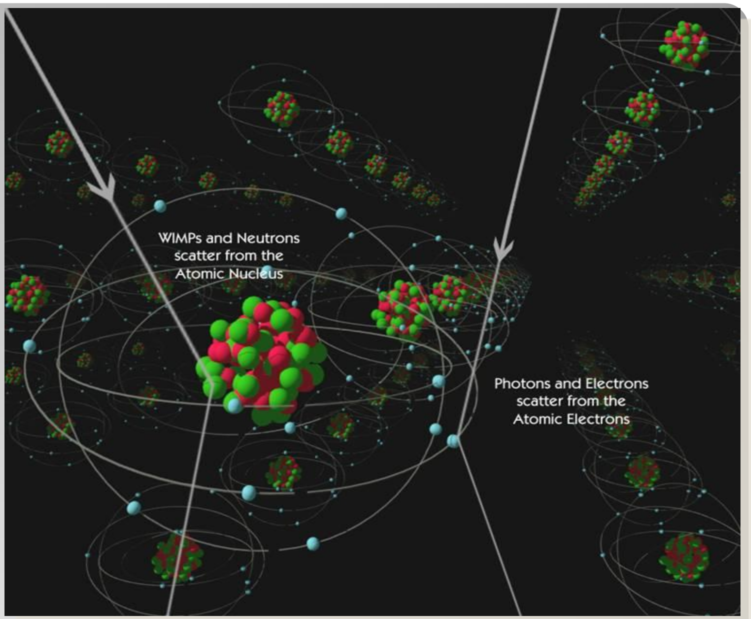
# Results from the Final Runs of the CDMSII Experiment

**Mark Kos**
**Syracuse University**

Detect energy deposited from WIMP-nucleus scattering

**Discriminate between nuclear and electron recoils**




CDMS: **Z**-sensitive **I**onization and **P**honon detectors

# Terrestrial dark matter detection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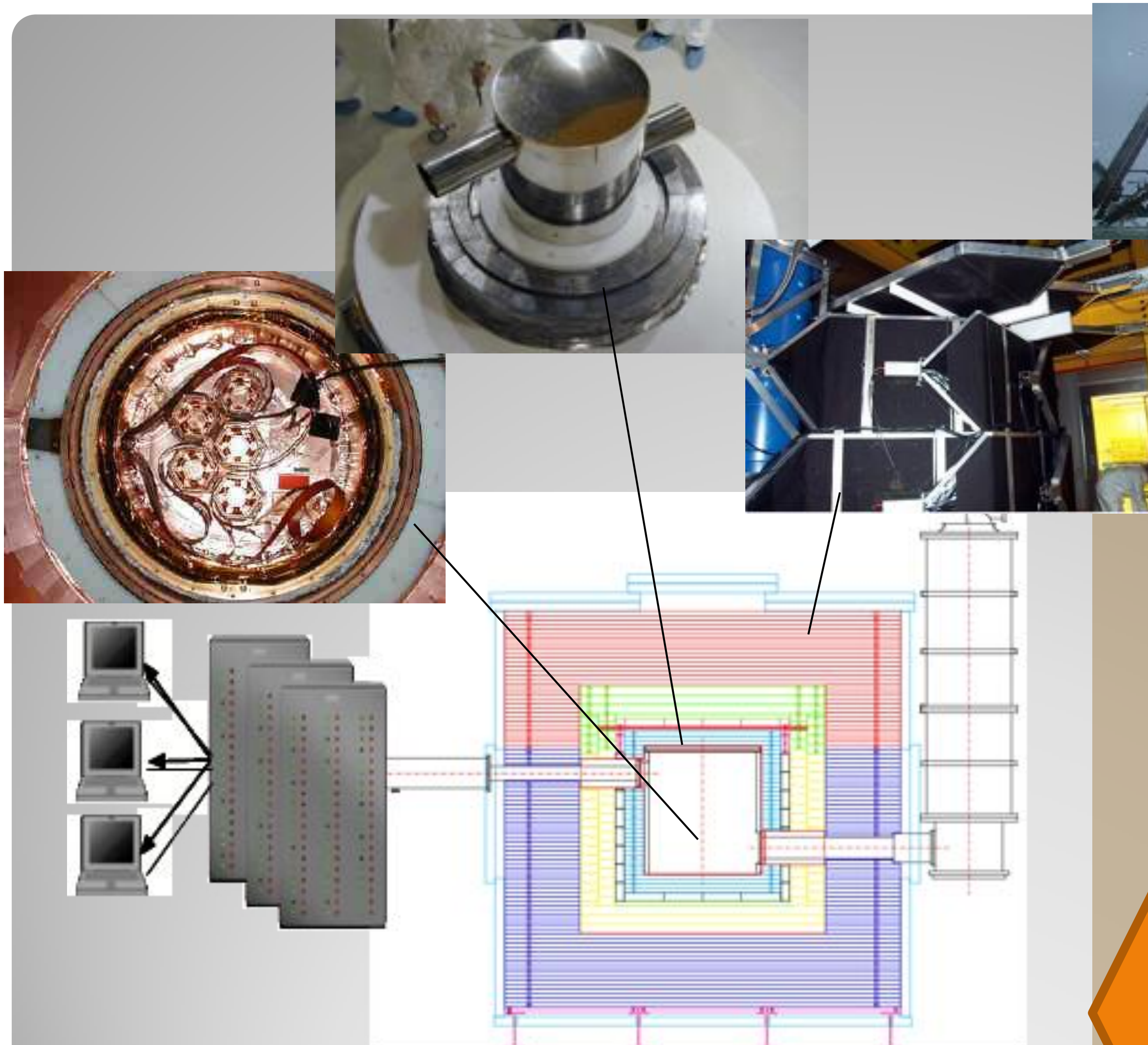
About 50 people from 15 institutions in the US, Canada, and Switzerland.



MINOS

CDMS

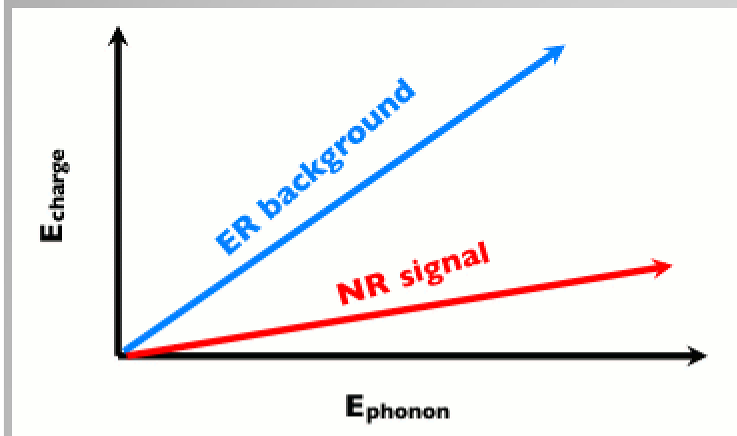
2090mwe

# Experimental Setup

# WIMP detection and background rejection

Phonon sensors

Charge sensors

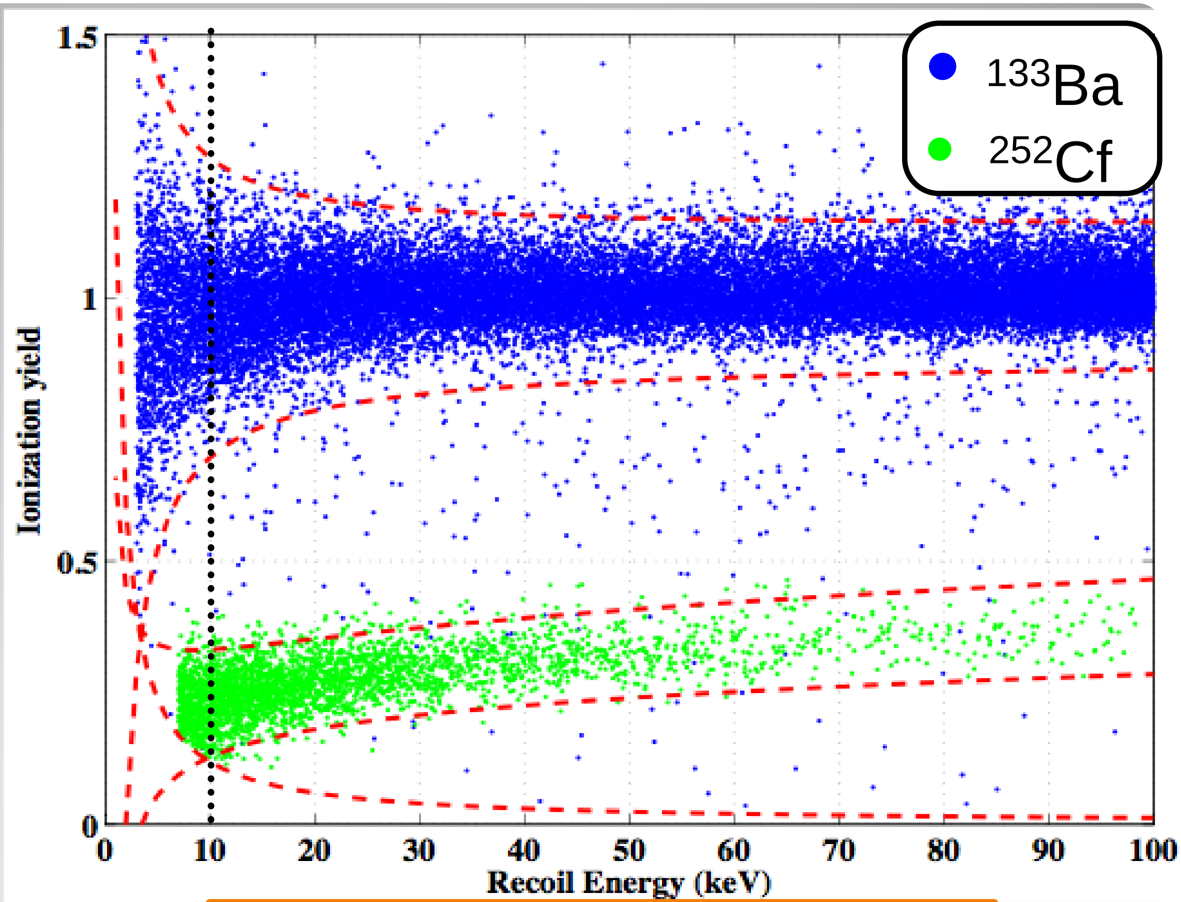



Yield = $E_{charge}/E_{phonon}$

- 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

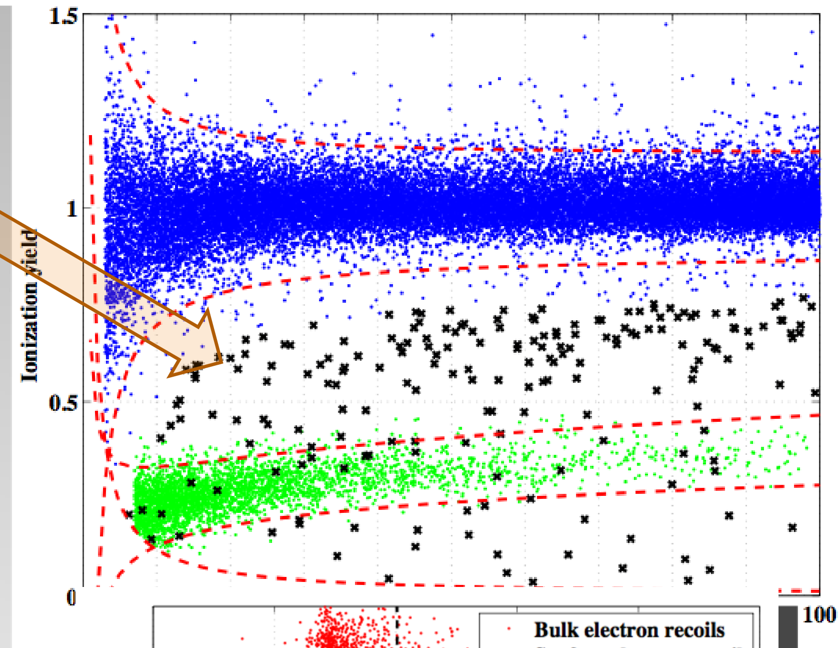
# Yield based rejection

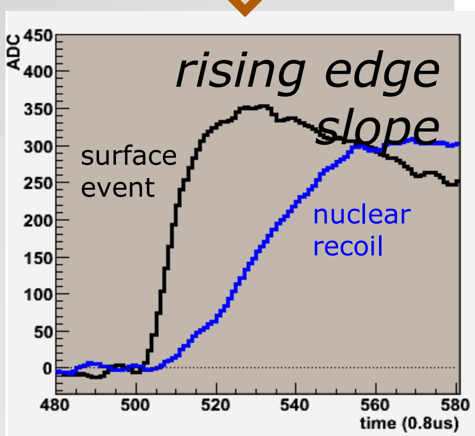
Better than 1:10000 rejection based on ionization yield

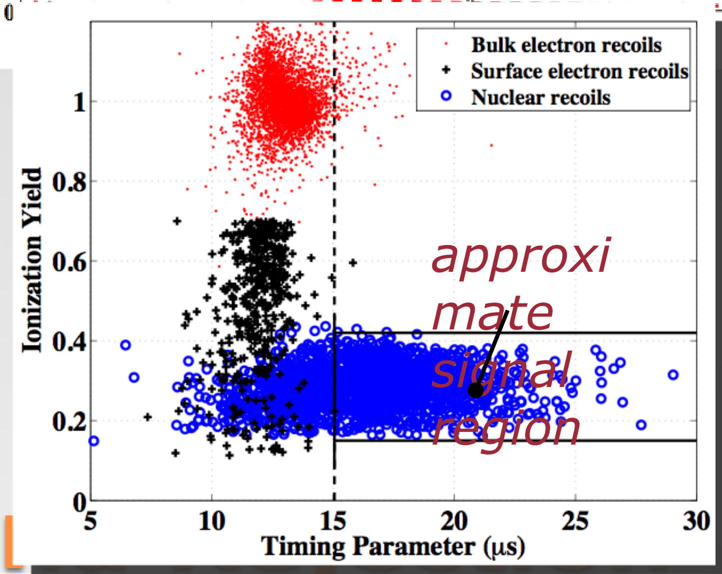



Yield = $E_{charge}/E_{phonon}$

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



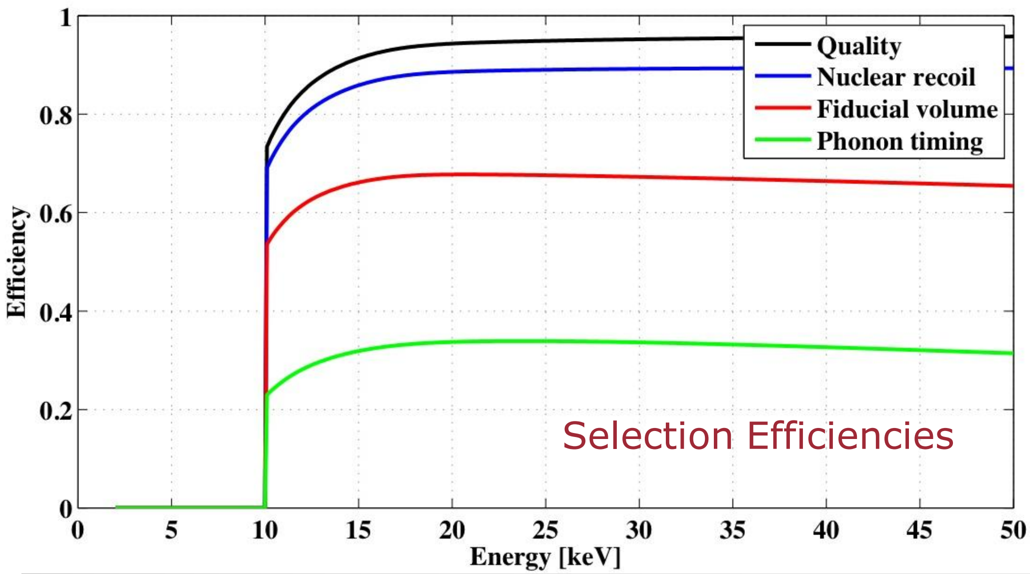




# Surface Backgrou

- 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

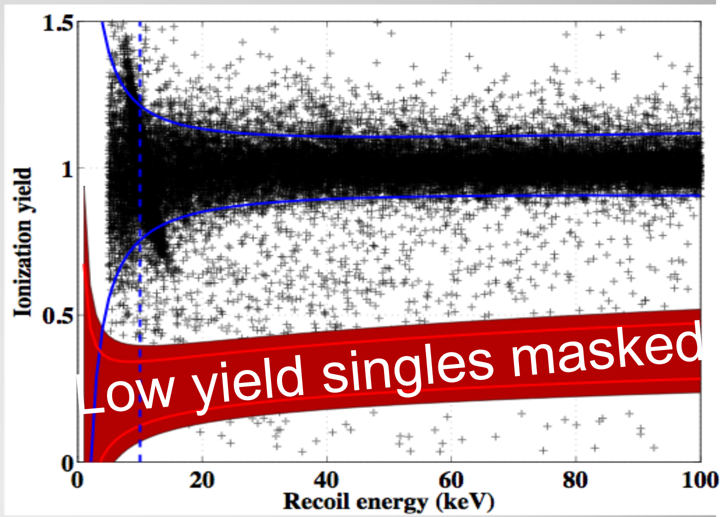
# Recent Published Analysis

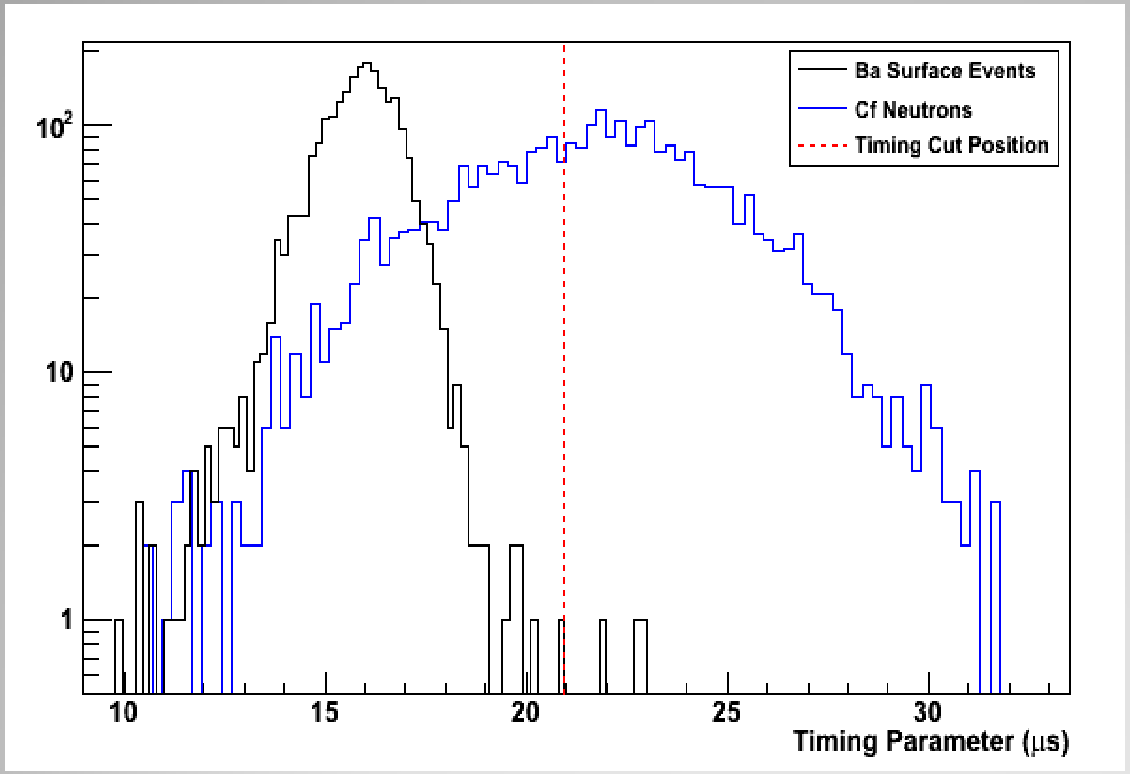
# Analysis Overview




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!**

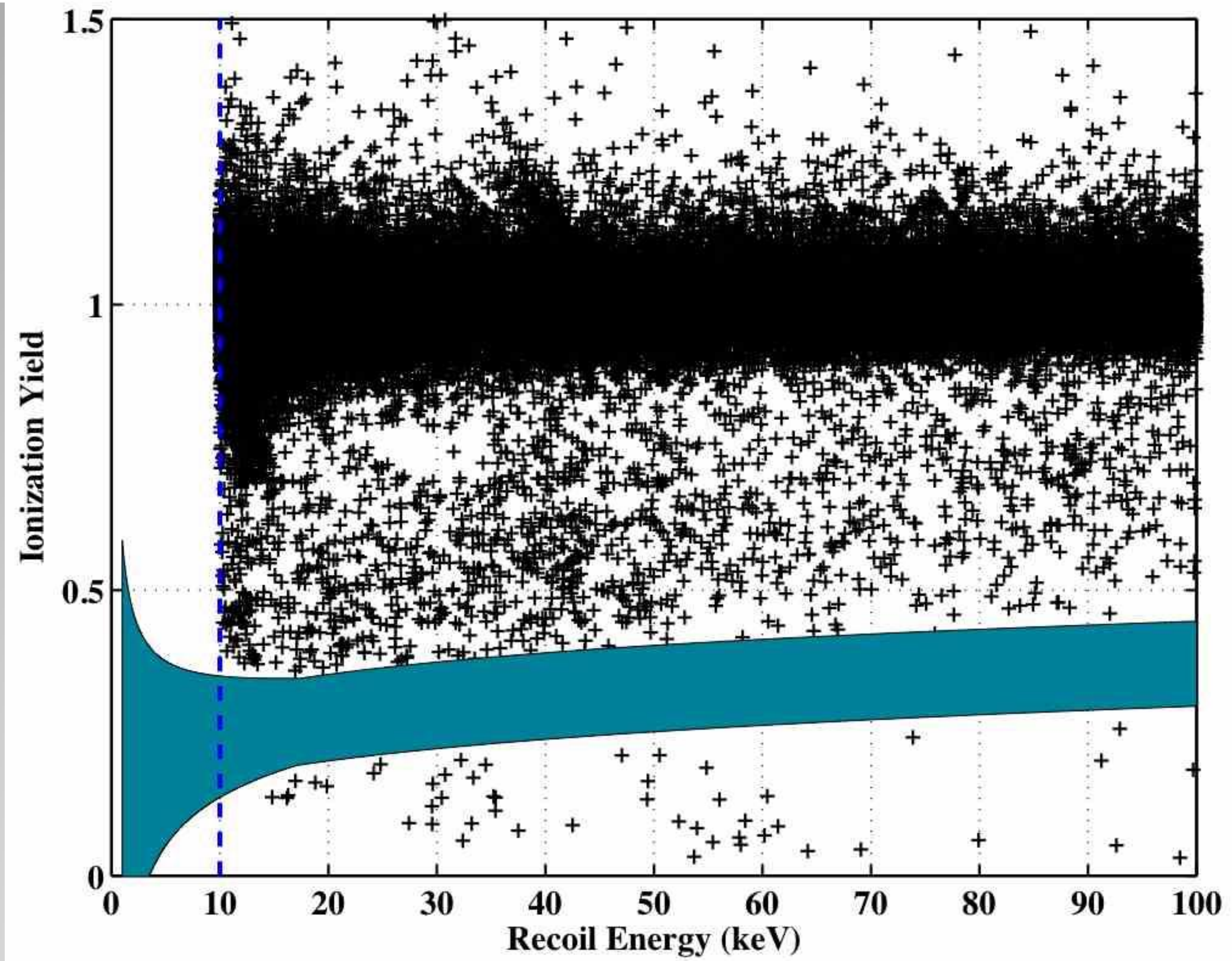




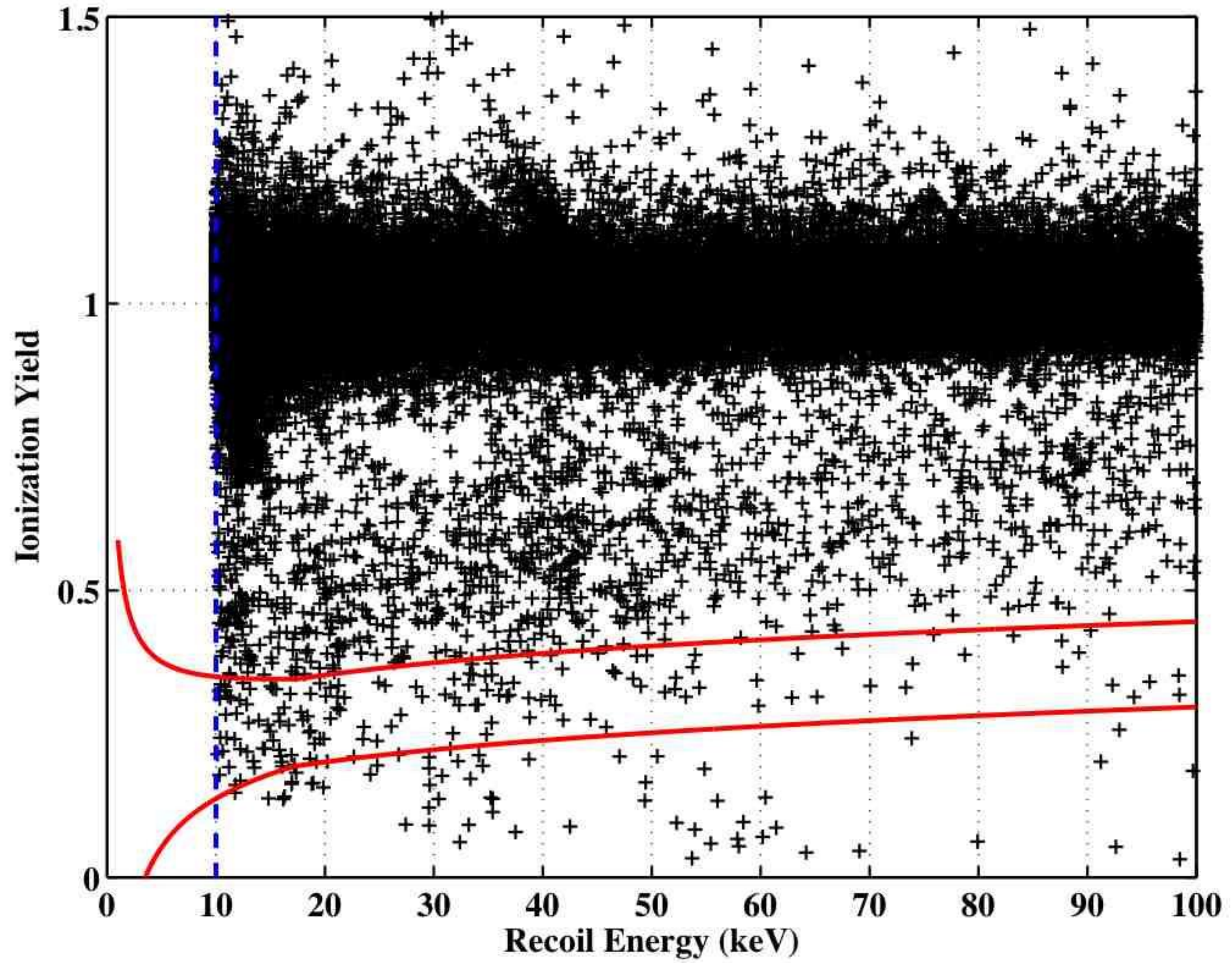

We optimized for the best sensitivity (results in < 1 expected background).

Rejection based on phonon timing is 200:1

# Surface Events

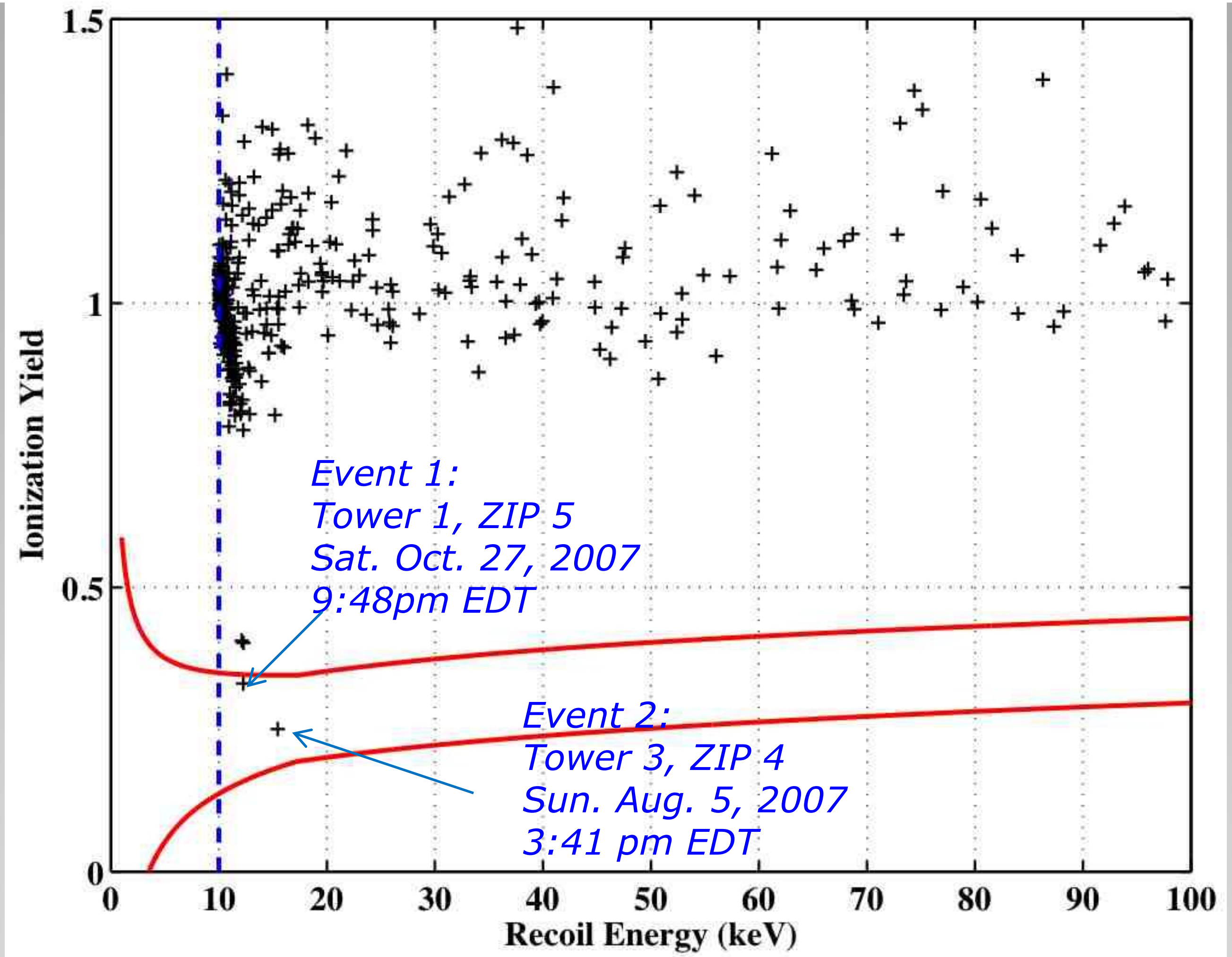



# Unblinding the WS data




150 events in NR band fail timing cut

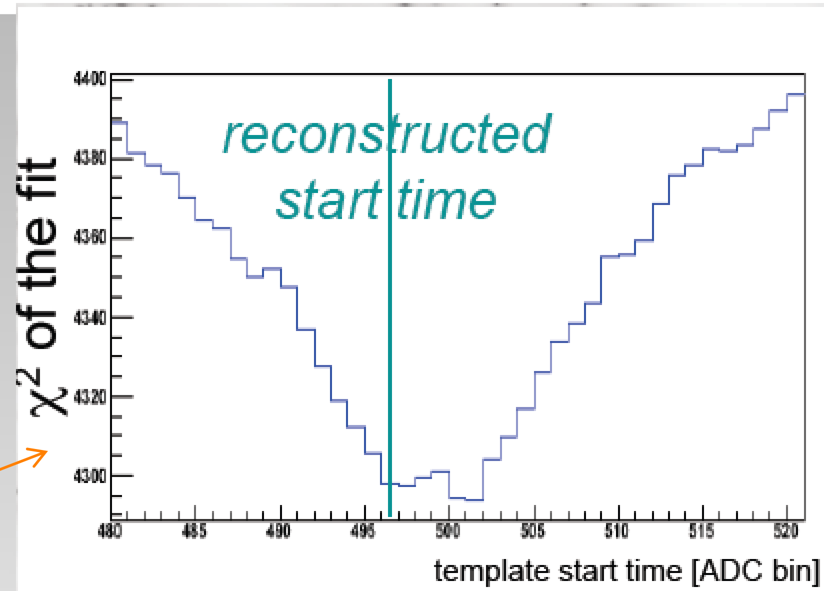
# Events failing timing cut

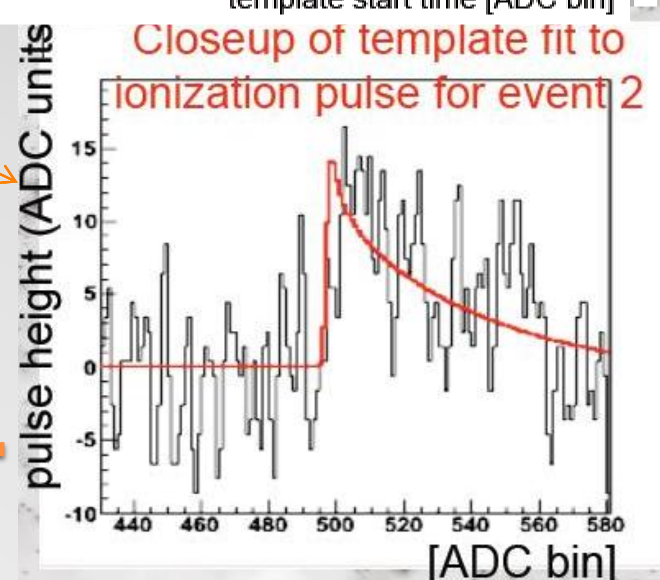



# Events passing timing cut

# Post-unblinding studies :

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




## Big question: signal or background?

# Comments about surface events

**The final surface event background estimate is:**

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

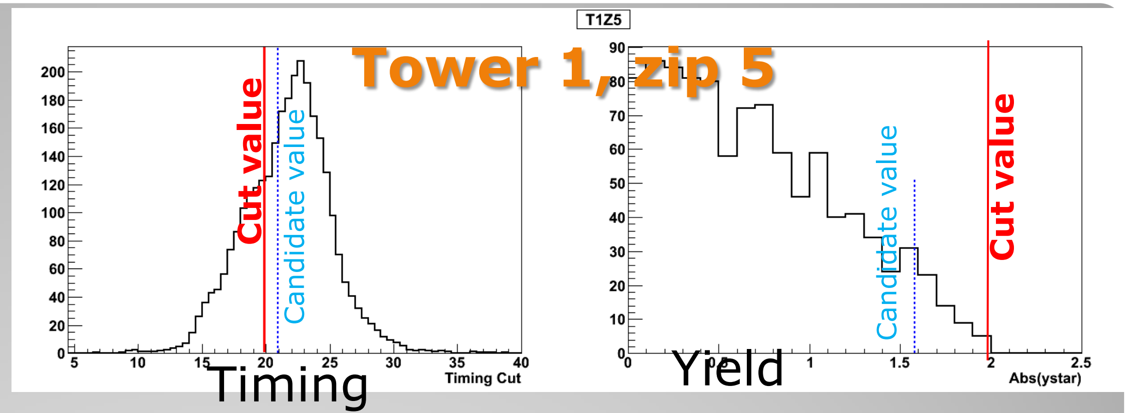
**The probability to observe 2 or more surface events based on the estimated background is 20%**

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

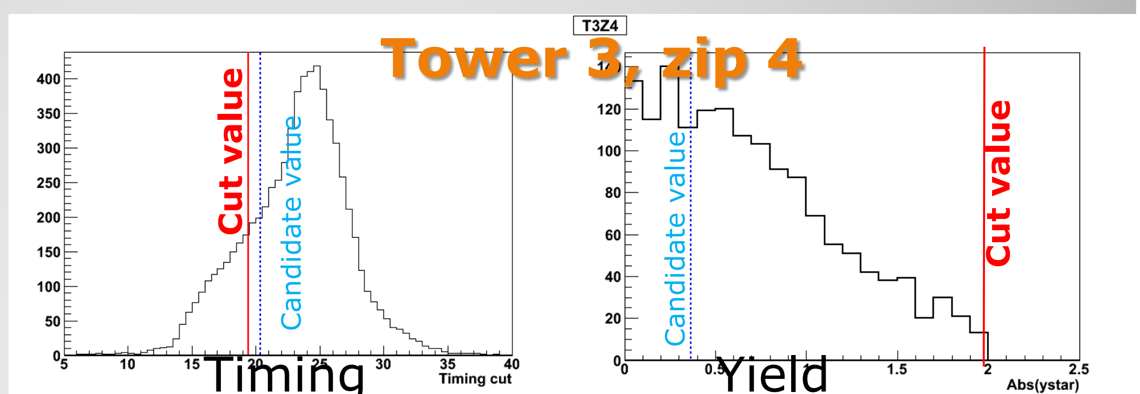
***Likelihood analysis encourages suspicion about event in T1Z5, and reconstruction makes us suspicious of event in T3Z4***

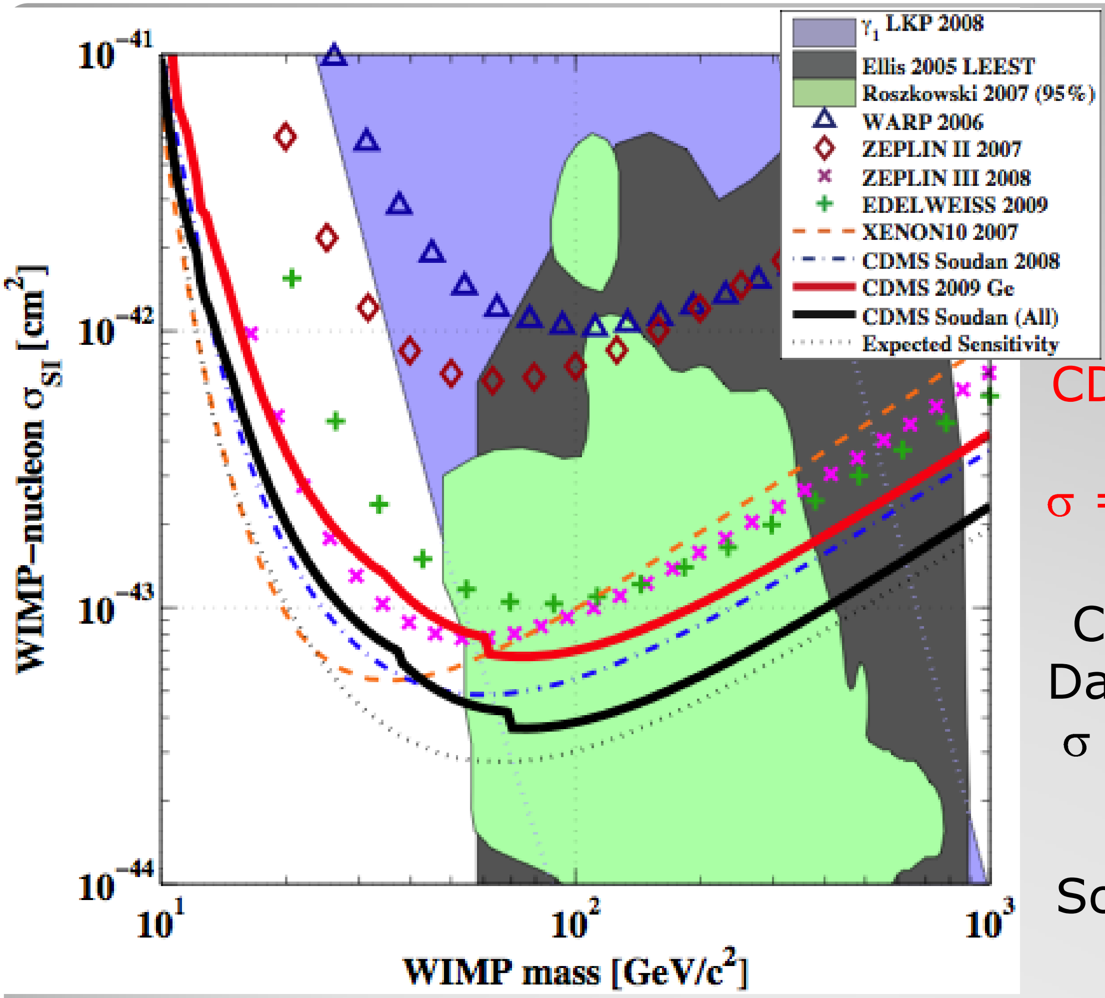
# Likelihood Analysis

**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.)

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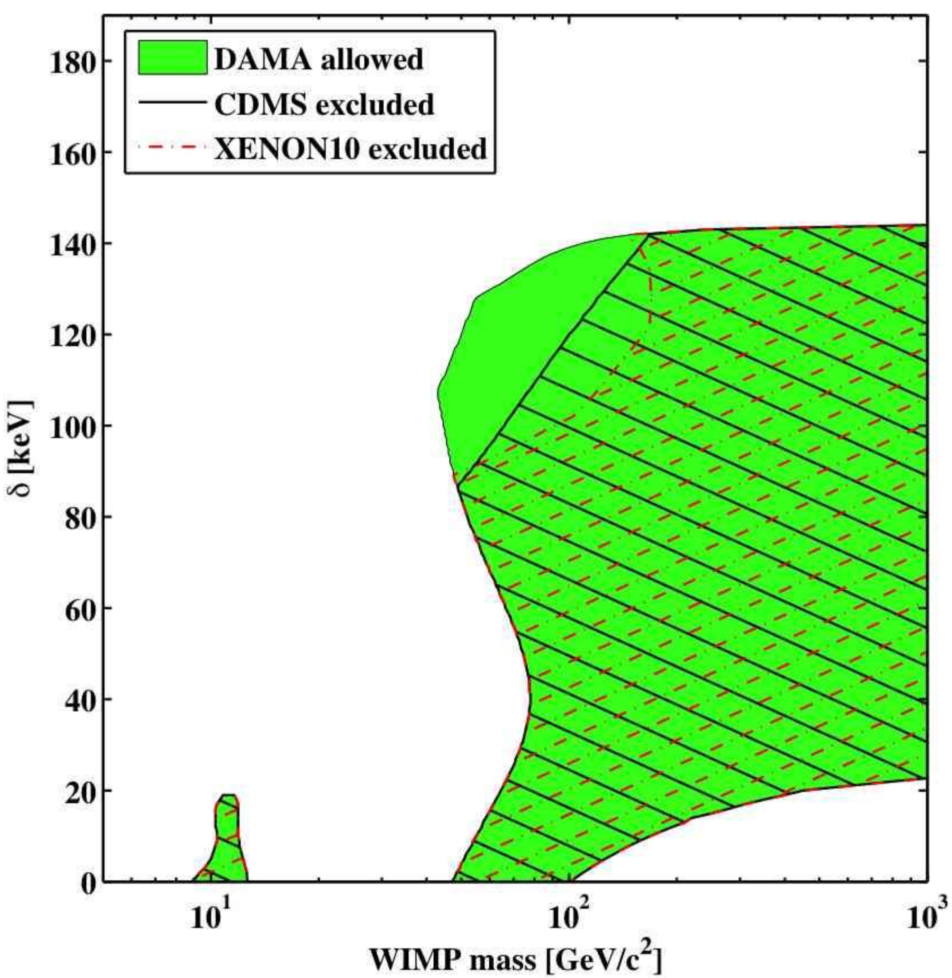
# Spin Independent Limit

# Inelastic dark matter

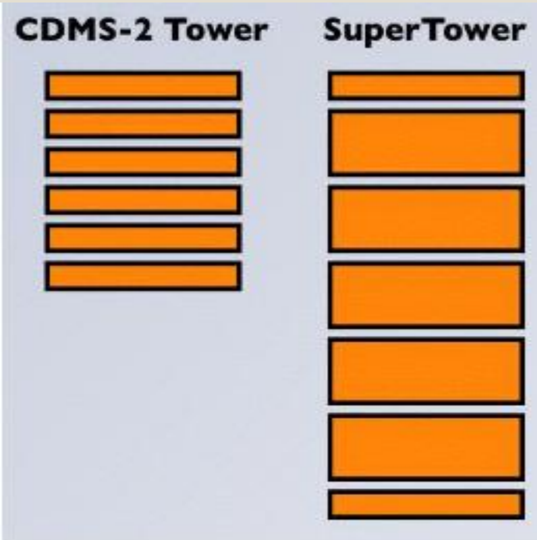


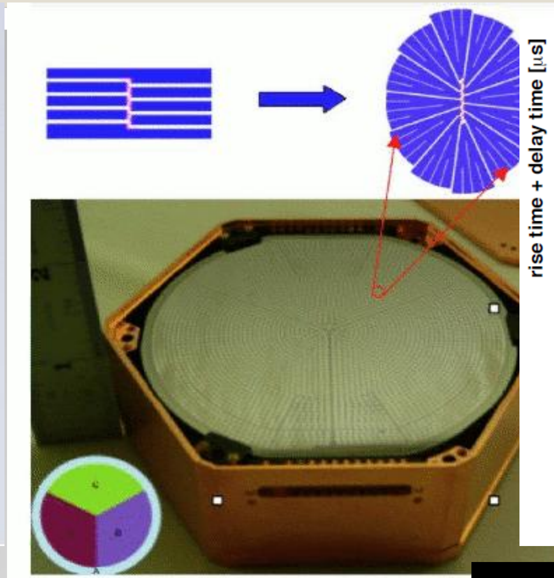

Has been invoked by Weiner et al. to explain DAMA/LIBRA data, among other things.
[Phys. Rev. D 64, 043502 (2001)]

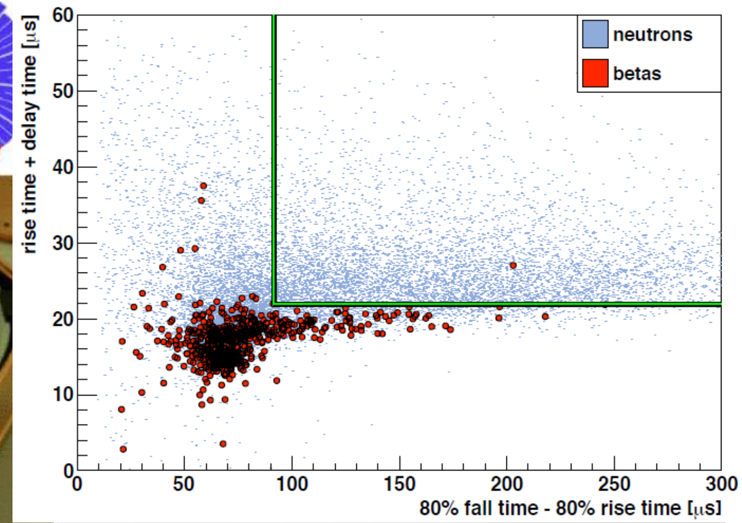
Scattering occurs via transition of WIMP to excited state (with mass splitting $\delta$)

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

# Next step: SuperCDMS mZIPs






New detectors are 2.5 times thicker

Installed in Soudan and successful engineering run Oct 2009-Dec2009

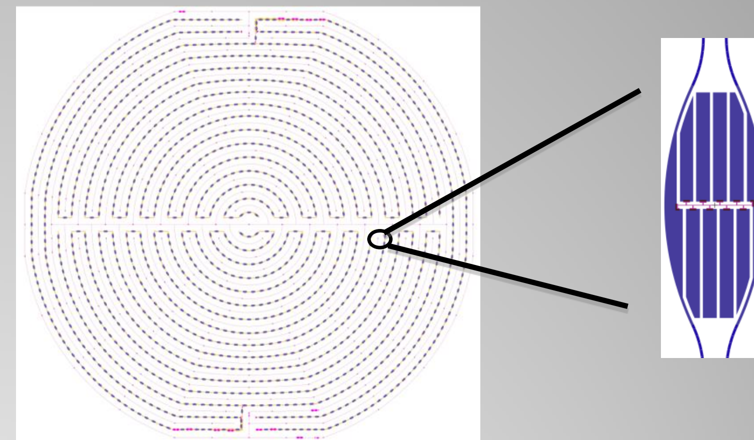
Based on backgrounds, surface discrimination, And neutron efficiency determined from the engineering run a 2yr mZIP exposure would result in a 4X improvement in sensitivity compared to CDMS II ($\sim 1X10^{-44}$ cm$^2$)

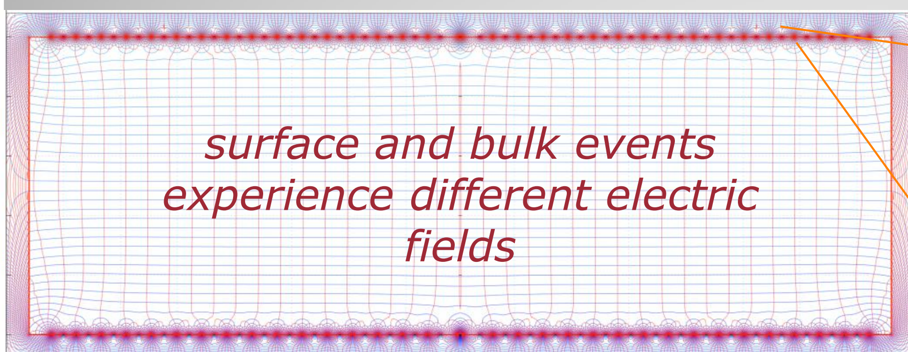
# Next generation of detector design: iZIP

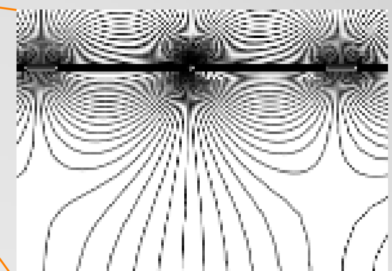
***iZIP = interleaved charge and phonon channels***

**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

- 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
  **$3.8 \times 10^{-44} cm^2$ 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

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

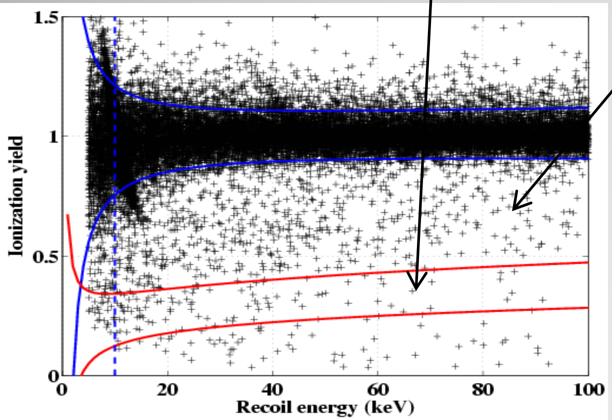
*3 independent sidebands for estimating the passing/failing ratio*

## SIDEBAND 1

Use multiple-scatters in NR band

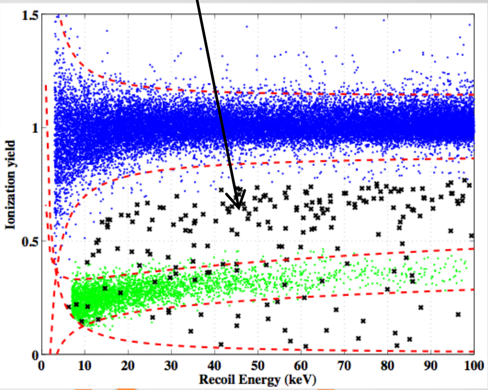
## SIDEBAND 2

Use singles and multiples just outside NR band




## SIDEBAND 3

Use singles and multiples from Ba calibration in wide region



# Neutron Background Estimates

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

*From GEANT4 and FLUKA simulations*

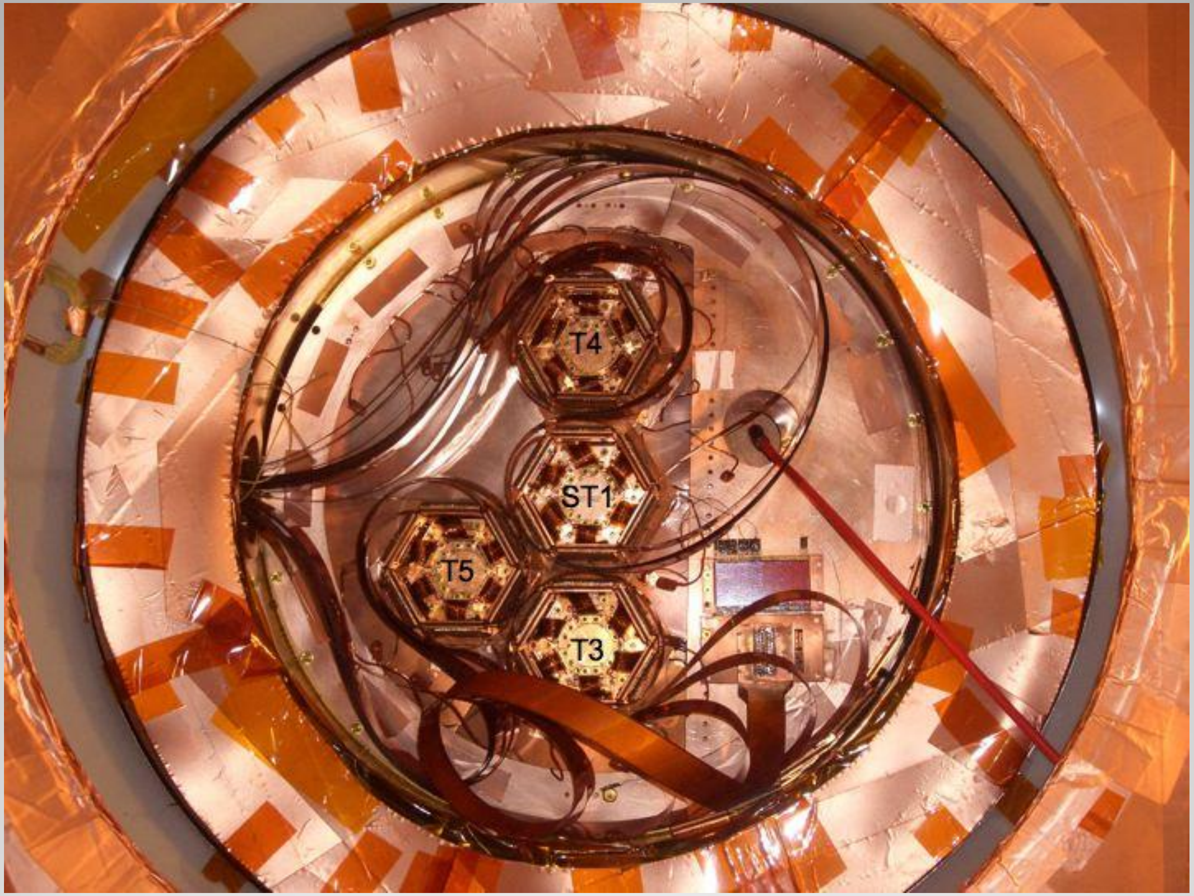
*3 vetoed, single NR (in Soudan dataset)*

*correct for efficiency and exposure*

Radiogenic Neutron Estimate:

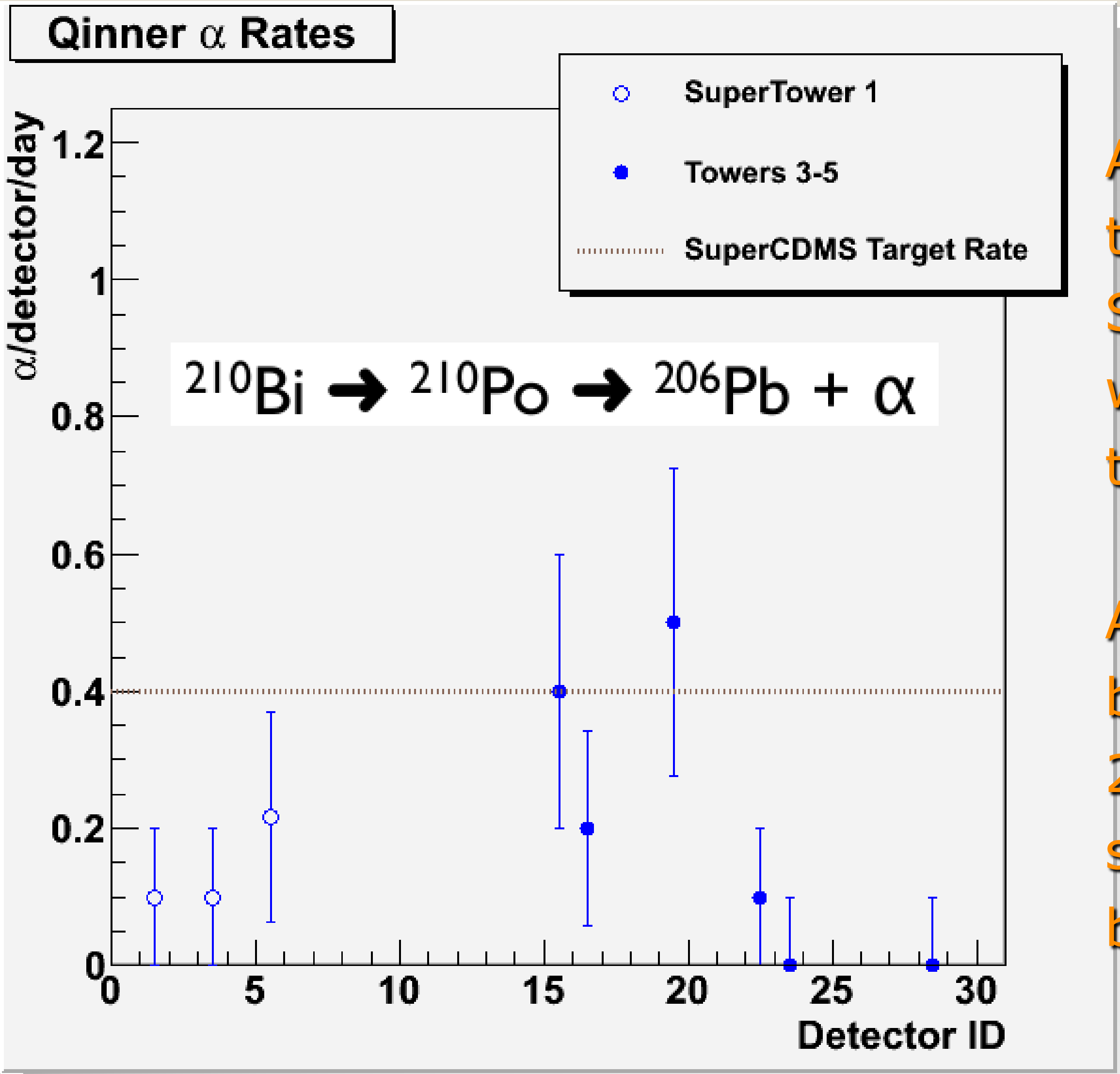
0.03 - 0.06 events

*- fission, ($\alpha$,n) in Cu, Poly, Pb*




# SuperTower installation

# First look at surface backgrounds



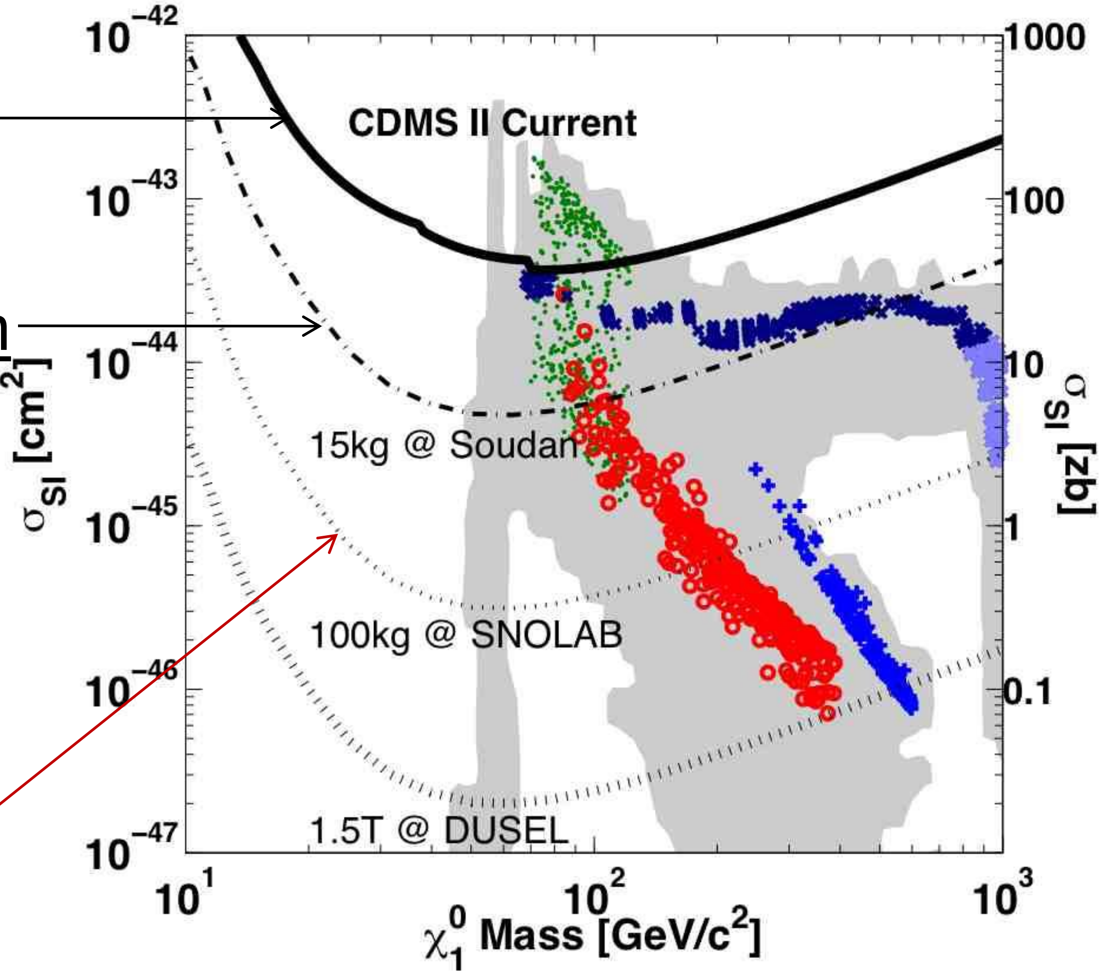

A preliminary look at the Alpha rate for SuperTower 1 shows we are ~2X better than our target rate

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

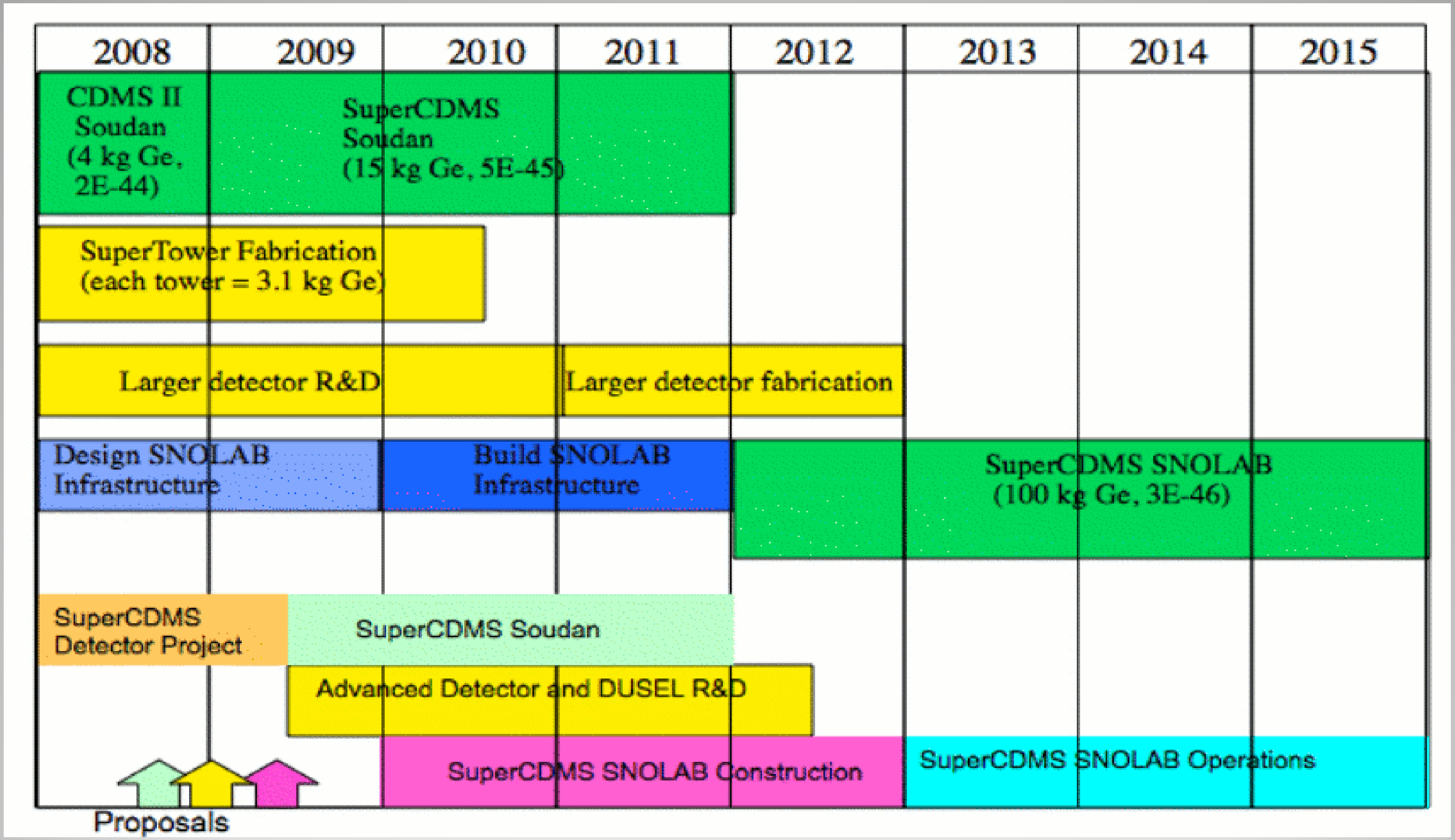
CDMS II
4 kg Ge
~ 2 yrs operation

SuperCDMS @ Soudan
15 kg Ge
~ 2 yrs operation

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

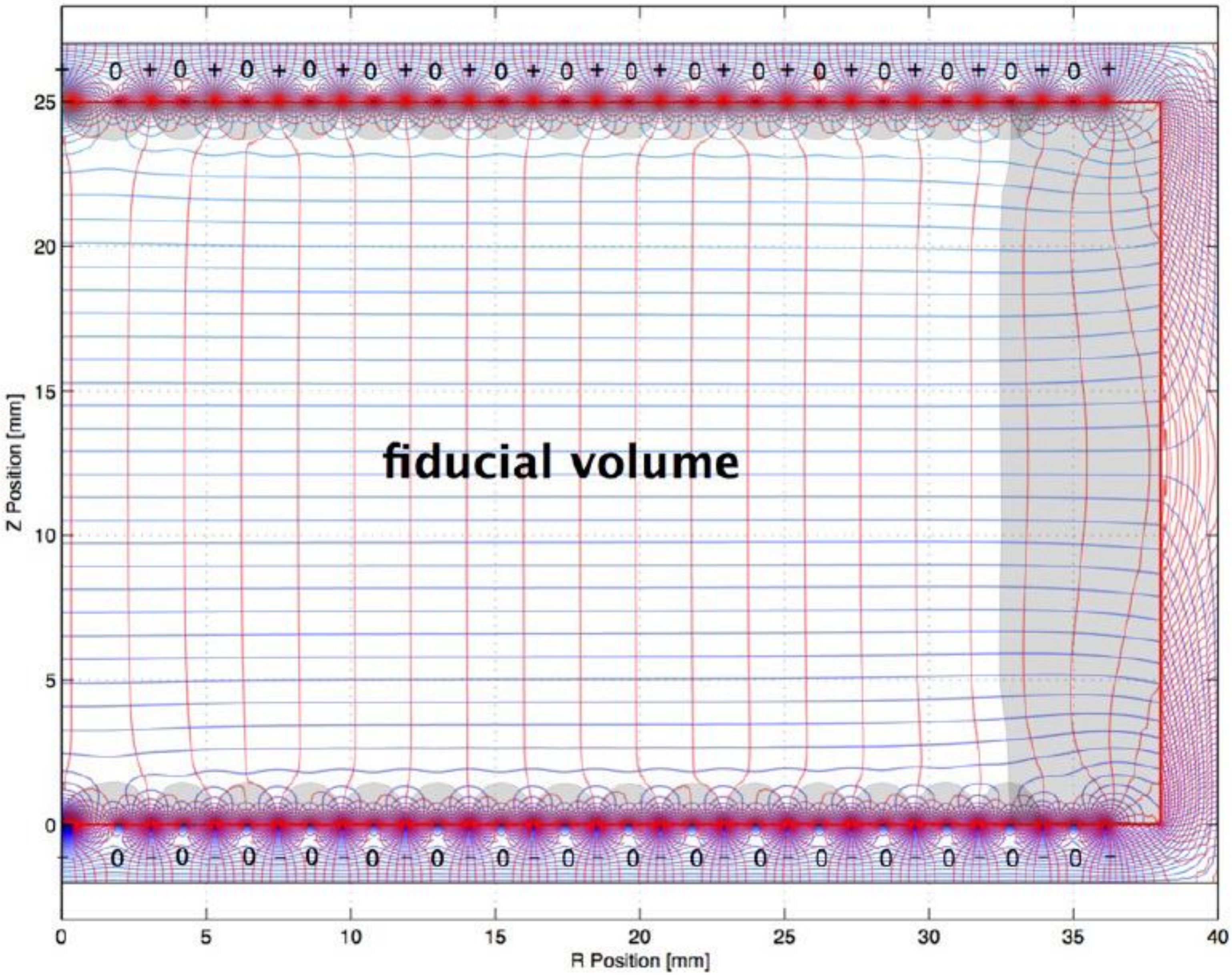


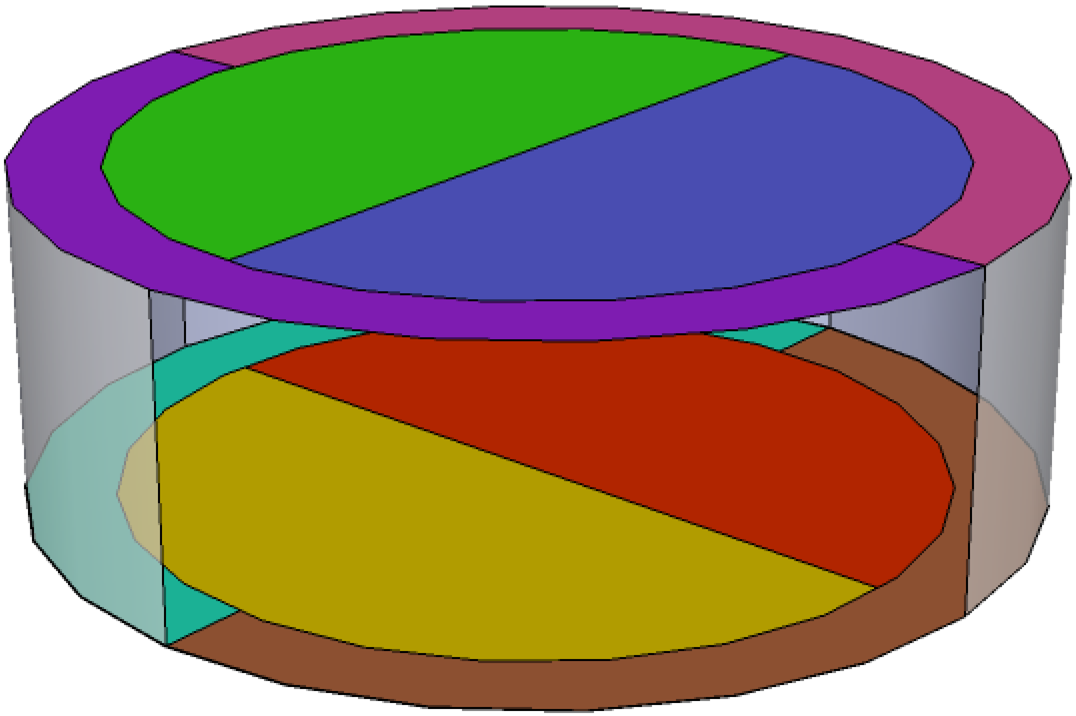

# Future projections

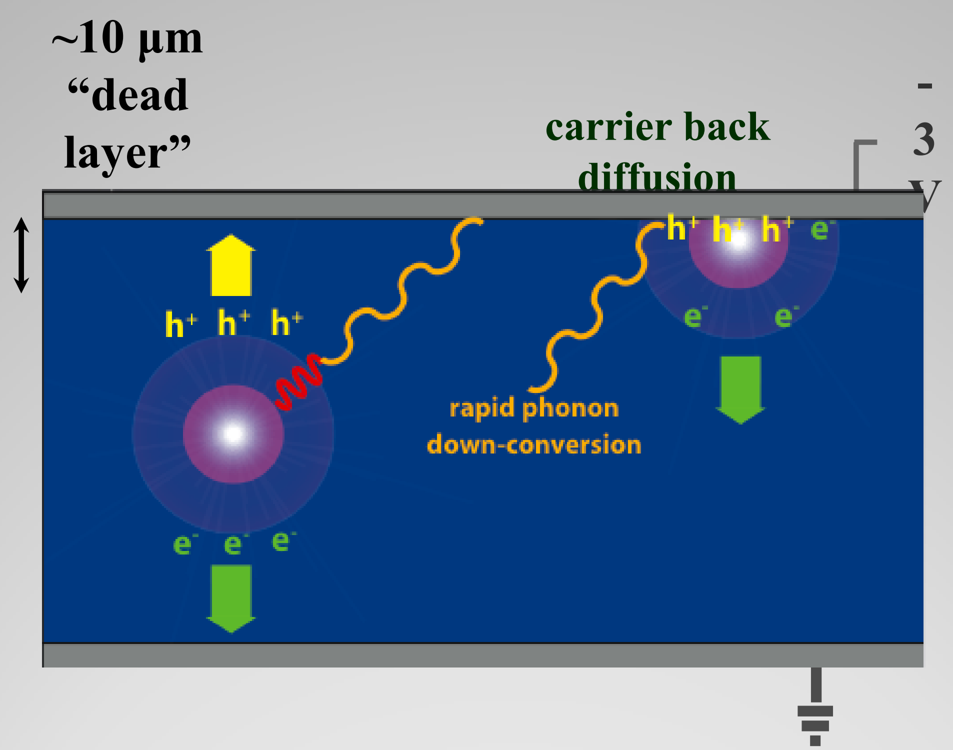


2008
2009
2010
2011
2012
2013
2014
2015
CDMS II Soudan (4 kg Ge, 2E-44)
SuperCDMS Soudan (15 kg Ge, 5E-45)
SuperTower Fabrication (each tower = 3.1 kg Ge)
Larger detector R&D
Larger detector fabrication
Design SNOLAB Infrastructure
Build SNOLAB Infrastructure
SuperCDMS SNOLAB (100 kg Ge, 3E-46)
SuperCDMS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


# Timeline


fiducial volume
Z Position [mm]
R Position [mm]
0
5
10
15
20
25
30
35
40






# Surface events

# Phonon detection