Dan Bauer
DOE review
May 18, 2006

CDMS - Direct Detection of Dark Matter

CDMS Collaboration at Soudan

CDMS Institutions

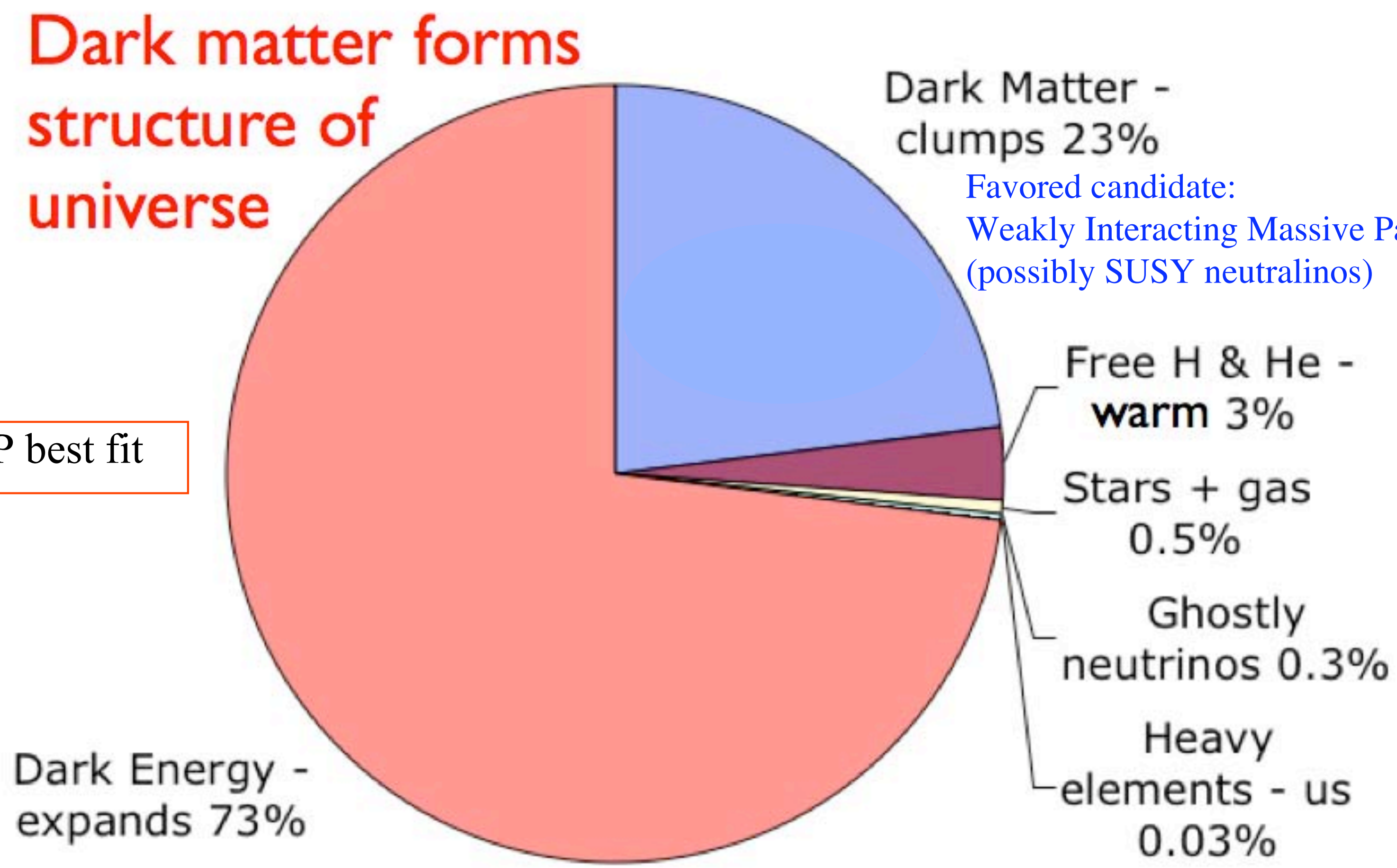
DOE Laboratory
Fermilab
LBNL

DOE University
Brown
Minnesota
Stanford
UC Santa Barbara

NSF
Case Western Reserve
Colorado (Denver)
Santa Clara
UC Berkeley

Other
Caltech
Florida

Composition of the Cosmos



Favored candidate:
Weakly Interacting Massive Particles
(possibly SUSY neutralinos)

WMAP best fit

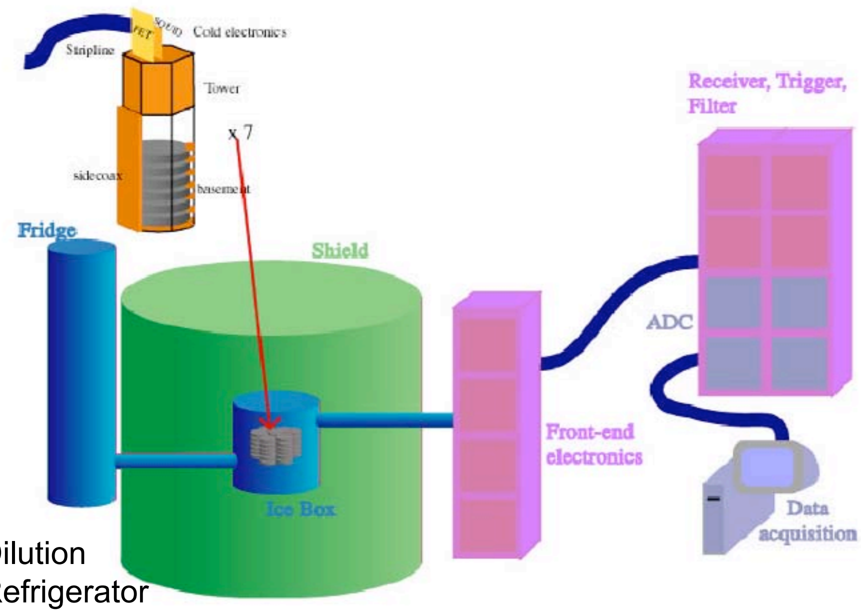
CDMS in a nutshell

Dark Matter Search
- Direct detection of WIMPs

Cryogenic
- Ge and Si detectors, < 50 mK

Active Background Rejection
- Distinguish between nuclear recoils (WIMPS, neutrons) and electron recoils (backgrounds)
- Reject neutrons using
  - multiple scattering
    - Neutrons do, WIMPS don't
  - comparison of Ge to Si rates
    - Neutron cross sections similar, but WIMP cross sections x5 higher in Ge
  - depth
    - Neutrons mainly from cosmic ray interactions

Detector Tower



Dilution Refrigerator

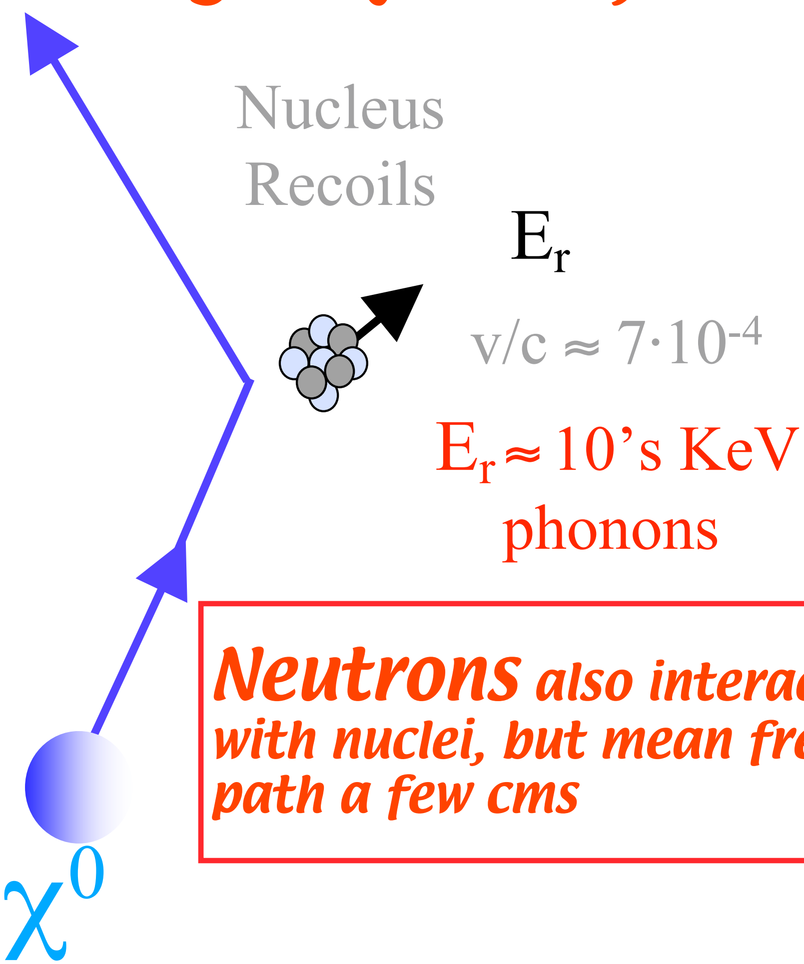
Shield/Muon Veto

Electronics and Data Acquisition

Shielding
- Layered shielding (Pb, polyethylene, Cu) against radioactive backgrounds and active scintillator veto (>99.9% efficient against cosmic rays).

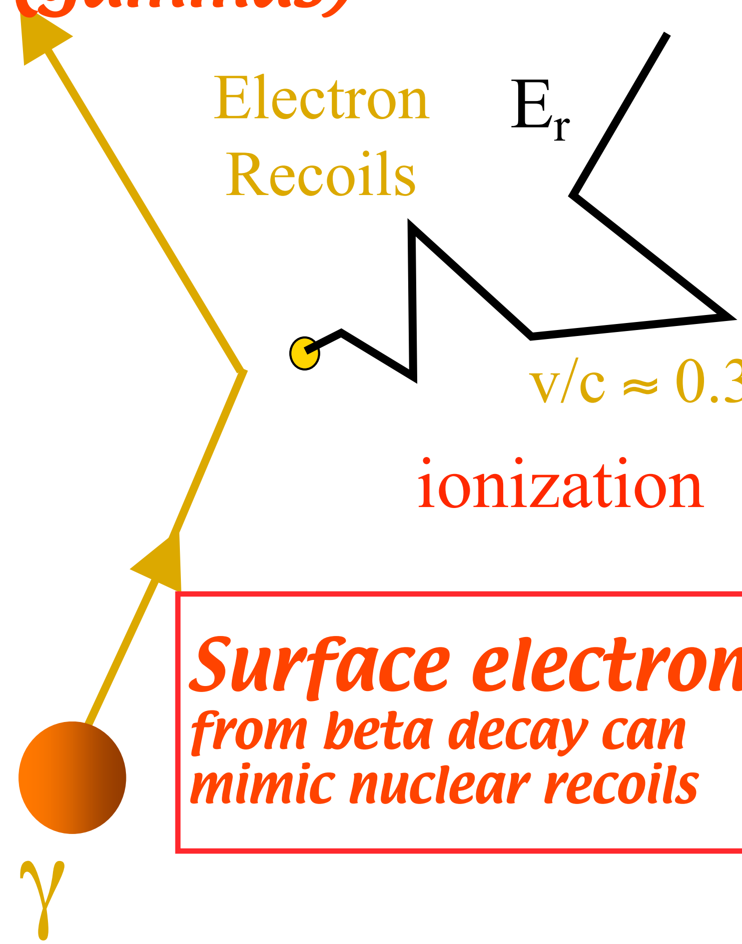
The Signal and Backgrounds

Signal (WIMPs)



***Neutrons** also interact with nuclei, but mean free path a few cms*

Background (gammas)

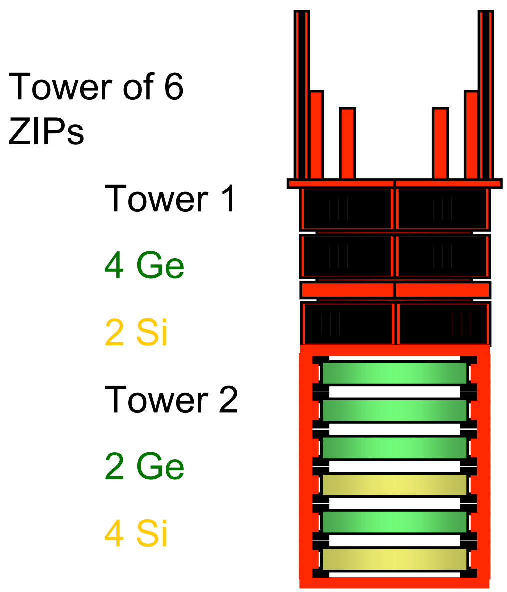


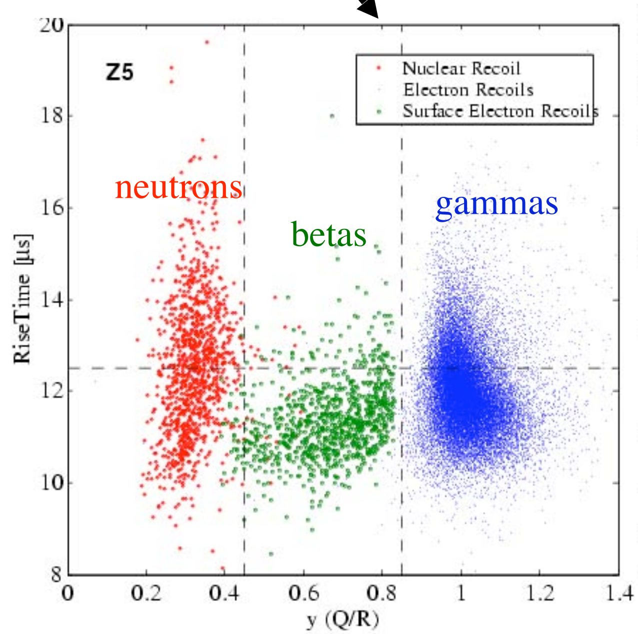
***Surface electrons** from beta decay can mimic nuclear recoils*

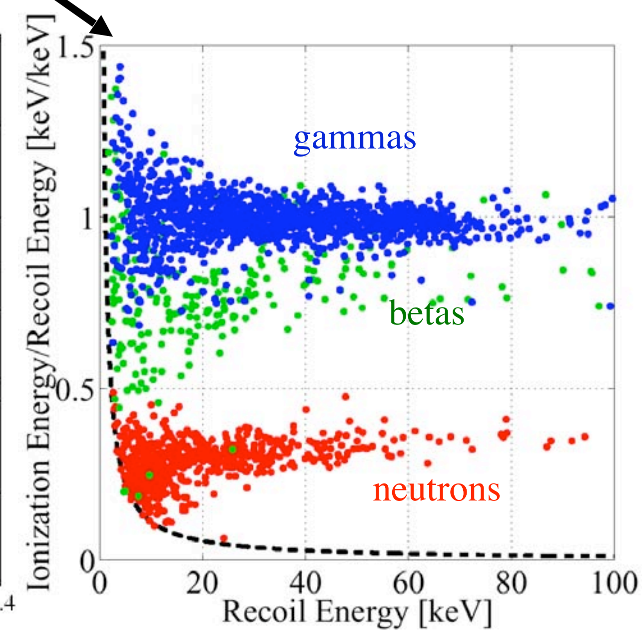
CDMS Active Background Rejection

Detectors with excellent event-by-event background rejection

Measured background rejection:
99.995% for EM backgrounds using charge/heat
99.4% for β's using pulse risetime as well
Much better than expected in CDMS II proposal!







Advantages of CDMS approach to direct detection

We are taking data at a deep site!

- Edelweiss, CRESST are rebuilding (larger mass, better shielding)
- Xenon, bubble chamber are promising technologies, but in R&D stage

We have very low energy thresholds (< 10 keV recoil)

- Due to large phonon signal (10^6 phon/keV)
- Big advantage with respect to Xenon (~1 pe/keV)

We have a lot of information about candidate events

- Ionization yield (ratio of charge to phonon signal)
- Timing (discrimination against surface events)
- Segmented charge electrode (fiducial cut against outer regions of crystal)
- Position resolution (mostly from phonon signals)
- Multiple detectors (multiple scattered events = neutrons)
- Si vs Ge (neutrons or WIMPs)

In a discovery, we will have many checks that events are WIMPs

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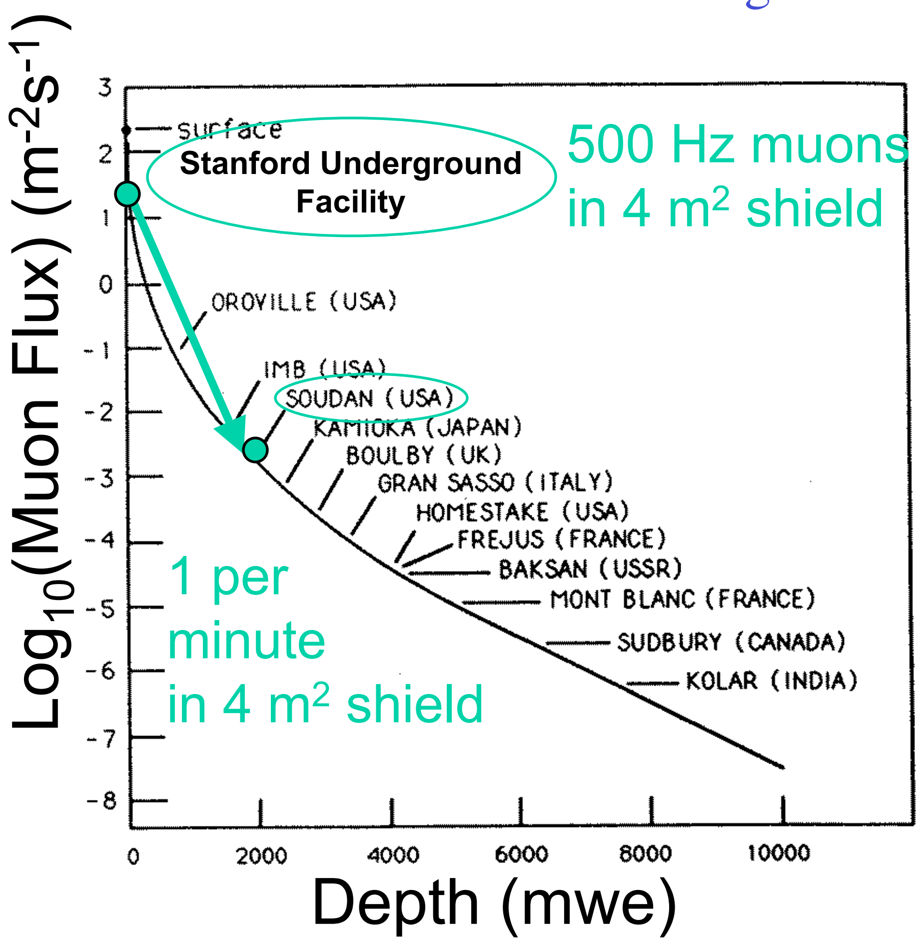
Why are we at Soudan?

Depth of 2000 mwe reduces cosmic-ray-induced neutron background to ~1 / kg / year at Soudan => sensitivity to < 10 WIMPs/year

Eventually we will need to go deeper yet

Construction of CDMS II begin 1999; operations began in 2003



First detectors arriving: winter 2003

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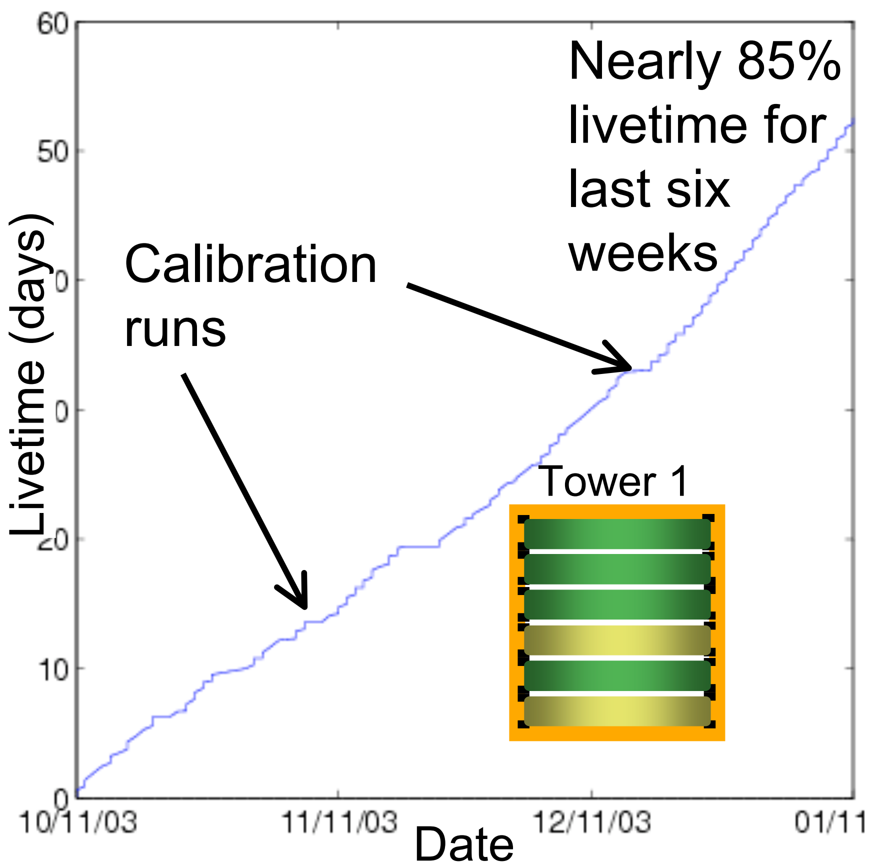
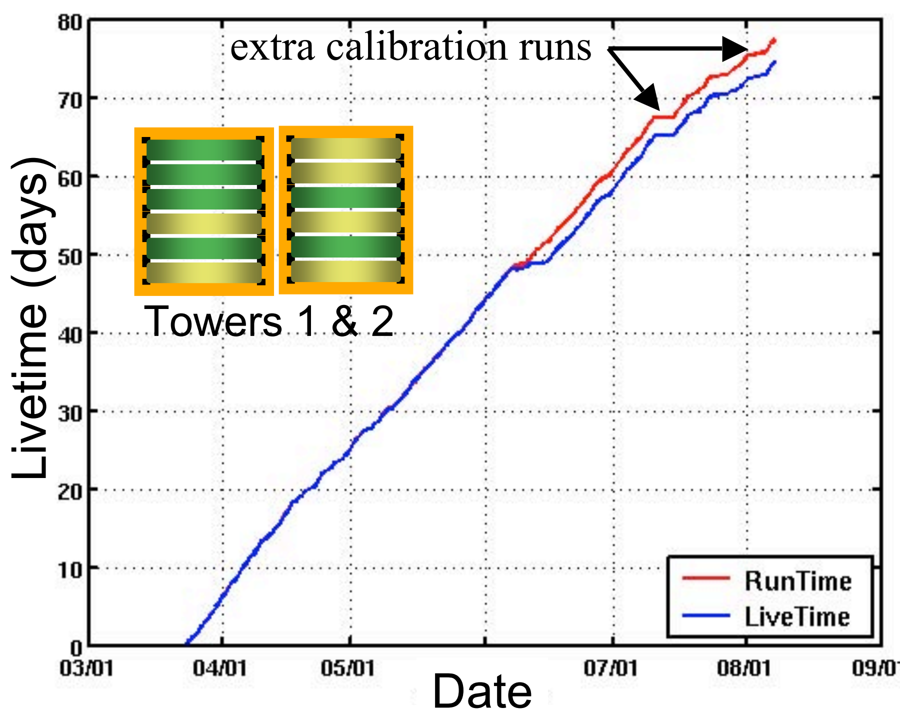
Full Year of Running CDMS II at Soudan

- October 2003- January 2004 “Tower 1”
  - 1 kg of Ge, 0.2 kg of Si
  - 62 “raw” livedays, 53 livedays after cutting times of poor noise, etc.

- March-August 2004 “The Two Towers”
  - 1.5 kg of Ge, 0.6 kg of Si
  - 76 “raw” livedays, 74 livedays
  - Nearly doubled exposure, expected sensitivity, and calibration data

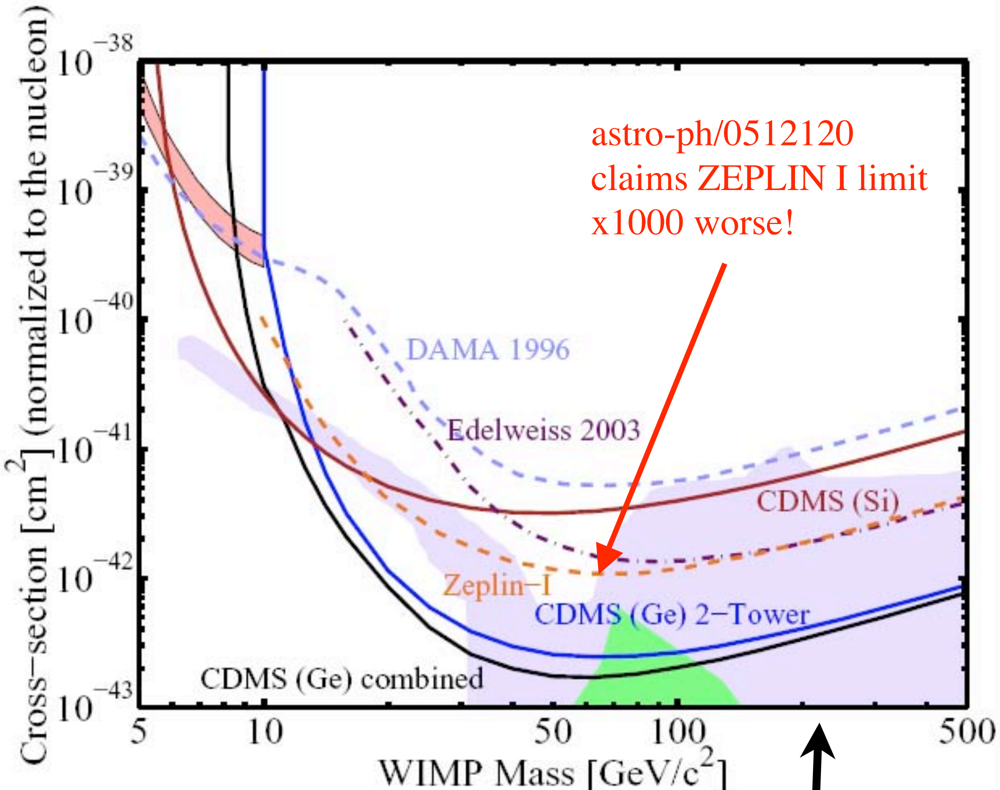


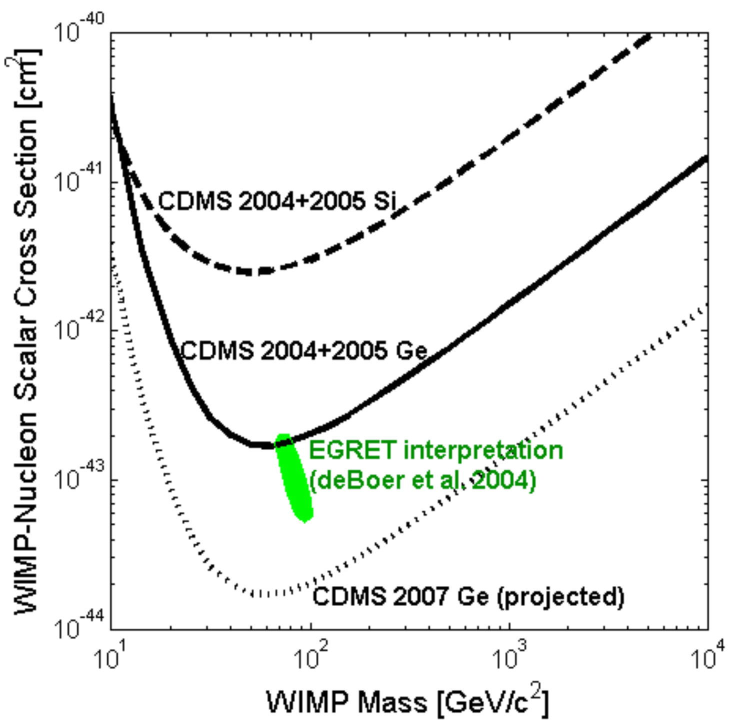


CDMS-II Results for Spin-Independent Interactions

Experimental Motivations

DAMA/NaI
Bernabei et al.,
astro-ph/0307403
(claim DM signal)





EGRET
de Boer et al., astro-ph/0412620

- Interpret EGRET gamma ray excess as DM annihilation

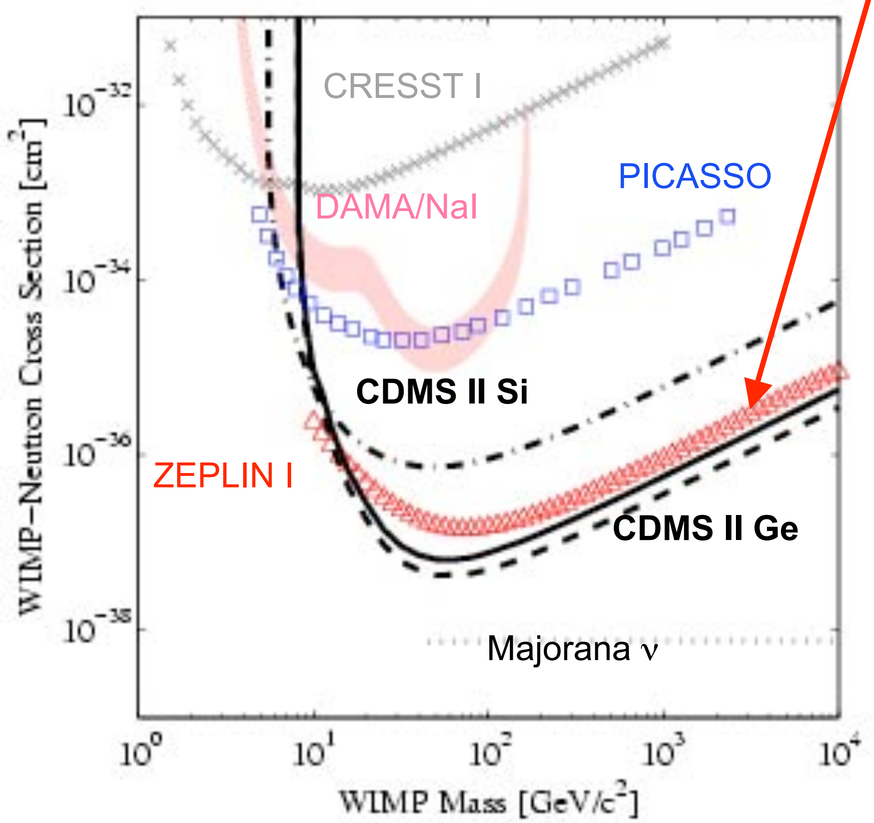
For further details see PRL 96, 011302 (2006)

Spin Dependent WIMP limits

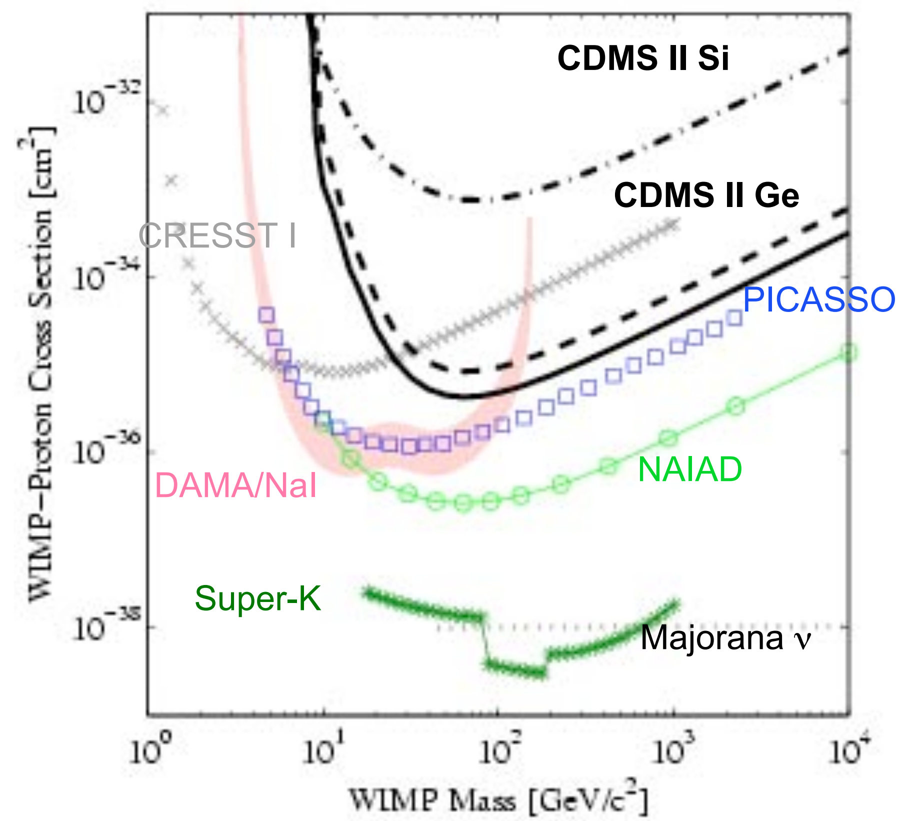
Spin-sensitivity from ^{73}**Ge** (J=9/2, 7.7%) and ^{29}**Si** (J=1/2, 4.7%)

astro-ph/0512120
claims ZEPLIN I limit
x1000 worse!

"n" scattering



"p" scattering



For further details see PRD D73, 011102 (2006)

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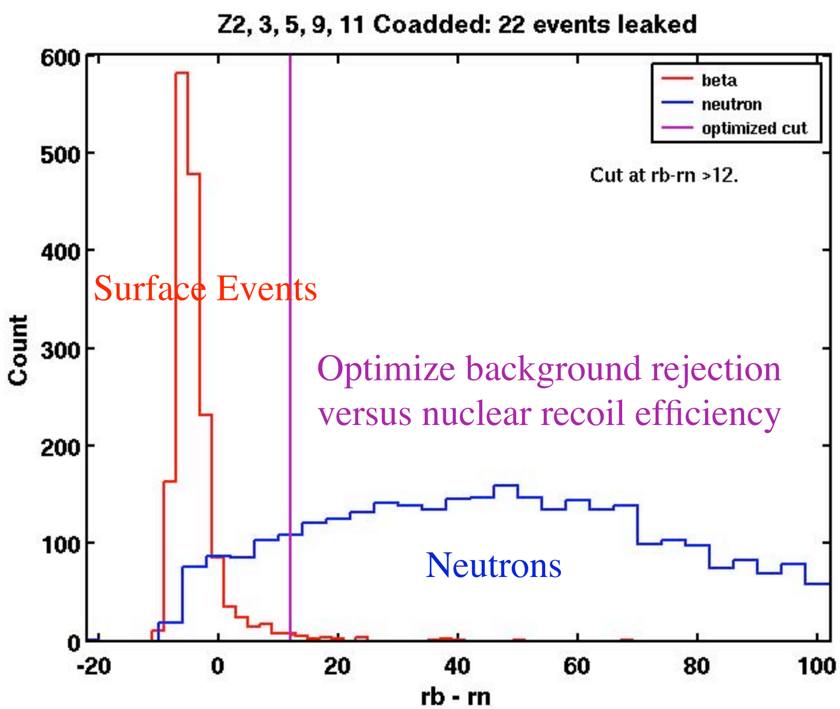
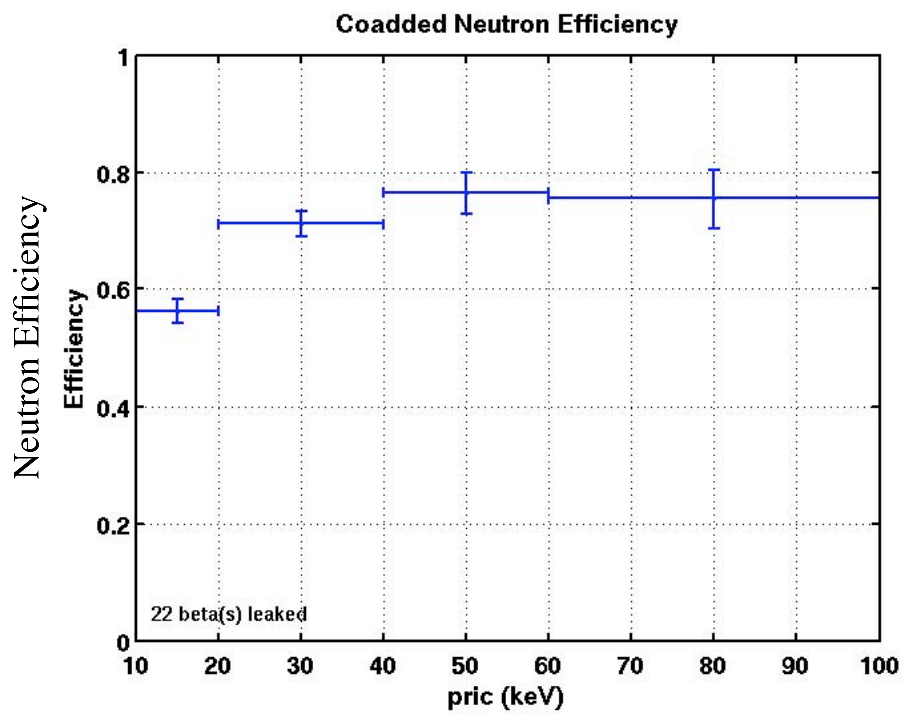
Improvements in Surface Event Rejection

- Continuing improvements in our analysis of phonon timing information
  - Surface event rejection improved by x3; keeping pace with exposure increase!
  - Cuts are set from calibration data (blind analysis)
- We still have more discrimination power available as needed
  - Can continue to keep backgrounds < 1 event as more data accumulates
  - This is the real strength of CDMS detectors!

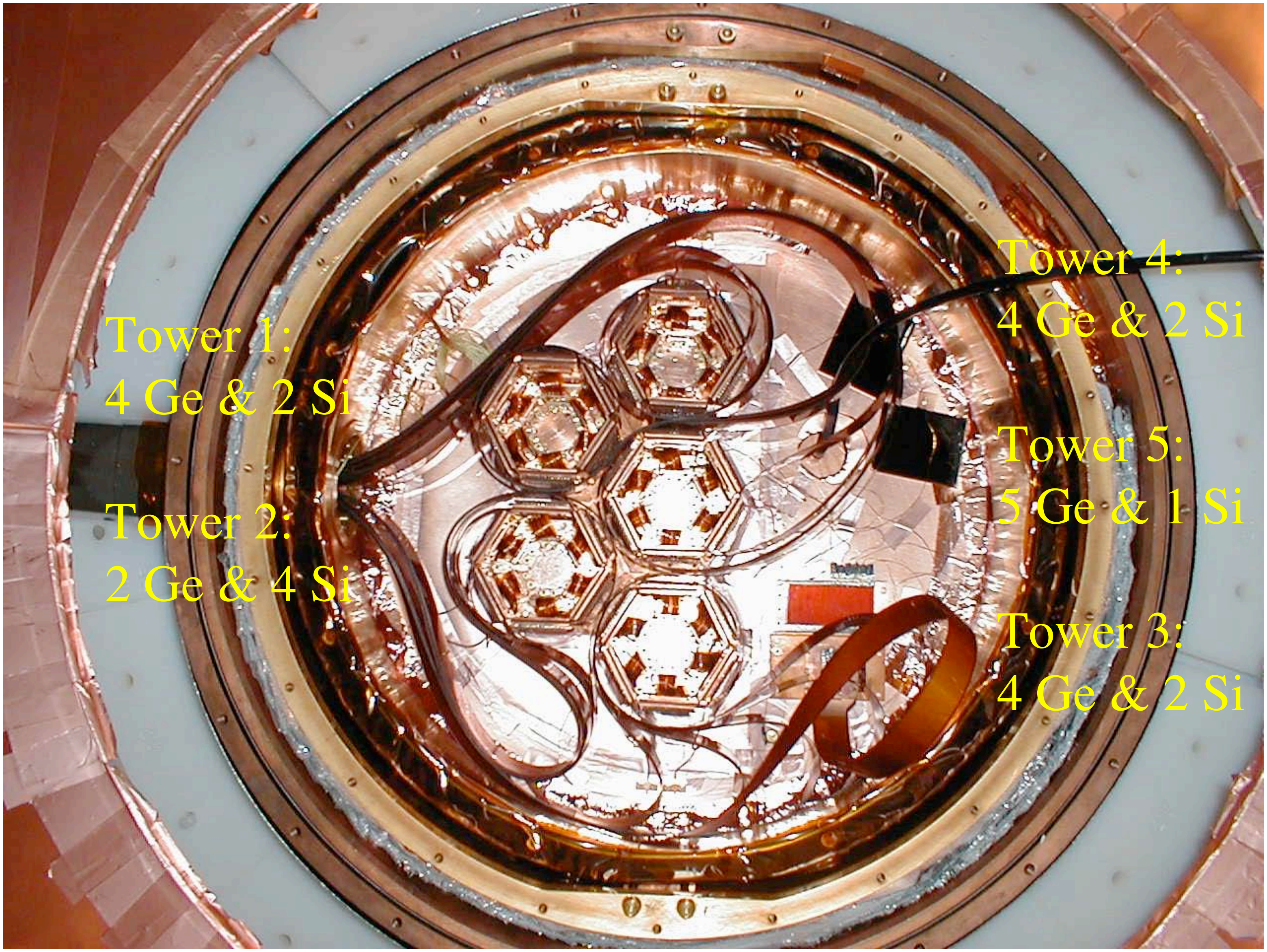


Chi-square (background pulse shape) - Chi-squared (neutron pulse shape)



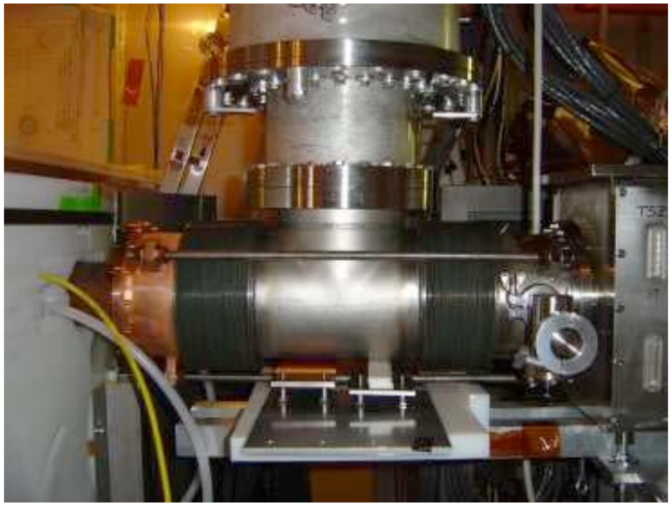
Recoil Energy (keV)

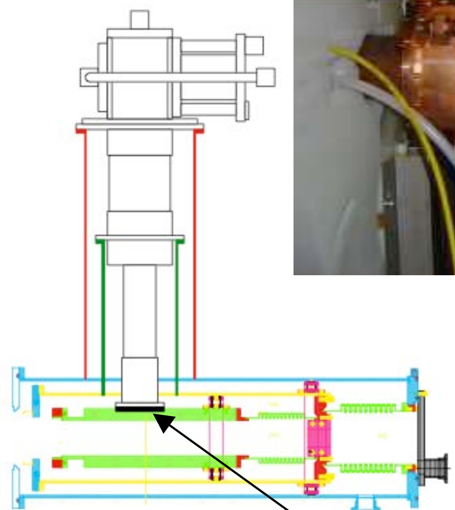
Five Towers now in Soudan

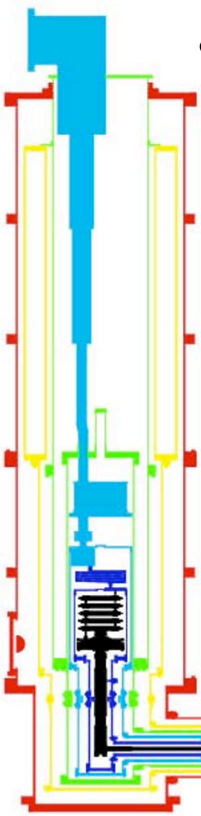


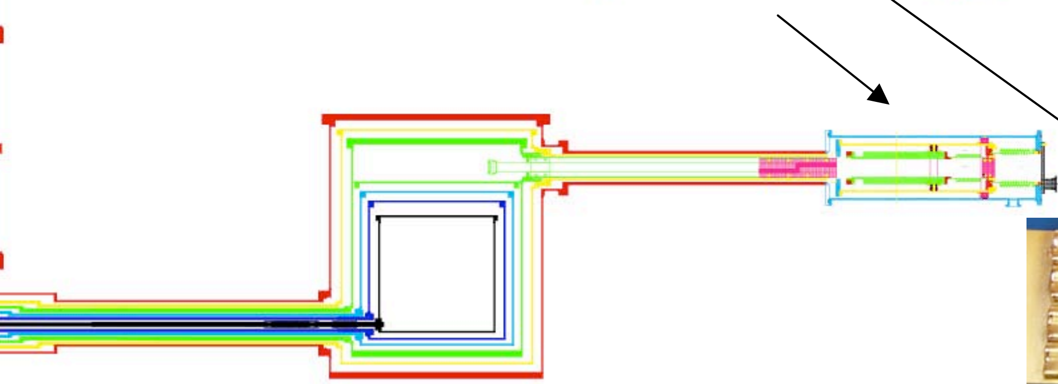
Added Cryocooler w/ Vibration Isolation

- We added cryocooler to estem to reduce additional heat load from 33 striplines for 5 Towers versus 15 striplines for 2 Towers
- In addition need to learn to use cryocoolers for larger experiments

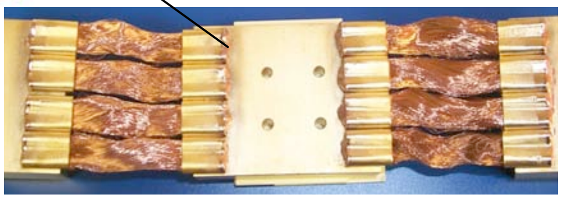








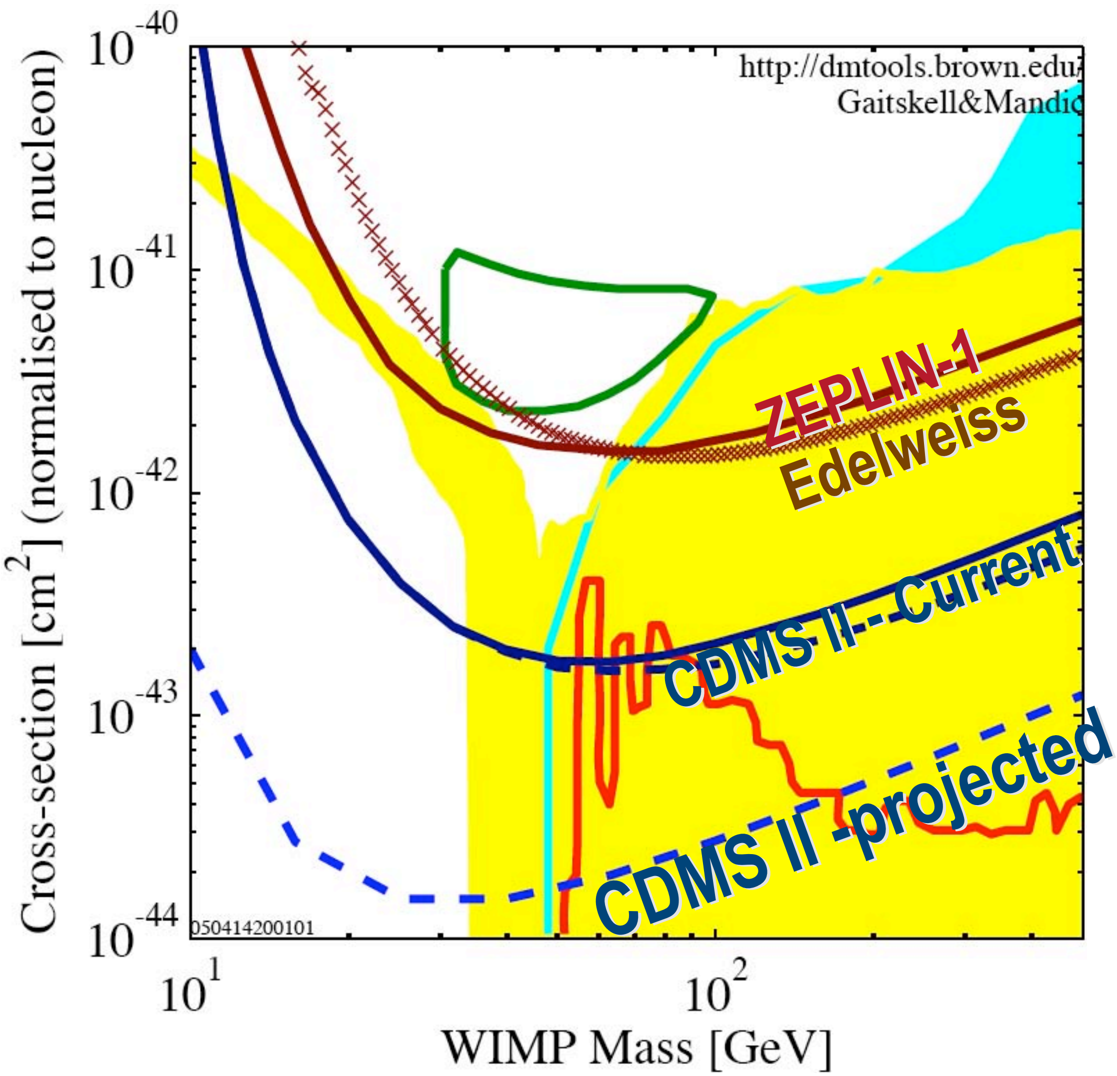
- Add vibration isolation straps from Janis between 4K and cryocooler
- Tested successfully reduce vibrations by x100 during last run at Soudan



Cryogenic Problems Over the Last Year

- Dilution fridge blockage
  - Fixed in spring 2005
- Cryocooler vibration leading to excessive electrical noise
  - Installed vibration isolation in fall 2005
  - Successfully demonstrated operation in early 2006
- Detectors too warm to operate (~200 mK while fridge at 40 mK)
  - Thermal connections of towers to fridge are not good enough
  - Designed and currently installing improved thermal connections
  - Expect to cool down again in June
- We believe that a five tower run will be successful this time!

The Future of CDMS at Soudan



Five tower run of two years duration yields x10 improvement in sensitivity

Many MSSM models indicate signal should begin to appear

- For example, Baltz *et. al.* (hep-ph/0602187) predict ~7 events in CDMS II at Soudan for their LCC2 mSUGRA model

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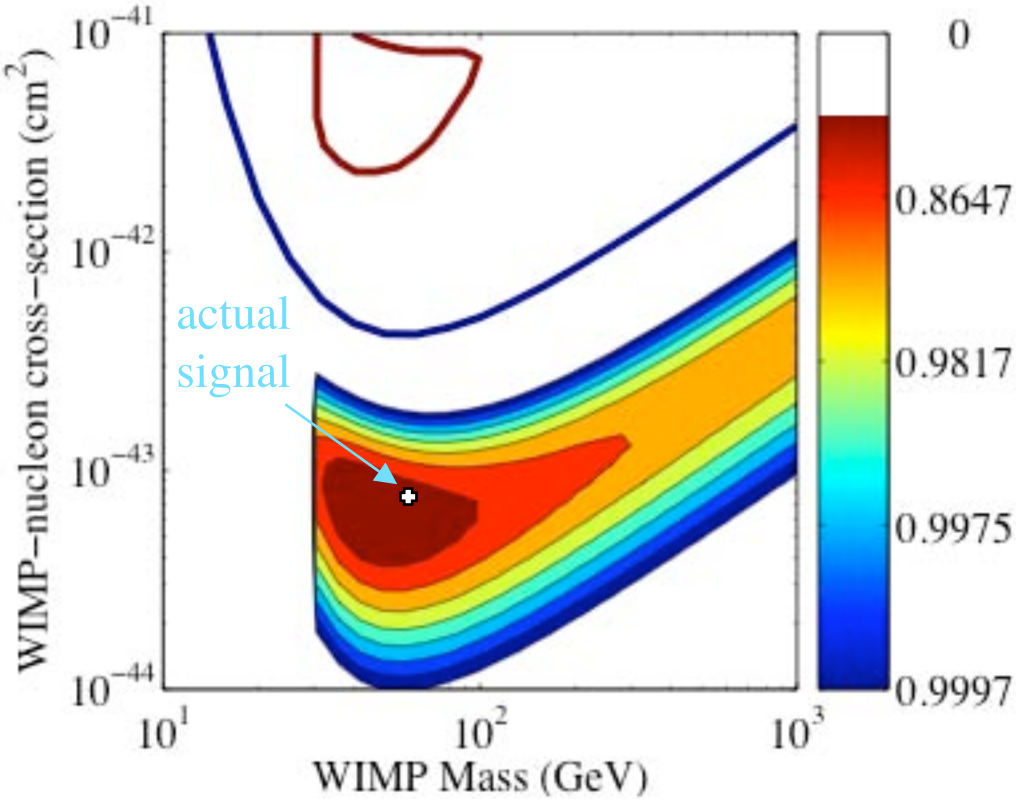
What do we learn if we see a signal?

- Best 90% C. L. corresponds to < 1 evt per 8 kg-d for Ge
- Suppose we see 8 events at rate of
  1 evt per 50 kg-d
- Then mass & cross section determined as shown and SI vs SD determined from different targets
- Suggest properties to look for at LHC and future ILC



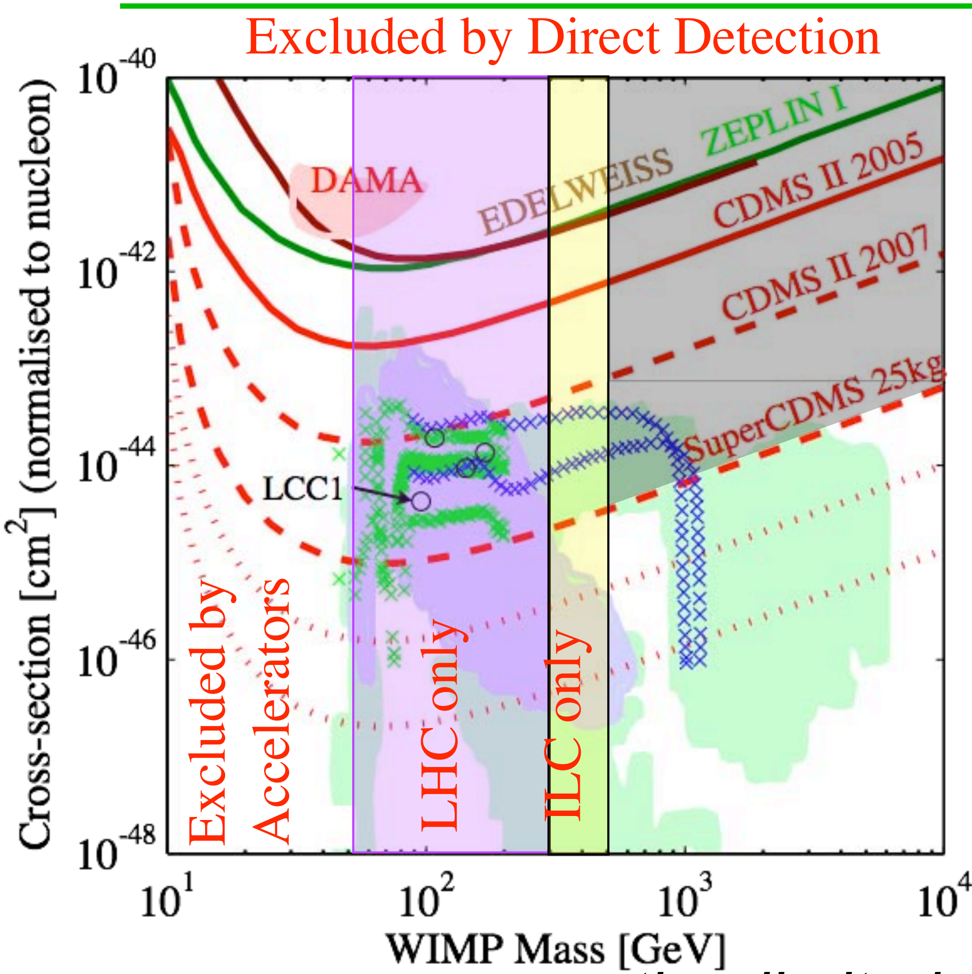
A convincing signal would motivate large TPC such as DRIFT for velocity distribution

If SUSY seen first at LHC would still want to determine if LSP is the dark matter, SO NEED TO PUSH DIRECT DETECTION EITHER WAY

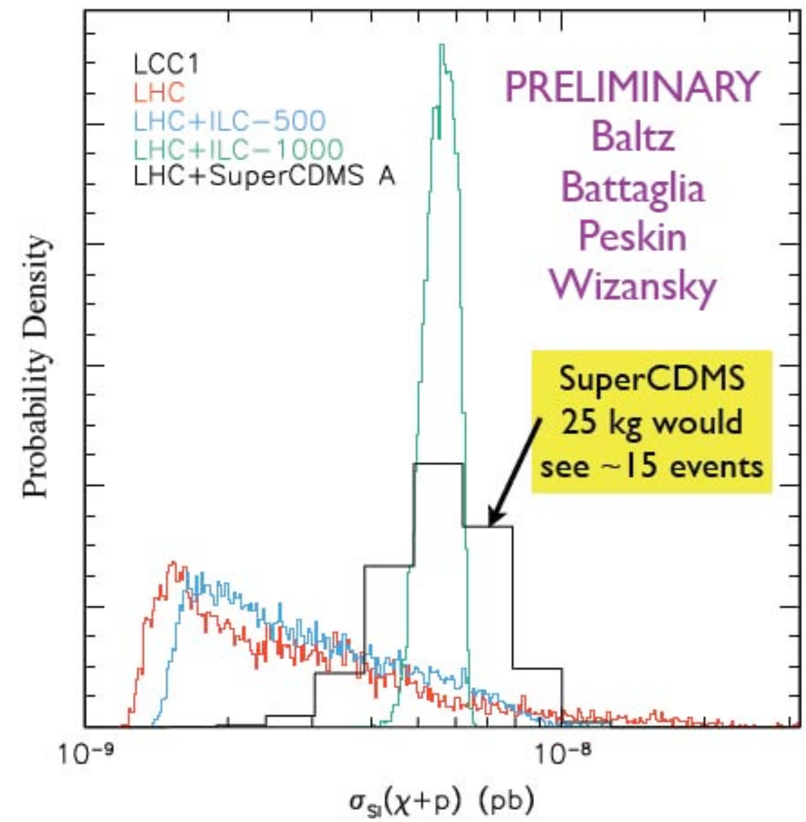
SuperCDMS Strategy

- Straightforward expansion of CDMS technology to 25 kg target mass at a deeper site (SNOLAB) can be done on time scale commensurate with LHC results
- Either follow up on signal detected during CDMS II or greatly increase chances of seeing a signal
- Strong complementarity between LHC searches for SUSY and direct detection
- Techniques developed for the 25 kg experiment can then point the way towards further expansion of target mass
- Strong backing from national review committees for continued direct detection experiments (most recently EPP2010).

Complementarity between LHC and SuperCDMS



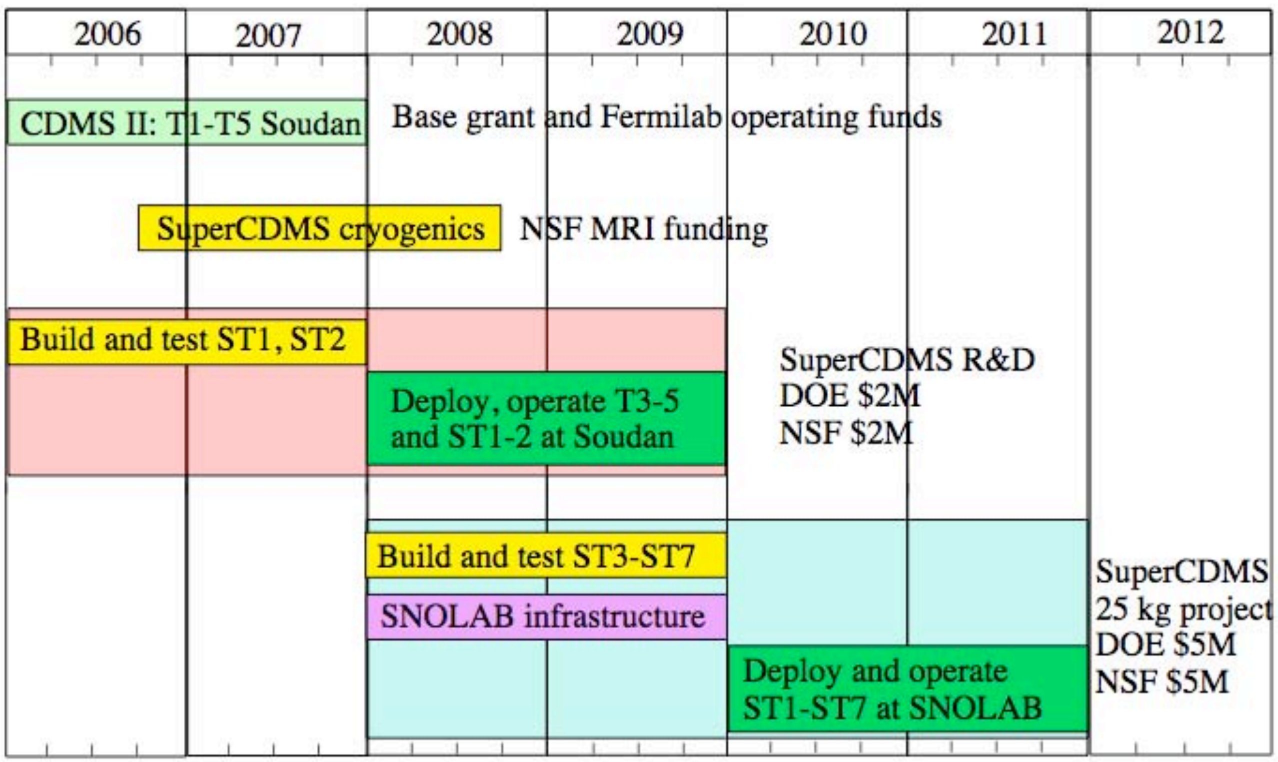
Colliders are *mass-limited*
⇒ spectral info, but often can't see LSP or deduce its relic density



CDMS is *cross section-limited*
⇒ TeV WIMPs detectable, direct connection to cosmology

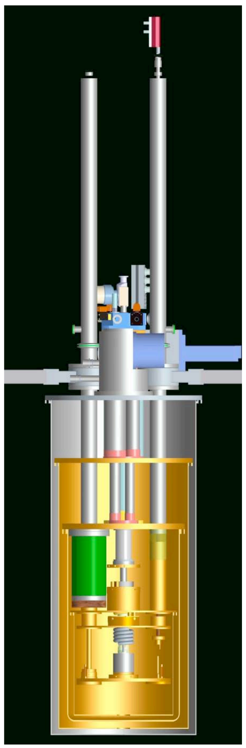
Two SuperCDMS Projects: Soudan & SNOLab

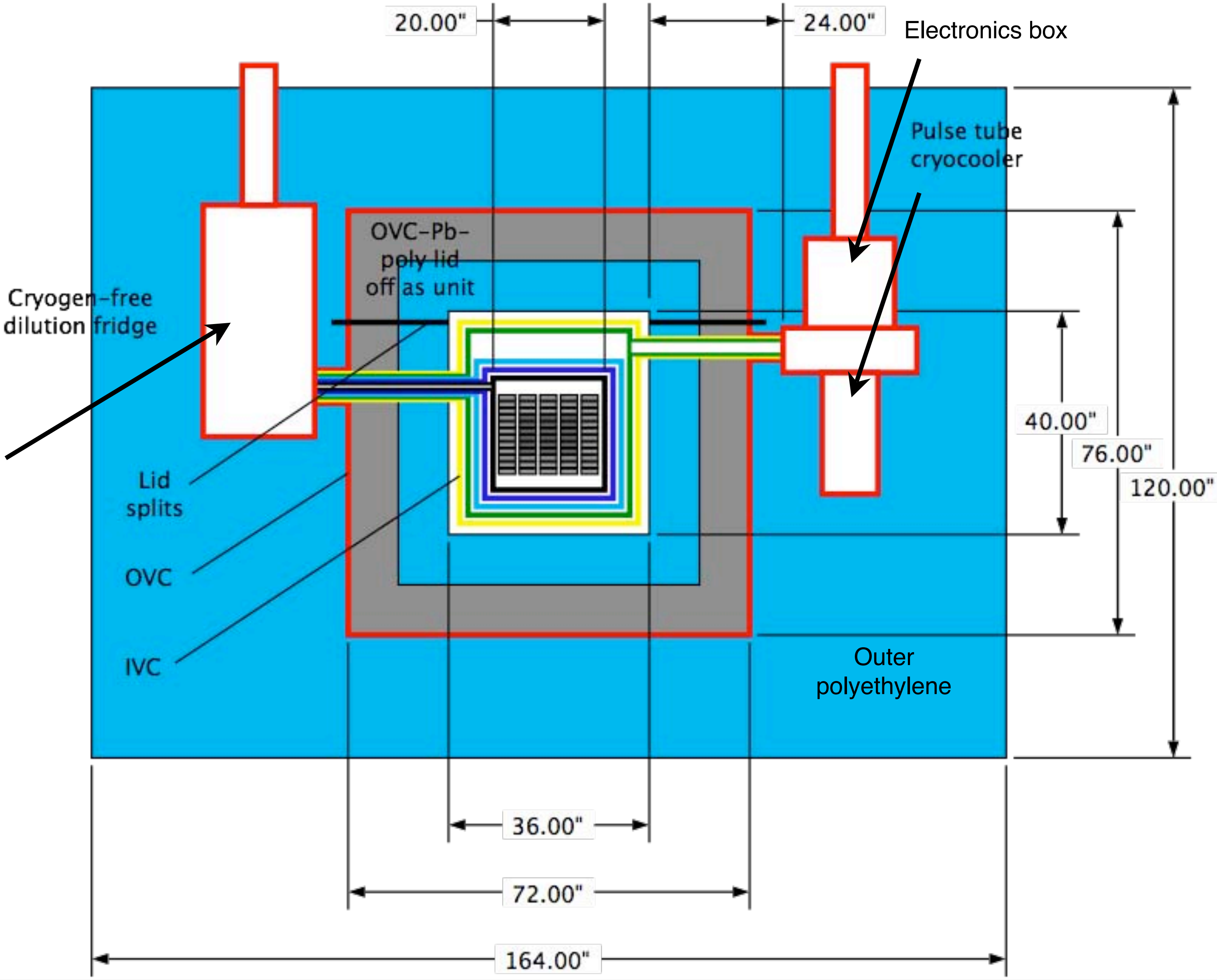
- 2 SuperTowers and run at Soudan (x2 science)
  - need R&D supplements FY06 & project start FY07
- 7 SuperTowers and run at SNOLab (x10 science)
  - need line item pencilled about Apr 06 for FY08 start



Cryogenic design effort has begun at Fermilab

Exploring cryocooler system with little or no cryogen servicing





Fermilab role in CDMS

- Scientific (3 FTE -> 5 FTE)
  - **Dan Bauer (100%) - Staff scientist**
    - Project Manager, Soudan operations and infrastructure, cryogenics, electronics, analysis
  - **Jonghee Yoo (100%) - Research Associate**
    - Spearheading Fermilab analysis effort
  - **Fritz DeJongh (50%) - Staff Scientist**
    - Electronics
  - **Erik Ramberg (25%) -Staff Scientist**
    - Analysis
  - Mike Crisler (<25% and decreasing)
    - Was CDMS electronics but now mainly bubble chamber (CUOPP) and PPD
  - Don Holmgren (<25% and decreasing)
    - Was DAQ, computing, analysis but now mainly lattice QCD
  - Roger Dixon - On temporary loan to Accelerator Division!
  - Andrew Sonnenschein - Wilson Fellow
    - May collaborate in alpha and neutron backgrounds measurements, MC
  - **Need another research associate and staff scientist**
    - Cryogenics/detector/electronics interface + analysis
- Technical and Administrative
  - 8 FTE Engineering/Technician -> 16 FTE (SuperCDMS design, construction)
  - 0.25 FTE administrative -> 1 FTE (need more project management help)

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CDMS budget at Fermilab

Expect modest growth over next five years

Type of Funds	2005	2006	2007	2008	2009	2010
M&S	435	460	471	483	495	507
Labor	848	1283	1341	1405	1462	1520
Total	1283	1743	1812	1888	1956	2027

Years are fiscal; amounts in k$

Summary

- CDMS II at Soudan leads the direct detection field by x10 - spin-independent limits PRL 2006 and spin dependent limits PRD RC 2006.
- Five tower run at Soudan will start mid-2006 and run through mid-2007 for an additional x10 improved sensitivity.
- Strong case for expansion of target mass to 25 kg on same time scale as LHC (complementary approach to understanding of dark matter)
- SuperCDMS has demonstrated technology to pursue the next phase of direct detection experiments
- Fermilab is a vital component in CDMS, providing project management, cryogenics, electronics, operations and analysis efforts.