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FNAL DOE review
Mar. 24, 2004

CDMS and Pierre Auger
Status and Future Plans

Dan Bauer, Fermilab
CDMS Project Manager

CDMS (Cryogenic Dark Matter Search)

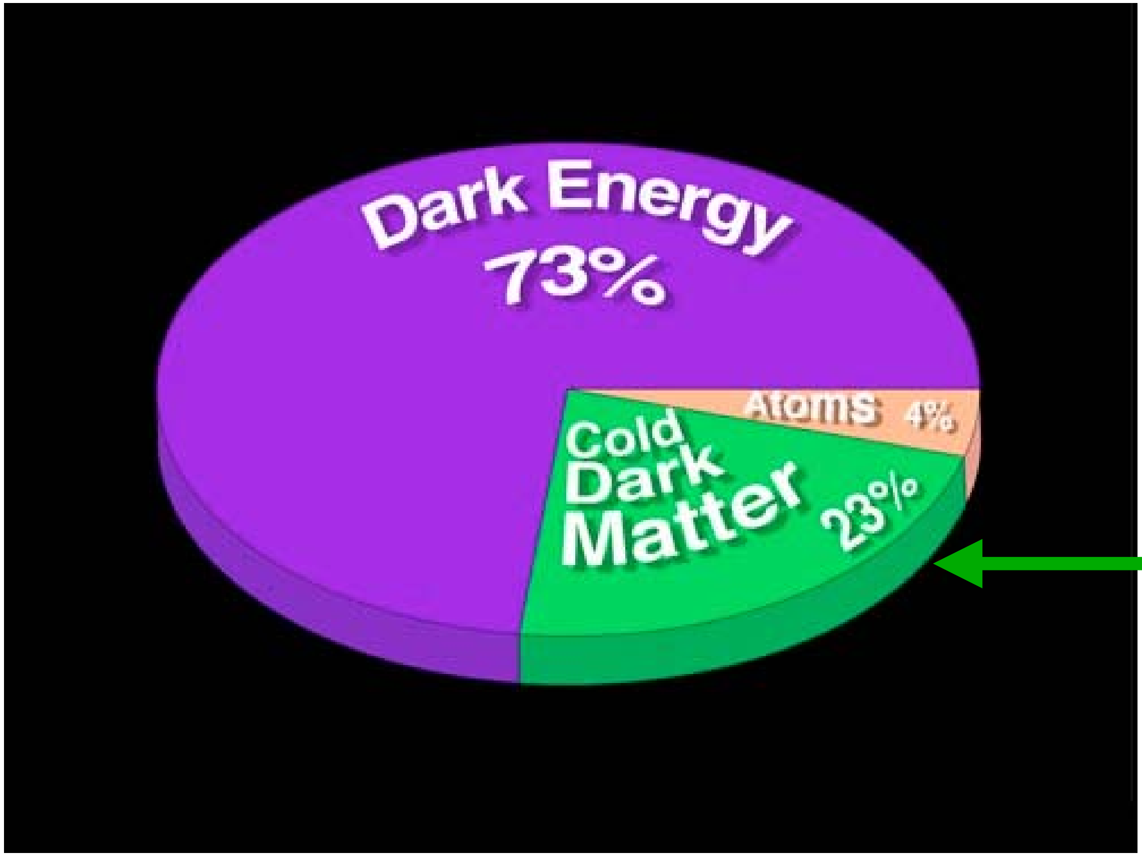
- What are we looking for?
- Status of the experiment
- First look at data from Soudan
- Goals and future program

PIERRE AUGER

- Science objectives
- Construction status
- Early data from Auger South
- Future program

What is CDMS looking for?

23% of the Universe, according to WMAP



Best candidate: WIMPS

Particle theory: SUSY neutralino

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CDMS in a nutshell

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

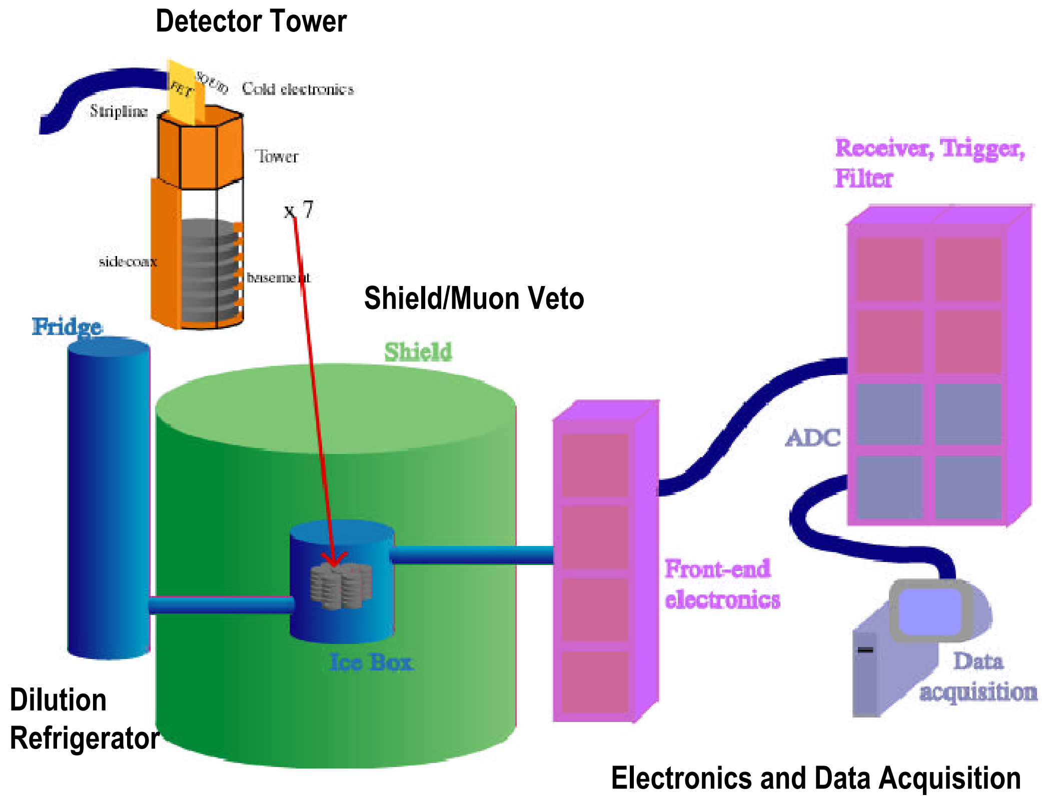
Reject Neutrons

Neutrons multiple scatter, WIMPS don't

Look for single scatters

WIMP cross sections x5 higher in Ge than in Si but neutron cross sections similar.

Look for Ge recoils, not Si

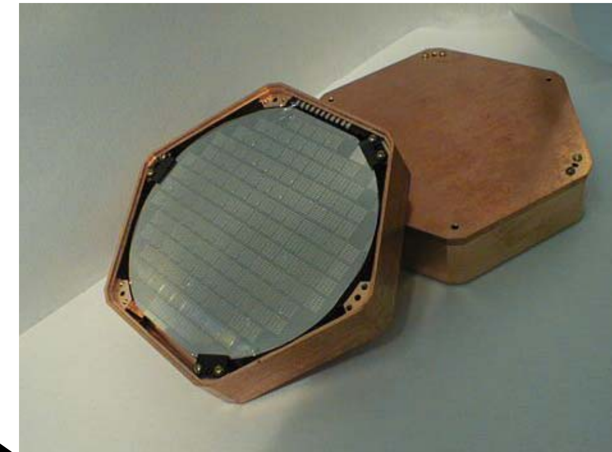


Shielding

Layered shielding (Pb, polyethylene, Cu) against radioactive backgrounds and active scintillator veto (>99.9% efficient against cosmic rays).

CDMS Active Background Rejection

Detectors with excellent event-by-event background rejection and low energy threshold (< 10 keV)



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!

But still room for further improvement!

Tower of 6 ZIPs

Tower 1

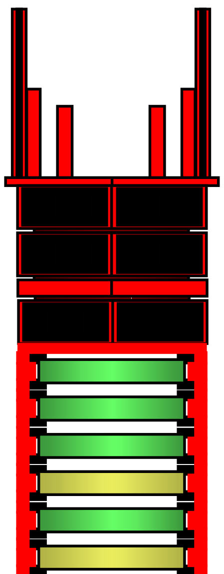
4 Ge

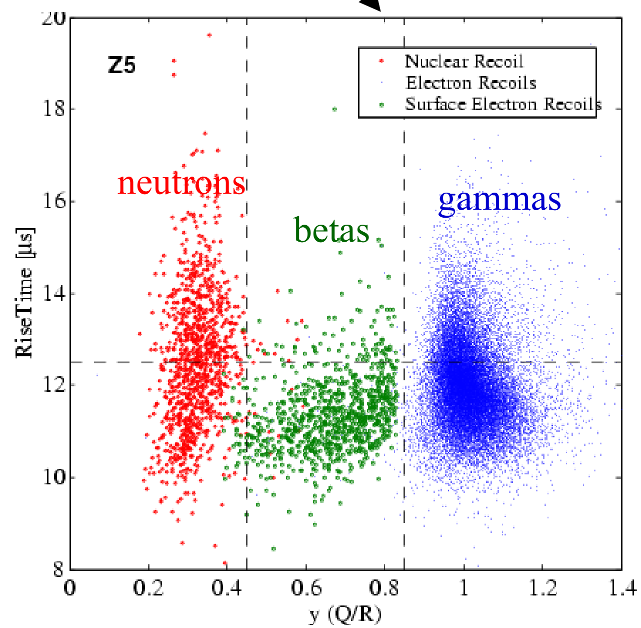
2 Si

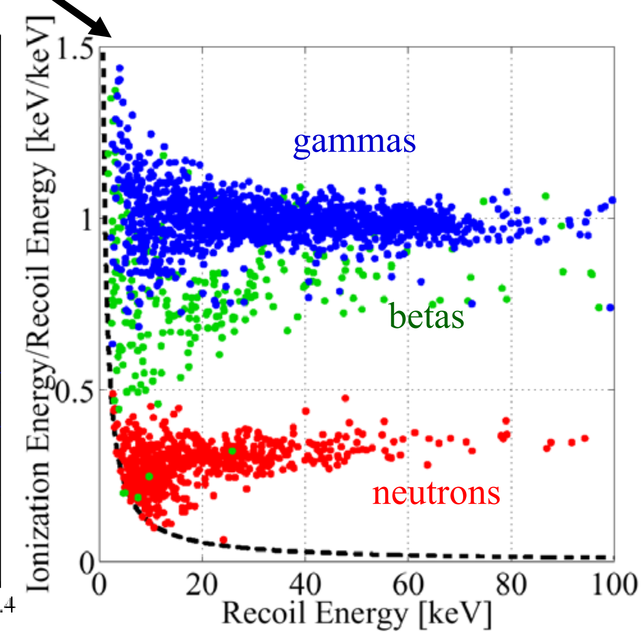
Tower 2

2 Ge

4 Si







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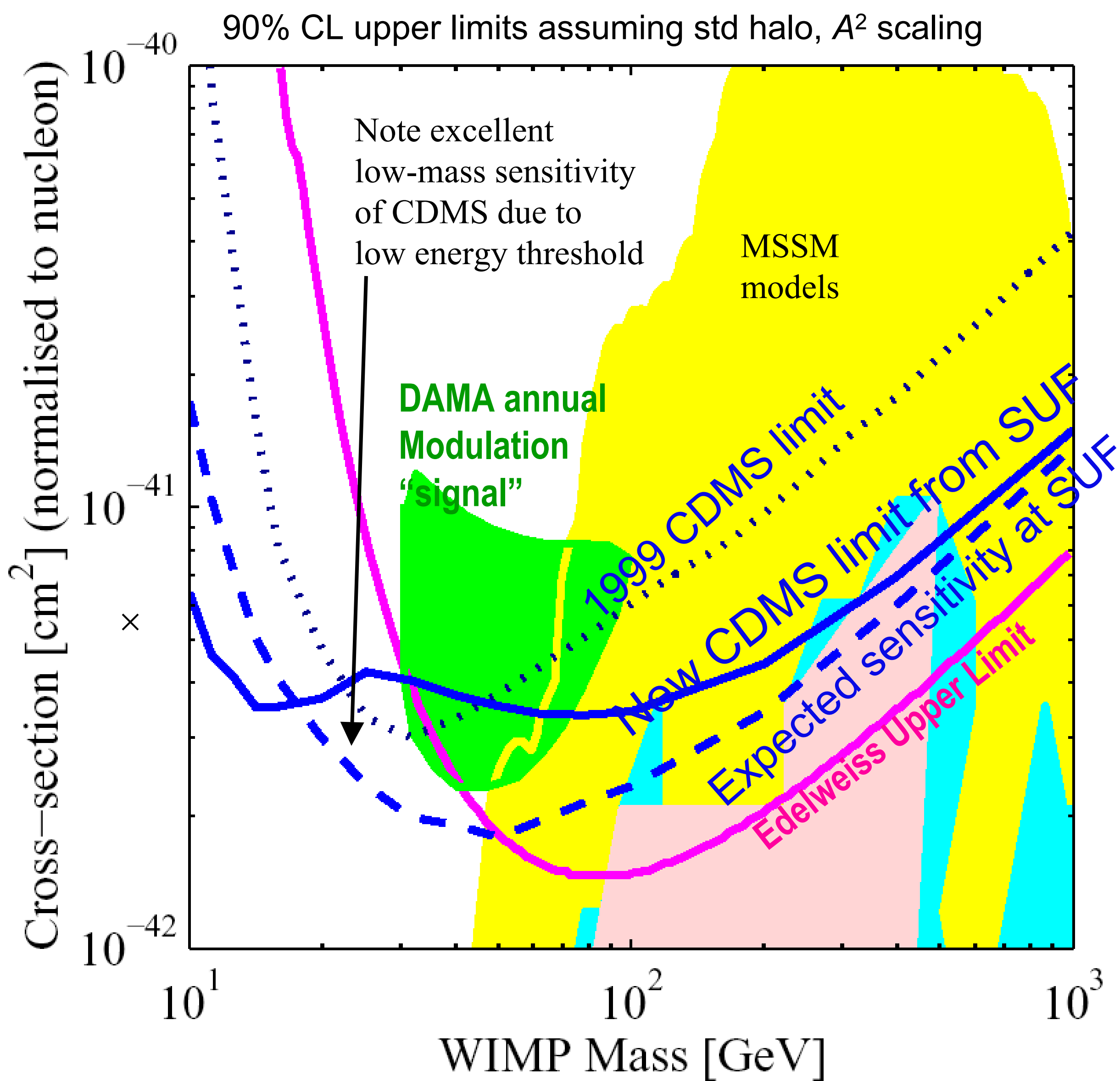
Some recent WIMP direct detection experimental results

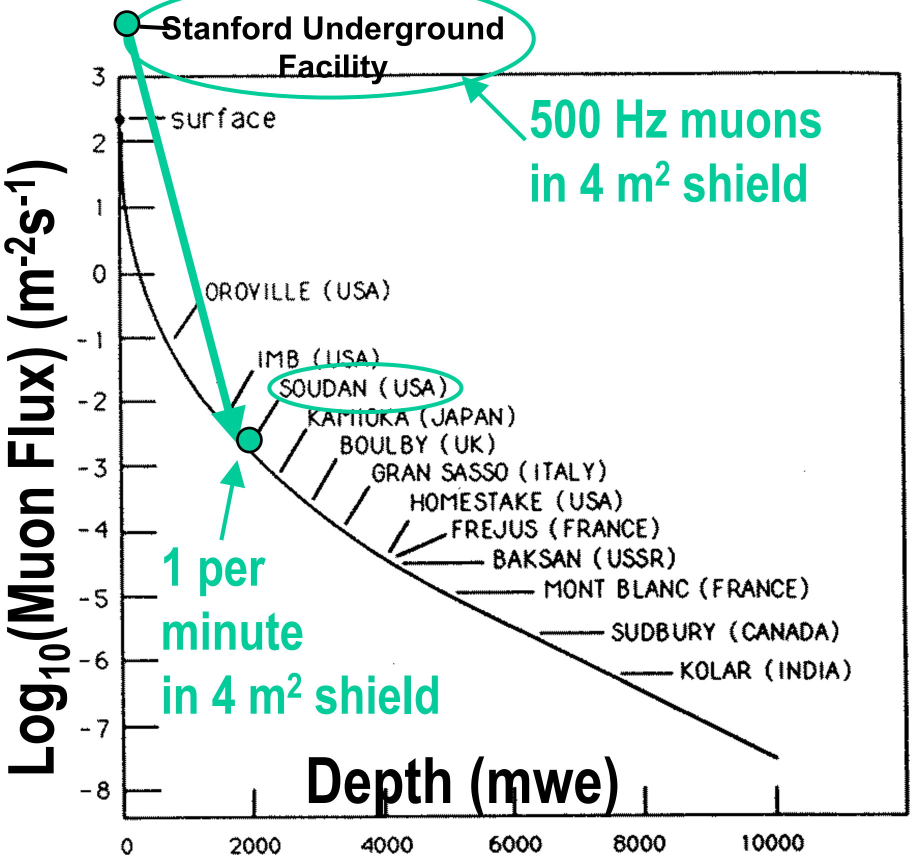


EDELWEISS and DAMA already at deep sites but SUF is shallow.

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

Dominant background in CDMS I at SUF was due to 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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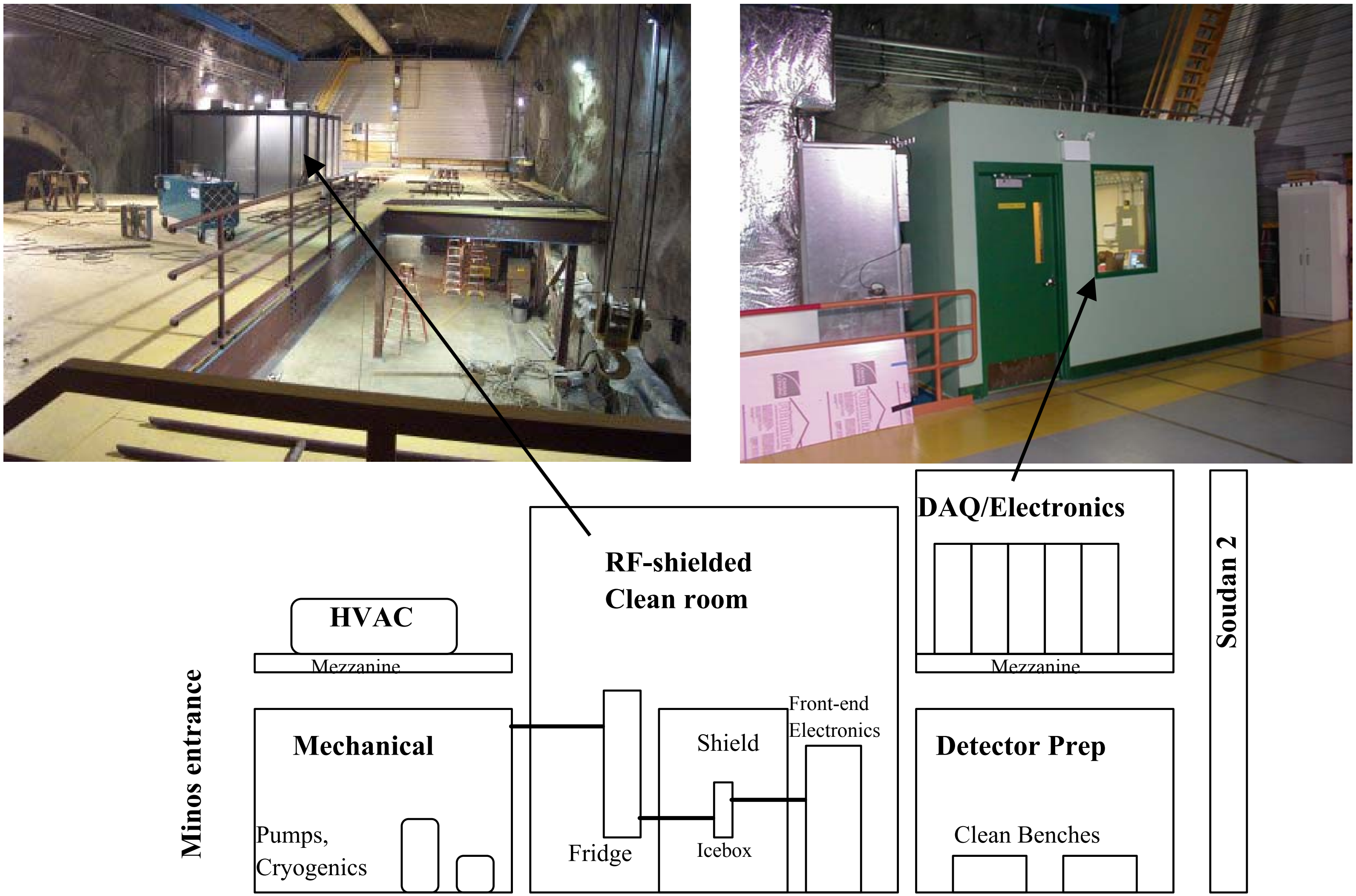
Soudan Facility

- CDMS II Experimental Enclosures (Fermilab)



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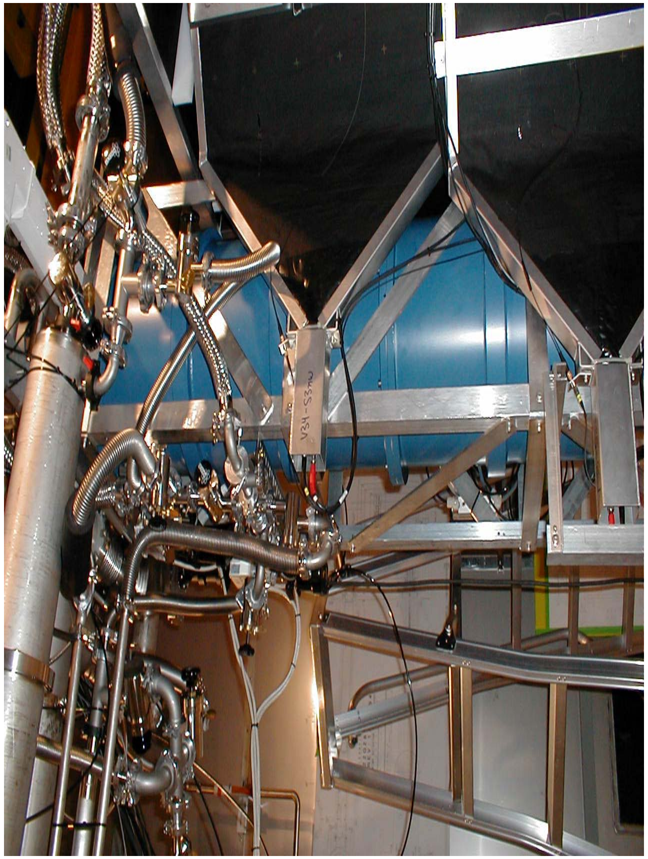
Cryogenics

- CDMS II Icebox, Fridge (Fermilab)
  - Oxford 400 dilution refrigerator (identical to one we used 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 7 months**
    - Living with a small leak between helium bath and vacuum
    - LHe consumption x2 higher than it should be
    - Hope to repair this in summer

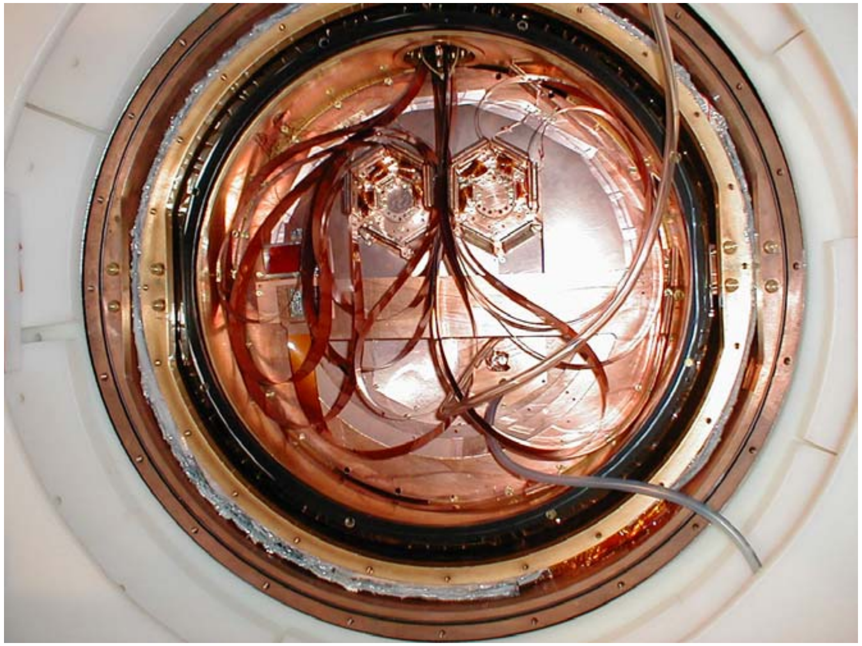
Fridge

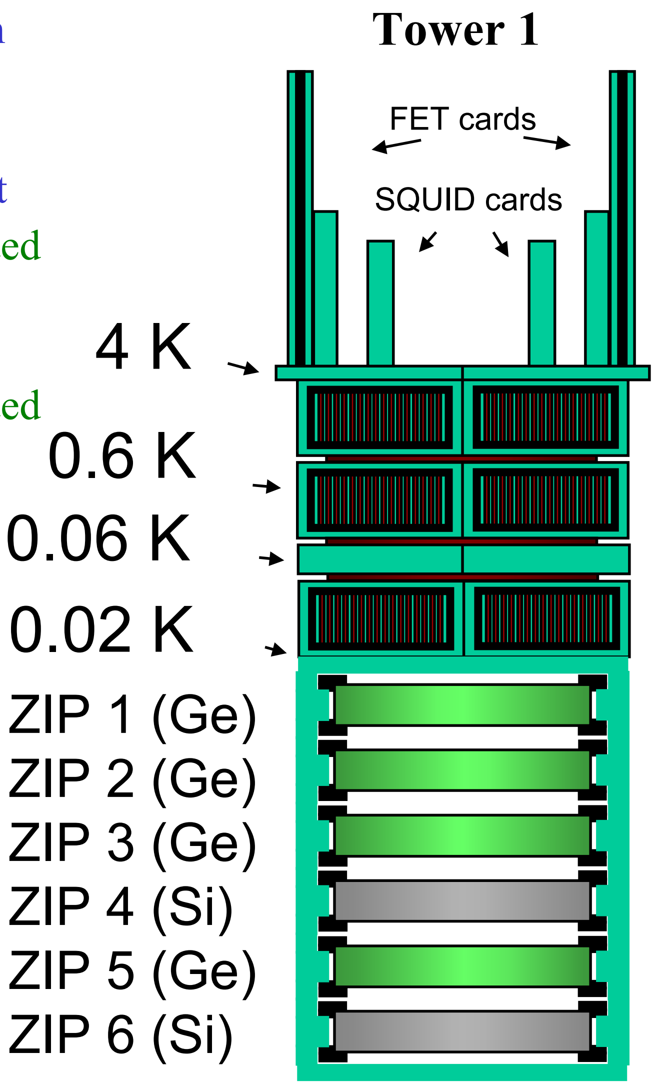
Icebox



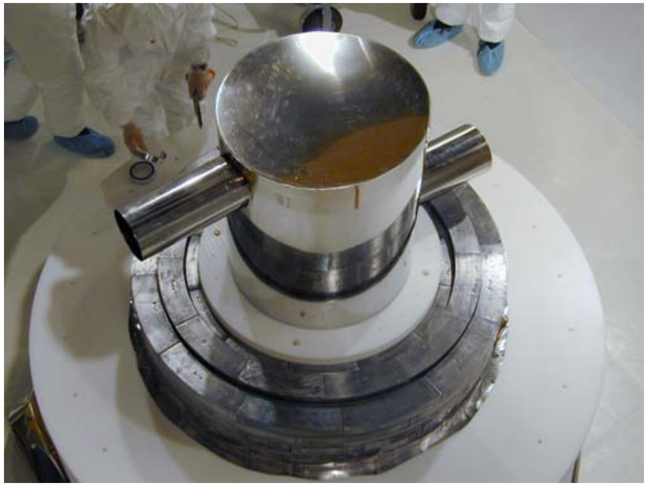
Detectors

- Tower-1 thoroughly understood at SUF; now data at Soudan
  - 4 Ge and 2 Si ZIPs - background rejection better than expected; beta background on bottom Si detector (Z6)
- Tower-2 installed at Soudan; just starting to take data with it
  - 2 Ge and 4 Si ZIPs - backgrounds unknown, but expected to be lower due to better handling
- Tower-3 finished; undergoing final tests at CWRU
  - 4 Ge and 2 Si ZIPs - backgrounds unknown, but expected to be still lower due to better handling
- Towers 4-5 under construction at Stanford

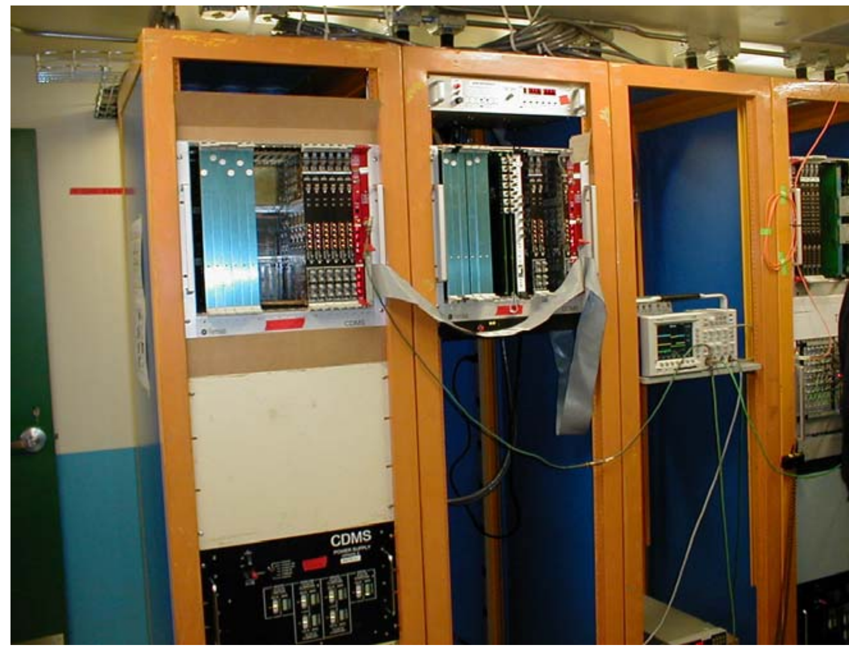




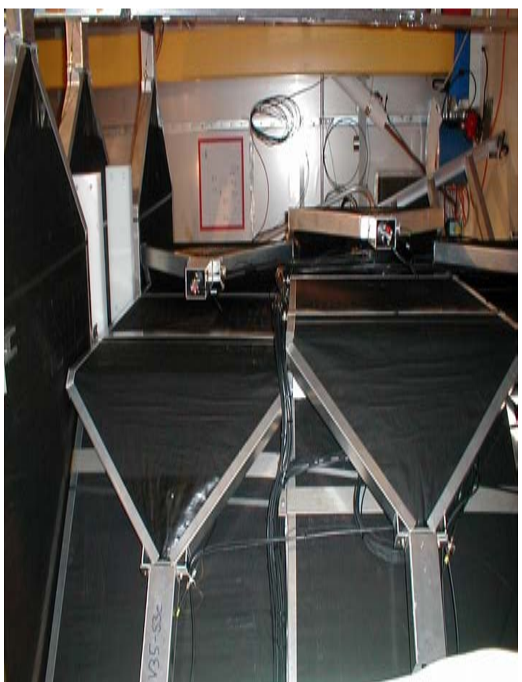
Shielding, Veto, Electronics, DAQ



Layered shielding (Pb, polyethylene, Cu) to minimize backgrounds from external radioactivity.



Sensitive front-end electronics combined with flexible triggering and high-bandwidth DAQ (20 MB/s). Extensive remote control and monitoring capabilities.



Hermetic, 2” thick plastic scintillator veto to reject residual cosmic-ray induced events. Expect > 99.99% efficiency for muons

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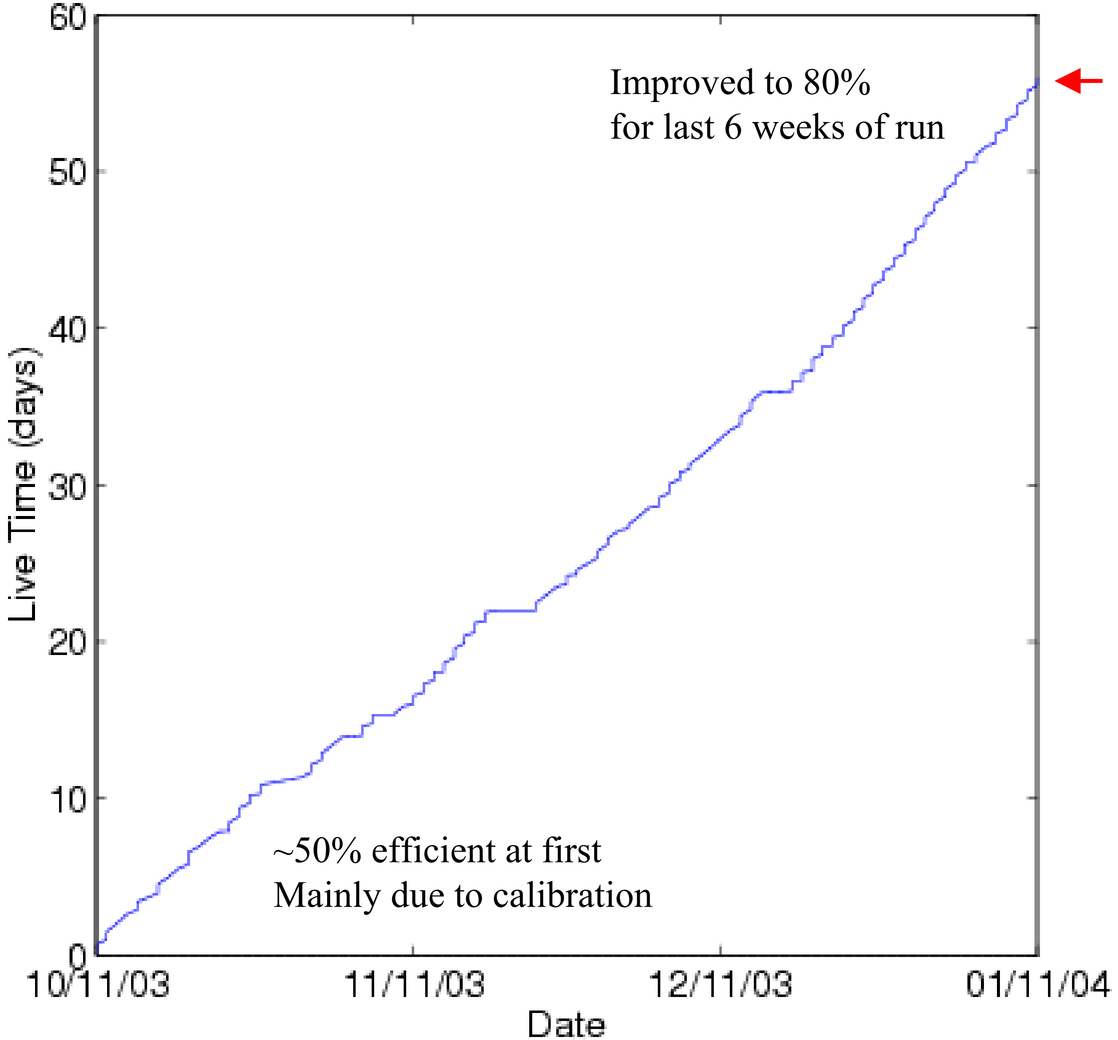
CDMS II Integrated Live time
First WIMP Search run at Soudan



56 live-days for Tower 1 at Soudan (90 calendar days)

Published SUF results for Tower 1 from 57 live-days

But expect x10 better sensitivity at Soudan for same exposure since no neutron background!

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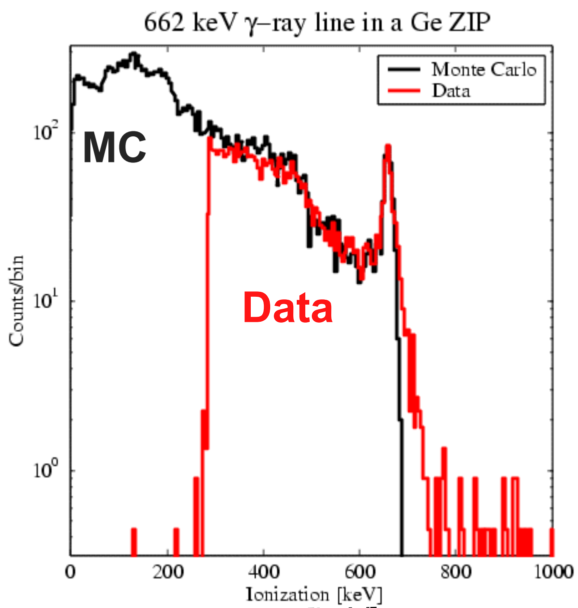
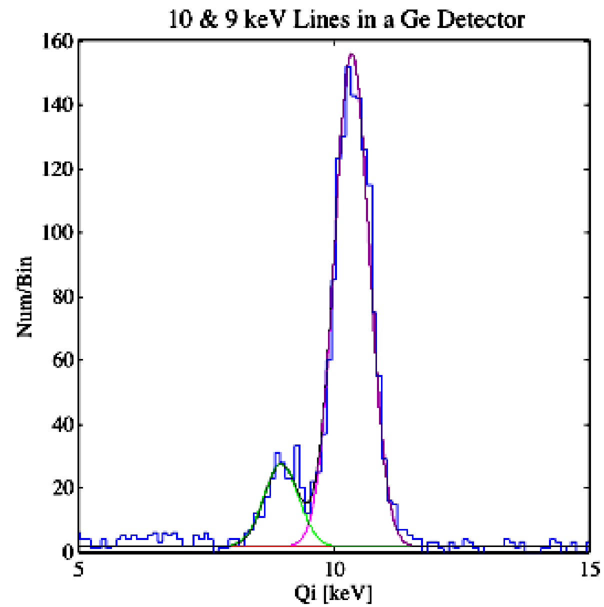
Energy calibration



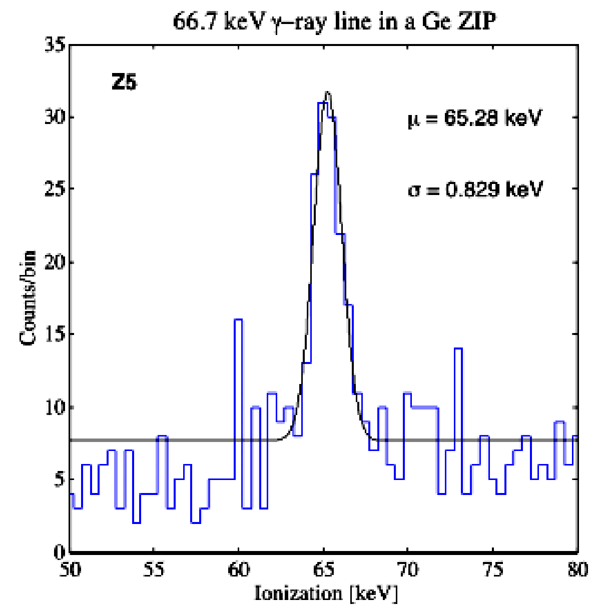
Ionization [keV]

^{137}Cs line: 662 keV



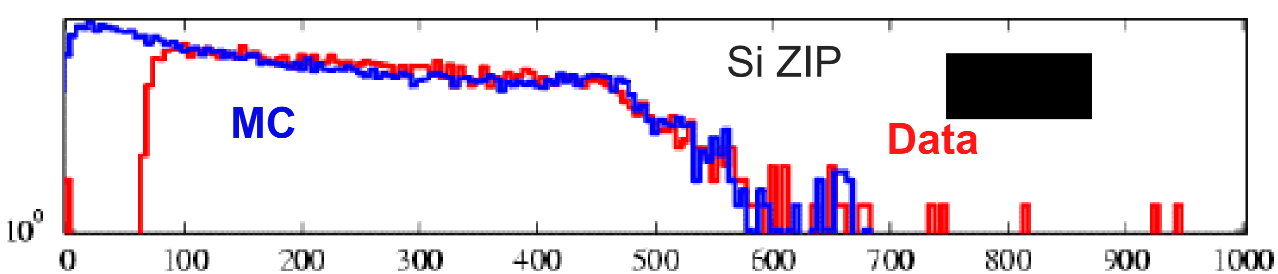
Ionization [keV]

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



Ionization [keV]

^{73m}Ge line: 66.7 keV



Ionization [keV]

^{137}Cs line Compton edge: 467 keV

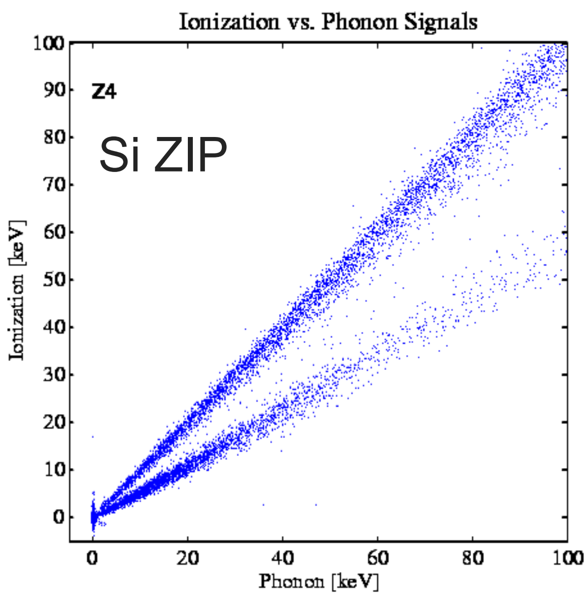
Gamma and Neutron Calibration

The response of the detectors is best demonstrated by using gamma (133Ba) and neutron (252Cf) calibration sources.

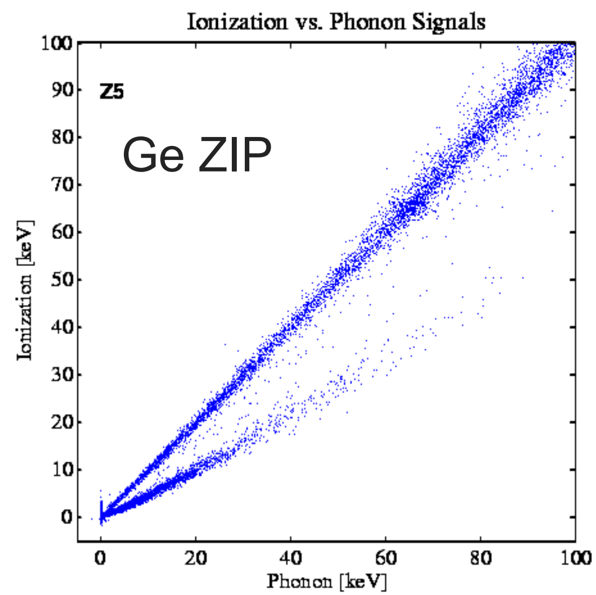
Gamma calibration: Energy scale, phonon uniformity corrections, defines betas ejected from gamma scattering, leakage into nuclear recoil band

Neutron calibration: Defines nuclear recoil band (where WIMPs will appear)

Ionization [keV]



Phonon [keV]



Phonon [keV]

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Backgrounds at Soudan

- Gammas
  - 2.5 events/keV/kg/day measured at Soudan, about x2 higher than at SUF
  - Consistent with having no Pb right around detectors at Soudan
  - Detector rejection => **<0.2 γ in nuclear recoil band for ENTIRE CDMS II exposure**
- Betas
  - 1-2 events/day measured at Soudan, similar to SUF
  - Detector rejection => **<4 β in nuclear recoil band for ENTIRE CDMS II exposure**
  - Expect improvements in subsequent towers and with further analysis
- Neutrons
  - Veto-coincident (cosmic-ray induced)
    - Two events so far in first run; consistent with Monte Carlo. Veto operating well.
  - Veto-anticoincident
    - Monte Carlo predicts **<2 external neutrons for ENTIRE CDMS II exposure**
    - Probably can be reduced further by analysis of veto pulse heights, multiplicity

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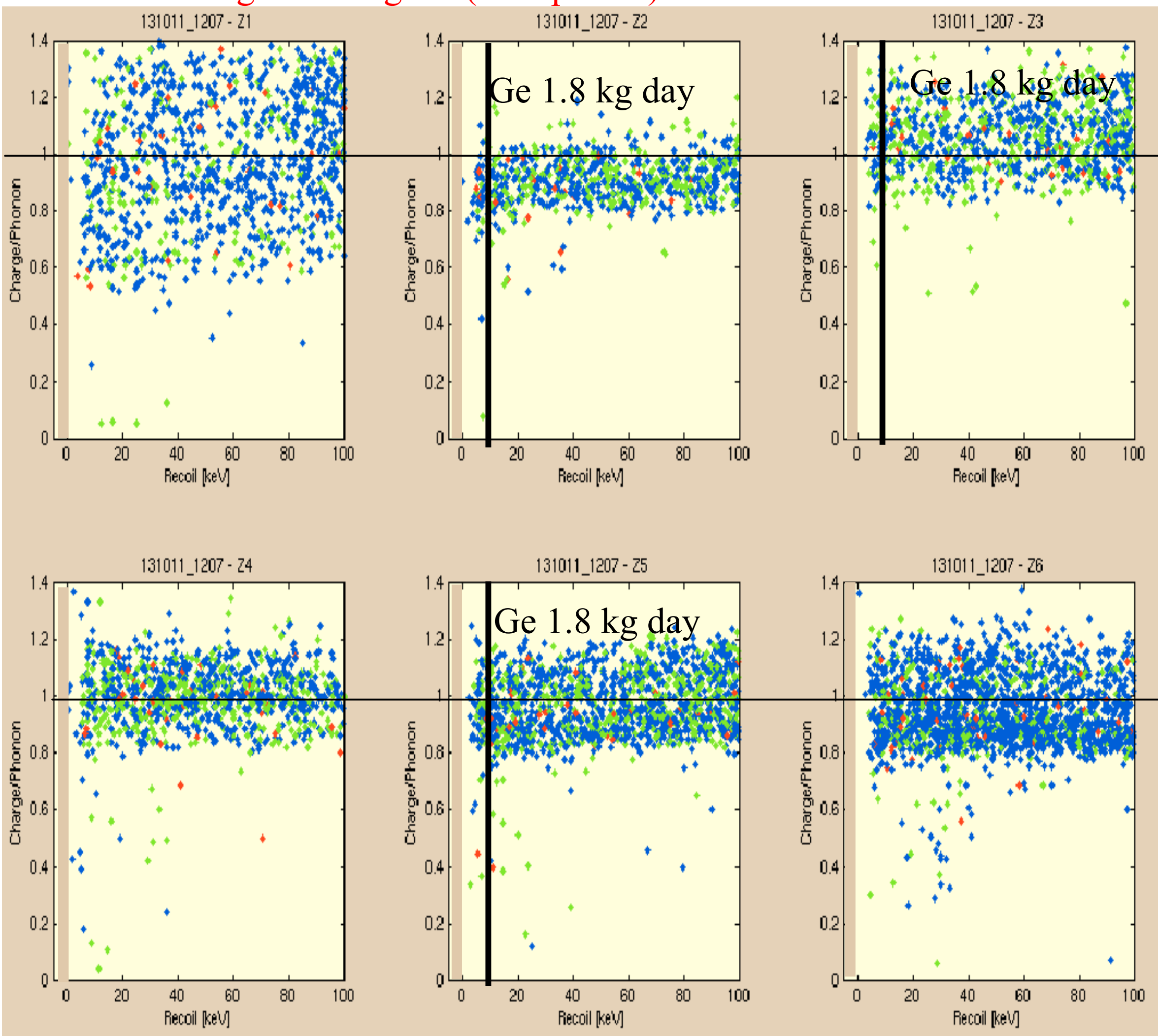
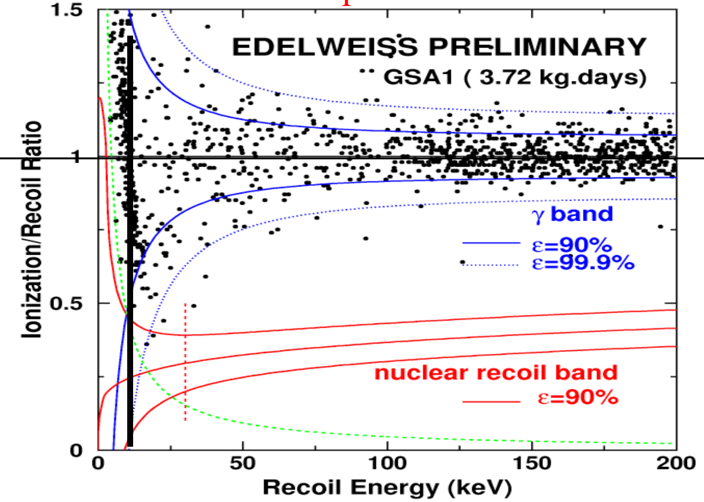
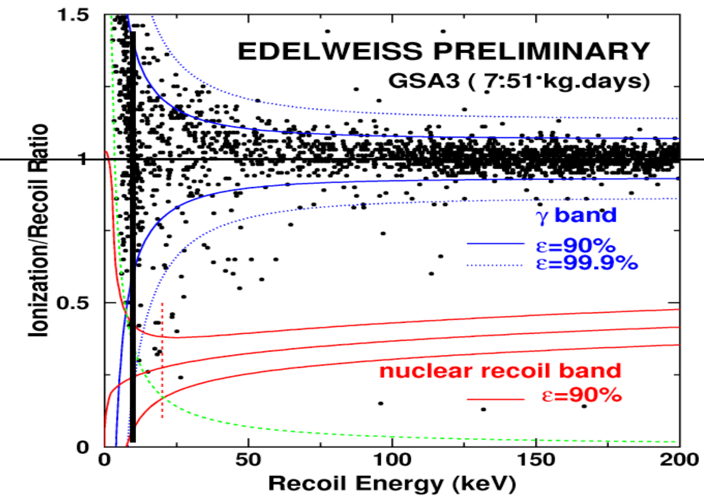
A sneak peak: the first few days of Soudan data

Neutron background is gone (as expected). Nuclear recoils consistent with small EDELWEISS sample.







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

Plan to “open the box” this week!

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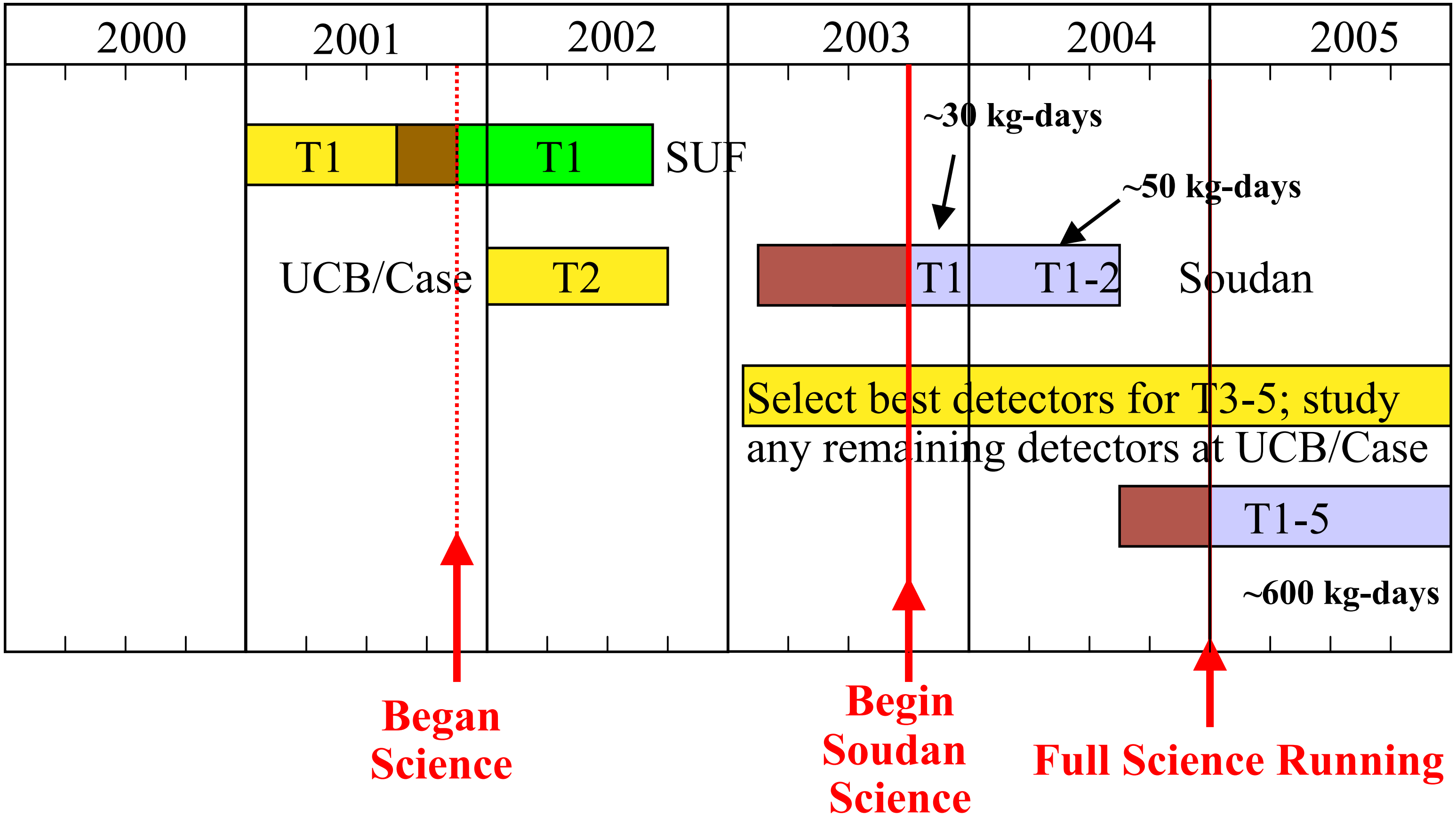
CDMS-II Schedule



Two Tower run until July; understand backgrounds and improve analysis.
Perhaps start to see a WIMP signal (we hope)
Warm up for cryogenic upgrades, other repairs during July, August
Install Towers 3-5 in September and commission them by end of 2004
Full CDMS II WIMP search run during 2005

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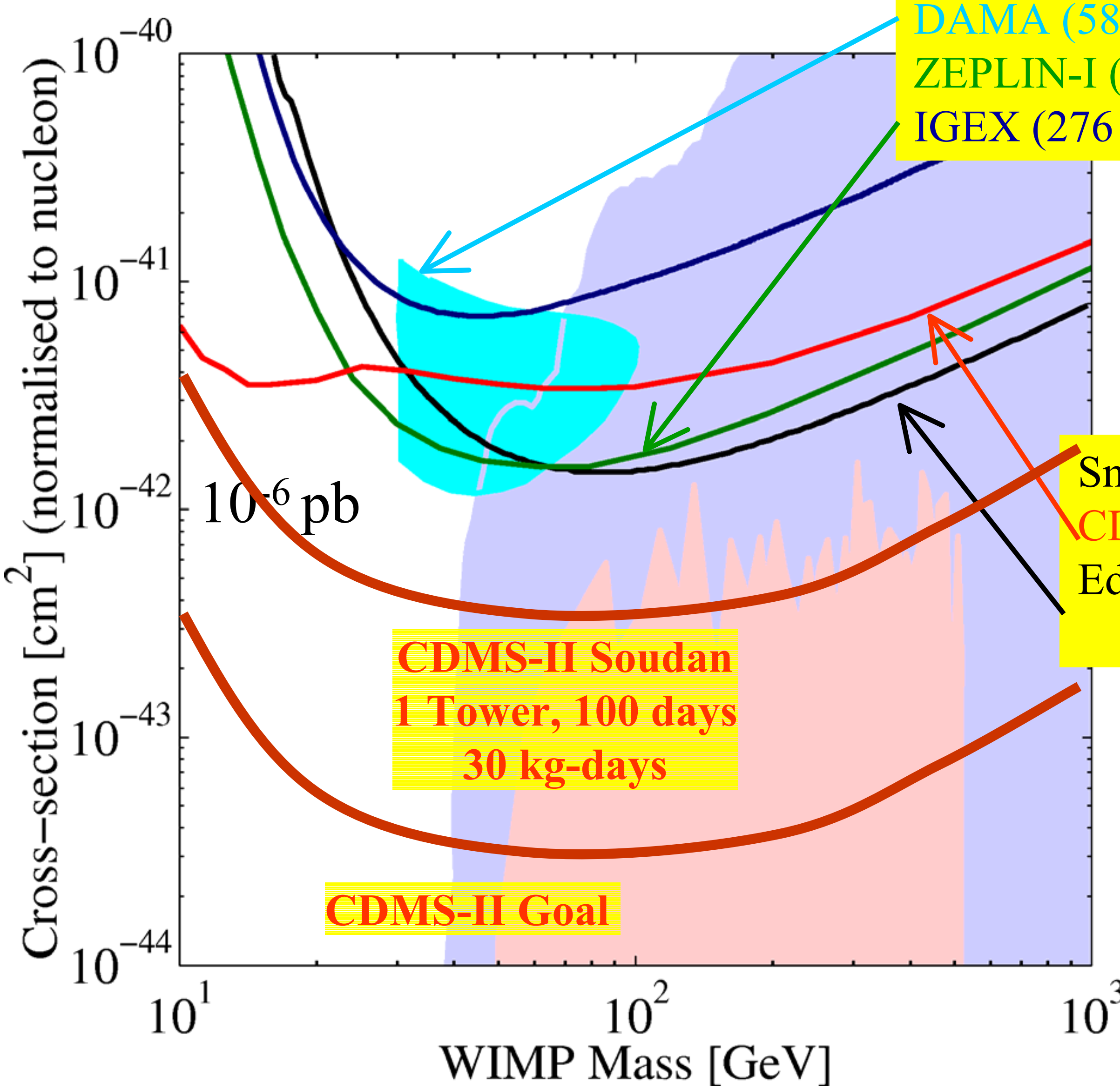
CDMS II Science Goals



Large Exposure, Background:
DAMA (58K kg-days, NaI)
ZEPLIN-I (230 kg-days, Xe)
IGEX (276 kg-days, Ge Ioniz)

Small Exposure, Background:
CDMS@SUF (28 kg-days, Ge)
Edelweiss (12 kg-days, Ge):
no background

If a signal appears, CDMS is in the best position to determine whether it is due to WIMPS!

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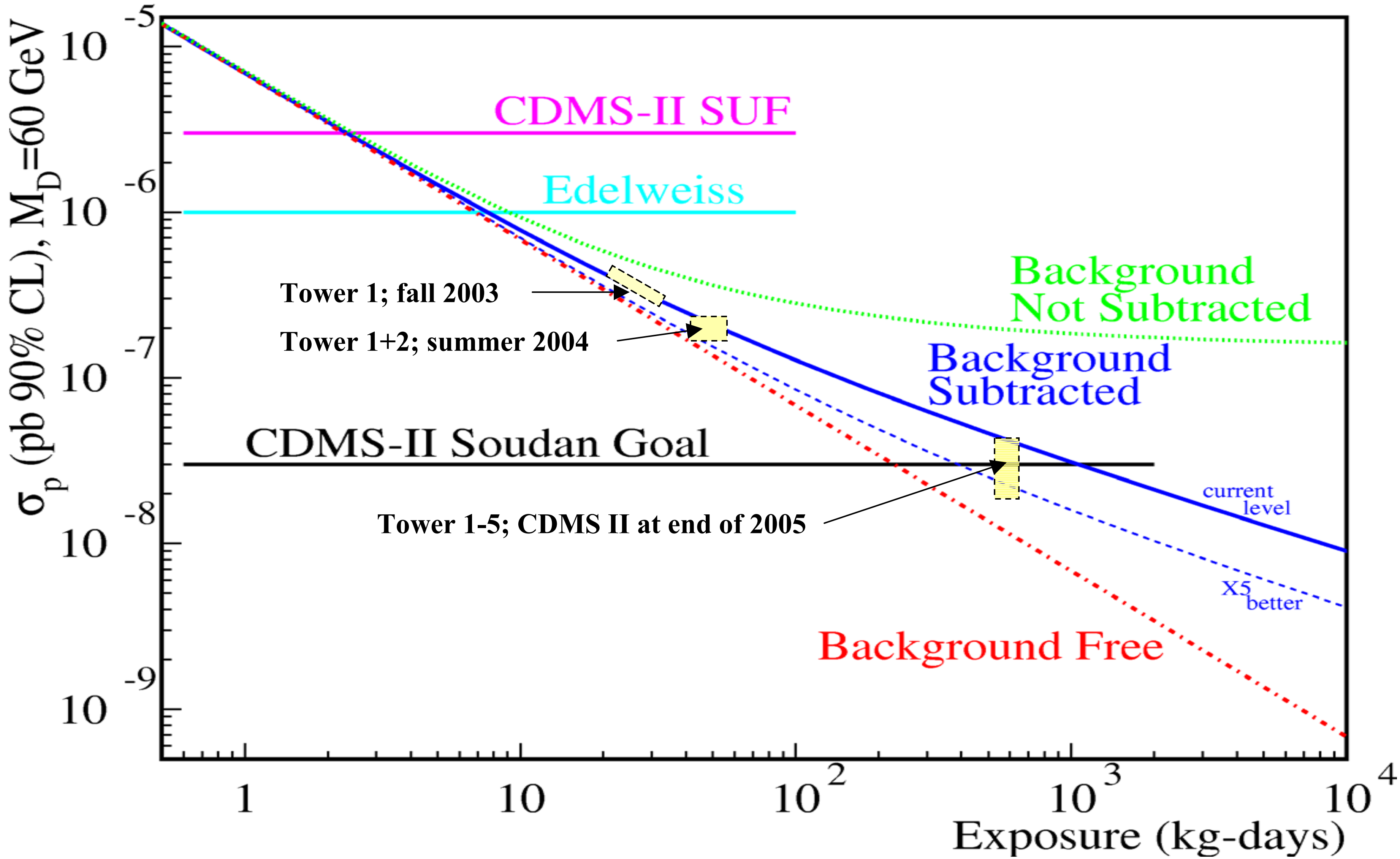
CDMS-II Soudan Sensitivity



R&D towards improving CDMS

- Primary Goal
  - Increase sensitivity x10 beyond CDMS II by reducing beta background
- Three-fold strategy
  - Contamination: Reduce beta emitters by 10x
    - Surface analysis (e.g. SIMS, PIXE,…)
      - Identify specific common isotopes like 14C, 40K, 210Pb and eliminate from fabrication
    - MWPC or Cloud Chamber beta screener
      - Directly image beta contamination from materials or even detectors
      - Low-background screening facility at Soudan (first step towards NUSEL)
    - SUF low background facility
      - Measure actual backgrounds on towers before deployment at Soudan
  - 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
  - Analysis: Improve beta rejection with better position, timing reconstruction (complementary with detector improvements)
    - New position reconstruction method already gives Z information
    - New measures of risetime also showing promise

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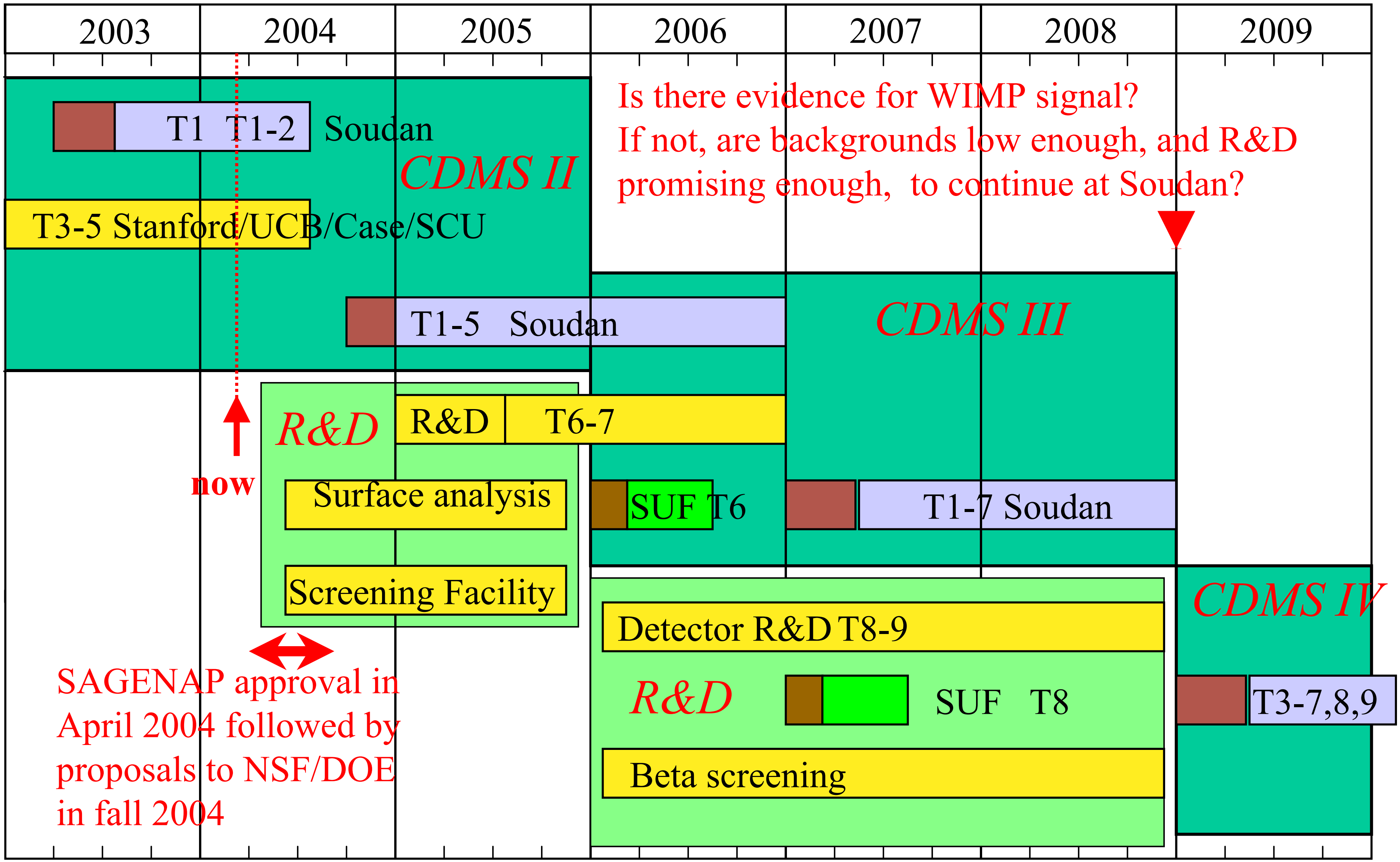
The Future of CDMS



Pierre Auger Observatory Science Objectives

- understand the nature, origin and propagation of UHECR
  - point sources?
  - isotropic arrival directions?
  - GZK cut-off or continuing spectrum?
  - primary particle mass, type?
  - acceleration or decay of exotics?
- detect cosmic rays with high statistics
  - aperture >7000km^{2}sr @10^{19}eV in each hemisphere
    - expect >5000 events at energies >10^{19} eV
      > 100 events at energies >10^{20} eV
  - full sky coverage and ~uniform exposure
  - ~degree angular resolution, $\theta \rightarrow 90°$
  - primary particle discrimination (light, heavy, γ, ν)
  - calorimetric energy calibration

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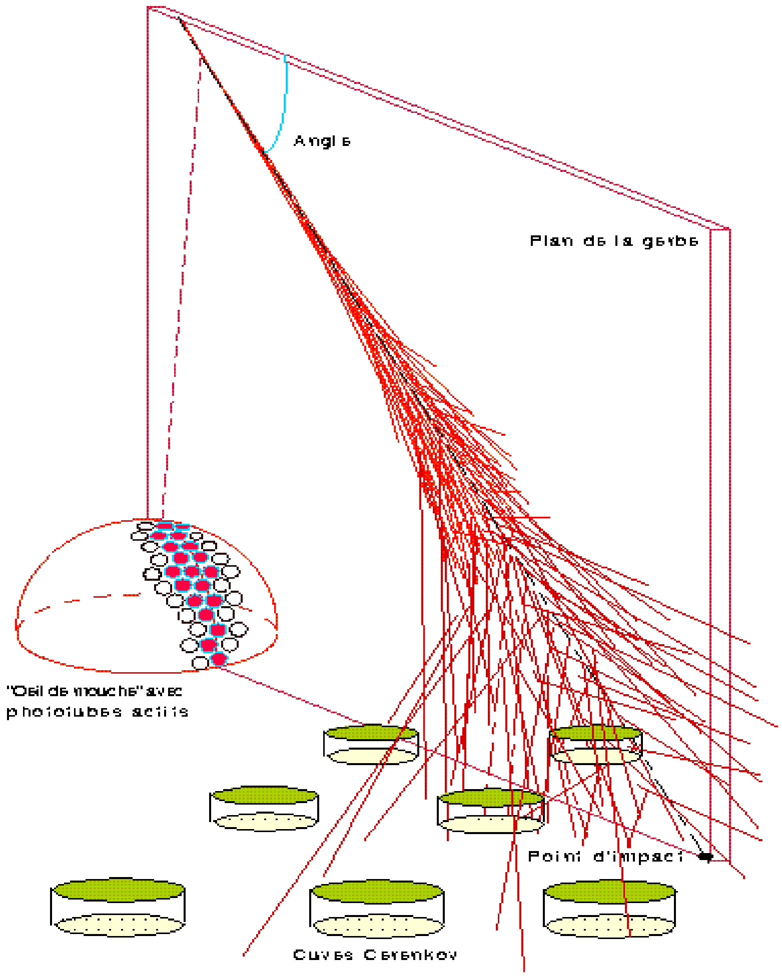
Detecting Cosmic Ray Air Showers

Fluorescence Telescopes



Surface Array

Air shower measurements are made by two techniques

1) **Surface Arrays**
2) **Fluorescence Telescopes**

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Features of the Air Shower Detector Techniques

Surface Array

- **100% duty cycle**
- **Uniform sky coverage**
- **Simple robust detectors**
- **Mass determination using rise time, muon/em**
- **Energy determination requires simulation**

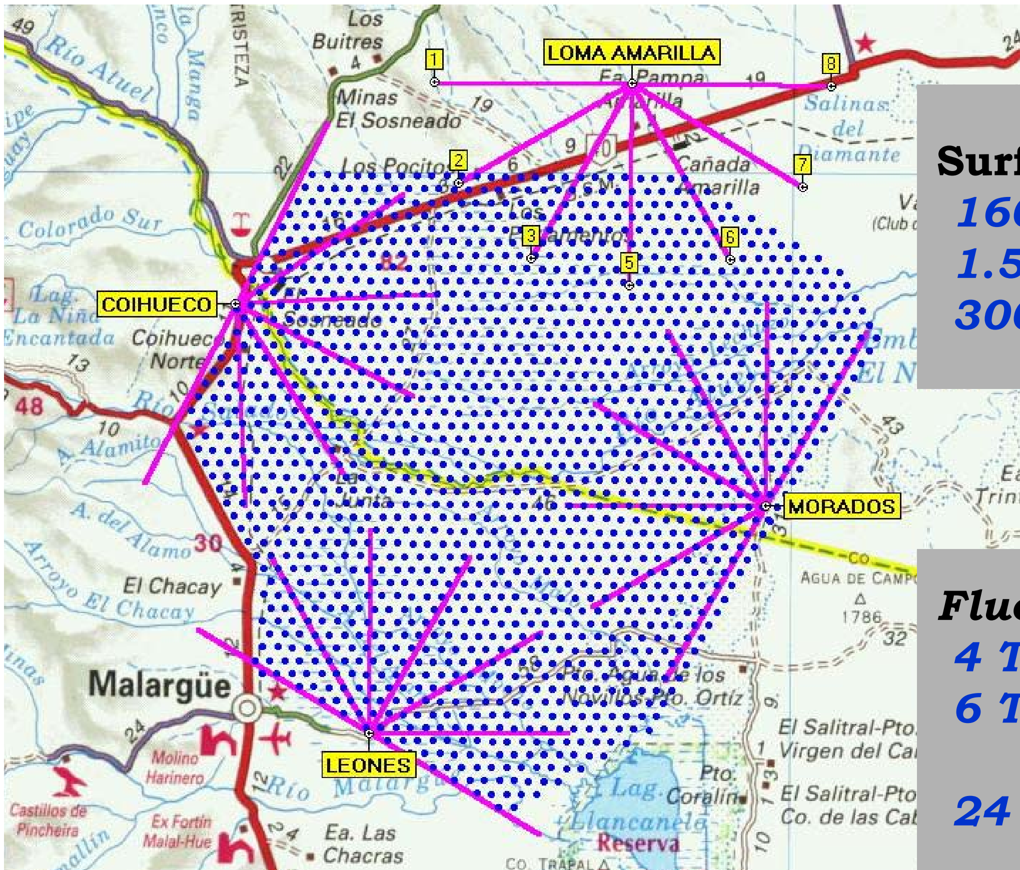
Fluorescence Detector

- **Calorimetric energy measurement**
- **Direct view of shower development**
- **Good angular resolution (< 1°)**
- **Correction for atmospheric attenuation**
- **10% duty cycle**

Hybrid detector (Surface array + Fluorescence Detectors)

- **Independent measurement techniques allow cross calibration and control of systematic errors**
- **More reliable energy and angle measurement**
- **Primary mass measured in complementary ways**
- **Uniform sky coverage**

The Pierre Auger South Observatory Plan



Surface Array

1600 detector stations

1.5 Km spacing

3000 Km^2

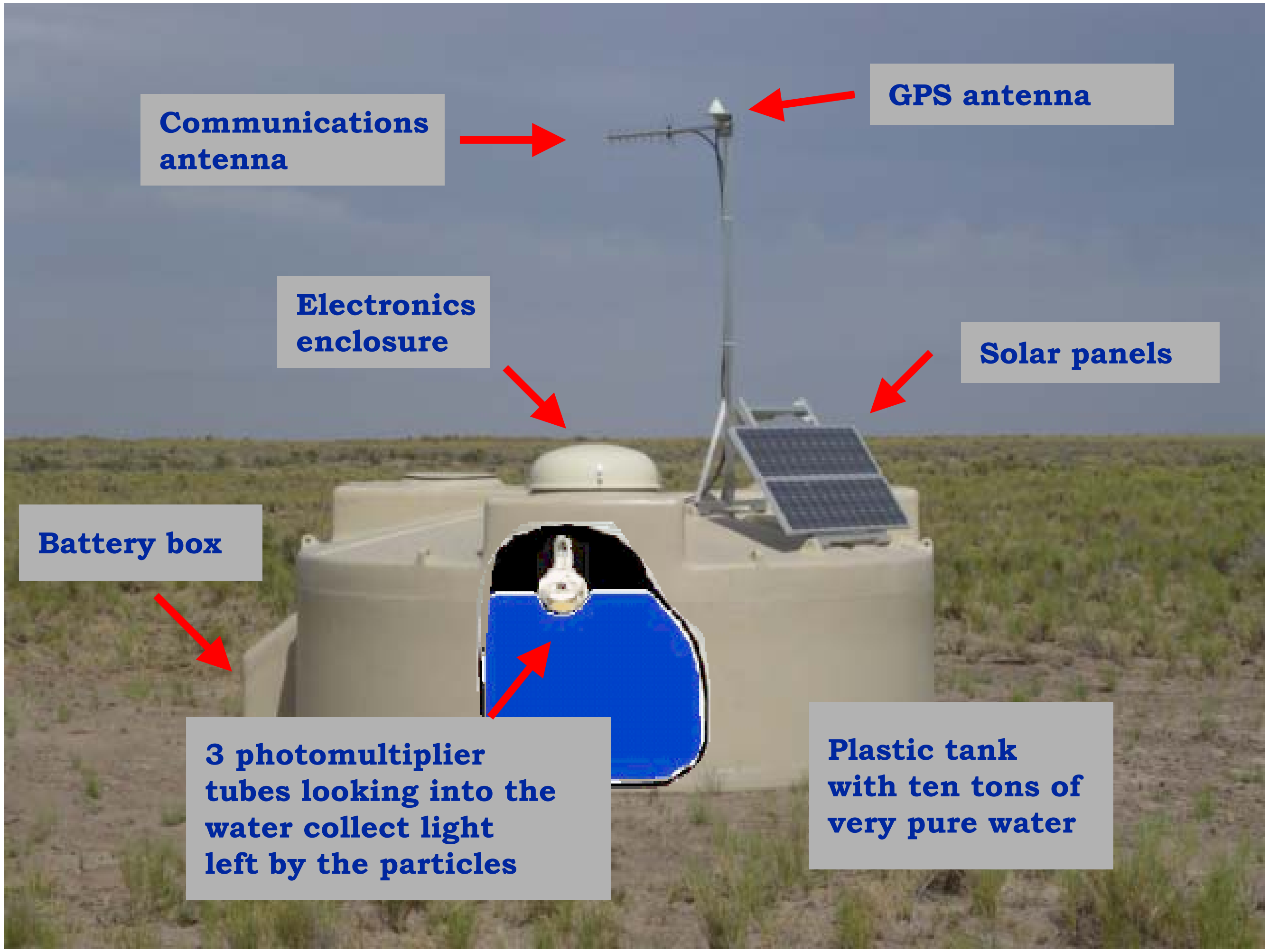
Fluorescence Detectors

4 Telescope enclosures

6 Telescopes per enclosure

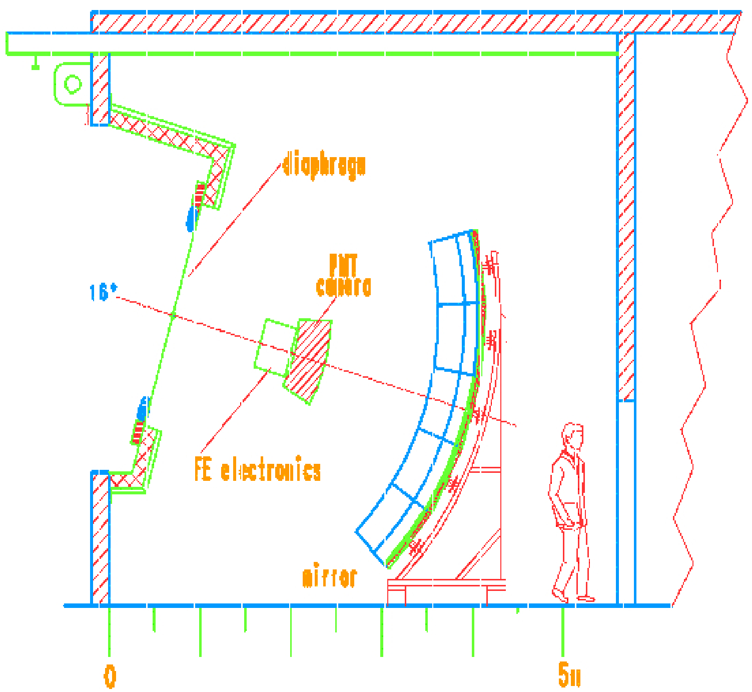
24 Telescopes total

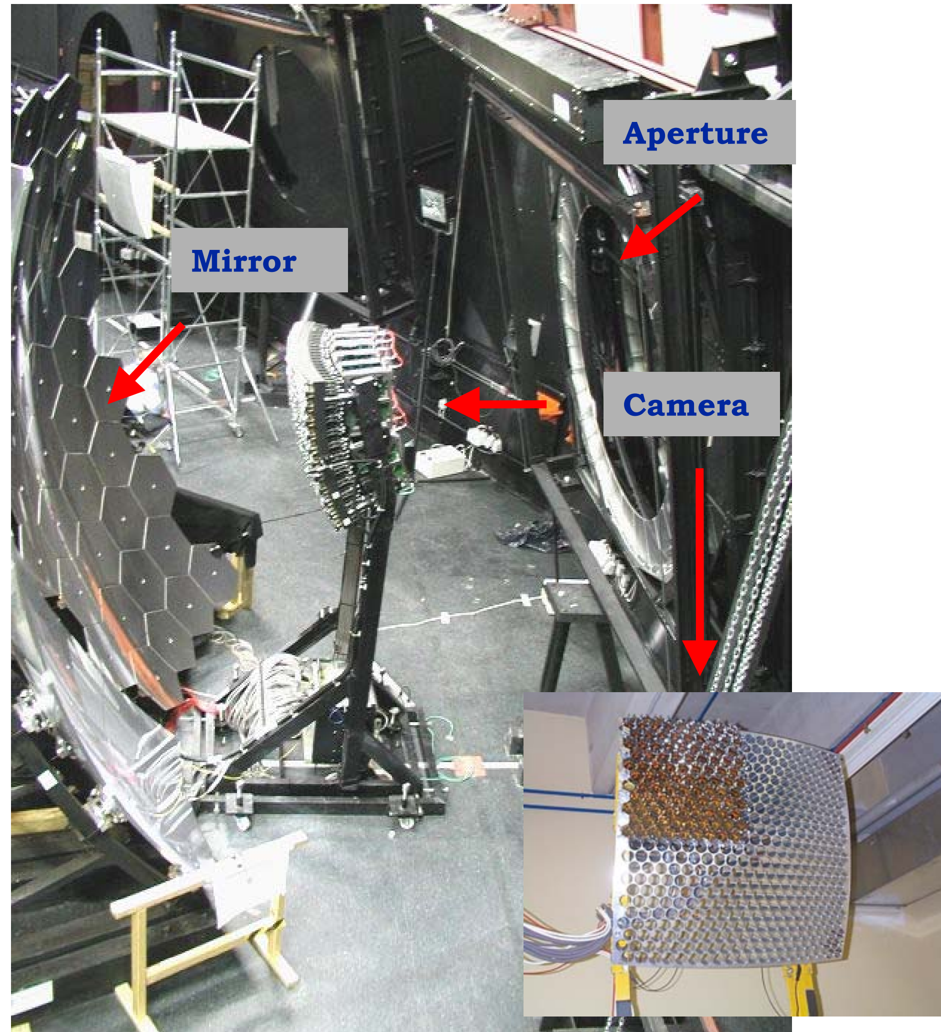
The Auger Surface Detector Station



The Auger Fluorescence Detector

3.4 meter diameter mirrors
440 pixels per camera

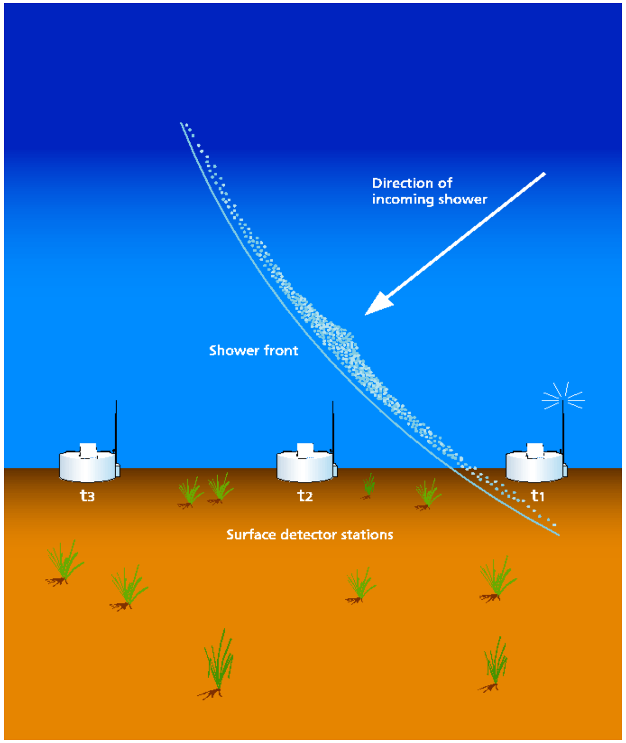


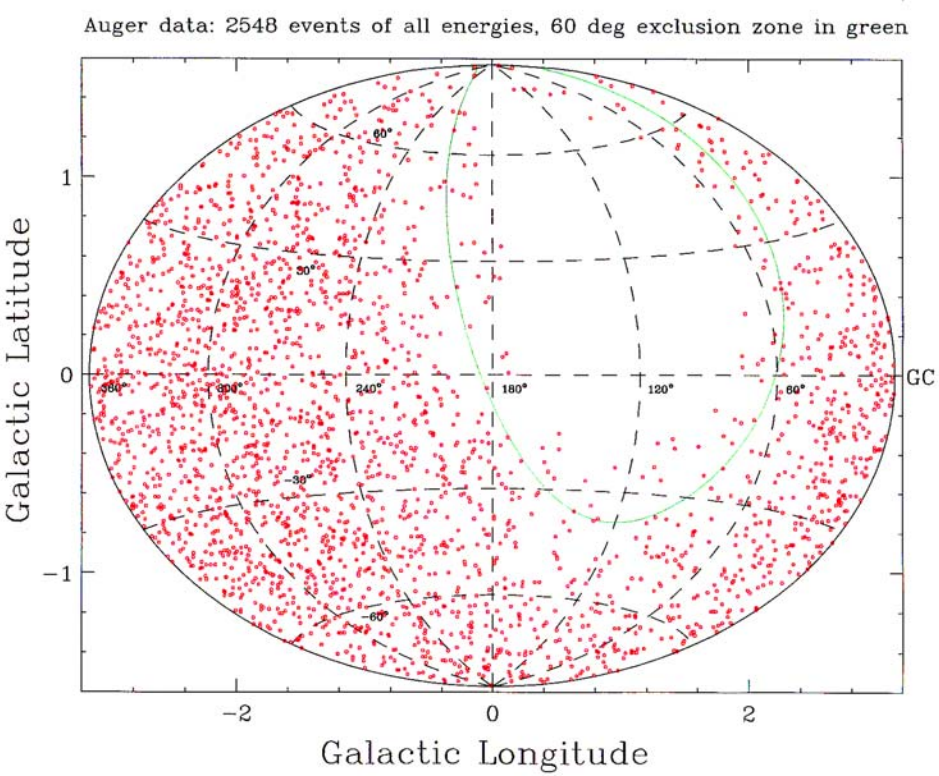


Cosmic Ray Air Shower Measurements

Direction

Direction obtained from shower timing between stations





Directions of measured showers

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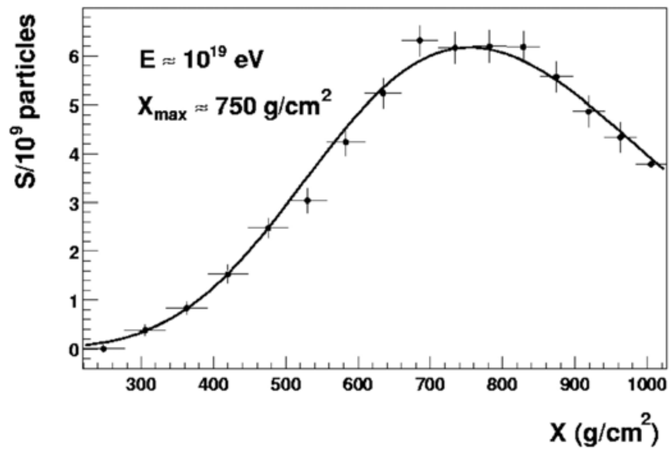
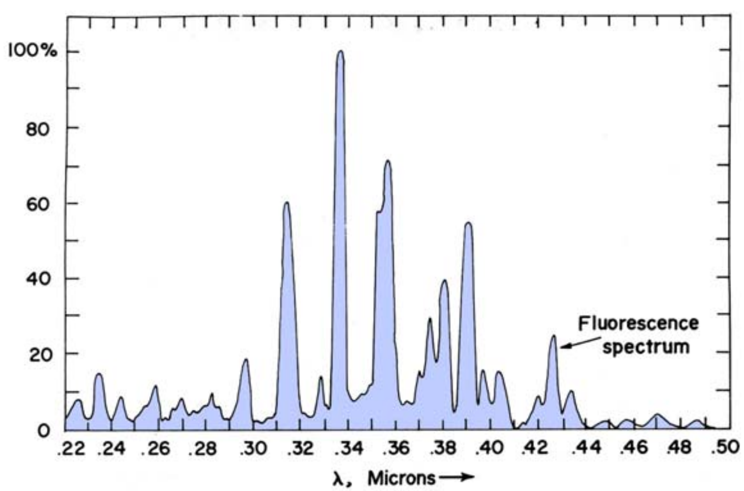
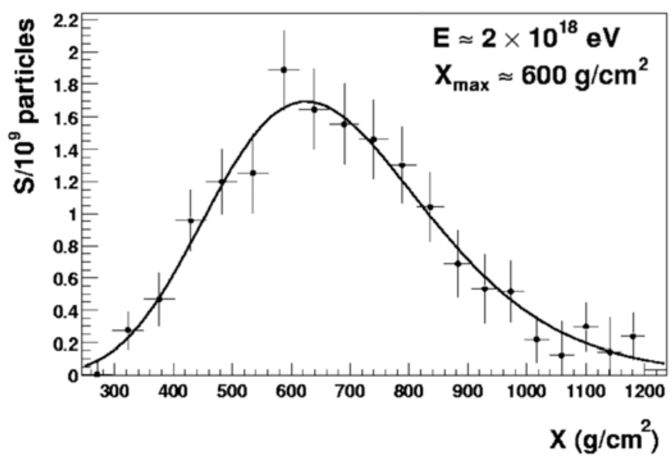
Cosmic Ray Air Shower Measurements

Energy – fluorescence detectors

Fluorescence Detectors: Measure the light produced by the shower







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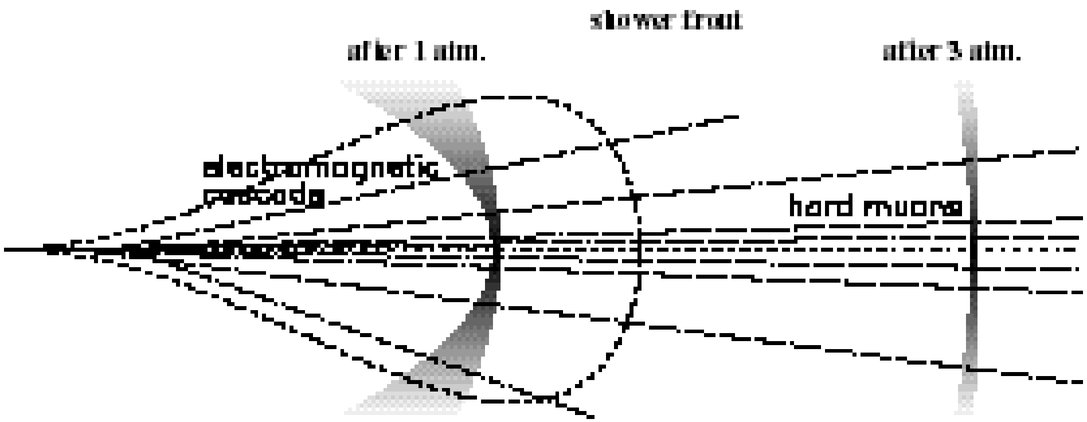
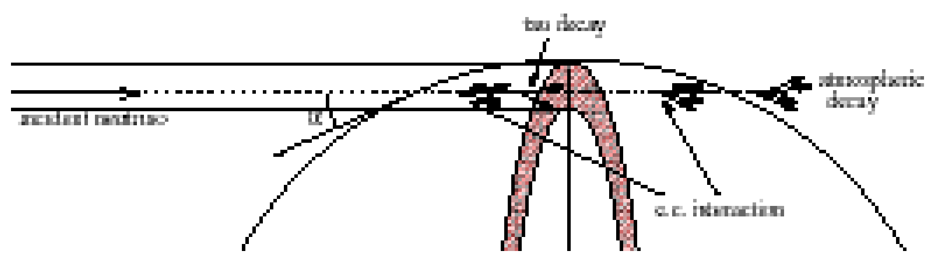
Cosmic Ray Air Shower Measurements

Sensitivity to Neutrinos



Large zenith angle (>60 degrees) hadron showers have lost most of their electromagnetic component.

Tau neutrinos can interact in the mountains or in the crust of the earth to produce taus that decay and shower over the detector.



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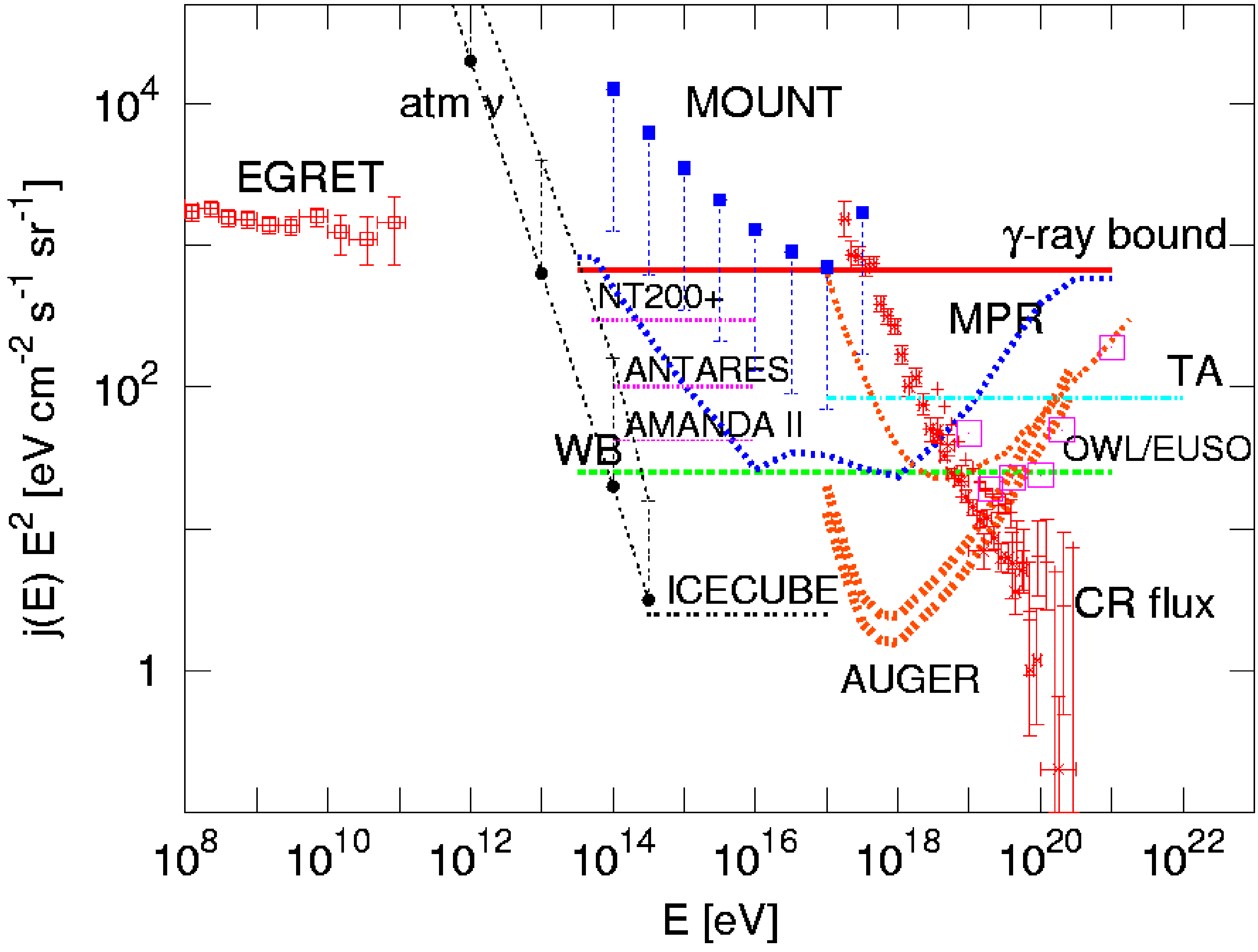
Future neutrino flux sensitivities



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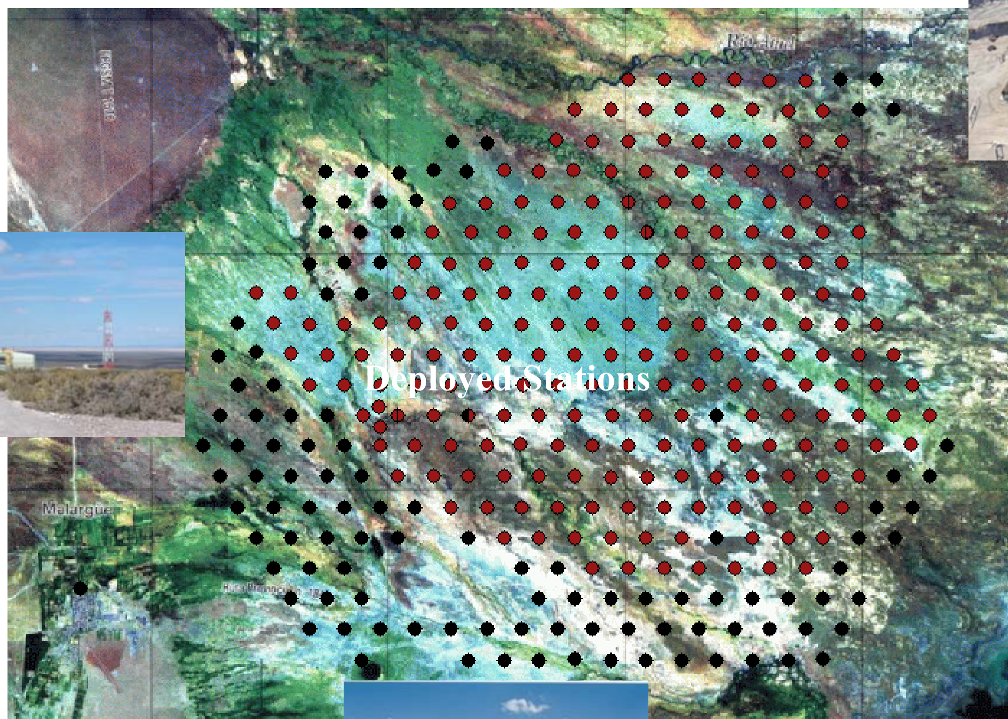
Current Status of Auger South

Los Morados

Coihueco



Los Leones

Surface Array

- **357 surface detector stations deployed**
- **239 surface detector stations operational –** ***World's largest array!***

Fluorescence detectors

- **4 telescopes operational in Los Leones**
- **2 telescope operational in Coihueco**

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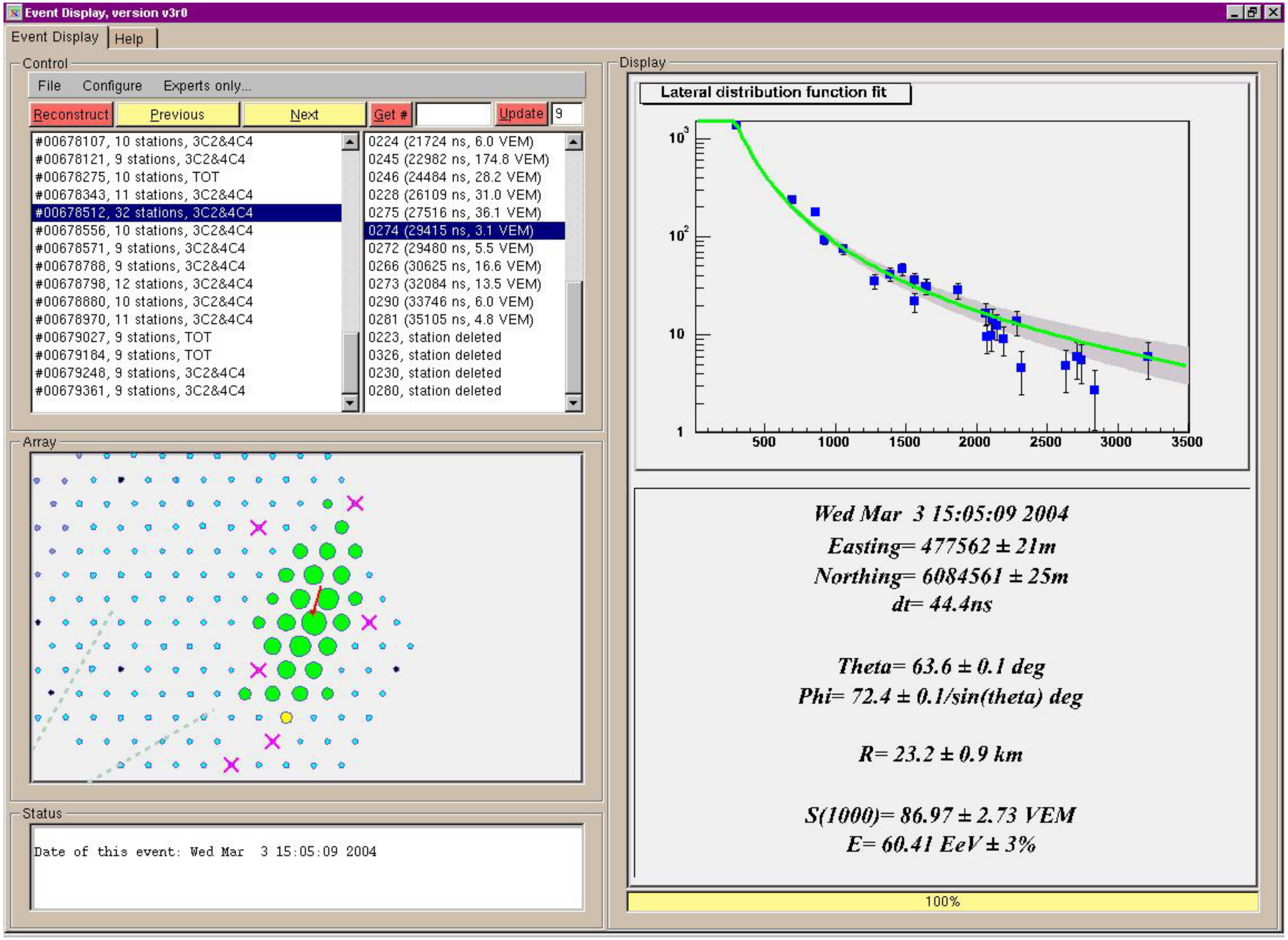
Typical Event from Auger South



Auger North

- Similar detector to allowseamless data integration
- Covers blind spot of Auger South (and vice versa)
- The site will be in Utah or Colorado.
- May expand to larger size and exploit new technologies (RF, cerenkov).
- Plan to submit a proposal for the northern site in 2004.
- Begin construction in 2006; complete by 2010.

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Aperture of Air Shower Detectors