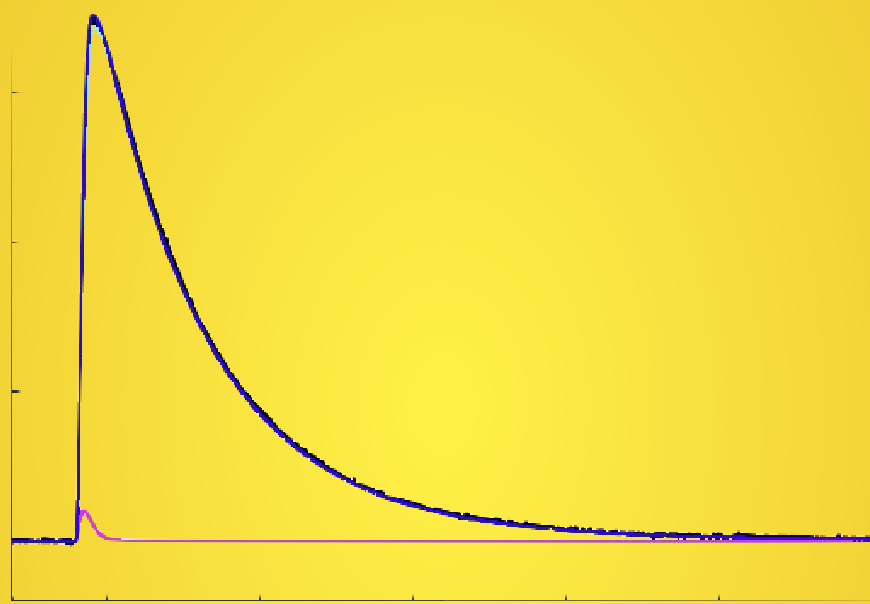
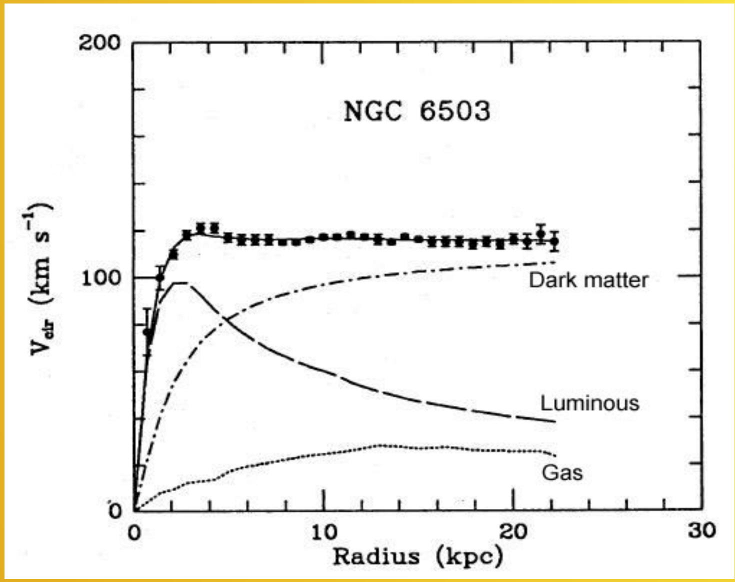
New Pulse Processing Algorithm for SuperCDMS



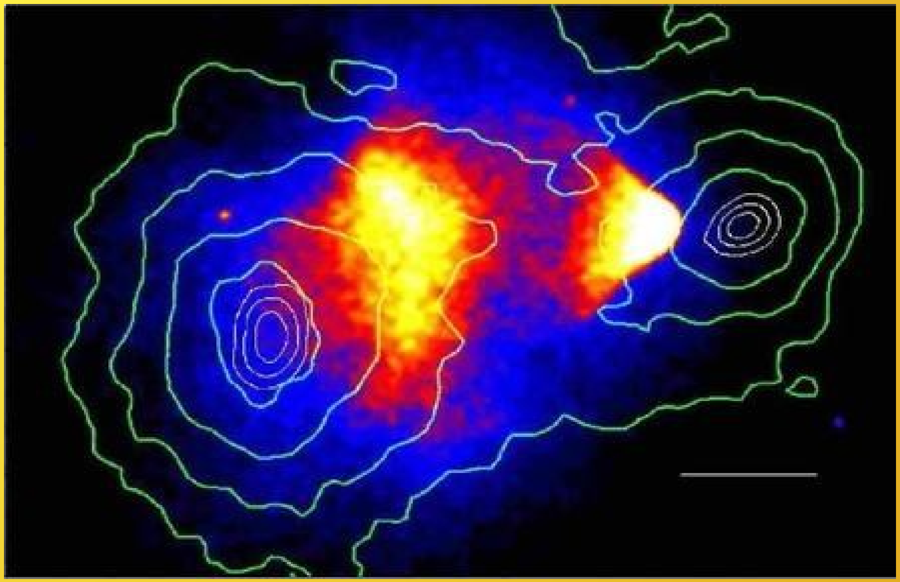
Ryan Underwood, Queen's University

WIMP Dark Matter

- Evidence for dark matter can come from galactic rotation curves and weak lensing surveys of galaxy clusters
- Dark matter outweighs baryonic matter by 5:1
- Direct searches for evidence of Dark Matter are ongoing
- SuperCDMS is one of these searches



Begeman, Broels and Sanders (1991)



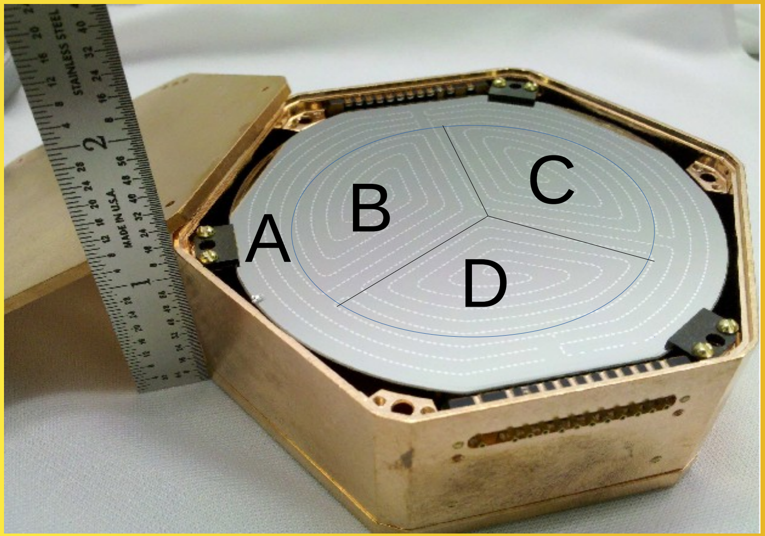
Clowe et al. 2006

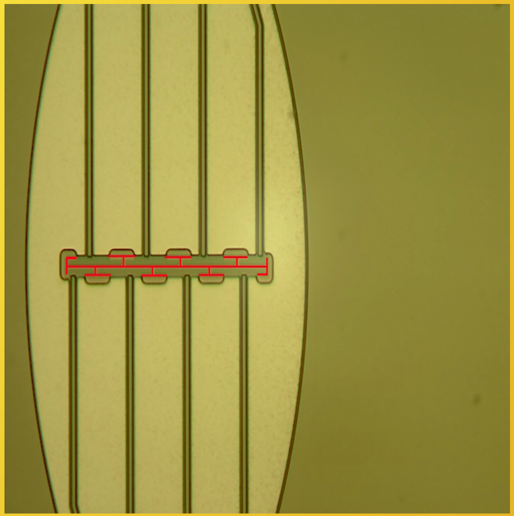
SuperCDMS

- Super Cryogenic Dark Matter Search
- Germanium Crystals
  - When dark matter (or background radiation) collides with atoms in the crystal, it deposits some energy in the form of heat
- Phonons
  - Heat- Vibrational excitation in crystals
- TES- Transition edge sensor
  - Thin superconducting film is operated in its transition state between superconducting and normal state
  - Small ΔT -> Large Δ Resistance
  - This creates a signal that can be read out as a pulse with the right electronics

Phonon Signal Pulse Shape

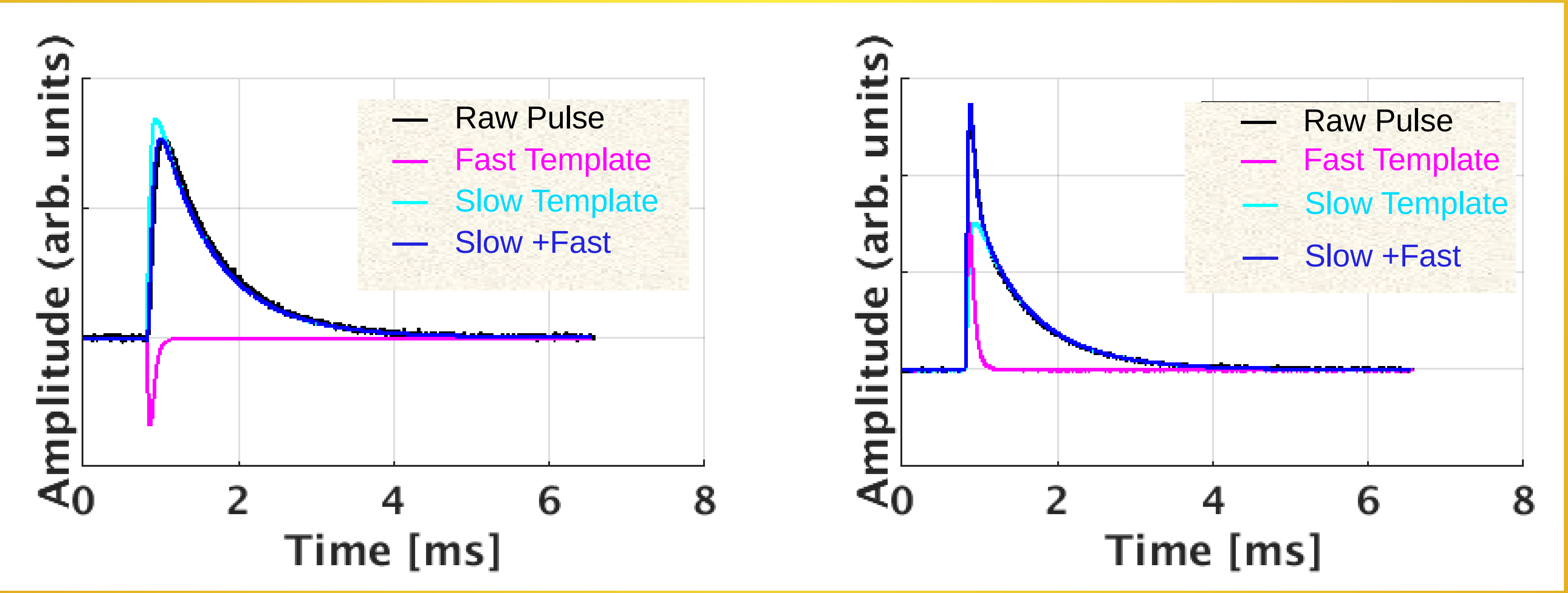
- Only a fraction of the top and bottom surfaces of the detector are covered by sensors
- The shape of the pulses is a quick rise followed by a slow drop-off
- A fraction of phonons are absorbed immediately in the nearest sensor leading to a fast peaky signal
- The rest bounce around and lead to a “slow” homogeneous signal in all sensors





Old Pulse Processing Algorithms

- Optimal Filter: The original pulse processing algorithm
  - This algorithm fits pulses in Fourier space, and works best for a fixed pulse shape
- This worked well with old CDMS detectors, but with the highly variable pulse shape in the new SuperCDMS iZIP detectors, it became evident that a new algorithm was needed.



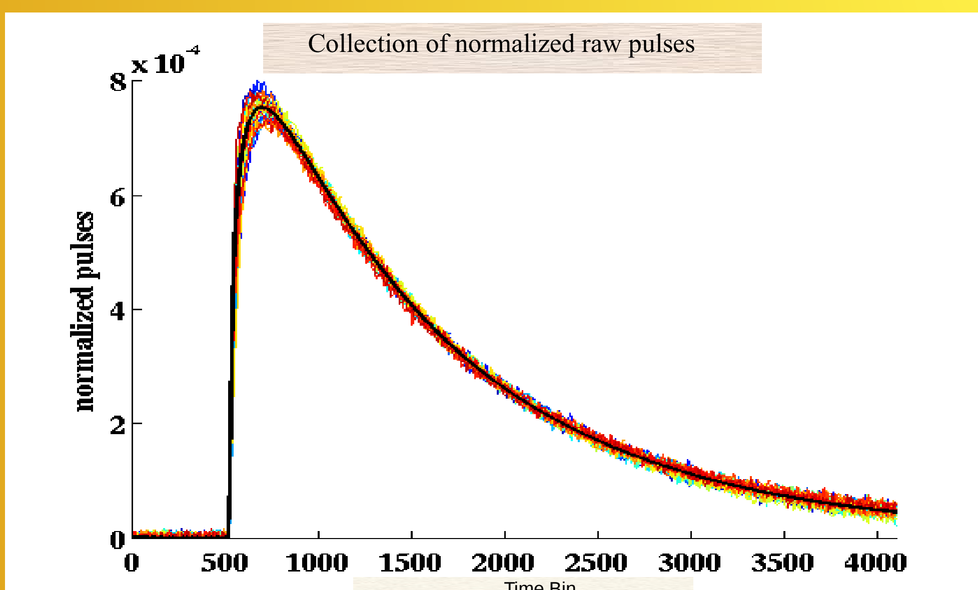
A non-peaky pulse (left) vs a peaky pulse (right)

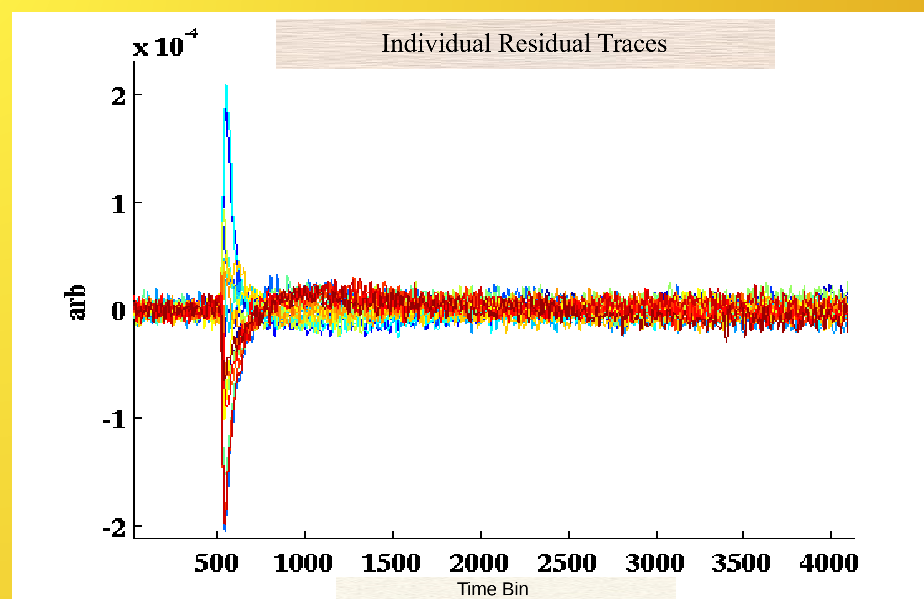
Peaky Pulses

- First attempt to fix: Non-Stationary Optimal Filter Algorithm (NF)
  - De-weights early (peaky) part of the pulse to obtain a better fit.
  - Obtains much better energy resolution
  - You lose information about event position

Two-Template Optimal Filter

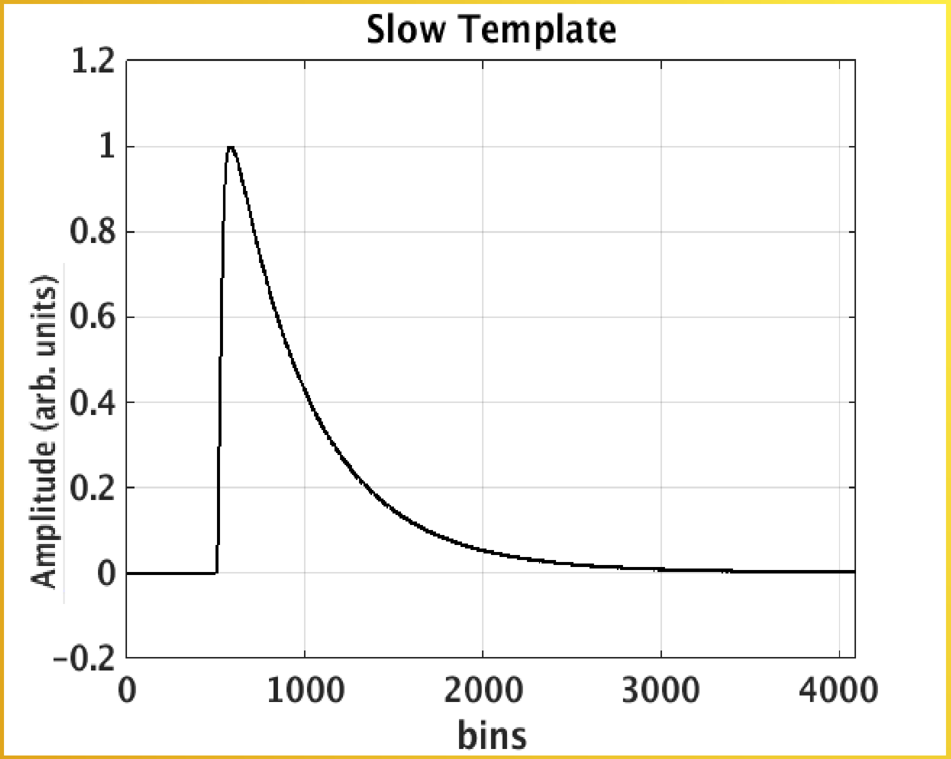
- This motivates a new algorithm to try and recapture that lost information
- Data from our test facilities showed the residuals (difference of individual from average pulse) all have similar shapes

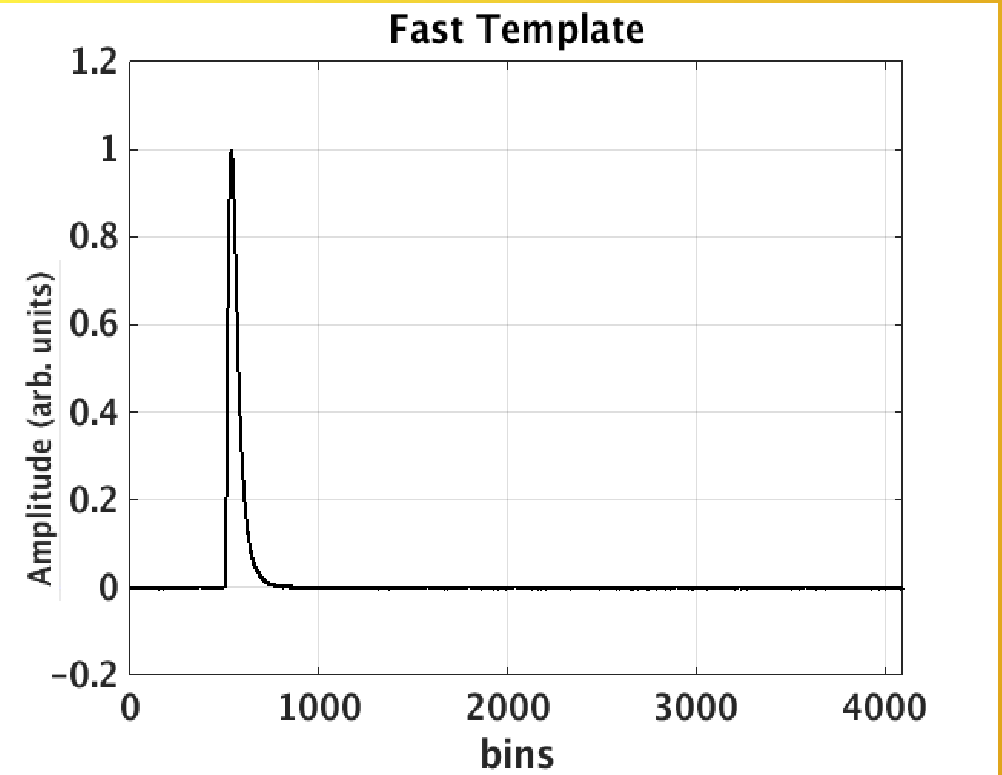




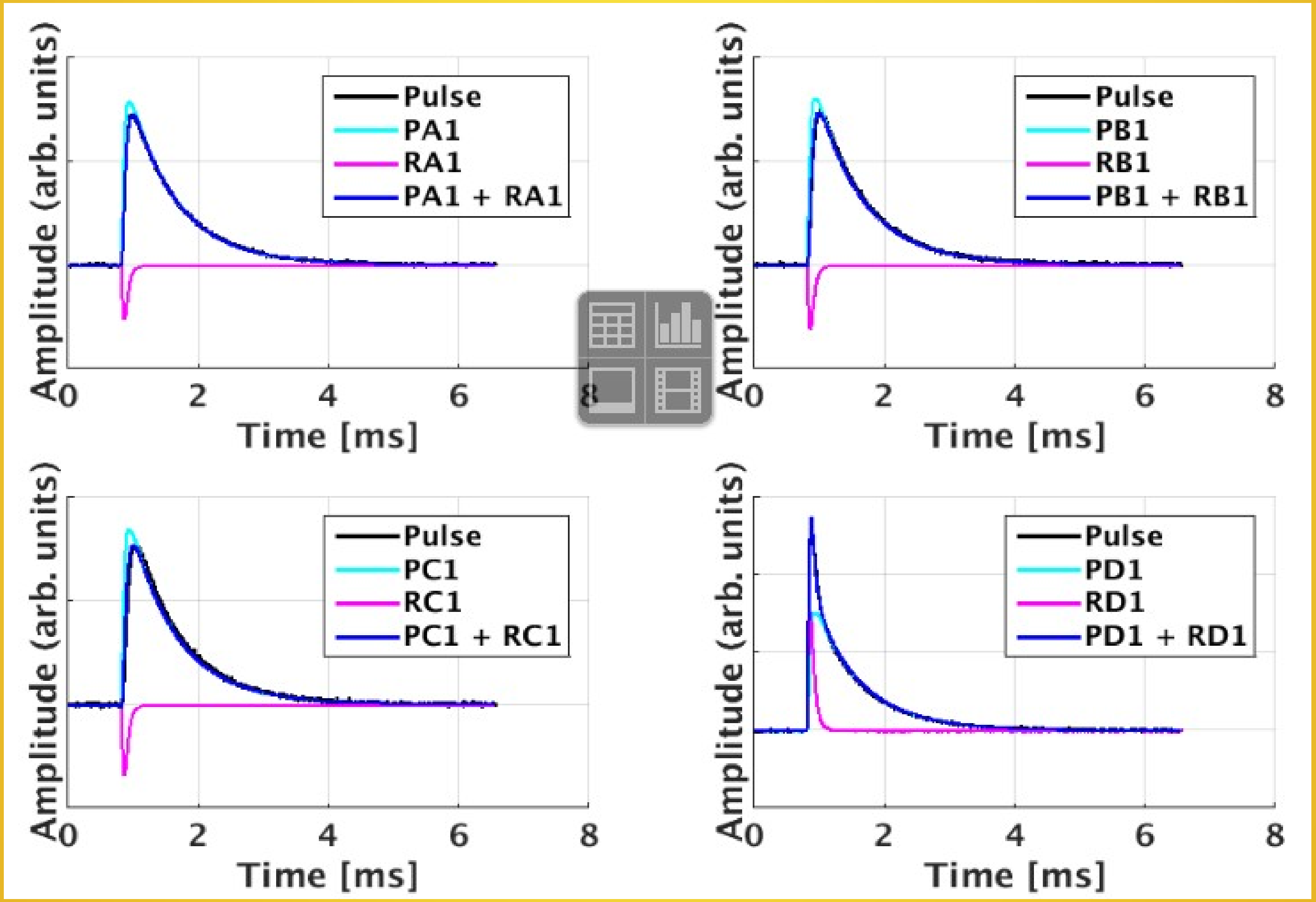
Templates

- The pulses are averaged to created a “slow template”
- The residuals are averaged (after flipping the signs of those with negative amplitudes) to form a “fast template.”
- Events are then fit to a combination of the two



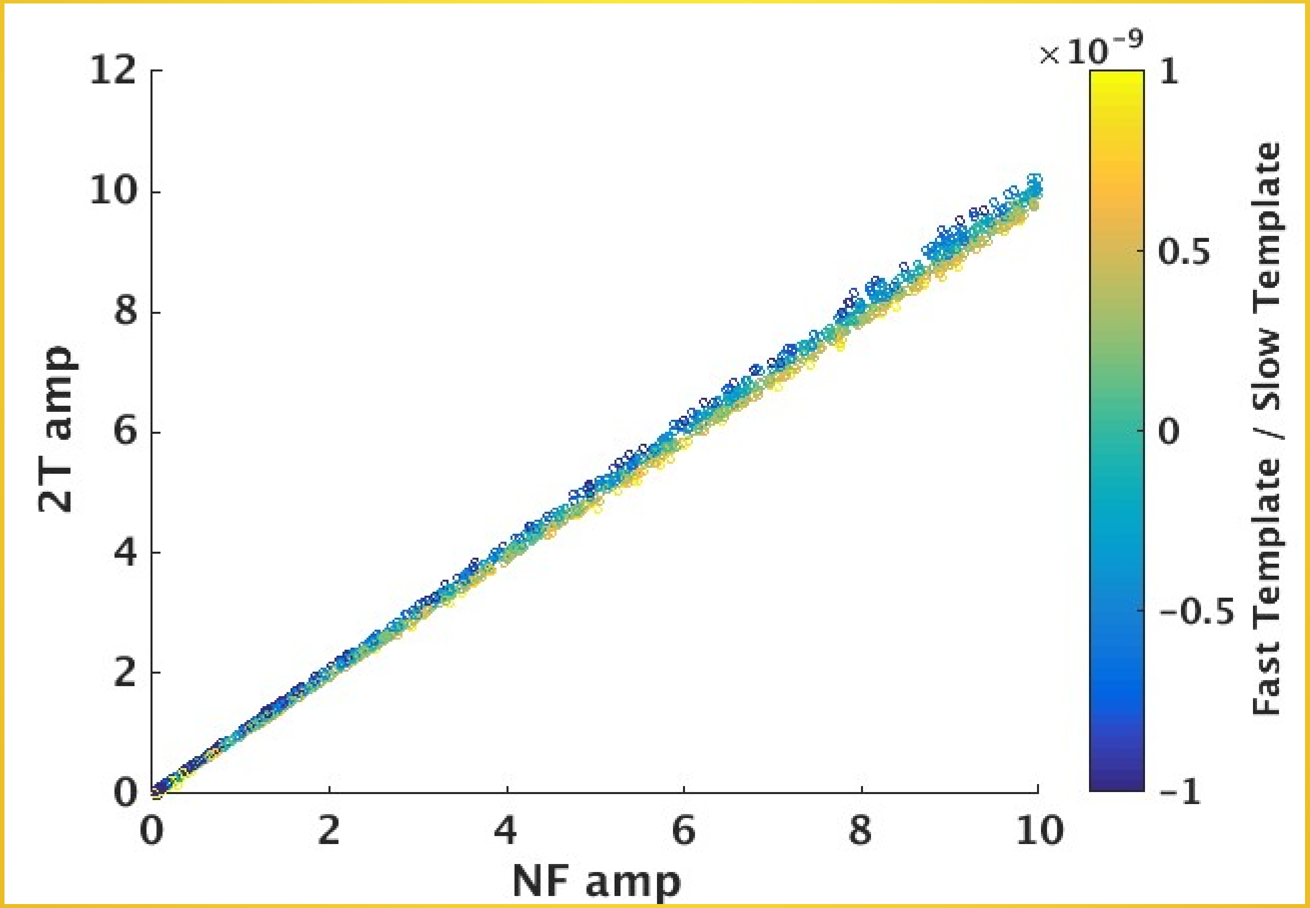


Collection of Raw Pulse with fit in 4 channels of a SuperCDMS detector



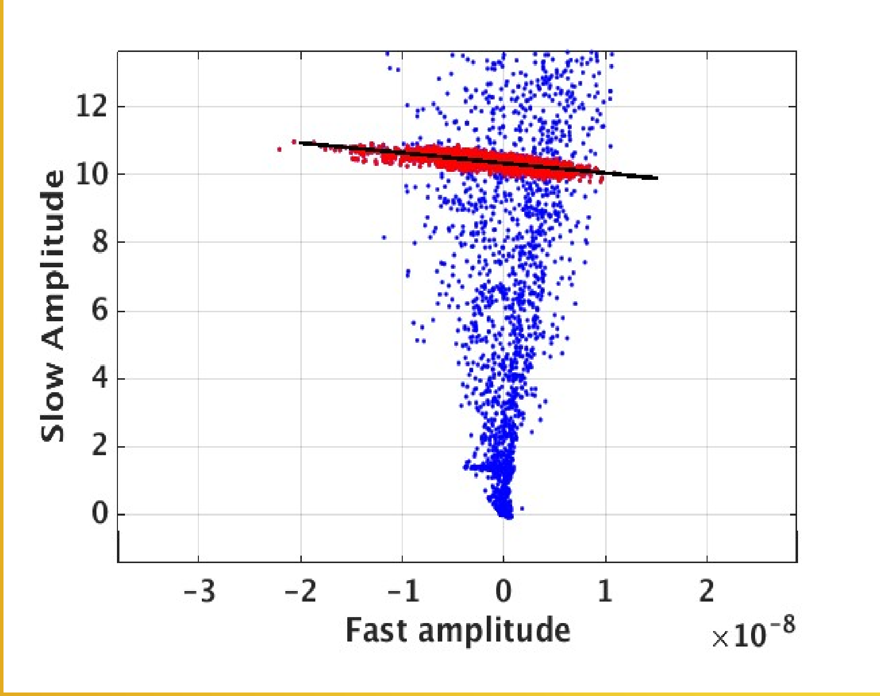
Slow amplitude Energy estimator

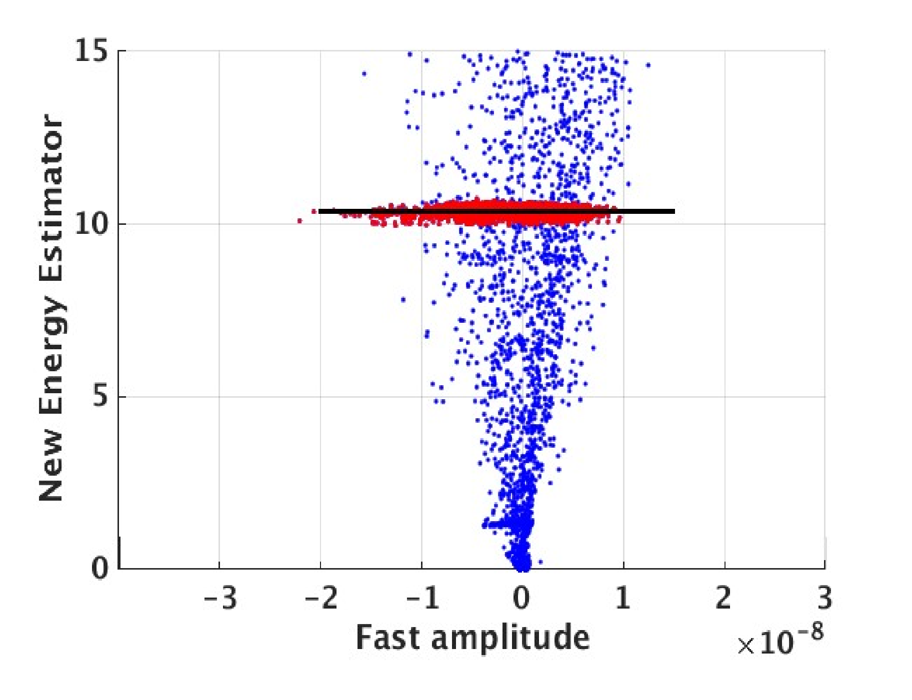
- The slow amplitude alone does not make a perfect energy estimator.



10 keV line and corrections to Energy Estimation

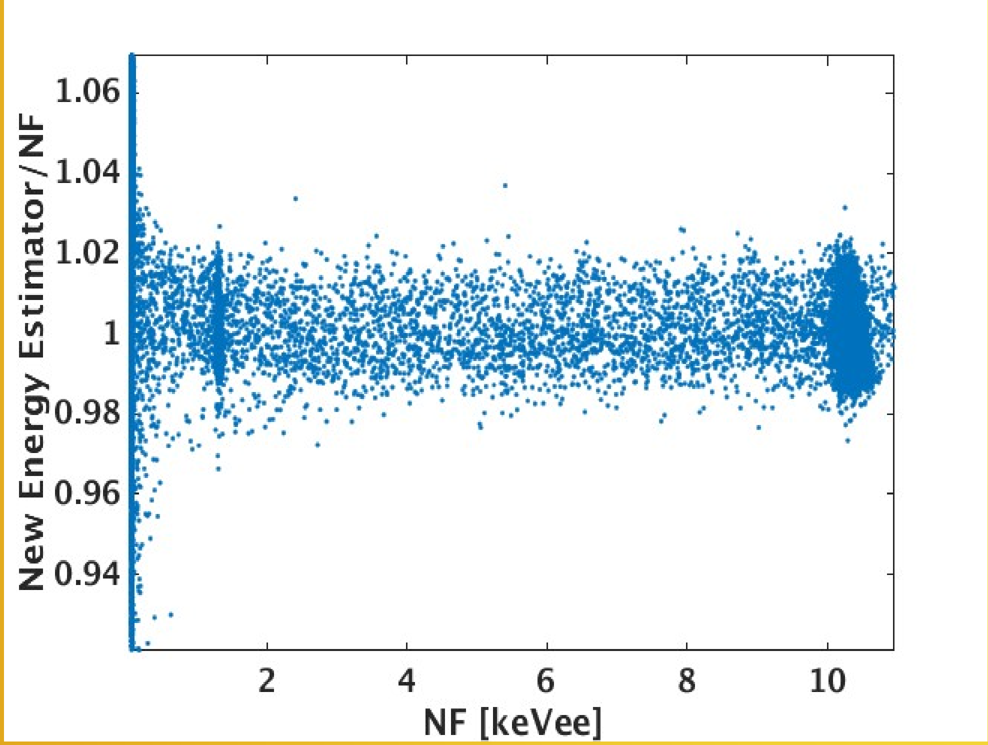
- Internal activation from Ge-71 can form a strong energy line which can be used to calibrate the detector/algorithms
- By plotting slow vs fast amplitudes, we can see their correlation. We can improve the energy estimator by adjusting for this.

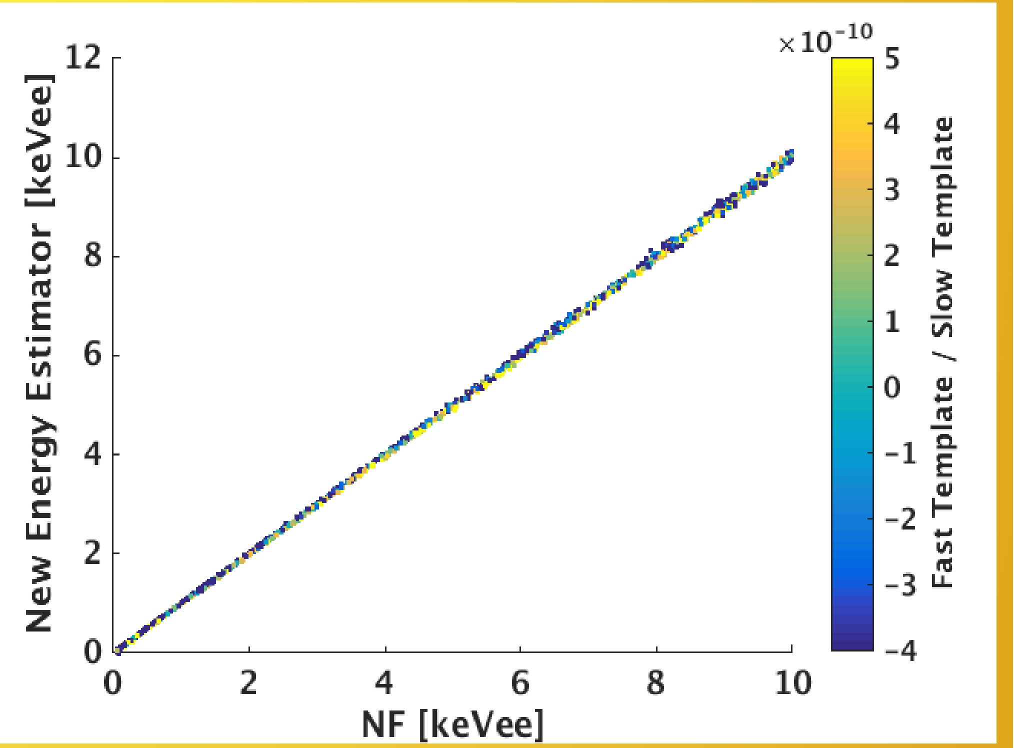




Comparison to NF

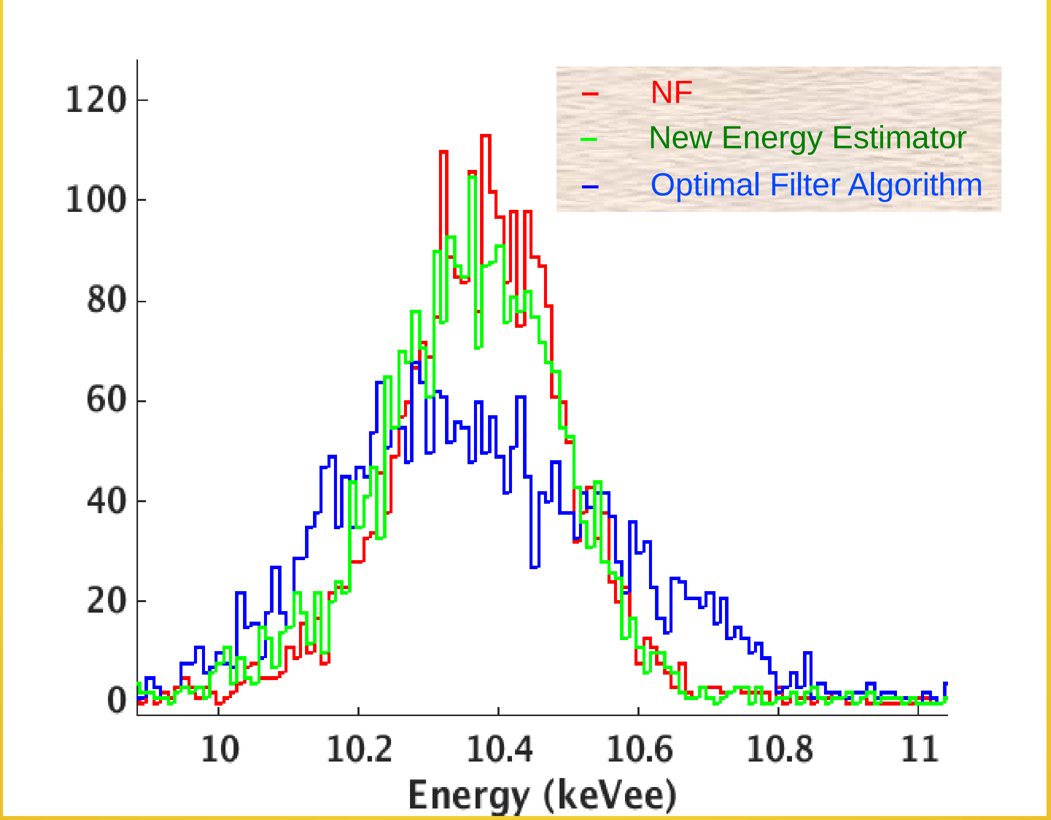
- Corrected Two-Template energy estimator differs by less than 2 percent from non-stationary optimal filter amplitude and has similar resolution





Energy Resolution

- The energy resolution at the 10 keV line of the Non-Stationary and Two-Template Algorithms is comparable



Is it worth it?

- Energy resolution appears to be comparable
- However, processing time for the new two-template energy estimator is faster
- Studies are underway which may show positional information reconstructed from the fast template can outperform current position algorithms