UCSB CDMS II

CDMS

The New Cosmology Confronts Observation

KITP

August 21, 2002

Harry Nelson

UCSB

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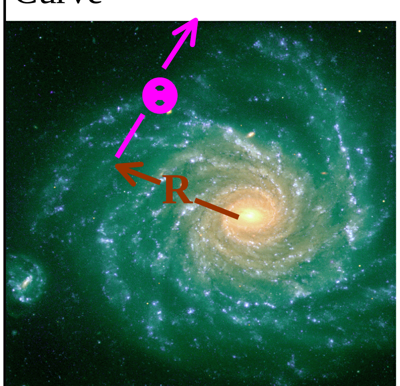
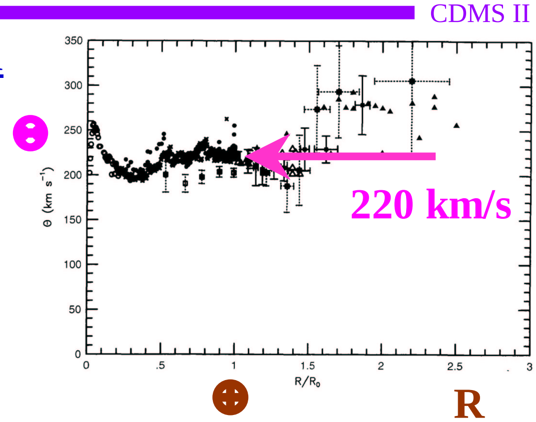
Physics Motivation

- Several Arguments for Dark Matter
- Milky Way's Rotation Curve





- Massive Particle Popular
- Weak Interactions (WIMP):
  » Dark/Luminous Balance
  » SUSY Broken at Weak Scale… χ^0 (neutralino)

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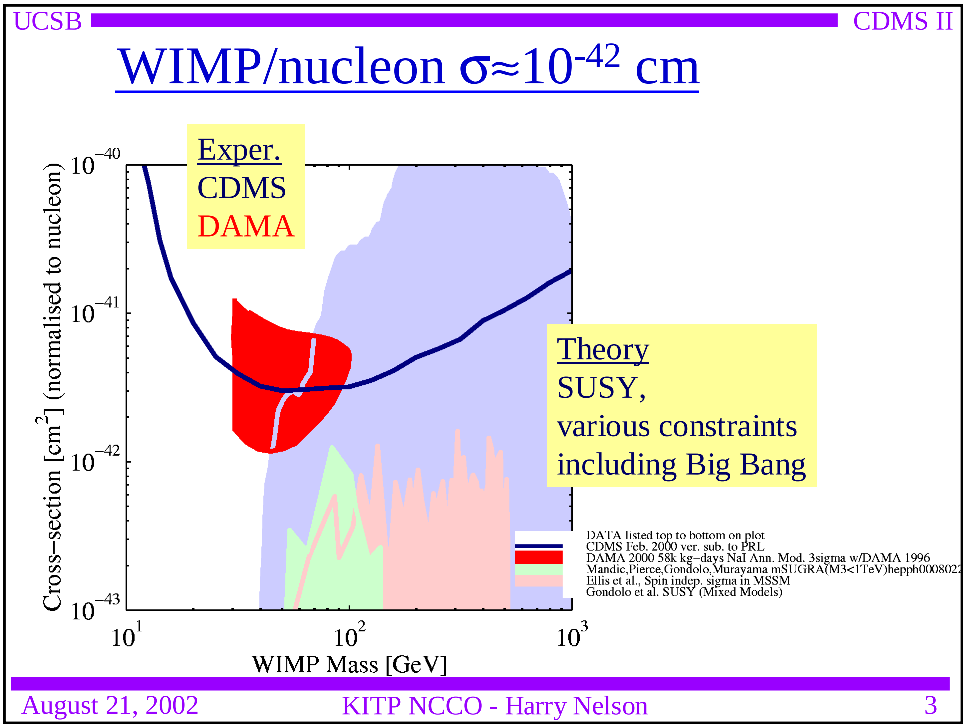
UCSB
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WIMP/nucleon σ≈10-42 cm
Exper.
CDMS
DAMA
Theory
SUSY,
various constraints
including Big Bang
Cross-section [cm2] (normalised to nucleon)
10−40
10−41
10−42
10−43
10¹
10²
10³
WIMP Mass [GeV]
DATA listed top to bottom on plot
CDMS Feb. 2000 ver. sub. to PRL
DAMA 2000 58k kg−days NaI Ann. Mod. 3sigma w/DAMA 1996
Mandic,Pierce,Gondolo,Murayama mSUGRA(M3<1TeV)hepph0008022
Ellis et al., Spin indep. sigma in MSSM
Gondolo et al. SUSY (Mixed Models)
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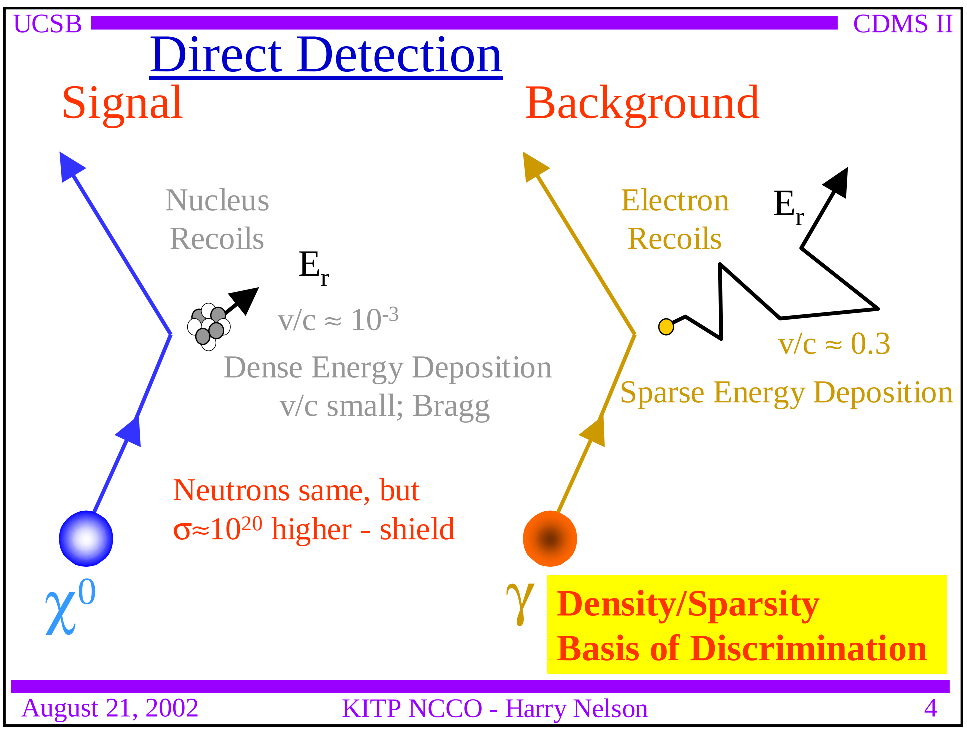
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Direct Detection
Signal
Background
Nucleus
Recoils
Er
v/c ≈ 10-3
Dense Energy Deposition
v/c small; Bragg
Electron
Recoils
Er
v/c ≈ 0.3
Sparse Energy Deposition
Neutrons same, but
σ≈1020 higher - shield
χ0
γ
Density/Sparsity
Basis of Discrimination
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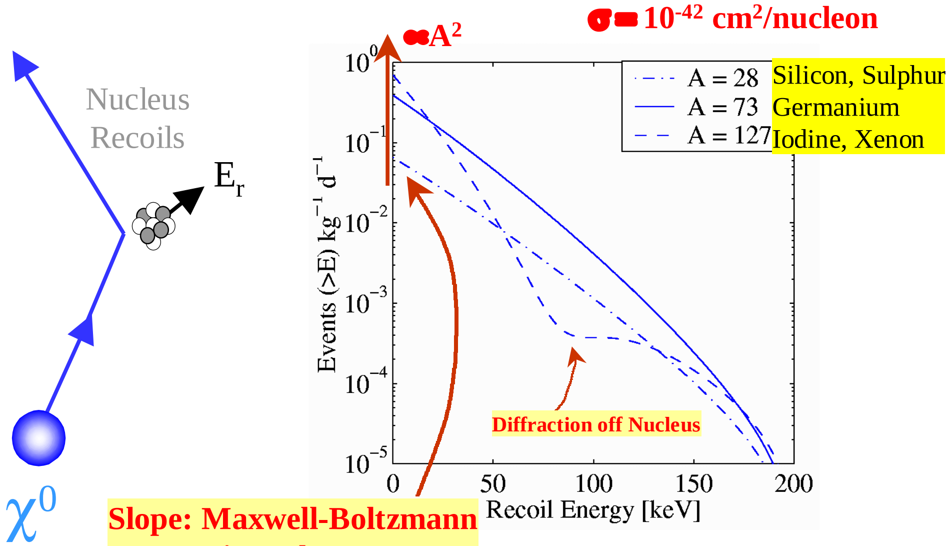
Rate, Energy Spectrum

M_{WIMP}=100 GeV
σ = 10^{-42} cm^2/nucleon



Slope: Maxwell-Boltzmann WIMPs in Galaxy

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The CDMS Collaboration

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University of Colorado at Denver
M. E. Huber

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The CDMS Experiments (Cryogenic Dark Matter Search)

Operate at ≈ 20 mKelvin

Use Germanium (WIMPs) and Silicon (neutrons)

Simultaneously measure charge (Q) and heat/phonons (R) for nuclear recoils: Q/R allows discrimination between nuclear recoil and electron recoil

Exist in a variety of permutations:

- Two detector types (BLIPs and ZIPs)
- Two sites: SUF(shallow), Soudan (deep)
- Two materials (Germanium and Silicon)

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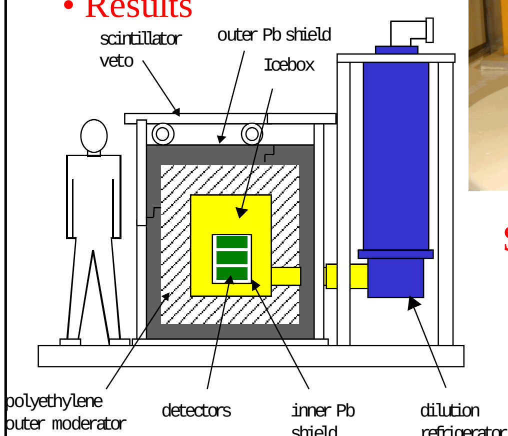
CDMS Sites

Stanford Site:

- 16 mwe
- Substantial neutron flux
- Results



Soudan Site:

- 2100 mwe
- Neutron flux down 1/300
- Commissioning fridge
- Operation this winter

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CDMS Detectors

`BLIPs' (Berkeley Large Ionization and Phonons)

- Germanium (1/6 kg) disks
- Heat/Phonons (R) - Thermistor
  - → slow - wait for thermalization
- Results - 3 of 4 detectors

Ionization (Q) drifted to electrodes by applied E for both

`ZIPs' (Z, Ionization and Phonons)

- Germanium (1/4 kg) and Silicon (1/10 kg) disks
- R - detect athermal phonons
  - → `TES' - Transition Edge Sensor
  - → Fast Signal
  - → x, y, and… z (with risetime)
- Performance at Stanford - results very soon (4 Ge, 2 Si)
- 42 of these to be deployed at Soudan (CDMS II)

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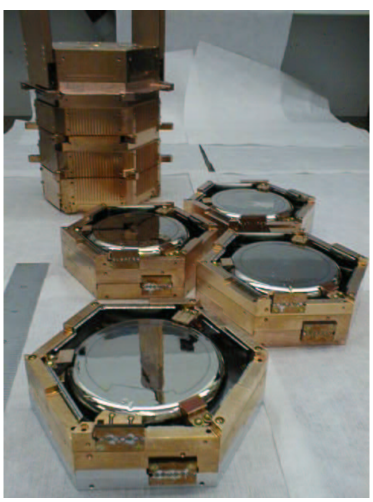

CWRU-P4-02/UCSB-HEP-02-0

Exclusion limits on the WIMP-nucleon cross-section from the Cryogenic Dark Matter Search

D. Abrams,[8] D.S. Akerib,[2] M.S. Armel-Funkhouser,[9] L. Baudis,[8] D.A. Bauer,[10] A. Bolozdynya,[2] P.L. Brink,[8] R. Bunker,[10] B. Cabrera,[8] D.O. Caldwell,[10] J.P. Castle,[8] C.L. Chang,[8] R.M. Clarke,[8] M.B. Crisler,[3] R. Dixon,[3] D. Driscoll,[2] S. Eichblatt,[3] R.J. Gaitskell,[1] S.R. Golwala,[9] E.E. Haller,[4] J. Hellmig,[9] D. Holmgren,[3] M.E. Huber,[11] S. Kamat,[2] A. Lu,[10] V. Mandic,[9] J.M. Martinis,[5] P. Meunier,[9] S.W. Nam,[5] H. Nelson,[10] T.A. Perera,[2] M.C. Perillo Isaac,[9] W. Rau,[9] R.R. Ross,[4,9] T. Saab,[8] B. Sadoulet,[4,9] J. Sander,[10] R.W. Schnee,[2,*] T. Shutt,[6] A. Smith,[4] A.H. Sonnenschein,[10] A.L. Spadafora,[9] G. Wang,[2] S. Yellin,[10] and B.A. Young[7]

(CDMS Collaboration)

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(Dated: August 14, 2002)

The Cryogenic Dark Matter Search (CDMS) employs low-temperature Ge and Si detectors to search for Weakly Interacting Massive Particles (WIMPs) via their elastic-scattering interactions with nuclei while discriminating against interactions of background particles. For recoil energies above 10 keV, events due to background photons are rejected with > 99.9% efficiency, and surface events are rejected with > 95% efficiency. The estimate of the background due to neutrons is based primarily on the observation of multiple-scatter events that should all be neutrons. Data selection is determined primarily by examining calibration data and vetoed events. Resulting efficiencies should be accurate to ~10%. Results of CDMS data from 1998 and 1999 with a relaxed fiducial-volume cut (resulting in 15.8 kg-days exposure on Ge) are consistent with an earlier analysis with a more restrictive fiducial-volume cut. Twenty-three WIMP candidate events are observed, but these events are consistent with a background from neutrons in all ways tested. Resulting limits on the spin-independent WIMP-nucleon elastic-scattering cross-section exclude unexplored parameter space for WIMPs with masses between 10–70 GeV c^{-2}. These limits border, but do not exclude, parameter space allowed by supersymmetry models and accelerator constraints. Results are compatible with some regions reported as allowed at 3σ by the annual-modulation measurement of the DAMA collaboration. However, under the assumptions of standard WIMP interactions and a standard halo, the results are incompatible with the DAMA most likely value at > 99.9% CL, and are incompatible with the model-independent annual-modulation signal of DAMA at 99.99% CL in the asymptotic limit.

PACS numbers: 95.35.+d, 14.80.-j, 14.80.Ly

astro-ph/0203500

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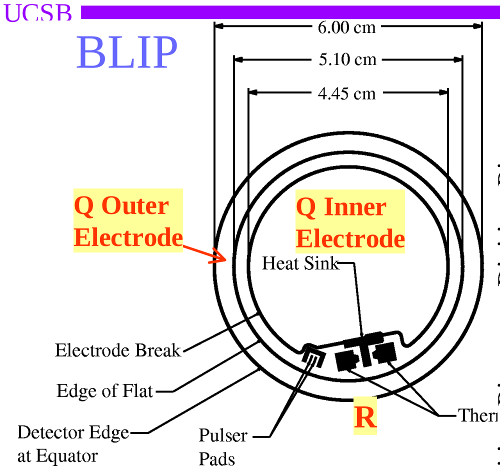
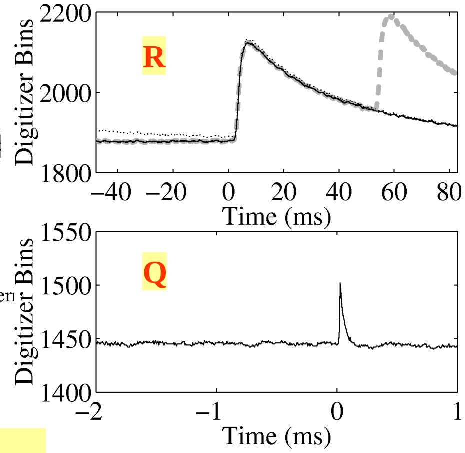
BLIP





2/2000 result: Q Inner Only
8/2002 result: QI + Shared… `QIS'

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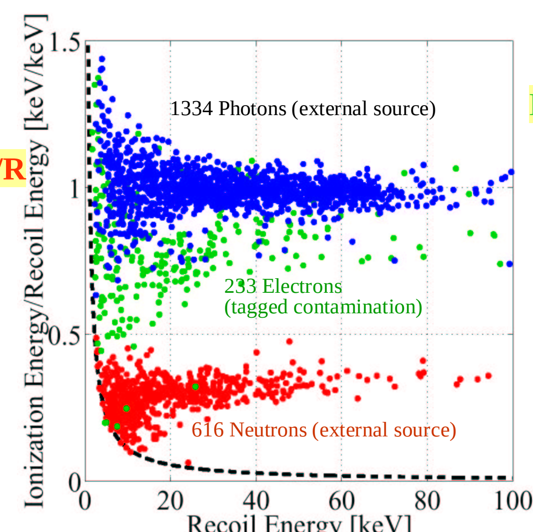
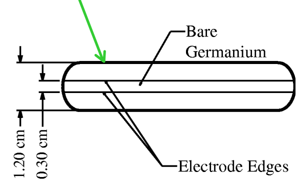
BLIP Calibration

Q/R



External Electrons



Q collection incomplete because ionization all a few microns from surface

10 KeV Recoil Energy Threshold

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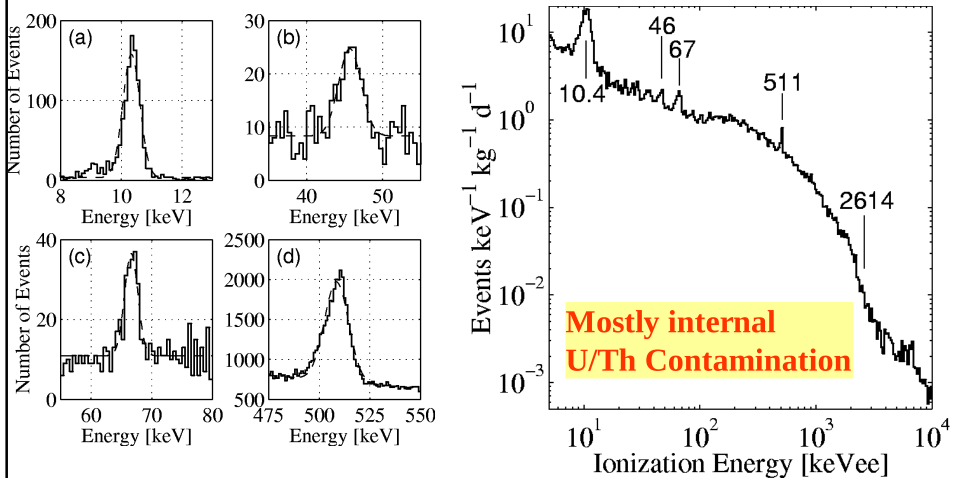
BLIP Calibration

No Pulses in Veto Shield, Electron Recoils



Mostly internal U/Th Contamination

Q/R Discrimination: 1/1000 Suppression

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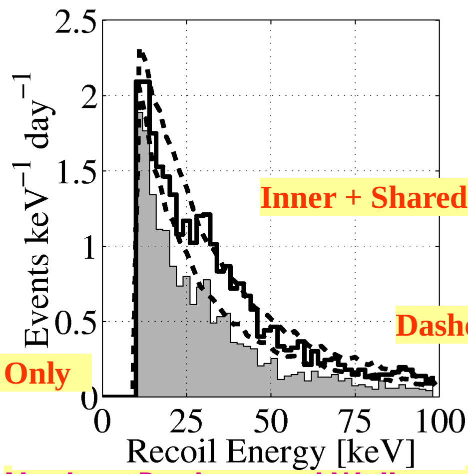
BLIP Calibration

Pulses in Veto Shield (not WIMPS), Nuclear Recoils (from neutrons)



Inner + Shared Electrodes

Dashed Lines: MC

Inner Electrode Only

Neutron Background Well Modeled

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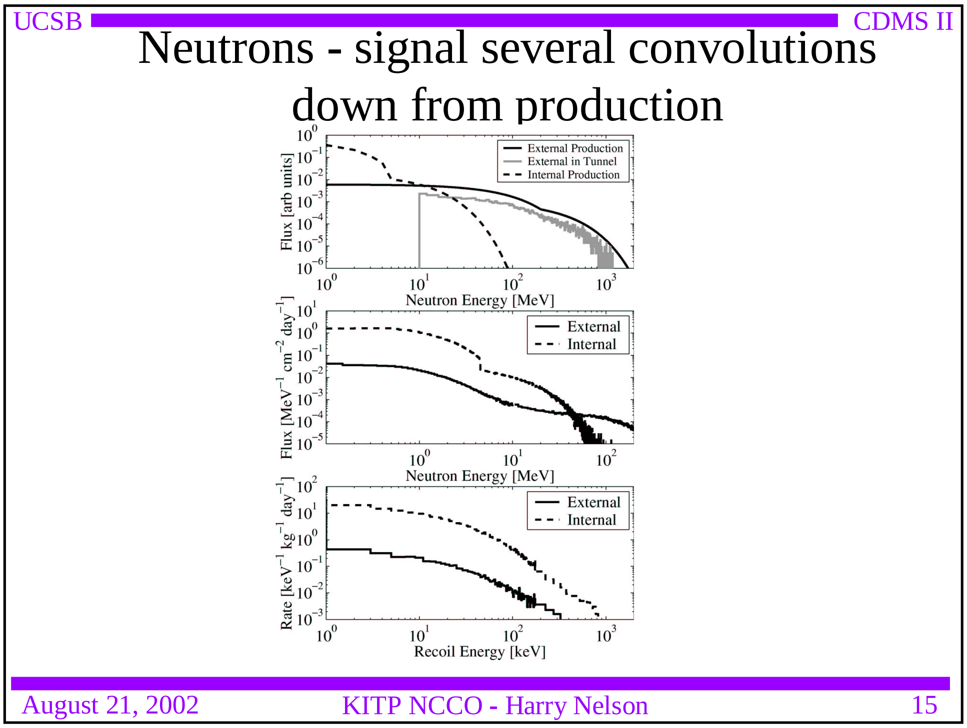
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CDMS II
Neutrons - signal several convolutions down from production
External Production
External in Tunnel
Internal Production
Flux [arb units]
Neutron Energy [MeV]
External
Internal
Flux [MeV−1 cm−2 day−1]
Neutron Energy [MeV]
External
Internal
Rate [keV−1 kg−1 day−1]
Recoil Energy [keV]
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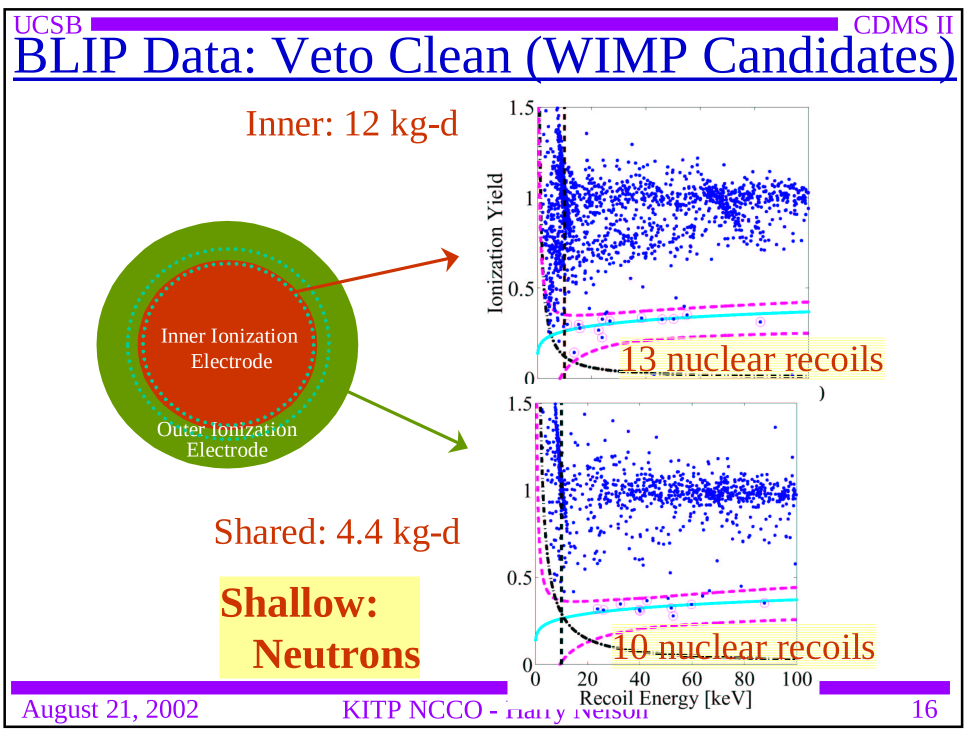
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CDMS II
BLIP Data: Veto Clean (WIMP Candidates)
Inner: 12 kg-d
Inner Ionization Electrode
Outer Ionization Electrode
Shared: 4.4 kg-d
Shallow: Neutrons
Ionization Yield
13 nuclear recoils
10 nuclear recoils
Recoil Energy [keV]
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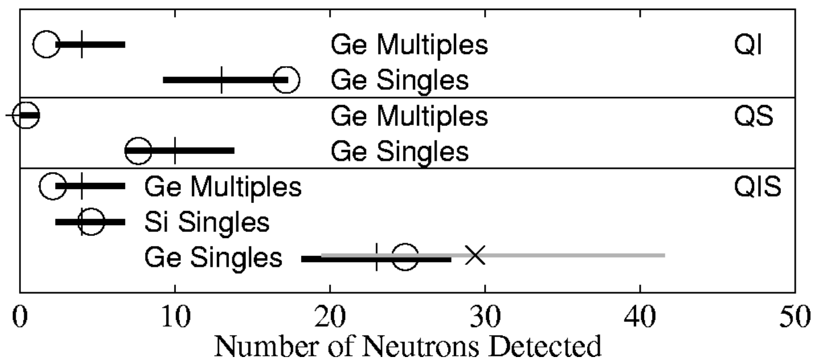
Neutron Checks

- Multiple Hits in the 4 Ge Detectors
- Short run with prototype Silicon ZIP



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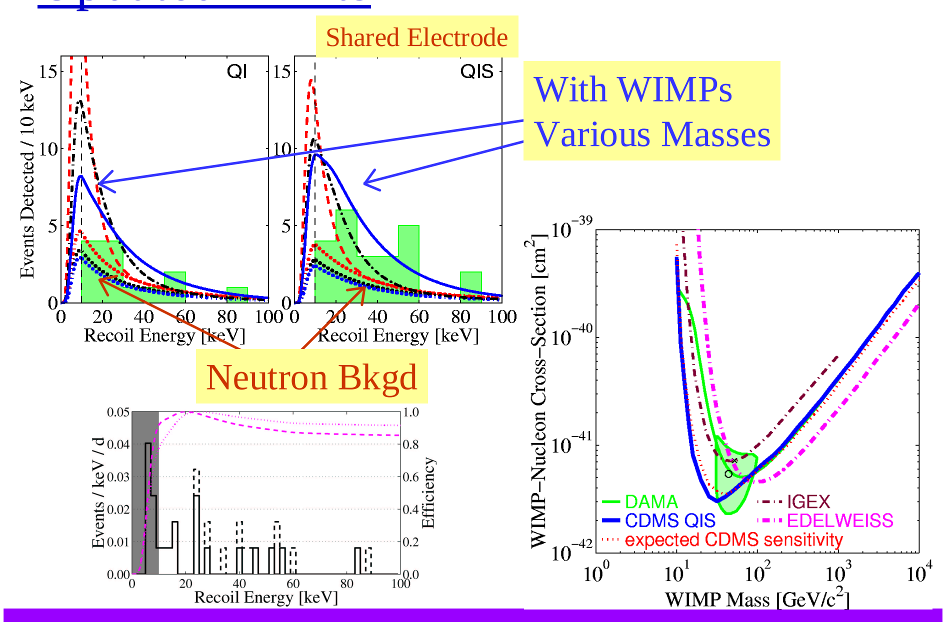
Updated Limits



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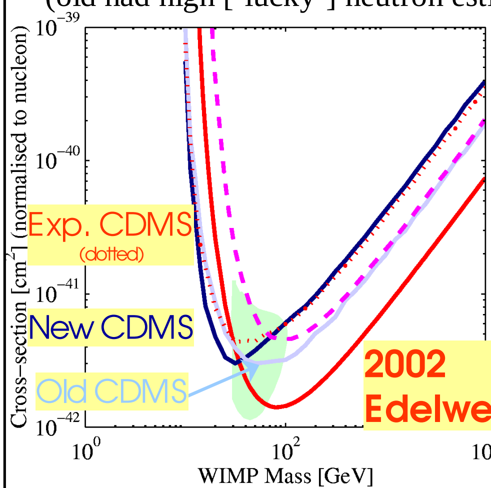
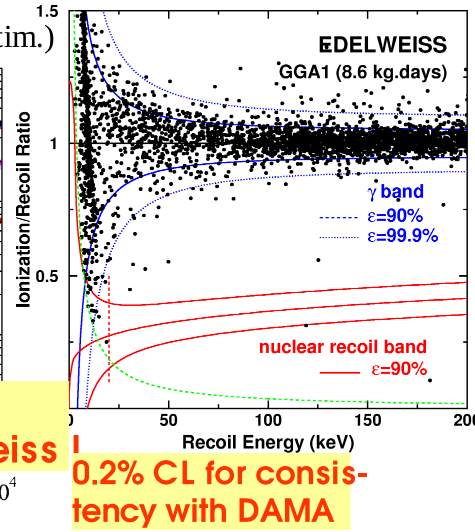
Explanation, Edelweiss

CDMS: shift toward expected
(old had high [`lucky'] neutron estim.)

Detectors: similar to CDMS





15.8 kg-d / 16 mwe depth

11.7 kg-d / 4500 mwe

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CDMS Status

- At Shallow Site (16 mwe):
  - ⇒ Neutron Shielding Added (reduce neutrons to 1/2)
  - ⇒ Detector Technology Completely Changed
    - → `ZIP'… detect athermal phonons
    - → Pulse faster - microseconds
    - → Pulse Risetime - rejection of external electrons
  - ⇒ 4 Ge Detectors, 2 Si Detectors
  - ⇒ 27 kg-d accumulated
    - → Data Terrific
    - → Results Later This Year
- Move to Soudan (2100 mwe) ASAP (42 det. Over 3 yrs.)

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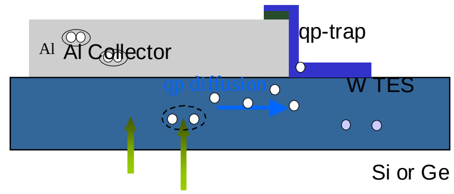
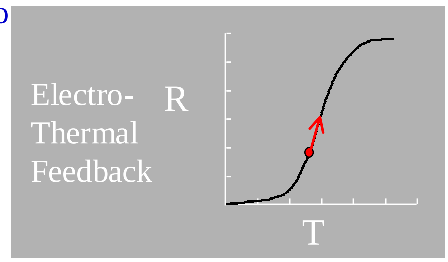
ZIP Detection Mechanism

- Recoil - THz phonons
- Phonons go to surface SC Al-fins, break Cooper pairs, giving quasiparticles.
- Quasiparticles diffuse in ~ μs to W transition-edge sensors (TES), where they release their energy to the W electrons
- Release energy, T is raised, R is raised
- Current change is measured with SQUIDs





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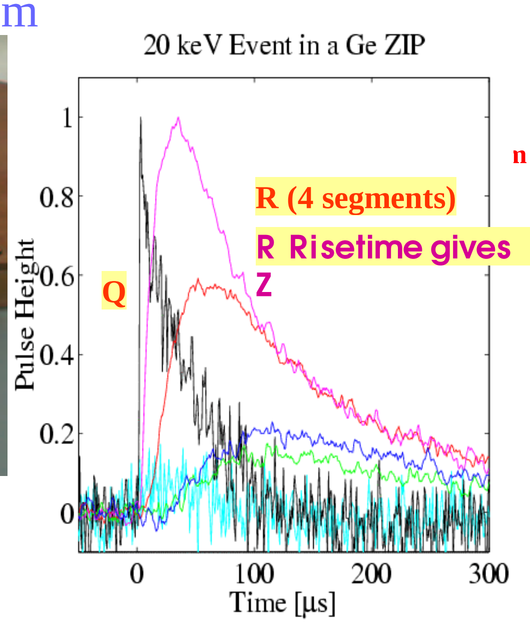
ZIPs on Germanium



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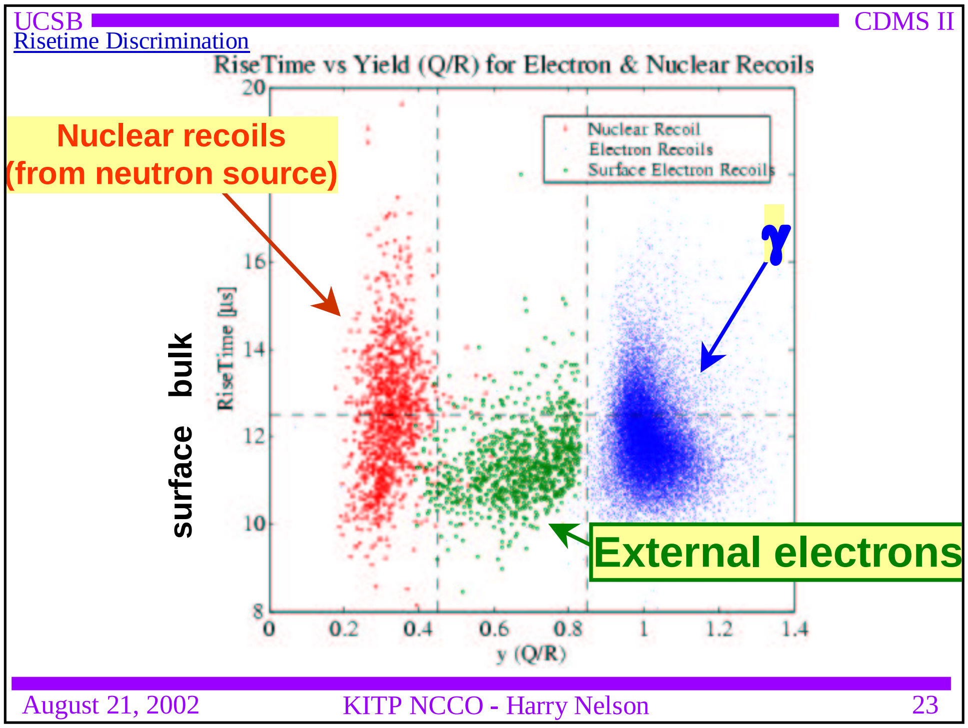
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CDMS II
Risetime Discrimination
RiseTime vs Yield (Q/R) for Electron & Nuclear Recoils
Nuclear recoils
(from neutron source)
Nuclear Recoil
Electron Recoils
Surface Electron Recoils
γ
bulk
surface
RiseTime [μs]
External electrons
y (Q/R)
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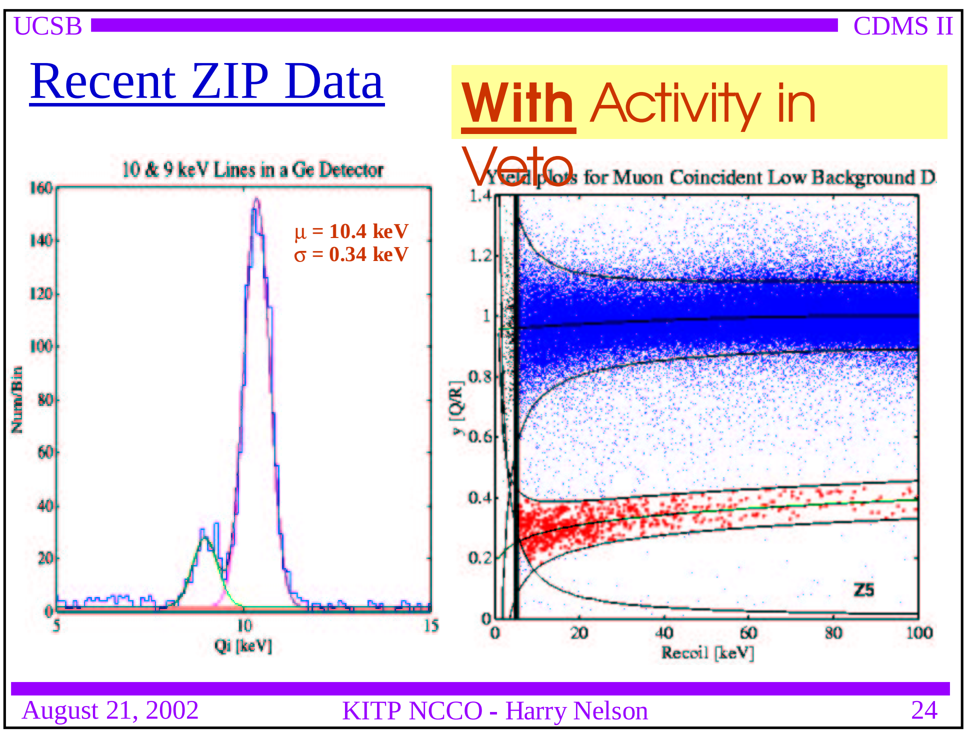
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CDMS II
Recent ZIP Data
With Activity in Veto
10 & 9 keV Lines in a Ge Detector
μ = 10.4 keV
σ = 0.34 keV
Num/Bin
Qi [keV]
Yield plots for Muon Coincident Low Background D
y [Q/R]
Z5
Recoil [keV]
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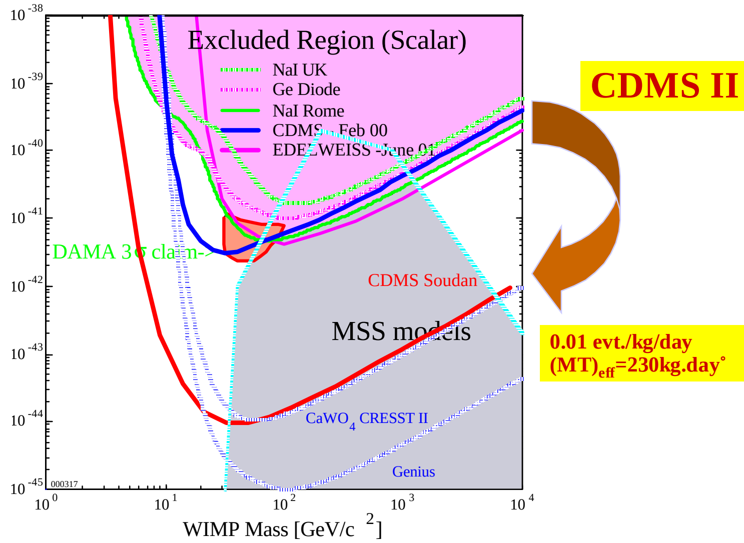
Next Step: Get to Soudan, suppress neutrons



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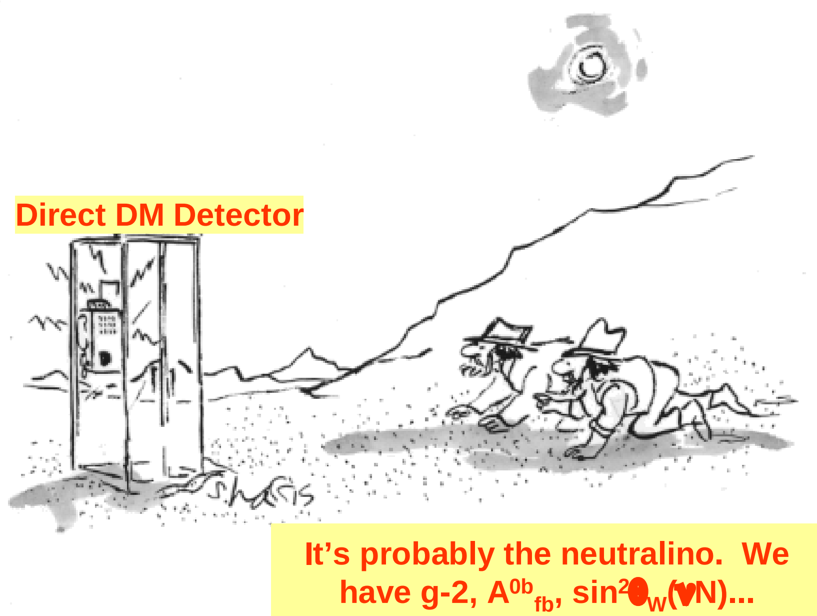

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