Cryogenic Dark Matter Search (SuperCDMS)

SuperCDMS collaboration

SuperCDMS Institutions

DOE Laboratory
Fermilab

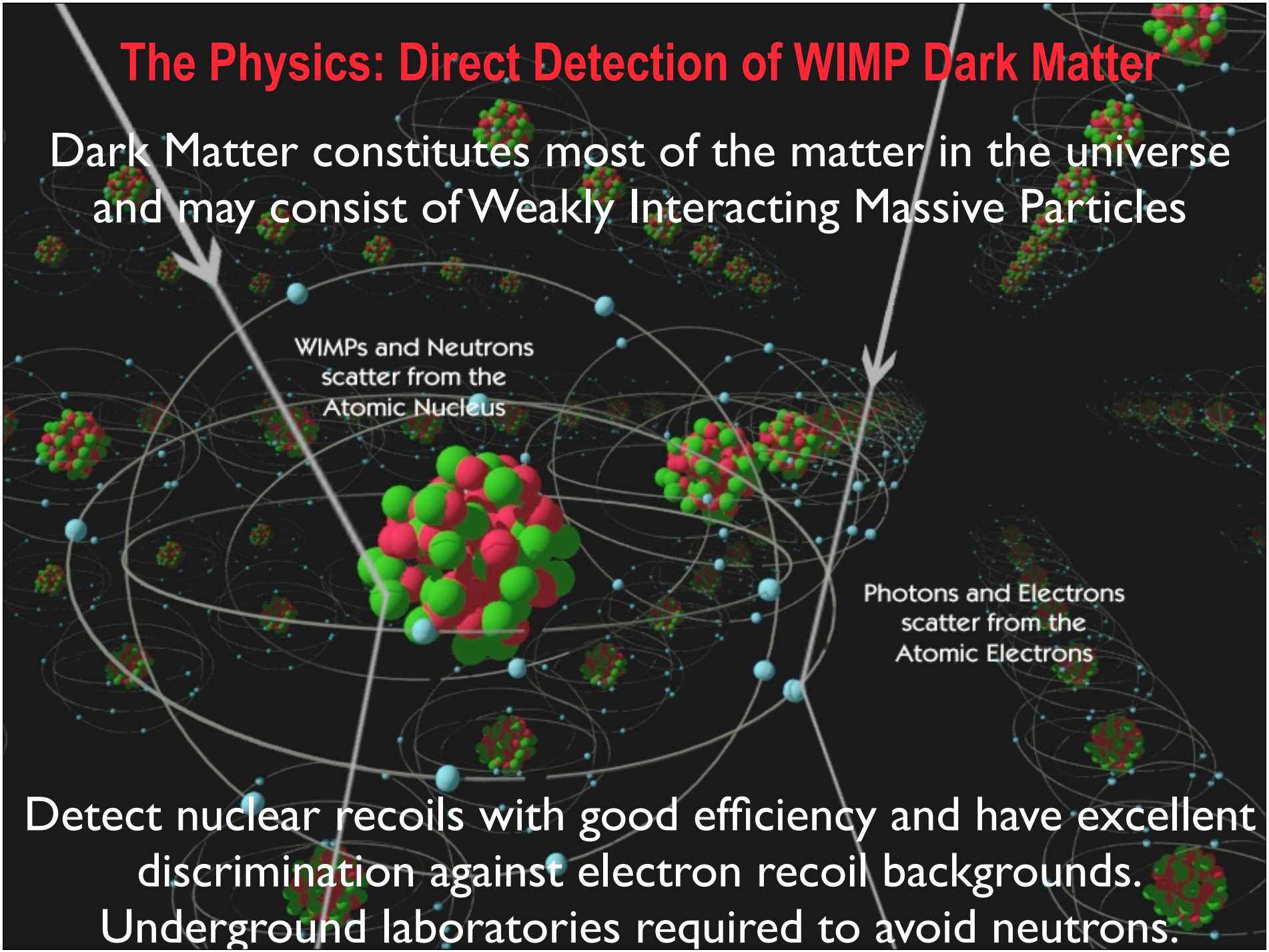
DOE University
CalTech
Florida
Minnesota
MIT
Stanford
UC Santa Barbara

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

Canada
Queens

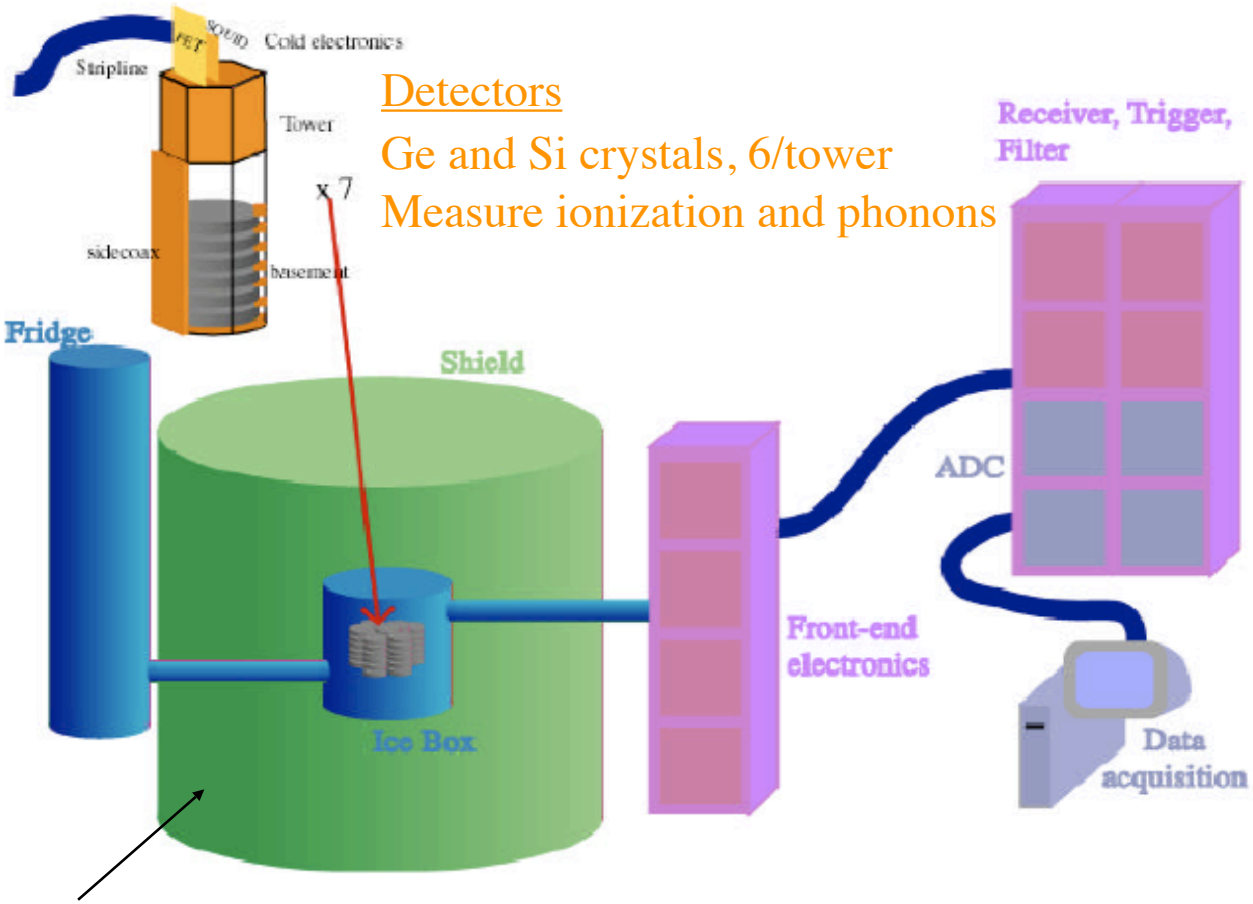
The Physics: Direct Detection of WIMP Dark Matter

Dark Matter constitutes most of the matter in the universe and may consist of Weakly Interacting Massive Particles



Detect nuclear recoils with good efficiency and have excellent discrimination against electron recoil backgrounds. Underground laboratories required to avoid neutrons.

CDMS in a nutshell



Detectors

Ge and Si crystals, 6/tower

Measure ionization and phonons

Cryogenics

Maintain detectors at <50 mK

Electronics /DAQ

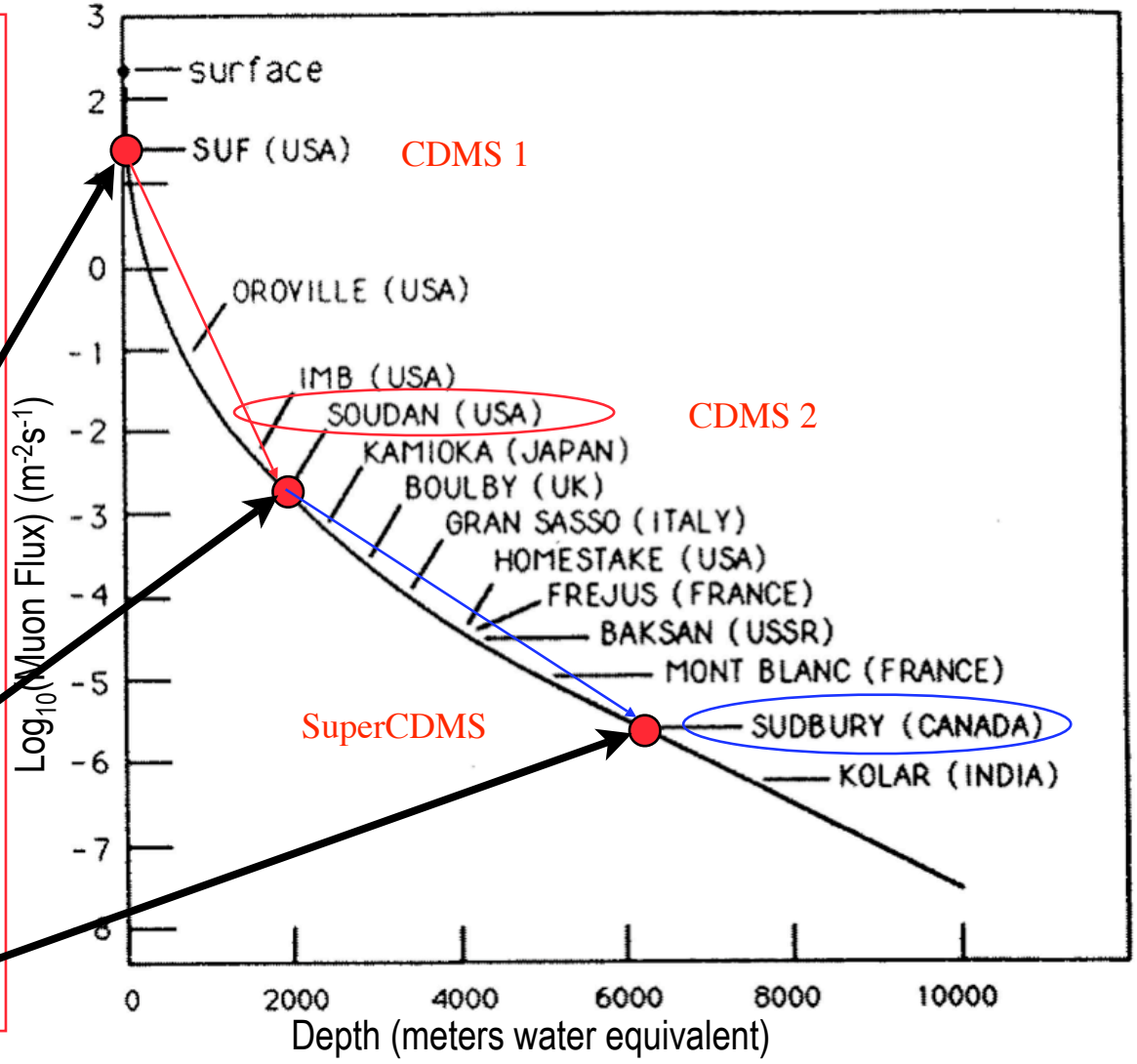
Record signals from detectors and veto; form trigger

Shielding

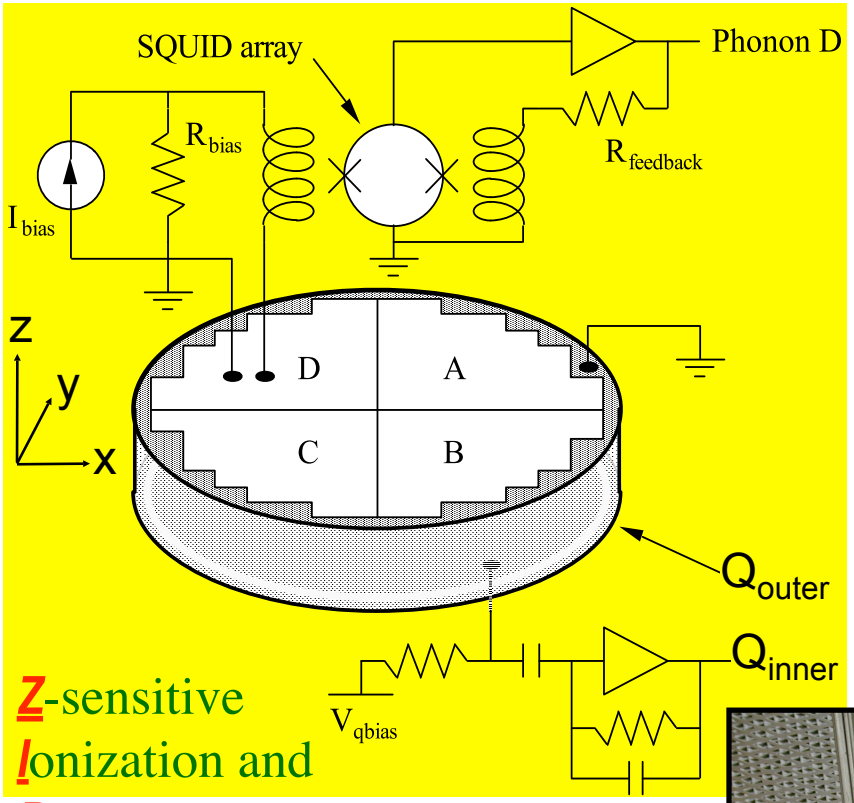
Layered shielding (Cu, Pb, polyethylene) reduces radioactive backgrounds and active scintillator veto is >99.9% efficient against cosmic rays. Soudan overburden (2341') reduces cosmic ray flux.

Why are we doing this deep underground?

- Neutrons from cosmic rays are irreducible background
  - At SUF
    - 17 mwe
    - 0.5 n/kg-d
  - At Soudan
    - 2090 mwe
    - 0.05 n/kg-y
  - At SNOLab
    - 6060 mwe
    - 0.2 n/ton-y



Really Cool Detectors: ZIPs



Z-sensitive
Ionization and
Phonon-mediated

Measure ionization in low-field (~volts/cm) with segmented contacts to allow rejection of events near outer edge

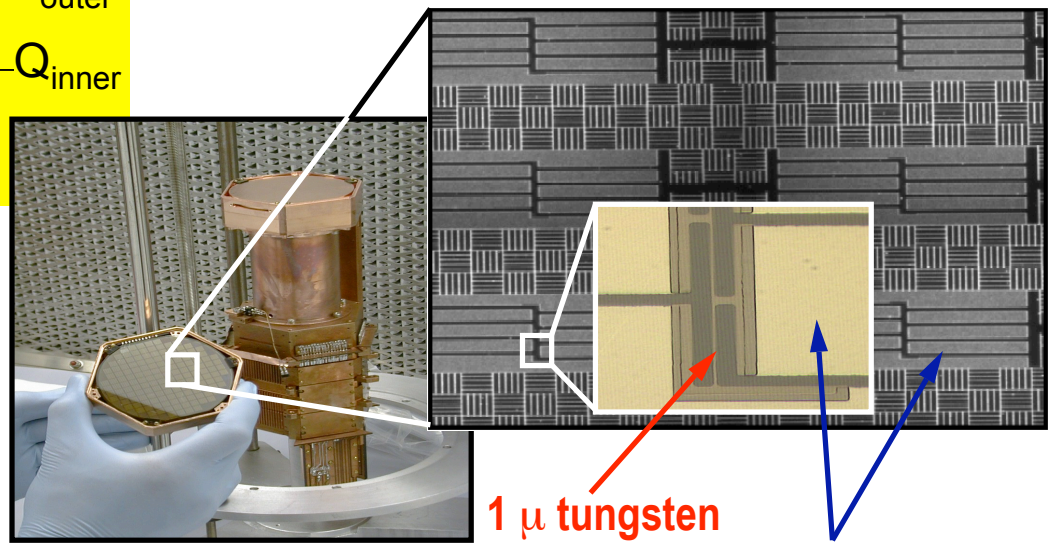
CDMS II: 250 g Ge or 100 g Si crystal

1 cm thick x 7.5 cm diameter

Photolithographic patterning

Collect athermal phonons:

- Crystal lattice vibrations
- Speed of sound in crystal ~ 1 cm/ms results in measurable delays between the pulses of the 4 phonon channels => position sensitivity



Active Background Rejection

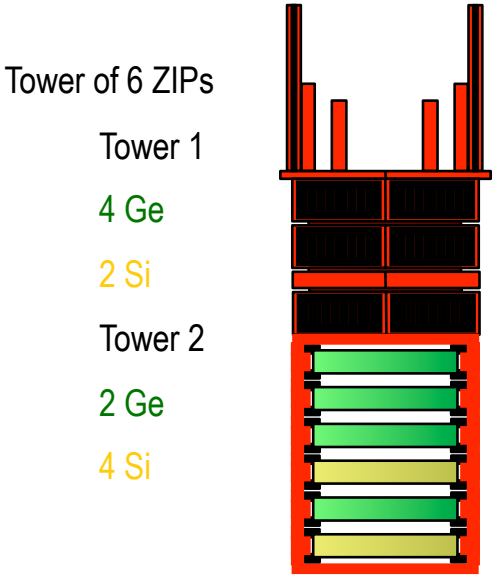
Detectors with excellent event-by-event background rejection

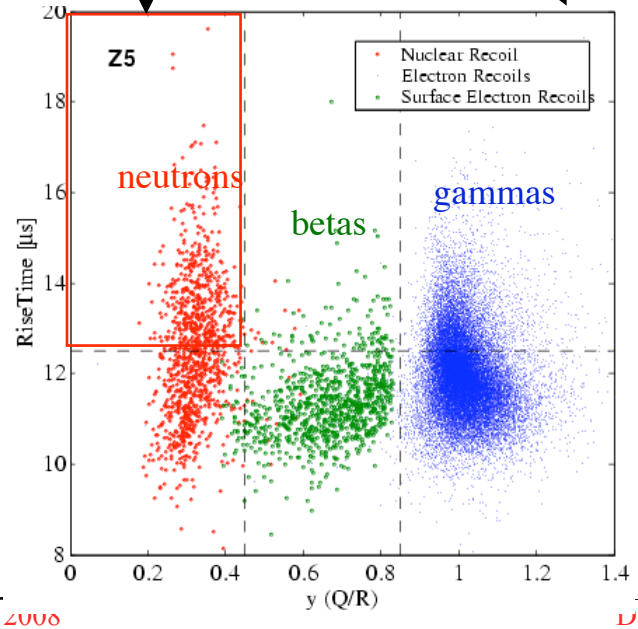
Use charge/phonon AND phonon timing

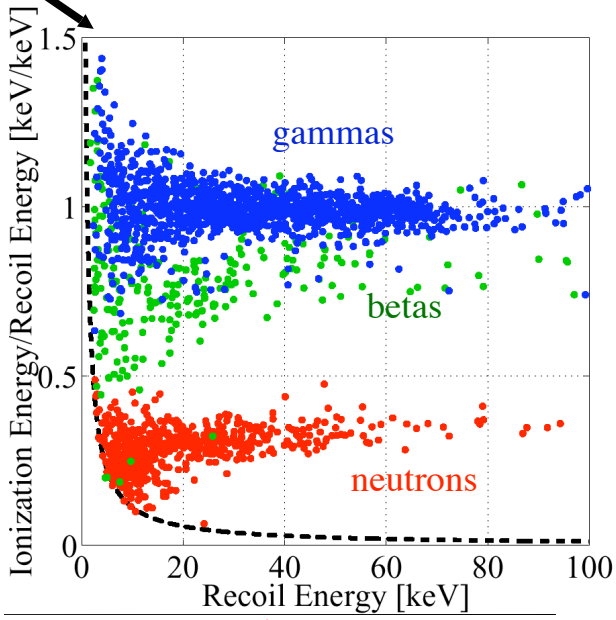
Measured background rejection:

99.9998% for γ's, 99.79% for β's

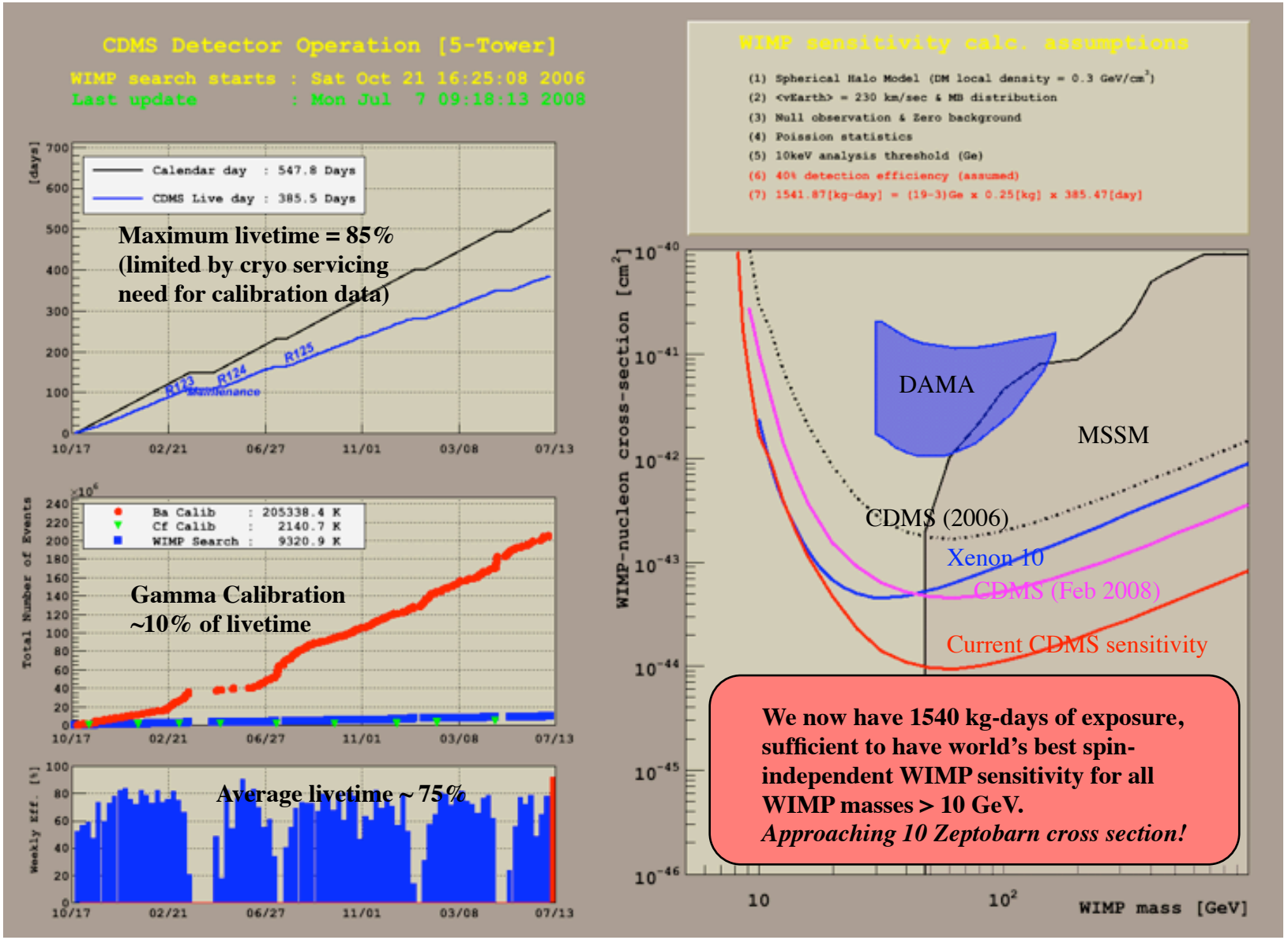
Clean nuclear recoil selection with ~ 50% efficiency





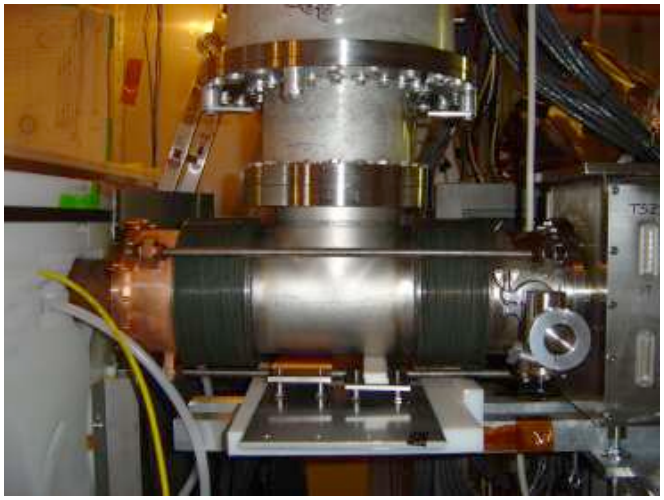


CDMS II taking data at Soudan

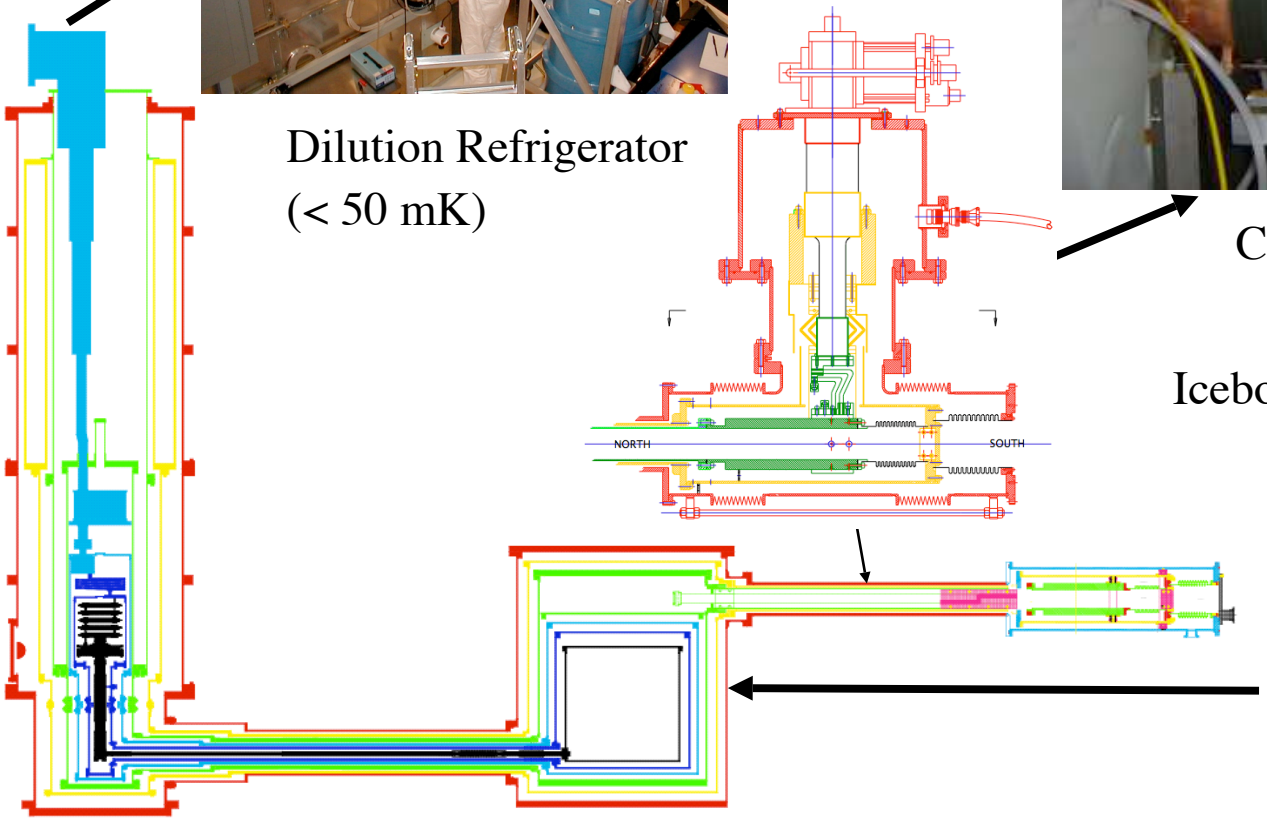


Cryogenics: How to get really cold in Minnesota!

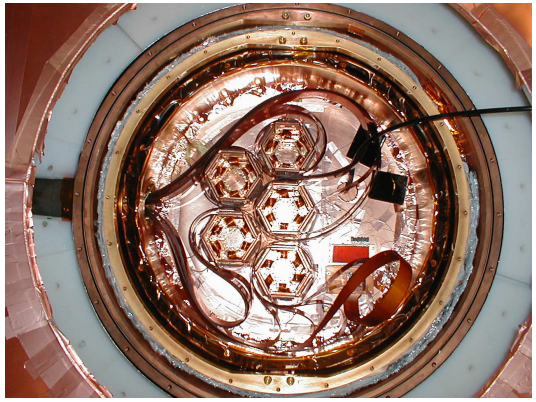
Dilution Refrigerator
(< 50 mK)



Cryocooler (77K and 4K)



Icebox (Detector Cold Volume)



Upgrades and Maintenance at Soudan

- Occasional short (~1 week) warming to 4-77K necessary
  - Service pumps, clean 3He/4He mixture
  - Important to have experienced technician help from Fermilab
    - Need about 4 weeks per year
- Would like to install He liquefier at Soudan

  Cryocooler-based liquefiers are now available

  Low maintenance, and low power (~7.5 kw), but capacity ~ 10 l/day

  Estimate a week of technician time to install

  Have surplus piston liquefier at FNAL

  Much higher capacity (20 l/hour), enough for our whole usage!

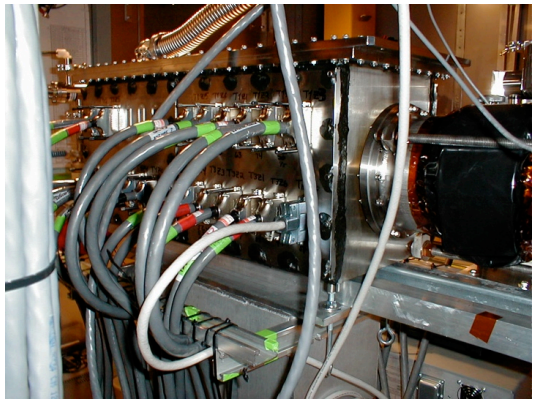
  Probably 2 weeks for installation and several trips per year to adjust

Note: Bruce Lambin has been our mainstay, but has just retired!
Two other FNAL techs have experience at Soudan: Bryan Johnson (D0) and James Williams (TD).

More upgrades (2009)

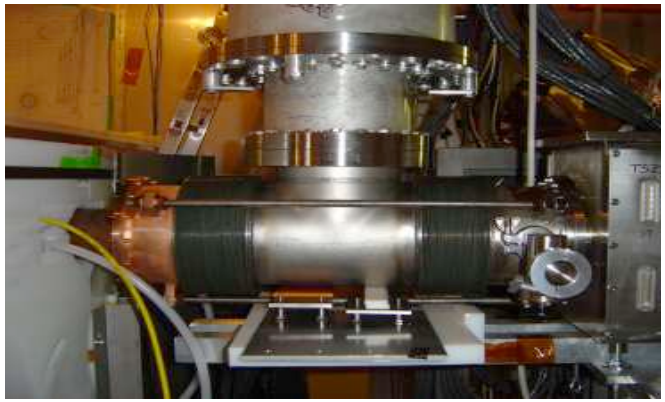
Replace vacuum bulkhead box where signals emerge (ebox)

- Continuing small air leak is troublesome
- New ebox tested and ready to ship to Soudan



Replace cryocooler head

- Already at 150% of recommended lifetime
- No sign of degradation yet, but better to be safe than sorry

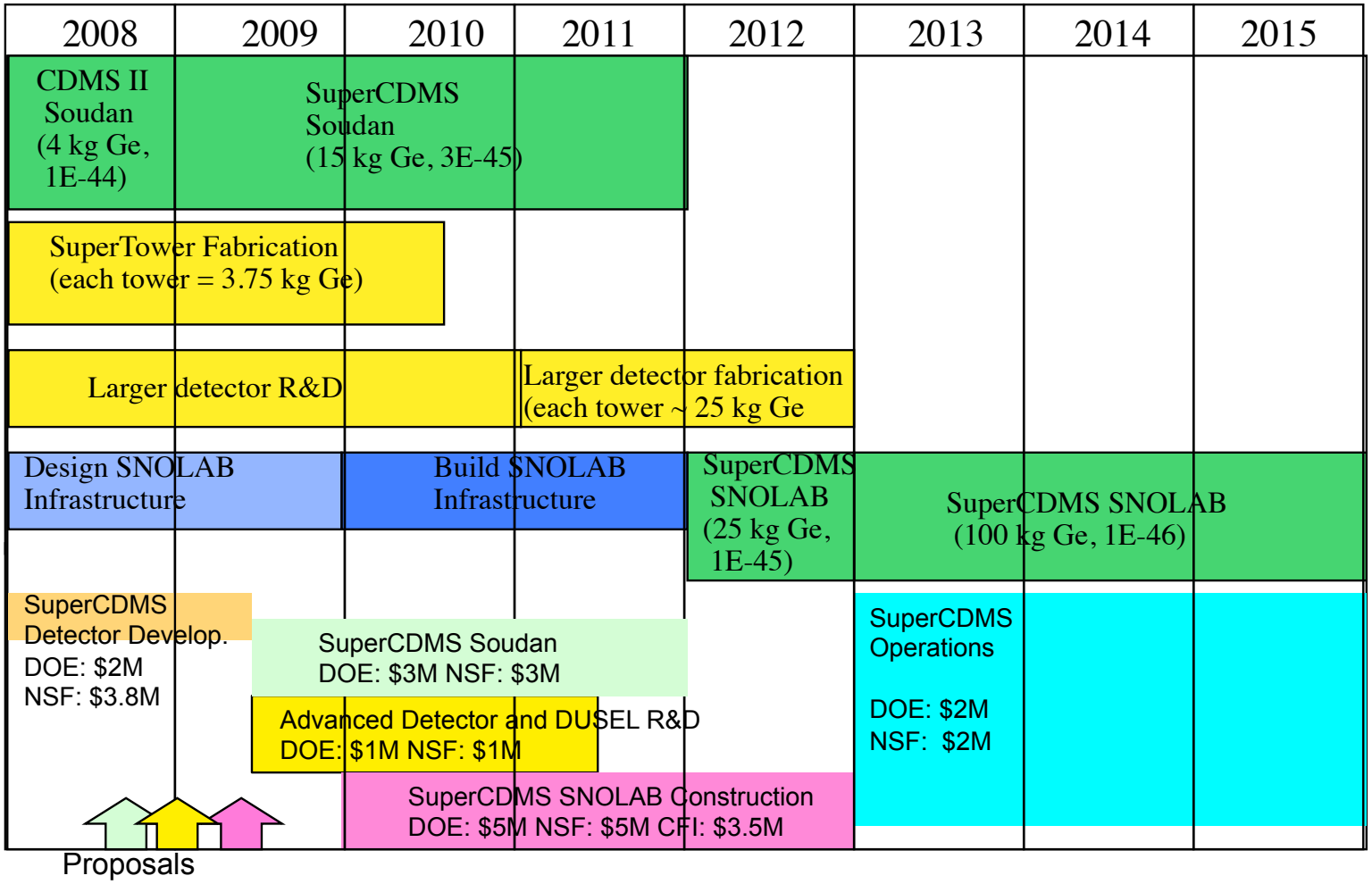


These two upgrades will require several weeks of technician time at Soudan

The Future: SuperCDMS

- Science goals
  - Increase sensitivity by x100 (compared with current)
    - Reach WIMP-nucleon cross section of 10^{-46} cm^2
  - Find WIMP signal and compare with LHC
- Technical goals
  - Increase detector mass in stages
    - Soudan (4 kg -> 15 kg by 2010)
    - SNOLAB (100 kg by 2012)
  - Stay background free
    - Challenge to deal with existing backgrounds at Soudan
    - New experiment needed at SNOLAB to reduce neutron background
- Current status
  - First Soudan stage funded by DOE/NSF
  - SNOLAB experiment has CD-0 and Stage 1 approval from FNAL Director
  - DMSAG review in 2009 needed for DOE/NSF to approve

SuperCDMS


2008
2009
2010
2011
2012
2013
2014
2015
CDMS II Soudan (4 kg Ge, 1E-44)
SuperCDMS Soudan (15 kg Ge, 3E-45)
SuperTower Fabrication (each tower = 3.75 kg Ge)
Larger detector R&D
Larger detector fabrication (each tower ~ 25 kg Ge
Design SNOLAB Infrastructure
Build SNOLAB Infrastructure
SuperCDMS SNOLAB (25 kg Ge, 1E-45)
SuperCDMS SNOLAB (100 kg Ge, 1E-46)
SuperCDMS Detector Develop.
DOE: $2M
NSF: $3.8M
SuperCDMS Soudan
DOE: $3M NSF: $3M
Advanced Detector and DUSEL R&D
DOE: $1M NSF: $1M
SuperCDMS SNOLAB Construction
DOE: $5M NSF: $5M CFI: $3.5M
SuperCDMS Operations
DOE: $2M
NSF: $2M
Proposals
Goals
1E-44
1E-45
1E-46

SuperCDMS Engineering Needs

Systems (Fermilab contributions)

Detectors
- Inspection/repair facilities (SiDet)
- Possible test facility (dilution refrigerator)

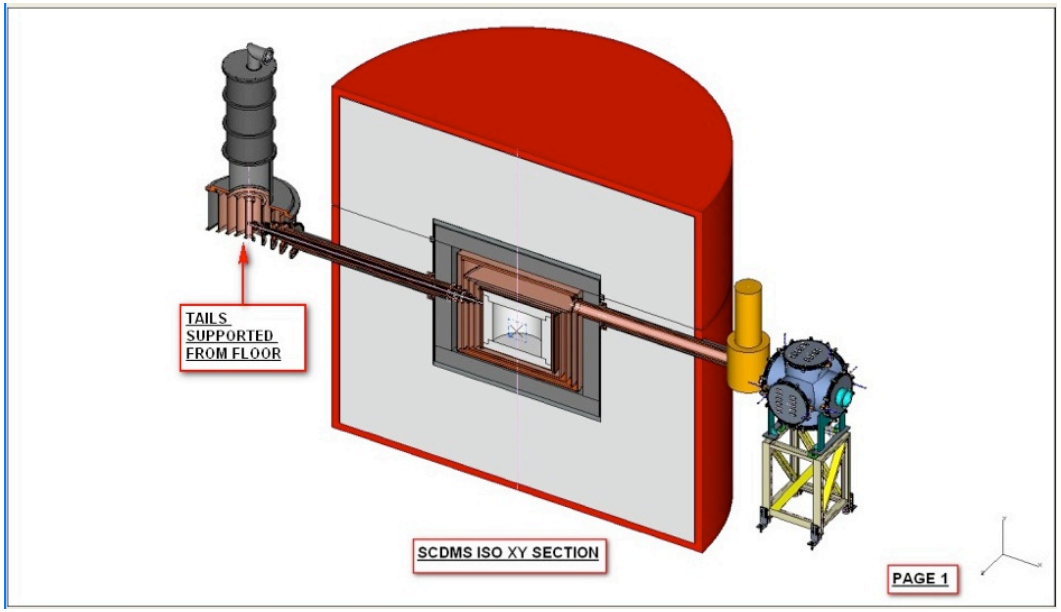
Cryogenics
- Mechanical and thermal design
- Construction

Shielding and Backgrounds
- Mechanical design
- Construction
- Background screening (alphas, neutrons)

Electronics
- New design for warm electronics
- Construction and testing

DAQ and Computing
- Data acquisition (event builder, control, monitoring)
- Onsite computing
- Analysis farm

Infrastructure
- Mechanical supports, crane, and clean rooms
- Electrical (especially power and computing)



Integration and System Testing

Vital to put all components of the experiment together at Fermilab and test thoroughly before moving to SNOLAB

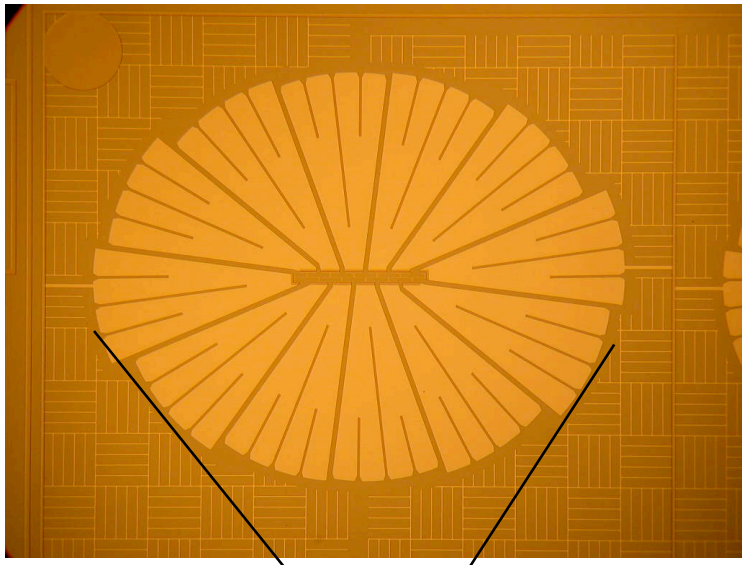
Detectors for SuperCDMS

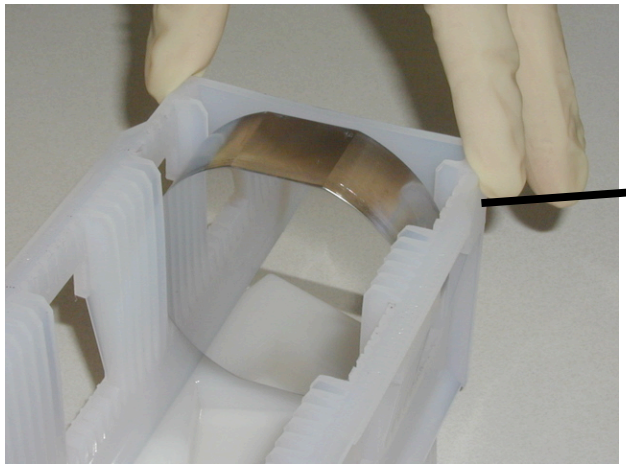
SuperCDMS ZIPs:
3" dia x 1" => 0.64 kg of Ge

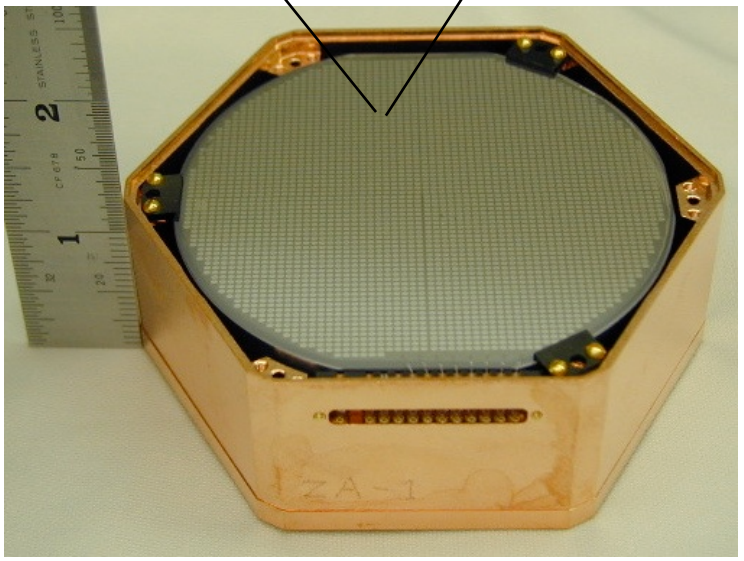
Inspection and repair facility

Use SiDet OGM and SiDet personnel to inspect and repair wire bonds, defects

The work load depends on rate of problems. Probably 2-6 weeks/year







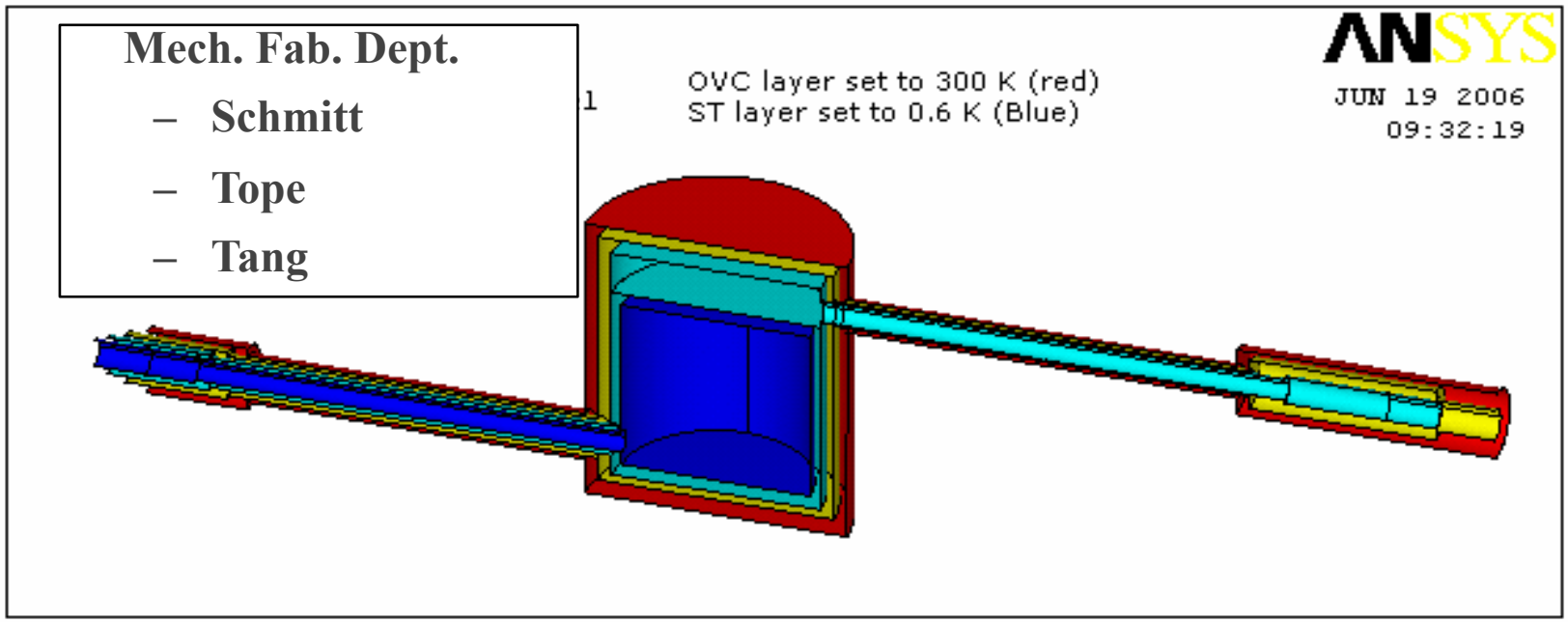
Cryogenic and Detector Testing

- Dilution Refrigerator and cryocooler
  - Trying to make salvaged fridge from Princeton work
  - Vibration testing on pulse-tube cryocooler
  - Ultimately will have to set up new cryogen-free fridge
- Lab Space and Technicians
  - Fridge in PAB now (Kendziora, Ruschman)
  - Lab 3 clean room has been modified to accommodate dilution fridge and area identified for pumps (Ruscinski, Wilson). Will need tech help there to operate.
  - Cryocooler testing in Lab 3

Cryogenic Design - Thermal Modeling

Mech. Fab. Dept.

- **Schmitt**
- **Tope**
- **Tang**



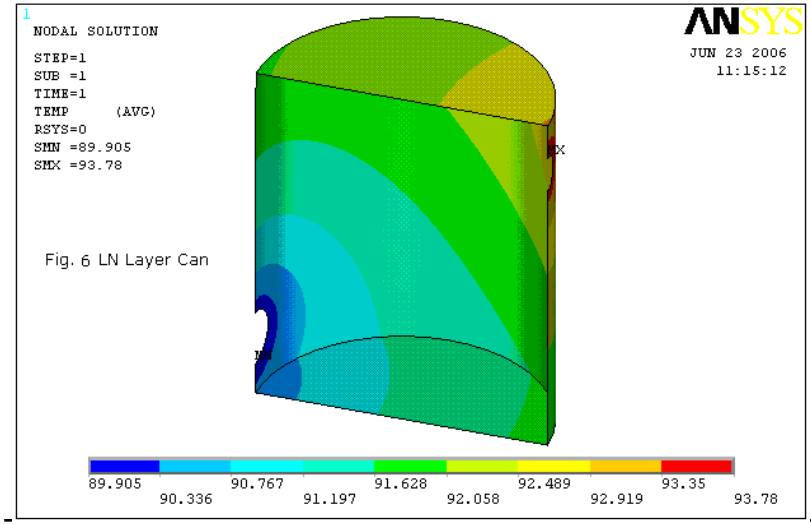


Fig. 6 LN Layer Can

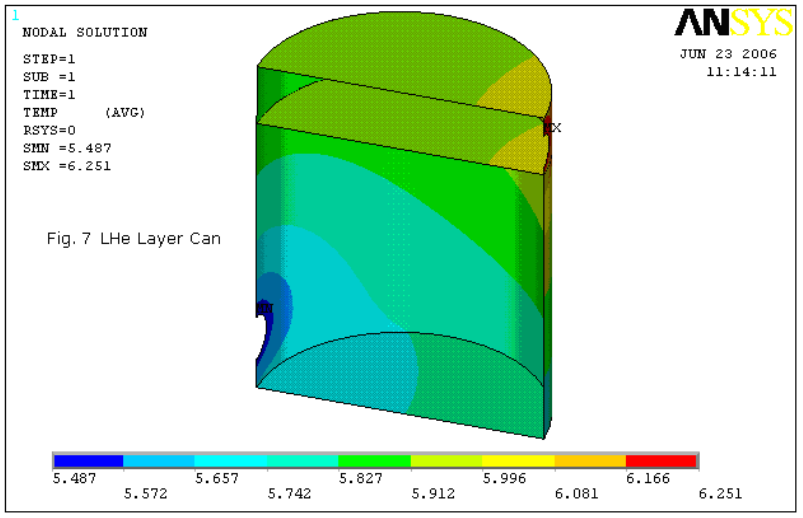
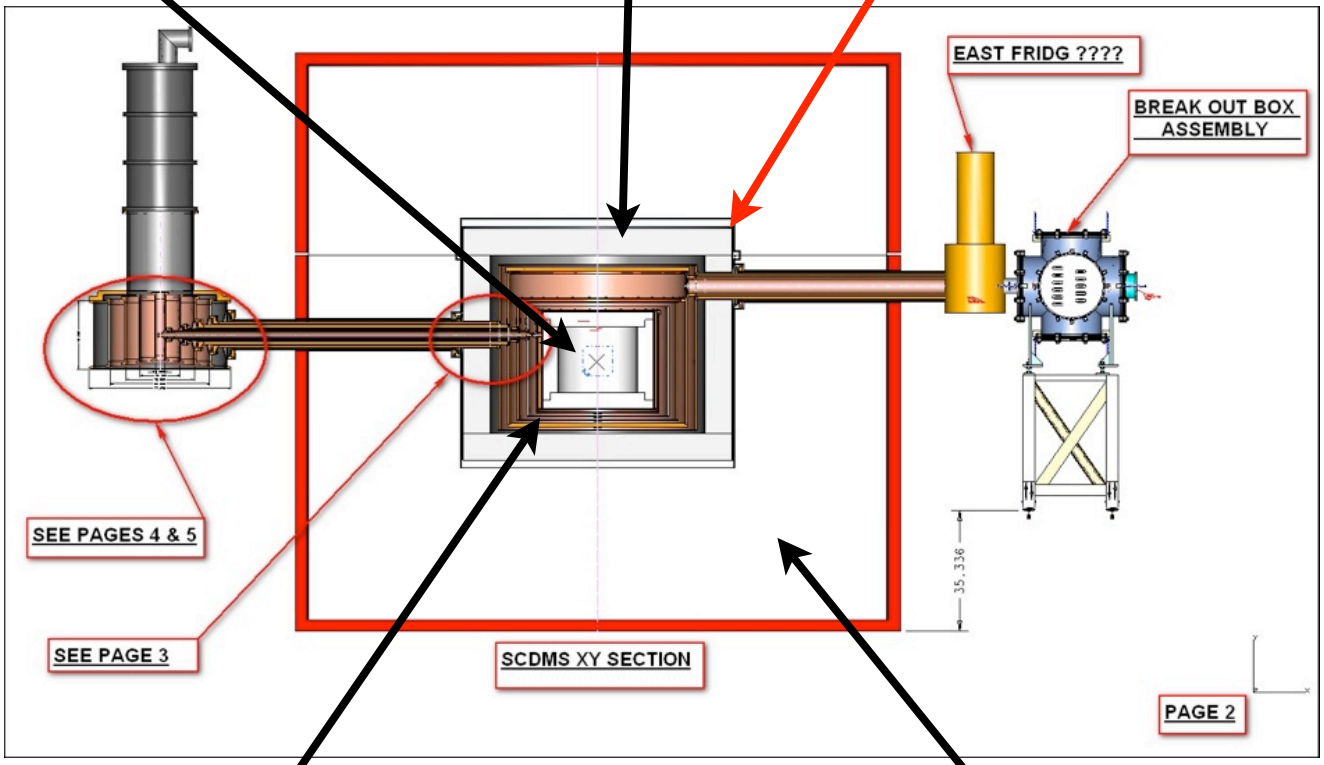


Fig. 7 LHe Layer Can

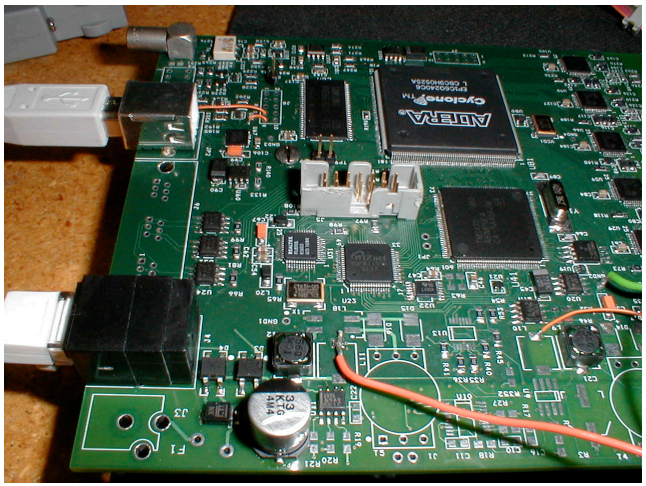
Shielding and Veto Design

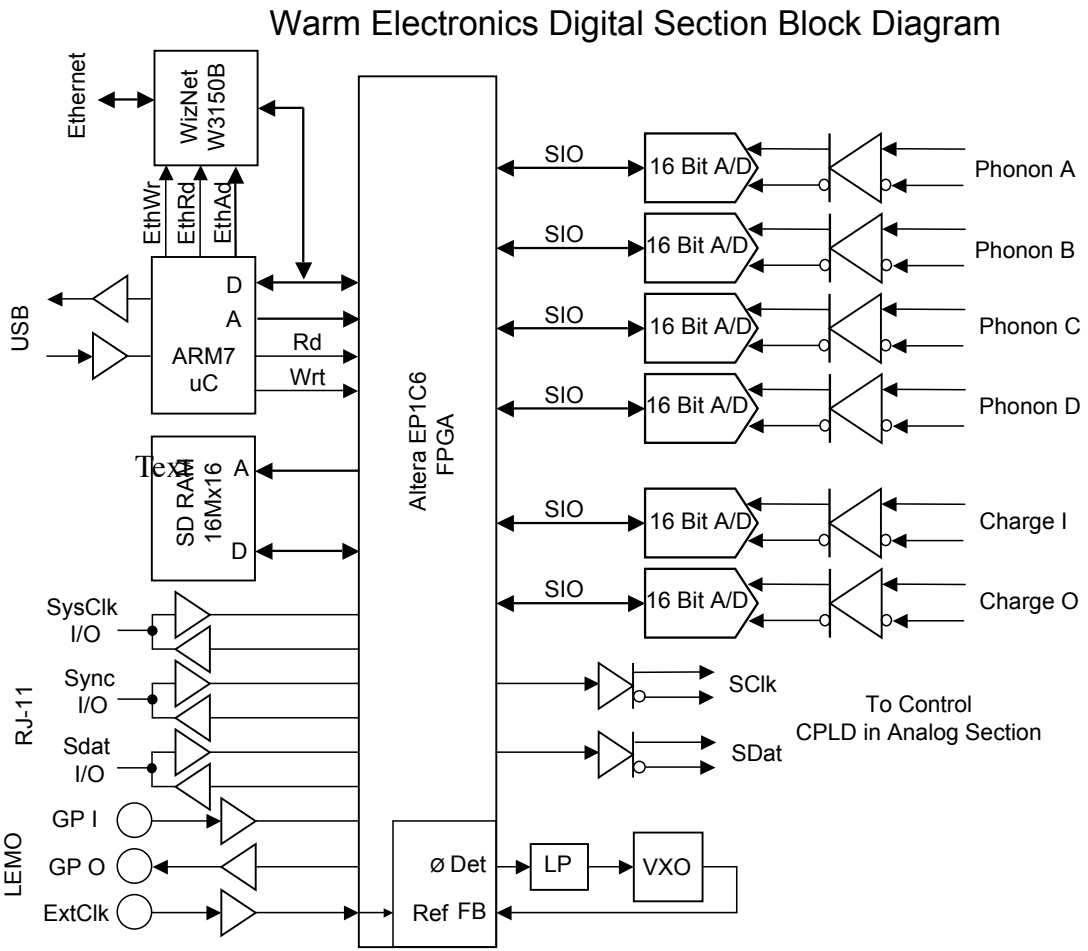
Mech. Fab. Dept.
Schmitt
Villegas
Drafters



Warm Electronics

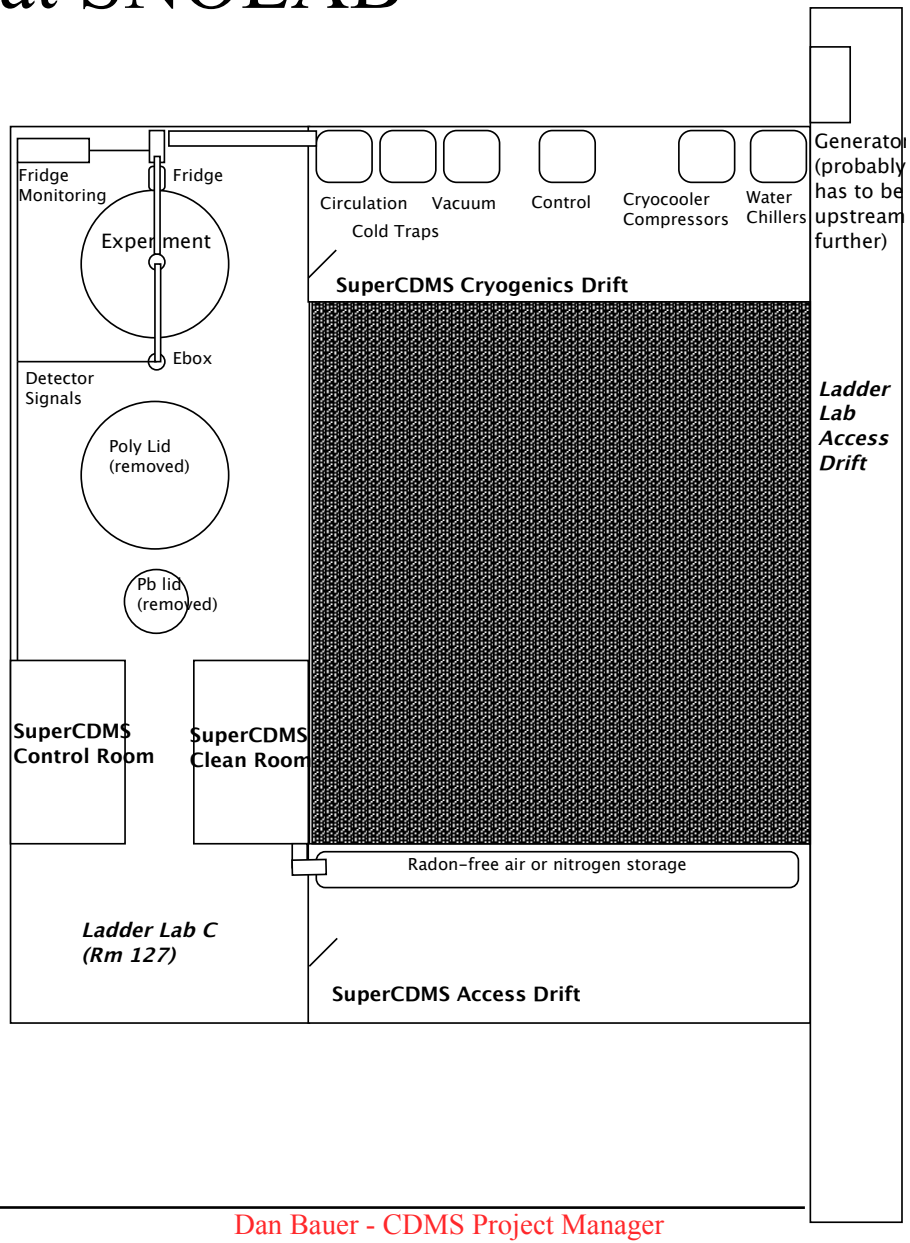
- One new card replaces functions for old front end card, trigger & filter card and the digitizer
- Units - powered, controlled and read out over ethernet
- **Electronics Dept,**
  - **Hansen**
  - **Kiper**
  - **Wayne Johnson**





Infrastructure at SNOLAB

- Tailored to layout of SNOLAB
- Main infrastructure in ladder lab
- Services in side drifts
- All access by hoist in active mine
- May need FESS help with infrastructure design
  - Substantial increase in engineering and technician time will be needed in 2010-2012 for system test at FNAL and deployment at SNOLAB.



Background reduction

SuperCDMS sensitivity depends on reduced backgrounds

- Gammas - Urgent need for low-level screening of materials (U/Th/K)
- Betas - Developing techniques to screen for beta-emitting contaminants
- Alphas - Counting may give alternate way to characterize U/Th backgrounds
- Neutrons - Need to measure fission and (alpha,n) sources
- Radon - Need to understand 210Pb deposition on materials

What can we do at Fermilab?

- Possible synergy with COUPP efforts on alphas, neutrons, Radon
- Explore capabilities of ES&H counting facility for gammas
- Setup and operate alpha and neutron counting facilities at Soudan

Modest level of engineering, technician help needed in next year.

Data Acquisition and Computing

- Plan to modify CDMS II DAQ
  - Main difference is communication with new electronics
  - Modify event builder fast loop (asyncronous operation)
  - Use LabVIEW for Control and Monitoring
- Online and offline computing
  - Mainly ‘off the shelf’ farm for SNOLAB
  - Use analysis farm here at Fermilab

Need ~0.25-0.5 FTE from CD for this work (Don Holmgren + ?)

Summary of engineering needs

FY2009 CDMS budget request to PPD/EPP/FCPA

Labor breakdown		FY 2005 FTE	FY2006 FTE	FY2007 FTE	FY2008 FTE	FY2009 FTE
Physicists						
	Bauer	1	1	1	1	1
	Yoo	1	1	1	1	1
	DeJongh	0.25	0.5	0.5	1	1
	Ramberg	0.25	0.25	0.25	0.25	0.25
	Hall	0	0	1	1	1
	Hsu	0	0	0	0.5	1
	Total Phys	2.5	2.75	3.75	4.75	5.25
Engineer						
	Schmitt	0.3	0.5	0.5	0.5	0.5
	Tope	0	0.5	0.5	0.5	0.5
	Hansen	0	0.5	0.5	0.5	0.5
	Total Eng	**0.3**	**1.5**	**1.5**	**1.5**	**1.5**
Mech. Fab. Design and Drafting						
	Villegas	0	0.25	0.25	0.5	0.5
	Drafting	0.25	0.25	0.25	0.25	0.5
	Total Desig	**0**	**0.25**	**0.25**	**0.5**	**1**
Technician						
	Electronics	0.5	0.5	0.25	0.25	0.25
	Mechanical	0.85	1	1	1	1
	Total Tech	**1.35**	**1.5**	**1.25**	**1.25**	**1.25**
Financial						
	S. Schulz	0.25	0.25	0.25	0.25	0.25
	additional	0	0	0	0.25	0.25
	Total Finanical	0.25	0.25	0.25	0.5	0.5
Admin/Project Support		0.25	0.25	0.25	0.25	0.25
CD Support (data acquisition)						
	Holmgren	0.25	0.25	0.25	0.25	0.25
	Other					
FESS support		0	0	0	0	0

Summary of budget

FY2009 CDMS budget request to PPD/EPP/FCPA

Item	FY 2006 funding	FY 2006 spent	FY2007 request	FY 2007 received	FY2007 spent	FY 2008 request	FY2008 Projected Spending	FY 2009 request
Cryogens	200	95	250	270	270	300	300	400
M&S	100	160	100	100	100	100	100	100
Travel	75	60	75	75	75	75	75	75
Phone	20	3	5	5	5	5	5	5
Computing		20	20	20	20	20	20	20
CDMS Total	395	338	450	470	470	500	500	600
SuperCDMS electronics			25	25	25	50	32	50
SuperCDMS Cryogenics	40	90	25	25	25	50	30	50
SuperCDMS Backgrounds						80	50	50
SuperCDMS Total						180	112	150
Grand total	**435**	**428**	**475**	**520**	**520**	**680**	**612**	**750**