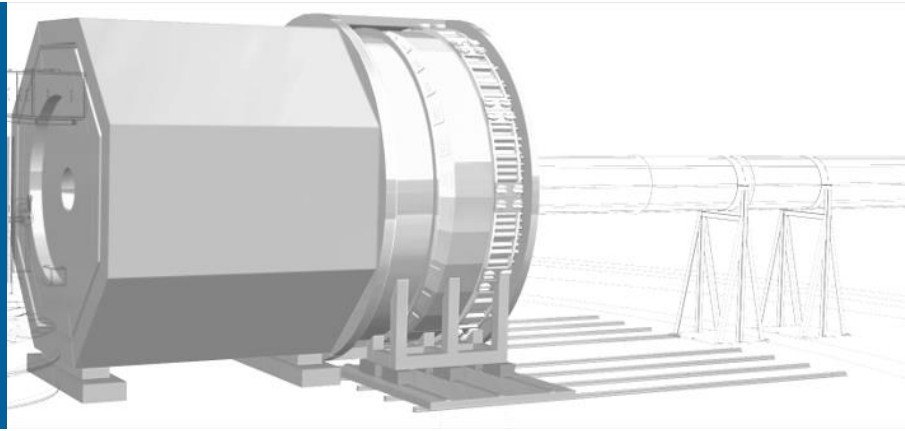
SoLID Collaboration Meeting 2021/06

ANALYSIS AND SIMULATION FOR THE BEAM TEST OF TELESCOPE CHERENKOV PROTOTYPE



CHAO PENG
Argonne National Laboratory

For SoLID Telescope Cherenkov Working Group

This work is supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357

06/10/2021

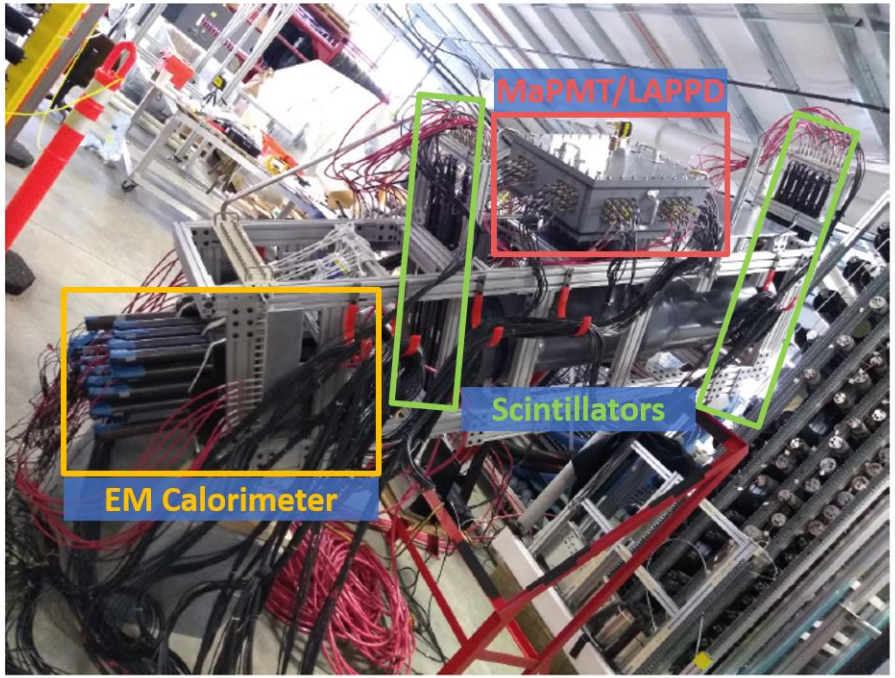
Outline

- Beam Test at Jefferson Lab
- Waveform Data Analysis
- Performance of LAPPD/MaPMT
- Summary and Plans

Telescope Cherenkov Detector Prototype

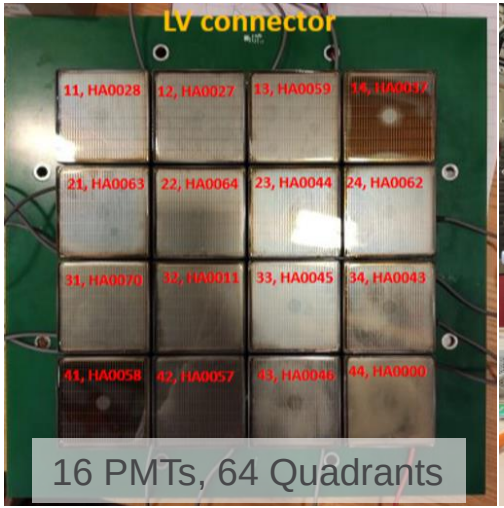
- Detector package includes
  - Cherenkov tank (CO_2 at 0.3 psi)
  - 2 scintillator planes
  - 9 calorimeter blocks
  - 16 MaPMTs (quadrant and sum channels) or LAPPD (64 pixels)

- Readouts: JLab FADC250
  - Raw waveform data recorded
  - 64 samples in 256 ns

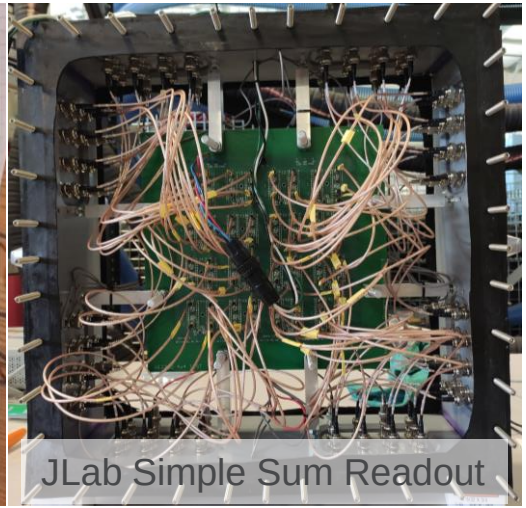


Photosensors

Hamamatsu MaPMT H12700-03

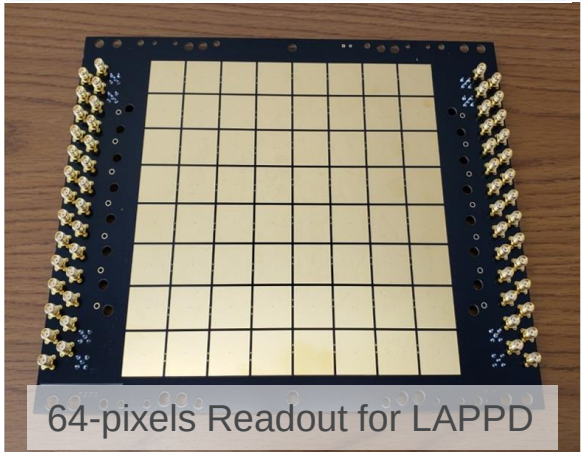


16 PMTs, 64 Quadrants


JLab Simple Sum Readout

Incom LAPPD Gen-II


Incom LAPPD 20x20 cm^2


64-pixels Readout for LAPPD

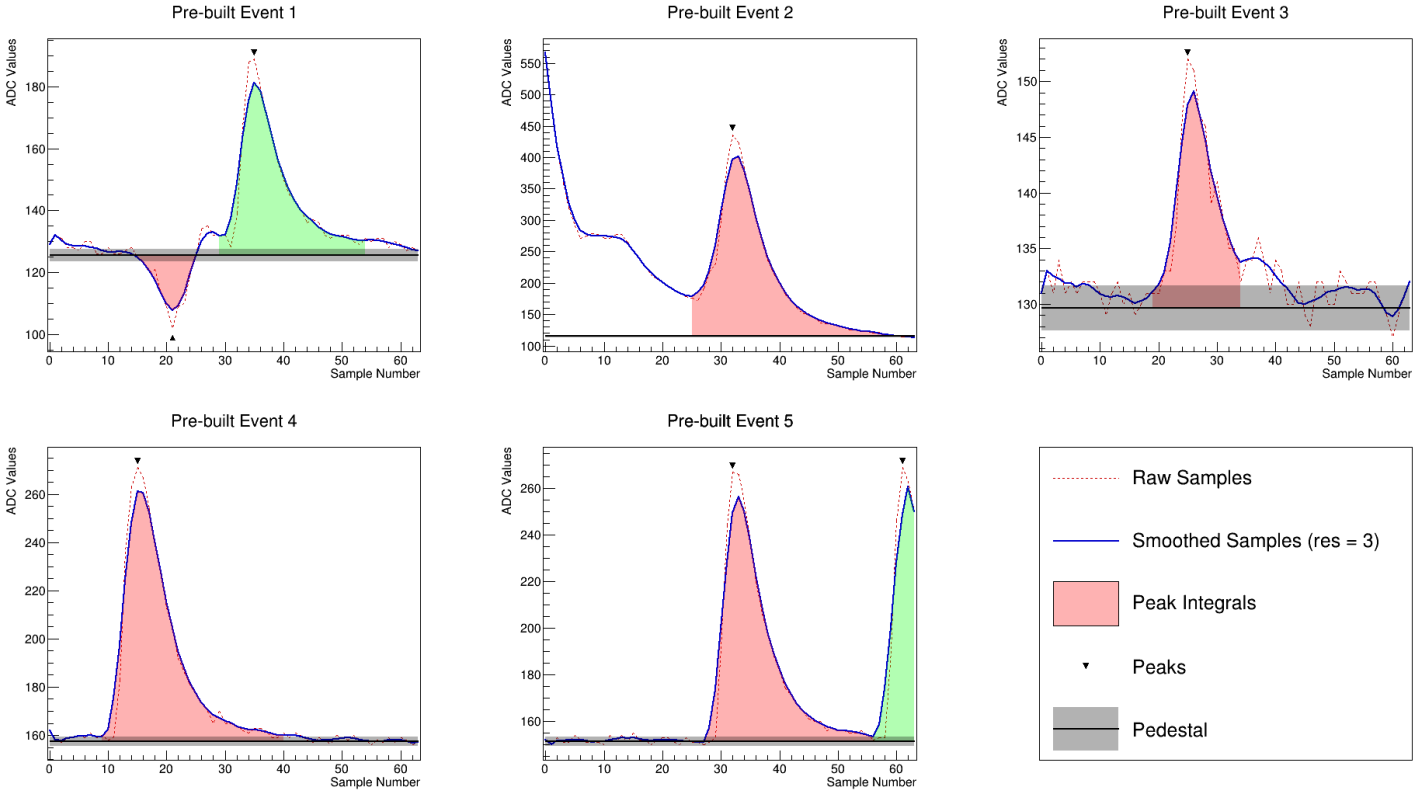
Refer to Bishnu's talk for MAROC readout

Beam Test at JLab

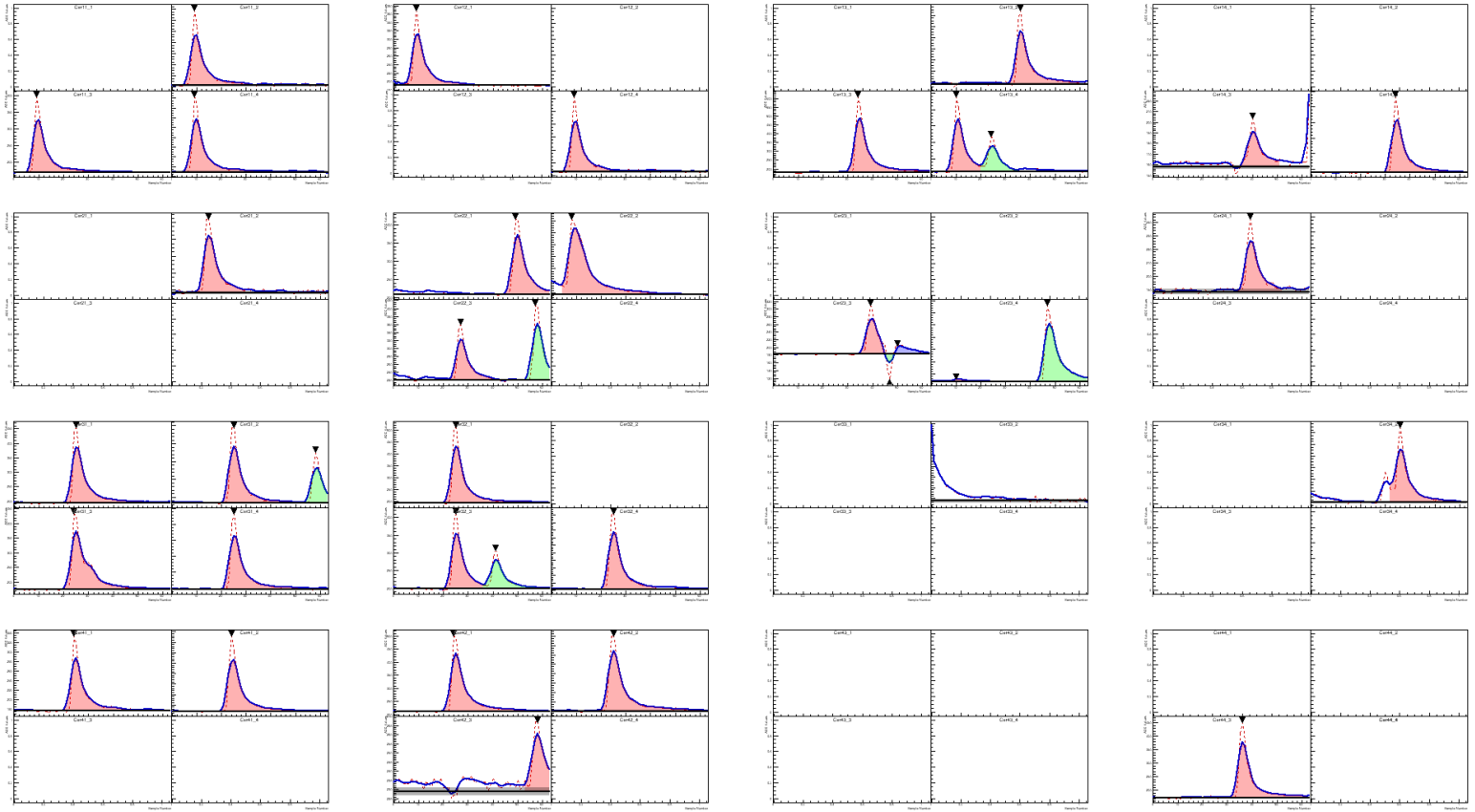
- High rate beam test
  - Parasitic runs in June - August, 2020
  - Small angle with 0.5 – 2 μA beam
  - MaPMTs tested with total rates > 8 MHz per PMT (300 kHz per cm^2)
- Low rate beam test
  - Parasitic runs in August - September, 2020
  - Large angle, rates is one order of magnitude lower
- Bench test for LAPPD and MAROC readouts
  - Analysis is ongoing

Waveform Data Analysis

- 64 samples
- Pedestal
- Peak height
- Peak integral
- Peak timing



Waveform Data Event Samples



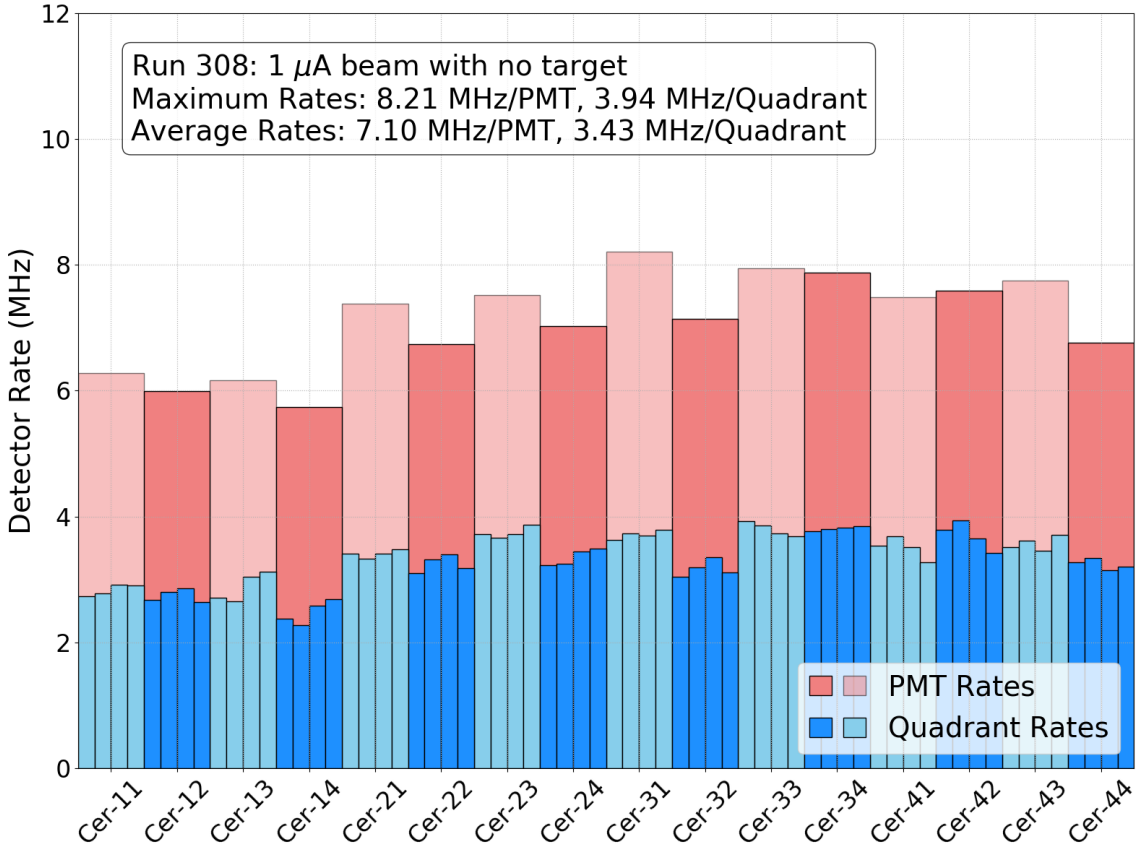
Total Rates from Pulser Triggered Runs

- Reference runs taken before production run
  - Triggered by pulser

- Total rates calculation

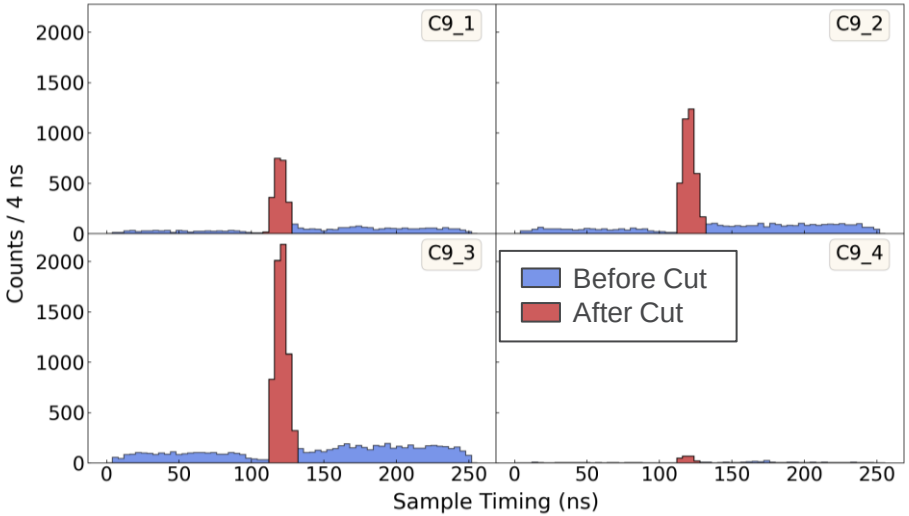
$$\frac{\overline{N_{peak}}\ per\ window}{T_{win}(256\ ns)}$$

- Peak height threshold
  - 0.25 SPE, max. 8 MHz/PMT
  - 1.0 SPE, max. 7 MHz/PMT

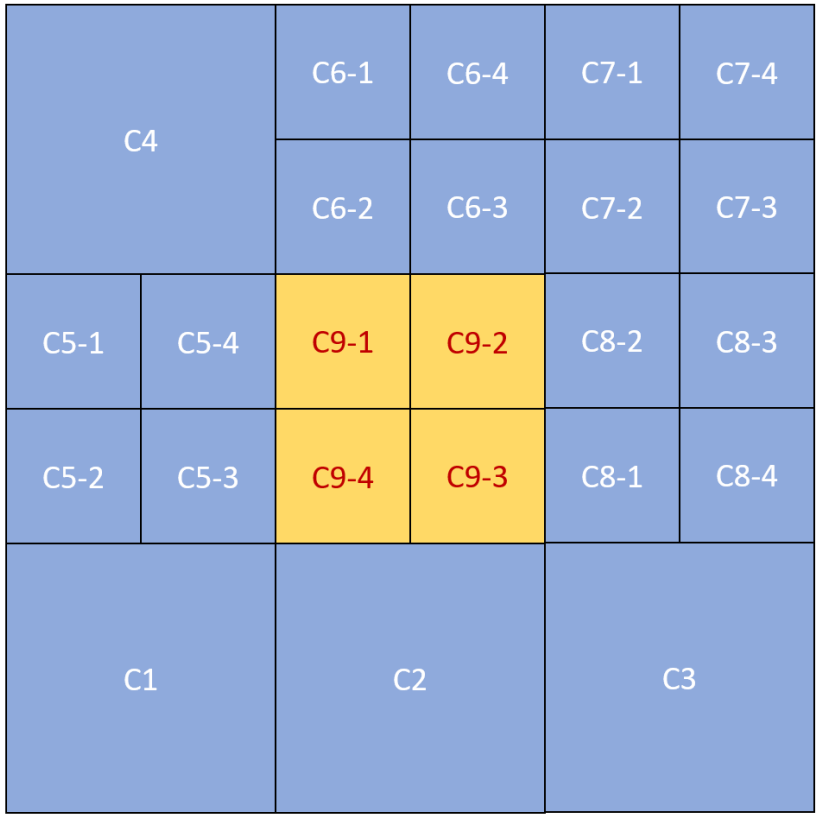


Calorimeter Trigger Cut

- Cut on central sub-blocks to select events with full acceptance
- Cut calorimeter timing with 20 ns window

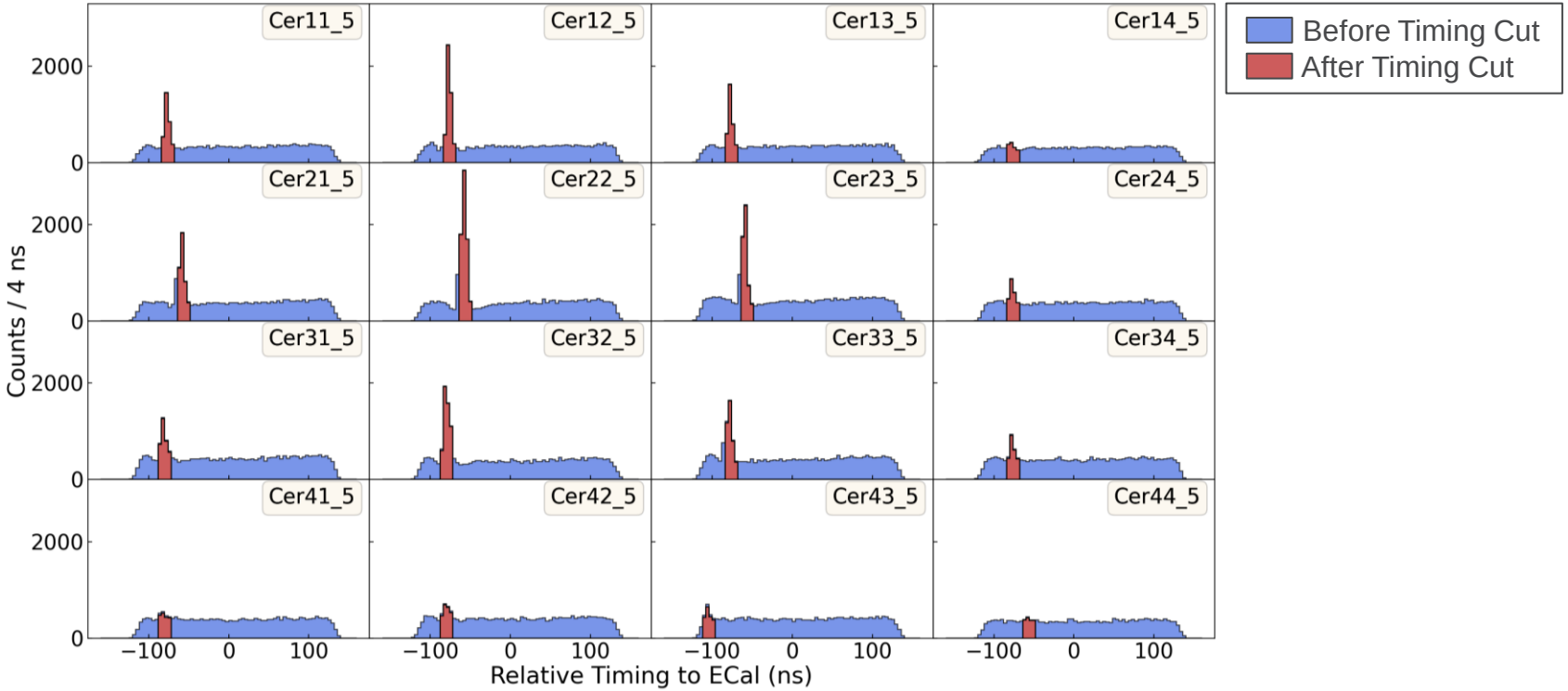


Back View

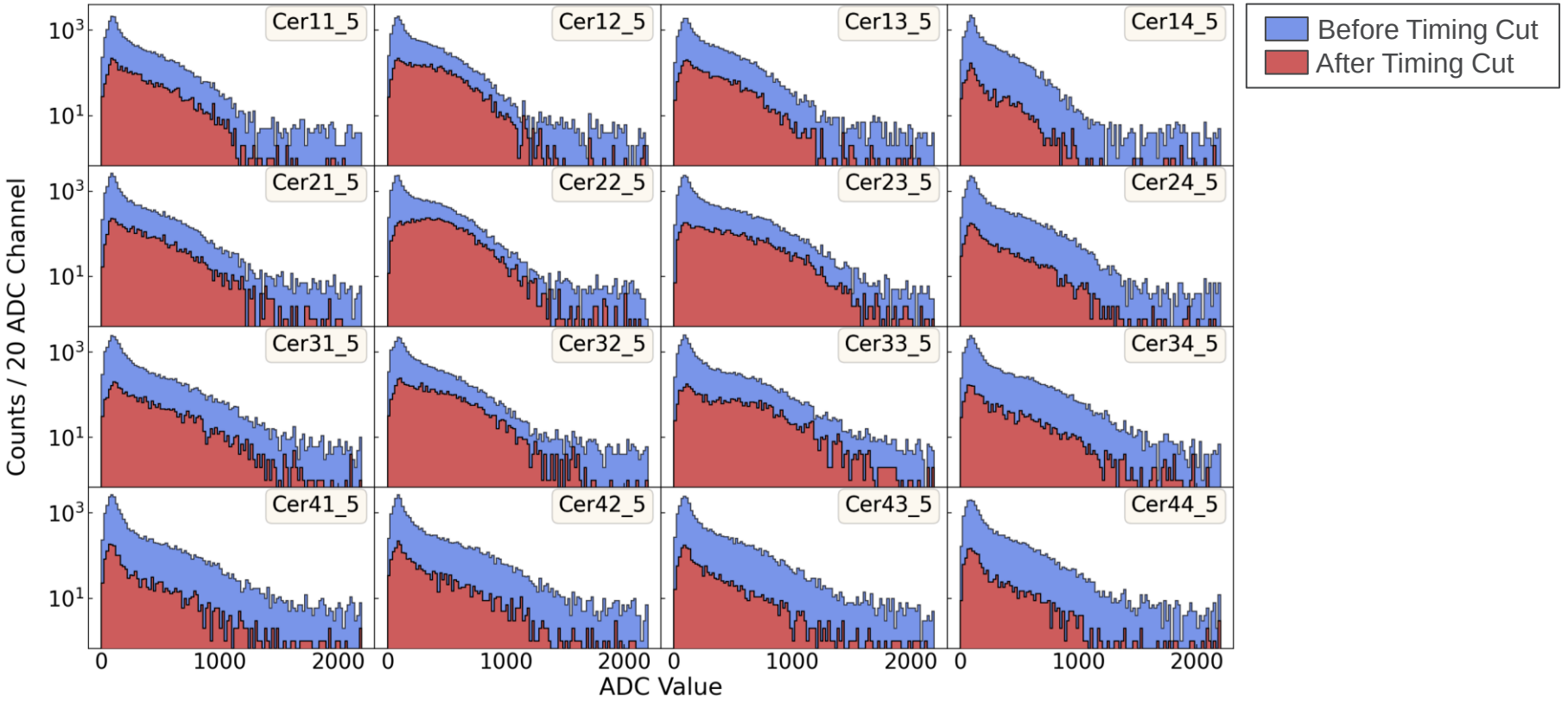


Signal Timing Cuts

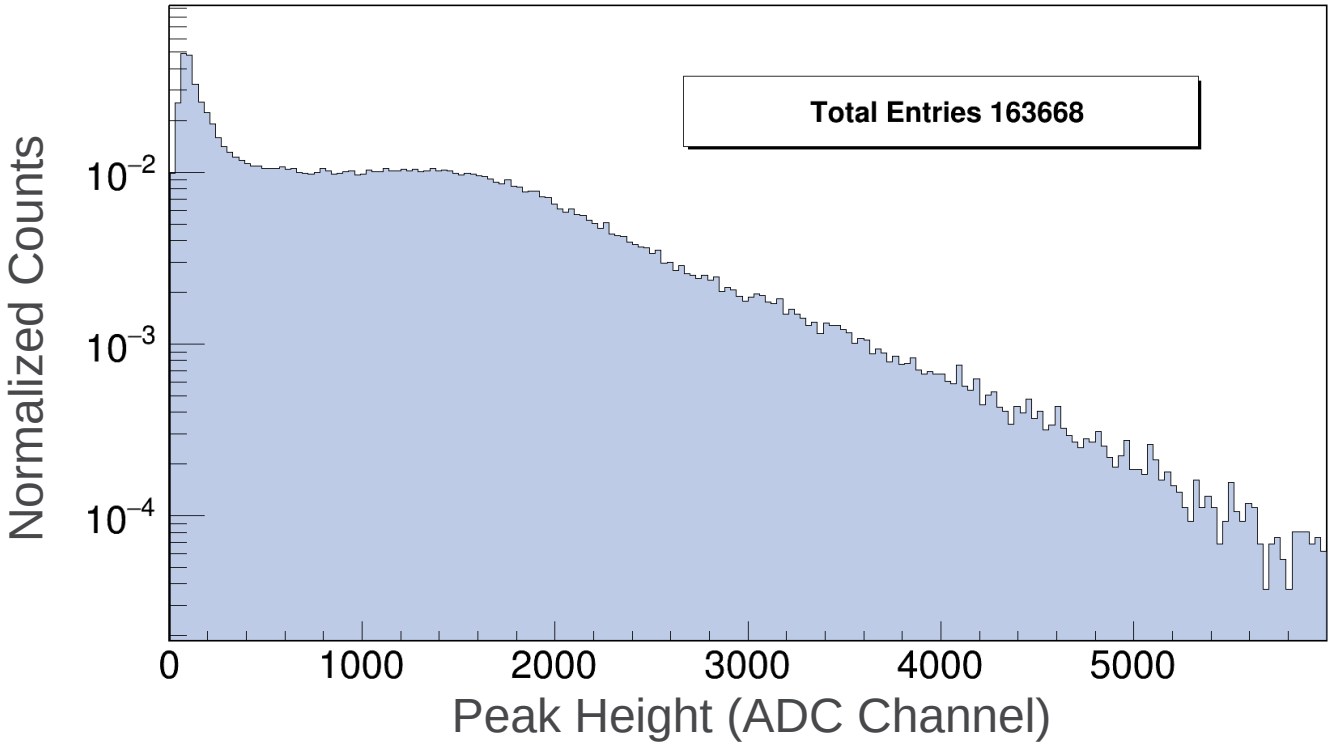
- Timing relative to the triggered calorimeter channel, ± 10 ns



Signal Height Distributions

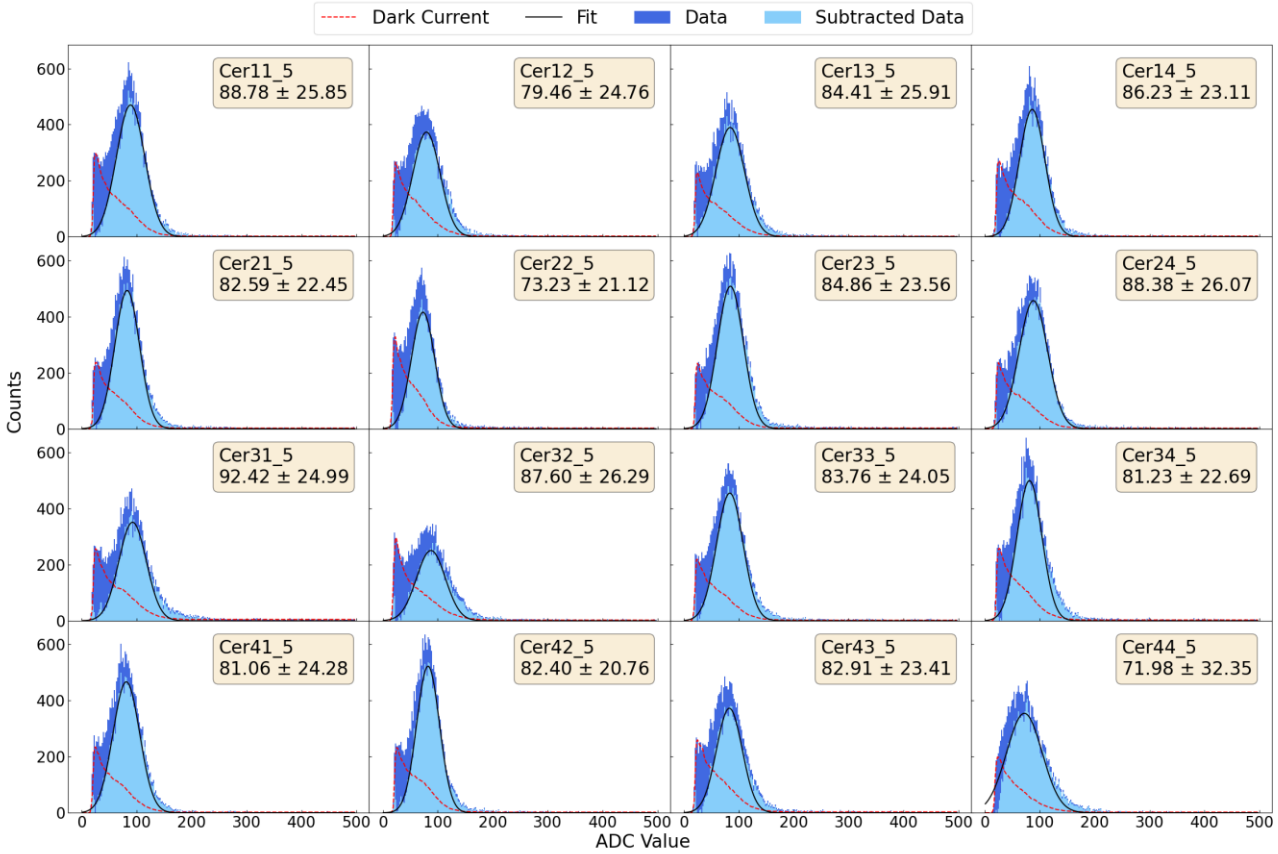


Signal Sum

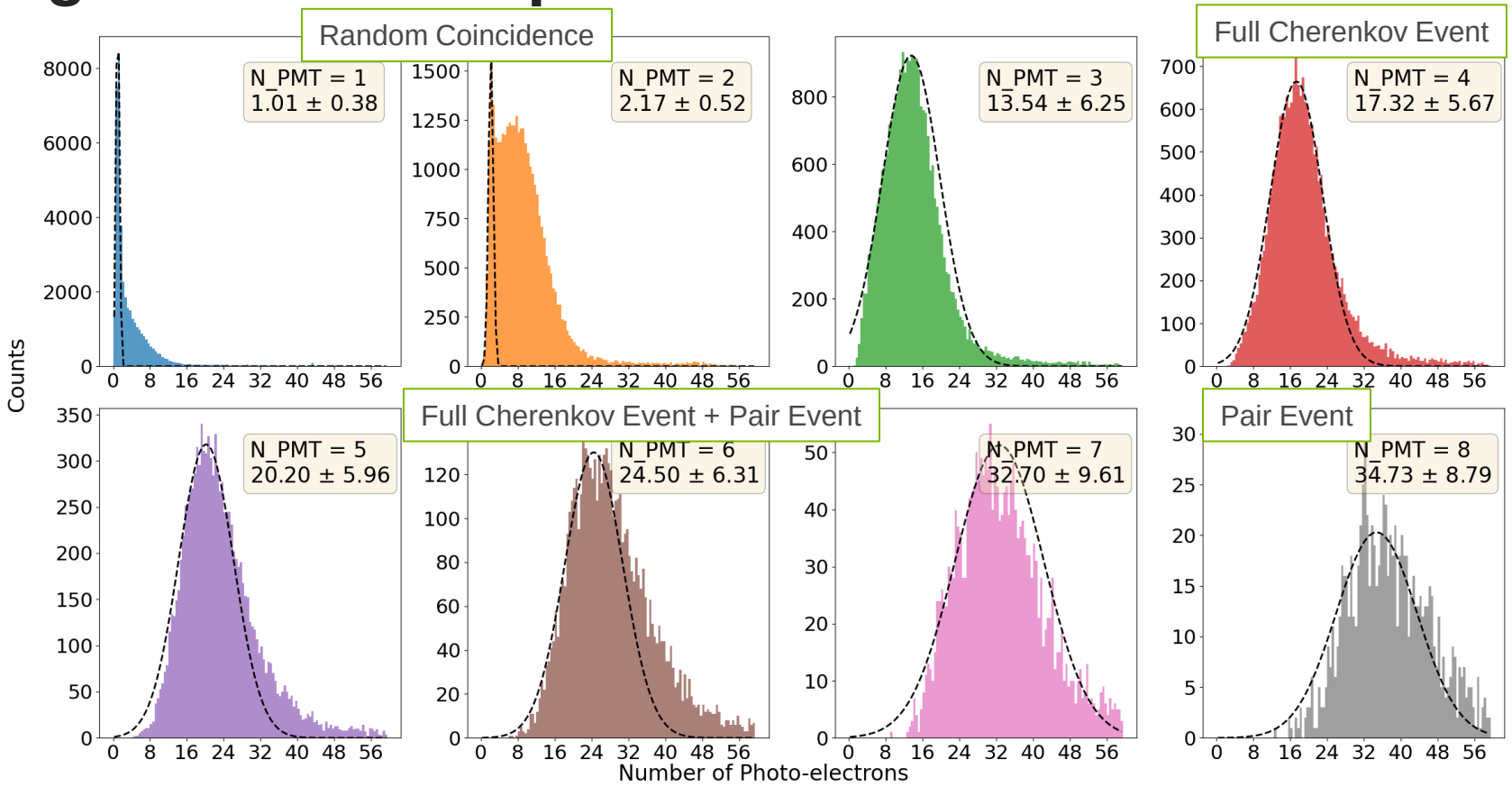

Total Entries 163668
Normalized Counts
10^{-2}
10^{-3}
10^{-4}
0
1000
2000
3000
4000
5000
Peak Height (ADC Channel)

Single Photo-Electron Signals

- Data off the timing cuts
- SPE ~ 80 ADC Channel
- Used to calculate NPE for each channel



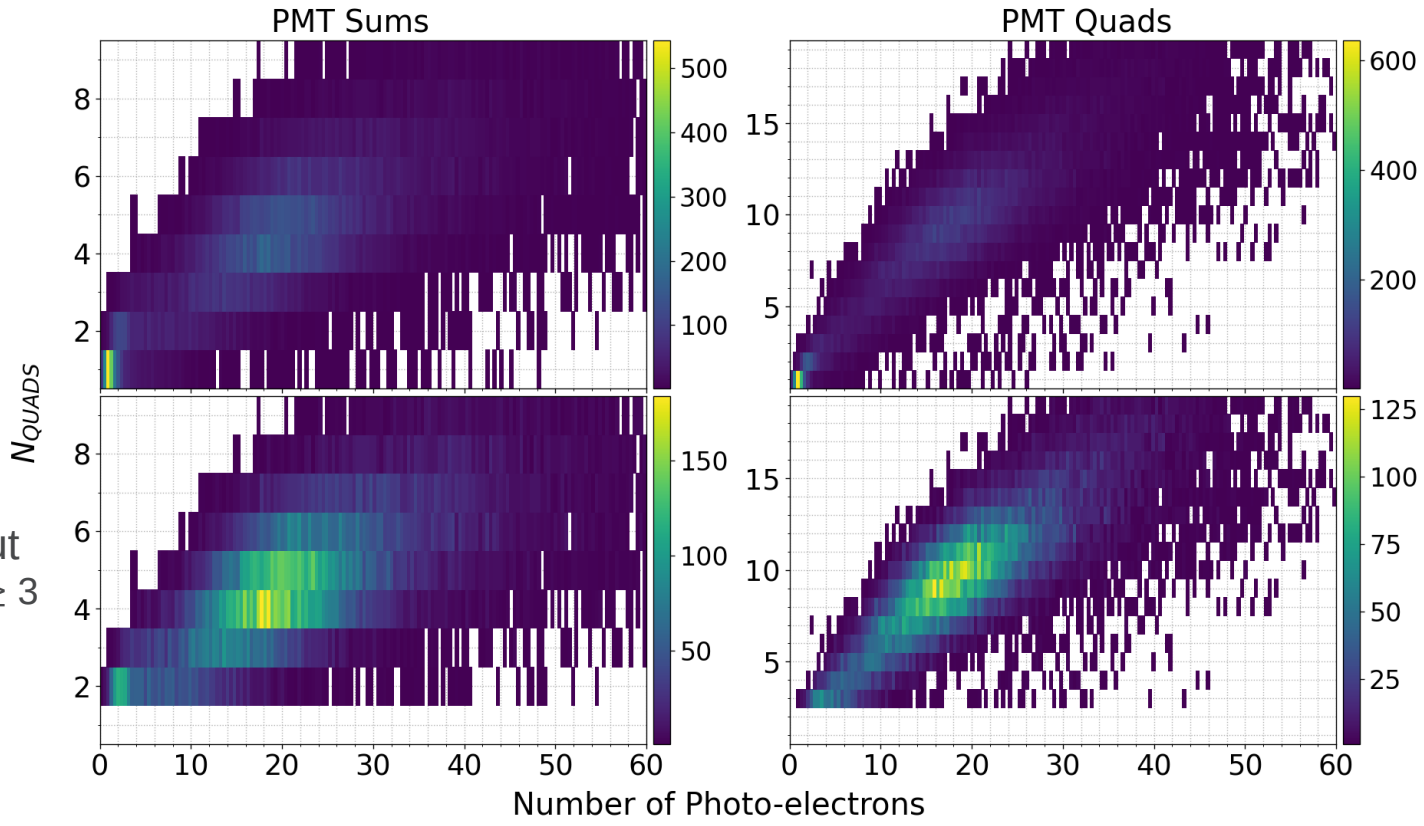
Signal Sum Groups



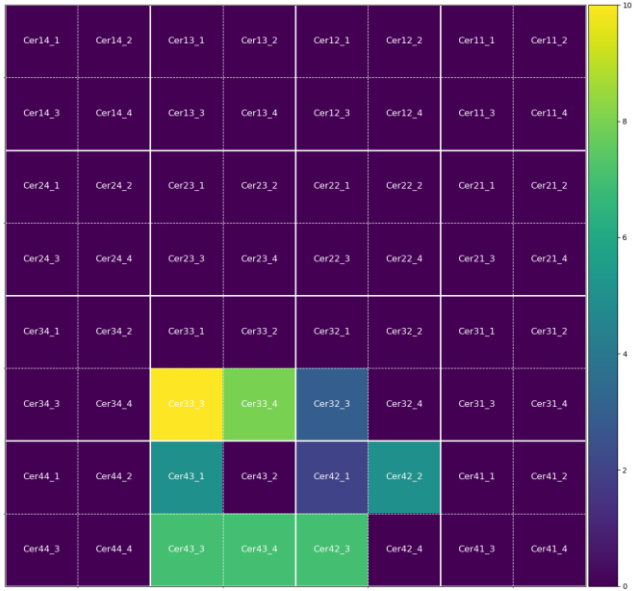
MaPMT Performance

- Signal Center
  NPE = 18
  N_{PMT} = 4
  N_{Quad} = 9,10

- Coincidence Cut
  $N_{PMT} \geq 2$, or $N_{Quad} \geq 3$



Event Samples



Cherenkov Signal

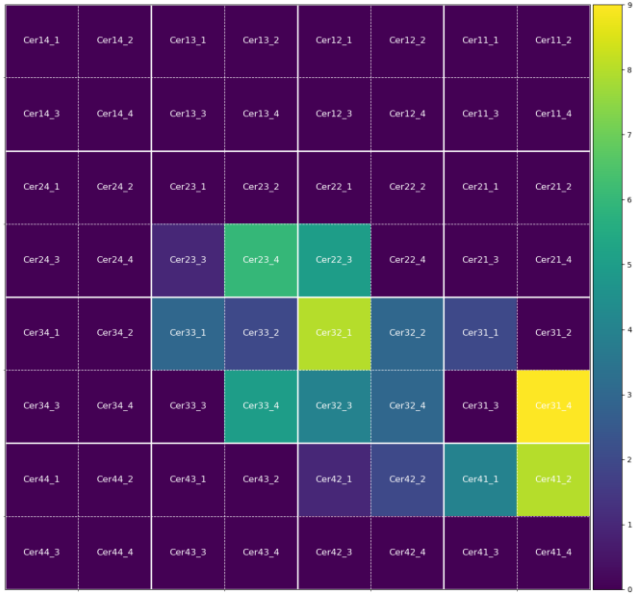
4 PMT Sum Channels

9 Quadrant Channels

Pair Production Signal

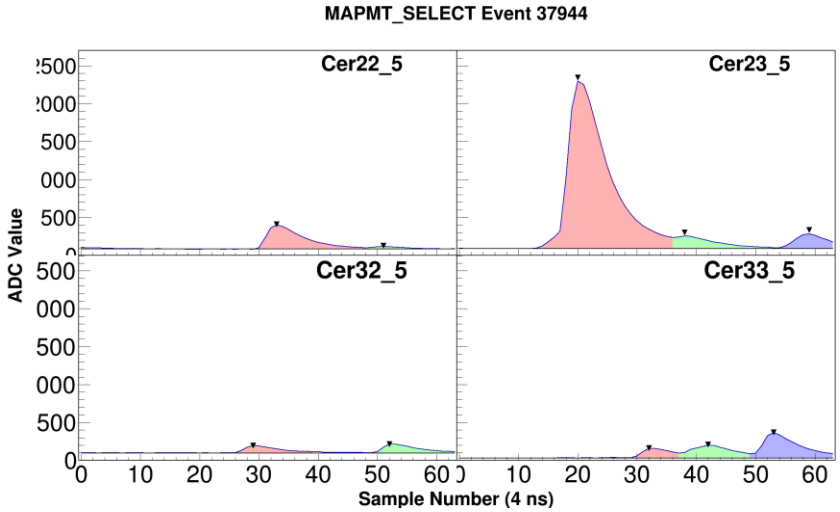
7 PMT Sum Channels

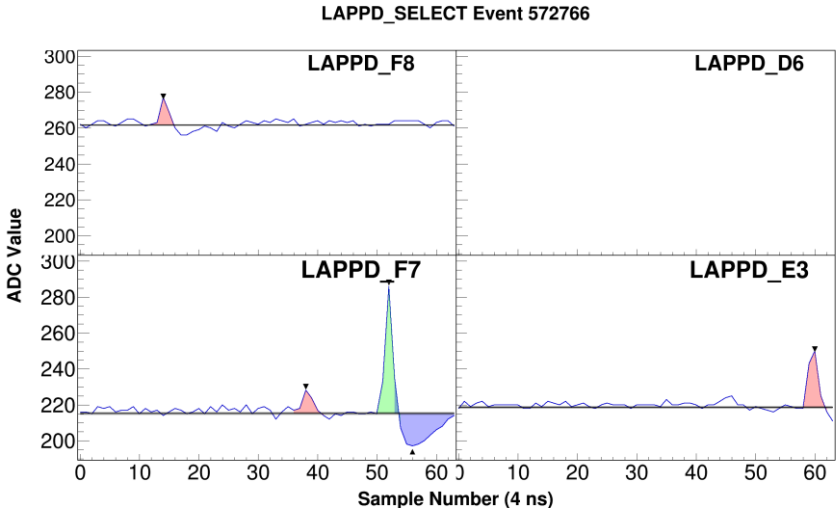
16 Quadrant Channels



MaPMT/LAPPD Comparison

- LAPPD signals are much narrower, but with lower amplitudes

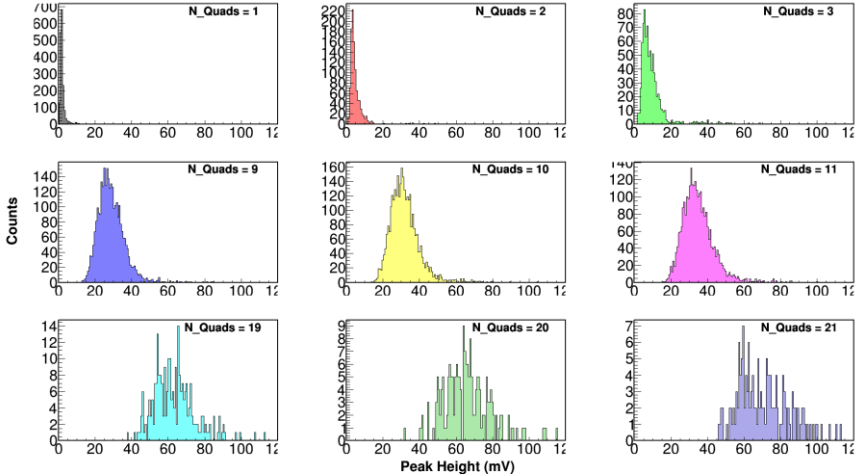




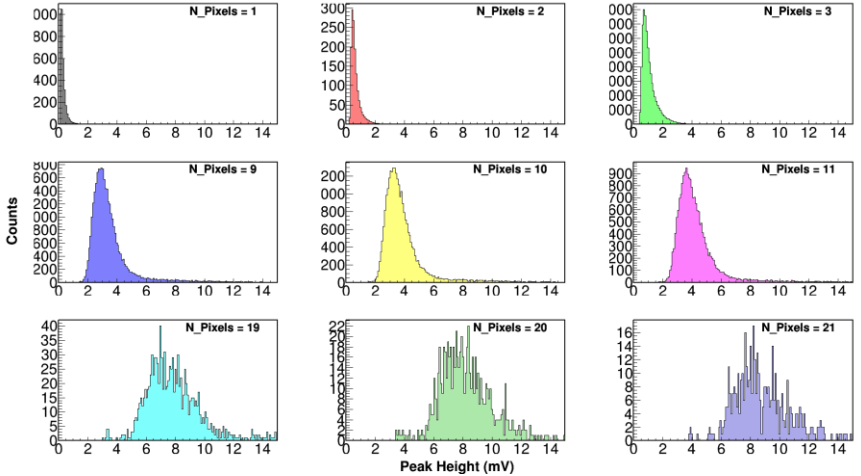
MaPMT/LAPPD Comparison

- Similar analysis has been performed on LAPPD data (low rate)
- LAPPD results behave similarly to MaPMT (low rate)
- Signal amplitudes are significantly lower in beam-test than that in gain-matching

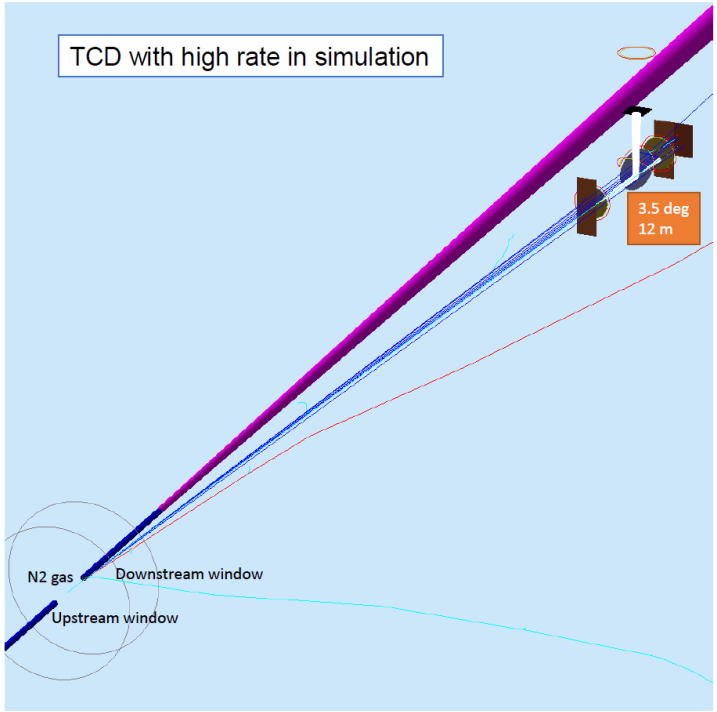
MaPMT



LAPPD



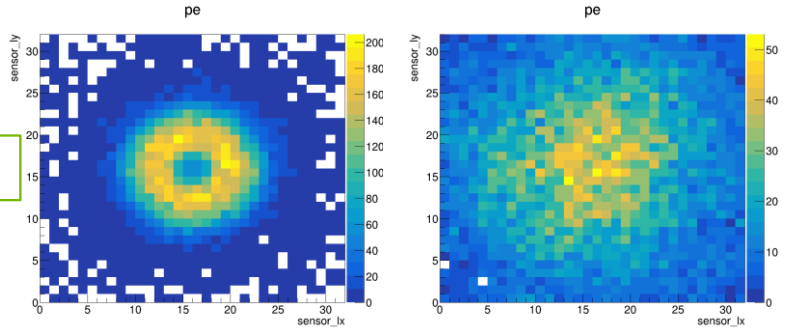
Simulation



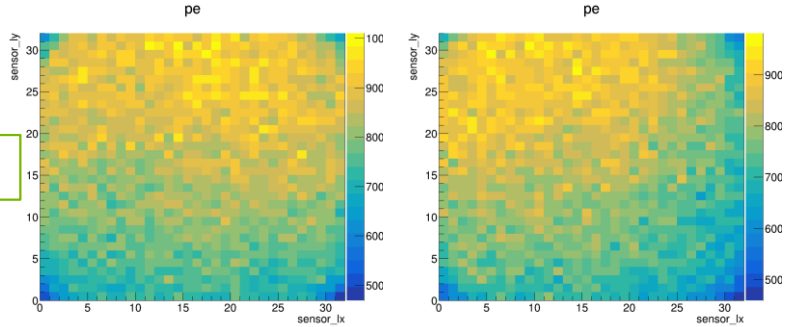
TCD only

TCD + beamline

e central



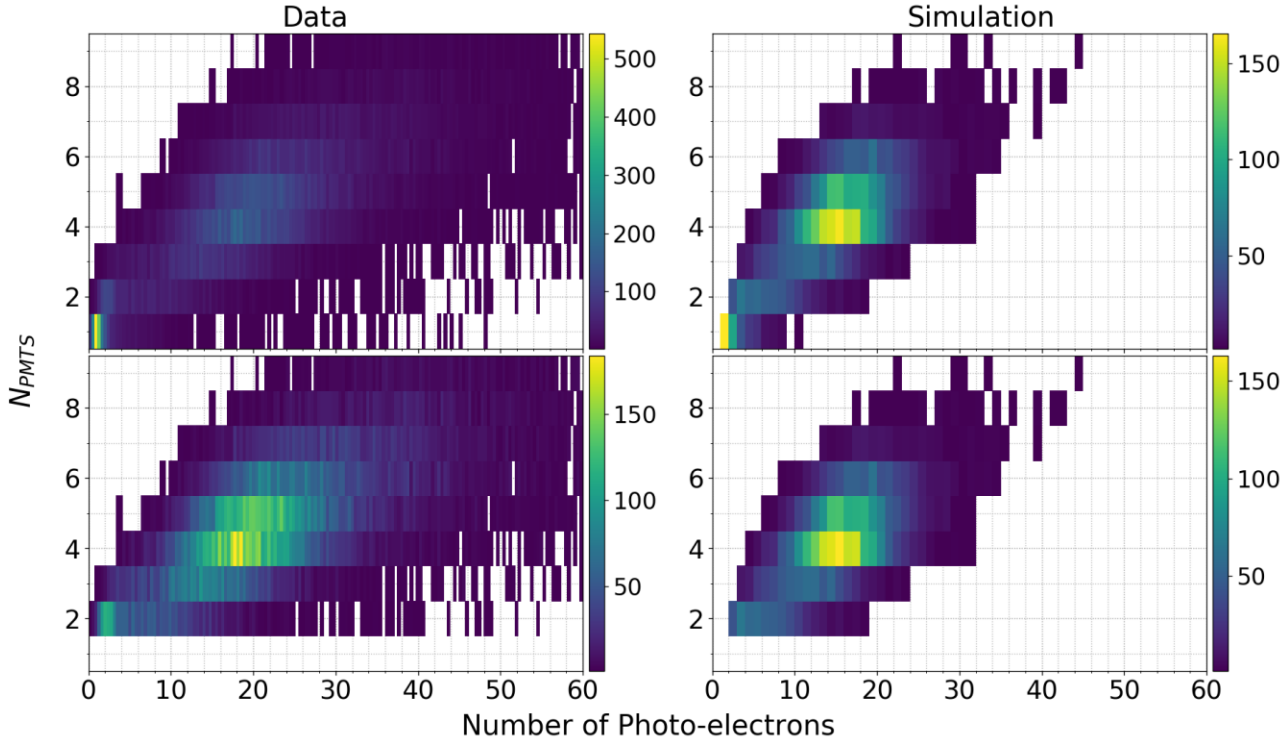
e broad



Courtesy of Zhiwen Zhao

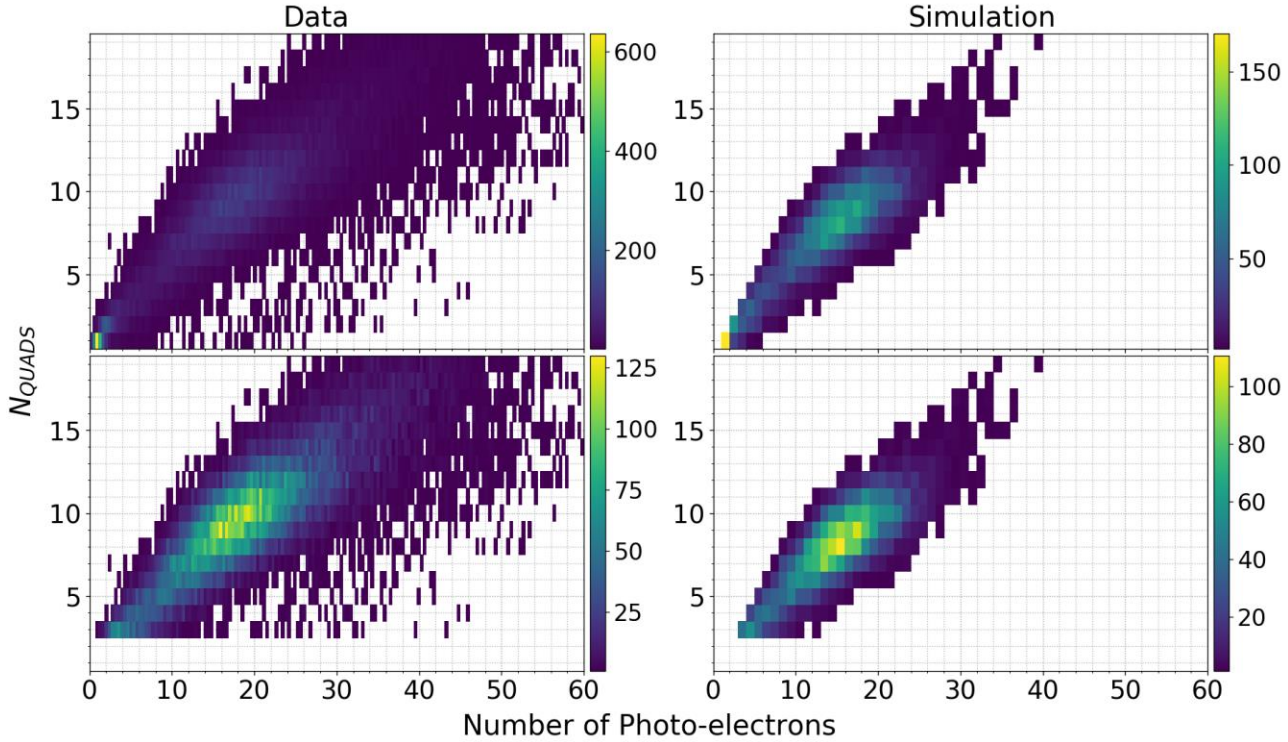
Simulation vs. Data

- Simulation results of NPE scaled by 0.6



Simulation vs. Data

- Simulation results of NPE scaled by 0.6



Summary and Plans

- MaPMT works well in a high-rate environment of 300 kHz per cm^2
  - Satisfy the requirement
  - Majority of the random background can be rejected by requiring coincidence between different PMTs/Quadrants

- LAPPD exhibits a similar performance
  - High magnetic field tolerance, narrow signal
  - Significantly lower amplitudes from beam-test data than that from oscilloscope

- Plans
  - Comparison study of MaPMT high-rate test taken with different beam currents
  - Investigate the “0.6” factor needed for simulation to match the data
  - Investigate the LAPPD signal amplitudes with bench test data