Recent results from the CDMS-II experiment

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Detection principle

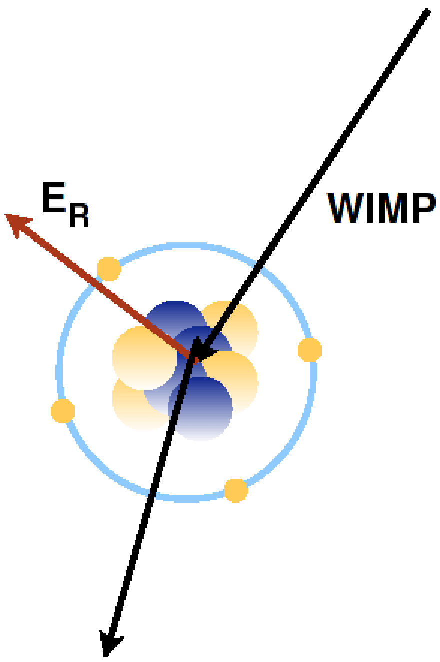
Detect the dark matter particles (WIMPs) by their elastic scattering on atomic nuclei

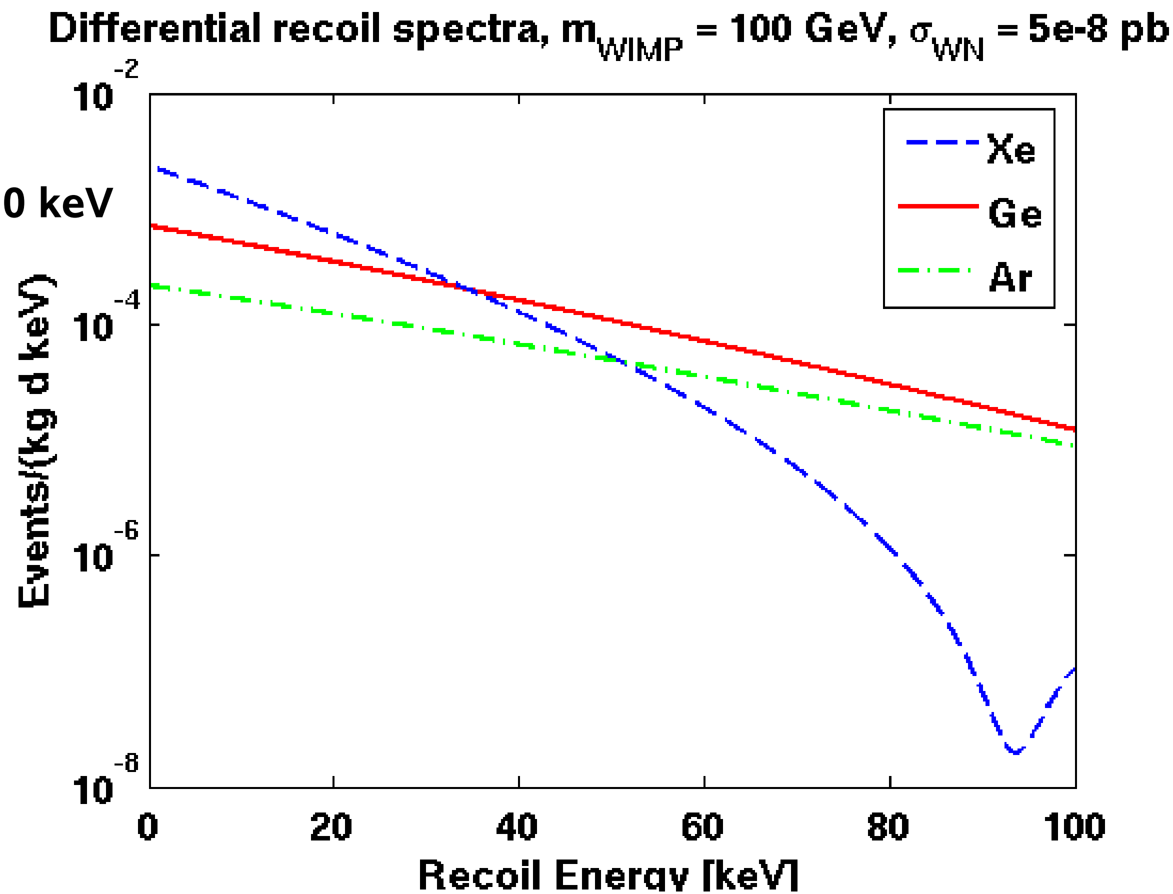
Coherent scalar (spin-independent) scattering: cross section scales with A^2 of the nuclei

Suppression by Formfactor

Roughly exponential spectrum of nuclear recoils

Achieve low detection thresholds: < 10 keV





CDMS-II 5 Tower Setup

5 towers a 6 semiconductor (Ge + Si) detectors operated at cryogenic temperatures (~ 40 mK)

2 signals from interaction (ionization + phonons): event by event discrimination

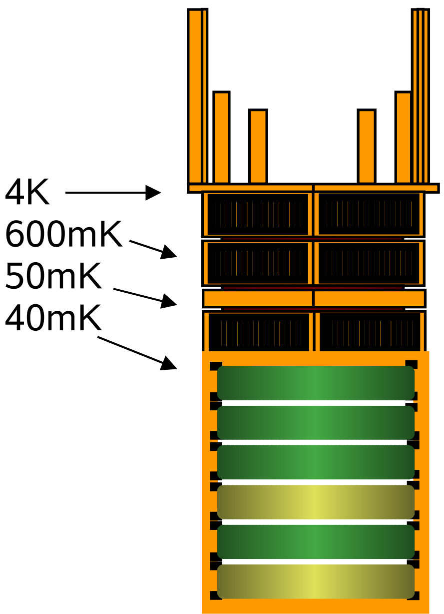
Underground laboratory shields well against cosmic radiation

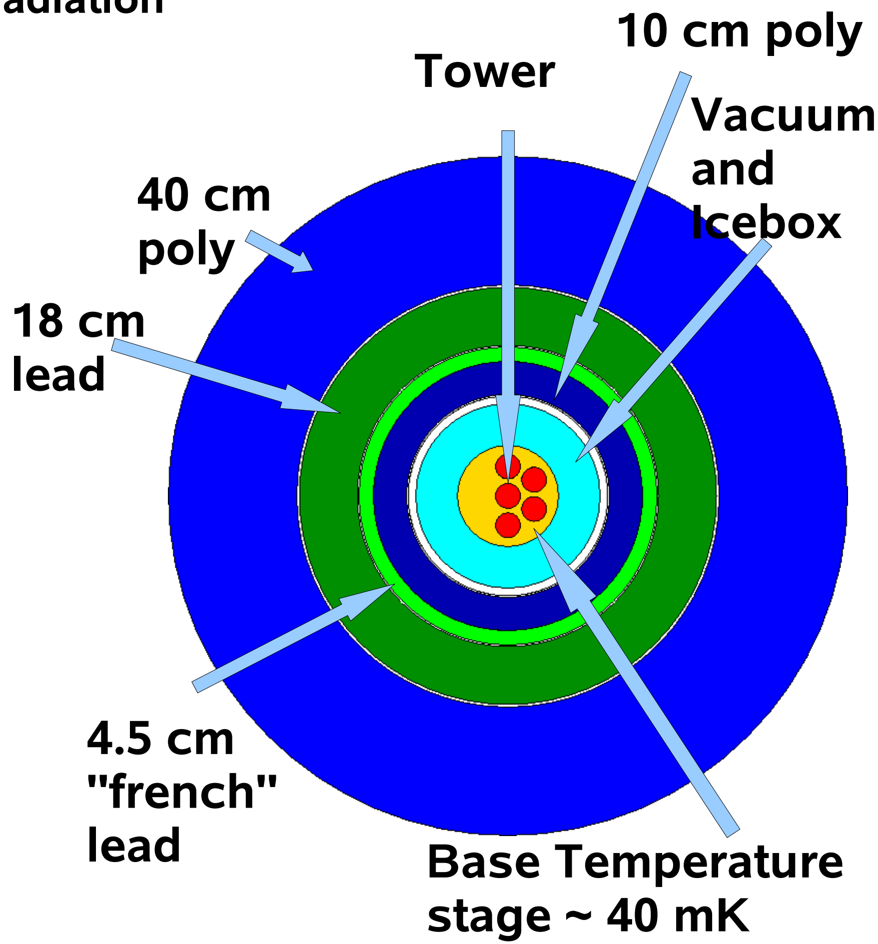
Active veto for high energetic muons

Passive shielding against environmental radioactivity

= Ge (250g)

= Si (100g)





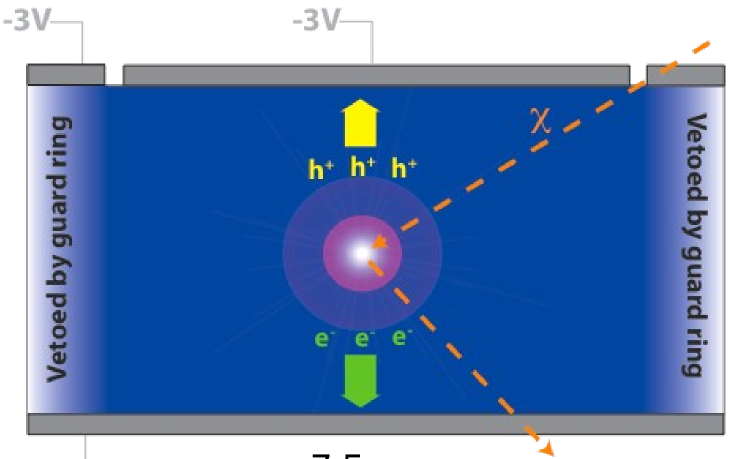
Ionization signal

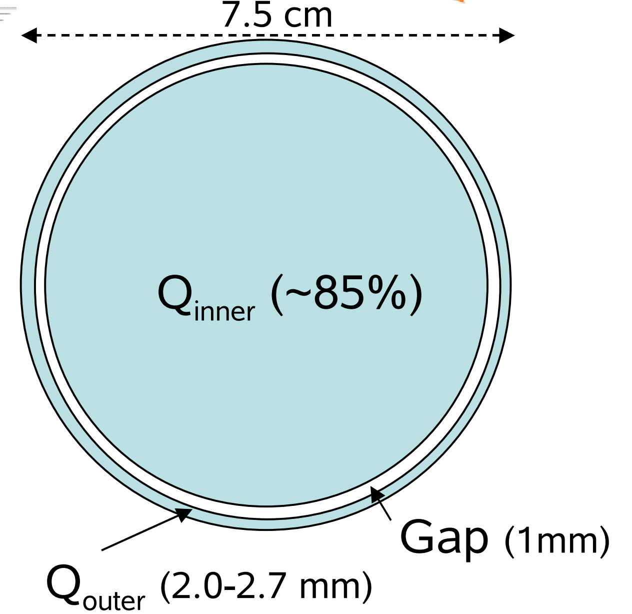
Drift field of -3V/cm / -4/cm on Ge / Si crystals

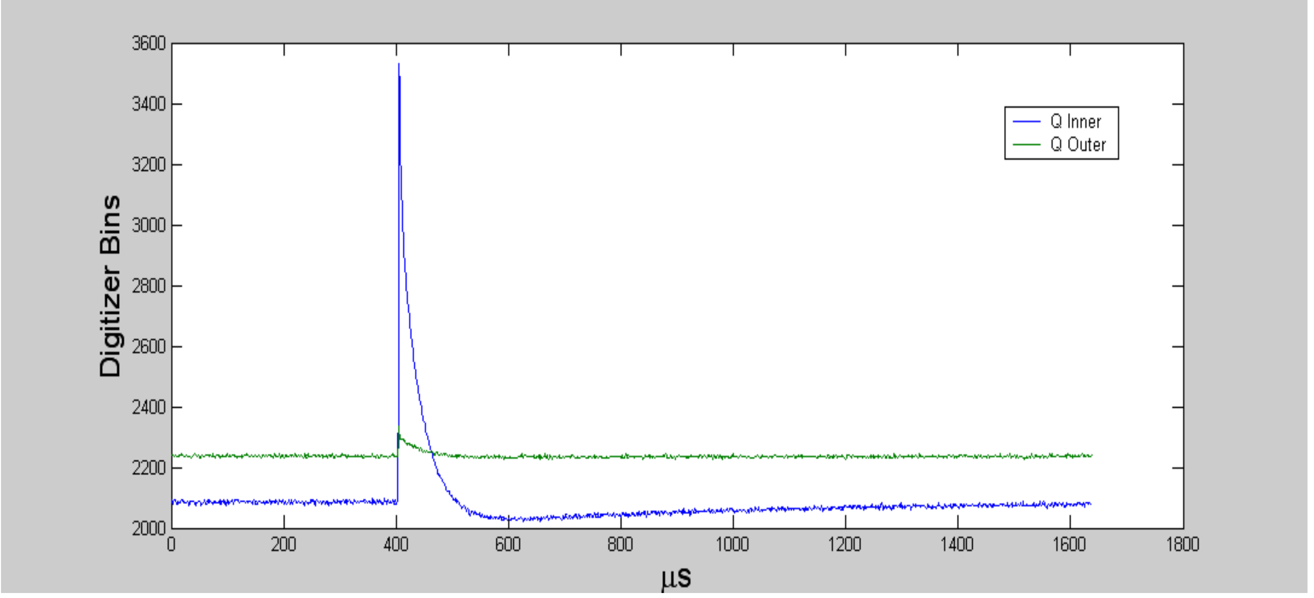
Zero energy resolution ~ 250 eV (~ 380 eV @ 10.4 keV)

Fiducial volume cut from diveded electrode

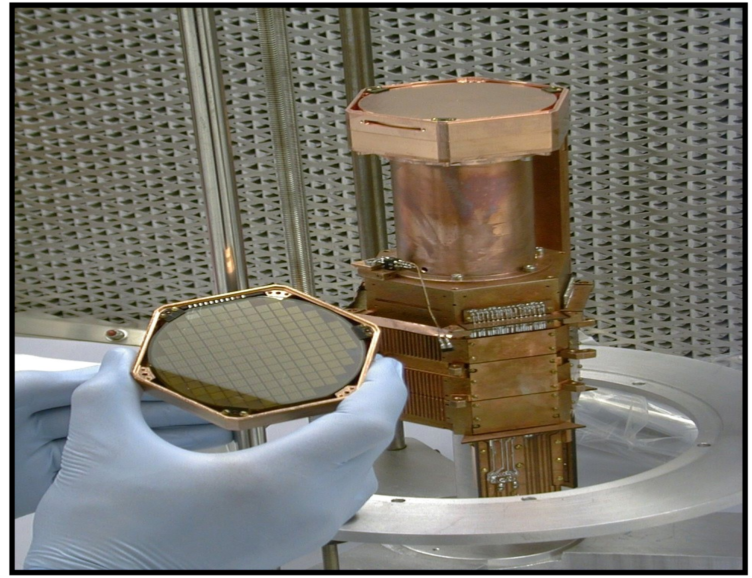
Outer electrode acts as „guard ring“ against incomplete collection at crystal edges







Calorimetry using phonons



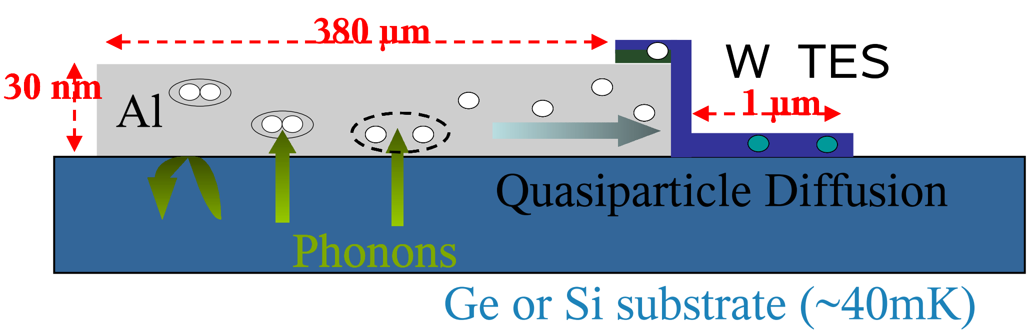
Segmented phonon readout (4 quadrants)

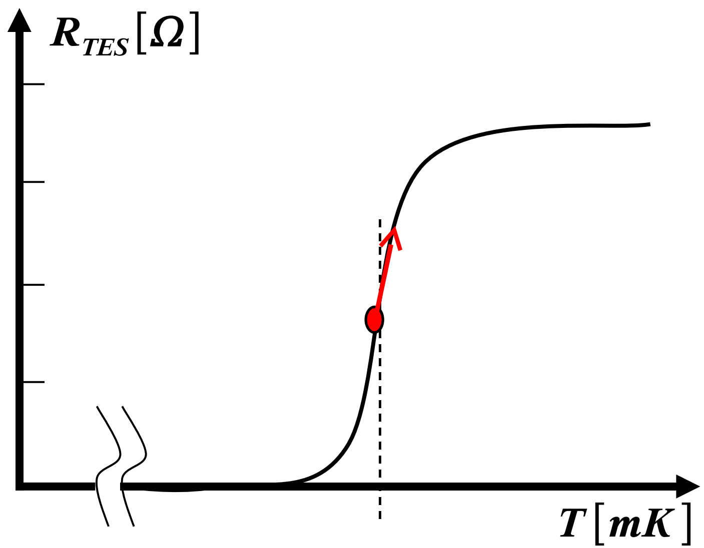
Each quadrant consists of 37 cells with 28 TESs per cell

Event localization in the x-y plane crucial to correct for position dependencies of athermal phonon signals

Fast response: risetime ~ 5 µs

Zero energy resolution ~100 eV per quadrant, total ~5% at higher energies





Background discrimination

Significant detection of a Dark Matter signal requires an efficient discrimnation between expected signal interaction and background interactions

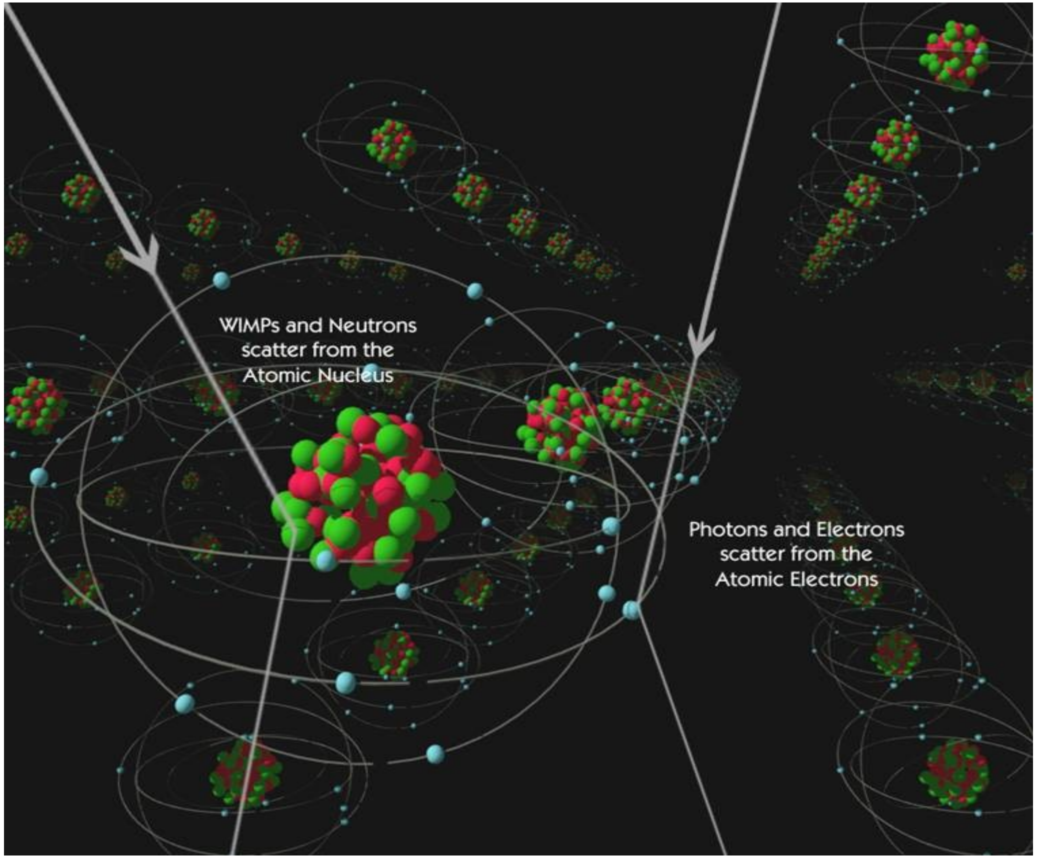
Suppresed ionization signal for nuclear recoils

True recoil energy of an event: E_{phonon}

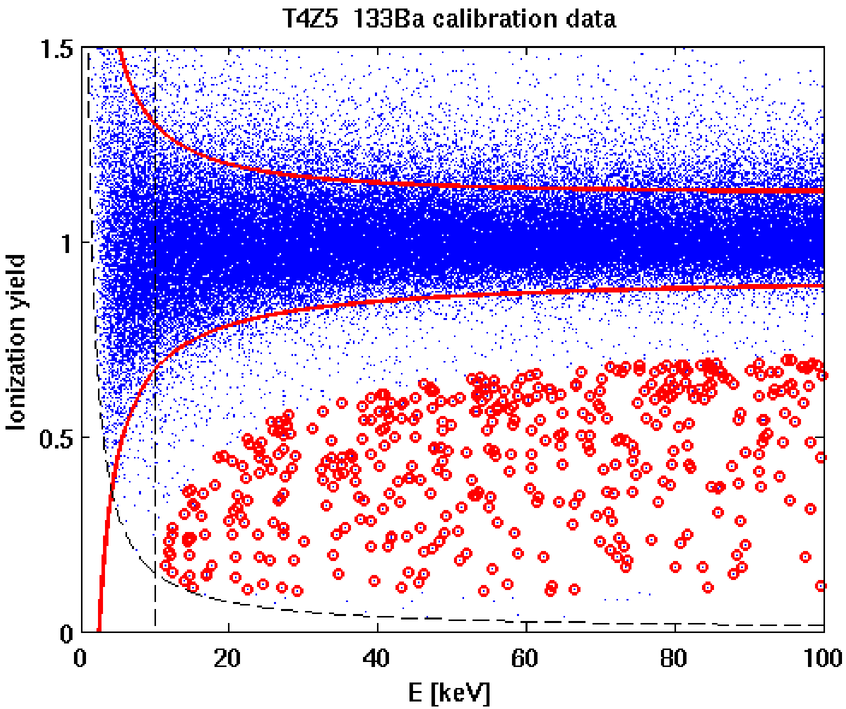
Yield defined as: $y = \frac{E_{charge}}{E_{phonon}}$

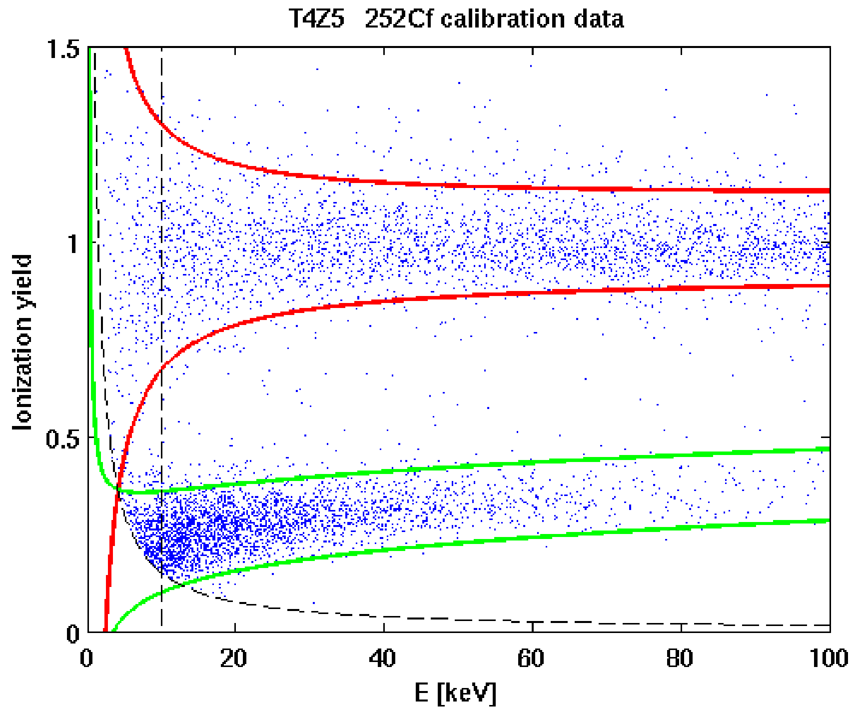
Electron recoil: $y = 1$

Nuclear recoil: $y \approx 1/3$



Yield based discrimination





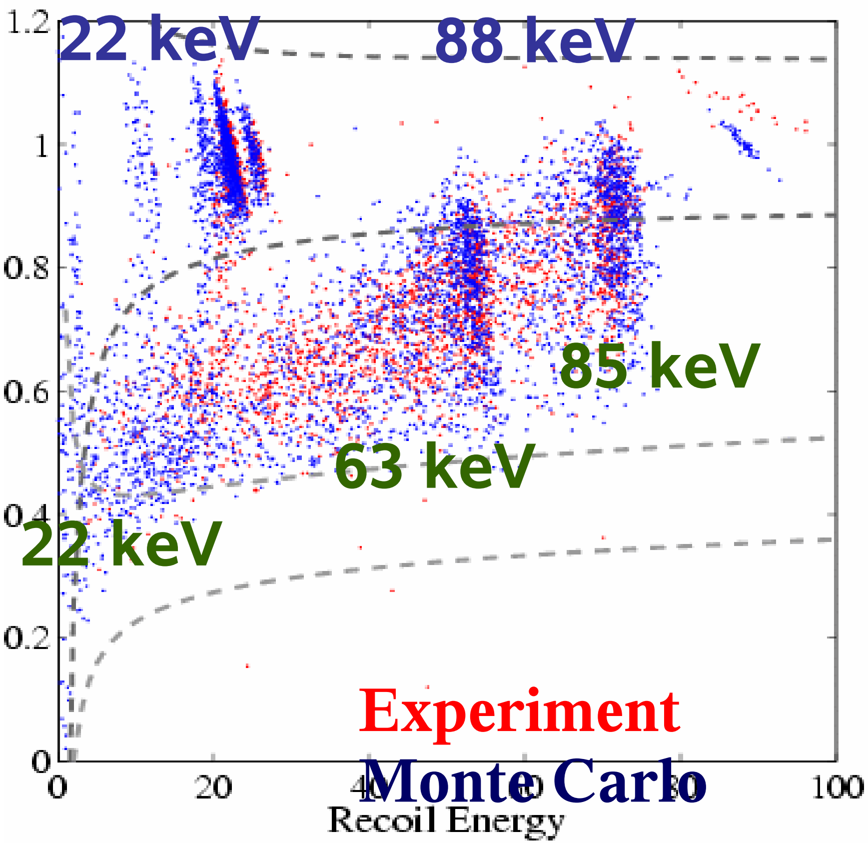
Primary electron recoil rejection: > 10.000:1

Population of events with reduced yield → near surface events

Signal region: 2σ nuclear recoil band

Ionization suppression in good agreement with Lindhard theory

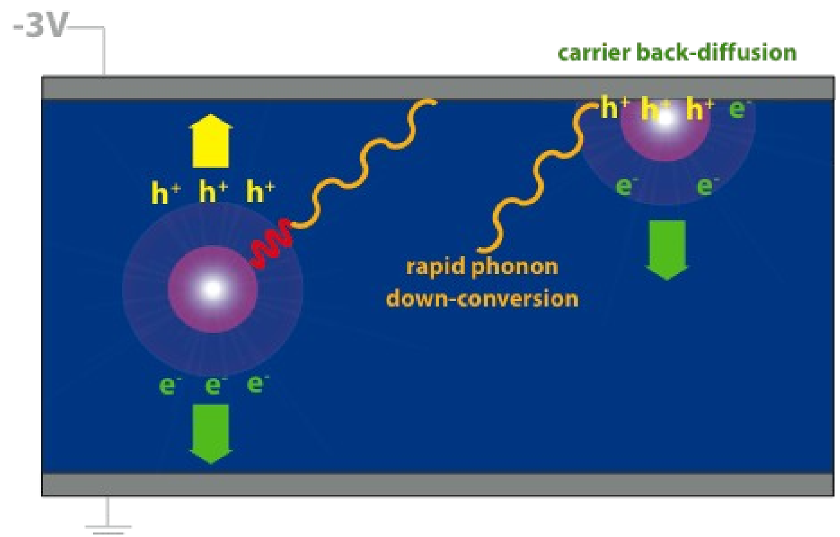
Surface events



Calibration with 60Co source

Interactions in the first few microns of the detector surface suffer from incomplete charge collection

Reduced ionization yield from surface events can mimic signal



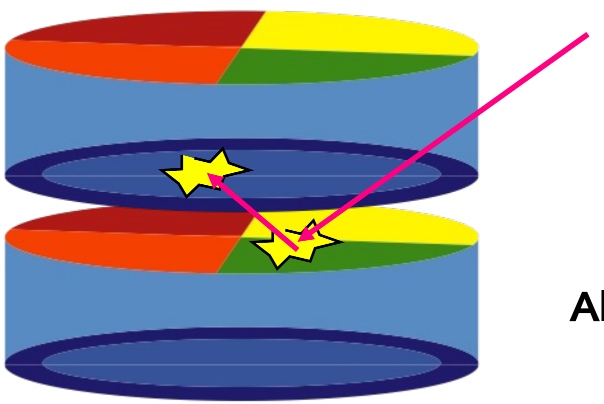
Dominant background of the CDMS-II experiment

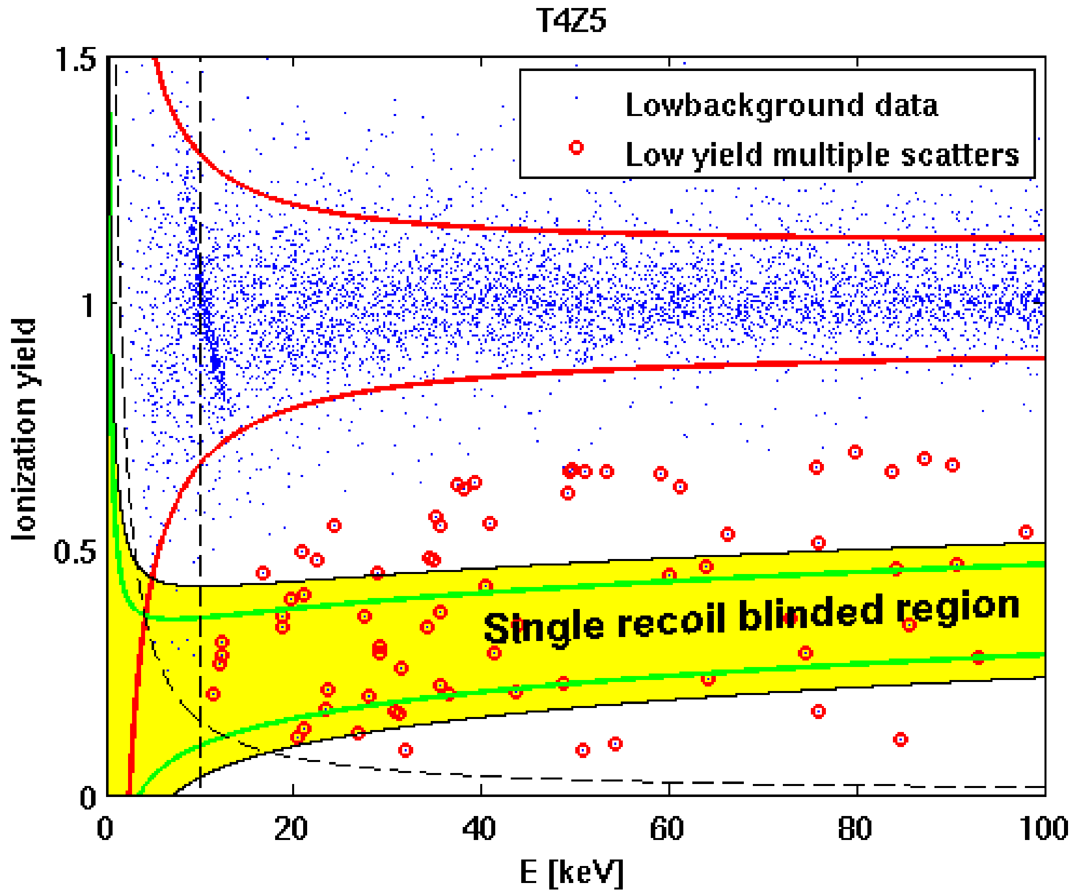
A first look at blinded low background data

Surface events in lowbackground data mainly from contamination of the detector surfaces with isotopes from Rn chain

Analysis is performed blind: No single scatters in the signal region while defining selection cuts

WIMPs are expected to scatter only once



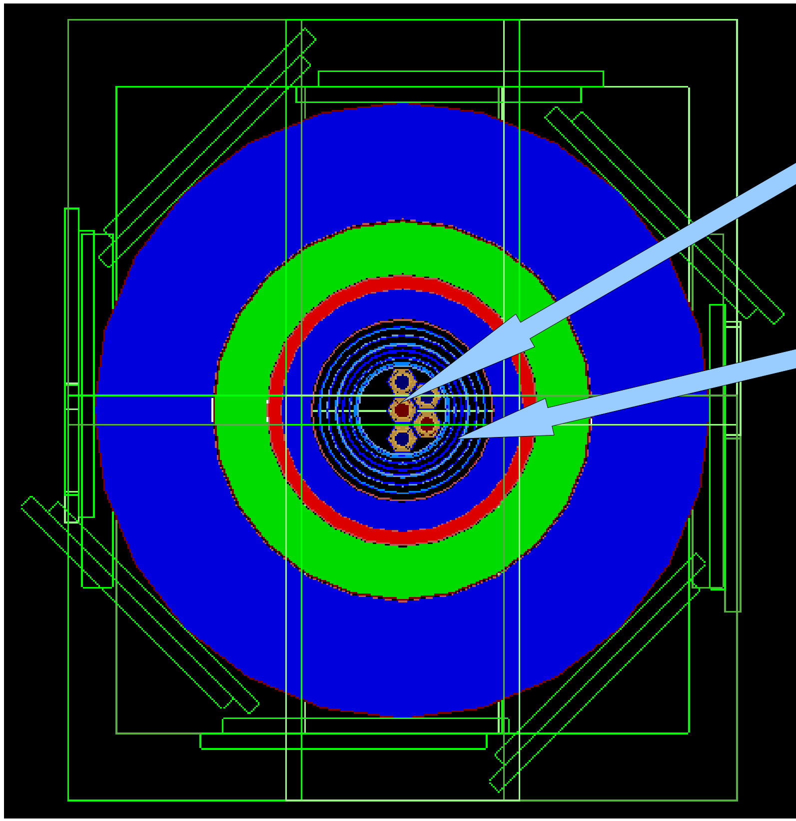


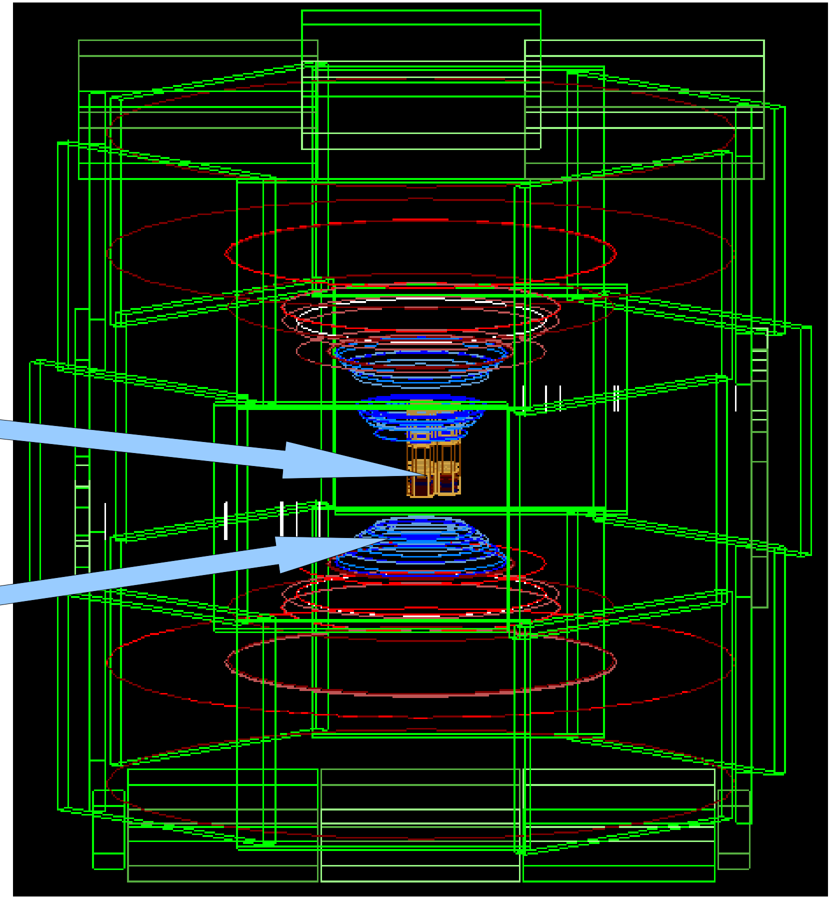
All 30 detectors are used to identify multiple scatters

Background simulation

Use GEANT4 to simulate the decay of several isotopes

Especially components which are close to the detectors with no shielding material (polyethylene, lead) in between.

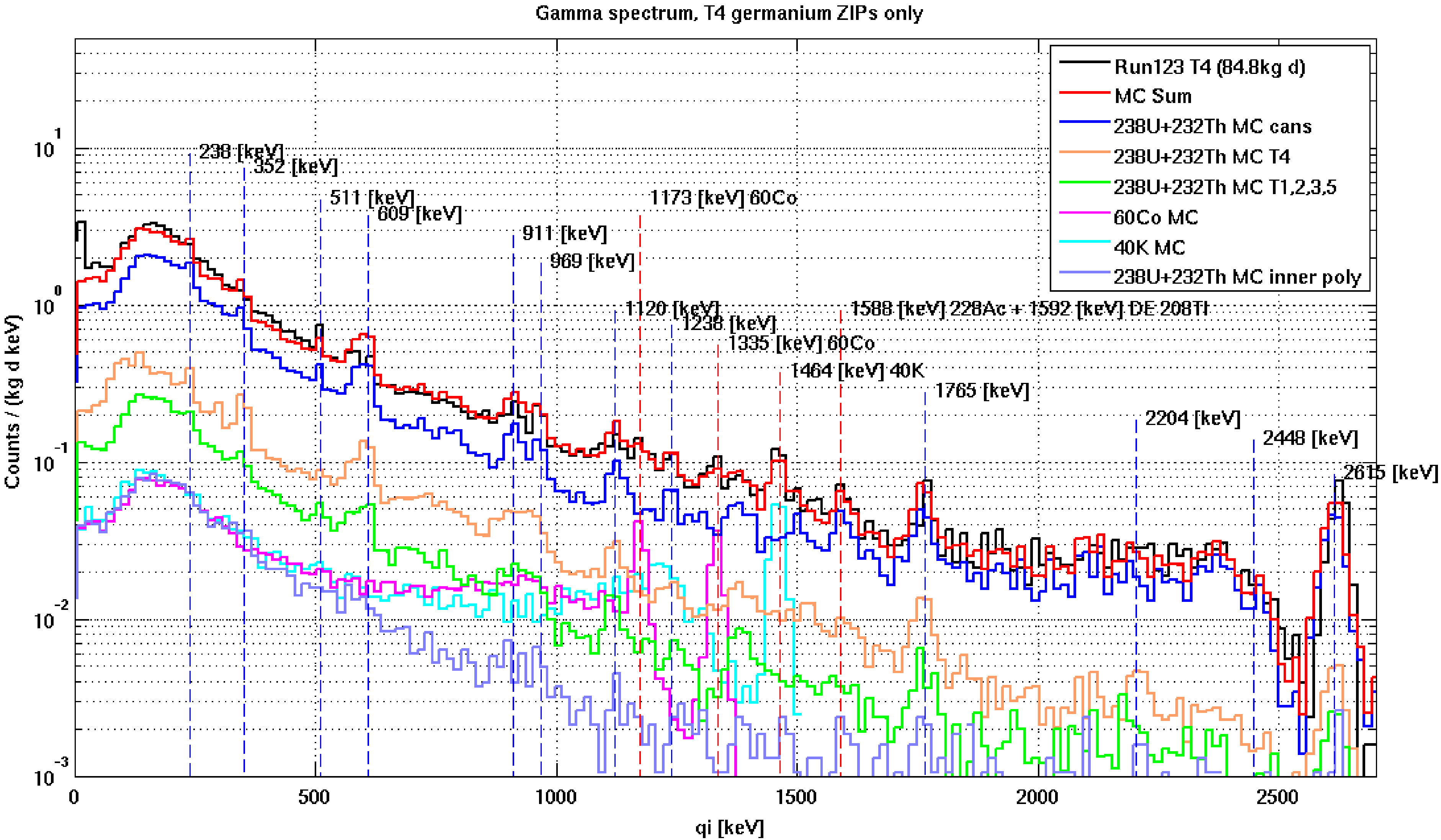




Decays of isotopes from the 232Th and 238U chain

Also take into account 60Co and 40K contaminations

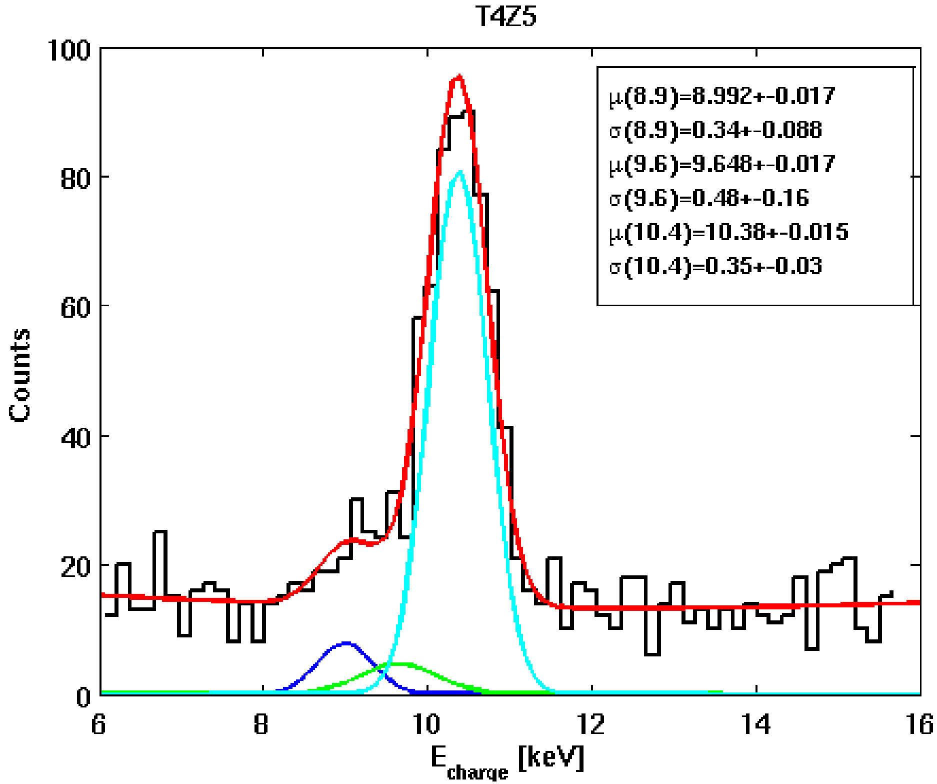
Understanding the origin of backgrounds

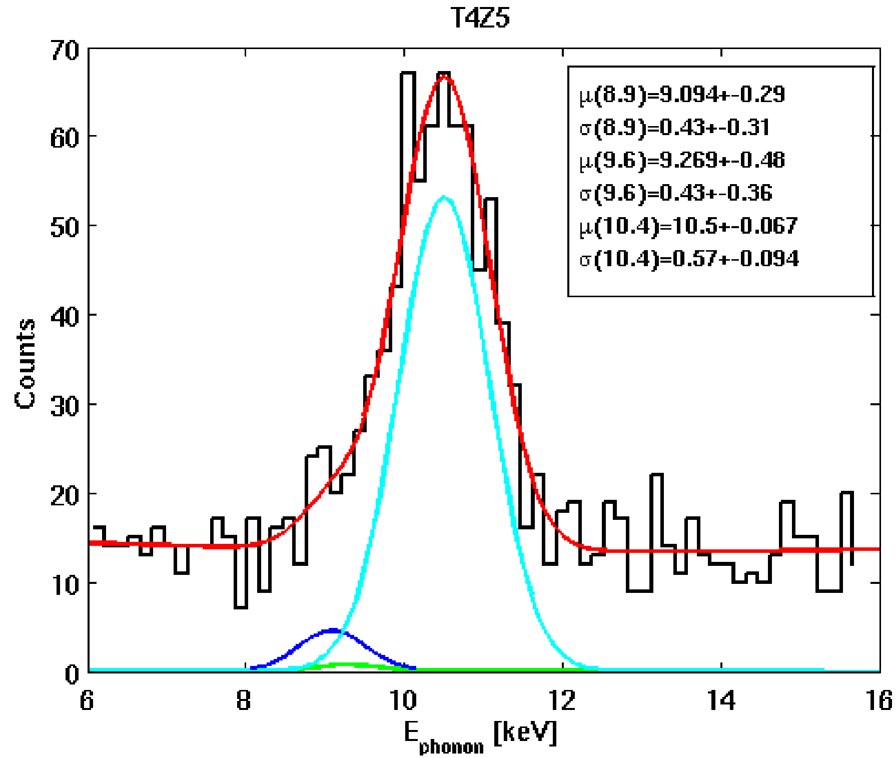


Energy calibration for low energy recoils

Determination of energy resoultion and calibration from neutron activated Ge isotope

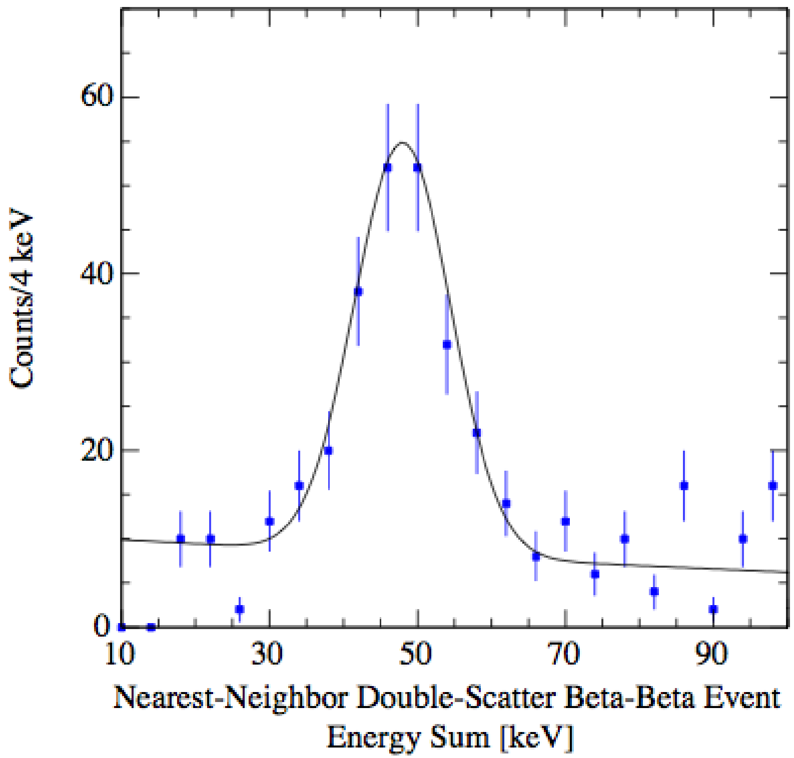
$$^{70}\mathrm{Ge}+n\rightarrow{}^{71}\mathrm{Ge}\rightarrow{}^{71}\mathrm{Ga}+\gamma(10.36\,keV),\tau_{1/2}=11.4\,days$$

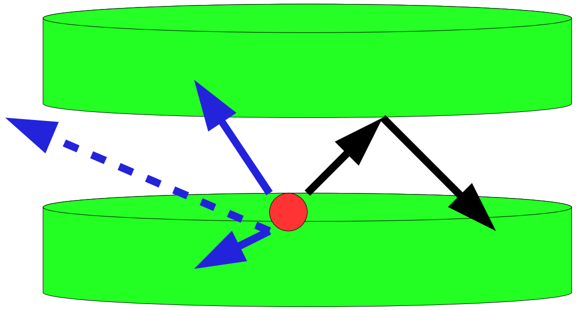




Additional cosmogenic contribution: 68Ga (9.66 keV) and 65Zn (8.98 keV)

Surface contaminations of the crystals





Detectors are exposed to Radon (Air) during fabrication, testing, ...

210Pb a decay product of 222Rn can be deposited on the detector surfaces

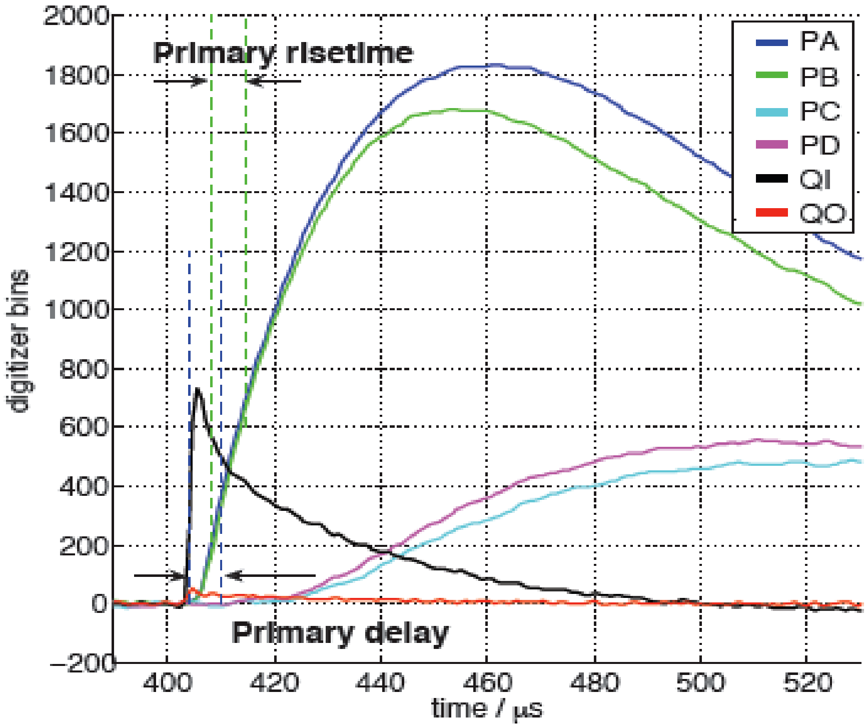
$$^{210}\mathrm{Pb} \rightarrow {}^{210}\mathrm{Bi} + (46.54\ keV),\ \tau_{1/2} = 22.3\ years$$

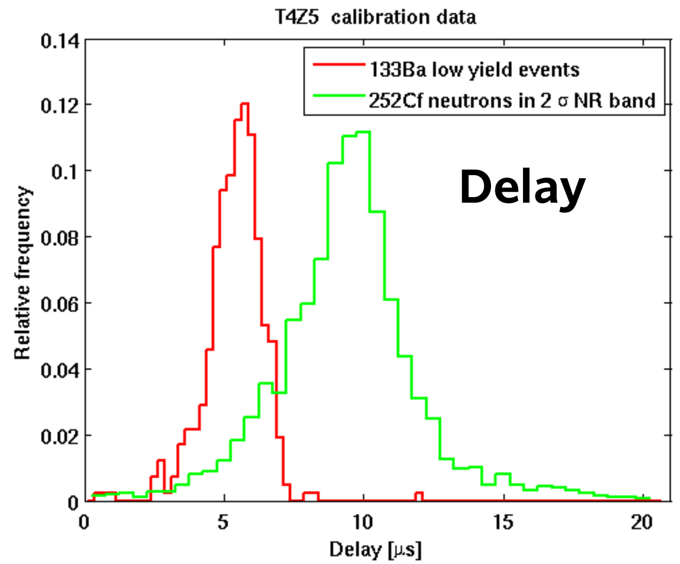
Decay can be identified by studying NND events

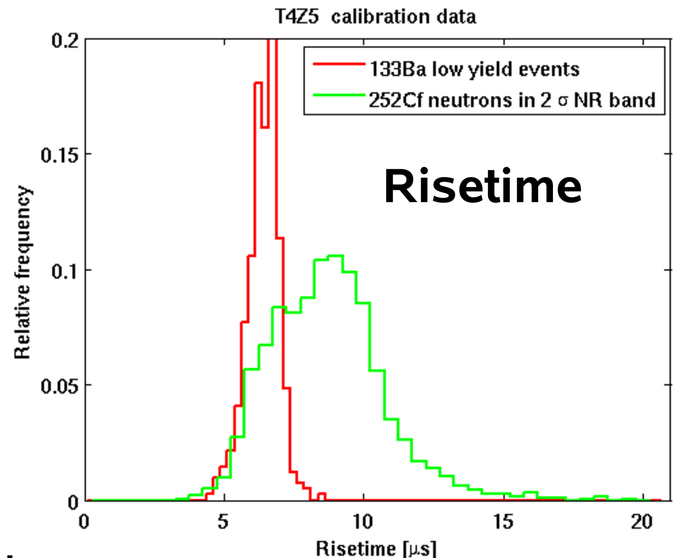
The low energetic gammas and electrons involved in this decay are the major contribution to the surface event population

Significantly reduced for new towers (T3-T5) by improved detector handling

A closer look at surface events





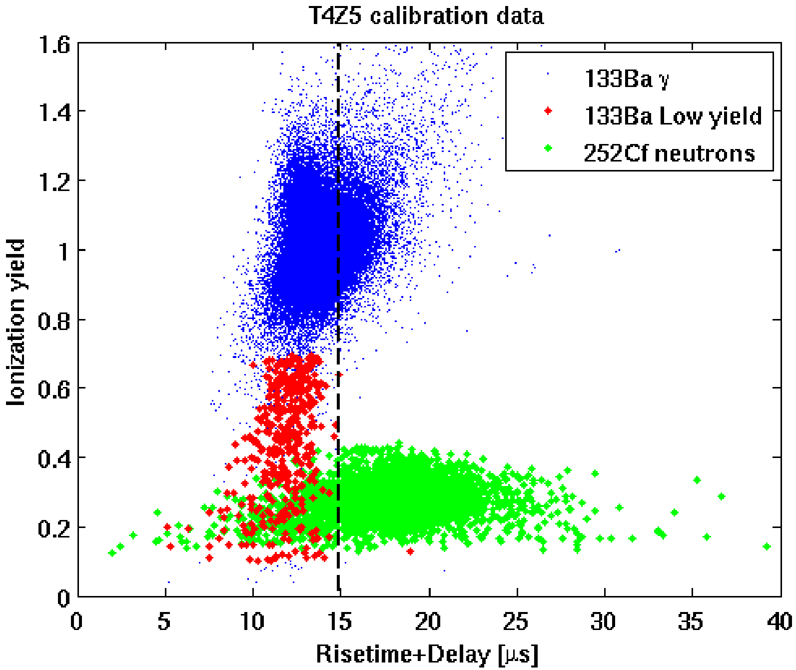


Surface events are faster in timing than bulk nuclear recoils

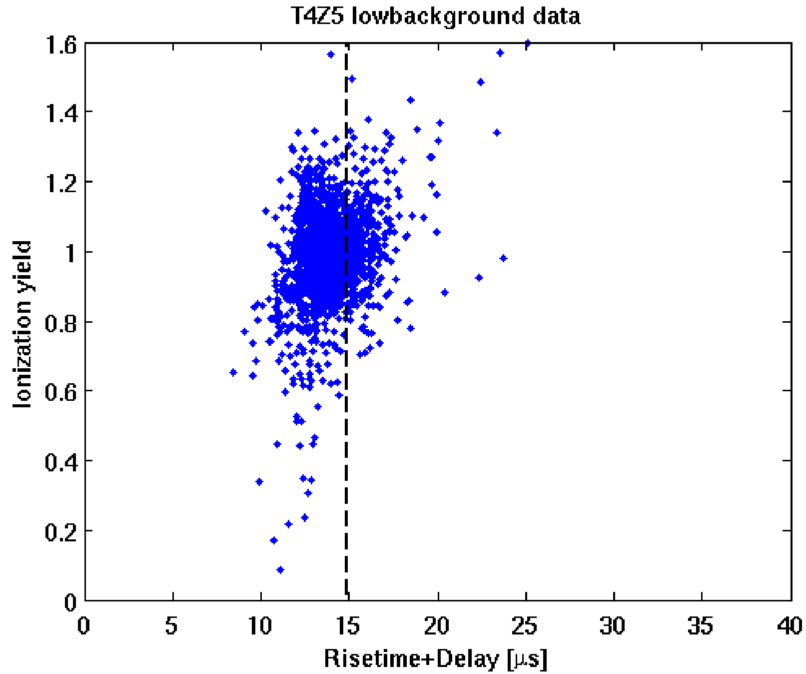
Timing is a powerful discriminator, used to get rid of surface events

Cut is designed on calibration data only

Surface event rejection cut



Defined on calibration data



Applied to lowbackground data

Surface event rejection ~ 200:1

Timing cut chosen at a level to contribute ~0.5 events total leakage to WIMP candidates.

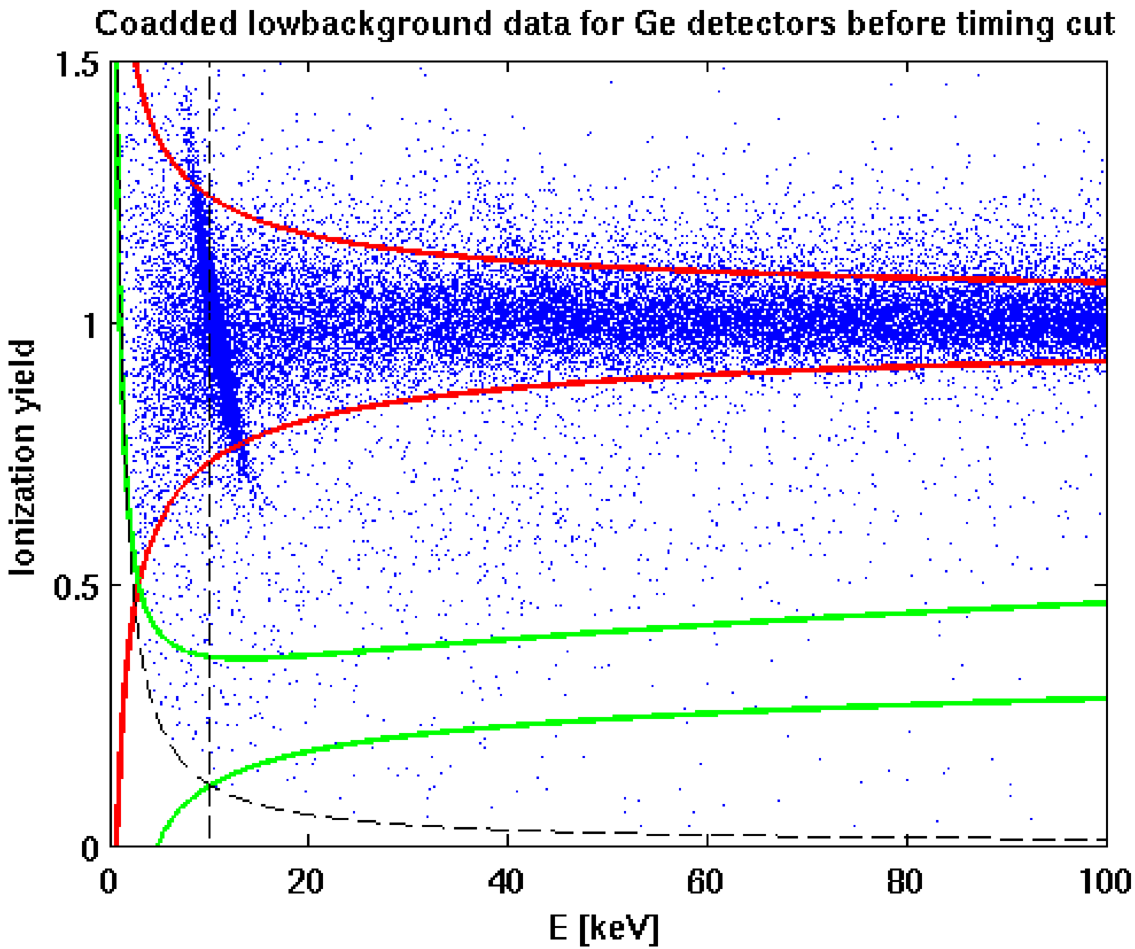
Expected background

Surface event discrimination capability of the surface event cut is determined from multiples in the 2σ nuclear recoil band.

Expected leakage:
ratio of the number of unrejected to rejected multiples times the number of observed singles in the 2σ nuclear recoil band.

Coadded data of 15 Ge ZIPs revealed 97 single scatters in the 2σ nuclear recoil band (signal region)

Expected leakage after timing cut into the signal region: 0.6 ± 0.5 events. (Preliminary uncertainty)



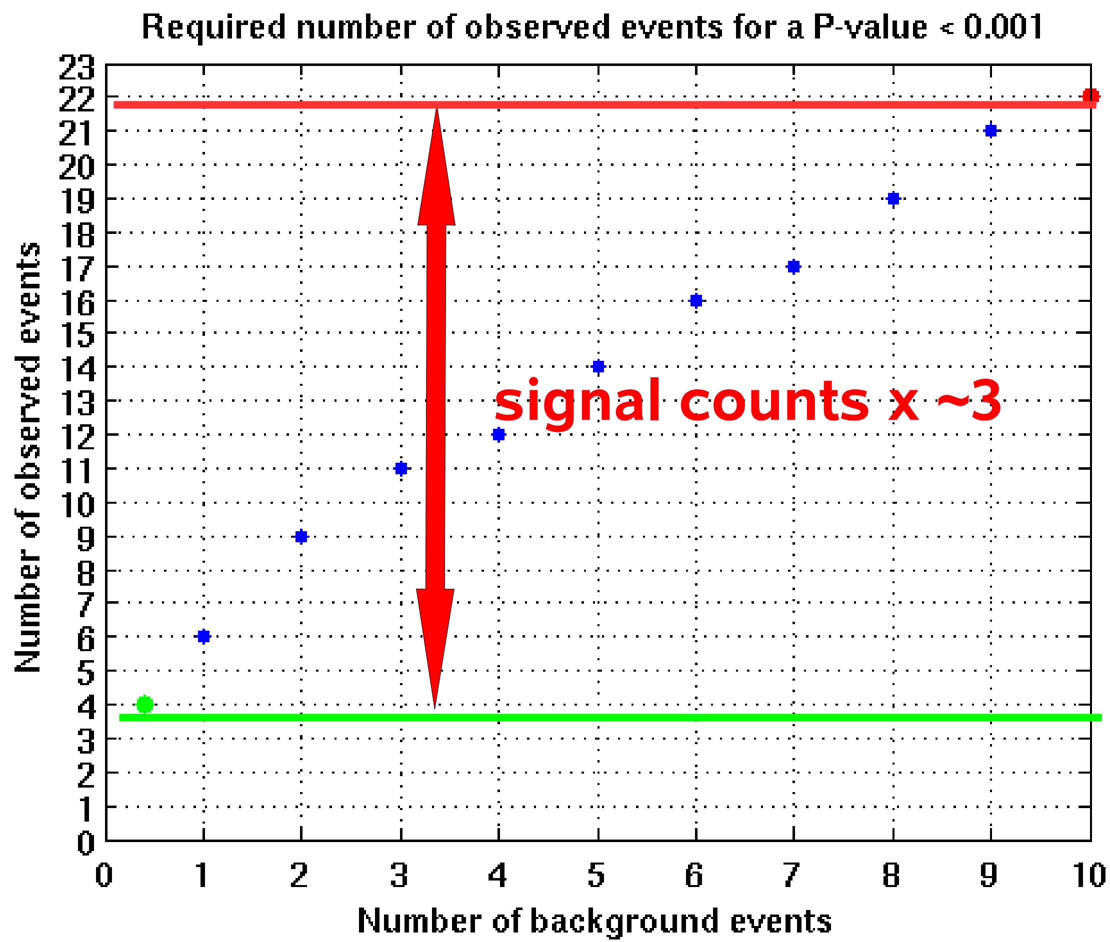
Significance of a signal

For perfectly known background, significance of a signal detection can be estimated by the P-value

$$P(n \geq n_{obs}) = 1 - \sum_{n=0}^{n_{obs}-1} \frac{n_b^n}{n!} \cdot e^{-n_b}$$

Probabilty for the number of observed events being caused by statistical fluctuation of the background

Actual significance has to be evaluated under consideration of statistical and systematic uncertanties on the background



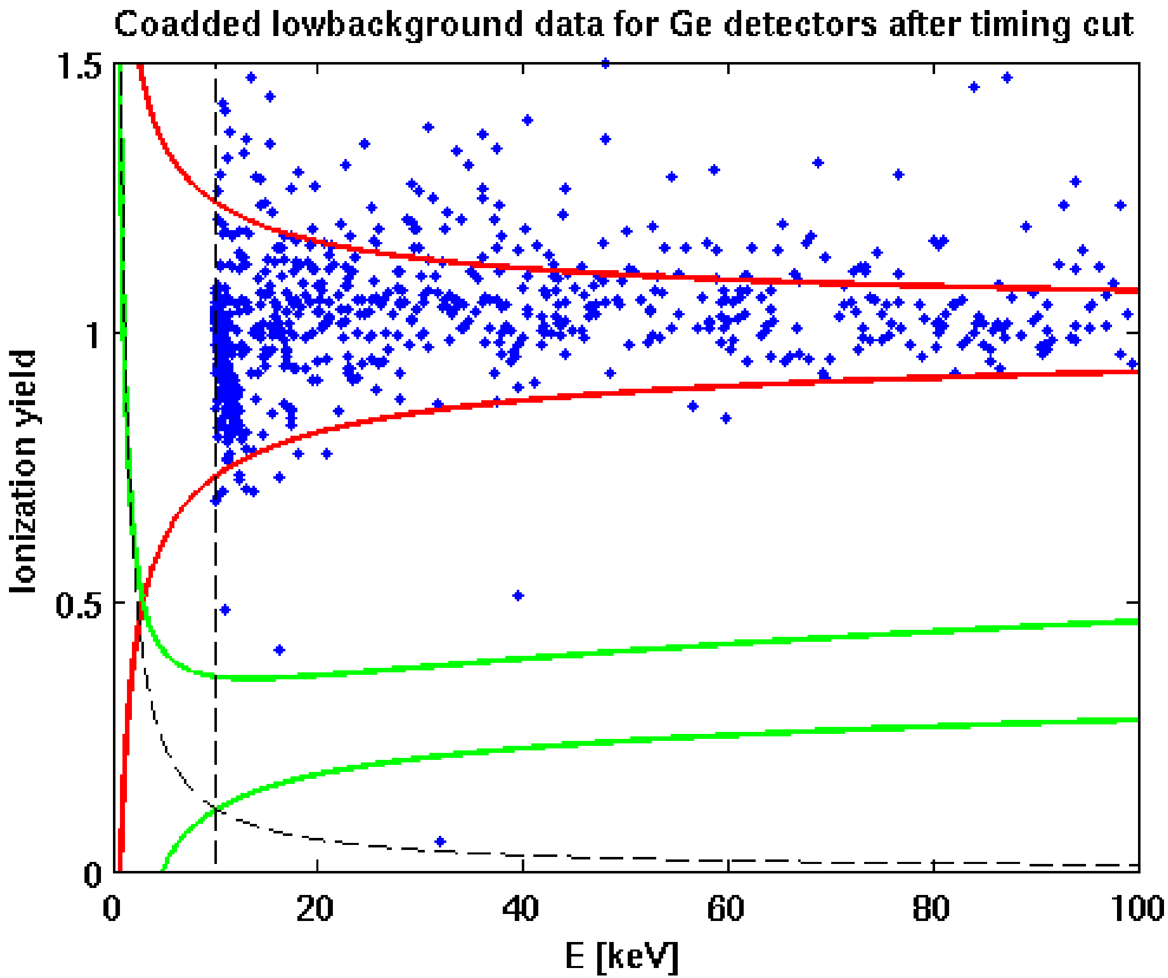
Zero events in unblinded data

Box opened Monday, February 4 for 15 Ge ZIPs.

Remaining 8 Si ZIPs and 1 Ge ZIPs still blinded for further analysis.

No events observed in the 2σ nuclear recoil band.

CDMS is operating in a quasi background free environment.

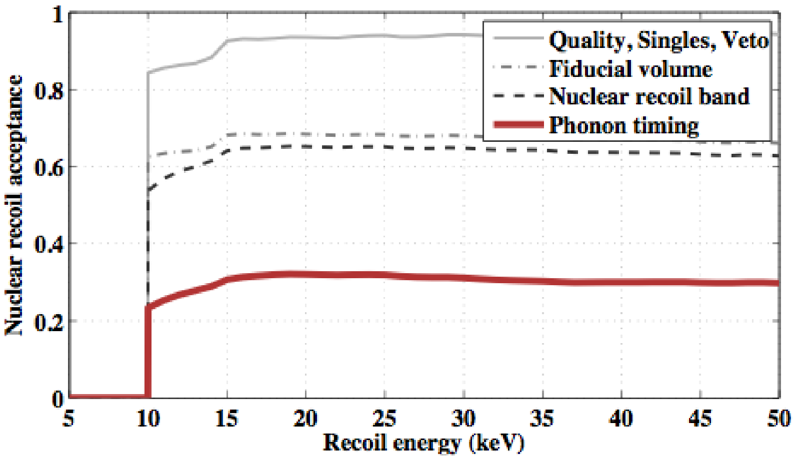


Expected background: 0.6 ± 0.5 leakage events

< 0.2 Neutrons (< 0.1 Cosmogenic + < 0.1 Fissions)

Recent results

Current Run 123/124 data :
397 kg-d Ge raw exposure (before cuts)

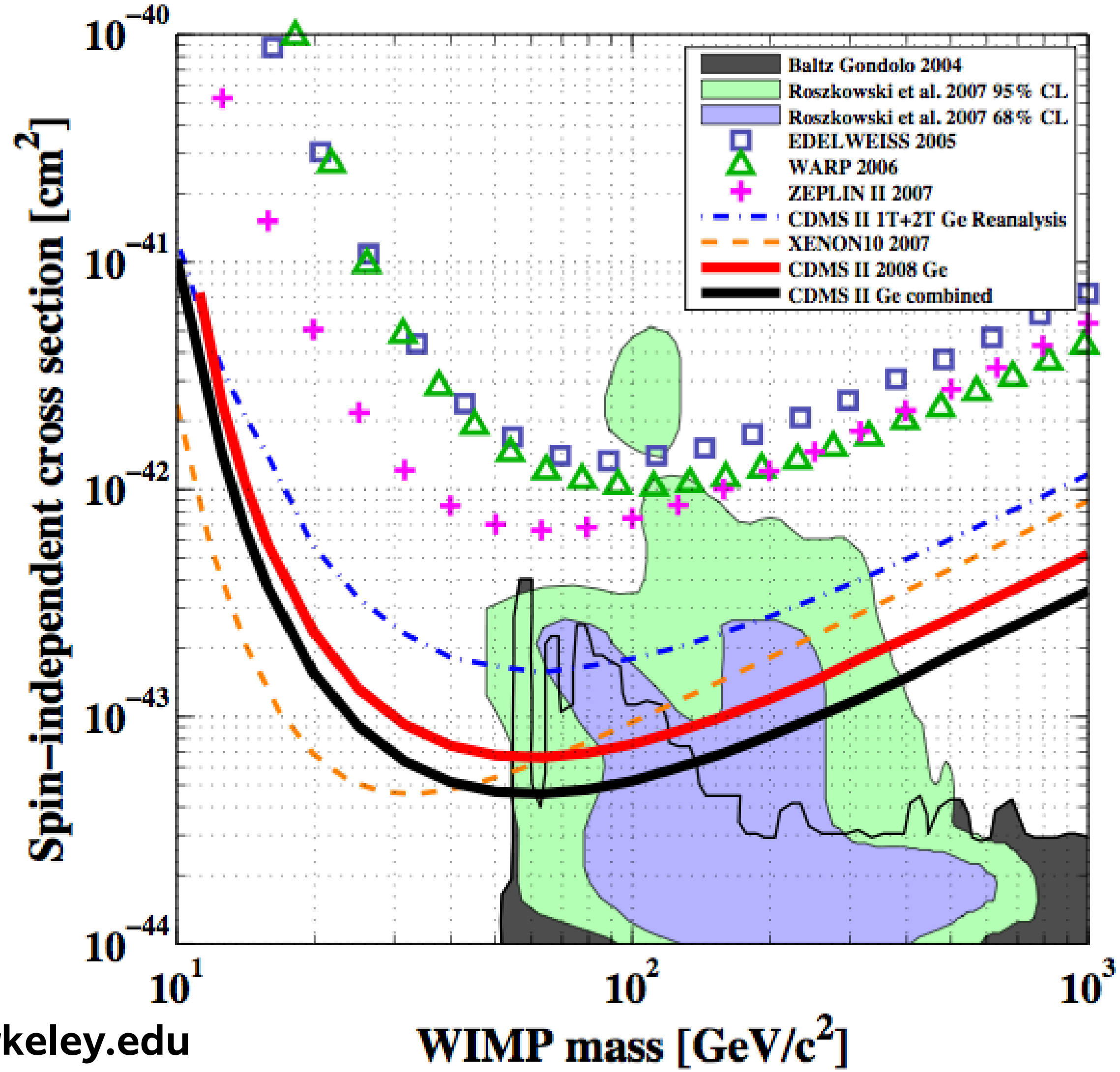


6.6 e-44 cm² @ 60 GeV

4.6 e-44 cm² @ 60 GeV
(combined with previous CDMS data)

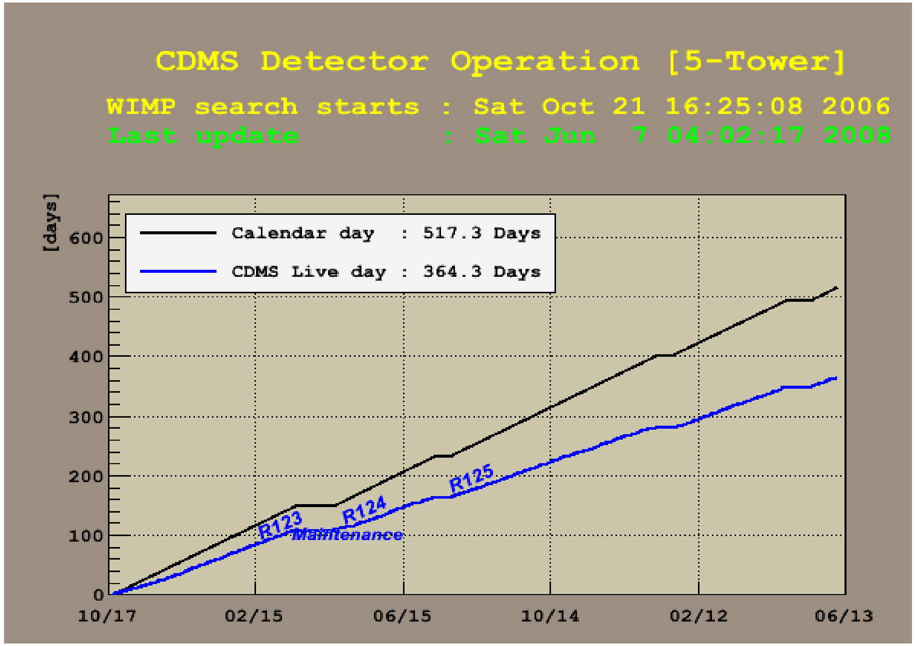
World leading exlusion limit for masses > 42 GeV

Result significantly restricts some of the favored supersymmetric models



Preprint: arXiv:0802.3530; http://cdms.berkeley.edu

Present and near future



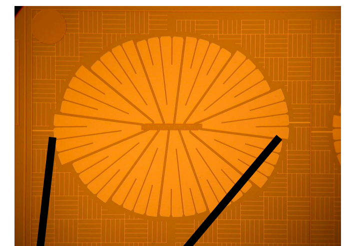
Additional data aquired :

Run 125/126 : 740 kg-d Ge raw expsoure

Run 123/124/125/126 : ~1400 kg-d Ge raw expsoure

Run 127 : ongoing

New detectors with increased mass and better surface/volume.



Improved active Al coverage → better phonon collection

ZIP used in CDMS II

x 2.54 mass

ZIP used in the first phase of SuperCDMS.

Also in development :
new sensor configurations,
double sided phonon sensors,
electric field shaping, ...

CDMS-II to SuperCDMS 25kg

CDMS combined (2005+2008) 90% CL (SI) limit:
σ = 4.6 e-44 cm² @ 60 GeV

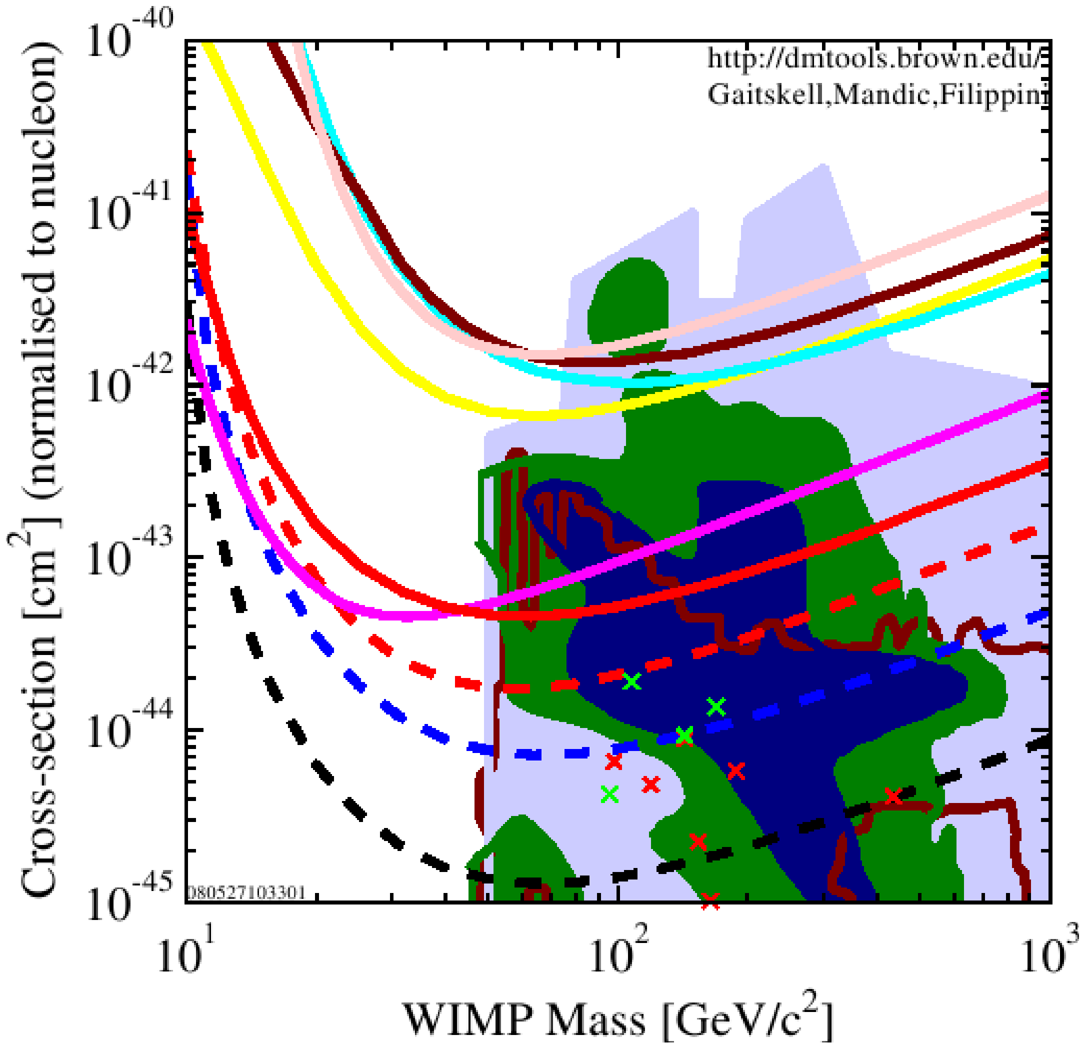
XENON10, 10 background events (2007).

CDMS II 5 Towers at Soudan projected sensitivity (2008).

CDMS II 2 SuperTowers at Soudan projected sensitivity (start 2009).

SuperCDMS 25kg at SNO-LAB projected sensitivity.

The next few years will be a very exciting time for direct detection Dark Matter searches



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