# Effects of Event Topology on CUORE $TeO_2$ Bolometer Energy Reconstruction


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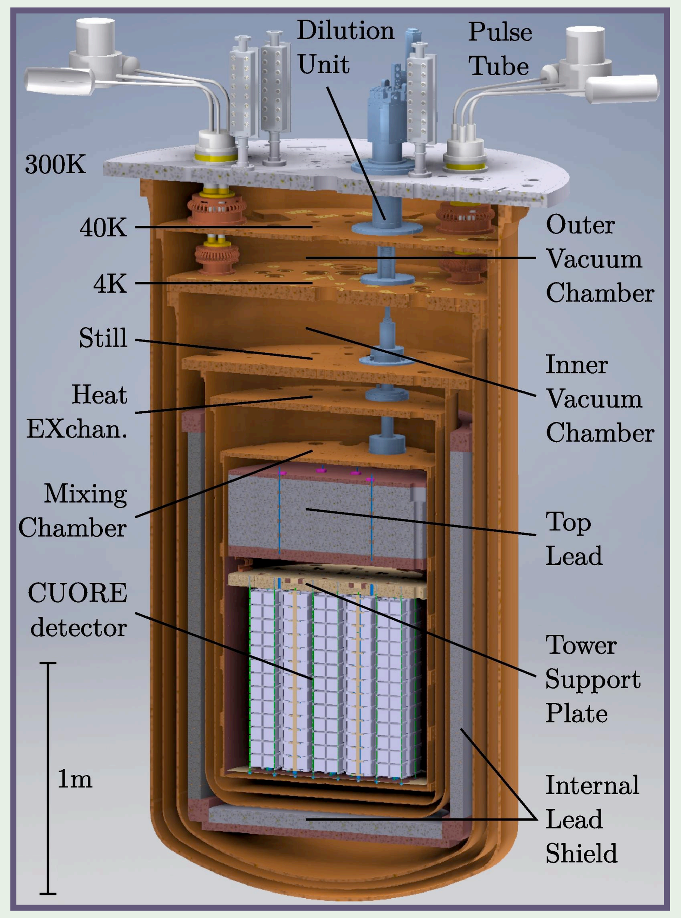
Poster #101


## THE CUORE DETECTOR

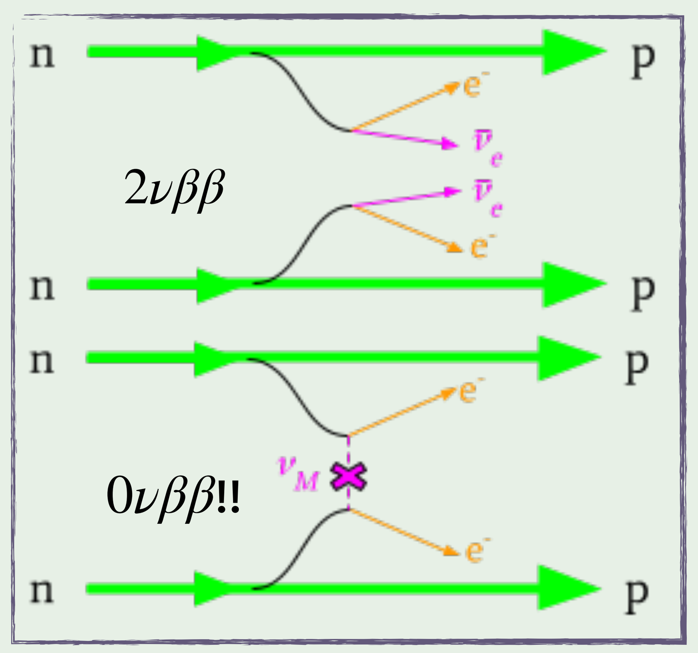



### Che is CUORE?

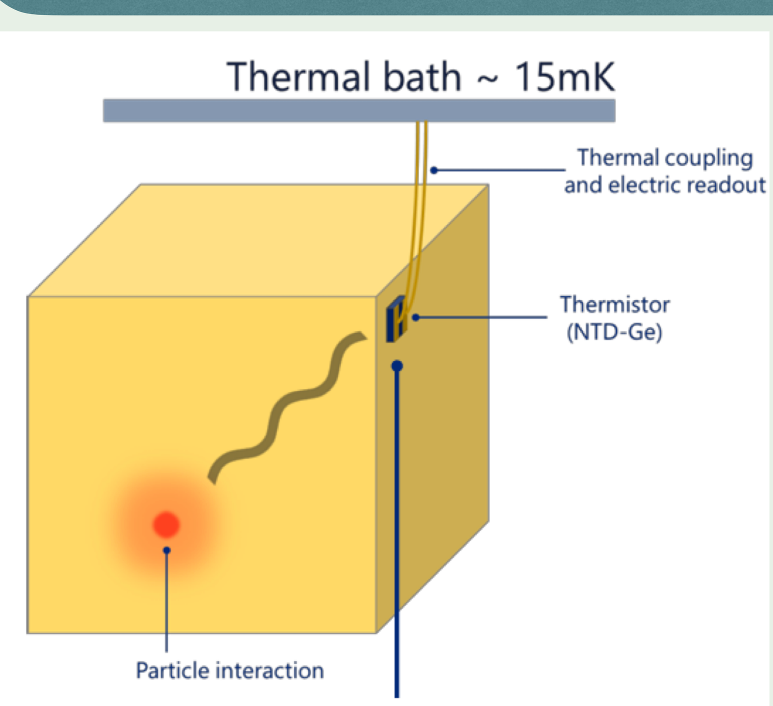
- The Cryogenic Underground Observatory for Rare Events
- 988 $TeO_2$ crystal cryogenic calorimeters
- 742 kg active mass
- 206 kg of $^{130}Te$ (double beta decay isotope)
- Located in LNGS, Gran Sasso, Italy
- Operating since 2017 — 3000+ kg•yr of $TeO_2$ exposure

### What are we looking for?

- Neutrinoless Double Beta Decay ($0\nu\beta\beta$)
- $Q_{\beta\beta} = 2527.5\ keV$




## CUORE BOLOMETERS

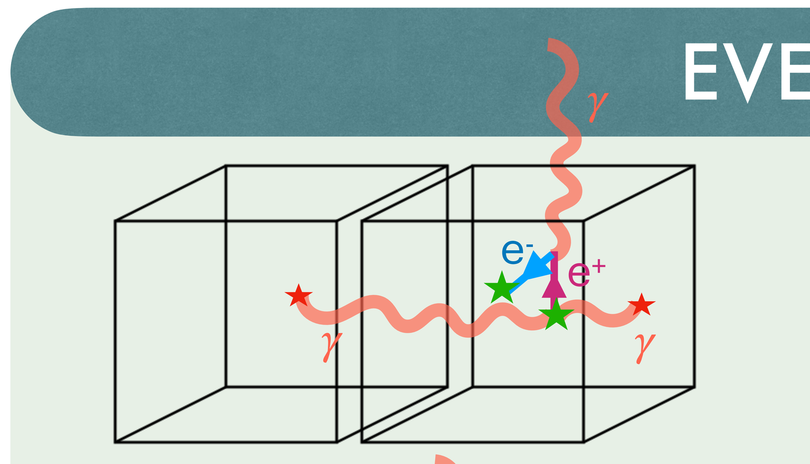



- $TeO_2$ crystal cryogenic calorimeters (bolometers)
- Maintained at ~10 mK
- Pulse energy readout by NTD-Ge (Neutron Transmutation Doped Germanium) thermistor

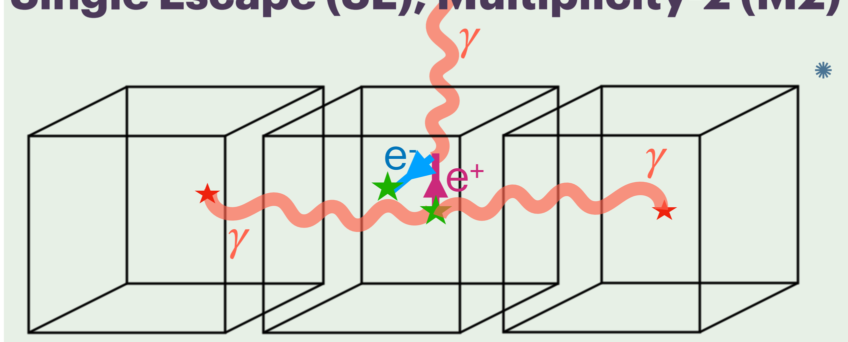
## CUORE/CUPID @ $\nu$ '26

- # 224: Latest Results from the CUORE Experiment, T. Hurst
- #291 : Event topology in energy reconstruction in CUORE, E. Brandani
- #326 : End-to-End Data Analysis Methods of CUORE, K. Alfonso
- #294 : Search for Baryon Number Violation with CUORE, V. Sharma
- #111: Low Energy Techniques in CUORE Experiment, R. Kowalski
- #307: The CUPID 0νββ Experiment, H. Khalife
- #149 : Towards CUPID-1T: microwave multiplexing, S. Ghislandi
- #312 : NTL Light Detectors for the CUPID Experiment, A. Giuliani
- #303: Multiplicity-2 Analysis in CUORE and CUPID Experiment, T. Zhu

## EVENT TOPOLOGY




**Single Escape (SE), Multiplicity-2 (M2)**




**Double Escape (DE) Multiplicity-3 (M3)**

- $0\nu\beta\beta$ and beta events in general have some probability of escape events
  - ★ 511 keV absorption
  - $\Sigma$ ★ Kinetic energy absorption: $E_{transfer} = hf_\gamma - 2m_ec^2$
- Signature of these events is a peak at
  - $E_\gamma$ - 511 keV for SE
  - $E_\gamma$ - 1022 keV for DE
- Escape events are most likely near calorimeter surface.
- Events are classified by topological relationships. Channels may share:
  - Face (F), Corner (C), Edge (E), None (N)

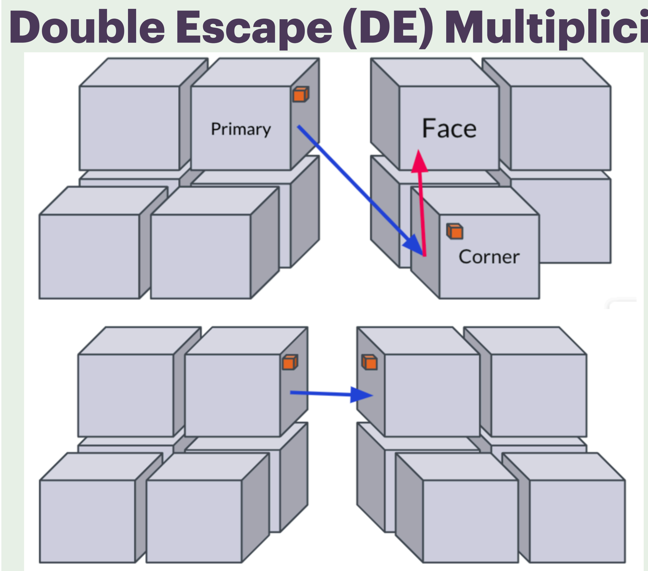
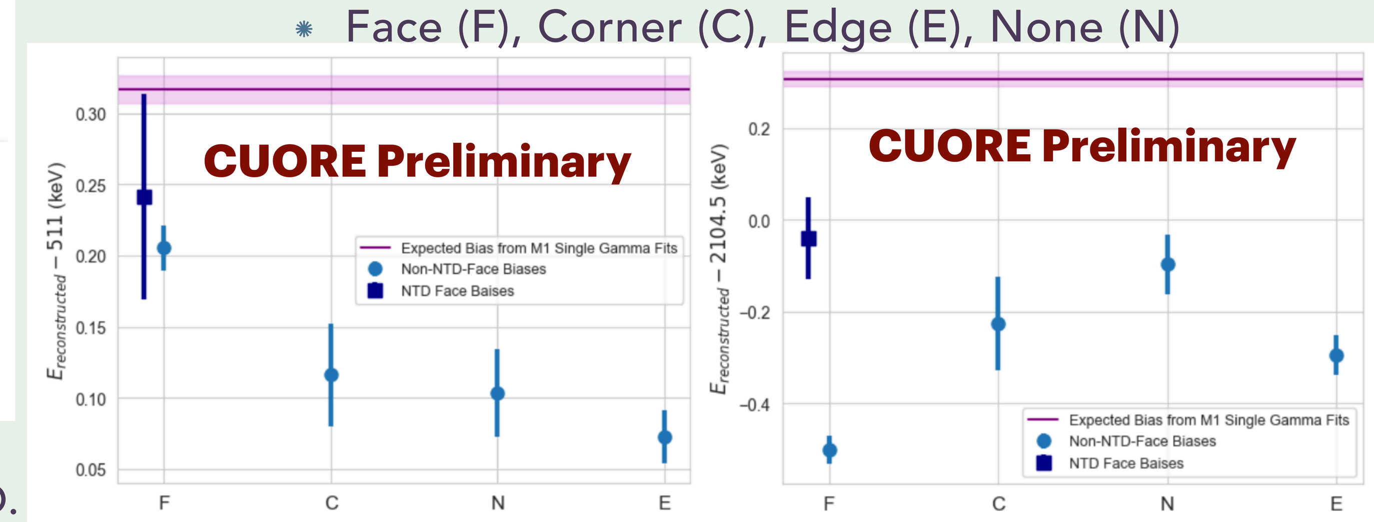
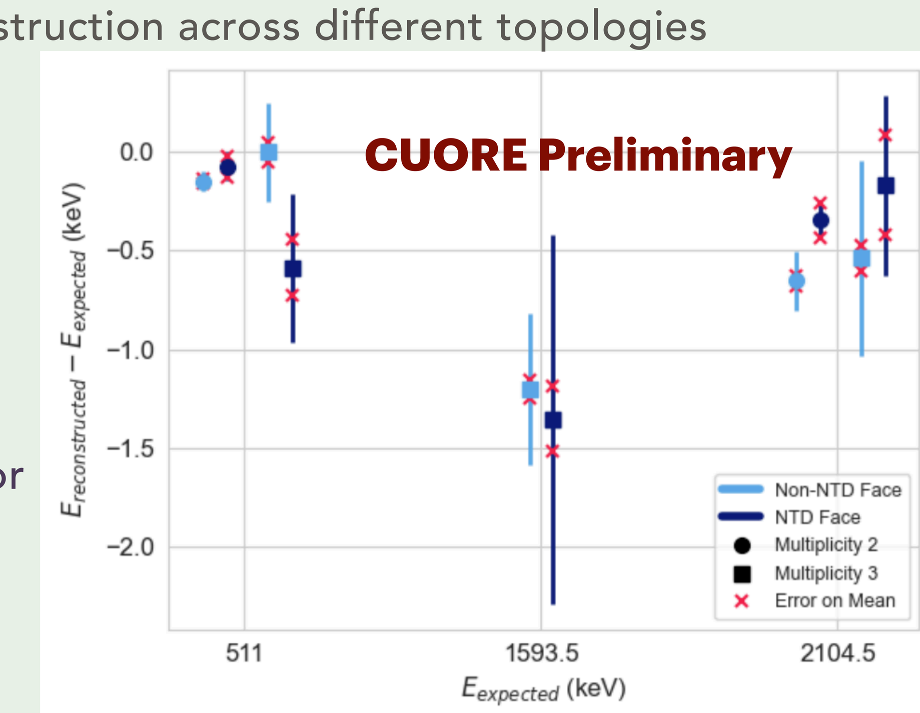



Illustration of possible event topologies. Orange cube is NTD. Bottom is NTD-Face event Top shows non-face M3 SE event with Compton scattering



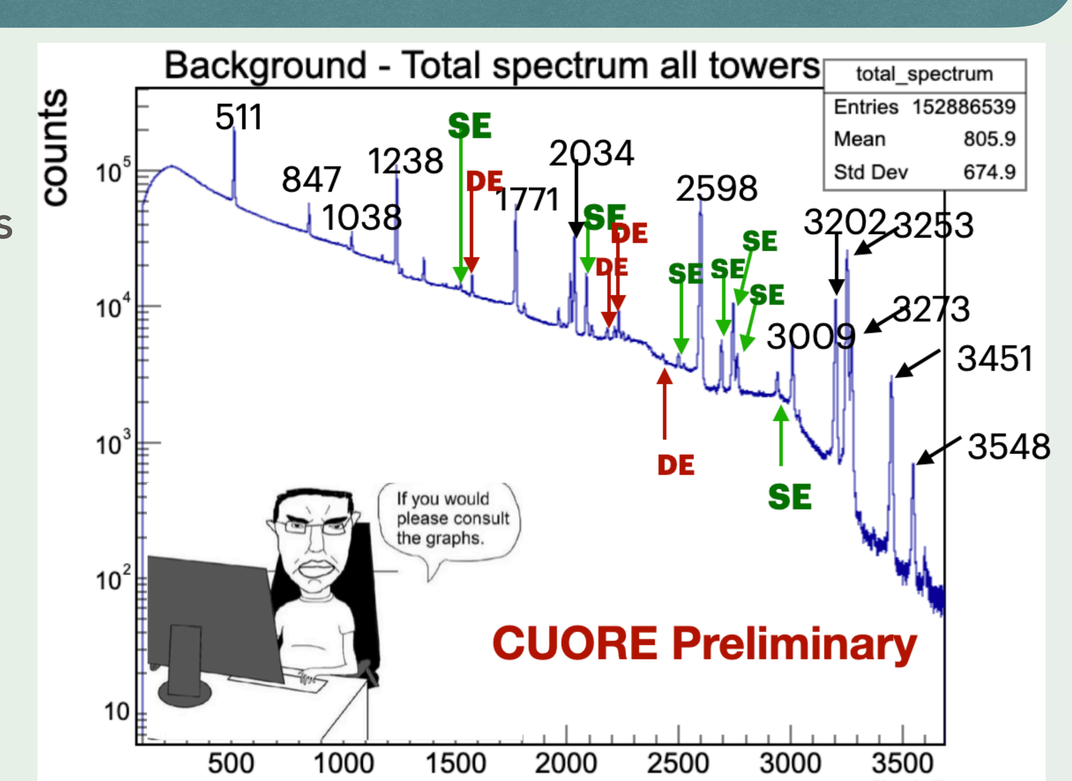

Multiplicity-2 (M2) events demonstrate distinct variation in energy reconstruction across different topologies

- By organizing events into NTD-Face events and non-NTD-Face events with defined topologies and fitting the energy distributions to multi-gaussians, we can directly analyze topological dependence.
- Plot to the right shows error bars, representing standard deviation in bias across all topologies for a given energy peak, growing with respect to energy for each multiplicity.
- This demonstrates positional dependence of phonon reconstruction in CUORE bolometers



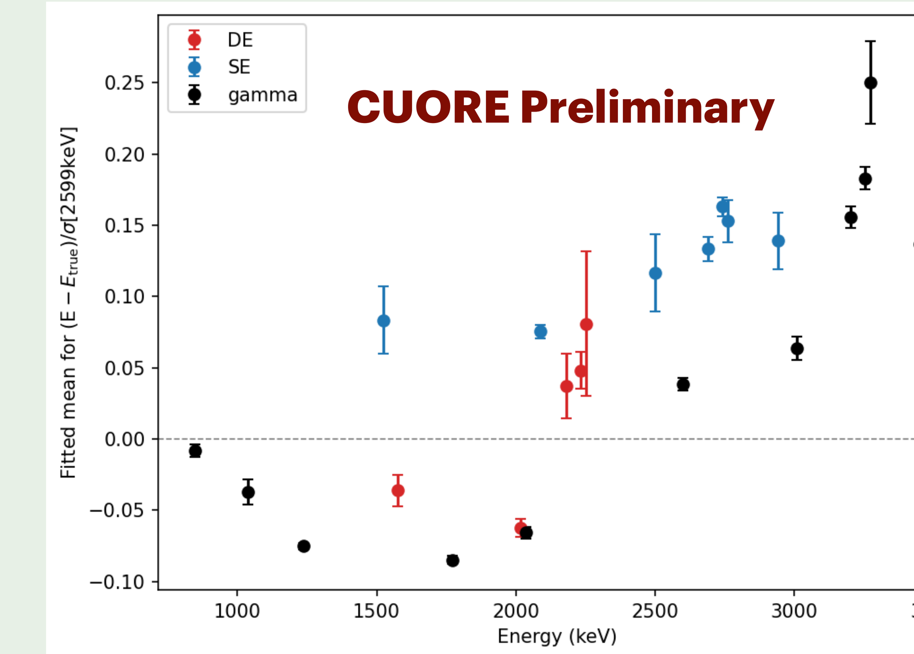

## COBALT-56 CALIBRATION

- CUORE datasets consist of 4-5 day calibration runs using $^{232}Th$ and $^{60}Co$
- $^{56}Co$ has many more prominent $\gamma$ peaks at a wider range of energies (but has a much shorter lifetime)
- Irradiated Nov 2024
- Deployed mid-April 2025
- 90 kBq activity early-May 2025
- ~1900 hours of data
- Optimal for widening the scope of these energy dependent analyses

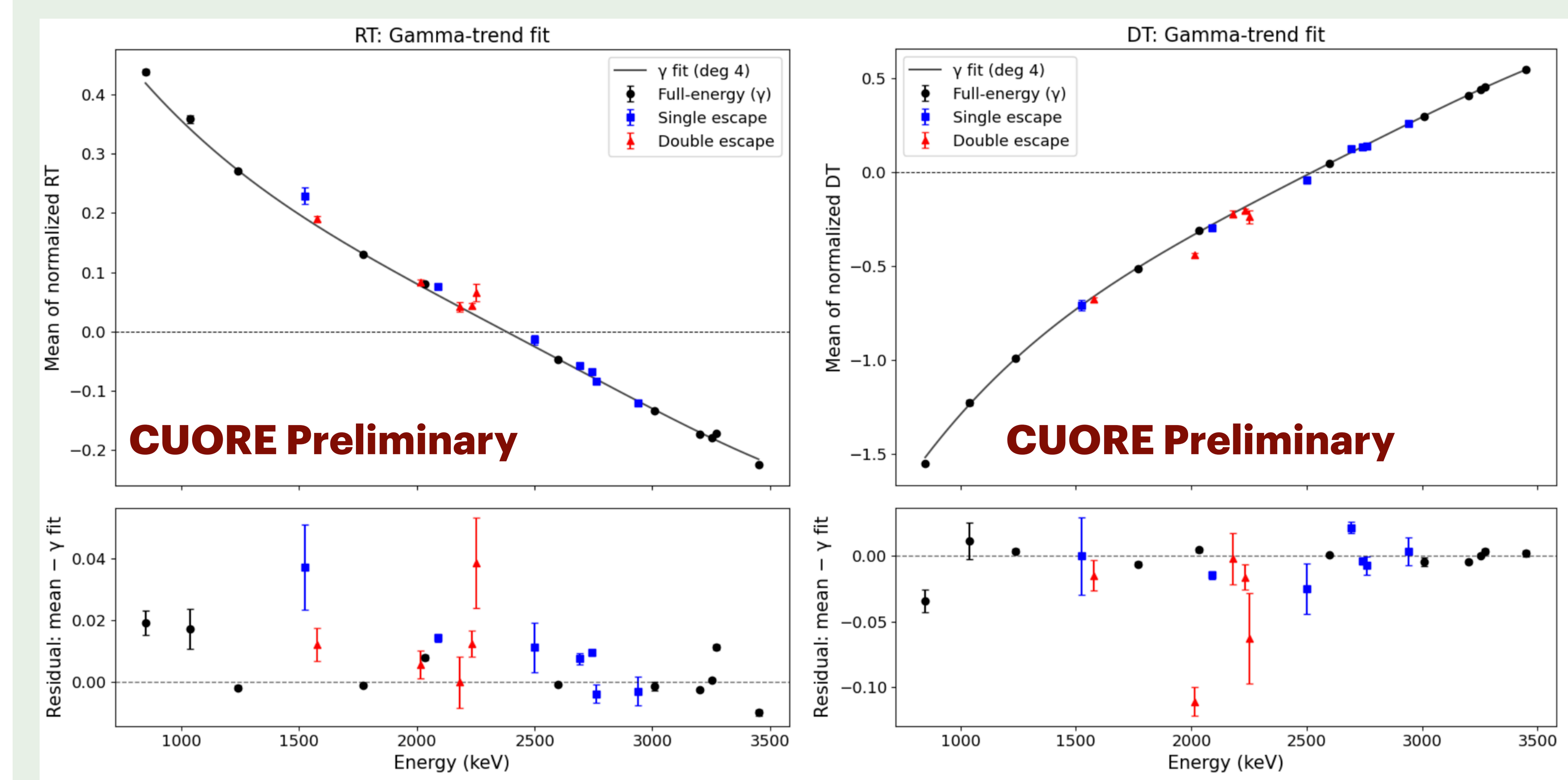



## ENERGY BIAS

- We use $^{56}Co$ calibration data to analyze energy dependence of energy reconstruction bias for different event types ($\gamma$, SE, DE).
- We see clearly separate bands of reconstruction bias for each event type




## PULSE PARAMETERS




- Using $^{56}Co$ calibration data, we look at pulse shape parameters and average the parameter distributions for each energy peak
- Parameter distributions are normalized by: $z_{\text{normalized}} = \frac{z - \langle z \rangle_{2599keV,\text{ch}}}{\sigma[z]_{2599keV,\text{ch}}}$, where ch is a given channel and $z$ is a given pulse shape parameter
- By classifying by $\gamma$, SE, and DE and understanding that these are correlated with event topology, we can investigate the discrepancies in energy bias across different event types.
- From the above plots, we see that there may be some anomalous behavior in SE and DE events relative to the behavior of gamma events for pulse rise time and decay time. This is an ongoing investigation.

## ACKNOWLEDGEMENTS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