THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

The MAJORANA Low-Background BEGe Detector at KURF

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The MAJORANA DEMONSTRATOR

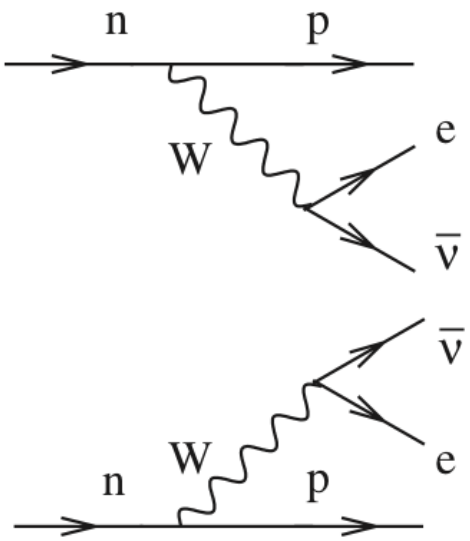
The MALBEK Detector

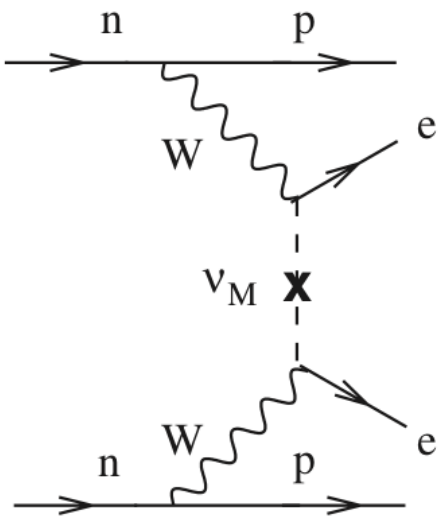
slow signal studies

background modeling

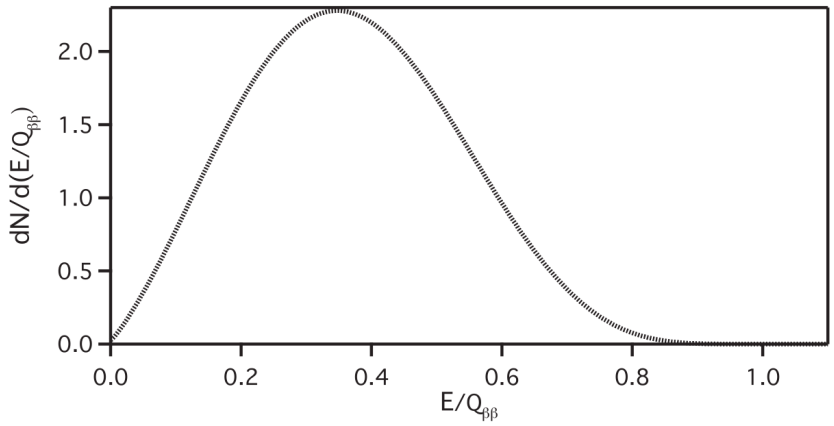
dark matter sensitivity

The 0νββ experimental signature

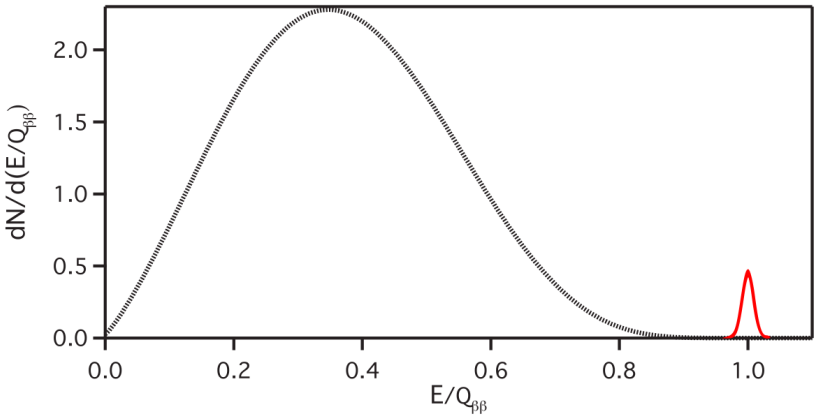




2νββ

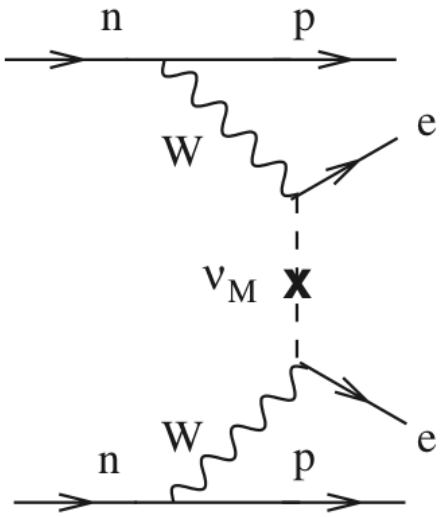


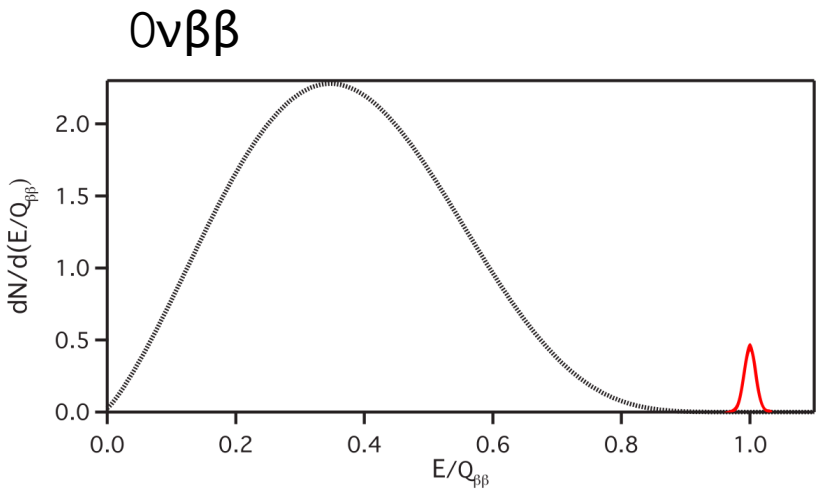
0νββ



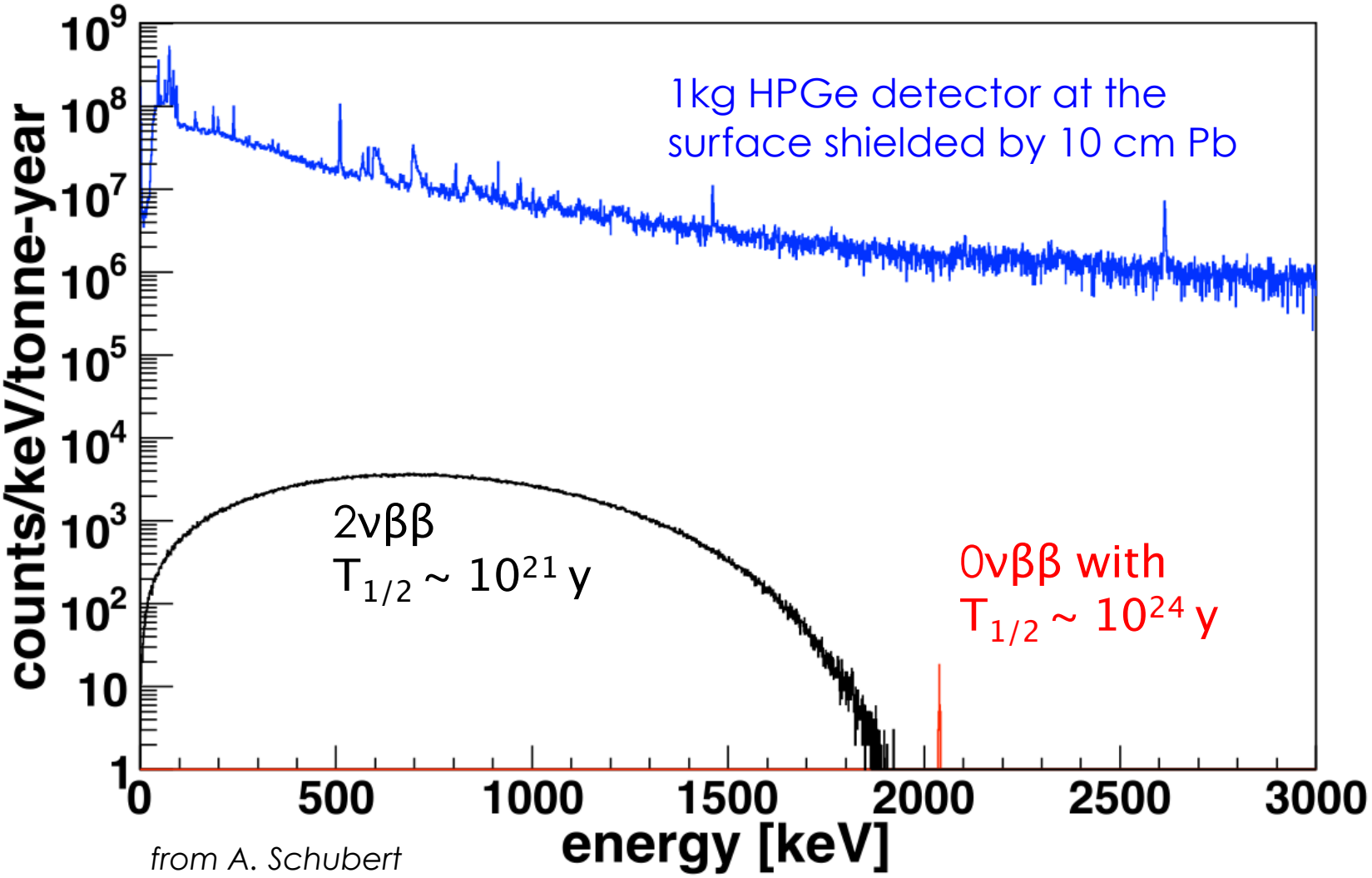
The 0νββ experimental signature

- observation implies
  - neutrino is a Majorana fermion
  - lepton-number violation
  - neutrino mass measurement



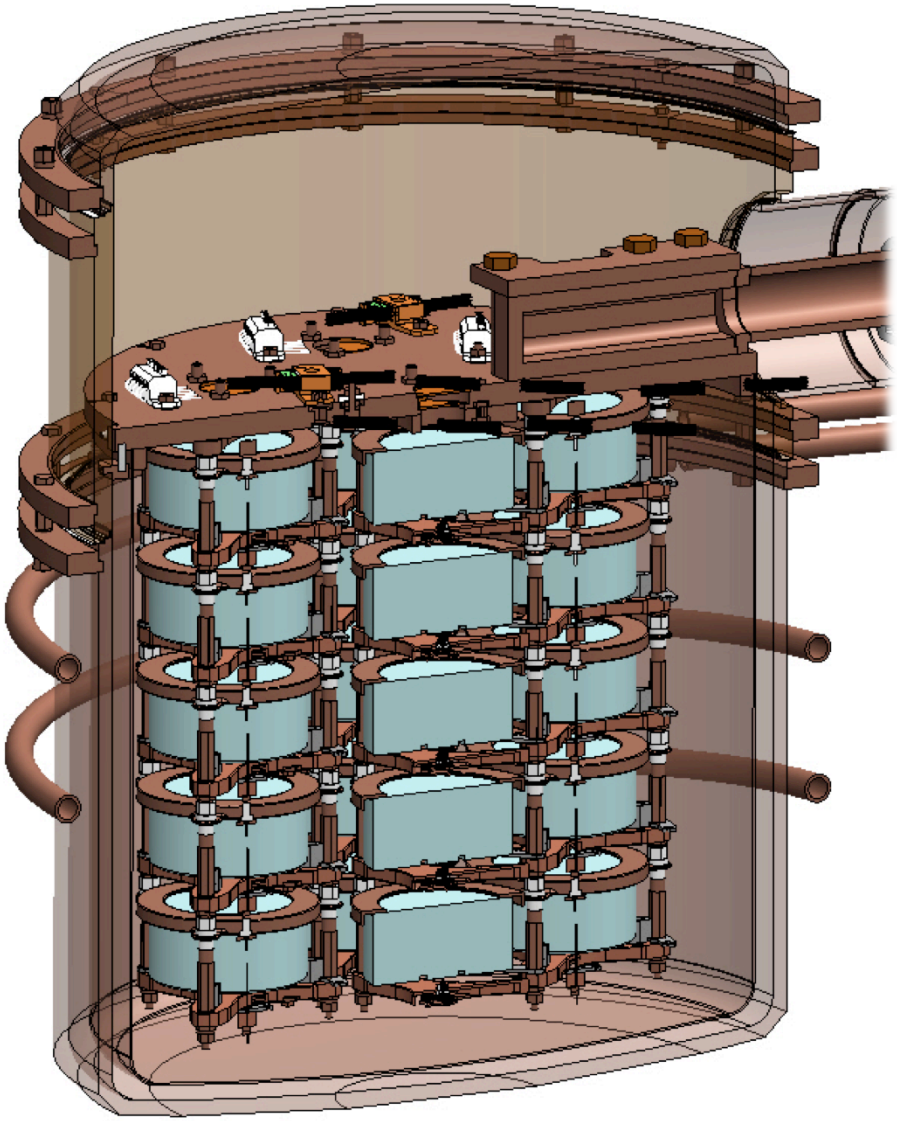


The reality of a 0νββ signal from 1 kg of ^{76}Ge,
Q-Value = 2039 keV



from A. Schubert

The MAJORANA DEMONSTRATOR

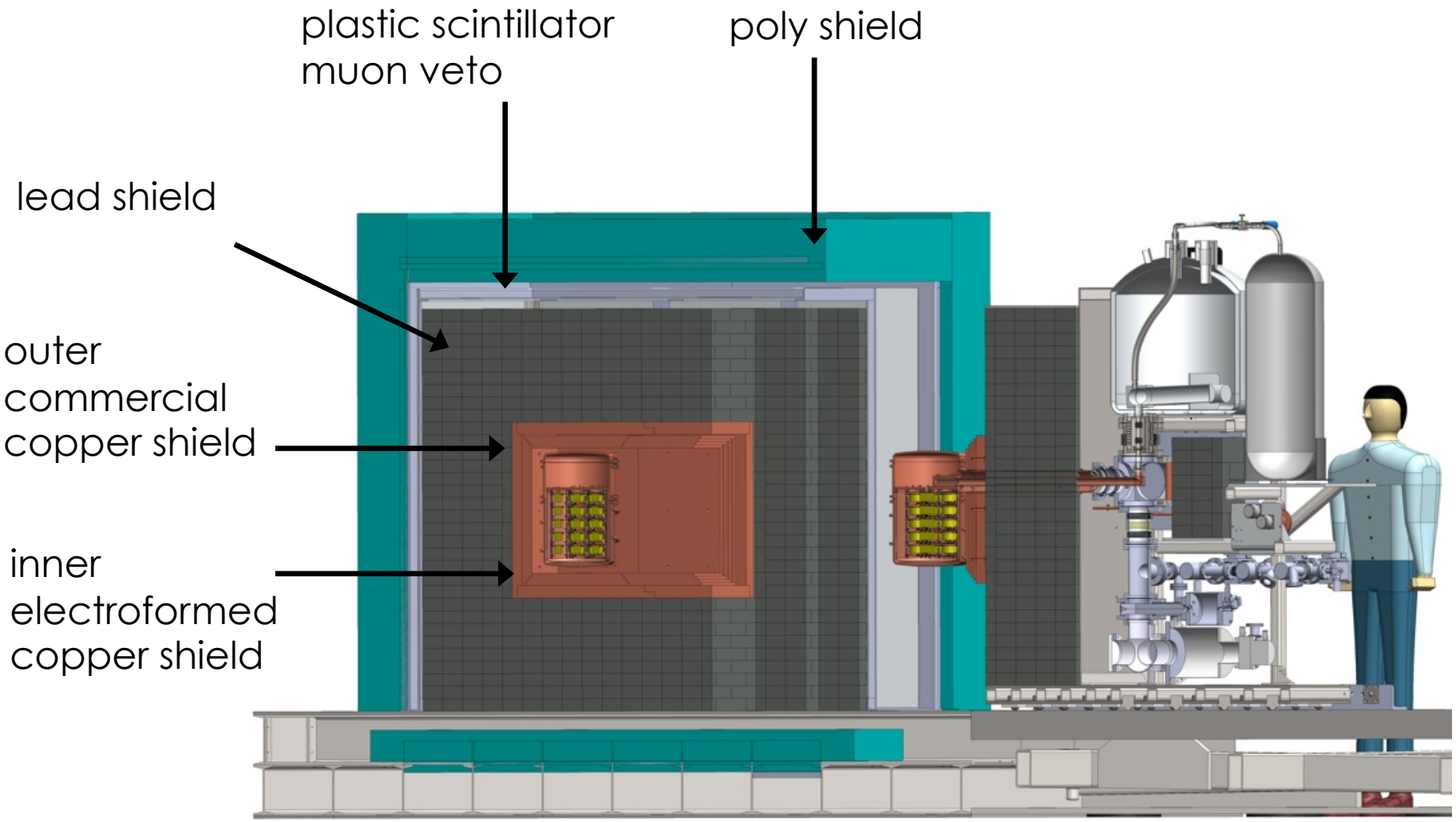


- 40 kg array of high purity Ge PPC detectors
- Up to 30 kg of detectors enriched in ^{76}Ge

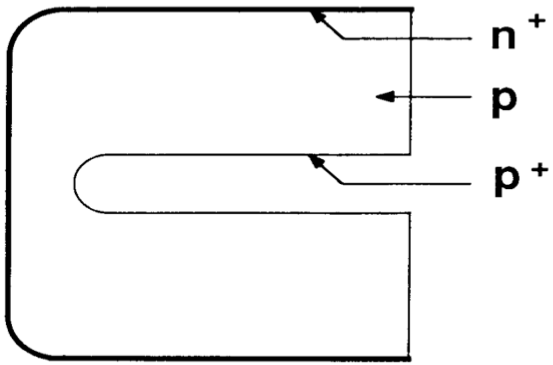
1. Demonstrate background levels of 3 counts/ROI/tonne/year, low enough to justify building a tonne-scale experiment
2. Demonstrate feasibility of constructing & fielding modular arrays of Ge detectors.
3. Test the Klapdor-Kleingrothaus claim of $0\nu\beta\beta$ signal *
4. Search for light WIMPs

** H. V. Klapdor-Kleingrothaus and I. V. Krivosheina, Mod. Phys. Lett. A21, 1547 (2006).*

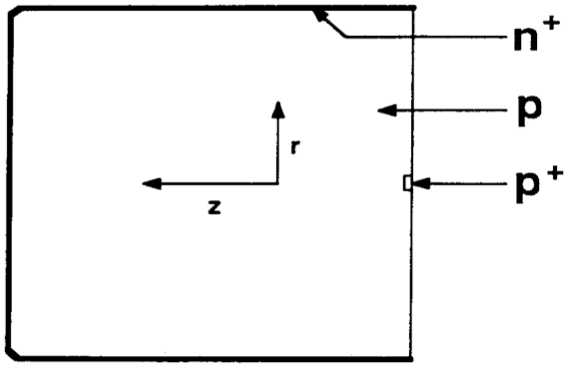
The MAJORANA DEMONSTRATOR



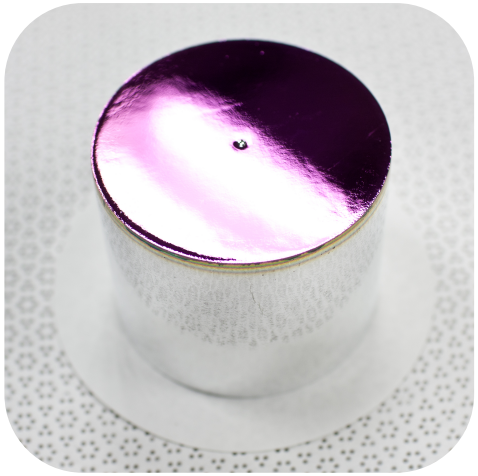
P-Type Point-Contact (PPC) Detectors



coaxial detector

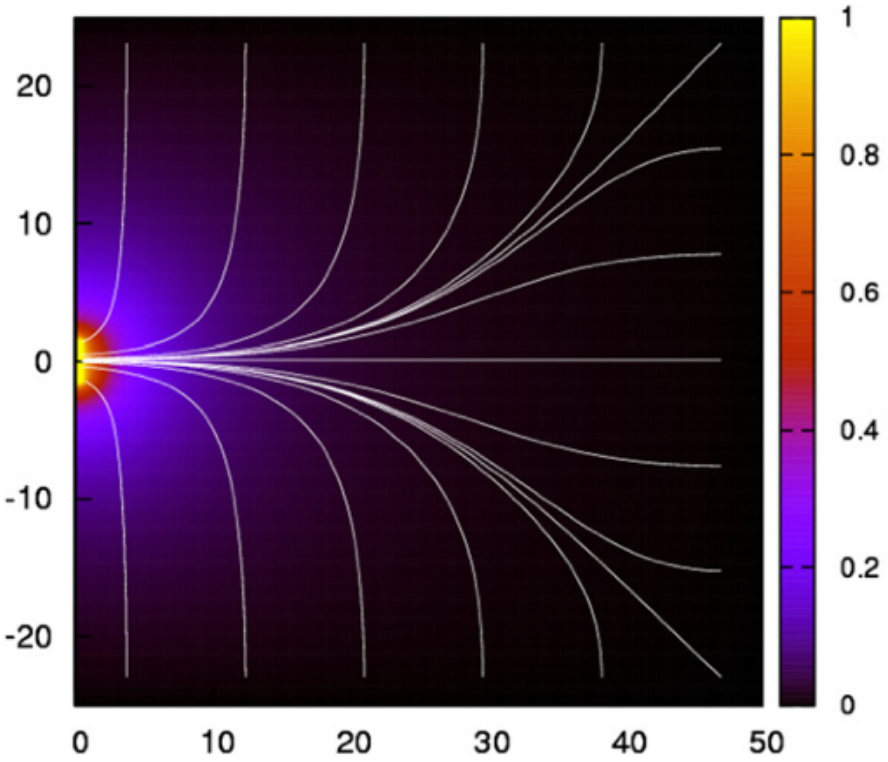


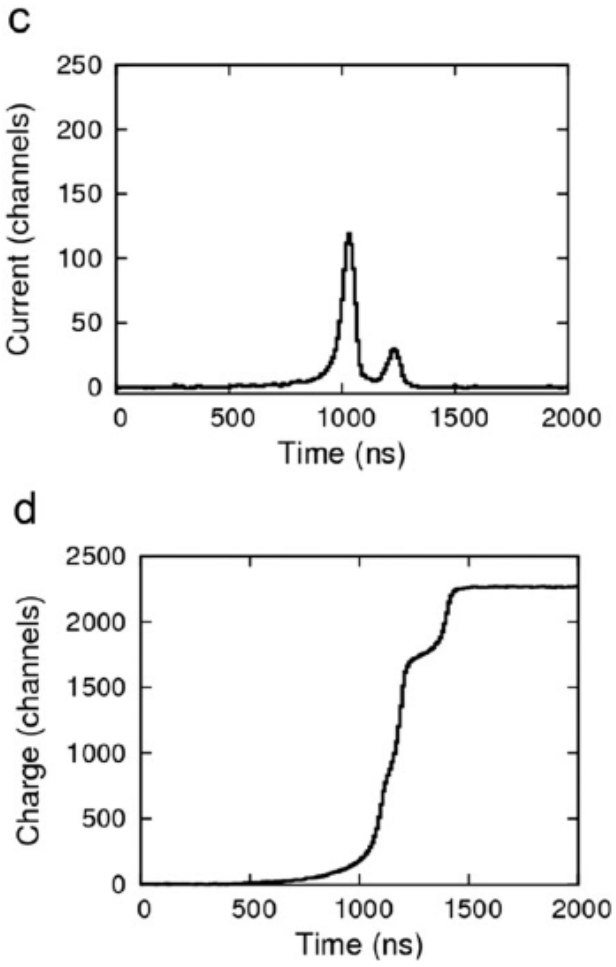
ppc detector



P-Type Point-Contact (PPC) Detectors

- allow multiple site scattering event discrimination





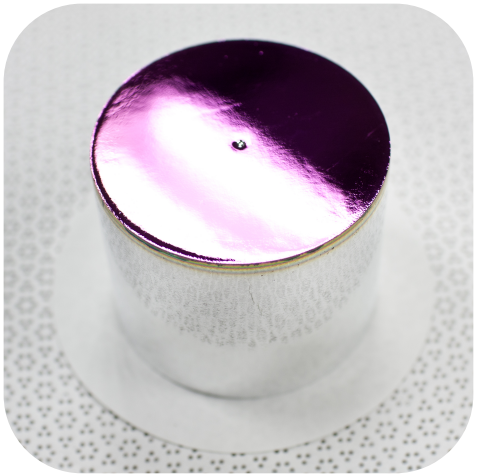
figures from R.J. Cooper et al., Nucl. Instr. and Meth. A 629, (2010) 11.
Luke et al., IEEE trans. Nucl. Sci. 36 , 926(1989).
P. S. Barbeau, J. I. Collar, and O. Tench, J. Cosm. Astro. Phys. 0709 (2007).

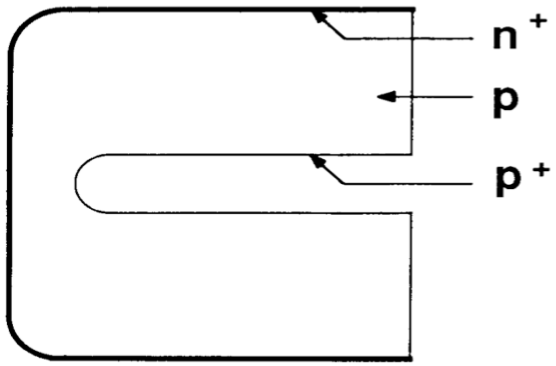
P-Type Point-Contact (PPC) Detectors

- allow multiple site scattering event discrimination
- simple, relatively cheap, and easy to handle

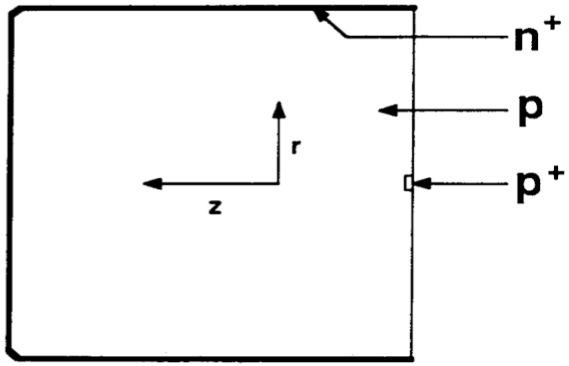
added benefits from sub-keV thresholds :

- allow rejection of events from cosmogenically produced ^{68}Ge, a background to $0\nu\beta\beta$.
- extends physics reach of the DEMONSTRATOR





coaxial detector



ppc detector

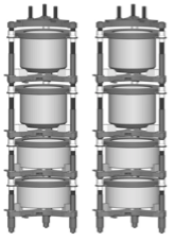
The DEMONSTRATOR construction schedule

Construction of the DEMONSTRATOR will proceed in three stages.


enrGe

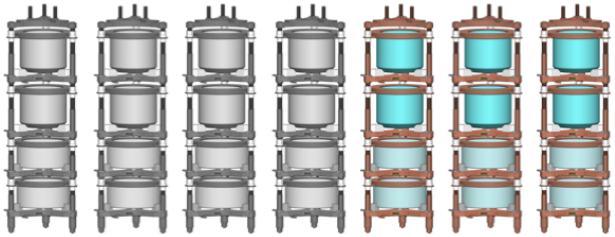

natGe

Prototype Cryostat*



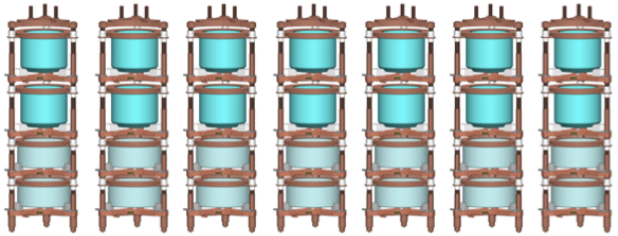
winter 2012

Cryostat 1



fall 2013

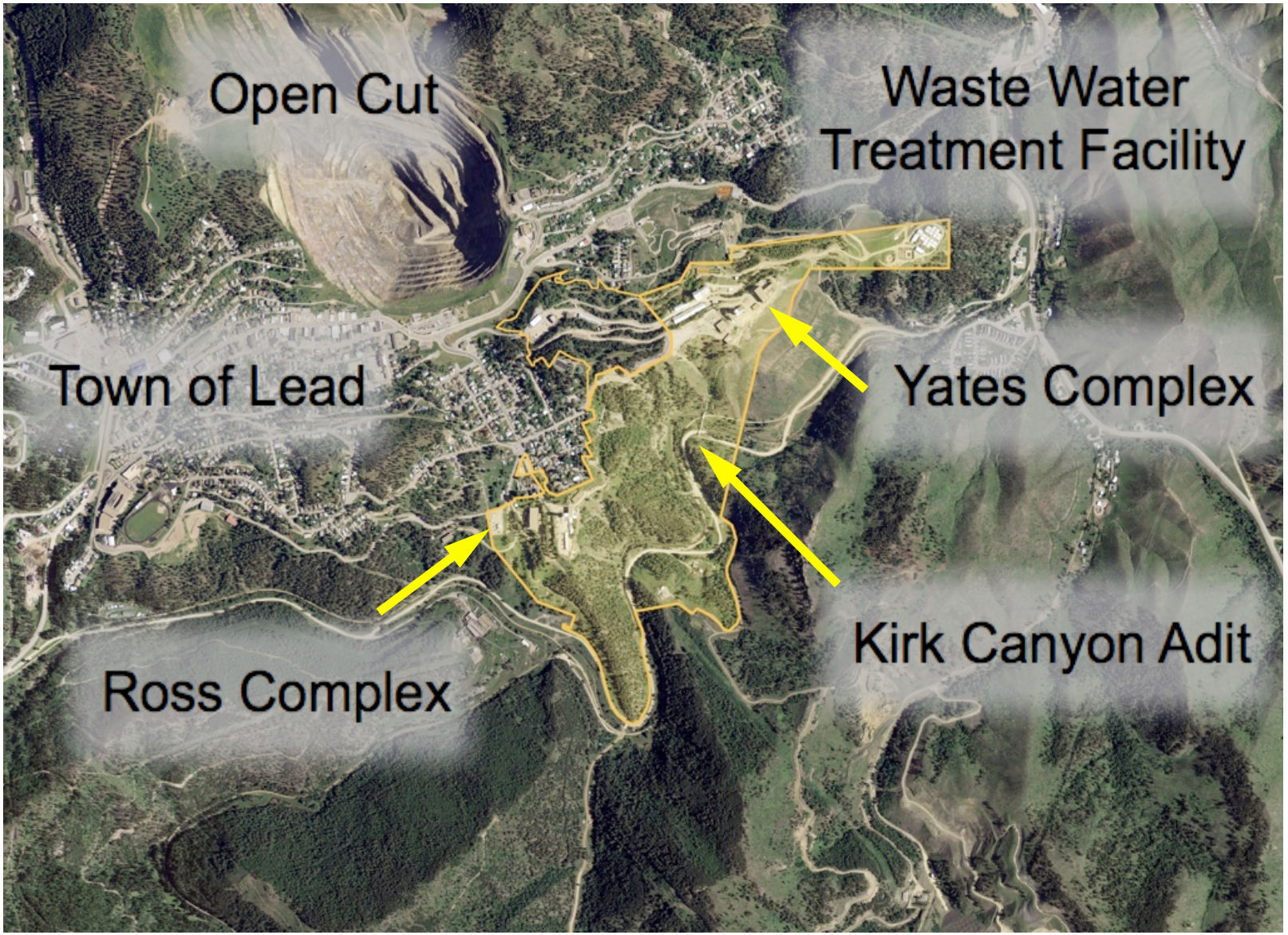
Cryostat 2



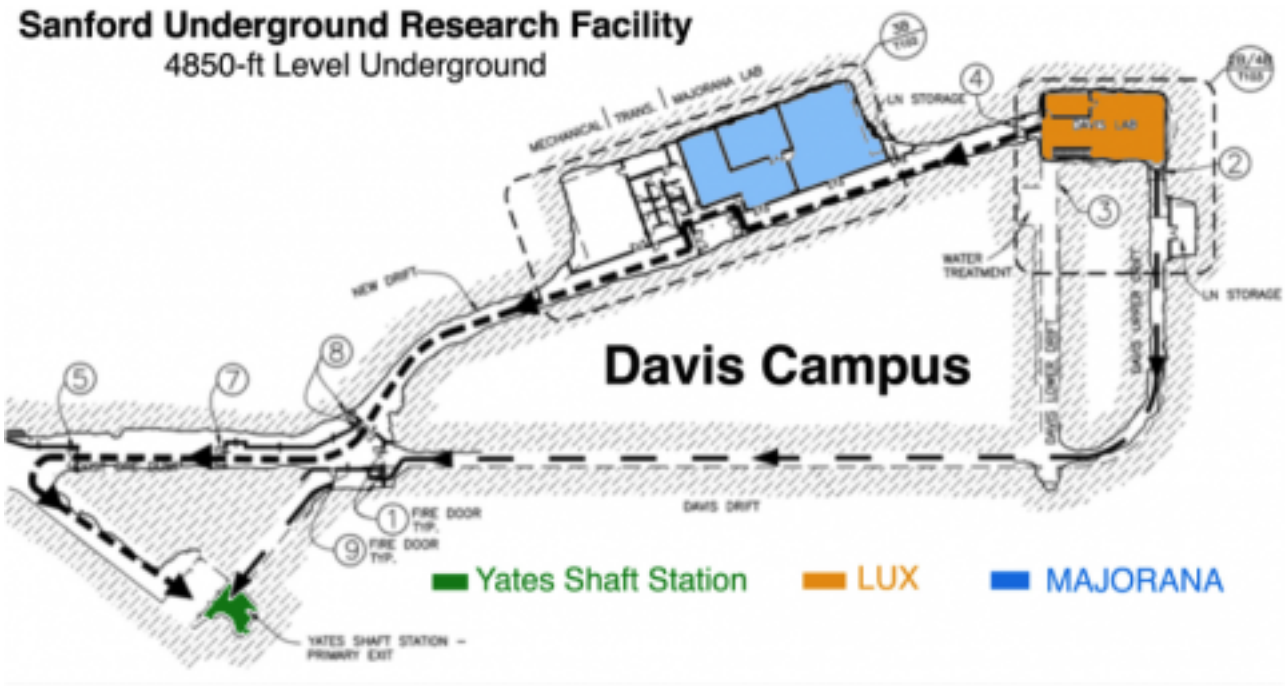
fall 2014

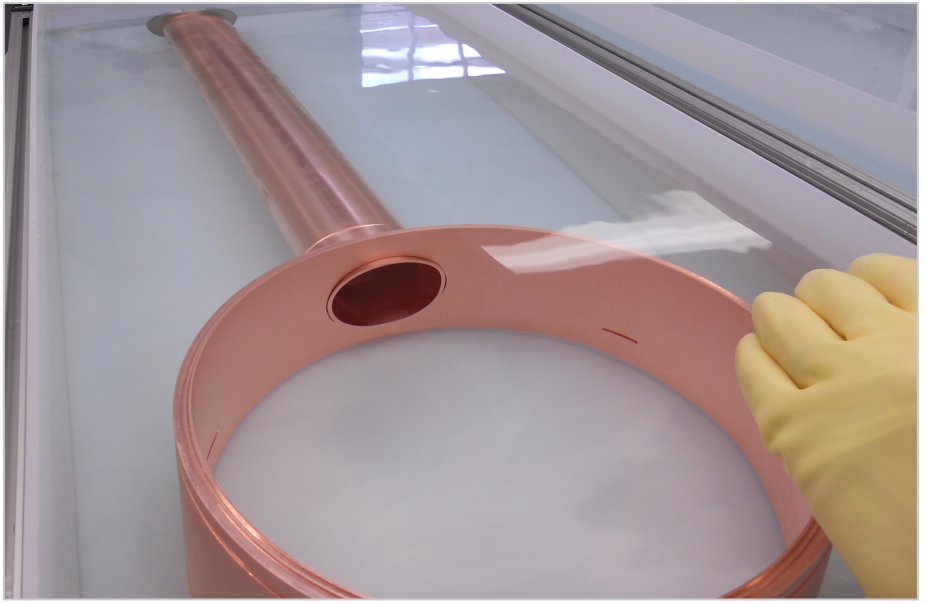
**The Prototype Cryostat components will be built from OFHC copper.*

Sanford Underground Research Facility

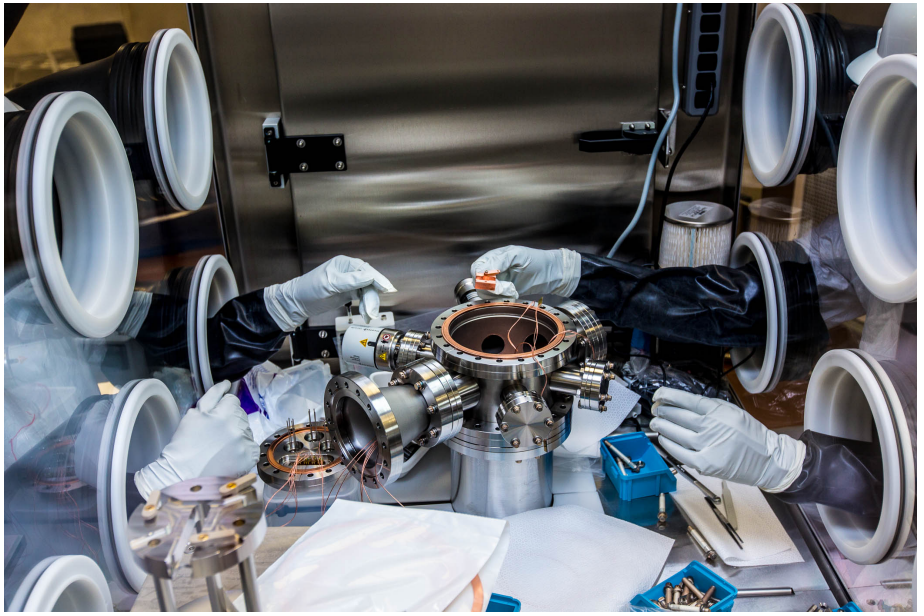


Sanford Underground Research Facility





The MAJORANA machine shop: July 2012
(first copper on a lathe)



The MALBEK Detector

slow signal studies

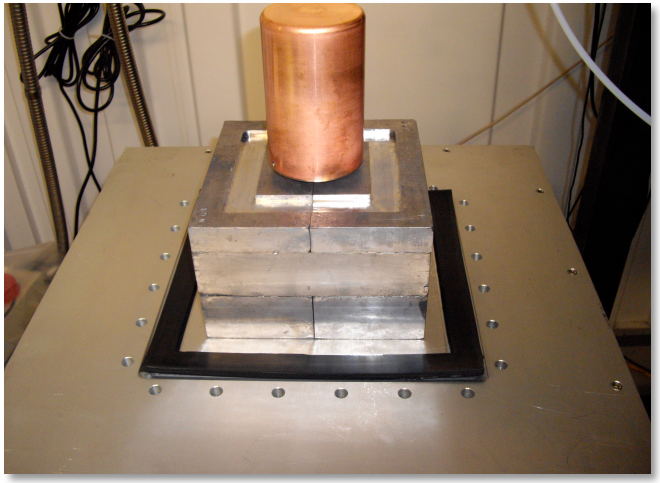
background modeling

dark matter sensitivity

MALBEK

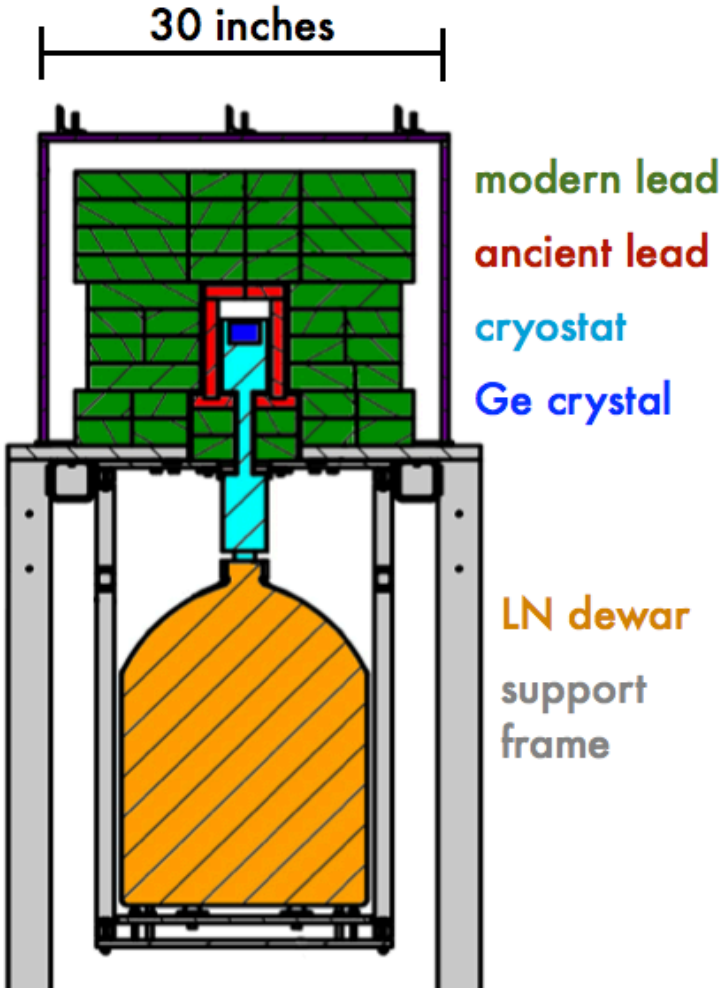
M*AJORANA* ***L****ow-Background* ***B****EGe* ***D****etector at* ***K****URF*

- 450g Canberra modified Broad Energy Ge (BEGe) detector with ultra low-background components
- small point contact size (4.0 mm)
- optimized larger ditch diameter (30.15 mm)
- housed in shield at 1450 m.w.e. at the Kimballton Underground Research Facility (KURF) in Ripplemead, VA



MALBEK

***M**AJORANA **L**ow-Background **BE**Ge **D**etector at **K**URF*

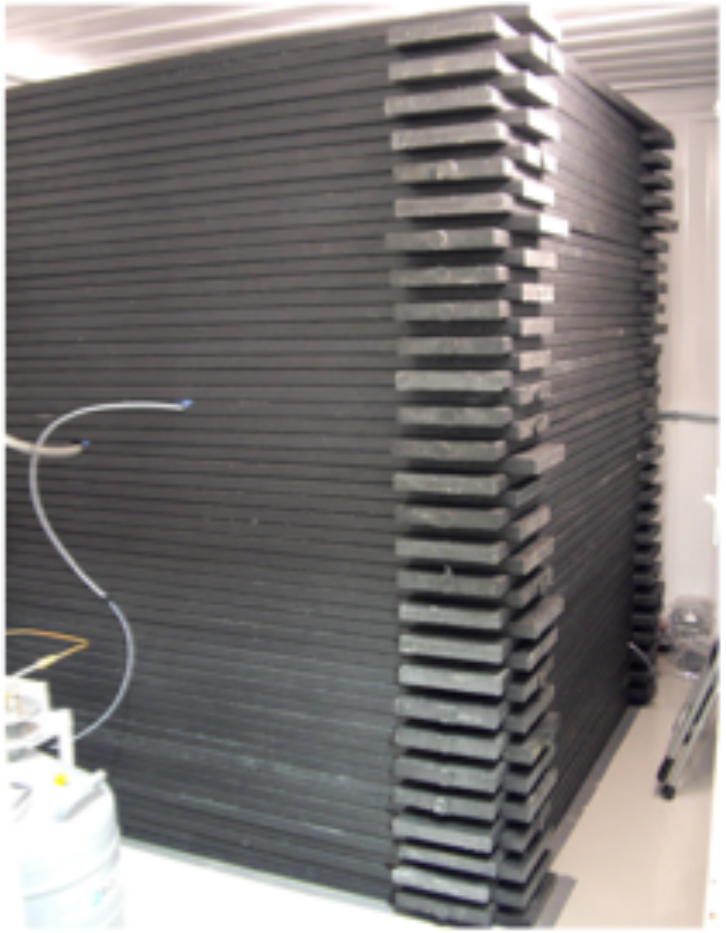


Goals

- Aspect ratio study
- Test MJD-like DAQ
- Examine backgrounds over a broad energy range, including surface events
- Validate the MJD background model
- Test the Dark Matter sensitivity of MJD

MALBEK

***M**AJORANA **L**ow-Background **B**EGe **D**etector at **K**URF*



KURF over the years

Orca

Object-oriented **R**eal-time **C**ontrol and **A**cquisition

- fully encapsulated objects represent hardware, data-readout tasks, data analysis and control modules.
- usage: KATRIN, SNO NCDs, MAJORANA, CENPA, UW Radiology, LANL, LBNL, LENA at TUNL, nTPC
- OrcaROOT provides ROOT support and interface
- written in Objective-C for Mac OS-X
- created by Mark Howe and John Wilkerson
- see **orca.physics.unc.edu**

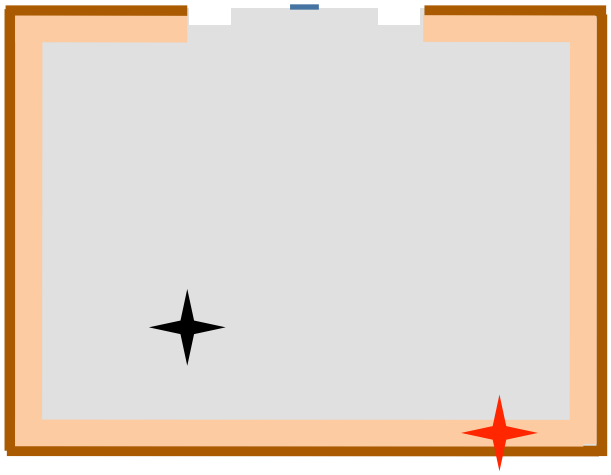
M.A. Howe, et al., IEEE Transactions on Nuclear Science 51, 878 (2004)

slow signal studies

background modeling

dark matter sensitivity

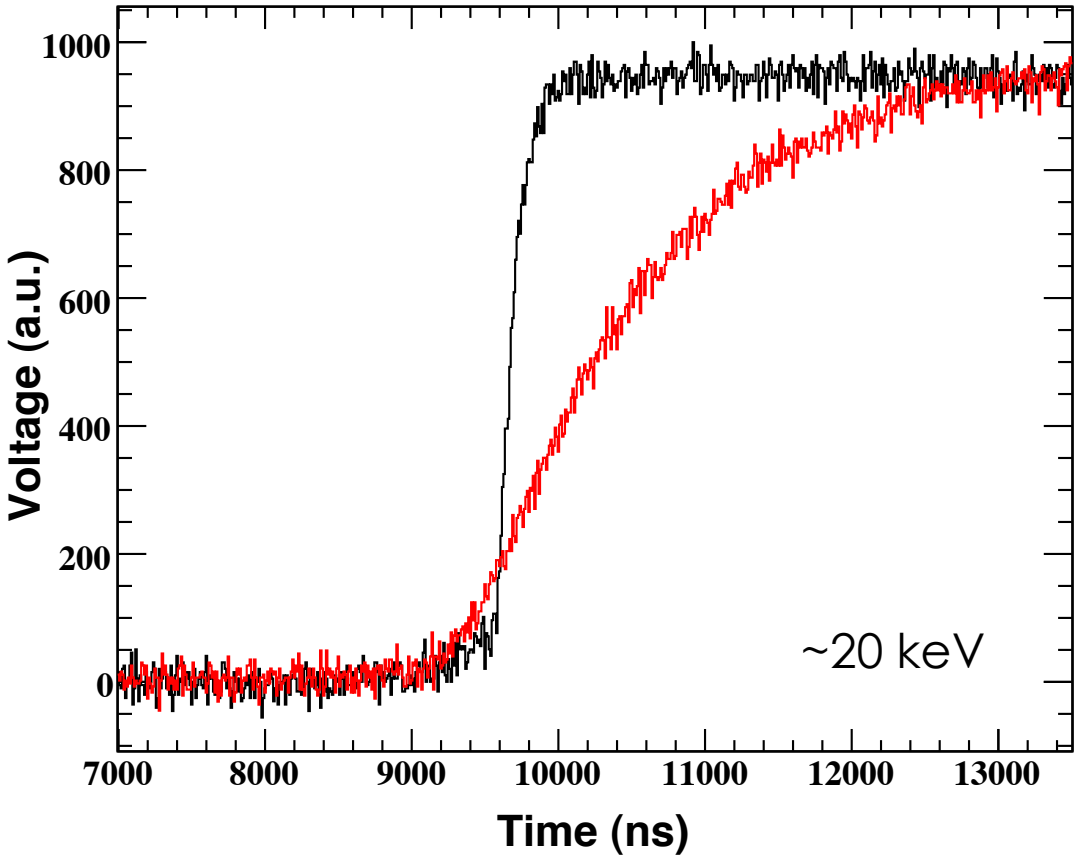
MALBEK as a tool to study "slow pulses"



active volume

n+ dead layer

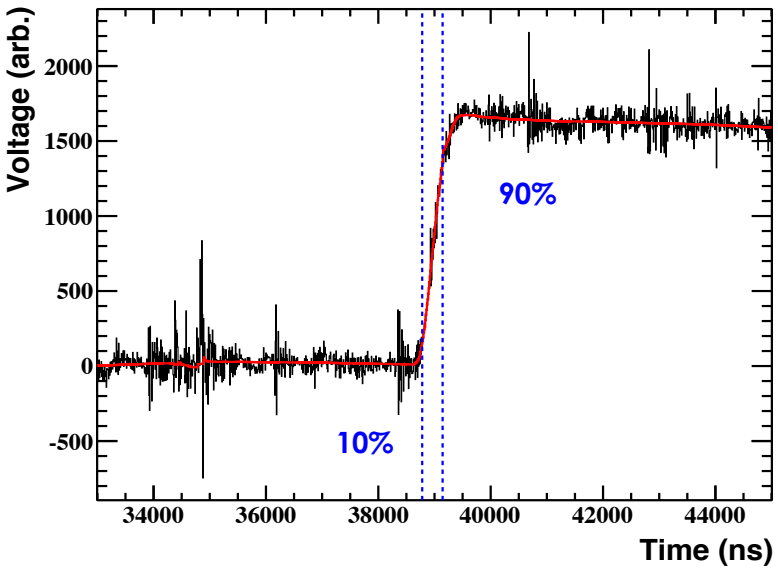
transition region – partial charge collection



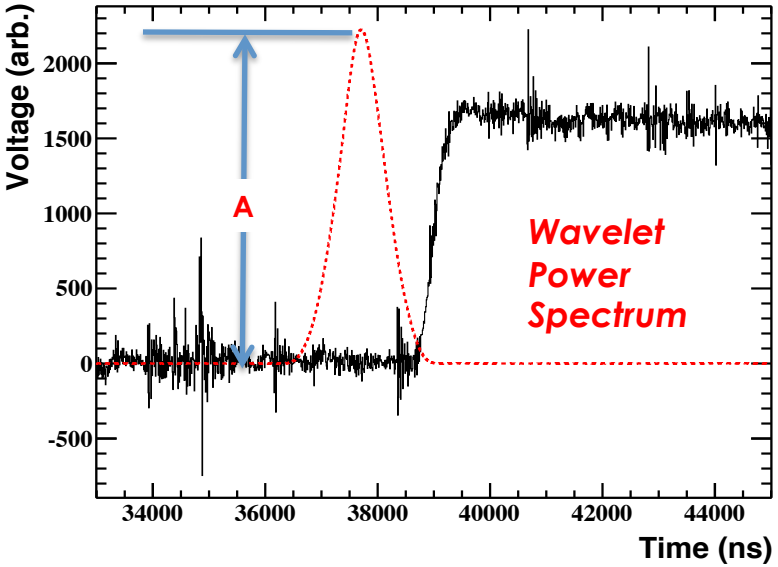
Wavelet PSA

from P. Finnerty thesis

$t_{10\text{-}90}$



$w_{par}=A/E^2$



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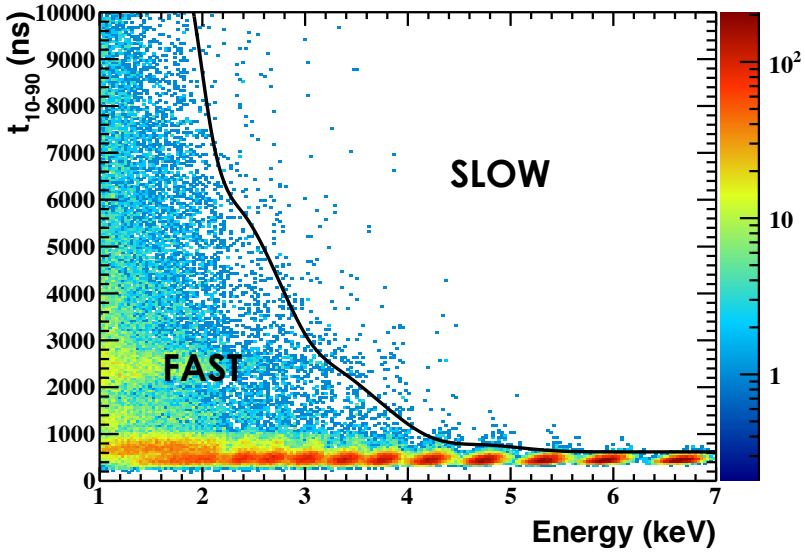
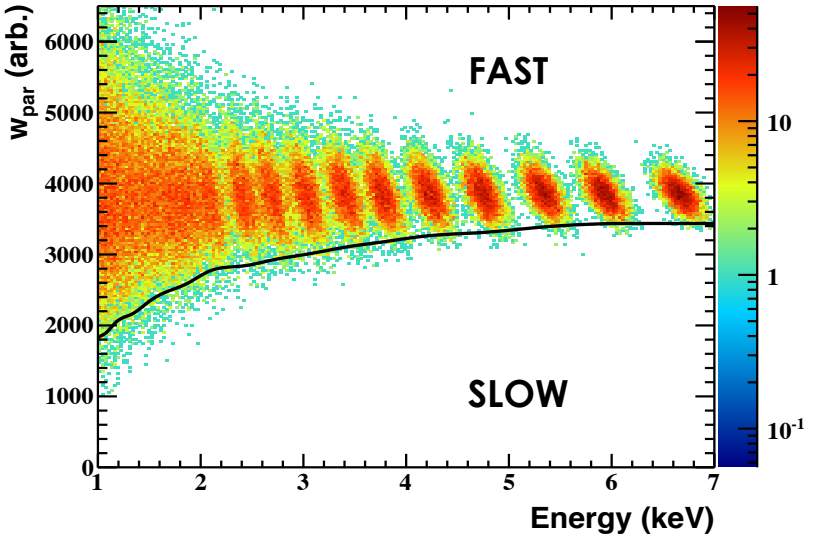
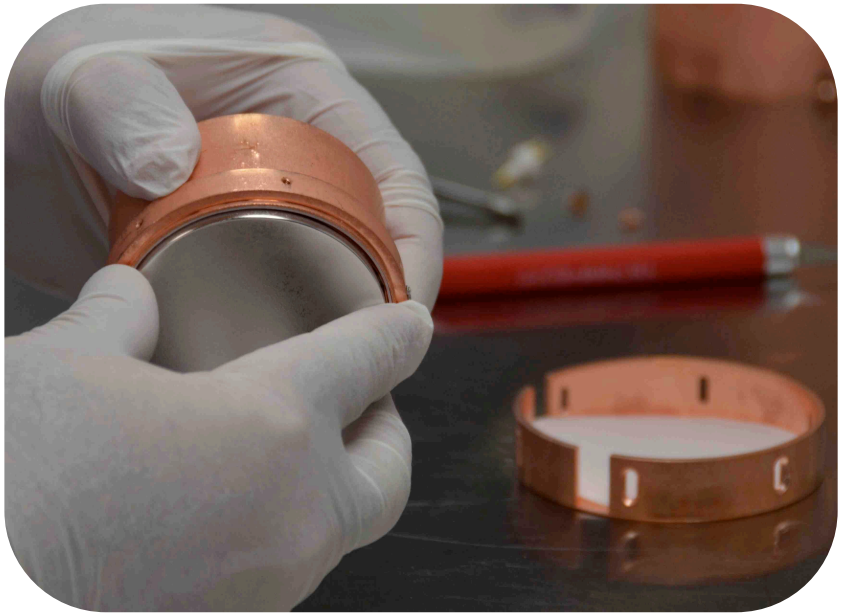


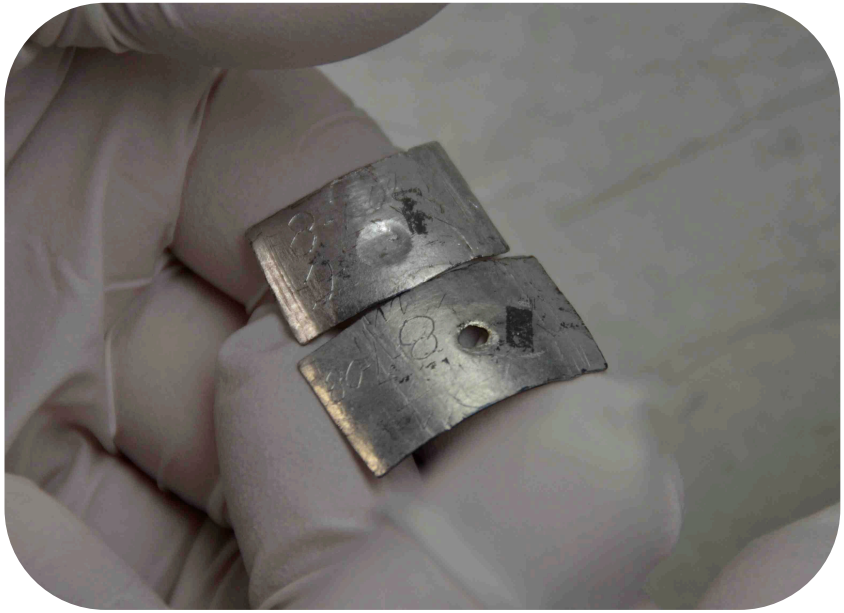
$w_{par}=A/E^2$



an inadvertent slow pulse source

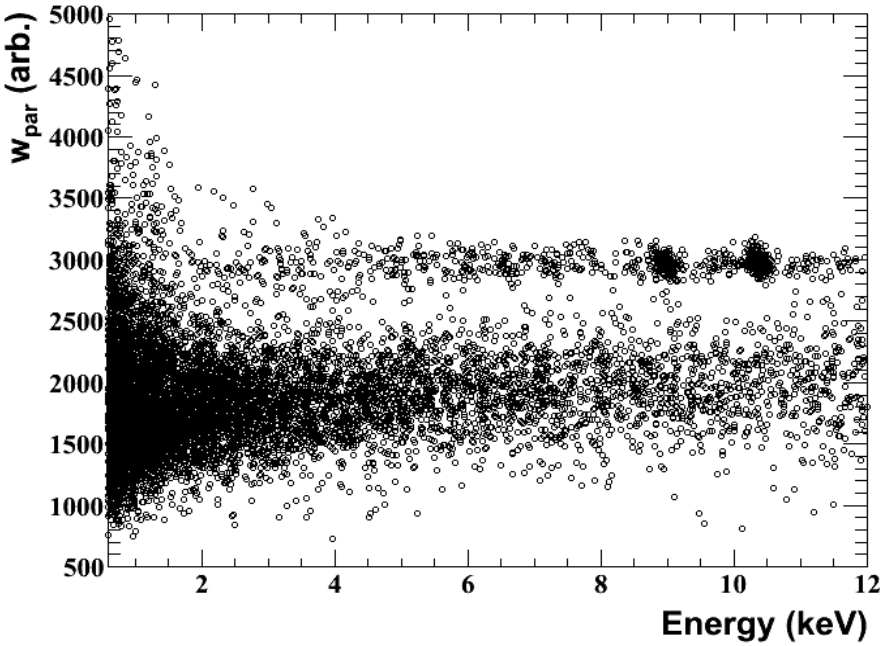


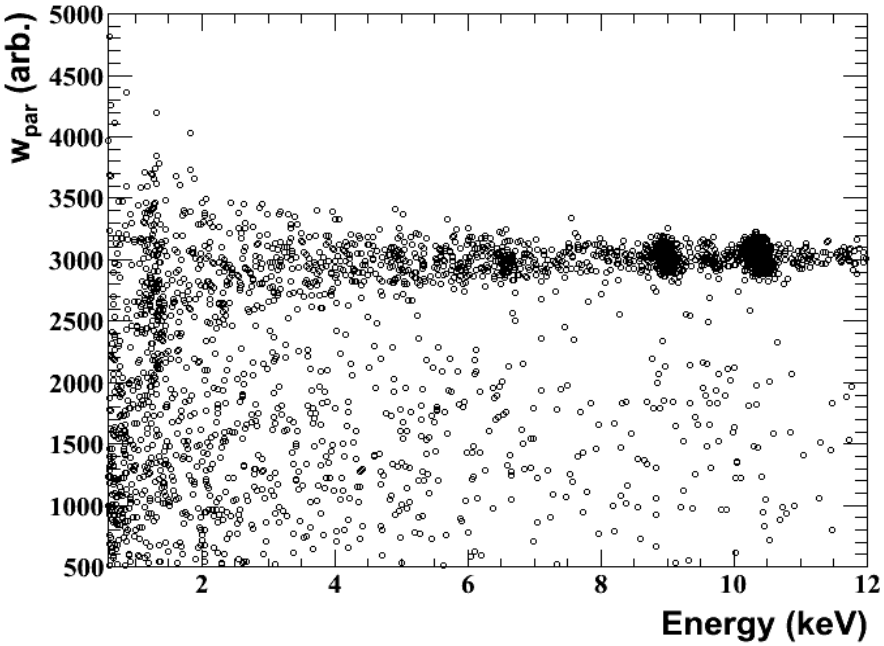
the MALBEK detector



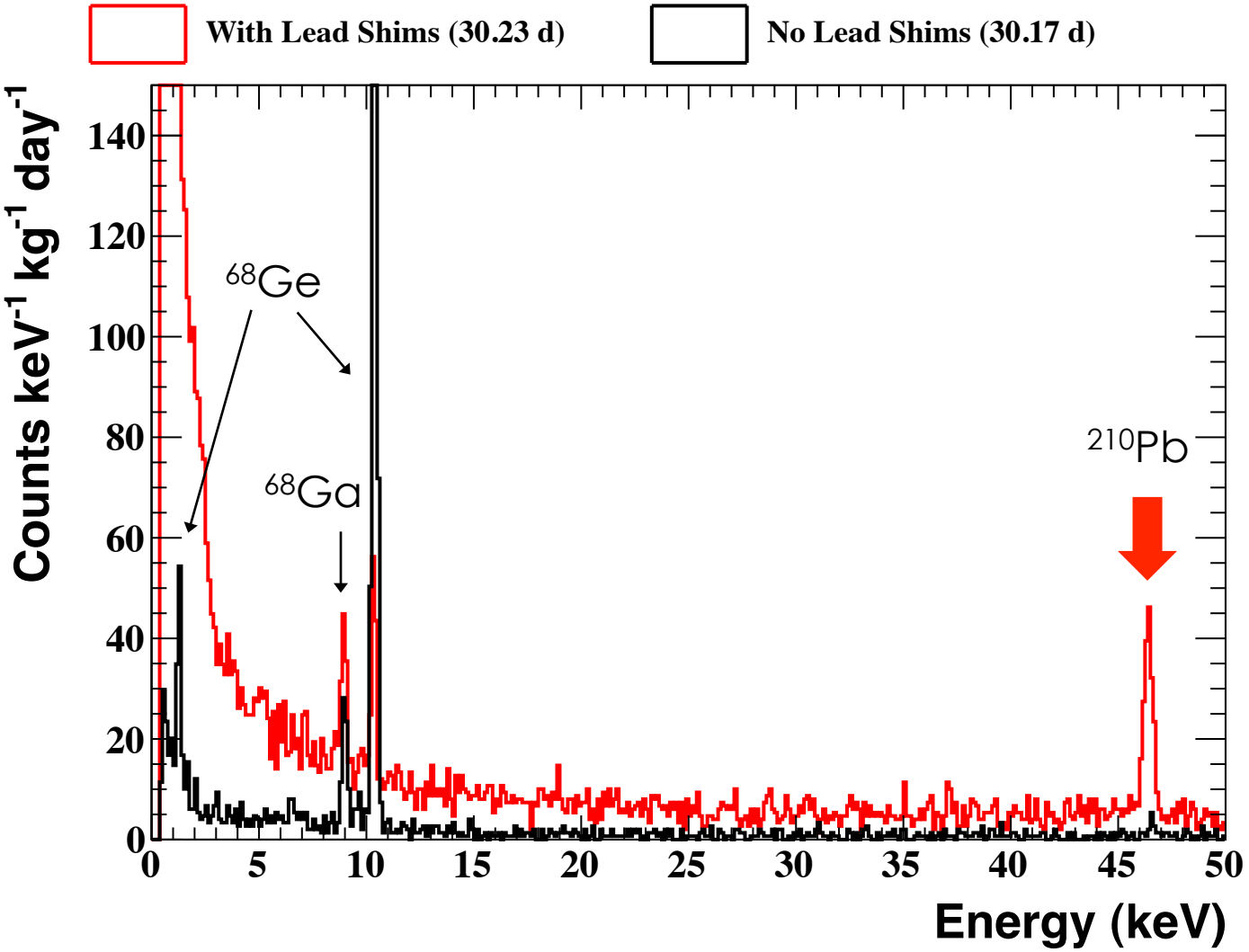
lead shims

an inadvertent slow pulse source



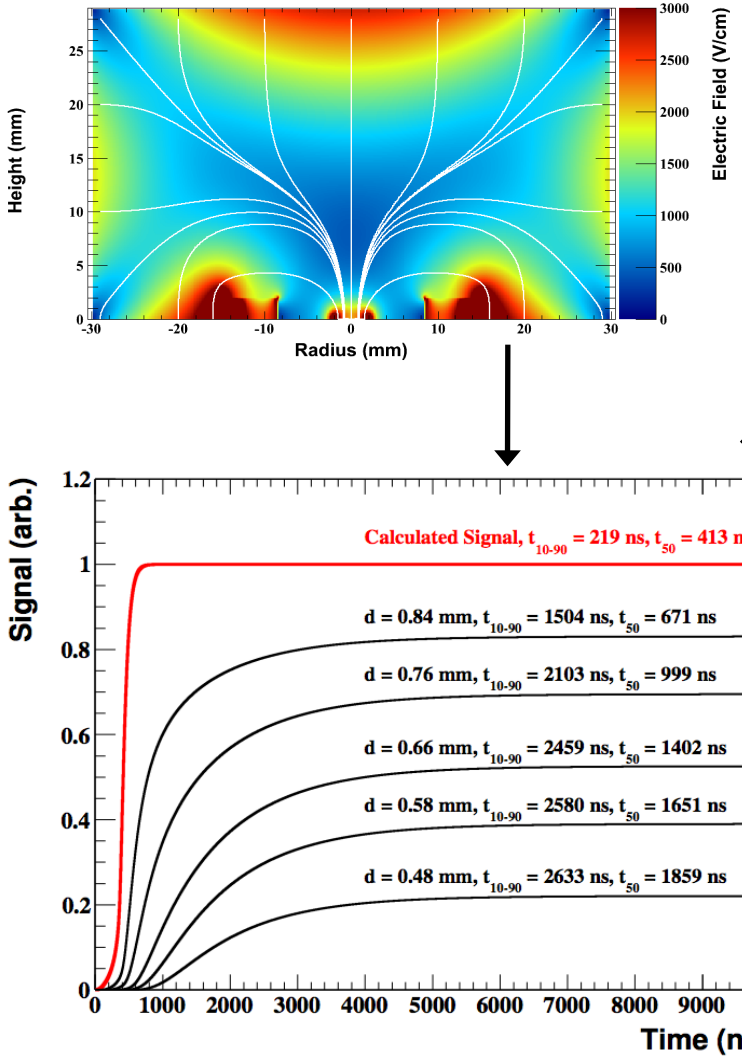


the effect of slow pulses

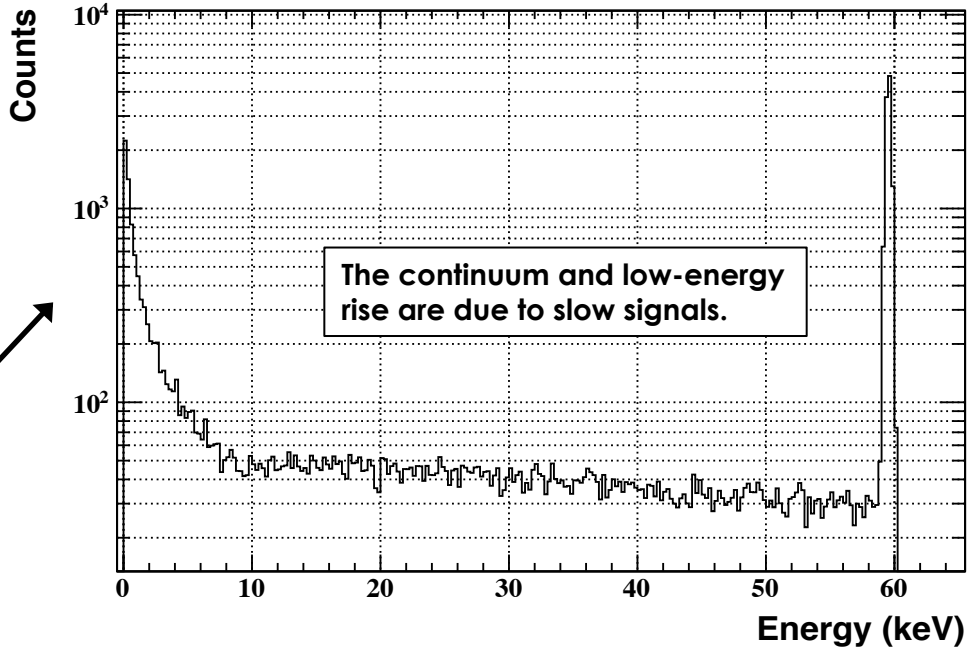


A slow pulse model

work by D.C Radford & P. Finnerty



simulated ^{241}Am spectrum



Big first step towards understanding physical mechanism responsible for slow-signals in PPC detectors.

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The MALBEK Detector

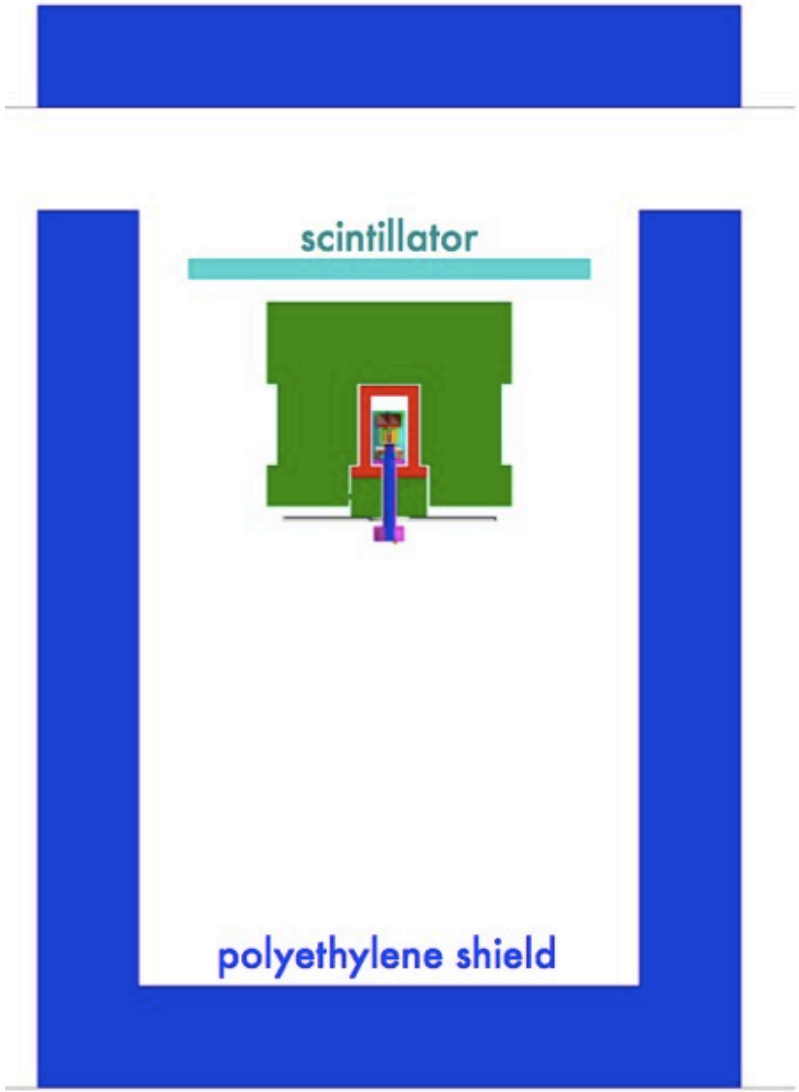
slow signal studies

background modeling

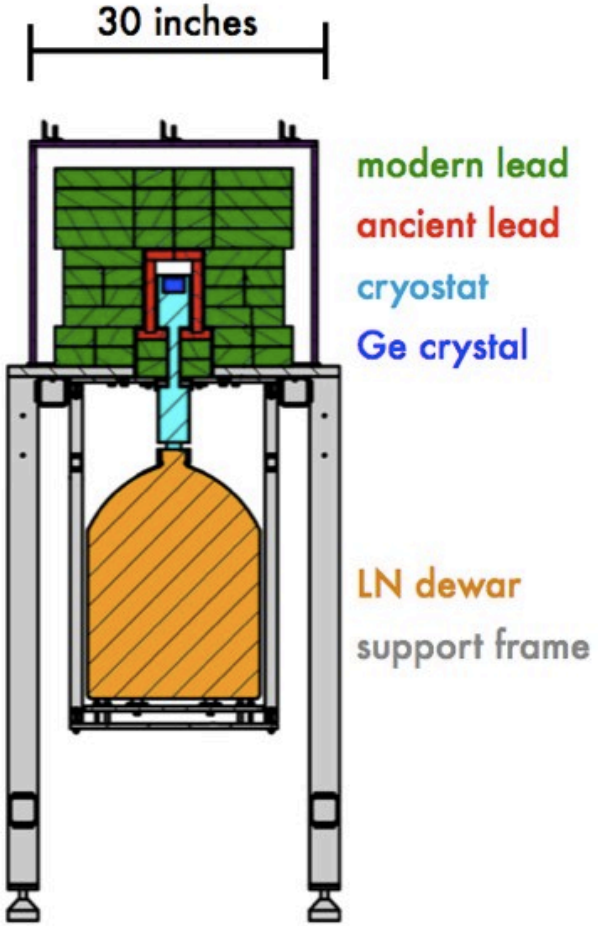
dark matter sensitivity

GEANT4 geometry

from A. Schubert thesis



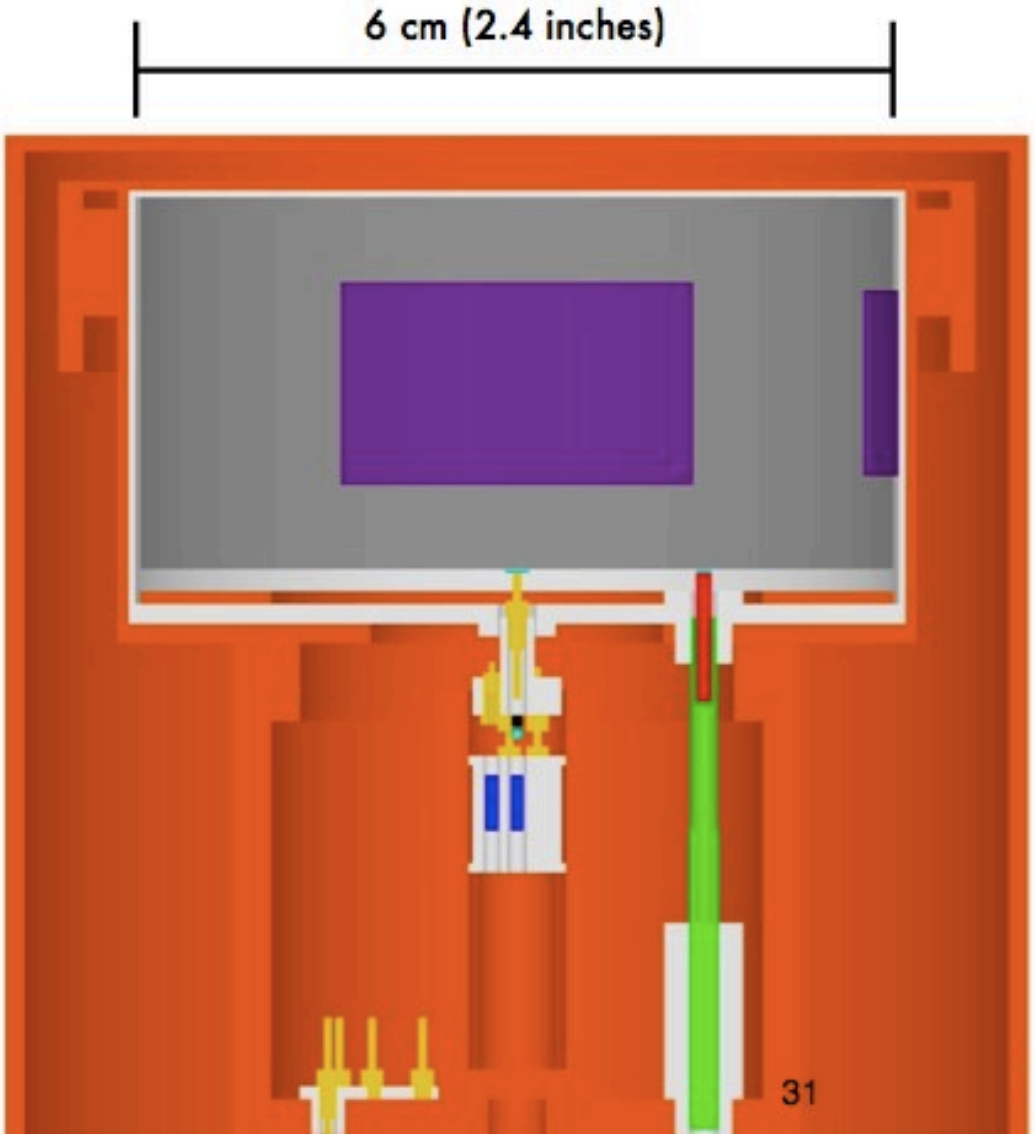
GEANT4 model



engineering drawing

GEANT4 geometry

from A. Schubert thesis

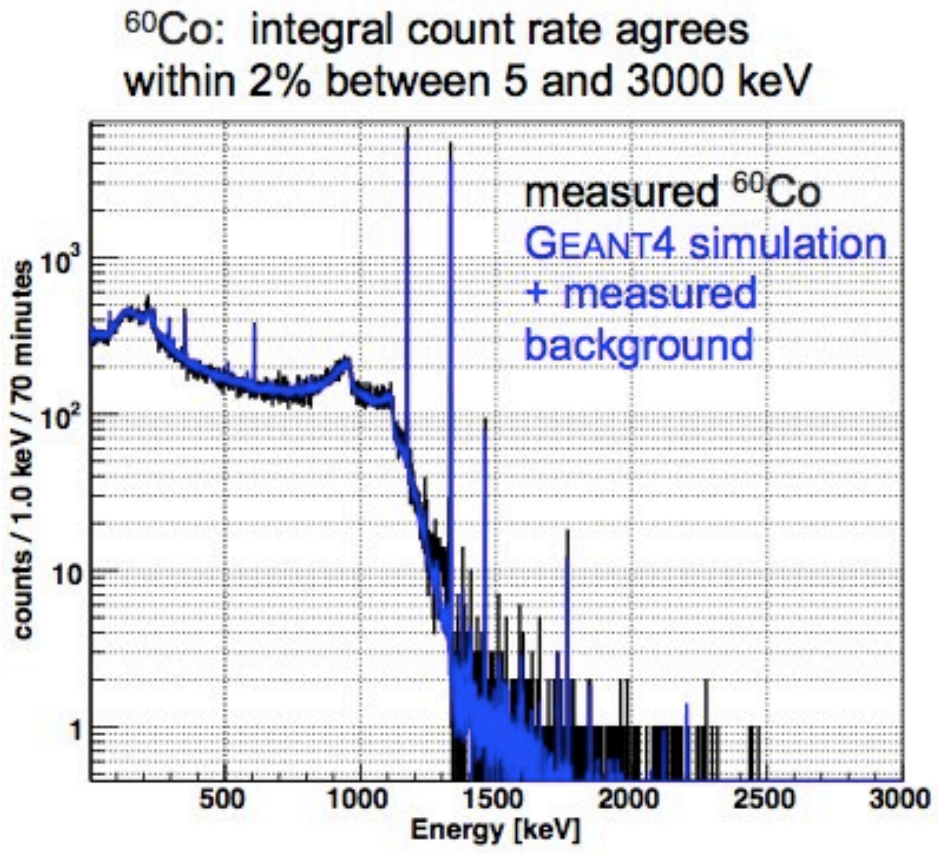


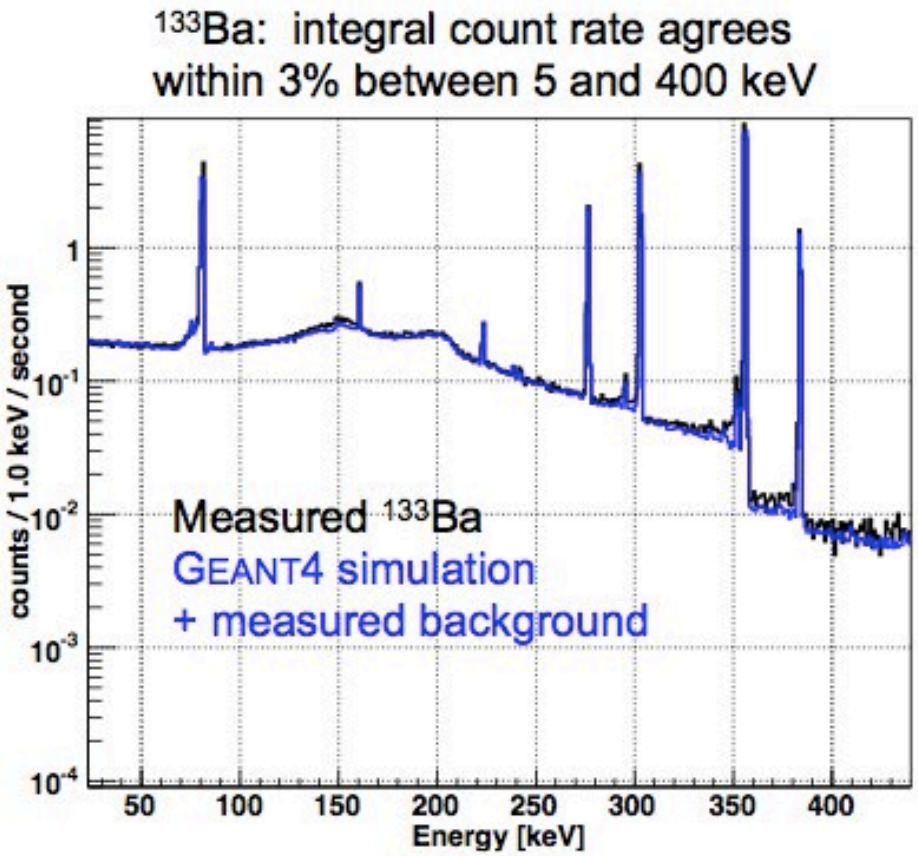
germanium crystal
lead
copper
teflon (white)
brass
tin solder
resistors
beryllium copper
nickel silver

cross section
of the cryostat

model validation

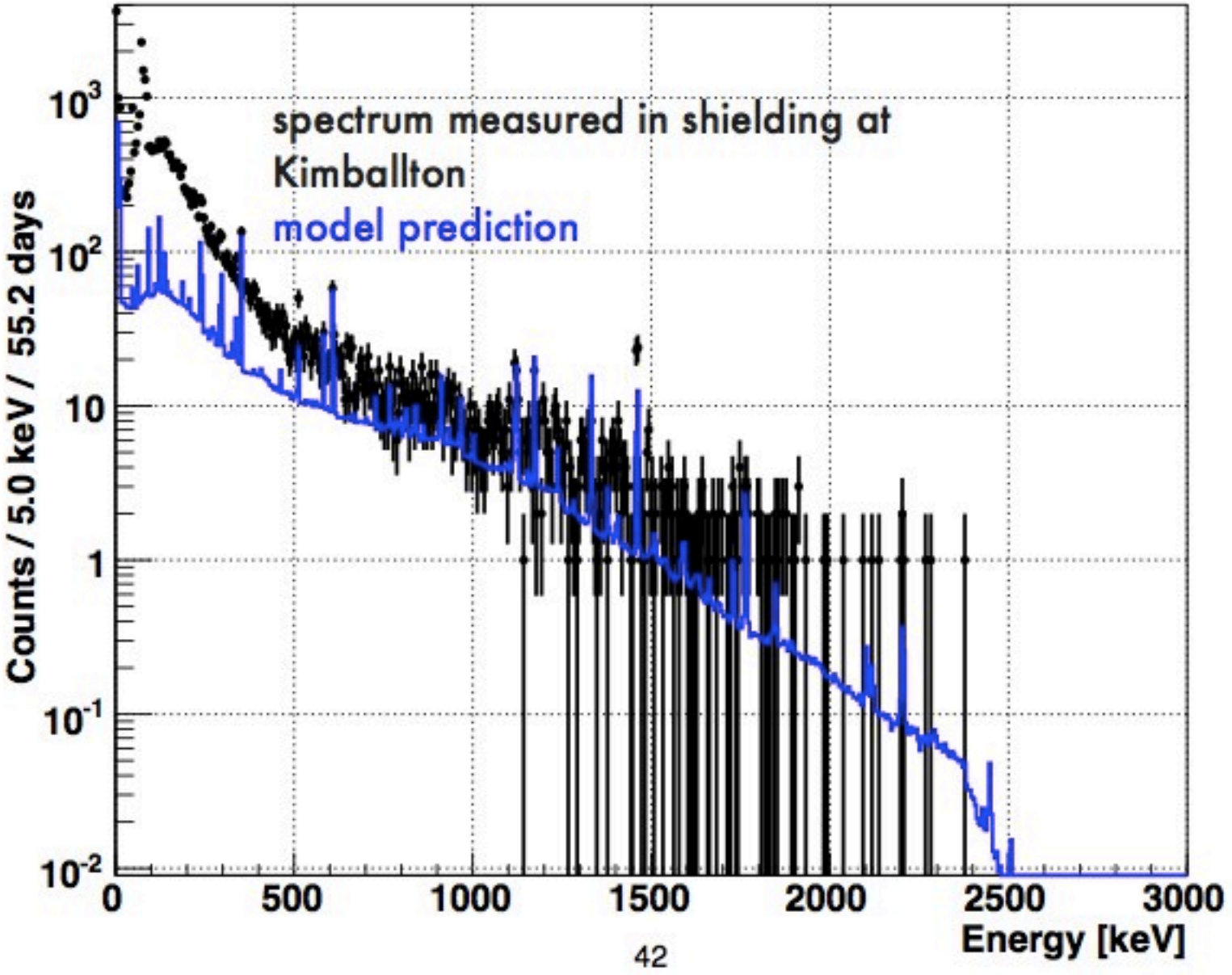
from A. Schubert thesis





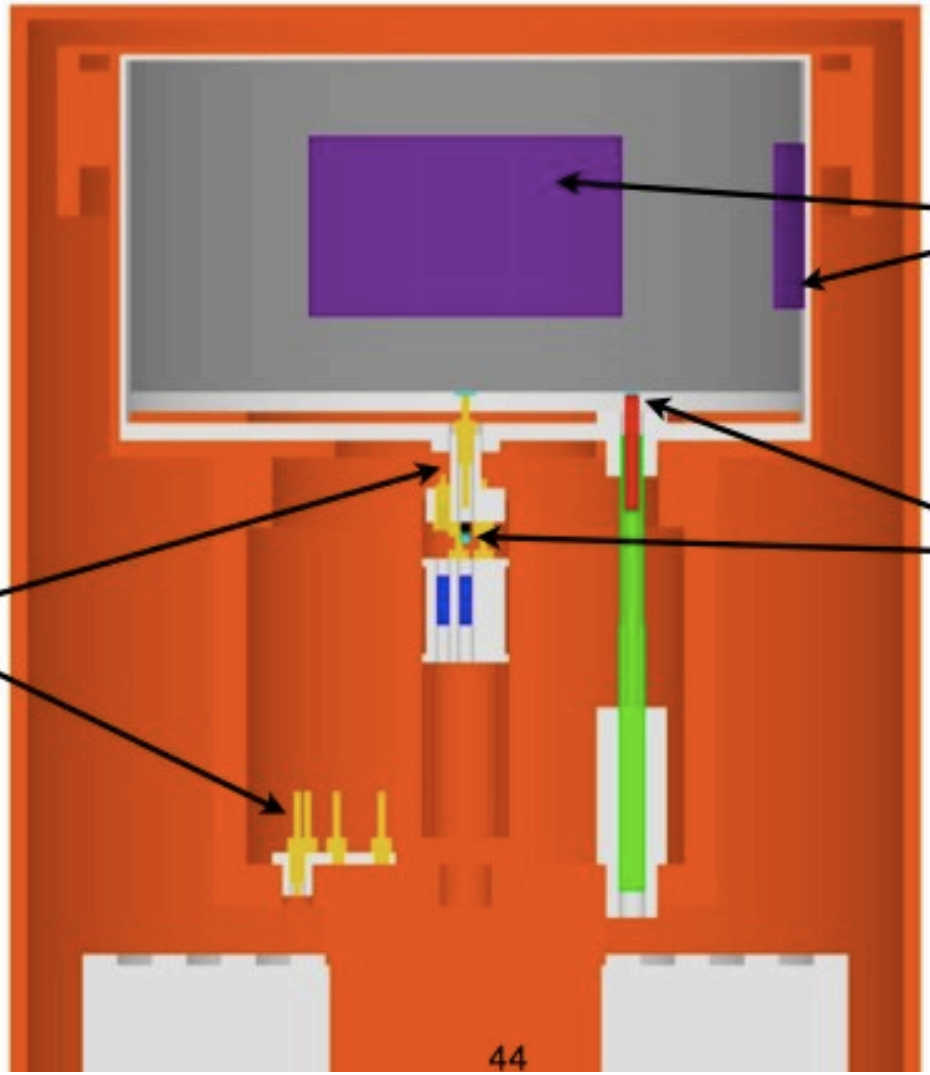
initial simulation results

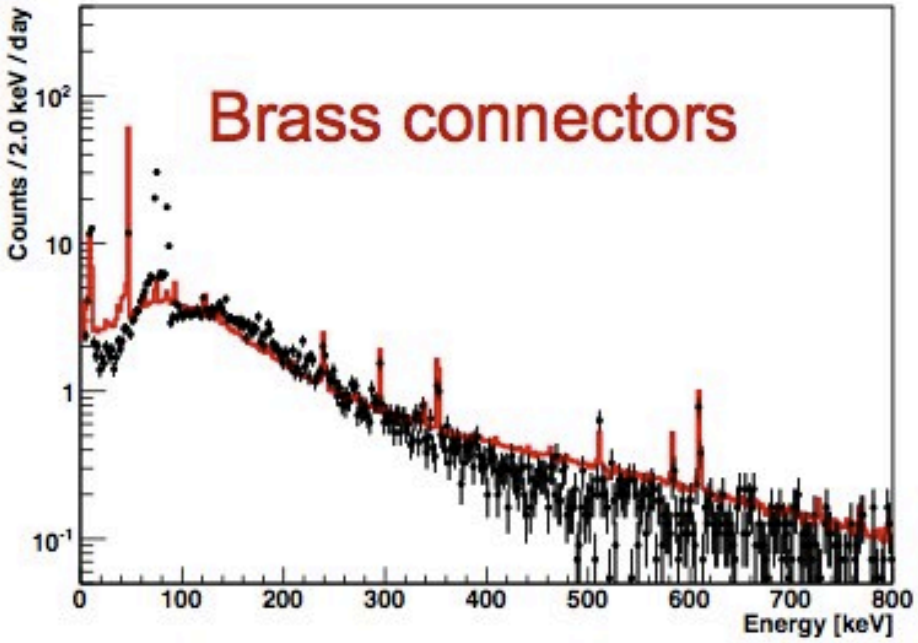
from A. Schubert thesis

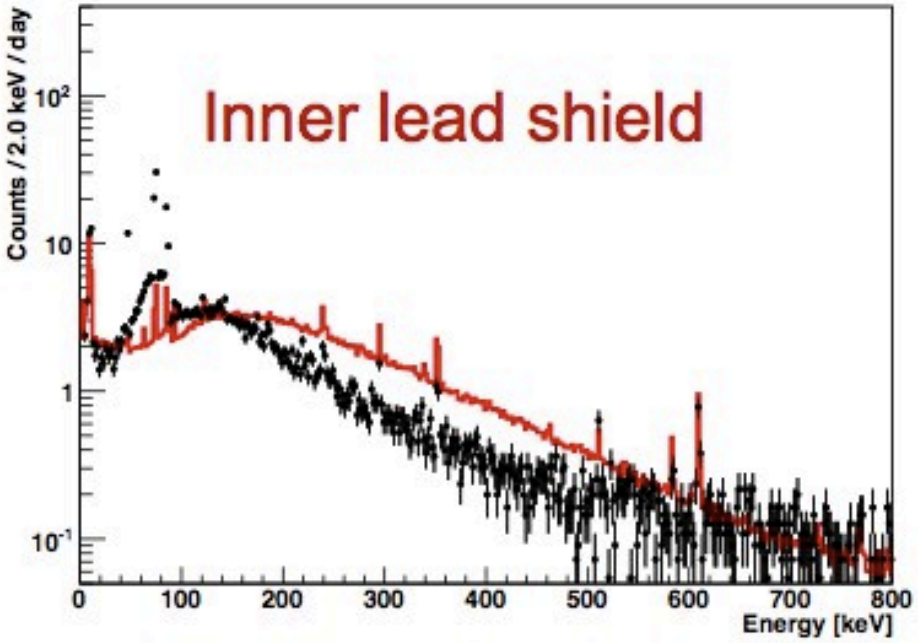


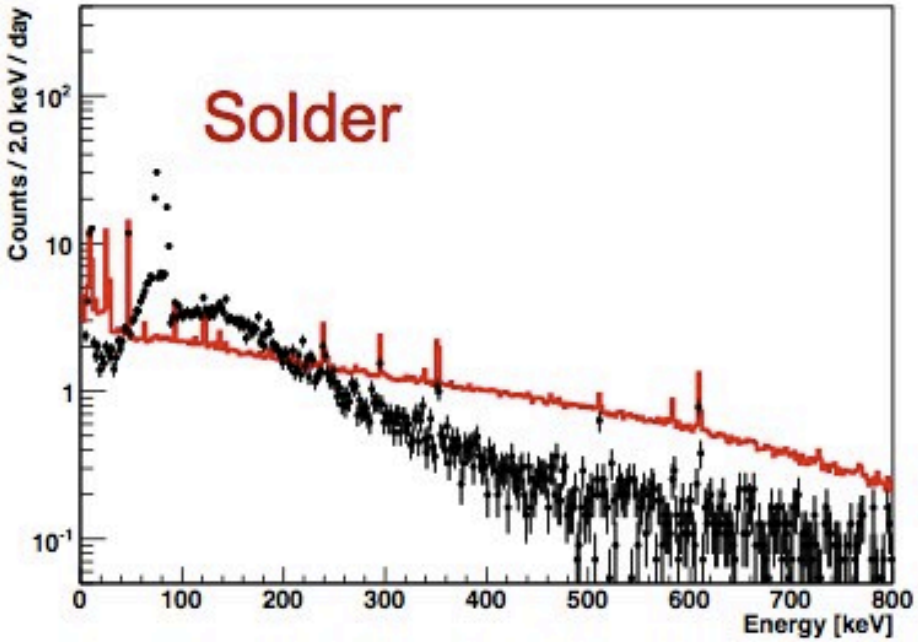
possible lead sources

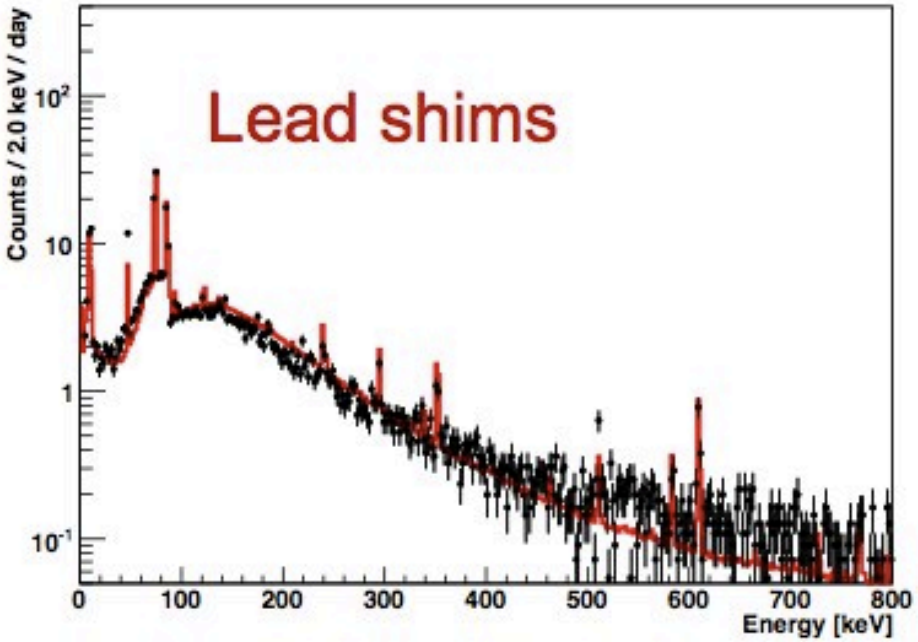
from A. Schubert thesis




Brass connectors
Counts / 2.0 keV / day
Energy [keV]

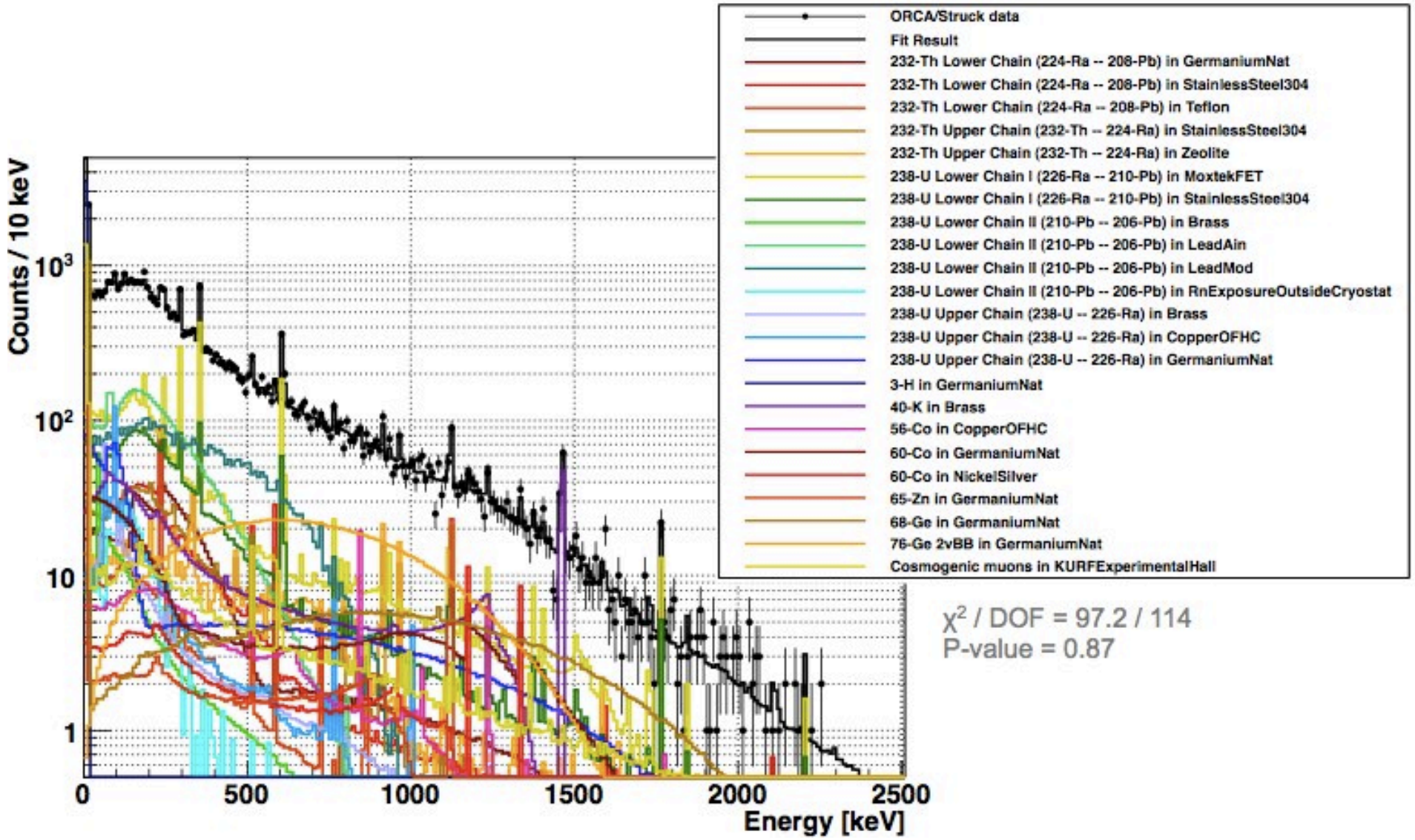

Inner lead shield
Counts / 2.0 keV / day
Energy [keV]


Solder
Counts / 2.0 keV / day
Energy [keV]


Lead shims
Counts / 2.0 keV / day
Energy [keV]

background model fit

from A. Schubert thesis



The MAJORANA DEMONSTRATOR

The MALBEK Detector

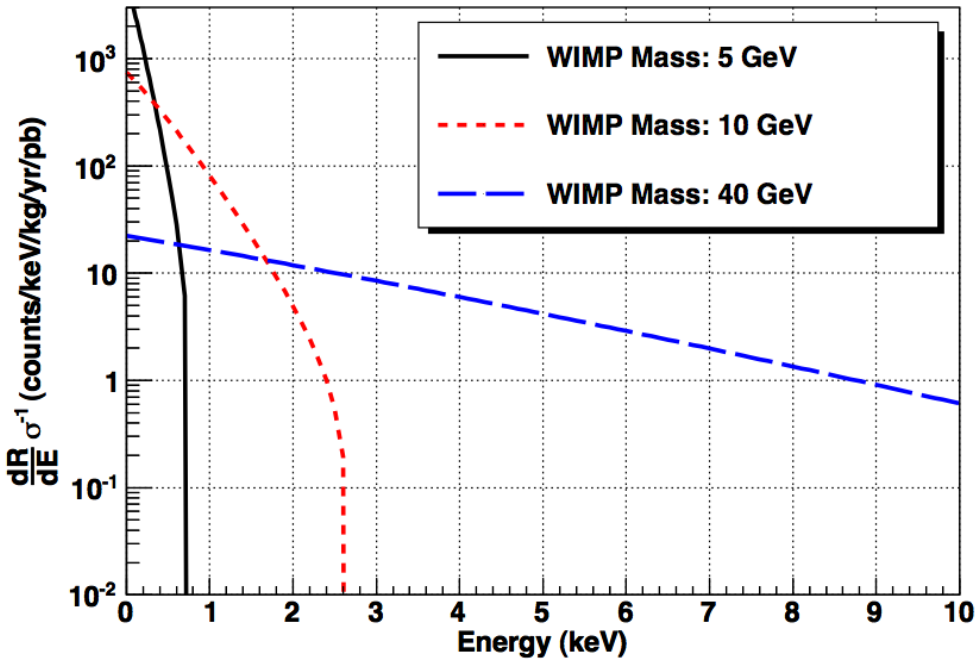
slow signal studies

background modeling

dark matter sensitivity

Dark Matter detection with PPCs

expected WIMP spectra



M.G. Marino, PhD Diss., Univ. of Washington (2010)

We are investigating what's required to make the MAJORANA DEMONSTRATOR sensitive to a WIMP signal.

- ✦electronic noise
- ✦digitizers
- ✦efficiencies

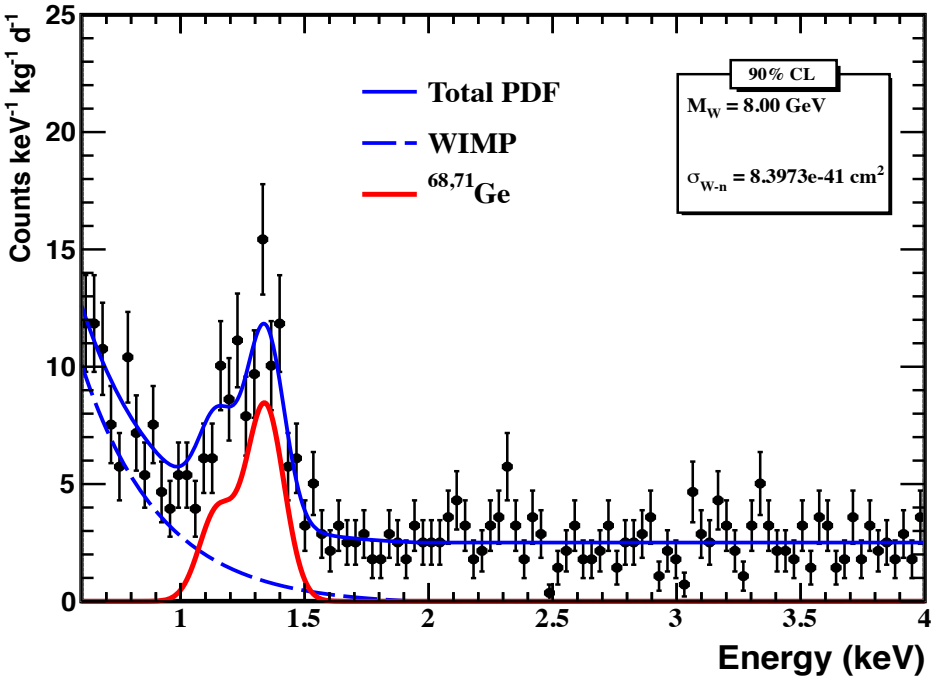
Extracting Spin-Independent WIMP Limits

from P. Finnerty thesis

- Maximum Likelihood (ML) based exclusion limits (90% CL).
- Treat backgrounds as nuisance parameters.

Description	Functional Form
Background PDF Components	
Flat background	$f_{flat}(E) = 1$
Exponential background[a]	$f_{exp}(E) = \exp(c_1 E)$
^{65}Zn L-capture γ line	$f_{Zn_L}(E) = \frac{1}{\sigma_{Zn_L}\sqrt{2\pi}} \exp\left(-\frac{(E-\mu_{Zn_L})^2}{2\sigma^2_{Zn_L}}\right)$
^{68,71}Ge L-capture γ line	$f_{Ge_L}(E) = \frac{1}{\sigma_{Ge_L}\sqrt{2\pi}} \exp\left(-\frac{(E-\mu_{Ge_L})^2}{2\sigma^2_{Ge_L}}\right)$
Signal PDF Components	
WIMP signal	$f_W(E) = \left(\frac{dR}{dE_R}\right)\left(\frac{dE_R}{dE_I}\right) F^2$

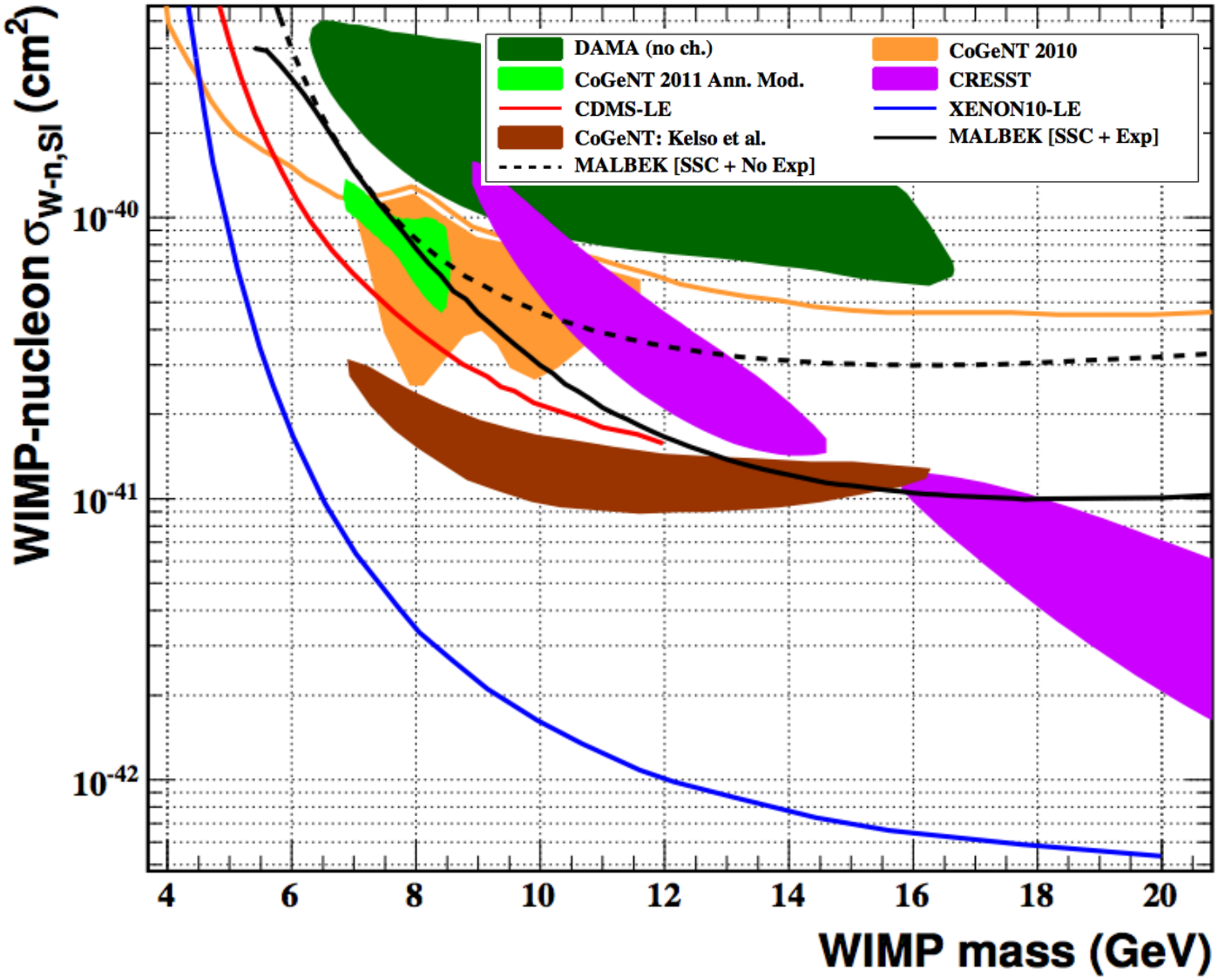
[a] The fit was performed both with and without the exponential component.



Have not corrected for slow-signal leakage. Limits will be conservative.

W. A. Rolke, A. M. Lopez, and J. Conrad, "Limits and confidence intervals in the presence of nuisance parameters," Nucl. Inst. & Meth. A 551 no. 2 – 3, (2005) 493 – 503.

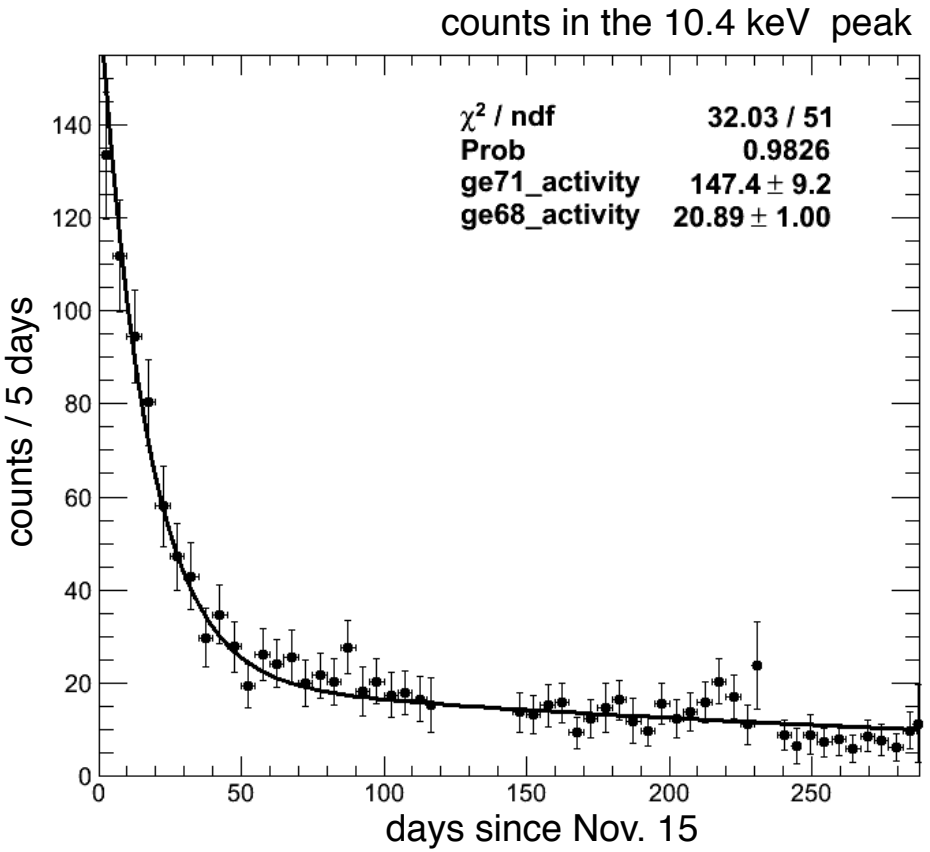
MALBEK Spin-Independent WIMP Limits



from P. Finnerty thesis

MALBEK modulation results

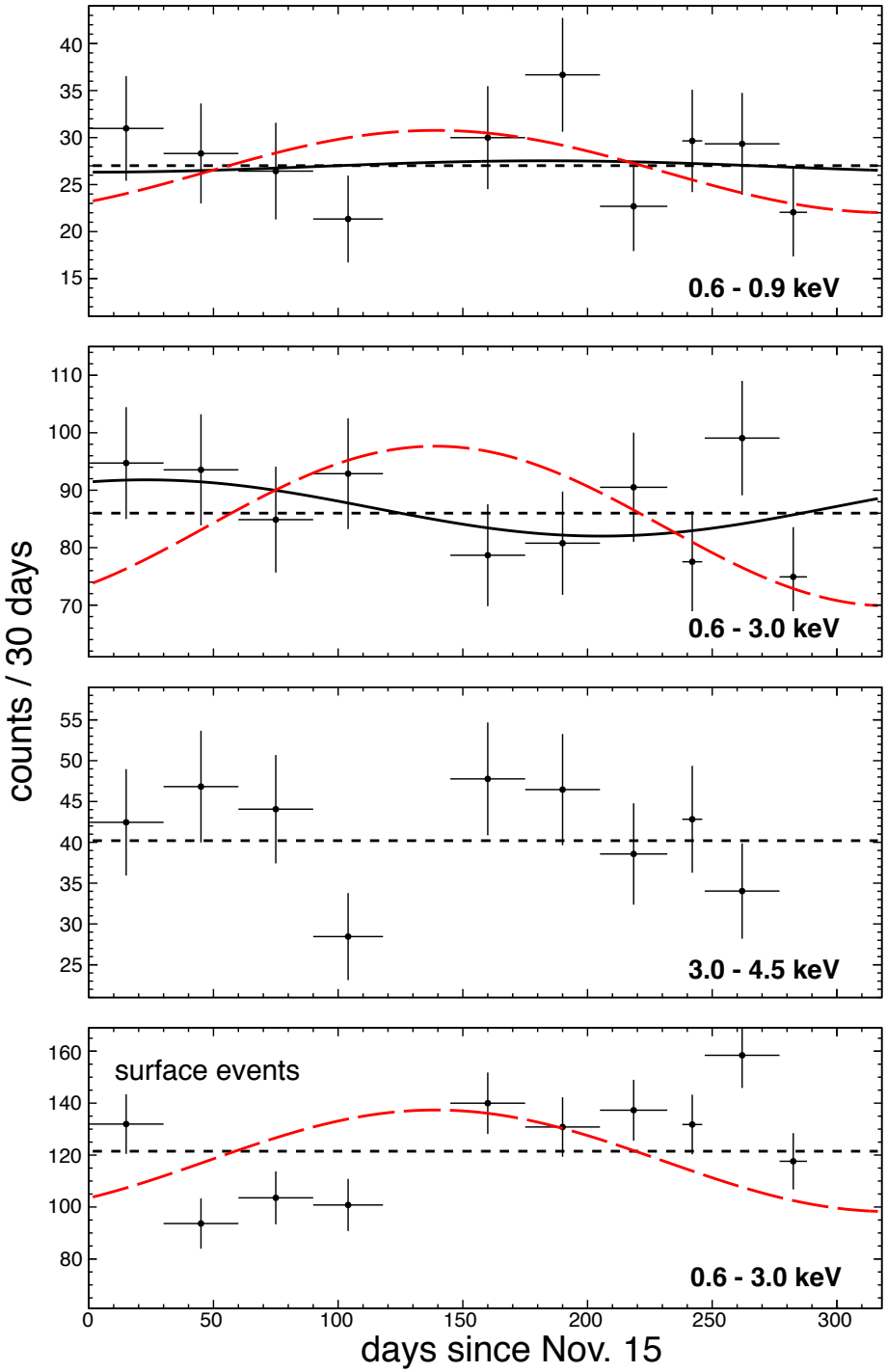
- determine the initial activities of the ^{71}Ge, ^{68}Ge, ^{68}Ga, and ^{65}Zn K lines
- strip the L lines based on the L to K ratio and correct for detector live time
- perform a simple analysis binning in time and energy and perform chi square fits of the following functions



flat distribution

modulation with fixed period, floating phase, floating flat rate, and floating modulating fraction

CoGeNT best fit with floating flat rate



	flat	modulation	CoGeNT
0.6 - 0.9 keV	X^2/NDF 7.3/9 p-value 0.61	osc. frac 2% ± 10% X^2/NDF 7.2/7 p-value 0.40	X^2/NDF 9.4/9 p-value 0.40
0.6 - 3.0 keV	X^2/NDF 7.5/9 p-value 0.59	osc. frac 5% ± 4% X^2/NDF 6.1/7 p value 0.54	X^2/NDF 17/9 p-value 0.06
3.0 - 4.5 keV	X^2/NDF 9.6/8 p-value 0.29		
surface events, 0.6 - 3.0 keV	X^2/NDF 31/9 p-value 3E-4		X^2/NDF 49/9 p-value 2E-7

future work

- MALBEK is still taking data
- we are currently working with 224 day dataset
- incremental improvements to the DAQ and calibration systems