New results from the CDMSII final Run at Soudan Deep Underground Laboratory

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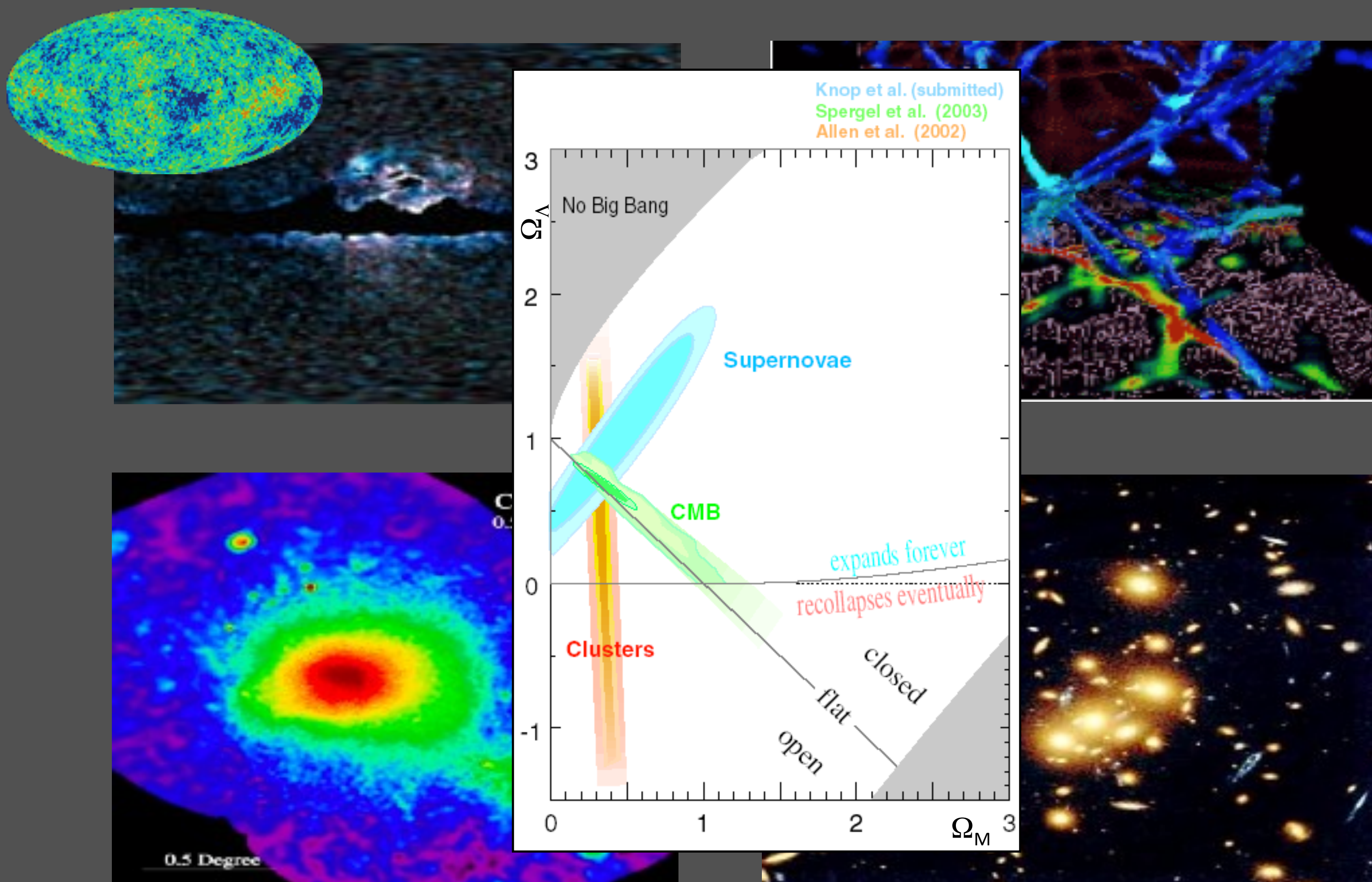
University of California, Berkeley

CDMS Collaboration

Aspen, January 2010

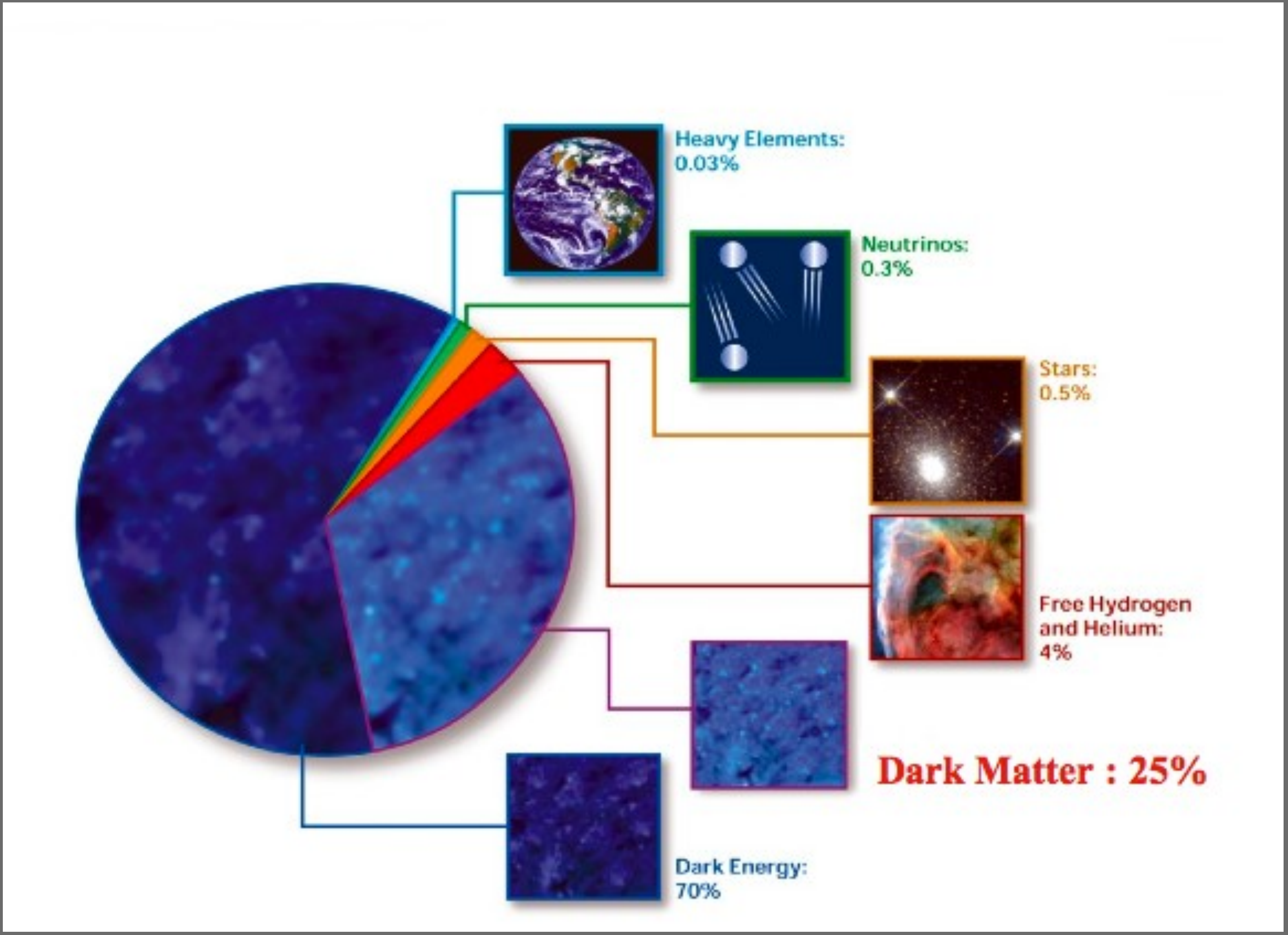
- Dark Matter and WIMPs
- CDMSII detection principle
- Results from the final run
- CDMS Future
- Conclusion

Dark Matter: Evidences



Confession:

95% of the content of the Universe is **unknown**

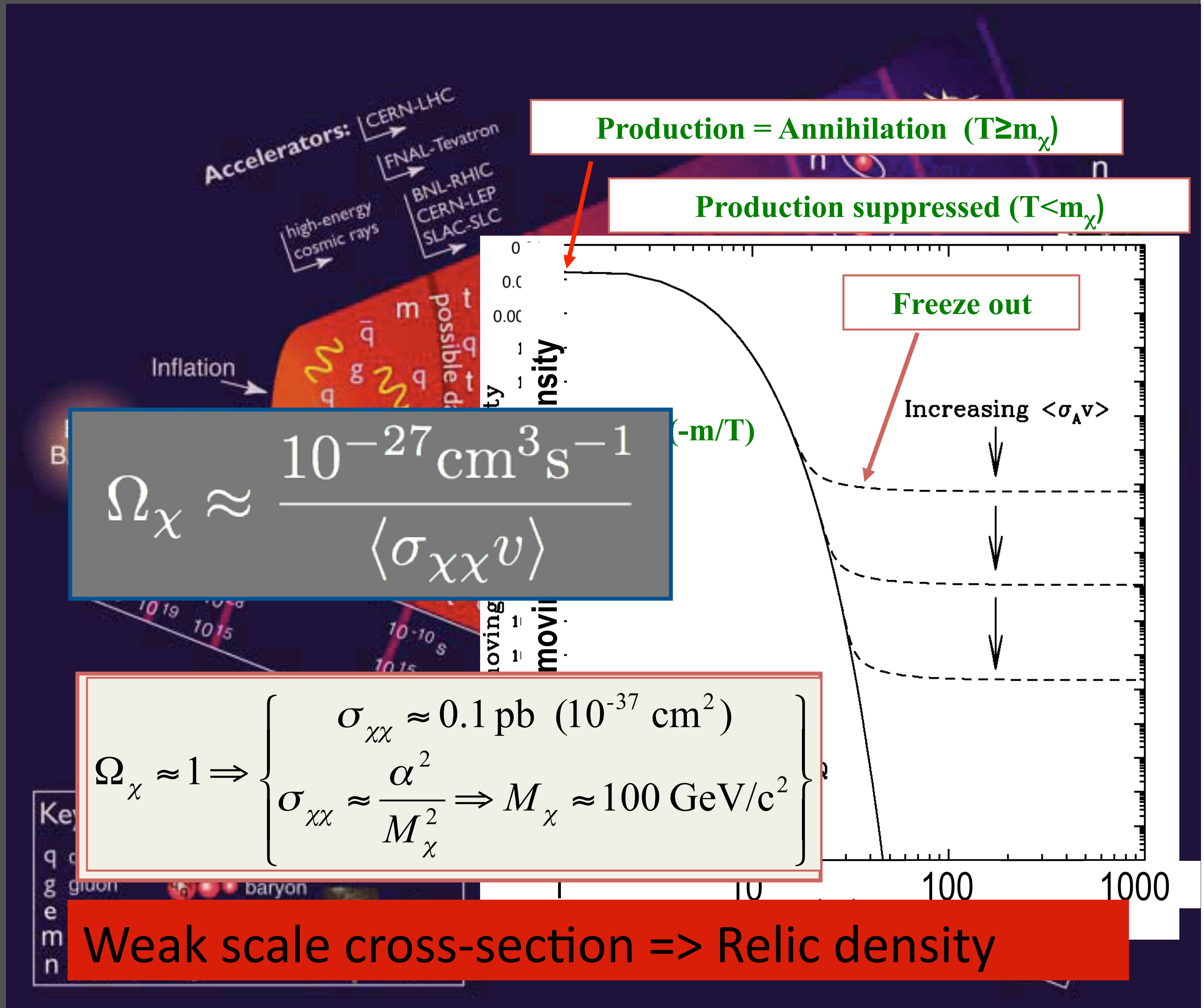


Weakly

Interacting

Massive

Particles



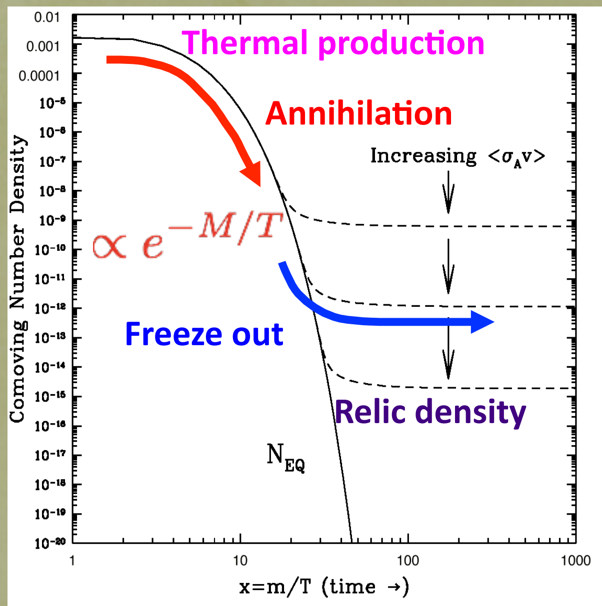
$$\Omega_\chi \approx \frac{10^{-27}\mathrm{cm}^3\mathrm{s}^{-1}}{\langle \sigma_{\chi\chi} v \rangle}$$

$$\Omega_\chi \approx 1 \Rightarrow \begin{cases} \sigma_{\chi\chi} \approx 0.1\ \mathrm{pb}\ \ (10^{-37}\ \mathrm{cm}^2) \\ \sigma_{\chi\chi} \approx \dfrac{\alpha^2}{M_\chi^2} \Rightarrow M_\chi \approx 100\ \mathrm{GeV/c}^2 \end{cases}$$

Weak scale cross-section => Relic density

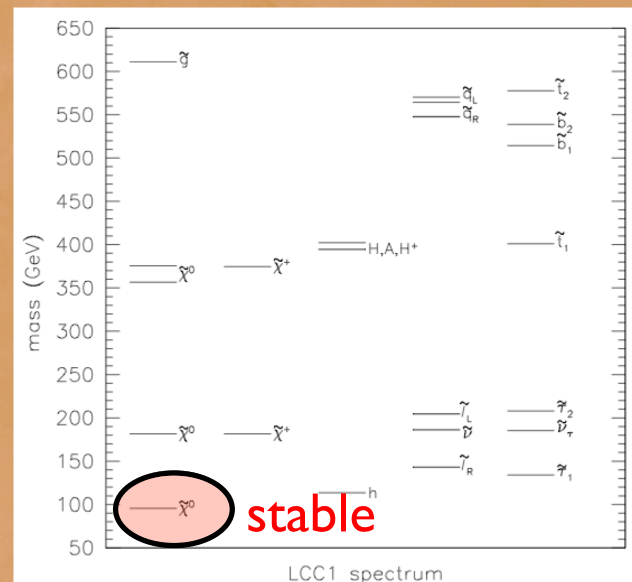
SUSY WIMPs

Cosmology



$$\Omega_\chi \approx \frac{10^{-27}\mathrm{cm}^3\mathrm{s}^{-1}}{\langle \sigma_{\chi\chi} v\rangle}$$

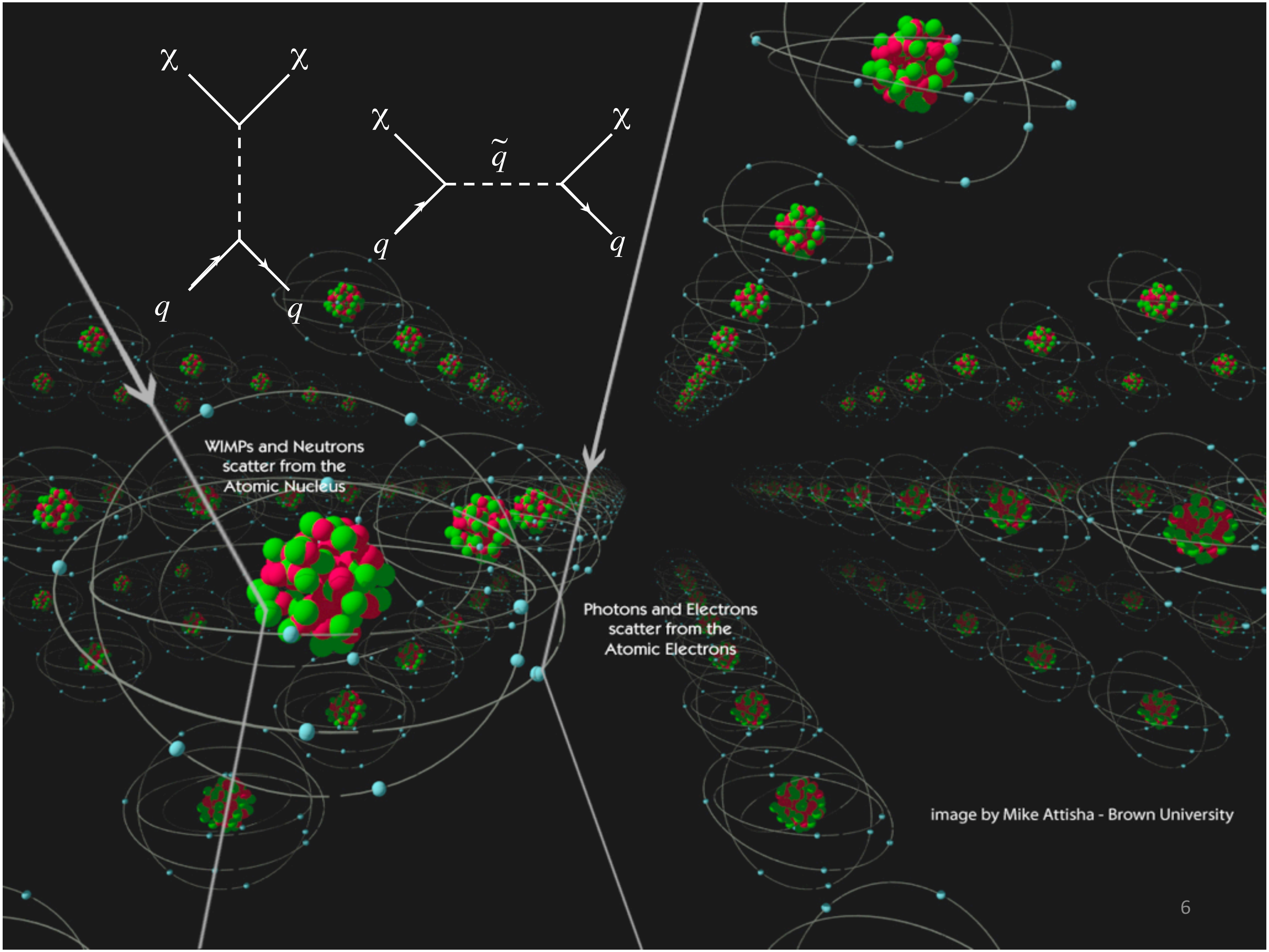
Particle Physics



Baltz et al., PRD **74**, 103521 (2006)

$$\Omega_\chi \approx 1 \Rightarrow \left\{ \begin{array}{c} \sigma_{\chi\chi} \approx 0.1\,\mathrm{pb}\ \ (10^{-37}\ \mathrm{cm}^2) \\ \sigma_{\chi\chi} \approx \frac{\alpha^2}{M_\chi^2} \Rightarrow M_\chi \approx 100\ \mathrm{GeV/c}^2 \end{array} \right\}$$

Strong theory motivation for **weakly interacting massive particles**


χ
χ
q
q
χ
$\tilde{q}$
χ
q
q
WIMPs and Neutrons scatter from the Atomic Nucleus
Photons and Electrons scatter from the Atomic Electrons
image by Mike Attisha - Brown University

Direct detection challenges:

Backgrounds, Backgrounds and again Backgrounds

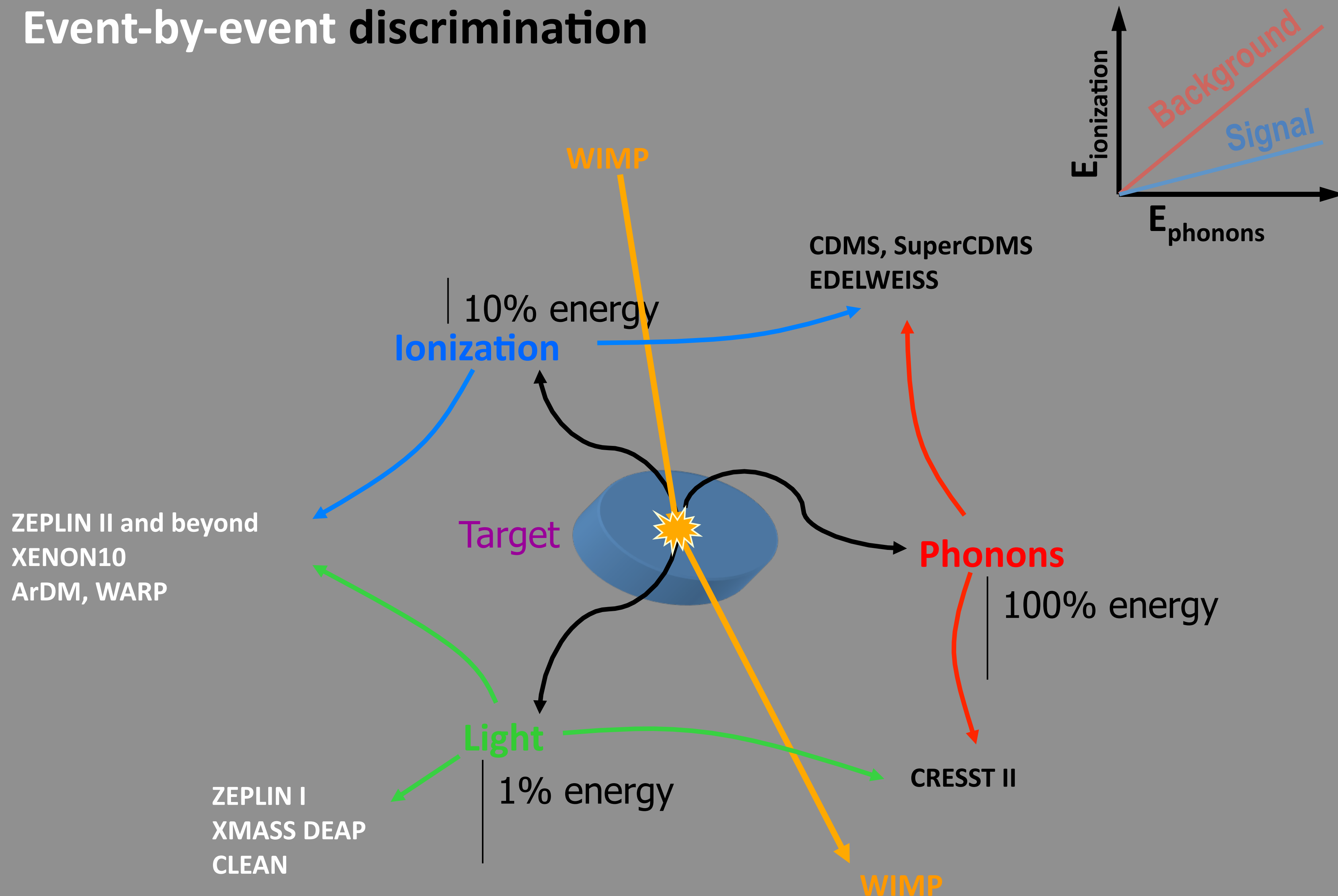
- Search sensitivity (low energy region <<100 keV)
  - ❑ **Current Exp Limit < 1 evt/kg/20 days, ~< 10^{-1} evt/kg/day**
  - ❑ **Goal < 1 evt/tonne/year, ~< 10^{-5} evt/kg/day**

- Activity of typical Human
  - ❑ **~10 kBq (10^4 decays per second, 10^9 decays per day)**

- Environmental Gamma Activity in unshielded detector
  - ❑ **10^7 evt/kg/day (all values integrated 0–100 keV)**
  - ❑ **This can be reduced to ~10^2 evt/kg/day using 25 cm of Pb**

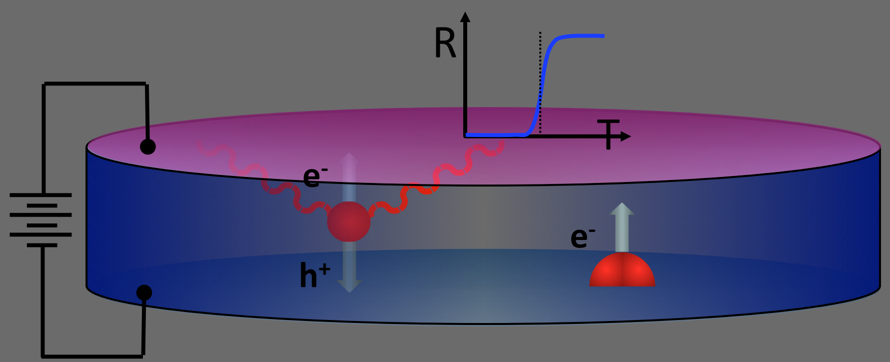
An event-by-event discrimination based on Nuclear versus Electron recoil is therefore inevitable!

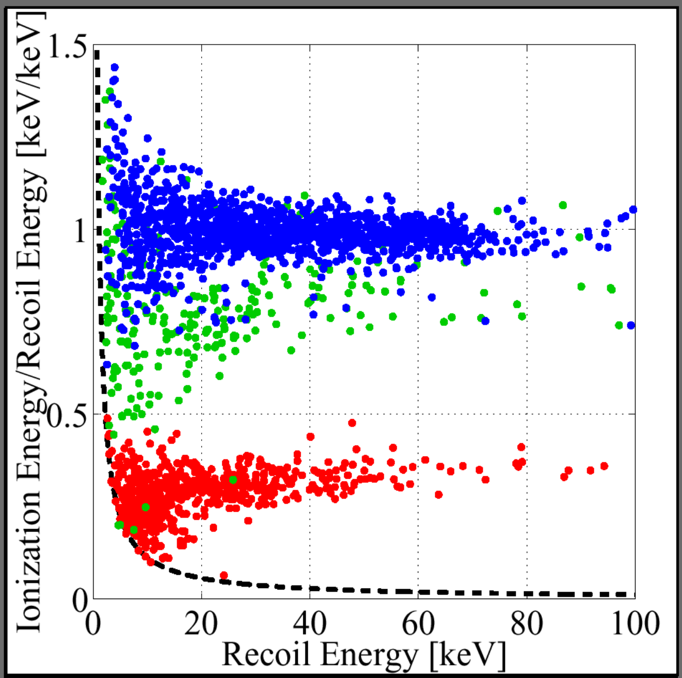
Event-by-event discrimination



CDMS Detection Principle

- Measure recoil energy via Lattice vibrations (phonons) in Ge or Si:
  - Very sensitive superconducting Transition Edge Sensors : Tc~0.08 K
- Measure the Ionization
- Ionizing power (Ionization yield:Y)
  - $Y_{electron\text{-}recoil} > Y_{nuclear\text{-}recoil}$
  - Event-by-event discrimination
- Near surface events
  - Electron recoil but poor charge collection
  - Near geometrical boundaries



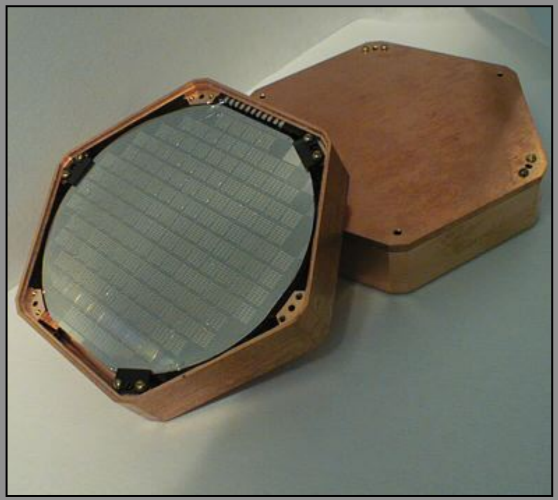


CDMS solution:

Use information in the athermal phonon signal: reconstruct history of the event

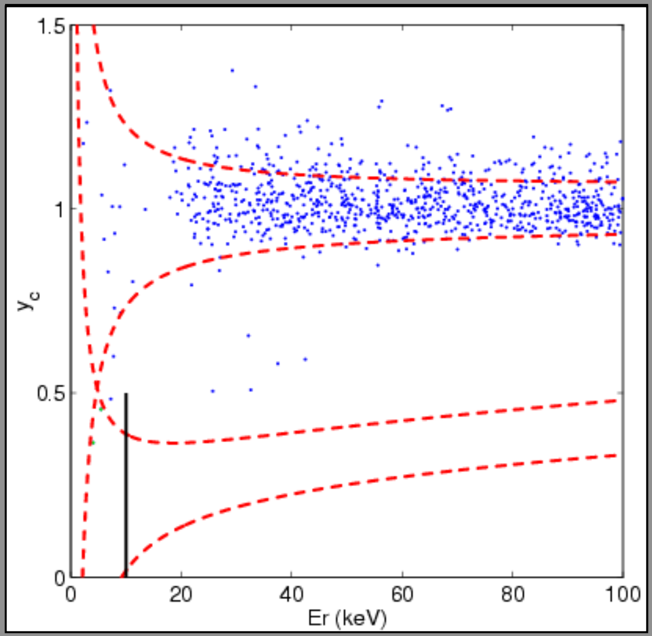
=> Identify near surface events

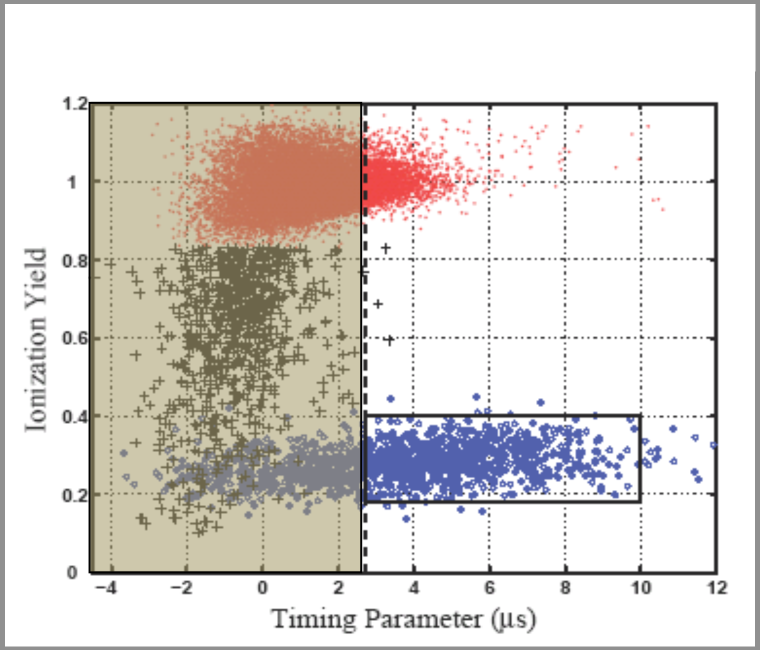
ZIPs，Timing Parameters and: Identification of the near surface events



- Ge (0.25 kg), Si (0.1 kg)
  - Φ=7.5 cm, h=1 cm
- Athermal phonon-sensors covering one face:

  Quasi particle trapping (Al 40% surface coverage) Transition Edge Sensors (Fe implanted W Tc~80 mK).
- Catch phonons before equilibrium: Measure **Energy** AND find **position**





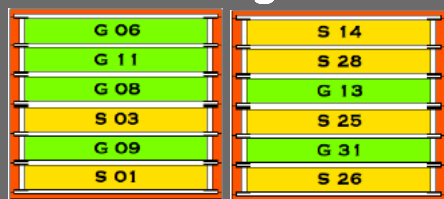
Reject 99.9998% of **Gammas**, 99.8% of **surface** events

Status Before this Analysis

1 kg Ge

52.6 kg.days
10/2003 to 01/2004

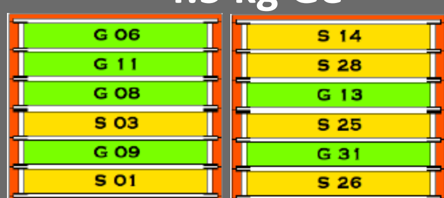
1.5 kg Ge



93.1 kg.days
03/2003 to 08/2004

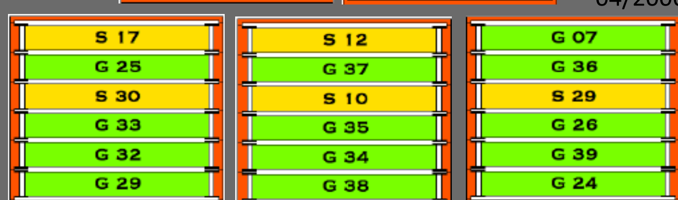
Important progress based on the previous runs:
Better timing rejection, Better phonon sensor tuning
Better background and background rejection

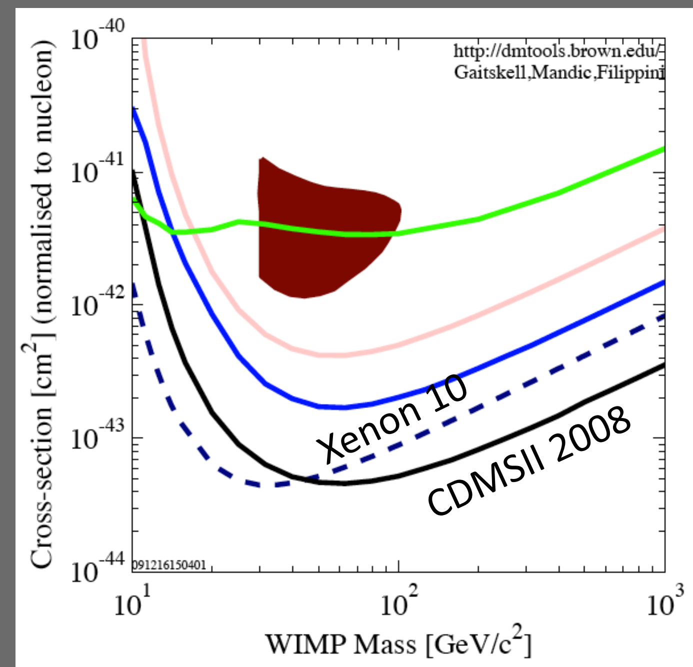
4.5 kg Ge



397 kg.days
10/2006 to 03/2007

1200kg.days
04/2006 to





Phys. Rev. Lett. **93, 211301 (2004)**
Phys. Rev. Lett. **96, 011302 (2006)**
Phys. Rev. Lett. **102, 011301 (2009)**

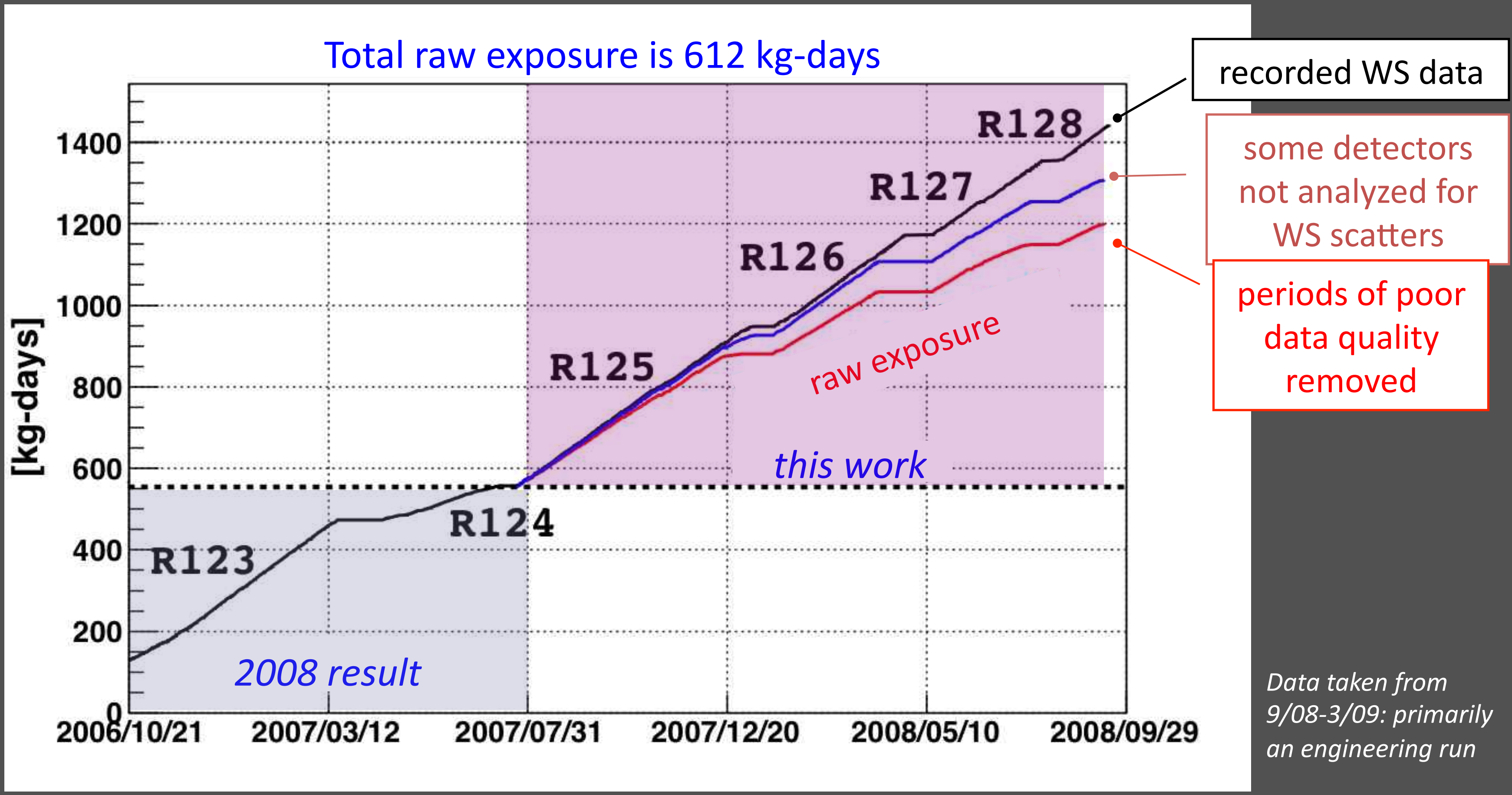
CDMSII run 125-128

(*This presentation*)

WIMP Search Exposure

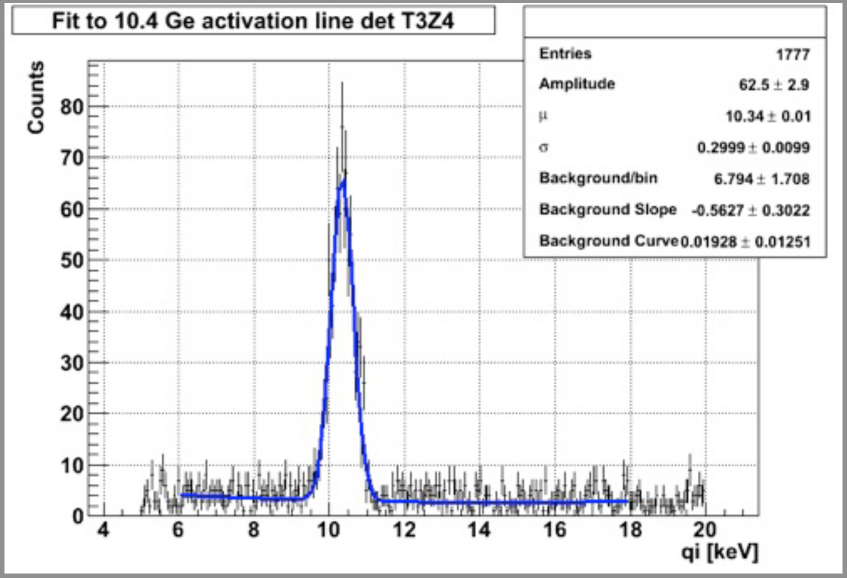
4 runs separated by partial warm-ups of cryostat

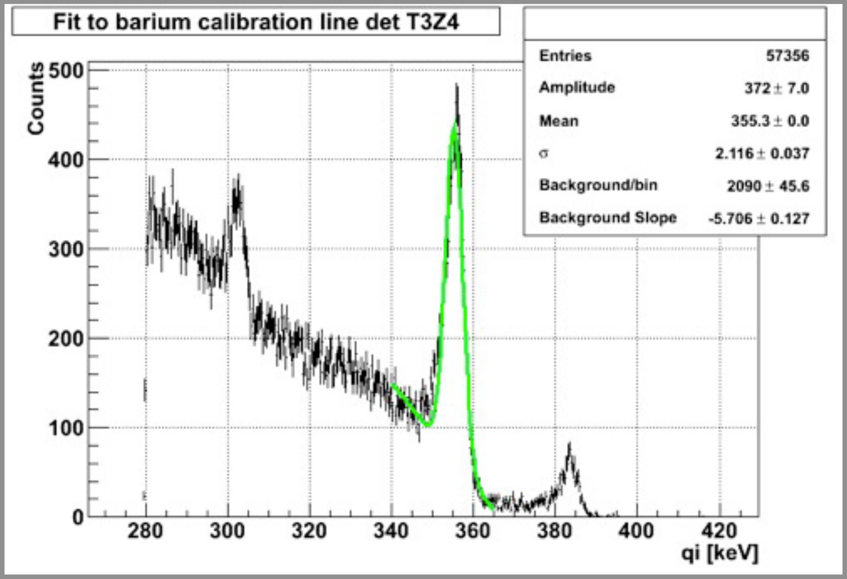
Dates of data taking: 7/2007 - 9/2008



Data taken from 9/08-3/09: primarily an engineering run

Calibration (1)





Two Sources:

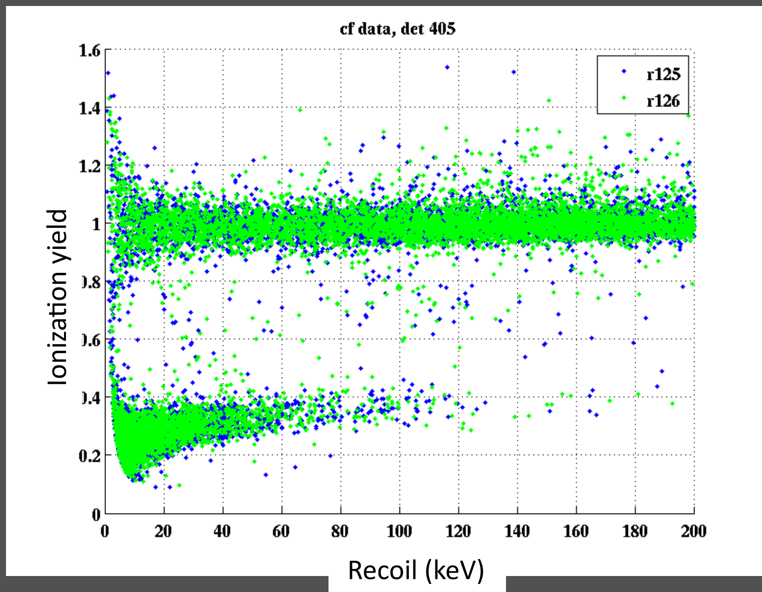
^{133}Ba: γ-lines at 303, 356 & 384 keV

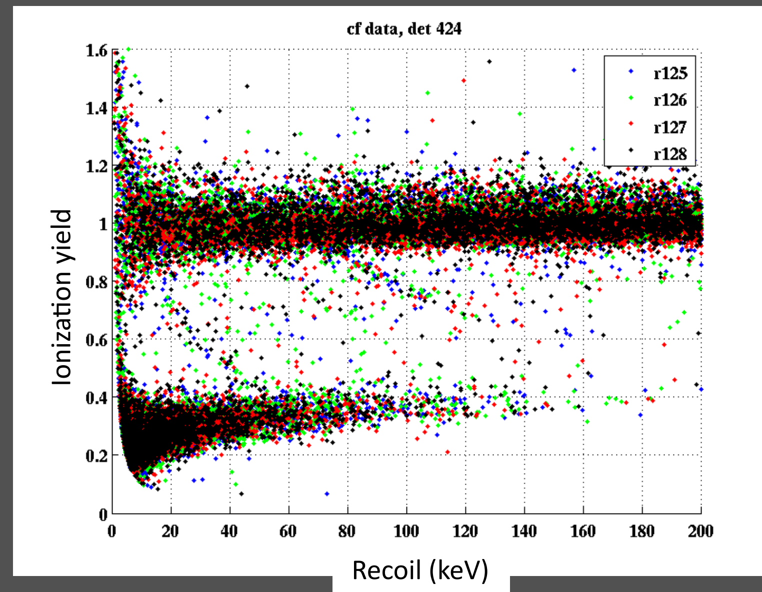
^{252}Cf: neutrons ~few MeV, neutron activation of Ge → 10.4 keV γ-line

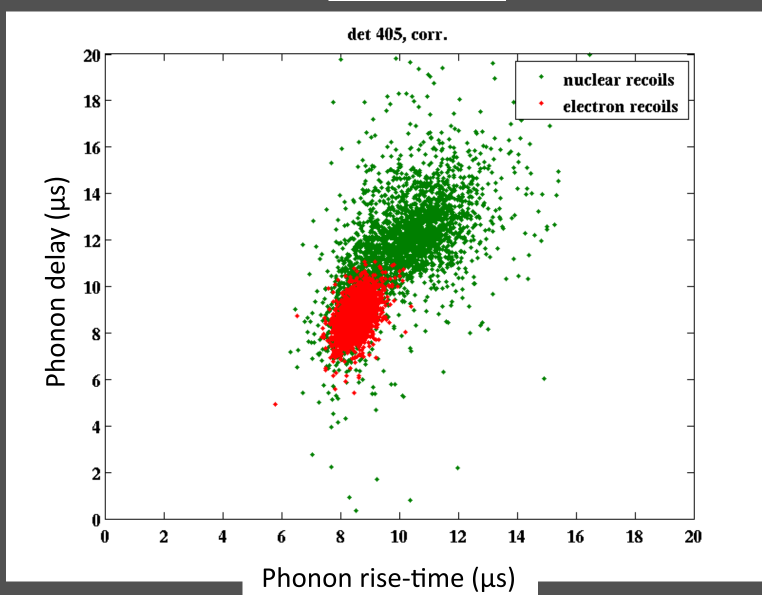
Many Uses:

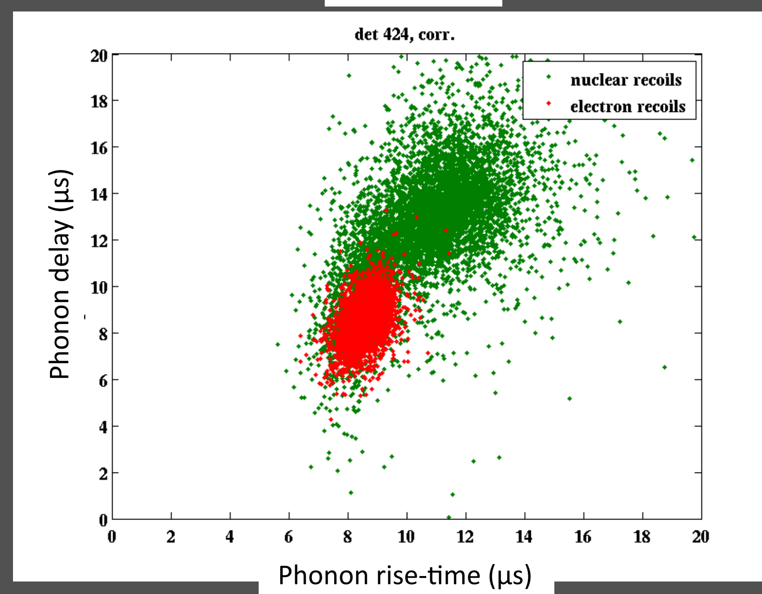
- In-situ measurement of energy scale
- resolution and linearity
- position correction
- measure selection efficiencies
- develop surface event rejection

Calibration (2)









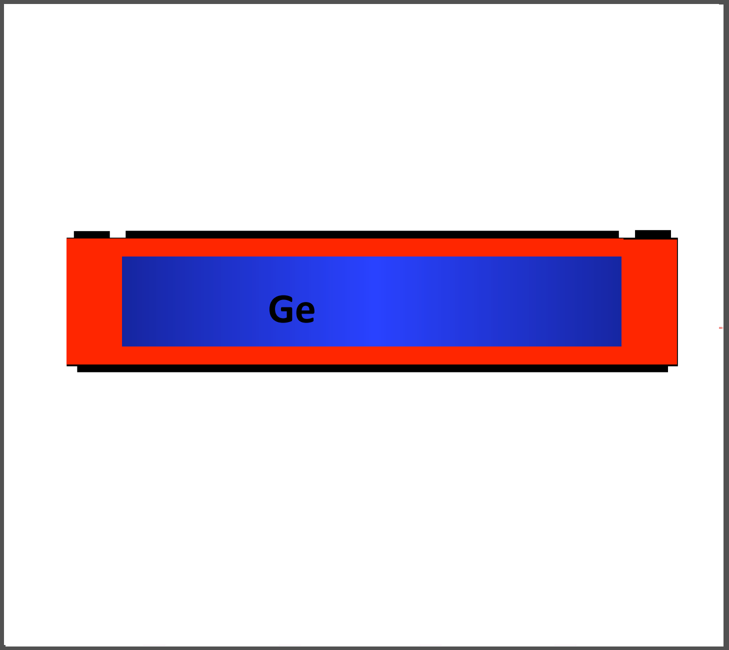
Analysis Steps

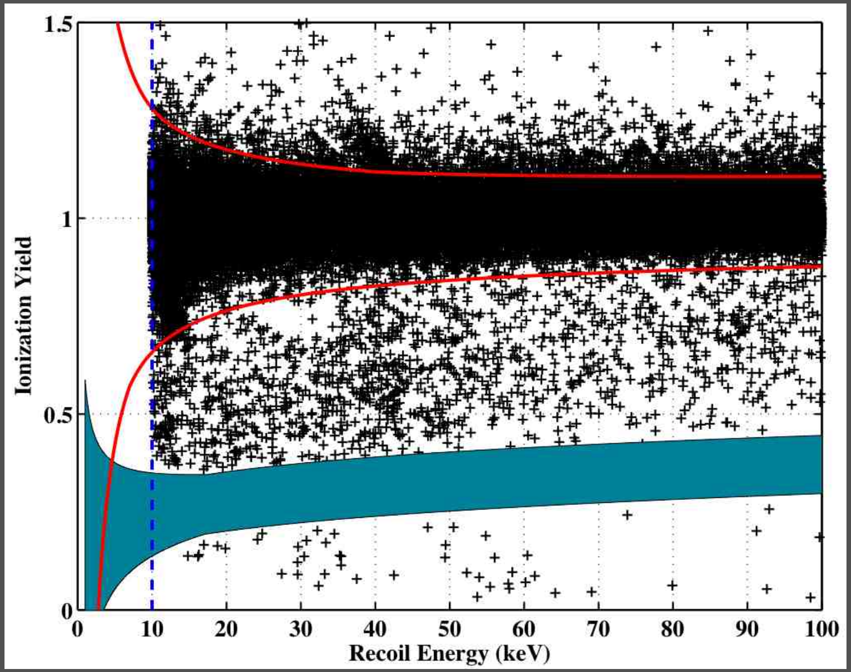
Blind analysis: NR singles veto anti-coincident masked (3σ)

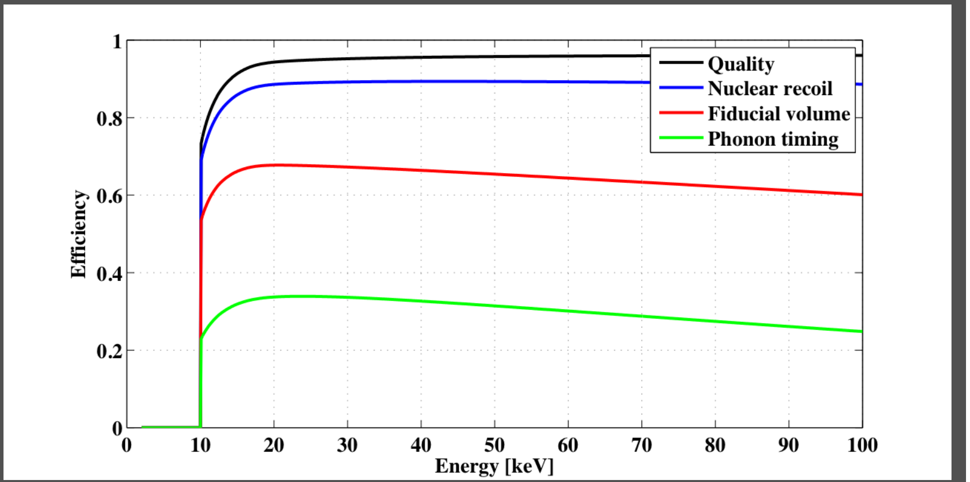
Data quality cuts

Physics cuts:

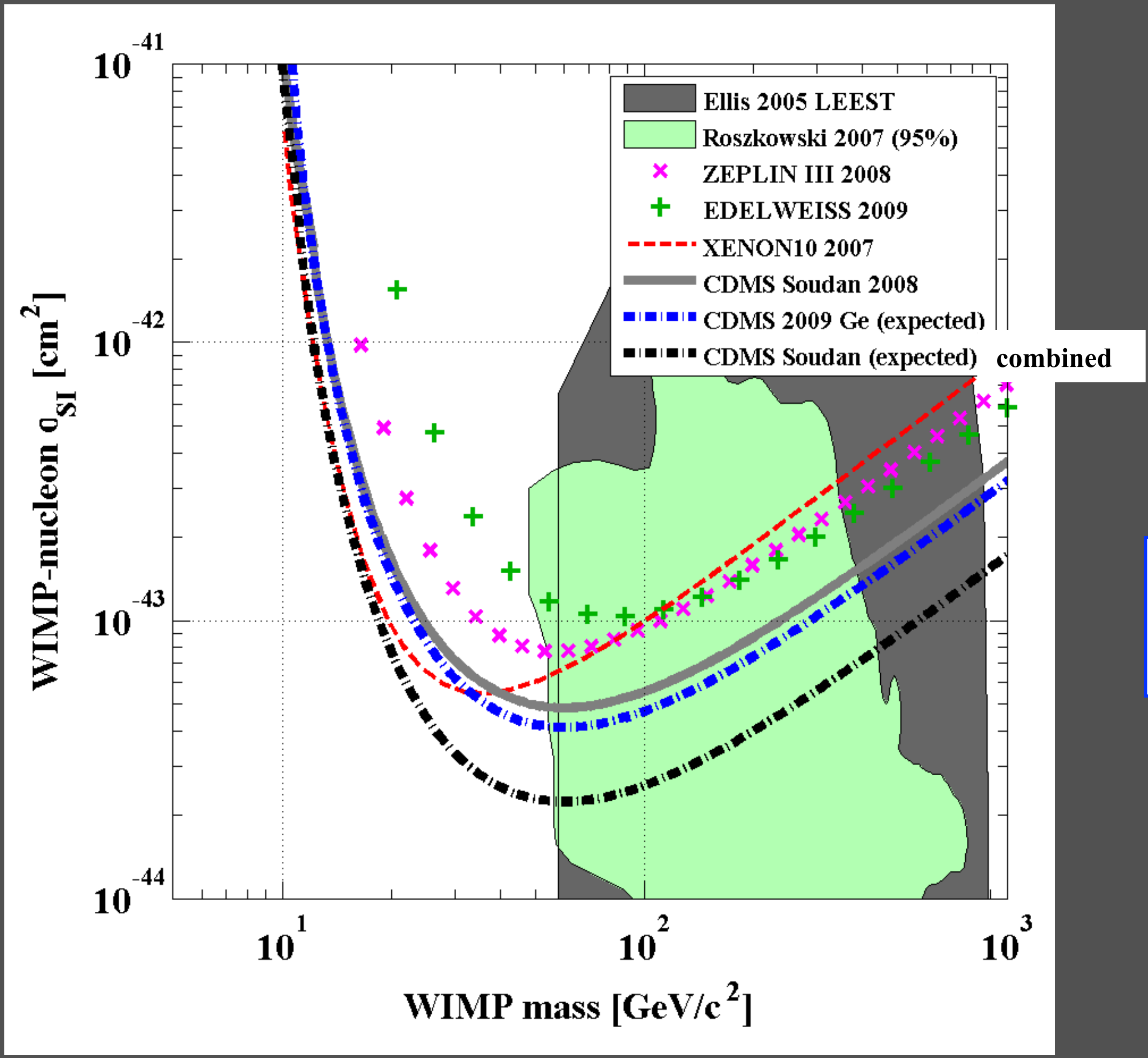
- Veto coincident
- Single scatter
- Q_{inner} (fiducial volume) cut
- Phonon timing







Expected Limit 90% C.L.



Total exposure after all cuts: 194.1 kg-days

Estimated Surface Events: 0.6 ± 0.1

Estimated Cosmogenic Neutrons: $0.04^{+0.04}_{-0.03}$

Estimated Radiogenic Neutrons: 0.03-0.06

results

Unblinding

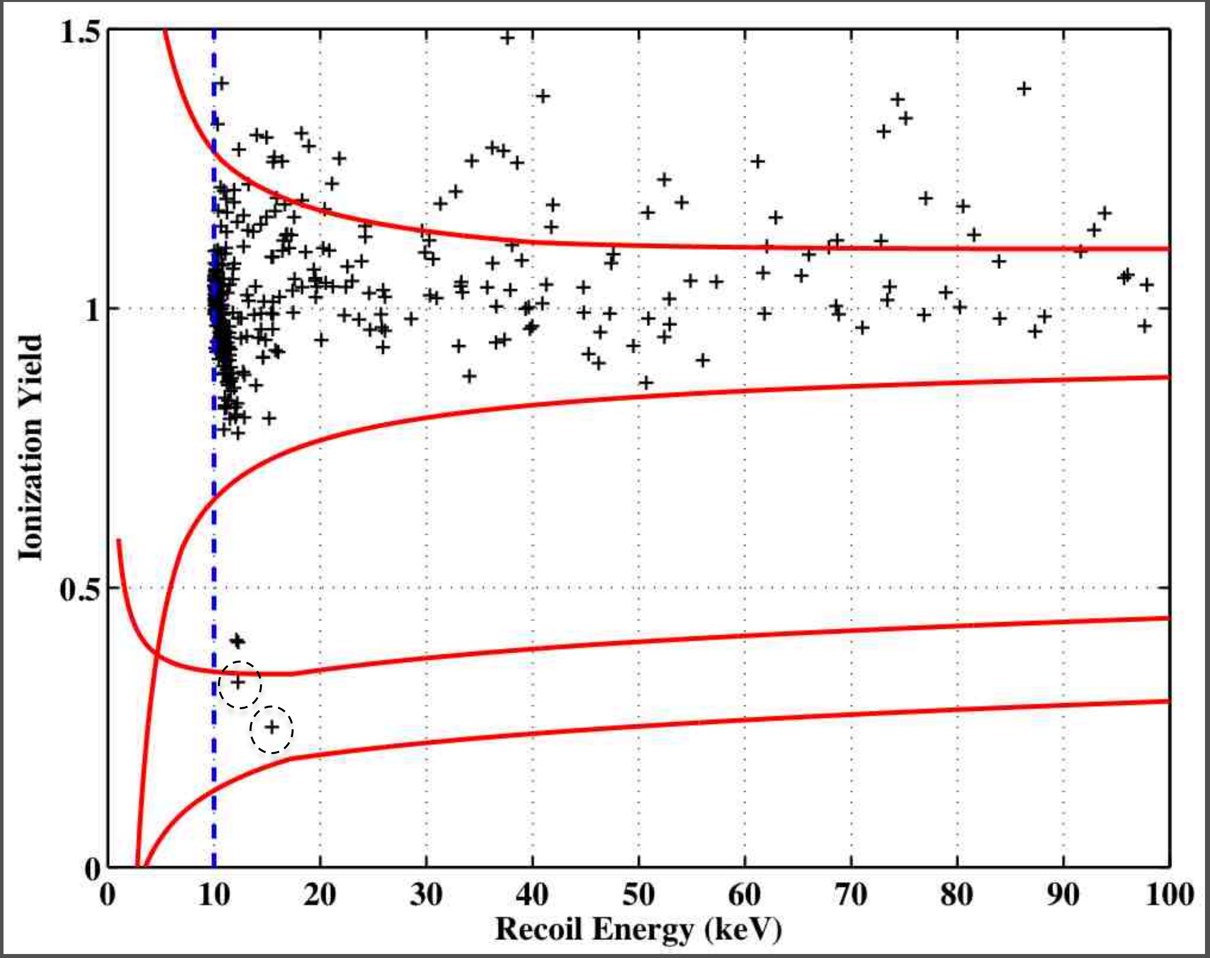
We opened the box on Nov 5th 2009 for 14 Ge ZIP detectors

3σ region masked

Lift mask saw 150 Singles failing timing cuts: ***Consistency deemed OK***

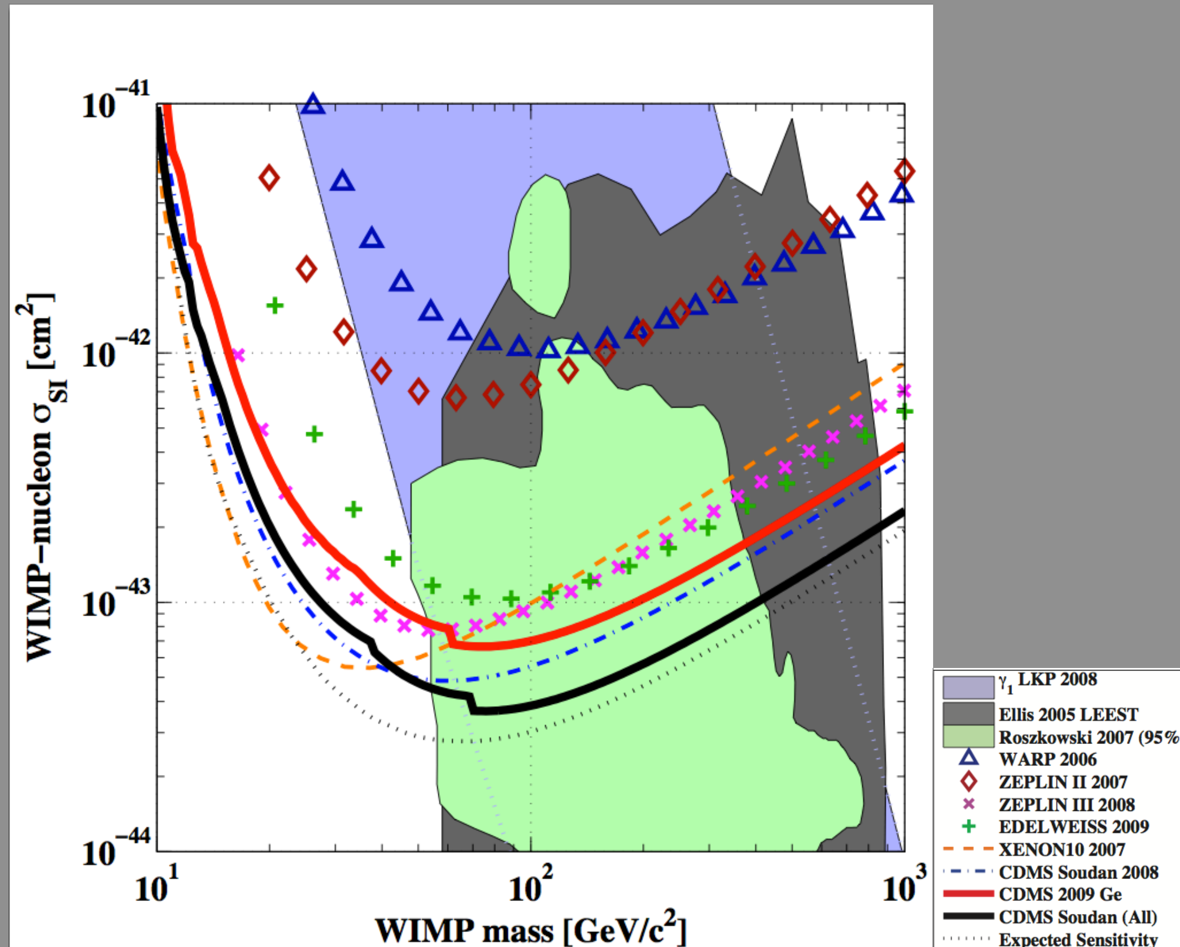
Apply timing cuts

2 events observed



arXiv:0912.3592v1 [astro-ph.CO] 18 Dec 2009

CDMS II Results



Upper limit at the 90% C.L. on the WIMP-nucleon cross section :

3.8×10^{-44} cm^2 for a WIMP of mass 70 GeV/c^2

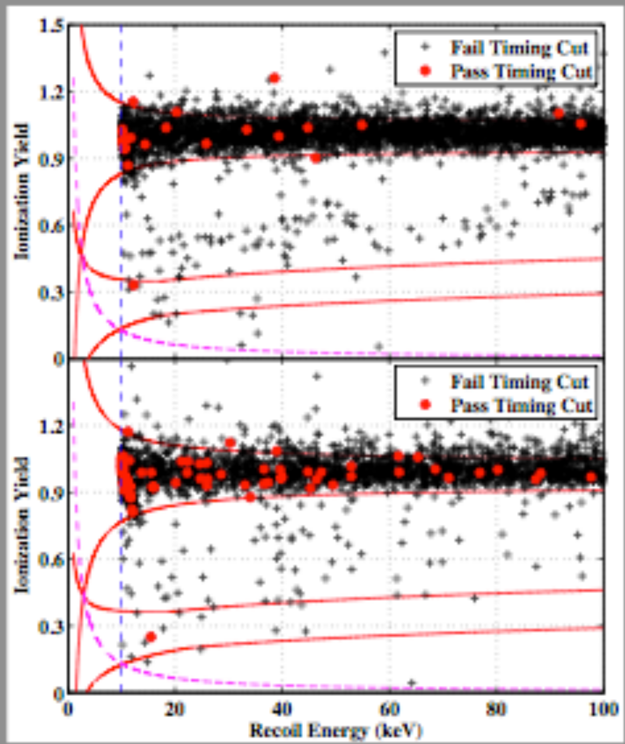
arXiv:0912.3592v1 [astro-ph.CO] 18 Dec 2009

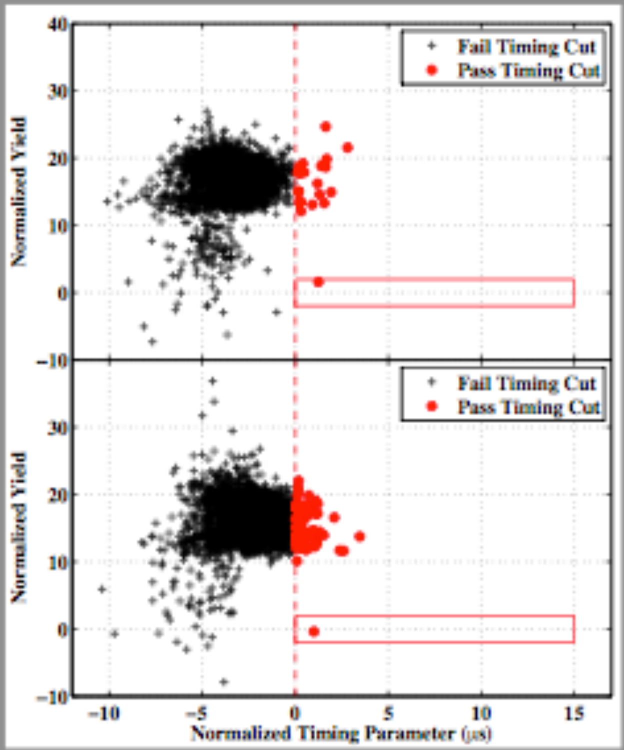
What about the 2 events?

Ionization Yield, Energy and Timing

Saturday Oct, 27th 2007

Sunday Aug, 5th 2007

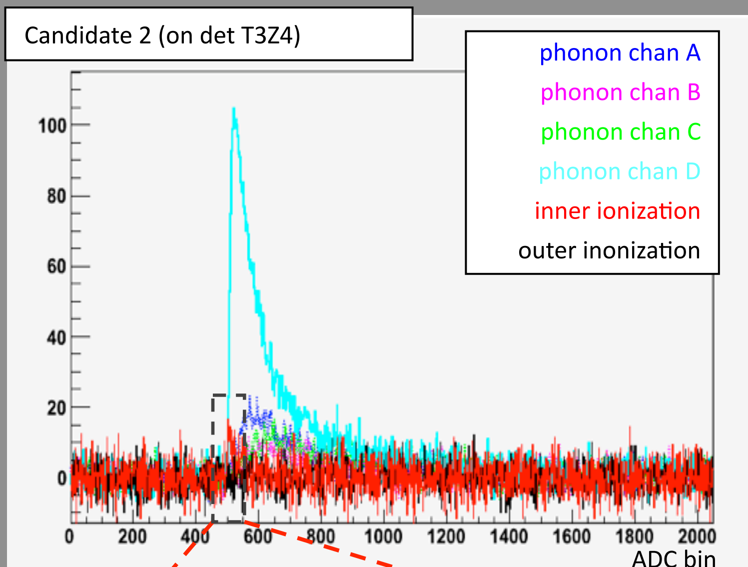


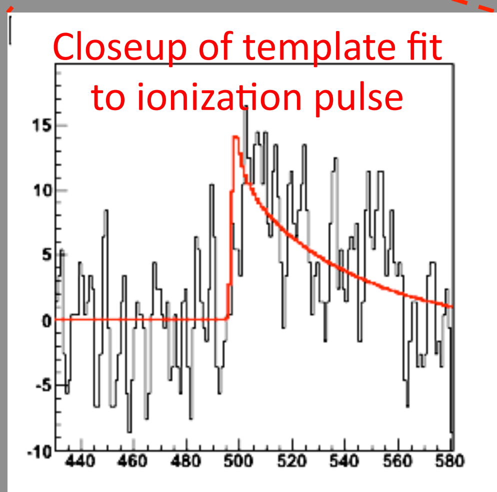


Events in two different detectors in two different Towers at well separated times

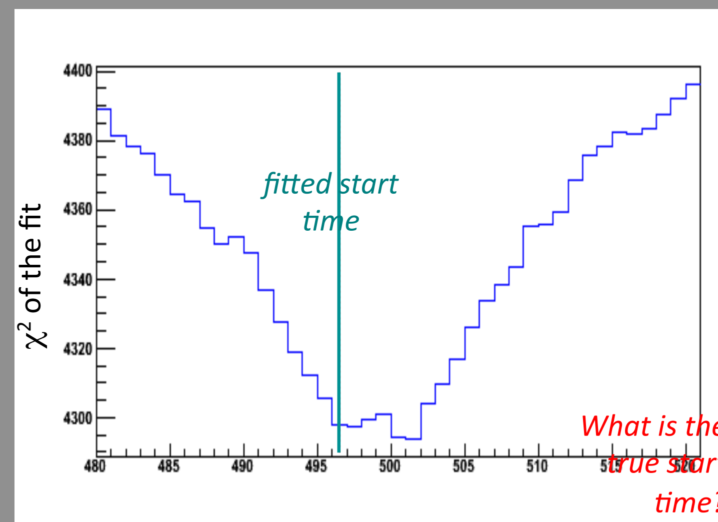
They occur in inner detectors: Better handle on backgrounds

Reconstruction Checks (T3Z4 event)





ionization and phonon energies look good, phonon timing looks good…



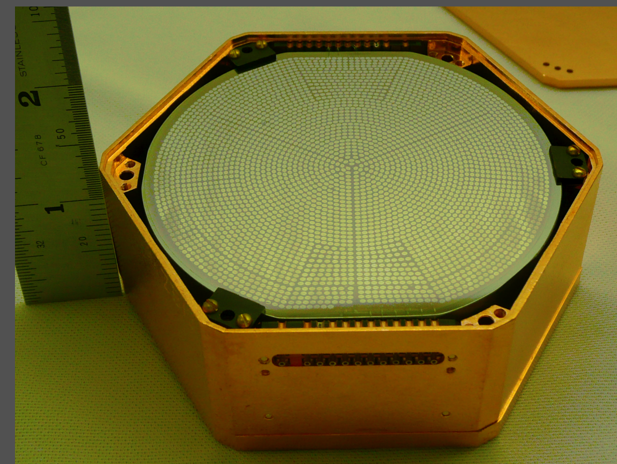
ADC bin

This effect is strongly correlated with the ionization energy *(affects events with < 6 keV ionization energy)* and was mostly accounted for in the pre-unblinding leakage estimate.

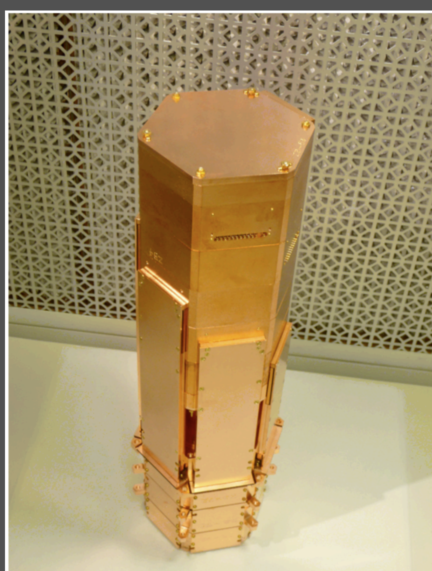
the future

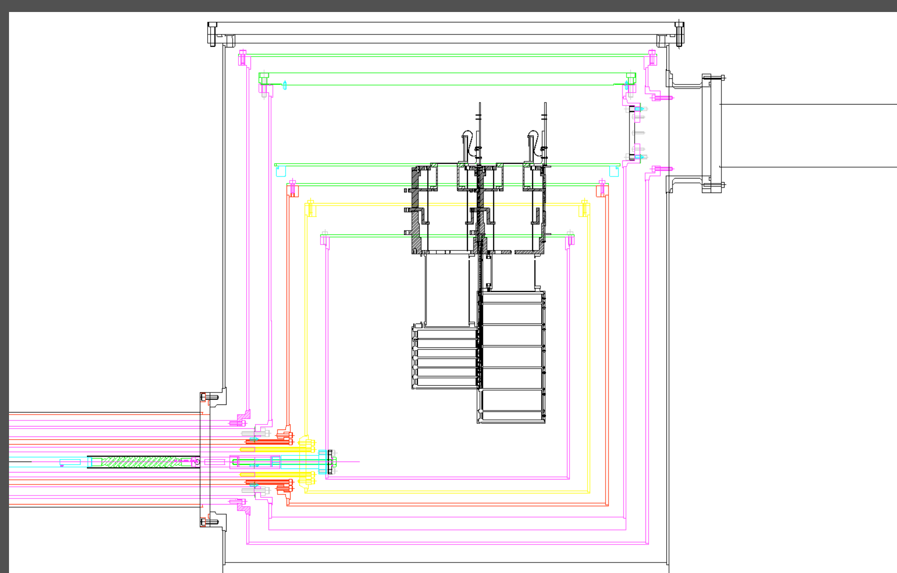
SuperCDMS Soudan 15kg

- New 1 inch thick detectors : 0.64 kg
  - improved phonon readout geometry
  - 2.5 × bulk/surface
  - Studied at the CDMS TF
- SuperTower: 5 × 1 inch detectors + 2 × 1 cm veto detectors



- SuperCDMS 5 ST: Approved
- ST1 installed at Soudan March 2009: Cold and running
- Summer 2010 install 4 more STs and run for 3 years: ~8000 kg-d
- Goal: $\sigma \sim 5\times10^{-45}$ cm^2



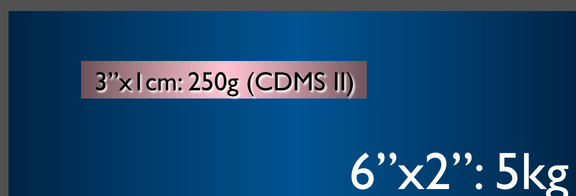


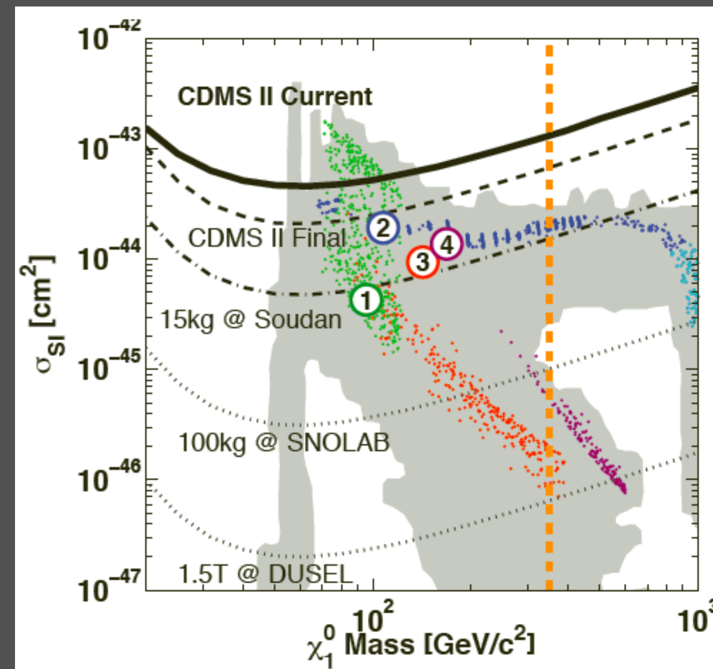
SuperCDMS future

CDMS SNOLAB 100 kg: 100 K kg-d

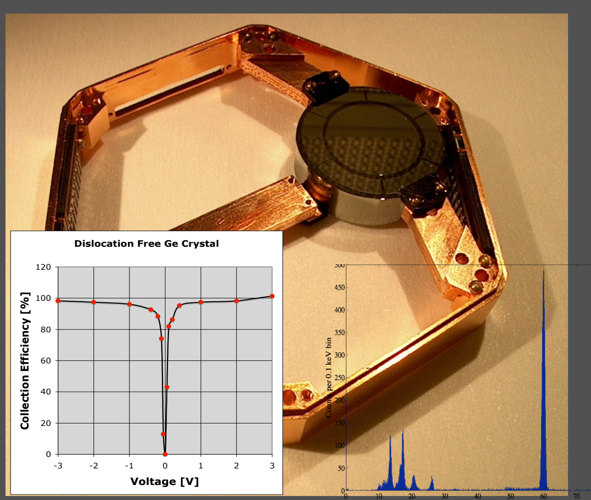
DUSEL: Germanium Observatory for DM (GEODM)
1500 kg: 1.5 M kg-d

Rule of the game:
Larger exposure only if better discrimination/kg
Proportionally

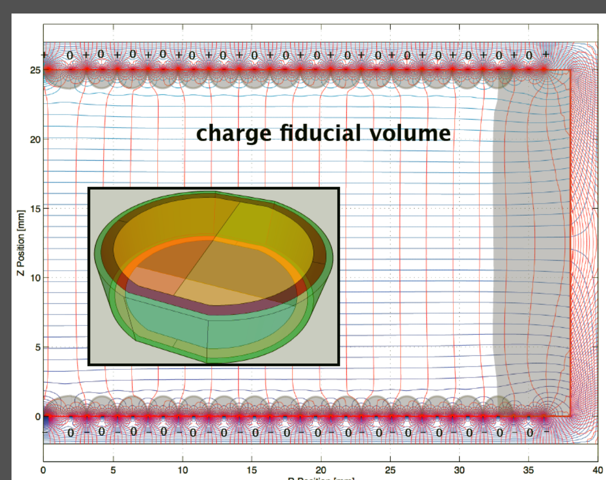




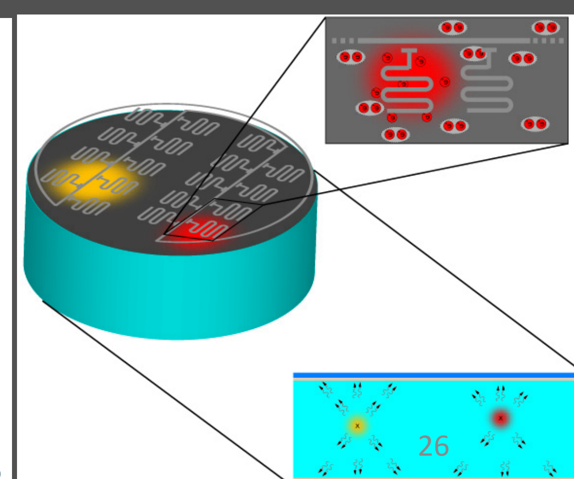
Large Ge substrate studies



New electrode geometry:



Kinetic Inductance Detectors (KIDs)



Conclusions

- We have reported 2 events from our blind analysis. Obtaining 2 or more event given our estimated background has a probability of 23%.
- As a result of this blind analysis we are reporting the world leading limit on SI WIMP-nucleon cross section $\sigma=3.8 \times 10^{-44}$ cm^{2}.
- Not a statistically significant to claim a signal (we would have needed ≈ 5 events).
- At this stage of the analysis we can not exclude that these events are WIMP signals..
- The detailed information provided by our detectors may allow us to sharpen our interpretation. Stay tuned!
- We are deploying 15kg in Soudan by summer 2010 and preparing for SuperCDMS SNOlab with 100 kg detectors. iZIP technology is very promising in terms of back ground rejection.
- Other experiments with low background and different systematics are needed to confirm an eventual signal: watch for XENON 100, LUX EDELWEISS

Thank you!