The ePIC Collaboration: Measuring the Effectiveness of the SiPM-on-Tile Hadron Calorimeter

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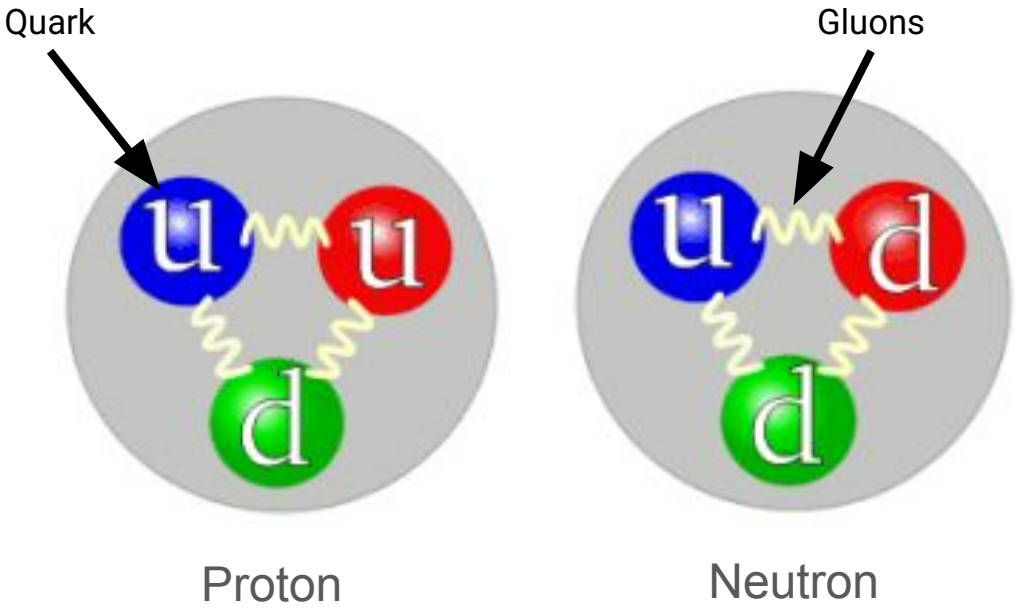
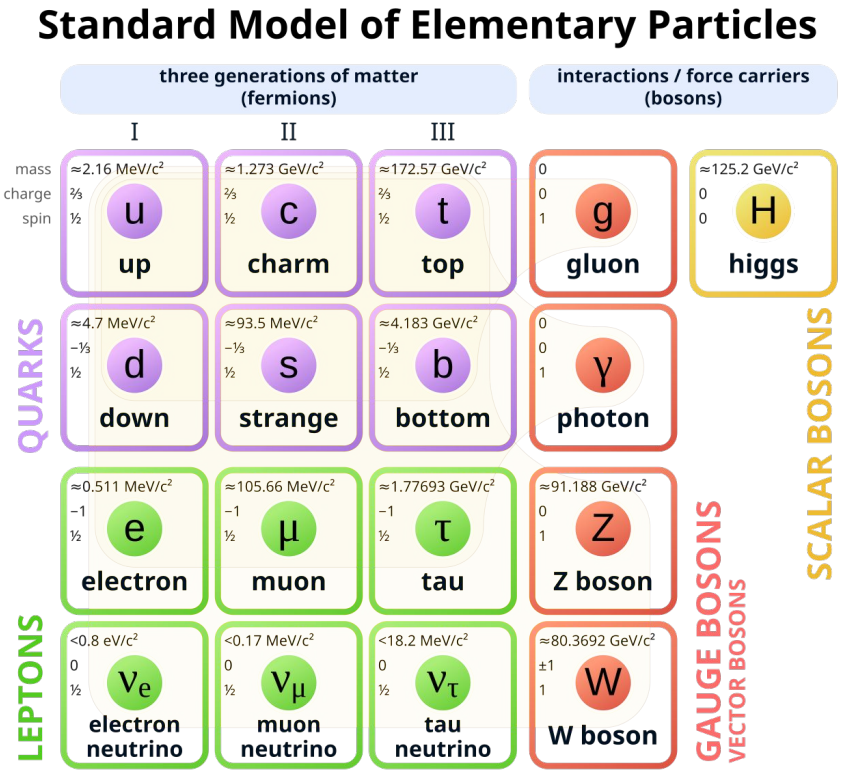
Yale

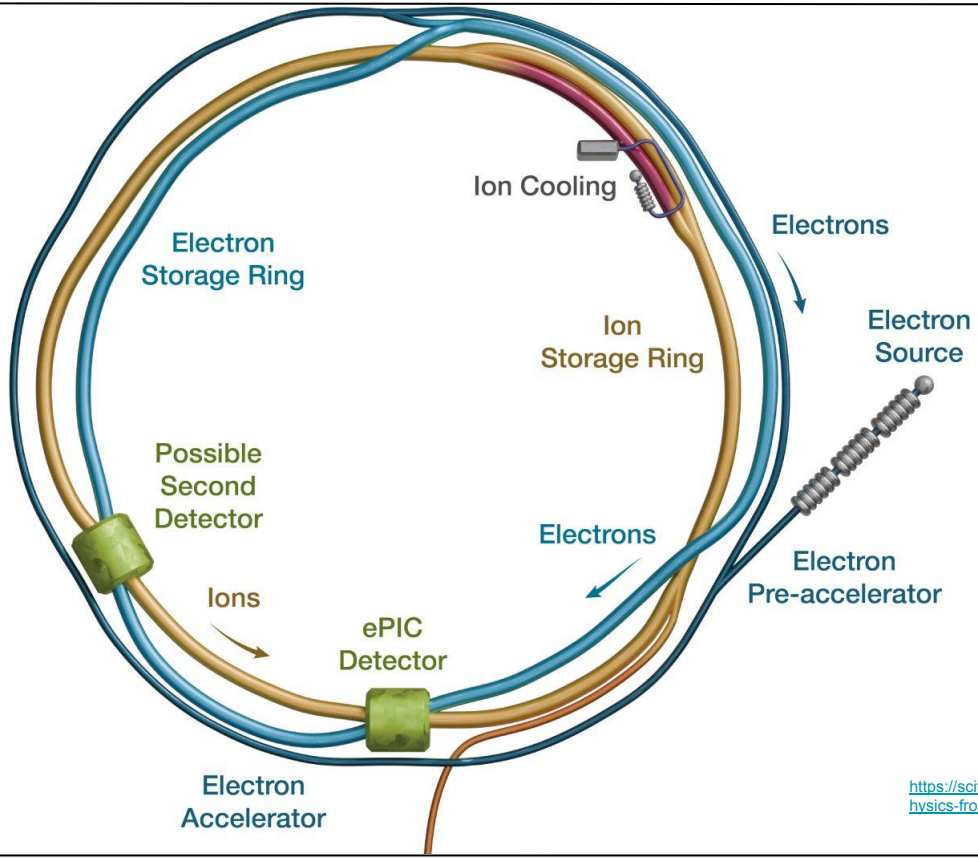
Quarks and Gluons





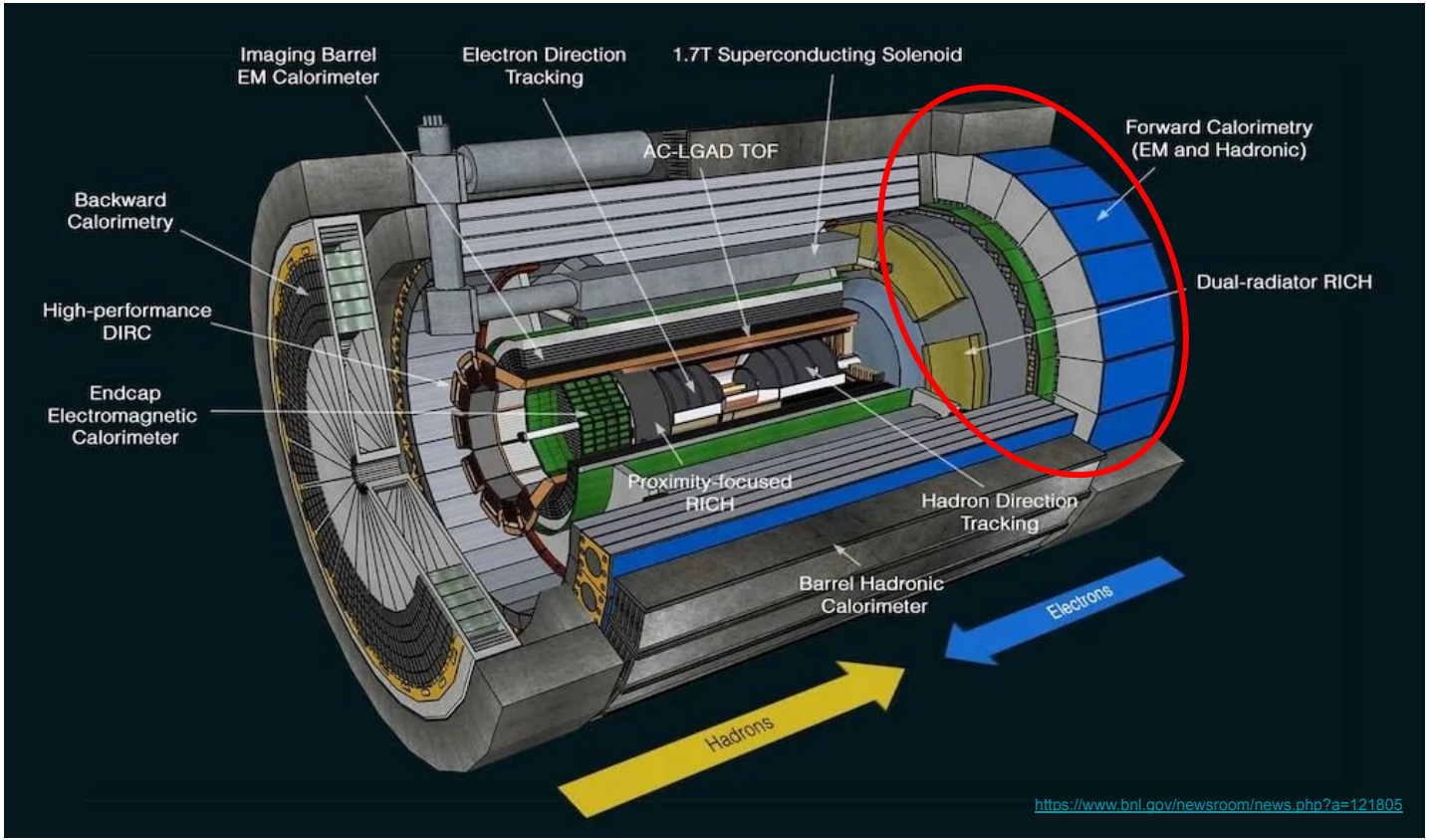
https://sites.uci.edu/energyobserver/2013/08/19/where-our-mass-comes-from/
https://commons.wikimedia.org/wiki/File:Standard_Model_of_Elementary_Particles.svg

The Electron-Ion Collider (EIC)

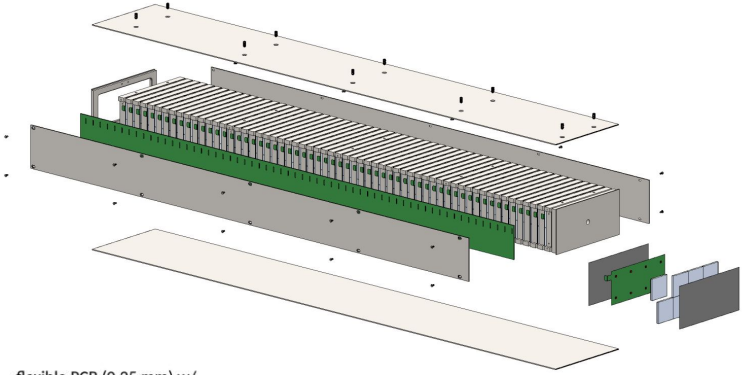


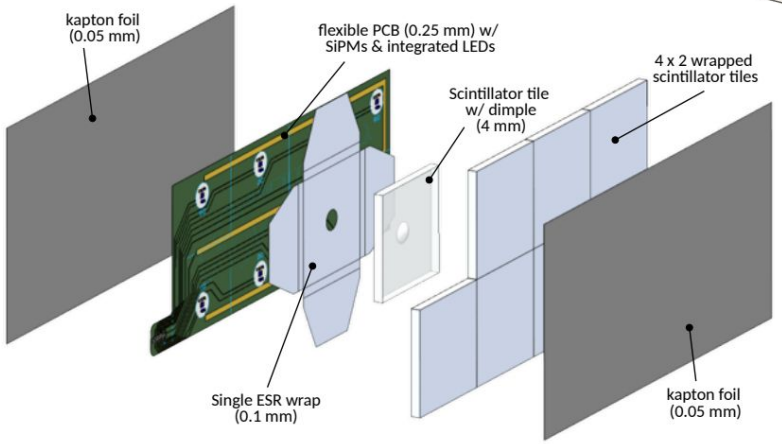
https://scitechdaily.com/how-a-24-year-old-collider-is-powering-the-next-big-physics-frontier/

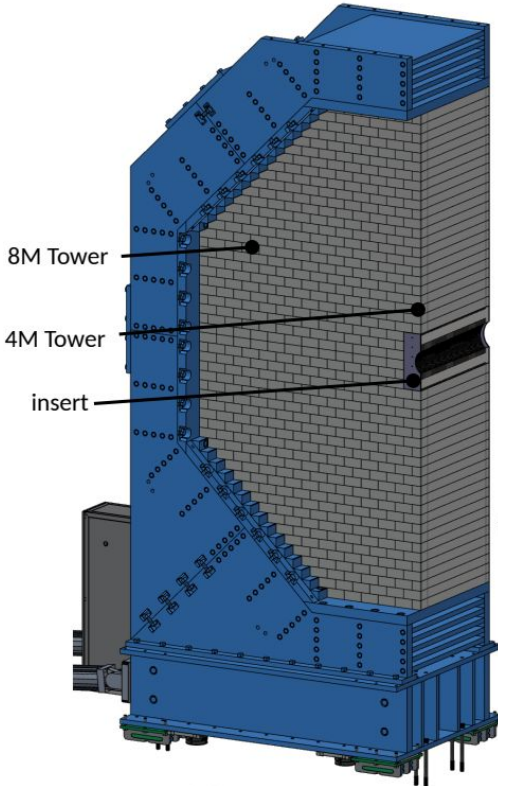
The ePIC Detector



The Longitudinally Segmented Forward Hadronic Calorimeter (LFHCal)

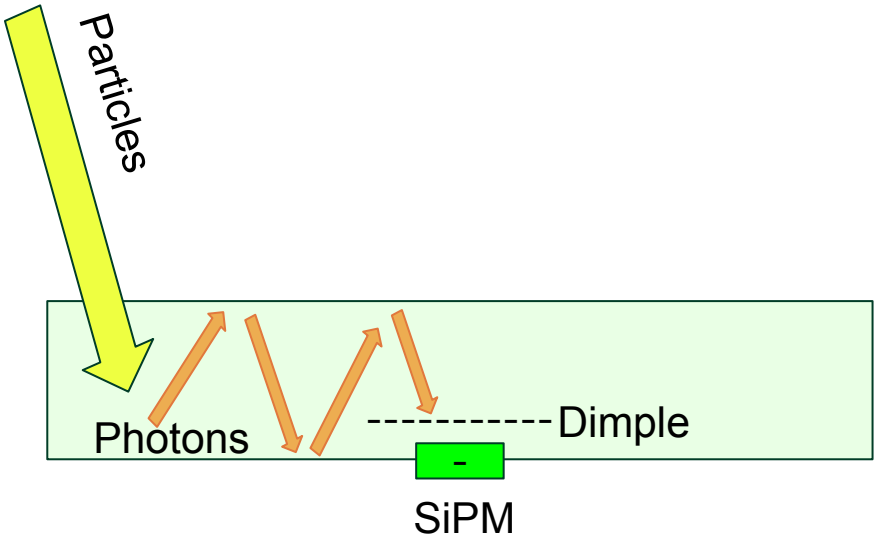


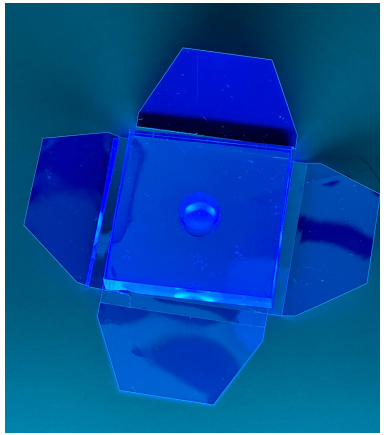




Science Requirements and Detector Concepts for the Electron-Ion Collider: EIC Yellow Report. Nucl Phys A 2022

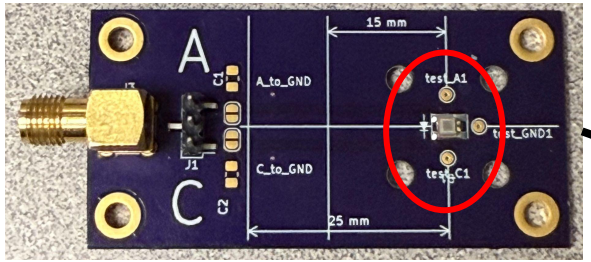
Scintillating Tiles





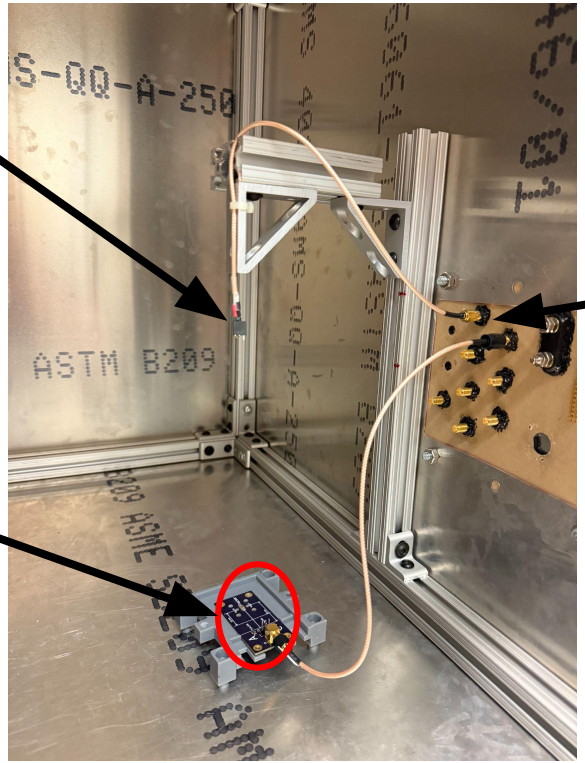
The Silicon-Photomultiplier (SiPM)

Hamamatsu S14160-1315



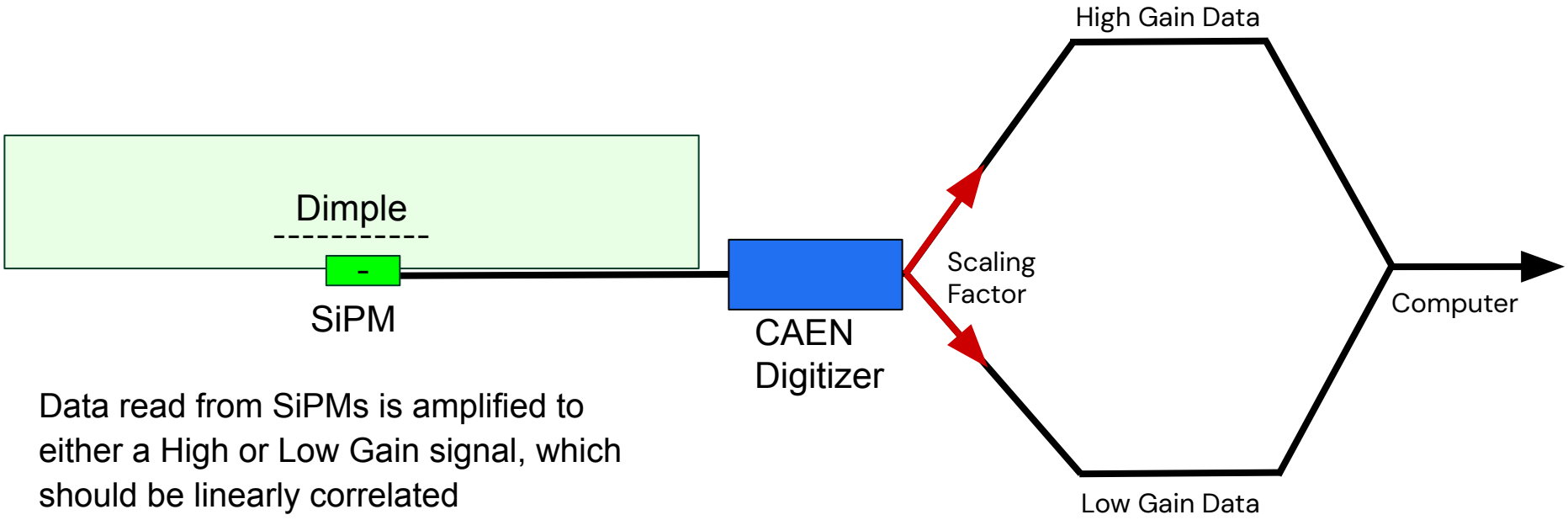
LED source

Wires to Waveform Generator and CAEN Digitizer



LED source hung inside a Faraday Cage to negate outside photons

High and Low Gain



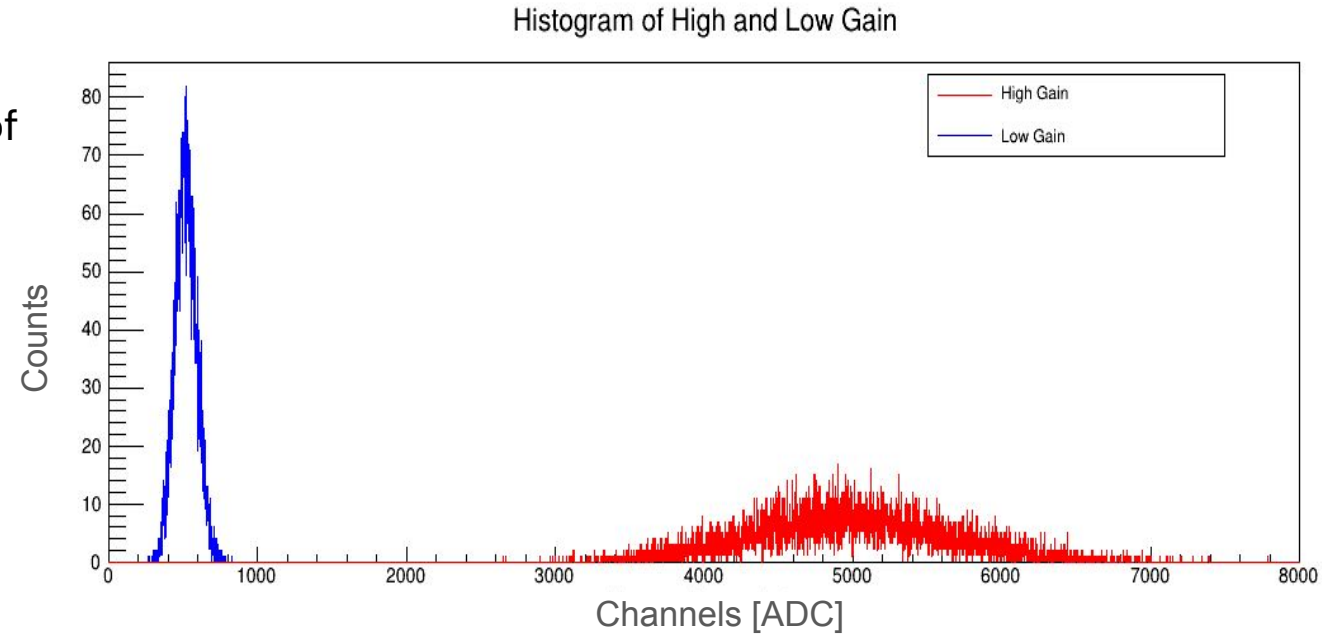
Data read from SiPMs is amplified to either a High or Low Gain signal, which should be linearly correlated

However, test beam data from CERN seems to not be linear

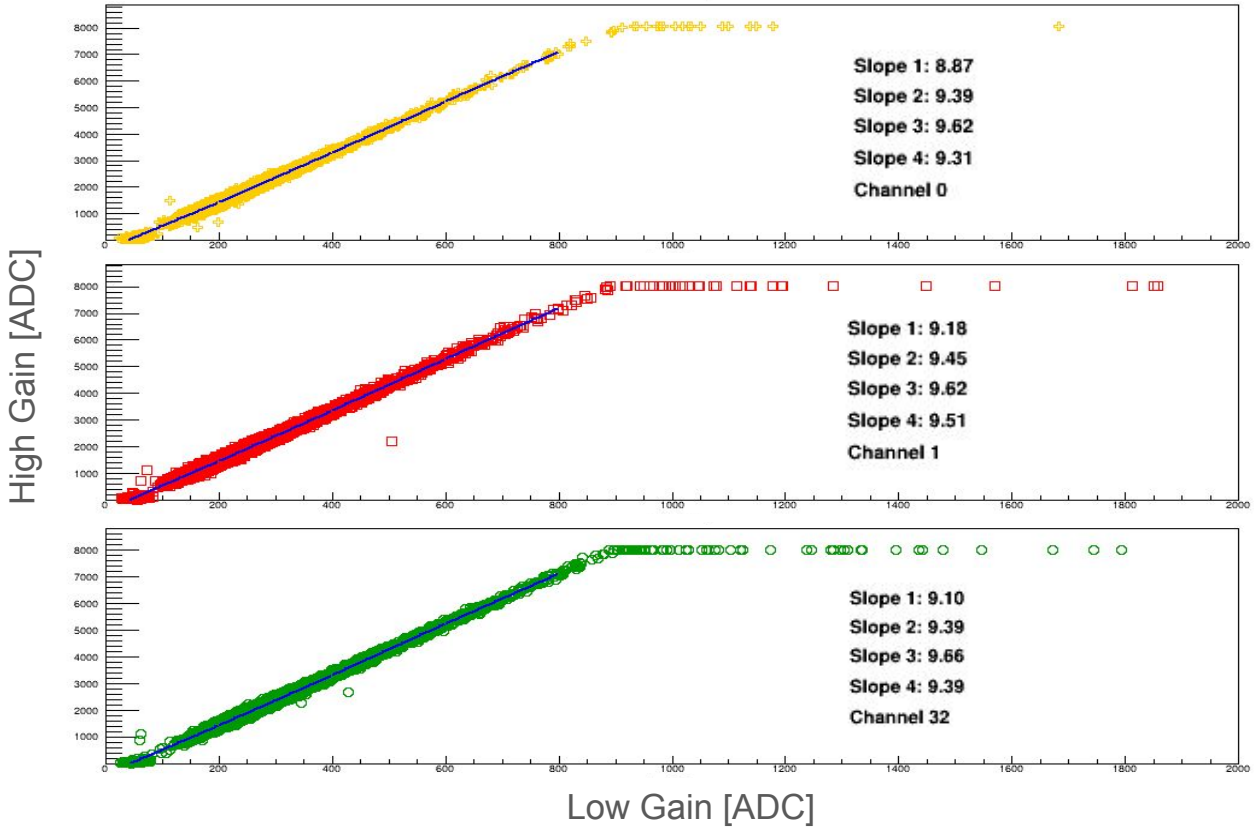
High and Low Gain

- High gain is better for smaller signals like MIPs; larger amplifier and can see spread of data

- Low gain is better for individual large-energy signals; smaller amplifier and avoids saturation of these signals that would occur for high gain

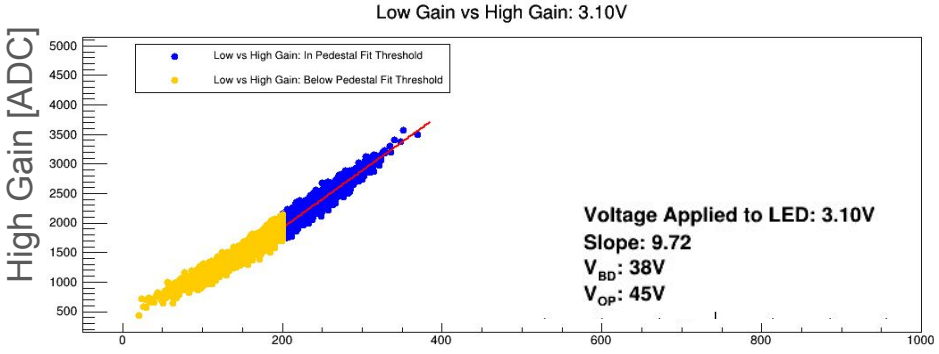


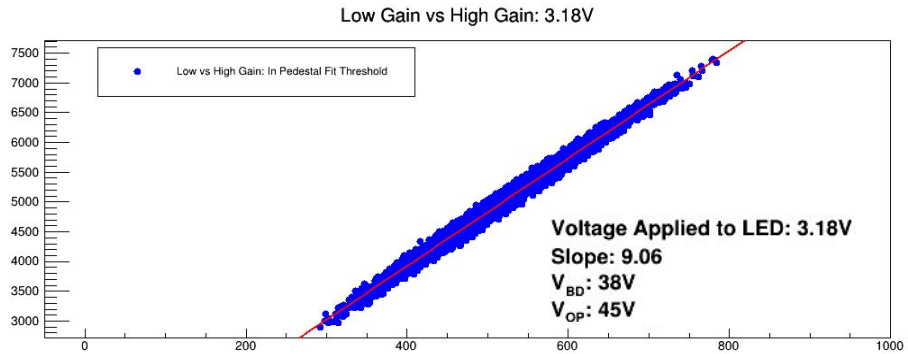
Cosmic Run Data (21 hours)

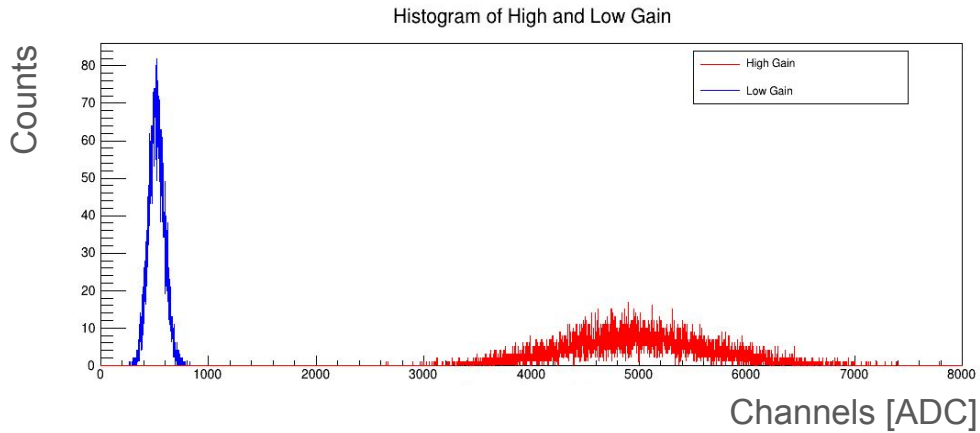


S14160-1315	Ch. 0
S14160-1315 (3)	Ch. 32
S14160-1315 (4)	Ch. 1

The LED Runs

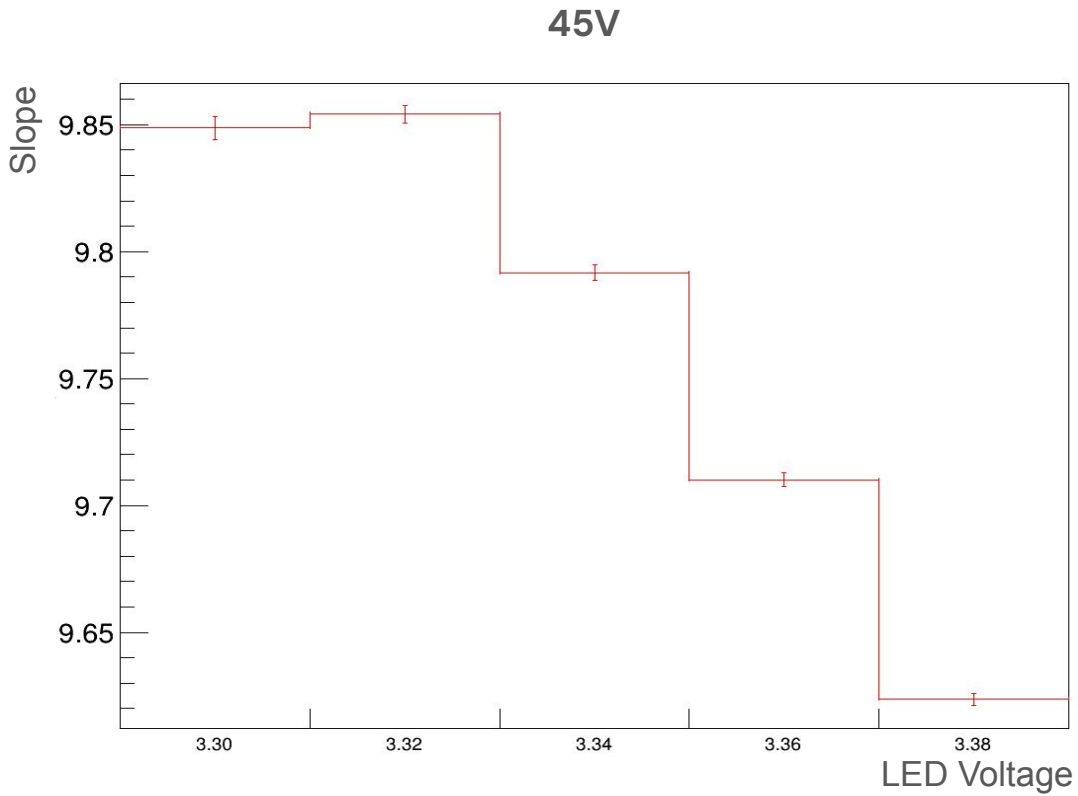

Low Gain vs High Gain: 3.10V
High Gain [ADC]
Low vs High Gain: In Pedestal Fit Threshold
Low vs High Gain: Below Pedestal Fit Threshold
Voltage Applied to LED: 3.10V
Slope: 9.72
V_{BD}: 38V
V_{OP}: 45V


Low Gain vs High Gain: 3.18V
Low vs High Gain: In Pedestal Fit Threshold
Voltage Applied to LED: 3.18V
Slope: 9.06
V_{BD}: 38V
V_{OP}: 45V
Low Gain [ADC]


Histogram of High and Low Gain
Counts
High Gain
Low Gain
Channels [ADC]

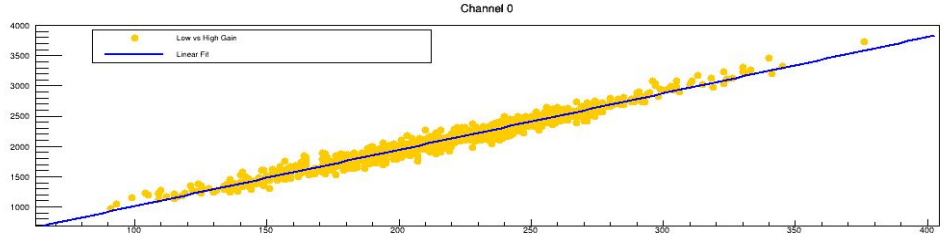
The Slopes of LED Runs

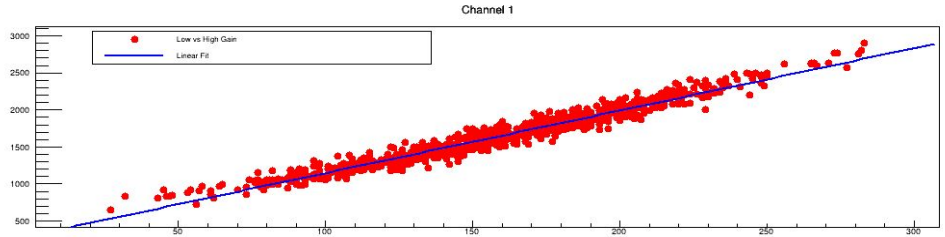
- Each run was done at different over-voltages (41, 43, 45V)
- Slopes were consistent
- Our data could not replicate test beam
- Moving on to the next test to try and replicate again

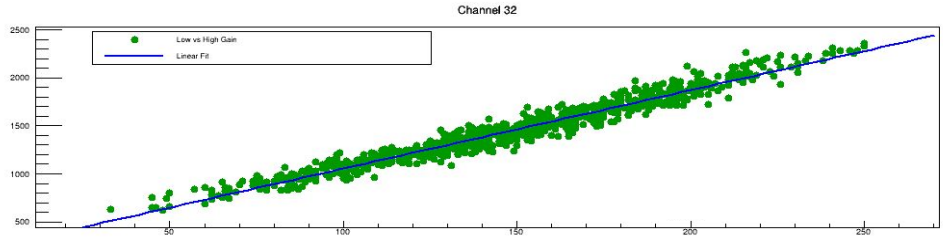


Testing Multiple SiPMs

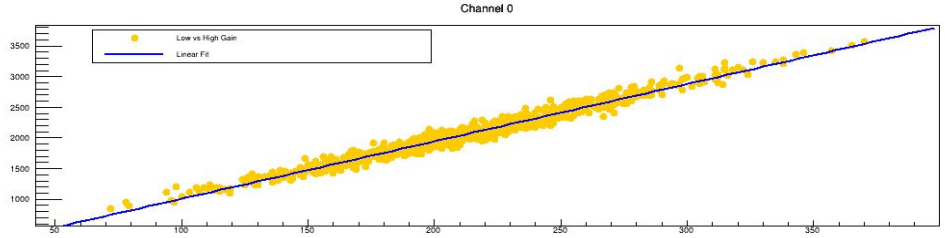
All 3 at the same time

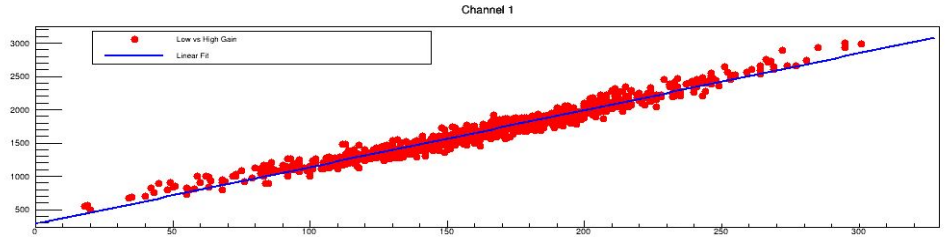


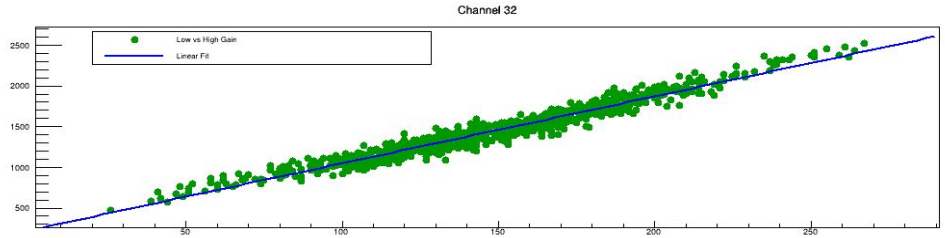




Individual

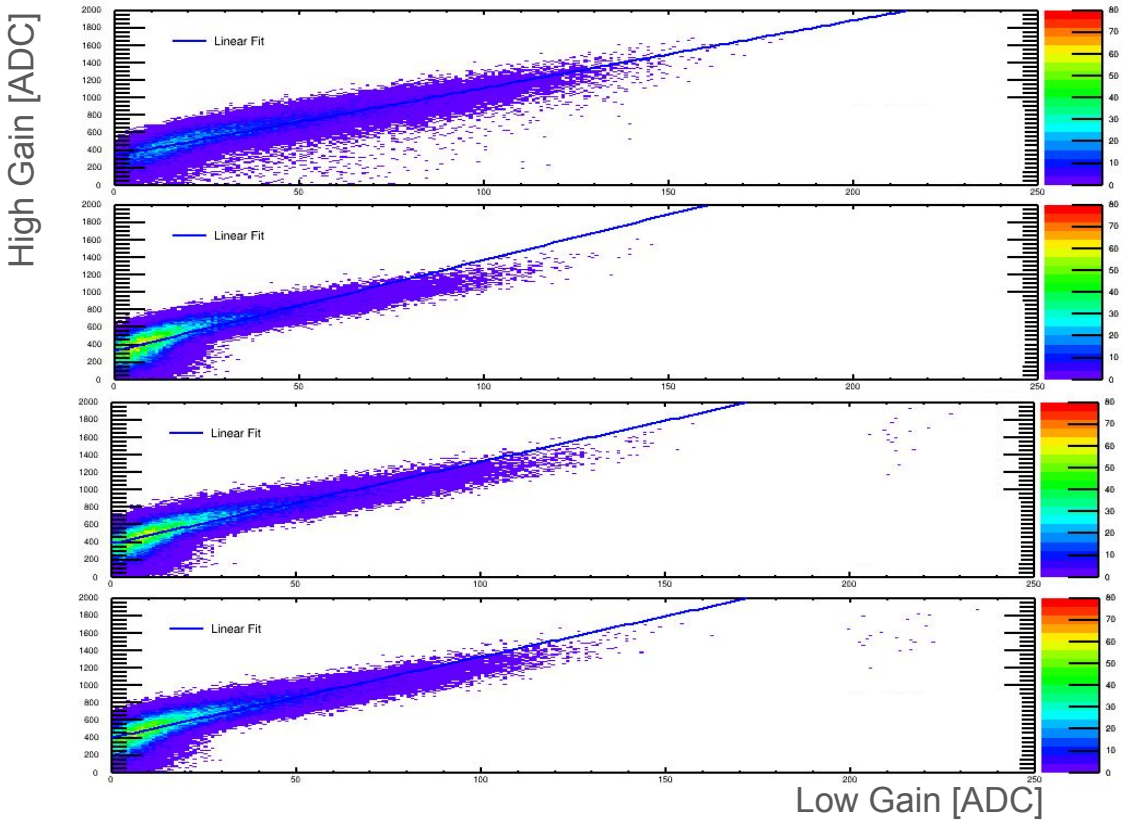




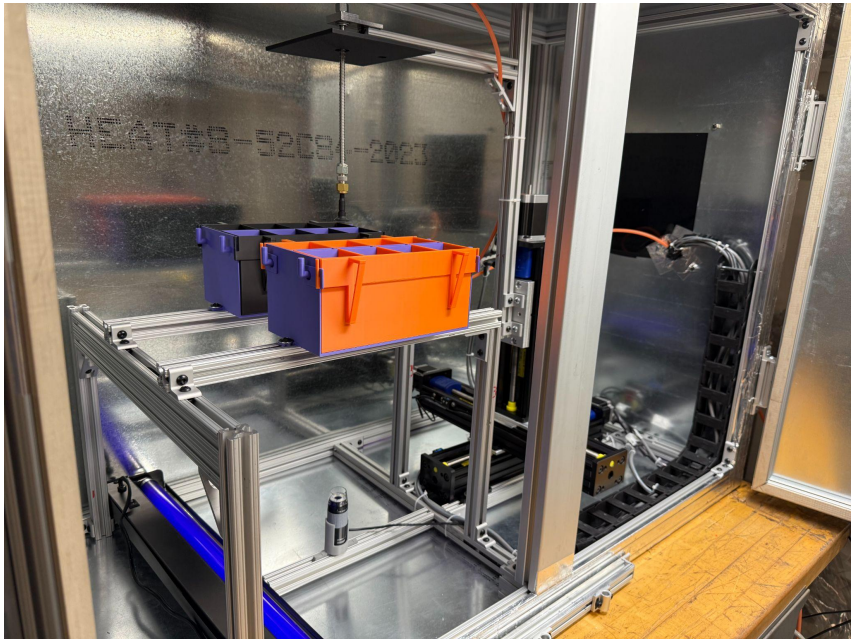


Running at Different Frequencies

- Same SiPM, ran at different frequencies generated by the waveform generator
- 3Hz, 6Hz, 9Hz, 12Hz
- This was similar to what was seen in the test beam data
- Conclusions and further tests are ongoing

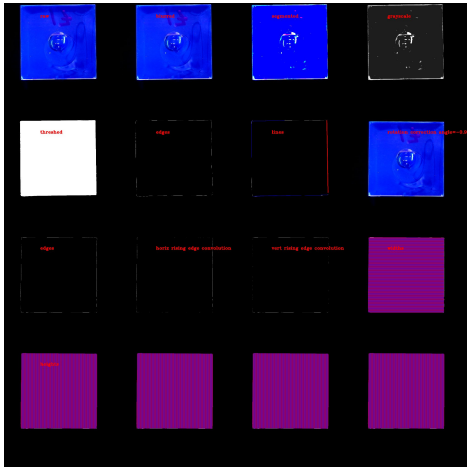


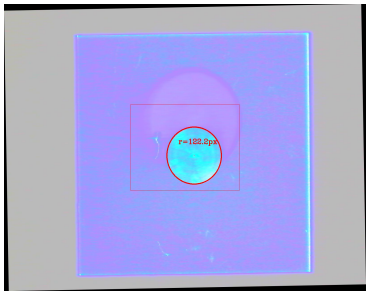
Ensuring the Measurements of Scintillating Tiles



Translational stage to measure 200 tiles at once

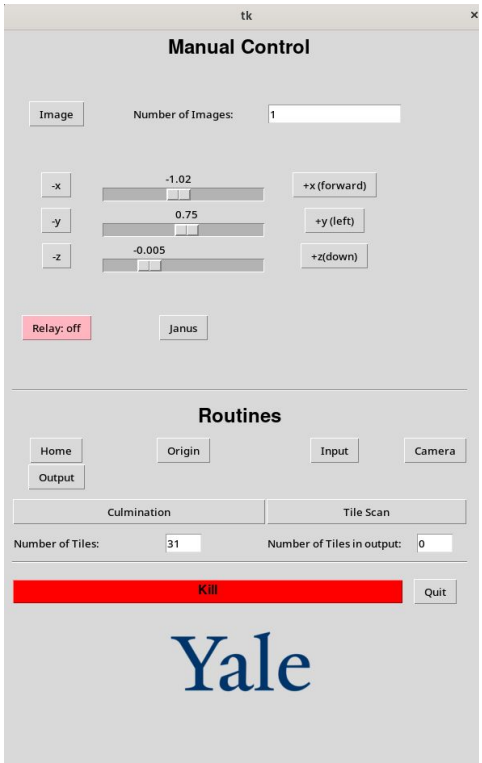
Pictures of a single tile



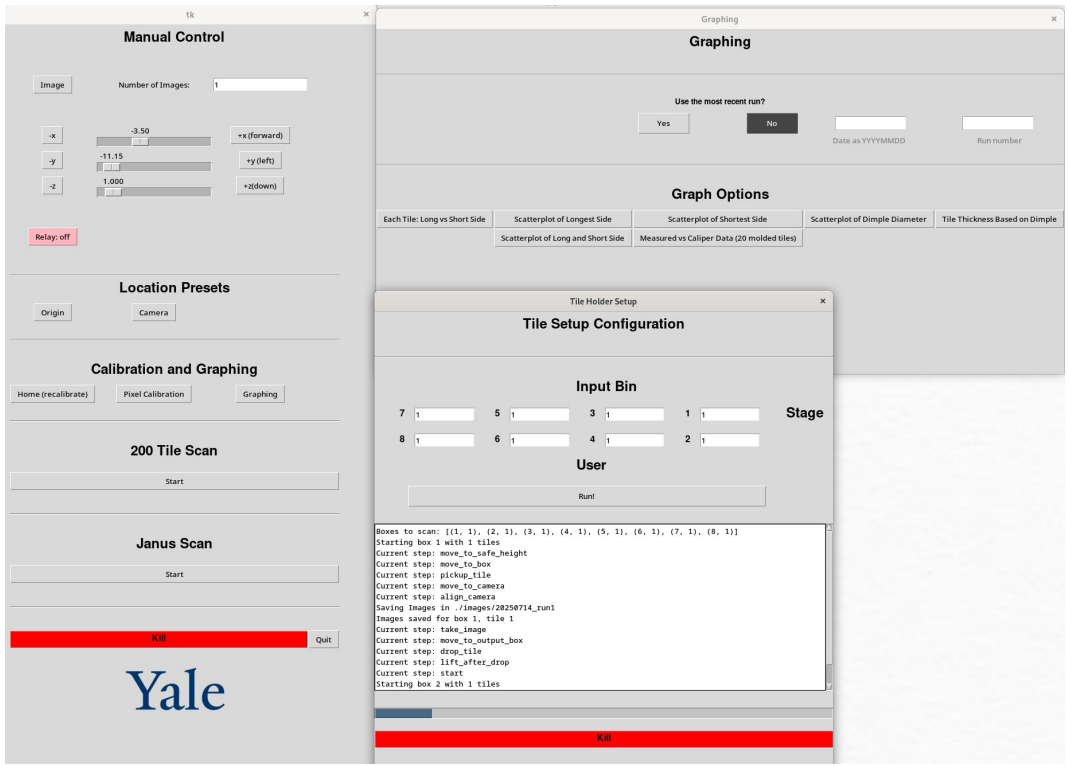


The Graphical User Interface (GUI)

Old GUI

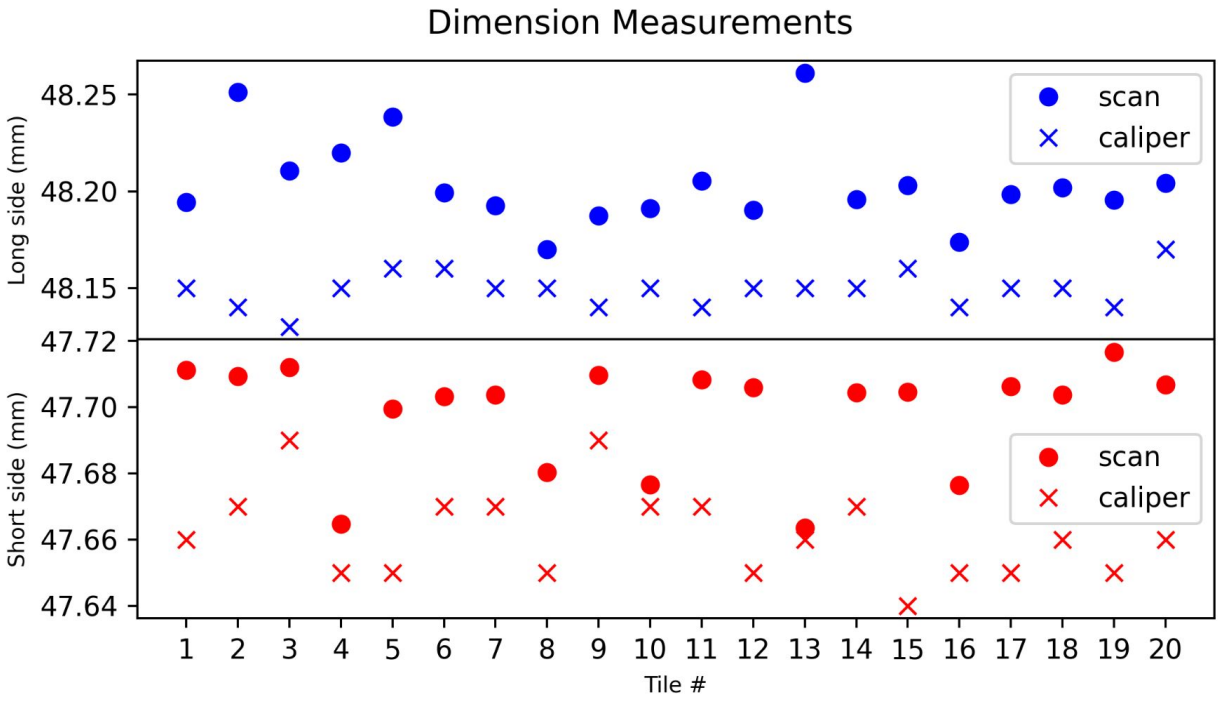


New GUI



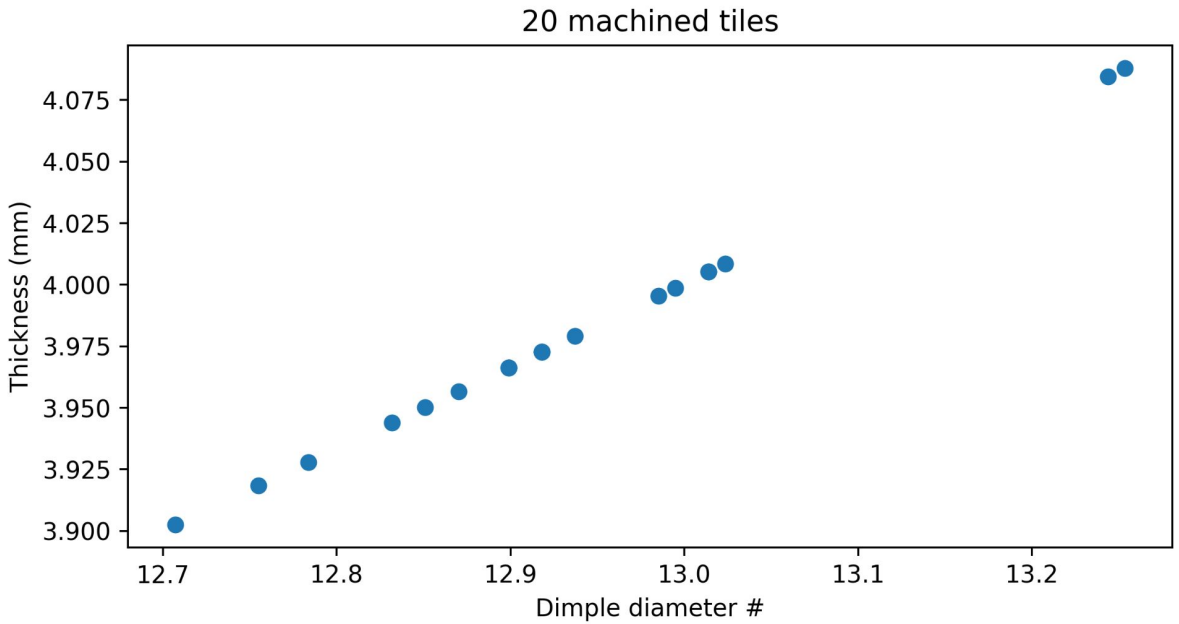
Ensuring the Measurements of Scintillating Tiles

- 20 molded tiles to measure effectiveness
- Scanned tile dimensions were within ±0.10mm (100 microns) of the caliper-measured tiles
- Small offset, but confident enough to move on to machined tiles



Finding the Thickness of the Tile

- All tiles were cut by the same diamond ball drill, so based on the radius of the left behind dimple, we can determine thickness
- Tiles too thick won't fit within parameters and will have differing light yield



Conclusions

SiPM

- Tested and coded analysis of multiple different methods, including normal LED, Cosmics, Daisy-Chained, and Differing Frequencies in attempt to replicate worrying test data from CERN
- Not able to exactly replicate test beam data from CERN
- However, the Differing Frequencies method proved similar to test beam data, enough to warrant further testing

Tiles

- Modified and created new code for a pixel-to-mm conversion translational stage in a new setup to be able to scan 200 tiles fully automated
- Modified graphical user interface (GUI) to be more accommodating and have more detailed options
- Able to take accurate measurements (within 100 microns) of tiles
- Implemented a method of discerning a tiles thickness via their dimple

Acknowledgements

STARS Summer Program

Yale College Dean's Office

Wright Laboratory
Helen Caines
Garg Prakhar

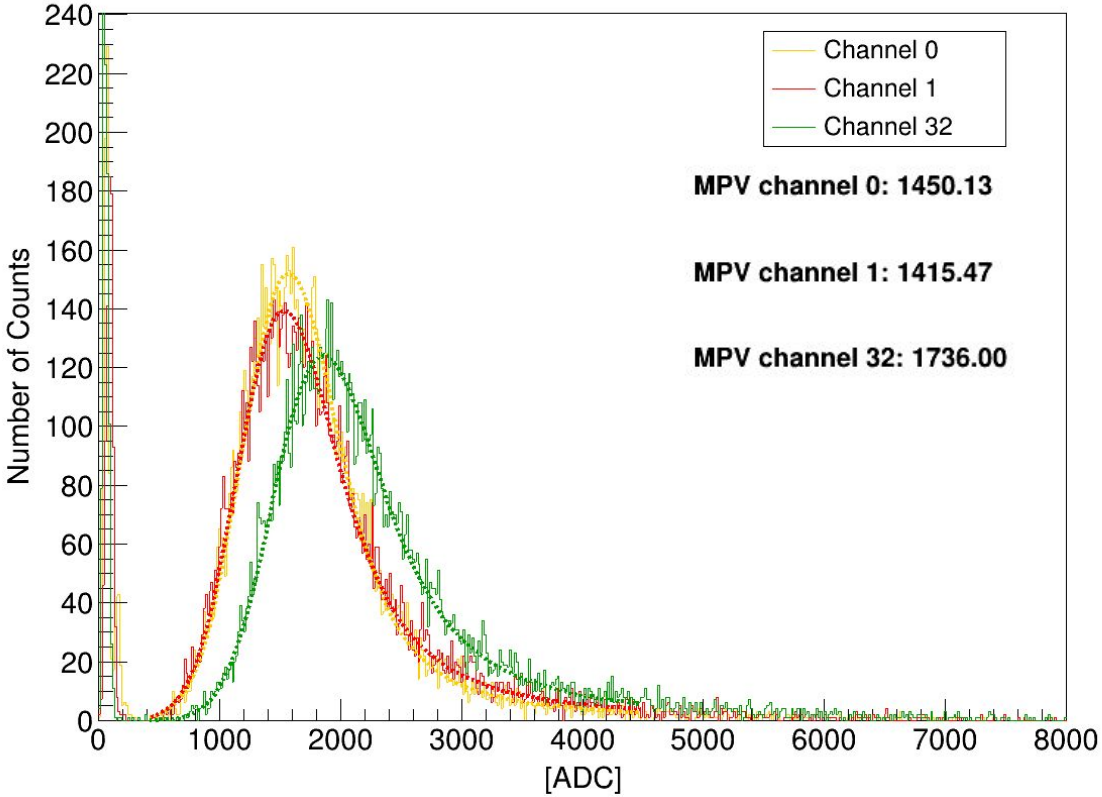
Brookhaven National Laboratory

Oak Ridge National Laboratory

ePIC Collaboration

Appendix

Cosmic Run Data (21 hours)



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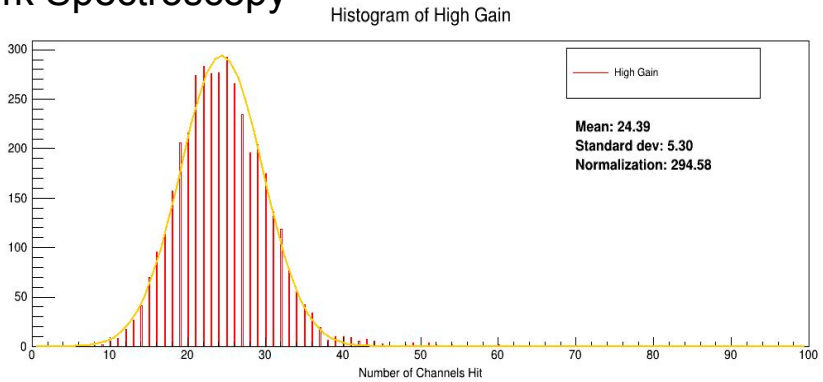
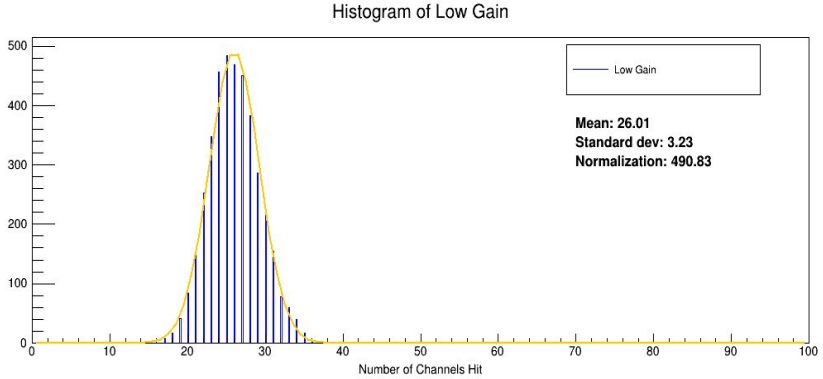
S14160-1315 (4)	Ch. 1

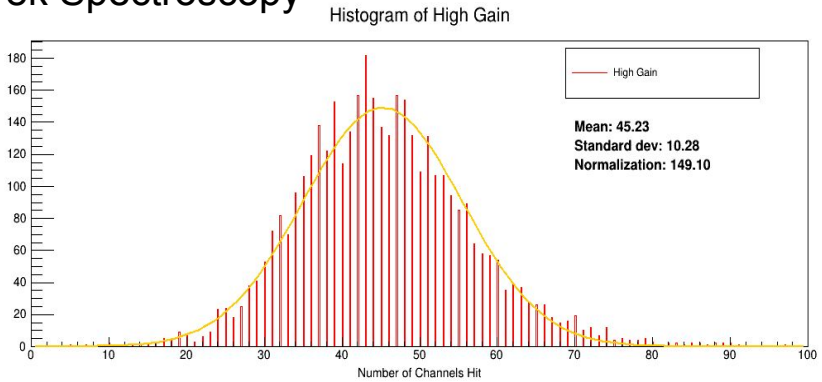
Pedestal Data

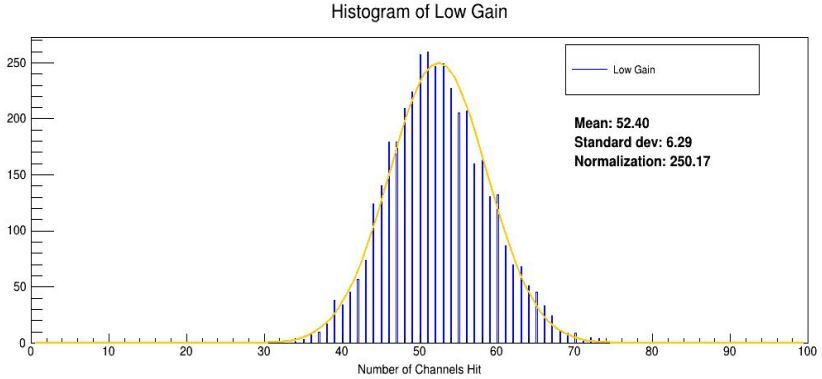
4k Spectroscopy





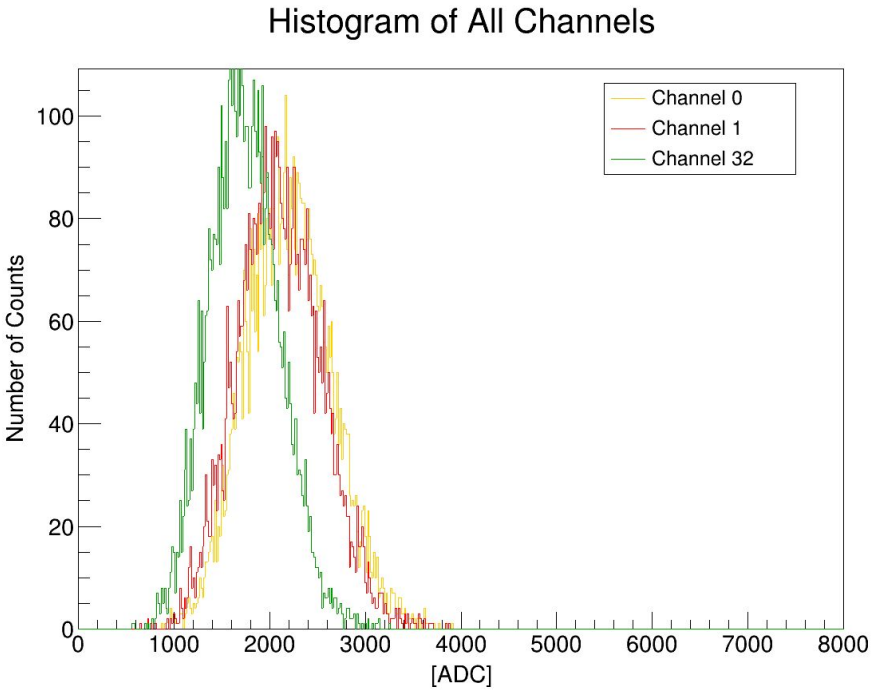
8k Spectroscopy



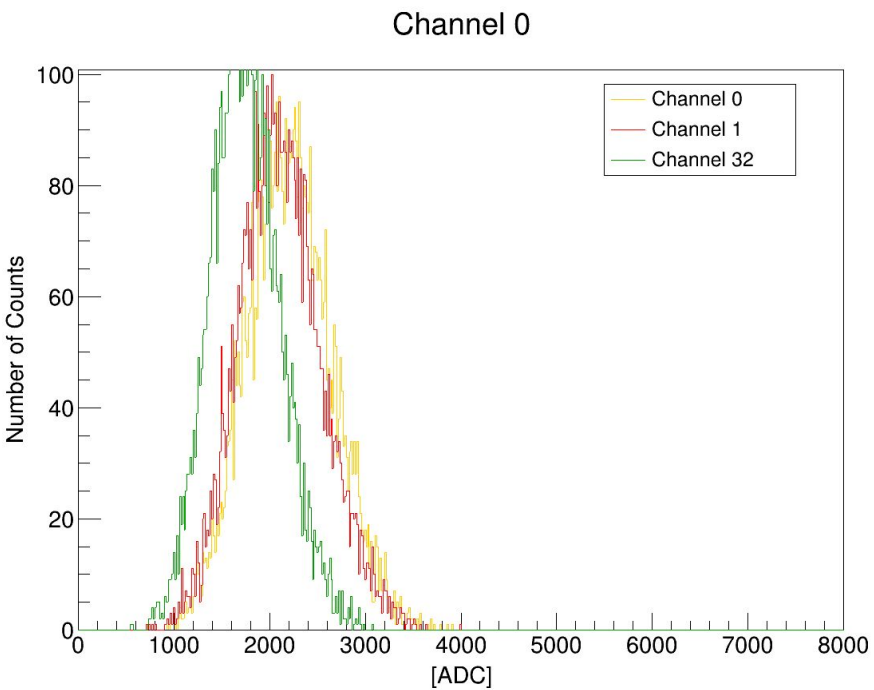


Actual Histograms of Multiple SiPMs

All 3 at the same time

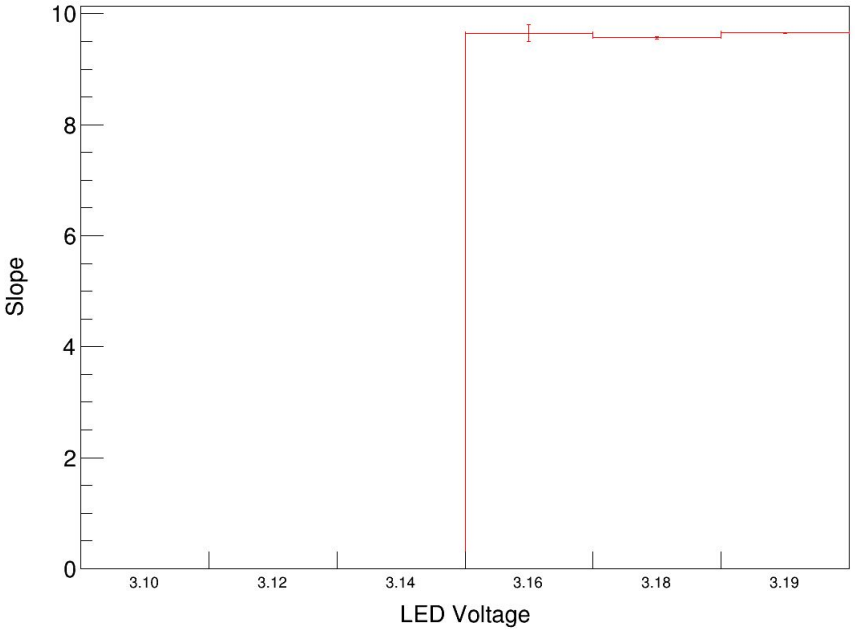


Individual

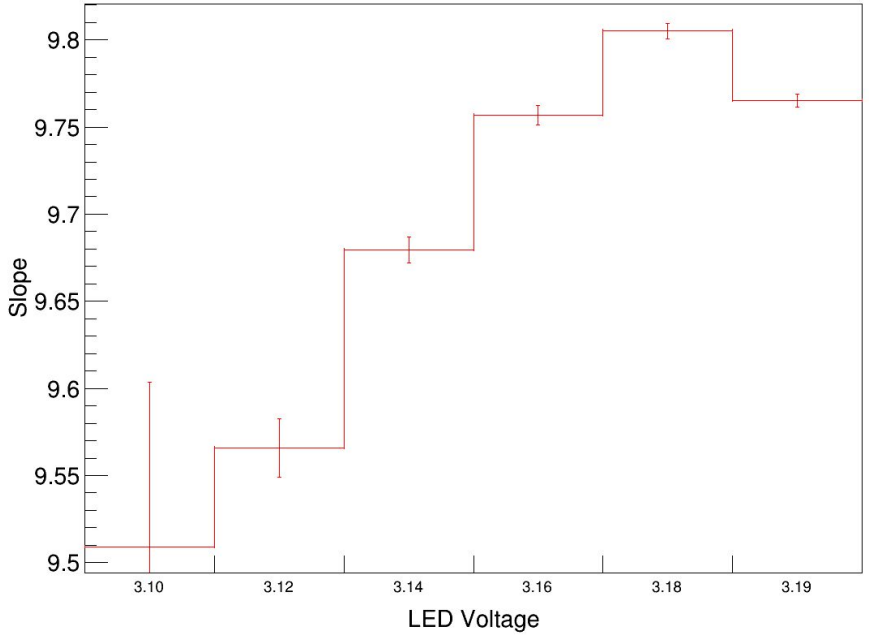


Actual Histograms of Multiple SiPMs

41V

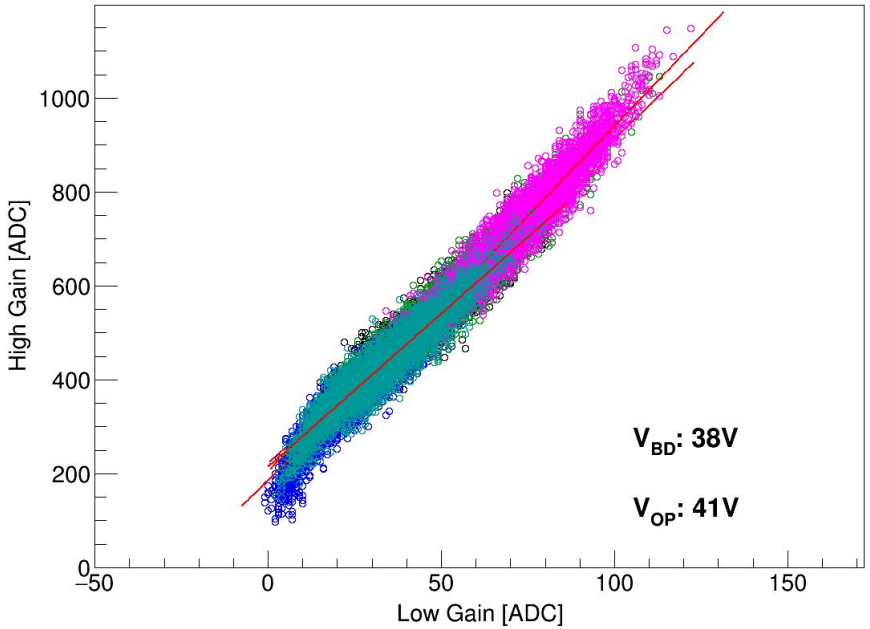


43V



Full Graphs

41V



45V