

Designing and executing a cosmic ray experiment

Phys150 Special topics

David Stuart, UC Santa Barbara



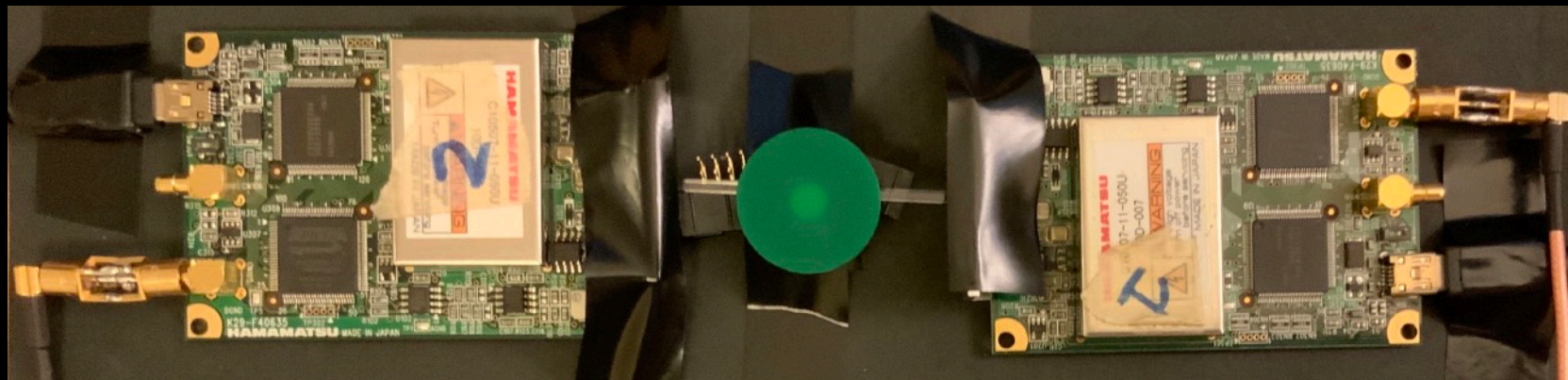
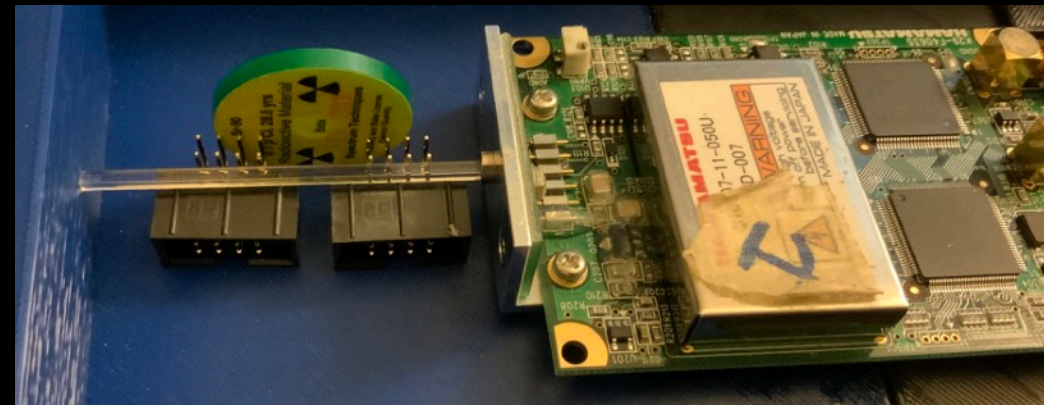
Review

Looked at scintillation light with and without a source

First checked that we saw more “bright” flashes (>6 photons) with source vs w/o

Moved to look at the light from both ends of the scintillator

- Triggering on CH1 and looking independently at CH2 avoided a trigger bias
- Triggering on CH1 AND CH2 gave an efficient, but biased way to see source
- If we remove the source we still see some coincident bright flashes, but rare.



Review

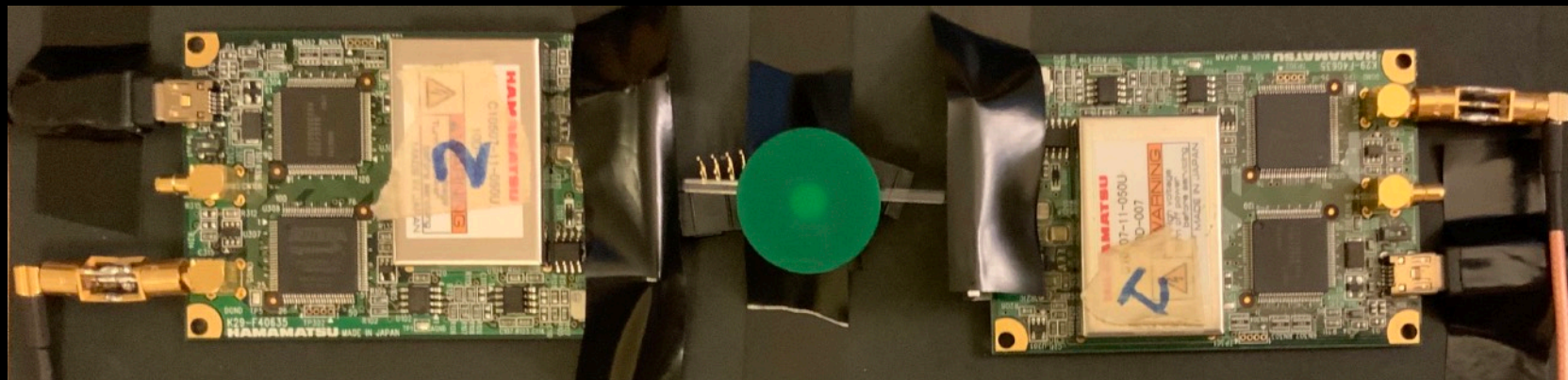
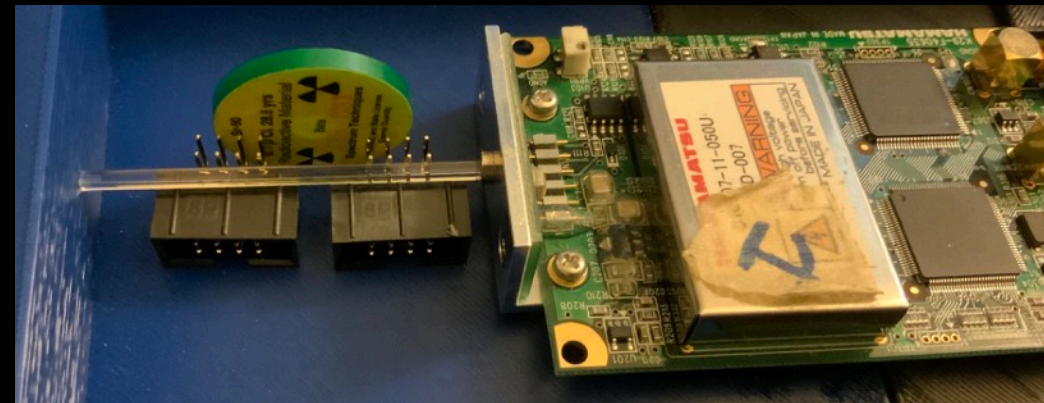
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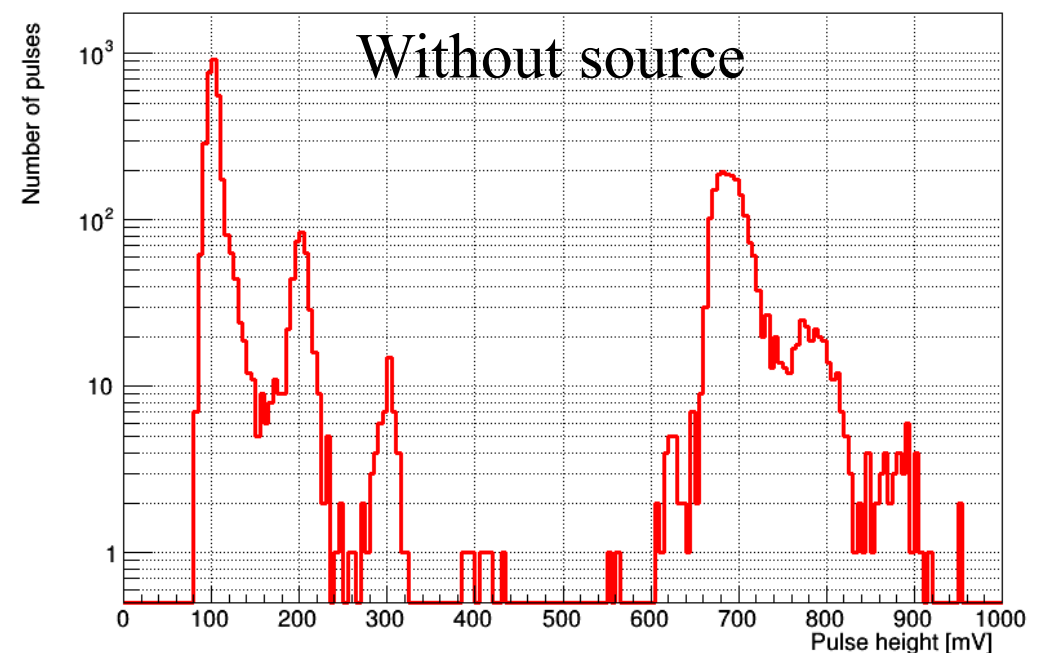
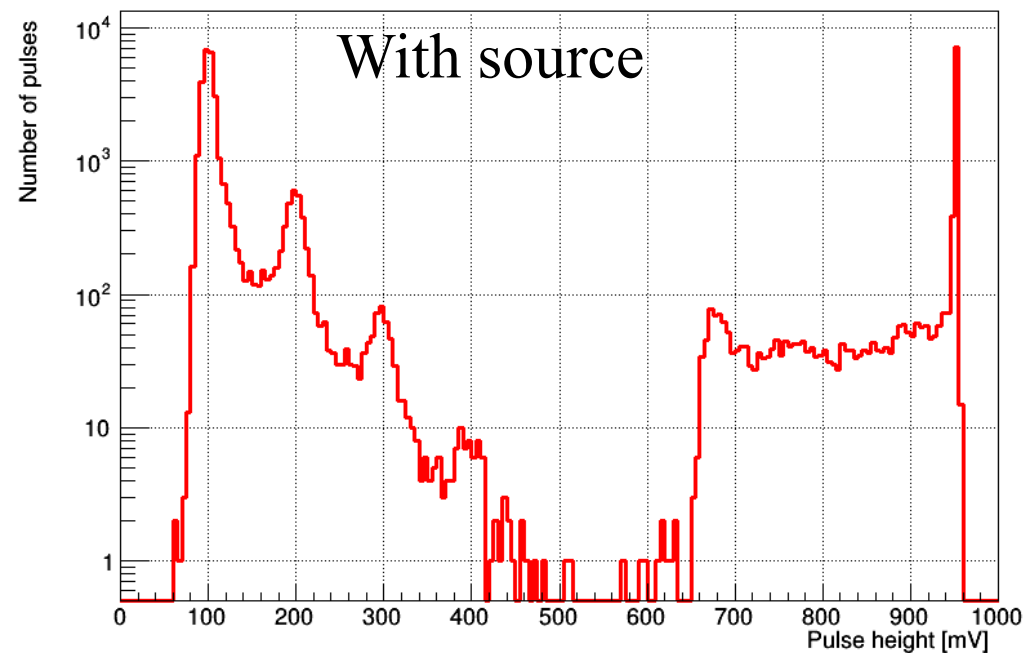
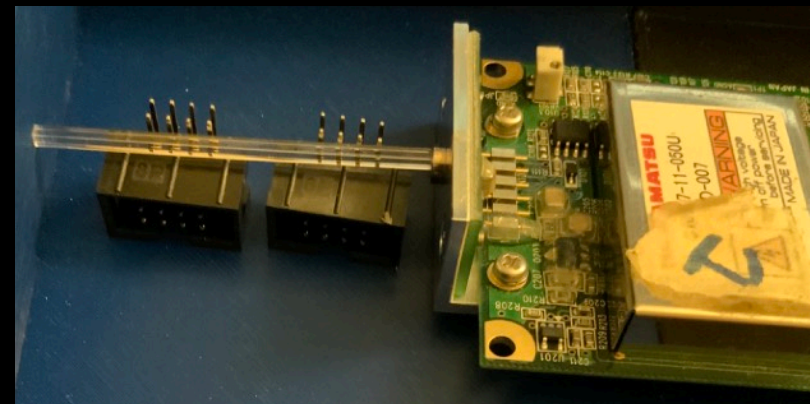
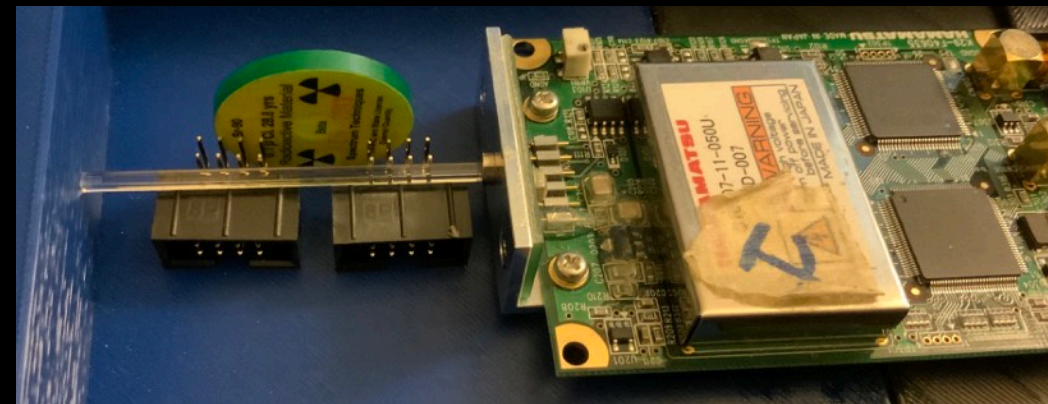
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Let's briefly review that data, and expand it a bit.



Detecting radiation with light

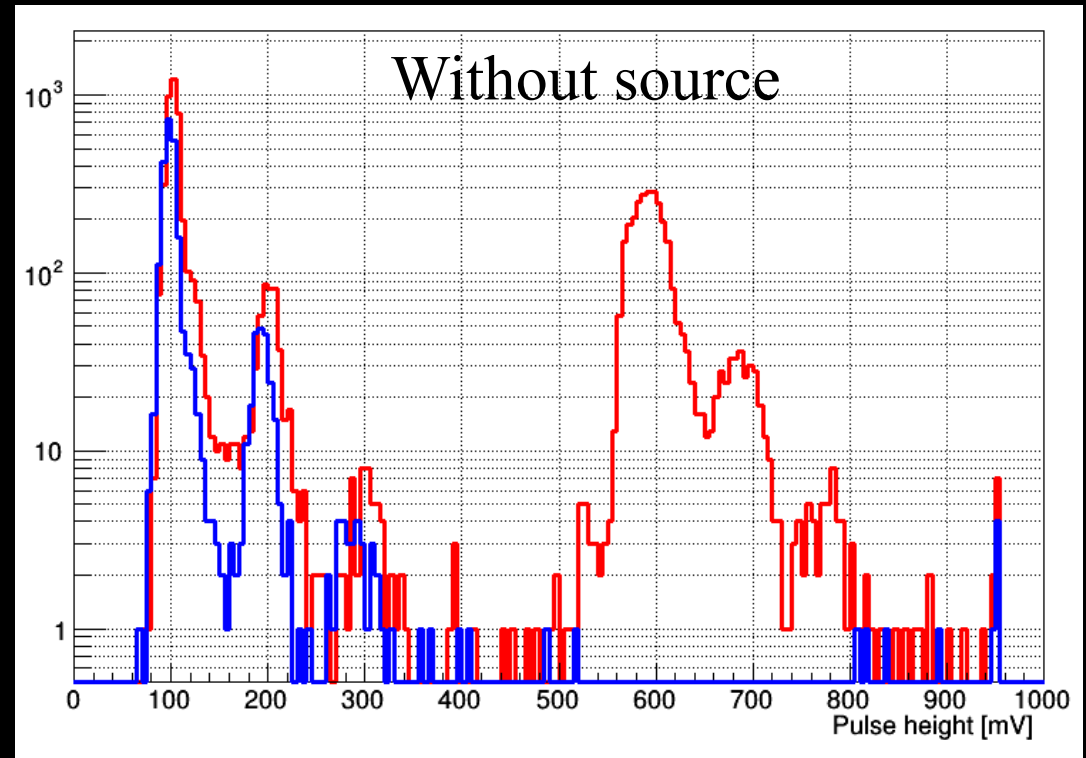
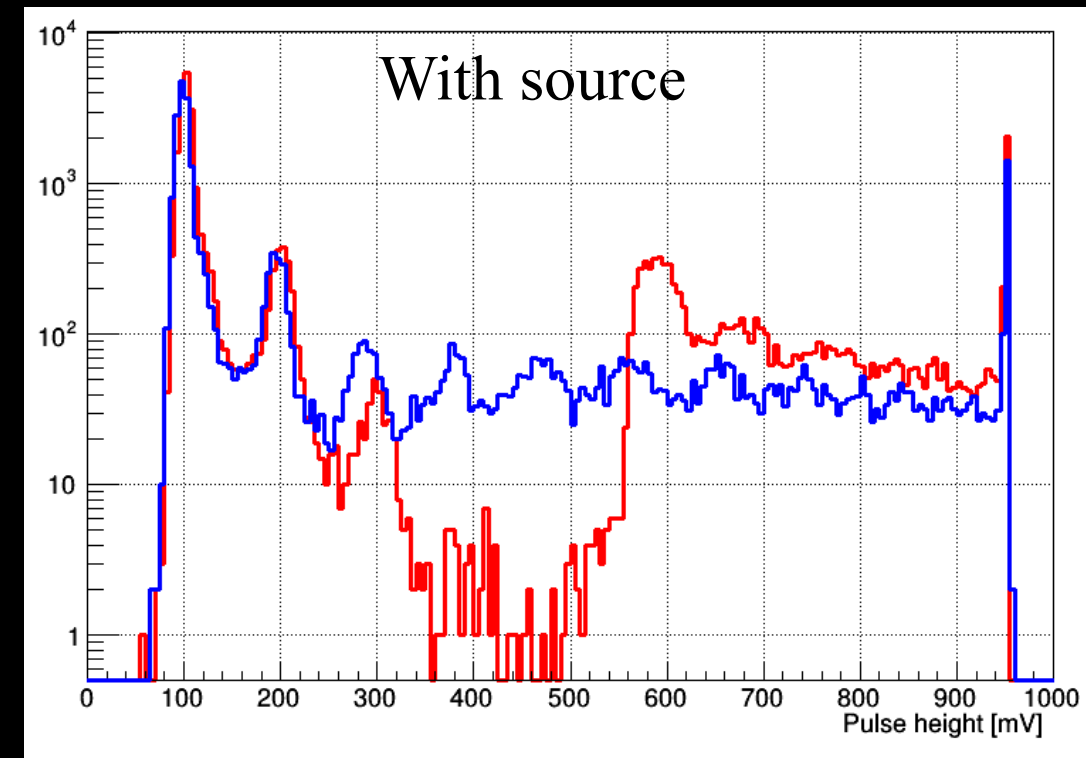
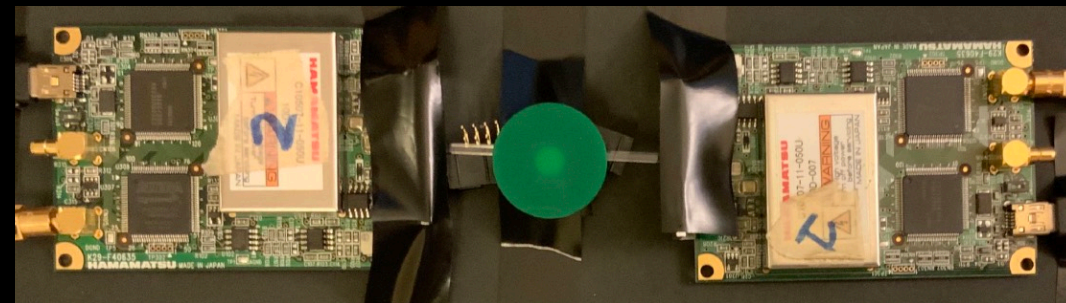
Use a single SiPM and trigger at ≥ 650 mV, which is ~ 7 photons
More large flashes with source present than without.



Detecting radiation with light

Use a SiPM on each end and trigger on one at ≥ 550 mV

More *correlated* large flashes with source present than without.

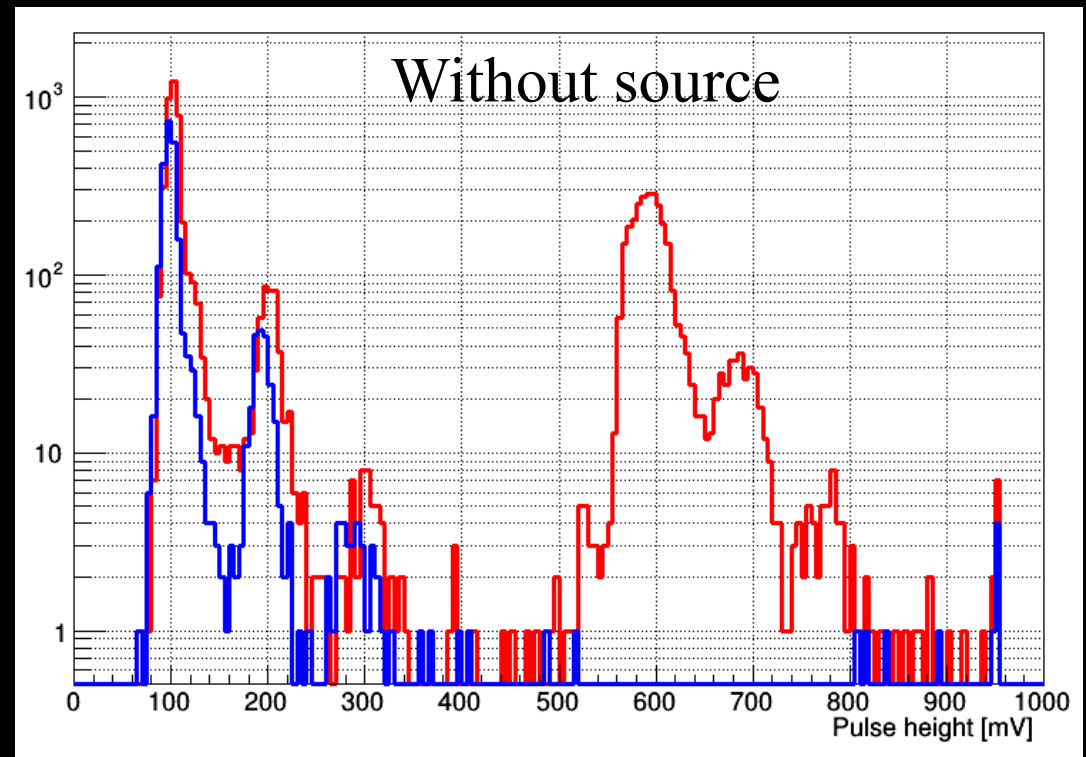
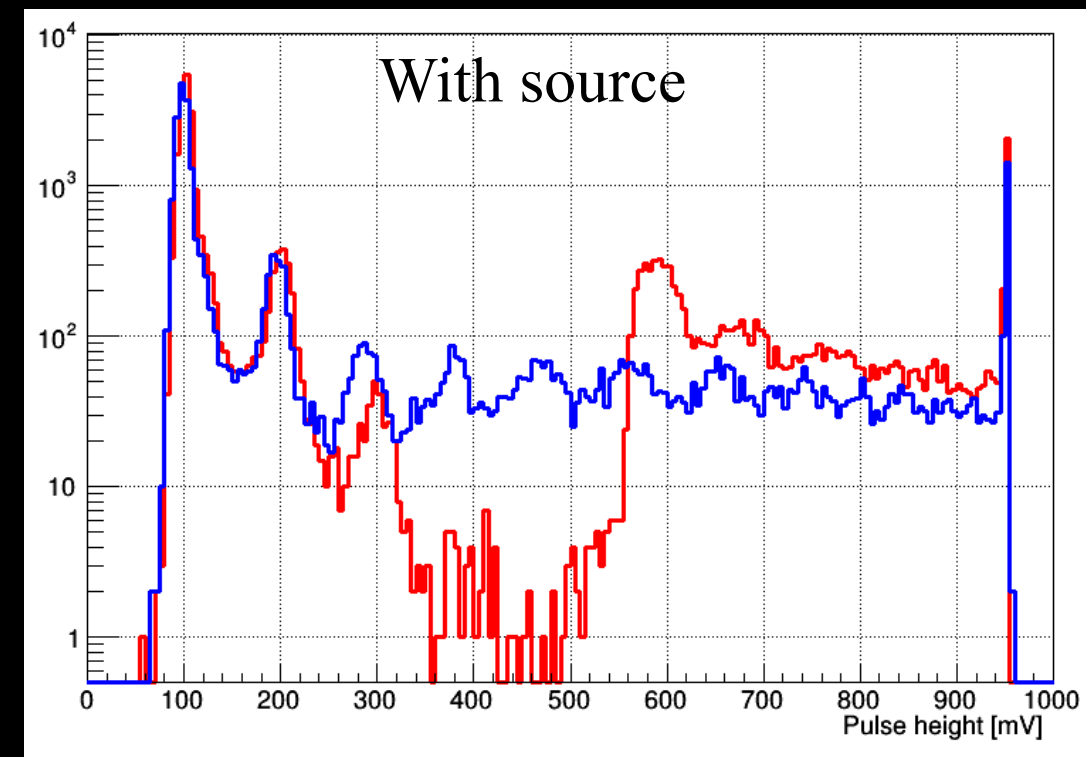
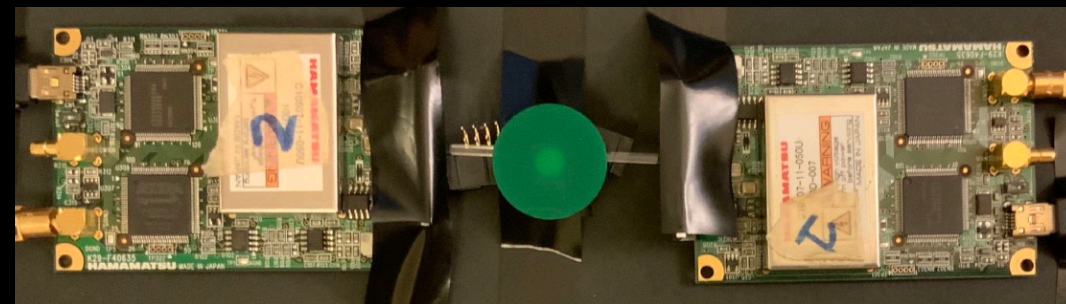


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Use a SiPM on each end and trigger on one at ≥ 550 mV

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But, still a lot of 1 and 2 photon pulses, could be random background. Check timing.



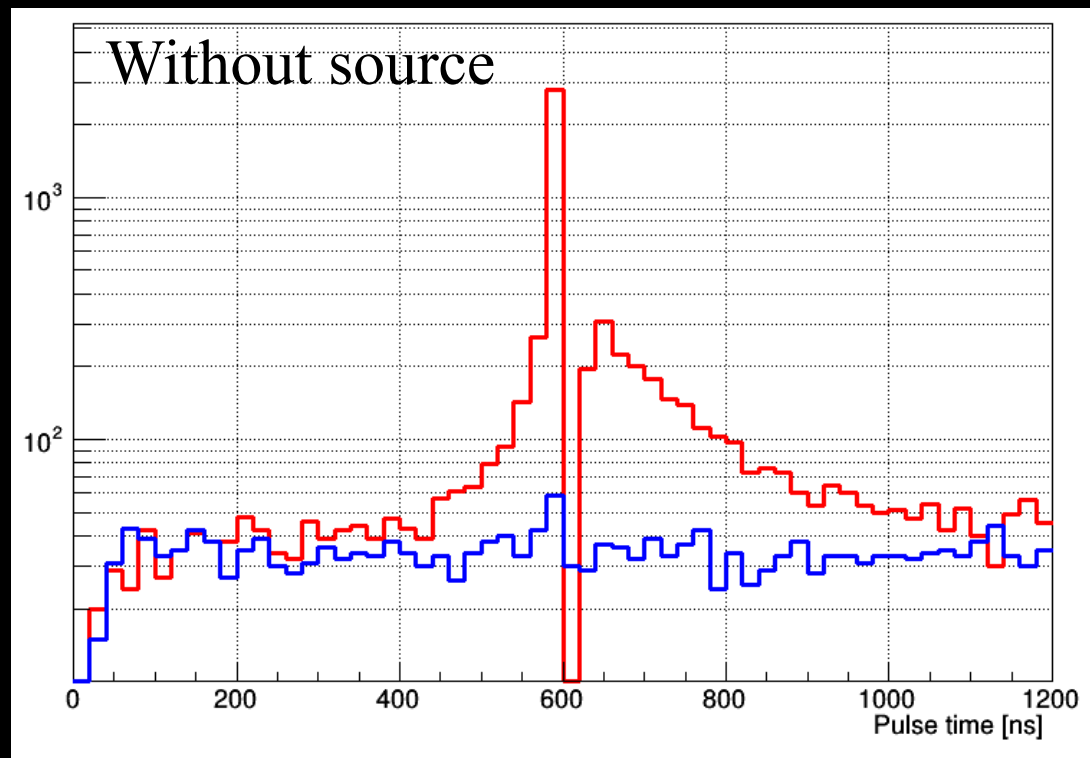
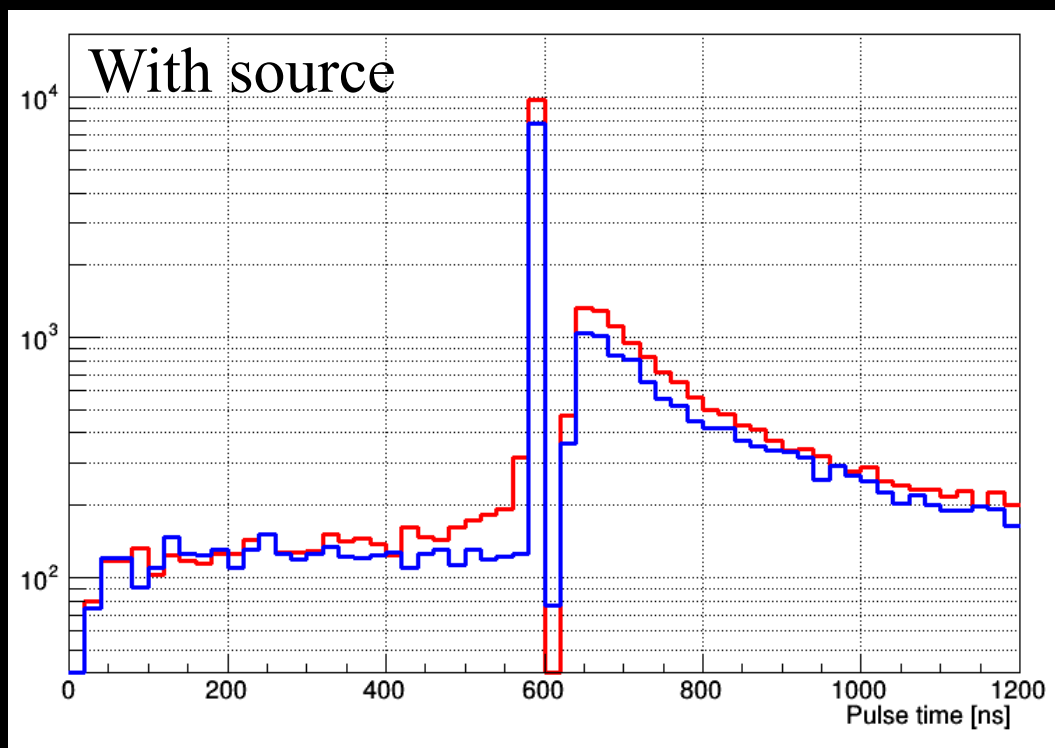
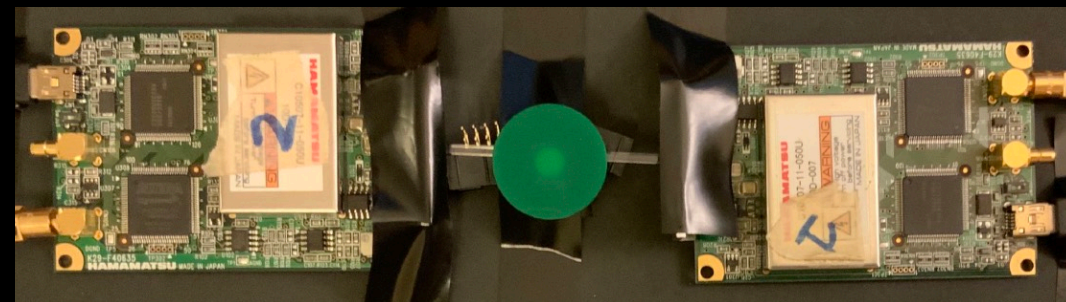
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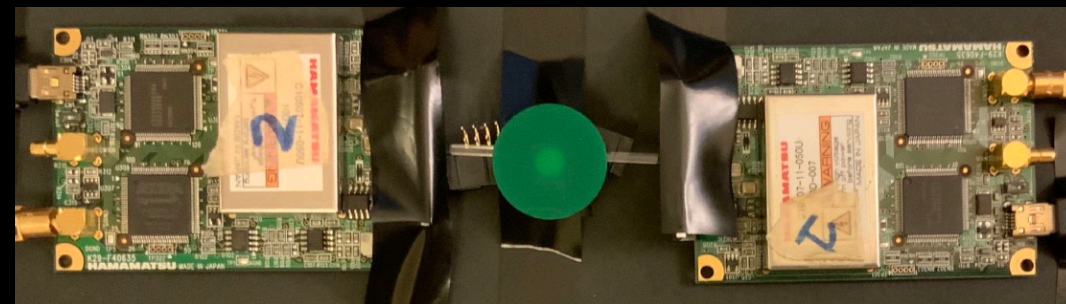


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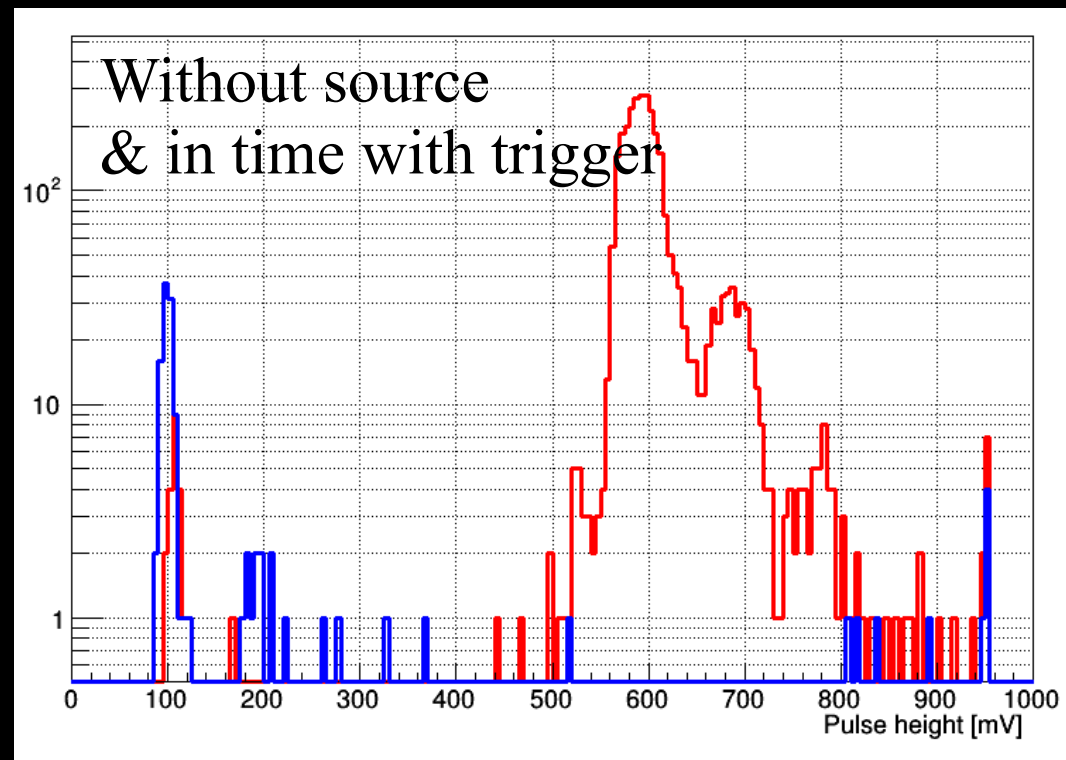
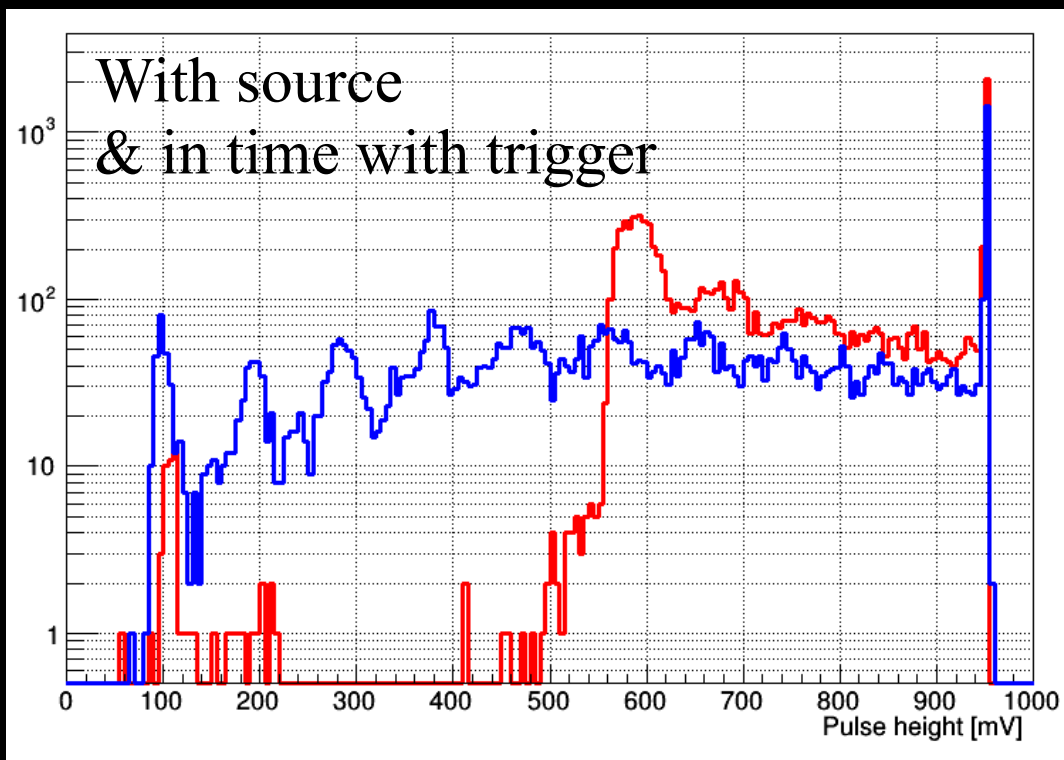
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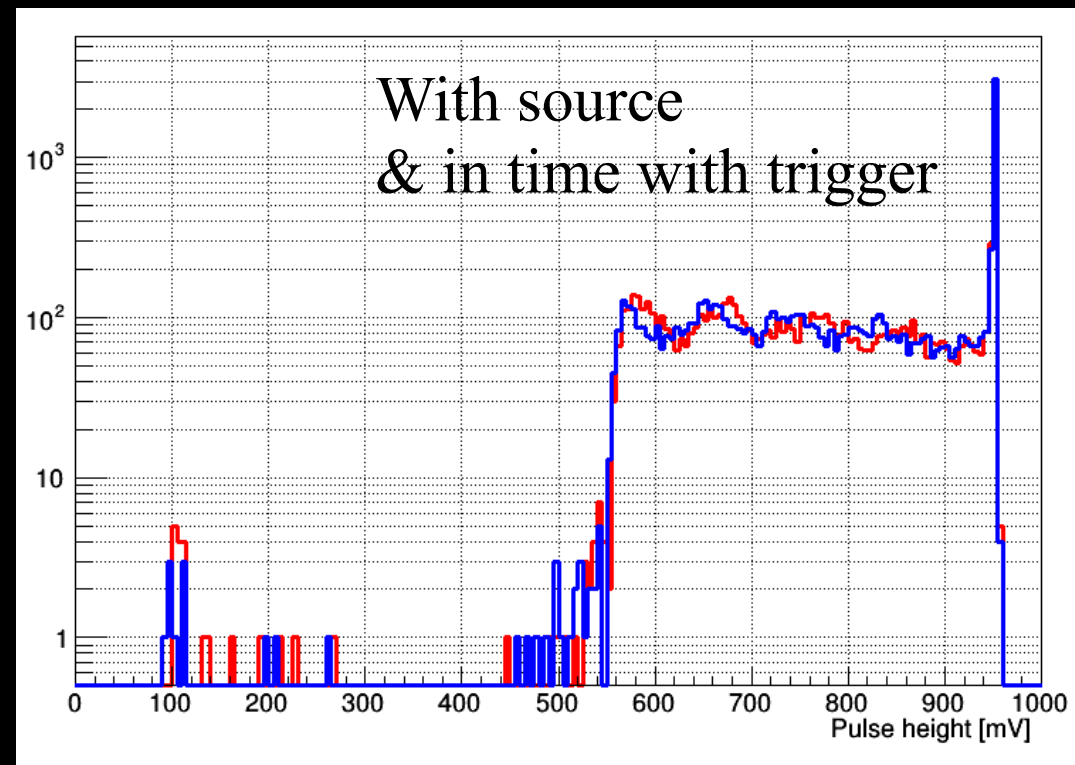
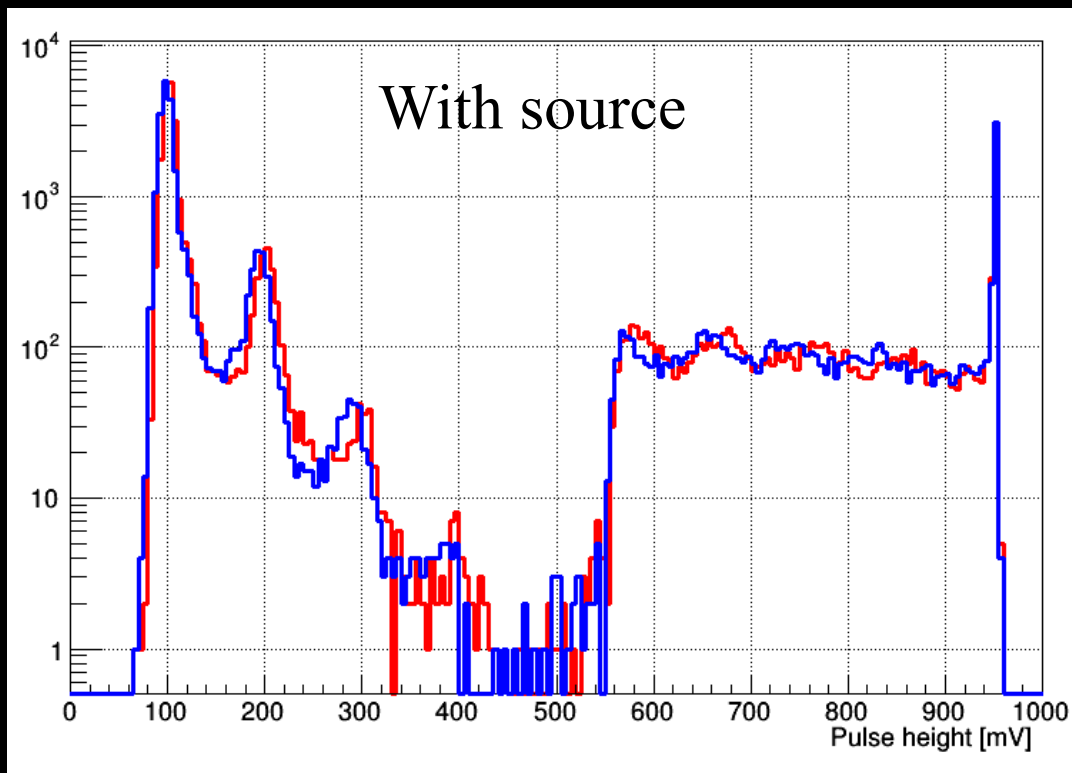
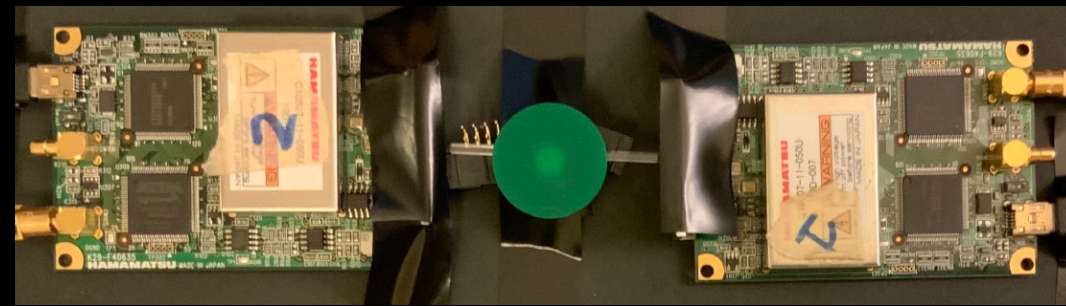


In time pulses, without trigger bias, show clear excess with source.
And a tiny hint of very large pulses without the source.



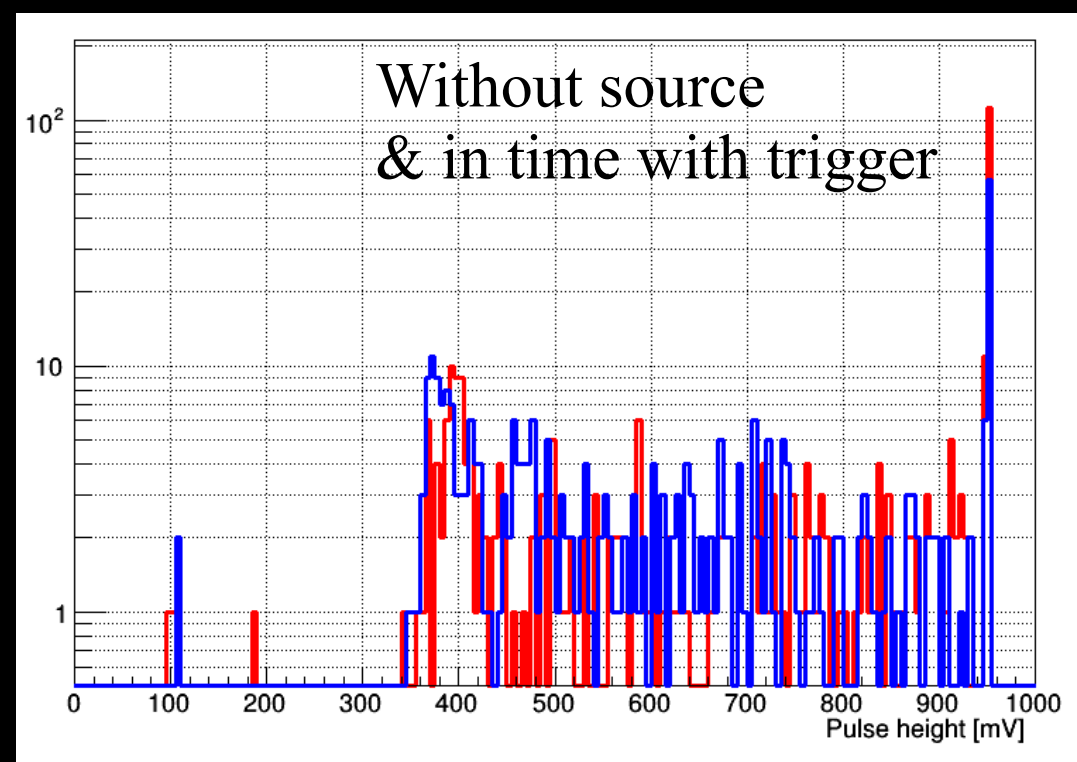
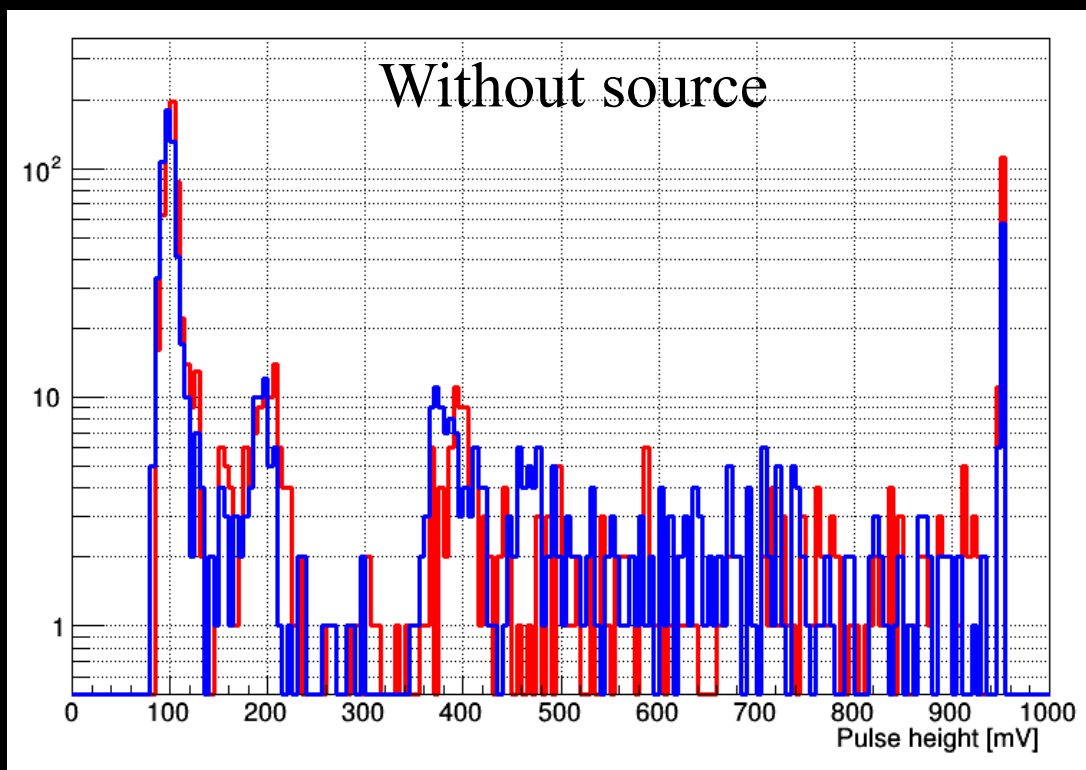
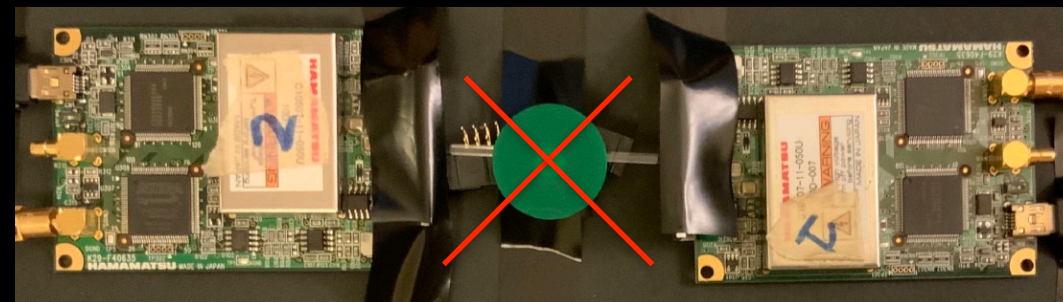
Detecting radiation with light

Collect more of these very large pulses by triggering on CH1 AND CH2....



Detecting radiation with light

When we remove the source, and patiently collect data slowly, we still see some *correlated* large flashes.

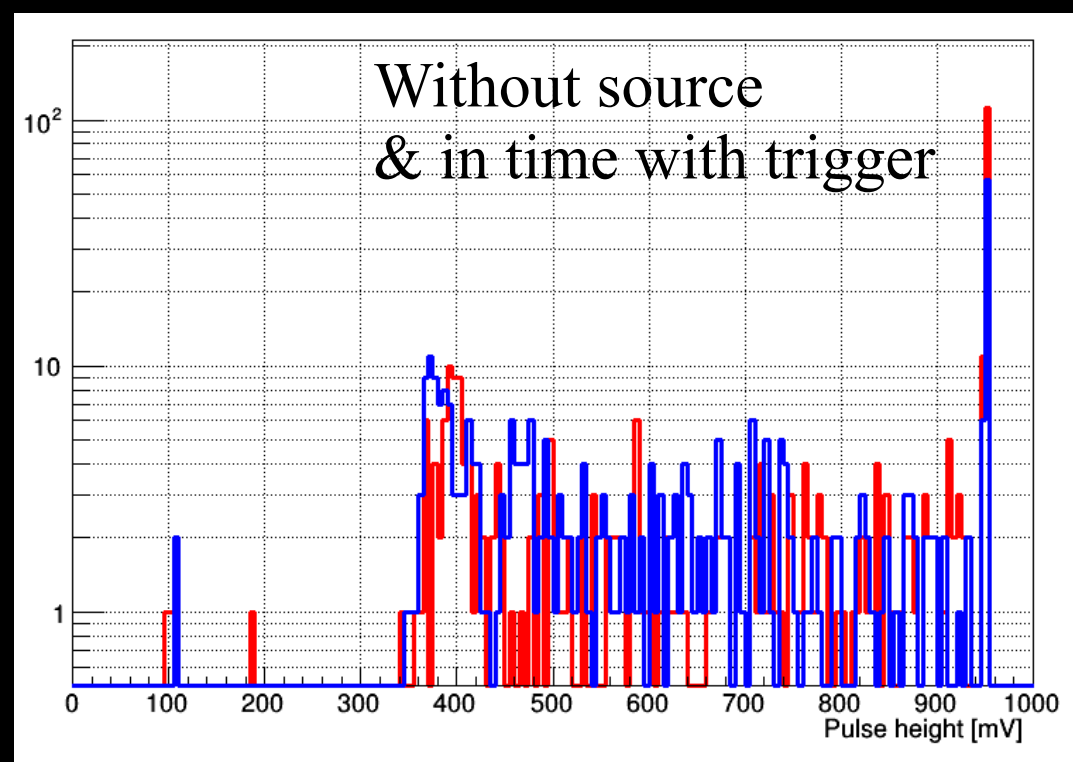
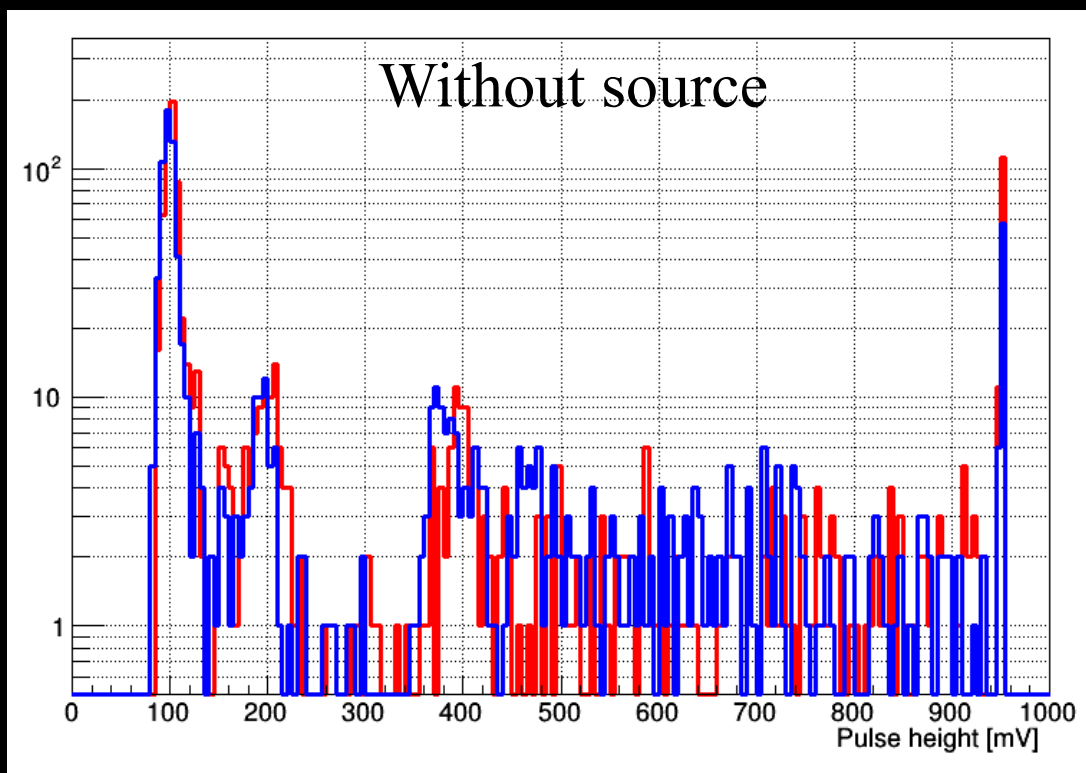
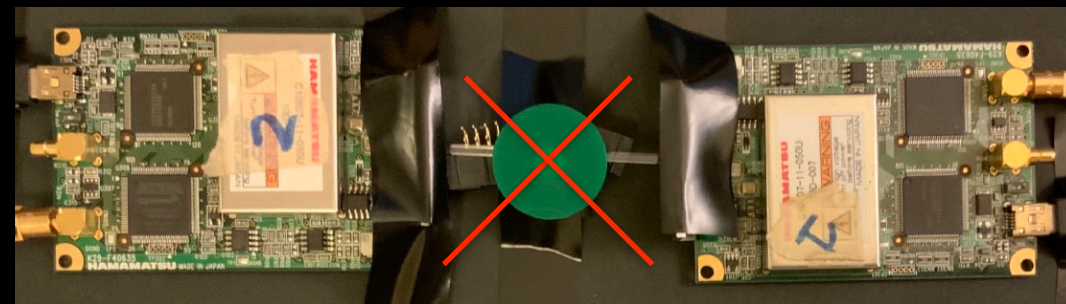


Detecting radiation with light

When we remove the source, and patiently collect data slowly, we still see some *correlated* large flashes.

There is a source of correlated bright flashes even without the source.

⇒ There is some background radiation.



Discovery of cosmic rays

Radioactivity discovered with an electroscope, where charge drained off due to ionizing radiation making the air conduct.

If there are no radioactive sources nearby, the charge still drains.

That was the early version of “the geiger counter still clicks” or “the scintillator still flashes”.

Something else is happening, something much more rare. Some background radiation? From where? How would you figure it out?



Discovery of cosmic rays

Several people measured how the level of background radiation varied as you moved around.

Is it coming from the air?

Is it coming from the ground?



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Measure under water:

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Measure under ground:

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Measure under water:

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Is it coming from the ground?

Measure up in the air



Measure rate of background radiation away from the ground

Is it coming from the ground?

Theodor Wulf measured a decrease at the top of the Eiffel tower, by about half.

If the source is in the ground, how can it reach 300 m up?



Measure rate of background radiation as a function of altitude

Is it coming from the ground?

Victor Hess went higher in a hydrogen balloon.

Initially he saw no change between ground and 1100 m.



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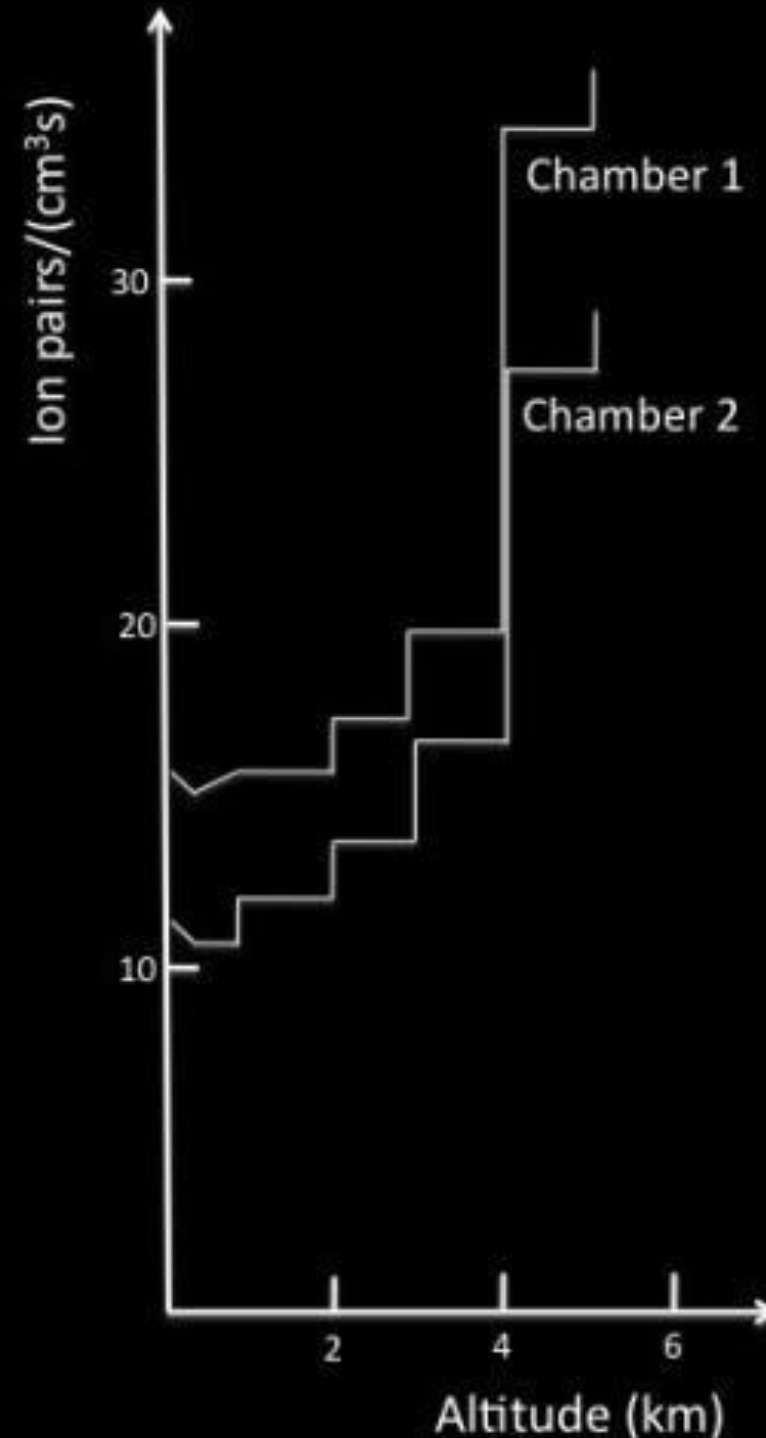
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Measure vs altitude and see strong growth.



Measure rate of background radiation as a function of altitude

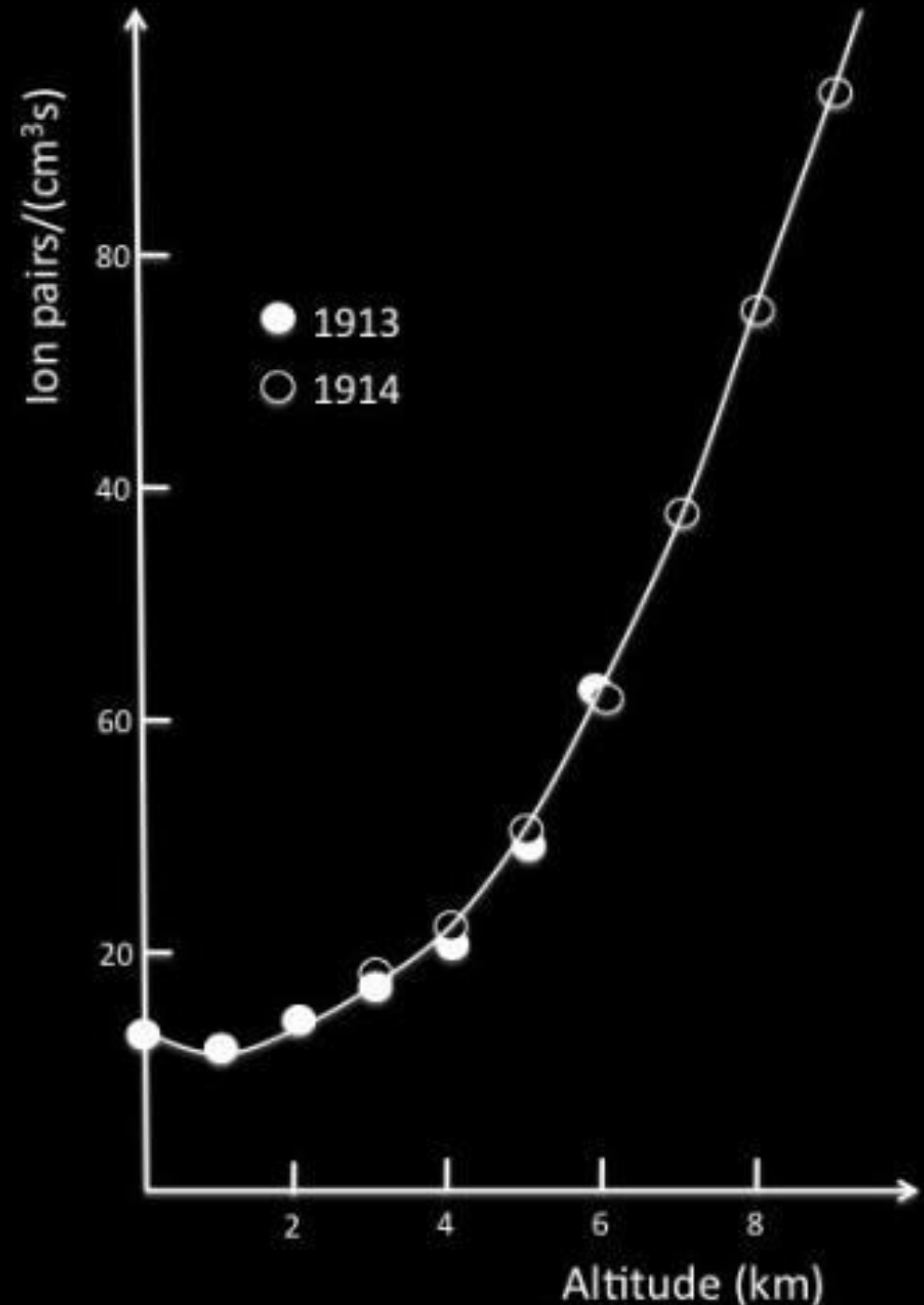
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Kolhörster got up to 9.3 km on June 28, 1914, then WWI.



Seem to be coming from above. Source? Cause for altitude dependence?

The sun?

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The sun?

Victor Hess made a measurement during a solar eclipse and found no difference when the sun was blocked by the moon.

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The sun? There is **low energy** radiation from the sun → aurora.



Seem to be coming from above. Source? Cause for altitude dependence?

Increase with altitude due to absorption?

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Increase with altitude due to absorption in air above us?

Millikan measured rate vs depth in water in lakes at different altitudes. Found rate at depth D in upper lake matched rate at depth $D - 2\text{m}$ in a lake that is 2 km lower elevation.

So:



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Absorption in air causes decrease toward the ground.

Coming from above.

Called them “Cosmic rays”

Very penetrating.

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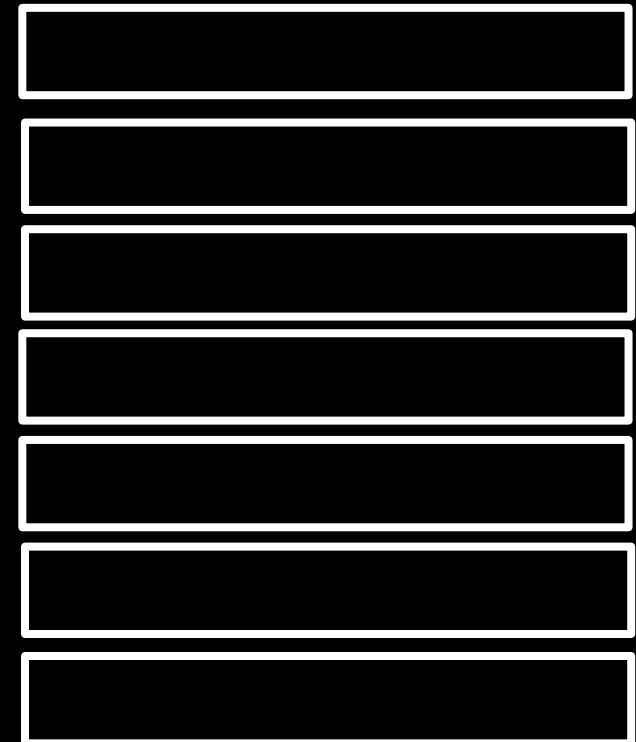
Could measure this absorption, per event, with a stack of detectors.

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The cosmic ray detector that you will use does this with two bars



Absorber



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But, with some modifications...

The cosmic ray detector that you will use does this with two bars



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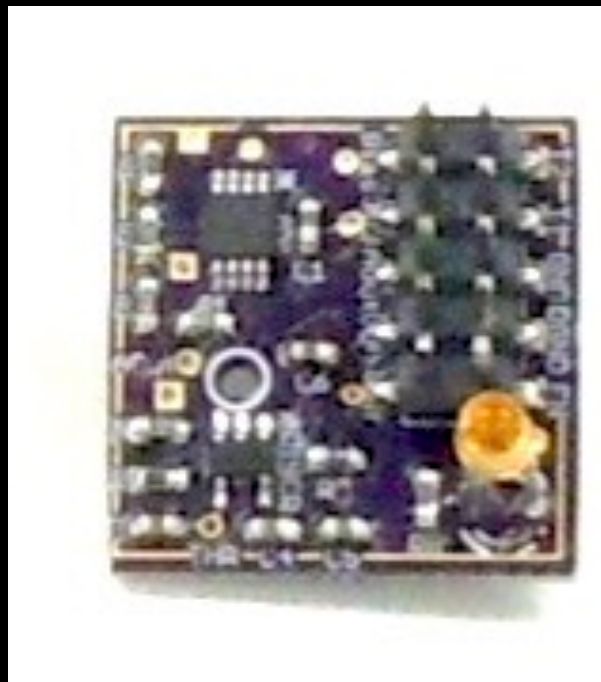
But, with some modifications:

- Only sense the light on one end (for cost)

- Use larger bars (for more sensitivity)

- Use cheaper SiPMs and electronics (for cost and ease).

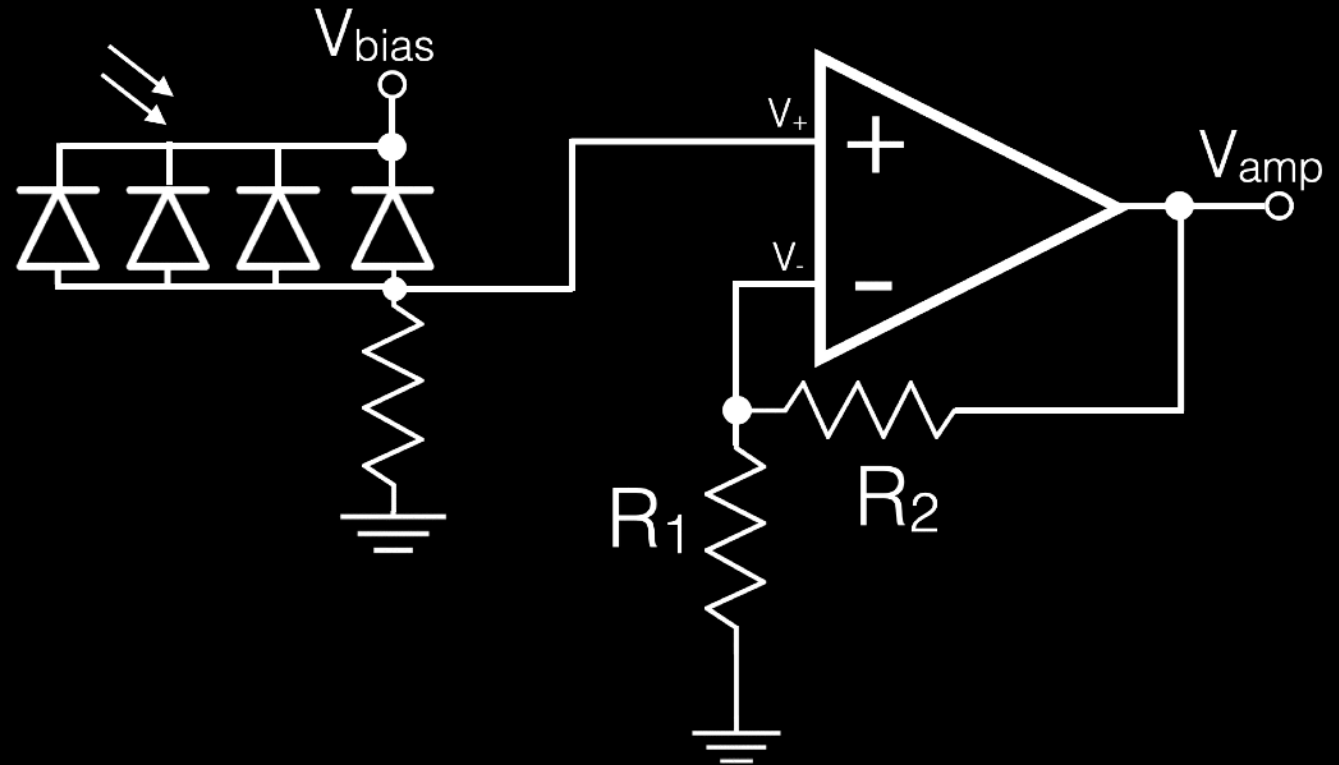
The cosmic ray detector that you will use does this with two bars



Electronics for the detector

SiPM gives current through a resistor so a voltage pulse.

We need to amplify it.



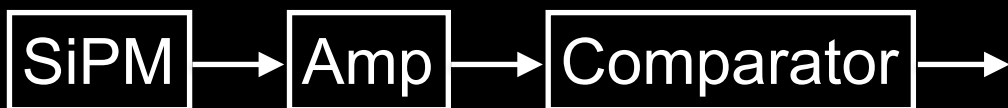
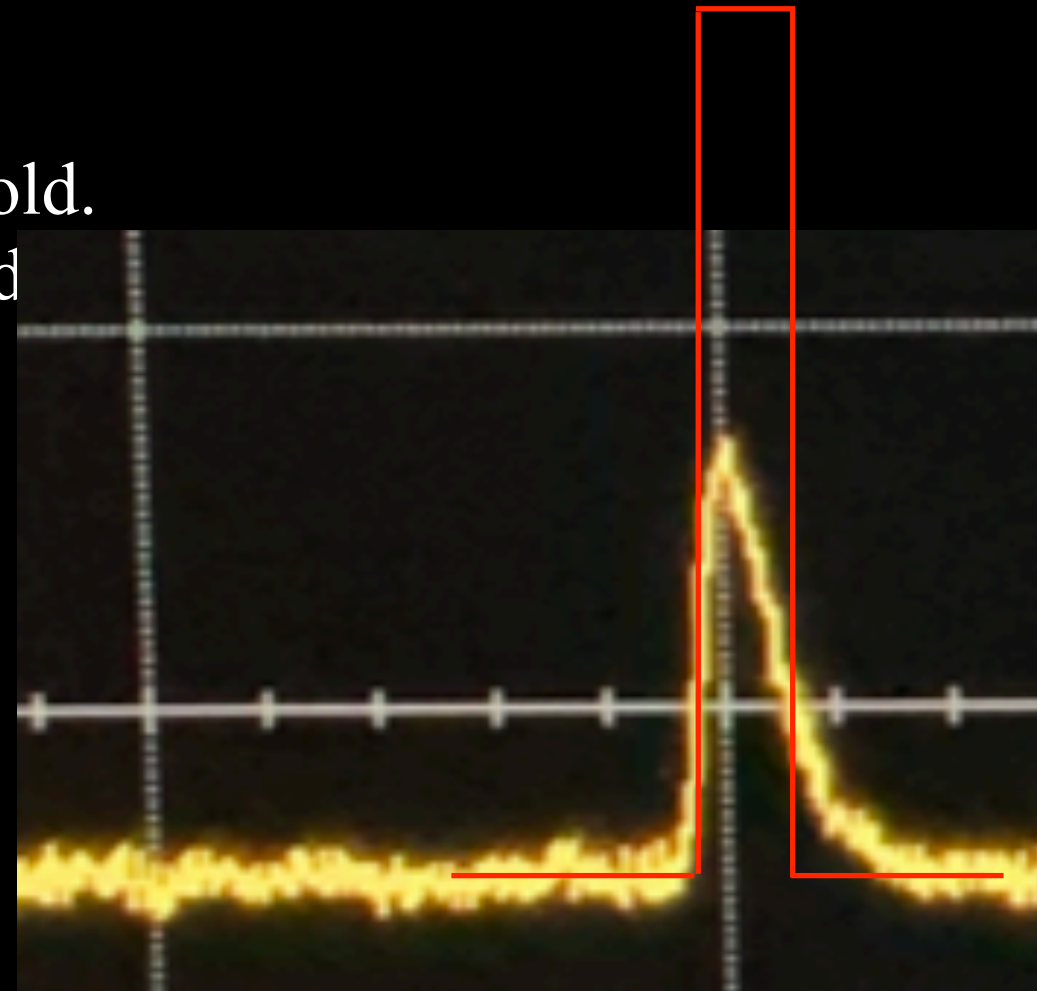
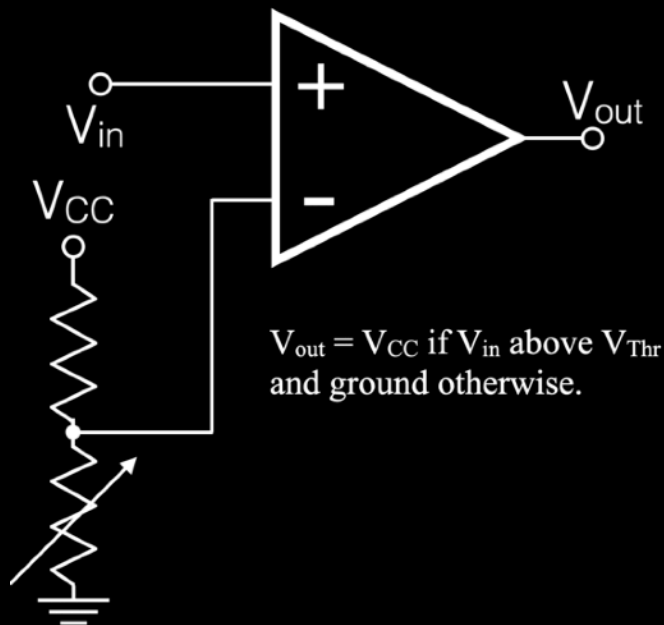
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Then compare it to a minimum threshold.

Record the times it goes over threshold



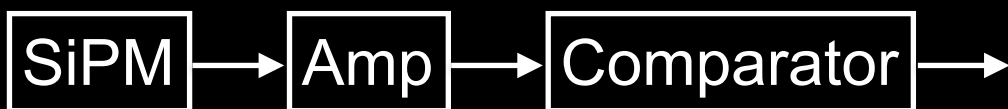
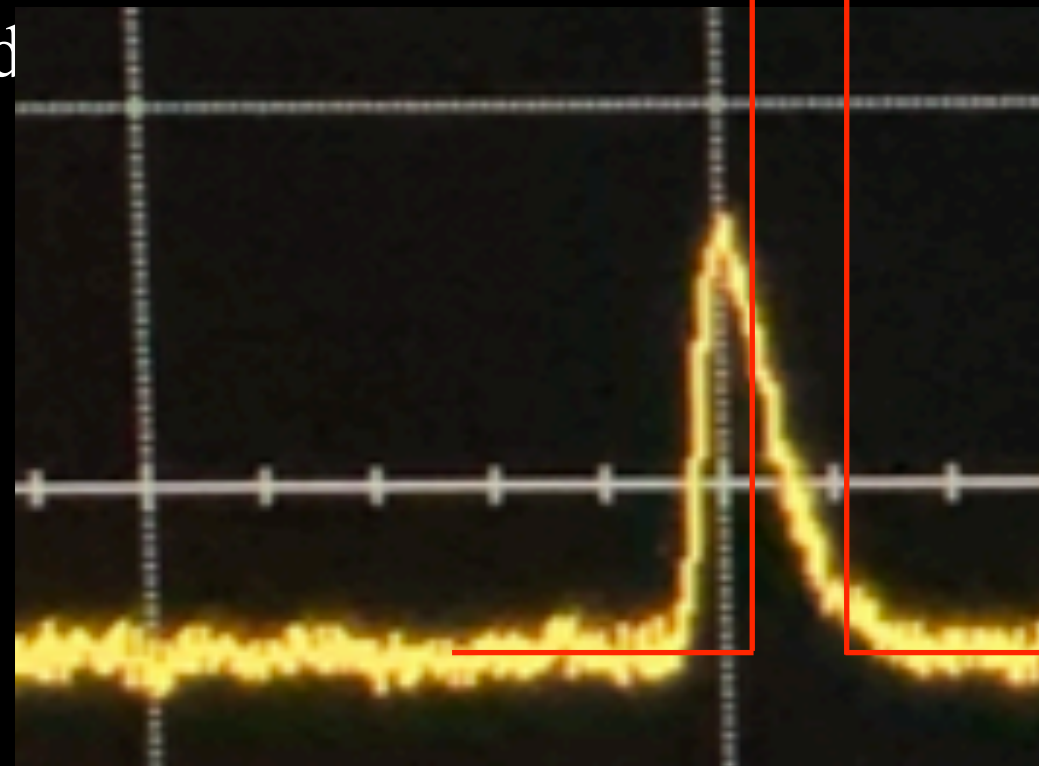
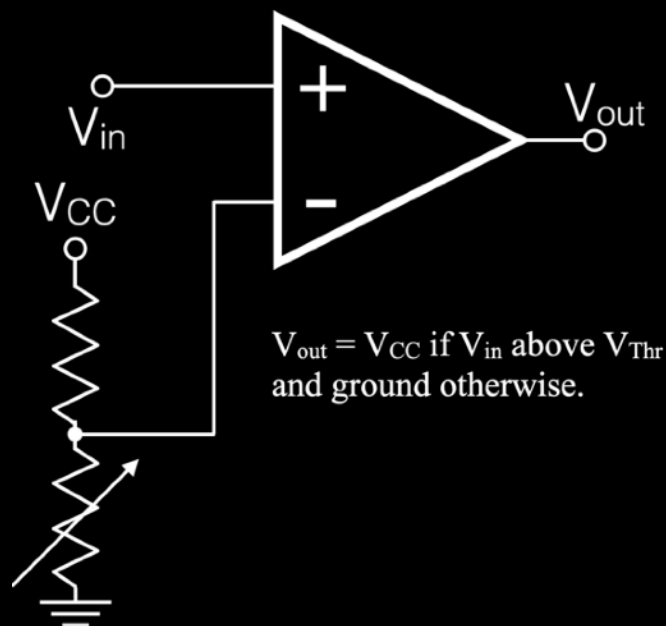
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There may be a propagation delay in the comparator, but it is just a common shift.

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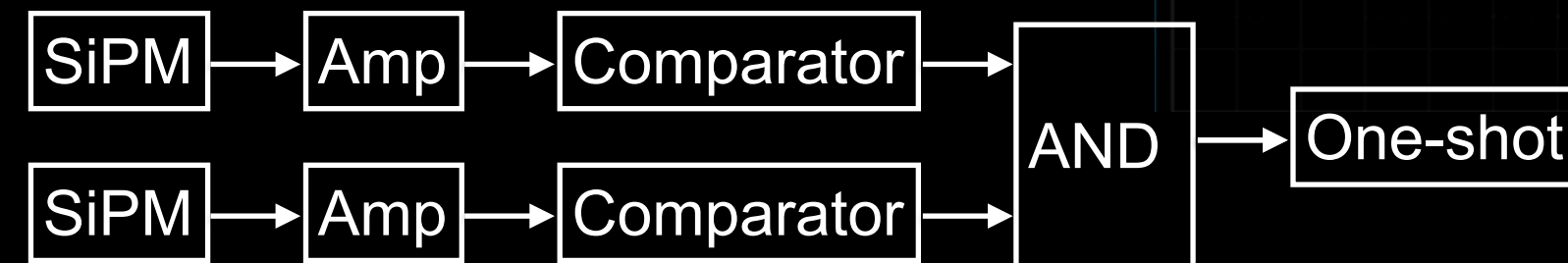
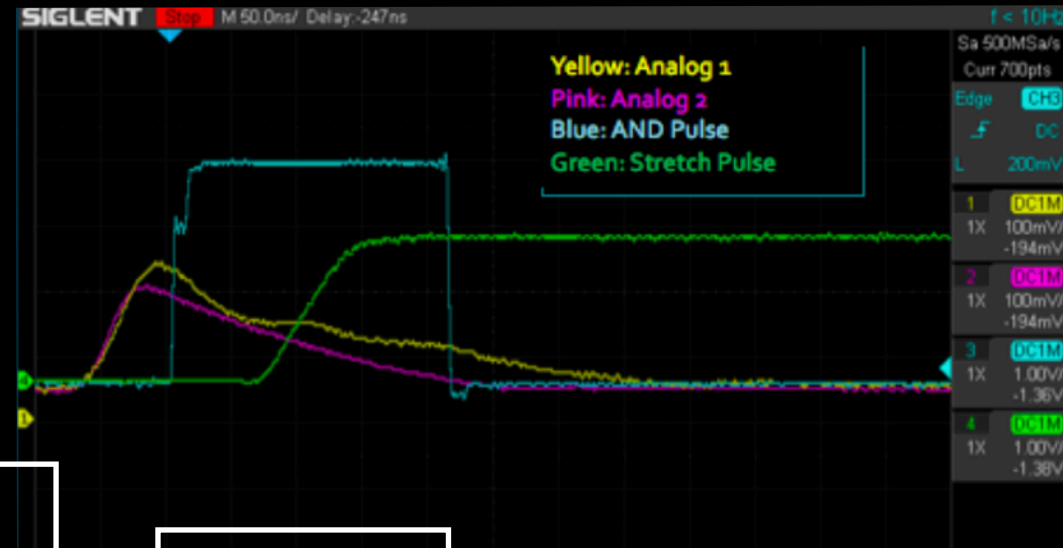
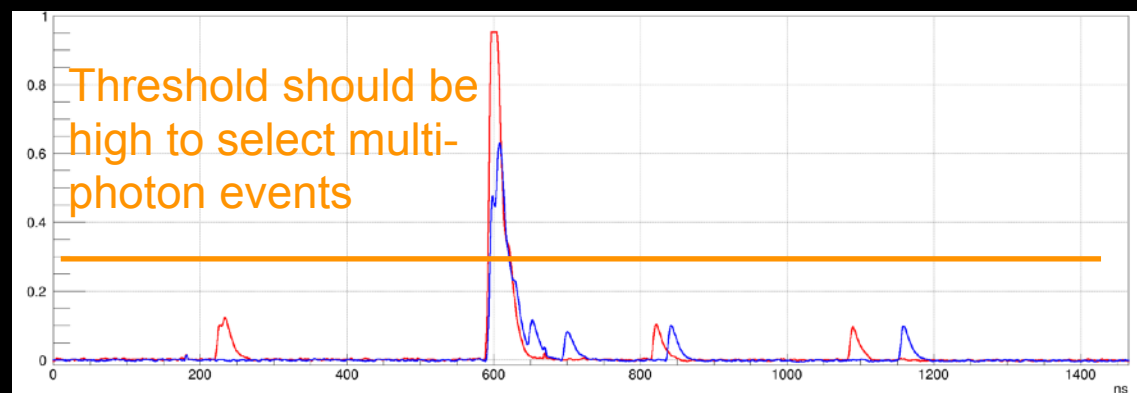
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Require coincidence of two SiPM signals

One-shot to give a longer digital pulse.



Electronics for the detector

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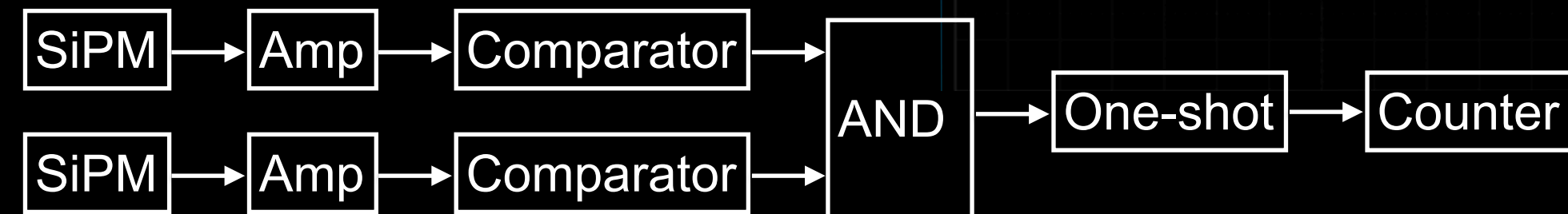
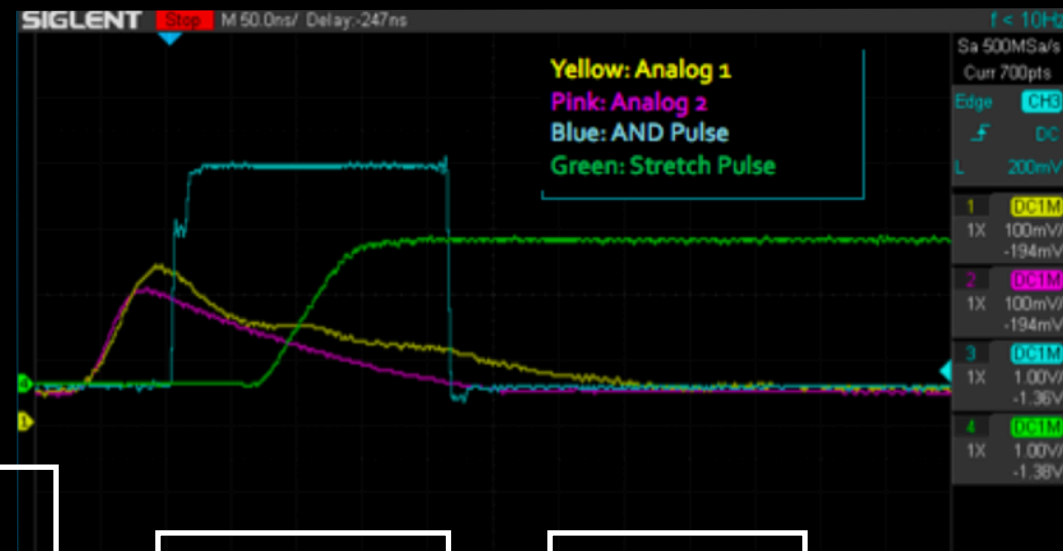
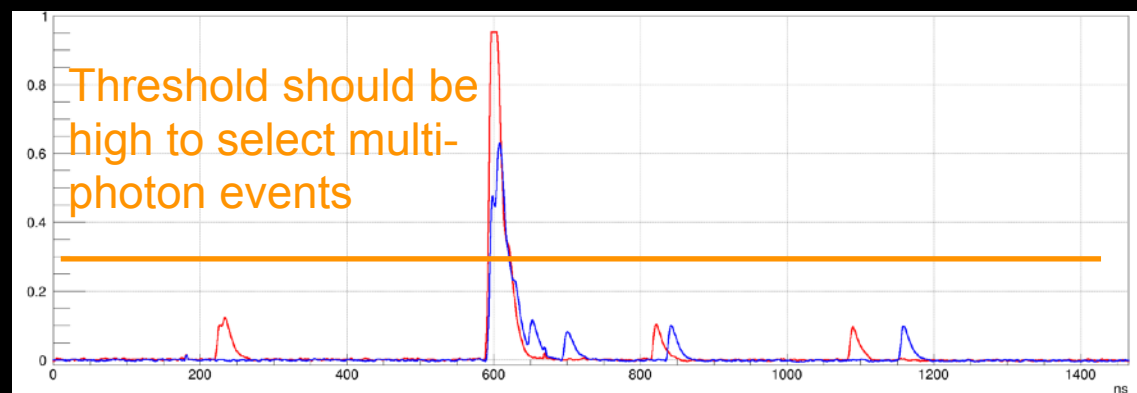
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Count coincident events somehow.



Electronics for the detector

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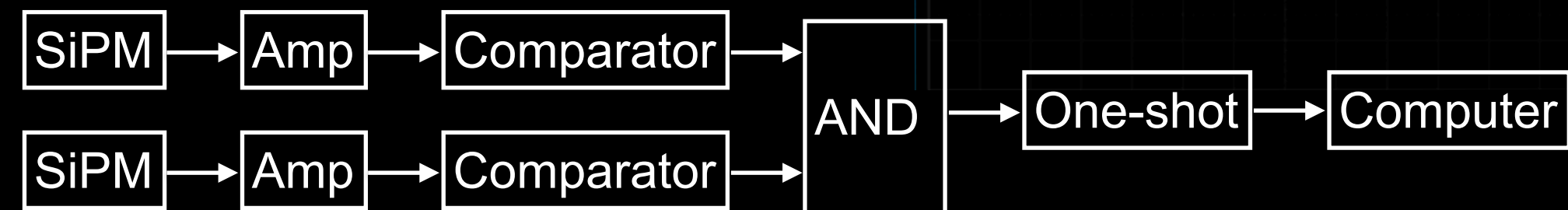
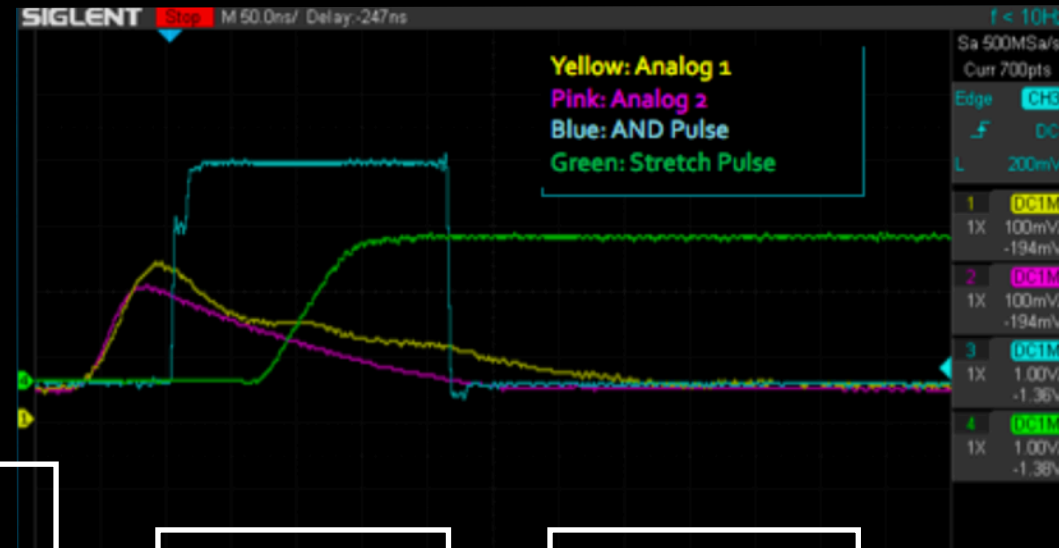
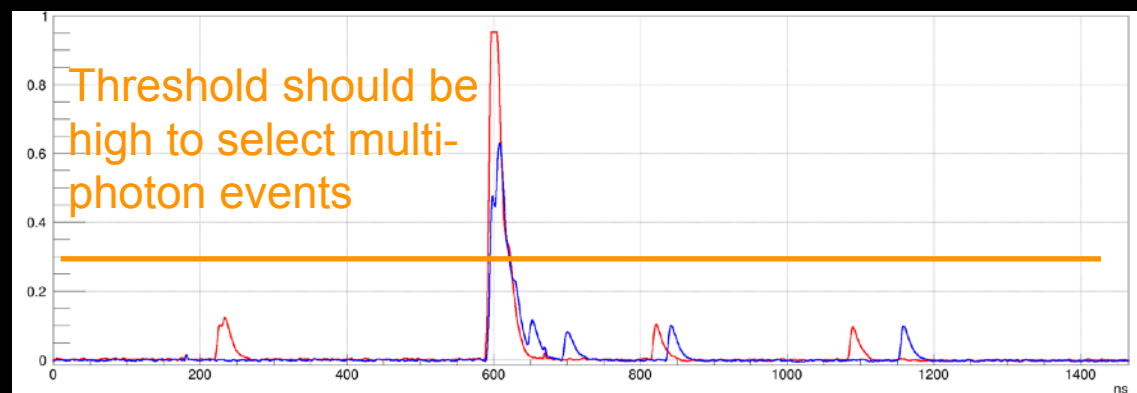
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Record the time of the pulse with a computer.



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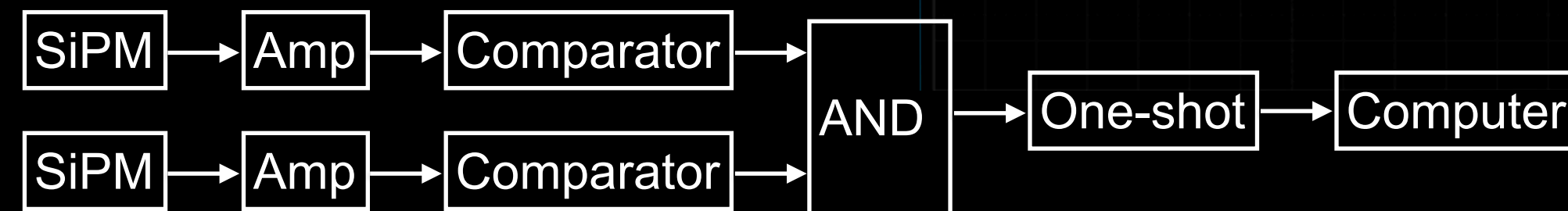
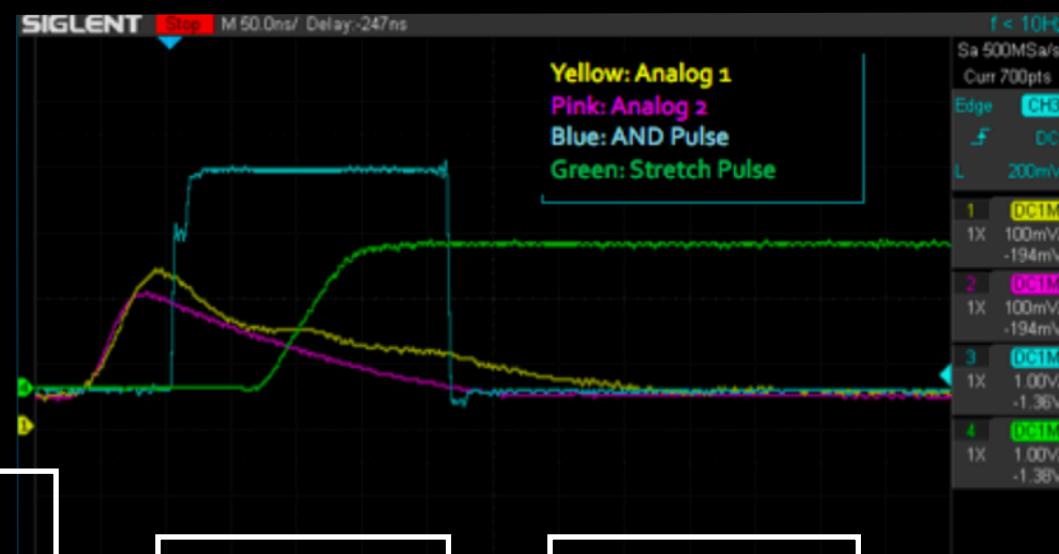
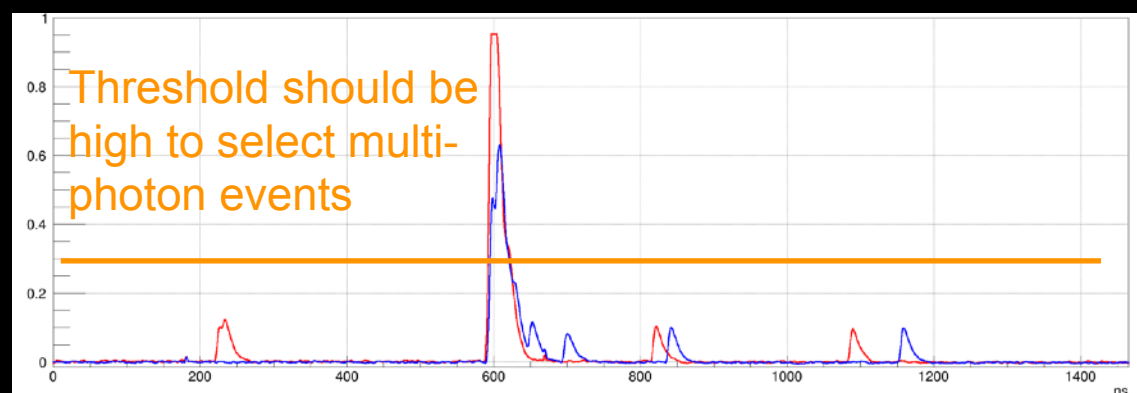
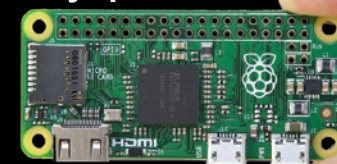
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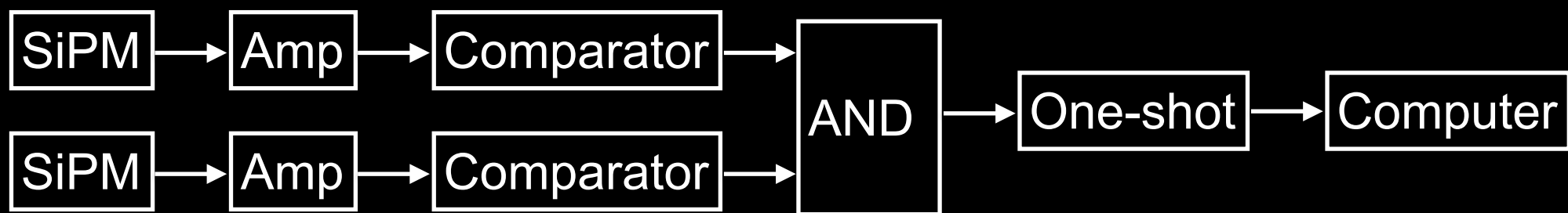
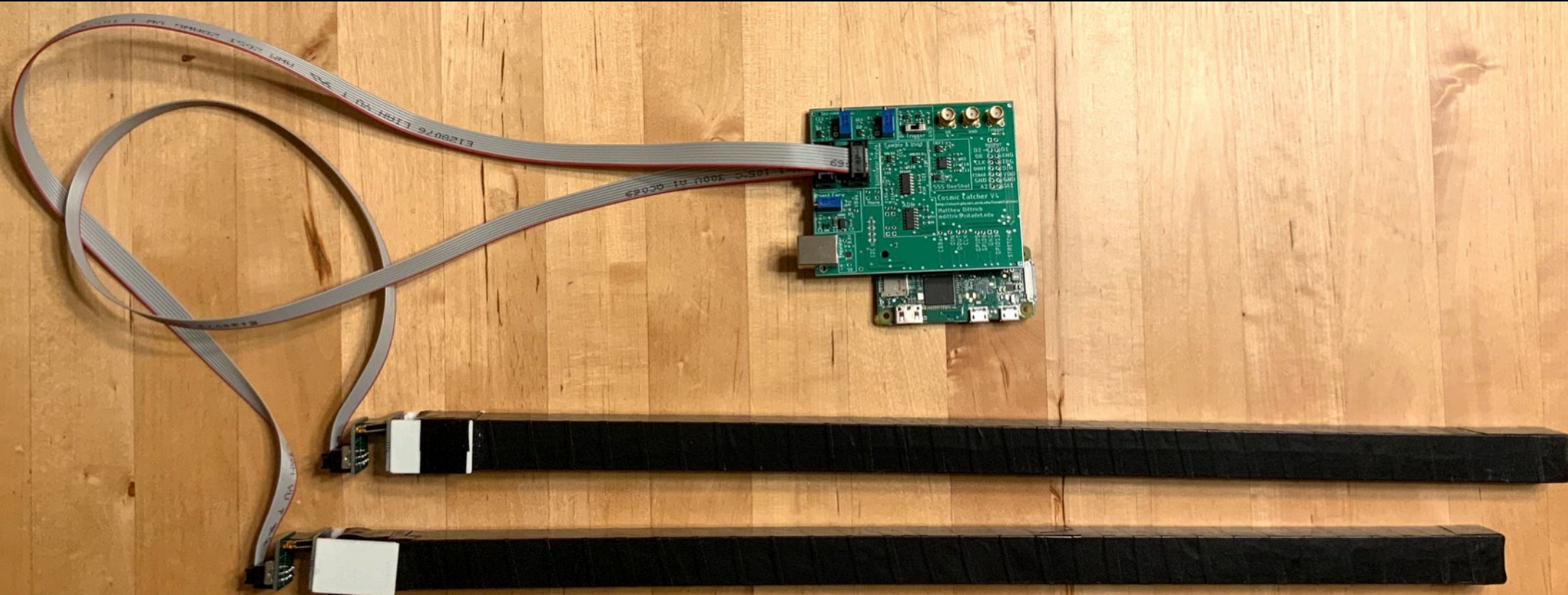
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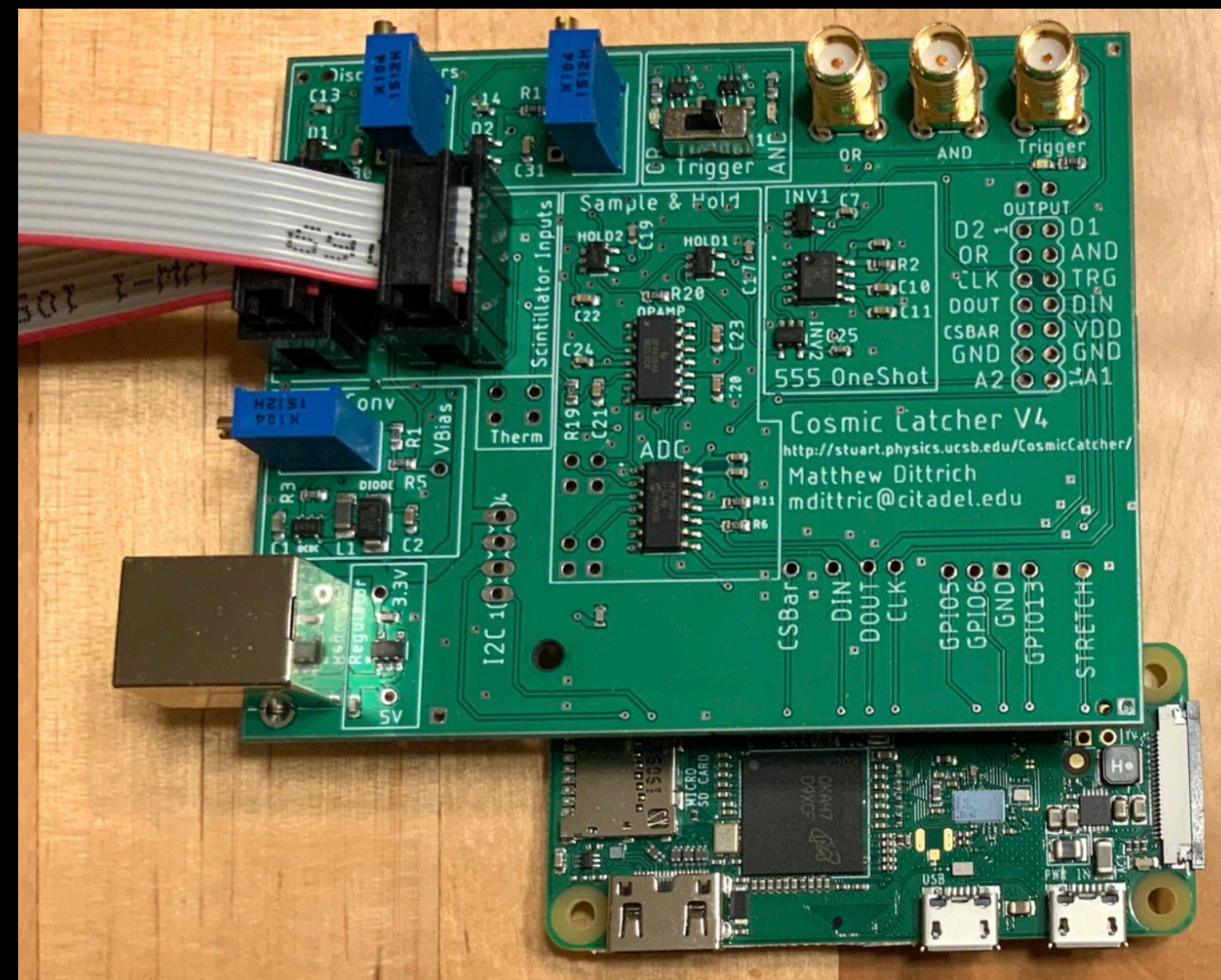
We'll use a raspberry pi



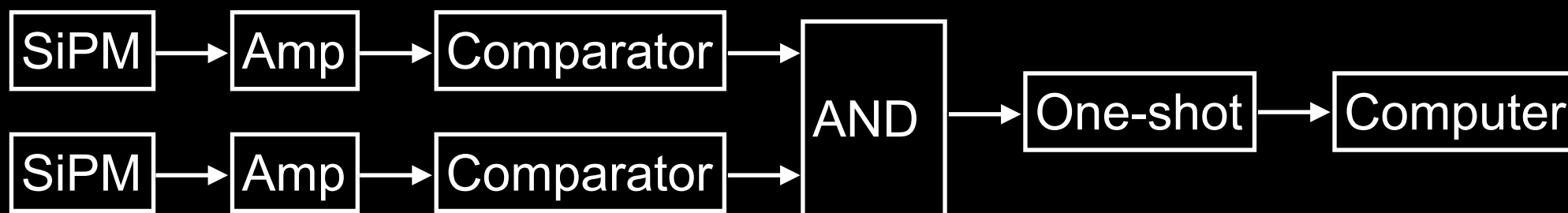
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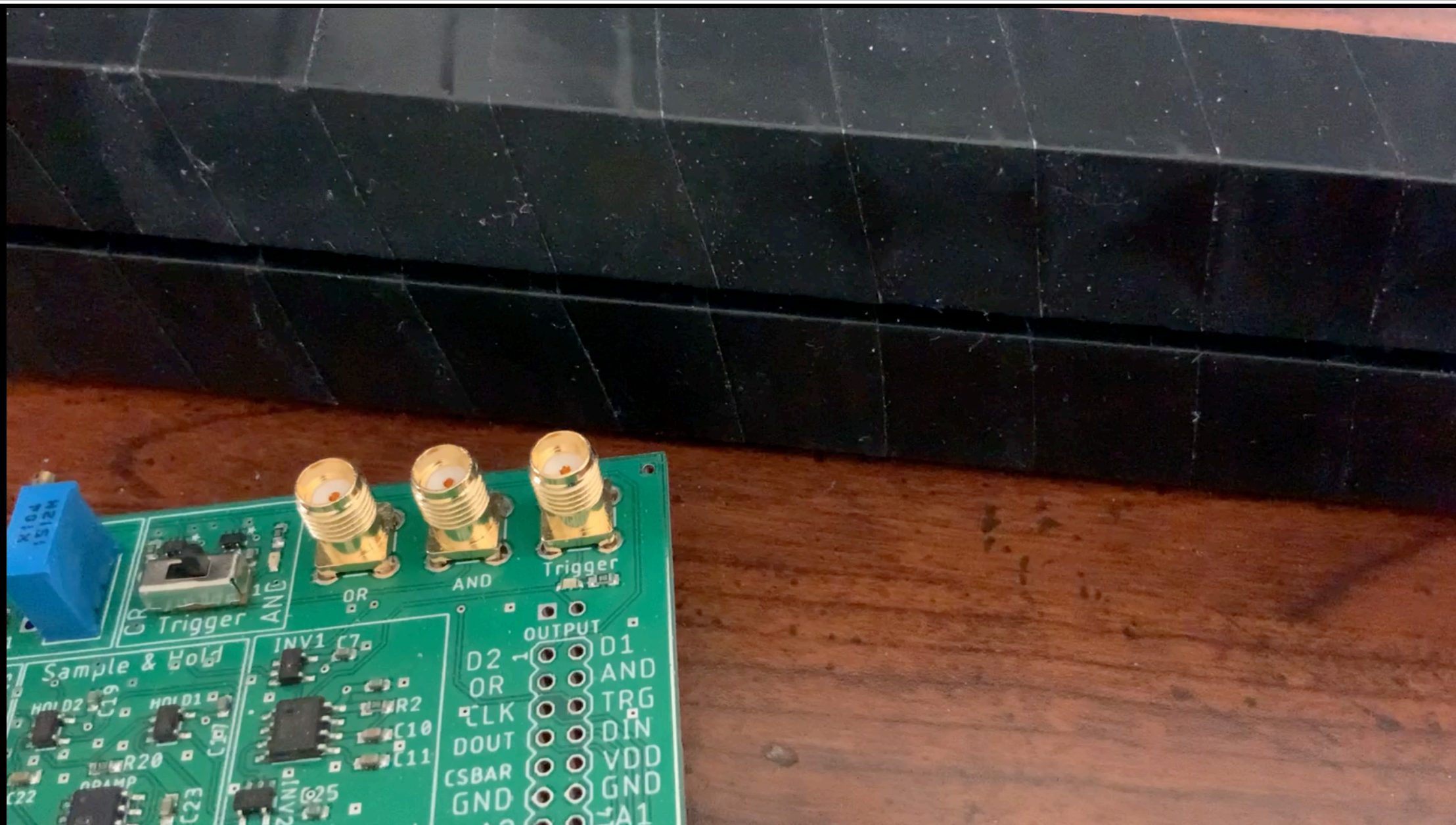
Electronics for the detector



Power input
Boost converter & pot
Cables to bars
Discriminators & pots
OR & AND
SMAs for scope spy
OneShot
LEDs
RPi monitors STRETCH
S&H, Amp, ADC
Expansion connector



Detect coincidence



Detect coincidence

