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Dec. 13, 2003

What is Cl

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- First loc
- Goals

Future Pla

- Backgrc
- Detector
- CDMS I

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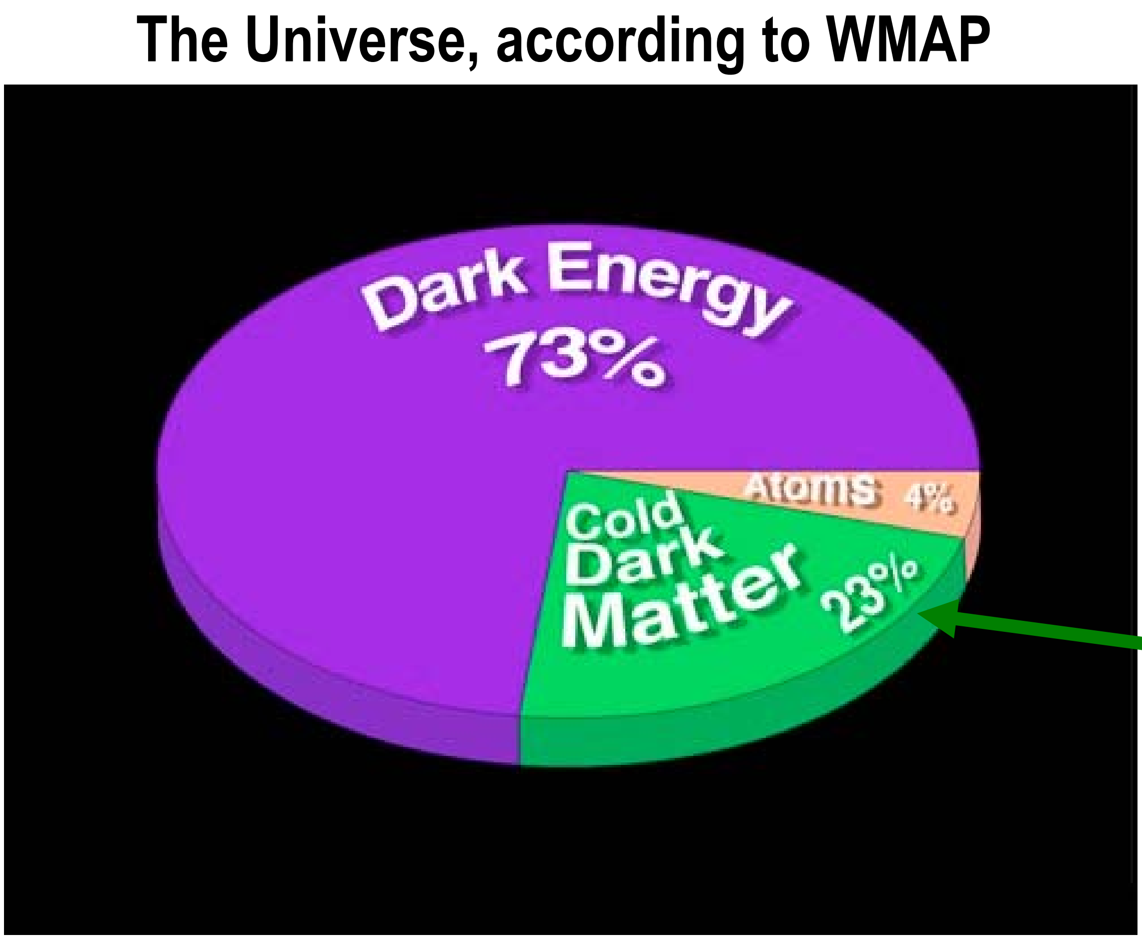
What are we looking for?

Cold Dark Matter



Best candidate:
WIMPS

Particle theory:
SUSY neutralino

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NSF/DOE review
Oct. 22, 2003

What is CDMS?

Dark Matter Search

Goal is direct detection of WIMP halo that holds our galaxy together

Cryogenic

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

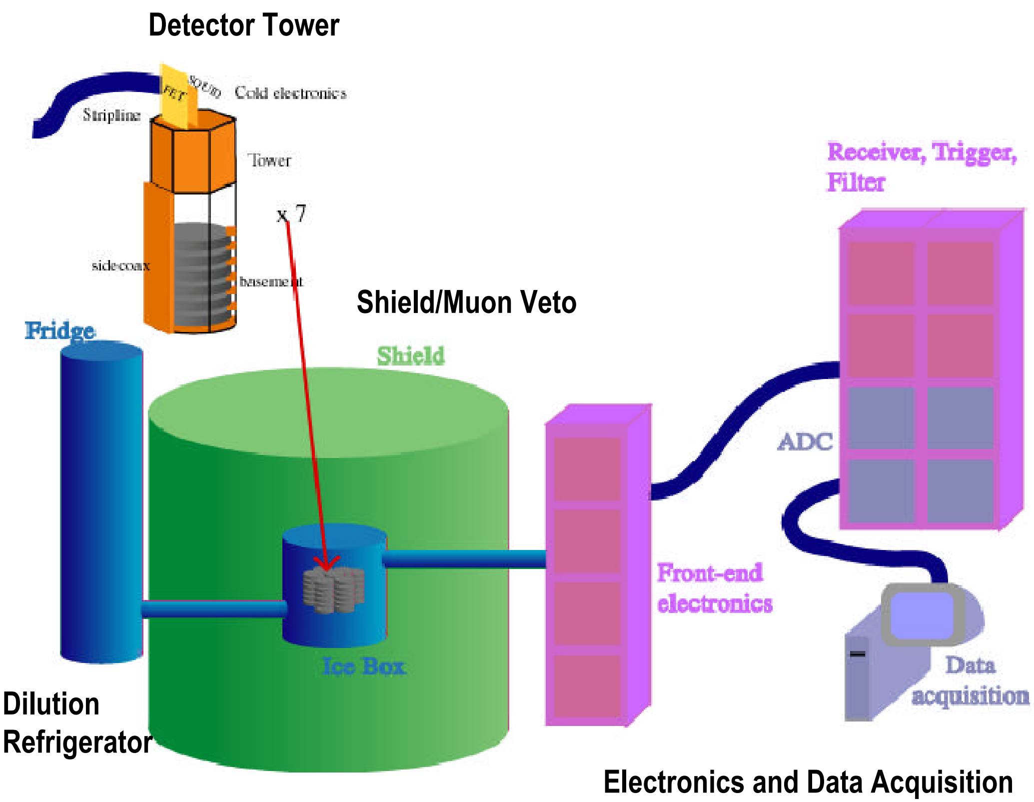
Active Background Rejection

Detect heat and charge

- WIMPS, neutrons => nuclear recoils
  - Charge/Heat ~ 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 (Pb, polyethylene, Cu) against radioactive backgrounds and active scintillator veto (>99.9% efficient against cosmic rays).

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CDMS Active Background Rejection

Detectors with excellent event-by-event background rejection

Measured background rejection:

> 99.98% for EM backgrounds using charge/heat

> 99% for β's using pulse risetime as well

Better than expected in CDMS II proposal!

Tower of 6 ZIPs

Tower 1

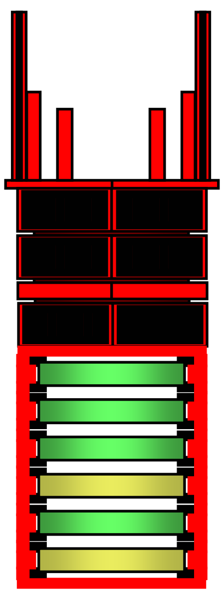
4 Ge

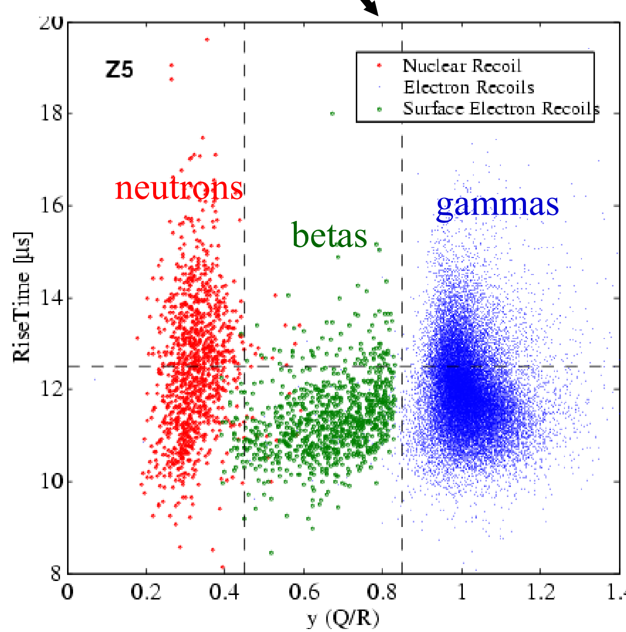
2 Si

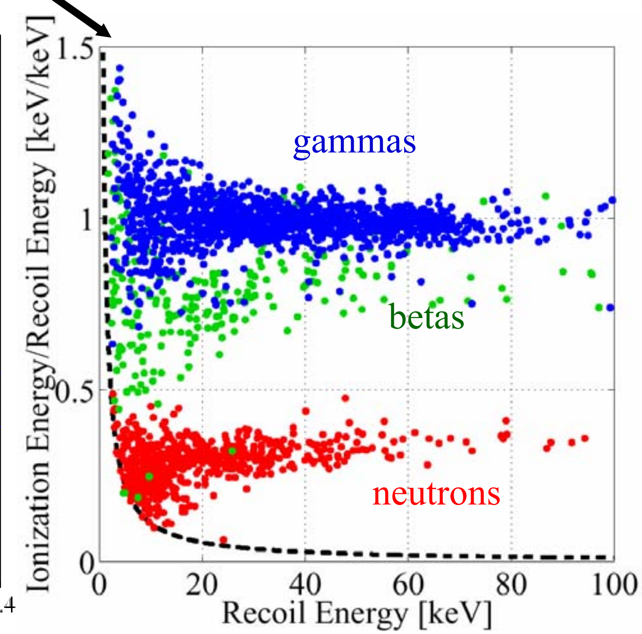
Tower 2

2 Ge

4 Si







How are we better than the competition?

Low thresholds (< 10 keV recoil)

- Access to lower mass WIMPs
- Factor 2 better than EDELWEISS
- Big advantage with respect to Xenon experiments

Better rejection => more information about events

- Ionization yield (ratio of charge to phonon signal)
- Rise time (discrimination against surface events)
- Segmented charge electrode (fiducial cut against outer regions of crystal)
- Position resolution (mostly from phonon signals)
- Multiple detectors (multiple scattered events = neutrons)
- Si vs Ge (neutrons or WIMPs)

In a discovery: we have many checks that events are WIMPs

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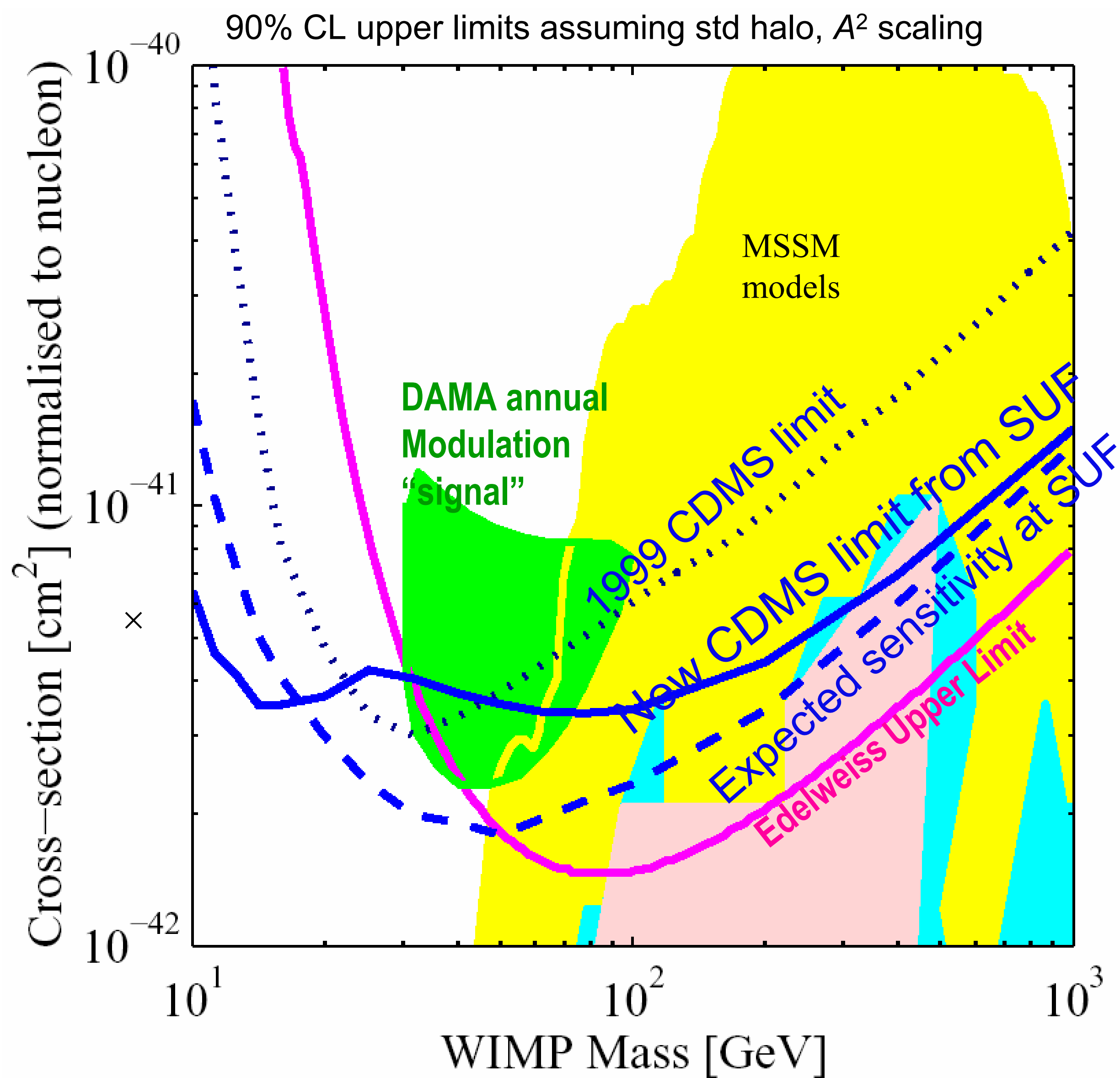
Some recent WIMP direct detection experimental results



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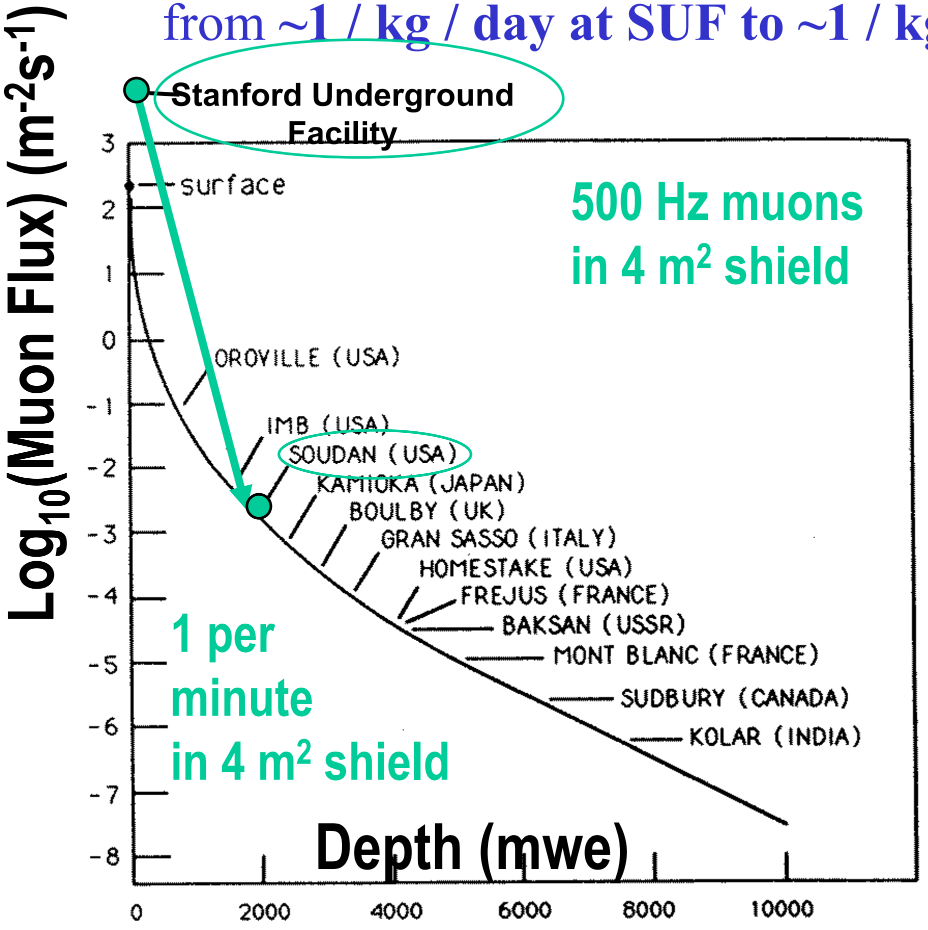
Why are we at Soudan (aside from the weather)?

- Dominant background in CDMS I at SUF is fast neutrons from cosmic ray interactions in surrounding rock.
- Depth of 2000 mwe reduces cosmic-ray-induced neutron background from **~1 / kg / day at SUF to ~1 / kg / year at Soudan**



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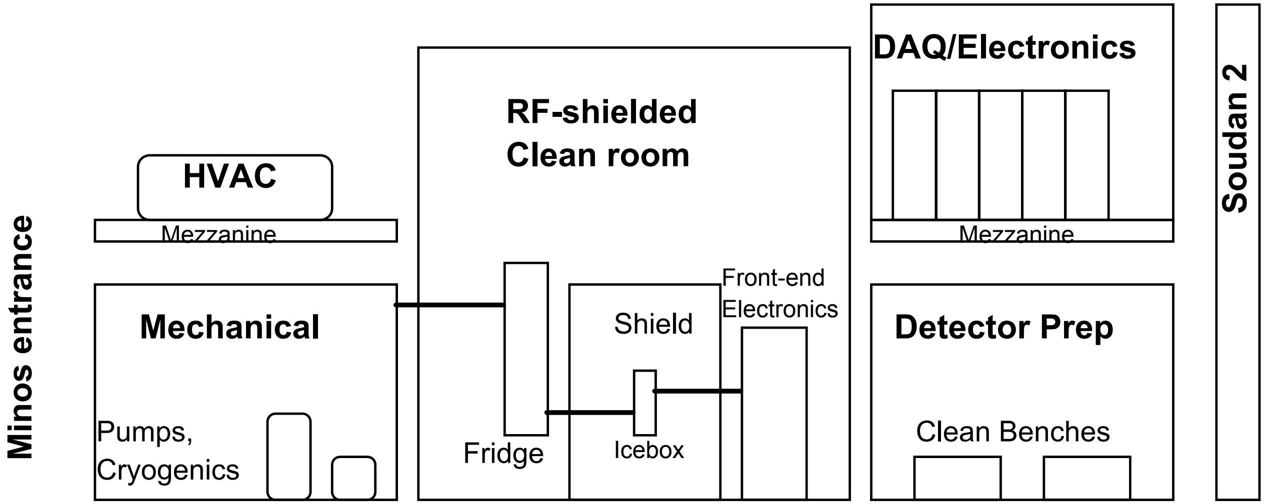
Soudan Facility

- CDMS II Experimental Enclosures (Fermilab, Minnesota)



Cryogenics

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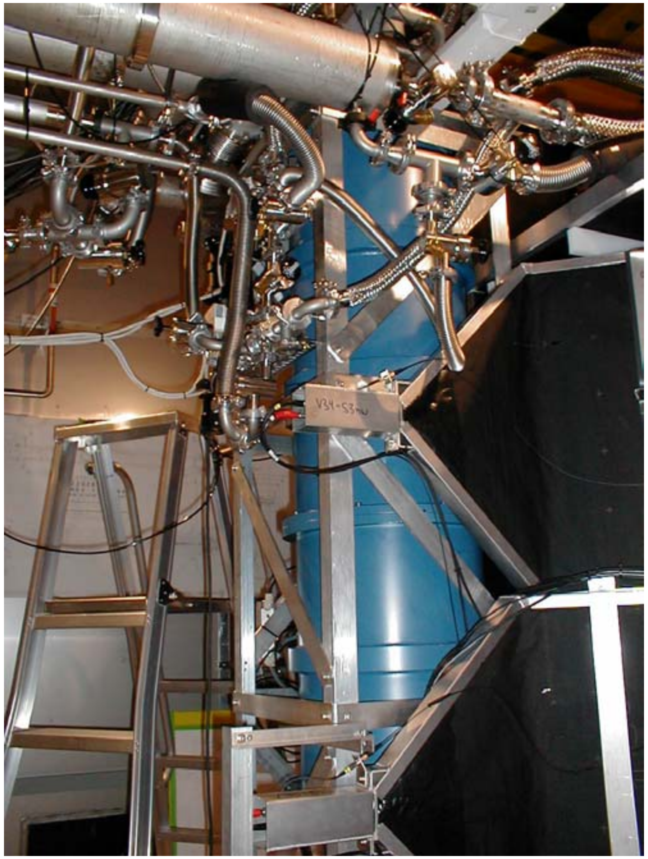
- CDMS II Icebox, Fridge (Fermilab)
  - Oxford 400 dilution refrigerator (identical to one we use at SUF)
    - Only one major problem in 6 years at SUF (2 months downtime to fix)
    - The Soudan fridge has been considerably more problematic
  - System has now been working reliably for 4 months
    - Living with a small leak between helium bath and vacuum
    - LHe consumption x2 higher than it should be => $$



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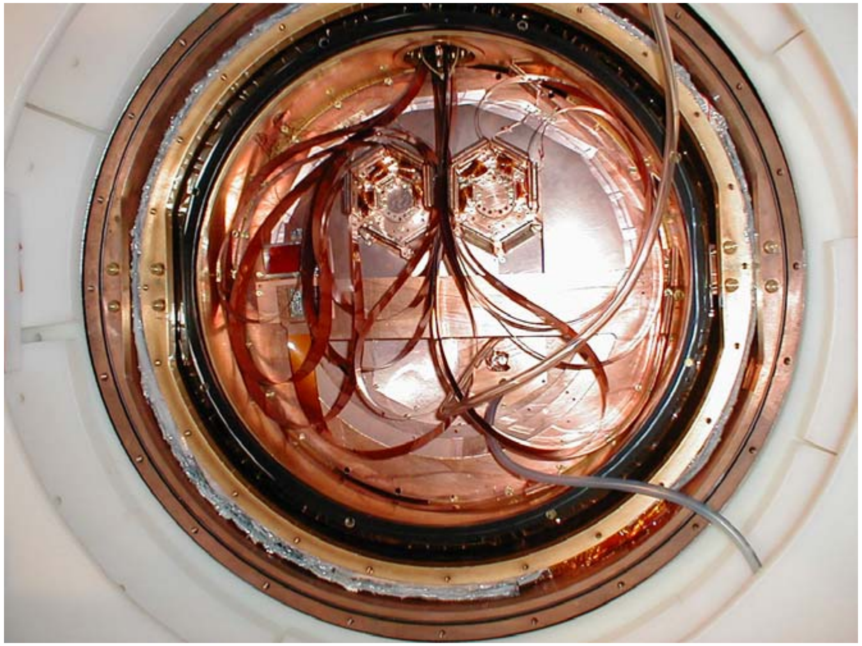
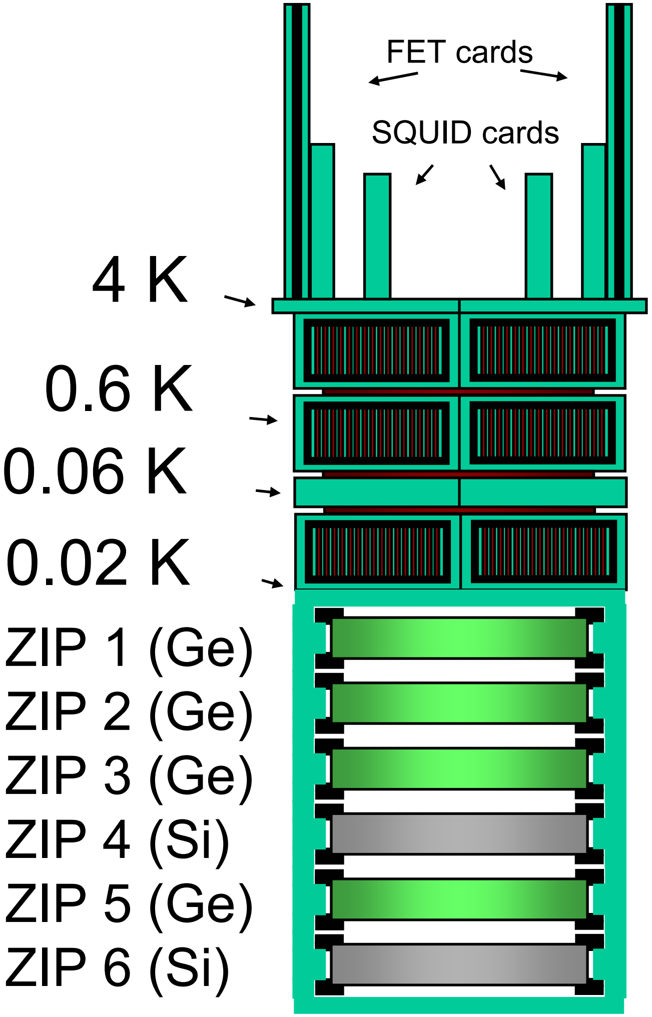
Detectors

- 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 (Z6)
- 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
- Issues
  - Radon gas => γ background; reduced by purge
  - Residual β background (more on this later)





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Shielding

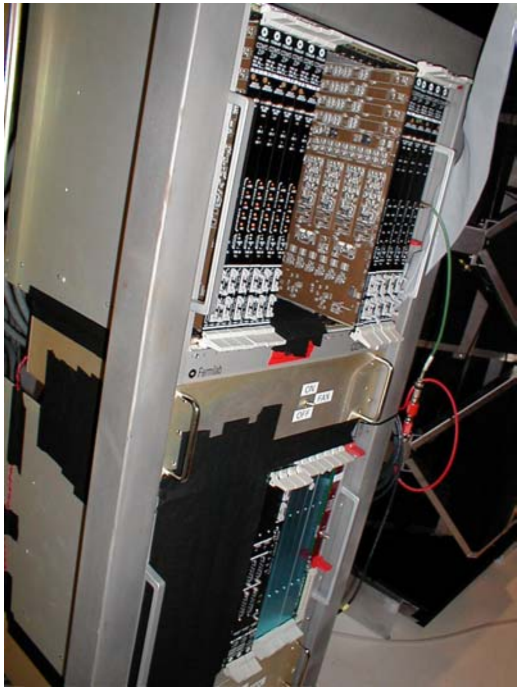
- CDMS II Shield (UC Santa Barbara)
  - Layered shielding
    - Active scintillator veto outermost (5 cm)
      - Reject cosmic-induced events
    - Polyethylene (50 cm)
      - Moderate neutrons to lower energies
      - Inner 10 cm layer to reduce neutron bouncing
    - Lead (22.5 cm)
      - Reduce γ's from radioactivity
      - Inner 4 cm is "old" (low in 210Pb)
    - Copper (~ 3 cm)
      - Radioactively-clean material
      - for detector volume

Muon Veto

- CDMS II Veto (UC Santa Barbara)
  - Goal is to reject events associated with cosmic rays (~ 1/minute in shield)
    - Plastic scintillator (2" thick), light guides, PMTs; wrap-around, hermetic coverage
    - Very high efficiency for muons (> 99.99%) without accepting too many γ's
    - Substantial efficiency for neutron rejection (under study with Monte Carlo)
  - Installation finished in June (had to wait for cryogenics, detectors)

Warm Electronics

- Warm Electronics (Fermilab)
  - Front-end boards: Apply bias voltages, flash LEDs, amplify/drive signals
  - RTF boards: receive and filter signals for digitizers, set trigger thresholds
  - STB: Test board to supply detector-like signals
- Production complete for 7 towers; sufficient boards at Soudan for 2 towers
- Working on low-level noise issues and back-up power



Data Acquisition (UCSB, Fermilab, UM)

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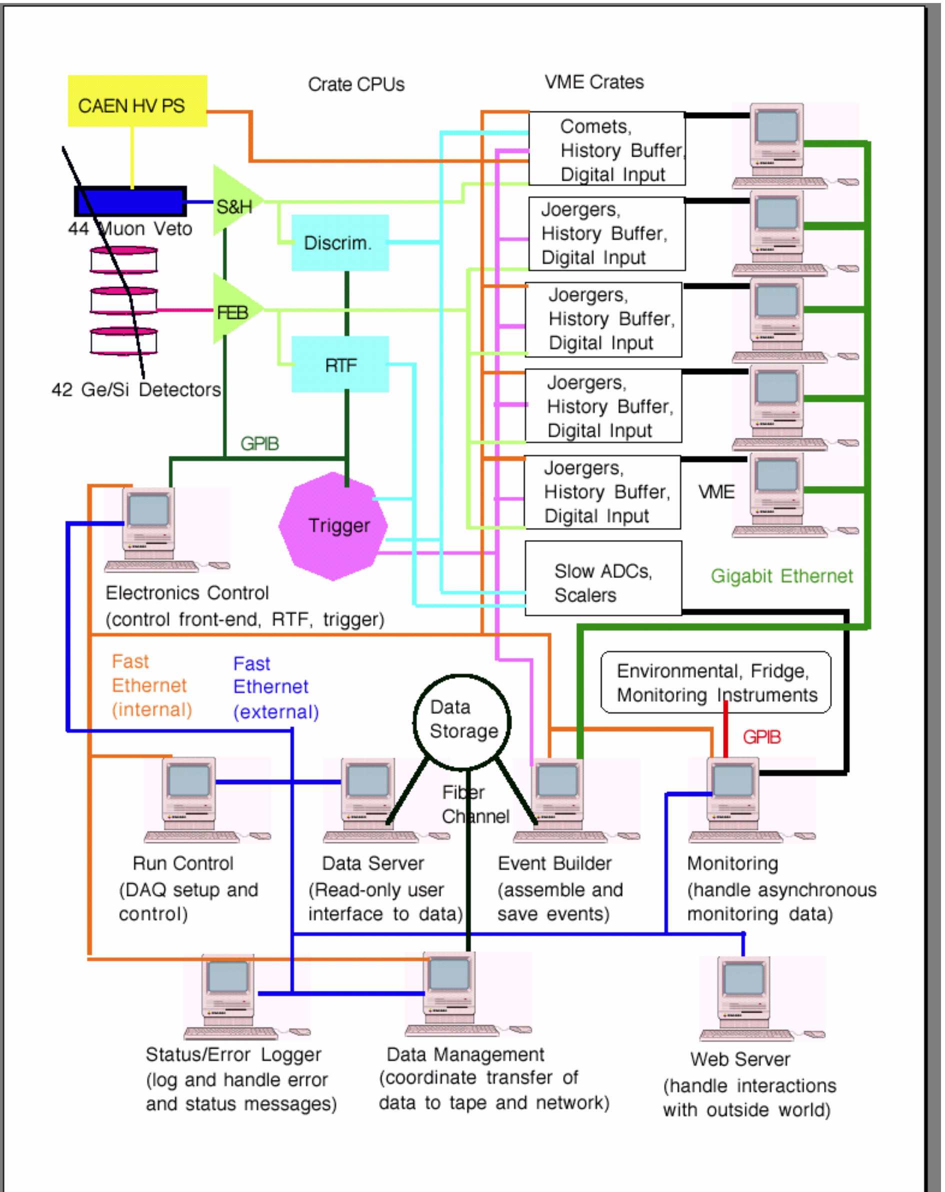

- Commercial VME waveform digitizers sample each signal and history buffers record times of veto and triggers
- Veto and trigger electronics designed and built at UCSB.
- Software model based on CDMS I experience but implemented in Java/C on Linux. Emphasize remote control and monitoring.
- Fast “event builder” package from Fermilab.
- Demonstrated 20 MB/s throughput allows >10 Hz calibration trigger rate.
- Remote control and monitoring from surface at Soudan and also from Fermilab.
- Offline software filter pass reduces data x10

First CDMS II Data from Soudan

- Have been taking data routinely since October 11
  - Only looking at Tower 1 so far (Tower 2 turn-on in January)
  - Tower 1 detectors functioning as well as at SUF
  - All other systems performing well
- Very early stages of understanding data
  - Gamma backgrounds higher than at SUF, but this is not a limiting factor due to excellent detector rejection of gammas
    - Mainly due to high Radon levels in the mine
    - Purge has recently reduced levels by x4
  - Beta backgrounds comparable to those at SUF
- Have been intermixing diagnostic and calibration runs (day shift) with WIMP search runs (nights, weekends)
- Will conclude the first run in early January (~3 months of data)
  - Expect x10 sensitivity improvement due to lack of fast neutron backgrounds from cosmic ray interactions

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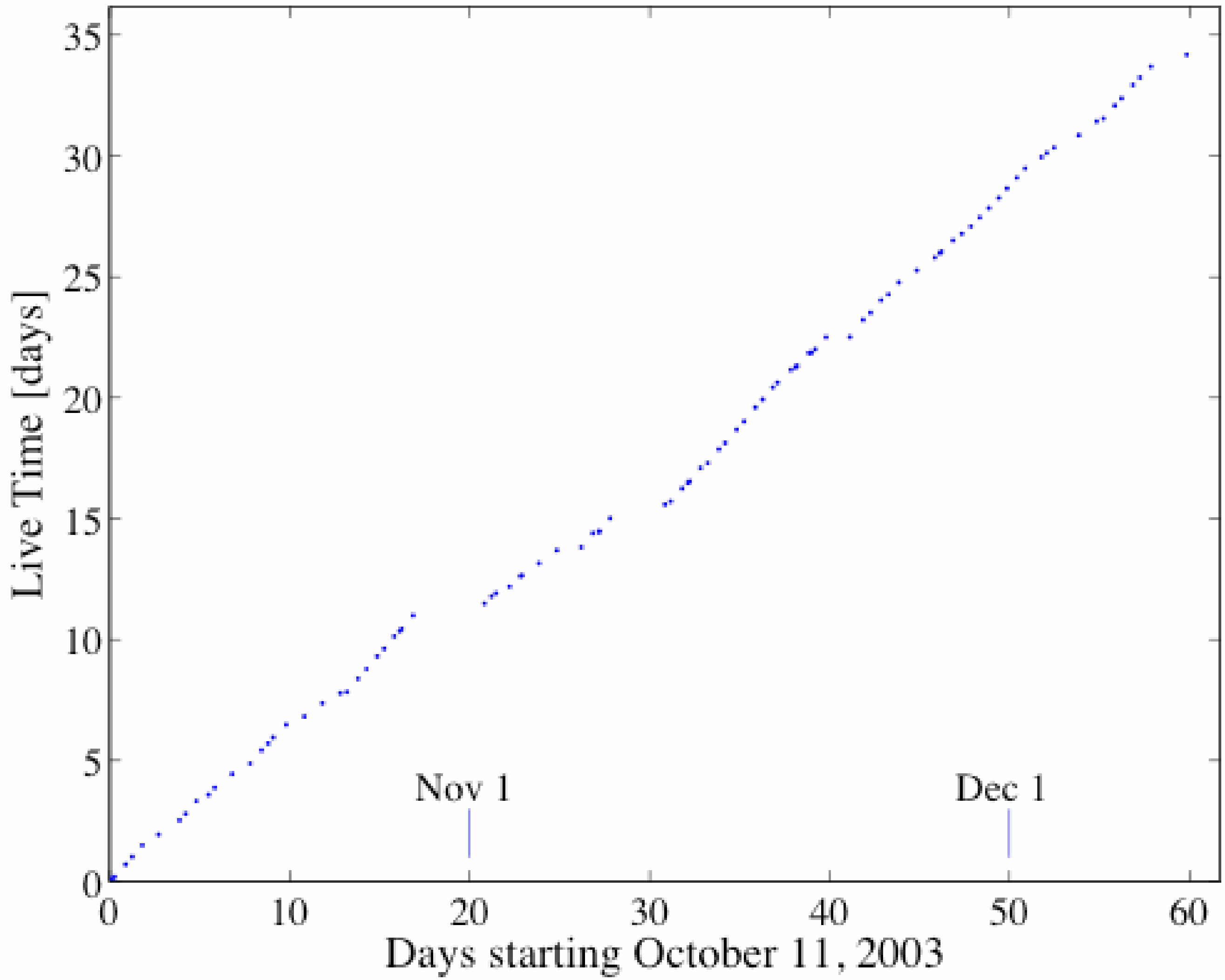
CDMS II Integrated Live time for WIMP Search

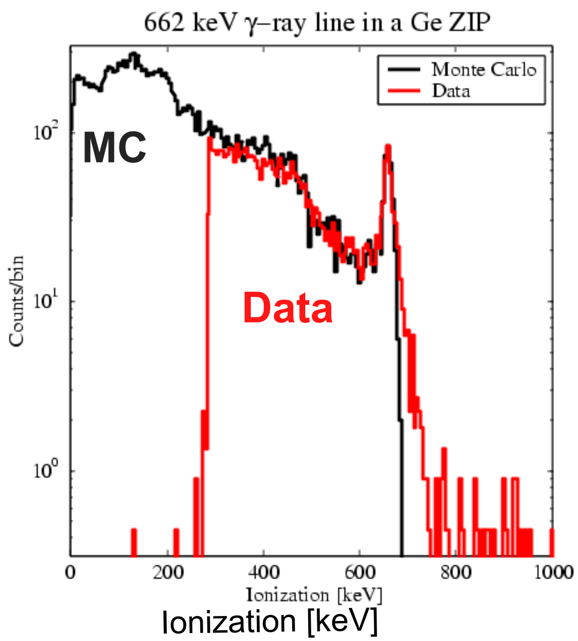


~50% efficient so far
Mainly due to calibration running during days

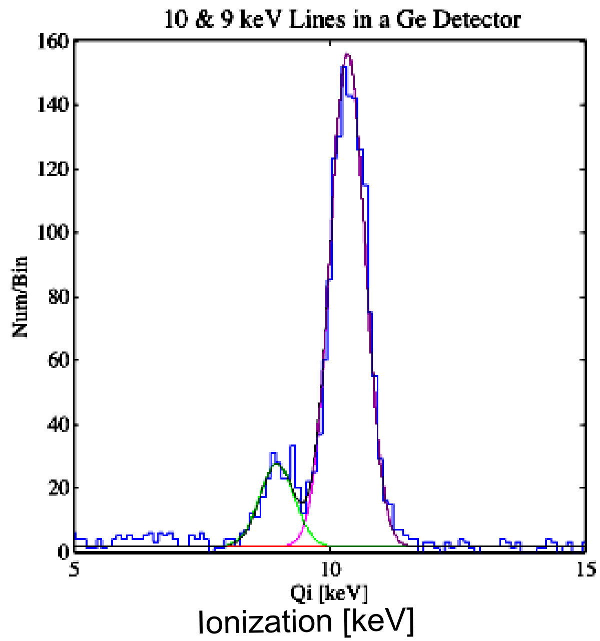
Will improve to ~80%
When calibration finishes next week.

SUF run = 119 live days
Published results from 57 live days.

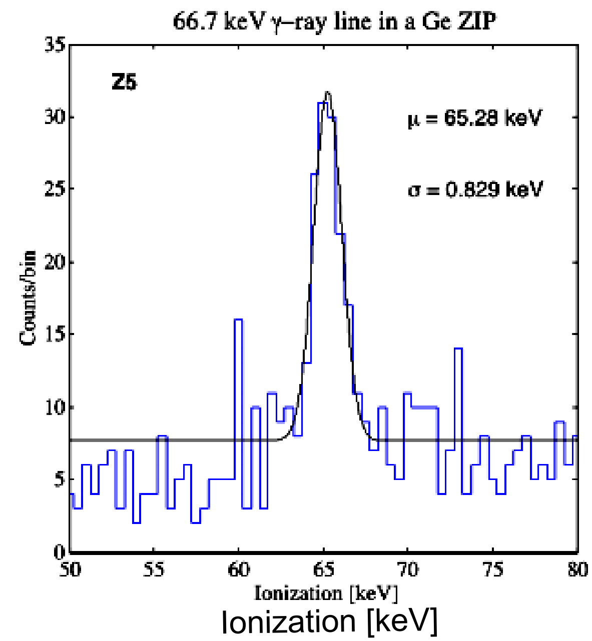
Energy calibration



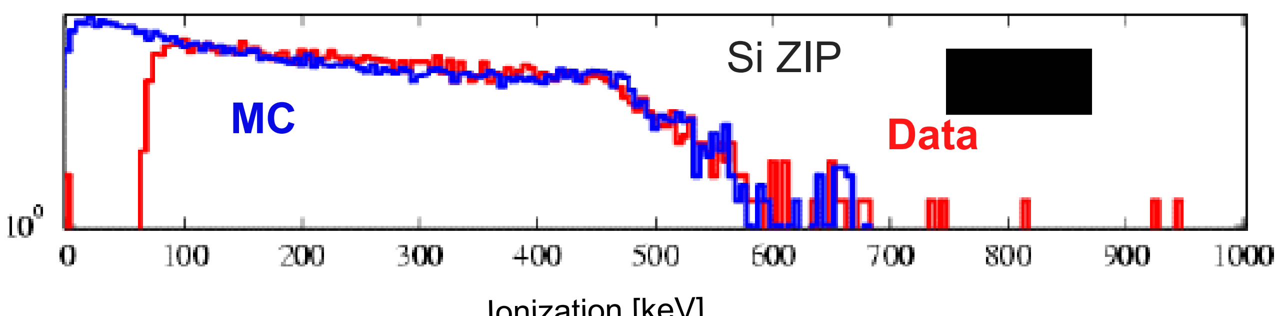
^{137}Cs line: 662 keV



Ga X-ray: 10.4 keV
Cu X-ray: 8.9 keV



^{73m}Ge line: 66.7 keV

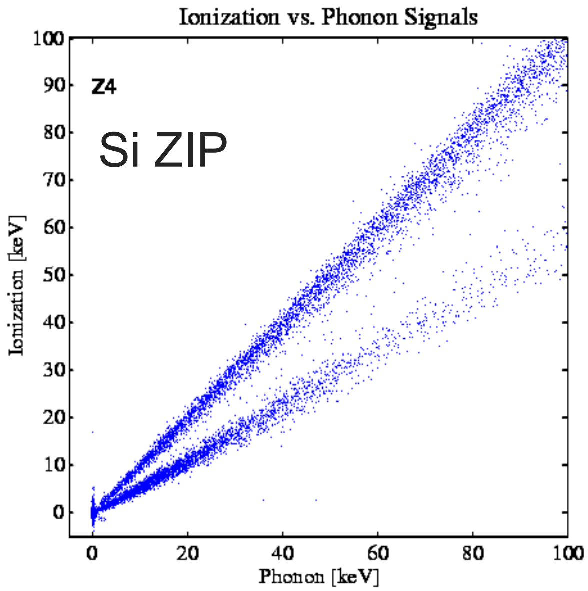


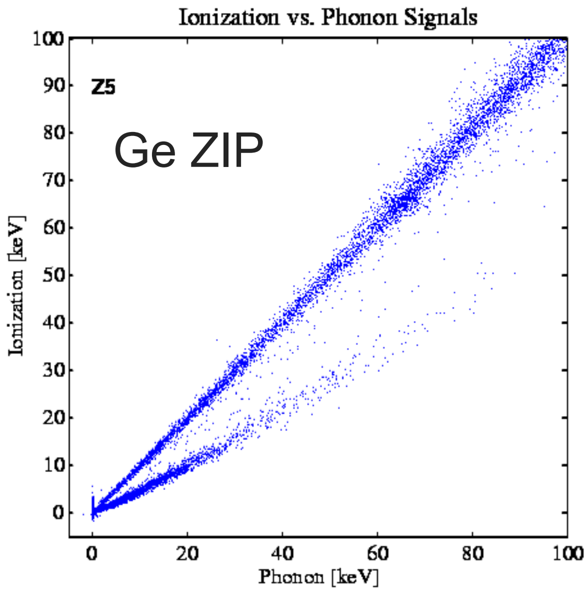
^{137}Cs line Compton edge: 467 keV

Photon and neutron calibrations

The response of the detectors is best demonstrated by using gamma and neutron calibration sources: ‘2-d plots’ - phonon vs charge

Ionization [keV]





Phonon [keV]

Phonon [keV]

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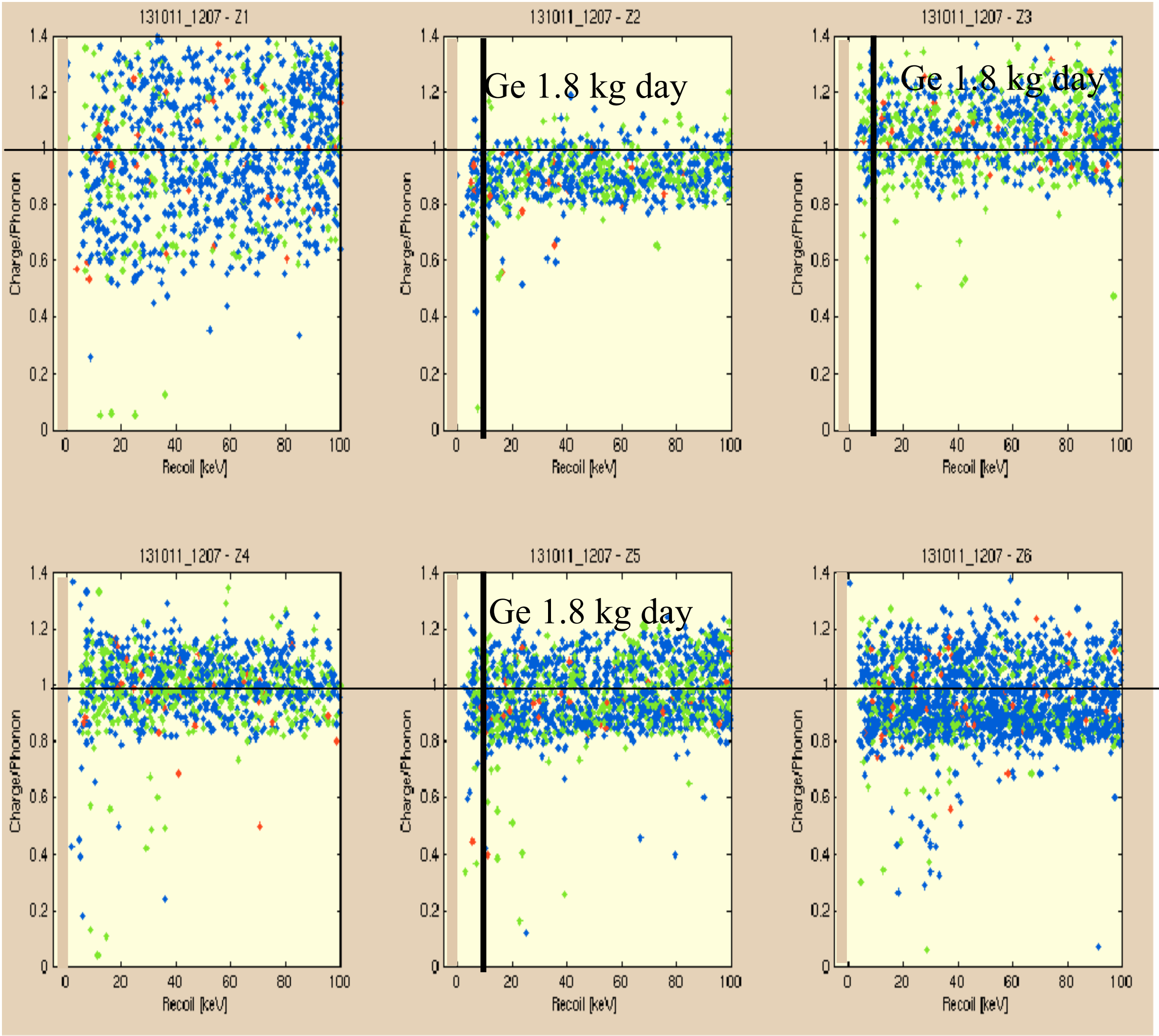
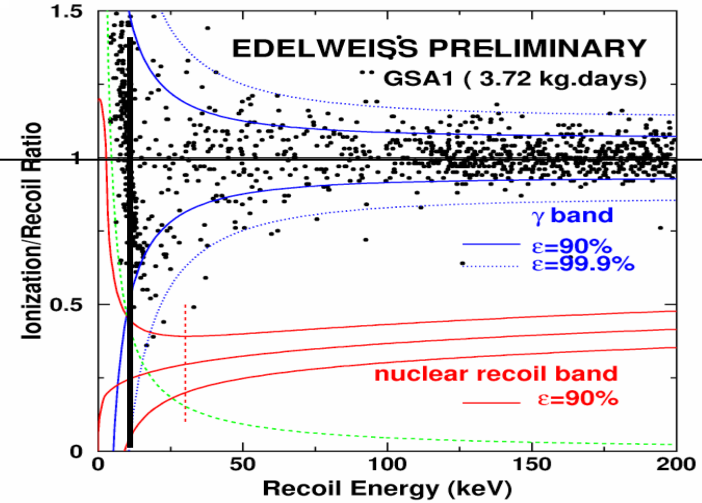
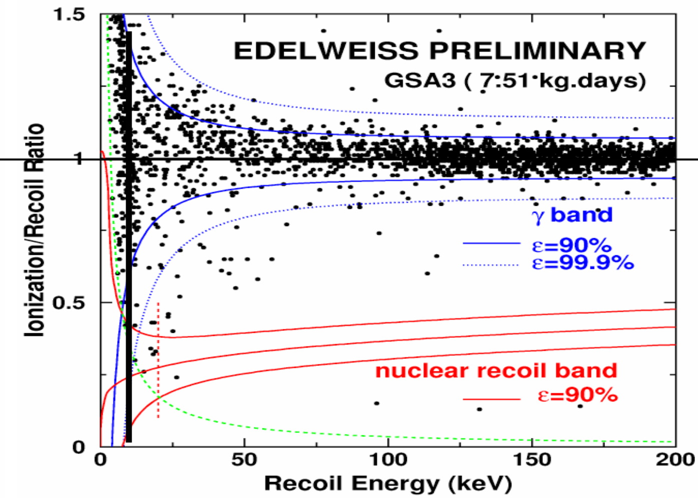
A sneak peak at the first few days of Soudan data (w/o position corrections, rise time cuts)







Analysis blinded from nuclear recoil region after this to prevent bias when setting cuts

What's the near-term plan?

- Focus has been strongly on getting first towers running at Soudan
  - Run Tower 1 for 3 months to achieve big gain in sensitivity
  - Turn on Tower 2 in January (no warmup required) and run until summer
- Project Decisions made to achieve this
  - Significant allocation of contingency to achieve operations as quickly as possible
  - No background screening of detectors since Tower 1
  - Very limited characterization of detector response to beta backgrounds
    - No SUF run of Tower 3
- Now need to shift focus to science optimization
  - Allocate remaining project resources to
    - Understanding source of beta backgrounds (surface screening)
    - Understanding response of detectors to beta backgrounds
  - Number of CDMS II towers deployed will depend on background studies
    - Budget will limit to 5 towers
  - Will run out of contingency to fabricate and test detectors in mid-2004
    - Supplemental funding to continue this work under discussion with agencies

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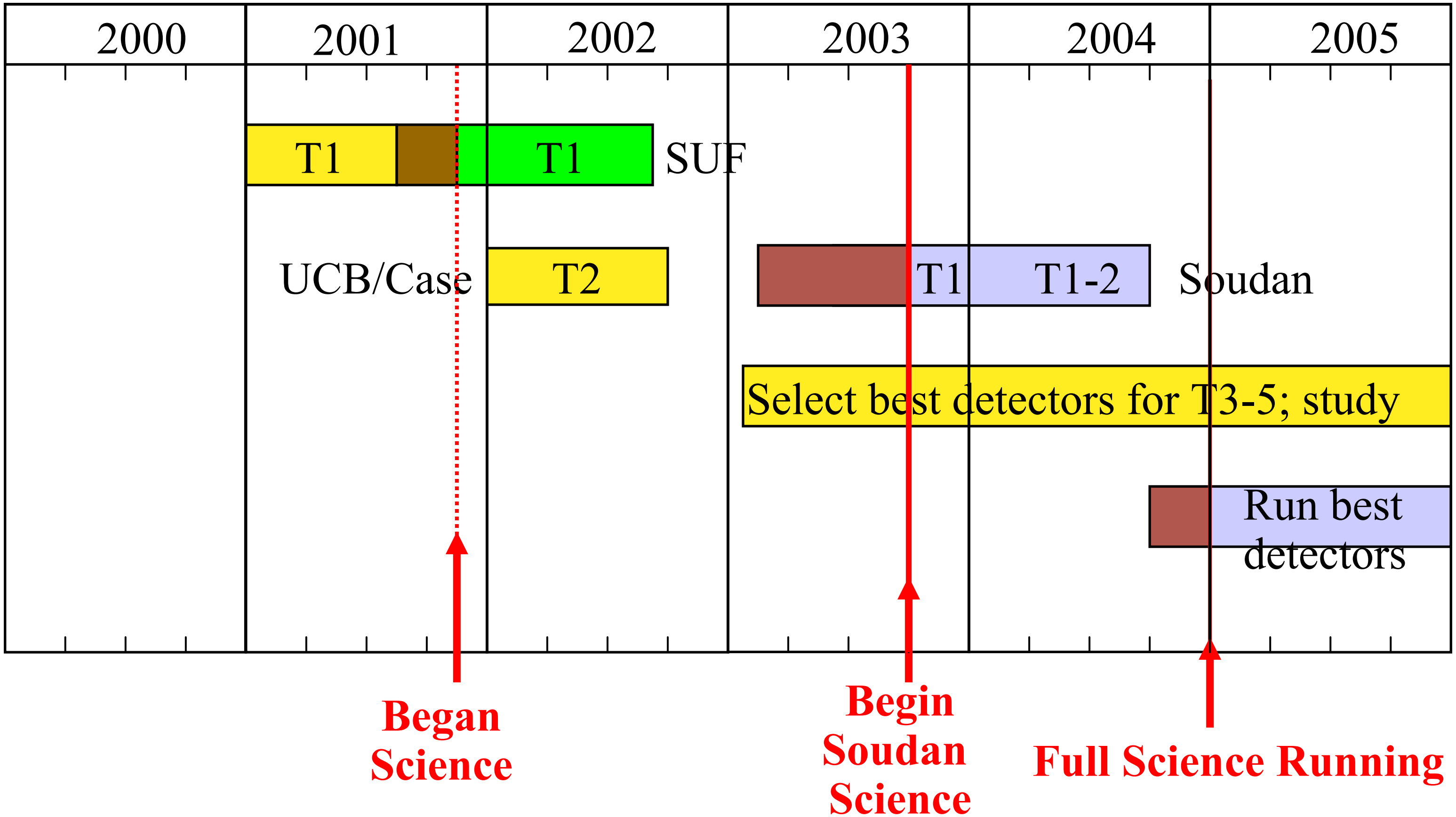
CDMS-II Schedule



Requires $750K from DOE to continue detector fabrication through 2005

Select best detectors for final tower by interaction with surface screening, detector characterization

Requires $300K from NSF to continue detector testing through 2005

Beta calibration of detectors headed for Soudan; reduce systematics on beta subtraction

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Exepcted Soudan Backgrounds

Total background events expected at Soudan (CDMS II proposal)

Background sou rce	Shielded	Muon Veto	After detector rejection	Background subtracted	Systematics
γ's , external radioactivity	750	750	4		
γ's , cosmics in shield	188	2	0.02		
γ's, internal single scatters	18750	18750	98		
Total γ's	19688	19502	102	22	7
β's, surface contamination	1500	1500	75	18	10
n's, external radioactivity	0.4	0.4	0.4		
n's, cosmics in shield	38	0.4	0.4		
n's, cosmics in rock	8	8	8		
Total neutrons	46	9	9	8	1
Total background	21234	21011	186	30	12

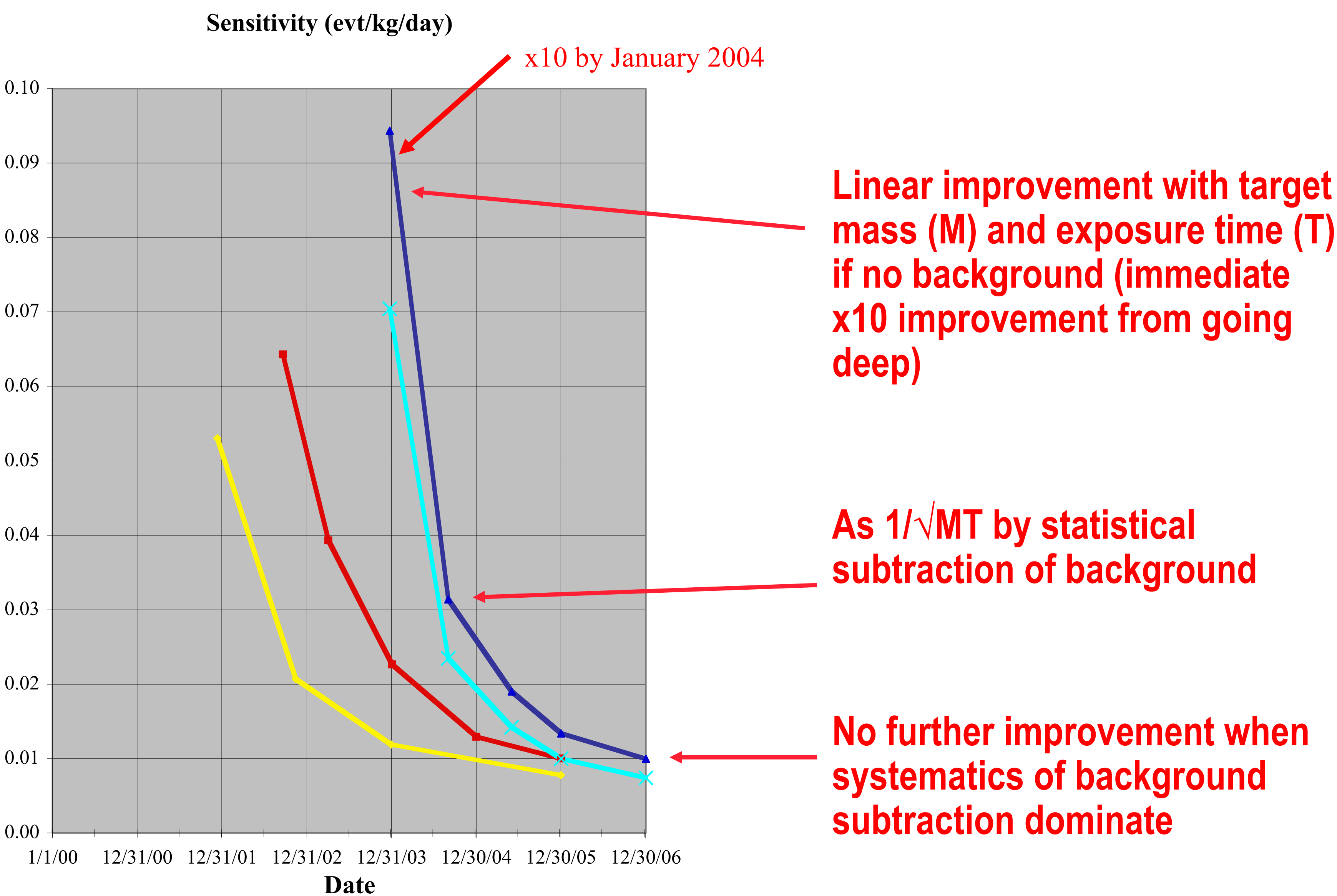
~1 event with improved γ rejection (99.98% instead of 99.5%)

< 4 events with improved β rejection (99% instead of 95%)
But Tower 1 has x4 more betas than expected
=>16 events expected
Dominant background

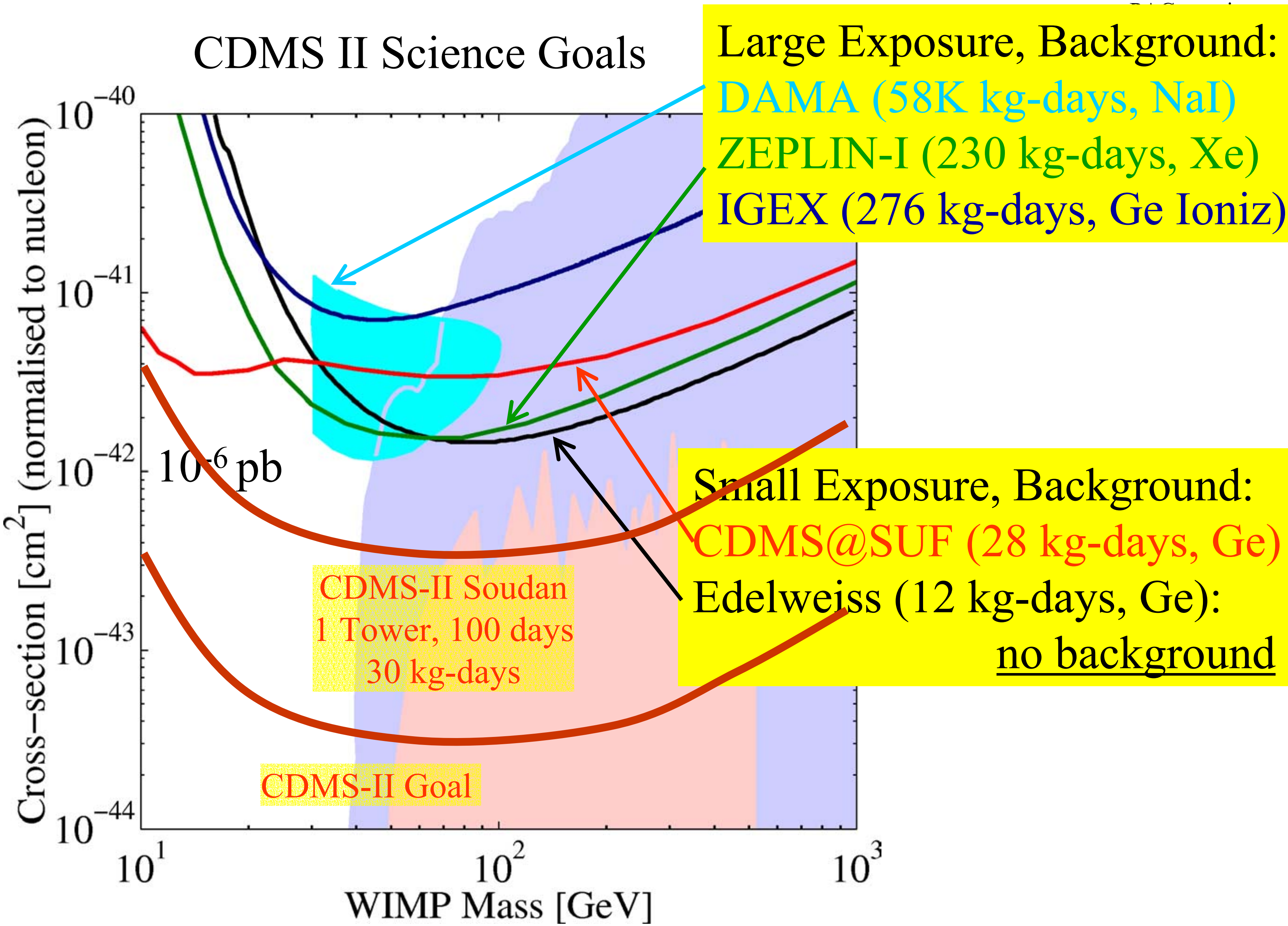
< 4 neutrons with active veto;
subtract using multiples and Si vs Ge

Table 4.2: This table lists the total number of even ts expected at 15 keV in germanium from each background source in CDMS II. "Shielded" means the component that penetrates the shielding and interacts in the detectors. "Muon-Veto" refers to the subset of t hese that are anticoincident with a 99% efficient muon veto. "After detector rejection" is the smaller subset of events that are misidentified by the detectors as nuclear recoils. "Background subtracted" refers to the 90% C.L. limit obtained using formulae above, where MT= 2500kg days and ΔE = 30 keV.

CDMS II Sensitivity



CDMS II Science Goals



R&D towards CDMS III

- Primary Goal
  - Increase sensitivity x10 beyond CDMS II by eliminating beta background
- Two-fold strategy
  - Contamination: Reduce beta emitters by 10x
    - Surface analysis (e.g. SIMS, Auger,…)
      - Identify specific common isotopes like 14C, 40K, 210Pb
      - Find ways to eliminate these from detectors
    - MWPC or Cloud Chamber beta screener
      - Directly image beta contamination from materials or even detectors
      - May combine with gamma, alpha, neutron detectors into low-background screening facility at Soudan
    - SUF low background facility
      - Measure actual backgrounds on detectors before deployment at Soudan
      - Need additional manpower, resources to do this (Caltech, SLAC/Kavli groups)
  - Detectors: Increase beta rejection 10x
    - Better charge sensor design
      - Allows discrimination against surface events in charge signal as well as phonon
    - Linearize response of phonon sensors
      - Improved depth information => better surface rejection

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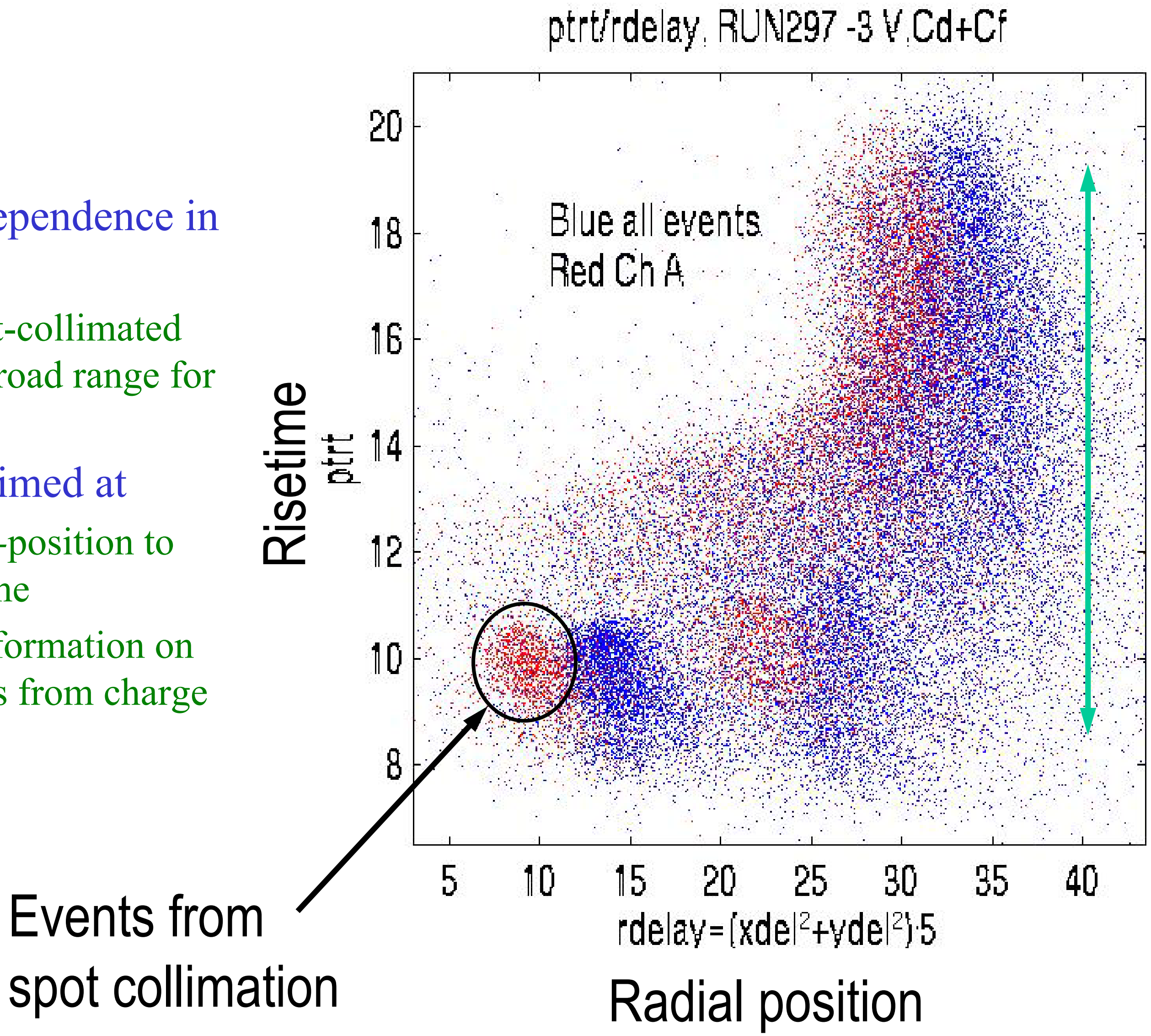
Improving the Risetime cut

- Clear position dependence in the risetime
  - Compare spot-collimated events with broad range for all event
- Detector R&D aimed at
  - Improving *xy*-position to correct risetime
  - Improving information on surface events from charge signals



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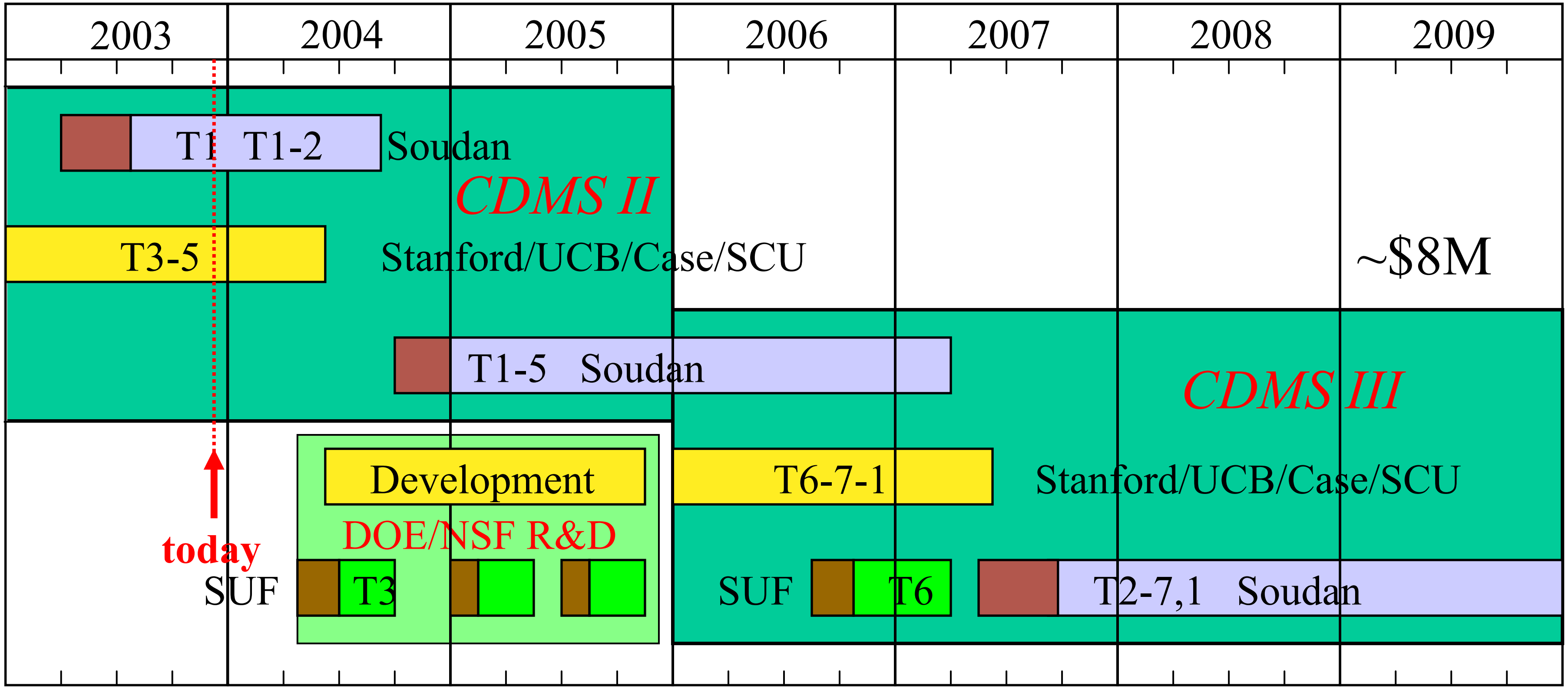
CDMS III: Improved detectors, lower backgrounds



Proposal before SAGENAP in May, 2004 to complete Towers 6-8 as follow-on with improved science reach. R & D mid 2004 through 2005 and CDMS-III from start of 2006 through end of 2009.

Need for continued FNAL operations support ~$400K/year.


UC Berkeley, Stanford, LBNL, UC Santa Barbara,
Case Western Reserve U, FNAL, Santa Clara U,
NIST, U Colorado Denver, Brown U, U Minnesota