SAMPA Time Resolution Study 1

- <u>Ideal case </u>study
- Inject charges into 2 separate channels; time difference between charge pulses is stable and adjustable
- Record SAMPA pulse pairs and compute time difference Δt and time difference resolution $\sigma(\Delta t)$
- Time resolution $\sigma(t)$ for a channel is estimated as:

$$\sigma(t) = \sigma(\Delta t) / 1.414$$

EJ – 1/14/20

Pulse Time

- The JLab FADC250 hardware uses the pulse's leading edge ADC samples and interpolates to compute the pulse time as the time where the amplitude is ½ the peak value of the pulse
- We found that if a pulse has ~3 samples on it's leading edge we can obtain a timing resolution of about 1 – 1.5 ns (~1/3 the sample period) for the pulse
- This suggests that we should be able to at least achieve a SAMPA timing resolution of ~15 - 20 ns (50 ns/3)
- The shaping time for the SAMPA pulse is 160 ns, which assures that at least 3 samples are on the leading edge.

SAMPA Pulse Time

- Since the SAMPA shaping time (160 ns) is large compared to the expected spread in charge arrival time (< 50 ns) for detectors under consideration (TPC, our GEM prototype), the SAMPA pulse shape is very stable.
- (See report: *Effect of Charge Collection Time on SAMPA Pulse Shape.*)
- We can thus fit the entire SAMPA pulse to the expected pulse shape to extract the pulse time.
- Expect timing resolution *better* than 15 -20 ns that is achievable by only using leading edge.

SAMPA Pulse Time

- The pair of shaping circuits in the SAMPA produce a 4-th order semi-Gaussian pulse that can be adequately described by the following functional form:

$$f(x) = A\left(\frac{x-t}{\tau}\right)^{N} e^{-N\left(\frac{x-t}{\tau}\right)} + Bl.$$

- *A* is the peak, *N=4* is the shaping order of the amplifier, τ is the shaping time (nominally 160 ns), *Bl* is the baseline, and *t* is the start time.
- <u>We use *t* as the SAMPA pulse time in this study</u>.

SAMPA Pulse Fit

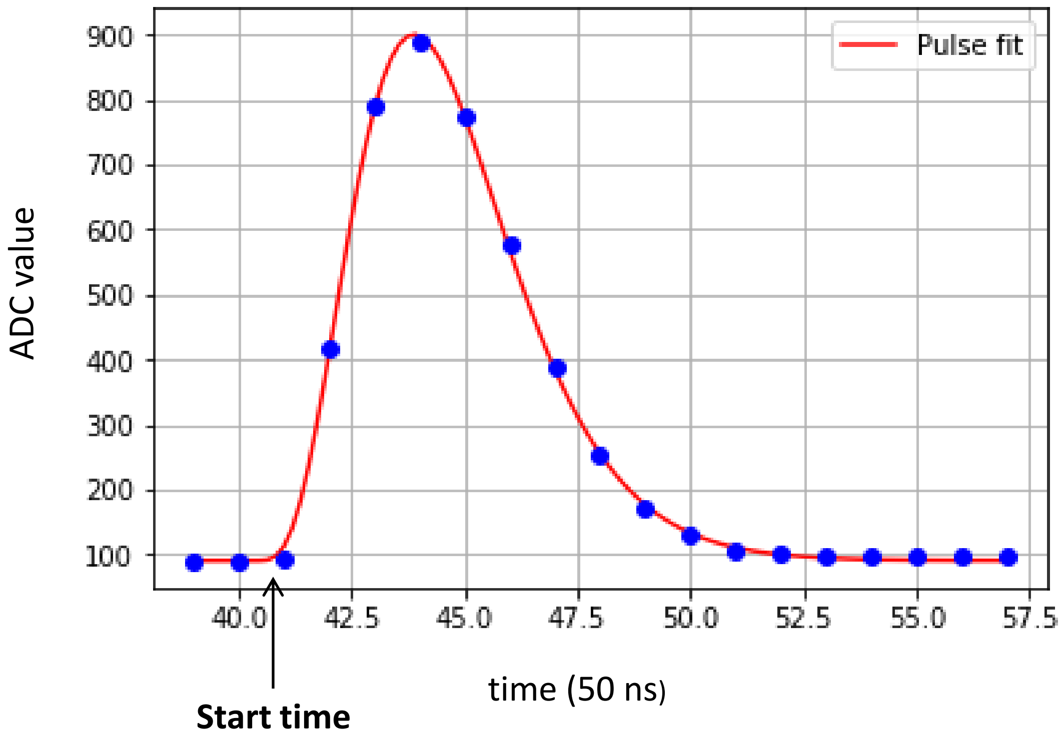


Figure 1. Pulse data and fit to the SAMPA shape. Charge injection period = 4 ns. Start time from fit is shown.

Input Pulse Generation

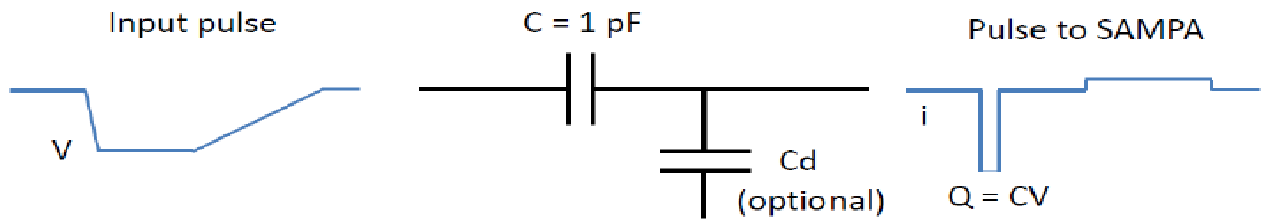


Figure 2. Test pulse generation. (C_d = 0 in tests)

The 1 pF capacitor is implemented on a Test Pulse Card.

The Test Pulse Card plugs directly into a SAMPA Front-end Card (FEC) connector; each FEC connector handles 40 channels.

Odd and even channels of the Test Card can be pulsed independently.

<u>Channels 1 and 4</u> of SAMPA 0 on FEC 0 are used for this study.

Pulse pairs with a stable time relationship are generated with a 2-channel pulse generator (Tektronix AFG3252C)

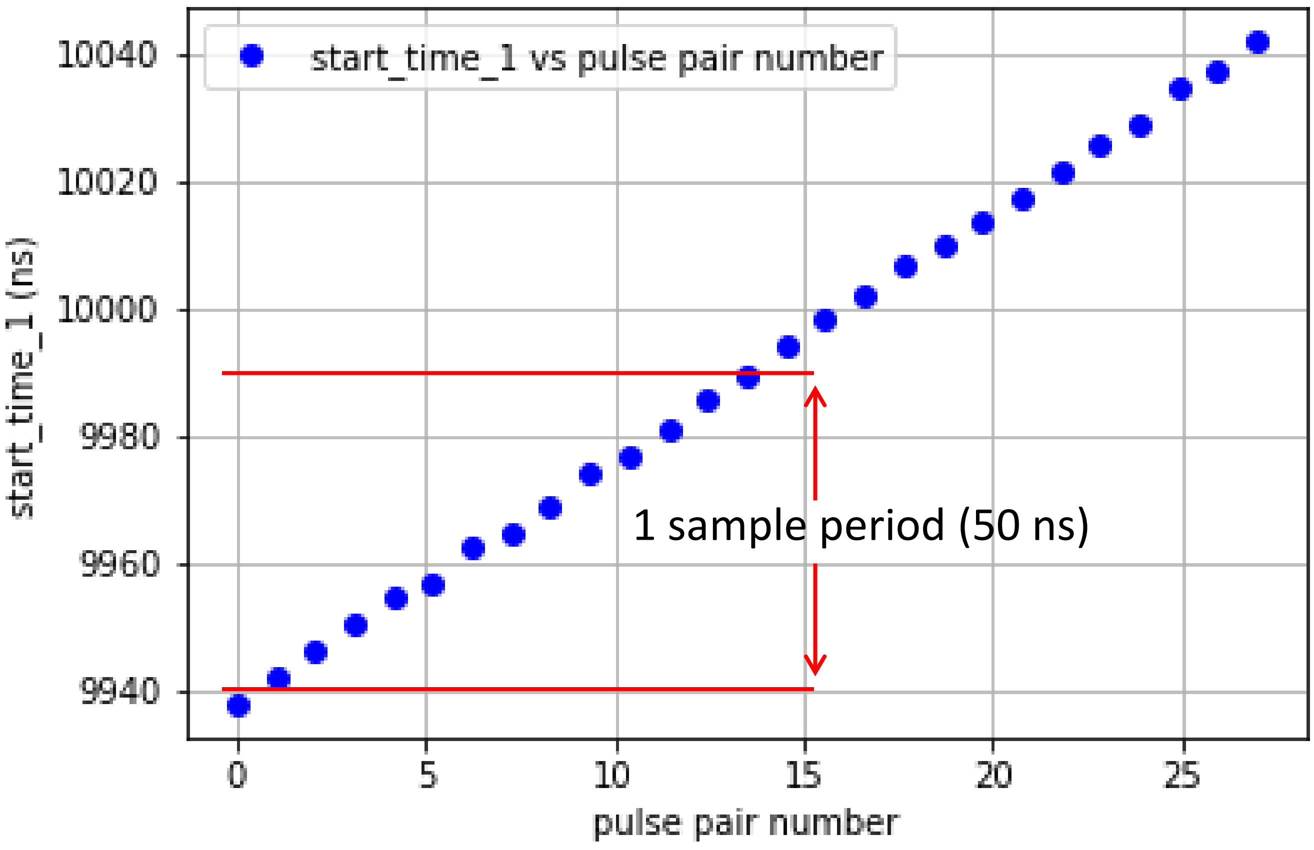
Data Acquisition Details

- SAMPA is operated in continuous mode with a 50 μs processing window (1000 ADC samples).
- If an input pulse occurs in a processing window the SAMPA reports a *packet* of data consisting of the raw ADC samples of the shaped pulse and the time of the 1^{st} sample that crosses the programmed threshold.
- Thresholds for channels 1 and 4 were set to 10 ADC counts above their respective pedestals. All other channels were disabled on the Test Card.
- If no input pulse occurs in a processing window the SAMPA reports a special *sync header* that maintains synchronization of the serial link.
- We expect the time resolution to depend on input pulse size, so data was collected for input pulse pairs with 5, 10, 20, 40, 60, 80 mV amplitudes (1 mV = 1 pC).

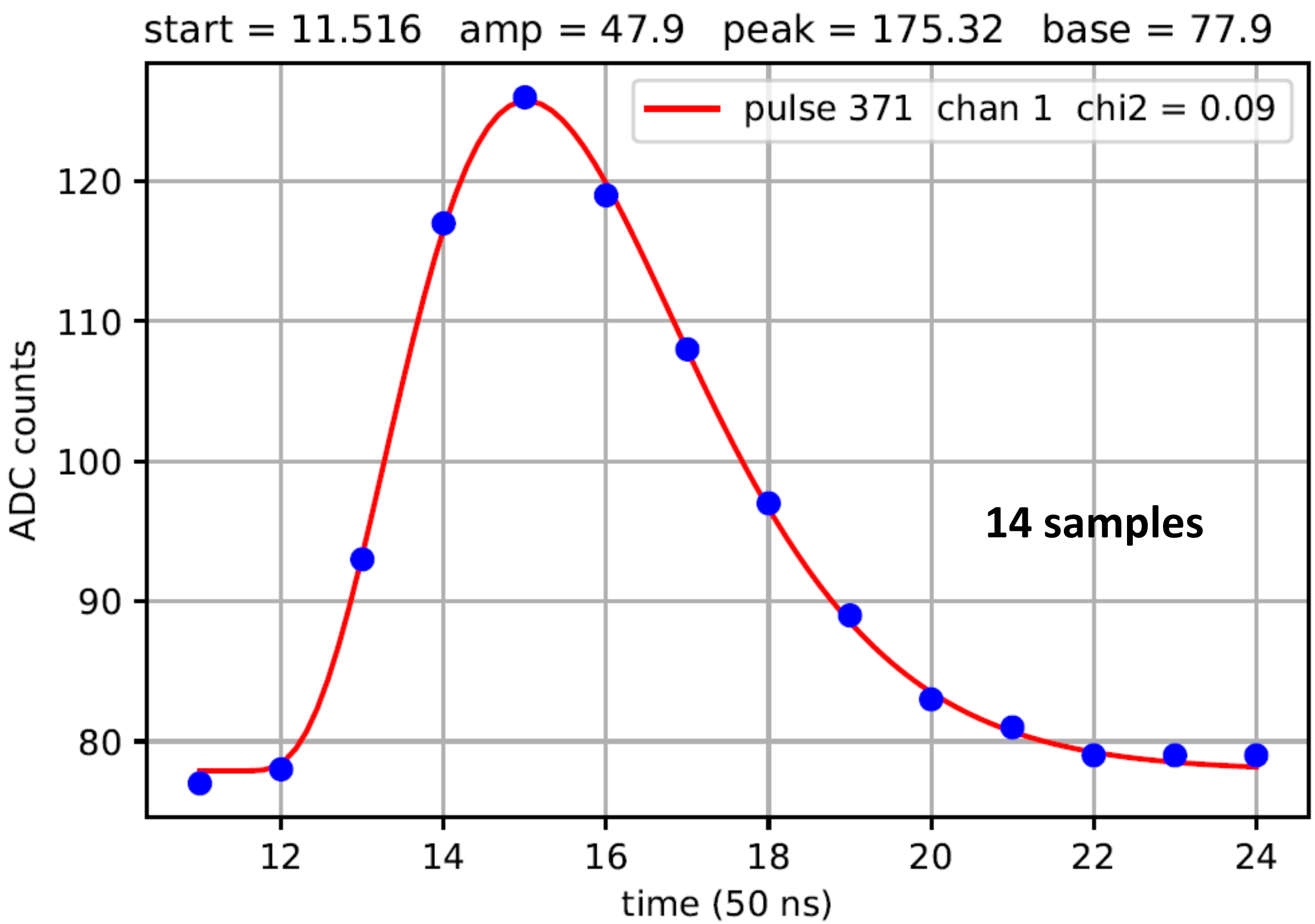
Data Acquisition Details

- 200 pulse pairs were measured for each run.
- Input pulse pairs were generated with a period of 50.004 μs. (Processing window = 50.000 μs.) This means that each input pulse is delayed by 4 ns relative to the ADC sampling clock over the previous pulse. Effectively we are averaging the results over the sampling clock period in steps of 2 ns, cancelling possible systematic effects.
- The pulse for channel 4 is delayed by > 600 ns relative to channel 1. This eliminates any contribution due to crosstalk.
- The time resolution *may* depend on the phase relationship of the pulses of the pair relative to the ADC sampling clock. To study this, data was collected for pulse delays of 600, 610, 620, 630, 640, 650 ns. (ADC sampling period = 50 ns.)
- A total of 36 data runs were made for this study (6 amplitudes, 6 delays)

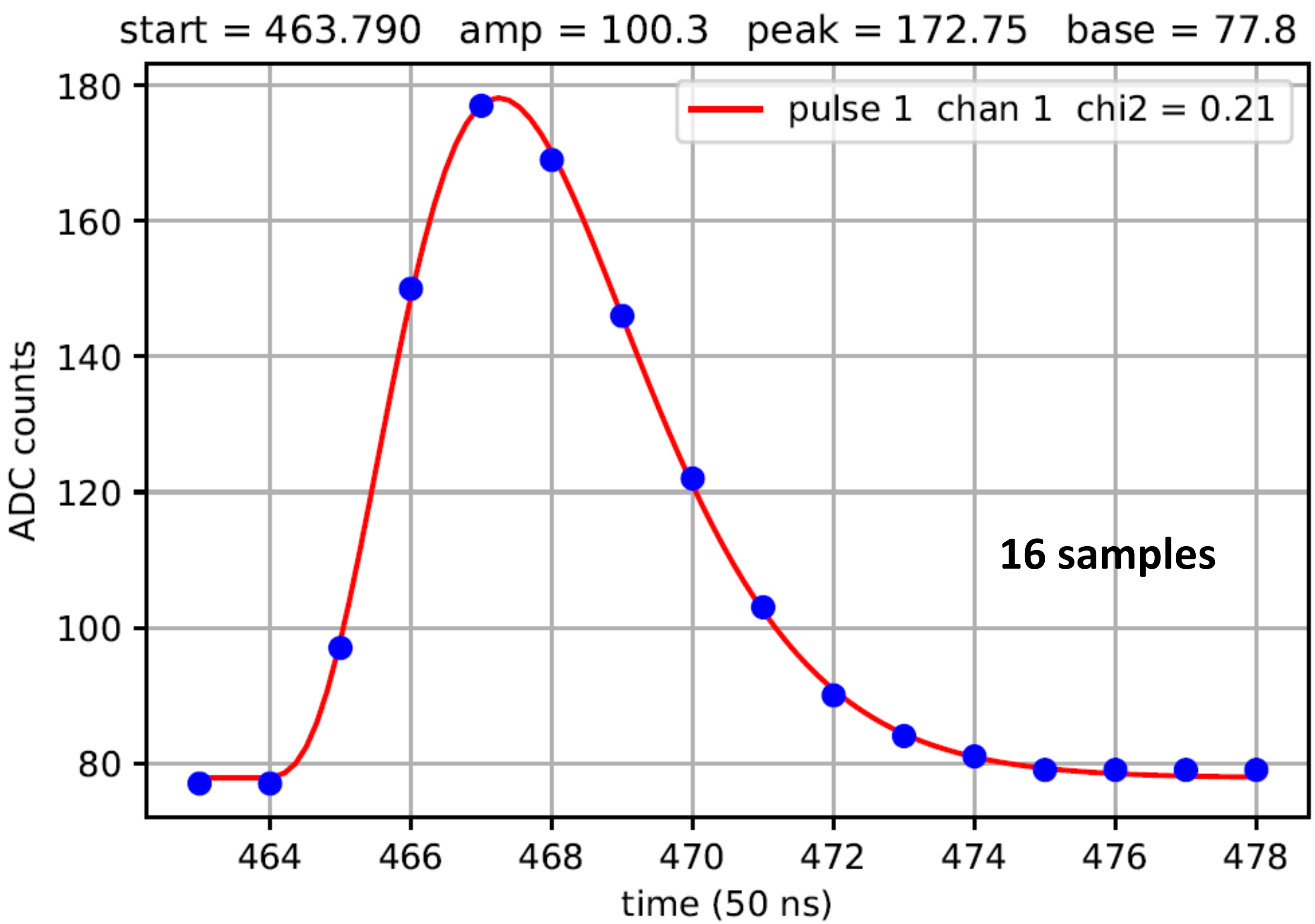
Shift of Input Pulses Across Sample Period



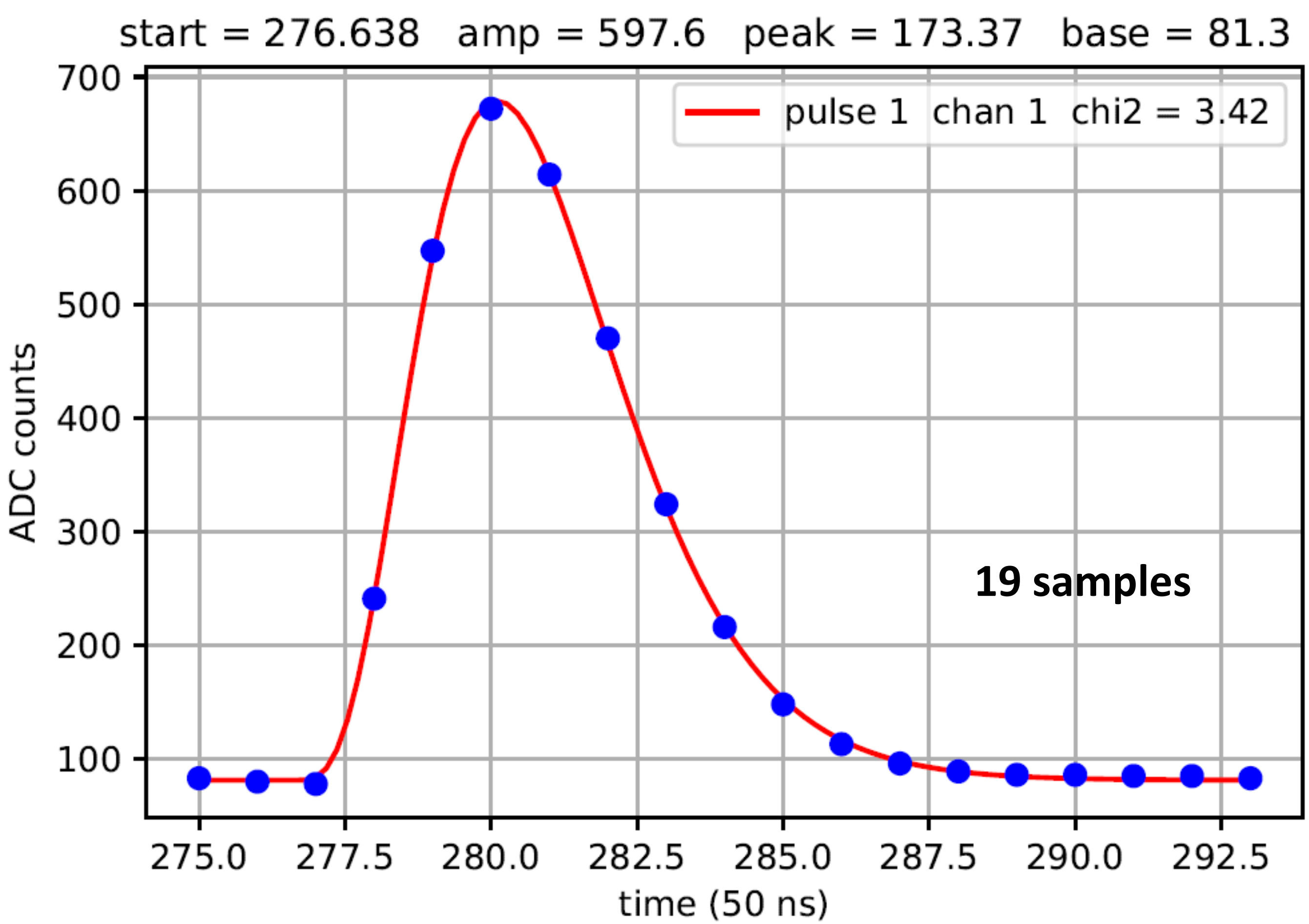
Input Amplitude = 5 mV



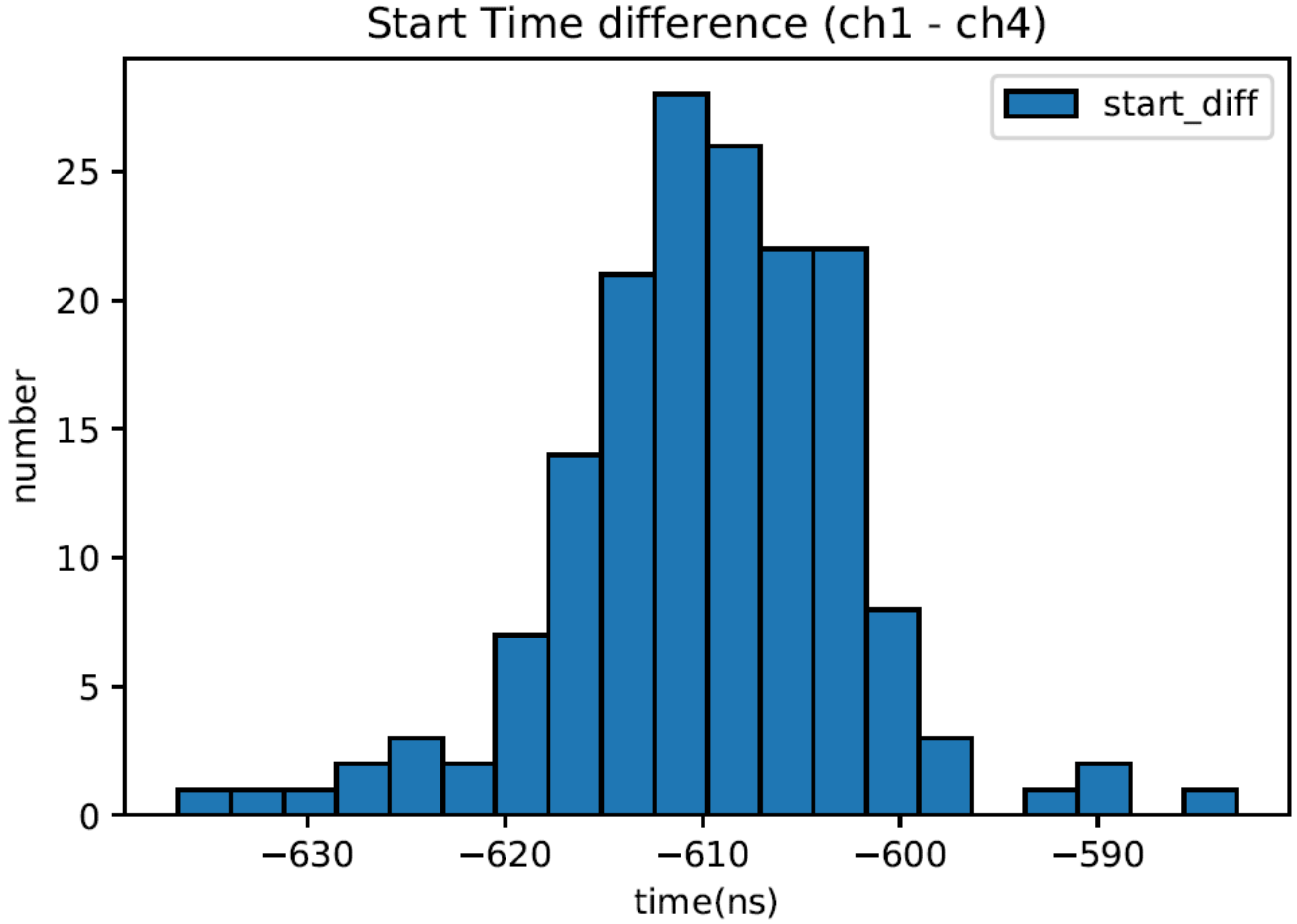
Input Amplitude = 10 mV



Input Amplitude = 60 mV

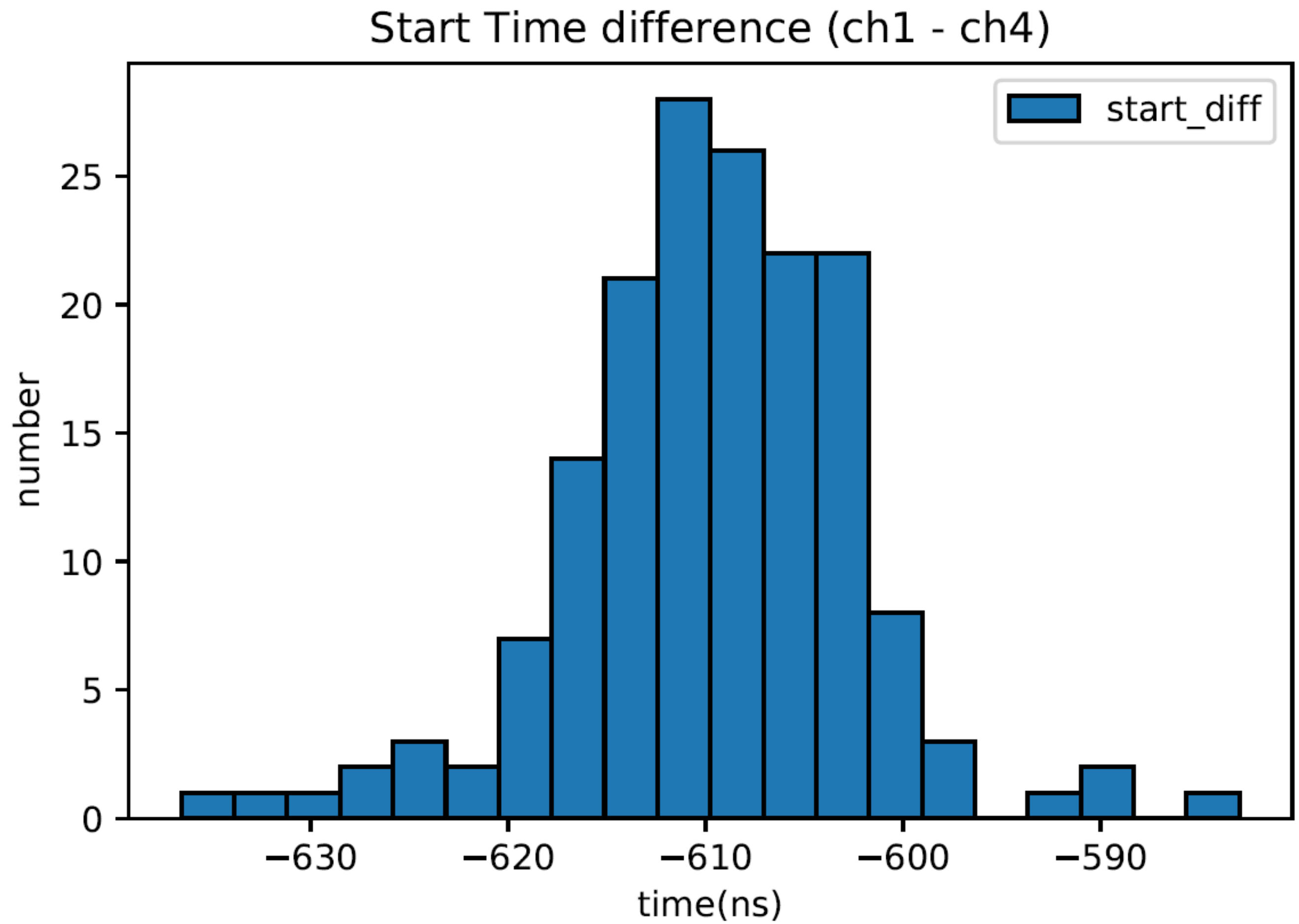


Input Amplitude = 5 mV, delay = 610 ns



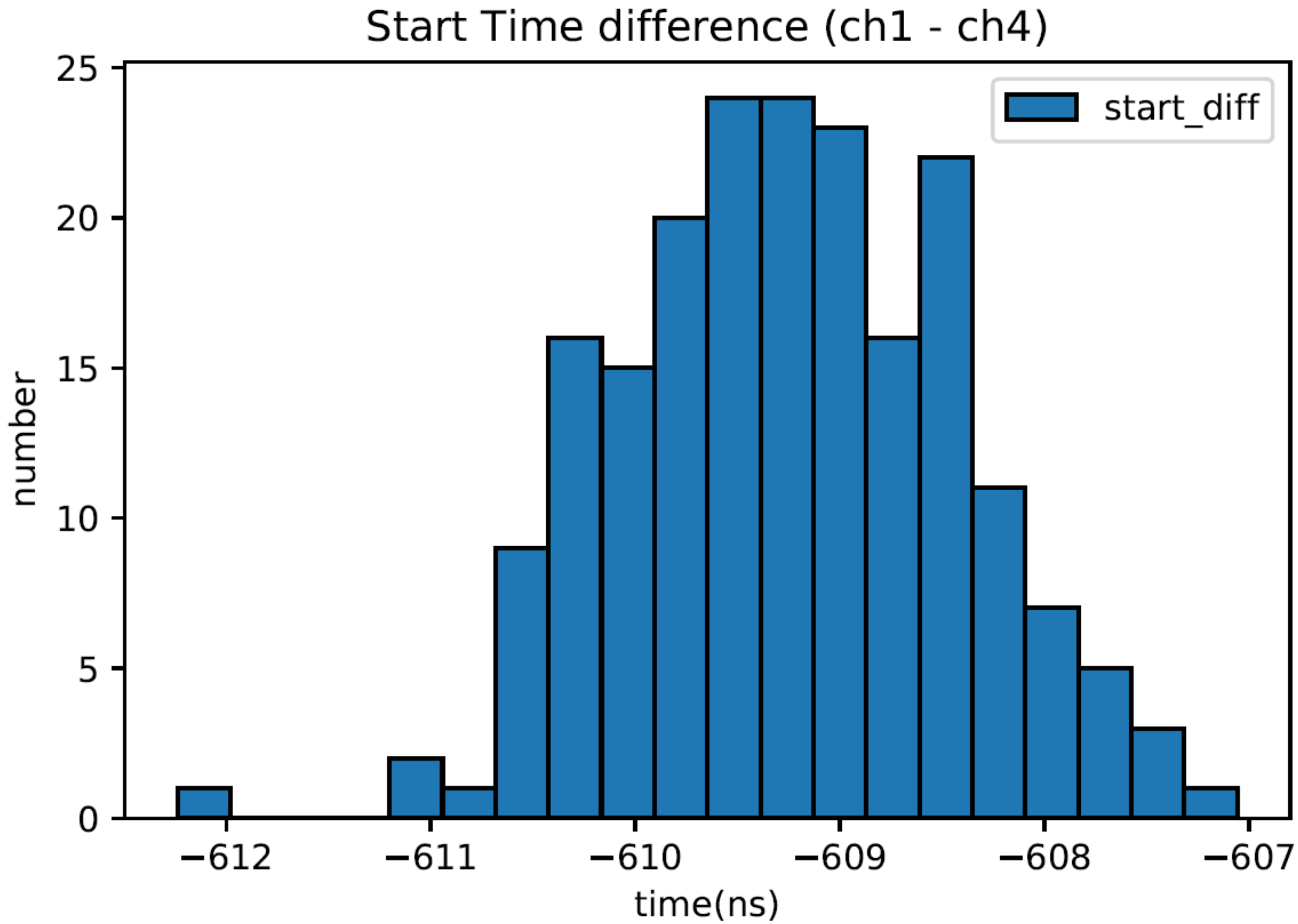
start_diff: AVG = -609.66 SIGMA = 7.3775 MIN = -636.54 MAX = -582.96

Input Amplitude = 10 mV, delay = 610 ns



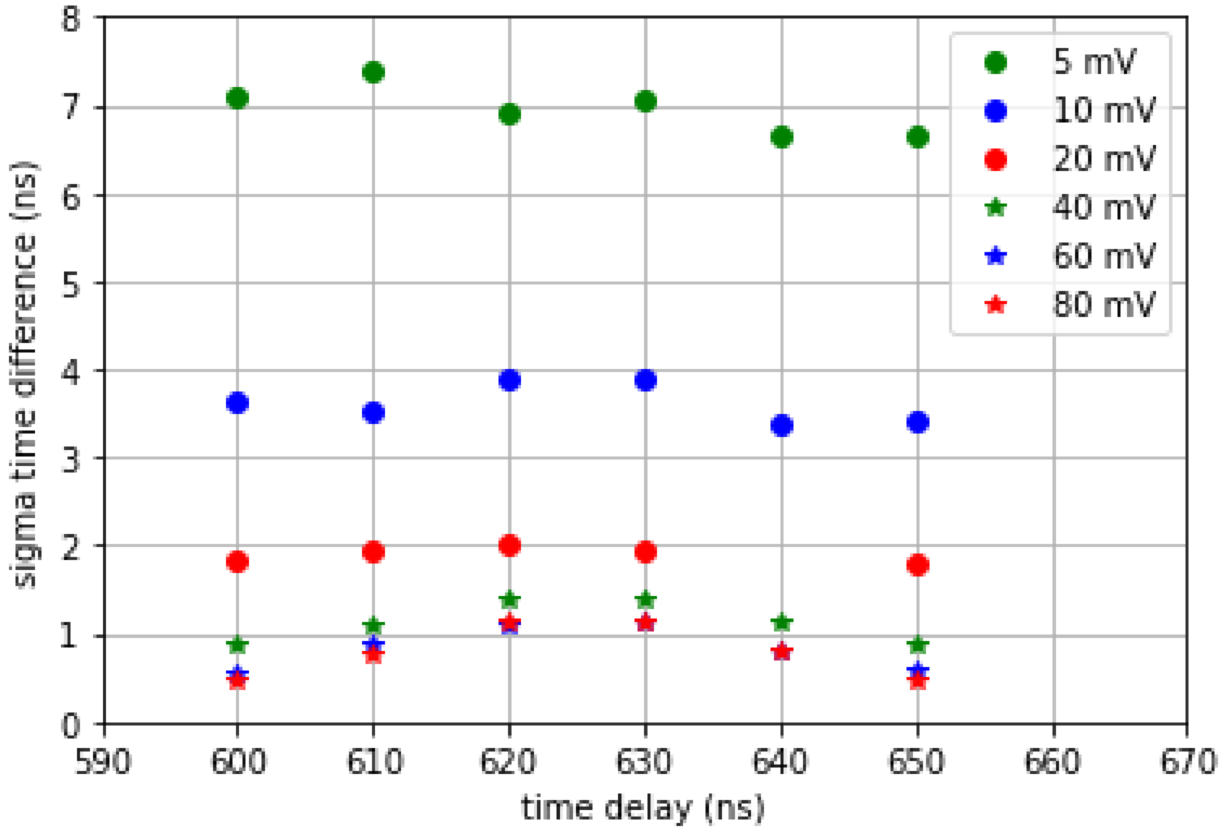
start_diff: AVG = -609.38 SIGMA = 3.5359 MIN = -627.72 MAX = -599.30

Input Amplitude = 60 mV, delay = 610 ns



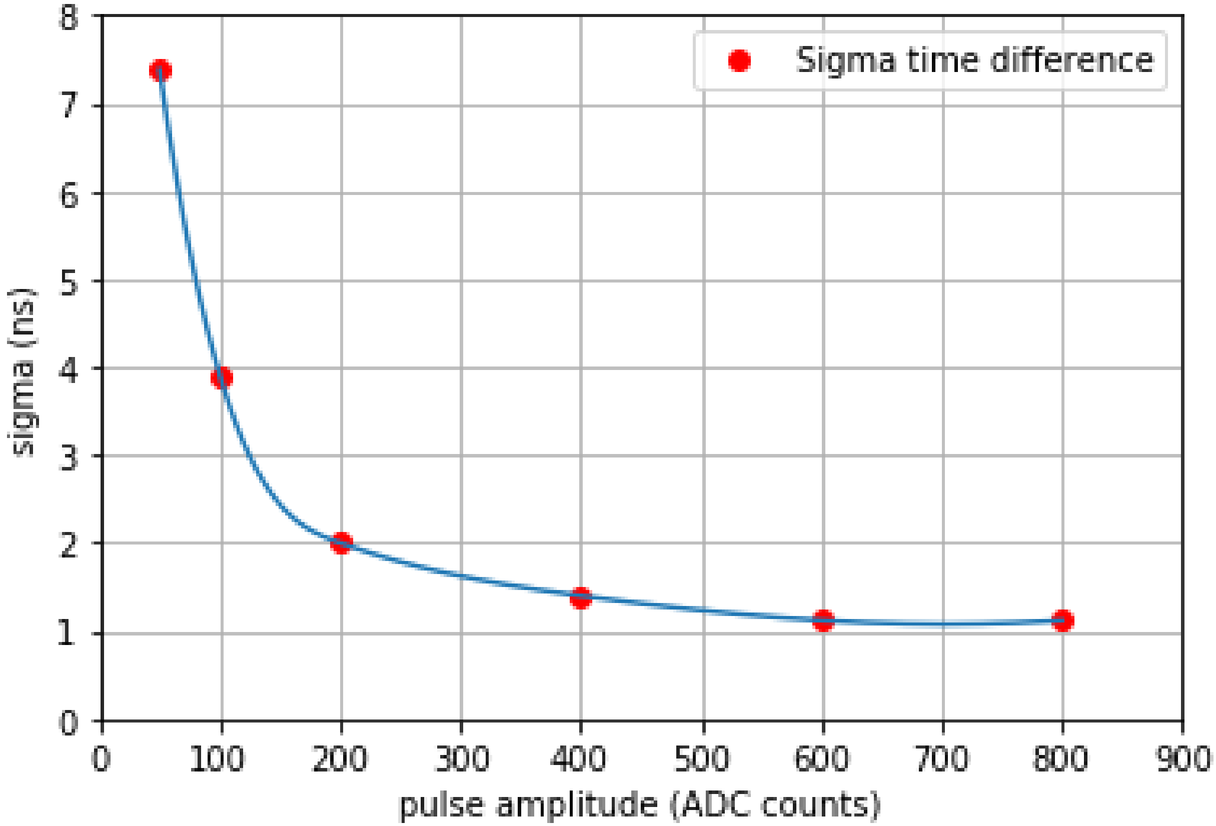
start_diff: AVG = -609.25 SIGMA = 0.8260 MIN = -612.24 MAX = -607.06

σ(Δt) vs. Δt



sigma time difference (ns)
time delay (ns)
0
1
2
3
4
5
6
7
8
590
600
610
620
630
640
650
660
670
5 mV
10 mV
20 mV
40 mV
60 mV
80 mV

σ(Δt) vs. Pulse Amplitude



Next Step

- Use real pulses from prototype GEM detector
- Compute time differences for pulses associated with a cluster from a cosmic ray
- (x1, x2), (y1, y2) – adjacent strips
- (x, y) – different layers