Active and Passive Summing of SensL SiPMs

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We have been looking carefully at active and passive ganging of SensL Series C SiPMs

Although the SensL SiPMs are no longer available to the Project in a package that works cryogenically, we studied these SiPMs for 2 reasons

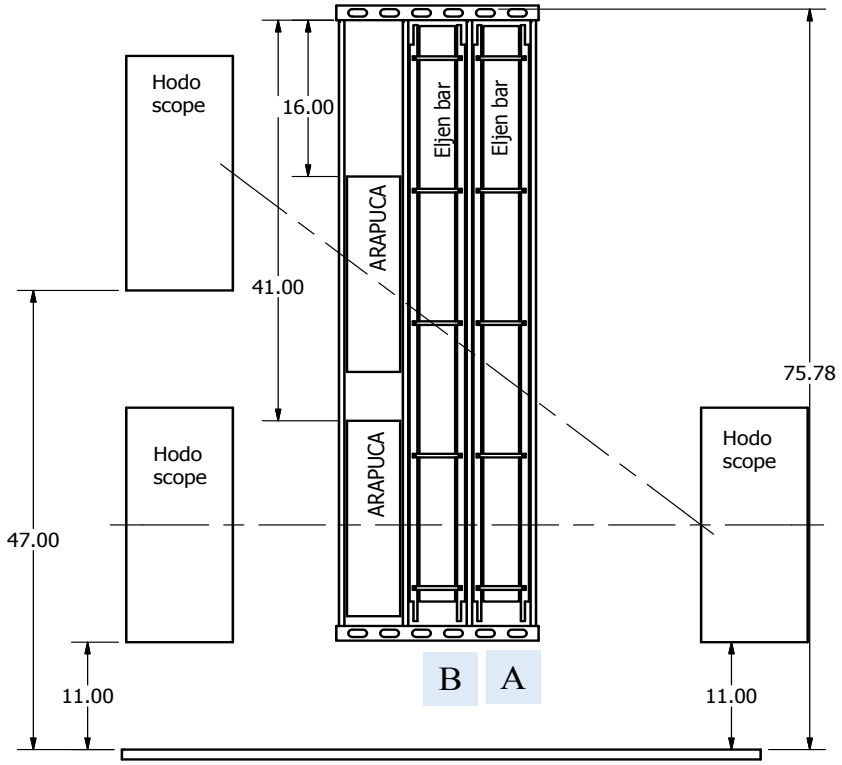
- SensL Series C SiPMs were used on the active summing boards in our TallBo experiment in Fall 2017
- SensL SiPMs are passively summed in the protoDUNE experiment and we were interested in revisiting their operating characteristics and their bias voltage settings for optimum performance

We have begun to study passive ganging with Hamamatsu MPPCs

Currently we have not reproduced the successful operation of the MPPCs seen at Fermilab

1. Active ganging with 12 SensL Series C SiPMs

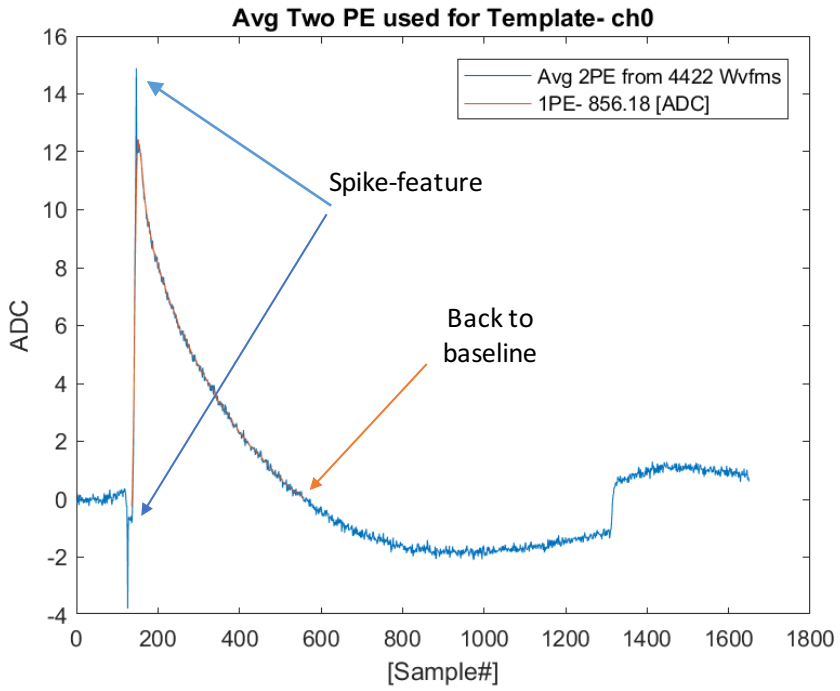
From September 2017 – November 2017, we studied the IU PD technology and the Arapuca PD technology side-by-side at the TallBo dewar facility at Lab PAB at Fermilab



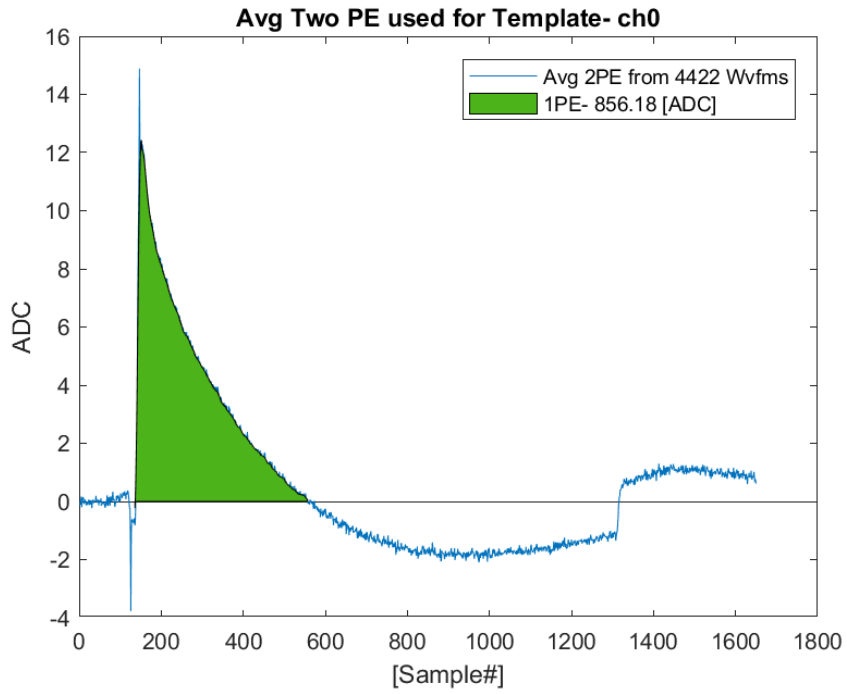
TallBo Experiment at Fermilab

- 2 IU PD paddles (A, B) with double-ended readout (4 cold summing boards)
- Cold summing boards designed and manufactured by Gustavo Cancelo at Fermilab
- Each board populated by 12 SensL 6 mm x 6 mm SiPMs
- boards read out by Argonne SSP
- Readout triggered by 4-fold coincidence from flanking hodoscopes

Calibration of the active summing boards proved to be quite challenging due to complicated waveforms from the cold summing boards



average (inverted) 2 pe waveform from free-run (dark) calibration runs



region used to calibrate the cold summing board output

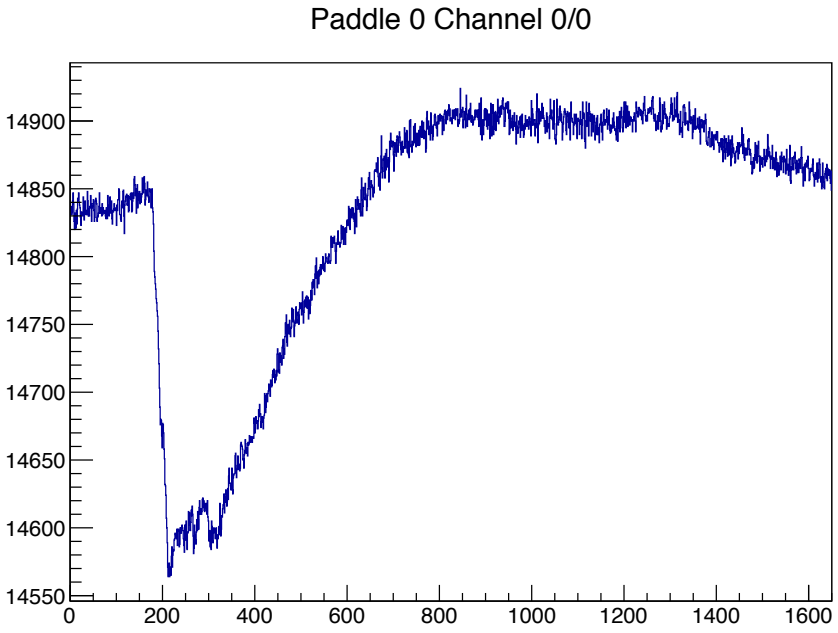
At conclusion of the TallBo experiment, boards were studied at IU

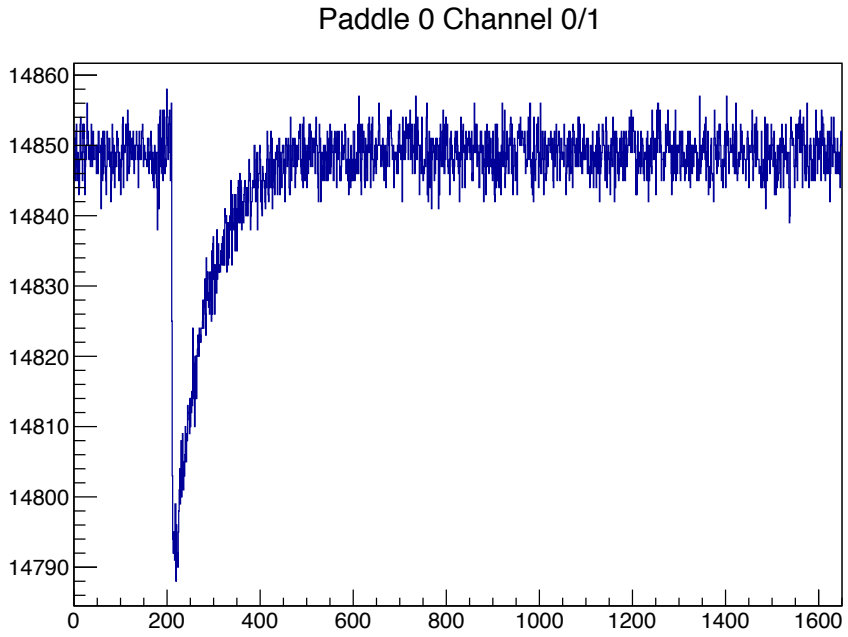
- boards tested in LN2
- boards exposed to a 430 nm LED flashing at 10 Hz with 30 ns pulse width
- LED light passed through an aperture (20, 28, or 40 mil) and then a diffuser; diffuser meant to mitigate solid angle effects
- LED light source outside dewar and approx. 4 feet above board
- single monitoring SensL SiPM mounted on the cold summing board

cold summing board

monitoring SiPM

Waveforms from the active summing board and monitoring SiPM (bin width 6.67 ns; waveform ~ 10.5 μs)

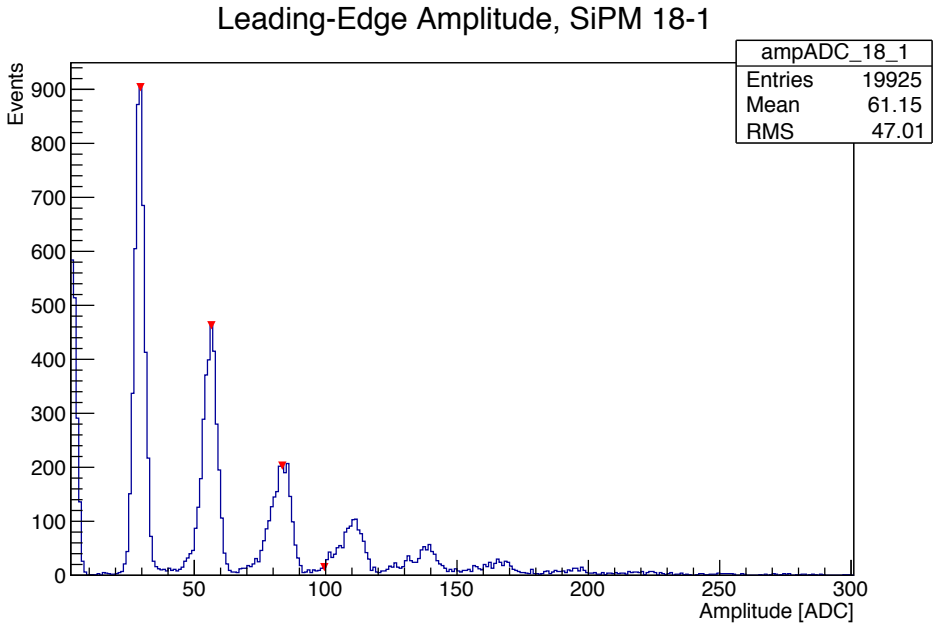




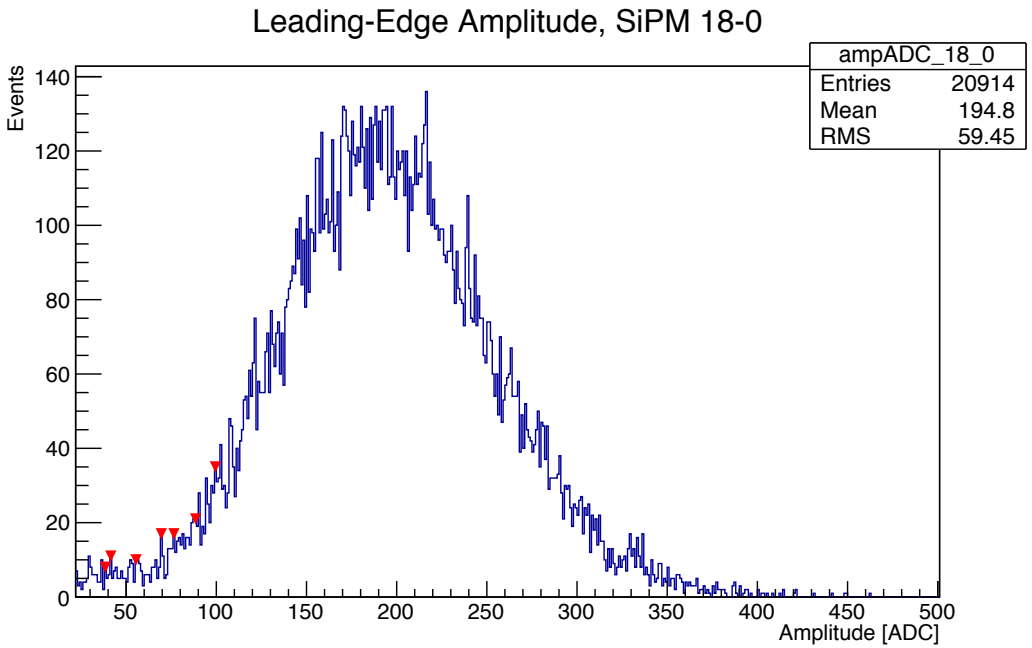
active ganging board

monitoring SiPM

Leading edge amplitudes for monitoring SiPM and active summing board
28 mil aperture, 105 s run

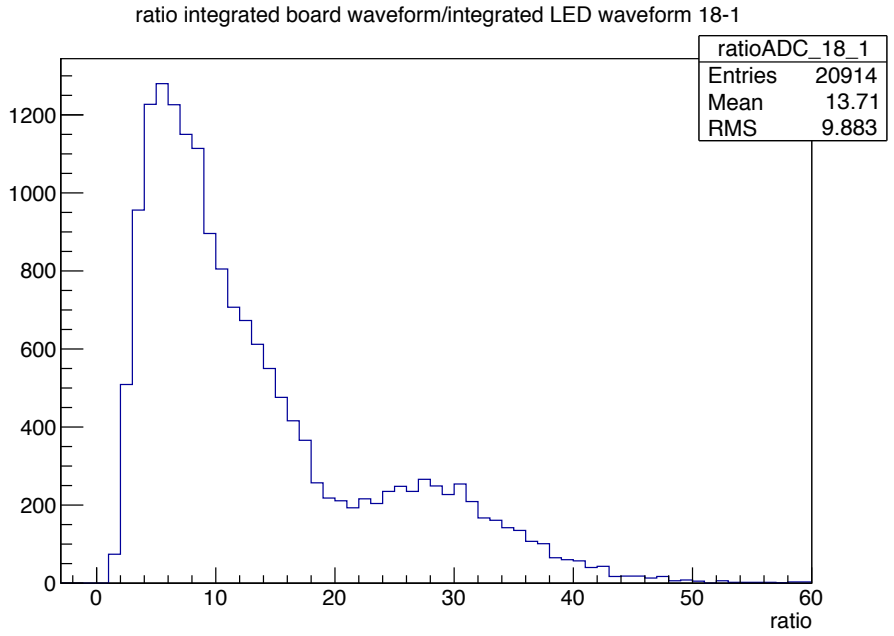


monitoring SiPM
behaving normally

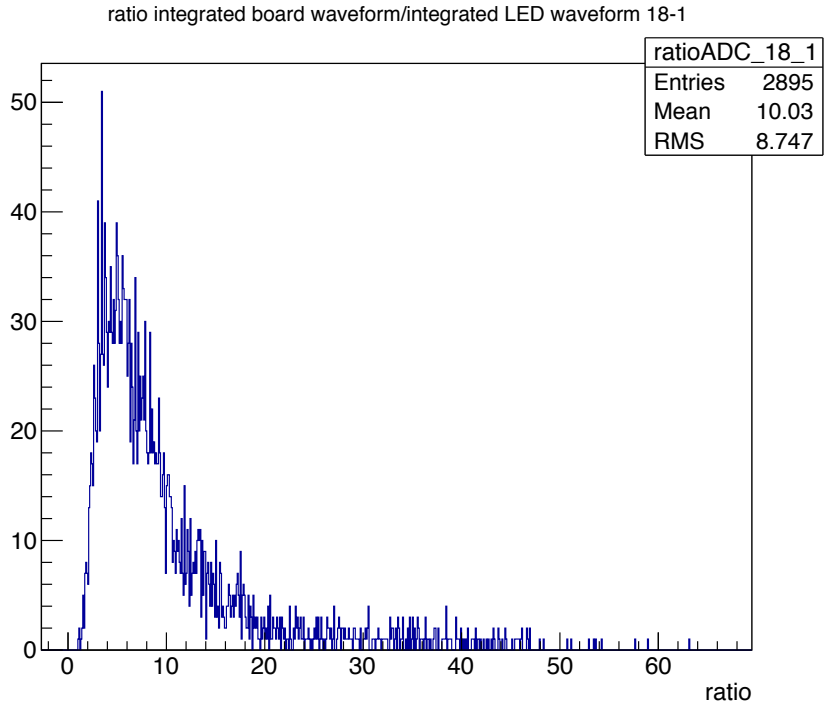


active summing board
unmatched SiPMs, no peaks visible

histograms of ratio of (board response/monitoring SiPM response) for all LED pulses



active summing board
peculiar large ratio feature

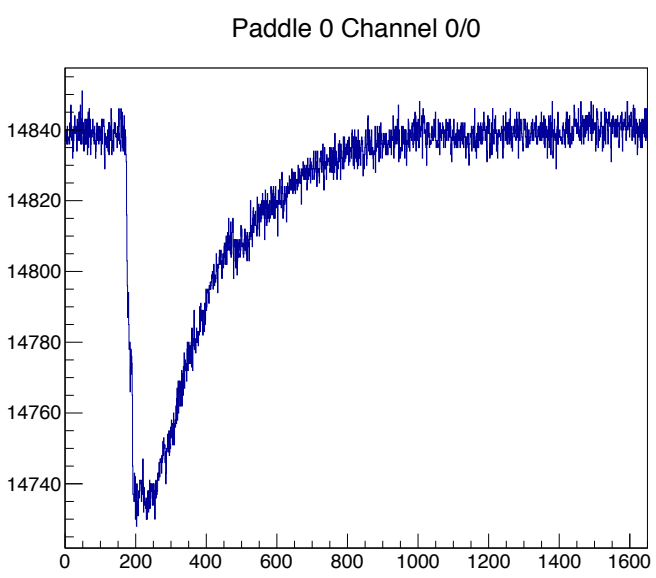


6 passively ganged SiPMs
large ratio feature not seen

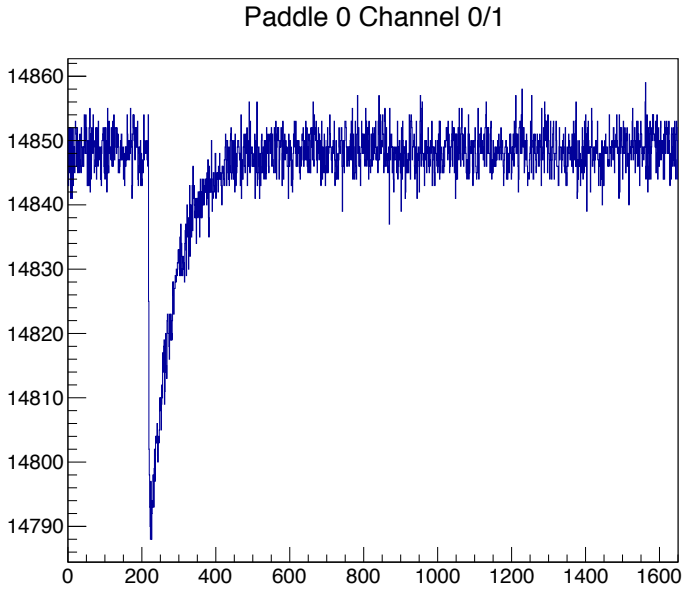
1. Passive ganging with 3, 6, 8 SensL Series C SiPMs

10, 12 passively ganged SiPM studies failed – SiPMs ganged in pairs and 2 pairs failed

waveforms from 6 passively ganged SiPMs

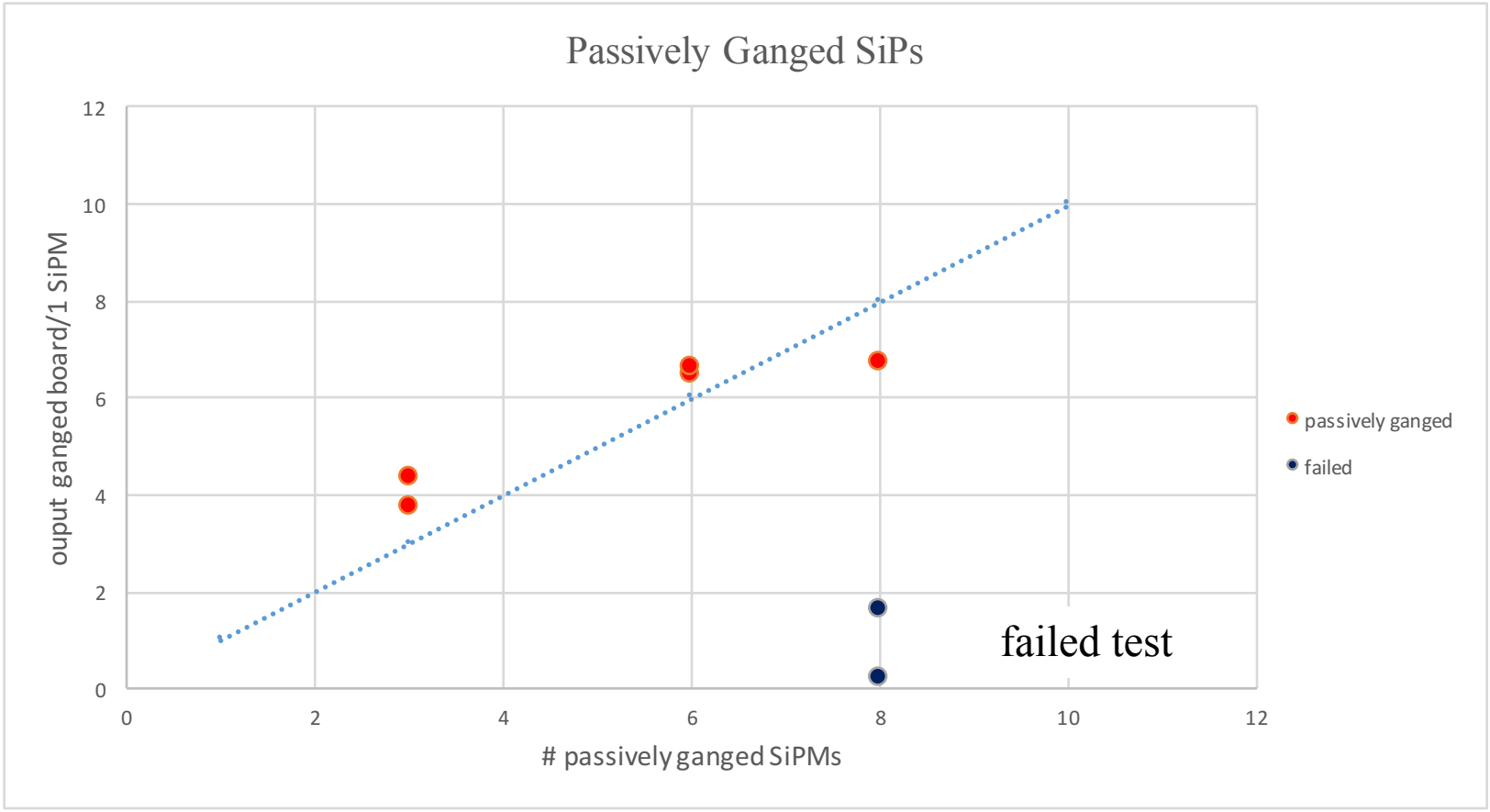


6 passively ganged SiPMs



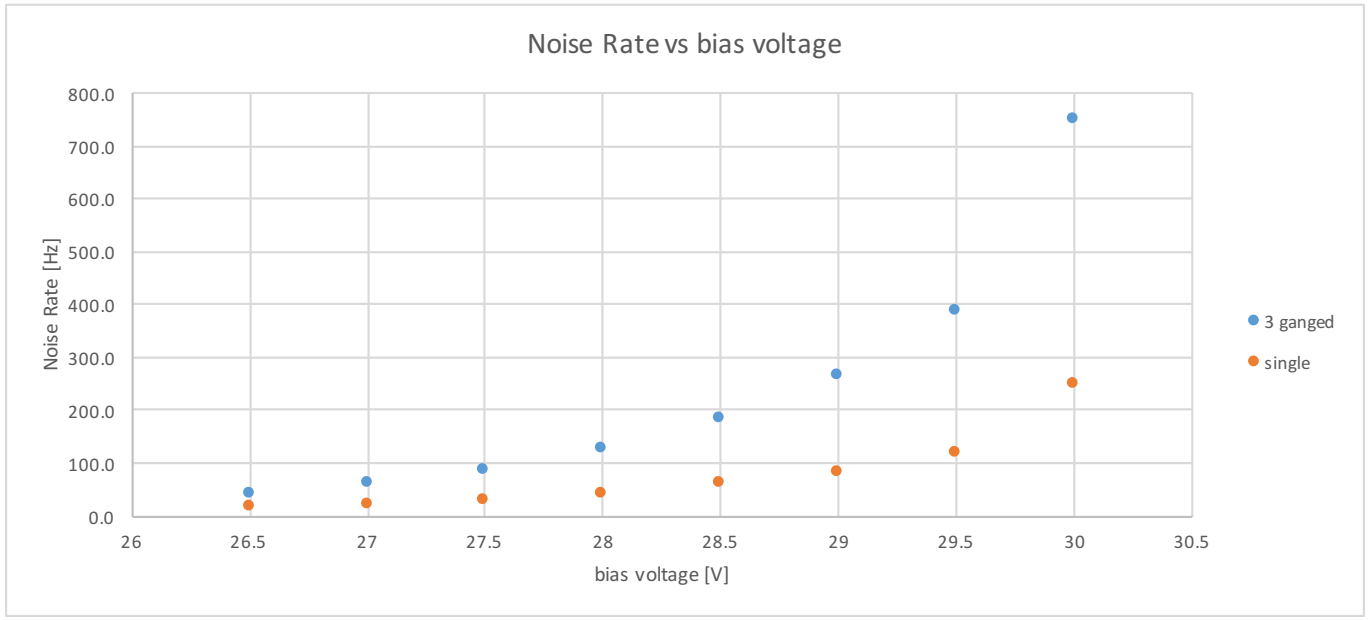
monitoring SiPM

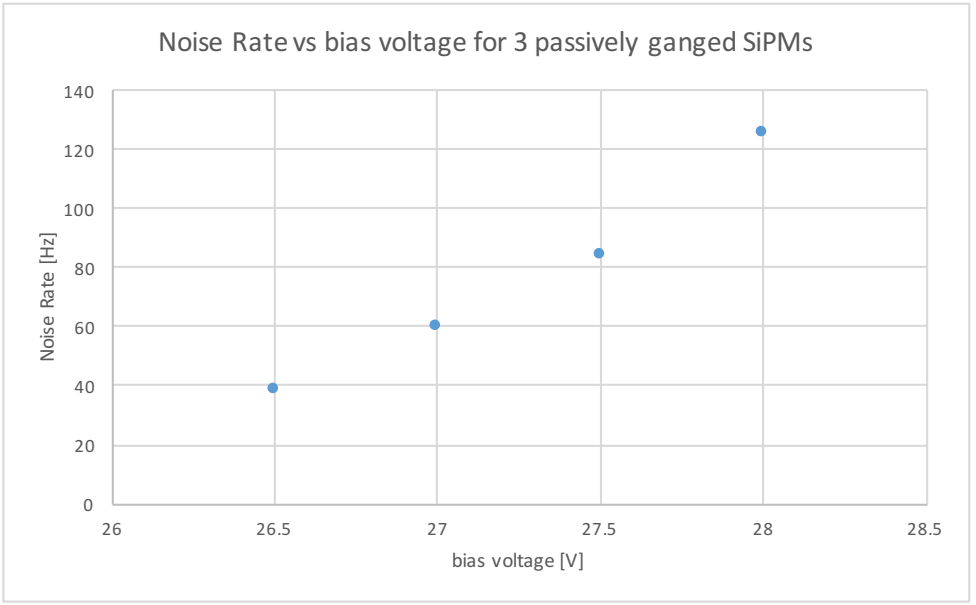
Response of passively ganged boards compared with response of 1 SiPM



Studied ganging 3 SiPMs most extensively because that is the configuration in protoDUNE

Dark Studies





noise rate (Hz) vs bias voltage for 3 passively ganged SiPMs

linear rise in noise from 26.5 V to 28 V bias for 3 passively ganged SiPMs

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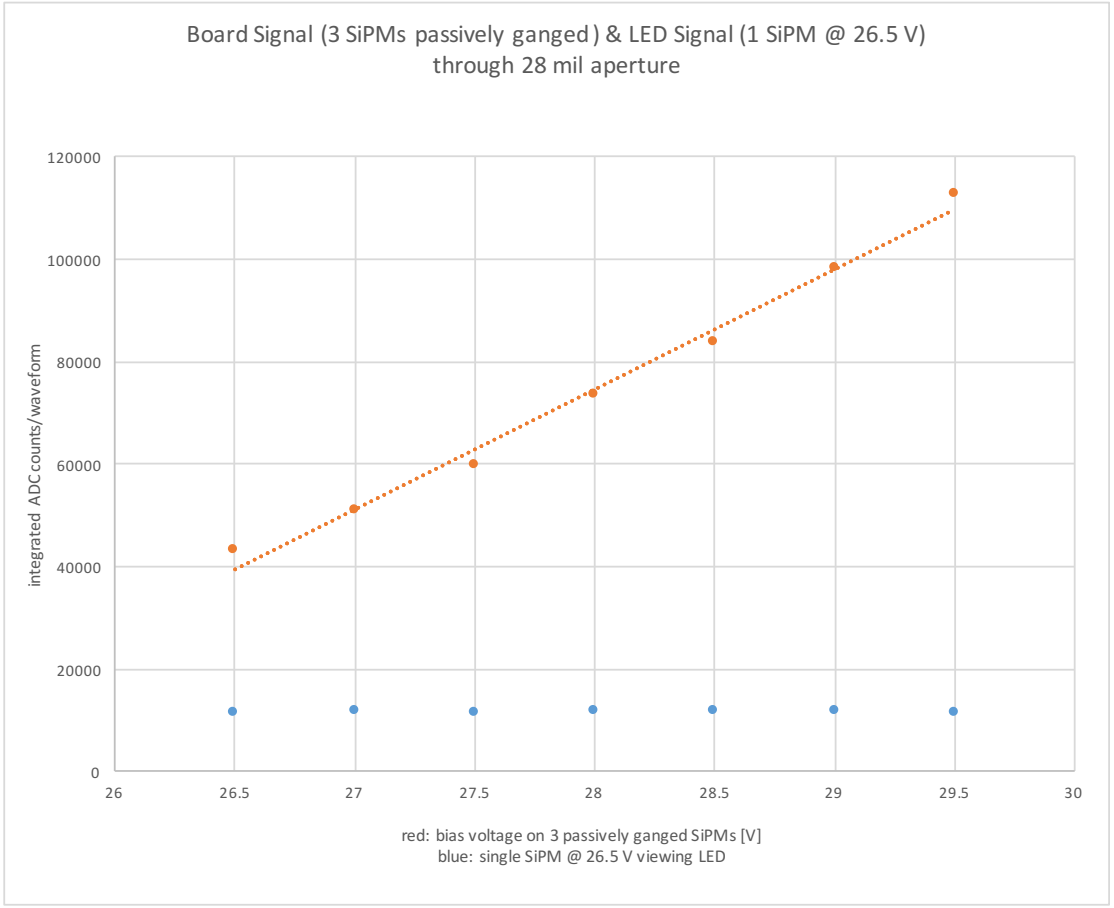
Signal Strength



Signal strength rises linearly with bias voltage as expected