Results from the Final Runs of the CDMSII Experiment

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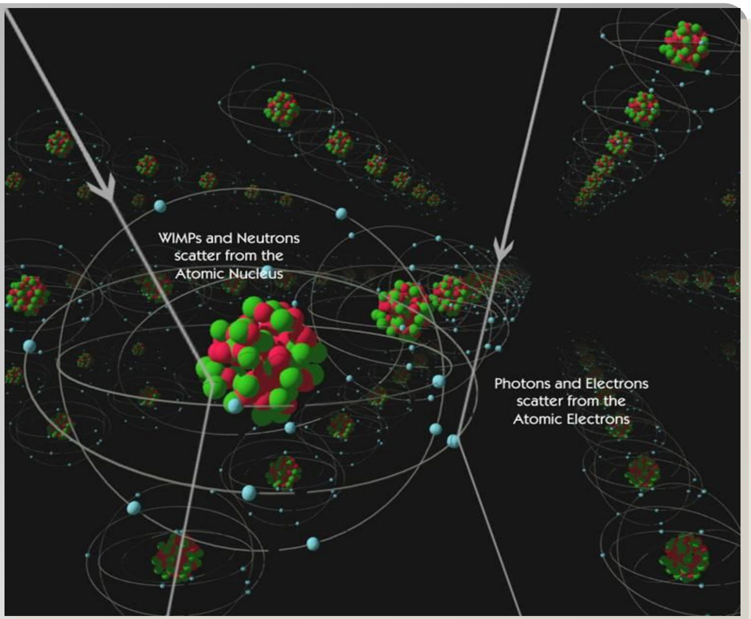
7/23/2010 ICHEP 2010

Terrestrial dark matter detection

Detect energy deposited from WIMP-nucleus scattering

Discriminate between nuclear and electron recoils



CDMS: Z-sensitive Ionization and Phonon detectors

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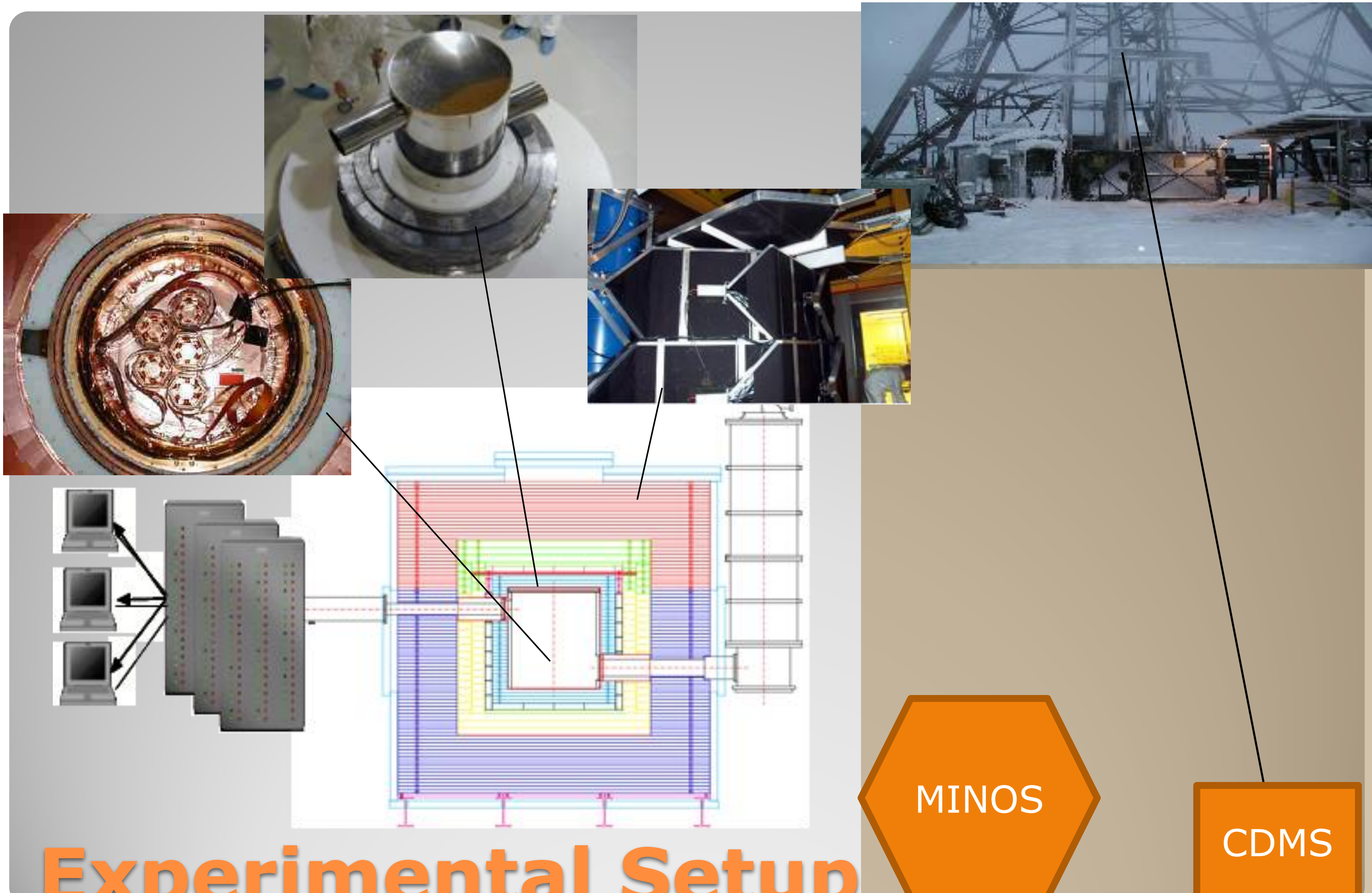
About 50 people from 15 institutions in the US, Canada, and Switzerland.

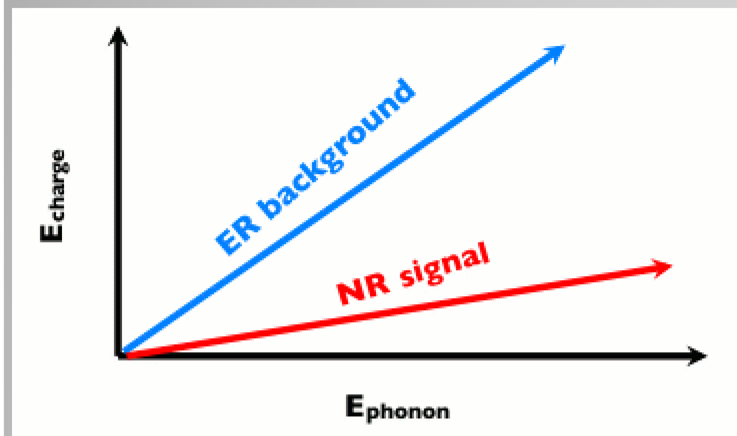
Experimental Setup



WIMP detection and background rejection

Phonon sensors

Charge sensors

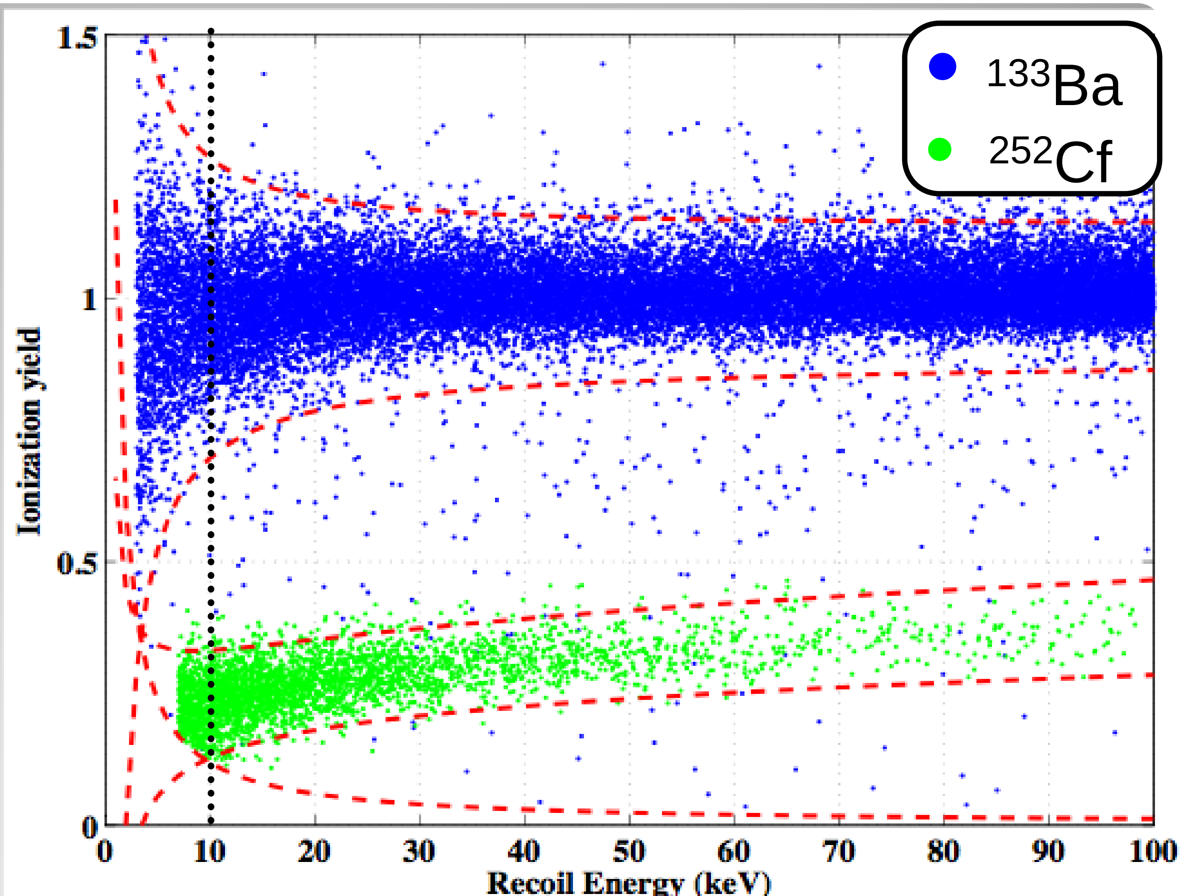


Yield = E_{charge}/E_{phonon}

- Separate readout of phonon and charge channels
- Nuclear recoil interactions (like WIMPs) deposit most of their energy as phonons
- Electromagnetic recoils have higher charge signal

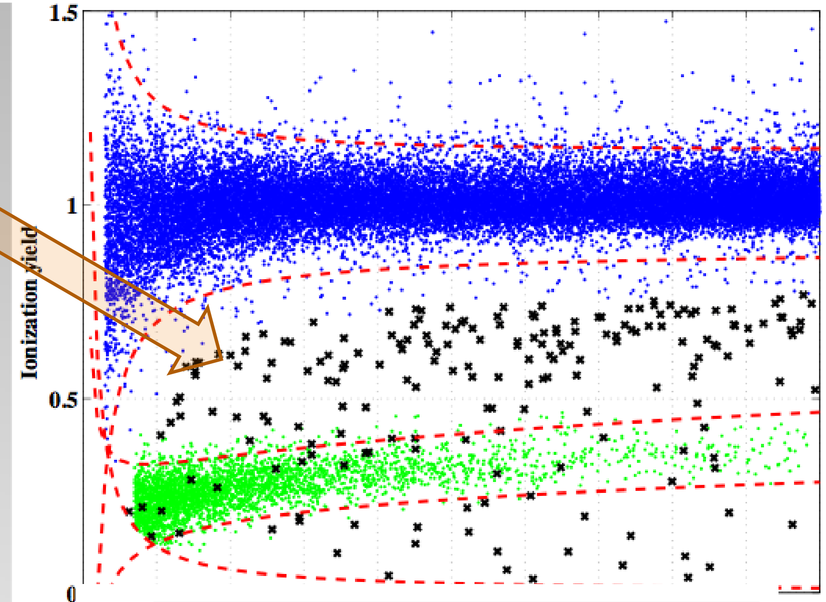
Yield based rejection

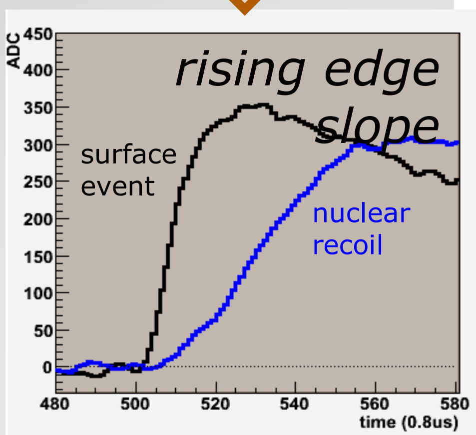
Better than 1:10000 rejection based on ionization yield

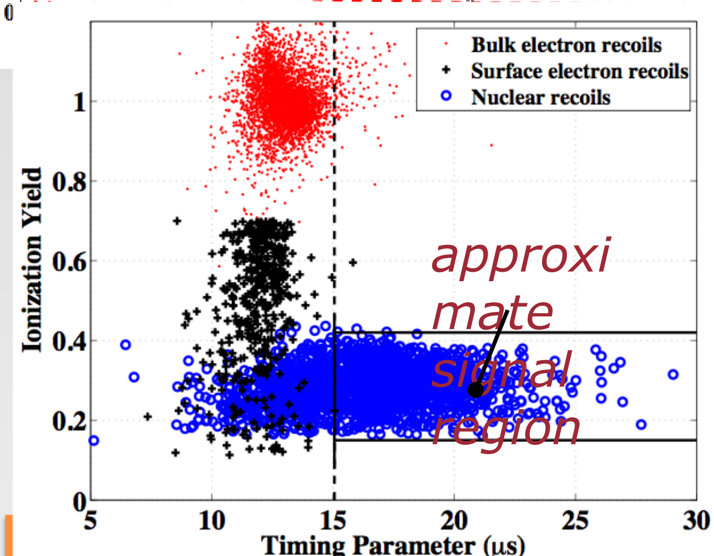


Yield = E_{charge}/E_{phonon}

- Events near surface can have reduced charge collection
- Discrimination handle is timing of phonon pulses







Surface Backgrou

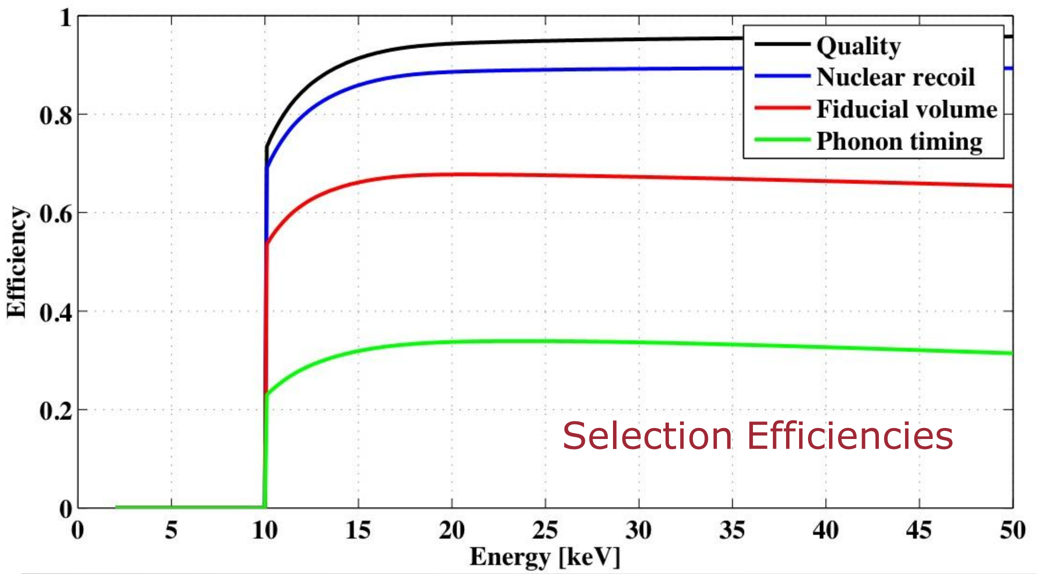
- Analysis of data runs beginning July 2007 and ending September 2008

- New data pipeline: Complete revamp of reconstruction software, migrated processing to ROOT. Processed 8TB of data in 1 month, much faster than before!

- Analysis tuned to keep expected background at <1 event

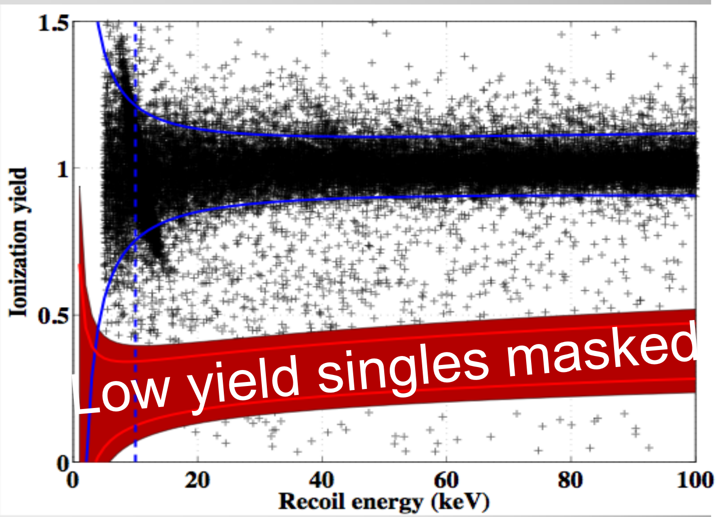
Recent Published Analysis

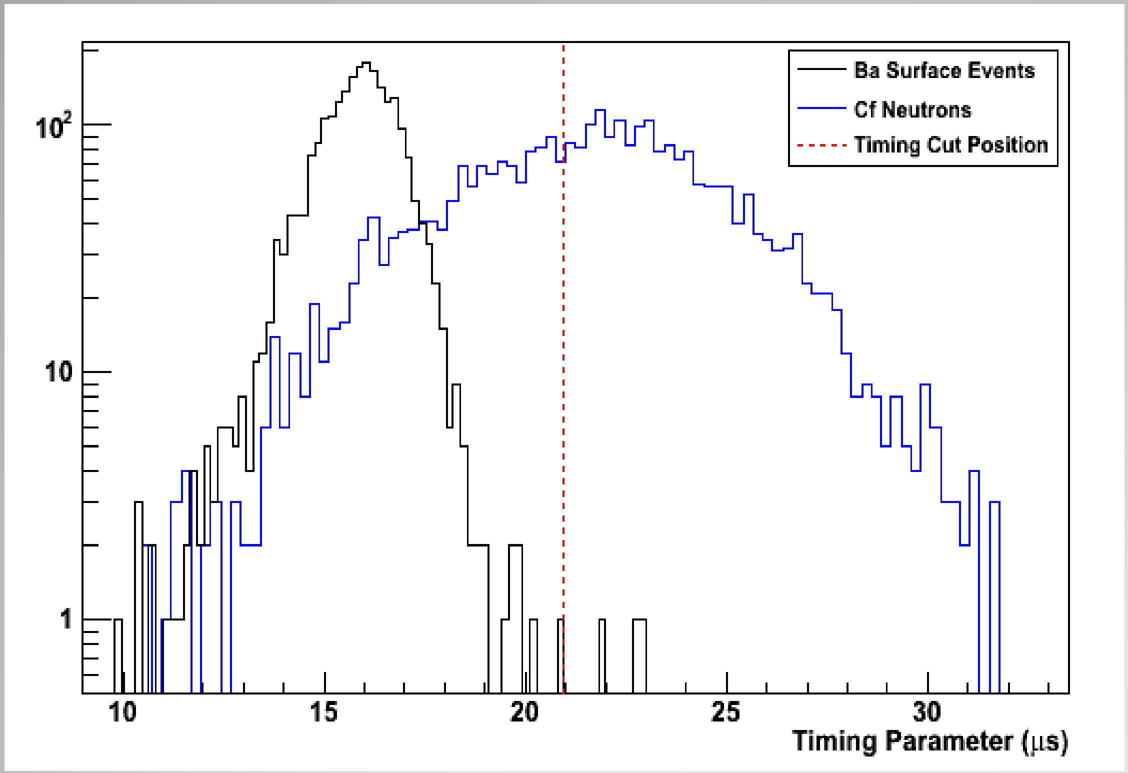
Analysis Overview



Candidate event criteria:
- Data quality + fiducial volume cuts
- Muon-veto anticoincident
- Single scatter
- Ionization yield within 2σ nuclear recoil band
- Phonon timing cuts to get rid of surface events

All cuts developed before unblinding using WIMP-search sidebands and calibration data!

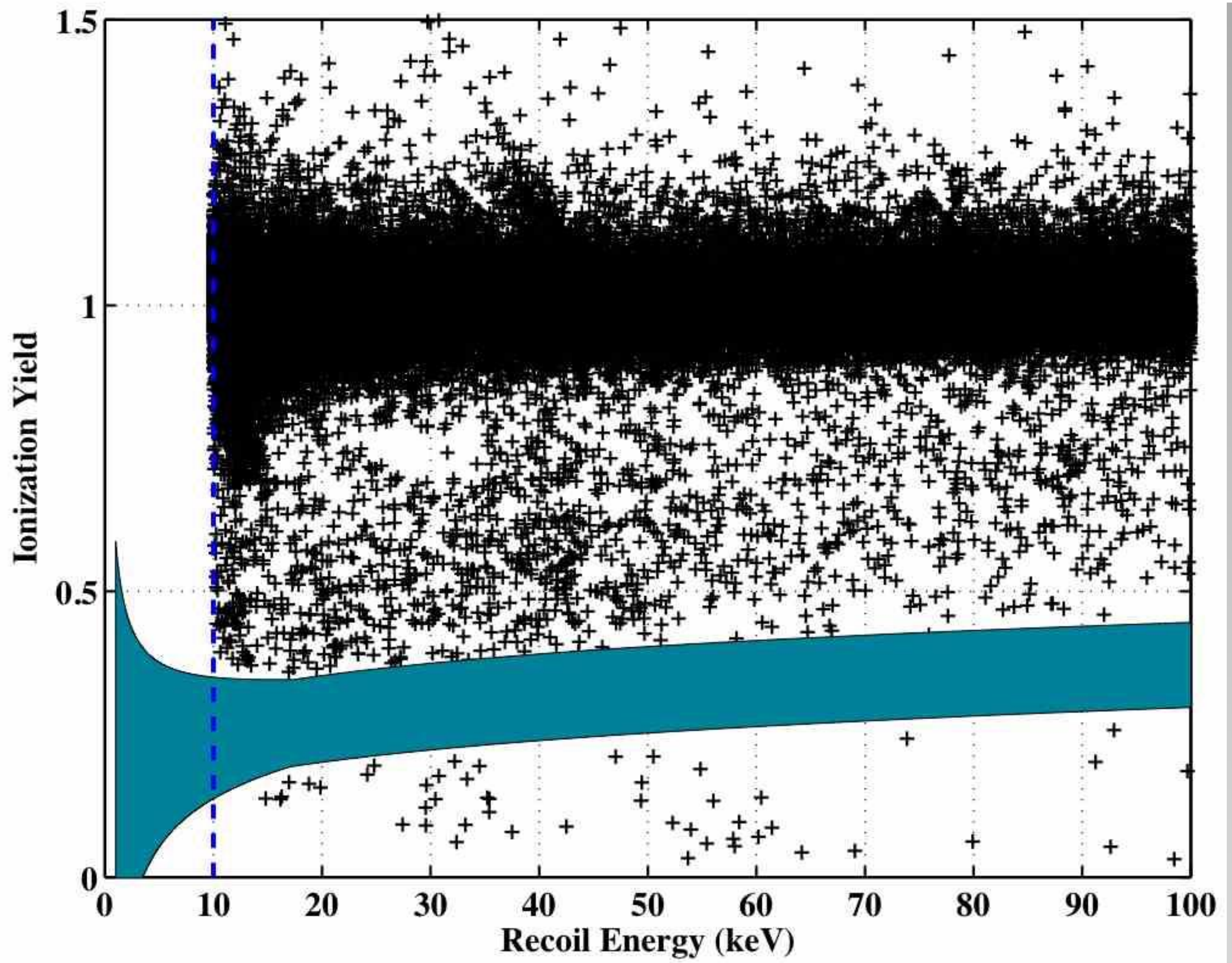




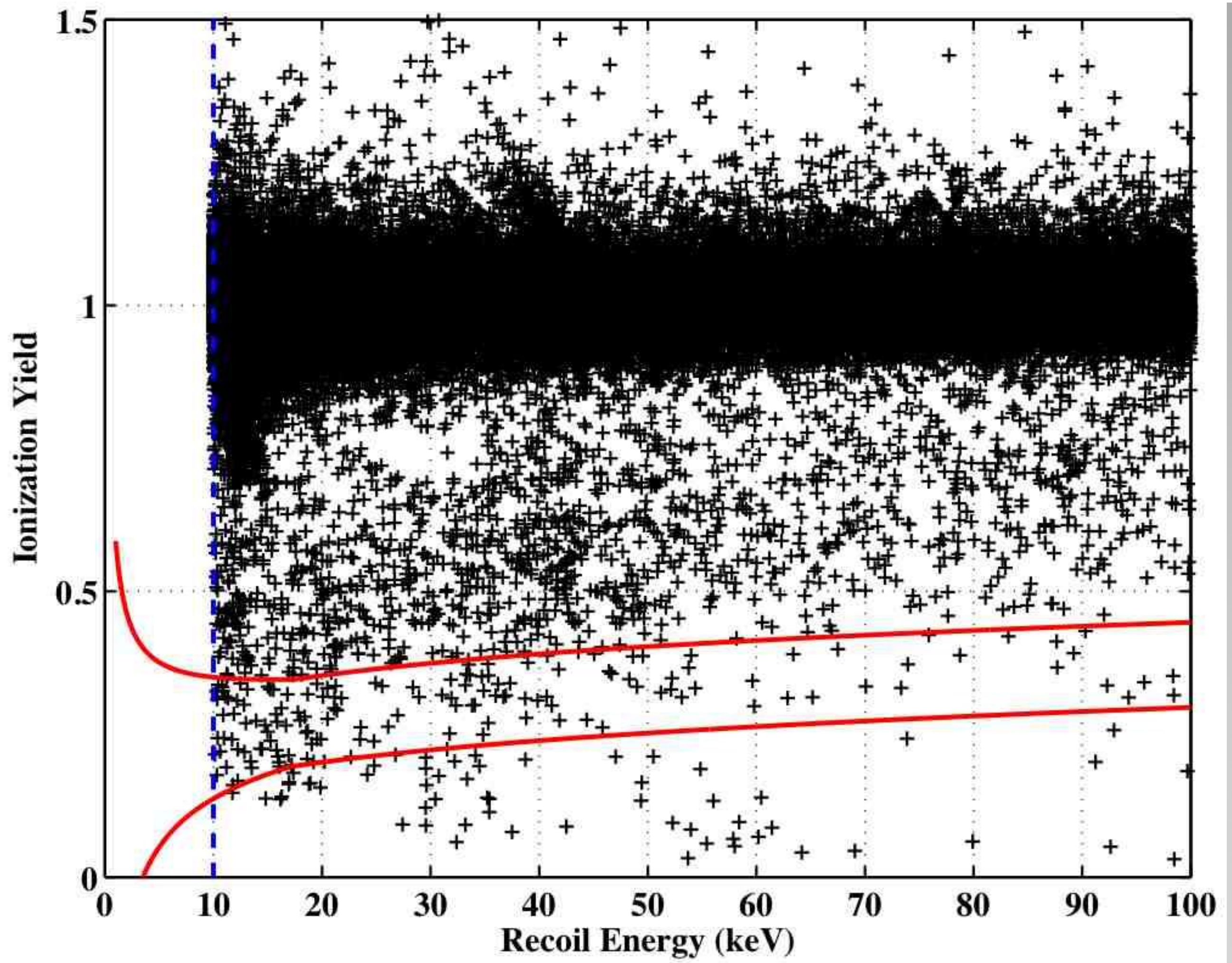
We optimized for the best sensitivity (results in < 1 expected background).

Rejection based on phonon timing is 200:1

Surface Events

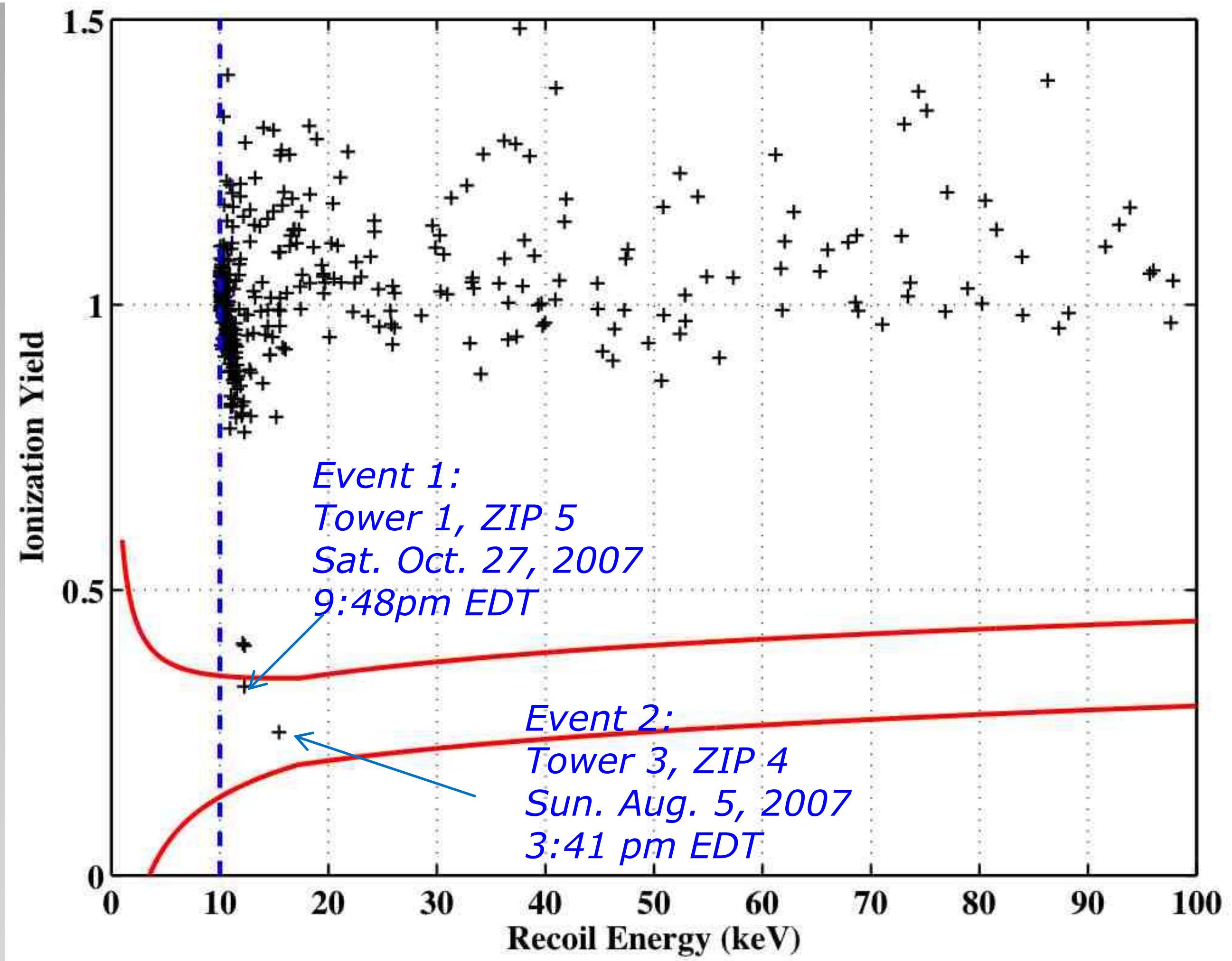


Unblinding the WS data



150 events in NR band fail timing cut

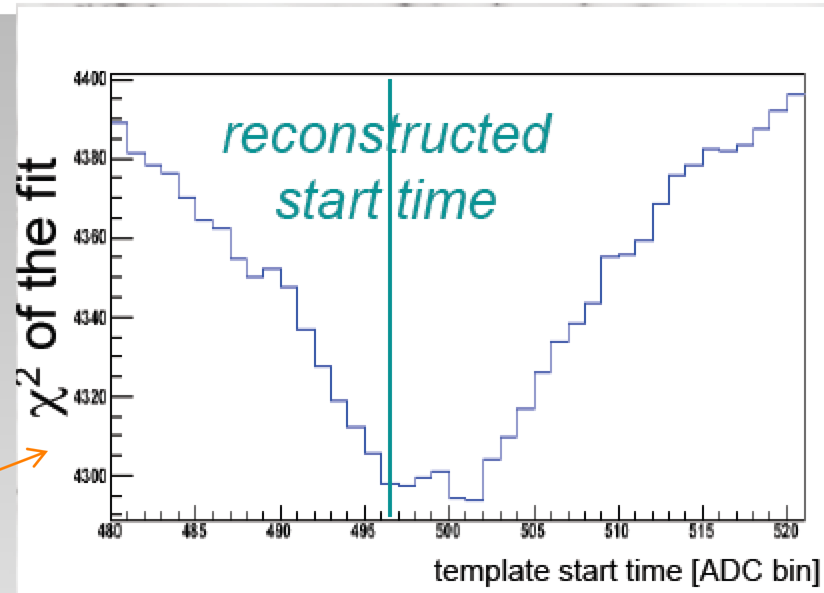
Events failing timing cut

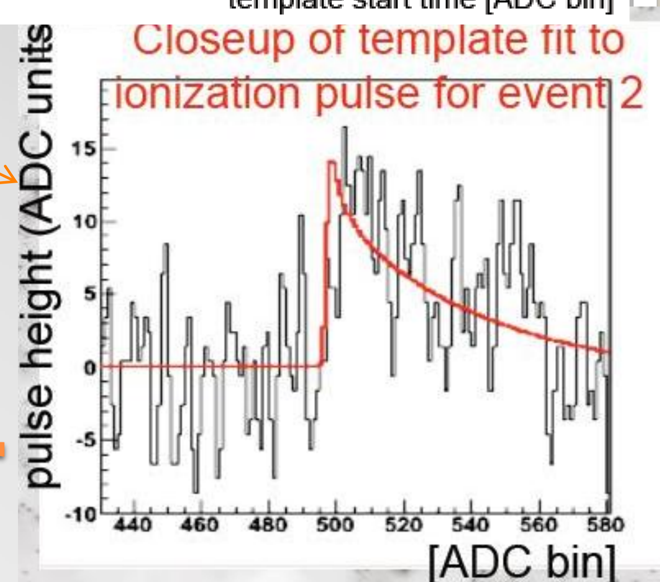


Events passing timing cut

Post-unblinding studies :

- Data quality (re-checks)-- **passed**
- Reconstruction quality (re-checks)
- cut varying studies
- likelihood analysis





Big question: signal or background?

The final surface event background estimate is:

$0.8 \pm 0.1(\text{stat}) \pm 0.2(\text{sys})$ events

The probability to observe 2 or more surface events based on the estimated background is 20%

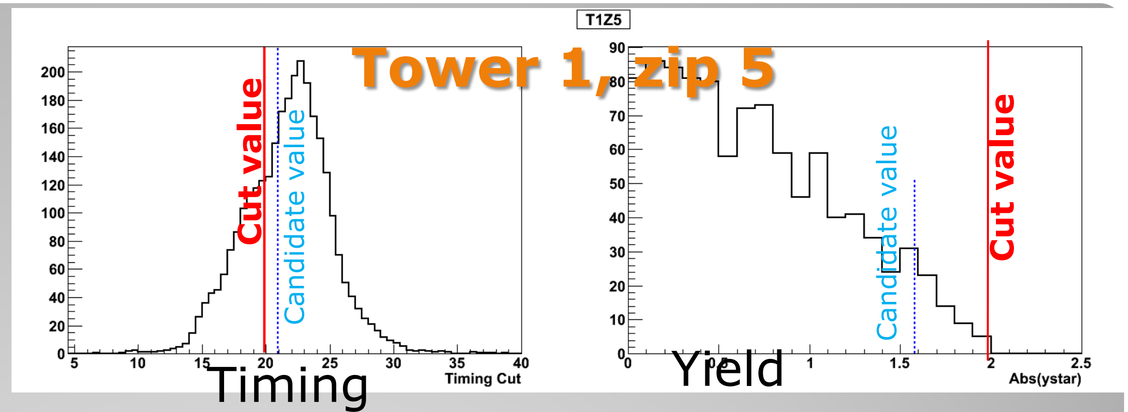
After including the neutron background, the probability to observe 2 or more events is 23%

Likelihood analysis encourages suspicion about event in T1Z5, and reconstruction makes us suspicious of event in T3Z4

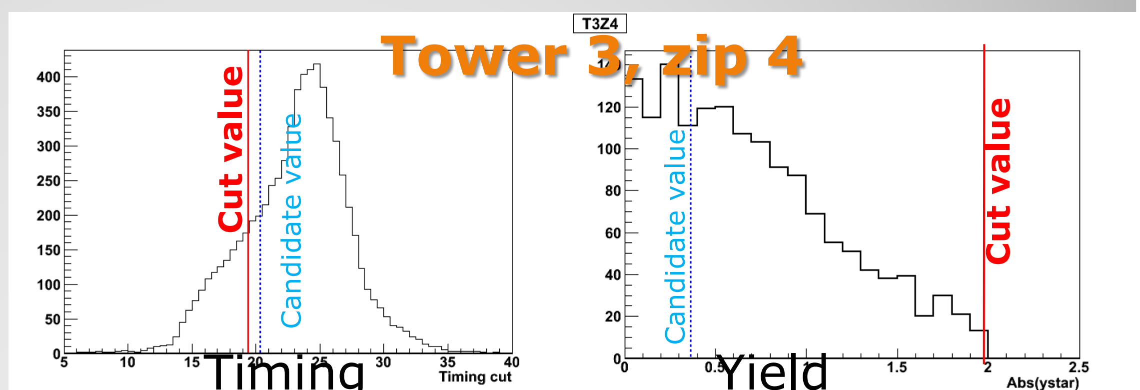
Comments about surface events

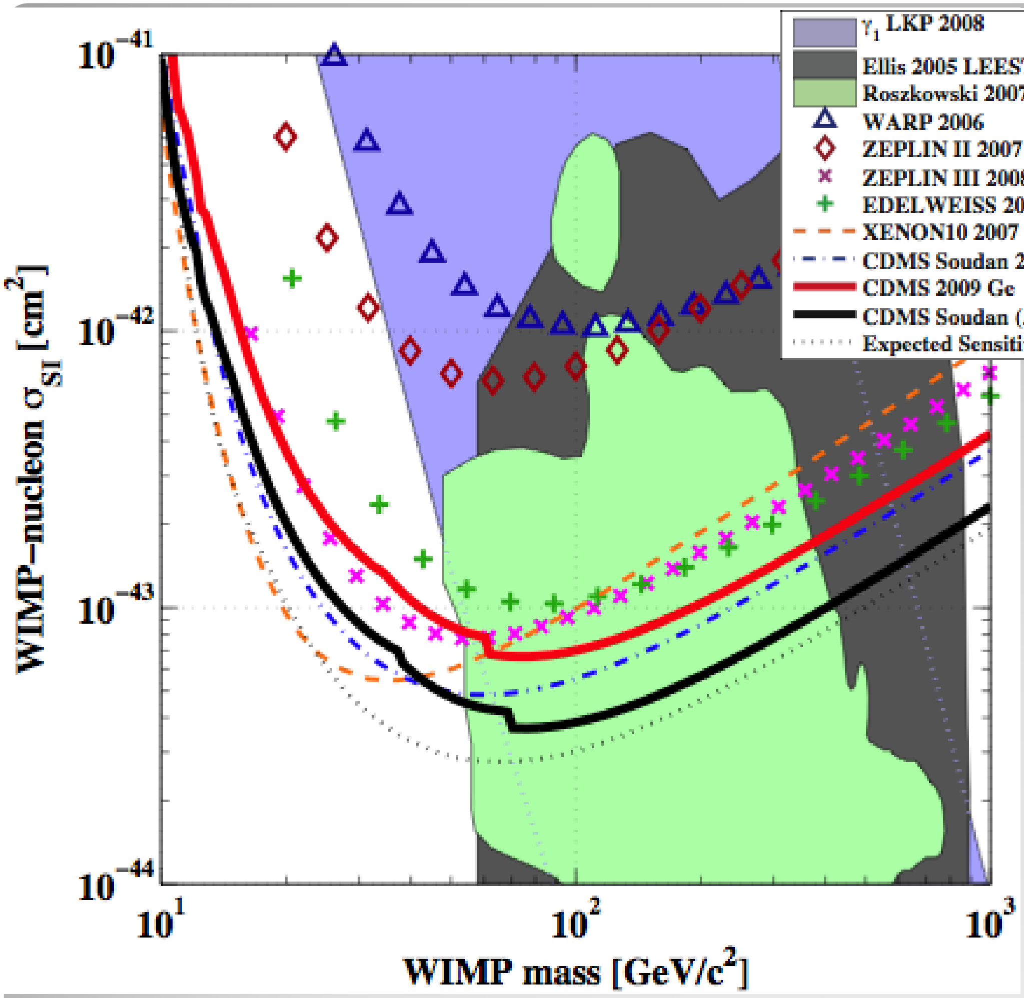
Likelihood Analysis

What is the probability that a true nuclear recoil in the acceptance region is as close to the cut boundaries as the candidate events are?



	3D unbinned (timing,energy, yield	2D fit (yield, timing) with fit	2D no fit (yield,timing)
Event 1 T1Z5	1%	3%	4%
Event 2 T3Z4	12%	2%	19%





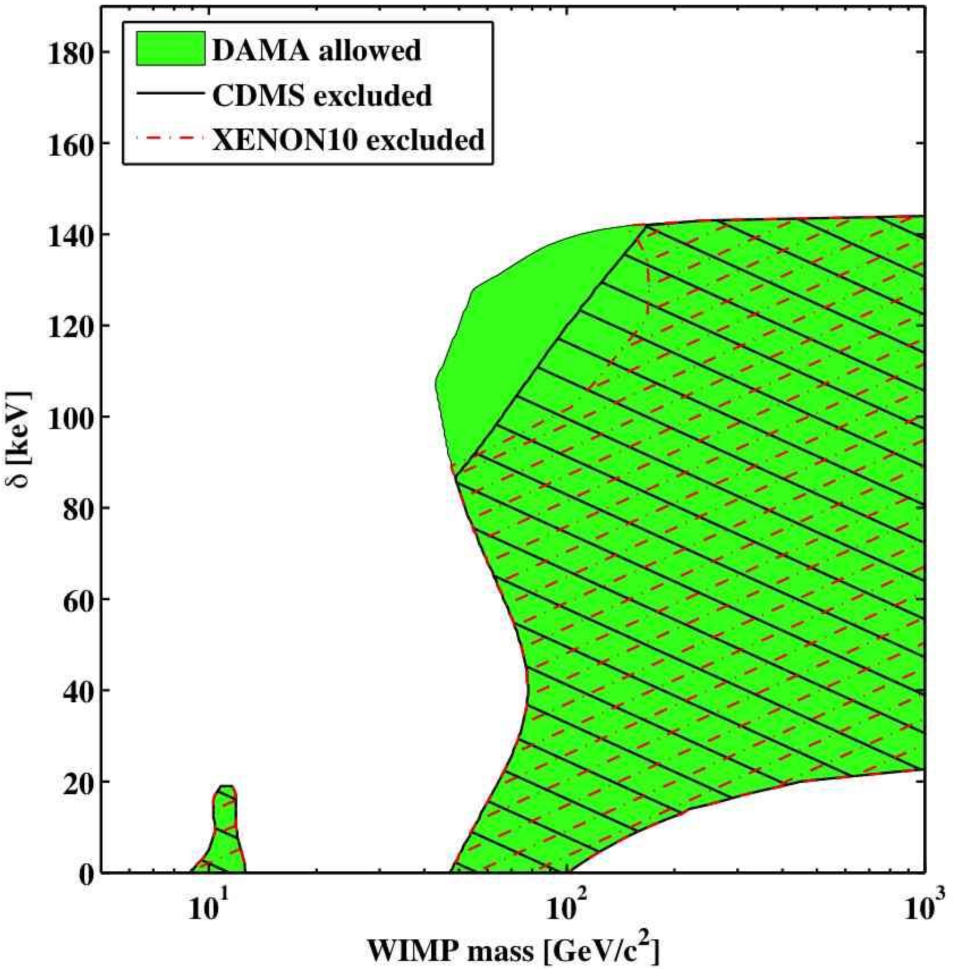
CDMS 2009@WIMP mass 70 GeV
$\sigma = 7.0 \times 10^{-44}$ cm^2 (90% C.L.)

CDMS Combined Soudan Data @WIMP mass 70 GeV
$\sigma = 3.8 \times 10^{-44}$ cm^2 (90% C.L.)

Science vol. 327 p.1619

Spin Independent Limit

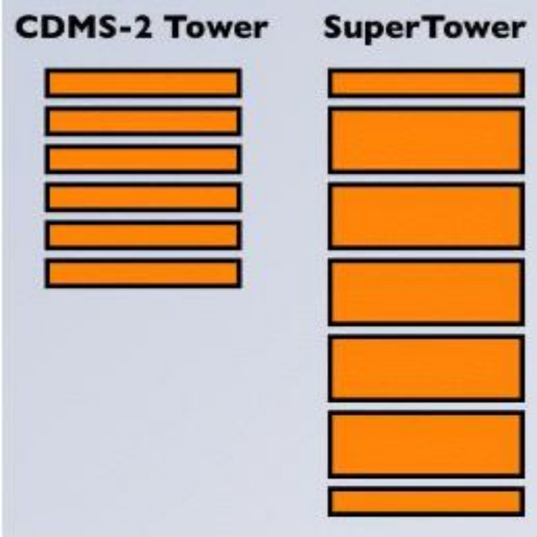
Inelastic dark matter

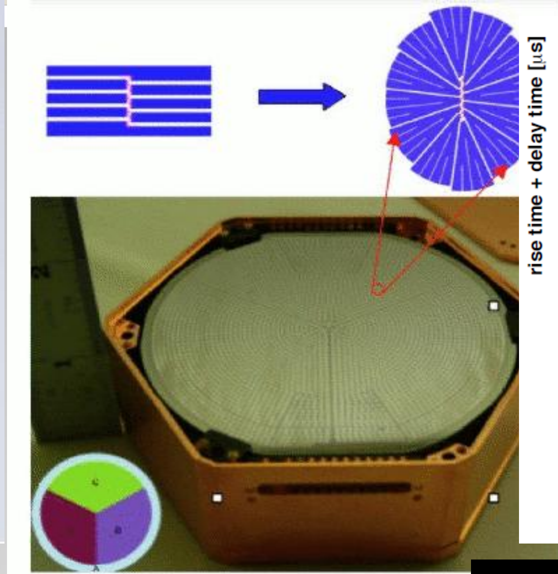


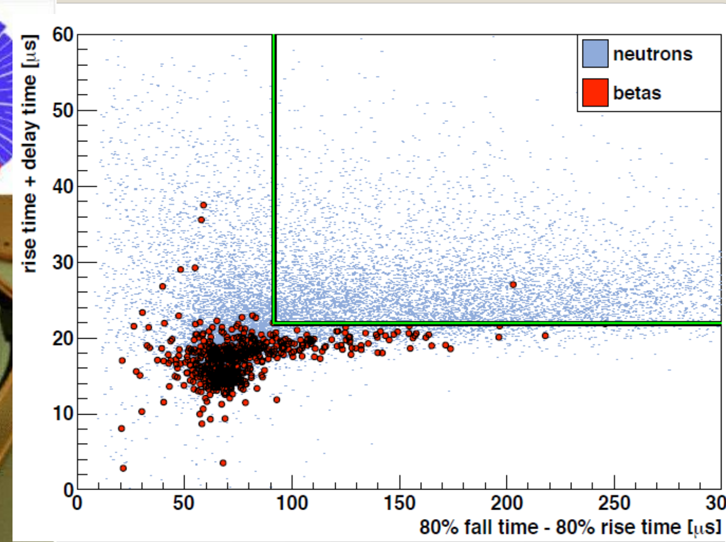
Has been invoked by Weiner et al. to explain DAMA/LIBRA data, among other things.
[Phys. Rev. D 64, 043502 (2001)]

Scattering occurs via transition of WIMP to excited state (with mass splitting δ)

DAMA, allowed regions (at 90% C.L.) computed from χ^2 goodness-of-fit and standard truncated halo-model [JCAP 04 (2009) 010]







New detectors are 2.5 times thicker

Installed in Soudan and successful

engineering run Oct 2009-Dec2009

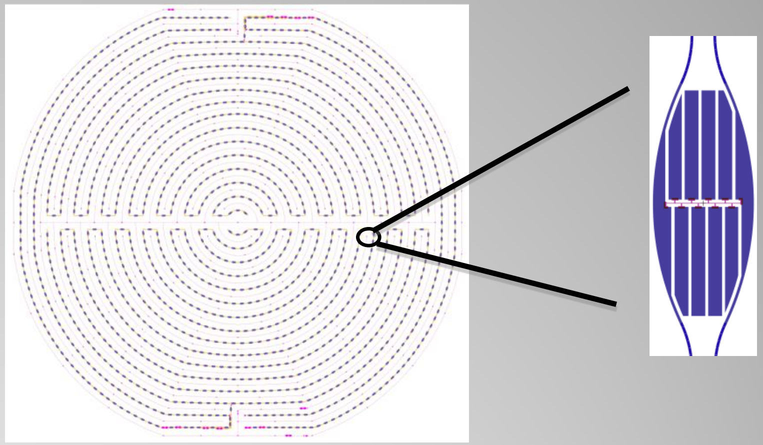
Based on backgrounds, surface discrimination, And neutron efficiency determined from the engineering run a 2yr mZIP exposure would result in a 4X improvement in sensitivity compared to CDMS II ($\sim 1X10^{-44}$ cm^2)

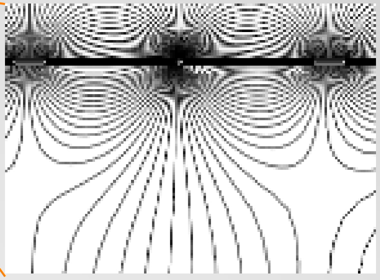
Next step: SuperCDMS mZIPs

__iZIP = i__nterleaved charge and phonon channels

1/3000 rejection of surface events in NR band based only on charge collection

If we include phonon timing the surface event rejection may be ~10^3-10^6 X better!





Charge near surface is collected by electrodes on only one side

Next generation of detector design: iZIP

- Analysis of 612 (raw) kg-days of data, last of the CDMS-II data
- 2 events were observed in the signal region (0.8 surface events and < 0.1 neutrons were expected)
- We cannot interpret this result as a statistically significant signal but, within the blind analysis, we cannot exclude either event as signal
- World leading limit on spin-independent WIMP-nucleon cross-section
  3.8×10^{-44} cm^2 at 90% CL (for 70 GeV/c^2 WIMP mass)
- **Successful good quality data run of first SuperTower! Next run at Soudan will be a mixture of iZIP and mZIP detectors (~10X improvement over CDMSII)**

Summary

Backup

Surface leakage estimate

$$\text{Expected surface leakage} = \frac{N^{\text{Sideband}}_{\text{Passing cut}}}{N^{\text{Sideband}}_{\text{failing cut}}} * N_{\text{failing cut}}$$

3 independent sidebands for estimating the passing/failing ratio

SIDEBAND 1

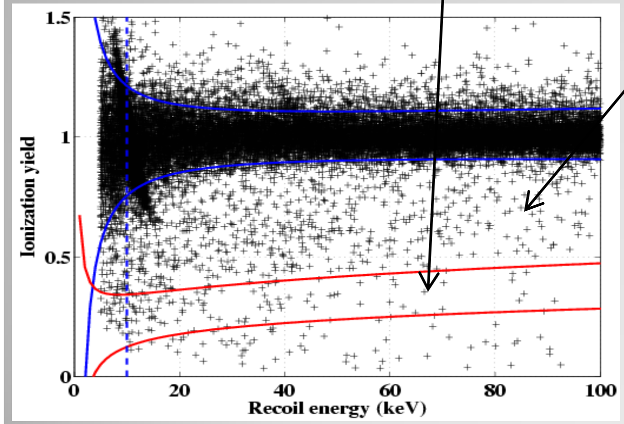
Use multiple-scatters in NR band

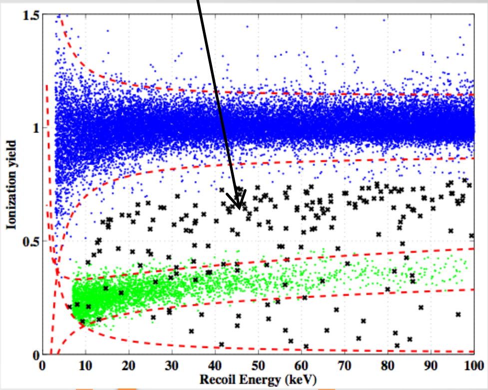
SIDEBAND 2

Use singles and multiples just outside NR band

SIDEBAND 3

Use singles and multiples from Ba calibration in wide region





Neutron Background Estimates

$$\frac{N^{MC}_{\text{unvetoed, single NR}}}{N^{MC}_{\text{vetoed, single NR}}} * N_{\text{vetoed, single NR}} * \varepsilon_{\text{neutron}} = 0.04^{+0.04}_{-0.03}$$

From GEANT4 and FLUKA simulations

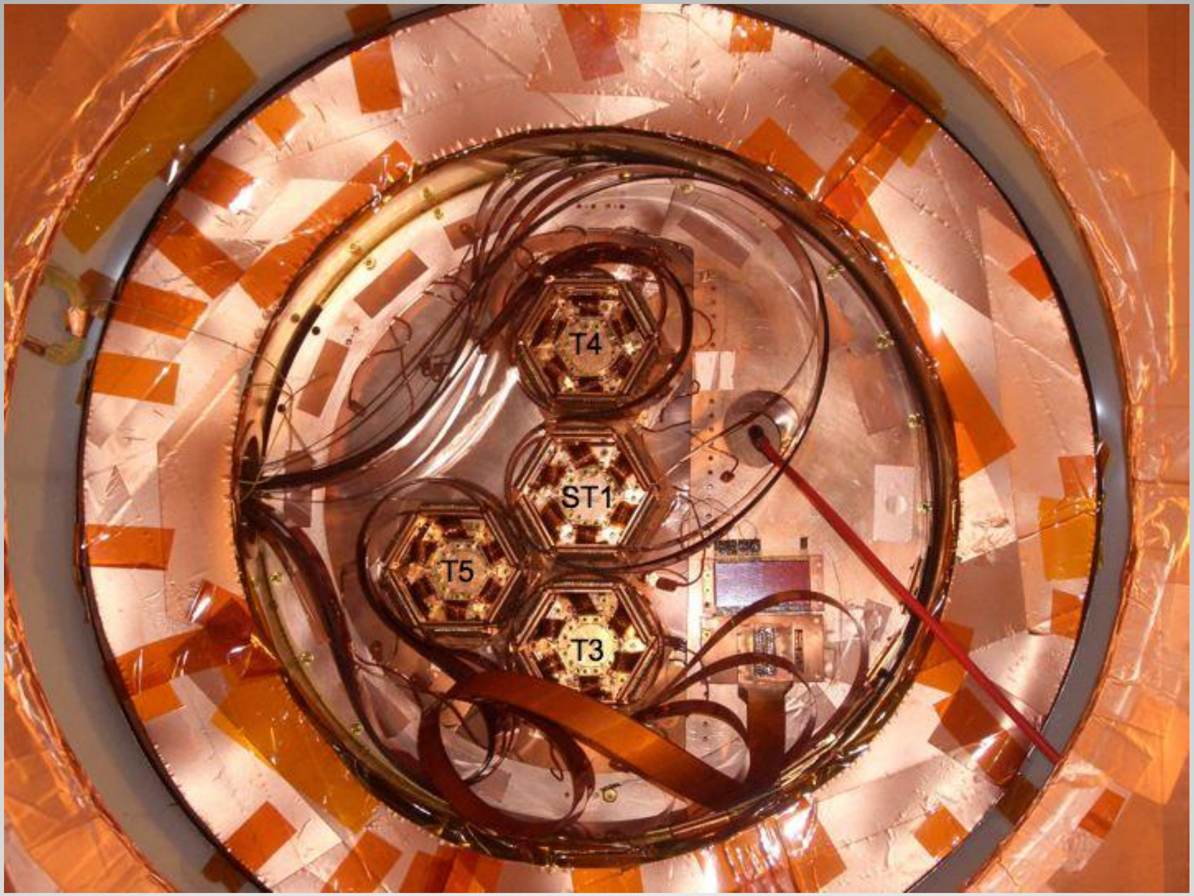
3 vetoed, single NR (in Soudan dataset)

correct for efficiency and exposure

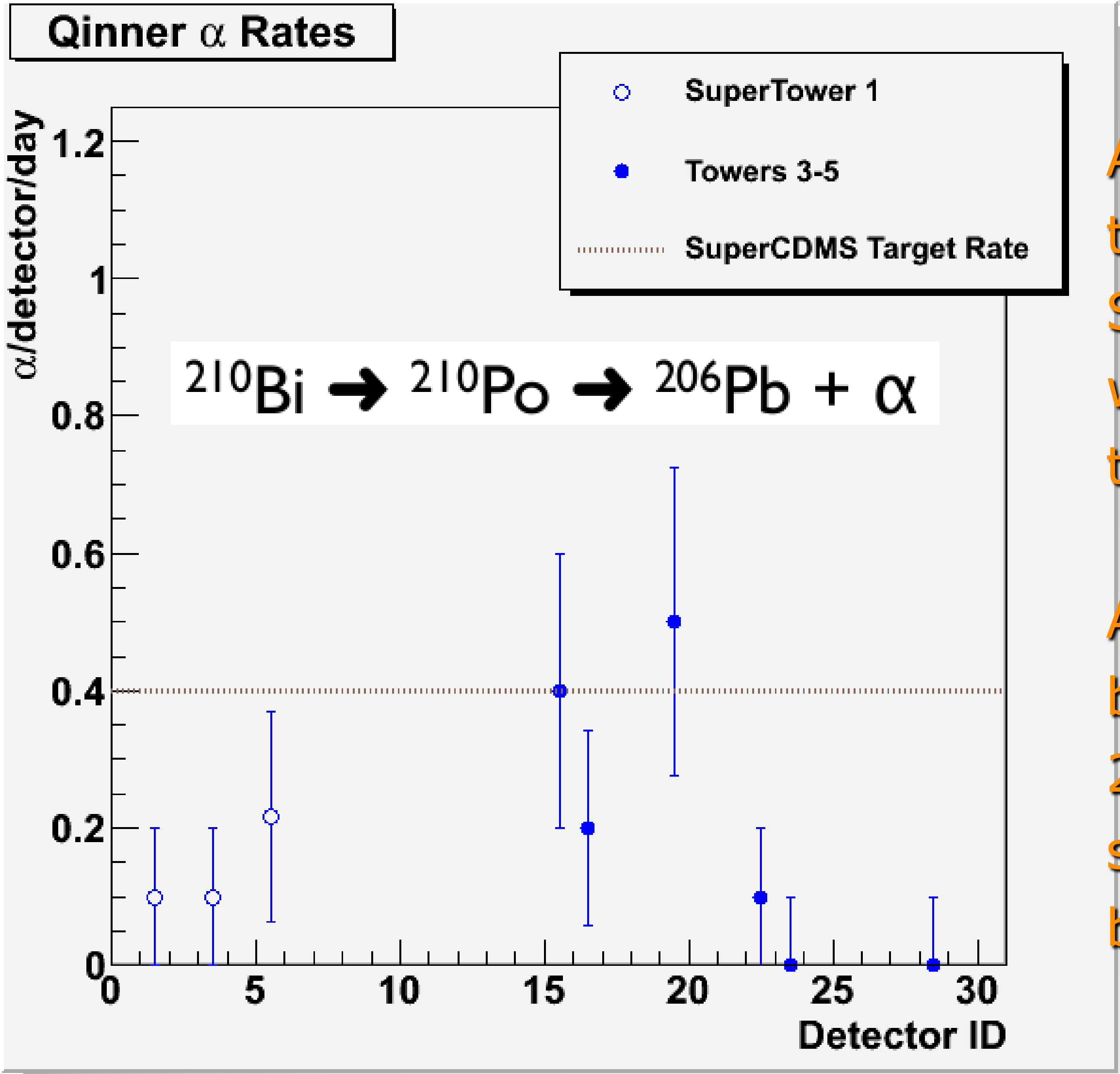
Radiogenic Neutron Estimate:

0.03 - 0.06 events

- fission, (α,n) in Cu, Poly, Pb



SuperTower installation



A preliminary look at the Alpha rate for SuperTower 1 shows we are ~2X better than our target rate

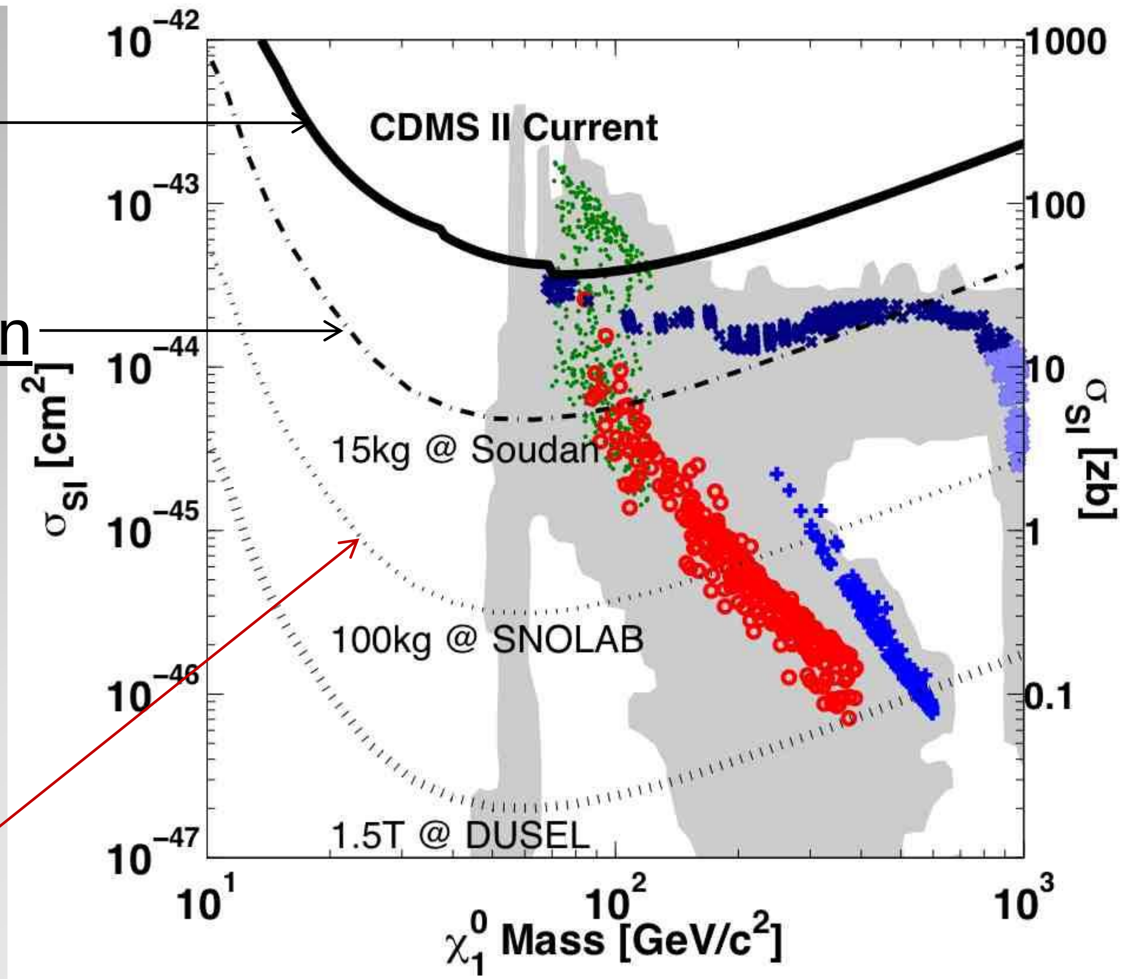
Alpha rate is the best measure of 210Pb, our dominant source of background

First look at surface backgrounds

CDMS II
4 kg Ge
~ 2 yrs operation

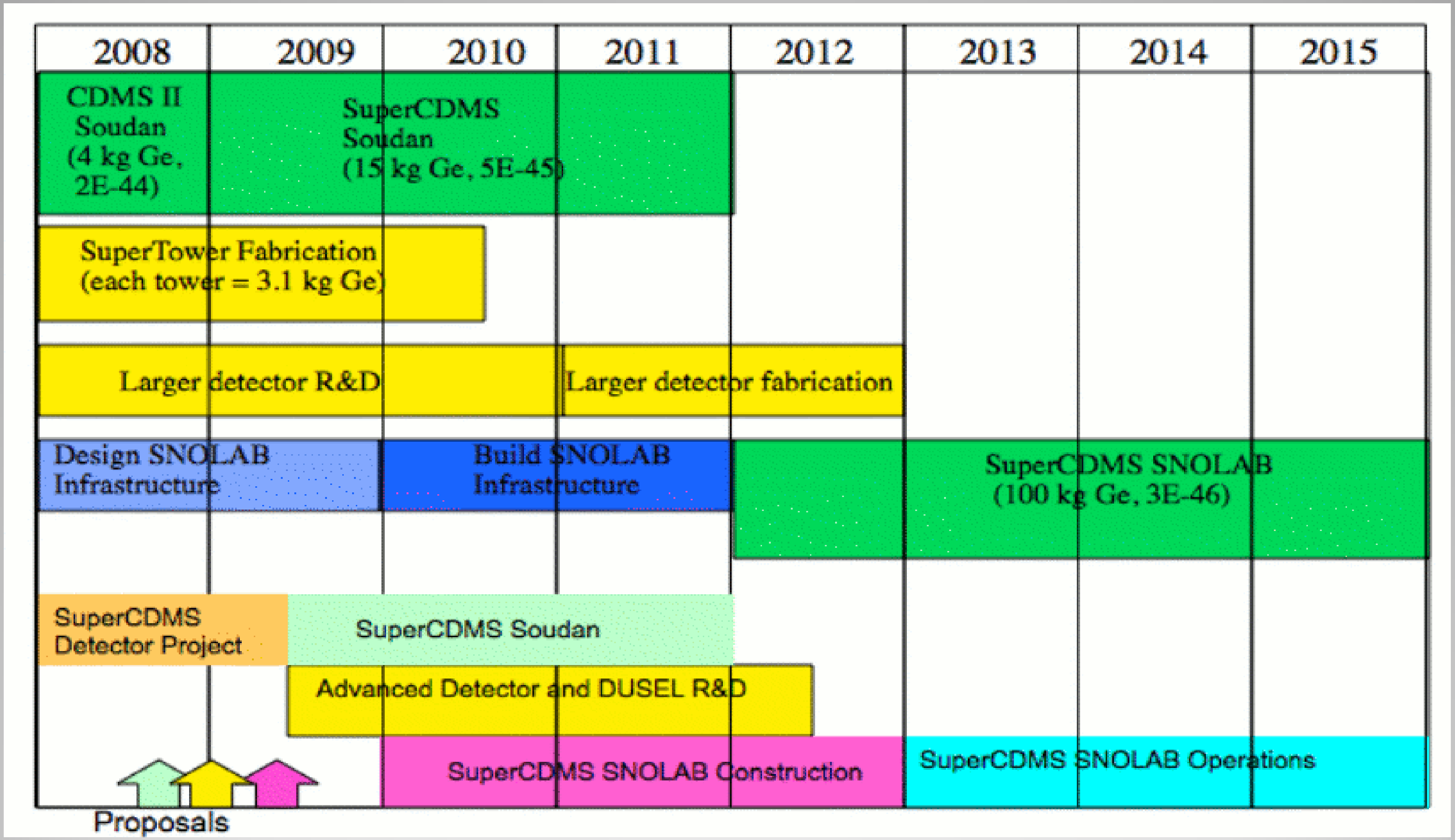
SuperCDMS @ Soudan
15 kg Ge
~ 2 yrs operation

SuperCDMS @ Snolab
100 kg Ge
~ 3 yrs operation, interleaved charge and phonon sensors

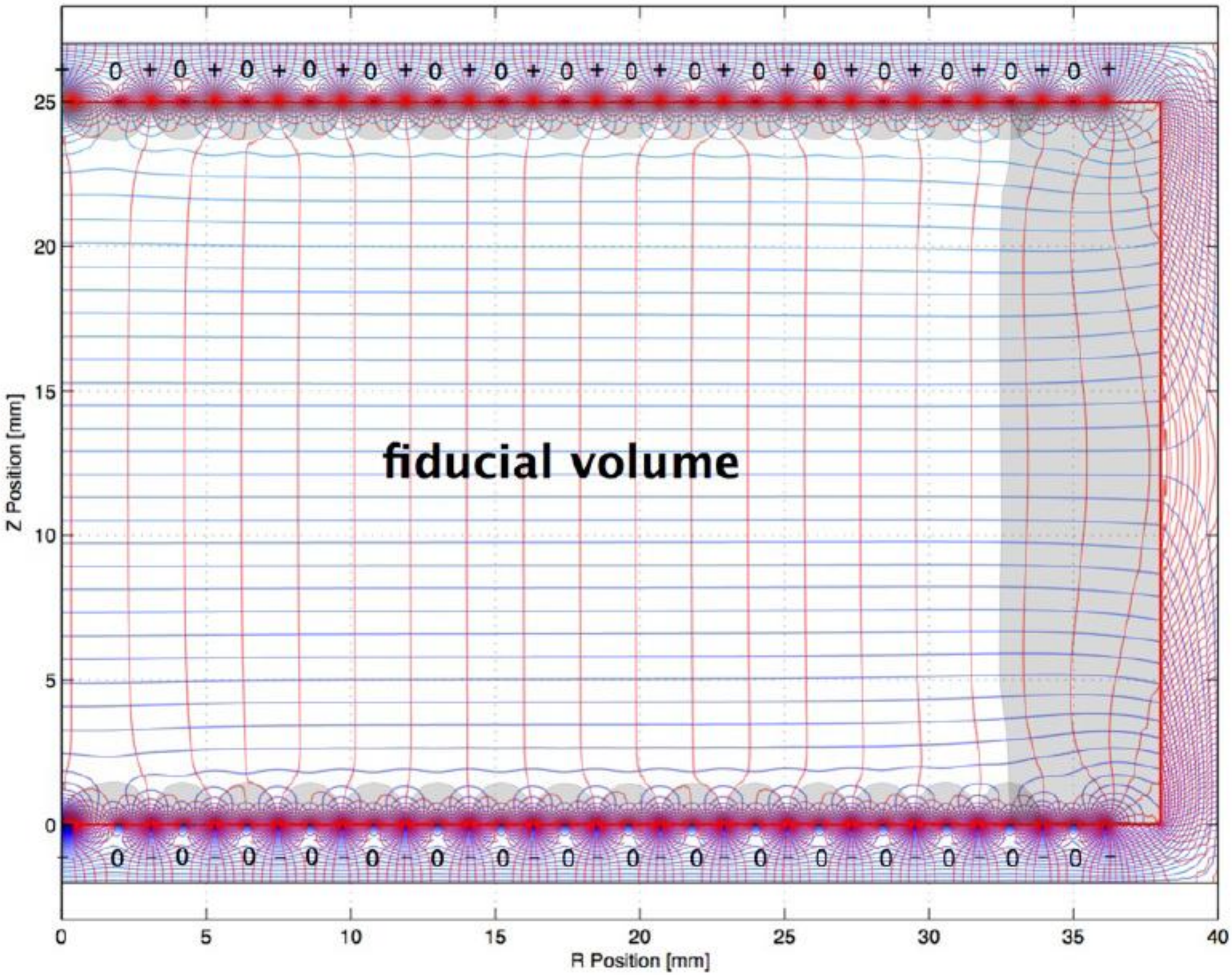


Future projections

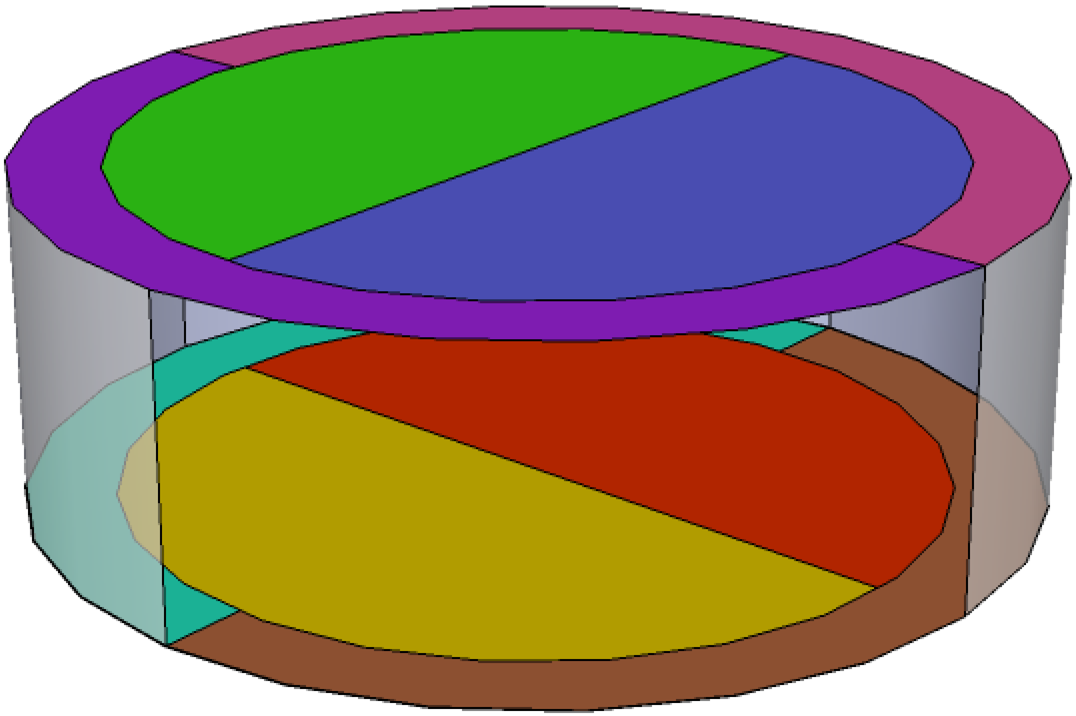
Timeline



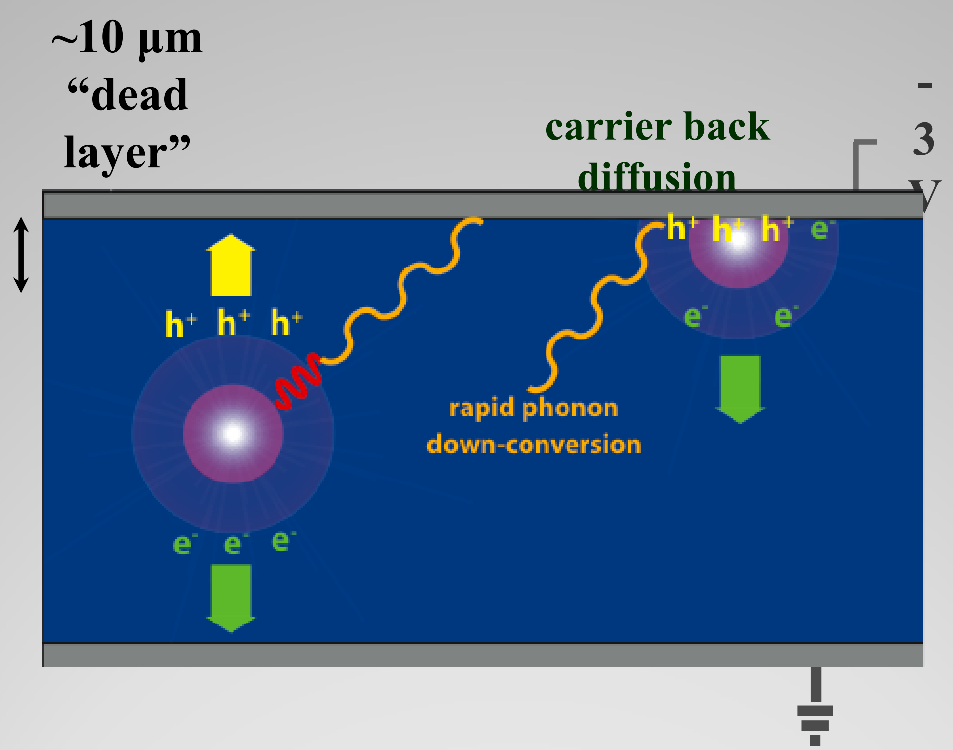
2008
2009
2010
2011
2012
2013
2014
2015
CDMS II Soudan (4 kg Ge, 2E-44)
SuperCDMS Soudan (15 kg Ge, 5E-45)
SuperTower Fabrication (each tower = 3.1 kg Ge)
Larger detector R&D
Larger detector fabrication
Design SNOLAB Infrastructure
Build SNOLAB Infrastructure
SuperCDMS SNOLAB (100 kg Ge, 3E-46)
SuperCDMS Detector Project
SuperCDMS Soudan
Advanced Detector and DUSEL R&D
SuperCDMS SNOLAB Construction
SuperCDMS SNOLAB Operations
Proposals

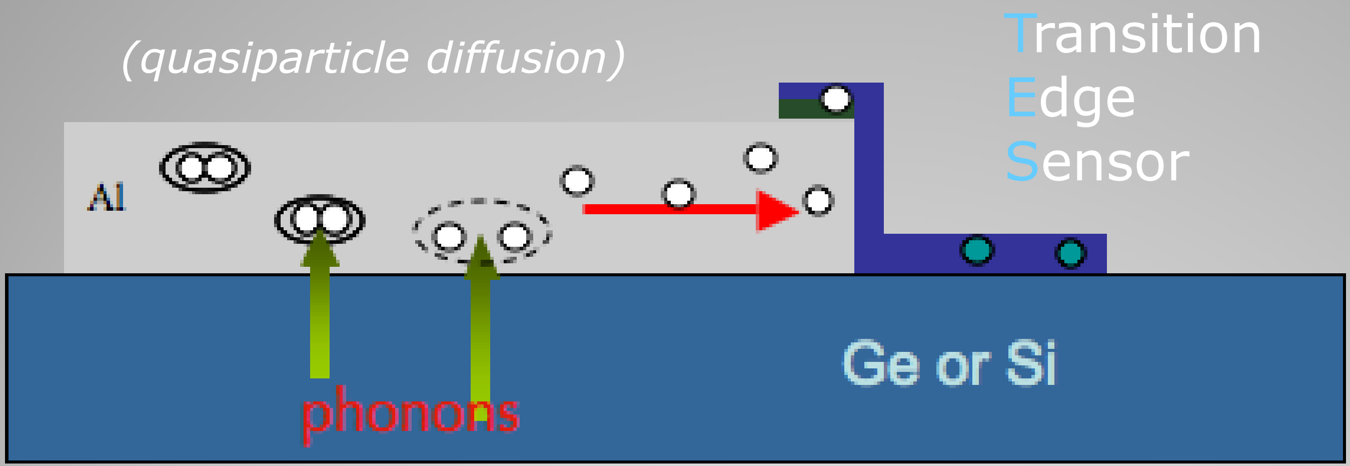


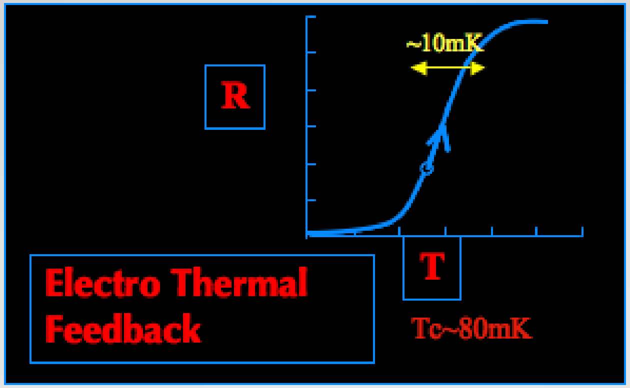
fiducial volume
Z Position [mm]
R Position [mm]



Surface events







Phonon detection