Results from CDMS

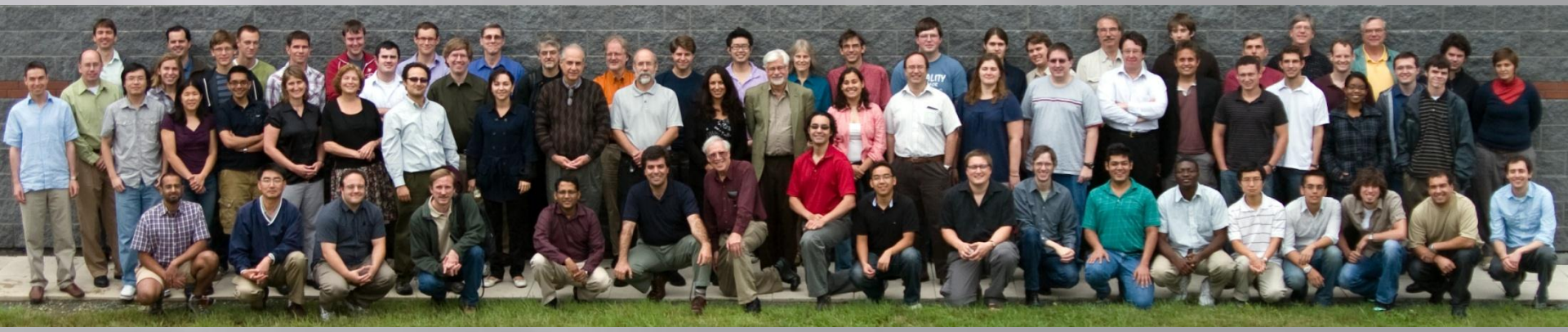
PPC 2012

Joel Sander

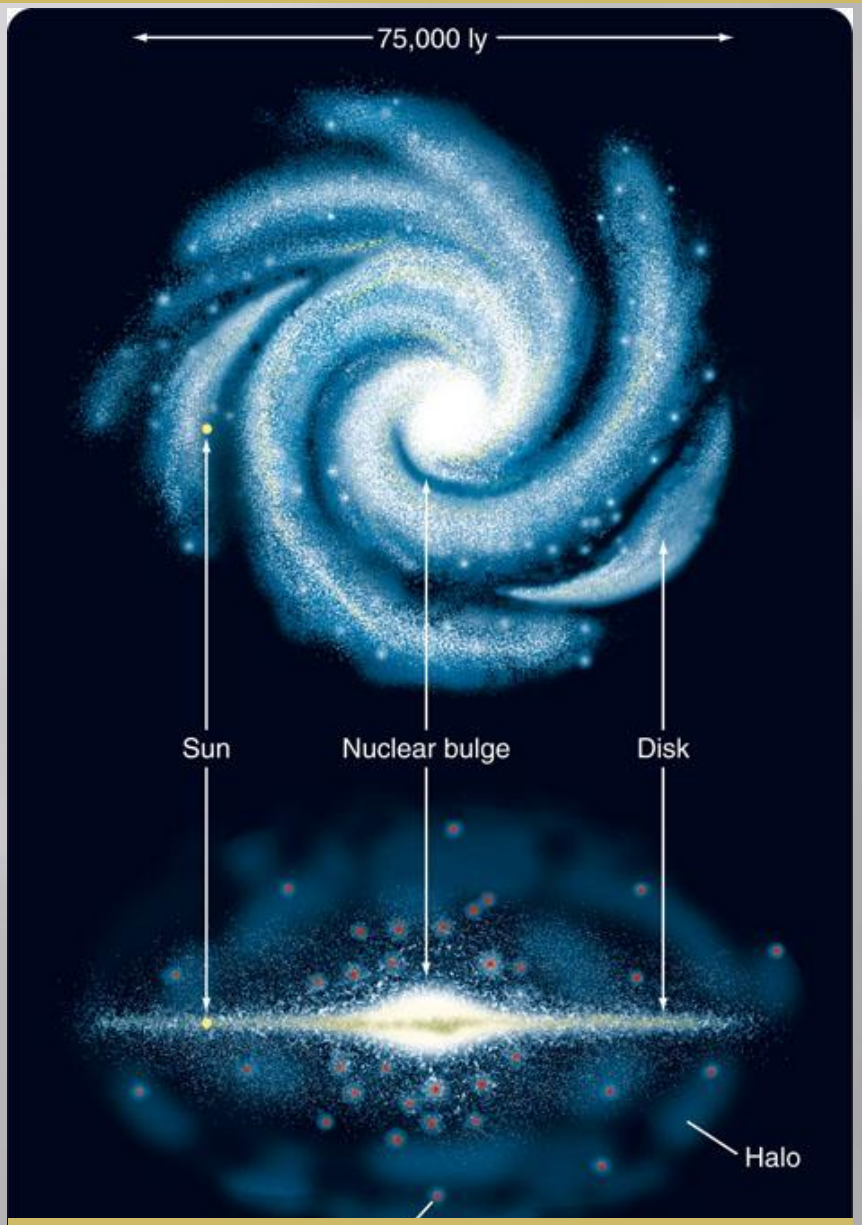
Outline

- WIMP Detection
- The CDMS Experimental Setup
- Recent results from a low energy WIMP-search analysis
- Preliminary results and projections from a search for fractionally charged particles

The CDMS Collaboration



The Challenge in WIMP Detection



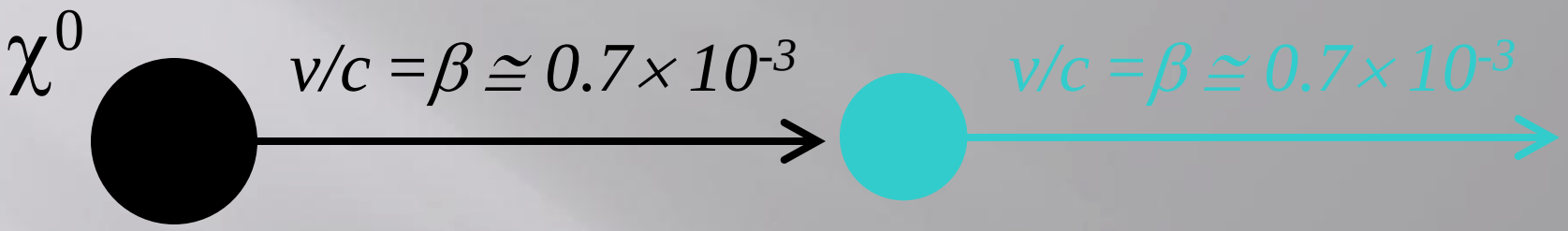
Out there and may interact on Earth!

Goal: Detect WIMP recoil on terrestrial detector, as we move through halo

$\rho \sim 1/3$ GeV/cm^3

NUTRITIONAL WARNING: may contain few 100-GeV WIMPs. 10 billion WIMPs may pass through each sec

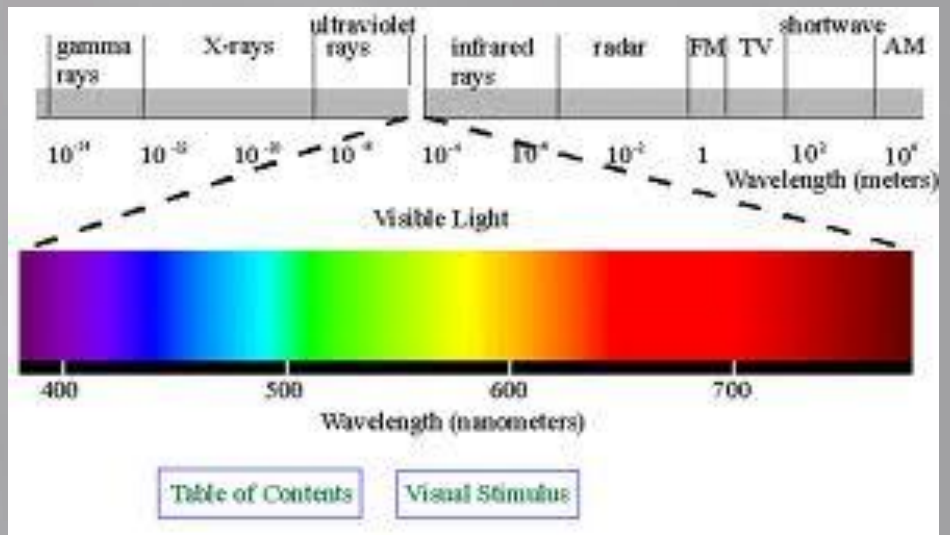
Modern Chadwick Experiment



Billiard ball scattering by slow galactic WIMPs on nuclei inside our detector

$E_R \approx \mu^2 v^2/m_{Ge} \approx 10$ keV
$\approx$ x-ray energy! Easy!

Best Sensitivity when WIMP and Target Nucleus Mass are similar



The Challenge in WIMP Detection

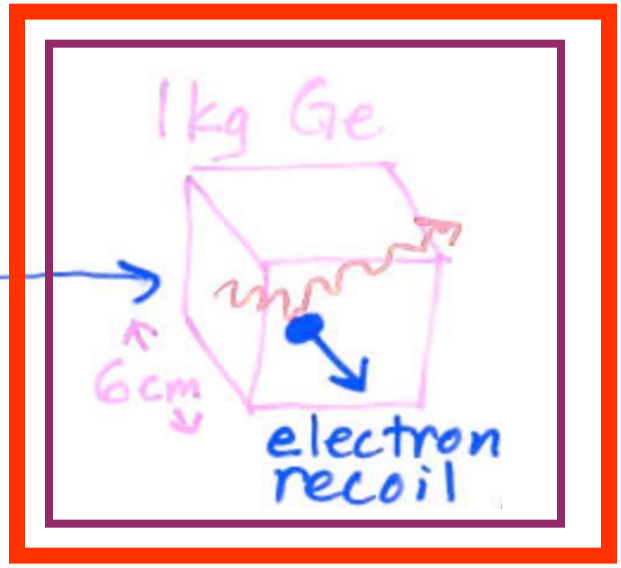
Expected WIMP interaction rate < 0.01 event/1kg-day

^{40}K: 7x10^{4} γ/day

(E ≃ 1.5 MeV)

Shield it!

1m

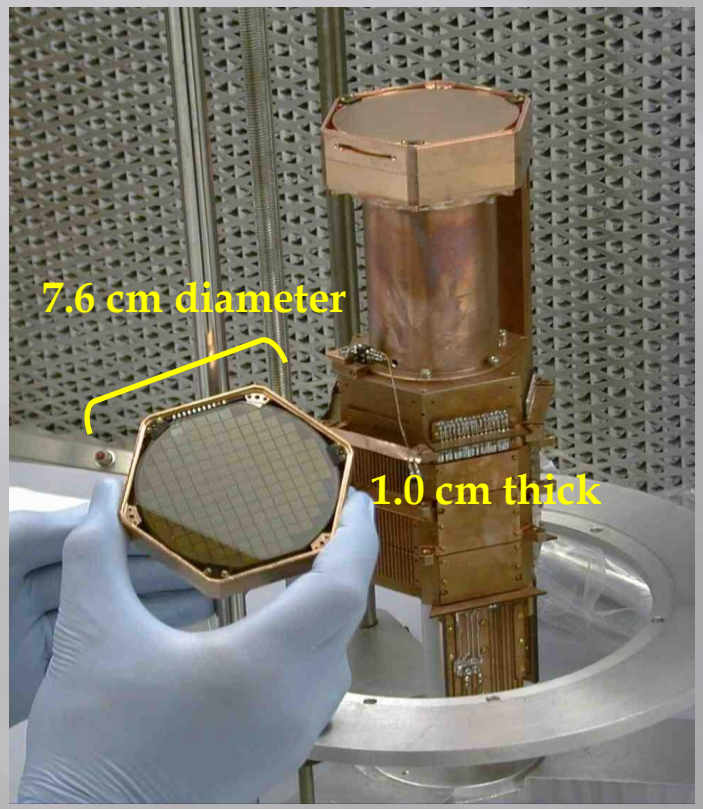


Rate about 20 / (kg-day) !

Strategies: shield Cosmogenic and Radioactive backgrounds, and reject remaining background through detector technology

CDMS (ZIP) Detectors

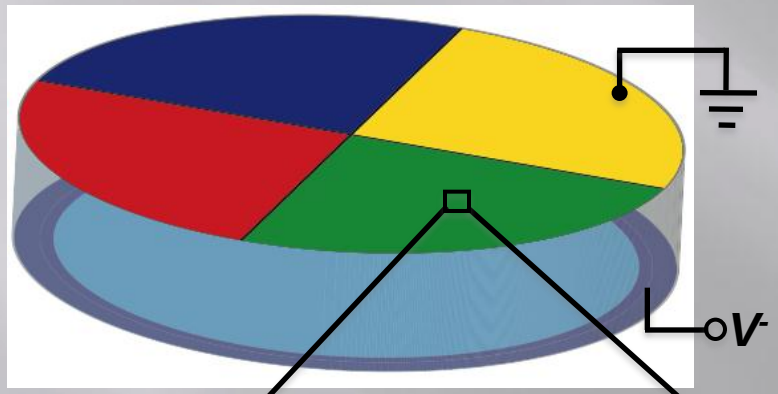
- 30 Ge & Si Crystals
- Arranged in verticals stacks of 6 called “towers”



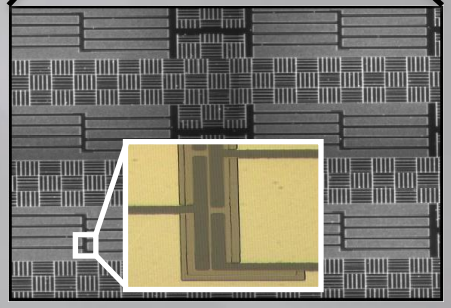
CDMS (ZIP) Detectors

- 30 Ge & Si Crystals
- Detector dimensions 7.6cm diameter, 1cm height
- Each has 4 phonon sensors; inner and outer ionization electrodes

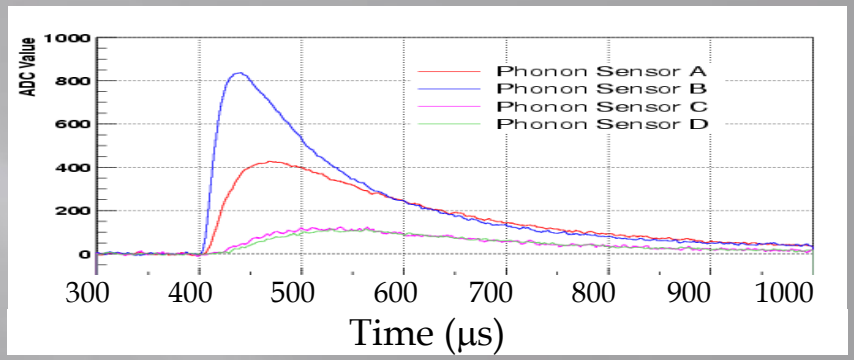
Phonons



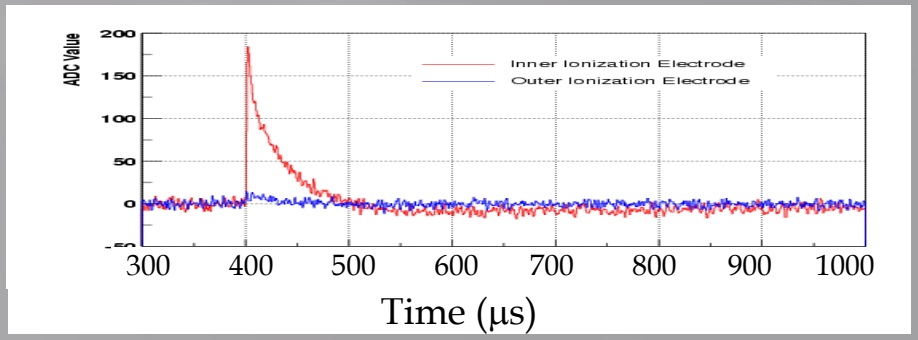
Ionization



Phonon Pulses



Ionization Pulses



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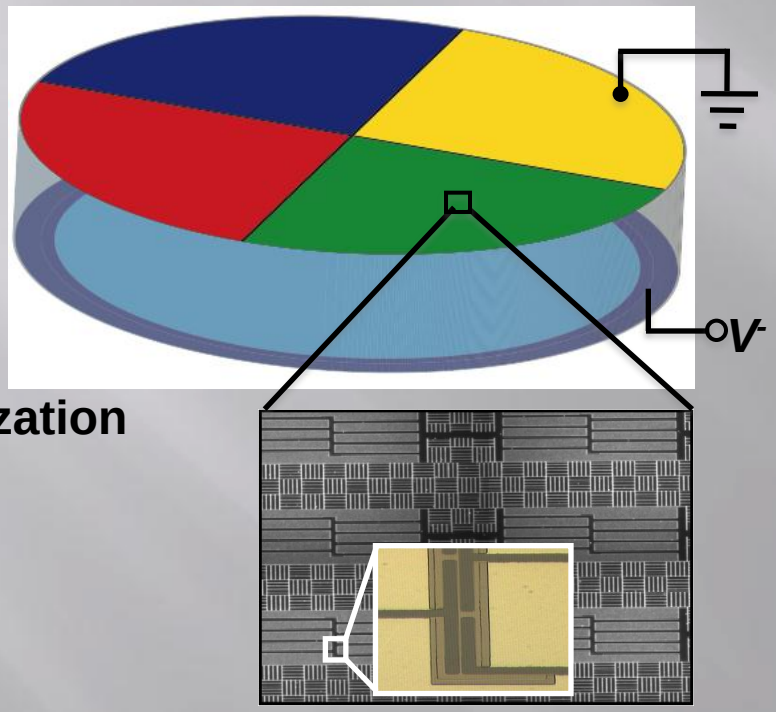
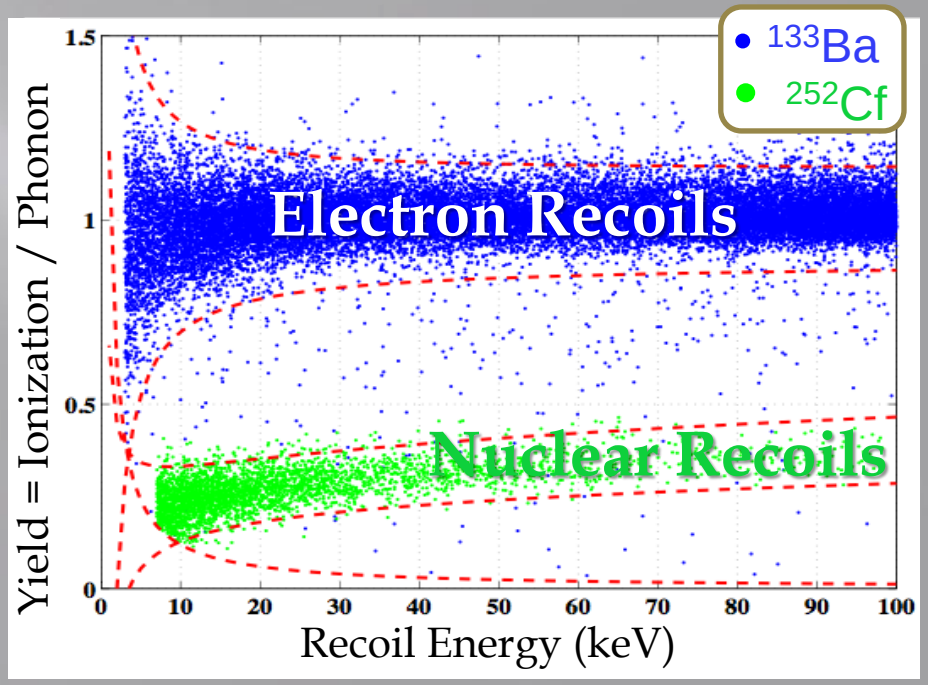




- The name of the game is background reduction and **rejection** (detectors).

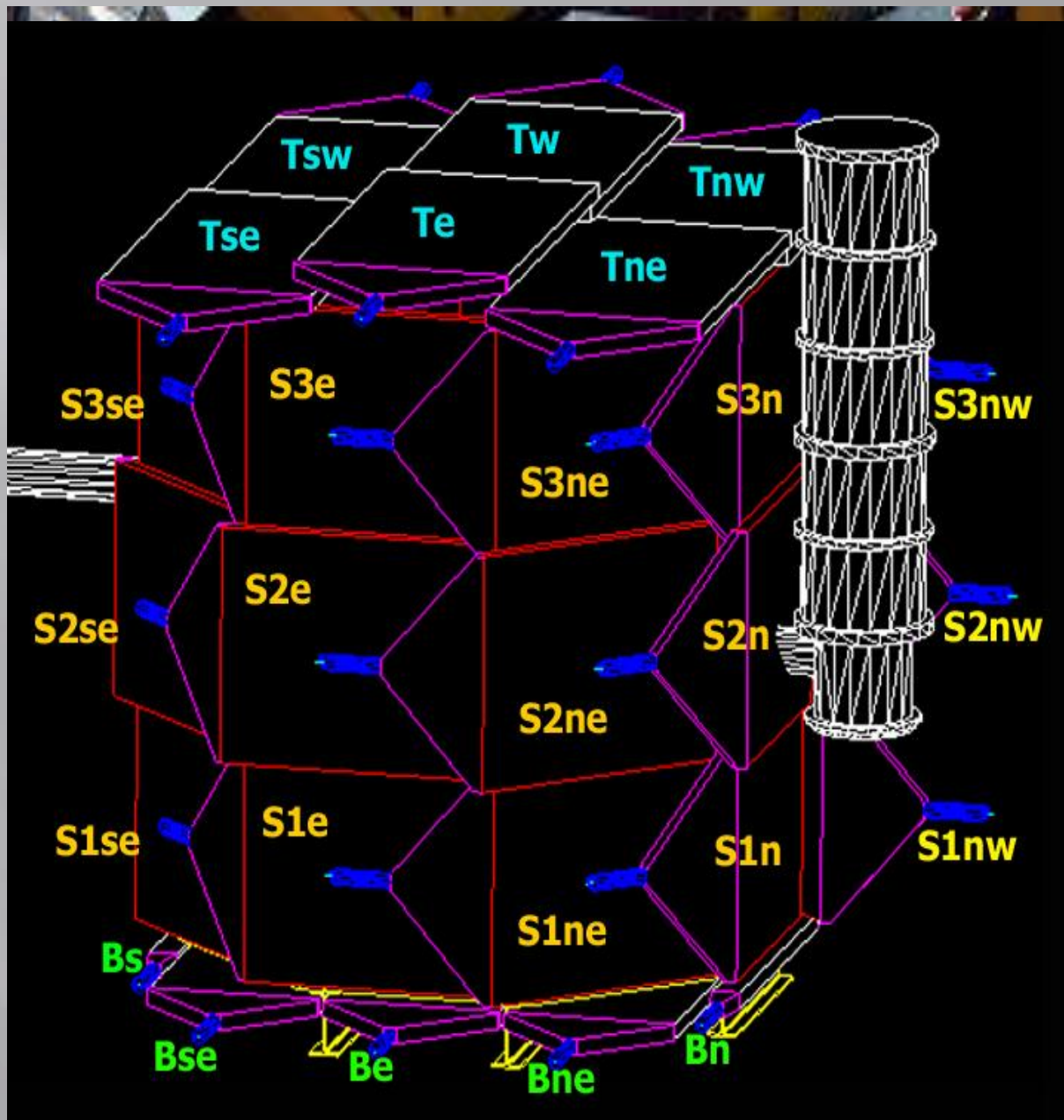
CDMS Shielding & Veto

Surround detectors with active muon veto

Use passive shielding to reduce γ/Neutrons

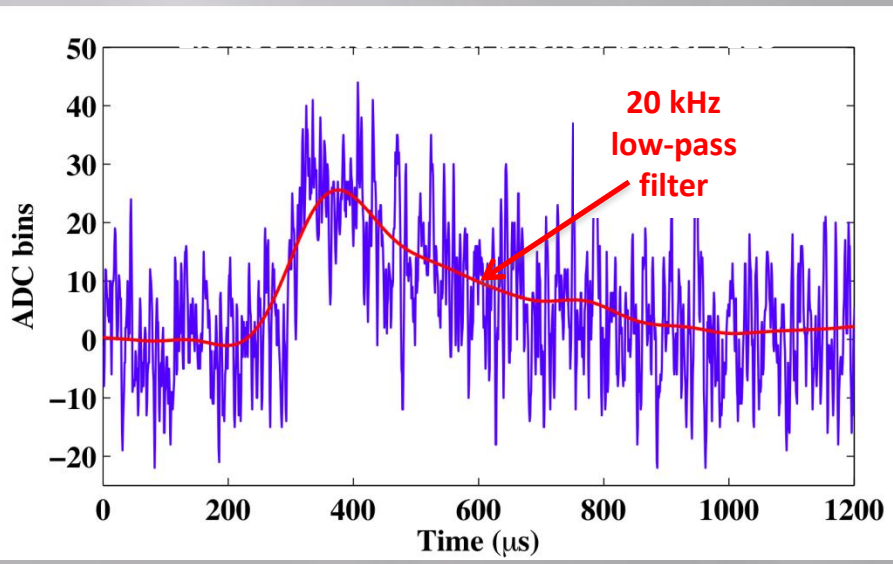
- Lead and Copper for photon
- Polyethylene for low-energy neutron

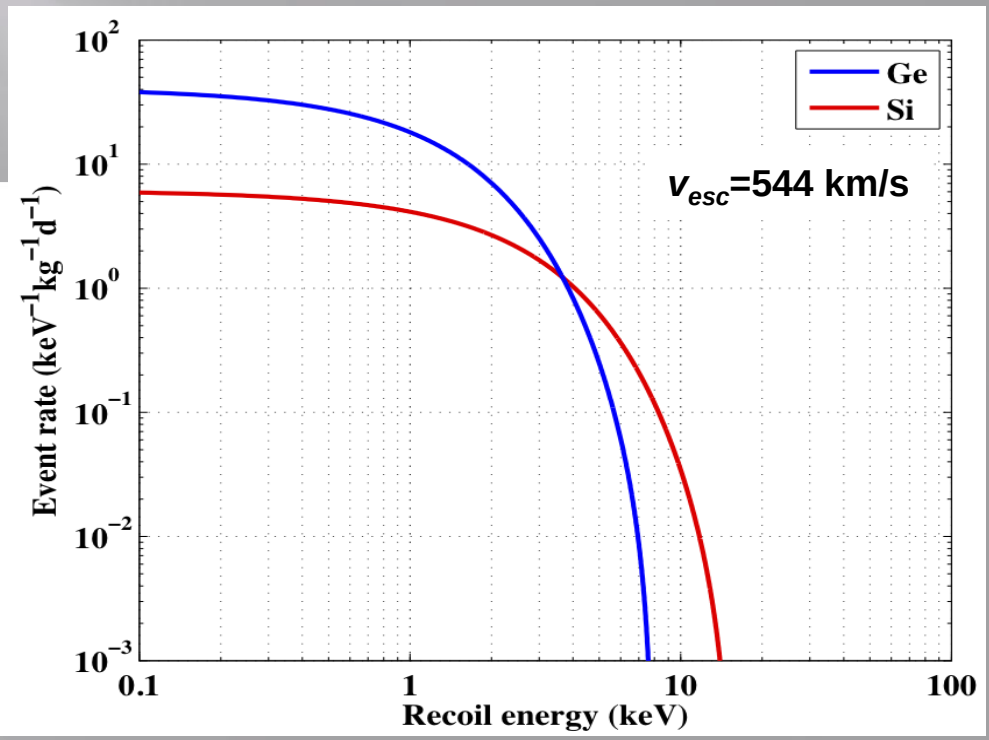
Typical for any dark matter experiment



Low-Mass WIMP Detection

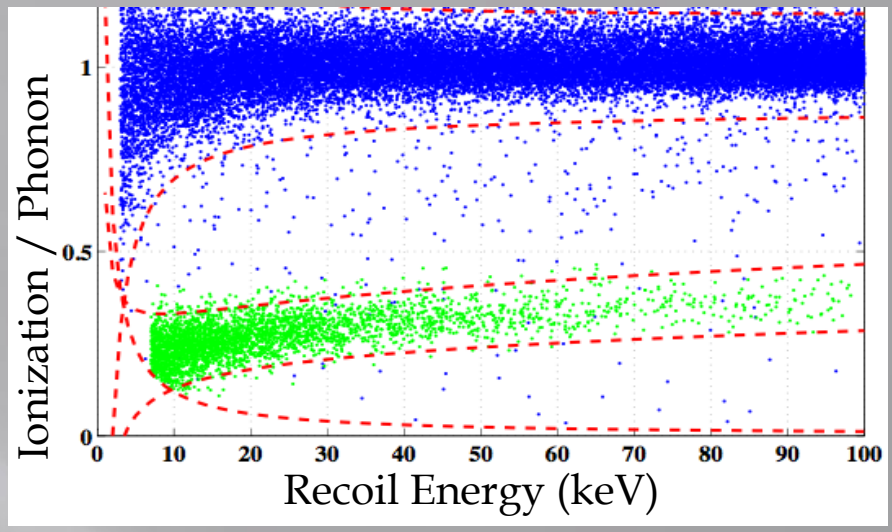
- Results from DAMA/LIBRA, CoGeNT and others have been interpreted as possible evidence for elastic scatters from WIMPs with m_x~7 GeV and σ_{SI}~10^{-40} cm^2
- Previous CDMS Ge results not sensitive to these models since thresholds were ~10 keV (to maintain expected backgrounds <1 event)
- Can lower thresholds
- Tradeoff: higher backgrounds



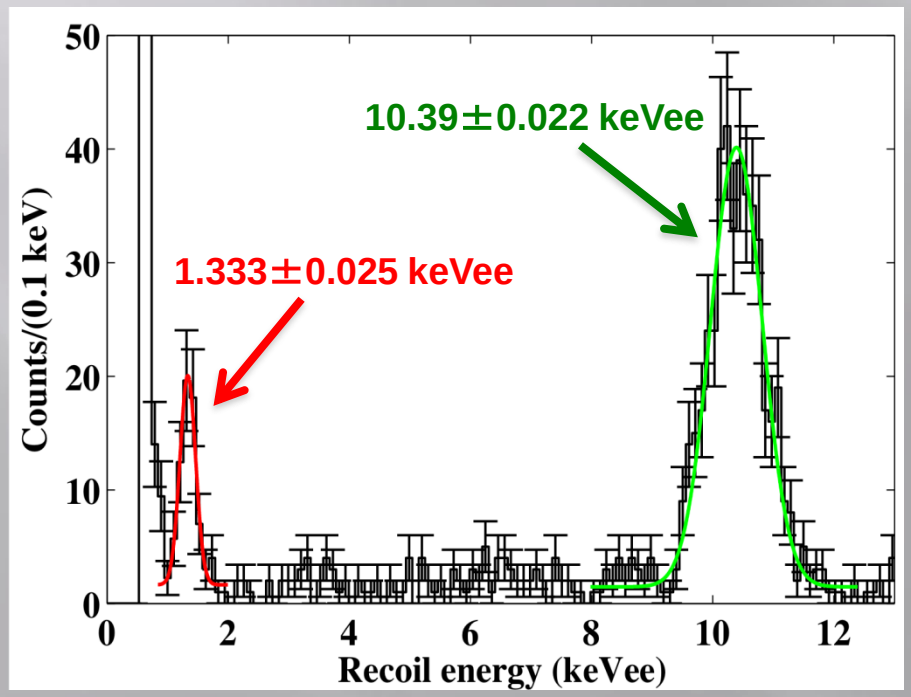


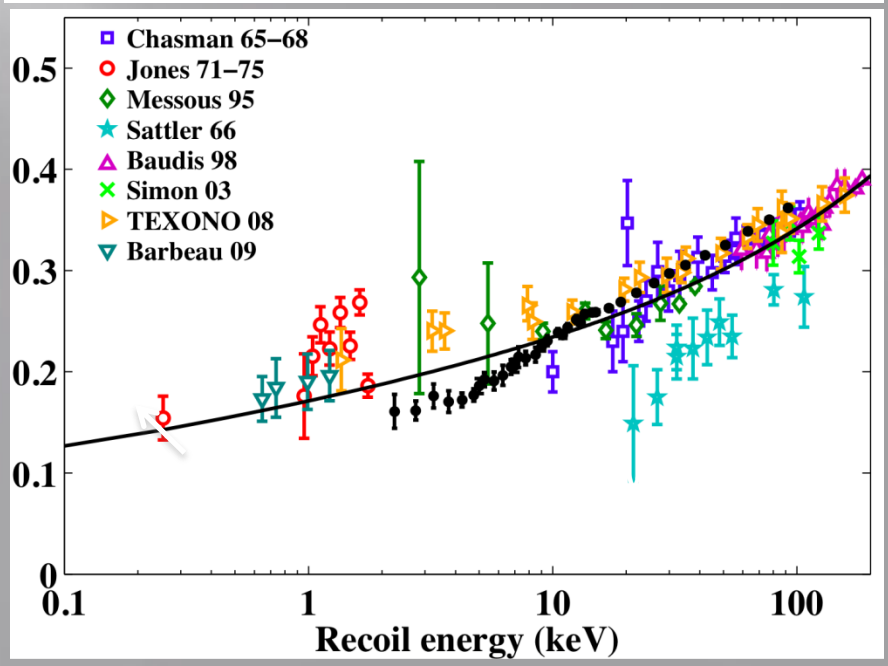
Energy Calibration

- Phonon energy scale calibrated with electron recoil lines at 1.3 keV and 10.37 keV
- Nuclear recoil energy reconstructed from phonon signal alone after subtracting Luke-Neganov phonons (~15% of signal)

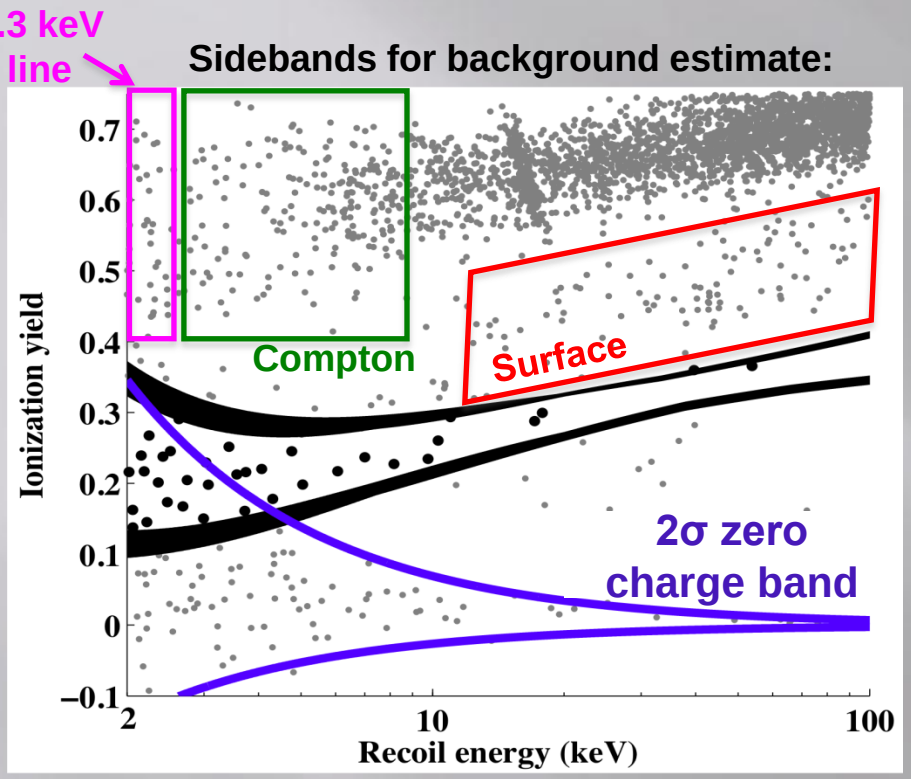


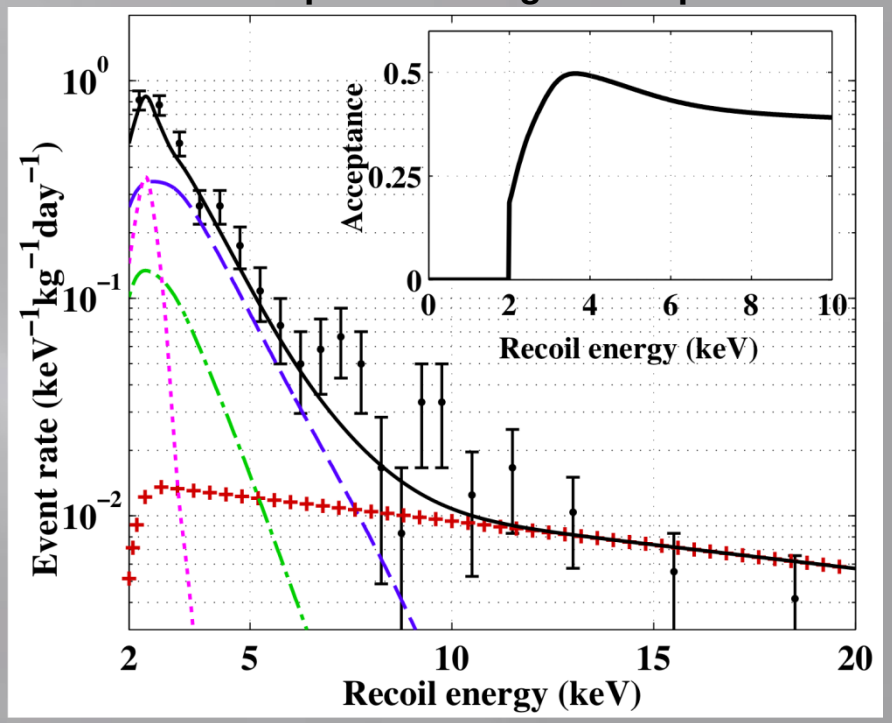
Electron recoil phonon spectrum, T1Z5





Signal Region & Expected Bkg.

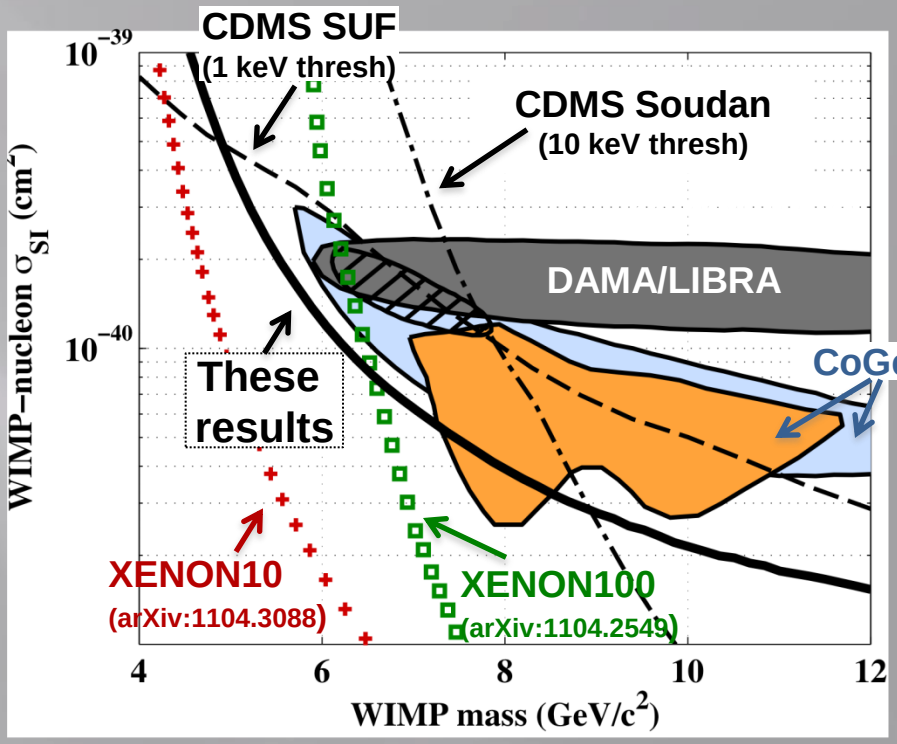




- Expected background from background extrapolations reasonably consistent with observed candidates
  - Possibly significant systematic errors due to extrapolations to low energy

Low Threshold Result

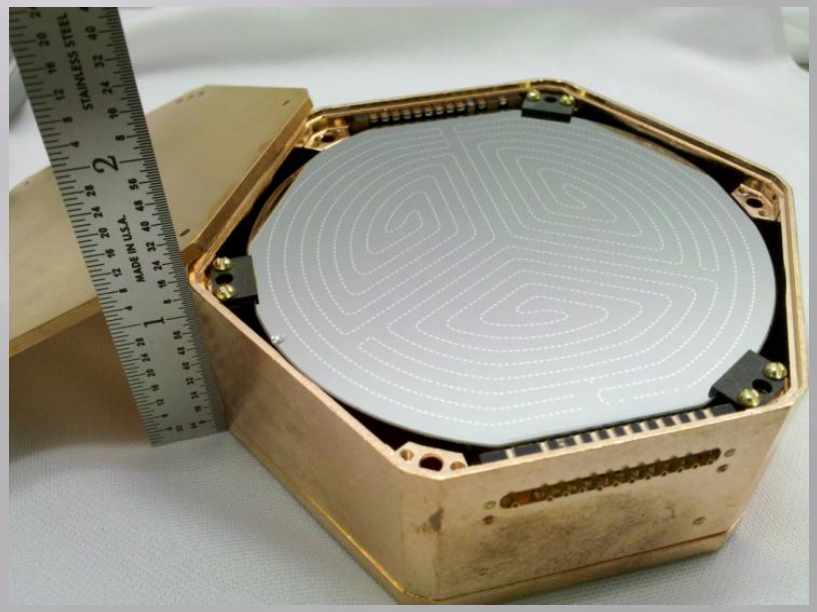
- No background subtraction, ie assume all events could be WIMPs
- For spin-independent, elastic scattering, 90% CL limits incompatible with DAMA/LIBRA and entire CoGeNT excess

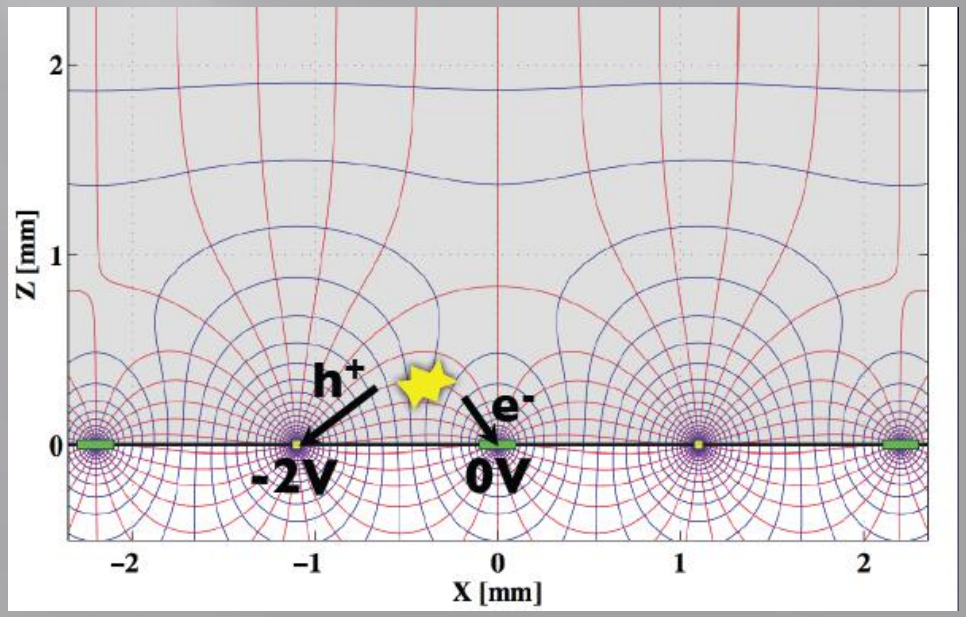


- Some parameter space for CoGeNT remains if majority of excess events not due to WIMPs

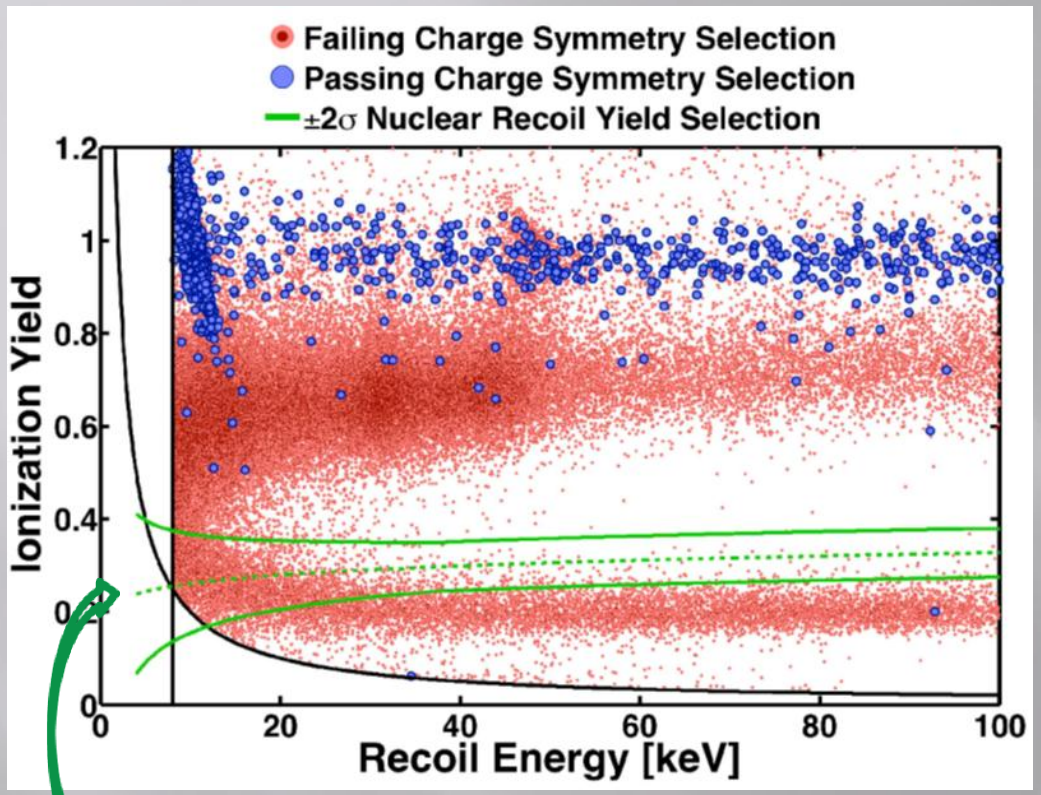
CDMS Now: IZIPs!

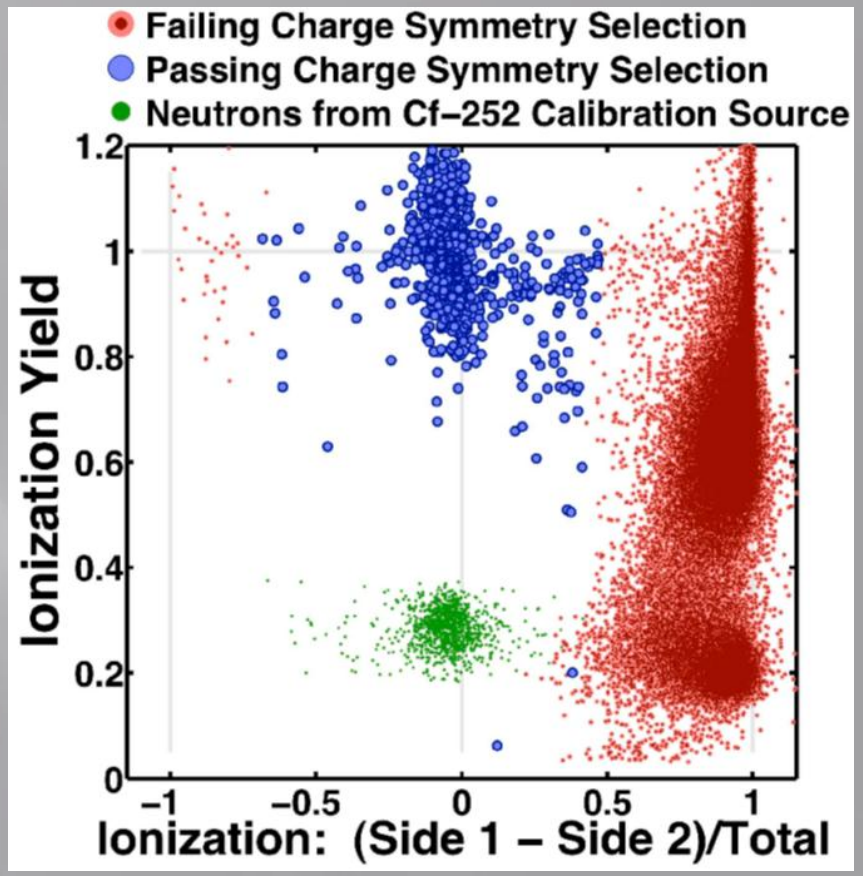
- 15 detectors each with 2.5x greater mass taking WIMP-search data
- phonon and interleaved ionization sensors on both sides
- Intentionally "contaminate" 2 detectors with a ^{210}Pb beta source to get large sample of surface events
  - 65k electron scatters observed
  - 15k ^{206}Po scatters observed
- 100% of observed surface events rejected
- Potent rejection power from phonons not yet applied.





Surface Event Rejection

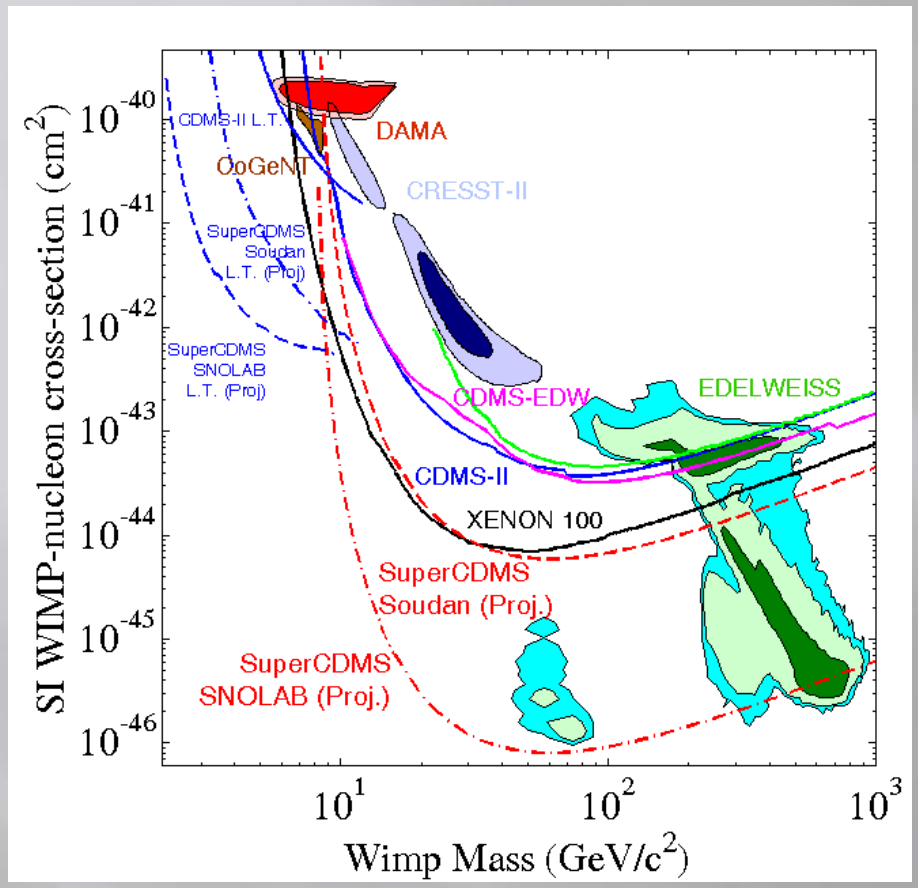


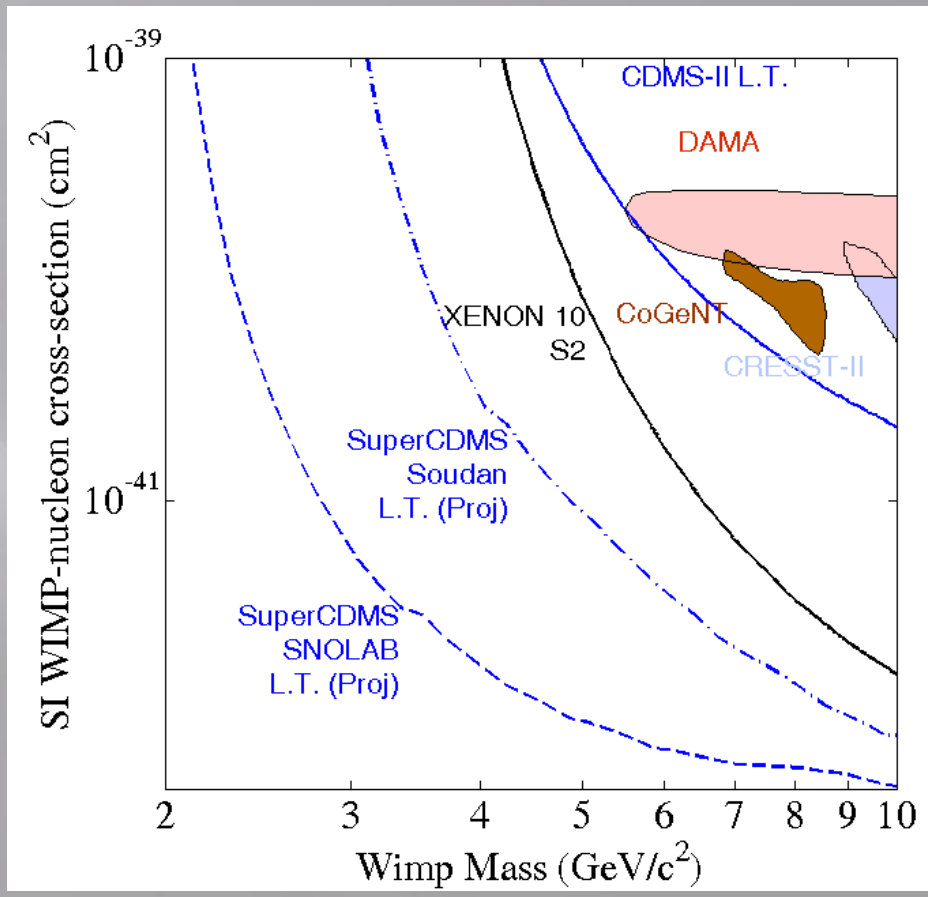


This is the WIMP signal region. Some of the events shown here that passed a phonon surface event rejection cut would be background events for the old detectors…

…but they are all rejected by utilizing data from the interleaved electrodes

Projected Sensitivity

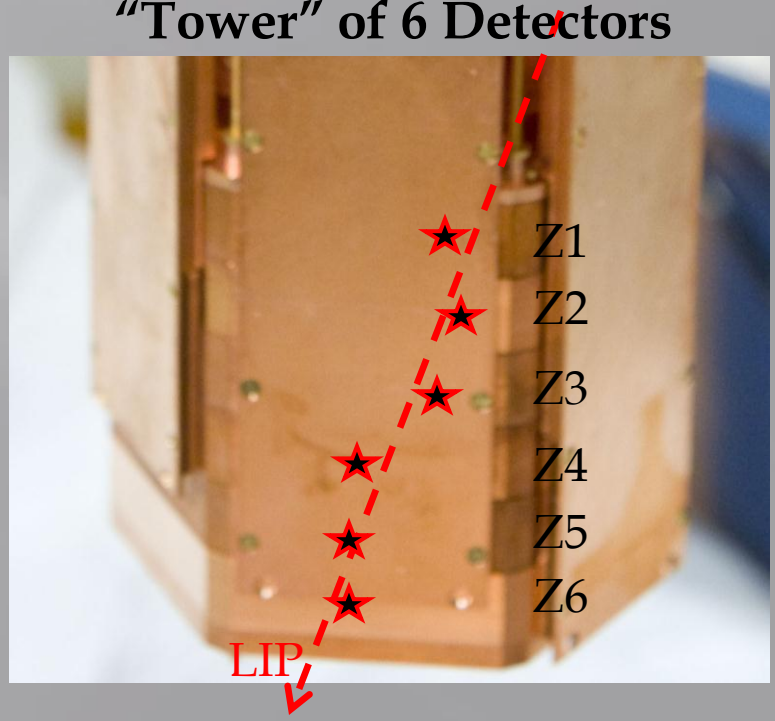




Improved threshold for low WIMP-mass analysis: < 1keV

Lightly Ionizing Particles (LIPs)

- Particles with fractional charge?
  - Quarks, but confined in hadrons.
- ***Anything not explicitly forbidden is required.* – Murray Gell-Mann**
- Large Number of searches
- Unique opportunity for us!
  - Cross section and hence # of interactions scales with f^2
  - Also depends on track length and detector type (Si or Ge)
  - Low, 2.5 keV threshold; > 10^3 times lower than typical muon
  - Sensitive of fractional charges of order 1/100!
  - Expected background (< 0.1 events)

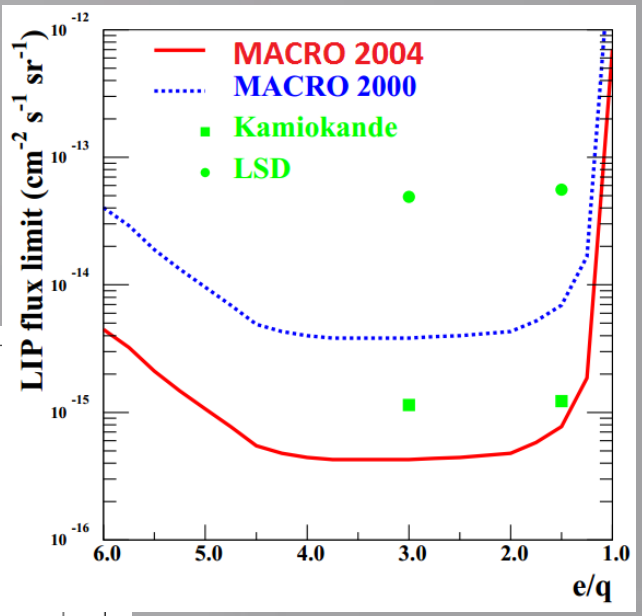


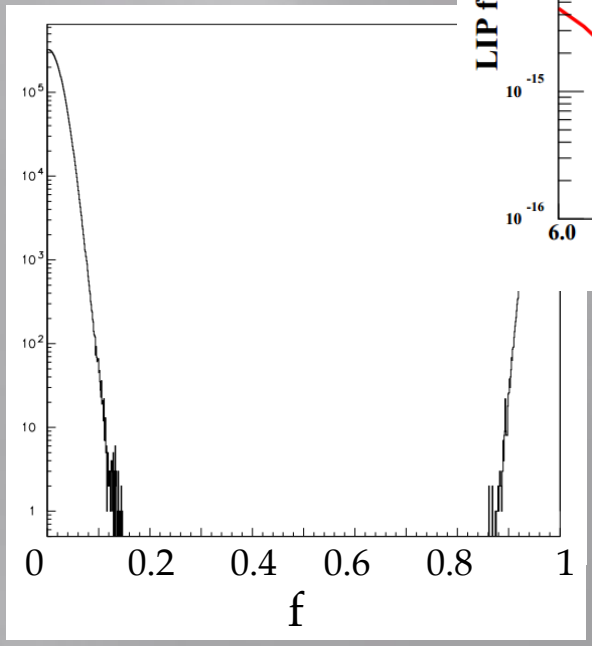
Assuming LIPs are minimum ionizing.

Past LIP Searches

- Three types of searches:

1. Examine cosmic ray (or cosmically produced) LIPs
   - Insensitive below f=1/6th
2. Production in accelerators
   - Multiple modes: $e^+ e^- \rightarrow f^+ f^-$, etc
3. Search in normal matter
   - Millikan oil drop
   - Exclude 0.18 < f < .82





LIP Analysis in a 

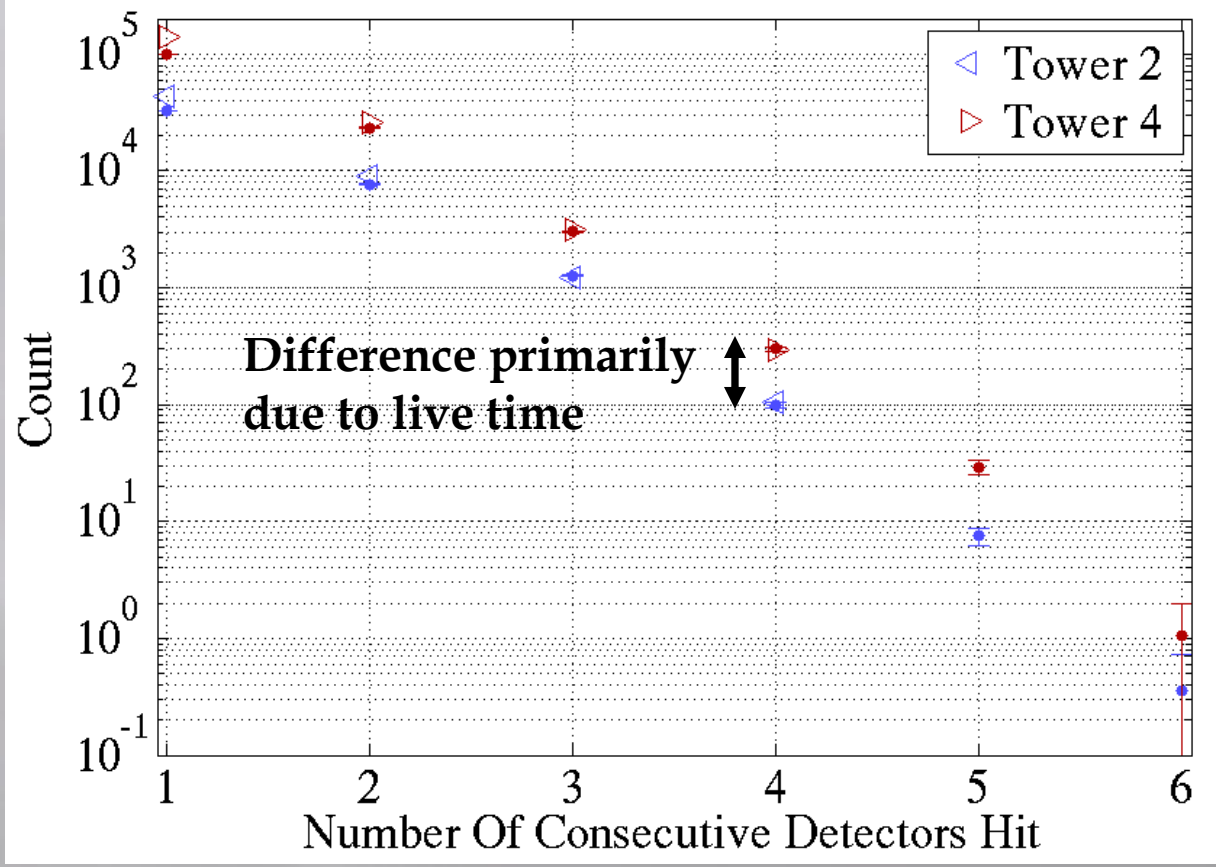
- All cuts defined with the signal region blinded.
- About 3% of the data has been unblinded to check for large unexpected backgrounds.

- All dete[illegible] a tower hit

events

Multiplicity

Electromagnetic background events tend to interact in a few detectors…



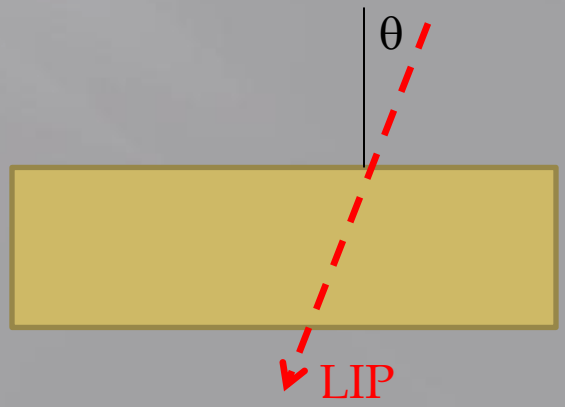
…a LIP is required to interact in all detectors in a tower

Energy Consistency I

Require energy deposited to be consistent with expected energy deposition

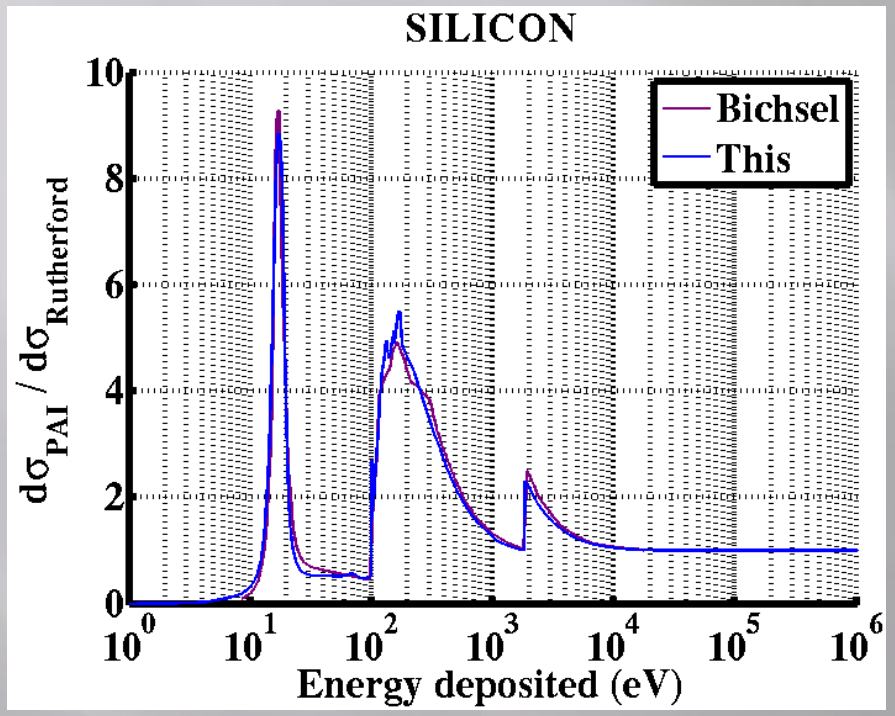
…but what is the expected energy deposited?

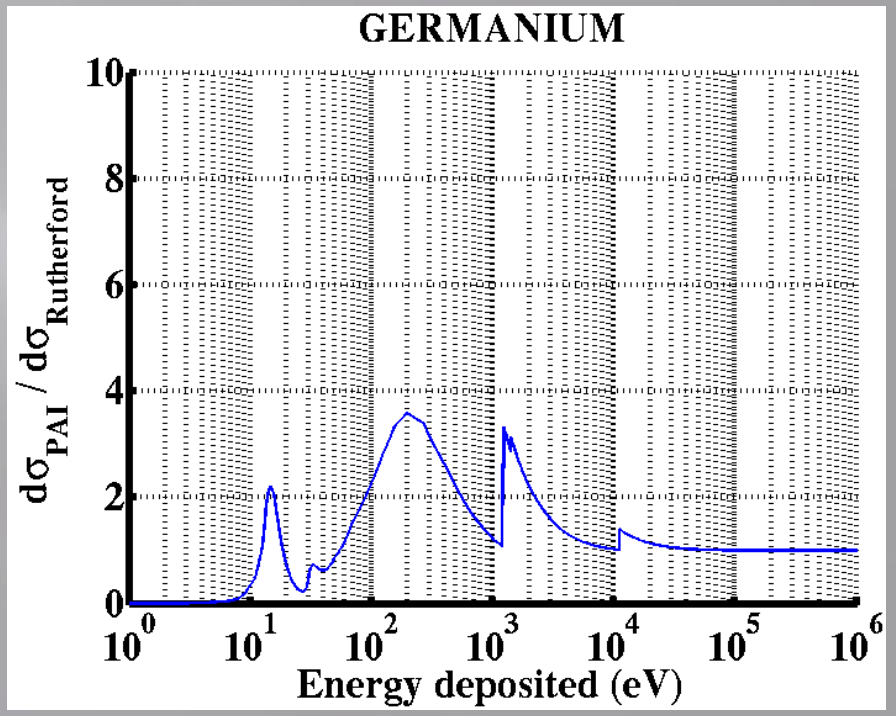
- Estimate single interaction PDF
- Convolve to obtain n-interaction PDF
- Number of interactions obeys Poisson statistics and depends on:
  - Fractional charge squared, f^2
  - Track length: θ and thickness
  - Detector type (Ge, Si)



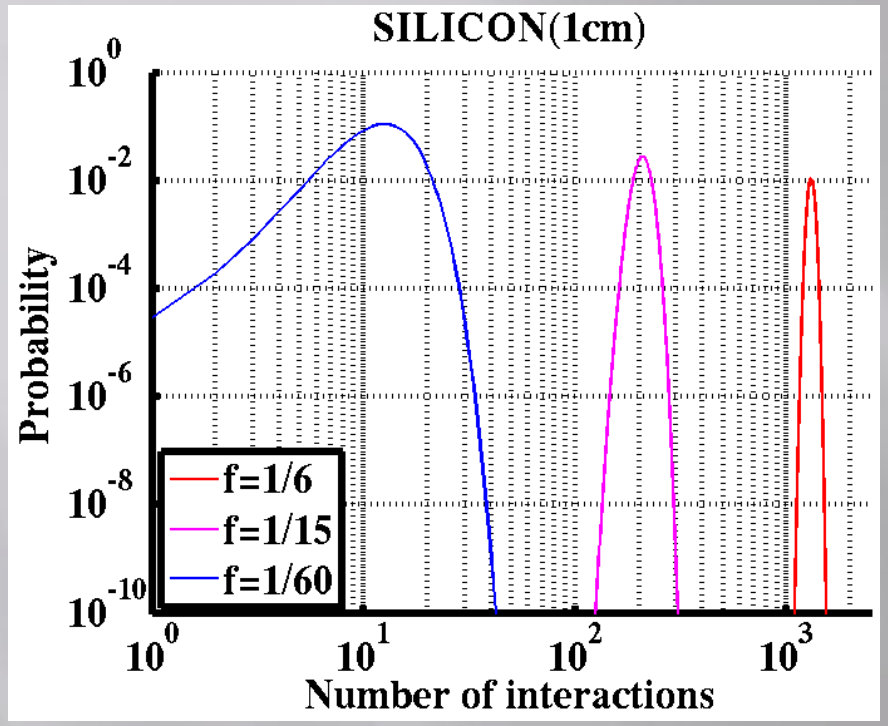
Single Interaction PDF

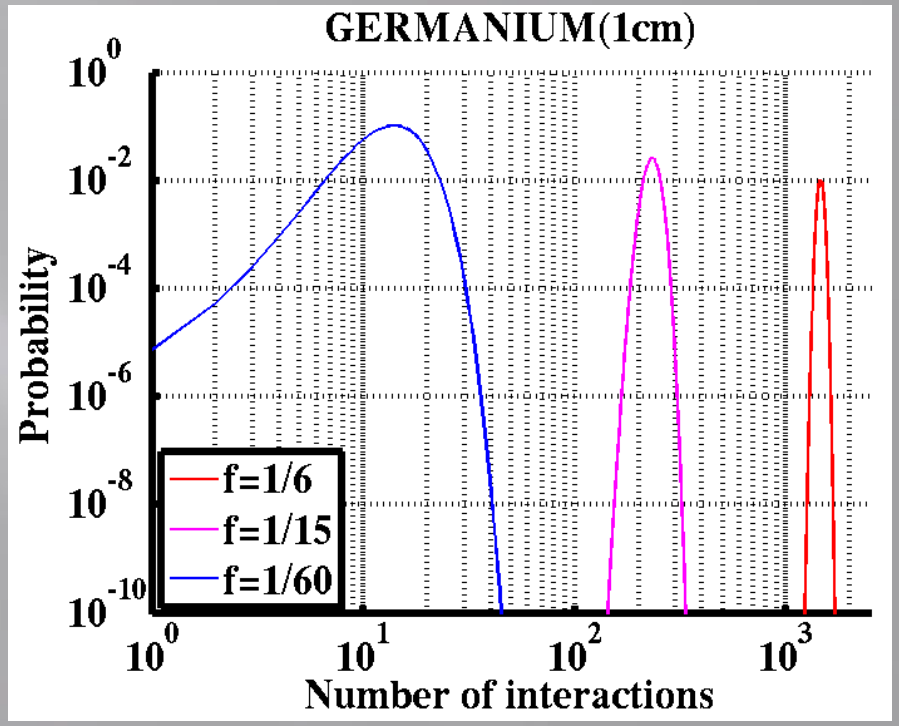
Assuming the photo-absorption-ionization model, we get:





Number of Interactions

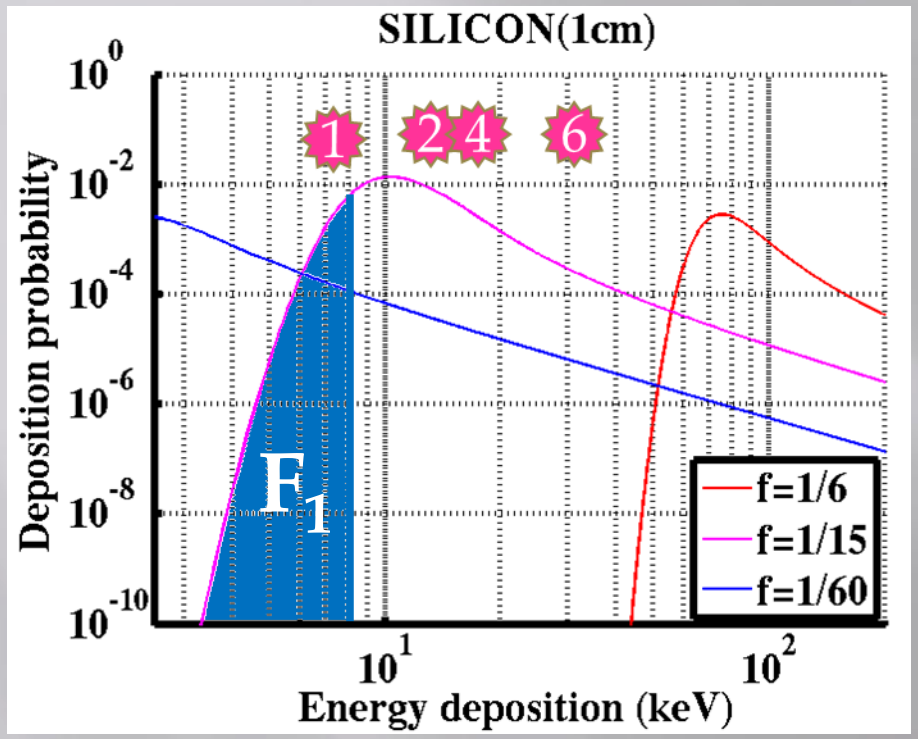


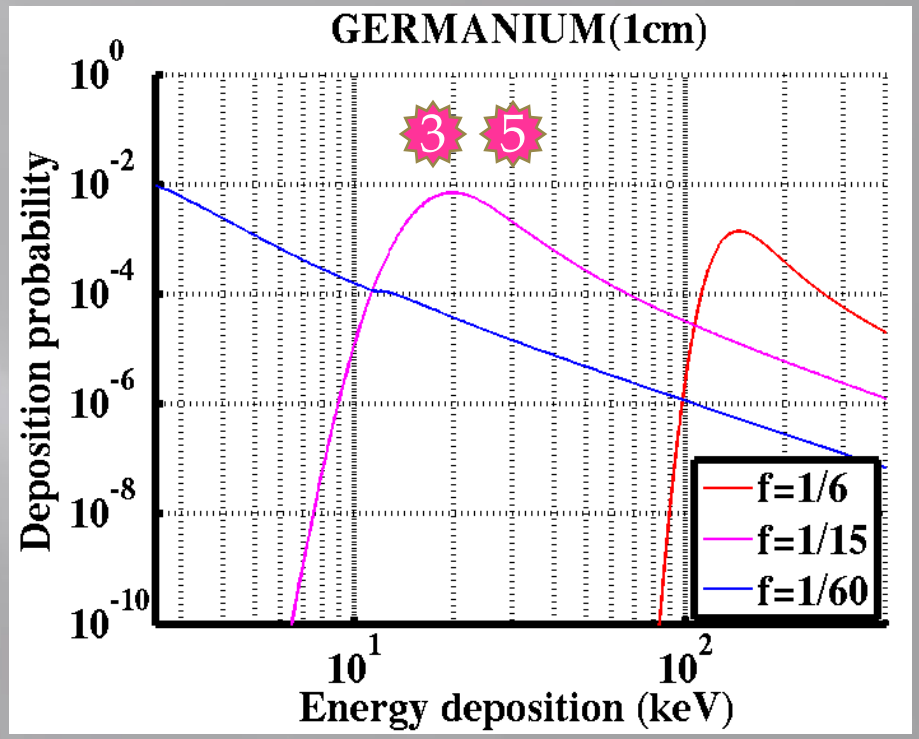


…for normally incident LIPs

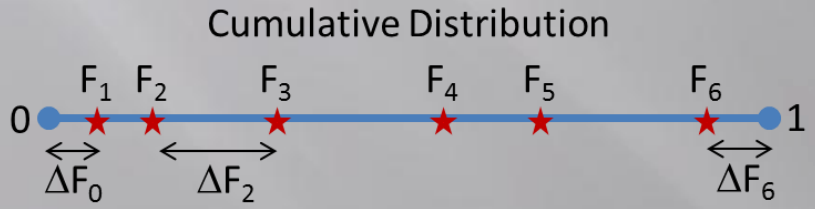
Energy Consistency II

Combine and smear resulting PDF for energy resolution.





Order events…



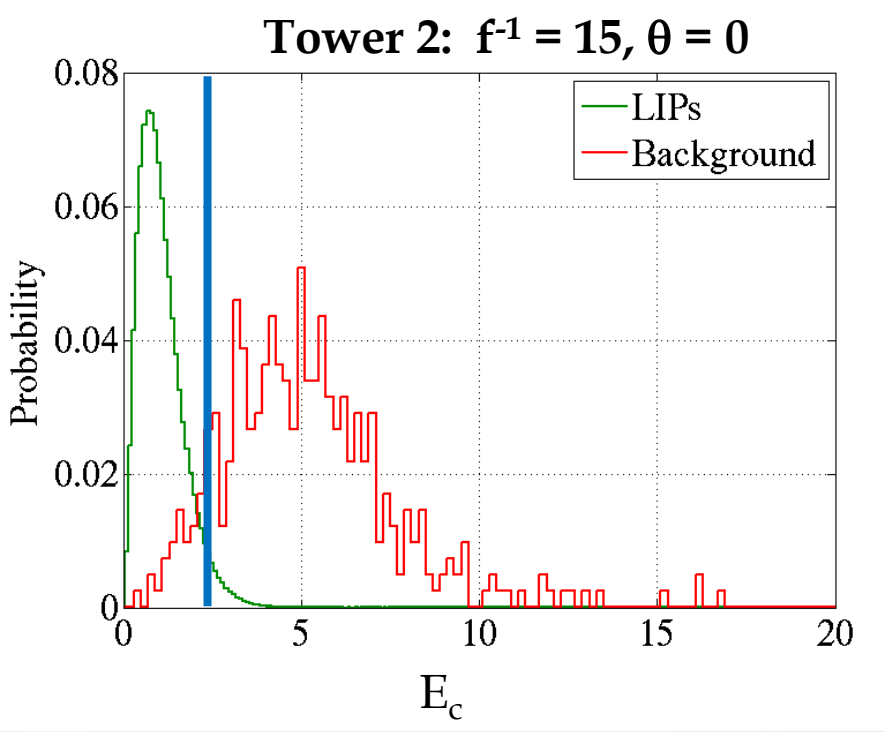
Define:

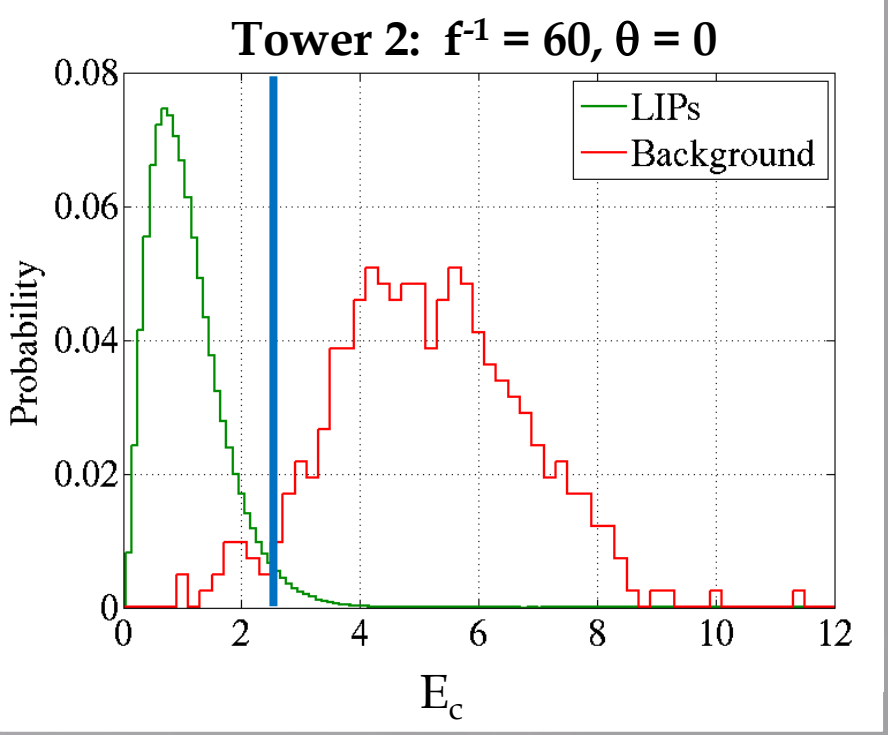
$$E_c = -2\sum_{n=0}^{6}\left(w_i \log\frac{\Delta Fi}{w_i}\right)$$

…where the w_i's are the mean ΔF_i values

Energy Consistency III

Resulting rejection power:

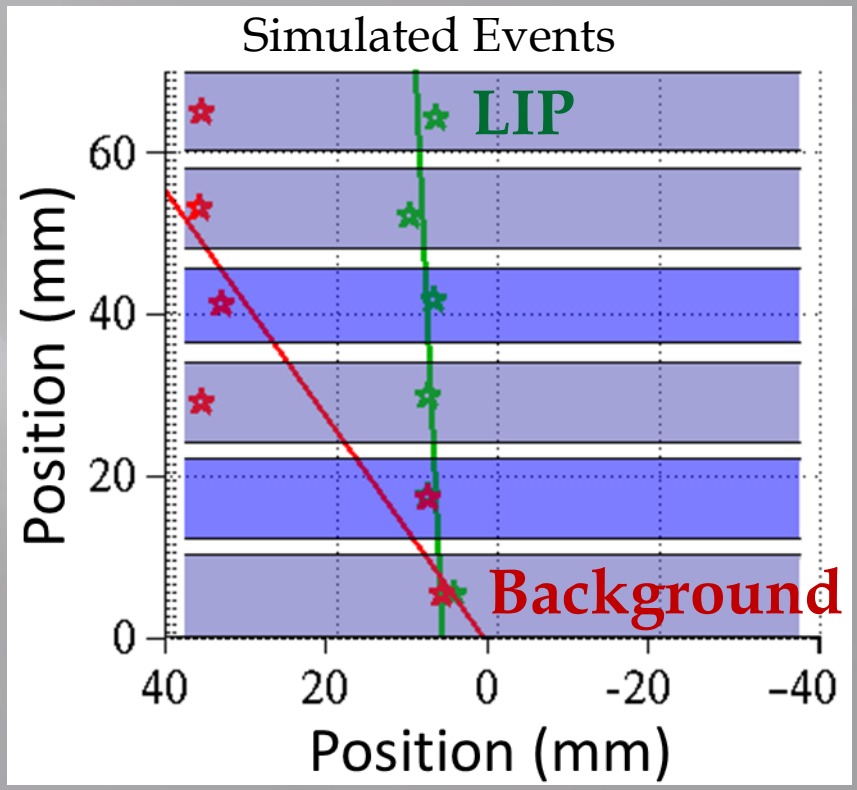




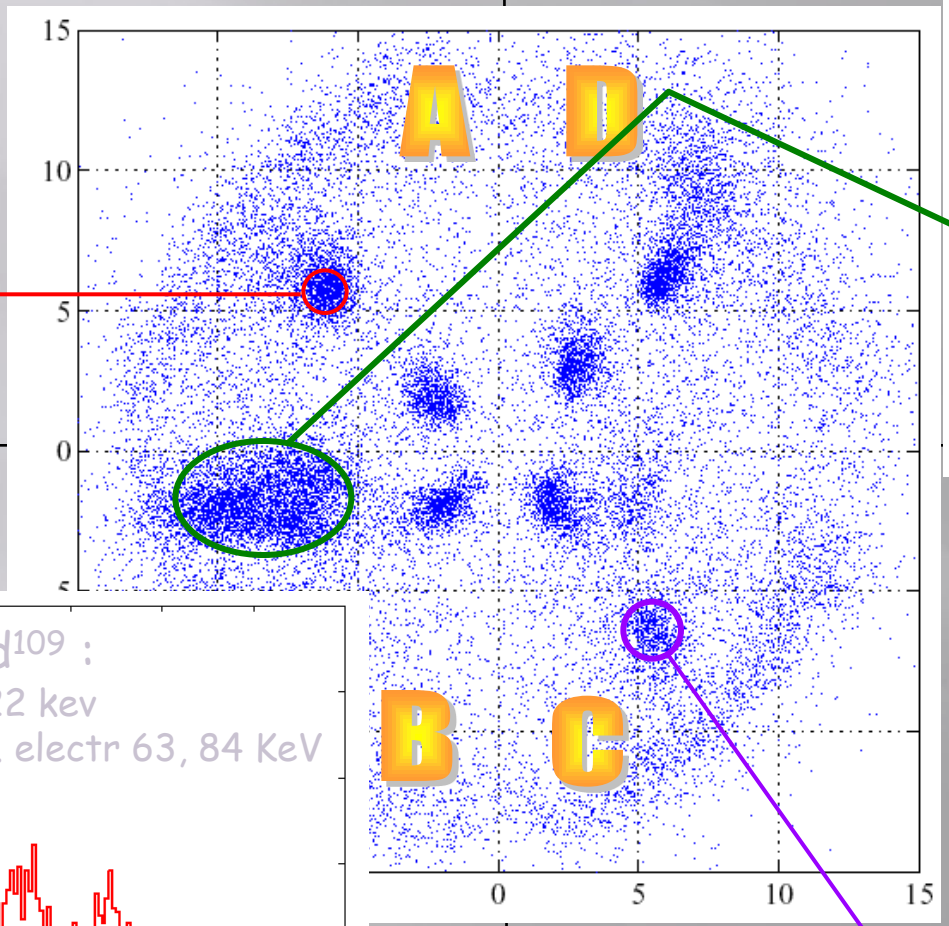
Set the ***cut*** for 99% LIP acceptance.

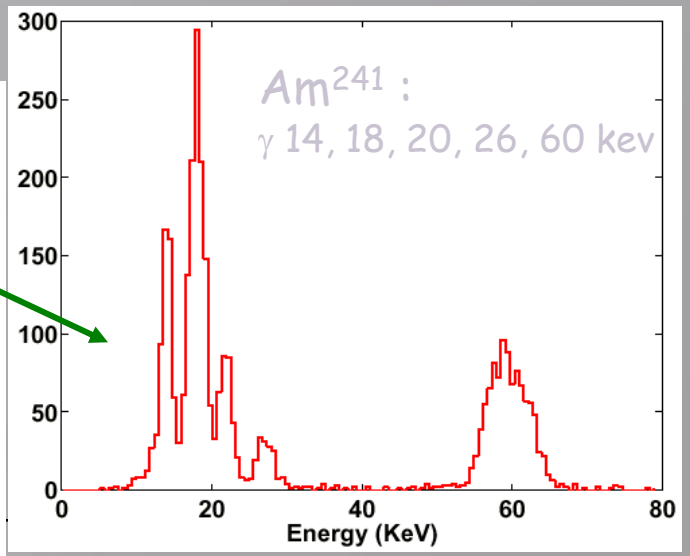
Tracking Cut

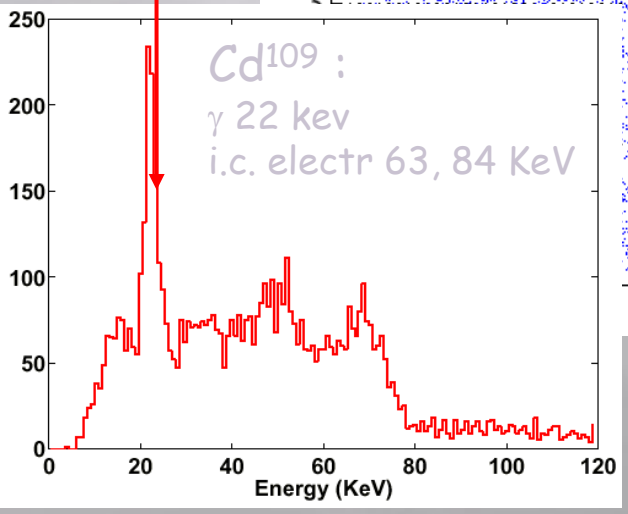
- LIP tracks should be well fit by a straight 3-D line
- Background gammas are deflected as they interact
- Perform a full 3-D fit minimizing χ^2 / DOF and accounting for each detector's position resolution

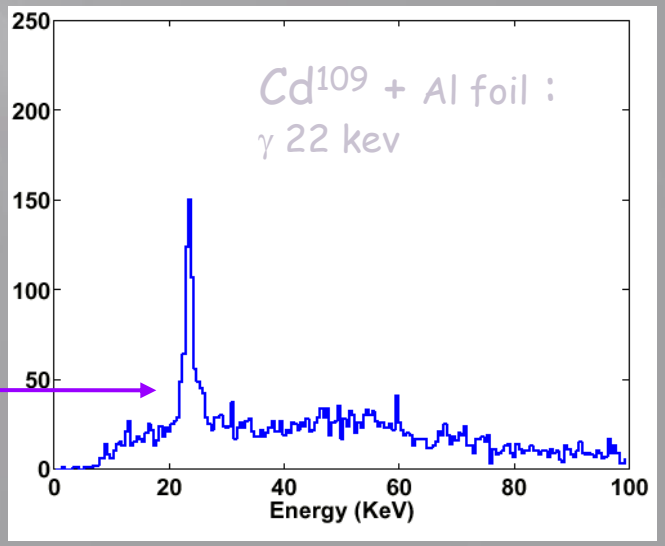


Position Resolution







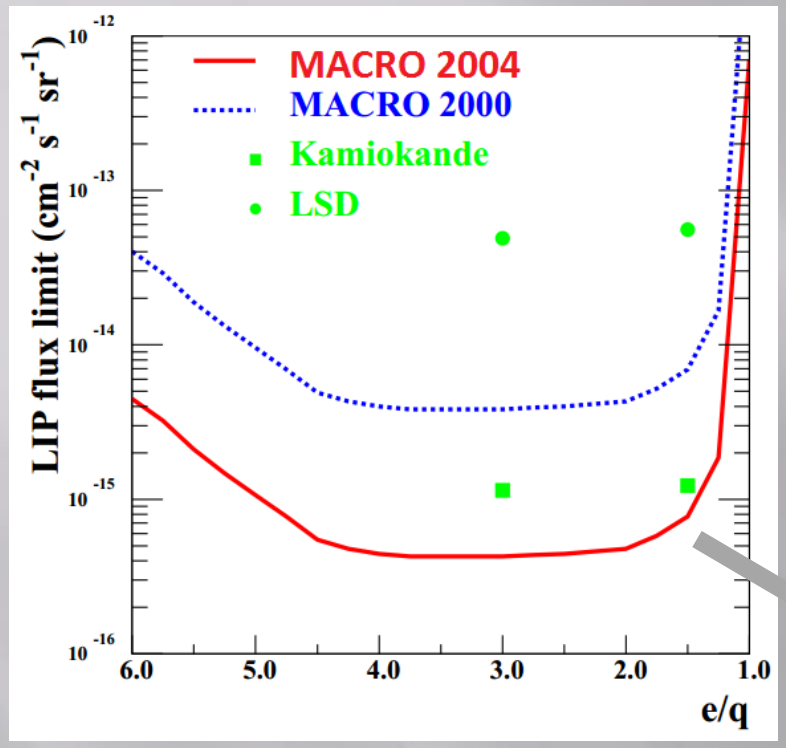


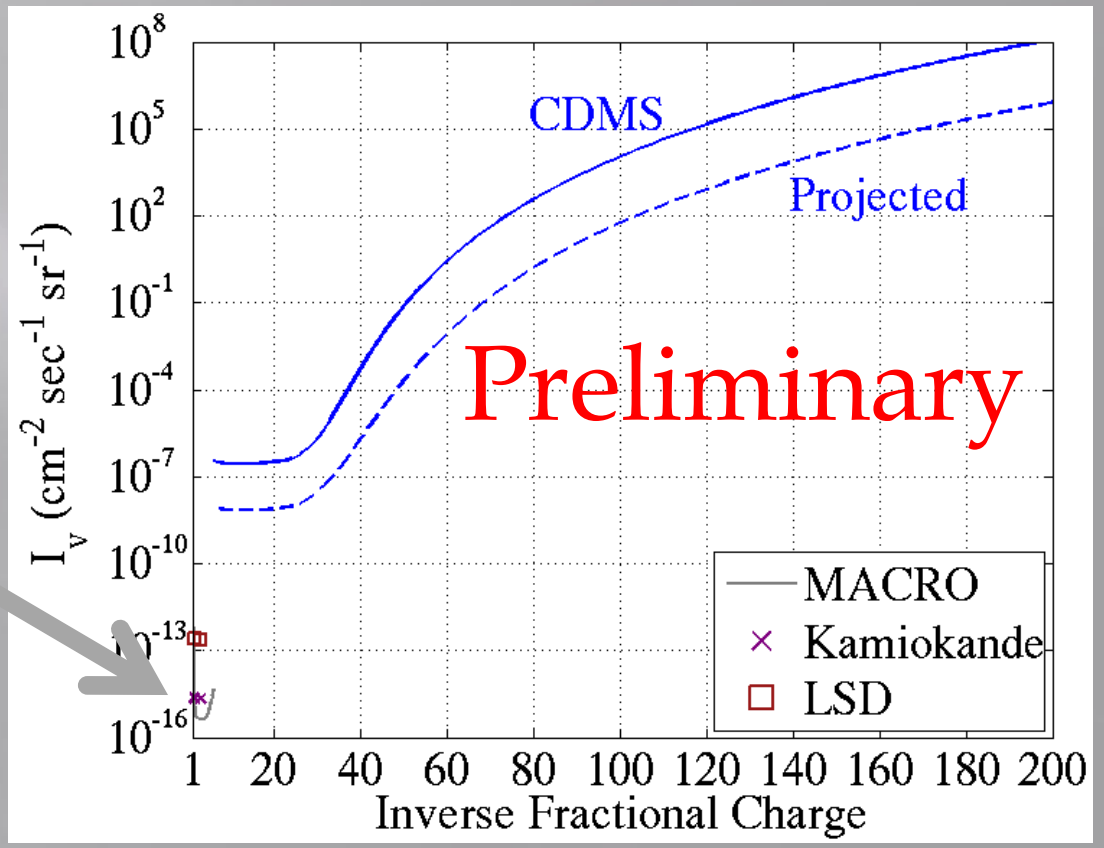
Results from 3% of Data

- Look at 10% of tower 2 data (3% of total live time)
- Expected number of "raw" background events: 0.04
- Expected background after energy consistency ~< 0.005
- Any single event observed could constitute a large unexpected background

- No LIPs observed
- No unexpected backgrounds either
- Compute resulting limit and expected sensitivity of the remaining 97% of the data

Expected Sensitivity



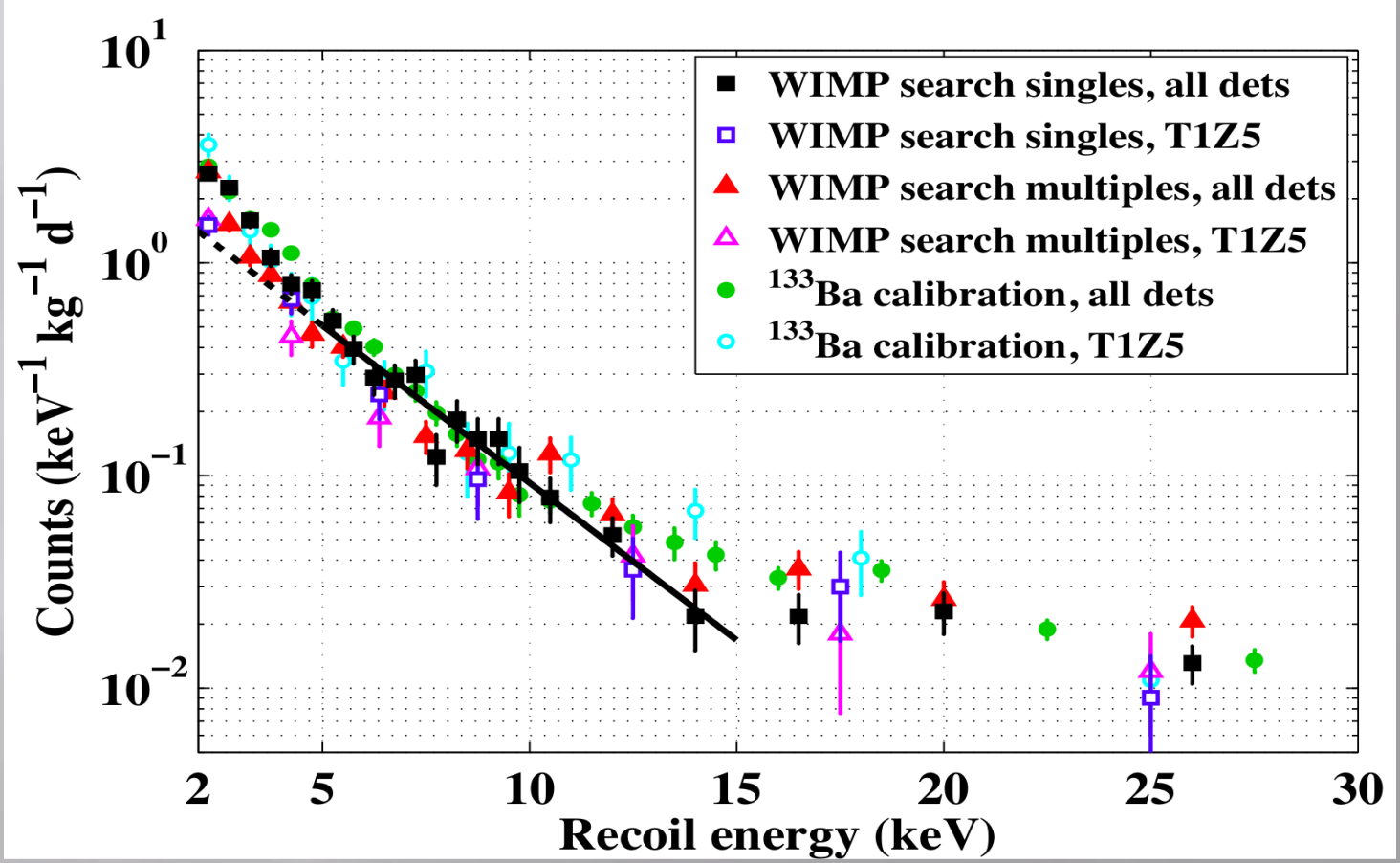


The End…for now

Low Threshold WIMP Detection

- Soudan data from Oct. 2006-Sept. 2008 reanalyzed with 2 keV recoil energy threshold
- Used 8 Ge detectors with lowest trigger thresholds (1.5-2.5 keV)
- Small subset (1/4 of the data) used to study backgrounds at low energy
  - Limits calculated from remaining 241 kg-day raw exposure
  - Results driven by detector with best resolution (T1Z5)

Zero Charge Events



Zero charge events seen in WIMP search singles, WIMP search multiples, and Ba calibration data with similar spectra