SuperCDMS Update and Status

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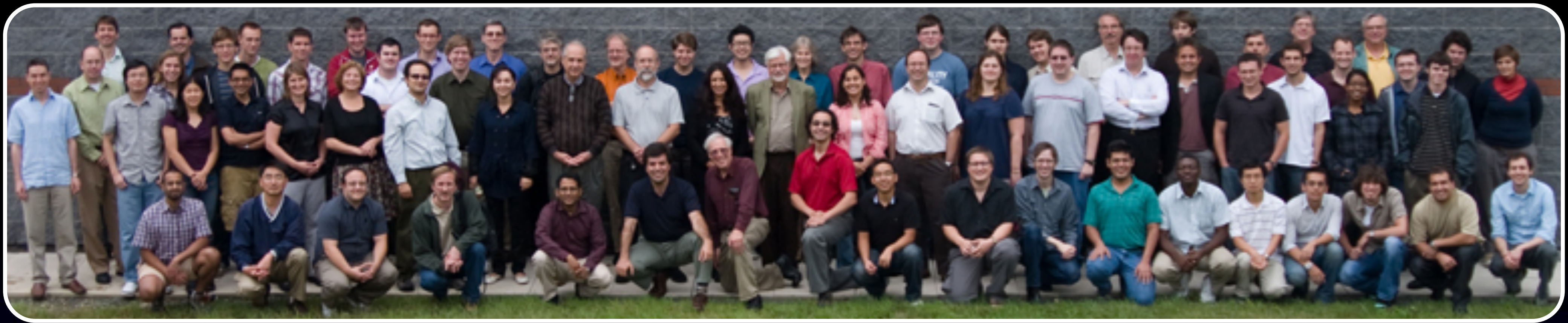
2012.07.20

PATRAS 2012 Chicago, IL USA

SuperCDMS collaboration



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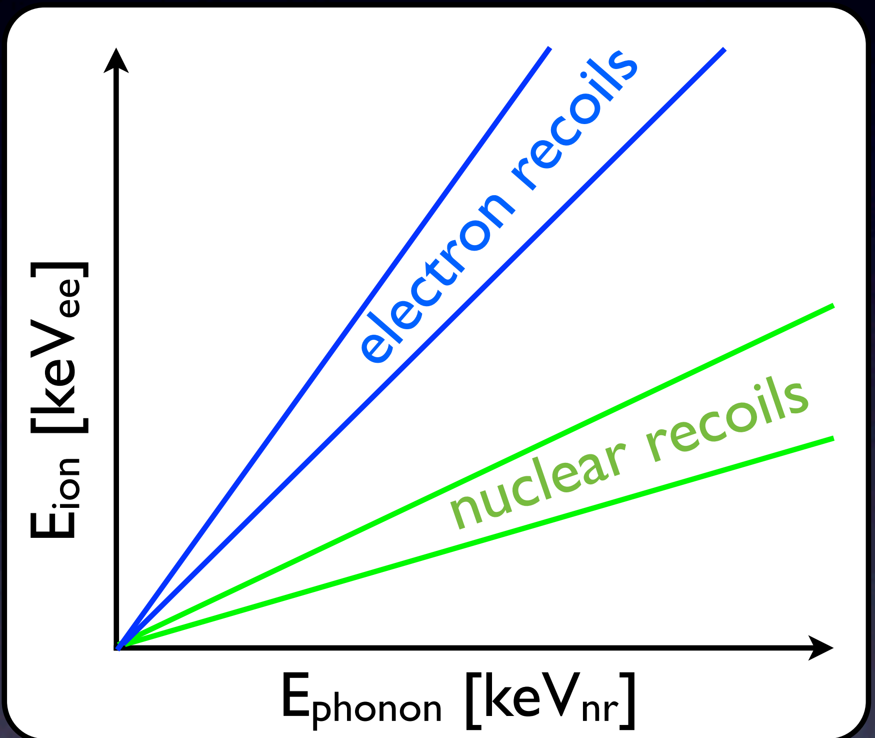
18 institutions; 90 collaborators

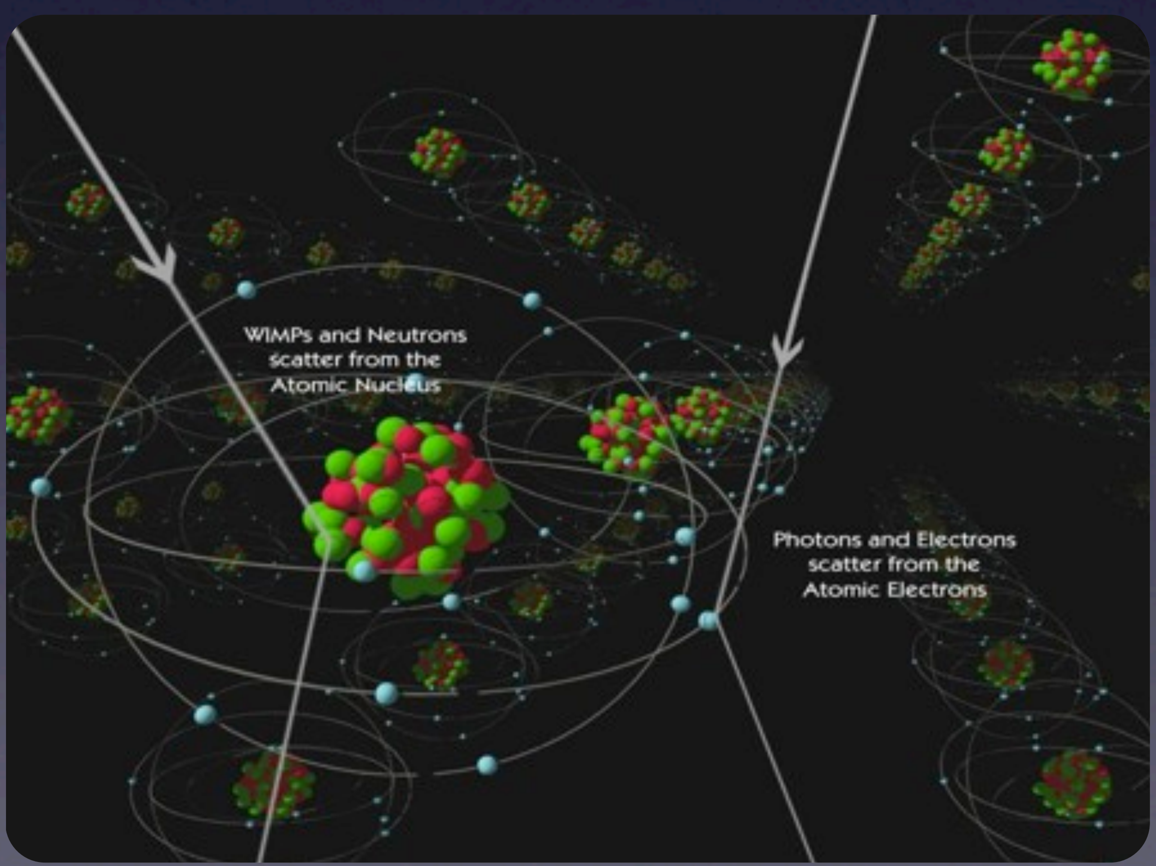
Special thanks to the Soudan Underground Laboratory and Minnesota Department of Natural Resources

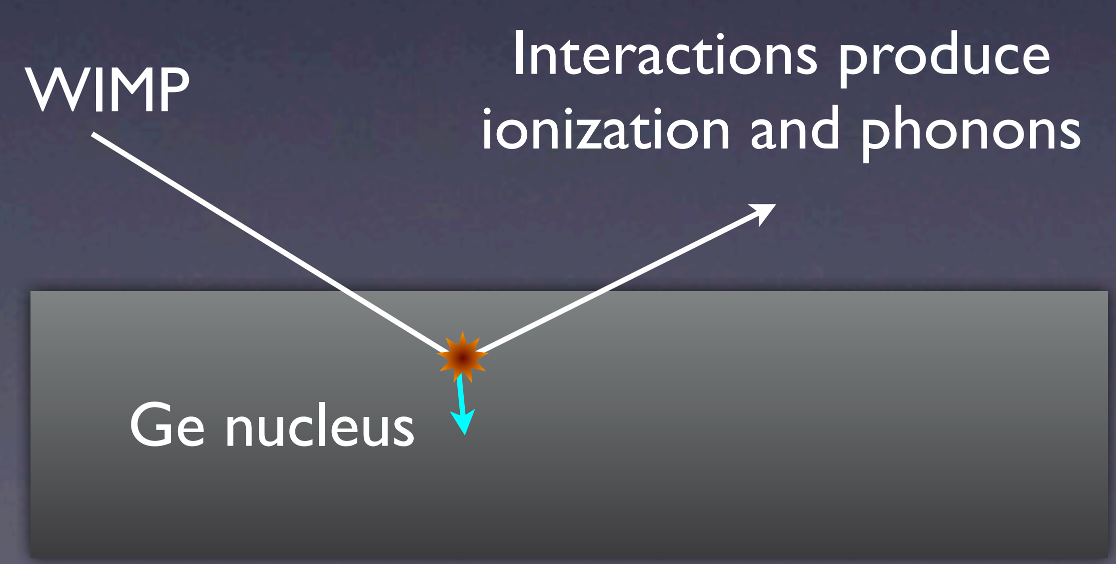
Cryogenic solid-state WIMP detectors

- Spin-independent WIMP-nuclei elastic scattering is expected to be proportional to A^2:
  - Bigger the nucleus, the larger the cross-section.
  - Maximum sensitivity to WIMPs on order the nucleus' mass.
  - Electron recoils are distinguished by the ratio of ionization to phonon energy; nuclear recoils produce less ionization.

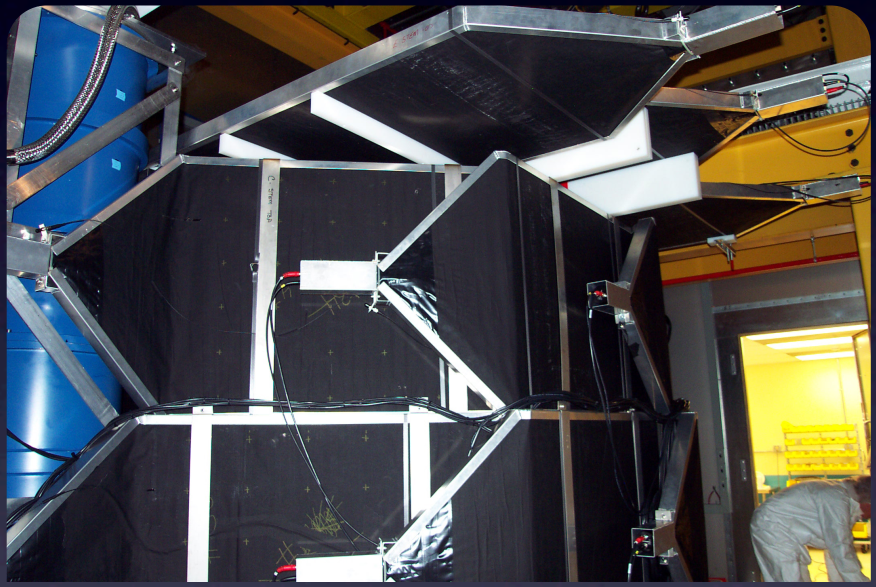
$$\boxed{\text{yield} = \frac{E_{\text{ion}}}{E_{\text{phonon}}}}$$

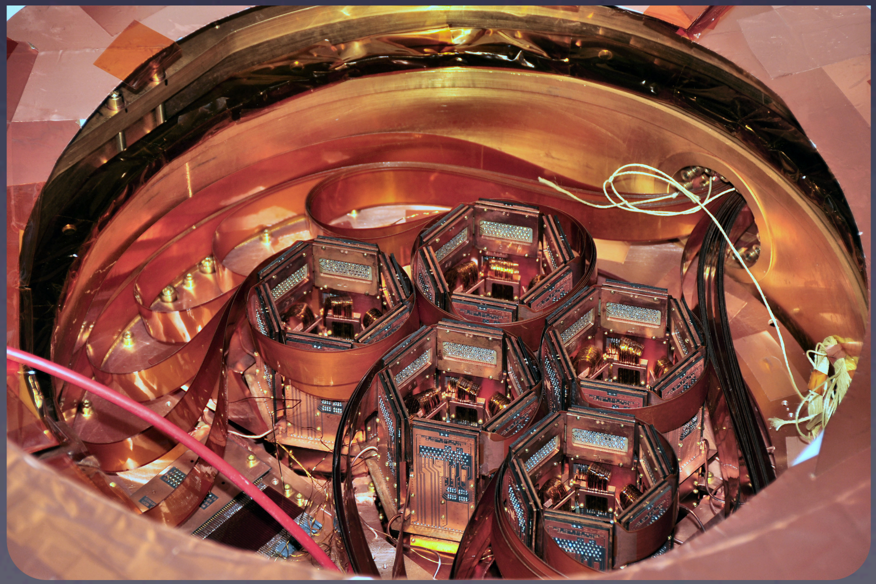






Soudan infrastructure

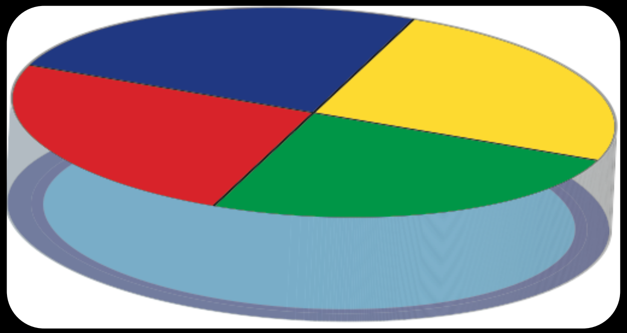


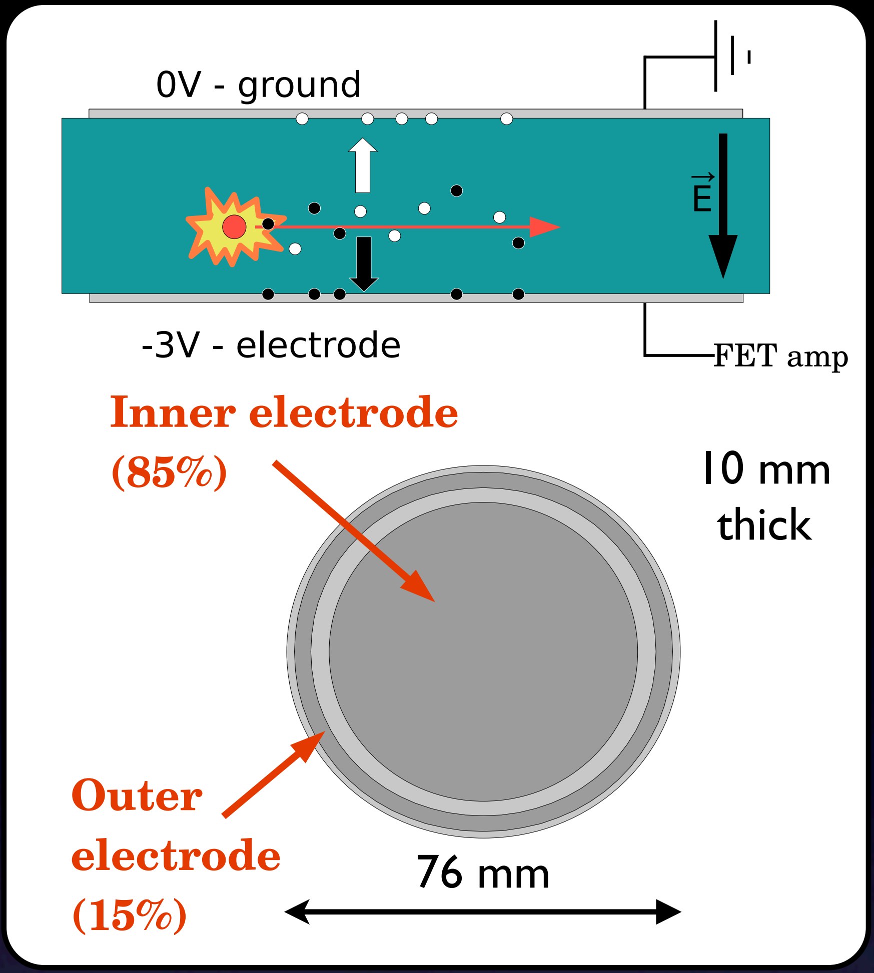


- The Soudan Underground Laboratory is 2341 ft beneath the surface in northern MN.
- The apparatus consists of an RF shielded clean room, Oxford dilution refrigerator, lead and poly passive shielding, and a scintillating muon veto.
- Cryostat cools detectors to ~50 mK.
- This apparatus was commissioned by CDMS II with continued usage by SuperCDMS: Soudan.
- Muons provide the largest external source of radiation (including neutrons from showers).
- Muon veto provides > 99% rejection efficiency.

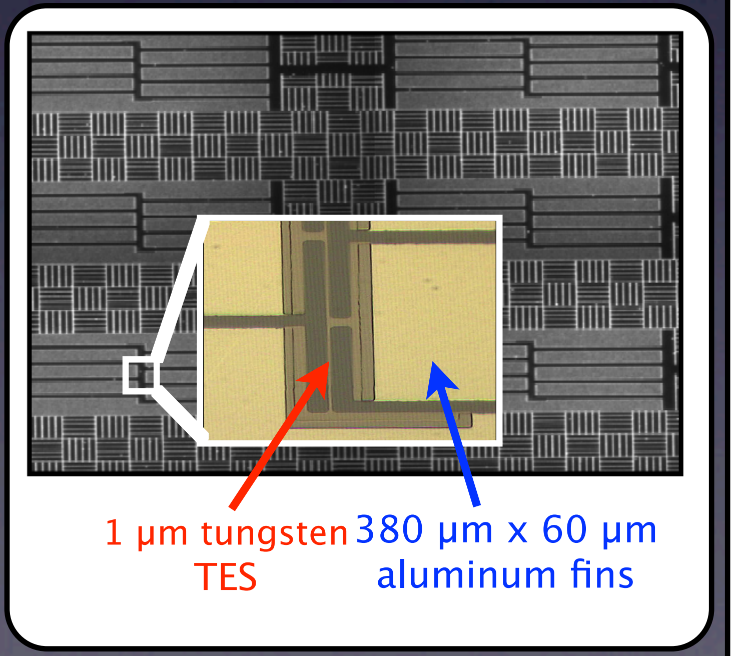
CDMS II: ZIP

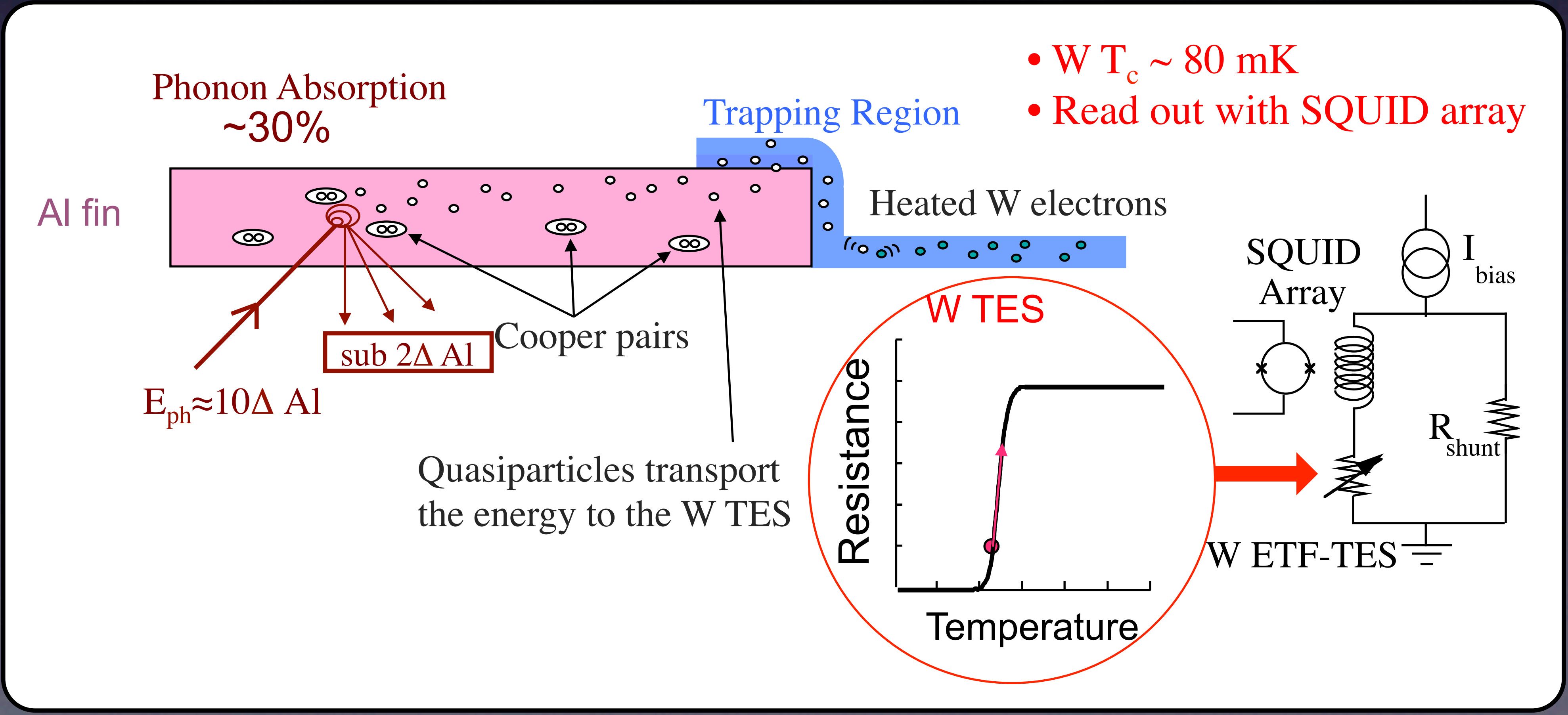
Z-sensitive Ionization and Phonon





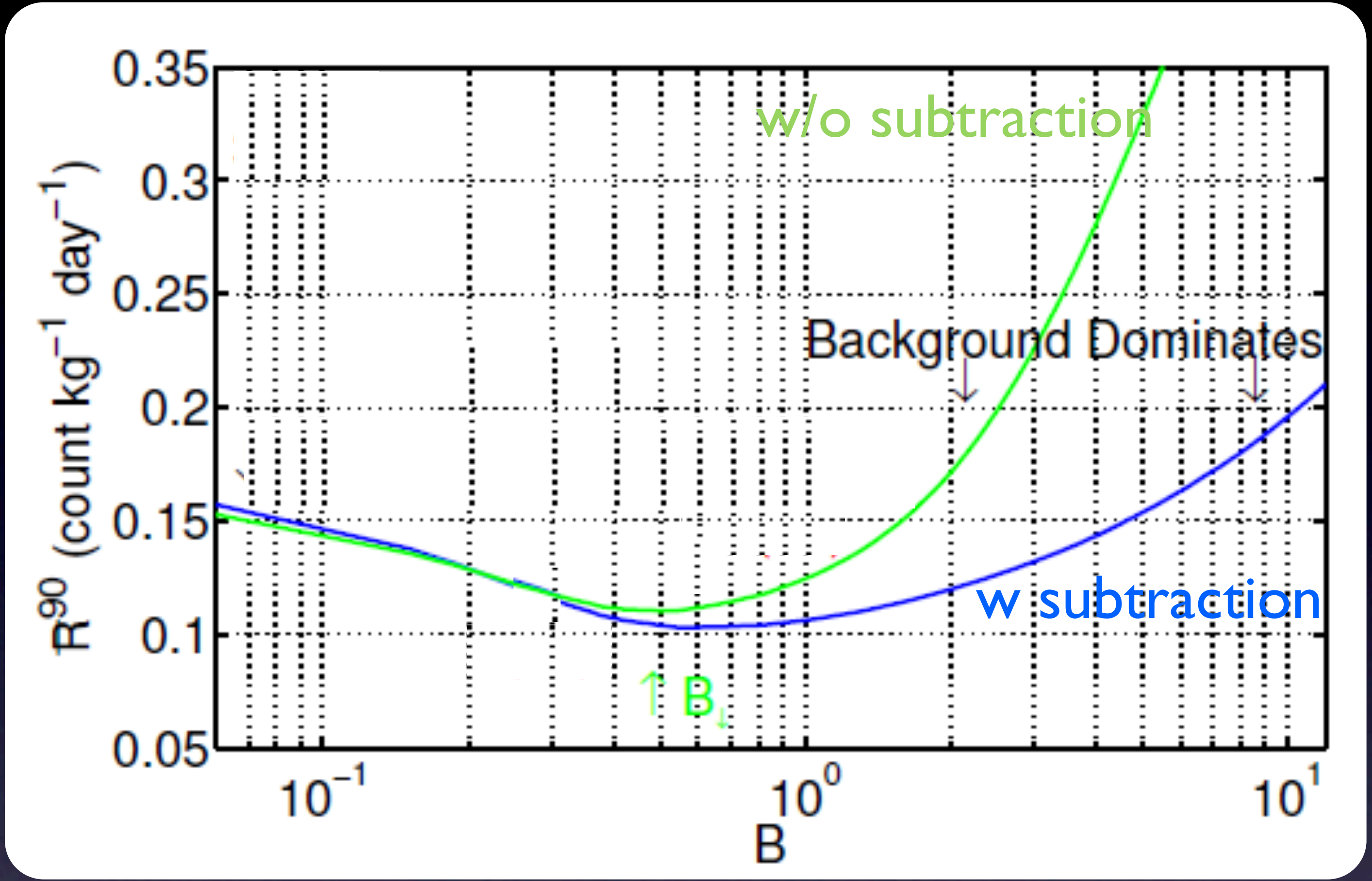
- Recoiling nuclei/electrons ionize the detector; 3V field drifts electrons/holes across the crystal. FET read out.
- Athermal and Neganov-Luke phonons break cooper pairs in Al fins, quasi-particles get absorbed in W ETF-TES sensors. SQUID array read out.
- 30 detectors in 5 towers (4.75-kg Ge and 1.1-kg Si); 2 charge and 4 phonon channels per detector.

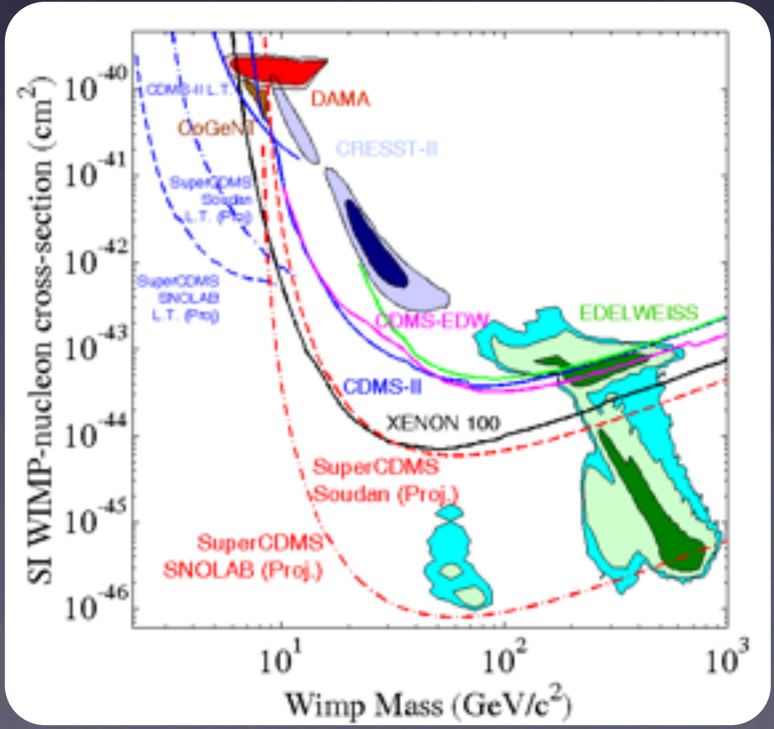




CDMS: analysis strategies

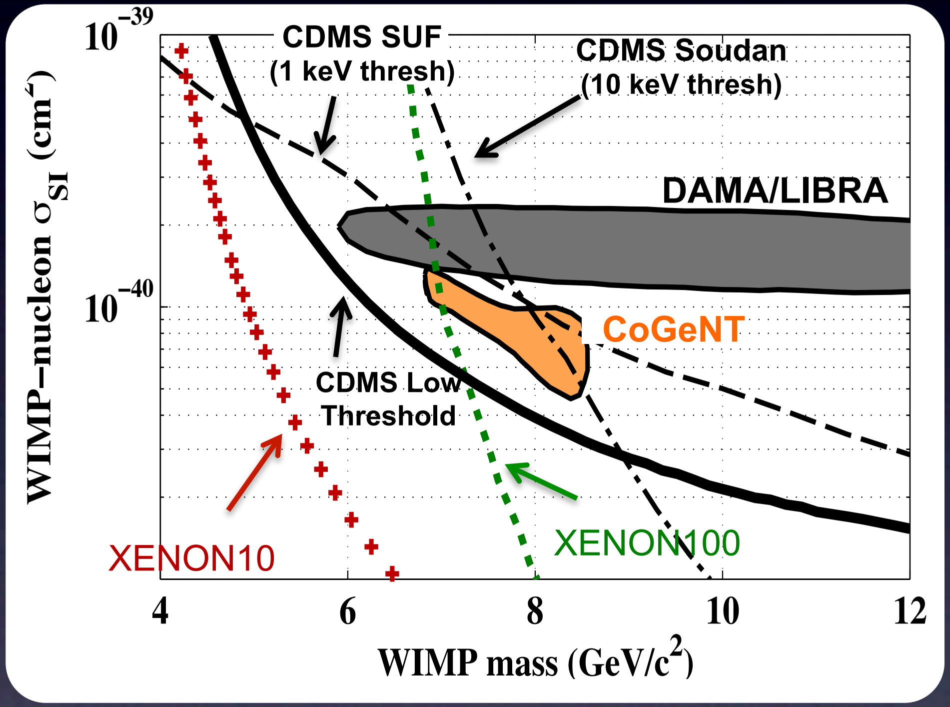
- Sensitivity is maximized when the expected background is < 1 event. This is because the cross section is linear with exposure and then goes as the square root of exposure with subtraction.
  - To keep the backgrounds < 1 event, requires around ~10 keV threshold. Limits the sensitivity to low-mass WIMPs < 10 GeV/c^2.
  - This standard analysis is performed "blind," where the cuts are set prior to looking at the WIMP search data. Sensitivity is based on the expected exposure.
  - Limits are set based on what is found in the "box."
- To go to lower WIMP mass, the threshold must be reduced, sacrificing the < 1 background requirement.

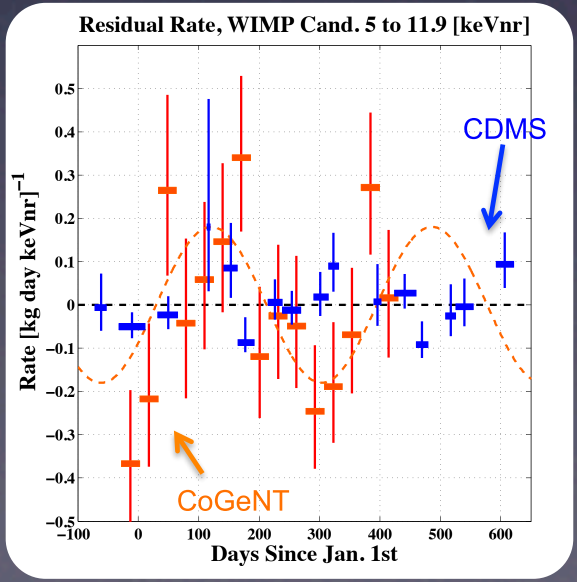


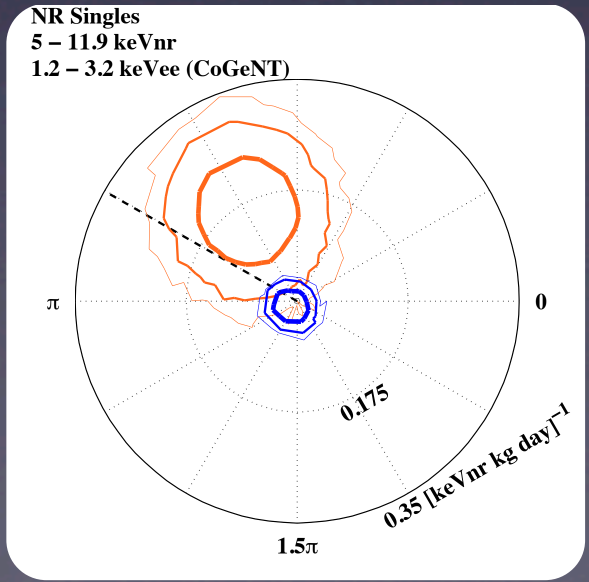


CDMS II: results summary

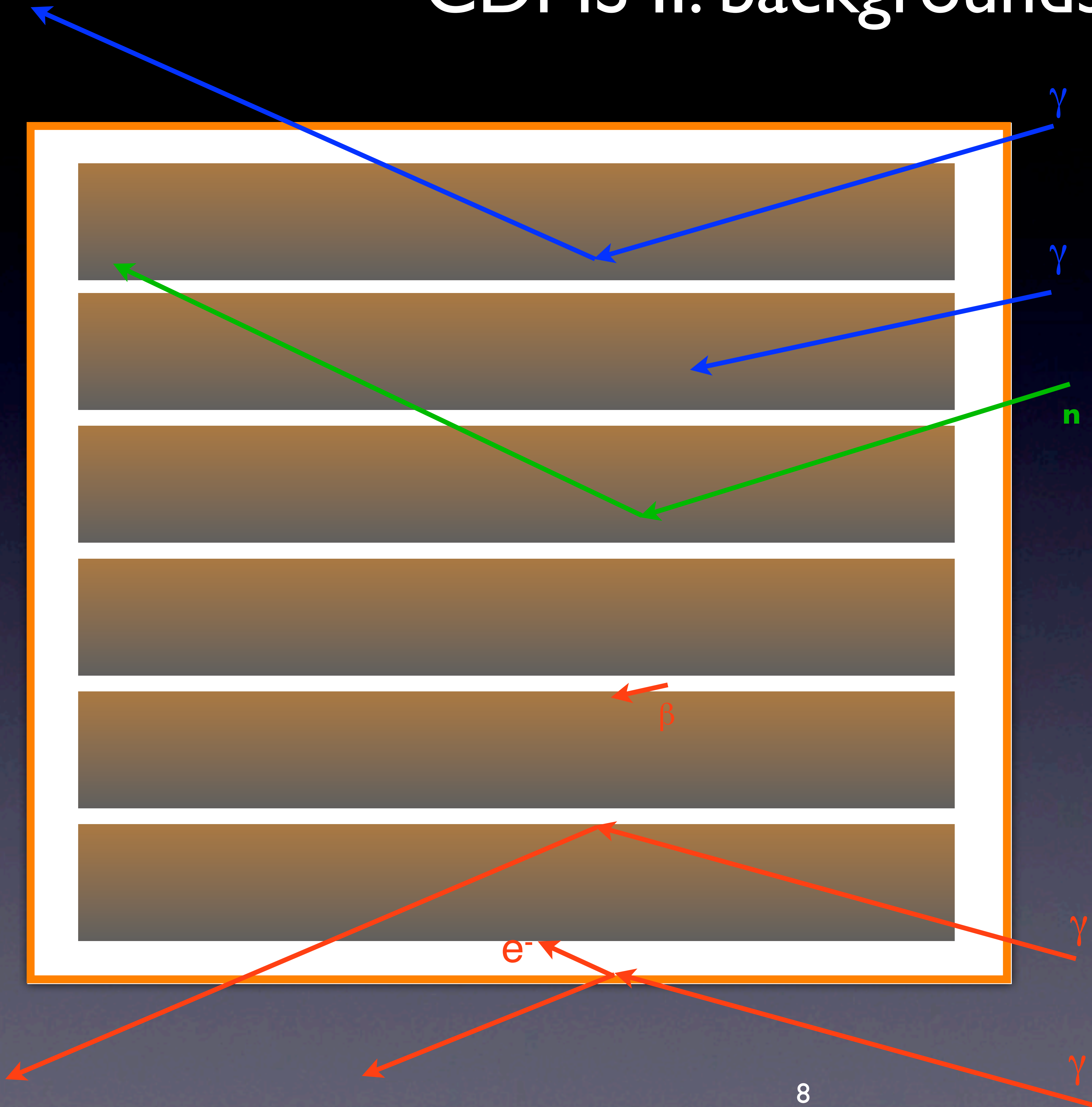
- Standard WIMP scenario analysis, want < 1 background event (~100 GeV/c^2 mass; standard halo):
  - Ahmed et al., Science **327**, 1619-1621 (2010)
  - Reanalysis in progress!
- Low-threshold analysis, lots of background (extends limits to lower mass):
  - Phys. Rev. Lett. **106** 131302 (2011)
  - Likelihood analysis in progress!
- Annual-modulation analysis, lots of background:
  - arXiv:1203.1309
- Inelastic dark matter analysis, want < 1 background:
  - Phys. Rev. D **83**, 112002 (2011)
- Combined analysis with Edelweiss:
  - Phys. Rev. D **84**, 011102 (2011)







CDMS II: backgrounds



Photons (γ)

primarily Compton scattering of broad spectrum up to 2.5 MeV

small amount of photoelectric effect from low energy gammas

Neutrons (n)

radiogenic: arising from fission and (α,n) reactions in surrounding materials (cryostat, shield, cavern)

cosmogenic: created by spallation of nuclei in surrounding materials by high-energy cosmic ray muons.

Surface events ("β")

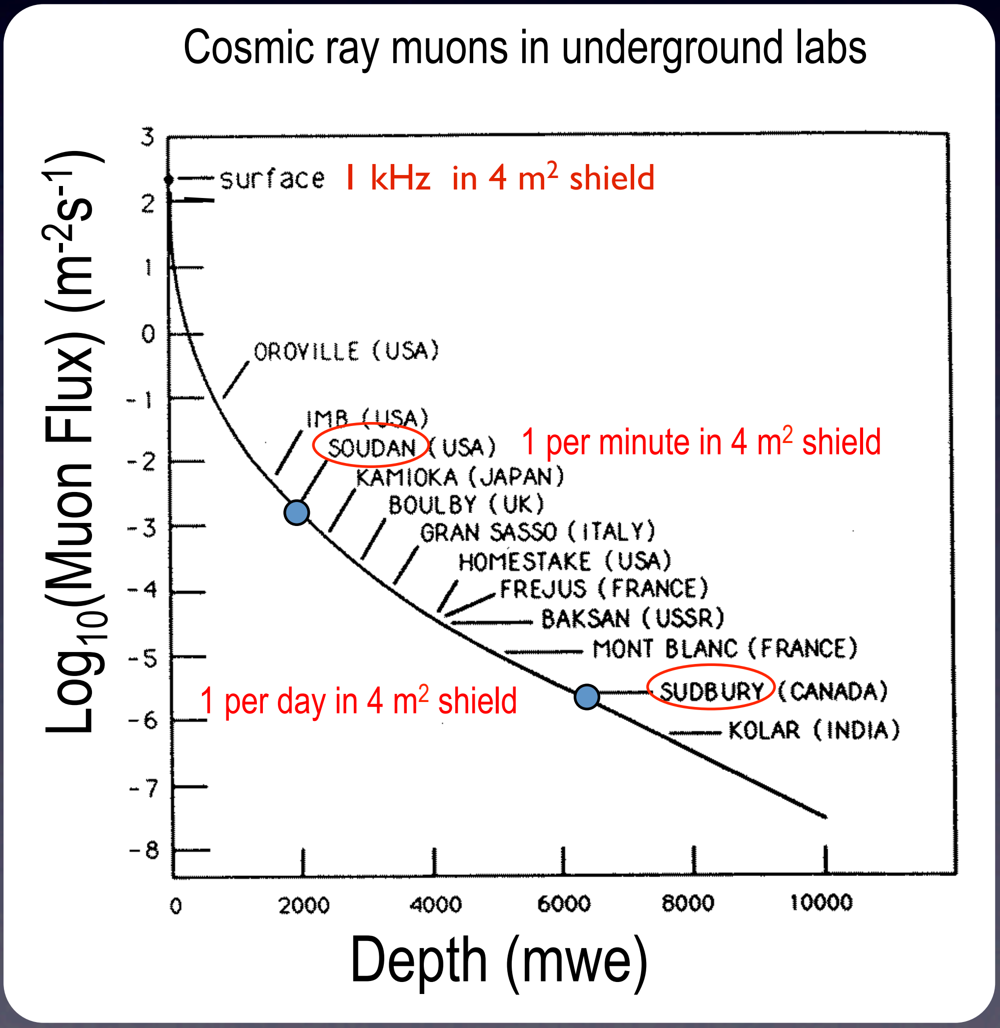
radiogenic: electrons/photons emitted in low-energy beta decays of ^{210}Pb or other surface contaminants

photon-induced: interactions of photons or photo-ejected electrons in dead layer

50% gamma Comptons and photoelectric
50% ^{210}Pb decays

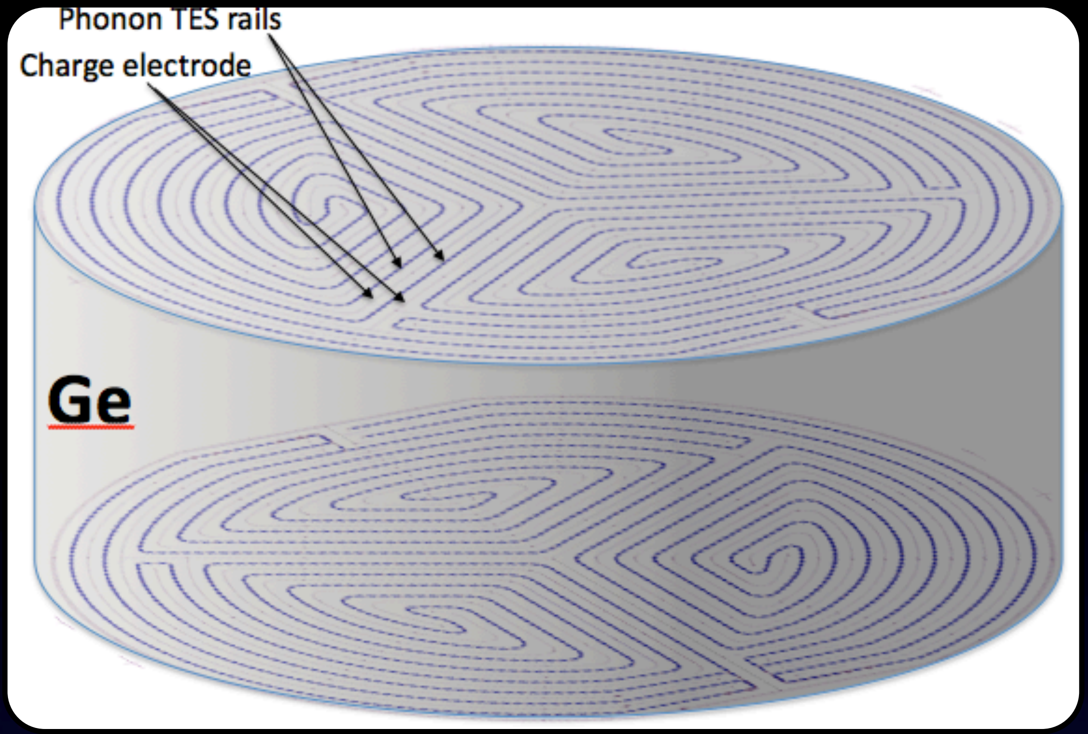
Tackling backgrounds

- In CDMS II surface events were the dominant background.
- Using a two-pronged approach to tackle surface backgrounds in SuperCDMS:
  - Better in-situ surface event rejection (advanced detector technology; Soudan and SNOLAB).
  - Better material screening (particularly β-emitter screening; SNOLAB). Often the best measure of an experiment's intrinsic contamination comes from the experiment itself. Nobody wants to run for a few years to discover that they are background limited!
- Eventually cosmic ray-induced neutrons dominate. This will be tackled by going deeper underground (SuperCDMS: SNOLAB). From 0.71 km deep at Soudan to 2 km at Sudbury.

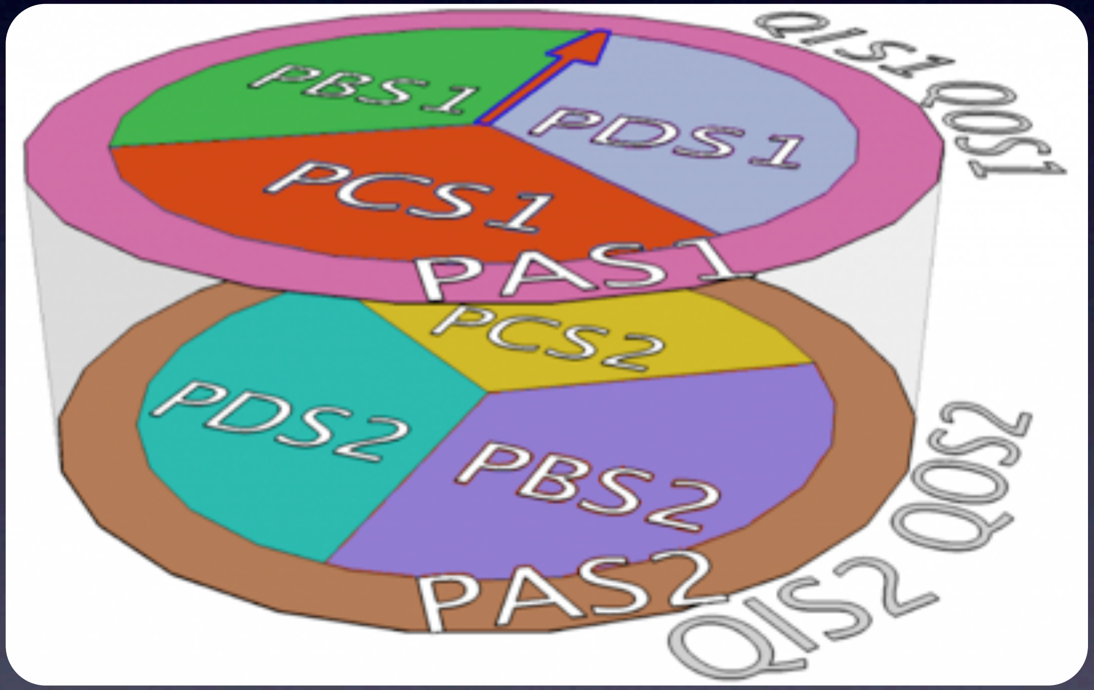


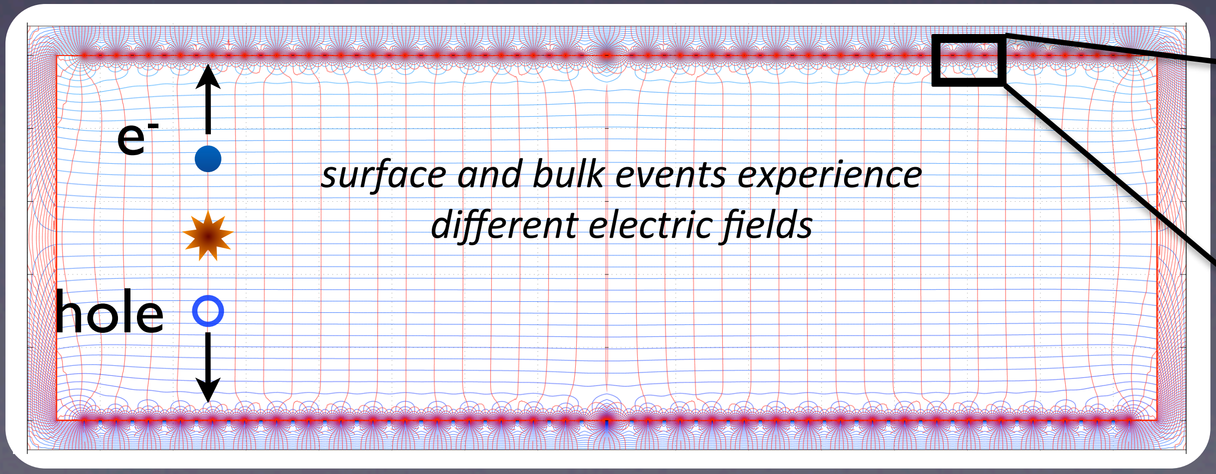
SuperCDMS: iZIP

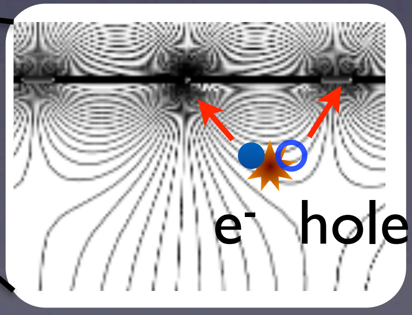
interdigitated Z-sensitive Ionization and Phonon



- By interdigitating electrodes on each surface, the electric field near the detector surfaces traps both the electrons and holes if they are created at the surface, while interactions in the bulk drift to both surfaces. Collects charge on both sides!!
- EDELWEISS II has used this technique with great success.
- Surface events should have charge on one side only!!
- iZIPs are 76 mm diameter x 25 mm thick (up from 10 mm ZIP).
- 15 Ge detectors (9 kg); 4 charge channels and 6 phonon channels per detector.

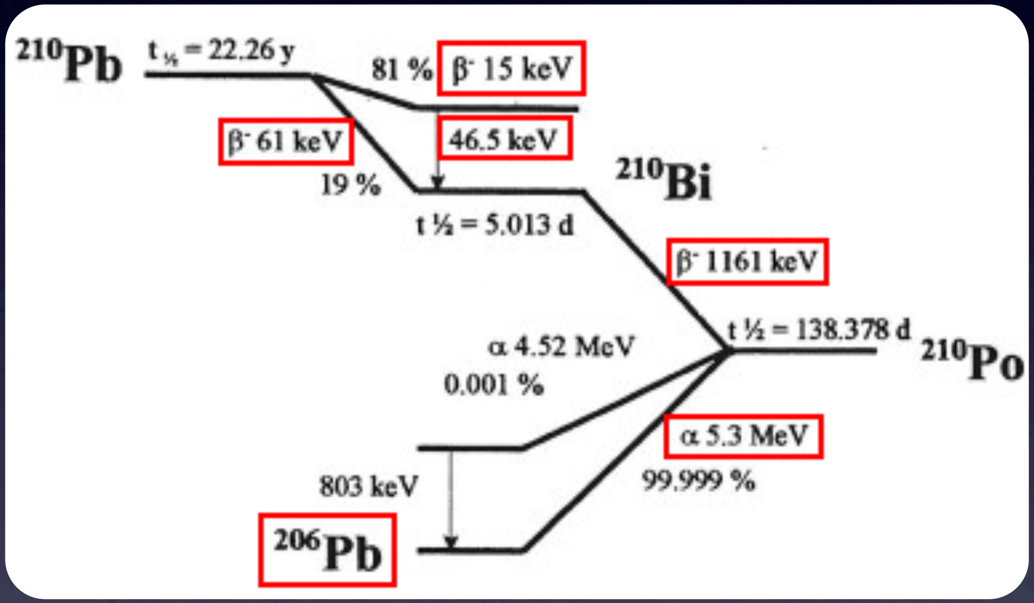






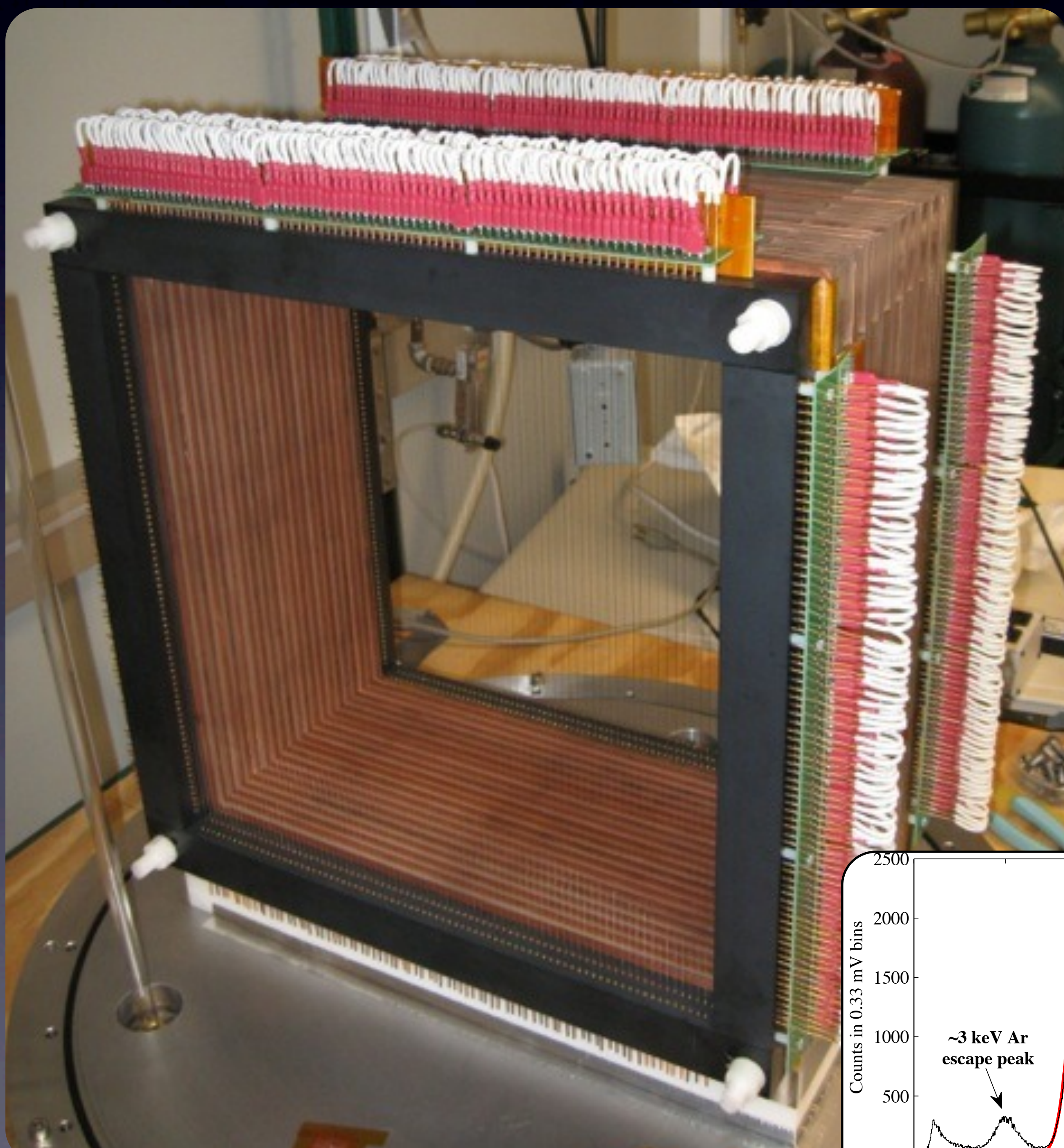
β-emitter screening (advertisement!)

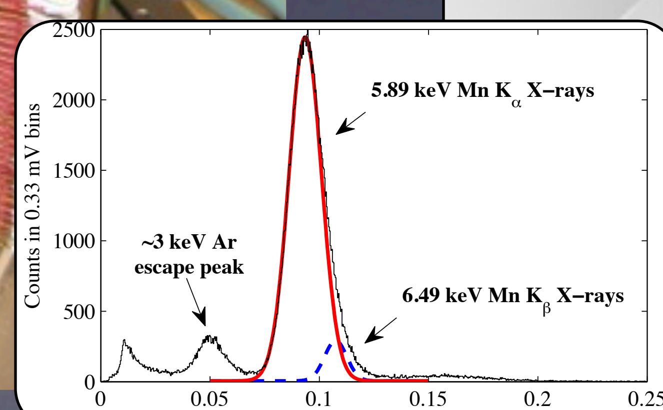
- ^{210}Pb is a β-emitter that eventually has an α-emitter in its decay chain. Rather than wait for the ^{210}Po to “grow in” it might be nice to tag the ^{210}Pb directly from its β.
- The ideal detector would have:
  - Low-intrinsic backgrounds.
  - Measurements of both α and β particles.
  - Low energy threshold (few keV).
- A neon drift chamber satisfies these requirements as neon has no long-lived naturally occurring isotopes.
- Goal is to reach a sensitivity of 10^{-5}/keV/cm^2/day.

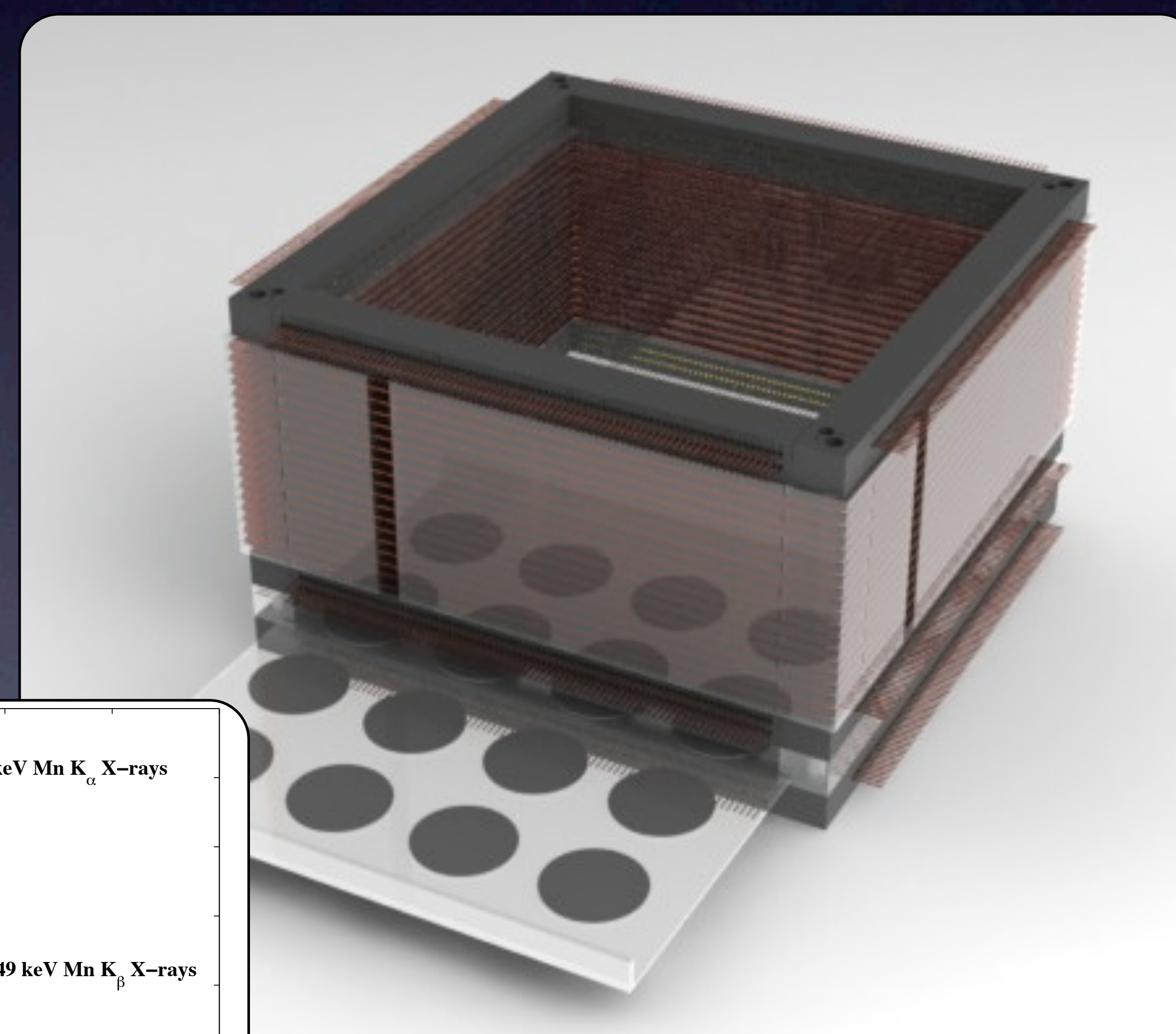


BetaCage

- Currently testing a non-radiopure prototype at Caltech.
- Materials chosen so that the final version will be radiopure.
- A neon-methane drift chamber can provide the sensitivity and quick turn around desired for screening materials for future low-background experiments.
- Will be able to screen any less than 200 keV β-emitter (possible higher energies too!).
- Timescale for SNOLAB (not required, but helpful).



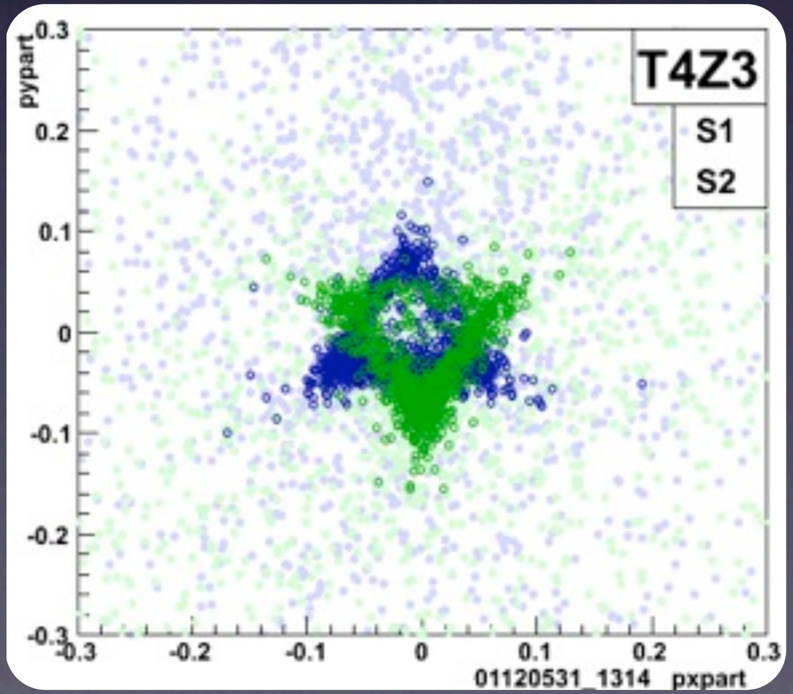




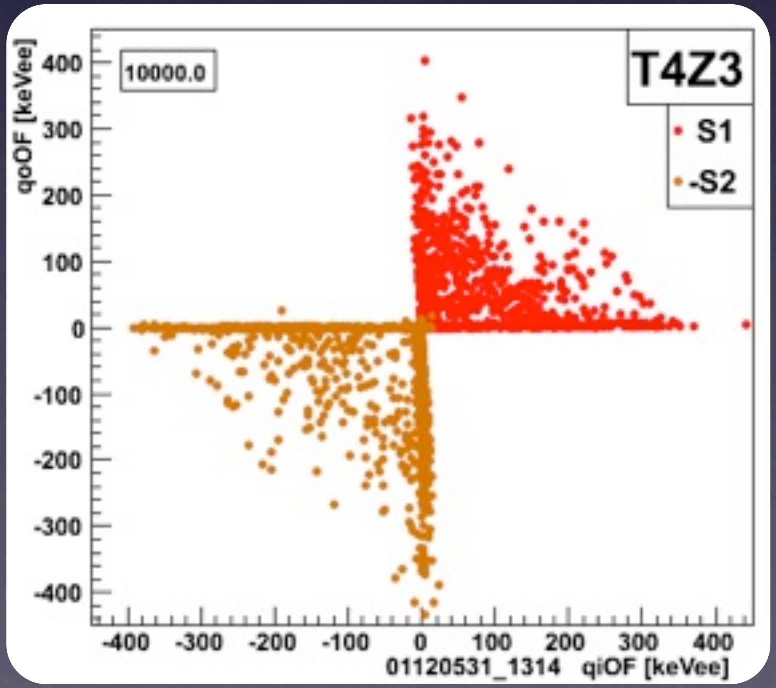
SuperCDMS: Soudan

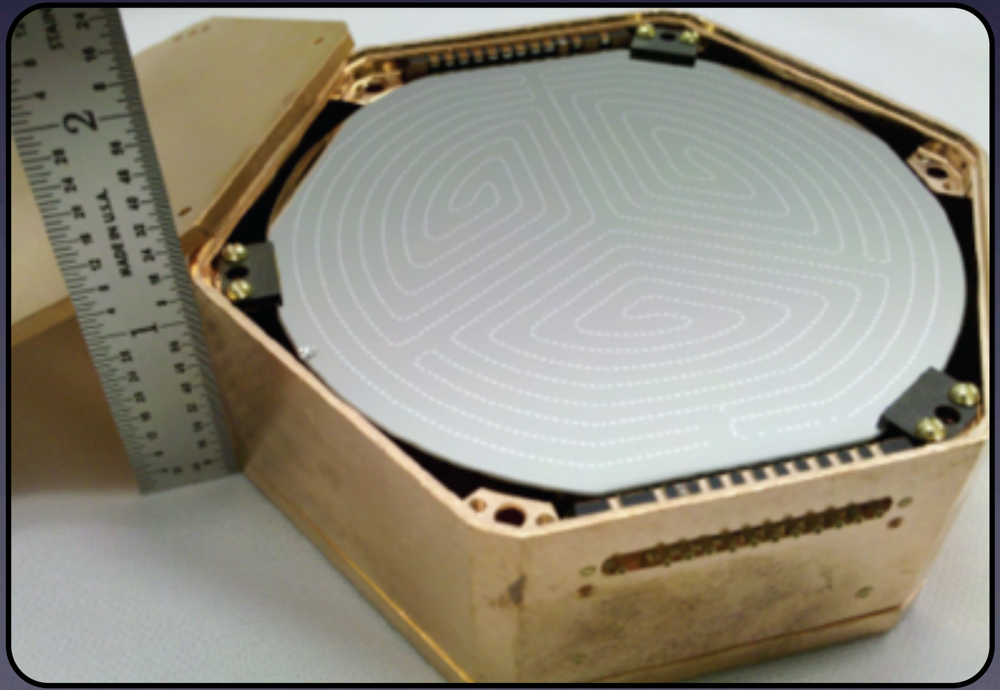
- Operating 15 Ge iZIP detectors (9 kg) since March 14th, 2012.
    - Plan is to run for a few years with the first data release after the first year.
- Plotted are data-quality monitoring plots showing all channels working on a representative detector.

Raw phonon partitions



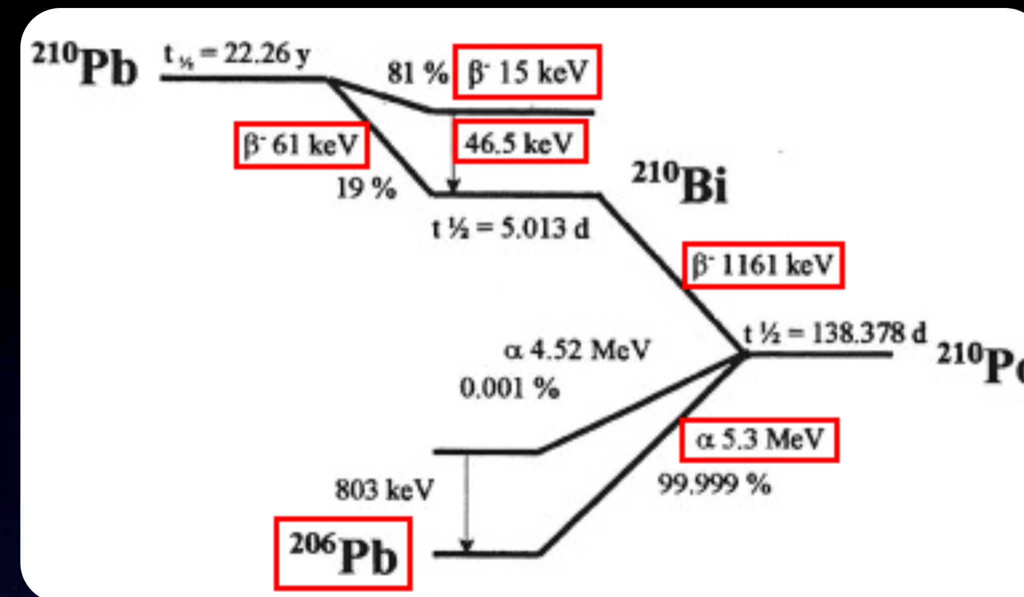
charge channels

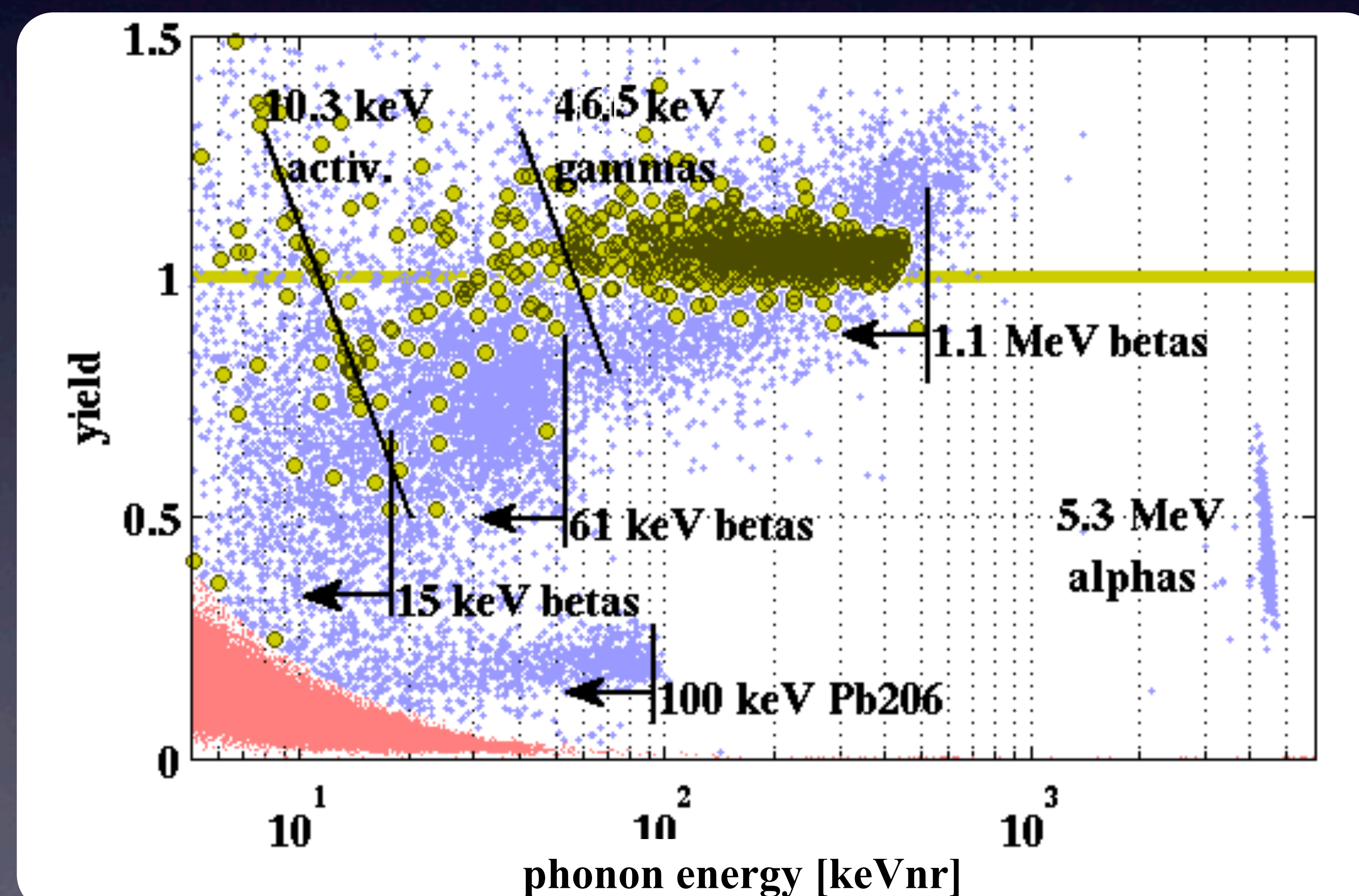




SuperCDMS: Soudan

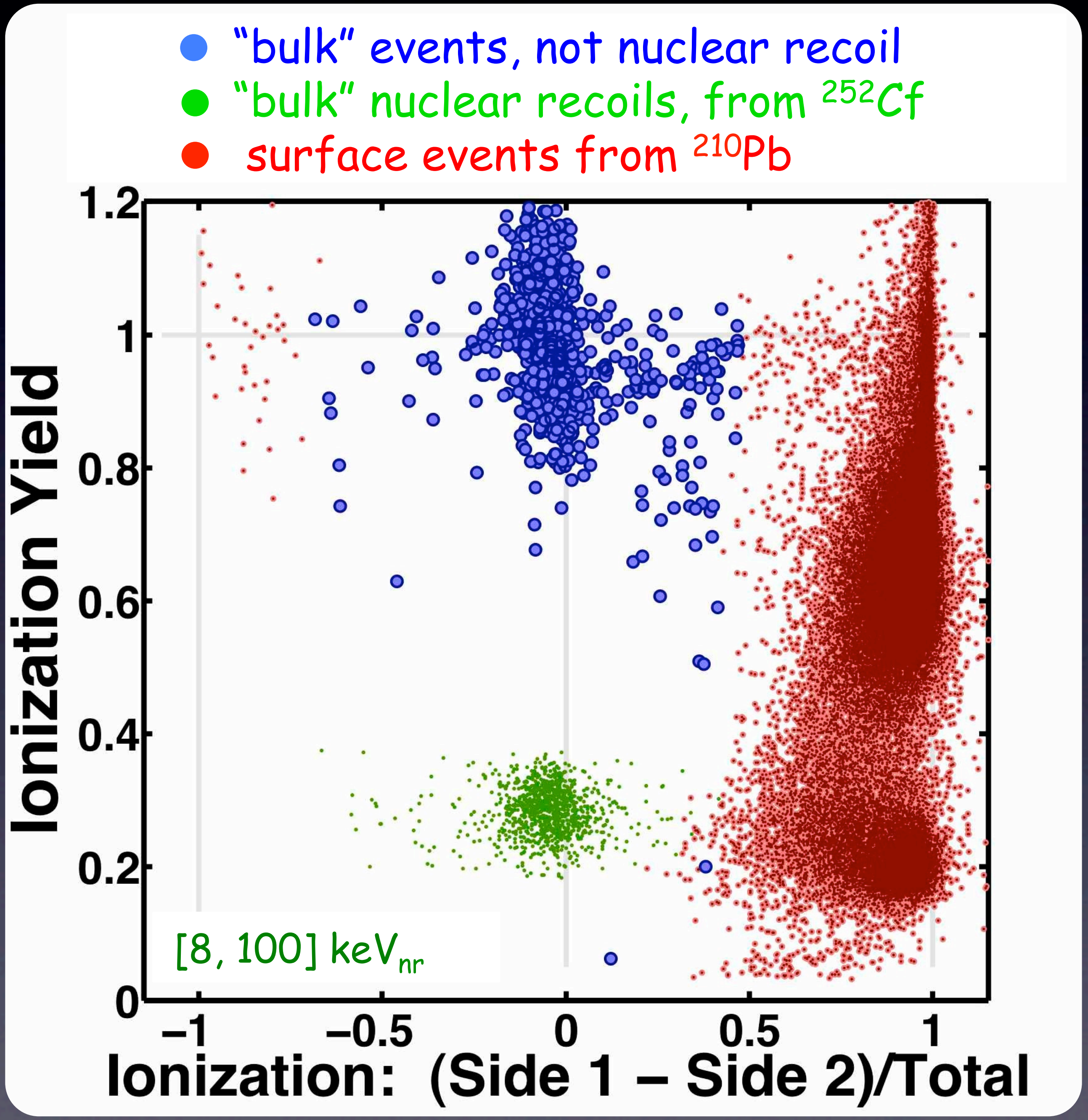
- Two detectors doped with ^{210}Pb sources (~1 event/min). Shouldn't affect WIMP-search sensitivity goal of 5x10^{-45} cm^{2}.
- These sources allow for the measurement of surface event rejection cut efficacy for SuperCDMS: SNOLAB and beyond.
- ^{206}Pb surface recoils have higher yield than expected.
- Goal of 1:30,000 surface event rejection.





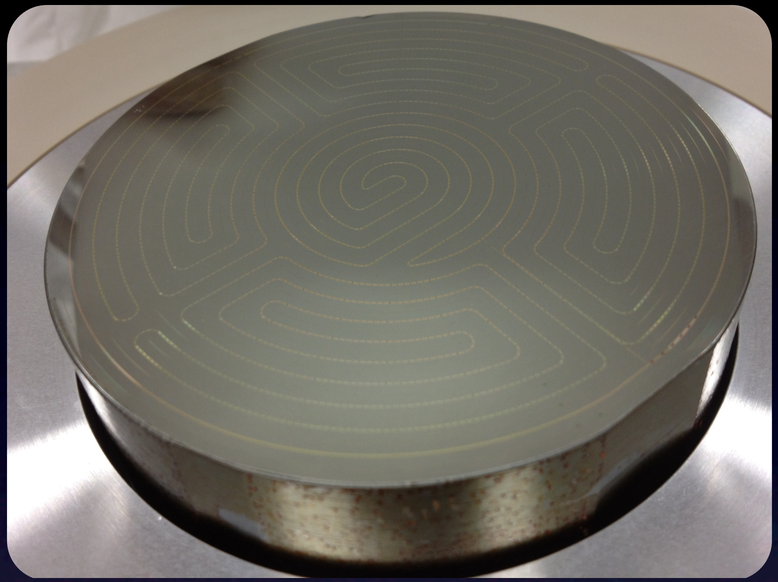
SuperCDMS: Soudan

- Absolutely clear surface event rejection by comparing the yield to the charge symmetry.
- Observed zero leakage in 79,000 surface events.
- Along with 80,000:1 rejection results in <0.5 total background events in 200 kg experiment running 4 years at SNOLAB!
- Surface events will not be the limiting background at Soudan. Limiting background will likely be radiogenic neutrons.



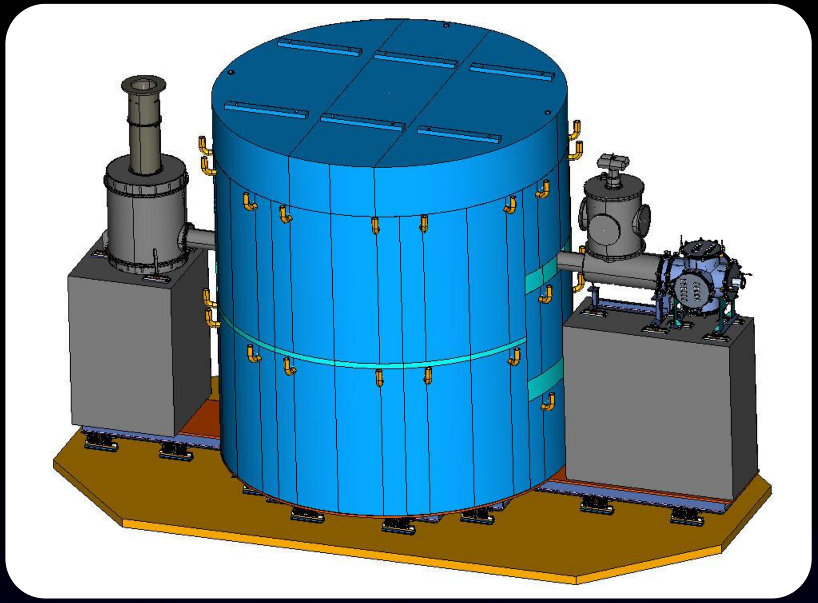
SuperCDMS: SNOLab

100 mm iZIP!

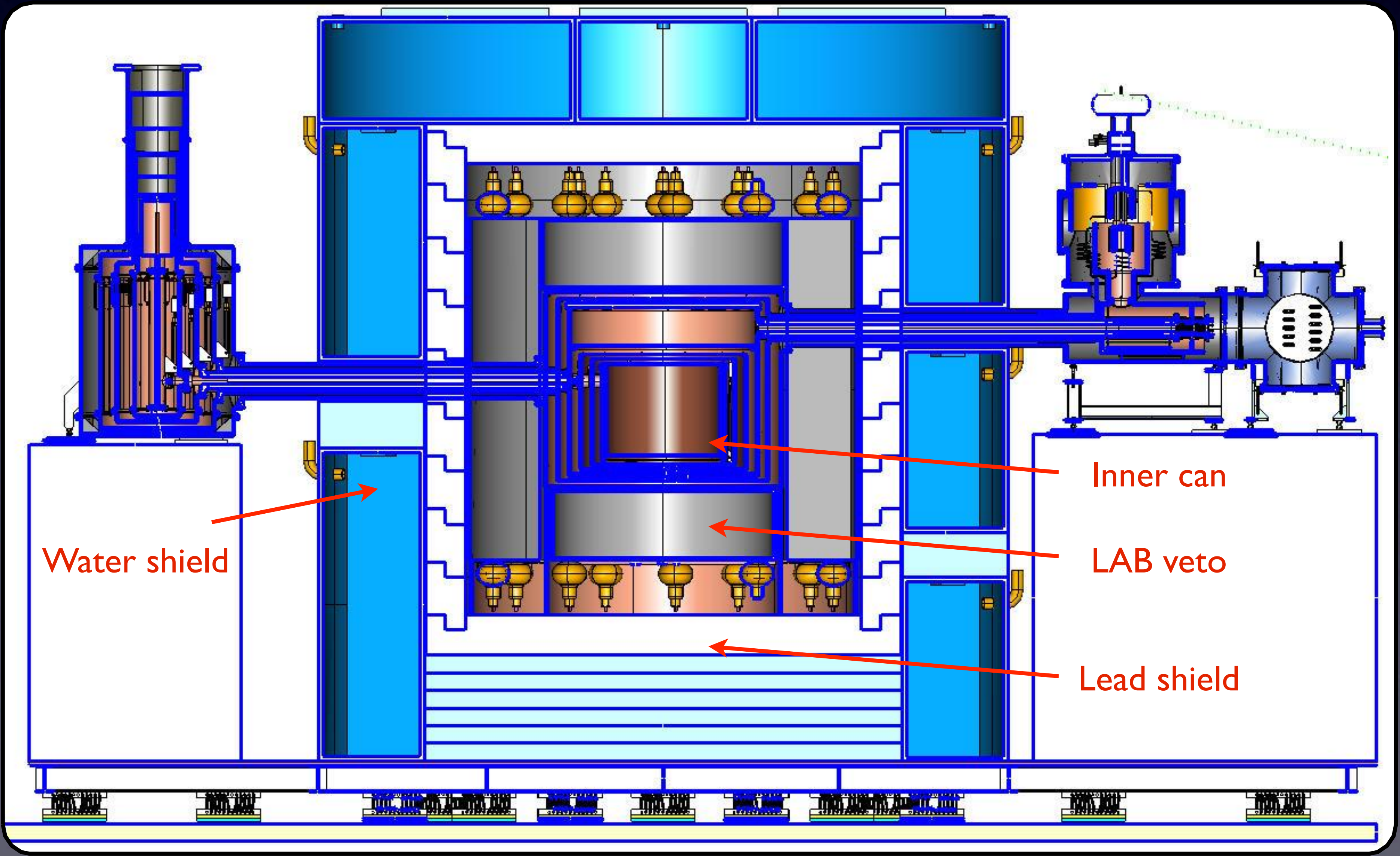


- Neutron veto instead of muon veto.
- Plan is for 200 kg of Ge of 100 mm iZIPs to be deployed in a staged fashion.
- WIMP-nucleon cross-section sensitivity goal of 8 x10^{-47} cm^2 @ 60 GeV/c^2.

SuperCDMS: SNOLab Neutron Veto

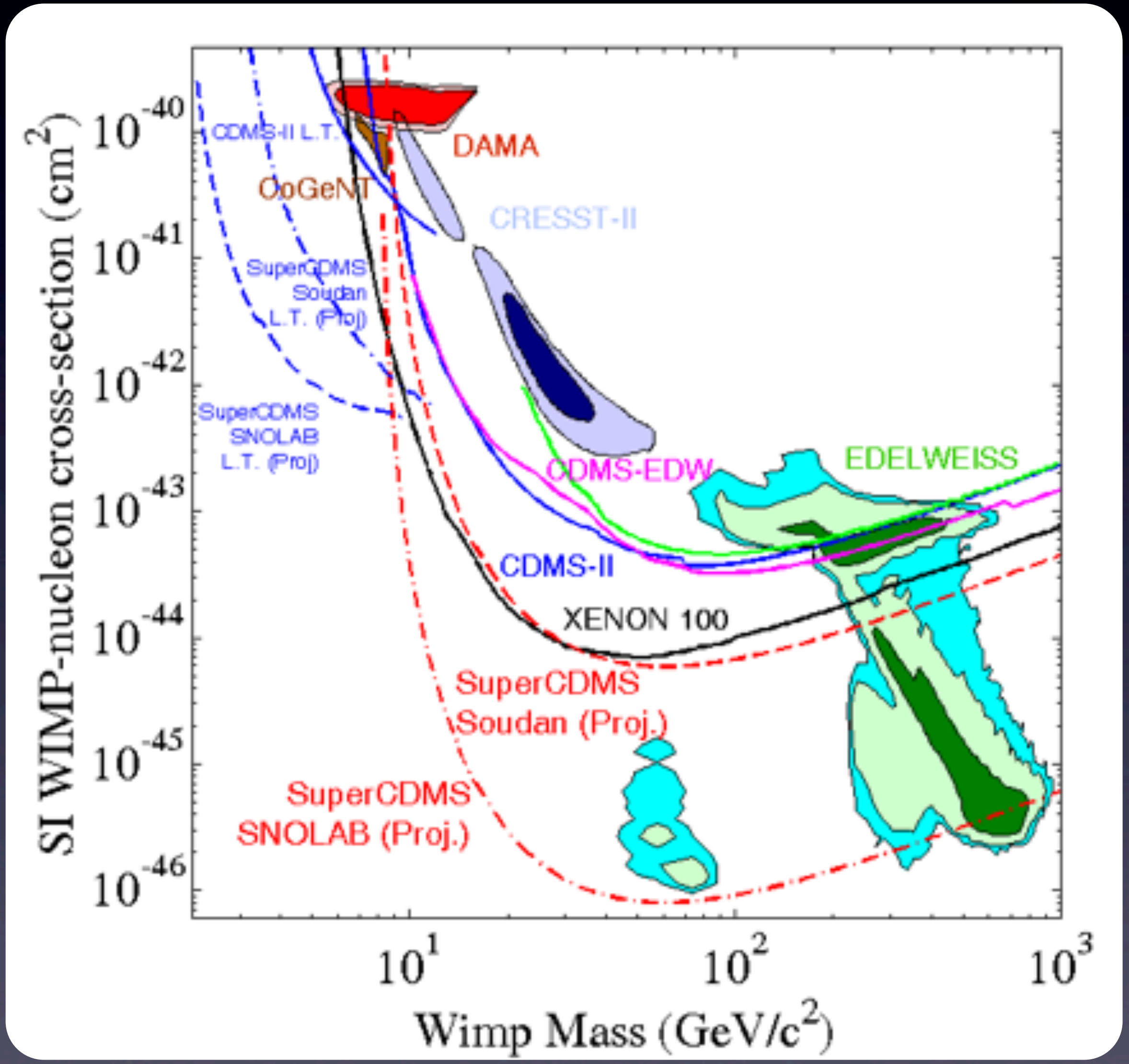


- Muons are no longer a significant source of events.
- Radiogenics provide the largest external source.
- Linear Alkylbenzene (LAB) scintillator doped with boron or gadolinium.
- > 90% neutron rejection efficiency expected.
- Surrounded by Pb and water shielding.



Conclusions

- CDMS II continues to produce many interesting results.
- Several ways to address surface-event backgrounds in cryogenic Ge detectors have been demonstrated:
    - Most importantly the new iZIP design.
    - A new screening regimen for the next generation.
- Moving from Soudan to SNOLAB changes the dominant external event rate from cosmics to radiogenics.
- SuperCDMS: Soudan is in full swing and has been taking physics data since 3/14/2012.
- SuperCDMS:SNOLAB is in the development stages. Proposals submitted to NSF and DOE. G2 experiment.



Thanks!!!