Time dispersion of the SPE signal

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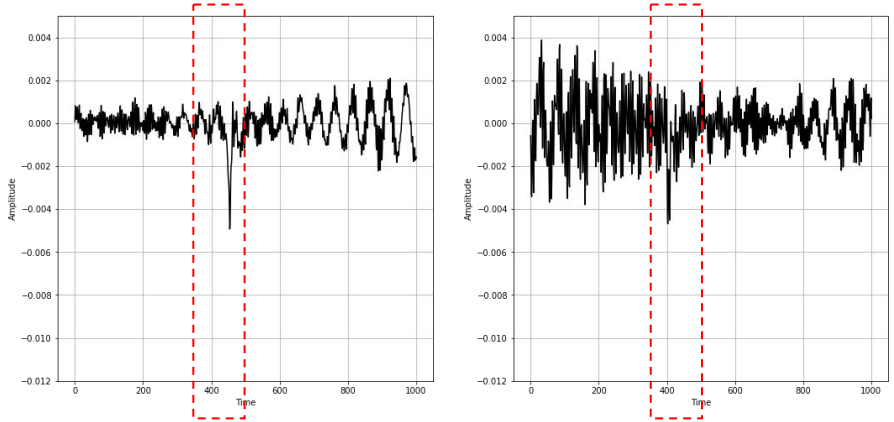
April 18, 2023

Introduction

Previously…

- **SPE characterization:**

Typical SPE signals



Introduction

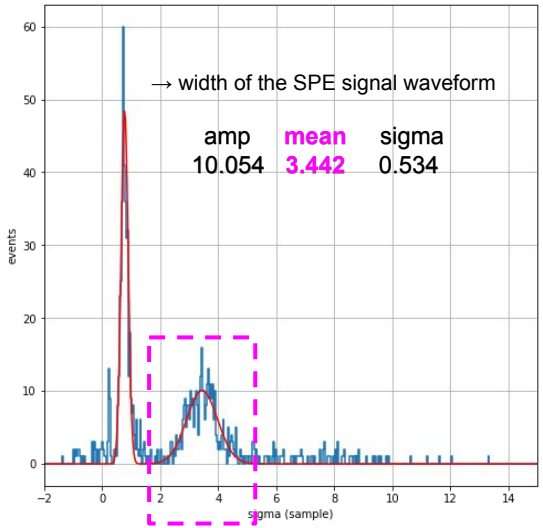
SPE signal - Gaussian shape

- Sigma = 3.4 samples (0.68 ns)
- Amplitude
  - mean = 0.0030 V
  - sigma = 0.0014 V

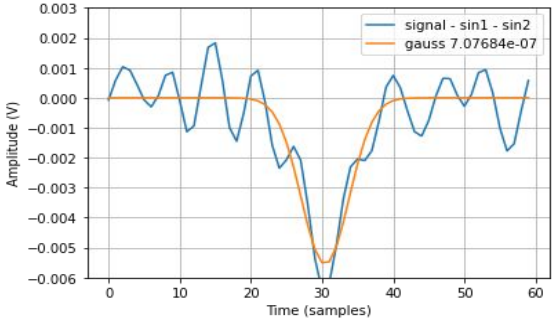
Previously…

- **SPE characterization:**

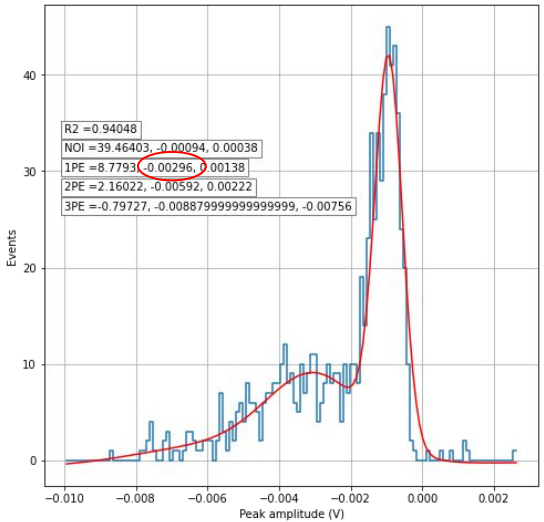
Sigma of the gaussian fits



Typical SPE signal



Peak amplitude distribution

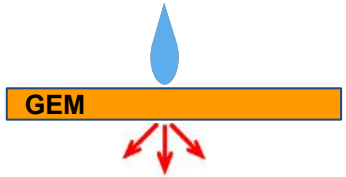


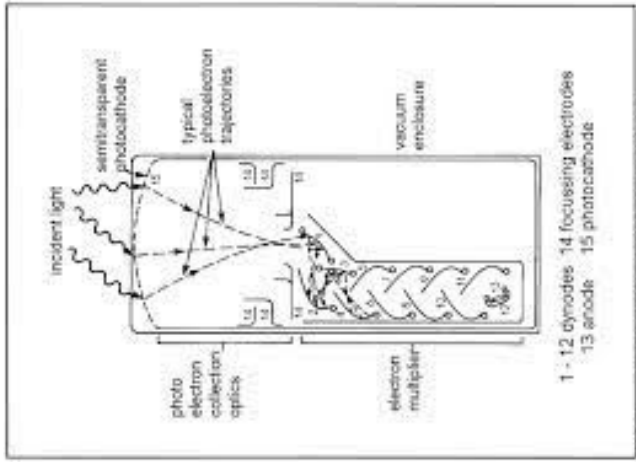
Introduction

The proposed simulation is based on a sum of SPE:

Dispersions:

- **PMT** (electron multiplication process)
- **TPC electron longitudinal diffusion** (z dependent)
- **GEM time response** (light production process)





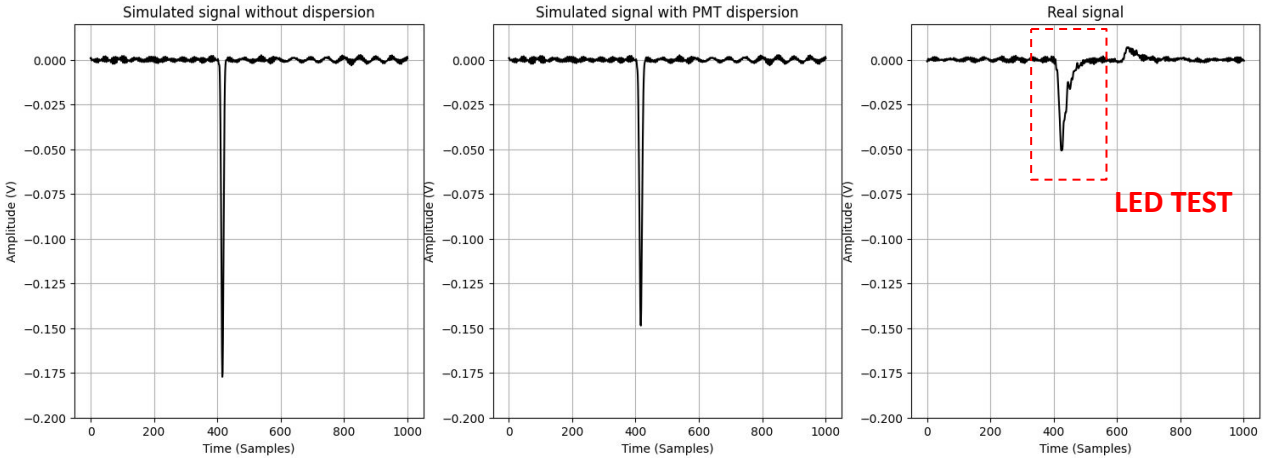
Introduction

- **PMT datasheet:**
  - **T.T.S = 0.9 ns**

`1 Sample = 0.2 ns`

CHARACTERISTICS (at 25 °C)

Parameter		Min.	Typ.	Max.	Unit
Cathode sensitivity	Luminous (2856 K)	60	90	—	µA/lm
	Radiant at 420 nm	—	85	—	mA/W
	Blue sensitivity index (CS 5-58)	9	10.5	—	—
Anode sensitivity	Luminous (2856 K)	50	180	—	A/lm
Gain		—	2.0×10^6	—	—
Anode dark current (after 30 min storage in darkness)		—	3	20	nA
Time response	Anode pulse rise time	—	1.5	—	ns
	Electron transit time	—	17	—	ns
	Transit time spread (T.T.S.)	—	0.9	—	ns
Pulse linearity at ±2 % deviation		—	30	—	mA

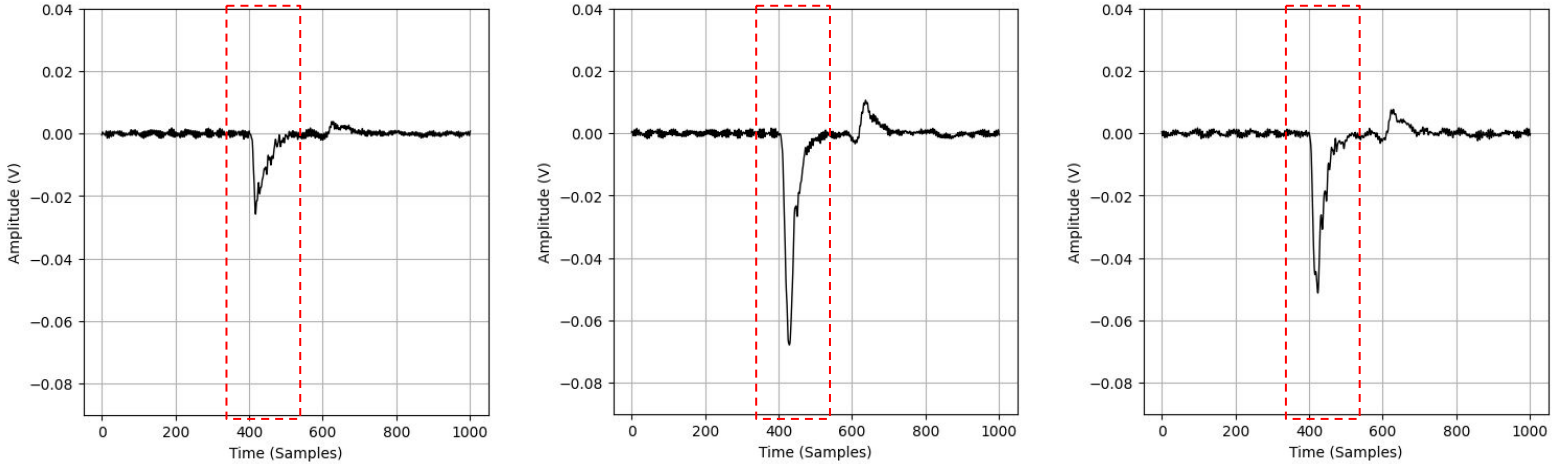


`…/PMT-Test-270922/BA1642/900V`

- **Used database:**
  - LED emitting photons to a PMT
  - Sampling rate 1 GS/s
  - ~1000 acquisitions

Introduction

Typical signals …/PMT-Test-270922/BA1642/900V

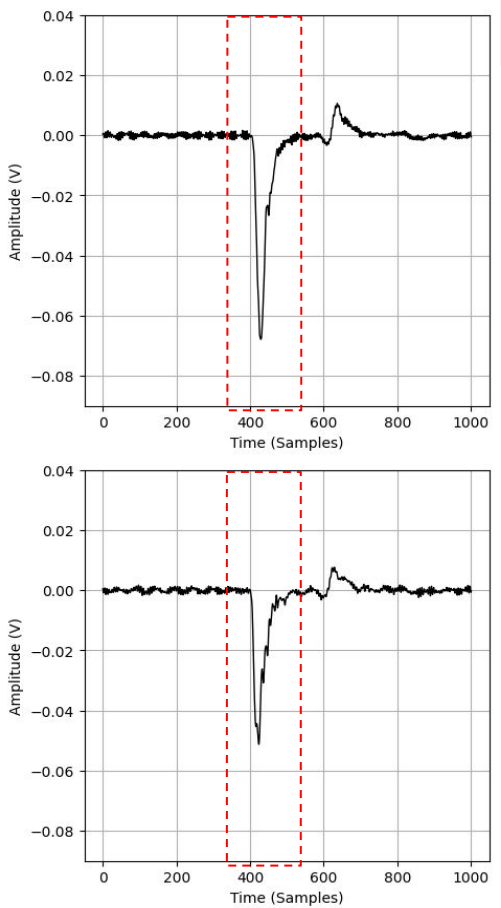


Dispersion characterization

Dispersion characterization

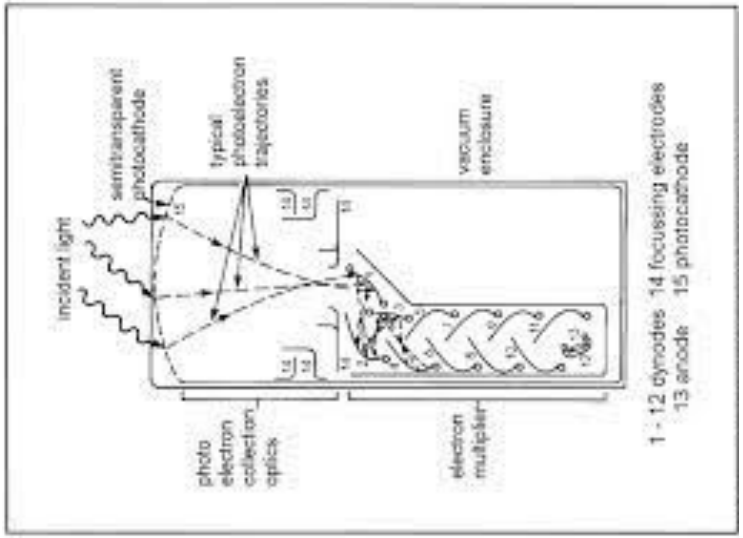
To start characterizing the dispersion, we can do a signal analysis based on:

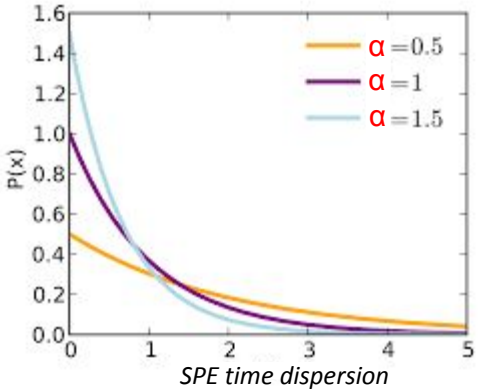
- FWHM
- Peak
- Rise Time
- MSE



Dispersion characterization

Approach idea: exponential dispersion $\Longrightarrow \alpha\, e^{-\alpha x}$





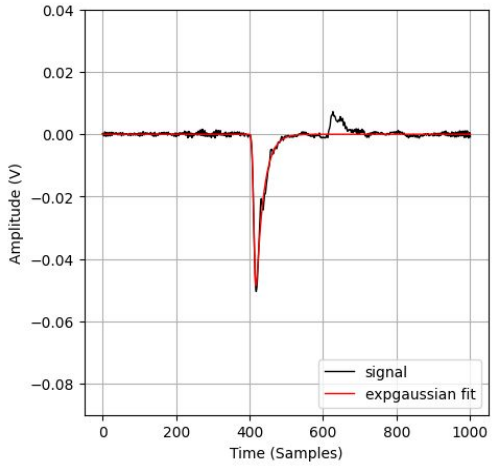
SPE time dispersion

Dispersion characterization

Finding the best exponential parameter alpha $\Longrightarrow \alpha\, e^{-\alpha x}$

- Selecting only signals from the dataset with peak mean of -0.05V
  - Fit each signal with a expgaussian and get the fit parameters mean

Example

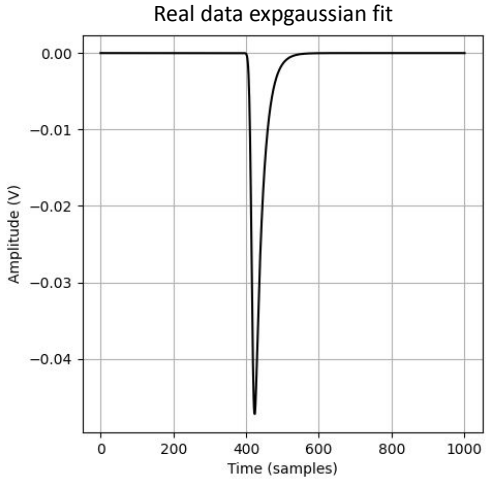


- FWHM = 23.121 Samples
- Peak = -0.048 V
- Rise Time = 8 Samples

Dispersion characterization

Finding the best exponential parameter alpha $\Longrightarrow \alpha e^{-\alpha x}$

- Simulate a dataset scanning the **α** and **N** parameters
  - Compare with the expgaussian fit obtained from the real data



- FWHM = 26.862 Samples
- Peak = -0.0472 V
- Rise Time = 11 Samples

$$\begin{array}{c} \\ N_1 \\ N_2 \\ N_3 \\ \vdots \\ N_m \end{array} \begin{array}{c} \begin{array}{ccccc} \alpha_1 & \alpha_2 & \alpha_3 & \cdots & \alpha_n \end{array} \\ \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & a_{m3} & \cdots & a_{mn} \end{bmatrix} \end{array}$$

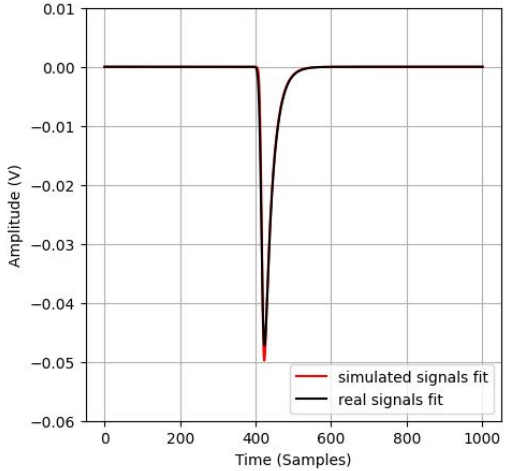
(N: Number of photoelectron signals)

Dispersion characterization

Finding the best exponential parameter alpha $\Longrightarrow \alpha e^{-\alpha x}$

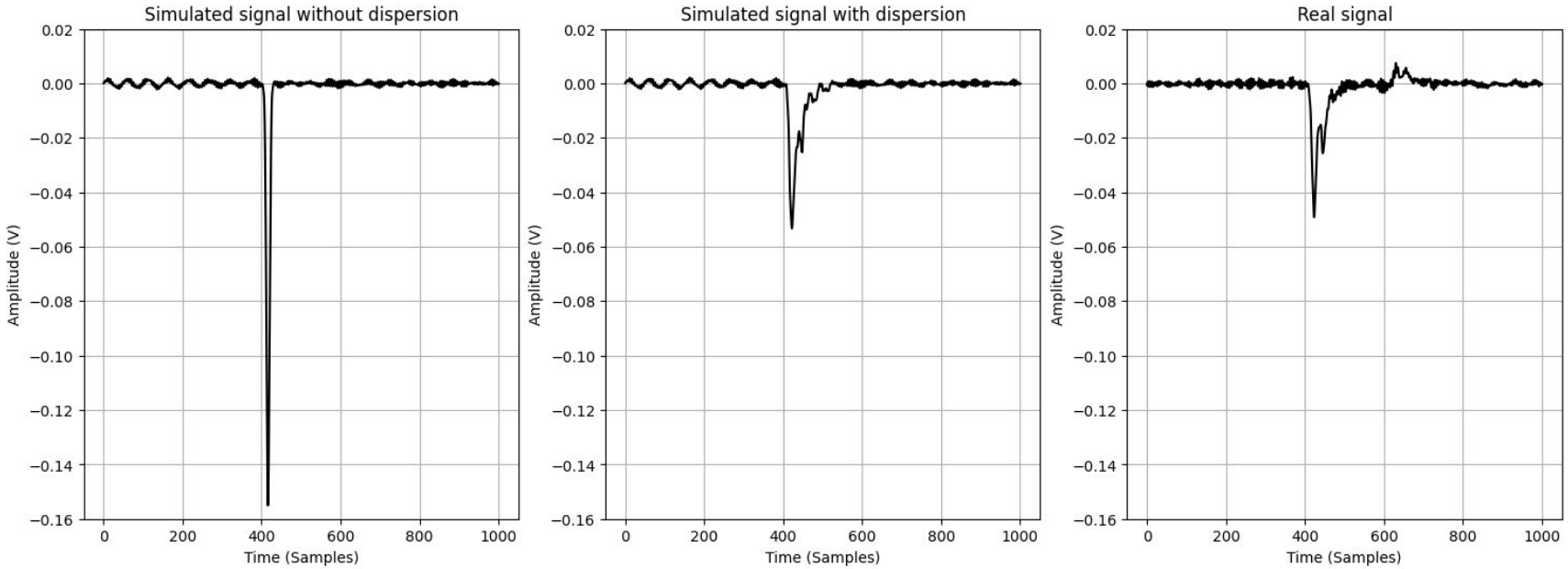
- For the minimum value of MSE:
  - **Alpha = 0.0422 ± 0.0021**
  - N = 61.30 ± 1.49
  - Δ_{FWHM} = 1.783 ± 0.467 Samples
  - Δ_{Peak} = 0.0016 ± 0.0007 V
  - $\Delta_{Rise\ Time}$ = 0.36 ± 0.62 ns
    - Simulated signals rise time = 9.6 ± 0.5 Samples
    - Real signals rise time = 11.4 ± 3.1 Samples
  - MSE = 0.0000001938 ± 0.0000000197

`1 Sample = 0.2 ns`



Dispersion characterization

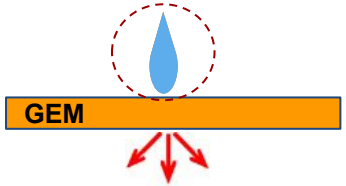
Comparison between simulated and real signal



Conclusions

Conclusions

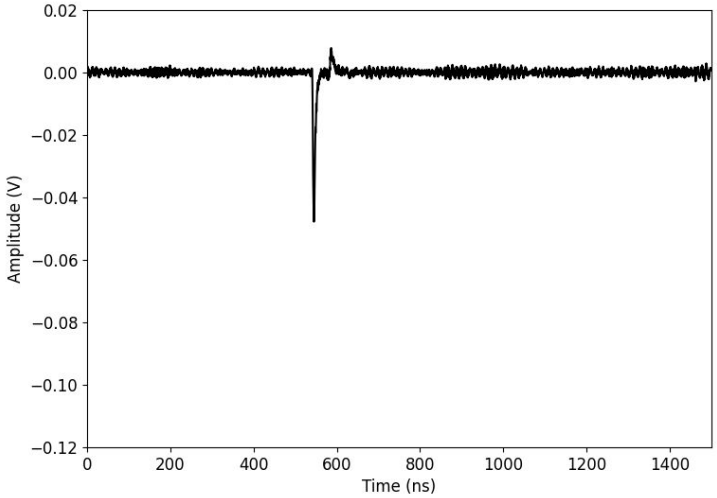
- The presented analysis was for the led database signals
  - As a next step, we will do the same analysis for the Fe55 database
- The dispersion analysis is not considering the dispersion in the GEM
- We would like to know:
  - Is someone simulating the dispersion in the GEM for the photon generation branch?



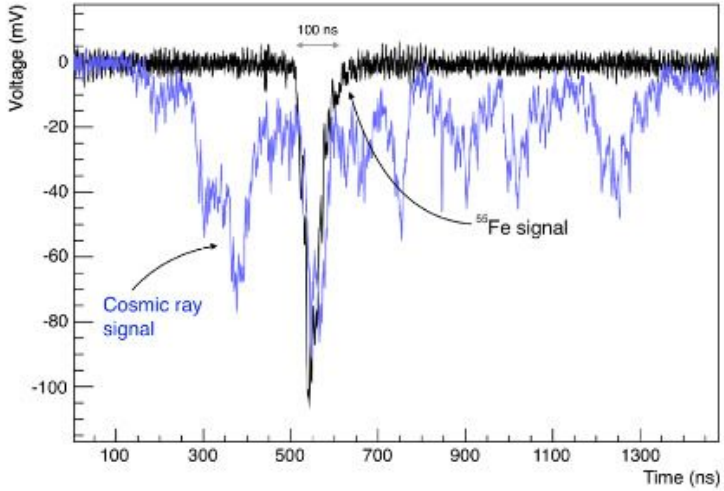
Dispersion characterization

Comparison between LED and Fe55 database signals

LED signal



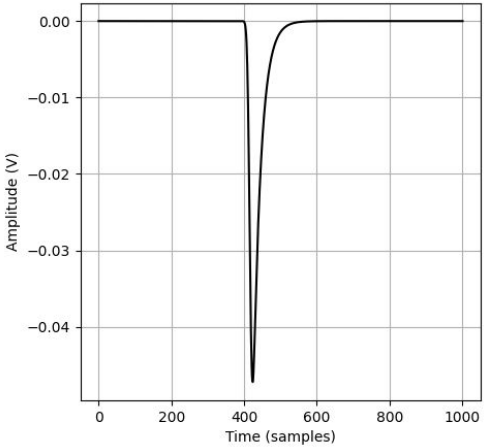
Fe55 signal



Dispersion characterization

Finding the best exponential parameter alpha $\Longrightarrow$ $e^{-\alpha x}$

- Selecting only signals from the dataset with peak mean of -0.05V
  - Fit each signal with a expgaussian and get the fit parameters mean
  - Create a fit with these values



- FWHM = 26.862 Samples
- Peak = -0.0472 V
- Rise Time = 11 Samples

The simulation results will be compared to this fit