



# Recent Results from SuperCDMS Soudan

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# SuperCDMS Collaboration



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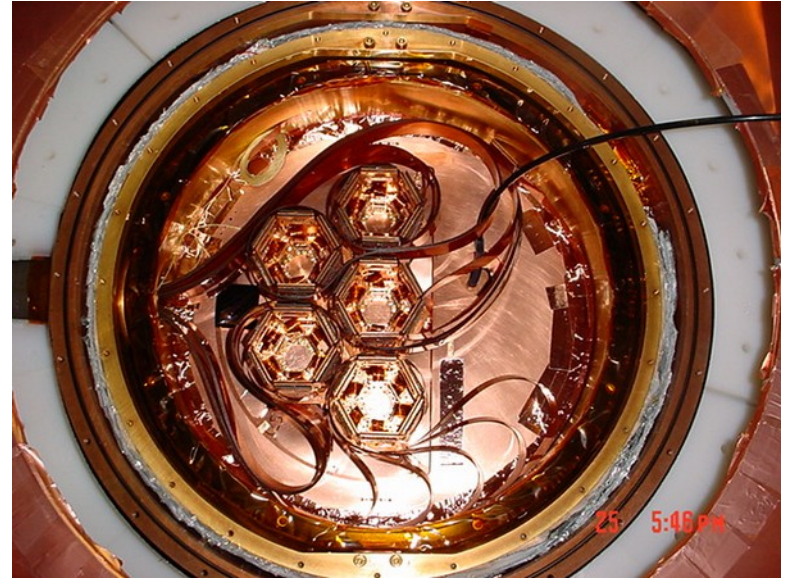
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# CDMS Operations at Soudan, MN (2003–2015)



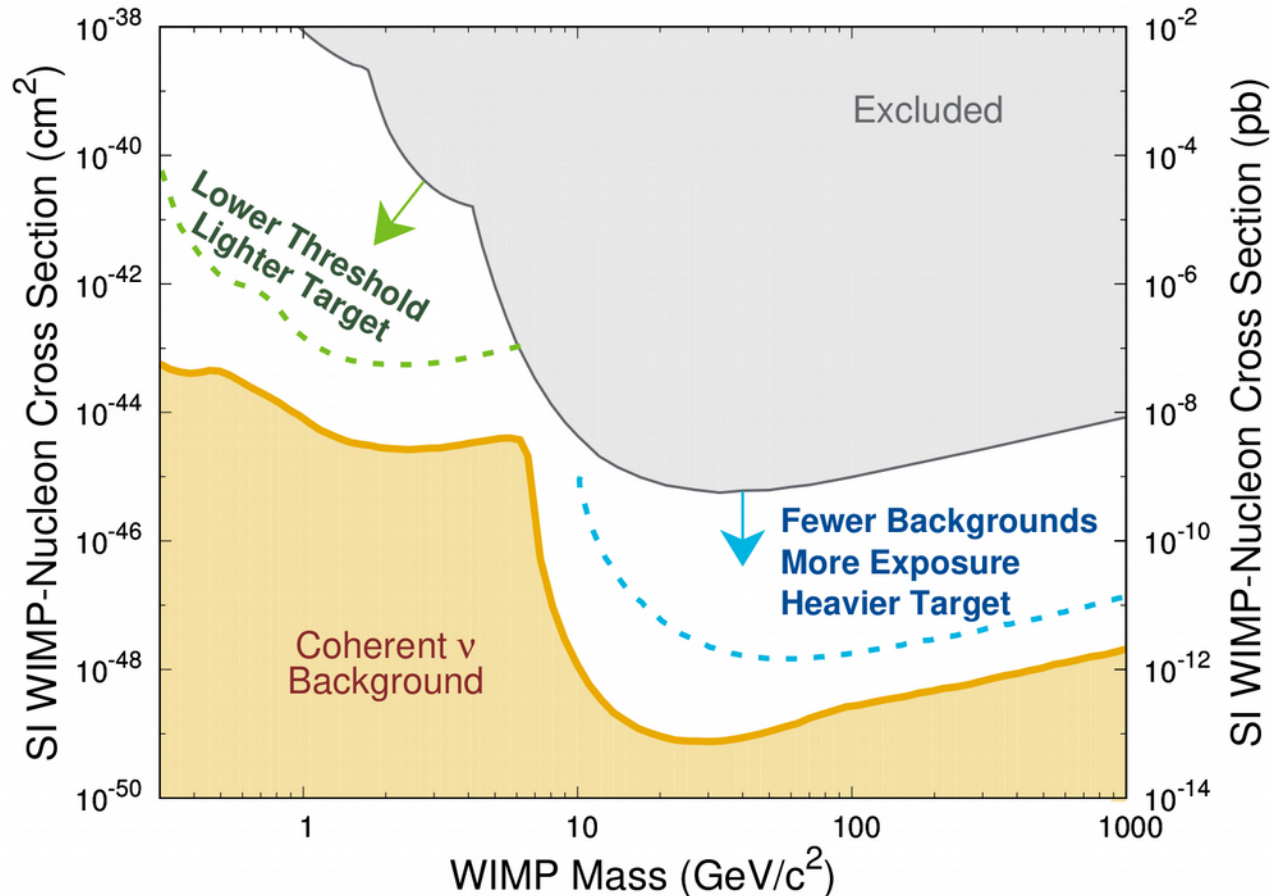
# SuperCDMS Soudan Data

Operated October 2012 to November 2015

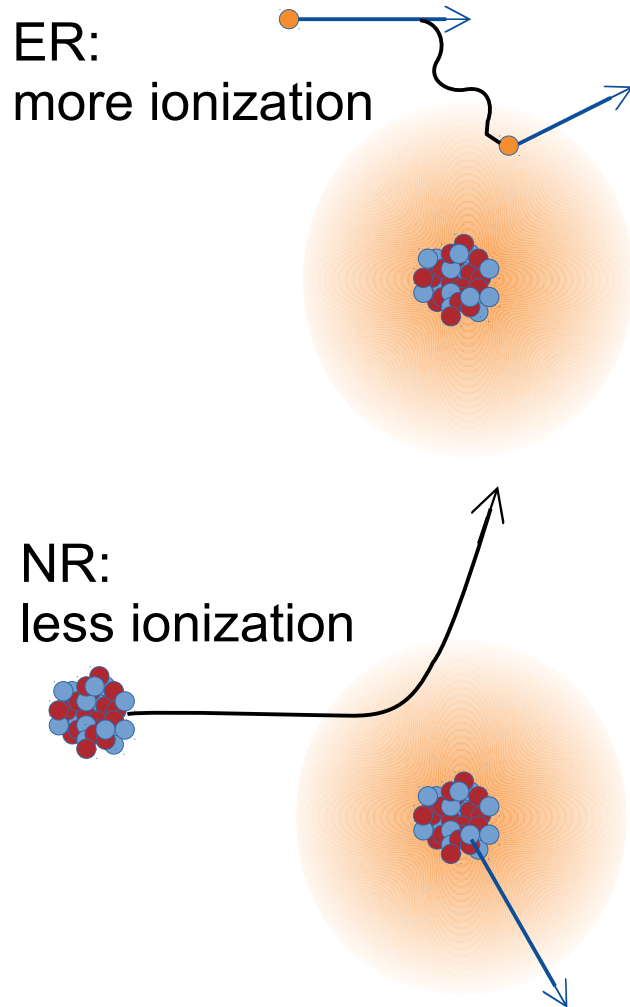
- **Published** and *in preparation* dark matter limits:
  - **CDMSlite**
  - **Low-threshold analysis**
  - *High-threshold analysis*
  - **Lightly ionizing particles search**
  - *Improved analyses and additional exposures*
- Background studies:
  - **iZIP surface background rejection**
  - *Cosmogenic tritium production*
- Calibration and efficiency studies:
  - **Effective field theory sensitivity**
  - *Photoneutron recoil energy scale calibration*

# Dark Matter Direct Detection

- CDMS combines high electron recoil / nuclear recoil discrimination AND low threshold.



# Background Rejection

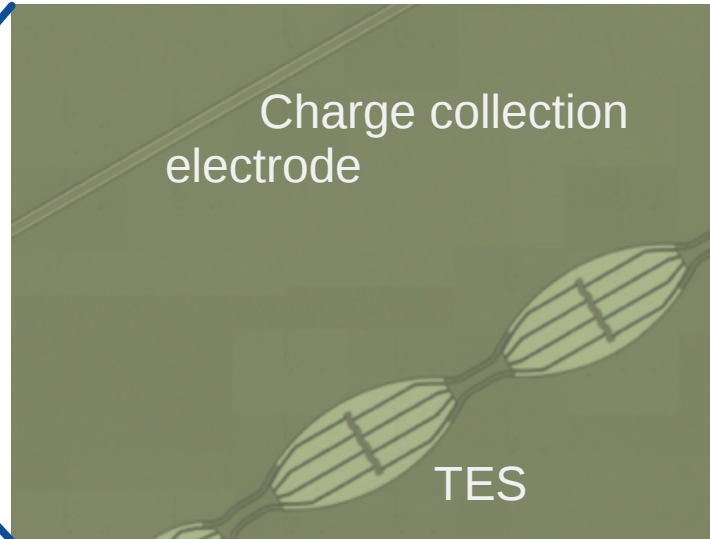
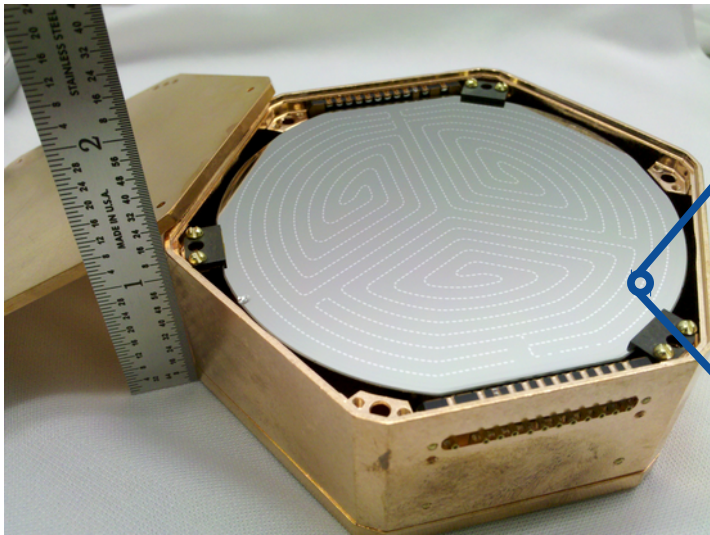


- Dark matter signal:  
~10 keV nuclear recoil (NR)
- Penetrating  $\gamma$  and  $\beta$ :  
Electron recoil (ER)  
background
- **Ionization / Heat / scintillation**  
ratios differ for NR vs. ER

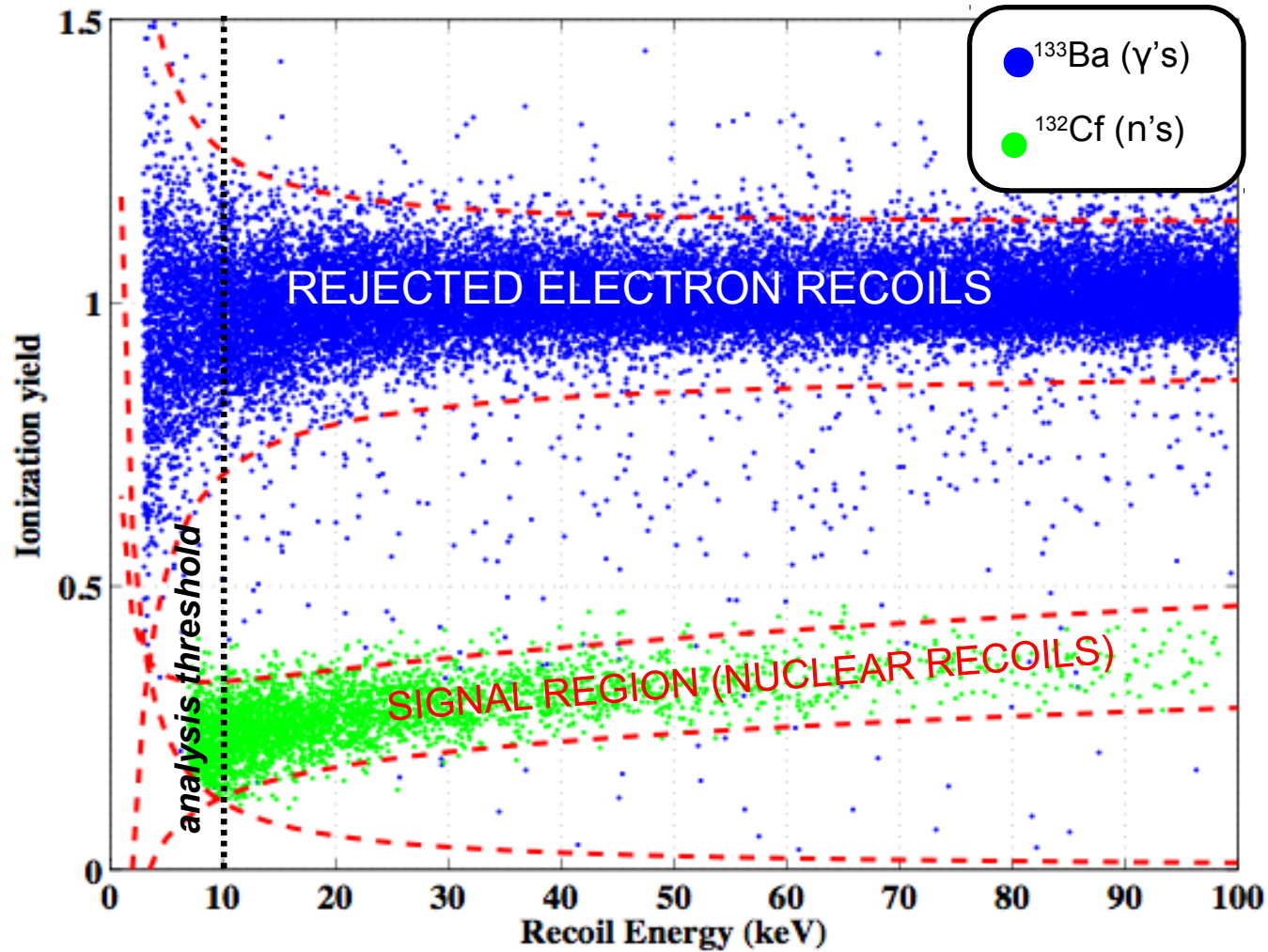
# SuperCDMS Soudan Detectors

Ge iZIP (interleaved Z-sensitive Ionization and Phonon sensors)

- Measure heat and ionization
  - Athermal phonons measured with Transition Edge Sensors (TES)
  - $e^-/h^+$  pairs drifted across  $\pm 2$  V bias.
  - 15 detectors, 0.6 kg each at  $\sim 50$  mK

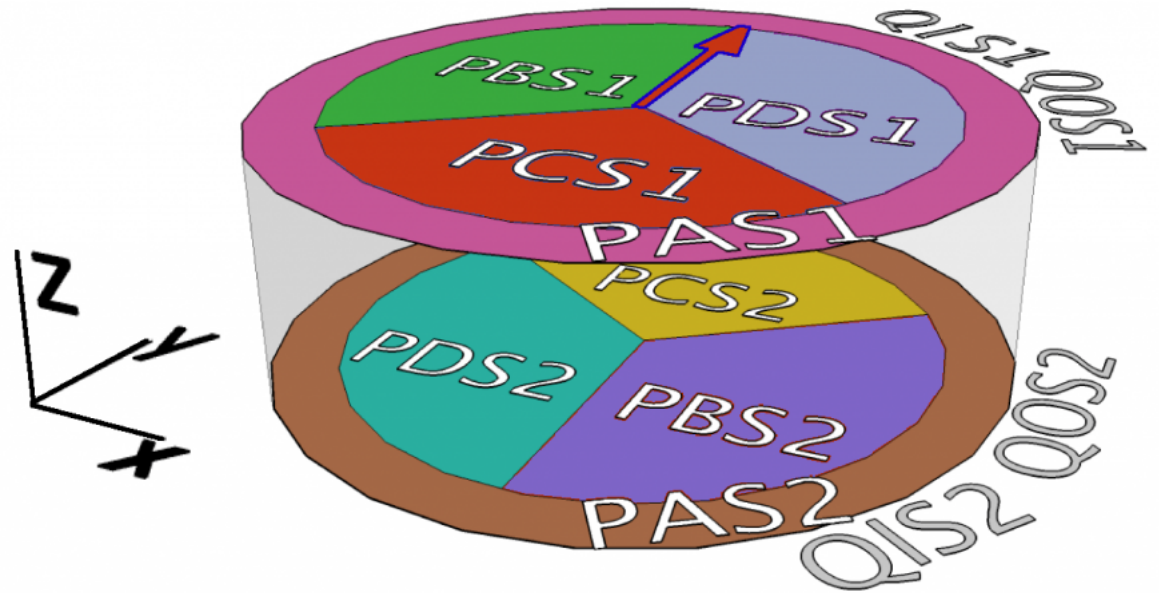


# Background Rejection



# Background Rejection

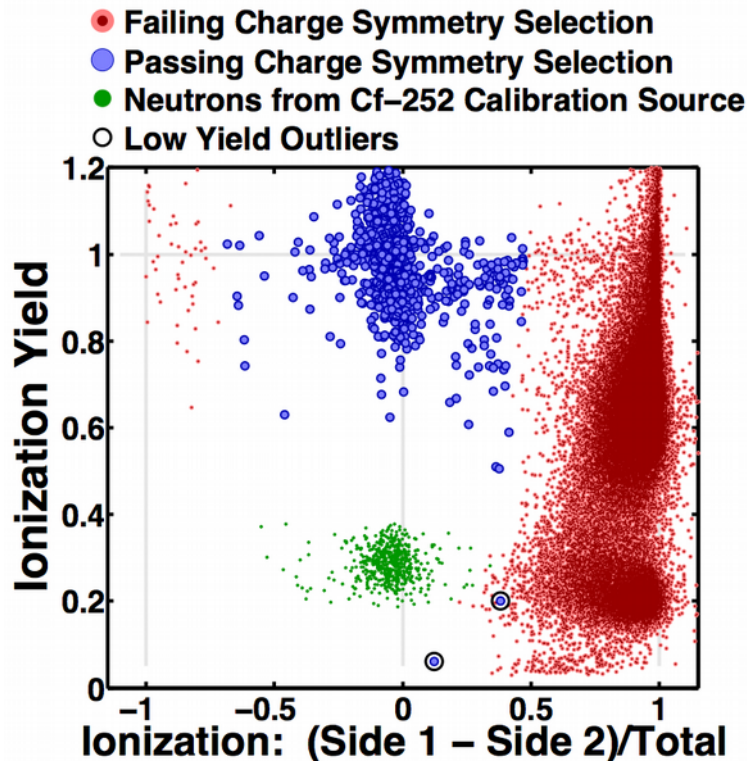
- Surface Events
  - Nuclear recoils from radon.
  - Ionization from electron recoils trapped at surfaces.
- Radial discrimination



# Background Rejection

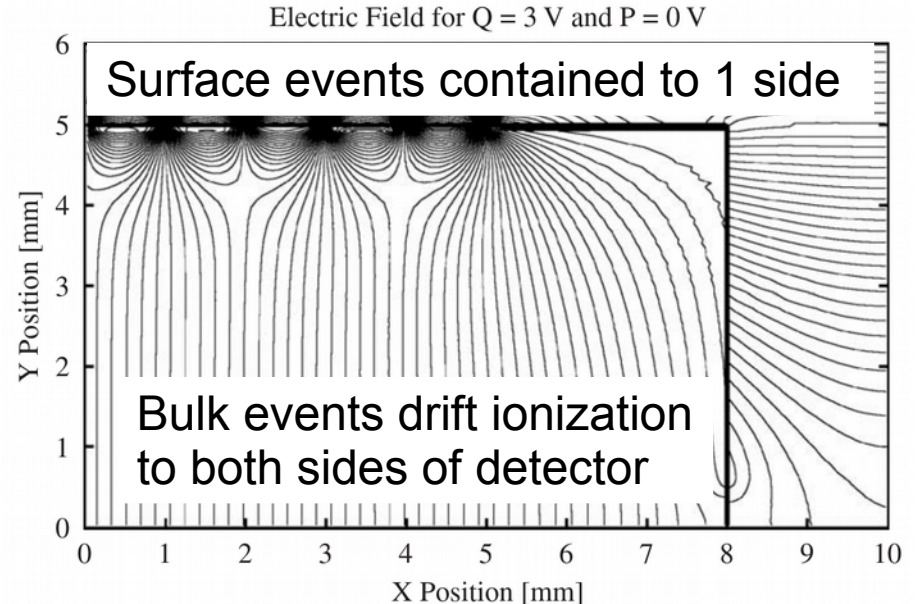
Interleaved electrodes allow charge symmetry cut

Cut efficiency calibration using  $^{210}\text{Pb}$  source



$< 1.3 \times 10^{-5}$  surface event leakage

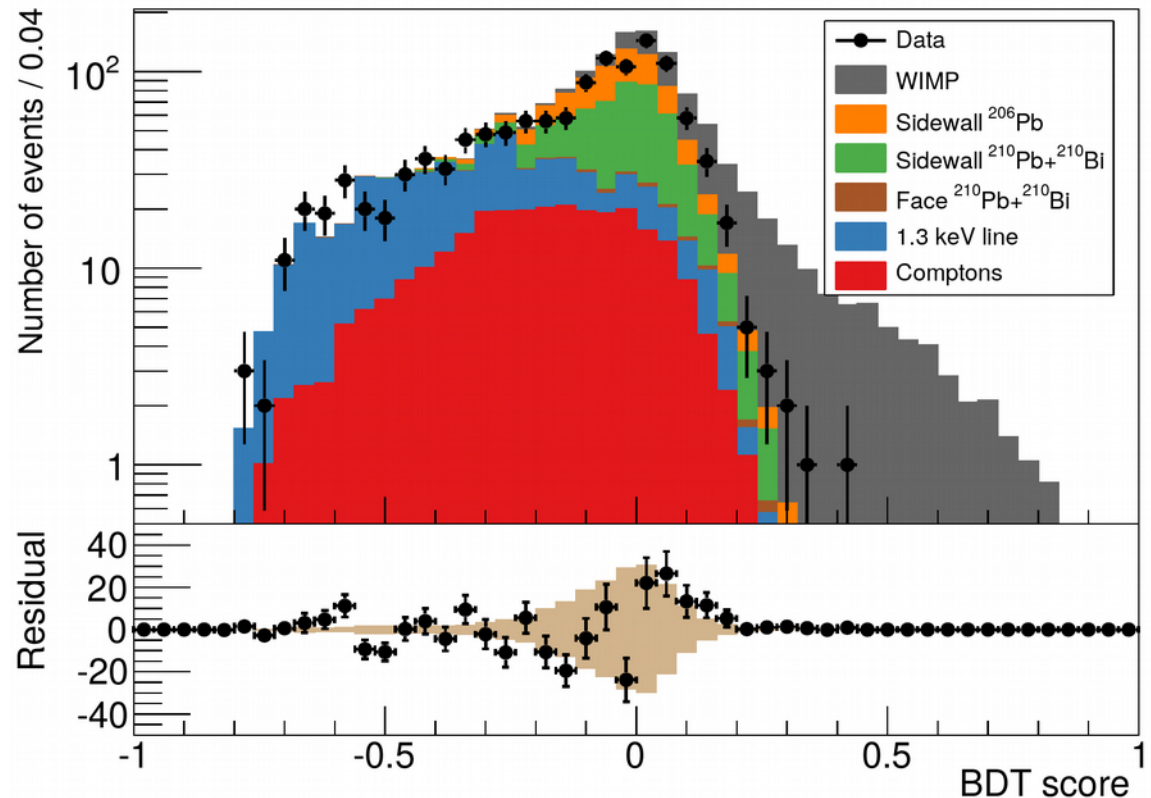
## Electric drift field simulation



# iZIP Low Threshold Analysis

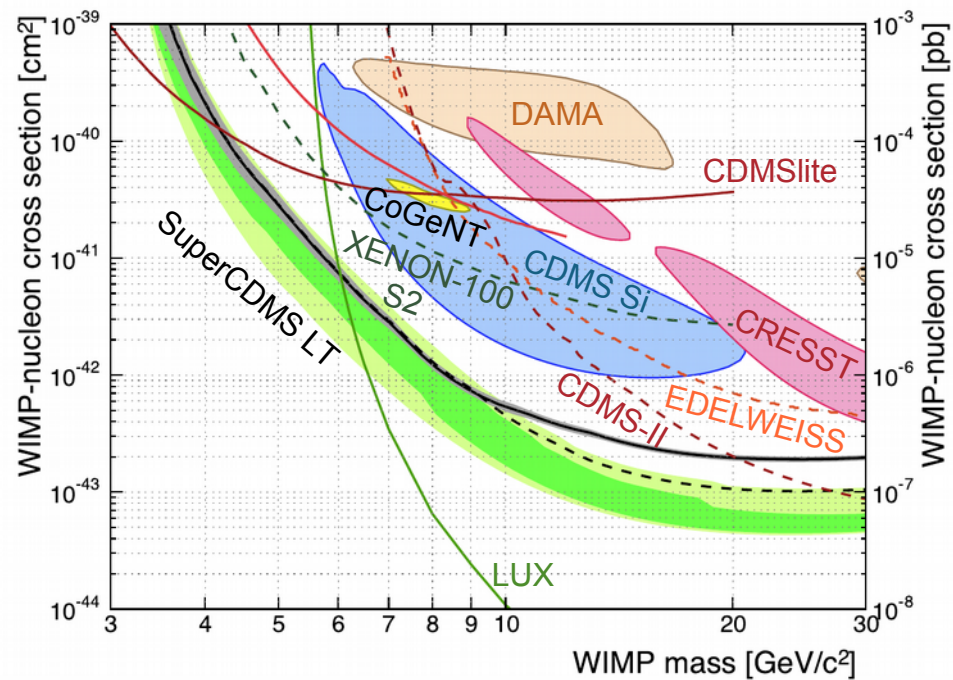
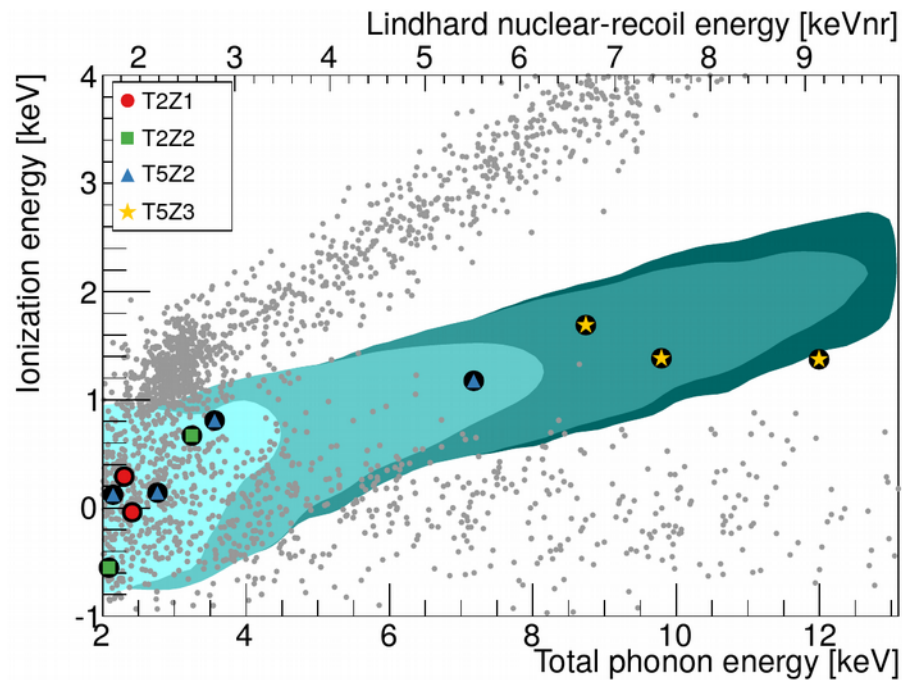
Tuned for low energy efficiency using first 577 kg·days of exposure – PRL 112 241302 (2014)

- Surface events rejected using phonon radial and z information.
- Blinded analysis using Boosted Decision Trees.



# iZIP Low Threshold Analysis

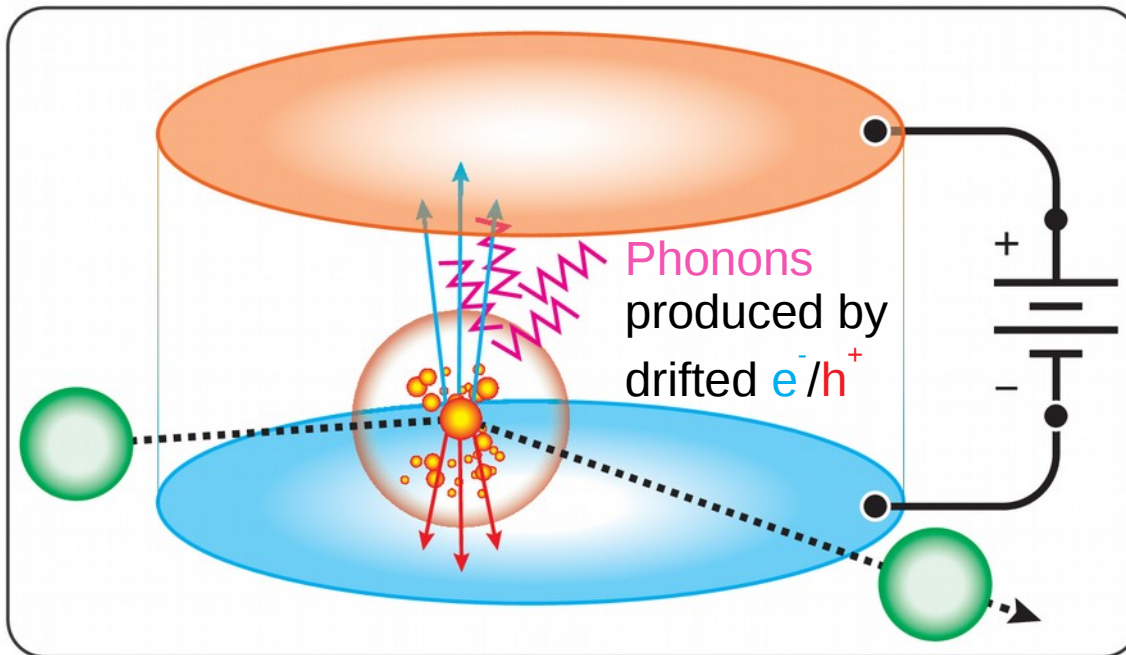
- Rules out CoGENT WIMP interpretation.



# Looking to the Future – CDMSlite mode

Use phonons as information carriers

- Average energy of information carriers
  - LXe: ~70 eV per S1 photoelectron
  - Ge: 3 eV per electron/hole pair or ~0.001 eV per phonon

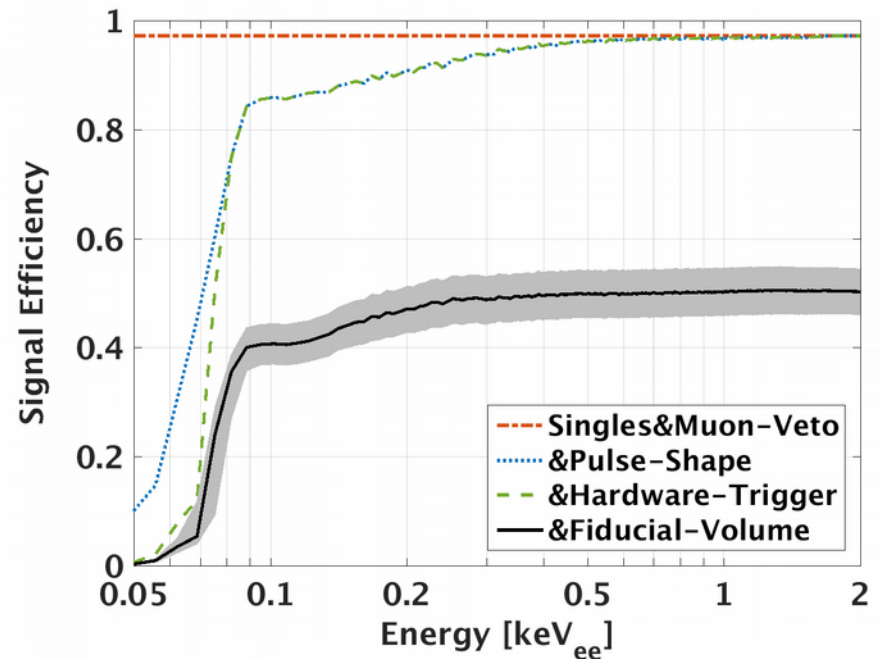
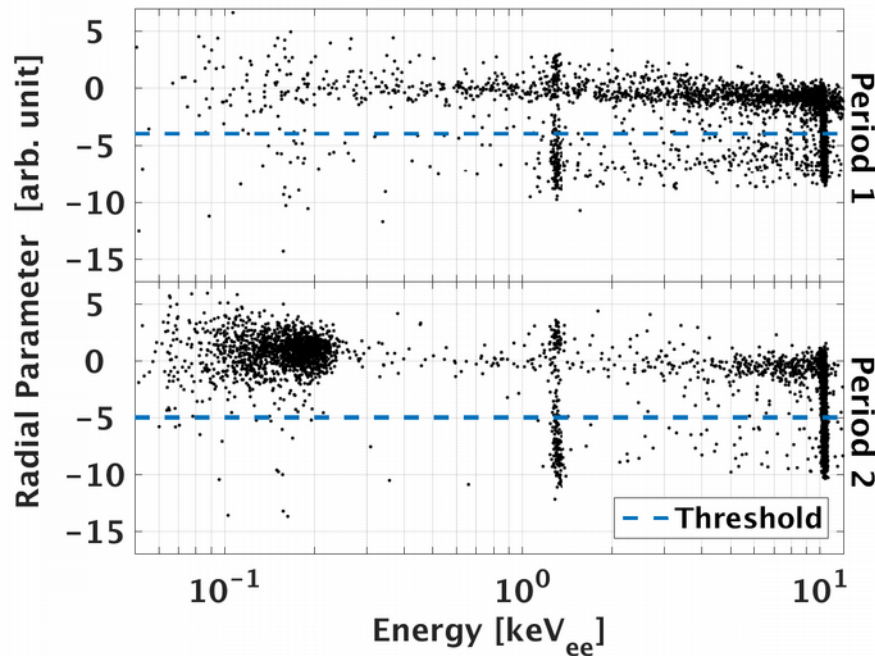


$$\text{Phonon energy} = E_{\text{heat}} + n_{\text{eh}} e\Delta V$$

# CDMSlite

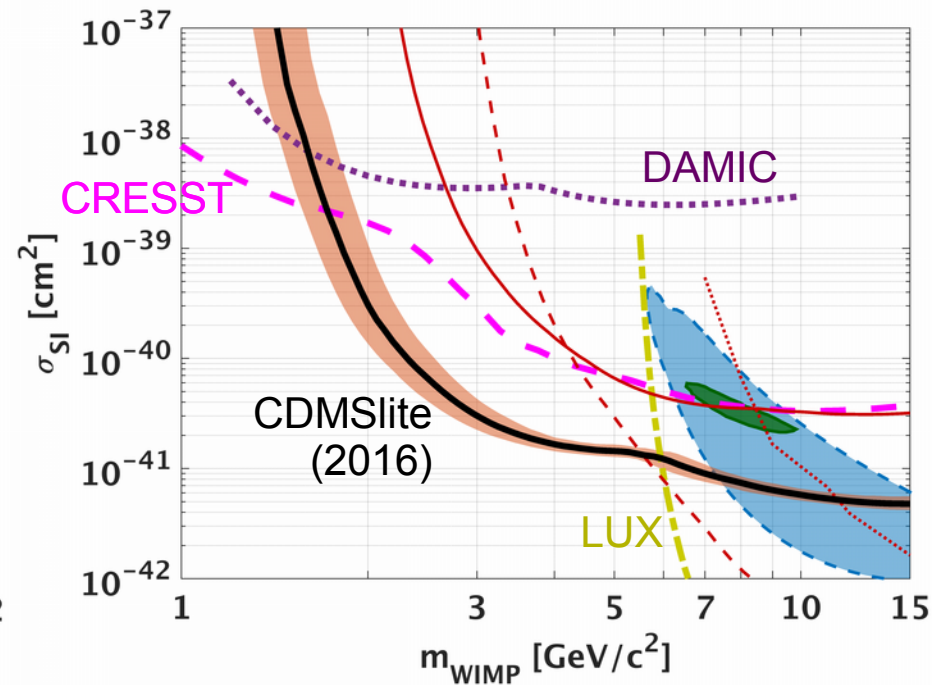
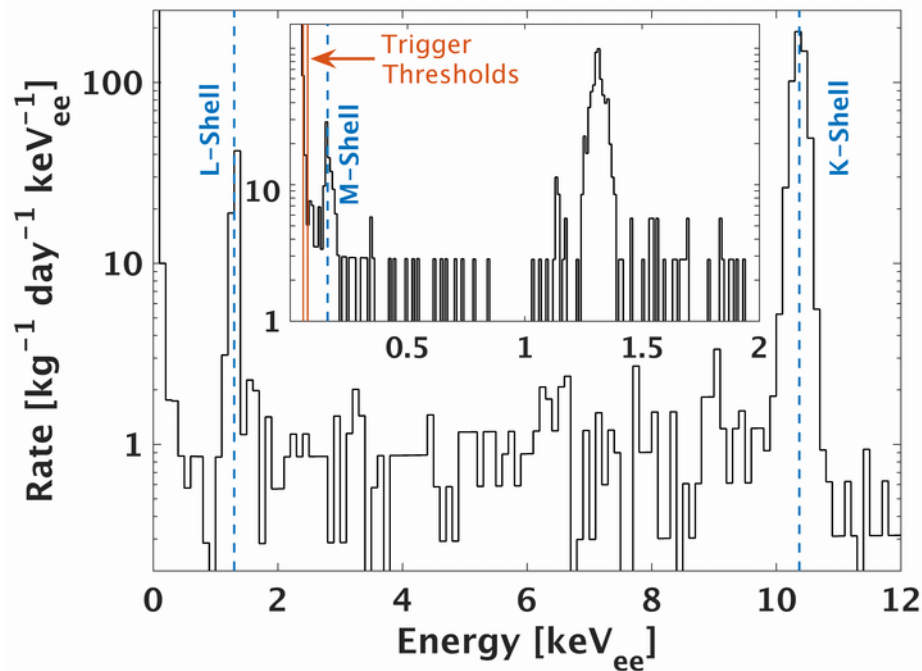
PRL **116** 071301 (2016)

- Thresholds at  $75 \text{ eV}_{ee}$  (period 1) and  $56 \text{ eV}_{ee}$  (period 2) limited by low-frequency vibrations.
- Fiducial cut using phonon pulse shape and radial cuts.



# CDMSlite

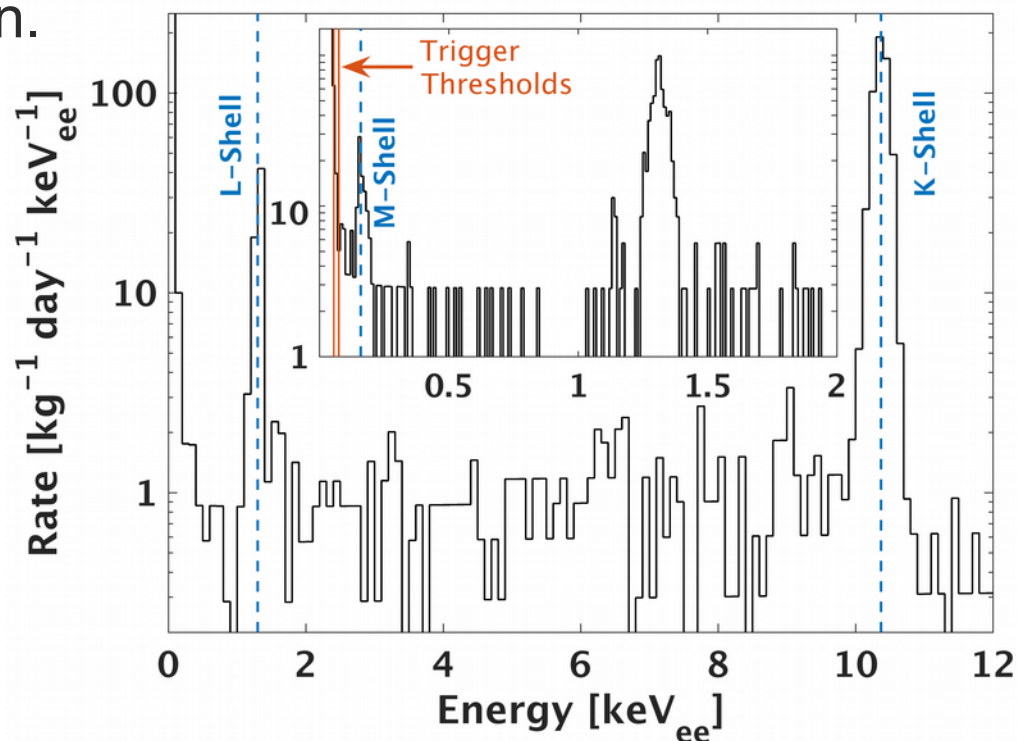
- New results – PRL **116** 071301 (2016)
  - World leading low-mass WIMP limits.
- Final data set with lower hardware threshold under analysis.



# Tritium Backgrounds

Critical background for SuperCDMS SNOLAB (see Lauren's talk)

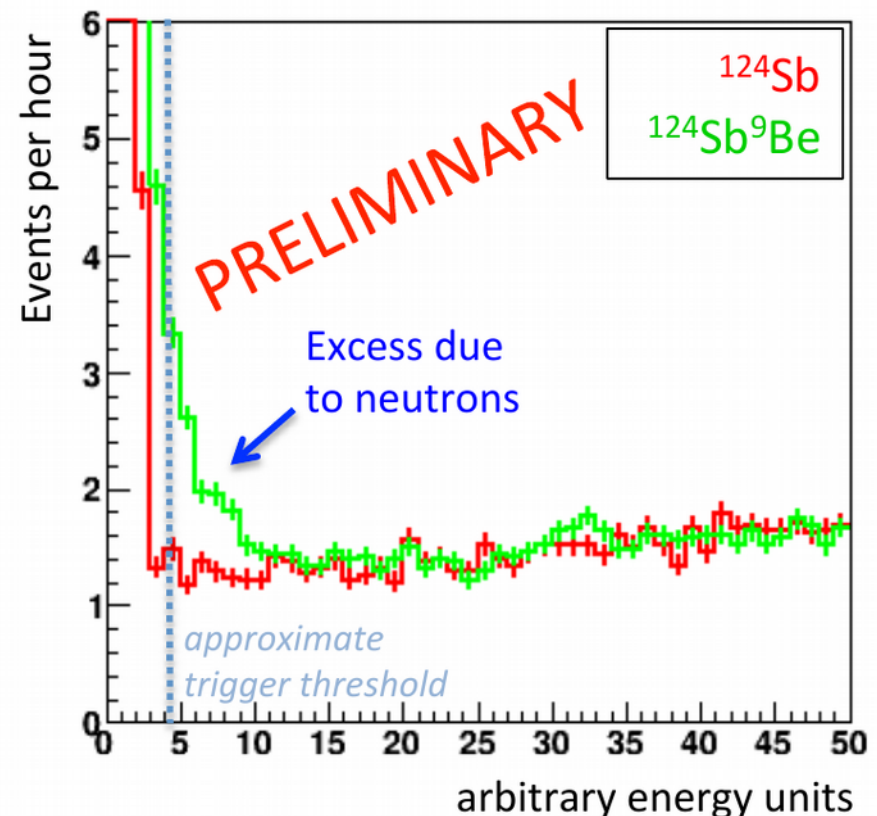
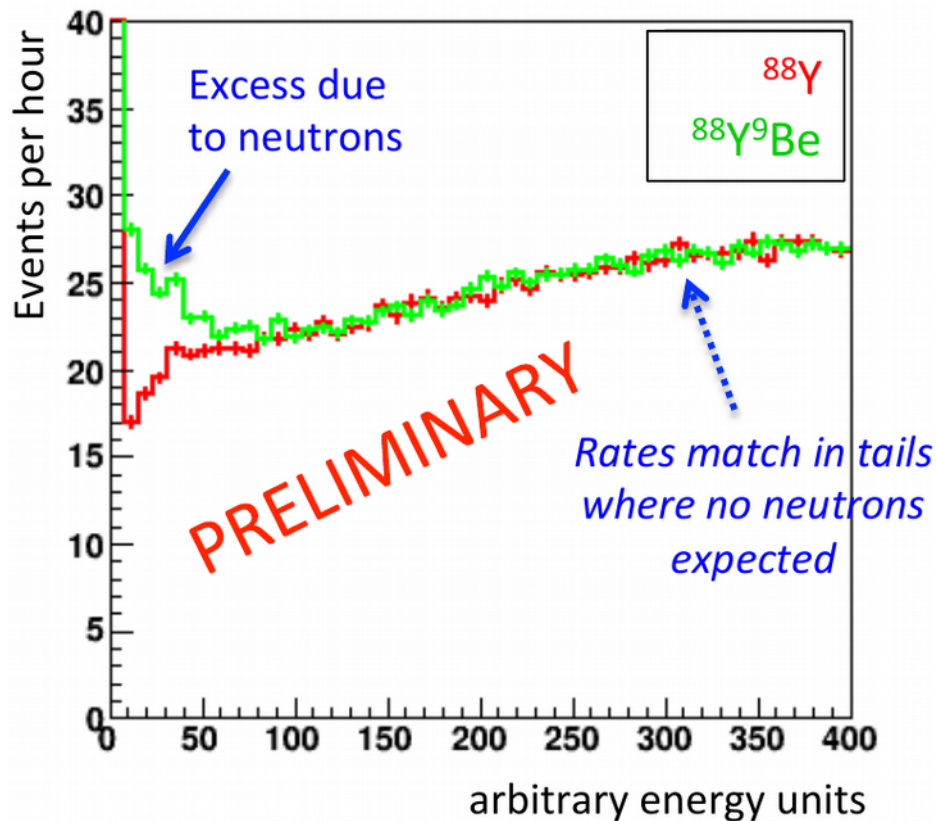
- EDELWEISS measured  $82 \pm 21$  atoms/kg/day production at SL
- Consistent with CDMSSlite background after multiyear surface exposure.
  - Publication in preparation.



# Nuclear Recoil Energy Scale

Use neutron scattering to simulate dark matter signal

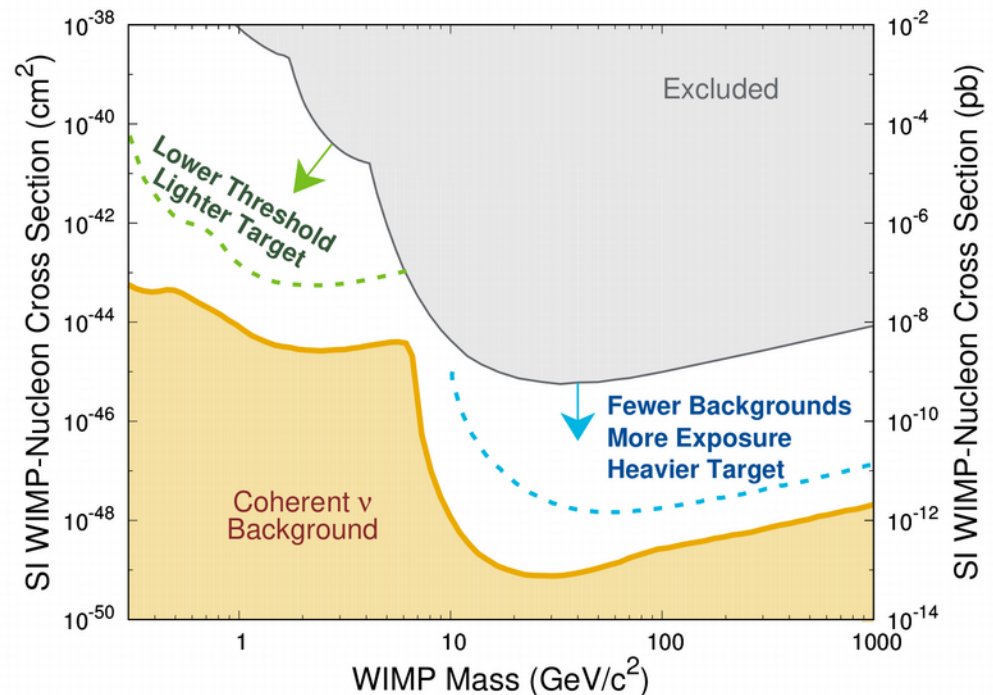
- New energy regime w/ ultralow threshold CDMSlite detectors



# Onto SuperCDMS SNOLAB

Aiming for world's best sensitivity for  $<10$  GeV WIMPs

- Using Soudan experience to understand
  - Thresholds
  - Calibration
  - Backgrounds
  - Technical challenges
- See Lauren Hsu's talk



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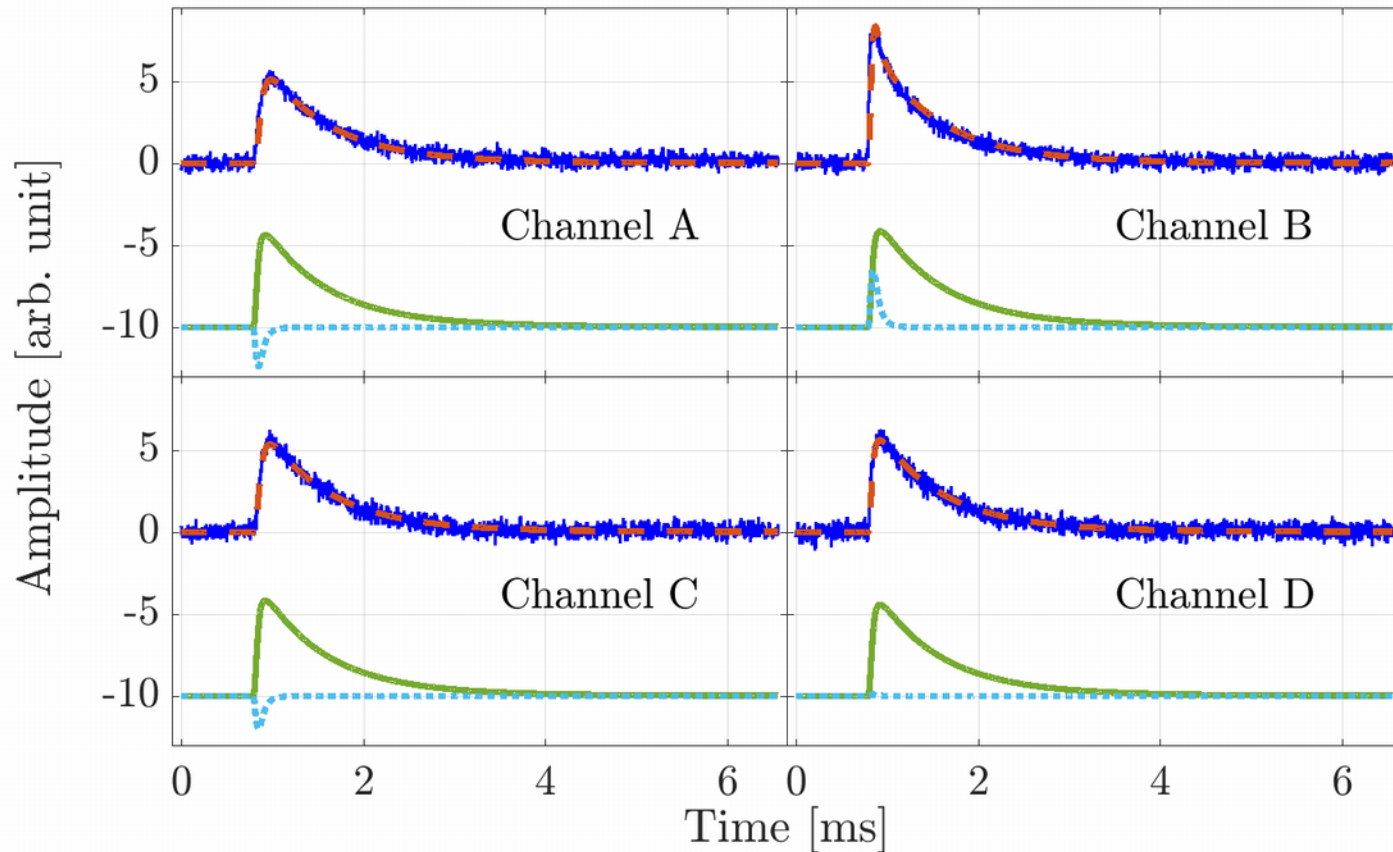
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## **Extra Slides**

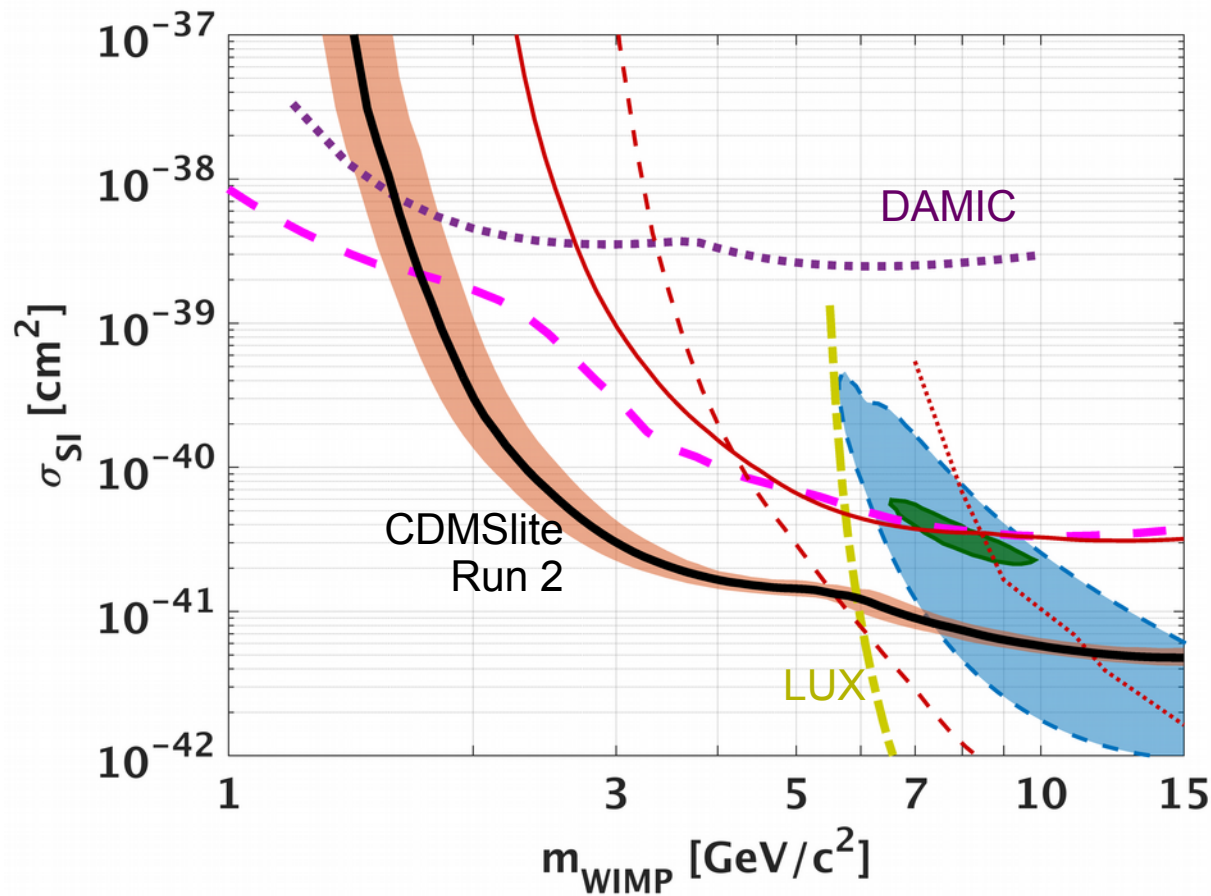
# Phonon Pulse Shape

Fast (diffusive) and slow (ballistic) phonon absorption



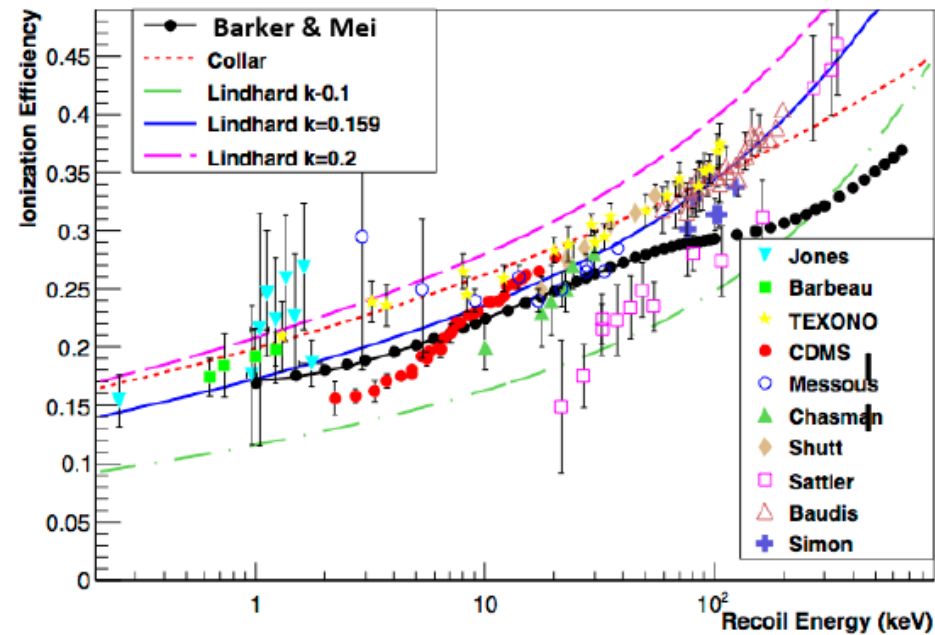
# Effect of deviations from Lindhard

Plot of sensitivity vs threshold



# Current status on ionization yields

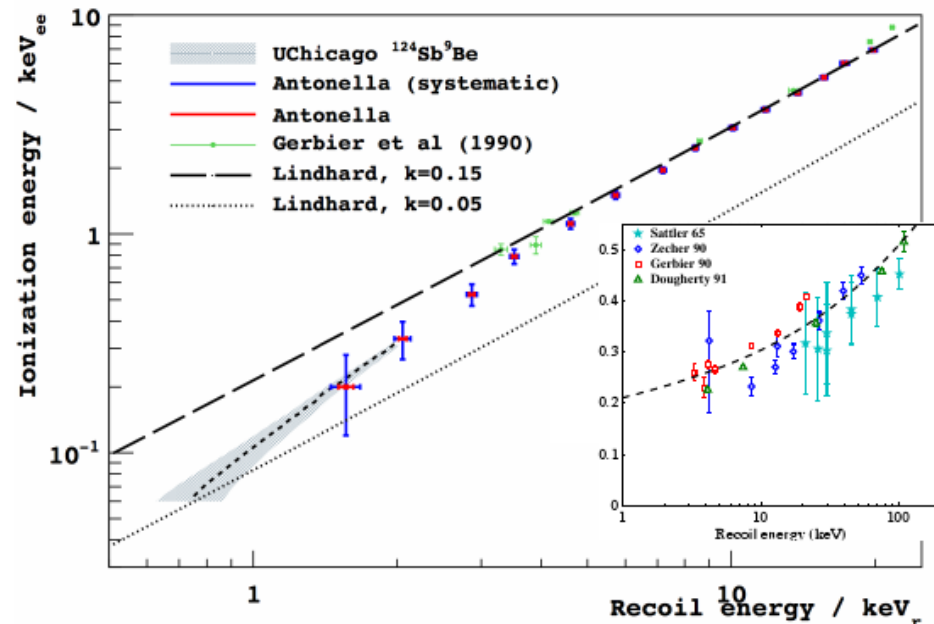
## Germanium



Note sensitivities on previous slide assumed 40 eV ionization threshold and that ionization yield follows Lindhard down to that point.

*In addition to how much the yield differs from Lindhard, at some point we expect a physical turnoff in ionization yield. Where this cutoff is can have large implications.*

## Silicon



A. Chavarria, LowECal workshop, Chicago (2015)

ICHEP, August 2016