Recent results from CDMS II
Status and future of the SuperCDMS experiment

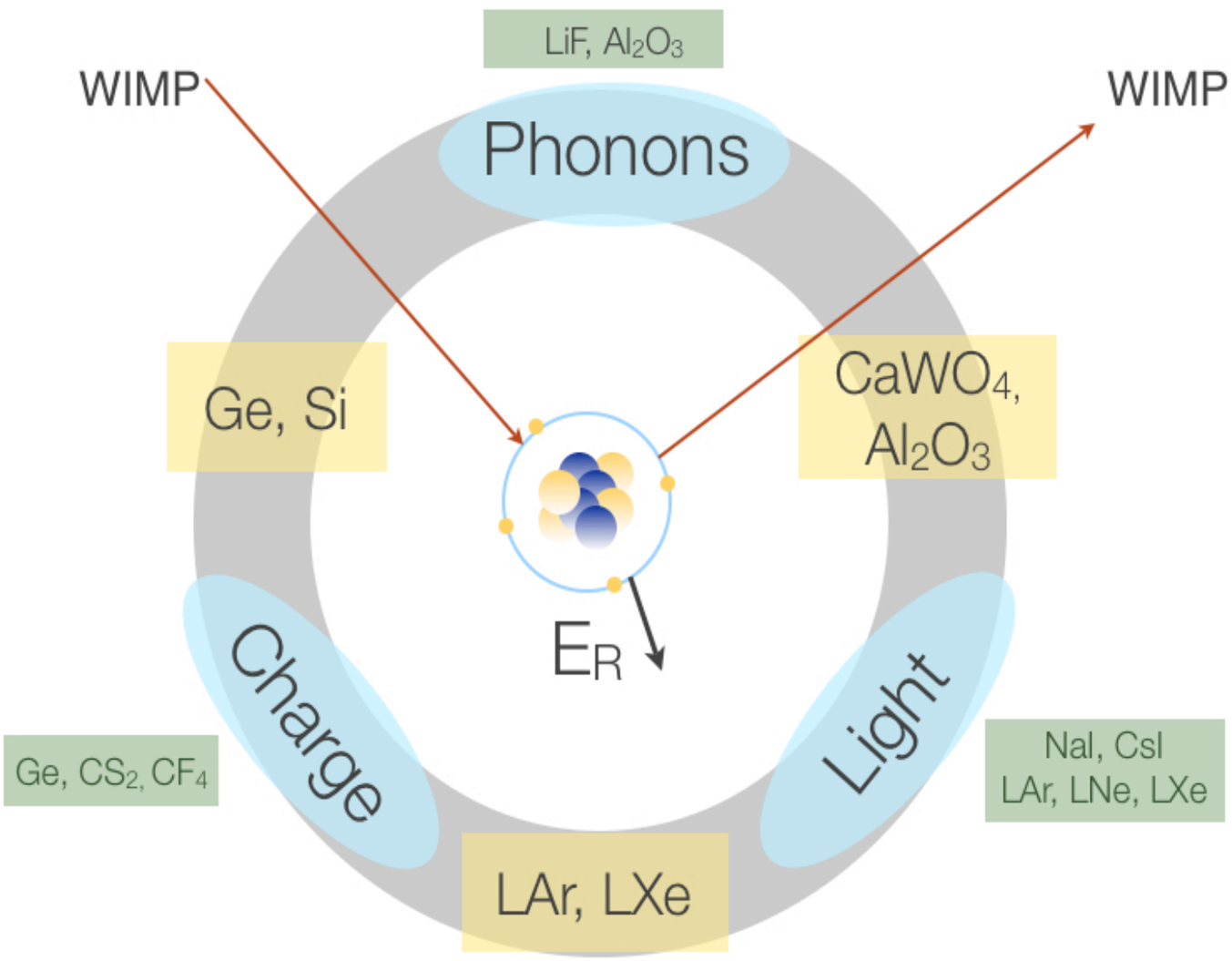
Silvia Scorza
Southern Methodist University
for the SuperCDMS Collaboration

New Perspectives in Dark Matter 2013

SMU

Direct Dark Matter Experiment

Detection of the energy deposited due to
elastic scattering off target nuclei



- Low energy thresholds (~10 keV)
- Long exposures

  Large masses, long term stability
- Rigid background controls

  Clean materials

  Shielding

  Discrimination power
- Substantial Depth

  neutrons look like WIMPs

The SuperCDMS Collaboration

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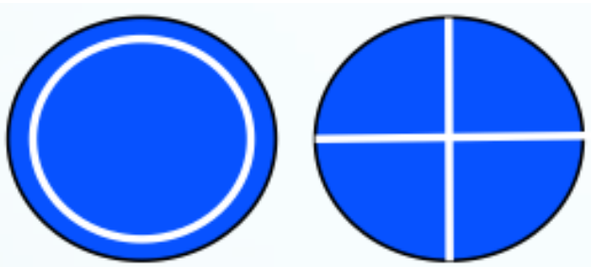
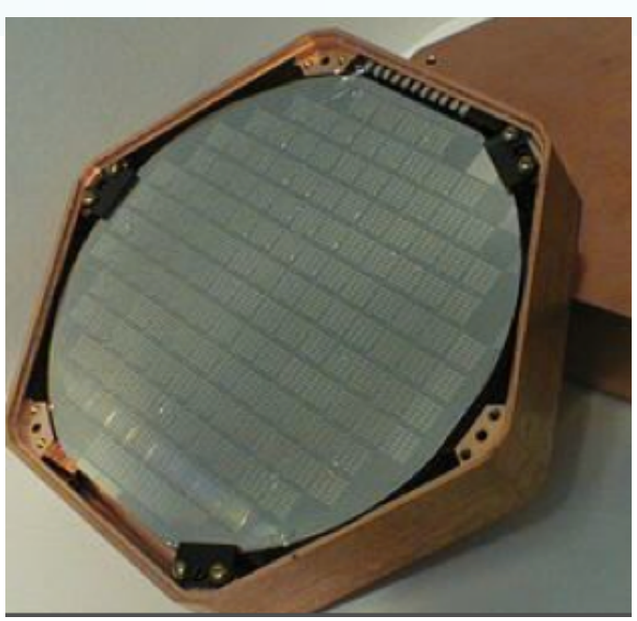
Time

CDMS II (Ge+Si)

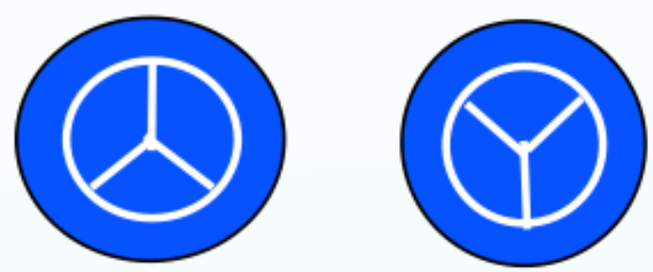
- 4.6 kg Ge (19 x 240 g)
- 1.2 kg Si (11 x 106g)
- 35% NR acceptance

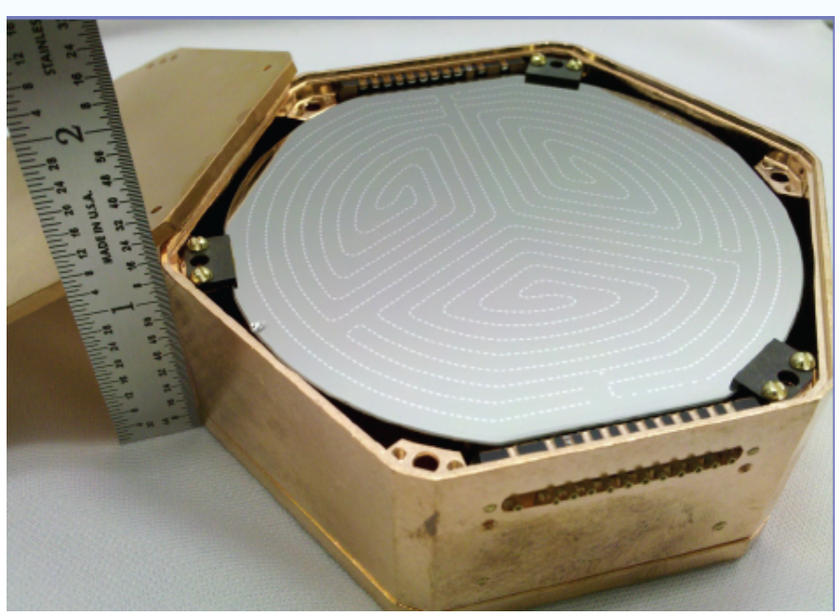




SuperCDMS Soudan

- Increased mass: 9.0 kg Ge (15 x 600 g)
- Increased acceptance
- Improved surface event discrimination

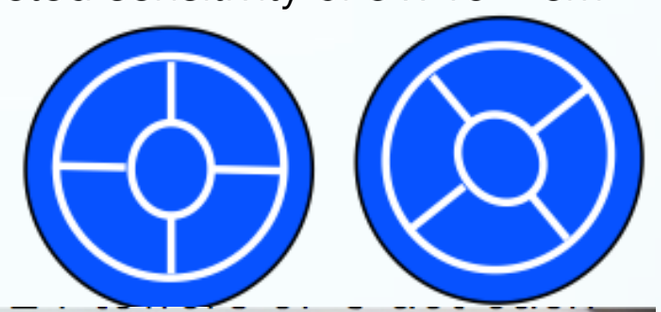


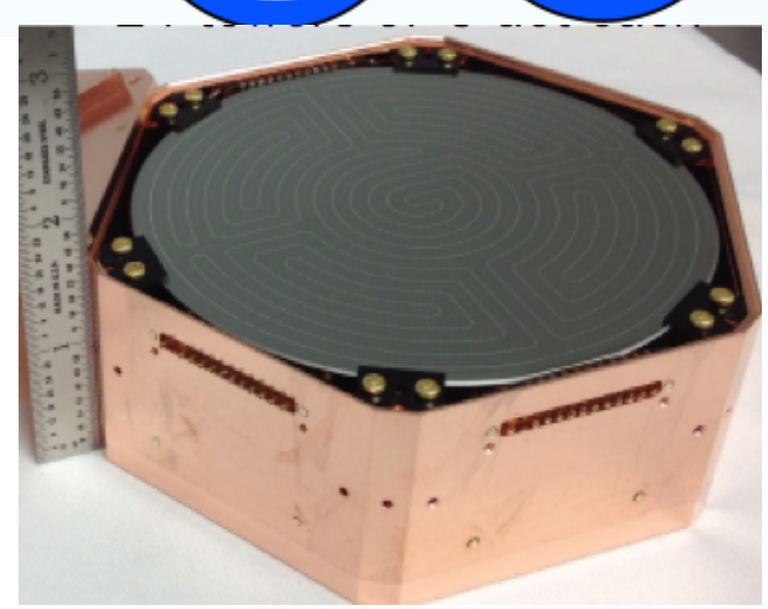


SuperCDMS SNOLAB

- Proposed 150 kg Ge (108 x 1.4 kg) and 22 kg Si (36 x 0.6 kg)
- Extensive R&D underway
- Scale to 1 kg crystals

Projected sensitivity of 8 x 10^{-47} cm^2





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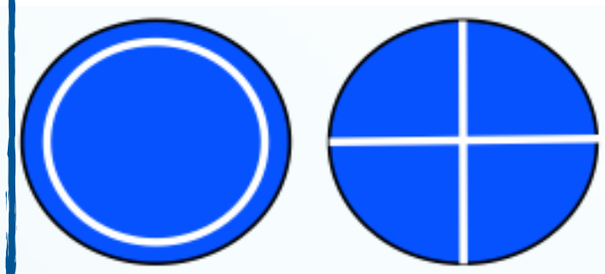

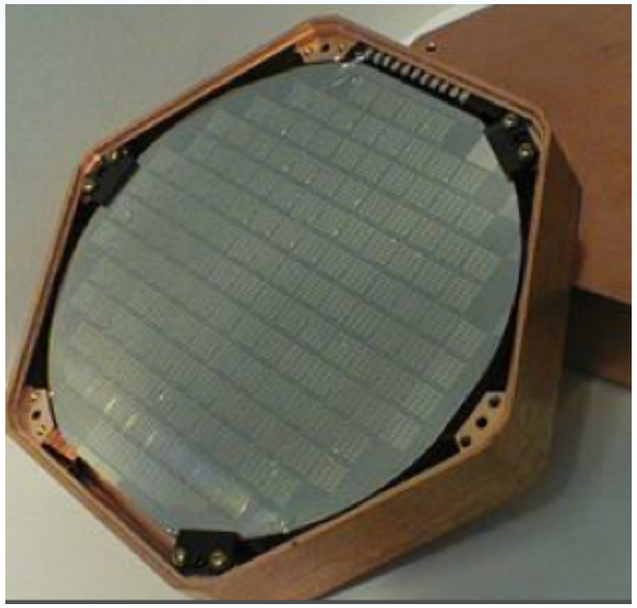

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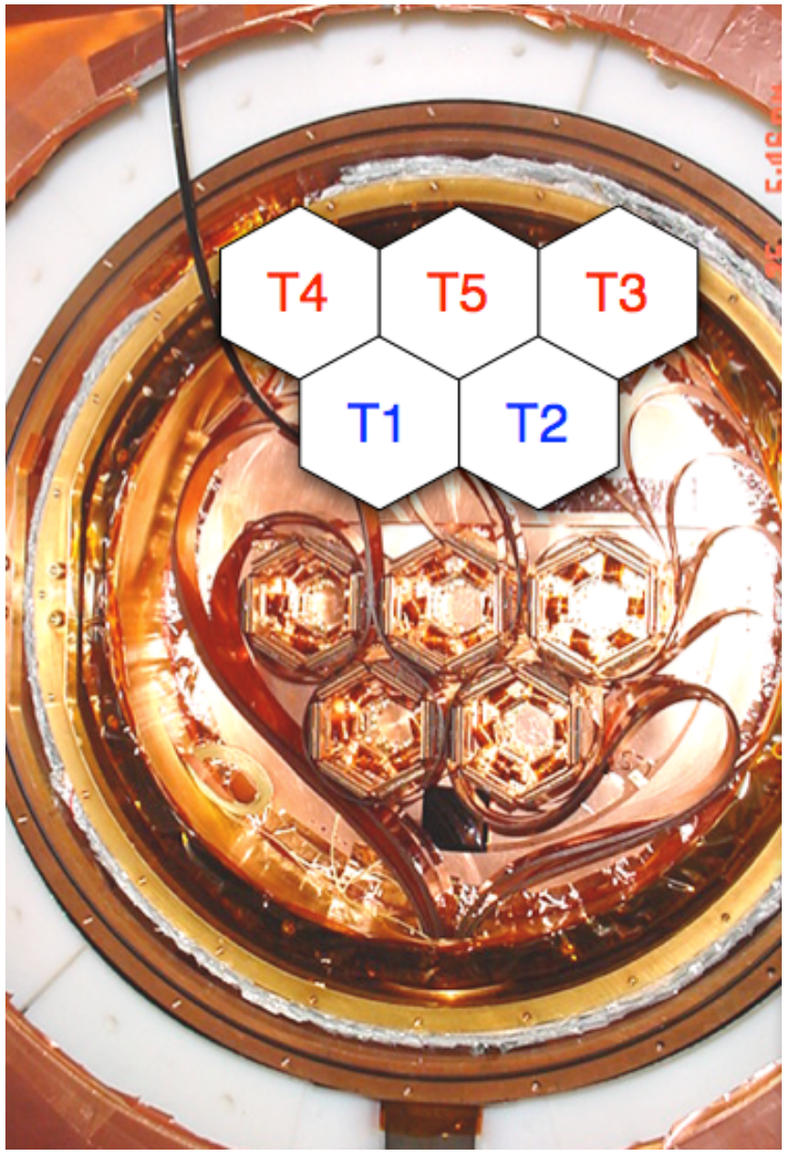
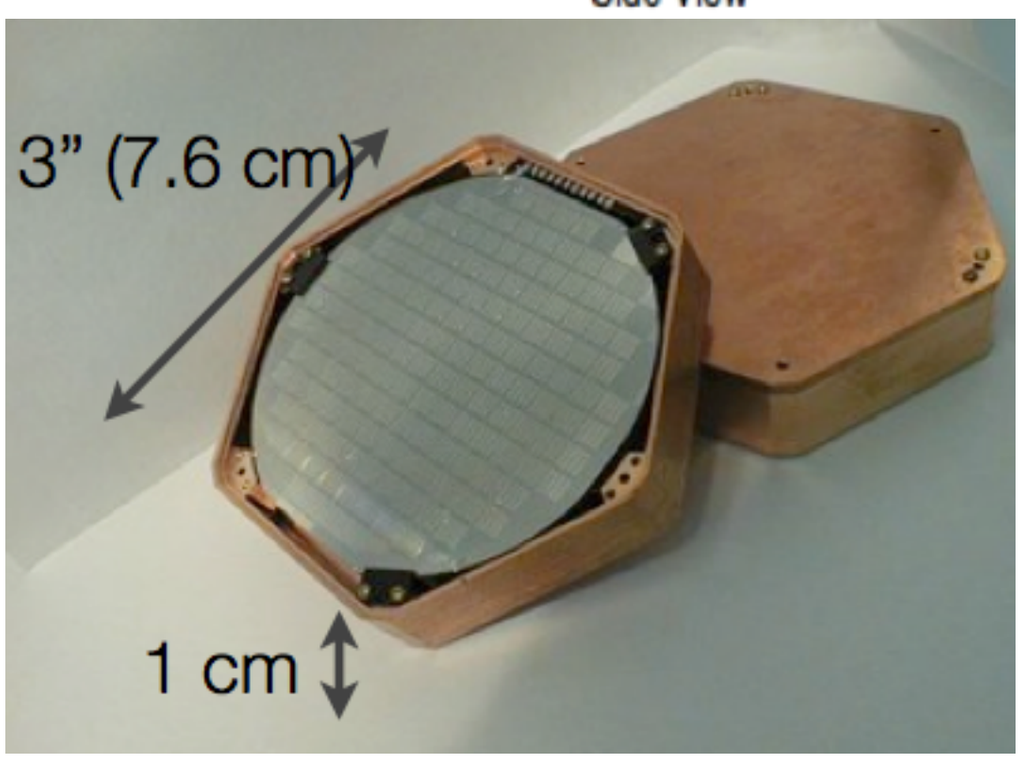
LEVEL NO. 27
2341 FEET BELOW THE SURFACE
689 FEET BELOW SEA LEVEL

CDMS II: Si Analysis

CDMS II: Five towers, 30 detectors (19 Ge, 11 Si) installed and operated in the Soudan Underground Laboratory, MN, USA



Side View



- Silicon ZIP Detectors

  106 g crystals (1 cm x 7.6 cm)

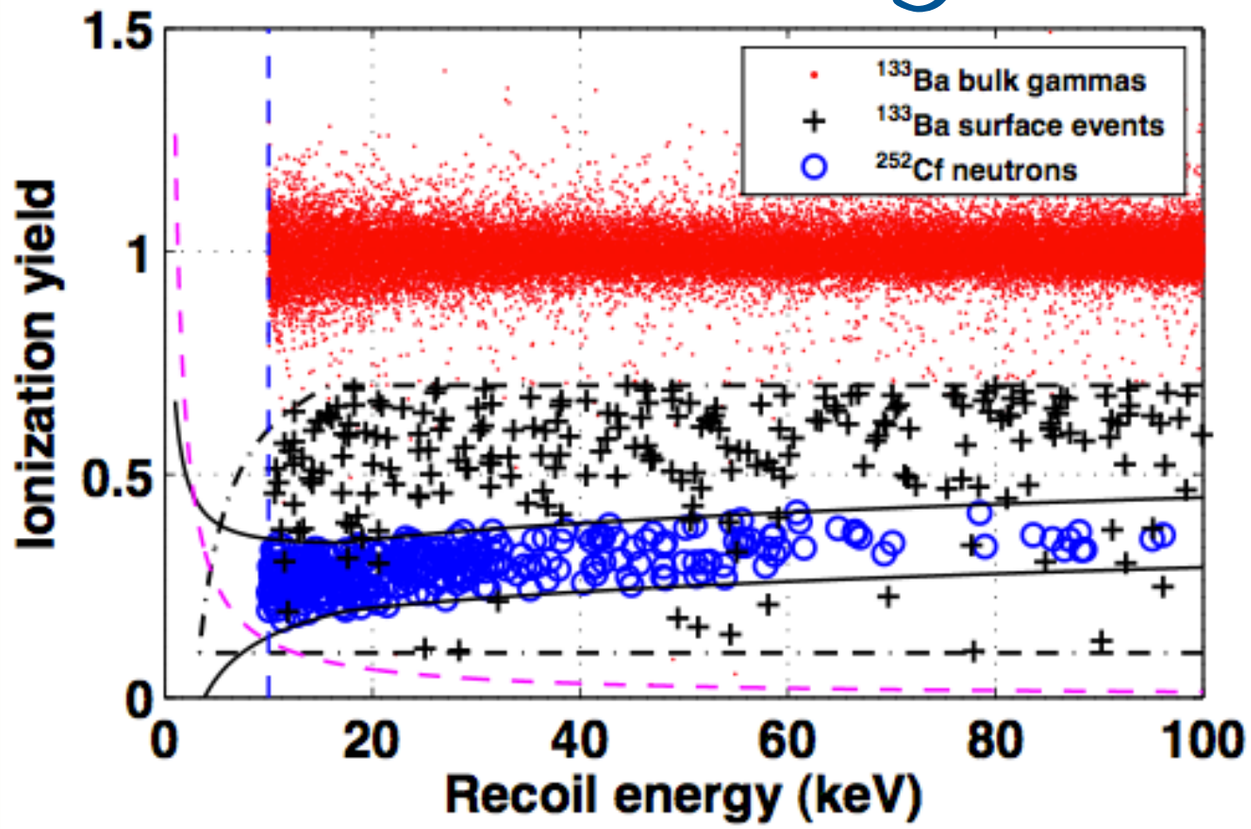
- CDMS II Exposure

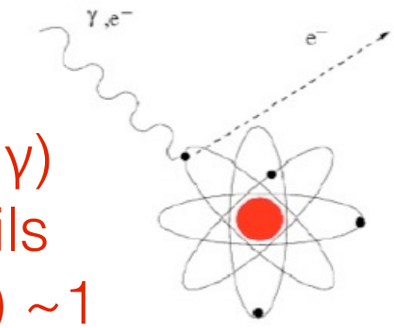
  July 2007 - Sept. 2008

  140.23 kg-days in 8 Si detectors

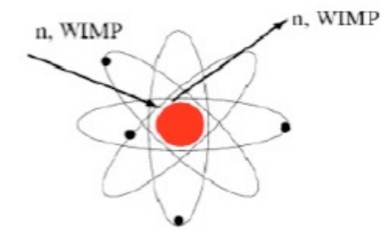
Lighter Si target nucleus is advantageous for low mass WIMP searches

Background Rejection

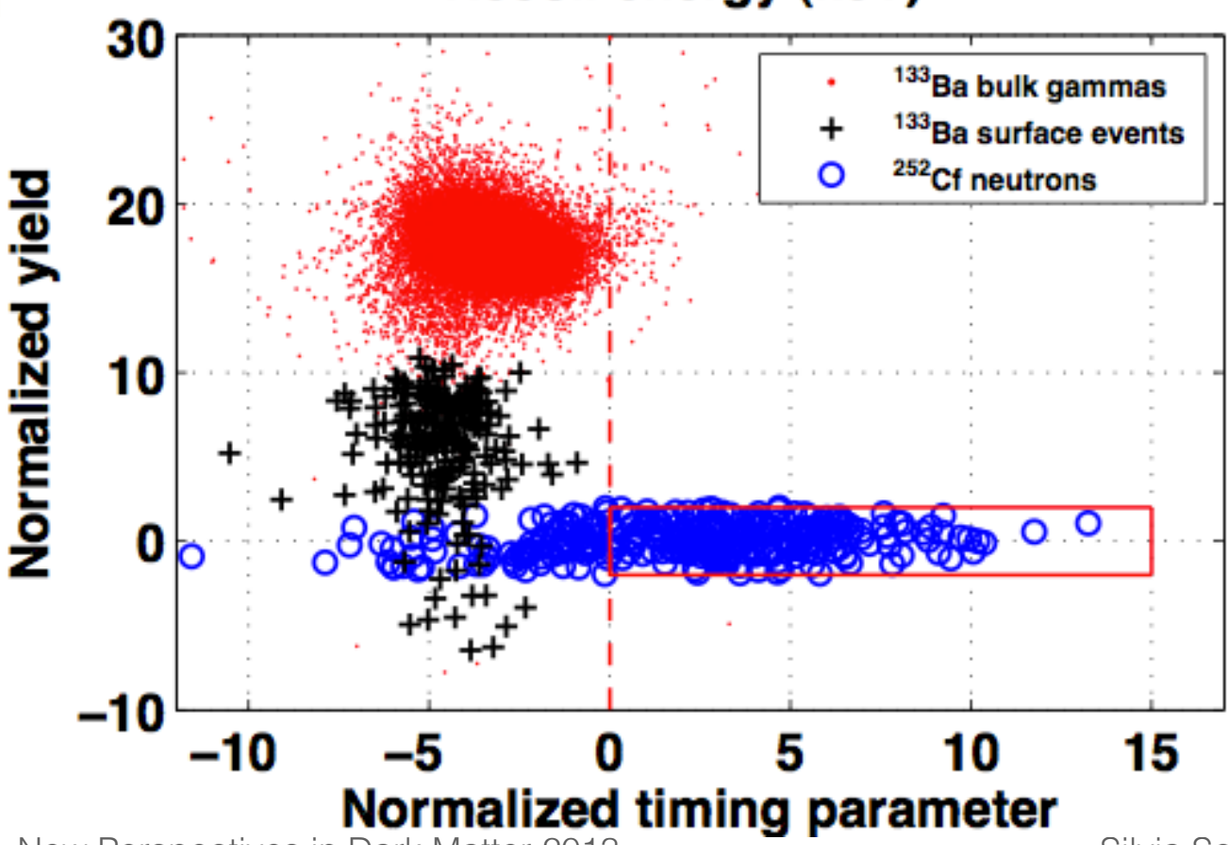




Most backgrounds (e, γ) produce electron recoils
Yield (Ionization/recoil) ~1



WIMPs and neutrons produce nuclear recoils
Yield (Ionization/recoil) ~0.3



Particles that interact close to the "surface dead layer" result in reduced ionization yield.
Surface events can be identified using timing properties of phonon signal

Ionization Yield + Timing Cut:
<1 in 10^6 electron recoils leaking in the ROI

Background Estimate

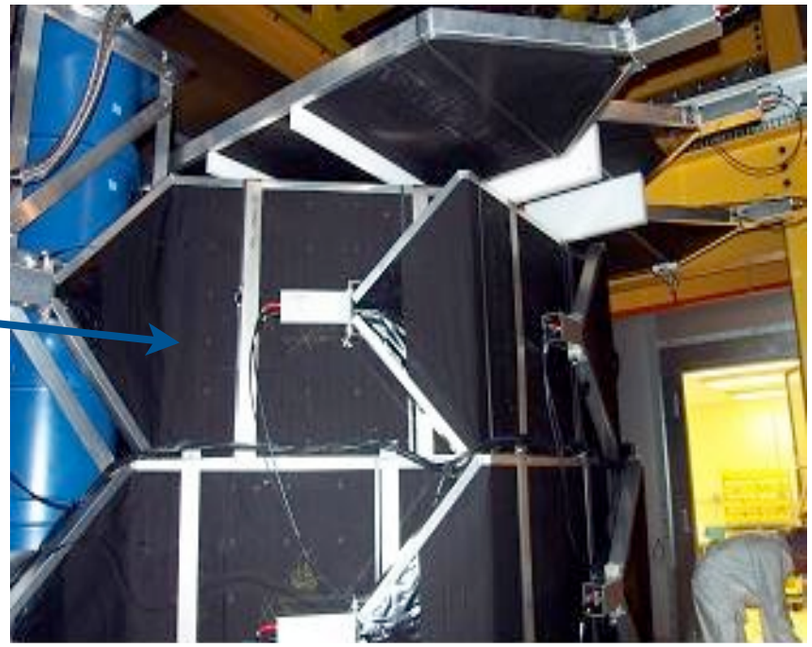
- Neutrons

  Indistinguishable from WIMPs!

  Cosmogenic: active veto

  Radiogenic: passive shielding & materials screening

  < 0.13 expected events



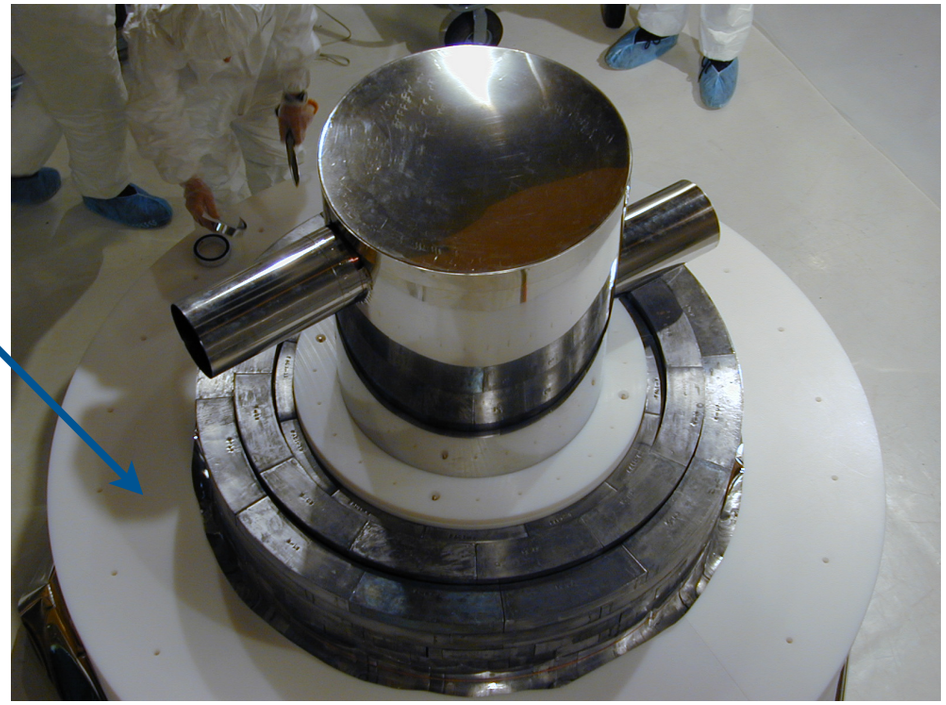
- Surface events

  Discriminate using phonon timing

  Optimize in 3 energy bins

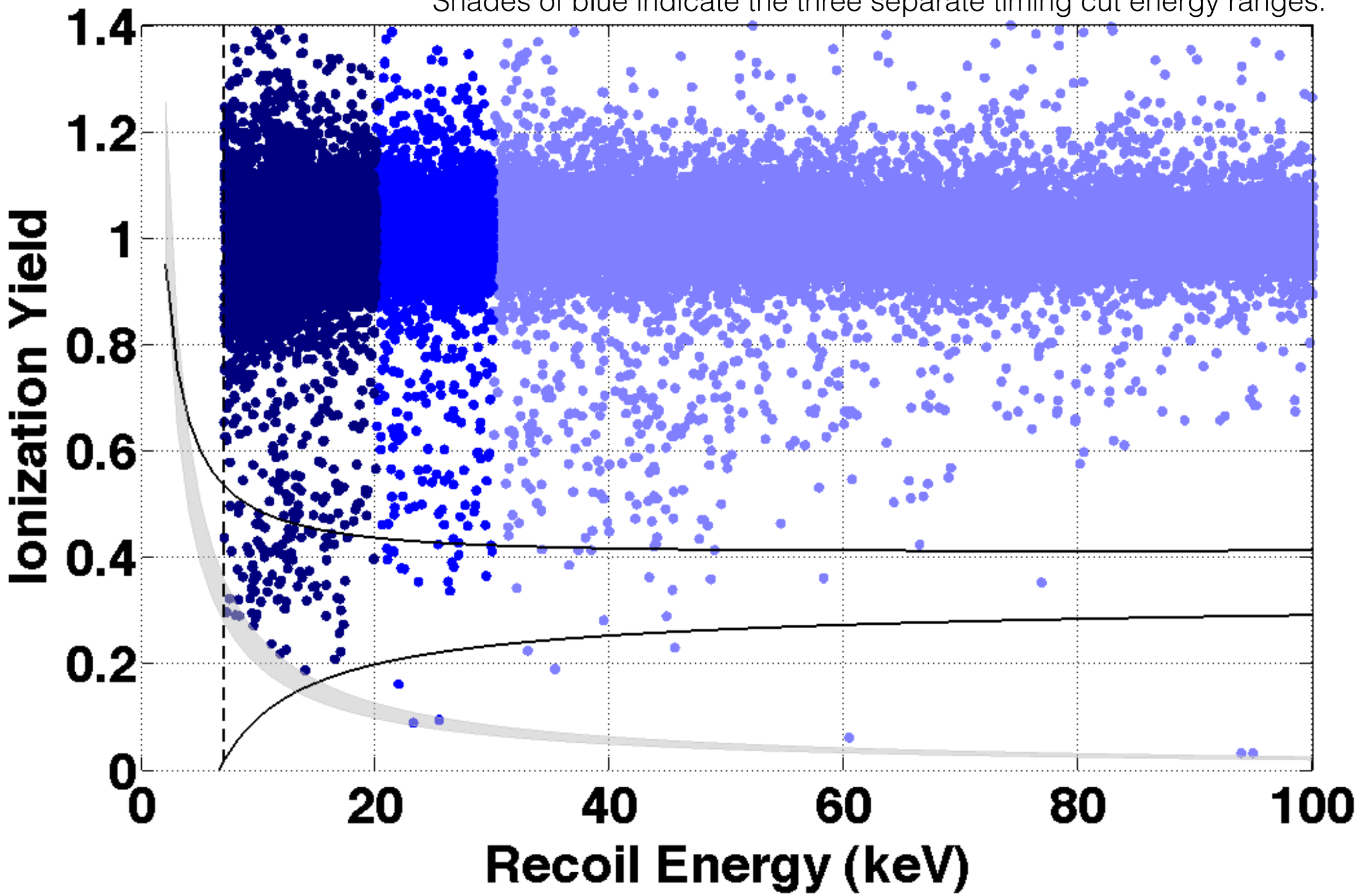
  7-20, 20-30, 30-100 keV

  0.47 expected events estimated before unblinding.



Unblinding Results - before timing cut

Shades of blue indicate the three separate timing cut energy ranges.



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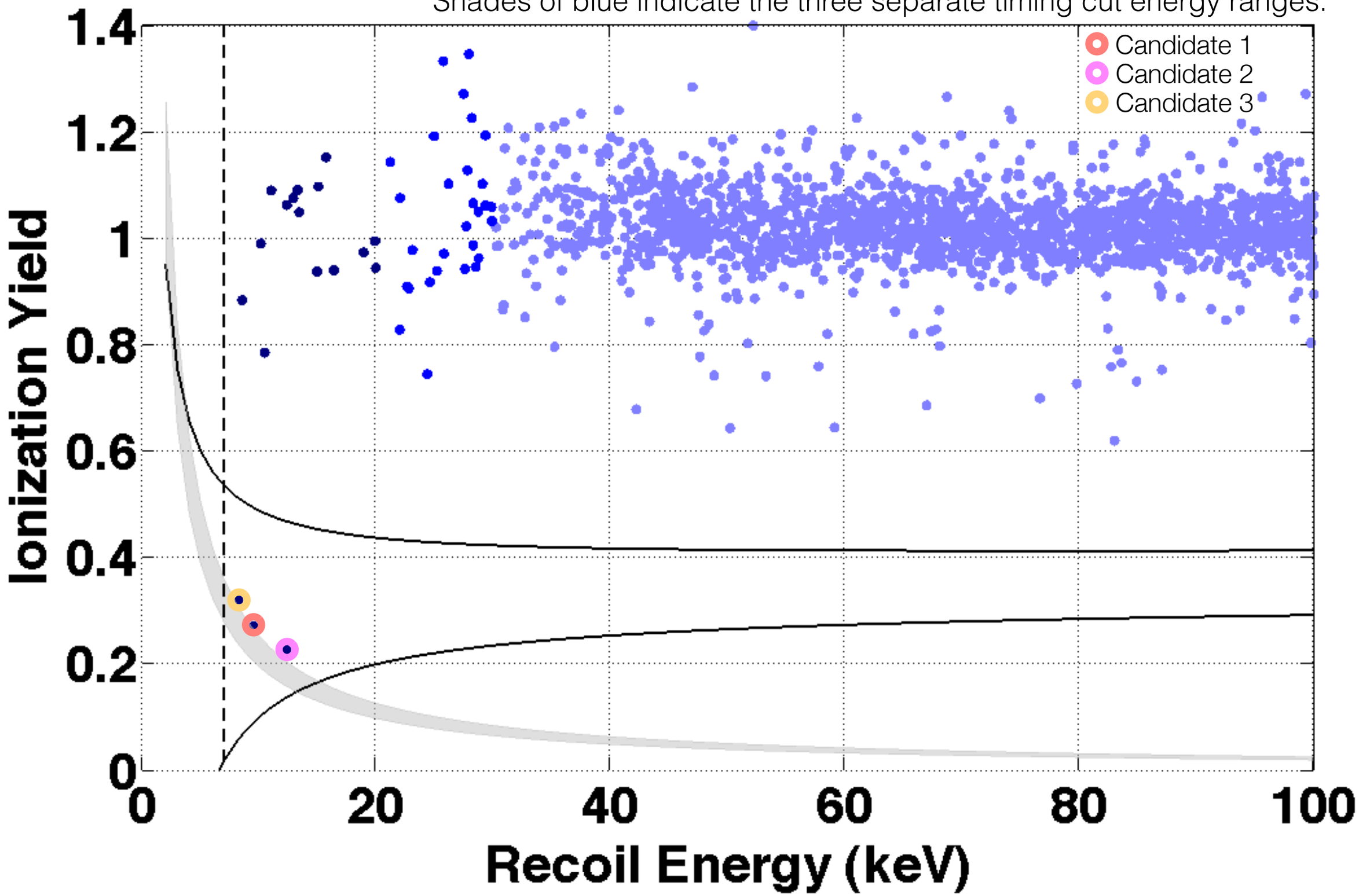
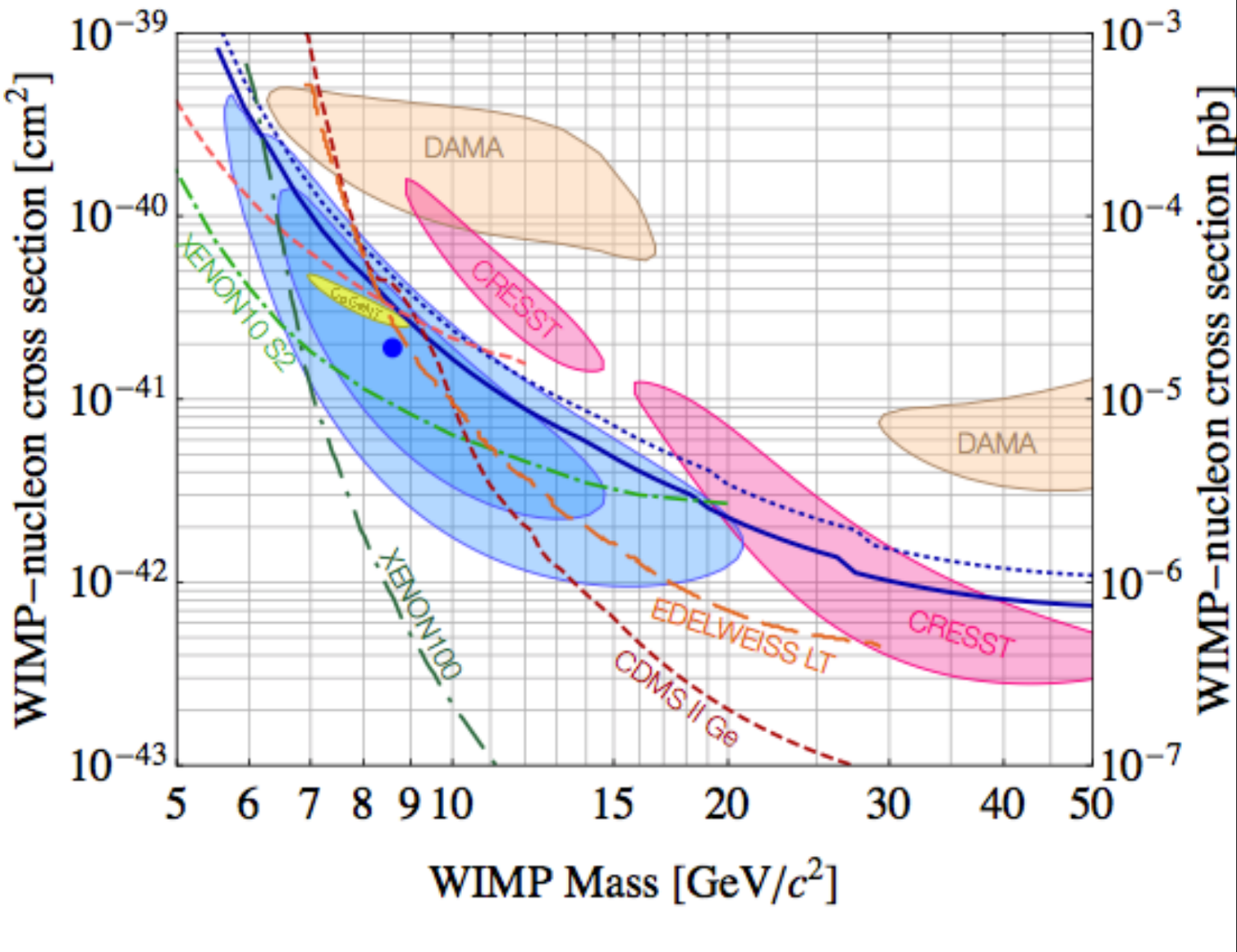


CDMS II Si - Results

- Profile likelihood analysis favors WIMP+background hypothesis over known backgrounds as the source of signal at the 99.8% C.L. (~3σ)
- The maximum likelihood occurs at a WIMP mass of 8.6 GeV/c^2 and WIMP-nucleon cross section of $1.9 \times 10^{-41} cm^2$
- Not significant enough to be a discovery, but does call for further investigation.

- Optimal interval sets SI cross section < $2.4 \times 10^{-41} cm^2$ @ 90% C.L. for 10 GeV/c^2 WIMP



http://arxiv.org/abs/1304.42791304.4279v2

SuperCDMS Soudan

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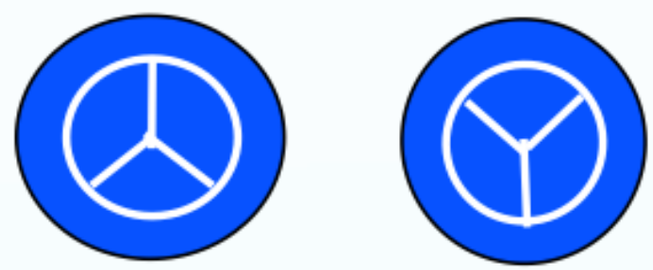
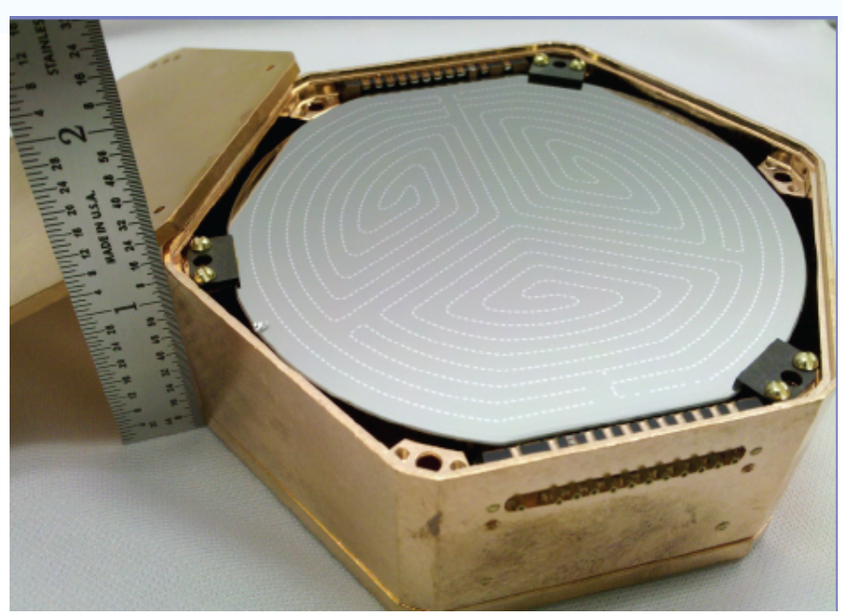
- **Increased acceptance**
- **Improved surface event discrimination**





SuperCDMS SNOLAB

Installation complete Nov. 8, 2011.

Detectors have been operating in DM-search mode since March 2012.

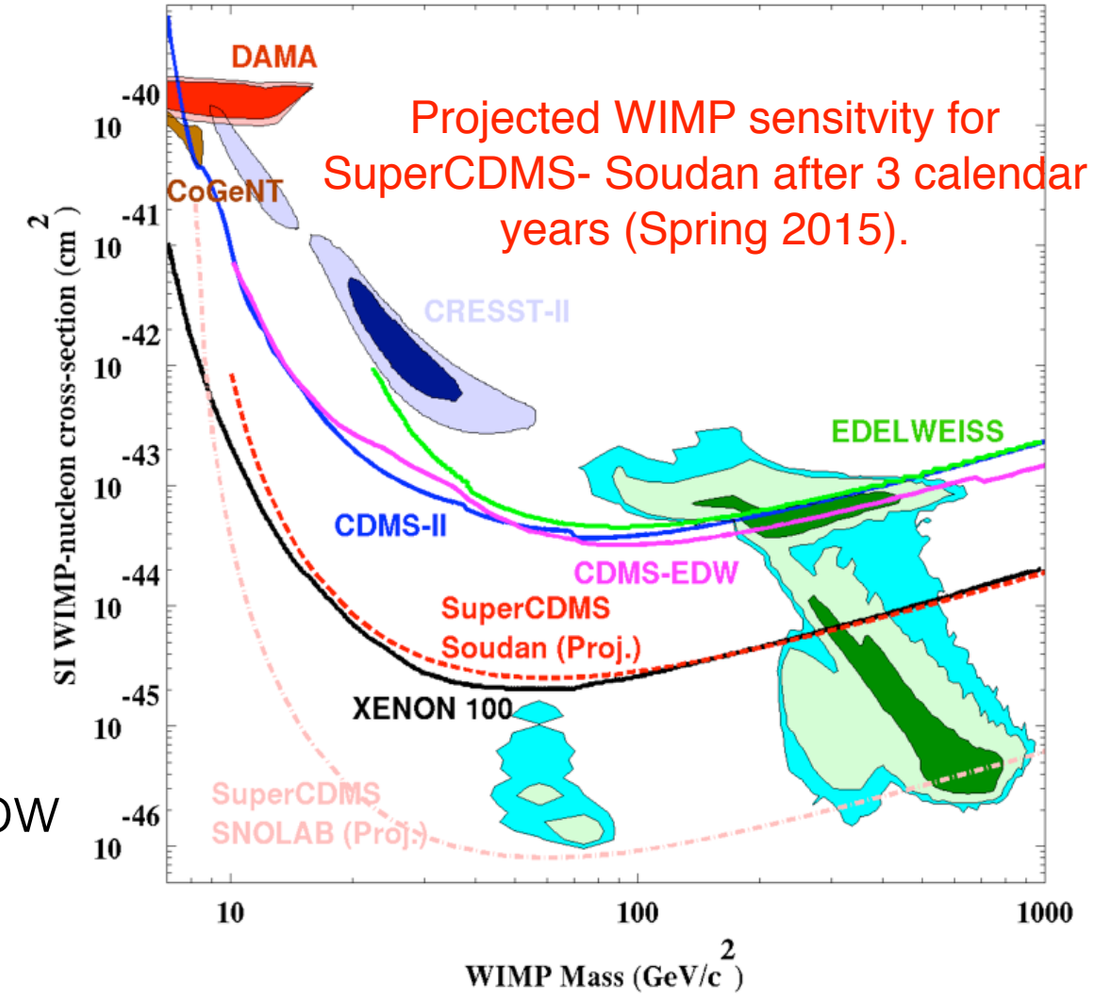
- Proposed 1[illegible] kg Ge (1[illegible] x 1.4 kg) and [illegible] kg Si (6[illegible] x 0.6 kg)
- Extensive R&D underway
- Scale to 1 kg crystals

Projected sensitivity of 8 x 10^{-47} cm^2

Array of 15 iZIPs in the Soudan infrastructure built for CDMS-II

Factor >x10 sensitivity increase over CDMS-II

- Larger detector mass (x2.5 thicker detectors)
- Fiducial fraction improved to ~50% from ~35%
- Surface background negligible



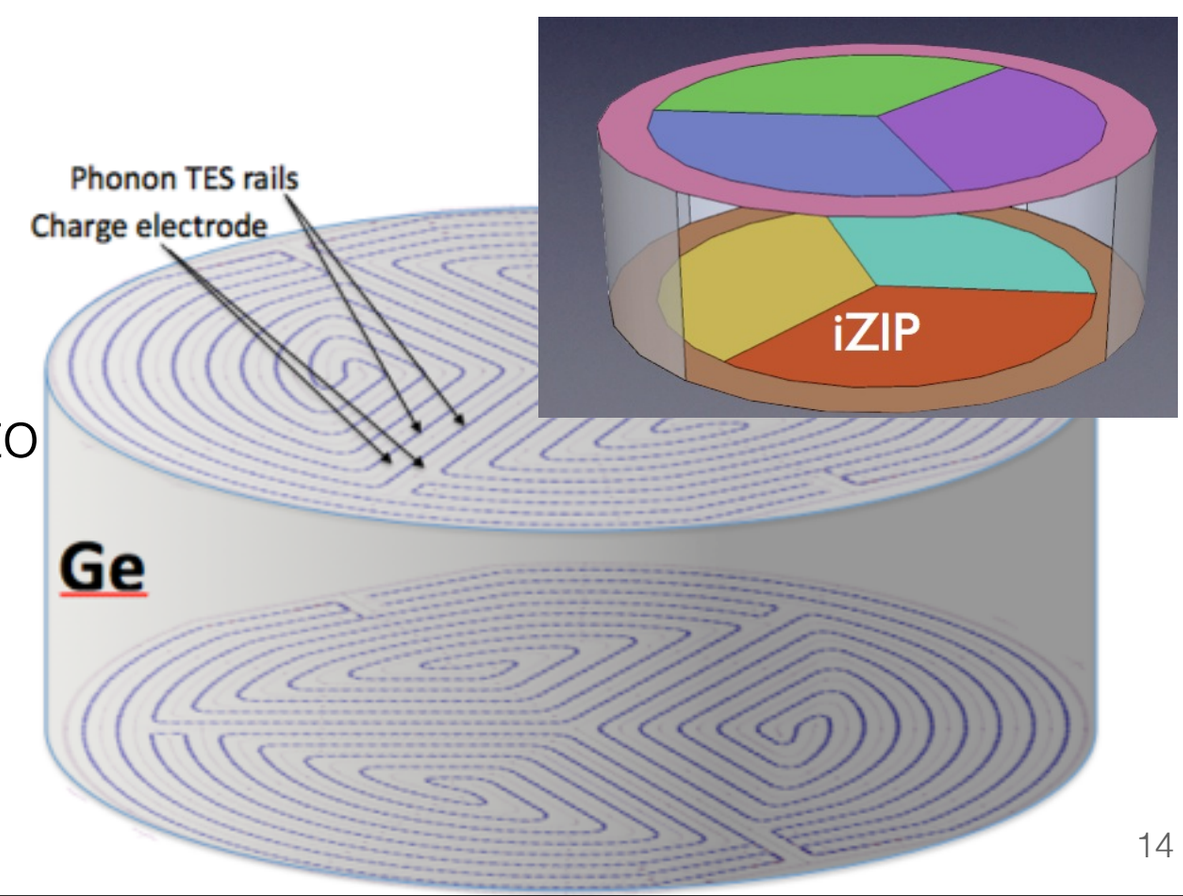
Ionization electrodes are interleaved with narrow strips of phonon sensors.

Phonon sensors optimized to enhance phonon signal to noise ratio

Optimized phonon sensor layout

Each side has one outer channel to reject zero charge events and 3 inner channels to reject surface events.

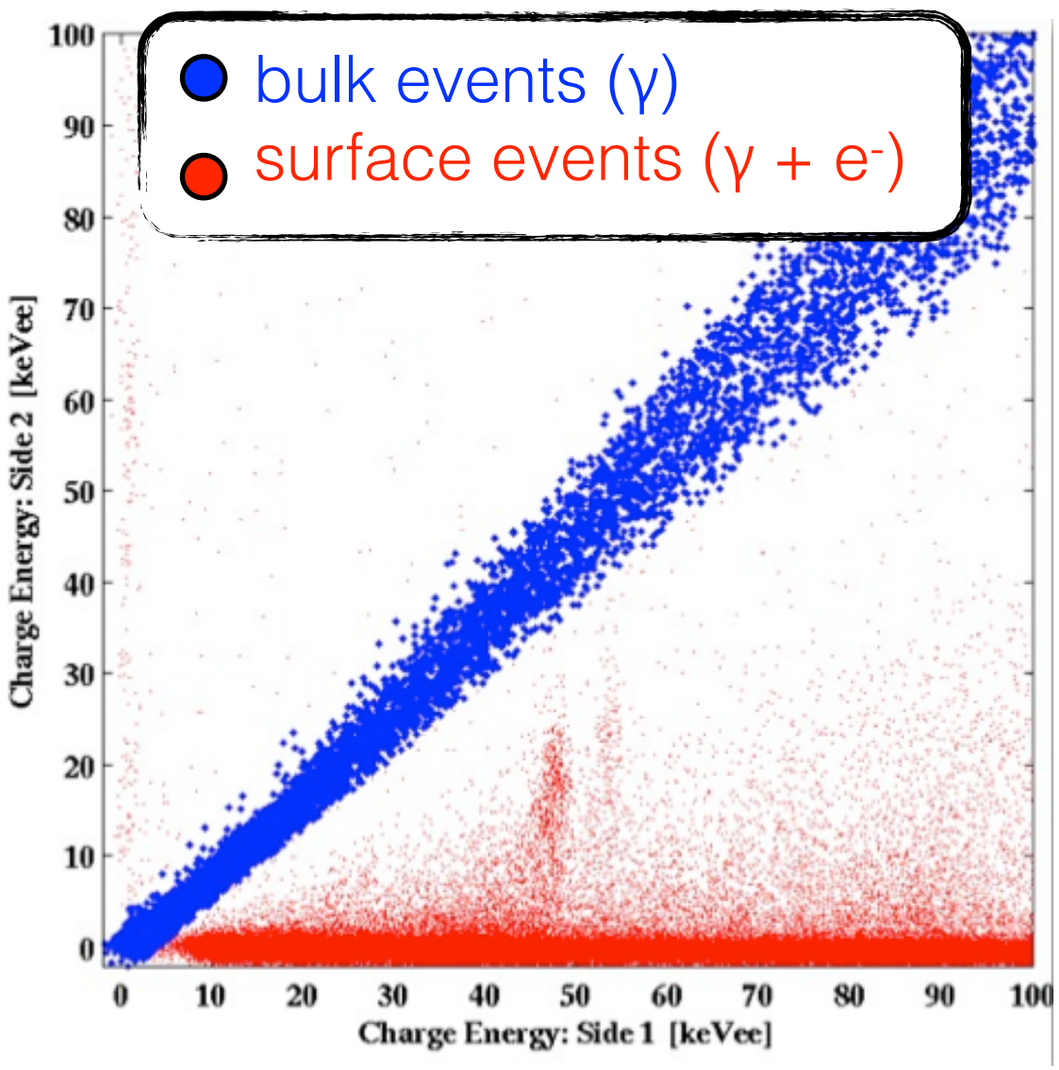
Ionization channels can be used to reject surface events

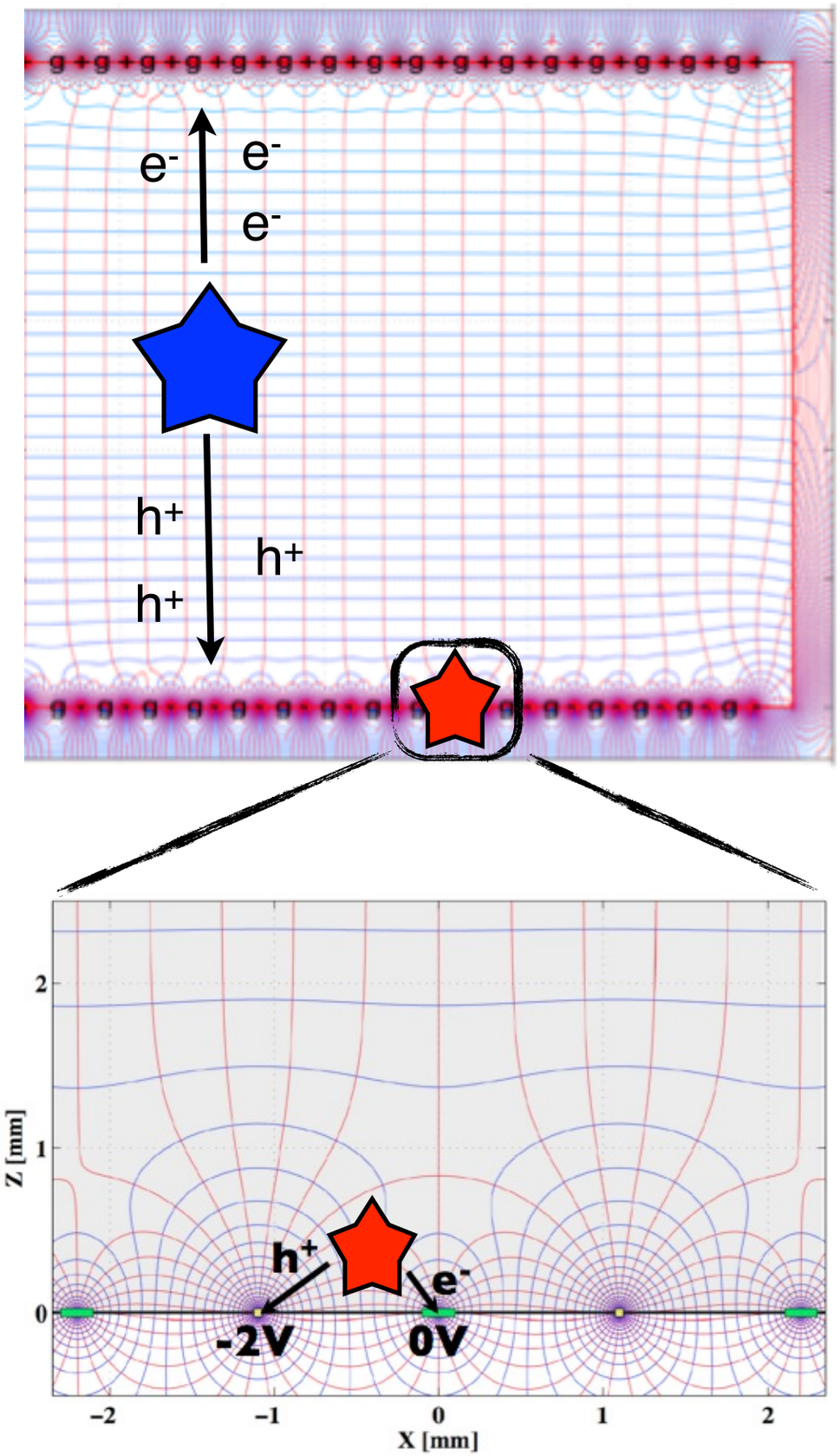


SuperCDMS iZIPs: Charge signal

Bulk Events:
Equal but opposite ionization signal appears on both sides of each detector (symmetric)

Surface Events:
Ionization signal appears on one detector side (asymmetric)





SuperCDMS Soudan: ^{210}Pb test

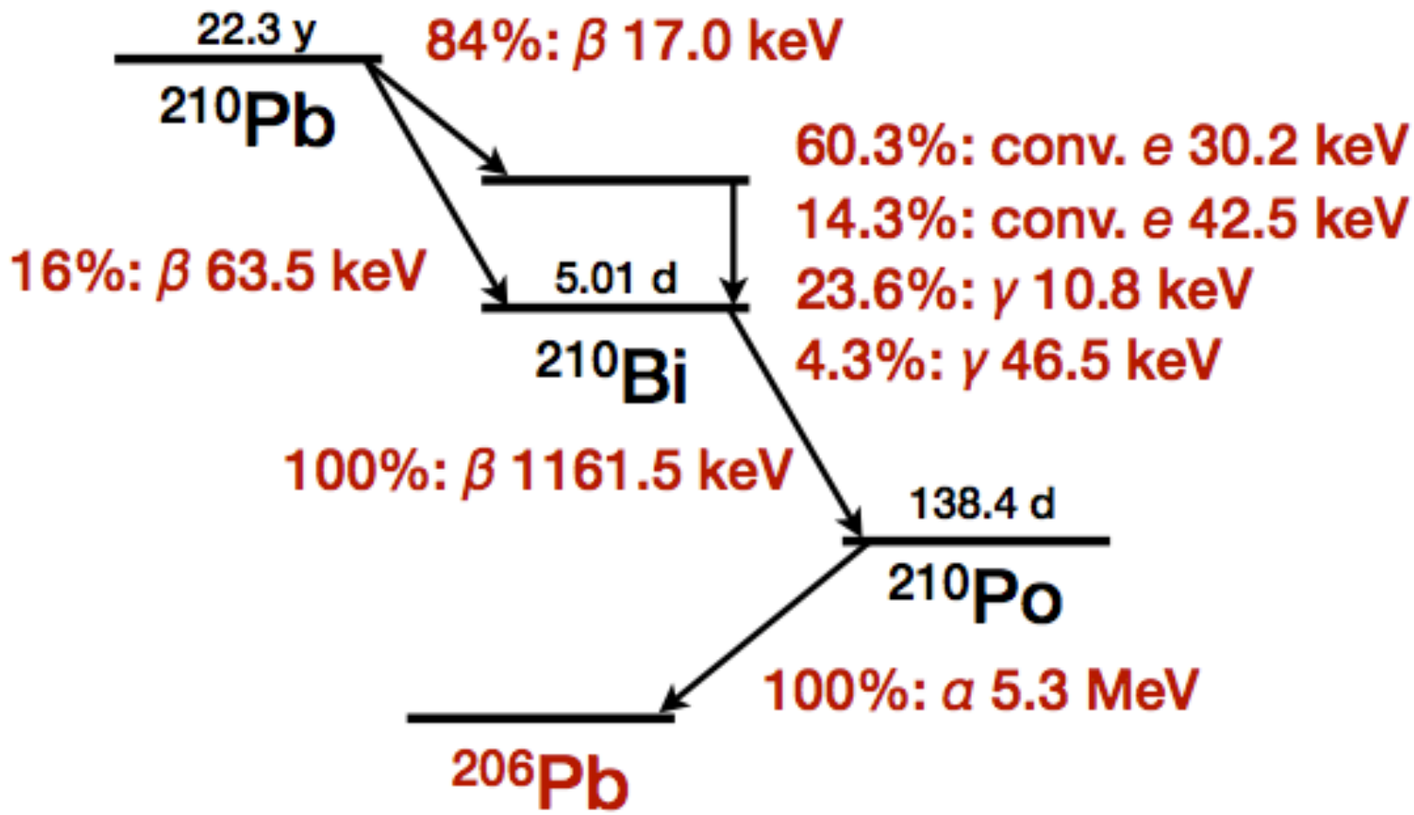
Installed ^{210}Pb implanted Si wafers facing two detectors

Activity of 1000 Pb decays per day

Allows performance verification of surface event identification

CDMS-II achieved 1:1200 rejection with a ~35% fiducial volume

The goal for a 200 kg array of iZIPs (SuperCDMS-SNOLAB) is 70 times better rejection with twice the fiducial volume



Applied Physics Letters (Vol.103, Issue 16)

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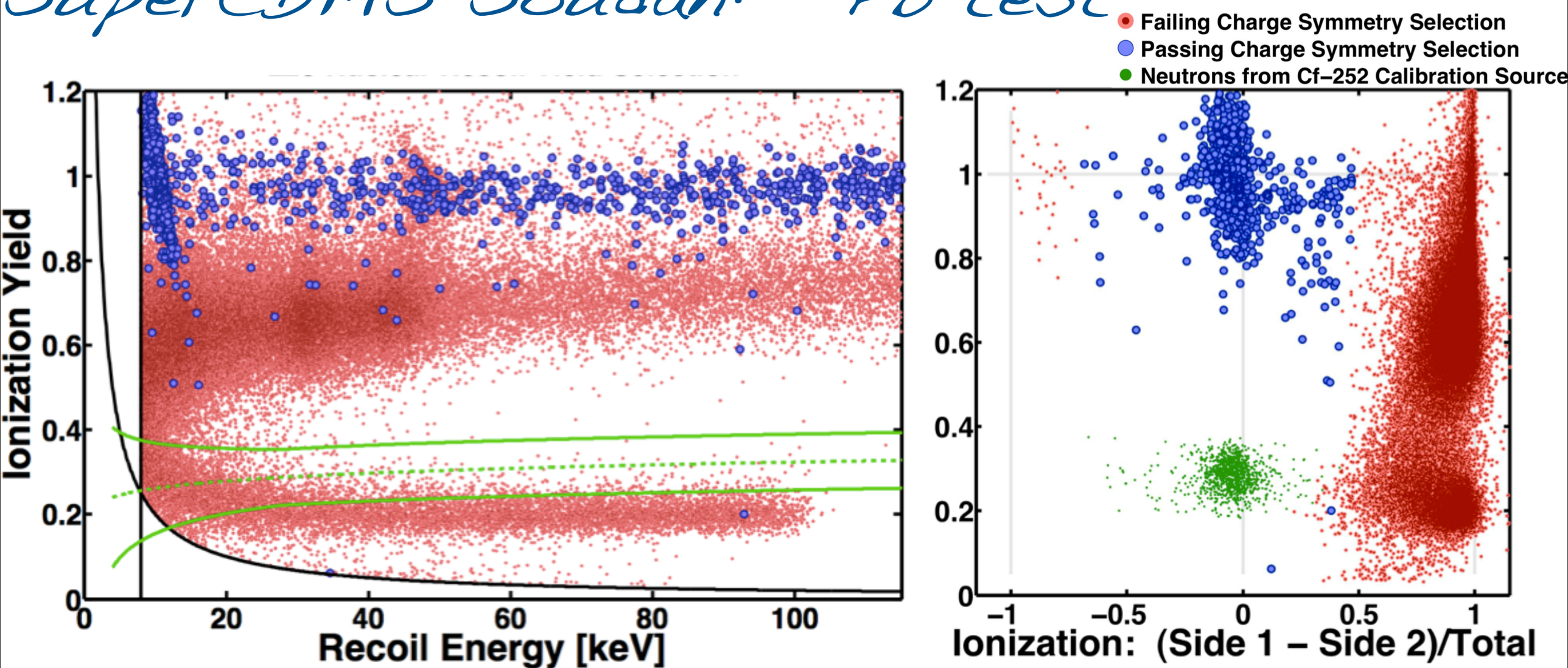
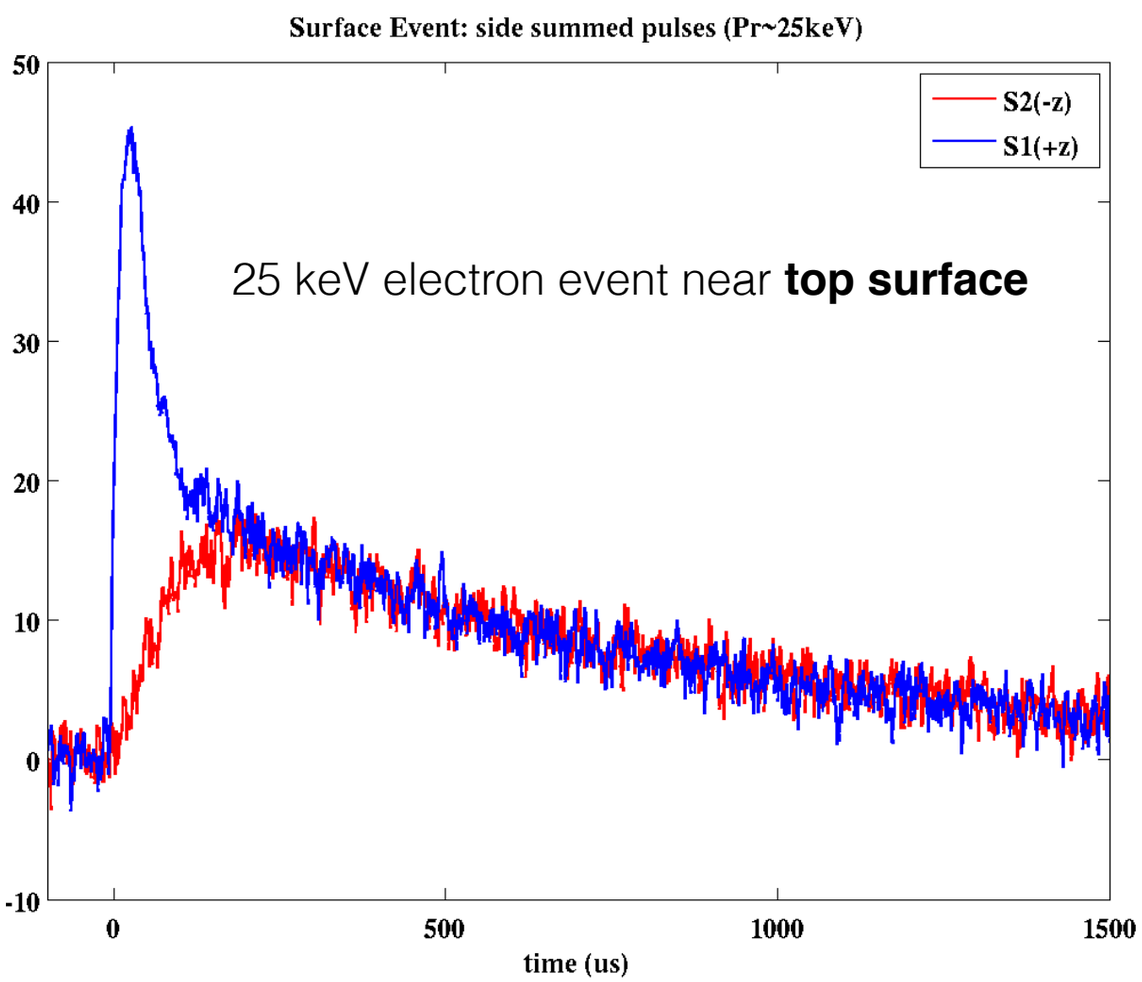
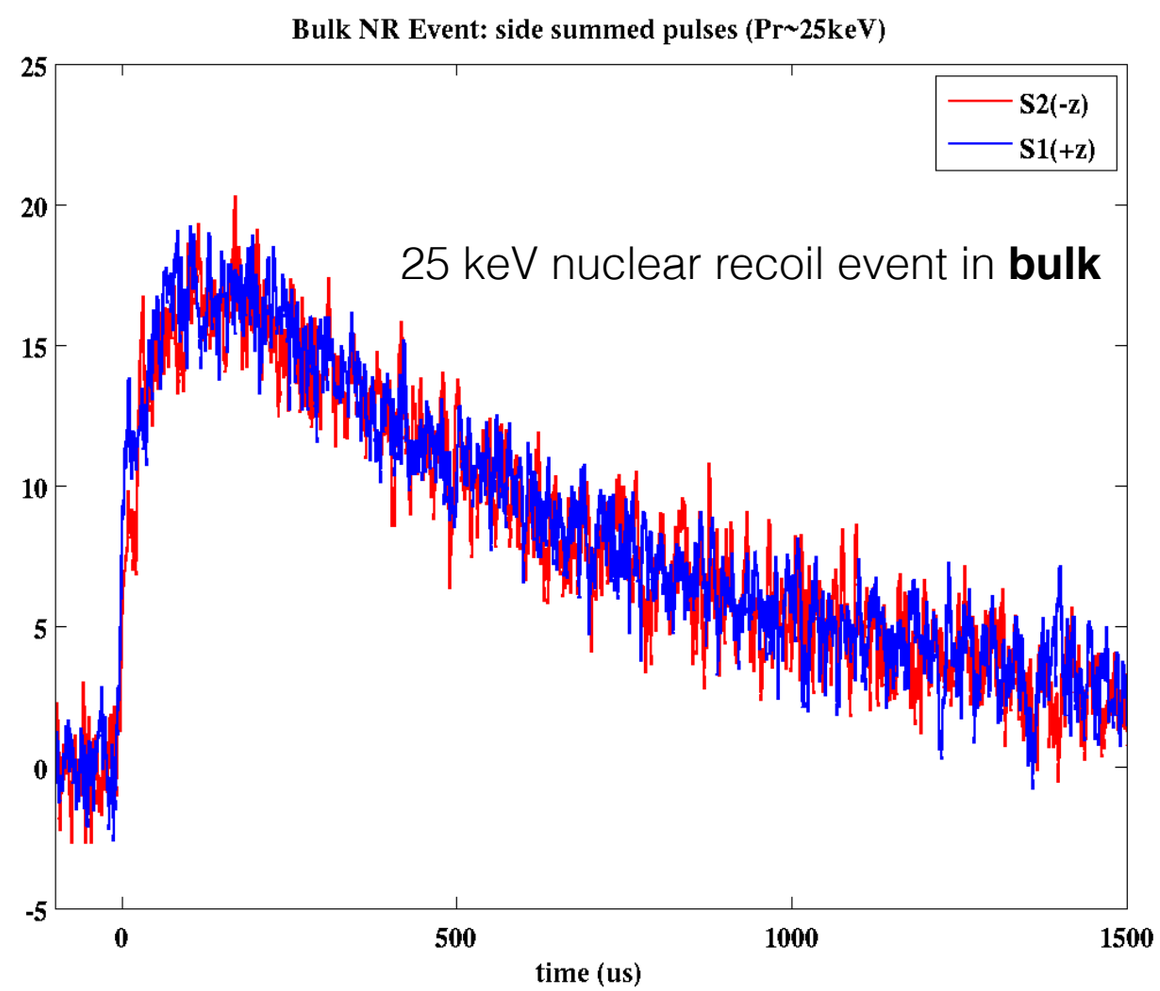


- 71,525 electrons and 16,285 ^{206}Pb recoil surface event collected from ^{210}Pb source in 905.5 live hours
- No events leaking into the signal region into ~50% fiducial volume (8-115 keVnr) in ~800 live hours (March - July 2012)
- Limits surface events leakage to <1.7 x 10^{-5} @90% C.L.
- Ionization collection at the surface is significantly improved over CDMS-II detectors
- Good enough for a 200kg experiment run for 4 years at SNOLAB!

SuperCDMS iZips: Phonon signal

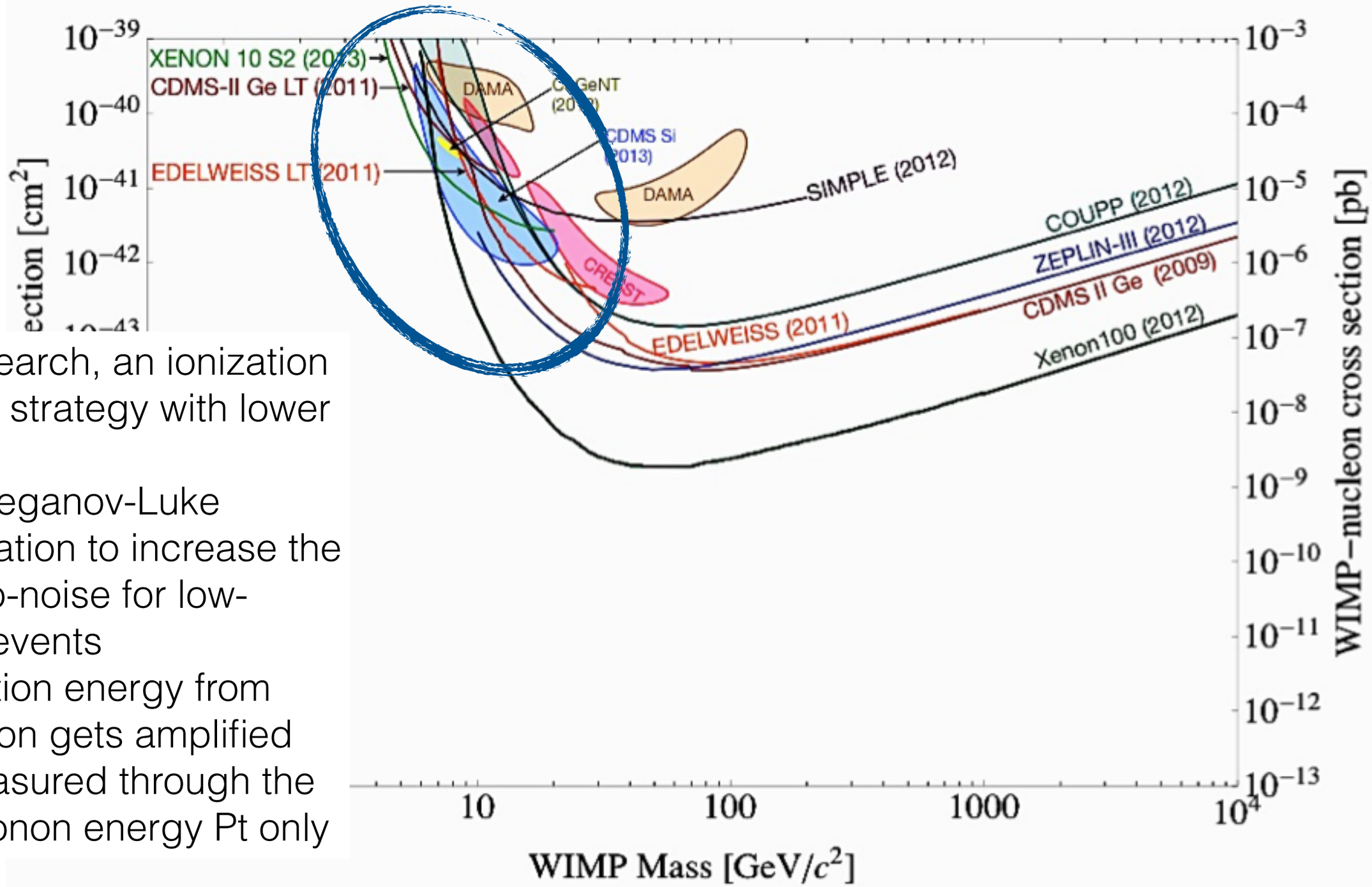
Phonon timing pulse information still possible.
Surface electron vs bulk nuclear recoil event discrimination





PULSE SHAPE HAS NOT YET BEEN USED! (It's not needed.)

Low mass WIMP search



CDMSlite search, an ionization only search strategy with lower threshold

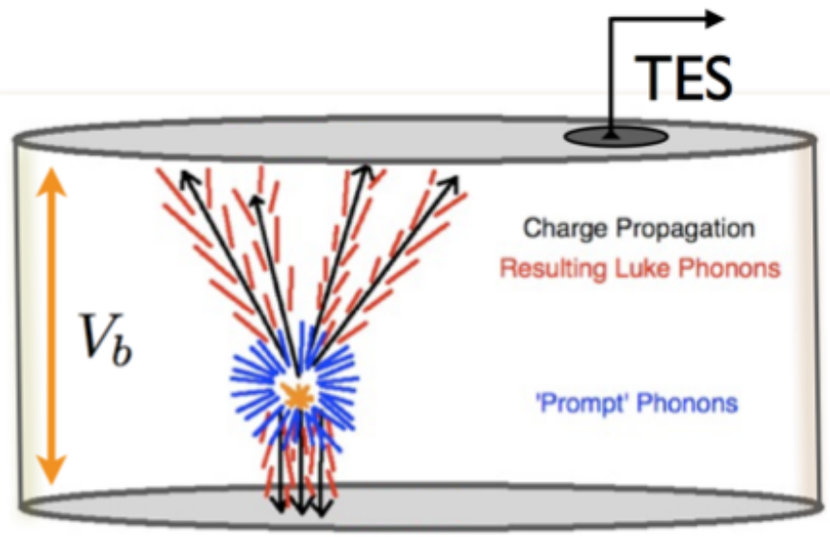
- Use Neganov-Luke amplification to increase the signal-to-noise for low-energy events
- Ionization energy from interaction gets amplified and measured through the total phonon energy Pt only

Low-Threshold search, optimizing the analysis to approach the hardware trigger threshold

- Nuclear recoil discrimination down to 2 keVr, but significant overlap of electron and nuclear recoil distributions
- Note that this projection assumes fewer events with no ionization detected

CDMSLite:

Low Ionization Threshold Experiment



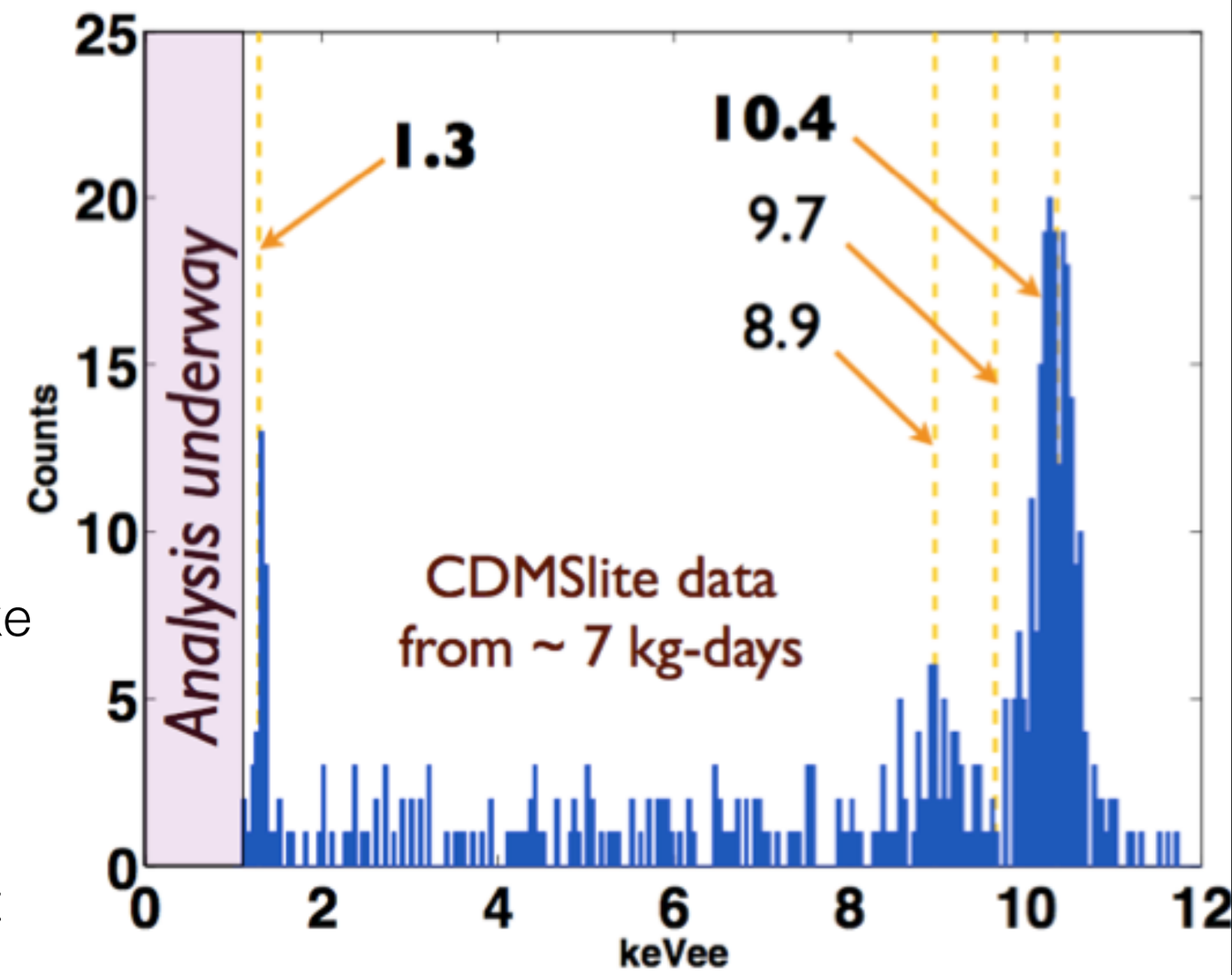
Drifting N_e electrons across a potential, V, generates N_eV electron volts of heat

CDMSlite strategy leverages Neganov-Luke amplification to realize low thresholds with high-resolution

Achievable by using the ionization readout to measure phonon.

For V_b ~ 69 v (Ge iZIP stable running)

Gain ~ 24

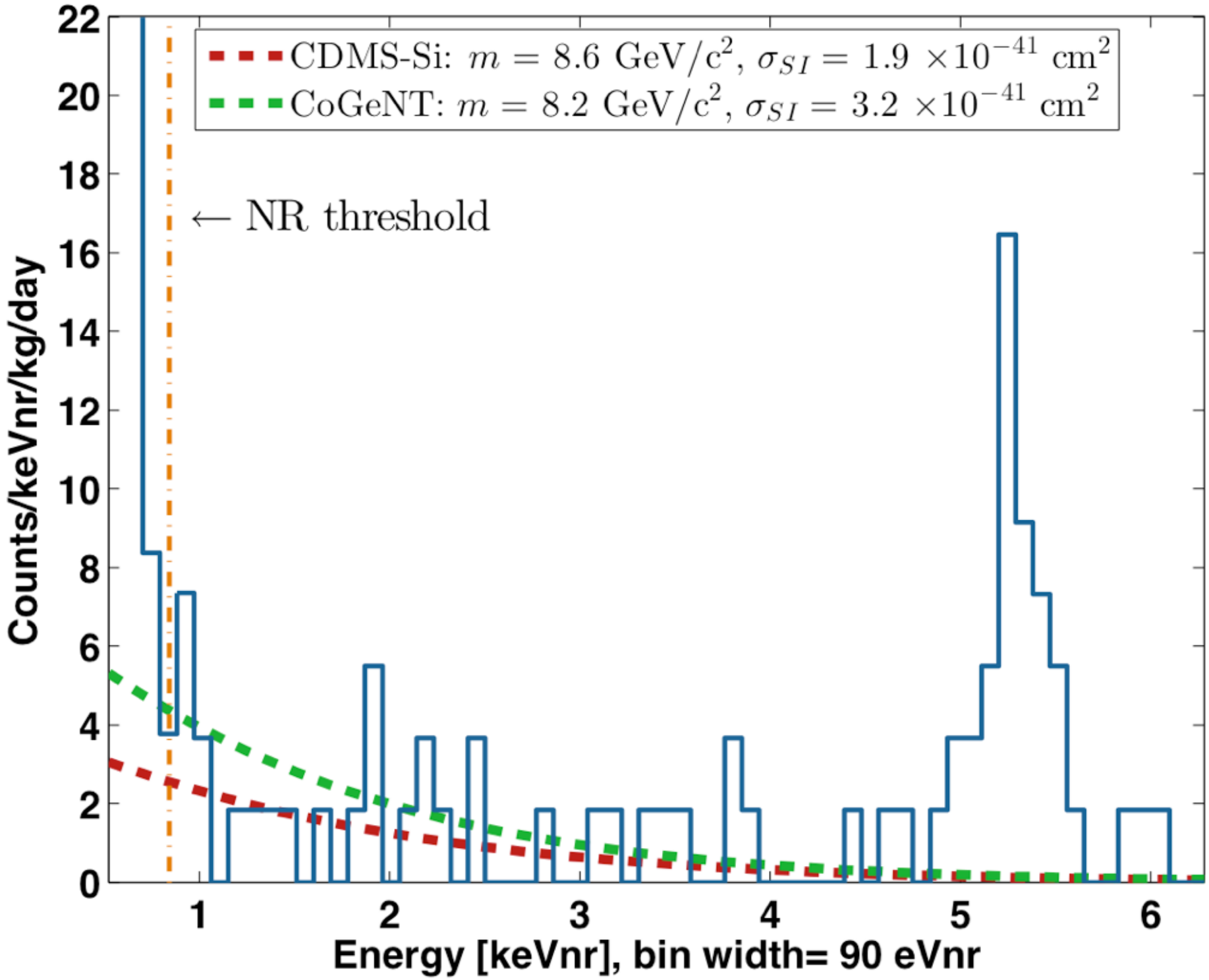


As a result of amplified Luke signal has excellent energy resolution ~13 eVee

Can resolve various Ge activation lines

CDMSLite Run 1 @Soudan

http://arxiv.org/abs/1309.3259



~6 kg-day exposure

No background subtraction, only basic quality cuts

~13 eVee baseline resolution

840 eVnr (170 eVee) threshold

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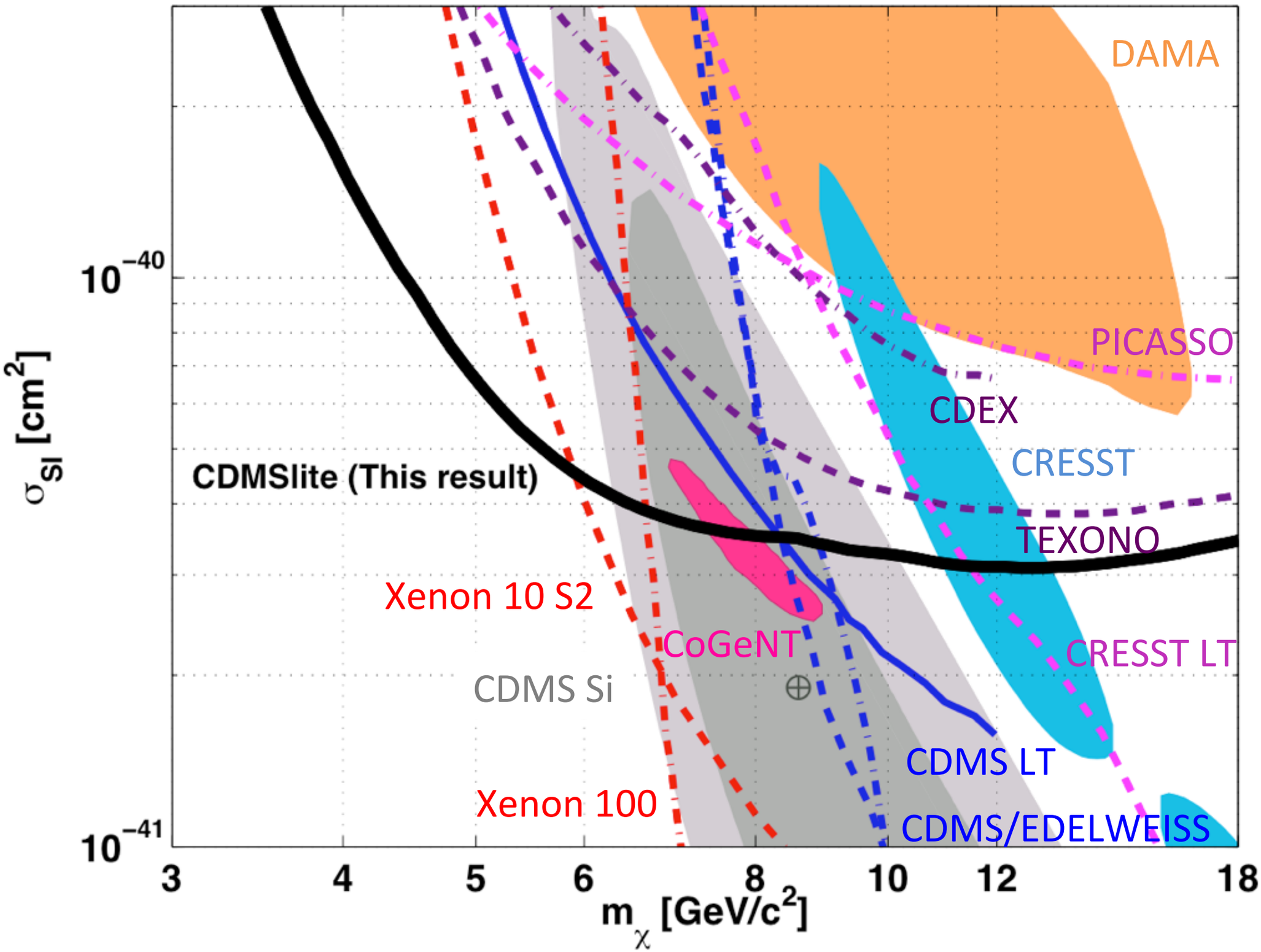
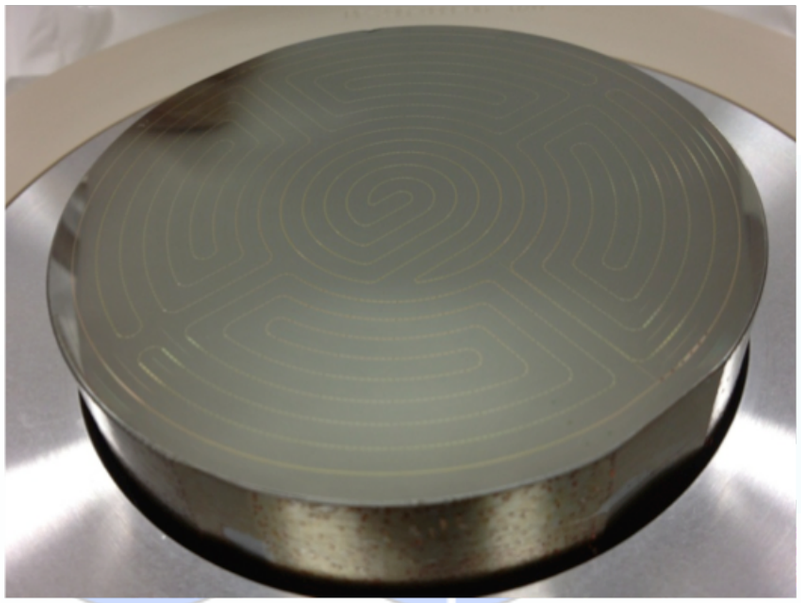


SuperCDMS SNOLAB

Bigger Detectors: better scalability & volume to surface ratio

CDMS II (Ge+Si)

SuperCDMS Soudan



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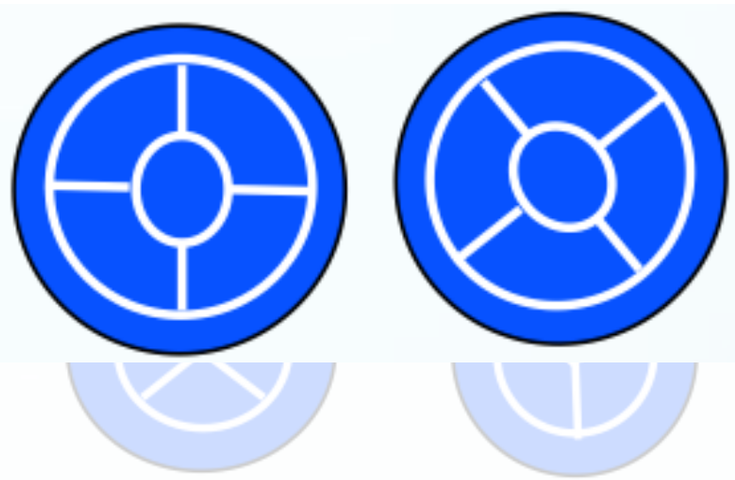

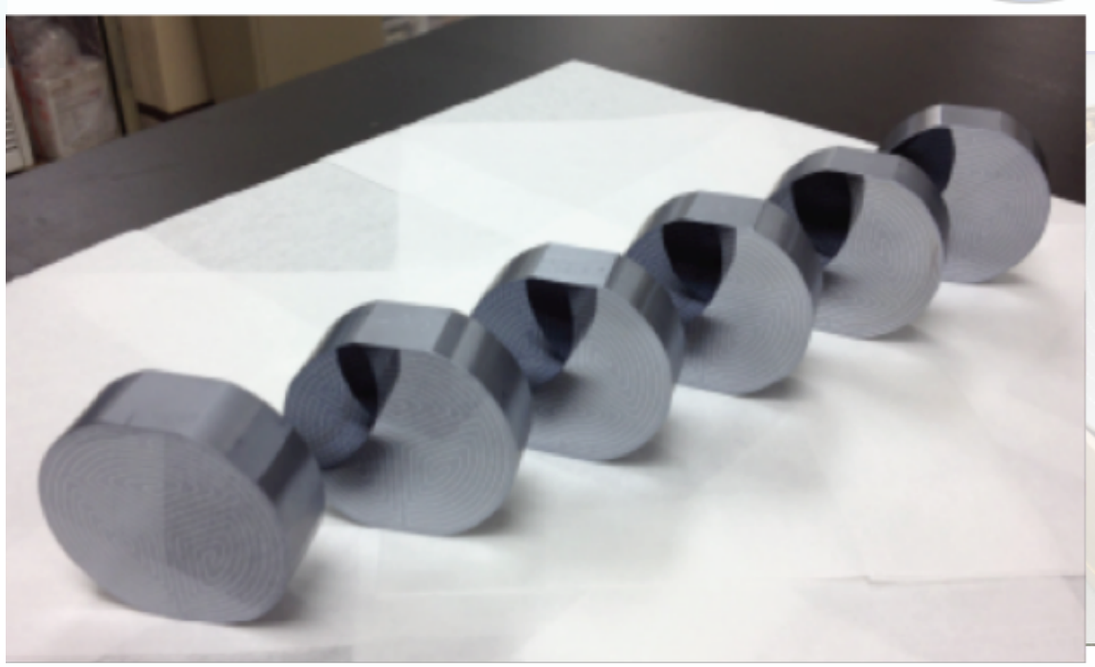

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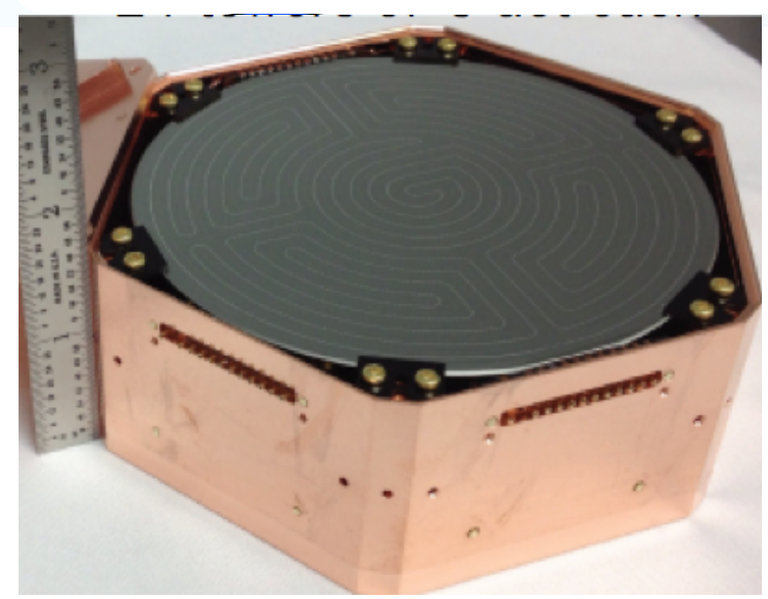
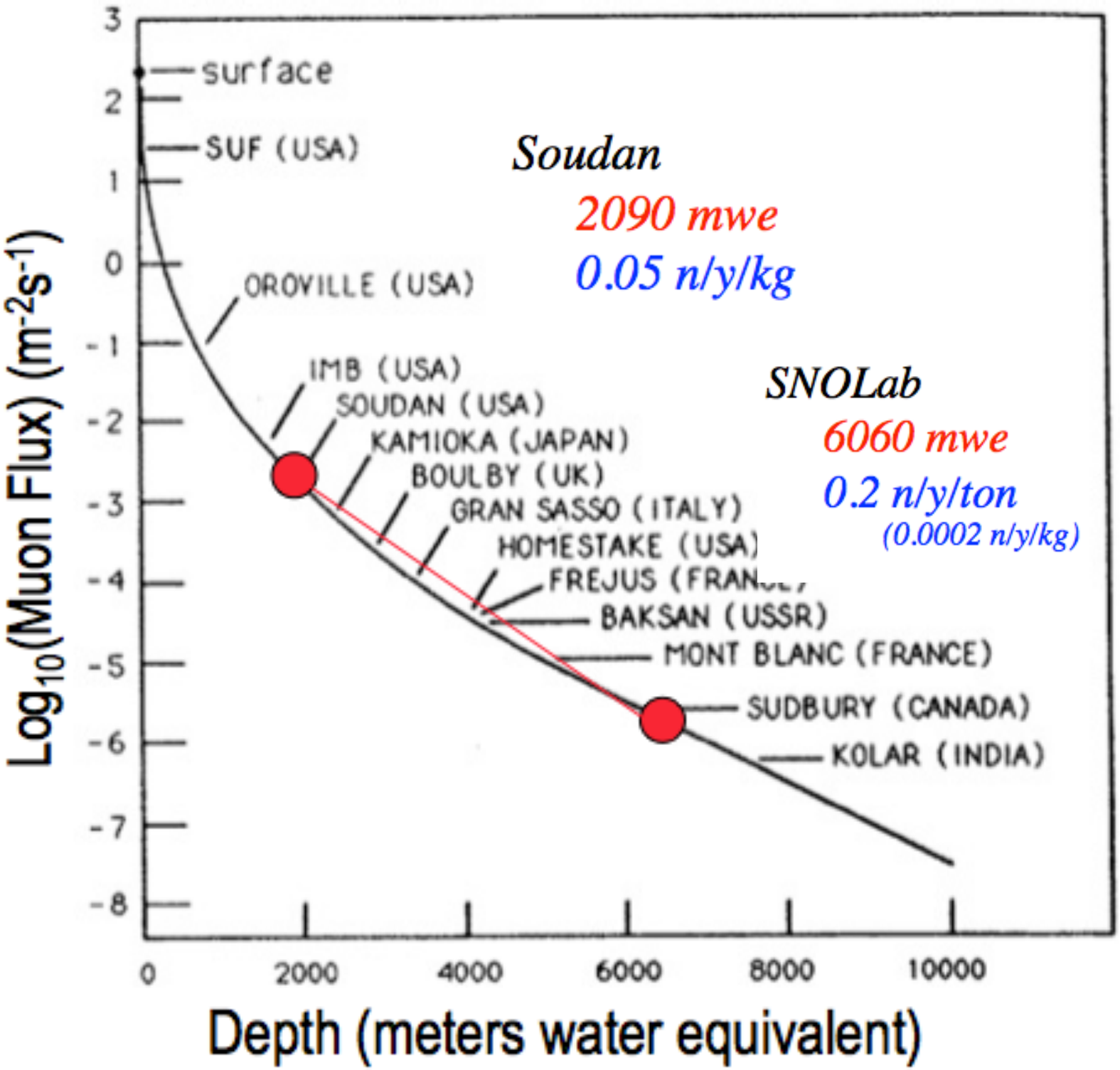


Deeper underground



- Reduce muon flux by factor of 500
- Reduce high-energy neutron flux by a factor 100
- Only need to worry about neutrons from residual radioactivity only

Resulting from fission and alpha-n interactions from U, Th in cavern rock

-> Expected to be negligible with passive shielding

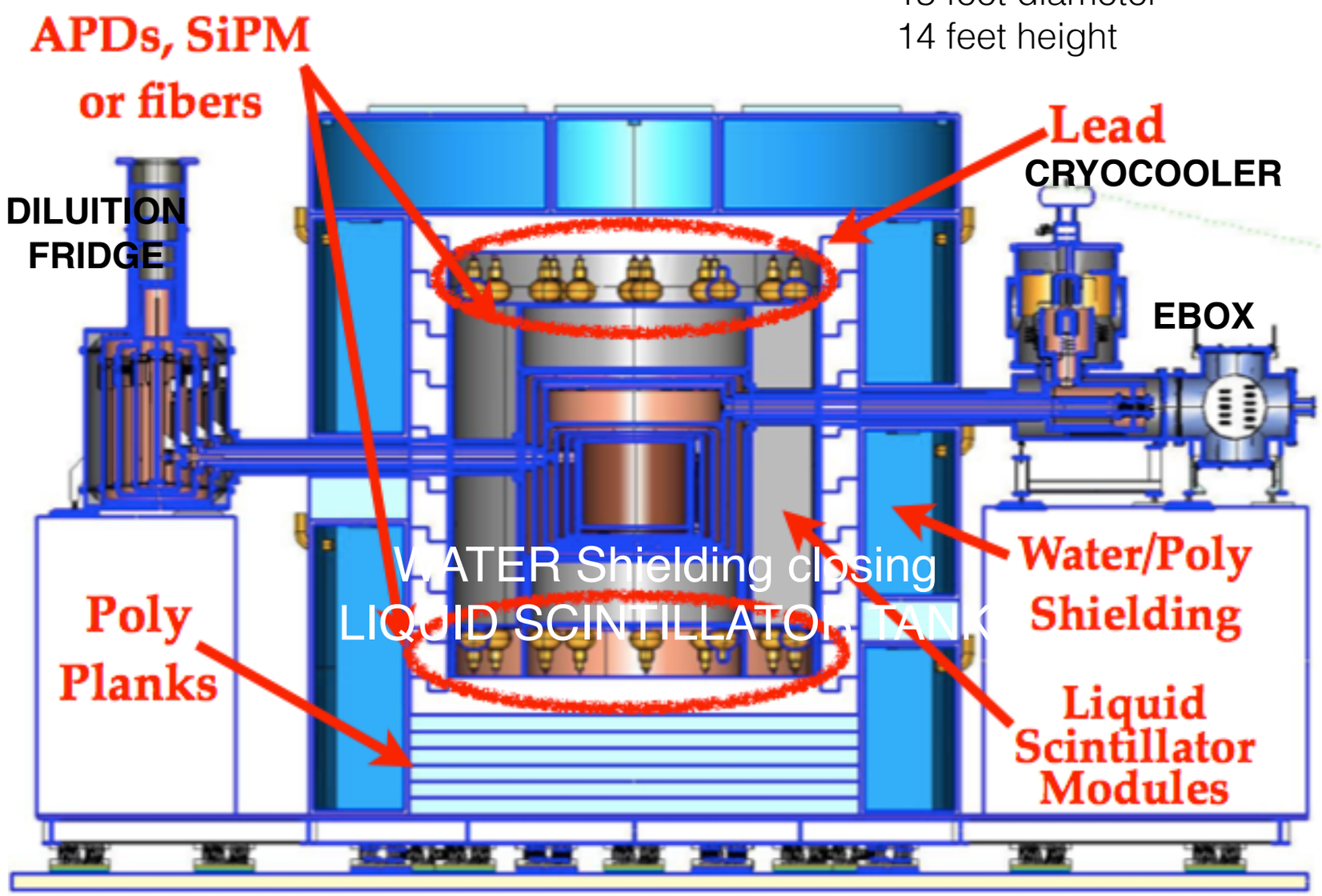
Resulting from fission and alpha-n interactions from U, Th in copper cans, shielding and supports.

-> Expected to be ~1 events depending on material cleanliness

Experimental Set-up

Cryostat volume of up to 400 kg target

Dimensions:
13 feet diameter
14 feet height

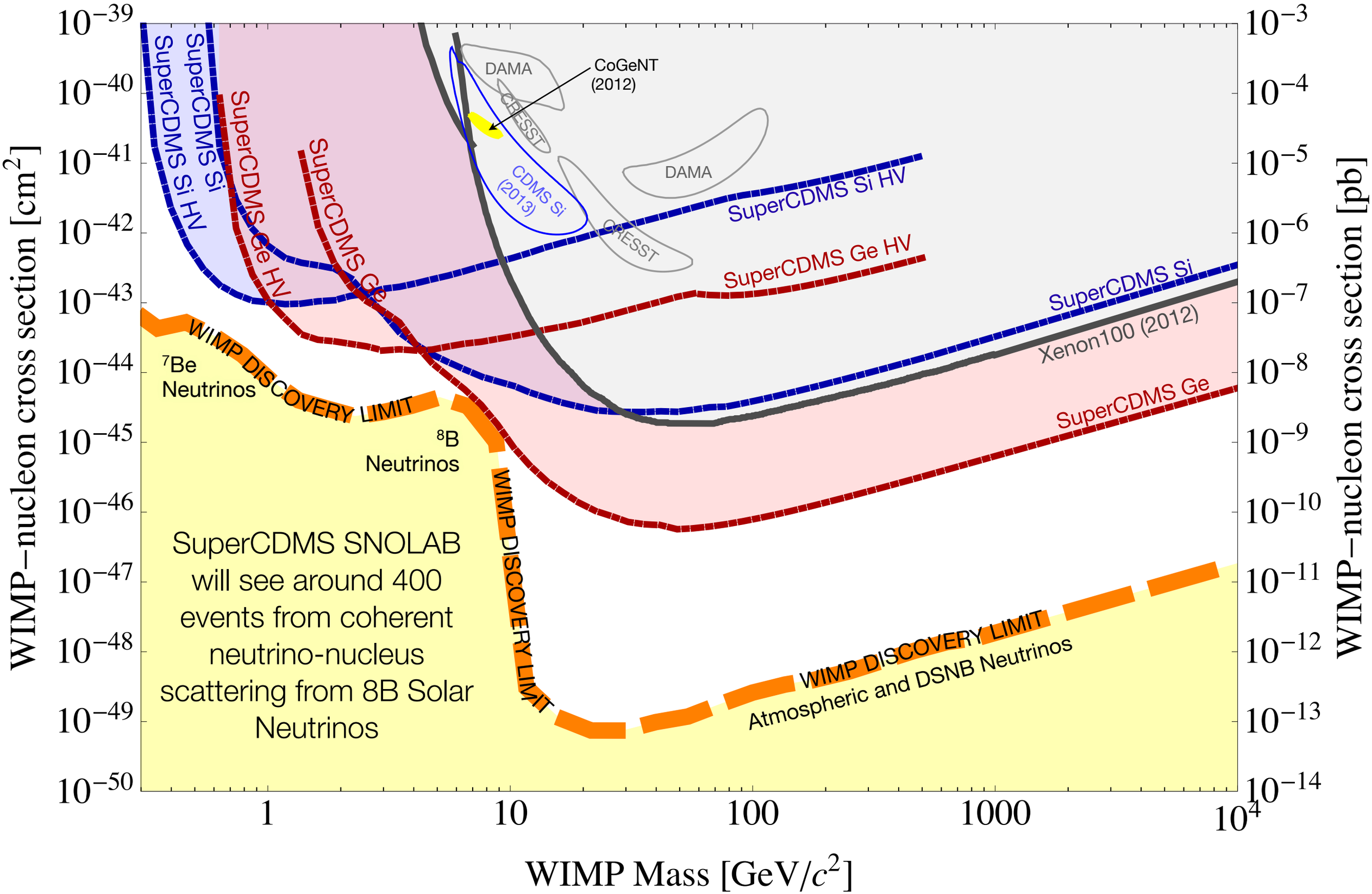


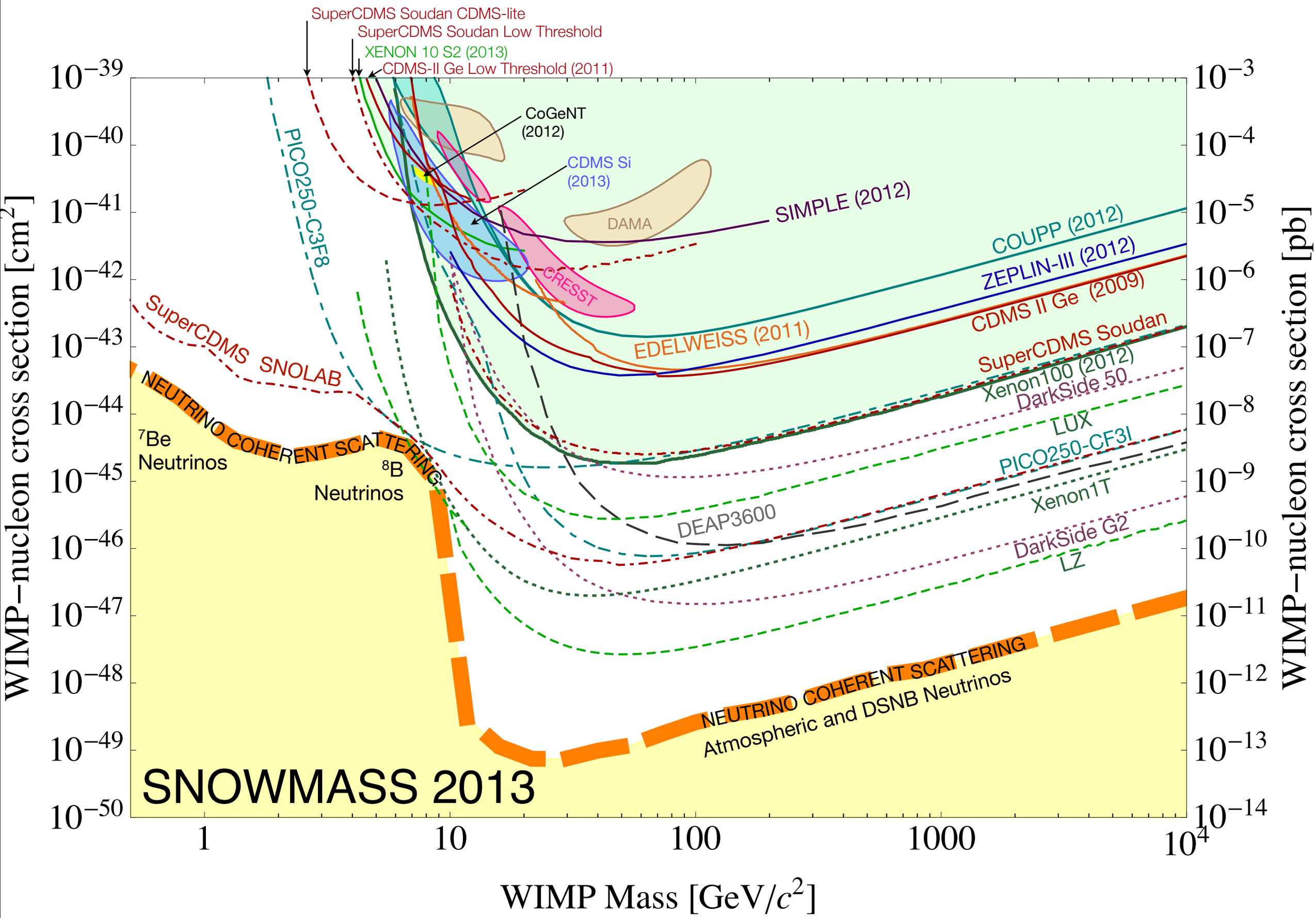
Pb/Cu shielding for external radiation

Increased **PE** shielding (neutrons)

Possible **neutron veto**
- Surround the cryostat with a high efficiency neutron detector to tag neutrons.
- Modular tanks of liquid scintillator, with radial thickness 0.4 m, viewed by phototubes.
- Details of scintillator to use (water, Gd or B loaded) under consideration.
- Alternate design: alternating layers of Gd-loaded poly/scintillator and lead.

Background: Billard et al, 2013
arXiv:1307.5458v2




SuperCDMS Soudan CDMS-lite
SuperCDMS Soudan Low Threshold
XENON 10 S2 (2013)
CDMS-II Ge Low Threshold (2011)
CoGeNT (2012)
CDMS Si (2013)
DAMA
SIMPLE (2012)
COUPP (2012)
ZEPLIN-III (2012)
CDMS II Ge (2009)
SuperCDMS Soudan
Xenon100 (2012)
DarkSide 50
LUX
PICO250-CF3I
Xenon1T
DarkSide G2
LZ
DEAP3600
EDELWEISS (2011)
CRESST
PICO250-C3F8
SuperCDMS SNOLAB
NEUTRINO COHERENT SCATTERING
^{7}Be Neutrinos
^{8}B Neutrinos
NEUTRINO COHERENT SCATTERING
Atmospheric and DSNB Neutrinos
SNOWMASS 2013
WIMP–nucleon cross section [cm^2]
WIMP–nucleon cross section [pb]
WIMP Mass [GeV/c^2]
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
1
10
100
1000
10^4

Conclusions

- CDMS II detectors continue to provide great science. The Si analysis result does not rise to the level of discovery, and more data will be needed to understand if we are looking at a signal or background.
- SuperCDMS Soudan (~9 kg) is taking data with iZIP detectors and first results are forthcoming.
- We have demonstrated surface event rejection with the new iZIP detector design using ^{210}Pb sources which paves the way for better than 10^{-46} cm^2 sensitivity at SNOLAB.
- CDMSLite sets best low mass WIMP limits < 6 GeV with only 6.3 kg-day exposure, a threshold of 170 eVee (0.8 keVnr) and no background subtraction. Another data run is planned for next year.

- Ongoing R&D studies are assessing the necessity and feasibility of including a neutron veto in the SuperCDMS-SNOLAB design
- SuperCDMS-SNOLAB will extend the sensitivity by over an order of magnitude with an increased target mass of 200 kg and suppression of backgrounds through better shielding design, materials selection, and materials handling as well as the added depth to suppress backgrounds from cosmic-ray showers
- The SuperCDMS SNOLAB G2 experiment will enable unparalleled sensitivity to low-mass dark matter with two different target materials, while at the same time being sensitive to almost the entire parameter space covered by XENON1T

Thanks!