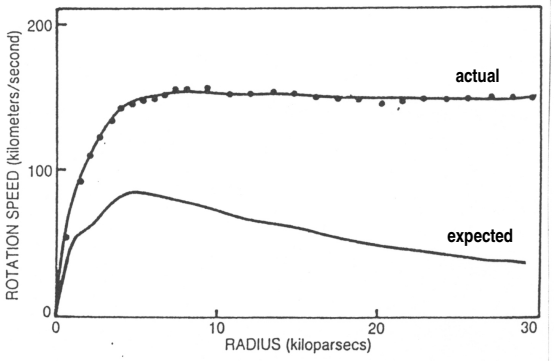
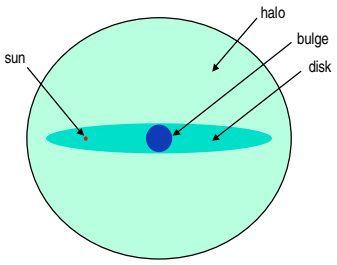
Looking for WIMPs:
Dark Matter Relics from the Big Bang

Dan Akerib
Case Western Reserve University
and
CDMS Collaboration

Dark Matter: the Missing Mass Problem



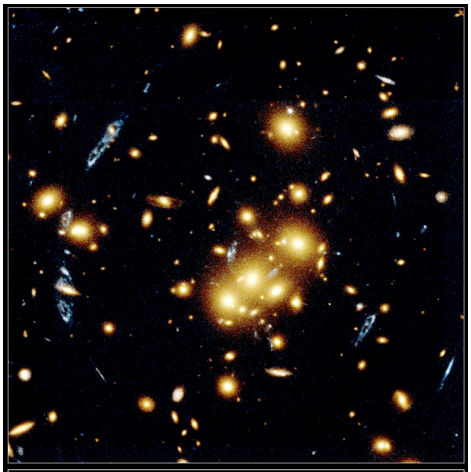


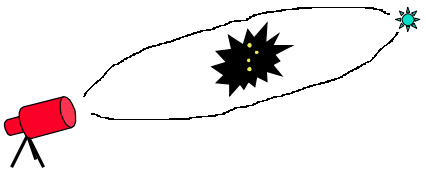
The Milky Way

Speed of orbits
→ Strength of Gravity
→ Missing Mass

2

Other ways to 'see' it – gravitational lens





Mass warps space,

Lensing indicates strength of gravity → dark matter!

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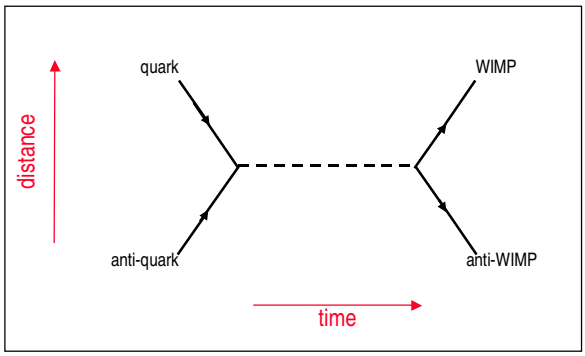
What is it? Extraordinary stuff!

- **Early Universe as Particle Factory**
  - **Not enough protons and neutrons produced in the Big Bang**

Convert energy to mass

$E=mc^2$



- ***A new type of particle:*** **WIMPs = weakly interacting massive particles**

Massive: source of gravity **Weakly-interacting: not star forming**

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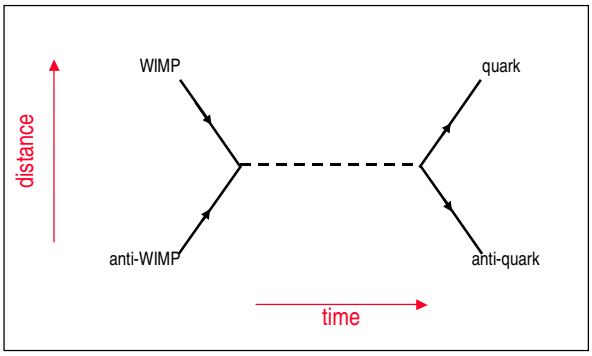
Still around?

Expanding Universe and Weak Interactions – annihilations stop



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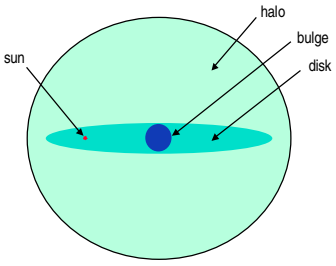
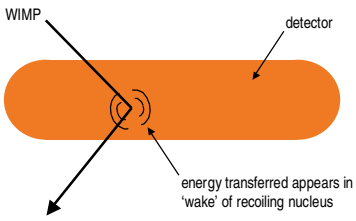
WIMPs in the Galactic Halo

WIMPs – the source of Mass in the Rotation Curves?



The Milky Way



WIMP-Nucleus Scattering

Scatter from a Nucleus in a Terrestrial Particle Detector

Big Problem: weakly interacting. Expect less than one-a-day in a kilogram detector

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In physics, we measure voltages…

Particle Detection

It's simple – detected particle ionizes the gas, collect the charge…

Or detected particle produces a flash of light, which is converted to 'photoelectrons'…

Or detected particle interacts with a nucleus, which ionizes the gas, which…

Or…

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Background Radioactivity

8

It's in the air: a practical demonstration

Before…

9

It's in the air: a practical demonstration

During…

10

It's in the air: a practical demonstration

After…

11

What nature has to offer

What you hope for!

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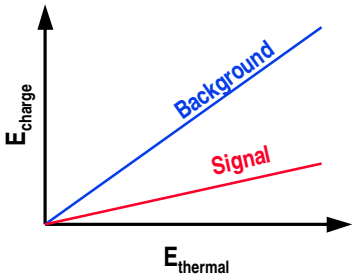
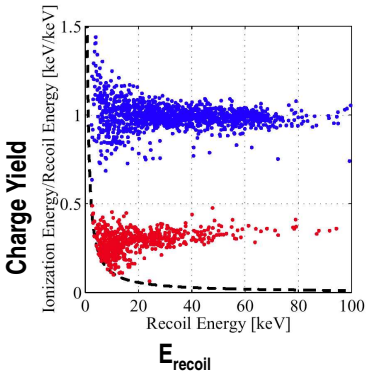
Getting rid of the haystack

WIMPs 'look' different

Photons and electrons collide with electrons

WIMPs (and neutrons) collide with nuclei





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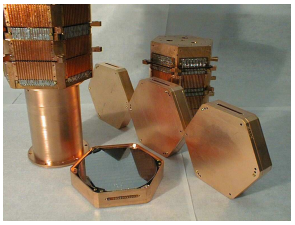
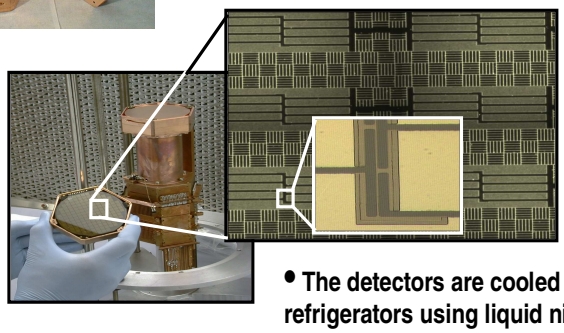
CDMS detectors



- Heat sensitive detectors sensitive to *individual particle interactions.*
- Operated near absolute zero ("cryogenic")
- Our experiment is called the Cryogenic Dark Matter Search (CDMS)



- The detectors are cooled in special refrigerators using liquid nitrogen and liquid helium

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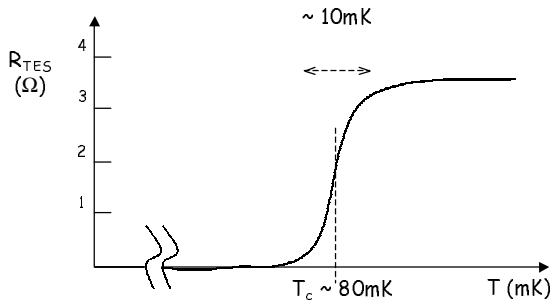
Superconducting Films: Ultrasensitive Thermometers

Superconducting films that detect minute amounts of heat



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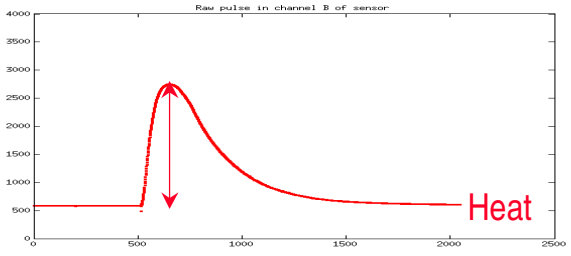
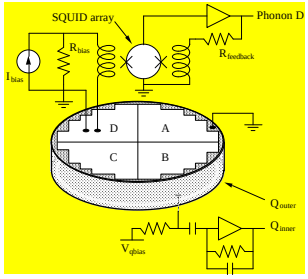
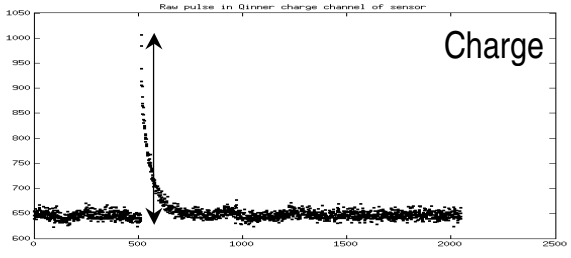
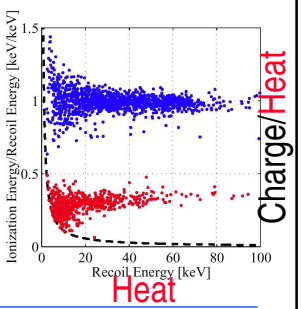
The Voltages We Measure









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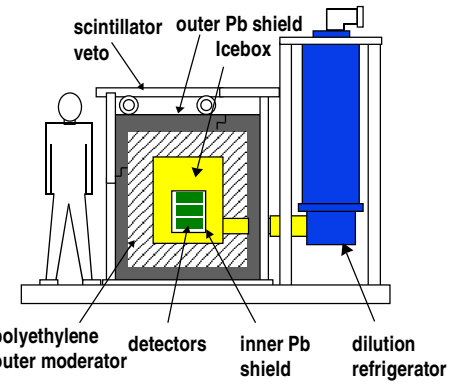
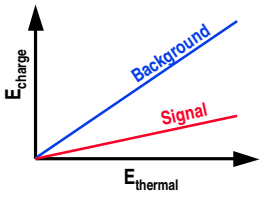
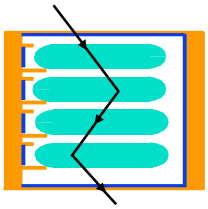
CDMS Strategy

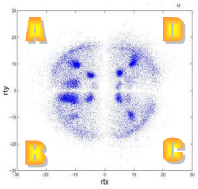
Lines of defense

- Underground site: hadrons, μ
- Muon veto: cosmogenic γ, β, n
- Pb shield: γ, β
- Poly shield: n
- Recoil type: γ, β
- Multiple-scatters: n
- Position sensitive









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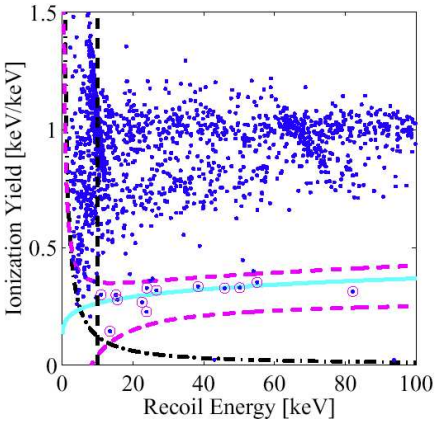
CDMS Data 1999

The detectors were exposed for a period of several months. The circled blue dots could be WIMP candidates, but we believe most or all of them are due to neutrons.

Preparing a more sensitive experiment (CDMS II) to start running next year



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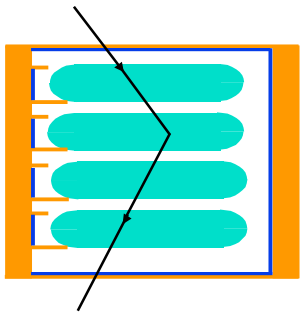
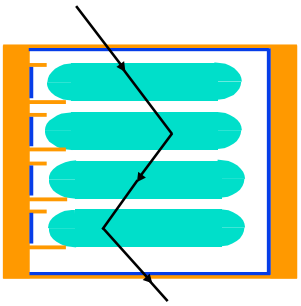
Neutrons: Single Scatters vs Multiple Scatters



Single-scatter nuclear-recoils are produced by WIMPs or neutrons.



Multiple-scatter nuclear-recoils are only produced by neutrons.

4 multiple-scatters are observed –

more than enough to account for 13 single-scatters.

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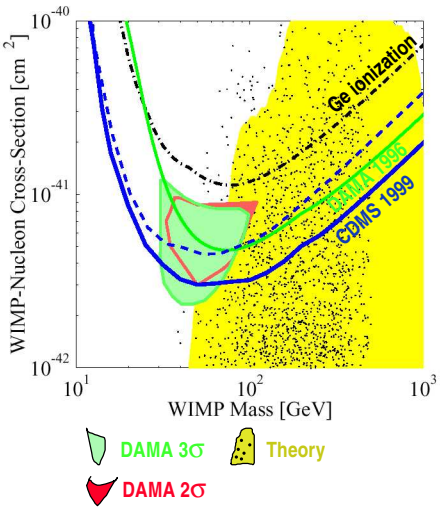
Limits on WIMP Size*

To quantify our non-detection of WIMPs for comparison with other experiments and theoretical predictions, a statistical analysis is performed. For each possible WIMP mass, we determine the largest WIMP size* that could have gone undetected in the data. The regions above the U-shaped curves are ruled out by various techniques.

The shaded/dotted regions are predictions from particle physics theories.



*Technically, these are point-like particles – by "size" we really mean a measure of the probability they will scatter from a nucleus. This probability is quantified by an effective "cross sectional" area.

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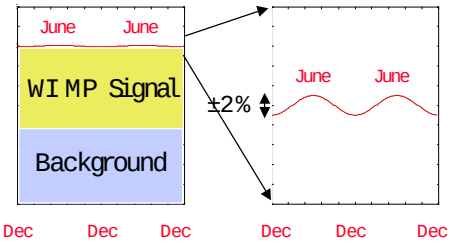
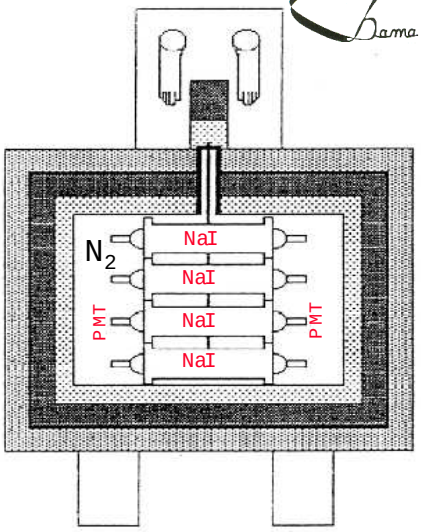
DAMA NaI Experiment

100x detector mass of CDMS, but living with the 'haystack!'

58,000 kg-days exposure (4 years)



See annual modulation signal!



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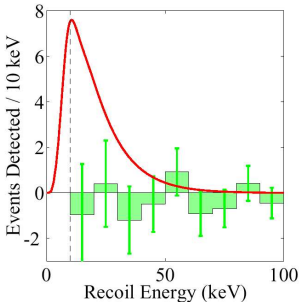
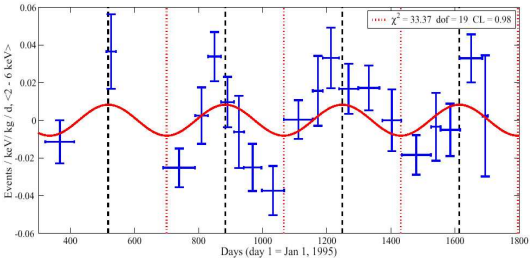
Interesting Times…

CDMS after background subtraction



The best simultaneous fit is shown in red -- too small to explain DAMA's amplitude but too large to go unseen in CDMS.

Amplitude of DAMA's modulation predicts significantly larger signal than observed in CDMS – only 1/1000 chance of a statistical fluctuation



DAMA 4 year data set

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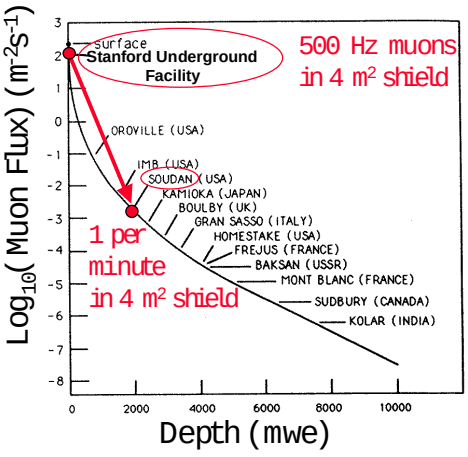
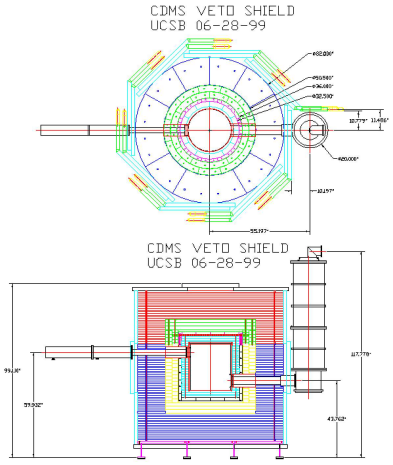
CDMS II in the Soudan Mine

Depth of 2000 mwe reduces neutron background from ~1 / kg / day to ~1 / kg / year





Experimental apparatus

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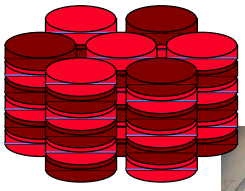
The CDMS II Apparatus



- **Eventually we will build 7 stacks of 6 detectors each and install them in the Soudan Mine**

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The CDMS II Apparatus (cont'd)

The Soudan Mine refrigerator includes a low-radioactivity '*clean room*' shielded environment (partially shielded in the photo).

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Working at Soudan

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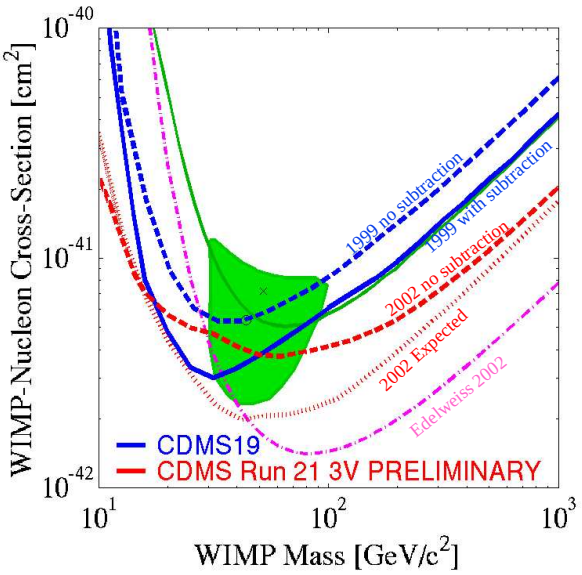
Looking ahead: curves, curves, and more curves



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The CDMS Collaboration

..at a recent collaboration meeting, 2000 feet underground

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The CDMS Collaboration

Case Western Reserve University
D.S. Akerib, D. Driscoll, S. Kamat, T.A. Perera, R.W. Schnee, G.Wang

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University of Colorado at Denver
M. E. Huber

Brown University
R.J. Gaitskell, J.P. Thompson, M. Attisha

And with support from the US Department of Energy and the National Science Foundation

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The Soudan Mine: Northern Minnesota

QUIZ:

– What season is it?

– Which one of us is British?

– Which one of us went to Russia last year?
(That's a whole different story...)

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Thank you…

…visit us on the web at

cdms.cwru.edu

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Missing Mass: the Search for WIMPs

The Cryogenic Dark Matter Search (CDMS) Collaboration

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The plan for today

- A little astrophysics
- A little particle physics
- Our experiment to look for dark matter
- Along the way…
  - What is particle-astrophysics?
  - What is it like to pursue a career in science?
- Please stop and ask questions!

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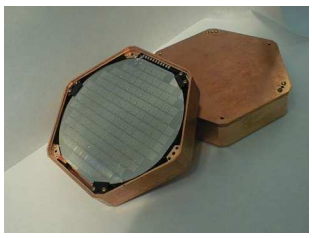
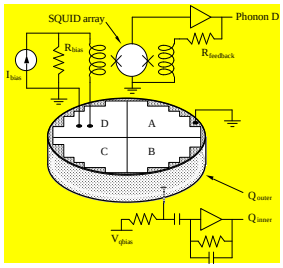
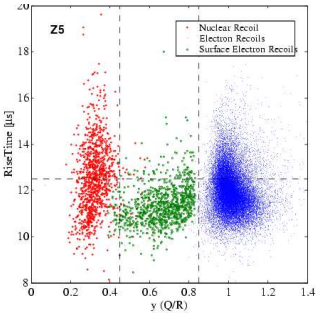
ZIP Detectors

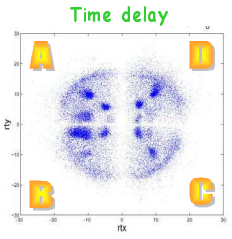
- **Z-sensitive Ionization and Phonon Detectors**

- Technology involves Transition Edge Sensors (TES), trapping of quasiparticles, and SQUID arrays
- Position information (xy and z) due to collecting phonons on faster time scale









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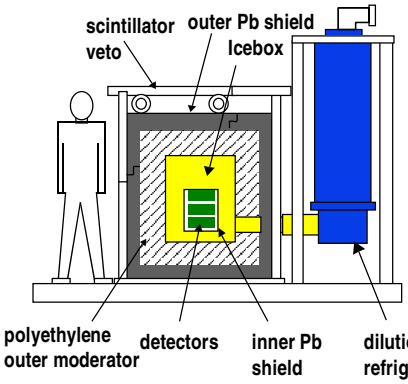
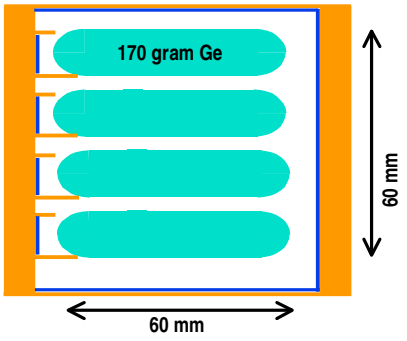
The CDMS I Experiment





Stack of germanium detectors

The thermal measurement requires that the detectors be ultra-cold. They are maintained at a temperature of 10 milli-Kelvin by a dilution refrigerator. Because the rate for WIMP scattering is so low, the experiment must also be carefully designed for background suppression: high-purity materials with low radioactivity, shielding against external radiation, an underground site to reduce the flux of cosmic radiation, and a veto to detect residual cosmic rays.

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CDMS Refrigerators

In our lab at CWRU, open…

closed…

and in the Soudan Mine.

The Soudan refrigerator includes a low-radioactivity shielded environment (partially shielded in the photo).

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Working at soudan

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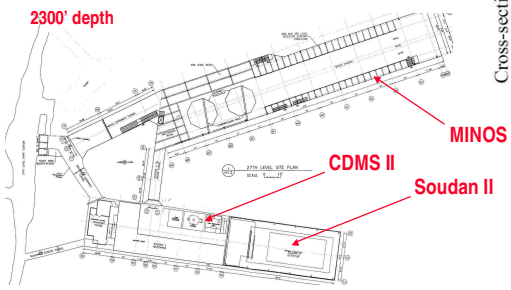
Looking Ahead

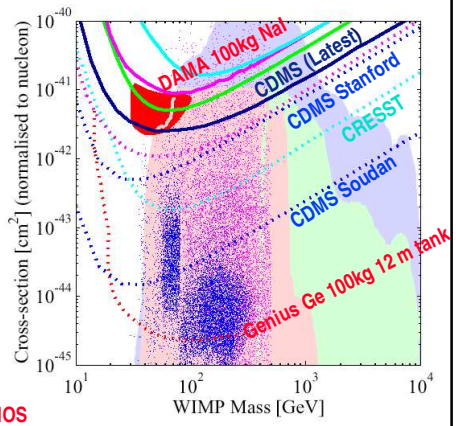
The next step for CDMS

- Larger array & longer exposure
- Second generation detectors with event positions
- Deeper site for further reduction in cosmic-ray background

Soudan Mine, Northern Minnesota

2300' depth





Sensitivity goals of future experiments

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