FIRST DARK MATTER RESULTS FROM THE CDMS 5-TOWER RUN AND THE PATH TOWARDS $\sigma = 10^{-45}$ CM^2 WIMP SENSITIVITY

Tarek Saab
for the CDMS Collaboration

SUSY 08, Seoul, Korea

The CDMS Collaboration

- Caltech
- Case Western Reserve
- FNAL
- Florida
- LBNL
- MIT
- NIST
- Queen's
- Santa Clara
- Stanford
- Syracuse
- UC Berkeley
- UC Denver
- UC Santa Barbara
- Minnesota
- Zurich

PRINCIPLES OF DIRECT DETECTION

Input from Particle Physics

$$\sigma_0 = \left(\frac{m_r}{m_{r-p}}\right)^2 A^2 \sigma_{\chi-p}$$

Knowledge of Nuclear Structure

$$F^2(Q) = \left[\frac{3j_1(qR_1)}{qR_1}\right]^2 \exp\left(-(qs)^2\right)$$

$$\frac{dR}{dE_R} = \frac{\sigma_0 \rho_0}{\sqrt{\pi} v_0 m_\chi m_r^2} F^2(Q) T(Q)$$

Our choice of Target Nucleus

$$m_r = \frac{m_\chi m_N}{m_\chi + m_N}$$

$$m_{r-p} = \frac{m_\chi m_p}{m_\chi + m_p}$$

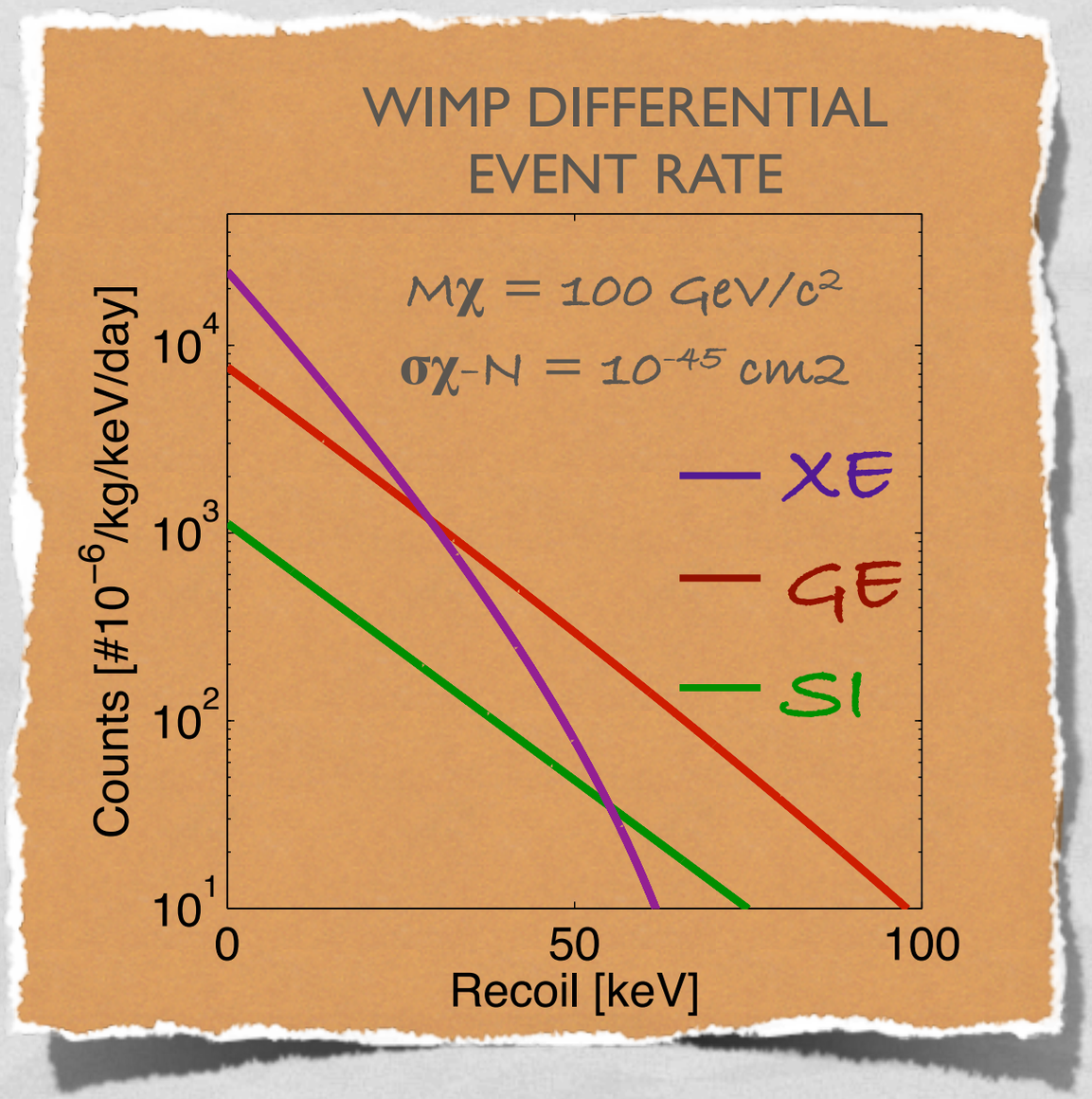
Input from Astrophysics

$$T(Q) = \exp\left(-v_{min}^2/v_0^2\right)$$

$$v_{min} = \sqrt{\frac{E_R m_N}{2m_r^2}} \qquad v_0 \approx 220\,\mathrm{km/s}$$

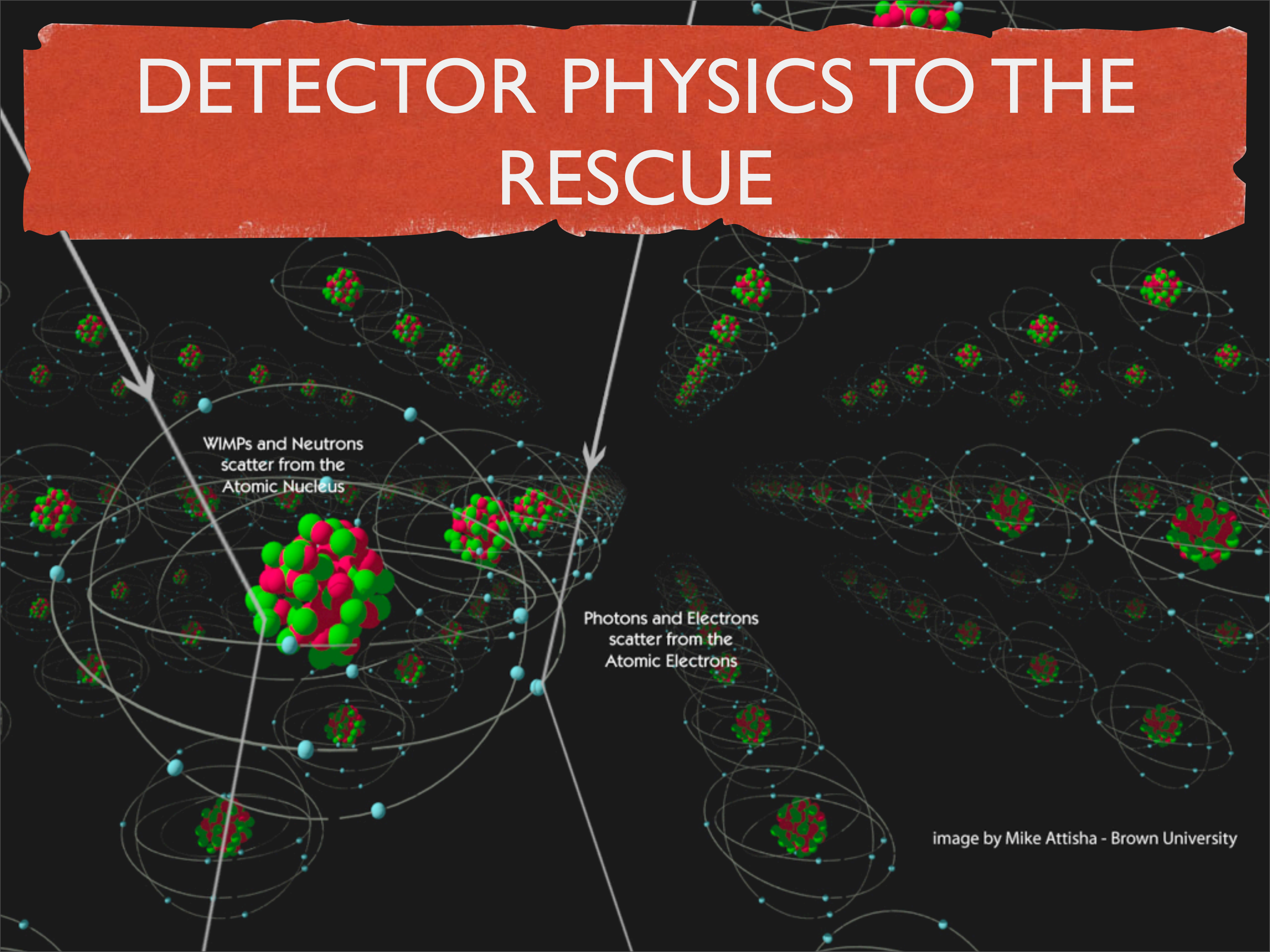
WIMP HUNTING

- Elastic scattering of a WIMP from a nucleus deposits a small, but detectable amount of energy ~ few x 10 keV
- Featureless exponential energy spectrum
  - no obvious peak, knee, break, ... that determines Mχ
- **Expected rate << 0.01/kg-day**
- Radioactive background million times higher
- Background Reduction/Rejection is key



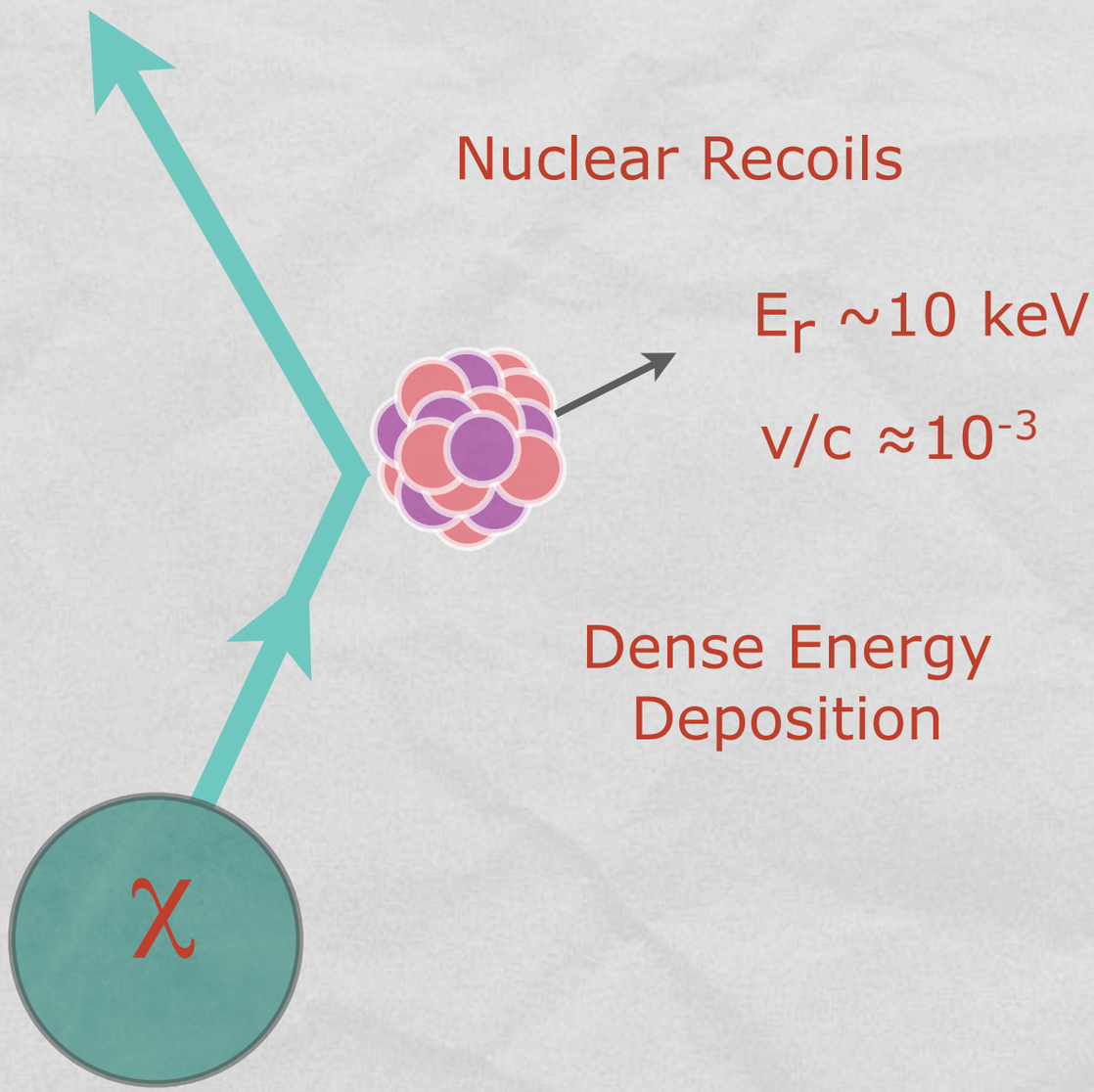
Low→no Background a Must for WIMP Discovery

DETECTOR PHYSICS TO THE RESCUE

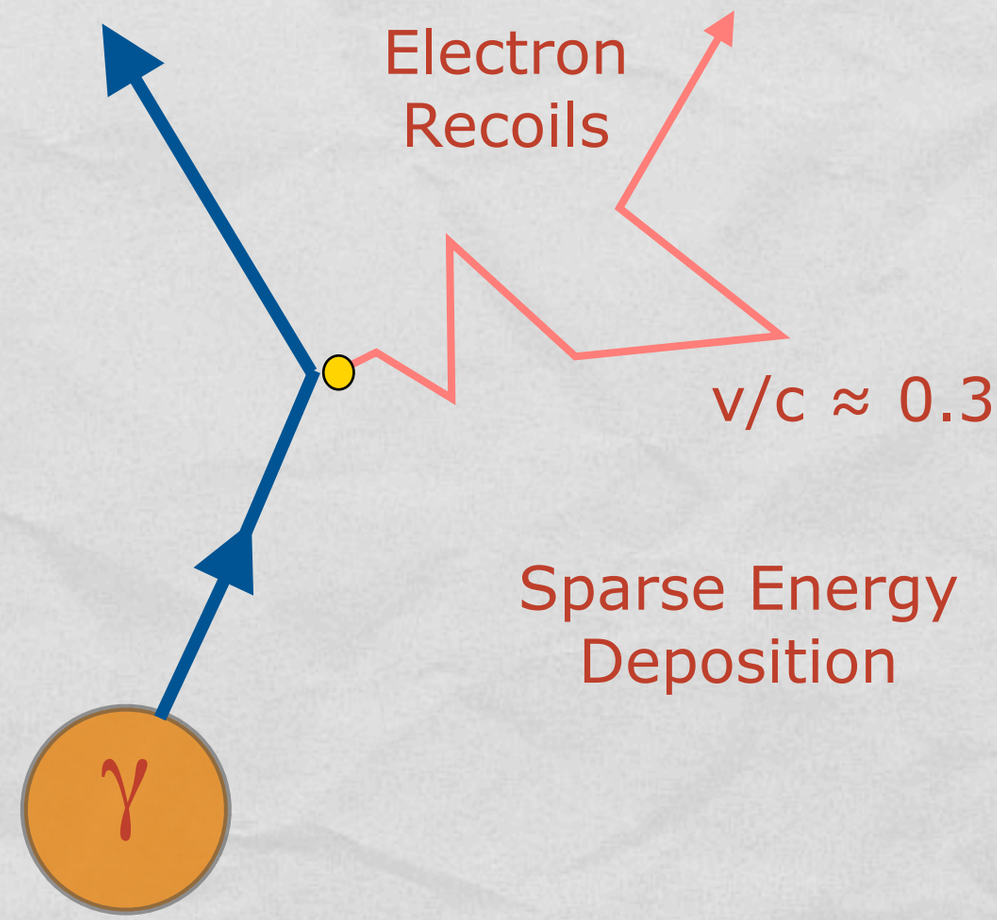


TWO TYPES OF RECOIL

Signal

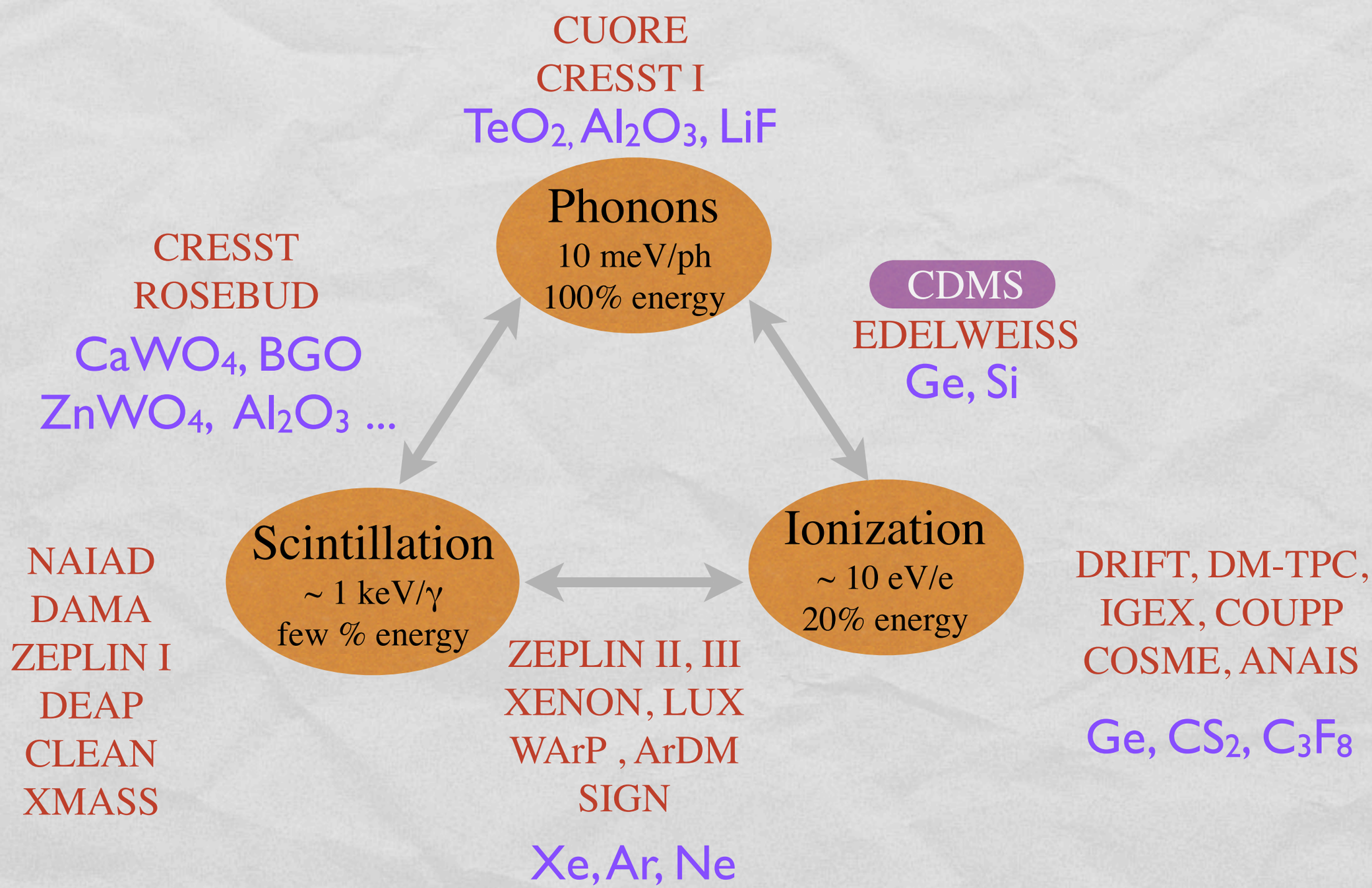


Background



Density/Sparsity: Basis of Discrimination

DISCRIMINATION STRATEGIES



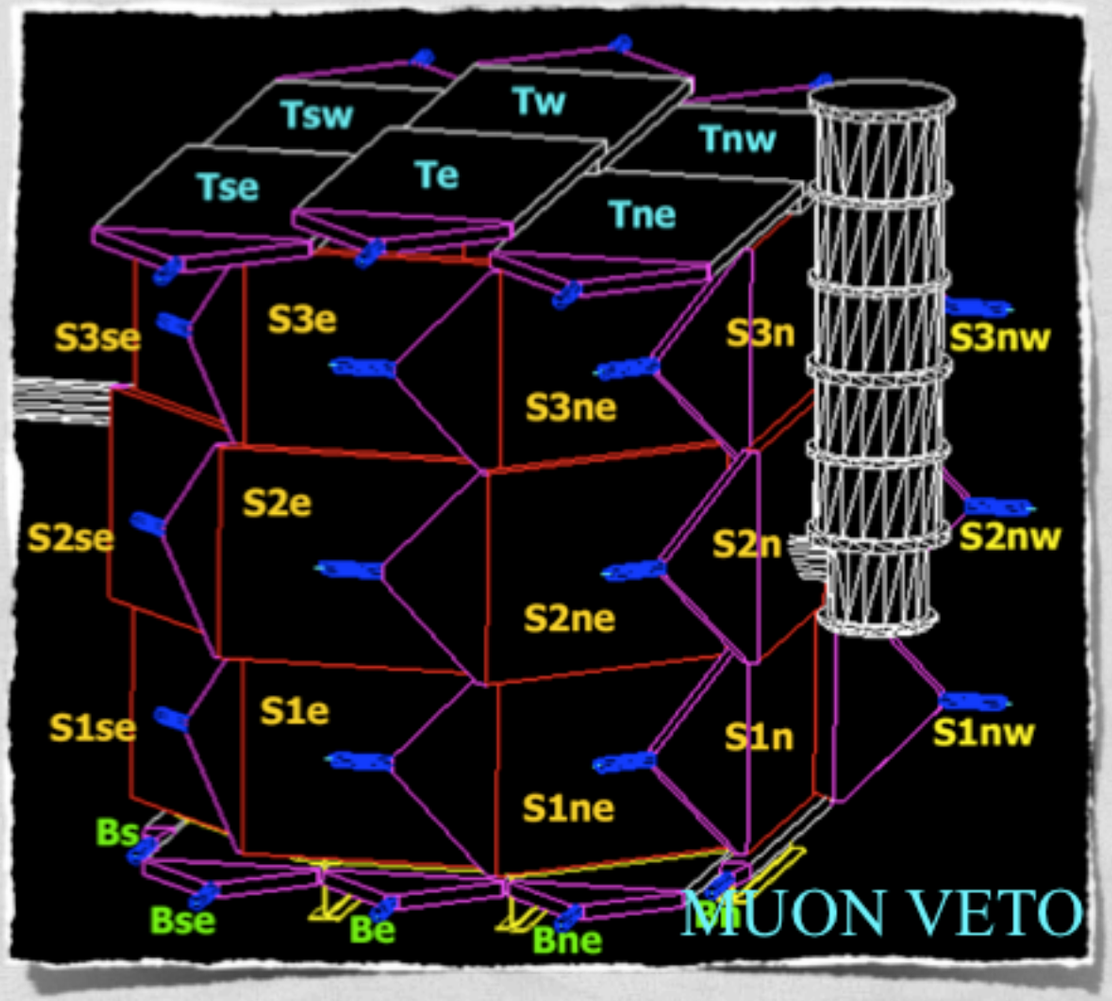
CDMS: THE BIG PICTURE

Use shielding and discrimination to maintain a Background Free experiment with cryogenic semiconductor detectors

- Shielding
  - Passive: Mine Depth, Pb, Poly
  - Active: muon veto shield
- Energy Measurement/Discrimination
  - Phonon (Full recoil energy)
  - Ionization (Reduced for nuclear recoil wrt electron recoils)
- Position measurement (x,y,z)
  - From phonon pulse timing

CDMS APPARATUS

- Surround detectors with active muon veto
- Use passive shielding to reduce γ/n
  - Overburden reduces μ-induced neutrons
  - Polyethylene for low-energy neutron
  - Lead and Copper for gammas
- 5 Towers now installed and taking data



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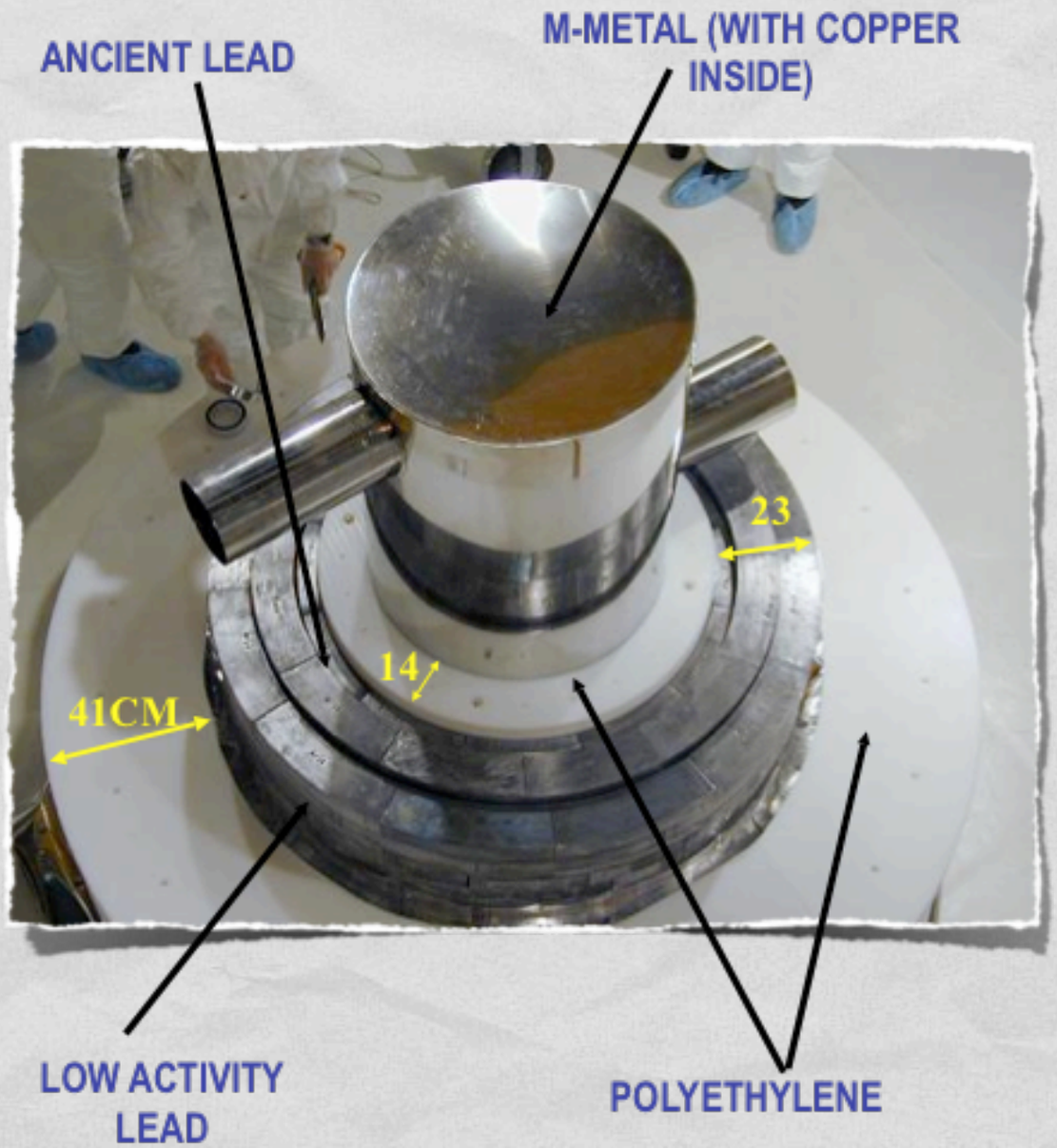

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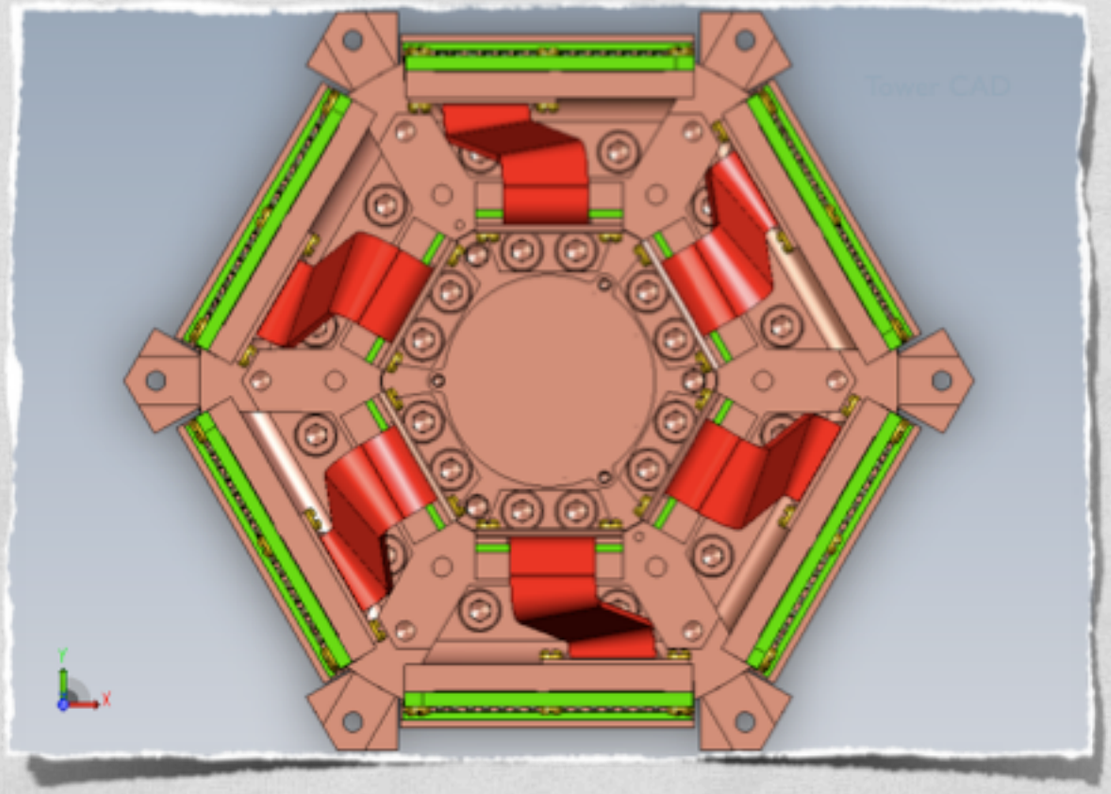

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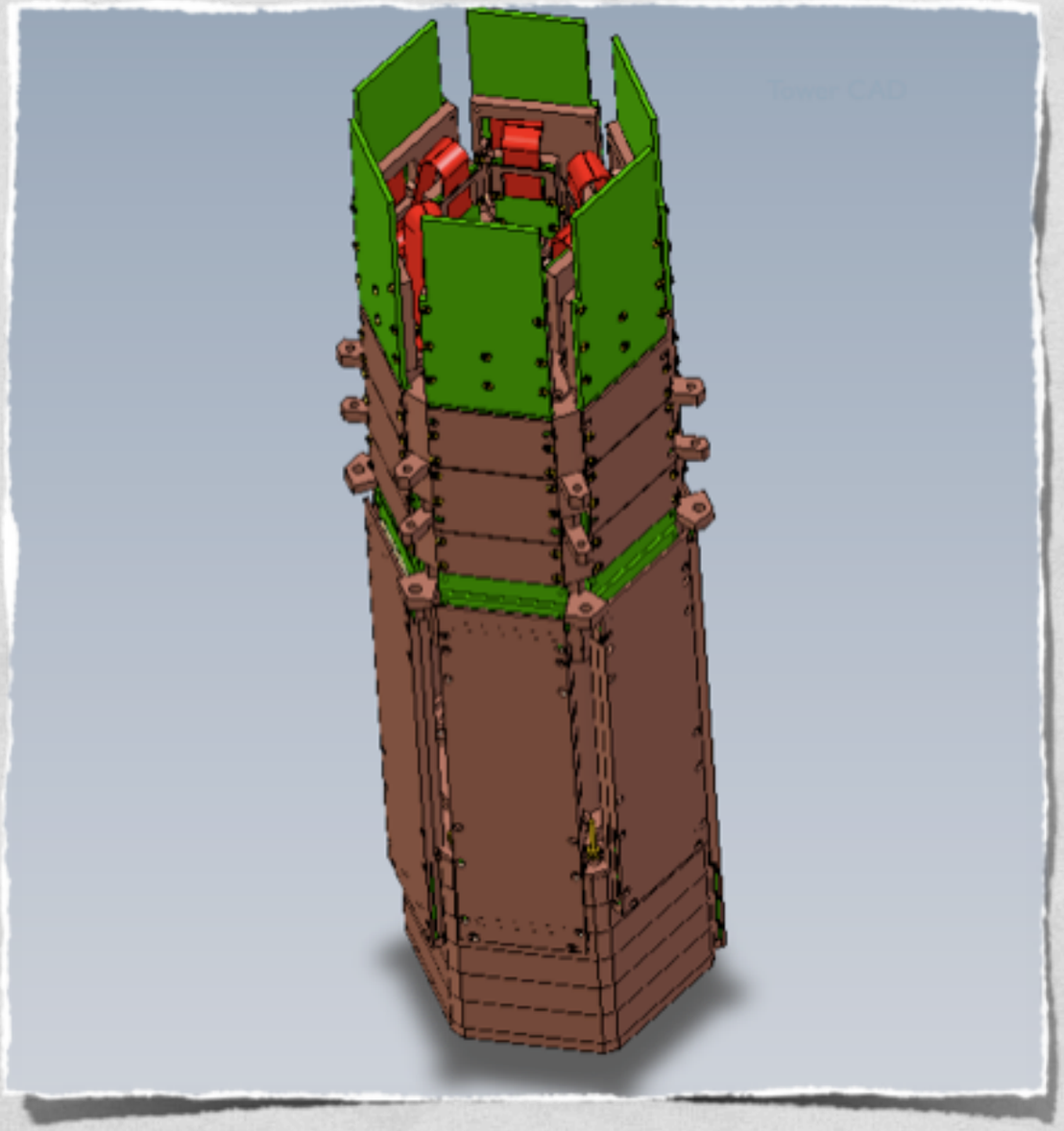

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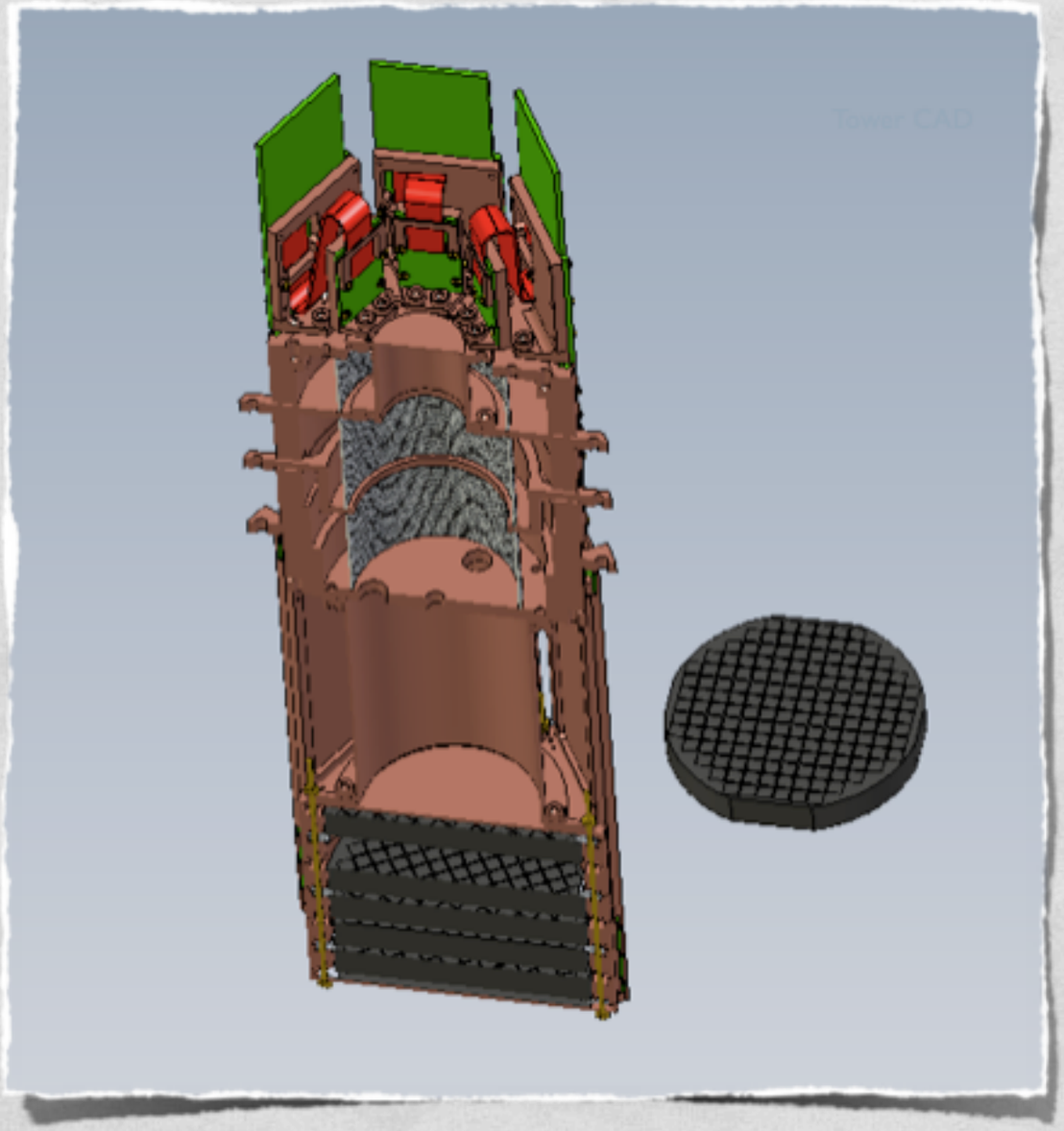

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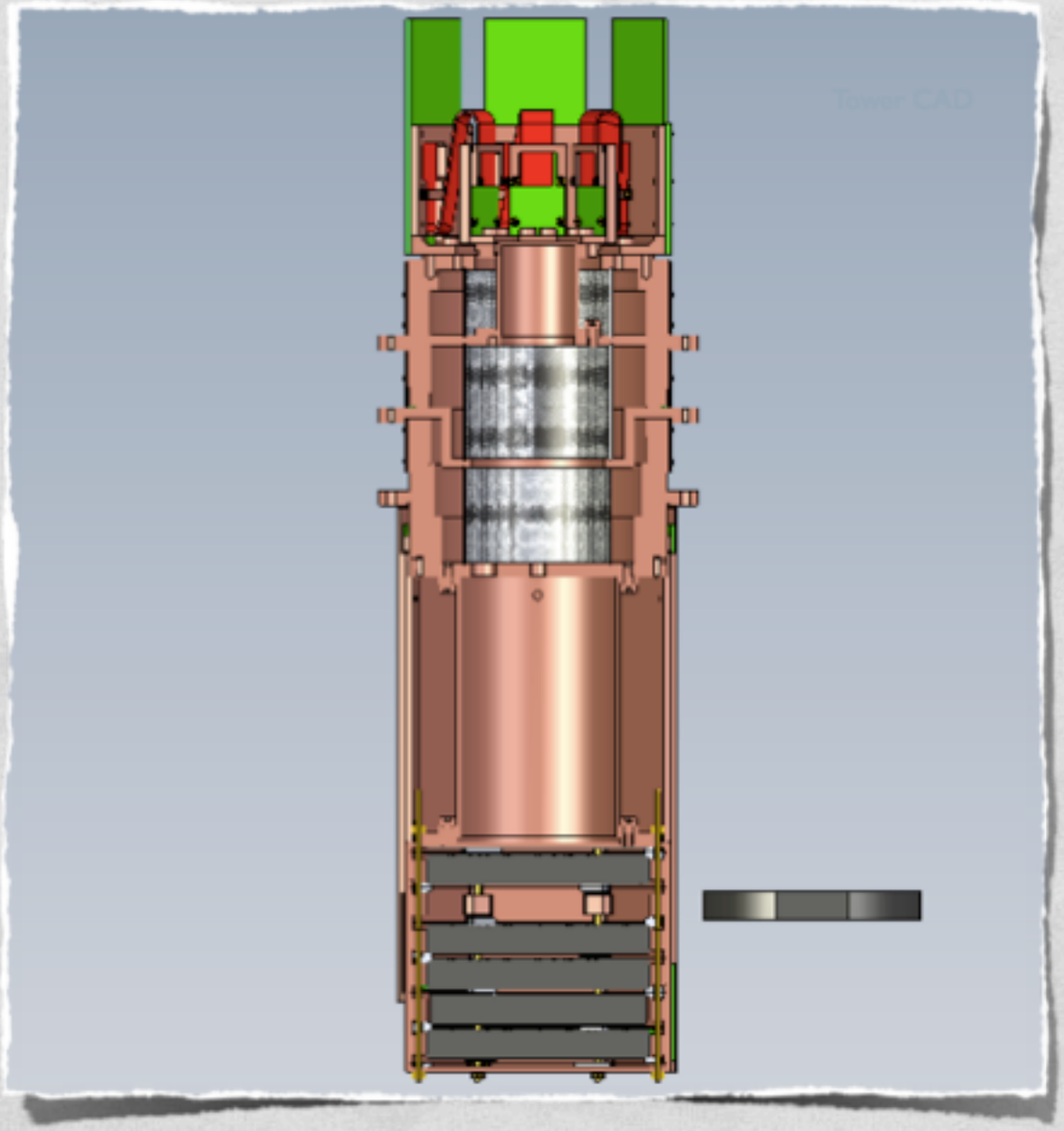

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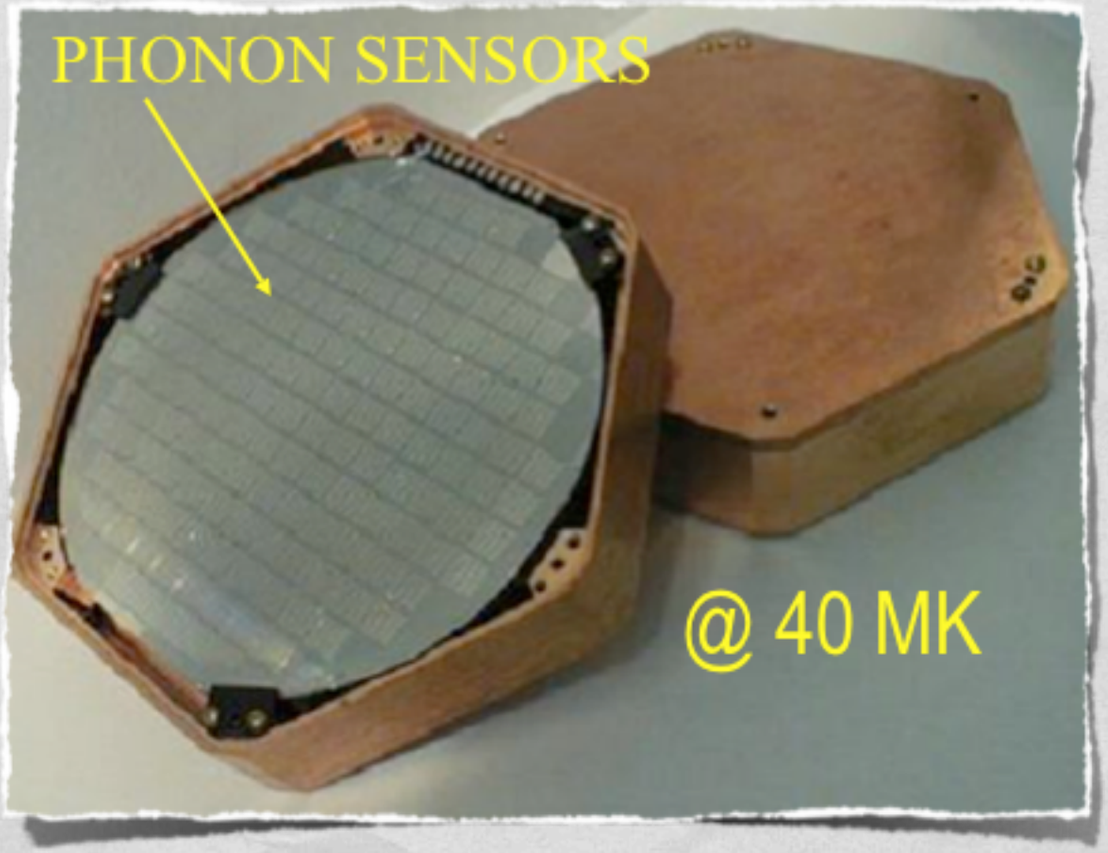
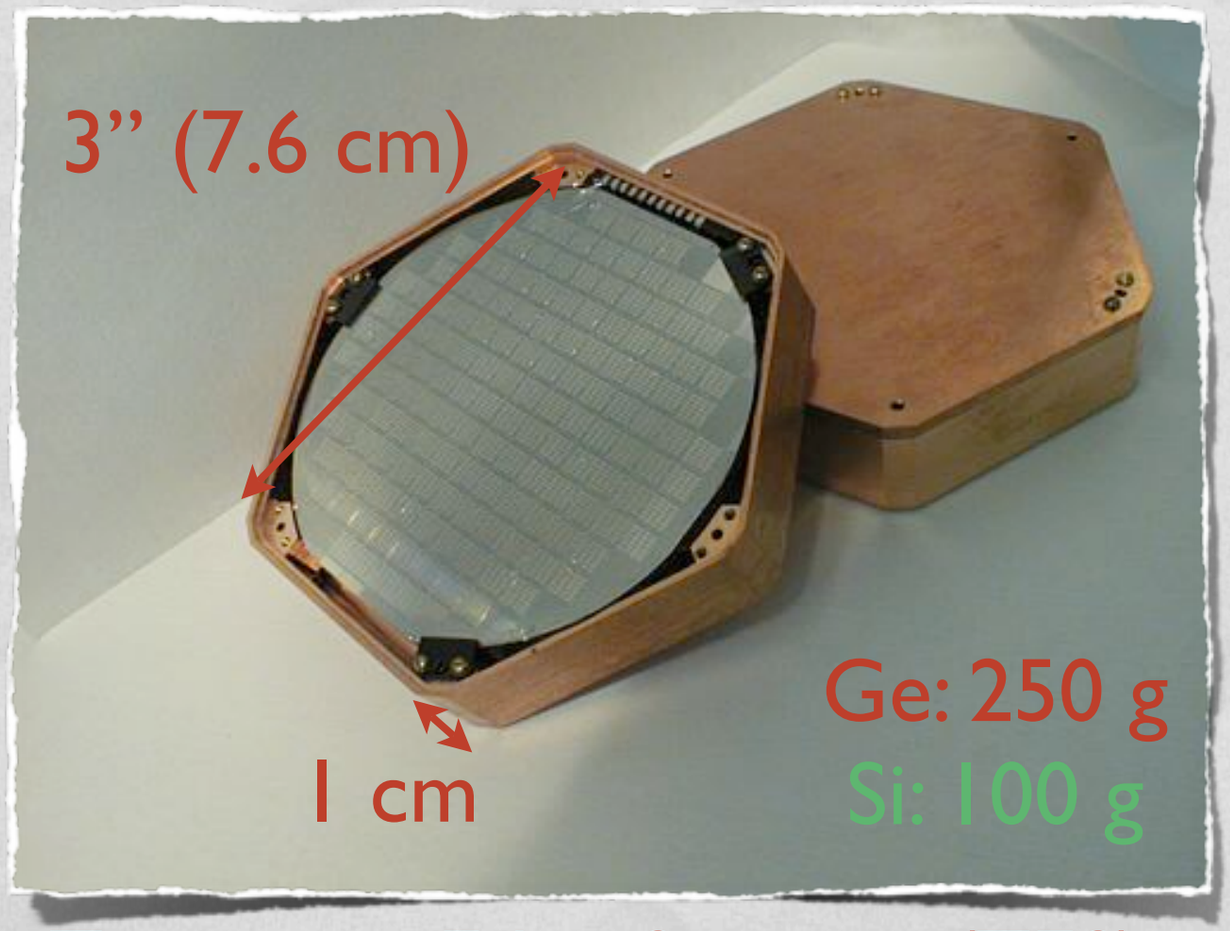


Z-SENSITIVE IONIZATION PHONON DETECTORS

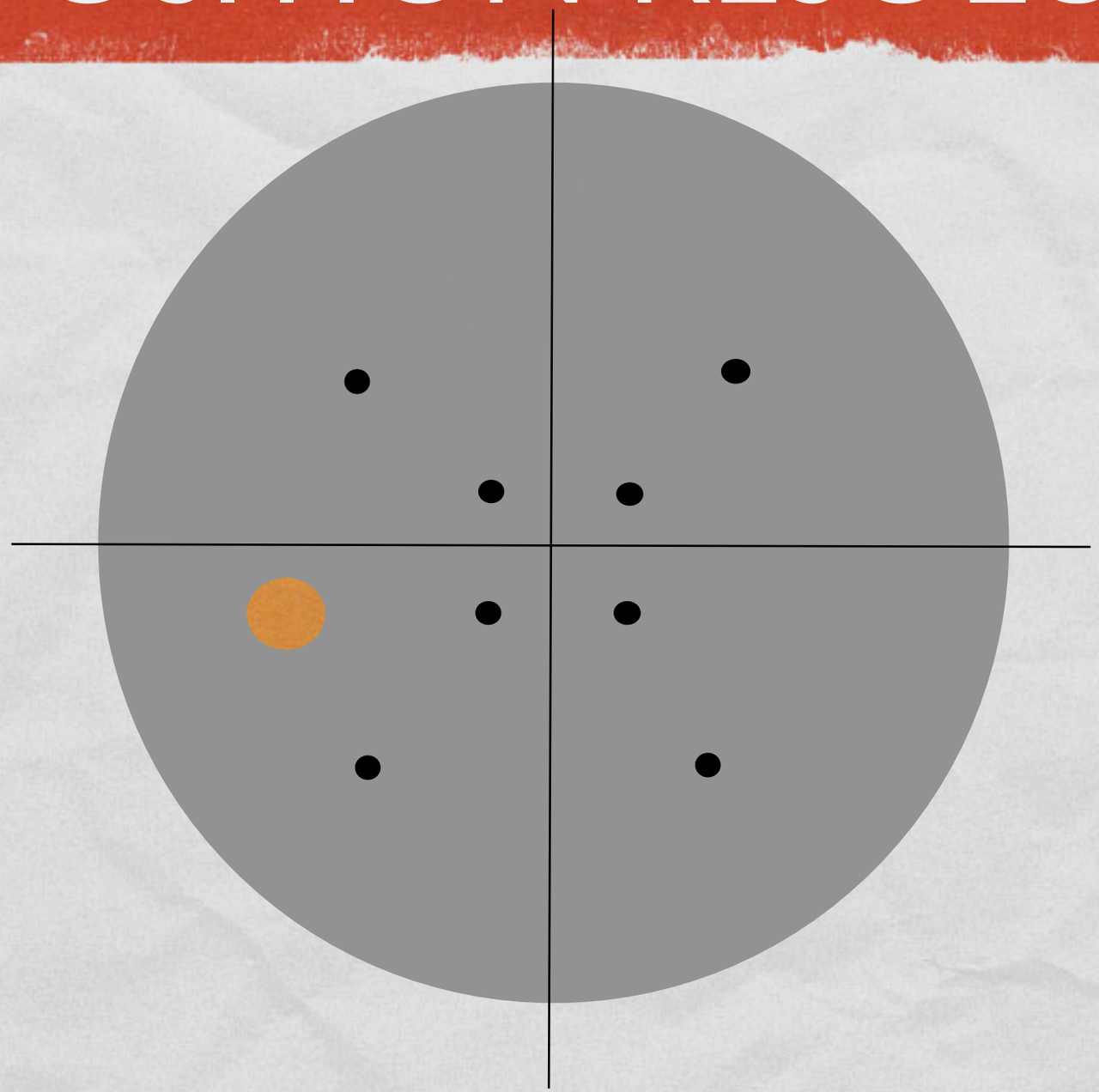


Transition Edge Sensors (TES)
Operated at ~40 mK for good phonon signal-to-noise

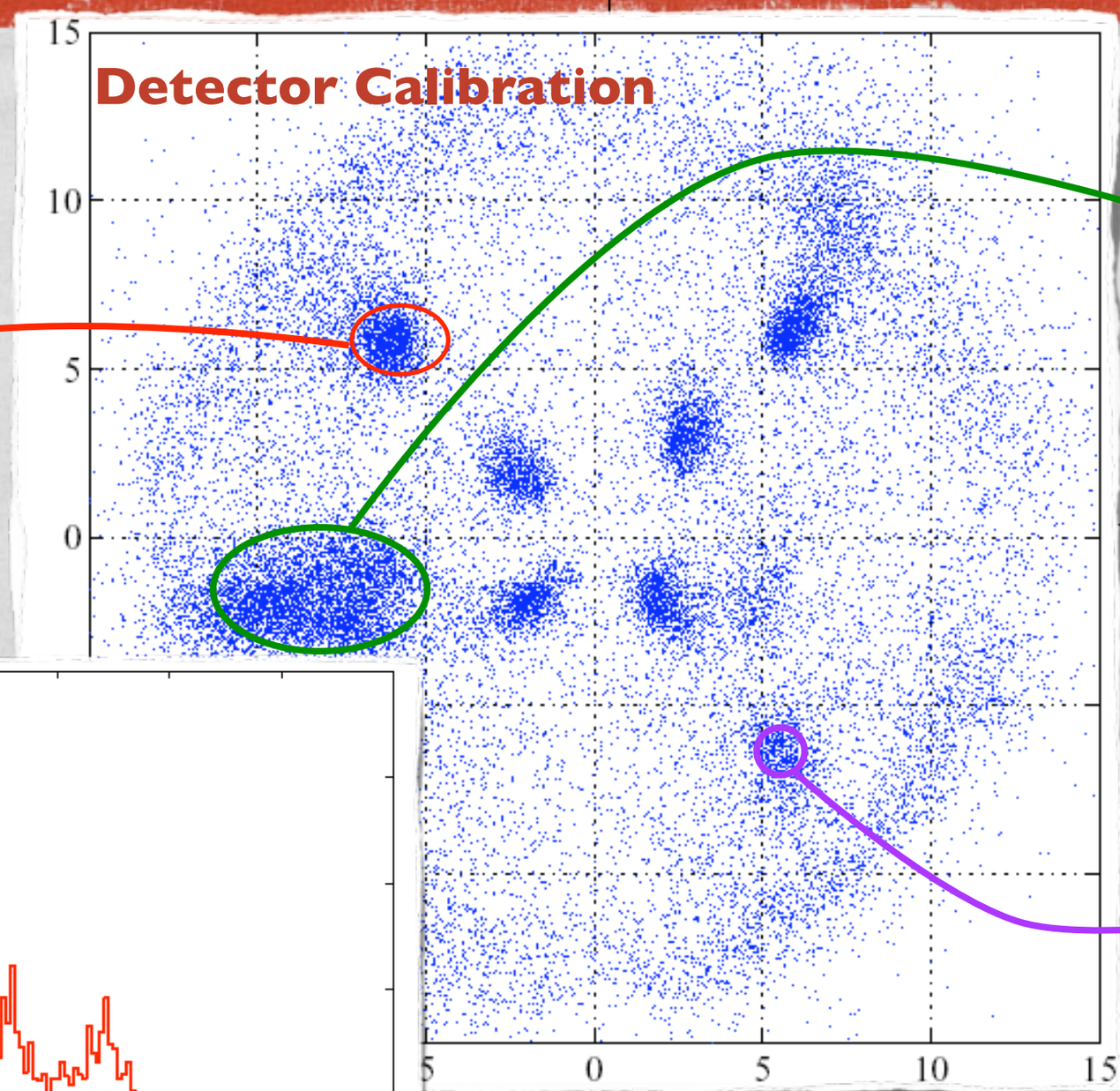
Phonon side: 4 quadrants of athermal phonon sensors
Energy & Position (Timing)

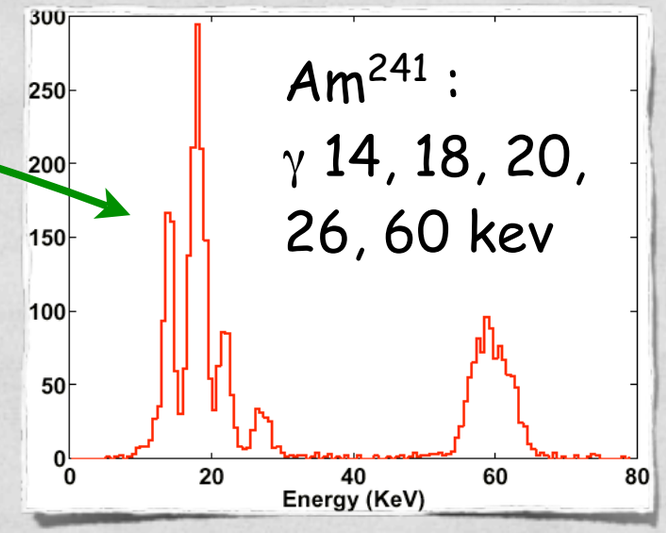
Charge side: 2 concentric electrodes (Inner & Outer)
Energy (& Veto)

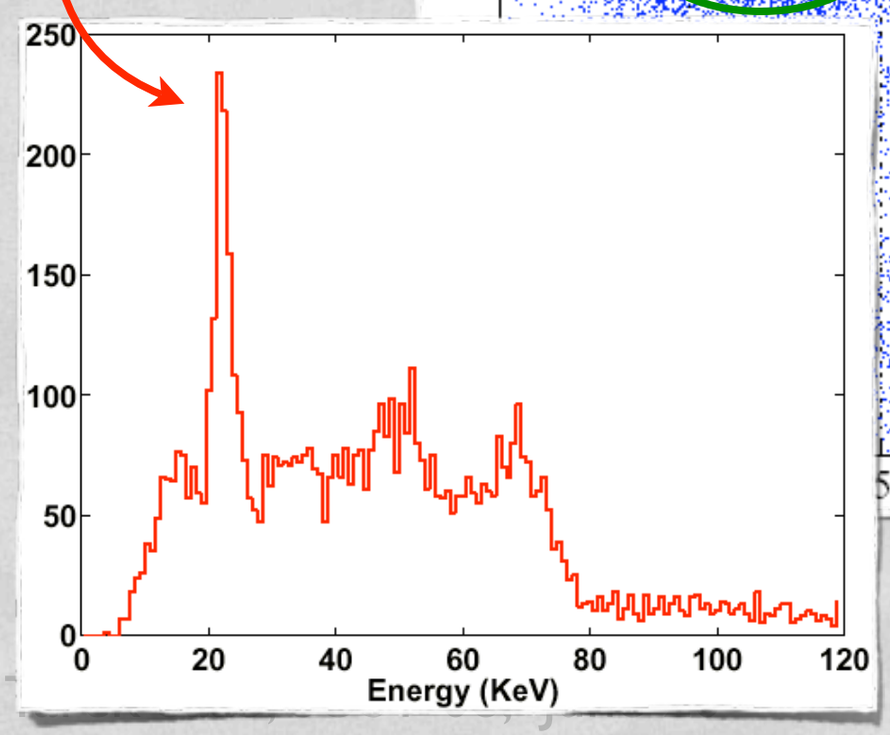
EXCELLENT ENERGY, POSITION RESOLUTION

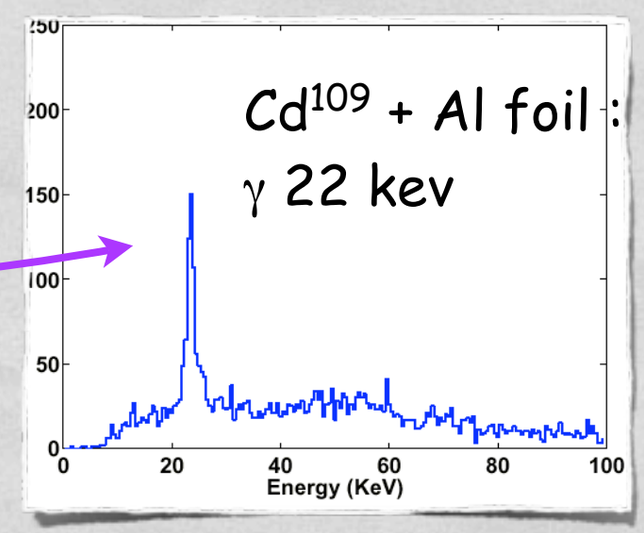


EXCELLENT ENERGY, POSITION RESOLUTION

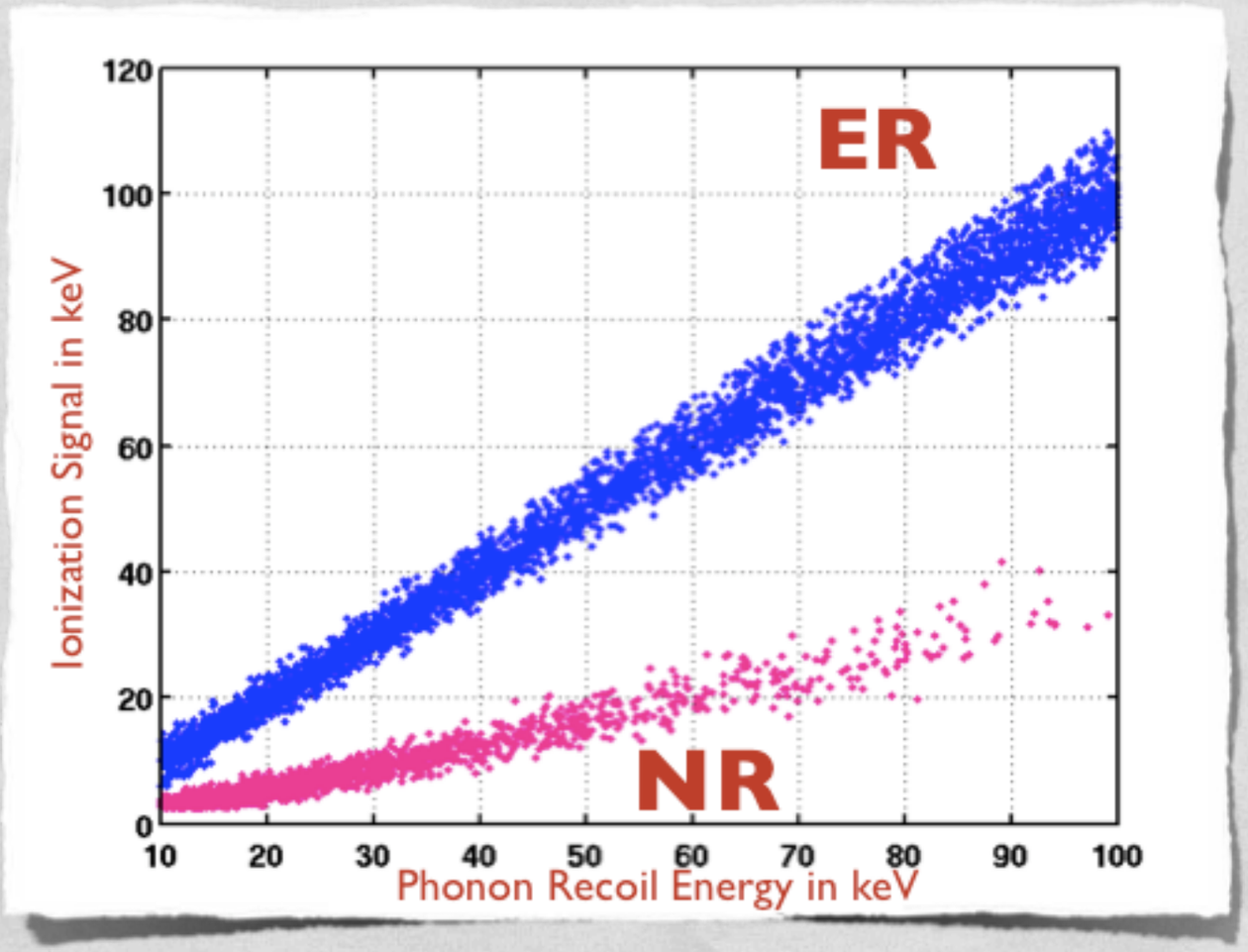








EXCELLENT PRIMARY (γ) BACKGROUND REJECTION



- Radioactive source data defines the signal (NR) and background (ER)
- Yield = Ionization/Phonon
  Most effective Particle ID
- $>10^4$ Rejection of γ
- Drooping events from β Ionization collection incomplete on surface. Yield can be sufficiently low to pollute the signal region

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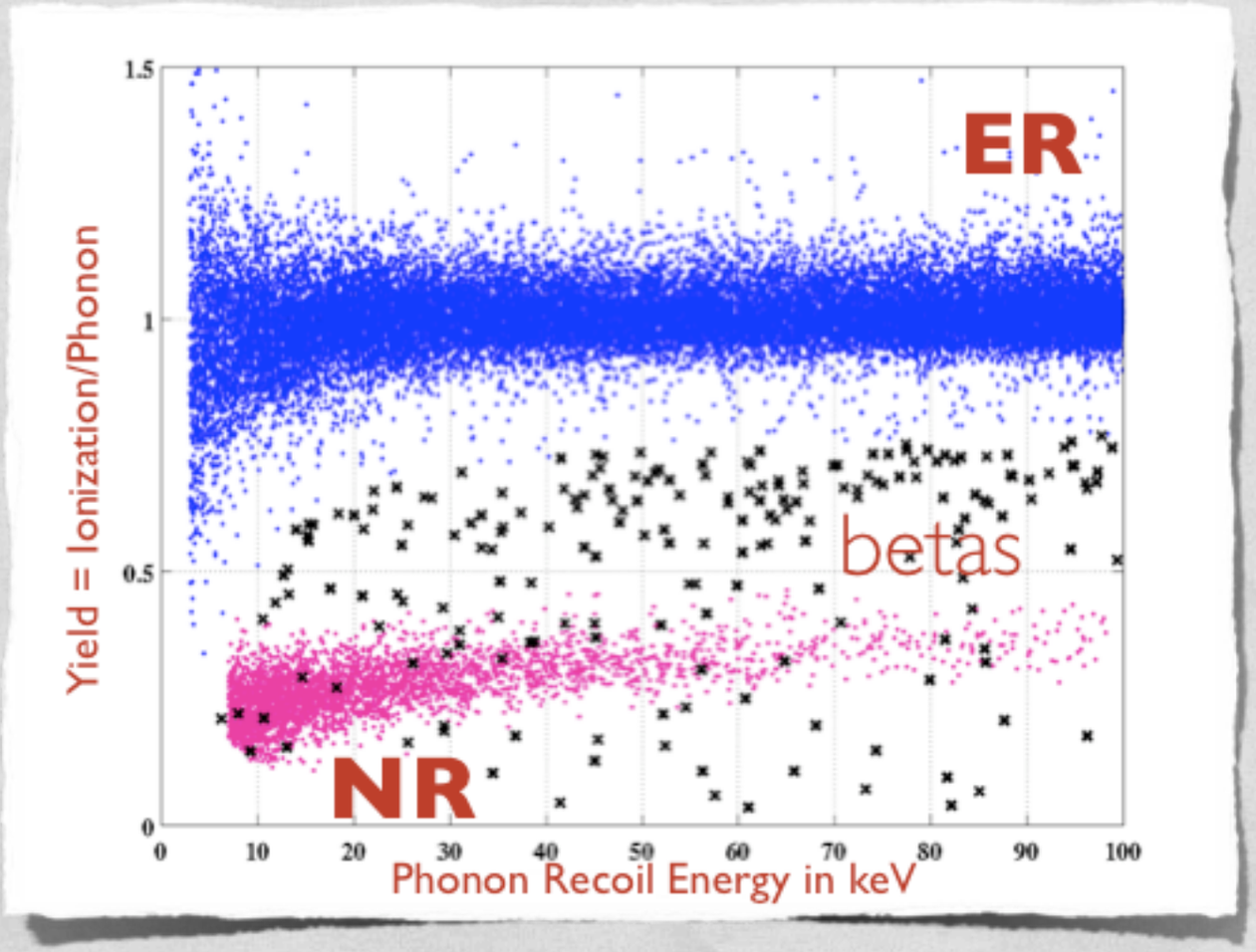

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- Yield = Ionization/Phonon
  Most effective Particle ID
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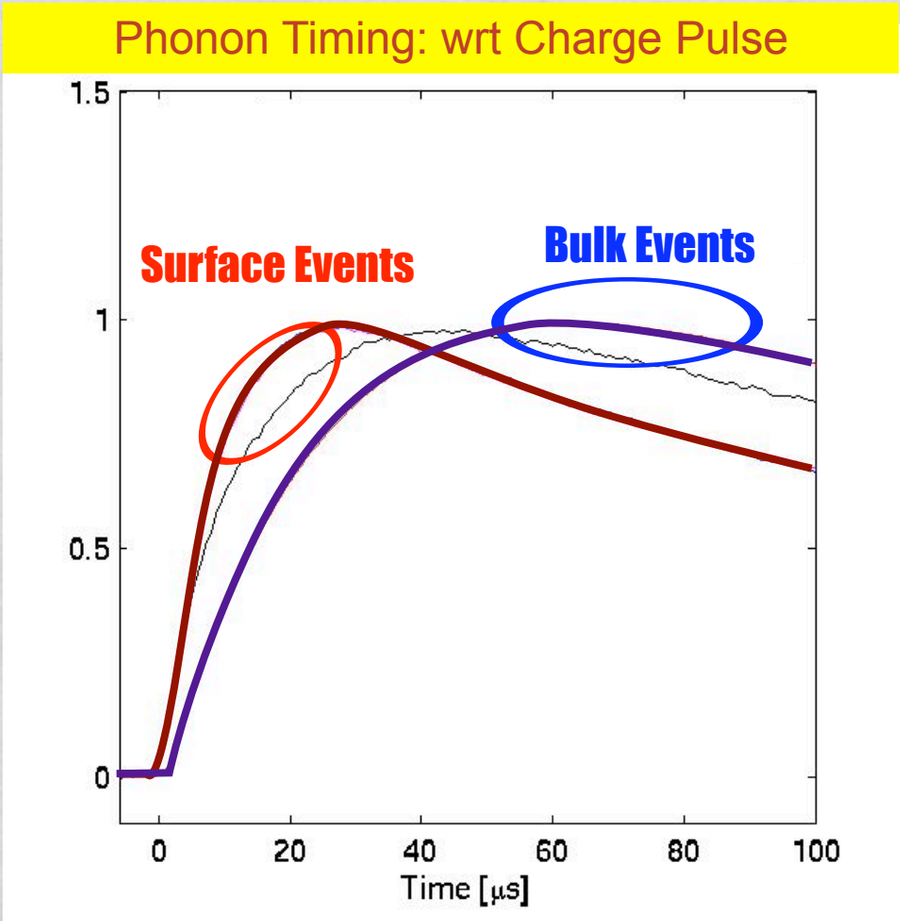
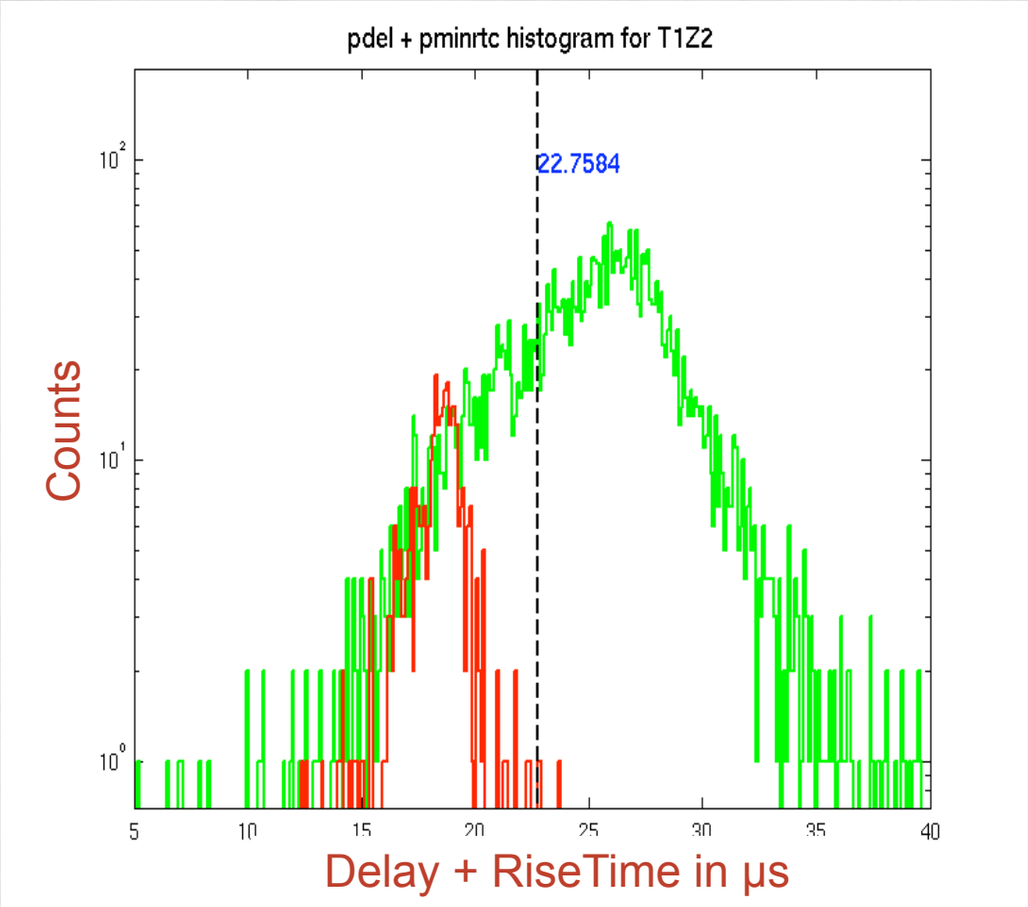
Need extra handle to reject βs in signal region

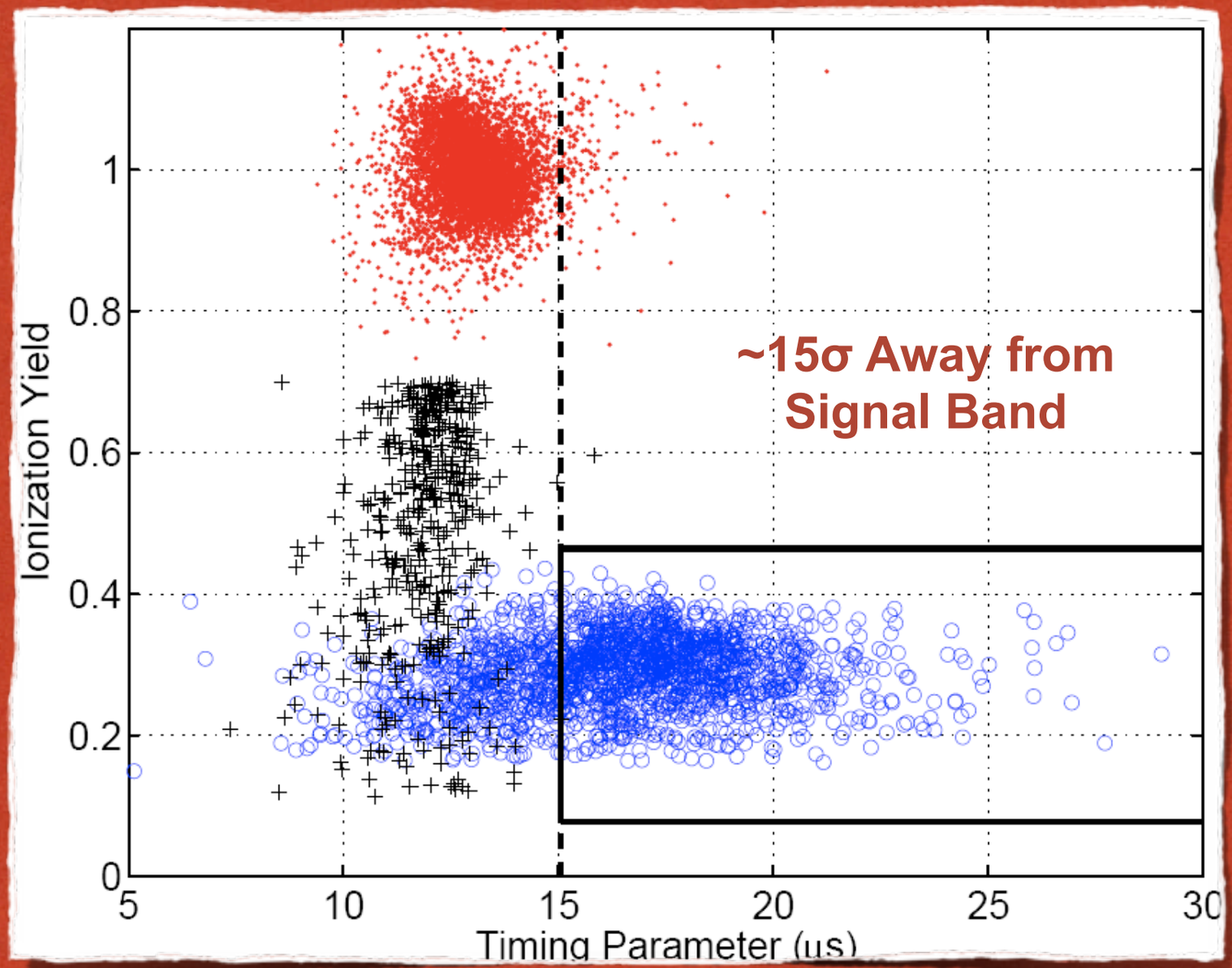
SURFACE β REJECTION

Faster down conversion of athermal phonons at surface provides faster phonon signal for βs





Cut chosen at a level to contribute ~ 0.5 event total leakage to WIMP candidate



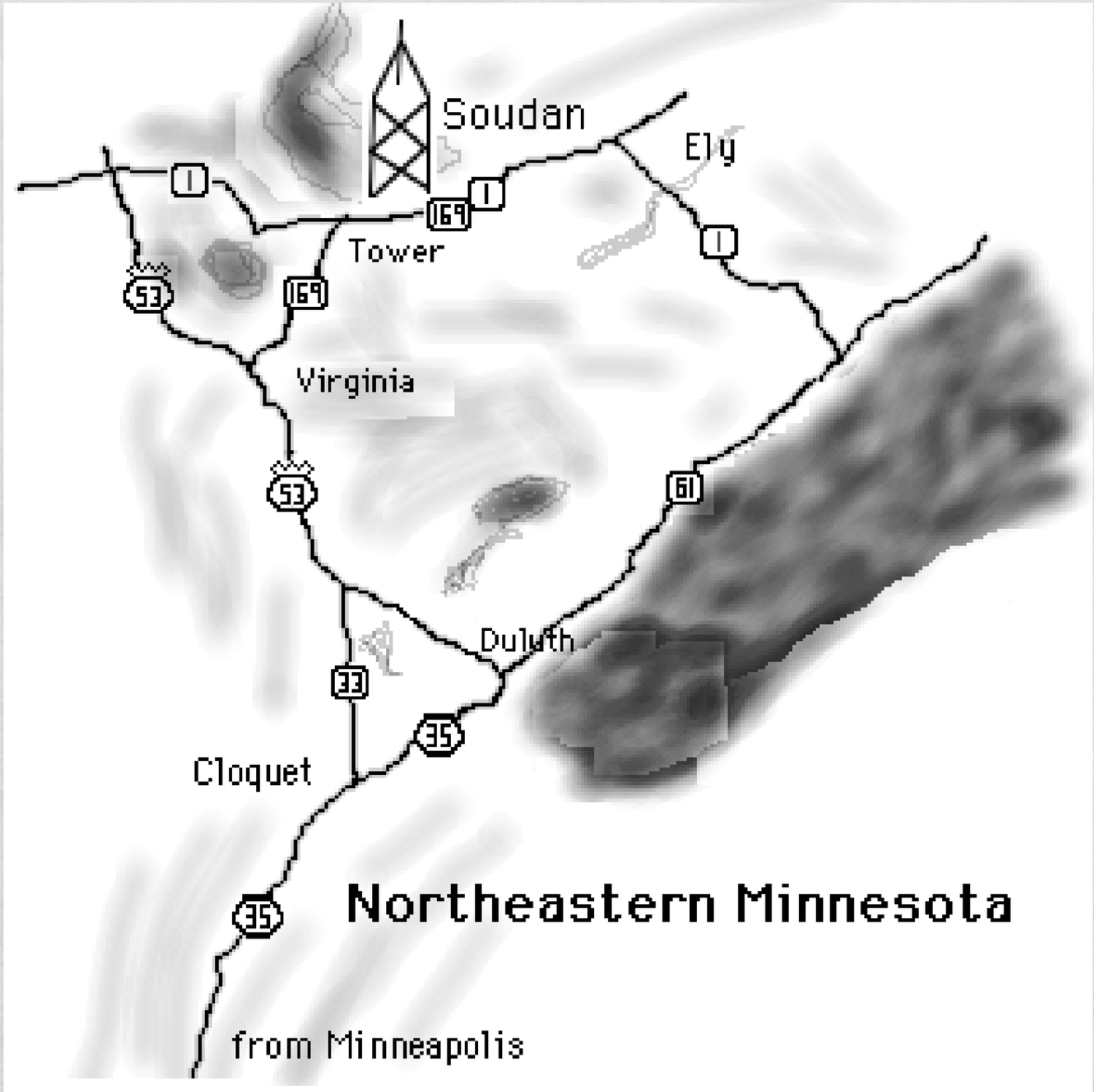
NET CDMS REJECTION

YIELD + TIMING PROVIDE EXCELLENT (>MILLION:1)
REJECTION OF E-M BACKGROUNDS

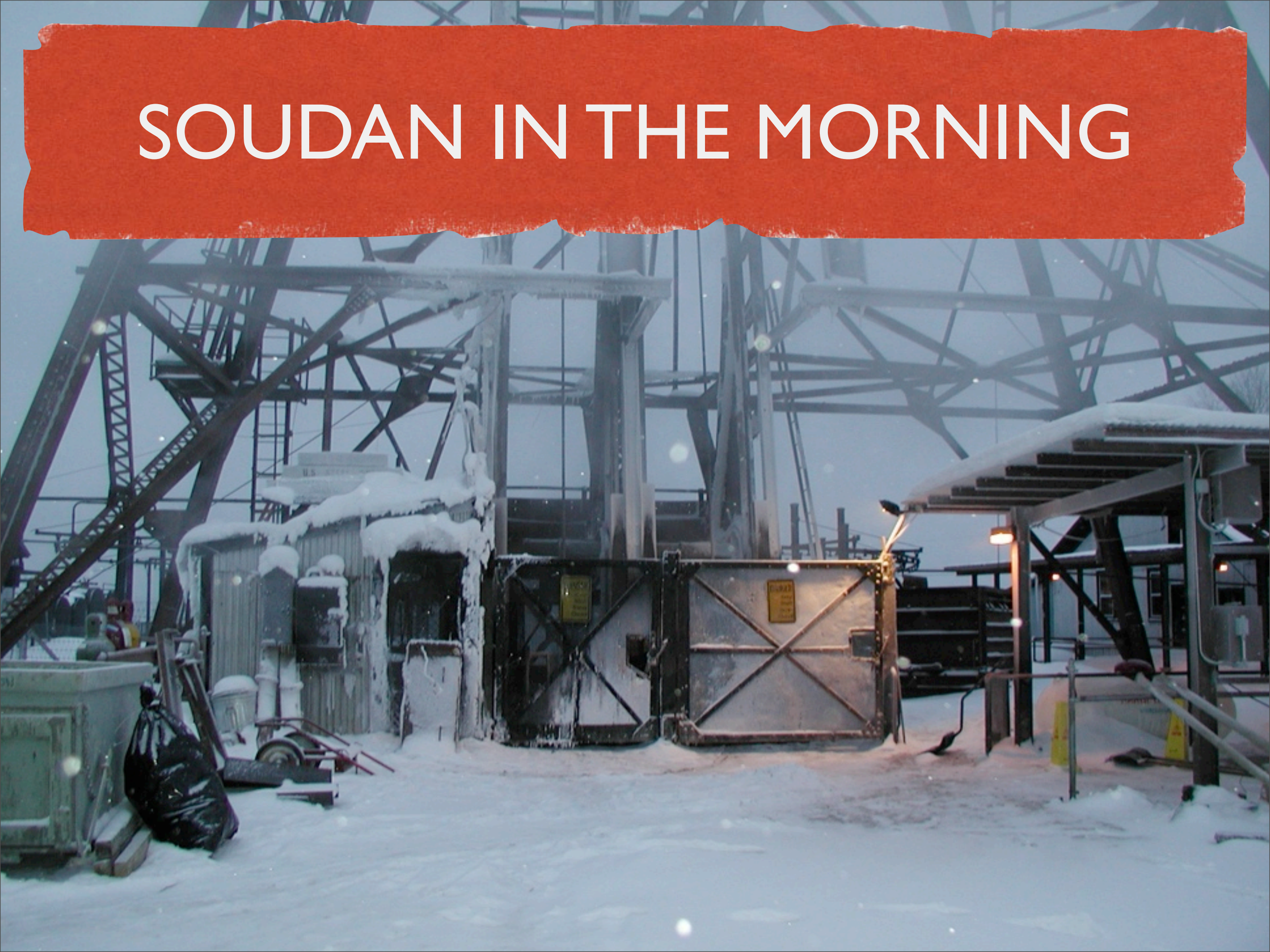
CDMS 5-TOWER DATA AT SOUDAN

CDMS @ Soudan

4 hours drive North of Minneapolis



SOUDAN IN THE MORNING



SOUDAN IN THE EVENING

CDMS Institutions

National Laboratory
-Fermilab
-NIST

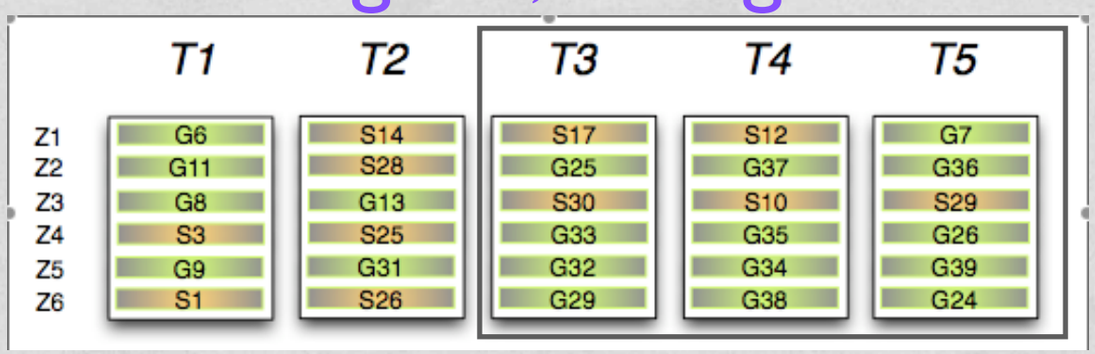
US University
-CalTech
-Case Western
-Colorado (Denver)
-Florida
-Minnesota
-MIT
-Stanford
-Santa Clara
-Syracuse
-UC Berkeley
-UC Santa Barbara

International
-QUEENS
-Zurich

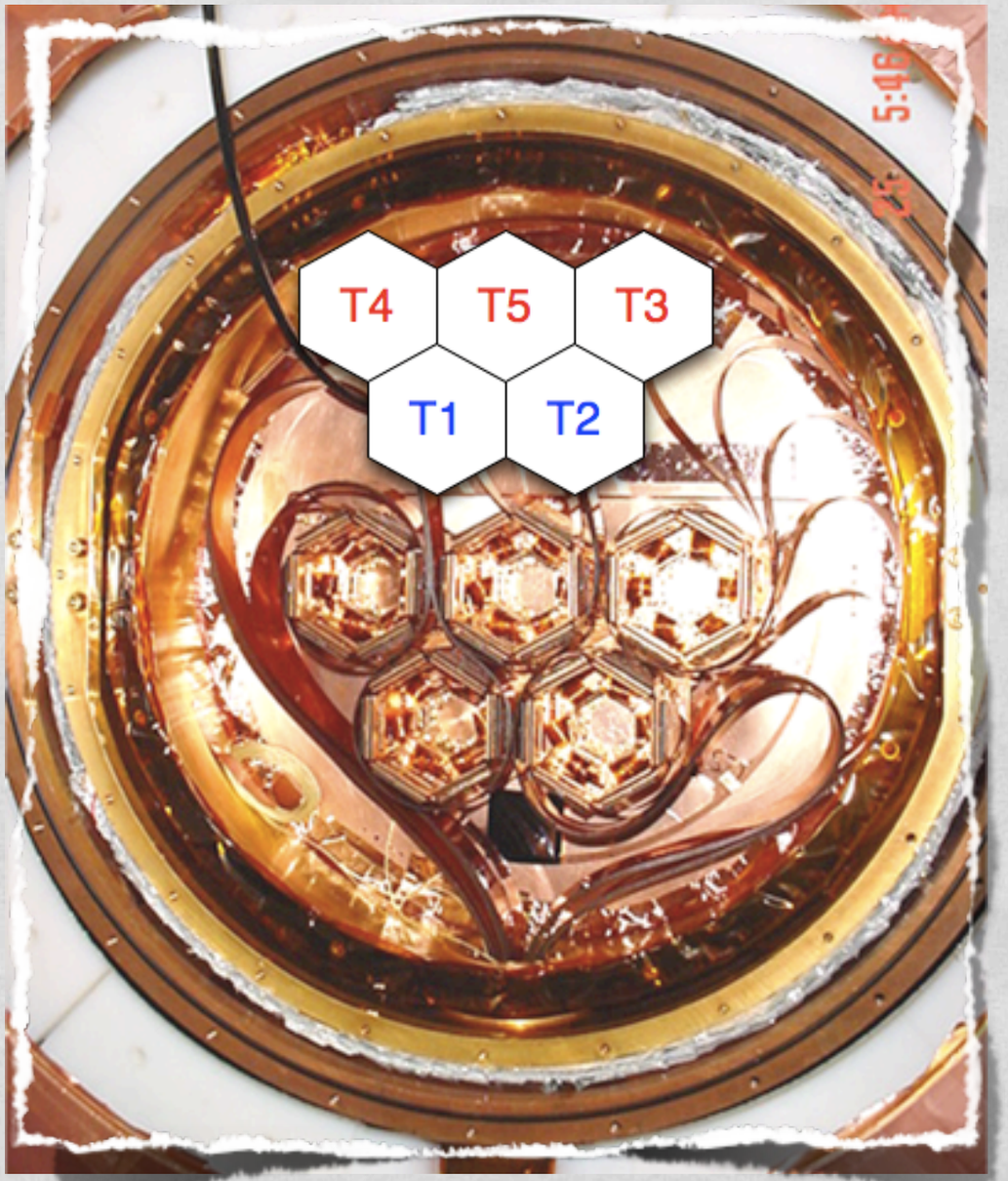
THE CDMS COLLABORATION

FIVE TOWER RUNS (2006-8)

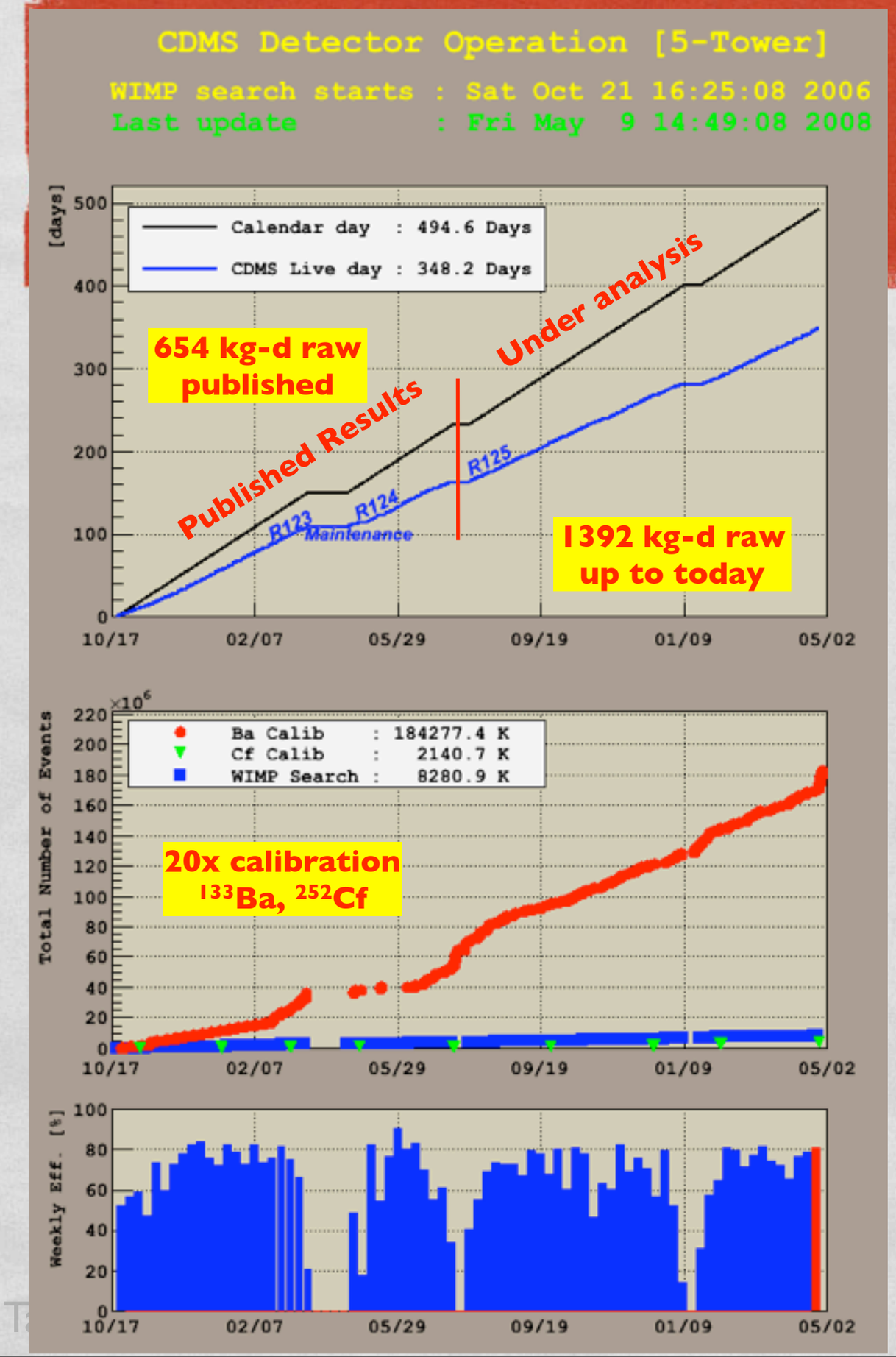
- 30 ZIPs (5 Towers) installed in Soudan icebox:
  - 4.75 kg Ge, 1.1 kg Si



- Combination of Ge and Si Detectors
  - Neutron background measurement
  - WIMP Mass Measurement
  - Ge more sensitive to higher mass WIMPs. Si to lower mass WIMPs



FIVE TOWER STATUS



- Four successful 5-T data runs so far:
  - ☑ Run 123 (10/06-3/07): 430 kg-d Ge (raw)
  - ☑ Run 124 (4/07-7/07): 224 kg-d Ge (raw)
  - ☐ Run 125 (7/07-1/08): 465 kg-d Ge (raw)
  - ☐ Run 126 (1/08-05/08): 273 kg-d Ge (raw)
  - ☐ Run 127 just started...
- >10x the 2-Tower exposure so far!
- Results shown today are for 123+124 data
- Will more than double the exposure with data in the can...

WIMP CANDIDATE: BLIND ANALYSIS

All cuts set blind, without looking at the signal.
i.e. we do not look at events which are:

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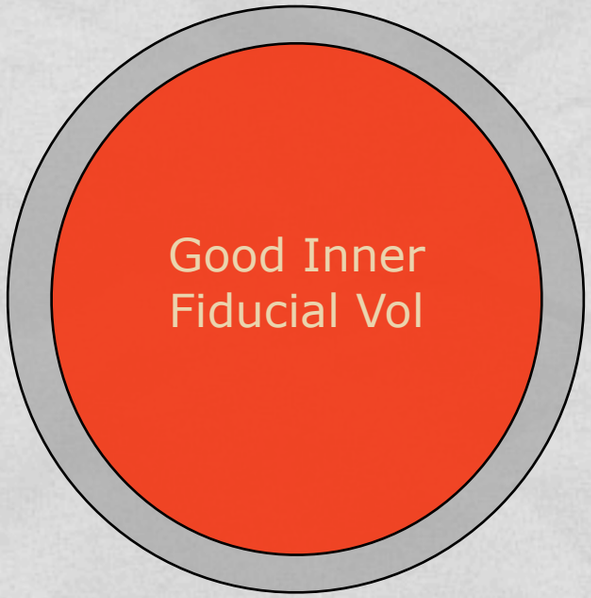

WIMP CANDIDATE: BLIND ANALYSIS

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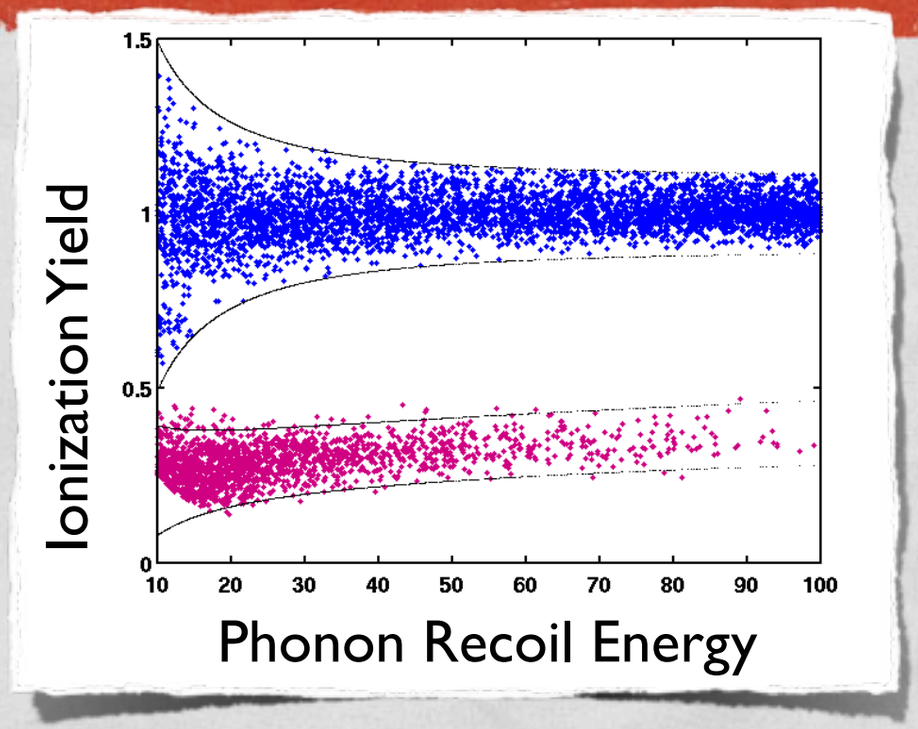
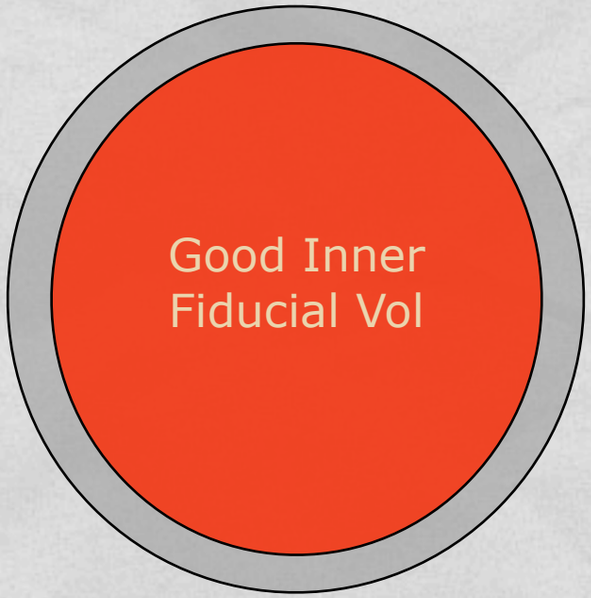
- ☑ Inside the good fiducial volume
- ☑ In the Nuclear Recoil Band





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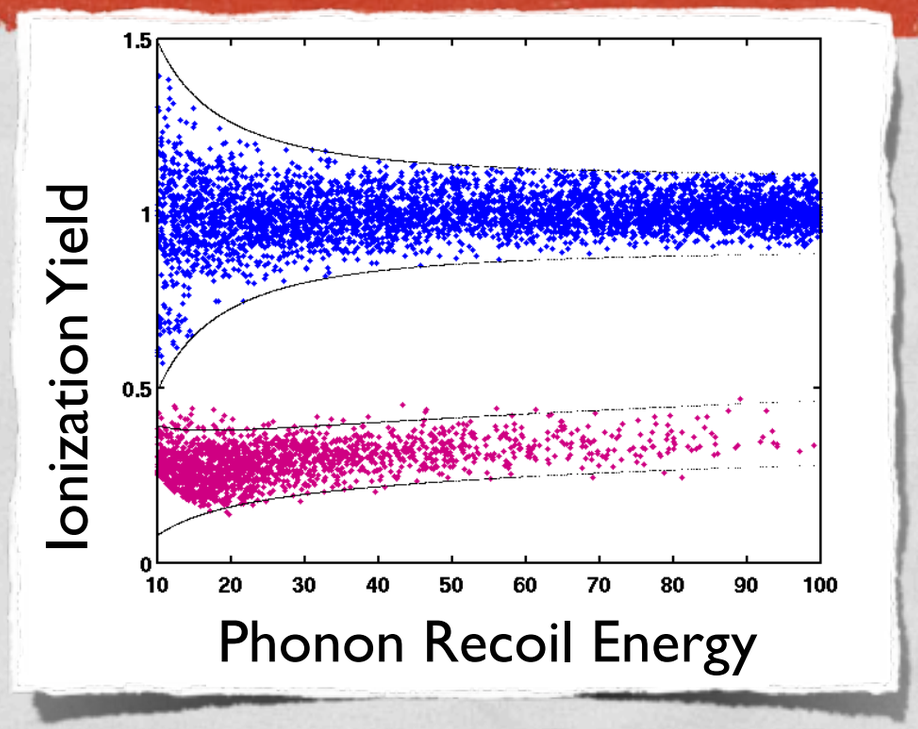
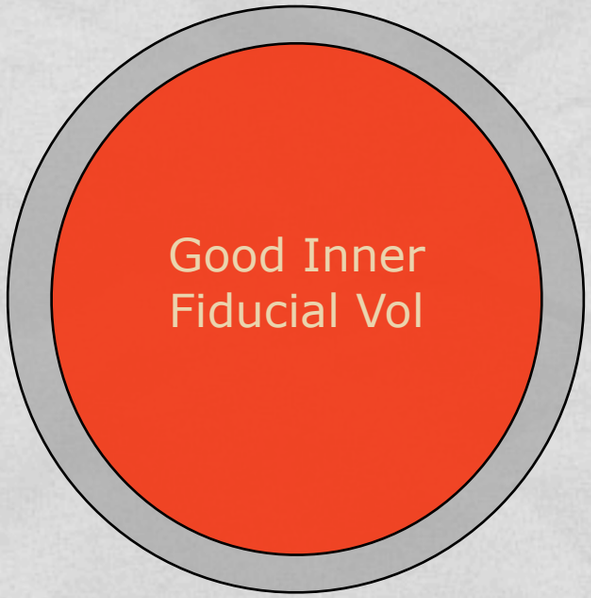
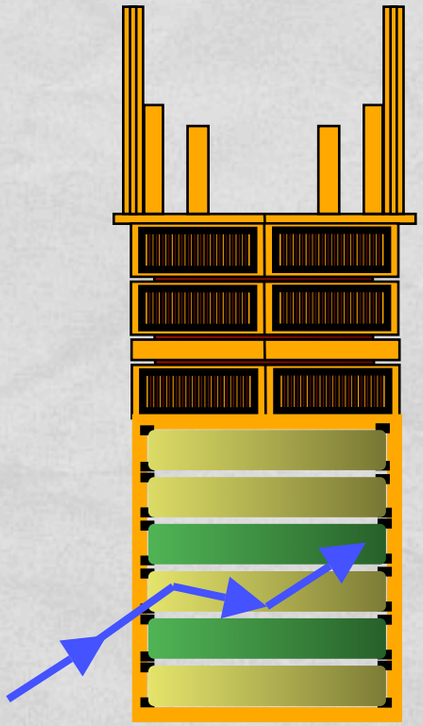
- ☑ Not a Multiple Scatter







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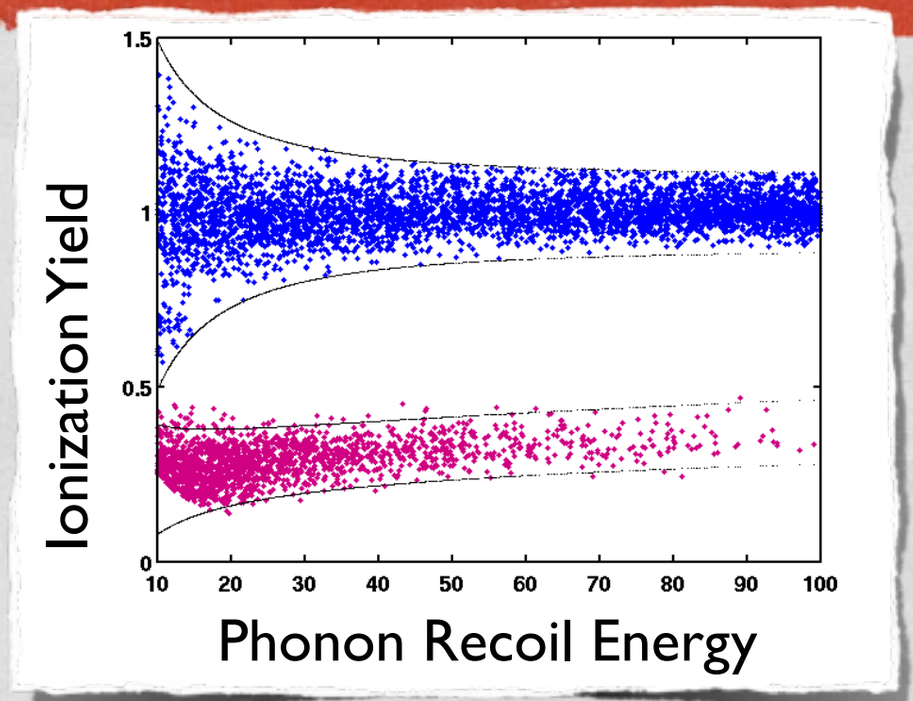
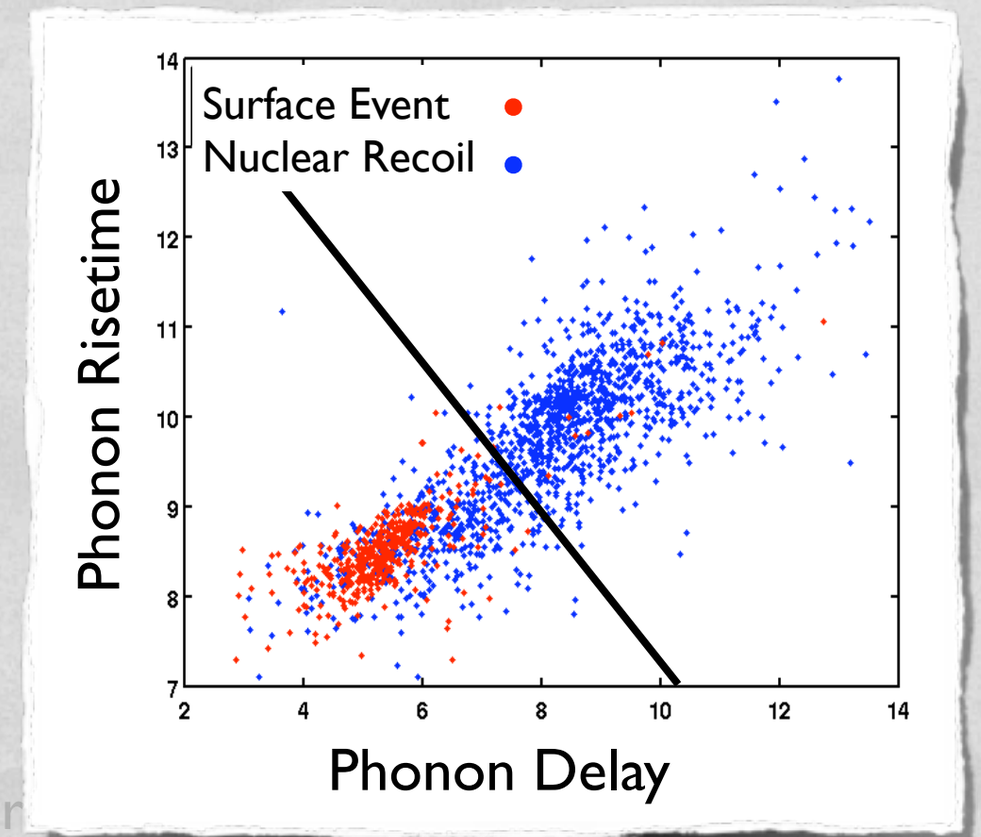
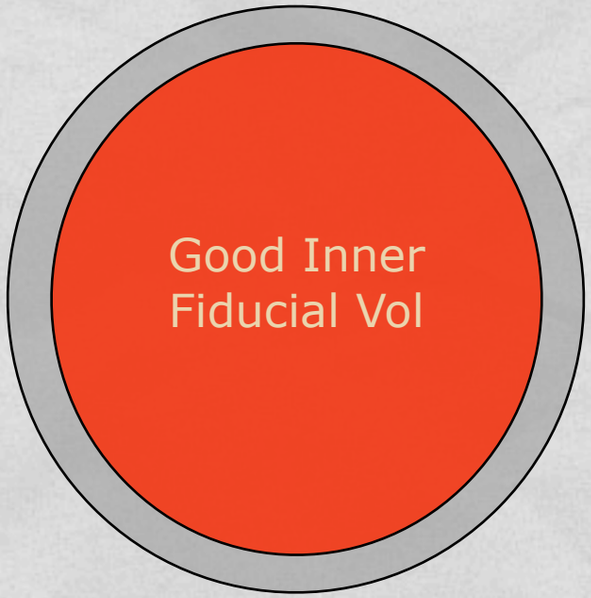
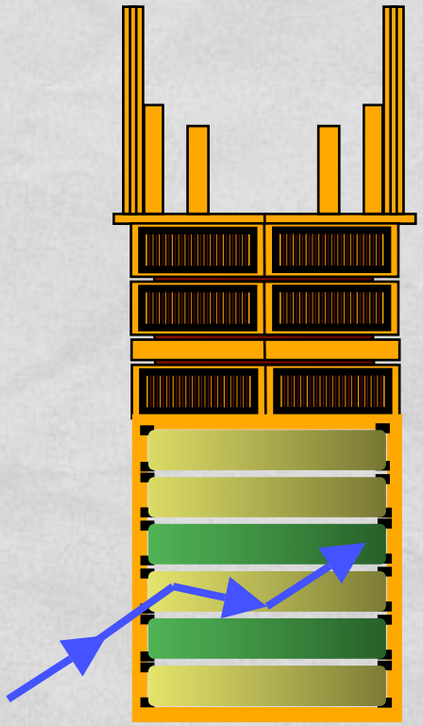
- ☑ Not a Multiple Scatter
- ☑ Not a surface event: phonon timing cut









EXPECTED β LEAKAGE

- ~300:1 Rejection is chosen on calibration Data
  - Provides Near Optimum Sensitivity
- WIMP side bands show 200:1 Rejection
- Difference dominated by differences in phonon/charge side rejection and β energy spectrum in calibration
- Expected Leakage ~ 0.6 ± 0.5 events
- Uncertainty on Leakage Preliminary and Conservative

EXPECTED NEUTRON BACKGROUND

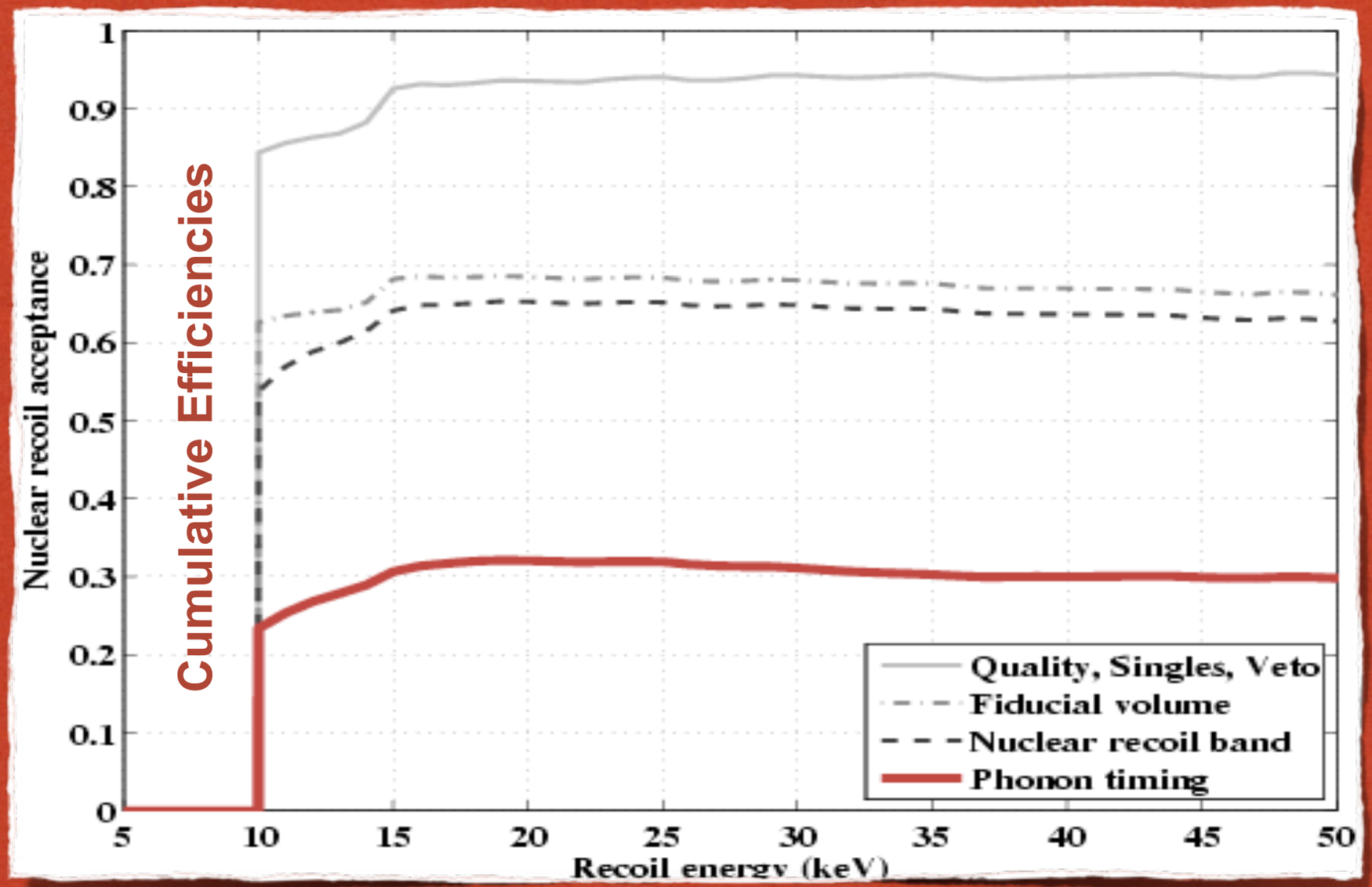
Cosmogenic

- 8 Vetoed nuclear recoil multiples observed
- No Vetoed Singles Observed
- Use MC Predicted singles/ multiples ratio and vetoed to unvetoed ratio
- Expect < 0.1 unvetoed neutron background

Fission/alpha-N

- Fission neutron < 0.1 from Pb counting
- Alpha-N < 0.03 from Uranium in Poly

Expect Total Neutron background <0.2 events

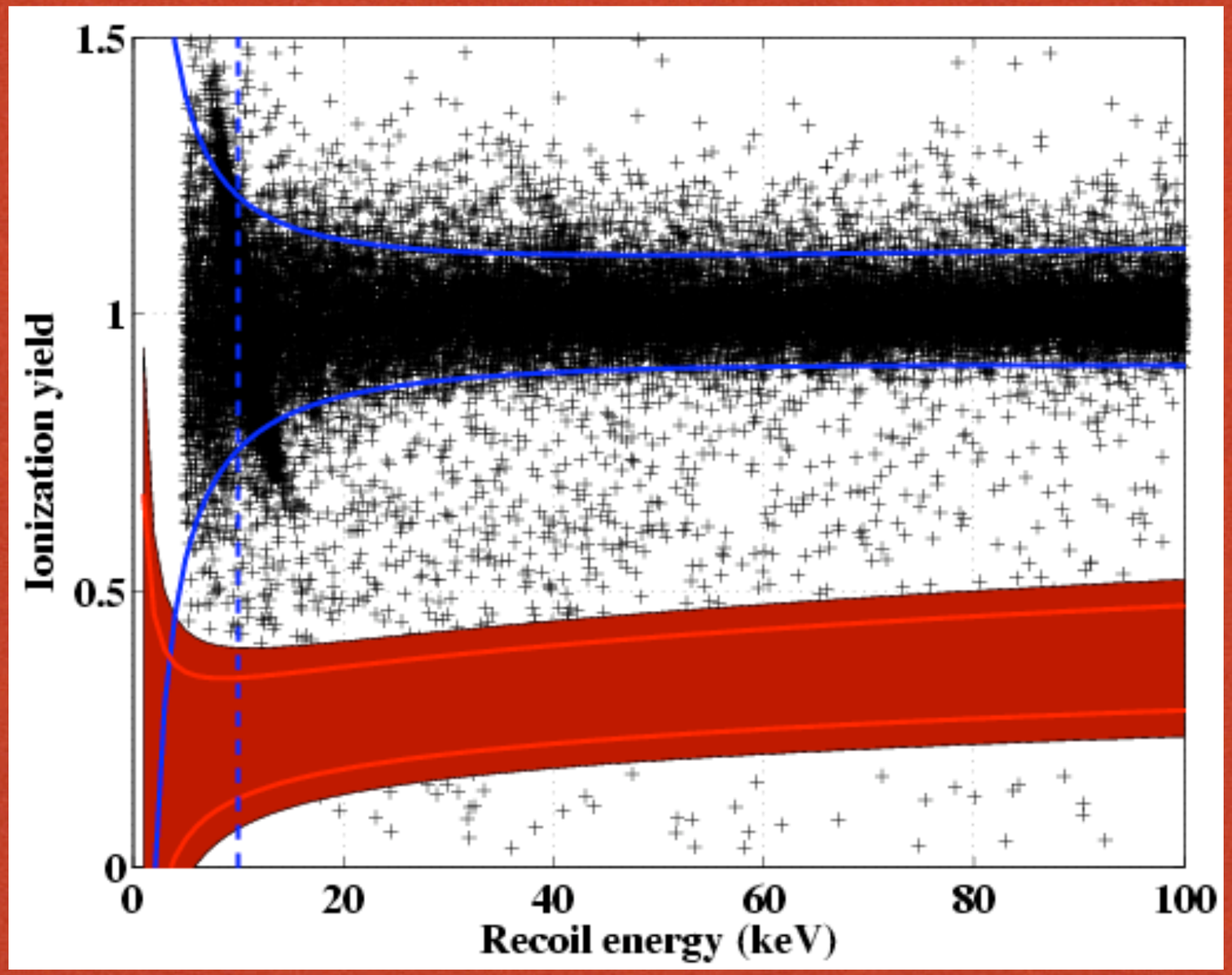


EFFICIENCIES

TOTAL EFFICIENCY WITH RESPECT TO FULL DETECTOR MASS

All cuts set and frozen!

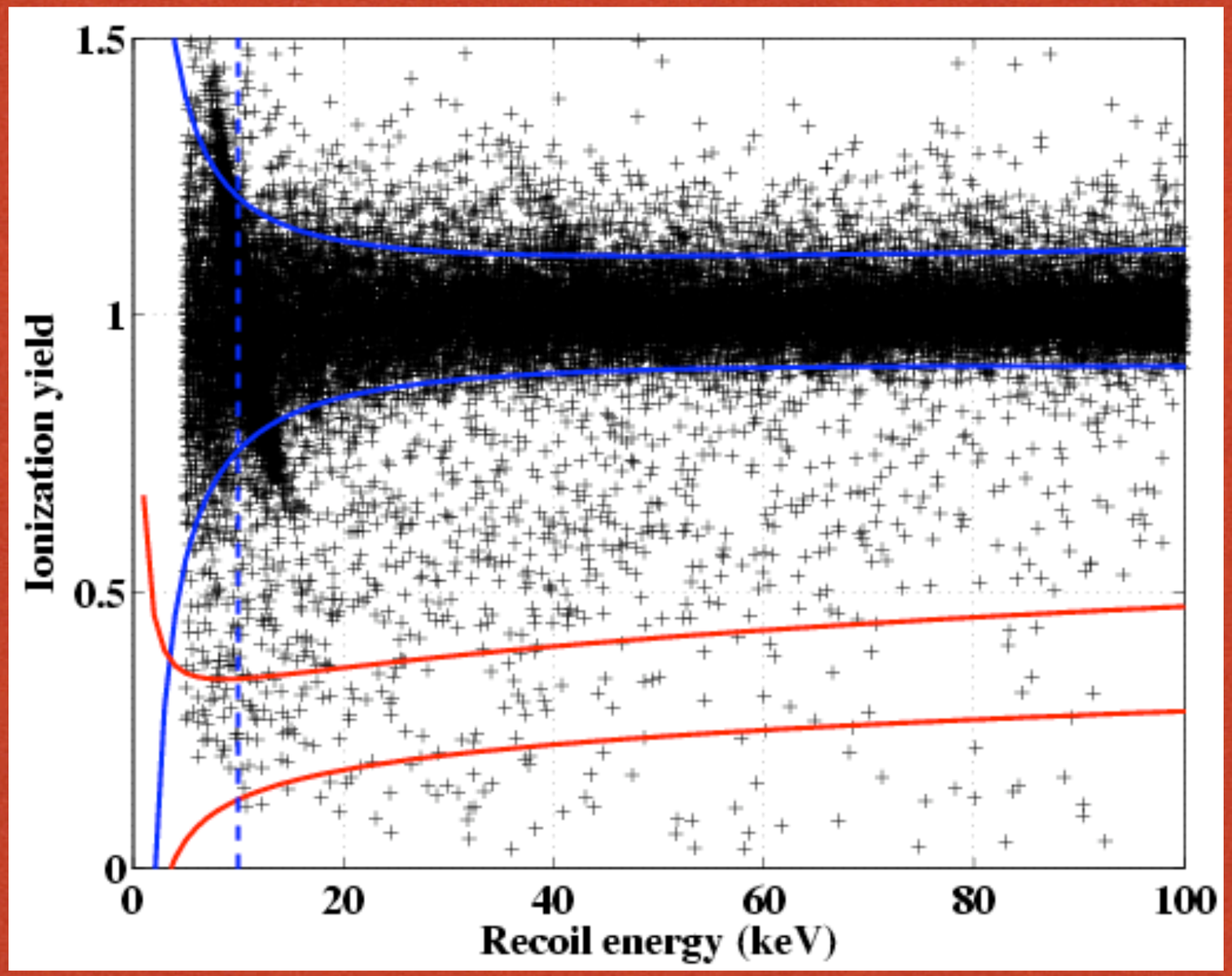
Expected Events: 77 ± 15 single scatters in NR



THE WIMP SEARCH DATA: GE

PRIOR TO, 4TH OF FEB, 2008

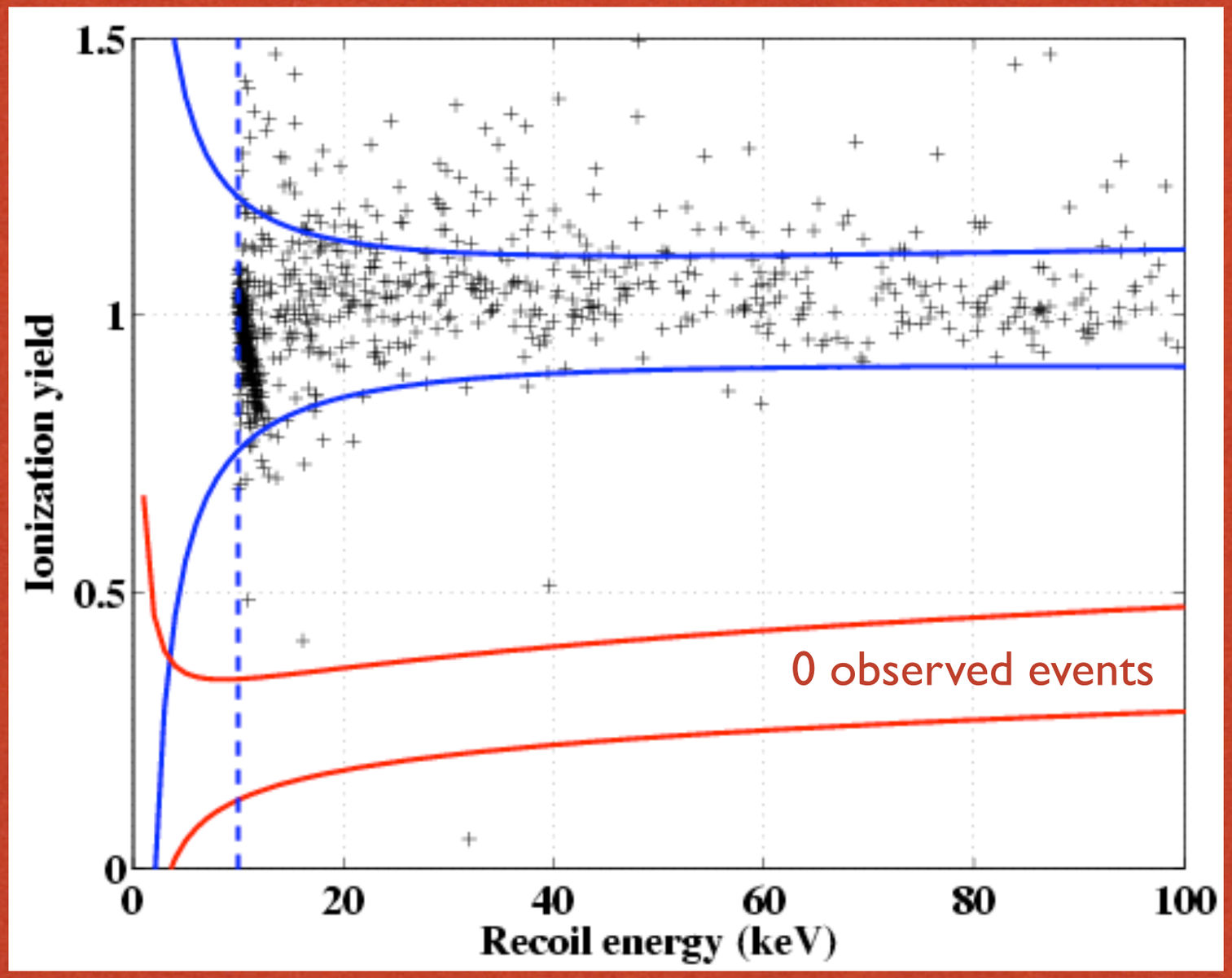
97 singles in signal region before applying surface cut



THE WIMP SEARCH DATA: GE

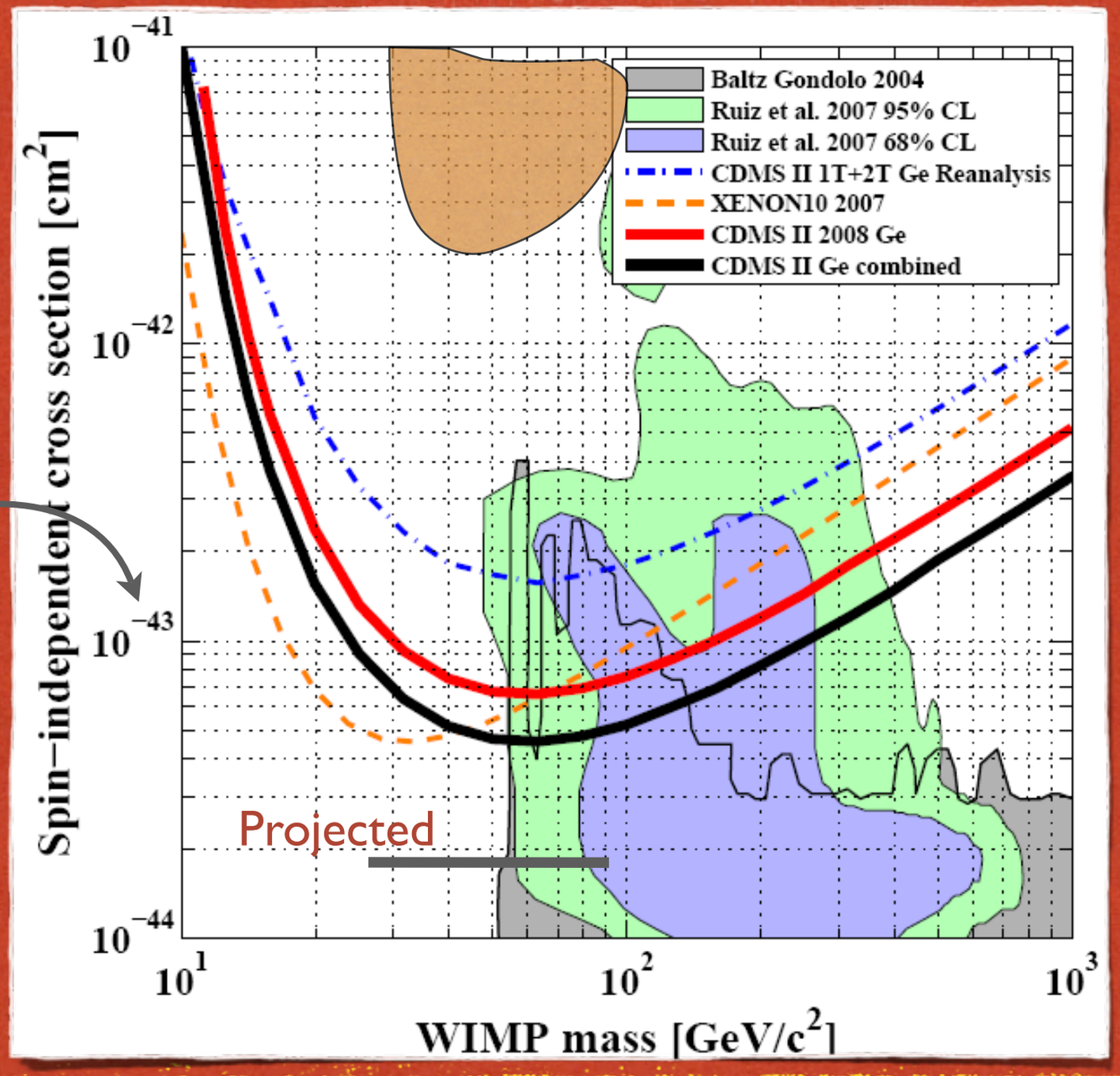
MIDNIGHT PST, 4TH OF FEB, 2008

Expected Background: 0.6 ± 0.5 surface events and < 0.2 neutrons



OPEN THE BOX: SURFACE EVENT CUT

MIDNIGHT PST, 4TH OF FEB, 2008



10^{-7} pb

SPIN-INDEPENDENT EXCLUSION LIMIT

CDMS 5-TOWER RESULTS

- Zero Events Observed! (654 kg-days of raw data)
- Best Spin-Independent limit above 40GeV/c^2 WIMP Mass
- ~ Twice the exposure of current analysis waiting in analysis pipeline. Double again by end 2008
- Will surpass target sensitivity of $2 \times 10^{-44} cm^2$
- Preprint available @ http://cdms.berkeley.edu and on arXiv article id 0802.3530

LOOKING AHEAD TOWARDS $\sigma = 10^{-45}$ CM^2

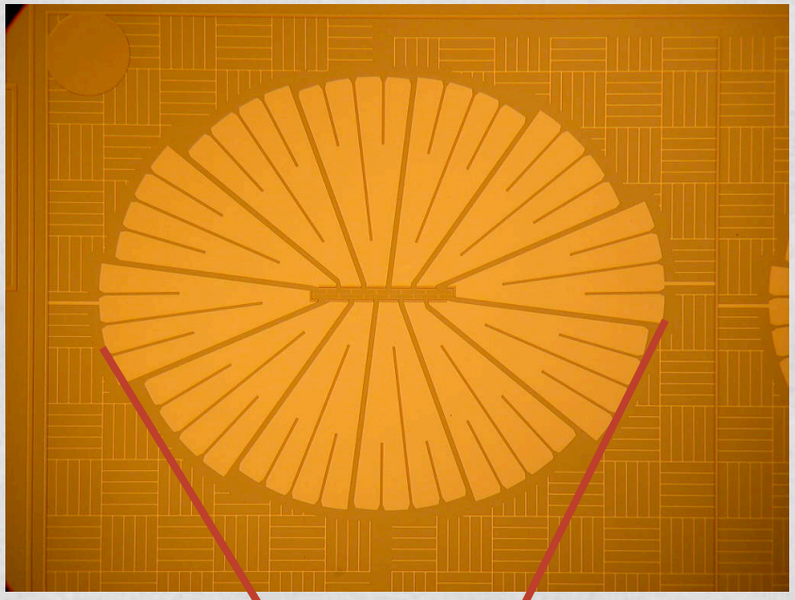
BASELINE DETECTOR FOR SUPERCDMS

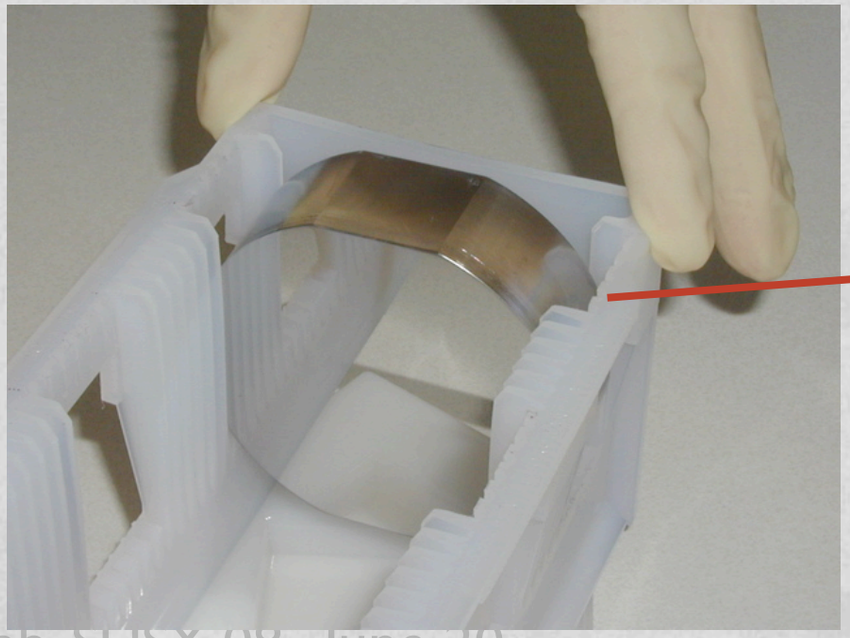
CDMS-II ZIPs:
3” dia x 1 cm => 0.25 kg of Ge

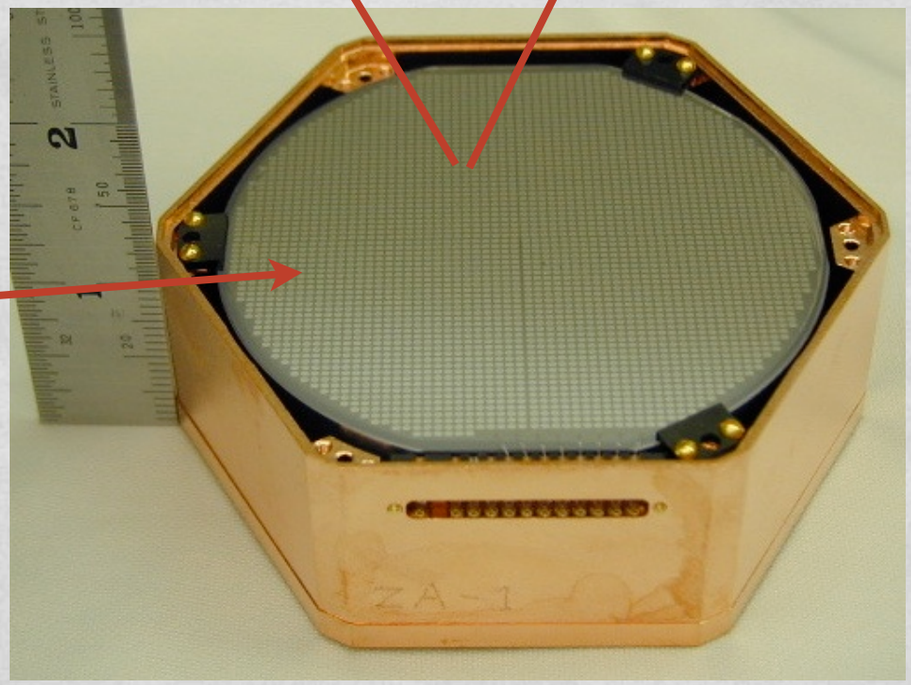
Existing ZIPs

SuperCDMS ZIPs:
3” dia x 1” => 0.64 kg of Ge

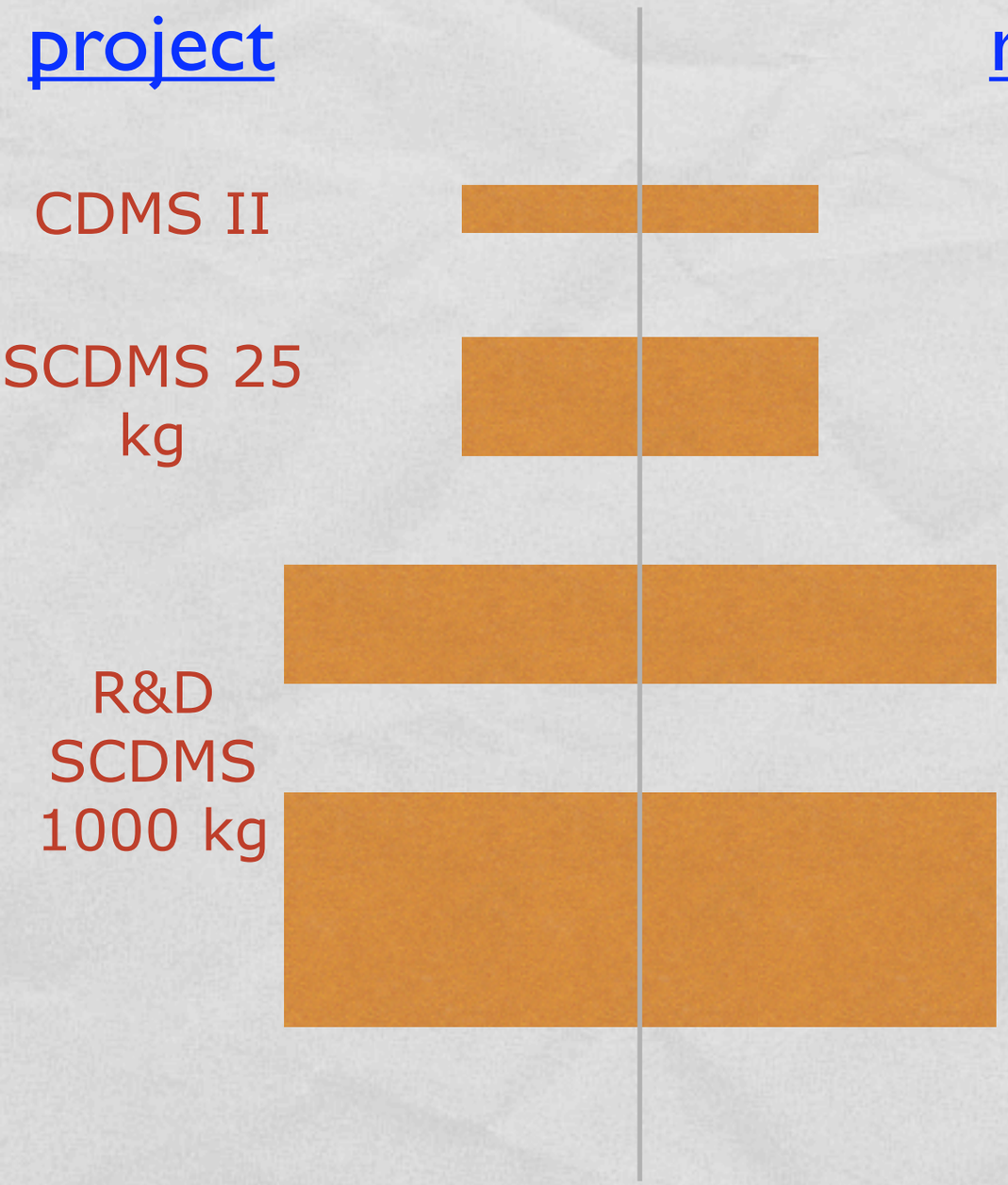
ZIPs for SuperCDMS







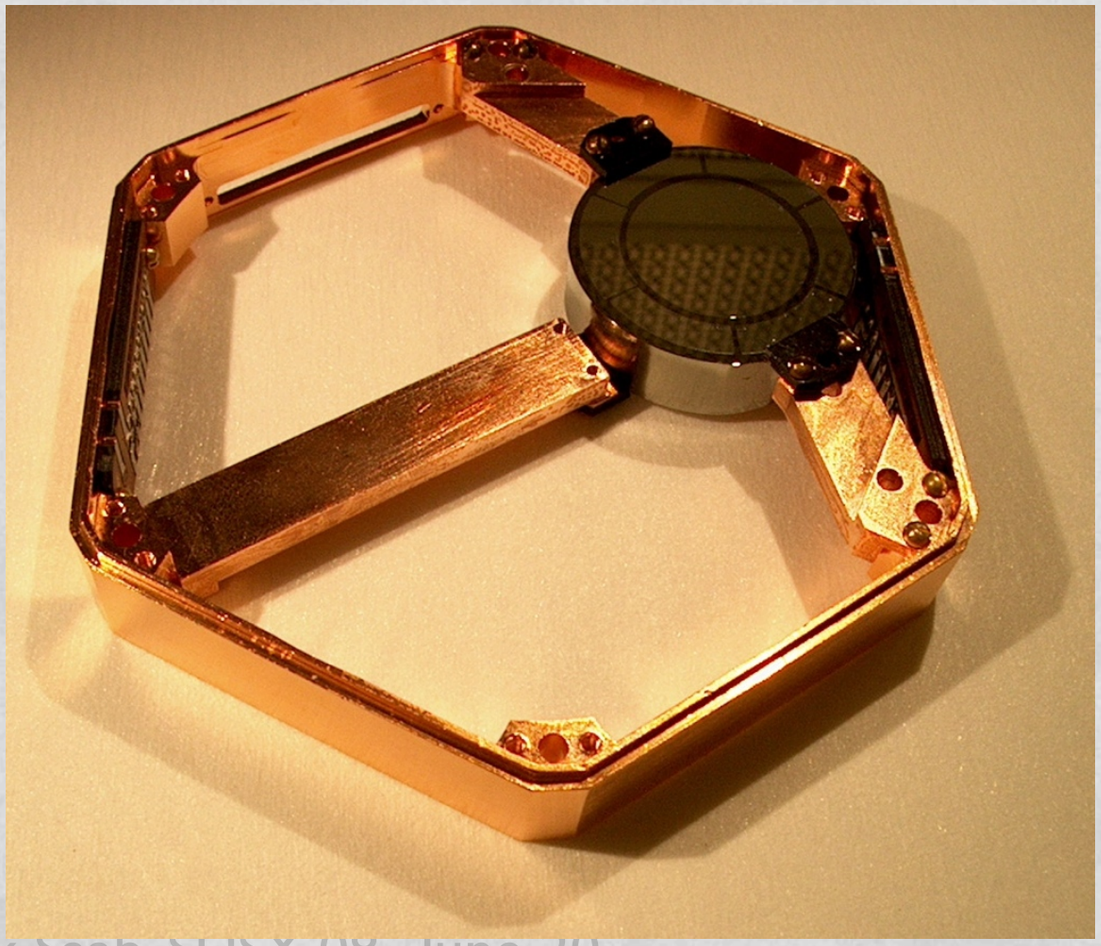
GE DETECTOR MASS SCALING

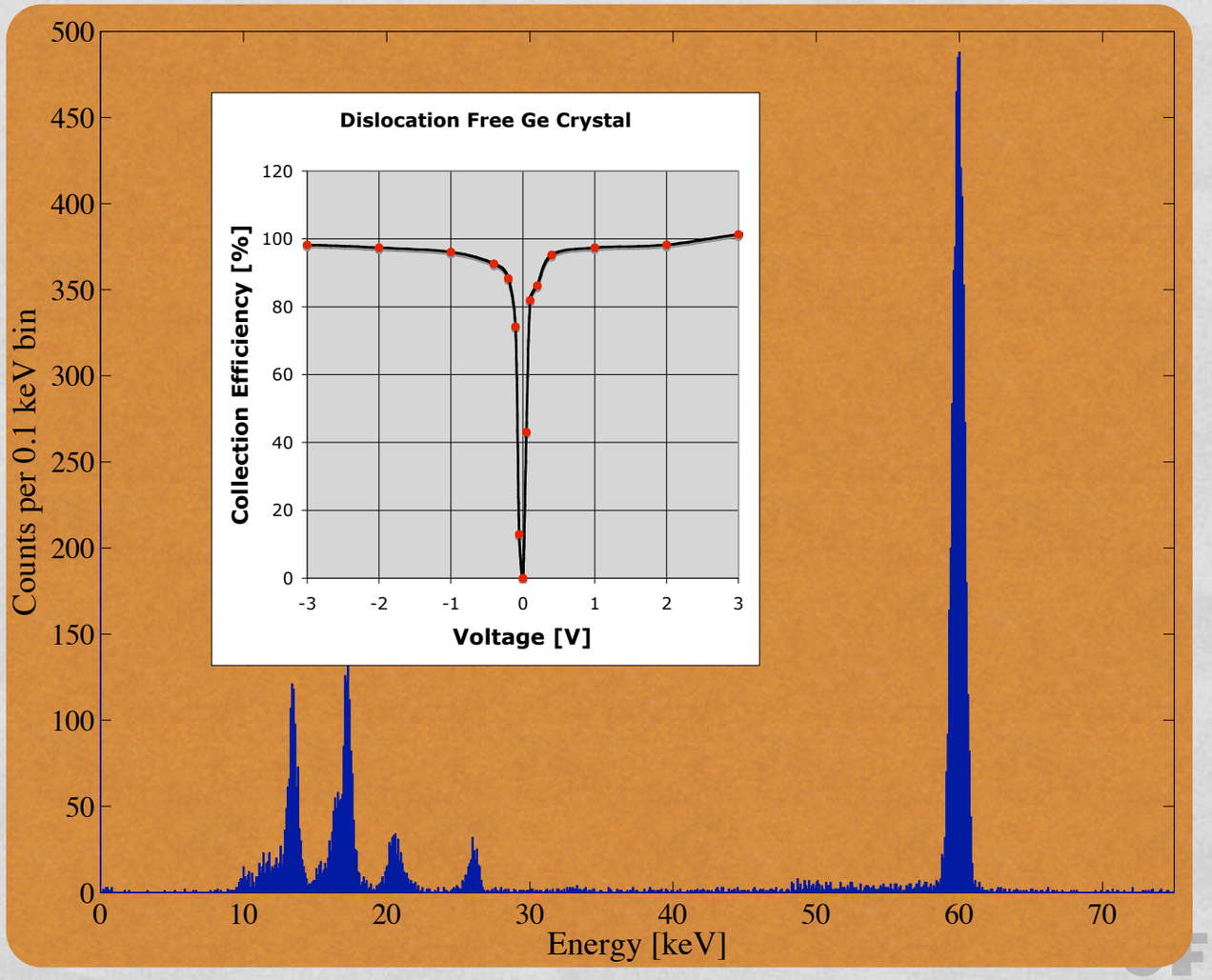


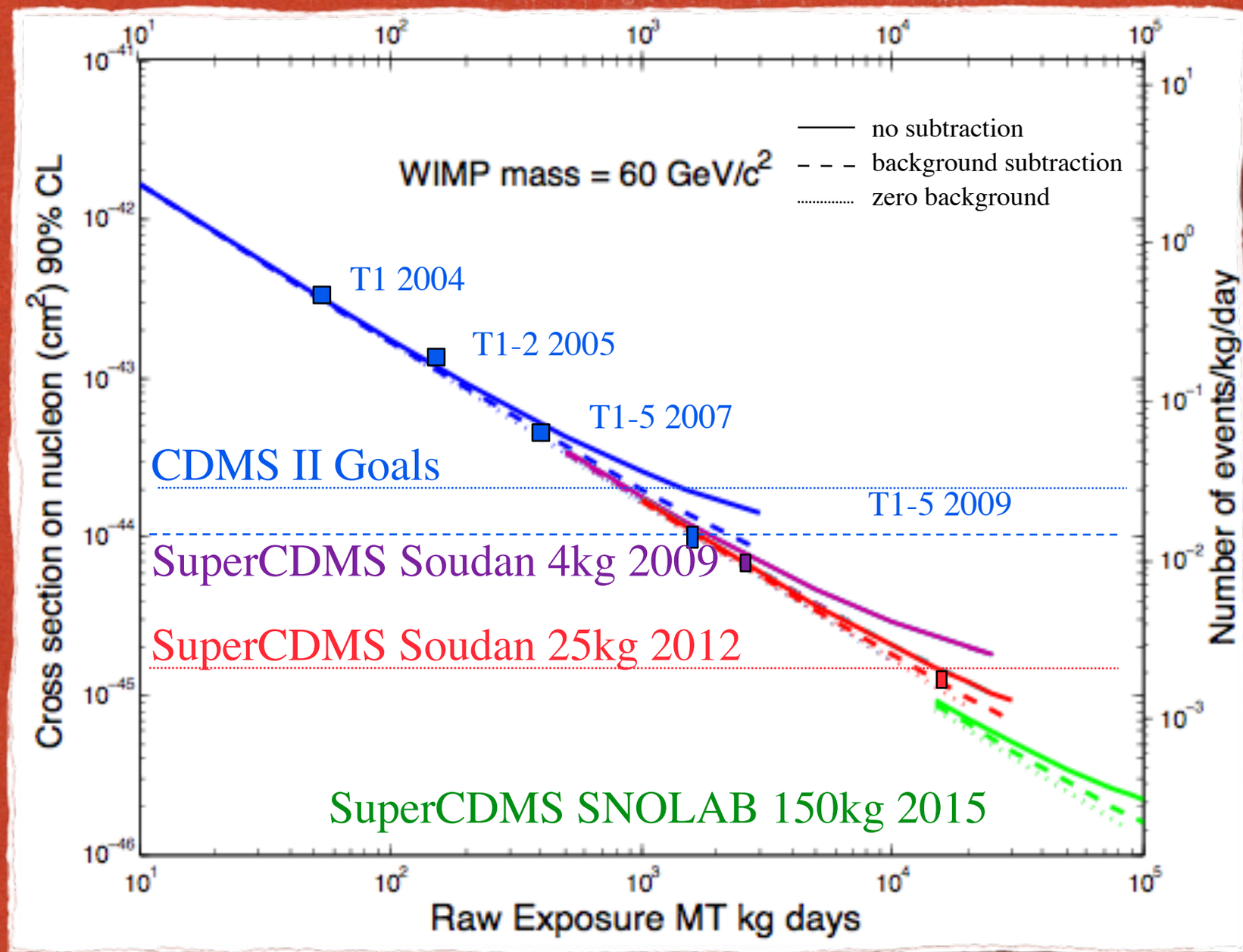
project	ratio	kg/det	# det	tot kg	fiducial
CDMS II	x 1	0.25	16	4.0	50%
SCDMS 25 kg	x 2.5	0.64	42	27	80%
R&D SCDMS 1000 kg	x 10	2.5	228	570	80%
	x 20	5.0	228	1140	90%

DISLOCATION FREE GE NEEDED FOR 6 IN DETECTORS

- 1 cm thick by 30 mm diameter dislocation free crystal from E.E. Haller illuminated with ^{241}Am source operated at ~40 mK
- Excellent resolution and charge collection efficiency







ZERO BACKGROUND NECESSARY FOR DISCOVERY

FIRST DARK MATTER RESULTS FROM THE CDMS 5-TOWER RUN AND THE PATH TOWARDS $\sigma = 10^{-45}$ CM^2 WIMP SENSITIVITY

Tarek Saab
for the CDMS Collaboration

SUSY 08