CONSTRAINTS ON LIGHT DARK MATTER FROM CDMS II

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on behalf of the CDMS Collaboration

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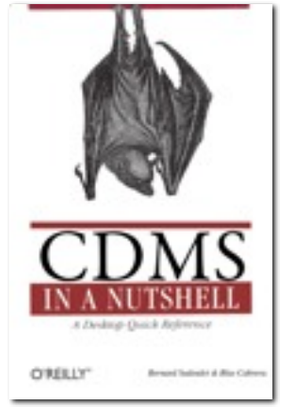
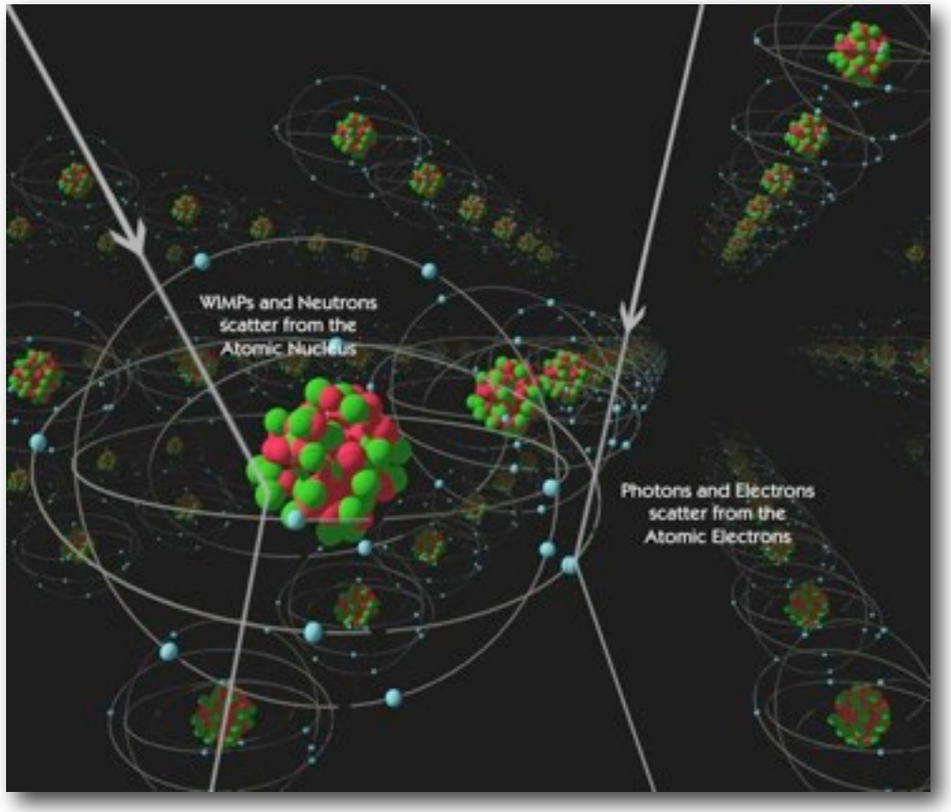
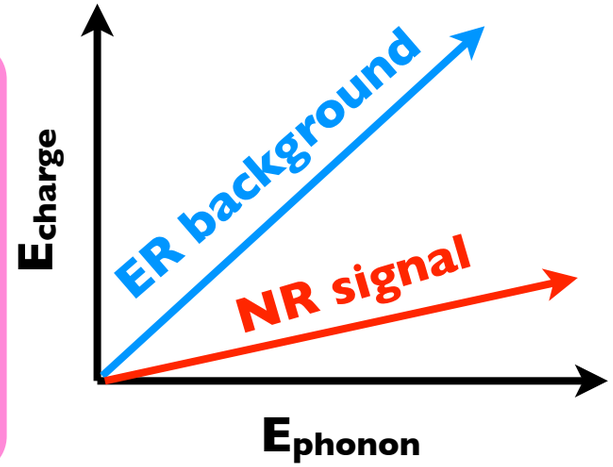
THE BIG PICTURE



Use a combination of **discrimination** and **shielding** to maintain a **"<1 event expected background"** experiment with **low temperature** semiconductor detectors



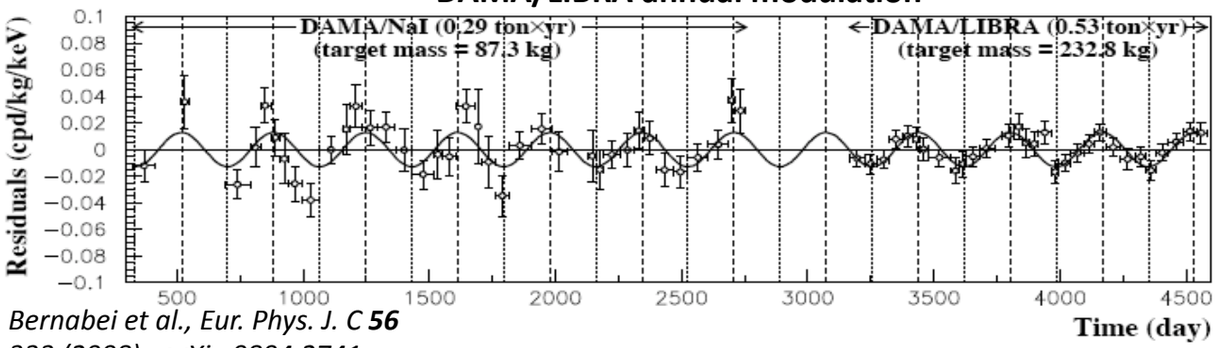
Discrimination from measurements of **ionization** and **phonon energy**.



Keep backgrounds low as possible through shielding and material selection.

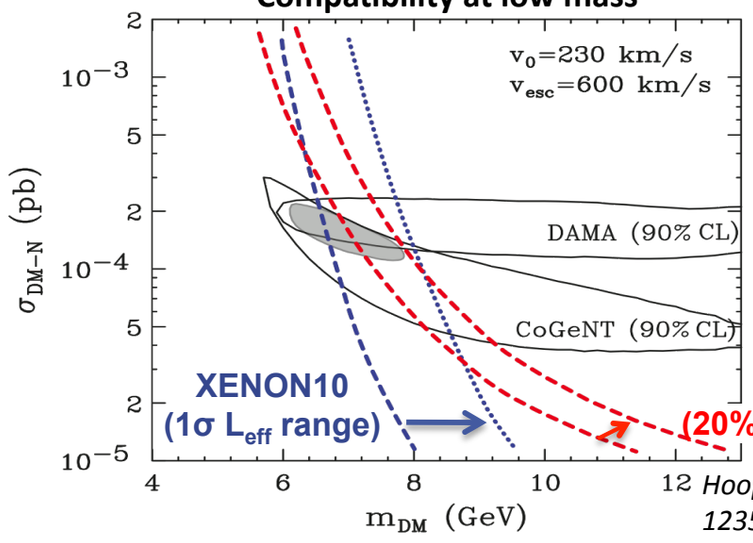
LOW MASS WIMPS

DAMA/LIBRA annual modulation



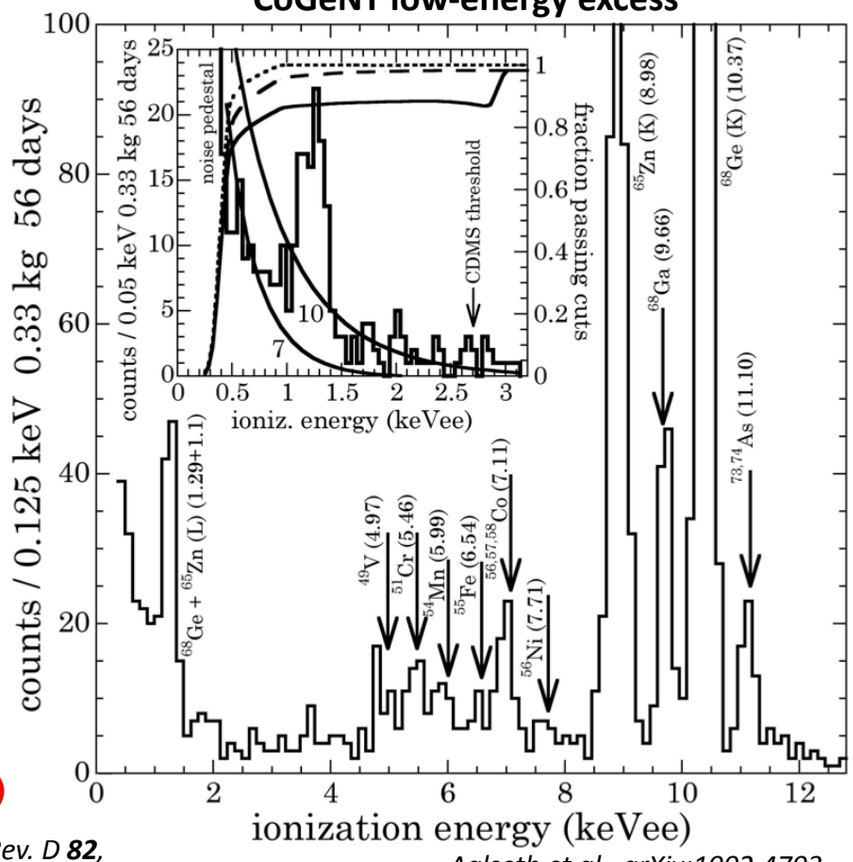
*Bernabei et al., Eur. Phys. J. C **56** 333 (2008), arXiv:0804.2741*

Compatibility at low mass



*Hooper et al., Phys. Rev. D **82**, 123509 (2010), arxiv:1007.1005*

CoGeNT low-energy excess

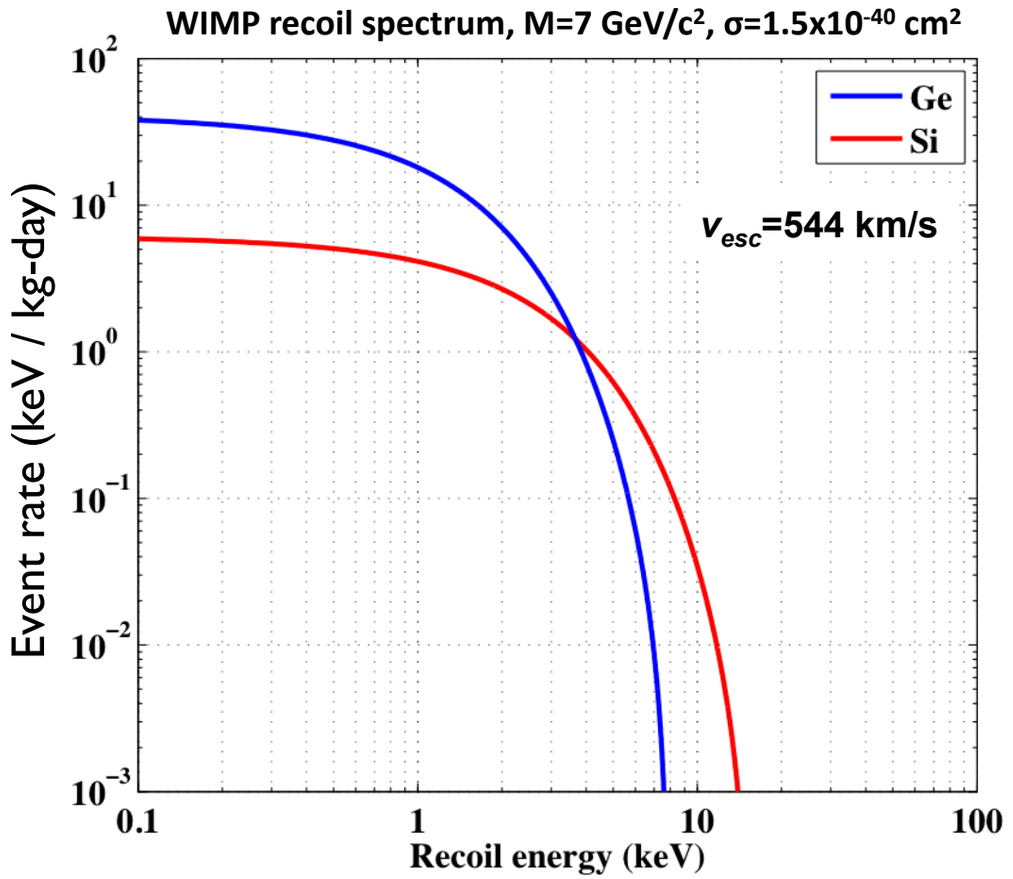


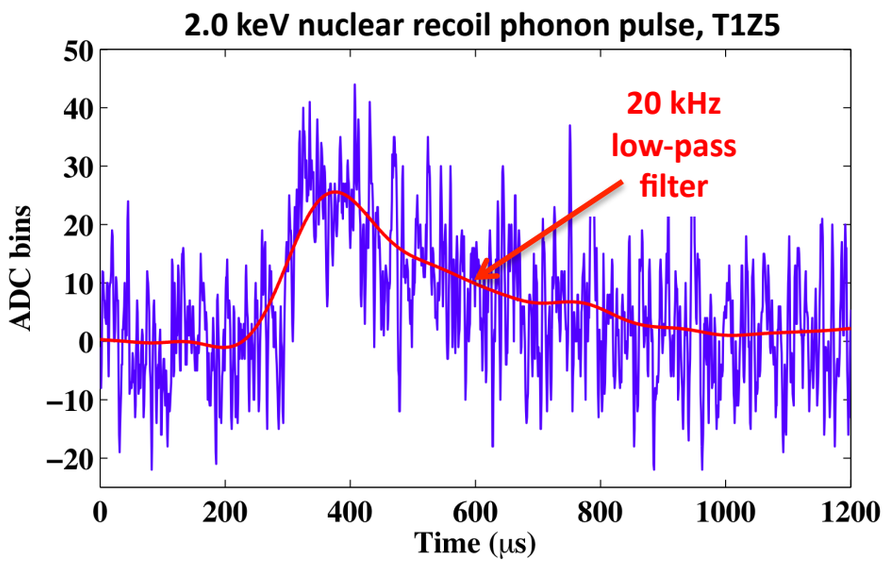
Aalseth et al., arXiv:1002.4703

- RESULTS FROM DAMA/LIBRA AND COGENT HAVE BEEN INTERPRETED AS WIMPS with $m_\chi \sim 7$ GeV and $\sigma_{SI} \sim 1\times10^{-40}$ cm^2.
- POSSIBLY COMPATIBLE WITH CDMS (SI) AND XENON RESULTS DUE TO CALIBRATION UNCERTAINTIES AT LOW ENERGY.

CAN CDMS SAY ANYTHING ABOUT LOW MASS WIMPS?

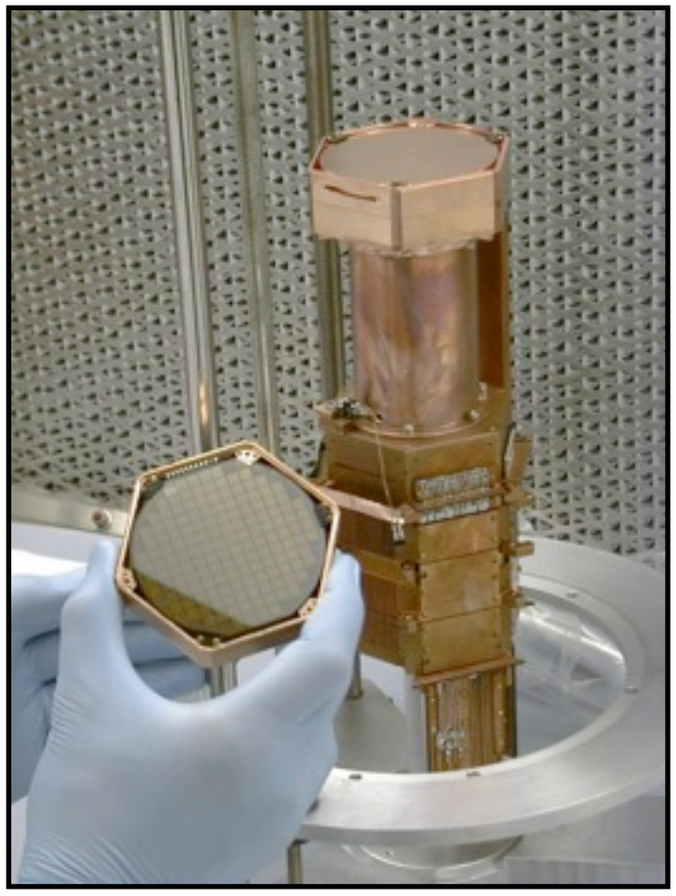
- Traditional CDMS analyses used ~10 keV analysis thresholds to maintain a < 1 event background
  - No sensitivity to WIMPS with mass below ~7 GeV/c^2
- We can lower the analysis threshold at cost of higher backgrounds.





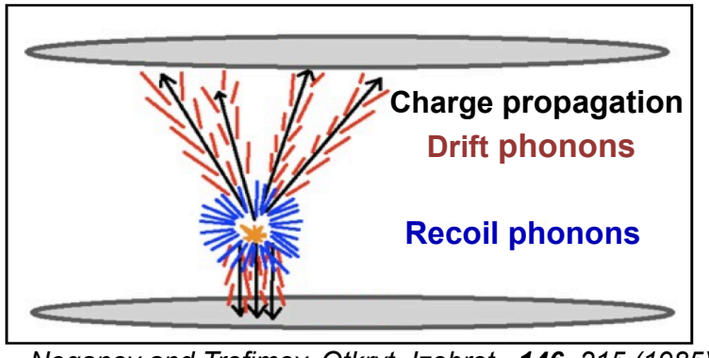
LOW MASS WIMPS

- Lower threshold (2 keV), increases sensitivity to WIMPs with mass below ~10 GeV/c^2
- Used 8 Ge detectors with the lowest detector thresholds (1.5 - 2.5 keV)
- Data taken from Oct. 2006 - Sept. 2008 (241 kg-days "raw" exposure)
- A small subset (1/4) of data was used to study backgrounds at low energies
  - Results were dominated by detector with best resolution (T1Z5)
- Measure both ionization and phonons to discriminate against low-energy electron recoil backgrounds

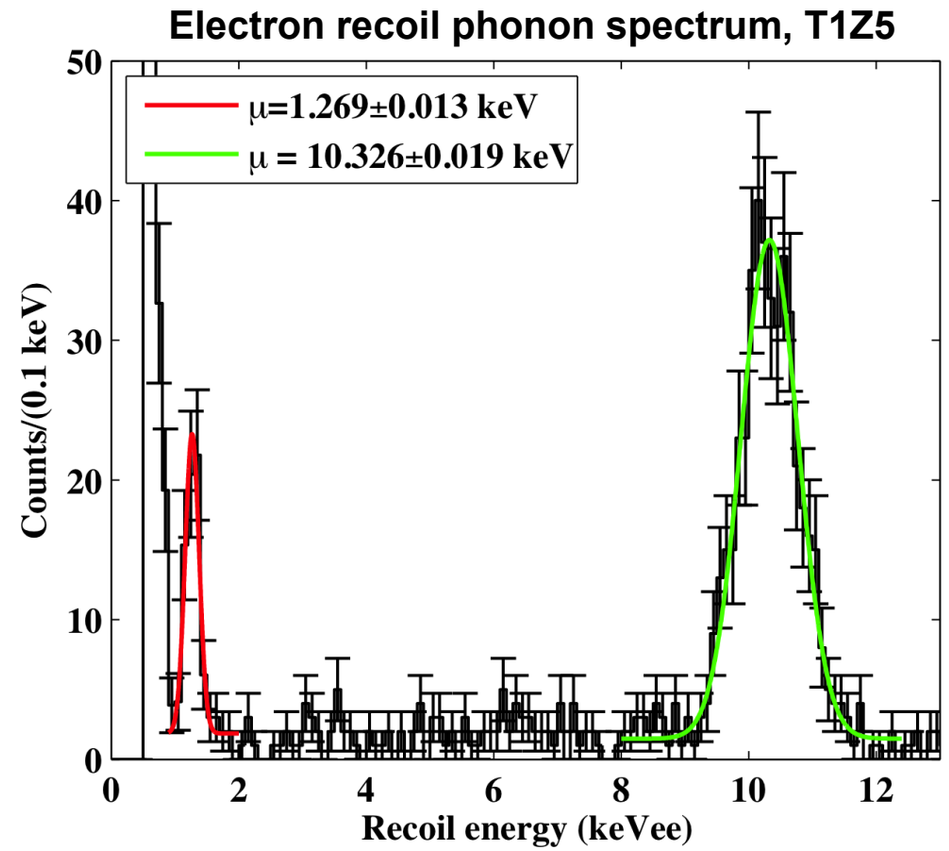


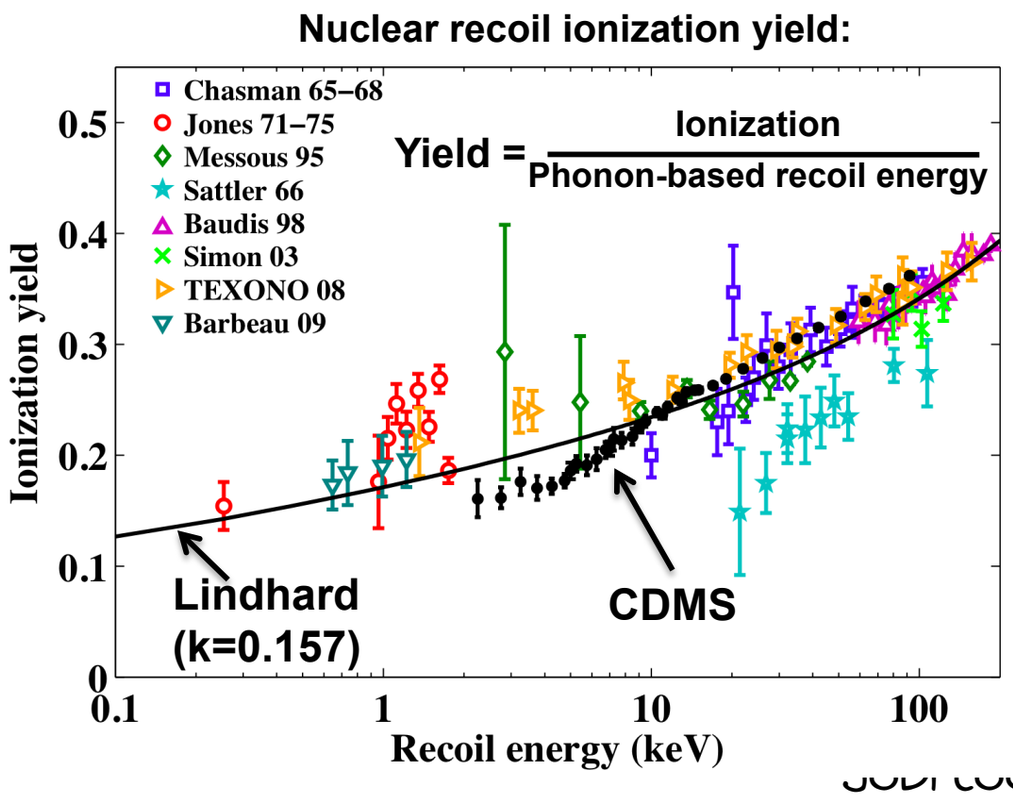
CALIBRATION OF ENERGY SCALES

- Phonon energy scale calibrated with electron recoil lines at 1.3 keV and 10.37 keV.
- Nuclear recoil energy is reconstructed from recoil energy alone after subtracting off phonon energy due to "drift" across the crystal (drift heating).
- Measured yields agree well with previous measurements and theory.

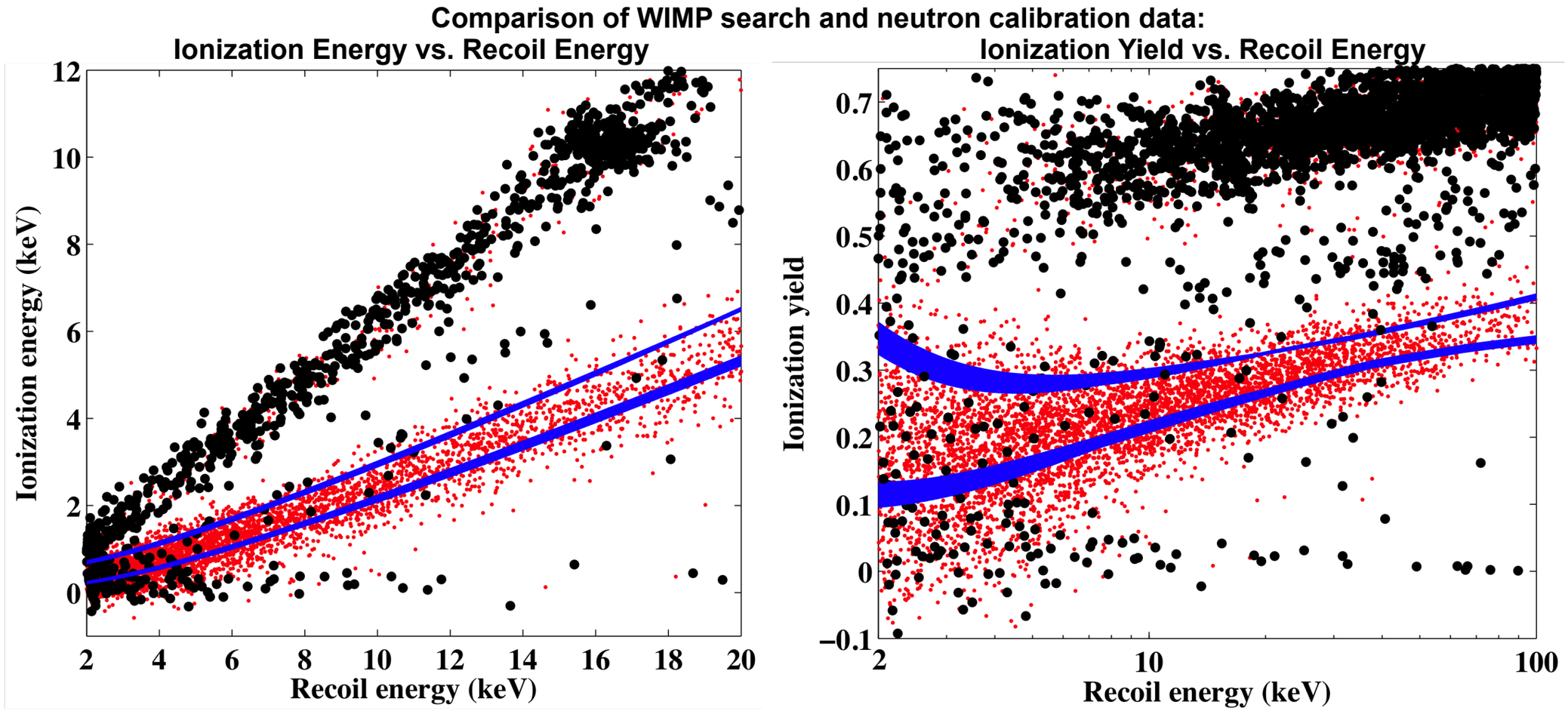


*Neganov and Trofimov, Otkryt. Izobret., **146**, 215 (1985)*
Luke, J. Appl. Phys., 64, 6858 (1988)





NUCLEAR RECOIL SELECTION



- Nuclear recoil acceptance region is defined as (+1.25, -0.5)σ band in ionization energy using neutron calibration data.
  - Maximize sensitivity to nuclear recoils while minimizing backgrounds.

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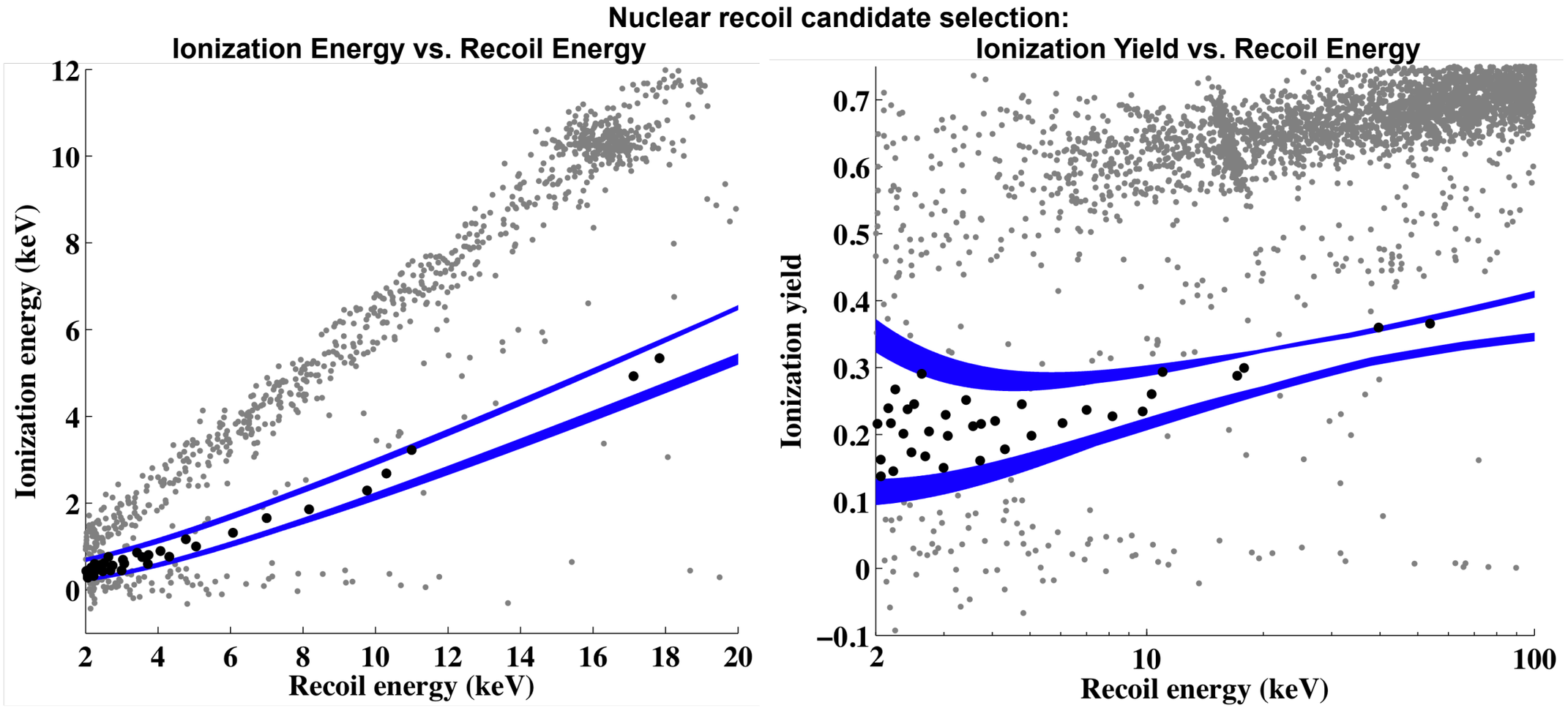

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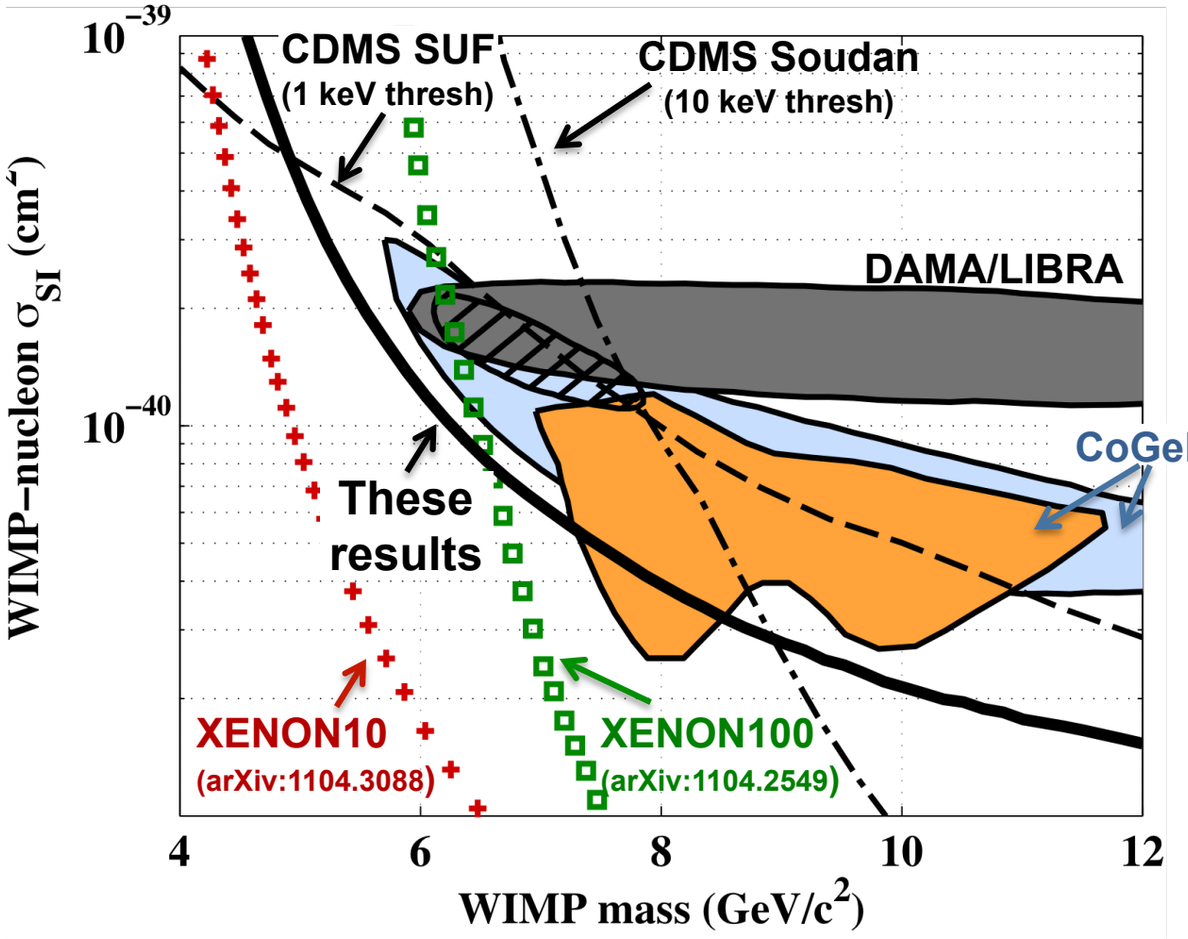
LOW MASS RESULTS

90% CL upper limits on elastic scattering cross section



Phys. Rev. Lett. 106:131302
arXiv: 1011.2482

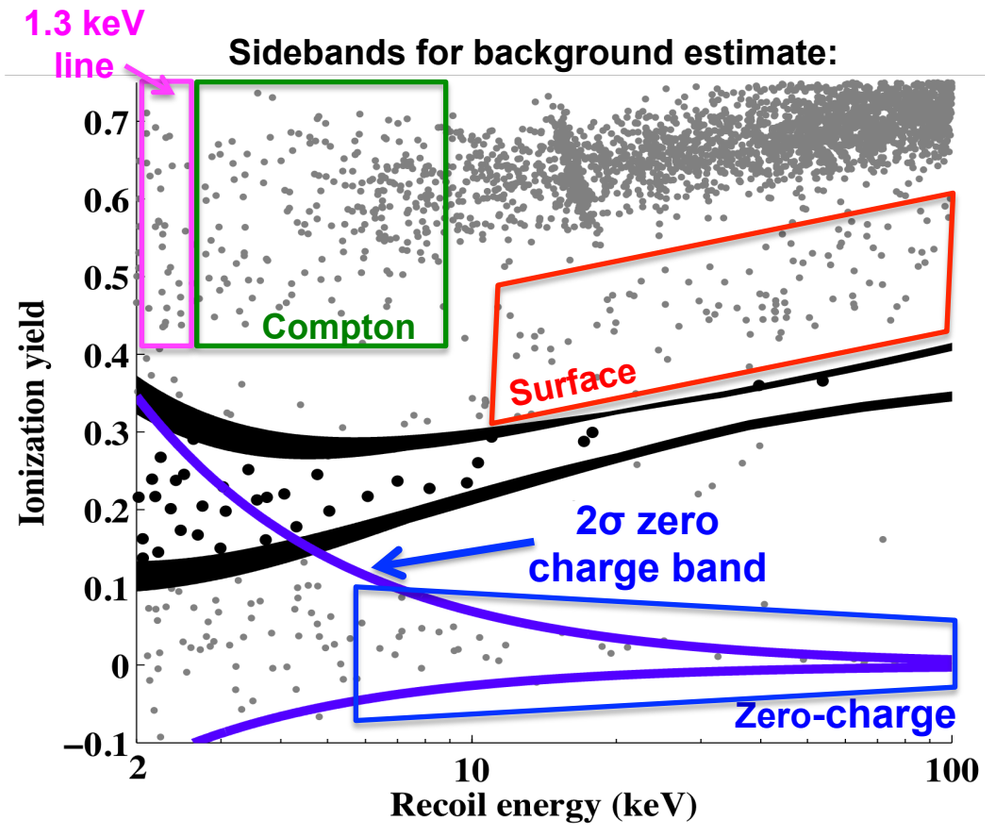
- Assumed that all events could be WIMPs (no background subtraction).
- Limits set using the Yellin Optimum Interval Method.

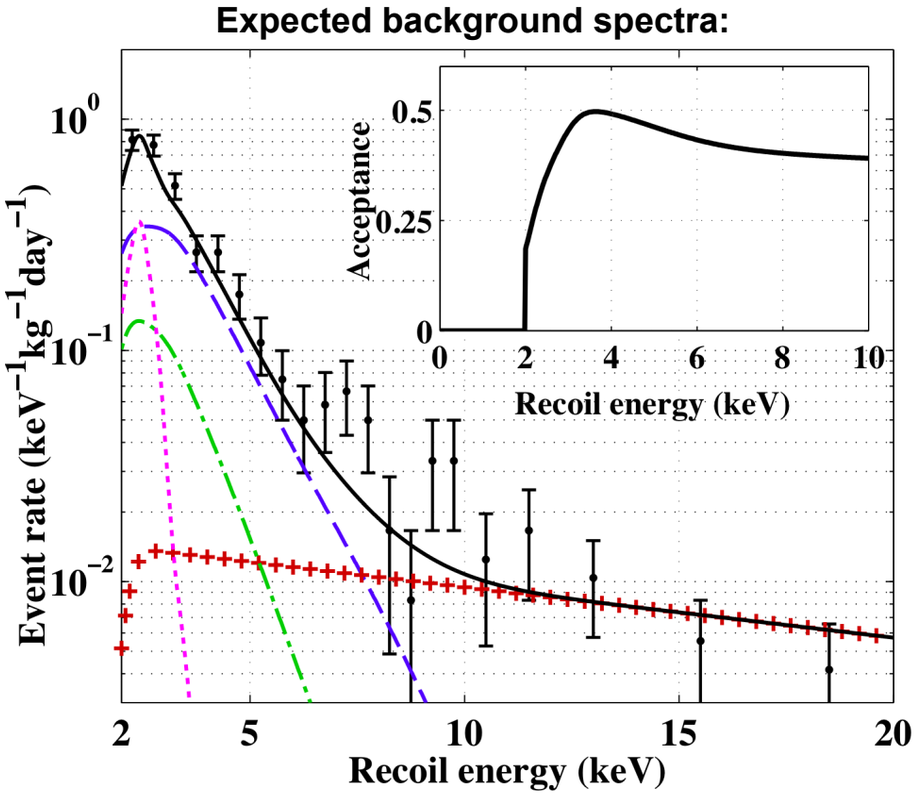
S. Yellin, PRD, 66, 032005 (2002); arXiv:0709.2701v1 (2007)

- 90% CL limits are incompatible with DAMA/LIBRA and CoGeNT for spin-independent elastic scattering.

ELECTRON RECOIL BACKGROUNDS

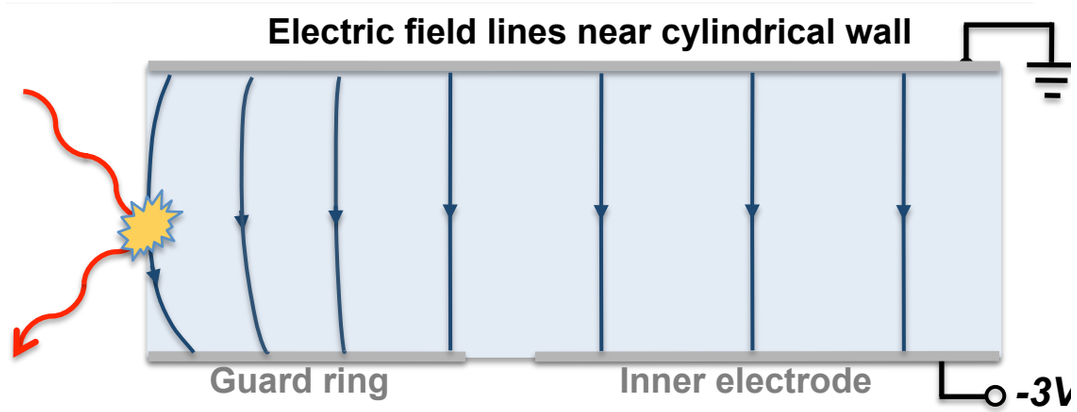
- Observed candidates can be explained by extrapolations of background estimates.
  - Possible significant systematic errors due to extrapolations to low energy.
- We do not subtract off these backgrounds when setting limits.

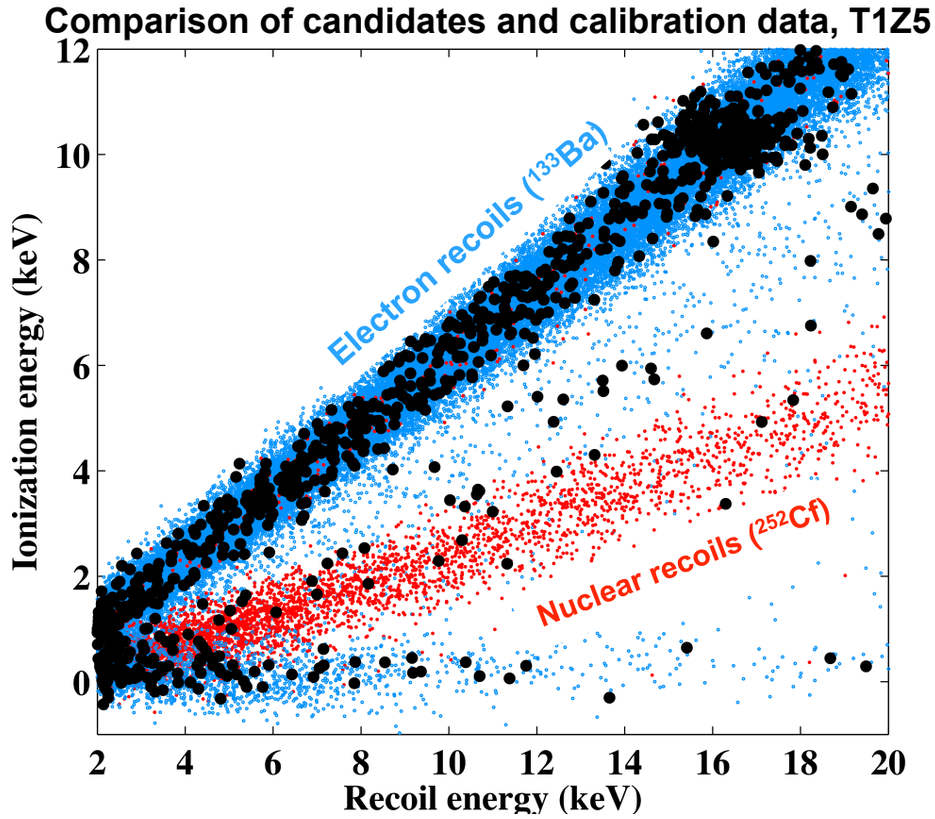




ZERO CHARGE EVENTS

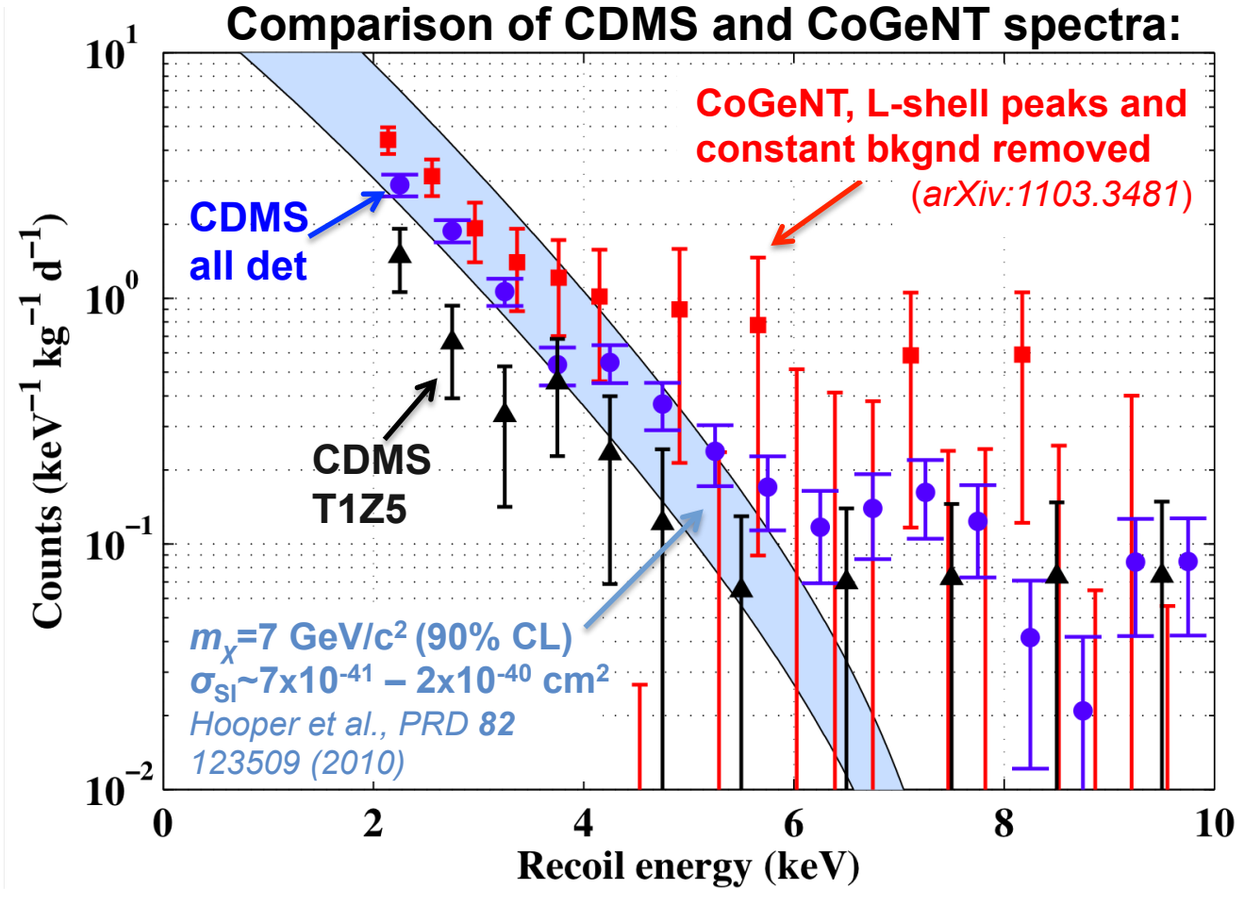
- Dominant expected background below 10 keV.
- Consistent with electron recoils where charge is collected on the sides of the cylindrical surfaces
- Pass fiducial volume selection (guard signal consistent with noise)
- Zero charge events scale with electron-recoil rate, not exposure
- Exponential spectrum above ~5 keV extrapolated to lower energies.





COMPARISON TO COGENT

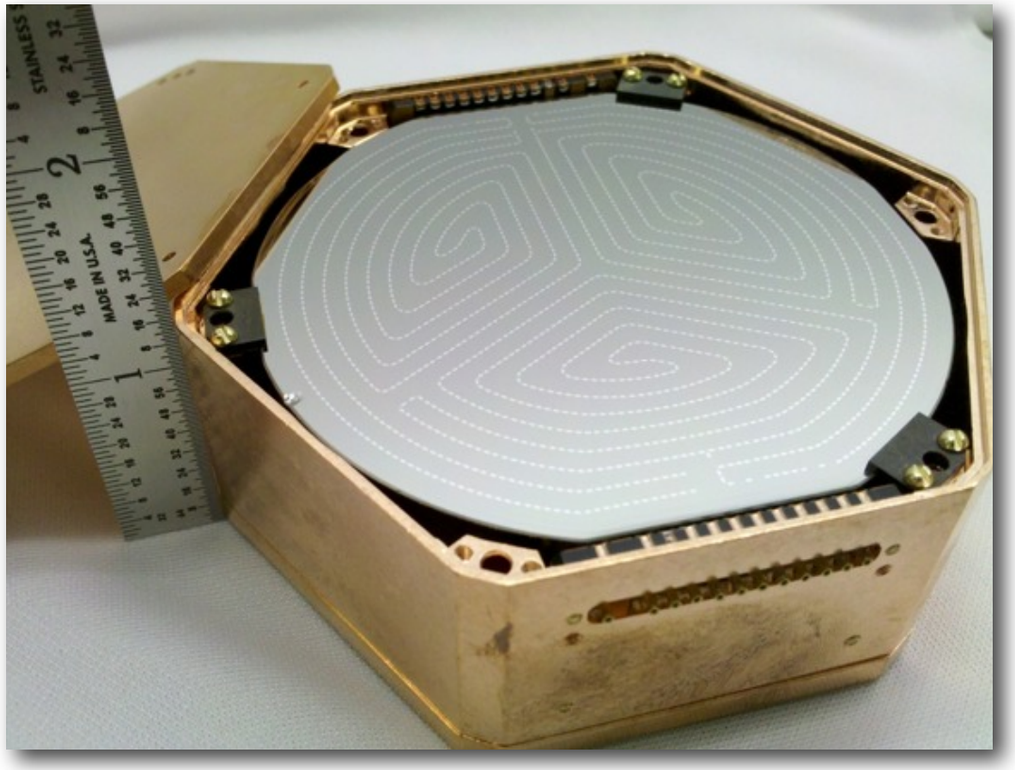
- CoGeNT and CDMS II use the same target material (Ge)
- Both experiments see an exponential spectrum above threshold.
- Rate in CDMS for best detector is inconsistent with low mass WIMP explanation for CoGeNT excess.
- No background subtraction!

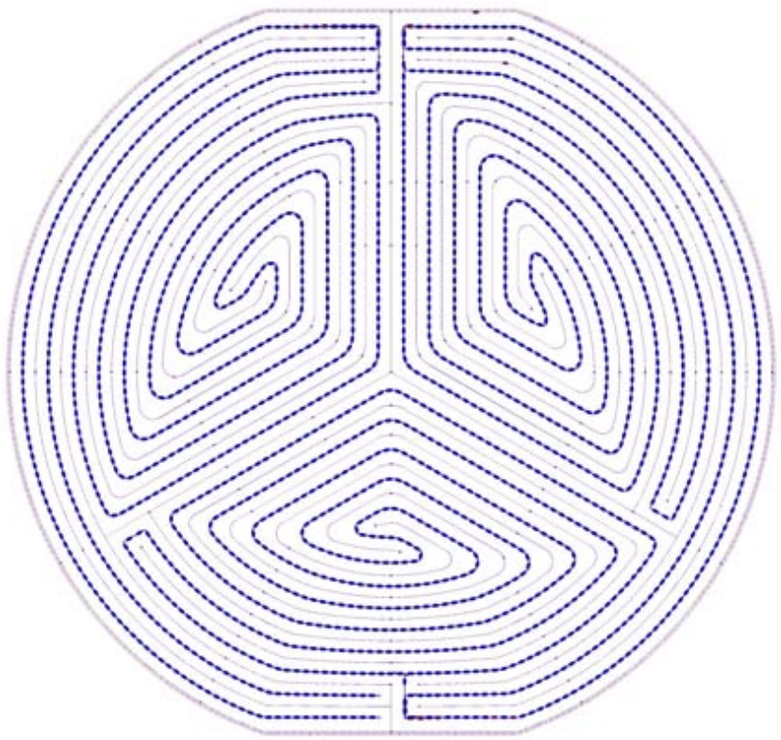


SUPERCDMS @SOUDAN

- Approved to deploy 5 towers of of advanced iZIP detectors (~10 kg Ge) in the existing cryostat at the Soudan Underground Laboratory.
- Analysis of data from commissioning run of the first tower of iZIP detectors is underway.
- Fabrication of remaining iZIP detectors expected to be completed this summer.
- Start of operation -- 2011.

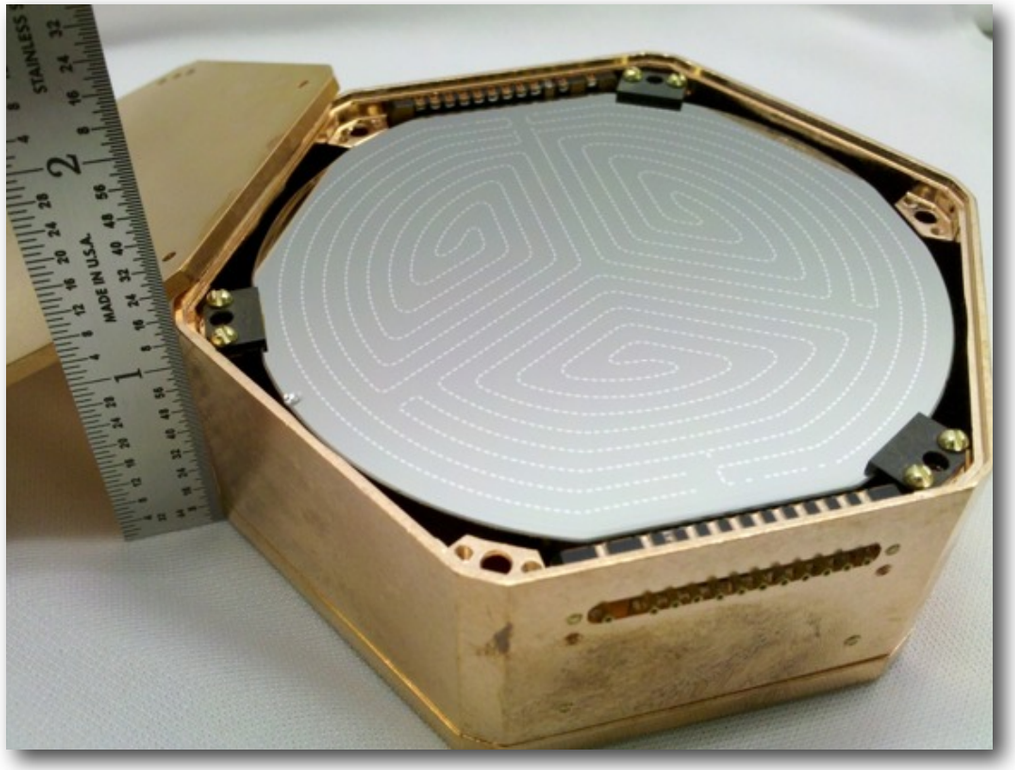
iZIP DETECTORS





- 2.5 cm thick interleaved ZIP (iZIP) double sided detectors
  - (2.5x thicker than CDMS II)
- Charge electrodes are interleaved with narrow strips of phonon sensors.
  - Phonon sensors optimized to enhance phonon signal to noise ratio
- Optimized sensor layout
  - Each side has one outer channel used to define the fiducial volume of the detector and 3 inner channels to reject surface events.
- Charge channels can be used to reject surface events

IZIP DETECTORS



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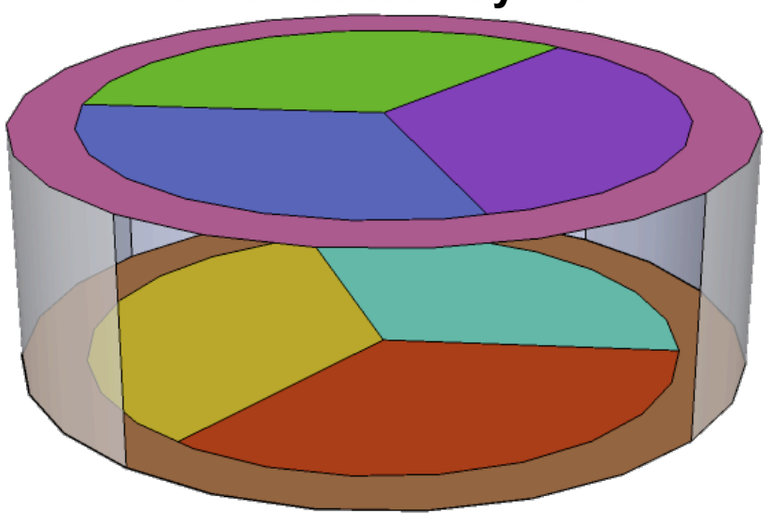
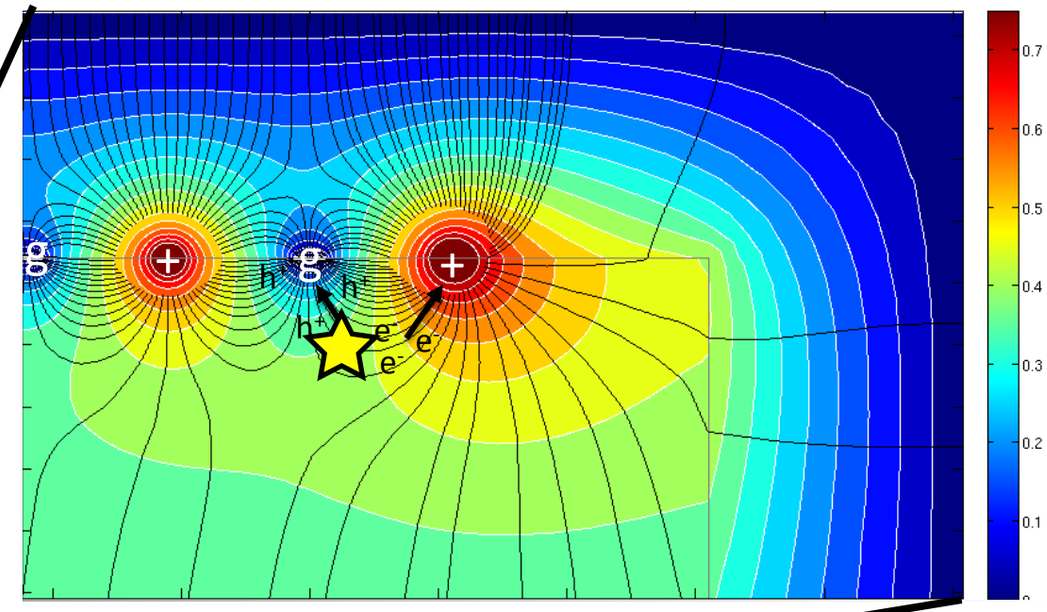
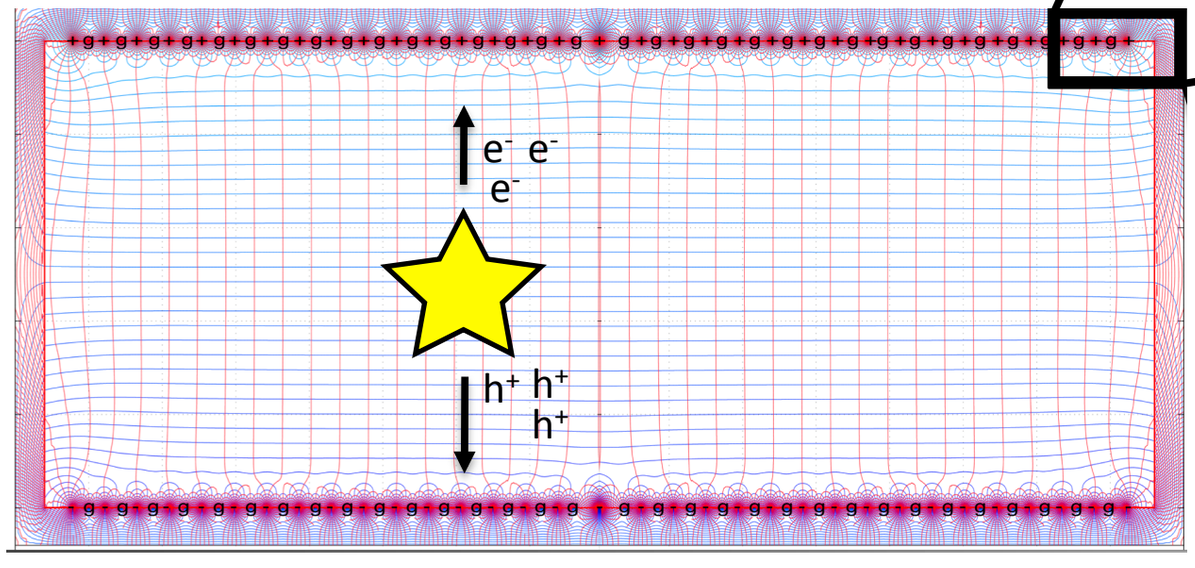
Phonon sensor layout:



IZIP CHARGE DISCRIMINATION

- **Bulk Events:**
  Equal but opposite ionization signal appears on both detectors sides (symmetric)
- **Surface Events:**
  Ionization signal appears on one detector side (asymmetric)

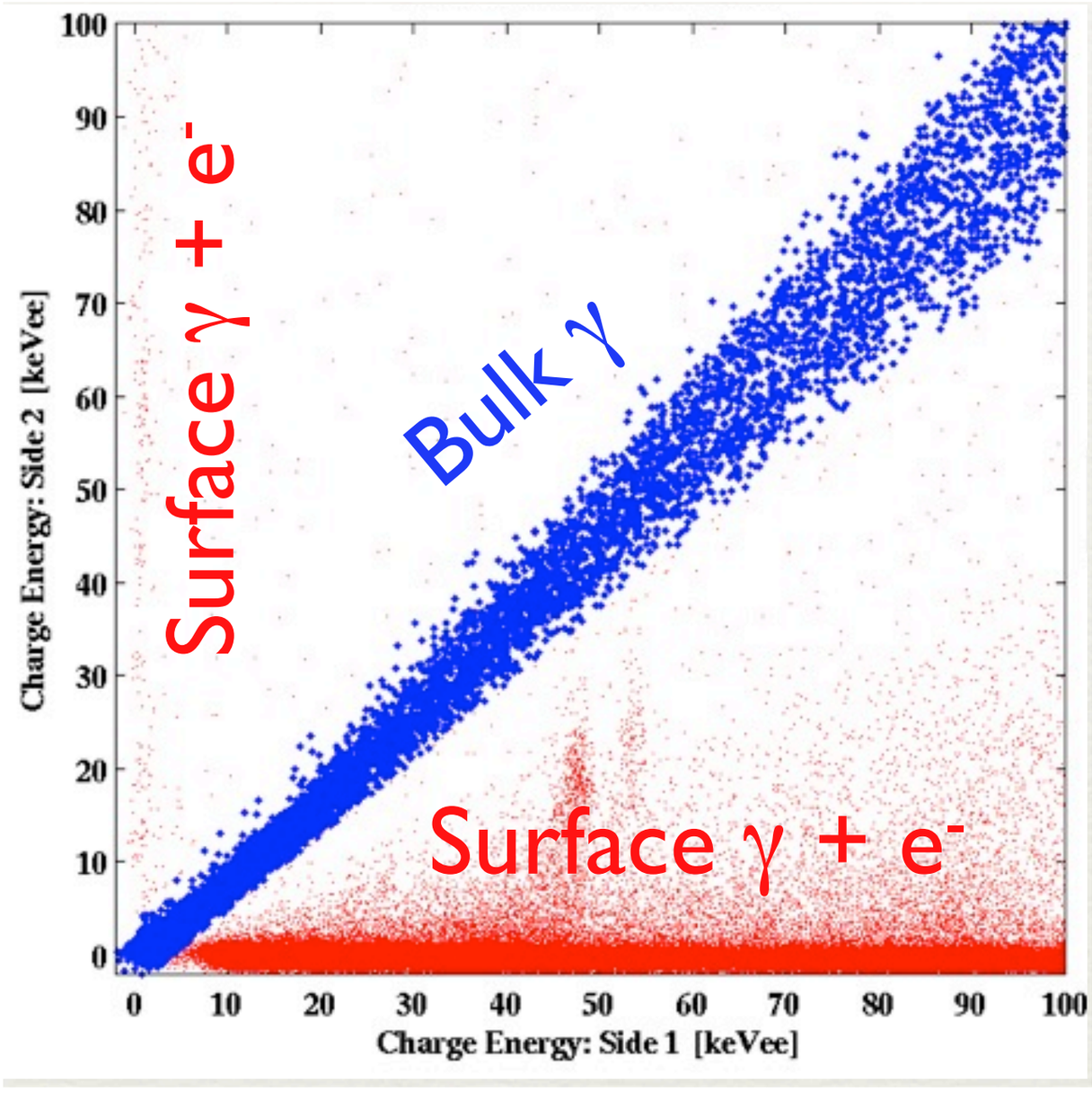




- **phonon timing pulse information still possible**

IZIP CHARGE DISCRIMINATION

- 1:10^4 surface event discrimination from ionization signal asymmetry
- Still have discrimination from ionization yield and pulse shape



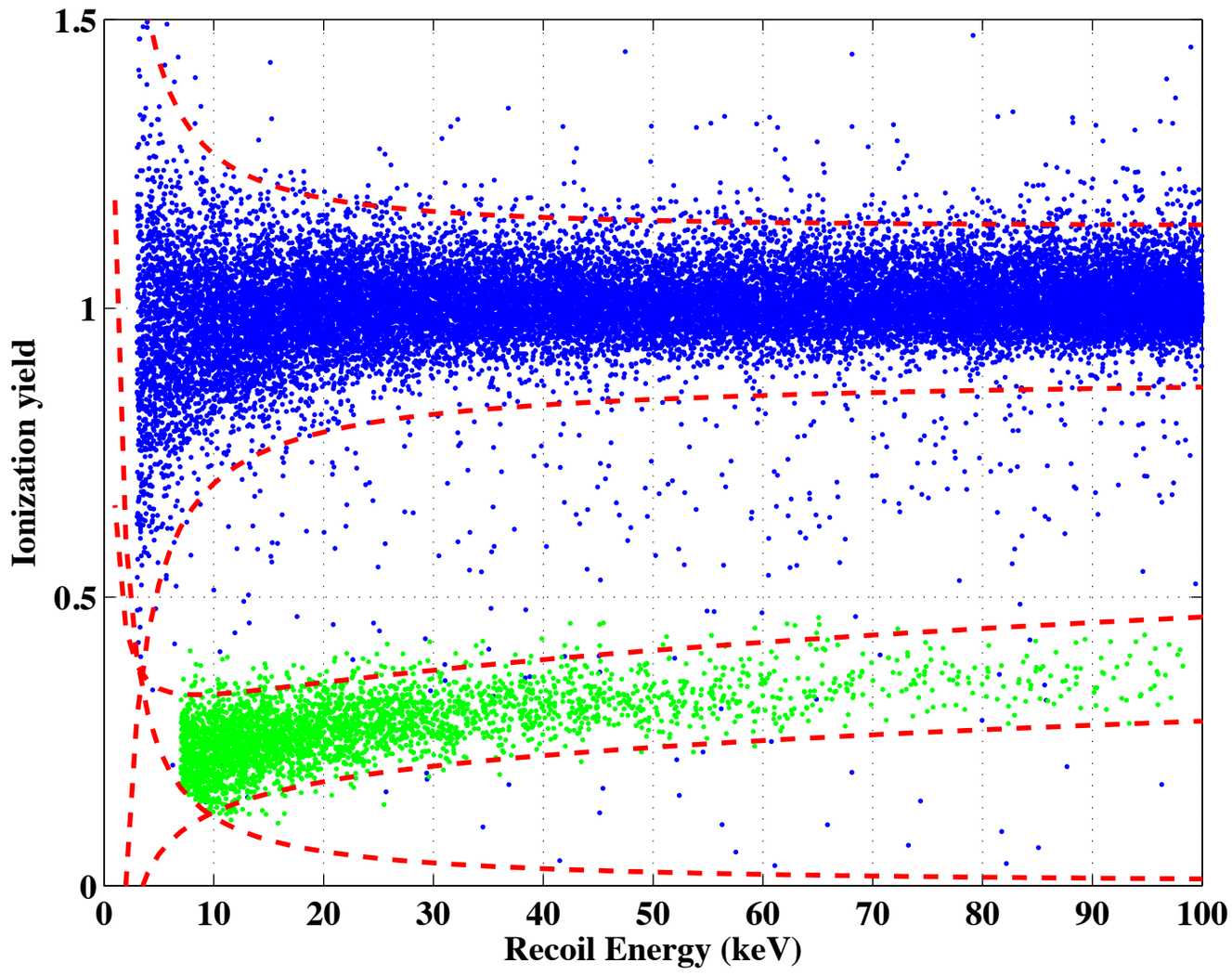
SUMMARY

- The CDMS II data has been reanalyzed with a lower 2 keV recoil energy threshold.
- The lower threshold introduces significant background into the analysis.
- Even without background subtraction, results from this analysis are incompatible with an interpretation of DAMA/LIBRA and CoGeNT in terms of spin-independent elastic scatters of low mass WIMPs.
- SuperCDMS at Soudan is expected to start operations later this year utilizing new iZIP detectors.

BACK-UP SLIDES

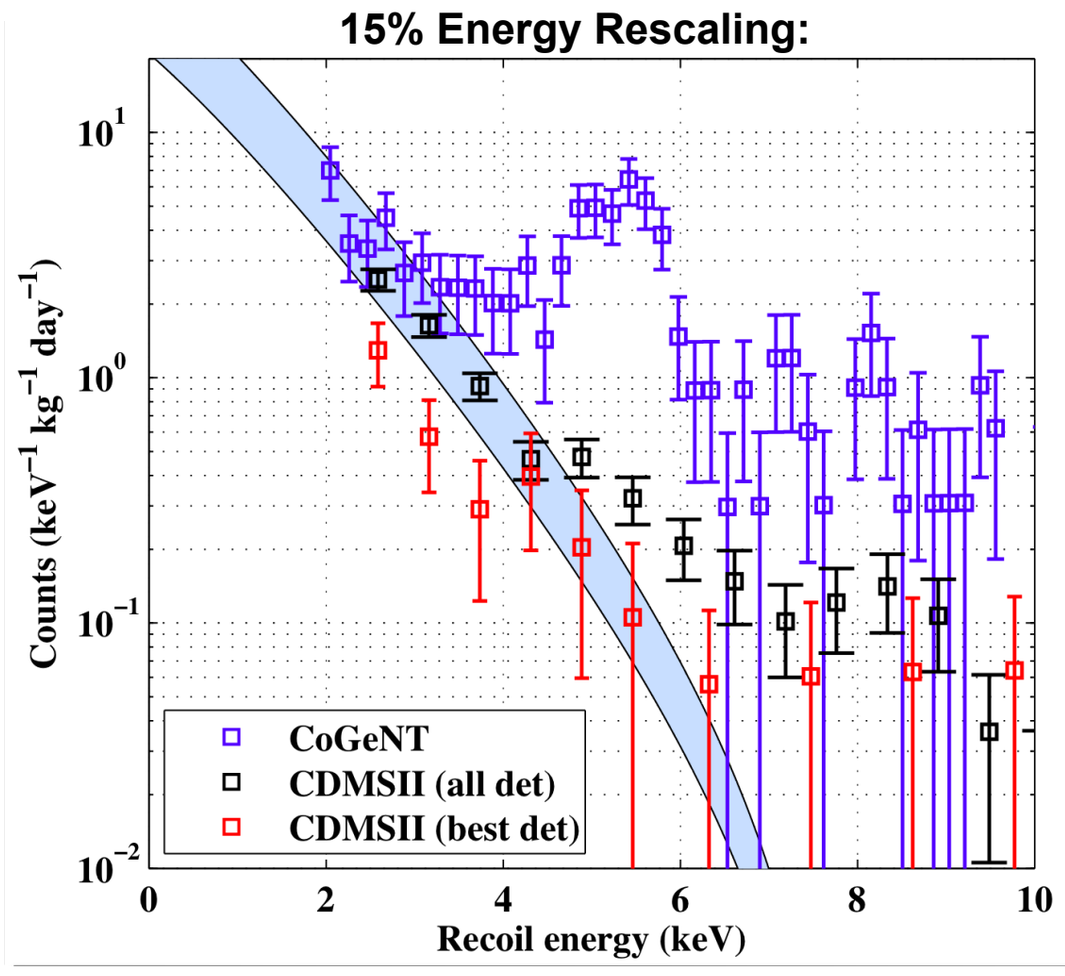
BACKGROUND REJECTION: YIELD

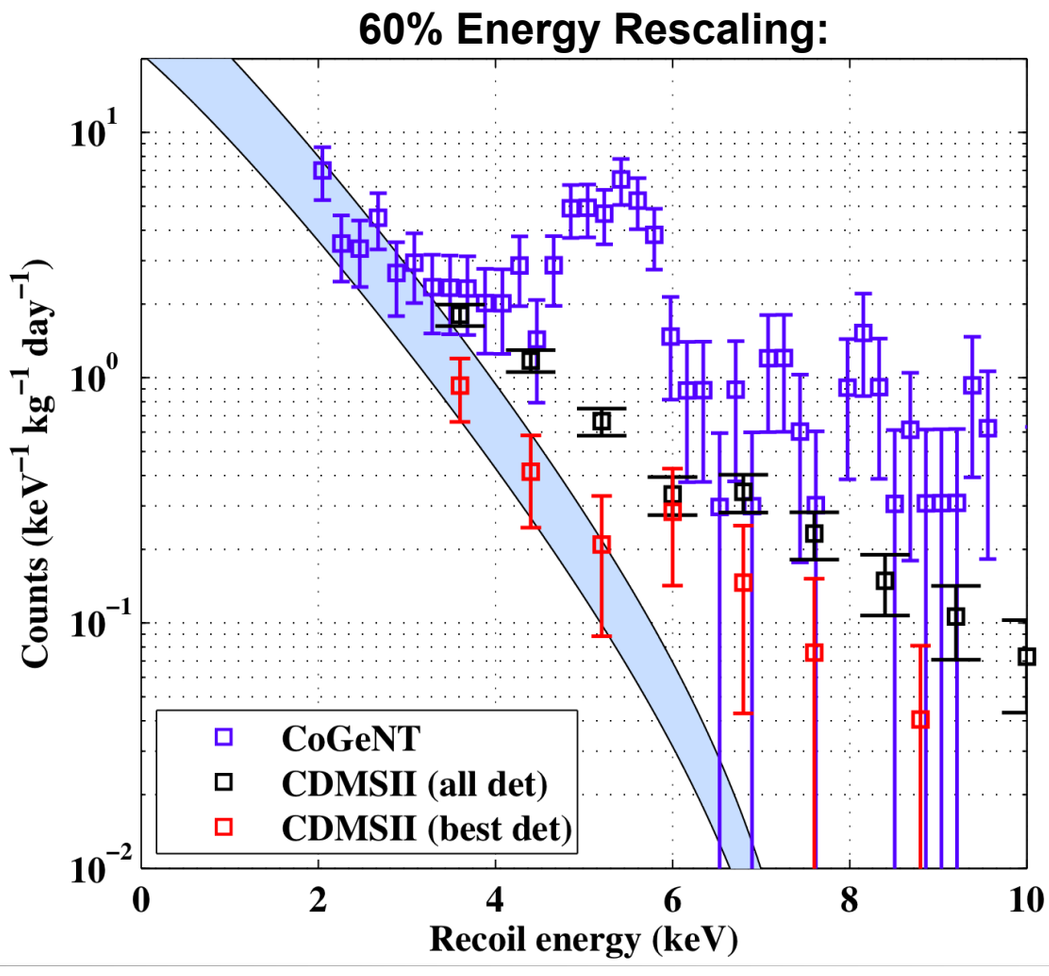
- ☑ Ionization yield (ionization energy per unit phonon energy) depends strongly on particle type.
- ☑ Most backgrounds produce elecron recoils
- ☑ Wimps and neutrons produce nuclear recoils
- ☑ Excellent yield-based discrimination for electron recoils:
  < 10^{-4} mis-id probability



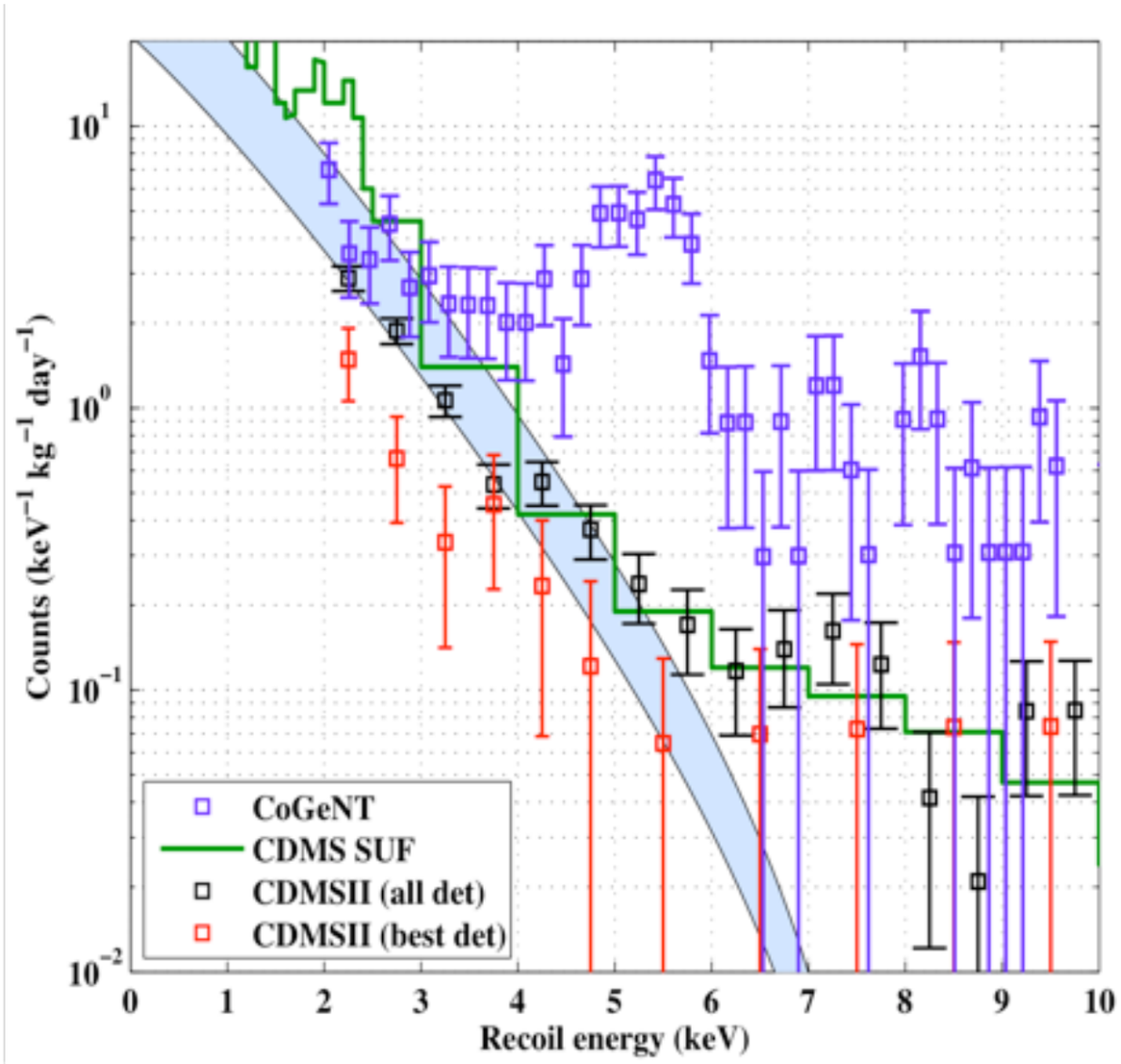
RESCALING RECOIL ENERGY

- The recoil energy scale would need to be off by 15% for coadded detectors or 60% in our best detector for good agreement with CoGeNT (7 GeV/c^2 WIMP).
- Energy scale already assumes most conservative values consistent with 1.3 keV activation recoil line at 90% CL.





COMPARISON TO SUF DATA

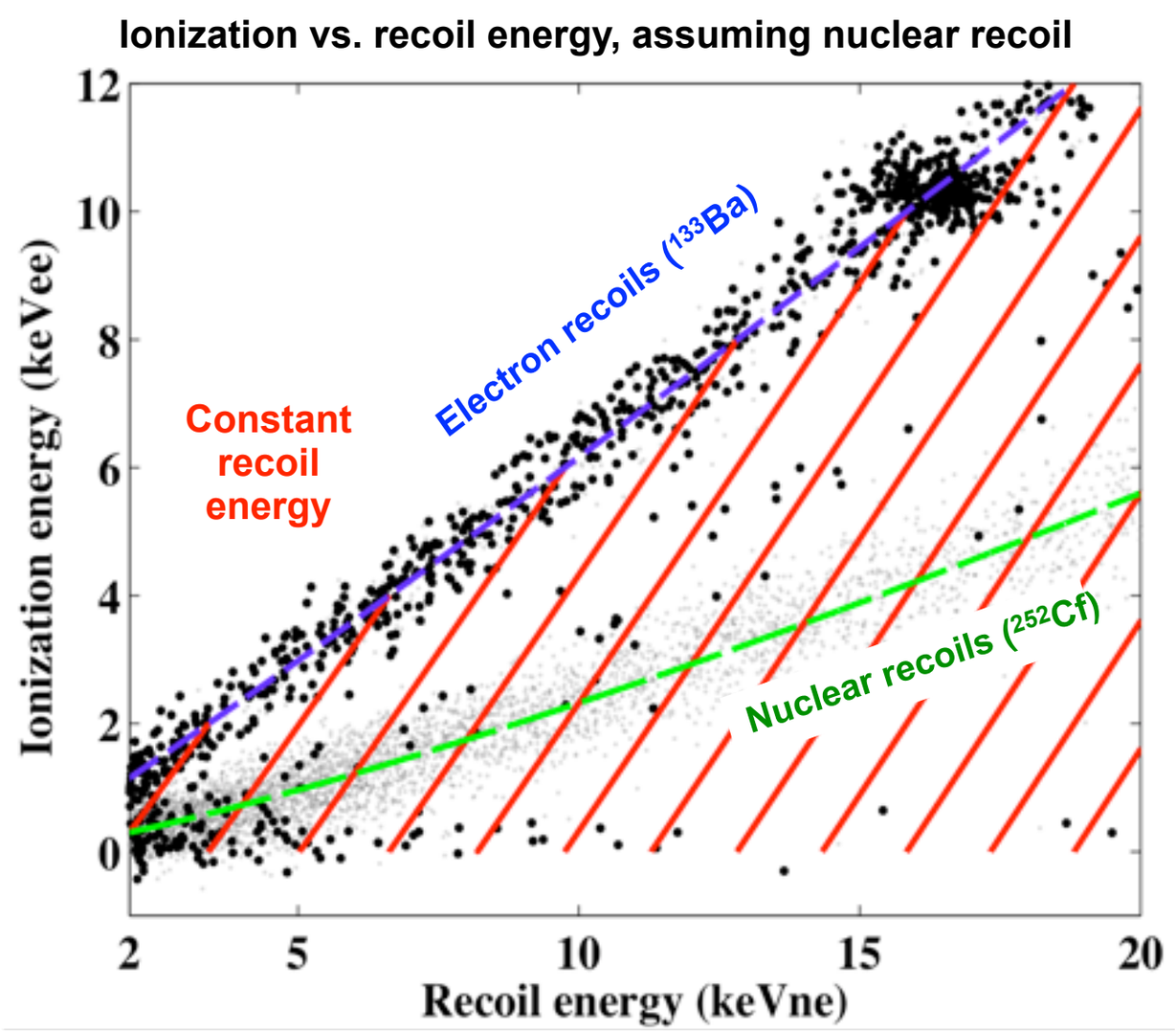


- **Similar analysis using SUF data has been published**

  Akerib et al. PRD 82 122004 (2010)
  arXiv:1010.4290

- **Spectra agrees well at high energies.**
- **Primary difference at low energies are due to nuclear-recoil band cut and less activation of 1.3 keV line**

NUCLEAR RECOIL ENERGY SCALE



- Energy scale assumes "drift heat" consistent with phonons produced by drifting ionization from a nuclear recoil.
- Electron recoils are pushed to higher recoil energies and lower yields due to the larger drift heat contribution.
- 1.3 keV electron recoil activation line is pushed partially above the 2 keV threshold.

LIMIT SETTING PROCEDURE

- Limits are set using optimal interval method ordered by detector.
- Allows choice of most constraining energy interval on lowest background detector (applies statistical penalty for freedom of interval choice.
- Background limited, so most constraining choice contains events from a signal detector.
- Limit procedure and ordering set prior to opening data to avoid bias.

Example ordering of events by detector: