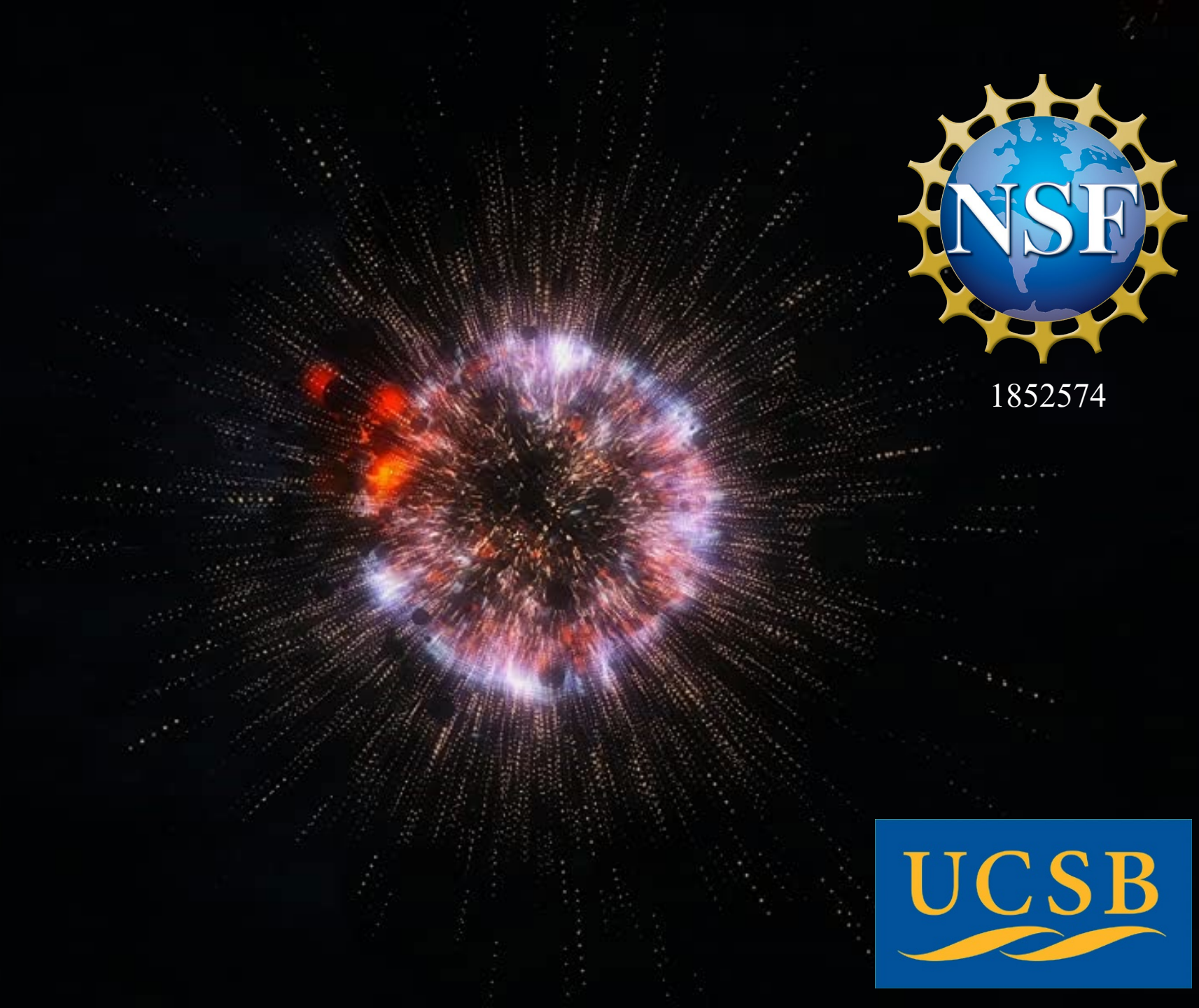
Catching Cosmic Rays



Matthew Dittrich

1852574

What is a Cosmic Ray?

- First discovered in 1912 by Victor Hess
- Found relation between charge in atmosphere and altitude
- Awarded Nobel prize in 1936 for discovery of cosmic rays.

Cosmic Rays

- Primary Rays
  - 89% protons
  - 10% helium nuclei
  - 1% heavy nuclei
- Secondary Rays
  - Wide variety of particles but most are short lived

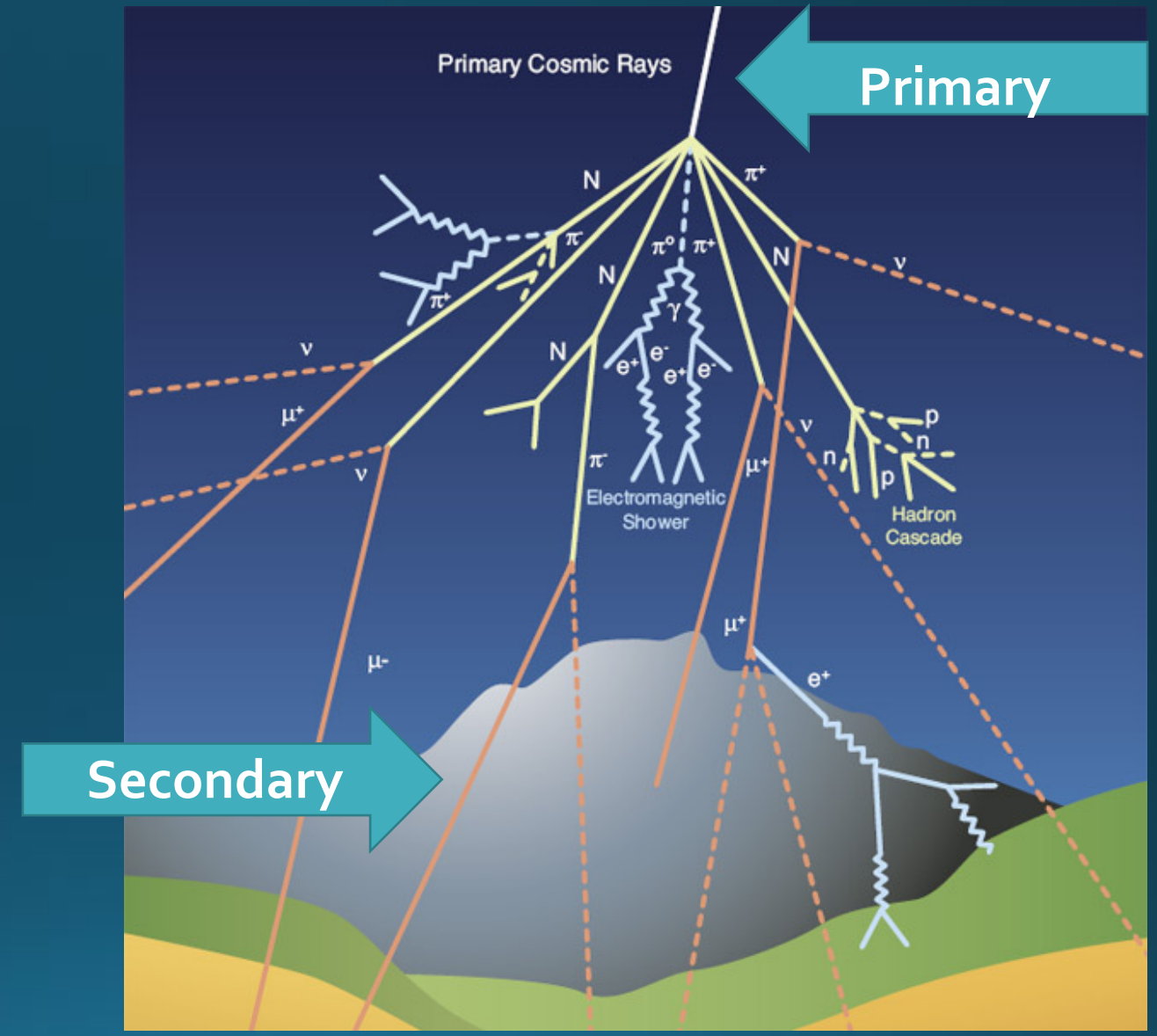


Photo: home.cern/science/physics/cosmic-rays-particles-outer-space

Secondary Cosmic Ray Decay

Pion

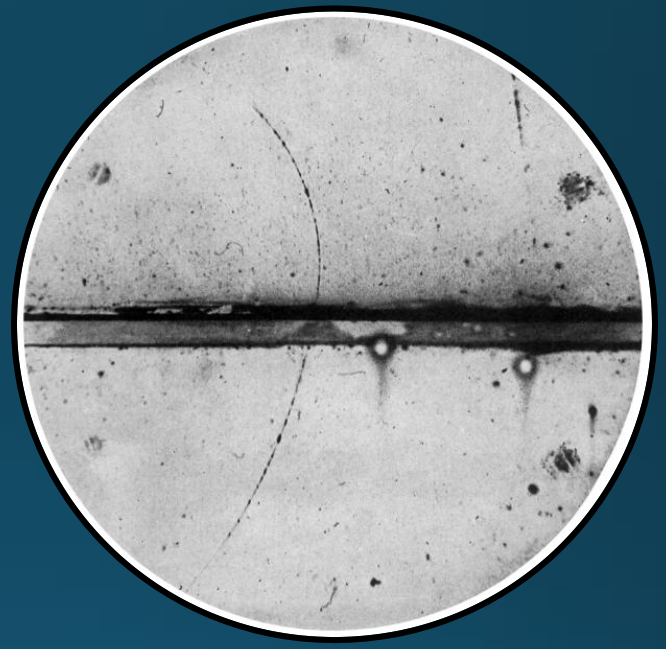
- **Lifetime:** 26.033 ns
- **Typical decay:** muon and nuetrino
- $\pi^- \longrightarrow \mu^- + \nu_\mu$
- **<u>Lifetime μ^-: 2,196.98 ns</u>**

Kaon

- **Lifetime:** 12.38 ns
- **Typical decays:** pions and nuetrinos
- $K^+ \rightarrow \pi^+ + \nu_\mu$
- $K^+ \rightarrow \pi^+ + \pi^+ + \pi^-$

Historical Significance

- From the 1930s-1950s, cosmic rays served as the biggest source for particle experiments
- Particles were studied using cloud chambers
- Led to the discovery of particles such as muon and positron



First positron identified by Carl D Anderson in 1932. Photo: home.cern/news

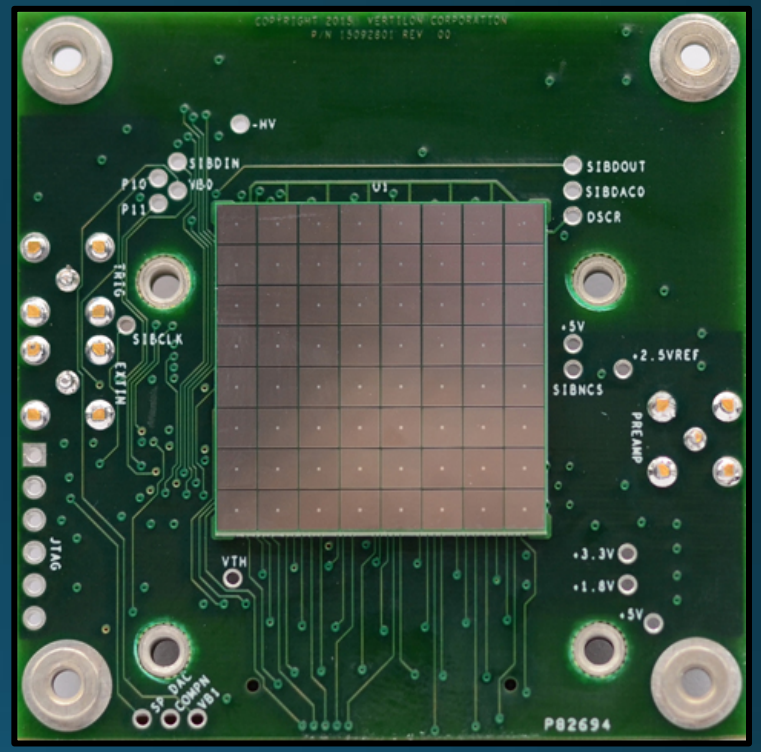
Modern Detectors

- Historically, advancement in technology has driven the discoveries in particle physics
- One such advancement: Silicon photomultiplier (SiPM)

CMS detector at CERN.
Photo: home.cern/detectors

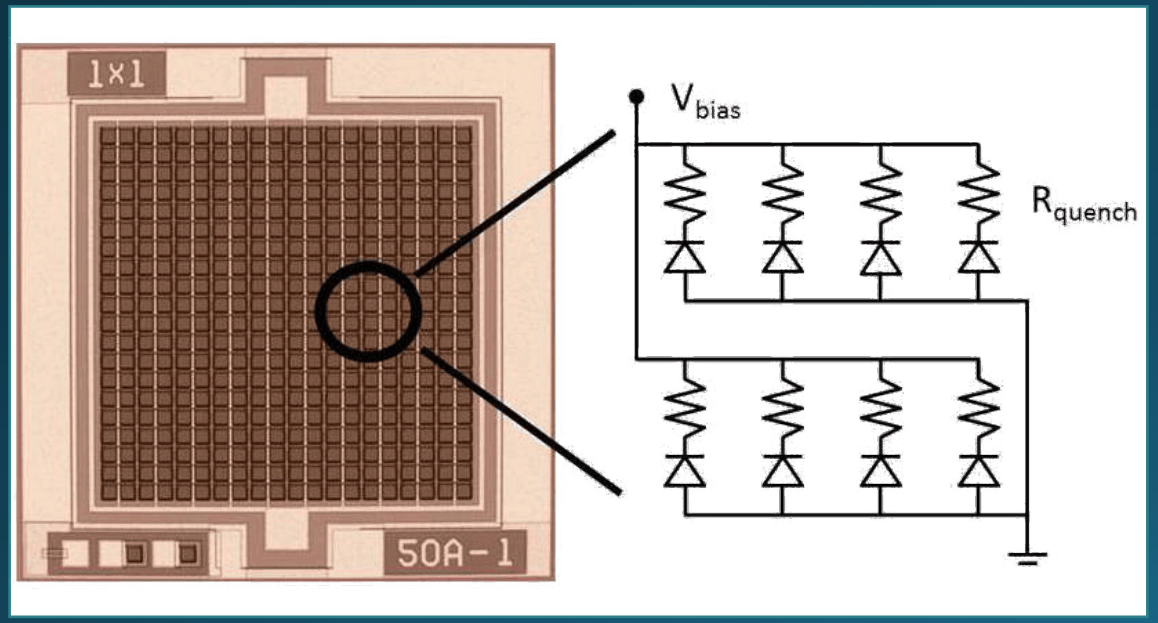
What is a SiPM?

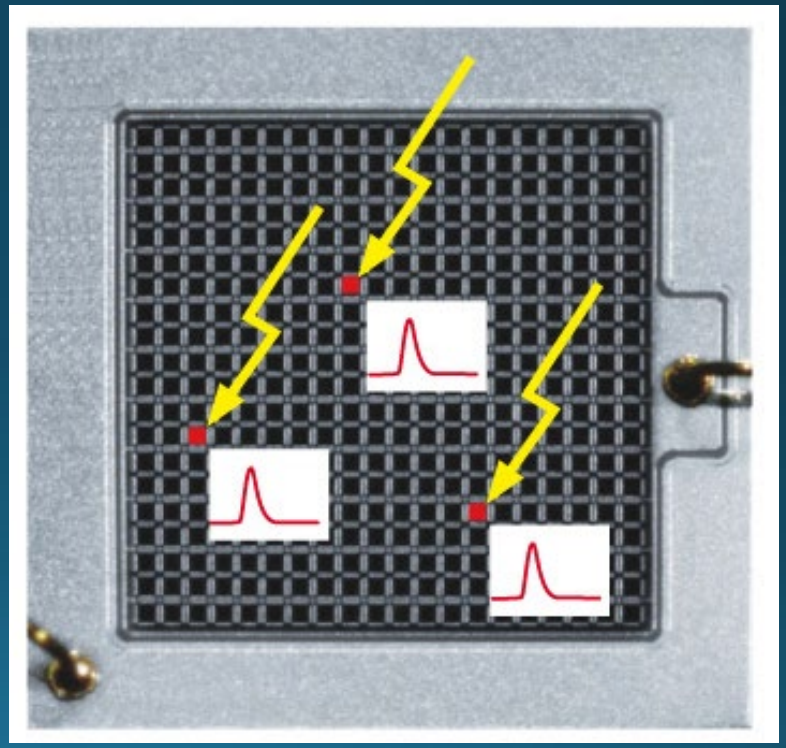
- Silicon Photomultipliers can detect single photons
- Photodiode running at reverse voltage breakdown
  - Single photon will break it down causing a current pulse



Silicon photomultiplier
Photo: http://vertilon.com/products_sensor2/

What is a SiPM?





Making a Basic Detector

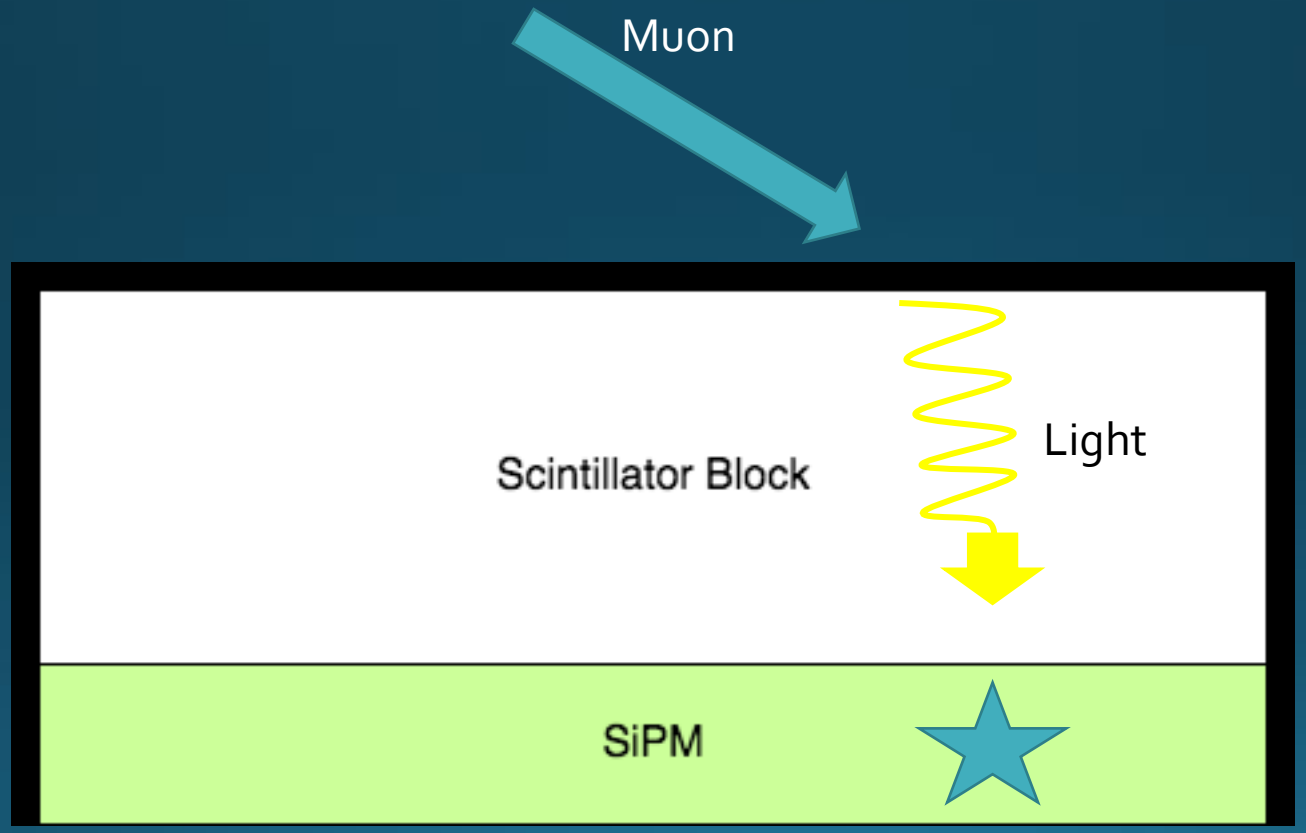
Scintillator Block

- Absorbs ionizing radiation and emits light.

Silicon Photomultiplier (SiPM)

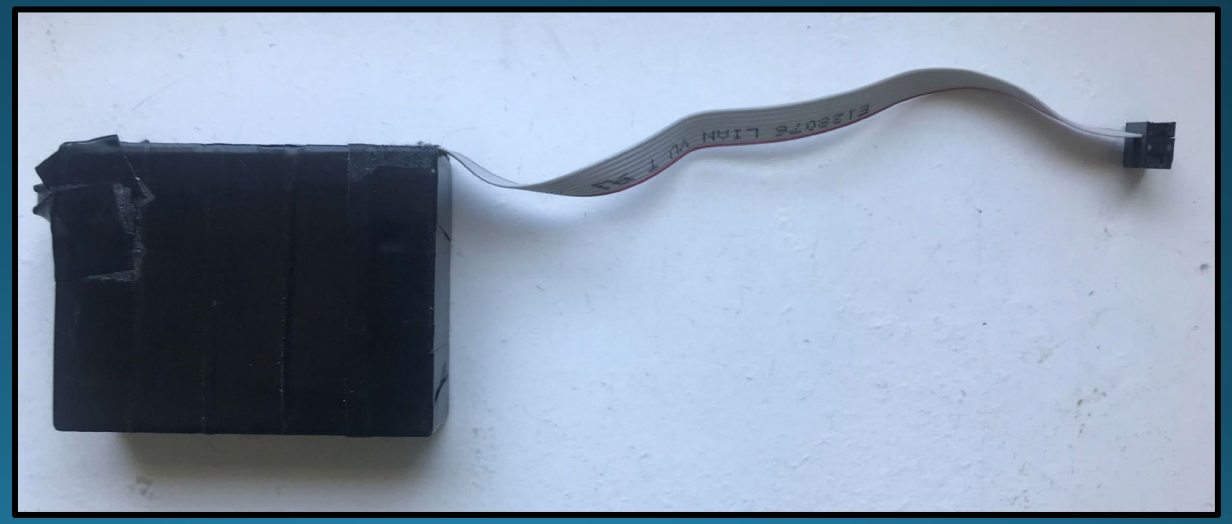
- Can detect single photons.

Silicon Photomultiplier



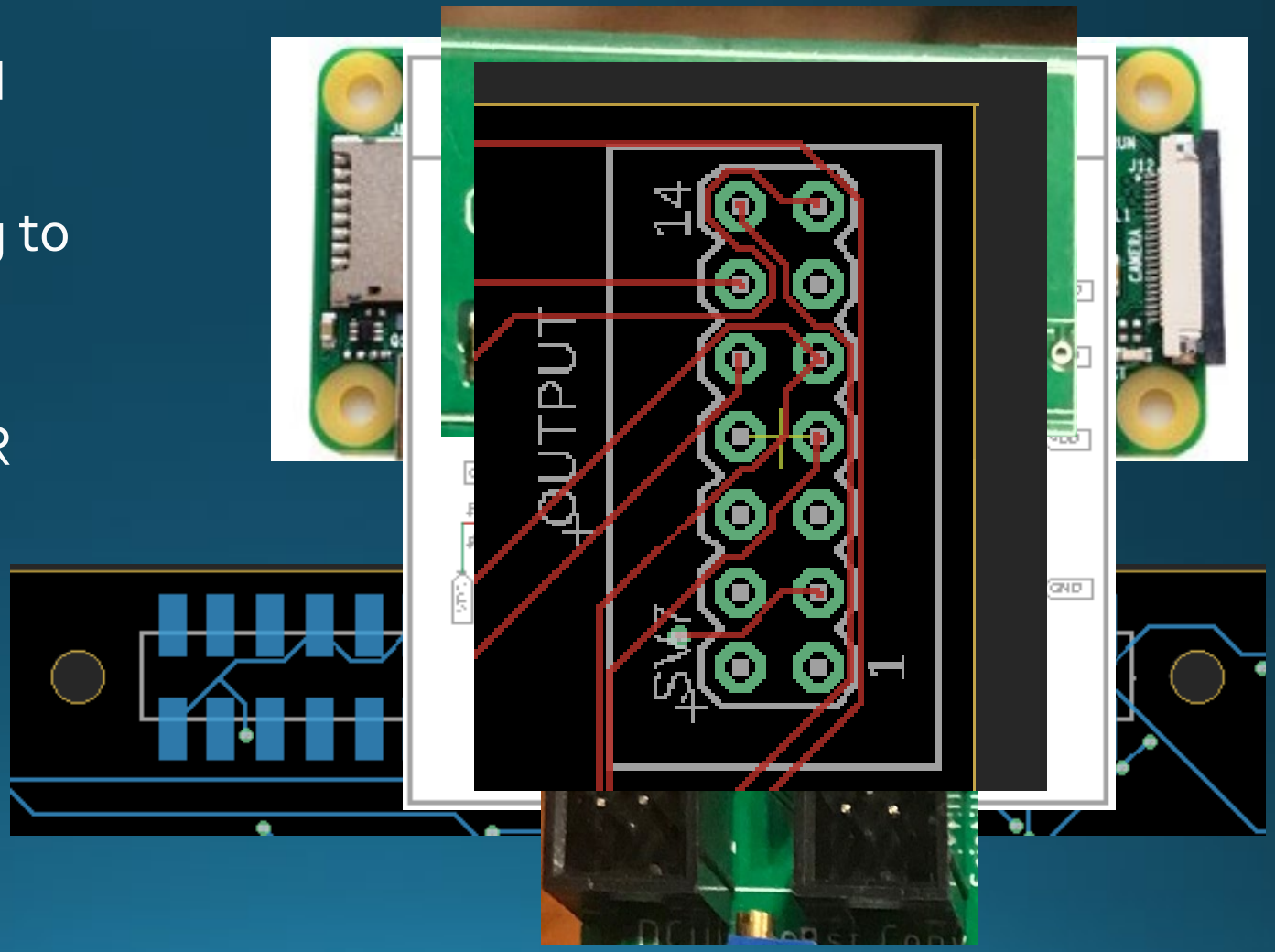
Innovation in Classroom

- SiPMs have allowed particle detectors to make their way into the classroom.
- The scintillator block and SiPM is housed and secured in a 3D printed holder that is then wrapped in electrical tape.
- To use these "pucks", a readout board will still be required.

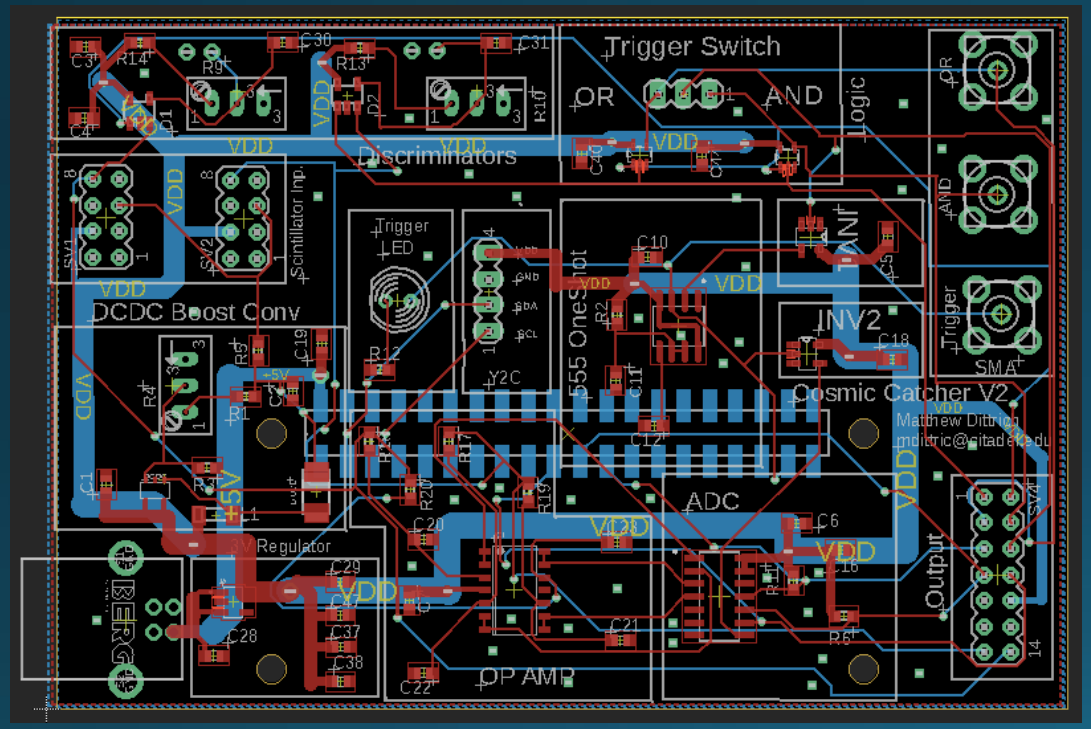


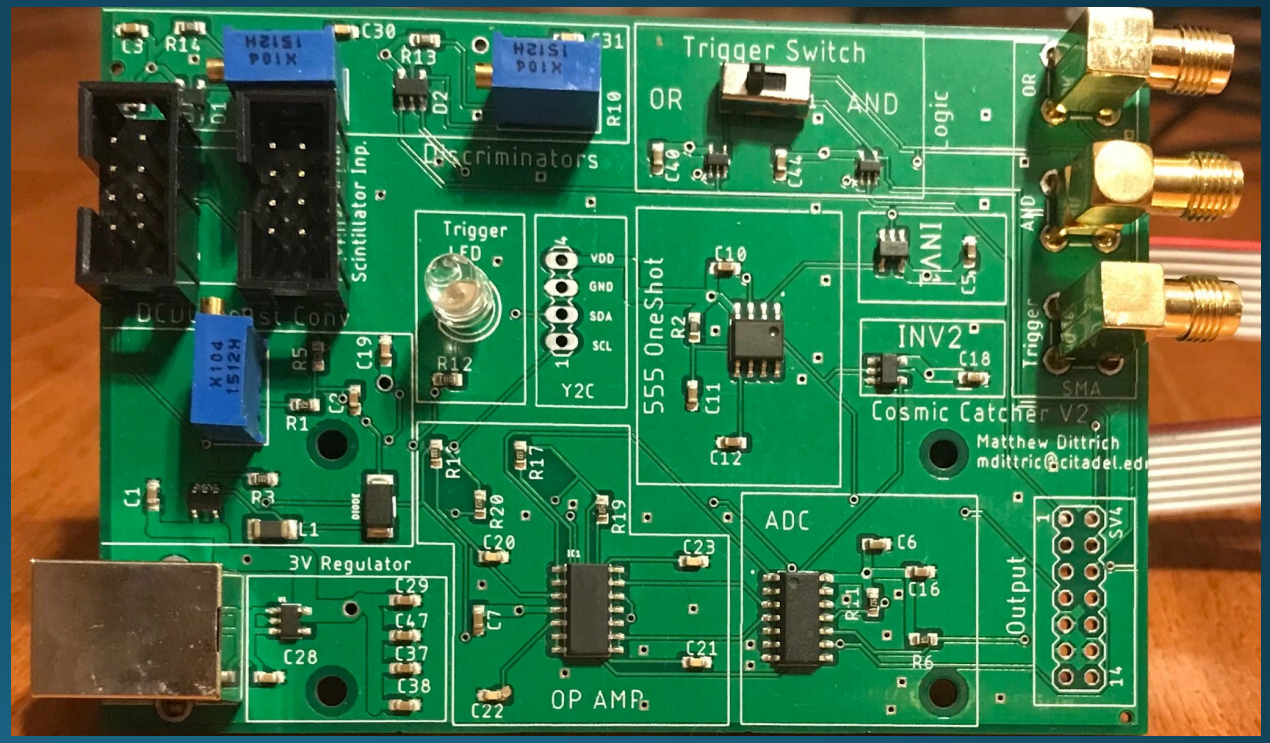
Amplifier and Readout: Goals

- Connection to a Raspberry PI
- Implementation of an analog to digital converter
- Switch between AND and OR pulse
- Output pins for future development



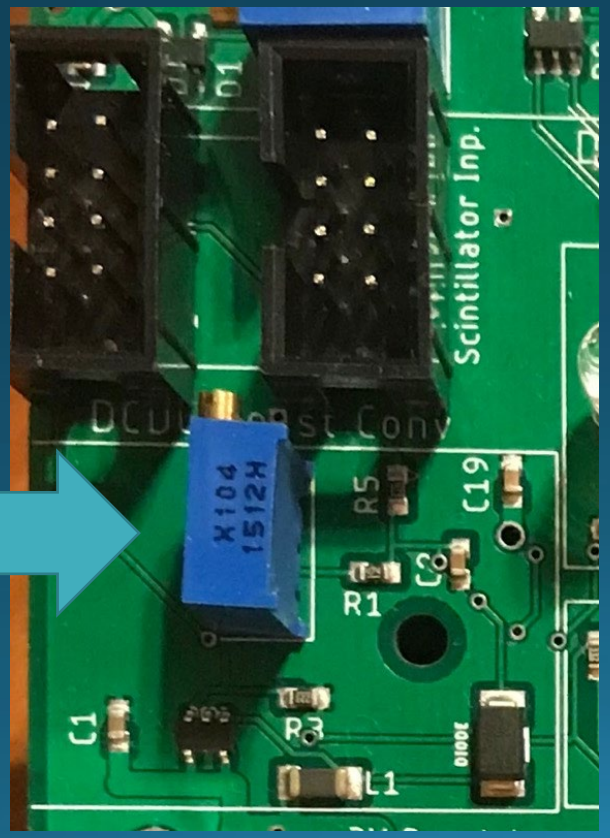
Finished Product





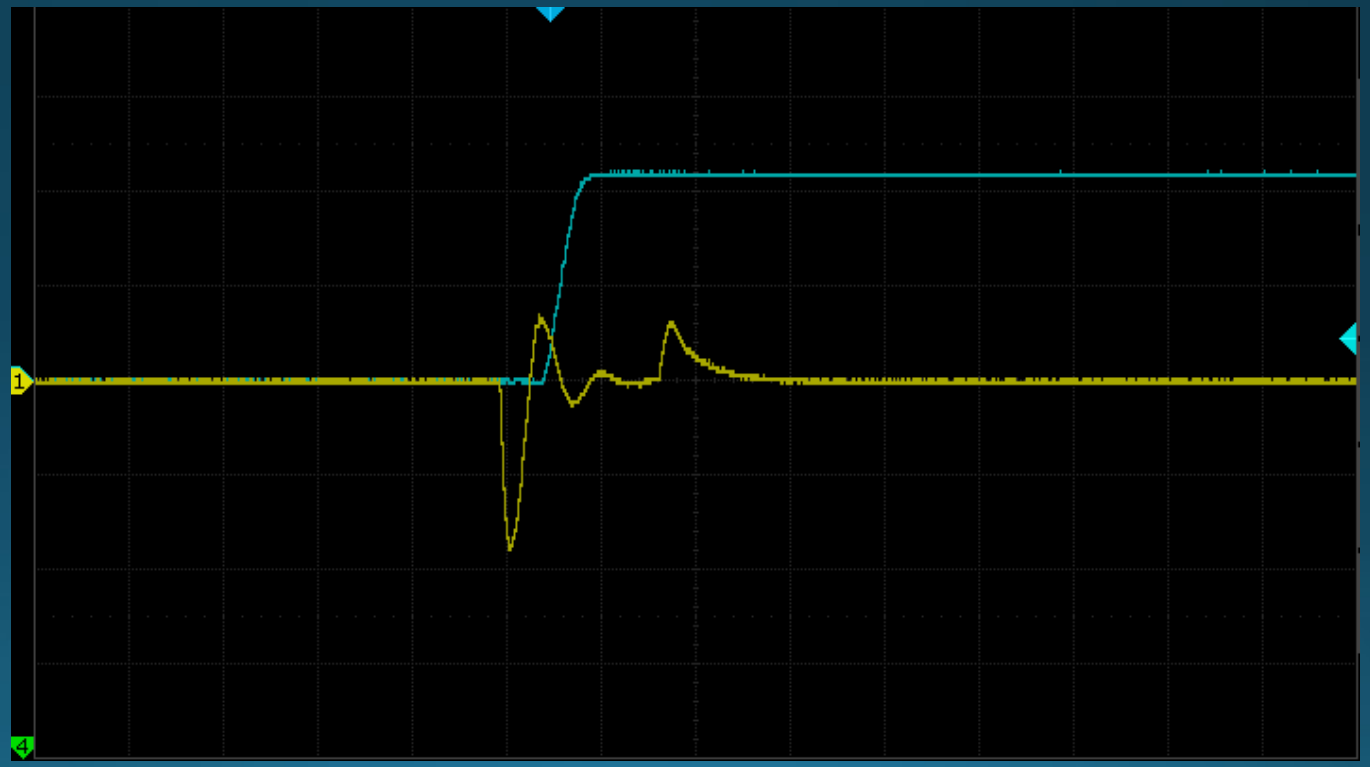
Boost Converter

- Supplies high voltage to particle detectors
- Voltage can be changed with variable resistor



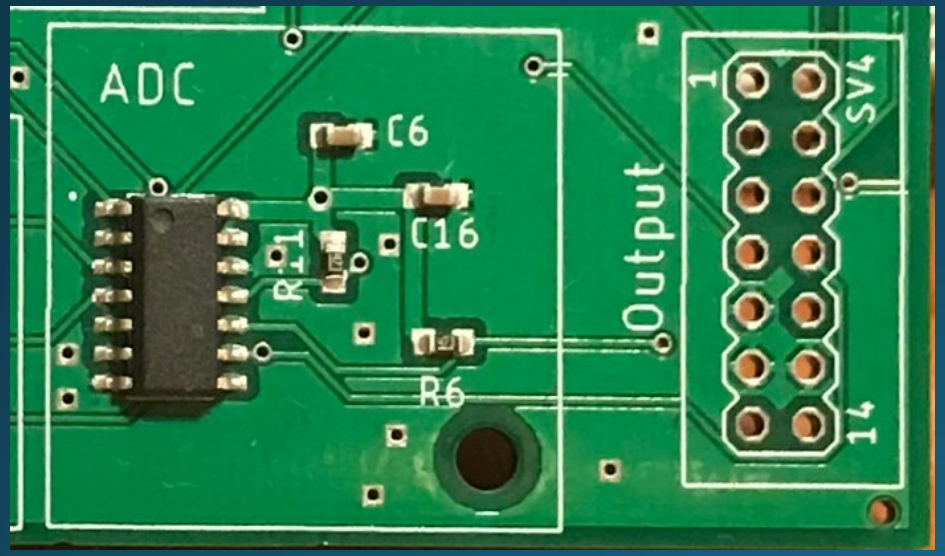
OneShot

- Stretches signal to flash LED



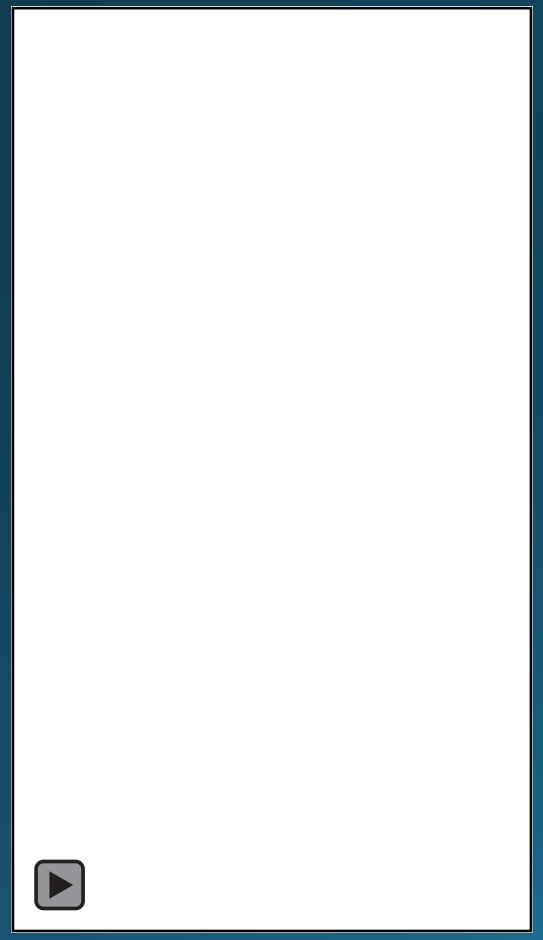
Analog to Digital Converter (ADC)

- Translate analog signal from particle detector to digital signal

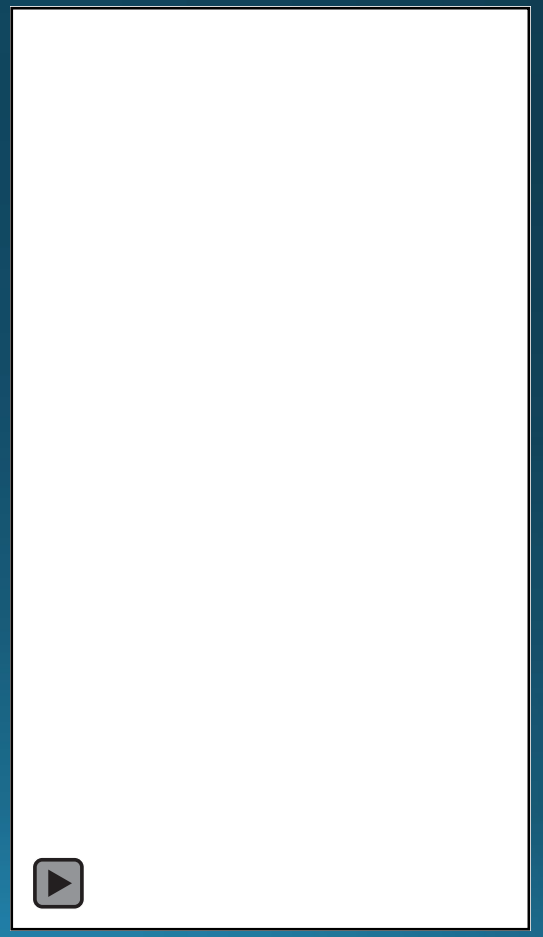


Testing Pulses

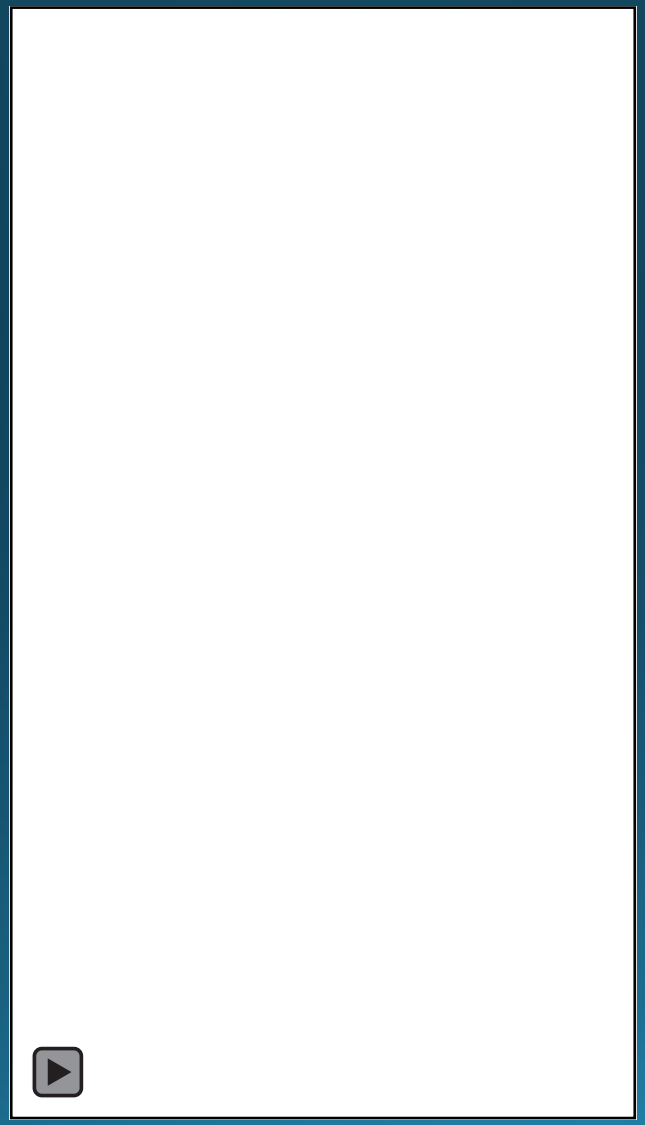
OR Pulse



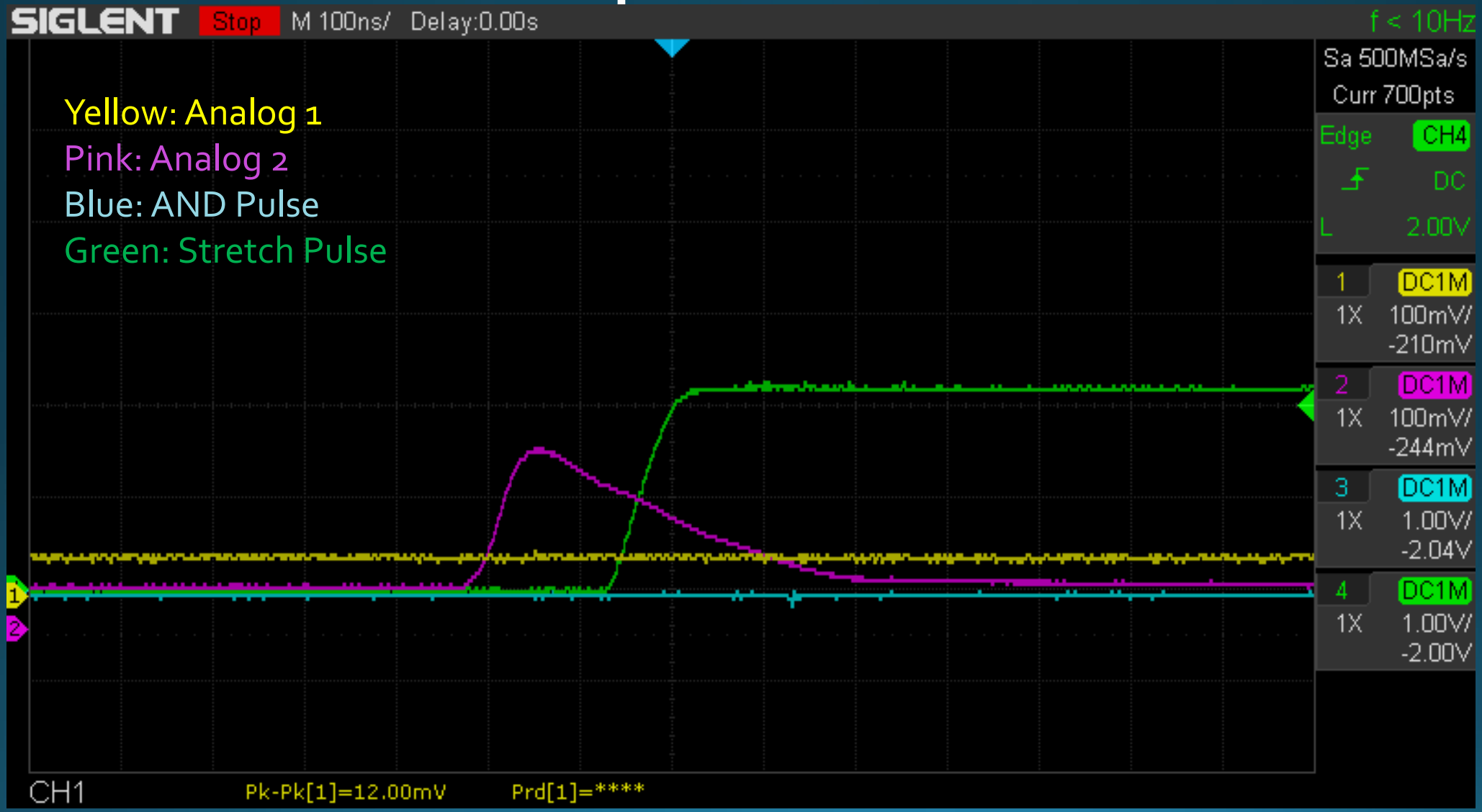
AND Pulse



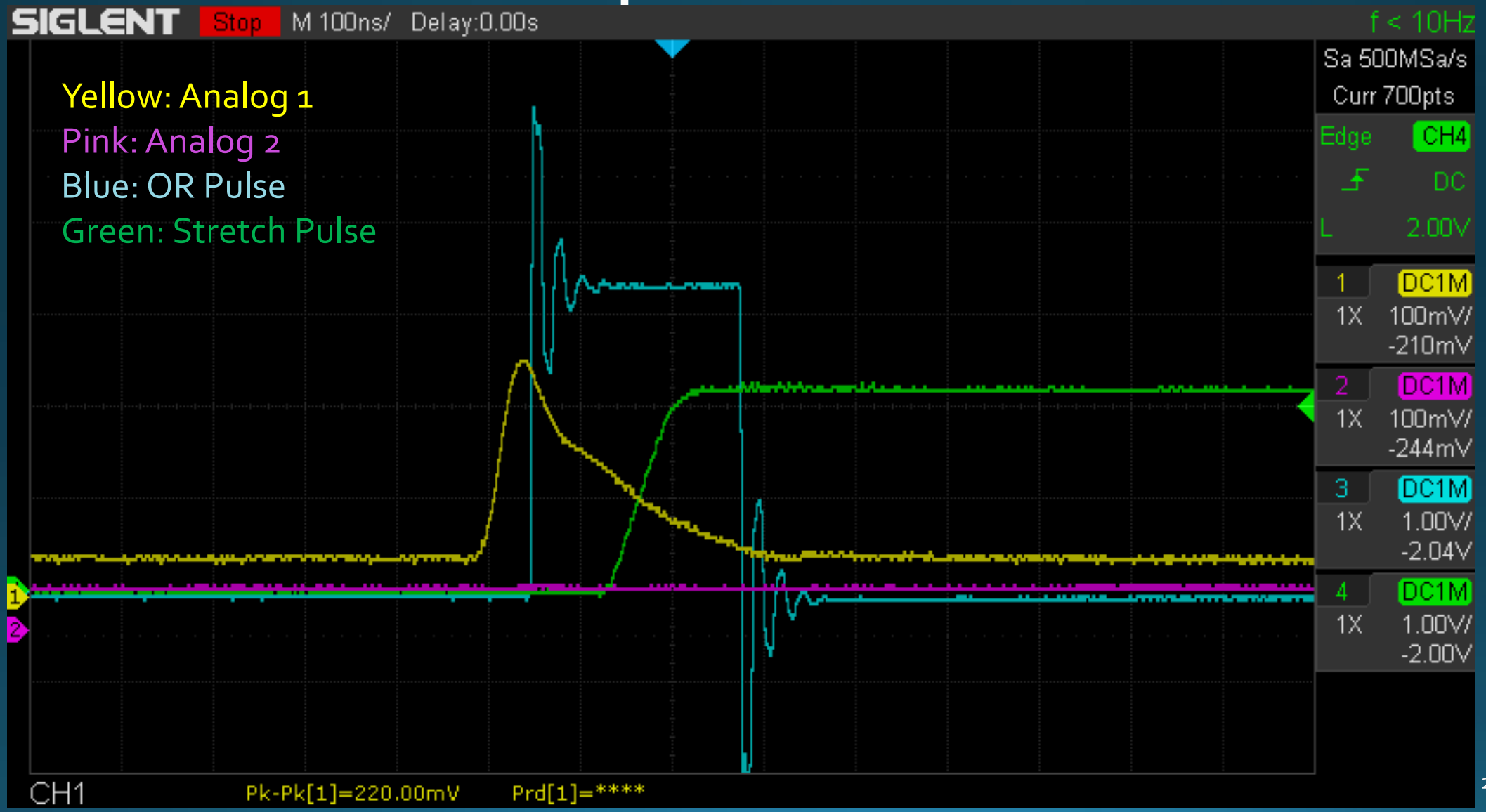
AND Pulse Stacked



OR Pulse Example



OR Pulse Example 2



AND Signal


SIGLENT
Stop
M 50.0ns/ Delay:-247ns
f < 10Hz
Yellow: Analog 1
Pink: Analog 2
Blue: AND Pulse
Green: Stretch Pulse
Sa 500MSa/s
Curr 700pts
Edge
CH3
DC
L
200mV
1
DC1M
1X
100mV/
-194mV
2
DC1M
1X
100mV/
-194mV
3
DC1M
1X
1.00V/
-1.36V
4
DC1M
1X
1.00V/
-1.38V
CH4
Pk-Pk[1]=200.00mV
Prd[1]=****

Future Work

- Better develop code for communicating between RPi and amplifier board

Conclusion

- Cosmic rays are ionized radiation that can be detected by using a silicon photomultiplier and a scintillator block.
- These readout boards will give students their own opportunity to conduct basic particle physics experiments.
- Students can add/improve on the board as they see fit.

Acknowledgments

- Dr. David Stuart
  - PI and Mentor
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