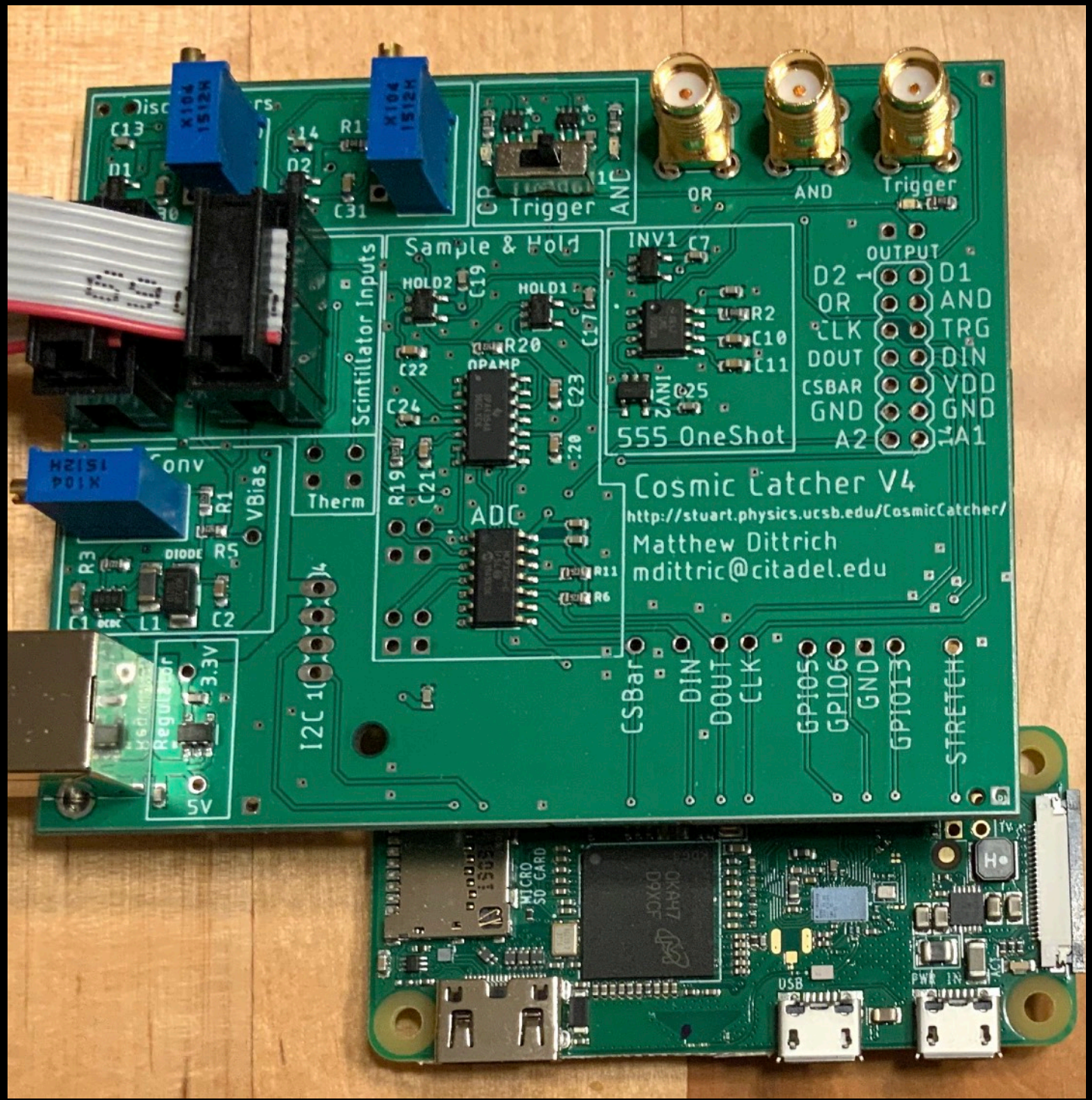
Studying the signal size
Phys150 Special topics

David Stuart, UC Santa Barbara

We motivated the detector as "Cosmic rays are large signals occurring in both channels in coincidence."
What can we learn from the size of the signals.

Lets look at the analog signals



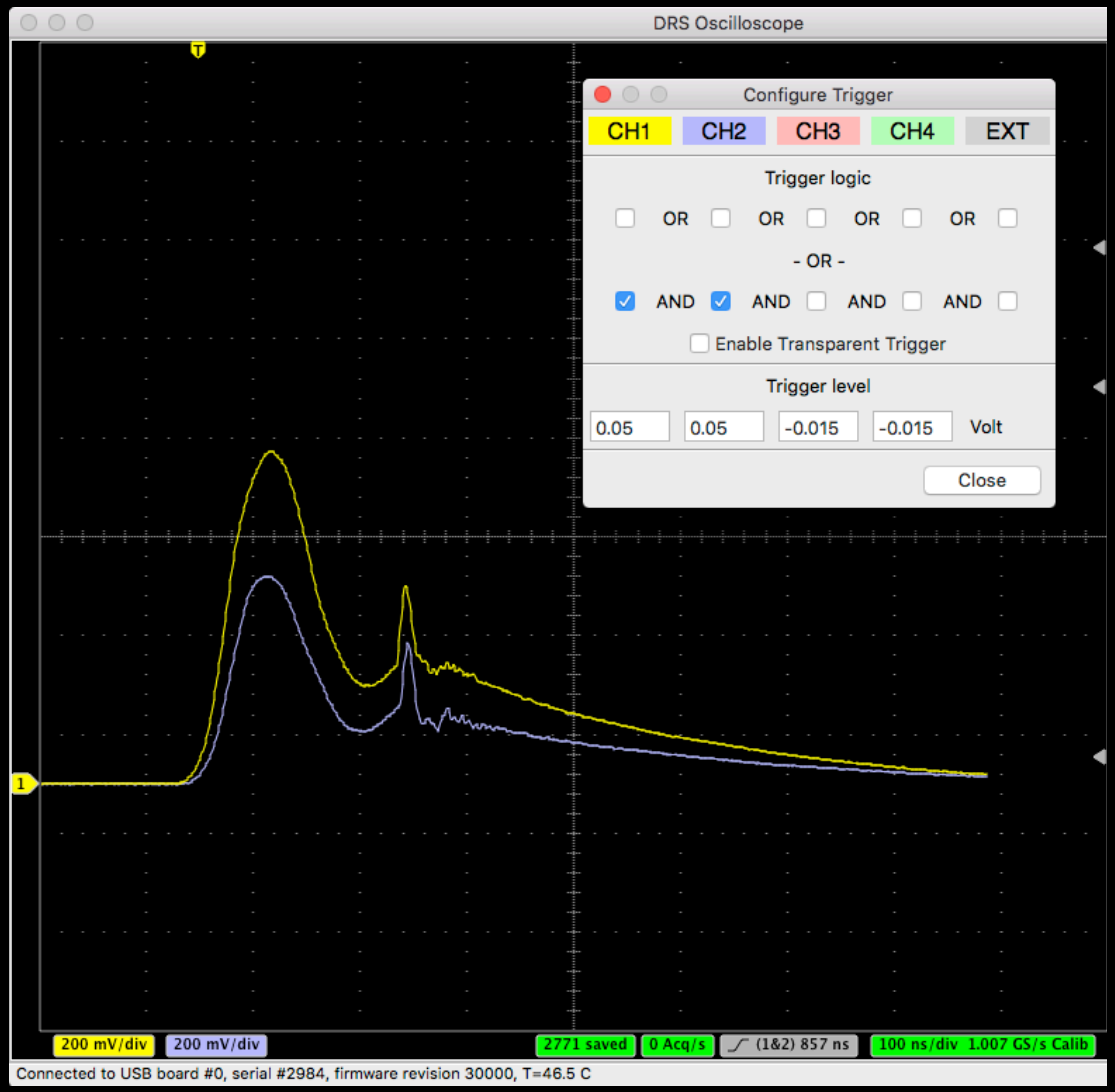
We've only been counting the rate of stretched AND signals.

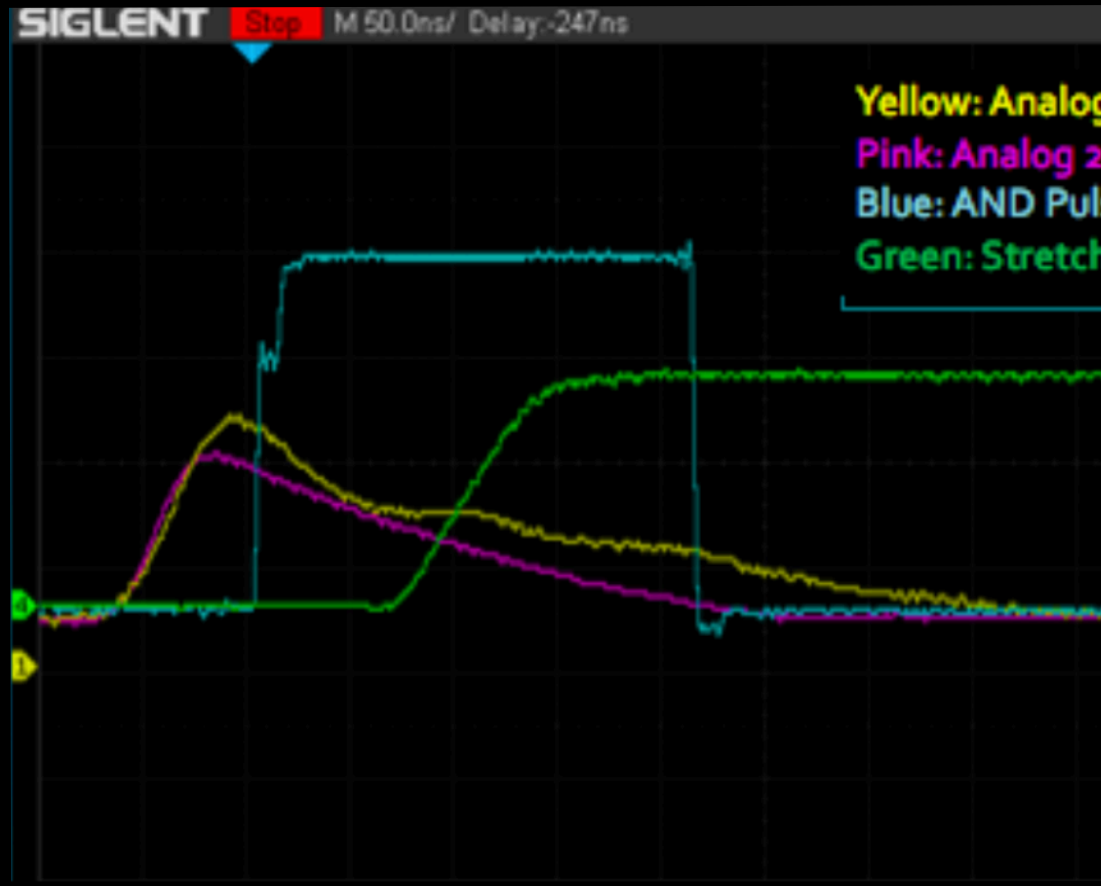
There is an expansion port with the analog signal from both channels, A1 and A2.

Let's look at them with a scope.

Lets look at the analog signals

I will use the same fast USB oscilloscope I did for the first LED photon measurements.
It modifies signals a bit: faster fall due to 50 Ω and pickup from STRETCH. But we can get the pulse height.





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See example events here. Scope triggered at 15 mV on CH1 AND CH2

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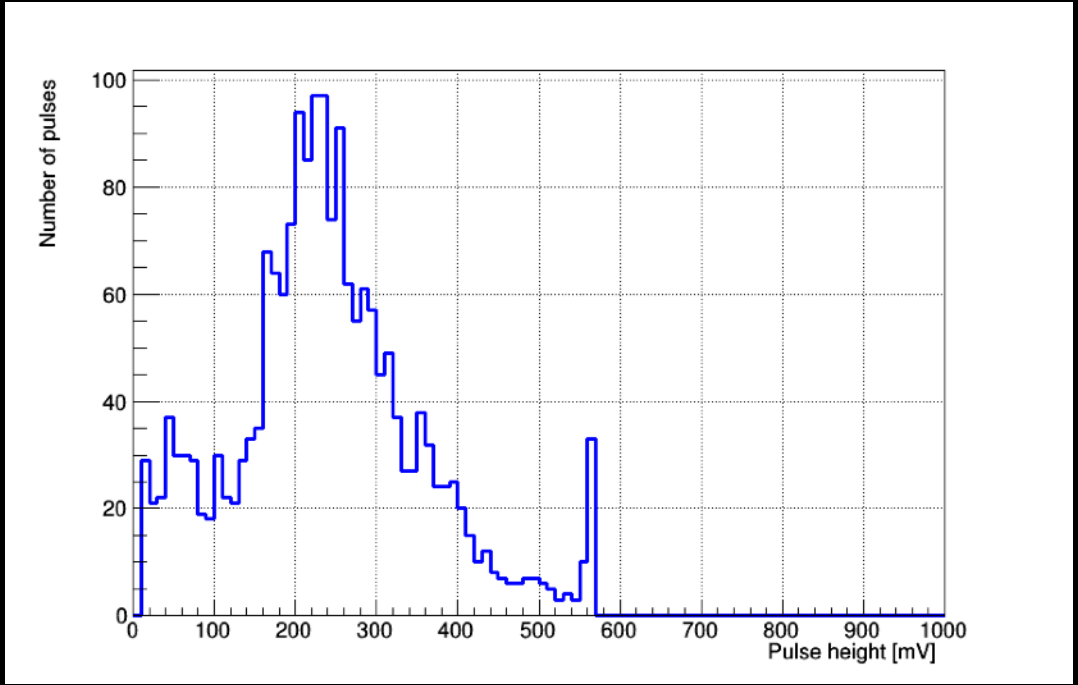
Distribution of pulse height shows us something interesting.
Note that 100 mV per photon from previous detector unrelated to this since electronic amplification very different.



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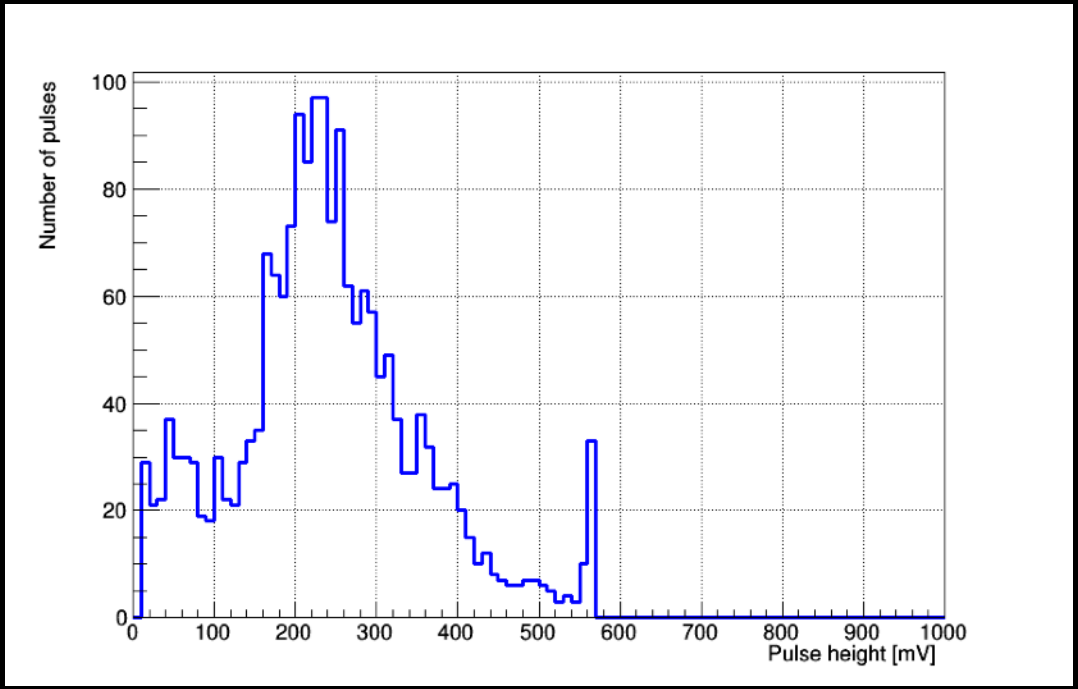
Spike at high end is scope saturation.

Bin to bin variations are sqrt(N) fluctuations.

Peak
High tail
Low tail.



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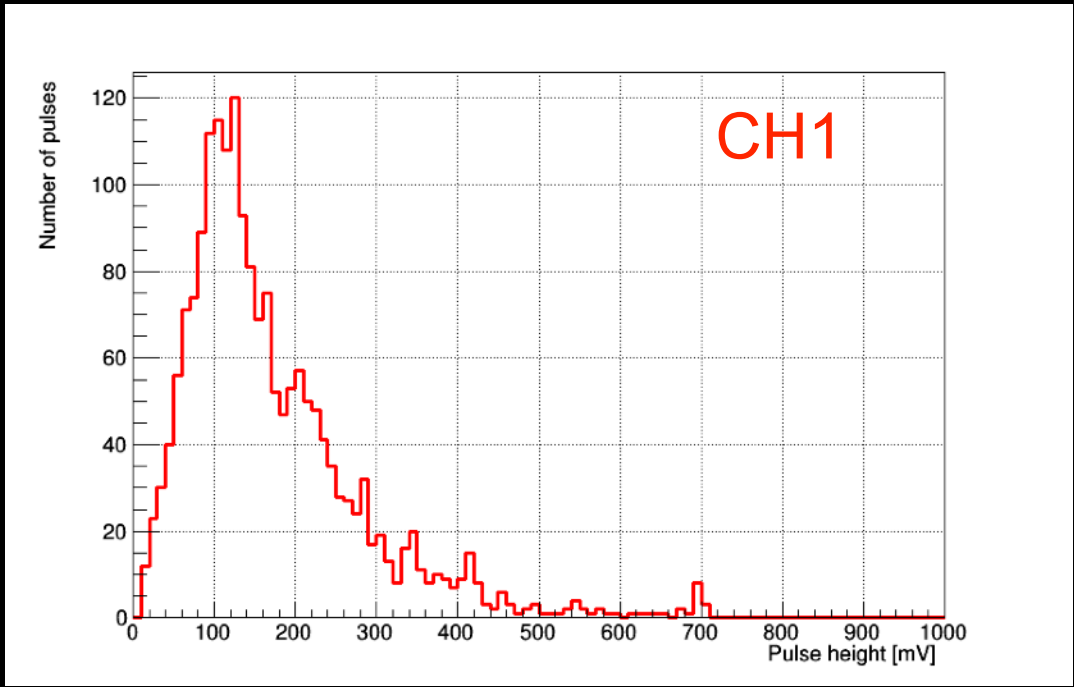

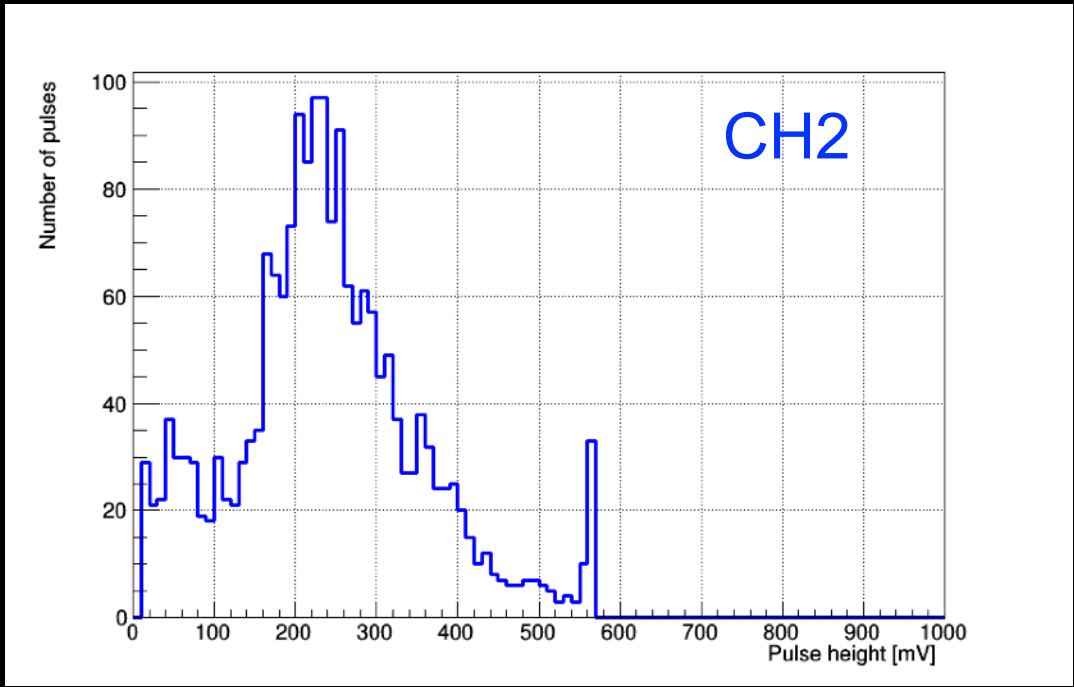

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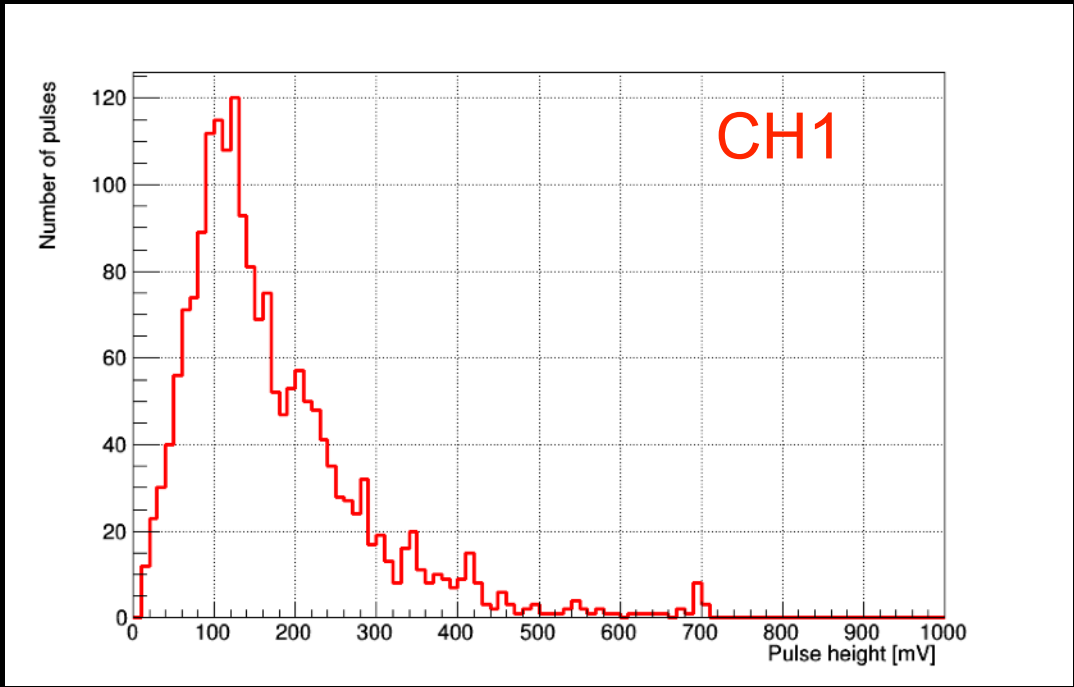
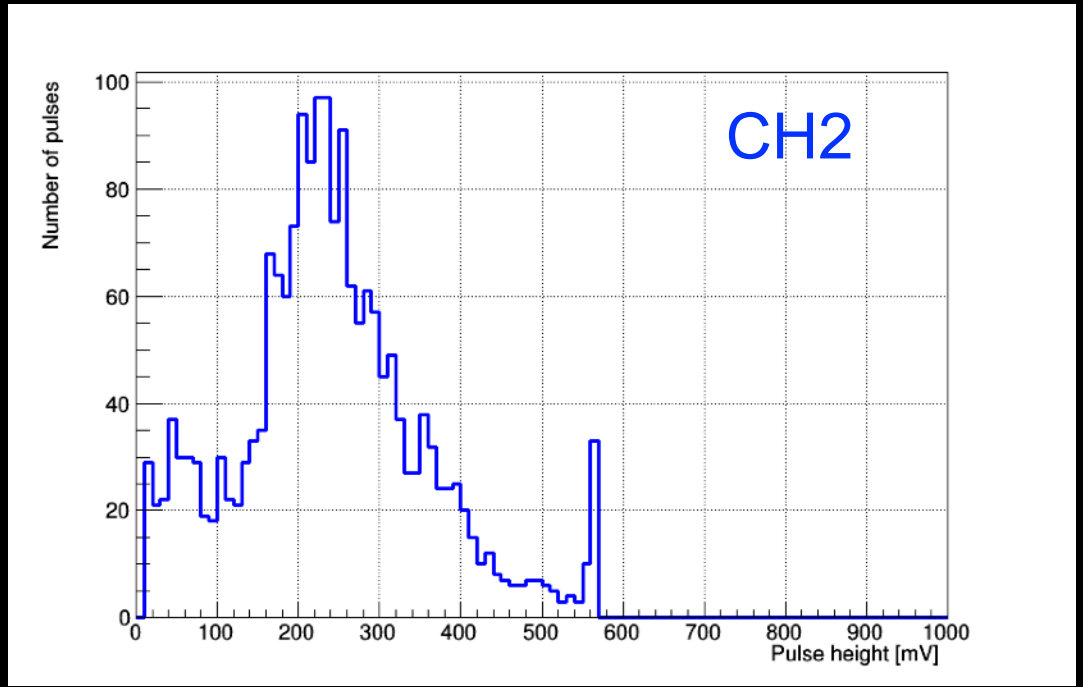
Distribution of pulse height shows us something interesting.

- There is a peaking structure with both a low and high tail.
- Two channels are not the same.





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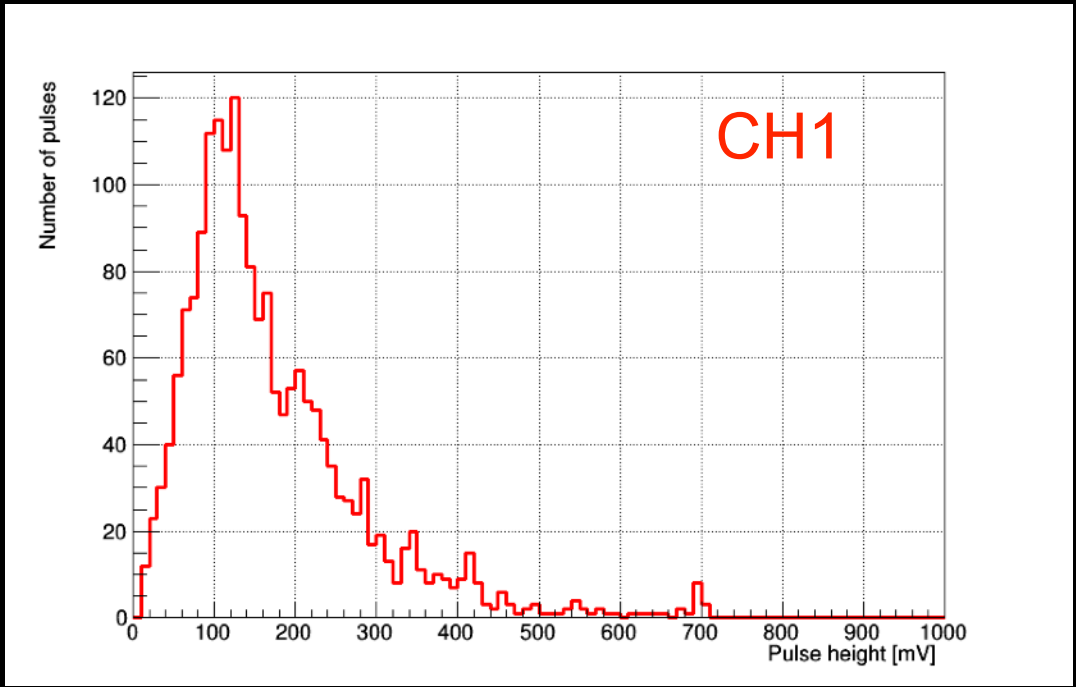
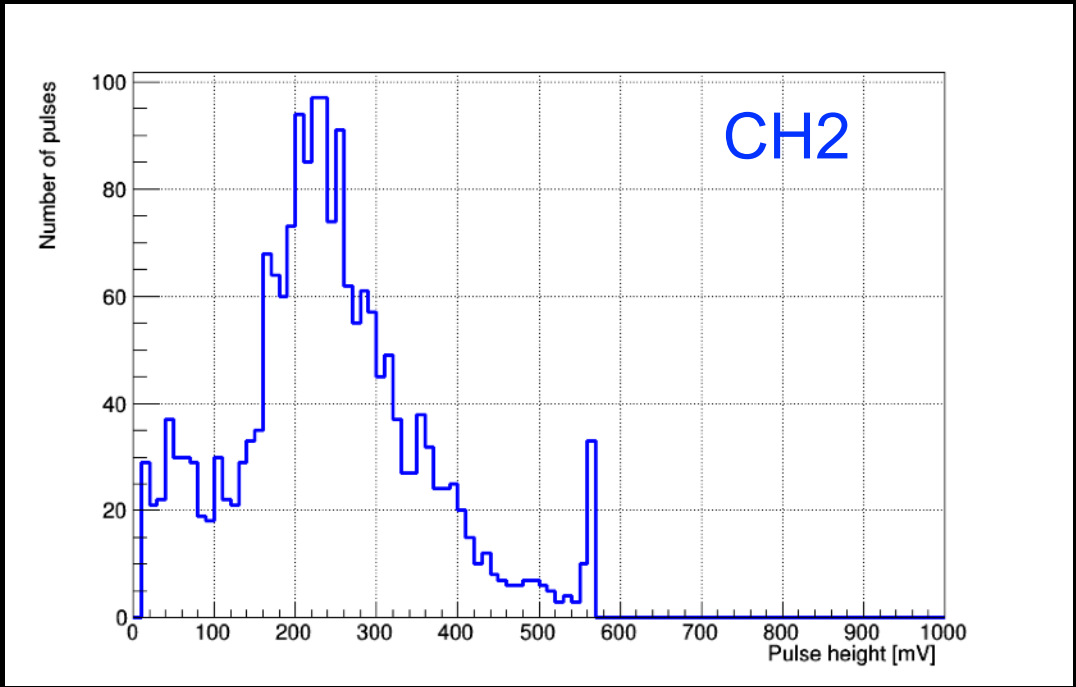
What causes the peak?

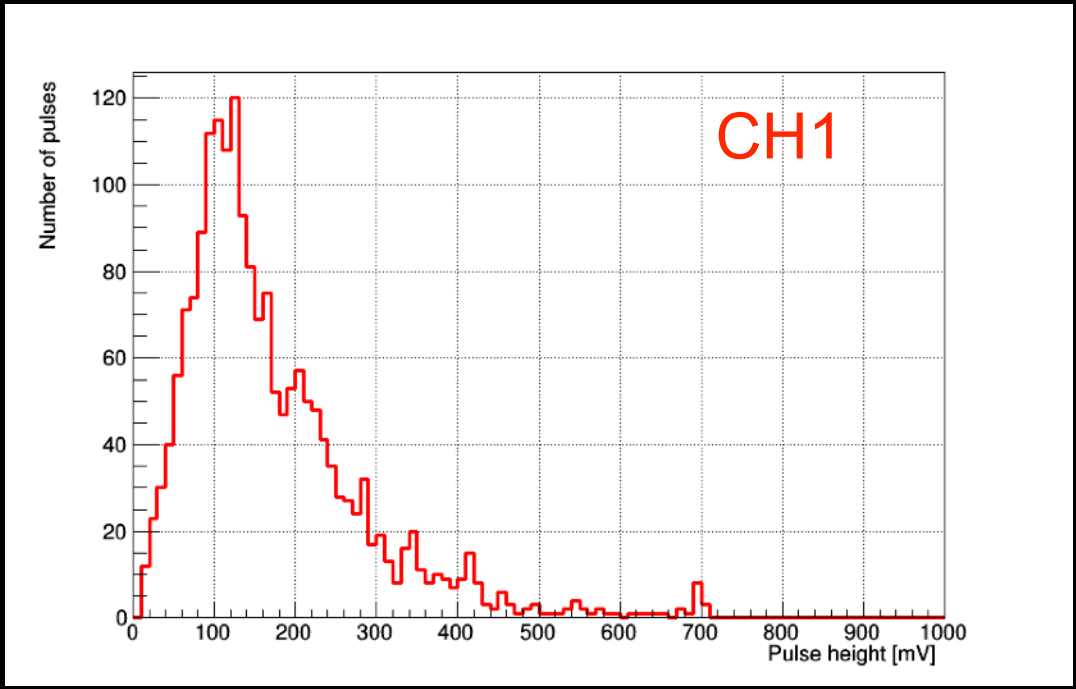


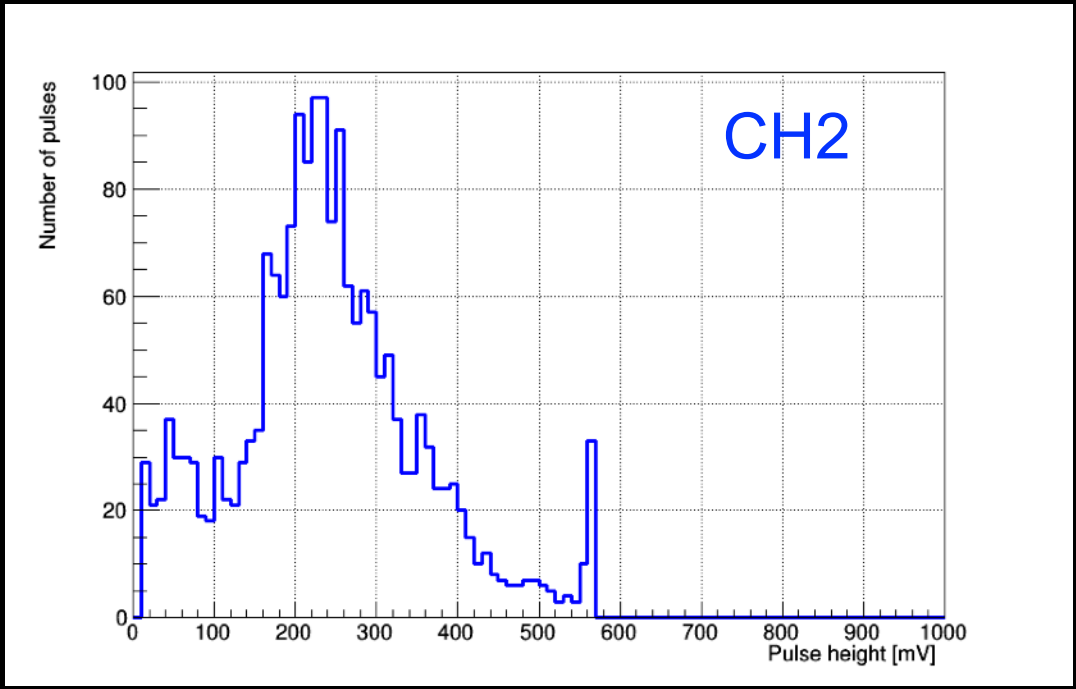


Lets look at the analog signals

What causes the peak?

- Energy of the particle hitting the bar?
- Energy deposited in the bar ⇒ amount of light produced.
- Light leaks into the bar?





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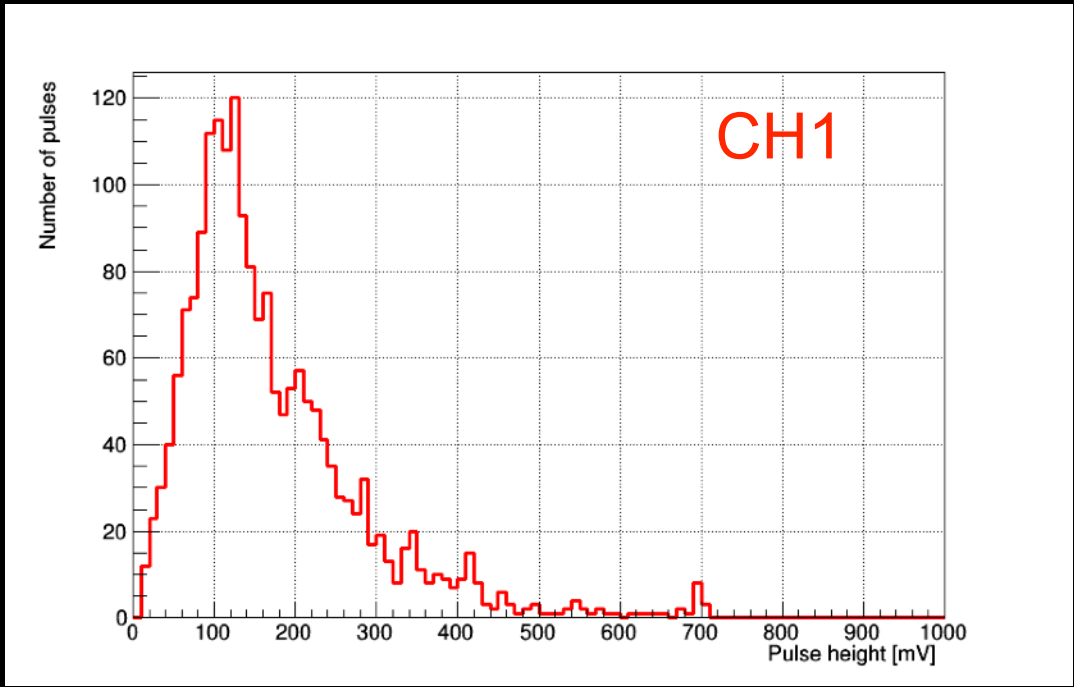
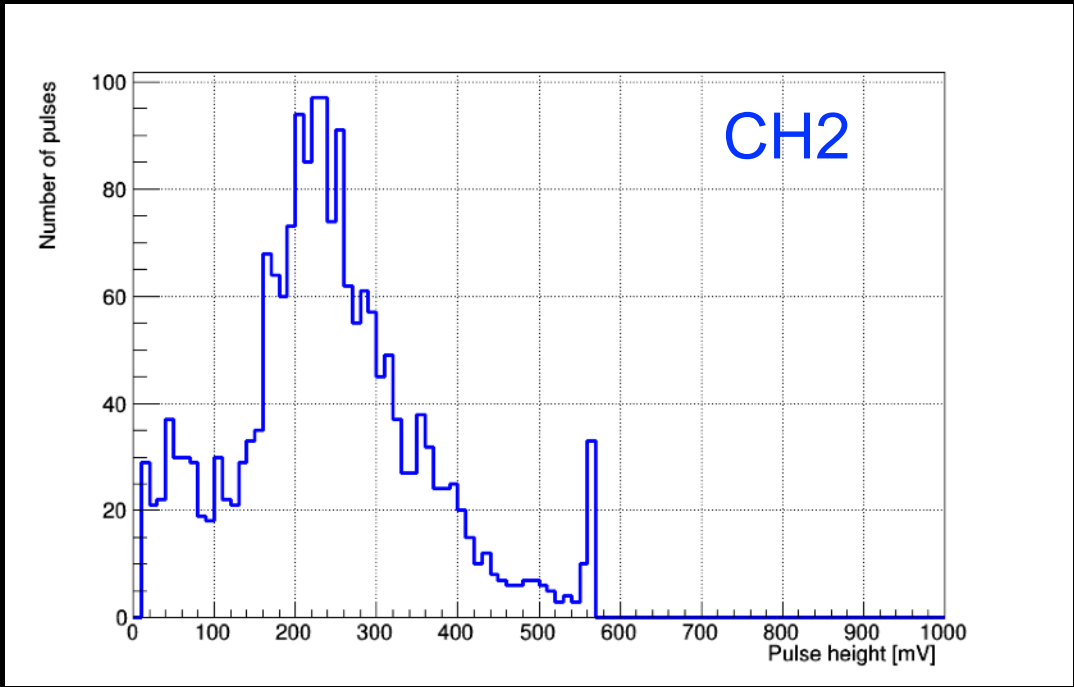
What is the detector and electronics doing?





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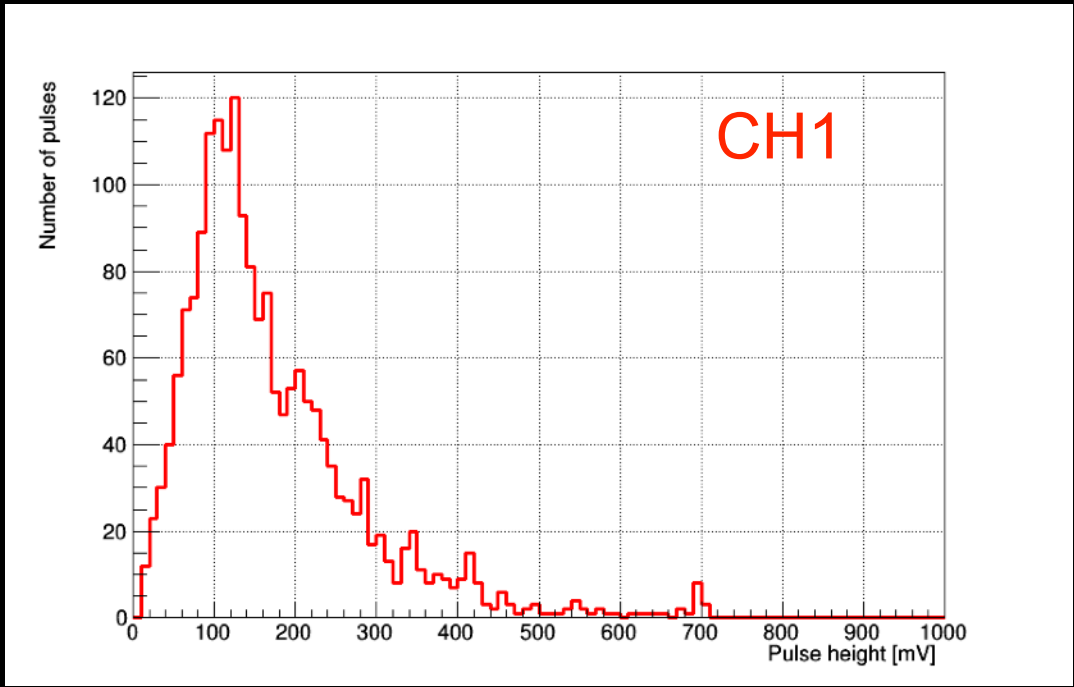
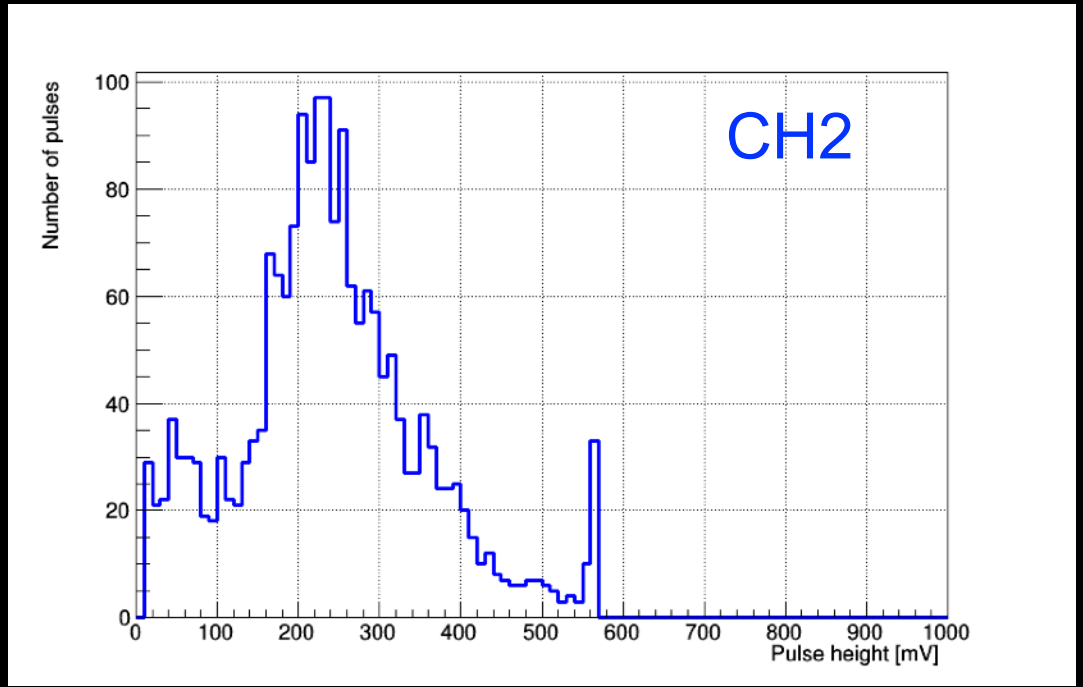
What is the detector and electronics doing?

Recall SiPM converts scintillator light into a voltage pulse that is proportional to number of photons, with some gain.

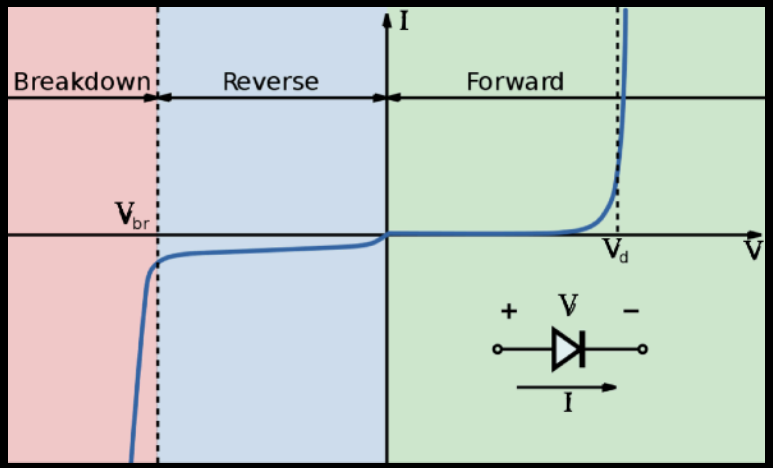
Peak voltage pulse ⇒ characteristic brightness ⇒ characteristic E_{dep}

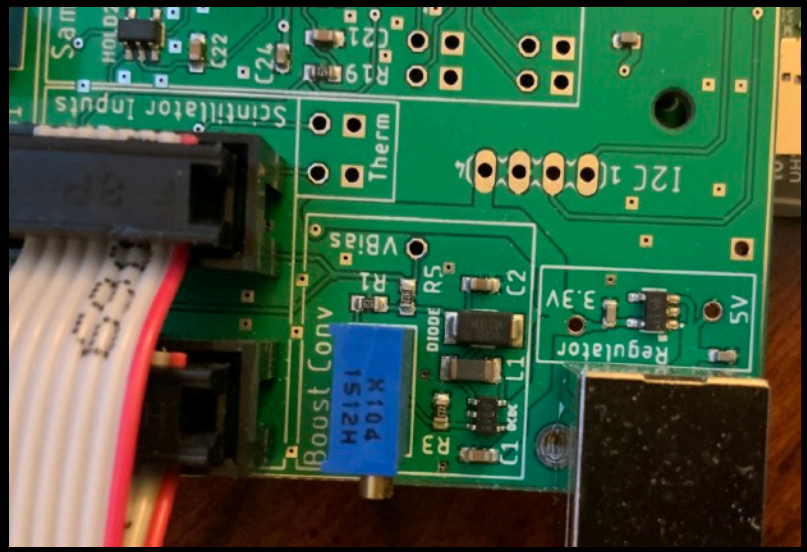


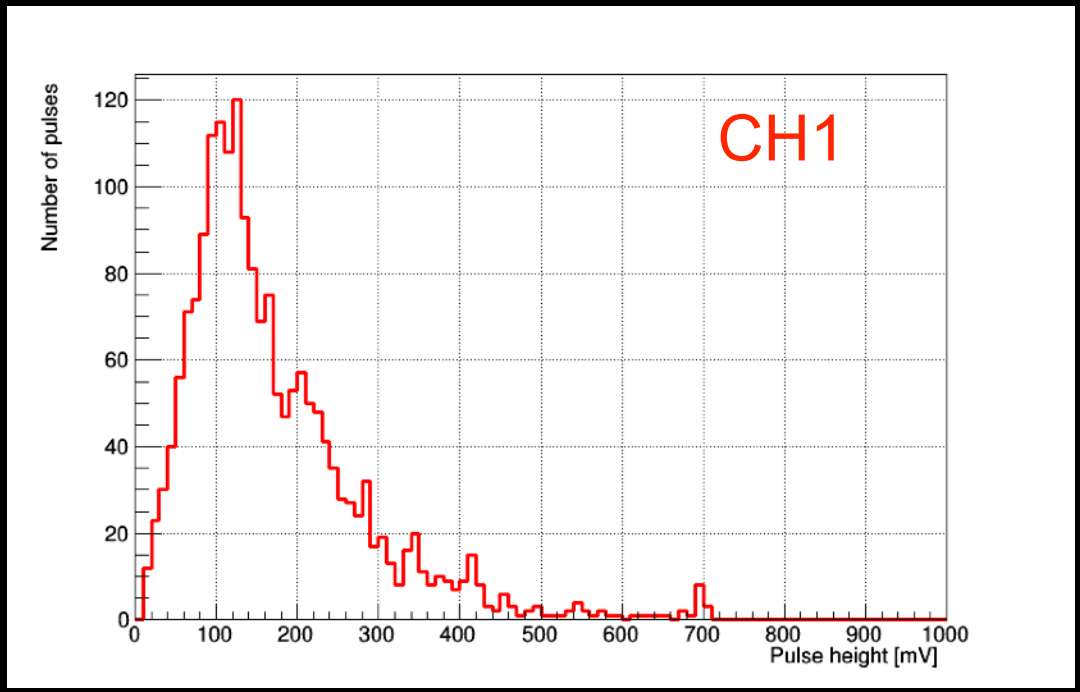


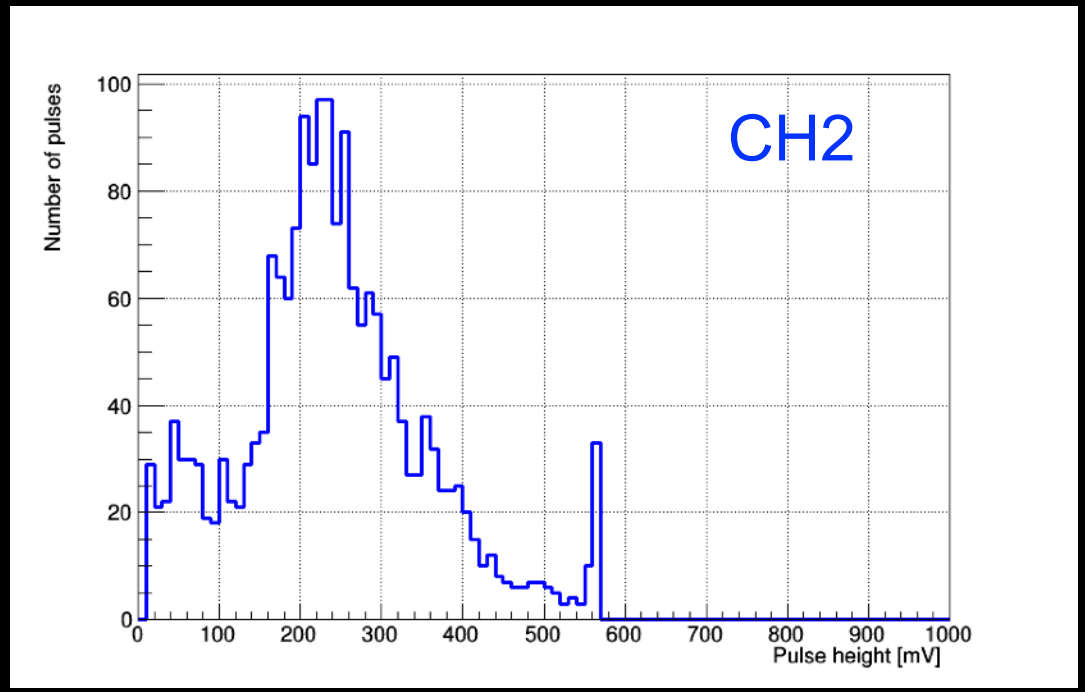
Lets look at the analog signals

Different SiPM gain in different channels will move that peak.
Changing the bias voltage changes SiPM gain.
V_{bias} - V_{br}
Channels have a different V_{br}.



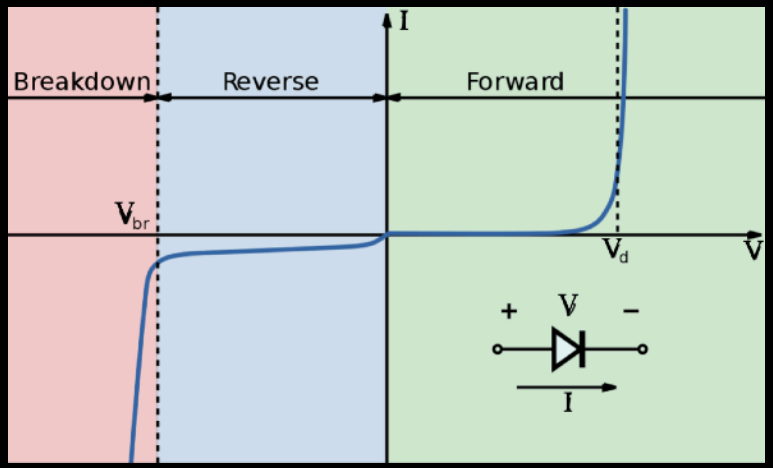


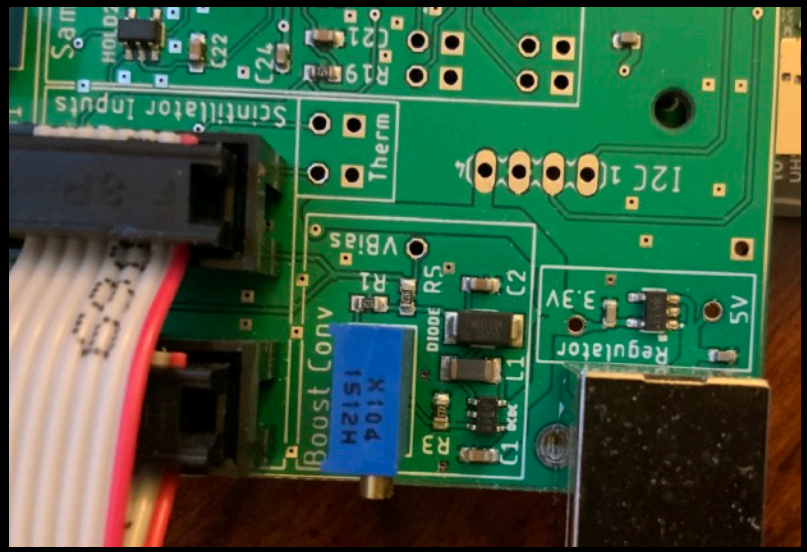


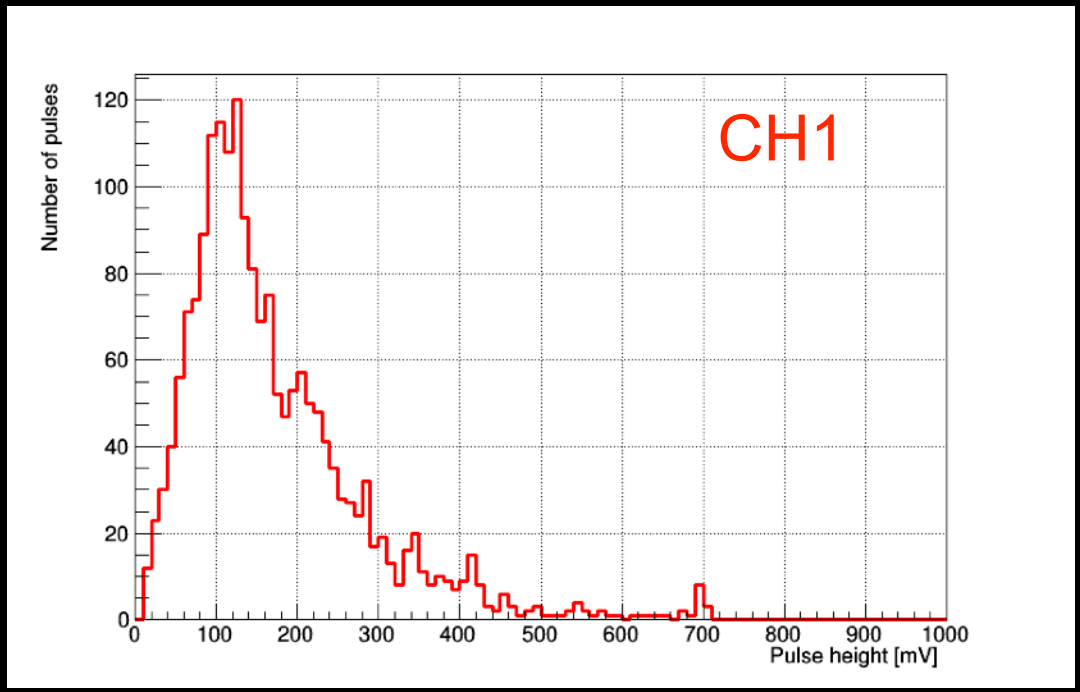


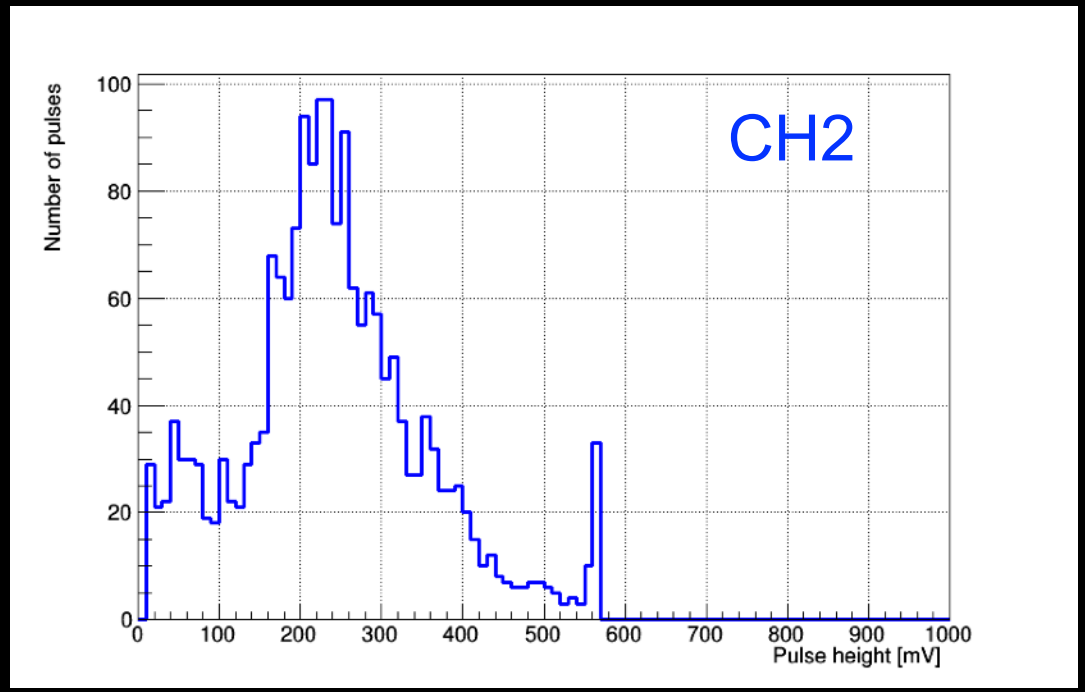
Lets look at the analog signals

Channels have a different V_{br} and so different gain at same V_{bias}.
Expect gain to change with V_{bias}
so peaks will move.

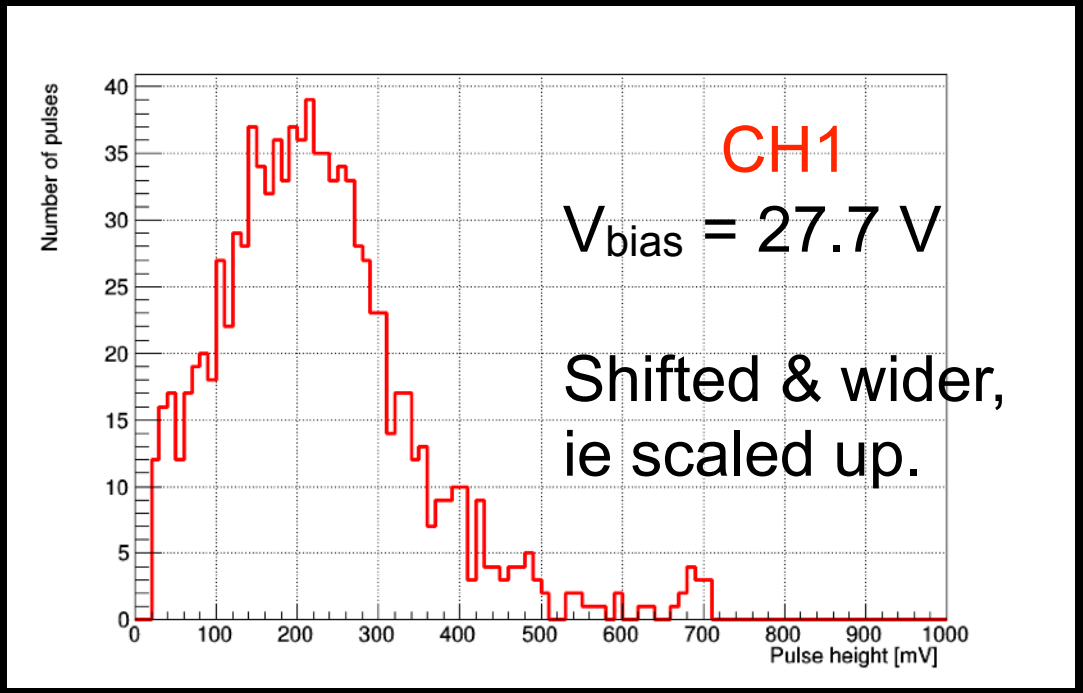


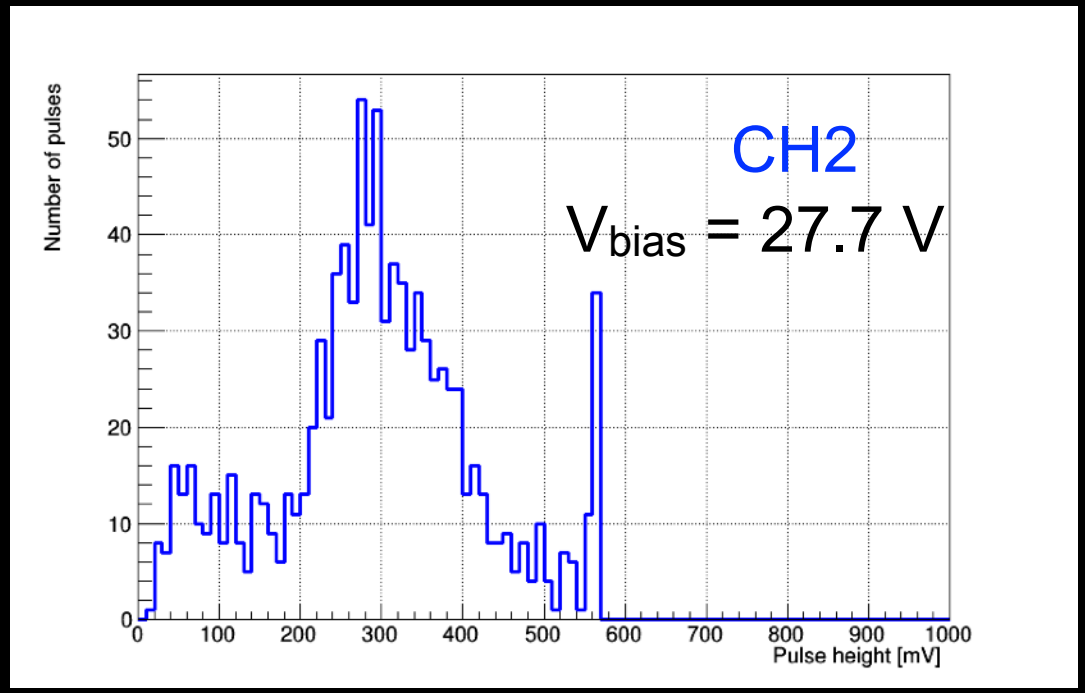


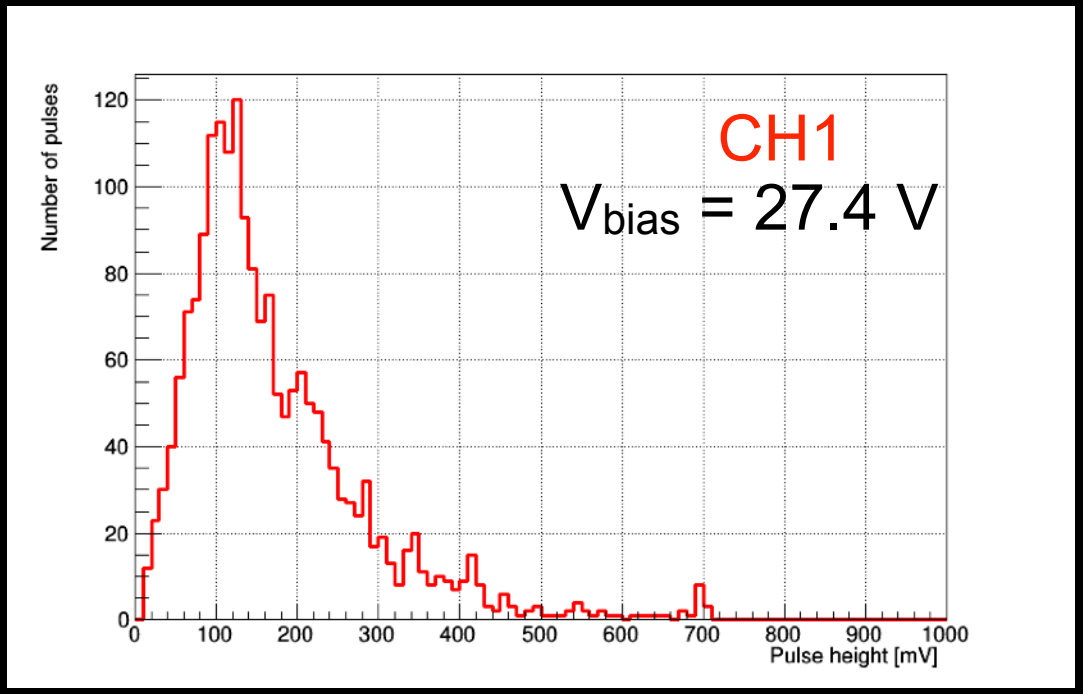


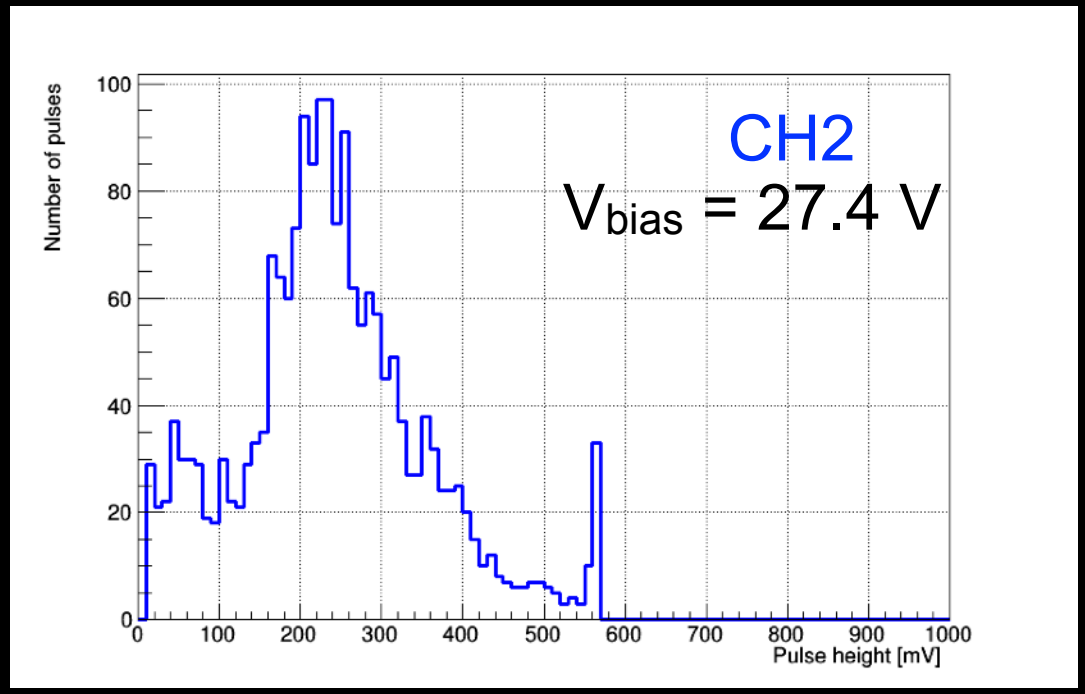


Checking gain variation with V_{bias}.









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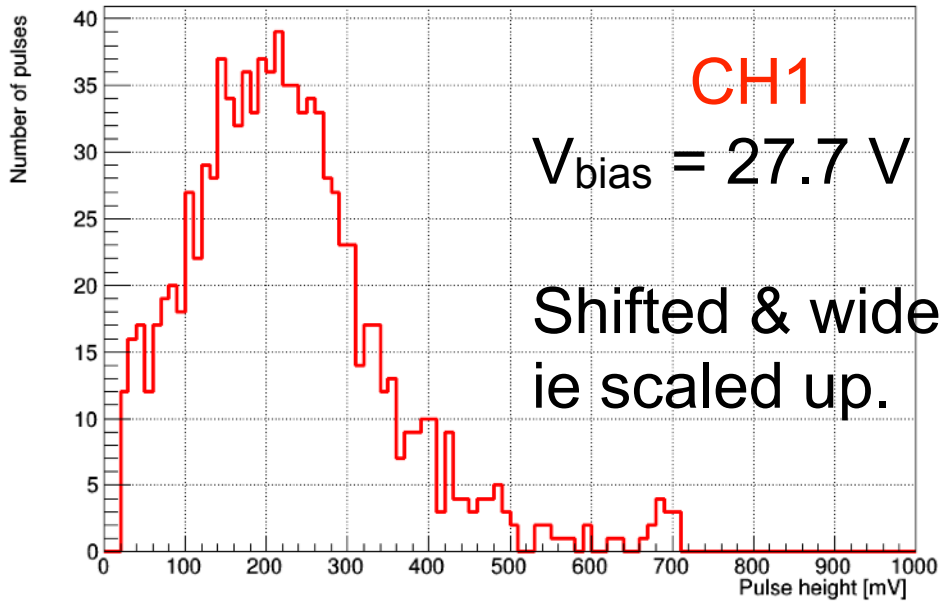

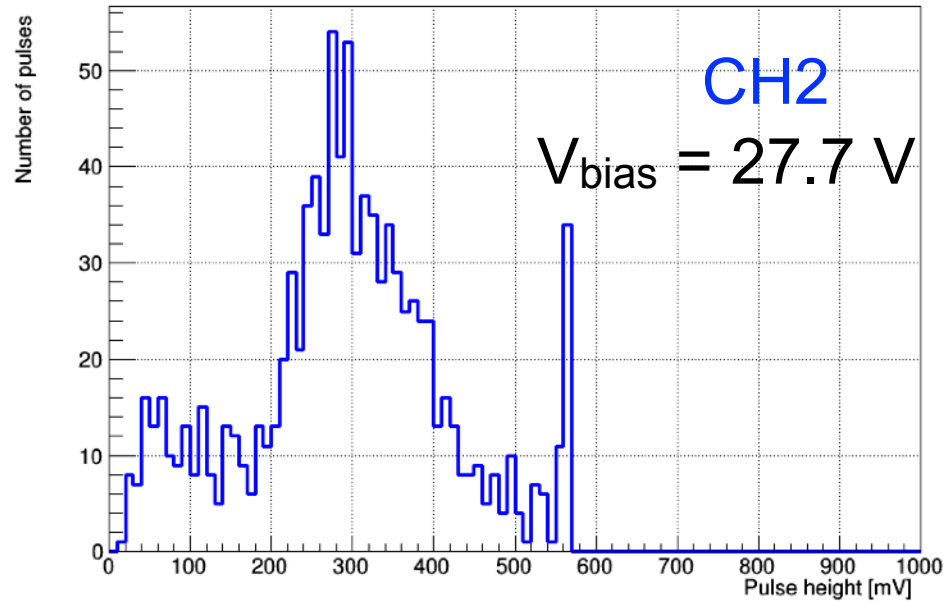

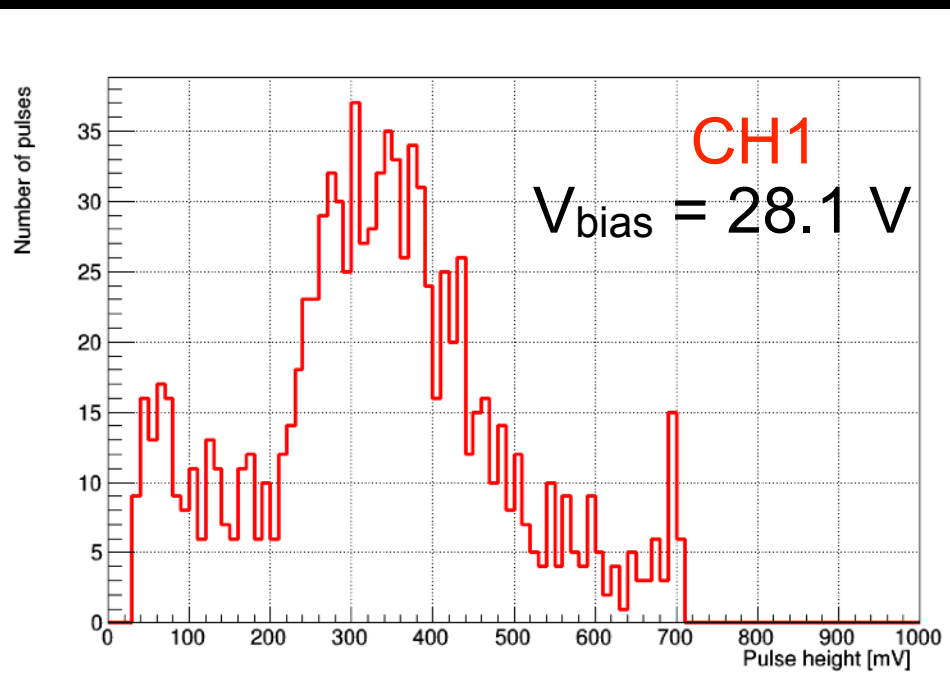

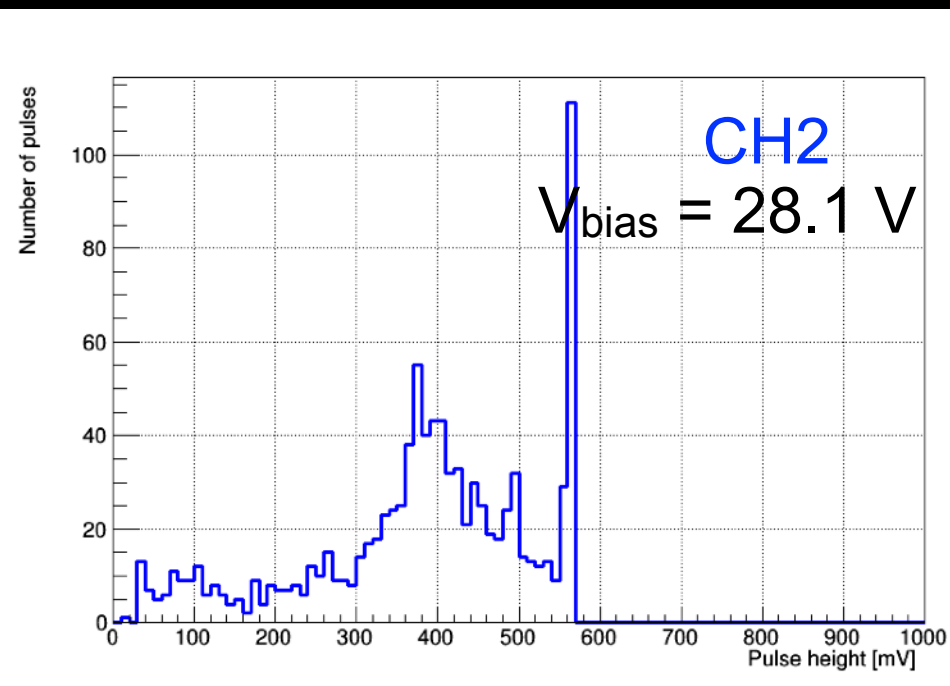

Understanding the energy deposition shape

Difference between channels is different SiPM gain.
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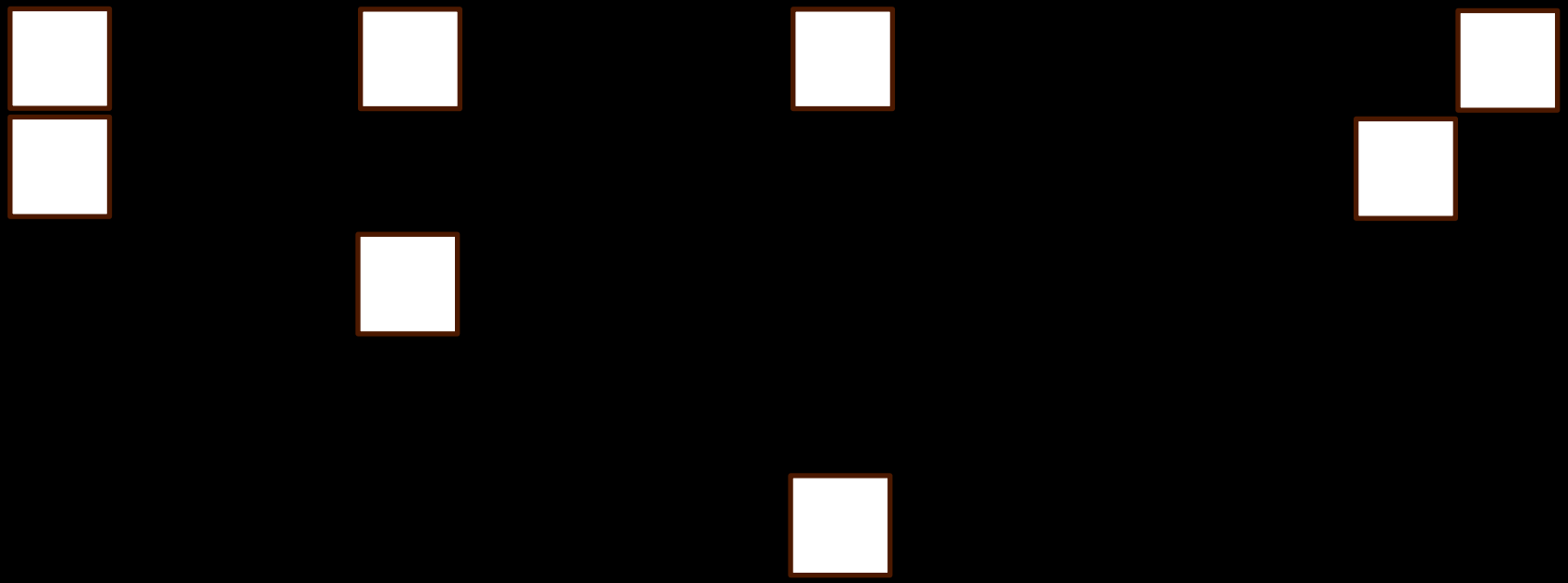
Change the path length of the cosmic ray through the scintillator.

Changing path length

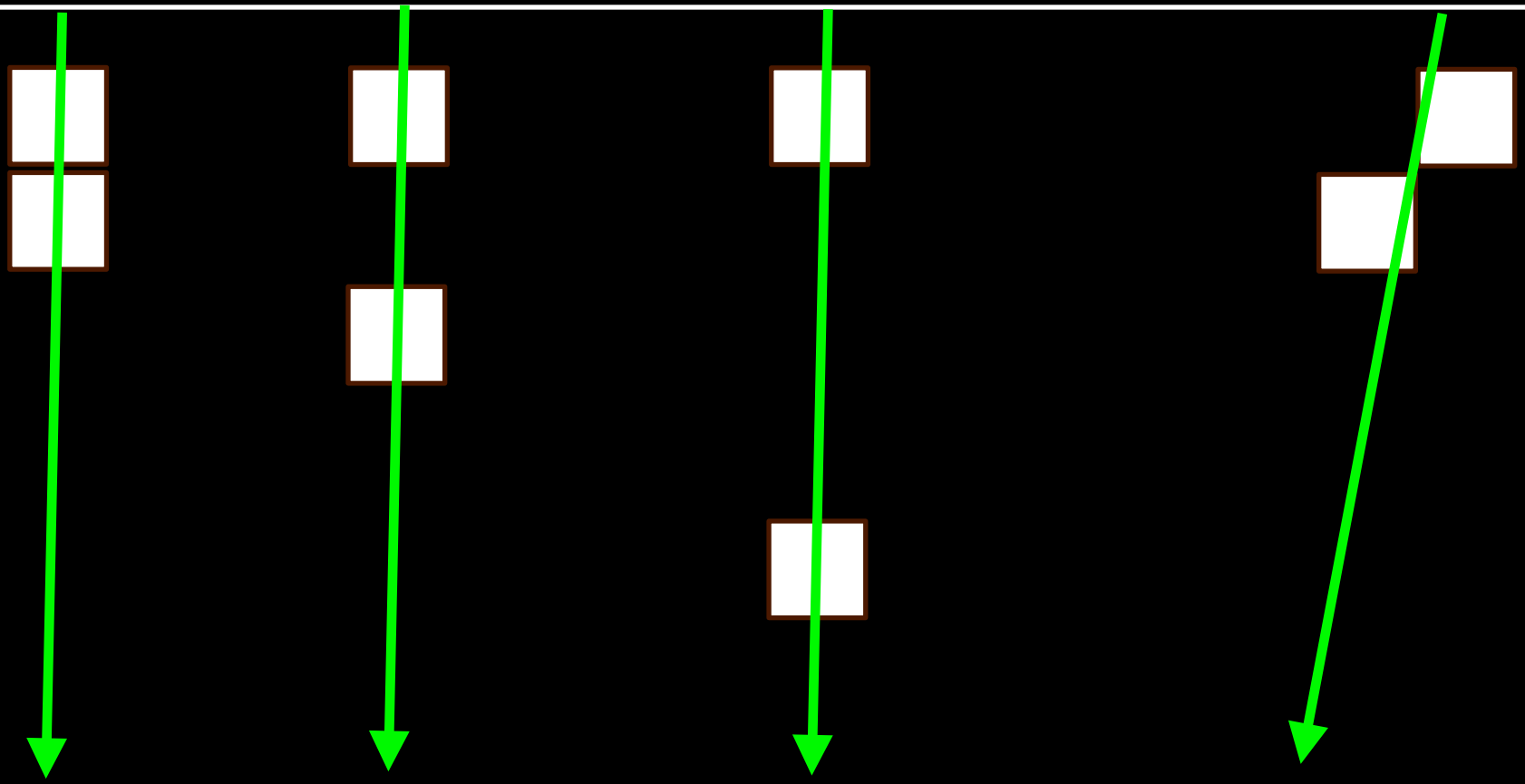


We can reconfigure positions of bars to vary the number of cosmic ray paths that are: clipped vs full width vs sqrt(2)* full width

What do you expect pulse height distributions to look like for each?

Changing path length

Straightest pathlength



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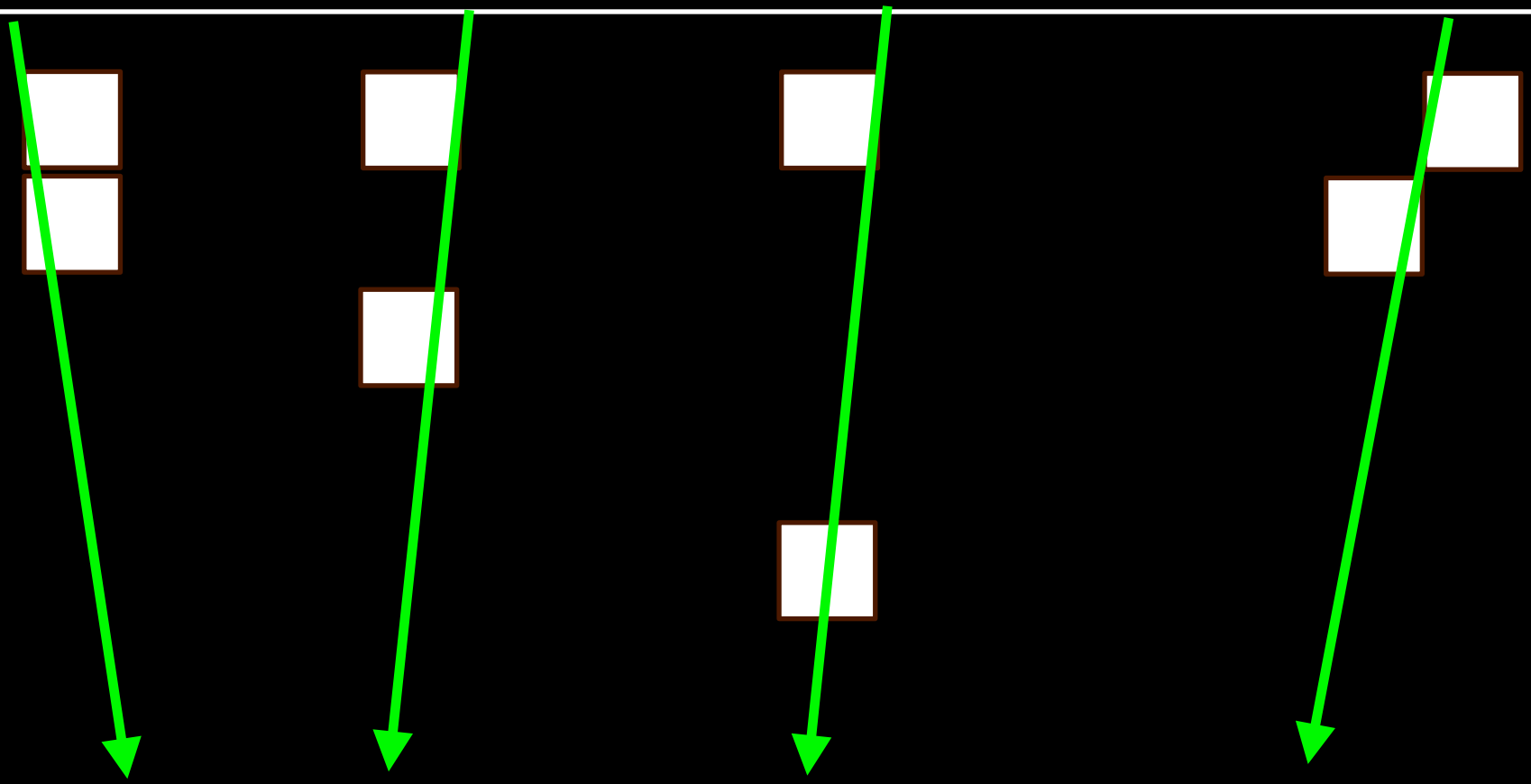
Min pathlength



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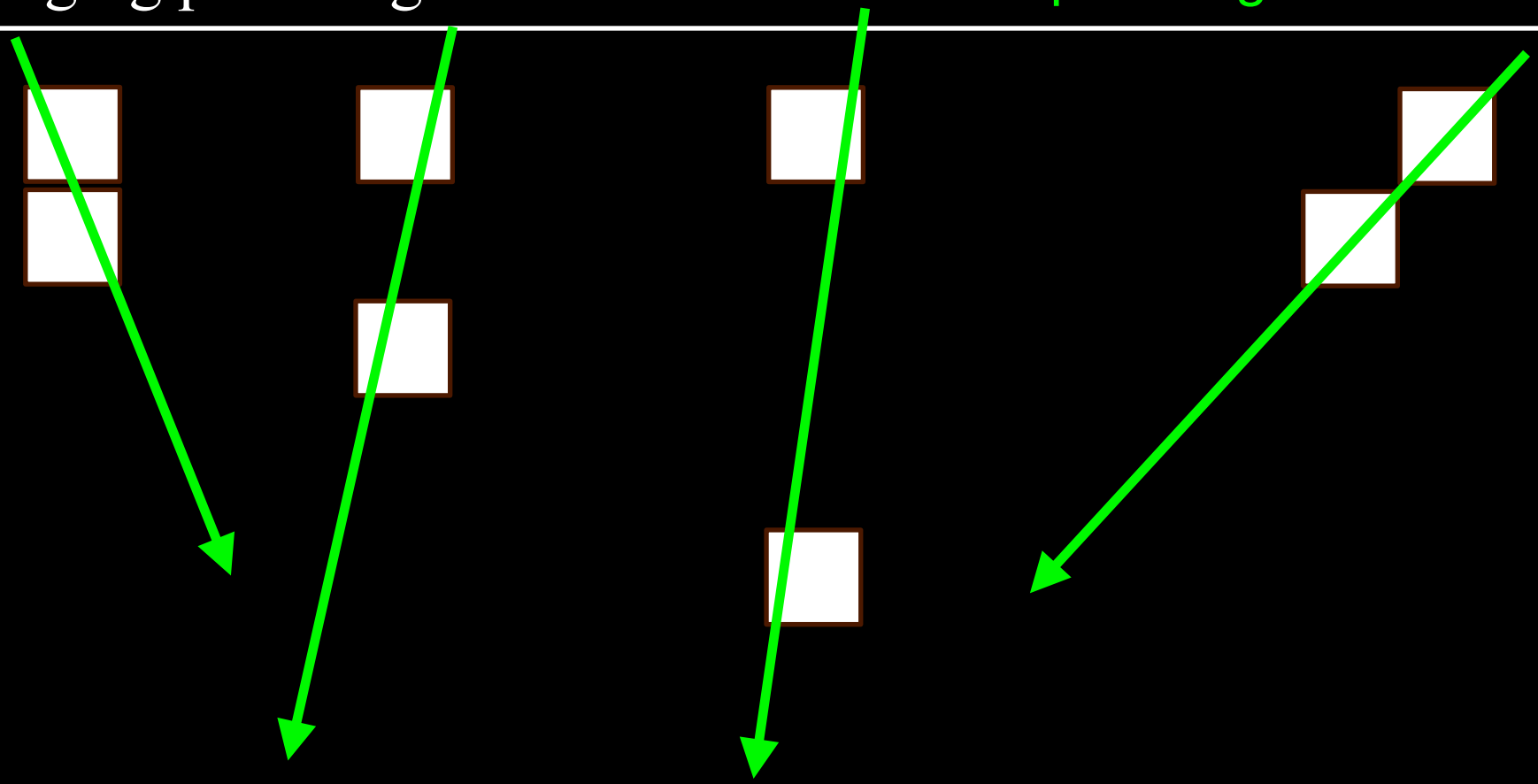

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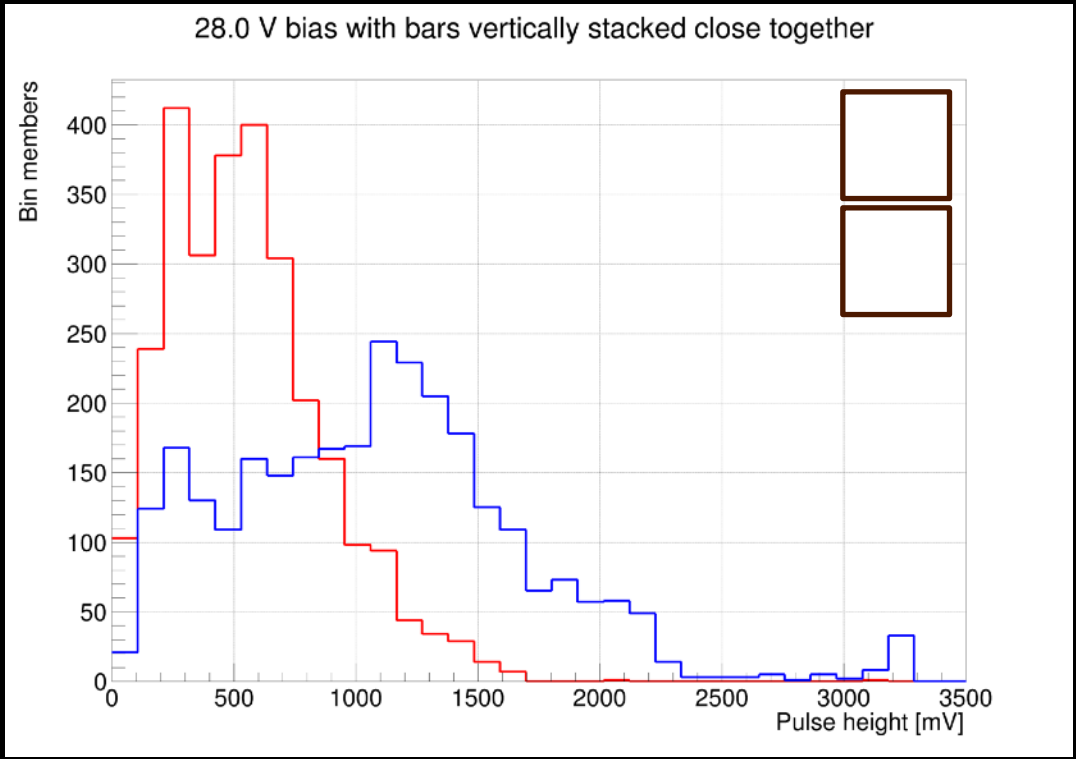

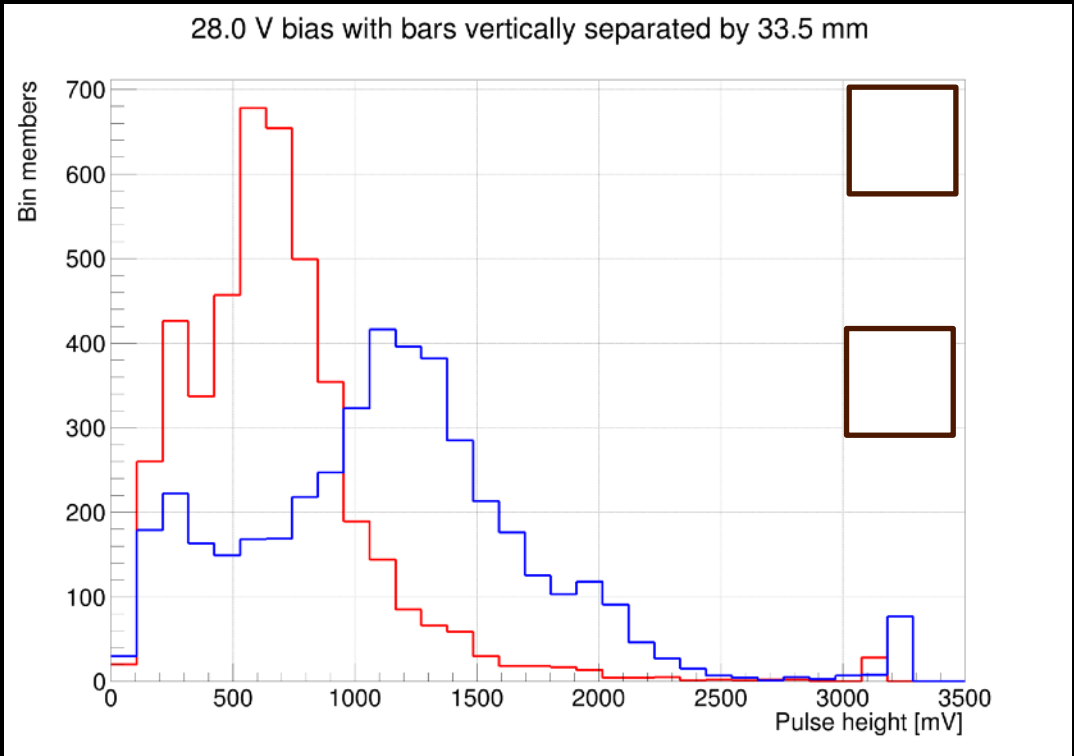

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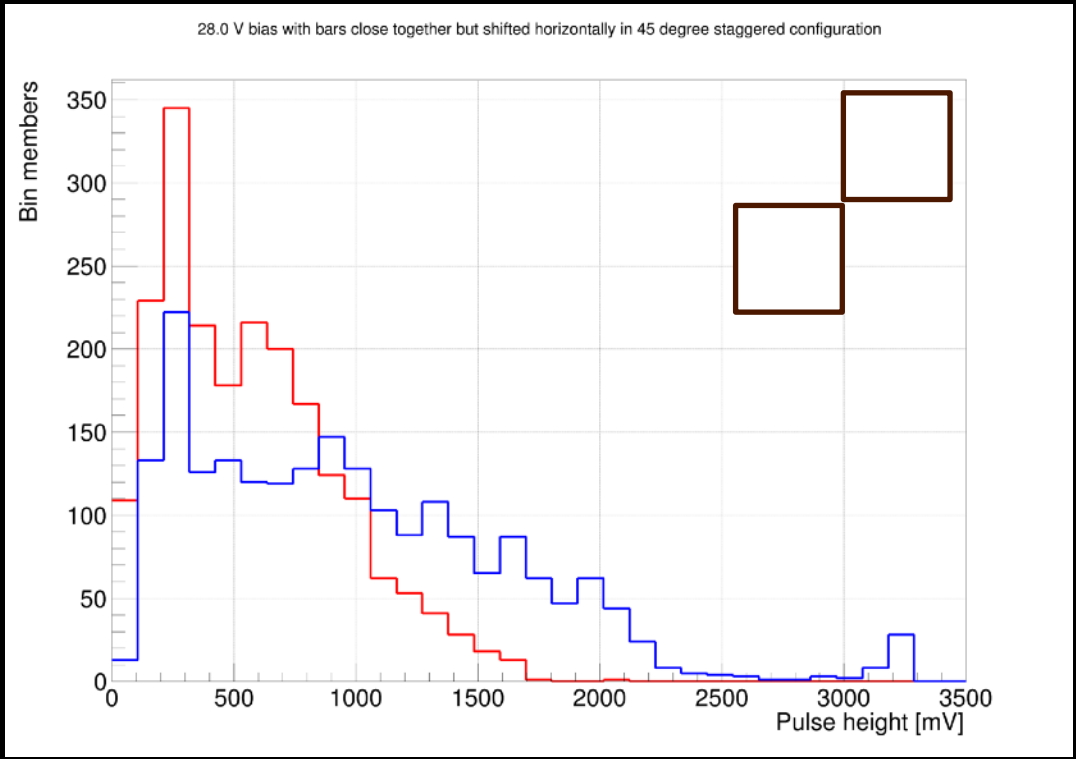
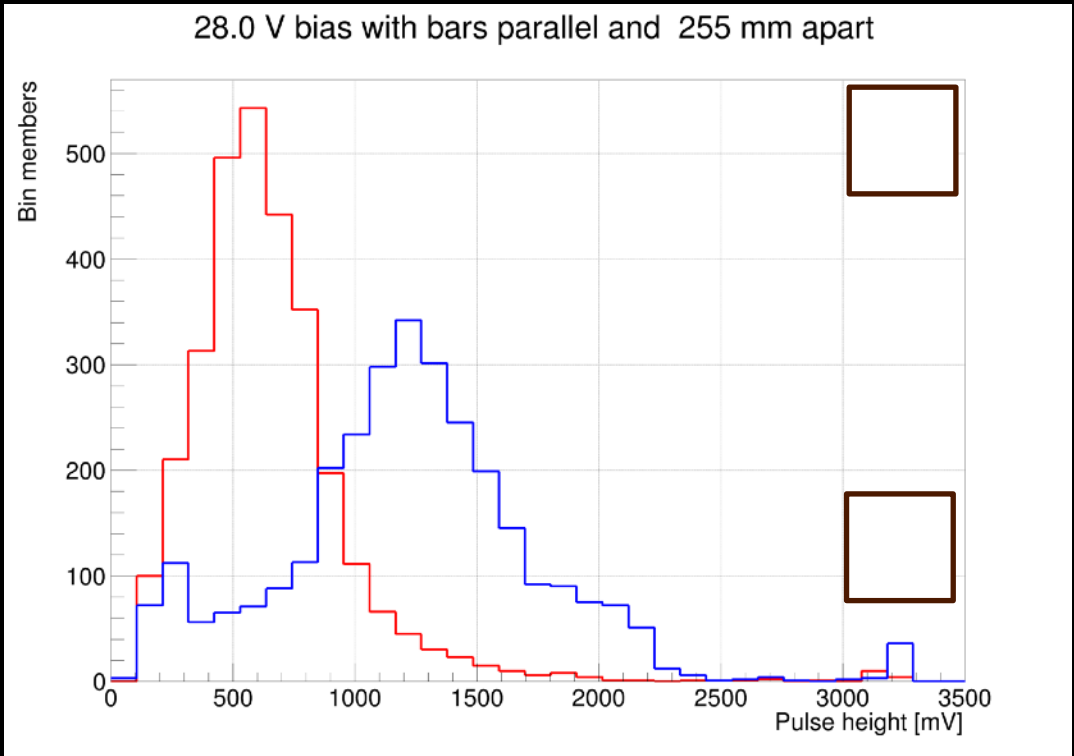
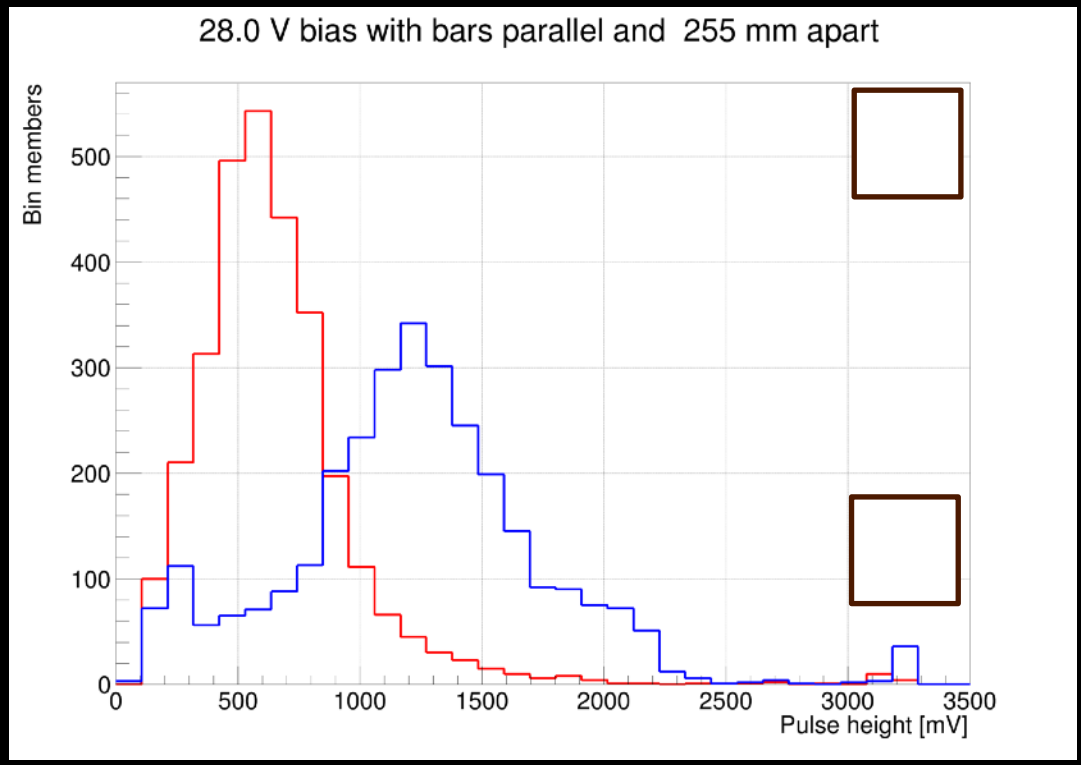




What about the other dimension?



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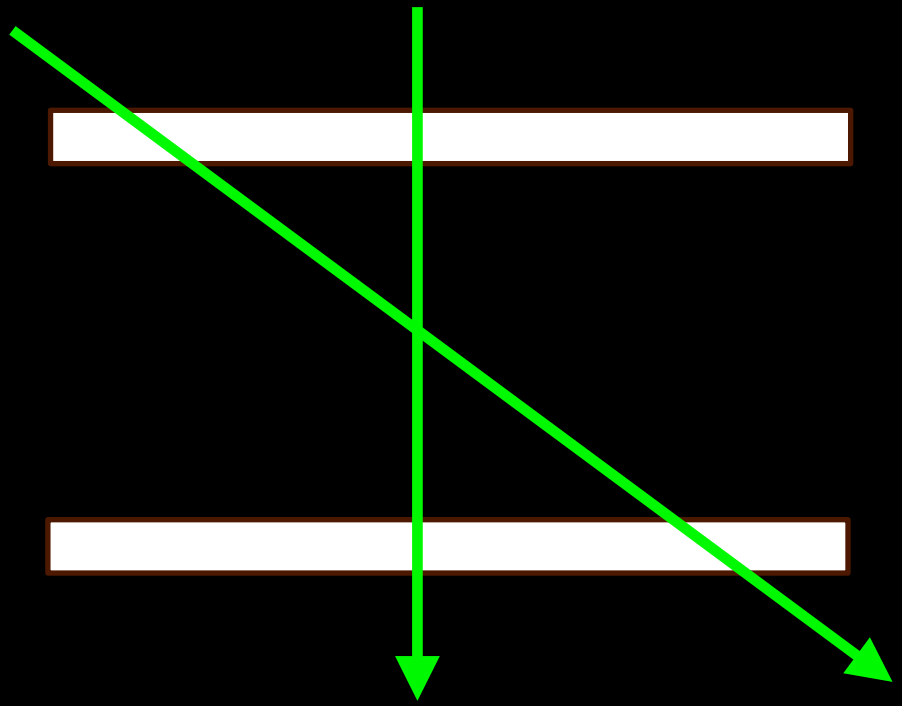

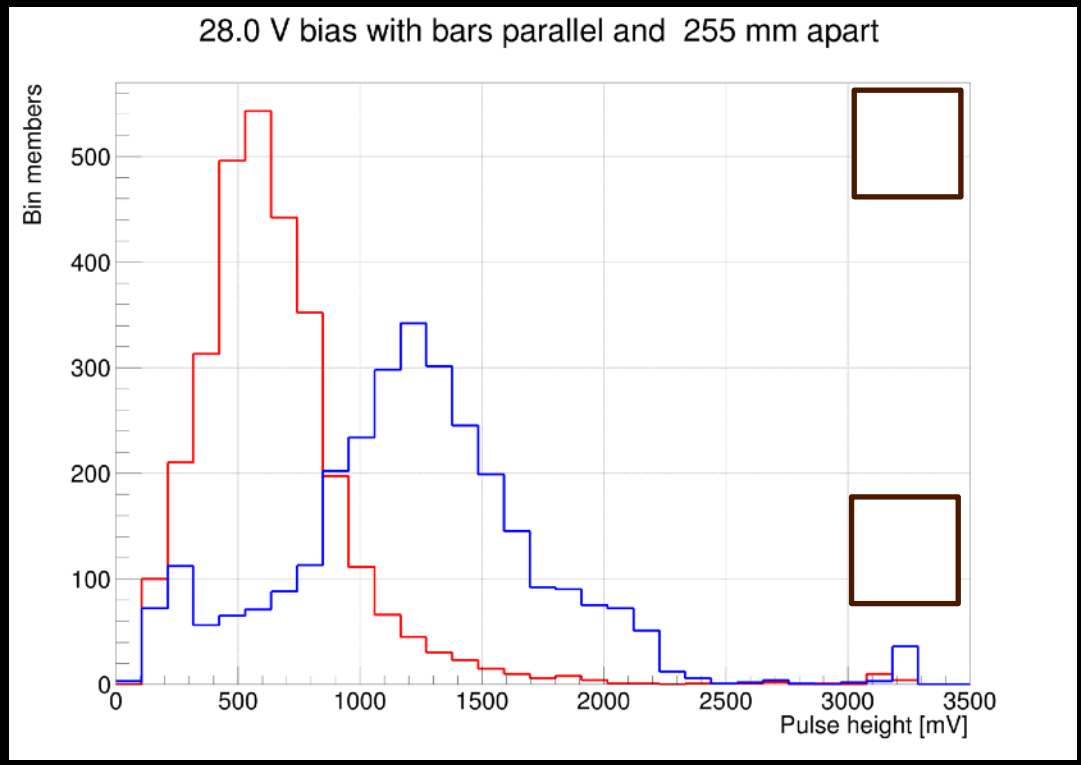

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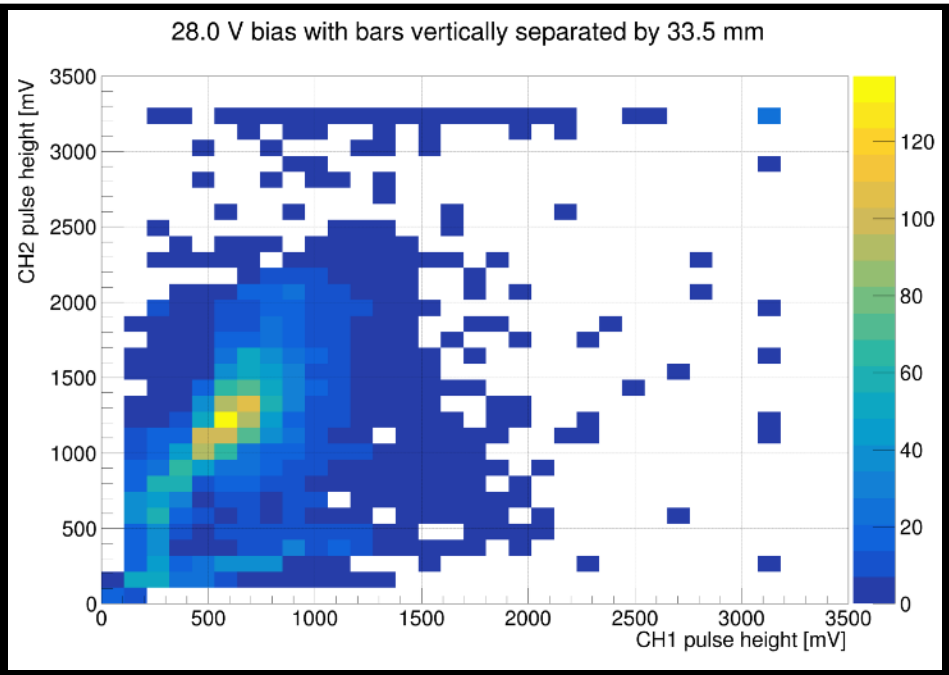

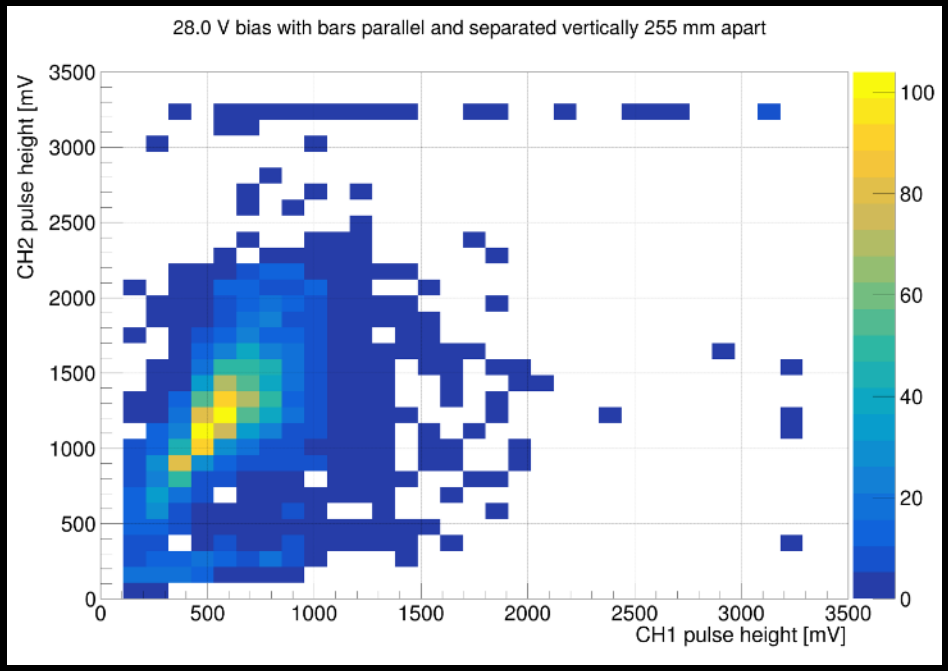

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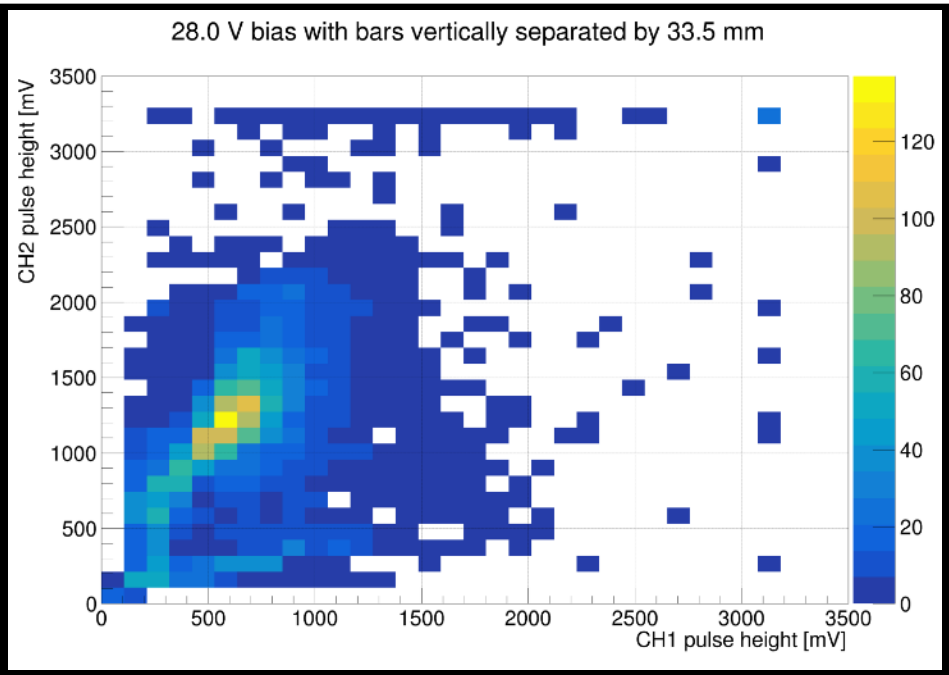

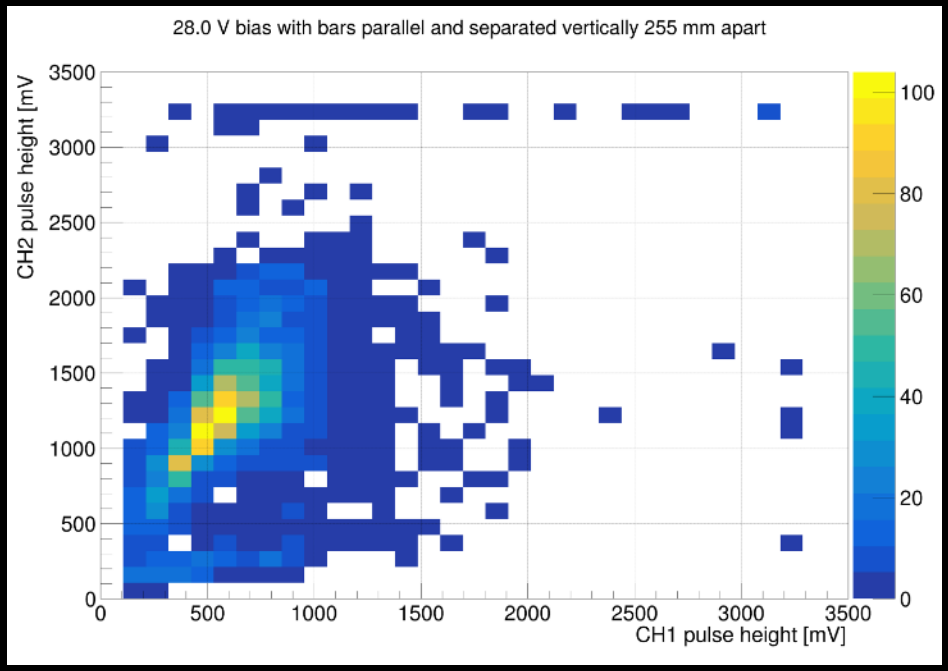

But what are the overflows?

A quicker way to measure the pulse height

It is painfully slow to readout the full waveform from a scope and then run software to find the pulses and extract their height.
It would be better to just convert the analog pulse height to a digital value in the electronics.

We could use I2C. E.g., here is a 1 MSPS SAR ADC
https://www.newark.com/texas-instruments/ads7886sdbvt/ic-adc-12bit-1msps-sar-sot23-6/dp/28AH1865

That is fast enough for the 100 µs STRETCH signal…

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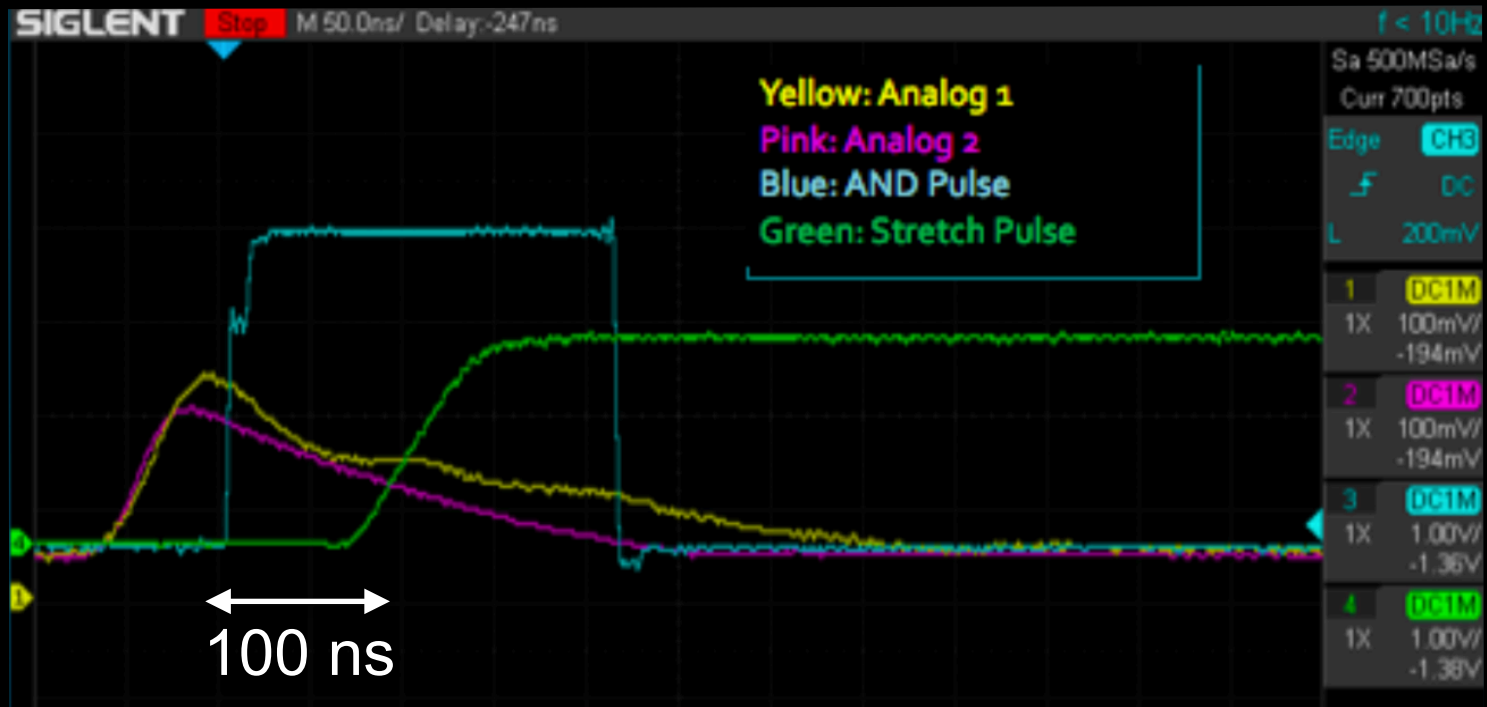
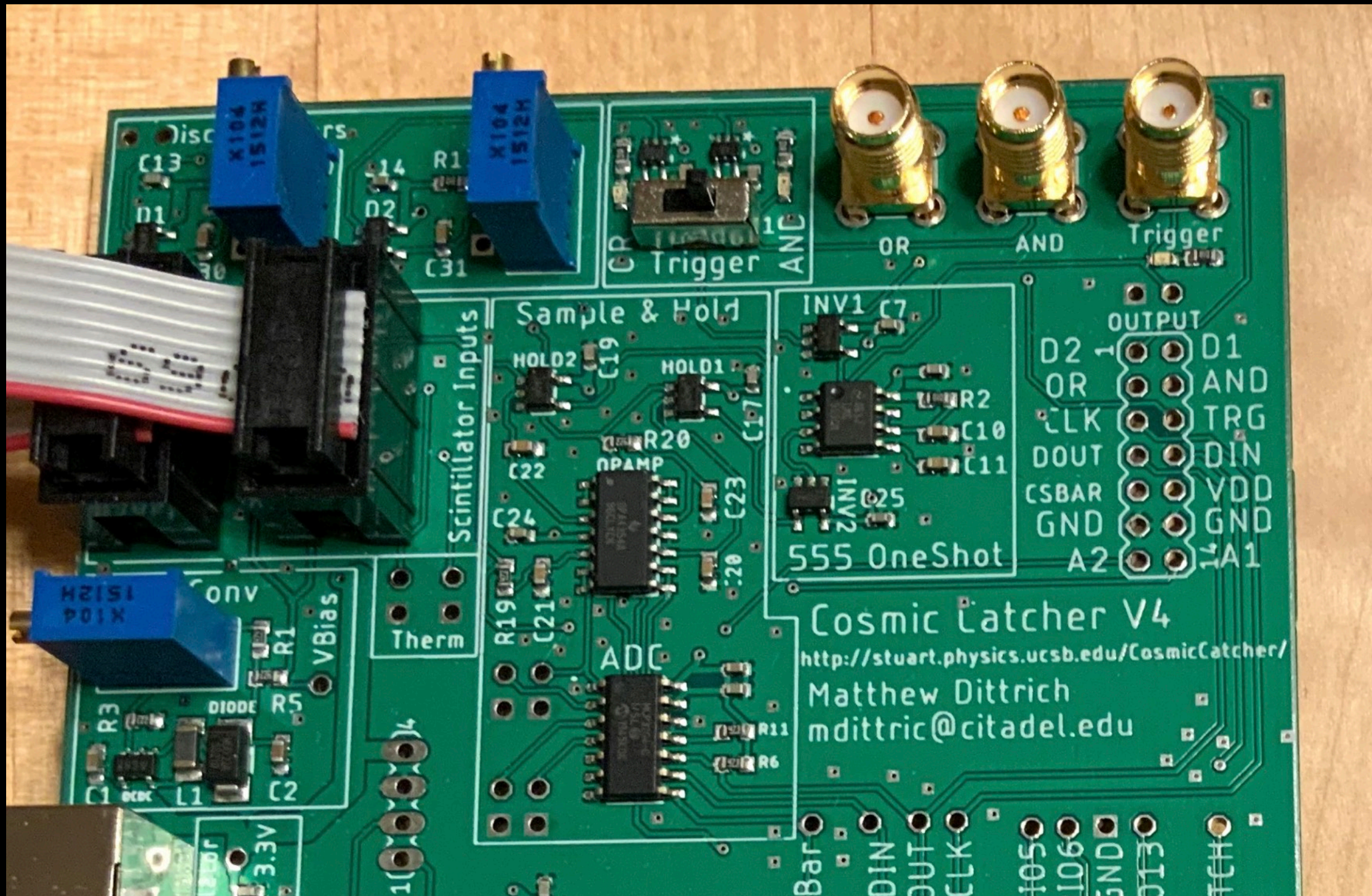
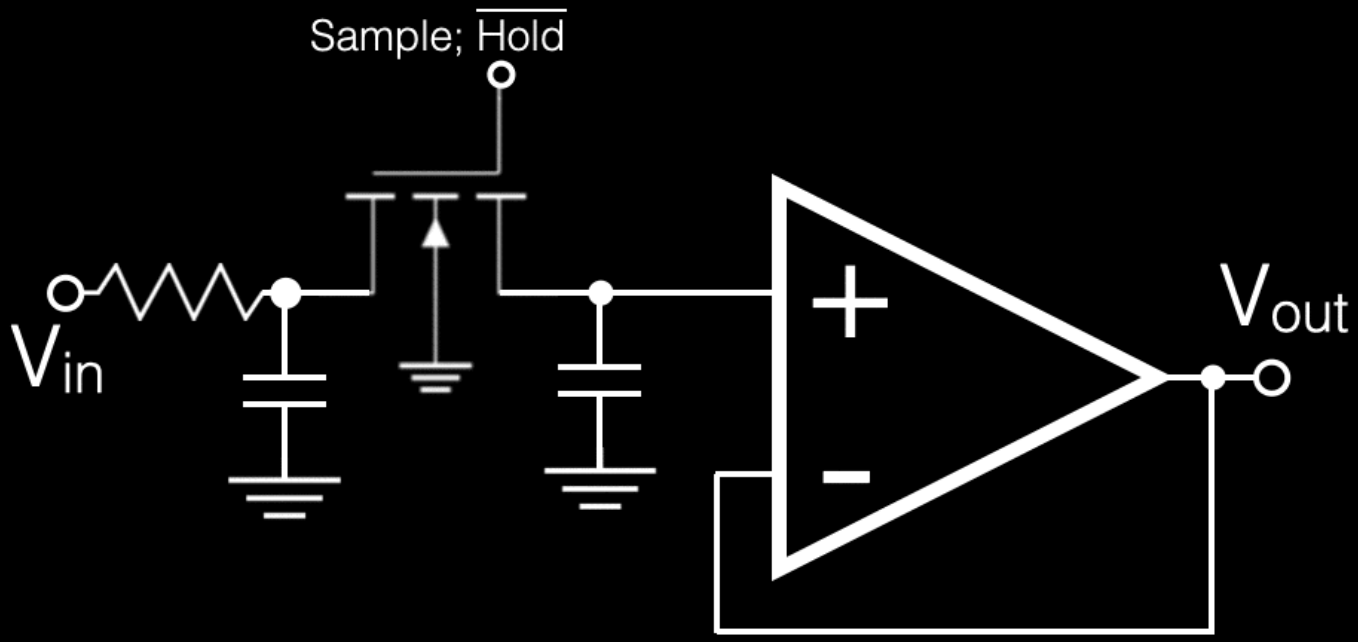
That is fast enough for the 100 µs STRETCH signal…
But the analog signal falls faster.

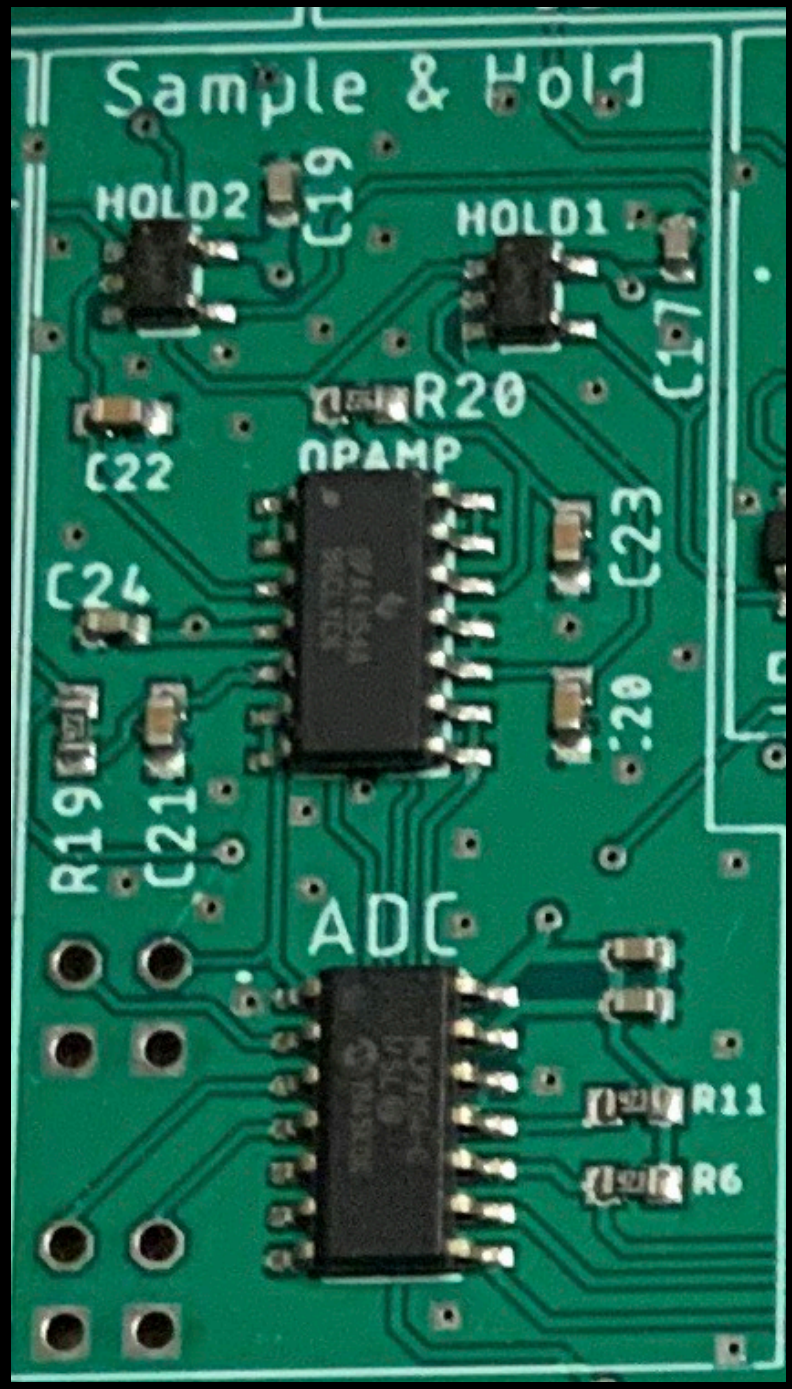


RC slowing, Sample and hold, and ADC

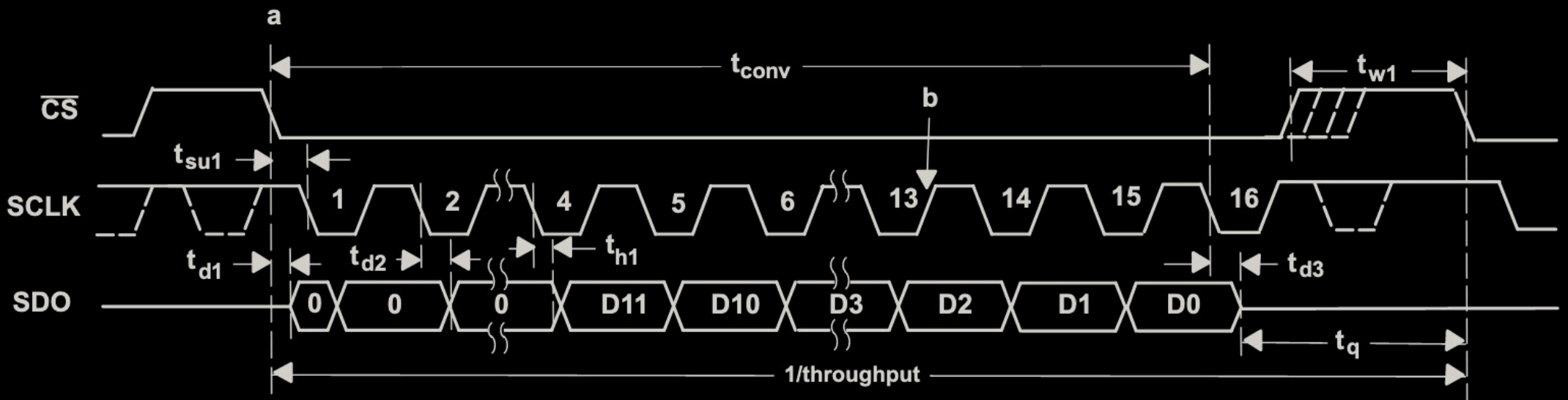


RC slowing, Sample and hold, and ADC



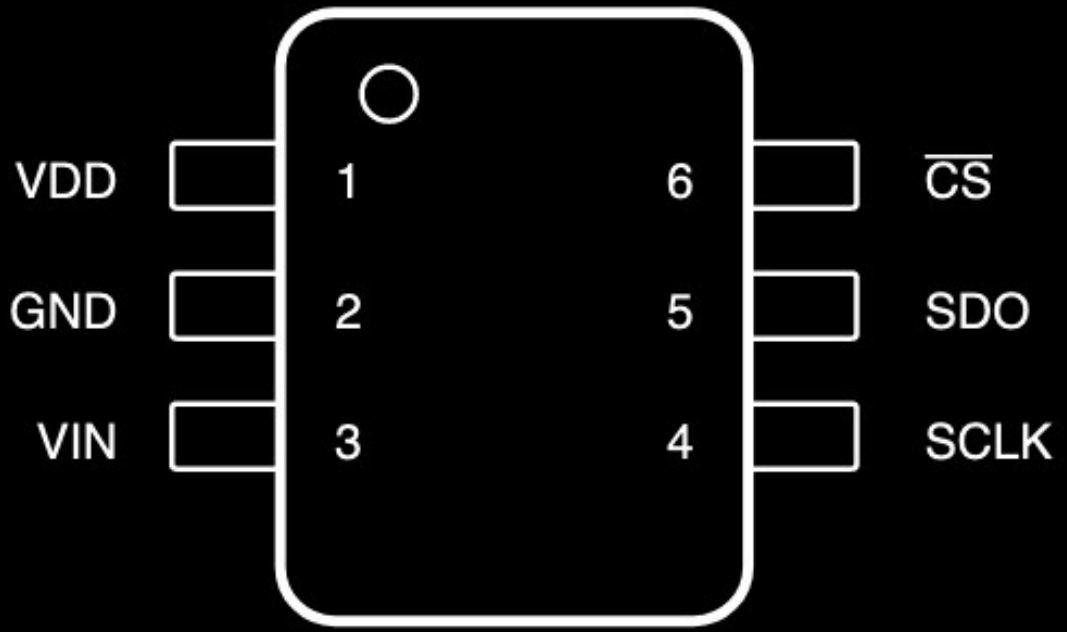


Reading out a SAR ADC (ADS7886)



$\overline{CS}$ triggers the sample. Then send three SCLKs to process the conversion and 12 more to get bits out, one per clock edge.

Bits out in reverse order.



Reading out your SAR ADC

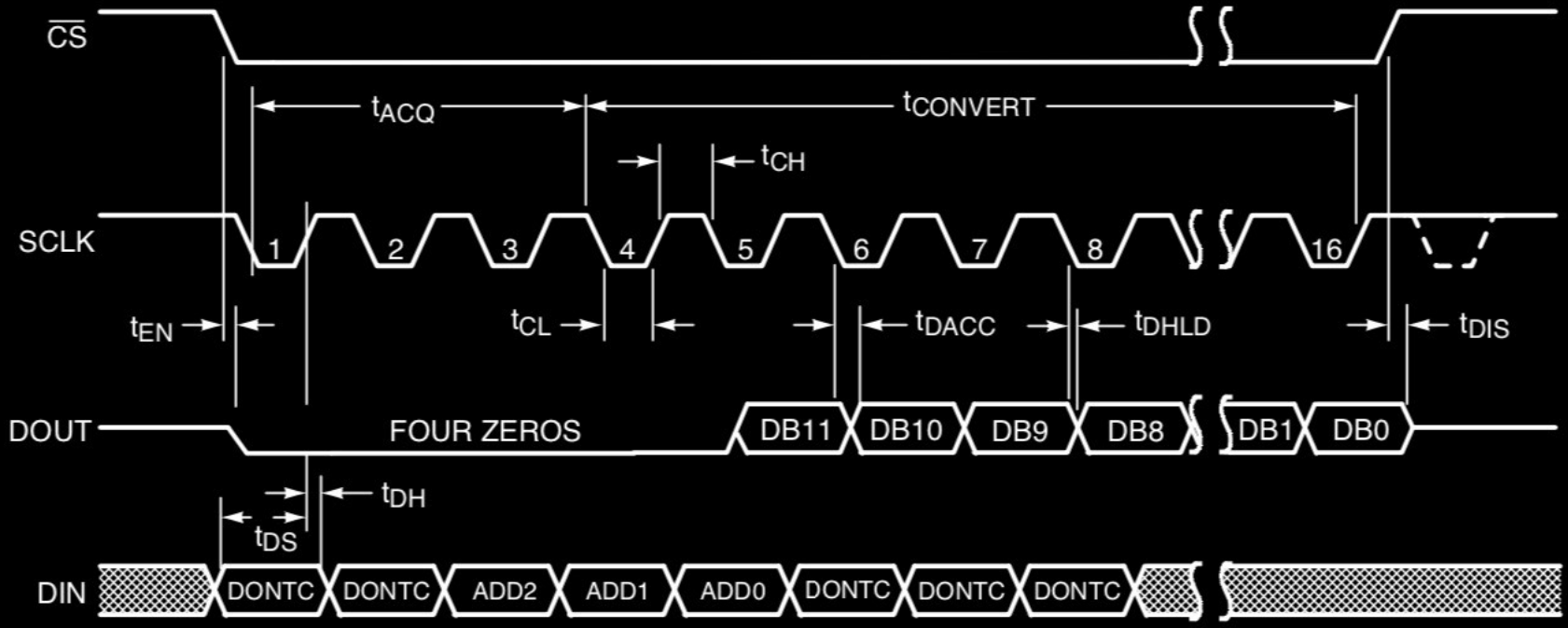


Figure 2. ADC128S022 Serial Timing Diagram

Your board has a four channel ADC with a DIN pin that sets the address of the *next* channel to be read while reading the current one. So can read both A1 and A2 and a slowed version.

Reading out your SAR ADC

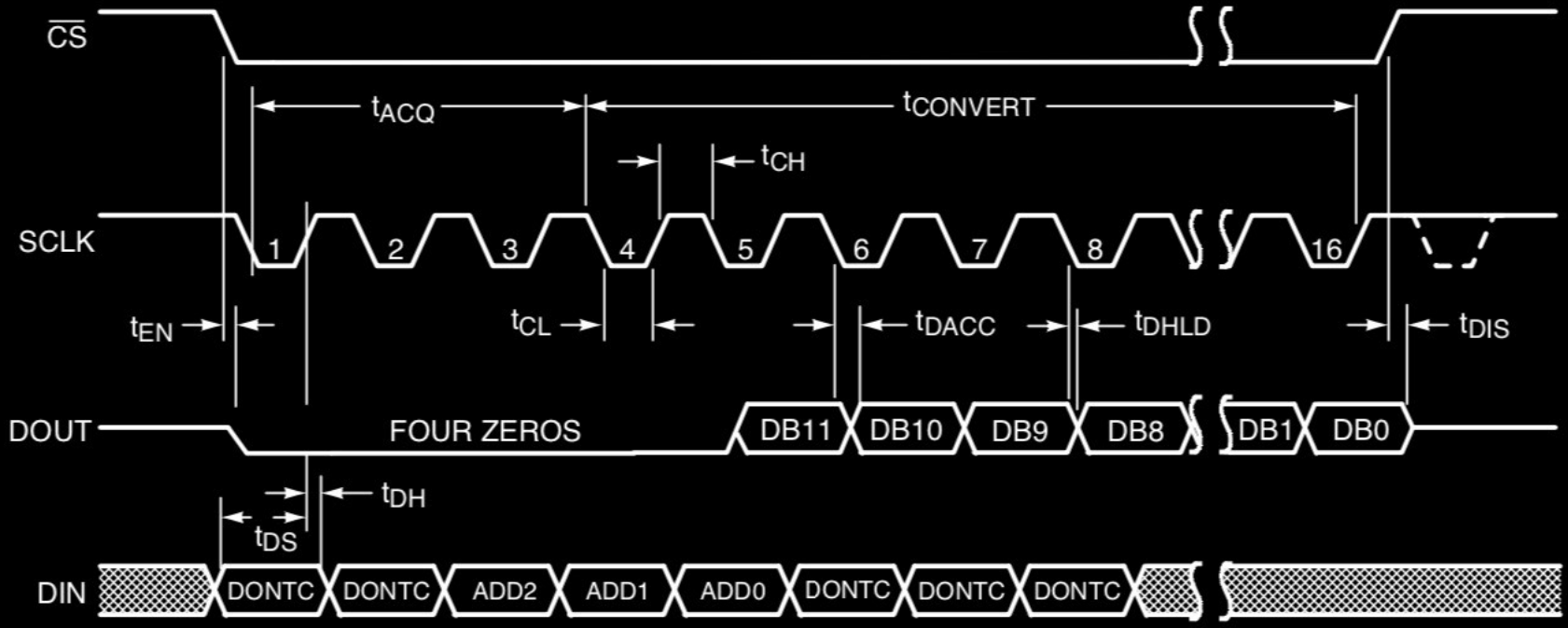


Figure 2. ADC128S022 Serial Timing Diagram

Your board has a four channel ADC with a DIN pin that sets the address of the *next* channel to be read while reading the current one. So can read both A1 and A2 and a slowed version.

But, the board uses a 0.1 MHz version instead of 10 MHz version. Plots above use a hacked in 10 Mhz version.

Next time:

Next time we talk about designing an add-on board to use the expansion port for other measurements:

- A fast ADC, perhaps with peak detector or integrator.
- A fast counter to measure all the D1, D2, and AND signals.
- An I2C DAC to adjust the thresholds within the RPi program.

You will see how to quickly layout a circuit board to do something like that and have a homework exercise to design a simple circuit board. I'll order a couple examples for you to play with at the end of the quarter.

The goal here is to give you enough intro that you can say
"I've designed a circuit board."
And maybe even "…and it worked."