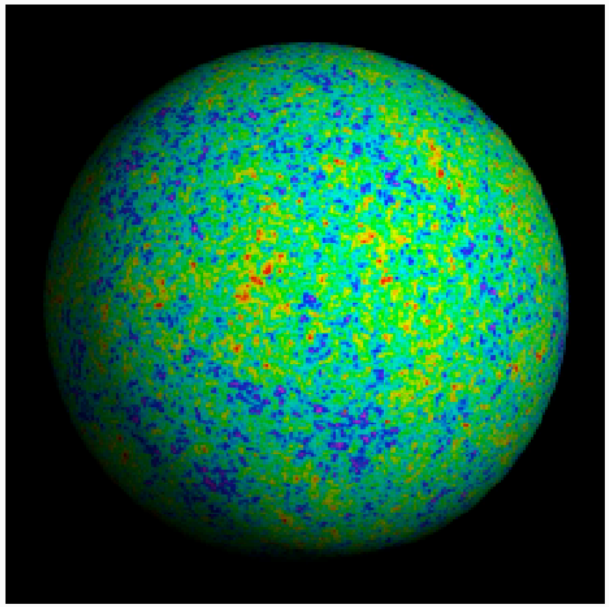
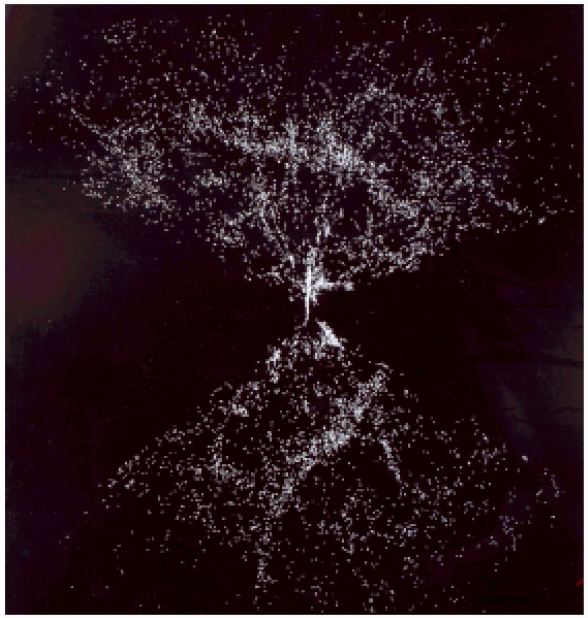
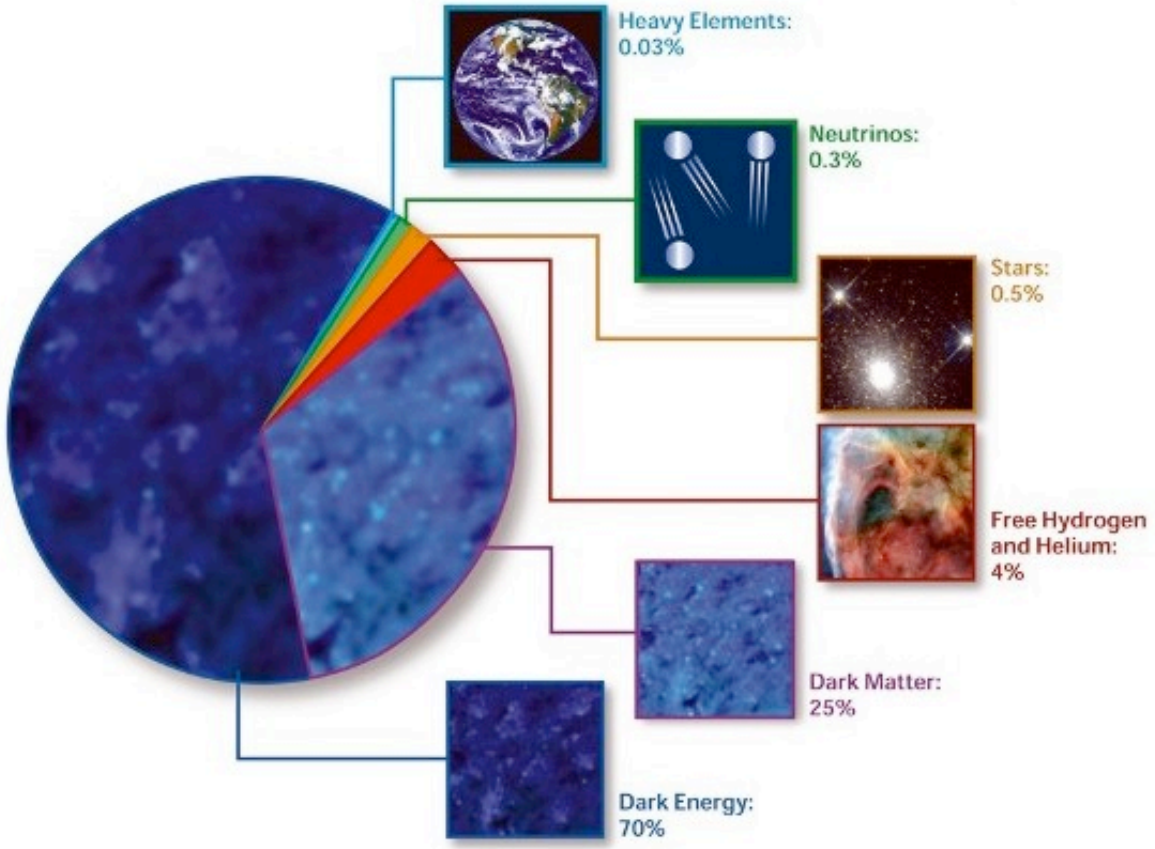
Latest Results from the Cryogenic Dark Matter Search Experiment

Tobias Bruch
University of Zürich
CHIPP Annual Plenary Meeting 2010

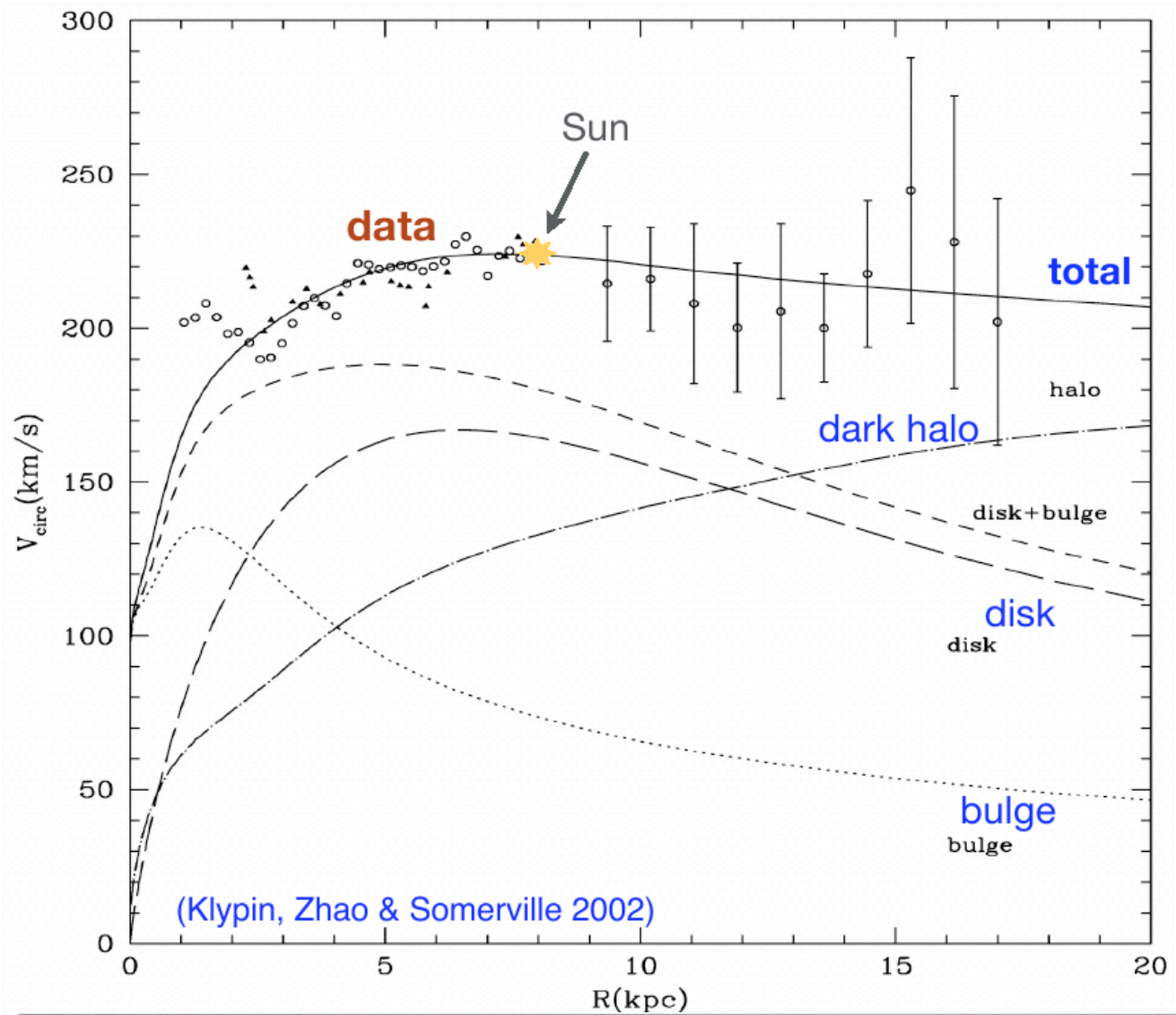
Dark Matter in the Universe







Dark Matter in the Milky Way



$M_{tot,lum} \approx 9 \times 10^{10} M_{Sun}$

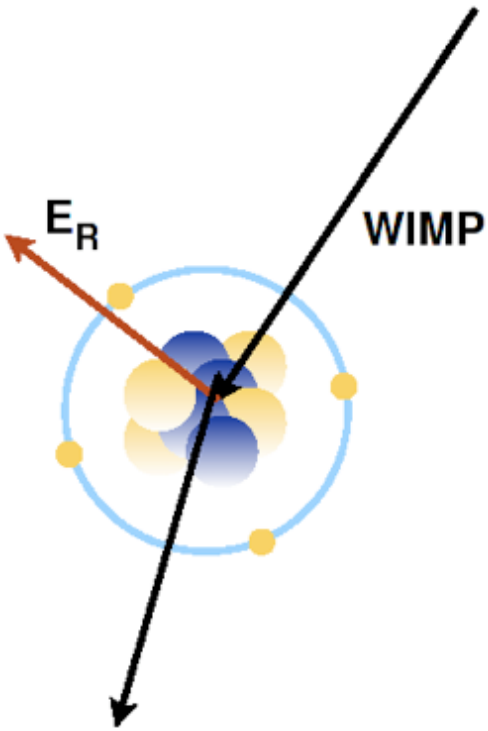
$M_{virial} \approx 1 \ldots 2 \times 10^{12} M_{Sun}$

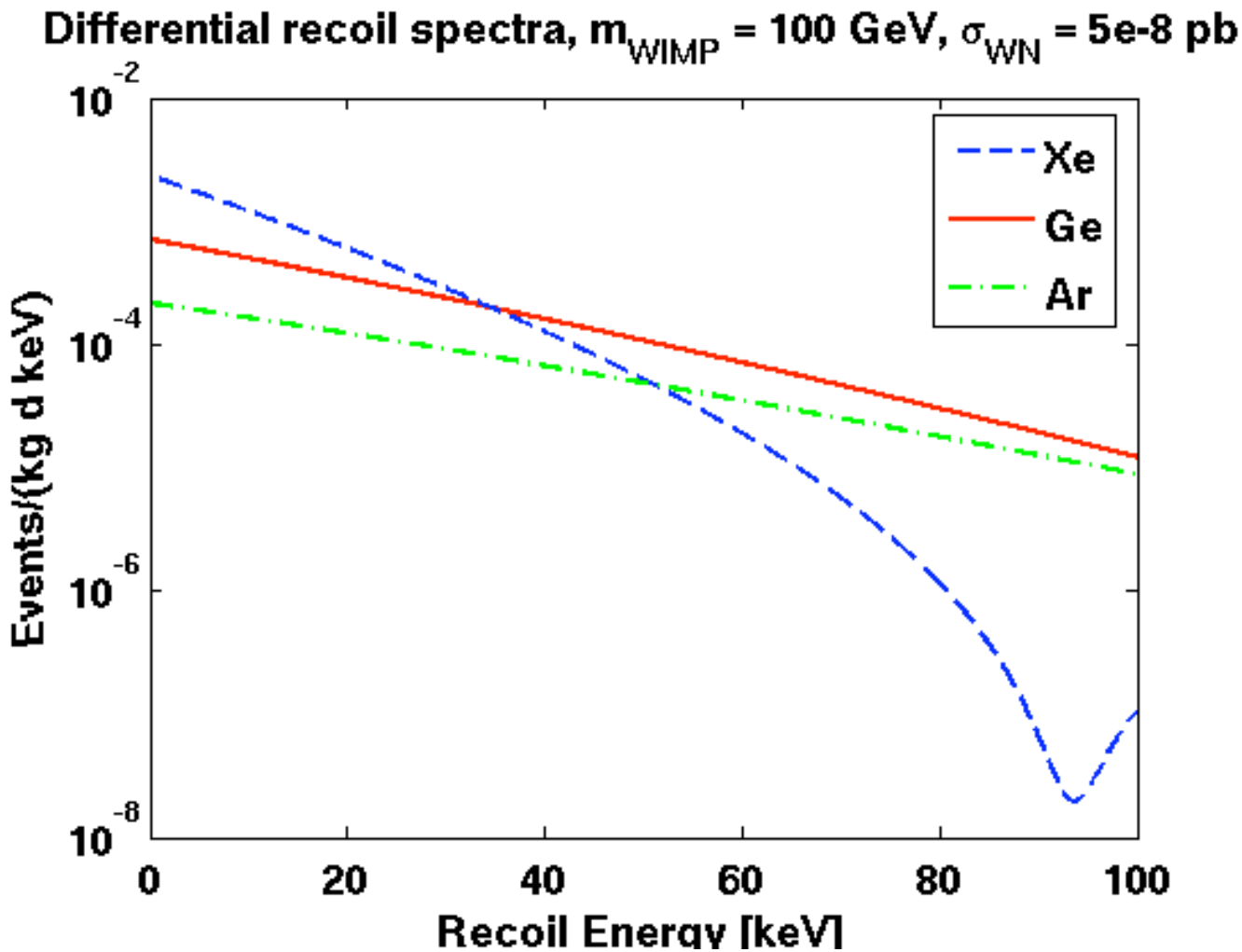
Non luminous "dark" matter component

$\rho_{dark} \approx 0.3 - 0.6$ GeV/cm^3

Direct detection principle

Detect the dark matter particles (WIMPs) by their elastic scattering off atomic nuclei.





Going underground

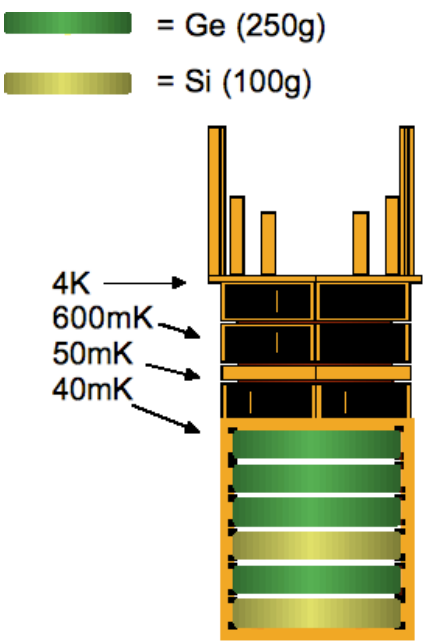
CDMS-II 5 Tower setup

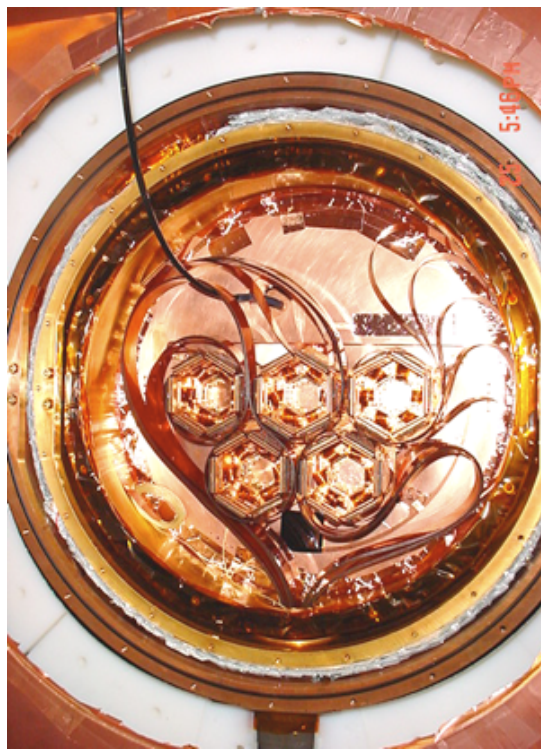
5 Towers a 6 detectors (Ge/Si) operated at cryogenic temperatures (~40 mk)

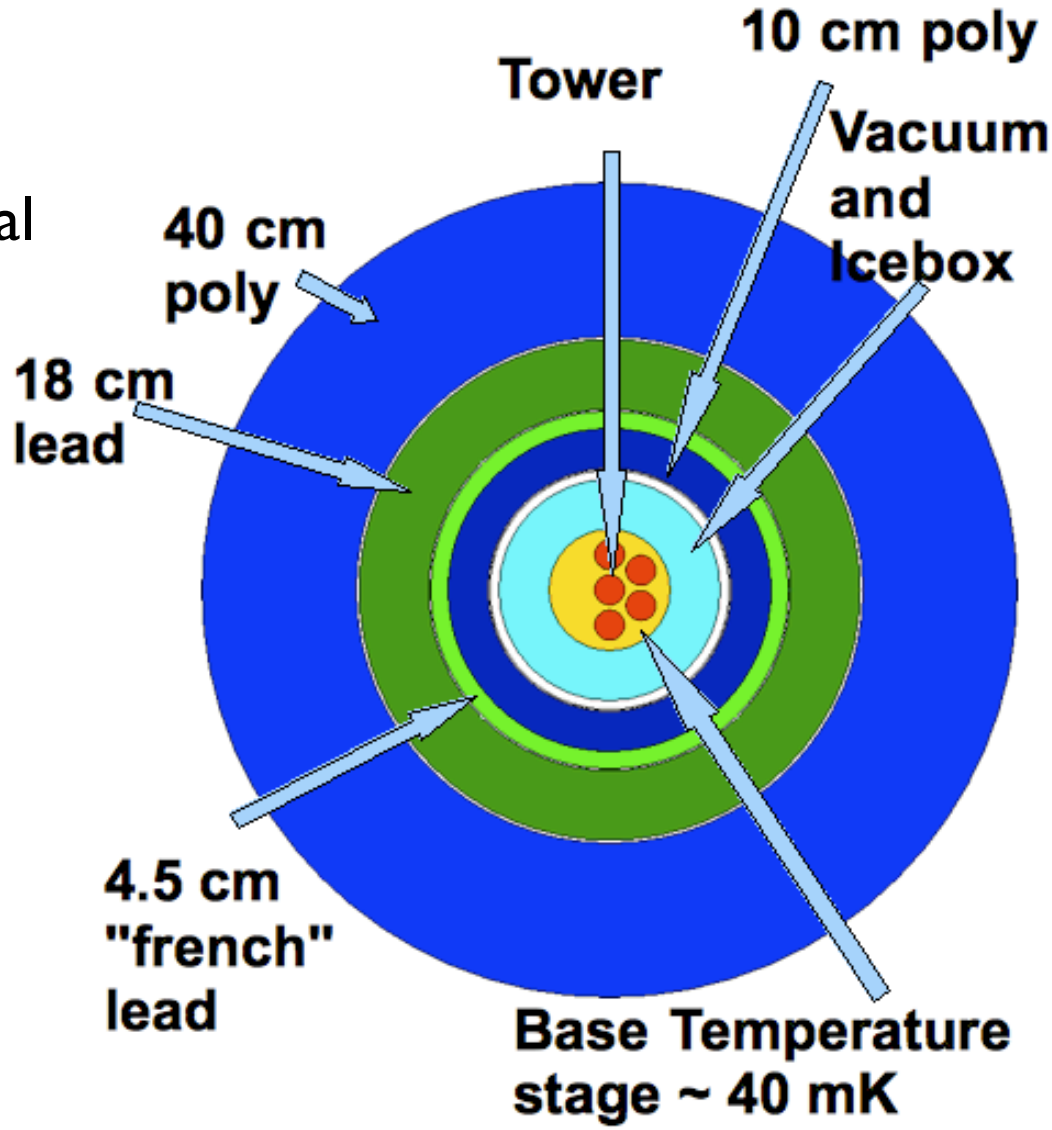
Underground laboratory shields well against cosmic radiation

Active veto for high energetic muons

Passive shielding against environmental radioactivity

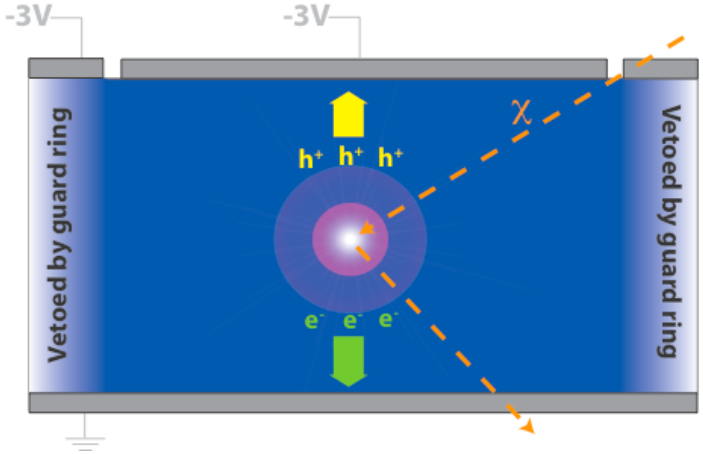


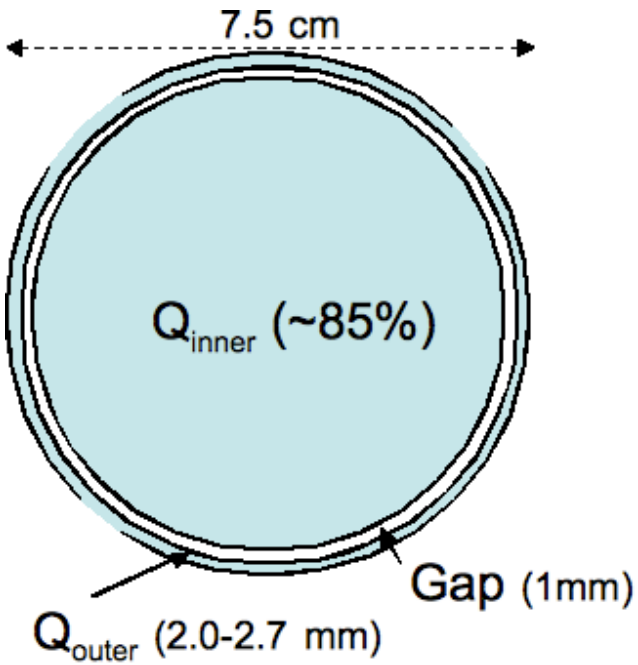




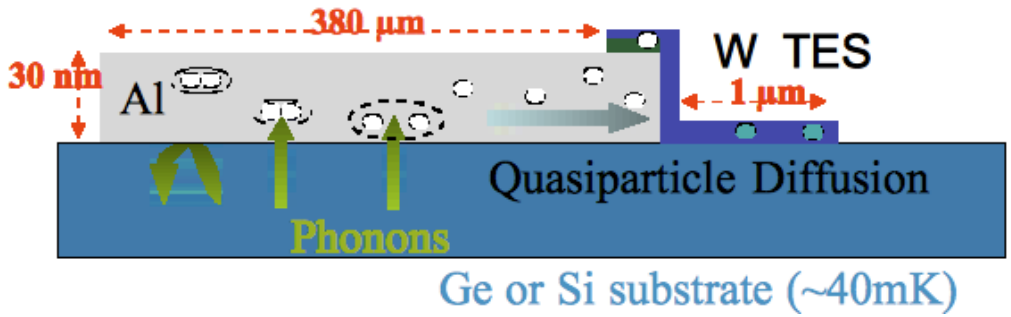
CDMS detectors

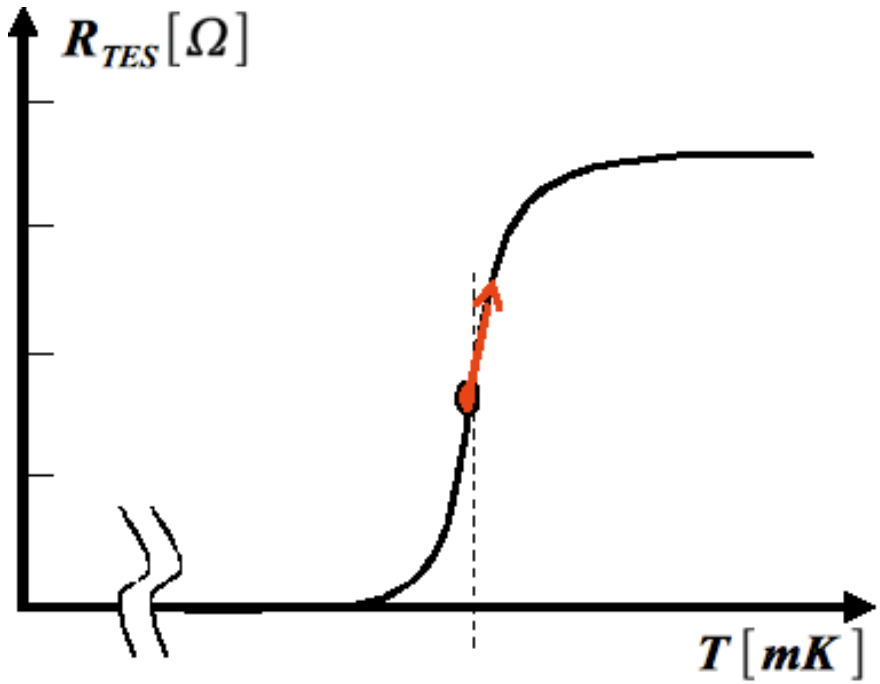
Ionization Signal





Phonon Signal





Primary background rejection

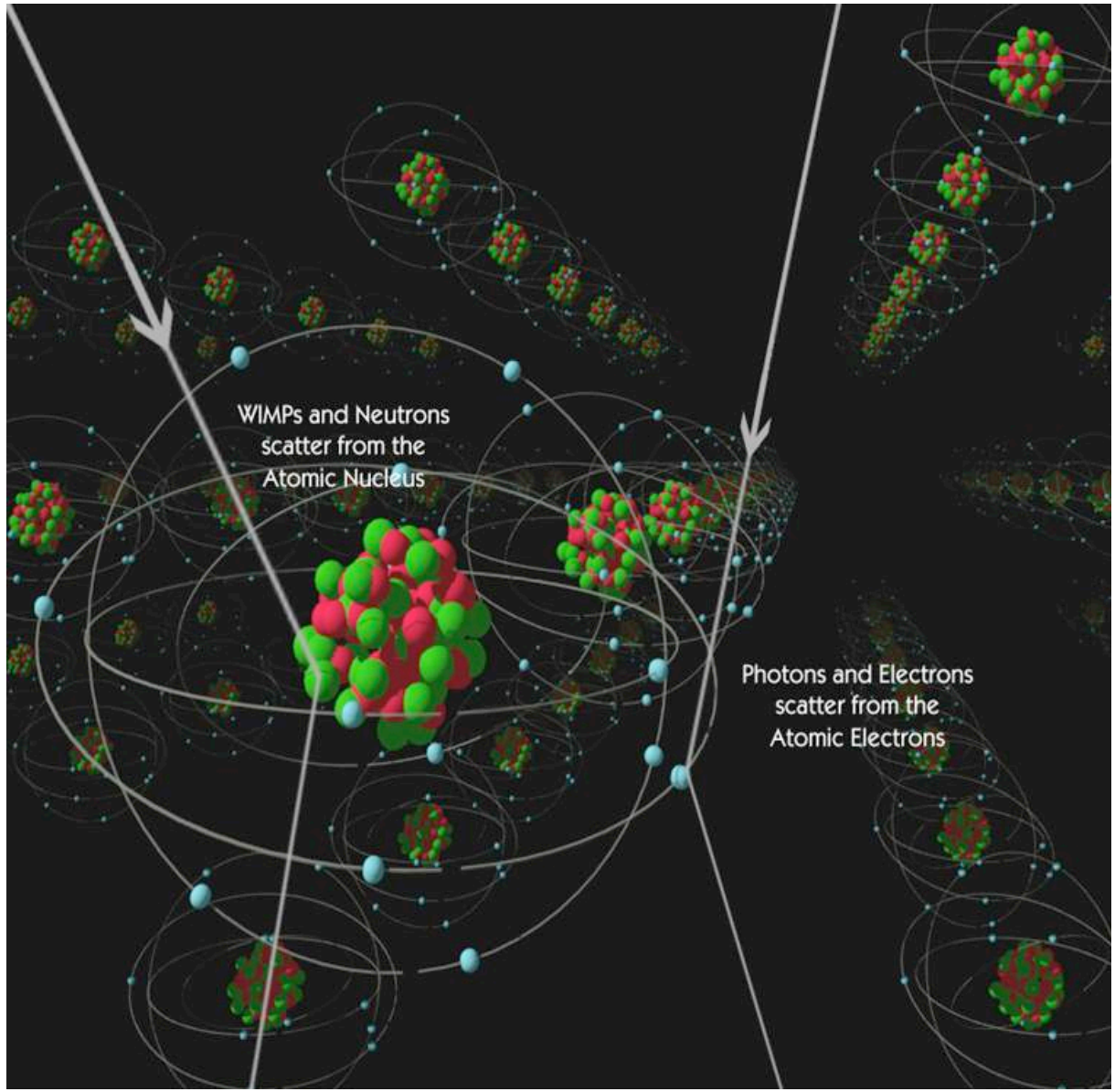
Dominant backgrounds (γ, $e^{\pm}$) produce electron recoils

WIMPS and neutrons produce nuclear recoils

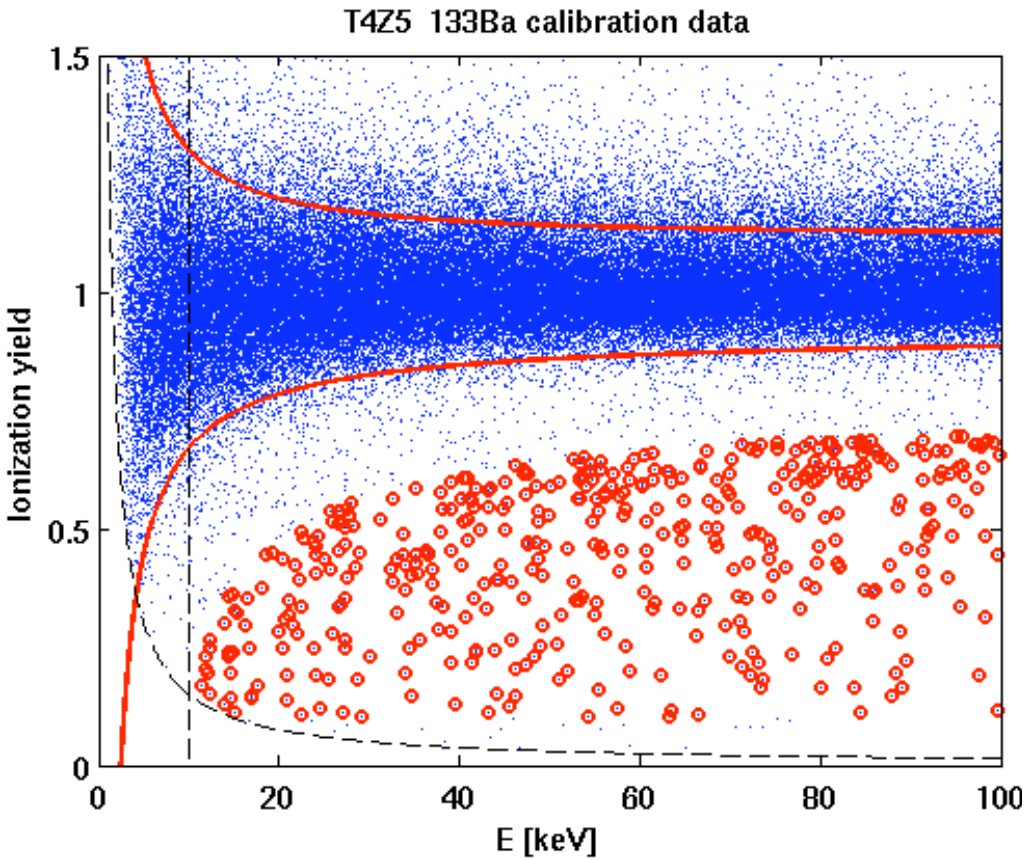
Suppressed ionization signal for nuclear recoils

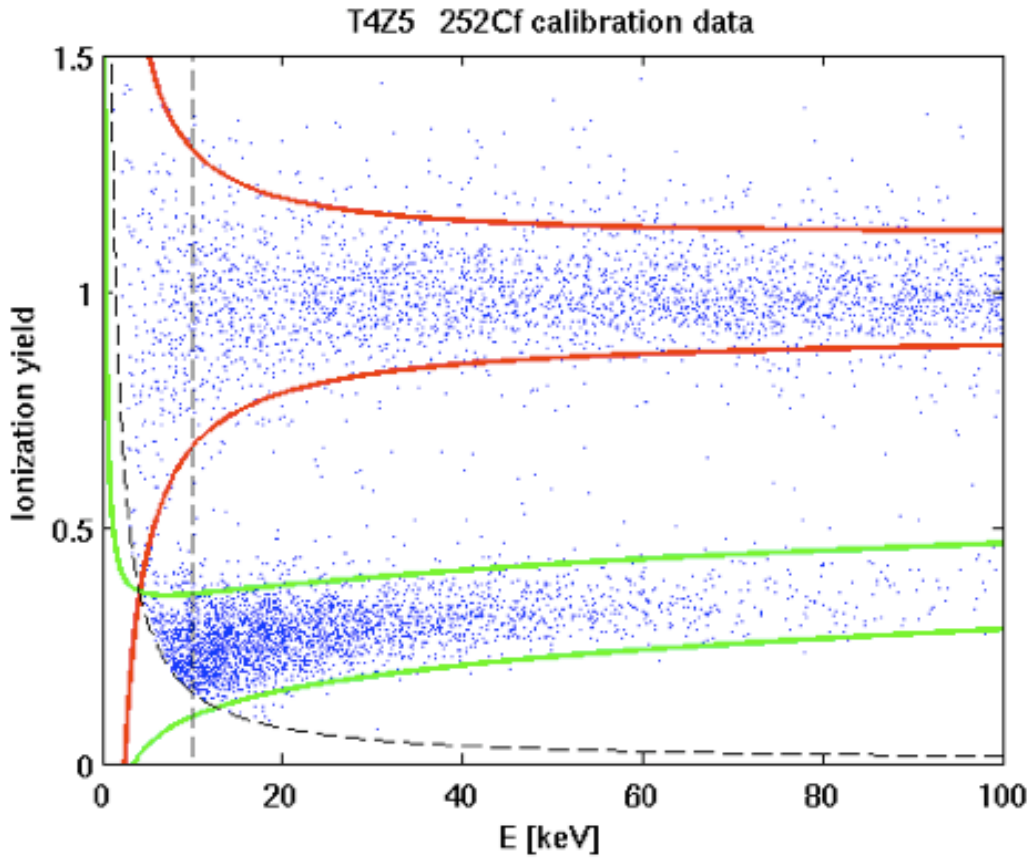
Define ionization yield:

$$y = \frac{E_{charge}}{E_{phonon}}$$



Yield based rejection





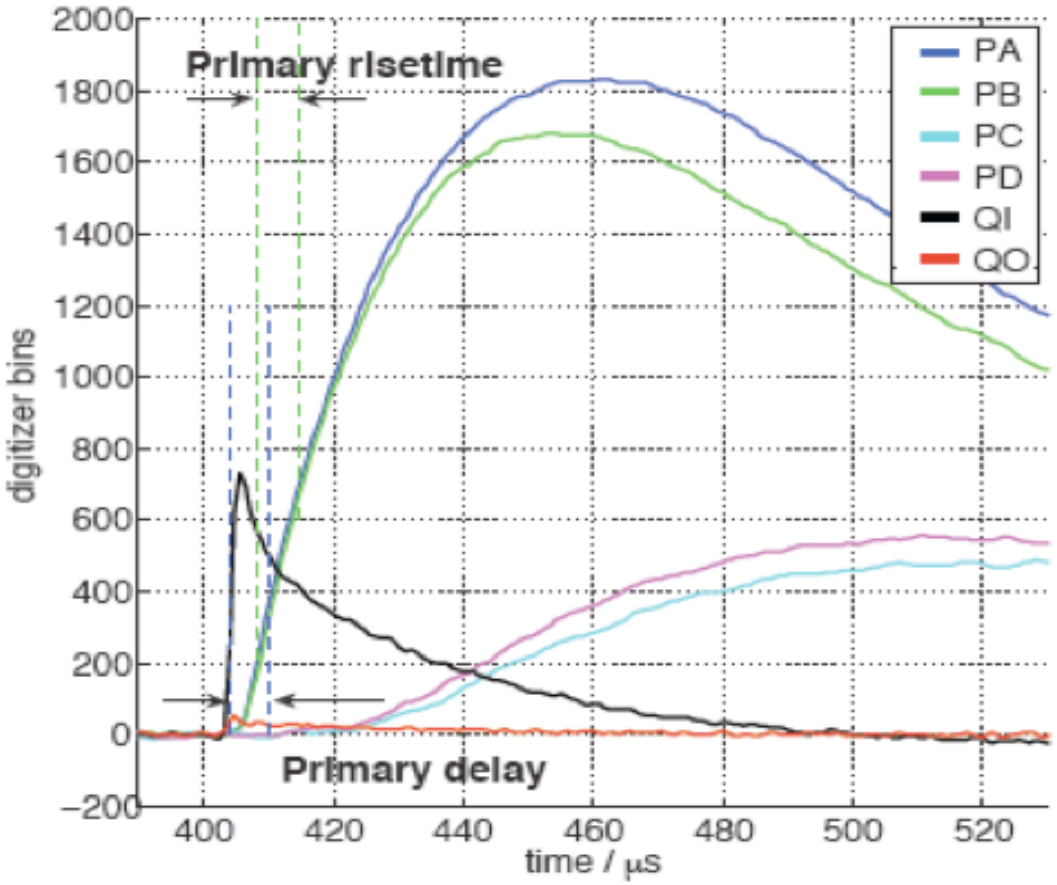
Primary electron recoil rejection 10.000 :1

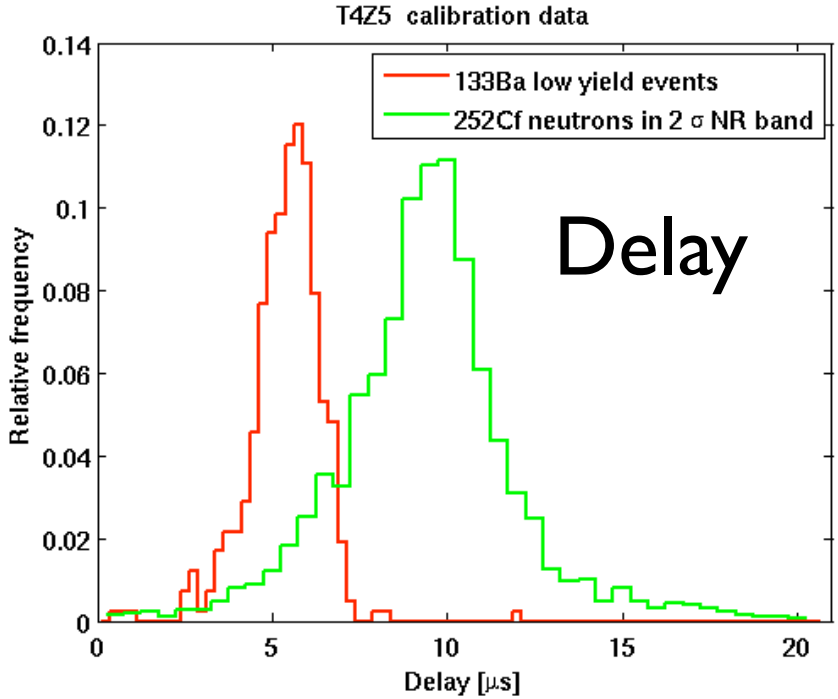
Low yield surface event population remains.

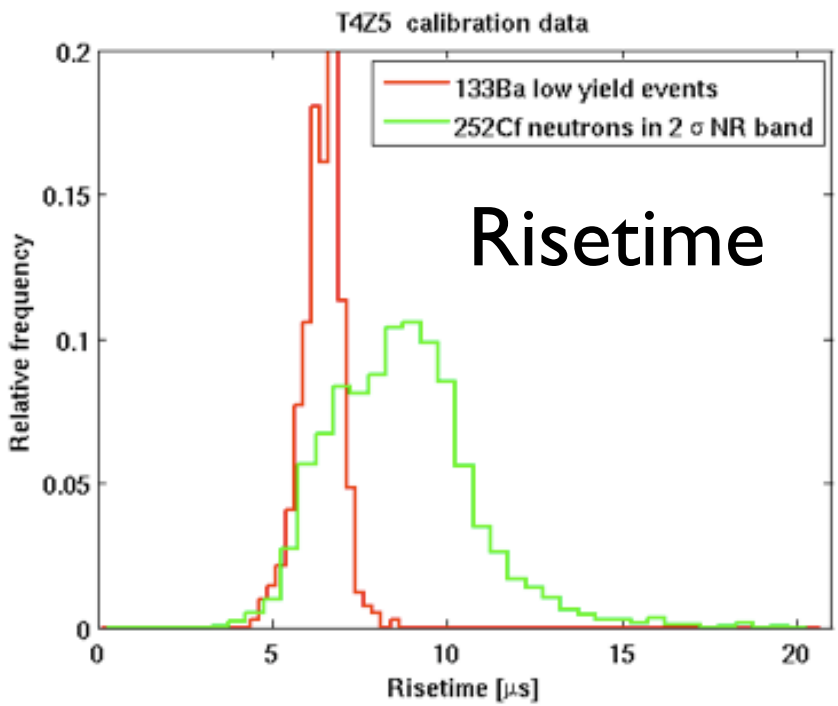
Signal region: 2σ nuclear recoil band

Ionization suppression in good agreement with Lindhard theory

Timing of phonon signals



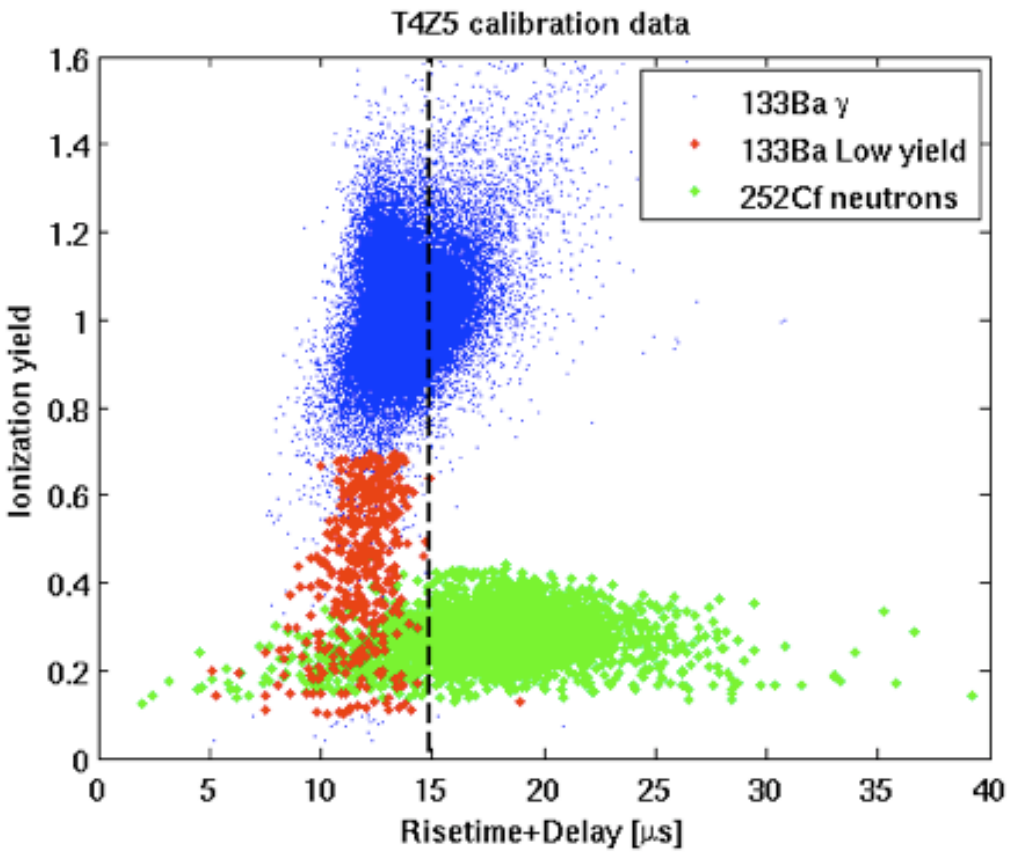


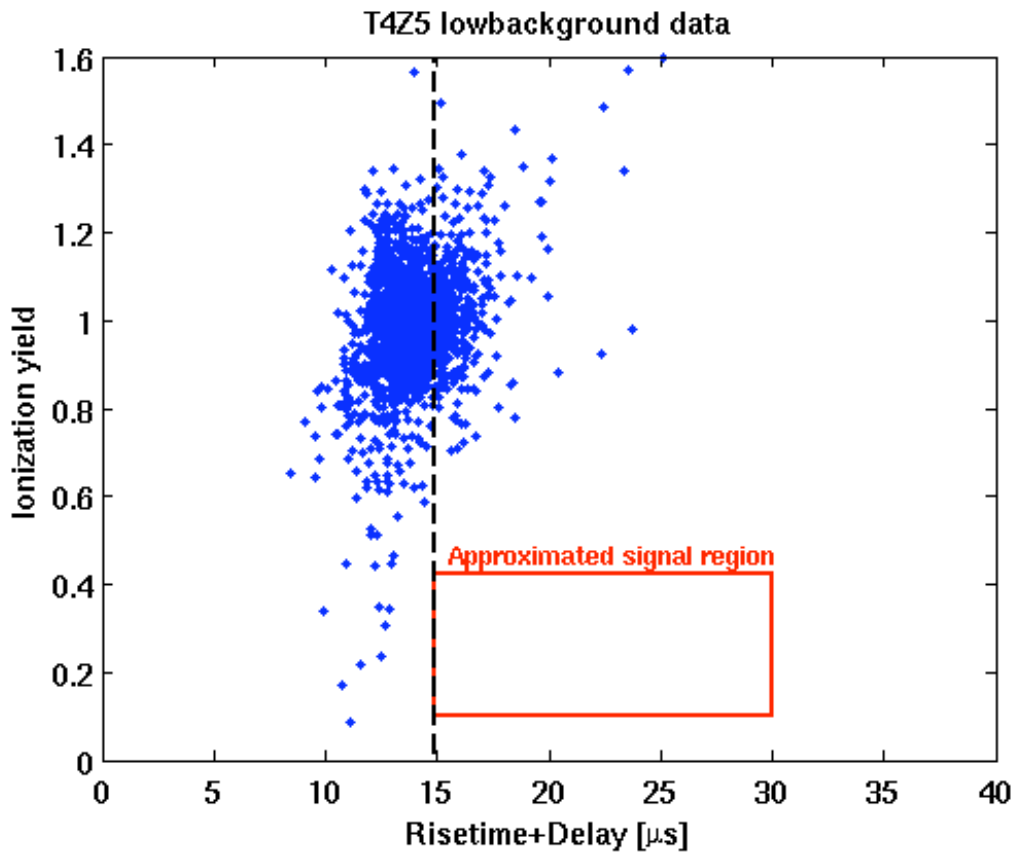


Surface events are faster in timing than bulk nuclear recoils

Timing is a powerful discriminator for surface events

Surface event rejection cut





Defined on calibration data

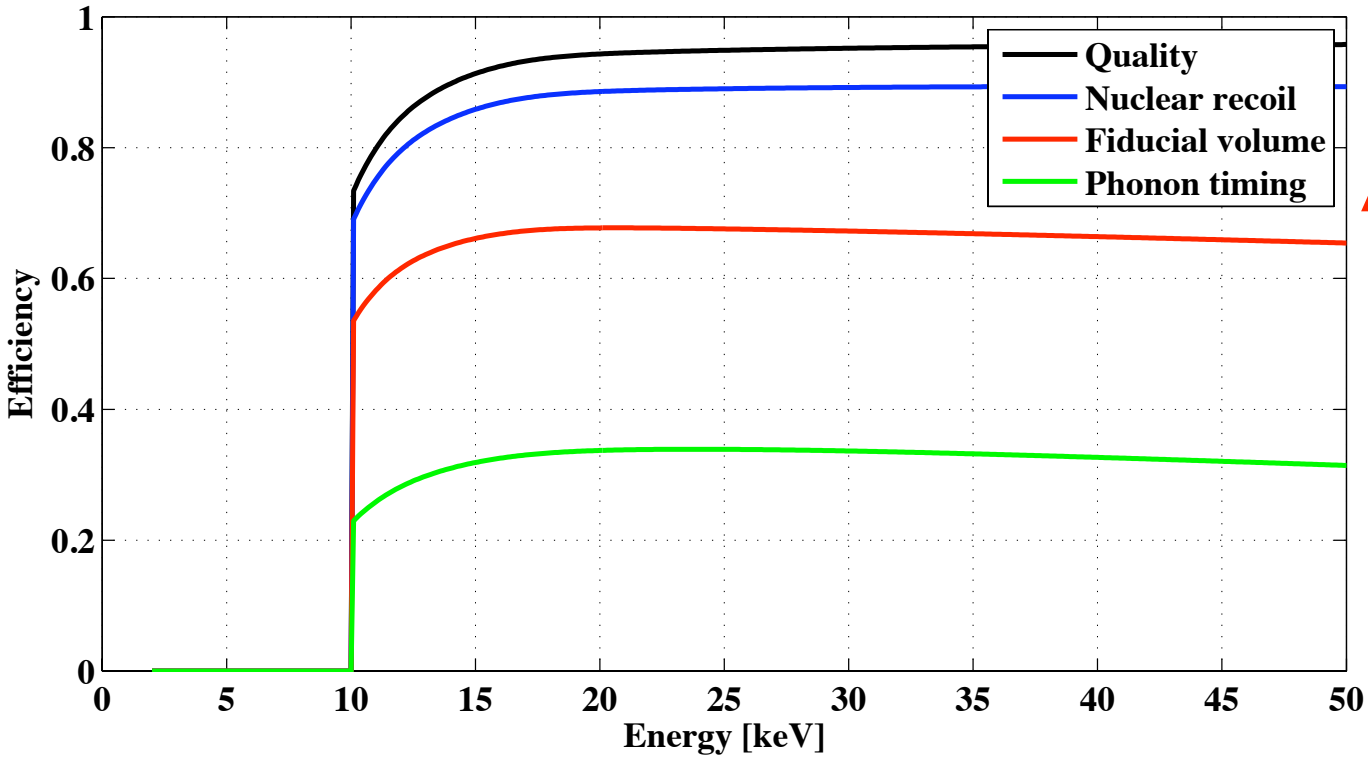
Applied to low background data

Cut set to allow ~0.5 events total leakage to WIMP candidates

Analysis Overview

Candidate Criteria:

- ☑ Data Quality + Fiducial Volume Cuts (UZH contribution)
- ☑ Muon-veto anti-coincident
- ☑ Single-Scatter (energy deposition in 1 ZIP only) (UZH)
- ☑ Ionization yield within 2σ nuclear recoil band
- ☑ Phonon timing cut (surface event rejection)



All cuts are defined on blinded data set!

(sidebands and calibration data are used for cut development)

Unblinding the signal region

Box opened November 5, 2009 for 14 Ge detectors

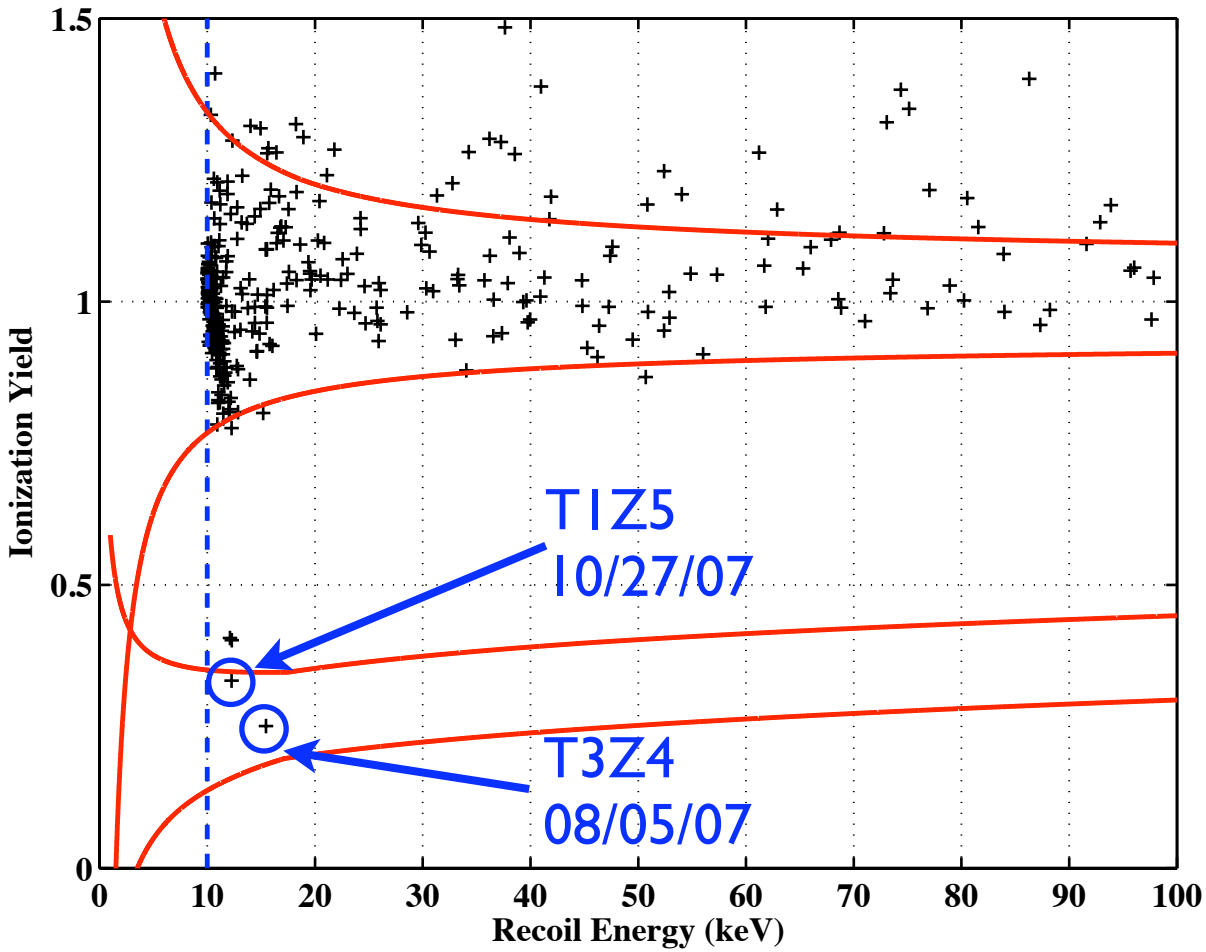
3σ NR region masked

☑ Hides unvetoed singles

Lift mask, see 150 singles failing timing cut

Apply the timing cut

2 CANDIDATE EVENTS OBSERVED



CDMS-II results

612 raw kg-days
194.1 kg-days WIMP equiv.
@ 60 GeV/c^2
(10-100 keV analysis range)

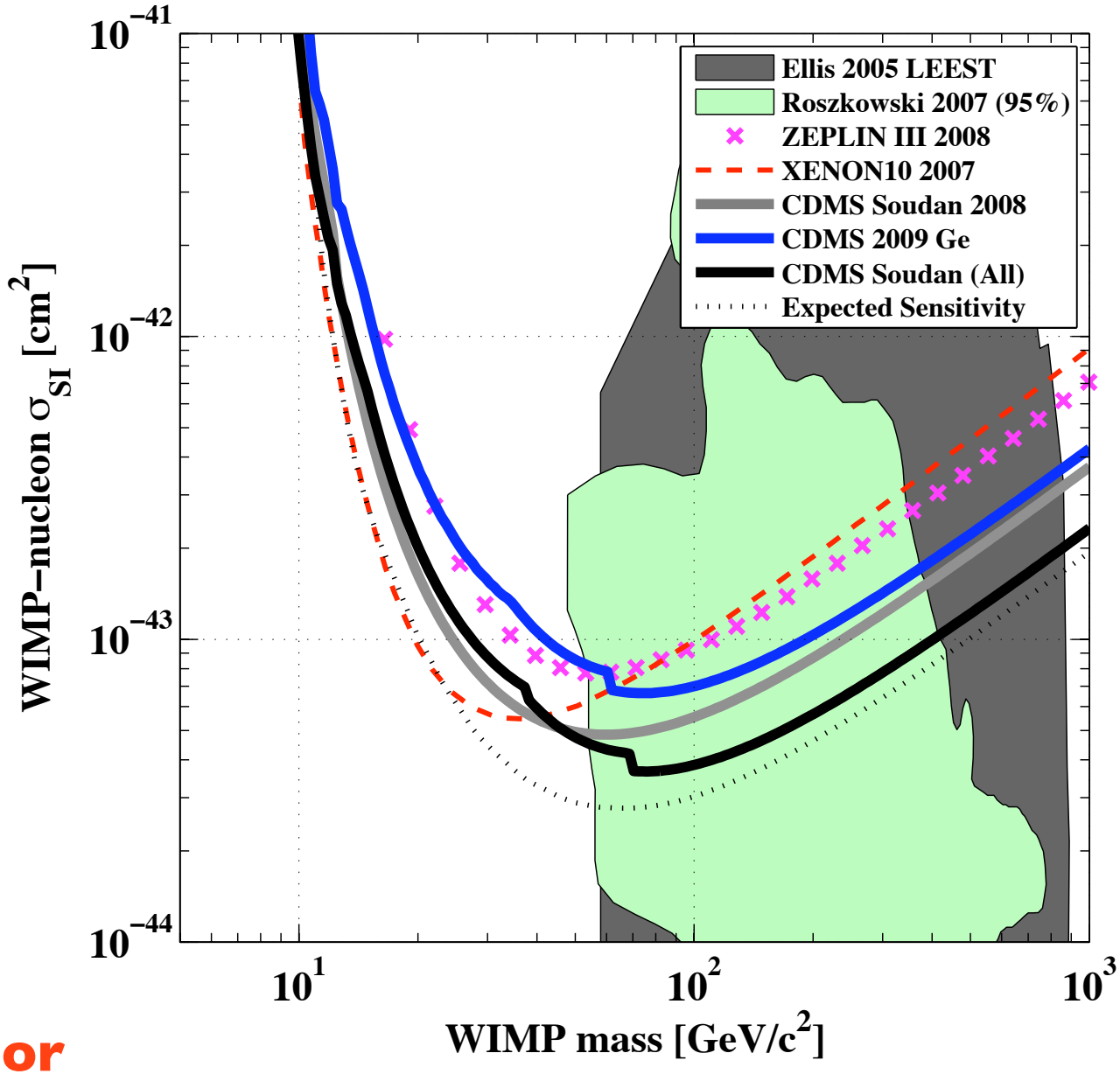
Surface event background:

0.8 ± 0.1 (stat.) ± 0.2 (sys.)

Neutron background

Cosmogenic $0.04^{+0.04}_{-0.03}$ (stat.)

Radiogenic 0.03 - 0.06



Probability to observe 2 or more background events is 23%

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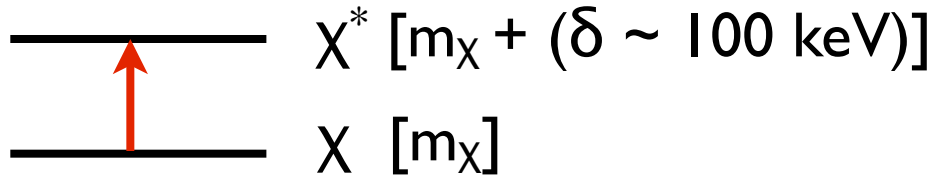
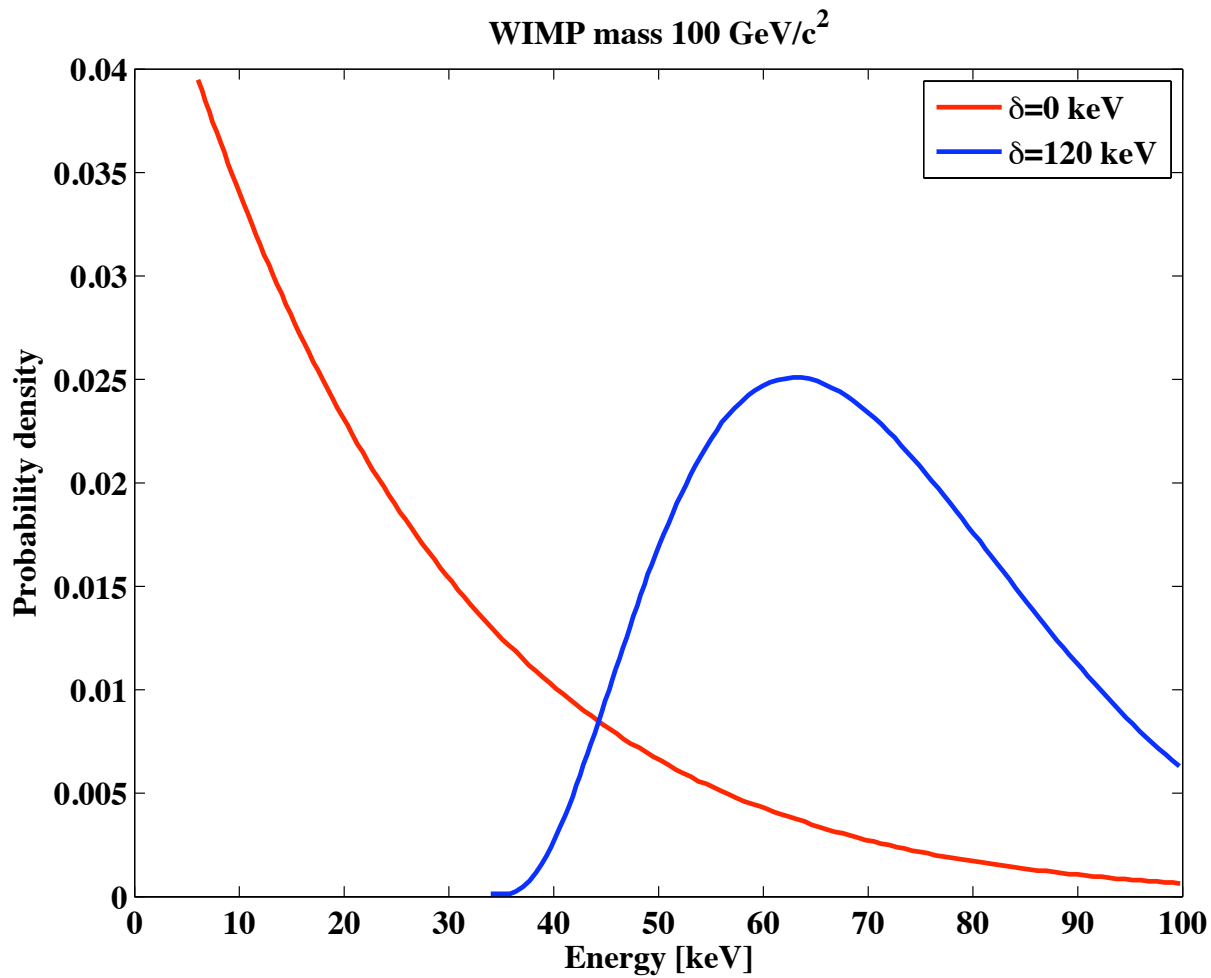
The Inelastic Dark Matter model

Scattering from the ground state in an excited state.



Difference in the recoil spectra and large modulation amplitudes possible.

The DAMA result can be made compatible with null observations of other experiments.

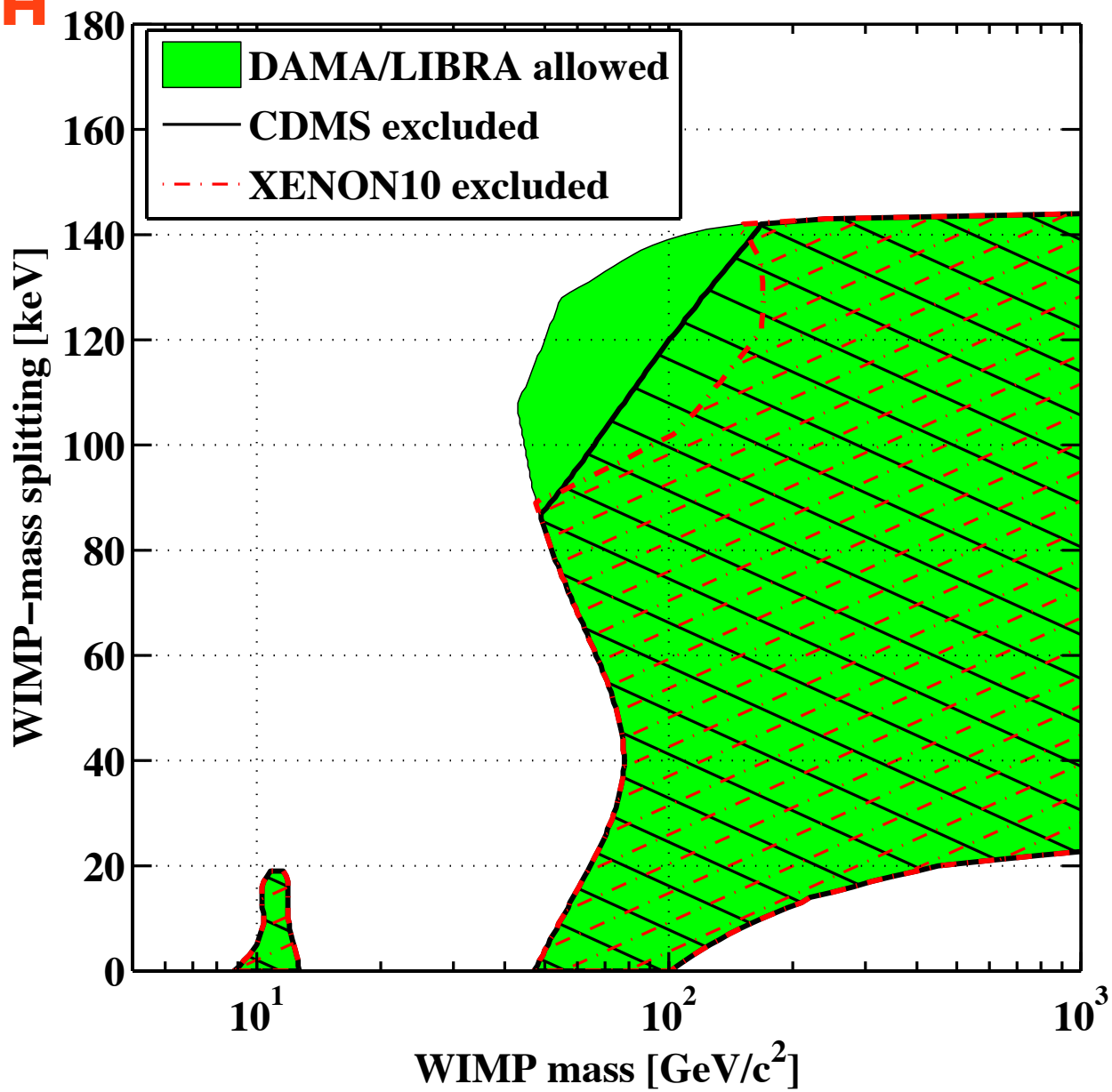


Constraints on inelastic scattering

Analysis performed at UZH

Disfavor all DAMA/LIBRA allowed region except for WIMPs of mass ~100 GeV with mass-splittings ~80-140 keV

Shown are only regions for which CDMS-II and XENON10 results are not compatible with DAMA/LIBRA at the 90% CL



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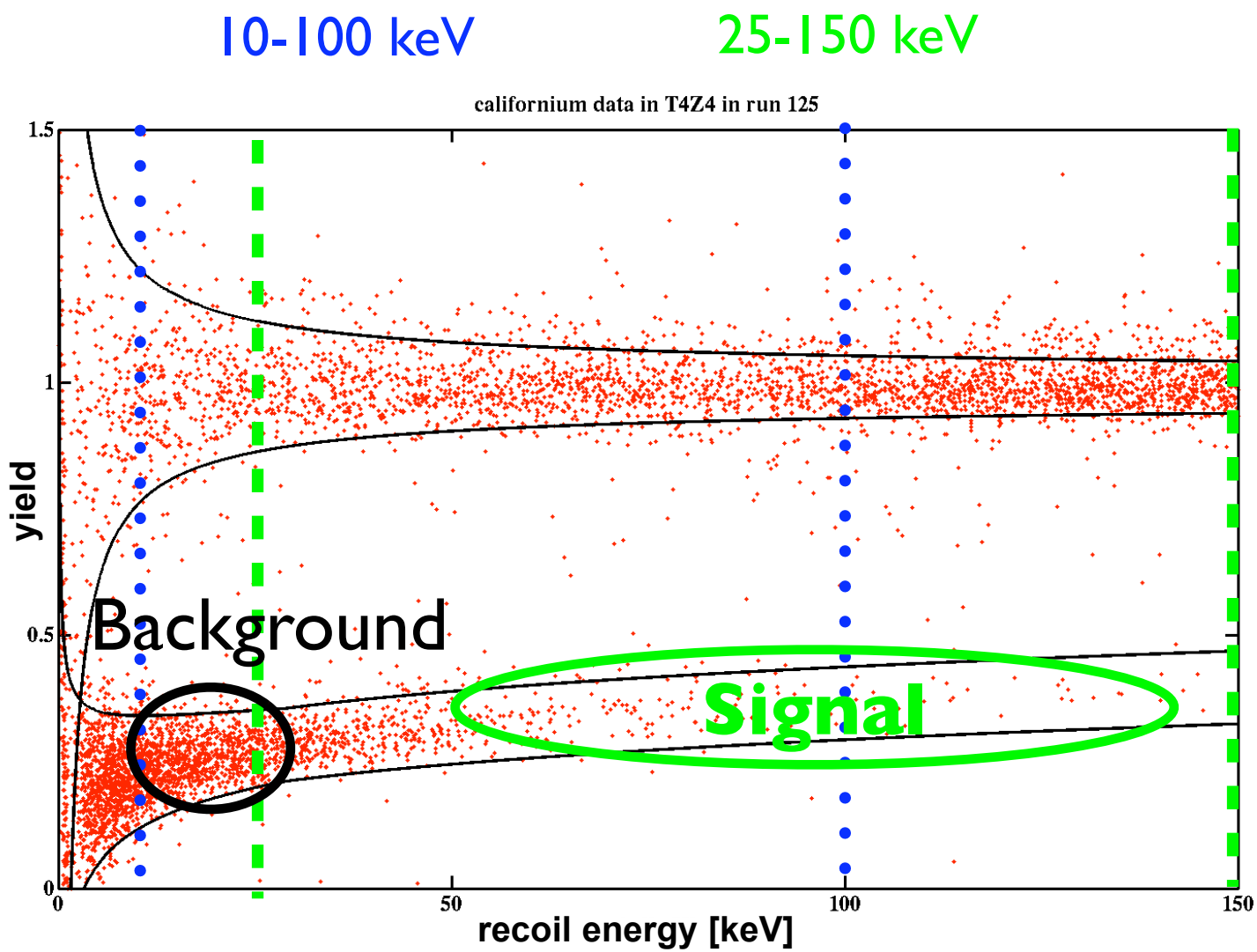
Improved iDM analysis at UZH

Extend analysis to higher recoil energy → improved sensitivity by maximizing the signal rate and better background rejection.

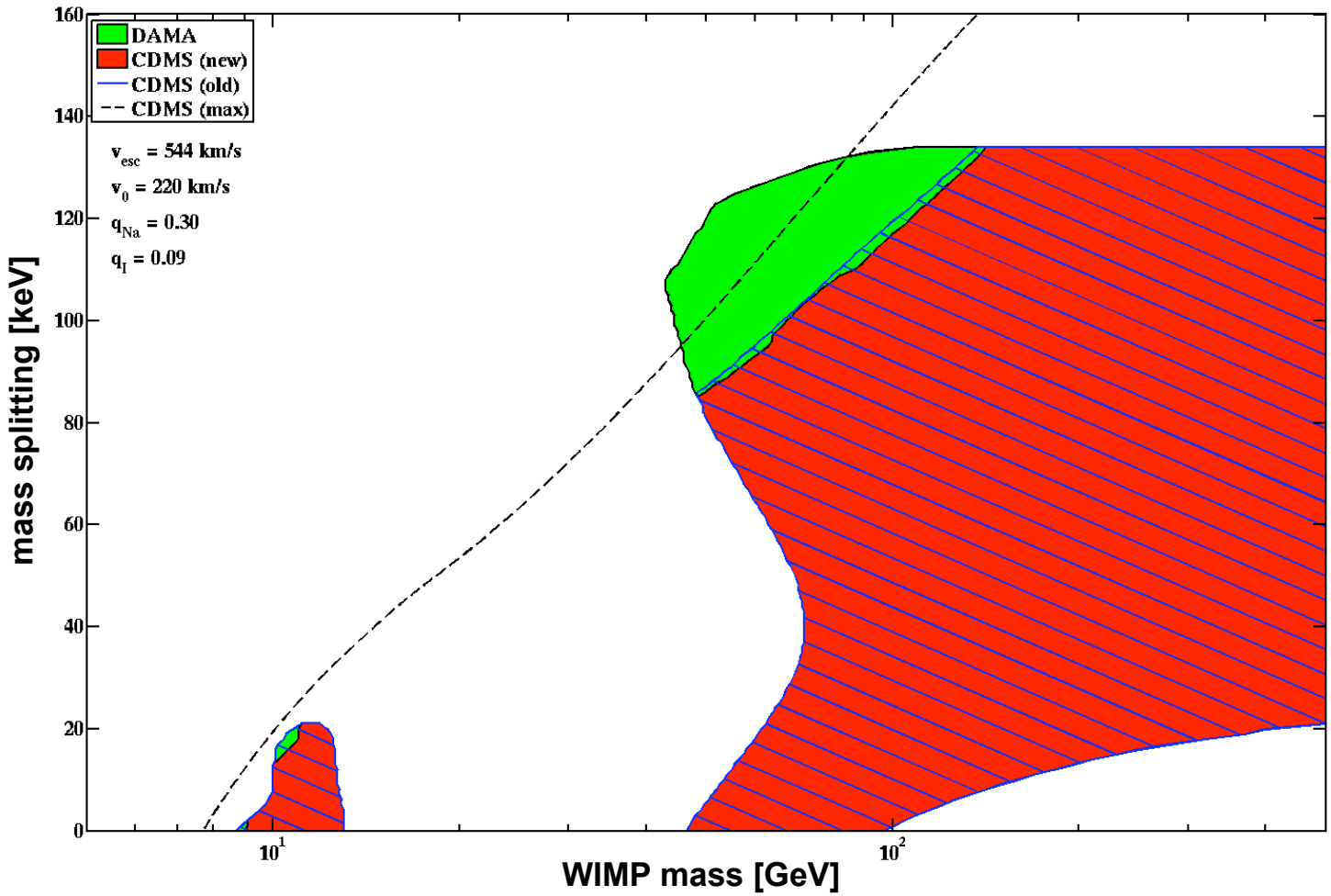


CDMS constraints on the iDM model

969.4 raw kg-days Ge exposure (25-150 keV analysis range)

Surface event background: $0.83\,^{+0.45}_{-0.27}\,(\text{stat.})\,^{+0.30}_{-0.21}\,(\text{sys.})$

Three candidate events [37.3 keV, 73.3 keV, 129.5 keV]
(9.1% probability to observe 3 or more events for the given background)

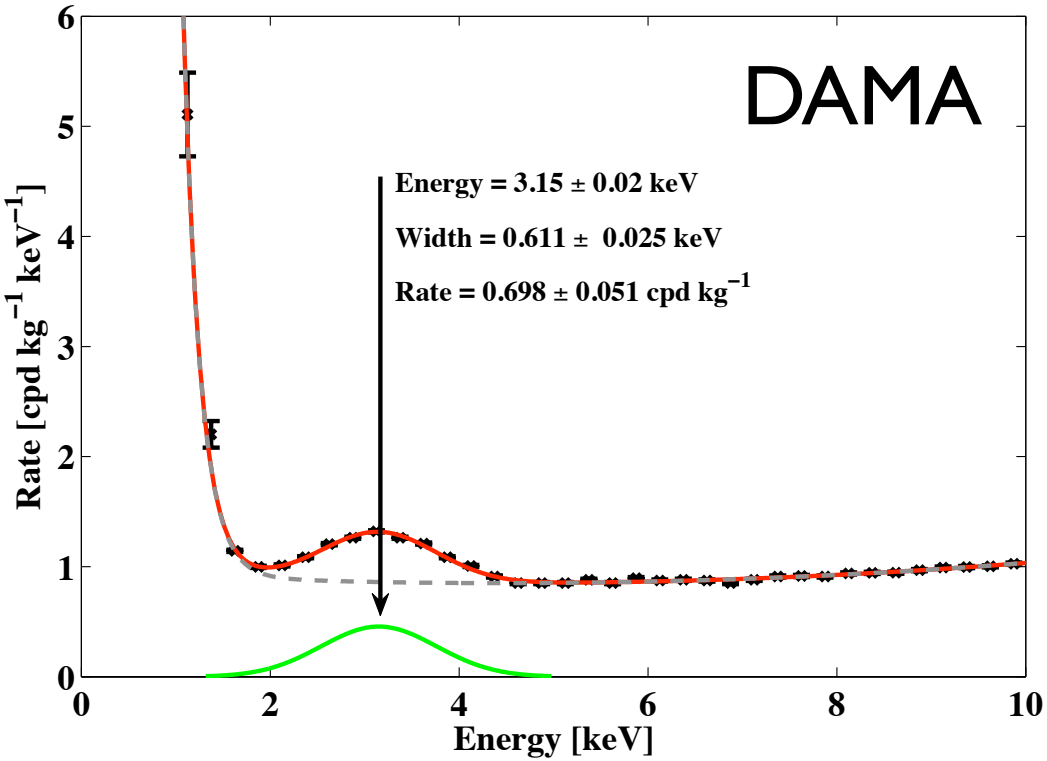


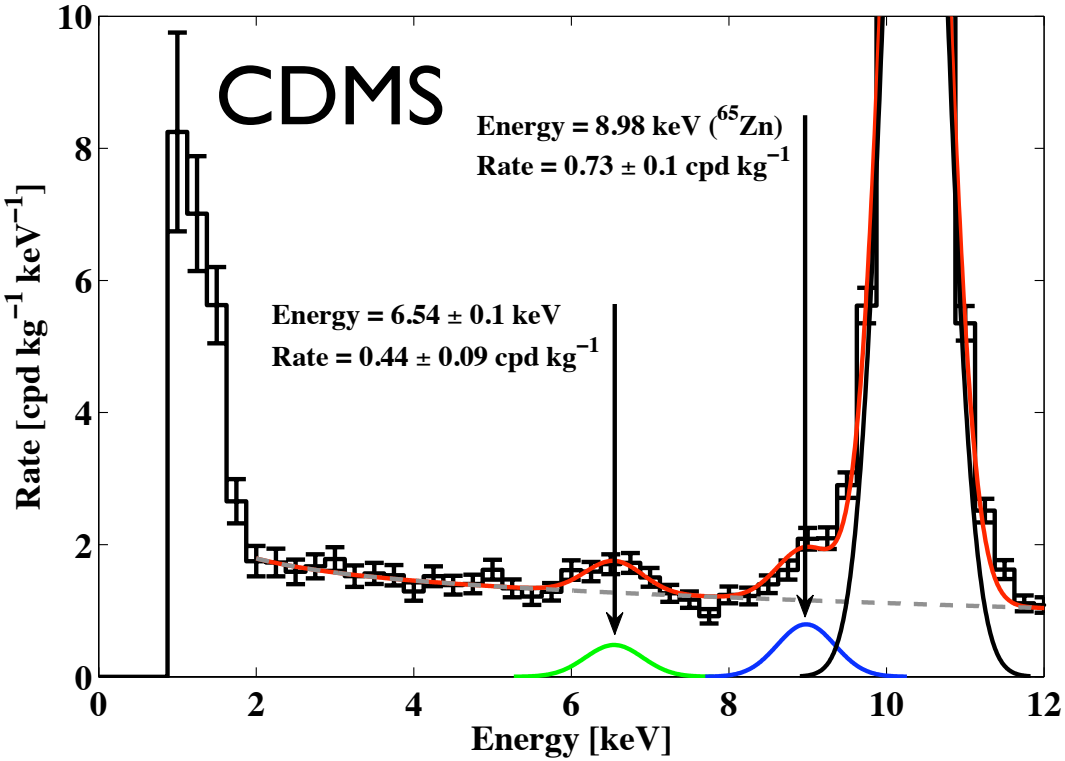
DAMA/LIBRA rate excess

So what if the signal is caused by an electromagnetic interaction?

In addition to the modulation in the 2-4 keV range they observe an excess in rate at 3.15 keV.

UZH group investigated the low energy electron recoil spectra.





CDMS vs DAMA

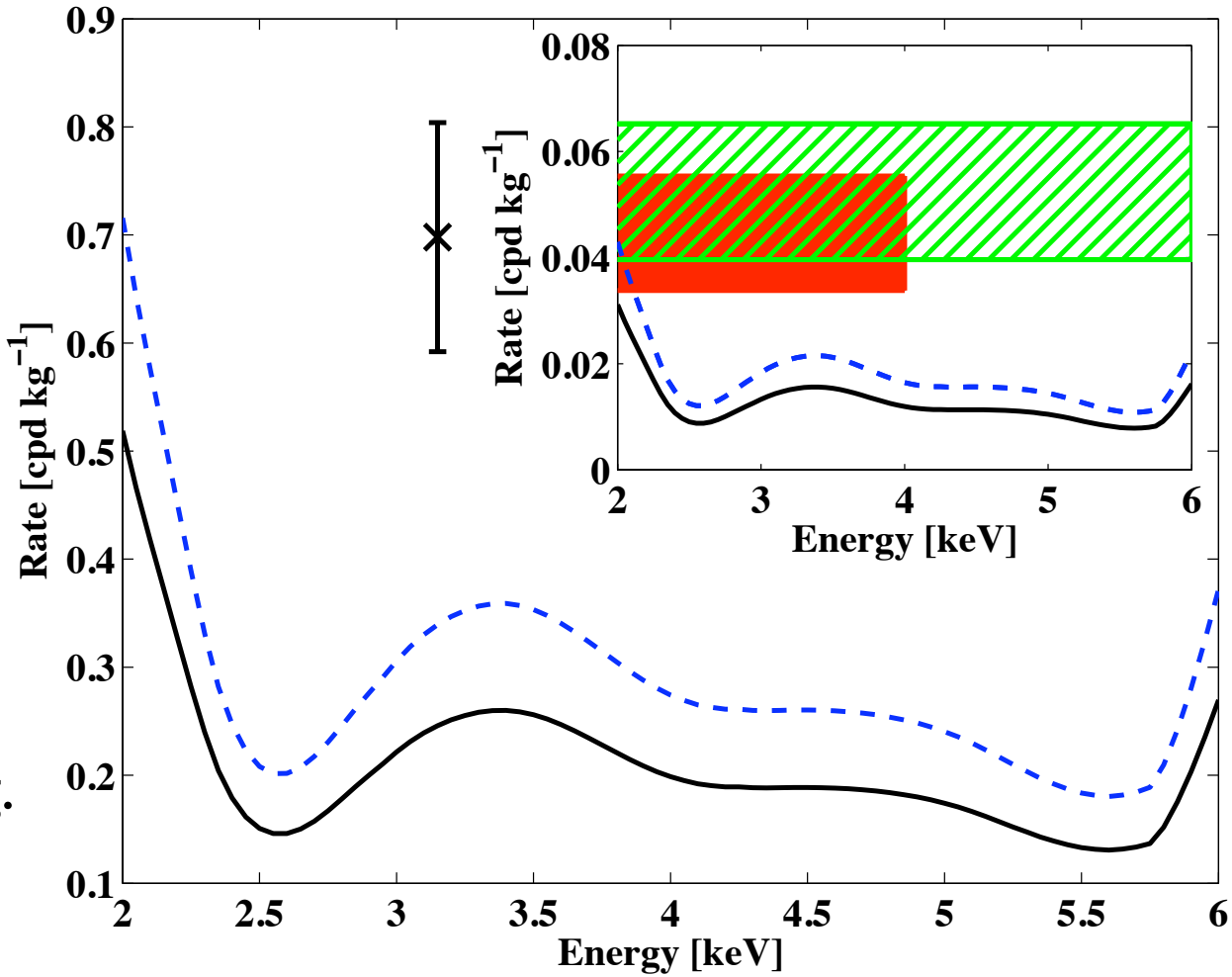
Upper limits set by CDMS are inconsistent with the rate observed by DAMA, for the total rate as well as for a 6% modulation amplitude (inset).

Direct comparison is shown as the black line.

Z^2 scaling of the dark matter interaction cross section comparison is shown as blue/ dashed line.

More or less arbitrary choice of scaling, need real particle model to provide actual scaling.

PRD 81, 042002 (2010)



Does such a model exist? We are not aware of such a model!

Summary

- Excellent discrimination makes the CDMS-II experiment a nearly zero background experiment.
- Latest CDMS-II results revealed the detection of two candidate events.
- This observation cannot be interpreted as a statistical significant evidence for WIMP interactions, but either event can not be rejected as a signal.
- Analyzes from the UZH group exclude a large portion of the DAMA/LIBRA allowed parameter space in the inelastic dark matter model.
- If the DAMA signal is of electromagnetic origin it should also be detectable in CDMS.
- The analysis of the low energy electron recoil spectrum performed at UZH did not reveal any rate excess above background and thus constrains models which can explain the DAMA signal.

The CDMS Collaboration

California Institute of Technology
Z. Ahmed, J. Filippini, S. R. Golwala, D. Moore,
R. W. Ogburn

Case Western Reserve University
D. S. Akerib, C. N. Bailey, K. Clark,
M.R. Dragowsky, D. R. Grant, R. Hennings-Yeomans

Fermi National Accelerator Laboratory
D. A. Bauer, F. DeJongh, J. Hall, D. Holmgren, L. Hsu,
E. Ramberg, R.L. Schmitt, J. Yoo

Massachusetts Institute of Technology
E. Figueroa-Feliciano, S. Hertel, S.W. Leman,
K.A. McCarthy, P. Wikus

NIST
K. Irwin

Queens University
W. Rau

Santa Clara University
B. A. Young

Southern Methodist University
J. Cooley

Stanford University
P.L. Brink, B. Cabrera, M. Pyle, A. Tomada, S. Yellin

Syracuse University
M. Kiveni, M. Kos, R.W. Schnee

Texas A&M
R. Mahapatra

University of California, Berkeley
M. Daal, N. Mirabolfathi, A. Phipps, B. Sadoulet, D. Seitz,
B. Serfass, K.M., Sundqvist

University of California, Santa Barbara
R. Bunker, D. O. Caldwell, H. Nelson, J. Sander

University of Colorado at Denver
B.A. Hines, M. E. Huber

University of Florida
T. Saab, D. Balakishiyeva

University of Minnesota
J. Beaty, P. Cushman, S. Fallows, M. Fritts, O. Kamaev,
V. Mandic, X. Qiu, A. Reisetter, J, Zhang

University of Zurich
S. Arrenberg, T. Bruch, L. Baudis, M. Tarka