# Data analysis of the NUCLEUS experiment with the DIANA framework

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The main data analysis difficulty for cryogenic detectors is background rejection due to the presence of several different pulse shapes at low signal to noise ratio. Background reduction is particularly important for the NUCLEUS experiment [1] since the aim is to produce ultra-low threshold (~ 20 eV) cryogenic detectors to measure reactor coherent elastic neutrino-nucleus scattering. The data analysis procedure performed for the NUCLEUS experiment with the DIANA analysis framework [2] is presented along with several upgrades made to the framework.

## C++ & ROOT Backend

- Speed
- Robustness
- Backcompatibility
- TXT file interface
- No coding required
- Tested for 10+ years
- Many "algos" ready to use

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## Python Frontend (NEW)

- Easy Analysis Coding
- Remote Interface
- Data Interoperability
- Interactive and editable plots
- Jupyter notebooks
- Easy onboarding
- PyROOT interface for fitting [3]

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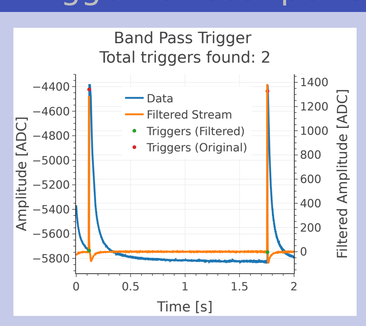
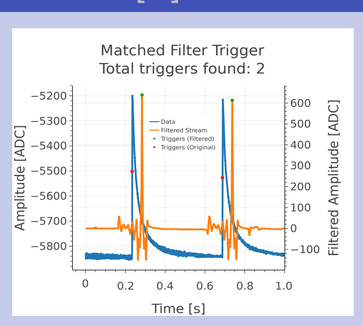
**EASY AND QUICK ANALYSIS**

# Raw Waveform Analysis

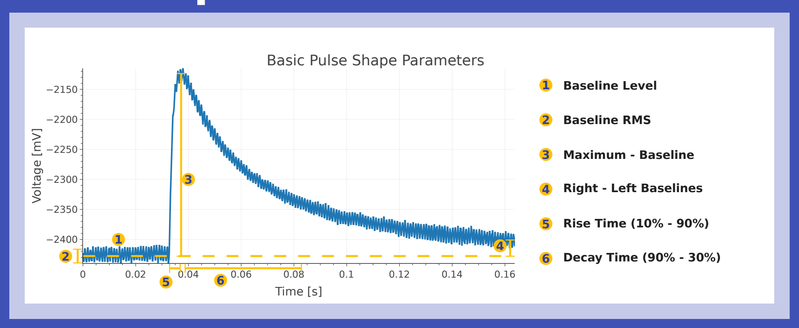
## 1. Offline Triggering

- Band Pass Trigger for first look at data
- Matched filter trigger for best performance [4]



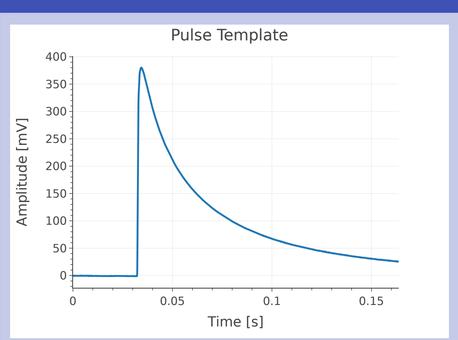



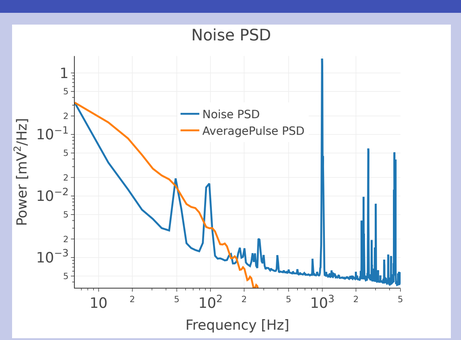

## 2. Extraction of pulse features




## 3. Pulse Template and Noise PSD Estimation

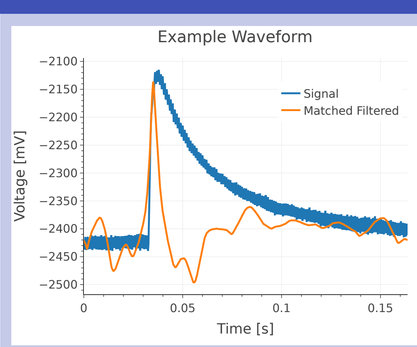
- Select Pulse and Noise traces using cuts based on pulse features
- Average O(100) traces for a (nearly) noiseless estimation of the expected pulse shape
- Average O(100) FFTs of noise traces for a robust estimation of the noise power spectral density (NPSD)

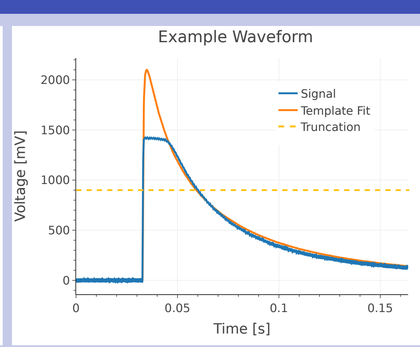



## 4. Pulse Amplitude Estimation

- Matched Filter (normal/differentiative) [4]
- Template Fit on linear response region for expanding detector's dynamic range



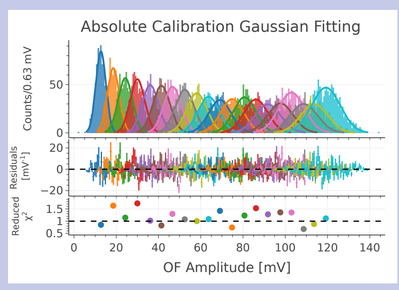



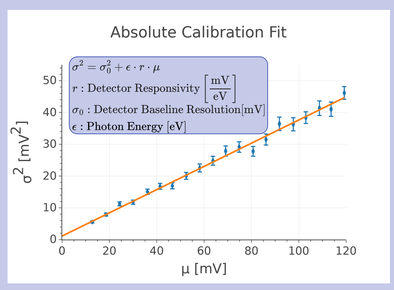

References, Contacts and Poster Download

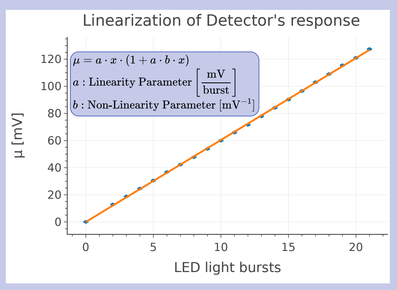
# Distribution Analysis

## 1. Calibration

- Radioactive $^{55}$Fe source plus XRF source
- Absolute Calibration (LED Based) using photon statistics [5]
- Detector's response linearization

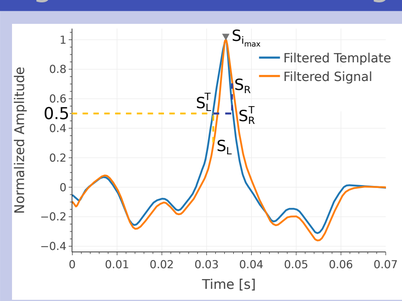



## 2. Quality Cuts

- Matched Filter Variables: $\chi^2$, $\chi_L$, $\chi_R$
- Linearization of cuts to remove energy dependence
- Remove correlations from data for eliminating detector drifts and gaining in maximum cutting sensibility




Time Domain

$$\chi_i = \frac{S_i - a_i \cdot S_{i_{max}}}{\sqrt{\sigma_0^2 \cdot (1 + a_i^2) - 2a_i \cdot R(i - i_{max})}}$$

$i$ : Time index taken at FWHM (L,R)

$S_i$ : Filtered Signal

$a_i = \frac{S_i^T}{S_{i_{max}}^T}$

$S_i^T$ : Filtered Template

$\sigma_0$ : Detector's Resolution

$R$ : Filtered Noise autocorrelation

Frequency Domain

$$\chi^2 = \sum_f \frac{|\tilde{S}_f - A \cdot \tilde{S_f^T}|^2}{N_f}$$

$f$ : Frequency index

$\tilde{S}_f$ : Filtered Signal

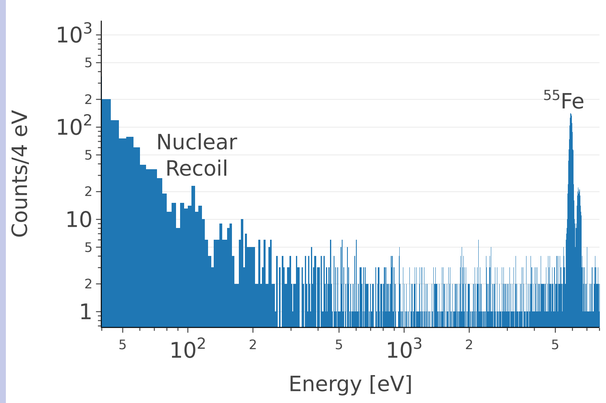
$\tilde{S_f^T}$ : Filtered Template

$N_f$ : Filtered Noise PSD

## 3. Efficiency Evaluation

- Trigger: Using LED/Heater or MC pulses with TTL triggers
- Reconstruction: Successful amplitude estimation (LED/Heater or MC pulses with TTL triggers)
- Cuts: Using LED/Noise/Radioactivity or MC pulses

## 4. Spectra Production




# Future Developments

- Exploring Wavelet Analysis
- Principal Components based cuts
- Background rejection with combined detector analysis