Status of the Cryogenic Dark Matter Search

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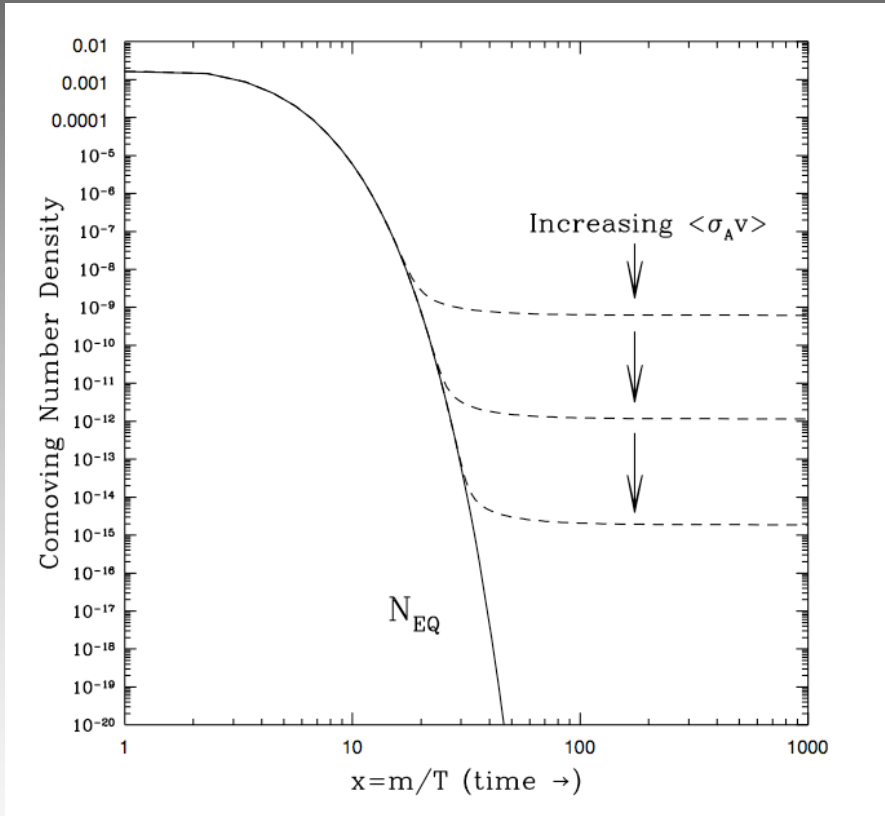
Fermilab

TeV Particle Astrophysics

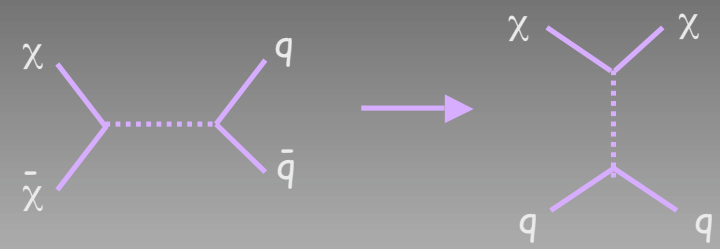
July 13, 2009

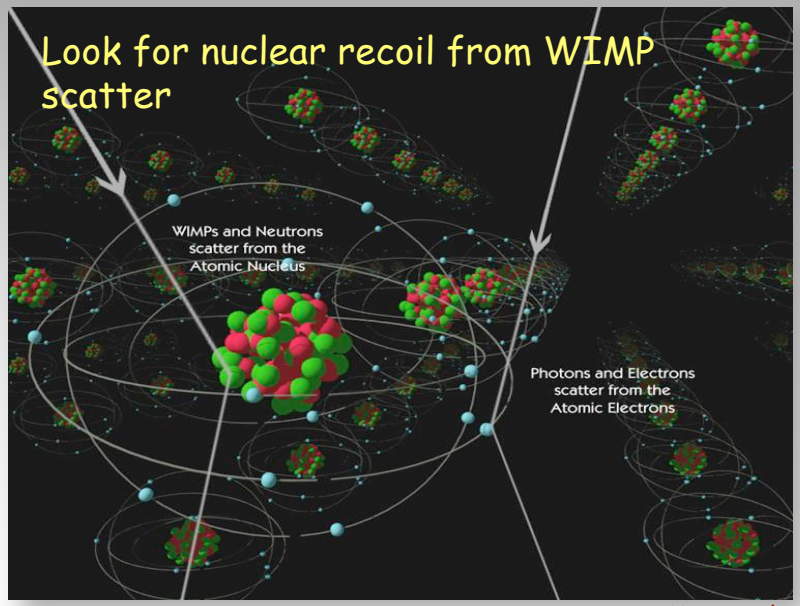
Is Dark Matter a WIMP?

particles with mass and annihilation cross section at the weak scale naturally yield correct relic density of CDM



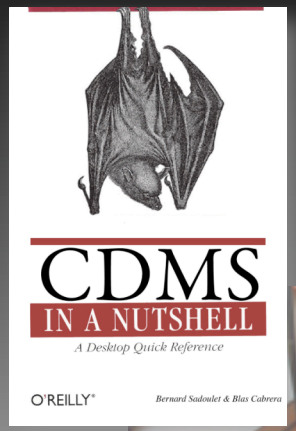
Kolb & Turner, "The Early Universse"

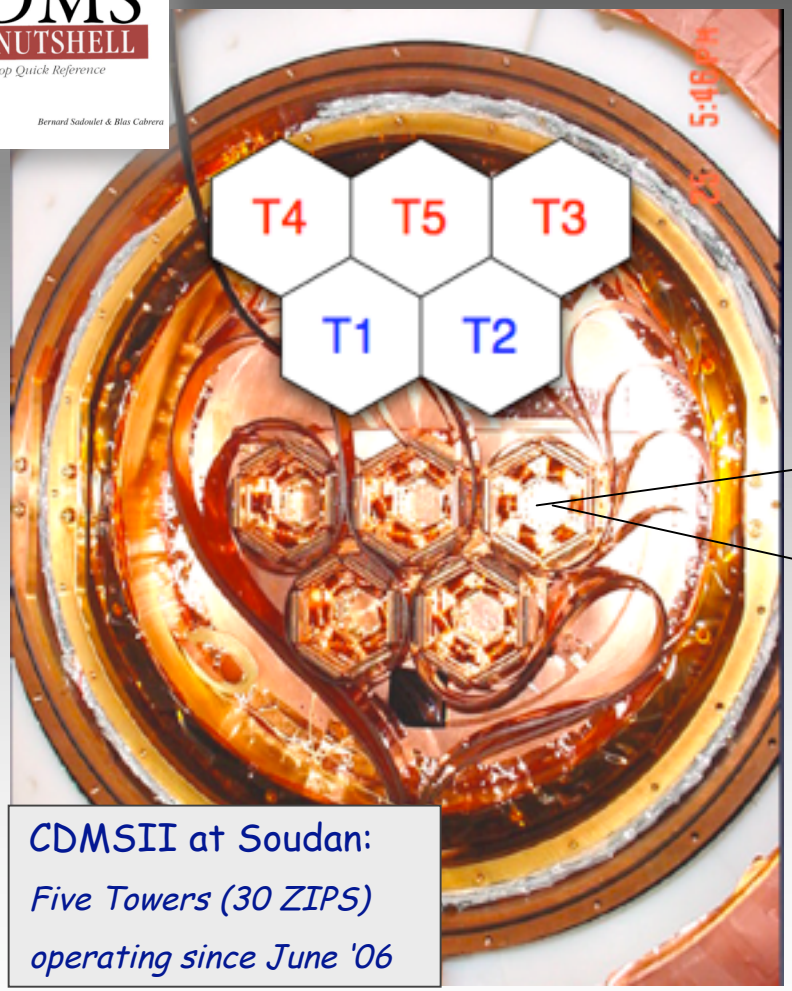




M. Attisha

CDMS Experiment

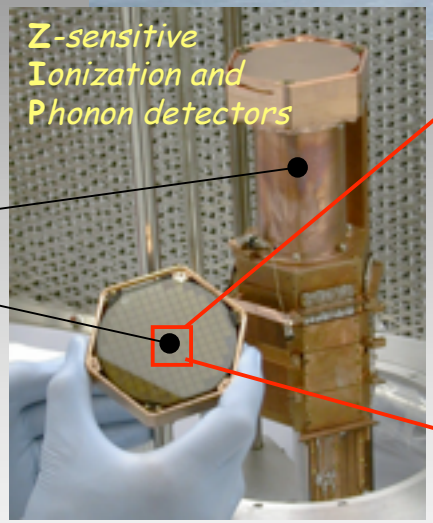


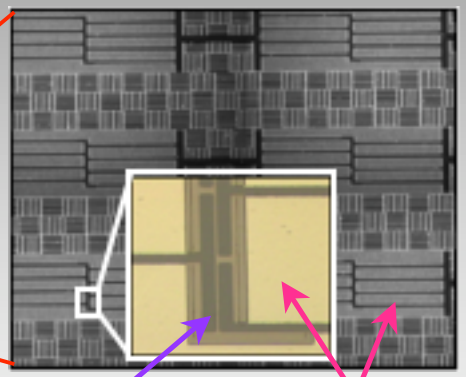


CDMSII at Soudan:

Five Towers (30 ZIPS)

operating since June '06





Most sensitive to spin-independent scattering: $\sigma \propto A^2$

4.75 kg Ge(A=73), 1.1 kg Si(A=28)

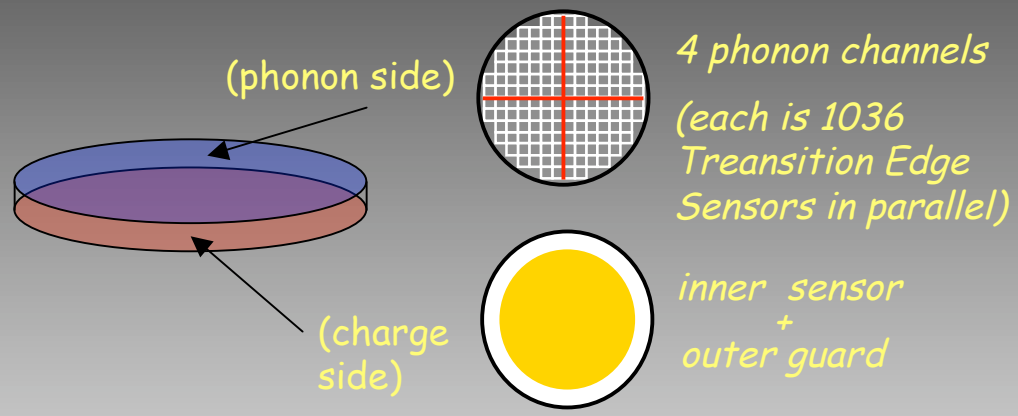
Detection Strategy

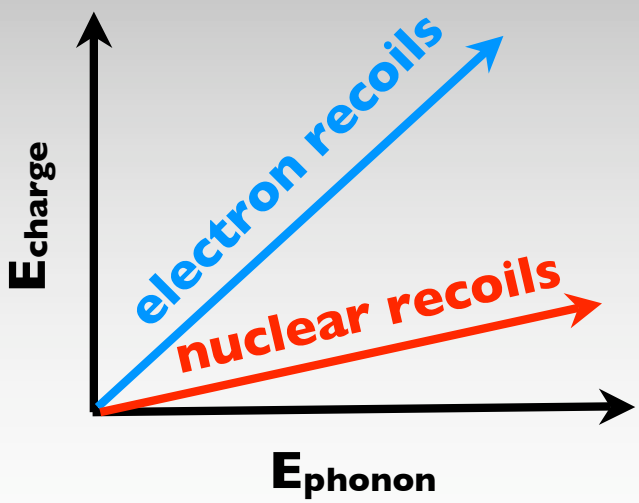
discrimination and shielding maintain a <1 event background experiment

19 Ge zips (250 g each)

11 Si zips (100 g each)

1 cm thick crystals





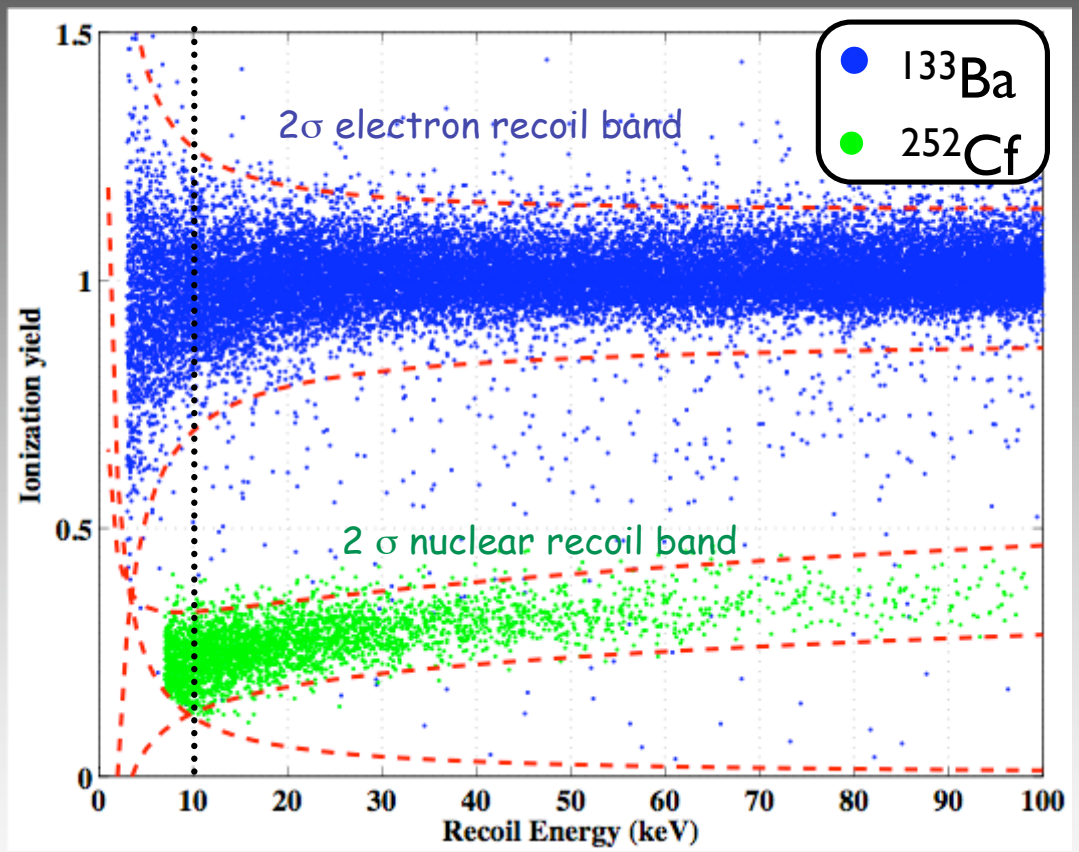
Signature of a Nuclear Recoil:

reduced ionization signal relative to phonon signal

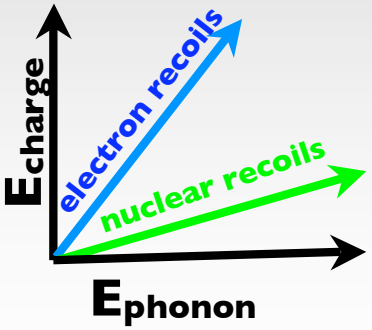
Major Backgrounds:

- *Gammas/Betas (electron recoils)*
- *Neutrons (nuclear recoils)*
- *Surface Events*

Gamma Rejection



$$\text{ionization yield} = \frac{E_{charge}}{E_{phonon}}$$



BETTER THAN 1:10^4 rejection of gammas based on ionization yield alone

Neutron Backgrounds

1. Go Deep:

Soudan Mine: 2090 mwe
(muon rate reduced by >10^4)

2. Use Active Shielding:

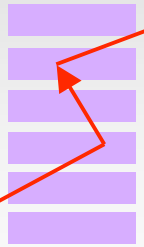
muon veto ~98% efficient

<< 1 unvetoed
single scatter
neutron / kg /year

5. Run Extensive Simulations:

GEANT4
FLUKA+MCNPX
MUSIC

4. Use Event Topology



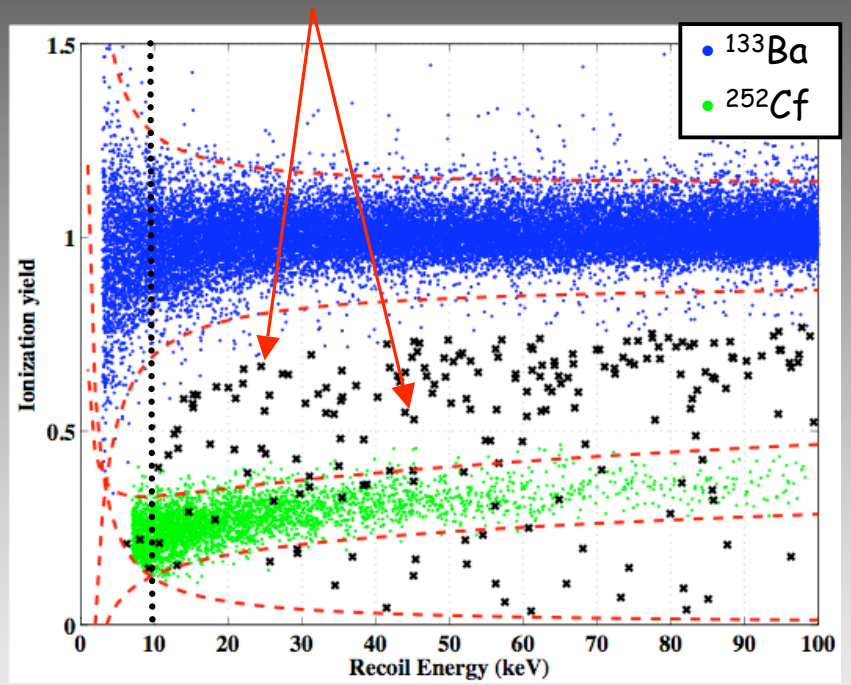
Neutrons may double scatter or be accompanied by EM shower

3. Use Passive Shielding:

2 layers polyethylene - shields from cosmogenic and radiogenic neutrons

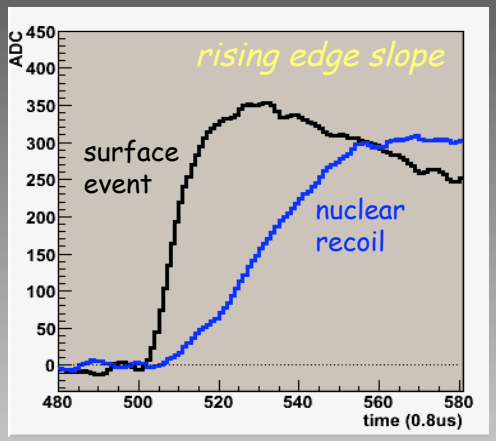
Surface Events

10 μm "dead layer" results in reduced ionization collection

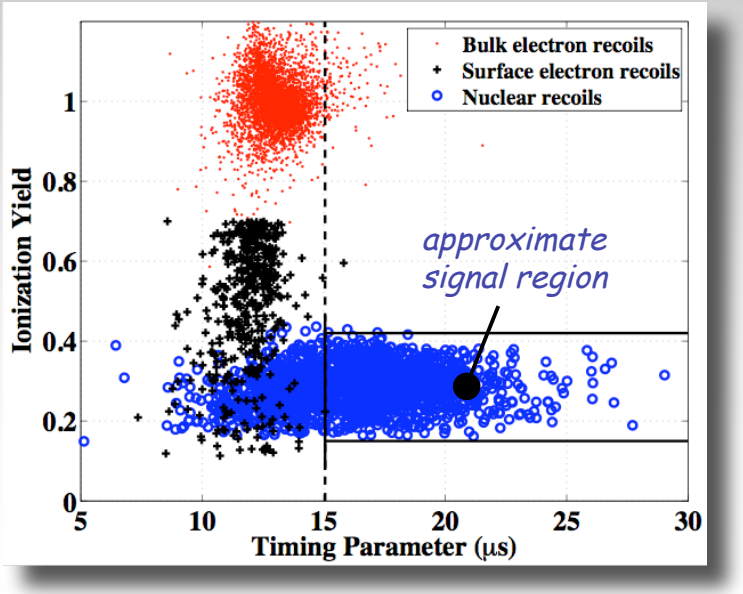


These events are primarily electrons, gammas and x-rays originating from surfaces of the detectors and surrounding materials

Phonon pulse shape (timing) distinguishes surface events

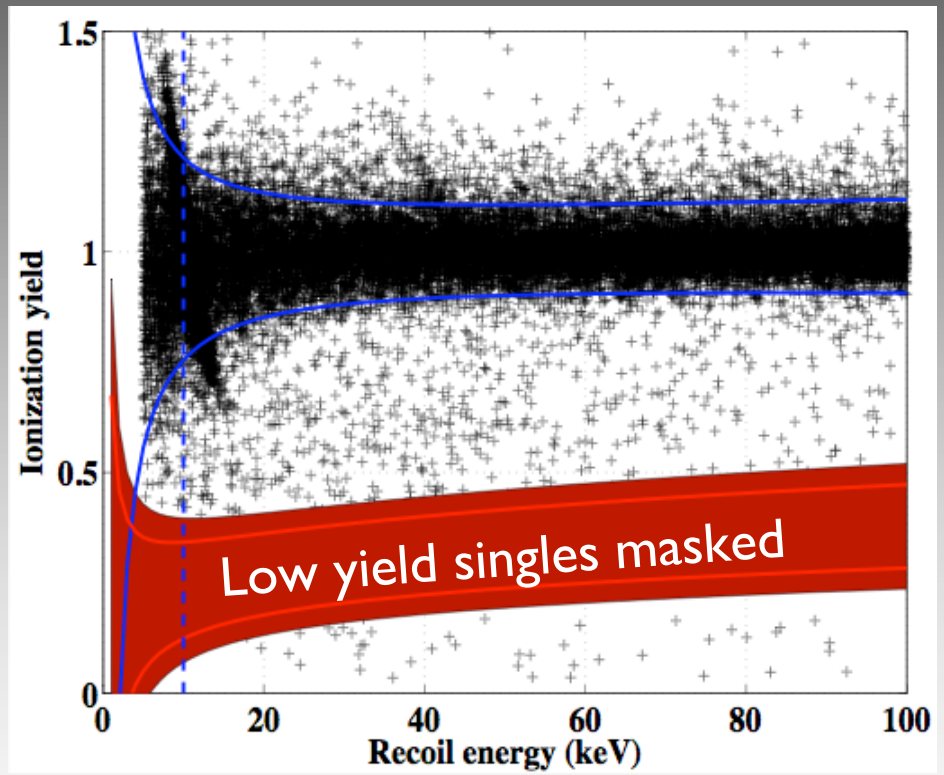


Both yield and "timing" rejects these events



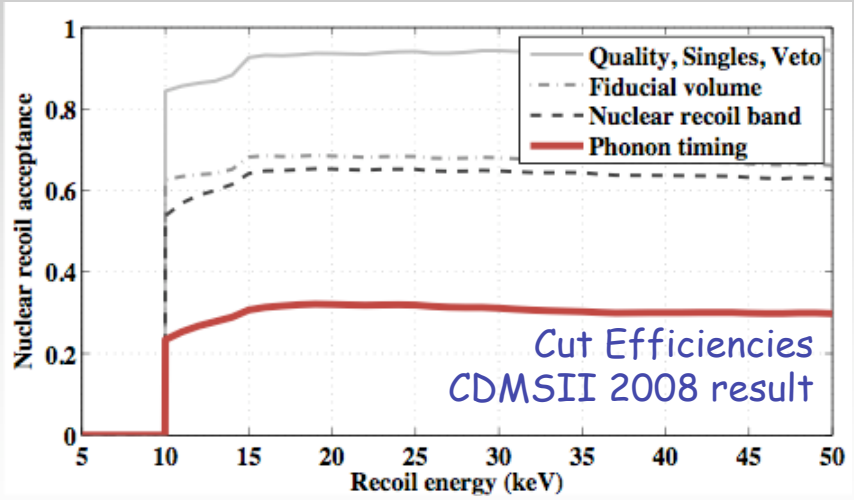
Analysis Technique

All cuts established before unblinding!



Candidate Criteria:

- Data Qualty + Fiducial Volume Cut
- Muon-veto anticoincident
- Single Scatter (only 1 zip w/ signal)
- Ionization yield within 2σ nuclear recoil band
- Phonon "timing" cut - reject surface events



Our Current Limit

CDMS II 2008: 1st Five Tower Result

398 raw kg-d
121 kg-d (for 60 GeV/c² WIMP)
10 - 100 keV analysis range

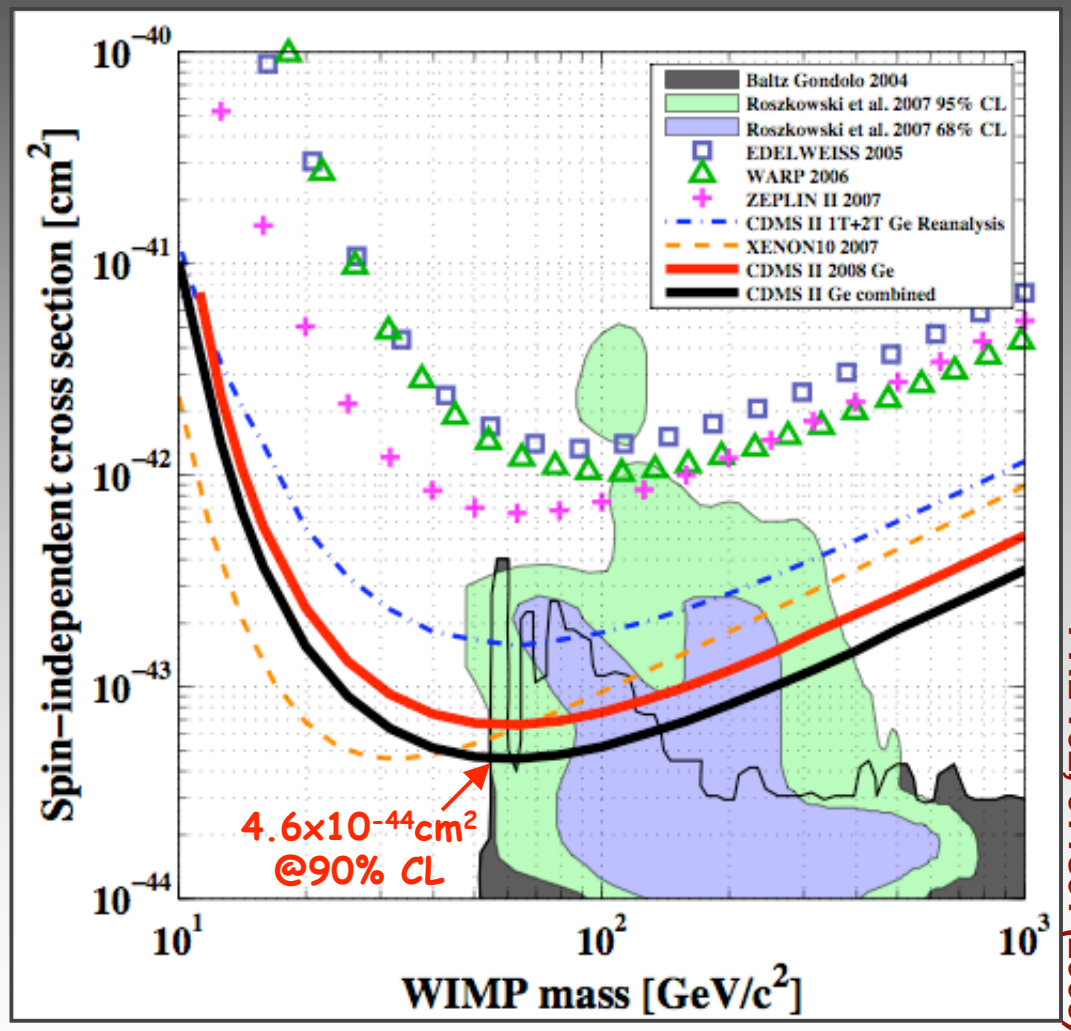
Expected Surface Events:

$$0.6^{+0.5}_{-0.3}(stat.)^{+0.3}_{-0.2}(syst.)$$

Expected Neutrons:

(α,n): < 0.03
(fission): < 0.1
Cosmogenic: < 0.1 (MC 0.03-0.05)

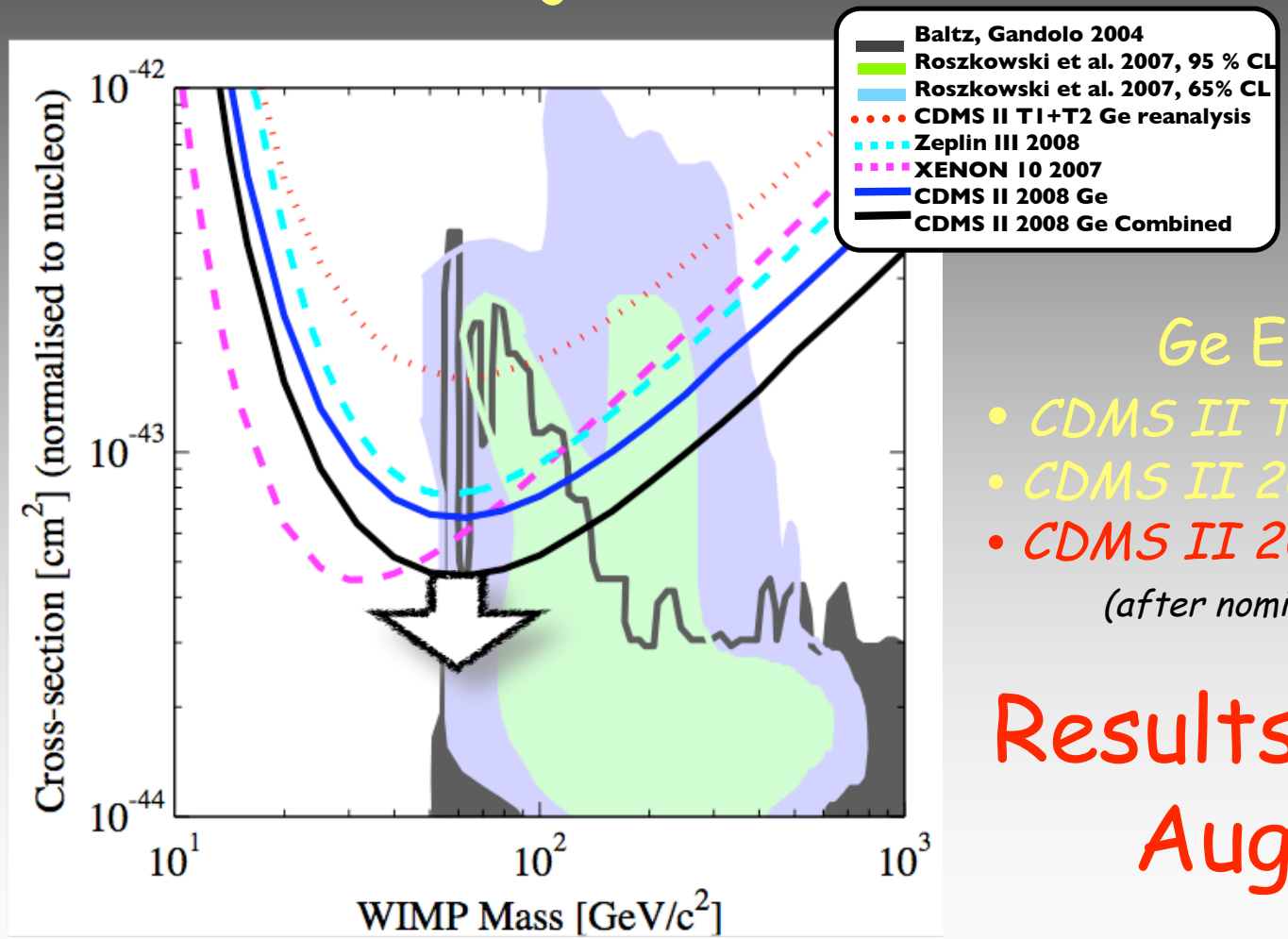
ZERO Events Observed in Signal Region!



PRL 102, 011301 (2009)

coming soon…

CDMS II 2009 Projected Sensitivity



~2.5X more total exposure

Ge Exposures:

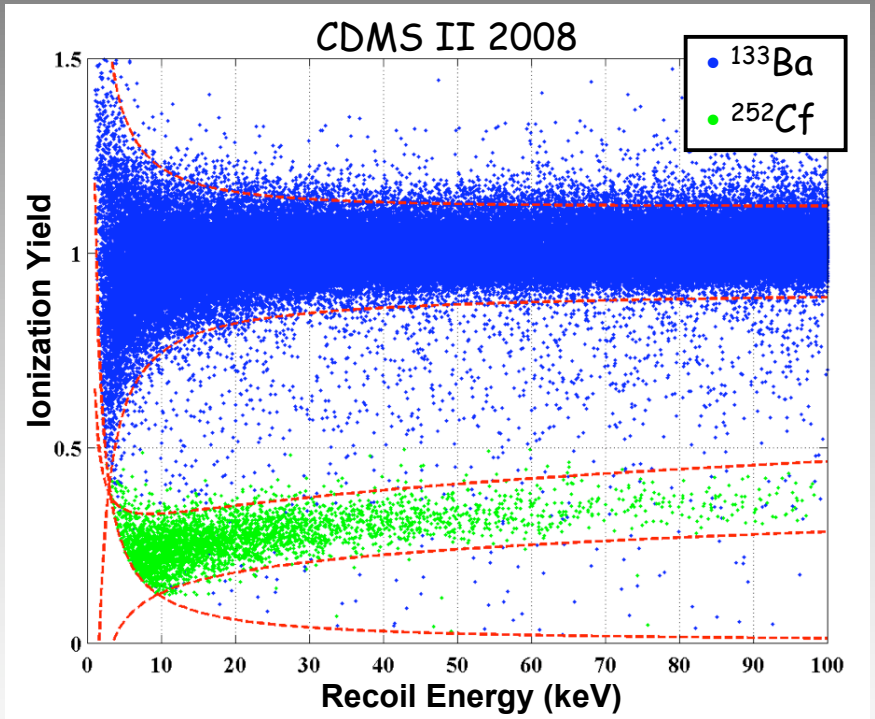
- *CDMS II T1+T2 ~120 kg-d*
- *CDMS II 2008 ~400 kg-d*
- *CDMS II 2009 ~750 kg-d*

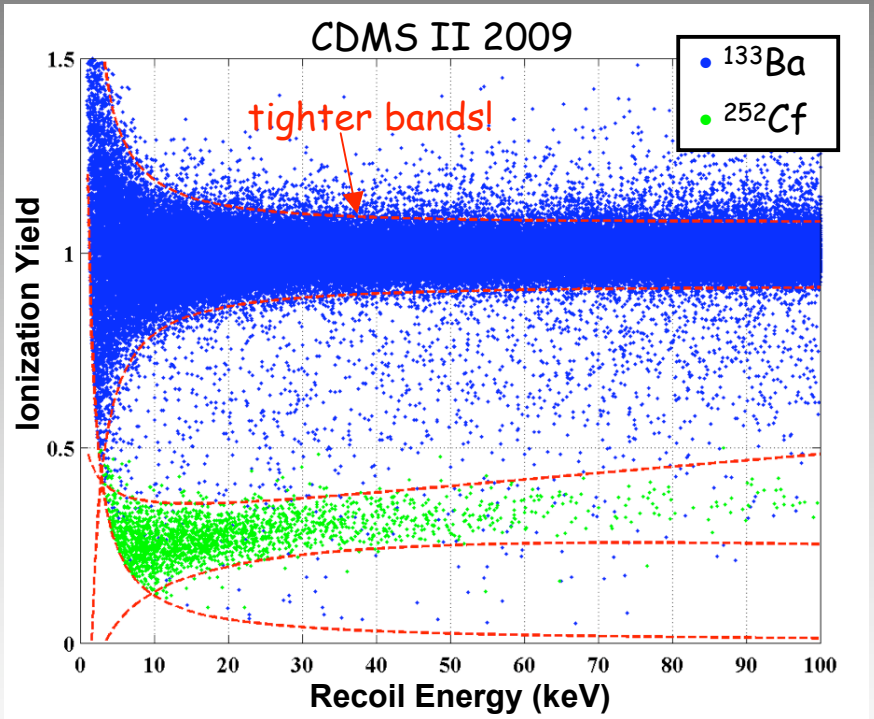
(after nominal quality cuts)

Results expected August '09

Calibration Data Preview

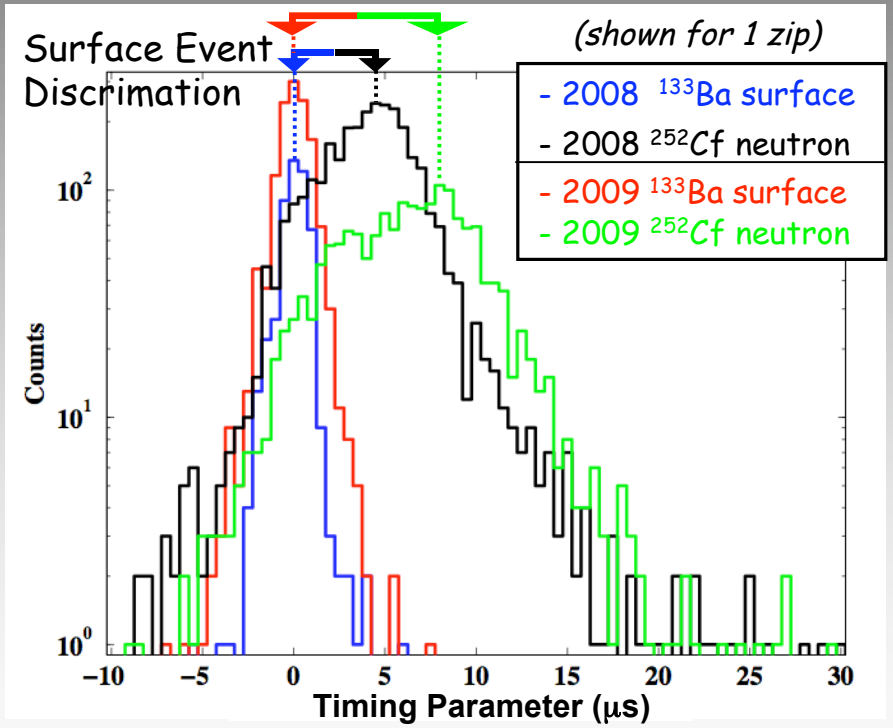
Initial studies indicate the data is very well behaved…
even better than previously published data!



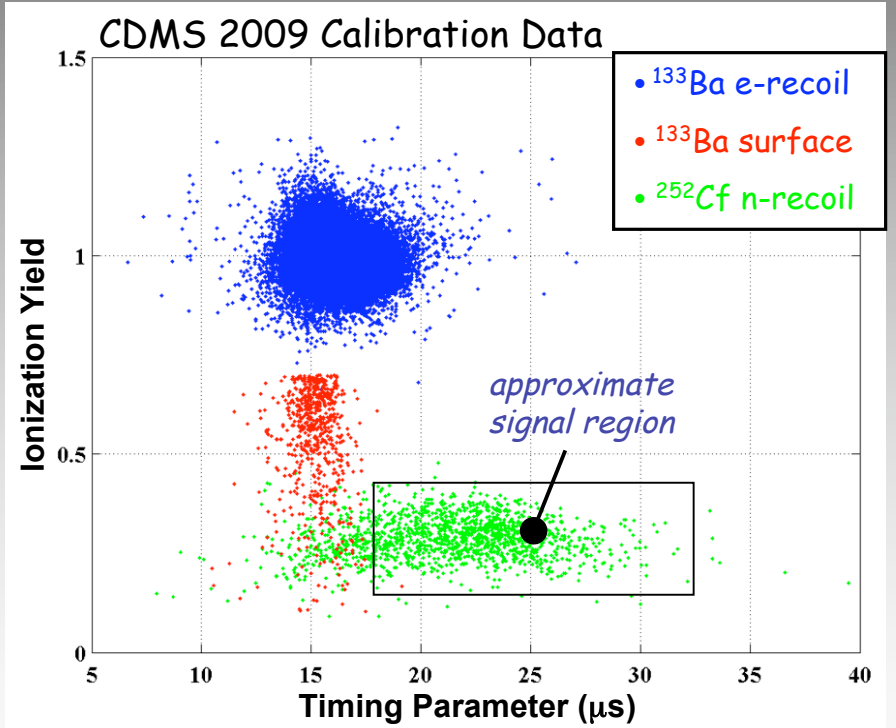


Promising Surface Event Rejection

Aiming for ~X2 better rejection of surface events to keep up with exposure potential and stay a <1 background experiment

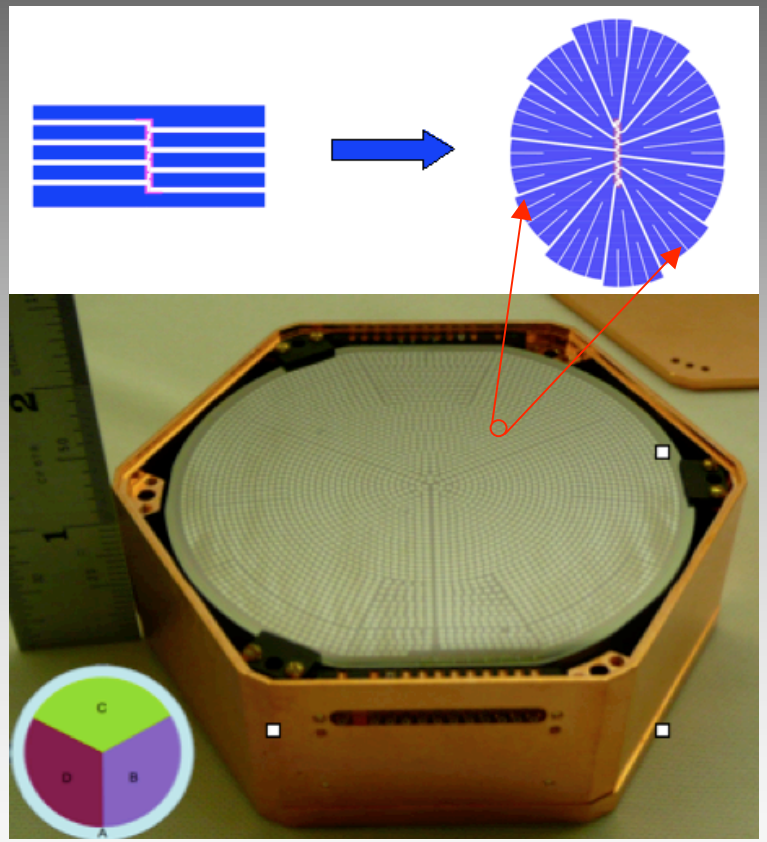


Note: Ba/Cf exposures are different between datasets and hasn't been corrected for here



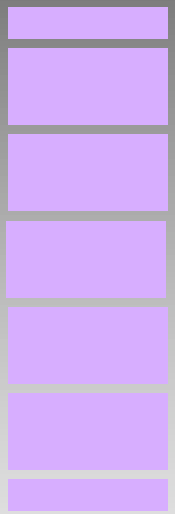
SuperCDMS

15 kg of Ge at Soudan, arranged as 5 SuperTowers

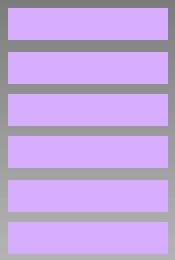


"mercedes" zip

SuperTower

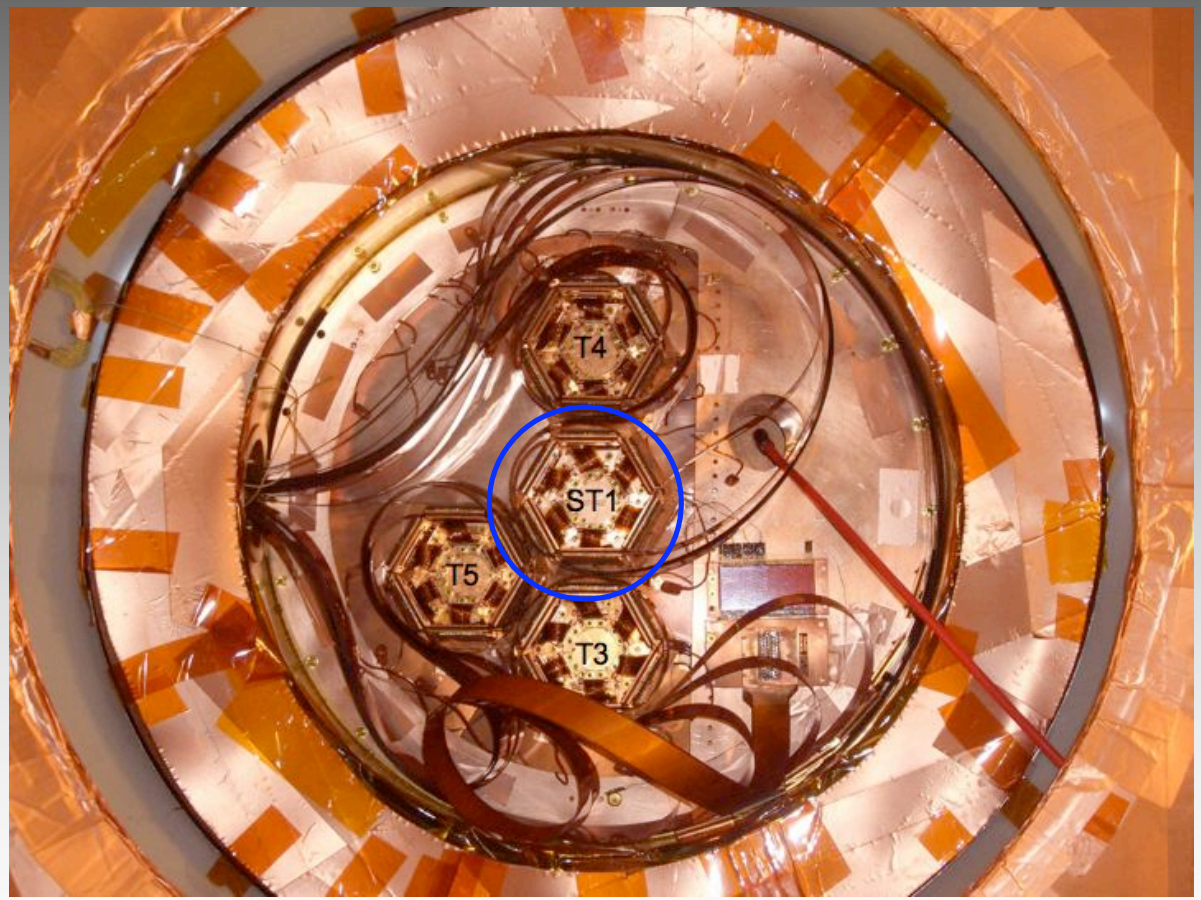


CDMSII Tower



- 2.5X thicker (1-inch) Ge crystals
- "endcap" Ge veto detectors in each tower
- modified Al fin layout, improves phonon collection efficiency
- cleaner, simplified, and streamlined production
- "mercedes" phonon sensor layout, outer phonon "guard"

First SuperTower Installation



CDMS II data-taking ended March 2009

First SuperTower installation is now complete!

Testing currently underway

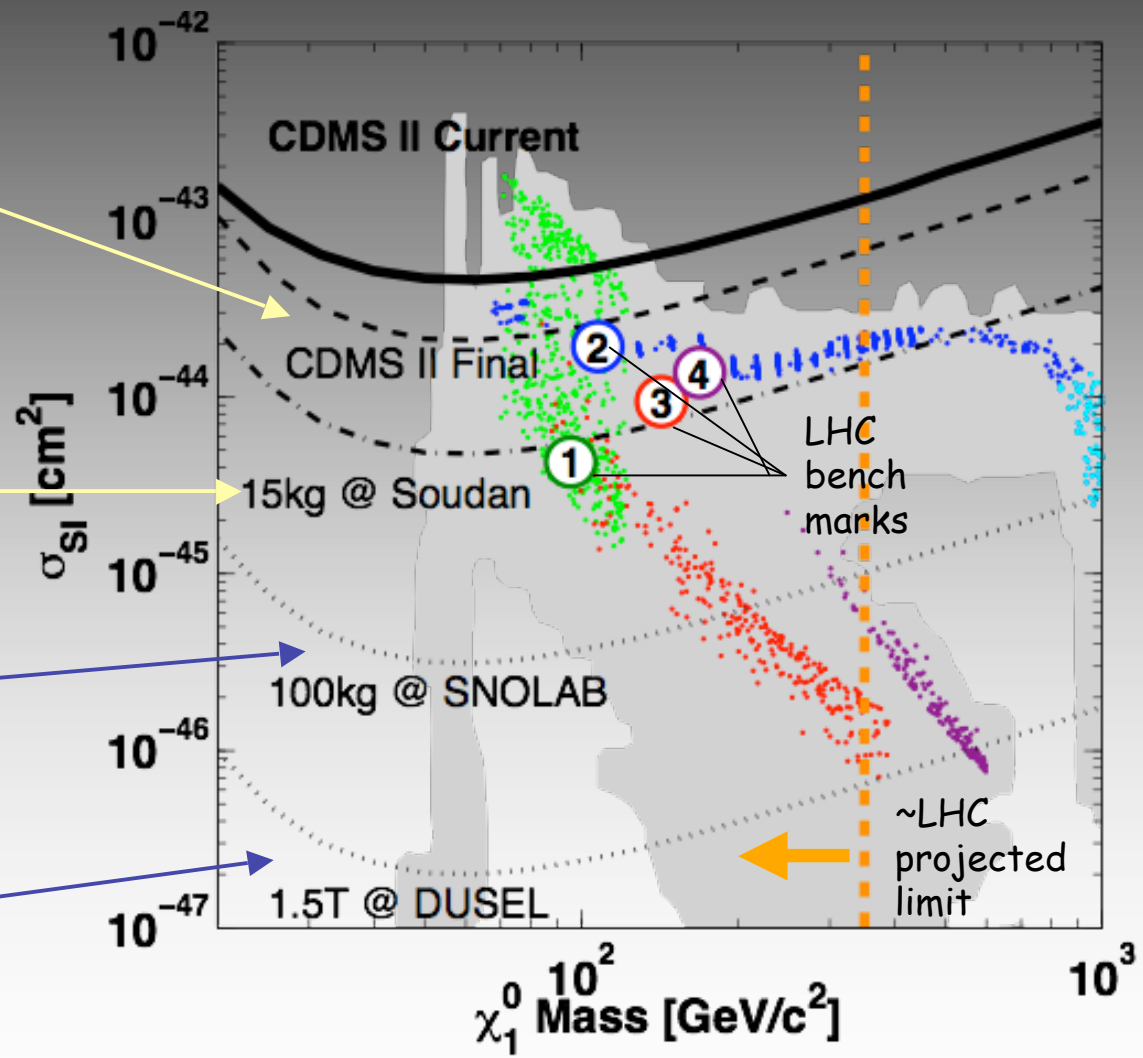
SuperCDMS Future

CDMS II
4 kg Ge
~ 2 yrs operation

SuperCDMS @ Soudan
15 kg Ge
~ 2 yrs operation

SuperCDMS @ Snolab
100 kg Ge
~ 3 yrs operation

DUSEL/GEODM
1.5T



summary

CDMS has a world-leading limit on the spin-independent WIMP annihilation cross section:

$4.6 \times 10^{-44} cm^2$ at 90% CL (for 60 GeV/c^2 WIMP mass)

~750 kg-days of five-tower data is currently being analyzed. Results expected by end of summer

First SuperCDMS tower is installed and is nearly ready for data-taking

Steady progress to zeptobarn cross sections and smaller!

Thank You

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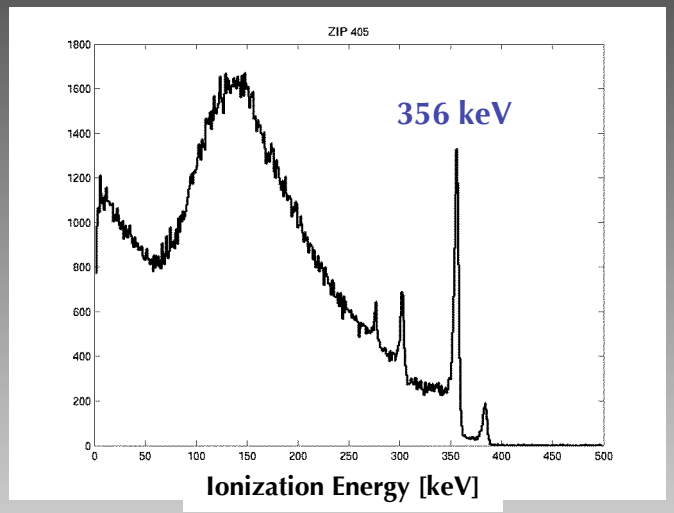
backup slides

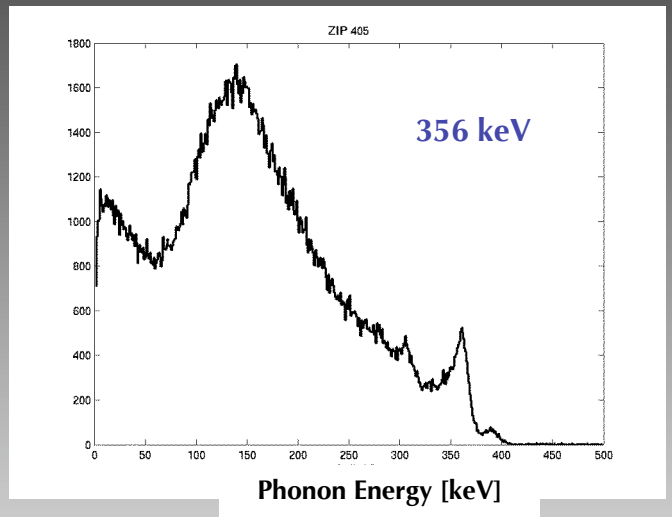
Other CDMS Results for 2009

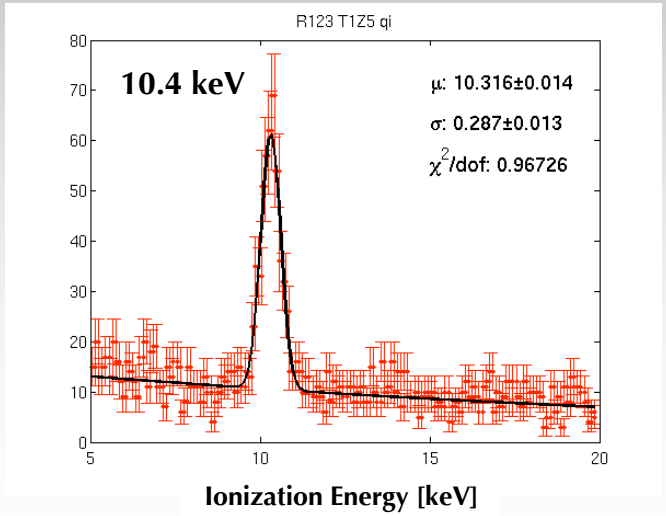
"Analysis of the low-energy electron-recoil spectrum of the CDMS experiment" - *arXiv: 0907.1438 [astro-ph]*

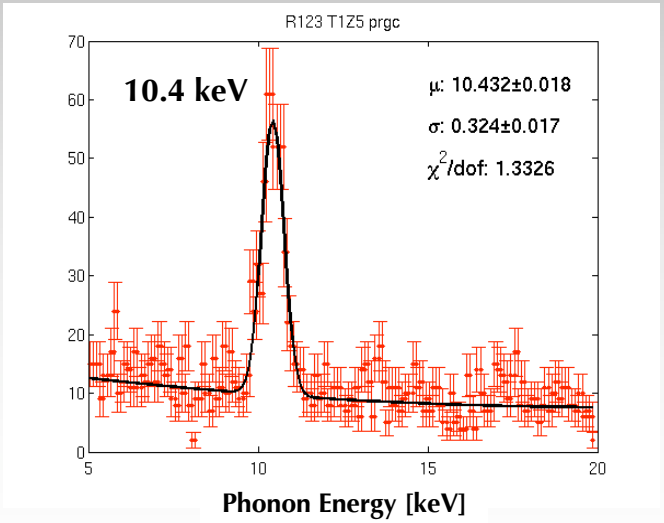
"Search for Axions with the CDMS Experiment"
- *arXiv:0902.4693 [hep-ex]*

Energy Resolution

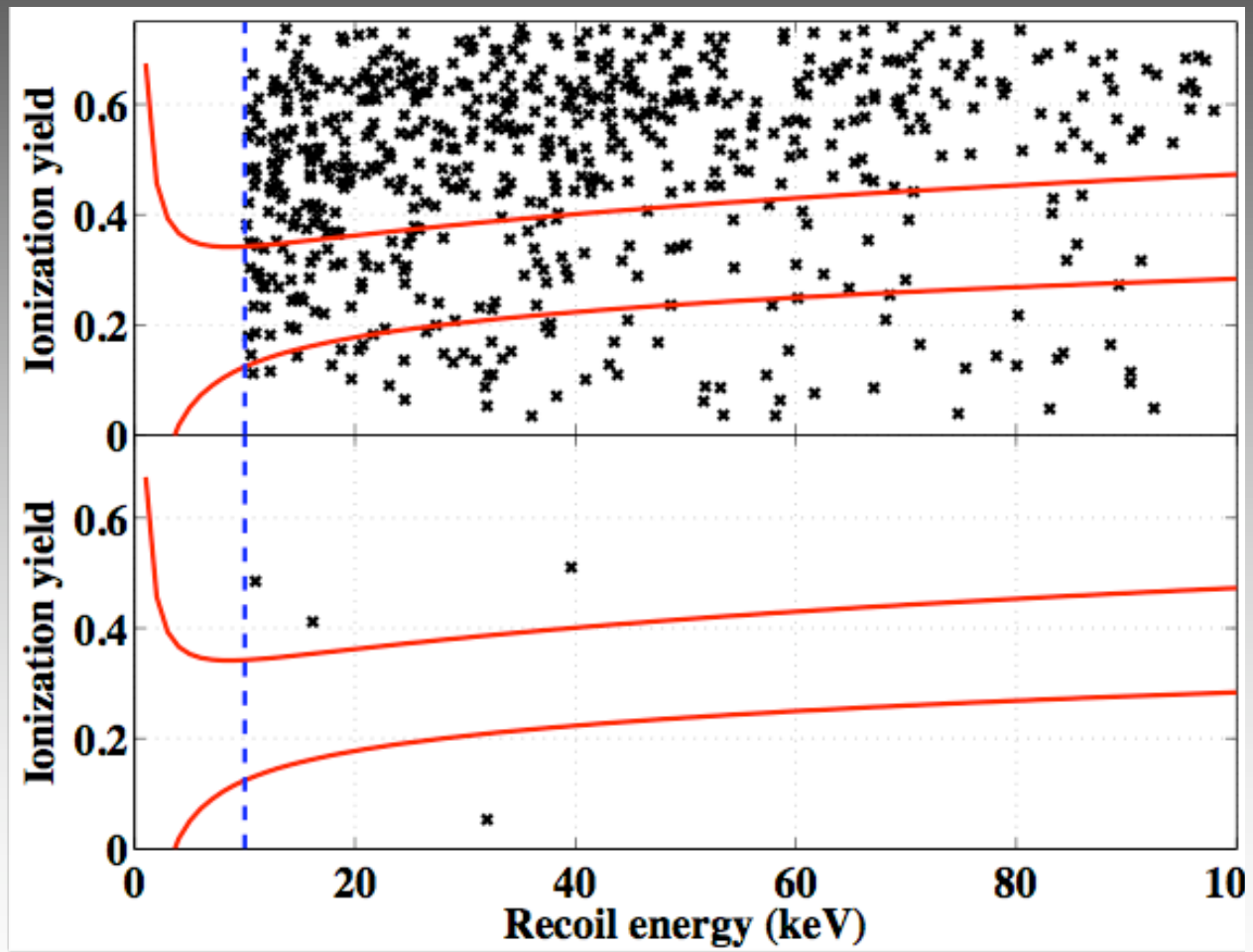








Signal Region CDMSII 2008



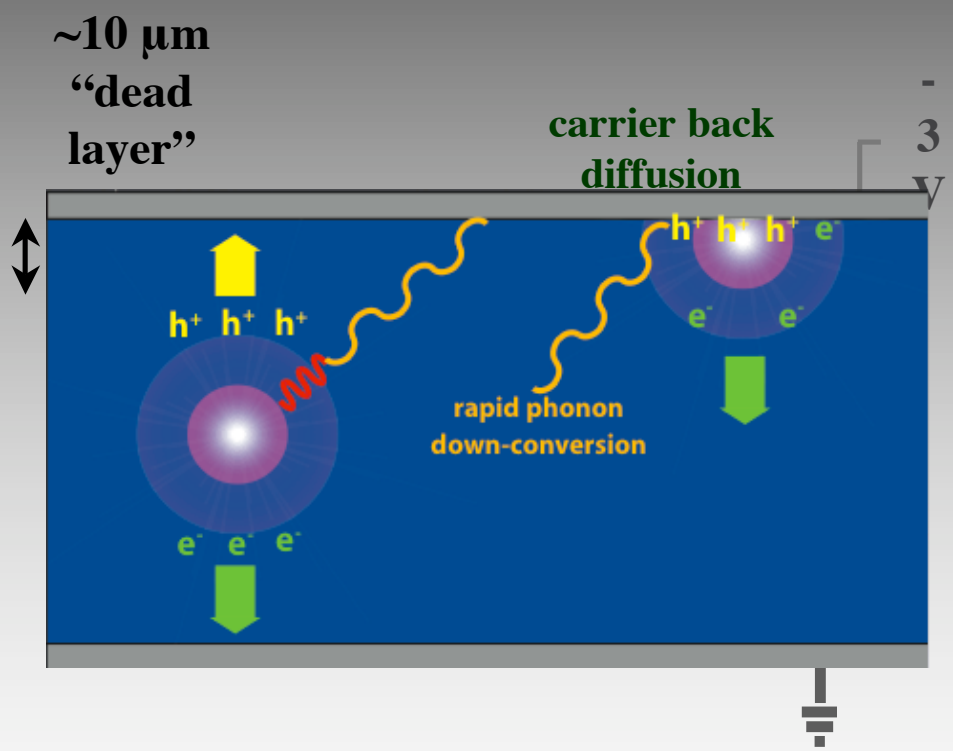
Without Timing Cut

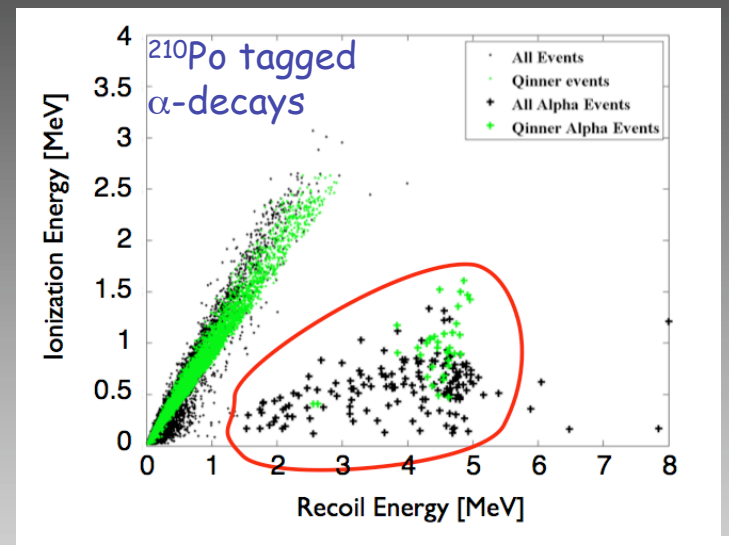
With Timing Cut

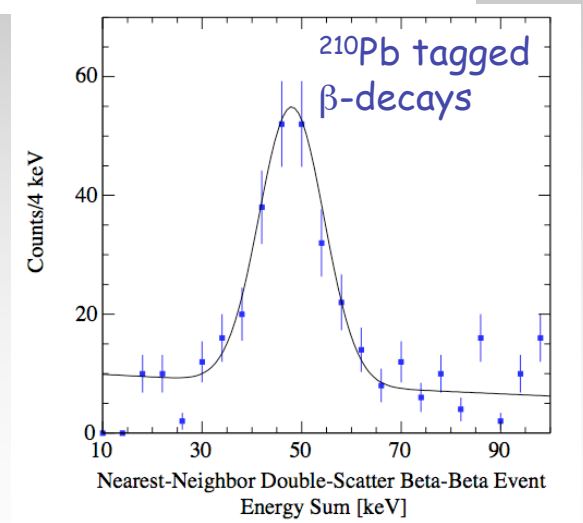
PRL 102, 011301 (2009)

What are Surface Events?

Reduced charge yield due to charge carrier back-diffusion in surface events.



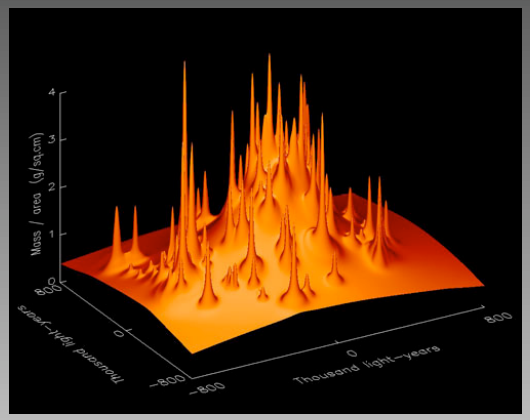




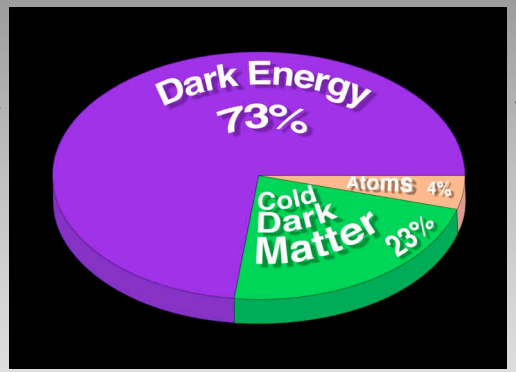
Correlations to ^{210}Pb contamination observed, most likely from beta decays on surface of detectors

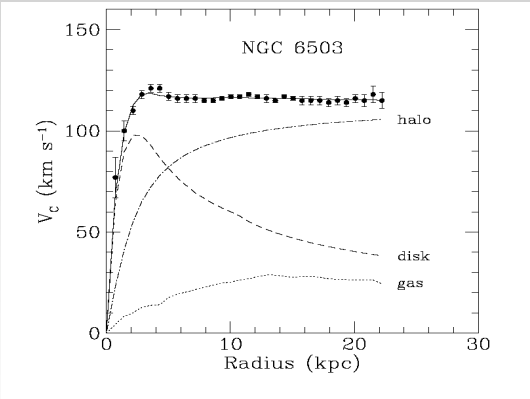
What is Dark Matter?

Bullet Cluster

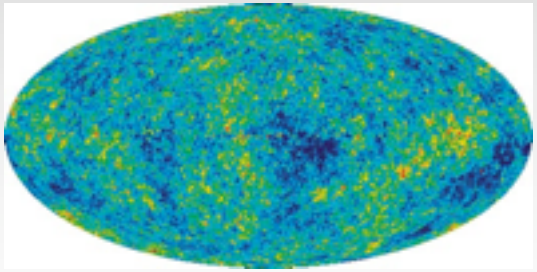


Strong Lensing





Rotational Curves



WMAP 5-year