Latest WIMP exclusion results from the CDMS II collaboration

Rencontres de Moriond - 1st April 2004

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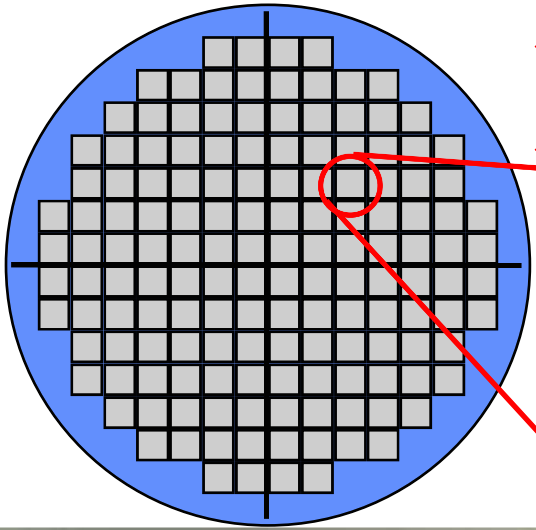
CDMS II Overview

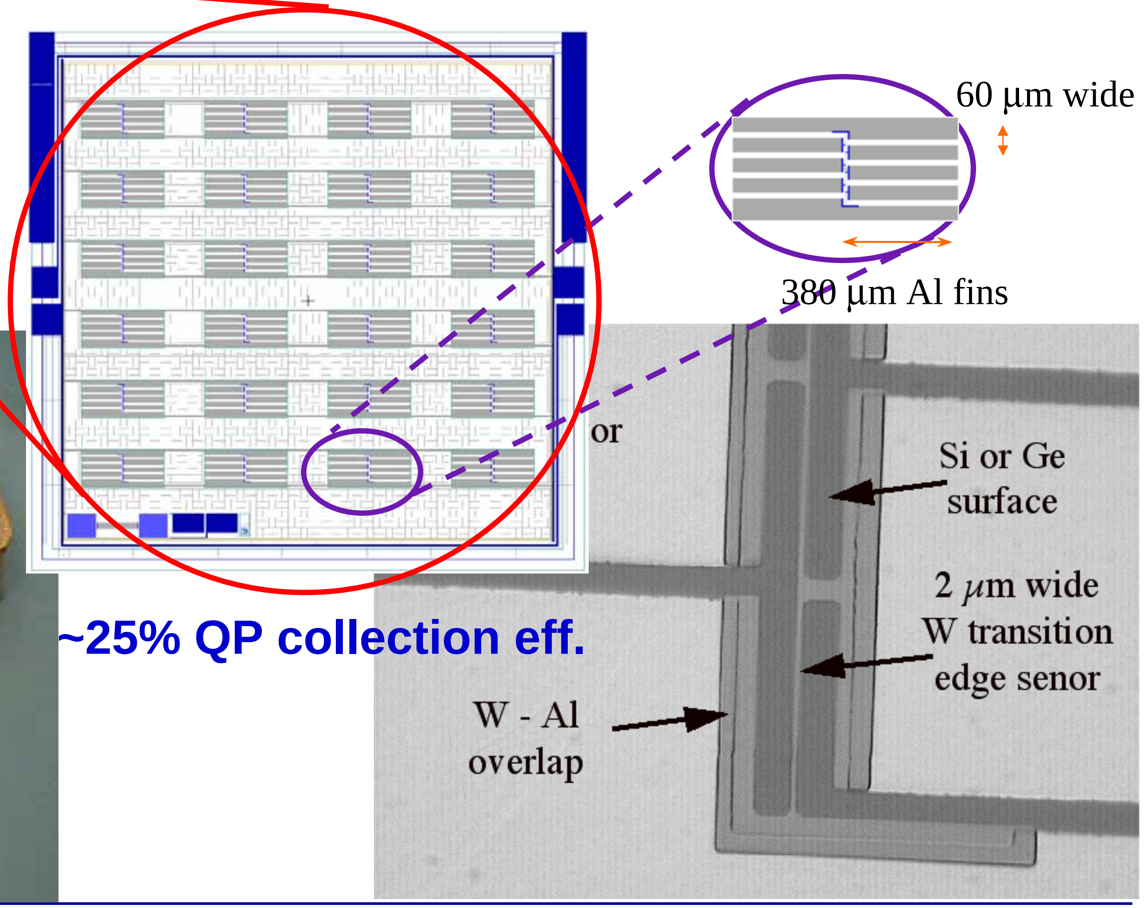
- Preparations for CDMS II at deep site
  - New athermal phonon technology
  - Calibration experiments, in particular using a Cd-109 beta source.
  - Ran first tower at SUF
  - Confirmed CDMS I results (Phys Rev D66, 122003 (2000) [astro-ph/0203500]), and published the ‘3 Volt only data’ Phys. Rev. D68, 082002 (2003) [hep-ex/0306001].
  - Our Conflict with DAMA, and agreement with Edelweiss, continues.
  - Measured ZIP detectors’ gamma and beta rejection efficiencies, better than CDMS II proposal.
  - Confirmed understanding of neutron Monte Carlos, correctly predicted neutron rate suppression with the addition of internal polyethylene.
  - Analysis of all data from SUF Run 21 (3 V + 6 V) nearly finished, with new risetime cut analyses. Expect new WIMP limit to be reported soon.

- Towers 1 and 2 installed at Deep site facility, Soudan, Minnesota.
  - First data set now being analysed, expect even better WIMP limit to be reported soon.
  - Still taking data …

ZIP detector phonon sensor technology

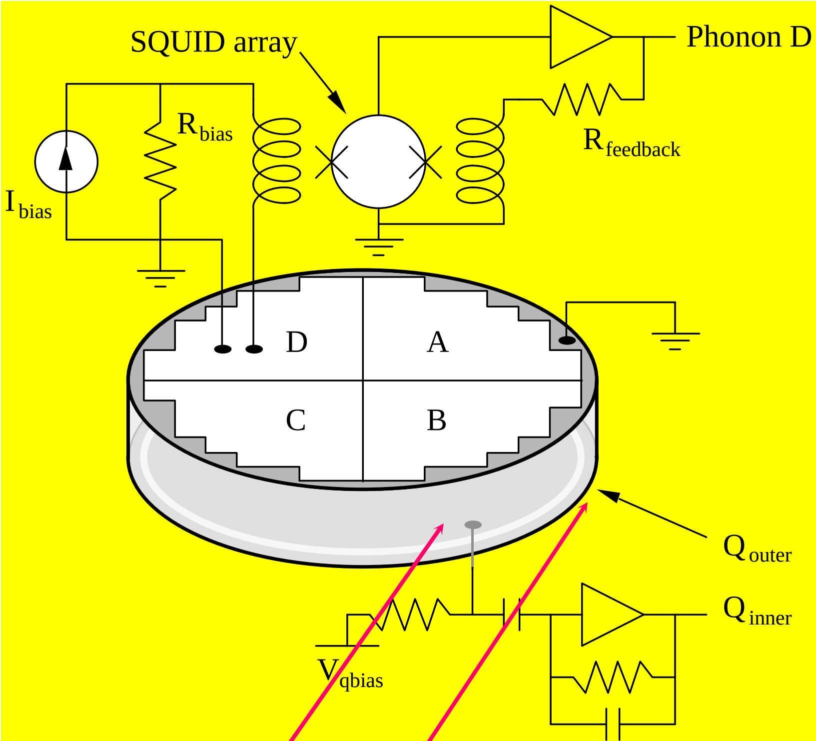
- TES's patterned on the surface measure the full recoil energy of the interaction
- Phonon pulse shape allows for rejection of surface recoils (with suppressed charge)
- 4 phonon channels allow for event position reconstruction

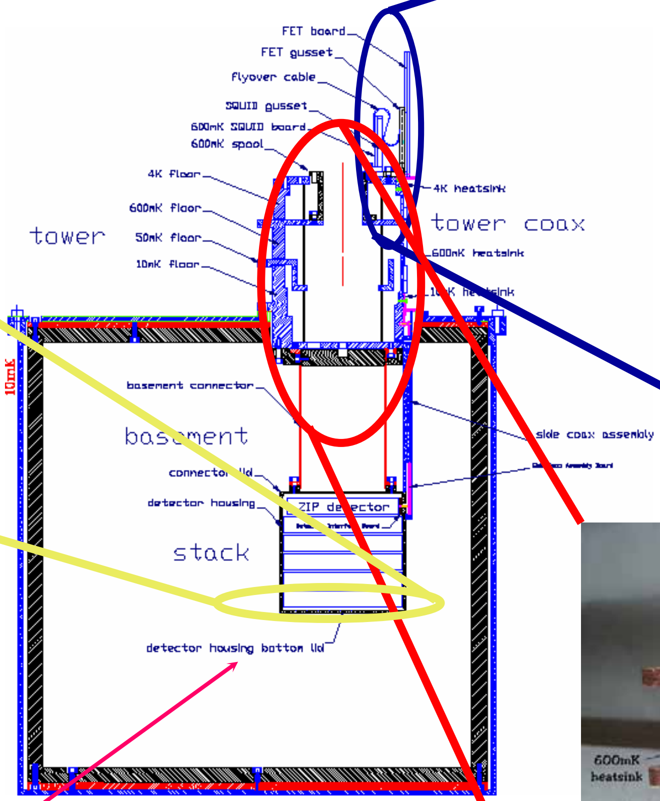




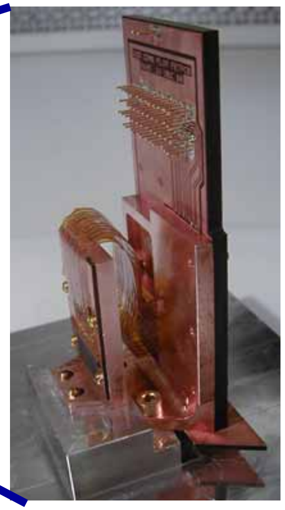
~25% QP collection eff.

CDMS II Experimental Setup

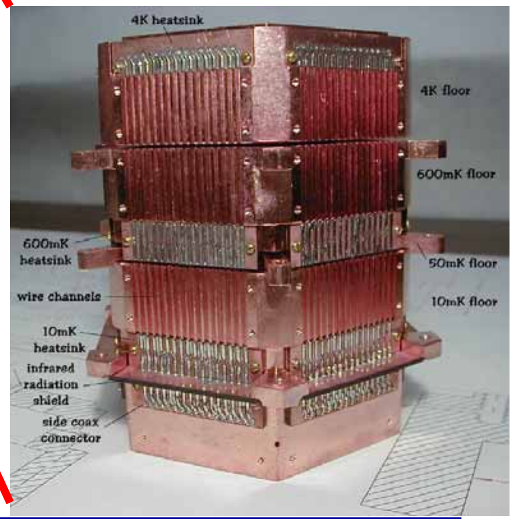




SQUET card



Tower

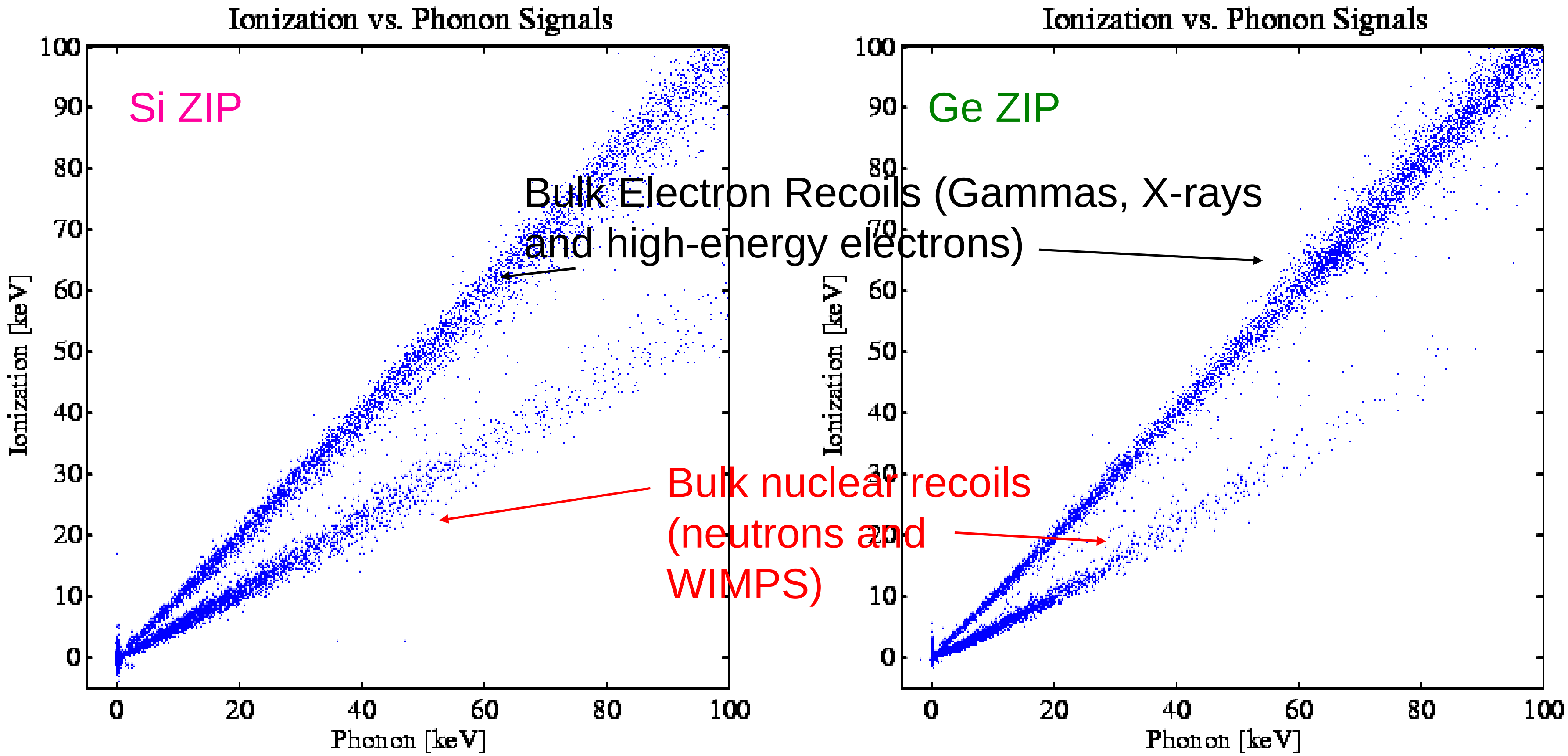


- Detectors: 250 g Ge or 100 g Si crystals 10 mm thick x 76 mm diameter.
- Two ionization electrodes, (Qinner and Qouter).
- Four phonon channels (A, B, C, D),
- reconstruct x, y and z coordinate.

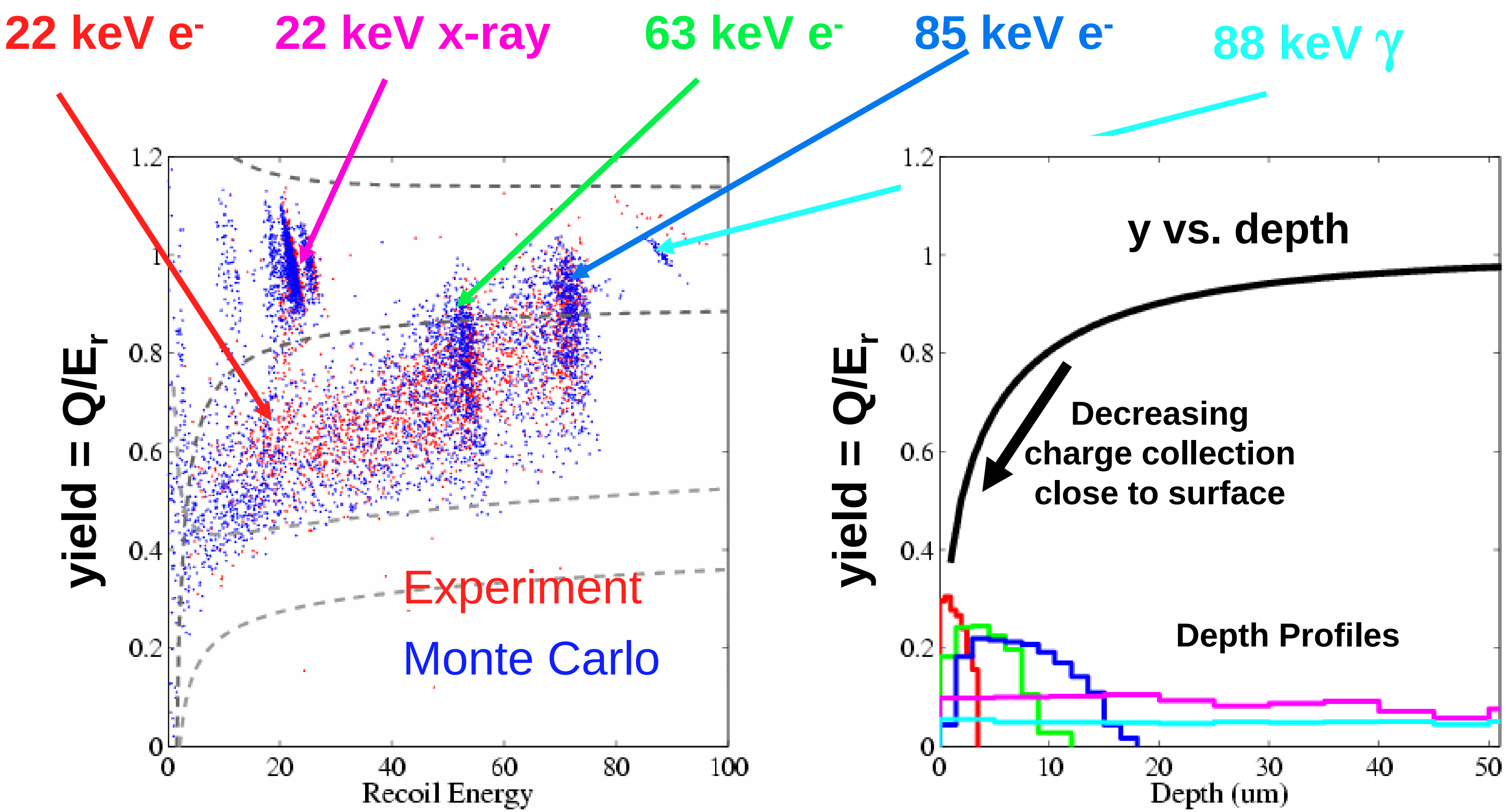
- Detector Stack contains 6 ZIP detectors within 10 mK can of the ‘icebox’

Photon and Neutron Calibration

The response of the detectors is best demonstrated with calibration photon and neutron sources

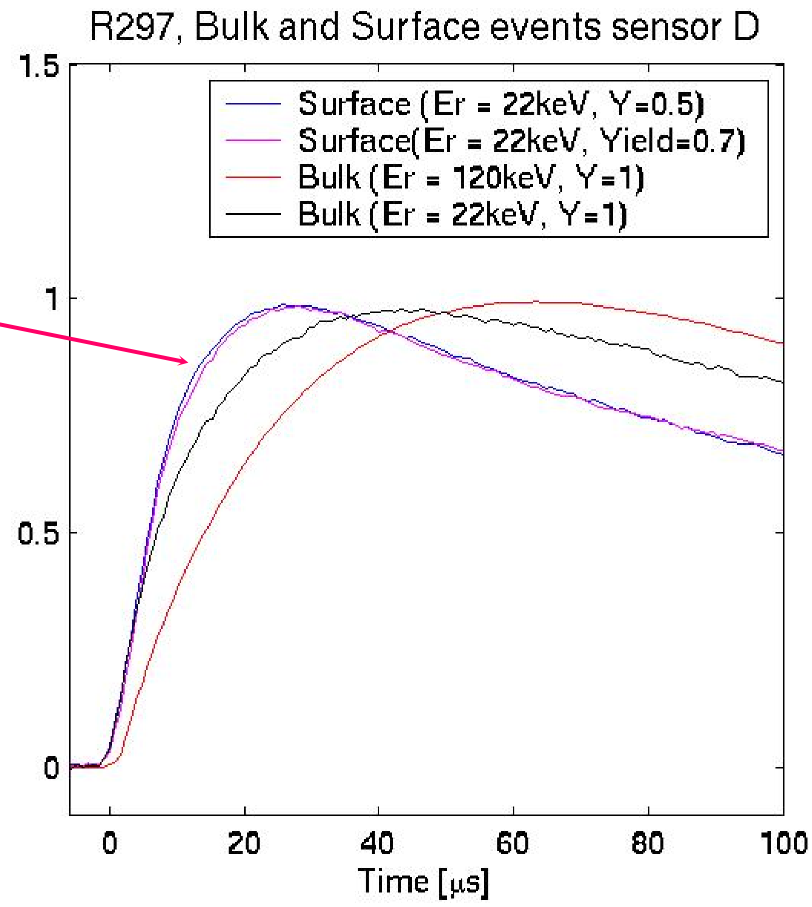


The Dead Layer (s) - ^{109}Cd calibration as probe



Surface Events and Phonon Pulse Shape

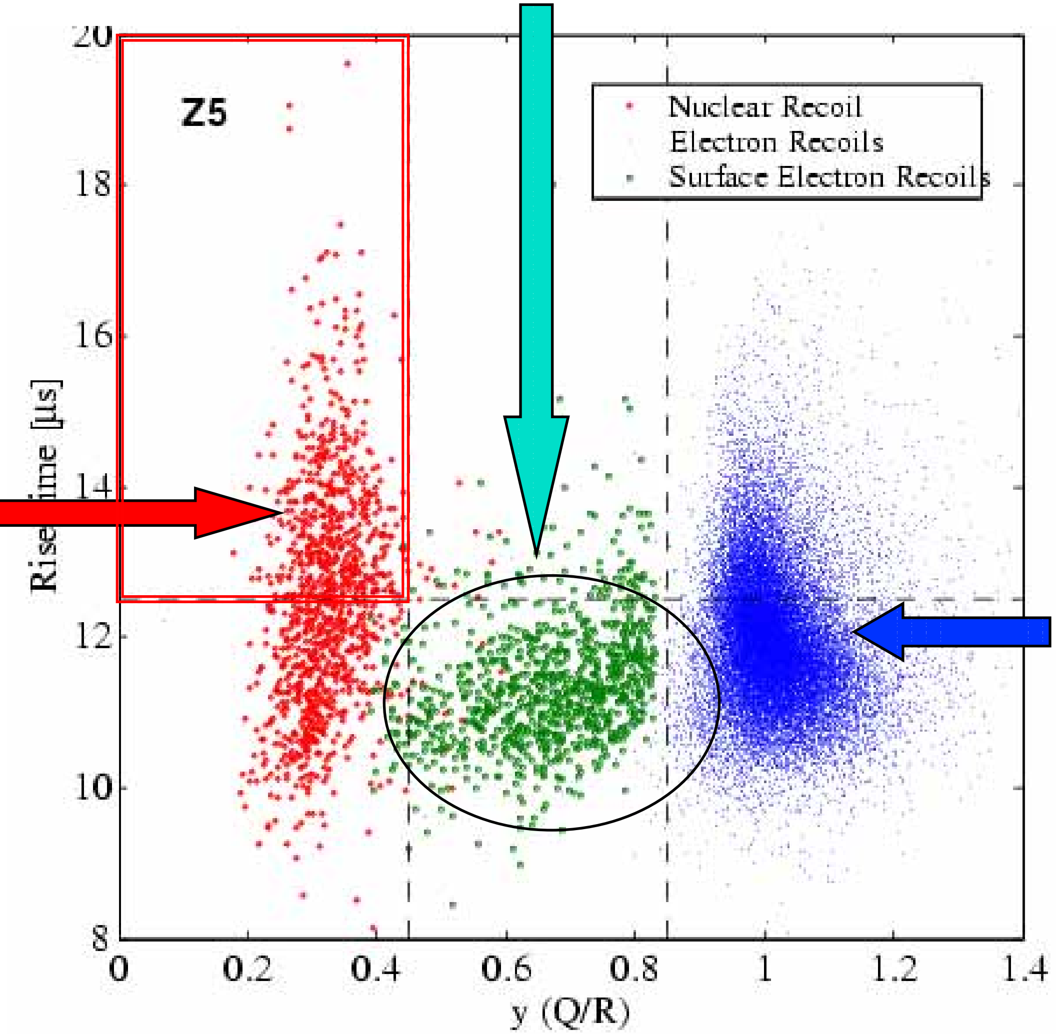
- Calibration run with ^{109}Cd source
- Phonon risetime for betas is faster
- This is why CDMS moved away from the NTD thermistor read-out of CDMS I to the TES based readout for athermal phonons.



Rejecting Dead Layer Events

Surface-electron recoils (selected via nearest-neighbor multiple scatters from ^{60}Co source)

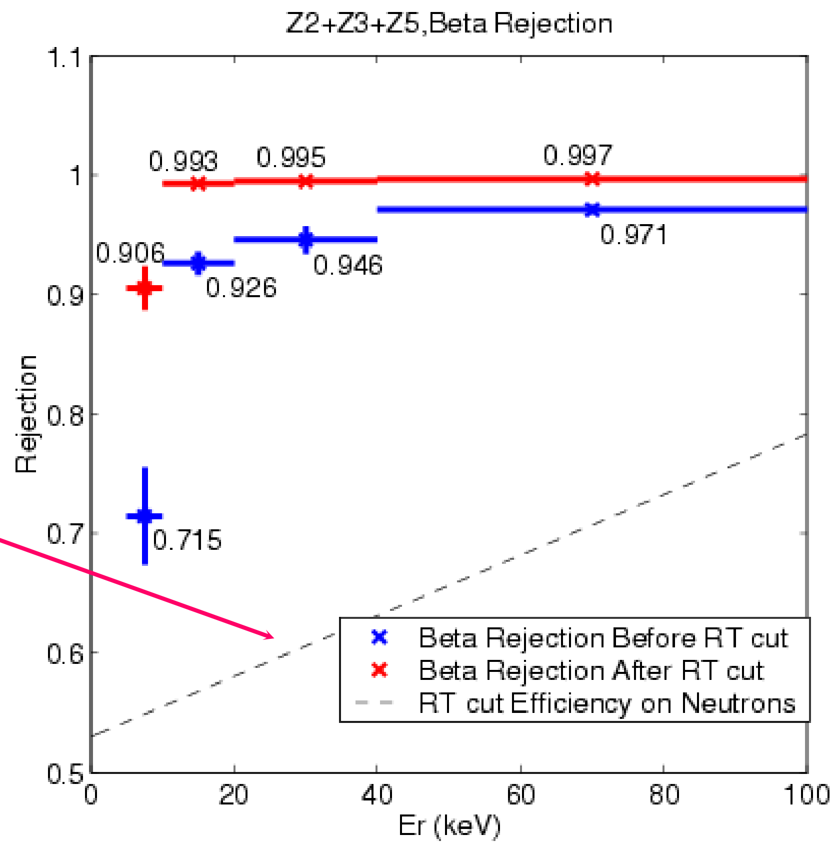
Neutrons from ^{252}Cf source



(Single-scatter) photons from ^{60}Co Source

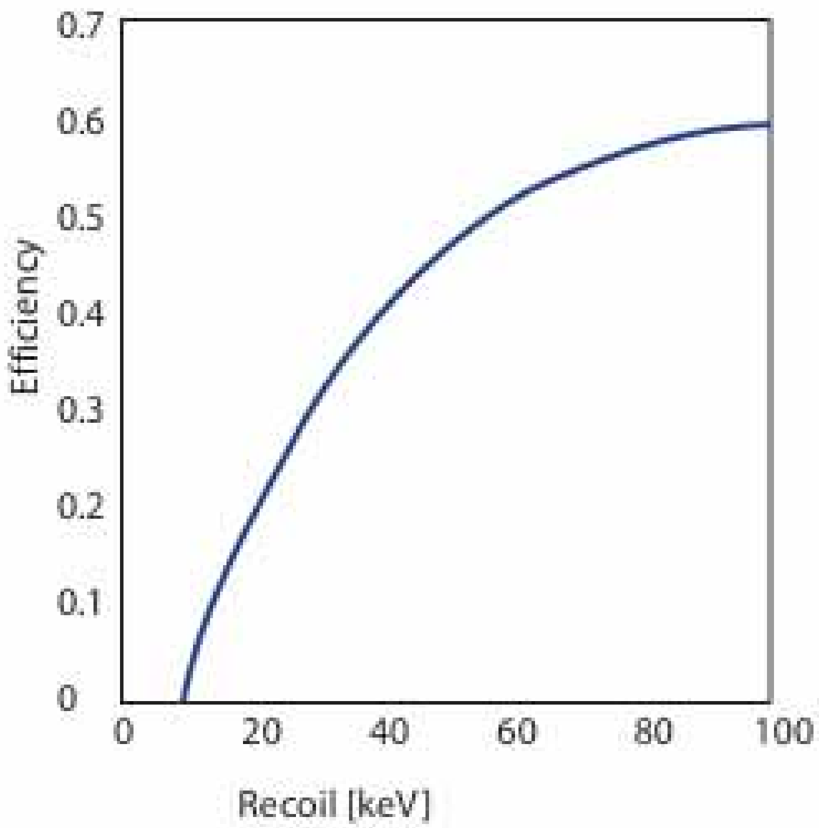
Surface Electron Recoil Rejection (3Volts)

- Rejection of dead layer events is ~ 90% using just the Yield (blue points)
- Risetime rejects ~80% of the surface events while retaining ~55% of neutrons (dashed line)
- Combined Yield and Risetime cut rejects >98% of the dead layer events above 10 keV (red points)



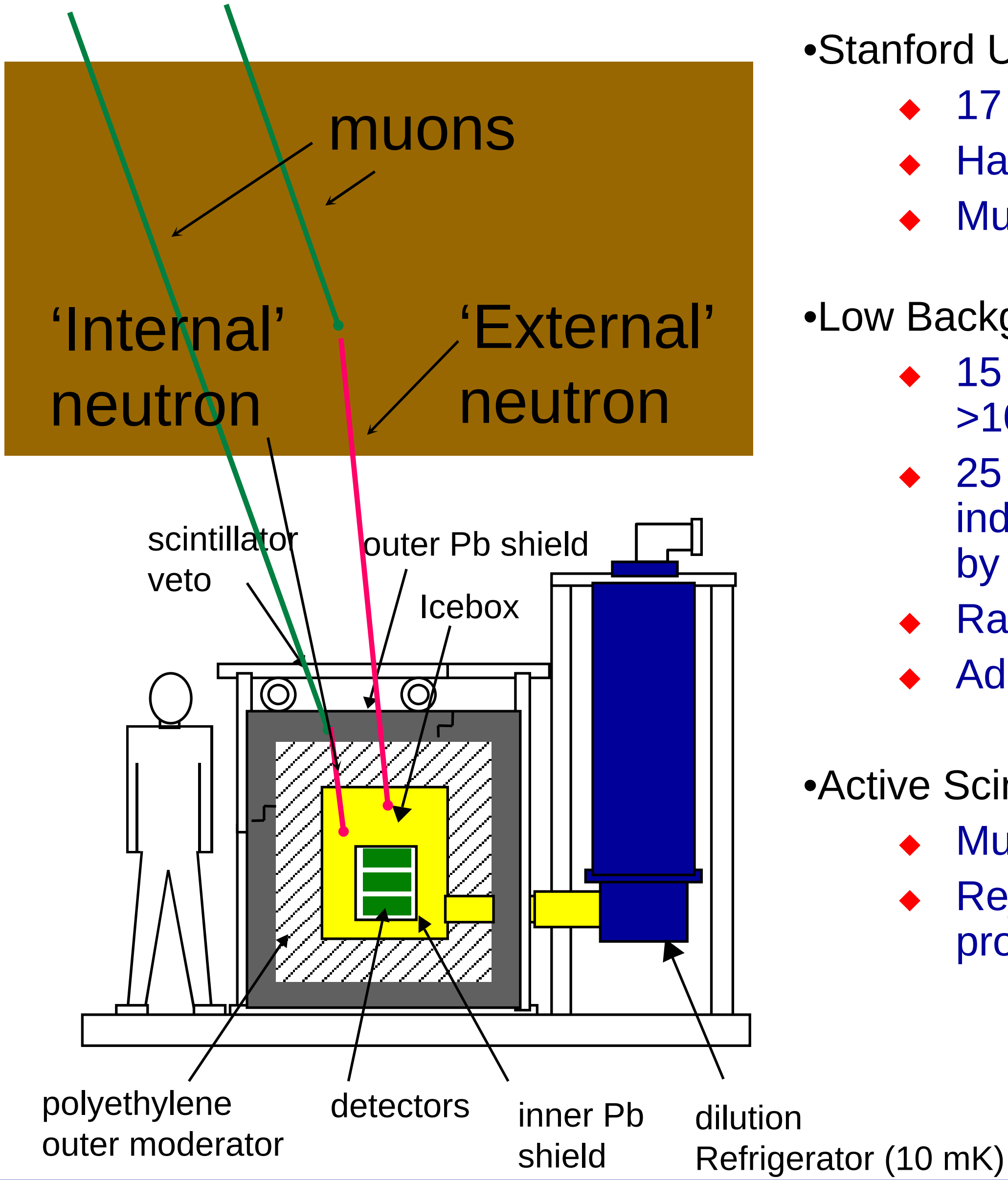
Acceptance efficiency of Nuclear recoils

Nuclear Recoil Acceptance vs Recoil Energy



- Declining sensitivity to Nuclear Recoils < 30 keV.
- Continuing to developing new cuts/ejection model so that beta-rejection remains high but NR acceptance increased.
- Preferred cuts depend on whether you want to maximize your sensitivity to low or high-mass WIMPs).

Stanford Underground Facility (SUF)

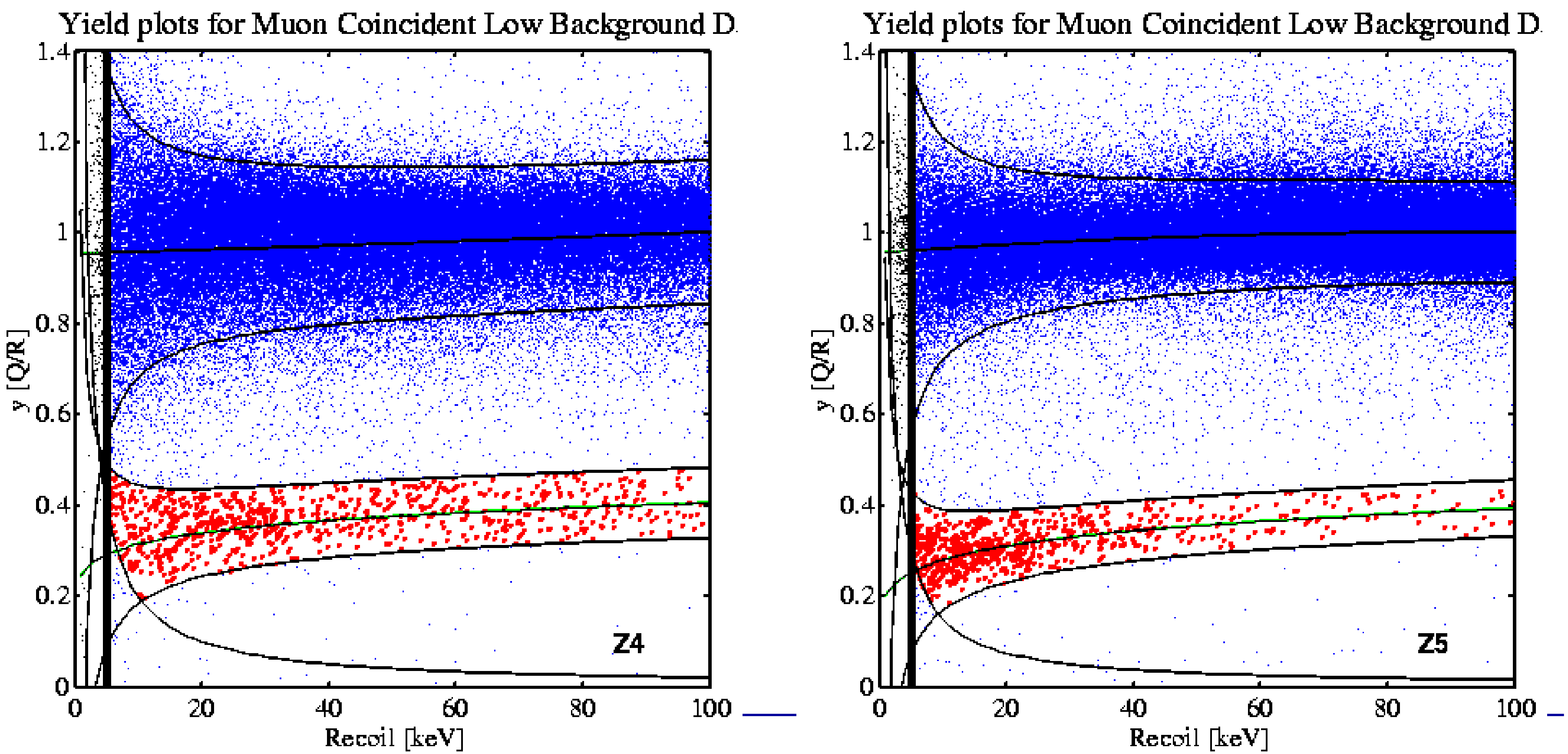


- Stanford Underground Facility
  - 17 mwe of rock
  - Hadronic component down by 1000
  - Muon flux down by ~5
- Low Background Environment
  - 15 cm Pb reduces photon flux by factor >1000
  - 25 cm polyethelyne reduces muon-induced neutron flux from rock and lead by factor >100
  - Radiopure cold volume (10 kg)
  - Additional internal (ancient) lead shielding
- Active Scintillator Muon Veto
  - Muon veto >99.9% efficient
  - Reject ~22 "internal" neutrons/ day produced by muons within shield

SUF 21 - Background Data

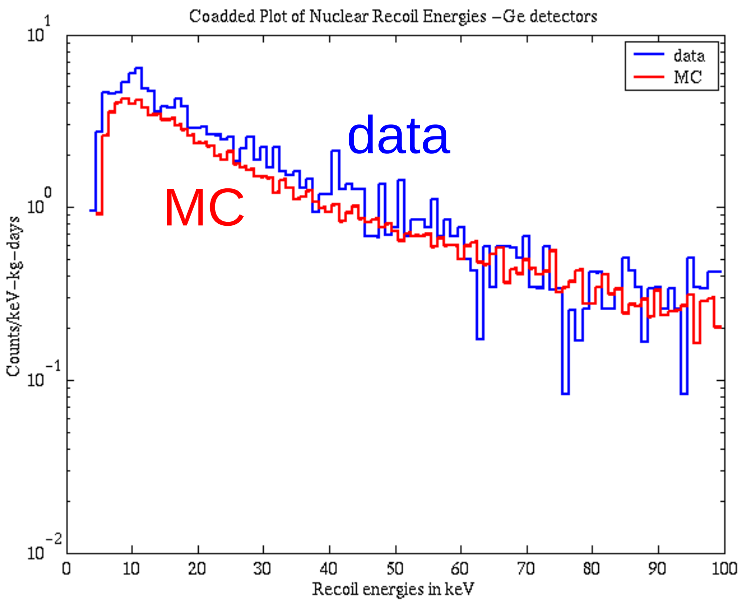
Yield plots for background data from the current run

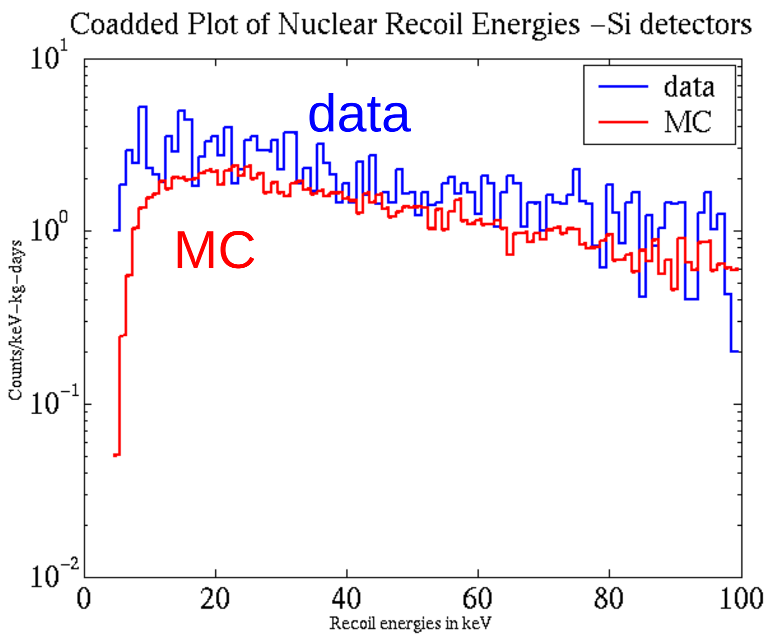
- –Muon Coincident Data
  - –Gamma background band is the dominant feature
  - –Muon coincident neutrons populate the nuclear recoil band
  - –A number of ‘*in between*’ events



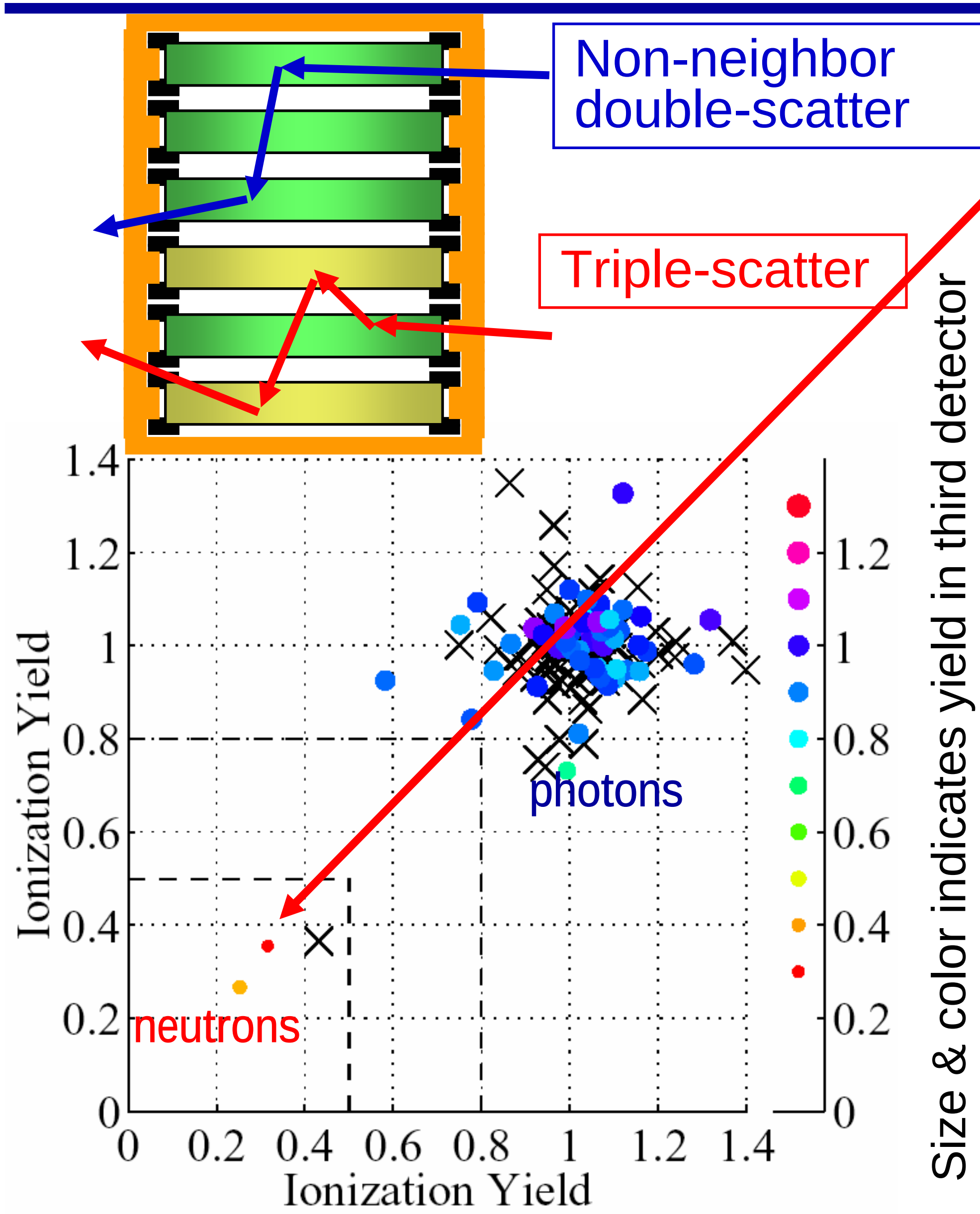
Neutron Singles to Multiples ratio

- Confirm validity of Neutron Monte Carlo by comparing with Veto-coincident Nuclear Recoils.
- After SUF Run 19, internal polyethylene was added. Predicted x3 drop in veto-coincident (internal) neutron rate; and x 2.3 drop in veto anti-coincident (external, punch-through) neutron rate. All confirmed in SUF Run 21.
- Singles/Multiples ratio of ~ 4.5 (depending upon NR acceptance cuts)
- ~39% of Multiples are non-nearest neighbor
- Ge/Si singles ~ 6



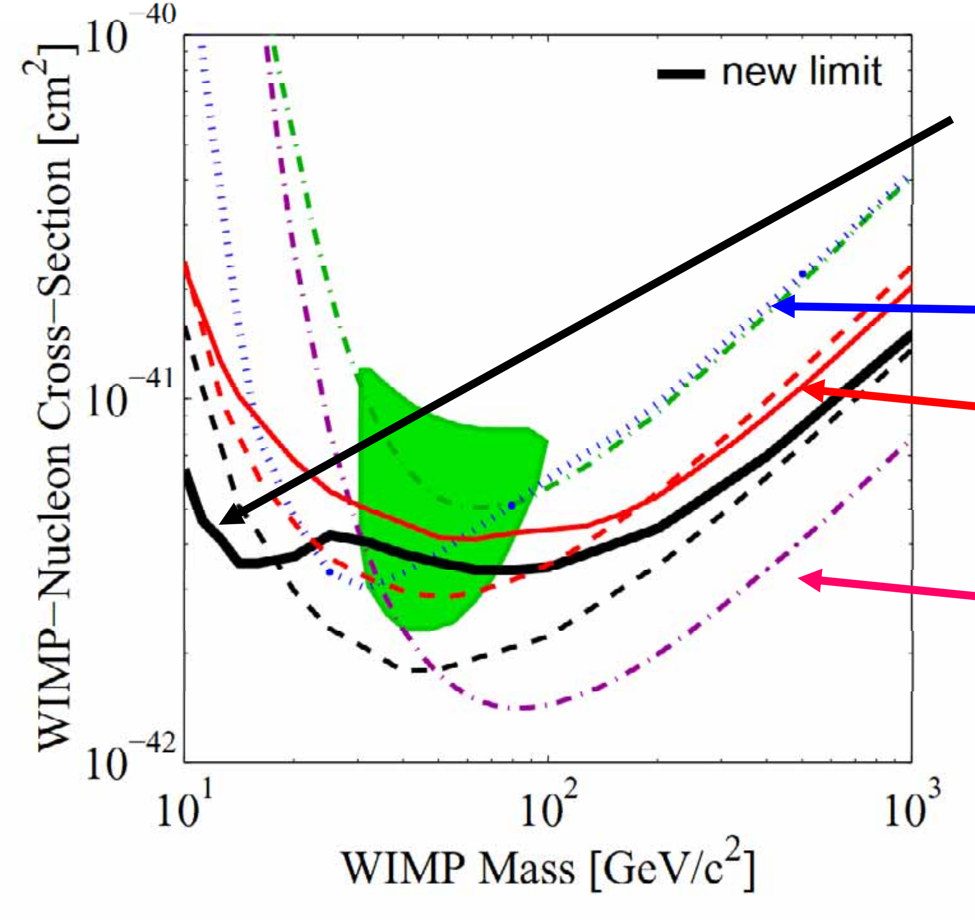


Neutron Multiple Scatters



- 2 triple-scatter (filled circles) and 1 non-nearest-neighbor double-scatter (X) NR candidates 5-100 keV
  - Ignore nearest-neighbor doubles because of possible contamination by surface electrons
- Expect ~16 single-scatter neutrons per 3 multiple scatters (exc. Nearest D)
  - Implies many (or all) of 20 Ge single-scatter WIMP candidates actually observed are neutrons

3 V bias SUF Run 21 WIMP limit



New CDMS II '3 V' SUF Run 21 limit, with neutron subtraction: Phys Rev D68, 082002 (2003)

SUF Run 19 limit

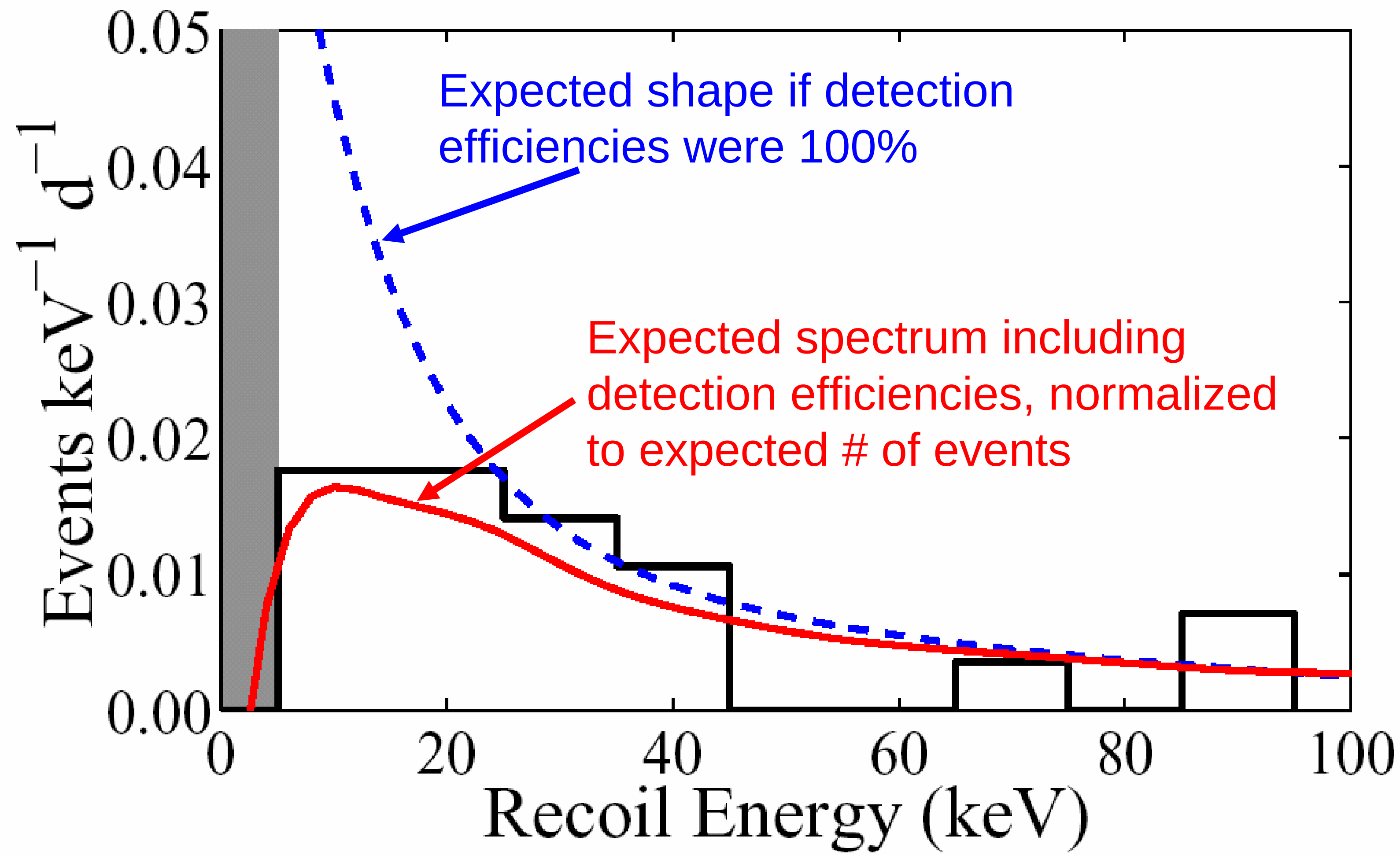
SUF Run 21 no neutron subtraction

Edelweiss 2002

- Exclude DAMA most likely points (x,o) at >90% even without neutron subtraction.

Expected sensitivities calculated from expected neutron background of 3.3 multiple-scatters, 18 single scatters in Ge, and an expected background in Si of 0.8 electrons and 3.6 neutrons.

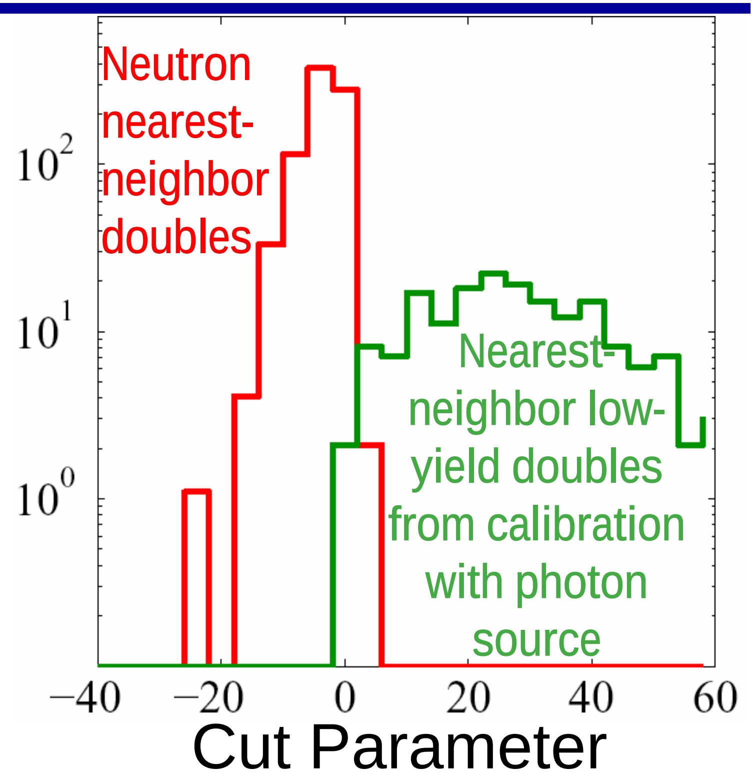
SUF 3V Nuclear-recoil energy Spectrum



- Energy spectrum agrees with expected neutron spectrum
  - Kolmogorov-Smirnof test indicates we should expect worse agreement 32% of time

Analysis of Full SUF Run 21 Data Set (3 V + 6V)

- Analysis of 119 livedays of data nearly complete
  - Two methods: One optimized for high-mass WIMPs, the other for low mass (10-30 GeV/c^2) WIMPs.
  - Performing crosschecks, estimating systematics
- Combined with increased exposure (54.3 kg-days vs 28.6 kg-days for 3 V only), and increased acceptance of nuclear recoils, expect a new WIMP limit with a 2x increased sensitivity to WIMPs at high mass.



- This new Analysis uses optimal cut parameter *f*(yield, risetime, energy). Allows separation of neutron nearest-neighbor doubles from surface-event background with negligible contamination

Neutron Backgrounds @ Stanford

- SUF Run 21 3V only (Akerib *et al.*, hep-ex/0306001)
  - 3 non-nearest neighbor multiples (2 triples and 1 double)
    - Nearest neighbor multiples not included due to background from ejectrons
    - Expect 16 Ge singles.
  - Observe 20 Ge and 2 Si singles in 28.6 kg days
  - Likelihood ratio test: expect worse agreement 30% of the time
- 3V + 6 V data *(preliminary 01/04/04)*
  - 7 multiples
    - 4 nearest-neighbor doubles - Introduced new beta cut which removes beta-contamination of nearest-neighbor multiples
    - Expect ~22 singles (harsher NR acceptance cut now in place for Z5)
  - Observe 19 Ge singles in 54.3 kg days
- Consistent with the story that we just see un-vetoed neutrons at SUF

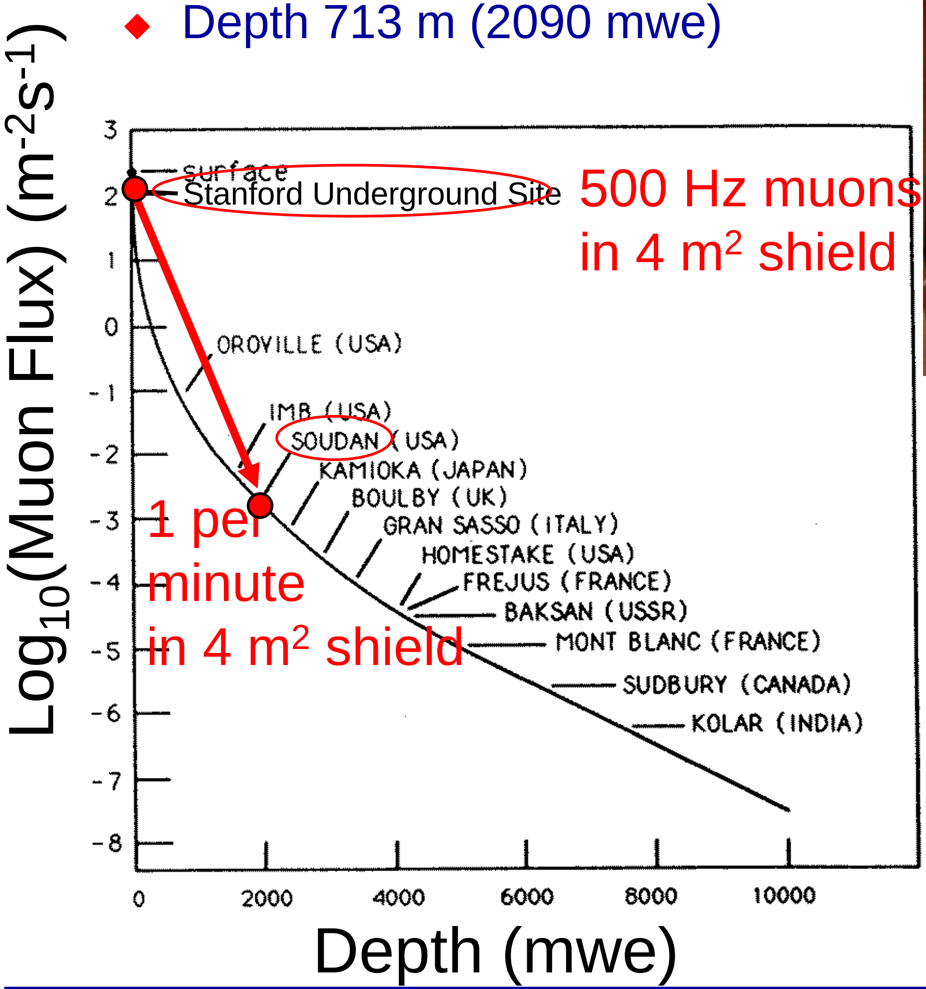
Soudan, Minnesota : The CDMS II Deep Site

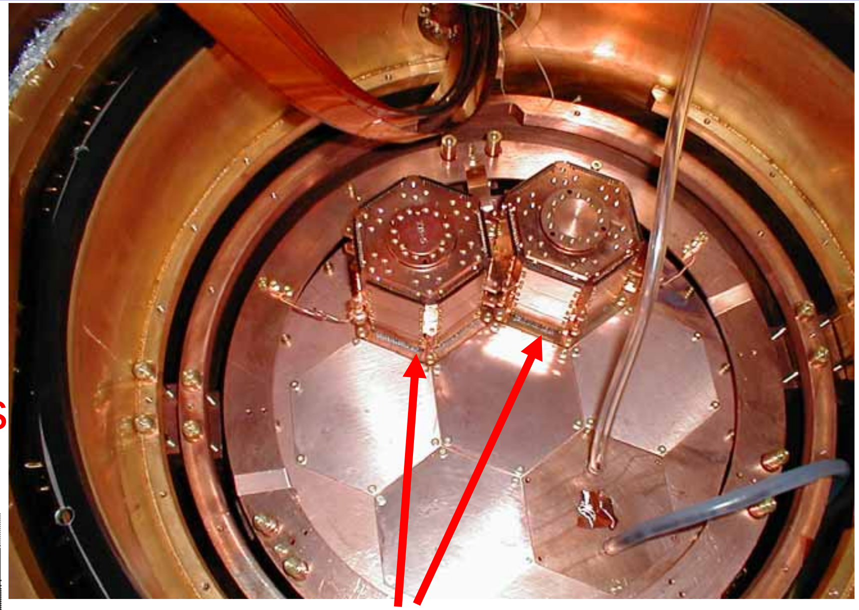
Preliminary 01/04/04

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

2003-2005: CDMS II at Soudan

- Reduce neutron background from ~1 / kg / day to ~1 / kg / year
  - Go to deep site: Soudan, Minn.
  - Depth 713 m (2090 mwe)

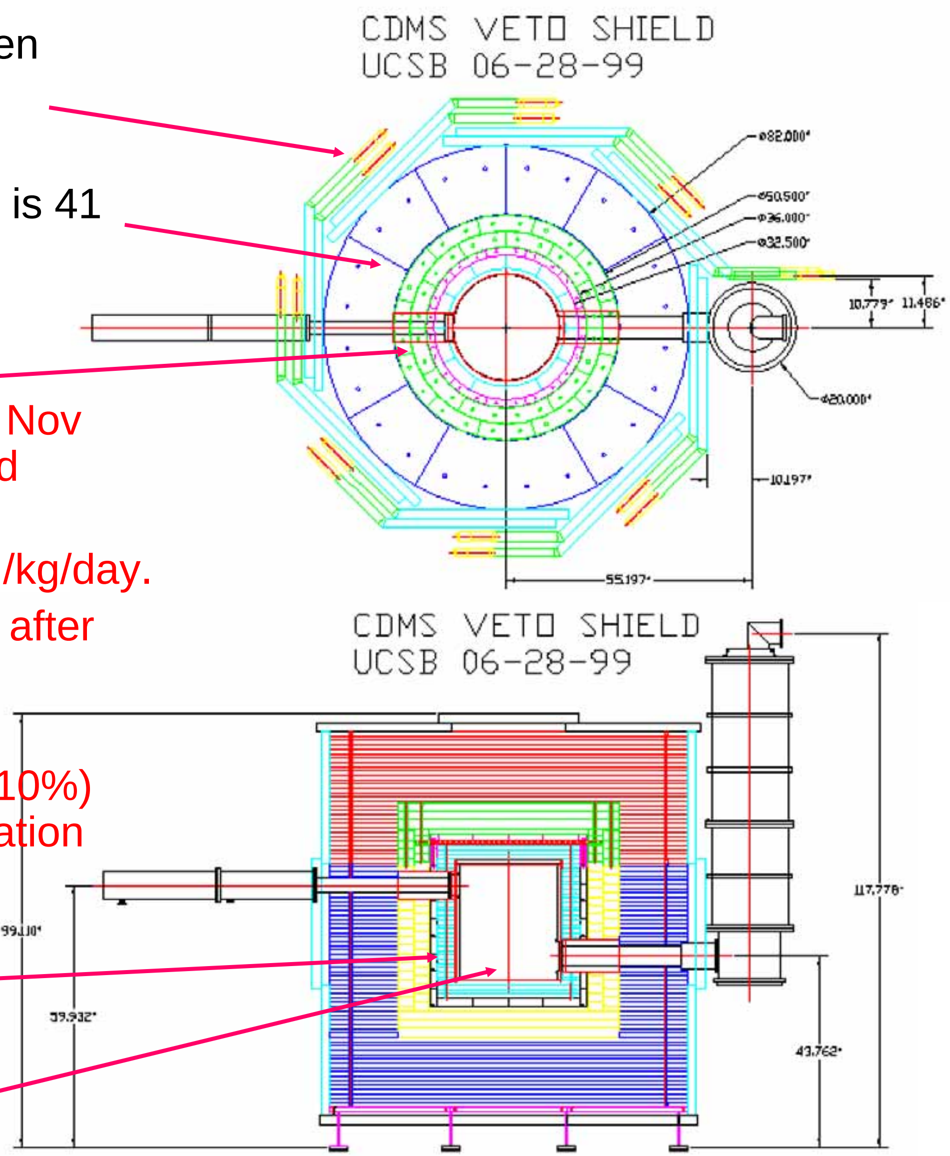




- 12 detectors in 2 towers of 6 each
  - 1.5 kg of Ge, 0.6 kg of Si
- 6 more detectors ready to go
- 12 more detectors in fabrication
  - 4 kg of Ge, 1.5 kg of Si total
- With current rejection and radioactive background rates, will improve sensitivity x100

CDMS II at Soudan - shielding and rates

- Muon veto paddles can discriminate between muons and high energy gammas.
- Outermost polyethylene neutron moderator is 41 cm thick.
- Outer lead gamma shield is 23 cm thick.
- Commenced Radon purge of lead shield in Nov ‘03: reduced gamma rate by x 5 and ejected electron rate by x 2.
- Now Ge ZIPs see 25 gammas (5 - 45 keV) /kg/day.
- And 0.005 beta leakage (5-45 keV)/kg/day, after cuts, into the nuclear-recoil band.
- Of which ~40% is due to the gamma rate.
- The rest is due to K-40 (~45%) , Pb-210 (~10%) and C-14 (~5%) detector surface contamination
- Secondary polyethylene neutron moderator is 14 cm thick.
- Icebox inner shield(s) will be optimized after first runs.



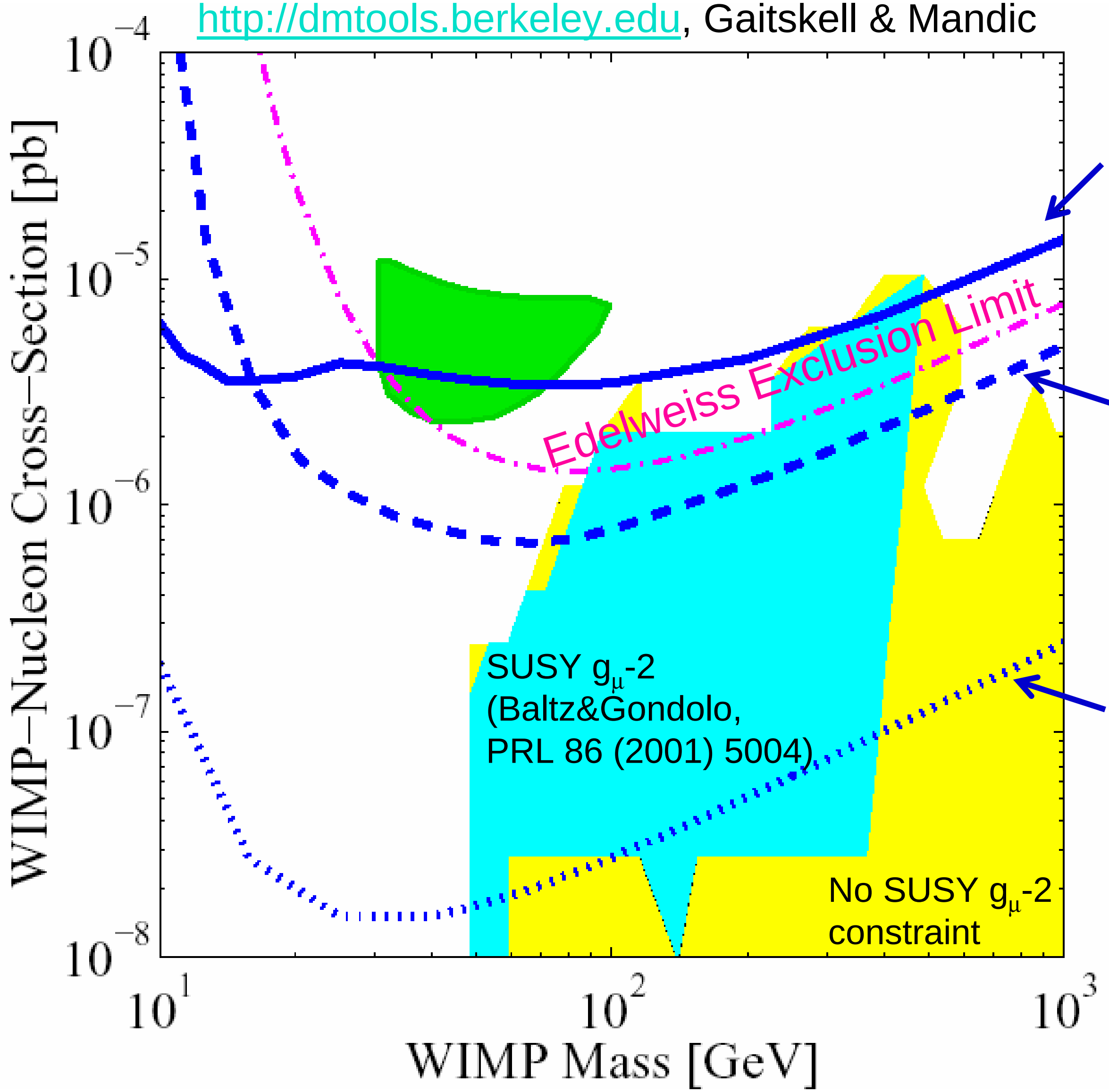
First Runs of CDMS II at Soudan

- October 2003- January 2004 run (118) of “Tower 1”
  - Same 4 Ge (0.85 kg) and 2 Si (0.17 kg) detectors run at Stanford
  - 52.6 livedays before any cuts.
  - Photon background same as Stanford with comparable shielding.
  - 24.5 kg-days Ge exposure after cuts set.(4.9 kg-days for Si)
  - Cuts were set ‘blind’ using gamma and neutron calibration sets. No access to single-scatter veto-anticoincident events that might be in the nuclear-recoil acceptance band.
  - Expect first WIMP results from Soudan to be reported this summer

- February 2004 - July 2004 run (119) of Towers 1 & 2
  - 6 Ge (1.3 kg) and 6 Si (0.5 kg) ZIPs in total.
  - The Tower 2 detectors are ‘newer’: less handling, more protection against Radon, may be cleaner.
  - First simultaneous running of all 12 detectors started last month.

Current and Projected CDMS Sensitivity

For more limit curves, see
http://dmtools.berkeley.edu, Gaitskell & Mandic



Current CDMS 'SUF R21 3 V' Limit

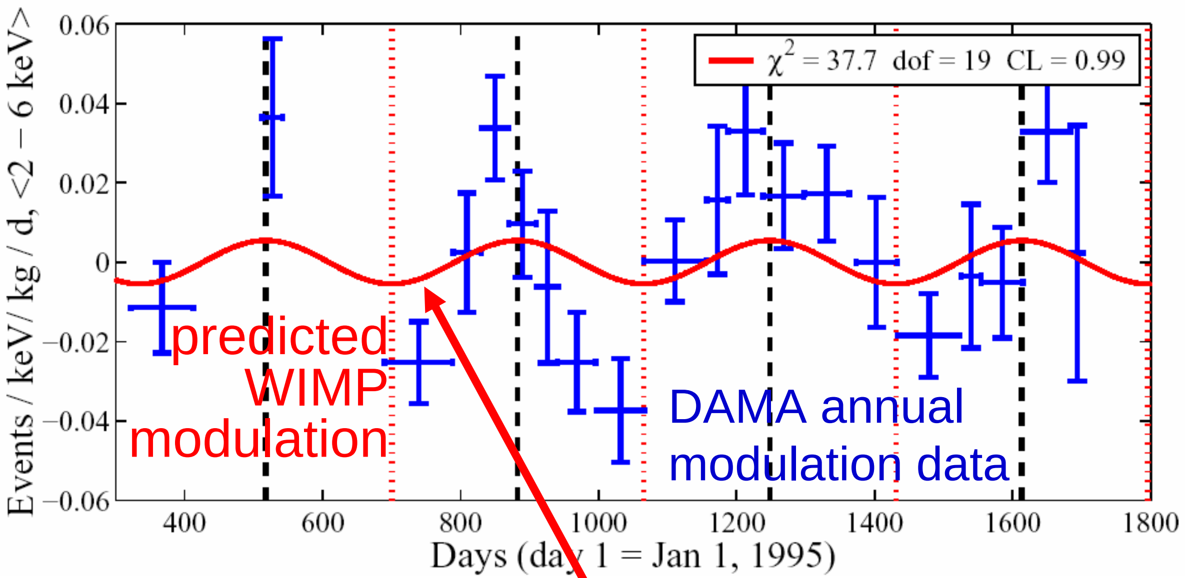
Expected sensitivity of data from CDMS Run118 at Soudan (Assuming 2 events in 25 kg-days).

Projected sensitivity for CDMS at Soudan, with 5 towers 4 kg Ge, 1.5 kg Si: 0.1 events/kg/keV/year (100x better than current limit).

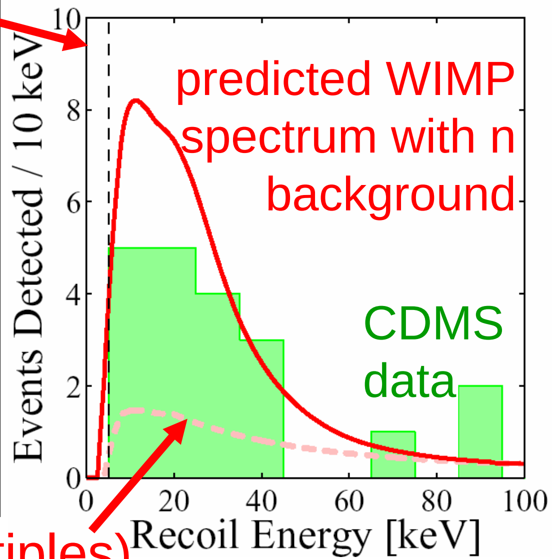
Conclusions

- CDMS II (at SUF)
  - First tower of 6 ZIP detectors exceed performance expectations.
  - Reduction of neutron background by factor of 2.3 due to installation of internal moderator at SUF in agreement with Monte Carlo predictions.
  - Sensitivity at SUF limited by external neutron background from muons interacting in surrounding rock.
  - Results for scalar-interacting ($\sigma \sim A^2$) WIMPs probed are best upper limits of any experiment for the mass range 10 to 35 GeV.
  - CDMS data are incompatible with DAMA signal at high confidence.
  - More work required on surface-beta rejection/identification/subtraction in order to fully utilize deep site?
- CDMS II (at Soudan)
  - First data set taken with Tower 1 at Soudan, 24.5 kg-days after cuts.
  - Willl announce new WIMP exclusion limit result in mid 2004.
  - Towers 1 & 2 now running at Soudan until mid 2004.

CDMS Incompatibility with DAMA



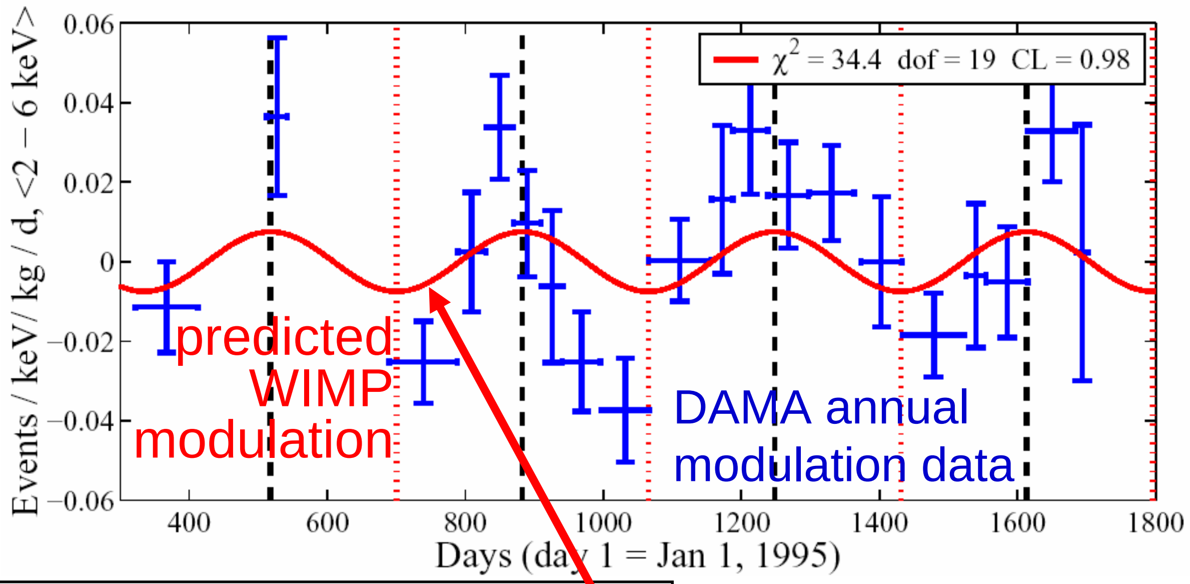
Best simultaneous fit to CDMS and DAMA predicts too little annual modulation in DAMA, too many events in CDMS (even for small neutron background)



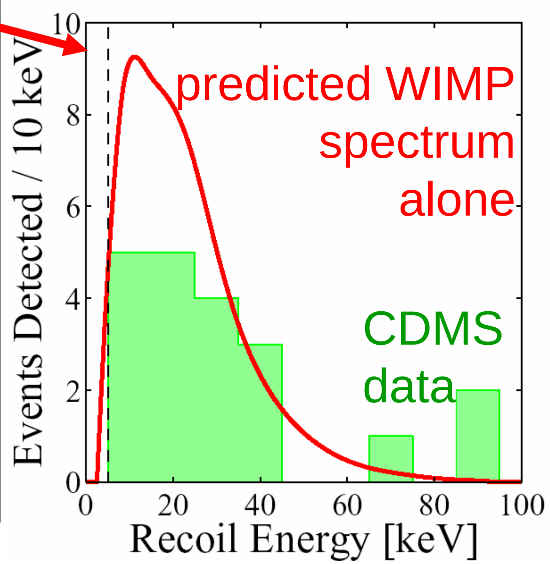
n background (1.4 multiples)

- Test under assumptions of
  - "standard" halo
  - standard WIMP interactions
- CDMS results incompatible with DAMA model-independent annual-modulation data (left) at > 99.98% CL

Incompatibility with DAMA (ignore CDMS n's)



Best simultaneous fit to CDMS and DAMA predicts too little annual modulation in DAMA, too many events in CDMS (even for no neutron background)



- Test under assumptions of
  - "standard" halo
  - standard WIMP interactions
- CDMS results incompatible with DAMA model-independent annual-modulation data (left) at > 99.8% CL even if all low-energy events are WIMPs