-Ge Canberra BEGe's on order
  - ∅ = 70±2.5 mm, h = 30±2.5 mm
  - 579 g active mass
  - contact r < 6.5 mm (5 mm nom.)
  - Front surface metalized for HV
- 4 to 6 crystals per string
- Front-ends mounted next to the crystal
- Closed cold plate and beefier Cu in detector mounts for added strength



Detector Mounts

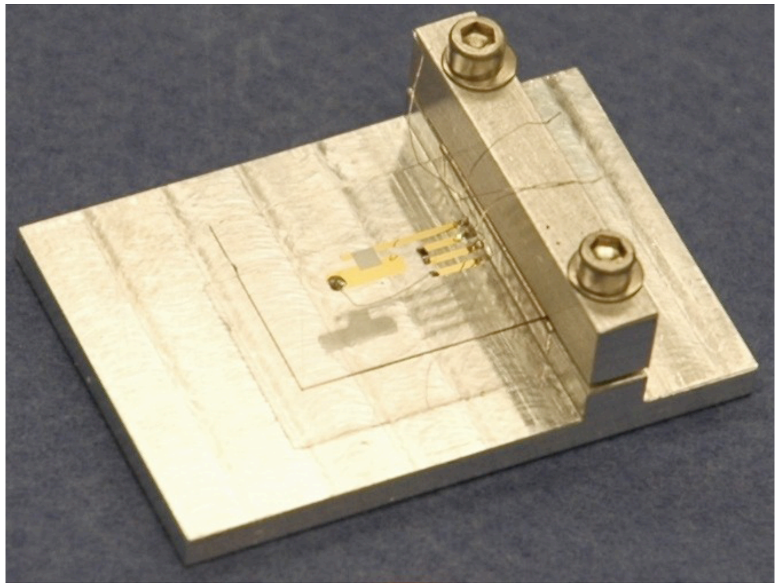
- Single detector units that attach to form strings
- HV on outer contact
- Mostly EFCu with minimal amount of plastics
- Front ends integrated into contact pin; encapsulate in EFCu for α, β shielding
- Currently iterating design and prototyping

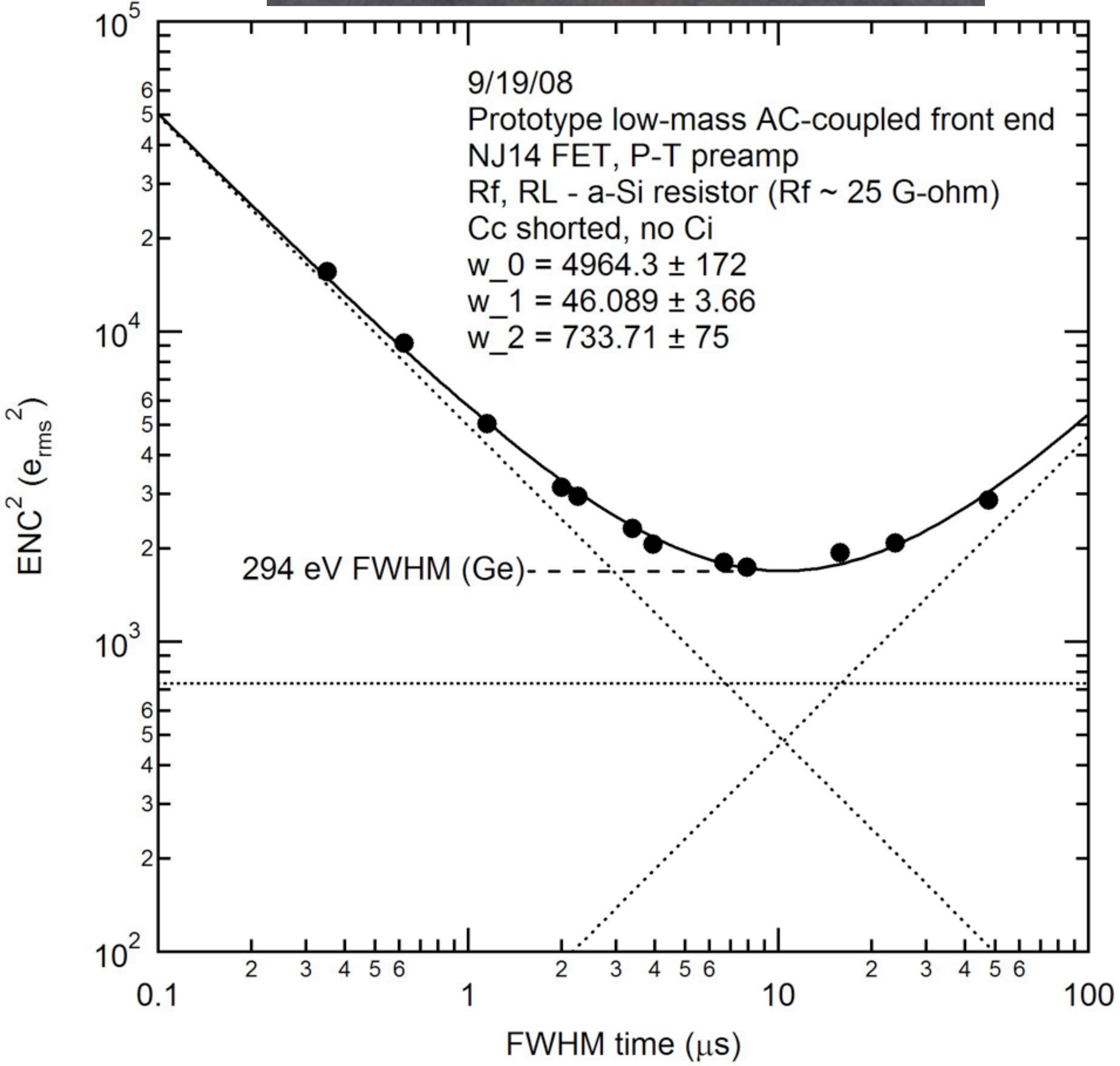


Detector Readout

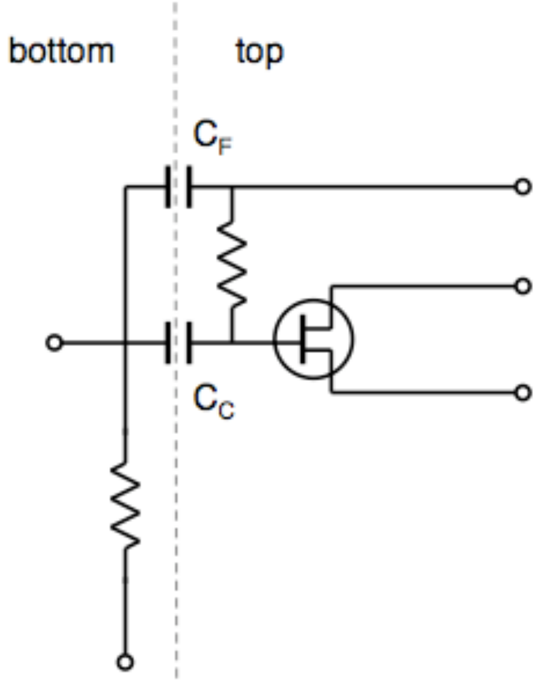
- Parallel development of resistive feedback (LANL) and pulse reset (UW) designs: trade off between noise and thermal / radioactivity challenges
- Integrated detector contact pin: currently under design
- Investigating multiple cable options: "pico"-coax, CuFlon-based flex cables, PEN flex cables, twisted pairs of parylene-coated extruded EFCu
- Cable connection options: wire bond, dimpled pressure connection, conducting adhesive, e-beam welding

Front Ends: Resistive Feedback





- Trace proximity provides ~1 pF capacitance
- Silica or sapphire substrate provides thermal control
- Amorphous Ge resistor: deposit in H environment gives proper R at low T
- MX-120 FET
- Possibility to add decoupling C inside feedback loop (substrate stands off HV)



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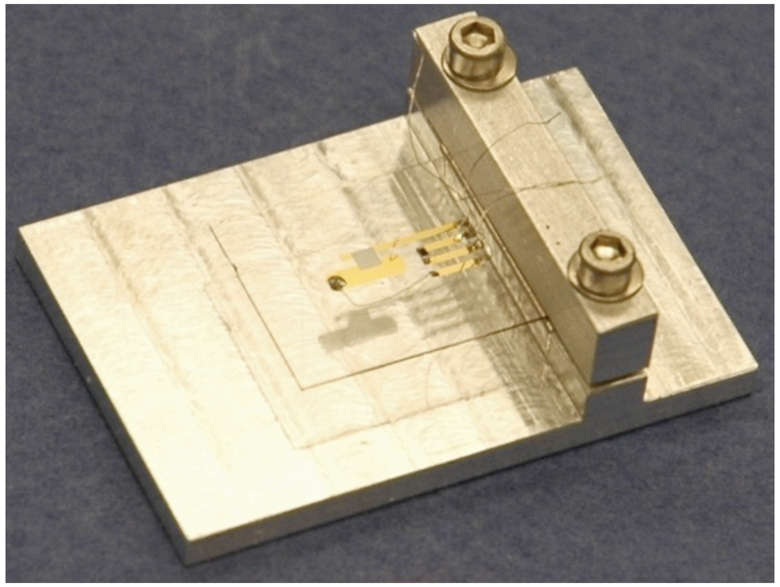

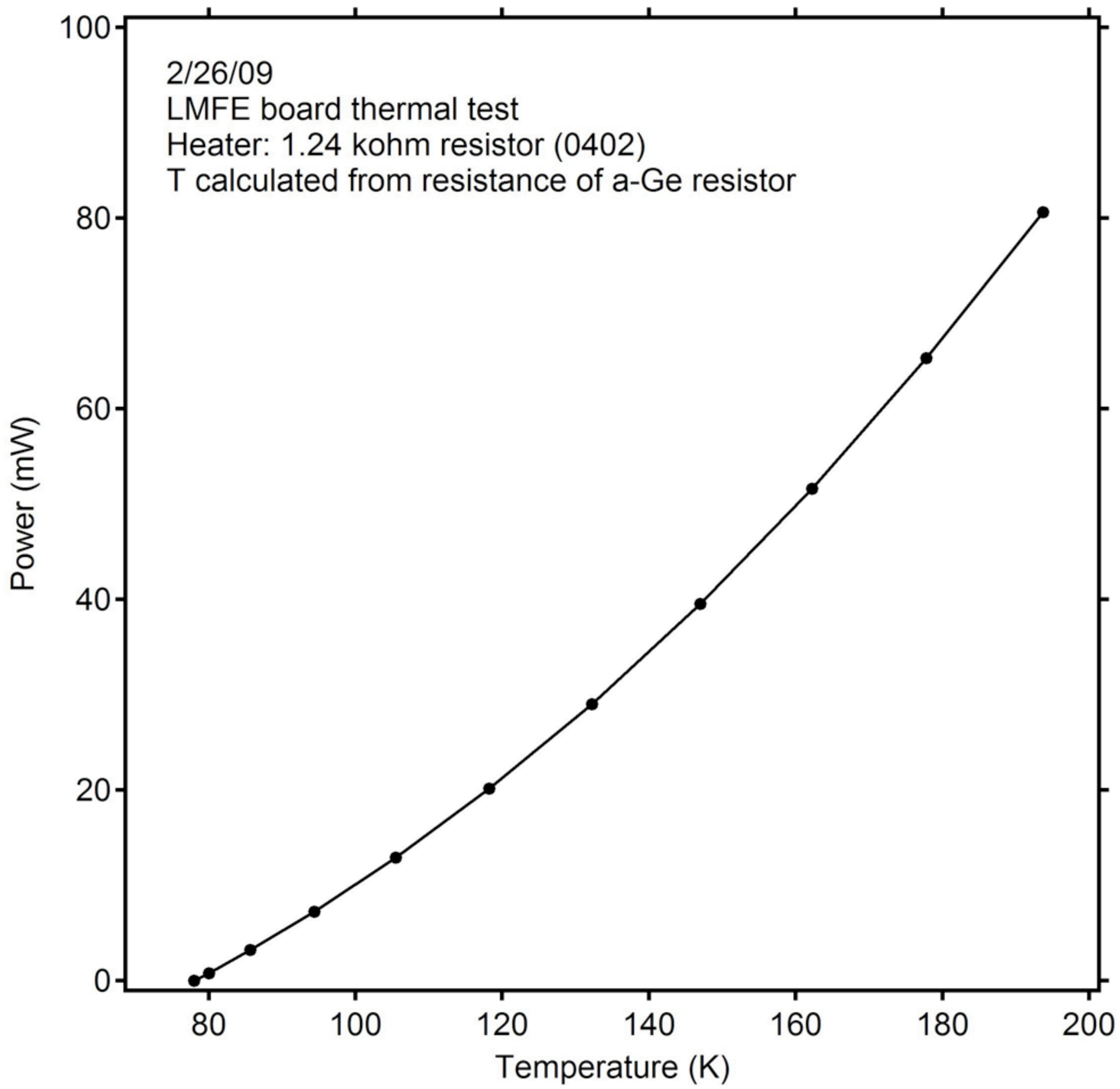

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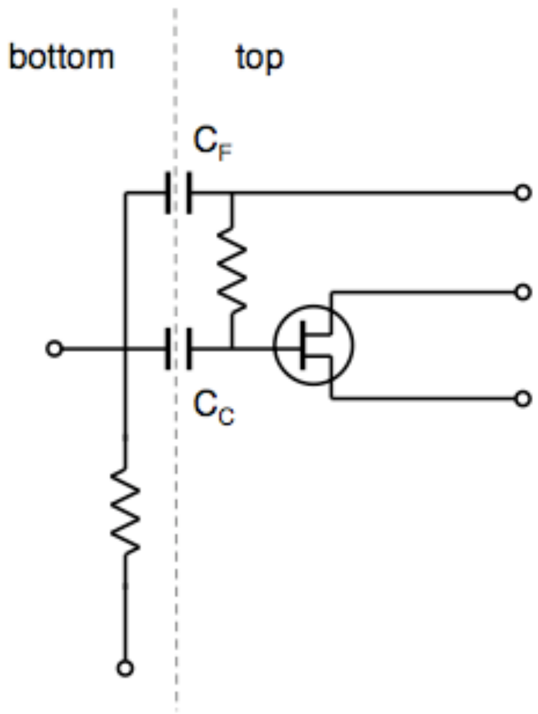

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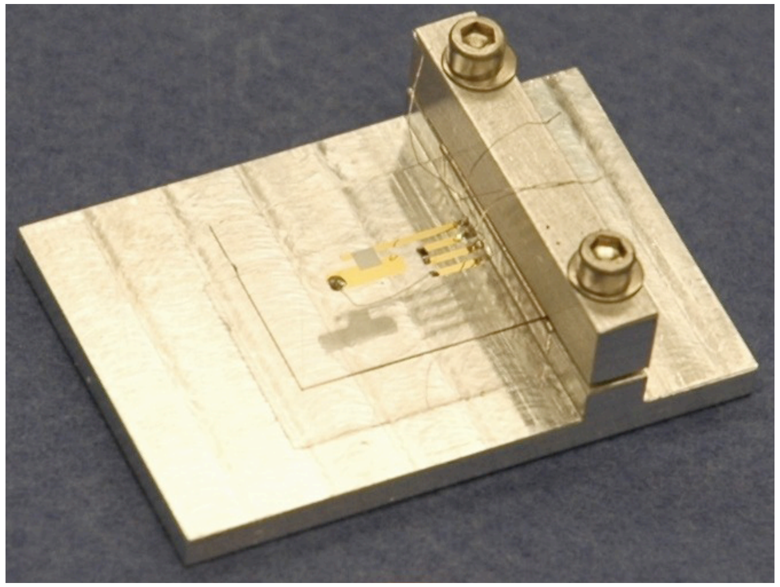

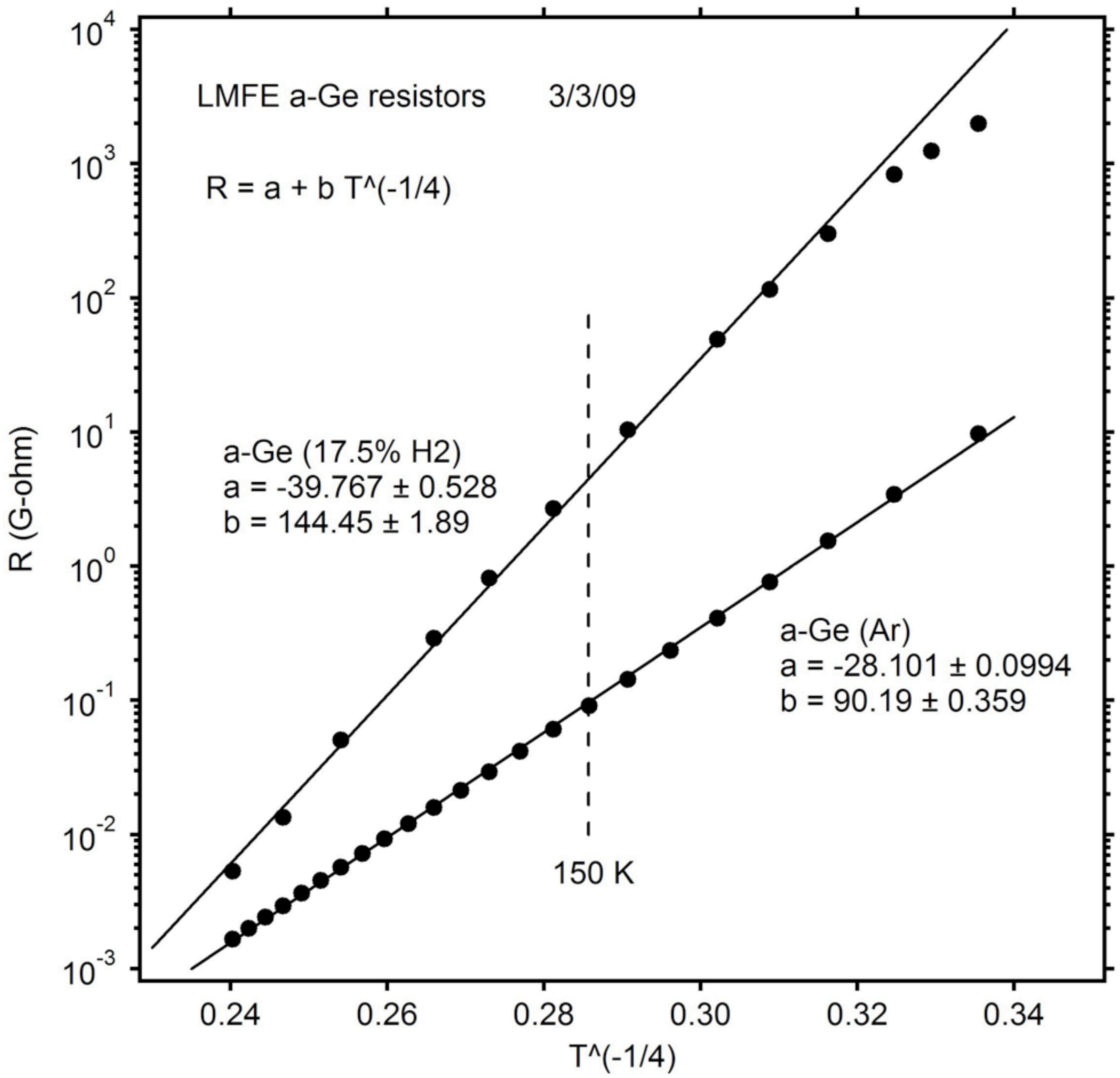

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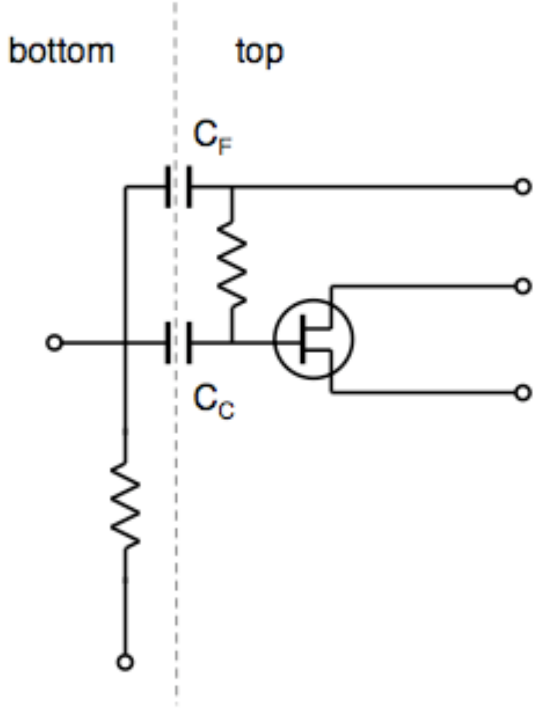
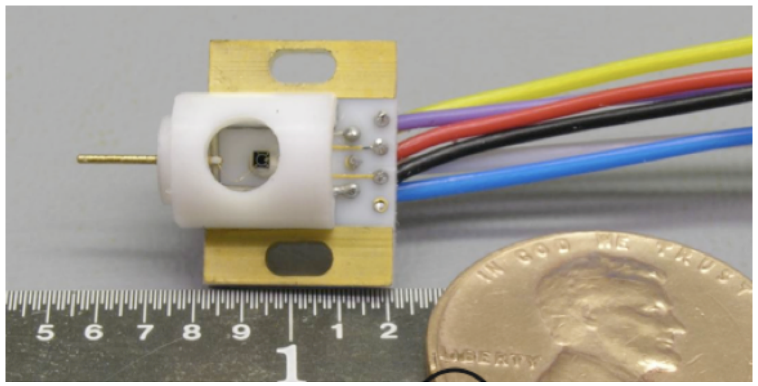
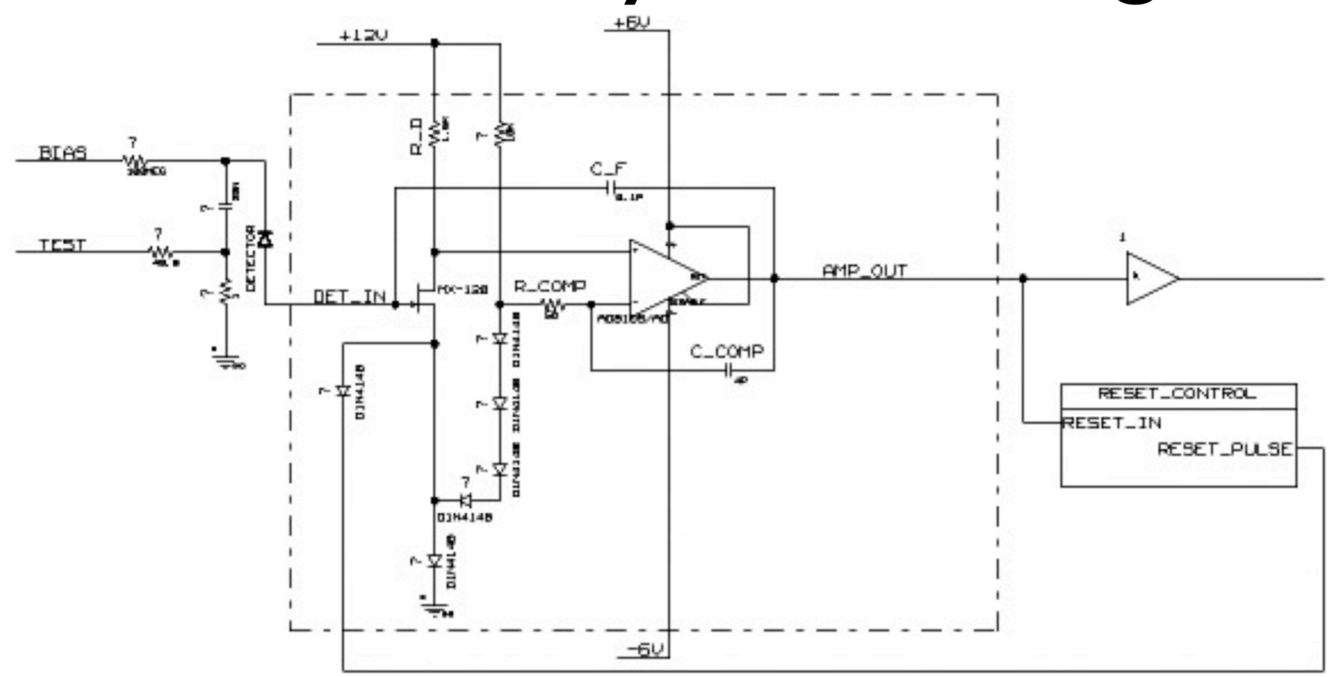
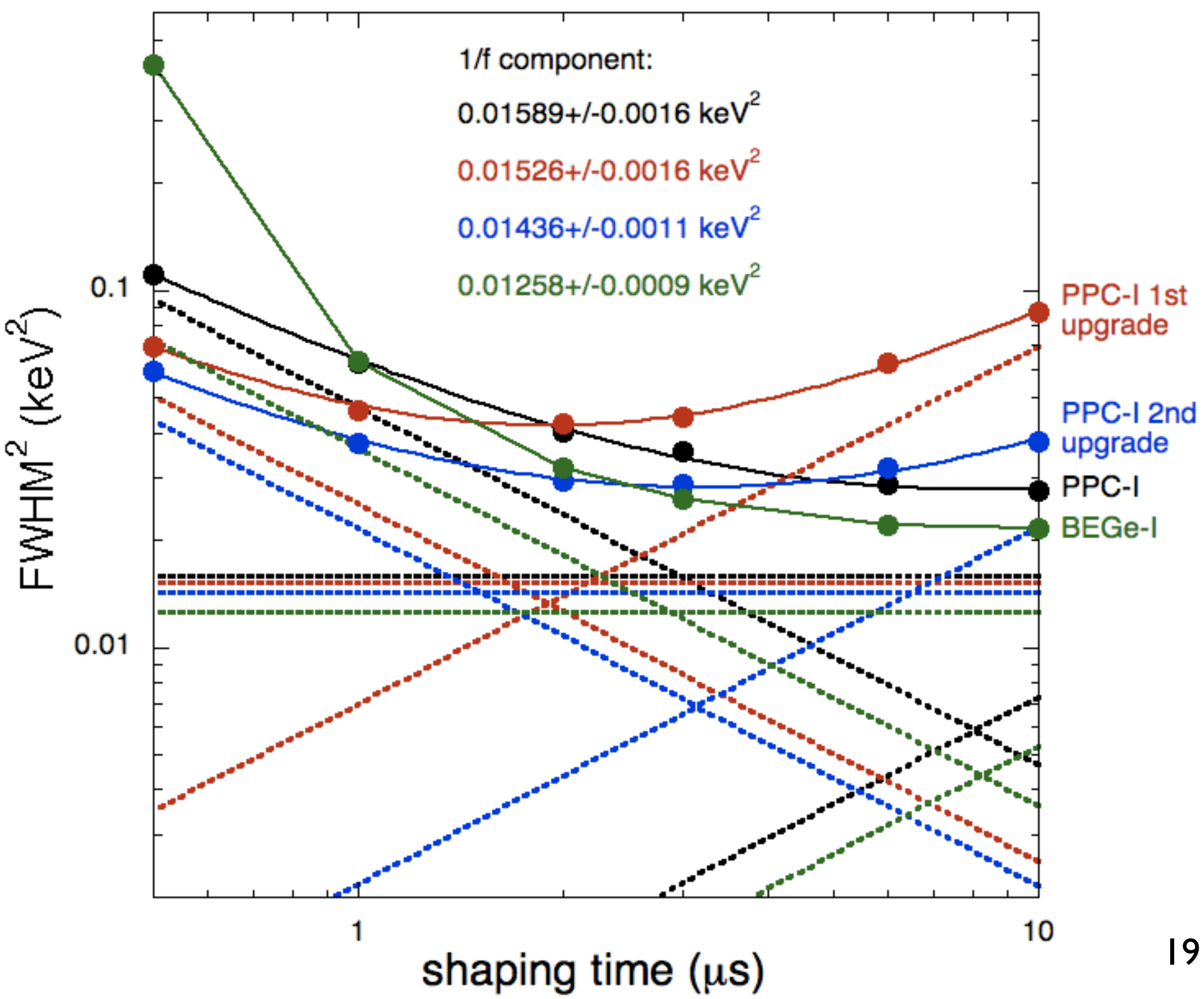


Front Ends: Pulsed Reset

COGENT front ends ⟶ UW "Hybrid" Design



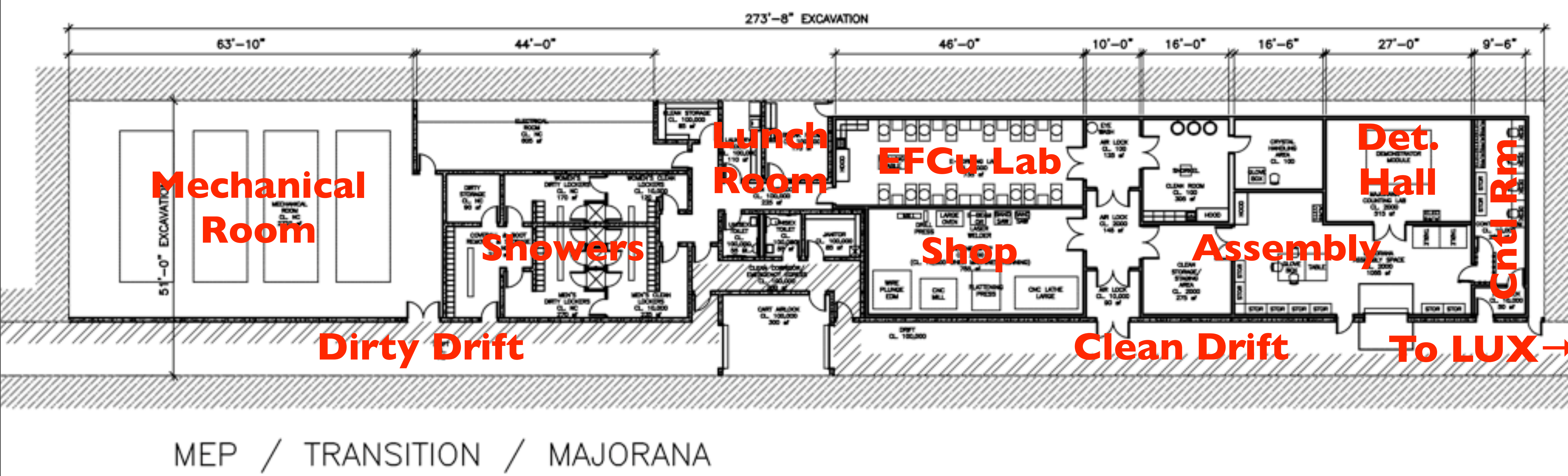




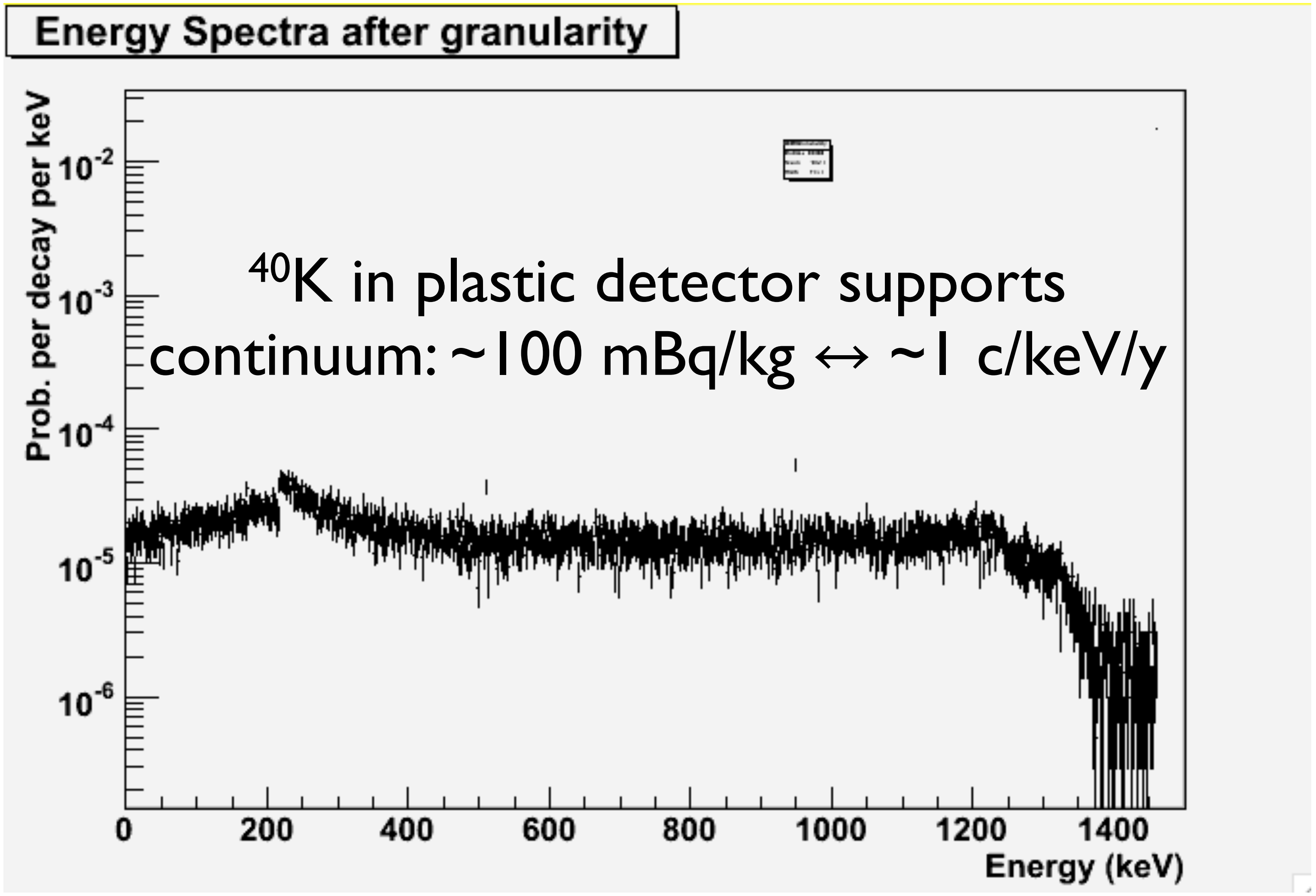
- Front-end and first stage "hybrid" design: close the loop near the detector
- Power dissipation and radioactivity levels may be challenging
- Currently prototyping

Site Facilities

- Current layout: EFCu and detector facilities in one campus at 4850' level in new drift to Davis cavity (LUX)
- Water removal proceeding faster than anticipated; may get to go UG at June collaboration meeting at Sanford Lab
- Beneficial occupancy by year's end



Simulations and Analysis



- Design simulations
  - Internal front-ends
  - Increased internal Cu
  - ^{40}K in plastics
  - Backgrounds from new structural components
- Background Simulation Campaign: Spring 2009
  - DEMONSTRATOR geometry
  - Full-spectrum background model
- Low-E modeling and verification
- DAQ / event building / analysis software under active development

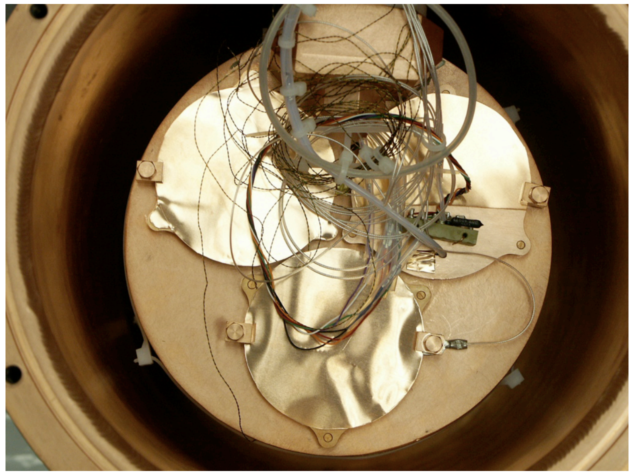
Materials Purity

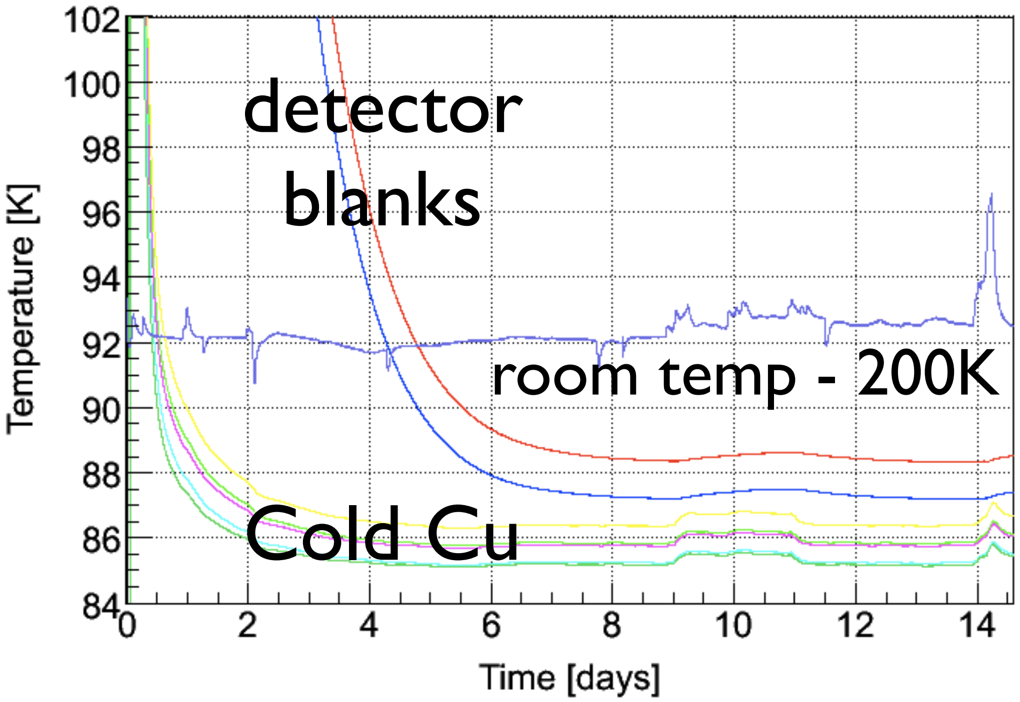
- 2009 campaign to further reduce limits on backgrounds in EFCu (previous best: ~0.7 μBq/kg, addressing bath purity)
- Procuring enough "EXO" plastic for detector supports, with NAA to follow
- Staged Pb procurement with ICPMS program for shield
- Cables and electronics materials screening

Other First Module Preparations

- Detector acceptance / characterization lab
- Designing tools, jigs, glove boxes for detector / string / cryostat assembly
- Thermal / mechanical / electrical testing in Canary Cage
- Construction procedure document drafts
- Preparing to procure GRETINA 10ch 100 MHz digitizers; extensive test stand usage and debugging well underway

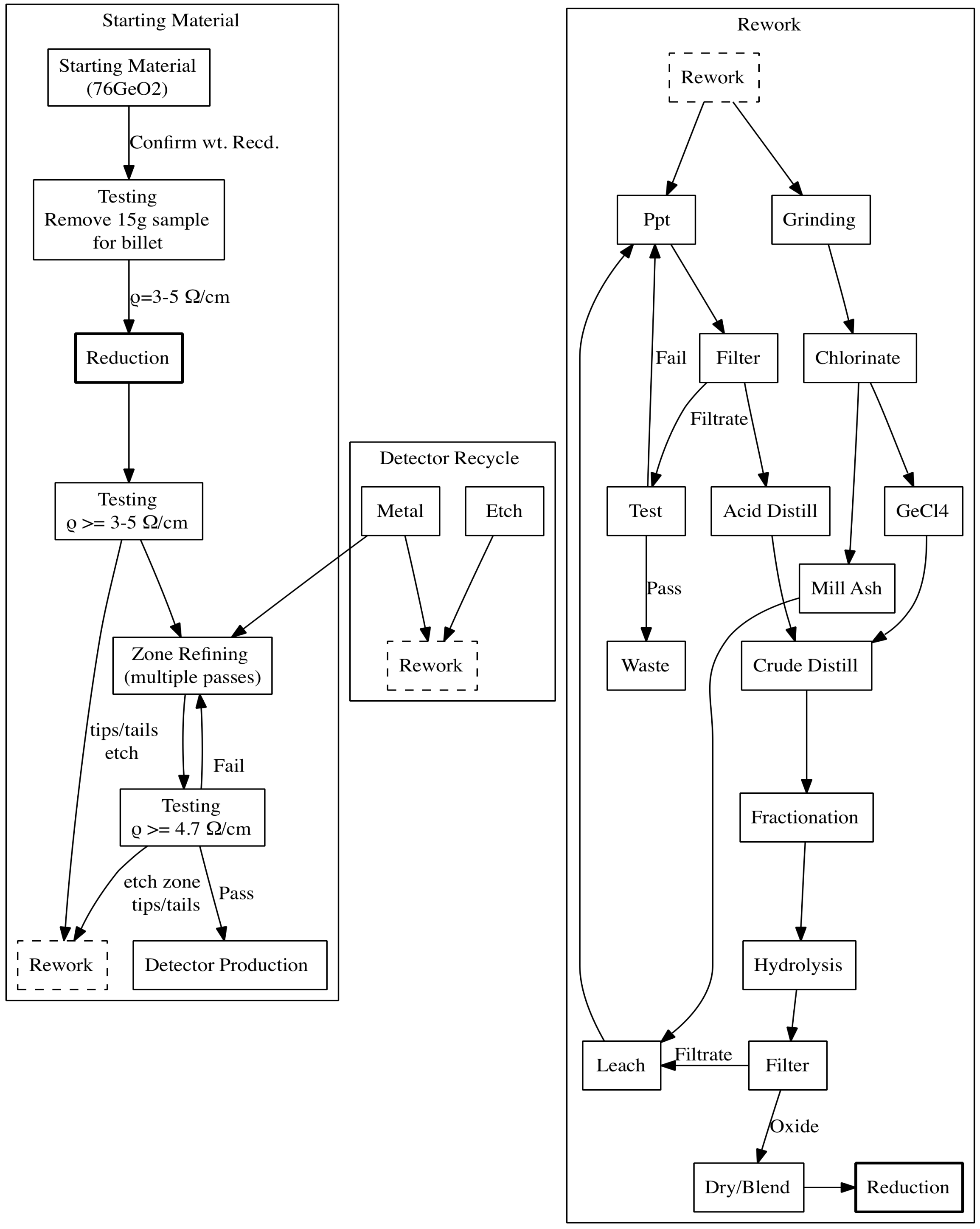
Canary Cage





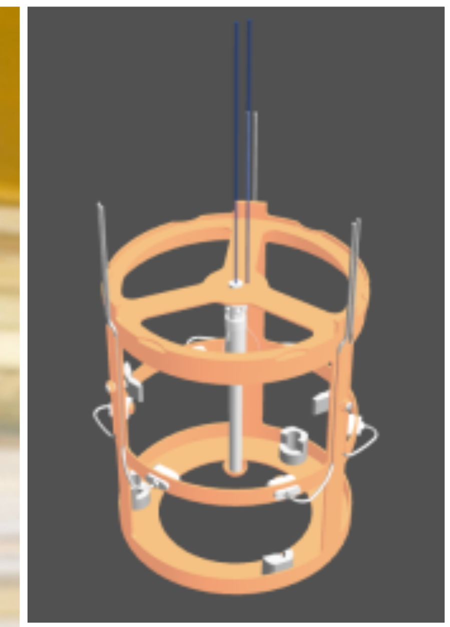
Enriched Germanium

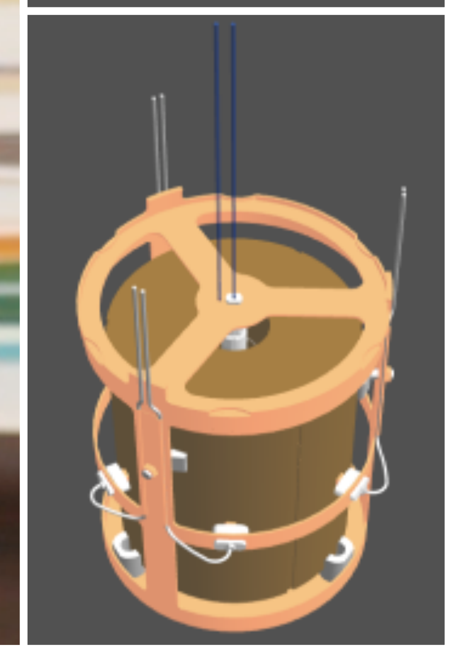
- UMICORE not interested in processing enriched Ge
- Fully costed plan to establish a small processing facility in Oak Ridge
- USD received SD funding for a UG crystal pulling lab
- Continue to monitor alternative enrichment methods, but not much promise at this point



SEGA

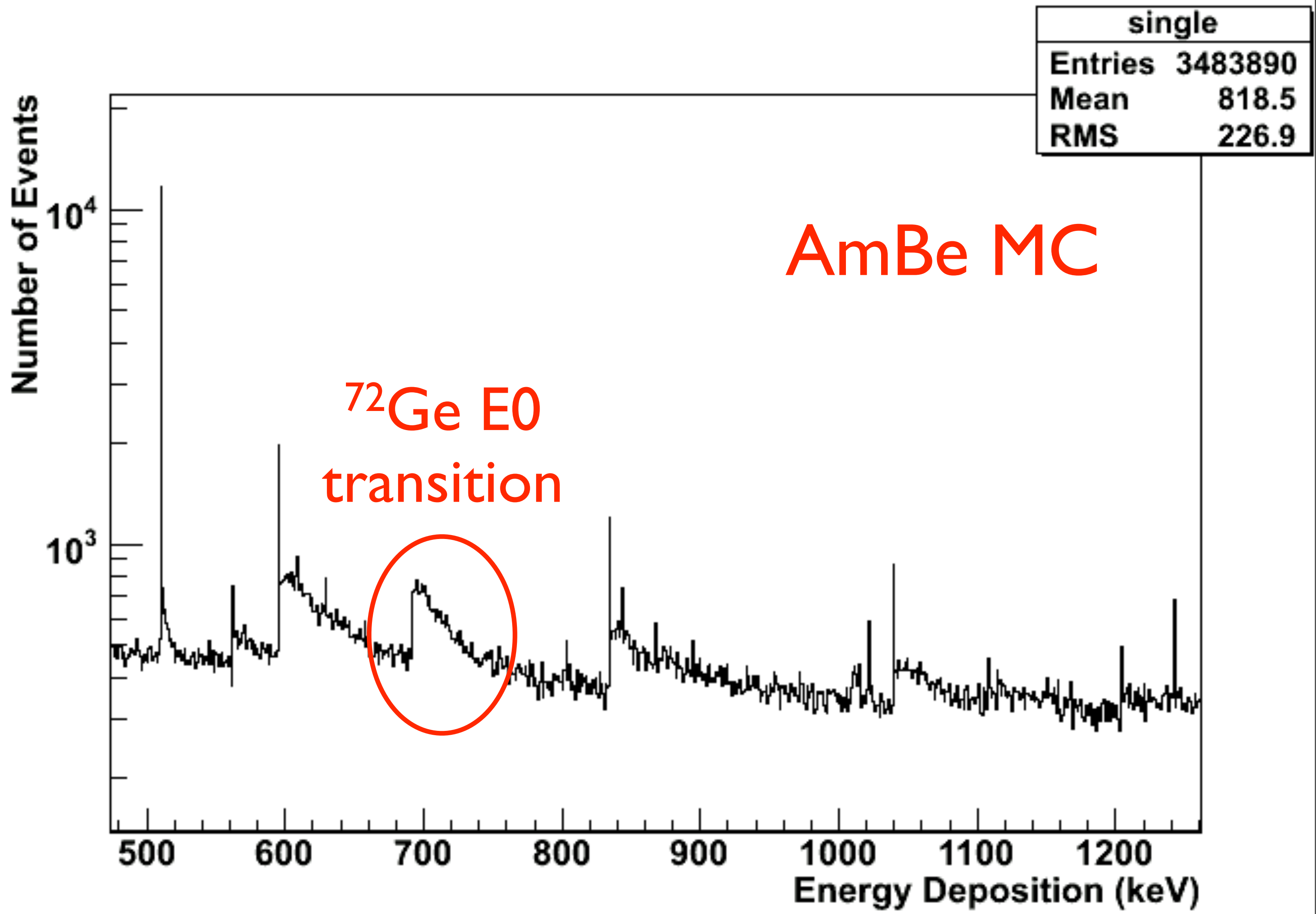
- 4x2 segmented n-type ^{enr}Ge detector
- Currently electroforming detector mount components
- Install in WIPP this Spring, Summer





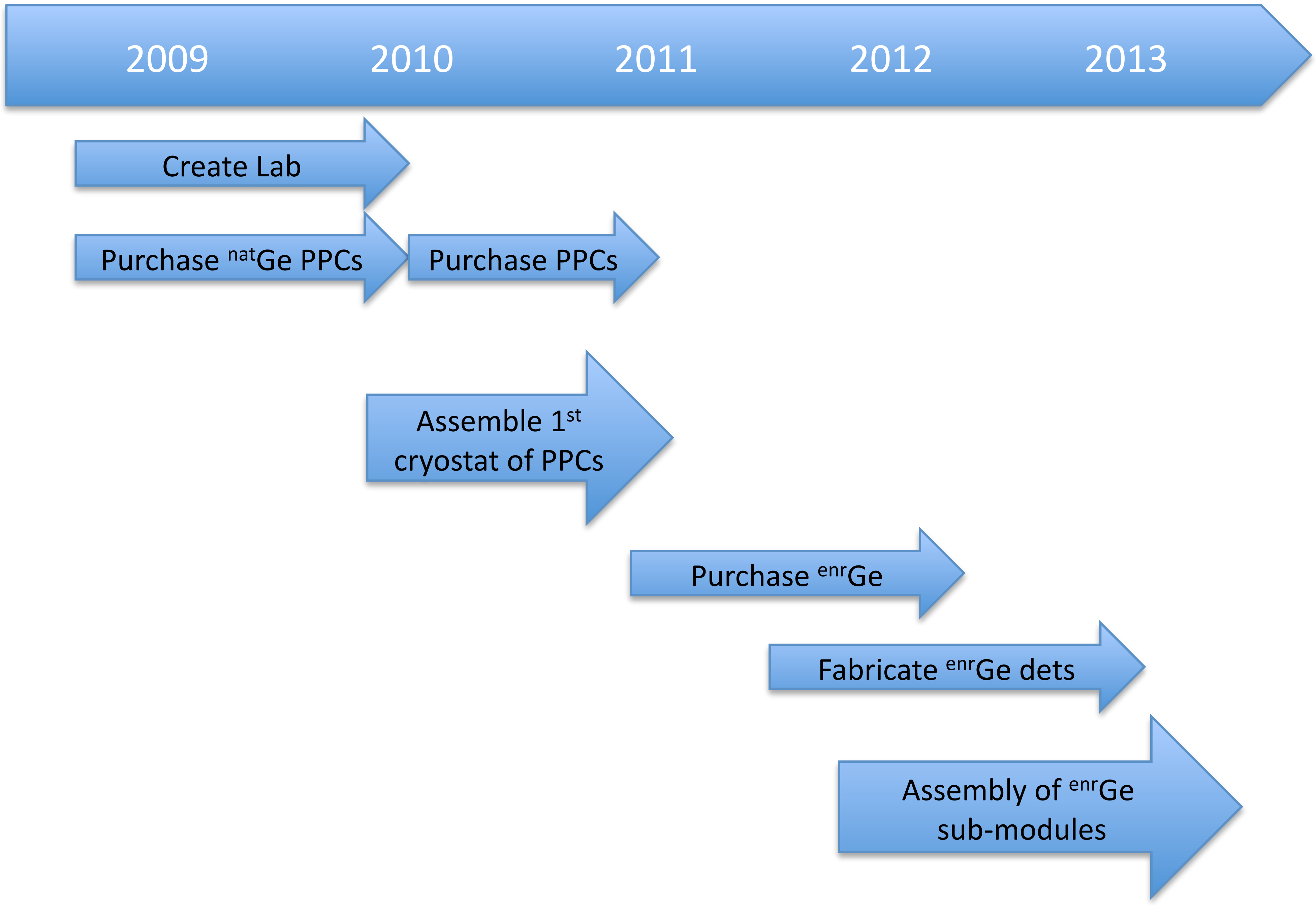
Other R&D

- Neutron interaction simulations
- Cross-beam characterization
- Rn deposition on crystal surfaces



- Surface alpha background characterization
- Spectral shape as a function of source position (see arxiv:0902.4370)

DEMONSTRATOR Schedule



S4 Proposal Status

- Requested funding for
  - Design of UG facilities and potential MJ-like aspects of design (cryostats, shields)
  - Ge detector production / acquisition issues
  - MJ-GERDA down-select studies in the later years
  - Project planning
- Submitted Jan 2009
- Response / funding scheduled for Summer 2009

Summary

- Primary focus is on first module, 18 BEGe's
- Much design work and prototyping in progress.
- Final detector mount / cryostat design and readout down-select for first module in the summer
- Homestake preparations are proceeding rapidly, hope to begin installation late 2009
- Next collaboration meeting: June 2-4 at Sanford Lab in South Dakota