Status of the Cryogenic Dark Matter Search

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What is CDMS?

Dark Matter Search

Goal is direct detection of WIMPs which may be what holds our galaxy together

Cryogenic

Cool very pure Ge and Si crystals to < 50 mK using dilution refrigerator

Active Background Rejection

Detect heat and charge

WIMPS, neutrons => nuclear recoils
Charge/Heat \sim 1/3
EM backgrounds => electron recoils
Charge/Heat = 1

Reject neutrons using multiple scattering

Neutrons do, WIMPS don’t

comparison of Ge to Si rates

Neutron cross sections similar, but WIMPs x5 higher in Ge

Shielding

Layered shielding against radioactive backgrounds and active scintillator veto (>99.9% efficient against cosmic rays).
ZIP Detectors

Z-sensitive Ionization and Phonon Detectors
Low-voltage ionization measurement
Athermal phonon measurement
low-noise SQUID readout

Measured background rejection:
> 99.9% for EM backgrounds using charge/heat
> 98% for $\beta$’s using pulse risetime as well
Better than expected in CDMS II proposal!

Tower of 6 ZIPs
Tower 1
4 Ge
2 Si
Tower 2
2 Ge
4 Si
CDMS 2001-2002 Data Run at Stanford


Early CDMS result w/o neutron subtraction
Early CDMS result with neutron subtraction
Present CDMS result w/o neutron subtraction
Expected CDMS sensitivity with neutron subtraction
DAMA signal essentially excluded
For standard halo and spin-independent interactions
Edelweiss at deep site
Higher energy threshold
Worse limits at low mass
No neutron background
Better limits at high mass
Priority for CDMS-II to “go deep”
CDMS II at Soudan

Increased depth reduces neutron background from ~1 / kg / day at Stanford to ~1 / kg / year at Soudan

Expect WIMP sensitivity of 0.01 / kg / kev /day

500 Hz muons in 4 m² shield

1 per minute in 4 m² shield

Soudan Mine, Northern Minnesota
713 m depth (~2000 mwe)
Commissioning nearly finished

All systems fully-installed and functioning
  Two towers of detectors installed
    only Tower 1 turned on so far
  Icebox steady at 50 mK
    cold enough to operate detectors, but not as cold as it should be
Cryogenics operation for last month has been stable
  Still some problems to sort out but lower priority
Warm electronics revisions essentially complete
  Haven’t completely understood the noise but good enough for now
New data acquisition functioning well
  But not all software tools available yet
Analysis system installed and functioning
  Need to debug further before routine data taking is possible
Calibration and some initial low-background data sets taken
  Plan to intermix data (nights, weekends) with testing and fixing (day)
Expect to be taking data most of the time by October 15
Soudan Facility
CDMS II Experimental Enclosures (Fermilab, Minnesota)
Cryogenics

CDMS II Icebox, Fridge (Fermilab)

Oxford 400 dilution refrigerator (identical to one we use at SUF)

Only one major problem in 6 years at SUF (2 months downtime to fix)
The Soudan fridge has been considerably more problematic

Superfluid leak in dilution unit (now fixed)
Leak from LHe bath to vacuum (manageable but high He consumption)

Offset “icebox” is cold volume for detectors

Modern cryogenic control and monitoring system

But reliability, electrical noise have been issues
CDMS II Installation at Soudan

Layered shielding and efficient veto vital for background reduction
Robust DAQ/analysis with remote control and monitoring
Detectors

Tower-1 for Soudan thoroughly tested in Run 21 at SUF
  4 Ge and 2 Si ZIPs - background rejection better than expected; beta background on bottom Si detector
Tower-2 for Soudan; detectors tested in final run at UCB
  2 Ge and 4 Si ZIPs - backgrounds unknown, but expected to be lower due to better handling
Two towers successfully installed in Soudan icebox
  Transport issues (shipping delicate towers)
  Installation issues (especially Radon)
Early Results from CDMS II at Soudan

Energy calibration: Data versus Monte Carlo

Good resolution of lines from 133Ba source
Agreement will get better when
- Data analyzed using new fit templates
- Higher statistics
Early Results from CDMS II at Soudan

First look at $\gamma$’s from calibration source
(neutron calibration coming soon)
This plan achieves science goals from CDMS II proposal. Nevertheless, delays encountered with cryogenics, detectors make this non-optimal for science.
CDMS II Expected Sensitivity

Deep site => reduced backgrounds => linear sensitivity improvement
Expect factor of 10 improvement over current CDMS results by end of 2003.

Detector performance improvements mean we should still reach original CDMS II goals
Crucial issue: where do backgrounds start to appear?

Marks change from linear to $\sqrt{MT}$ improvement
1/$\sqrt{MT}$ extrapolation assumes that background can be subtracted statistically with negligible systematic errors.
Lack of detailed knowledge may halt sensitivity improvement prematurely

Cleaner detectors or better background rejection extend linear improvement range.
Current CDMS result from Stanford site (blue curves)  
Best WIMP limits at low mass  

CDMS II should begin taking data in October 2003  
Expect x10 improvement in limits by end of 2003  
(or maybe hint of a signal?)  

No other running experiment will make such rapid progress  
Power of active background rejection.