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# SuperCDMS Soudan


## Ray Bunker

for the **SuperCDMS Collaboration**

# Detection Technique

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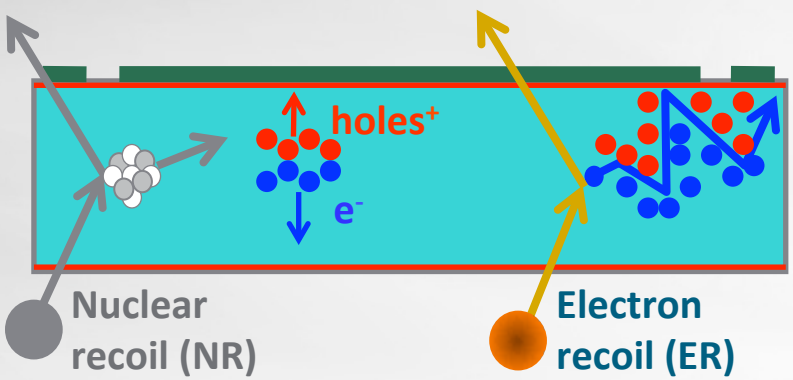
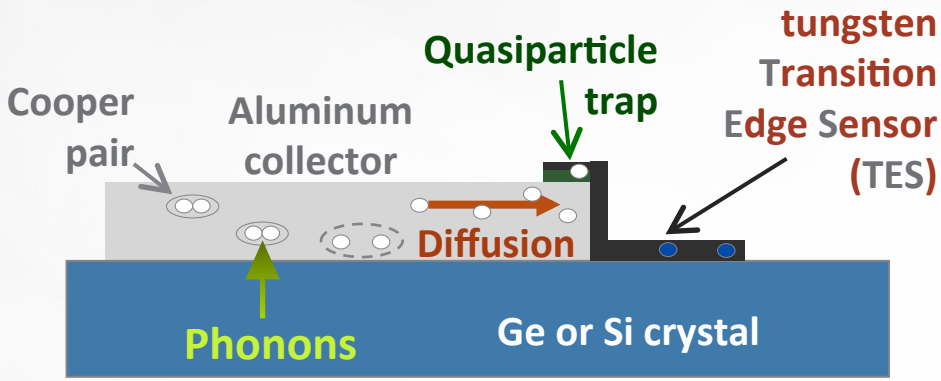
## Ionization & Phonons




Nuclear Recoil (NR) yields ≈20–30% ionization *vs.* Electron Recoil (ER)

Phonons provide equal measure of NR & ER recoil energies

# Detection Technique

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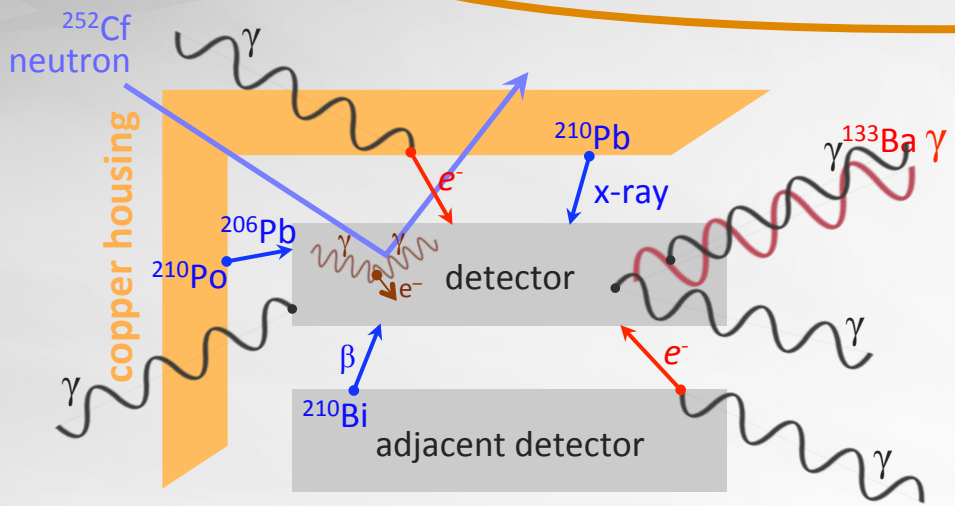
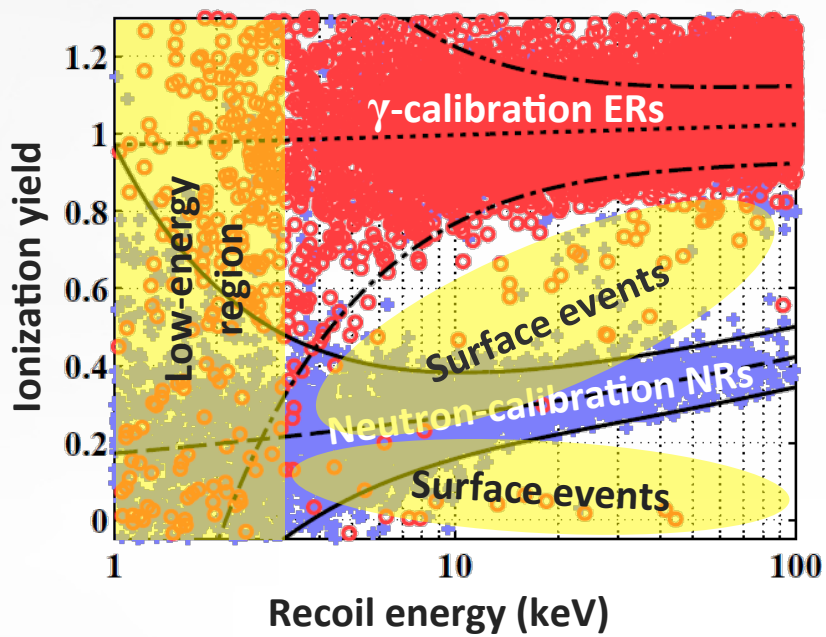
## Ionization & Phonons




Residual backgrounds are near surfaces:

- U/Th/K decays → γ-induced electrons, sidewall γ's
- $^{210}$Pb decay chain → betas, x-rays, $^{206}$Pb recoils

Low-energy region, all of the above plus:

- U/Th/K decays → γ-induced bulk ERs
- Internal activation (*e.g.*, $^{68}$Ge) → bulk ERs

# The SuperCDMS iZIP

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Interleaved ionization & phonon sensors

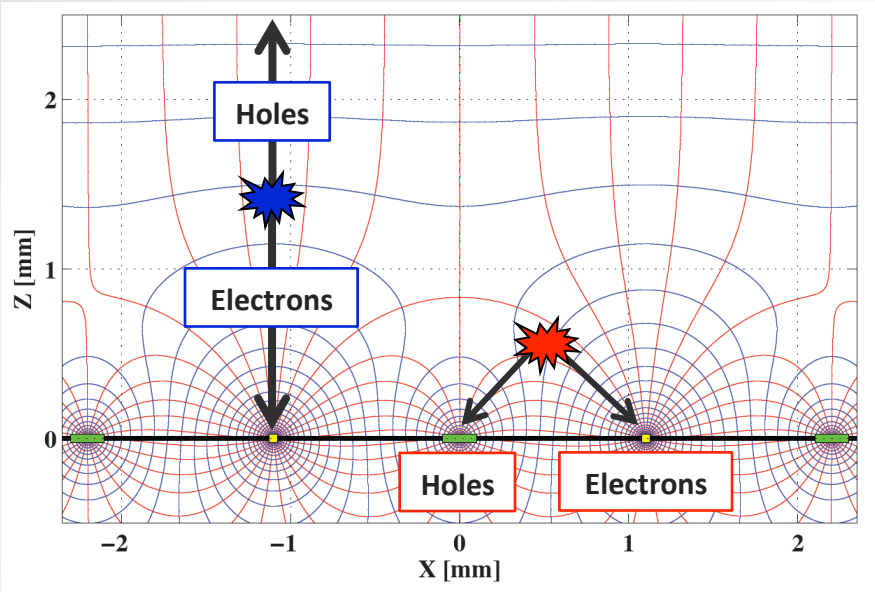
**Bulk event** → Side-symmetric ionization signal

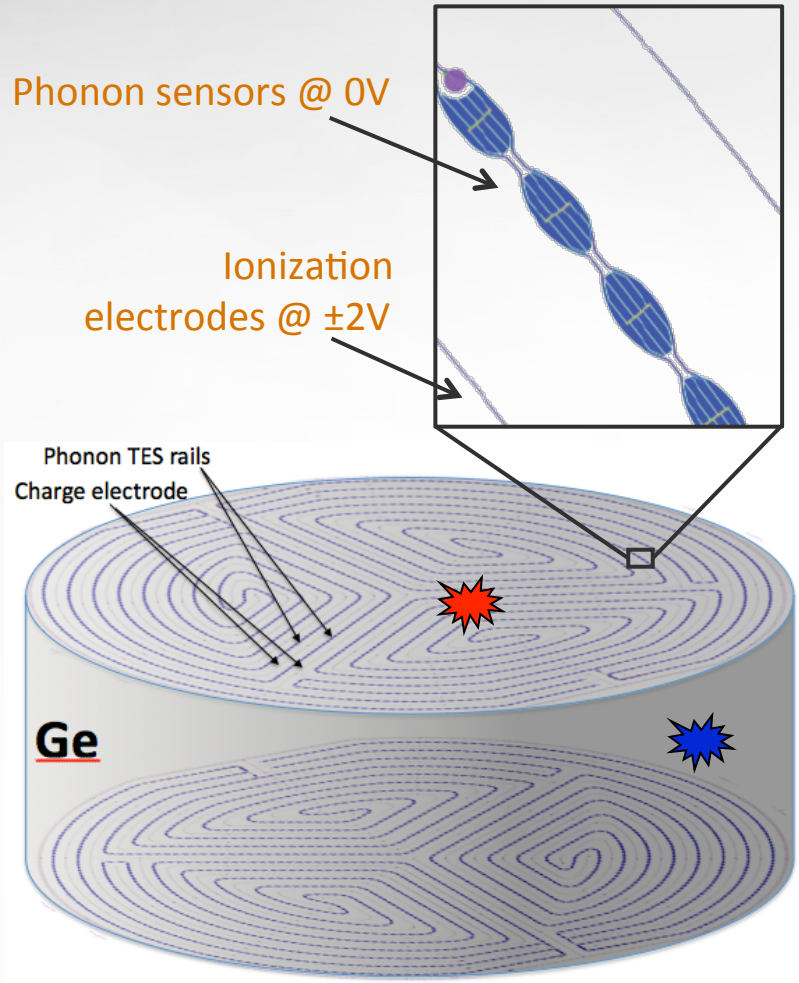
+

**Surface event** → Asymmetric ionization signal

=

**Significantly improved surface-event rejection**



# SuperCDMS Soudan

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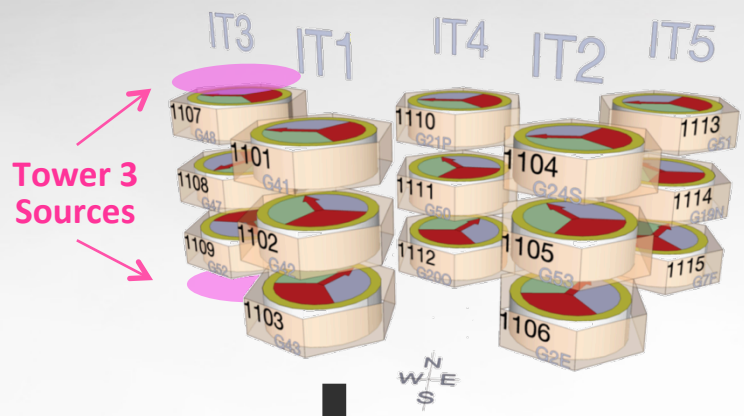
15 detector array of germanium iZIPs:

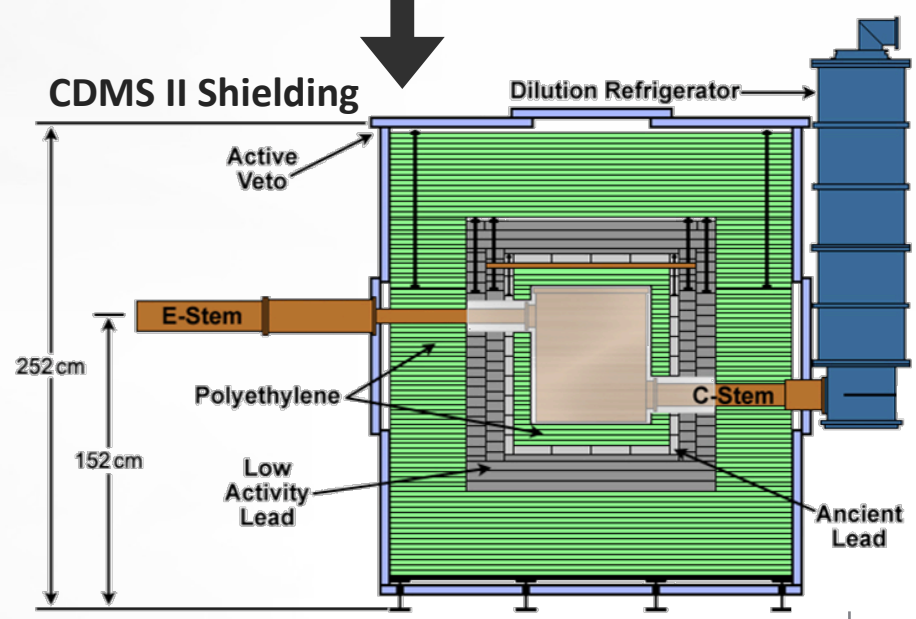
- 0.6 kg per detector
- *in situ* $^{210}$Pb sources
- Installed in CDMS II shielding
- In operation since early 2012
- Primary iZIP science run ended summer 2014
- More CDMSlite & calibrations through fall 2015




Broad science program:

- Demonstration of surface-event discrimination
- WIMP-search analyses:
  - 3 CDMSlite runs → $M_{WIMP} < 5$ GeV/$c^2$
  - Low-threshold iZIP → $M_{WIMP} = 5$–$10$ GeV/$c^2$
  - High-threshold iZIP → $M_{WIMP} > 10$ GeV/$c^2$
- Y/Be & Sb/Be photoneutron calibrations
- In general, high degree of experimentation to inform SuperCDMS SNOLAB

see talk by Sunil Golwala (next session)



# Surface-event Discrimination

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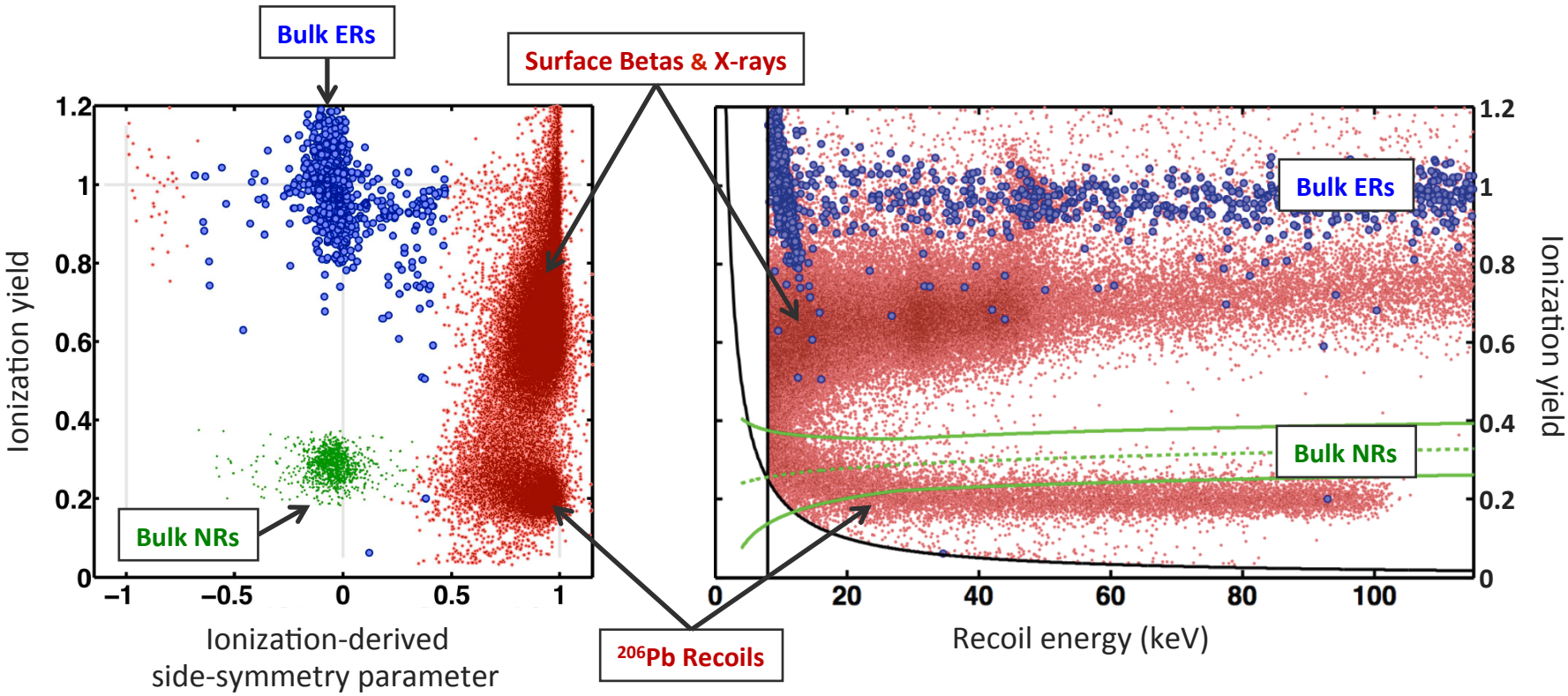
$^{210}$Pb sources placed above and below 2 detector faces:

- 50 live days → 0 of 132,968 leaked surface events in (symmetric) NR signal region
- More than sufficient face-event discrimination for SNOLAB iZIP payload




APL 103, 164105 (2013)

# Low-threshold Analysis

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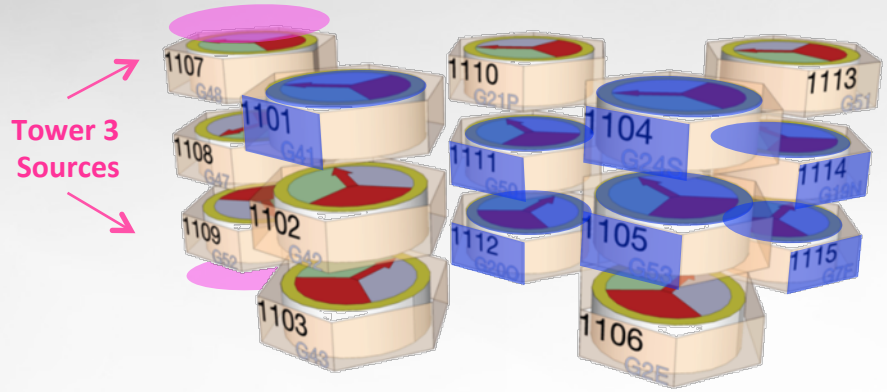
## Low-energy WIMP search:

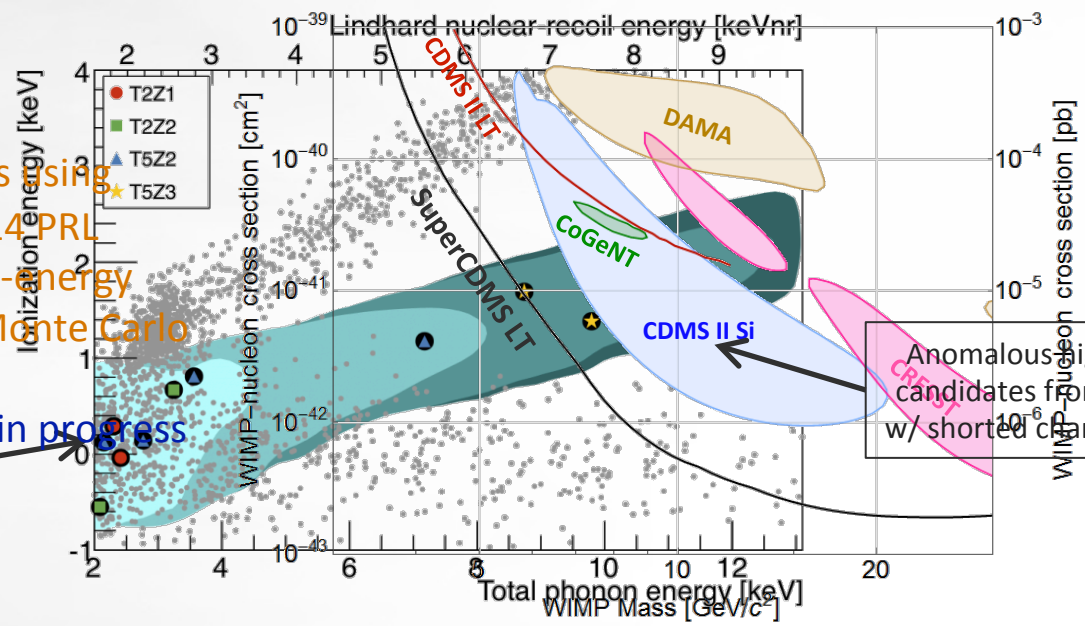
- Use 7 iZIPs w/ best low-energy performance
- Data period = Oct 2012 – July 2013
- 577 kg-day exposure (2.4x CDMS II)
- Range of thresholds: 1.6–5 keV
- Improved discrimination of sidewall events via phonon-derived fiducial volume




## Further LT studies:

- Maximum likelihood analysis using background model from 2014 PRL
- Understand anomalous high-energy candidates using Detector Monte Carlo

→ Stay tuned – PRD long paper in progress




Lowest energy background >10x lower than CDMS II, dominated by sidewall events

Anomalous high-energy candidates from detector w/ shorted charge channel

PRL 112, 241302 (2014)

# High-threshold Analysis

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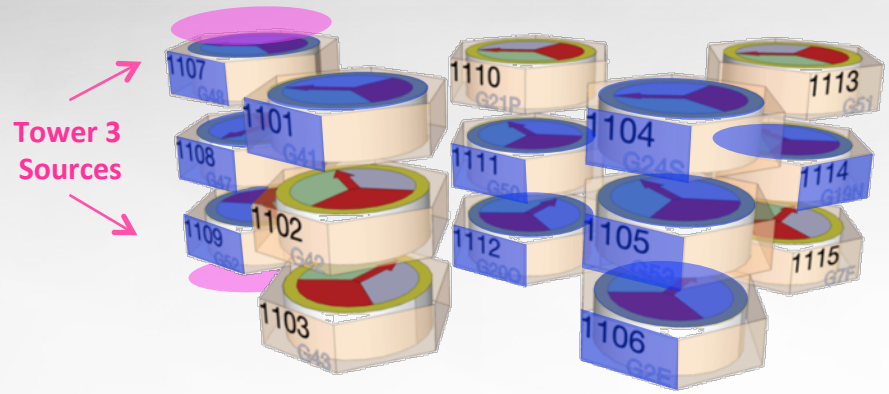
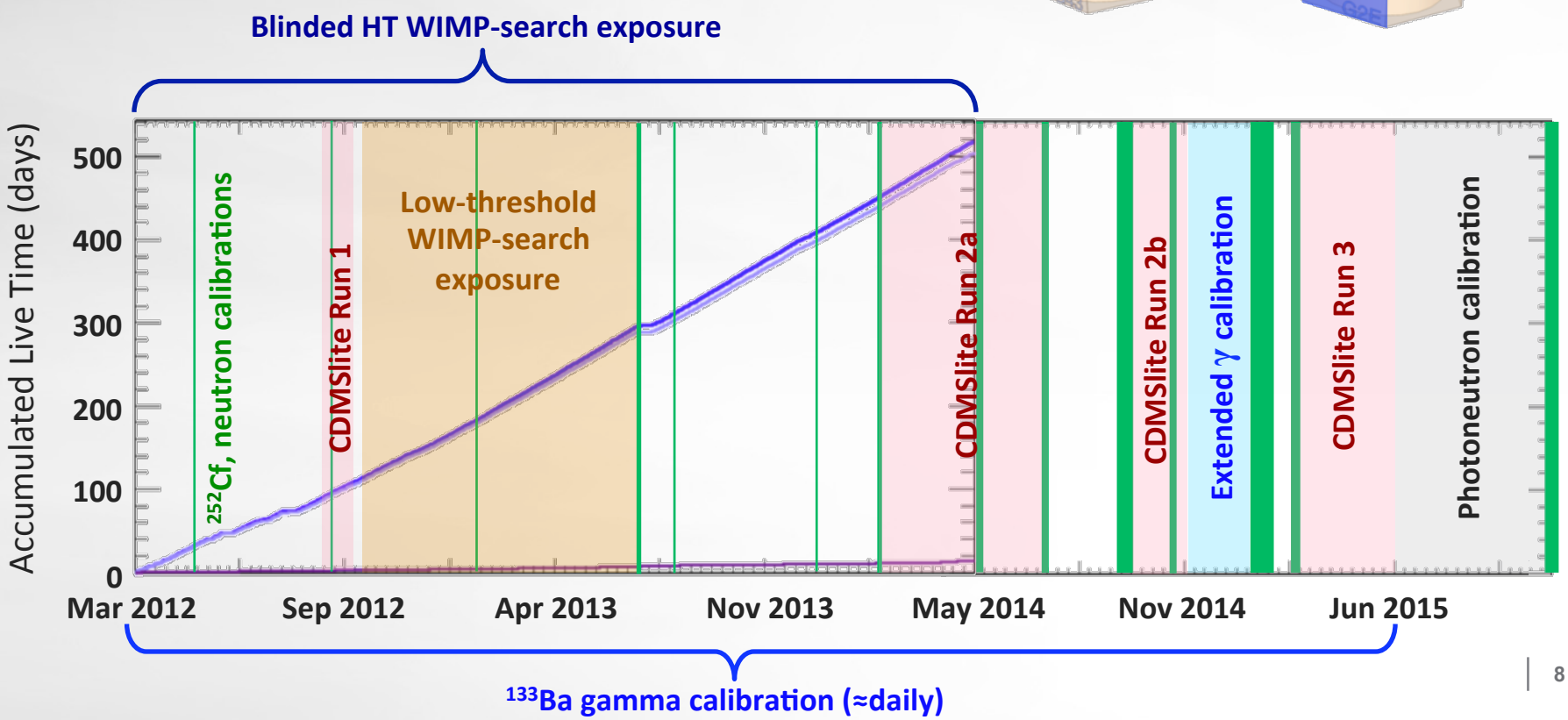
High-energy WIMP search:

- Different strategy: target high-mass WIMPs
- Higher thresholds to prevent background at low energy due to resolution smearing
- Use 10 iZIPs w/ fully operational charge channels
- Mix of WIMP search and γ & neutron calibrations



# High-threshold Analysis

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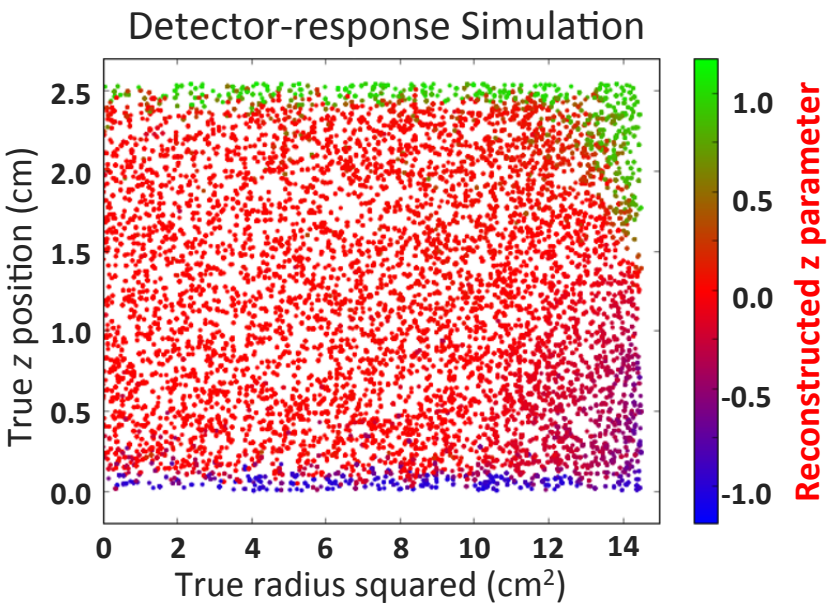
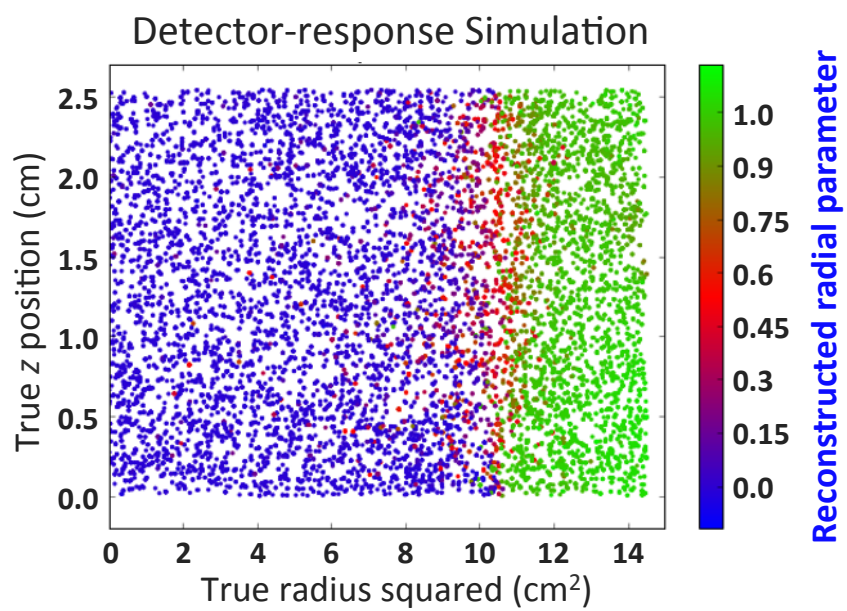
Analysis challenges:

- Exposure-limited → maximize fiducial volume with near-zero background
- Surface events (γ-induced electrons & $^{210}$Pb decay chain):
  - Faces: expect a few hundred such events → demonstrated ≈$10^{-5}$ rejection more than sufficient!
  - Sidewalls: more challenging to understand low-yield event rate *vs.* radial-position estimator (ongoing)



# High-threshold Analysis

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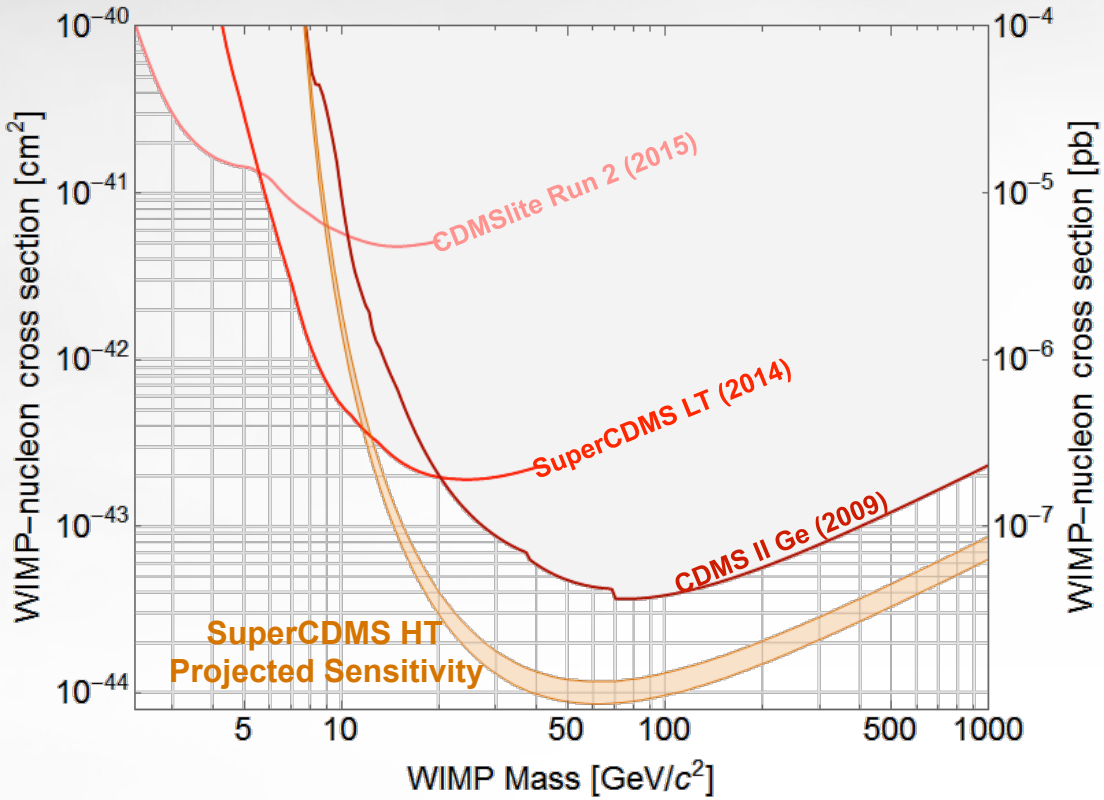
Projected sensitivity for:

- 1700 kg-day exposure (≈2.75x CDMS II)
- 7-15 keV thresholds
- 50-65% fiducial volume

Nice improvement *vs.* CDMS II considering modest exposure

Important demonstration of iZIP technology in advance of SuperCDMS SNOLAB



# Background Measurements

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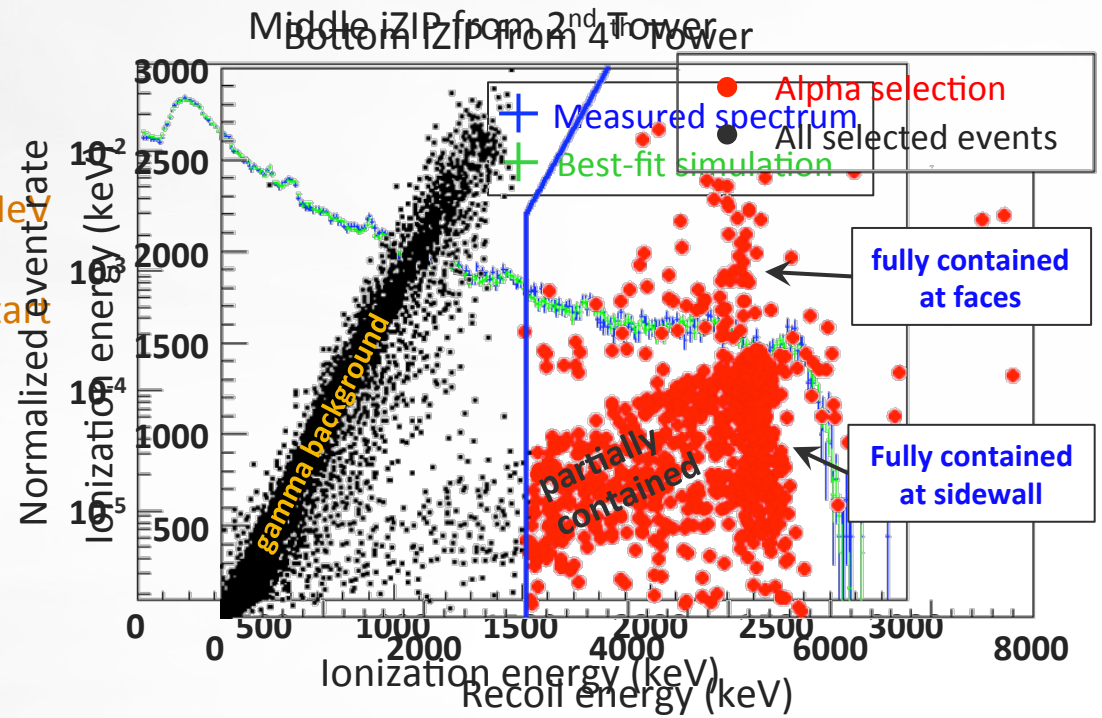
Global $\gamma$ background:

- Geant4 simulation of U/Th/K in materials of construction
- Simultaneous fit for activities using measured ionization spectrum
- Mystery: dominated by U/Th gammas coming from *below*!
- Attempting to understand with forensic assay → *e.g.* dust?

Surface $\alpha$ background:

- Alphas are easily identified!
- Primary contribution from $^{210}$Po at 5.3 MeV
  - → Normalizes $^{210}$Pb surface contamination
- Decay rate indicates more Po *vs.* Pb at start
- Ge crystal faces show ≈50 nBq/cm$^2$
- >10x higher rate at sidewalls
  - → Copper housings or crystal sidewalls?
  - → Planning to directly $\alpha$ assay both!



# Photoneutron Calibration

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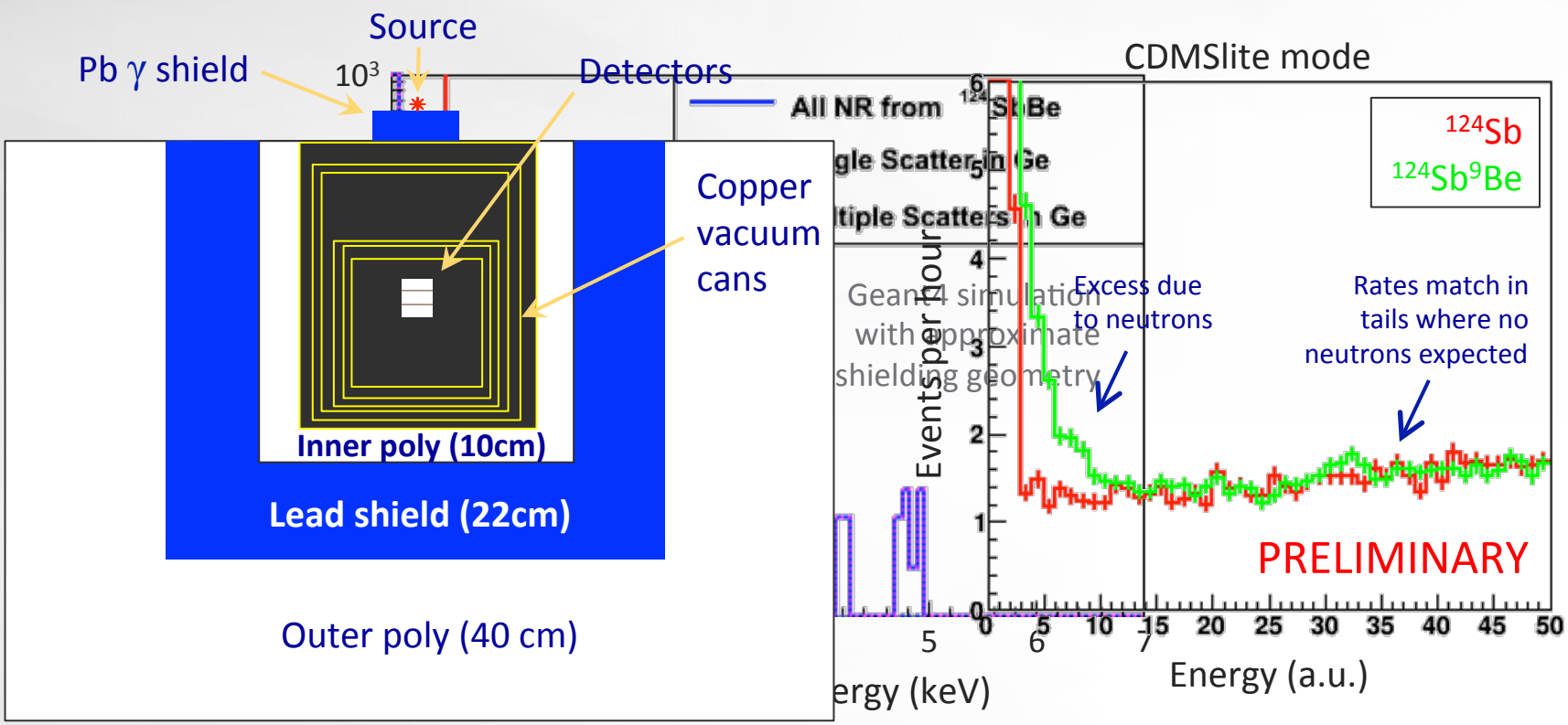
Purpose:

- Improve understanding of nuclear-recoil energy scale for CDMSlite & iZIP modes

Technique:

- Pair $^{88}$Y and $^{124}$Sb $\gamma$ sources with Be wafer → ≈mono-energetic neutrons (152 & 23 keV)
- Look for maximum elastic scattering shoulder off Ge at 8.1 & 1.3 keV



# Summary

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- SuperCDMS Soudan is a rich source of data for improving WIMP-search sensitivity and understanding SuperCDMS detectors
- The iZIP technology significantly improves rejection of the CDMS II limiting backgrounds
  - *e.g.*, demonstrated face-event rejection better than needed for SuperCDMS SNOLAB & improved phonon-sensor layout enables >10x reduction of low-energy backgrounds
- High-threshold analysis is ongoing (expect result this year) + backgrounds & calibrations

# Backup Slides

# CDMS II → Background-Limited

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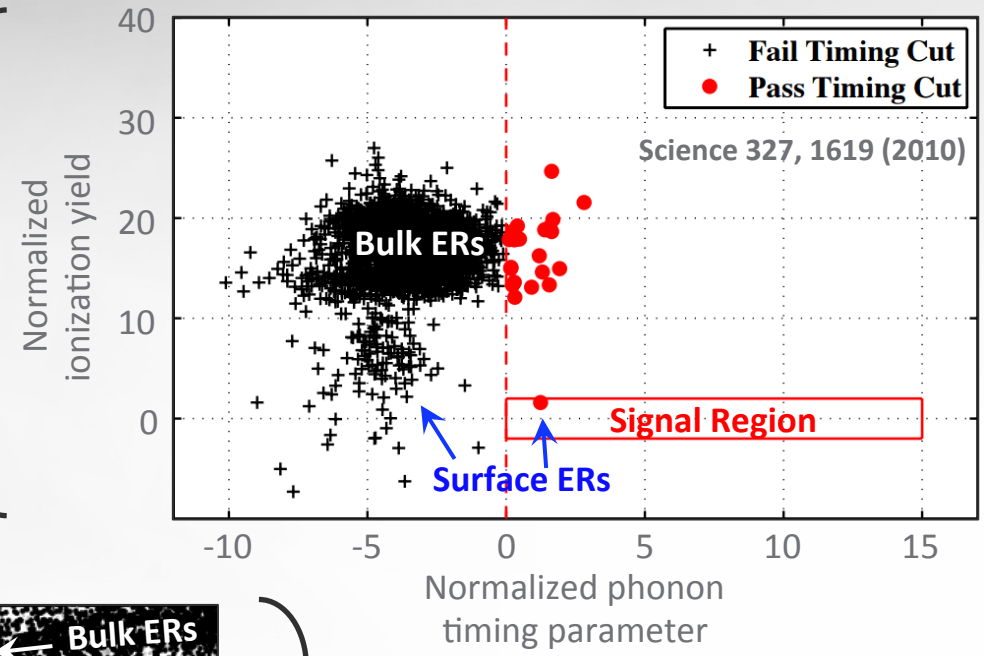
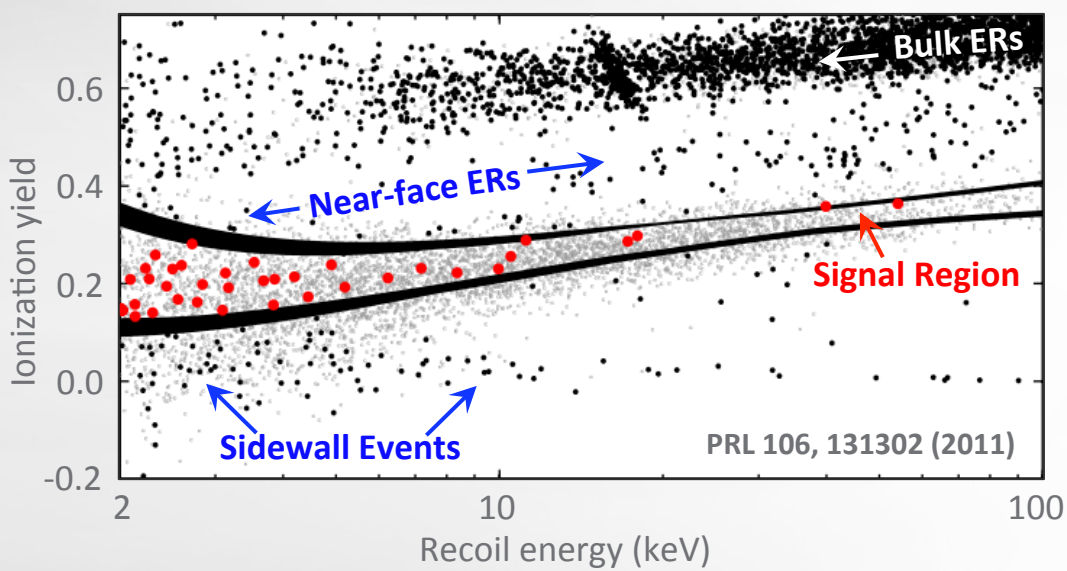
High-threshold analysis:

- Final CDMS II dataset
- 612 kg-day Ge exposure
- 10 keV threshold
- Limited by near-face ERs in high-energy region




Low-threshold analysis:

- Final CDMS II dataset
- 241 kg-day Ge exposure
- 2 keV threshold
- Limited by sidewall events in low-energy region

# LT Analysis – Detector Monte Carlo

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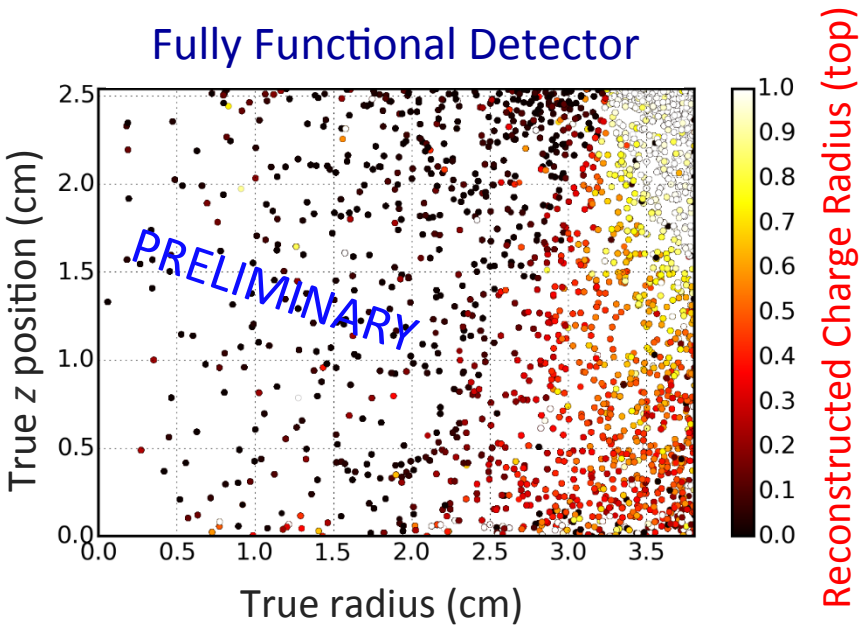
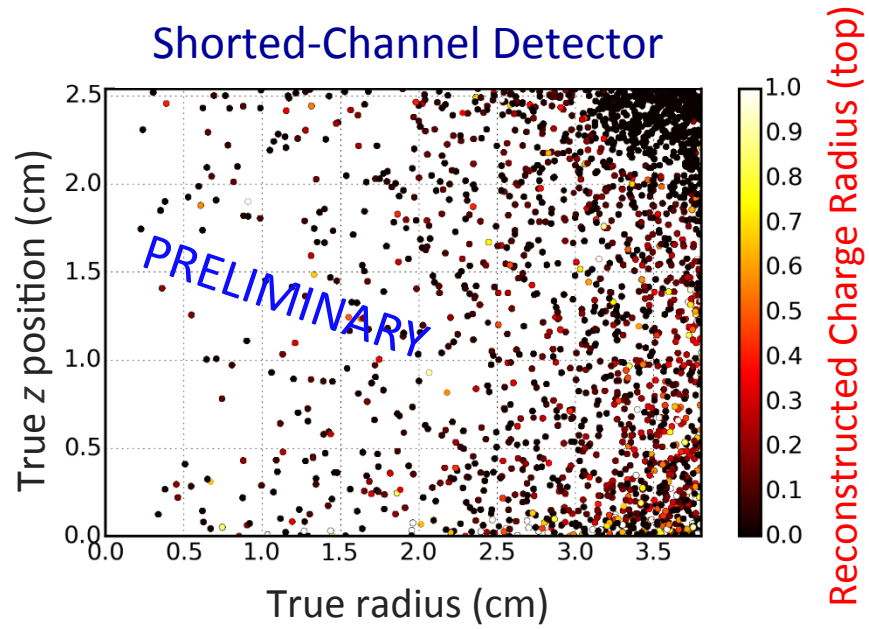
Charged-based radial preselection not effective on top side



# LT Analysis – Detector Monte Carlo

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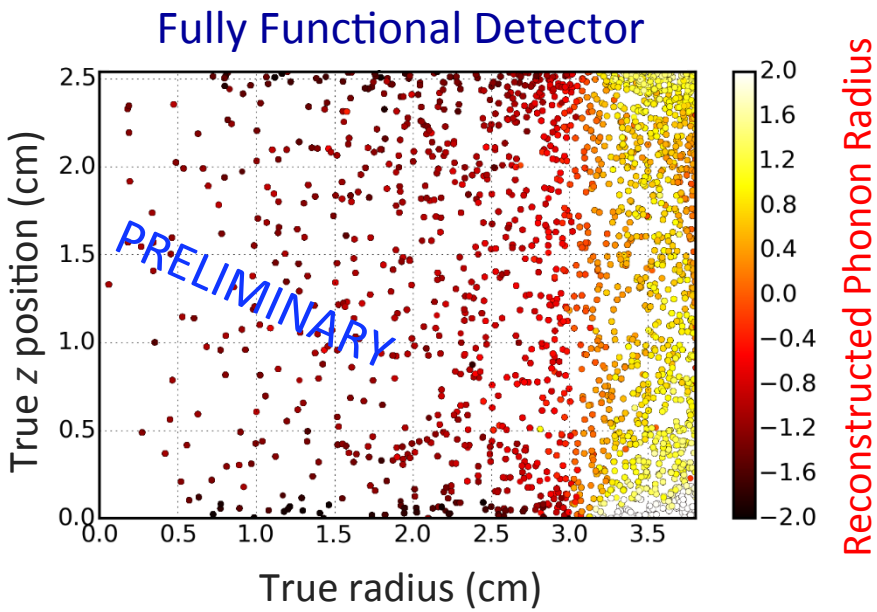
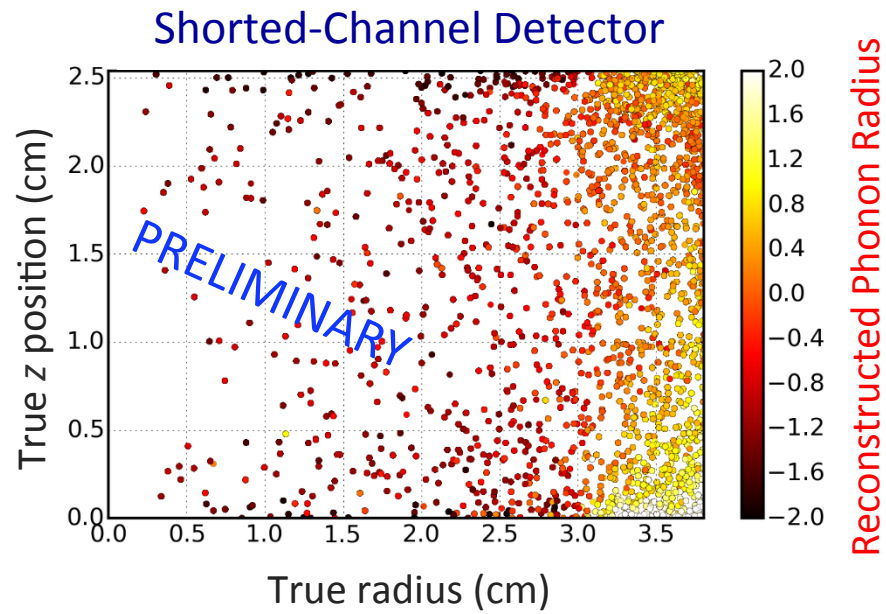
Phonon-based radial fiducialization less effective near top corner



# Photoneutron Calibration

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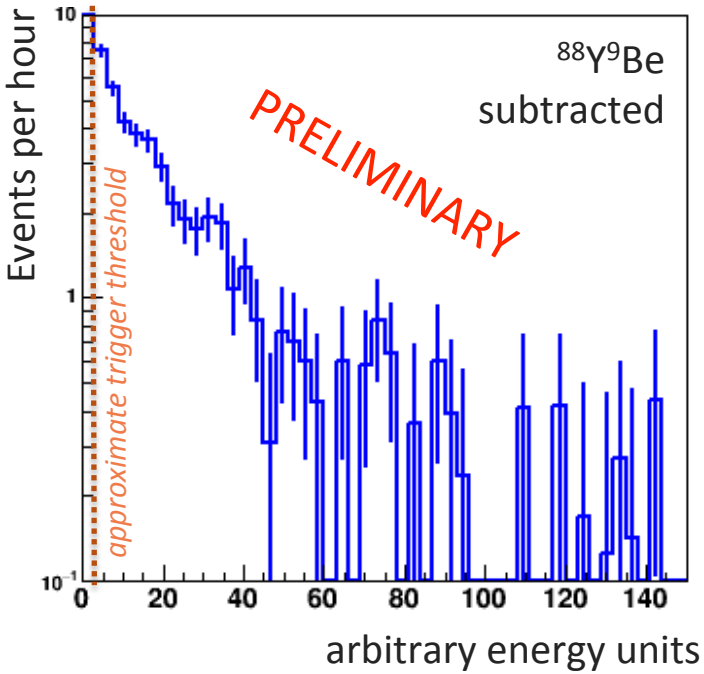
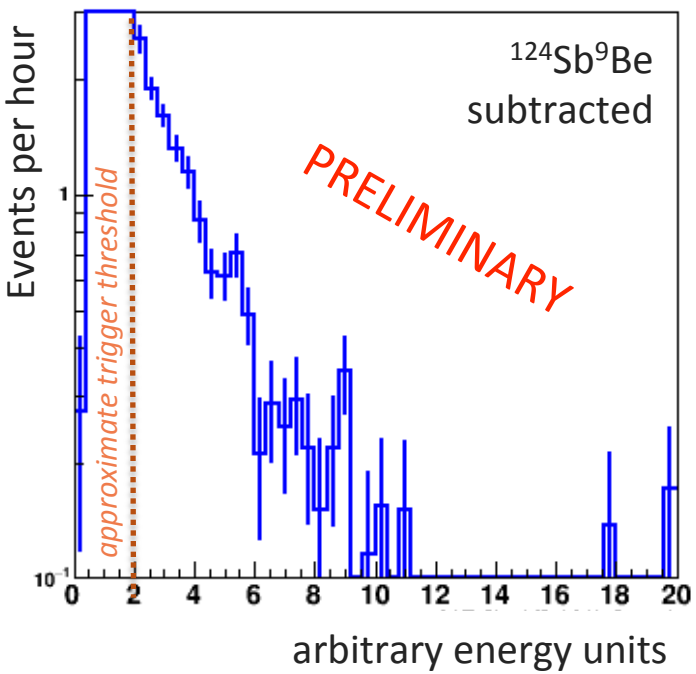
Plots shown here are result after subtracting neutron-off from neutron-on spectra; these plots are not efficiency corrected




x-axis units are not calibrated…but they are the same scale shown on previous slide

*error bars shown are statistical;*
*data shown is 5 weeks of Sb and 4 weeks of Y (additional data not yet analyzed)*