Cherenkov Prototype Test Data (Mode 1) Analysis

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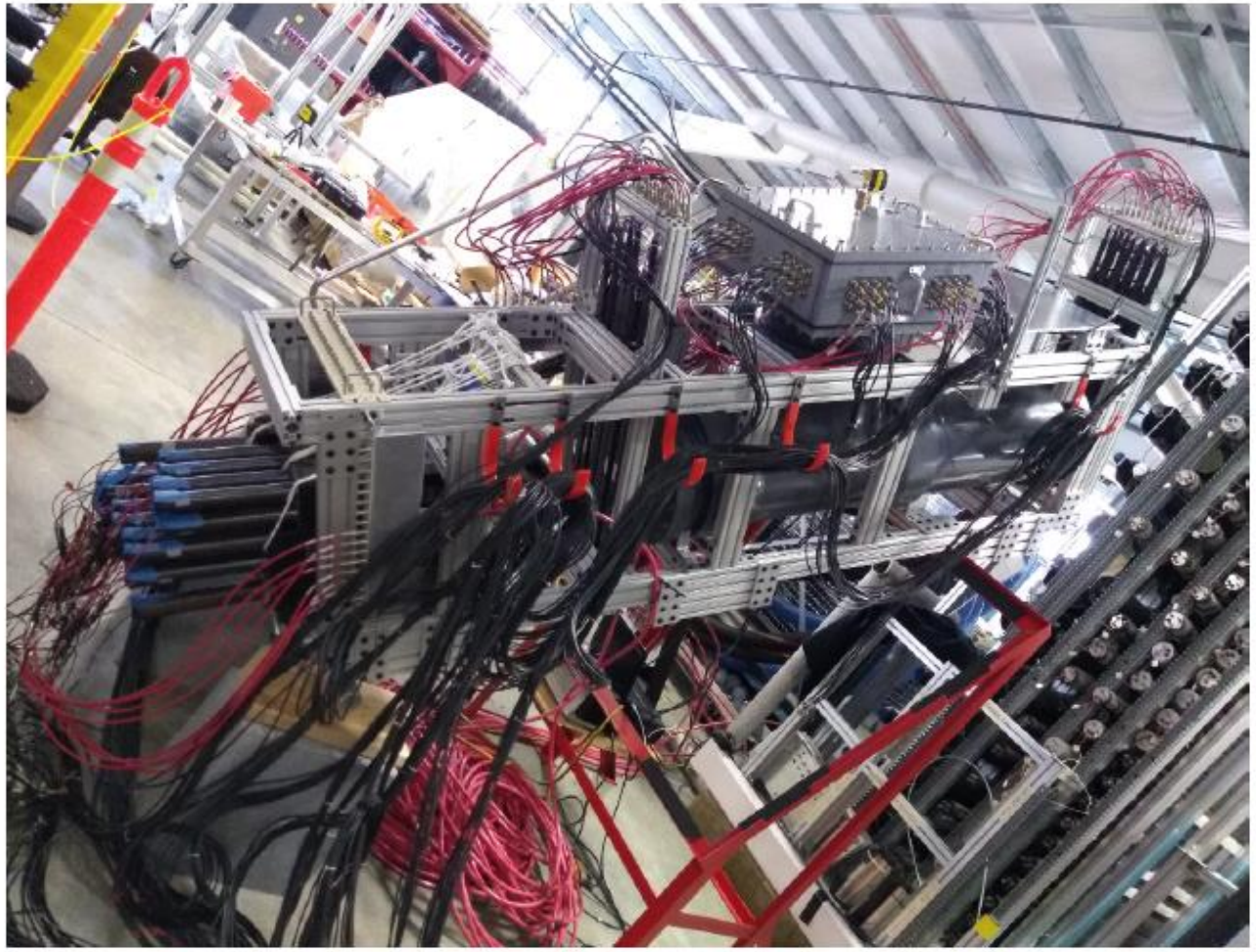
05/04/2020

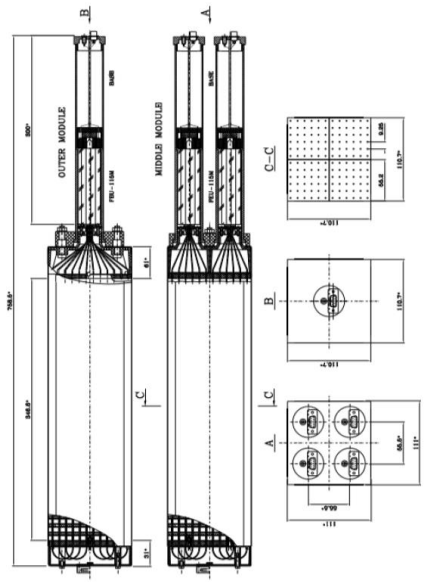
Cherenkov Prototype Detector

- Detector package includes
  - Cherenkov tank (CO_2 at 0.3 psi)
  - 2 scintillator planes
  - 9 calorimeter blocks
  - 16 maPMTs (5 channels: 4 pixels and 1 sum)
- Readouts: JLab FADC250



Plots from the quarterly progress report 1

Trigger channel alignment



Plots from the quarterly progress report 1

S11 S1

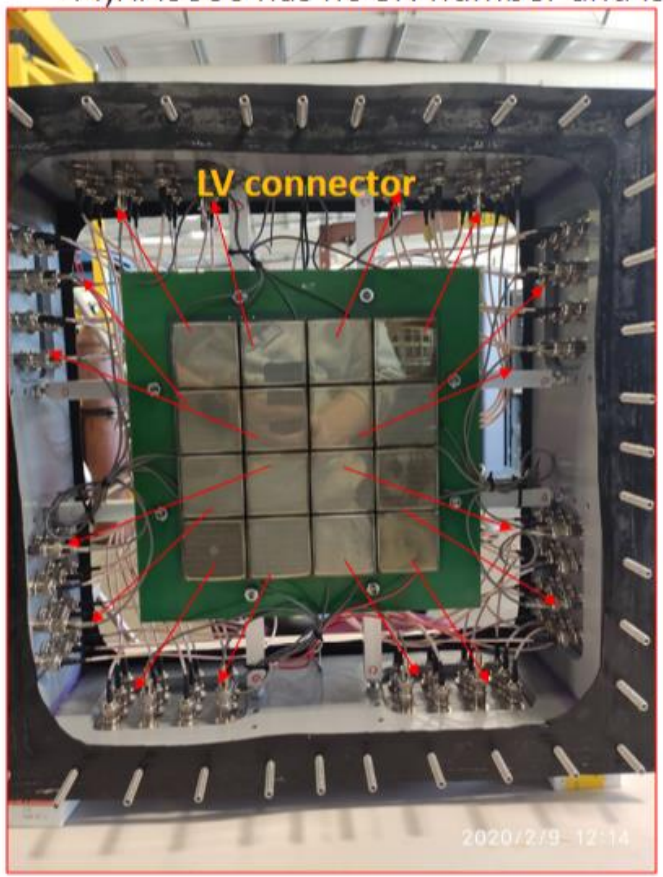
Top left

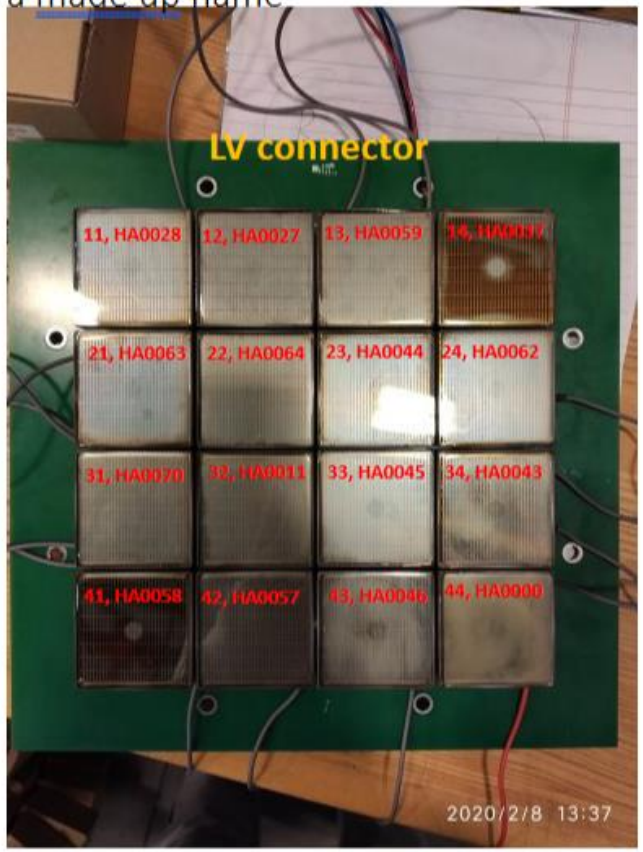
4	6-1 6-4 6-2 6-3	7-1 7-4 7-2 7-3
5-1 5-4 5-2 5-3	9-1 9-2 9-4 9-3	8-2 8-3 8-1 8-4
1	2	3

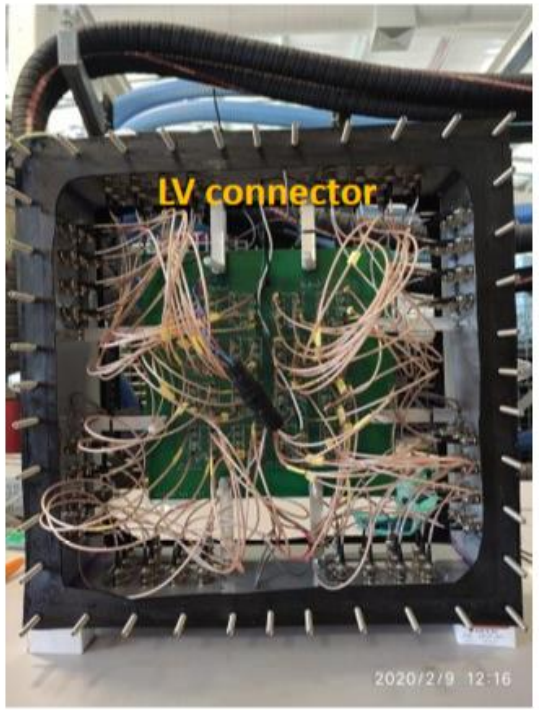
Channel alignment

MaPMT imple sum readout layout

- ID by Row and Column in position with matching MaPMT SN
- 14,HA0037 and 41,HA0058 WLS coating seem not good
- 44,HA0000 has no SN number and is a made up name







Plots from the quarterly progress report 1

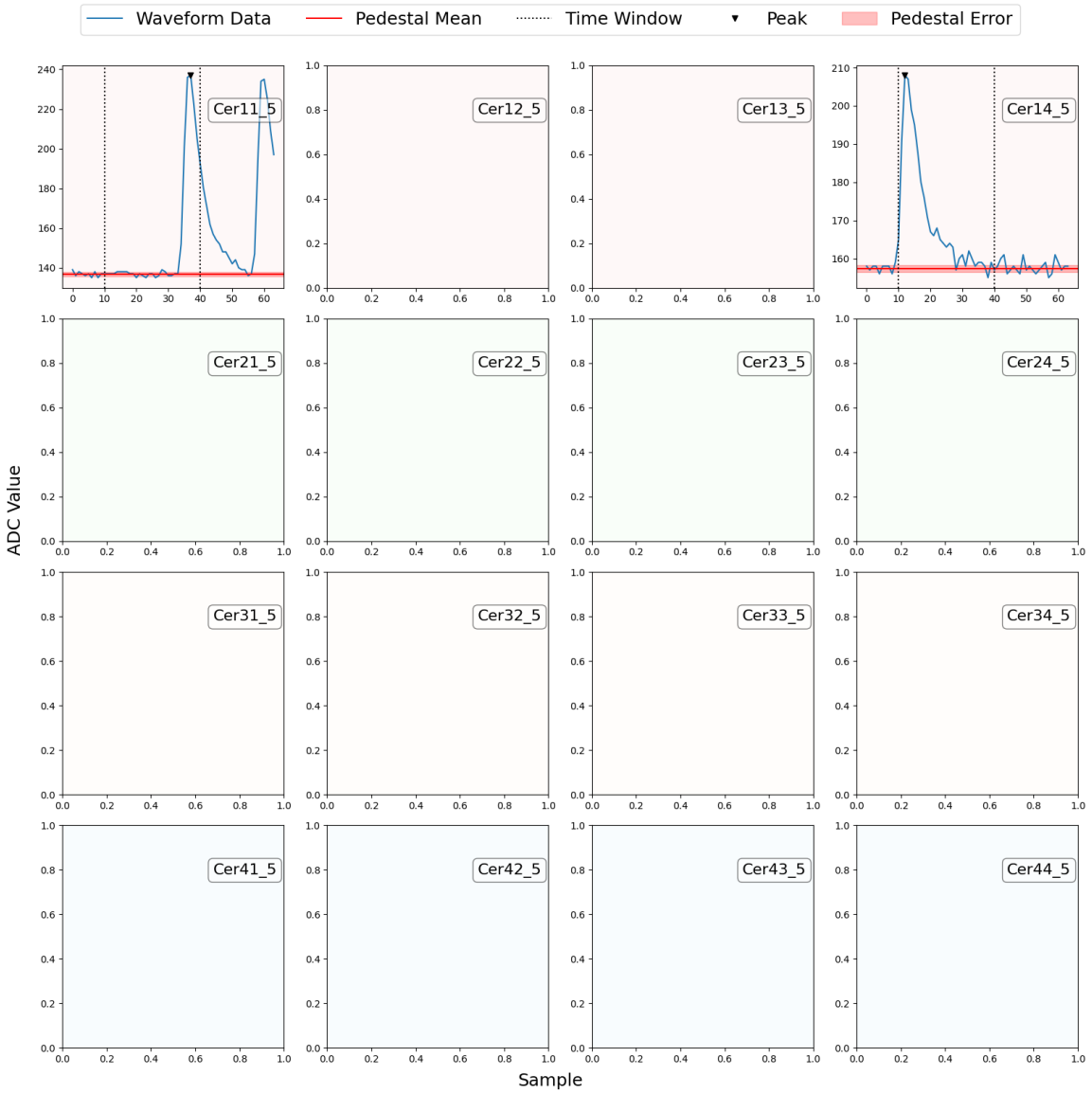
Recent Test in Hall C, JLab

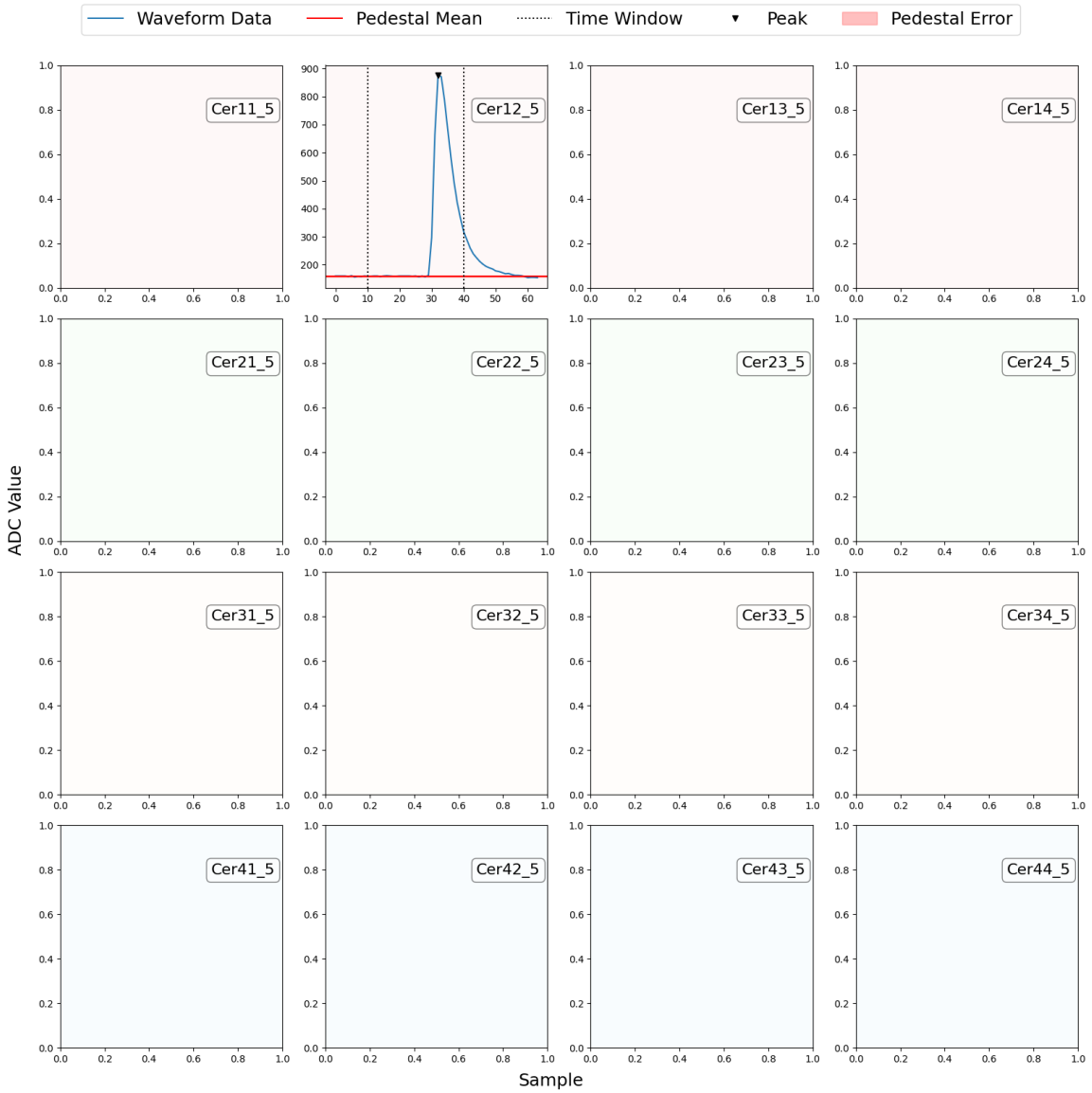
- Installation in Hall C
  - Not to interfere with the current experiment
  - Roughly 105 degree w.r.t the beamline, about 17 degree away from the target
- Took data for 2 days of beamtime before the COVID-19 shutdown
  - Multiple mode 3 (pulse integral + timing) runs and a few mode 1 (waveform) runs
- **MODE 1 Beam golden Runs - CO2; all detector channels ON** - S2 + calo
  - ***Run 158***: 30uA on multi-foil carbon target, Steve Wood took scaler rates before the run
  - ***Run 160***: 30uA on PolHe3 target, took scaler rates before this run
- Run 160 results are presented

Waveform Analysis

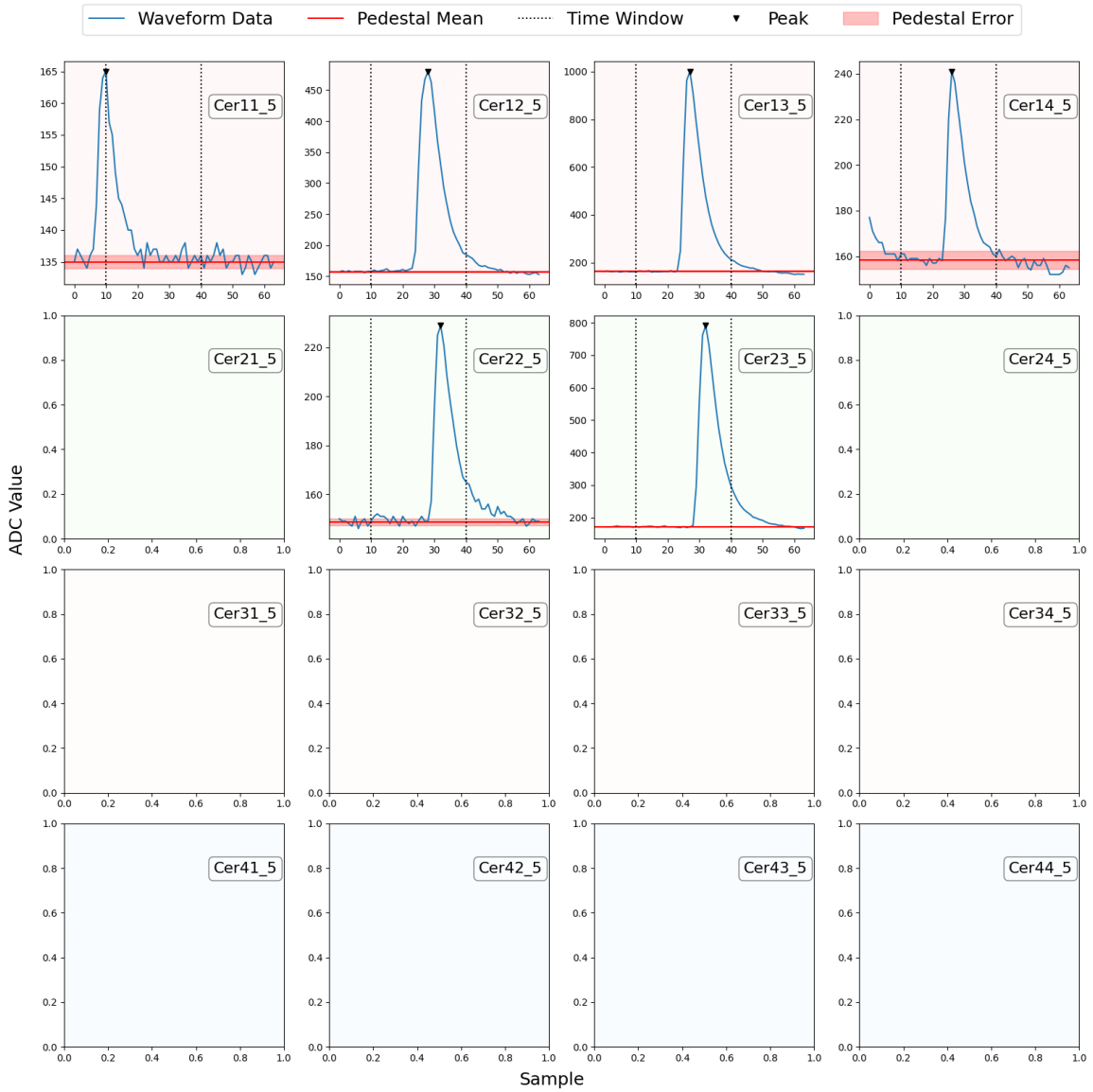
- Fit the pedestal from the samples
  - Exclude peaks and calculate mean and standard deviation for the rest of the samples
- Subtract the pedestal and find peaks
  - Peak heights, peak positions (timing) are extracted
- If given a timing window, the highest peak in this window is selected
  - Must higher than 5 times of the pedestal’s std. err.

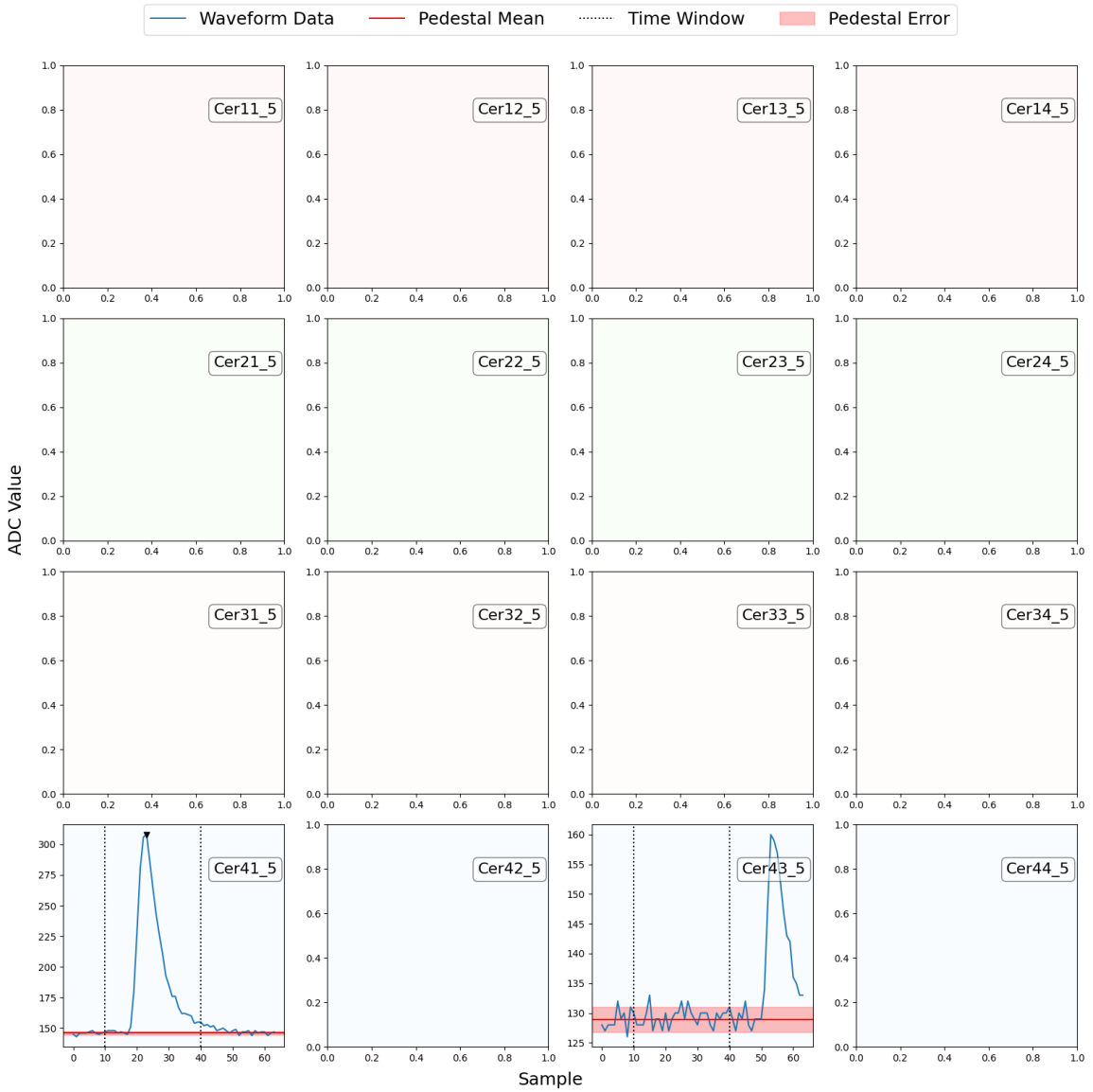
Waveform Analysis – Examples 1



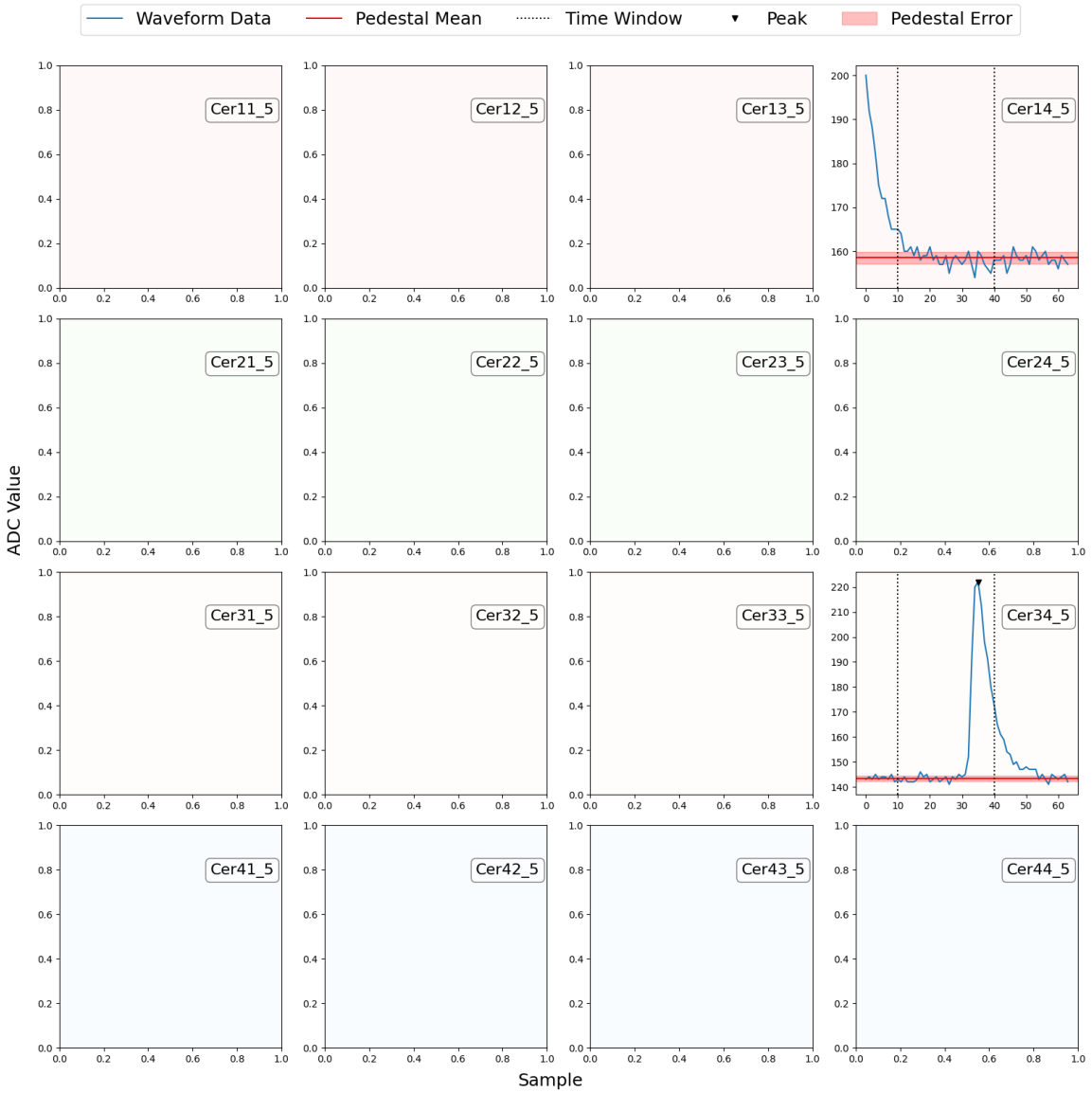


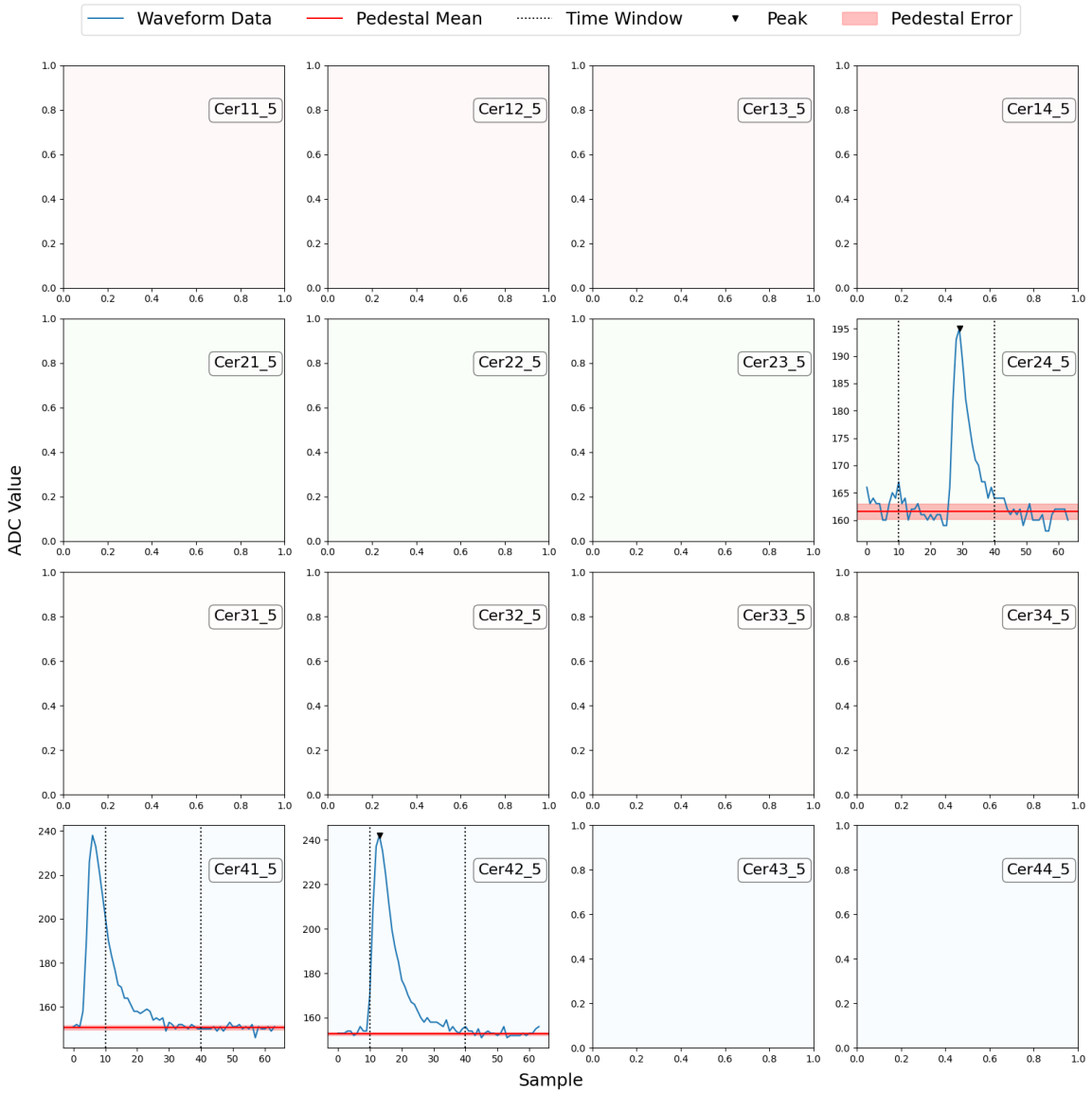
Waveform Analysis – Examples 2



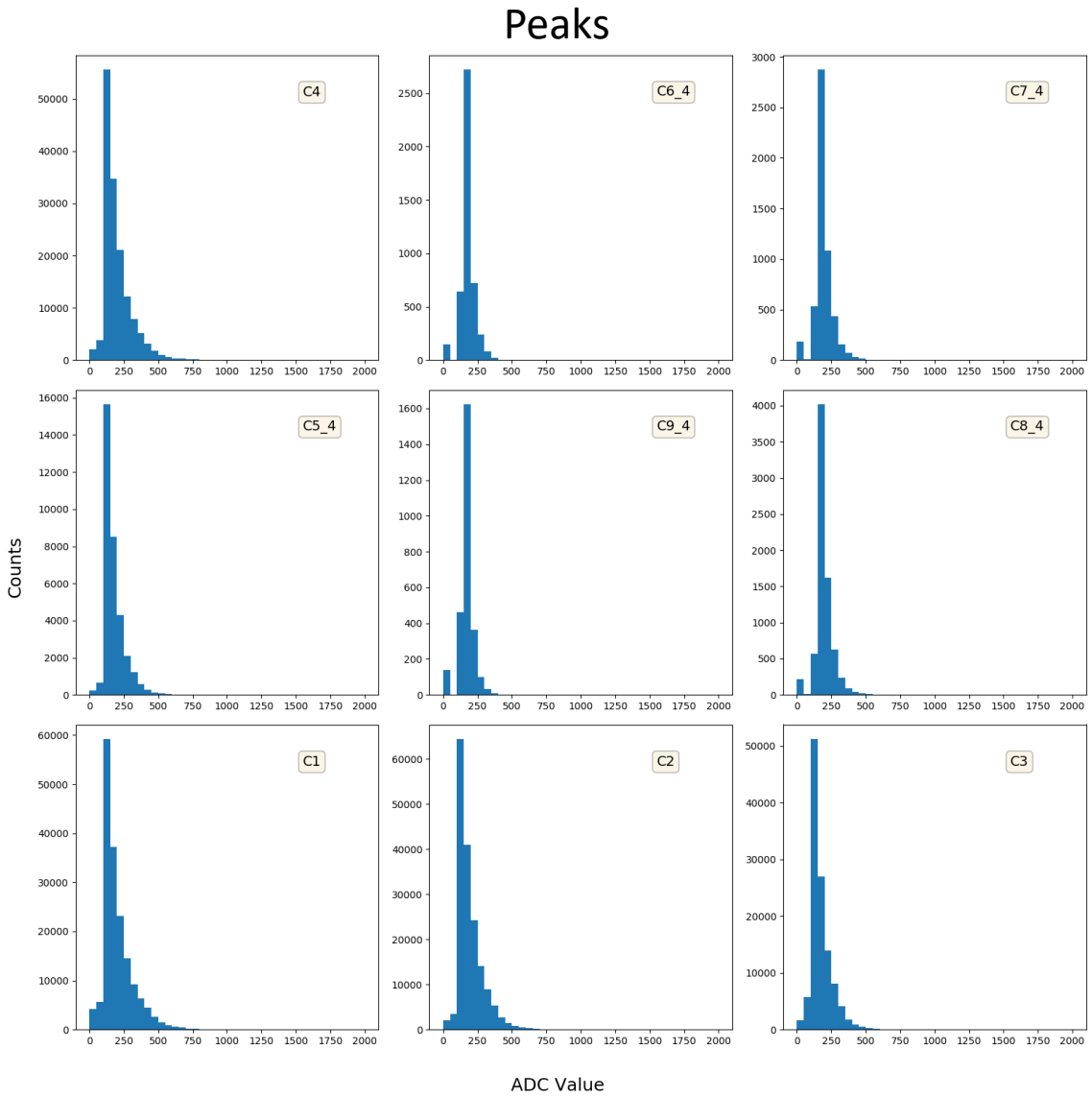


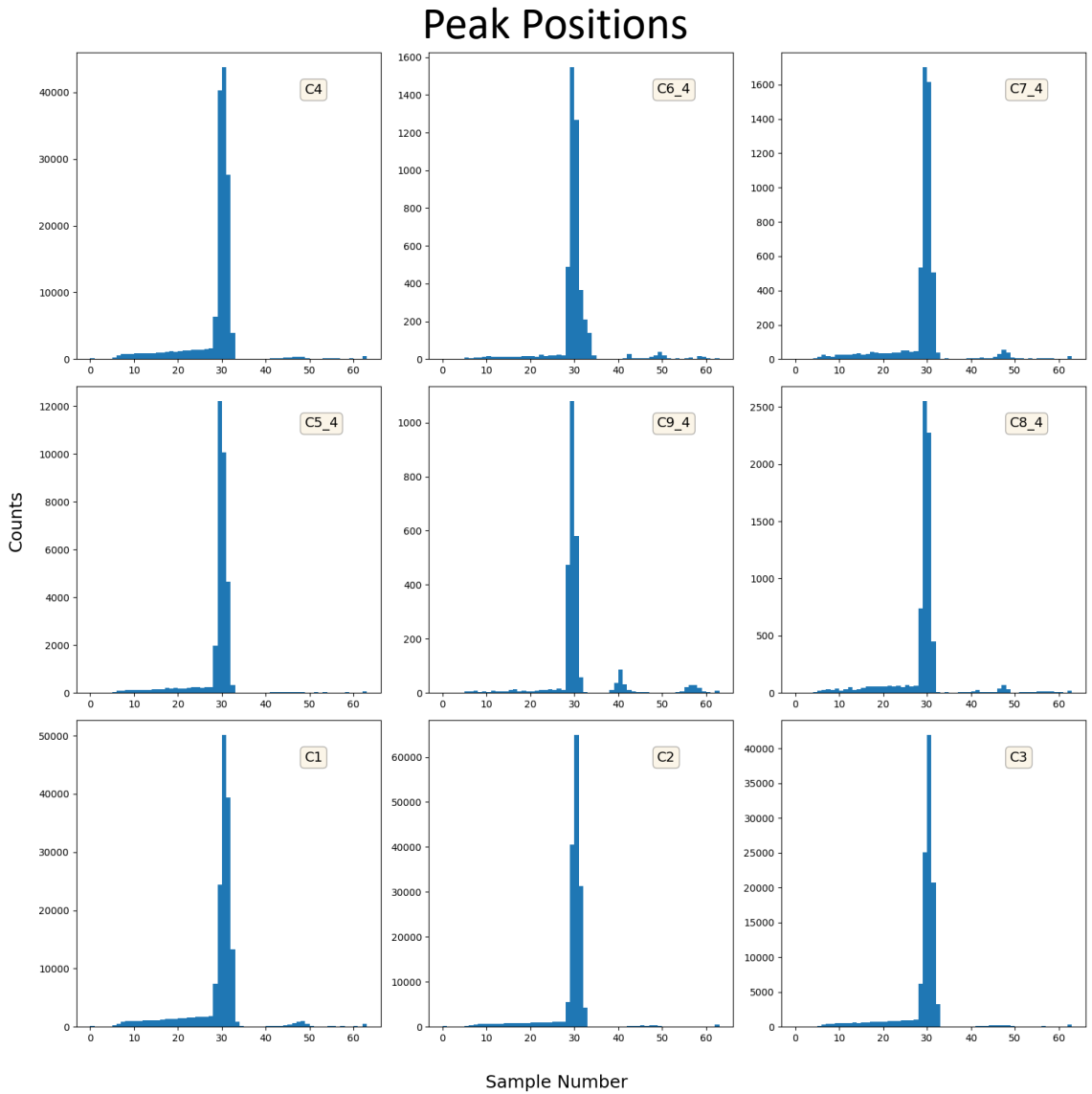
Waveform Analysis – Examples 3





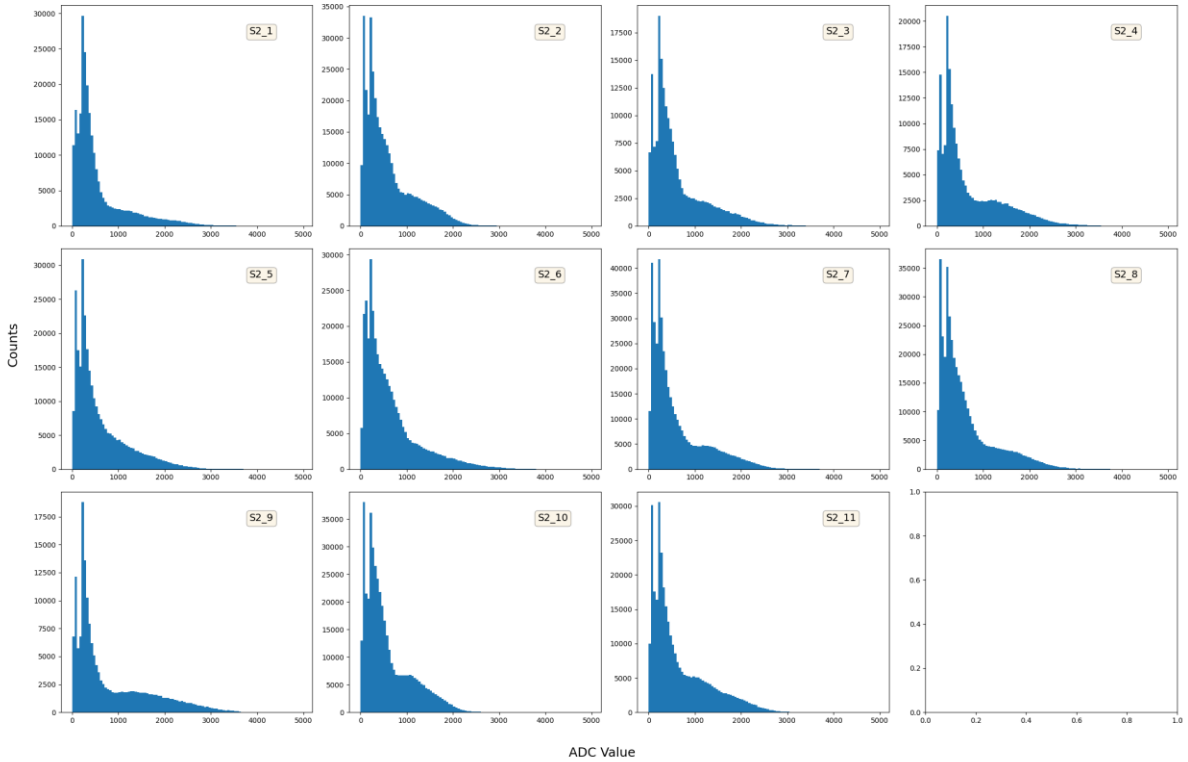
Calorimeter Channels – All Pulses



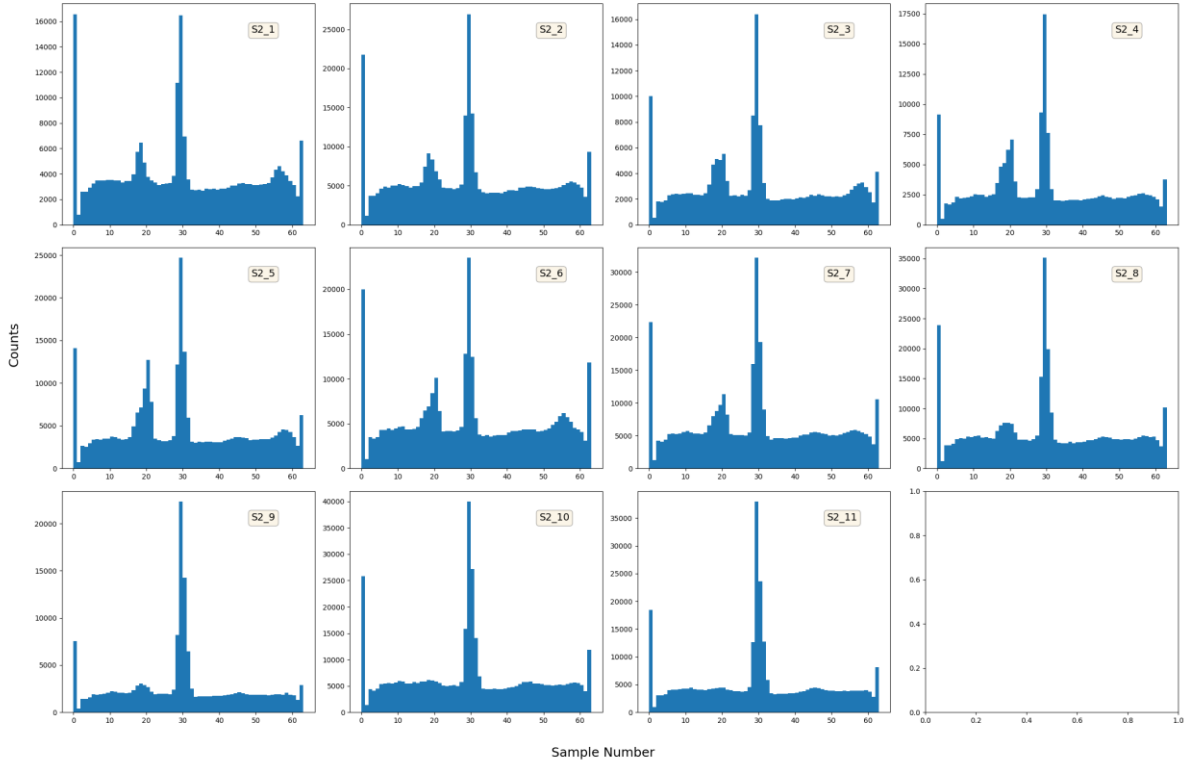


Scintillator Channels – All Pulses

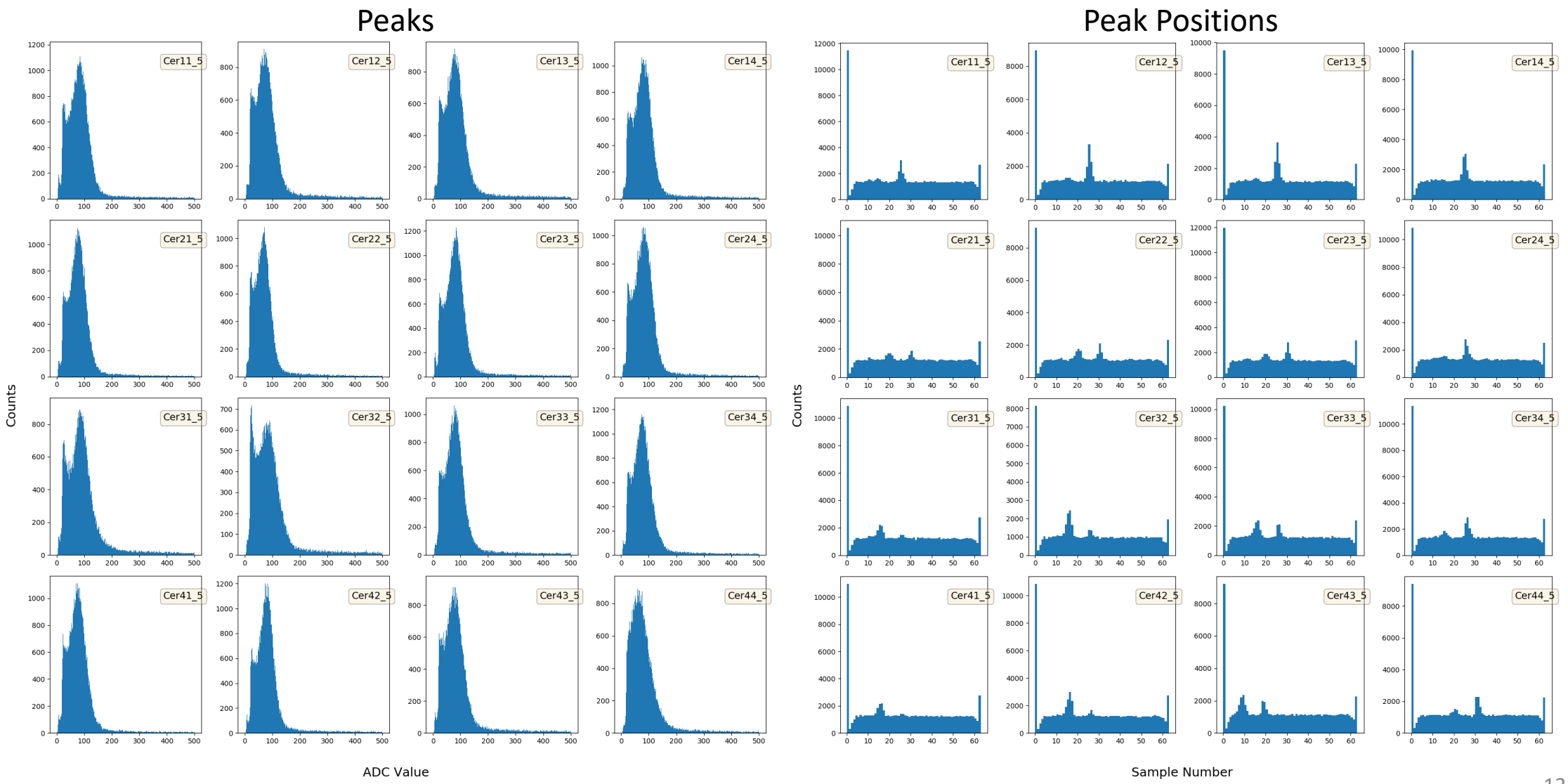
Peaks



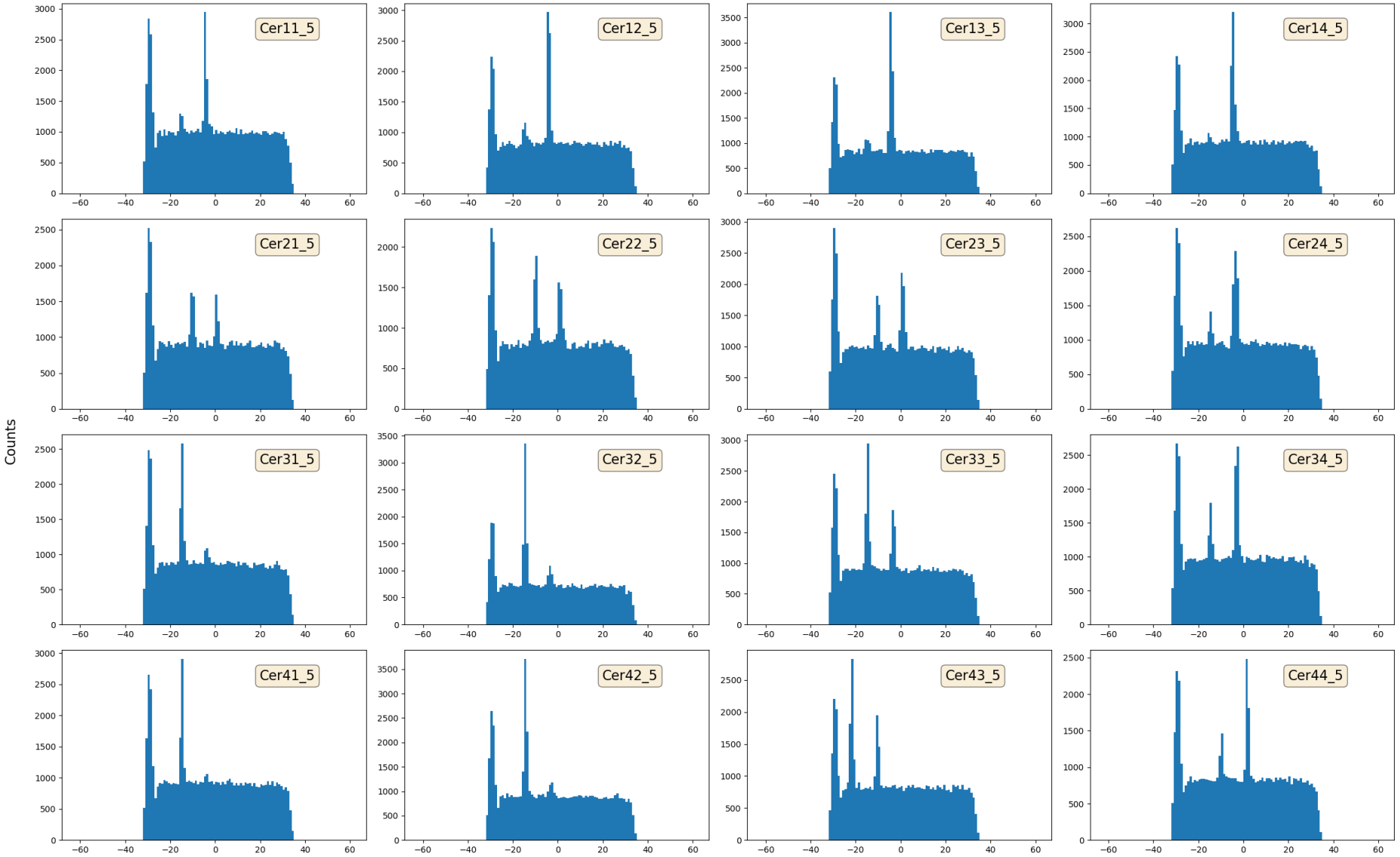
Peak Positions



Cherenkov Channels – All Pulses

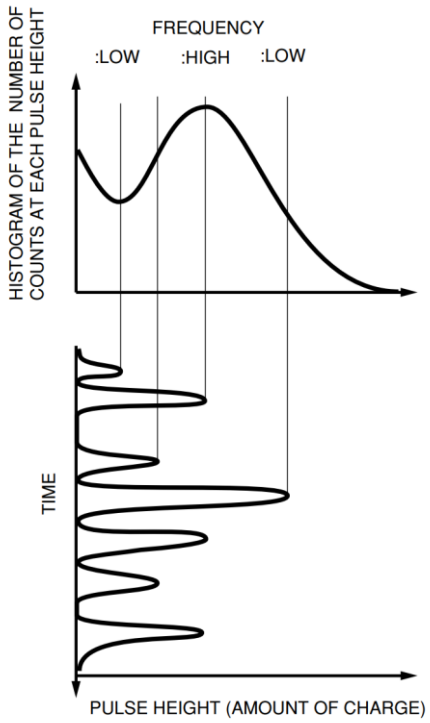


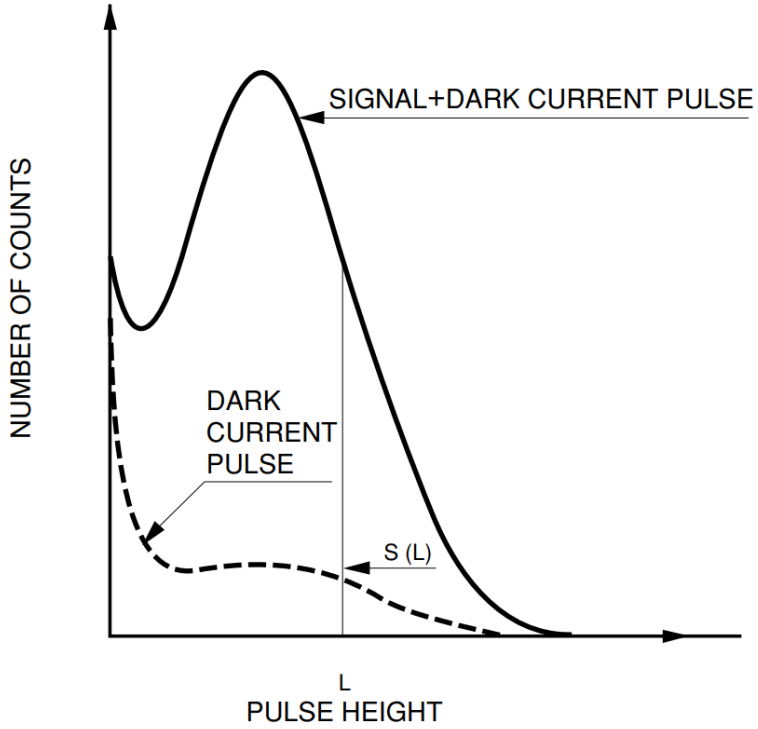
Cherenkov Channels – Timing relative to Cal.



Single Photo-electron Peak

- Typical Signal Shape



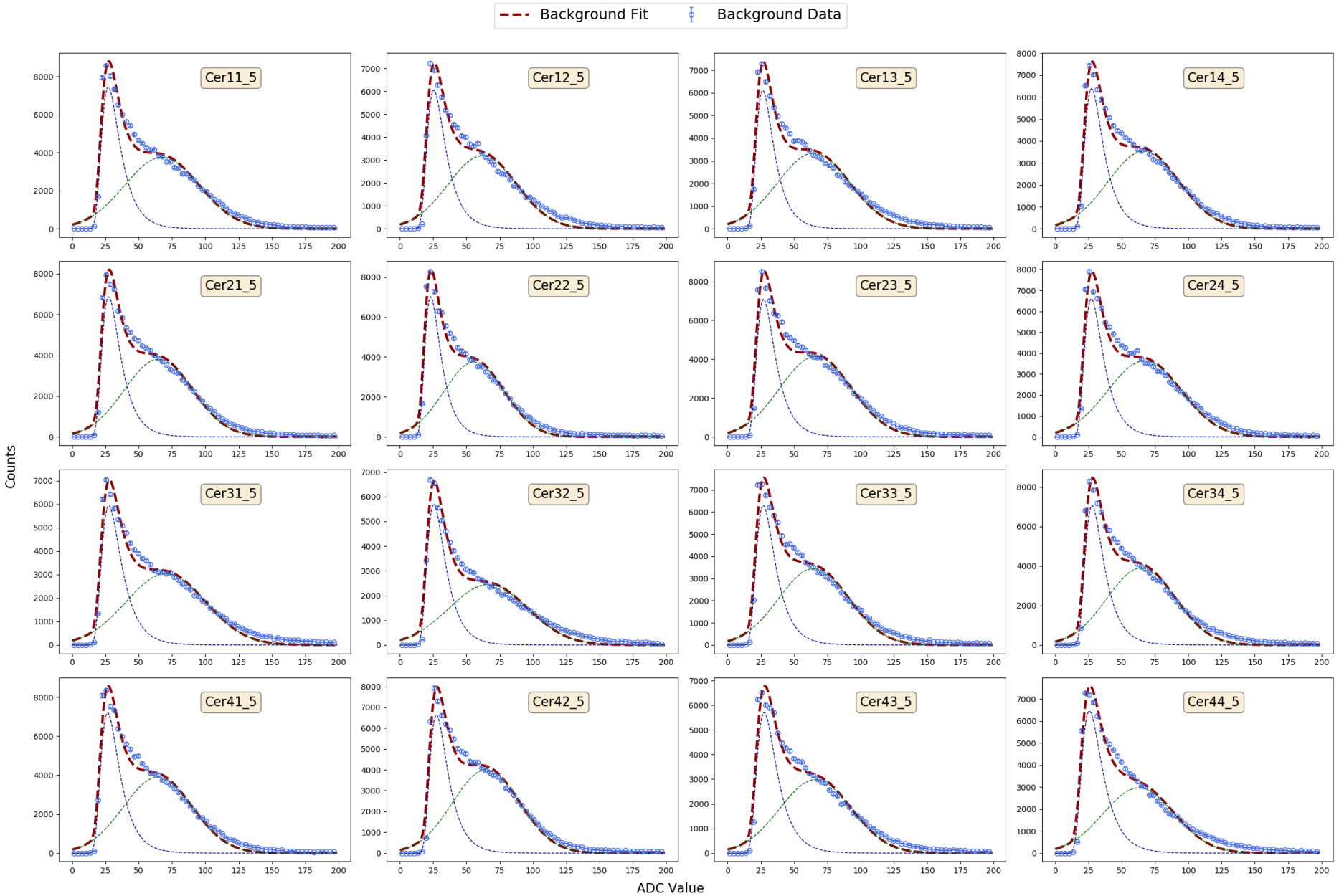


Plots from the Hamamatsu PMT handbook https://www.hamamatsu.com/resources/pdf/etd/PMT_handbook_v3aE.pdf

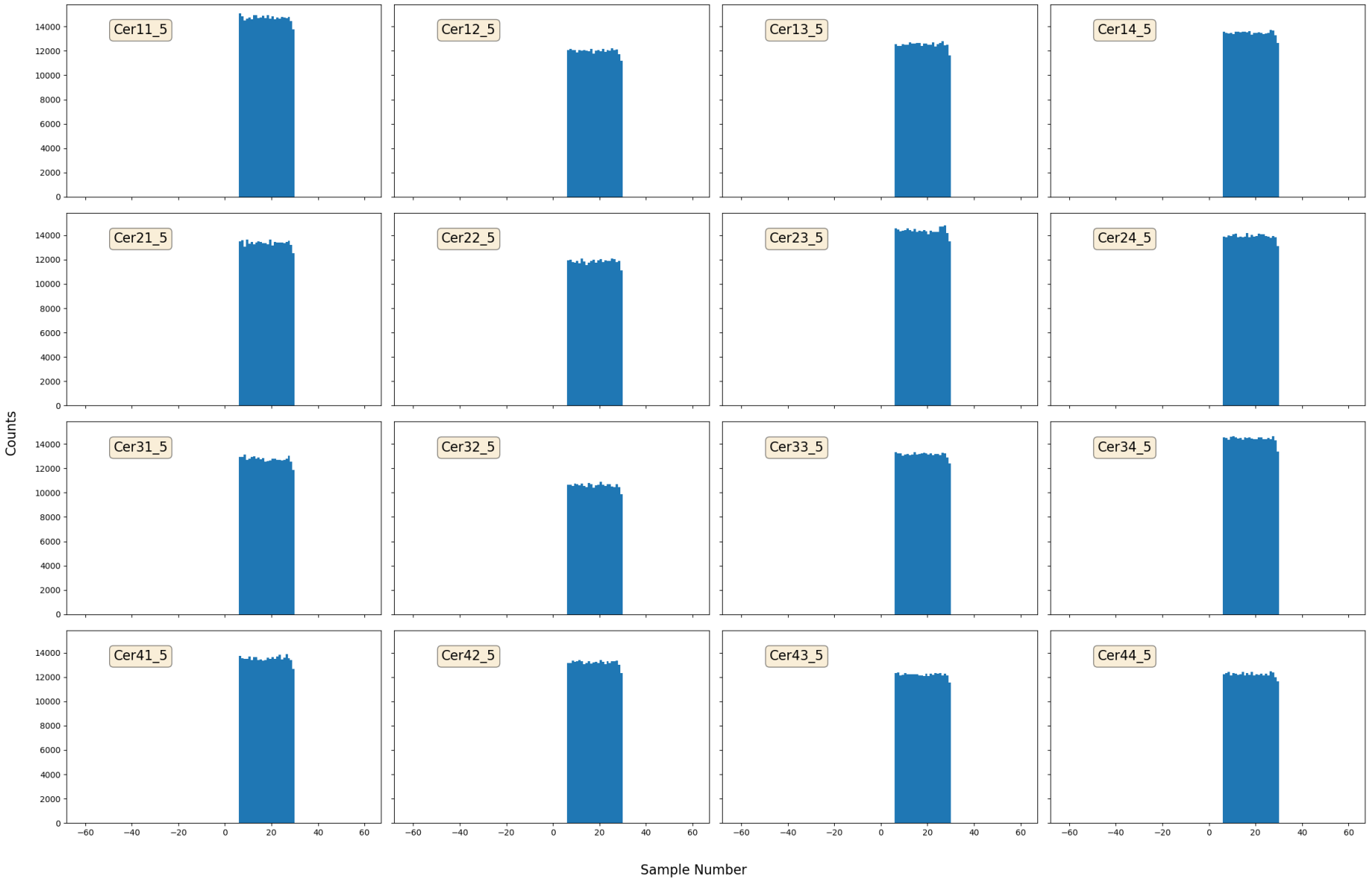
Single Photo-electron Peak

- Selection of single photo-electron signals
  - Time window for random background
- Background (dark current) subtraction
  - For cleaner distributions and better fits
- Fit the pulse height for each channel
  - Calibrate the signal amplitudes before the analysis of the signal sums

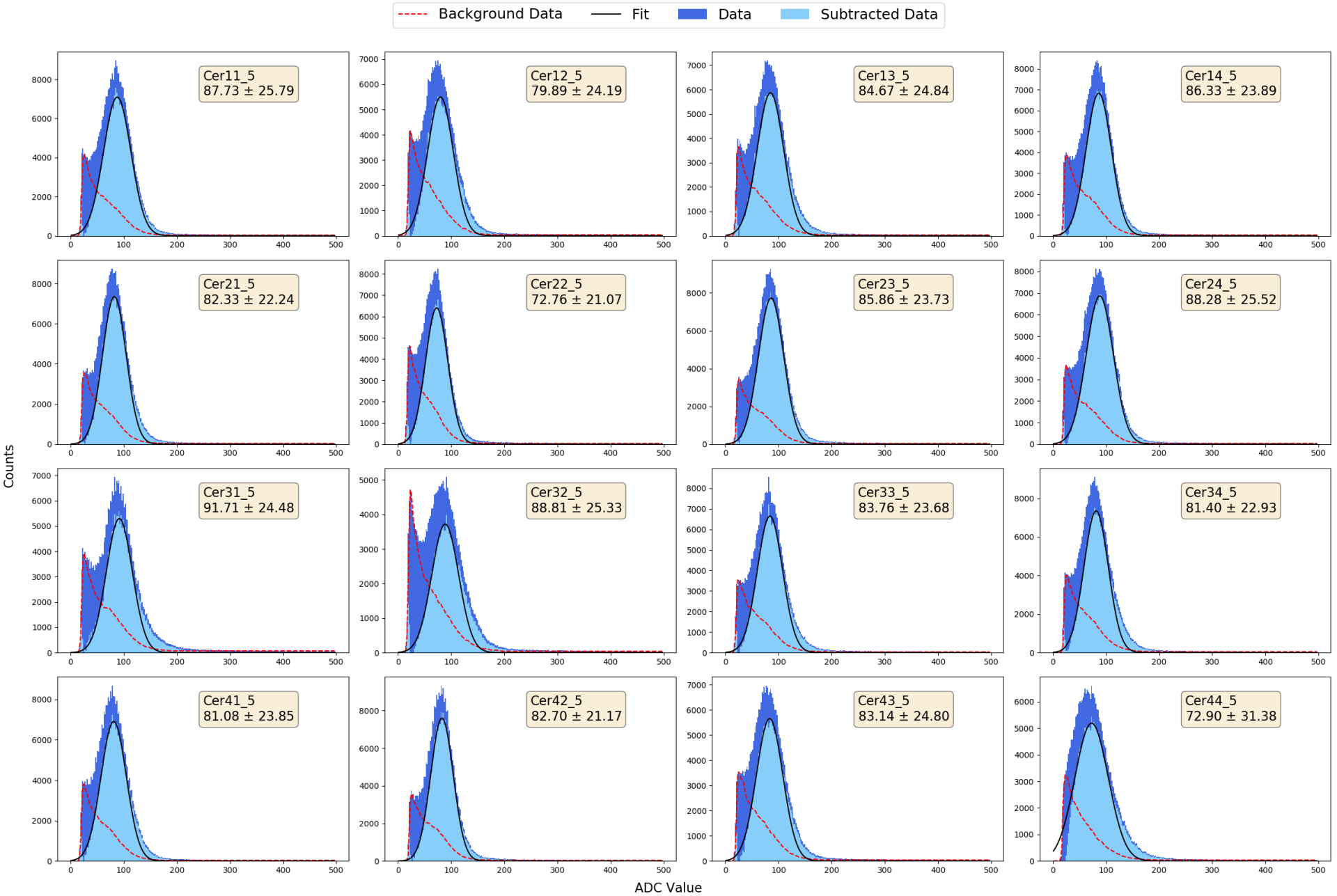
Background (pulse pos = 0)



Random Signals Selection



Random Signals – Single p.e. Peak Fit



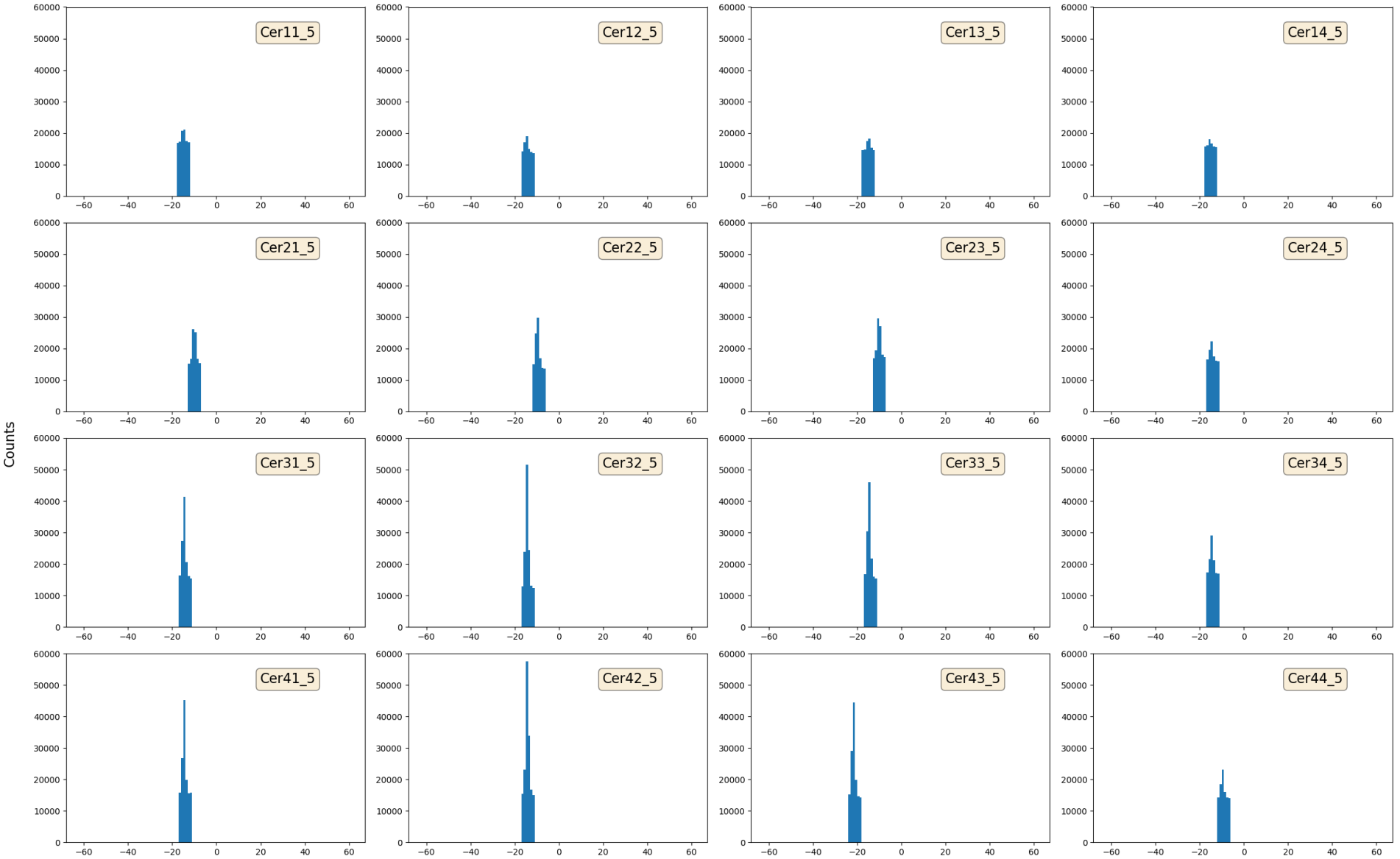
Signal Sum Analysis and N.p.e. fit

- The signals from each channel are normalized by single p.e. peak height
  - Around 70 ~ 90 for each channel
  - Then the signals are summed together

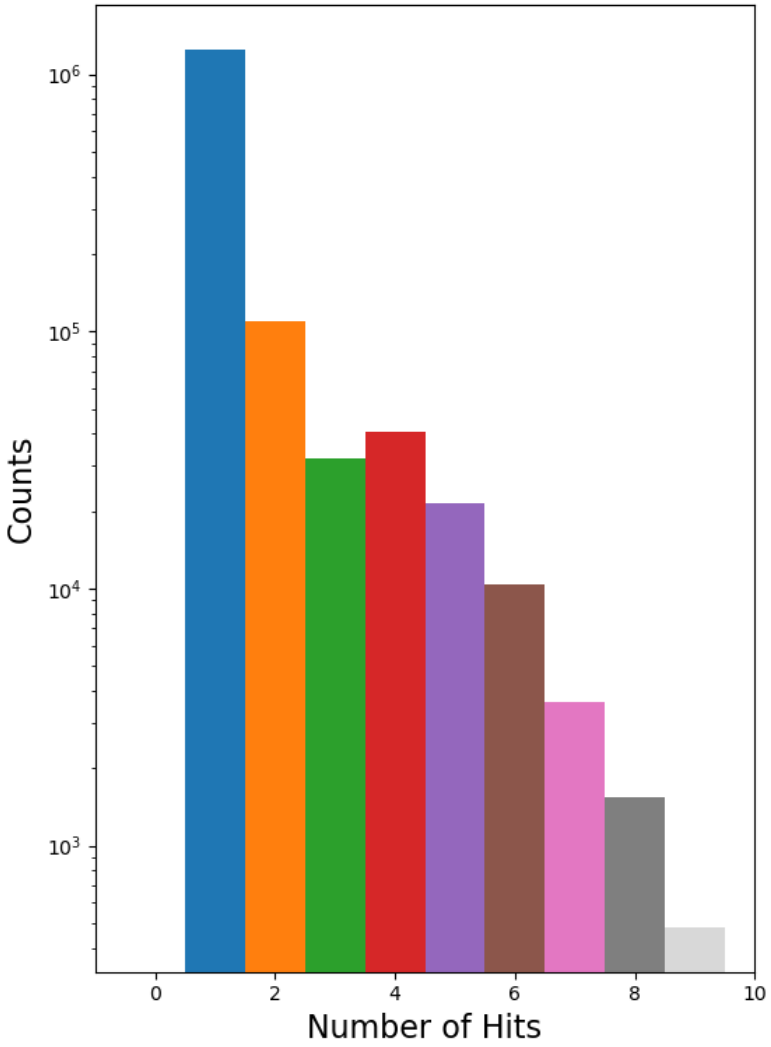
- Group the signal sums by the number of fired PMTs (Nhits)
  - Expect Nhits ~ 4 for an event
  - Estimate from Junqi: Critical angle Theta = 1.7 degree, 100 cm long tube, 47 cm long T section, Outer diameter is 147 cm*sin(1.7 degree) * 2 = 8.7cm, inner diameter = 2.8 cm

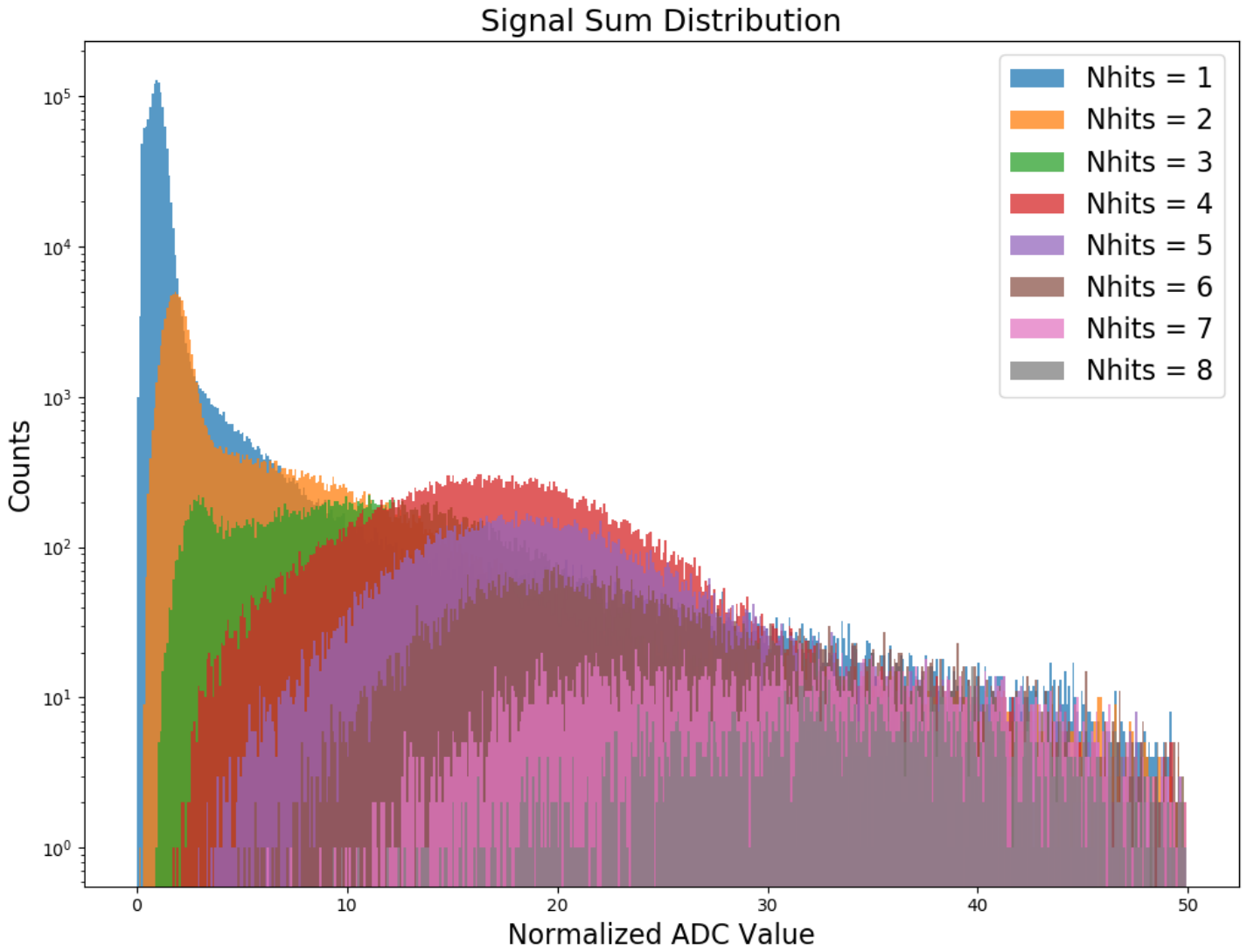
- Fit the signal and get N.p.e

Signal Selection – Timing Cut (rel. to Cal.)

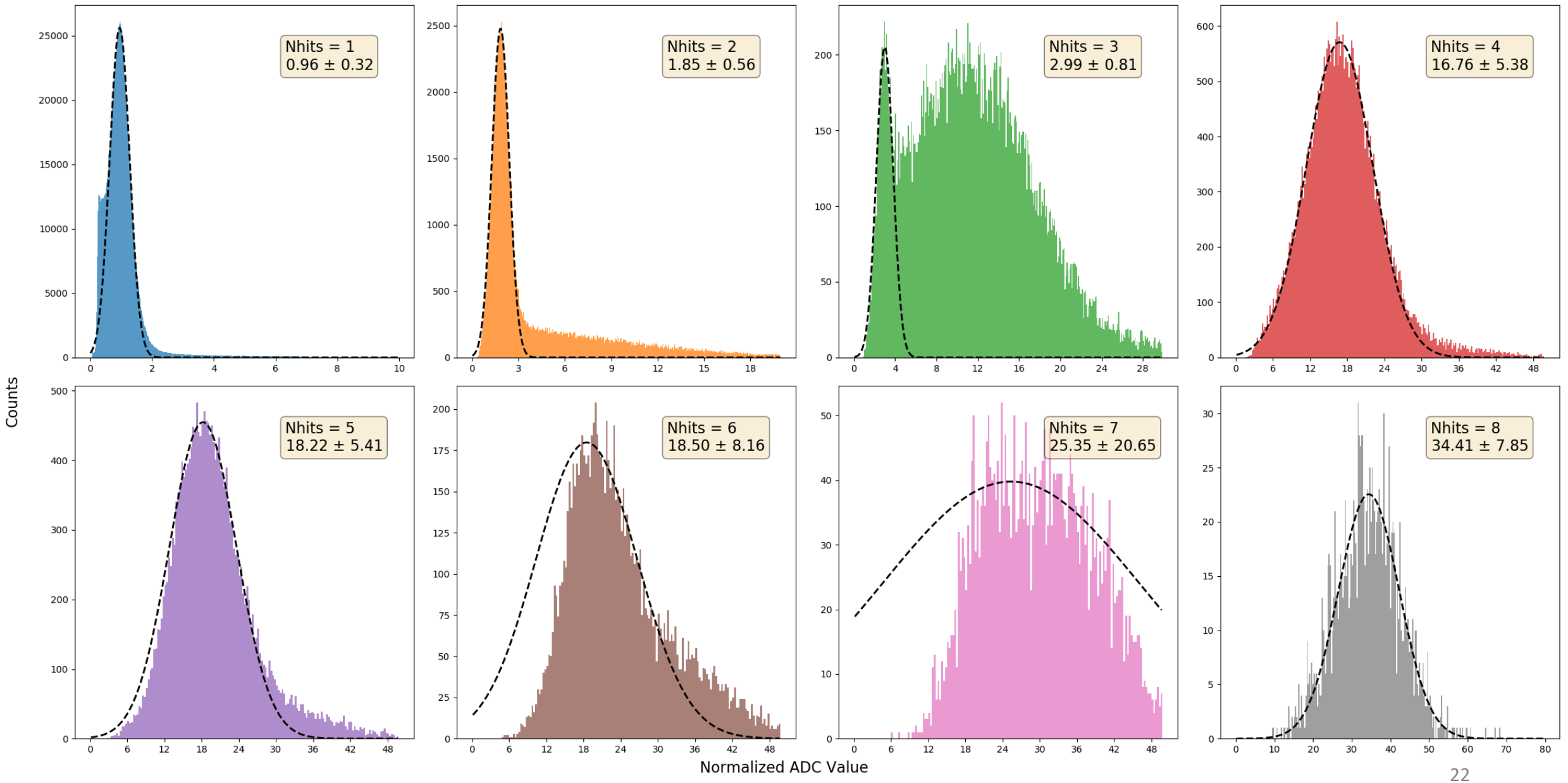


Signal Sums by Number of Fired PMTs

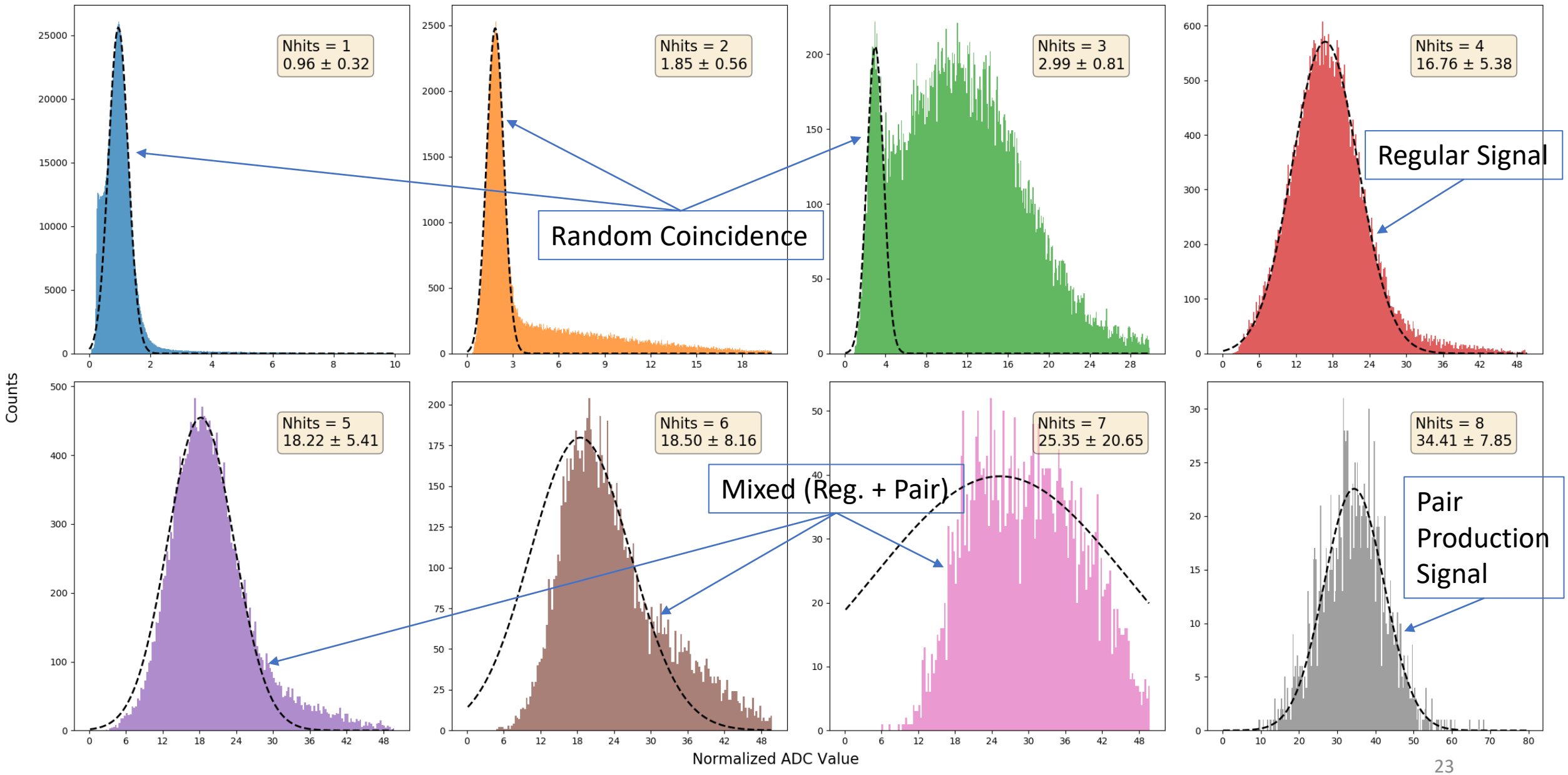




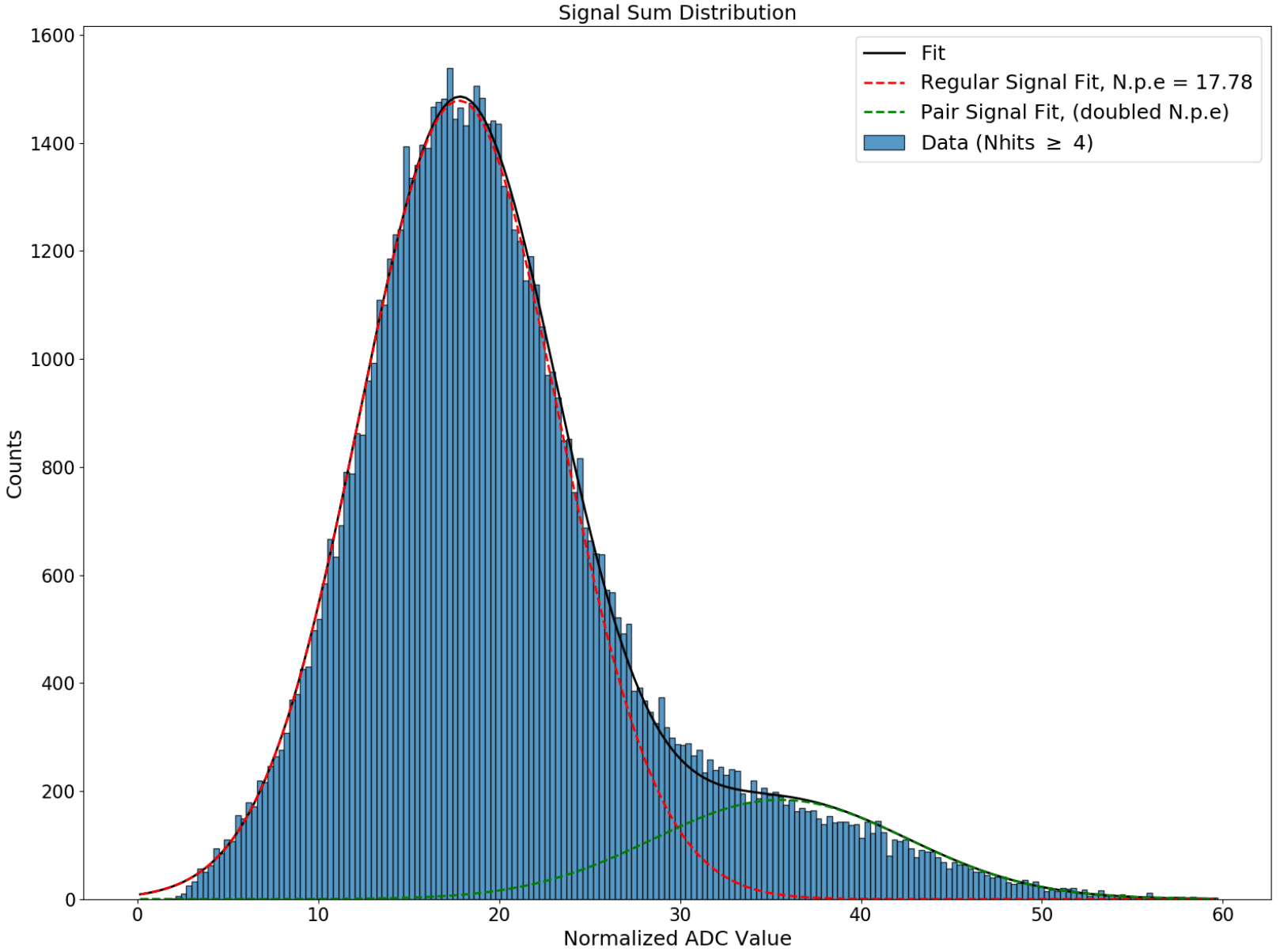
Signal Sums - Fits



Signal Sums - Fits



Signal Sums - Fits

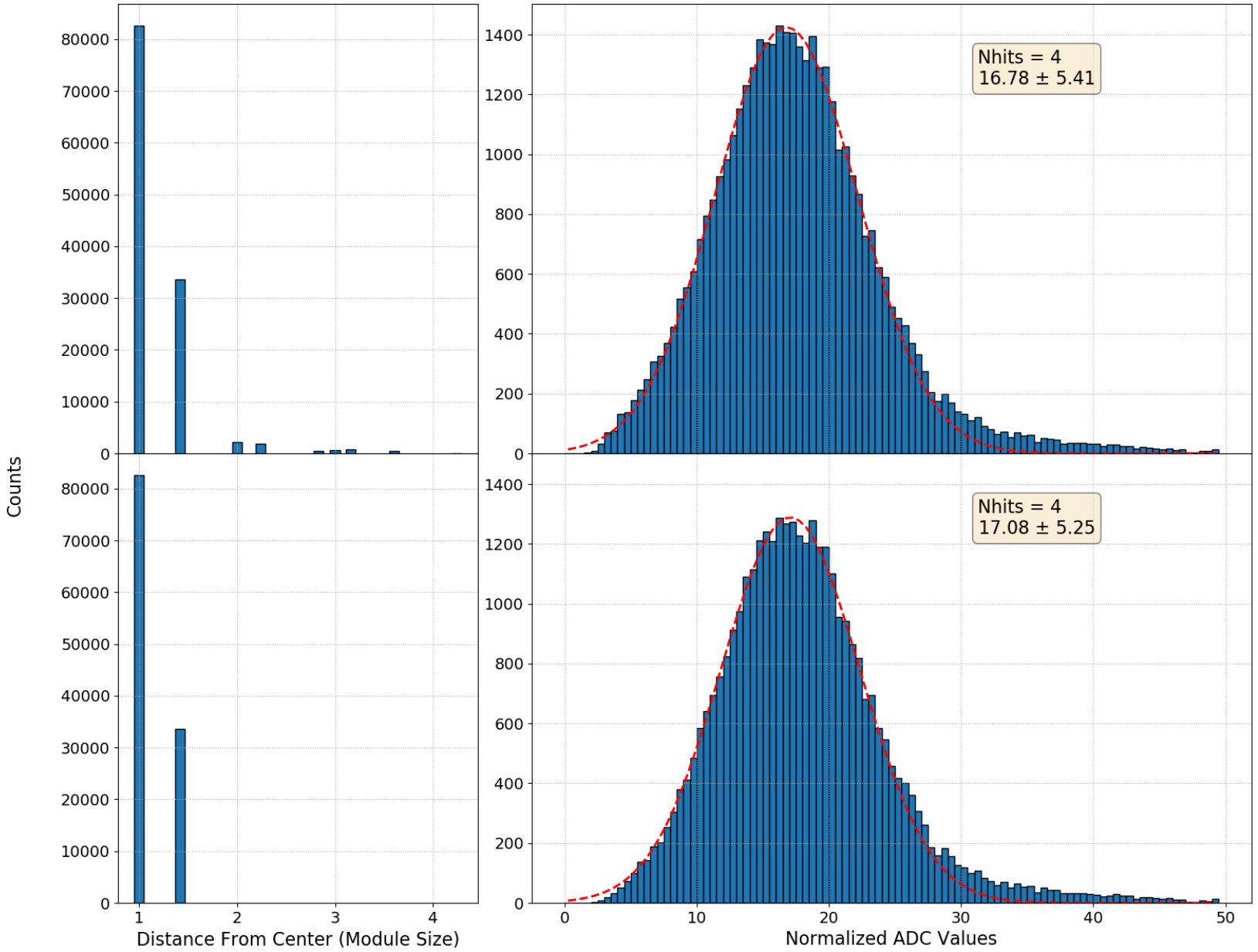


Positional Information

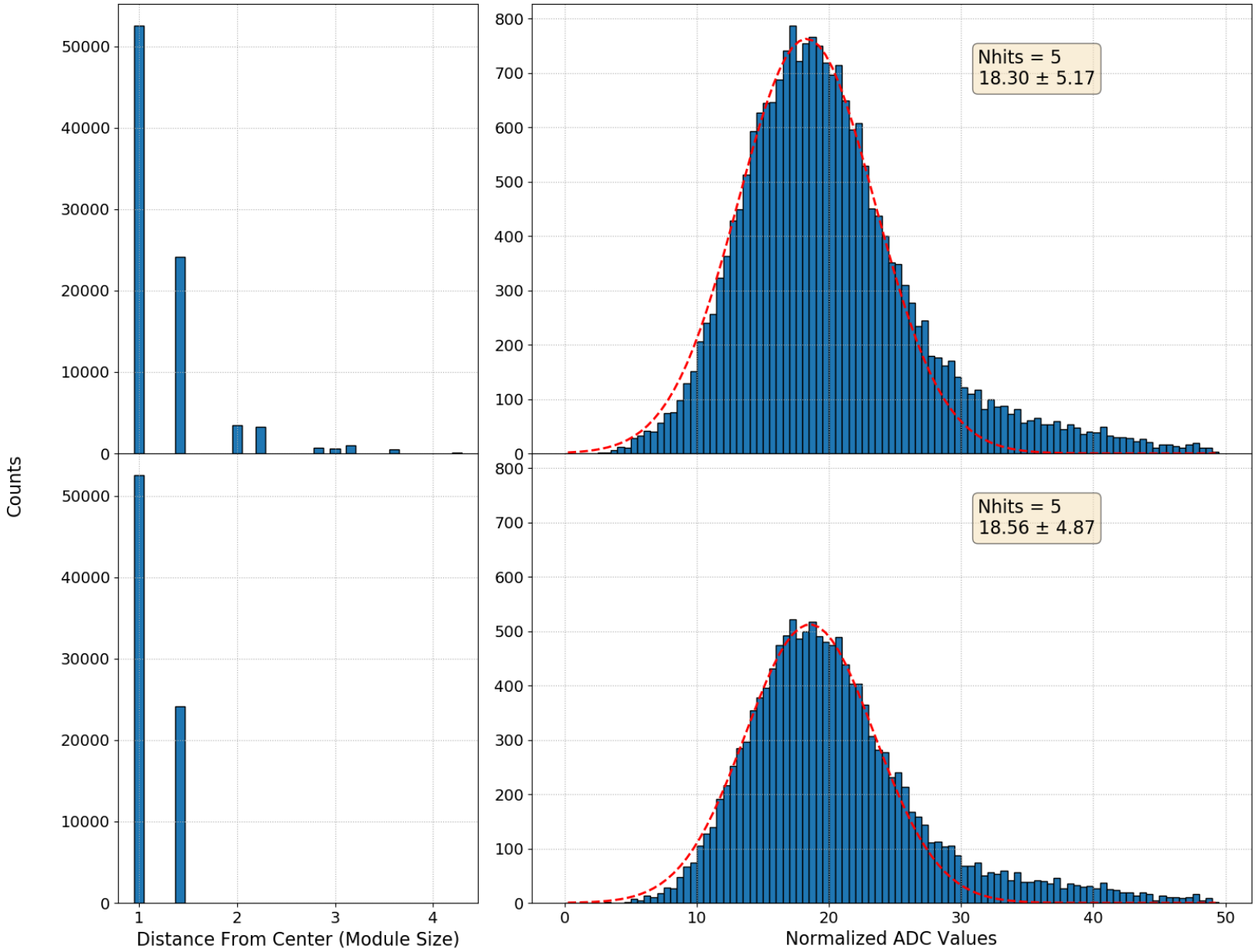
- We could utilize the positional information of each PMT (and the quadrants) to cut off the random signal that is far away from the hit center

- In this analysis, the event center is simply defined as the PMT center which has the maximum signal
  - Cut is put on distance > 2 module size

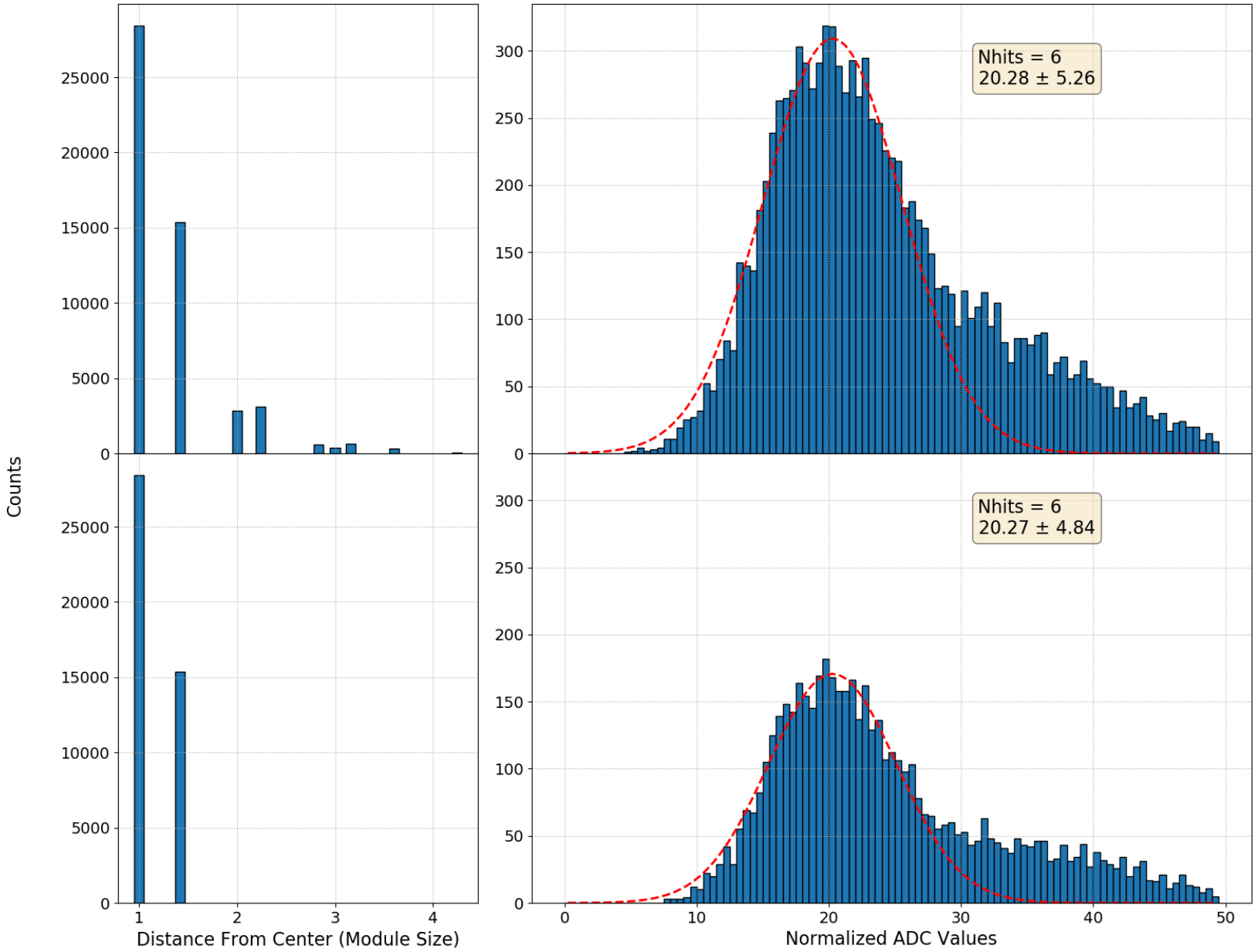
Distance Cut for Nhits = 4



Distance Cut for Nhits = 5



Distance Cut for Nhits = 6

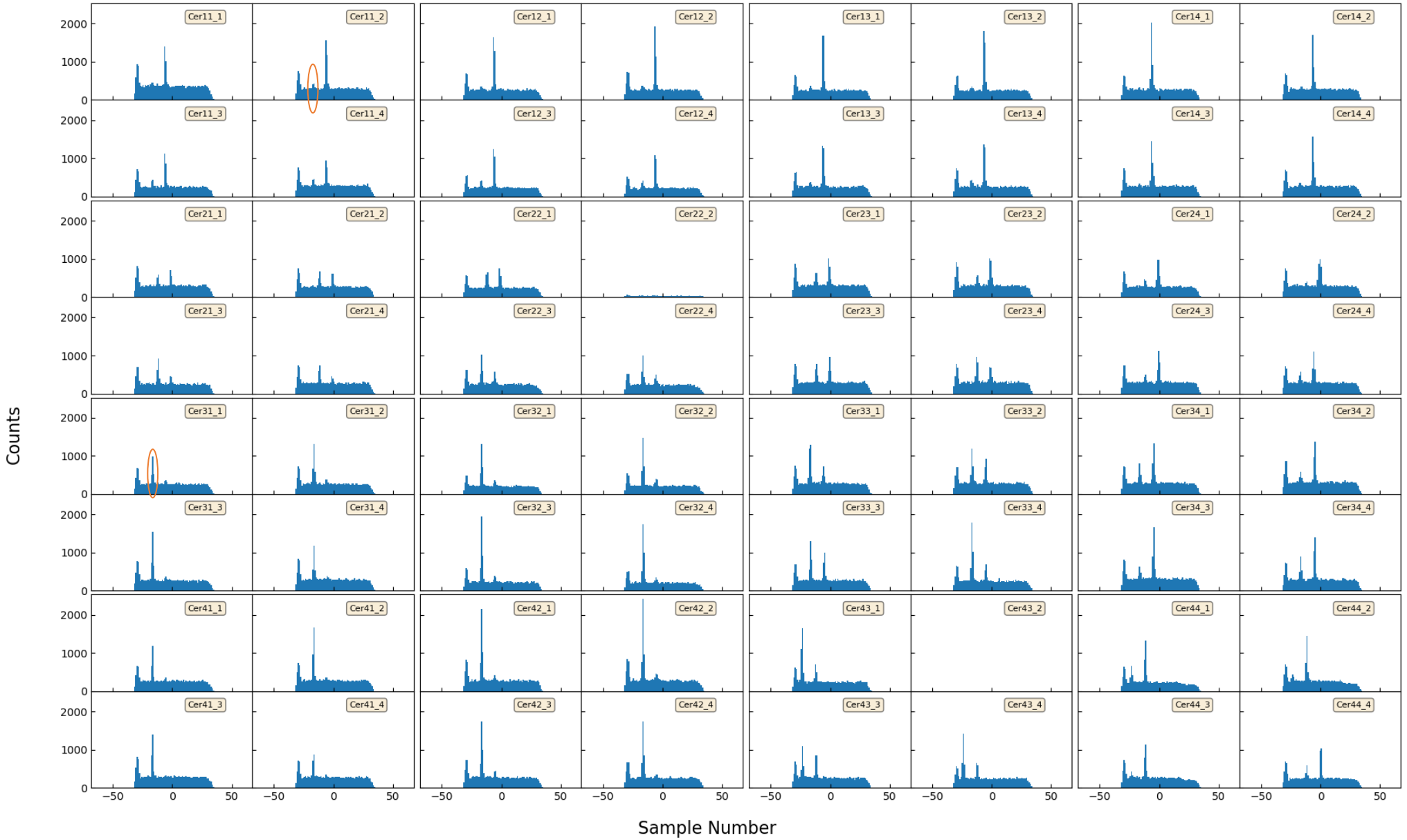


Quadrants Signals

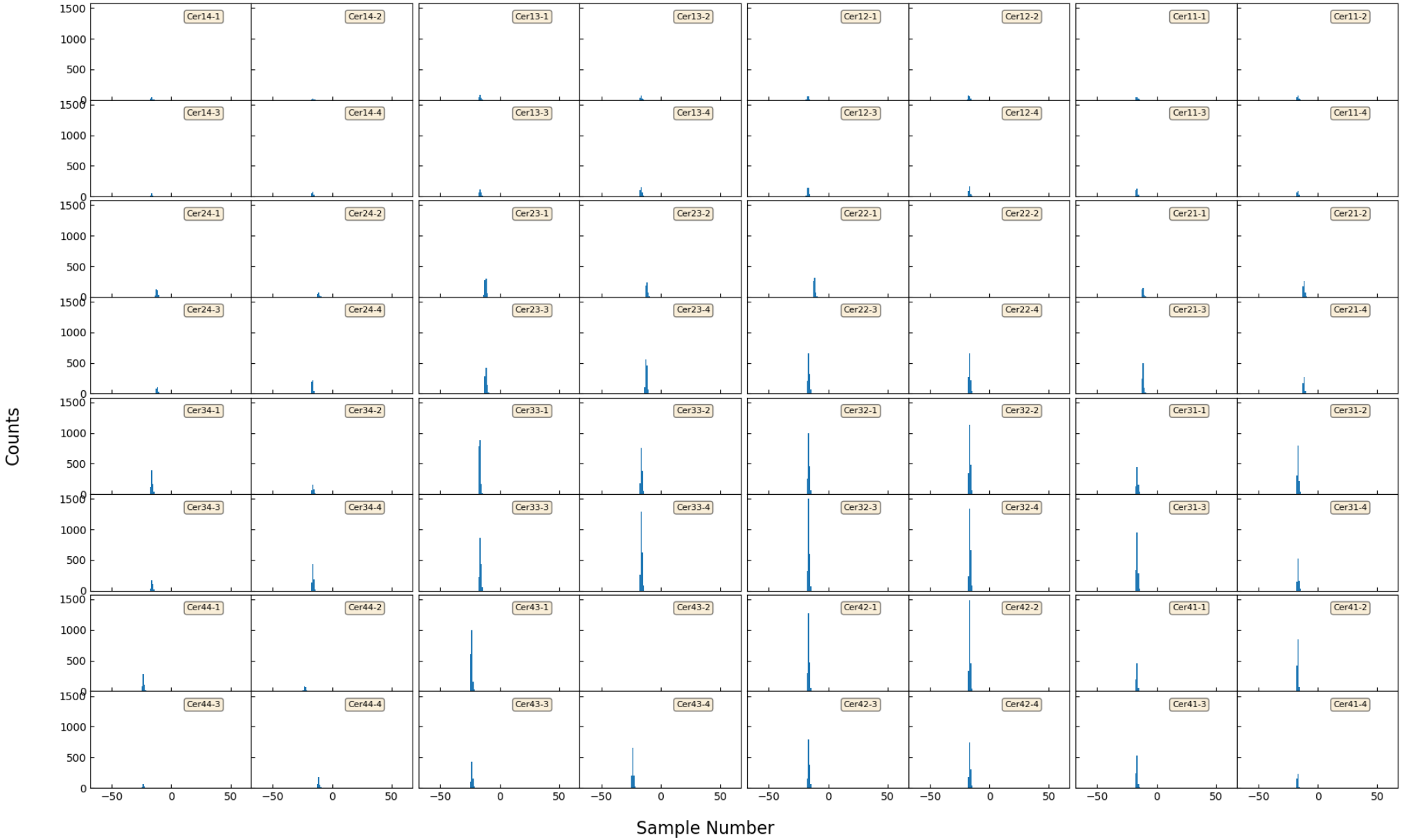
- Each PMT has four quadrants
  - Additional pixelized information

- Analyze quadrant signals
  - Required number of fired PMTs >= 4
  - Timing cut for each quadrant

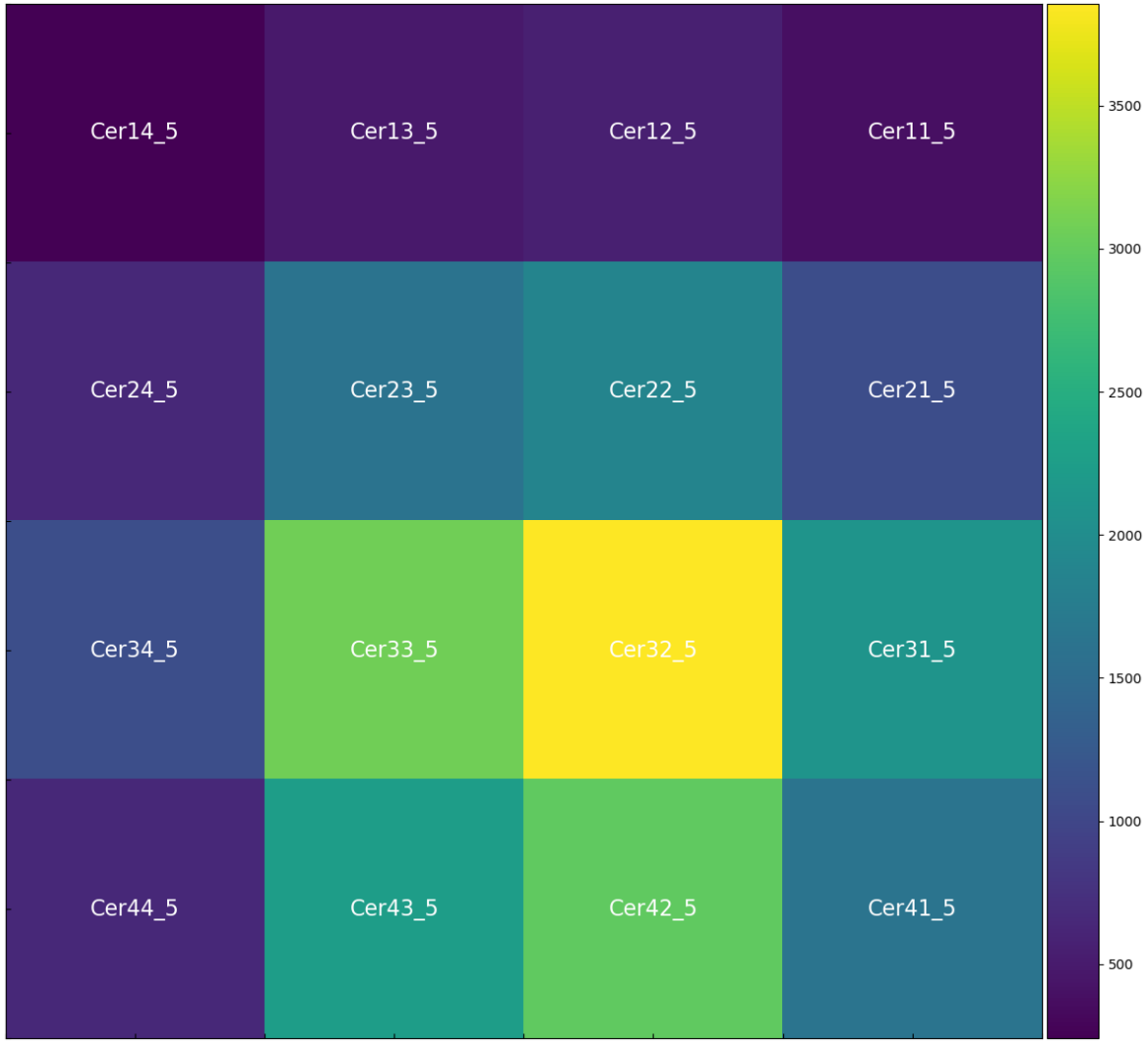
Quadrants Signals – Overall Timing (rel. to Cal.)

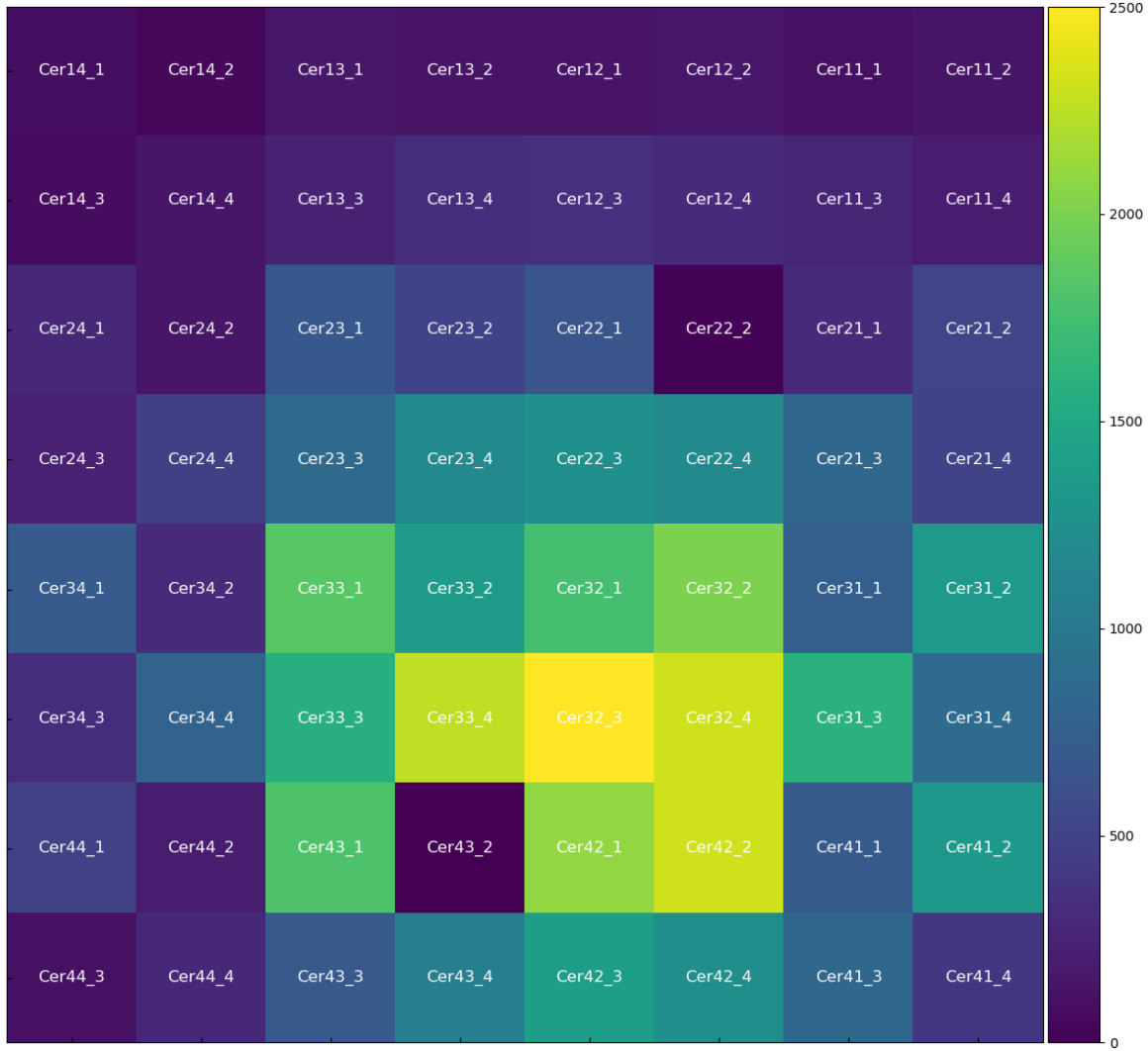


Quadrants Signals – Timing Cut



Heat Map


Cer14_5
Cer13_5
Cer12_5
Cer11_5
Cer24_5
Cer23_5
Cer22_5
Cer21_5
Cer34_5
Cer33_5
Cer32_5
Cer31_5
Cer44_5
Cer43_5
Cer42_5
Cer41_5
3500
3000
2500
2000
1500
1000
500


Cer14_1
Cer14_2
Cer13_1
Cer13_2
Cer12_1
Cer12_2
Cer11_1
Cer11_2
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Cer14_4
Cer13_3
Cer13_4
Cer12_3
Cer12_4
Cer11_3
Cer11_4
Cer24_1
Cer24_2
Cer23_1
Cer23_2
Cer22_1
Cer22_2
Cer21_1
Cer21_2
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Cer24_4
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Cer21_3
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Cer42_1
Cer42_2
Cer41_1
Cer41_2
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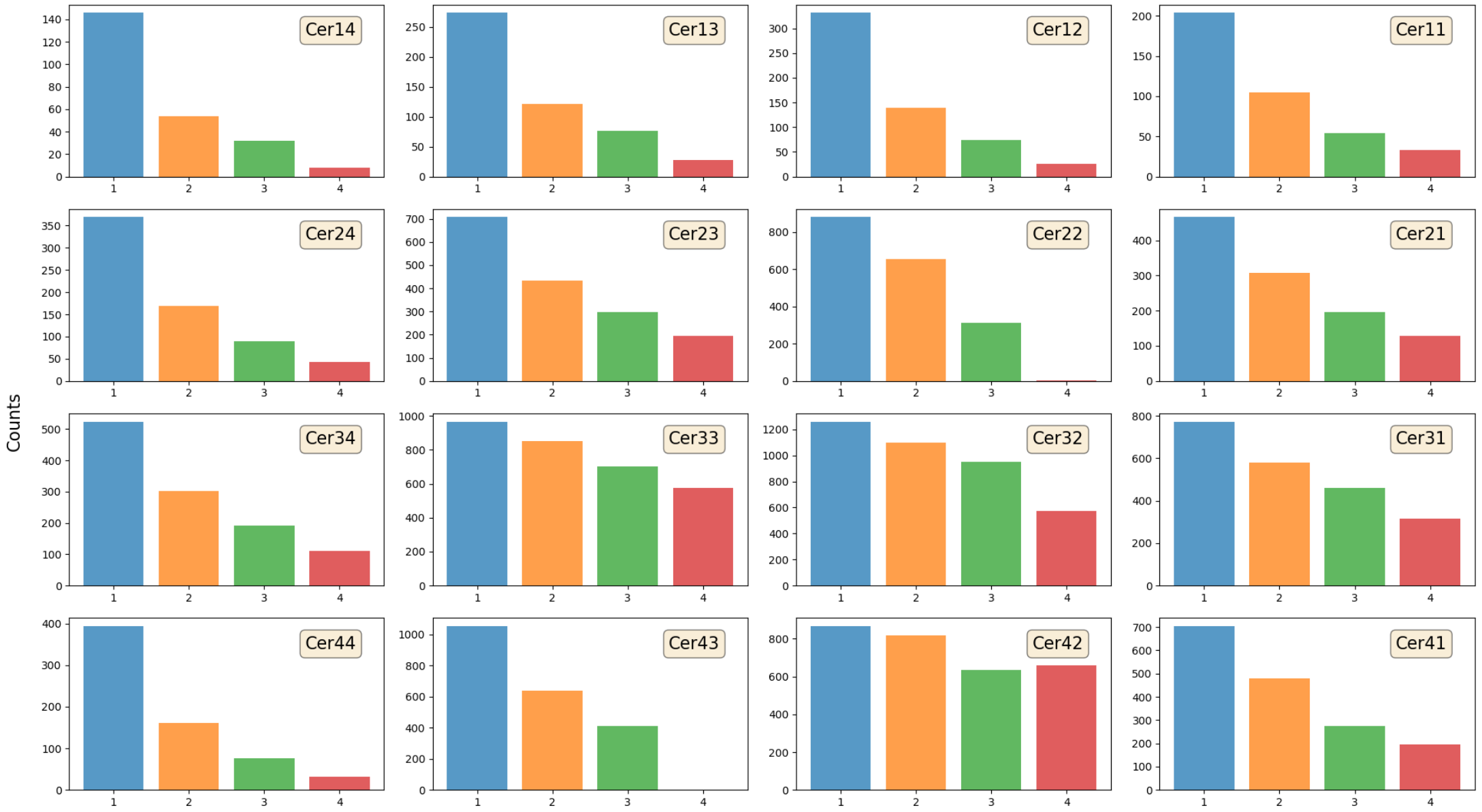
Cer44_4
Cer43_3
Cer43_4
Cer42_3
Cer42_4
Cer41_3
Cer41_4
2500
2000
1500
1000
500
0

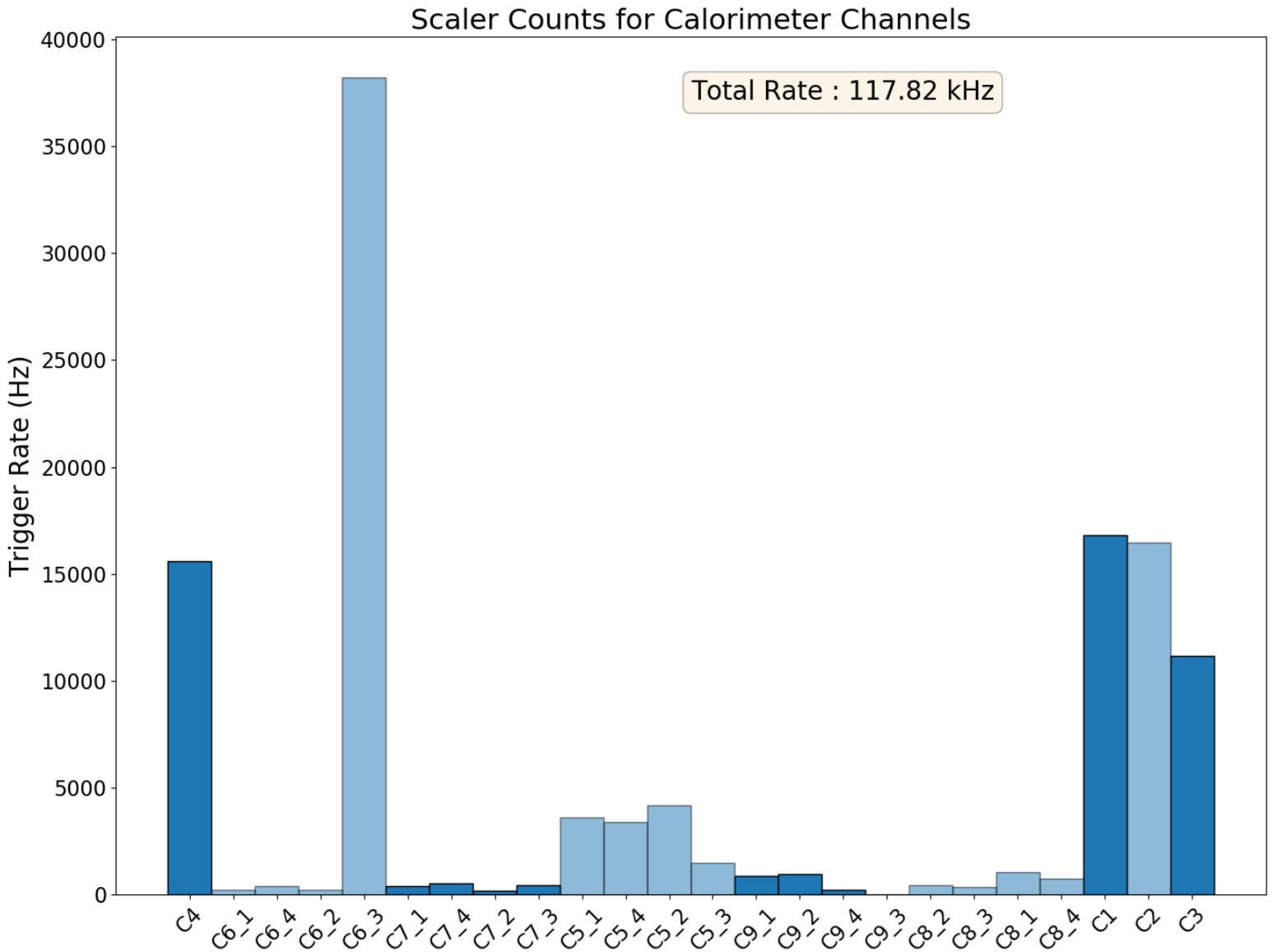
Number of Fired Quadrants



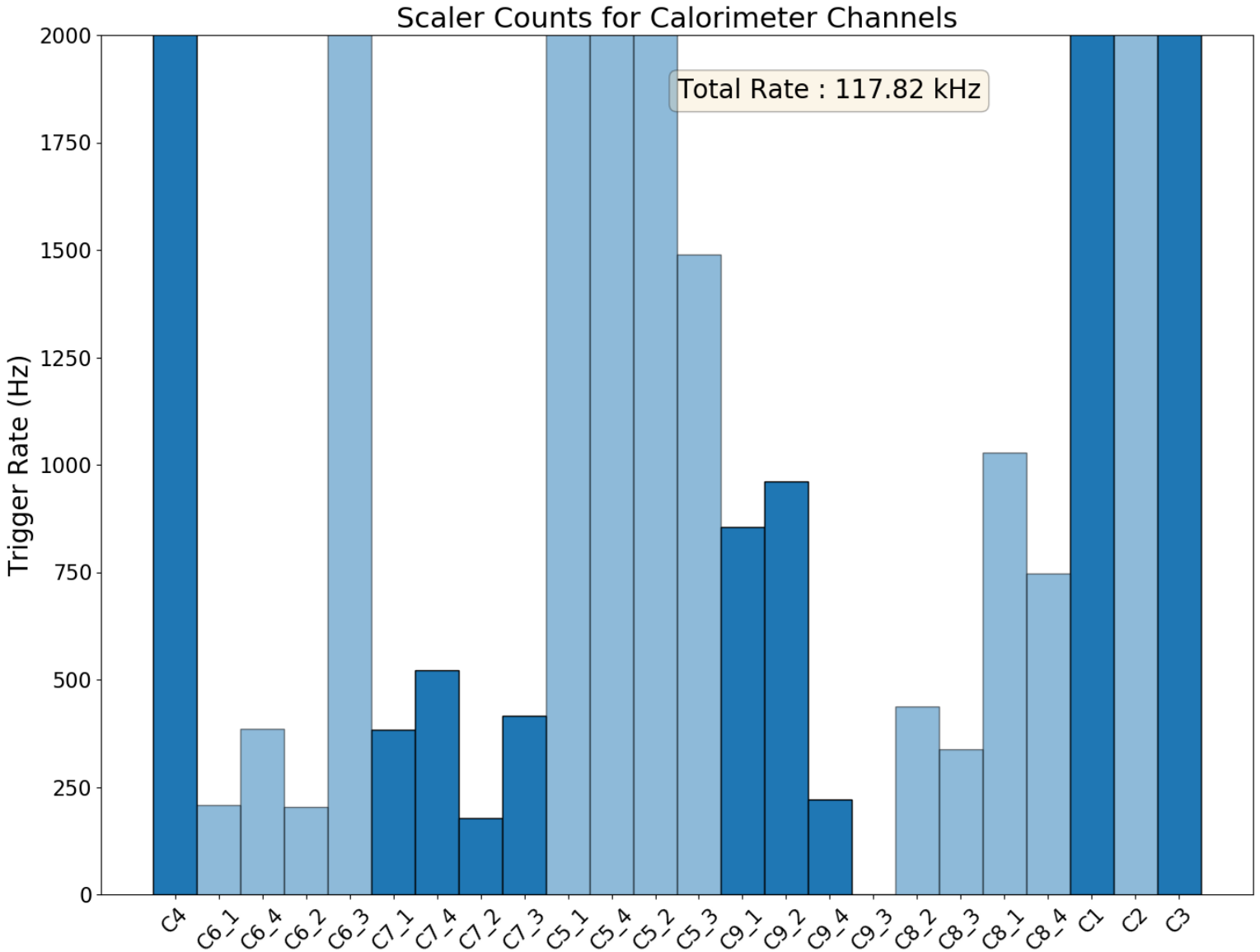
Scalers

- Scalers were read every 15 seconds
  - https://logbooks.jlab.org/entry/3808745
- 142 channels
  - https://logbooks.jlab.org/entry/3808730
  - 0-127 channels, 8 FADC slots
  - 128-139 channels, TIs
  - 140 Event counters
  - 141 Reference clock (60 Hz)
- We have data at roughly 0, 15, 30 seconds
  - Use reference channel to calculate the exact time
  - Calculate the average rates of these data

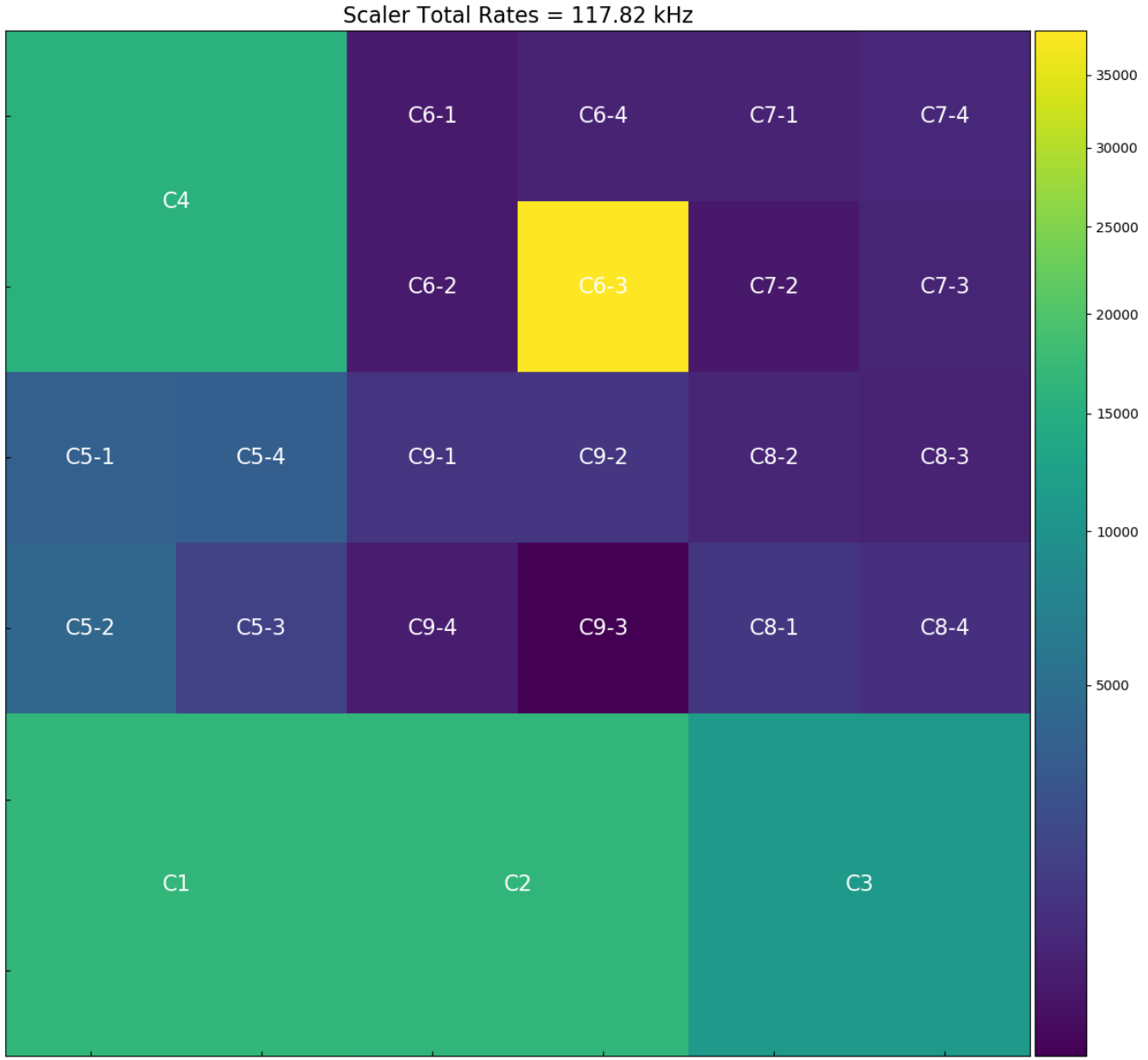
Run 160 – Scalers for Calorimeter



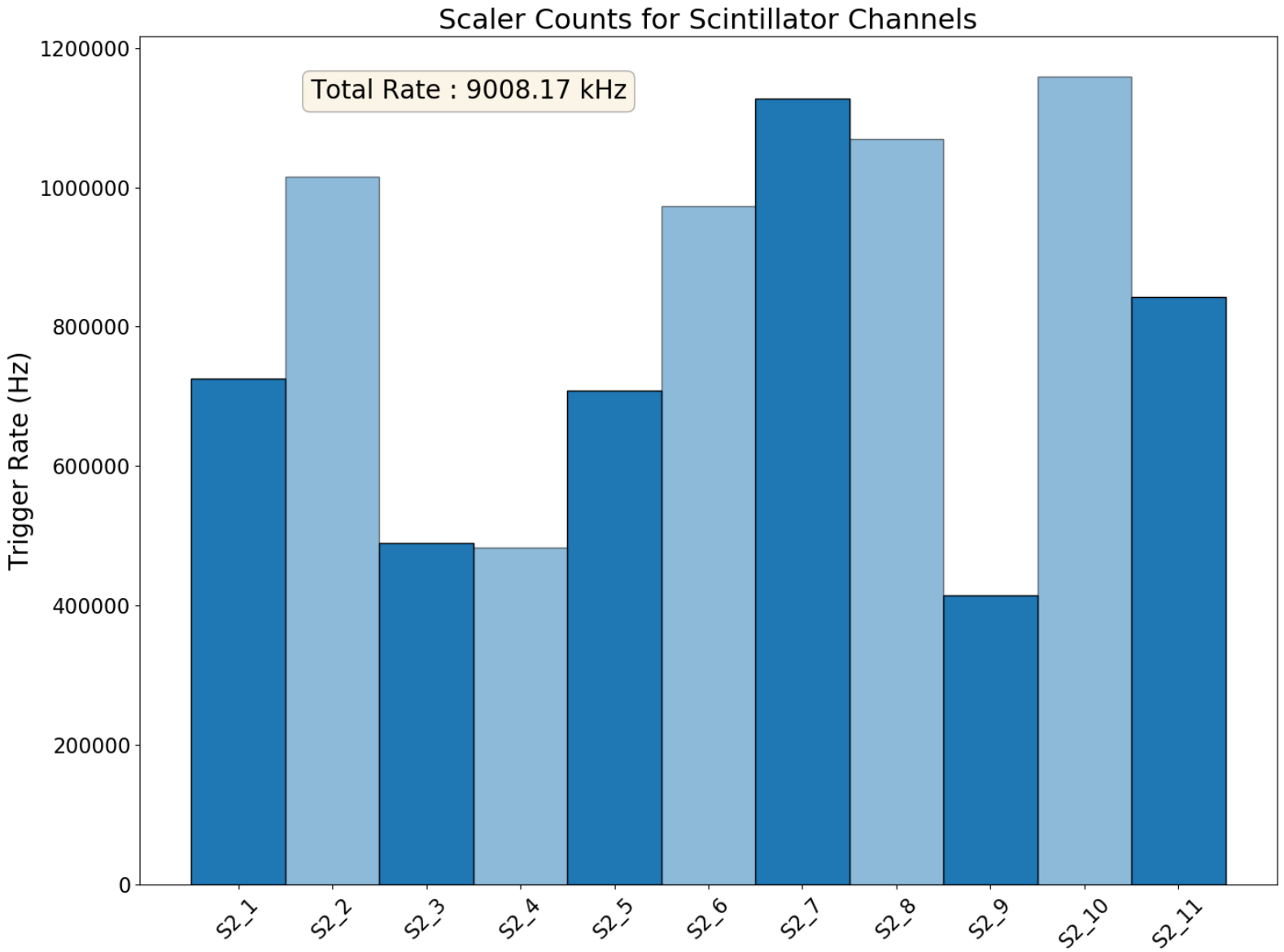
Run 160 – Scalers for Calorimeter



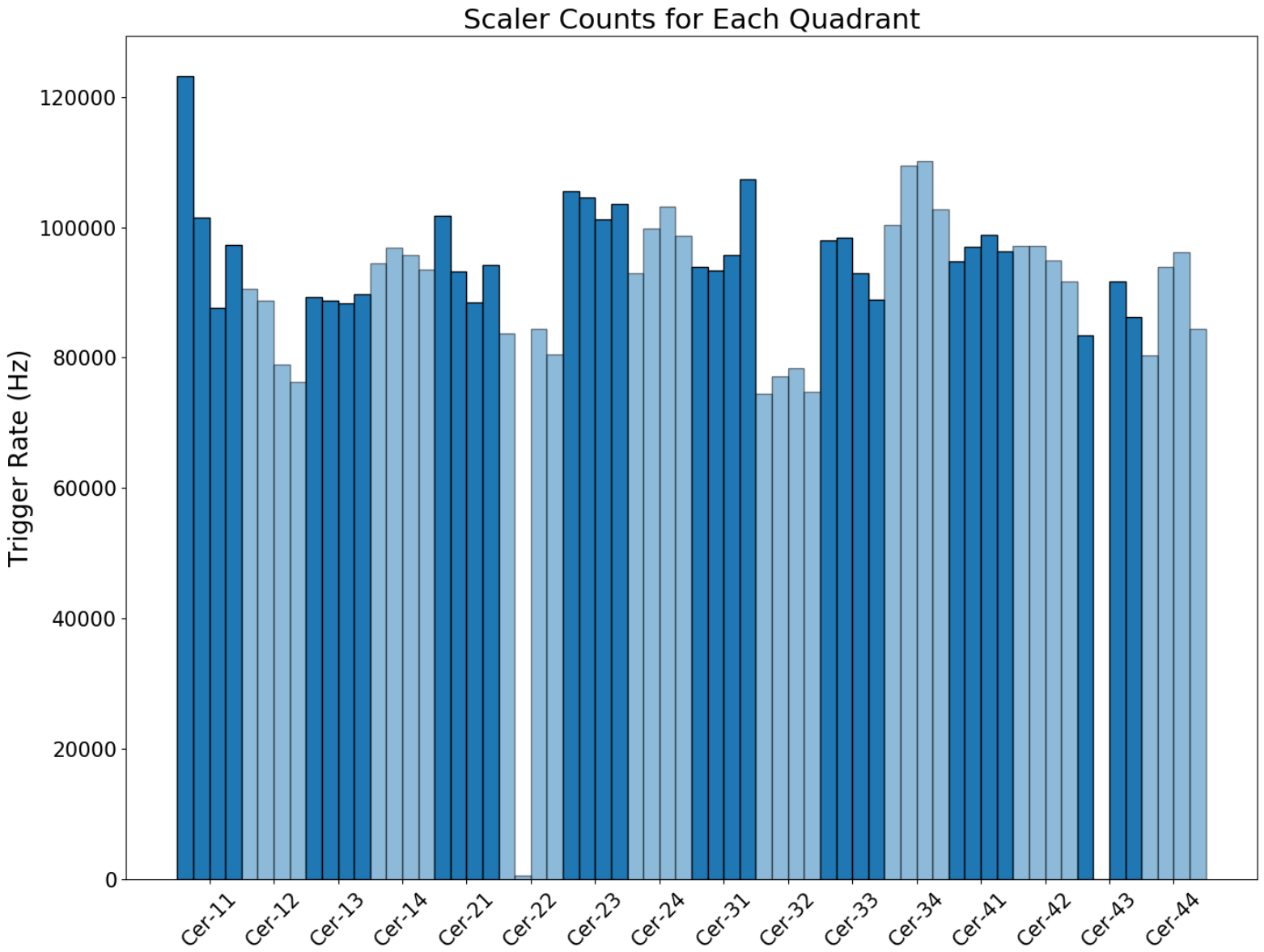
Run 160 – Scalers for Calorimeter



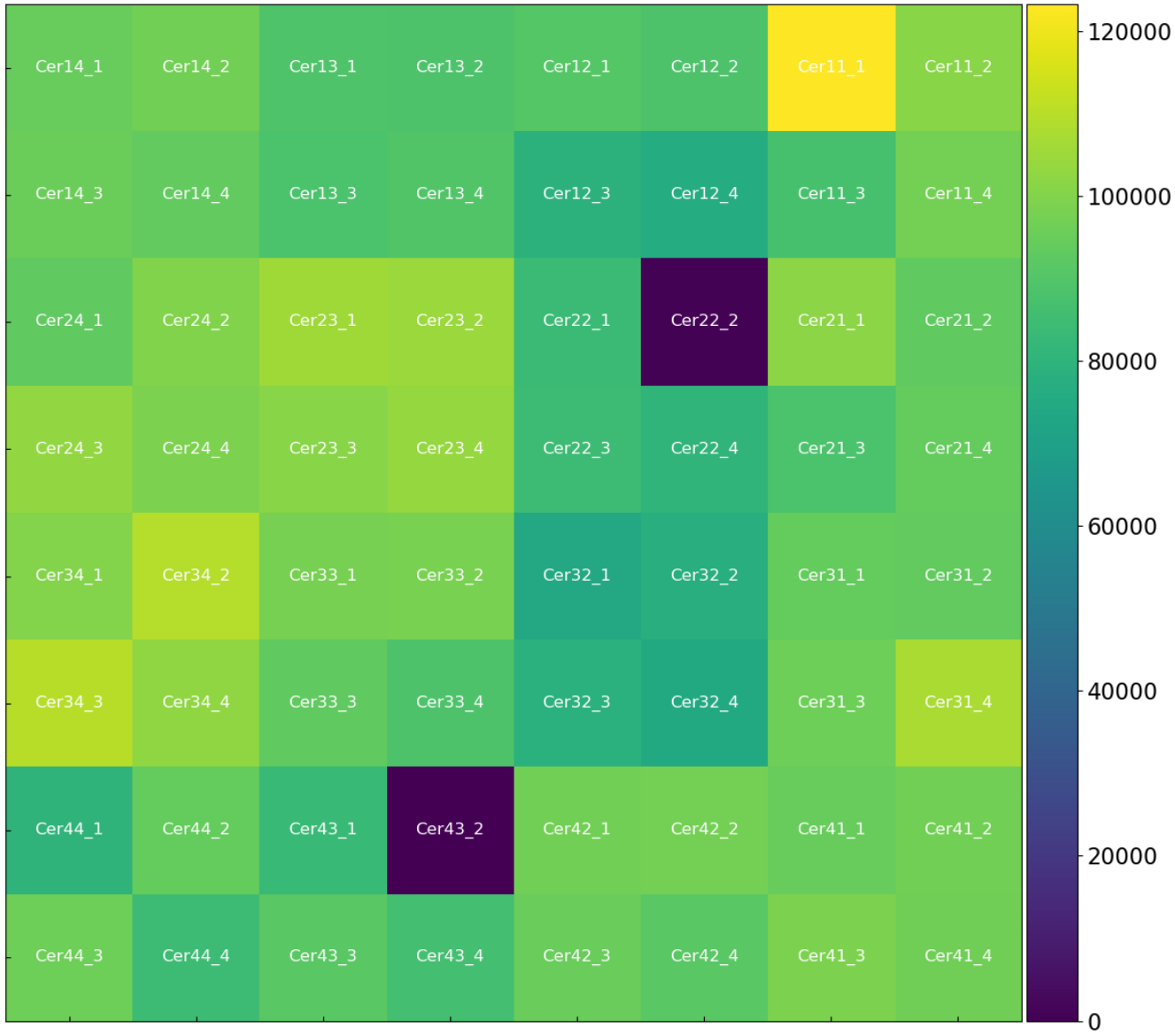
Run 160 – Scalers for Scintillator



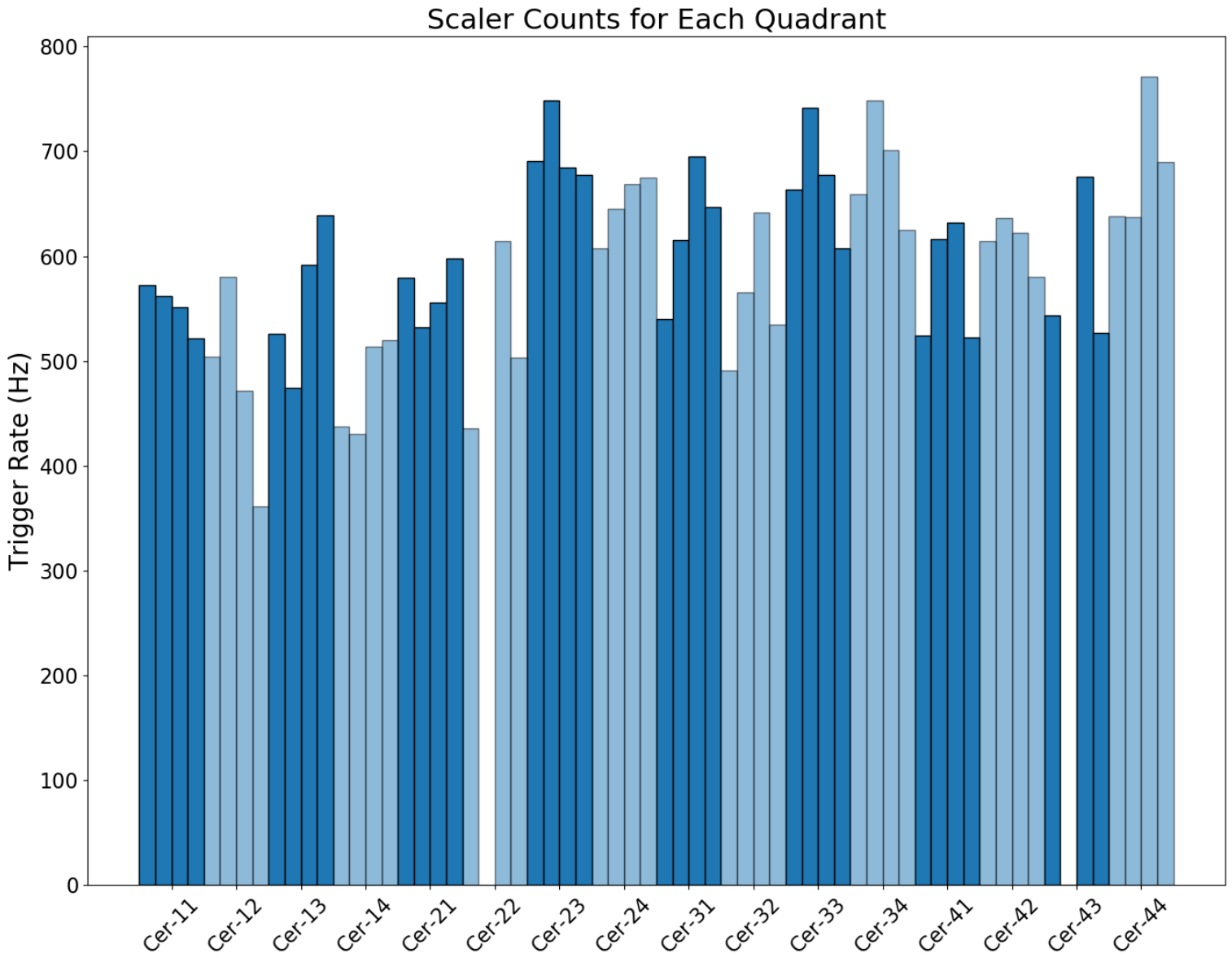
Run 160 – Scalers for MAPMT



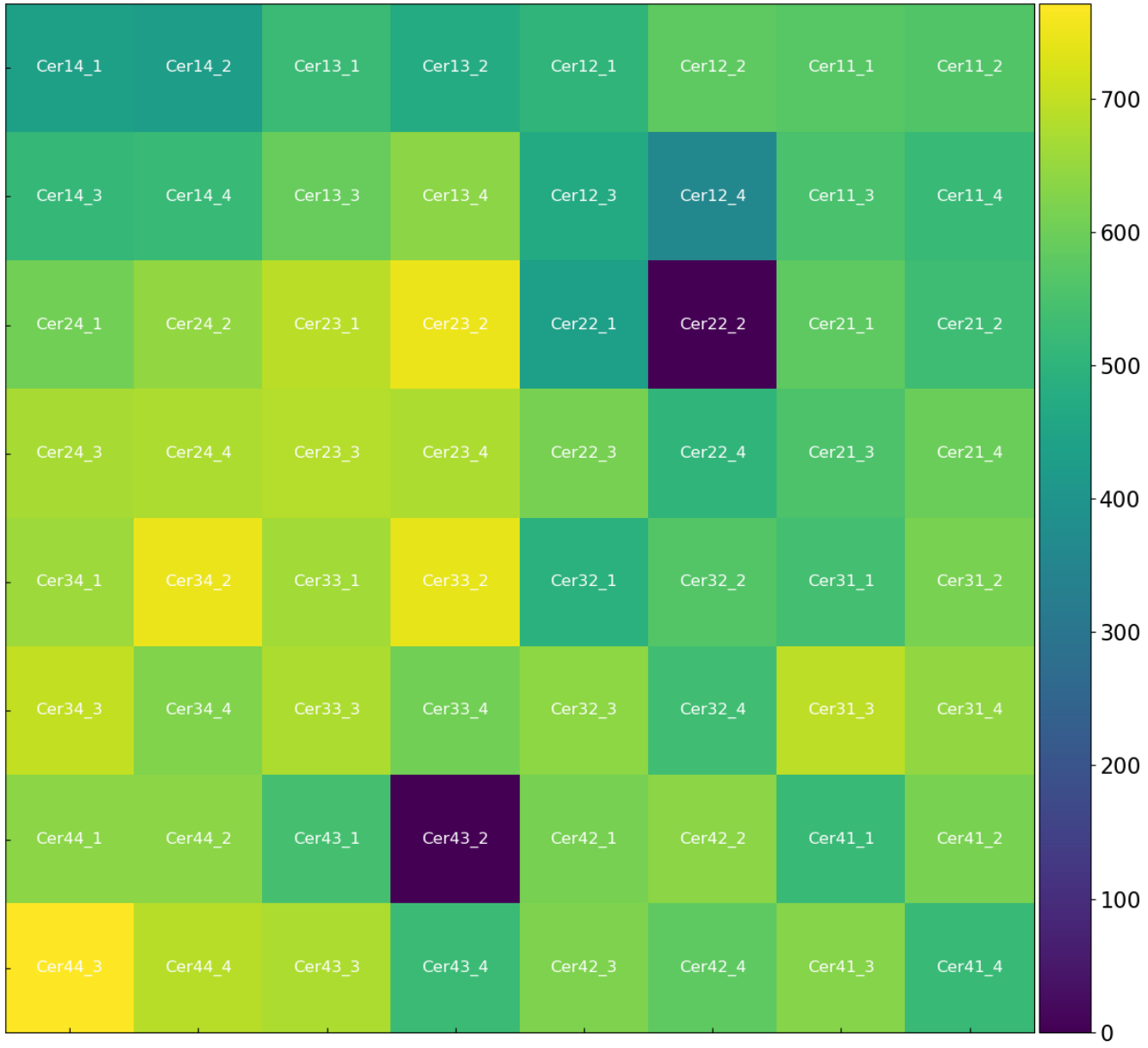
Run 160 – Scalers for MAPMT



Run 158 – Scalers for MAPMT



Run 158 – Scalers for MAPMT



Scalers Study

- Run 158
  - no counts for calorimeter, scintillator scalers, or MAPMT sums
  - 0.3 ~ 0.8 kHz per MAPMT quadrant

- Run 160
  - first two files are identical (solid.0, solid.15), 60 ~ 130 kHz per MAPMT quadrant
  - Overall rates from calorimeter channels is about 118kHz
    - Expected because we have a high FADC threshold
    - A single “hot” channel C6-3 (s7, c5), a single “dead” channel C9-3 (s8, c9)
  - The single photon rates for each PMT is about 300 ~ 360 kHz
    - Lower than the wanted rates at 2 ~ 3.5 MHz/PMT (4 x 4 array in PVDIS configuration)
    - Test runs at smaller angle will raise the rates

Summary

- Good signals observed from the test
- The mode1 data analysis gives N.p.e = 17.78
- Scalers data show the single photon rates for each PMT at ~374 kHz
  - Need smaller angle runs to reach MHz/PMT level
- Some issues that could be improved in the future tests?
  - Two quadrants have no (few) signals, Cer22-2 (s9, c9) and Cer43-2 (s5, c0)
  - Hot cal. channel C6-3 (s7, c5), dead cal. channel C9-3 (s8, c9)
  - The alignment