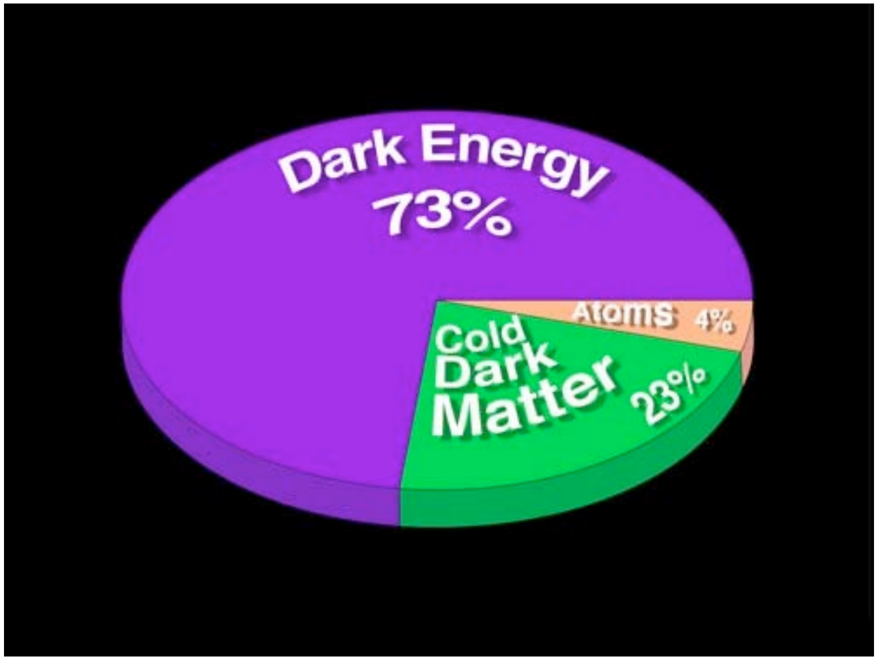
CDMS: Status and Future Plans

Dan Bauer
CDMS Project Manager

What is CDMS?

- Direct detection of cold dark matter



Status of CDMS II at Soudan

- Status of the experiment
- Current results
- Goals

Future Plans - SuperCDMS

- Continued running at Soudan
- Develop "deep site" design with more detector mass

CDMS in a nutshell

Dan Bauer
PAC Meeting
Nov. 12, 2004

Dark Matter Search

Direct detection of WIMPs

Cryogenic

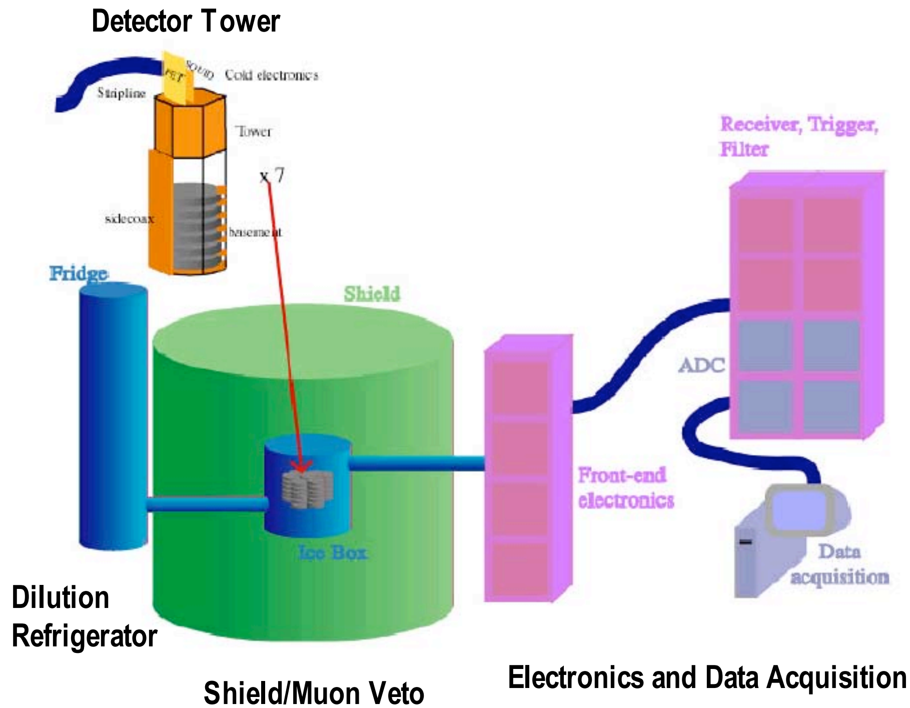
Ge and Si detectors, < 50 mK

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
- GO DEEP
  - Neutrons mainly from cosmic ray interactions



Shielding

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

Dan Bauer
PAC Meeting
Nov. 12, 2004

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!

Tower of 6 ZIPs

Tower 1

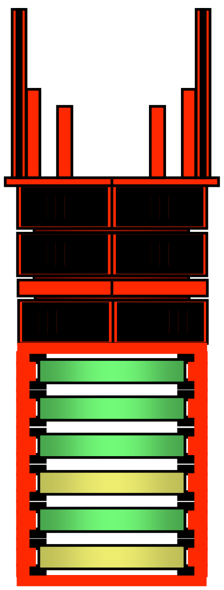
4 Ge

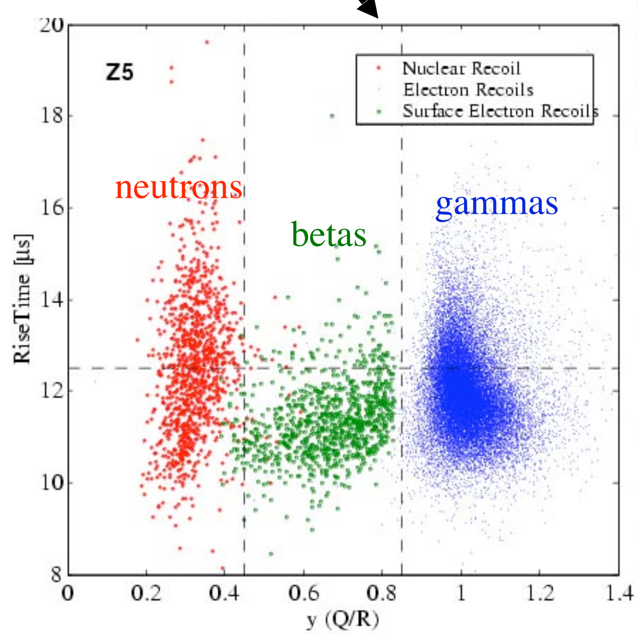
2 Si

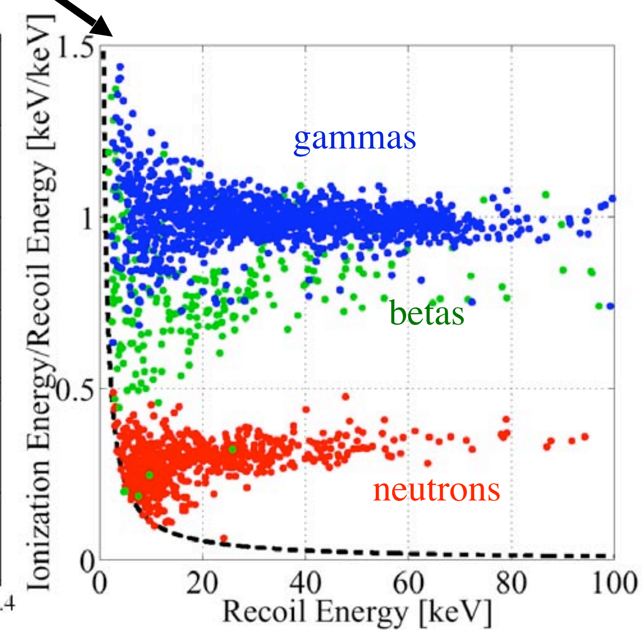
Tower 2

2 Ge

4 Si





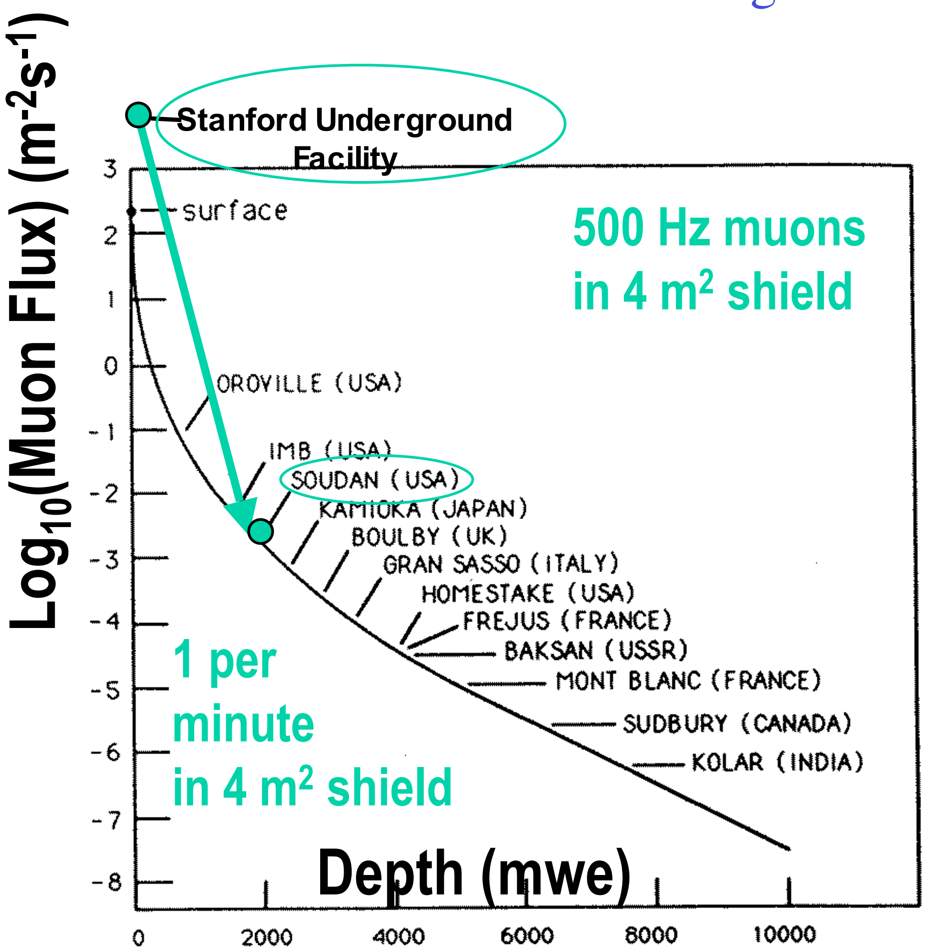


Dan Bauer
PAC meeting
Nov. 13, 2004

Status of CDMS II at Soudan

Depth of 2000 mwe reduces cosmic-ray-induced neutron background to ~1 / kg / year at Soudan

Construction of CDMS II begin 1999; operations began in 2003

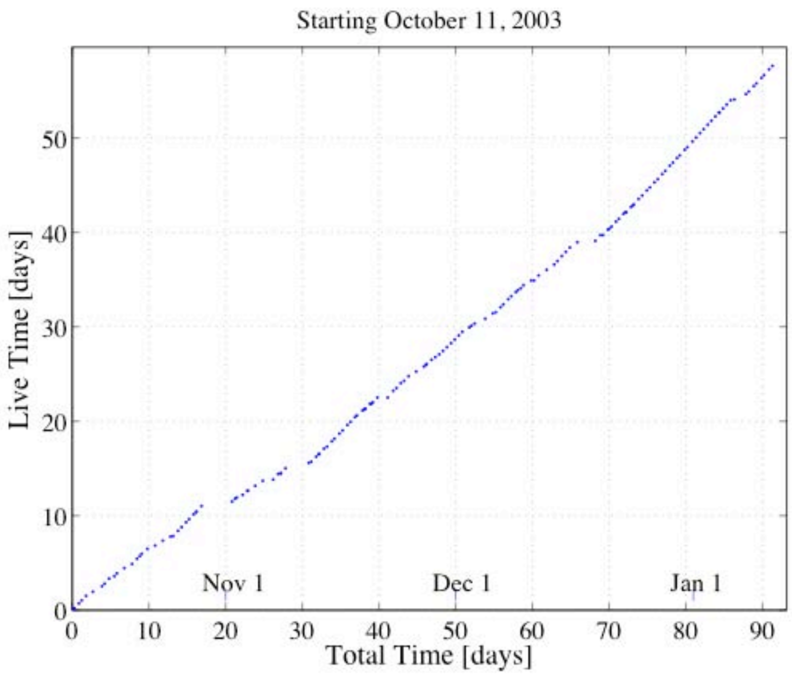


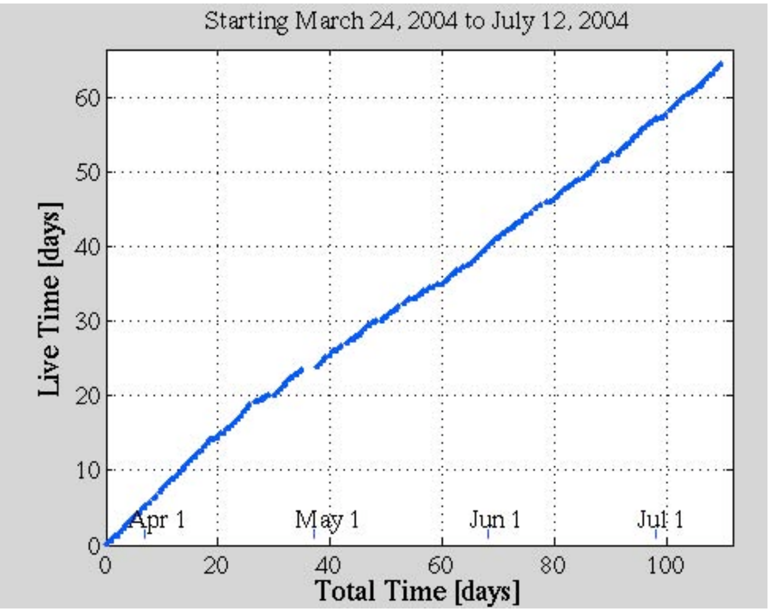
First detectors arriving: winter 2003

Dan Bauer
PAC meeting
Nov. 13, 2004

Soudan data sets

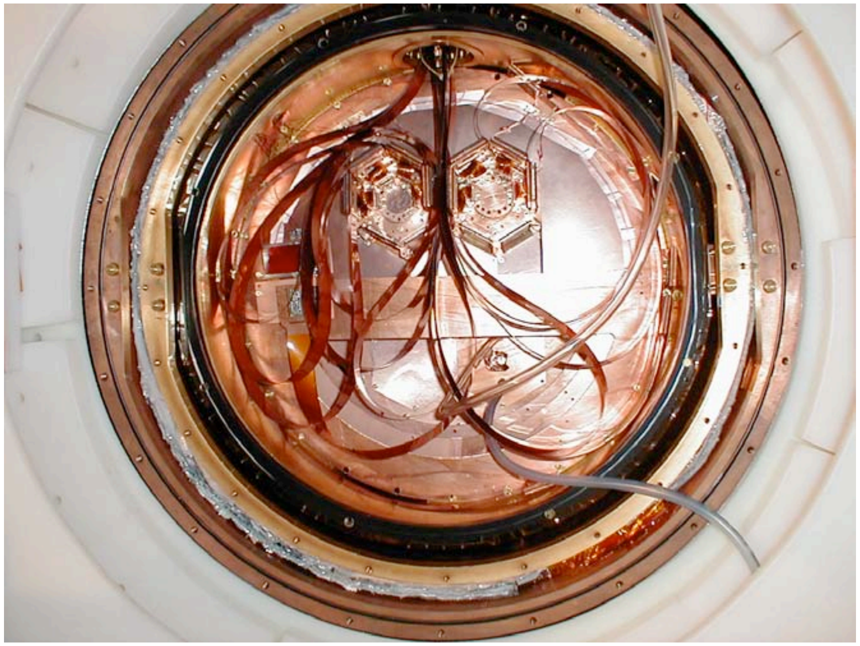
- Tower 1 (Nov 2003 - Jan 2004)
  - 52 live days, 22 kg-days Ge exposure
- Tower 1 + Tower 2 (March - August 2004)
  - 75 live days, at least 56 kg-days Ge exposure

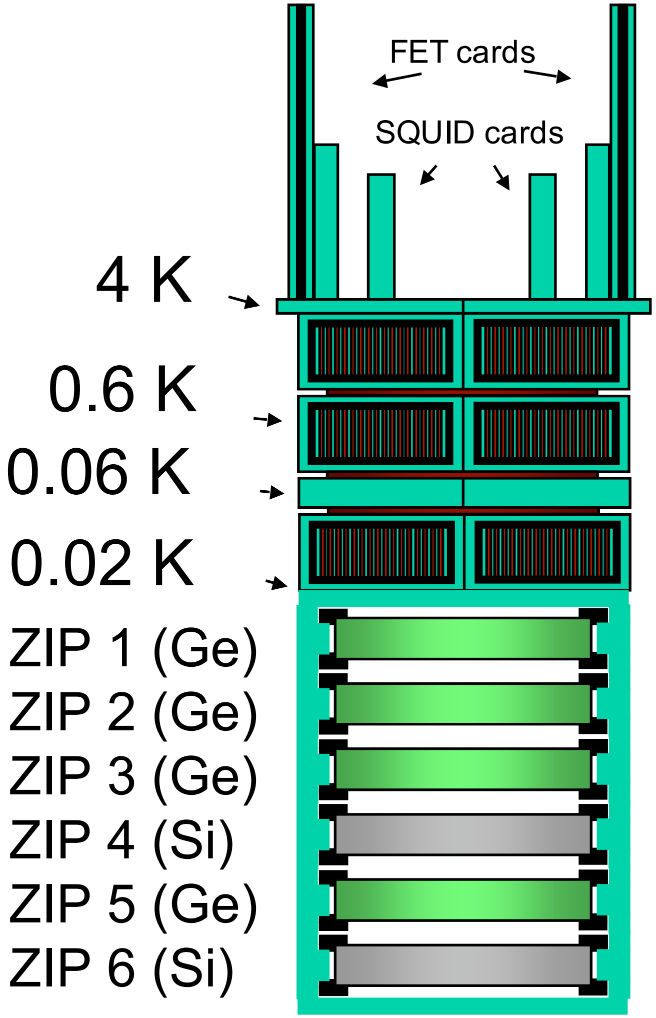




Detectors

- Tower-1 (Nov 2003-Jan 2004)
  - 4 Ge and 2 Si ZIPs - background rejection better than expected; beta background on bottom Si detector (Z6)
- Tower-2 (March-August, 2004)
  - 2 Ge and 4 Si ZIPs - backgrounds similar to Tower 1
- Issues
  - Radon gas => γ background; improved purging system
  - Residual β background; improved phonon analysis
  - Low-level electronics noise; improve grounding

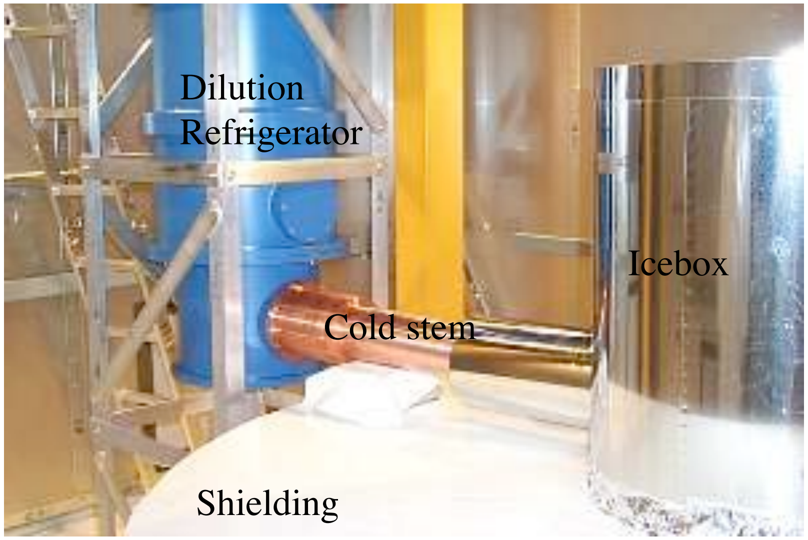




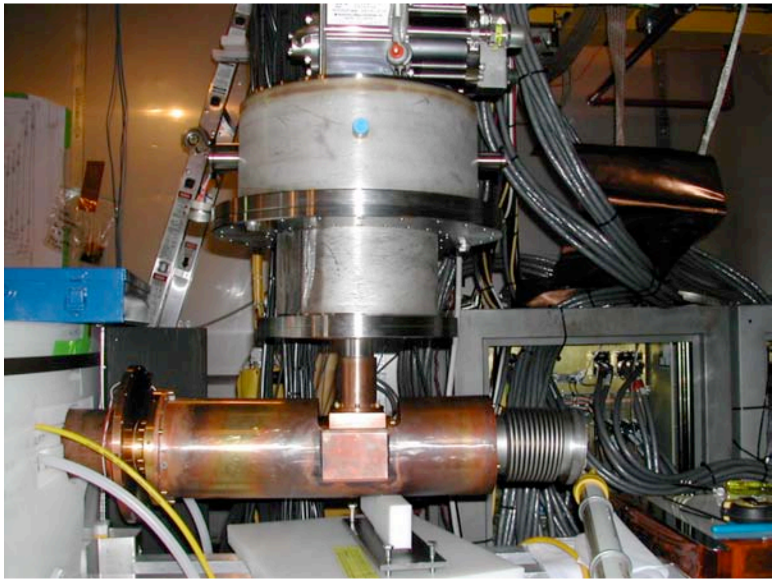
Cryogenics

Dan Bauer
PAC meeting
Nov. 13, 2004

- CDMS II Icebox, Fridge (Fermilab)
  - System has worked reliably for 1 year of running at 50 mK!
  - Upgrades being installed to:
    - Improve vacuum, decrease maintenance
    - Better control and monitoring
    - Improve cooling at 4K with cryocooler
      - Reduce Lhe consumption, costs



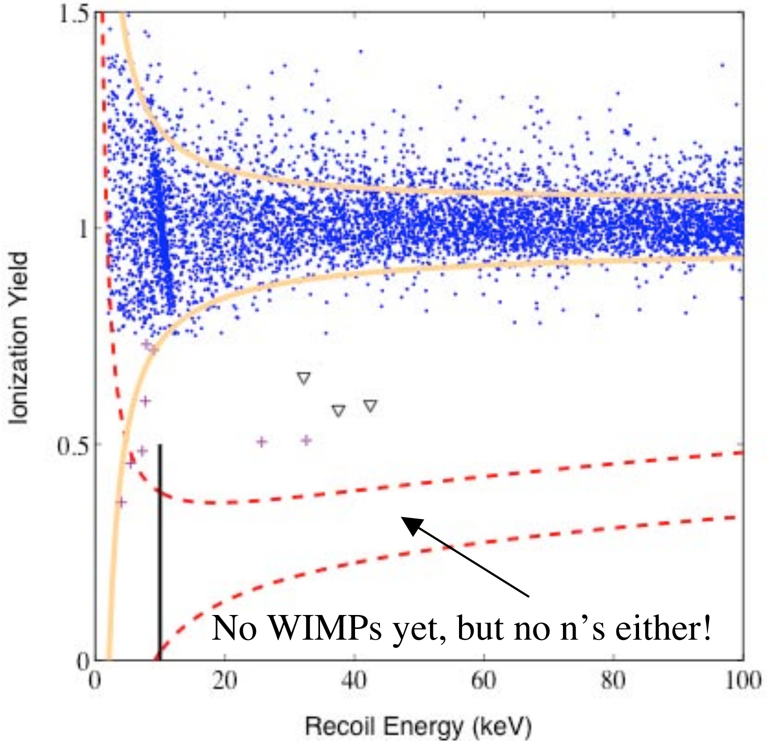
Test fit of cryocooler during October

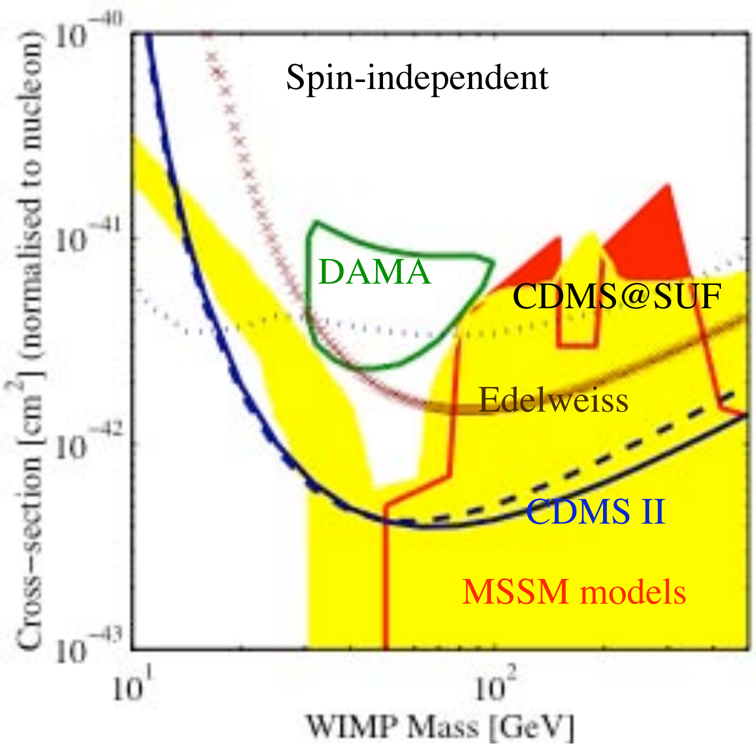


Dan Bauer
PAC meeting
Nov. 13, 2004

First WIMP limits from Tower 1 at Soudan

- x10 better than CDMS@Stanford, x4 better than Edelweiss
- DAMA is not seeing spin-independent WIMP interactions
- Probing significant section of MSSM model space
- Accepted for publication in Physical Review Letters; PRD nearly finished

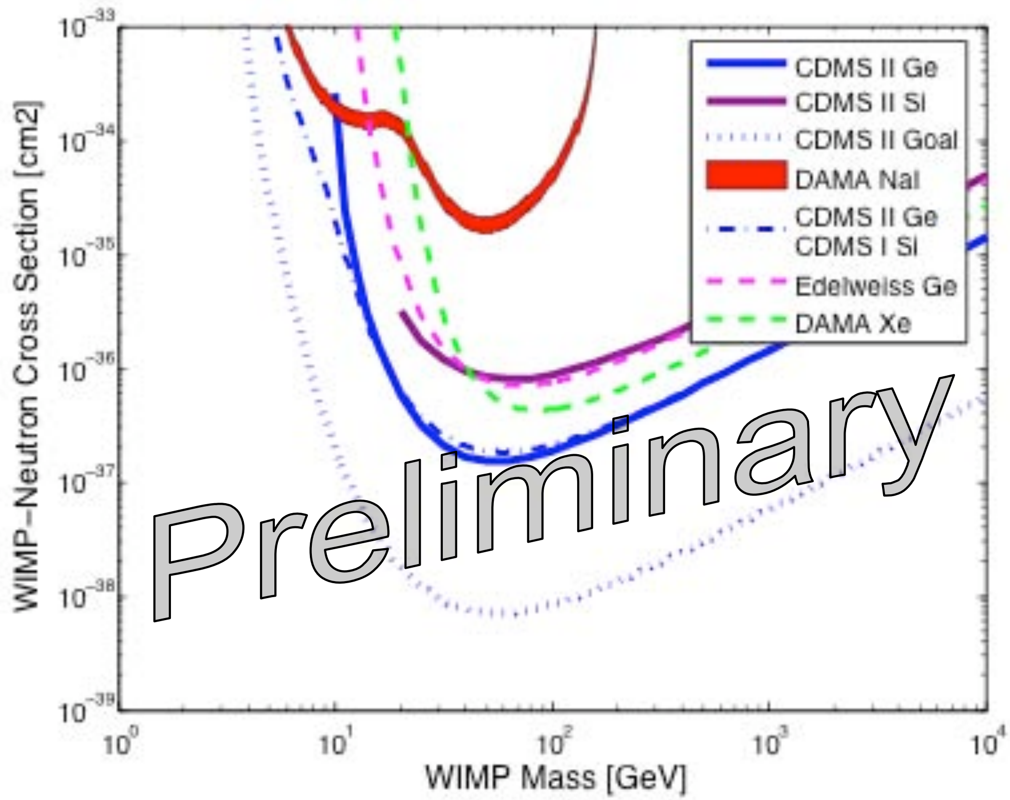




Dan Bauer
PAC meeting
Nov. 13, 2004

New Physics Result: Spin-dependent WIMP limits

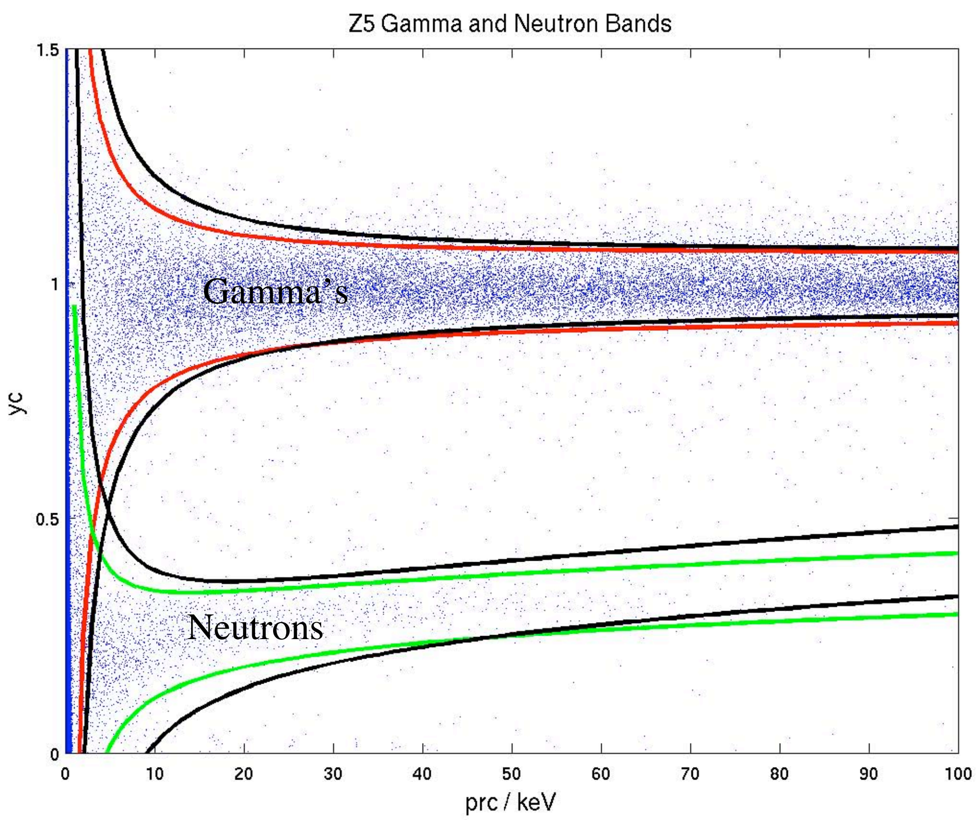
- Recent realization that we can set best limits on WIMP-neutron spin-dependent cross sections (from 8% 73Ge with odd number of neutrons)
  - So DAMA probably isn't seeing spin-dependent WIMP interactions either!
- Short paper in preparation



Dan Bauer
PAC meeting
Nov. 13, 2004

Analysis of Two-Tower Data progressing well

- Blind analysis
  - Cuts set only on gamma, neutron calibration data
  - WIMP-search nuclear recoil region has not been examined yet
  - Expect to 'open the box' in January, publish in spring 2005
  - Should yield x3 improvement in sensitivity over Tower 1 result



Dan Bauer
PAC meeting
Nov. 13, 2004

Completing CDMS-II

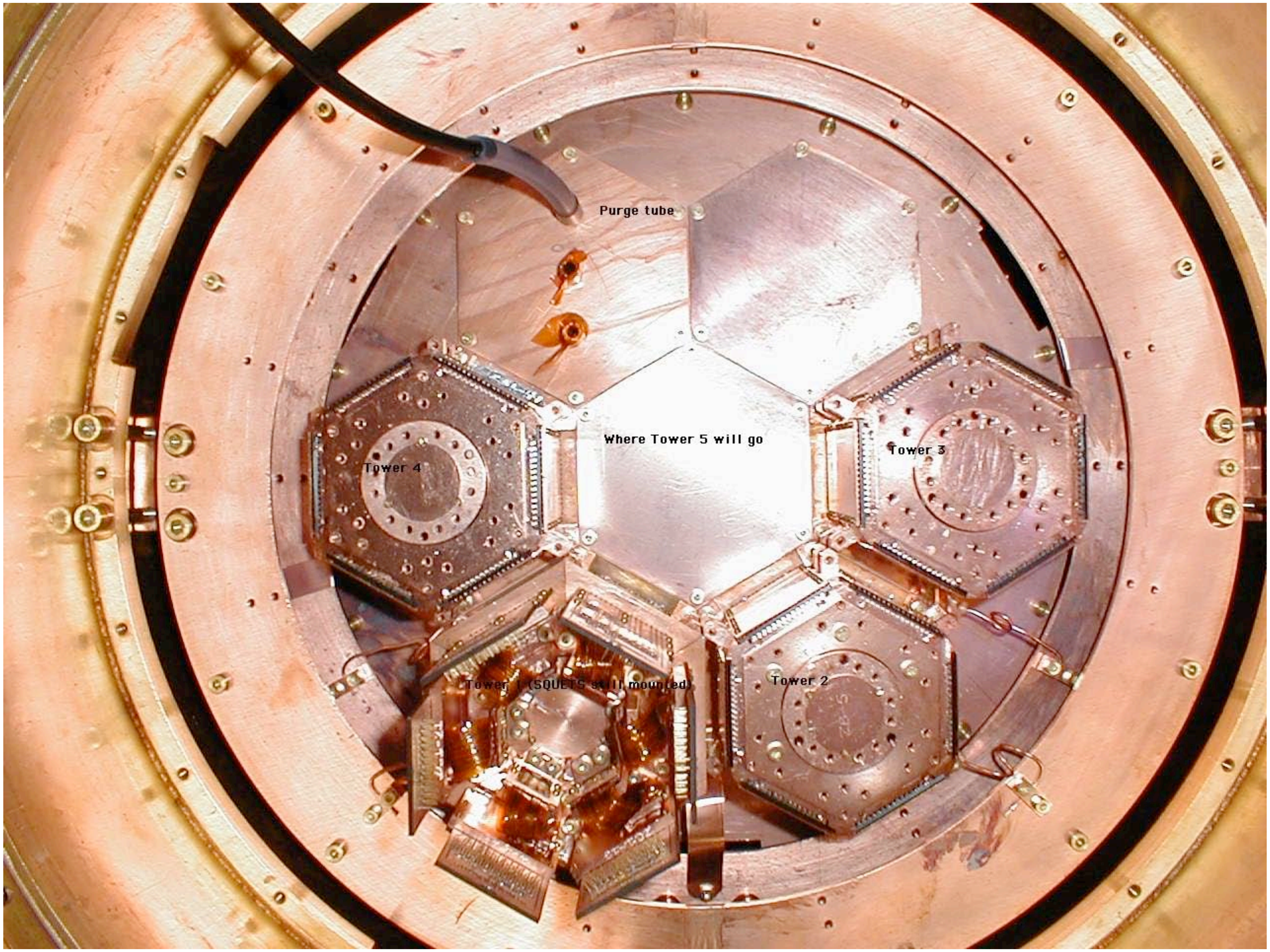
Tower 1 (published)
- 52 live days
- 1.0 kg Ge mass
- 22 kg-d net Ge
- 0.2 kg Si mass
- 4 kg-d net Si (PRD)

Towers 1-2 (analyzing)
- 75 live days
- 1.5 kg Ge mass
- 50 kg-d net Ge
- 0.6 kg Si mass
- 20 kg-d net Si

Towers 1-5 (2005)
- 200 live days
- 4.5 kg Ge mass
- 400 kg-d net Ge
- 1.2 kg Si mass
- 100 kg-d net Si

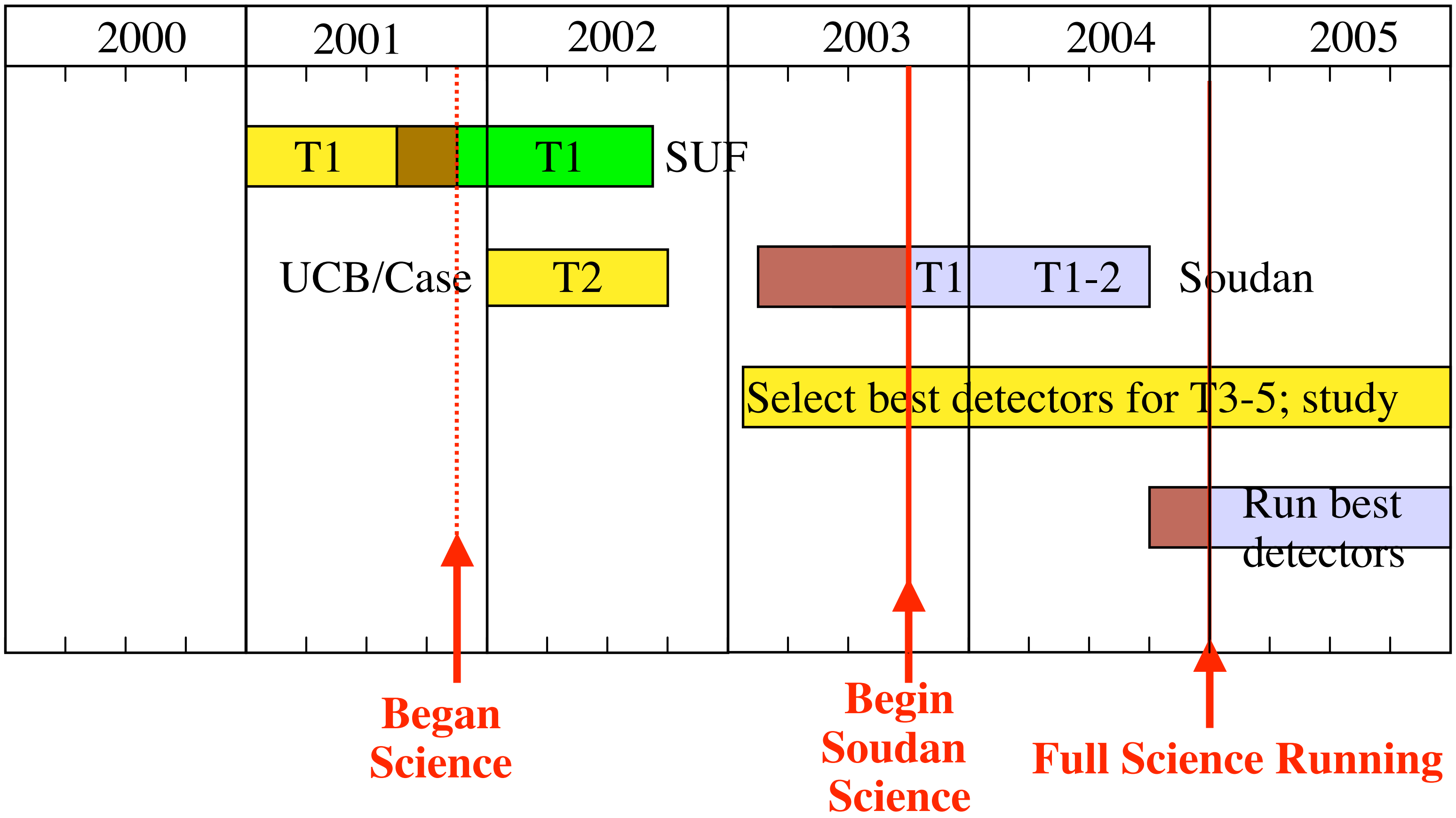
Dan Bauer
PAC meeting
Nov. 13, 2004

Towers 3 and 4 Installed; Tower 5 next week



Dan Bauer
PAC meeting
Nov. 13, 2004

CDMS-II Schedule



Continued operations support needed from DOE, NSF, FNAL
FNAL contribution about $500K/year

Dan Bauer
PAC meeting
Nov. 13, 2004

Expected Soudan Backgrounds

Total background events expected at Soudan
From 1999 CDMS II proposal

Background source	Shielded	Muon Veto	After detector rejection	Background subtracted	Systematics
γ's , external radioactivity	750	750	4		
γ's , cosmics in shield	188	2	0.02		
γ's, internal single scatters	18750	18750	98		
Total γ's	19688	19502	102	~~22~~ **0.2**	7
β's, surface contamination	1500	1500	75	~~18~~ **8**	10
n's, external radioactivity	0.4	0.4	0.4		
n's, cosmics in shield	38	0.4	0.4		
n's, cosmics in rock	8	8	8		
Total neutrons	46	9	9	~~8~~ **<1**	1
Total background	21234	21011	186	30	12

Table 4.2: This table lists the total number of events expected at 15 keV in germanium from each background source in CDMS II. "Shielded" means the component that penetrates the shielding and interacts in the detectors. "Muon-Veto" refers to the subset of these that are anticoincident with a 99% efficient muon veto. "After detector rejection" is the smaller subset of events that are misidentified by the detectors as nuclear recoils. "Background subtracted" refers to the 90% C.L. limit obtained using formulae above, where *MT*= 2500kg days and ΔE = 30 keV.

Great progress in background rejection since then!

Improved γ rejection (99.995% instead of 99.5%)

Improved β rejection (99.4% instead of 95%)
Analysis should improve further to 99.9%
(~1 event background)

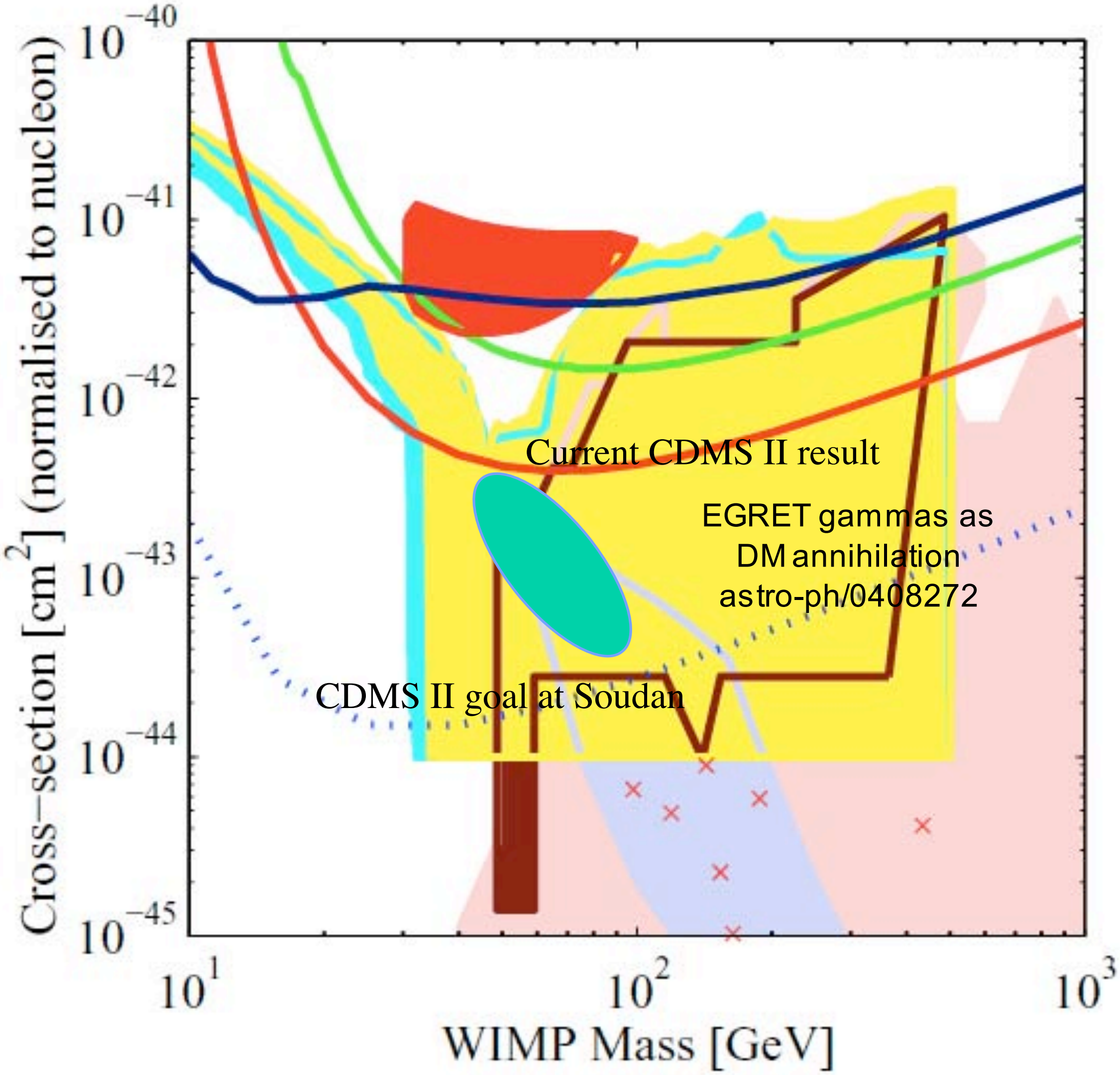
~60% vetoed by scintillator (could do even better with outer or inner veto)

Goal is to stay background-free as long as possible

Dan Bauer
PAC meeting
Nov. 13, 2004

CDMS-II Reach with five Towers

- We are exploring MSSM cross section range
- DAMA ruled out for spin independent scalar interactions
- Light mass region largely ruled out
- Another factor of 3-5 improvement possible at Soudan past CDMS-II
- To avoid neutron background, would then have to go deeper
- Alternative: stay at Soudan and work hard on active neutron veto

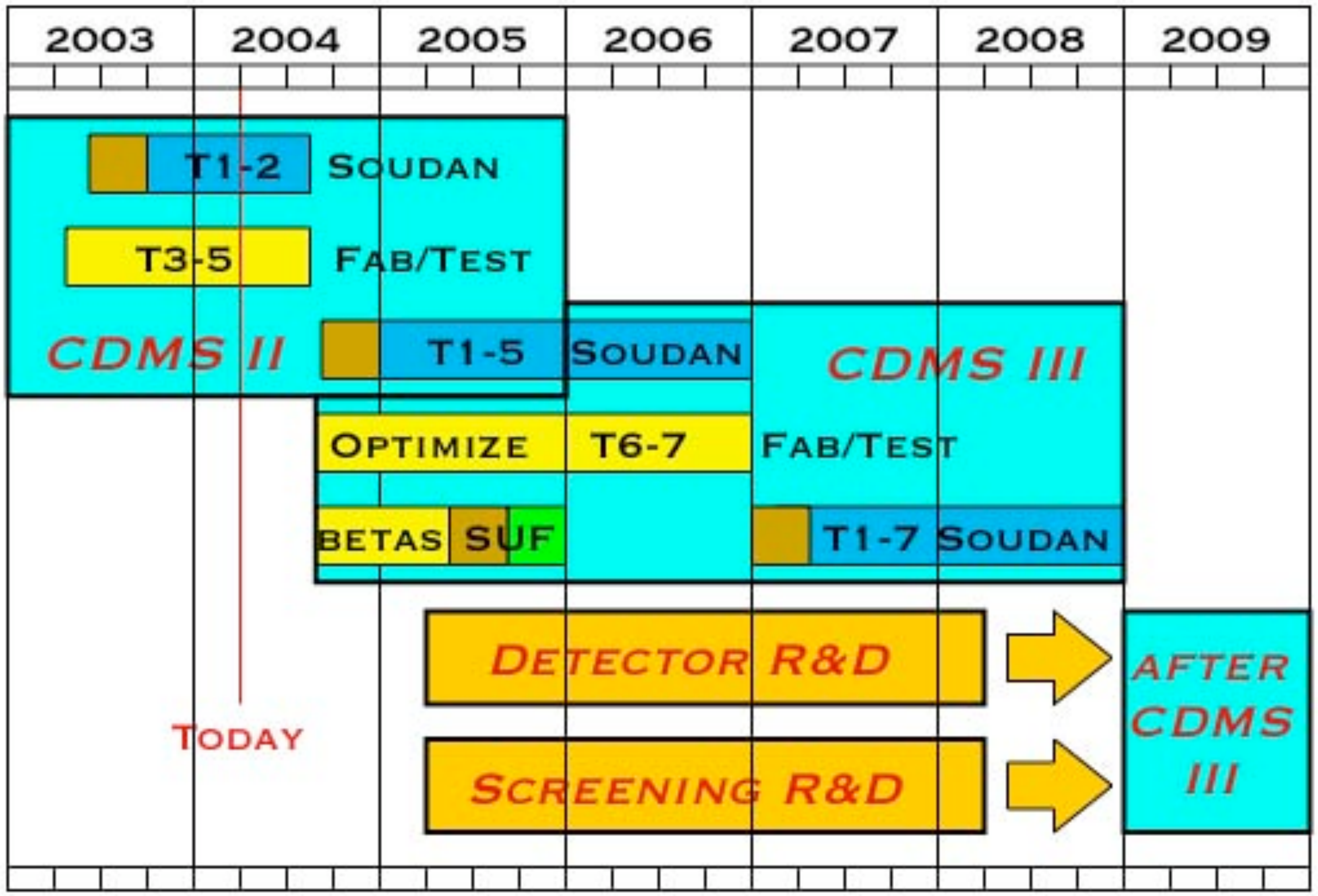


Dan Bauer
PAC meeting
Nov. 13, 2004

CDMS III Roadmap

What we presented to PAC and SAGENAP in April

- Two additional towers, slightly optimized and cleaner
- 1 additional year of running with 5 towers, 2 years of running with 7 towers
- No clear future path beyond CDMS III



Endorsements

- April 2004 PAC report

The Committee was pleased by the CDMS-II collaboration's completion of two towers in Soudan and the successful start of data-taking. The Committee was also very impressed by the first science produced from the Soudan operation, which already excludes a very interesting region of the Dark Matter parameter space, and is the current world-best limit. The Committee fully supports the science of a seven-tower CDMS-III that will make the most out of the investment already made. The Committee encourages the collaboration to aggressively try to increase the analysis role of the Fermilab group.

- Sept 2004 SAGENAP report to HEPAP (Rene Ong) on Dark Matter:

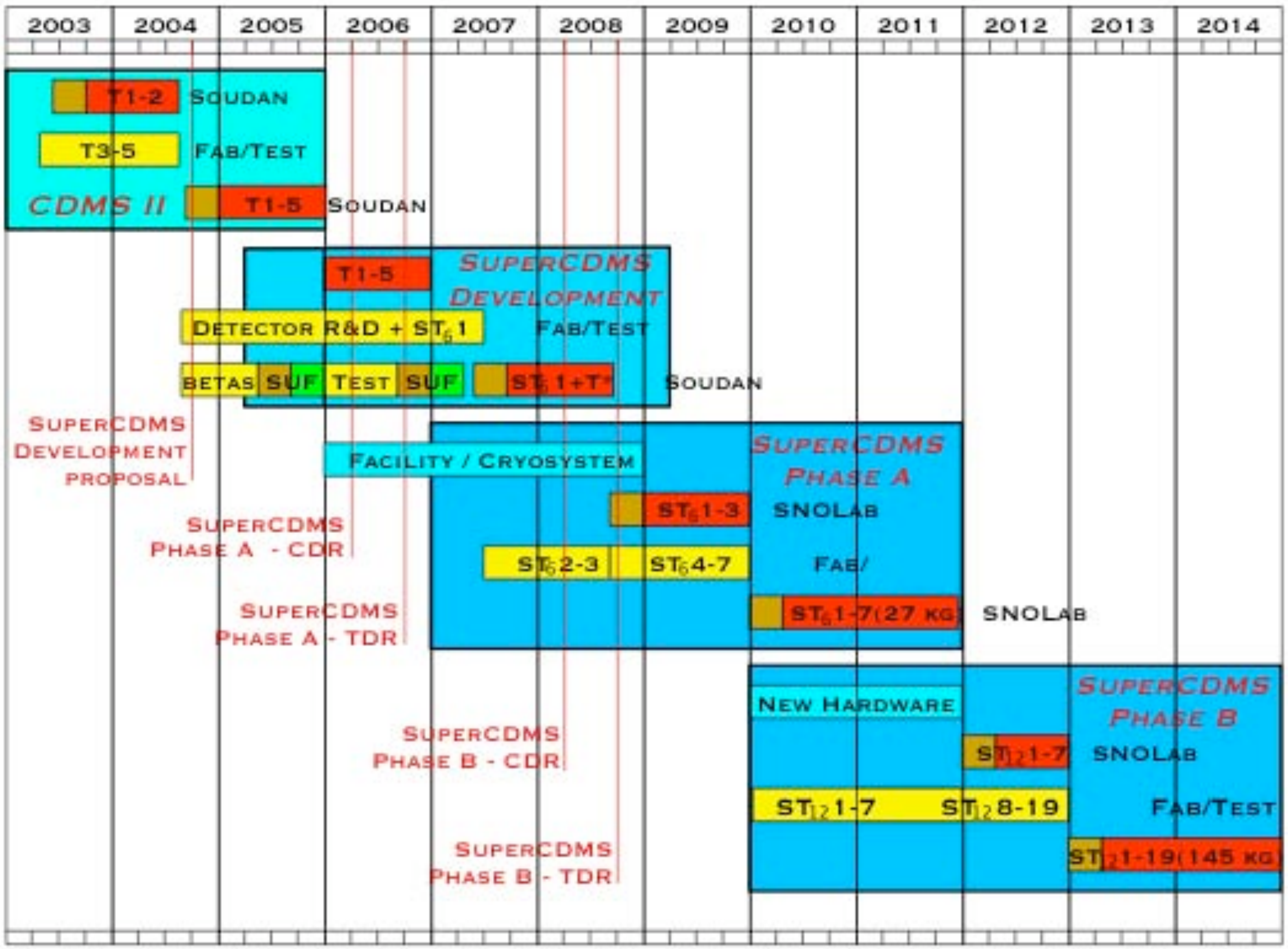
"CDMS is (and will remain) at the forefront. They should be supported."

Dan Bauer
PAC meeting
Nov. 13, 2004

New SuperCDMS Roadmap

Next few years very similar (SuperCDMS Development Project Proposal)
- 1 additional year of running with 5 towers
- 1.5 years of running including new ‘super tower’ with x2.5 more mass

Do R&D, develop infrastructure design for more mass at deeper site



Dan Bauer
PAC meeting
Nov. 13, 2004

Path to scale up CDMS detector mass

CDMS II ZIPs: 3" dia x 1 cm => 0.25 kg of Ge

Present ZIP

CDMS III tZIPs: 3" dia x 1" => 0.64 kg of Ge

Thicker ZIPs for 6th Soudan Tower

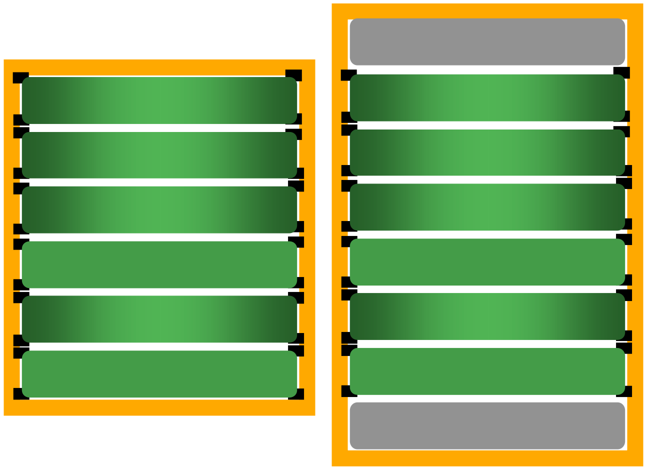
CDMS SNOLAB sZIPs: 4" dia x 1" => 1.13 kg of Ge

Even bigger ZIPs for SNOLAB

Dan Bauer
PAC meeting
Nov. 13, 2004

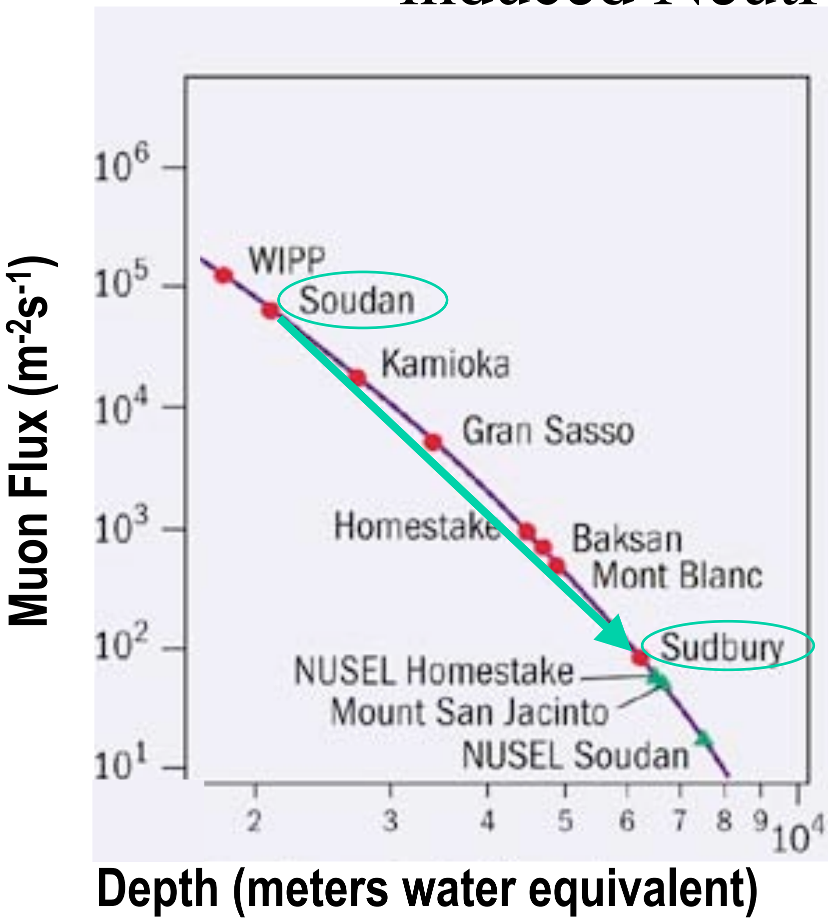
Background Reduction

- Reduce beta contamination via active screening/cleaning
  - Observed alpha rate indicates dominated by ^{210}Pb on detectors
    - Improved radon mitigation already in place -- will determine if it has effect
  - Materials surface analysis (PIXE/RBS/SIMS/Auger) (in progress)
    - Limits detector ^{14}C, ^{40}K beta contamination to ~10% of total
  - Developing multiwire proportional chamber or cloud chamber as dedicated alpha/beta screener (prototypes in progress)
    - Necessary for 17 beta emitters that have no screenable gammas/alphas
- Reduce photon background via improved shielding
  - Active (inexpensive) ionization "endcap" detectors to shield betas, identify multiple-scatters
  - Add inner Pb shielding (like we had at shallow Stanford site)



Dan Bauer
PAC meeting
Nov. 13, 2004

Go Deep (eventually) to remove Muon-induced Neutron background



- Move from Soudan to deep site would:
  - Reduce muon flux by 500x
  - Reduce high-energy neutron flux by >100x -- problem gone
  - Worry about neutrons from residual radioactivity only
- Soudan site still very important
  - Testing site for detectors, backgrounds
  - Can still continue WIMP search at Soudan if deep sites not ready
    - Would require additional neutron veto
    - Probably can get x10 reduction

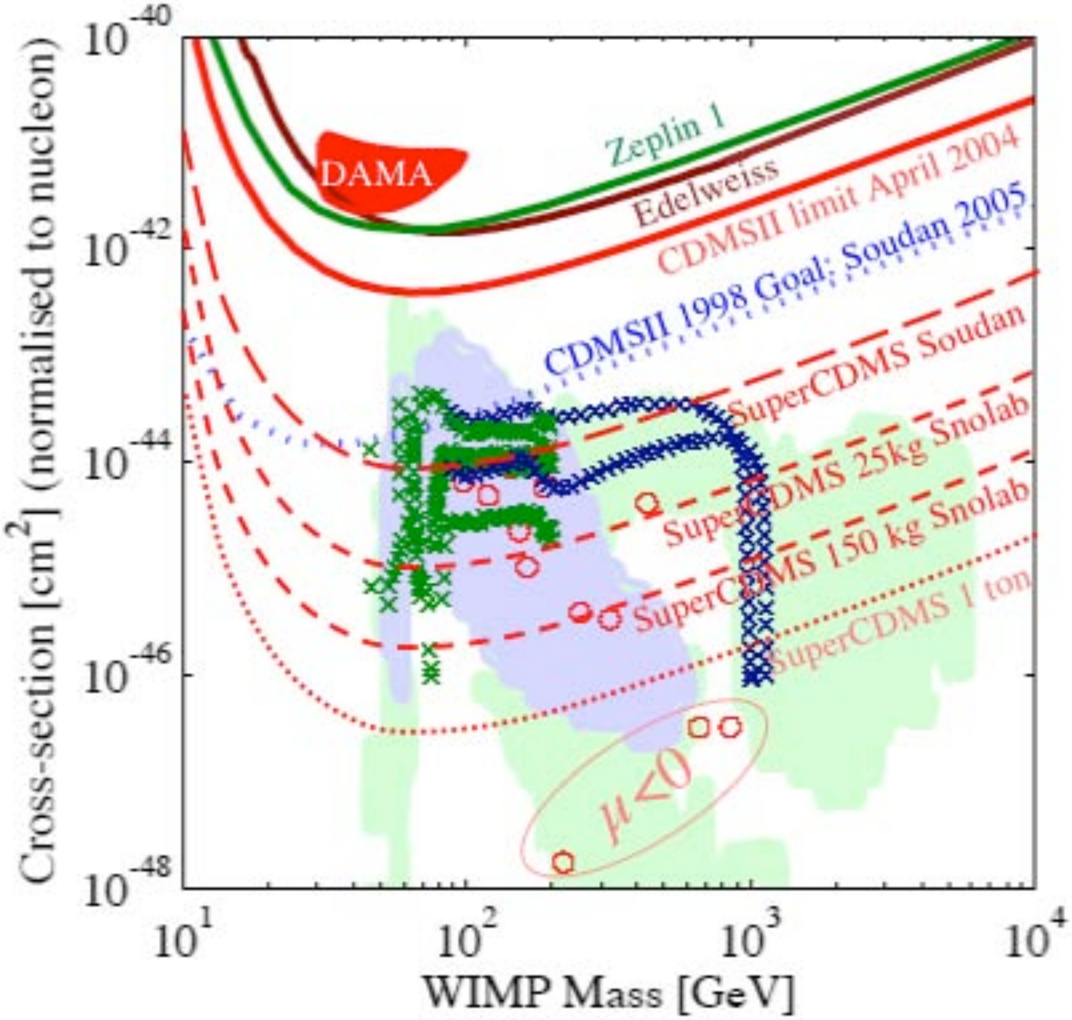
SNOLAB Letter of Interest response:

The EAC has reviewed your LOI and endorses it highly as a project appropriate for SNOLAB based upon its exceptional scientific merit, the technical accomplishments achieved to date by the CDMS collaboration, and the well defined program to proceed towards the Cryo-Array project.

Dan Bauer
PAC meeting
Nov. 13, 2004

Ultimate reach of SuperCDMS

- CDMS@Soudan covers top of currently-favored region (blue)
- Deep site and R&D required to achieve increased sensitivity
  - Increase detector mass
  - Reduce backgrounds
- Ton-scale SuperCDMS would probe neutralino cross section range similar to the LHC (red circles) but even higher mass!



Dan Bauer
PAC meeting
Nov. 13, 2004

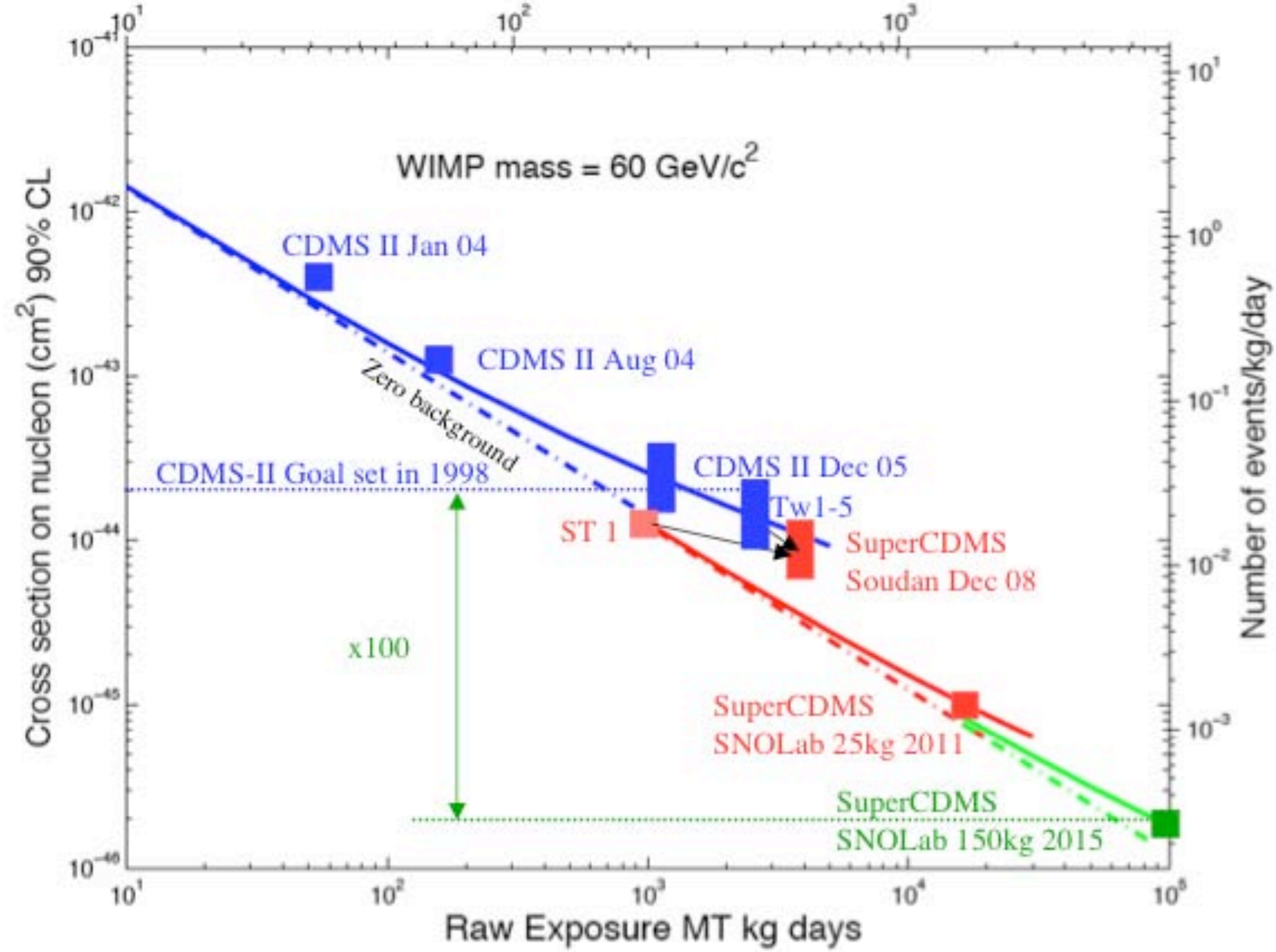
Summary

- CDMS II doing well at Soudan
  - Routine operations for the last year
  - Best WIMP limits in the world, with much more to come (x20 improvement)
  - ONLY running experiment with large detector mass, low backgrounds and active background rejection, deep underground (for now)
  - BUT, we're about to enter the last year of CDMS II project funding (2005)
    - **Must preserve our teams to fabricate and test detectors, study backgrounds**
- Clear path to the future
  - Continued running at Soudan combined with R&D towards larger mass, lower backgrounds (SuperCDMS Development Project Proposal)
    - **Note that this proposal does not commit Fermilab, NSF, or DOE to a deep site experiment**
  - We believe CDMS detector and background technologies ARE scaleable to 150 kG and probably to 1000 kg
    - **No other technology, including Xenon, has completed sufficient R&D to prove it works stably for long periods of time, with low thresholds and small backgrounds**
  - SuperCDMS will be complementary to the LHC for SUSY neutralino studies
    - **Only direct detection experiments can convincingly demonstrate that WIMPS constitute dark matter**
  - We would like to have PAC and FNAL endorsements for this approach

Dan Bauer
PAC meeting
Nov. 13, 2004

Sensitivity

Continued improvement requires increase in target mass and running time, decrease in backgrounds



Dan Bauer
PAC Meeting
Nov. 12, 2004

How are we better than the competition?

We are taking data at a deep site!
- Edelweiss, CRESST are rebuilding (larger mass, better shielding)
- Xenon, bubble chamber experiments still doing R&D, prototypes

Low thresholds (< 10 keV recoil)
- Access to low mass WIMPs
- Big advantage with respect to Xenon (worth x10 in mass)

Better rejection => more information about 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 have many checks that events are WIMPs

Comparison with other experiments

- CDMS - Ge and Si athermal and ionization
  - Very low threshold with additional rejection from timing
  - Very robust: insensitive to temperature and micorphonics
- EDELWEISS - Ge thermal and ionization
  - Our older and slower thermal detector technology
  - developing their own athermal sensors Nb_XSi_{1-X}
- CRESST - Ca_2WO_4 thermal and scintillation
  - Very low threshold but no light for W & O nuclear recoils
  - Have problems with phonon only signals from alphas
- ZEPLIN, XENON and XMASS - Xe ionization and scintillation
  - Worse threshold and no light for nuclear recoils
  - Can sufficiently low threshold be achieved with large mass ?
- DRIFT - CS_2 low pressure gas TPC
  - Only technology capable of determining event direction
  - Difficult to instrument sufficient mass to be competitive now

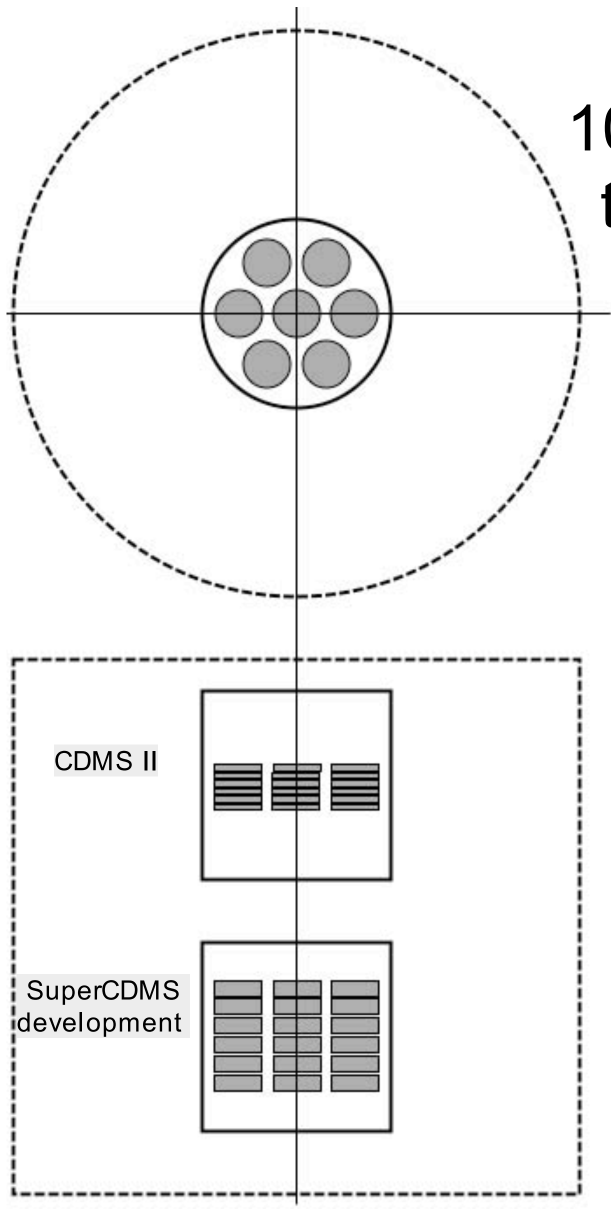
Cost of SuperCDMS Development Project

- Bottom line of $34M; comparable with CDMS II ($29M)
- Split almost evenly between DOE Lab, DOE University, and NSF
- DOE Lab is mostly Fermilab
  - Fermilab base = $1.7M/year fully-loaded salaries
    - Assumes 1 new associate scientist
  - Project = $0.6M/year operations costs
    - Dominated by cryogens, but significant travel, management costs
    - Modest increase from present level of $0.5M/year

Sum of Cost3 (w/contingency)	fund		
Agency	Base	Project	Grand Total
DOE Laboratory	6,727,047	3,751,233	10,478,280
DOE University	7,135,178	5,792,222	12,927,400
NSF	3,210,088	7,283,331	10,493,420
Grand Total	17,072,313	16,826,786	33,899,099

Dan Bauer
PAC meeting
Nov. 13, 2004

Soudan "Icebox" vs. "SNObox"

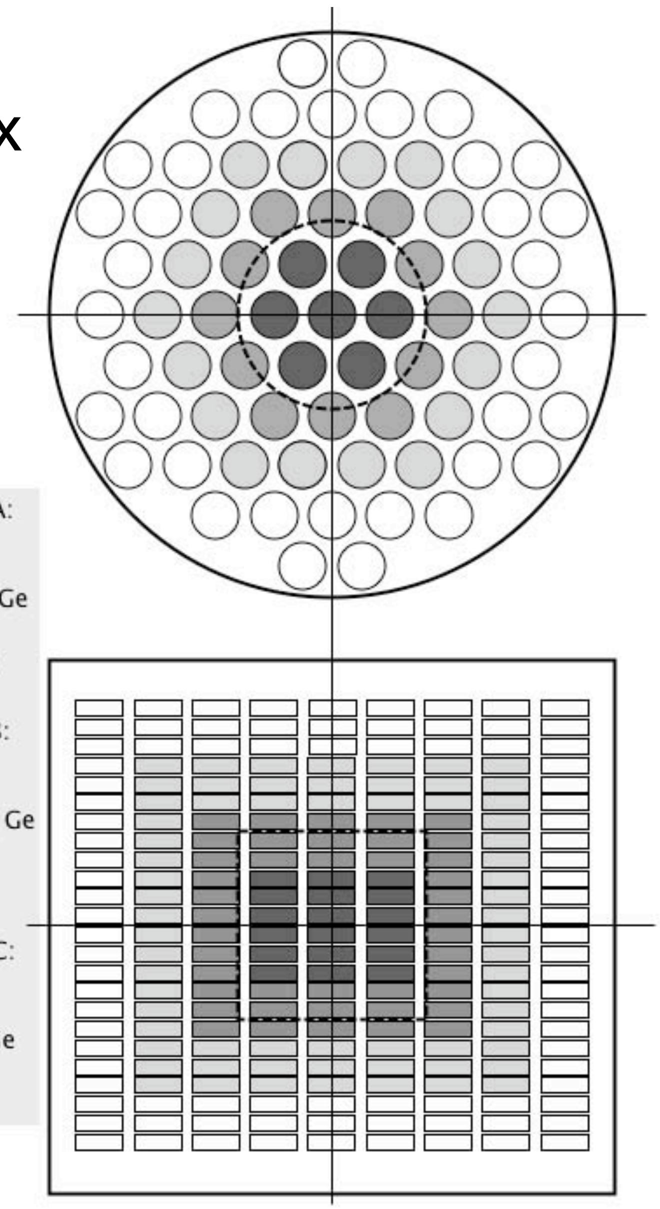


1000 kg (100x the detector volume) in 30x the volume

SuperCDMS – Phase A:
3"x1" => 0.64 kg Ge
7 x 6-Det Towers =
42 Dets =>to 26.7 kg Ge
Soudan -> SNOLAB
SUF testing (2 batches)

SuperCDMS – Phase B:
3"x1" => 0.64 kg Ge
19 x 12-Det Towers =
228 Dets =>to 145 kg Ge
Soudan/SUF testing
(6 batches)

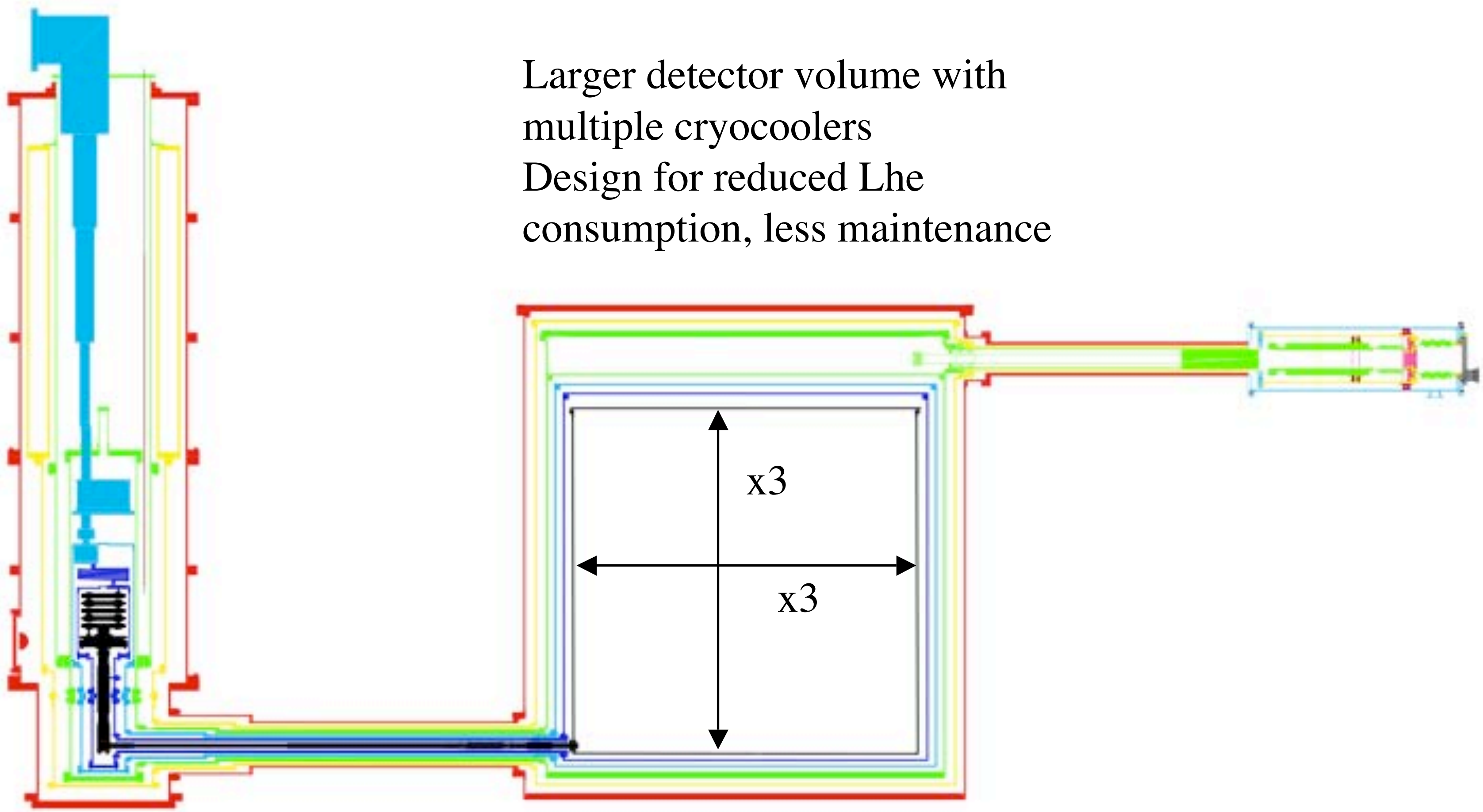
SuperCDMS – Phase C:
3"x1" => 0.64 kg Ge
73 x 24 Det Towers =
1752 =>to 1,113 kg Ge
Soudan/SUF testing
(45 batches)



Dan Bauer
PAC meeting
Nov. 13, 2004

More detectors; a larger cold volume

Larger detector volume with
multiple cryocoolers
Design for reduced Lhe
consumption, less maintenance



Fermilab role - past, present & future

- Past and present responsibilities
  - Front end and RTF electronics boards
  - Soudan cryogenics and infrastructure
  - Computing support
  - Management - PROJECT MANAGER
- Future during CDMS III (similar level of resources)
  - Continue Soudan cryogenics and electronics upgrades
    - New Cryogenics design for larger experiment
  - Continue project management and Soudan operations roles
- Future scientific leadership IF resources are increased
  - Additional senior research staff to lead analysis group
  - Major role in developing and maintaining analysis code
  - Will lead to success in postdoc hires

Since August, we have had a CDMS postdoc at Fermilab!

Dan Bauer
PAC meeting
Nov. 13, 2004

Current Fermilab Presence in CDMS

- Scientific (3 FTE)
  - Dan Bauer (100%)
    - Project Manager, Soudan operations and infrastructure, cryogenics, electronics, analysis
  - Mike Crisler (25%)
    - Electronics, analysis
  - Don Holmgren (25%)
    - DAQ, computing, analysis
  - Erik Ramberg (25%)
    - Analysis
  - Roger Dixon - On temporary loan to Accelerator Division!
  - **Jonghee Yoo (100%) - New Postdoc as of August!**
    - Much needed help in analysis
  - Possible Wilson Fellow or associate scientist
    - If Fermilab budget allows
- Technical (4 FTE)
  - 2 FTE Engineering (Schmitt, Orr, Kula, Kovlovsky)
  - 2 FTE Technician (Lambin, B. Johnson, W. Johnson)
  - 0.25 FTE administrative and budget support (Maxine Hronek)


UC Berkeley, Stanford, LBNL, UC Santa Barbara,
Case Western Reserve U, FNAL, Santa Clara U,
NIST, U Colorado Denver, Brown U, U Minnesota