DEEP UNDERGROUND NEUTRINO EXPERIMENT

Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Waveform Averaging + PDVD & PDHD Data Fitting +

Quick CERN Visit Update

Karla Téllez Girón Flores

08/08/2024

@BrookhavenLab


DEEP UNDERGROUND
NEUTRINO EXPERIMENT
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ENERGY
Quick CERN Visit Update
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NP04 Activity 07/08 – 08/07

- **CRP6 was uninstalled.**
- Taken to Building 185 in Meyrin Site.
- Exciting CRP work to be carried out!
- Data monitoring shifts with unstable beam during Beam On periods, mostly quiet during Beam Off ones.
- Last few of weeks of summer beam: kaon data-taking.

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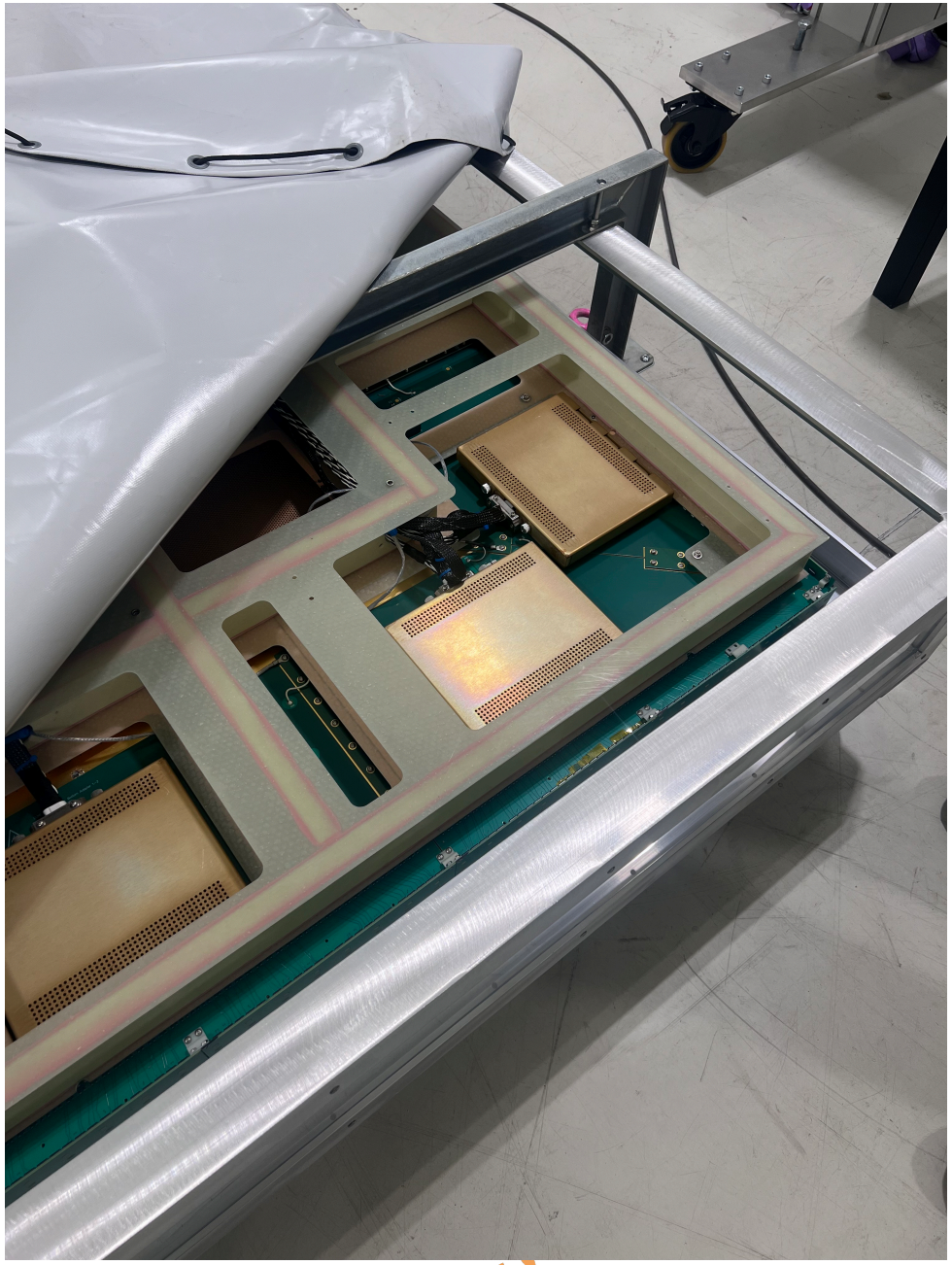

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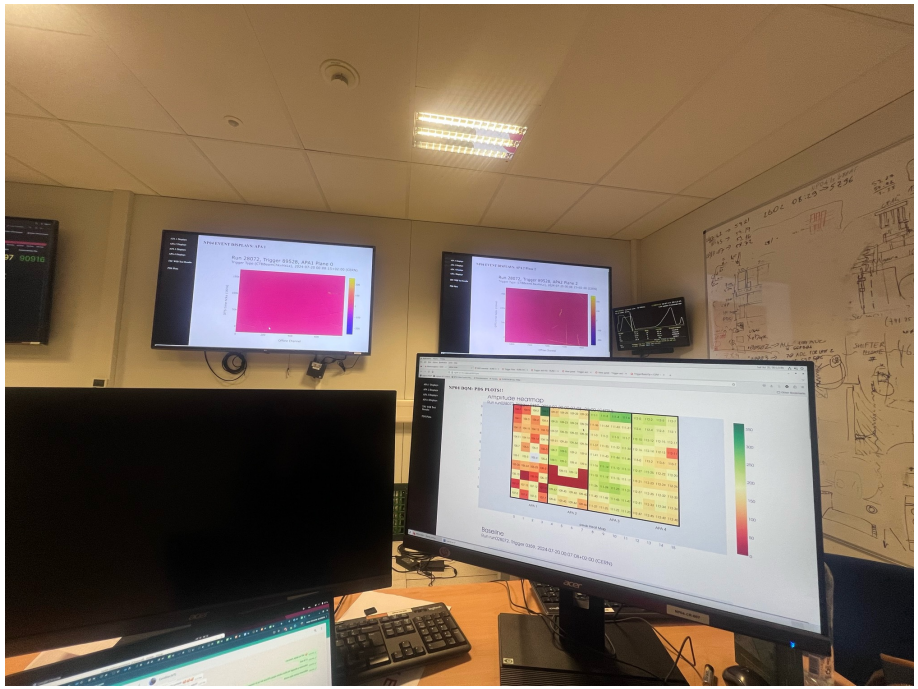

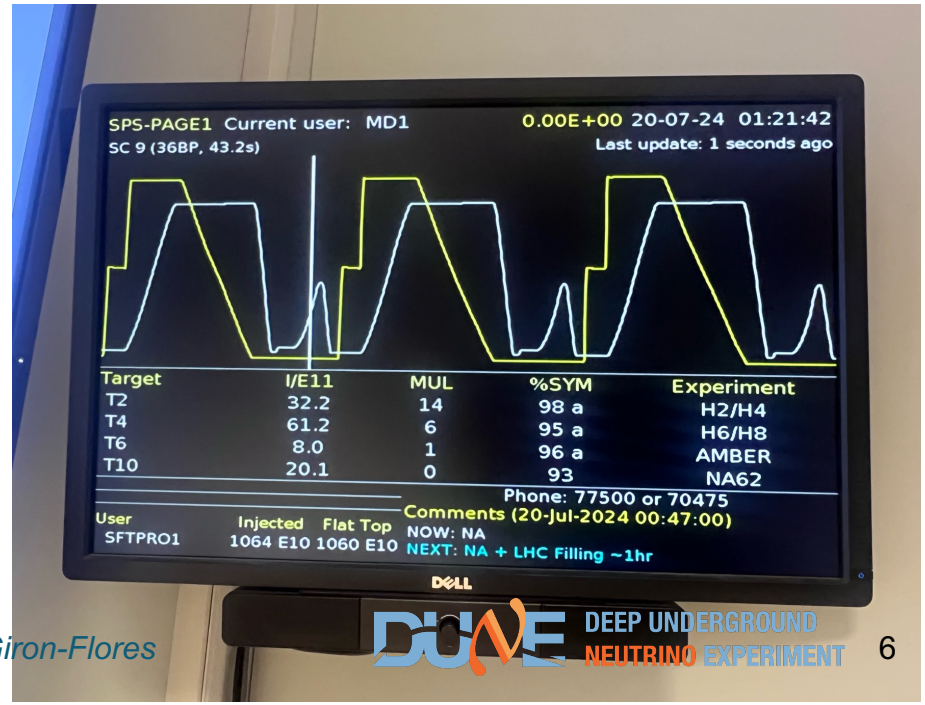

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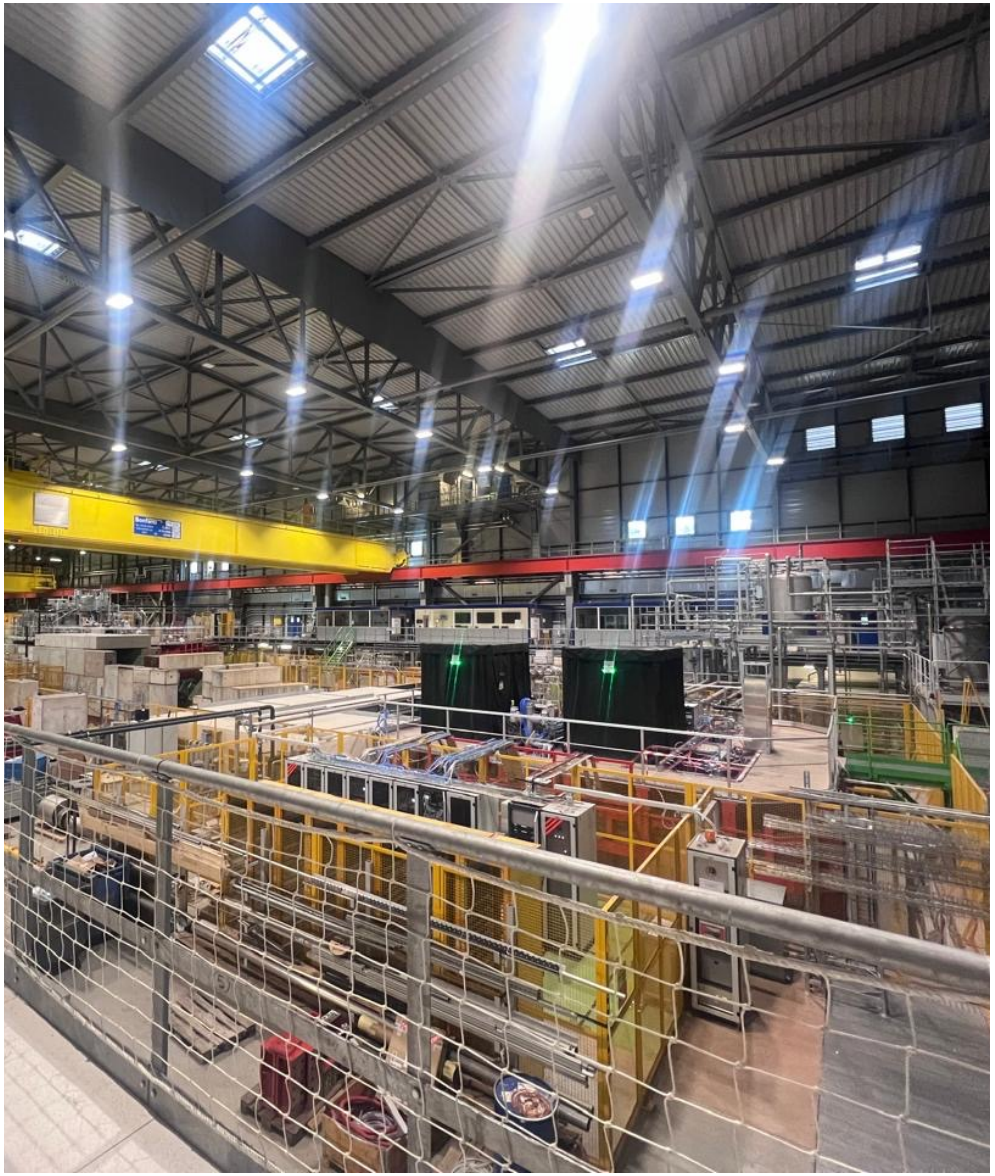
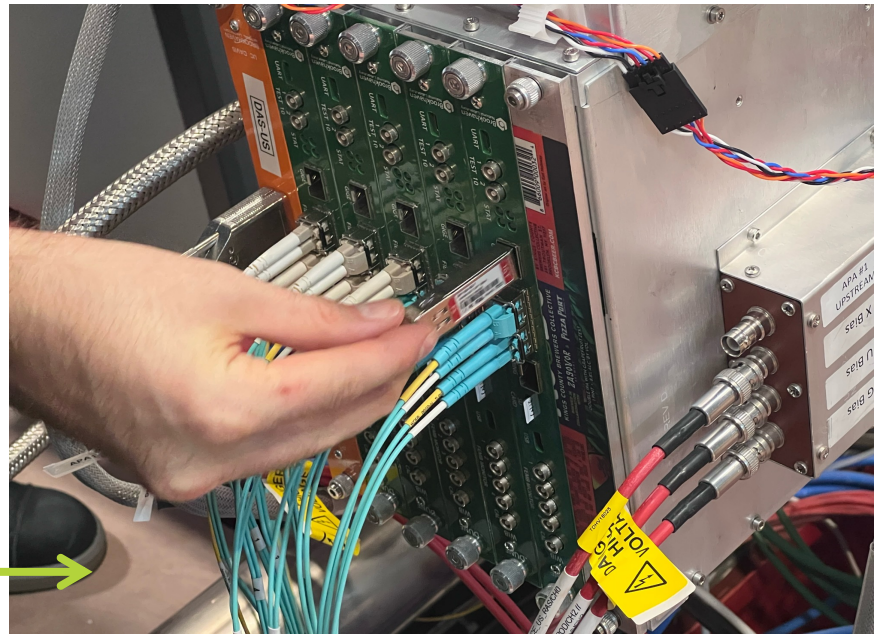


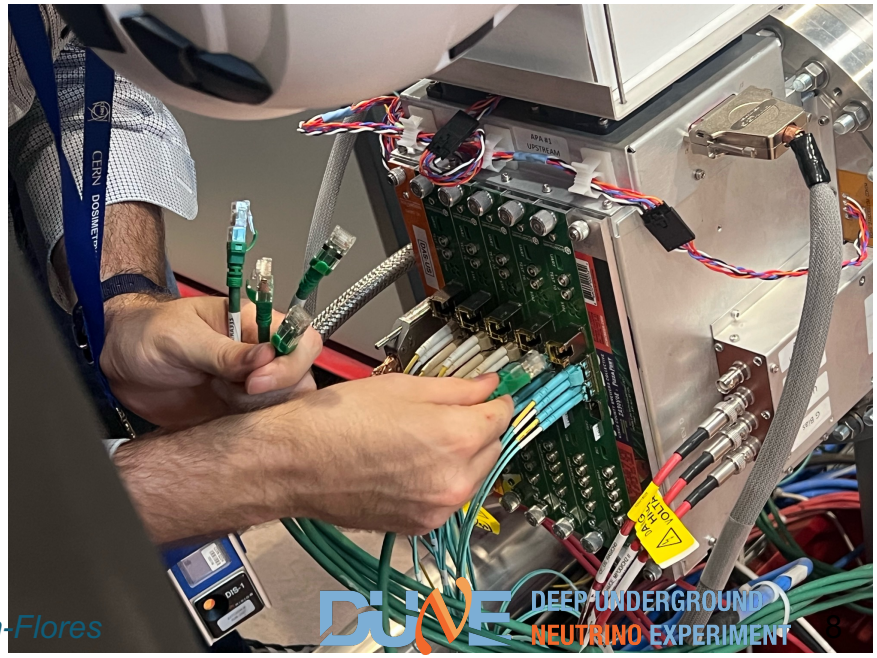
On 07/29 (beam off week)

CE tests ran with Cathode and APA bias OFF. (See Roger's report from 08/07 NP04 Coordination Meeting).

1. **Noise Study: Switch WIB connections from Fiber to Copper. No significant difference was found.**

2. **Pulser Calibration Studies (Roger):**
   - **Characterize the noise at the new lower gain setting. ~2% worse noise with new lower gain.**
   - **Investigate *Half-FEMB (–) pulse* effect. Further studies needed when beam is gone.**





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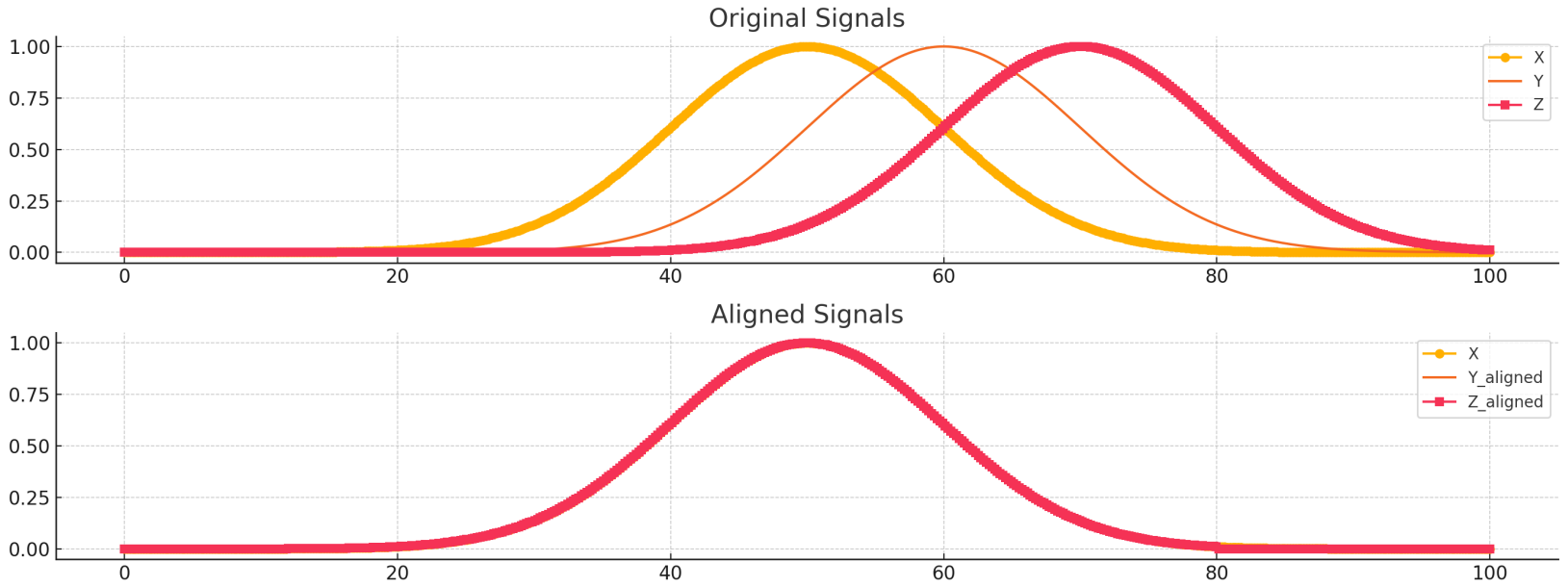
Cross-Correlation

Cross-correlation is a measure of similarity between two signals as a function of the displacement of one relative to the other.

It is commonly used in signal processing to find the relative time delay between two signals.



Waveform Aligning using Cross Correlation

- **The cross-correlation between two signals *X* and *Y* is defined as:**

Number of samples

Cross Correlation Function $\longrightarrow$ $$R_{XY}(k) = \sum_{i=0}^{N-1} X(i) \cdot Y(i+k)$$

Time Offset or Lag

- **To find the lag k_{XY}, maximize the cross-correlation function:**

$$k_{XY} = \arg\max_k (R_{XY}(k))$$

- **Then, we can use this lag to align the signals by shifting them accordingly.**

Waveform Aligning using Cross Correlation and FFT

1. **Compute FFT of both signals:**

(Zero-padded X, Y signals)

$$X_f = \mathrm{FFT}(X)$$
$$Y_f = \mathrm{FFT}(Y)$$

Go to Frequency Domain

2. **Multiply one FFT by the complex conjugate of the other**

$$C_f = X_f^* \cdot Y_f$$

Element-by-element multiplication

3. **Compute the Inverse FFT to get the cross-correlation function**

$$R_{XY} = \mathrm{IFFT}(C_f)$$

Going back to time domain

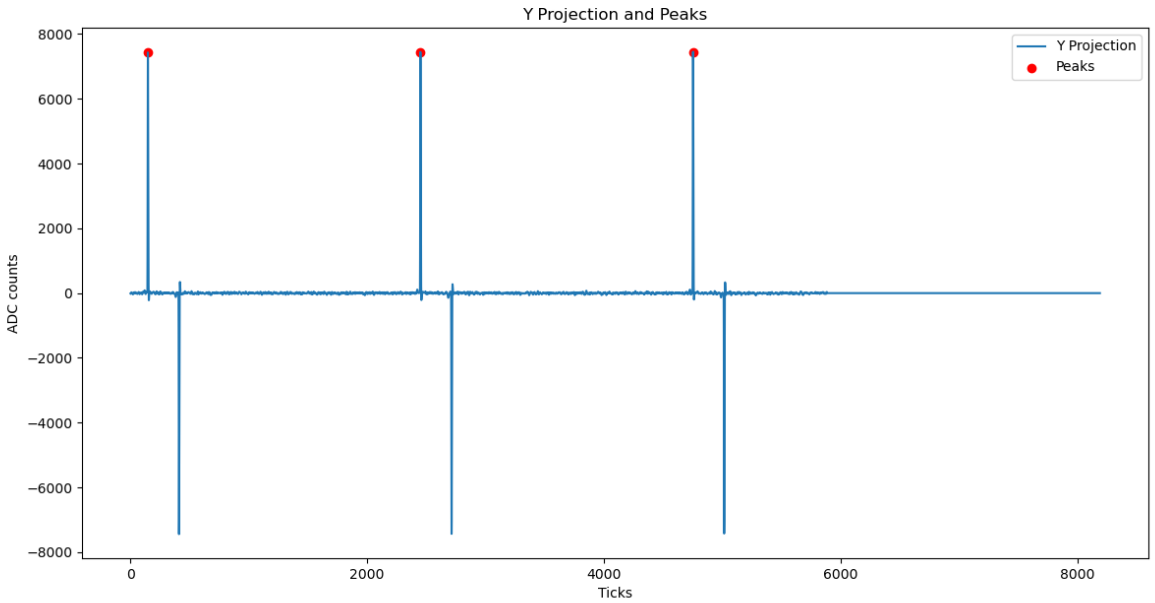
4. **Determine the lag k_{XY}**

The position of the maximum value

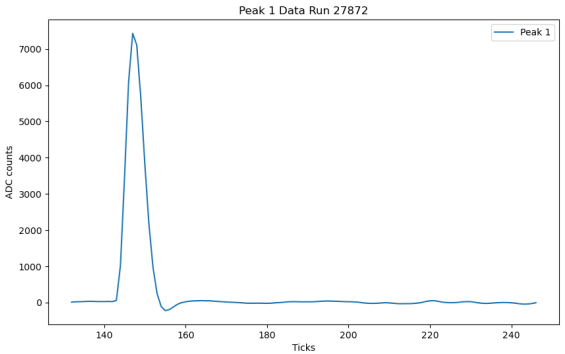
$$k_{XY} = \arg\max_k(R_{XY}(k))$$

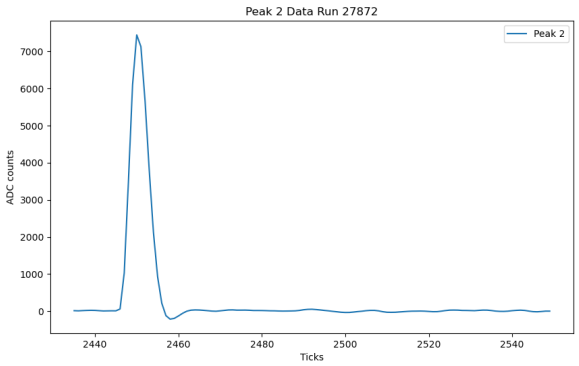
Use this lag to align our signals!

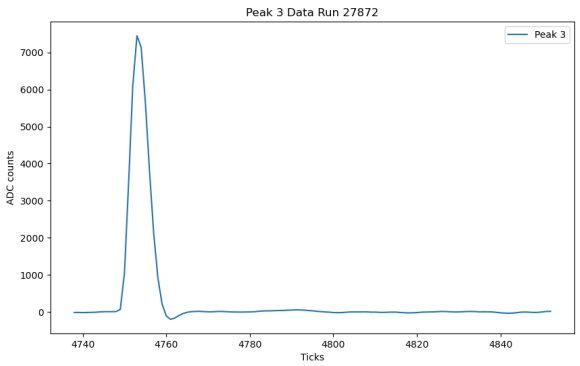
Aligning our Waveforms



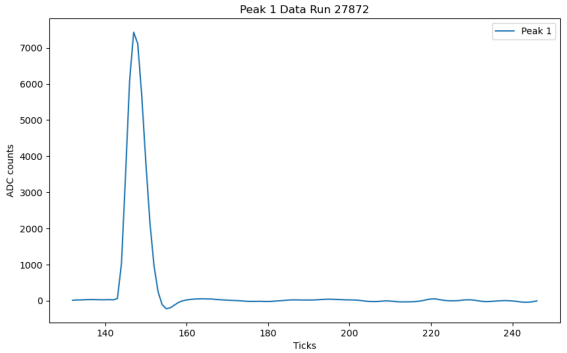
1. Identify peaks

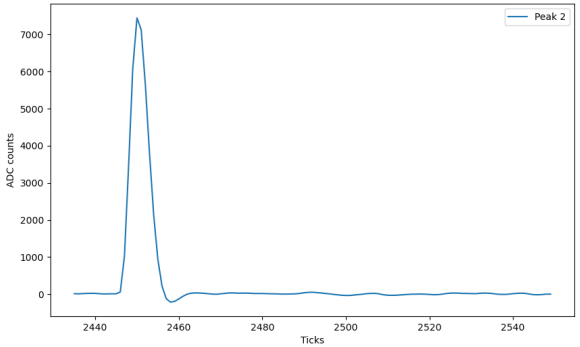


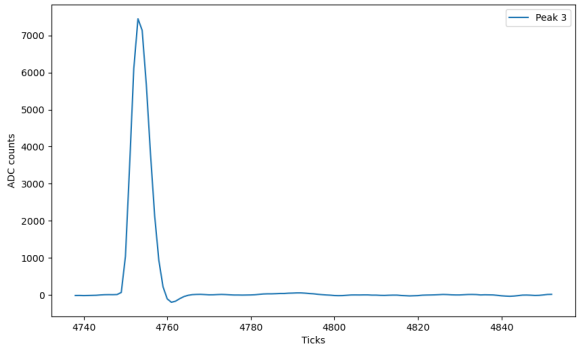




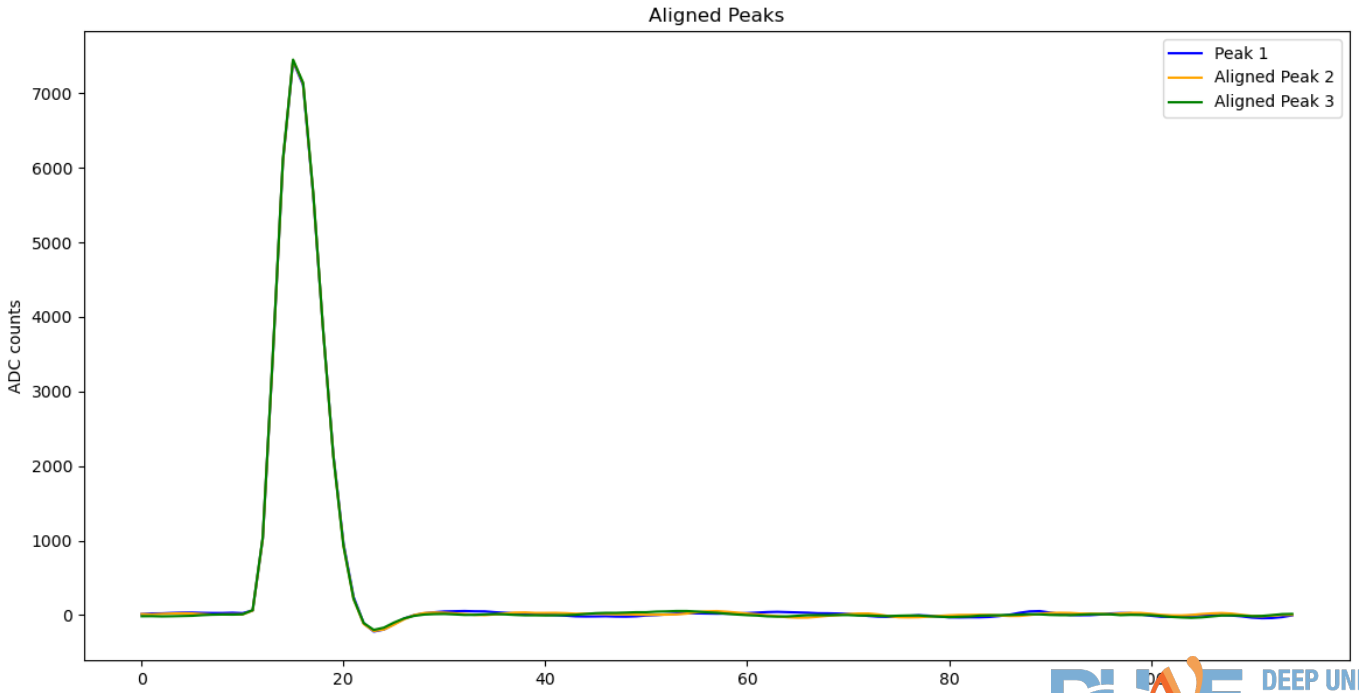
Aligning our Waveforms





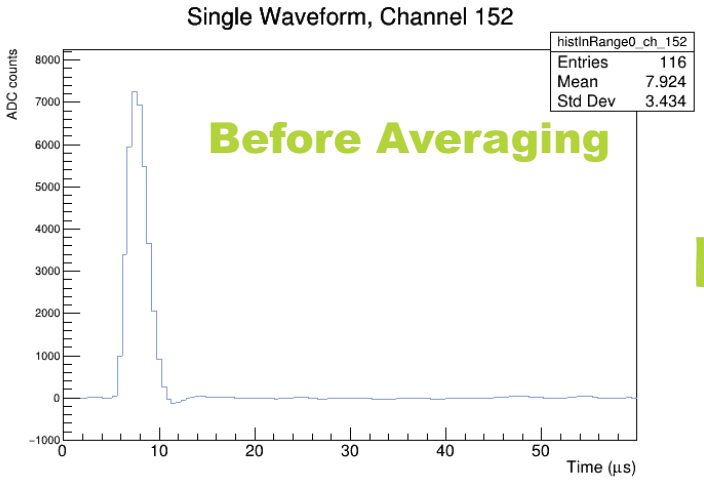


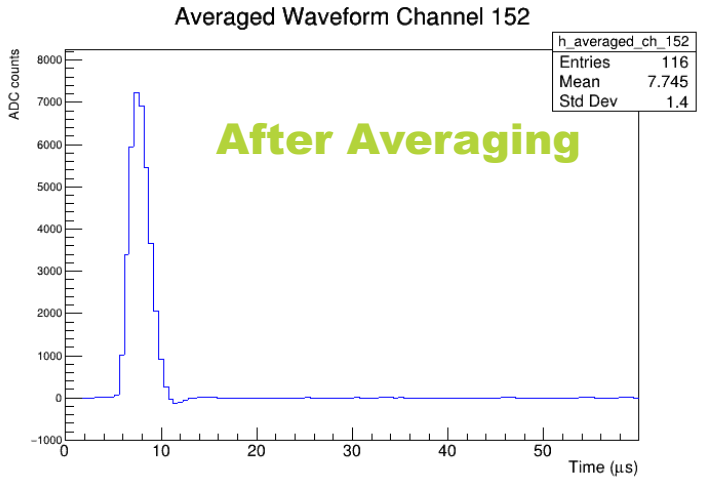
2. Align them using cross-correlation

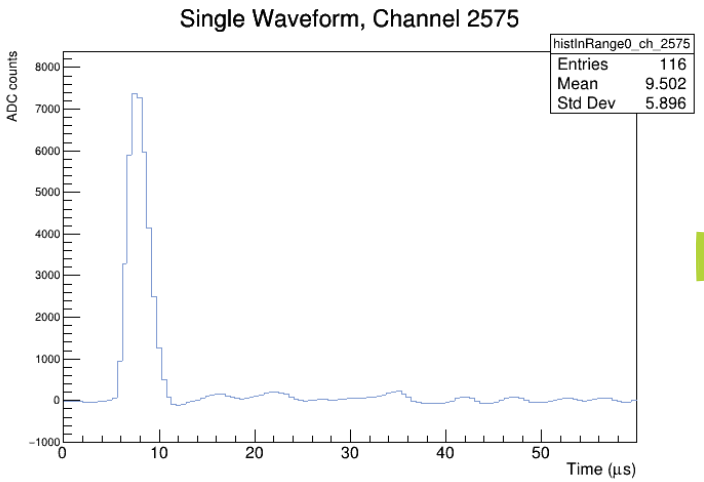


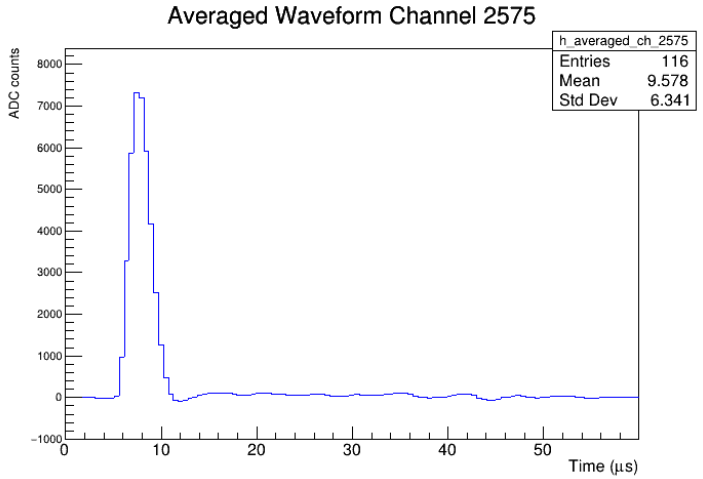
Averaging Waveforms

Started with PDVD Data (Pulser Run 21040)





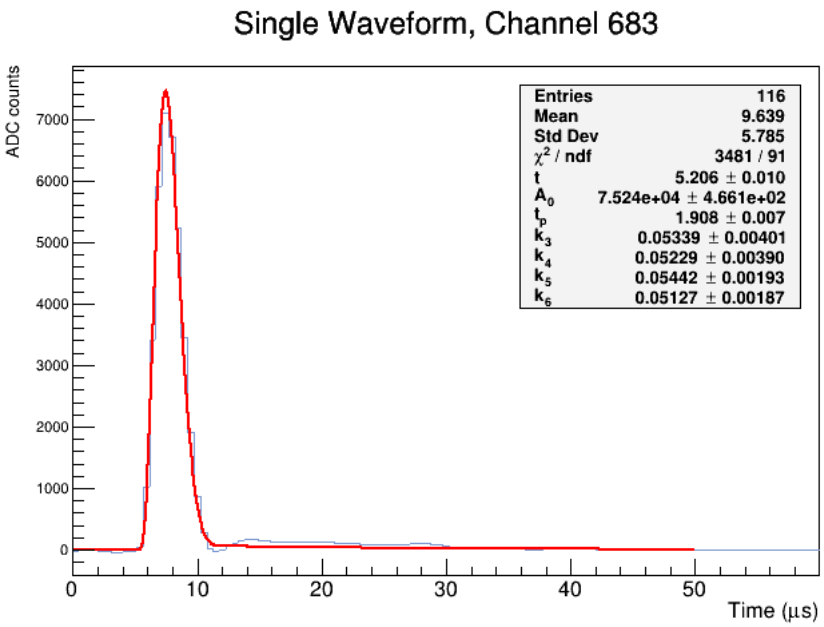




Fitter Performance Run 21040

Fitted Examples Before/After averaging

Before



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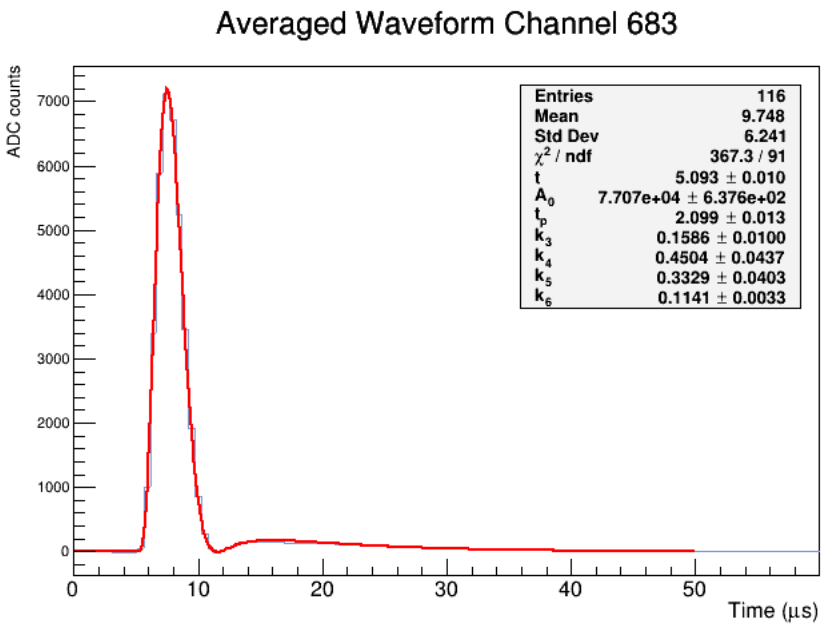

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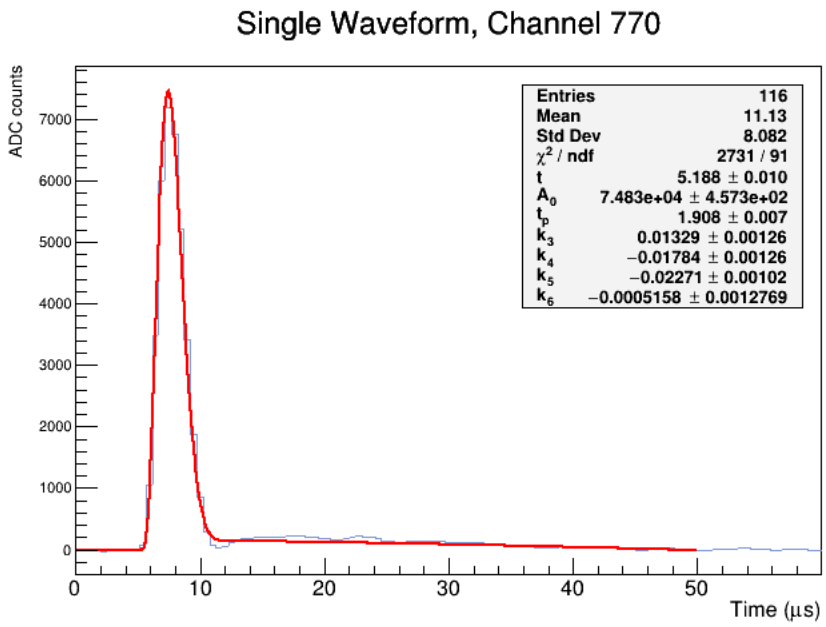

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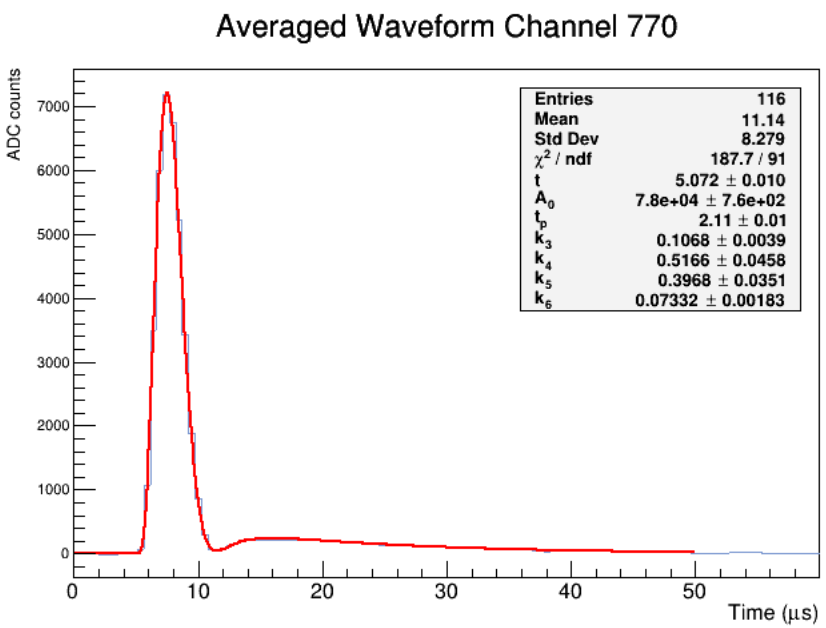

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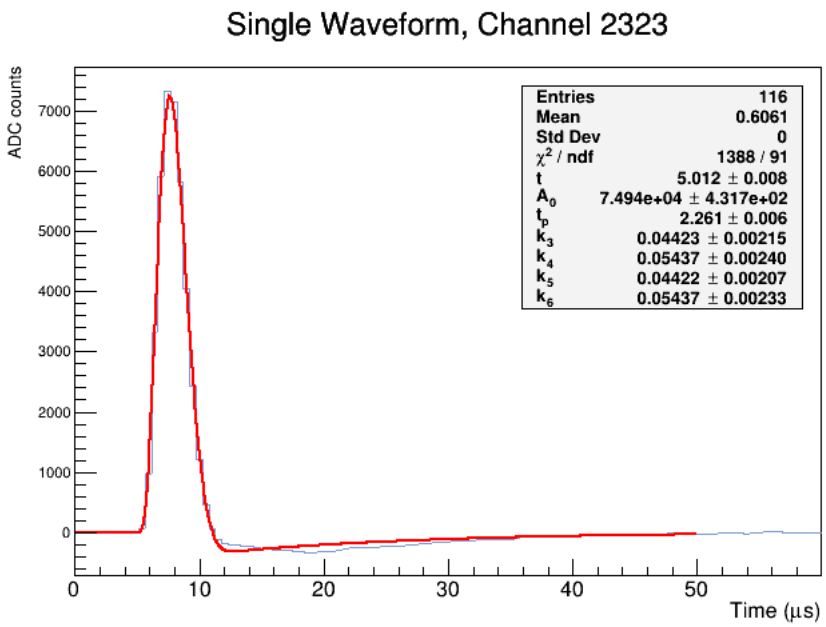

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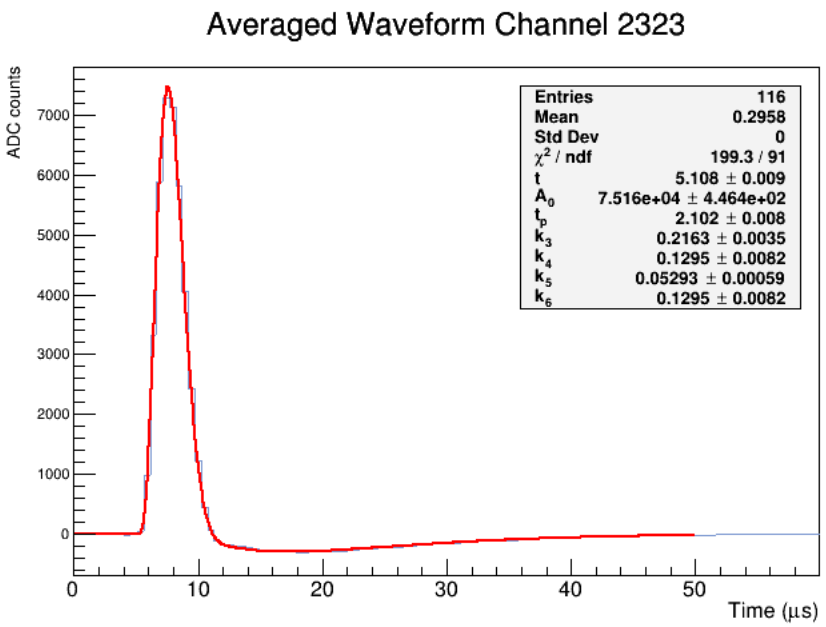

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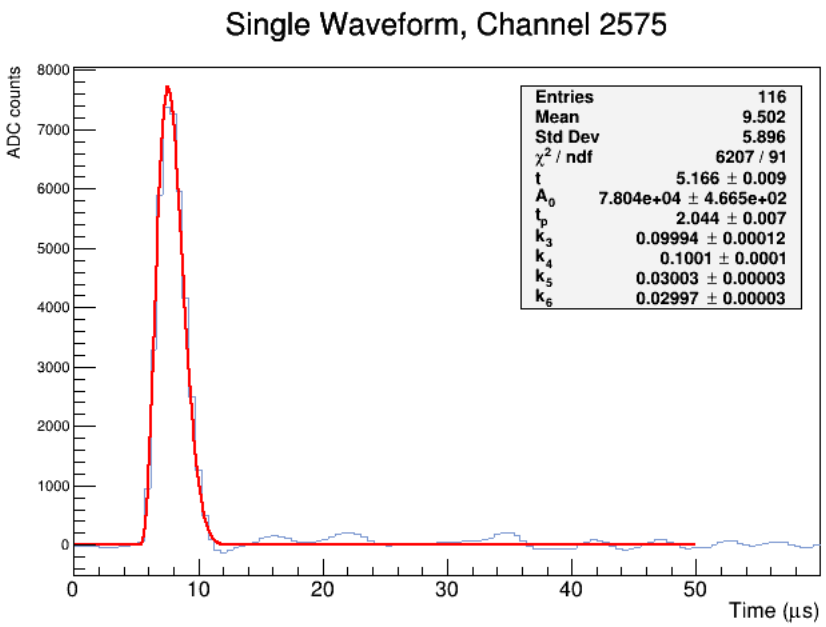

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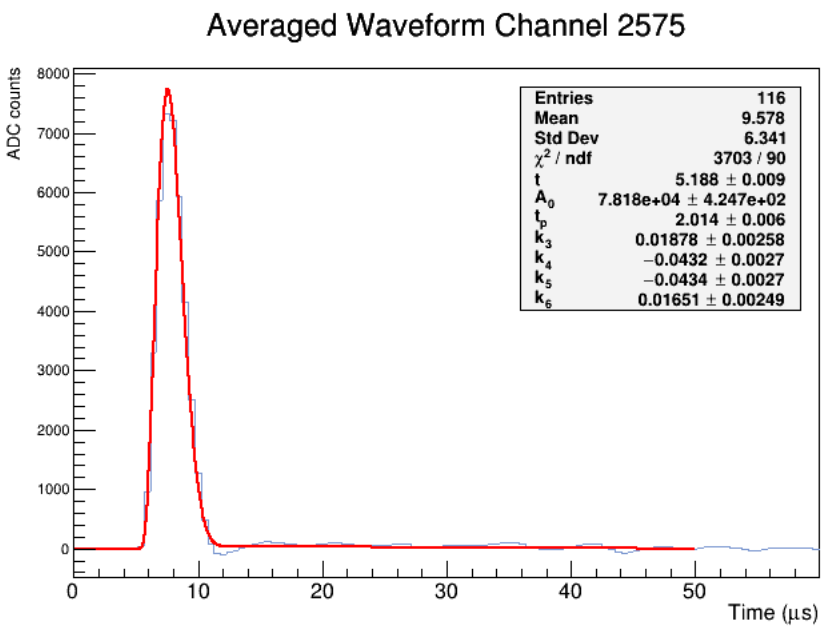

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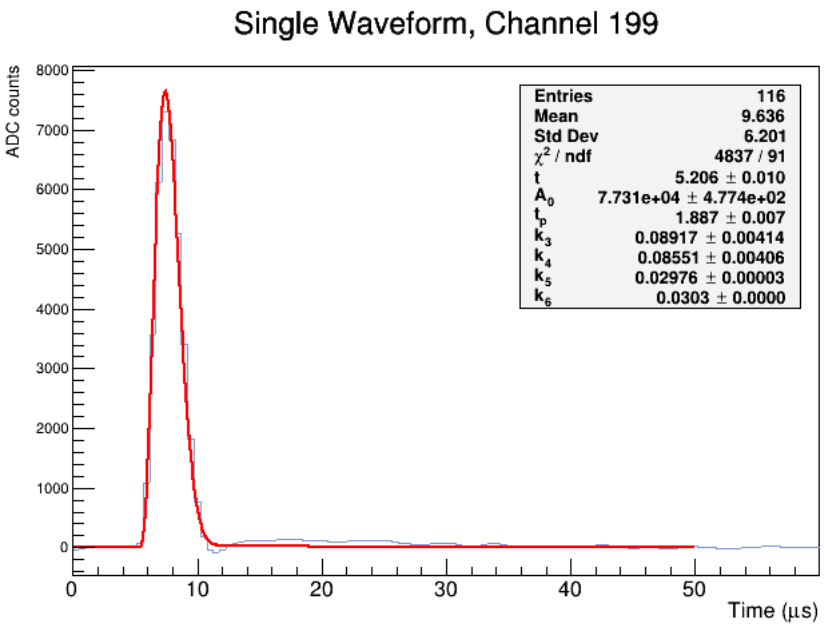

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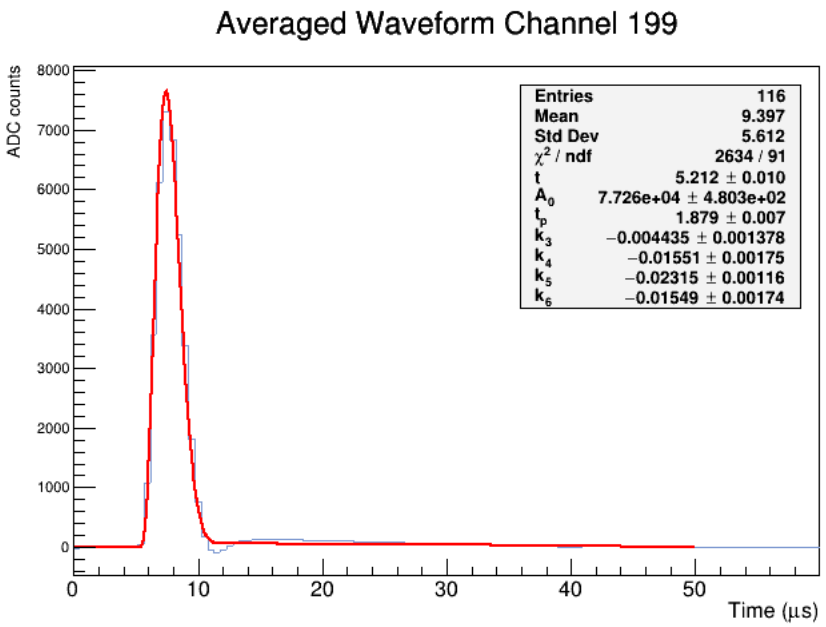
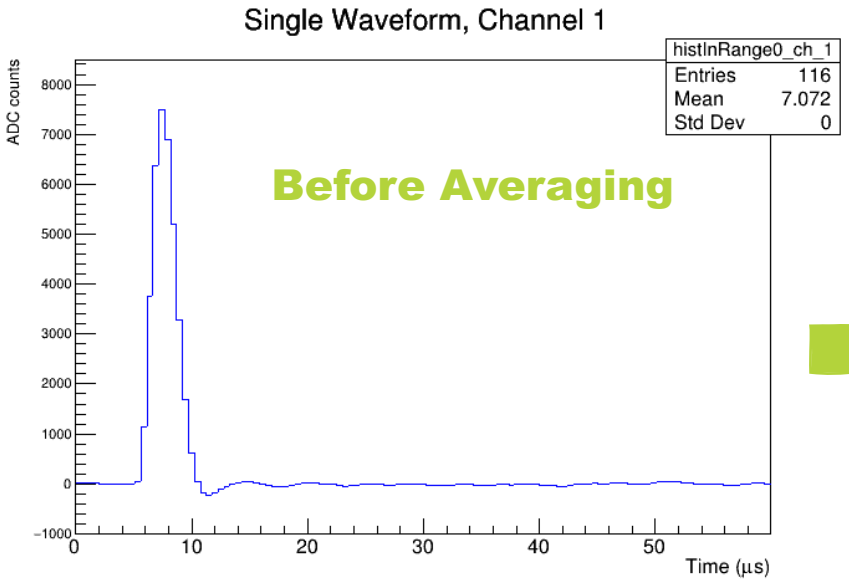


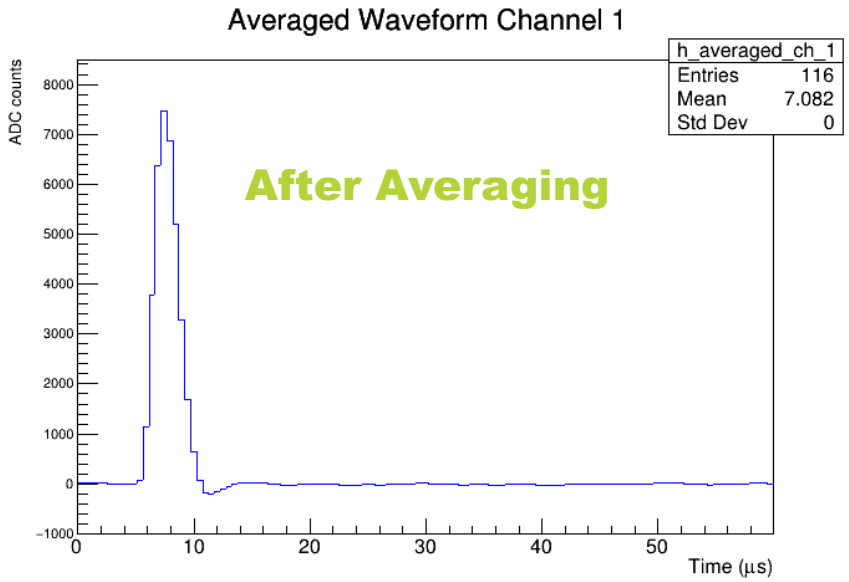
✓ Applied to PDHD Data

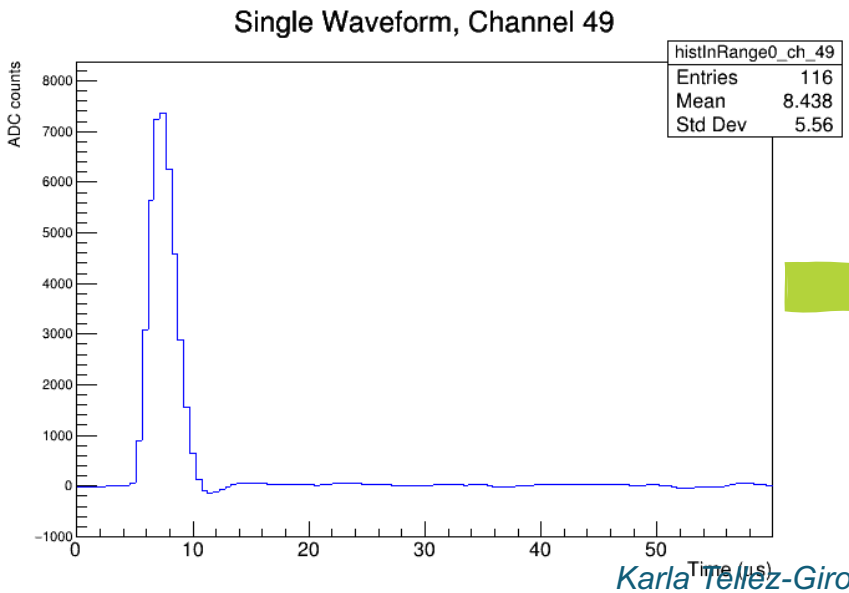
Dataset

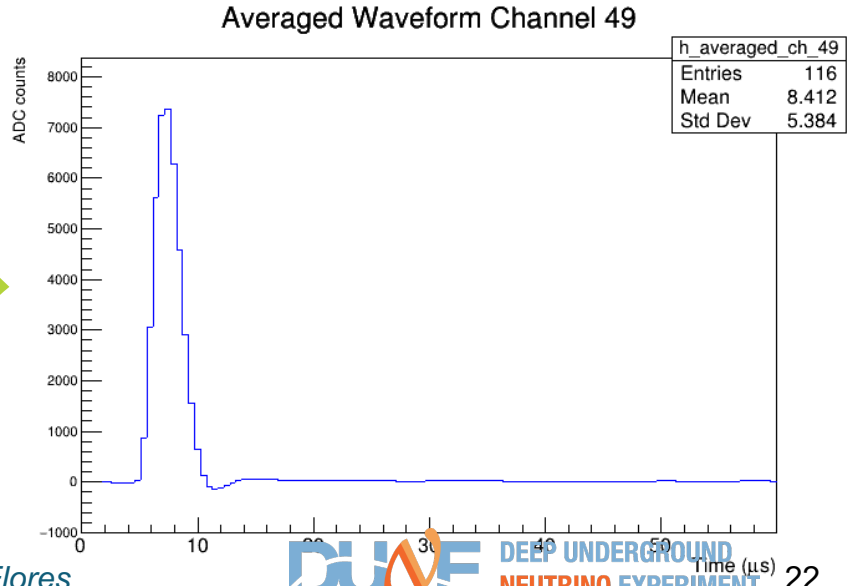
- NP04 TPC Electronics Studies Runs.
- Pulser Calibration **Run 27872** (no cosmics contamination).
- DAC = 30.
- 14 mV/fC LArASIC gain.
- 2 us Shaping Time.
- LArASIC Output Mode: Single-ended.

Averaging PDHD Data Run 27872

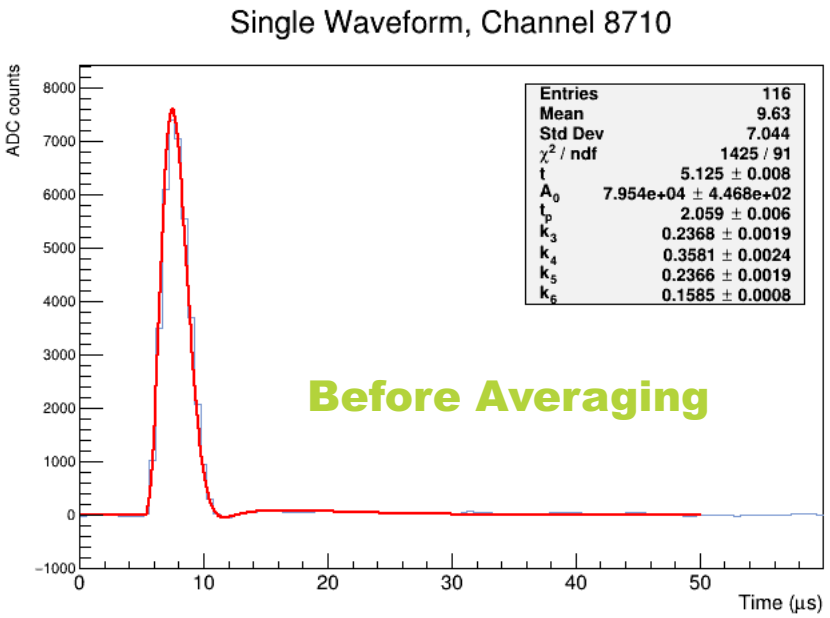


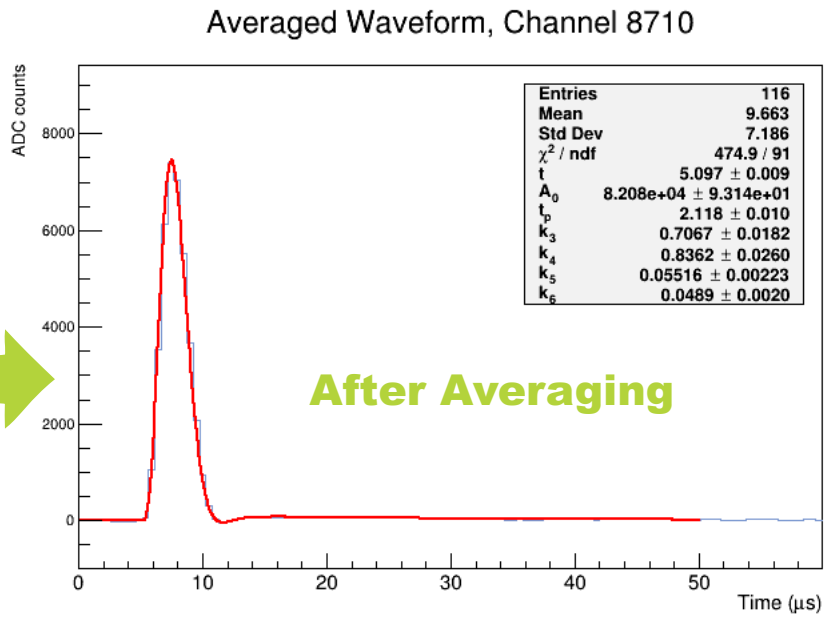


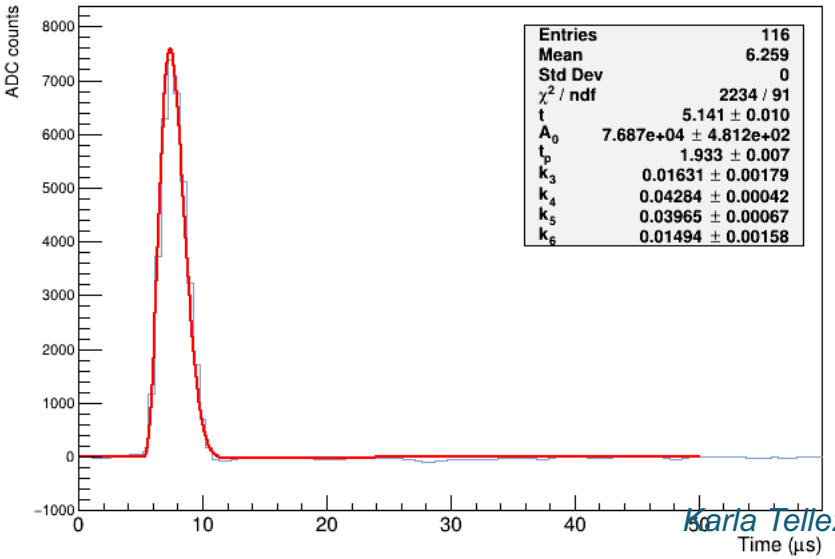


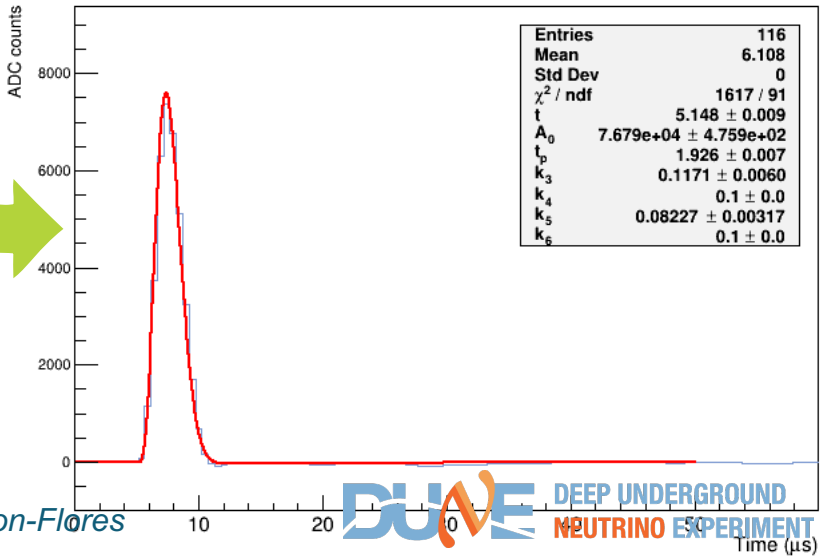


Fitter Performance Run 27872





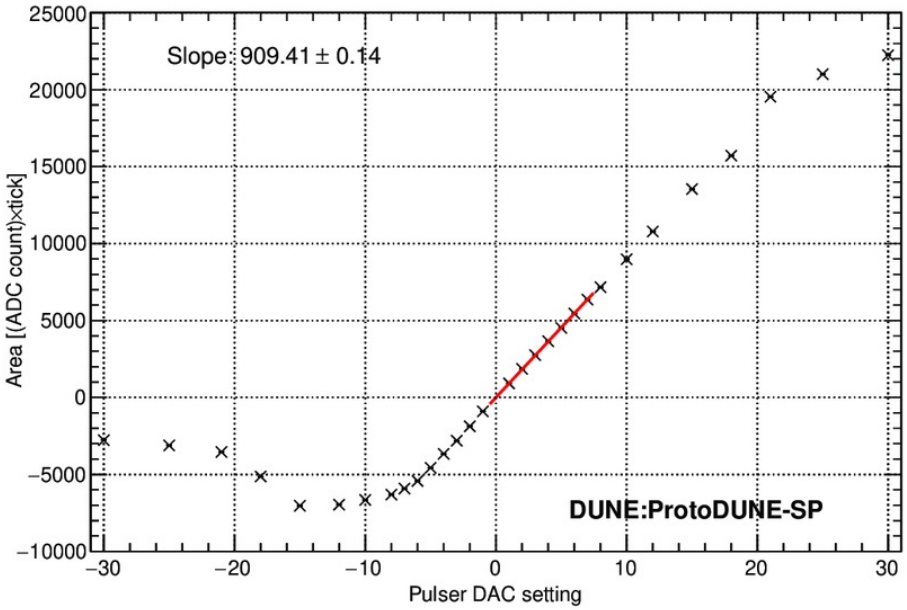




What would be next?

- Run this for all DAC settings, and the two different gains (7.8 and 14 mV/fC).
- Obtain an electron per ADC conversion.

https://arxiv.org/pdf/2007.06722



Measured pulse area vs. DAC setting for a typical collection channel. The red line shows the fit used to extract the gain.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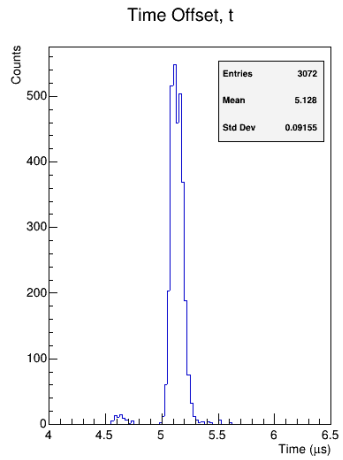
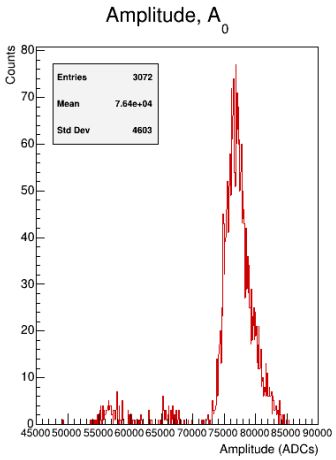
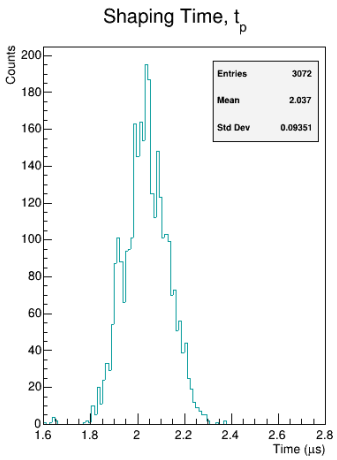
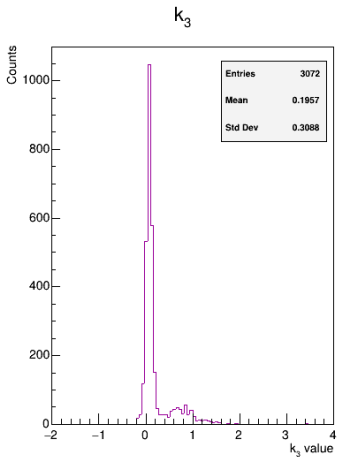
Fitter Performance Run 21040

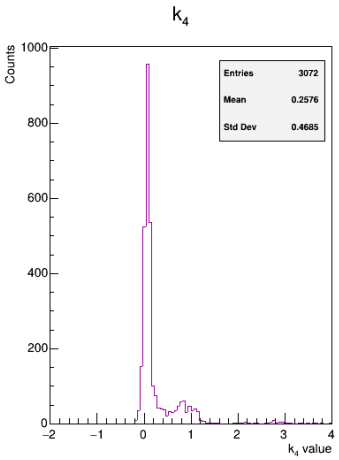
BEFORE AVERAGING

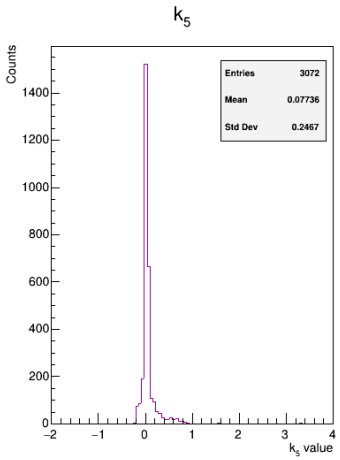


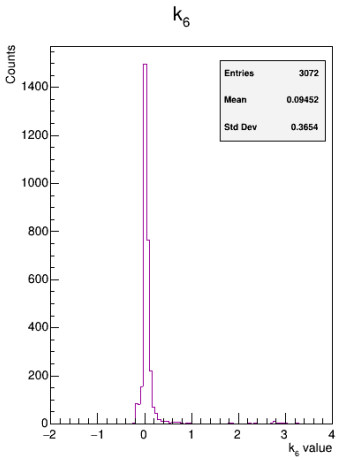


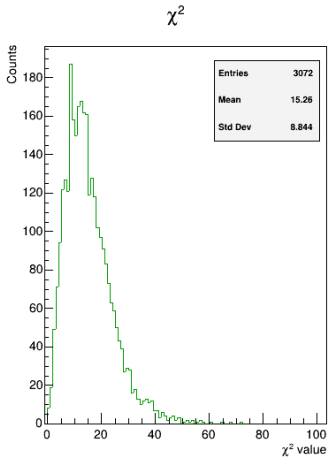






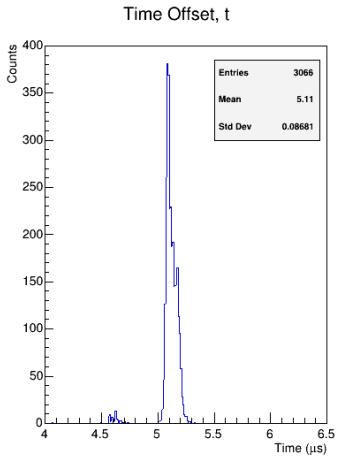


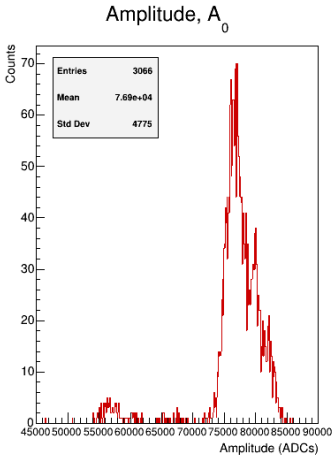


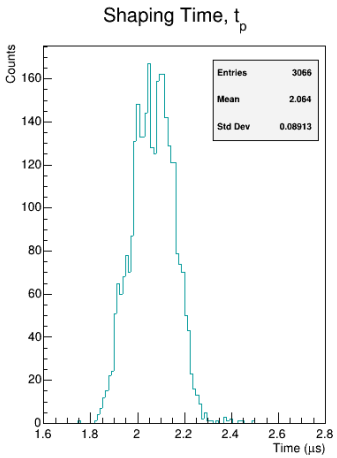


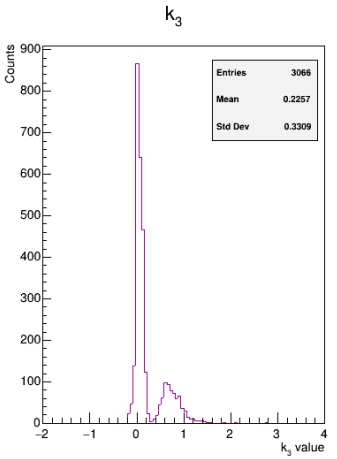
Fitter Performance Run 21040

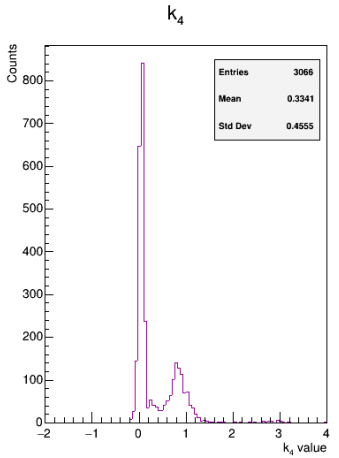
AFTER AVERAGING

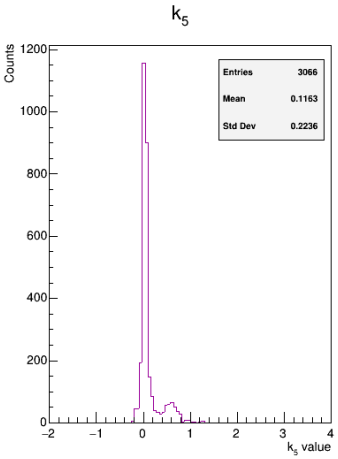


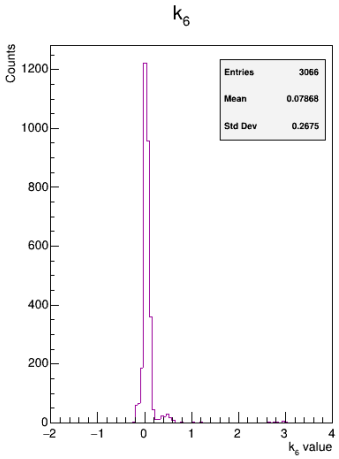


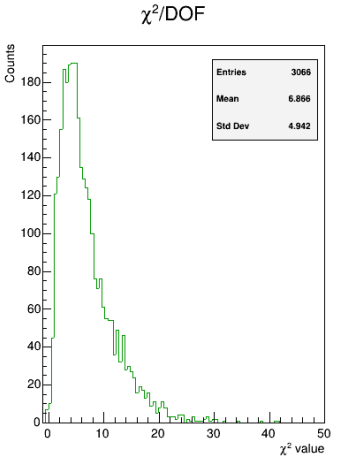












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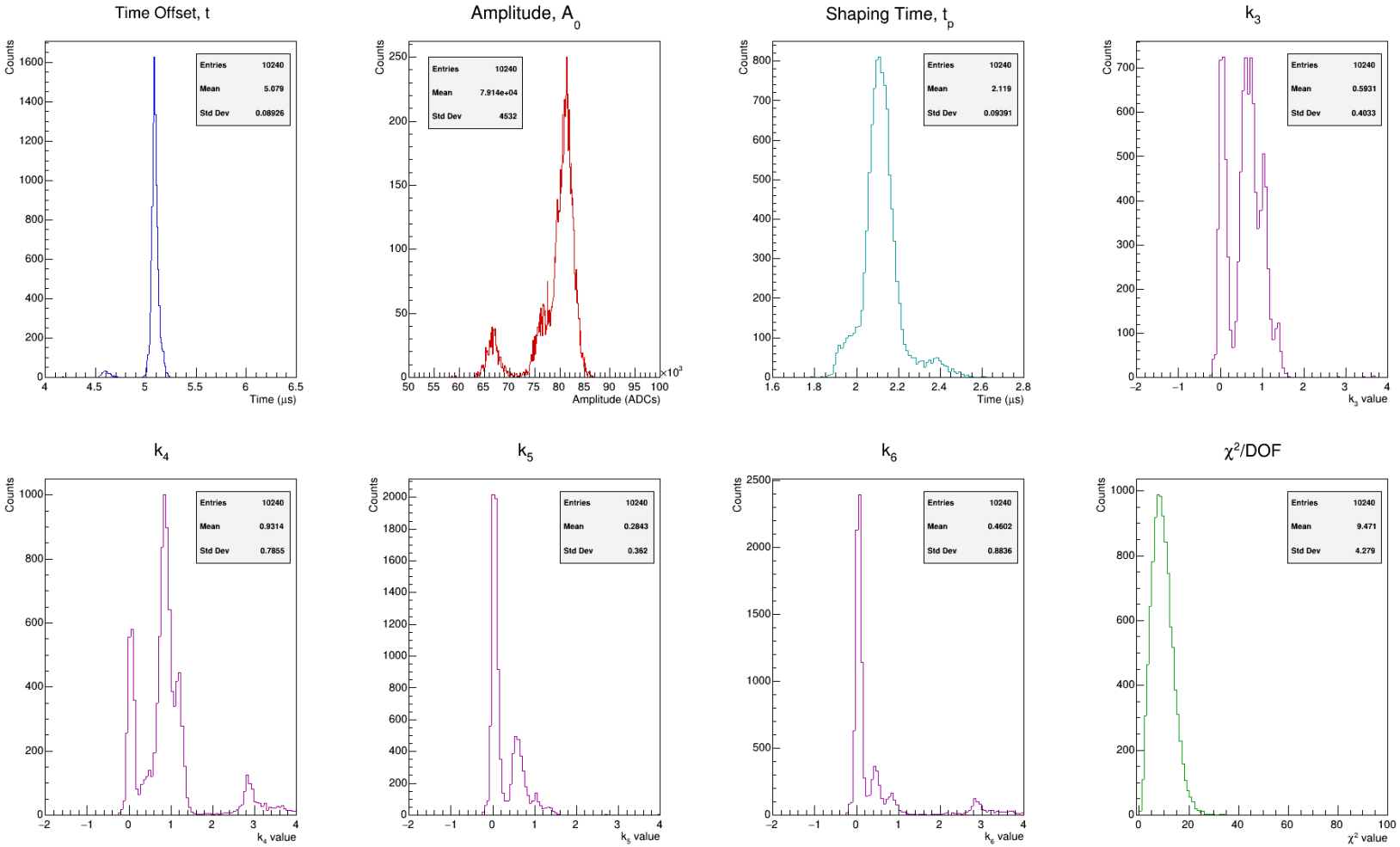

*** Trying a new fitting strategy (will talk about it next time!)**