# Recent results of the CoGeNT Dark Matter experiment

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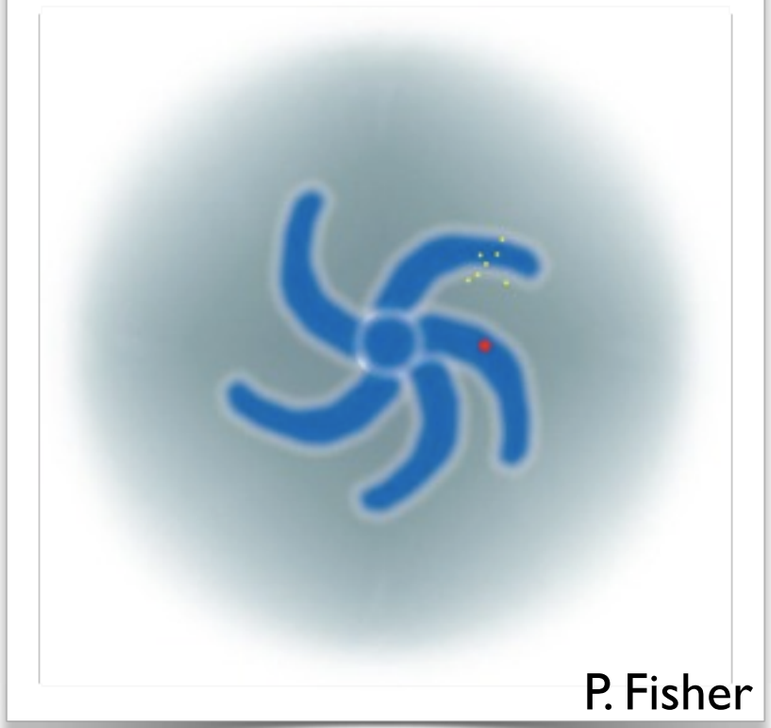
Moriond EW 2012
5 Mar 2012

# Outline

- Physics
- CoGeNT - Experiment + Technology
- Analysis, recent results

# DM Signals

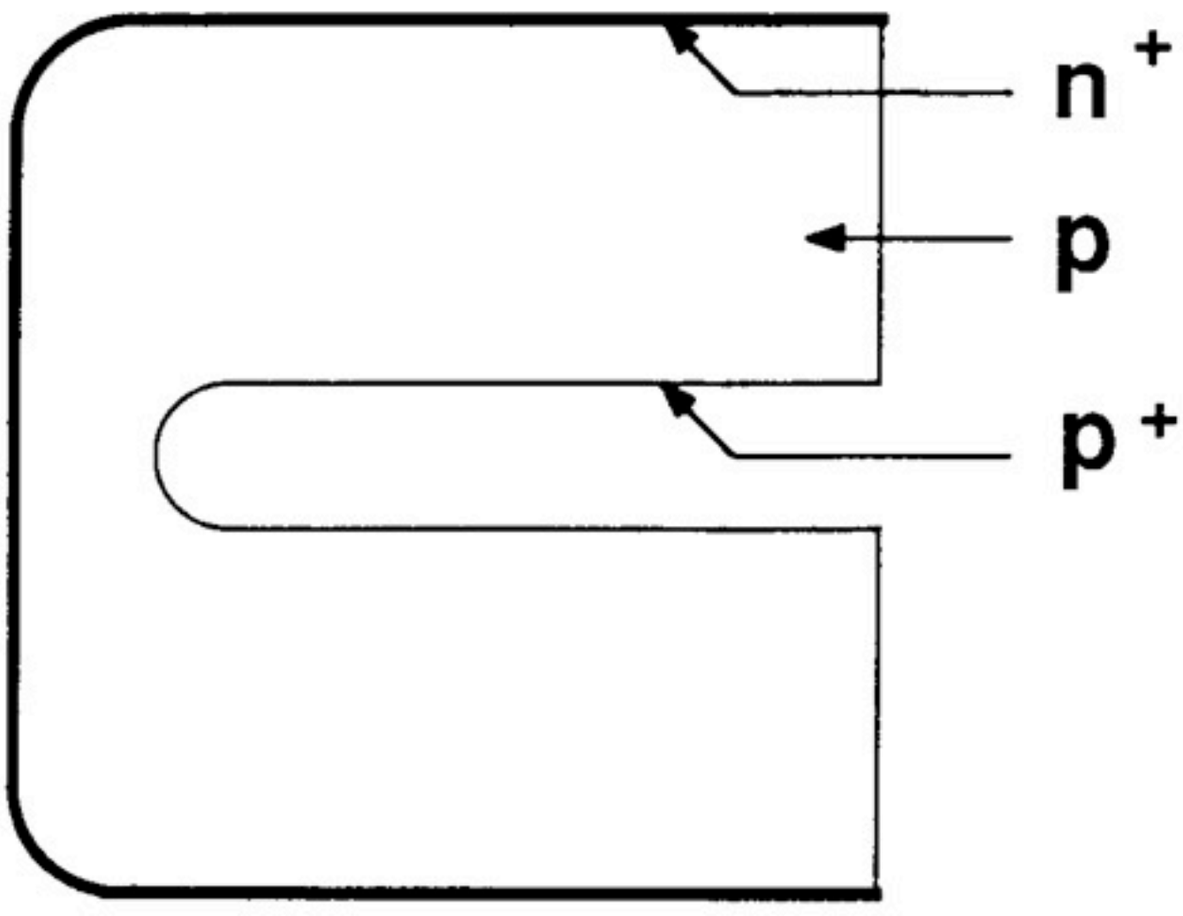
- Convincing signatures could include:
  - Preferred scattering direction
  - mass peak (non-WIMP)
  - Annual rate modulation

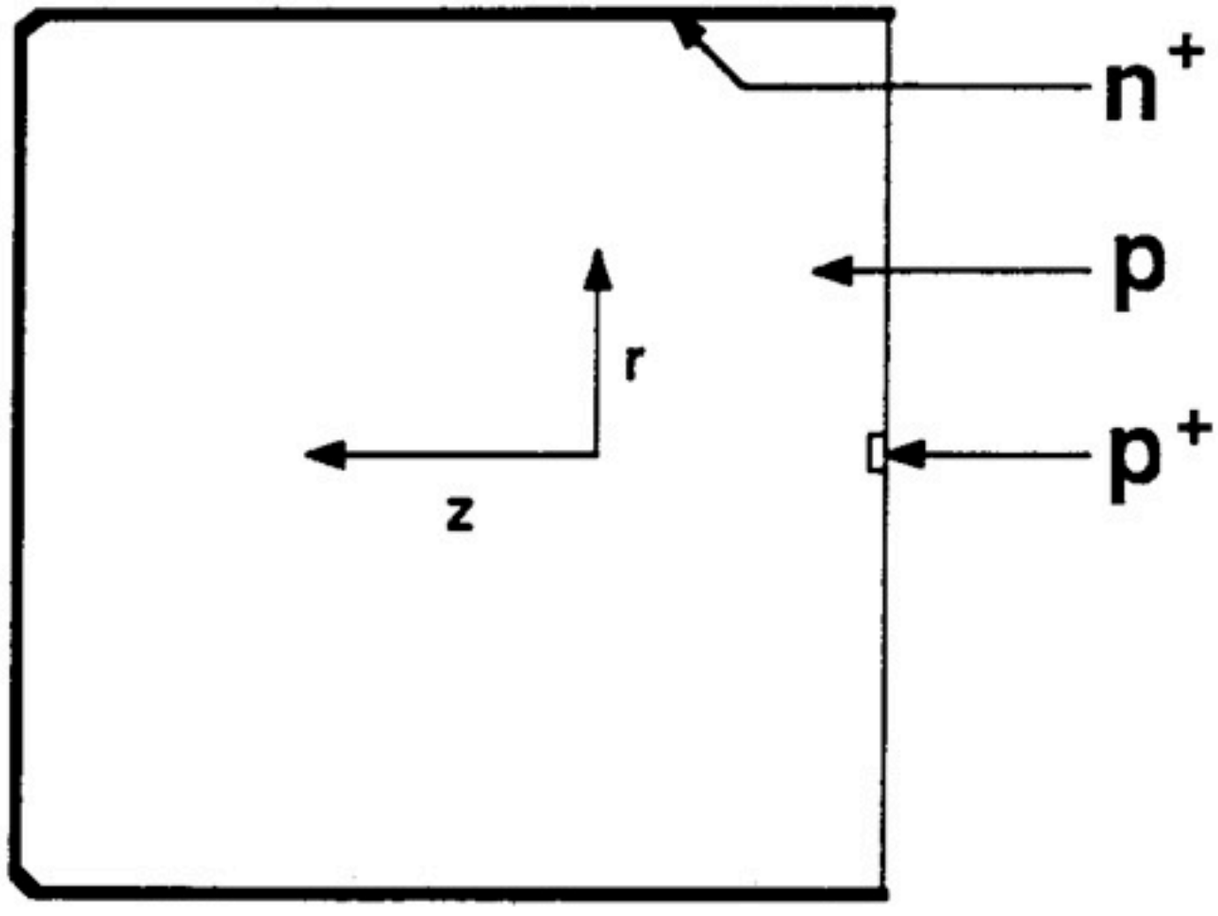



} sensitivity with P-PC/CoGeNT

# Point-Contact Detectors

- P-type Point-Contact (P-PC)
- Geometry: low capacitance, low noise; long charge drift times




Luke et al., IEEE trans. Nucl. Sci. 36 , 926(1989).

# Point-Contact Detectors

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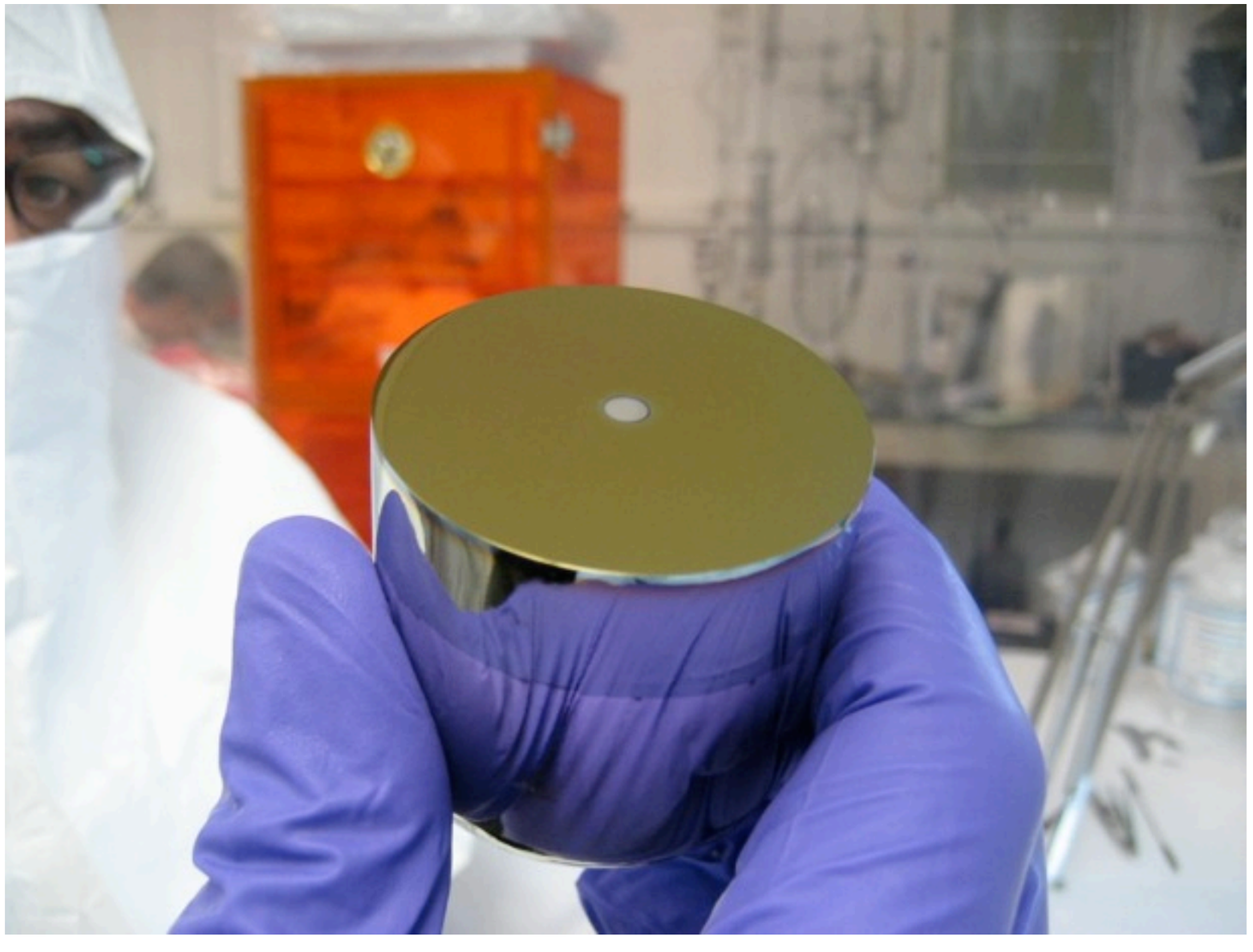
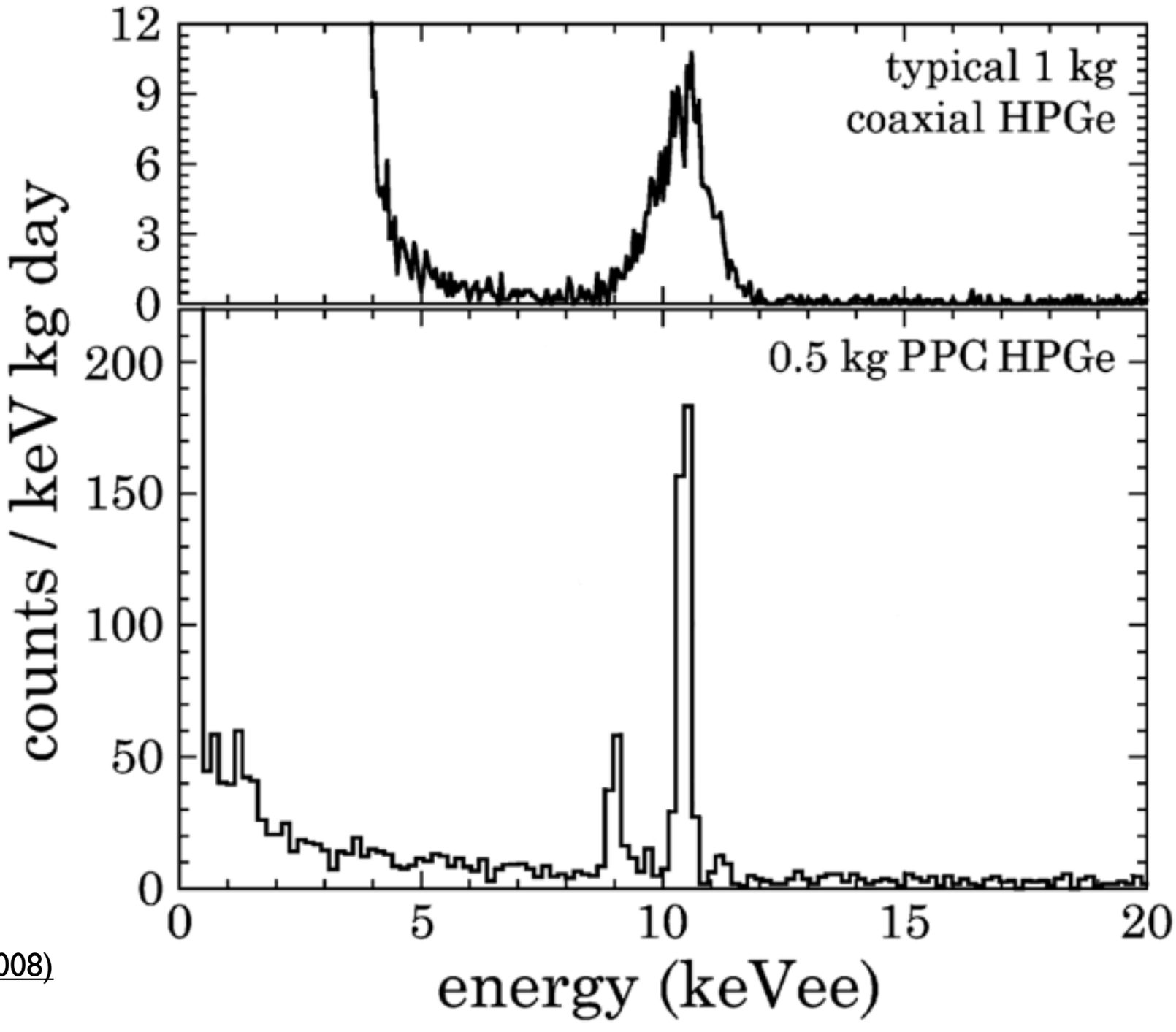


# P-PC Detector Physics Reach

- Low noise, low threshold (< 1keV)
- Excellent energy resolution
- Low-energy physics (<1 - 10s keV)



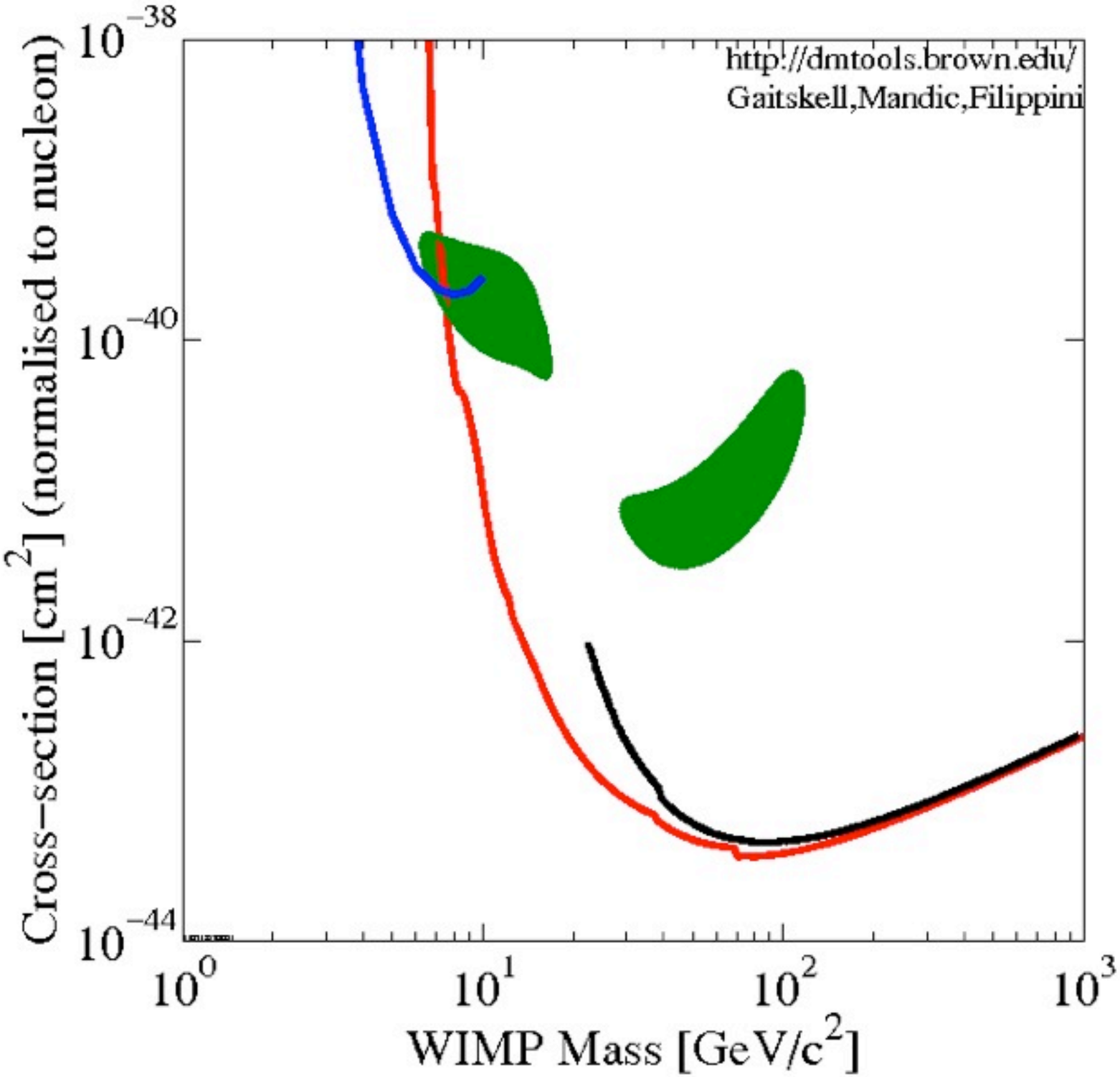

Aalseth, et al., PRL **101**, 251301 (2008)

# Dark Matter Limits

CDMS, 612 kg-d

CoGeNT, 8.4 kg-d

DAMA, 820 kg-yr,
3σ allowed region

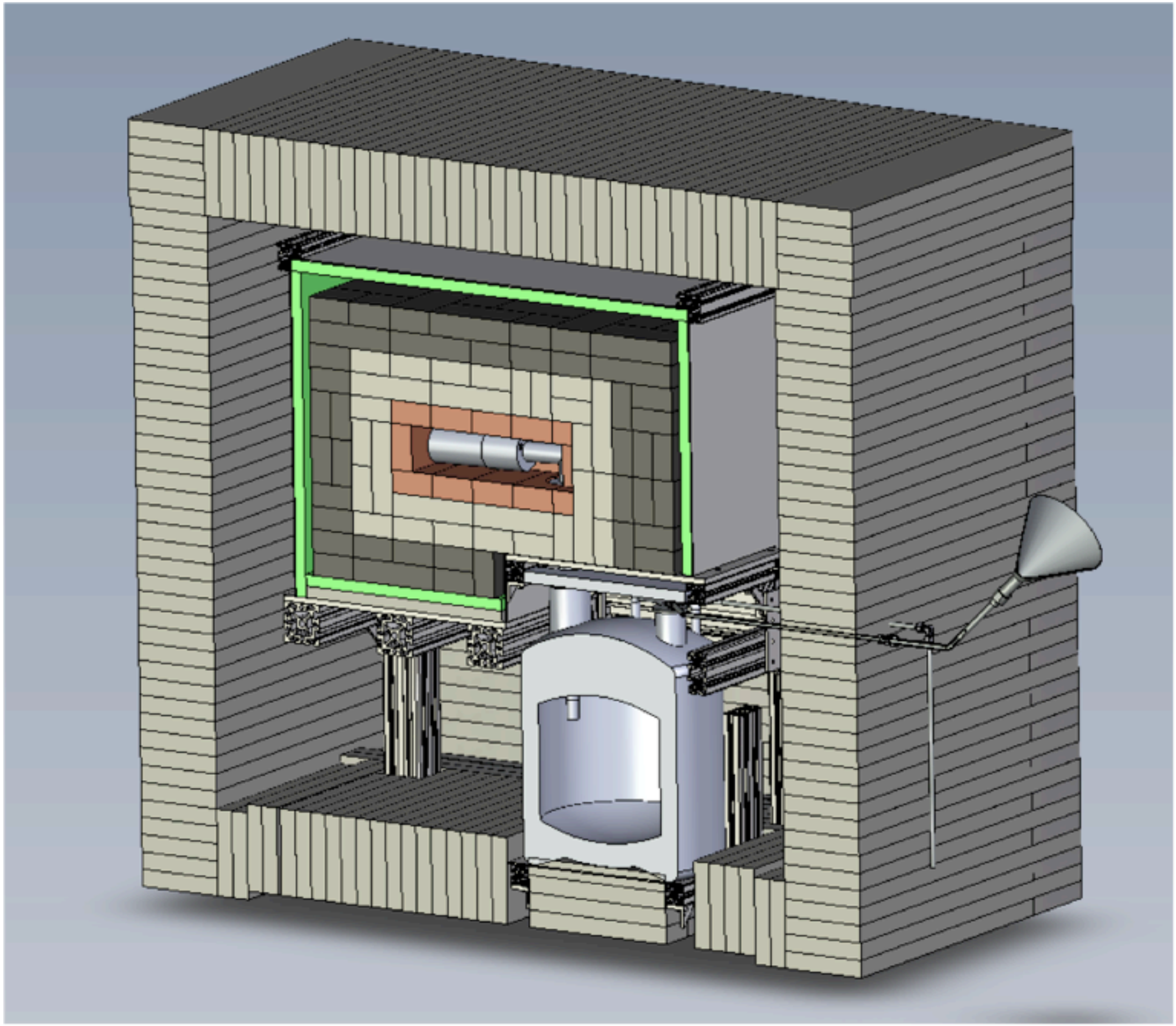



CDMS Collaboration, arXiv:0912.3592;
Aalseth, et al., PRL **101**, 251301 (2008);
DAMA Collaboration, EPJ **C56** (2008), 333, arXiv:0804.2741
Edelweiss-II, arXiv:1103.4070

# CoGeNT

## **Co**herent **Ge**rmanium **N**eutrino **T**echnology
## (and then Dark Matter)

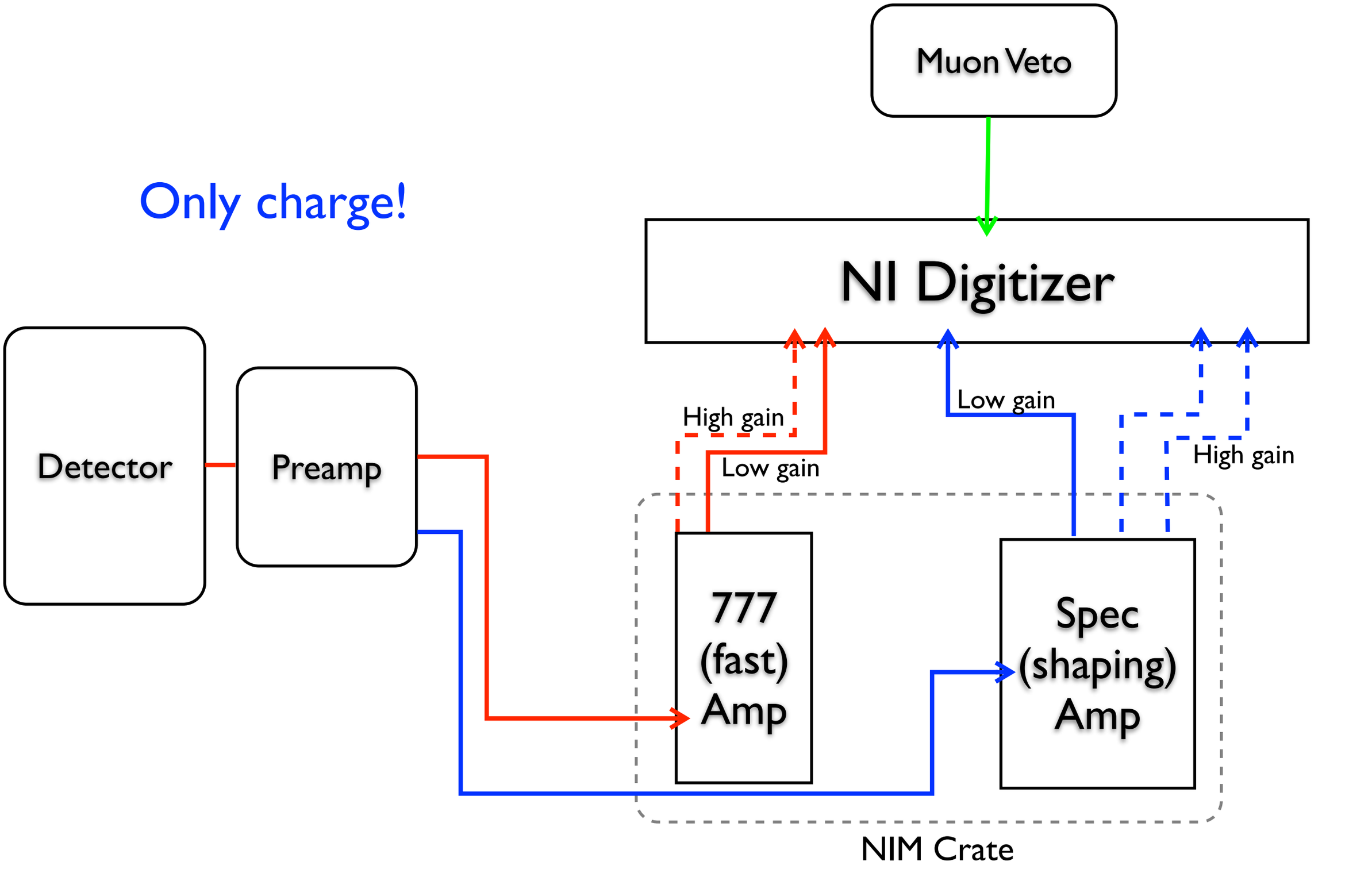
- 1st detector - DM(Tunnel and Reservoir Plan, TARP)
  PRL **101**, 251301 (2008)
- 2nd detector (R&D) - Soudan
- 3rd (current) detector (DM) - Soudan
  PRL 106, (2011) 131301

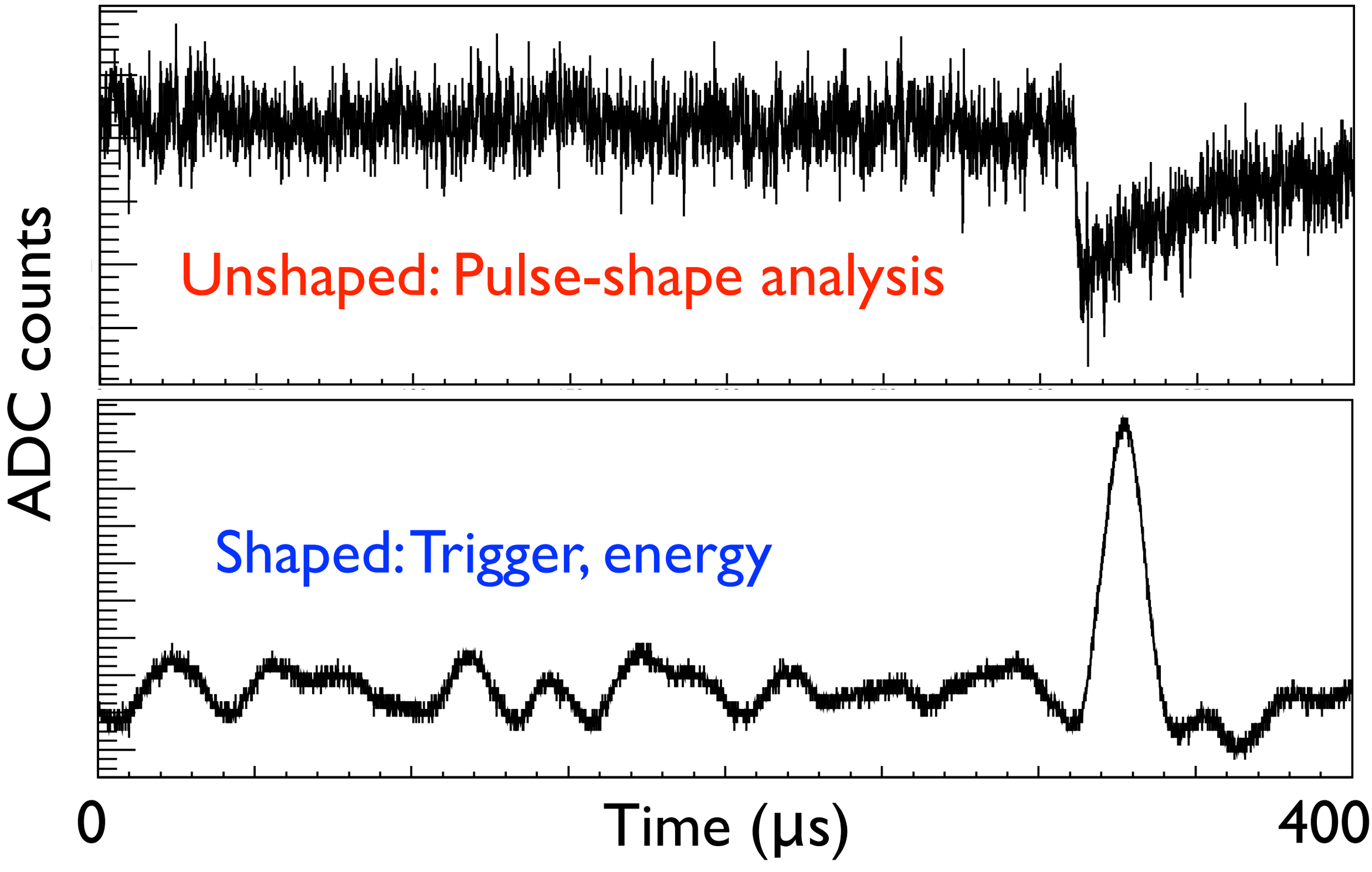


E. Fuller, J. Orrell

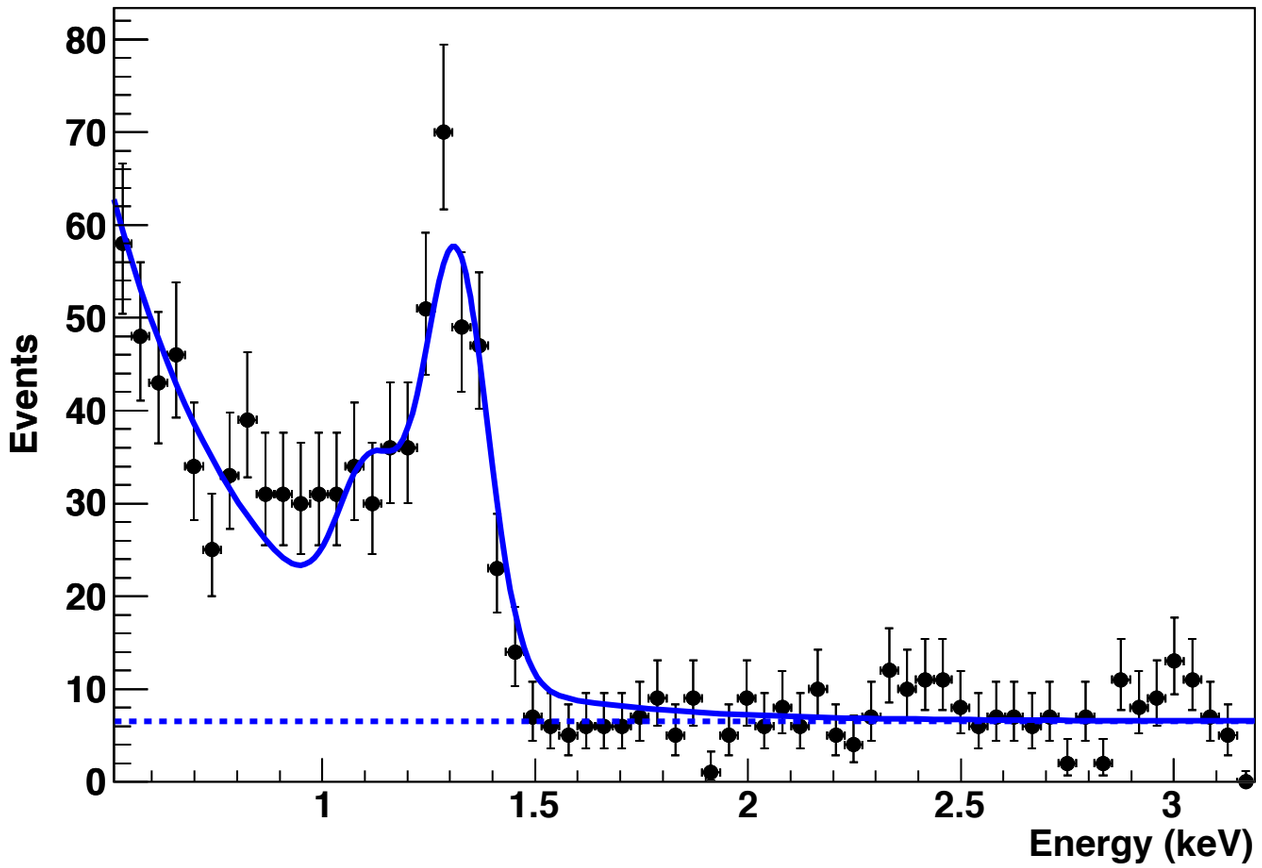
# What do we read out?

Only charge!



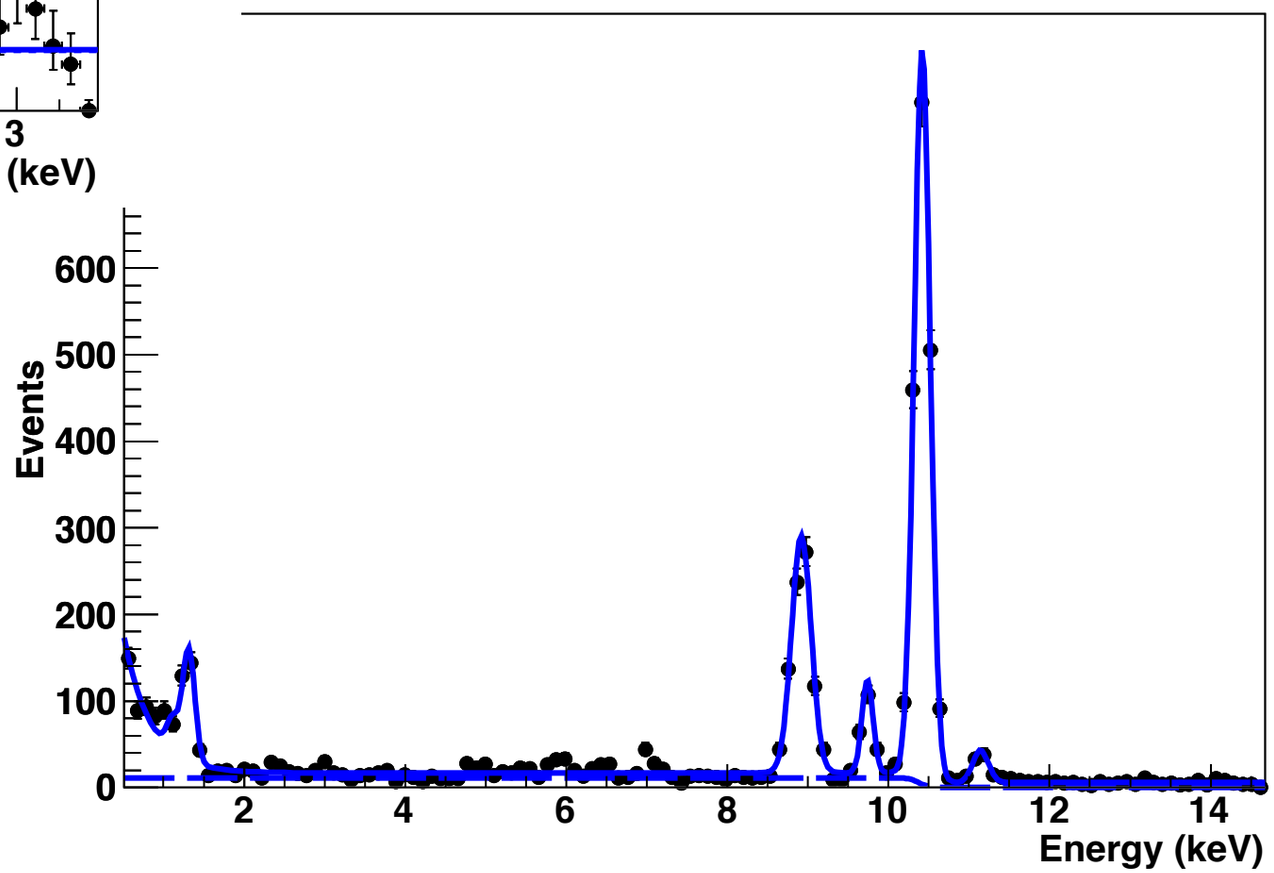

ADC counts
Unshaped: Pulse-shape analysis
Shaped: Trigger, energy
0
Time (μs)
400

# Data output




- Peaks in data arise from L-/K-electron-capture decays of cosmogenics
- Peaks are centered at the L/K characteristic energies of the daughter nuclei

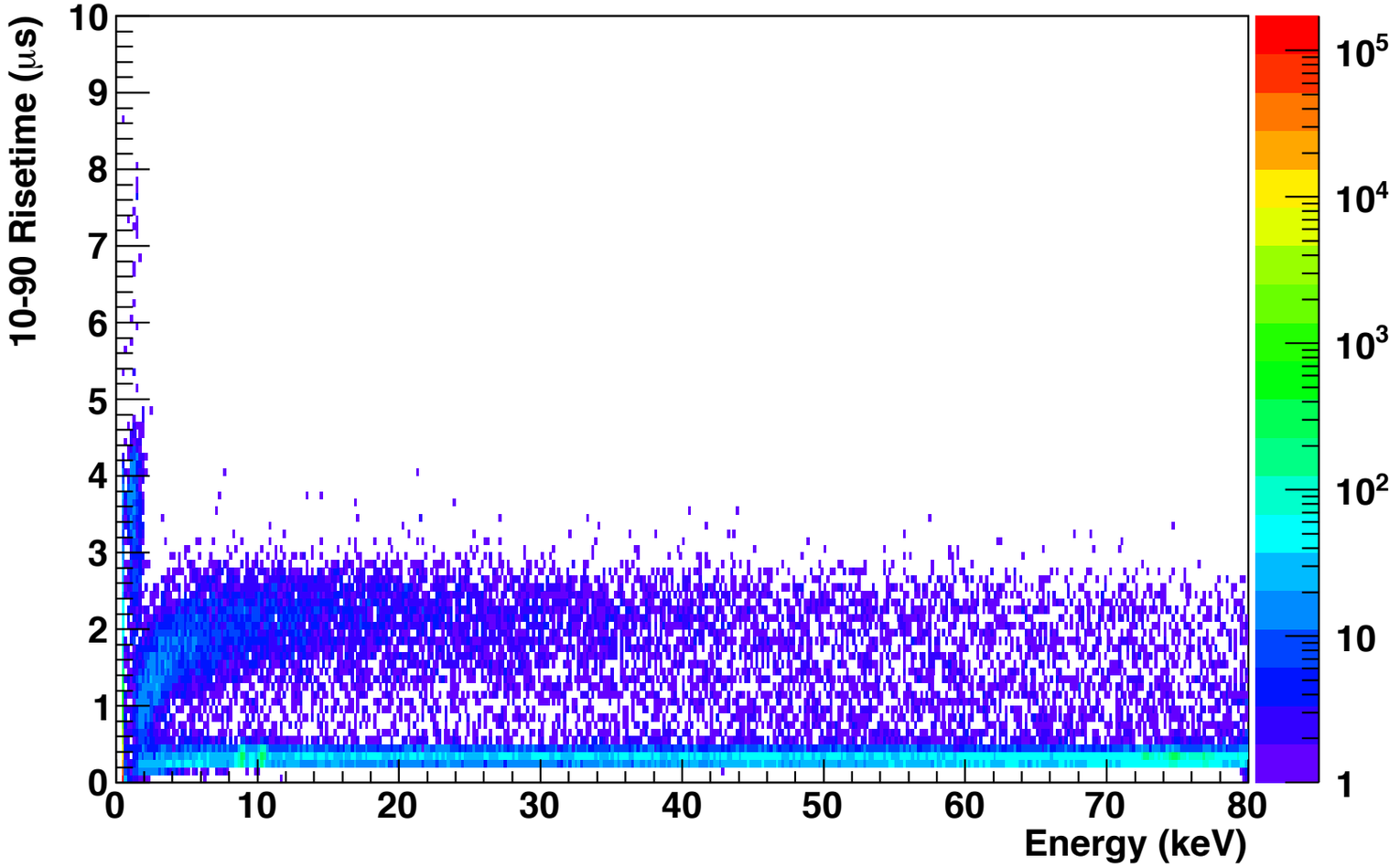
Two energy channels

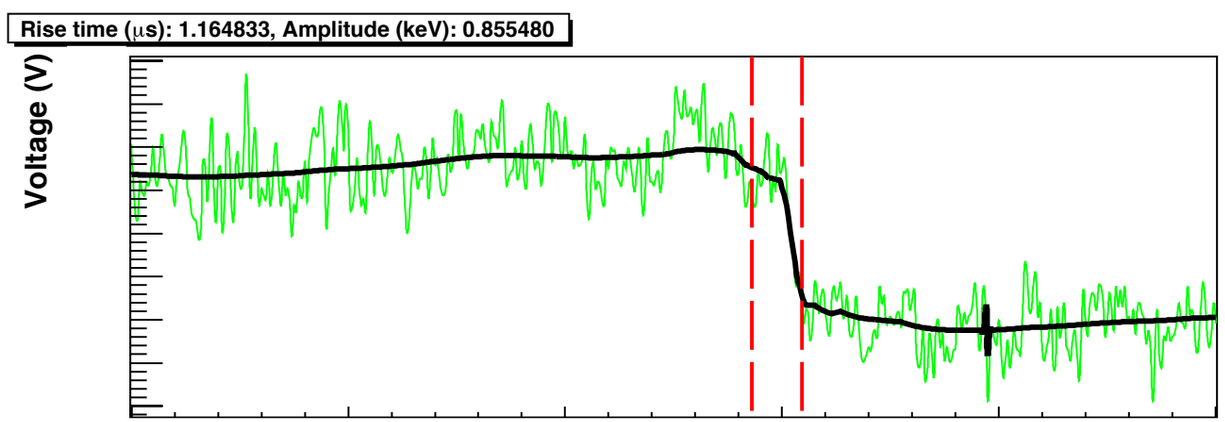


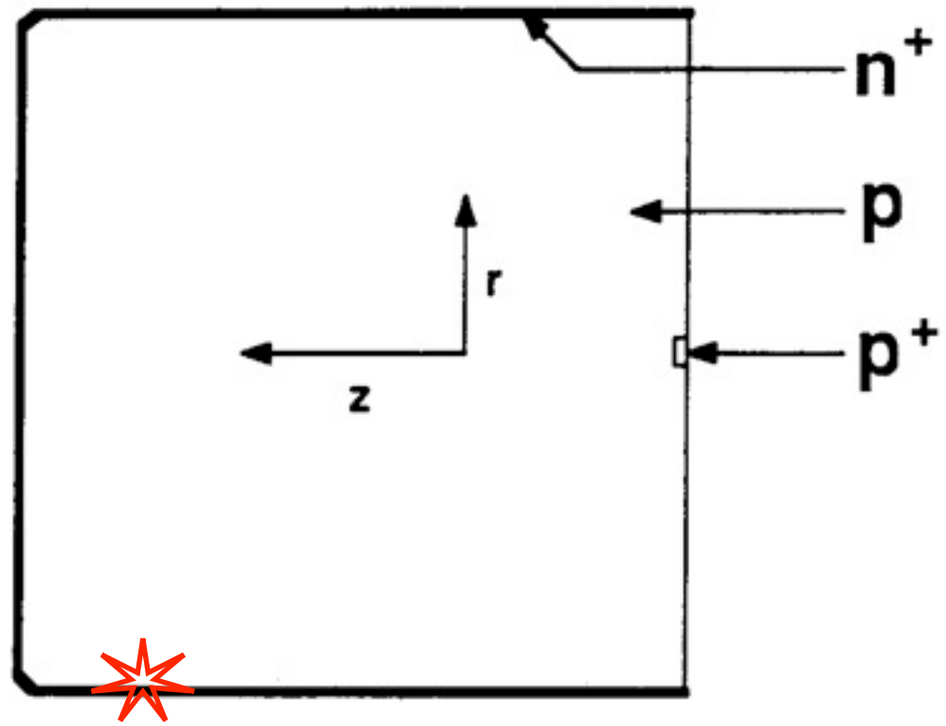
# Analysis cuts

- Three cuts:
  - Liquid Nitrogen fills
  - Microphonics cuts - analyze ratios of shaped channels (Morales, et al., NIM A **321** (1992) 410)
  - Rise-time cuts - Previous results indicated slow-pulse 'contamination'

# Rise-time vs. Energy




Incomplete charge collection near the dead layer

# Extracting Physics

- Energy spectrum (e.g. WIMP exclusion)
  - PRL **106**, (2011) 131301.
- Time (+ energy) spectrum, look for modulation
  - Subtraction analysis (U Chicago)
  - 2-D ML fit analysis (U Washington)

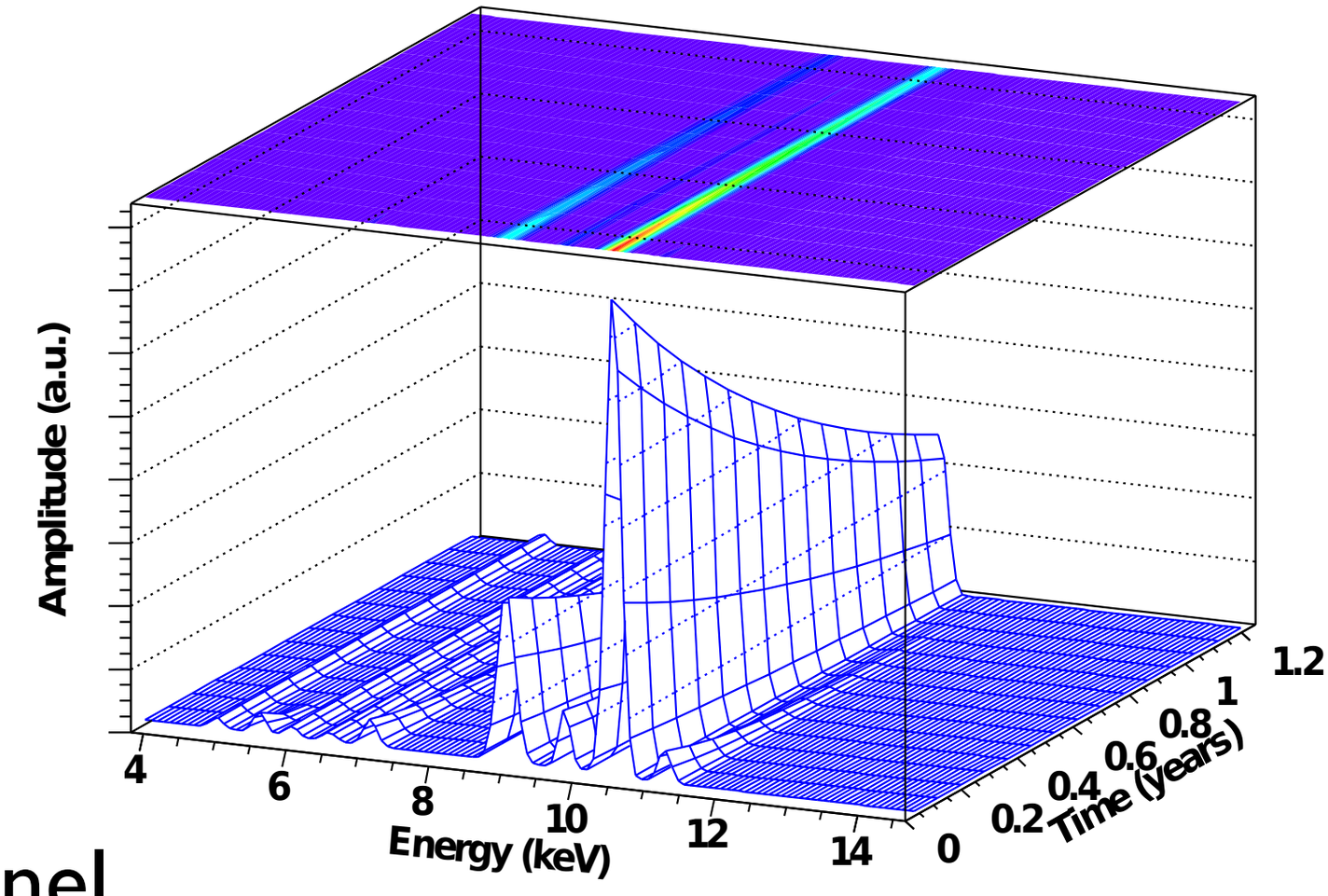
# Data set

- 4 Dec 2009 - 6 Mar 2011 (just before Soudan fire)
- 442 live days, 458 days span
- 3 periods of down time (lab-scheduled maintenance)

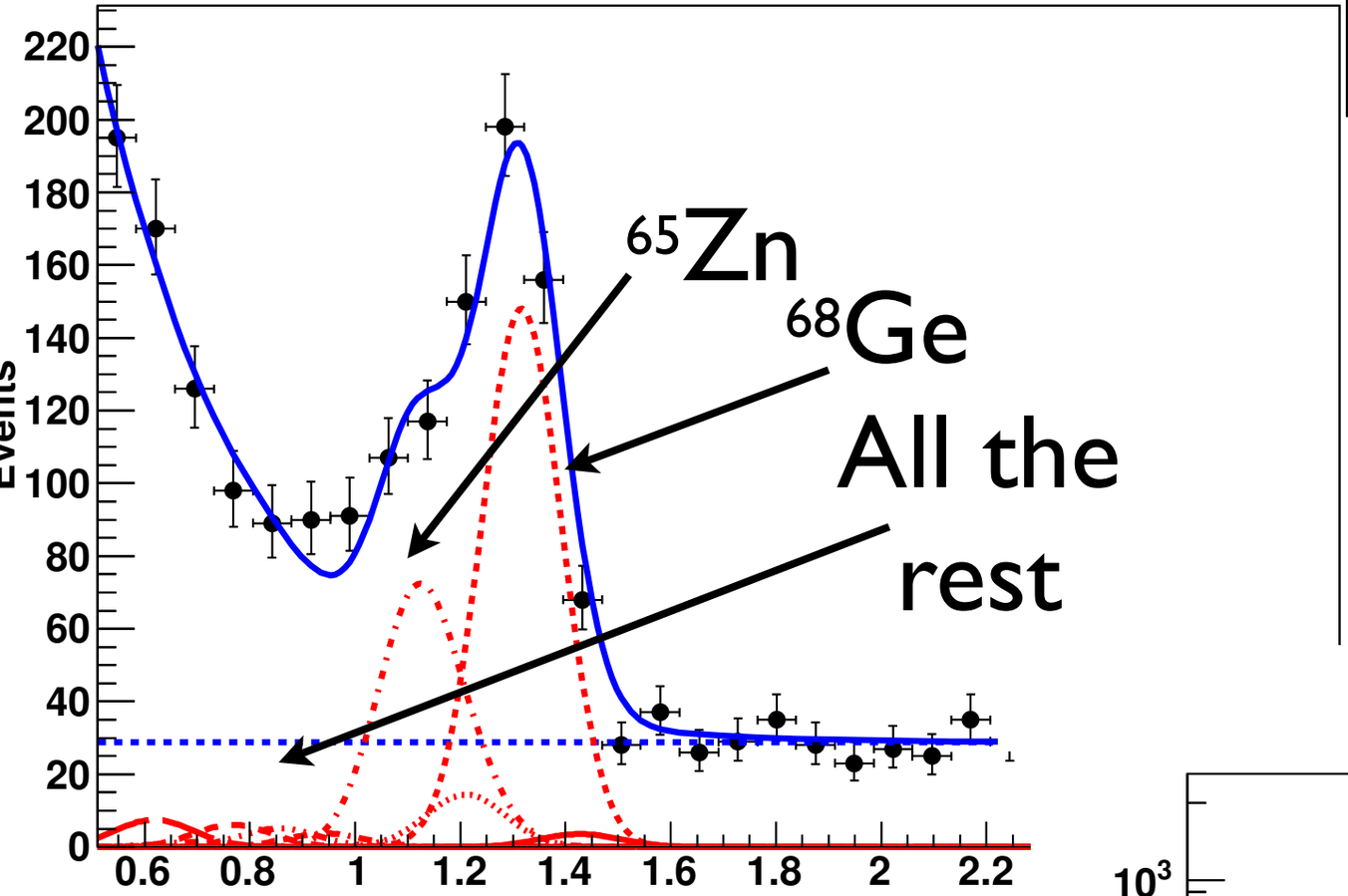

Steam rose from the fire in the mine shaft at the Soudan Underground State Park that started March 17. (MPR Photo/Derek Montgomery)

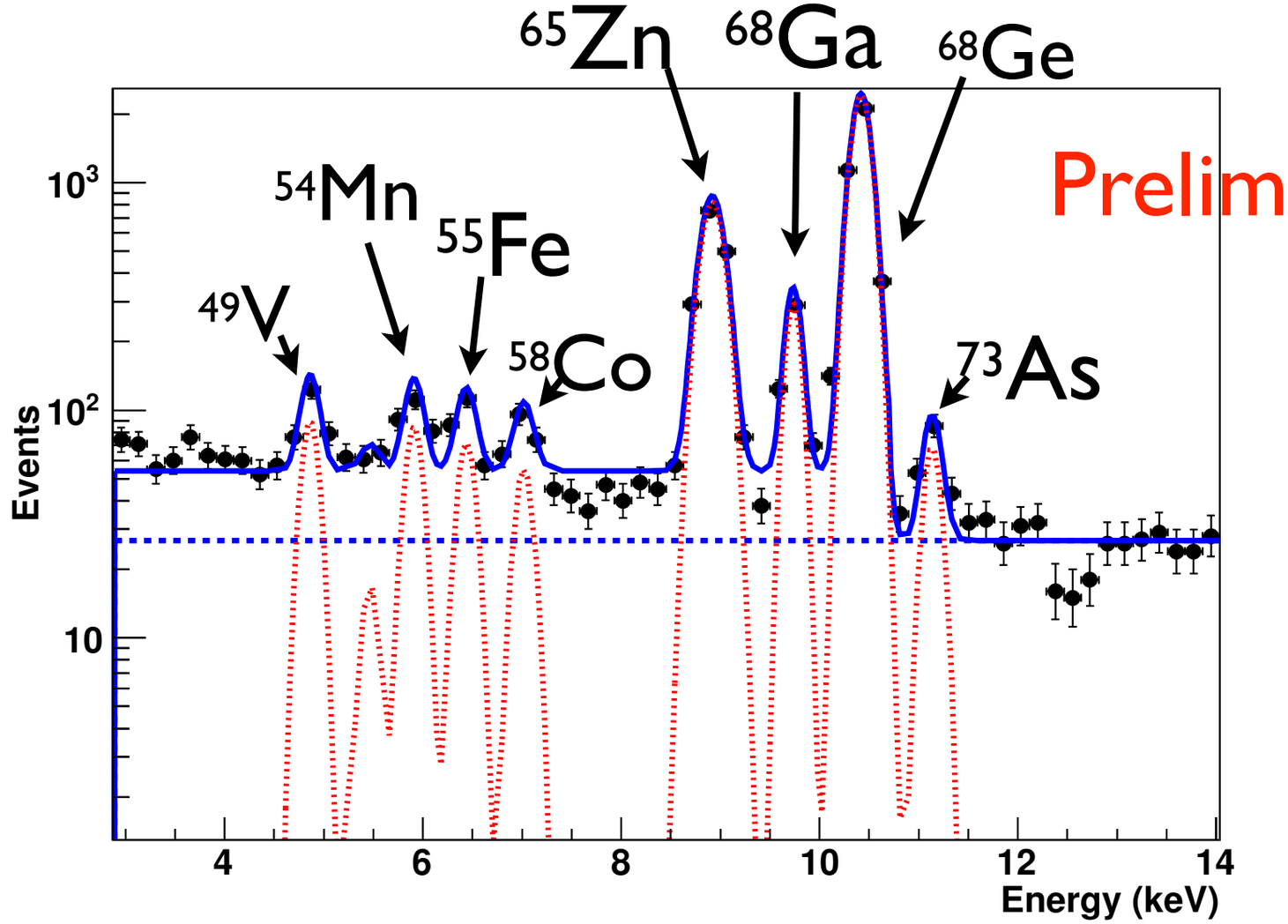
# Time analysis

- 2-D time vs. energy analysis across both channels
- Constrain L/K electron-capture peaks by their well-measured ratios
- Add floating oscillation PDF in low-energy channel

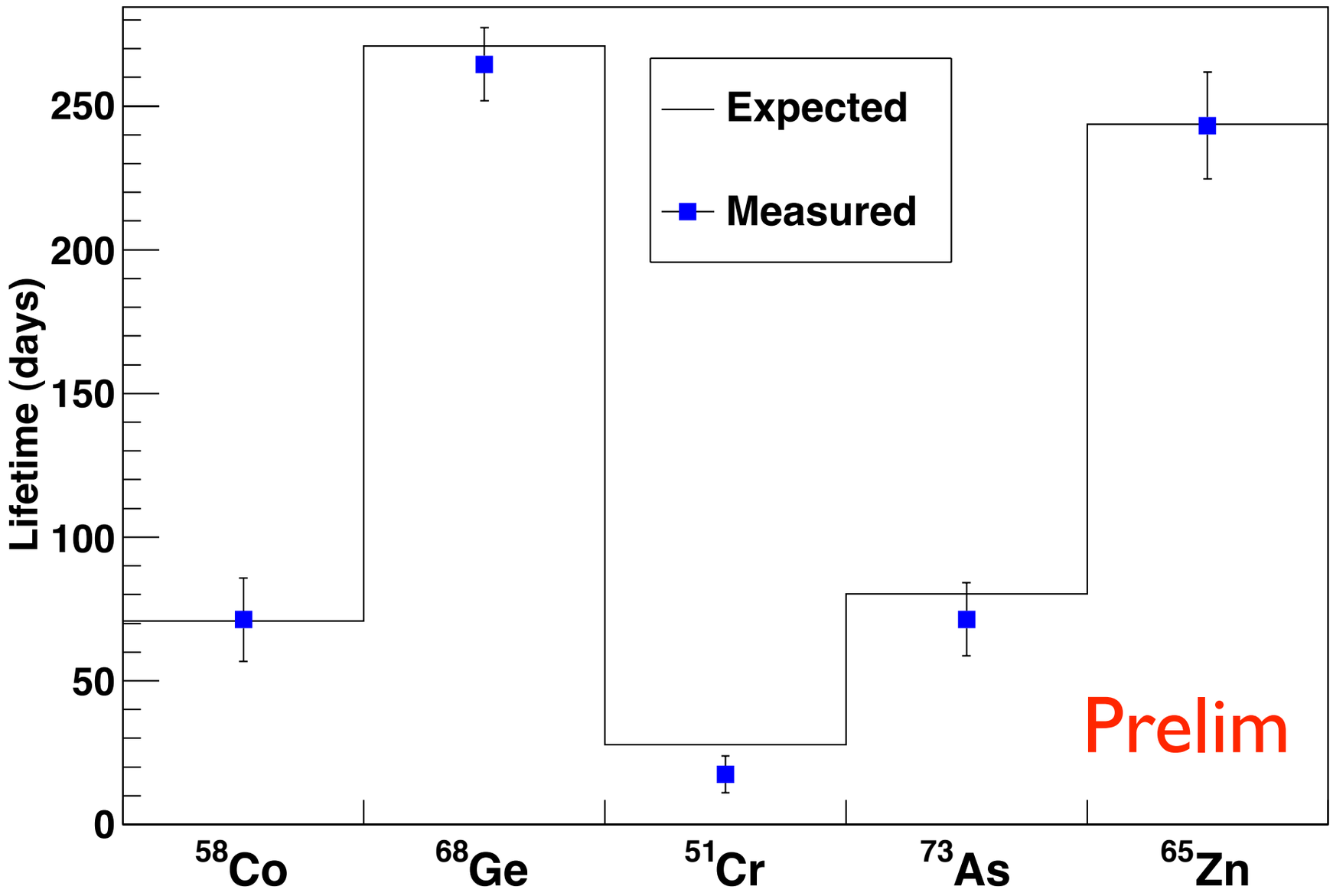


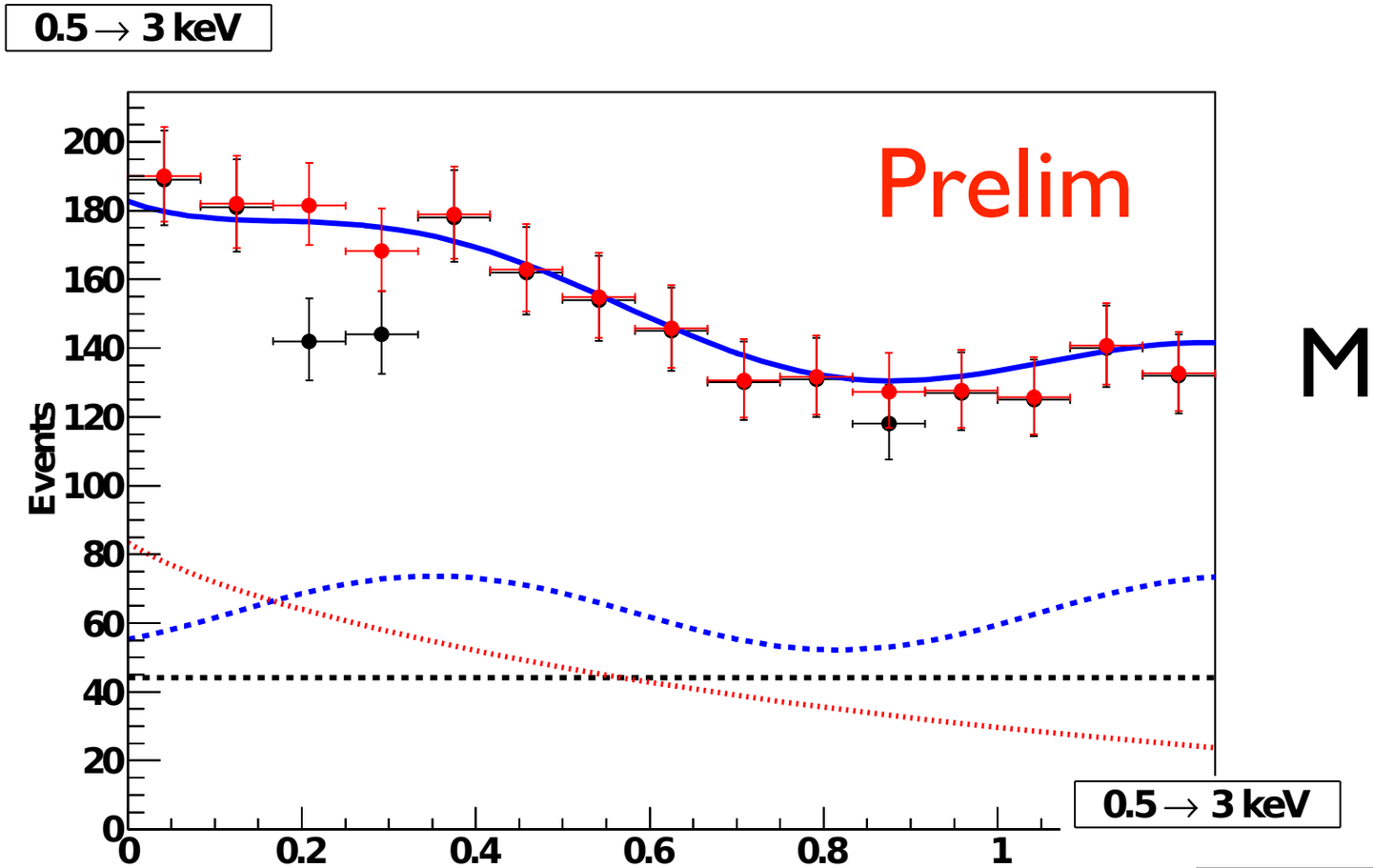
# Energy Channel



# Lifetimes


Lifetime (days)
250
200
150
100
50
0
Expected
Measured
Prelim
58Co
68Ge
51Cr
73As
65Zn



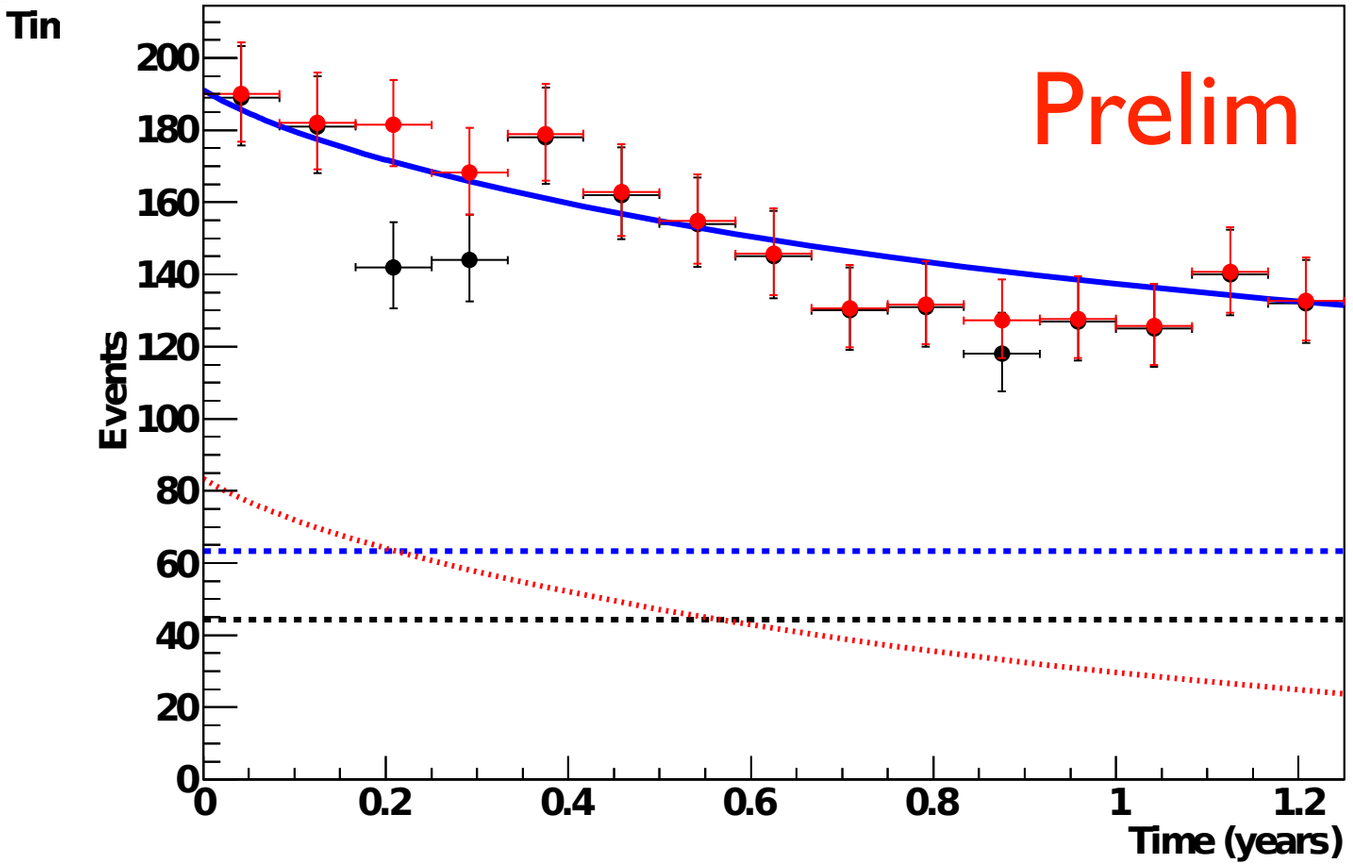

Time channel

Model with Oscillation

Raw data

Livetime corrected

NULL Model

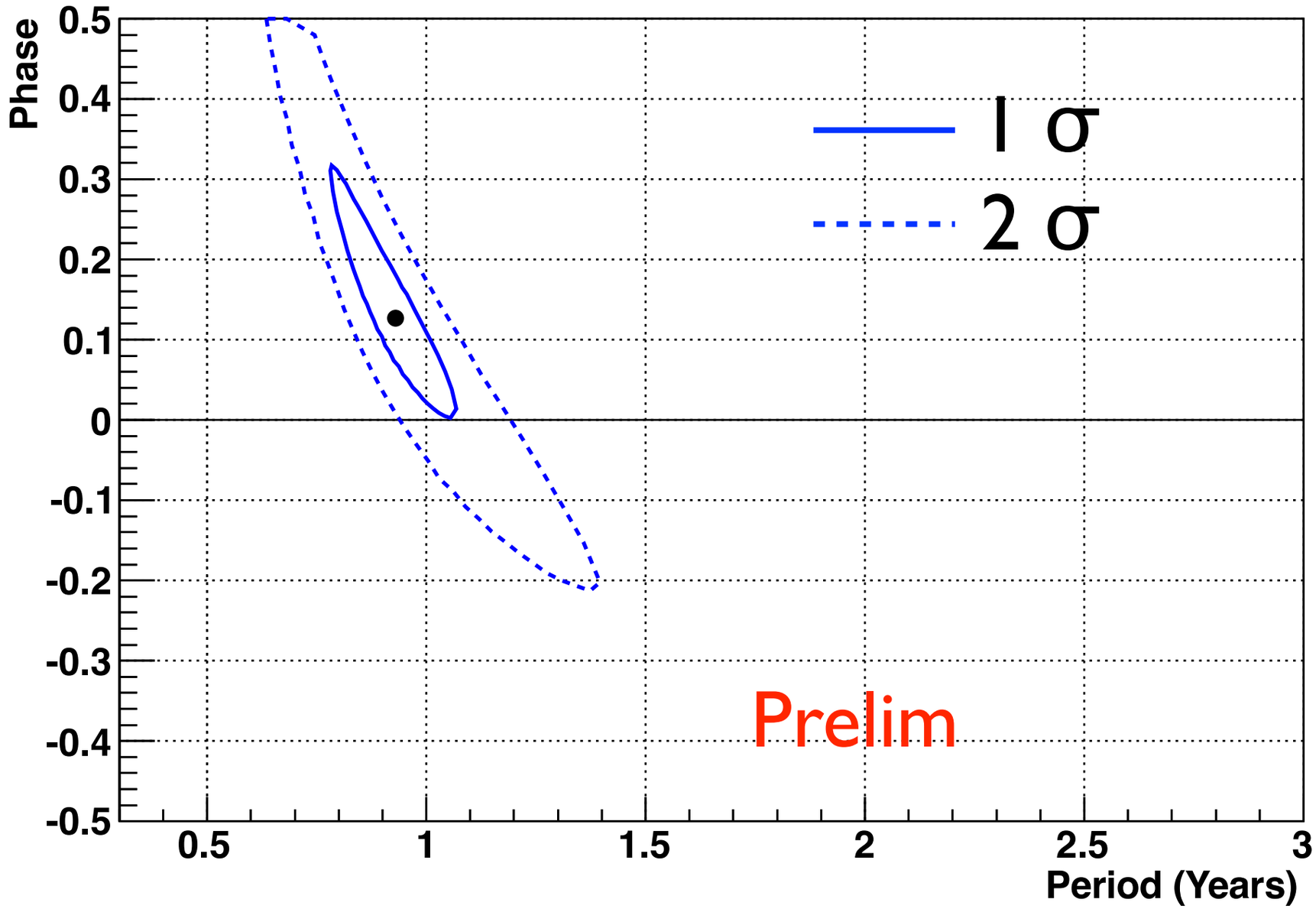


# Phase vs. Period

Best fit point:

Phase: 49.9 d
(Min ~23 Oct)

Period: 339.5 d



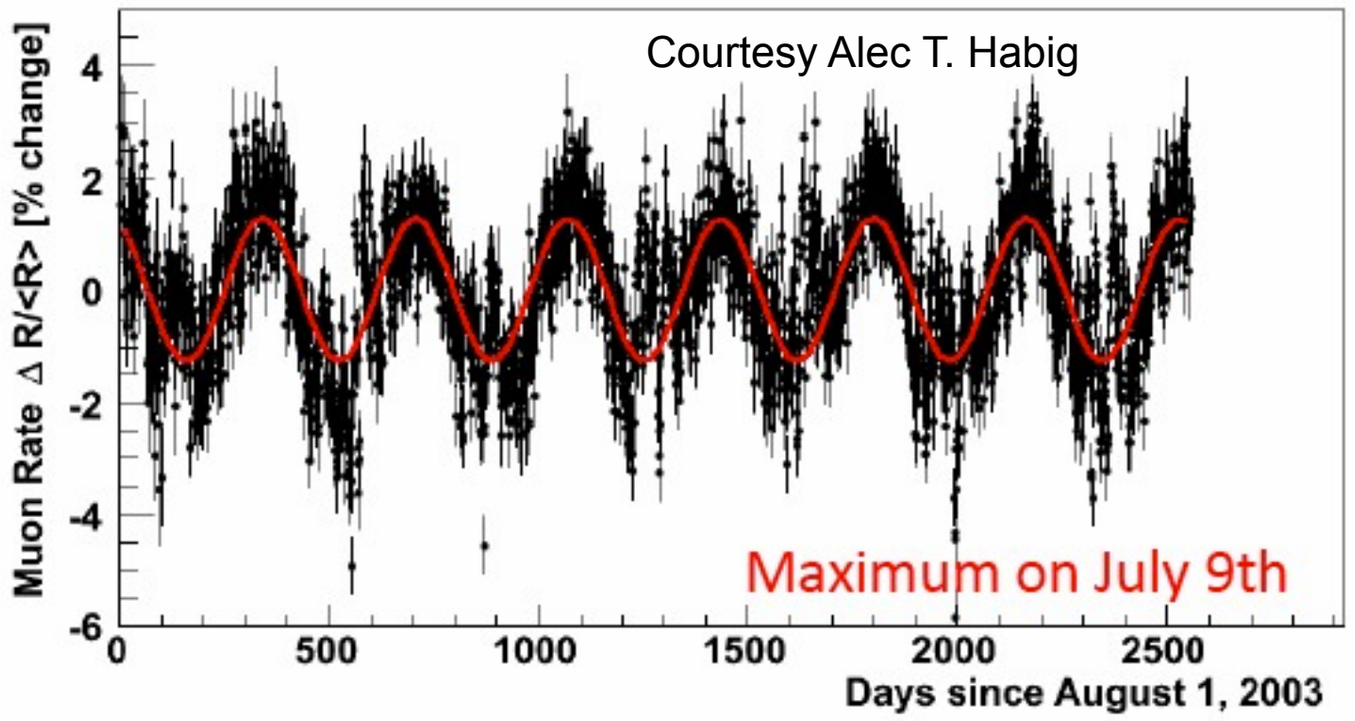
# Fit summary

- ML fit
  - Min 23 Oct, Period: 339.5 d,
    Ampl: 17.7 ± 6.5 %, significance 94.6%
- Subtraction (PRL 107 (2011) 141301)
  - Min 16 Oct ± 12 d, period 347 ± 29 d,
    Ampl: 16.6 ± 3.8 %, significance 99.4%

# Muon modulation

- MINOS muon flux modulation measured in Soudan
  - Approximately +/-1.5%
  - Peaks three months after best fit to present CoGeNT data.
  - A 1.5% modulation of the estimated 339 +/- 68 muon-induced events in shielding predicts a modulation of 5 events in the 0.5-3 keVee energy range

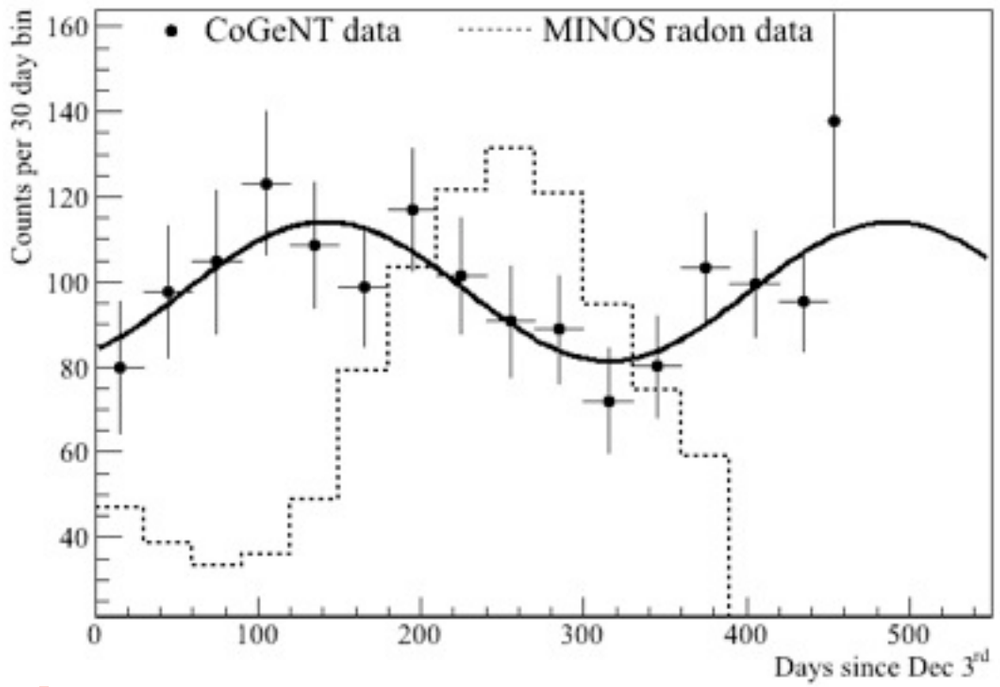
- The CoGeNT data set contains 2124 events in the 0.5-3 keVee energy range. **A 5 event modulation of muon induced events could only produce a 0.2% modulation effect in the CoGeNT data set.**




Slide: M. Kos, PNNL

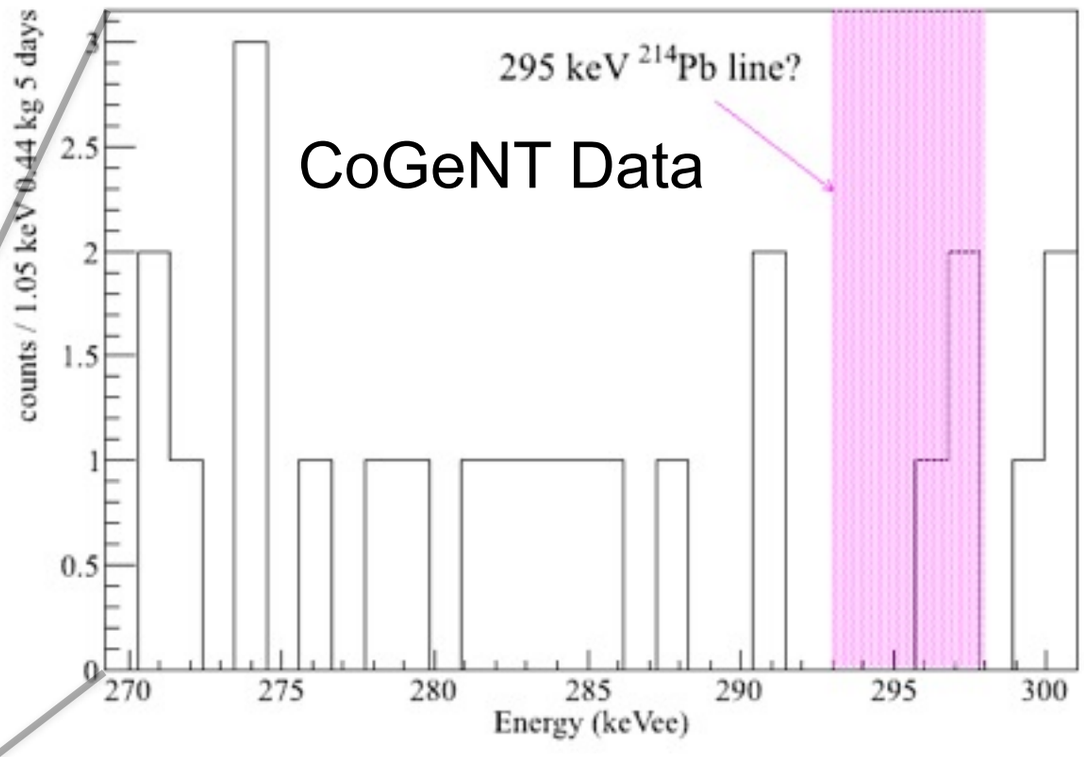
# Radon Modulation

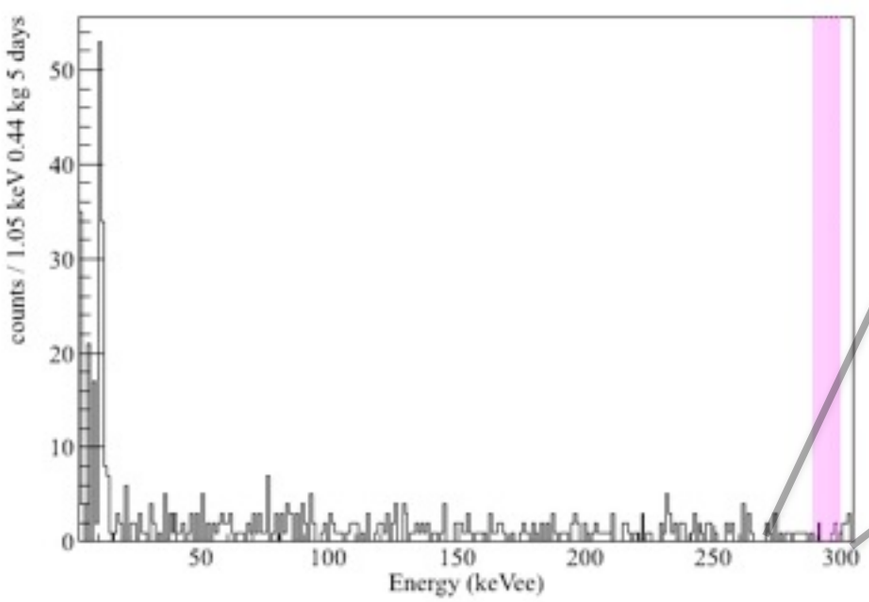
- Radon levels modulate underground – Measured by MINOS
  - Modulation out of phase!




- Also: Look at data out to 300 keV
- Infer the maximum number of events due to Rn in the data
- **2.8 events in 0.5 – 3.0 keV**

Prelim




Slide: M. Kos, PNNL

# Summary

- Recent CoGeNT data consistent with an annual modulation at low energies, PRL 107 (2011) 141301, this is confirmed by two fully independent analyses
- Background analyses suggest muons and Rn can **not** account for this modulation, still investigating other possibilities
- Longer paper in preparation detailing analysis
- Detector **is** back up and running, data not yet analyzed

# CoGeNT collaboration

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T.W. Hossbach,[1,2] M.E. Keillor,[1] J.D. Kephart,[1] A. Knecht,[4] M.S. Kos,[1] M.G. Marino,[4]
H.S. Miley,[1] M.L. Miller,[4] J.L. Orrell,[1] D.C. Radford,[5] J.F. Wilkerson,[6] and K.M. Yocum[3]
(CoGeNT Collaboration)

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[5]*Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA*
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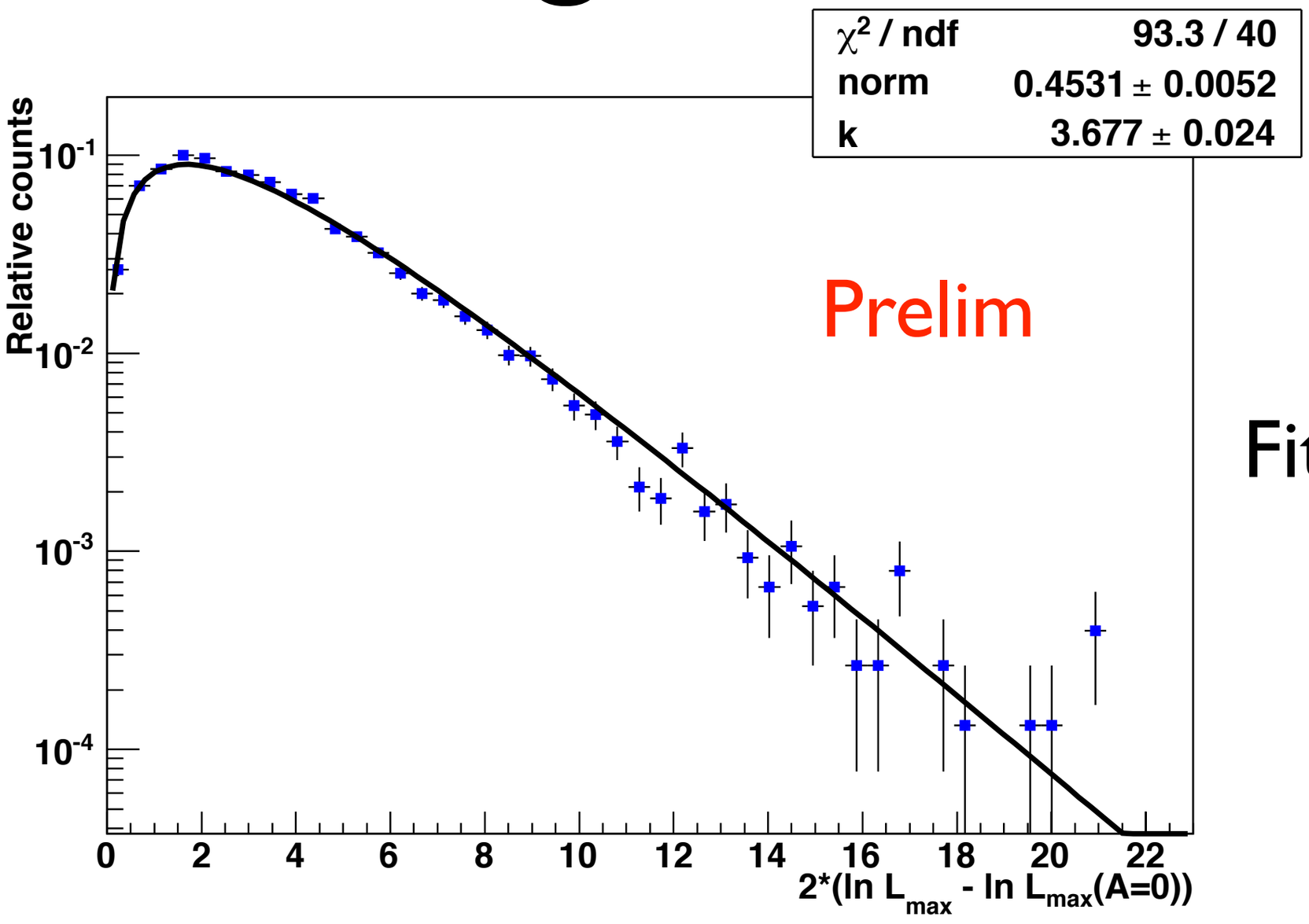
# Extra Slides

# Significance

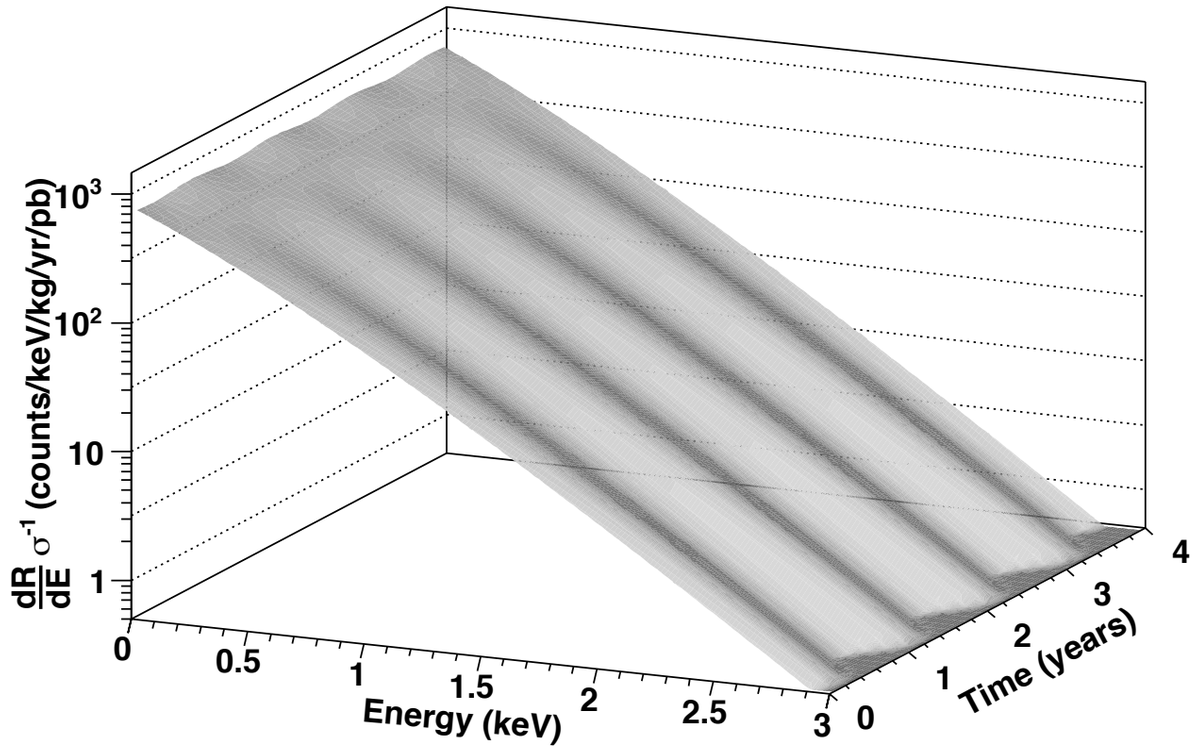



Fit to χ2 dist

- Generate many toy models of NULL hypothesis, fit to signal + background, calc: $2\left(\log L(B)_{max} - \log L(B=0)\right)$

# Analysis Tools

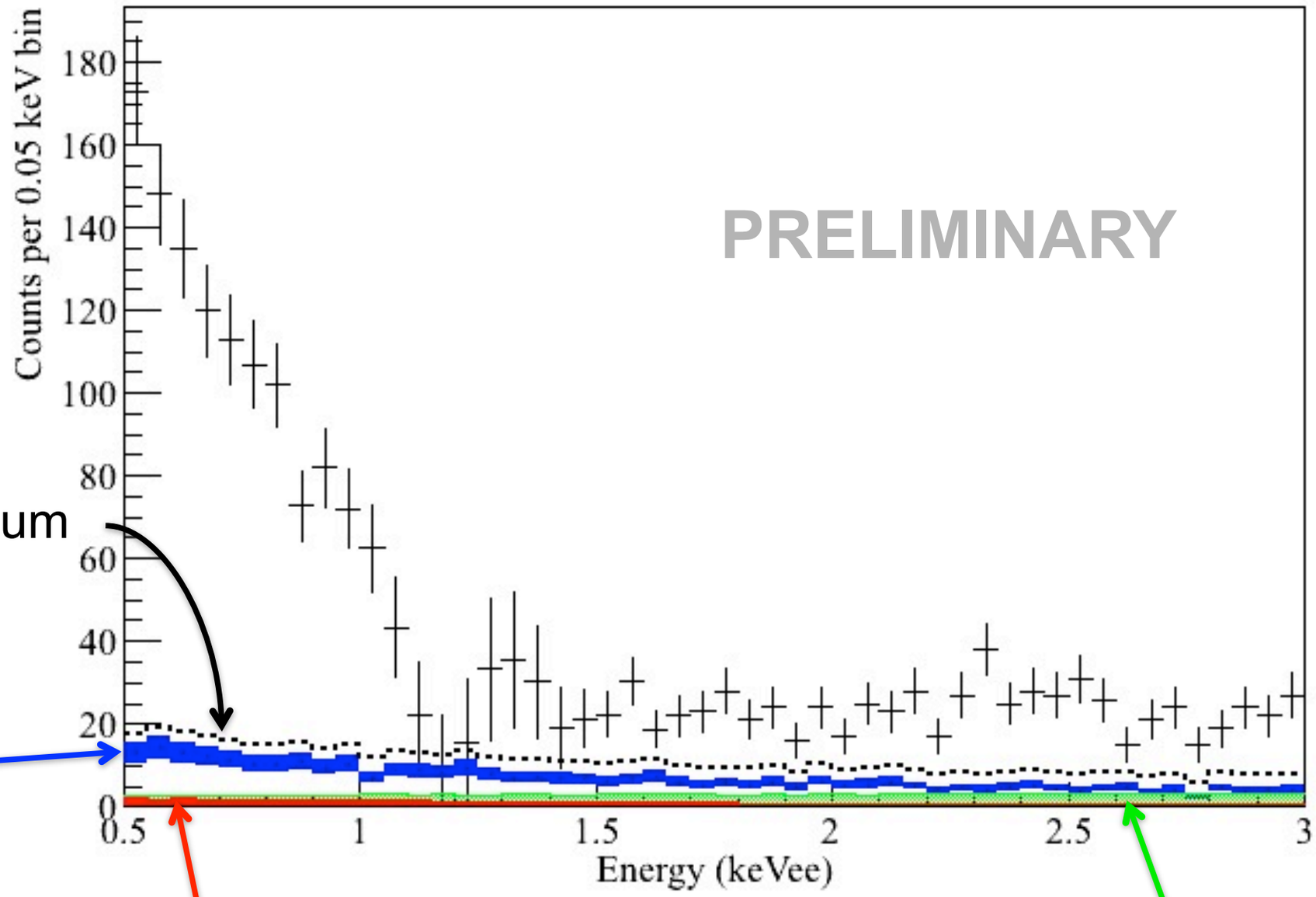
- pyWIMP - Extensions to RooFit for 1-,2-D (Energy/Time) DM fitting
- Tools - Generic oscillations, WIMP models, efficiently deal with data-taking gaps
- Available: http://github.com/mgmarino/pyWIMP




2-D PDF of 10 GeV WIMP in Ge

# Background estimates

# Backgrounds in low-energy region (0.5 – 3 keVee)

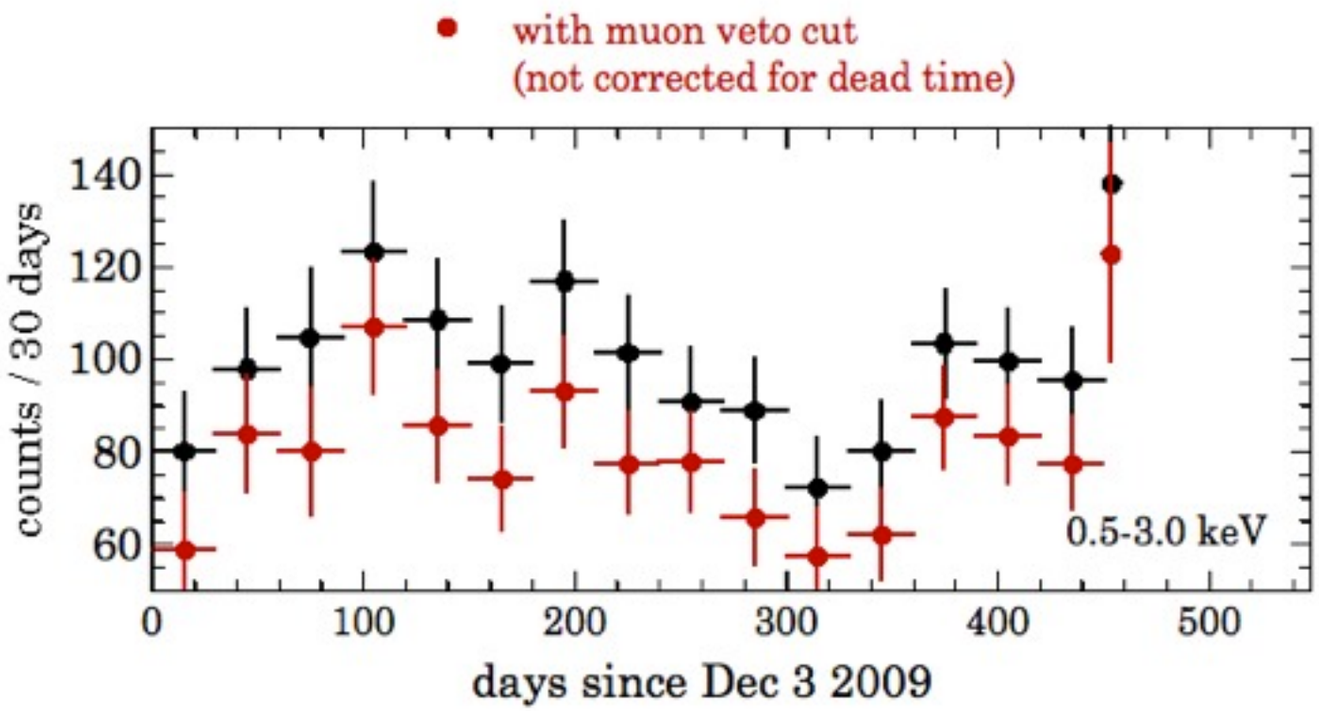


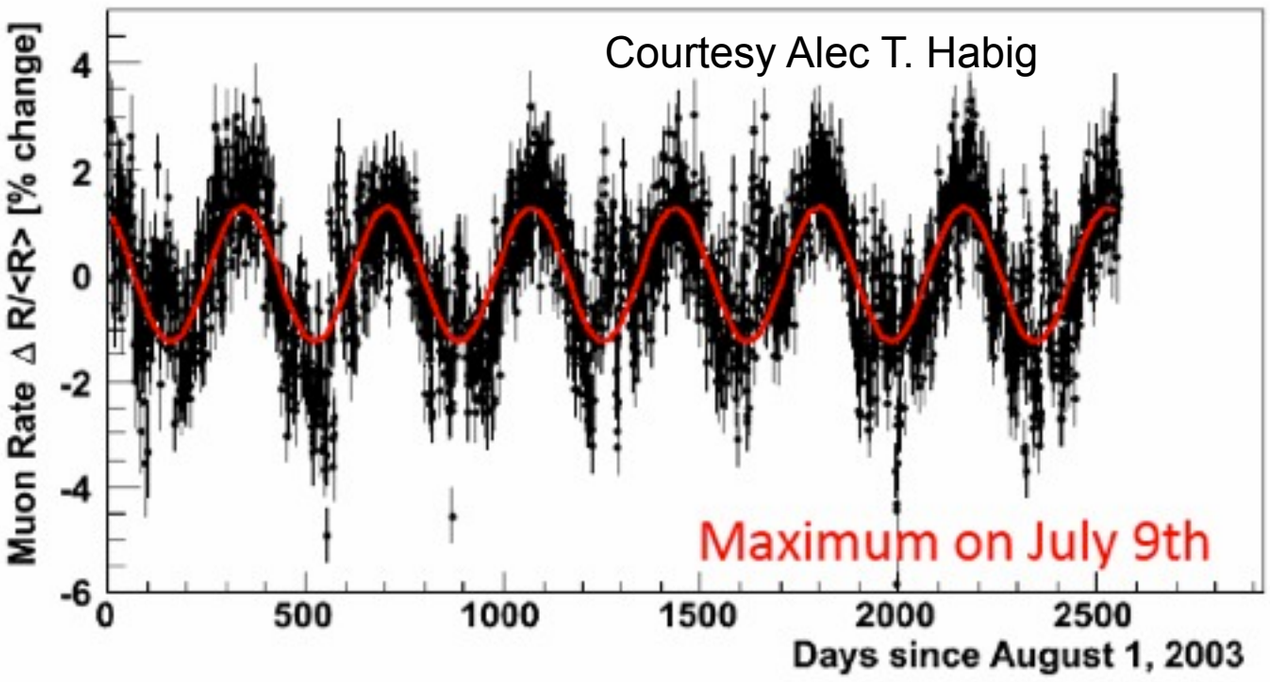

Slide: M. Kos, PNNL

# Muon-induced neutrons temporal variation

PRELIMINARY

- Muon veto cut is not applied in modulation analysis
  - Veto does not change energy spectrum after dead time correction
  - Veto efficiency fluctuations might lead to false modulation
- Applying muon veto does not remove the modulation
  - Just reduces event range
- MINOS muon flux modulation measured in Soudan
  - Approximately +/-1.5%
  - Peaks three months after best fit to present CoGeNT data.
  - Including simulated muon-induced neutron component lessons the ~1.5% muon modulation

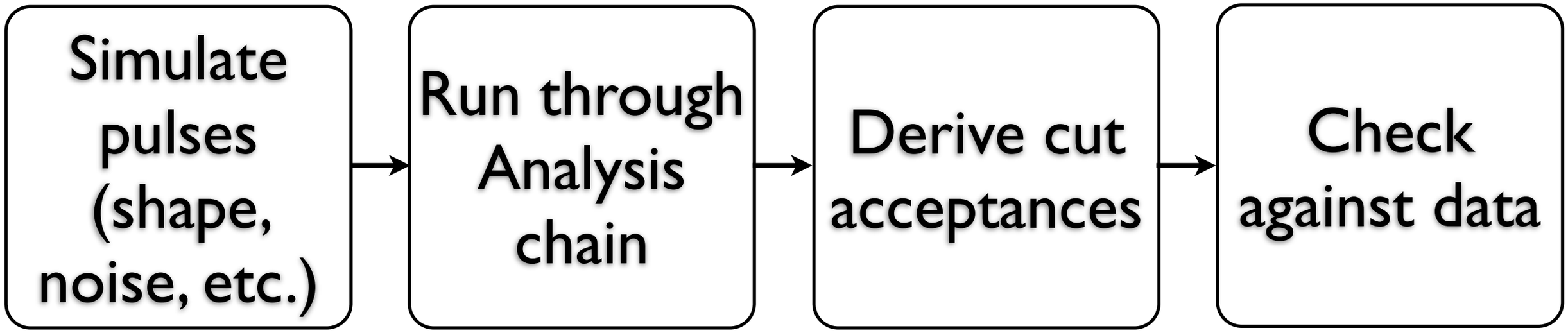



Slide: M. Kos, PNNL

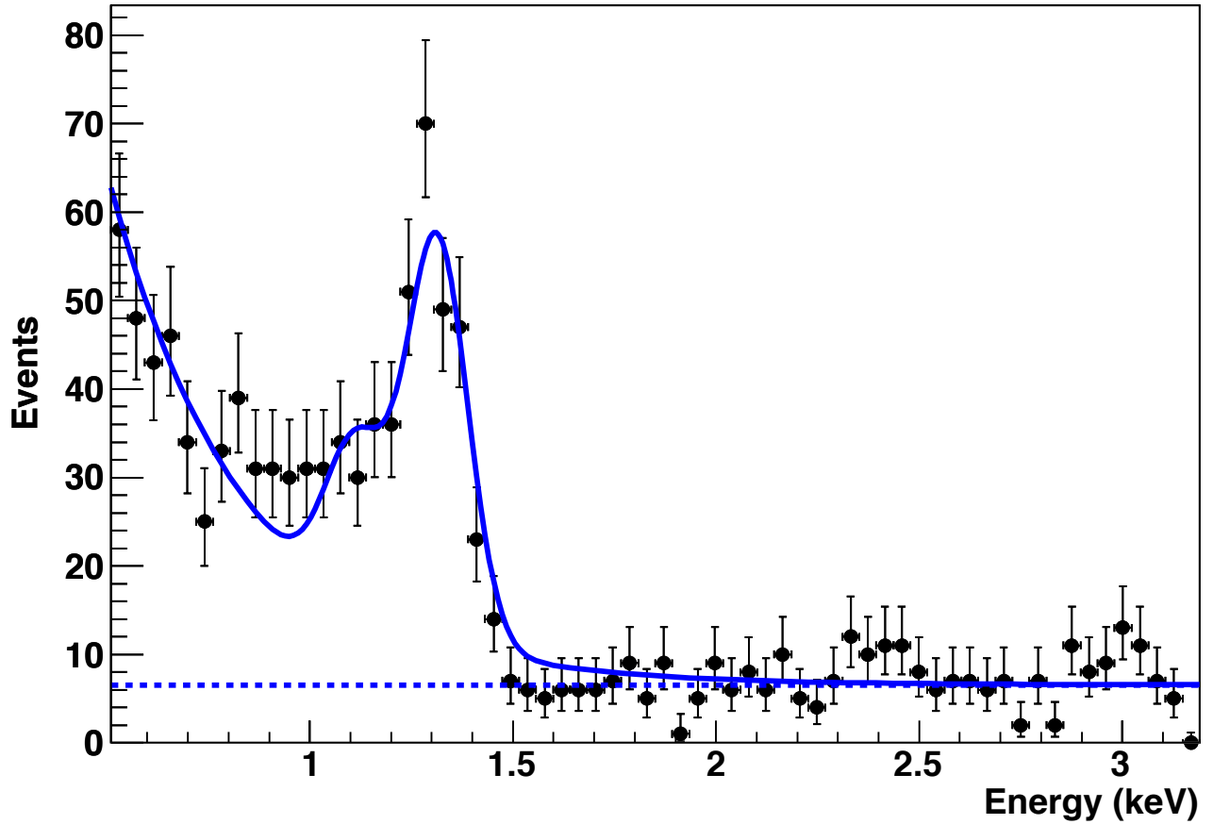
# Rise-time Studies

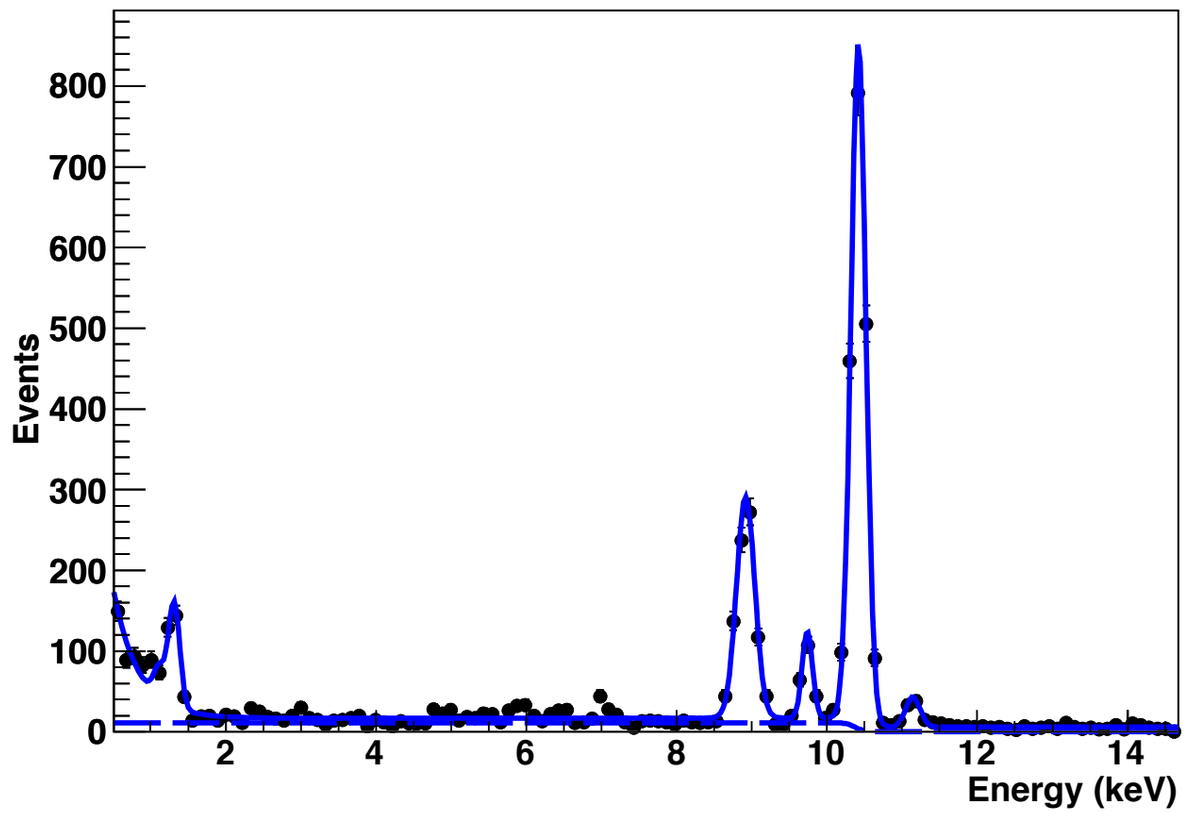
# Rise-time studies, estimating efficiencies



# Check cut against data

- Take cut
- Fit spectrum (peaks + exponential + flat background)
- Extract component amplitude information



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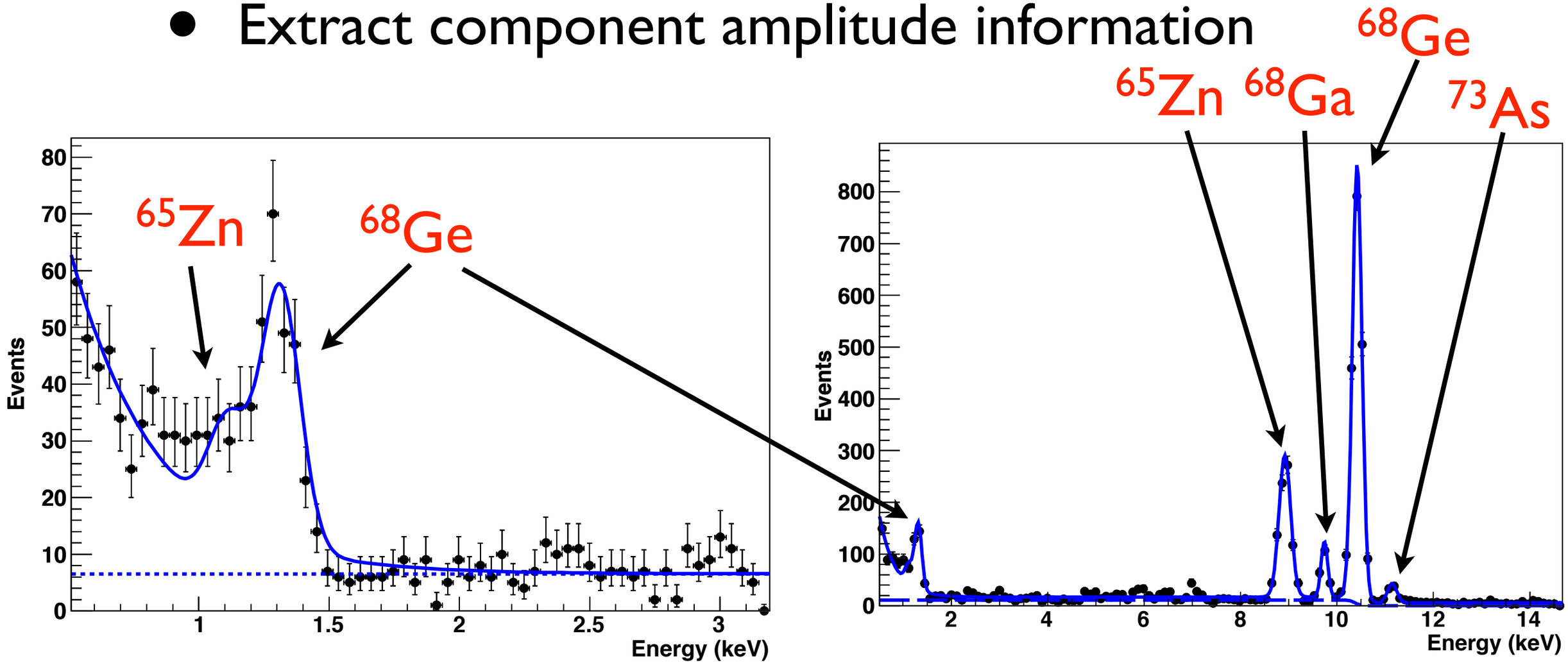

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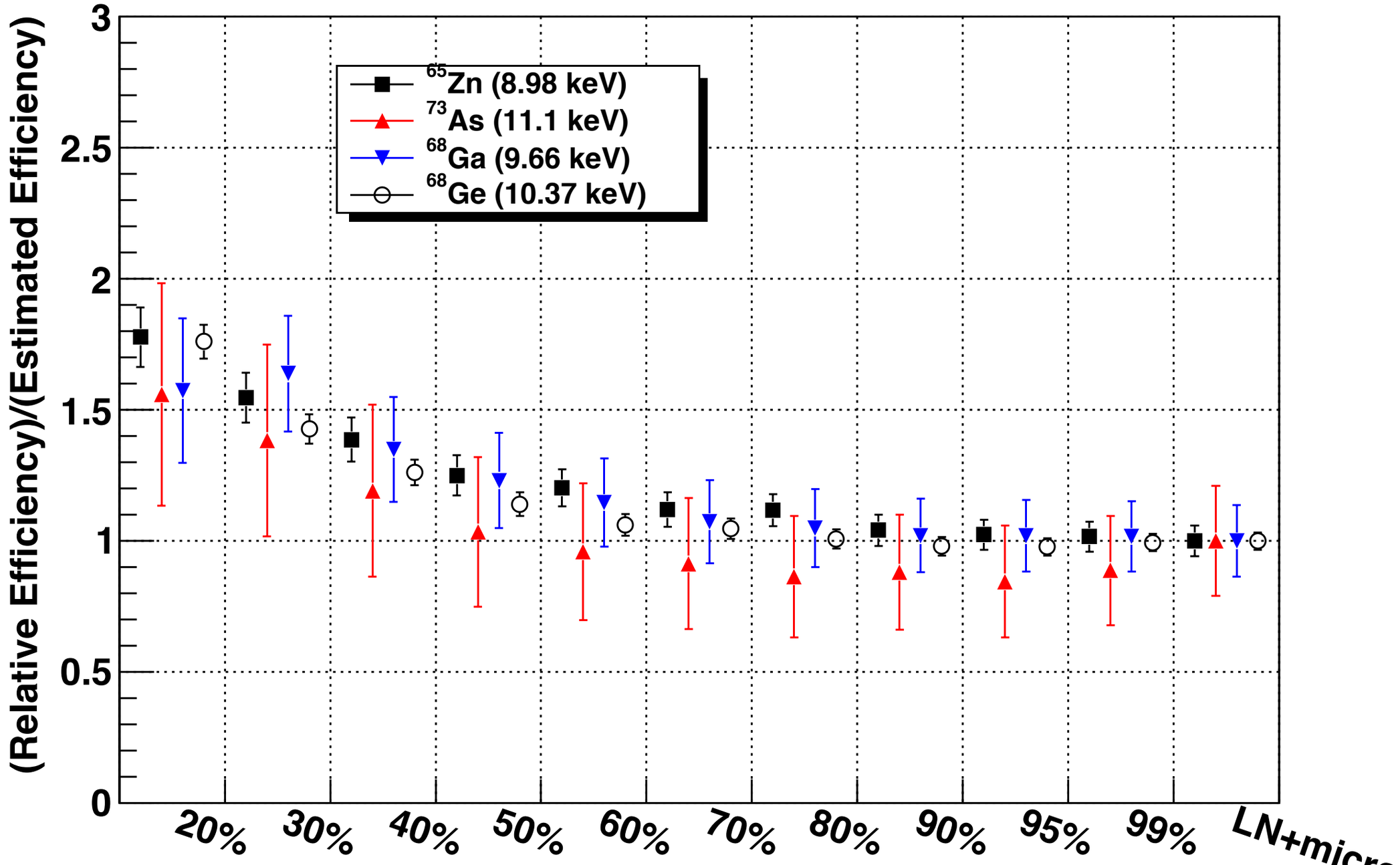

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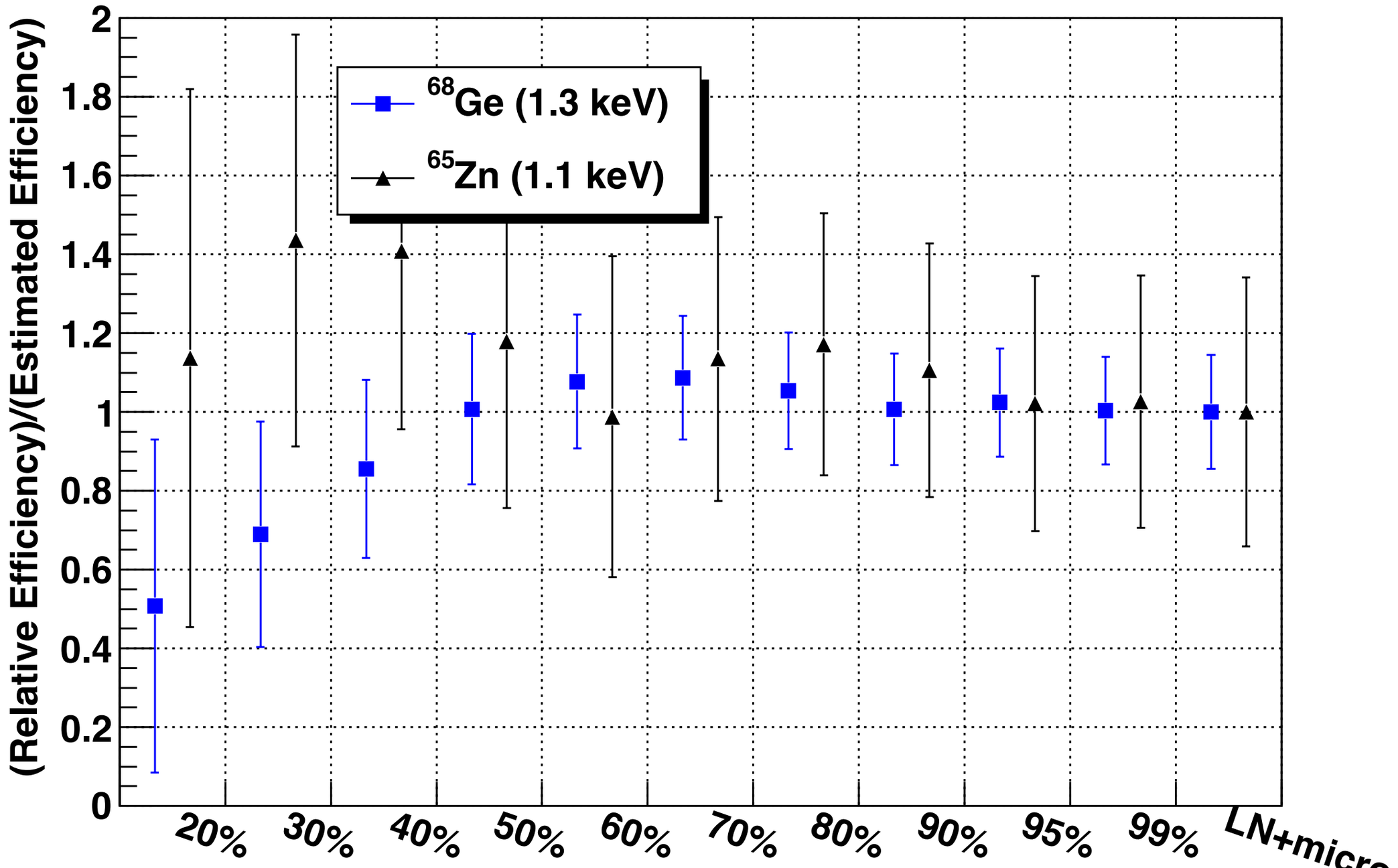

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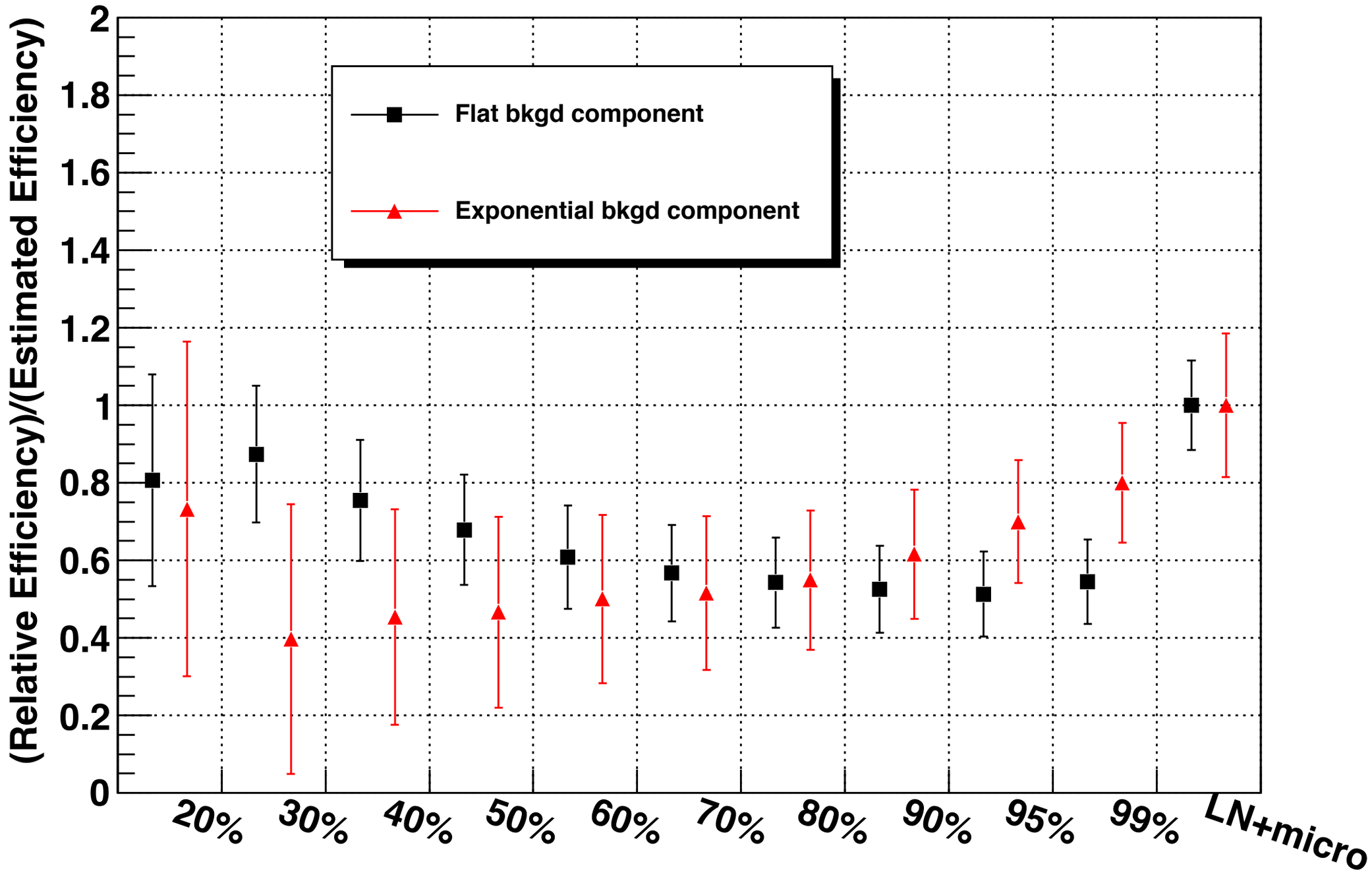
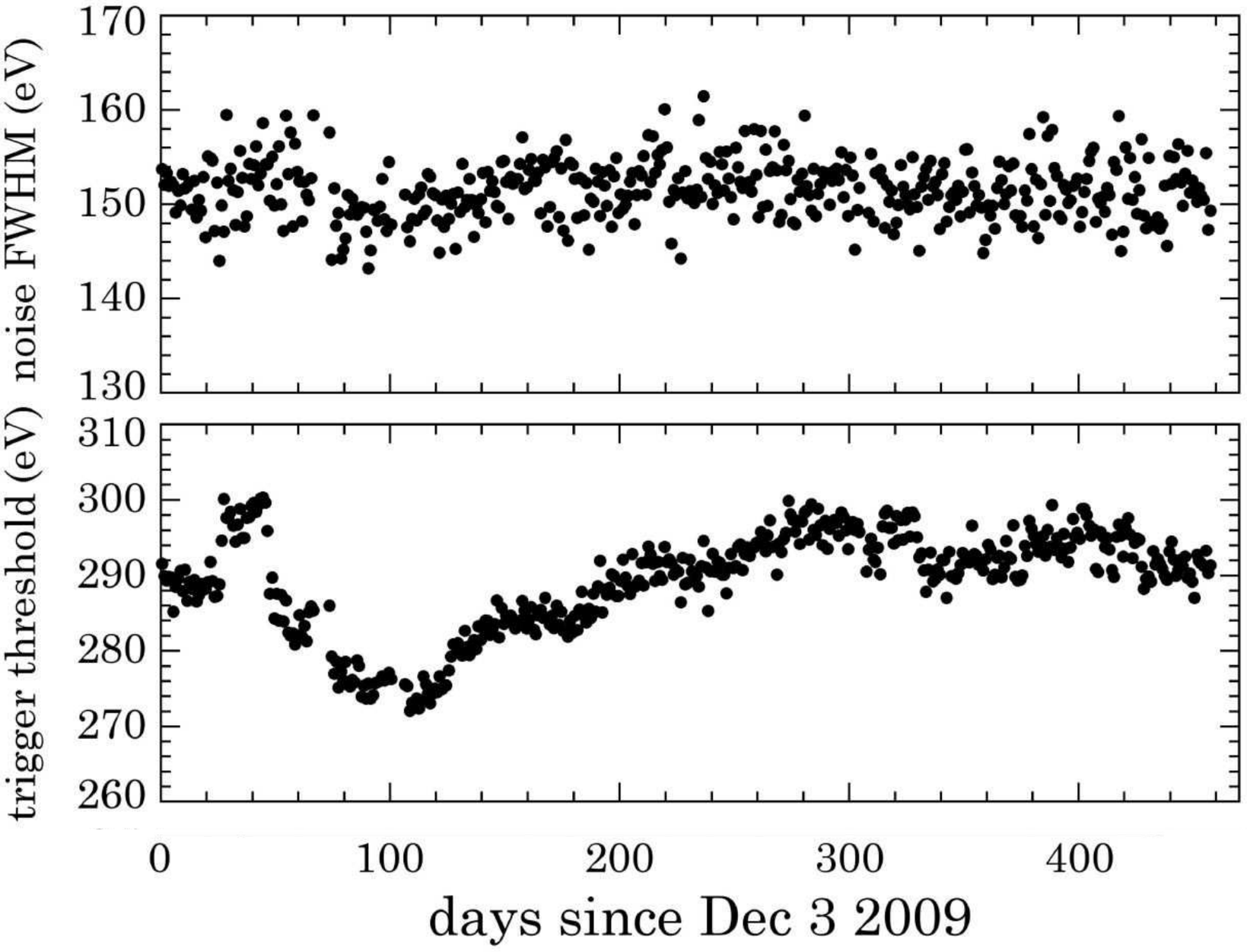


# Rise-time summary

- Sim used to derive cut acceptances
- Efficiency of cuts cross-checked using peaks, work well to at least 1 keV
- Fiducial volume cut: 0.4 → 0.33 kg active mass

# Stability Studies

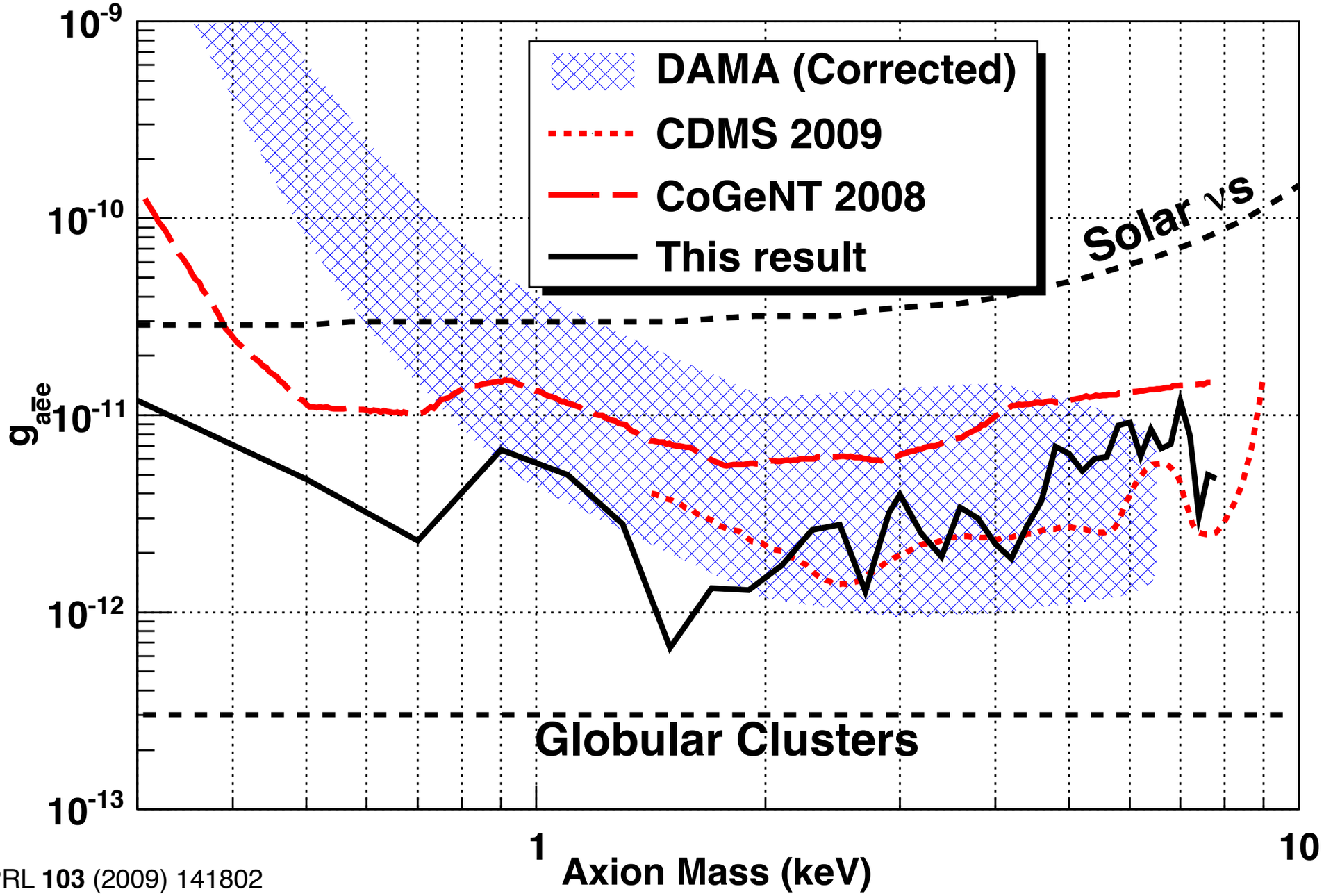
# Stability




Trigger, noise

arXiv:1106.0650

# Axioelectric Limits




CDMS: PRL **103** (2009) 141802

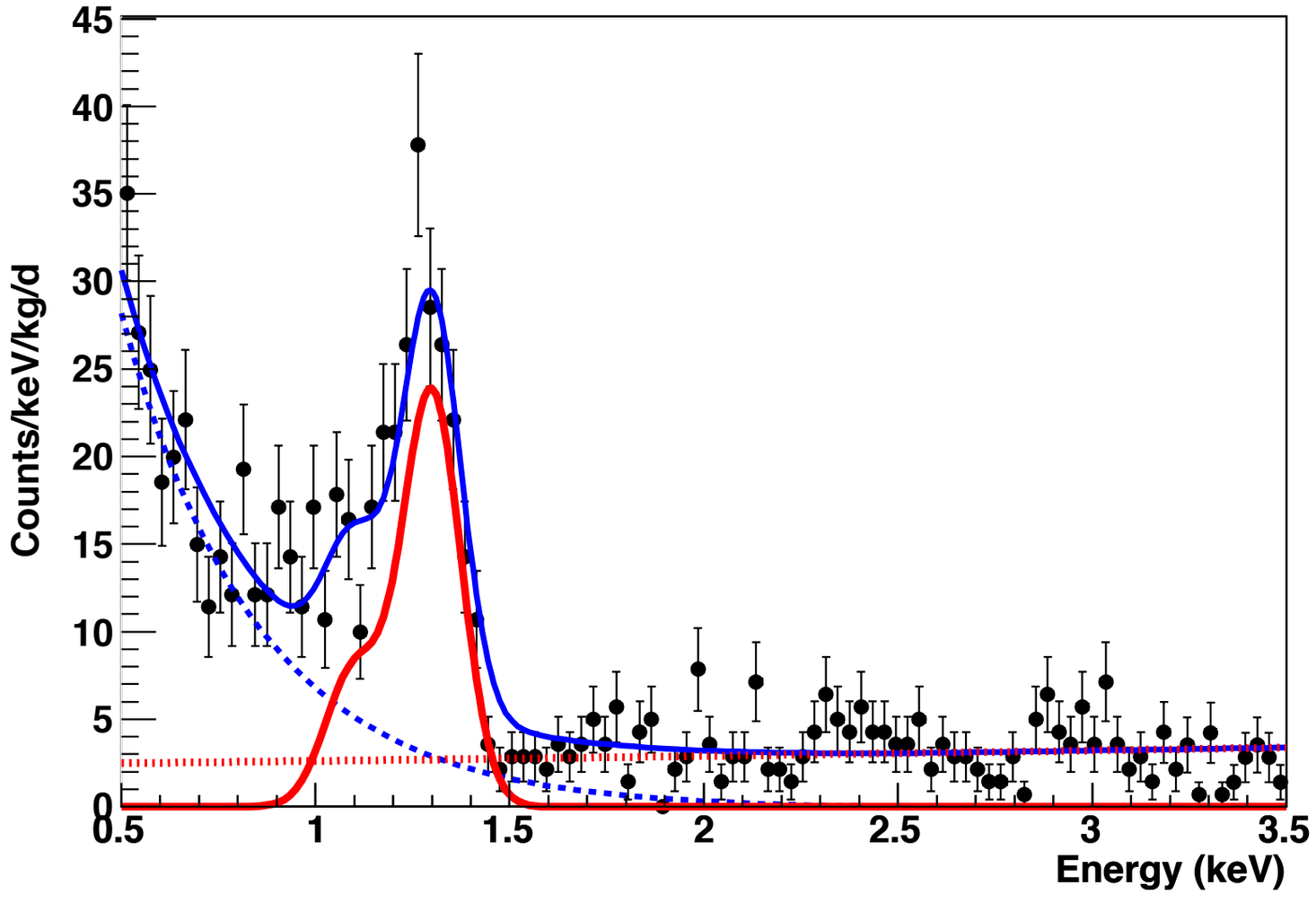
Solar neutrinos: PRD **79** (2009) 107301

Globular clusters PRD **51** (1995) 1495

# WIMP (Energy only)

# Extracting WIMP limits

- ML-based exclusion calculation
- Background uncertainty handled as nuisance pars:




90% CL exclusion of 8 GeV WIMP

Rolke, et al., NIM A **551** (2005) 493

# Low-mass WIMP limits

Black (49.7 kg-d):
solid 70% RT cut
dashed 95% RT cut

CDMS, 612 kg-d

DAMA, 820 kg-yr, 3σ, 5σ allowed region

CDMS Collaboration, arXiv:0912.3592;
DAMA Collaboration, EPJ **C56** (2008), 333, arXiv:0804.2741