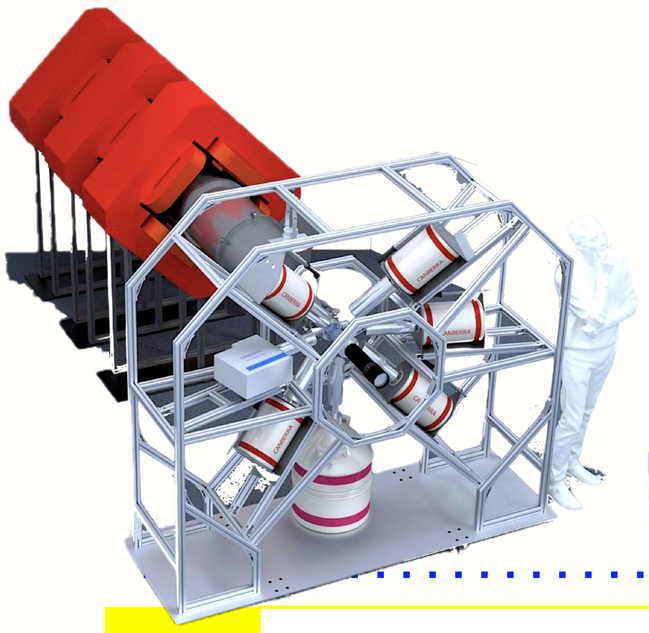
MAYORANA School II edition

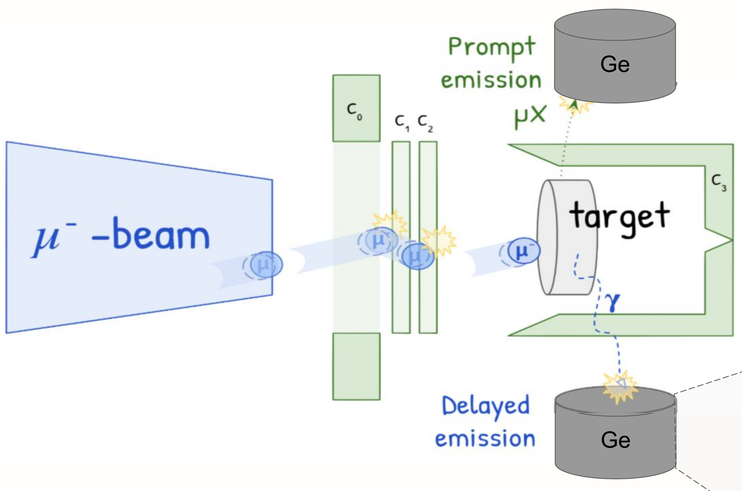
MAX-PLANCK-INSTITUT FÜR KERNPHYSIK



ANALYSIS CHAIN OF THE MONUMENT EXPERIMENT WITH ALPACA DAQ

Elizabeth Mondragón on behalf of the collaboration

1 Measurement principle



The MONUMENT experiment [1, 2, 3] measures the de-excitation of nuclei after ordinary muon capture. This allows the extraction of relevant nuclear information that helps to benchmark nuclear matrix element calculations, paramount for $0\nu\beta\beta$-decay searches.

The MONUMENT data enables the extraction of the intensity evolution of μX and γ rays following muons stopped in the target nucleus. The ALPACA[1] analysis follows a structured chain of selection and production steps [1, 2]. Selection removes data taken under unstable experimental conditions, while production applies a series of transformations that generate multiple data sets (Tiers) with additional attributes. Relevant information is progressively refined through these sequential steps:

A. **Tier 1**: data in ROOT format transformed from the binary data (Tier 0) that contains all waveforms and auxiliary FADC parameters required for subsequent analysis (timestamps, etc).

B. **Tier 2**: results from processing Tier 1 and contains event details (detector ID, trigger time, amplitudes..) derived using different modules from the GELATIO[4] software used to optimise timing and energy resolution.

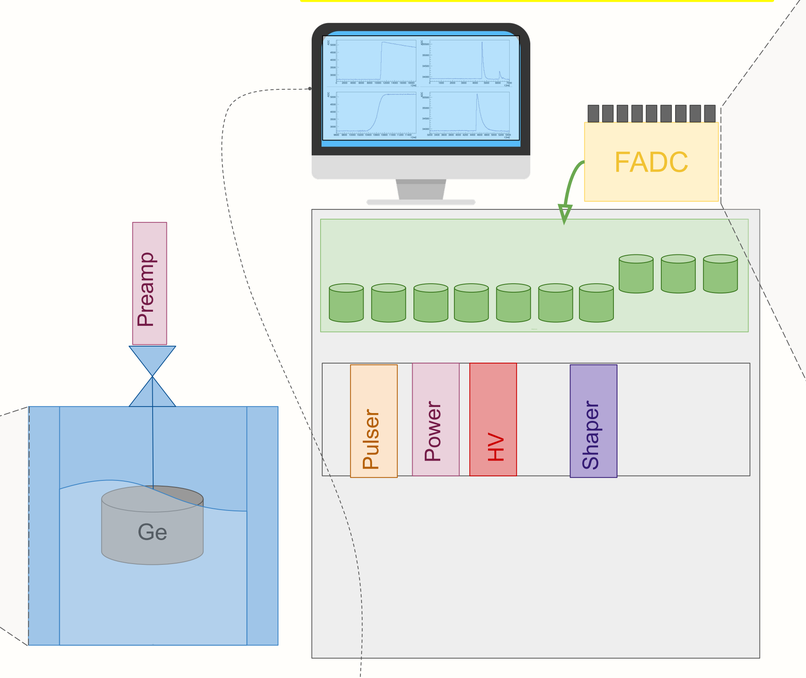
C. **Tier 3**: the calibrated and refined data from Tier 2 is combined at this stage in one single dataset using HPGe and PMTs data-streams to include parameters such as the time difference between signals.

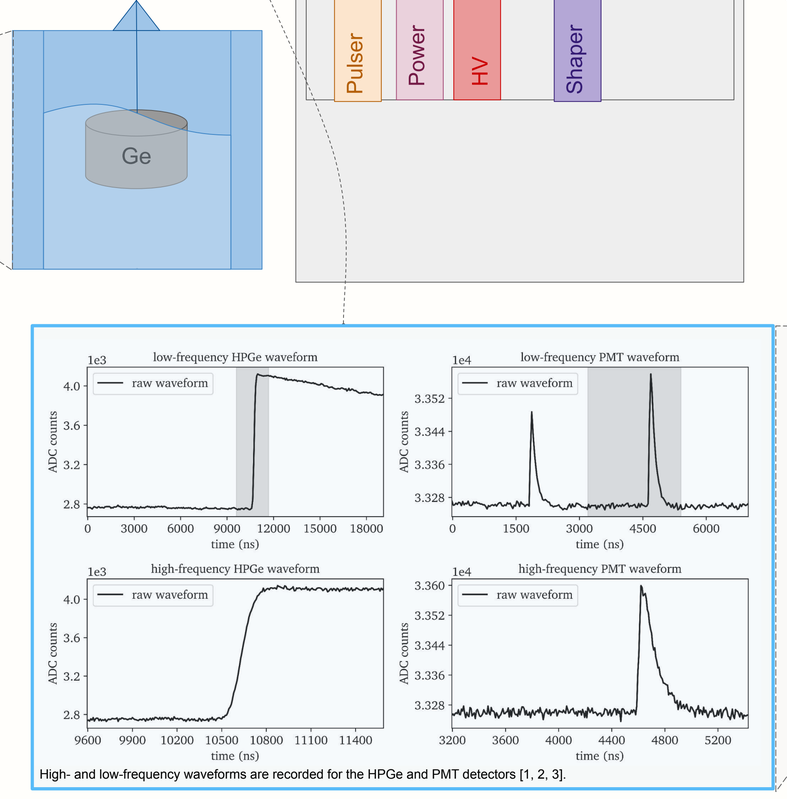
D. **Tier 4**: final stage of ALPACA's data structure. Events are classified as correlated, prompt, delayed, or uncorrelated. This last classification and consists of 2D histograms used for the high-level analysis.

The correlated energy spectrum is needed to identify the γ rays emitted by the nucleus after capturing a muon. The 2D histograms show the evolution of the correlated spectral lines over the coincident time window, and enables the extraction of the muon lifetime.

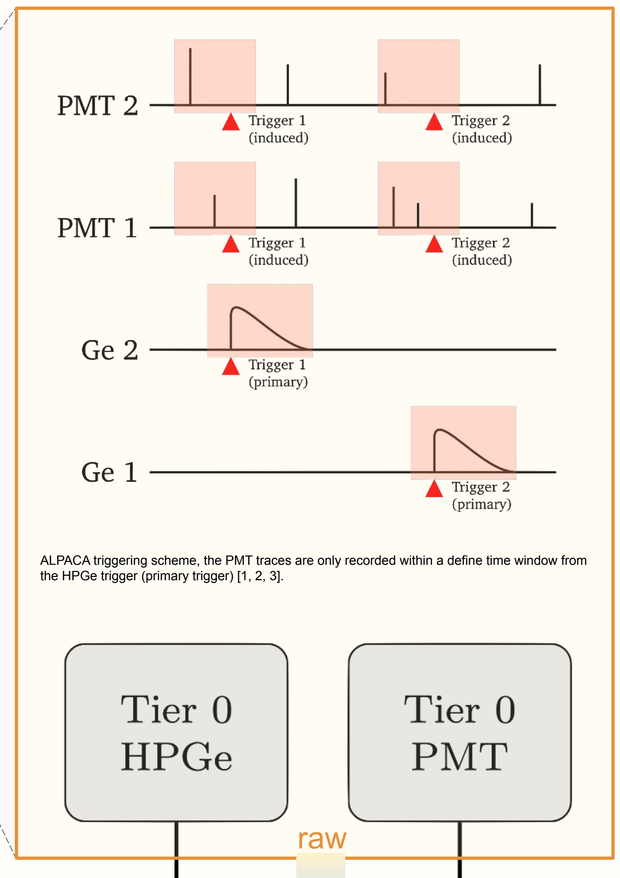
[1]The name ALPACA originates from the Legend Liquid Argon Monitoring Apparatus (LLAMA) software developed for the LEGEND experiment.

2 Data acquisition

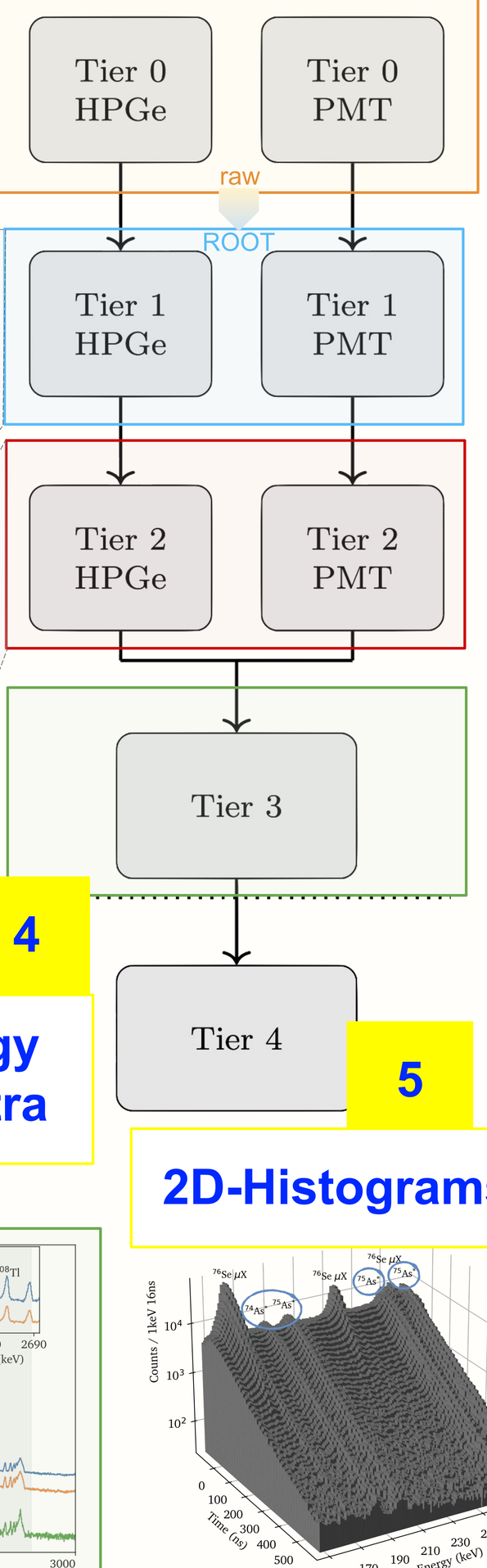




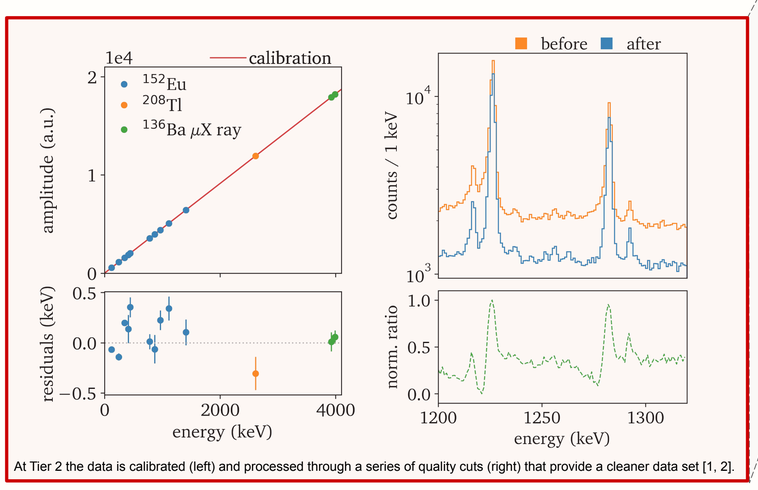
High- and low-frequency waveforms are recorded for the HPGe and PMT detectors [1, 2, 3].



ALPACA triggering scheme, the PMT traces are only recorded within a define time window from the HPGe trigger (primary trigger) [1, 2, 3].

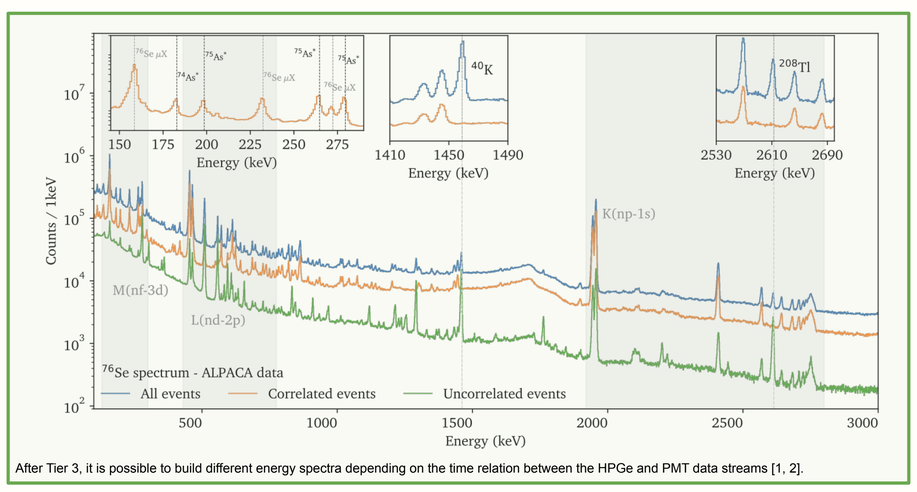


3 Data processing



At Tier 2 the data is calibrated (left) and processed through a series of quality cuts (right) that provide a cleaner data set [1, 2].

4 Energy spectra



After Tier 3, it is possible to build different energy spectra depending on the time relation between the HPGe and PMT data streams [1, 2].

5 2D-Histograms

The 2D histograms at Tier 4 show the evolution of the spectral lines after the muon is capture in the target [2].

[1] E. Mondragón, The MONUMENT Experiment: Ordinary Muon Capture for 0νββ-decay Nuclear Matrix Elements, PhD Thesis (2025)
[2] MONUMENT Collaboration, The Monument Experiment: Ordinary Muon Capture for $0\nu\beta\beta$-decay studies, Eur. Phys. J. C., vol. 84, p. 1188, (2024).
[3] E. Mondragon for the MONUMENT collaboration, The MONUMENT experiment: Ordinary Muon Capture as a benchmark for neutrinoless double beta decay nuclear structure calculations, AIP conf. Proc., Conference ID:C22-06-13.1, (2022).
[4] Agostini, M. and Pandola, L. and Zavarise, P. and Volynets, O., "GELATIO: A General framework for modular digital analysis of high-purity Ge detector signals," JINST, vol. 6, P08013, (2011)