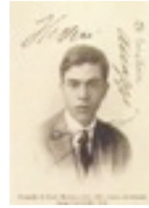
Office of Nuclear Physics



MAJORANA Status

John Wilkerson
Univ. of North Carolina & Oak Ridge National Laboratory

March 1, 2010

GERDA Collaboration Meeting
LNGS

The MAJORANA Collaboration

Note: Red text indicates students

Black Hills State University, Spearfish, SD
Kara Keeter

Duke University, Durham, North Carolina , and TUNL
Matthew Busch, James Esterline, Mary Kidd, Gary Swift, Werner Tornow

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,
Oleg Kochetov, M. Shirchenko, V. Timkin, E. Yakushev

Lawrence Berkeley National Laboratory, Berkeley, California and the University of California - Berkeley
Mark Amman, Marc Bergevin, Yuen-Dat Chan, Jason Detwiler,
Brian Fujikawa, James Loach, Paul Luke, Ryan MartinAlan Poon,
Gersende Prior, Jing Qian, Kai Vetter, Harold Yaver, Sergio Zimmerman

Los Alamos National Laboratory, Los Alamos, New Mexico
Melissa Boswell, Steven Elliott, Victor M. Gehman,
Vincente Guiseppe, Andrew Hime, Adam Montoya,
Kieth Rielage, Larry Rodriguez, David Steele, Jan Wouters

North Carolina State University, Raleigh, North Carolina and TUNL
Henning Back, Lance Leviner, Albert Young

Oak Ridge National Laboratory, Oak Ridge, Tennessee
Fred Bertrand, Greg Capps, Ren Cooper,
David Radford, Robert Varner, Chang-Hong Yu

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

Pacific Northwest National Laboratory, Richland, Washington
Craig Aalseth, James Ely, Jim Fast, Erin Fuller, Eric Hoppe, Todd Hossbach,
Marty Keillor, Jeremy Kephart, Richard T. Kouzes, Harry Miley, Allan Myers,
John Orrell, Bob Thompson, Ray Warner

Queen's University, Kingston, Ontario
Art McDonald

University of Alberta, Edmonton, Alberta
Aksel Hallin

University of Chicago, Chicago, Illinois
Phil Barbeau, Juan Collar, Nicole Fields

University of North Carolina, Chapel Hill, North Carolina and TUNL
Padraic Finnerty, Graham Giovanetti, Reyco Henning,
Mark Howe, Sean MacMullin, Dave Phillips, Jacquie Strain, John F. Wilkerson

University of South Carolina, Columbia, South Carolina
Frank Avignone, Richard Creswick, Horatio A. Farach,
Leila Mizouni

University of South Dakota, Vermillion, South Dakota
Tina Keller, Thomas Keenan, Dongming Mei, Chao Zhang

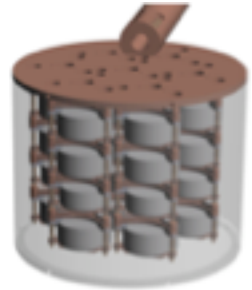
University of Tennessee, Knoxville, Tennessee
William Bugg, Yuri Efremenko

University of Washington, Seattle, Washington
John Amsbaugh, Tom Burritt, Peter J. Doe, Robert Johnson, Michael Marino,
Mike Miller, R. G. Hamish Robertson, Alexis Schubert, Tim Van Wechel

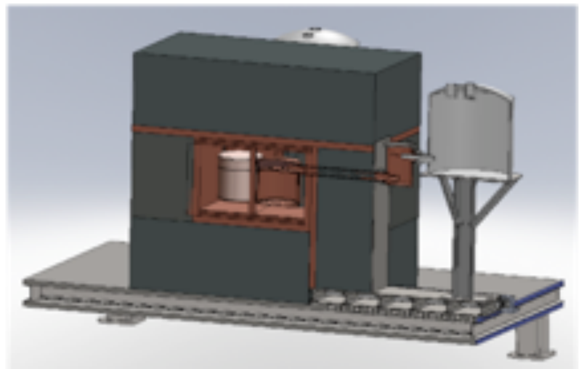
The DEMONSTRATOR

^{76}Ge offers an excellent combination of capabilities & sensitivities.

(Excellent energy resolution, intrinsically clean detectors, commercial technologies, best $0\nu\beta\beta$ sensitivity to date)

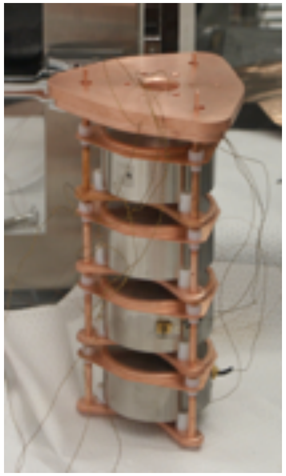


- 60-kg of Ge detectors
  - 30-kg of 86% enriched ^{76}Ge crystals and 30-kg of ^{nat}Ge
  - Detector Technology: P-type, point-contact.
- 3 independent cryostats
  - ultra-clean, electroformed Cu
  - ~20 kg of detectors per cryostat
  - naturally scalable

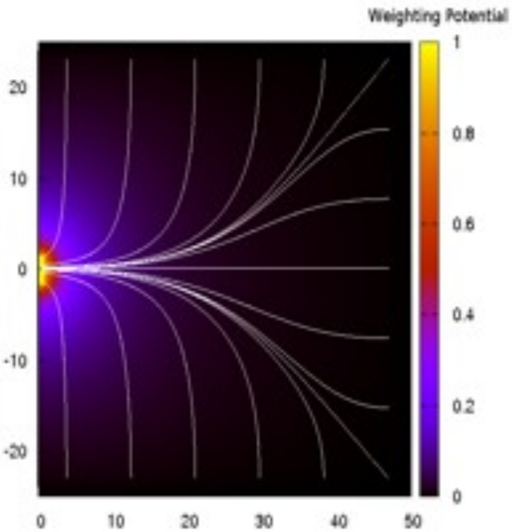


- Compact Shield
  - low-background passive Cu and Pb shield with active muon veto
- Located underground 4850’ Sanford Lab/DUSEL
- Background Goal for 1 Tonne in the $0\nu\beta\beta$ peak region of interest (4 keV at 2039 keV) **~ 1 count/ROI/t-y** (after analysis cuts) or 3 counts/ROI/t-y for the DEMONSTRATOR.

MAJORANA DEMONSTRATOR Status



- Funded by DOE Nuclear Physics and NSF Particle and Nuclear Astrophysics.
  - Managed following DOE project guidelines
  - ORNL is lead laboratory
  - Project team in place as of August 2009
  - FY10 funds provided by DOE Nuclear Physics
  - FY10 Electroforming funds provided by NSF



- Construction Underway
  - 20-kg of ^{nat}Ge modified BEGe p-type, point-contact. (10 kg (18 detectors) in-hand, additional 10 kg ordered)
  - Variety of PPC prototypes UG
  - Several string prototypes undergoing testing
  - Interim electroforming facility at 4850’ level of Sanford laboratory.
  - DEMONSTRATOR Lab in Davis cavity being excavated.
  - Ge refinement laboratory being established in Oak Ridge.

Updates

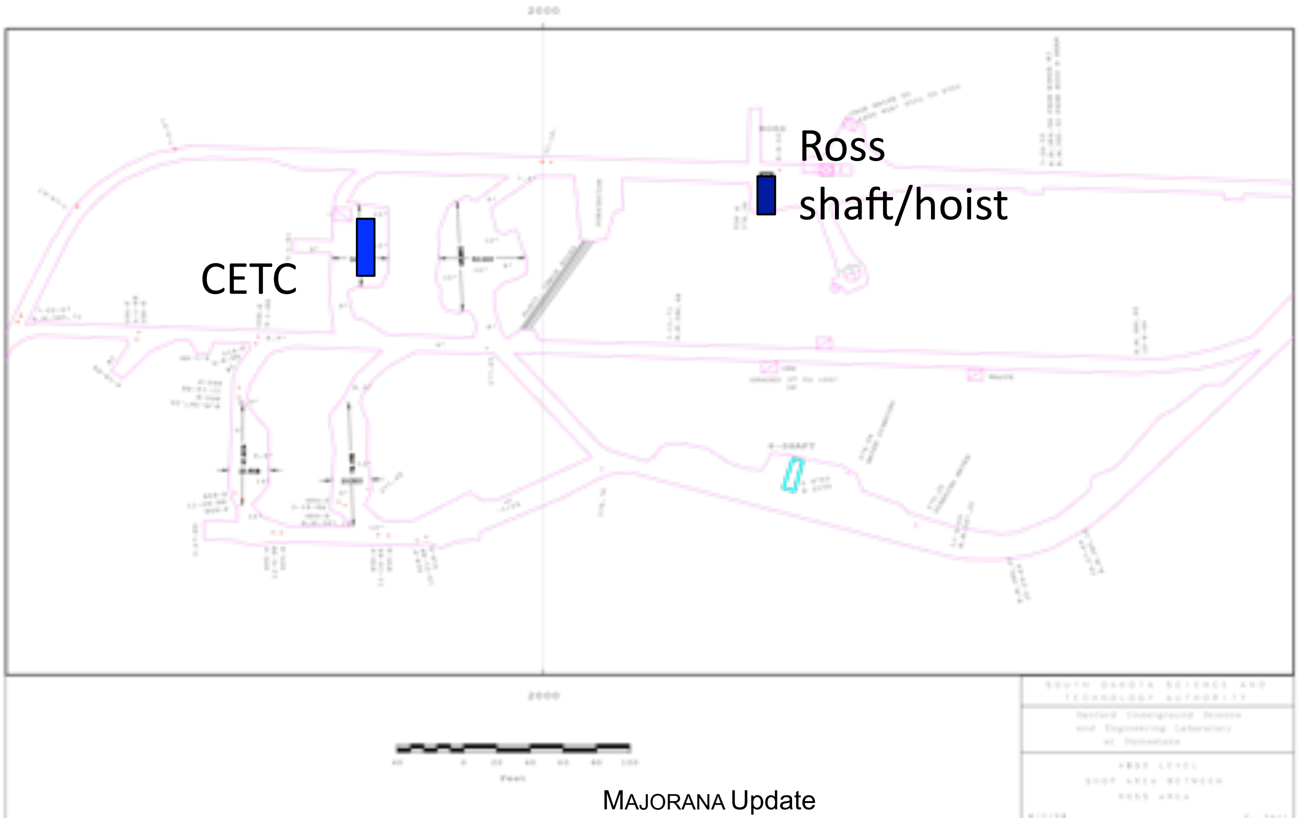
- DEMONSTRATOR selected highlights

- ^{68}Ge production rates

- PPC Developments
  - BEGe PSA work
  - PPC “surface charge slow pulses”
  - MALBEK
  - CoGeNT “dead-layer slow pulses”

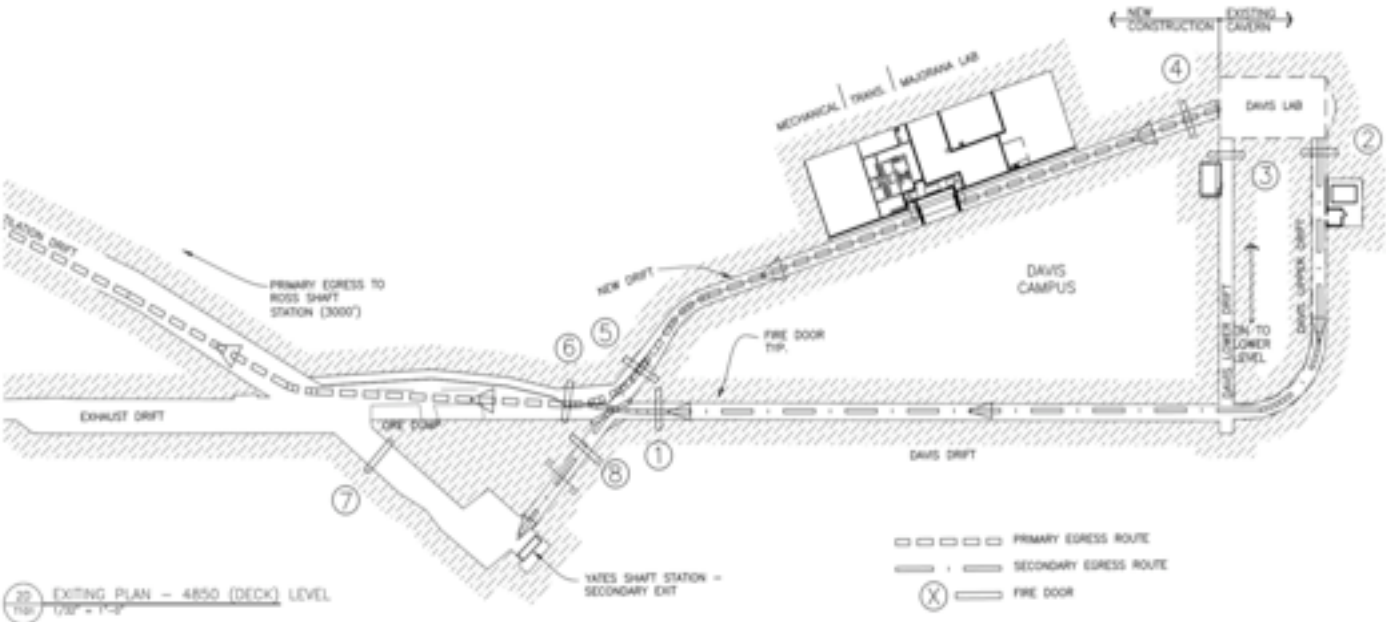
1.03 Host Lab Infrastructure Progress

- Site for Cu Electroforming Temporary Cleanroom (CETC) near Ross Shaft being prepared.
- Clean room building purchased, fabricated, on site.
- ESH reviewed, fire suppression and shower system design
- Jan 6-7 Electroforming Readiness review in Lead



1.03 Upcoming activities

- Commission Cu Electroforming Temporary Cleanroom (CETC).
- Finalize design of Davis Area MJD Laboratory.
- Prepare for machine shop implementation



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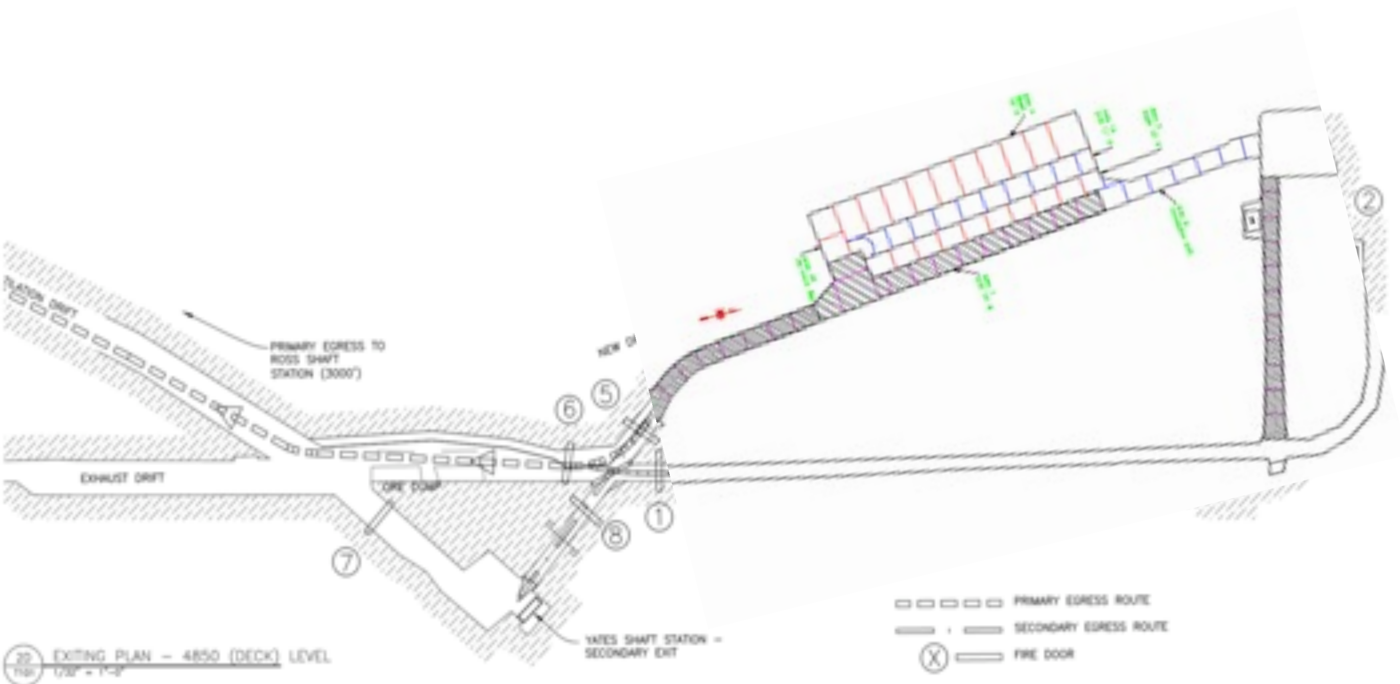
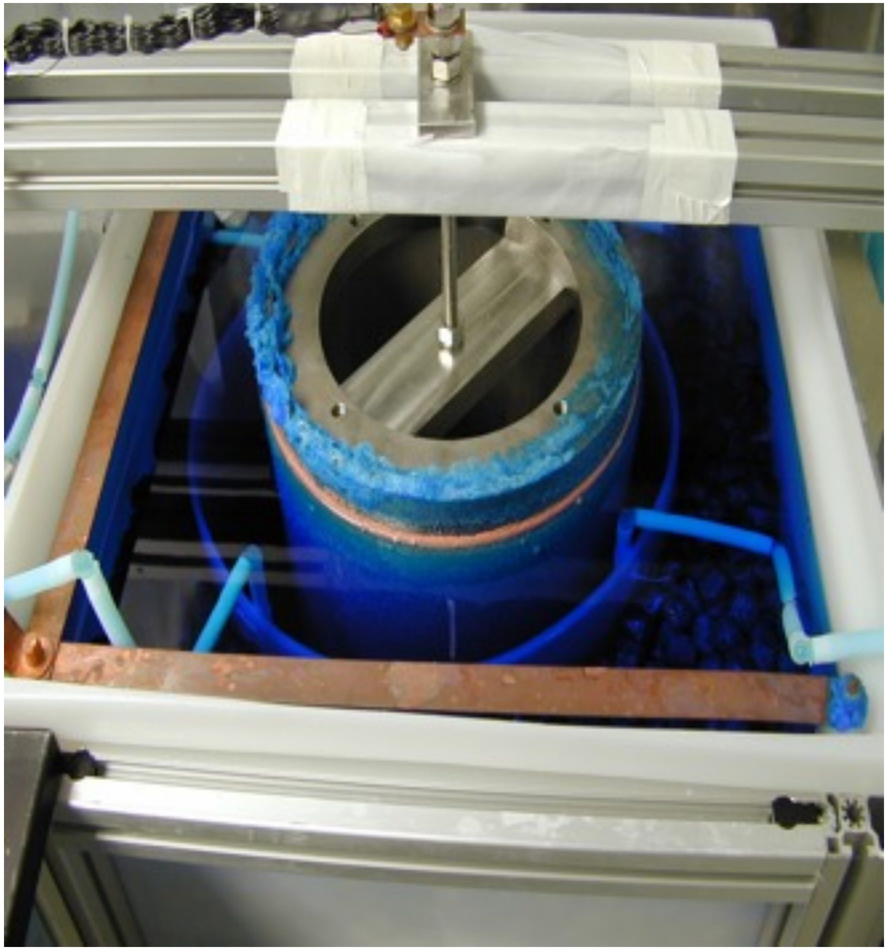


1.04 Materials & Assay Progress

- Setting up for next round of copper assay work, to demonstrate U sensitivity.
- Finished assay of Sullivan lead at Oroville.
- Finished assay of soapy solution for cable production at UW.
- Completed ICP-MS analysis of components for electronics: (tin, chromium, FTE dies, cables).
- Lead, and picocax cable counting completed at KURF

1.05 Electroforming Progress



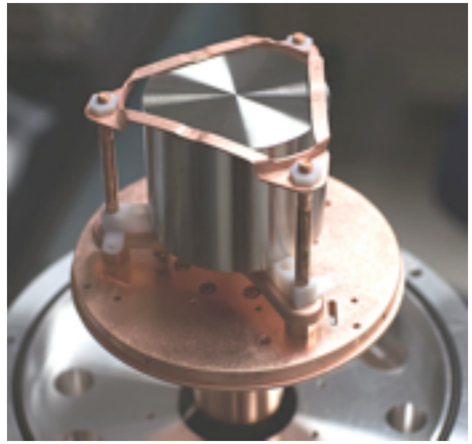
- Readiness Review, Jan. 6-7
  - M. Andrews, Chair (Fermilab), R. Ford (SNOLab), Minfang Yeh (BNL), M. White (LBNL).
- Continuing to electrodeposit copper on MAJORANA like prototype mandrel
  - Bulk chemistry parameters of electroforming bath also monitored and changing predictably
- Continuing electroforming facility planning and procurements
- Ongoing small scale chemometric R&D activities

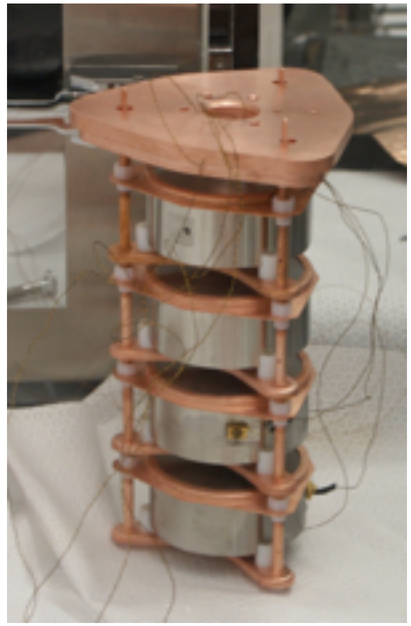
1.06 Ge Task Recent Activities

- Procurement discussions with ORNL procurement personnel
- Contractor acquired the building needed for the Task and renovated it as required
- Completed the design of the zone-refining facility and the equipment lay out
- Completed the design of the purification, zone-refinement , and recycling of ^{76}Ge

1.07 Detector Progress

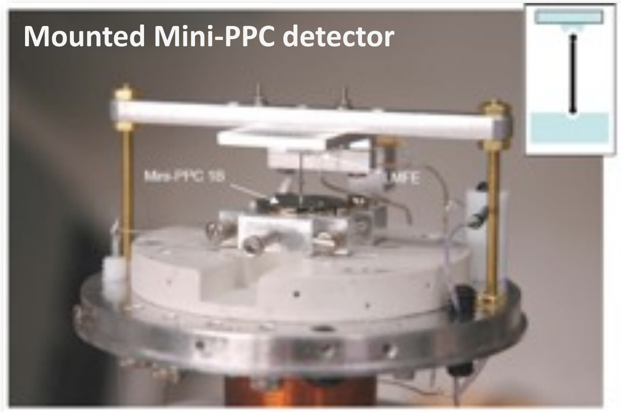
- Single detector module and string development
  - “Multi-nut” design (PNNL) (top): began single detector integration prototyping (LBNL).
  - “Tie-rod design” (CENPA) (bottom): began mechanical and thermal tests (LANL).
- P-PC detector characterization work at various institutions. Examples:
  - Mini-PPC (LBNL): continuous operation for over 4 months
  - “MALBEK” (UNC): Canberra BEGe accepted and being commissioned underground
  - “OPPI” (LANL): ORTEC PPC pulses taken
- Order for the second half of non-enriched detectors for use in first module placed (LANL).

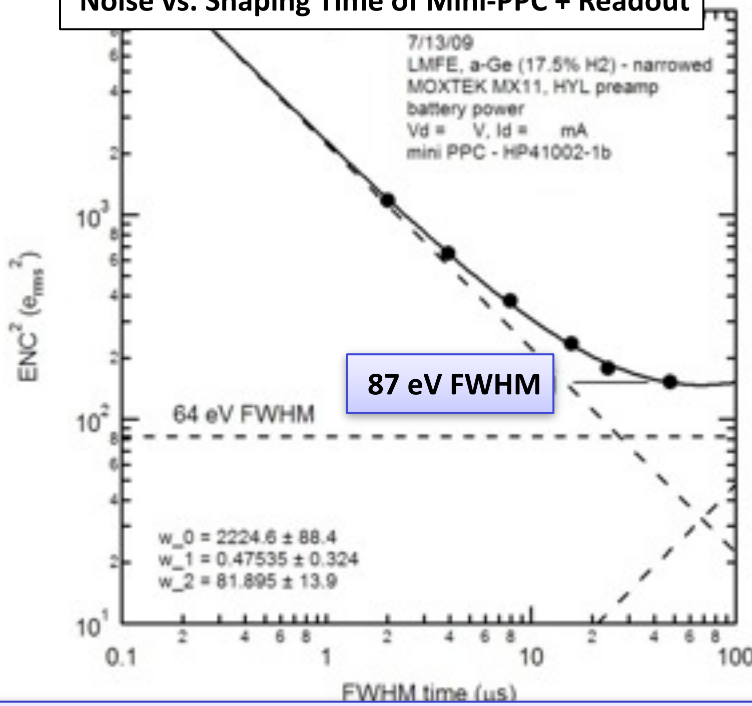




Mini-PPC Implementation

- We implemented and tested the new readout design with small (2cm diameter x 1 cm length), so-called mini-PPC detectors
- An electronic noise of better than 100 eV was achieved
- A “free-standing” contact approach was developed with pressure provided by the silica board
- With further improvements of the LMFE board layout (e.g. temperature of FET), the electronic noise was reduced to below 60 eV with the 1/f noise at ~ 30 eV

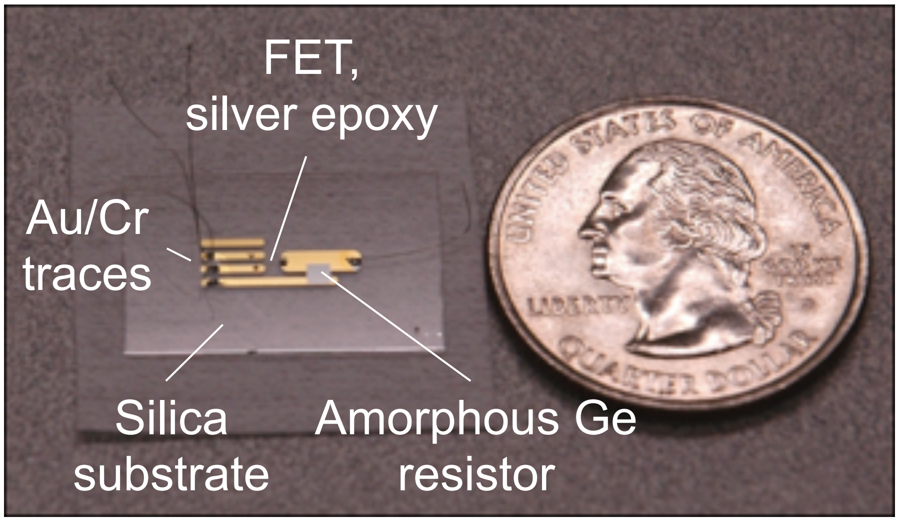




➢ **Very low-noise FE electronics developed and demonstrated with mini-PPC detector!**

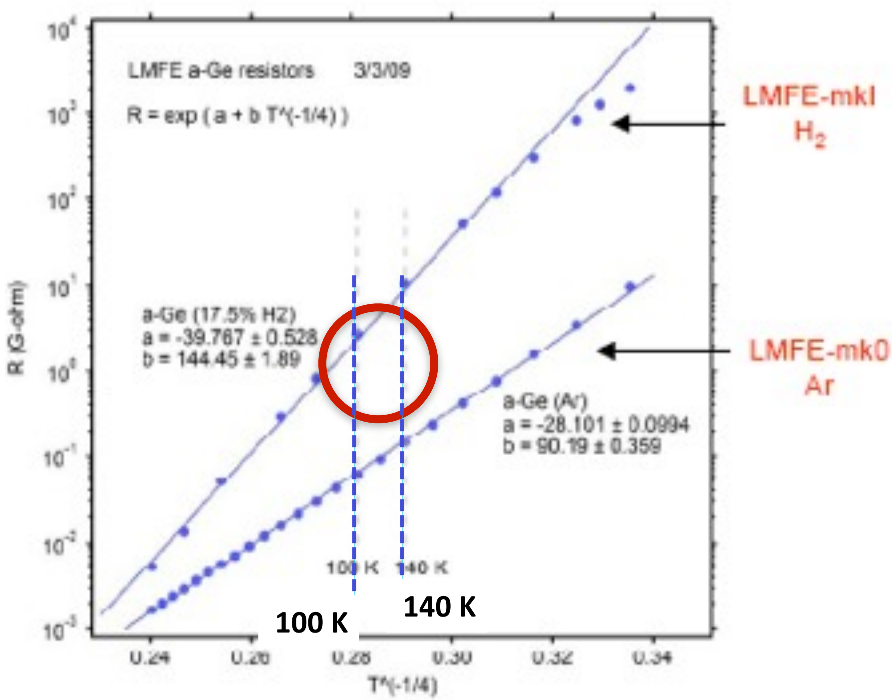
Resistive Feedback Front-End

- Silica or sapphire substrate:
  - Proper thermal environment, very-clean & low mass
- Amorphous Ge thin-film resistor:
  - Deposited in hydrogen environment can provide proper resistivity at low temperatures
  - Ultra-low background (material & mass)



- Feedback capacitance due to material between traces
- Low-capacity, low-noise FETs:
  - MOXTEK: MX11 / MX 120

Resistance vs Temperature of LMFE Amorphous Ge



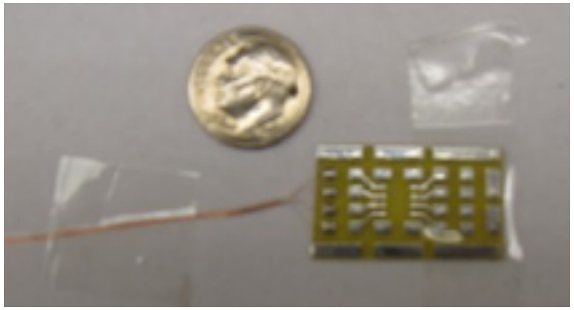
> ➢ **Very compact, low-mass, and clean resistive feedback FE electronics developed**

Monday, March 1, 2010

Signal cables

- parylene coating, Cu wires
- 0.003” wire (OD) spaced by 0.006” => ~1.5 mm wide
- automated winding (~50 m/day)

Cable characteristics



			Measurements have absolute uncertainty of ~4 pF				
L [m]	Wire Pair	C [pF]	LHS Meas. C [pF]	RHS Meas. C [pF]	Predicted C/L [ft]	LHS Measured C/L [ft]	RHS Measured C/L [ft]
0.79	c_12, c_23, c_34	42.90	42.50	43.50	16.6	16.4	16.8
0.79	c_13, c_24	28.04	25.00	25.50	10.8	9.7	9.9
0.79	c_14	23.41	20.00	20.00	9.1	7.7	7.7

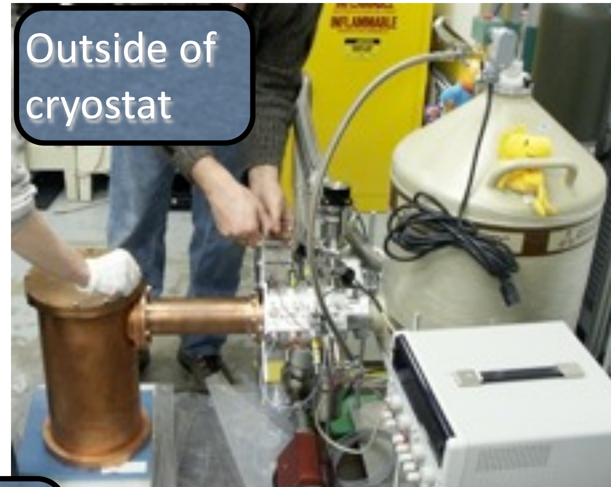
- Measured the impedance to be 100 +- 10 Ohm over any two adjacent wires, expected 100 Ohm, => good agreement
- We can dial the capacitance by choosing the wire spacing: 6 mil spacing => 17 pF/ft. 12 mil => 11 pF /ft, 18 mil => ~8 pF/ft
- On par with commercial ribbon (10-16 pF/ft) from 3M Series 3365, 3801, 8124, 8125

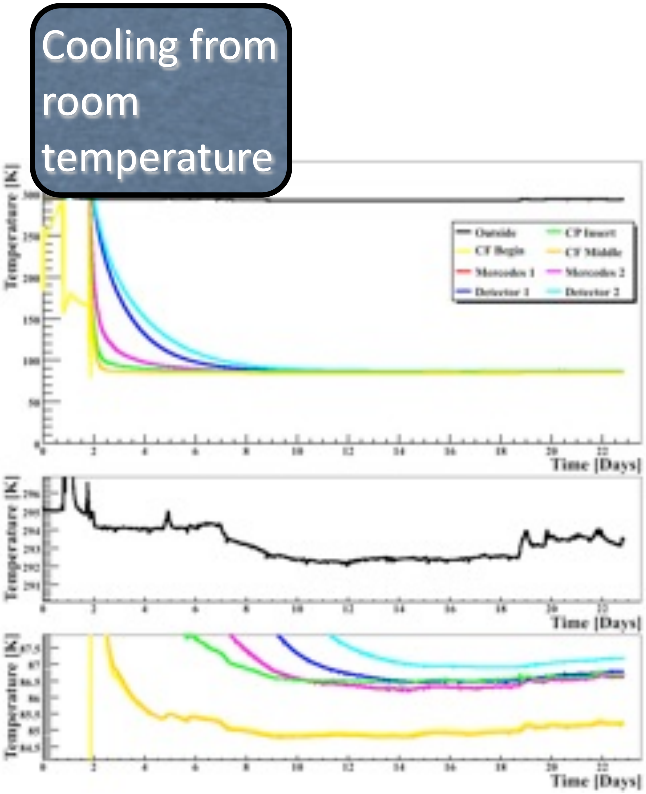
1.08 Detector Module Progress

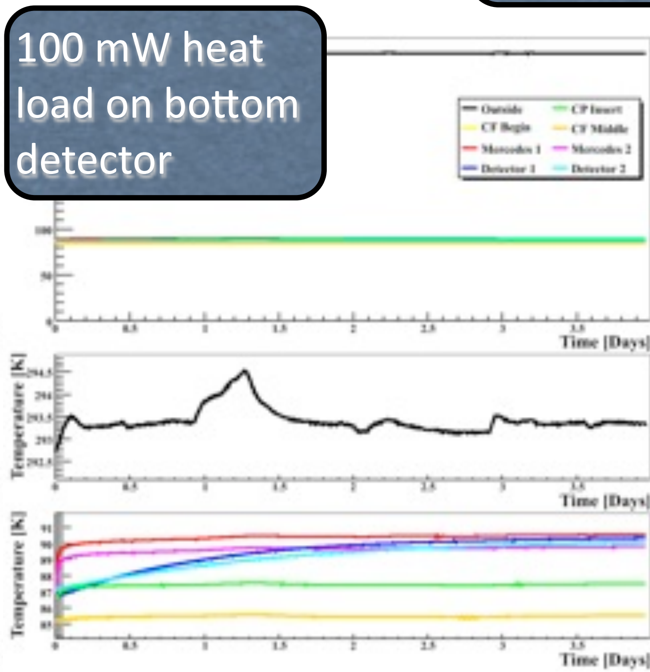
- Completed design, fabrication and commissioning of single PPC test cryostat. Cryostat being used at LBNL to test MAJORANA detector and front-end electronics mounting.
- Performed mechanical and thermal tests of "tie rod" string design in Canary Cage test cryostat.
- Completed specifications for MAJORANA String Test Cryostat. This cryostat will be the successor to the Canary Cage for string prototyping and testing to evaluate end-to-end electronics performance as well as evaluation of mechanical integration.

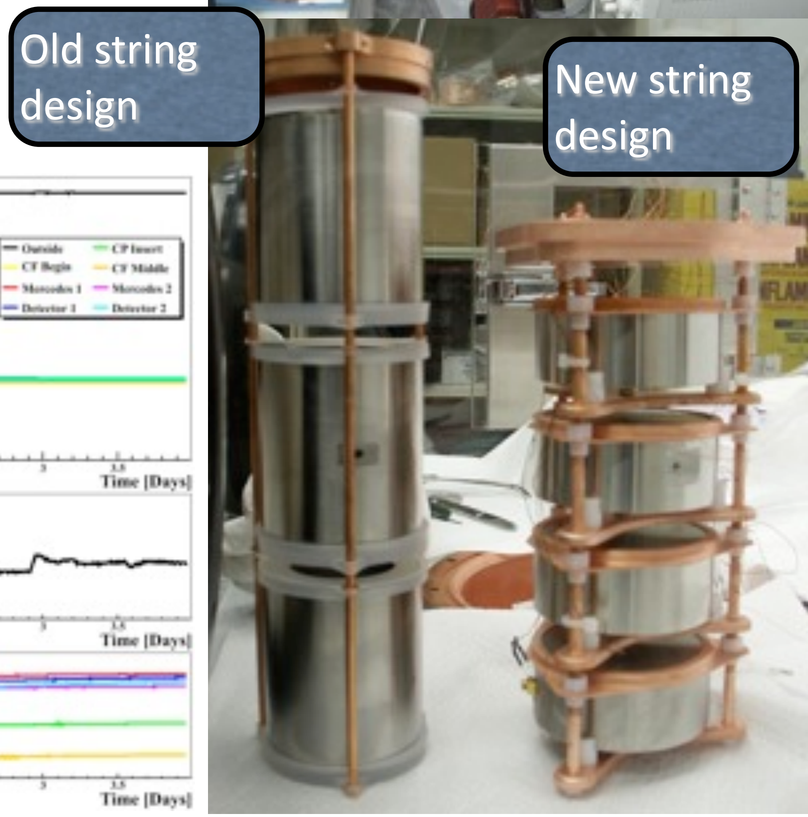
Thermal/Mechanical Studies

- Single-string test cryostat ("The Canary Cage")
- Used for thermal, mechanical and electrical tests. Already run a conventional detector in it!
- Now testing new MAJORANA string design: overall cooling from room temperature, and simulating heat loads from front-end electronics

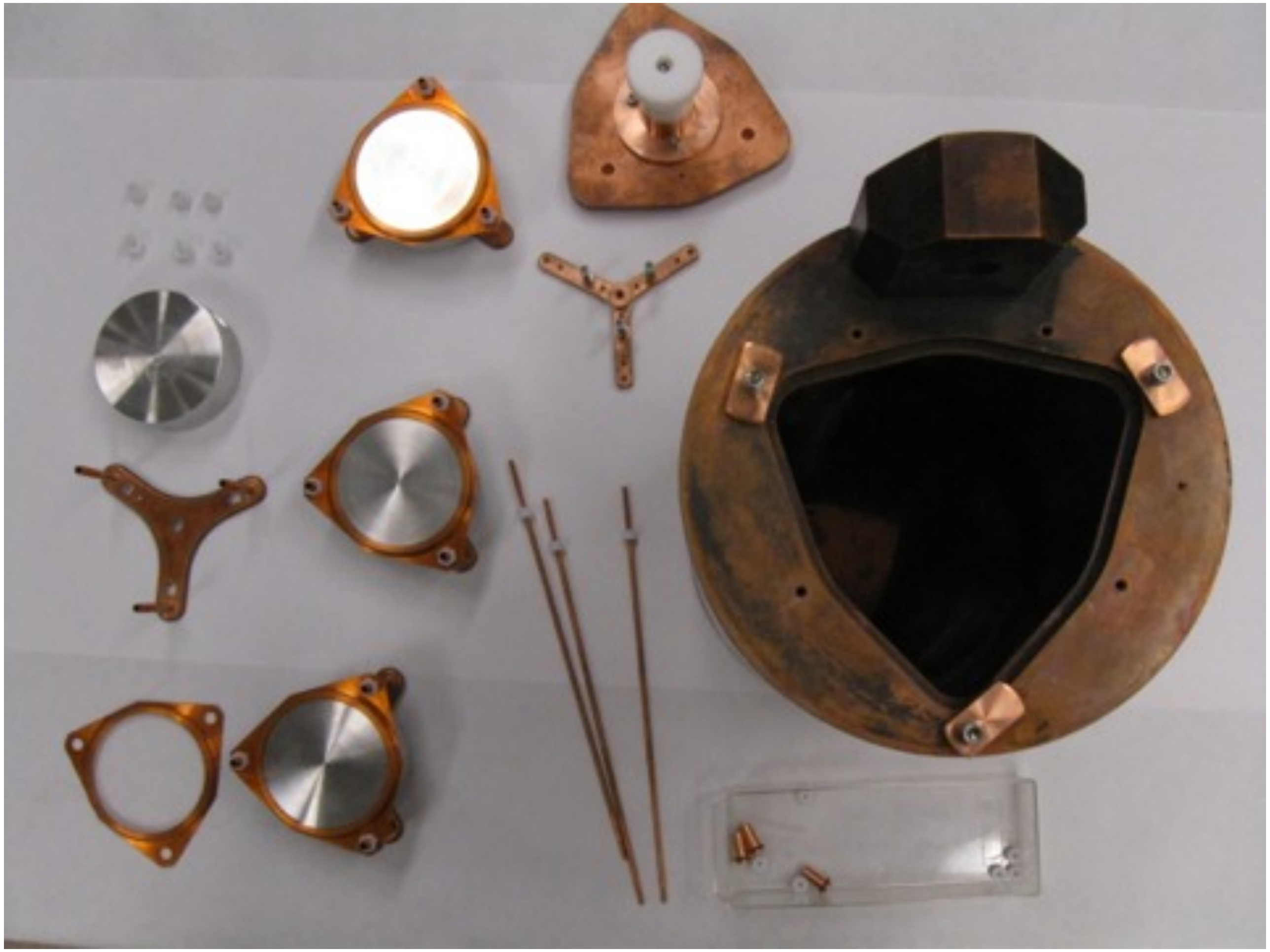




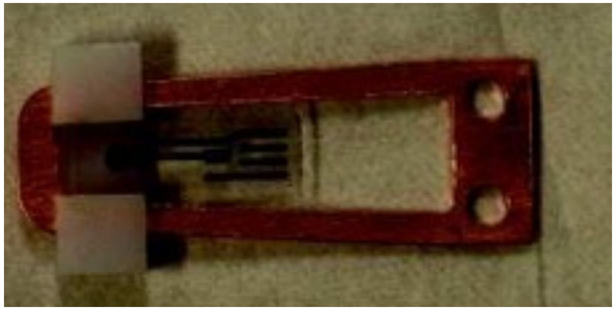


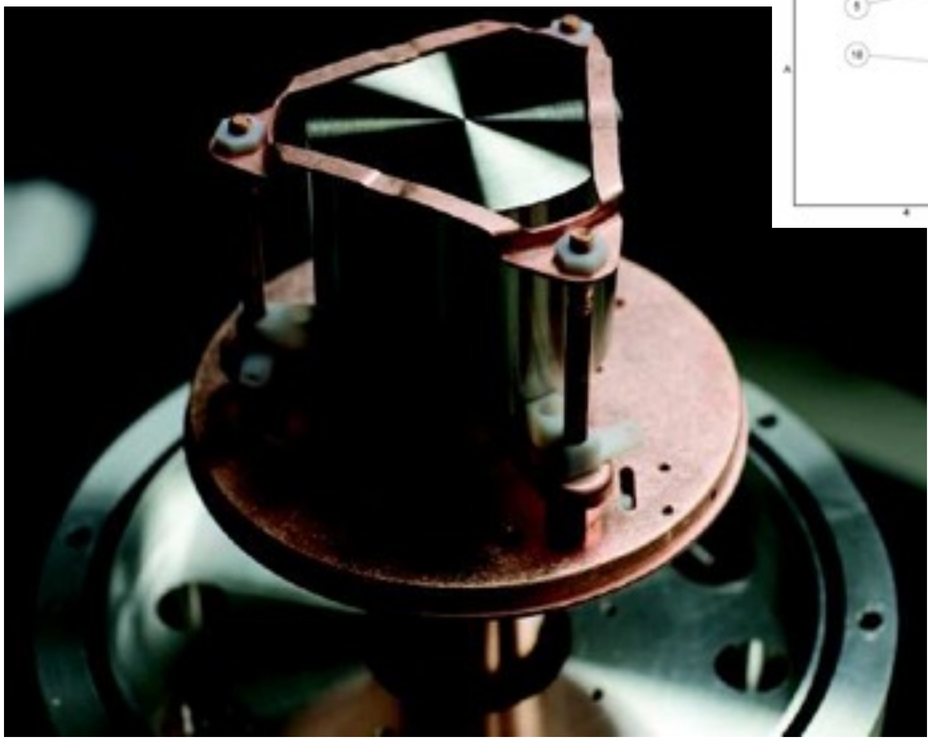


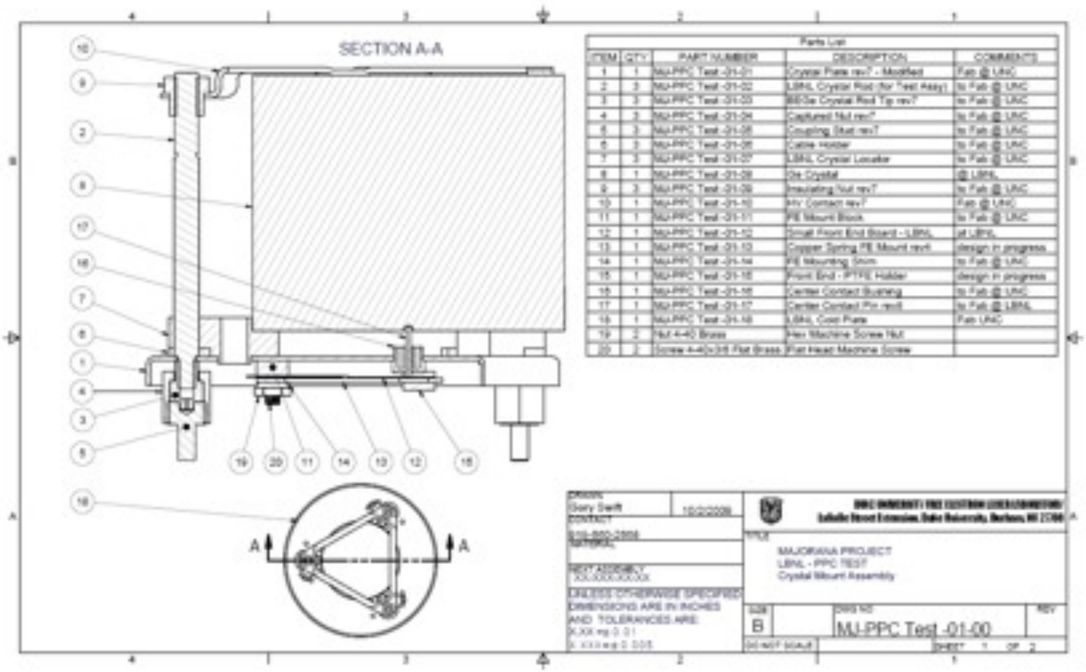
1.08 Tie Rod String Test

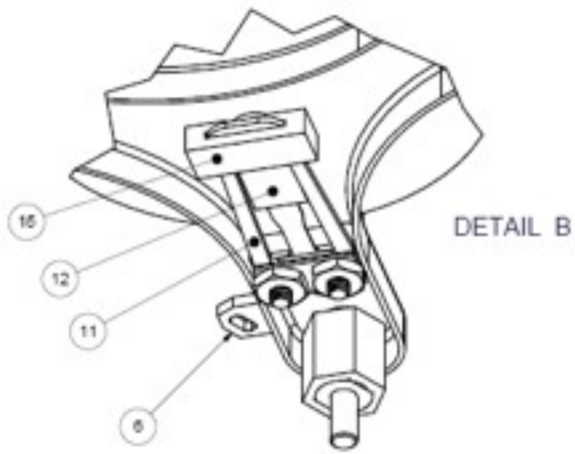


1.08 PPC Test Cryostat





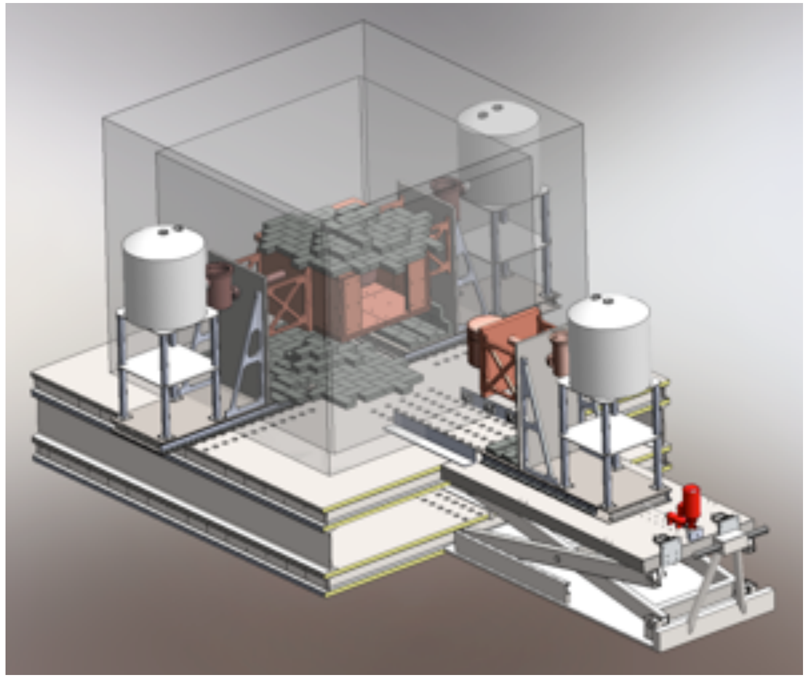


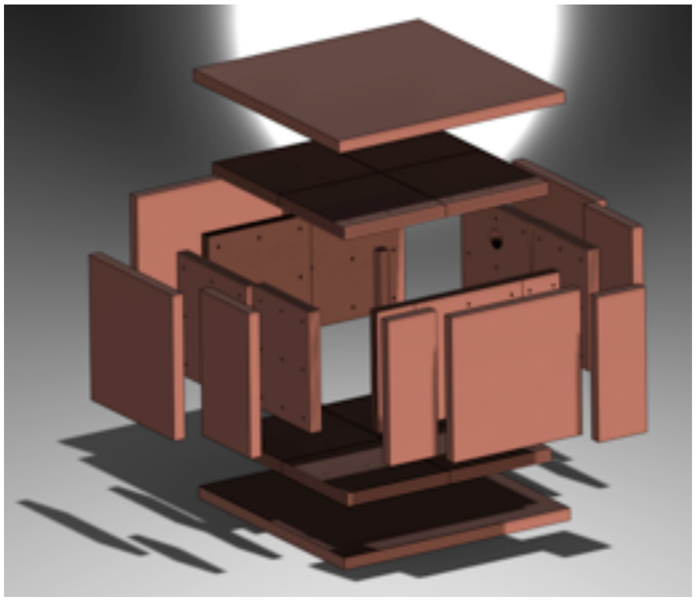


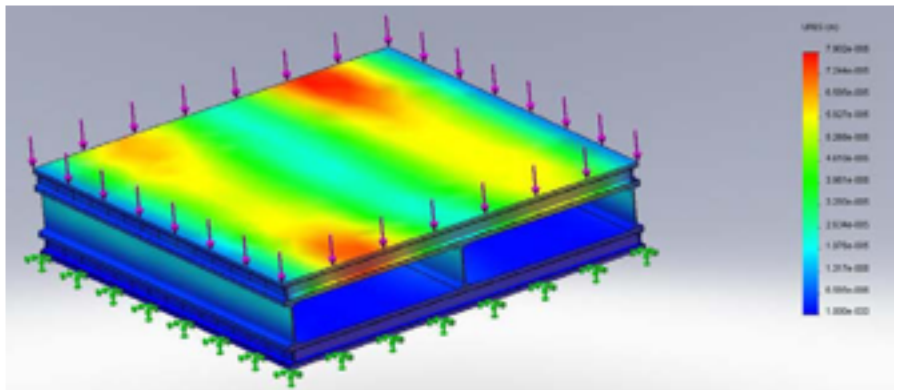
Monday, March 1, 2010

1.09 Mechanical Systems Update

- Recent progress on passive shield design
  - Ongoing conceptual design
  - Designing tables and performing structural analysis
  - Producing Cu part designs







How well do we know production rate of ^{68}Ge?

	[1]	[2]		[3]	[4]	[5]	[6]	[7]
		Meas.	Calc.					
^{nat}Ge	26.5	30 ± 7	29.6	58.4	82.8	89	45.8	41.3
^{enr}Ge	1.2		0.94		5.7	13	7.6	7.2

[1] H. S. Miley, F. Avignone, R. Brodzinski, W. Hensley, and J. Reeves, Nucl. Phys. B (Proc. Suppl.) 28A, 212 (1992).

[2] F. T. III. Avignone et al., Nucl. Phys. B (Proc. Suppl) 28A, 280 (1992).

[3] H.V. Klapdor-Kleingrothaus et al., Nucl. Instrum. Meth. A 481, 149 (2002)

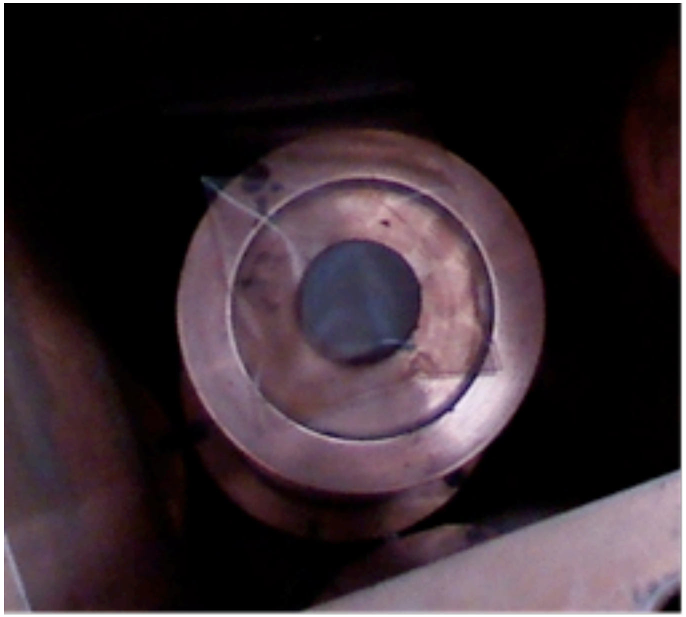
[4] I. Barabanov, S. Belogurov, L. Bezrukov, A. Denisov, V. Kornoukhov, and N. Sobolevsky, Nucl. Instrum. Meth. B 251, 115120 (2006).

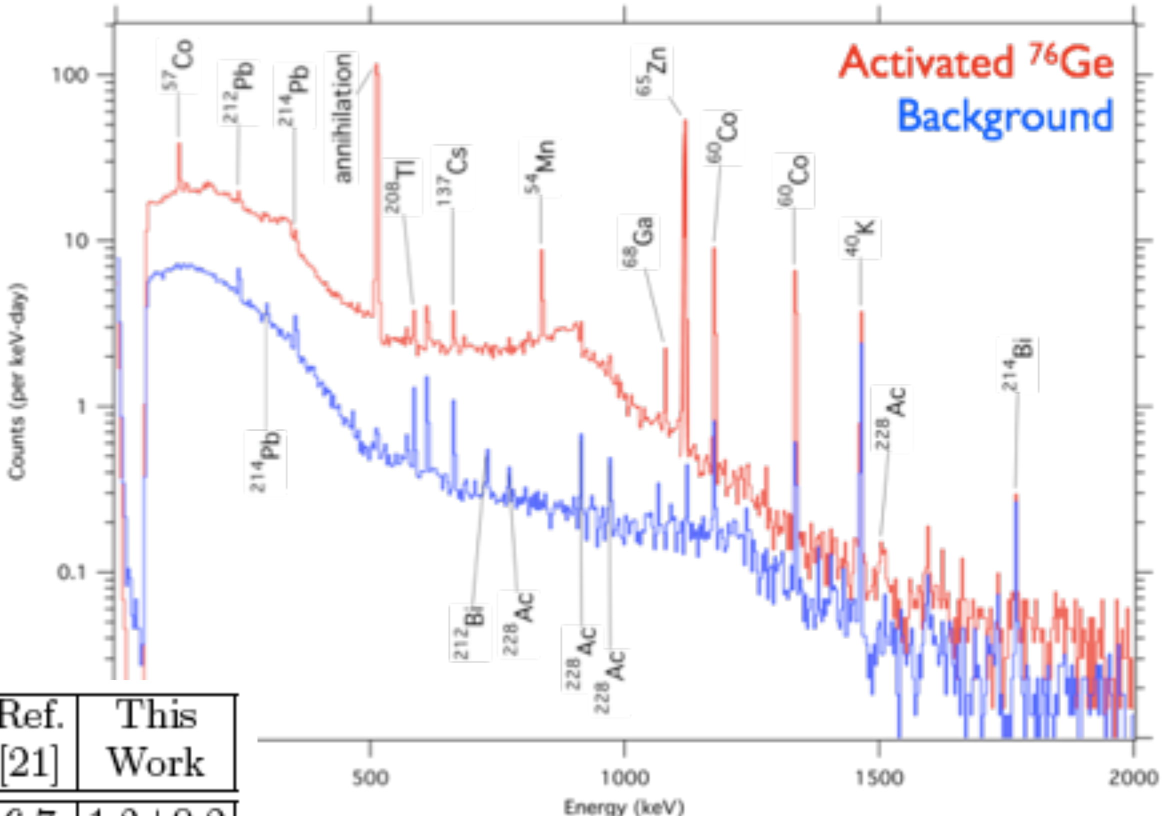
[5] S. Cebrian et al., Journal of Physics: Conference Series 39, 344346 (2006), TAUP 2005: Proc. Ninth Int. Conf. on Topics in Astroparticle and Underground Physics.

[6] J. Back and Y. Ramachers, Nucl. Instrum. Meth. A 586, 286 (2008).

[7] D.-M. Mei, Z.-B. Yin, and S. R. Elliott, Astropart. Phys. 31, 417420 (2009), arXiv:0903.2273.

Activated at LANSCE, Counted on WIPP-n Detector



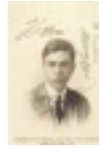


Production Rate in atoms/kg-d for 86% enrichment. **arXiv:0912.3748**

Isotope	Ref. [14]	Ref. [15]	Ref. [20]	Ref. [16]	Ref. [22]	Ref. [21]	This Work
^{57}Co	0.1	1.0		2.3	2.9	6.7	1.2±0.2
^{54}Mn		1.4		5.4	2.2	0.87	2.0±0.3
^{68}Ge	1.2	1.2	5.7	13	7.6	7.2	2.1±0.4
^{65}Zn	6.0	6.4		24	10.4	20.0	8.9±1.4
^{60}Co	3.5		3.3	6.7	2.4	1.6	2.5±0.4

Elliott et al.

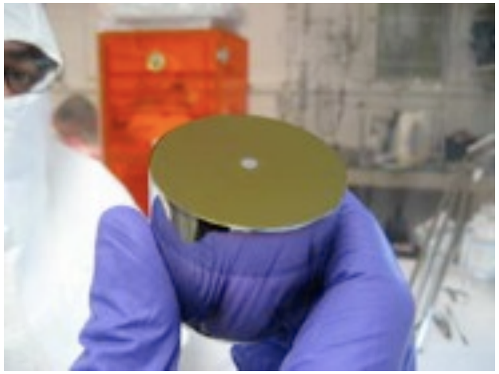
MAJORANA Point Contact Detectors



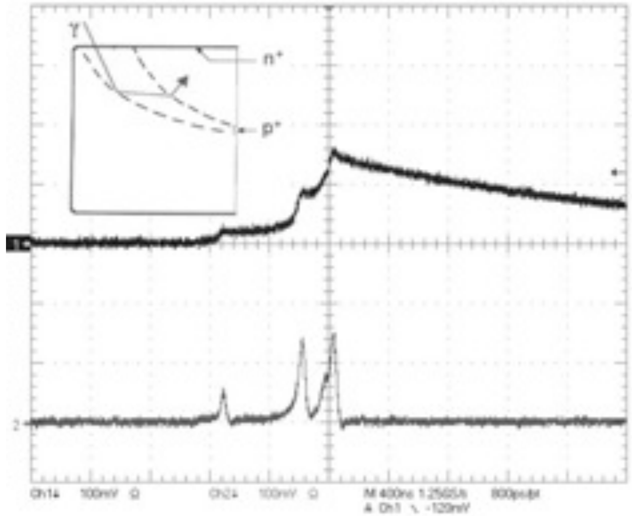
Institution	Manufacturer	Dimensions Dia. x length [mm x mm]	Type	Date
LBNL	Paul Luke	50 x 50 62 x 50 20 x 10 62 x 50	NPC S-PPC Mini-PPCs (3) PPC	1987 2008 2009 2009
Univ. Chicago	Canberra France Canberra USA	50 x 44 60 x 30	PPC BEGe	2005 2008
PNNL	Canberra France	50 x 50	PPC	2008
ORNL	PHDs Canberra USA	62 x 46 90 x 30	PPC BEGe (large)	2008 2009
LANL	PHDs Canberra USA ORTEC	72 x 37 70 x 30 65 x 50	PPC BEGe (x18) (x15 in 2010) PPC	2008 2009 2009
UNC	Canberra USA PHDs Canberra USA	61 x 30 70 x 30	BEGe PPC - inverted coax BEGe (x3)	2009 2010 2010

ultra low background cryostat

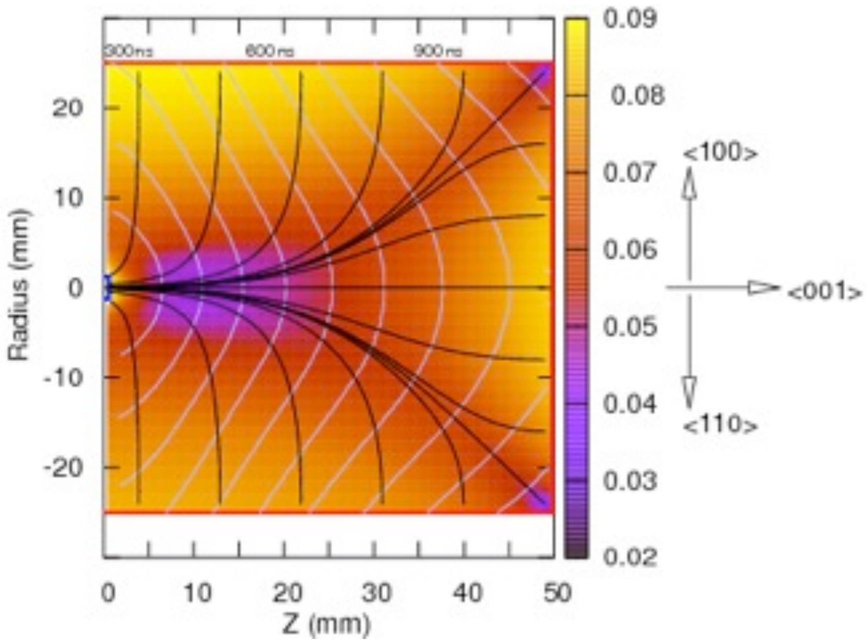
P-type Point Contact Detectors



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

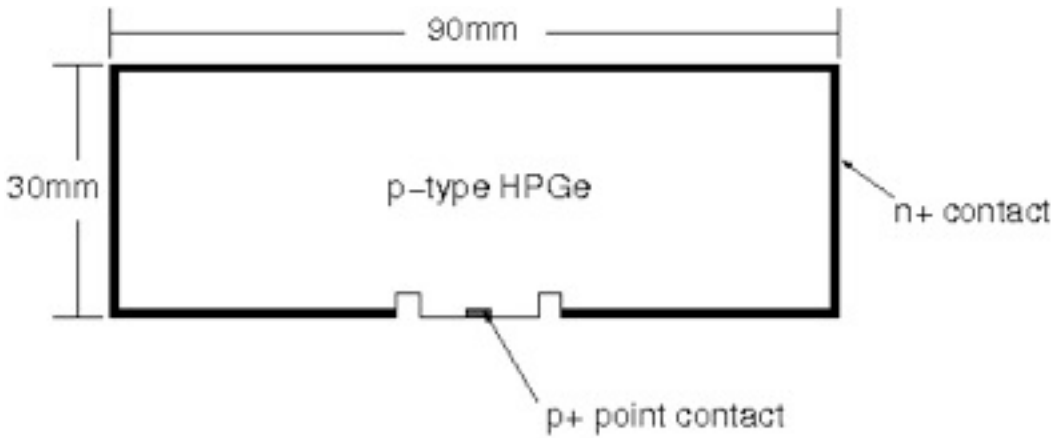


Hole vdrift (mm/ns) w/ paths, isochrones



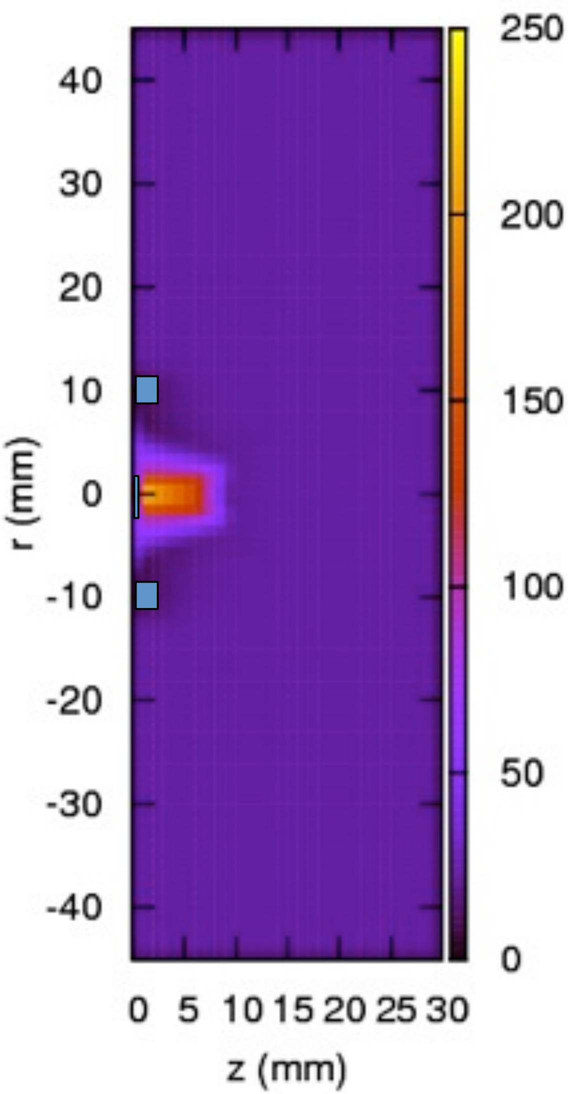
Experimental Study: BEGe Detector

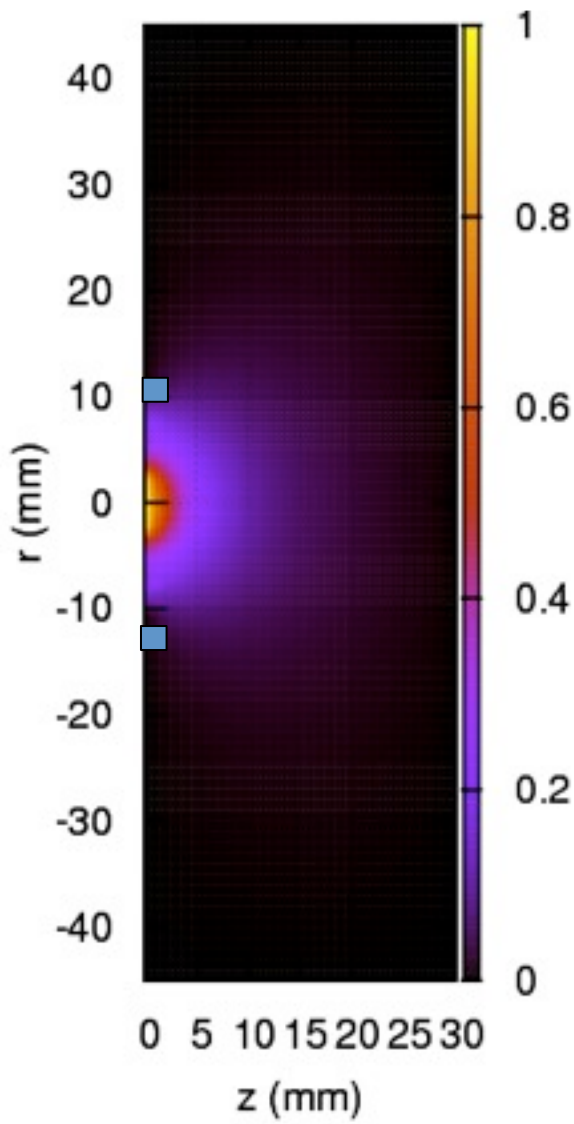
- Large volume BEGe detector from Canberra
- 90 mm diameter x 30 mm deep, 5 mm diameter point contact
- standard RC-feedback preamplifier
- pulse shape data recorded using GRETINA digitizer

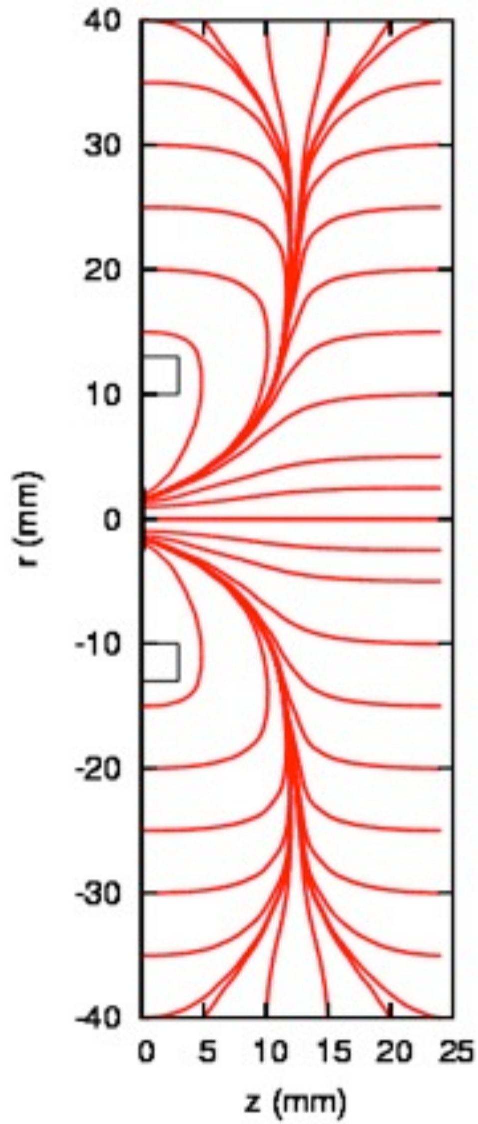


CANBERRA

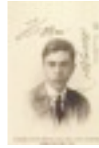
Risetime, Weighting Potential and Drift



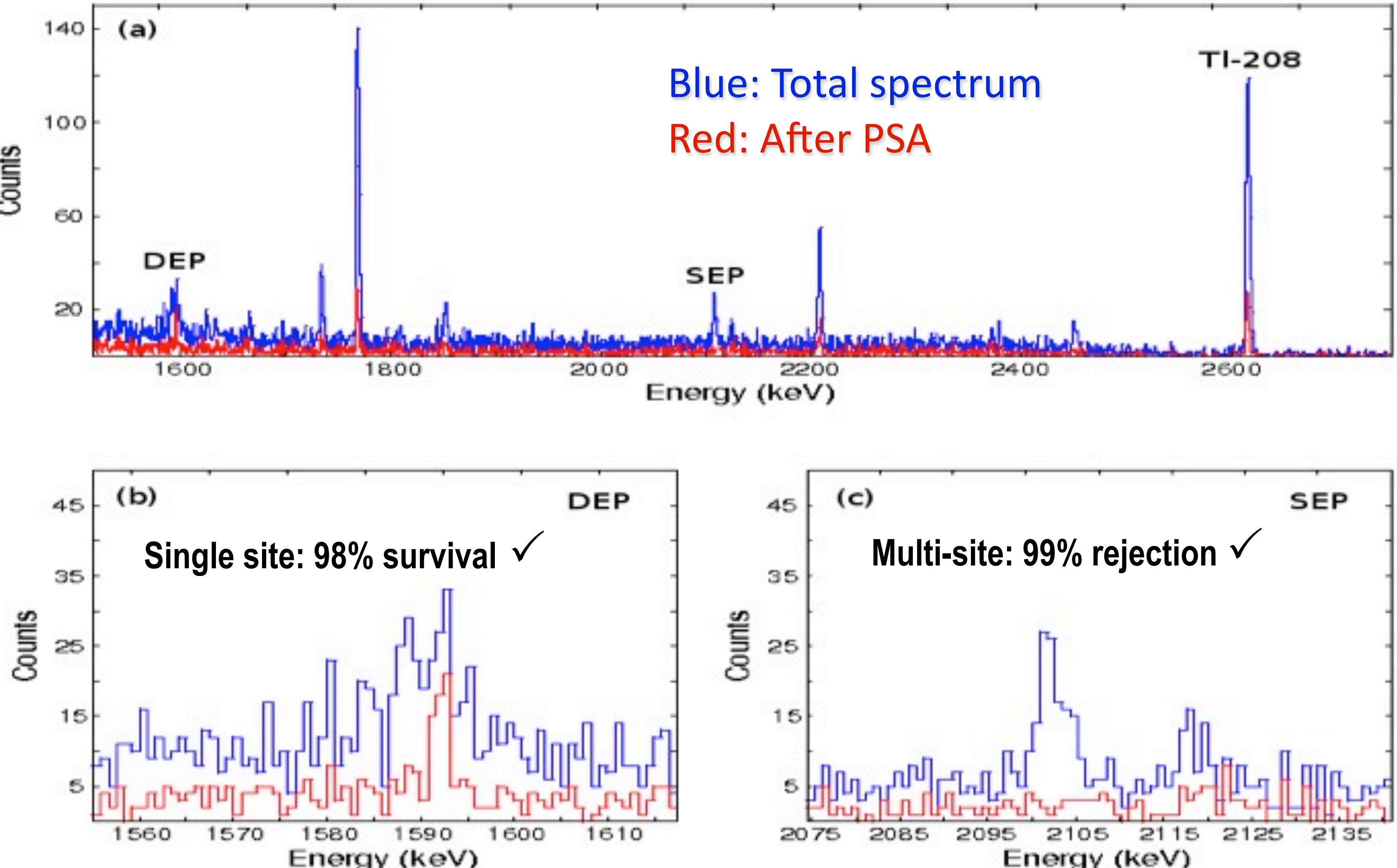




Pulse Shape Analysis - Efficacy

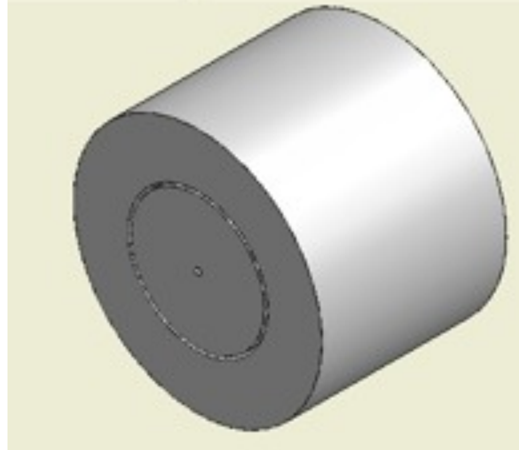


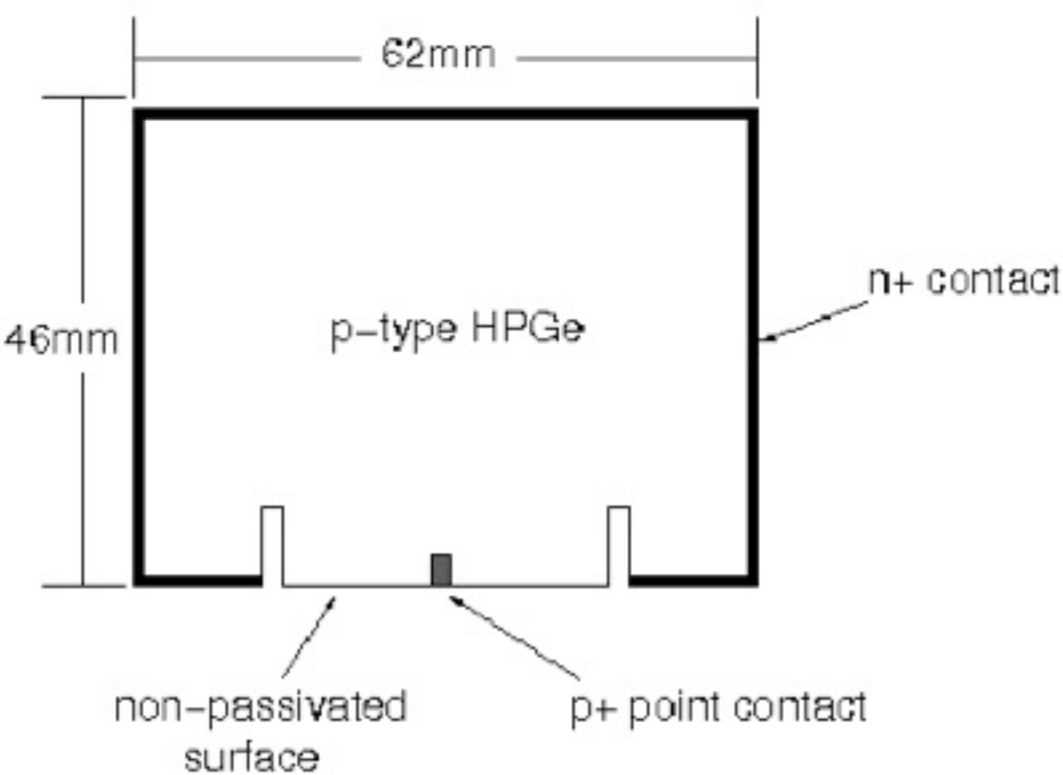
Large BEGe detector, loaned to ORNL from Canberra   ORNL Pulse-Shape Analysis algorithm

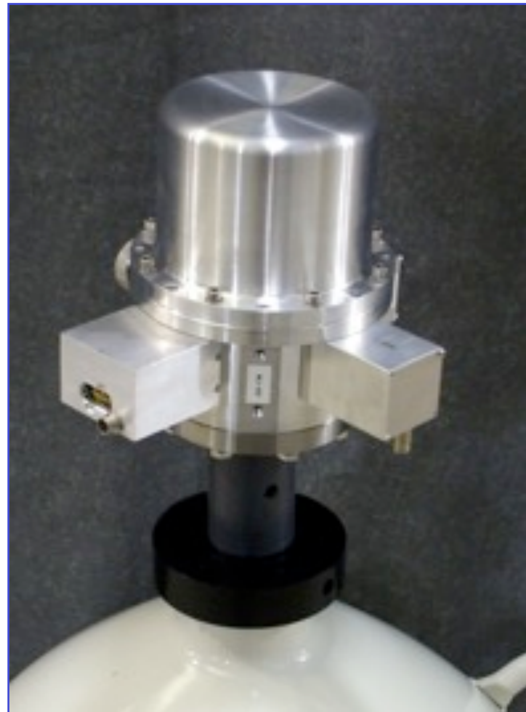


MJ60

- Cylindrical PPC detector
  - 62mm diameter x 46mm long
  - 1.5mm x 1.5mm point contact
  - 1.5mm wide x 8mm deep circular ditch at radius 15.5mm

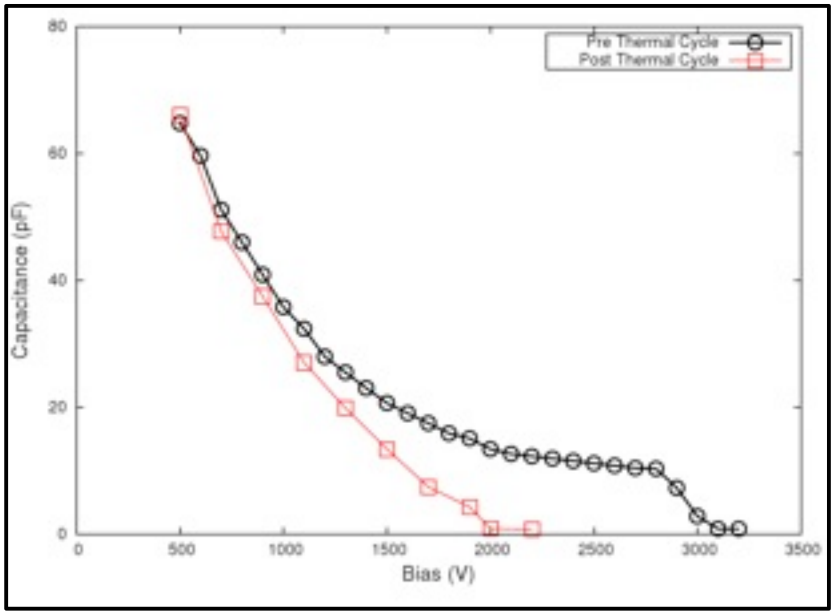


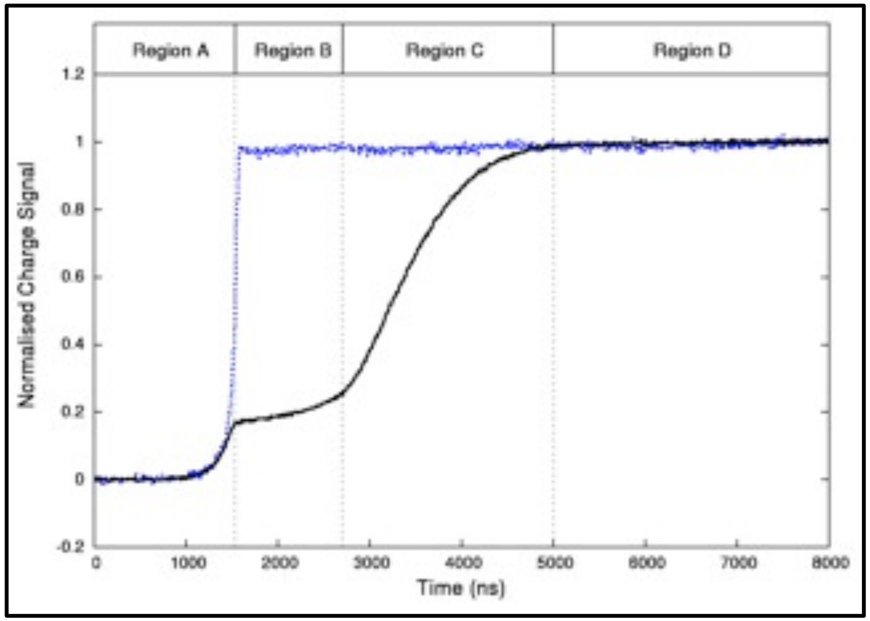




The Effect of Negative Surface Charge

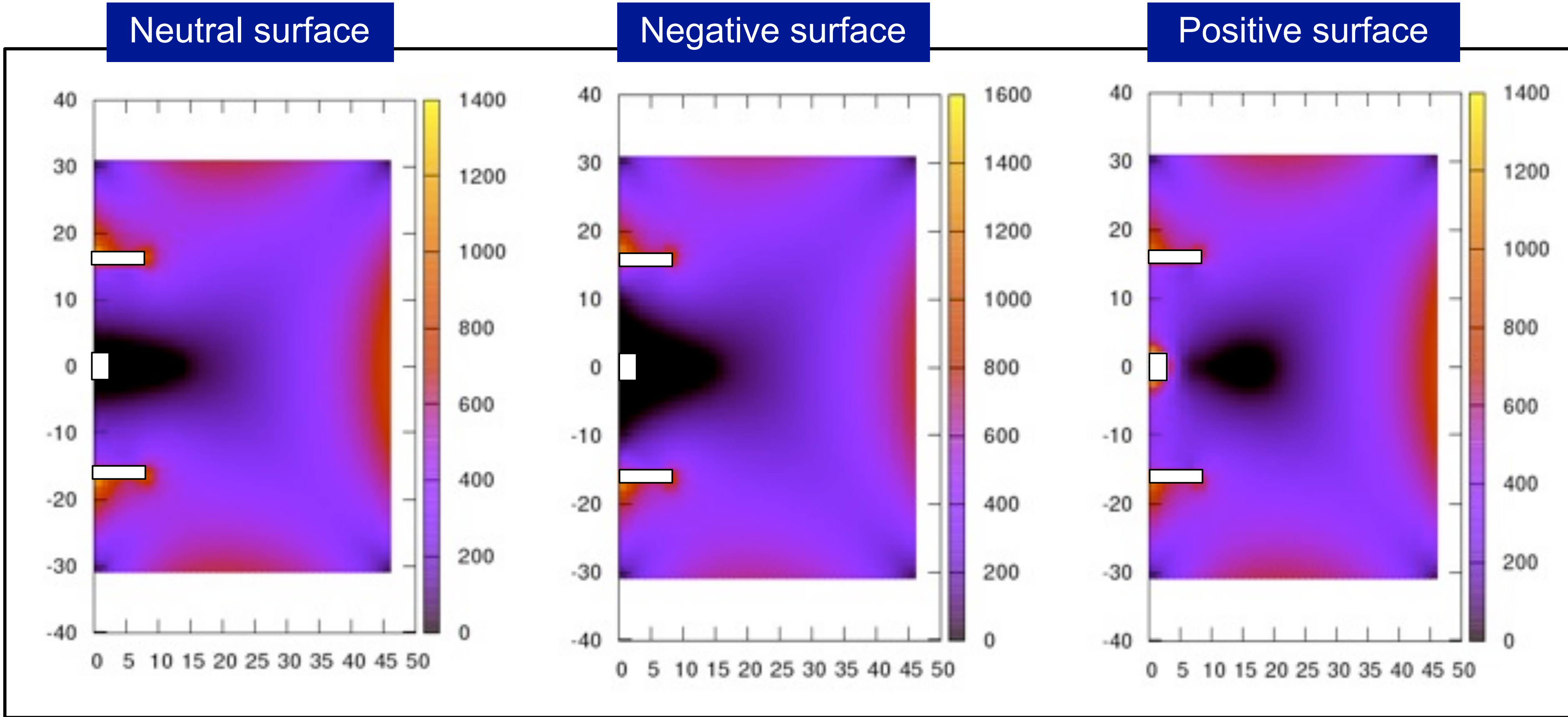
- The build of negative charge on the non-passivated surface of MJ60 has been discussed at length:
  - instability in depletion characteristics
  - anomalous charge collection
  - collection of charge to surface of crystal
  - derivation of reduced hole drift velocity at surface





The Effect of Surface Charge

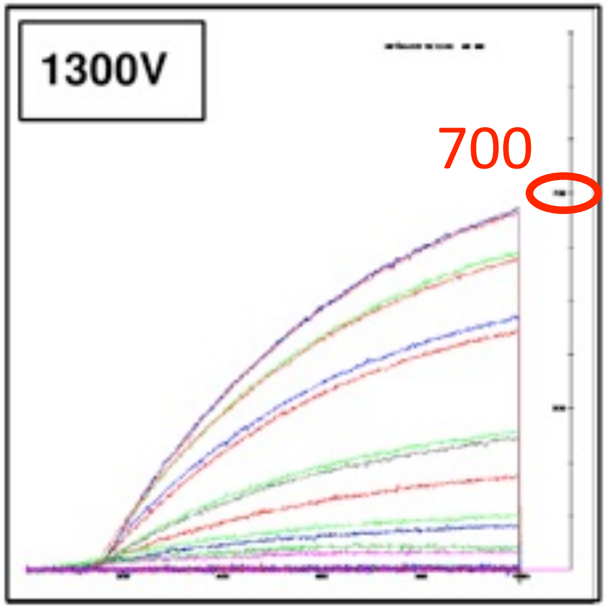
- Charged surface changes depletion profile of detector
  - particularly depletion around point contact

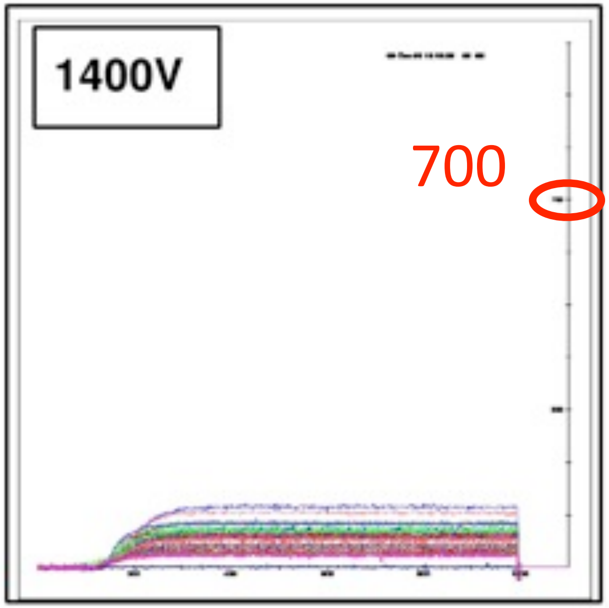


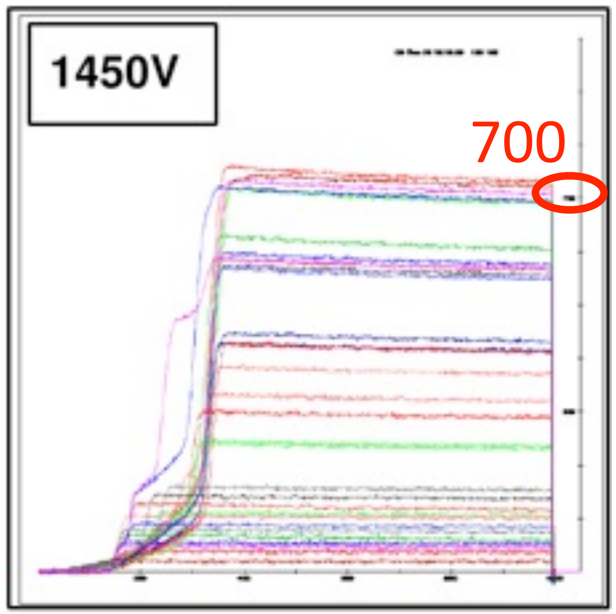
- Positive charge can lead to the occurrence of “pinch-off”

Signal Response to Pinch Off

- Pinch-off evident in experimental signals
  - signals suddenly become very slow (~1ms) during power up
  - significant ballistic deficit effects occur
  - transition region of around 100V after which signals appear “normal”
  - at operating voltage signals show a 'slow' component
  - *pinched off region has low field*



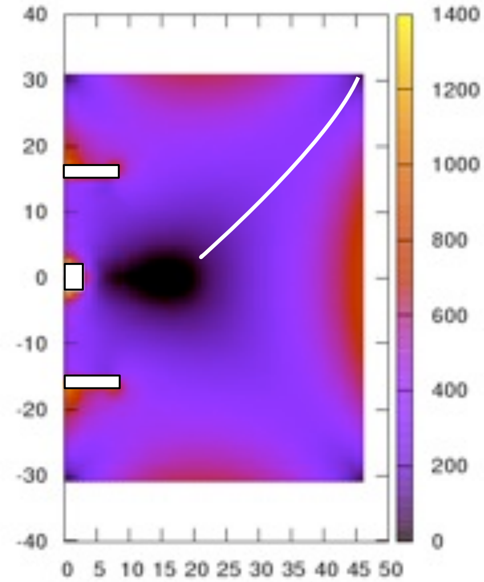


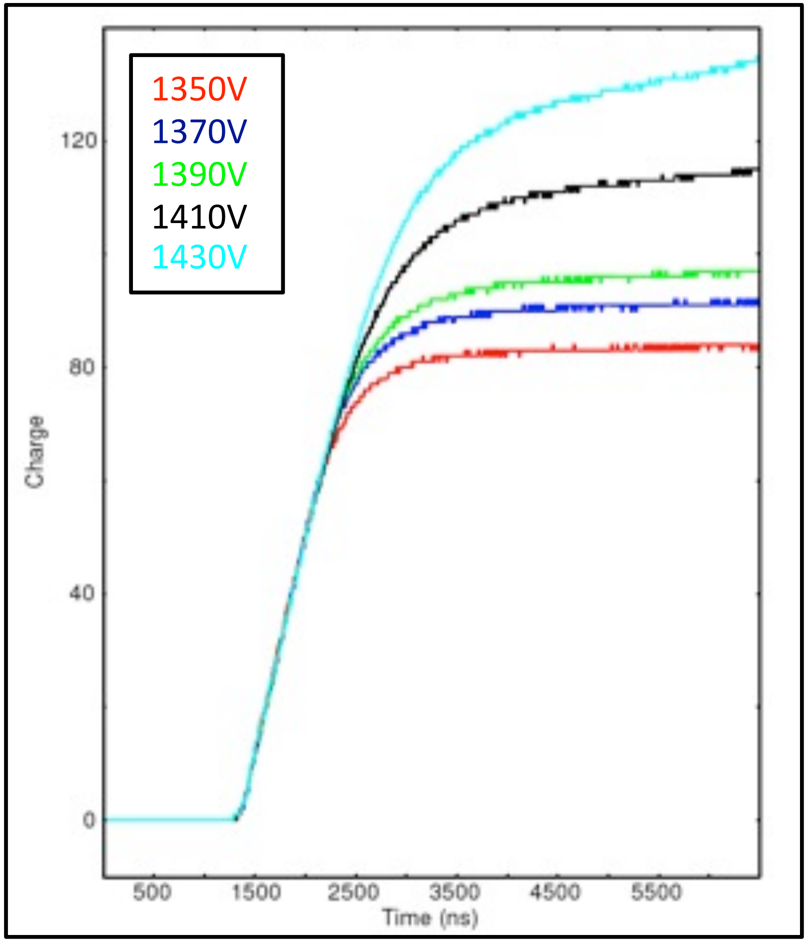


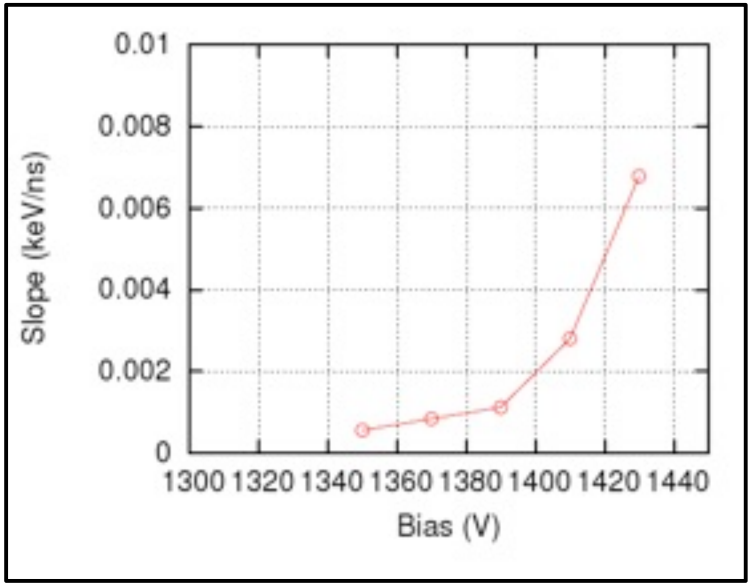
**** signals displayed have no preamp decay-correction applied***

Signal Response to Pinch Off

- Pinch-off evident in experimental signals
  - pinch-off region becomes smaller with increasing voltage
  - rate of change of charge release increases

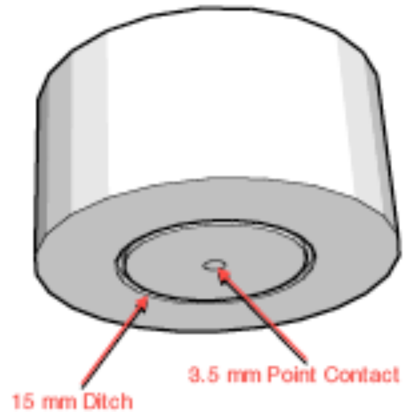






MAJORANA Low-background BEGE at KURF

- Prototype BEGe in an Ultra low-background cryostat.



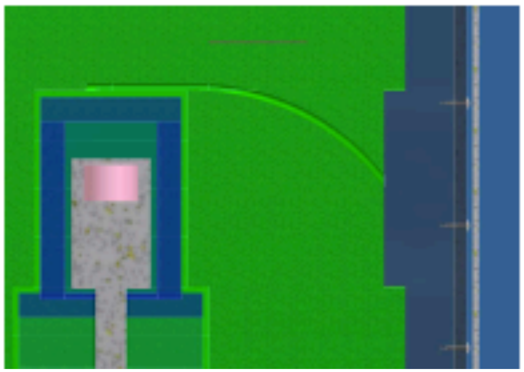
- Detector Similar to CoGeNT BEGe
  - smaller point contact size: 3-4 mm spot
  - larger ditch radius: optimum aspect ratio for depletion, based on Radford calculations
- Electronic noise: ~180 eV
  - pulse reset preamp
  - leakage current ~5 times CoGeNT BEGe
  - capacitance smaller

MALBEK (UG at KURF)

Working from the inside out of our (4π) shield:

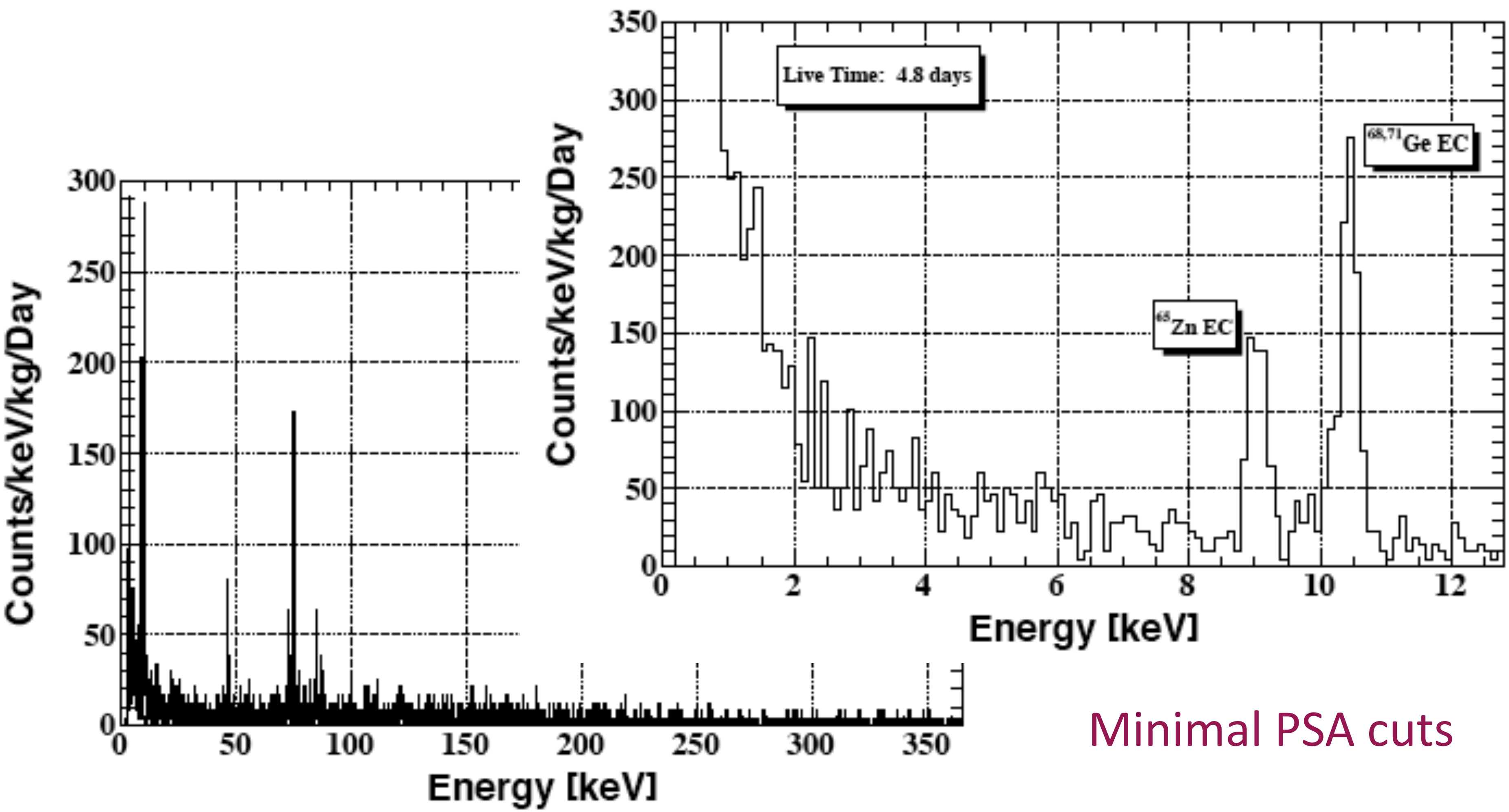
- 1" Spanish galleon ancient lead[a]
- 8" Low-Background lead
- Rn Exclusion Box
- 2" Muon Veto
- 1.46" Borated Polyethylene
- 10" Polyethylene

Calibration source (^{133}Ba):



MALBEK First UG Data

- Underground: mid-January 2010
- Backgrounds: ~ 10 x Soudan detector - suspect ^{210}Pb

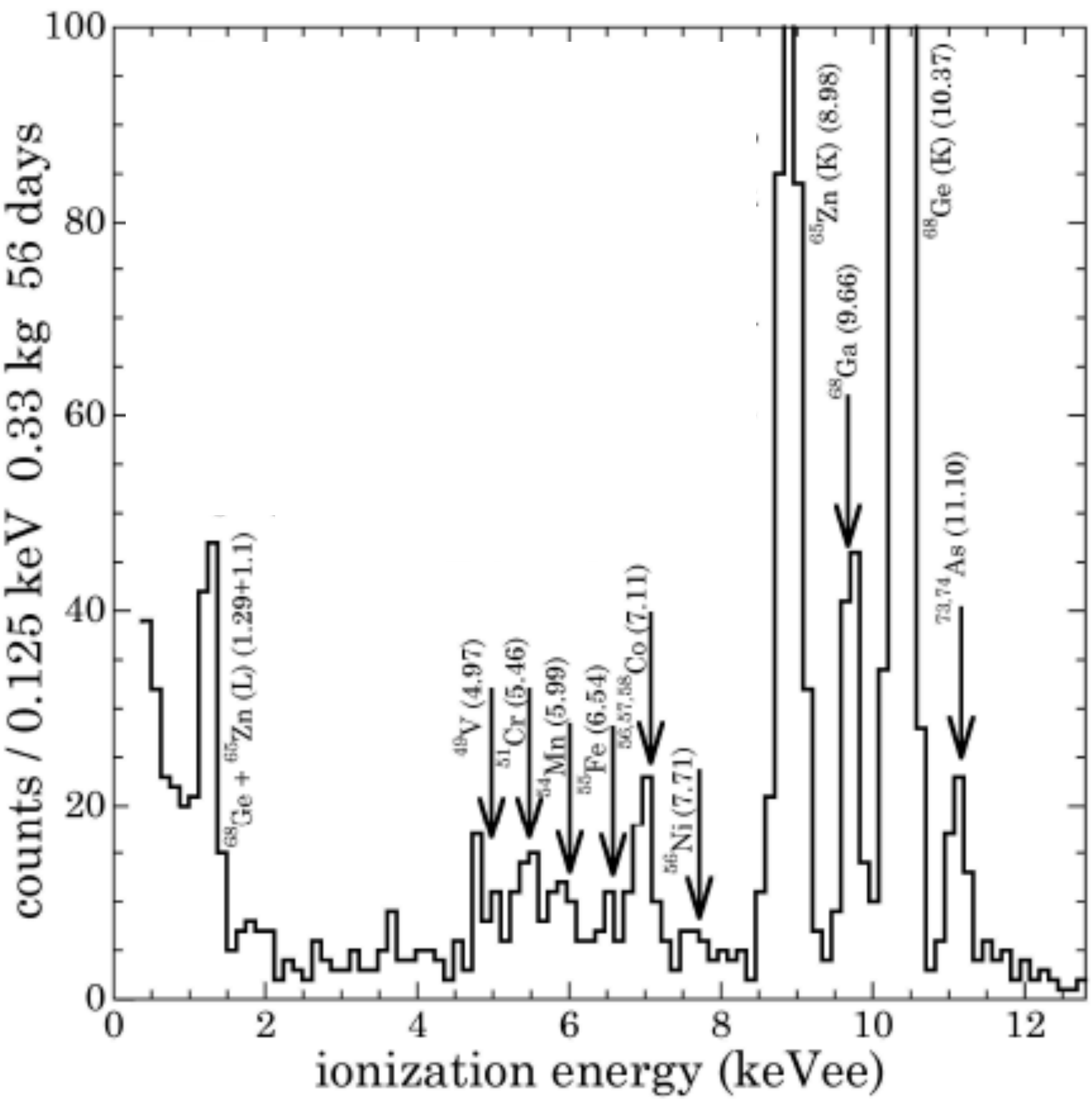


Minimal PSA cuts

CoGeNT BEGe Results (arXiv:1002.4703v1)

BEGe UG at Soudan

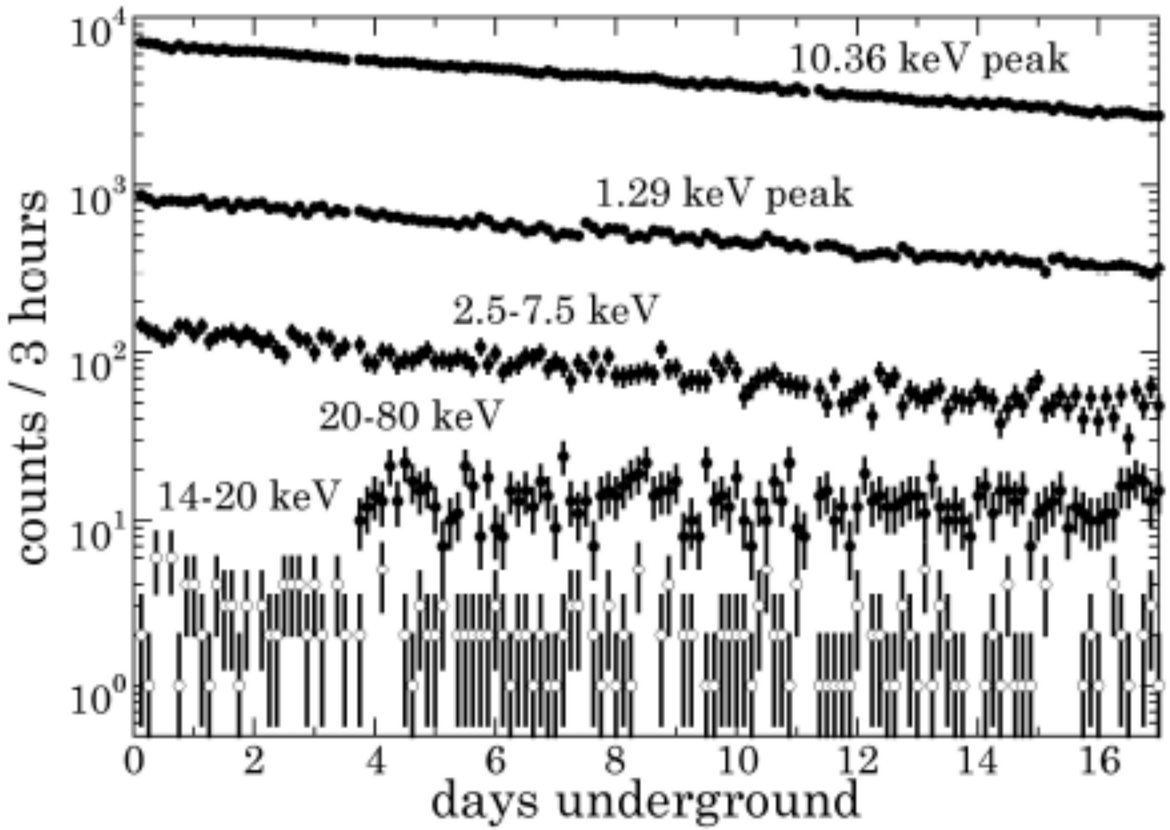
- 3 months cool-down
- 8 weeks of data
- after cuts of “slow events”.
    - 330 g fiducial
- Backgrounds low enough to see cosmogenics



Monday, March 1, 2010

CoGeNT BEGe (arXiv:1002.4703v1)

- Low-energy regions show decay rates characteristic of ^{71}Ge
- Consistent with partial charge collection in n+ region

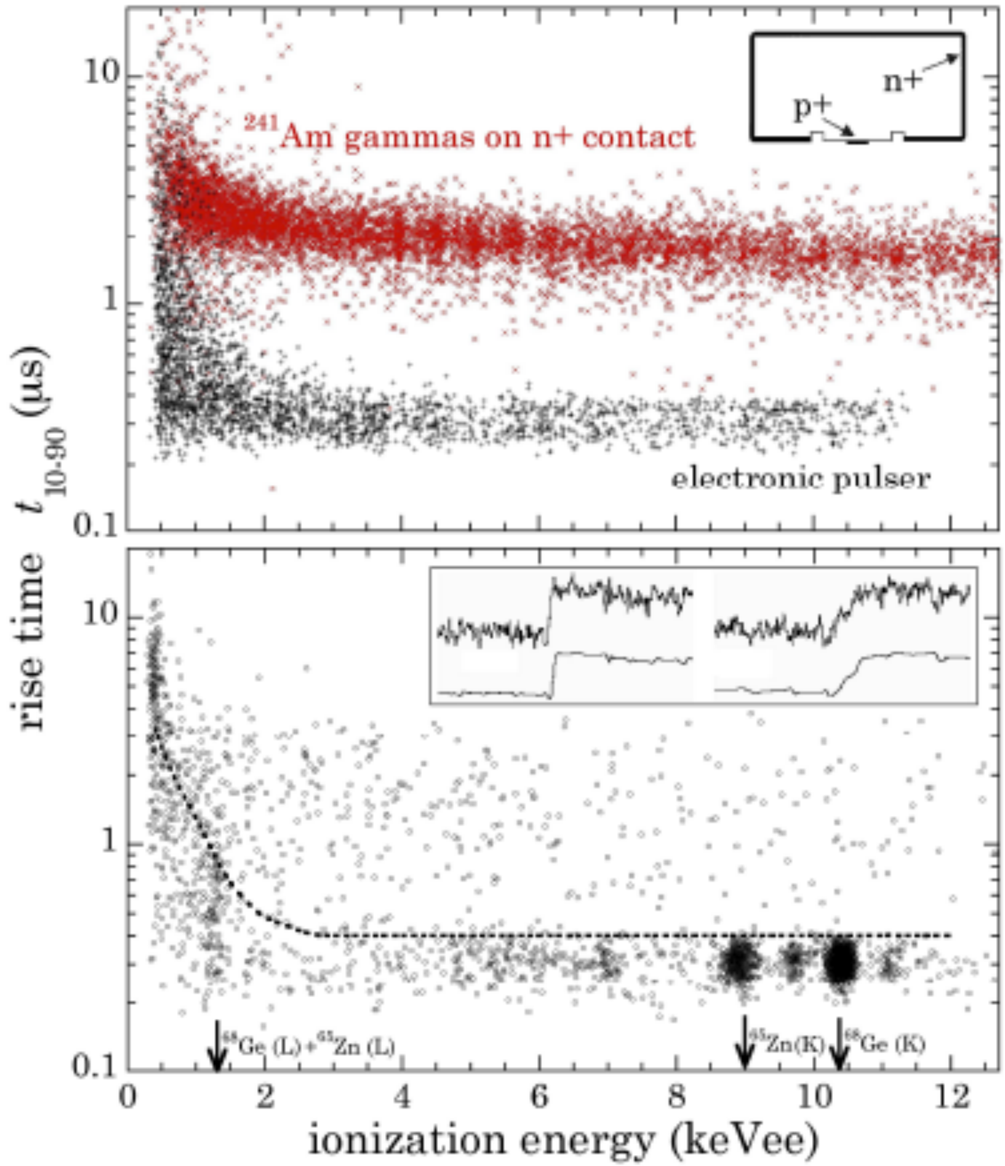


CoGeNT BEGe (Soudan)

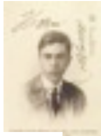
Partial charge collection within the n+ contact region. “Only 1/2 dead”

Slow-pulses provide signature for partial charge collection.

Consistent with simulations of detectors.



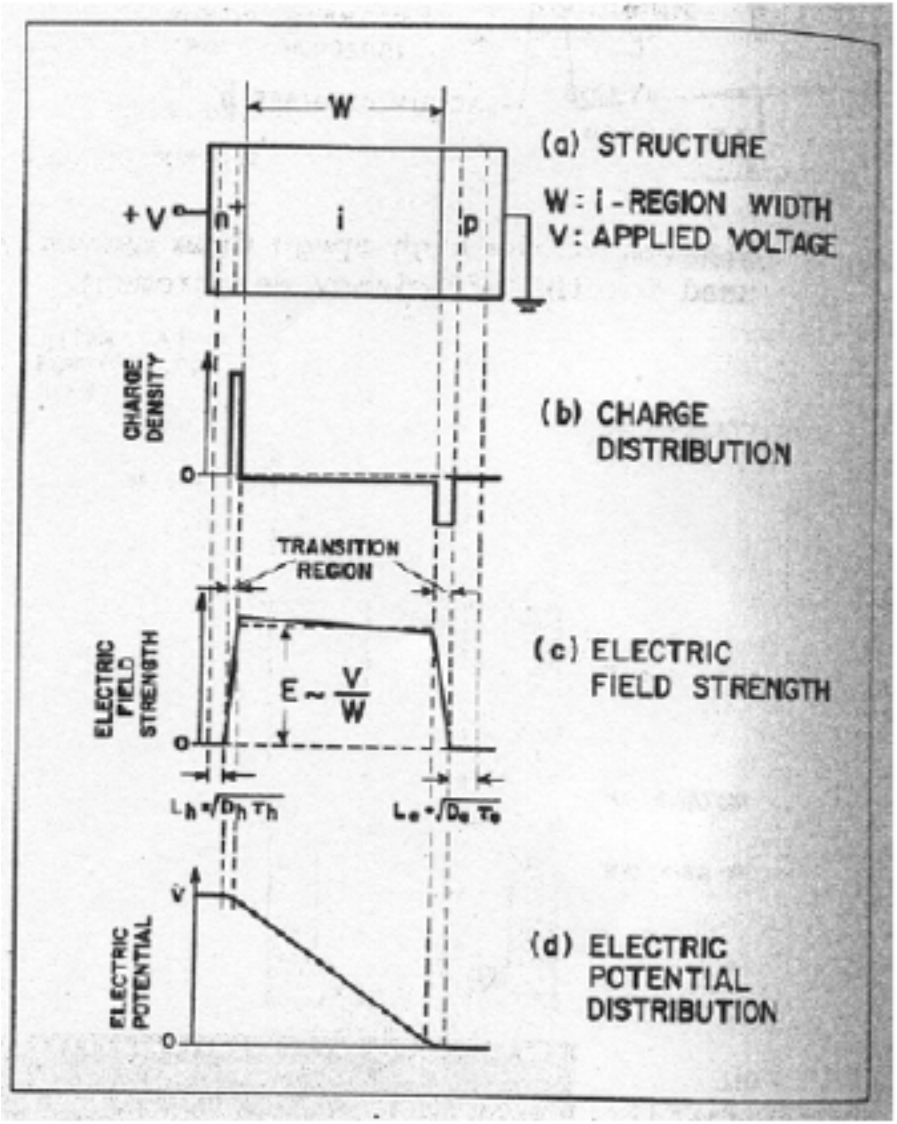
CoGeNT BEGe (Soudan)



Partial charge collection within the n+ contact region.

Slow-pulses provide signature for partial charge collection.

Consistent with simulations of detectors.



M.G. Strauss and R.N. Larsen, Nucl. Instr. Meth. 56 (1967) 80; E. Sakai, IEEE TNS 18 (1971) 208.

CoGeNT BEGe (Soudan)

Partial charge collection within the n+ contact region.

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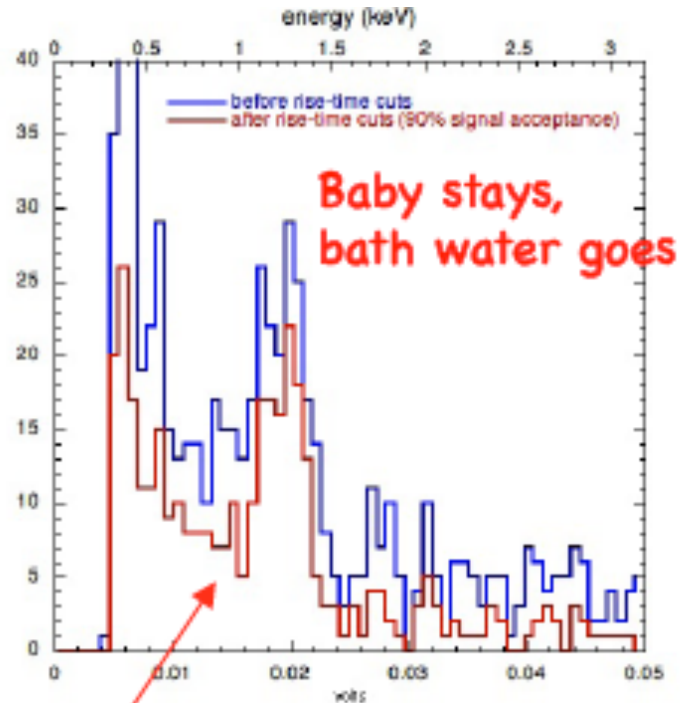

Bulk signal acceptance monitored down to 1 keVee via L/K EC peak ratios.
We need more info on surface background rejection, but it does not look bad at all.

MAJORANA DEMONSTRATOR Summary

- Significant technical progress.
- Funding via DOE Office on Nuclear Physics; NSF Particle and Nuclear Astrophysics; NSF DUSEL
- Construction of 1st module is underway.