CDMS and SuperCDMS

SLAC Summer Institute

August 2, 2007

Blas Cabrera

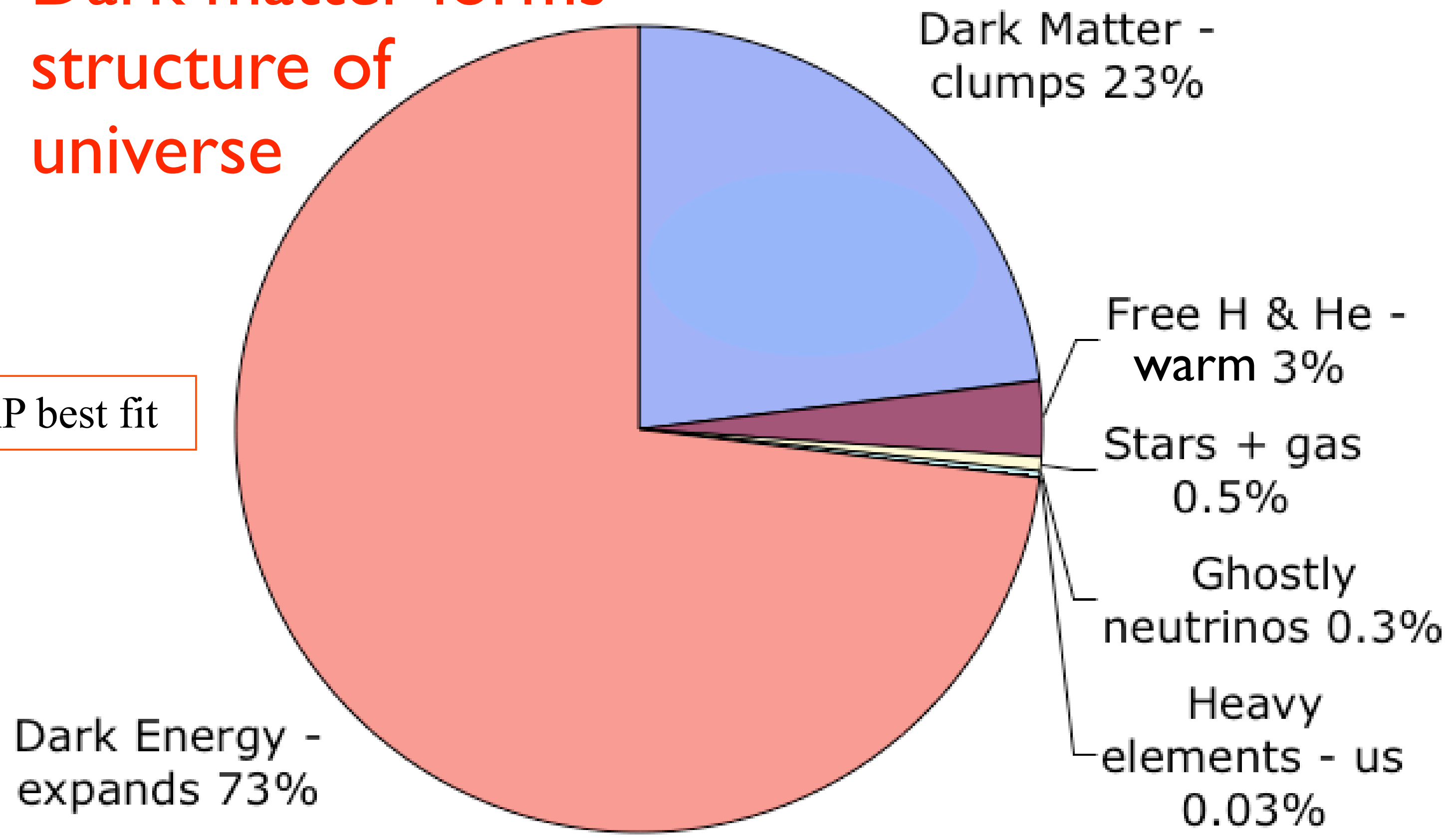
Co-Spokesperson CDMS & Spokesperson SuperCDMS

- CDMS-II science results - less than 1 evt / kg of Ge / month
- Status of CDMS-II 5-Tower run - target < 1 evt / kg of Ge / year
- SuperCDMS 25 kg experiment
  - Two SuperTowers at Soudan (DOE & NSF started FY07)
  - SuperCDMS 25 kg at SNOLab (review FY08 for FY09 start)
- EDELWEISS and CRESST status & plans leading to EUREKA
- Comparisons with liquid experiments: XENON, WArP, COUPP
- Conclusions

Composition of the Cosmos

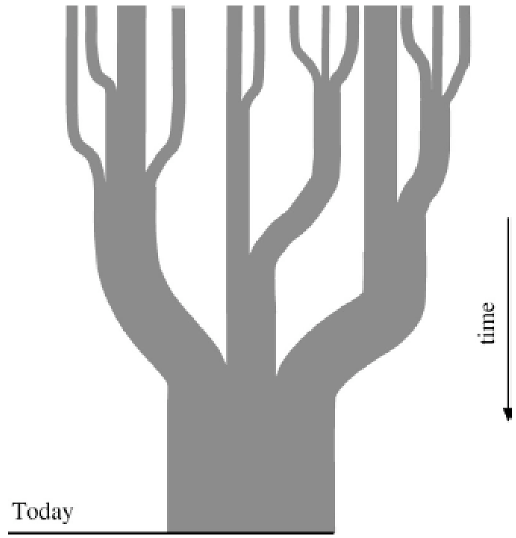
Dark matter forms structure of universe

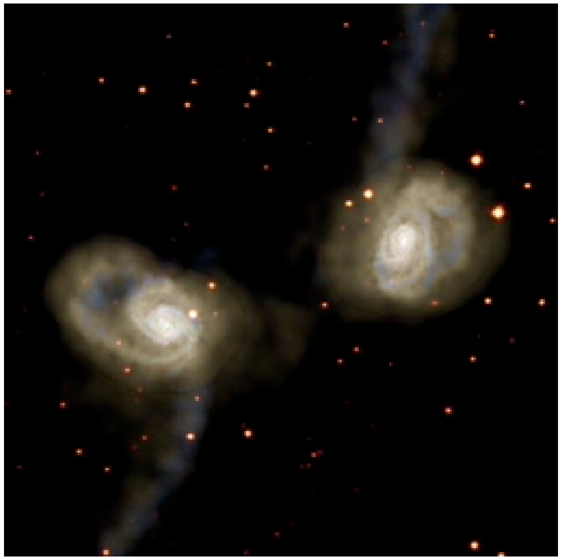
WMAP best fit

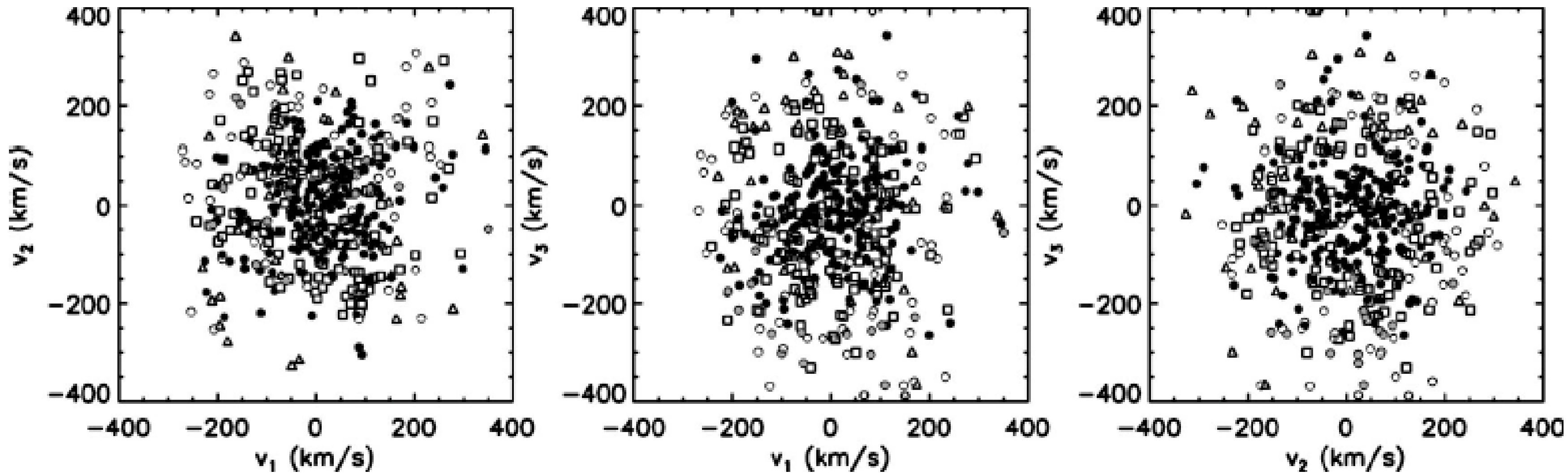


Numerical simulations for DM Halos

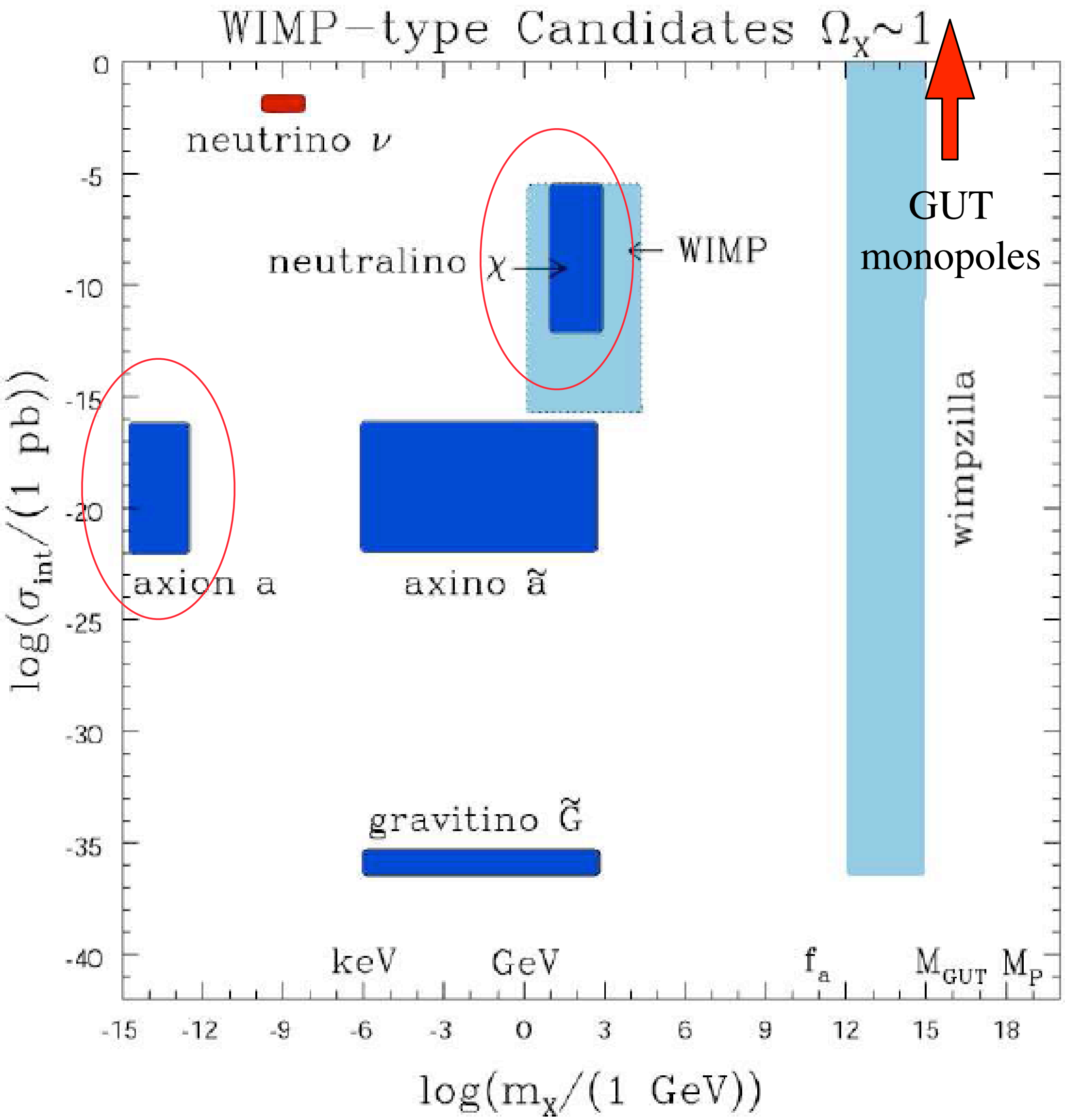
- The phase-space structure of a dark-matter halo: Implications for dark-matter direct detection experiments, e.g., A. Helmi, S. White, and V. Springel
  PRD 66, 063502 (2002)
- Solar system moves with respect to zero mean velocity halo at 220 km/s







What is the dark matter?

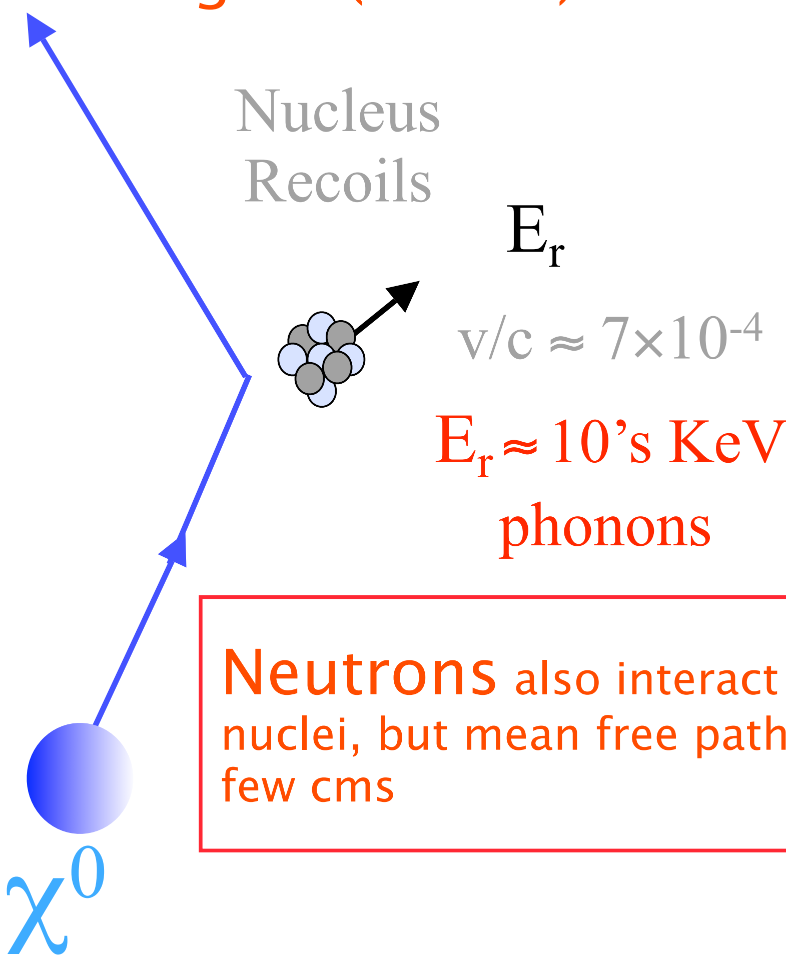


- neutrino ν – hot DM
- neutralino χ
- “generic” WIMP
- axion a
- axino $\tilde{a}$
- gravitino $\tilde{G}$
- wimpzilla,. . .

L. Roszkowski

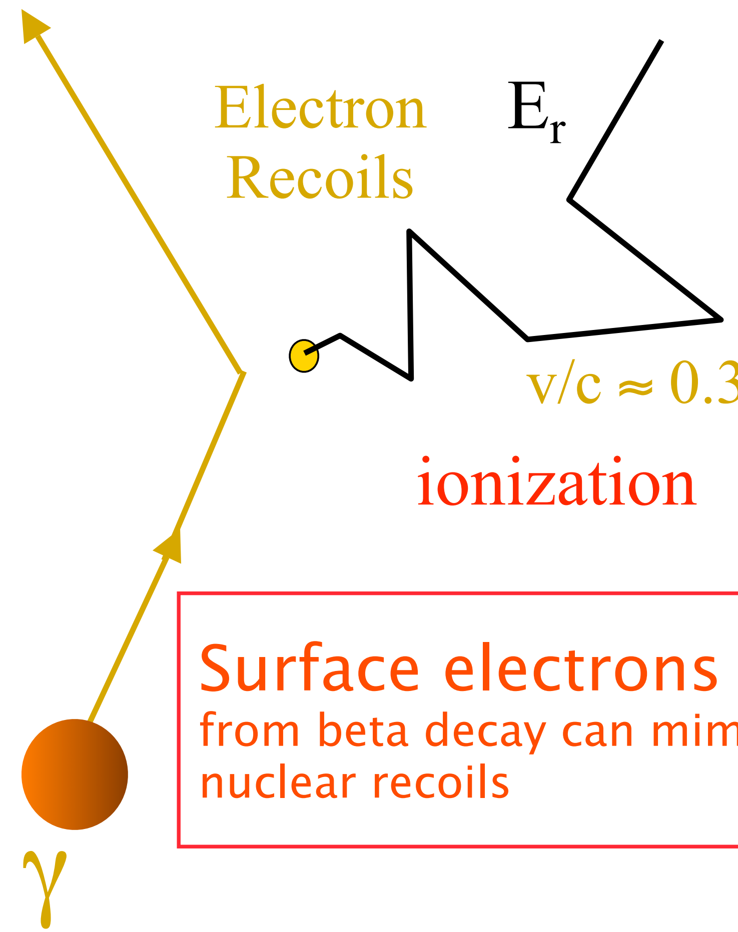
The Signal and Backgrounds

Signal (WIMPs)



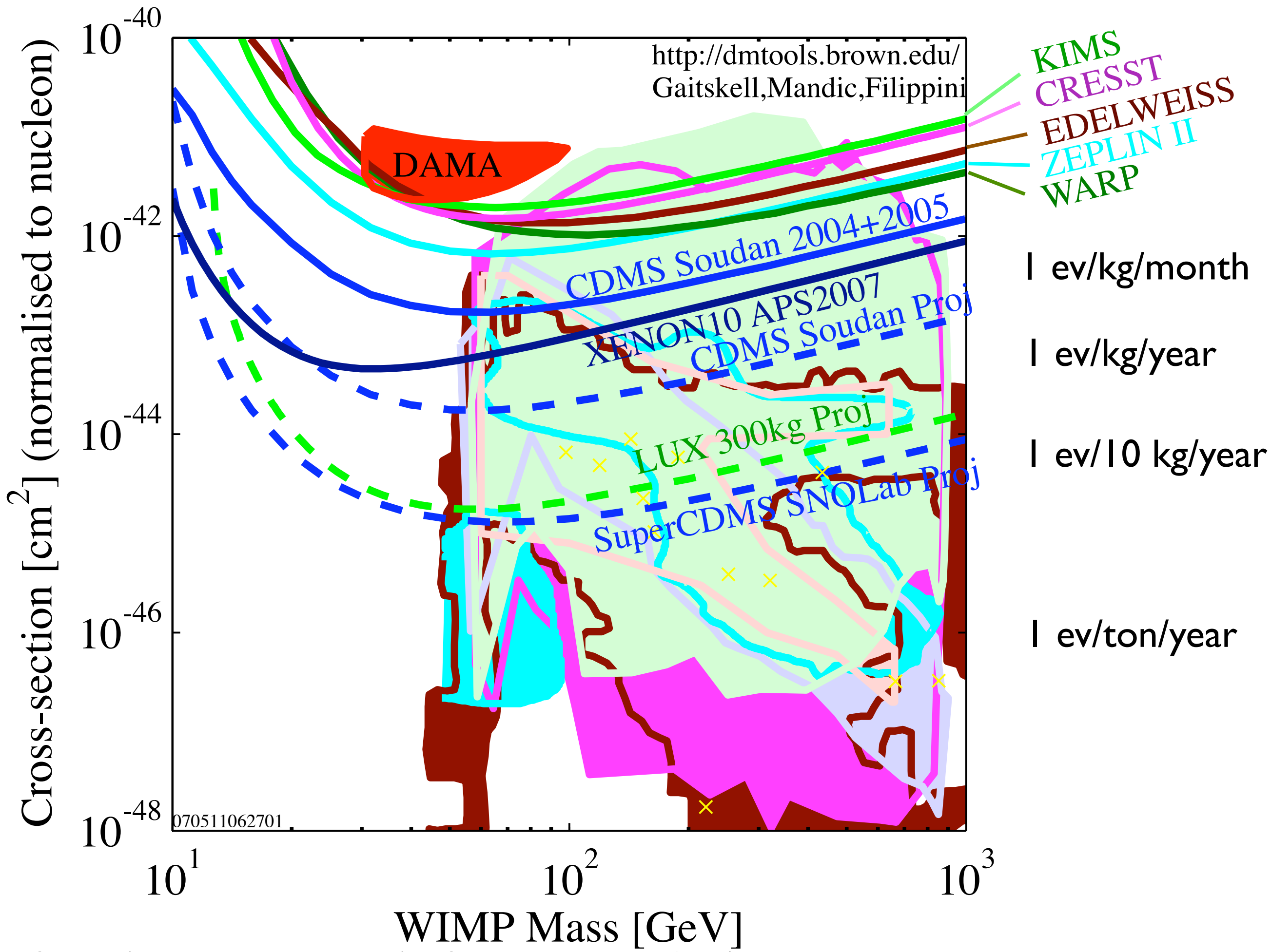
Neutrons also interact with nuclei, but mean free path a few cms

Background (gammas)



Surface electrons from beta decay can mimic nuclear recoils

Status of Direction Detection Search

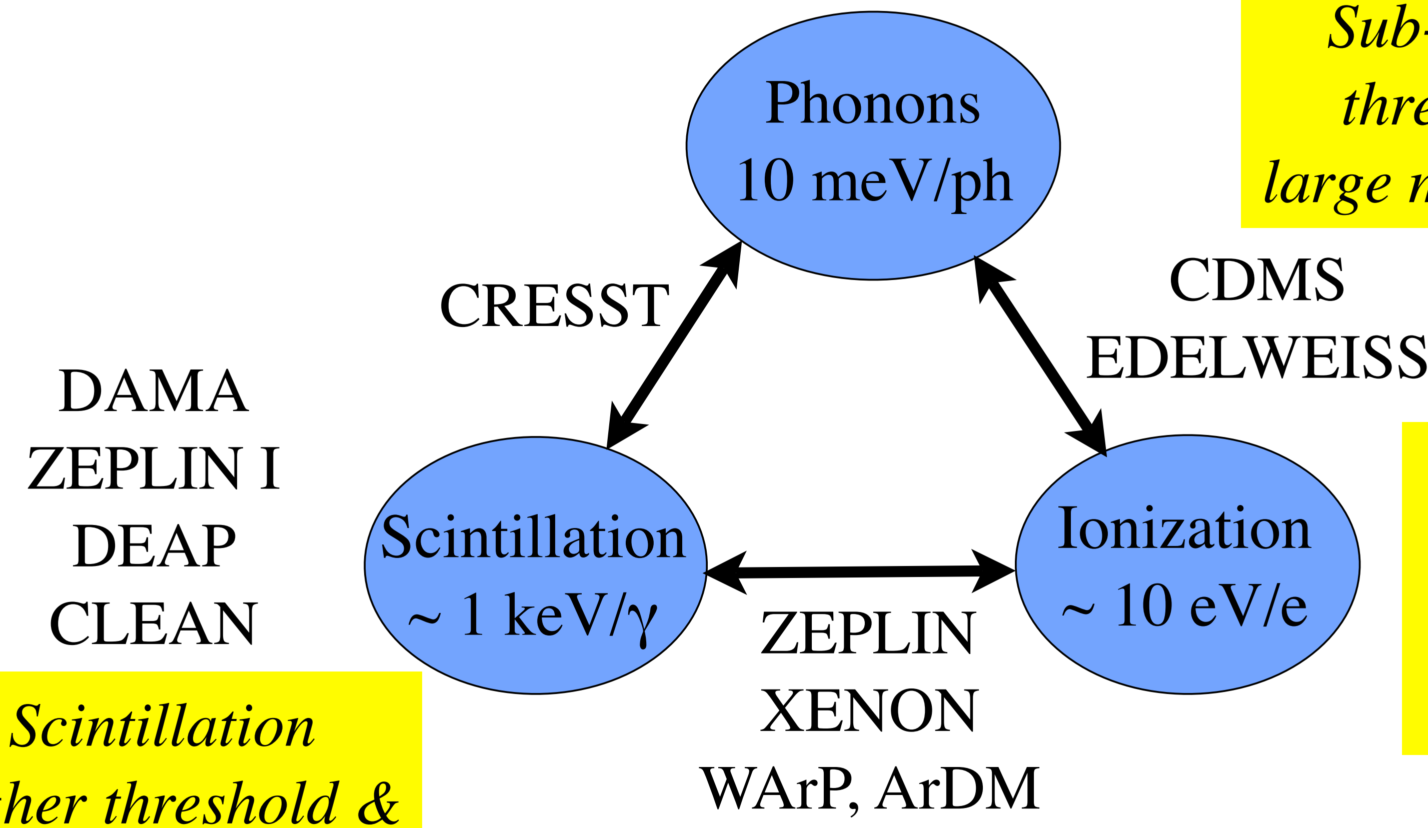


- Variety of techniques search for WIMP dark matter - interesting sensitivity
- Several have the potential to reach 10^{-44} cm^2 soon and 10^{-46} cm^2 in future

Discrimination strategies

- Most particle physics experience in MeV range
- Direct detection requires keV scale

Sub-K low threshold large mass >$$



need both to confirm results

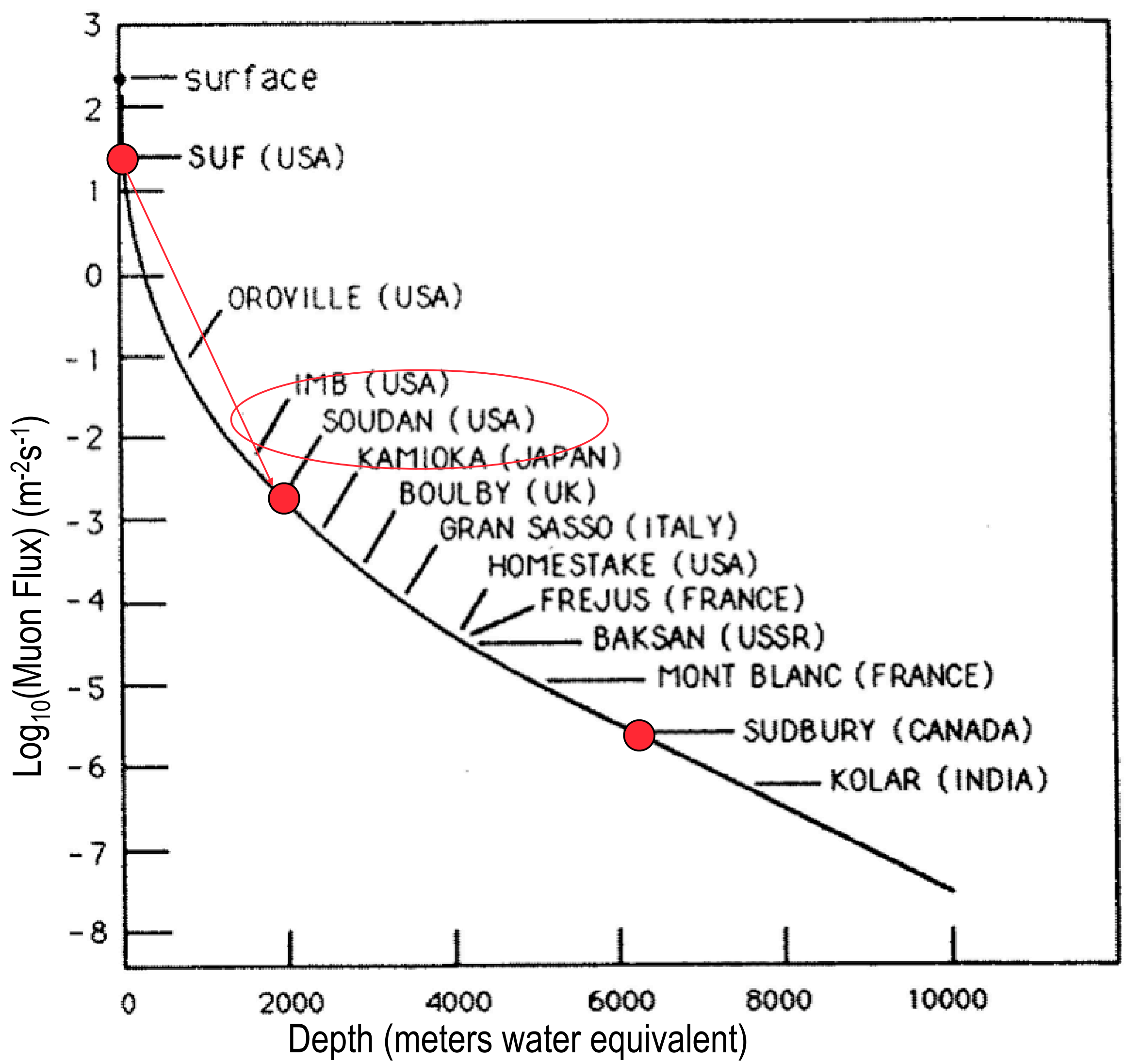
Scintillation higher threshold & large fluctuations

Noble liquids high threshold but large mass <$$

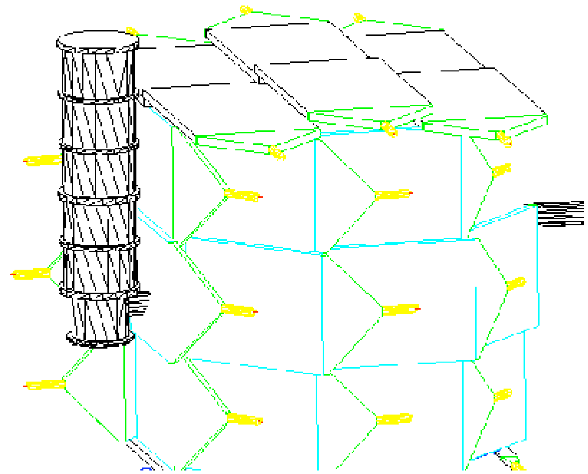
CDMS Collaboration

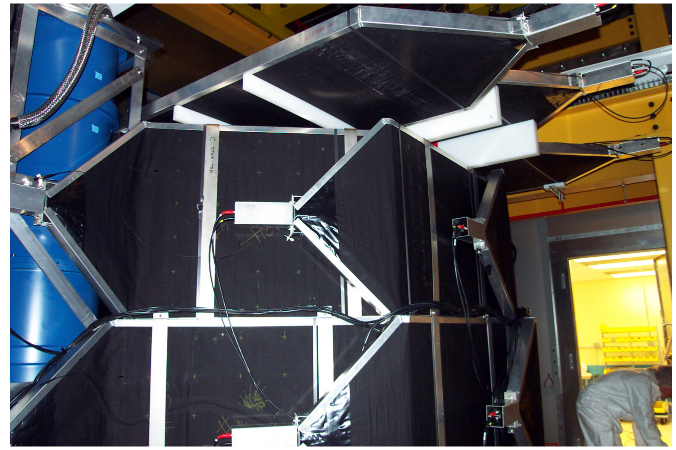
CDMS-II at Soudan (2090 mwe)

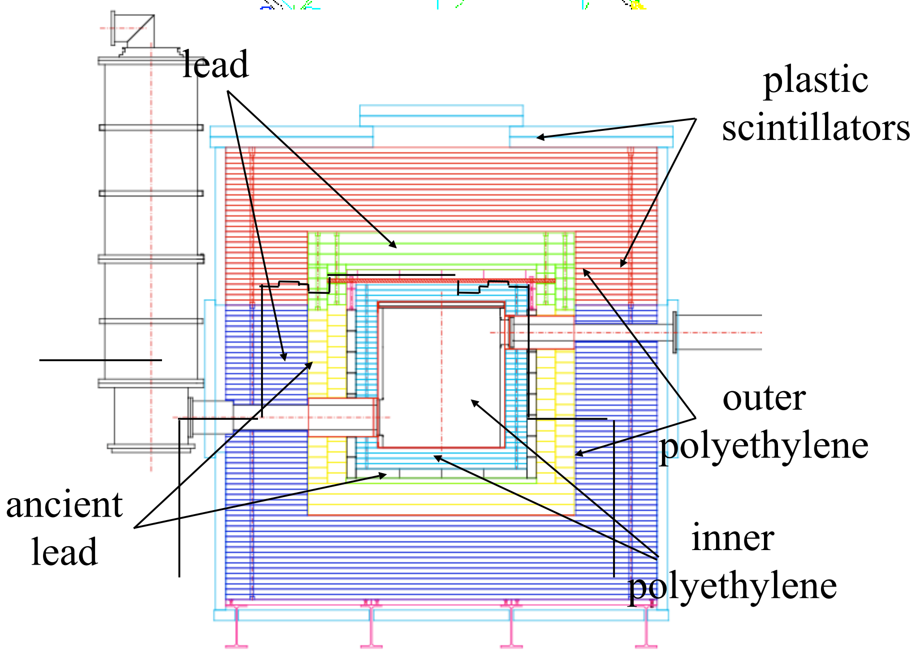
- At SUF
  - 17 mwe
  - 0.5 n/d/kg
- At Soudan
  - 2090 mwe
  - 0.6 n/y/kg
- At SNOLab
  - 6060 mwe
  - 1 n/y/ton



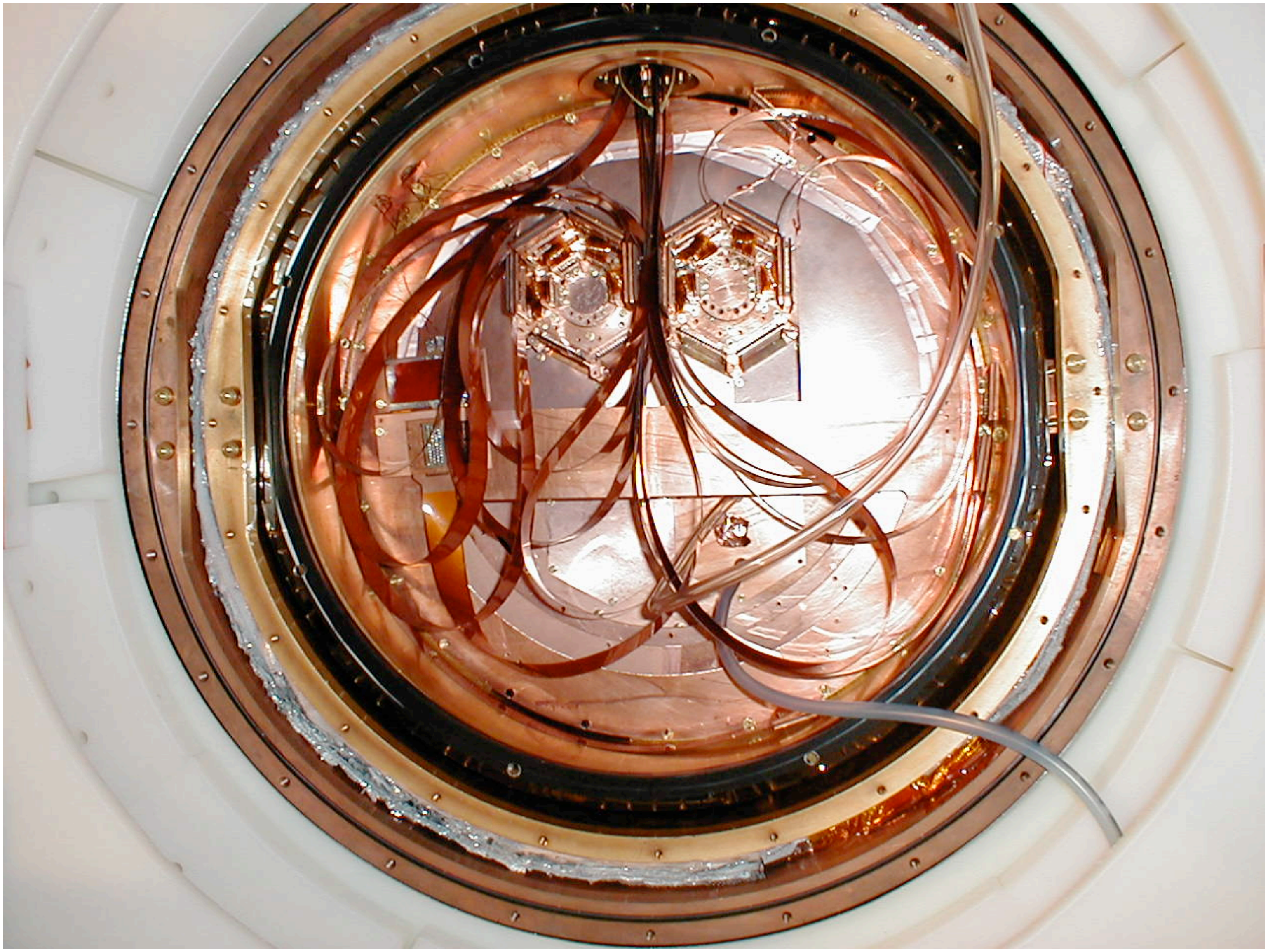
CDMS-II Soudan facility







Run 118 (1T) & Run 119 (2T) in Soudan



CDMS Active Background Rejection

Detectors with excellent event-by-event background rejection

- Measured background rejection:
- 99.995% for EM backgrounds using charge/heat
- 99.4% for β's using pulse risetime as well
- Much better than expected in CDMS II proposal!

Tower of 6 ZIPs

Tower 1

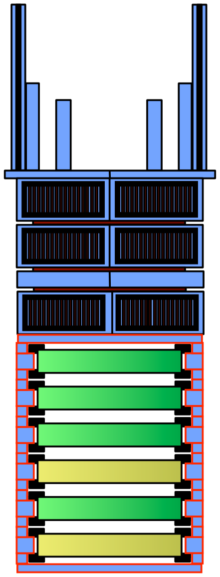
4 Ge

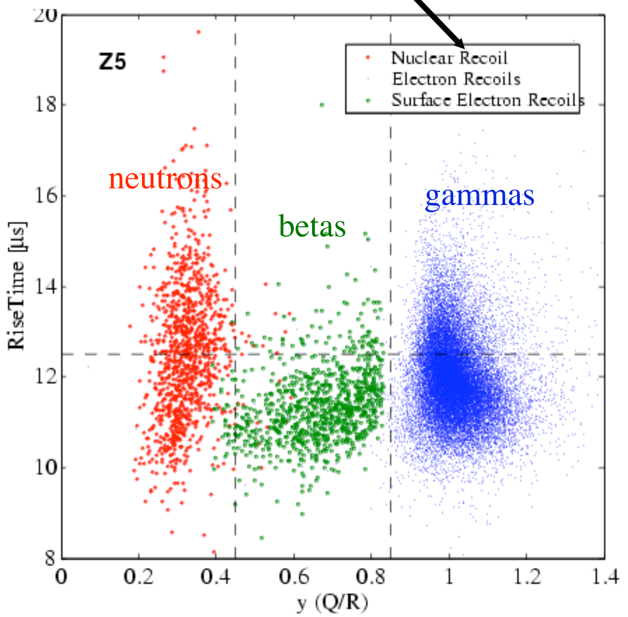
2 Si

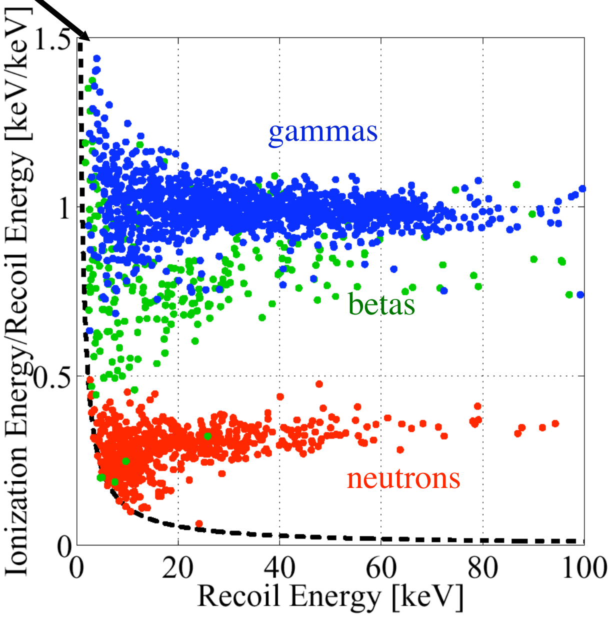
Tower 2

2 Ge

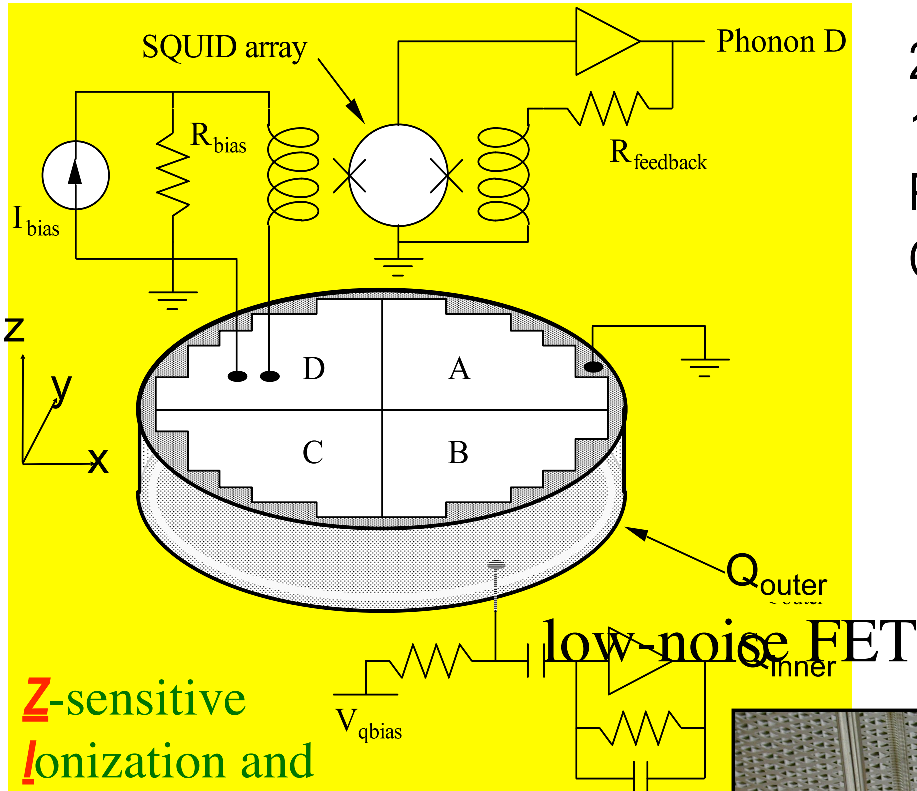
4 Si







Really Cool Detectors: ZIPs



250 g Ge or 100 g Si crystal

1 cm thick x 7.5 cm diameter

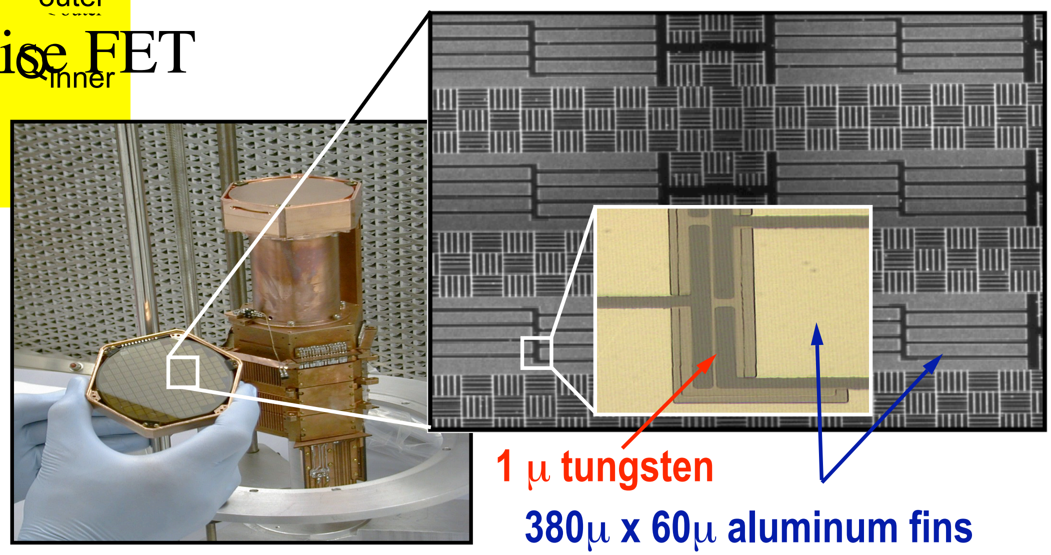
Photolithographic patterning

Collect athermal phonons:

- Crystal lattice vibrations
- Speed of sound in crystal ~ 1 cm/ms results in measurable delays between the pulses of the 4 phonon channels => distinguish surface from bulk events

Z-sensitive **I**onization and **P**honon-mediated

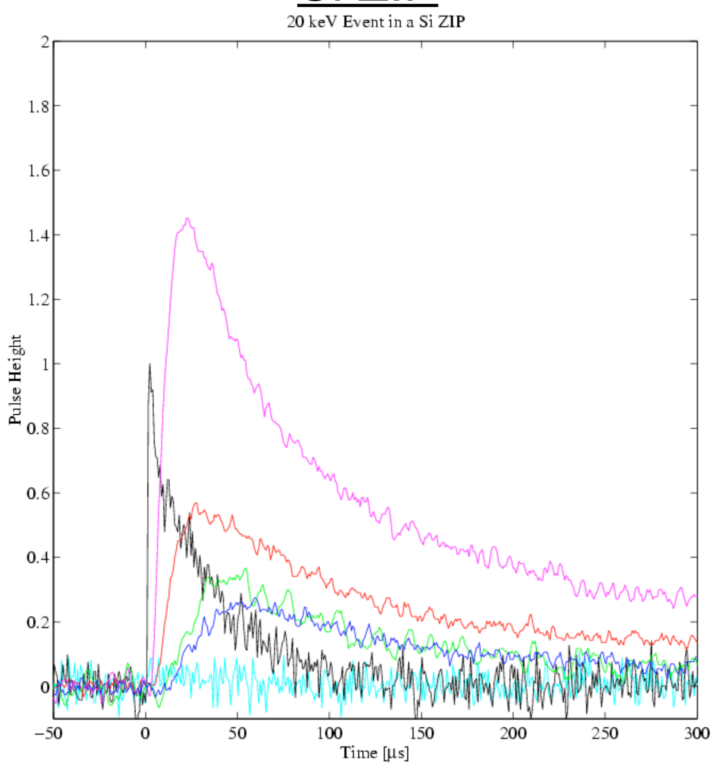
Measure ionization in low-field (~volts/cm) with segmented contacts to allow rejection of events near outer edge



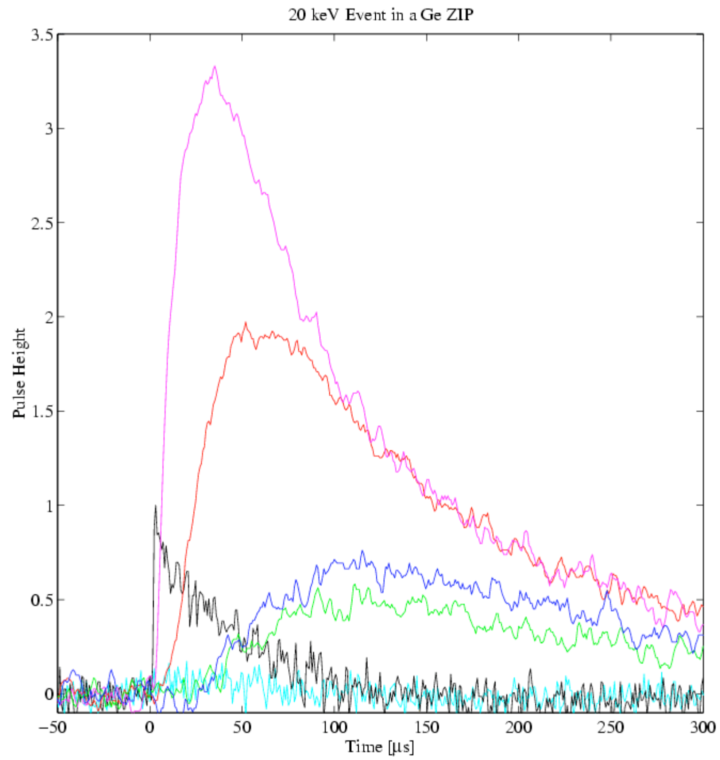
Model ZIP Detector Signal

- Charge & Phonon signals occur on a similar timescale
- Phonon pulse time of arrival allows for event position reconstruction
- 20 keV event in a Si & Ge ZIP

Si ZIP

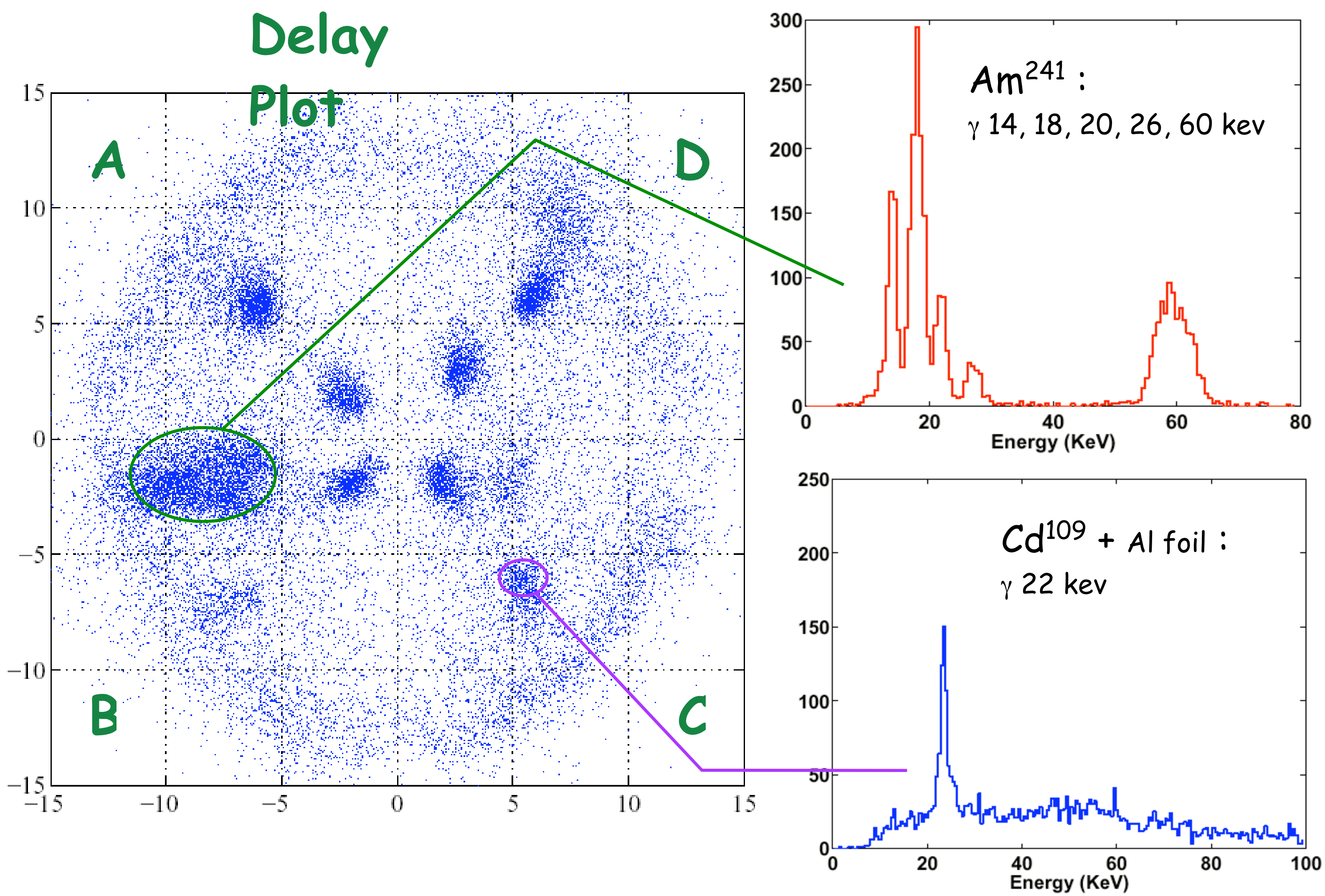


Ge



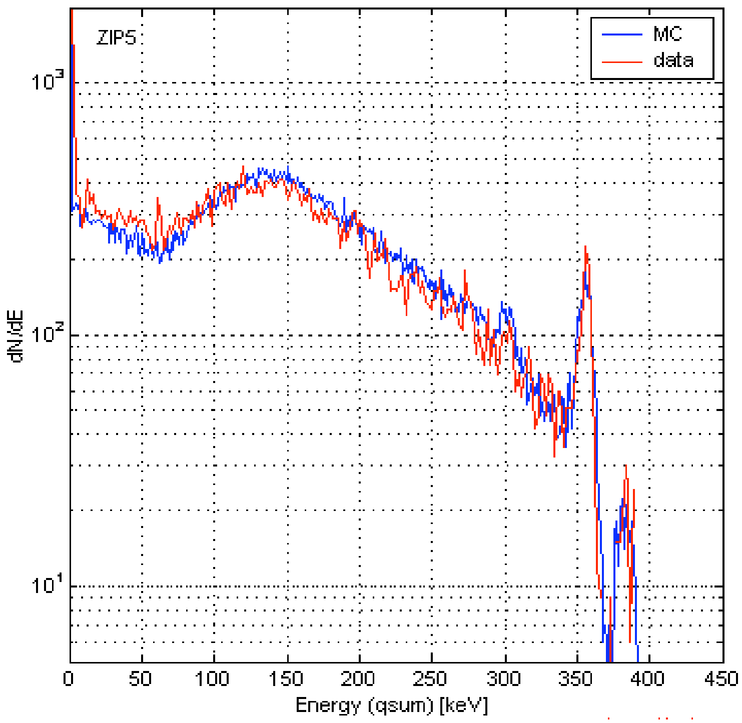
(EXCELLENT S/N FOR 20 KeV TRUE RECOIL ENERGY)

ZIP Phonon Position Sensitivity

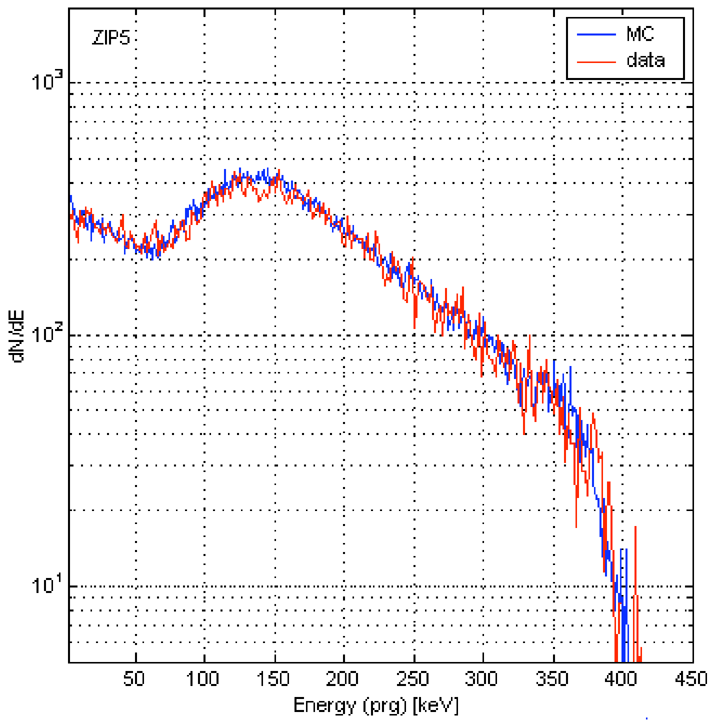


Energy calibration of Ge ZIP with ^{133}Ba source

Ionization energy in keV



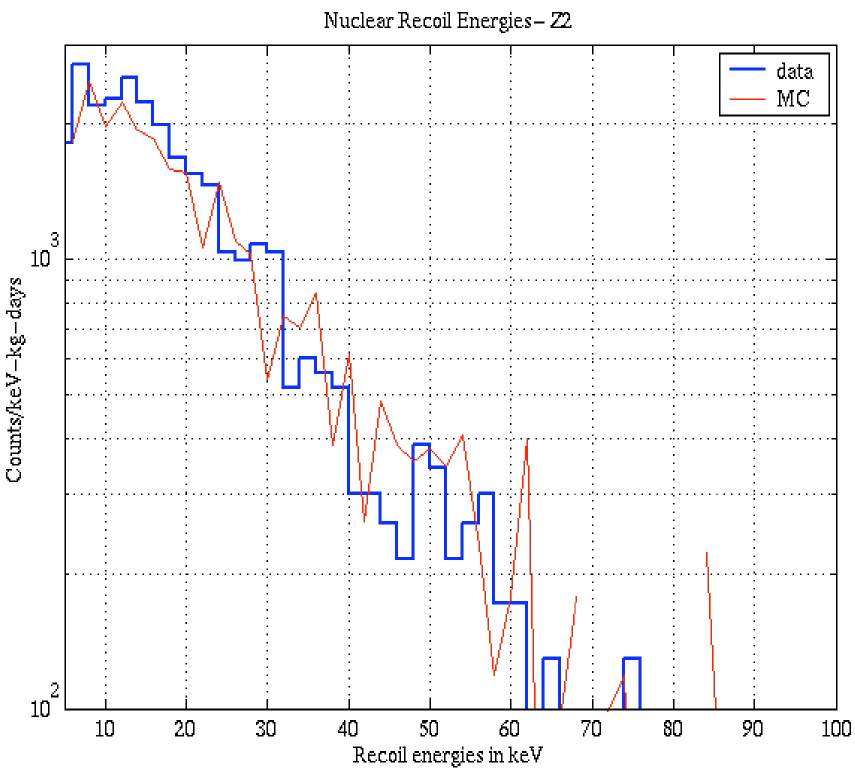
Phonon energy (prg) in keV



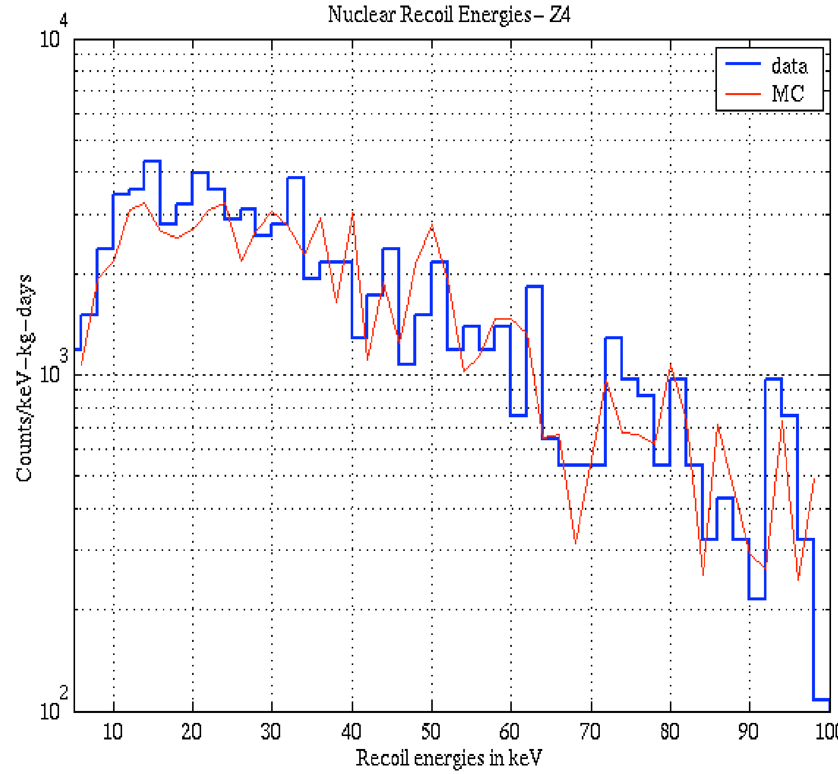
Excellent agreement between data and Monte Carlo

Nuclear recoil calibration: Ge&Si ZIPs w/ ^{252}Cf

Nuclear recoils in Ge ZIP



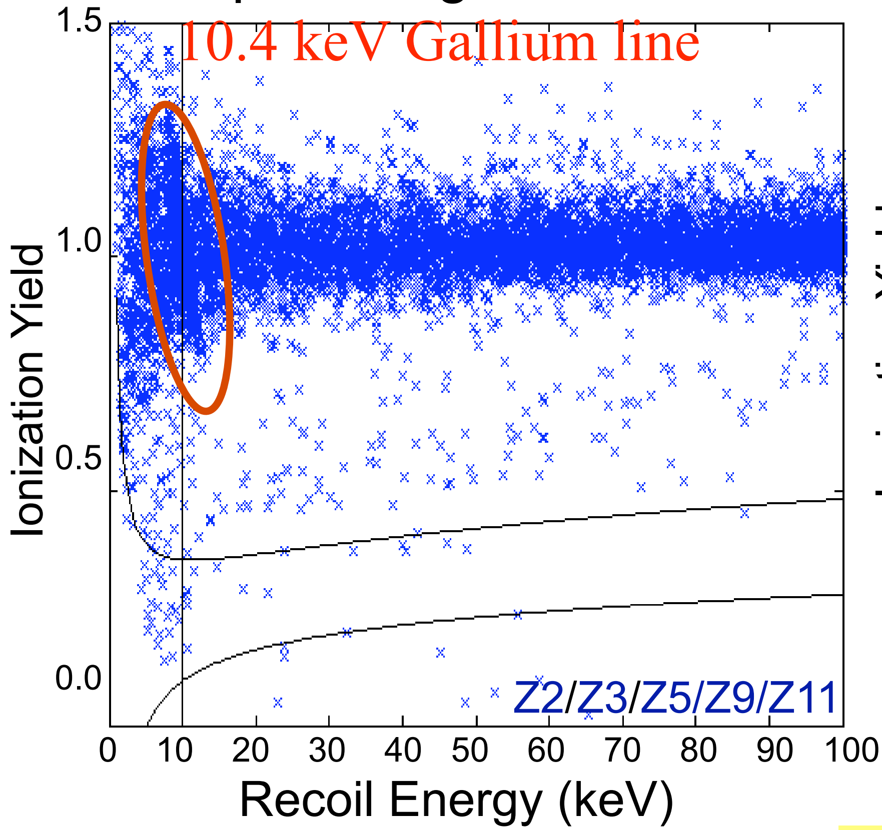
Nuclear recoils in Si ZIP



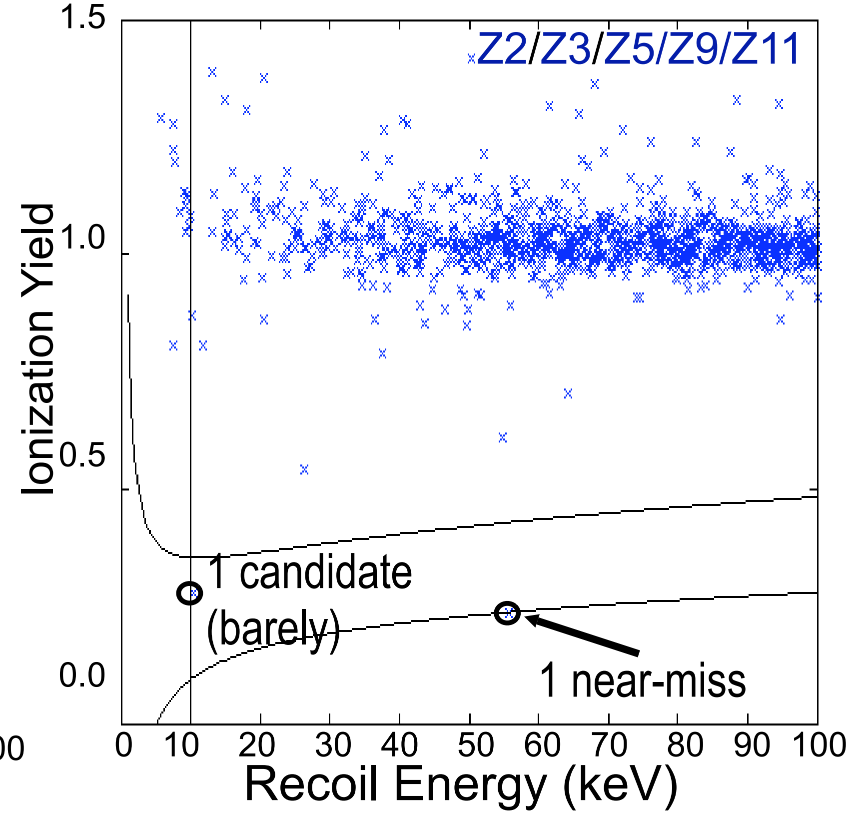
Excellent agreement between data and Monte Carlo

WIMP search data (5 Ge ZIPs ~53 kg-d)

Prior to phonon pulse shape timing cuts



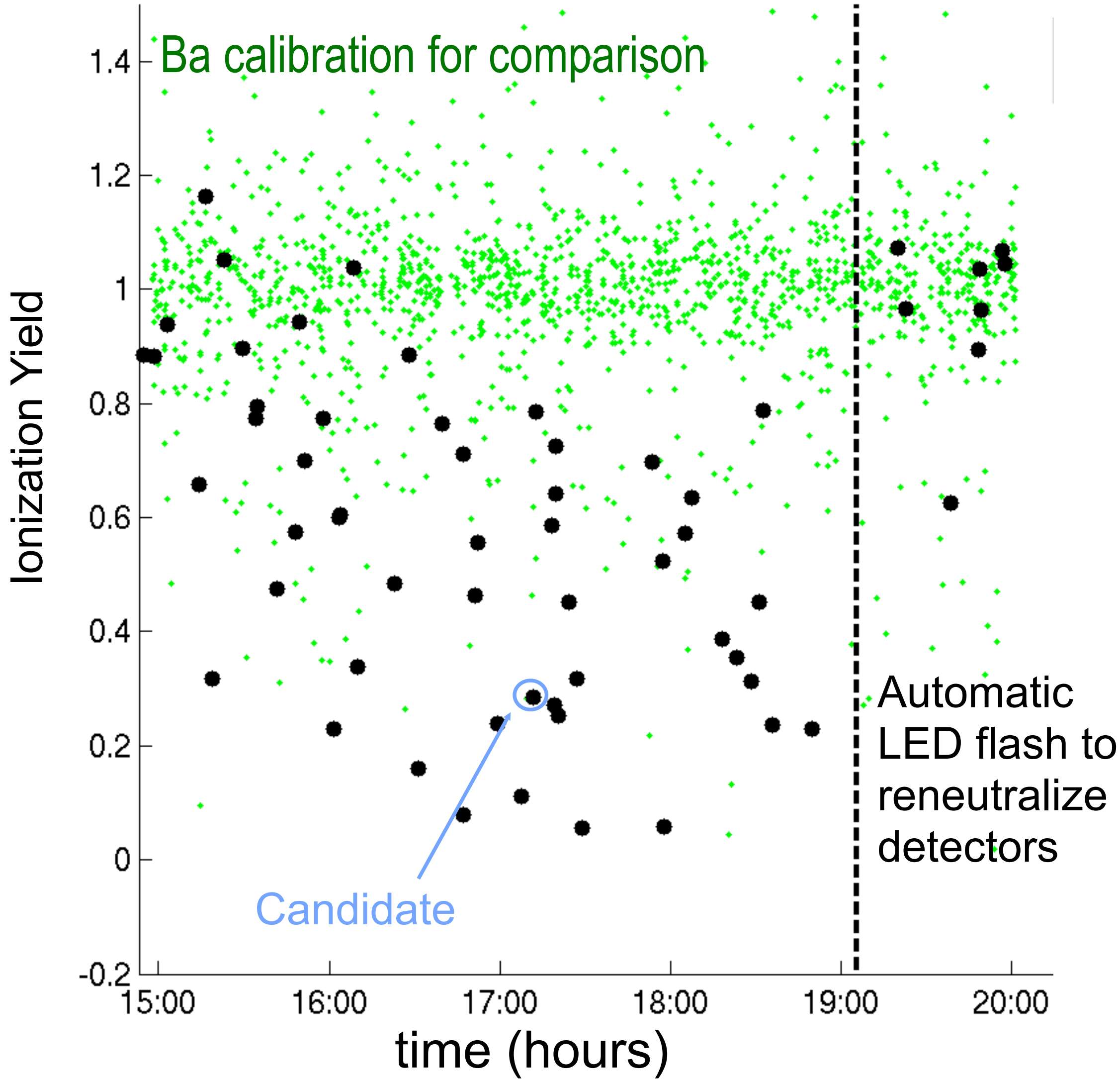
After timing cuts, which reject most electron recoils



Background ESTIMATE: 0.37 ± 0.20 (sys.) ± 0.15 (stat.) electron recoils, 0.05 recoils from neutrons expected

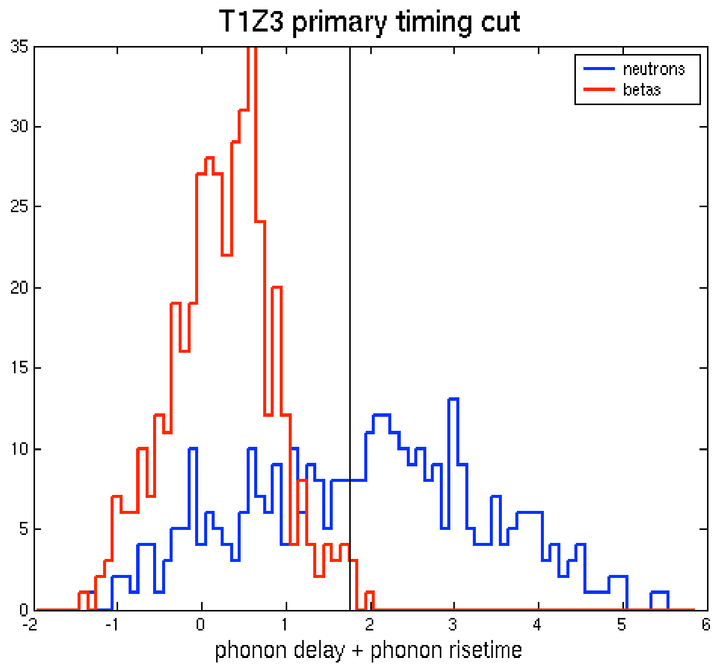
Is the Candidate Event Just Background?

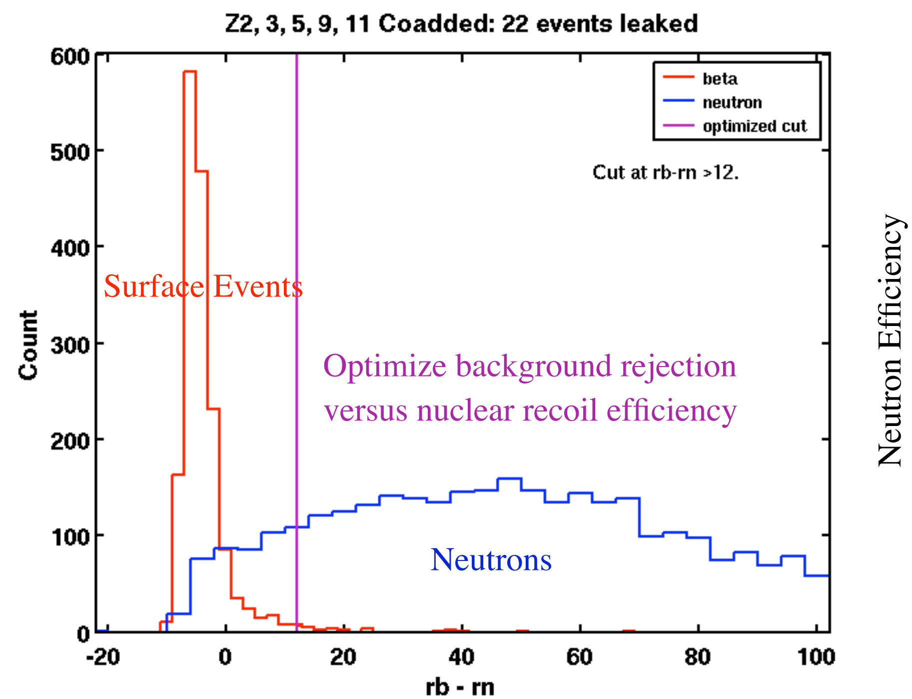
- Very likely so!
- Event occurred during run when its detector, Z11, suffered reduced ionization yield
  - Worst run for this detector
- In hindsight, our cuts on bad data periods for single detectors weren't strict enough
  - Some other detectors, without candidates, had similarly bad periods
- Will improve data quality screening for next run



Improvements in Surface Event Rejection

- Significant improvements in our analysis of phonon timing information
  - Surface event rejection improved by x3; kept pace with exposure increase!
  - Cuts are set from calibration data (blind analysis)
- We still have more discrimination power available as needed
  - Can continue to keep backgrounds < 1 event as more data accumulates
  - This is the real strength of CDMS detectors!

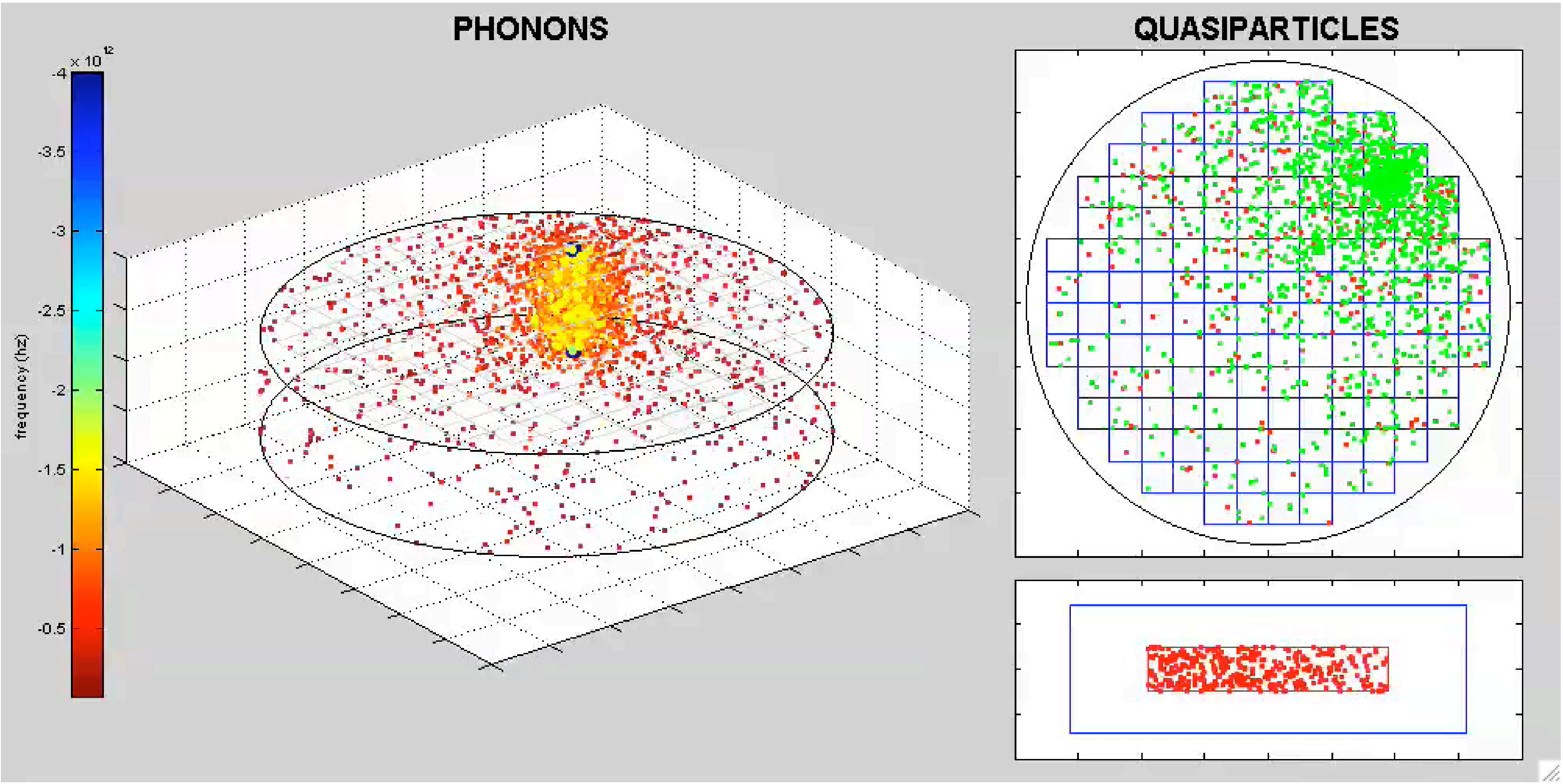




Chi-square (background pulse shape) - Chi-squared (neutron pulse shape)

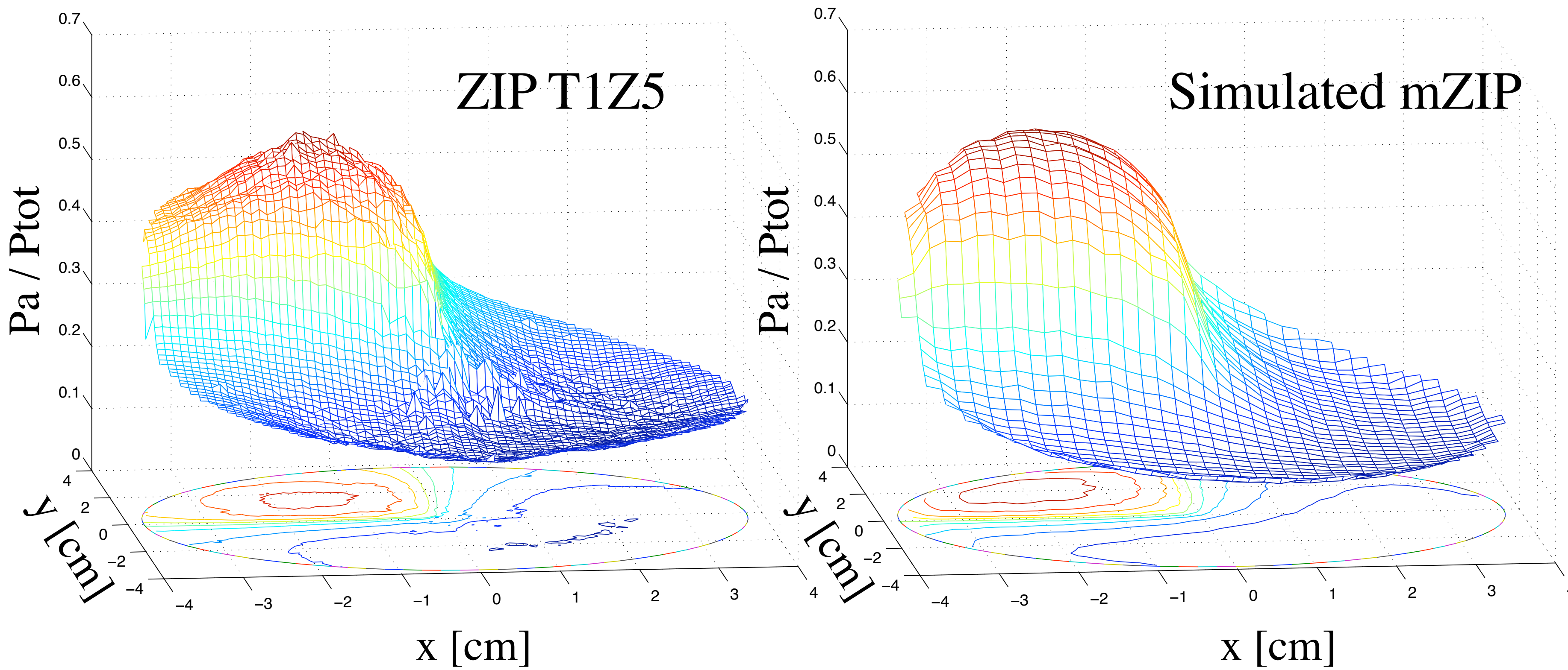
How the detectors work

- Measure both heat and ionization produced

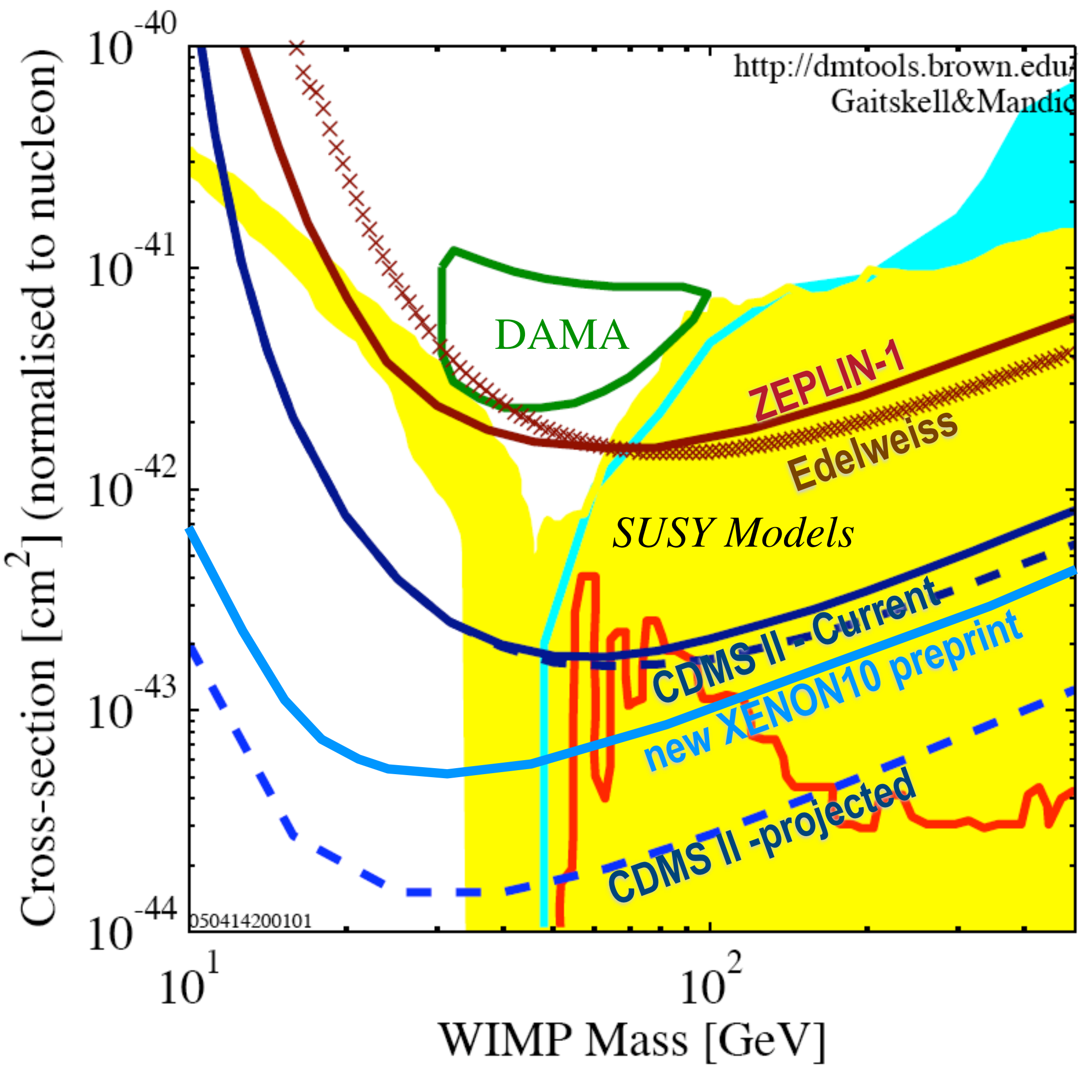


Develop detailed detector MC

- Compare signal collected in one quadrant versus x-y averaged over z for real ZIP T1Z5 (left) and simulated mZIP (right)

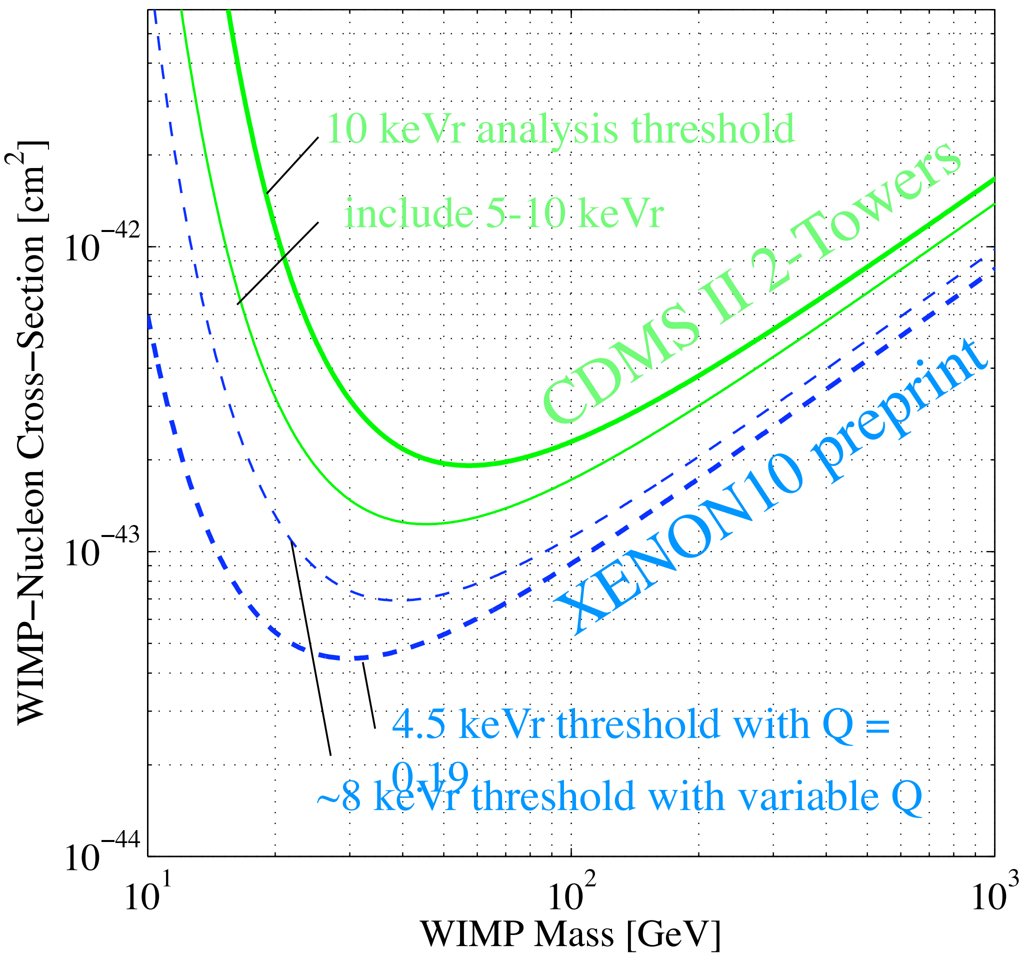


Scientific reach of CDMS at Soudan



Sensitivity issues for Ge and Xe

limits at low mass very sensitive to threshold effects

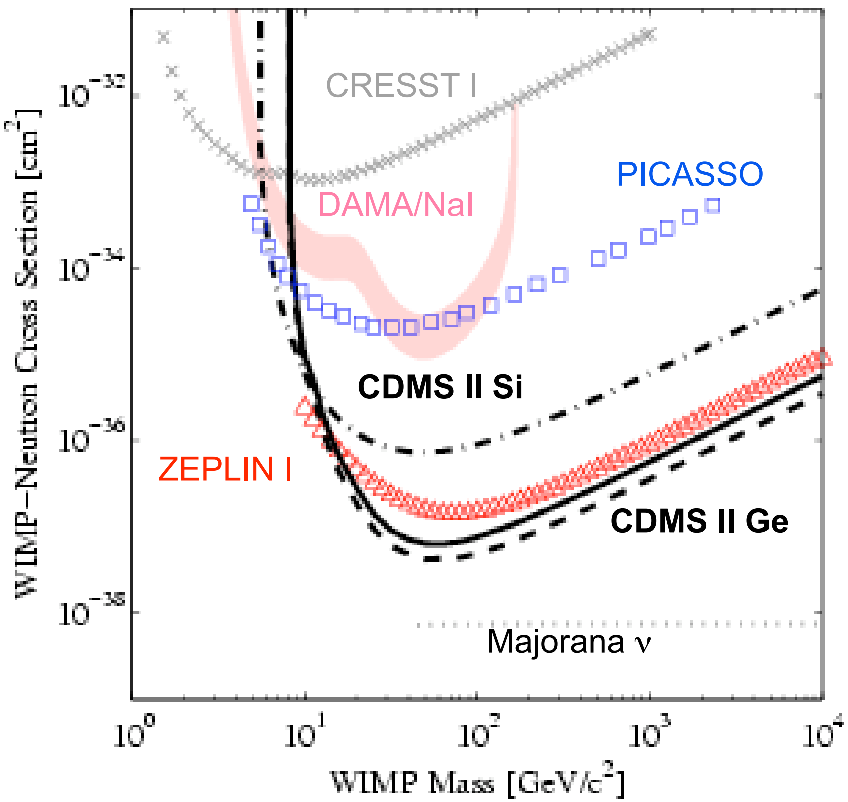


limits at high mass robust

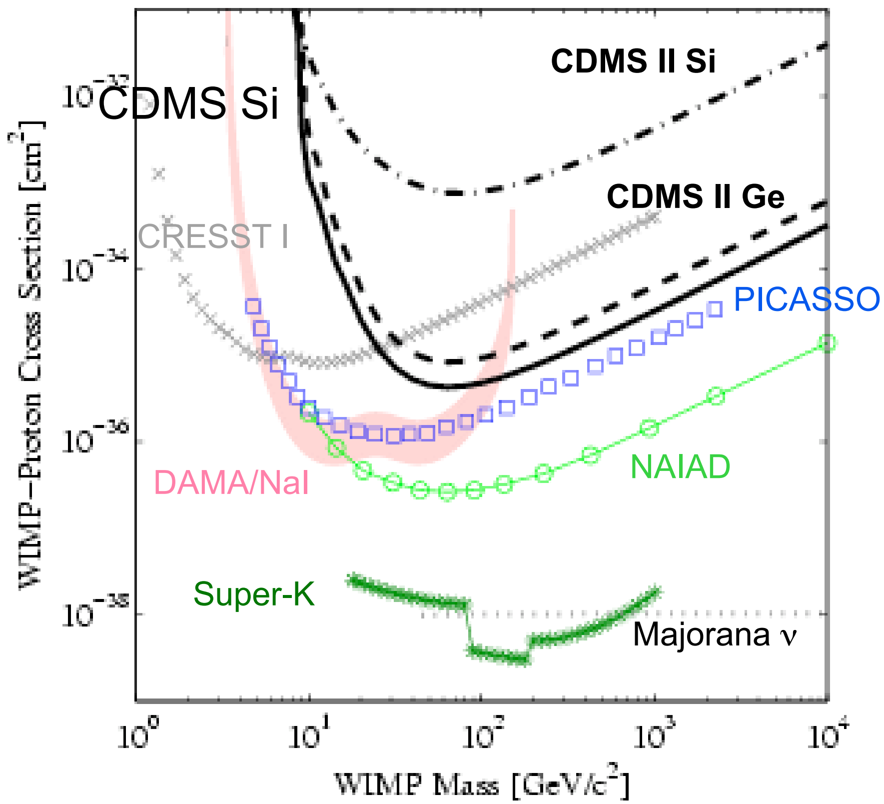
Spin Dependent WIMP limits

Spin-sensitivity from ^{73}**Ge** (J=9/2, 7.7%) and ^{29}**Si** (J=1/2, 4.7%)

"n" scattering

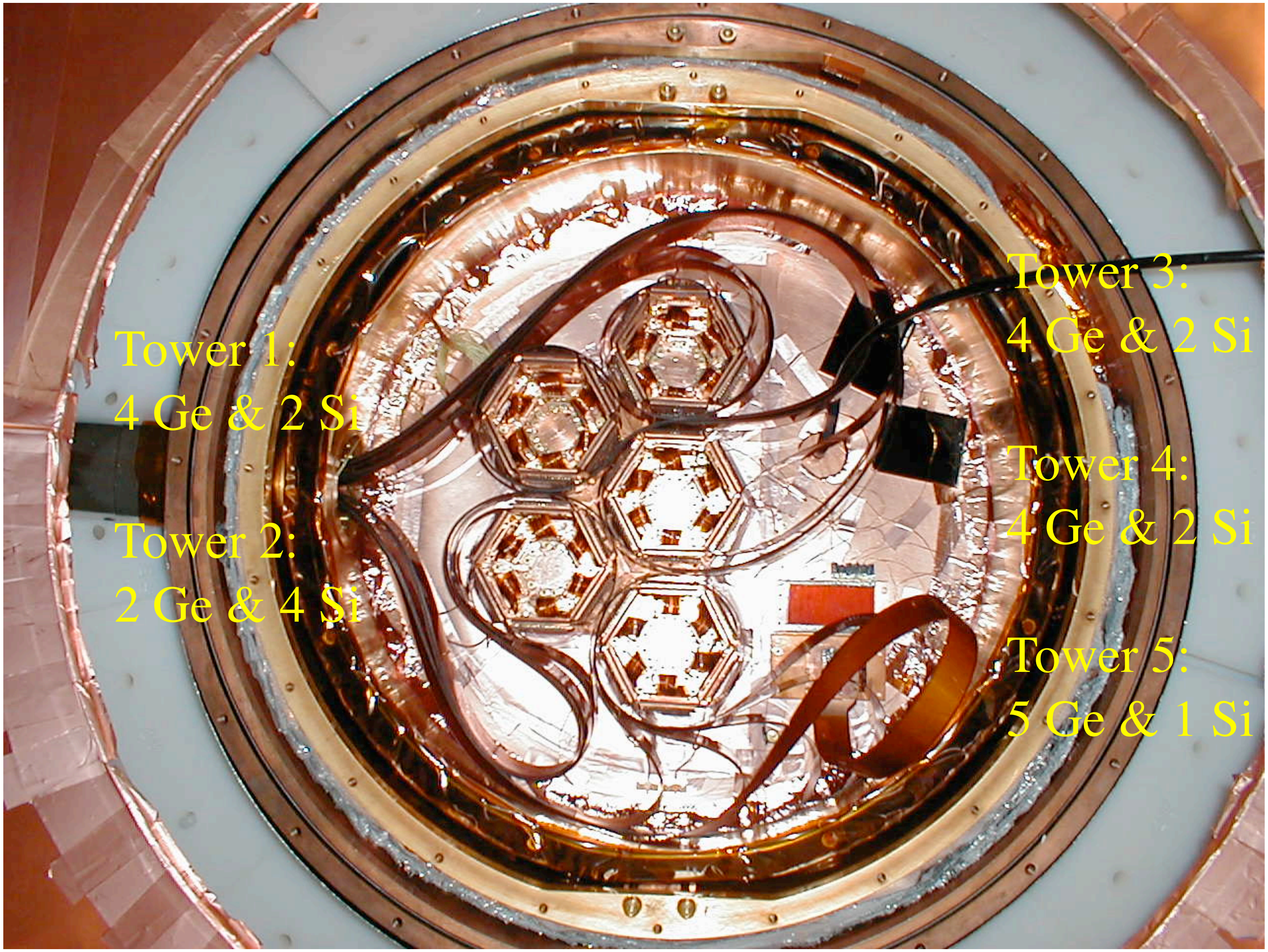


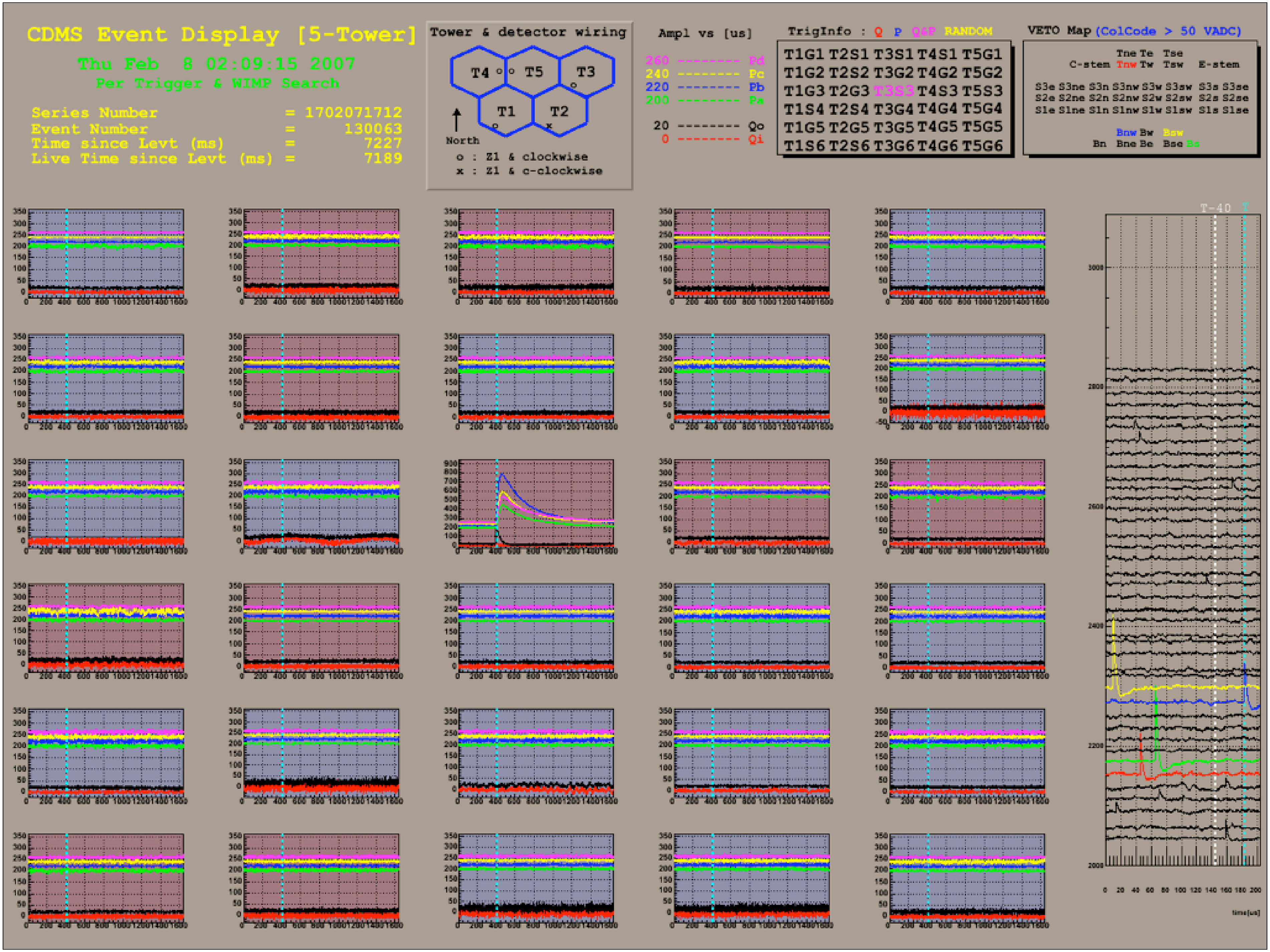
"p" scattering



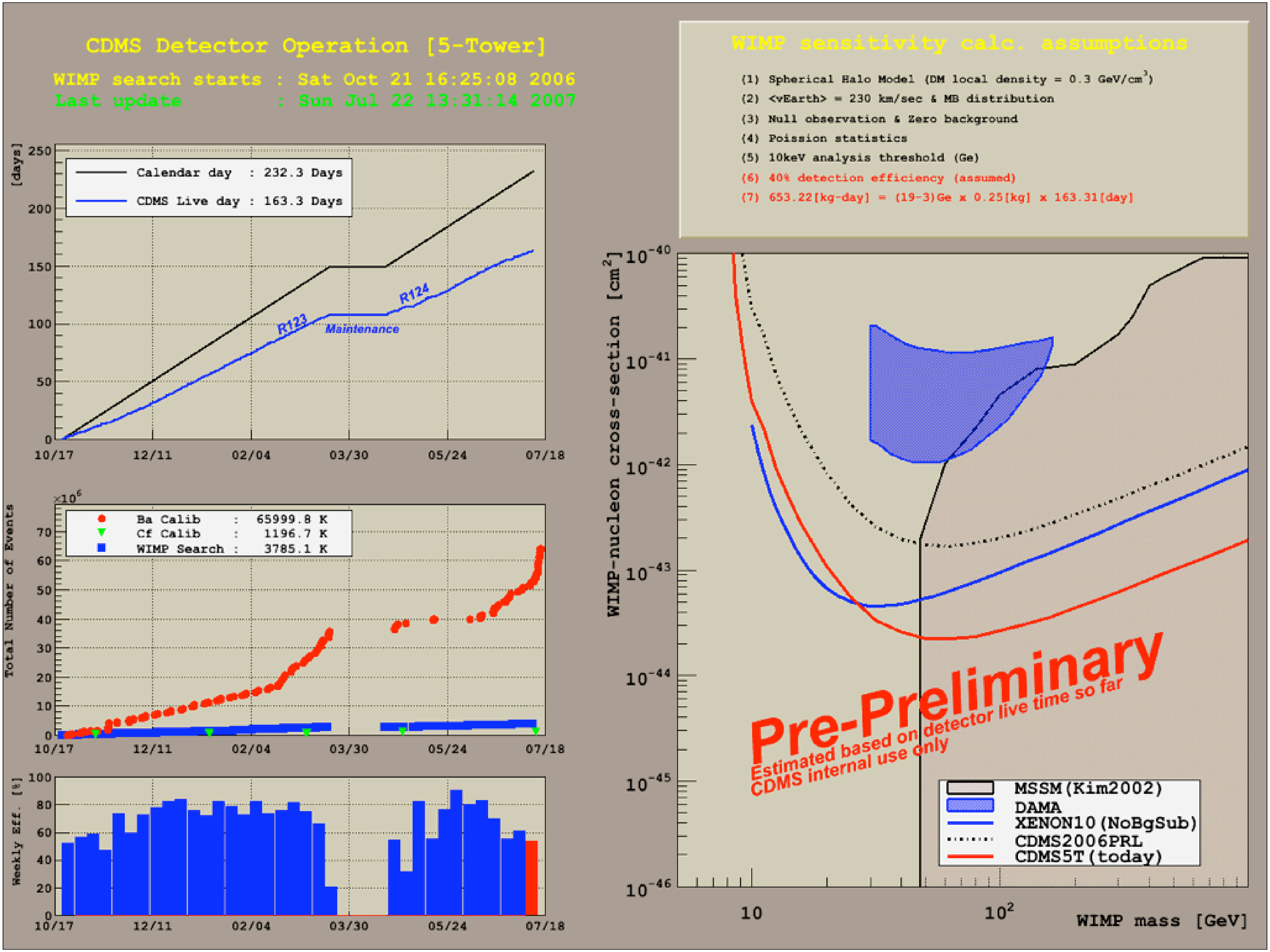
For further details see PRD D73, 011102 (2006)

Five Towers now in Soudan





CDMS Event Display [5-Tower]
Thu Feb 8 02:09:15 2007
Per Trigger & WIMP Search
Series Number = 1702071712
Event Number = 130063
Time since Levt (ms) = 7227
Live Time since Levt (ms) = 7189
Tower & detector wiring
T4 T5 T3
T1 T2
North
o : Z1 & clockwise
x : Z1 & c-clockwise
Ampl vs [us]
260 Pd
240 Pc
220 Pb
200 Pa
20 Qo
0 Qi
TrigInfo : Q P Q&P RANDOM
T1G1 T2S1 T3S1 T4S1 T5G1
T1G2 T2S2 T3G2 T4G2 T5G2
T1G3 T2G3 T3S3 T4S3 T5S3
T1S4 T2S4 T3G4 T4G4 T5G4
T1G5 T2G5 T3G5 T4G5 T5G5
T1S6 T2S6 T3G6 T4G6 T5G6
VETO Map (ColCode > 50 VADC)
Tne Te Tse
C-stem Tnw Tw Tsw E-stem
S3e S3ne S3n S3nw S3w S3sw S3s S3se
S2e S2ne S2n S2nw S2w S2sw S2s S2se
S1e S1ne S1n S1nw S1w S1sw S1s S1se
Bnw Bw Bsw
Bn Bne Be Bse Bs
T-40
time[us]



CDMS Detector Operation [5-Tower]
WIMP search starts : Sat Oct 21 16:25:08 2006
Last update : Sun Jul 22 13:31:14 2007
Calendar day : 232.3 Days
CDMS Live day : 163.3 Days
R123
R124
Maintenance
[days]
10/17 12/11 02/04 03/30 05/24 07/18
Ba Calib : 65999.8 K
Cf Calib : 1196.7 K
WIMP Search : 3785.1 K
Total Number of Events
Weekly Eff. [%]
WIMP sensitivity calc. assumptions
(1) Spherical Halo Model (DM local density = 0.3 GeV/cm^3)
(2) <vEarth> = 230 km/sec & MB distribution
(3) Null observation & Zero background
(4) Poission statistics
(5) 10keV analysis threshold (Ge)
(6) 40% detection efficiency (assumed)
(7) 653.22[kg-day] = (19-3)Ge x 0.25[kg] x 163.31[day]
WIMP-nucleon cross-section [cm^2]
WIMP mass [GeV]
Pre-Preliminary
Estimated based on detector live time so far
CDMS internal use only
MSSM(Kim2002)
DAMA
XENON10(NoBgSub)
CDMS2006PRL
CDMS5T(today)

Proposal to DOE and NSF - May 06

SuperCDMS 25 kg Experiment

The SuperCDMS Collaboration

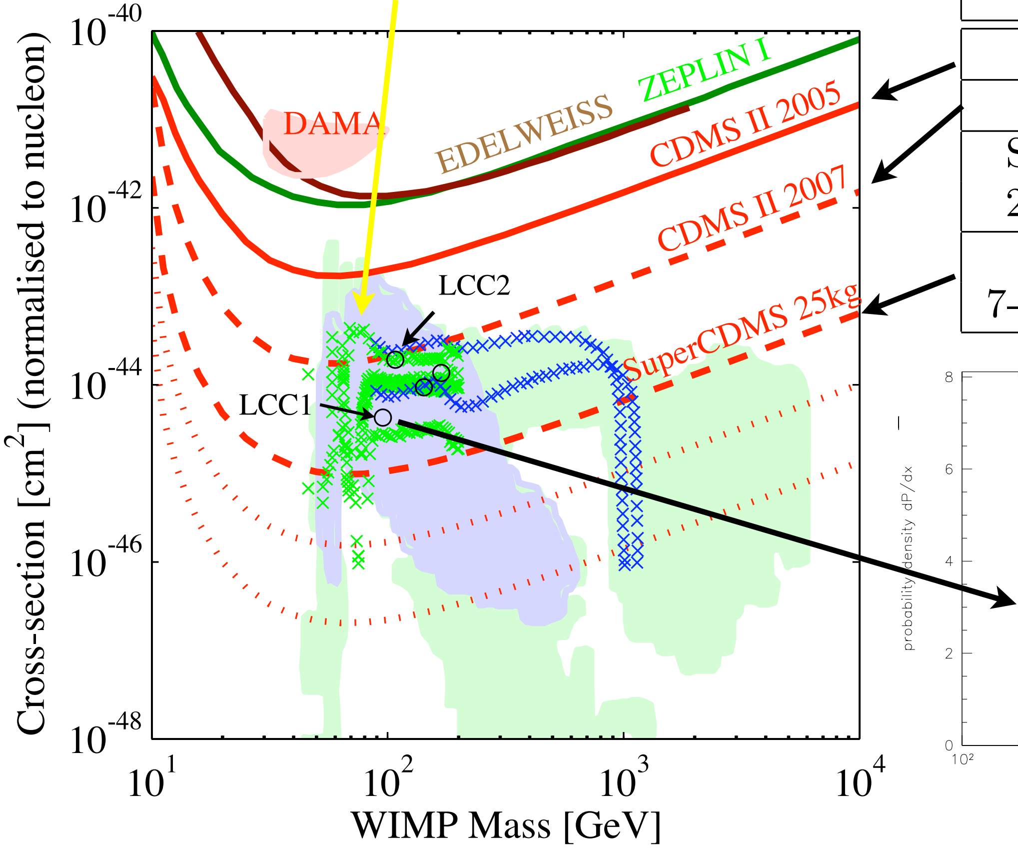
California Institute of Technology
Case Western Reserve University
Fermi National Accelerator Laboratory
Lawrence Berkeley National Laboratory
National Institute of Standards and Technology, Boulder
Queen's University, Canada
Santa Clara University
Stanford University
University of California at Berkeley
University of California at Santa Barbara
University of Colorado at Denver and Health Sciences Center
University of Florida
University of Minnesota

- Spokesperson: Blas Cabrera
  Co-spokesperon: Dan Akerib
  Project Manager: Dan Bauer
  Chair of Board: Bernard Sadoulet

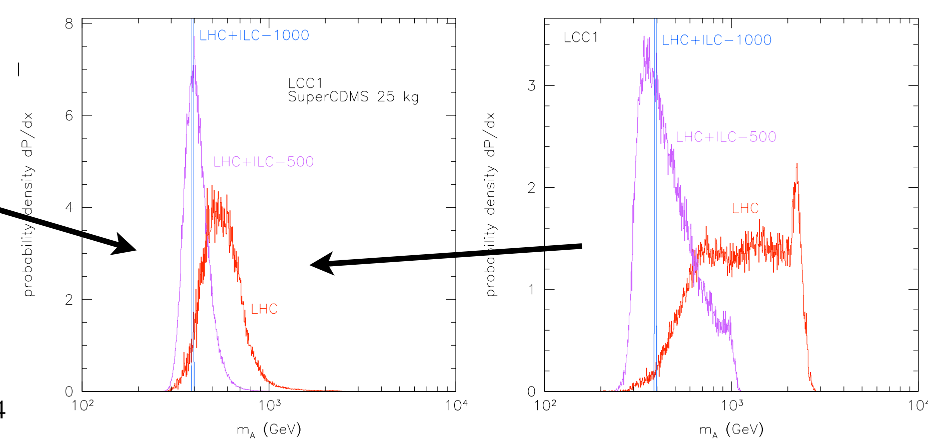
Scientific reach of SuperCDMS 25 kg

- Explore very interesting region which is complementary to LHC

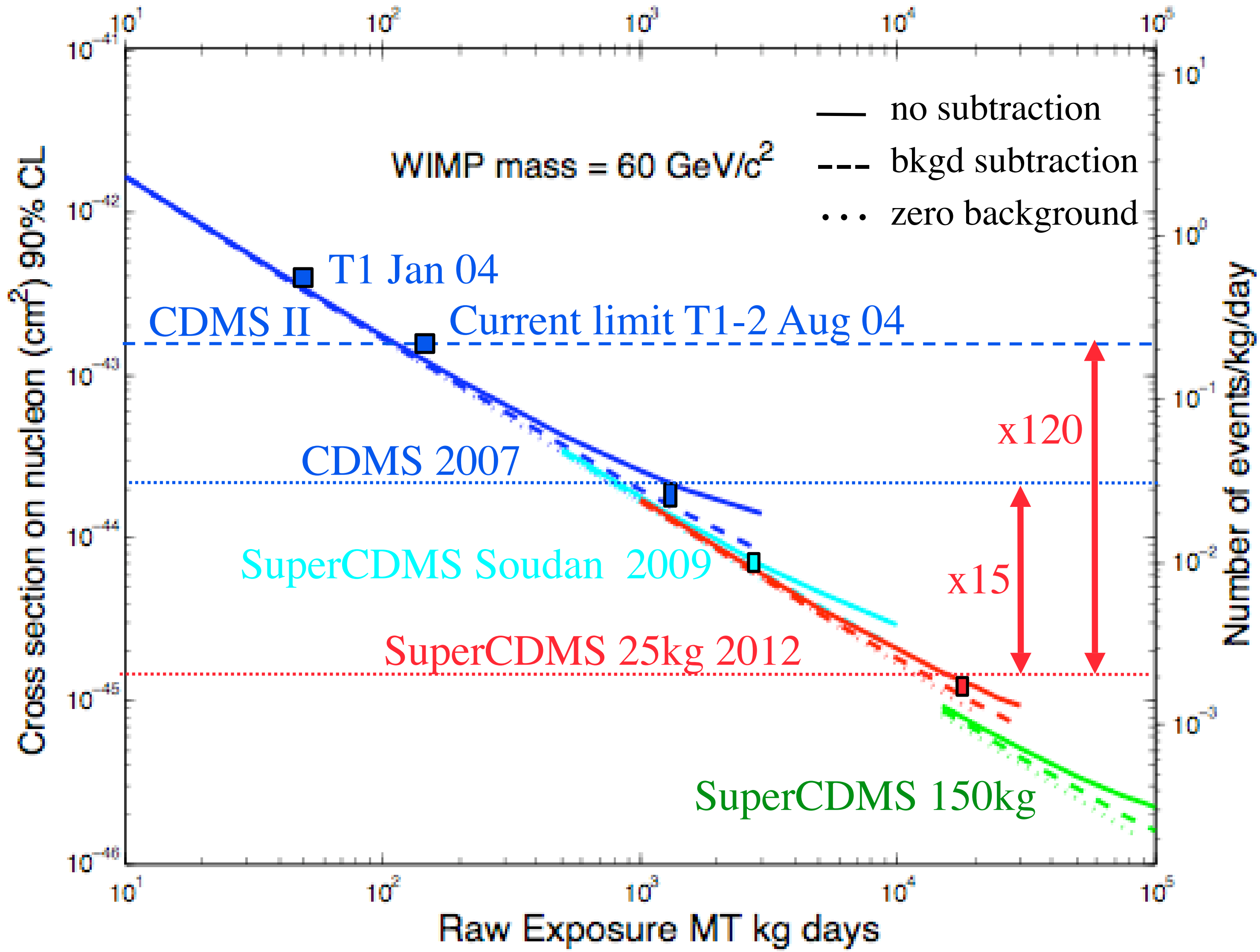
high discovery potential now including 5 events for LCC2



Experiment	Cross-section sensitivity
CDMS II 2-T (2005)	1.6×10^{-43} cm^2
CDMS II 5-T (2007)	2.1×10^{-44} cm^2
SuperCDMS Detectors 2-ST at Soudan (2009)	7.2×10^{-45} cm^2
SuperCDMS 25 kg 7-ST at SNOLAB (2012)	1.3×10^{-45} cm^2

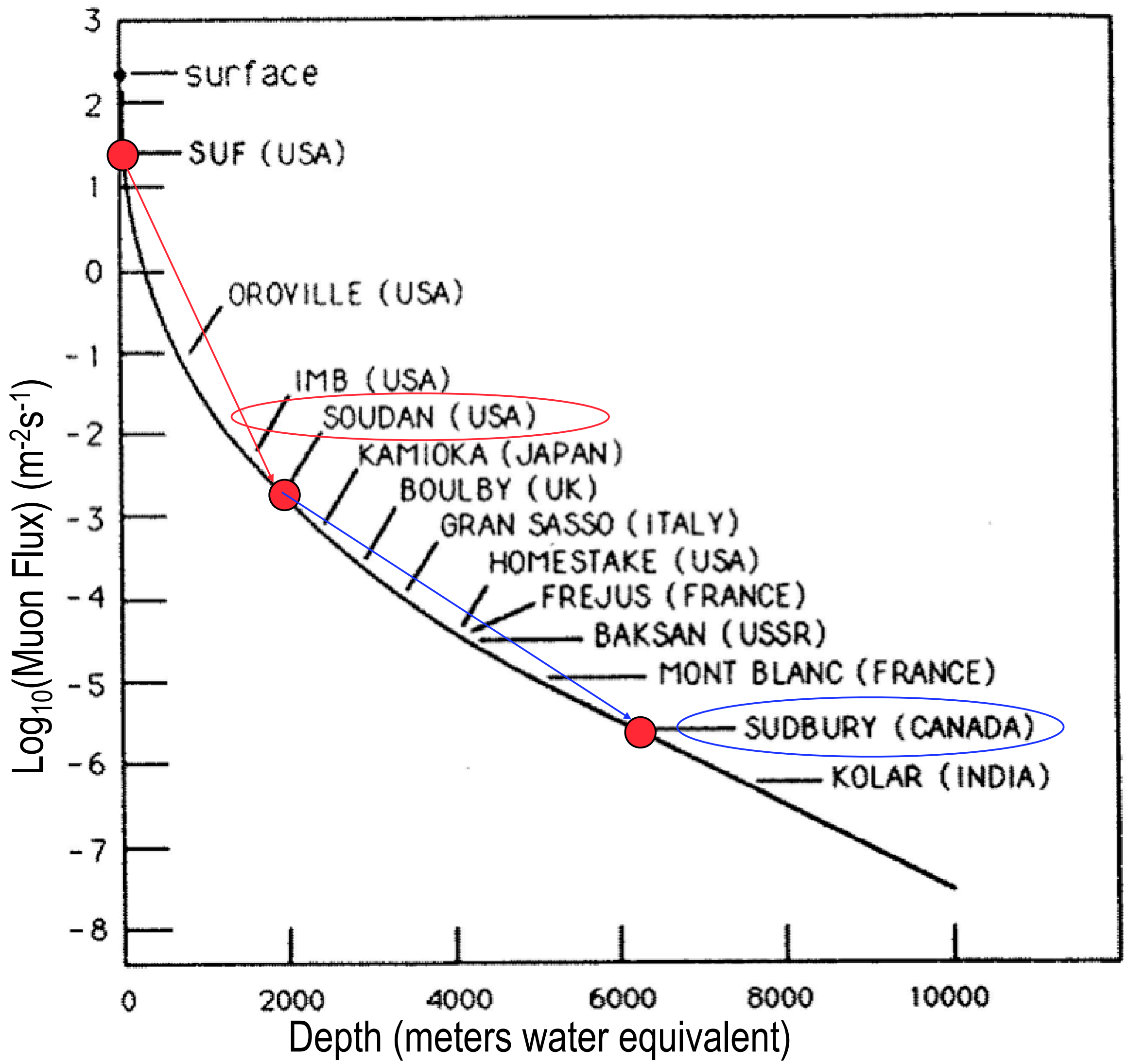


Sensitivity reach with full bkgd analysis



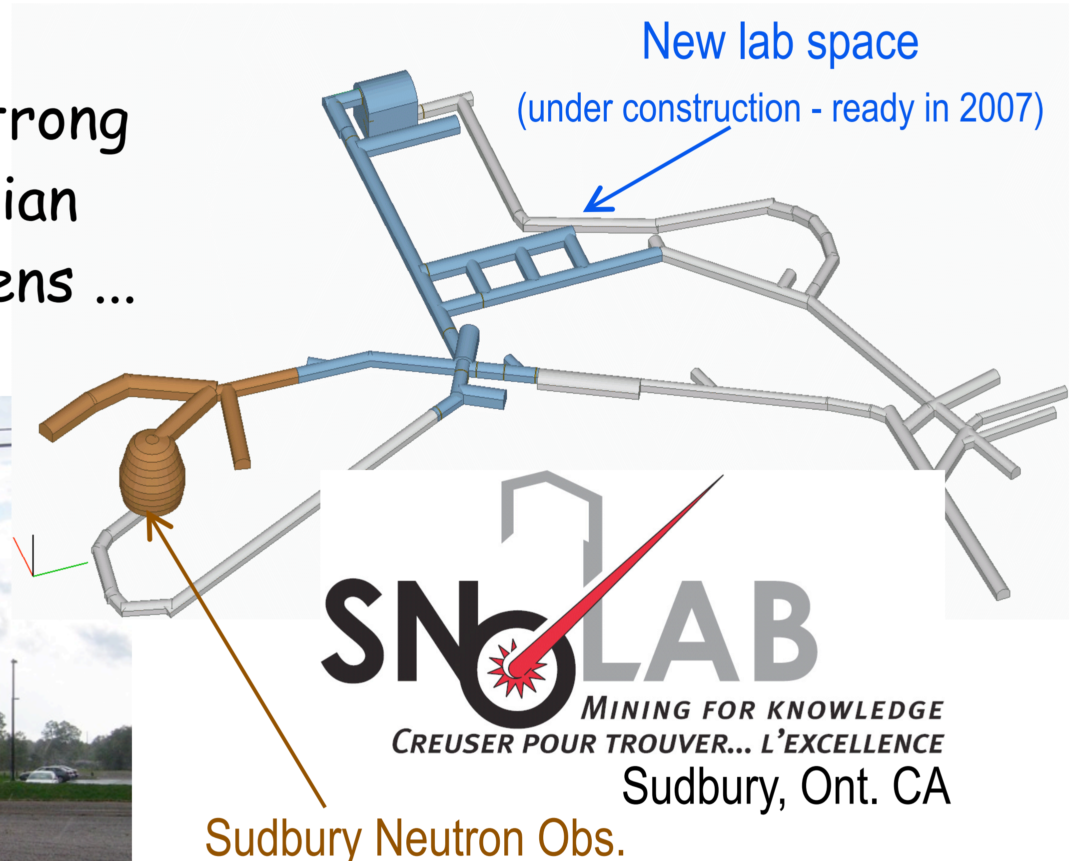
SUF (17 mwe), Soudan (2090 mwe), & SNOLab (6060 mwe)

- At SUF
  - 17 mwe
  - 0.5 n/d/kg
- At Soudan
  - 2090 mwe
  - 0.6 n/y/kg
- At SNOLab
  - 6060 mwe
  - 1 n/y/ton

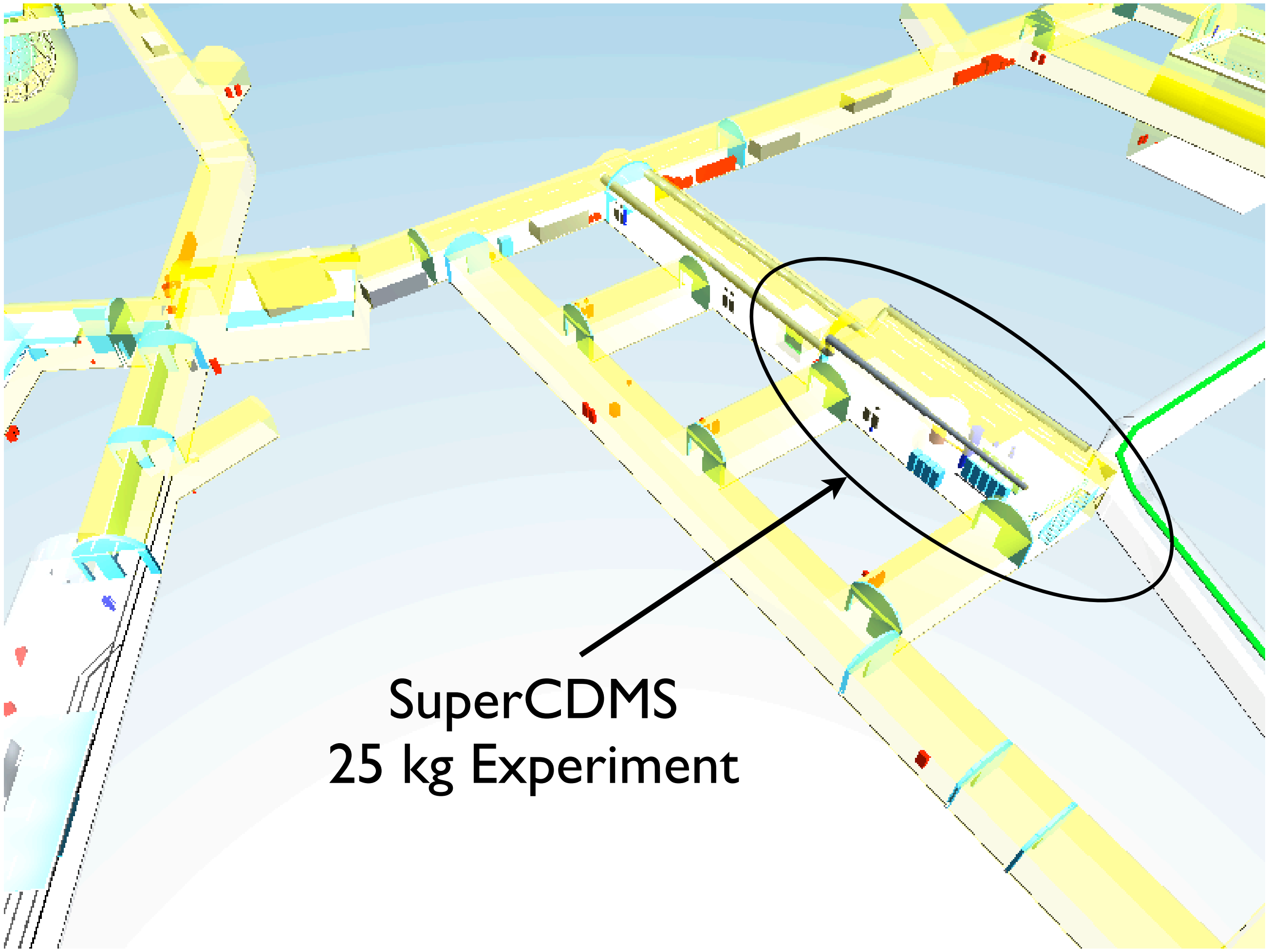


SuperCDMS at SNOLab

- ★ SuperCDMS is approved to be sited at SNOLab
  - ★ We have received strong interest from Canadian collaborators - Queens ...

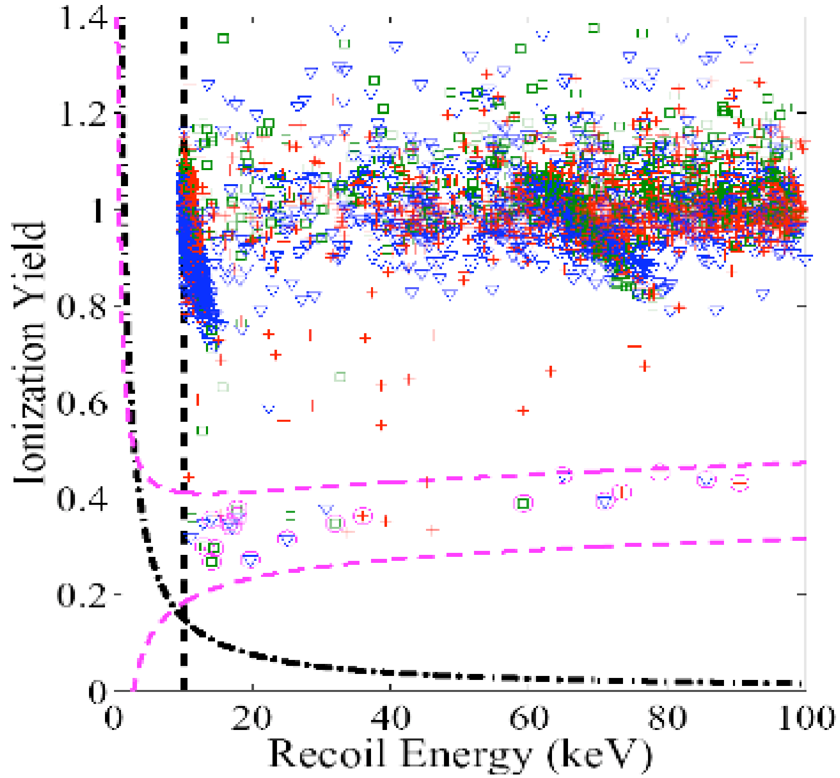


SuperCDMS in Expanded Ladder Lab

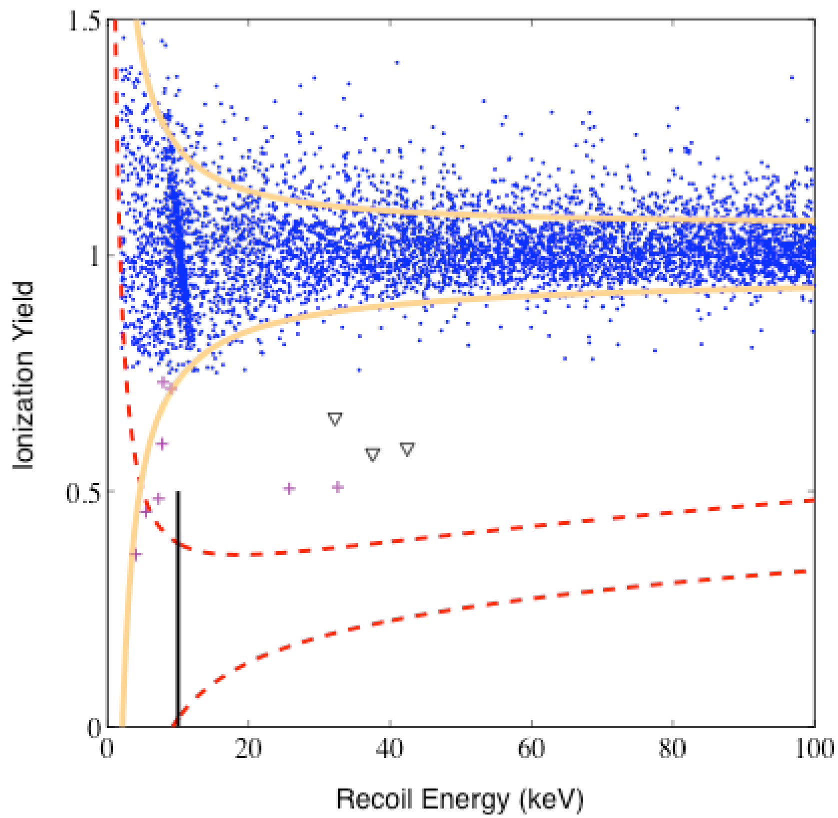


ST1&2 Soudan -> SNOLab like Tower 1 SUF -> Soudan

- Tower 1 (4 Ge & 2 Si) at SUF (Stanford) then at Soudan



19 neutron events at SUF



0 events at Soudan

Baseline detector for SuperCDMS

CDMS-II ZIPs:

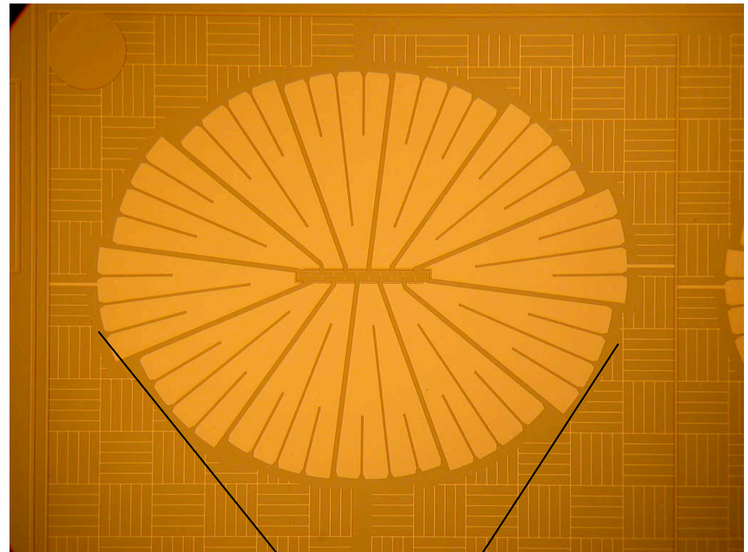
3" dia x 1 cm => 0.25 kg of Ge

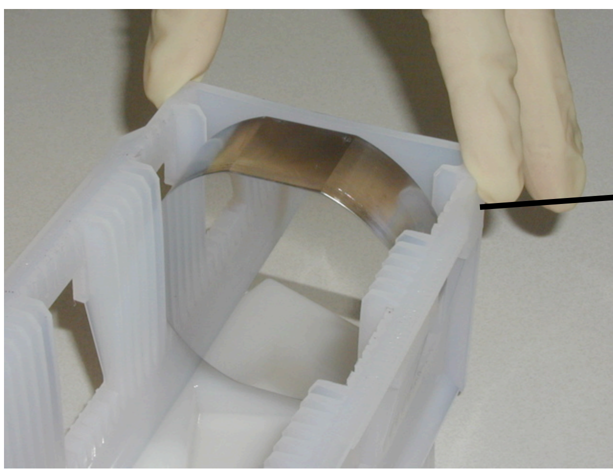
Existing ZIPs

SuperCDMS ZIPs:

3" dia x 1" => 0.64 kg of Ge

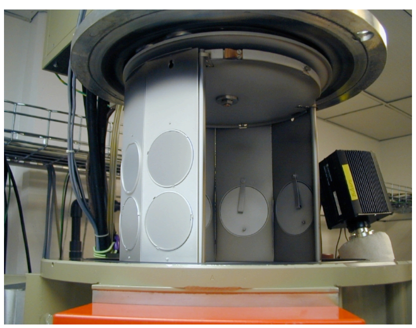
ZIPs for SuperCDMS

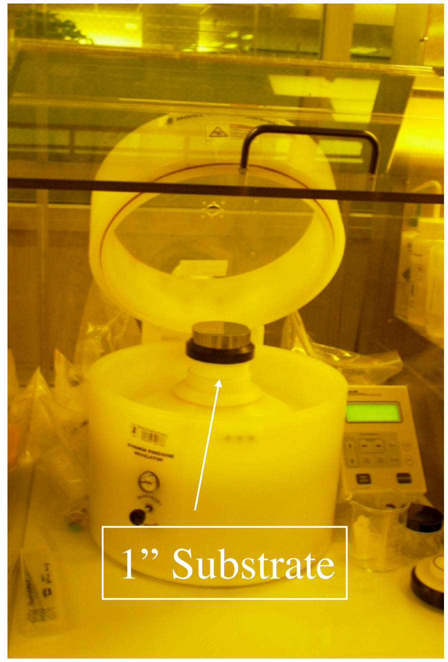




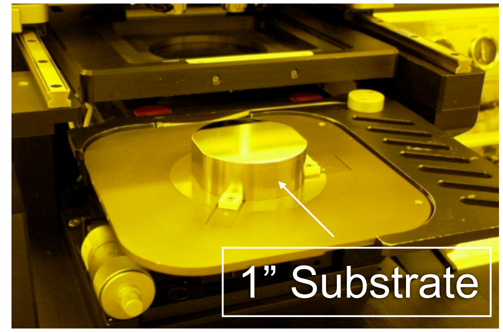
1" thick ZIP processing at Stanford

dedicated sputtering system (in use)





spinner (in use)

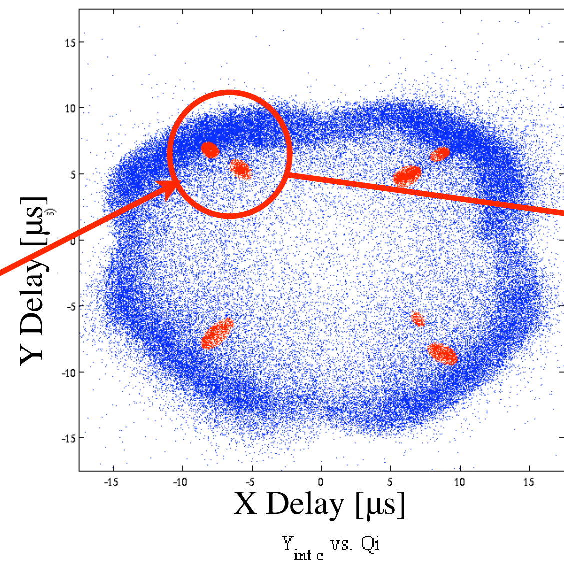


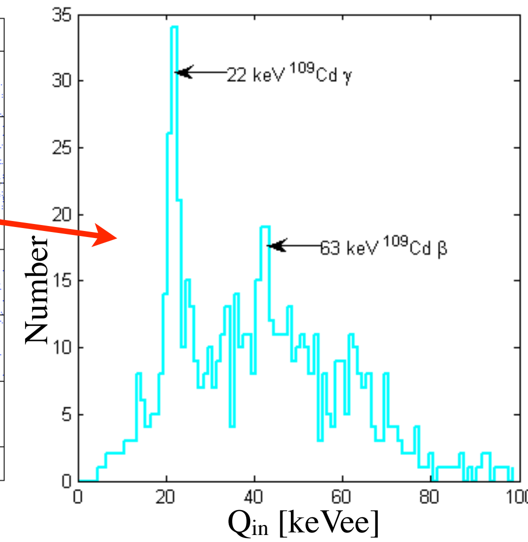
aligner (in use) - plan new dedicated unit

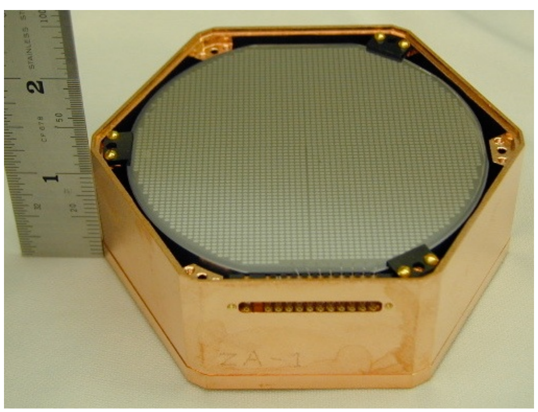
dry etch (in use)

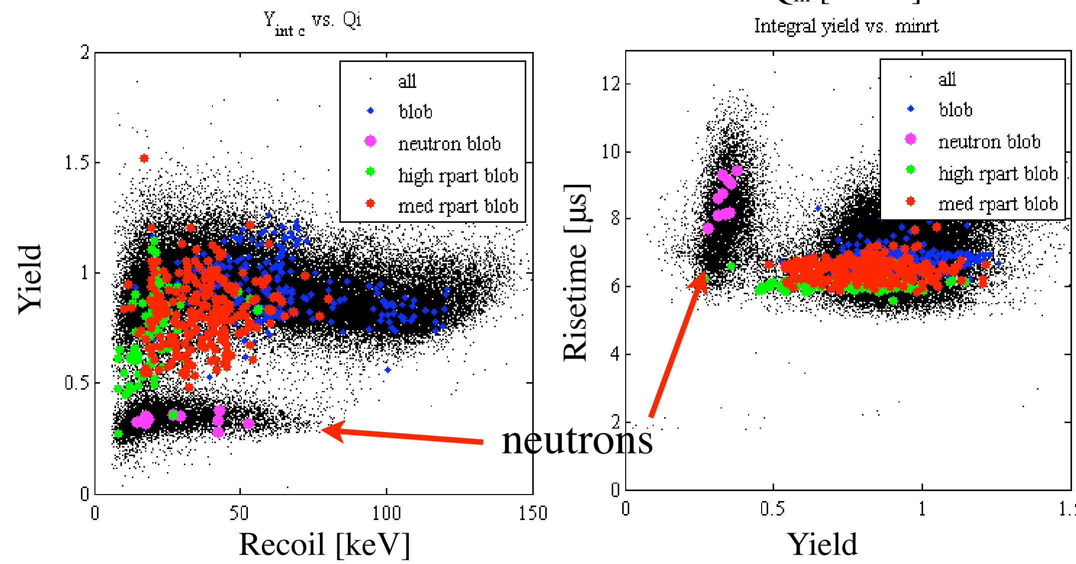
Data from UCB/Case TFs for Si 1" ZIP

- First data from 1" Si ZIP showing reconstructed location of ^{109}Cd events and spectrum



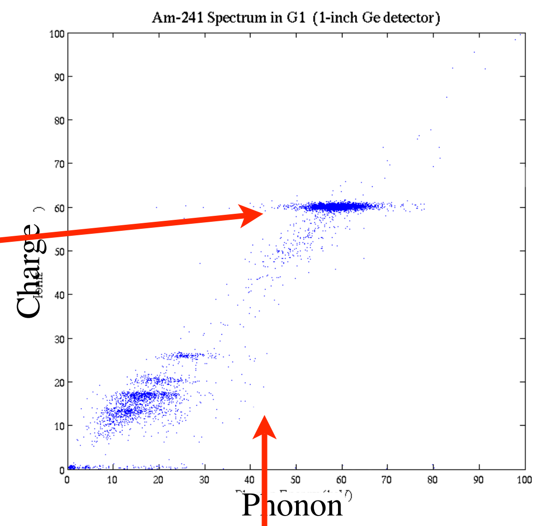


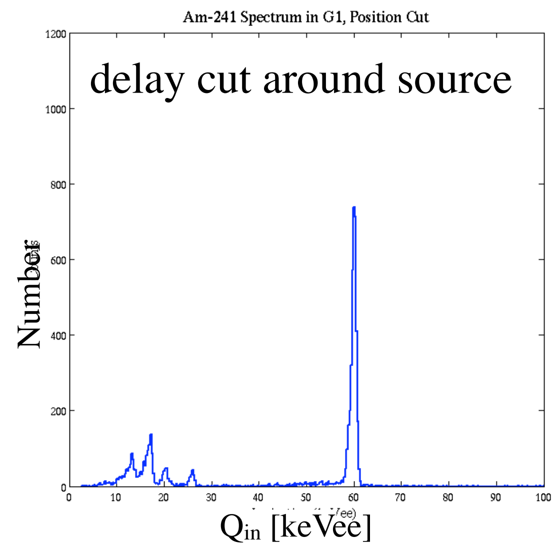


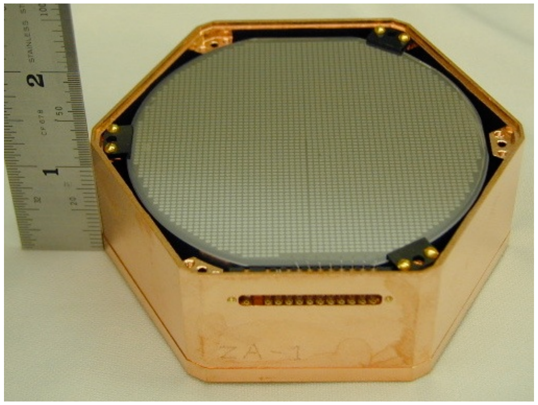


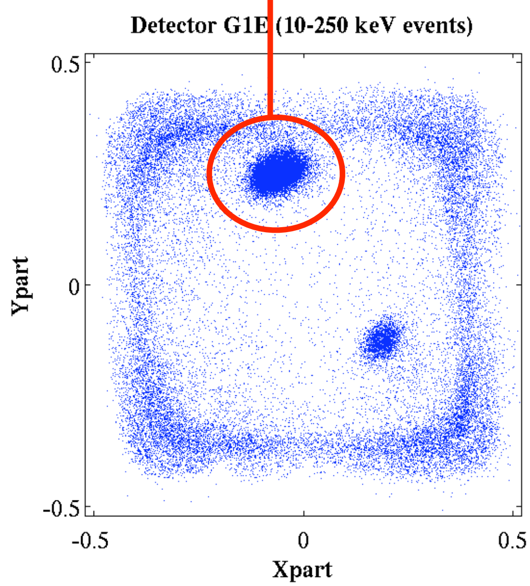
Data from UCB/Case TFs for Ge 1" ZIP

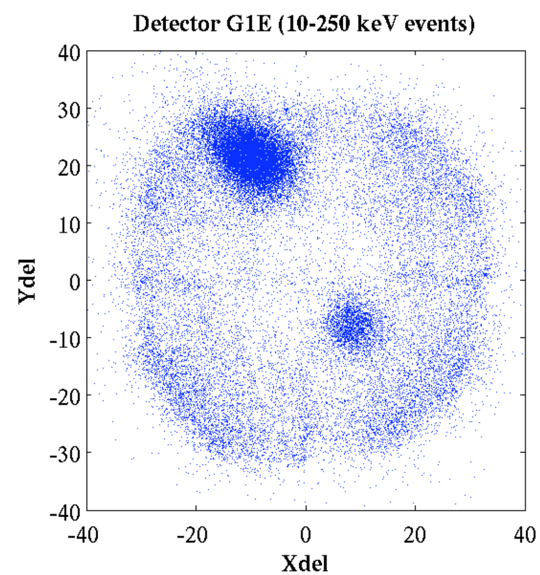
- First data from 1" Ge ZIP showing ^{241}Am 60 keV gamma events in phonon vs charge







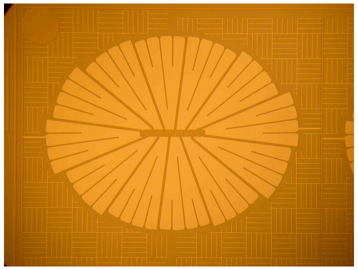




Improved background rejection and reduction

Background rejection	$\times 4$
Analysis discrimination	$\times 2$
Background reduction	$\times 5$
Total Improvement	$= \times \mathbf{40}$
Production rate per kg	$\times 5$

Table 2: Targeted improvement factors over CDMS II advanced analysis levels (see Section 3.2) to achieve SuperCDMS 25 kg sensitivities with zero background from internal sources. The cosmogenic fast-neutron background is eliminated by the SNO-LAB overburden of 6000 mwe.



Increase phonon collection area x2 and new H-a-Si electrodes suppress charge back-diffusion x2

Expect at least an additional x2 from advanced timing analyses

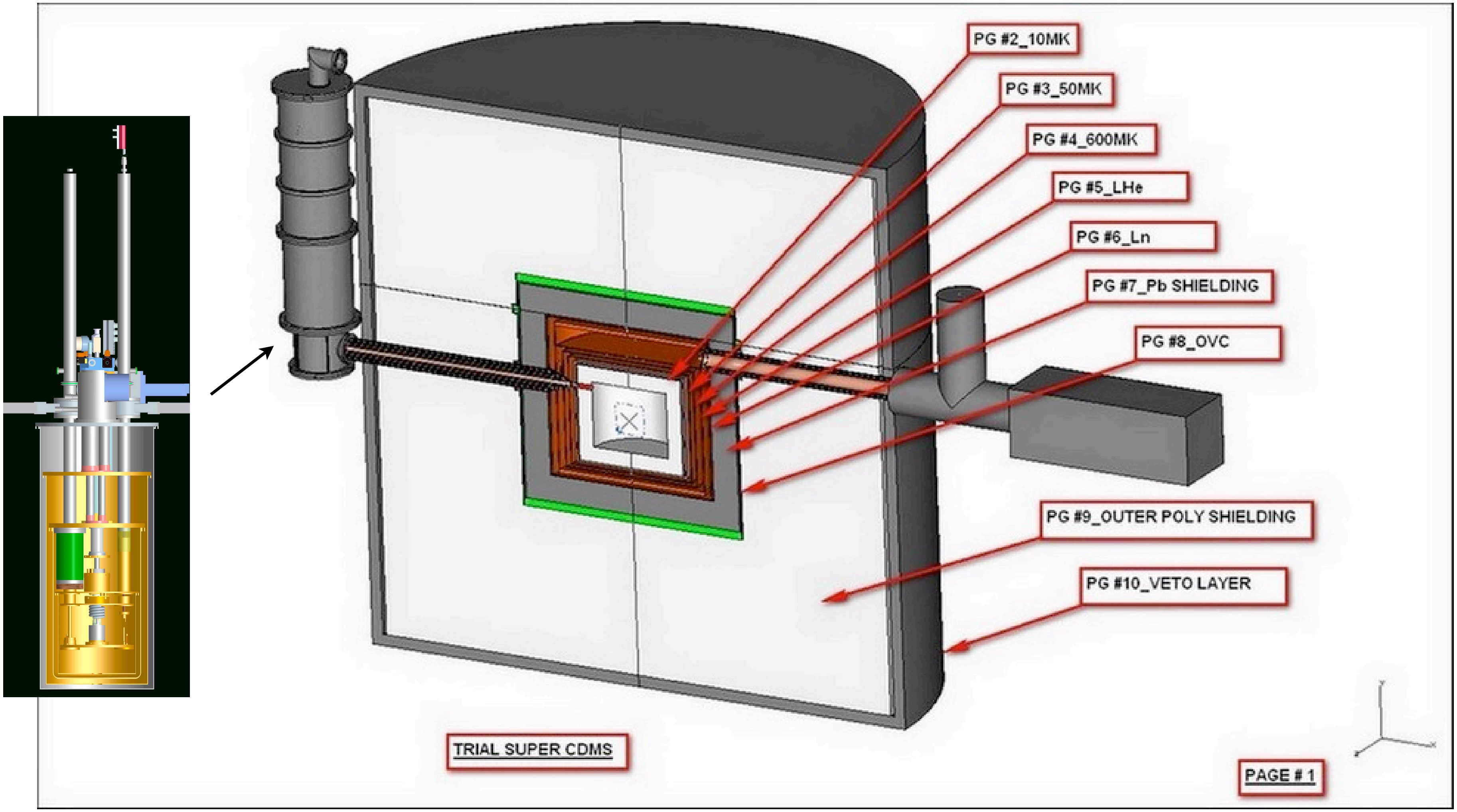
Expect x2.5 from additional thickness and x2 from better control of Rn

Need x20 of this x40 total for the SuperCDMS 25 kg target background

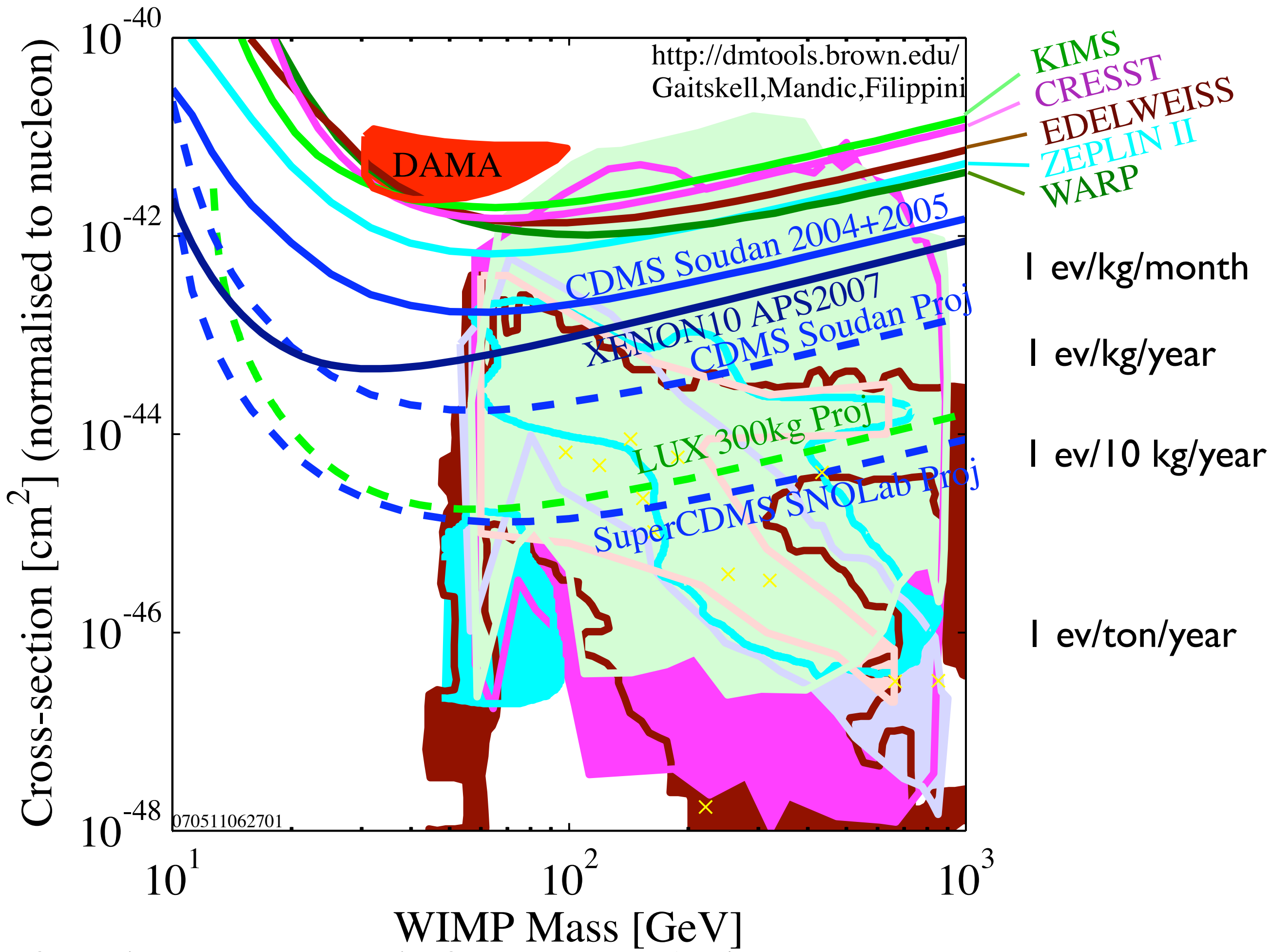
Expect x2.5 from additional thickness and x2 from improved fabrication efficiency

- to meet SuperCDMS 25 kg goals only need x20 actual

Schematic of new 'SNObox'



Status of Direction Detection Search



- Variety of techniques search for WIMP dark matter - interesting sensitivity
- Several have the potential to reach 10^{-44} cm^2 soon and 10^{-46} cm^2 in future

Conclusion

- Soudan Towers 1&2 lead field by x10 - spin-independent limits PRL 2006 and spin dependent limits PRD RC 2006.
- XENON10 preprint now leads field by x2 at high mass
- Soudan Towers 1-5 will start mid-2006 and run through 2007 for an additional x10 improved sensitivity.
- We have a great horse race for discovering WIMPs
- Strong science case for ton scale direct detection major projects, as endorsed by Dark Matter SAG and P5.
- WE ARE APPROVED TO PROCEED WITH 2 OF 7 TOWERS FOR SuperCDMS 25 kg EXPERIMENT, AND REVIEWS DURING FY08 FOR APPROVAL OF REMAING 5 TOWERS. WE CAN HELP MAINTAIN US LEAD IN THIS RESEARCH WHICH IS COMPLEMENTARY TO LHC AND FUTURE ILC.