Search for Dark Matter with the CDMS experiment

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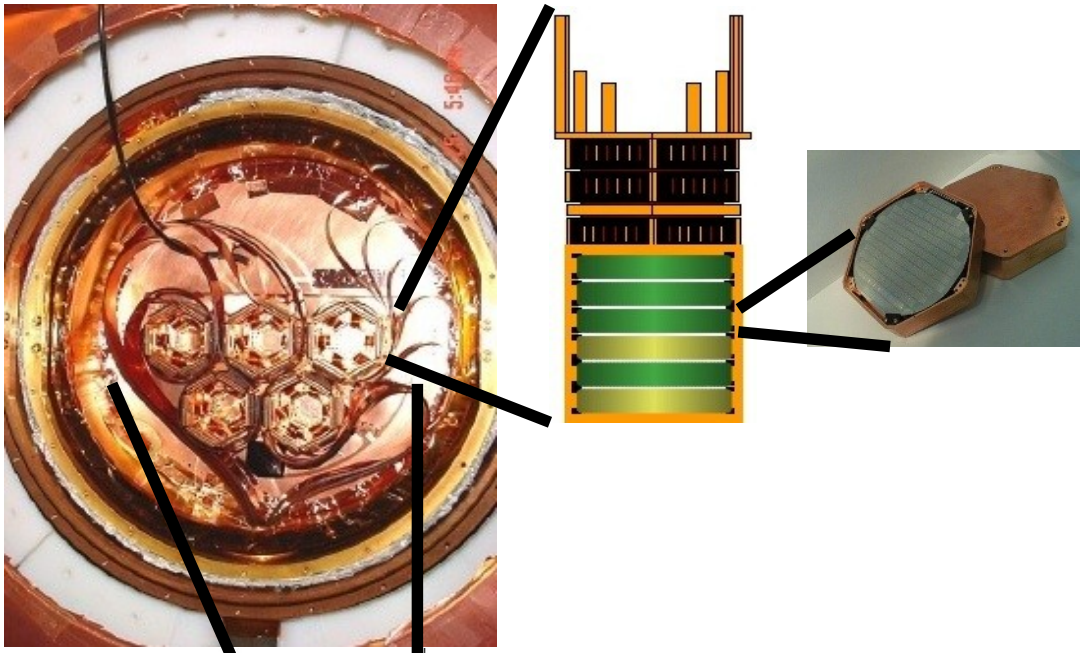
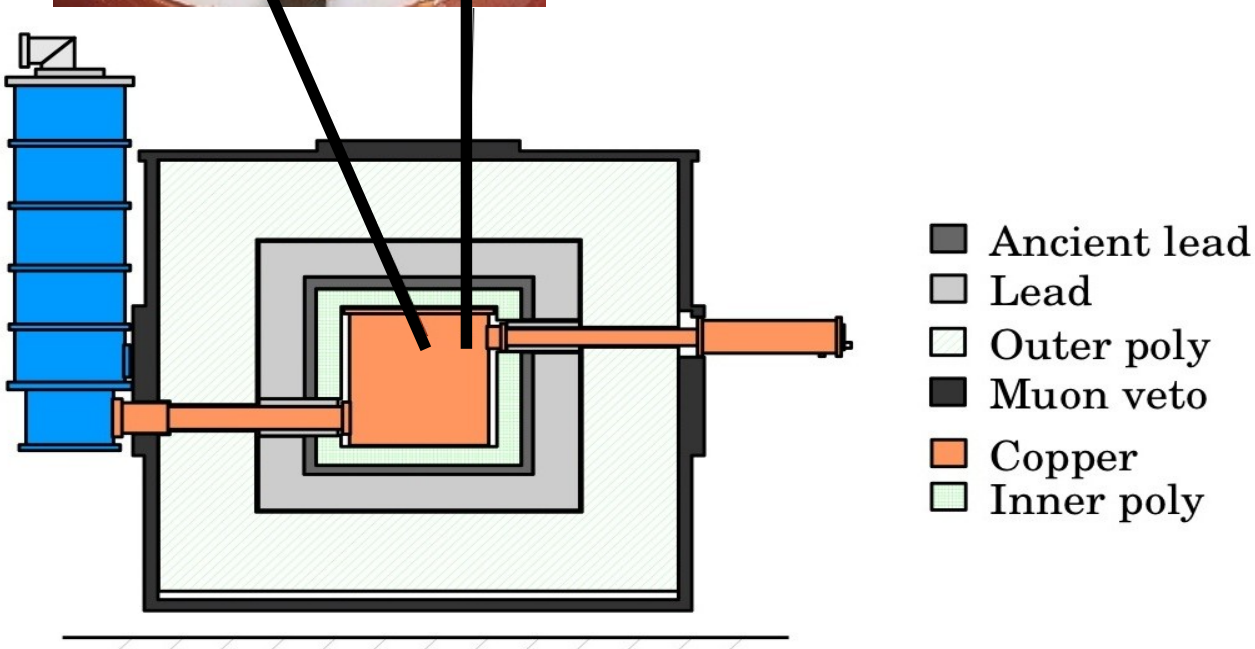
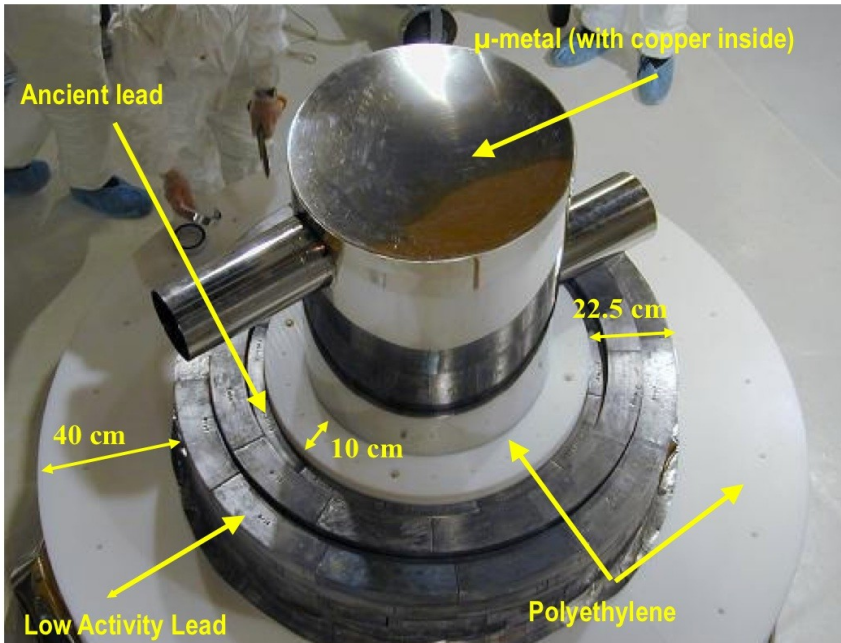
The CDMS Setup & Shielding



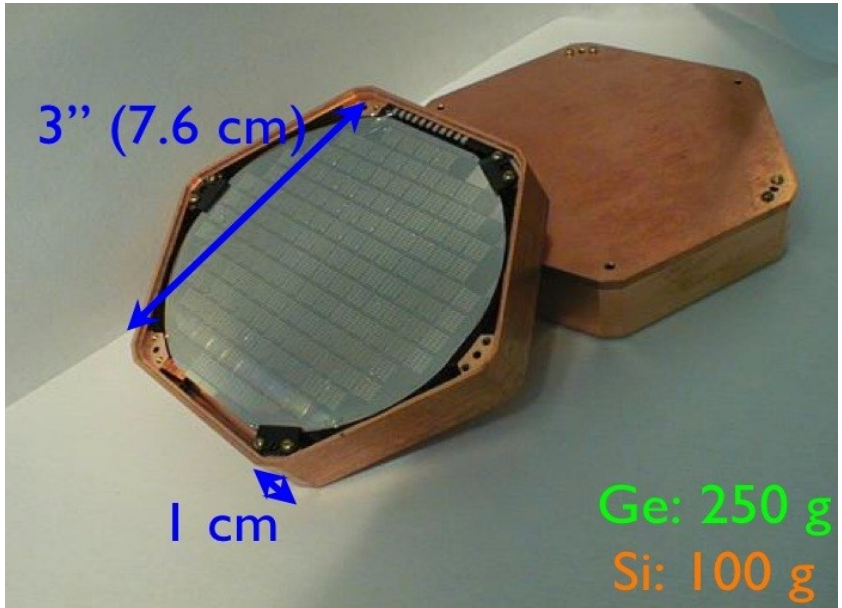


- 5 towers with 6 detectors each
- active veto against high energetic muons
- passive shielding:
  - lead against gammas from radioactive impurities
  - polyethylene to moderate neutrons from fission decays and from (α,n) interactions resulting from U/Th decays

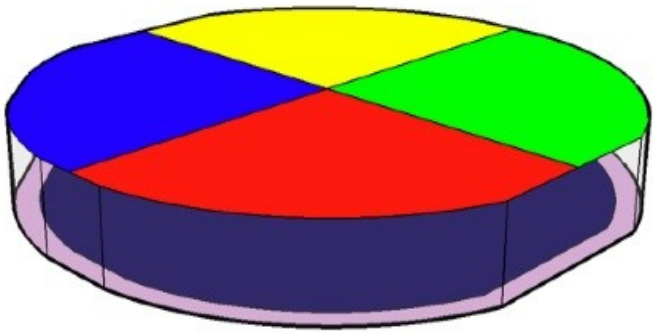


The CDMS ZIP Detectors

- 19 Ge and 11 Si semiconductor detectors
- operated at cryogenic temperatures (~40 mK)
- 2 signals from interaction (ionization and phonon) ⟶ event by event discrimination between electron recoils and nuclear recoils
- z-sensitive readout
- xy-position imaging



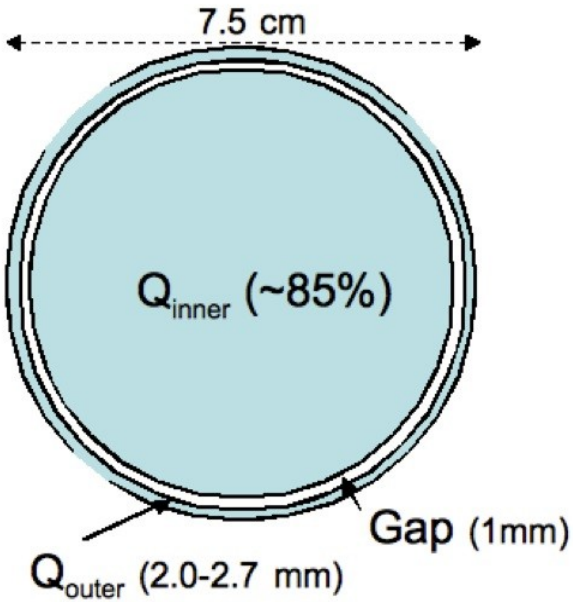
Phonon readout:
4 quadrants of
phonon sensors

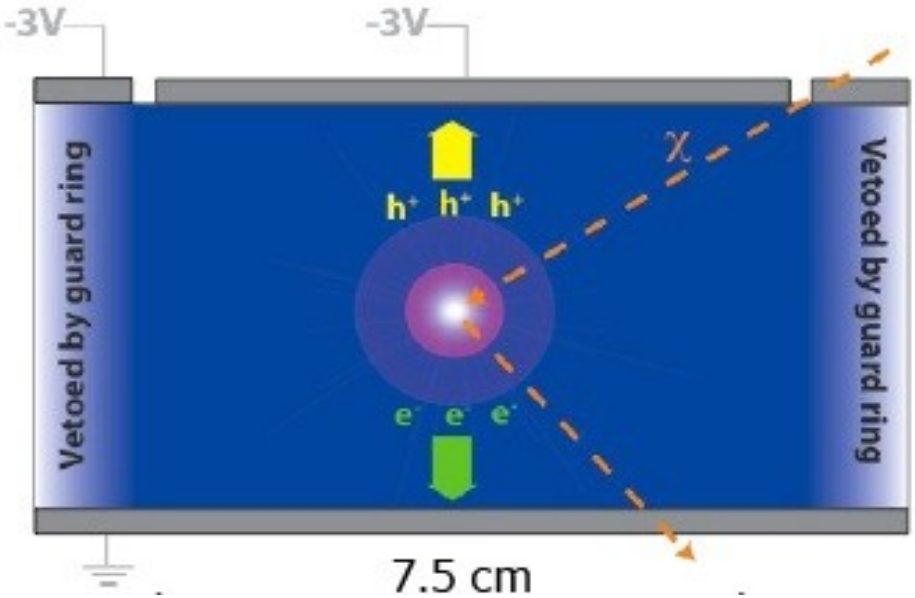


Charge readout:
2 concentric
electrodes

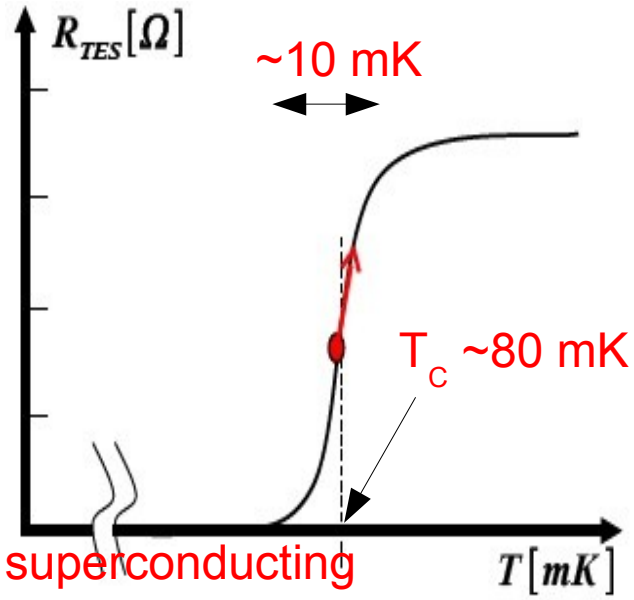
The Ionization Readout

- interaction creates electron hole pairs
  - seperate using applied electric field
    - collect charges on electrodes on surface
- drift field of 3 V/cm (4V/cm) on Ge (Si) detectors
- interaction at crystal edges can have incomplete charge collection
  - use outer electrode as guard ring
    - omit qouter events
- low-energy resolution: 3-4%





The Phonon Readout

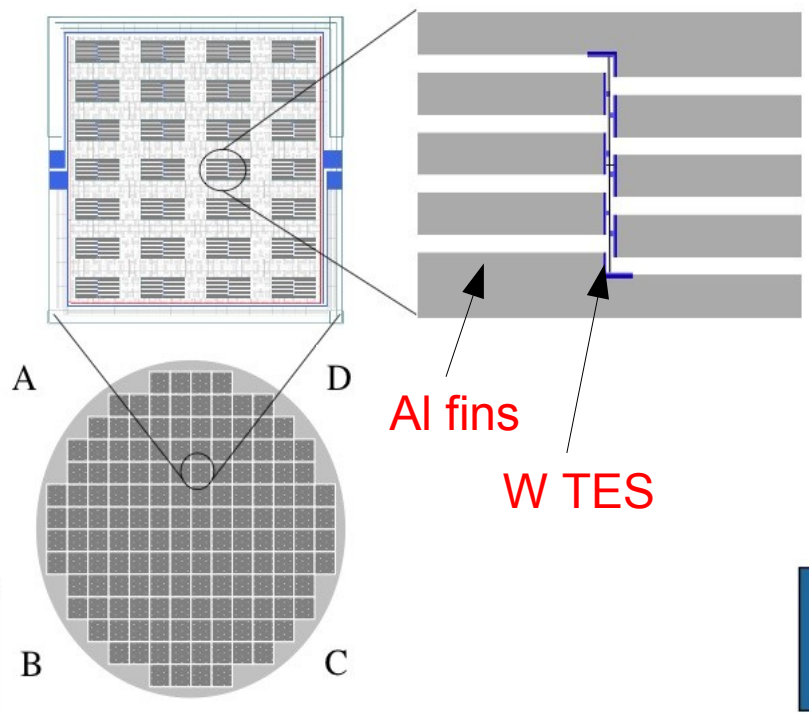


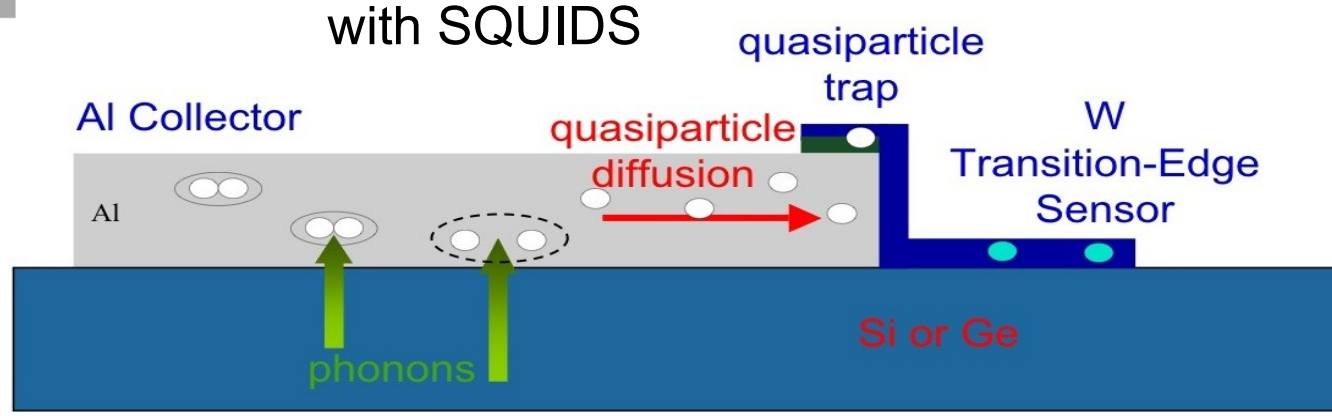
- segmented phonon readout (4 quadrants)
- each quadrant consists of 1036 tungsten TES (Transition Edge Sensors)
- fast response time ~5 μs
- low energy resolution: ~5%
- tungsten strips set just below the edge of superconductivity using bias voltage

→ energy deposition raises temperature

→ conductivity changes to normal

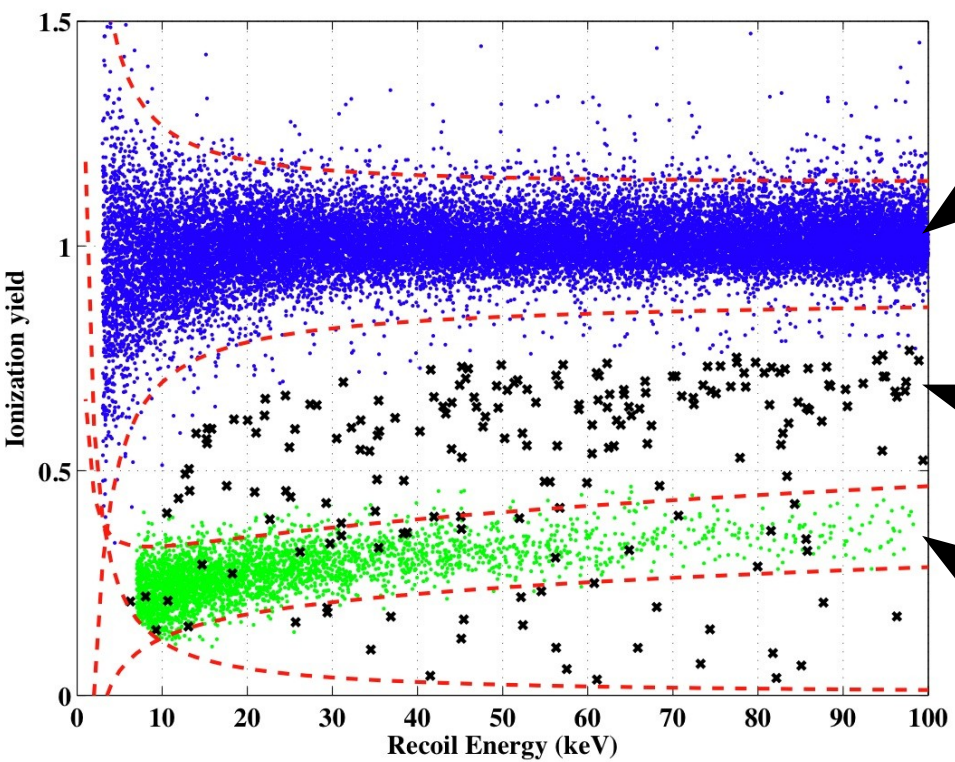
→ dramatic lowering of current read out with SQUIDS





Primary background rejection

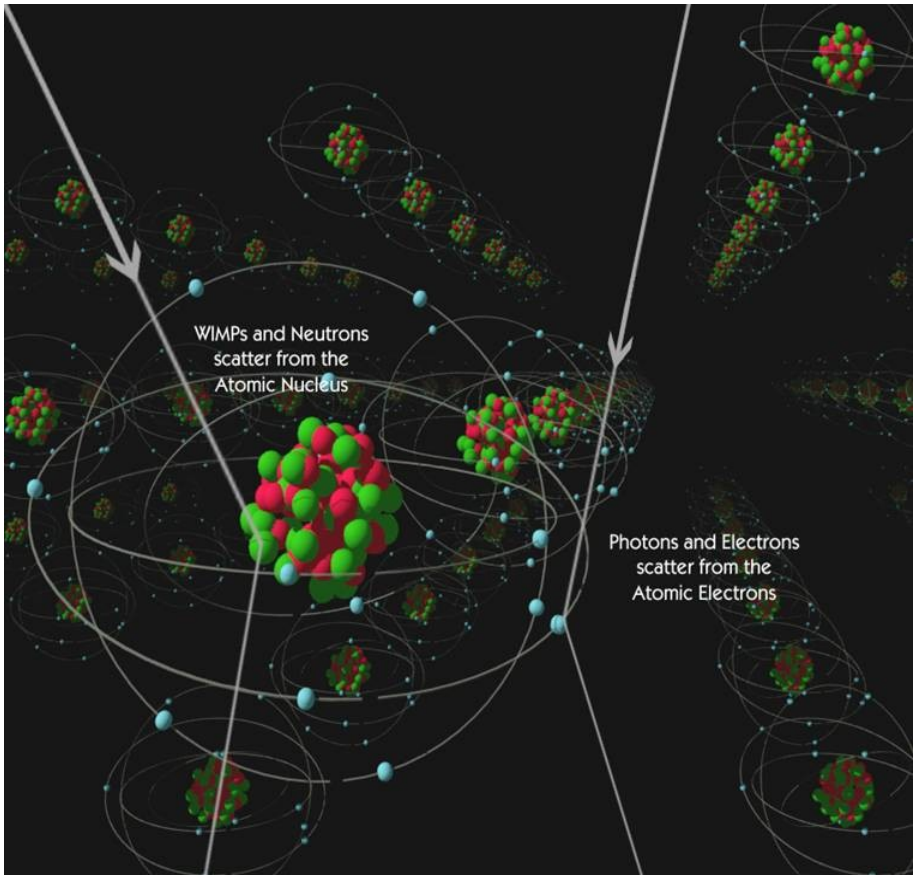
- most backgrounds (e, γ) produce electron recoils
- neutrons and WIMPs produce nuclear recoils which have a suppressed ionization signal
- define ionization yield as $y = \frac{E_{charge}}{E_{recoil}}$



electron recoils

surface events

nuclear recoils

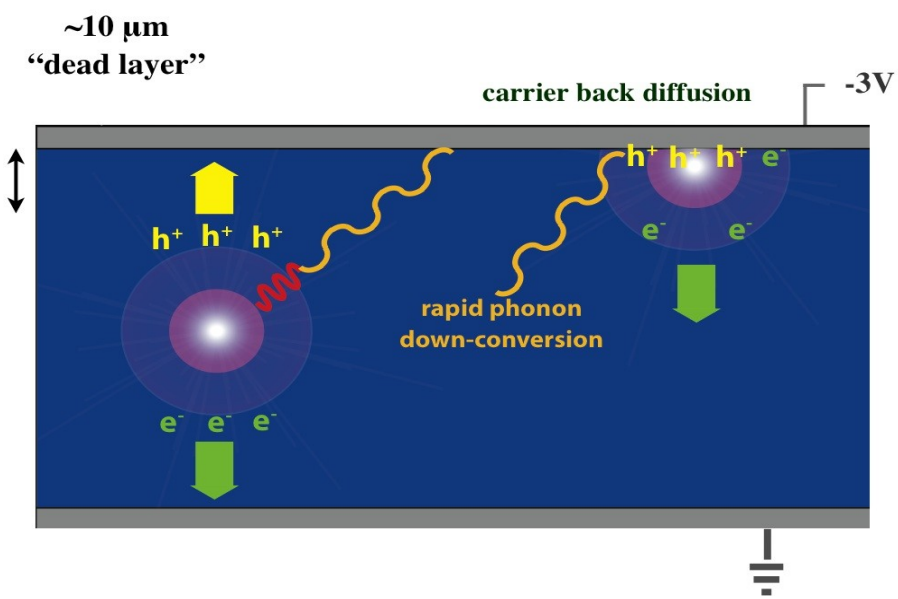


- better than 1:10000 rejection of electron recoils based on ionization yield alone
- dominant remaining background: Low yield surface events

Surface events and contamination

- reduced charge yield due to back-diffusion of charge carriers at the detector surface

- surface event background can be fully accounted for by two sources:
  1. low-energy electrons induced by the ambient photon flux from radioactive impurities in the experimental setup
  2. ^{210}Pb contamination of the detector surfaces

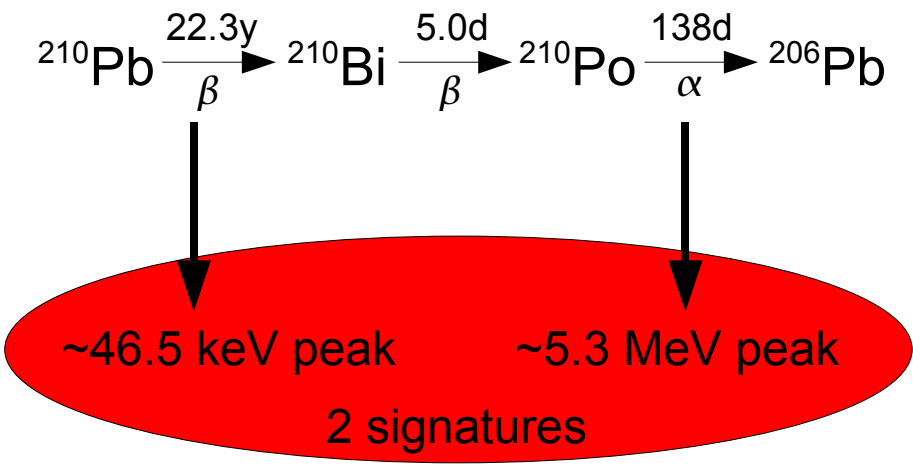


^{210}Pb contamination?

- detetctors are exposed to environmental Radon during fabrication, testing, ...

- ^{210}Pb is a decay product of ^{222}Rn and can be deposited on the detector surfaces

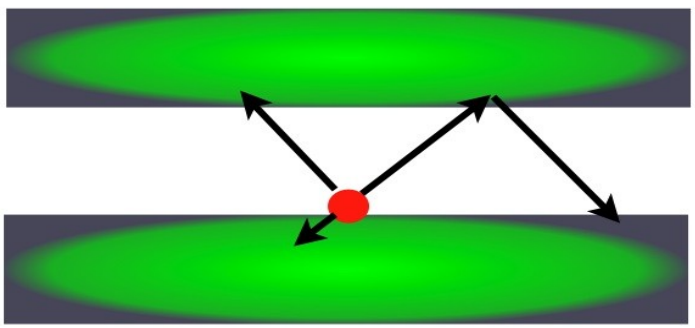
- decay chain:

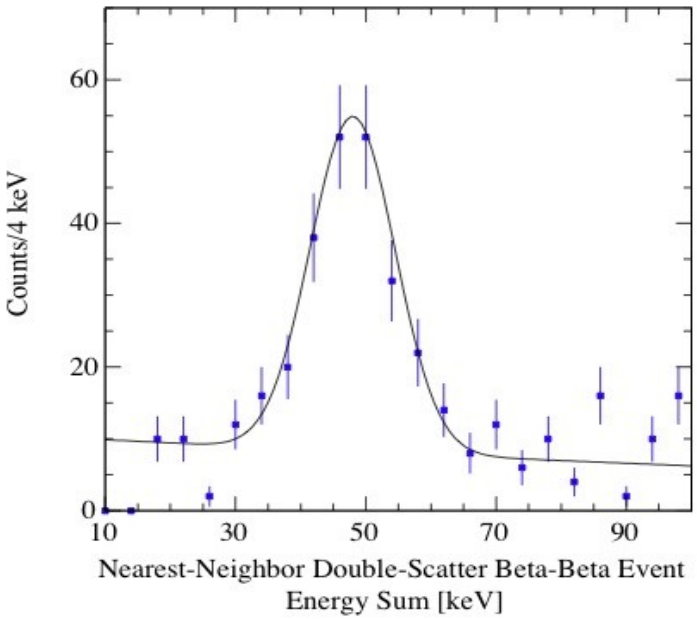


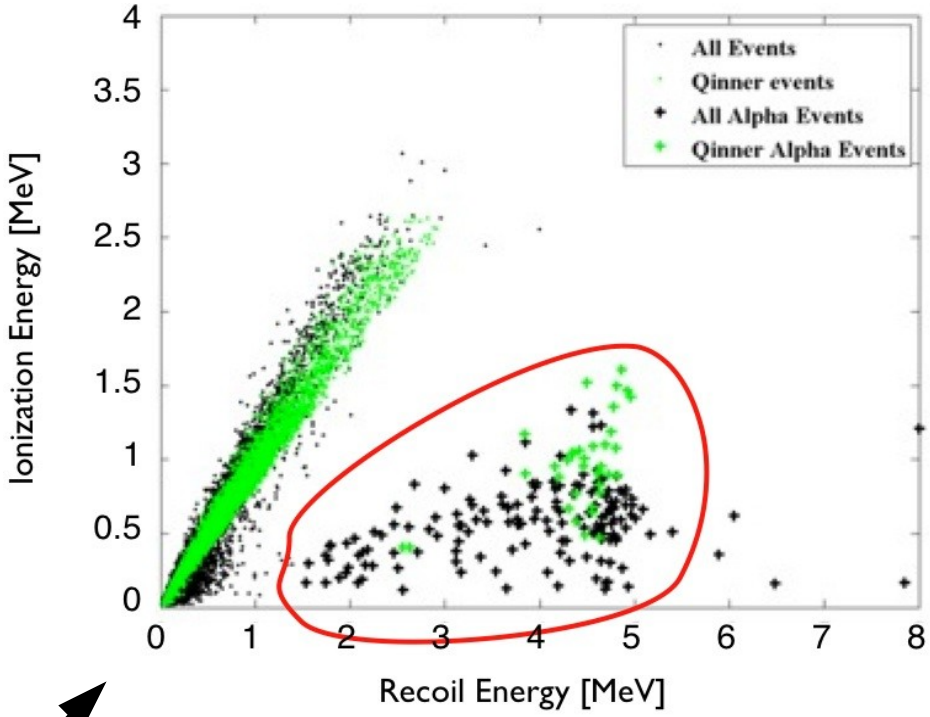
- significant reduction of this contribution for new towers (T3-T5)

Evidence for ^{210}Pb contamination

Sum over adjacent detectors (NND) to search for 46.5 keV peak!

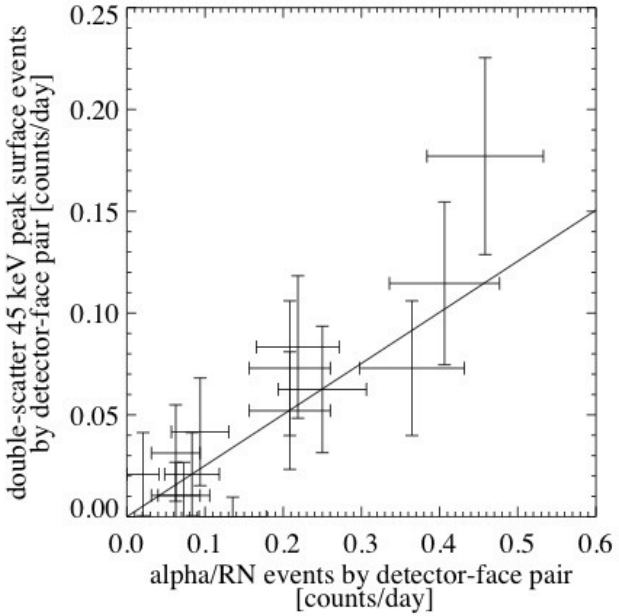






Check for low yield α's!

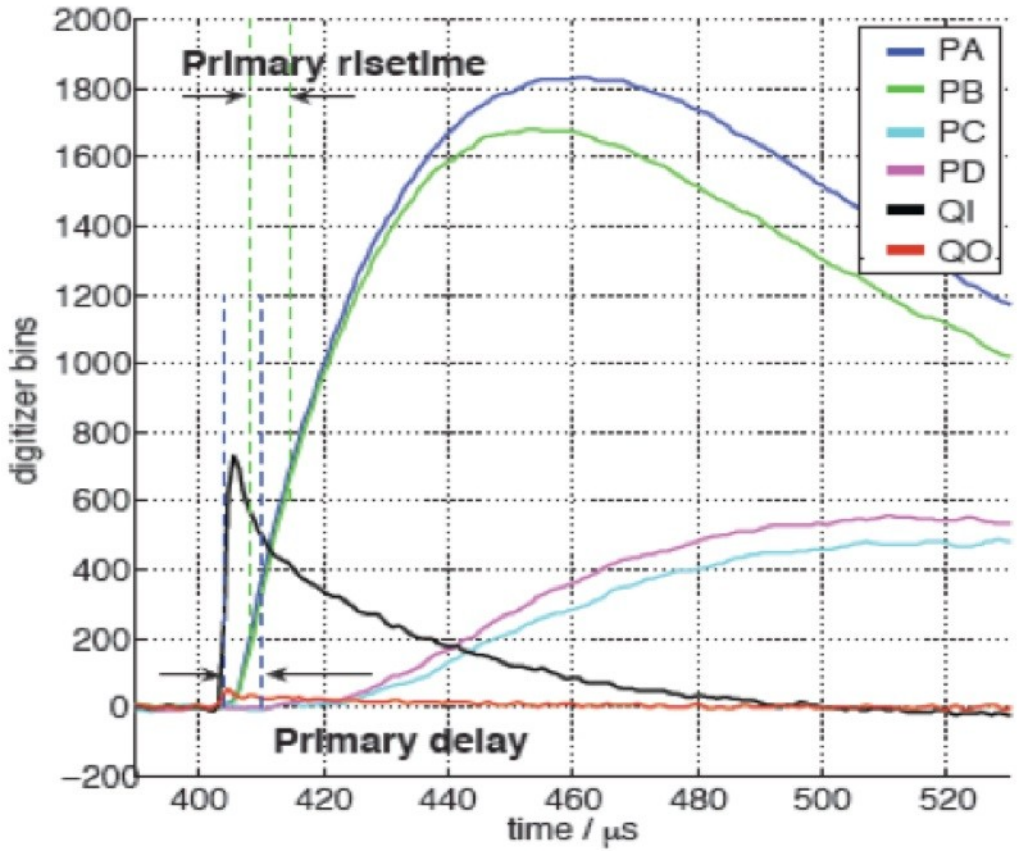
We see a strong correlation between both signatures.

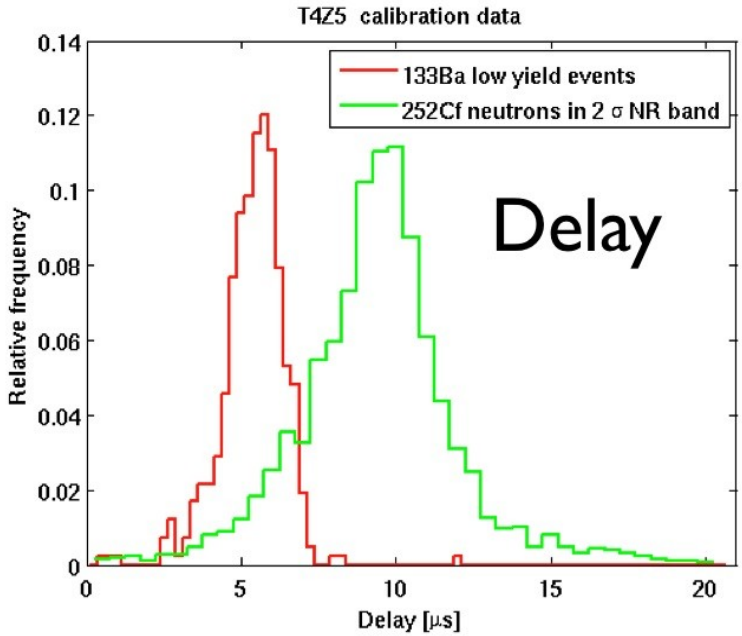


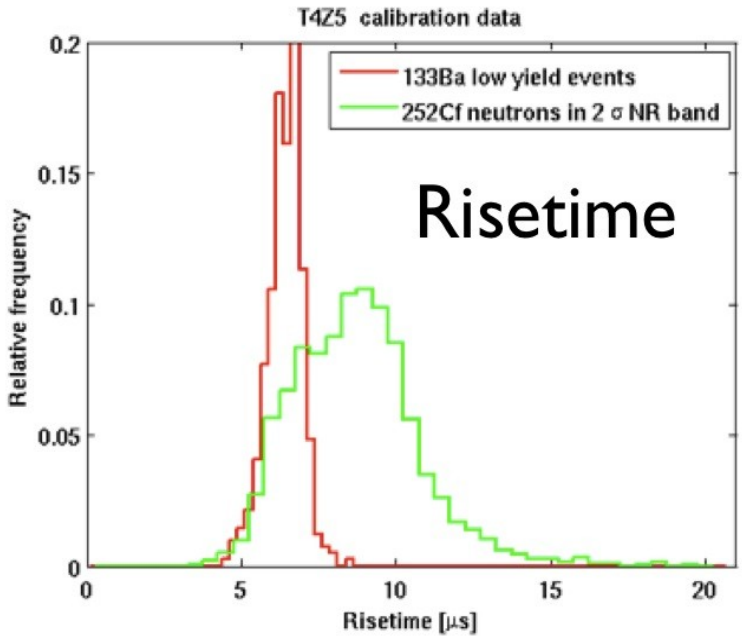
Phonon Timing

Surface events are faster in timing than bulk nuclear recoils.

Use timing as discriminator to get rid of surface events.





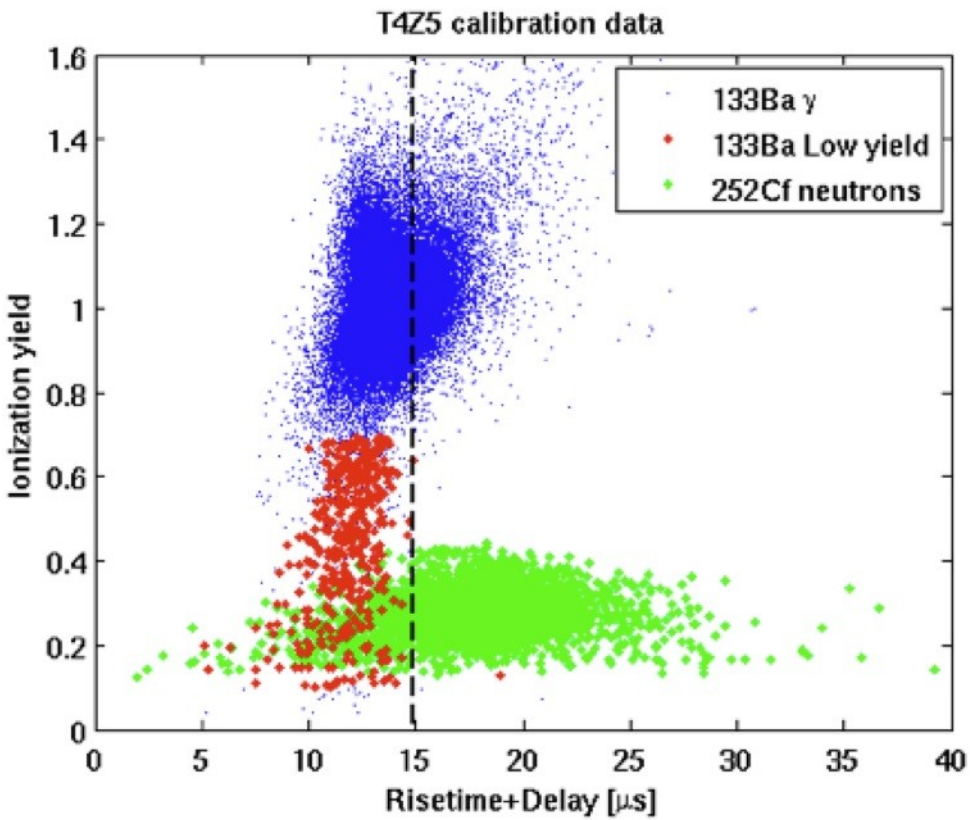


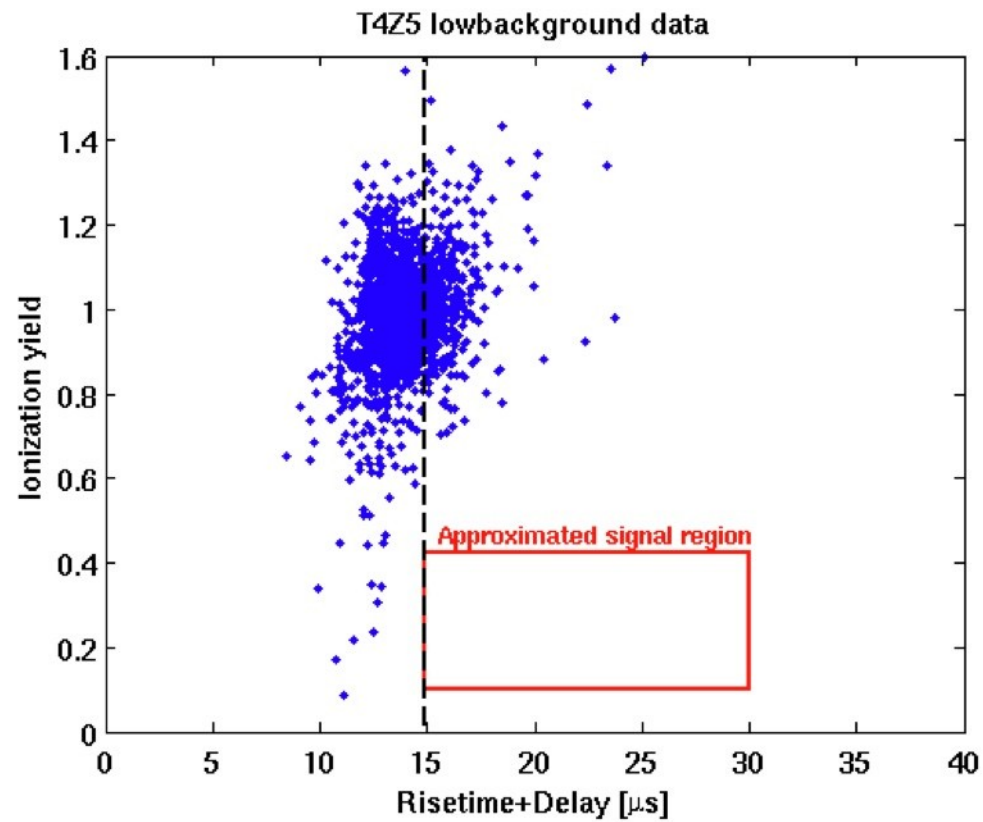
Surface event rejection

- use risetime+delaytime to define timing cut on calibration data
- allow ~0.5 events total laekage within WIMP search data

→

- apply cut to lowbackground data
- surface event rejection ~200:1

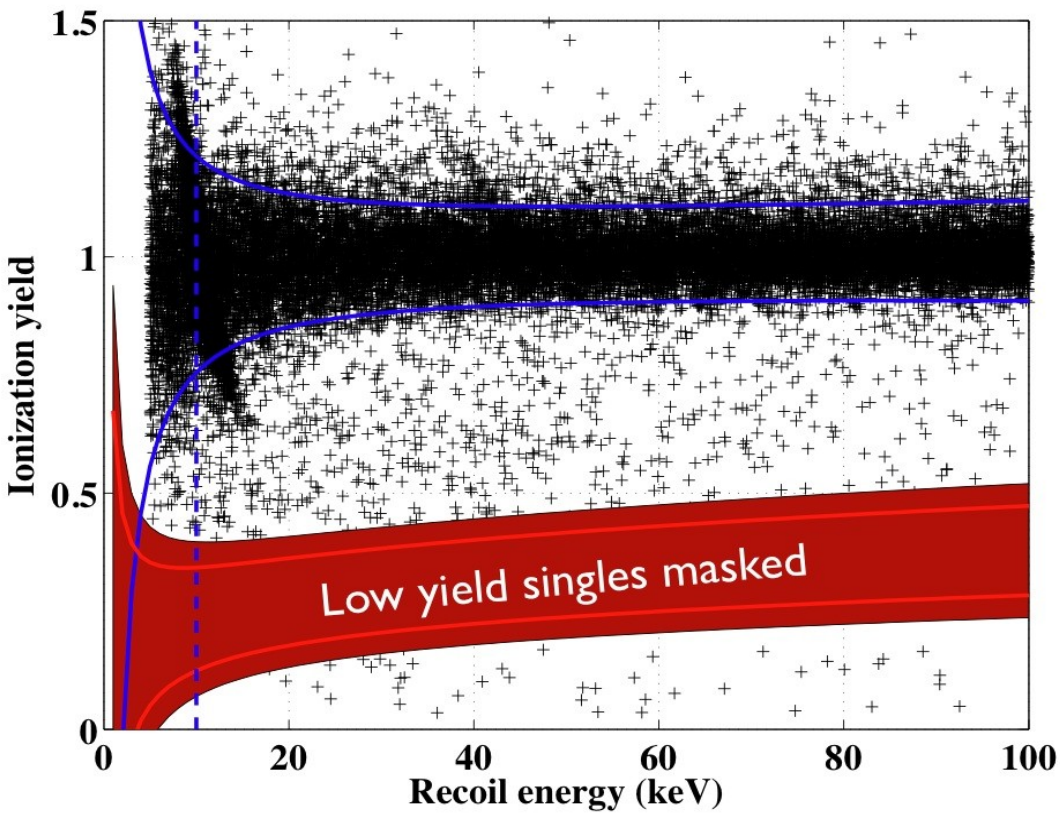


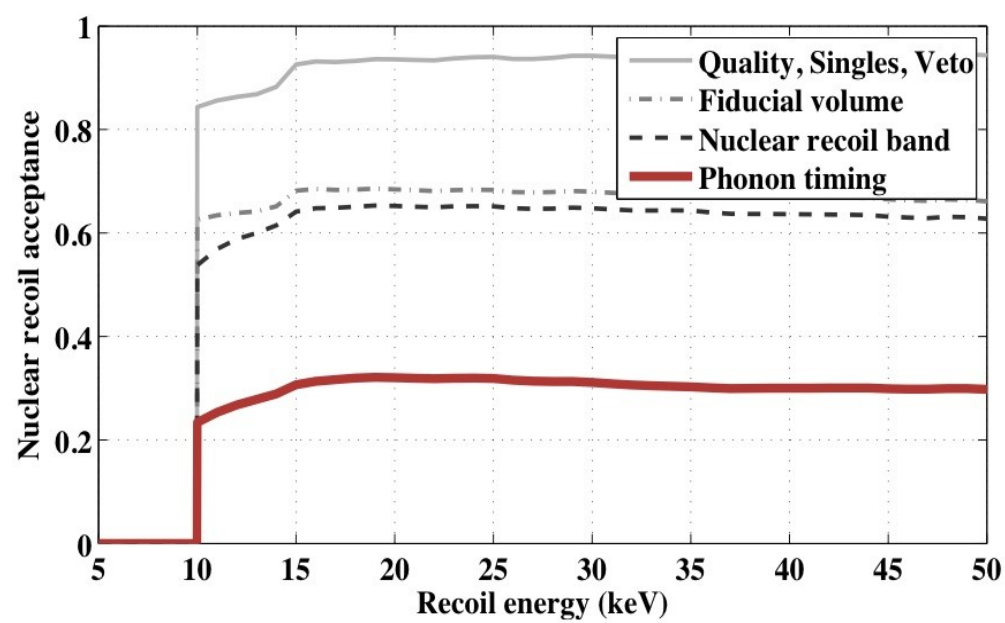


Analysis Technique

Blind Analysis
Set all cuts and calculate efficiencies **before** looking at the signal region of the WIMP-search data.

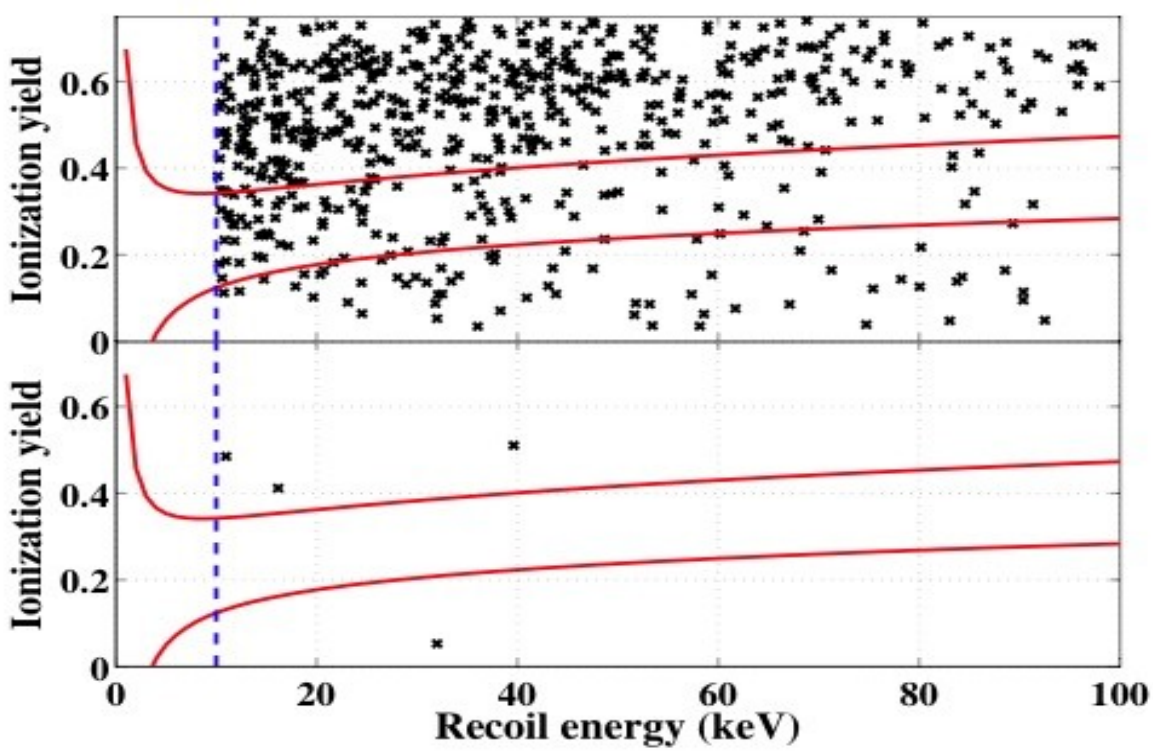
Cut criteria for WIMP candidates:
- energy range: 10-100 keV
- data quality
- veto-anticoincidence
- single-scatters
- inside fiducial volume (qinner cut)
- inside 2σ nuclear recoil band
- no surface event (phonon timing)





Analysis Summary

- 398 kg-days raw exposure
- no events observed in signal region after applying timing cut



Background summary
- expected number of surface leakage events:

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

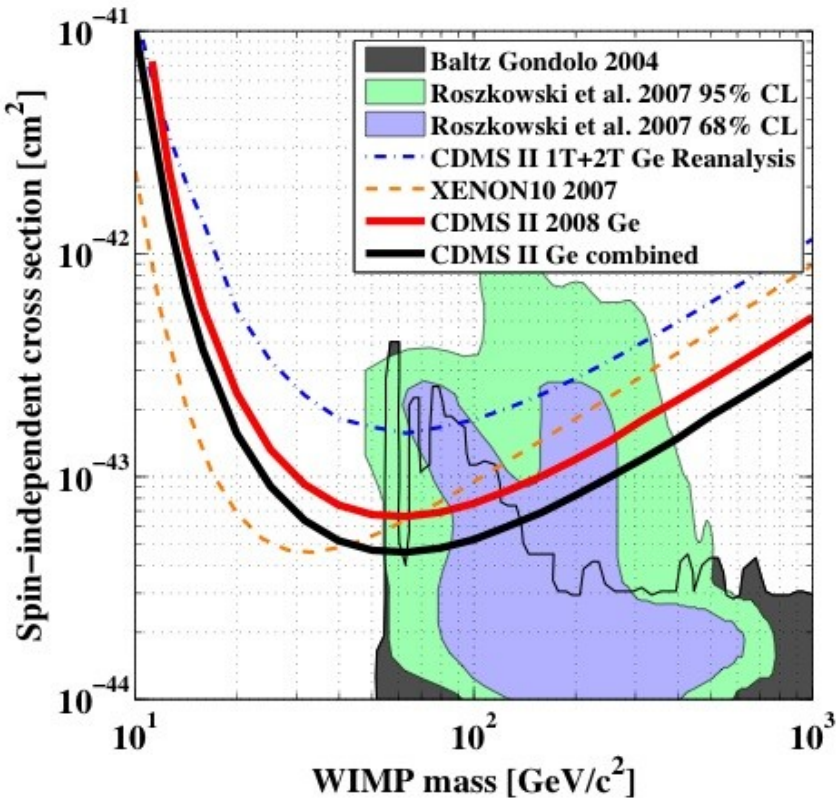
- estimated neutron background:
  (α,n): < 0.03
  fission: < 0.1
  cosmogenic: < 0.1

Before applying timing cut!

After applying timing cut!

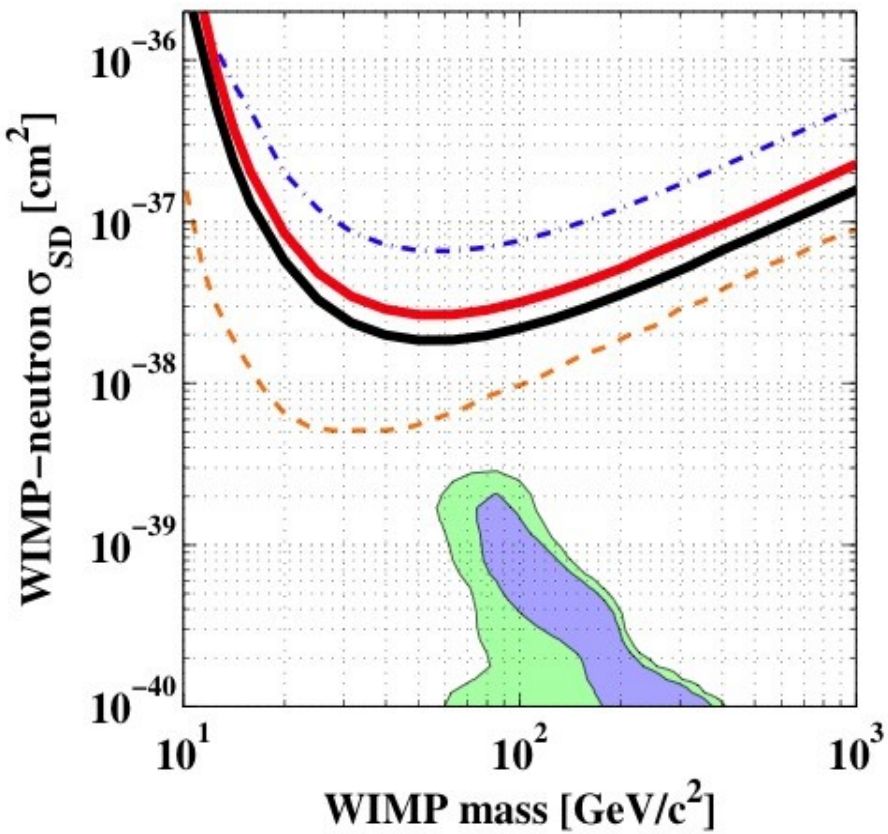
Results

Spin-independent cross section limits



4.6×10^{-44} cm^2 @ 60 GeV
(combined with previous CDMS data)

Spin-dependent cross section limits



1.8×10^{-38} cm^2 @ 60 GeV
(combined with previous CDMS data)

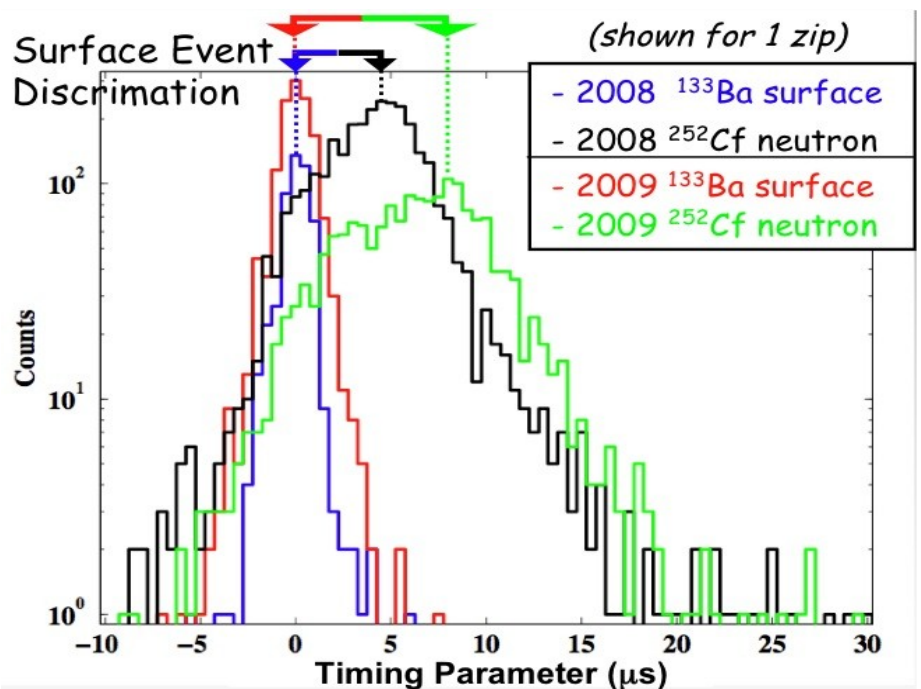
World leading 90% C.L. upper limit on scalar interaction cross sections for WIMP masses above 44 GeV!

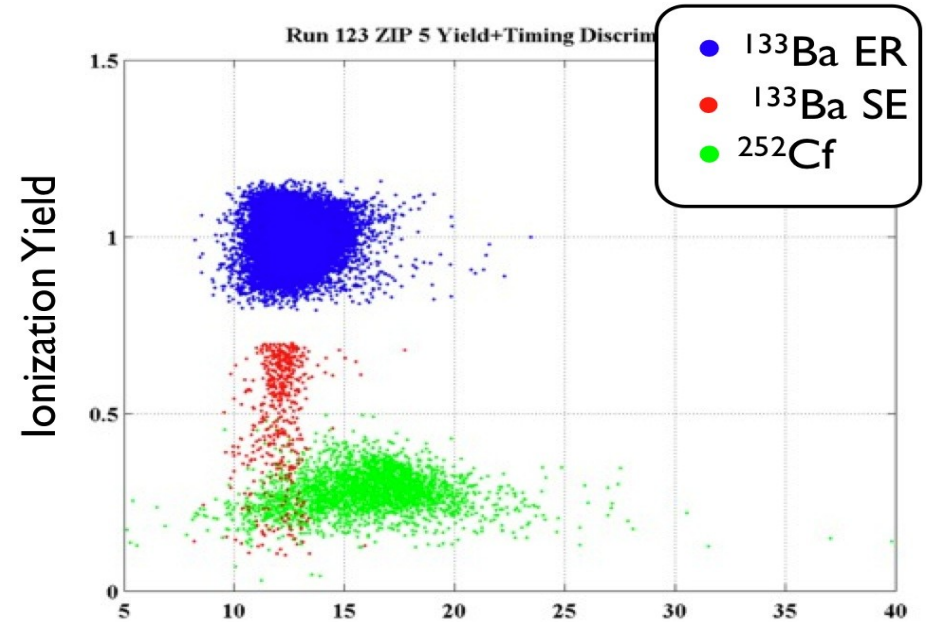
Ongoing analysis...

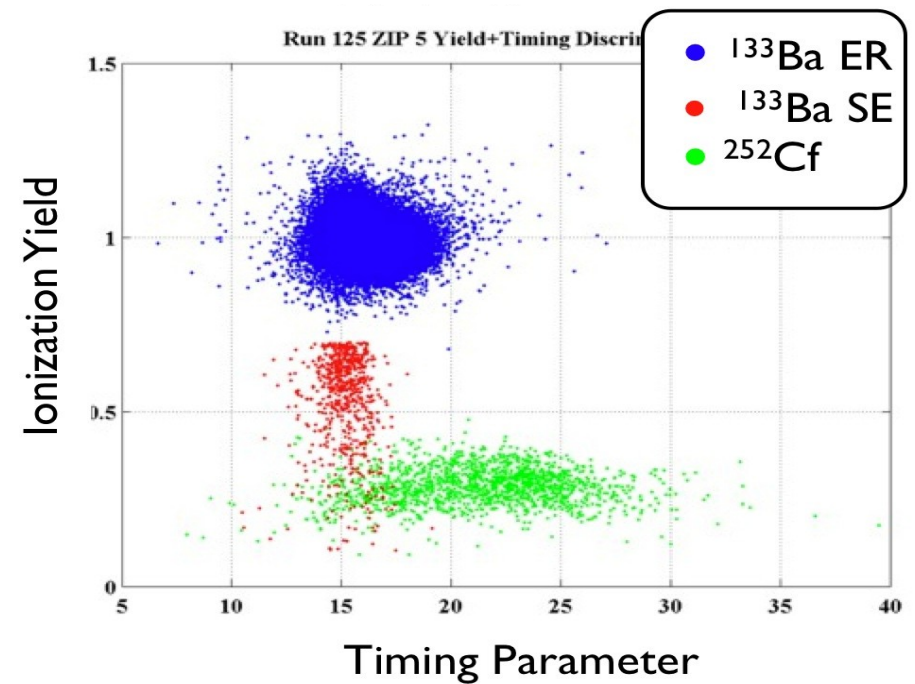
- exposure of ~700 kg-days after basic quality cuts in analysis pipeline

- timing of new data looks promising in obtaining higher detection efficiency

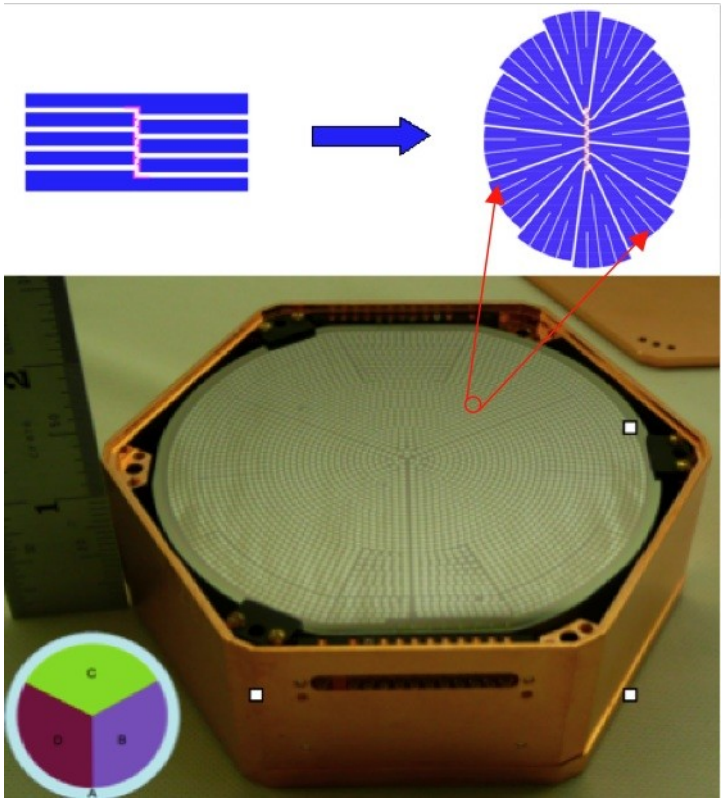
- new results expected in ~1 month



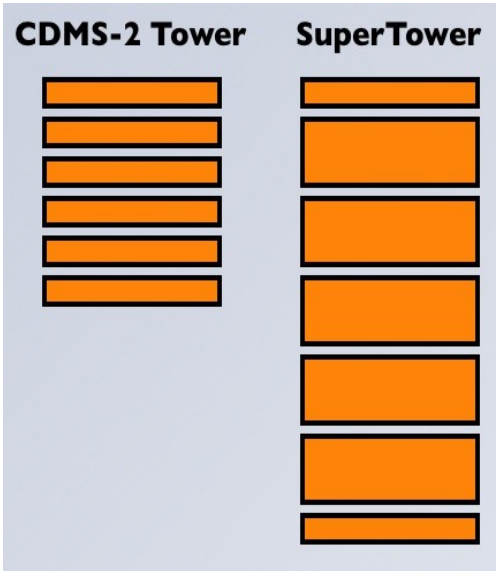


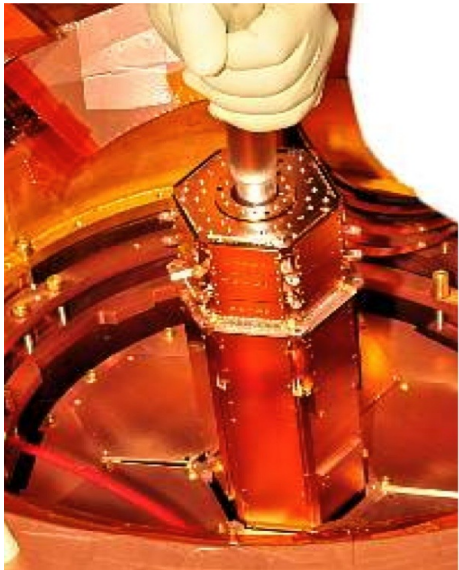


SuperCDMS



- 2.5 times more massive Ge detectors (1-inch thick)
- reduced surface/volume ratio to decrease background
- “endcap“ Ge veto detectors in each tower
- improved Al fin layout for better phonon collection
- modified phonon sensor layout with outter phonon guard ring similar to outter charge electrode
- first SuperTower already installed in Soudan





Summary

- Currently CDMS sets the world leading excluxion limit on scalar WIMP-nucleon cross sections above 44 GeV.

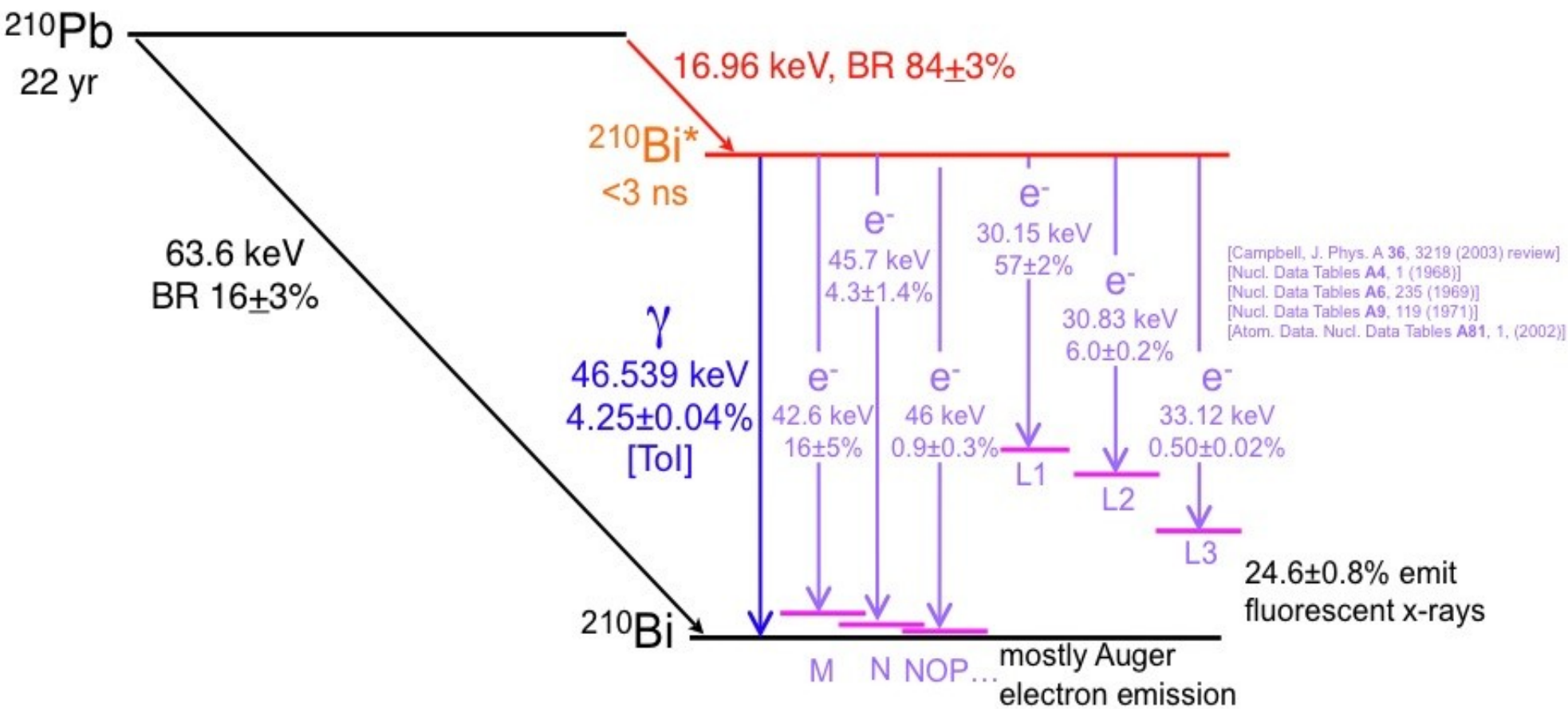
- Last CDMS data had zero background.

- New data-taking was finished on March 18th this year. New results are expected in about a month.

- First SuperCDMS Tower has been built and installed in the Soudan mine. Initial tests are ongoing.

Backup slides

^{210}PB decay scheme



Signature of ^{210}Pb decay: ~46.5 keV peak of NND events