CDMS-II to SuperCDMS

WIMP search at a zeptobarn

Tobias Bruch
University of Zürich
5th Patras Workshop on Axions, WIMPs and WISPs
University of Durham, 13 July 2009

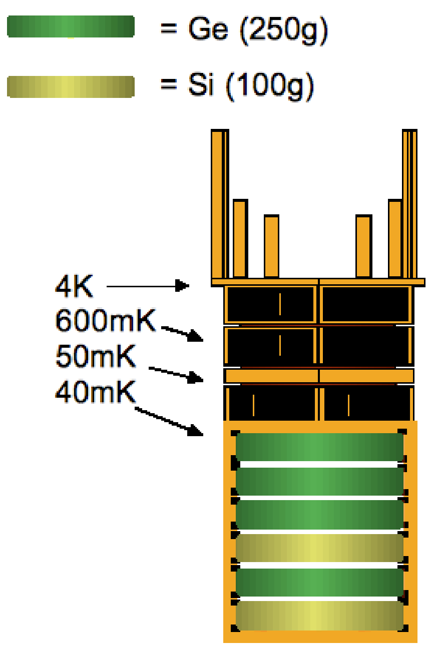
CDMS-II 5 Tower setup

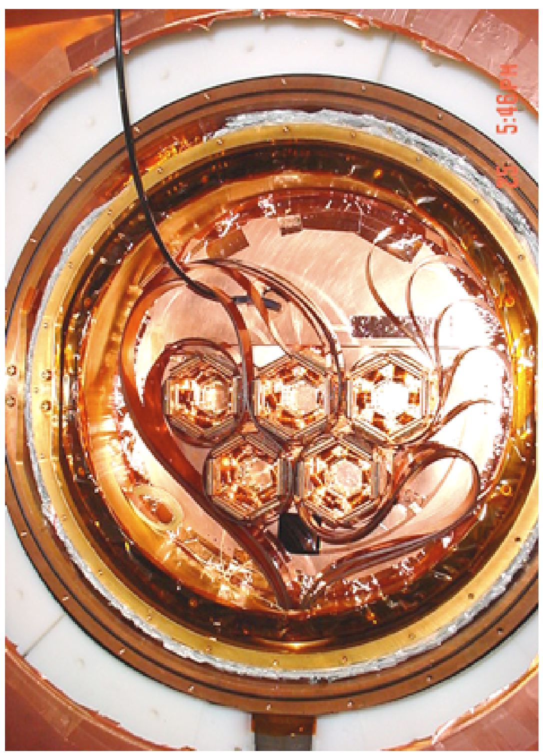
5 Towers a 6 detectors (Ge/Si) operated at cryogenic temperatures (~40 mk)

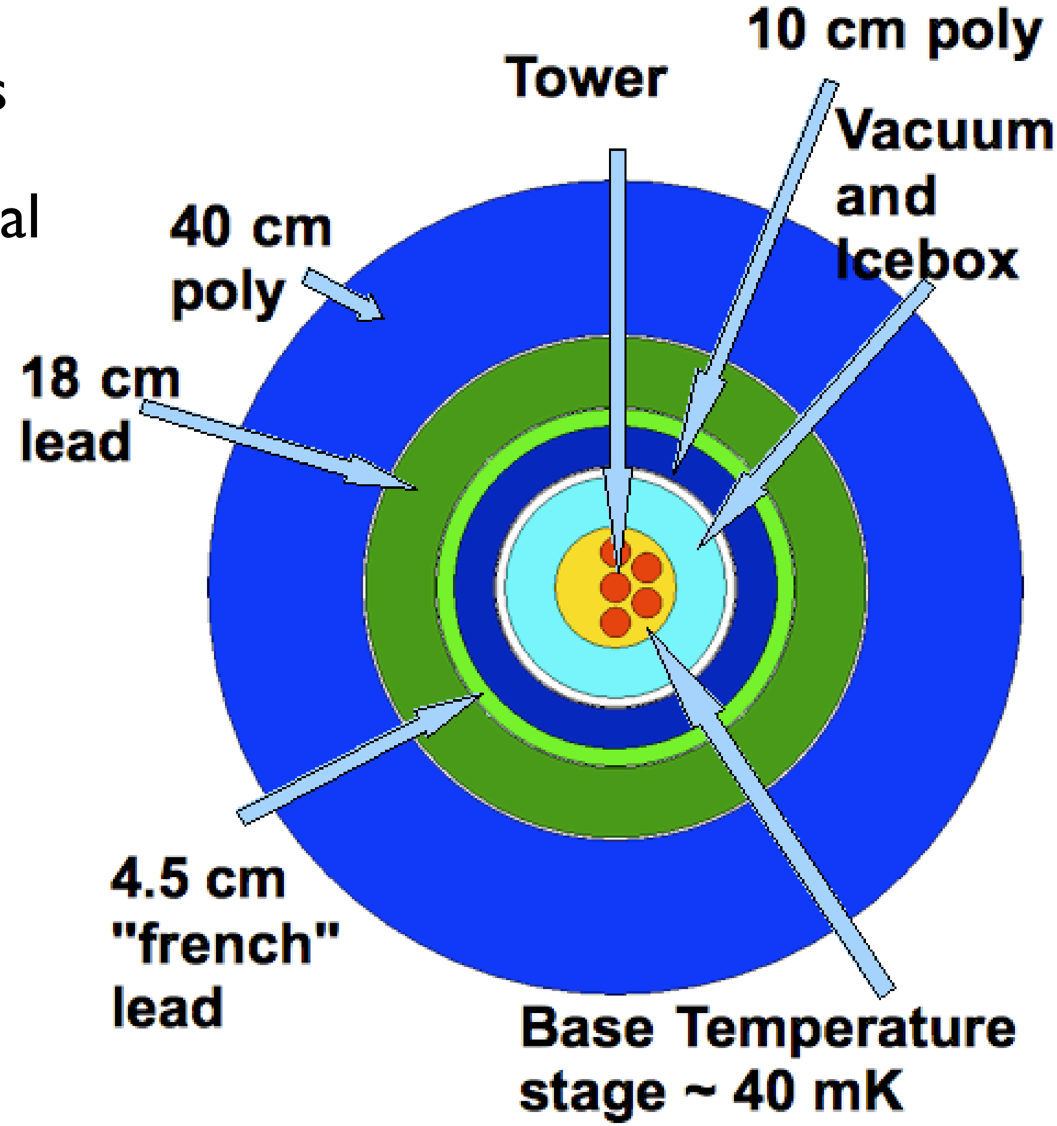
Underground laboratory shields well against cosmic radiation

Active veto for high energetic muons

Passive shielding against environmental radioactivity

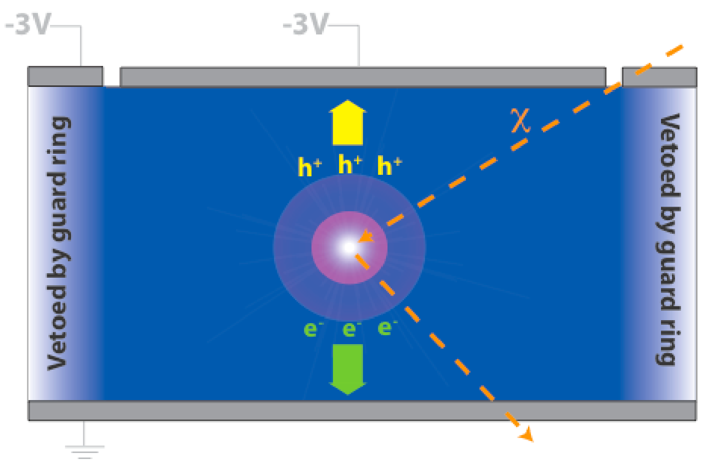


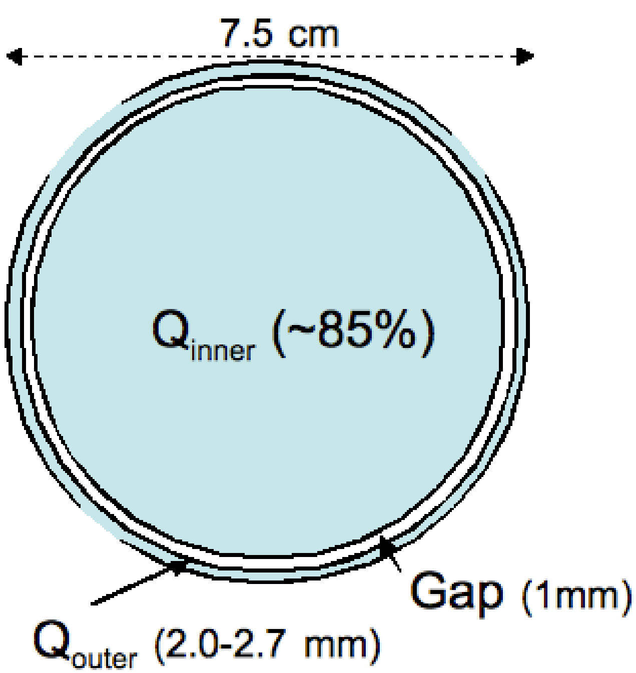




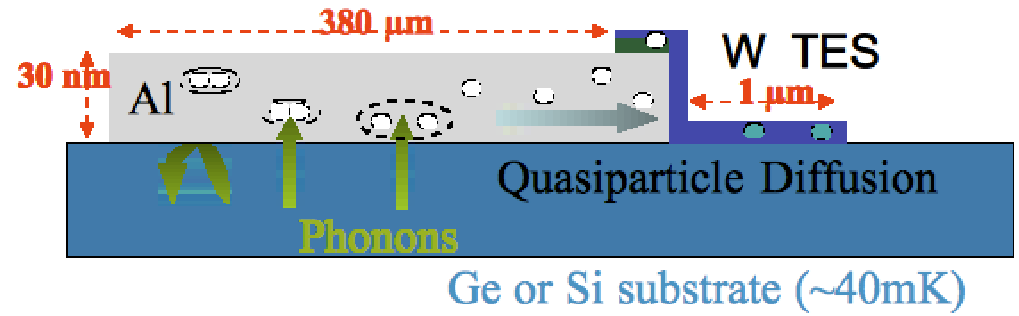
CDMS detectors

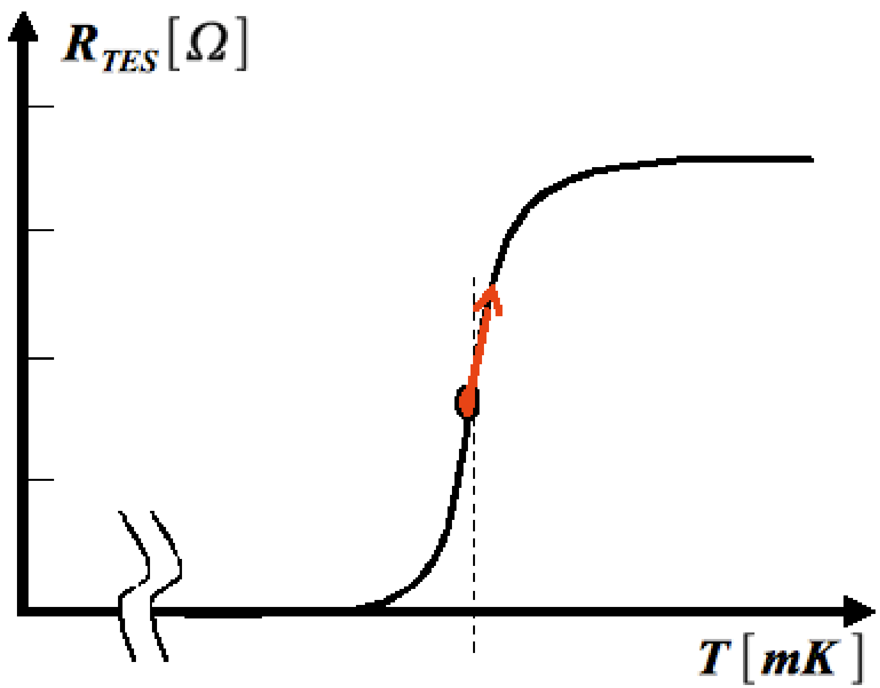
Ionization Signal





Phonon Signal





Primary background rejection

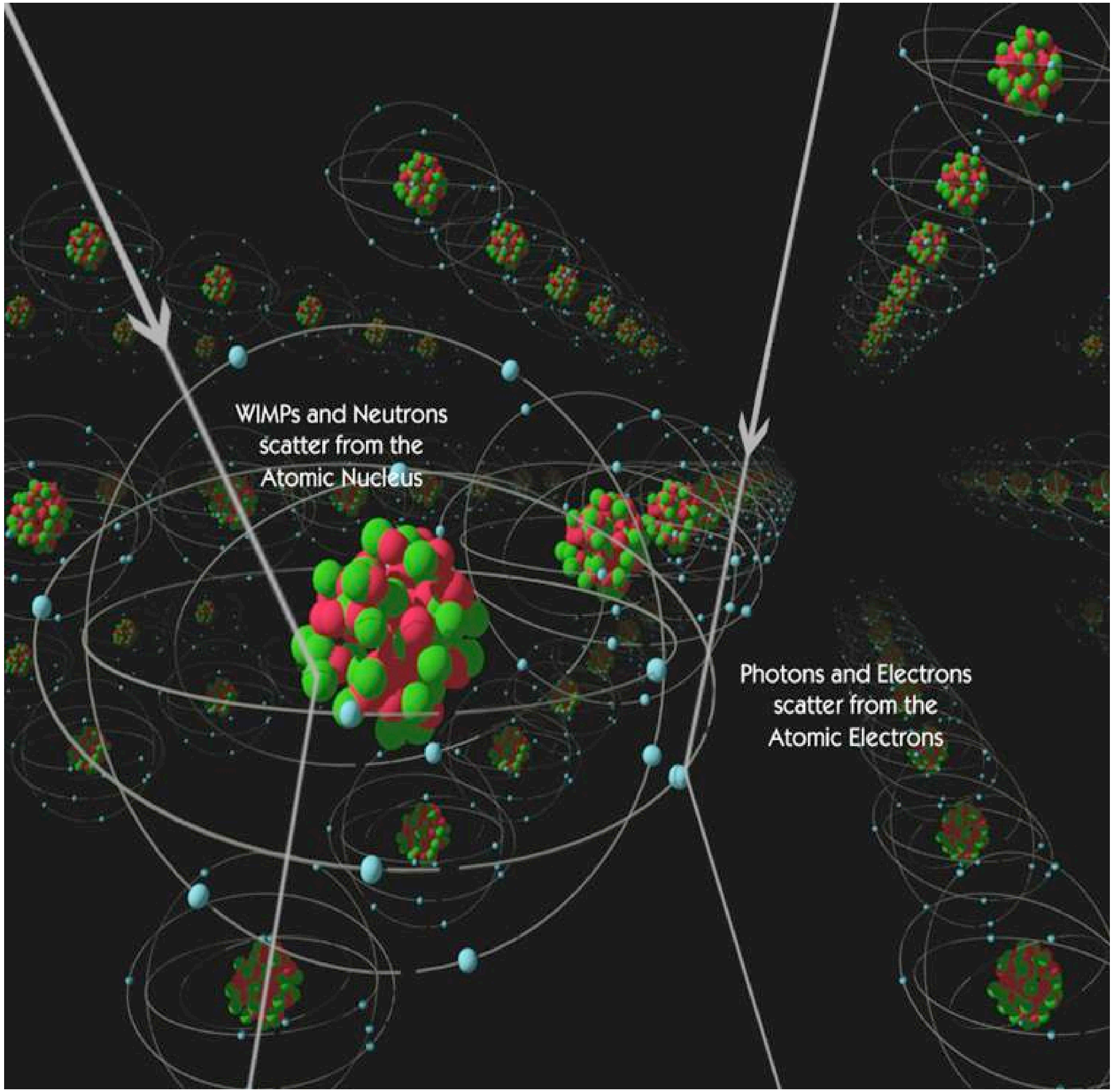
Dominant backgrounds (γ, $e^{\pm}$) produce electron recoils

WIMPS and neutrons produce nuclear recoils

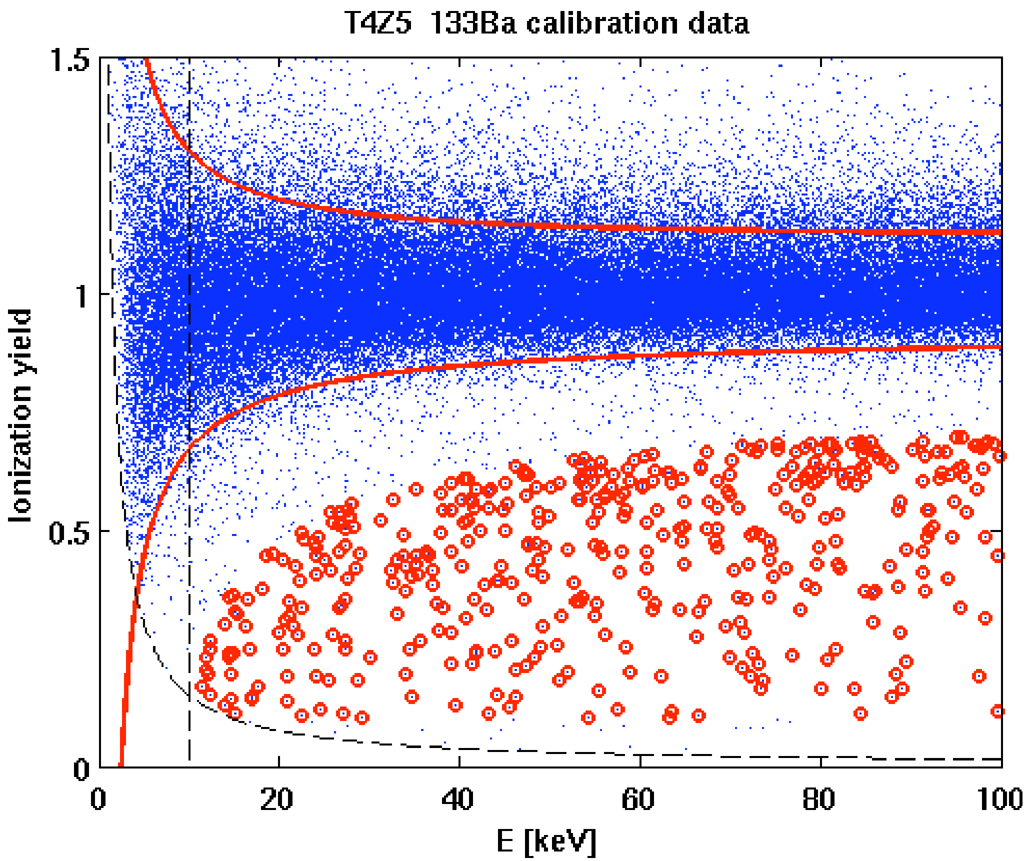
Suppressed ionization signal for nuclear recoils

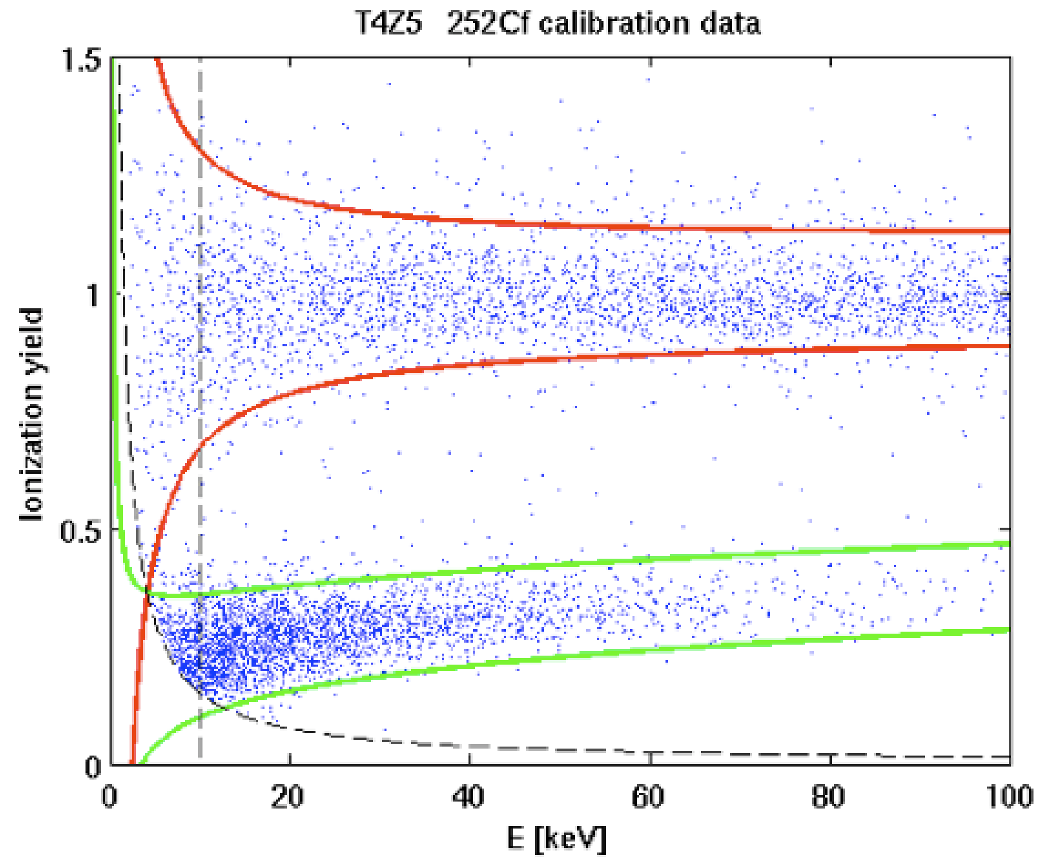
Define ionization yield:

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



Yield based rejection





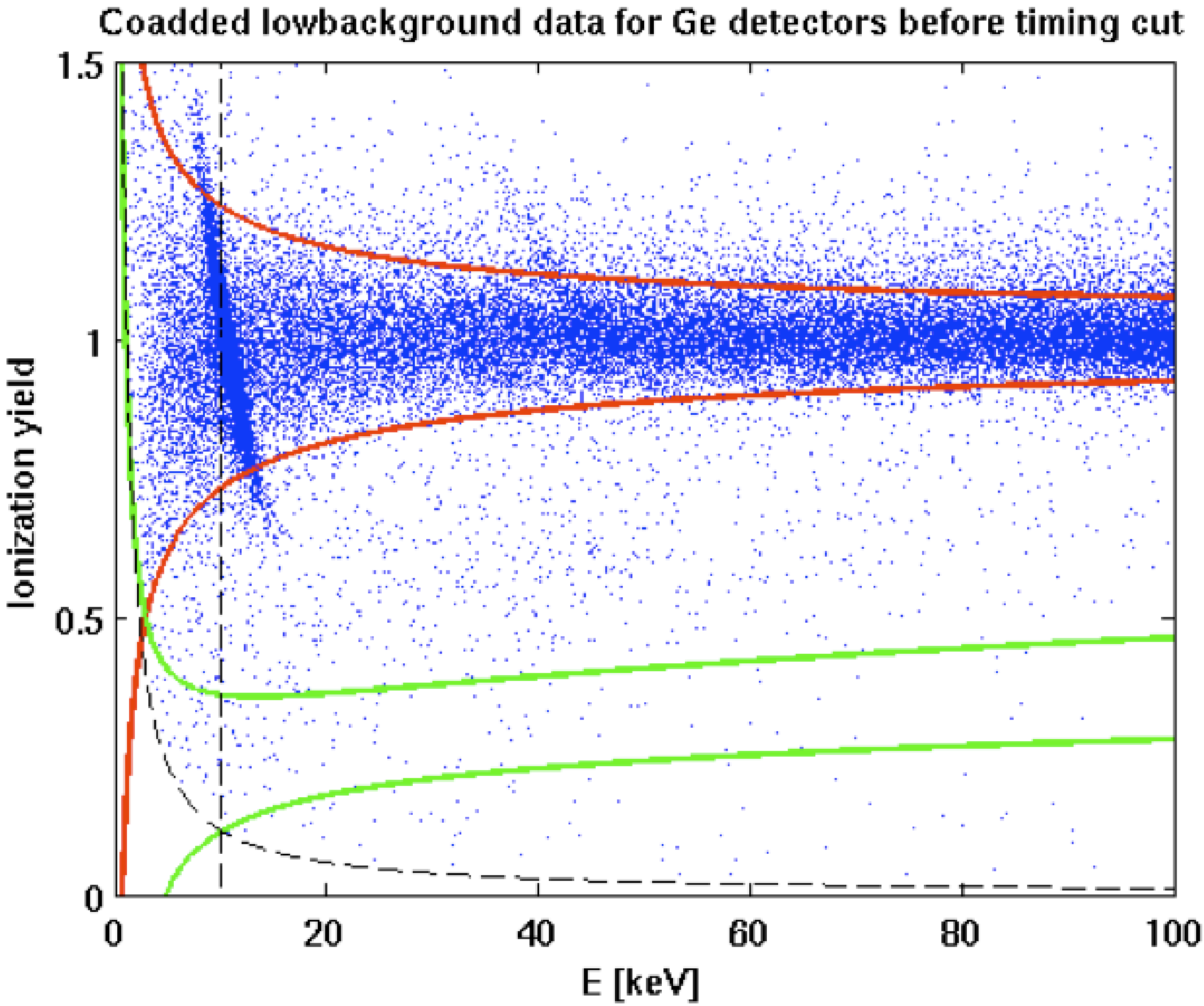
Primary electron recoil rejection 10.000 :1

Signal region: 2σ nuclear recoil band

Low yield surface event population remains.

Ionization suppression in good agreement with Lindhard theory

Backgrounds in CDMS-II



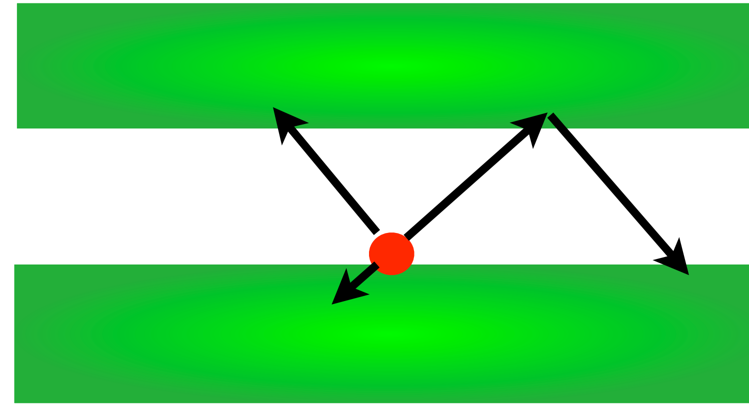
Low yield surface events are the dominating background

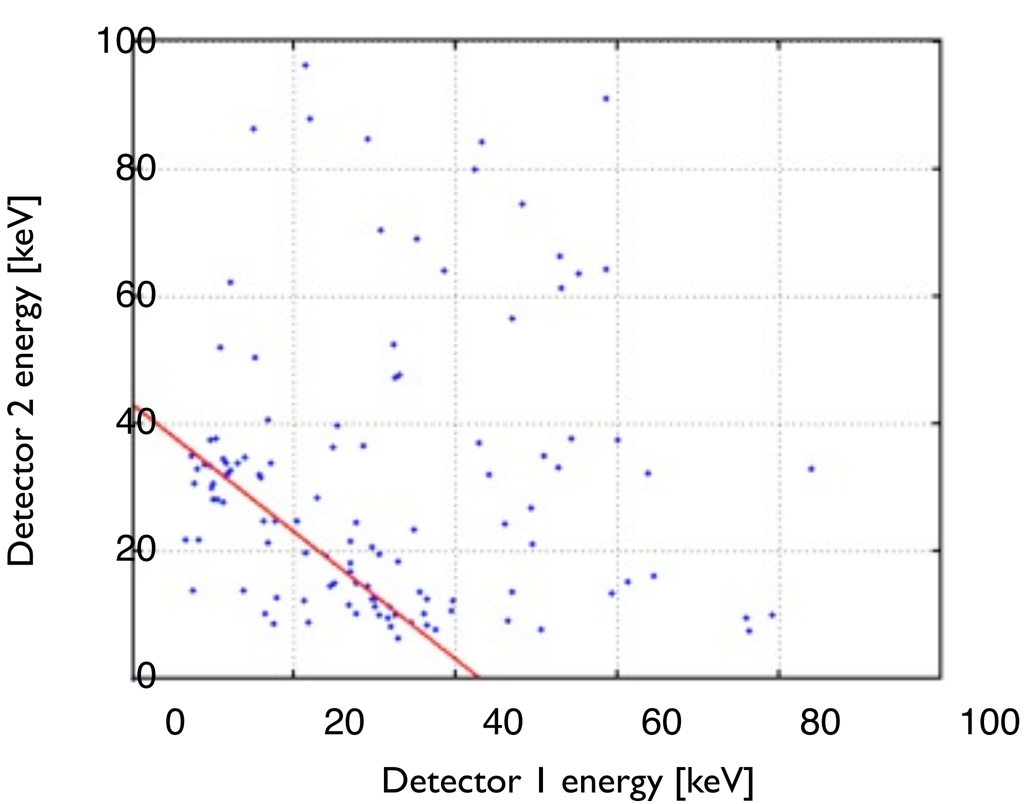
Surface contaminations of the crystals

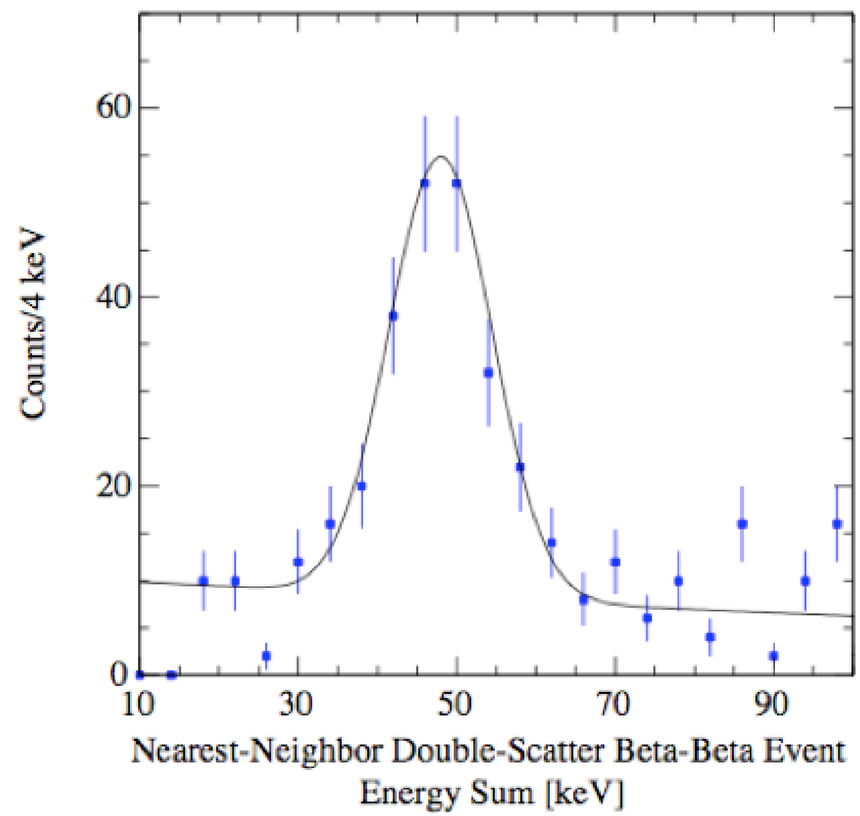
Environmental ^{222}Rn deposits ^{210}Pb β source on the surface of the crystals

Expected signature: Low energy β decay
➜ detect the ~46 keV peak

Select decay by NND events

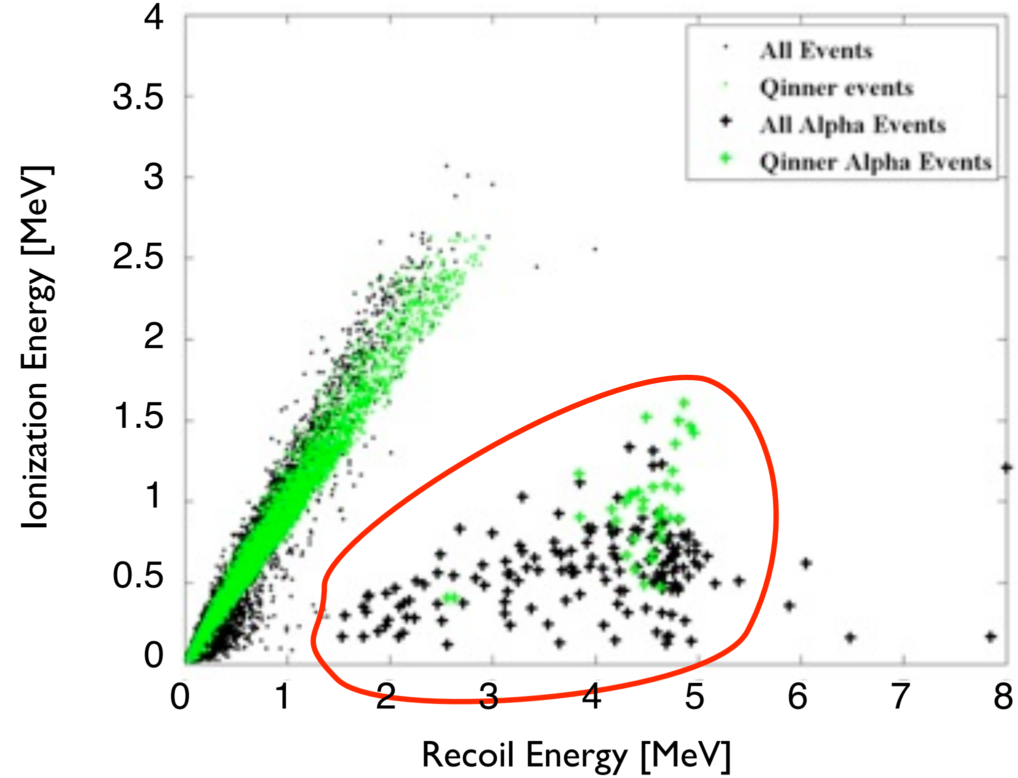




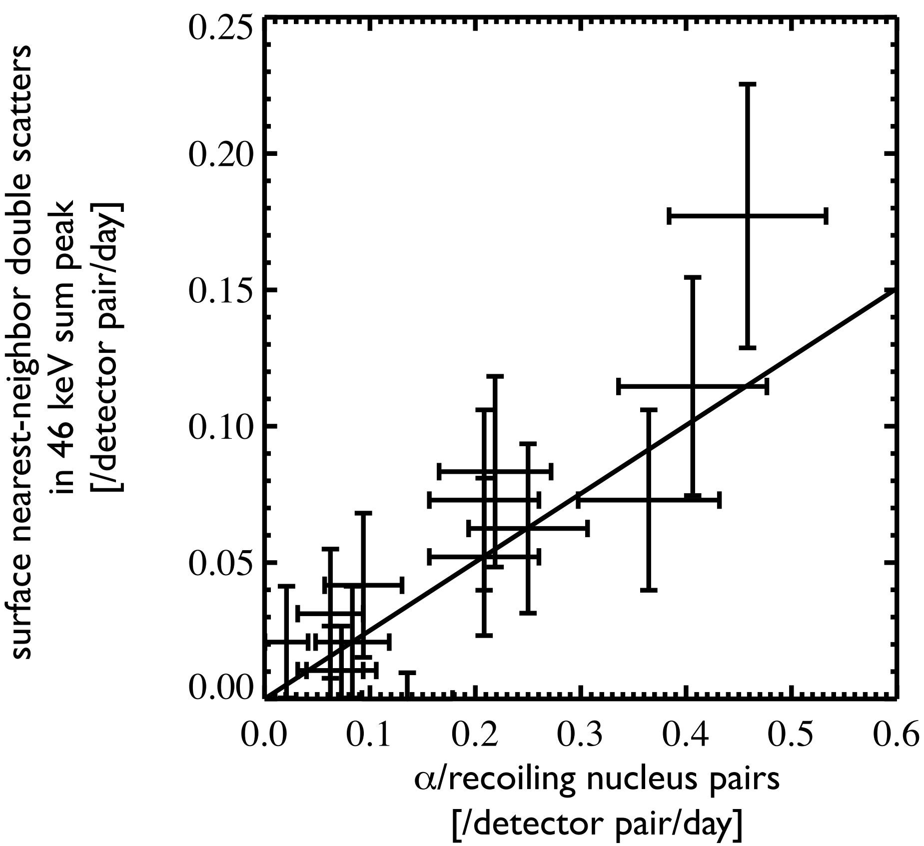


Second signature of 210 Pb

$^{210}Bi \rightarrow {}^{210}Po \rightarrow {}^{206}Pb + \alpha$



Select alphas from NND:
low yield α + recoiling ^{206}Pb nucleus



Correlation of ^{210}Pb surface NND and ^{210}Po α/recoiling ^{206}Pb strongly supports ^{210} Pb theory

Build full surface event model to determine the β rate from ^{210}Pb contamination

Break down of numbers

black = 10^{-3} counts/detector/day blue = 10^{-3} counts/kg/day (eff-corr.)	^{210}Pb decays	10-100 keV surface event singles
Total, all towers		65 ± 32
		371 ± 183
Total, T12		89 ± 29
		509 ± 166
Total, T345		49 ± 23
		280 ± 131
^{210}Pb, all towers	525 ± 420	42 ± 32
	3000 ± 2400	240 ± 183
^{210}Pb, T12	830 ± 420	66 ± 29
	4743 ± 2400	377 ± 166
^{210}Pb, T345	320 ± 280	26 ± 23
	1829 ± 1600	149 ± 131
non-^{210}Pb, all towers		23 ± 11
		131 ± 63
photon expected, all towers		38 ± 18
		217 ± 103

Old towers

Factor 2.5 ± 2.5 improvement

New towers

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Remanent β rate not associated with ^{210}Pb decays

Photons can knock off electrons from materials

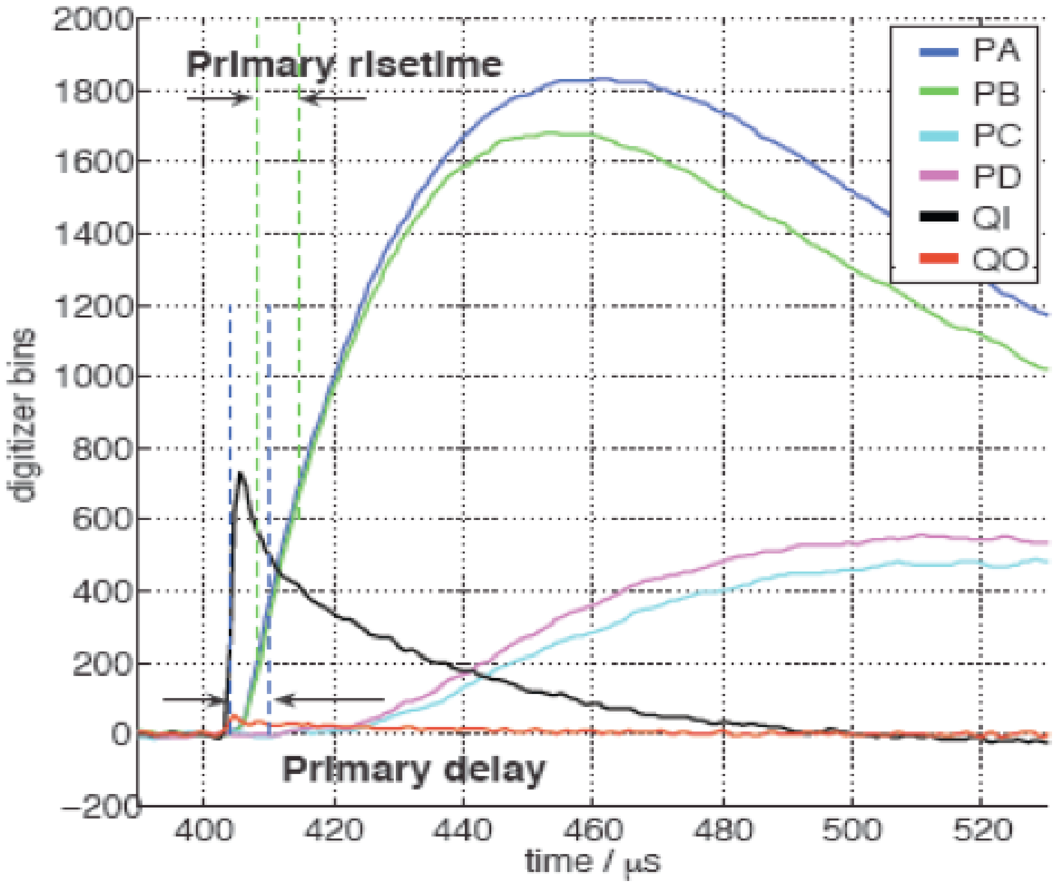
↓

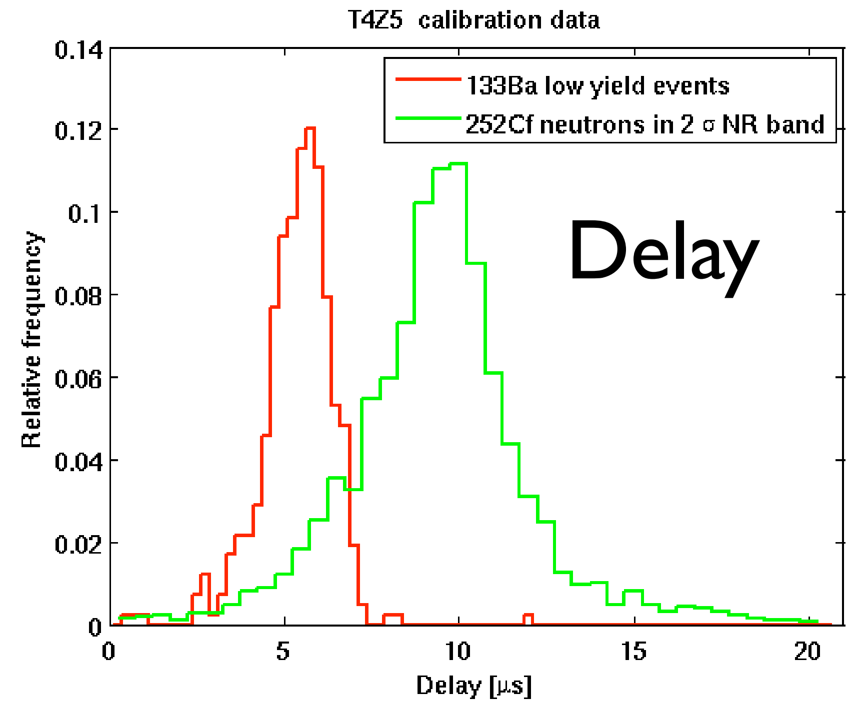
Additional source of β events

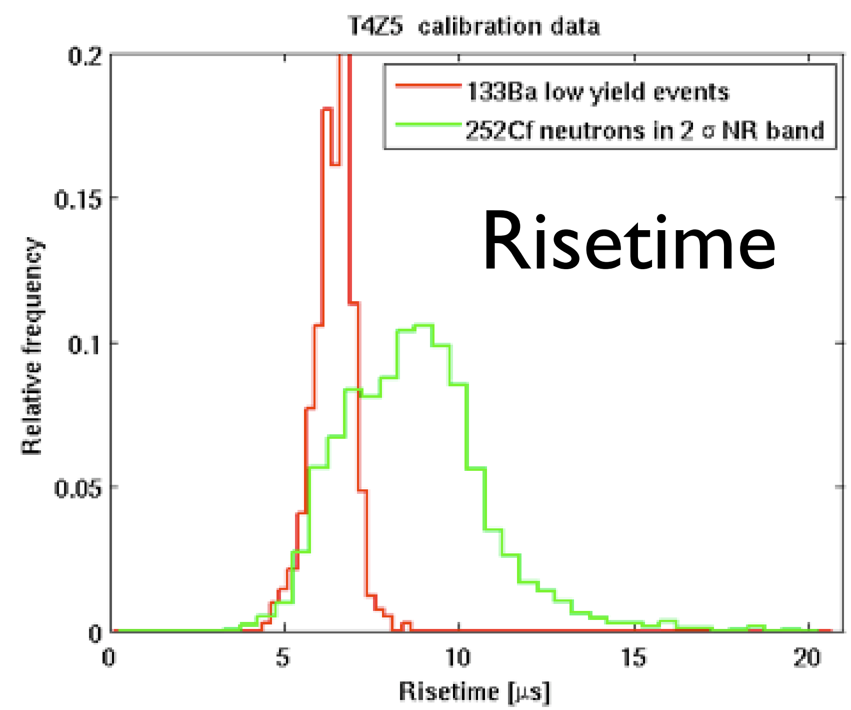
↓

Rate can be measured from calibration data

Timing of phonon signals



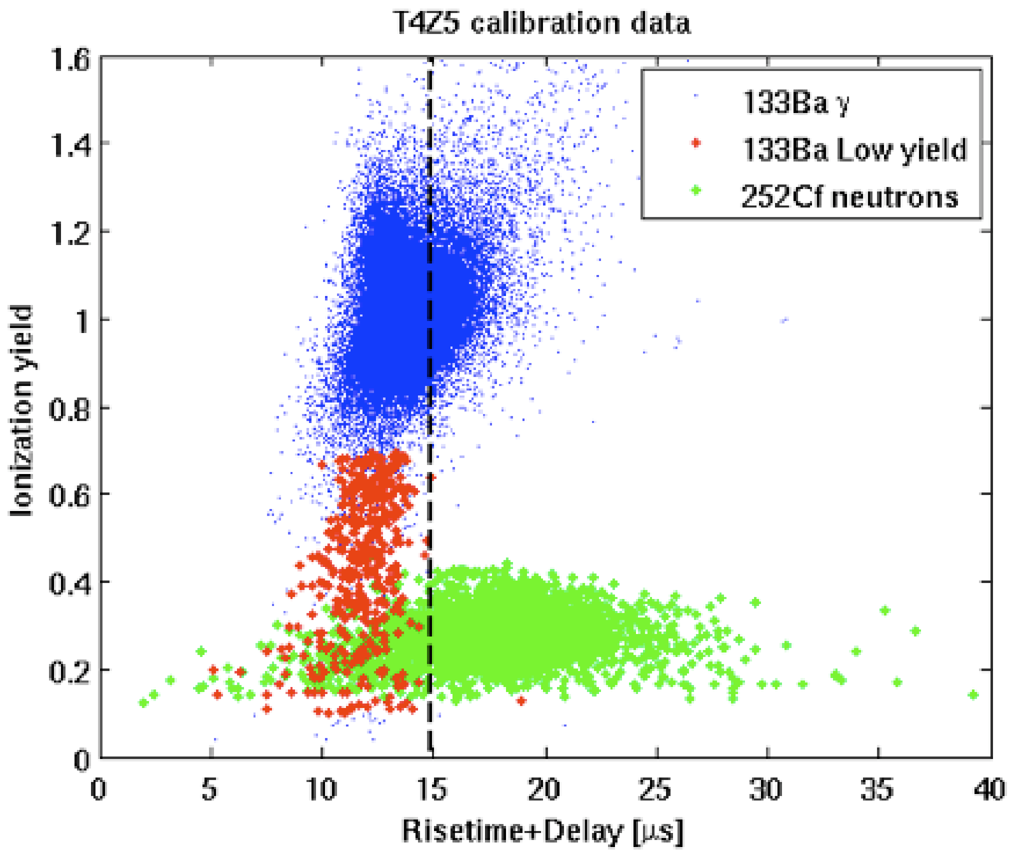


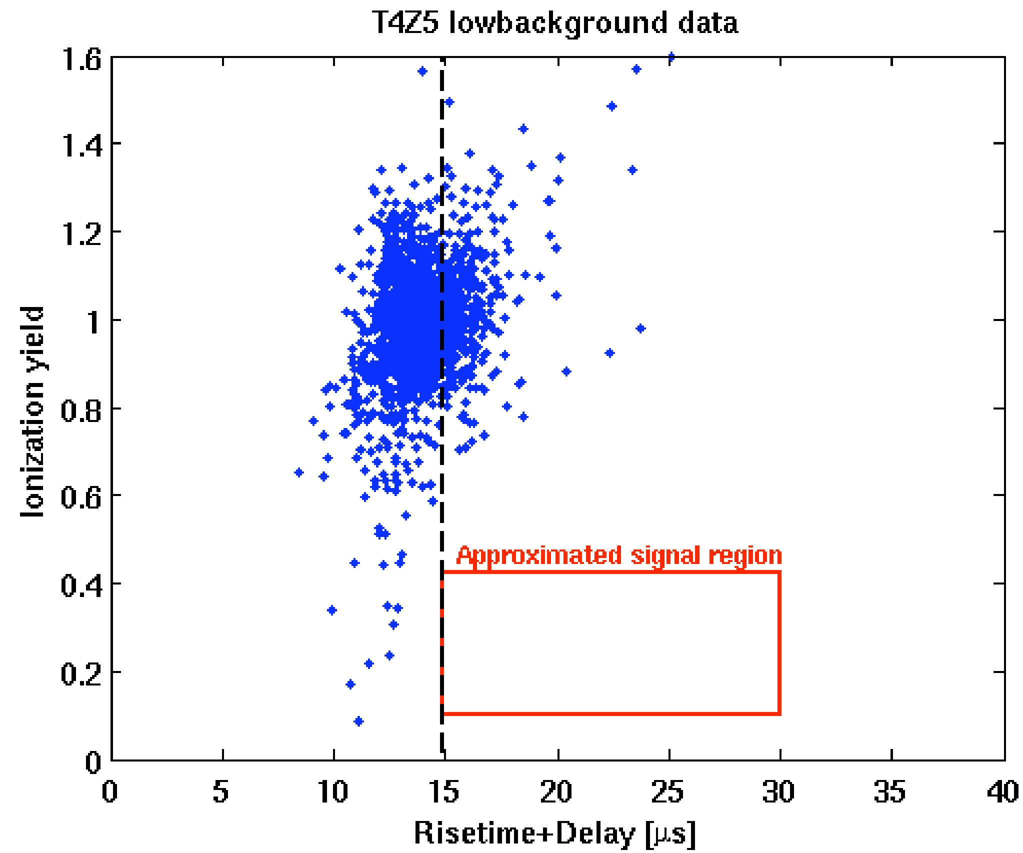


Surface events are faster in timing than bulk nuclear recoils

Timing is a powerful discriminator for surface events

Surface event rejection cut





Defined on calibration data

Applied to low background data

Surface event rejection ~ 200:1

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

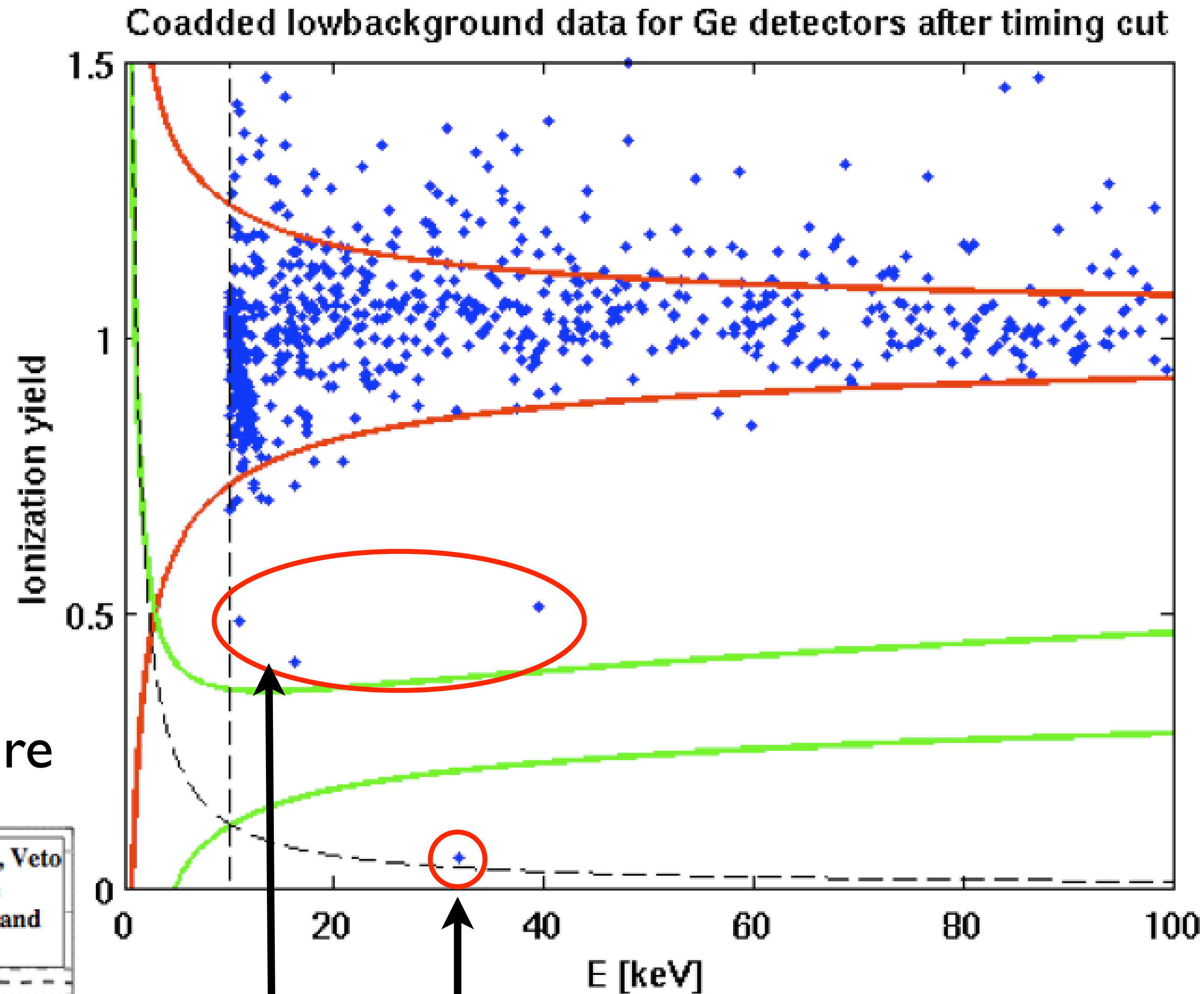
Unblinding the signal region

Use singles and multiples in the signal region to measure the expected leakage

$$0.6^{+0.5}_{-0.3}\,(\text{stat.})^{+0.3}_{-0.2}\,(\text{syst.})$$

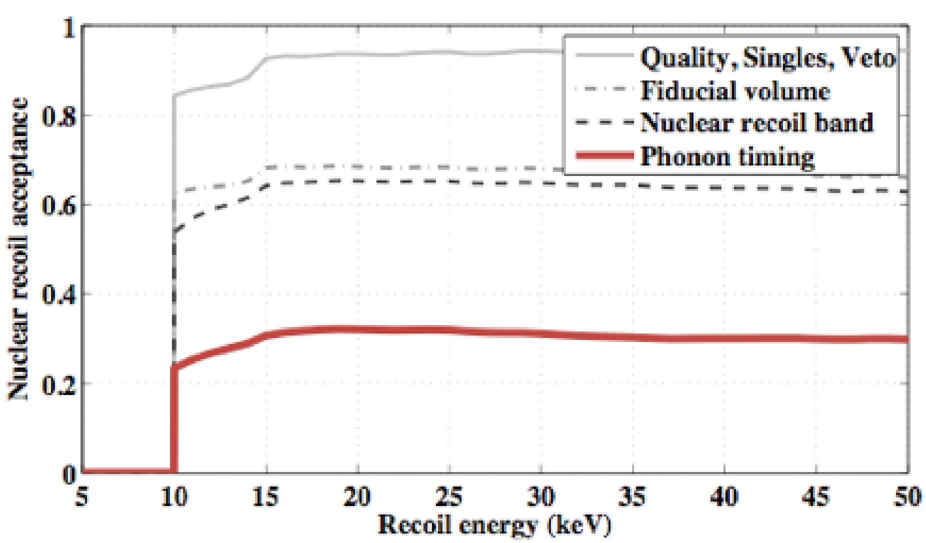
No events observed in the 2σ NR band

R123/124: 397 kg-d Ge exposure



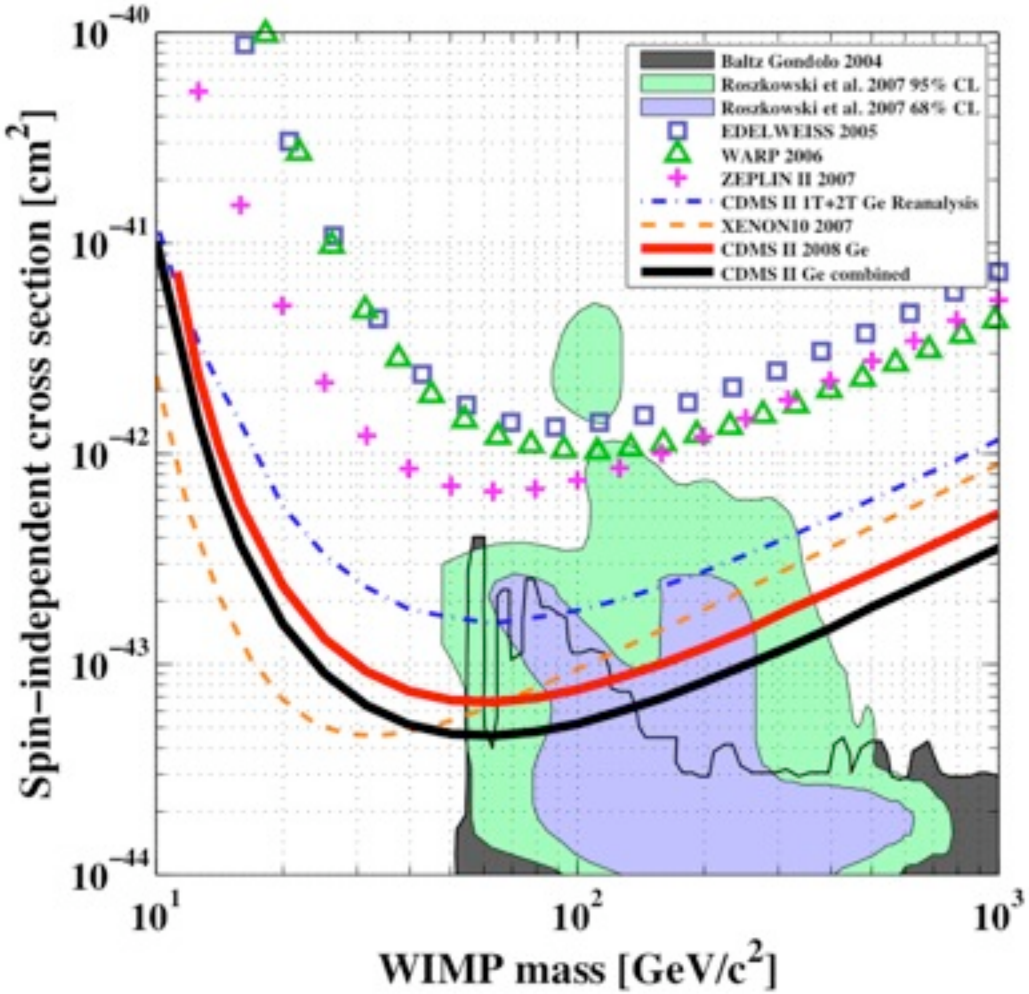
Likely α-induced NR

Consistent with leakage outside the signal region



Recent results

Spin-independent

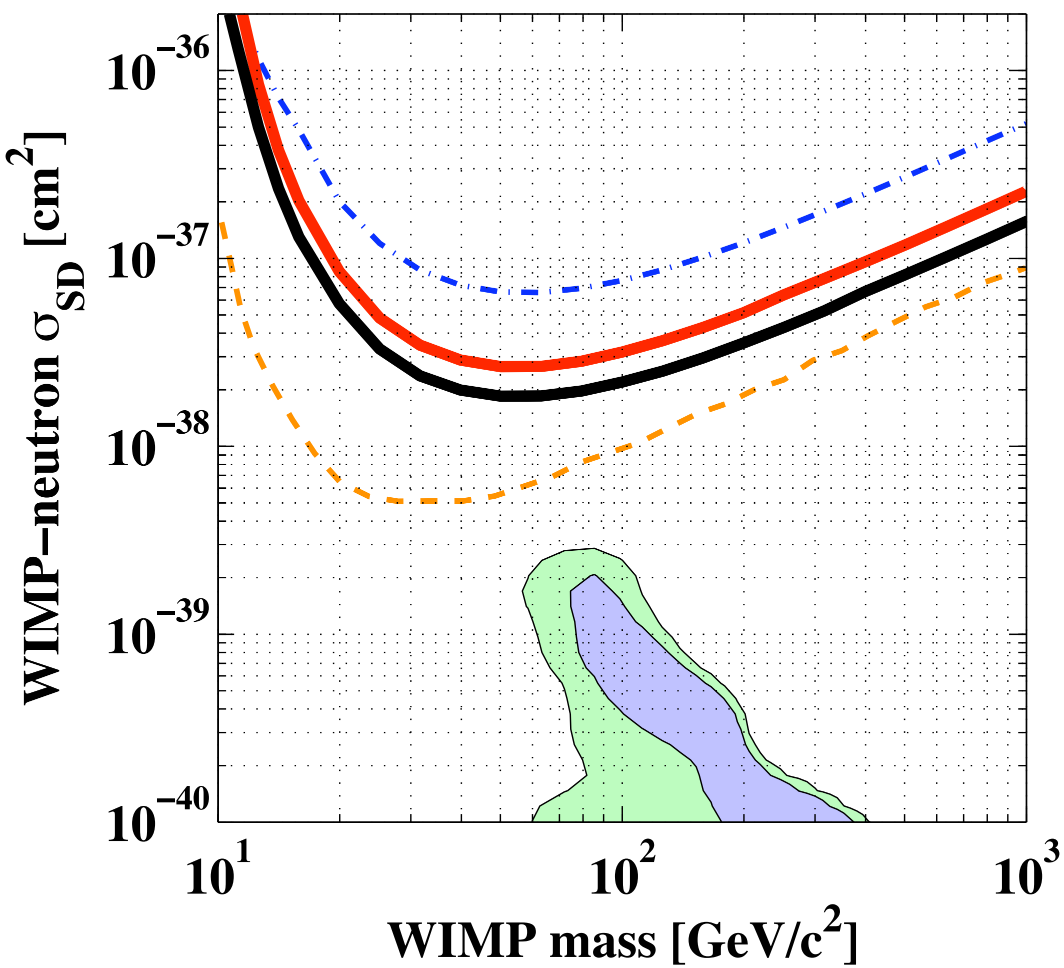


6.6×10^{-44} cm^2 @ 60 GeV

4.6×10^{-44} cm^2 @ 60 GeV

(combined with previous CDMS data)

Spin-dependent



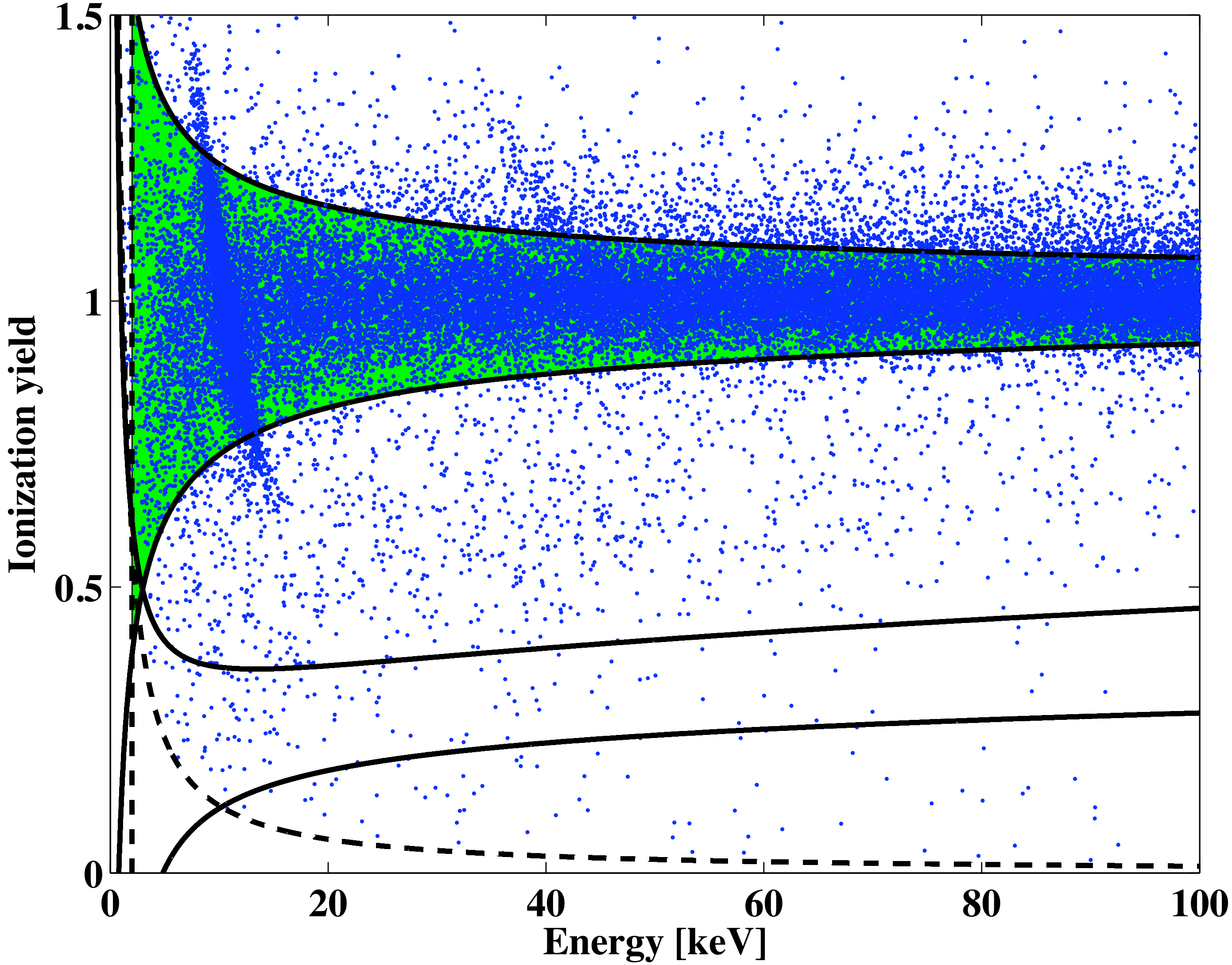
2.7×10^{-38} cm^2 @ 60 GeV

1.8×10^{-38} cm^2 @ 60 GeV

(combined with previous CDMS data)

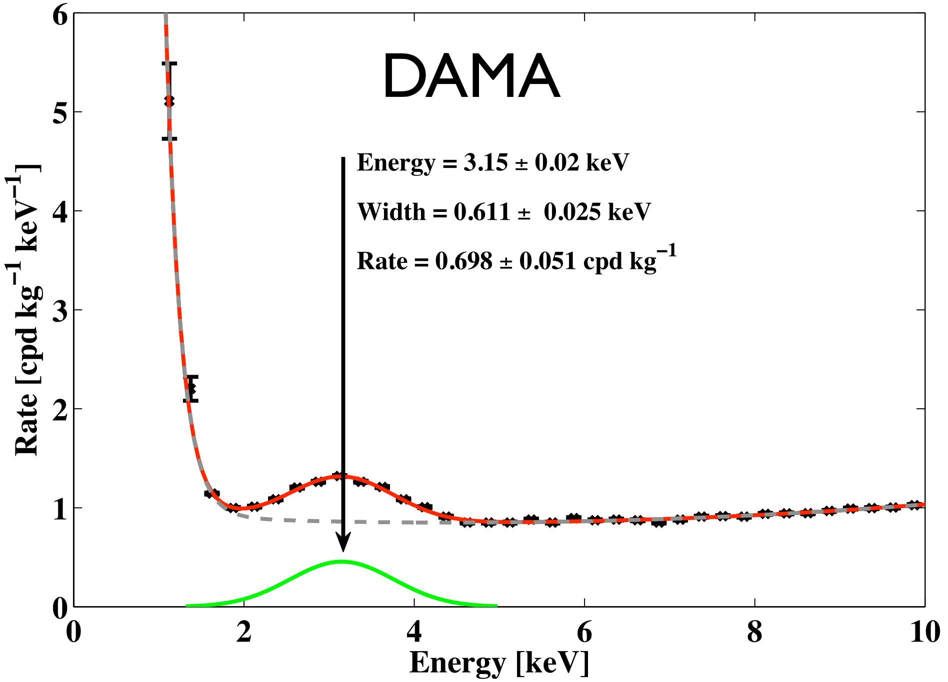
Electromagnetic Dark Matter signatures ?

What if we miss a dark matter signal due to an electron recoil interaction ?



Analysis motivated by the DAMA/LIBRA modulation signature.

Low energy spectrum

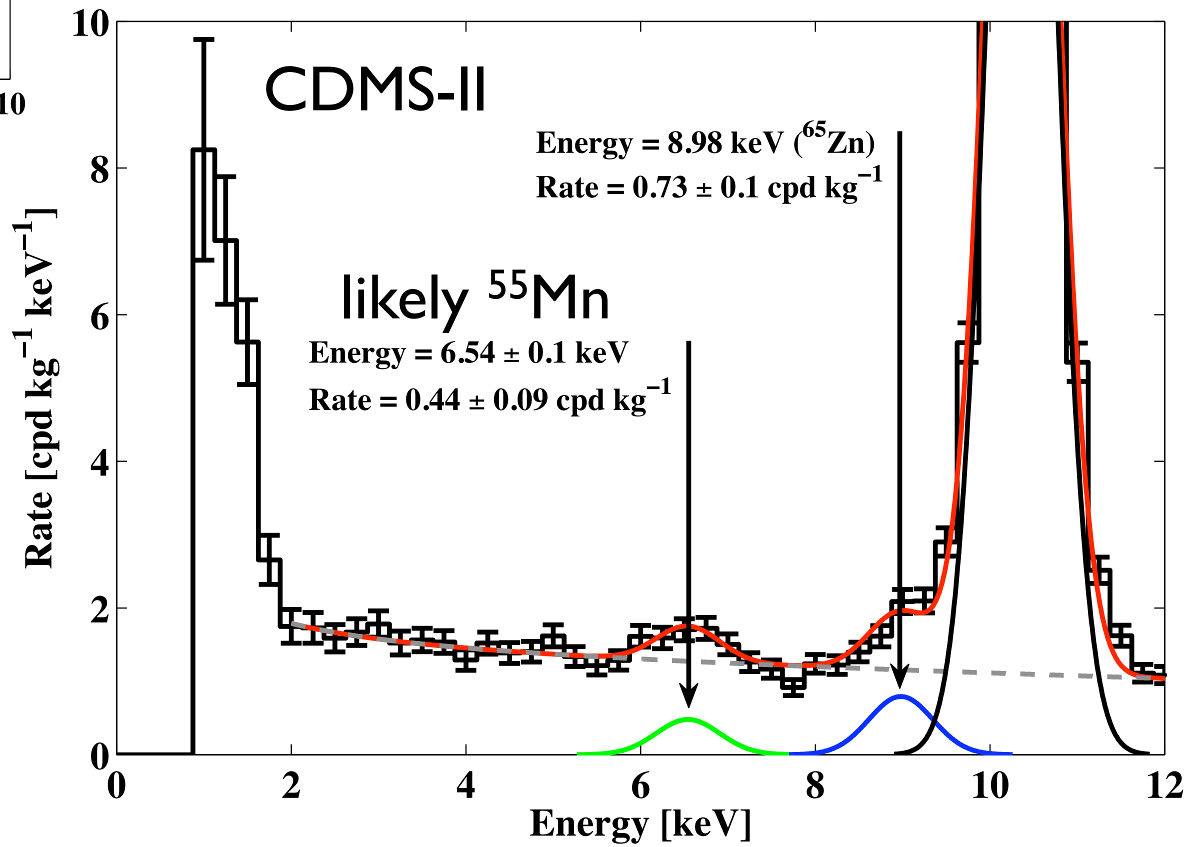


Excess in detected rate in the DAMA low energy spectrum

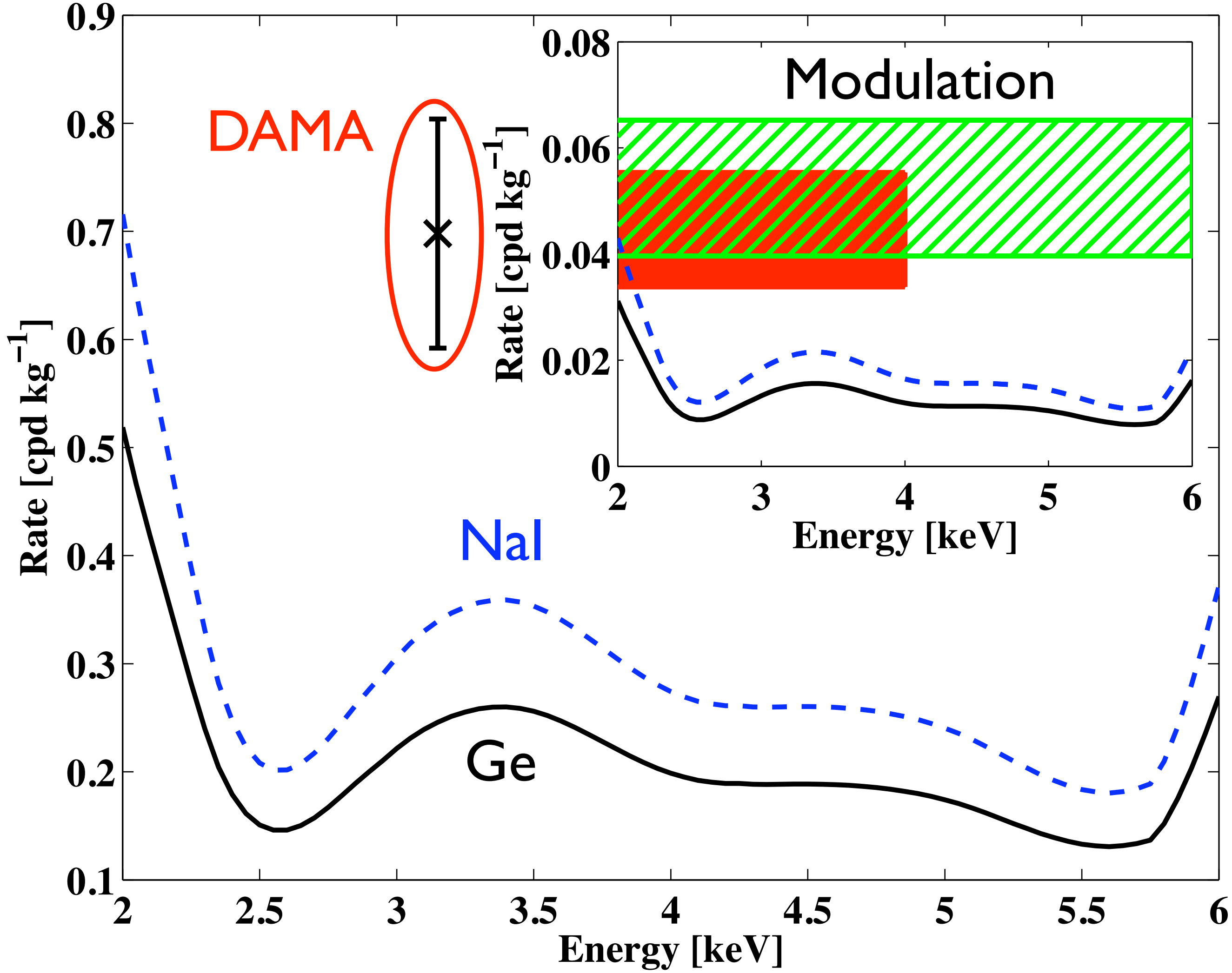
Contribution from ^{40}K (3.2 keV) unknown

<u>Assumption</u>: conversion of dark matter particle to electromagnetic energy

No excess rate above background detected



Comparison with DAMA/LIBRA



Z^2 scaling of the CDMS upper limits is an arbitrary toy model

In need of an actual particle model to perform physical interpretation

5 Towers - the second part

➜ **Second run with the 5 Tower setup since July 2007**

➜ **Factor ~2.5 more exposure**

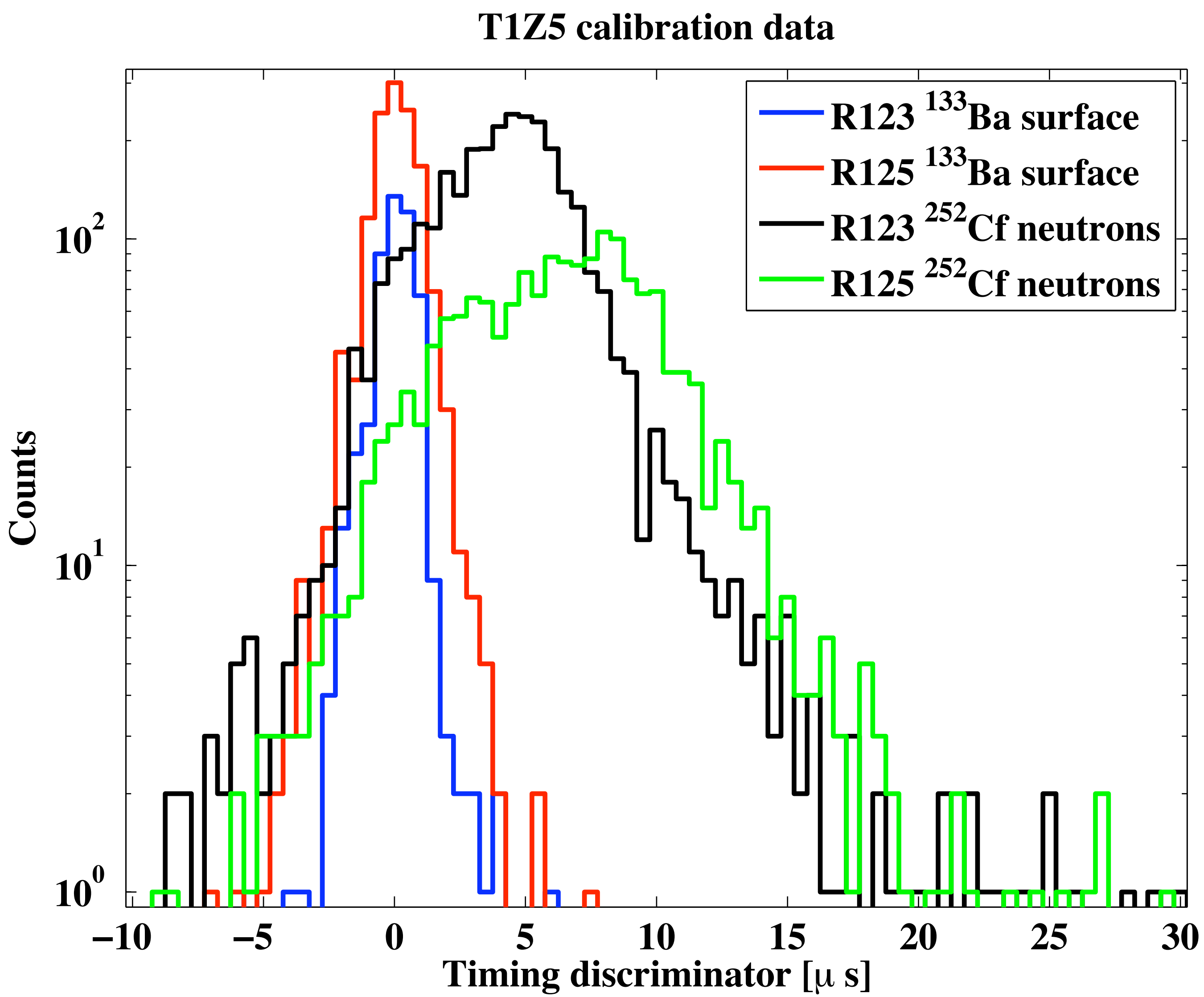
➜ **Improved data processing**

➜ **New phonon pulse information yielding possible discrimination potential**

➜ **Aim to keep expected backgrounds at the same (better lower) level as for the most recent analysis**

Analysis of the data is ongoing while we speak

Surface event discrimination



Timing for the new data looks promising in obtaining higher nuclear recoil detection efficiency

CDMS-II sensitivity till 2009

Raw Exposures

R118-119 ~120 kgd

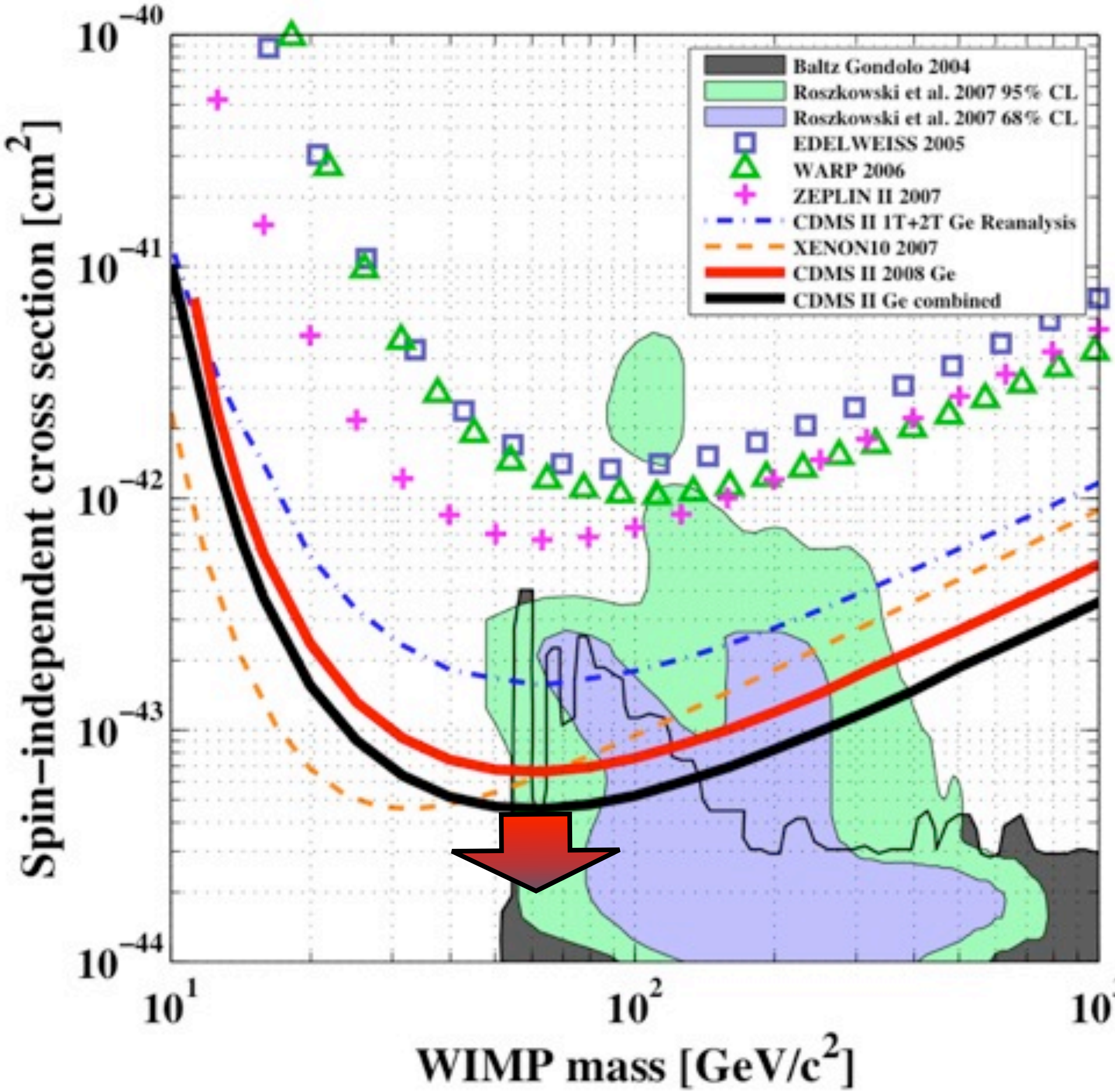
R123-124 ~400 kgd

R118-124 ~520 kgd

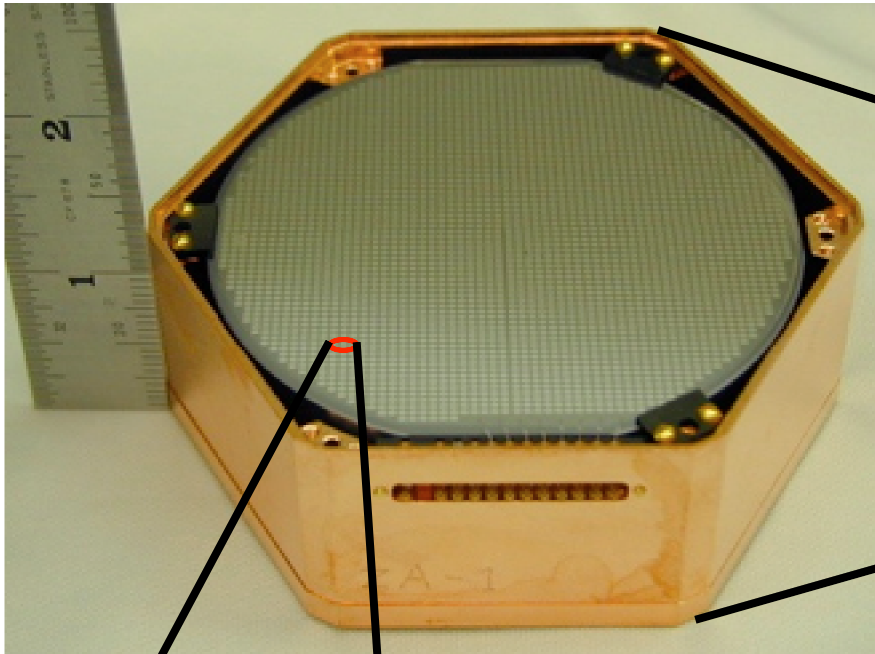
R125-128 ~750 kgd

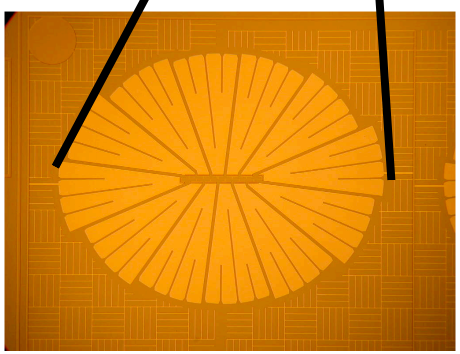
Total of ~1300 kgd

Final CDMS-II results expected in August

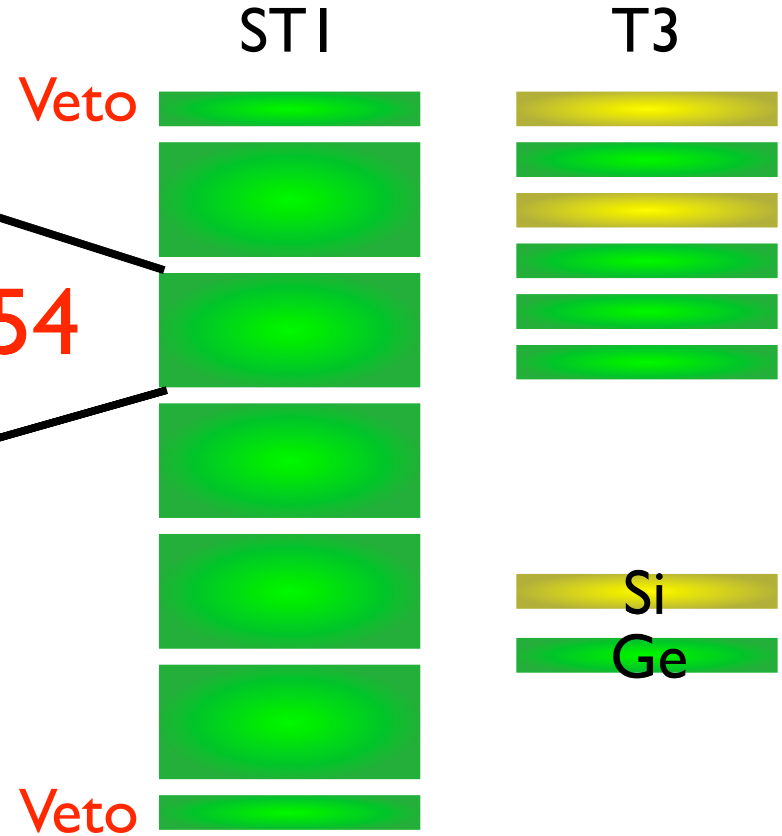


The dawn of a new age





Mass x 2.54

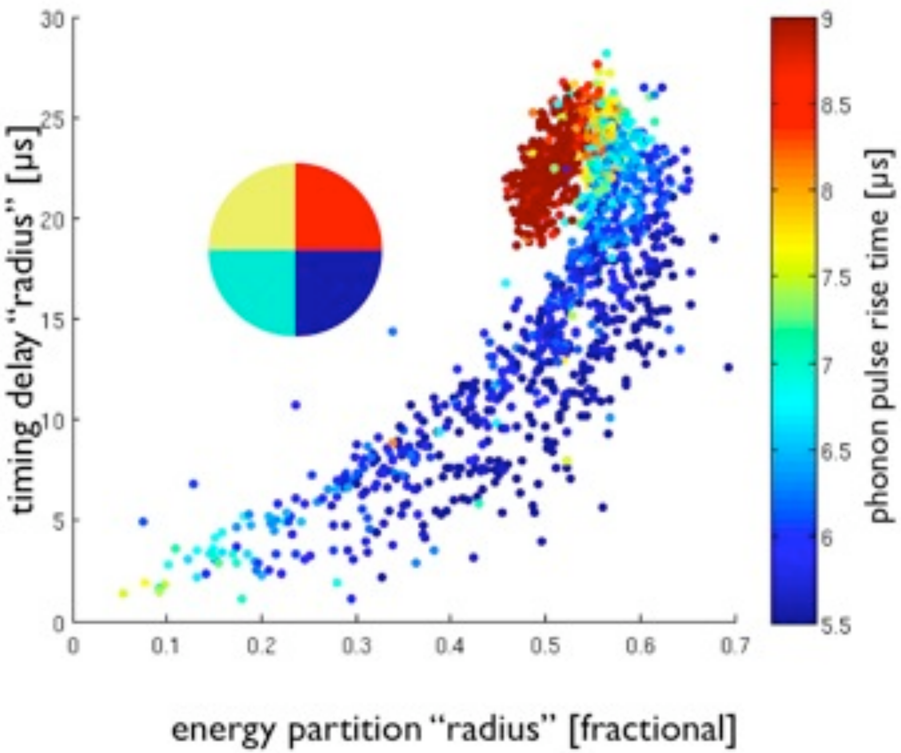


Improved active Al coverage
➜ better phonon collection

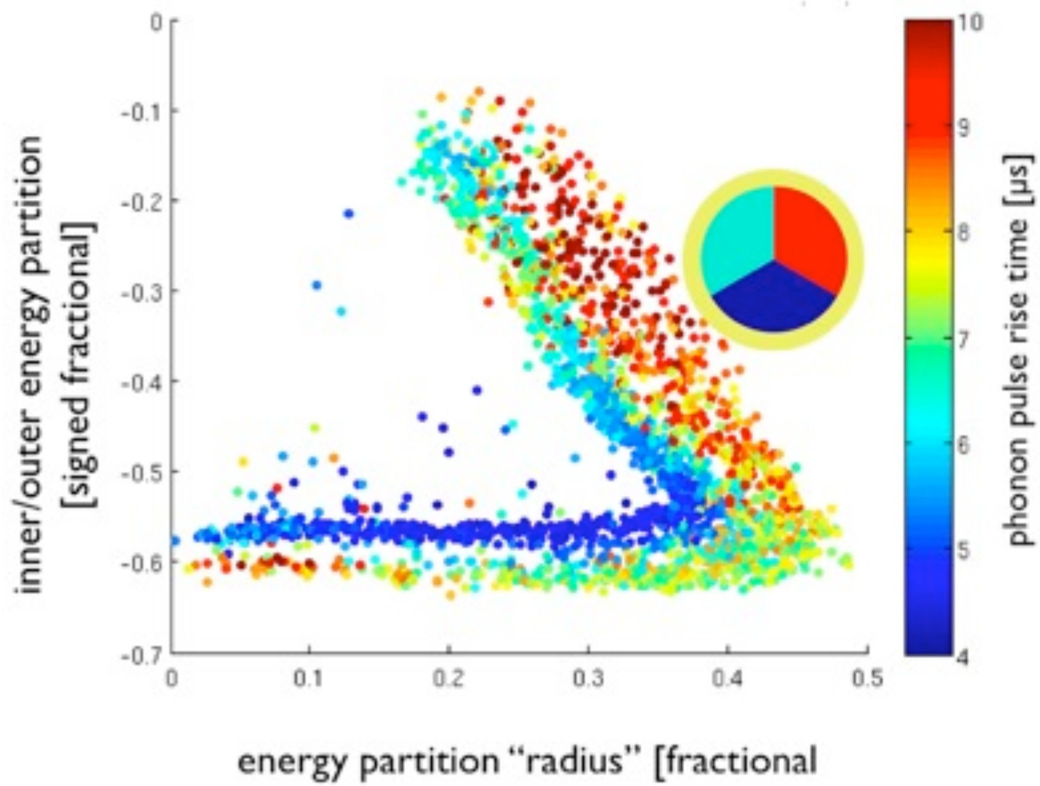
Final tuning of the first super tower last week
➜ ready for taking data

Improved timing information

CDMS-II configuration



ST-I configuration



New phonon sensor configuration strongly improves the timing discrimination

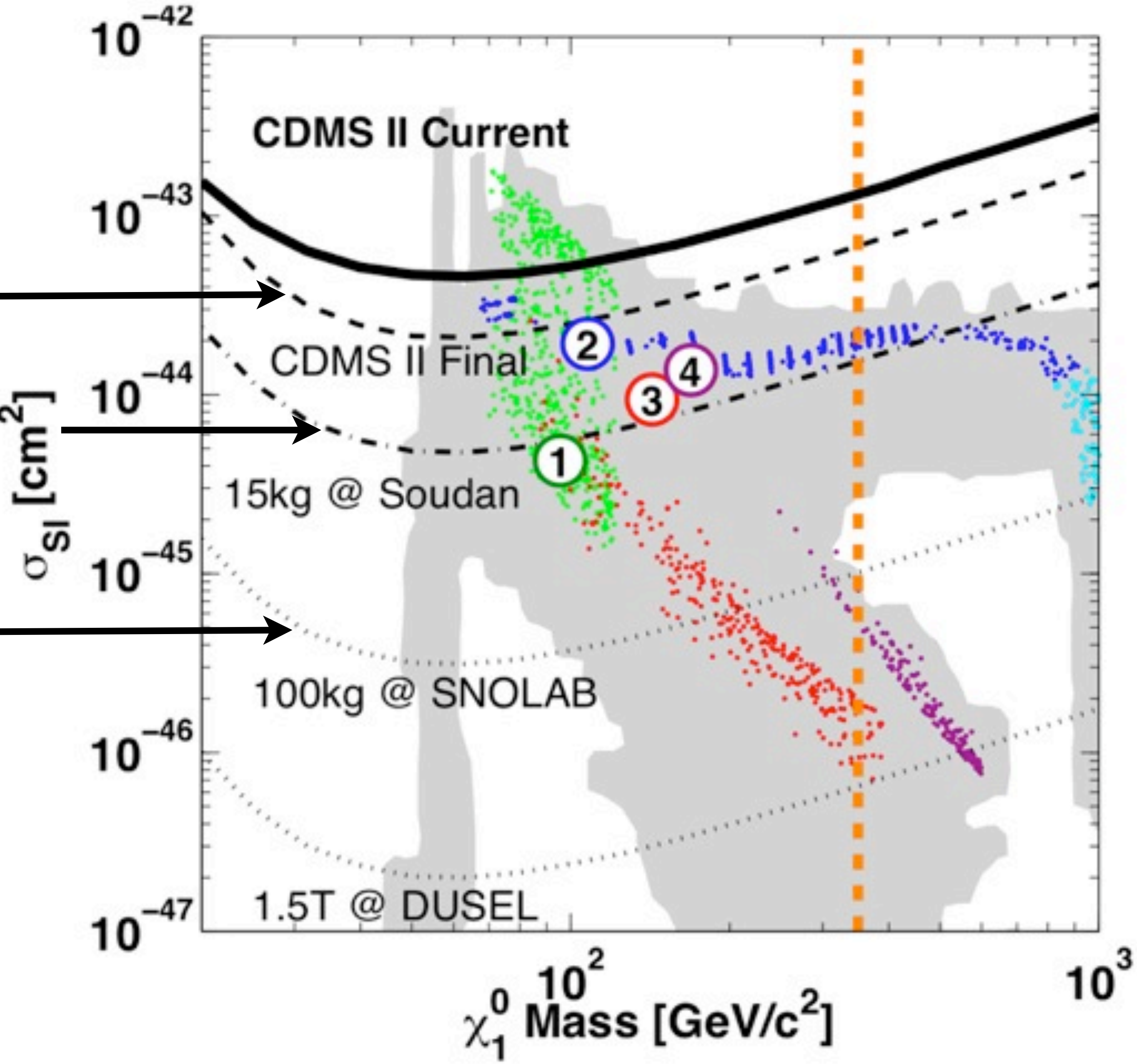
Detectors used in the next Stage of CDMS

CDMS-II to SuperCDMS 100kg

August this year

5 ST @ Soudan
~2 year sensitivity

SuperCDMS 100kg
zeptobarn sensitivity



Summary

- Excellent knowledge of the backgrounds and discrimination make the CDMS-II experiment to a zero background experiment

- Latest CDMS-II results set an world leading 90%CL exclusion limit on the WIMP nucleon cross-section for masses > 42 GeV

- Started to look not only for "standard" dark matter interactions

- Final CDMS-II data has been taken and is currently under analysis with final results expected in August this year

- Successful development and integration of the first SuperTower used in the next stage of the CDMS experiment

- Continuos improvements of the CDMS collaboration in reaching the zeptobarn sensitivity

The CDMS-II Collaboration

Caltech
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

Fermilab
D. A. Bauer, F. DeJongh, J. Hall, D. Holmgren, L. Hsu, E. Ramberg, J. Yoo

MIT
E. Figueroa-Feliciano, S. Hertel, S. Leman, K. McCarthy

NIST
K. Irwin

Queens University
W. Rau

Santa Clara University
B. A. Young

Stanford University
P.L. Brink, B. Cabrera, J. Cooley, M. Pyle, S. Yellin

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

Texas A&M
R. Mahapatra

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

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

University of Colorado at Denver
M. E. Huber

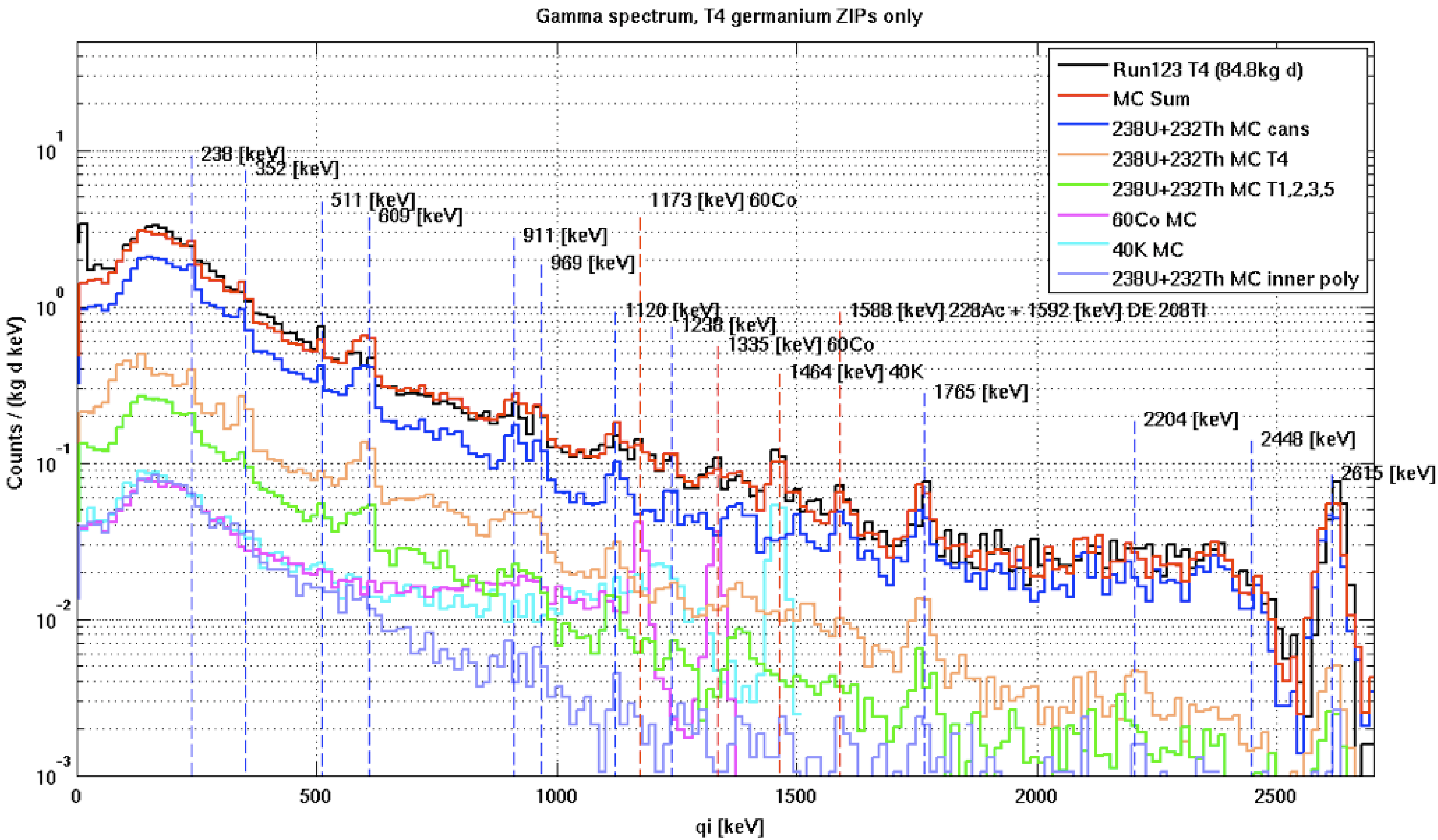
University of Florida
T. Saab, D. Balakishiyeva

University of Minnesota
P. Cushman, L. Duong, M. Fritts, V. Mandic, X. Qiu, A. Reisetter, O. Kamaev

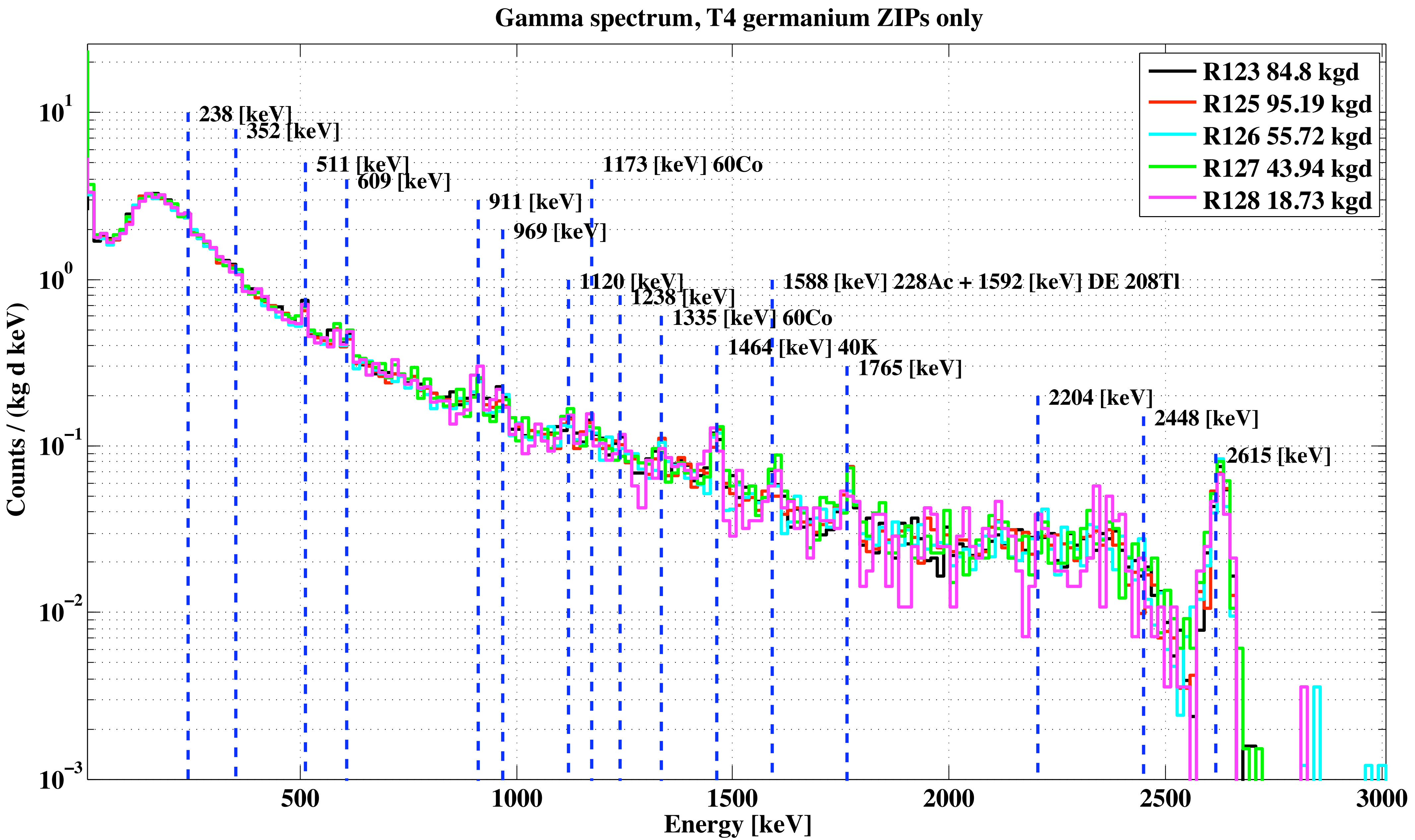
University of Zurich
S. Arrenberg, T. Bruch, L. Baudis

BACKUP SLIDES

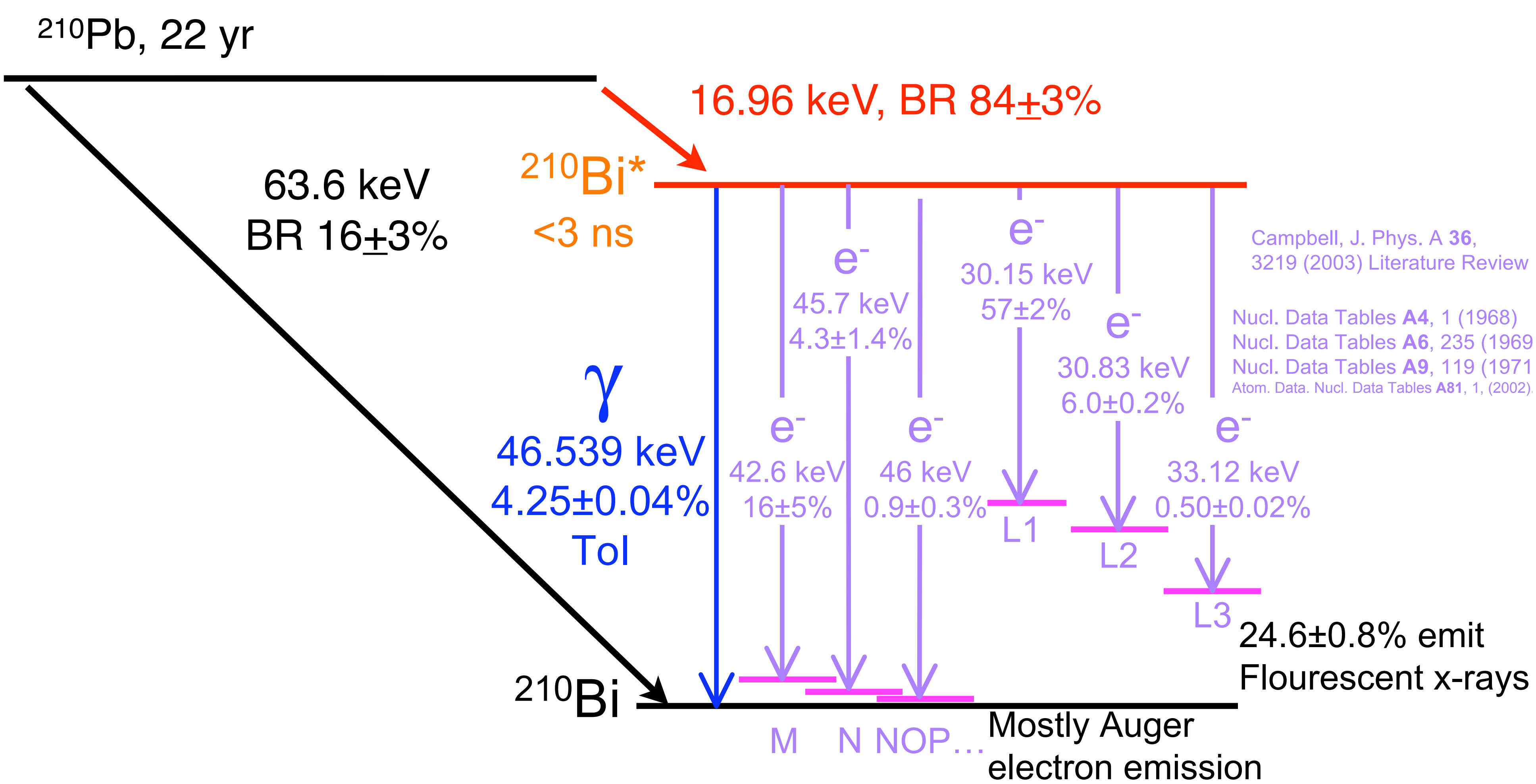
Understanding the origin of our backgrounds



Backgrounds for the new data



210 Pb decay scheme



H. Nelson

Expected signature: Low energy beta decay -> detect the ~46 keV peak