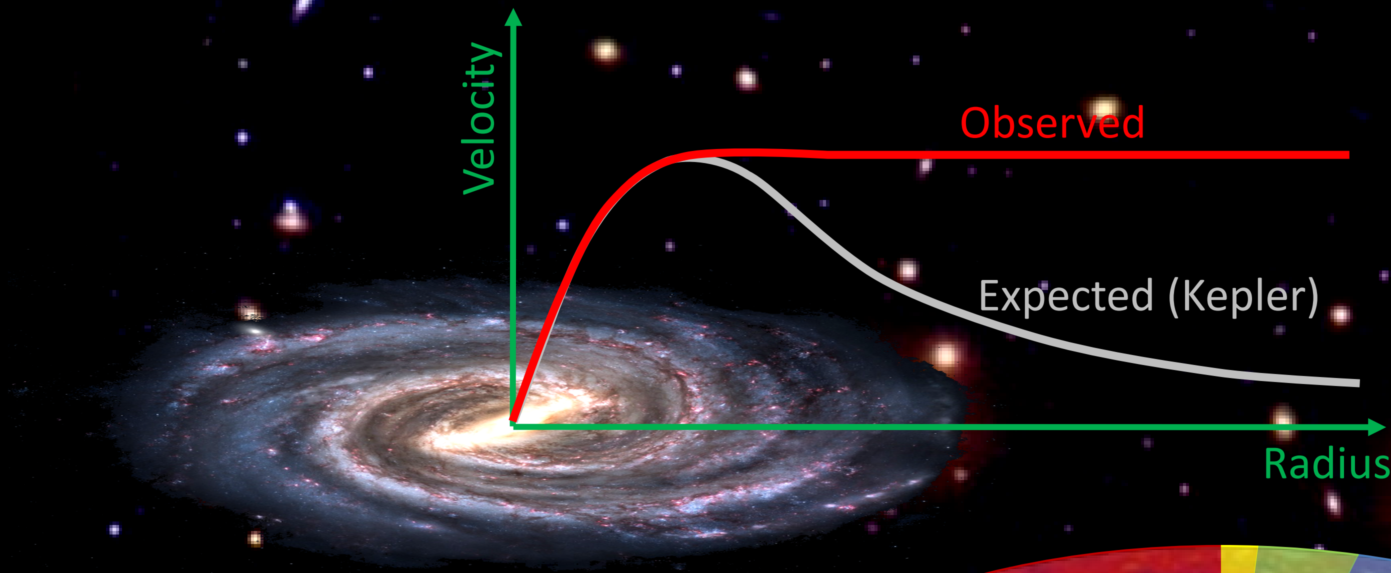
SuperCDMS

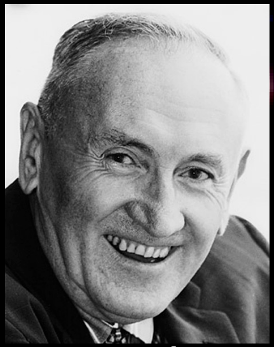
From Soudan to SNOLAB

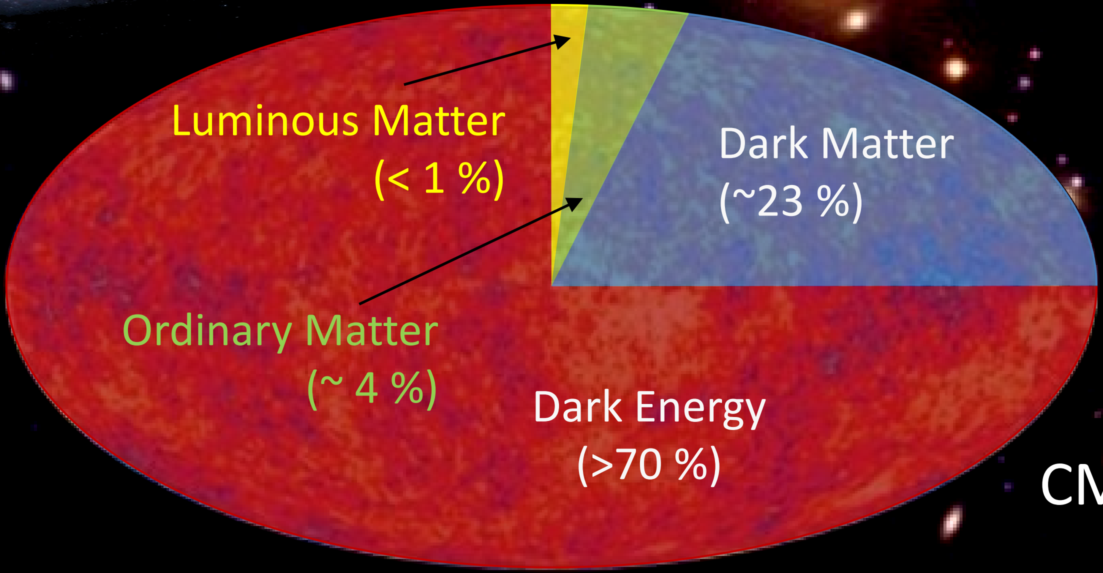
Wolfgang Rau
Queen's University

Dark Matter



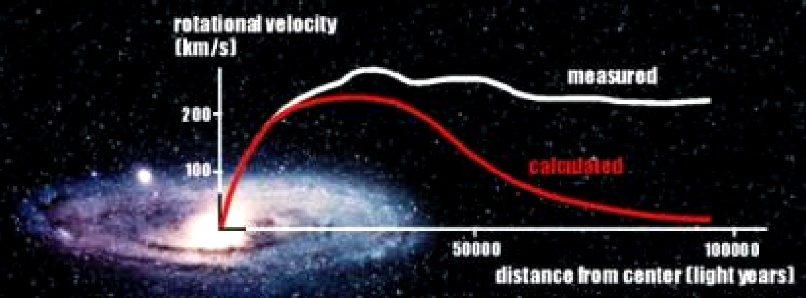

Cooper


Zwicky



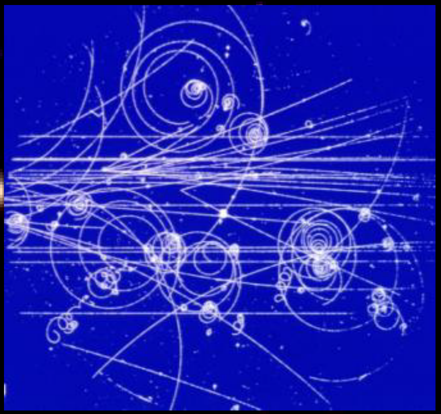
CMB

Dark Matter

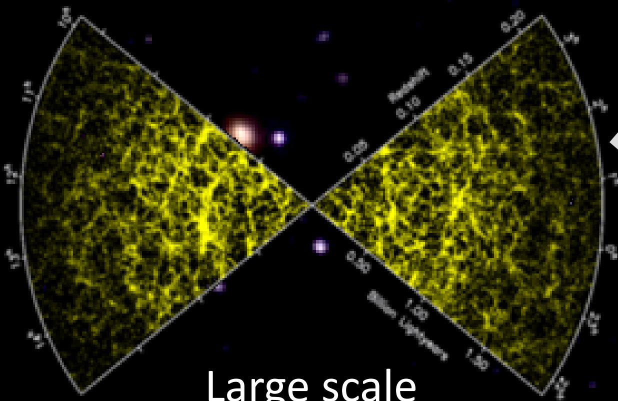


Here, but not yet observed in nature:
Weakly interacting

Not observed in accelerator experiments:
Massive



WIMP
(Weakly Interacting Massive Particle)

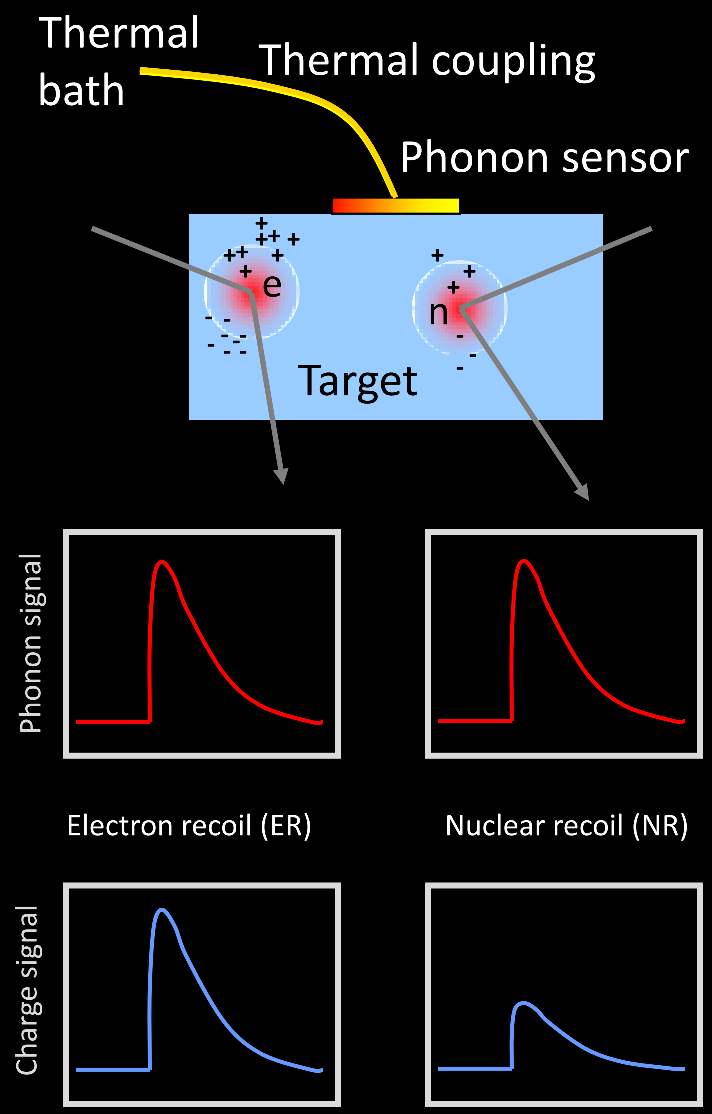


Large scale structure of the Universe:
Slowly moving ('cold')

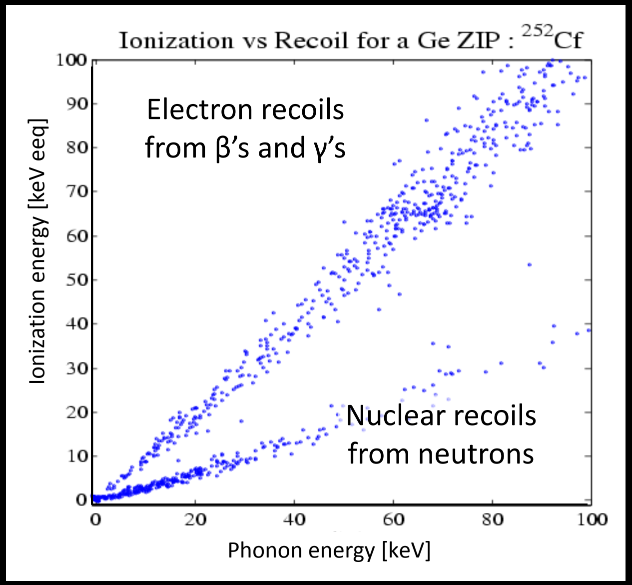
Interaction with ordinary matter:
Nuclear Recoils
(most backgrounds: electron recoils)

Predicted by SUSY:
Neutralino
Universal extra dimensions:
Kaluza-Klein particles

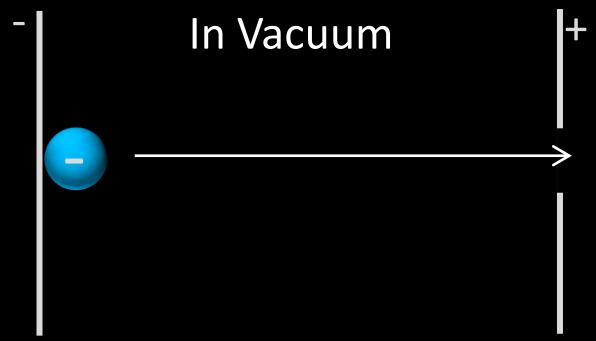
SuperCDMS Technology



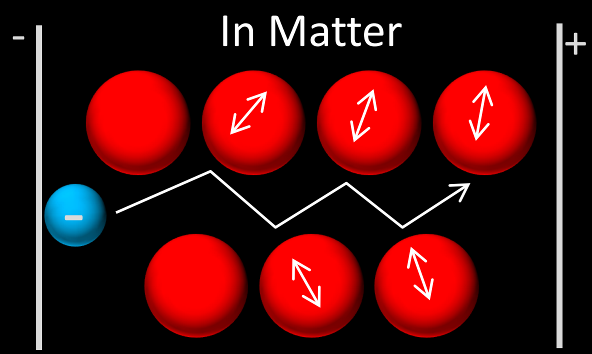
- Phonon signal (single crystal): measures energy deposition
- Ionization signal (semiconductor): quenched for nuclear recoils (lower signal efficiency)
- Combination: efficient rejection of electron recoil background



Neganov-Luke Phonons



Electron gains kinetic energy
(E = q · V → 1 *e*V for 1 V potential)



Deposited energy in crystal lattice:
Neganov-Luke phonons

$\propto$ V, # charges

- Luke phonons mix charge and phonon signal → reduced discrimination
- Apply high voltage → large final phonon signal, measures charge!!
- ER much more amplified than NR
  → gain in threshold; dilute background from ER

CDMS History

1998 - 2002

CDMS @ SUF
6 detectors
1 kg Ge (30 kgd)
$\sigma < 3.5\text{e-}42\ cm^2$

SUF, 10 mwe

2003 - 2009

CDMS II @ Soudan
30 detectors
~4 kg Ge (400 kgd)
$\sigma < 2\text{e-}44\ cm^2$

Soudan, 2000 mwe

2009 - 2014

SuperCDMS @ Soudan
15 (bigger) detectors
~9 kg Ge (~2500 kgd)
$\sigma < 3\text{e-}45\ cm^2$

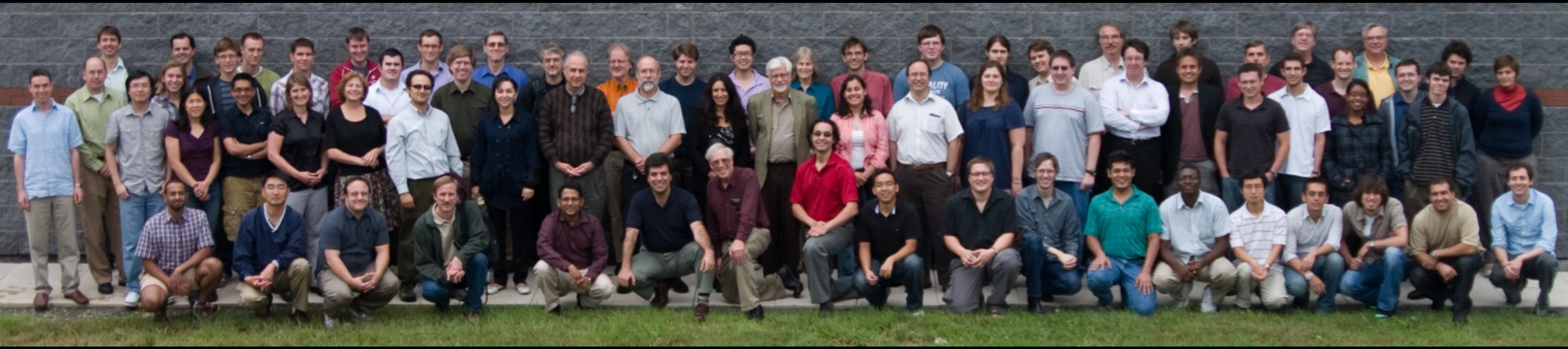
2017?

SuperCDMS @ SNOLAB
$\mathcal{O}$ (100) detectors
~100 kg Ge / ~10 kg Si
$\sigma \approx \text{e-}46\ cm^2$

SNOLAB, 6000 mwe

exposures are after all cuts!

SuperCDMS Collaboration



California Institute of Technology   CNRS/LPN   Fermi National Accelerator Laboratory

Massachusetts Institute of Technology   PNNL   Queen's University

Santa Clara University   SLAC/KIPAC   Southern Methodist University

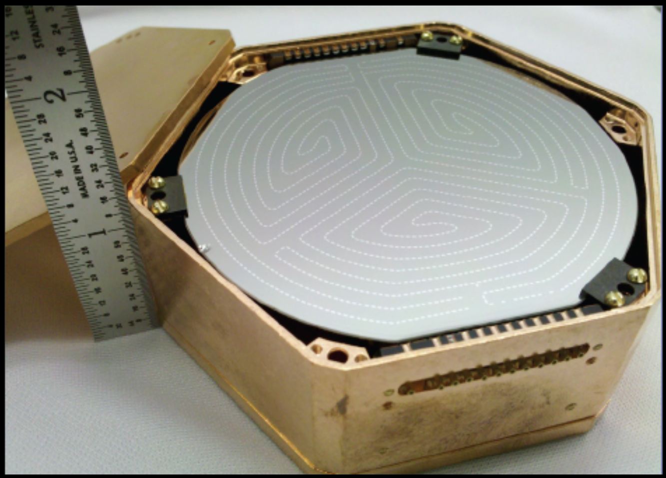
Stanford University   Syracuse University   Texas A&M   Universidad Atónoma de Madrid

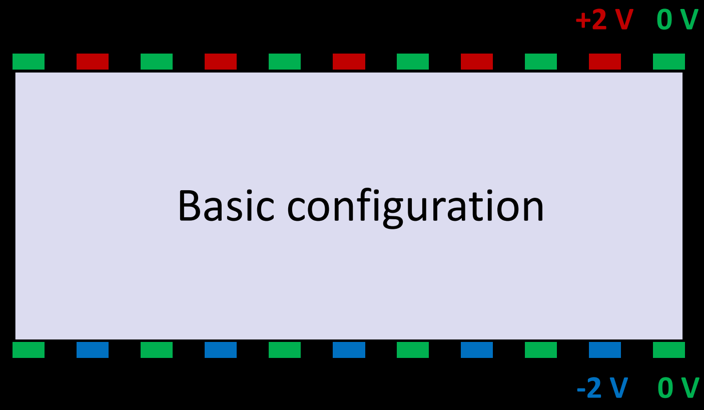
University of British Columbia   University of California, Berkeley

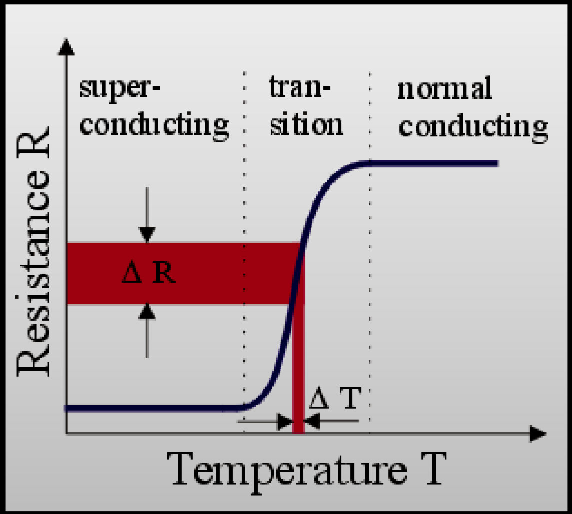
University of Colorado Denver   University of Evansville   University of Florida

University of Minnesota   University of South Dakota

Implementation

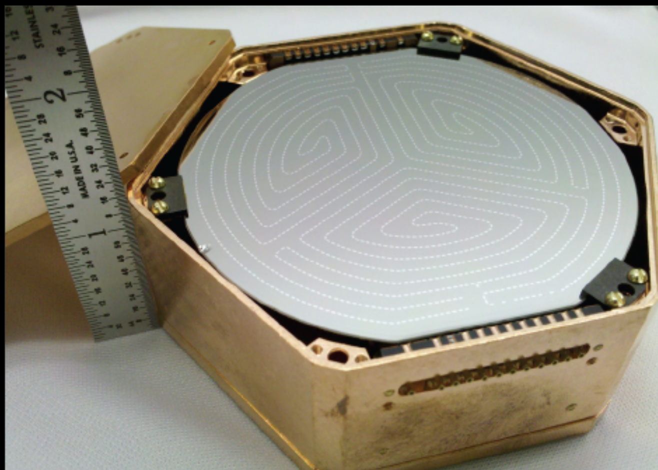


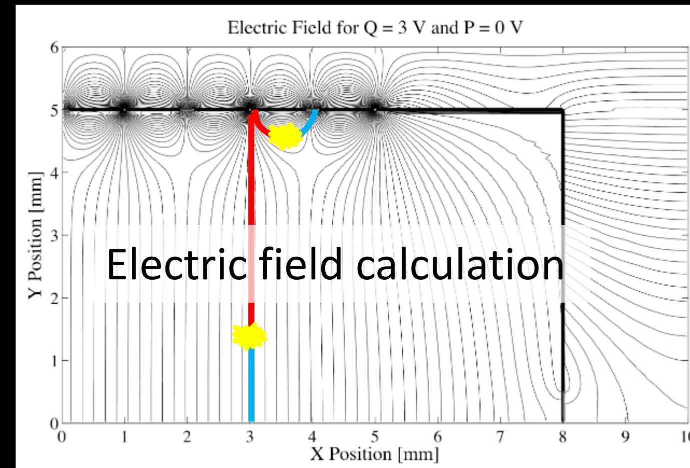


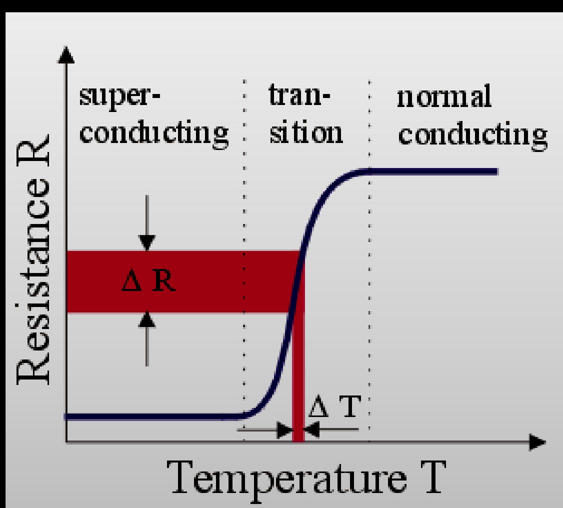


- Germanium single crystals (620 g modules)
- Thermal readout: superconducting phase transition sensor (TES); T_c = 50 – 100 mK
- Charge readout: Al electrode; interleaved with phonon sensors
- Low bias voltage (4 V) in regular operation

Implementation







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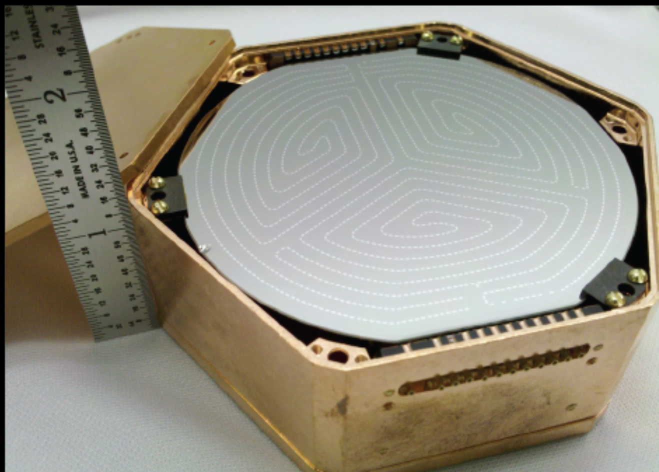

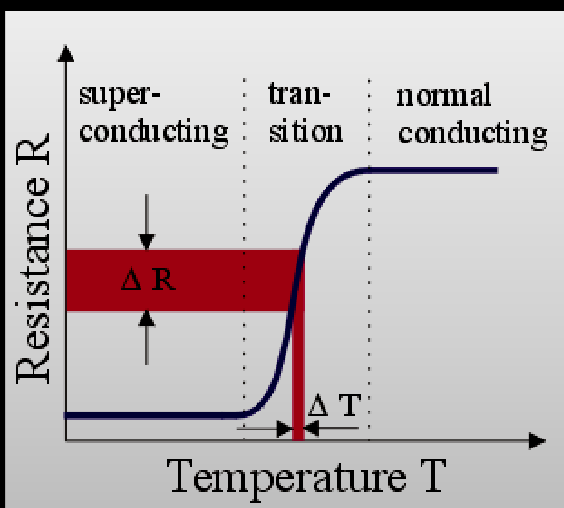

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- Thermal readout: superconducting phase transition sensor (TES); T_c = 50 – 100 mK
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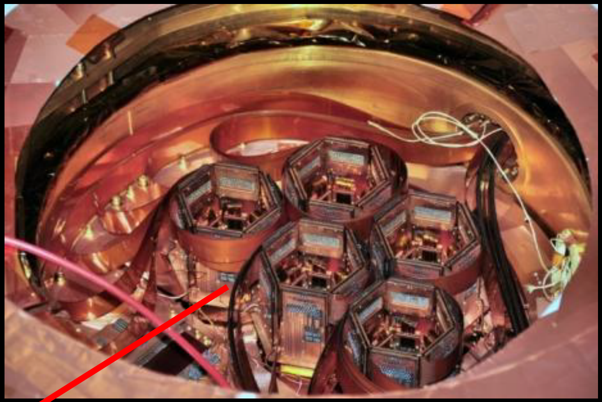
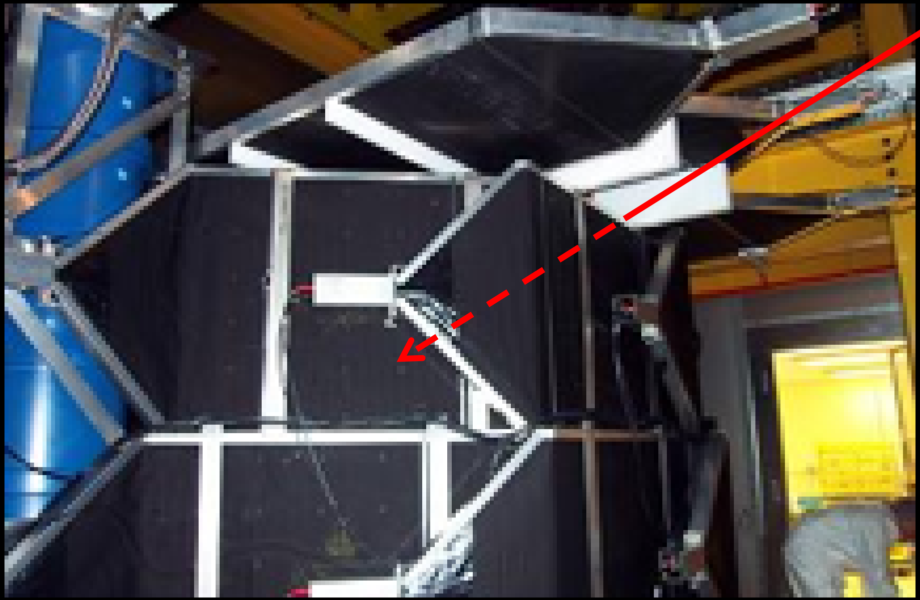
One detector: ~70 V for some time

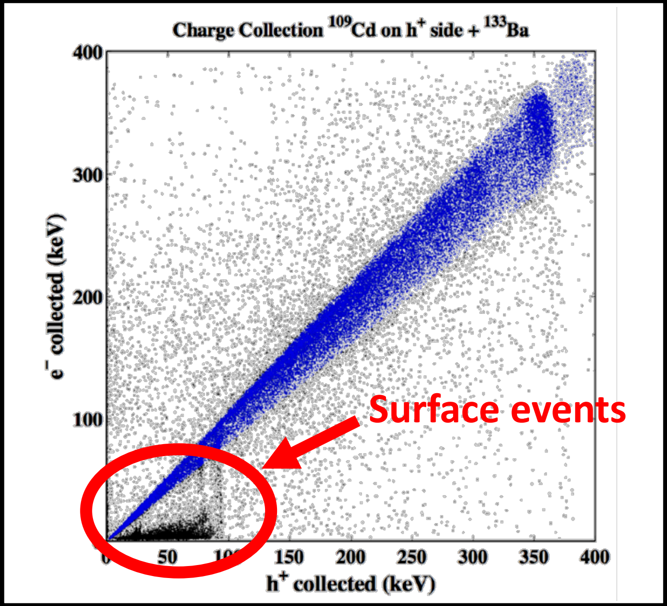
Implementation (CDMS setup)

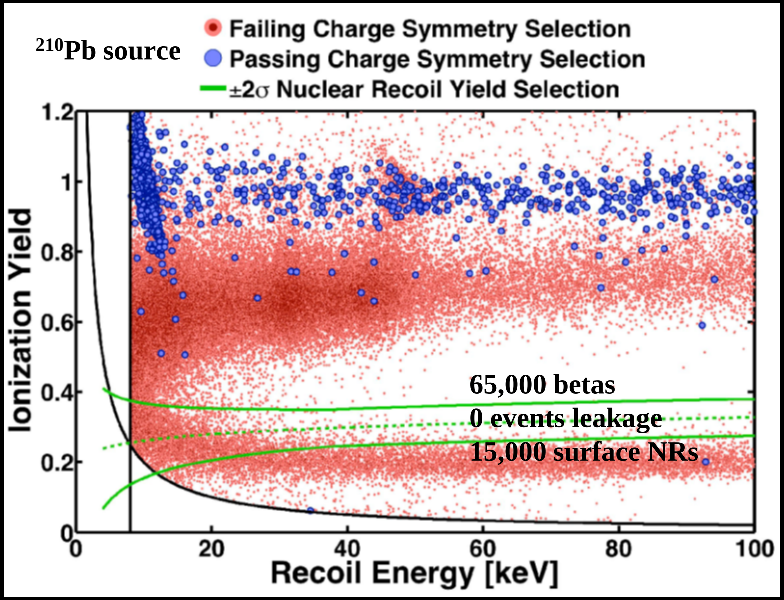
- Stack detectors (3) to mount ("tower")
- 5 towers deployed in cryostat (~9 kg Ge)
- Shielded with polyethylene (for neutrons), Pb (gammas) and muon veto (cosmic radiation)
- Located at Soudan Underground Lab (Minnesota) to shield from cosmic radiation

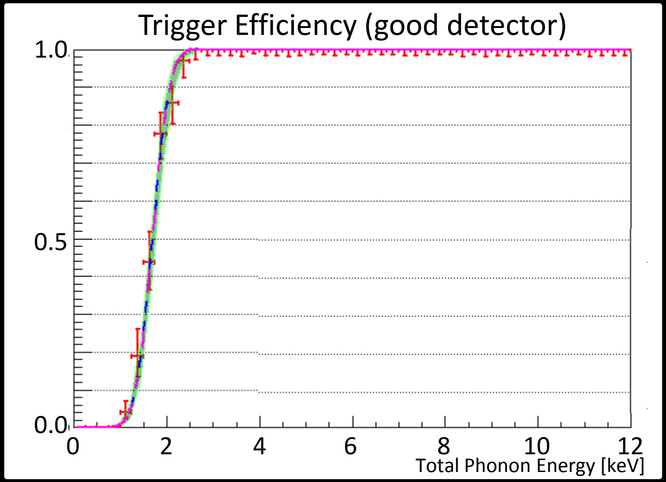


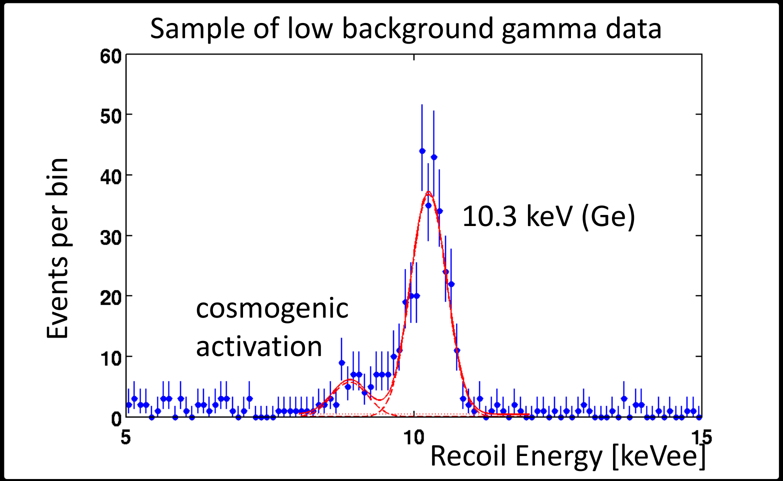


Detector Performance

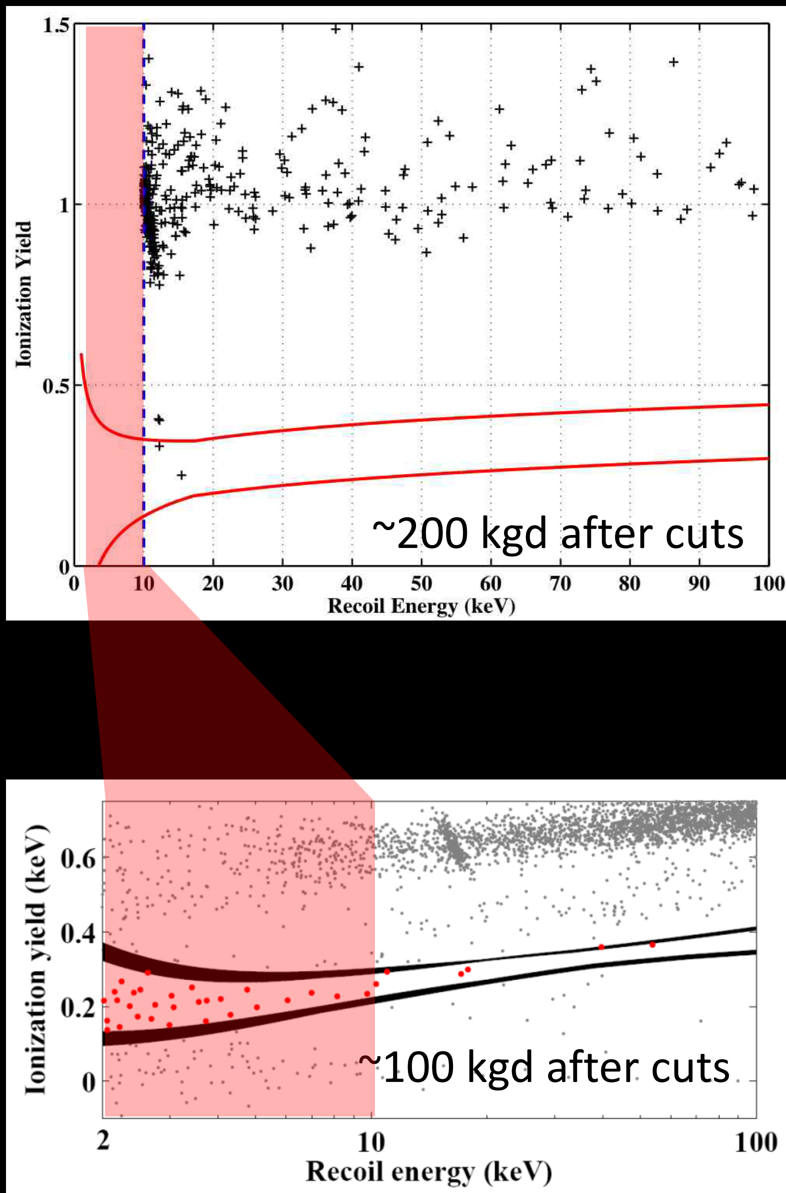




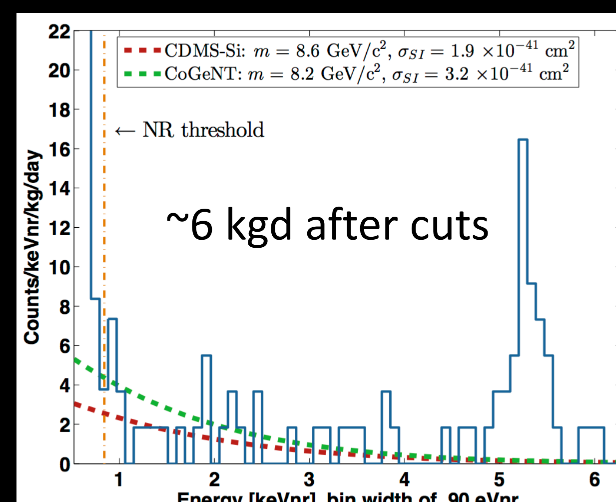




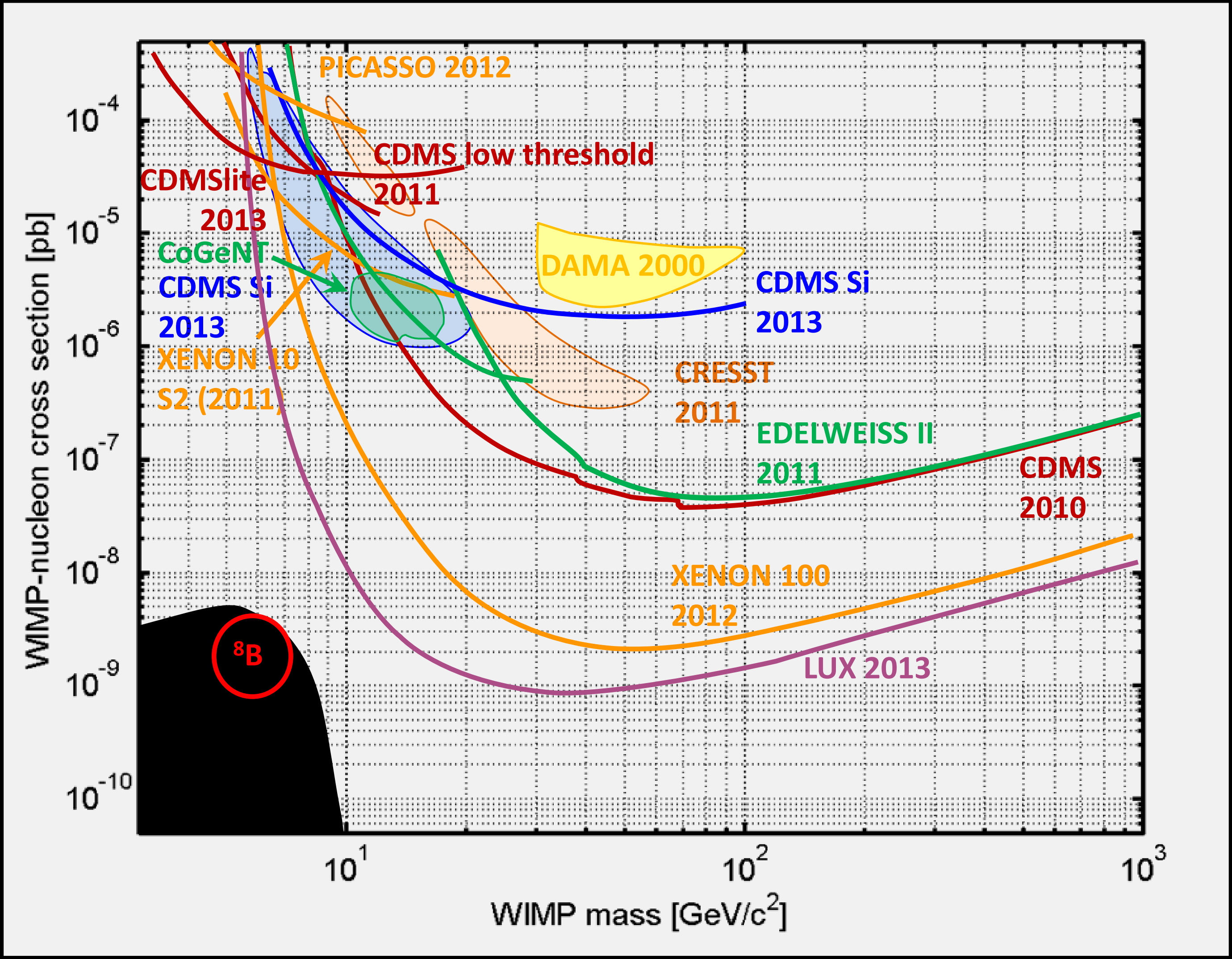
Past Analysis Approaches



- "Classic" CDMS approach: minimize expected BG (<1 for data set under analysis) → threshold ~10 keV (E_{recoil}: use Q signal for Luke correction)
- Low-threshold extension: strongly rising WIMP spectrum at low E → improved sensitivity in spite of BG (no surface event discrimination; E_{NR}: Luke correction based on mean yield)
- CMDSlite: no discrimination, but even lower threshold; BG diluted (E_{NR}: based on Lindhard model)



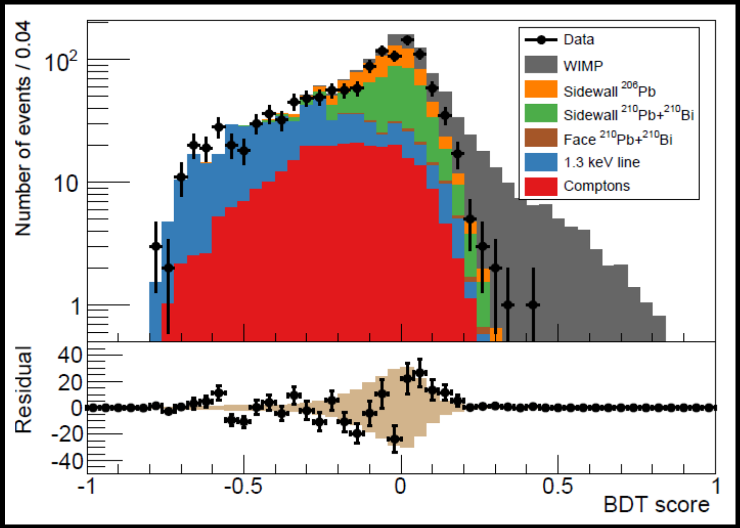
Results – before 2014



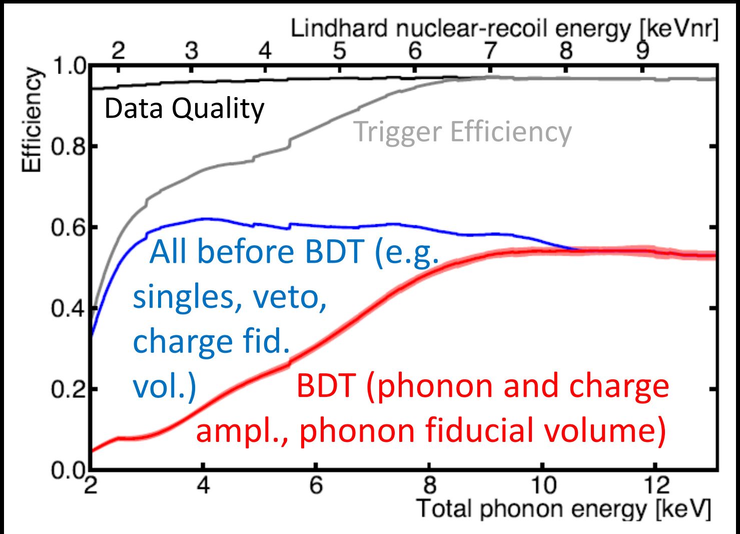
SuperCDMS Soudan – Latest Data

Low-threshold method, but now with:

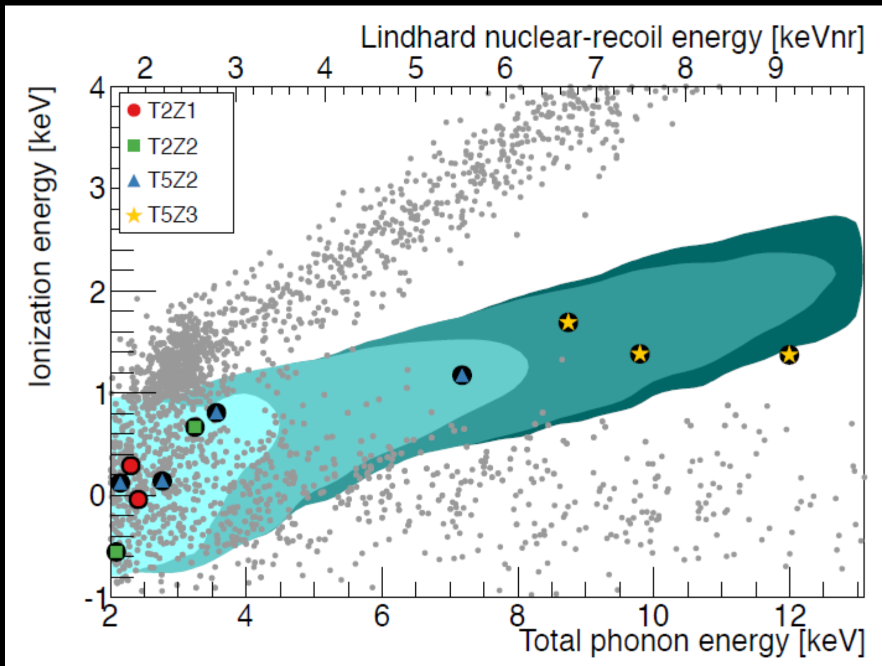
- Surface event rejection with charge signal (interleaved electrodes) AND phonon signal (sensors on top and bottom!)
- Edge event rejection with charge signal (was available in CDMS) AND phonon signal (new sensor layout)
- New Analysis method for improved efficiency (Boosted Decision Tree)



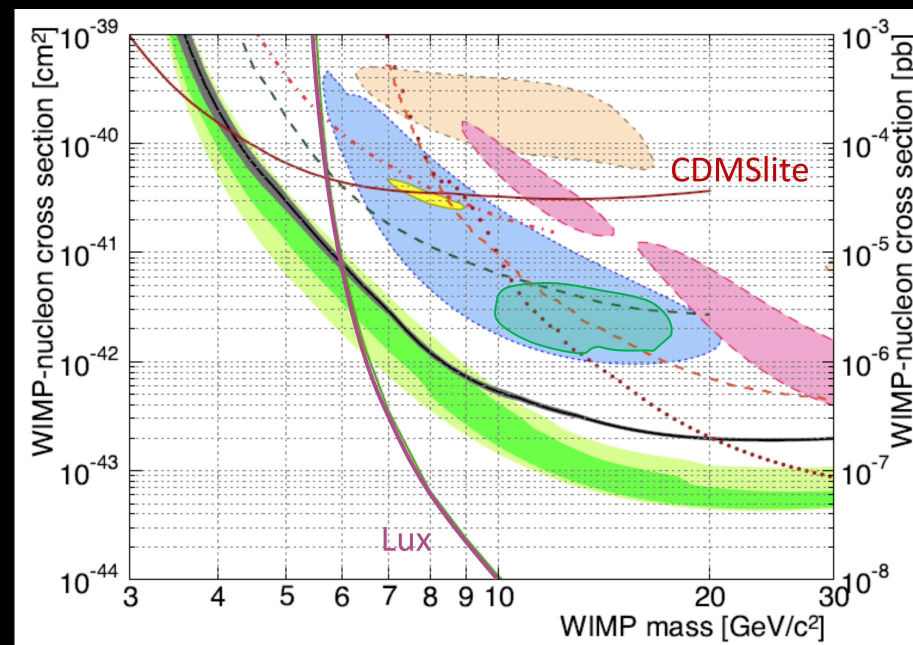
- Background Model to train BDT (cosmogenics, ^{210}Pb chain): MC to get distributions; use scaled pulses + real noise to generate `events' (gammas for BG, neutrons for signal)
- Optimize tree for different WIMP masses (5, 7, 10, 15 GeV/c^2)
- BG model only for BDT training; efficiency measured with neutrons



SuperCDMS Soudan – Results and Future



- BG model predicts ~6 events – BUT: difficult to make good prediction in this low energy range → only set upper limit
- "Open box": observed 11 events
- 3 highest energy events in detector with shorted outer charge channel

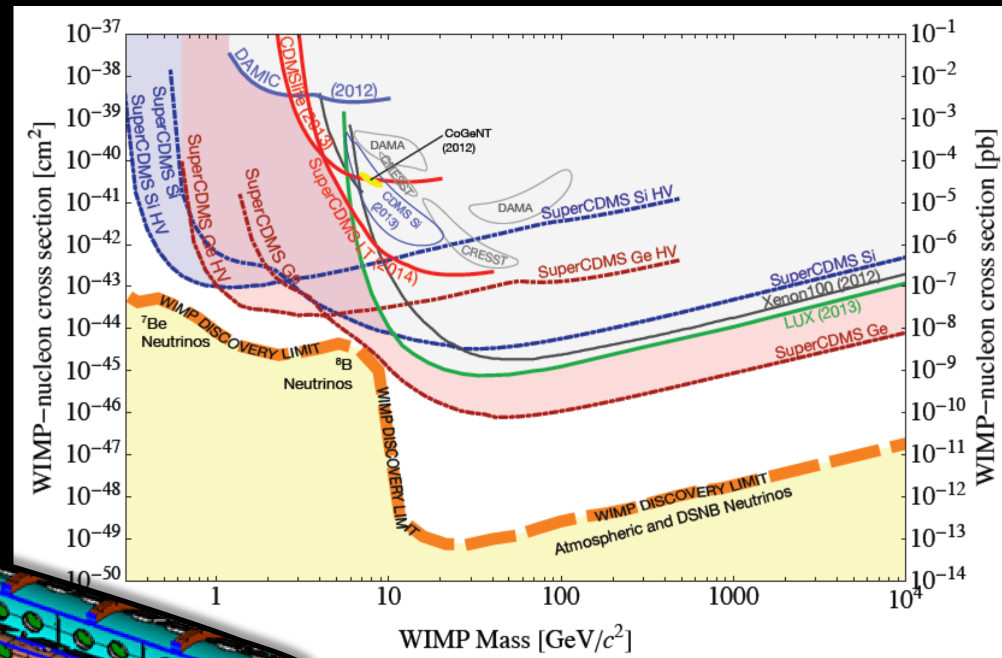


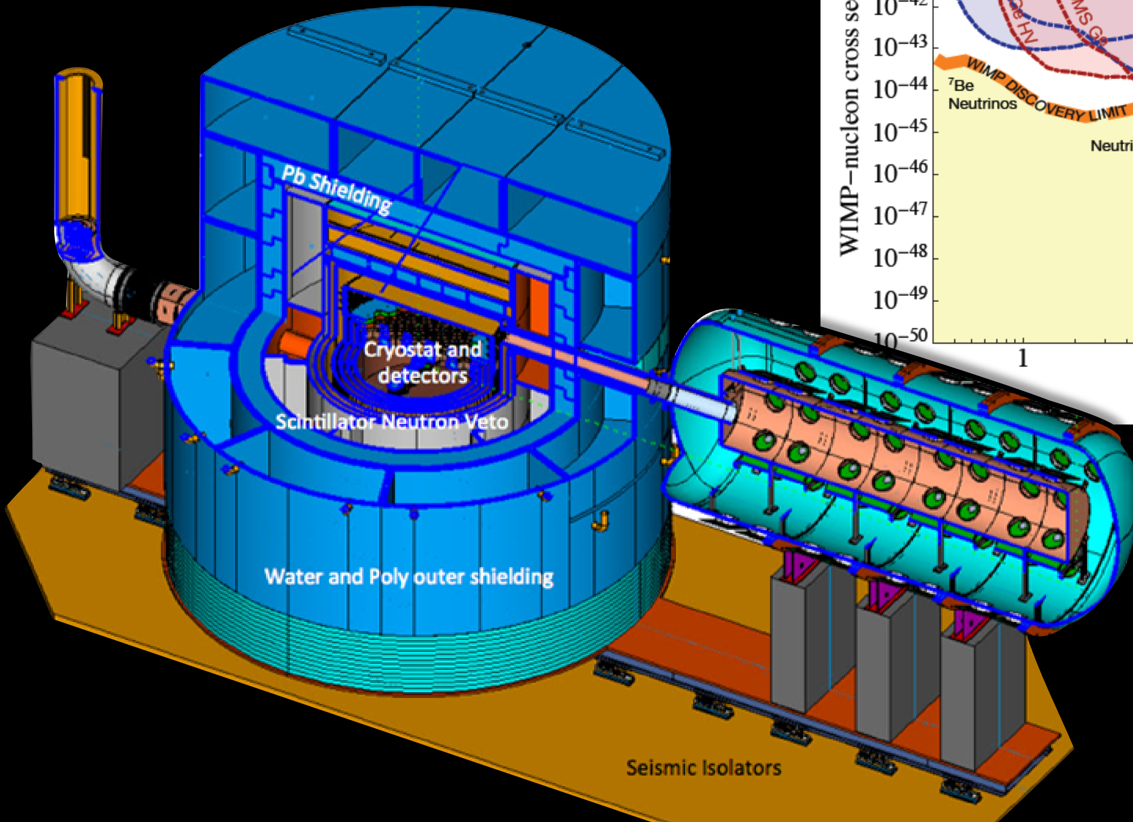
- Probe new parameter space between 4 and 6 GeV/c^2
- Incompatible with CoGeNT interpretation as NR signal from WIMPs

- Standard (high threshold) analysis in progress / additional CDMSlite data collected
- DM search until fall (expect to be limited by cosmogenic/radiogenic BG by then)
- Systematic studies until spring 2015

SuperCDMS at SNOLAB

- ~100 kg Ge / ~10 kg Si
- 1 tower of dedicated HV detectors





- Setup for ~400 kg detector mass for later upgrade
- EURECA indicated interest in contributing additional target mass
- Shielding includes neutron veto (scintillator)

- Timing: start construction in early 2015; takes ~2 years to build
- Funding: $3.4M from CFI / waiting for G2 decision in the US (expected anytime now)