Energy calibration of the GERDA experiment

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The main goal of GERDA

· Search for neutrinoless double beta decay (0νββ)
· Q value of the reaction: $Q_{\beta\beta}$= 2039.061(7) keV
· Signature: sharp peak at the endpoint of 2νββ spectra

Half life of 0νββ *decay:*

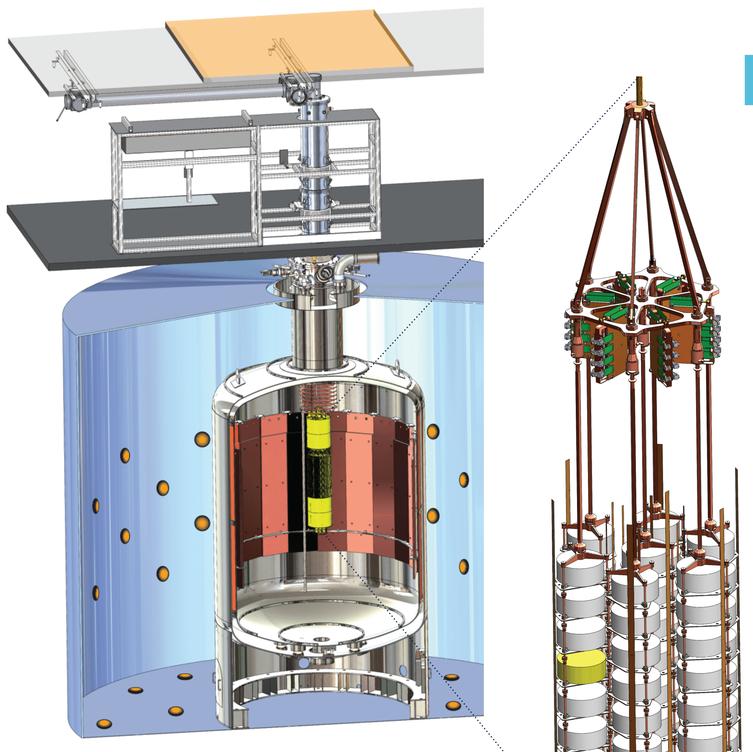
$$T^{0\nu}_{1/2} \propto \sqrt{\frac{M\,t}{BI \cdot \Delta E}}$$

M·t - exposure, BI - background index,
ΔE energy resolution (FWHM)

Peak position and resolution are strong priors for 0νββ analysis -> precise, accurate and stable energy scale is crucial.

^{76}Ge detectors in GERDA

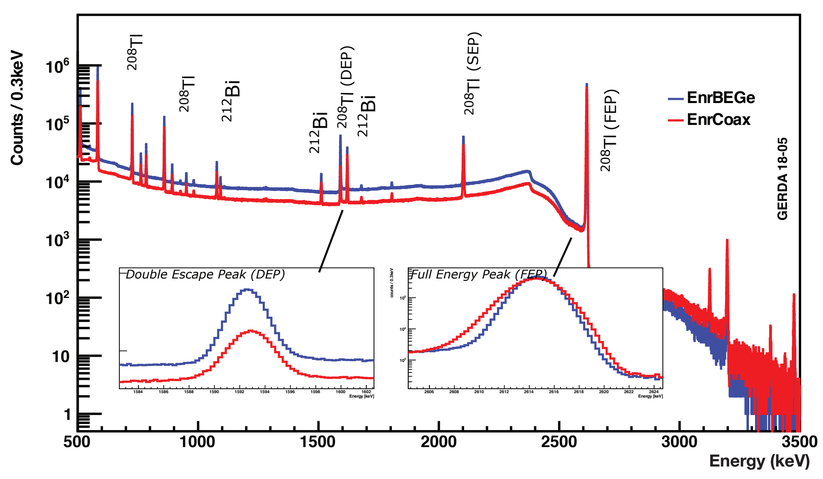
· Enriched up to 87% of ^{76}Ge
· Total mass: 35kg
· 40 channels
· Excellent relative energy resolution: 2‰ at $Q_{\beta\beta}$



Calibration

Three encapsulated low neutron emission ^{228}Th sources (from 24 to 41 kBq) are used for the regular energy calibration of germanium detectors. Three individual calibration units are mounted on the top flange of a liquid argon cryostat lock.

Calibration plays a crucial role in the experiment: determines energy scale and resolution of ^{76}Ge detectors.



Energy spectra from the combined calibration runs for the enriched BEGe (BEGe) and Coaxial detectors (Coax). The most prominent lines from the ^{228}Th decay chain are marked.

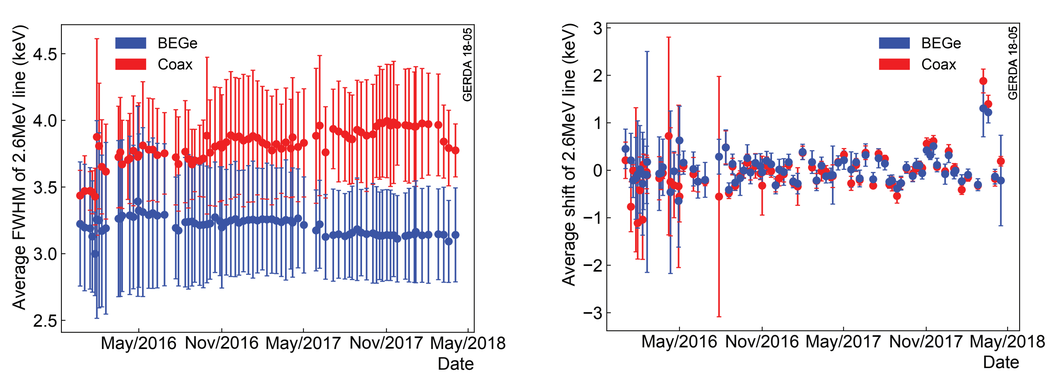
Analysis of the combined calibration data

Goal:
· Estimate average parameters over detectors and experiment run time for the 0νββ analysis

Recipe:
· Sum all obtained spectra from the calibration runs to study average over time performance
· Analyse data spectra, i.e. exposure-weighted sum of the detector spectra

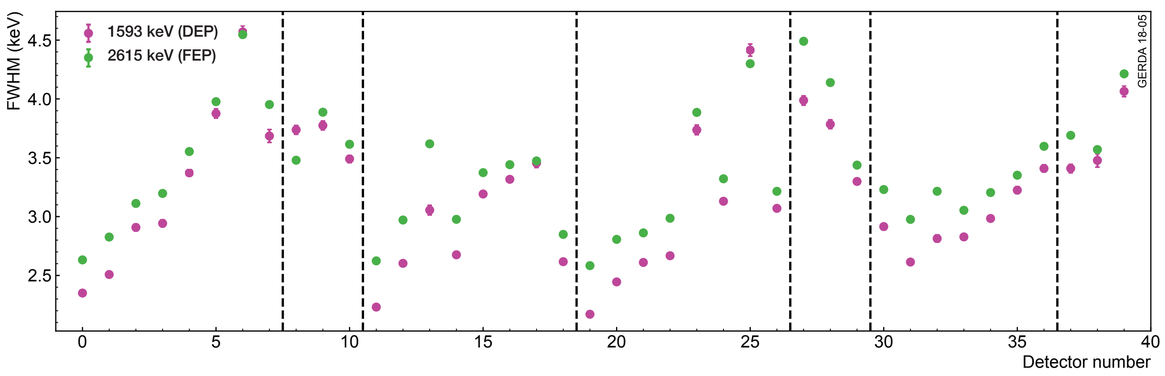
Energy scale and resolution stability

· Monitor detectors stability with the shifts and resolution of the most prominent gamma line from ^{208}Tl decay at 2.6 MeV
· Validate data selection for the 0νββ analysis



Average stability for the resolution and energy scale of the BEGe and Coax detectors over Phase II data taking.

Energy resolution from combined calibration data



Resolution of the Full energy and Double Escape peaks from the ^{208}Tl decay for individual detectors. The resolution of the 2.6MeV line is systematically worse, which is described by the energy depended function of the resolution.

Evaluation of the resolution at $Q_{\beta\beta}$

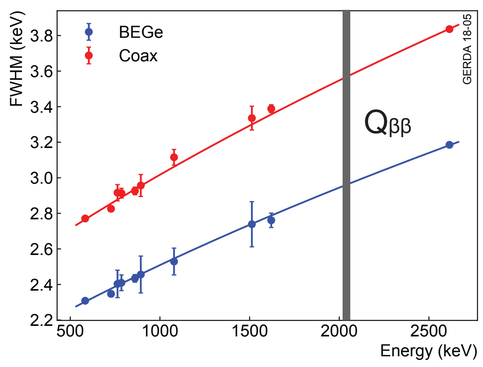
Combine spectra from individual detectors.
Estimated resolution of the individual peaks:

$$FWHM^2 = \frac{1}{Mt} \sum_{i=1}^{N_{det}} Mt_i \; FWHM_i^2$$

Extrapolated energy resolution over whole range with the function:

$$FWHM = \sqrt{A + B \cdot E}$$

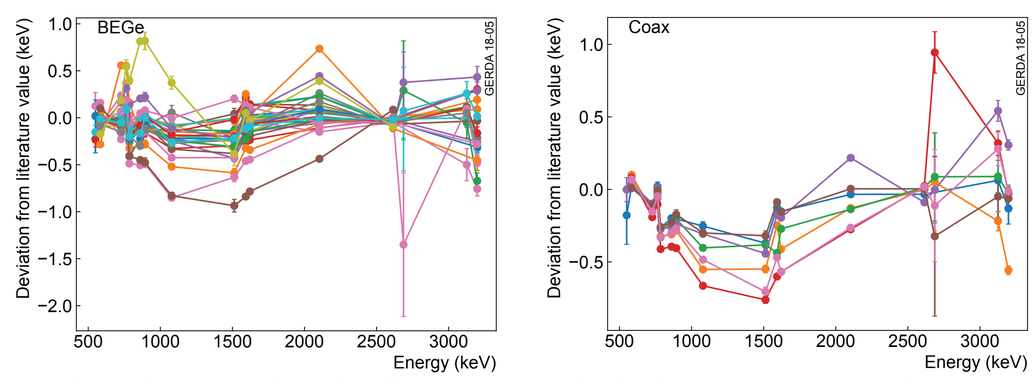
Estimated resolution at $Q_{\beta\beta}$:
BEGe: 3.0 ± 0.1 keV
Coax : 3.6 ± 0.1 keV



Average energy resolution (FWHM) for γ lines of the calibration spectrum. Error bars are estimated from the Gaussian fit of the peaks.

Systematic uncertainties

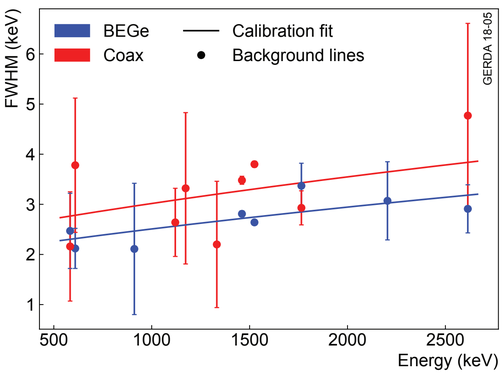
Caused by non-linearity from the electronics and calibration function uncertainties



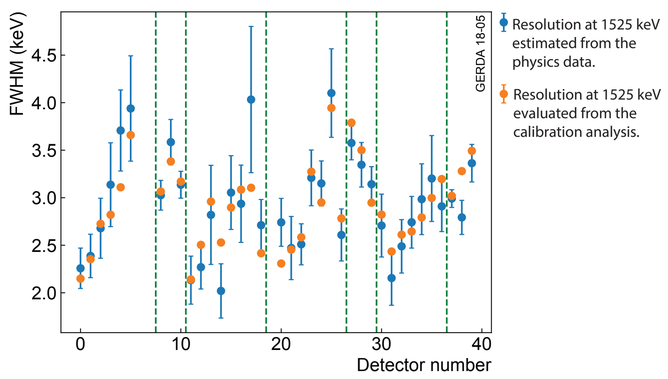
Deviation from the expected position of the gamma lines identified from the combined calibration data for all BEGe (left) and Coax (right) detectors.

The average over all detectors uncertainty is given by the RMS at $Q_{\beta\beta}$ value:
BEGe: 0.21 keV
Coax : 0.17 keV

Comparison with the background gamma lines



Resolution function from the combined analysis of the calibration runs compared with the resolutions of the low statistics background lines accumulated during much longer physics runs.



Resolution of the ^{42}K gamma line at 1525keV compared with values estimated from the resolution function for individual detectors.

Conclusion

- Precise, accurate and stable energy scale over Phase II data taking is crucial for the 0νββ analysis
- Calibration of GERDA with ^{228}Th sources
- System stability monitored with gamma lines from ^{208}Tl decay
- Systematic uncertainties at $Q_{\beta\beta}$ of 0.1‰ taken into account
- Resolution at $Q_{\beta\beta}$ energy for the 0νββ analysis estimated from the combined calibration spectra:
  BEGe: 3.0 ± 0.1 keV
  Coax : 3.6 ± 0.1 keV