Energy Calibration for the GERDA Experiment

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On behalf of the GERDA Collaboration

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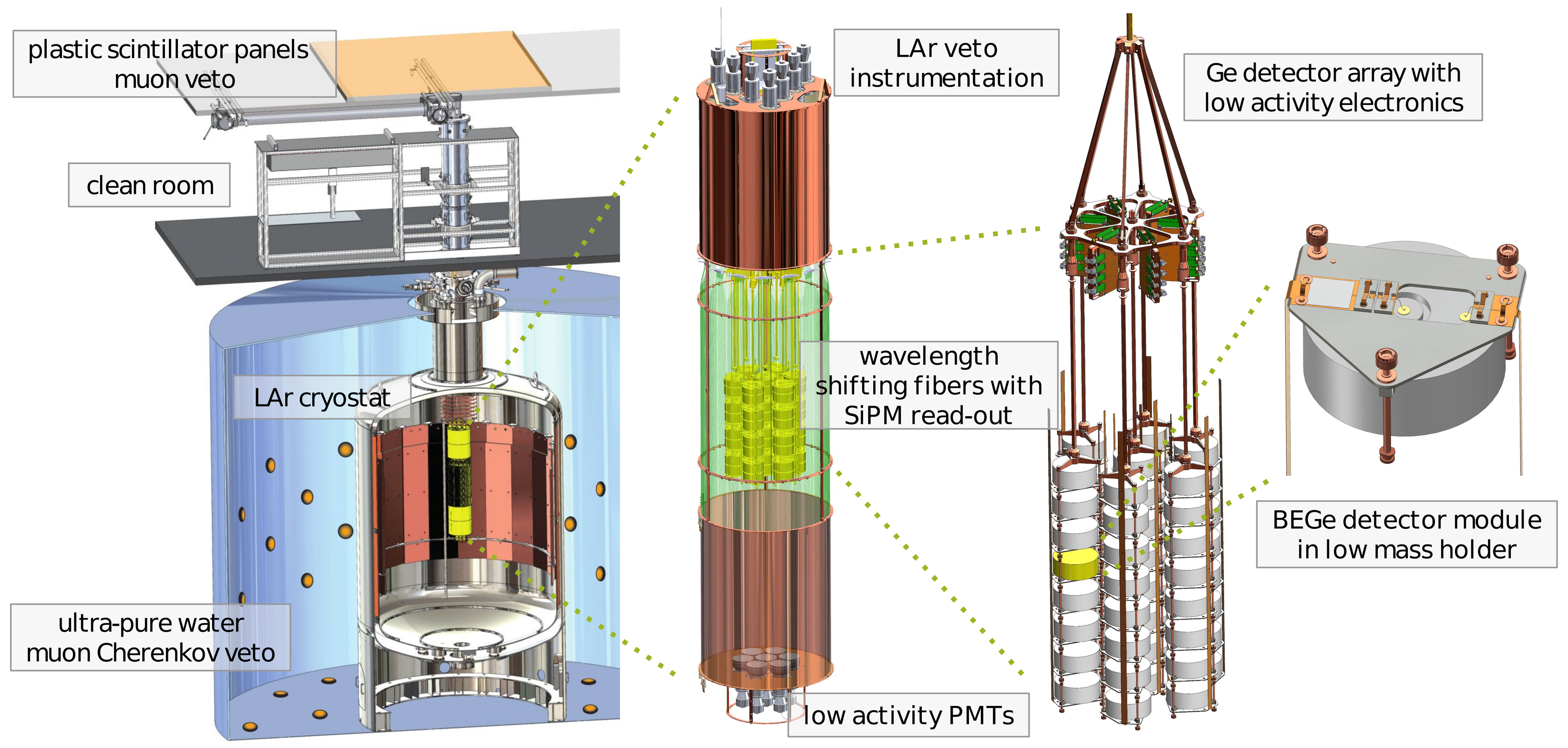
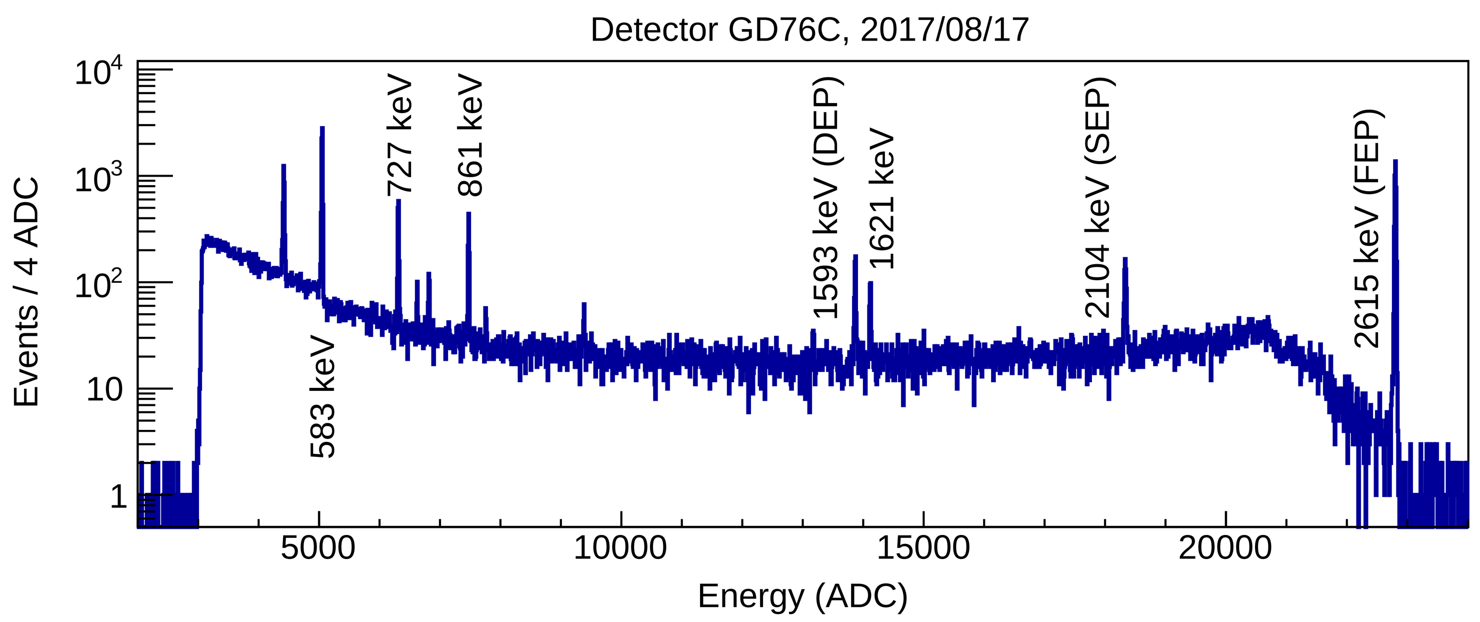
1. GERDA Experiment



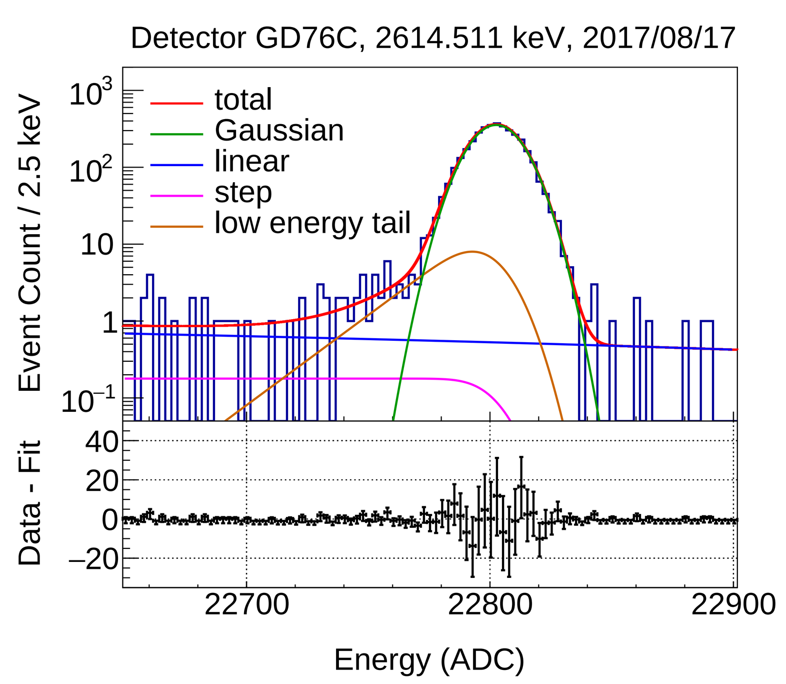
- Search for neutrinoless double beta decay in ^{76}Ge at LNGS.
- Use enriched high-purity Ge diodes as both source and detector.
- Energy resolution plays a key role in searching for signals at $Q_{\beta\beta}$.

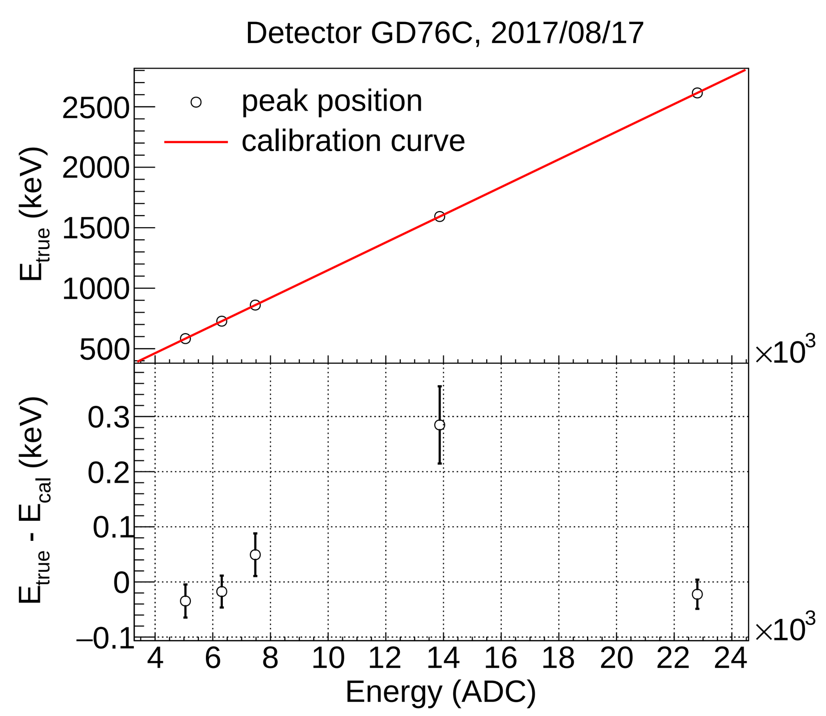
2. Calibration Spectrum



- Use ^{228}Th as the source, deployed by a source insertion system.
- Perform weekly calibrations. See above for an example spectrum.

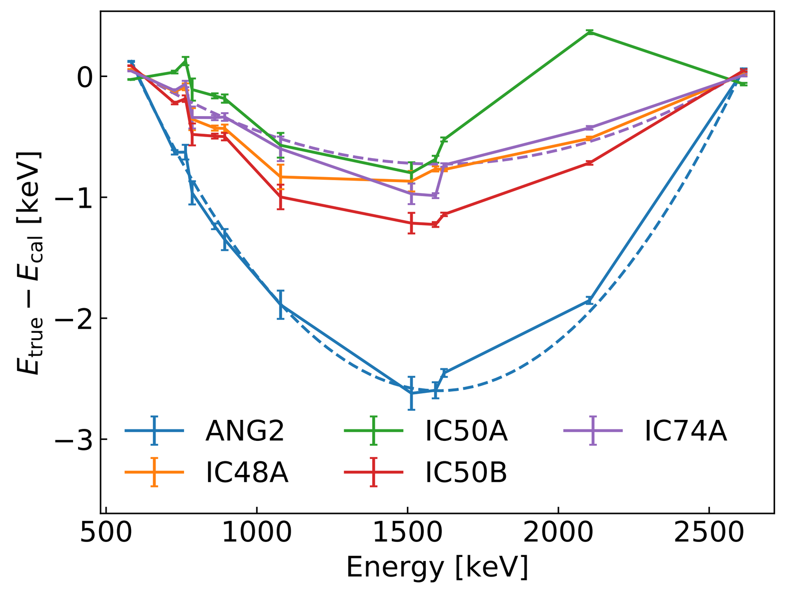
3. Energy Scale

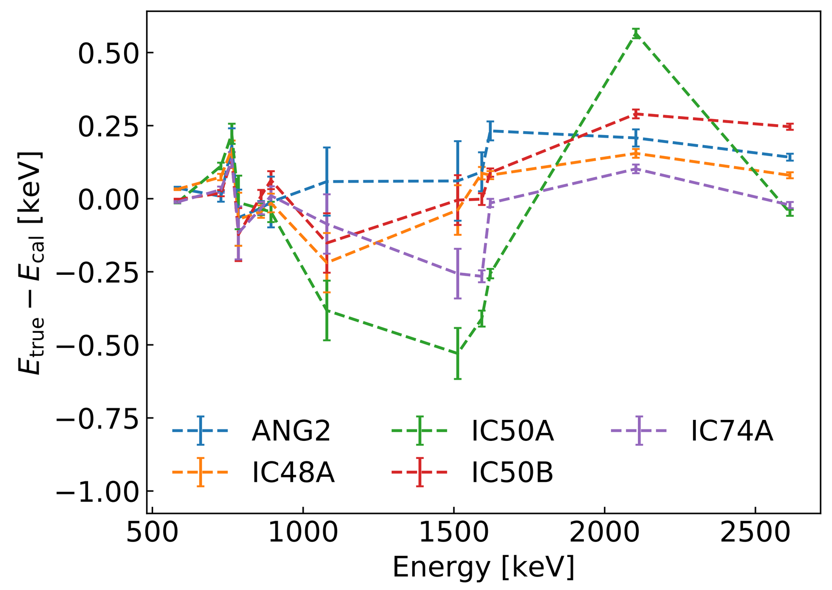




- Fit gamma lines with models of Gaussian plus backgrounds (left).
- Use linear calibration curve to convert ADC to keV (right).
- Extract FWHM from the width of the Gaussian component.

4. Quadratic Correction

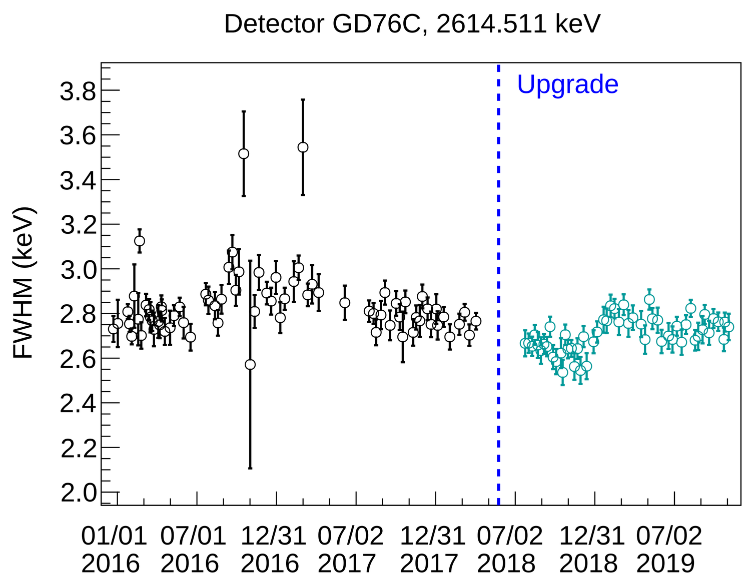


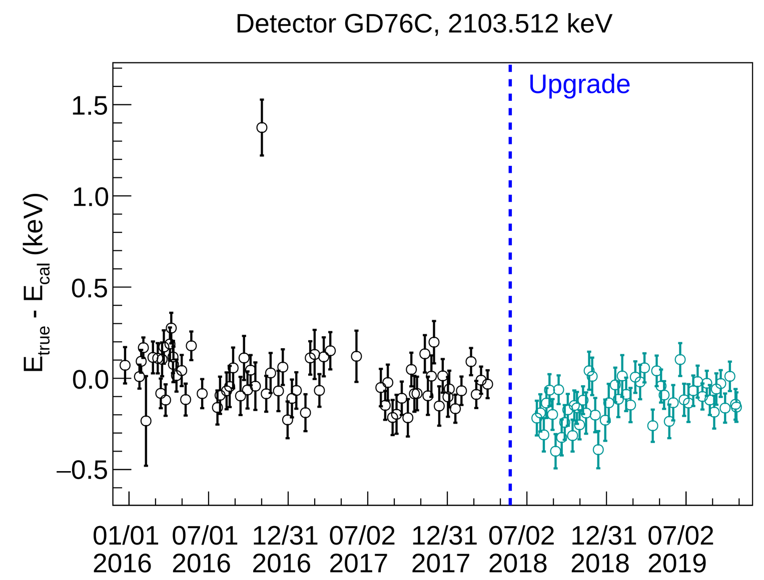


- 5 detectors have relatively large deviations from linearity. The residuals (true minus calibrated energy) are shown above (left).
- Apply quadratic corrections to reduce nonlinearity (right).

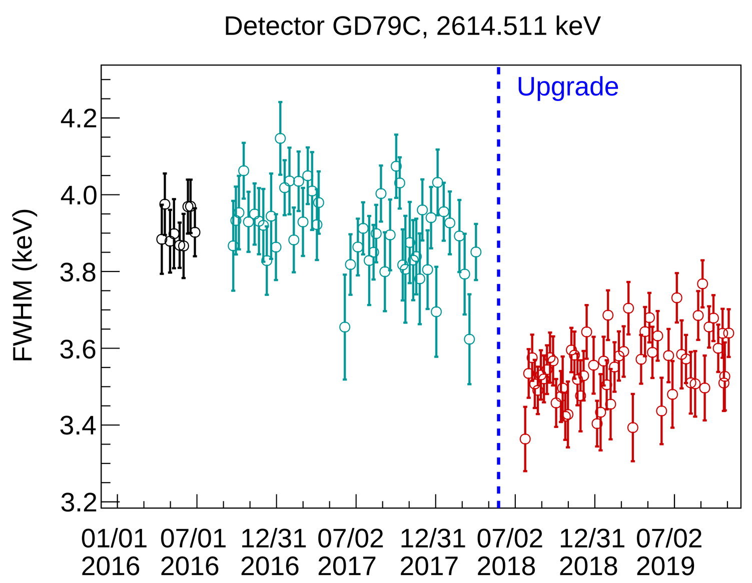
5. Partitioning of the Data Taking Period

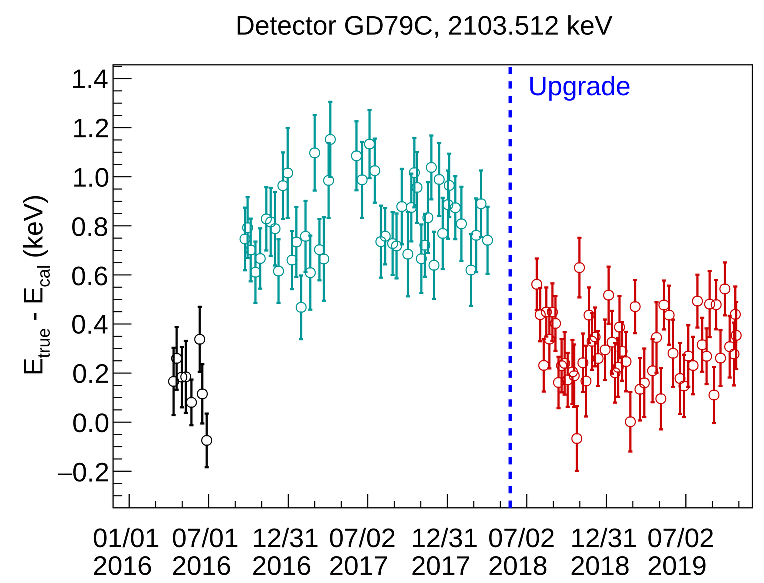
- Majority of the detectors operated stably during data taking.
- An example is shown below. Left: FWHM vs. time at the full energy peak (FEP). Right: residual vs. time at the single escape peak (SEP).





- Some detectors show "jumps" over time due to hardware changes. Below is an example. They show the same parameters as above, but for a different detector.

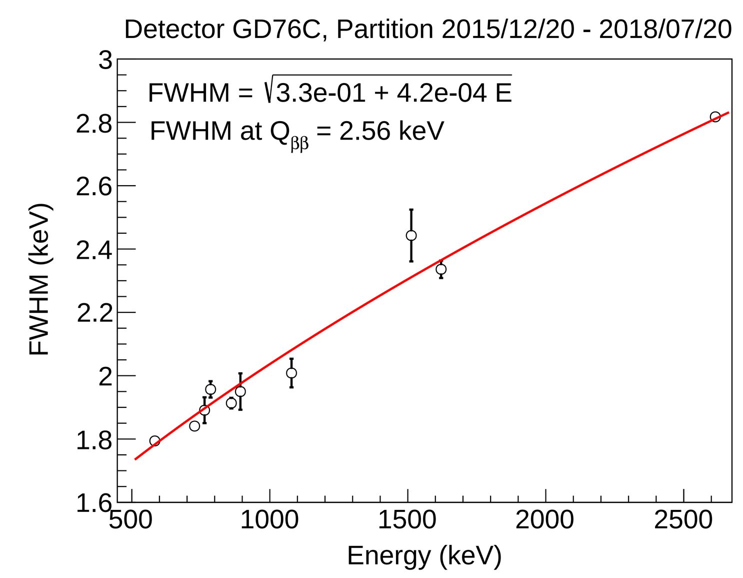


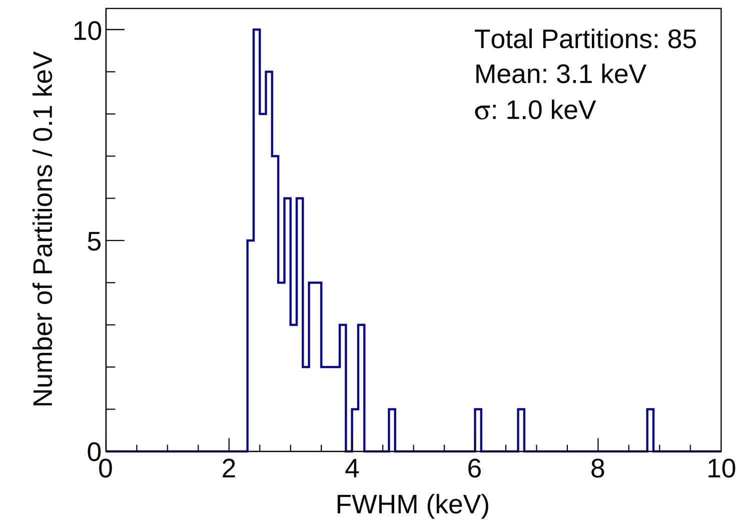


- Divide full data taking period into partitions for each detector (represented by different colors in the plots above):
  - Compute parameters, such as FWHM, for each partition.
  - Construct a lookup table for events in the region of interest.

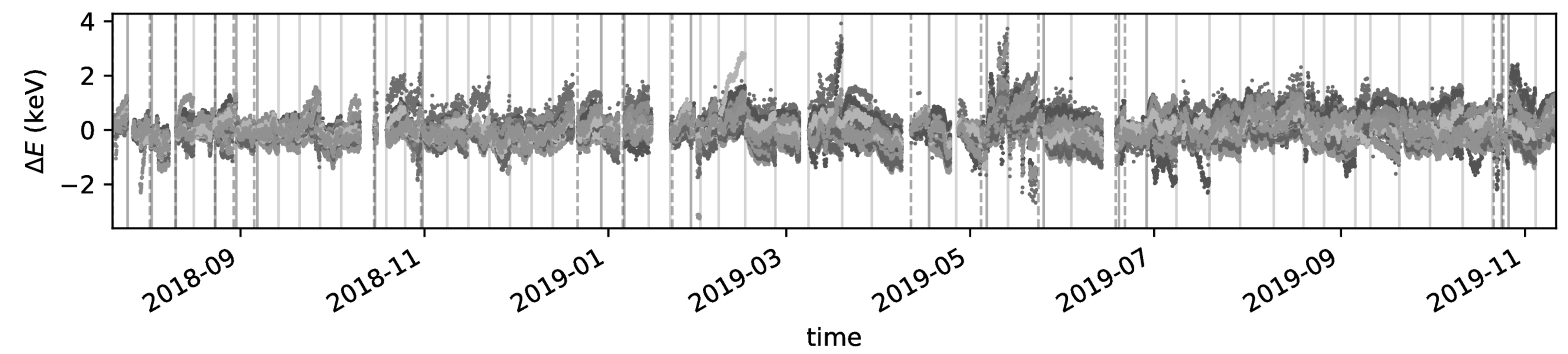
6. FWHM per Partition

- Aggregate the spectra in a partition, after normalizing them by exposure and weighting them based on their validity times.
- Fit the FWHMs from different gamma lines with $\sqrt{A + BE}$, obtain the value at $Q_{\beta\beta} = 2039.1$ keV (left below).
- **FWHM per partition is 3.1 keV** on average (right below).

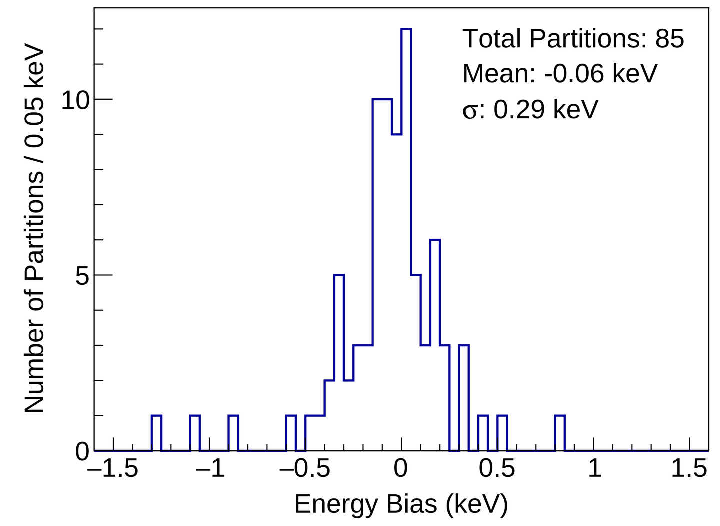


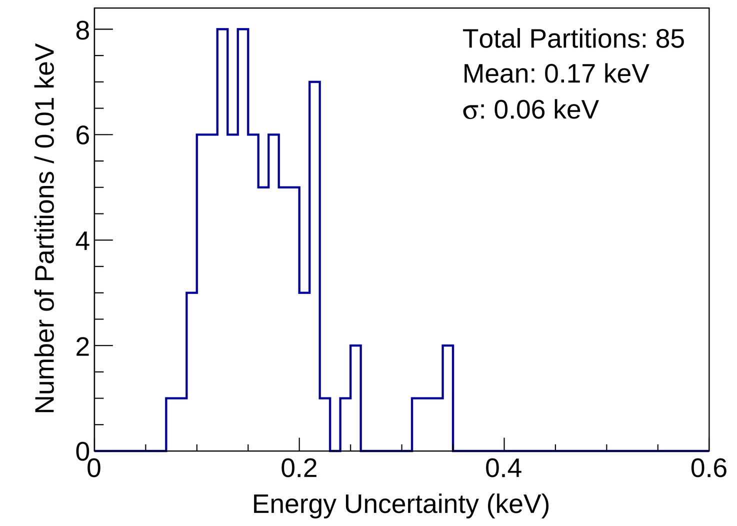


- **FWHM uncertainty is 0.14 keV** on average, mainly from:
  - The stability of the physics data measured by the test pulses injected into all preamplifiers every 20 s (see below).
  - Fluctuations at FEP scaled down to $Q_{\beta\beta}$ using $\sqrt{E}$ relation.



7. Energy Bias and Uncertainty near $Q_{\beta\beta}$





- **Little energy bias** on average, based on residual at SEP (left).
- **Energy reconstruction uncertainty is 0.17 keV** on average, determined by the fluctuation of the residual at SEP (right).

8. Reference

GERDA Collaboration (M. Agostini *et al.*), "Probing Majorana neutrinos with double-β decay," Science **365** (2019), 1445 doi:10.1126/science.aav8613 [arXiv:1909.02726 [hep-ex]].