DEEP UNDERGROUND NEUTRINO EXPERIMENT

Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Quantifying Differences Between Positive and Negative Pulses in PDHD Induction Channels

Karla Téllez Girón Flores

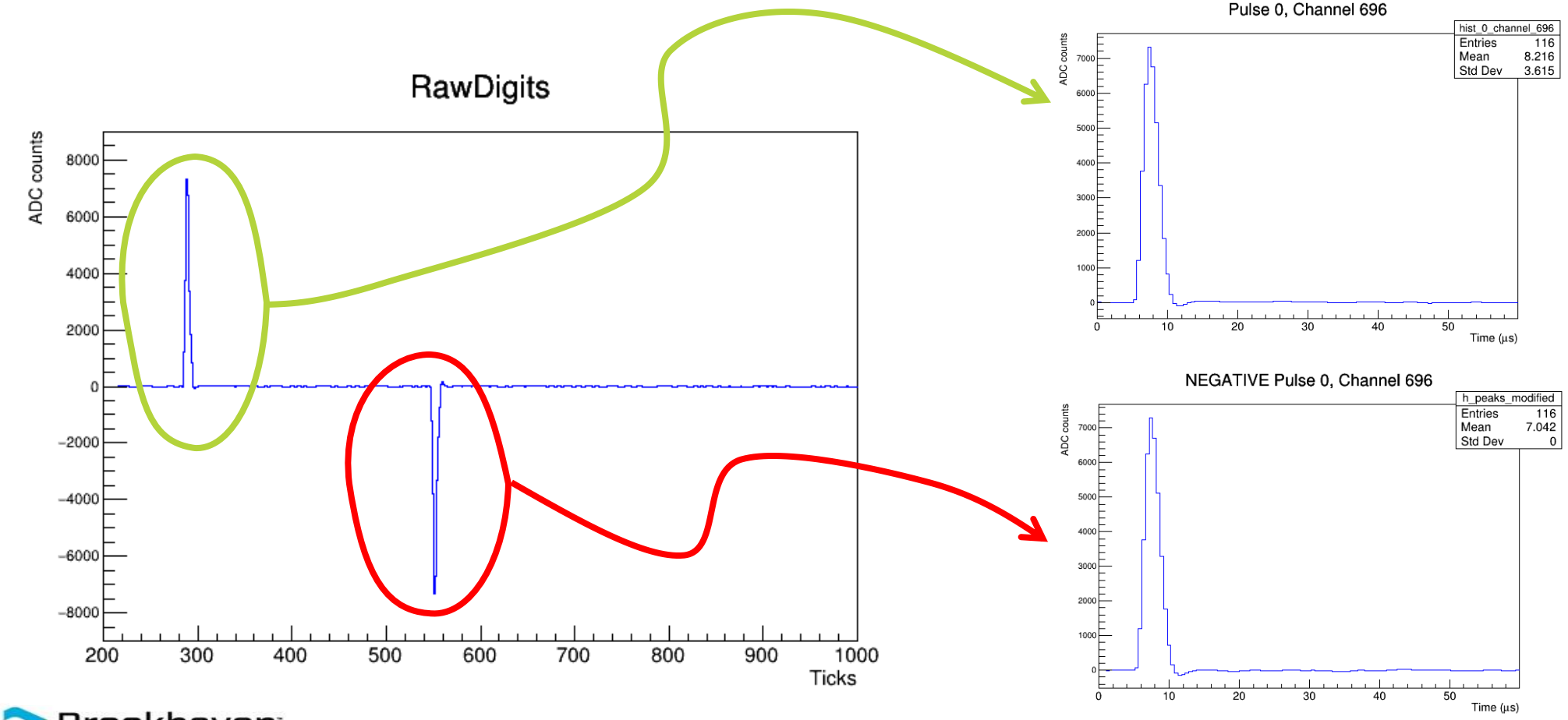
Local BNL ProtoDUNE Meeting

02/26/2025

@BrookhavenLab

How to quantify this difference?

1. Isolate both pulses:

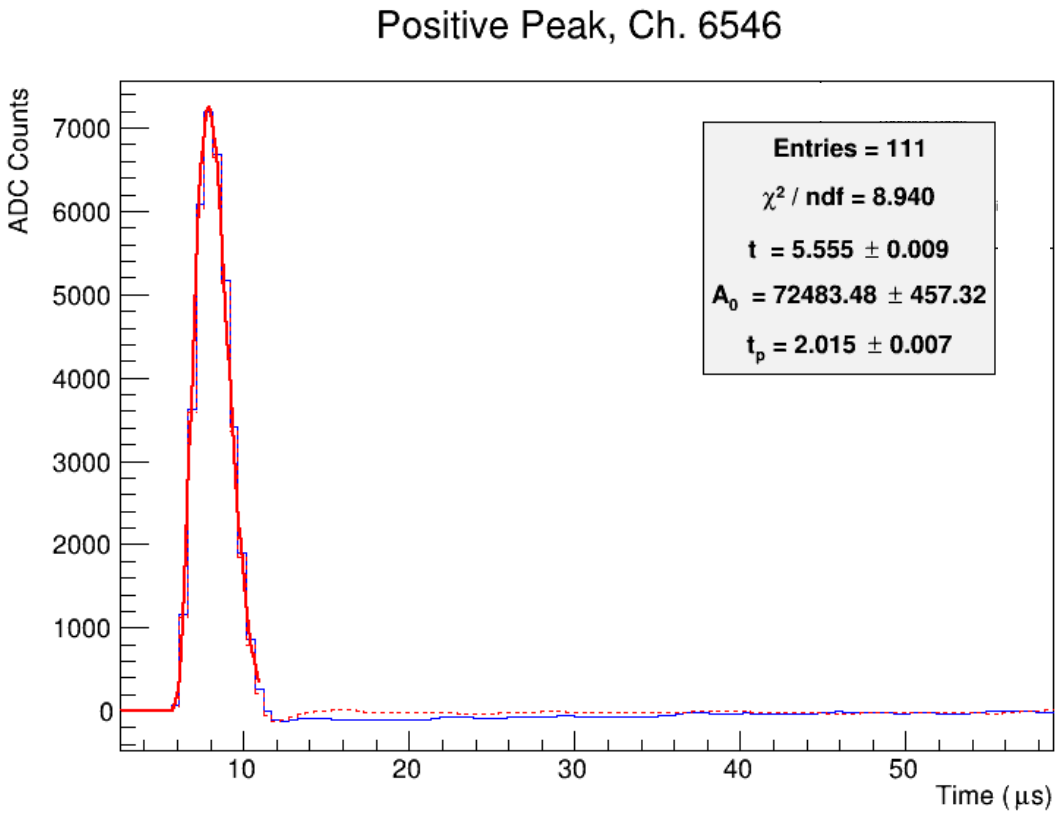


Brookhaven National Laboratory

How to quantify this difference?

Start with main peak

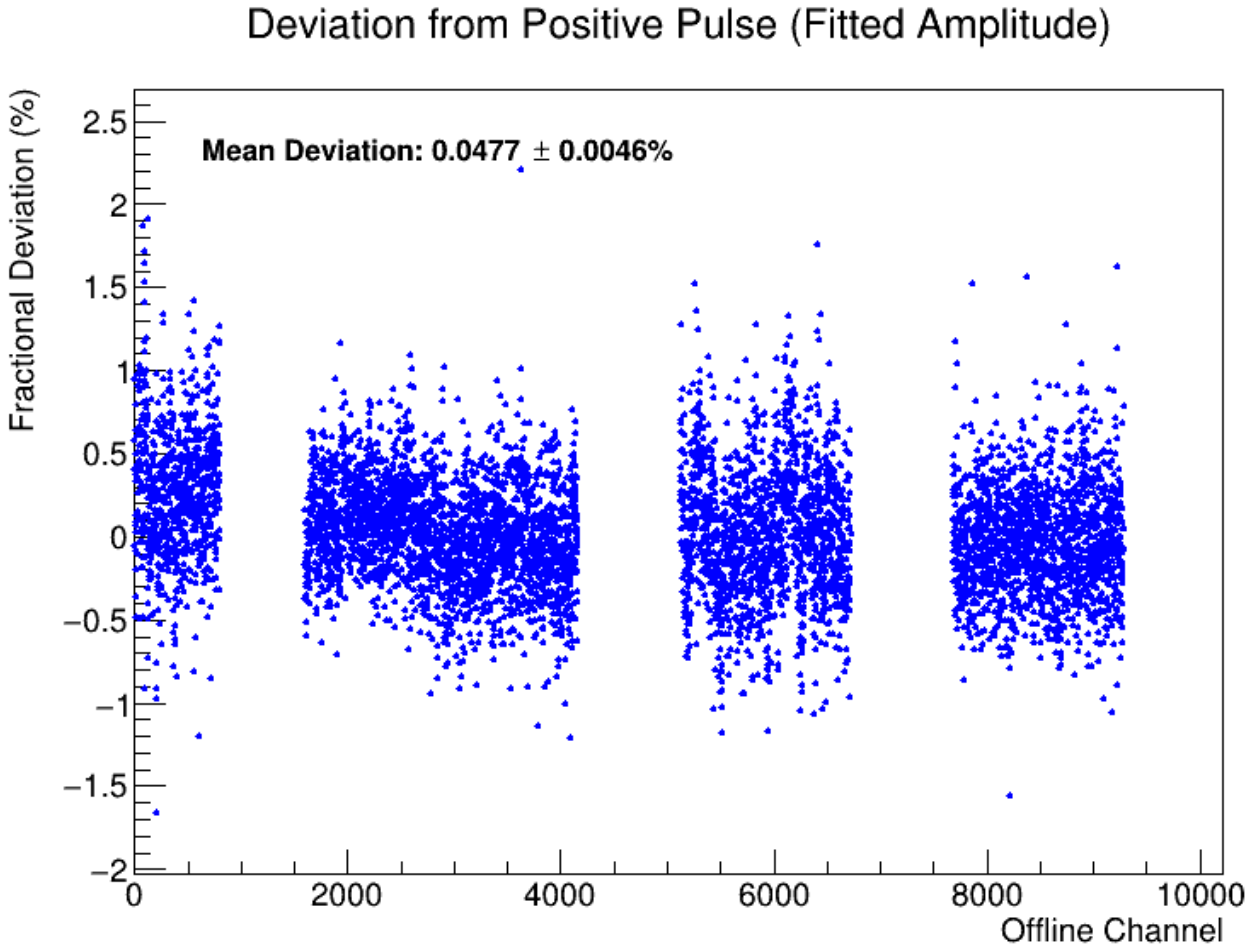
2. Fit both (+) and (-) peaks with IDEAL Electronics Response Function




```
double response_legacy(double *x, double *par){

        Double_t t = x[0]-par[0];
        Double_t A0 = par[1];
        Double_t tp = par[2];
        Double_t reltime = t / tp;
        Double_t gain = A0* 1.012;

        Double_t value = 4.31054 * exp(-2.94809 * reltime) * gain - 2.6202 * exp(-2.82833 * reltime)
        * cos(1.19361 * reltime) * gain - 2.6202 * exp(-2.82833 * reltime) * cos(1.19361 * reltime) *
        cos(2.38722 * reltime) * gain + 0.464924 * exp(-2.40318 * reltime) * cos(2.5928 * reltime) *
        gain + 0.464924 * exp(-2.40318 * reltime) * cos(2.5928 * reltime) * cos(5.18561 * reltime) *
        gain + 0.762456 * exp(-2.82833 * reltime) * sin(1.19361 * reltime) * gain - 0.762456 * exp(-
        2.82833 * reltime) * cos(2.38722 * reltime) * sin(1.19361 * reltime) * gain + 0.762456 * exp(-
        2.82833 * reltime) * cos(1.19361 * reltime) * sin(2.38722 * reltime) * gain - 2.620200 * exp(-
        2.82833 * reltime) * sin(1.19361 * reltime) * sin(2.38722 * reltime) * gain - 0.327684 * exp(-
        2.40318 * reltime) * sin(2.5928 * reltime) * gain + +0.327684 * exp(-2.40318 * reltime) *
        cos(5.18561 * reltime) * sin(2.5928 * reltime) * gain - 0.327684 * exp(-2.40318 * reltime) *
        cos(2.5928 * reltime) * sin(5.18561 * reltime) * gain + 0.464924 * exp(-2.40318 * reltime) *
        sin(2.5928 * reltime) * sin(5.18561 * reltime) * gain;

    return value;
}
```

How to quantify this difference?

Start with main peak



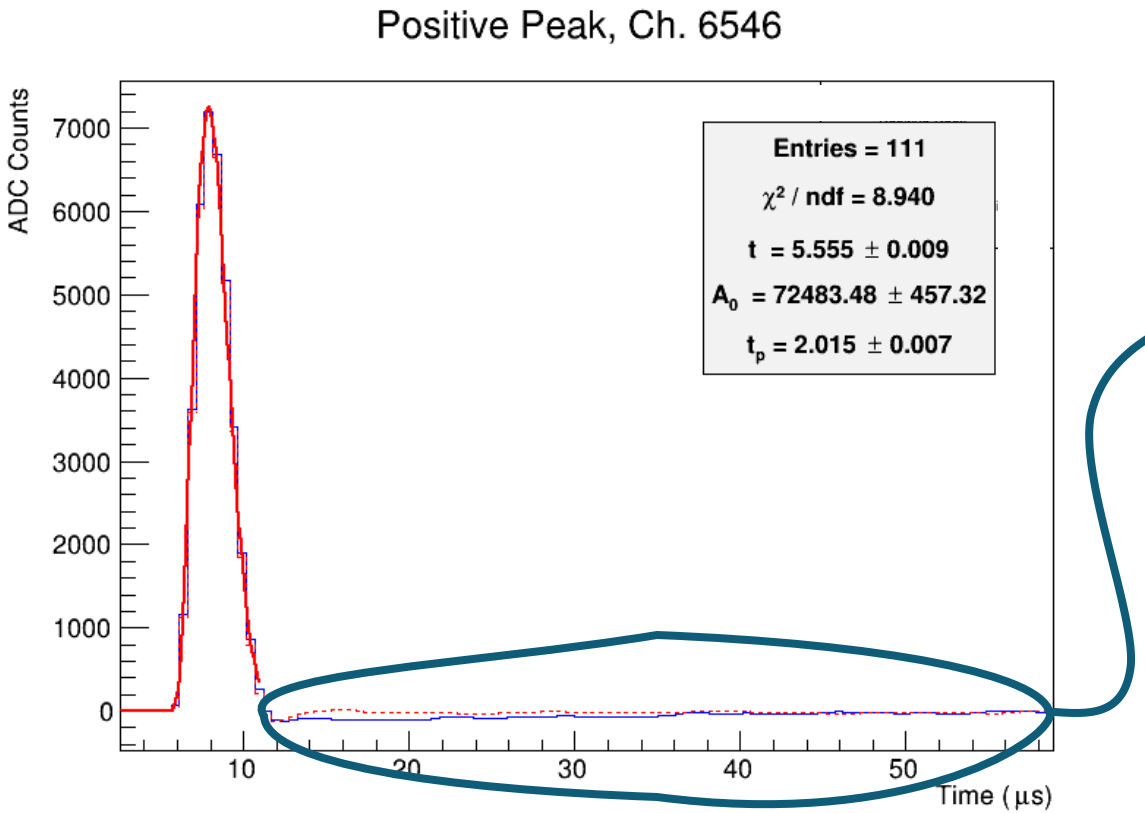
$$\textbf{Fractional Deviation} = \frac{A_- - A_+}{A_+} \times 100$$

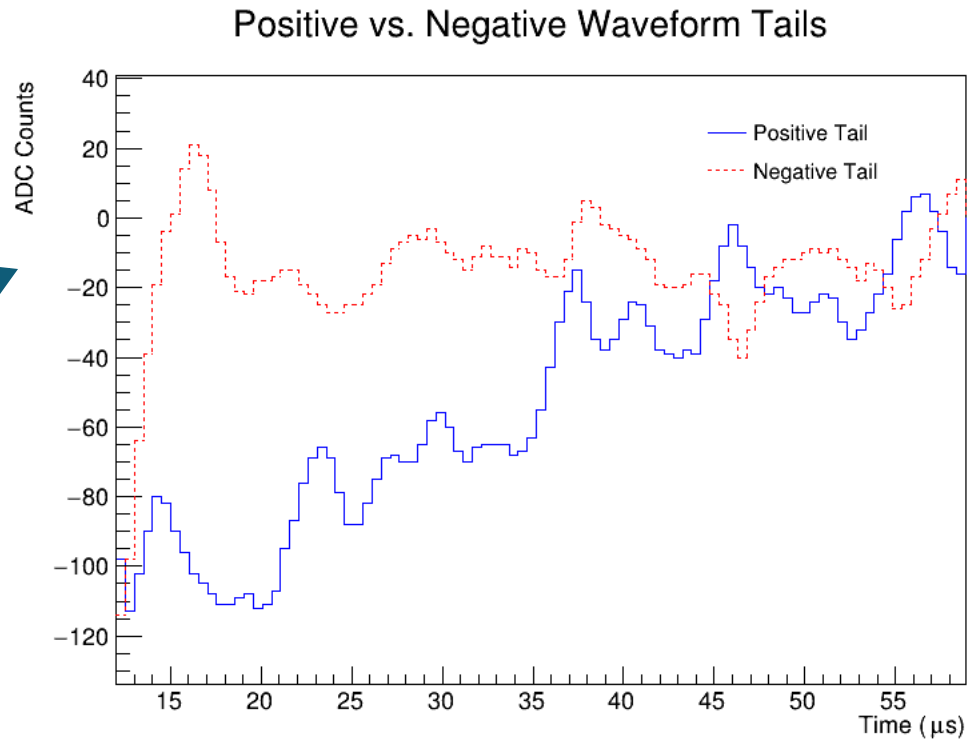
- If (–) main peak is the same as the (+): 0%
- If (–) main peak is larger than the (+): > 0%
- If (–) main peak is smaller than the (+): < 0%

✅ Amplitudes in this run generally differ between (-) and (+) pulses, but differences remain within ± 2%

How to quantify this difference?

3. Next, analyze the tails





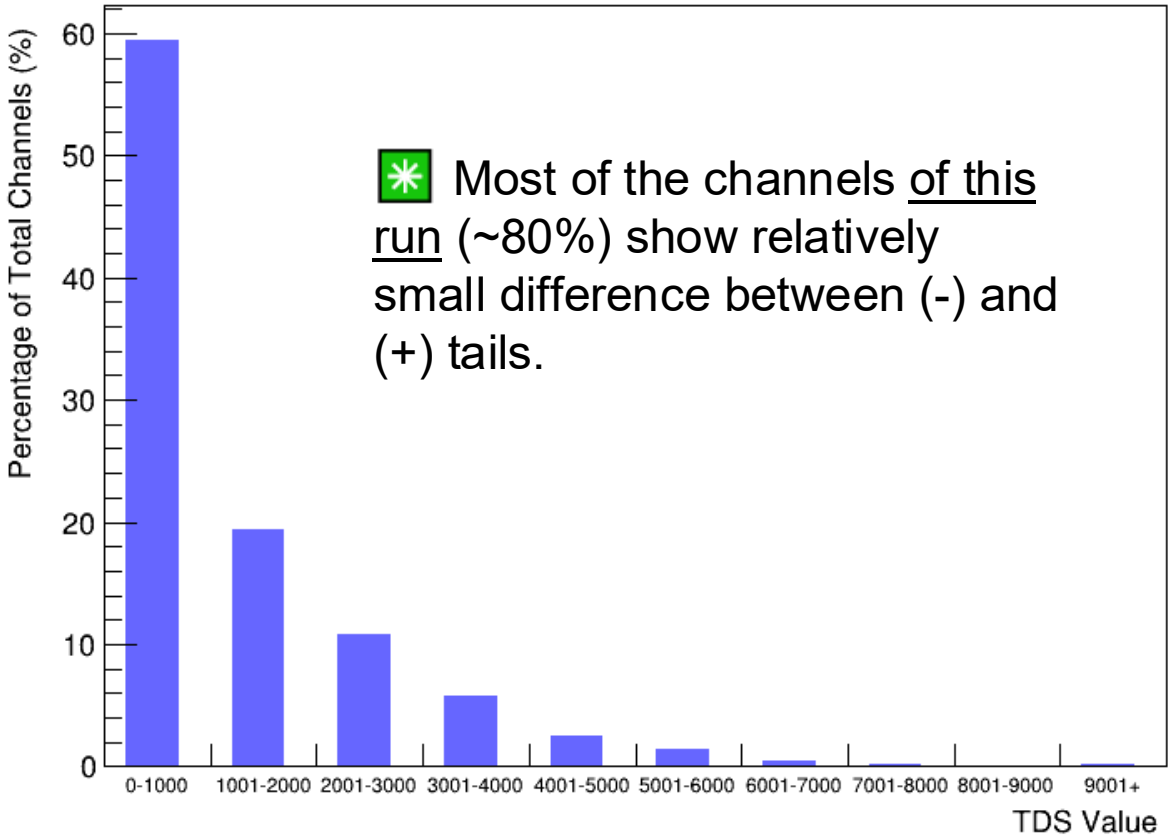
How to quantify this difference?
Combining different metrics

Calculated a TDS: *Tail Difference Score*

$$\mathbf{TDS} = A_{diff} + D_{ratio} + B_{rms}$$

- $A_{diff} = |A_- - A_+|$: **Absolute area difference** (total signal magnitude difference between tails).
- $D_{ratio} = \left|\frac{A_-}{A_+} - 1\right|$: **Deviation from unity** (to check for asymmetry) (How much A_- differs from A_+)
- $B_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Pos_i - Neg_i)^2}$: **RMS deviation** (to measure bin-to-bin variations, shape) Detailed Tail Structure

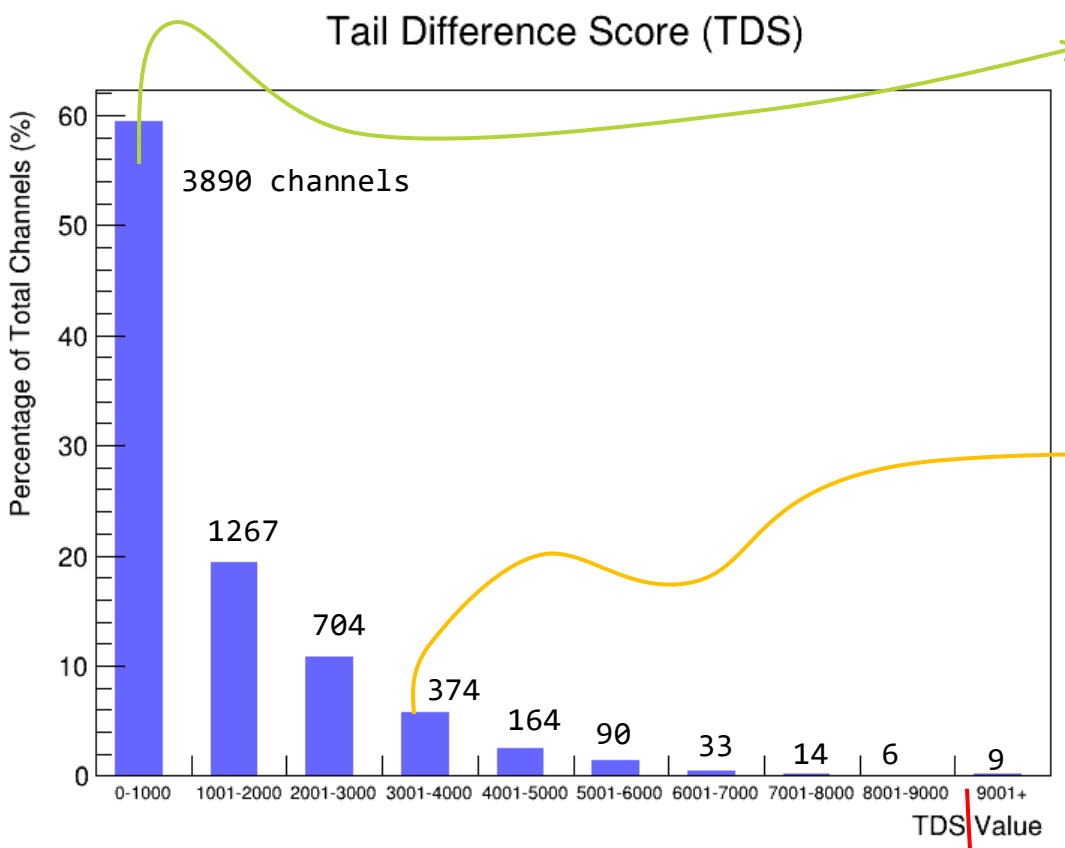
Tail Difference Score (TDS)

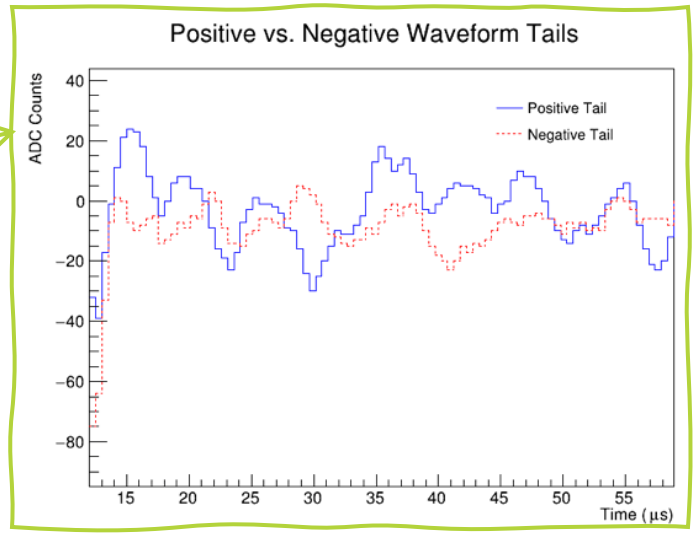


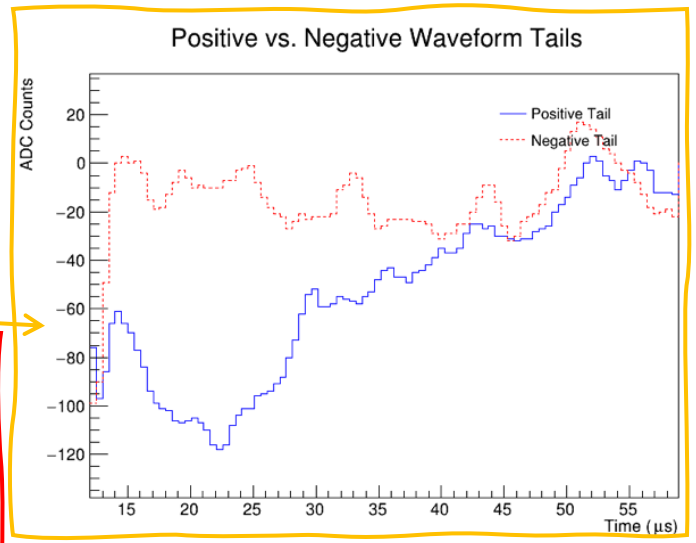
Most of the channels of this run (~80%) show relatively small difference between (-) and (+) tails.

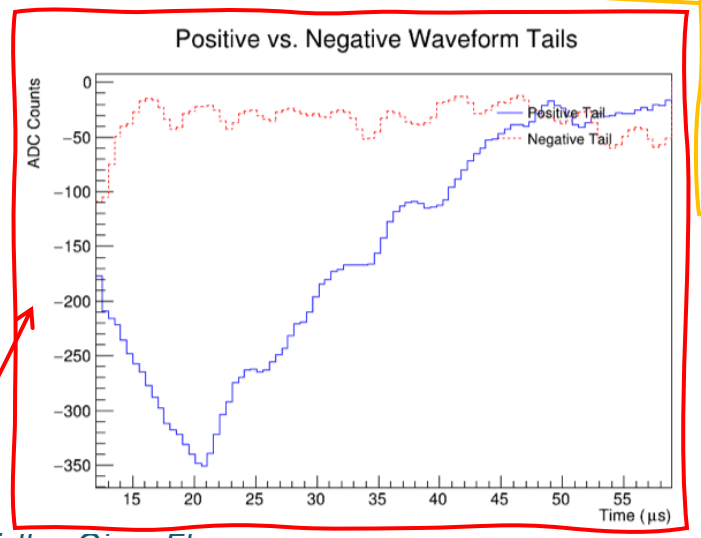
How to quantify this difference?

Verifying these results



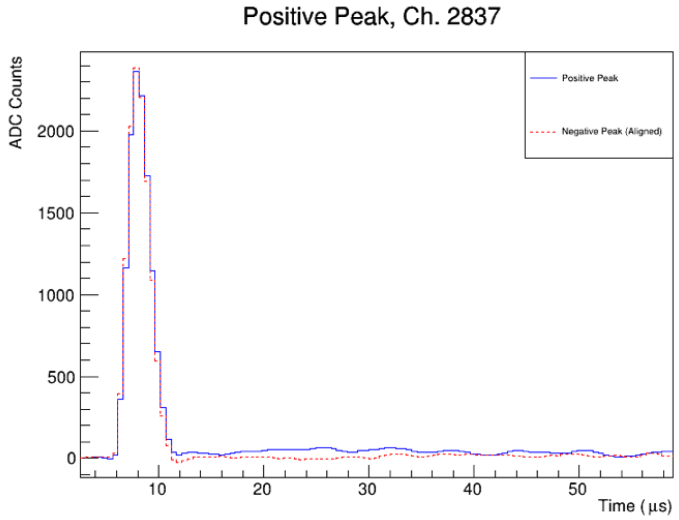


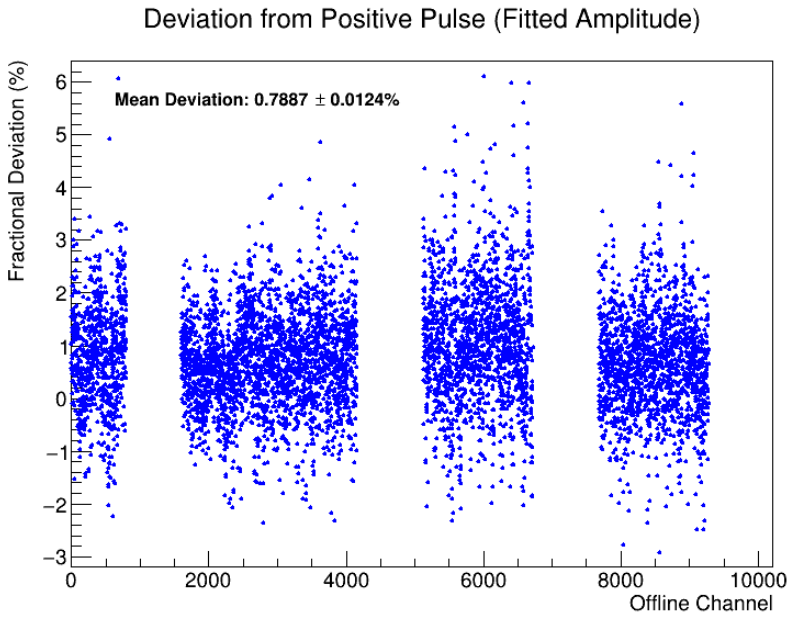


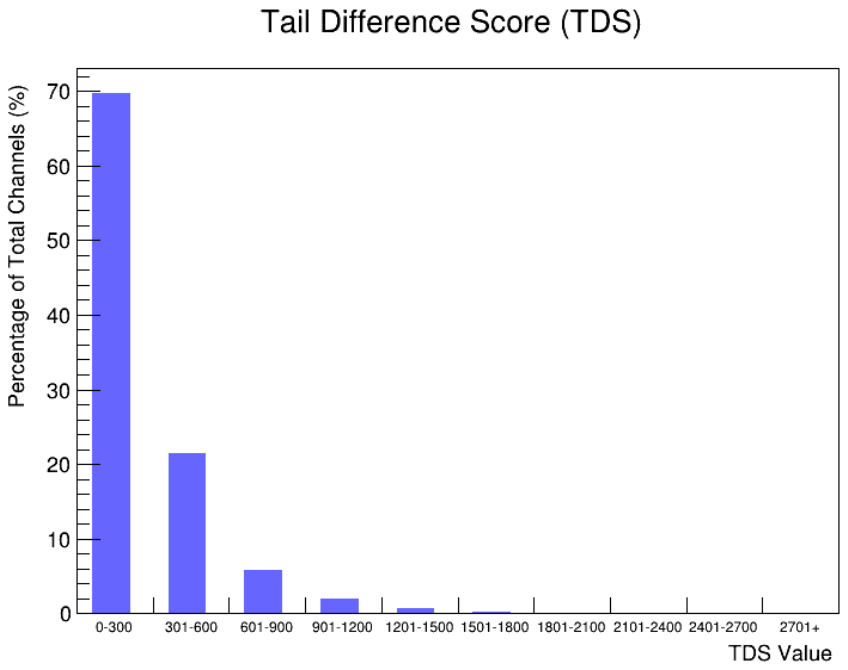


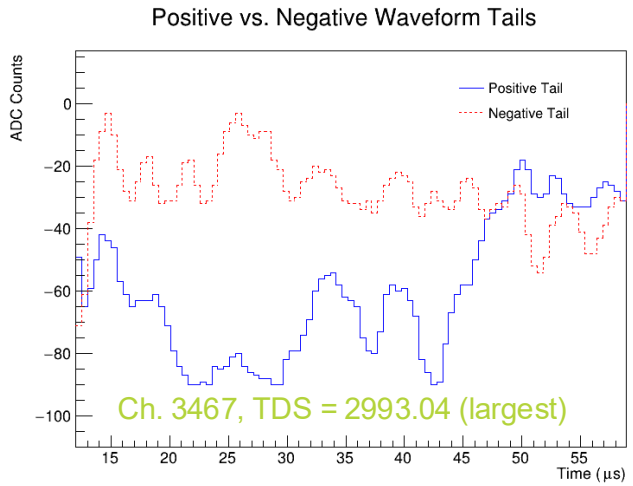
Does this change with different DAC settings?

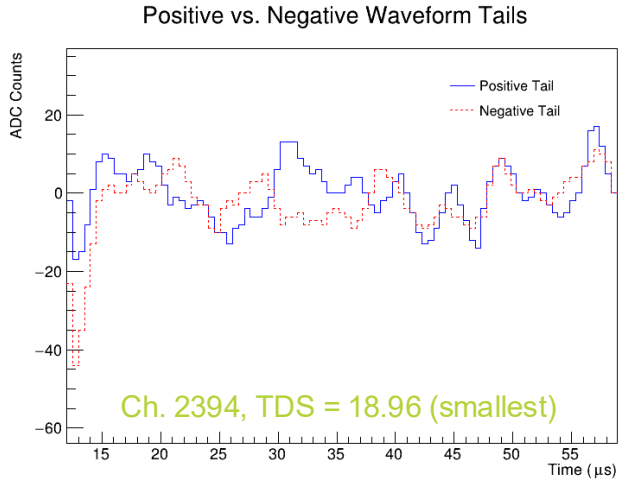
DAC = 10





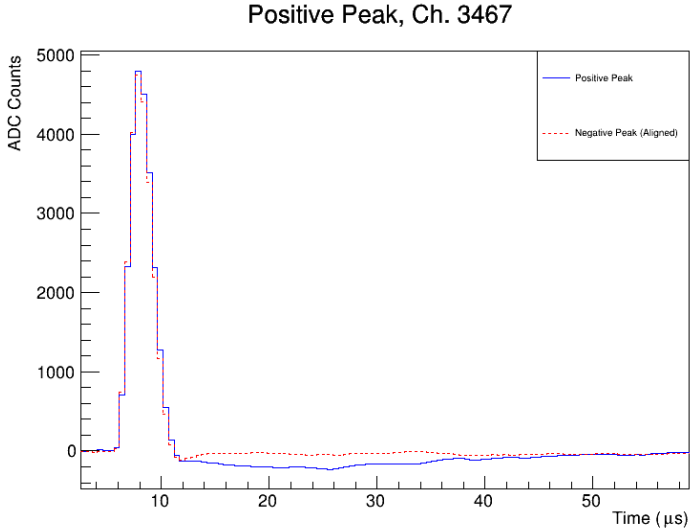


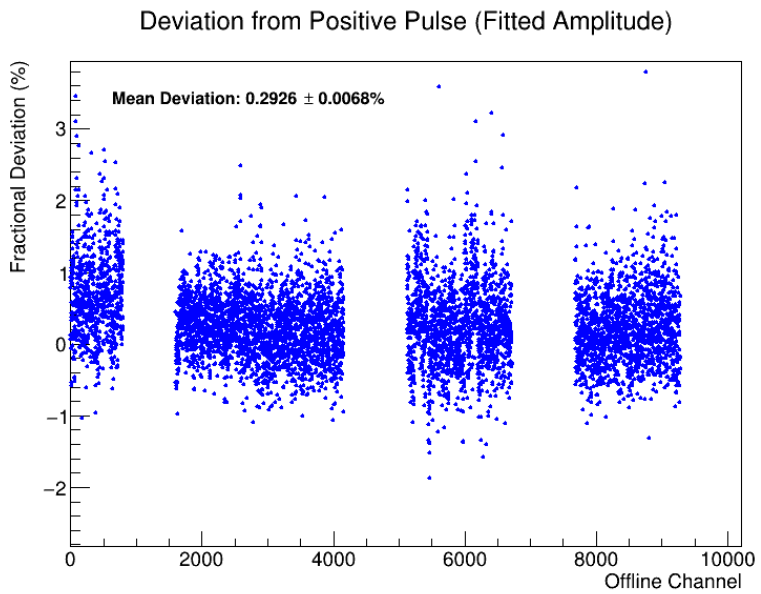


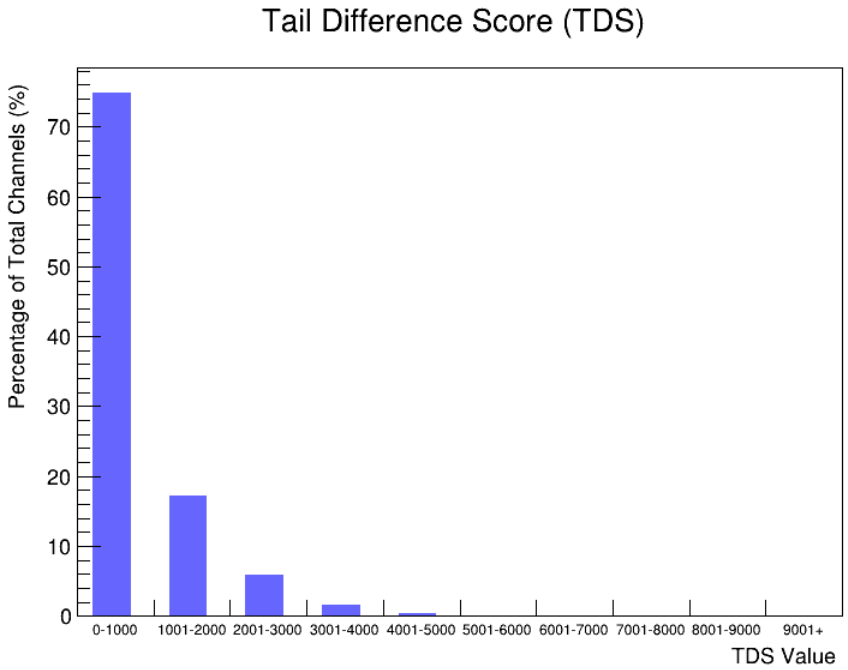


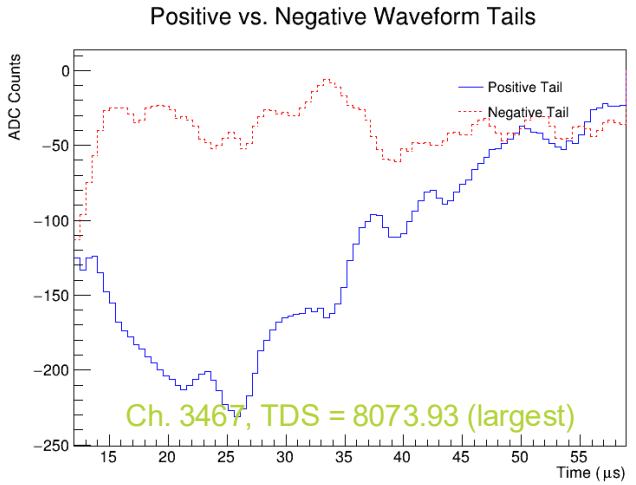
Does this change with different DAC settings?

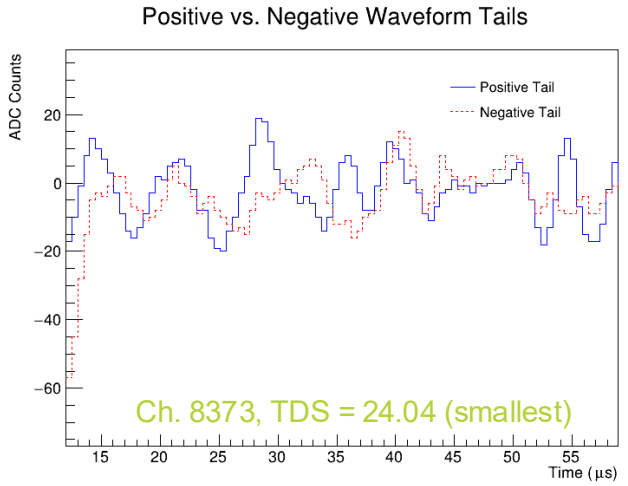
DAC = 20





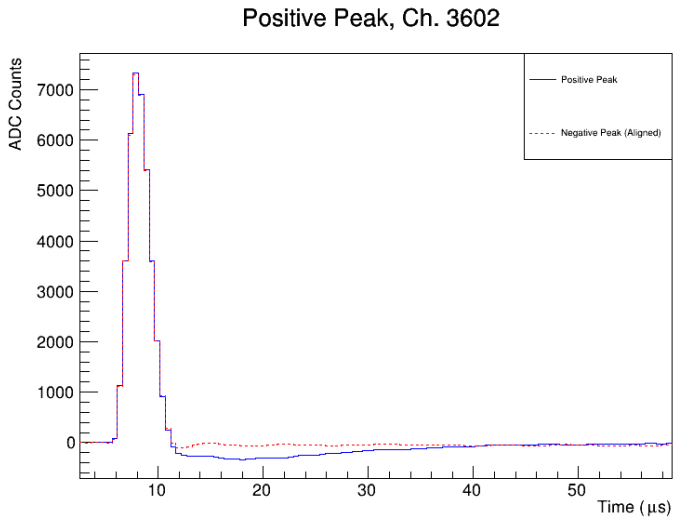


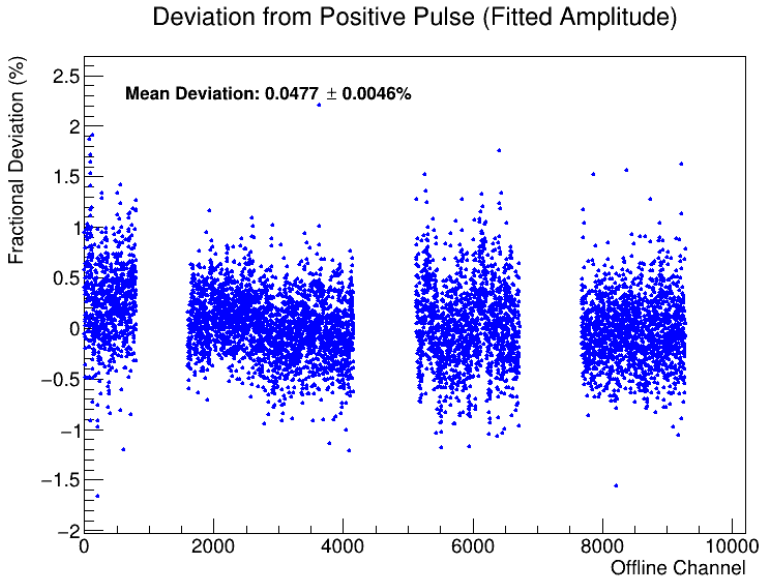


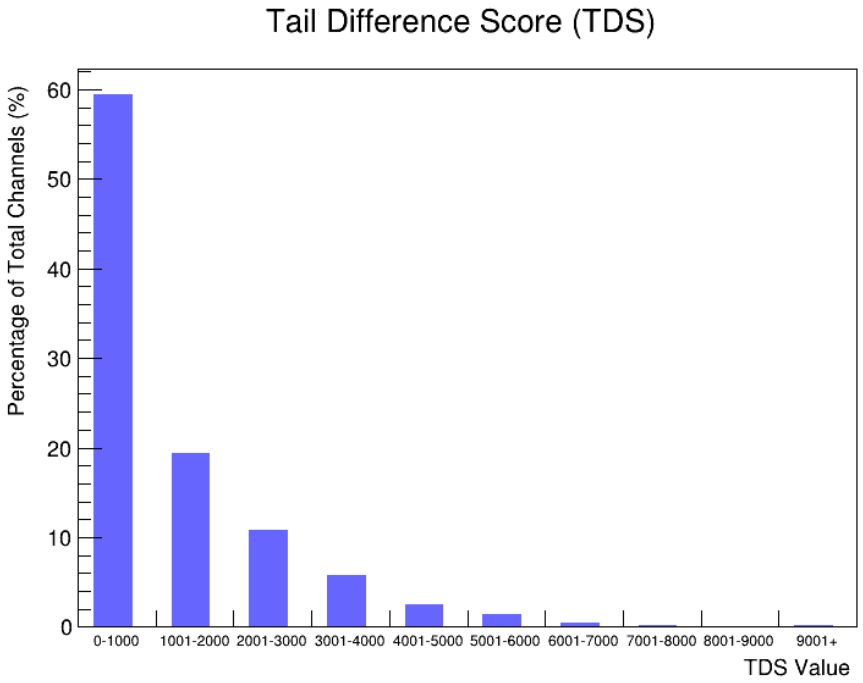


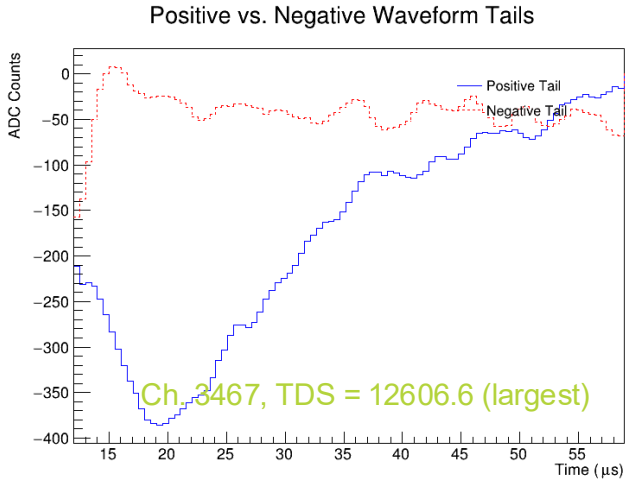
Does this change with different DAC settings?

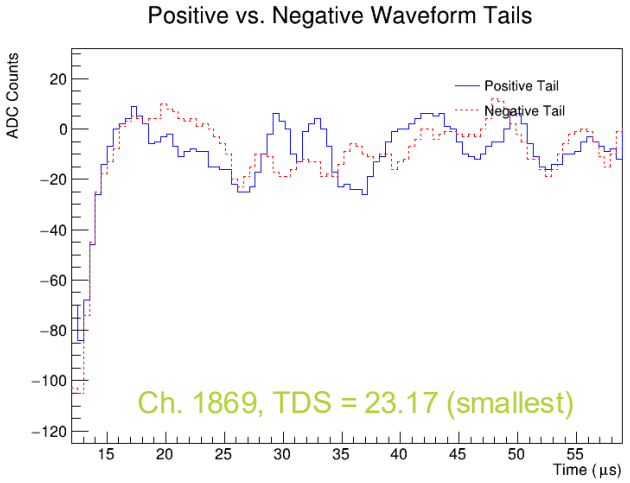
DAC = 30





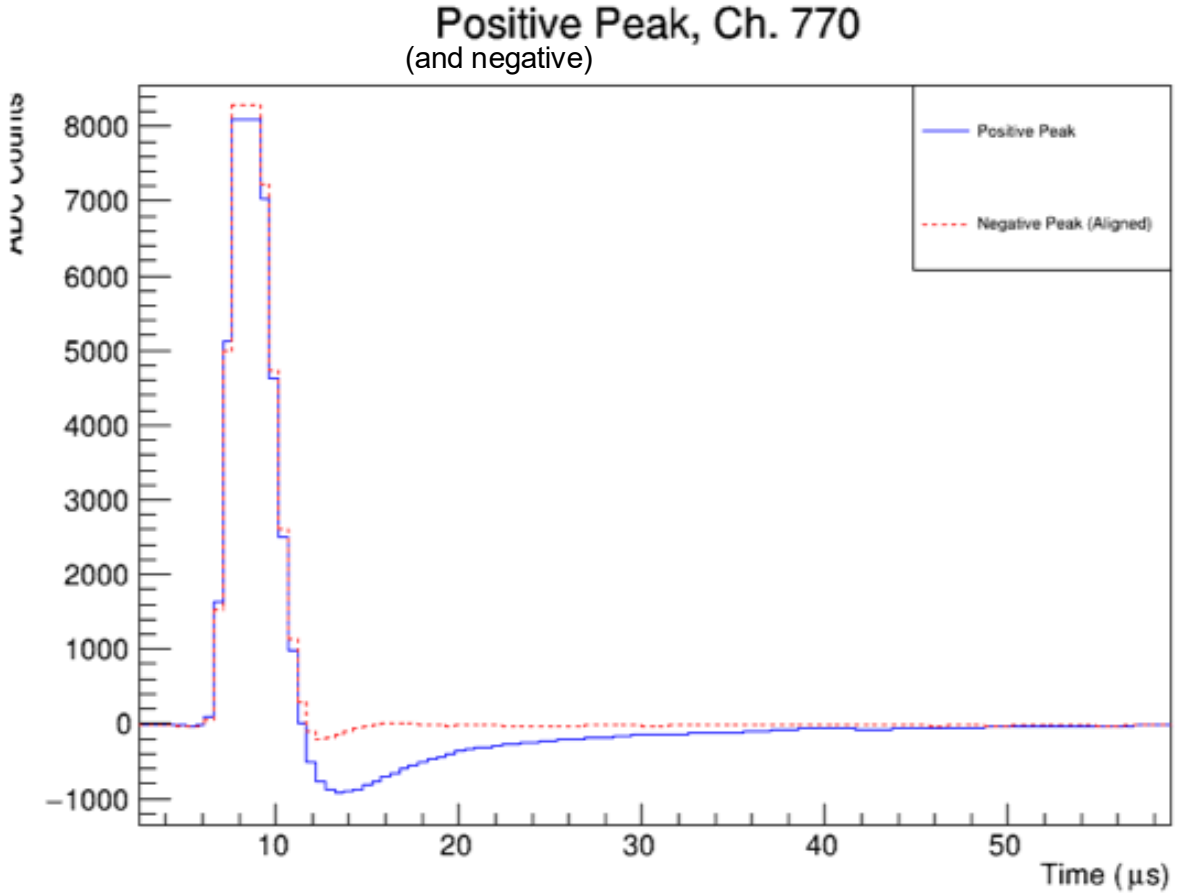


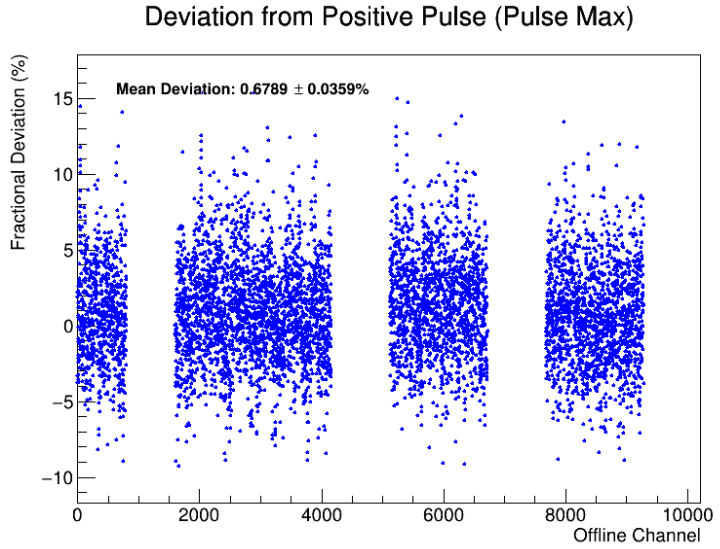


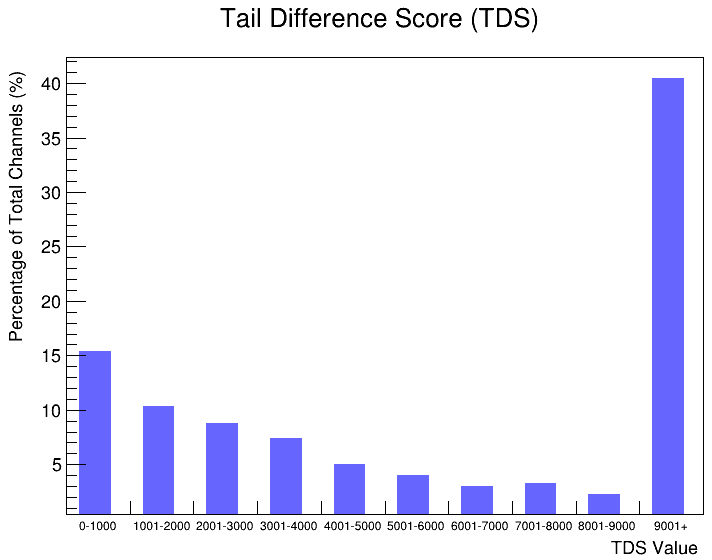


Does this change with different DAC settings?

DAC = 40







To Do Next

- Use the New Electronics Response function to quantify these differences between (+) and (-) pulses.
- Check these metrics on different waveforms, not just the first one of each event.

Some Answered Questions

1. Is this behavior expected? *Answer: Yes, but we don't know how big the differences are.*
2. Are these differences considered *small*? *Answer: Maybe? We need a deeper study.*
3. What are the implications of having such differences in positive and negative pulses? *Answer: This is more of a question for Analysis Experts --What are we using the negative peaks for?*
4. Can we fix this from a hardware perspective? *Answer: No, it is too late.*