

BNL DUNE

ProtoDUNE commissioning data

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BNL

August 22, 2018

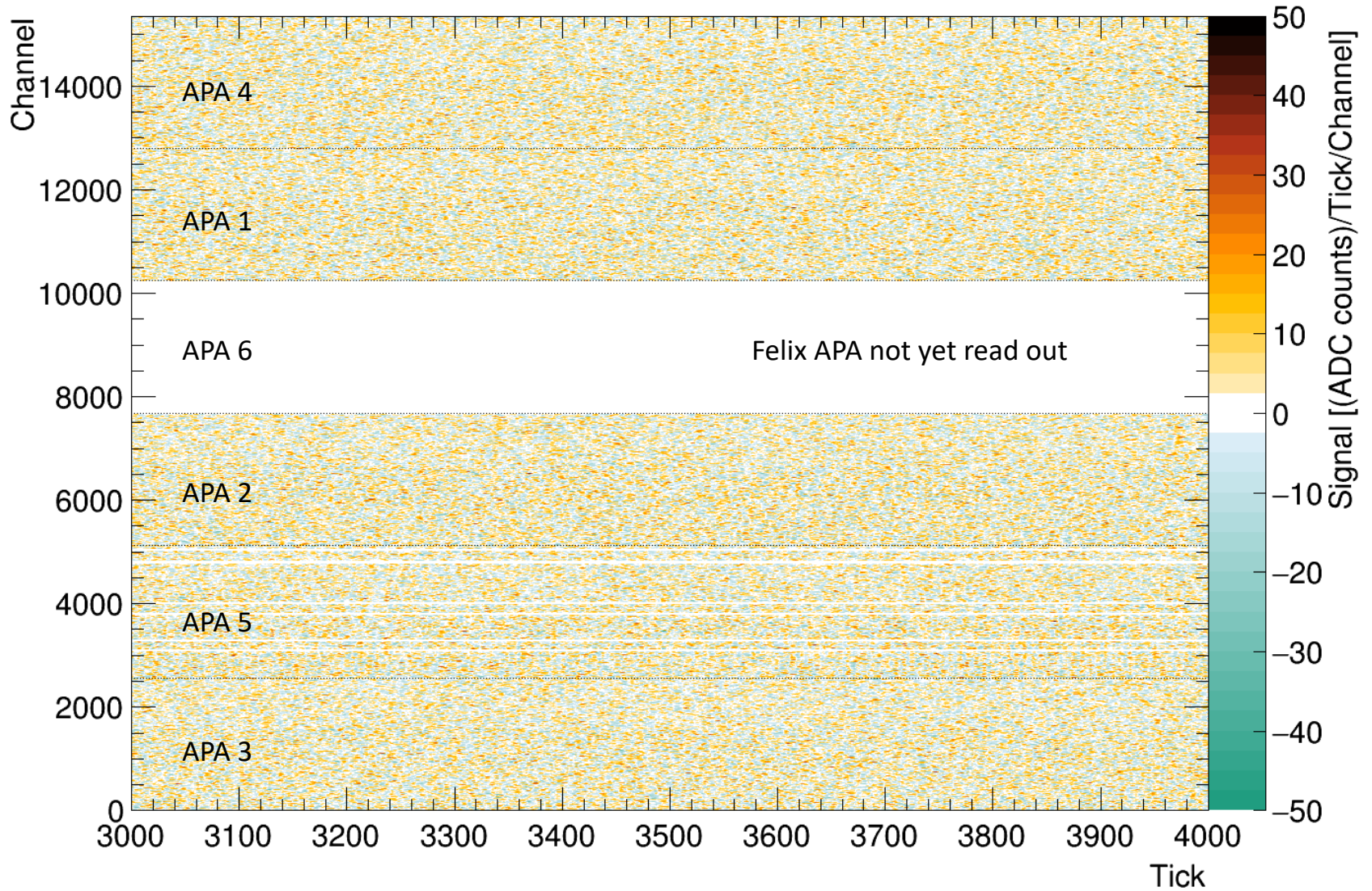
Introduction

The protoDUNE detector is being commissioned

- Filling with LAr this month
 - Now 40% full?
- Data taken sporadically as detector cools
 - List of runs I have studied is at [https://wiki.dunescience.org/wiki/ProtoDUNE_commissioning_runs_\(dla\)](https://wiki.dunescience.org/wiki/ProtoDUNE_commissioning_runs_(dla))
 - Please let me know if I have missed anything interesting
 - Still in commissioning mode—FEMBs will disappear and reappear

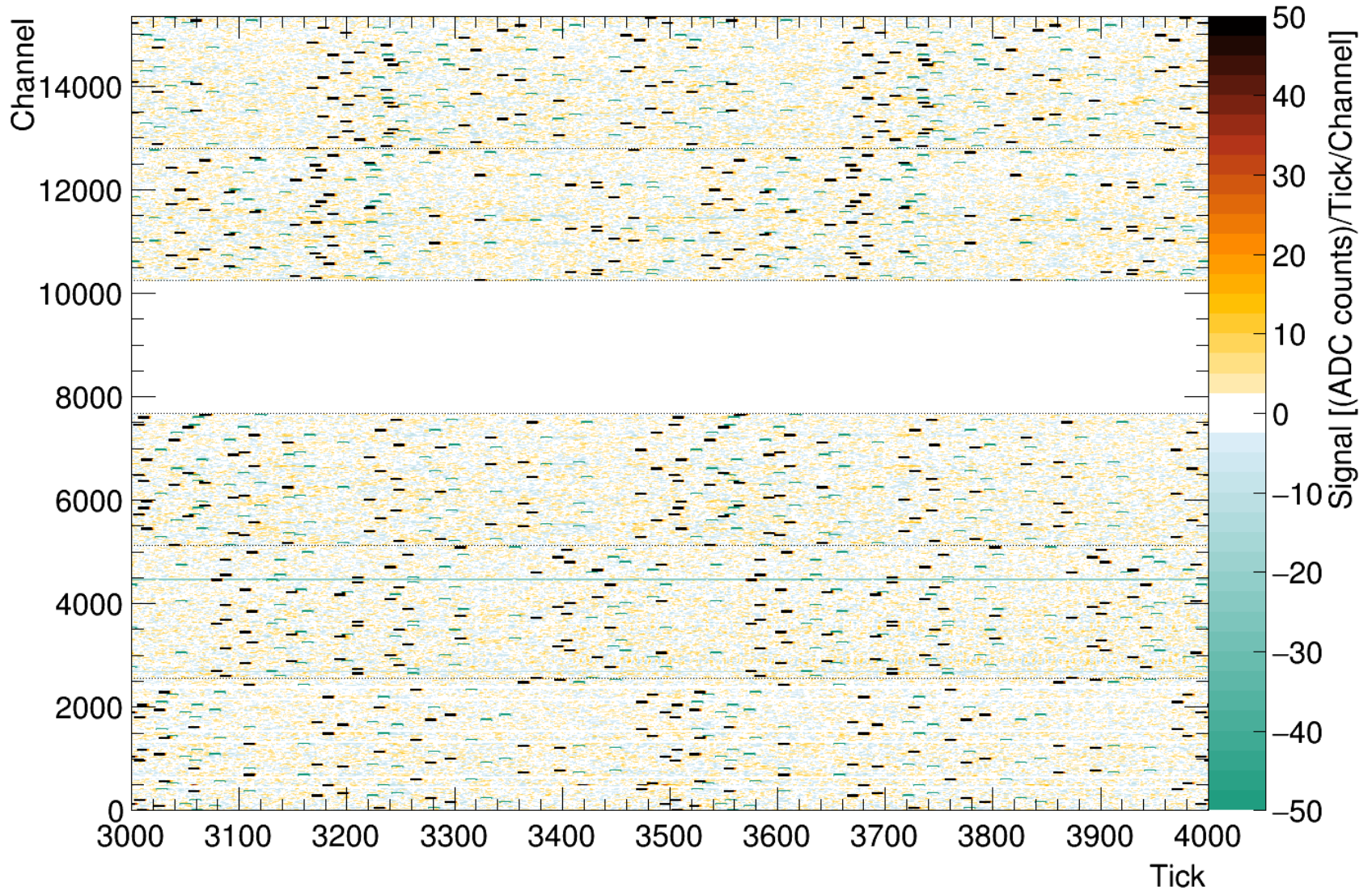
8/1

Raw ADC for run 2973 event 10 All



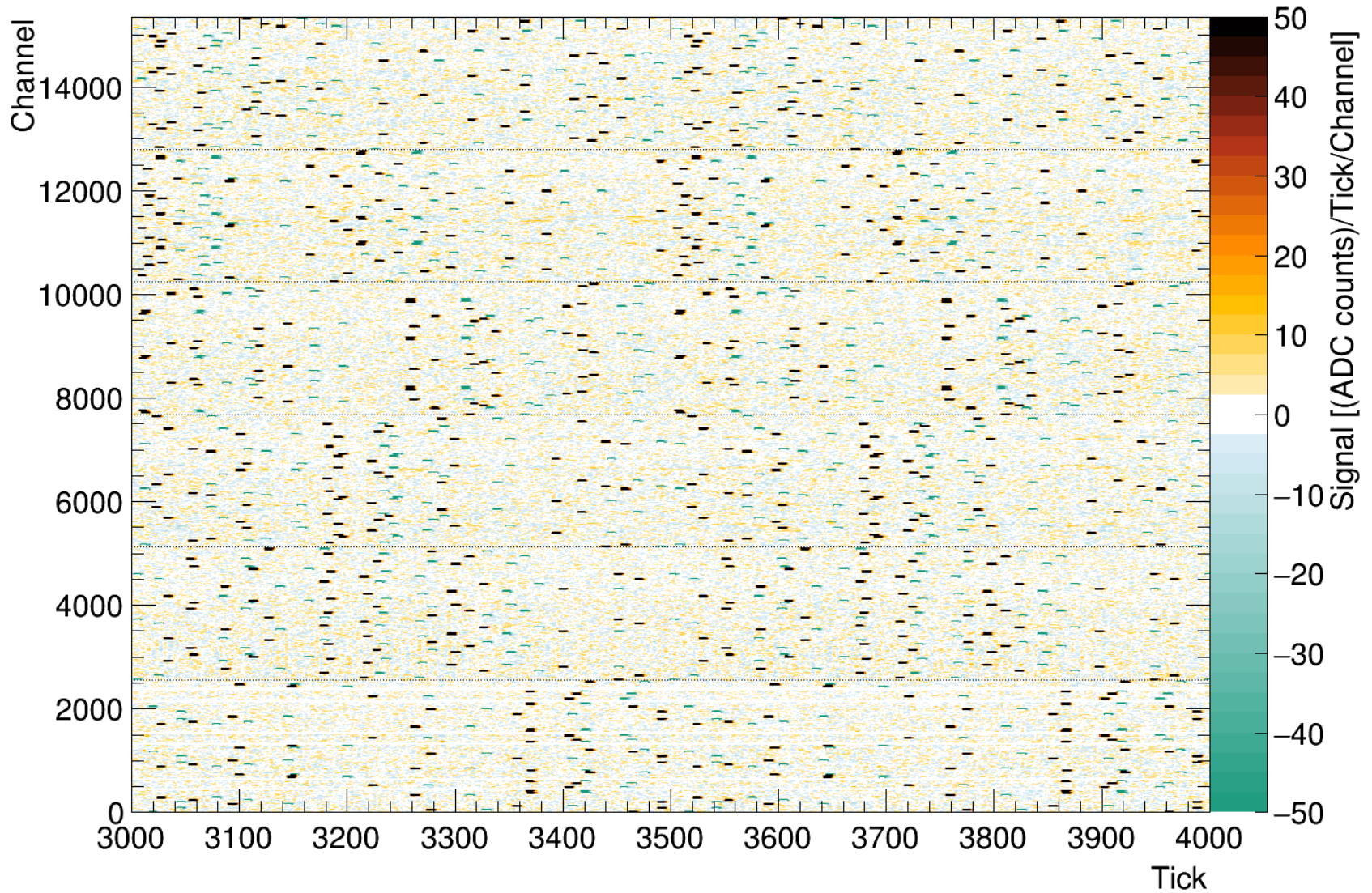
8/14 pulser run

Raw ADC for run 3363 event 92 All



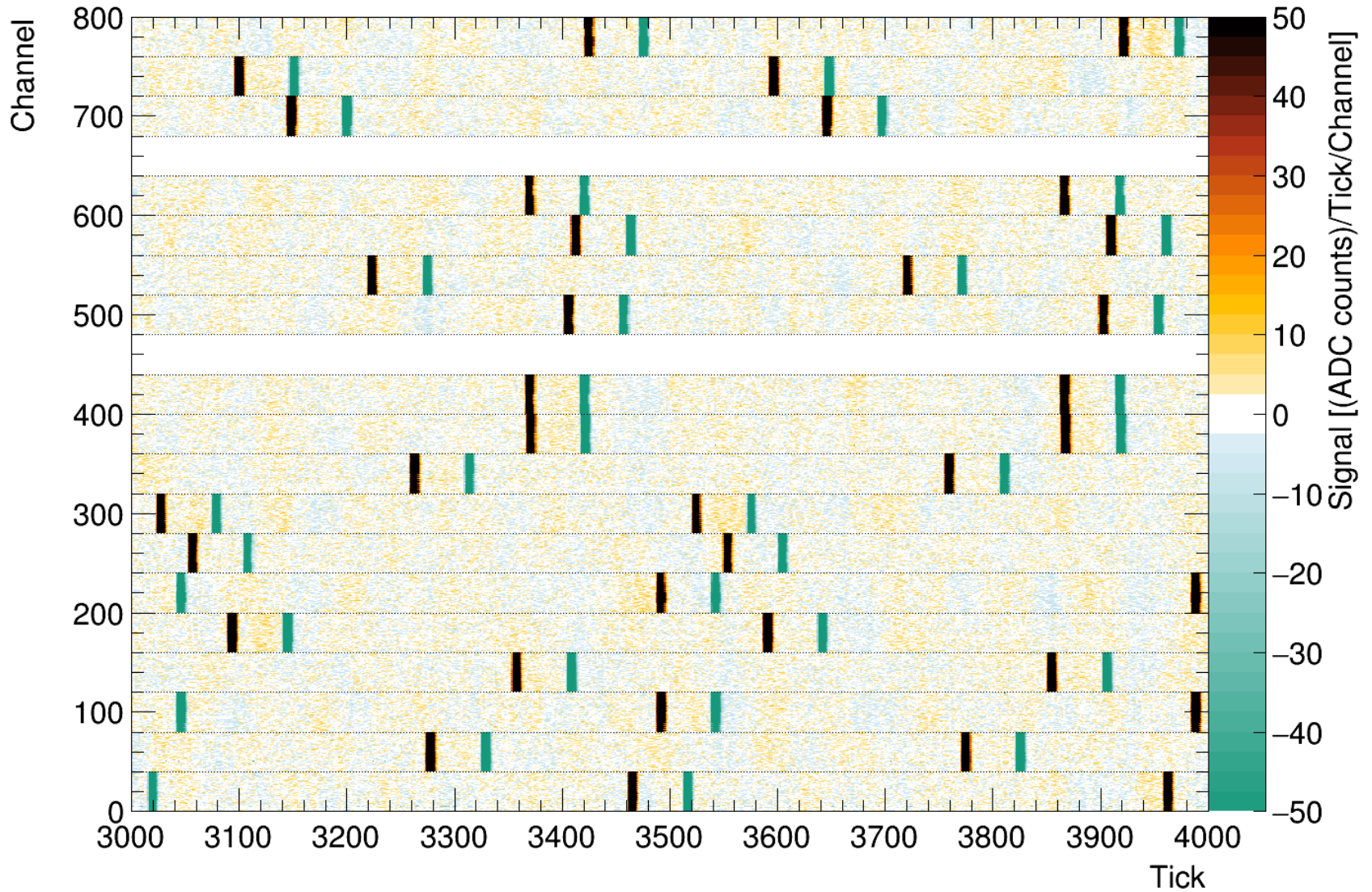
8/21 pulser run

Raw ADC for run 3494 event 218 All



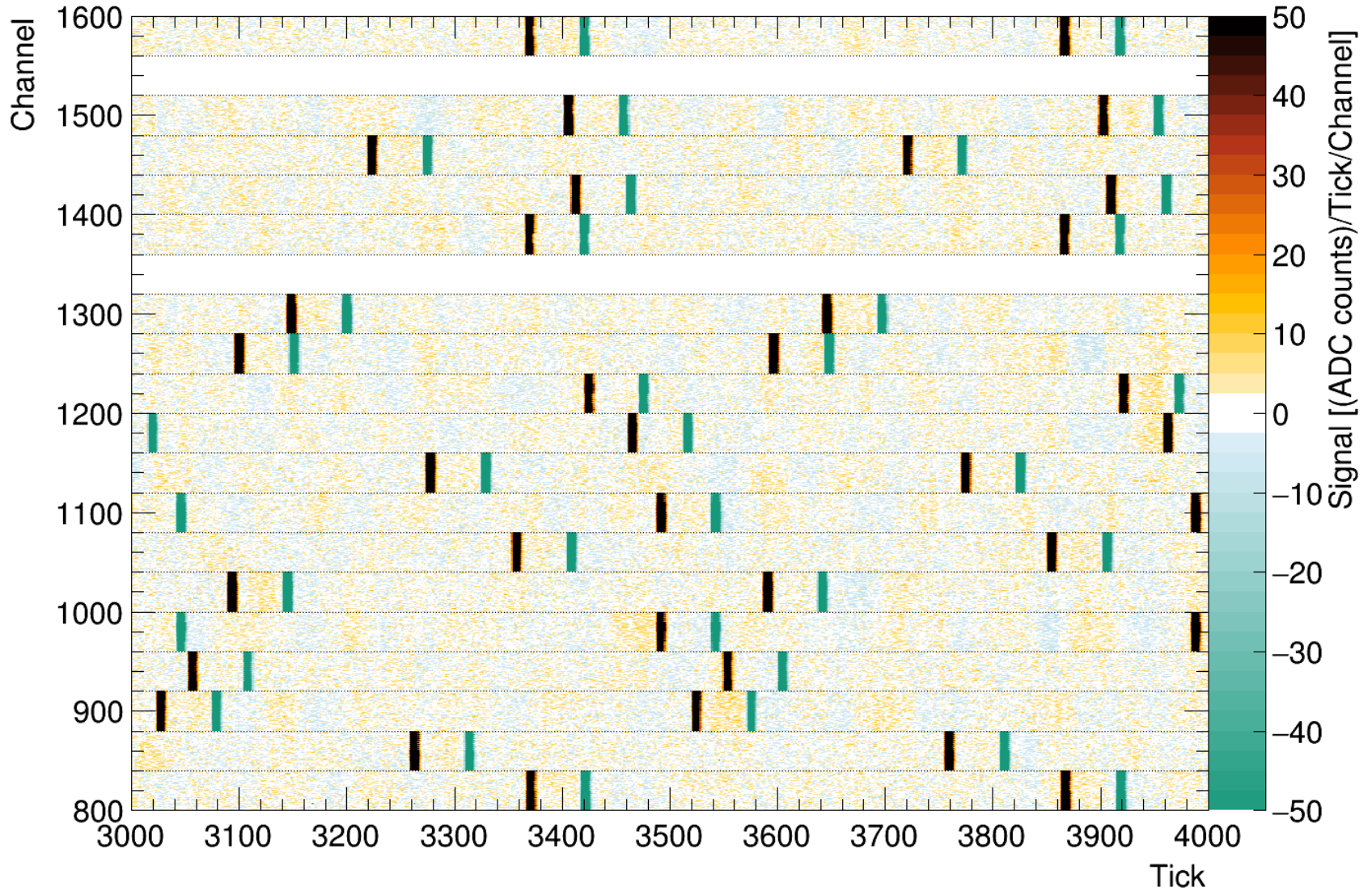
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 0u



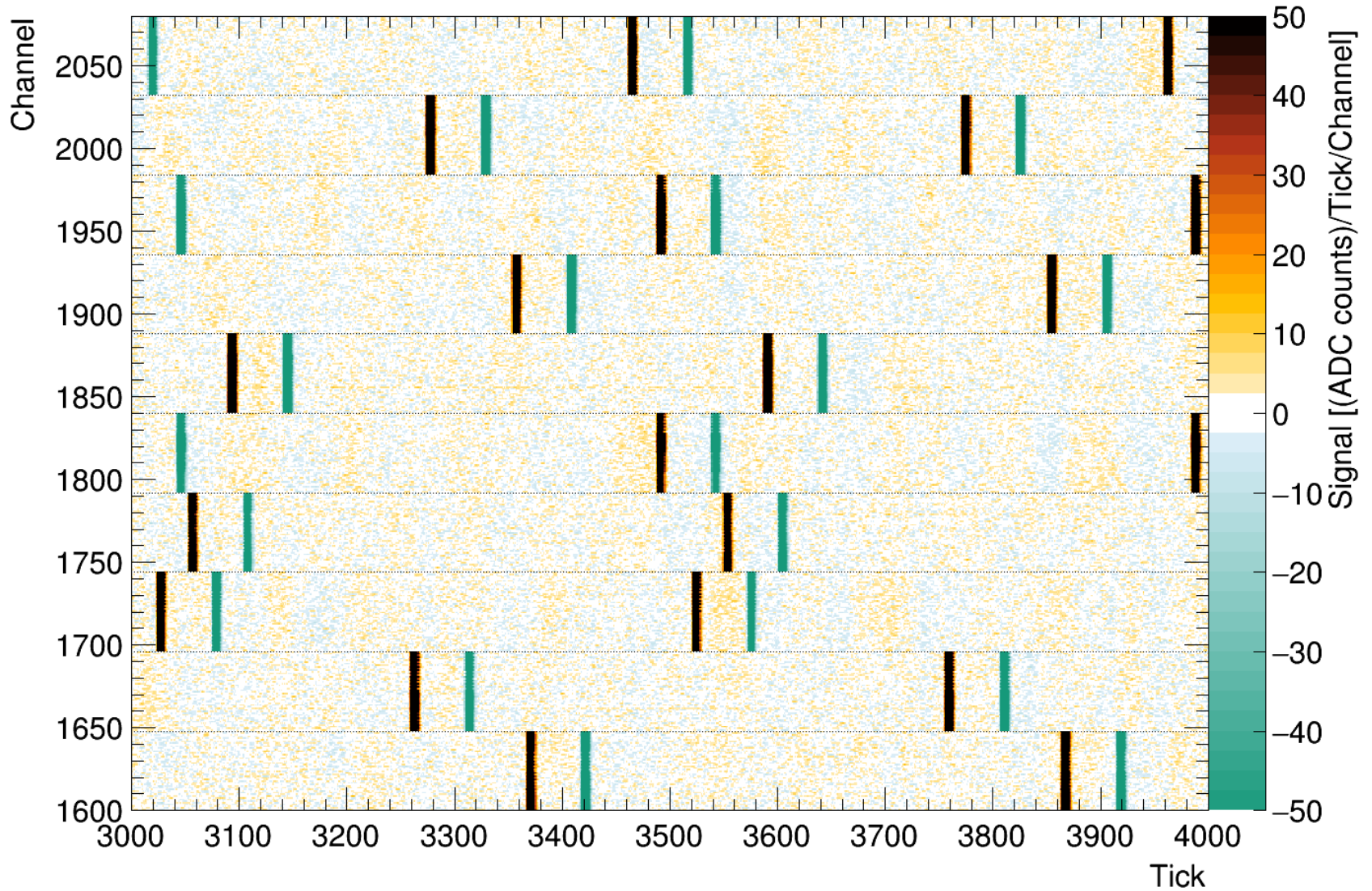
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 0v



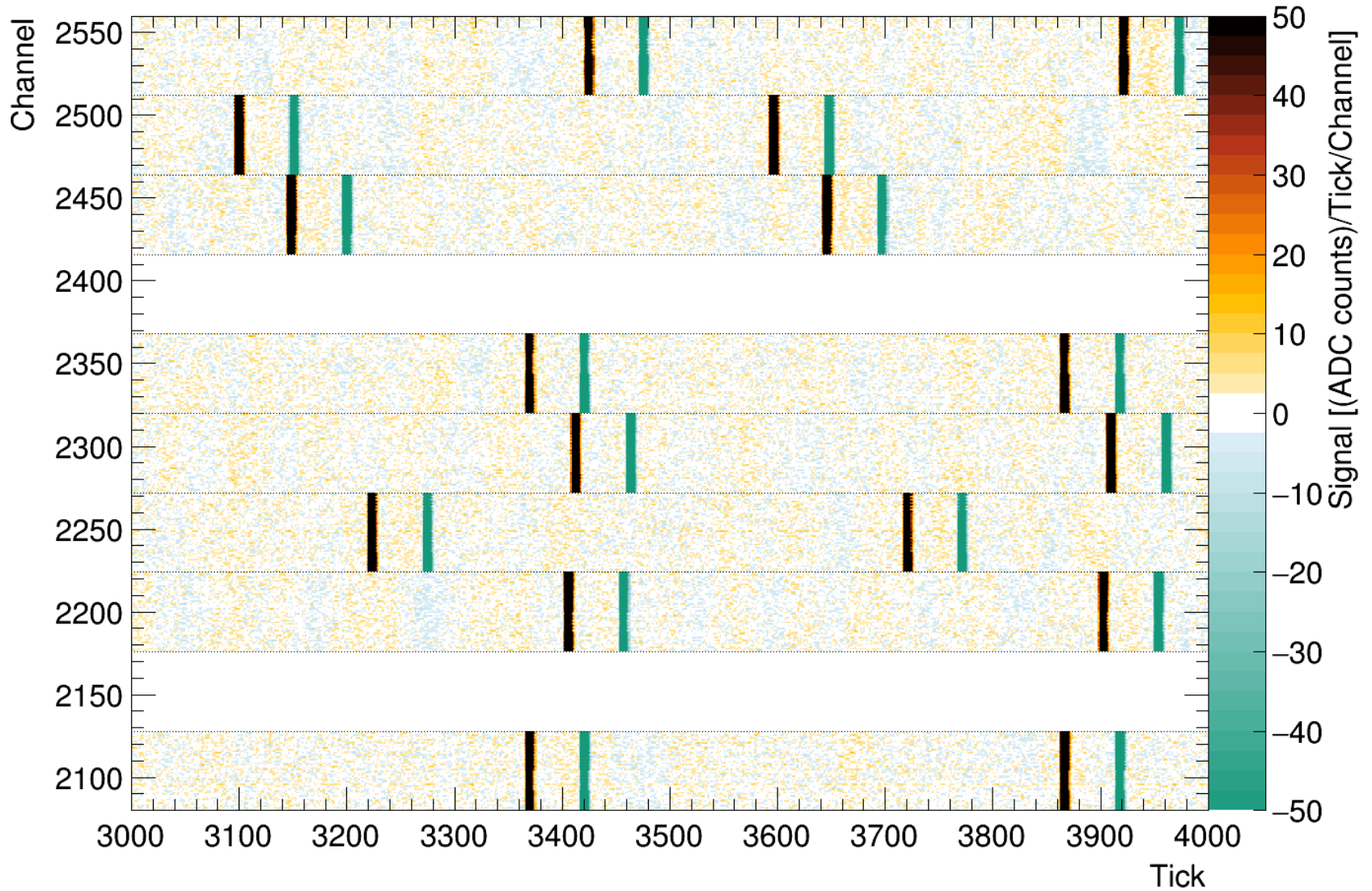
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 0c



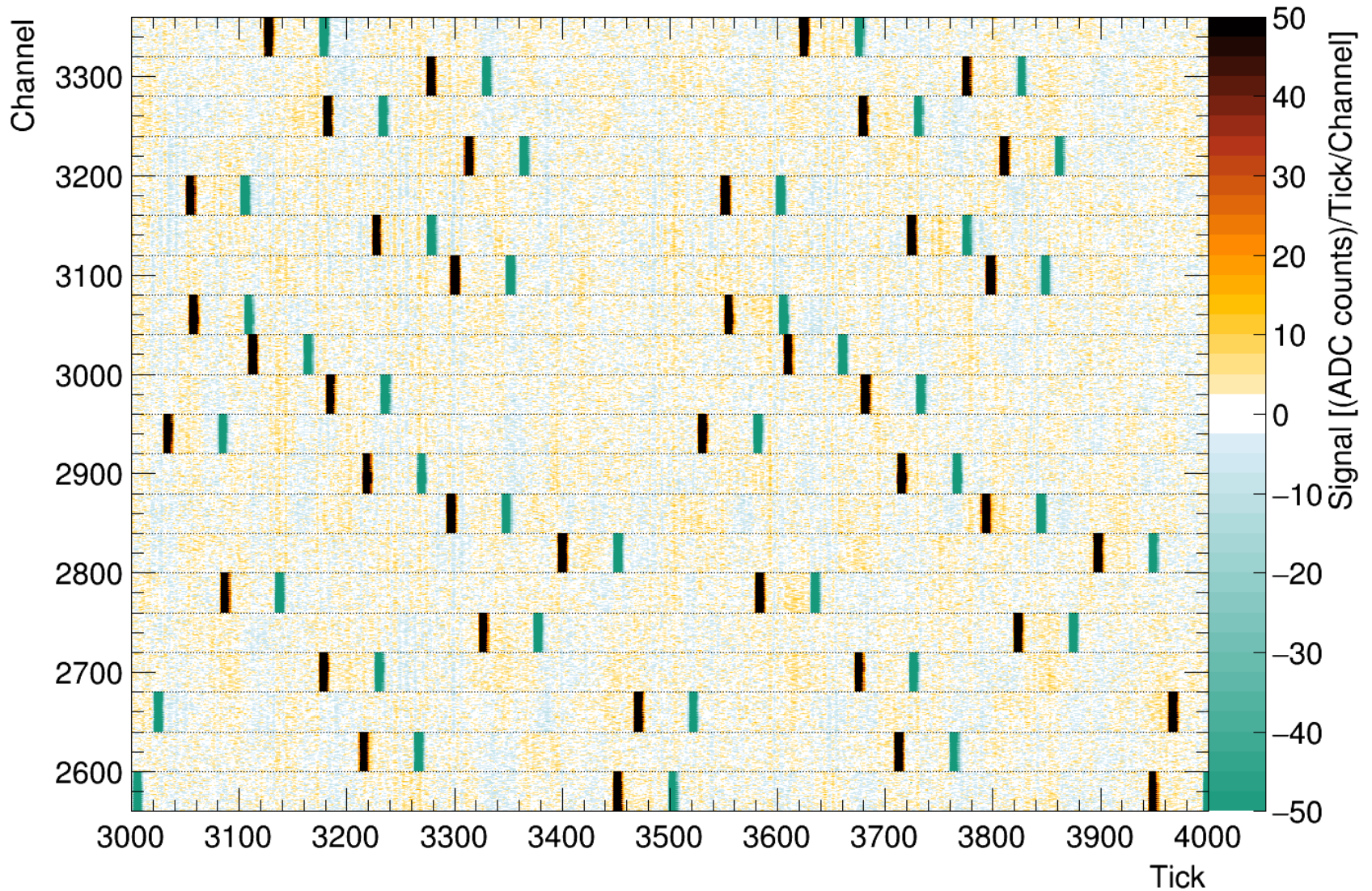
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 0z



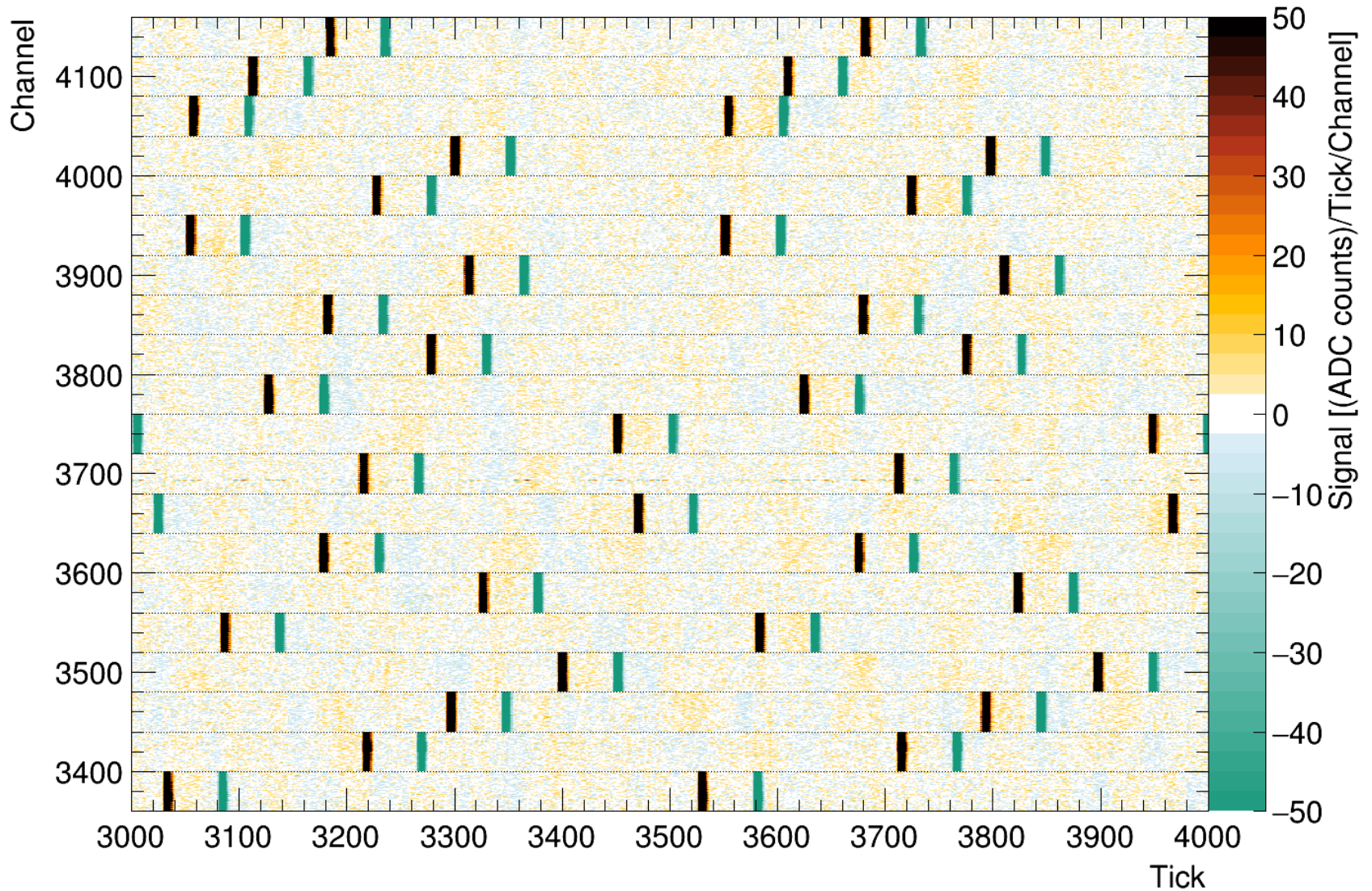
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 1u



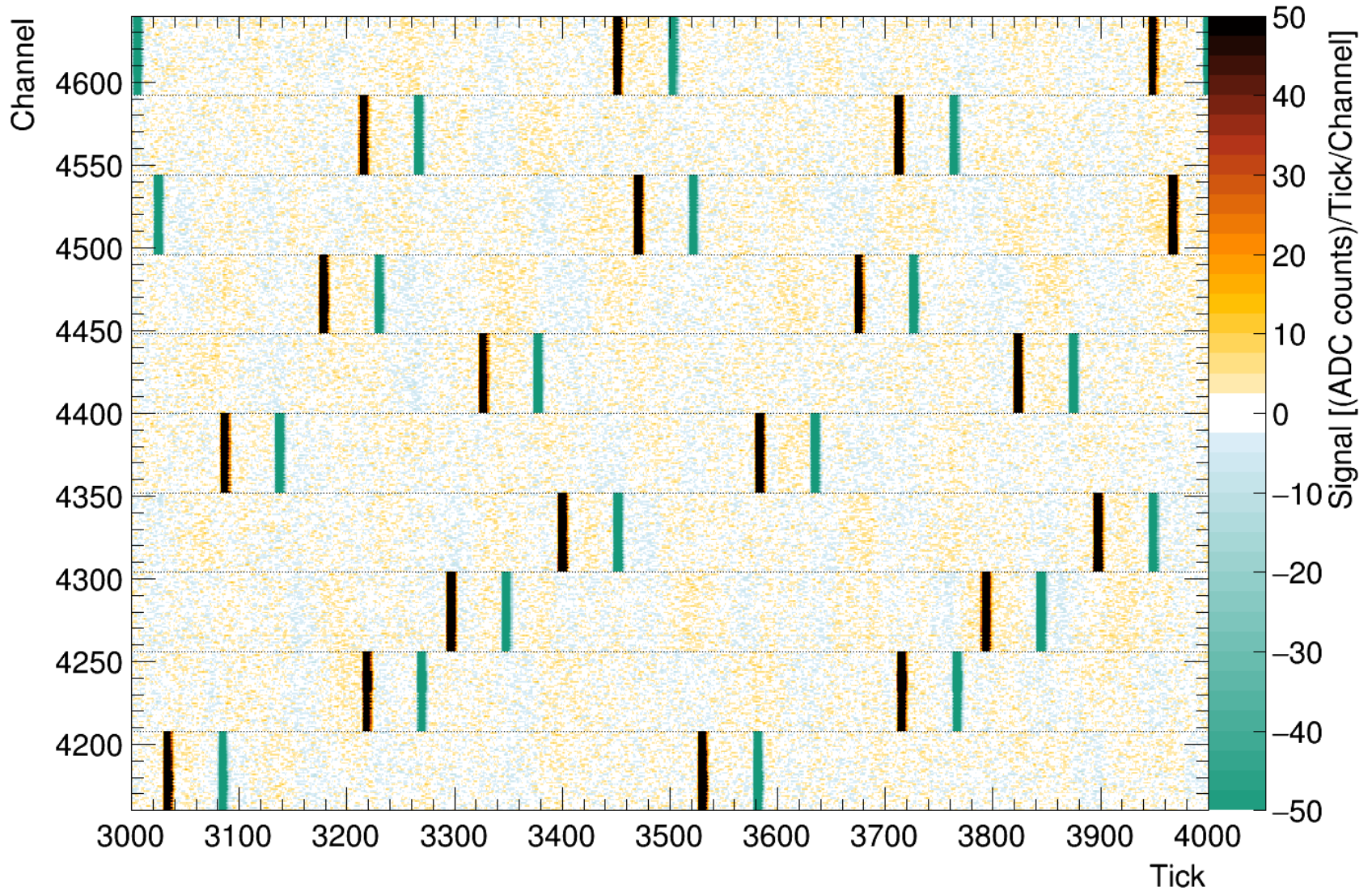
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 1v



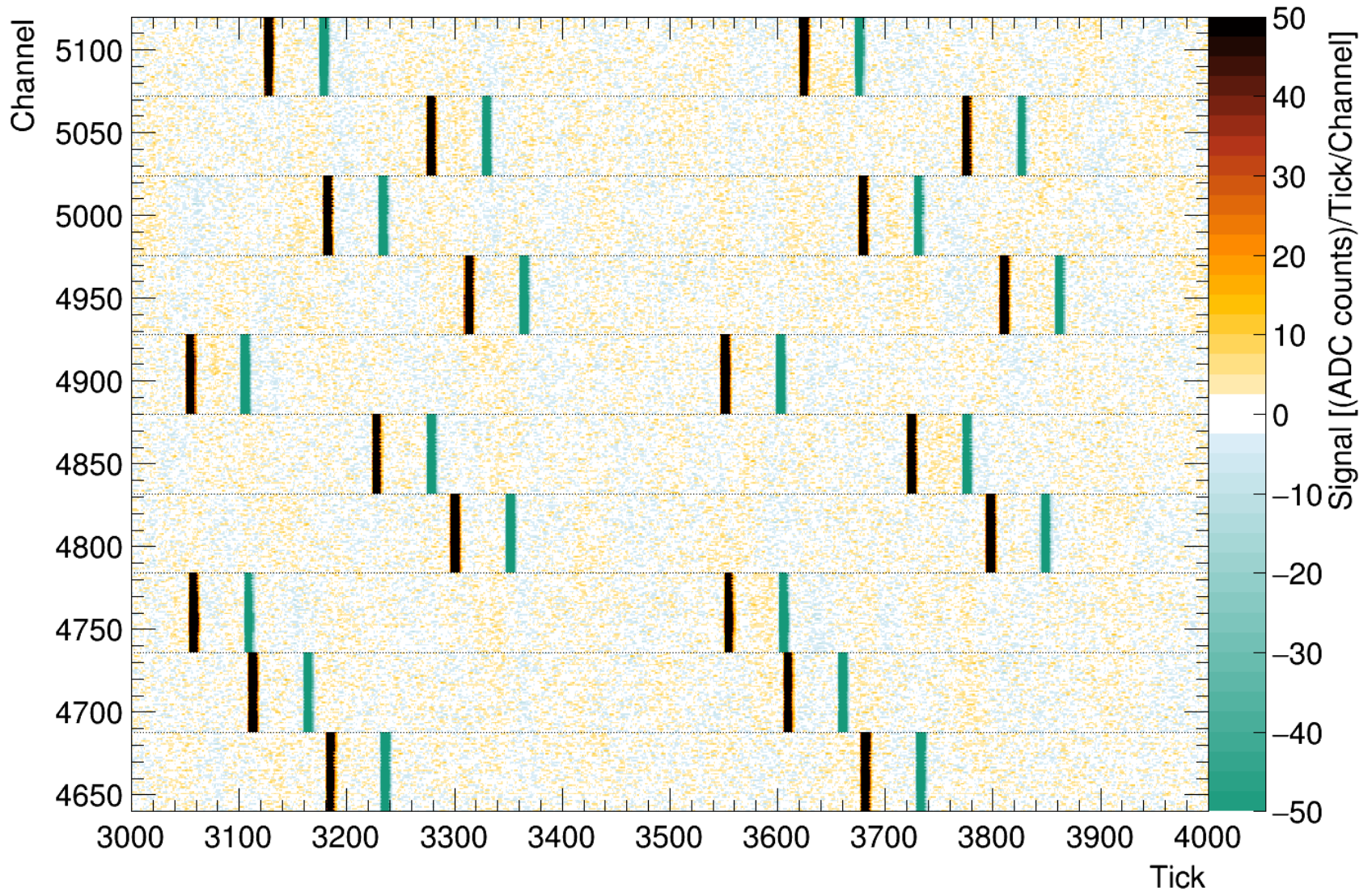
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 1z



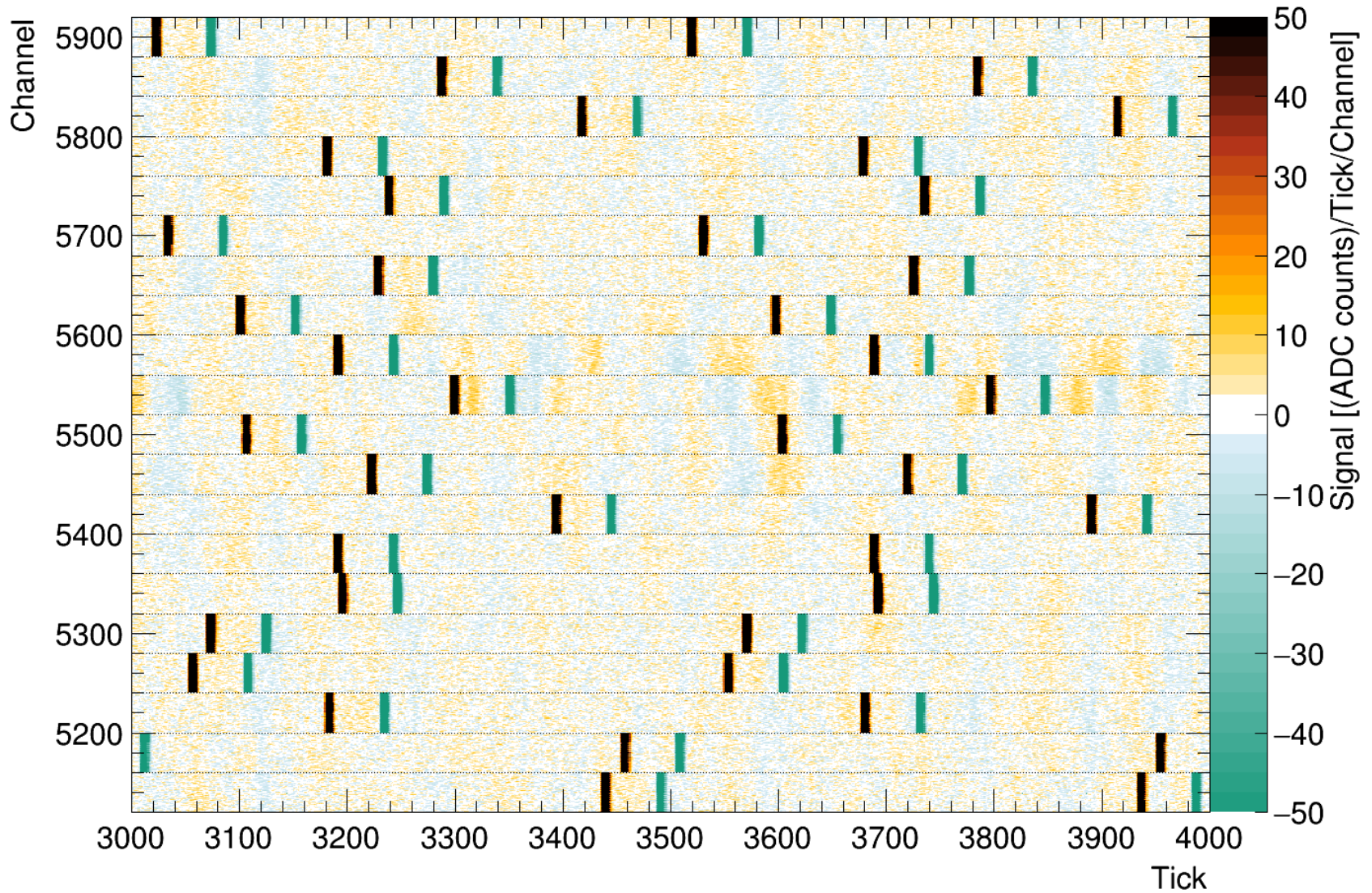
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 1c



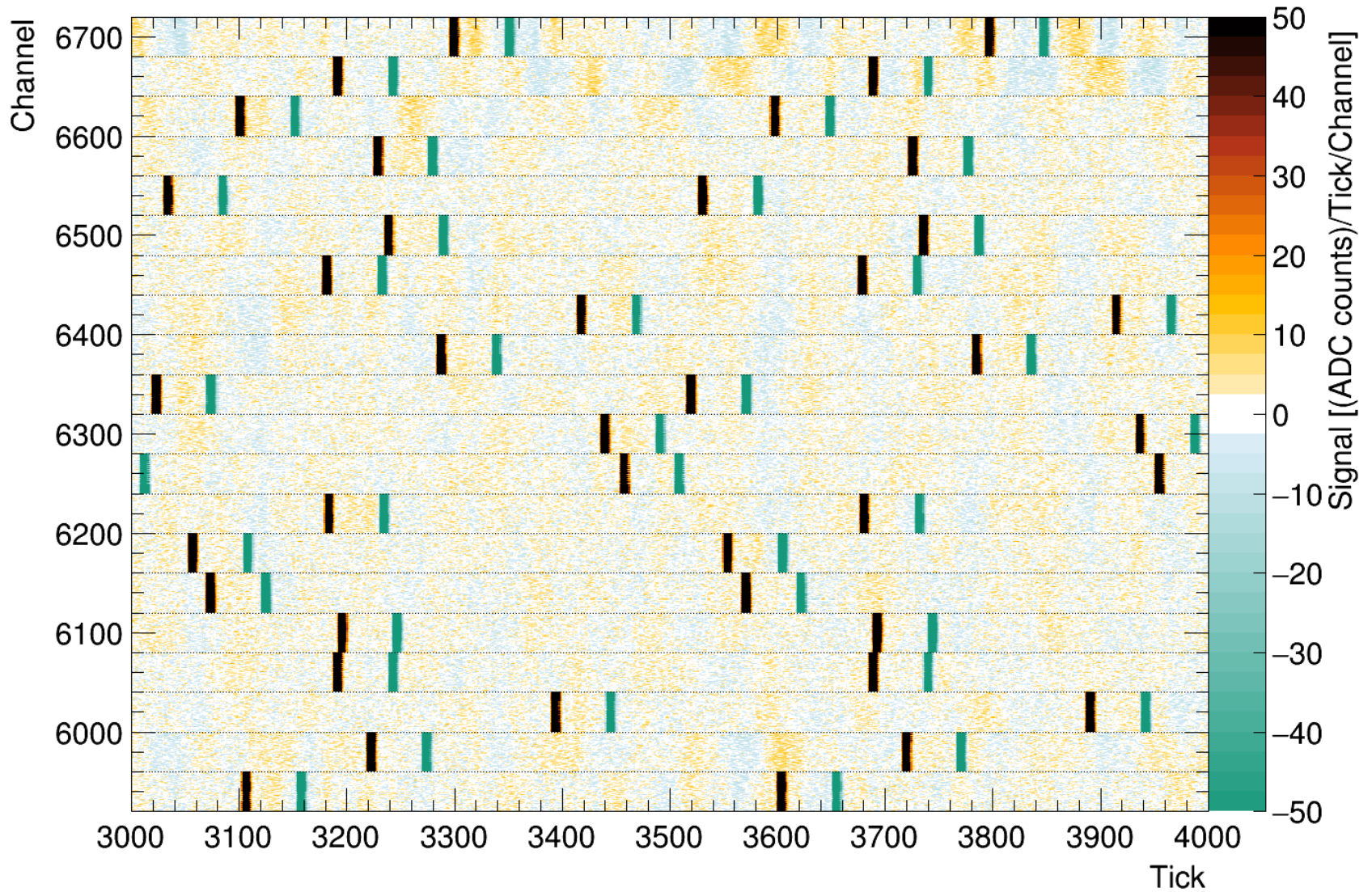
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 2u



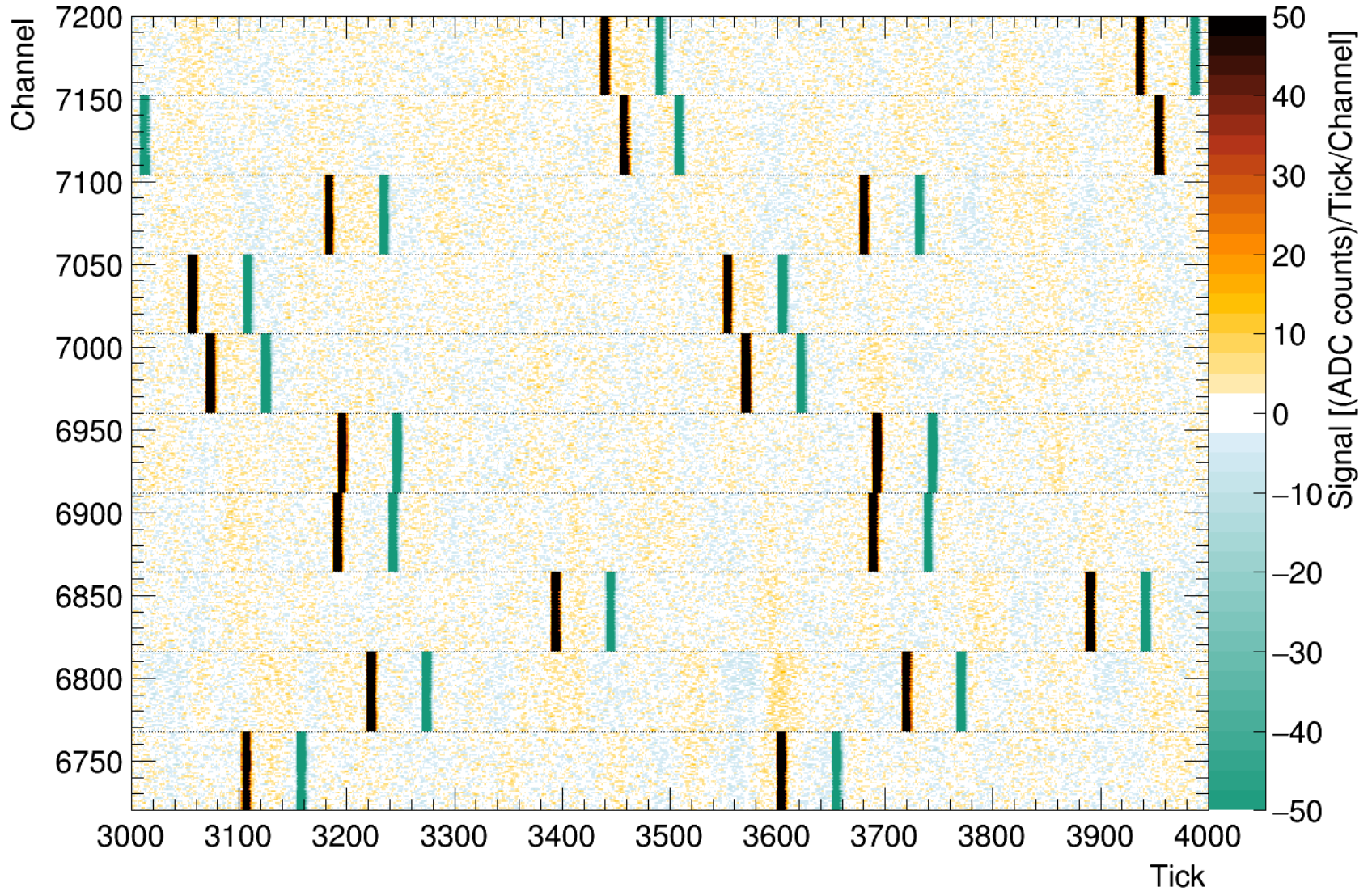
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 2v



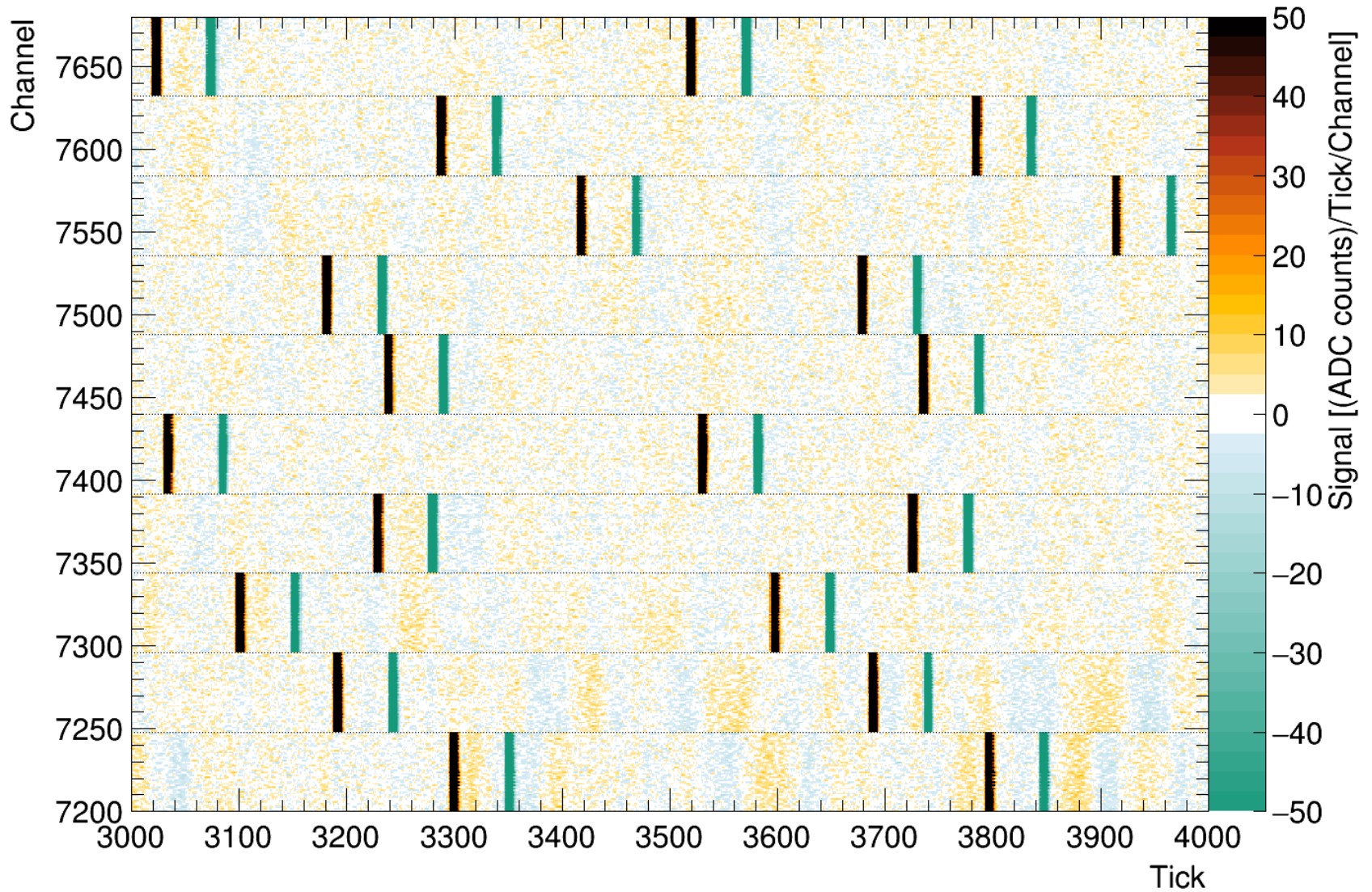
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 2c



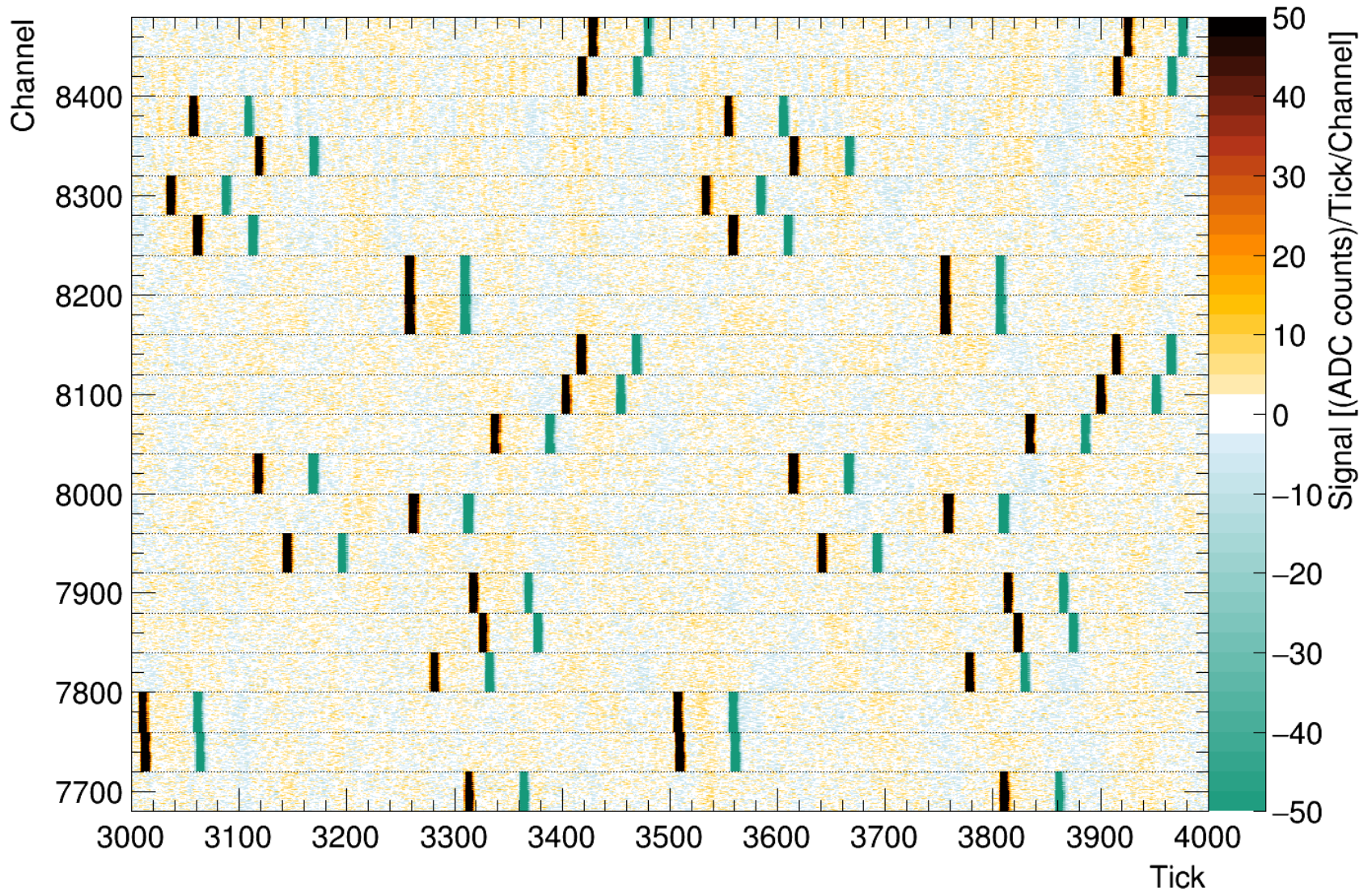
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 2z



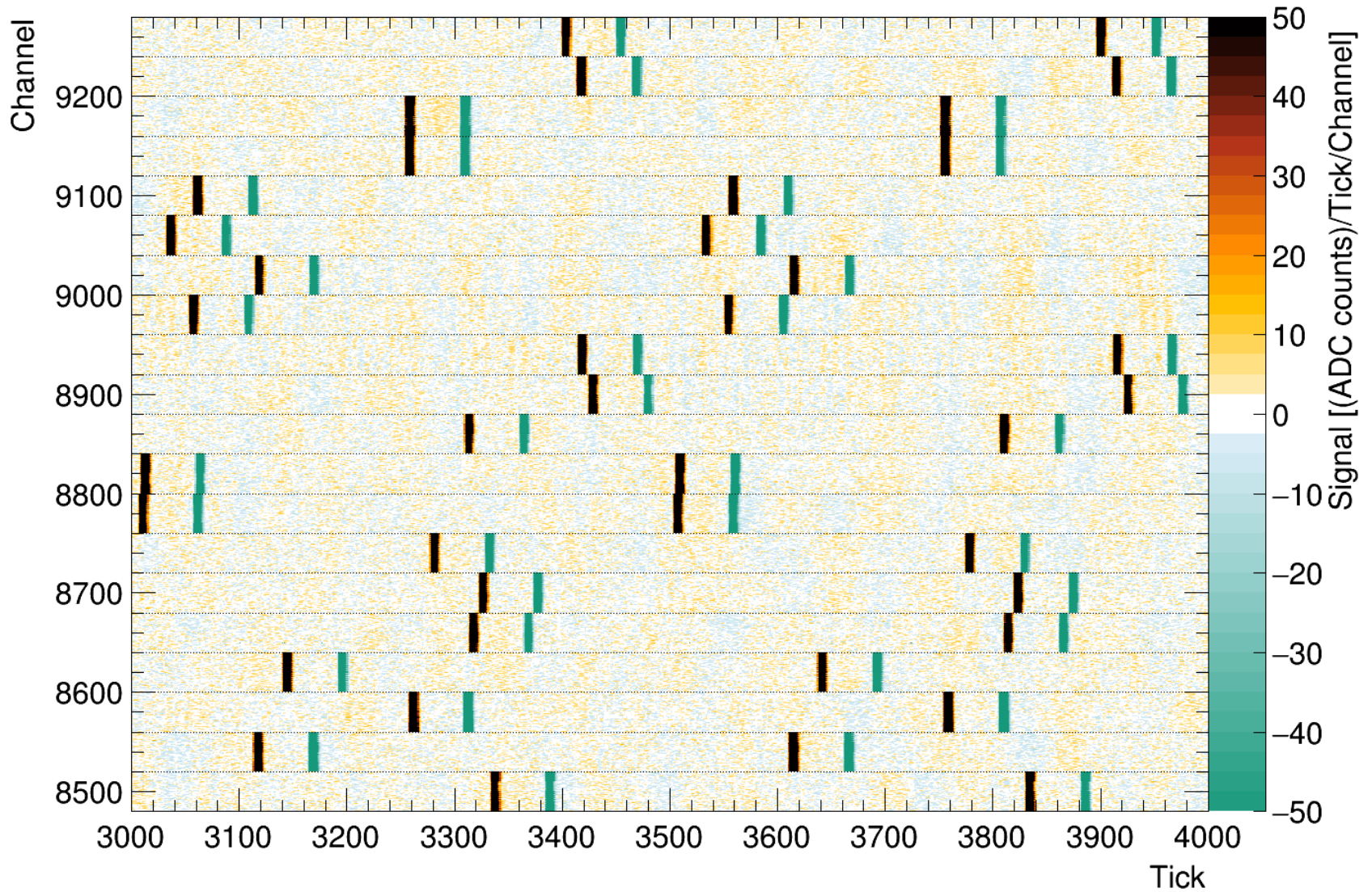
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 3u



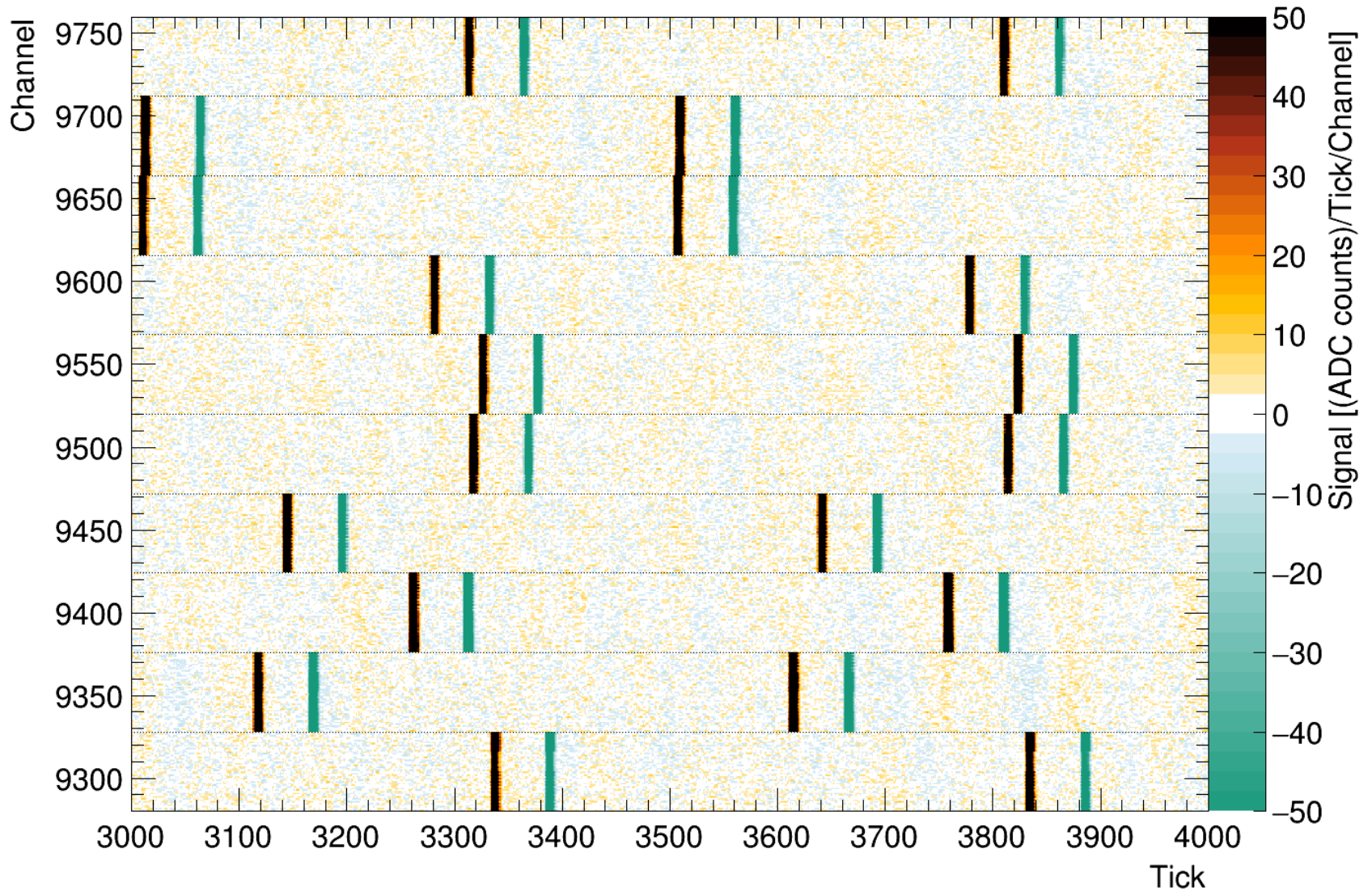
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 3v



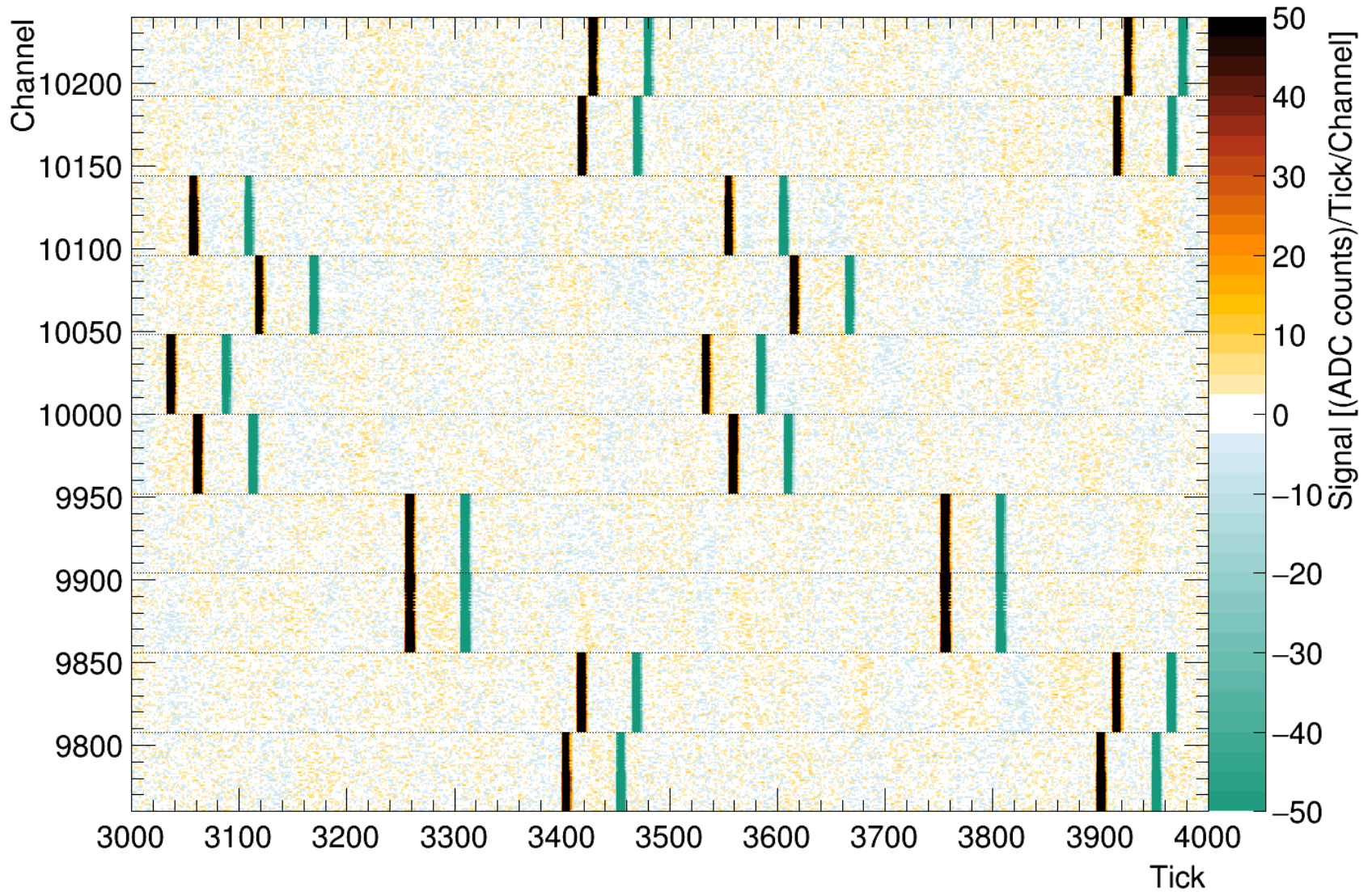
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 3z



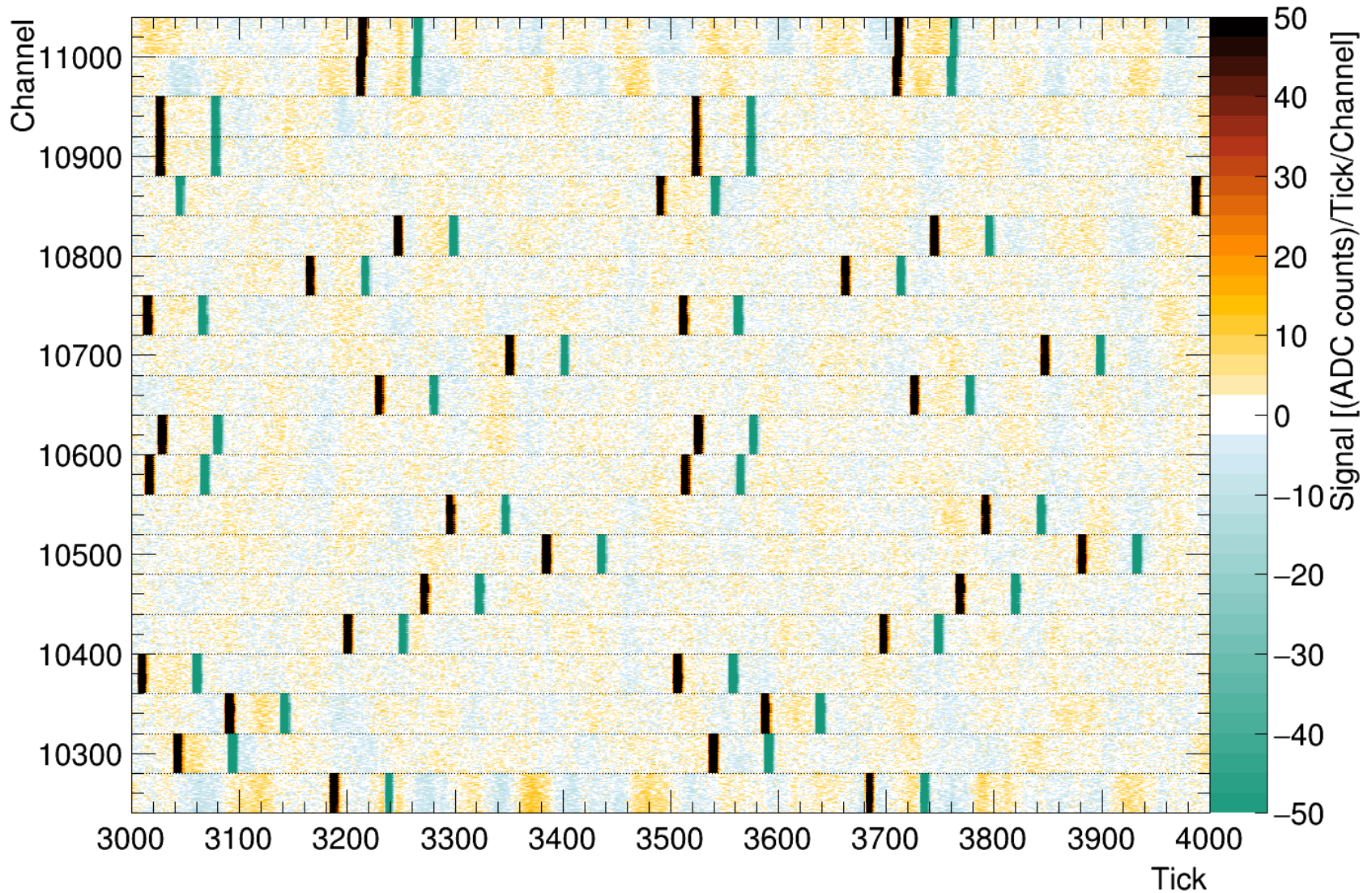
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 3c



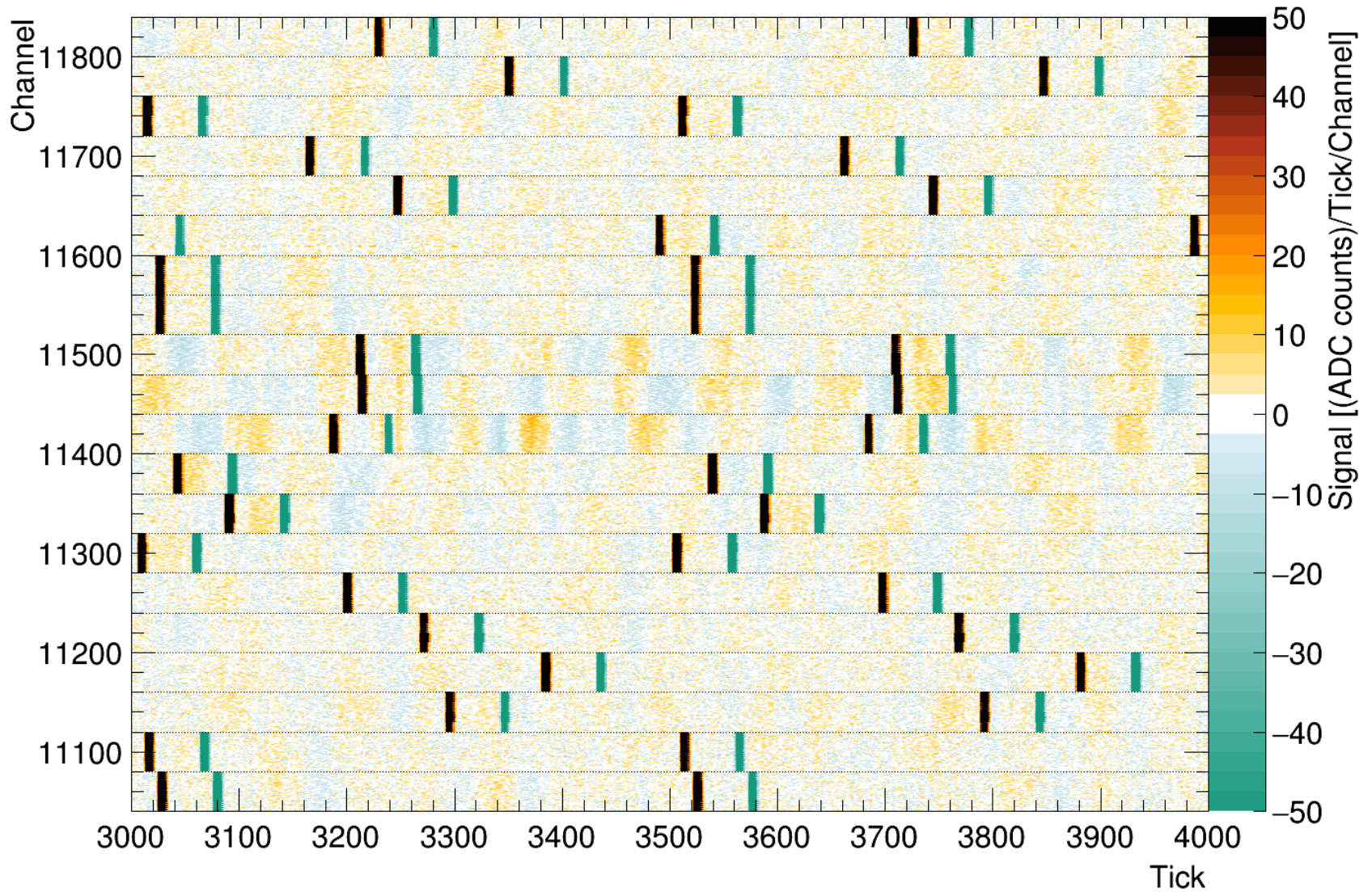
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 4u



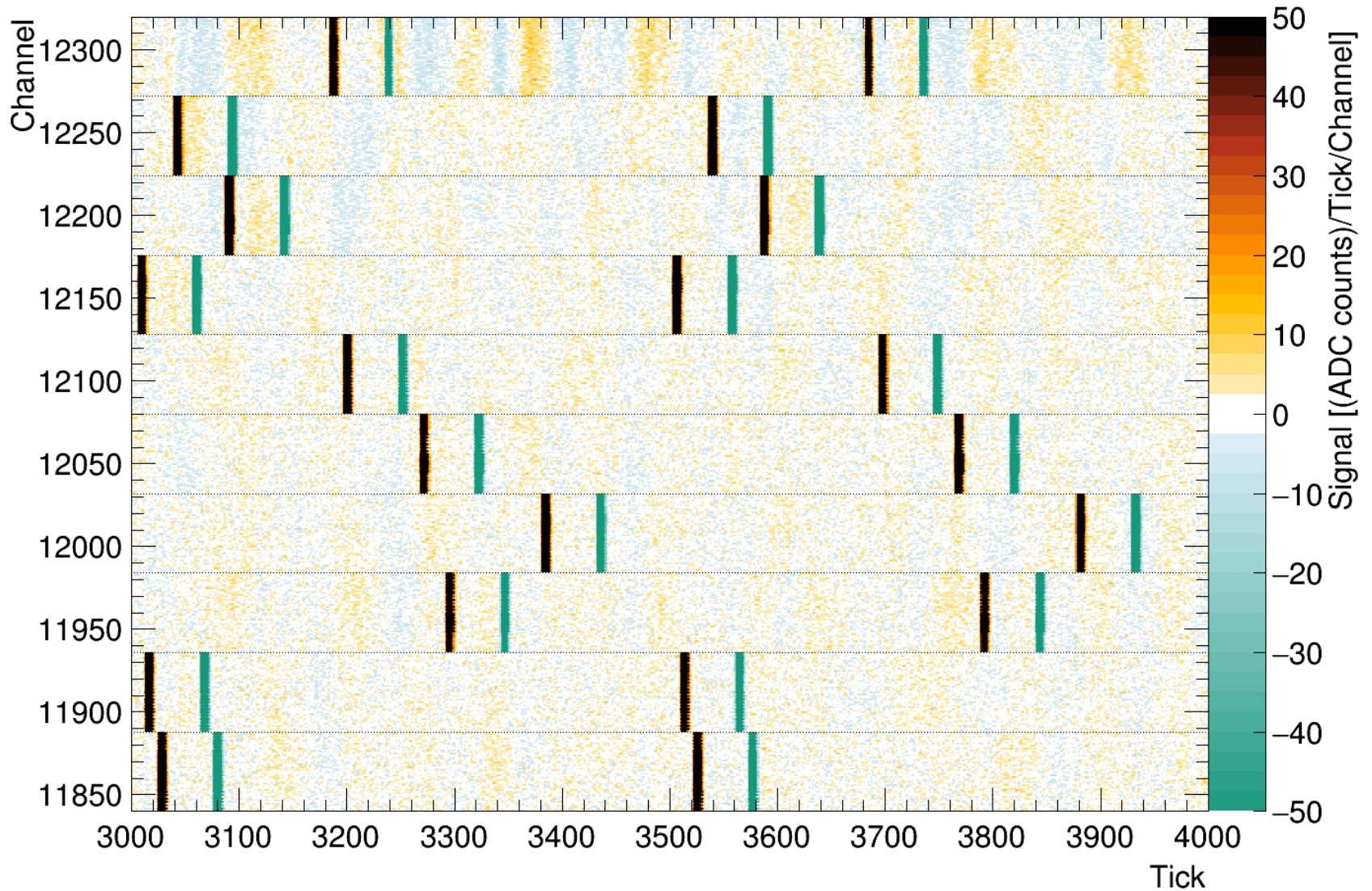
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 4v



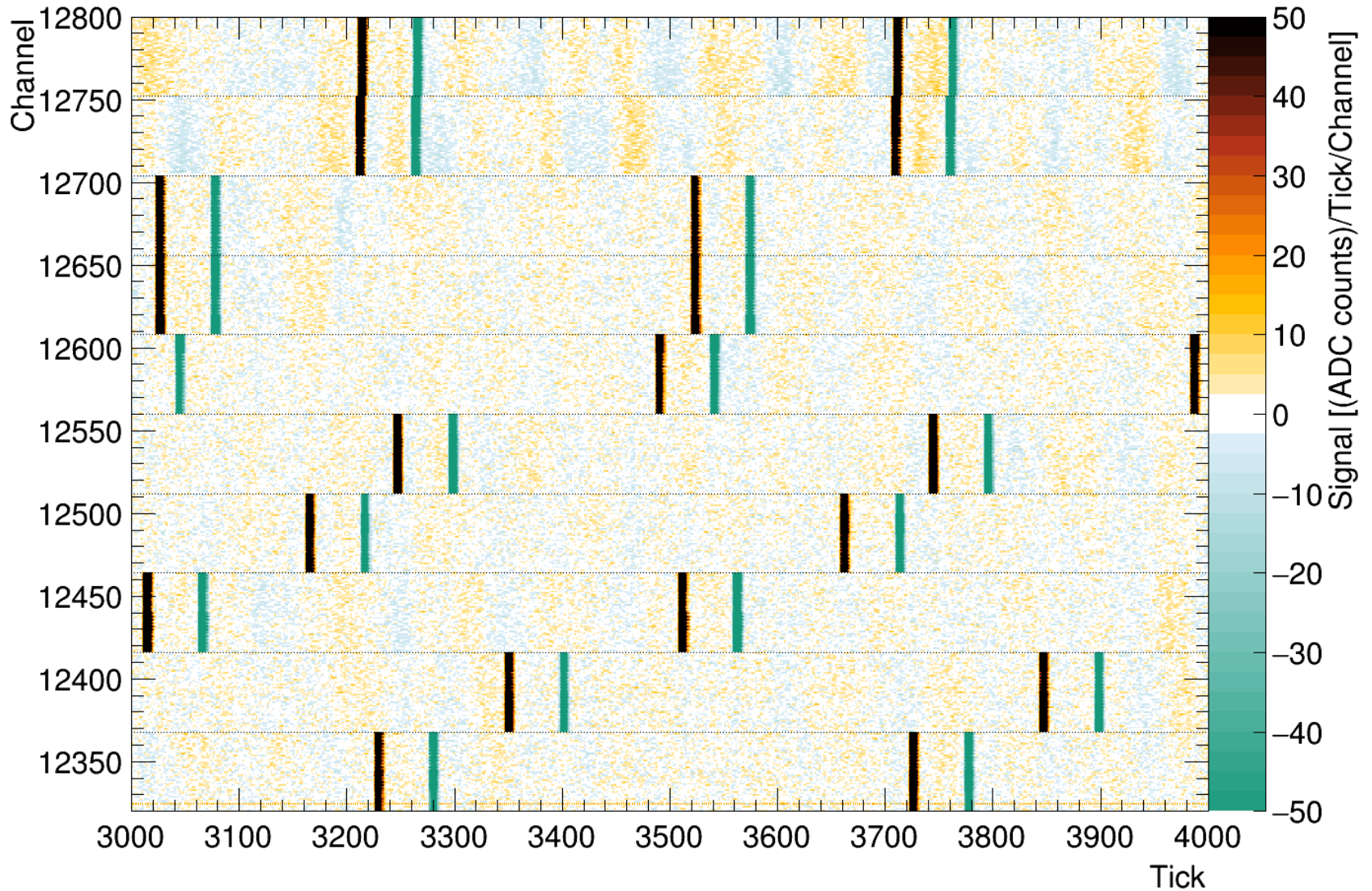
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 4c



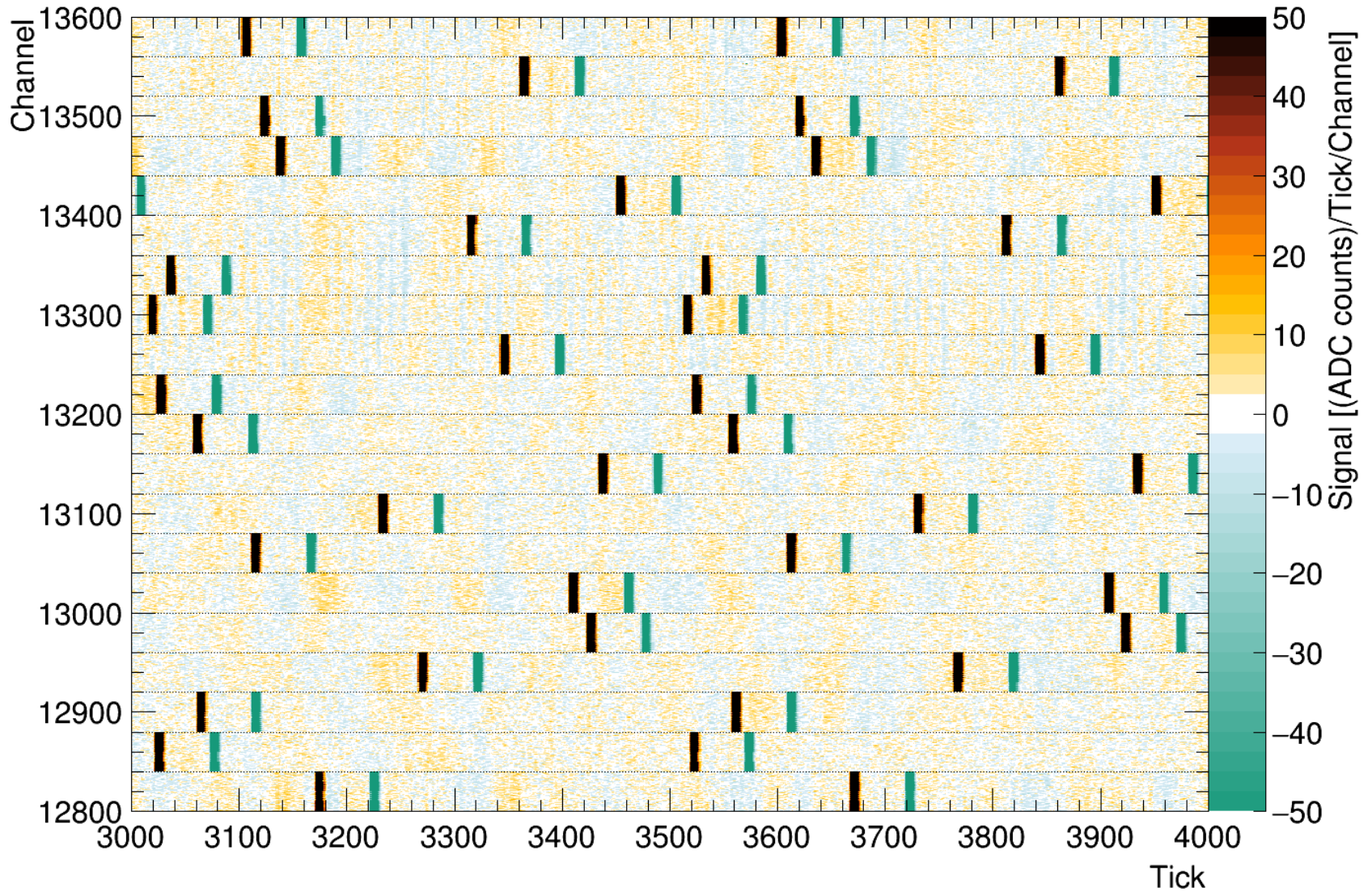
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 4z



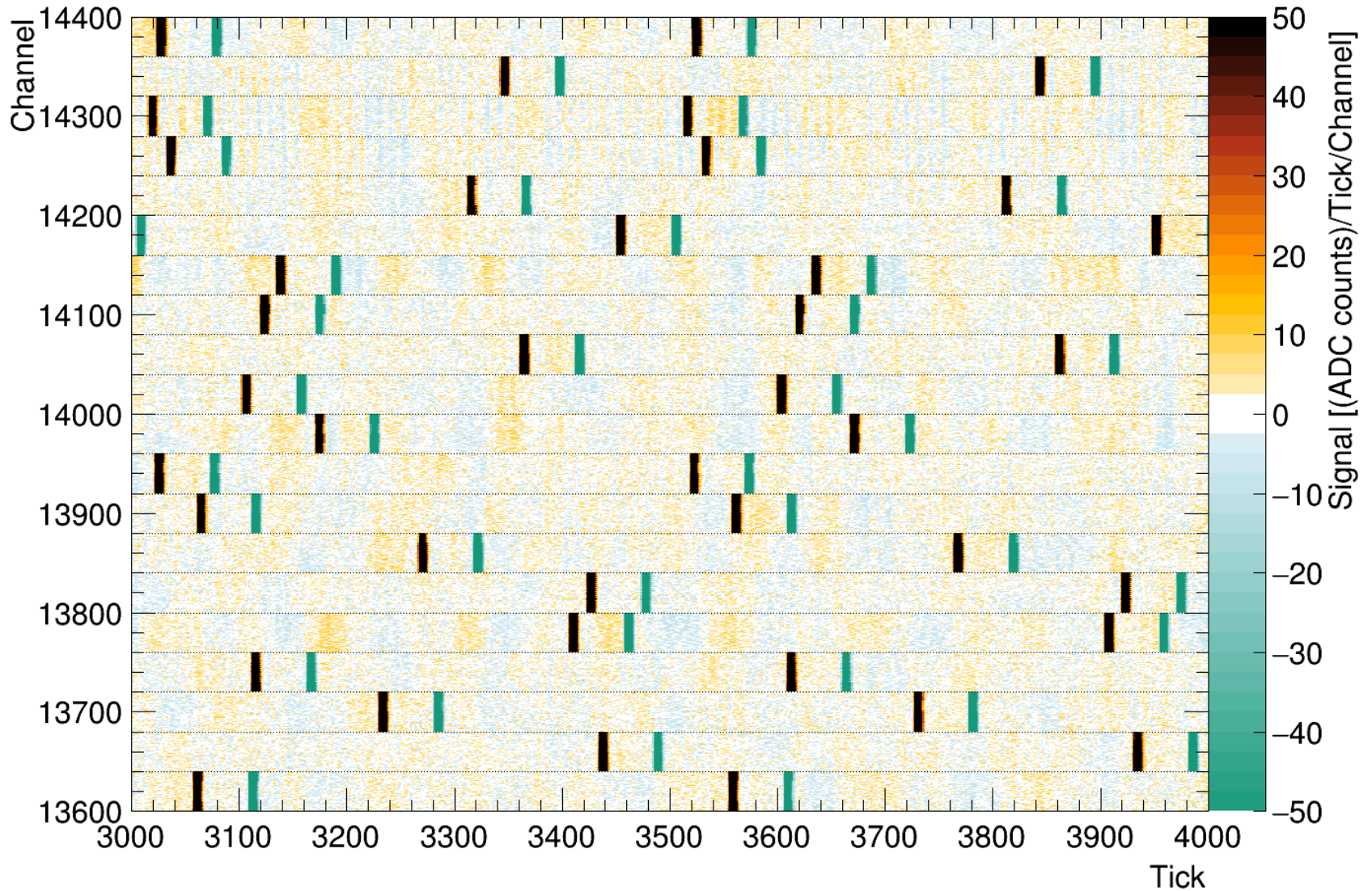
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 5u



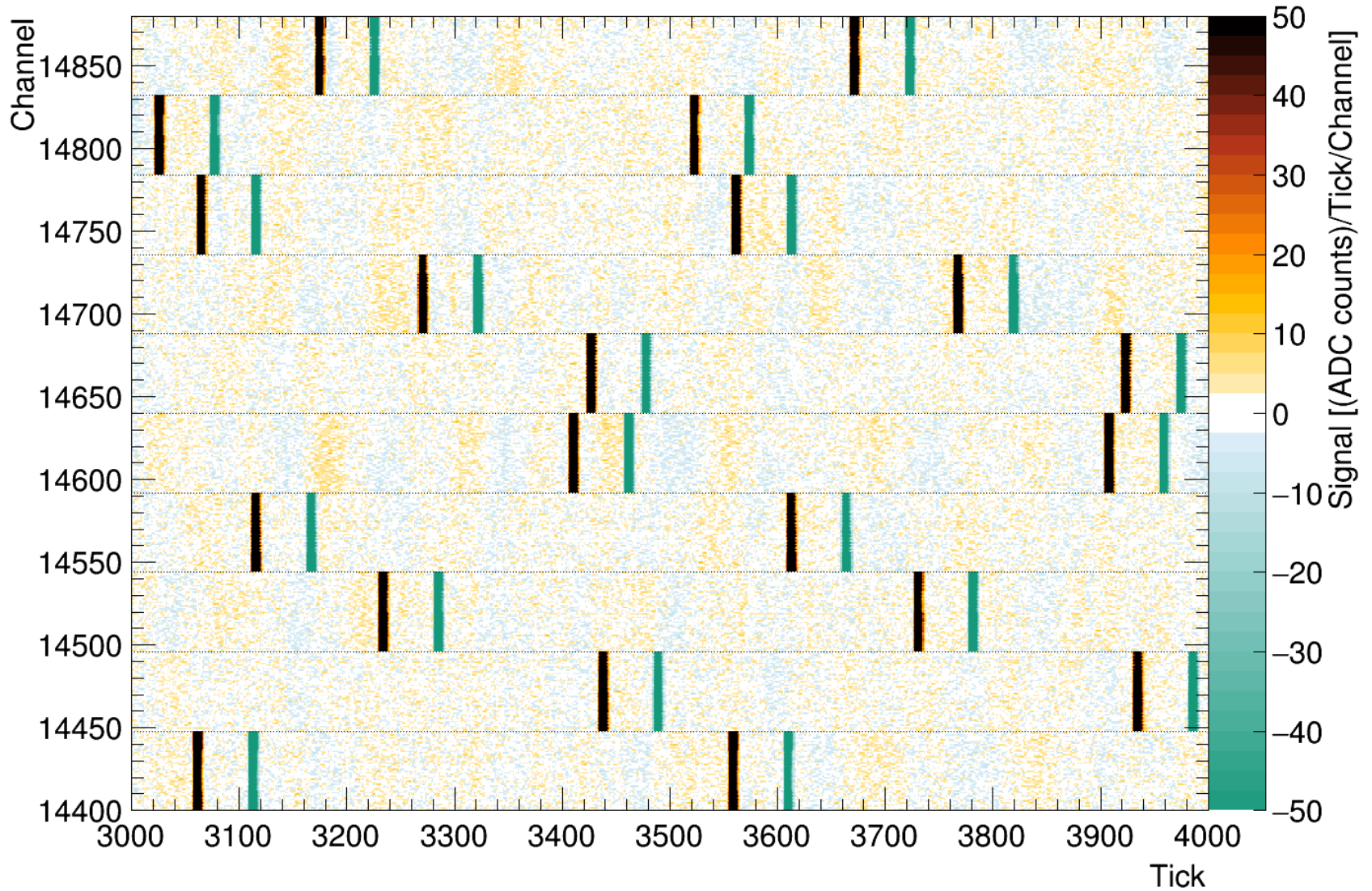
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 5v



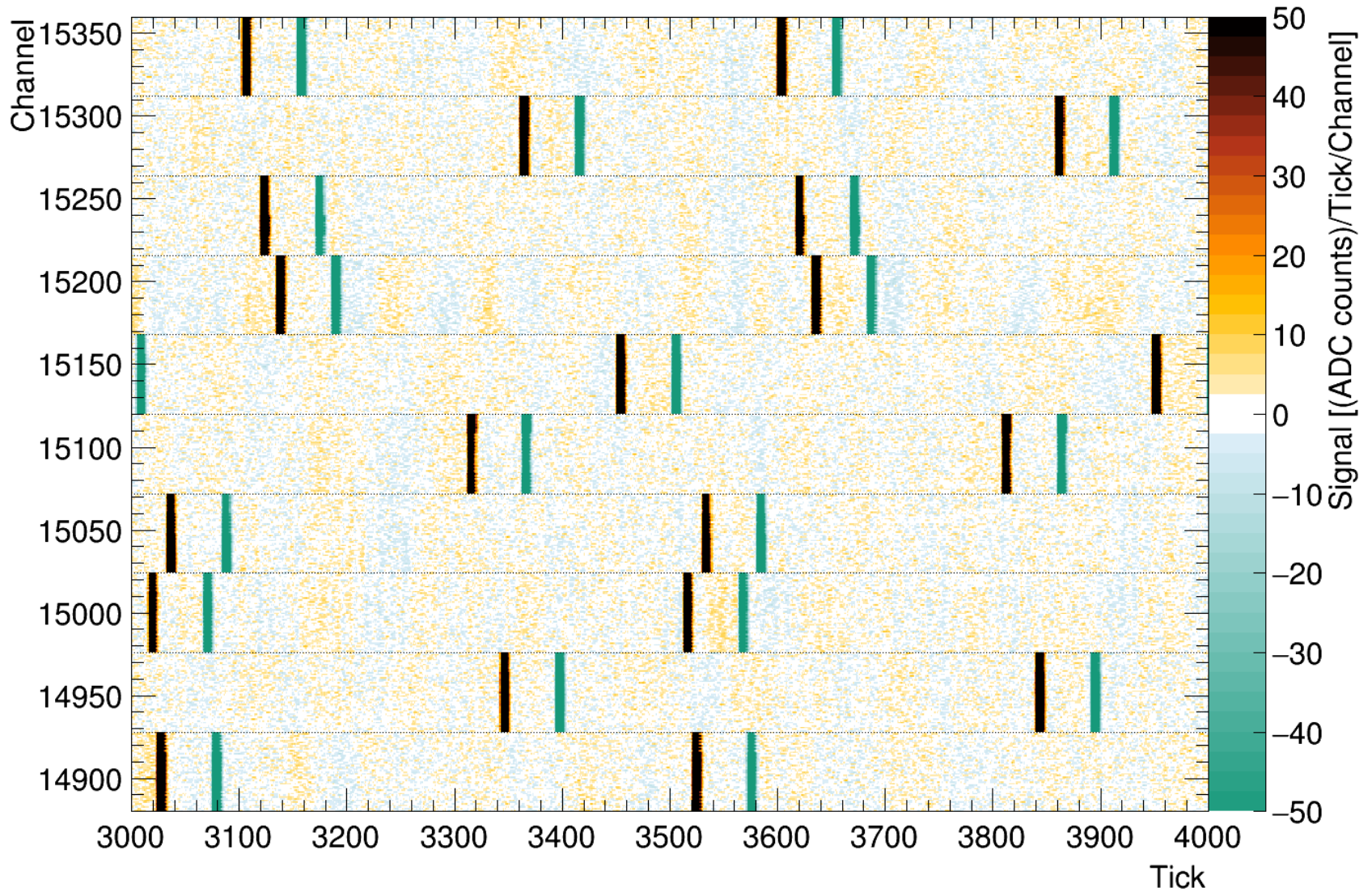
8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 5z



8/21 readout planes

Raw ADC for run 3494 event 218 TPC plane 5c

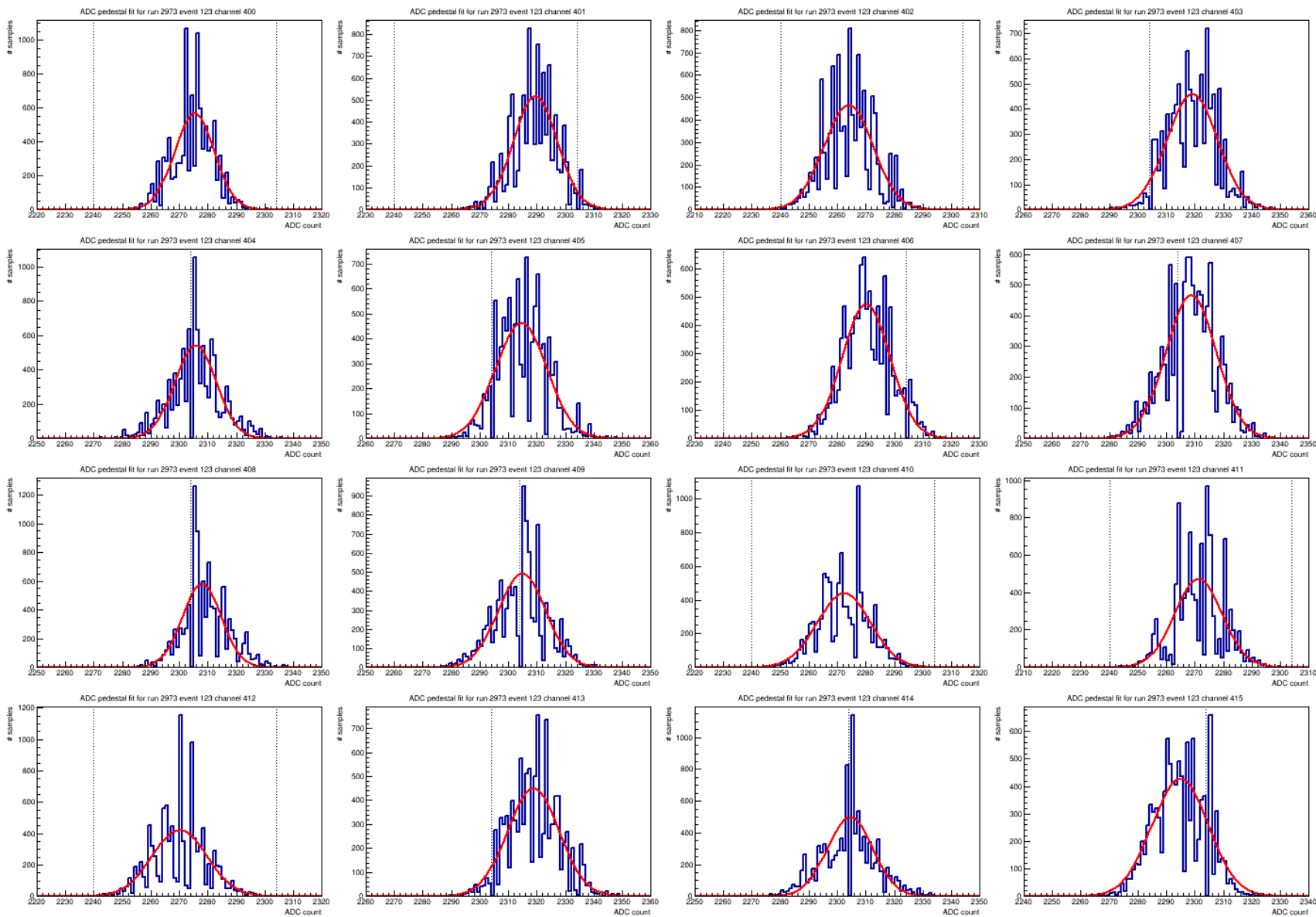


Pedestal analysis

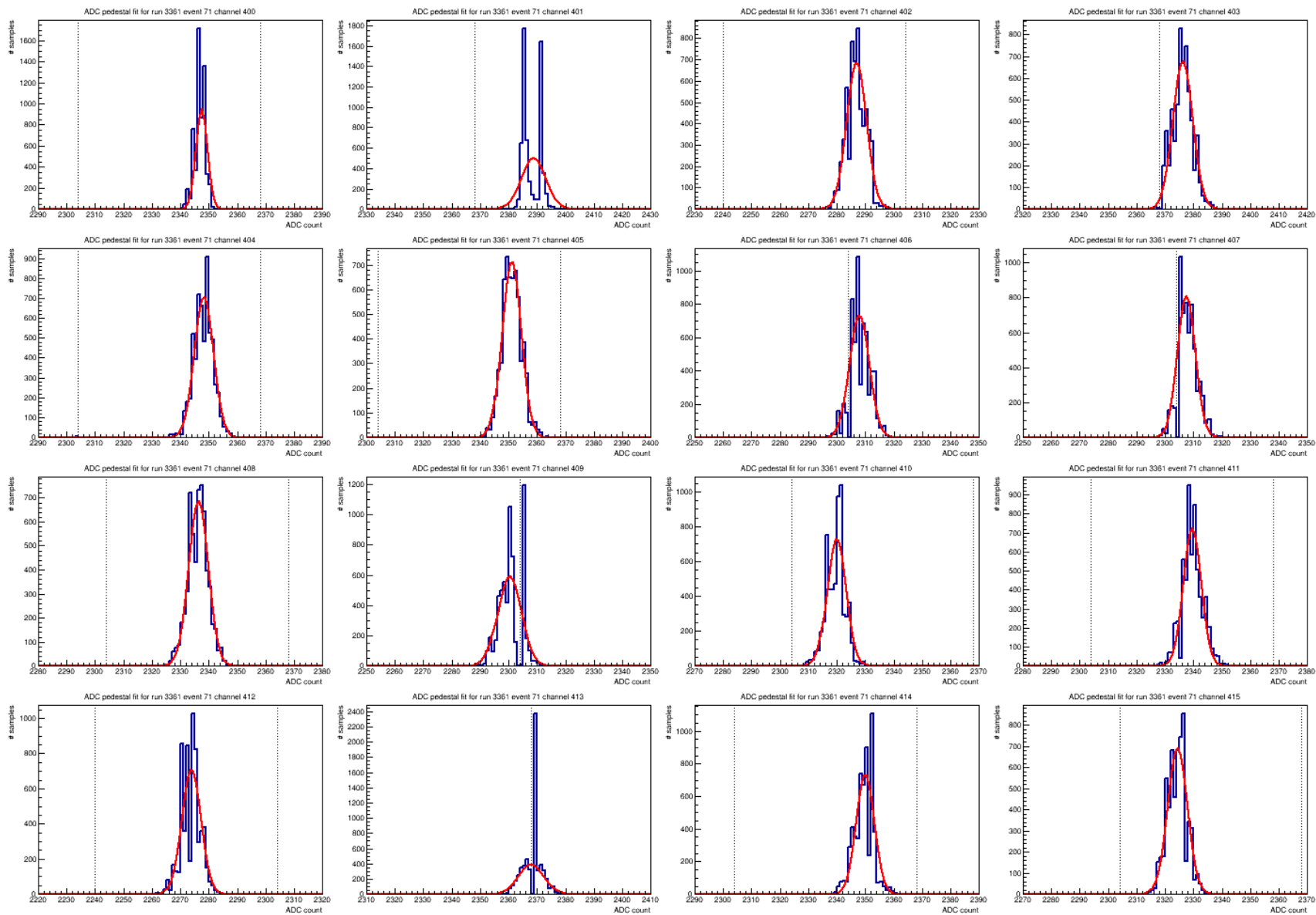
Pedestal properties deduced from pedestal spectra

- Tool AdcPedestalFitter
- Histogram ADC count for each channel each event
 - 100 bins roughly centered around the peak
 - **OORF** = out of range fraction is the fraction of counts outside the range
 - May indicate population of a distant sticky code
 - Or track or pulser signals
- For fitting, exclude peak bin if it holds $> 20\%$ and $< 99\%$ of entries
 - Peak bin fraction = fraction entries in that bin
 - Sensitive to sticky codes
- Fit with Gaussian
 - **Mean** is the pedestal position
 - **Sigma** provides measure of the noise (aka RMS)
- **Peak bin excess**
 - Fraction in peak bin after subtracting fit value
 - Better estimate of sticky code contribution

Example pedestal spectra 8/1



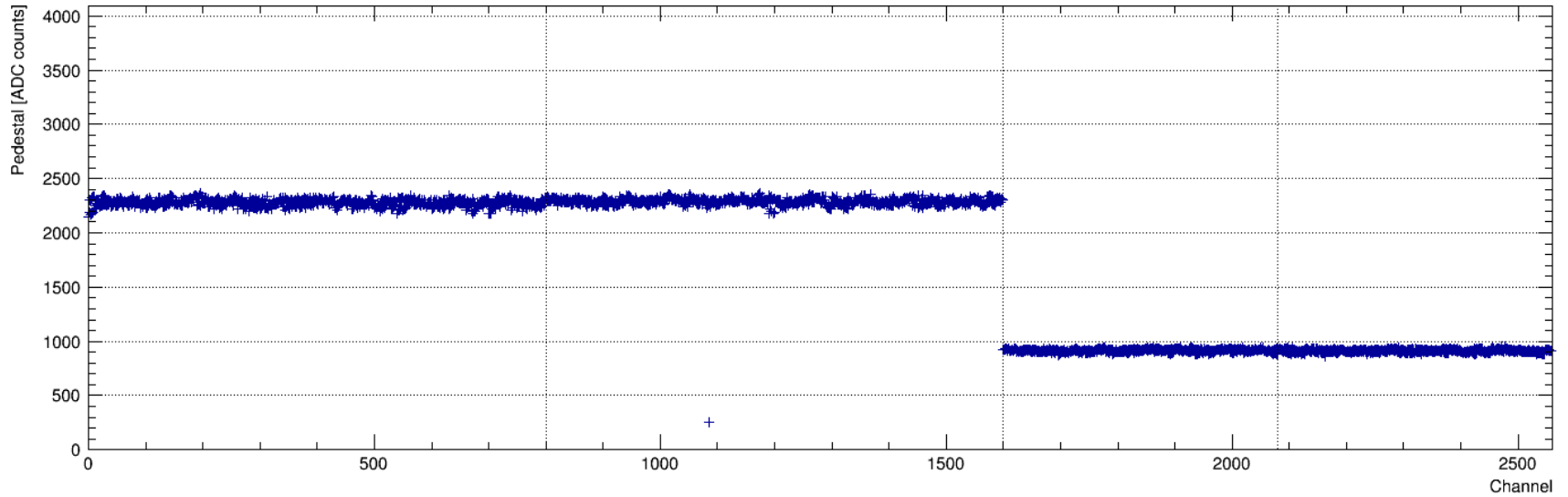
Example pedestal spectra 8/14



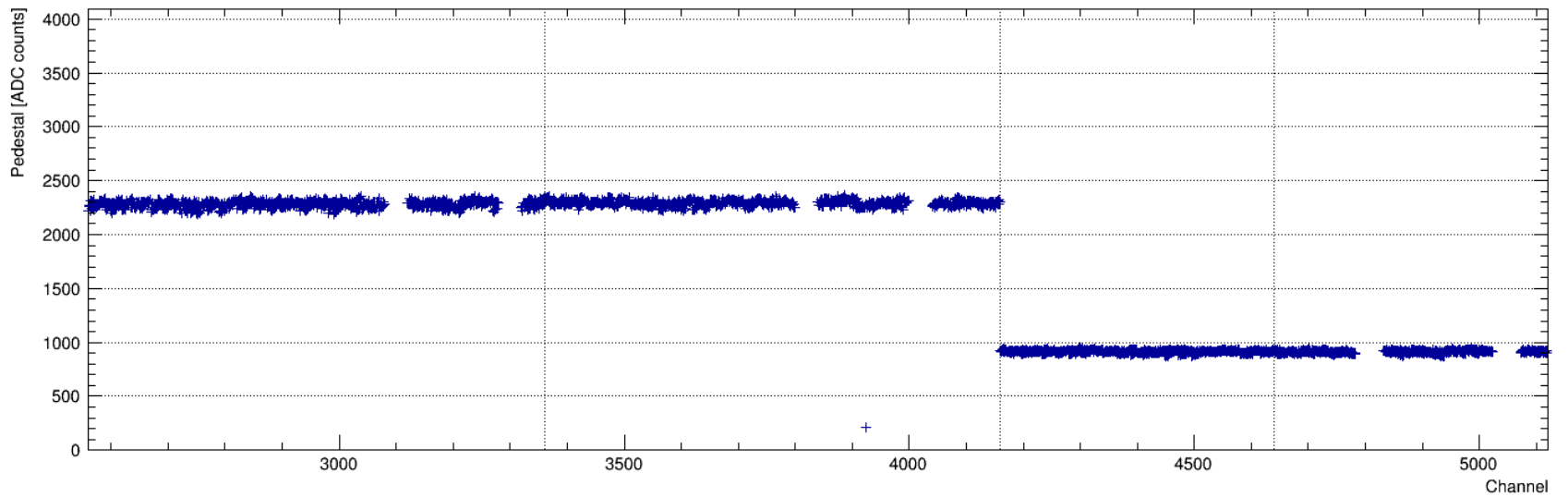
Pedestals

Pedestals 8/1

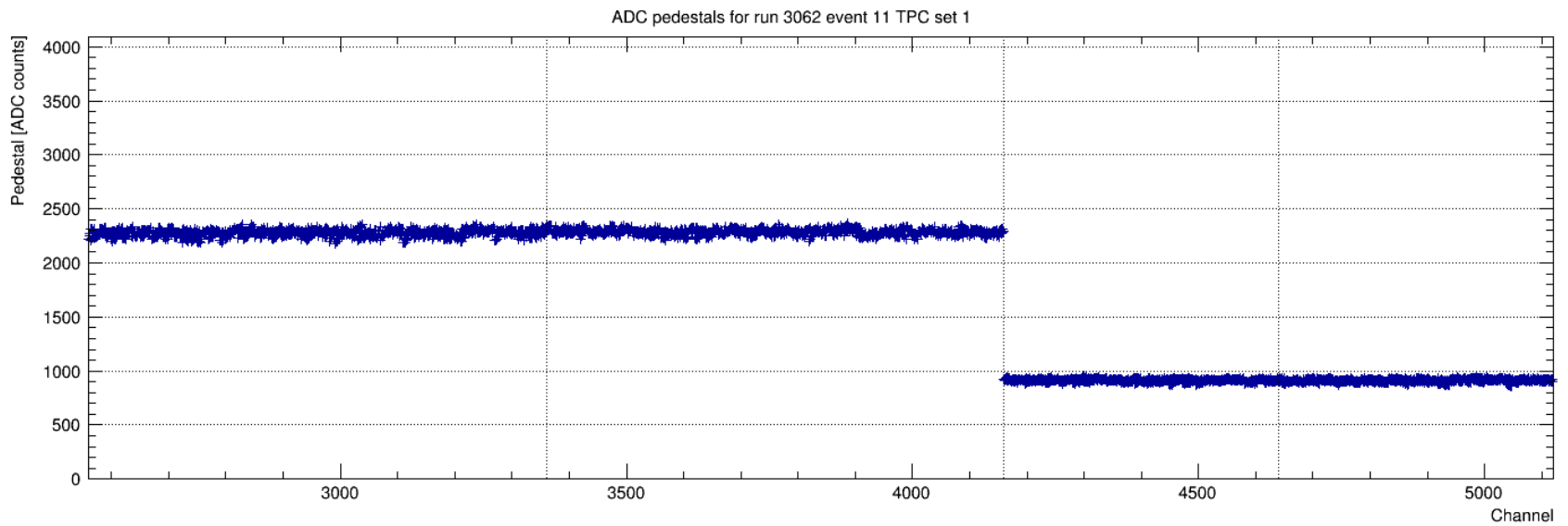
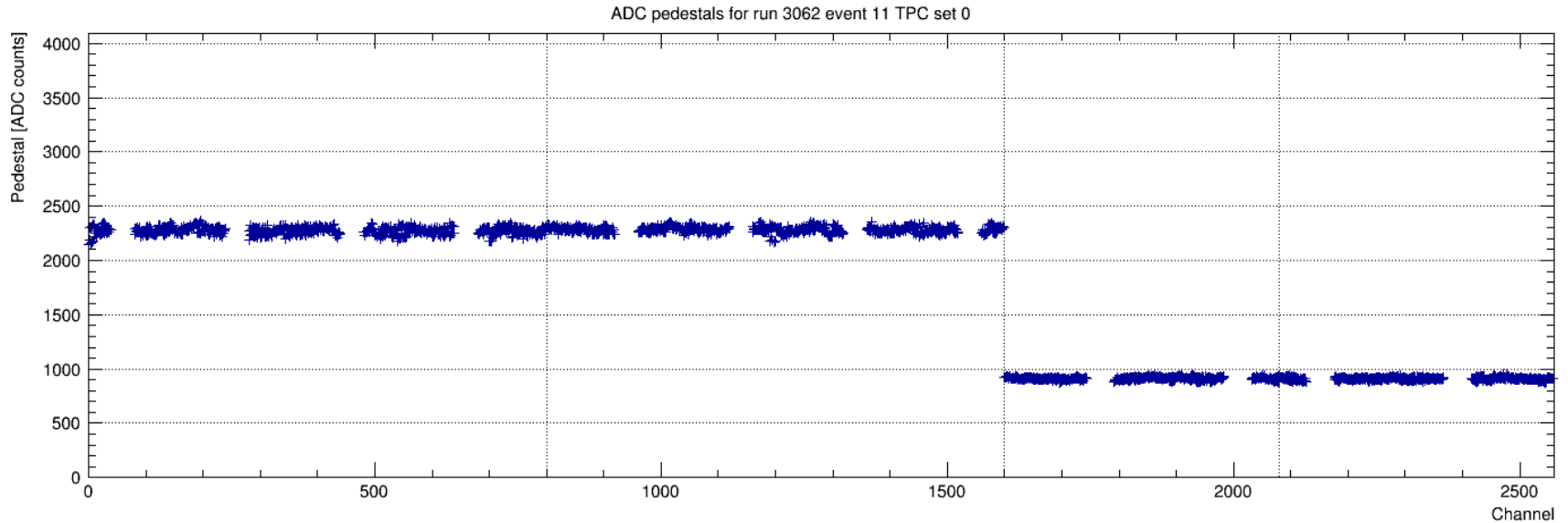
ADC pedestals for run 2973 event 10 TPC set 0



ADC pedestals for run 2973 event 10 TPC set 1

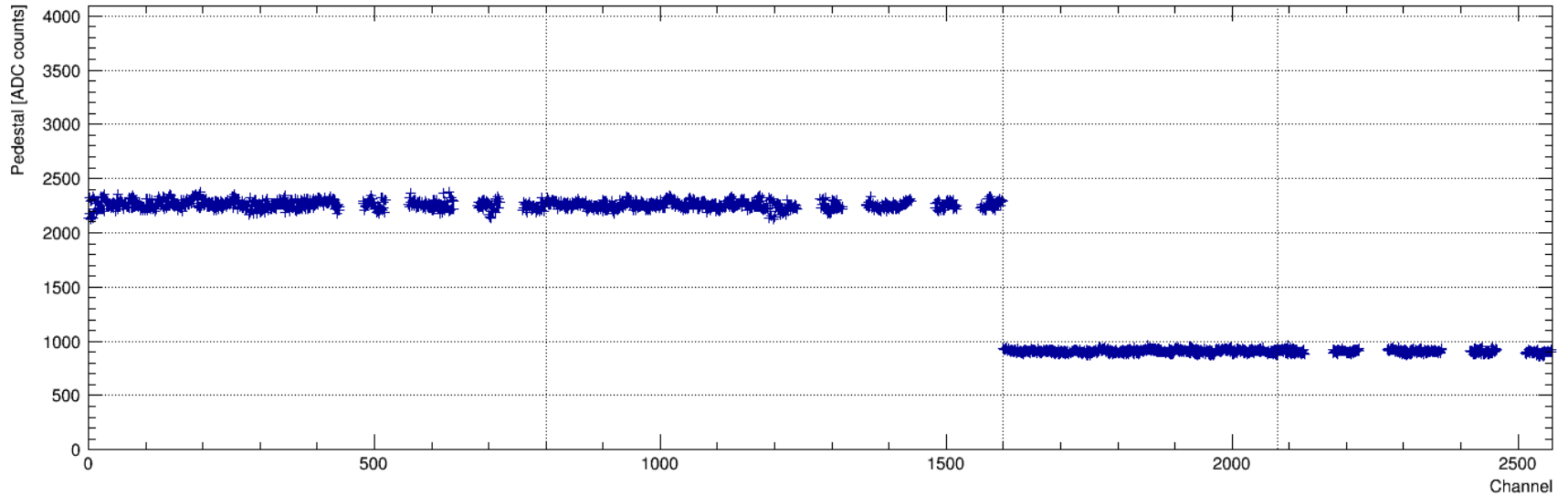


Pedestals 8/3, pulser DAC=5

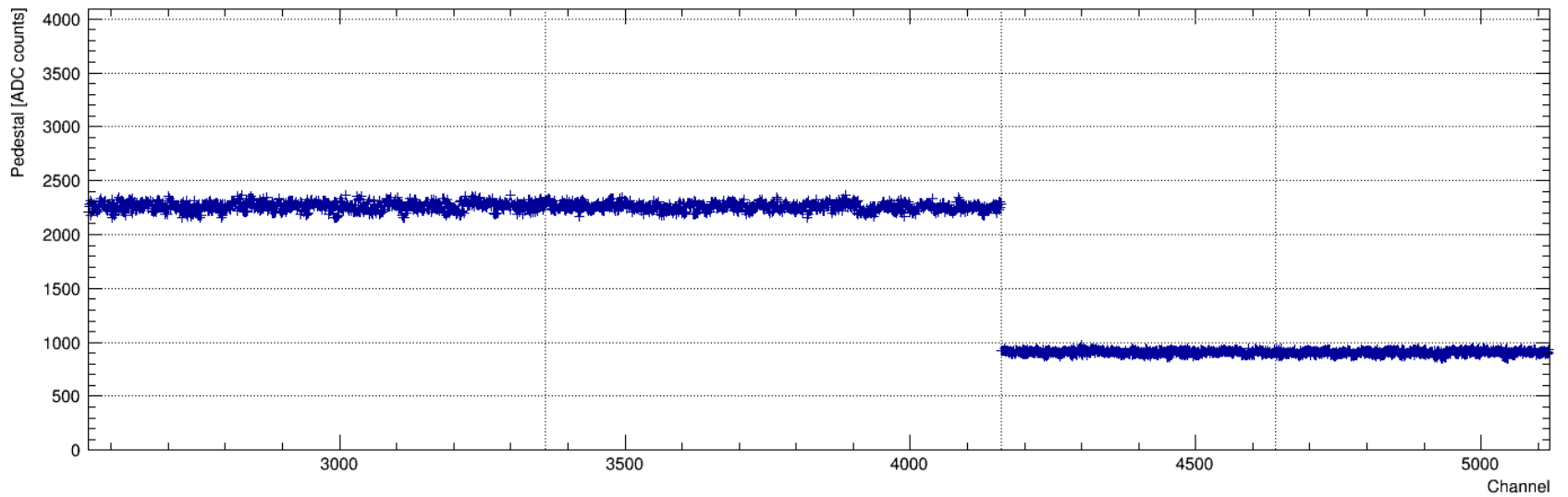


Pedestals 8/13

ADC pedestals for run 3298 event 83 TPC set 0

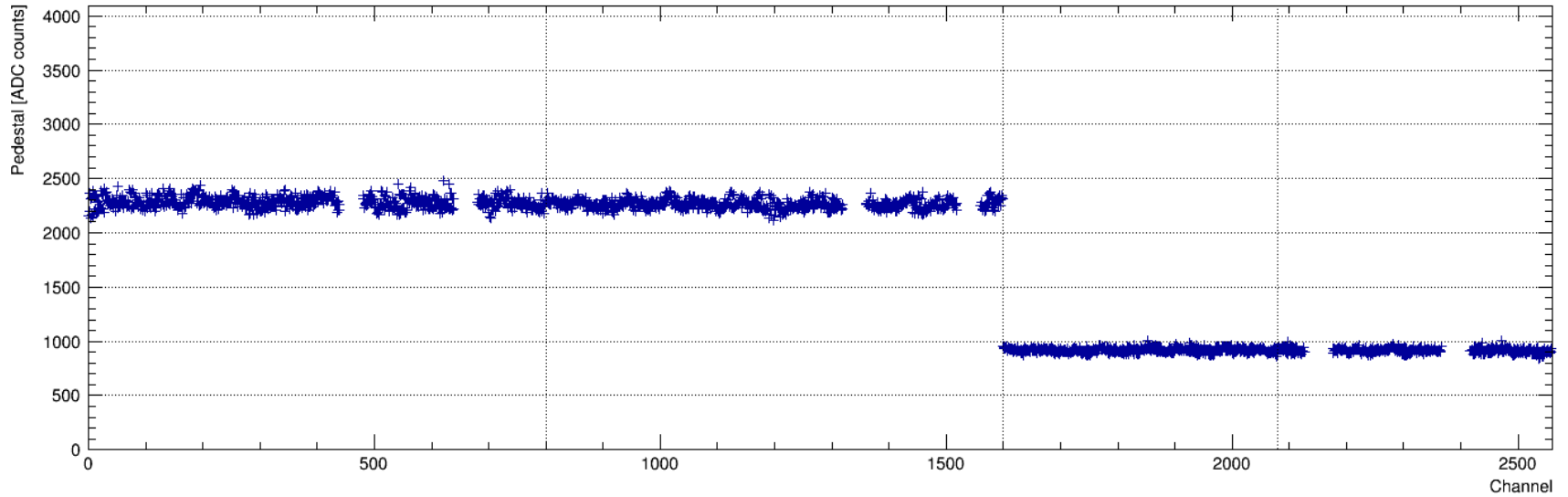


ADC pedestals for run 3298 event 83 TPC set 1

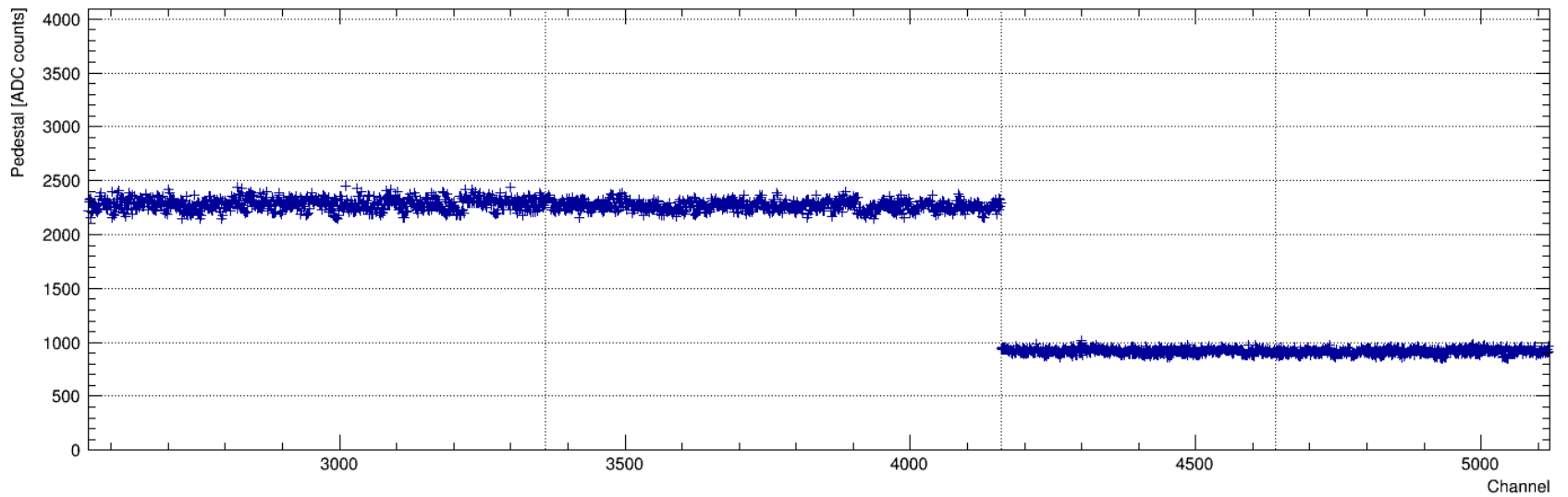


Pedestals 8/14

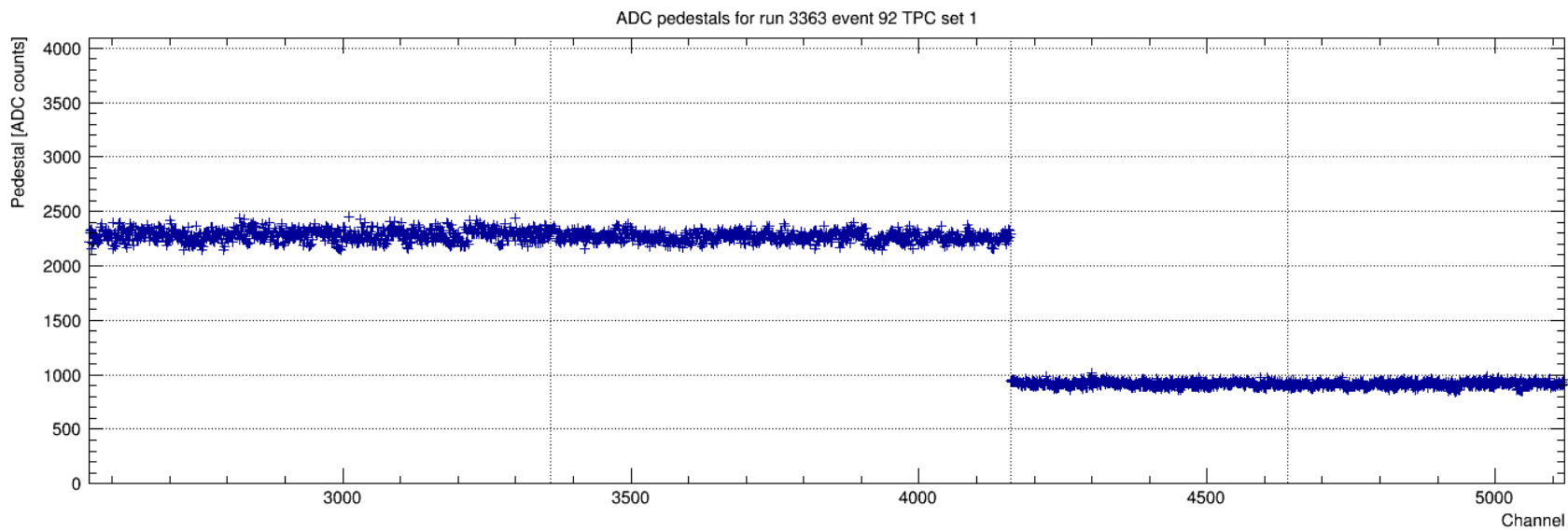
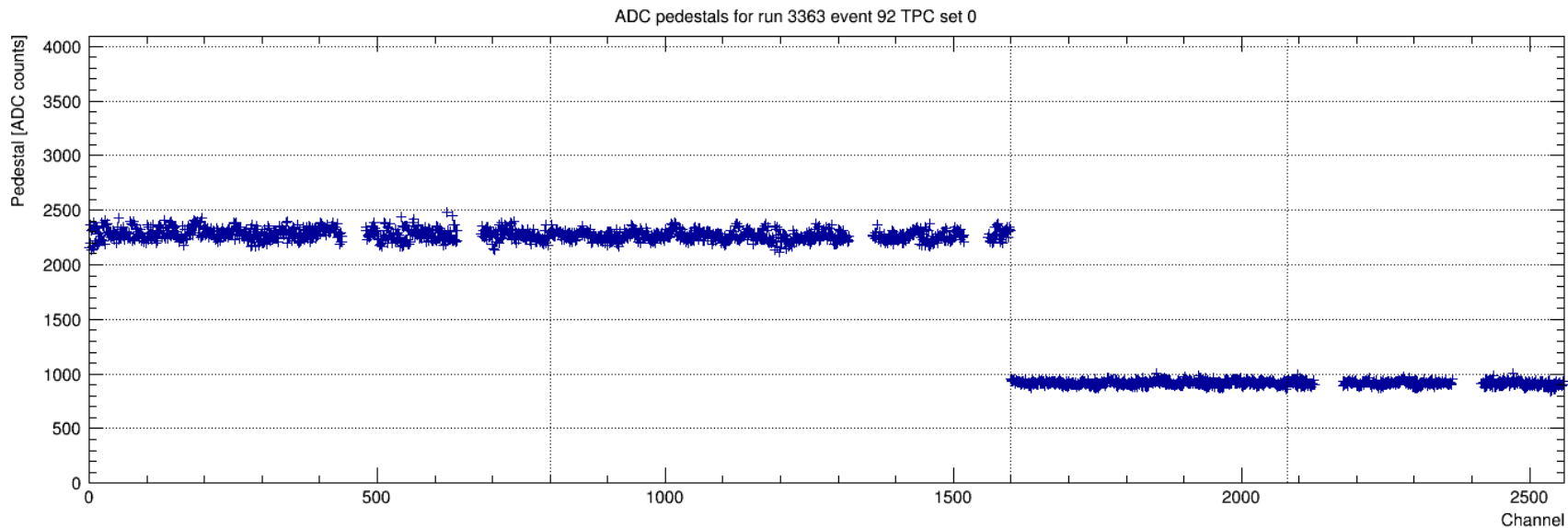
ADC pedestals for run 3361 event 71 TPC set 0



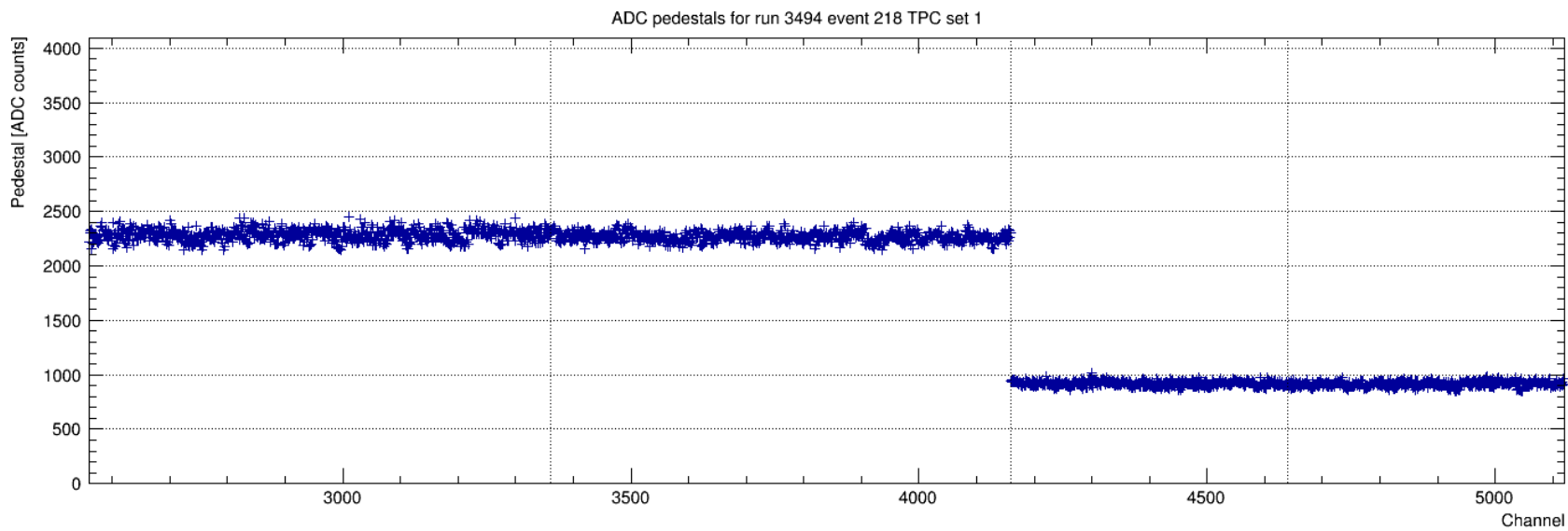
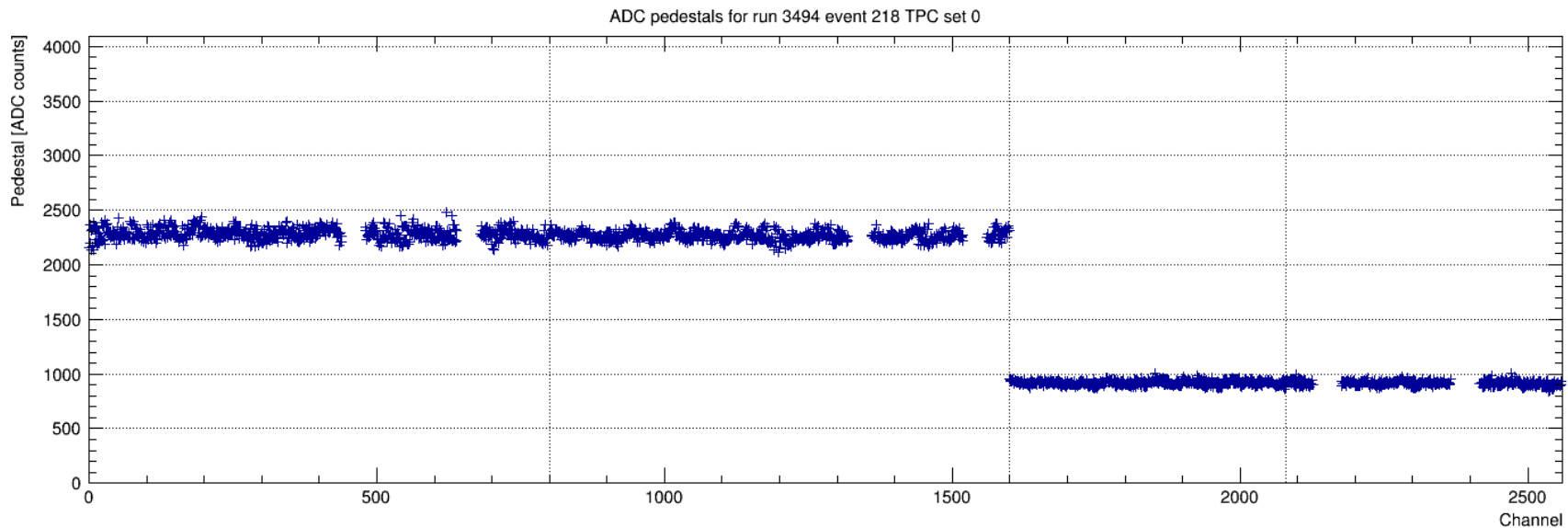
ADC pedestals for run 3361 event 71 TPC set 1



Pedestals 8/14, pulser DAC=5

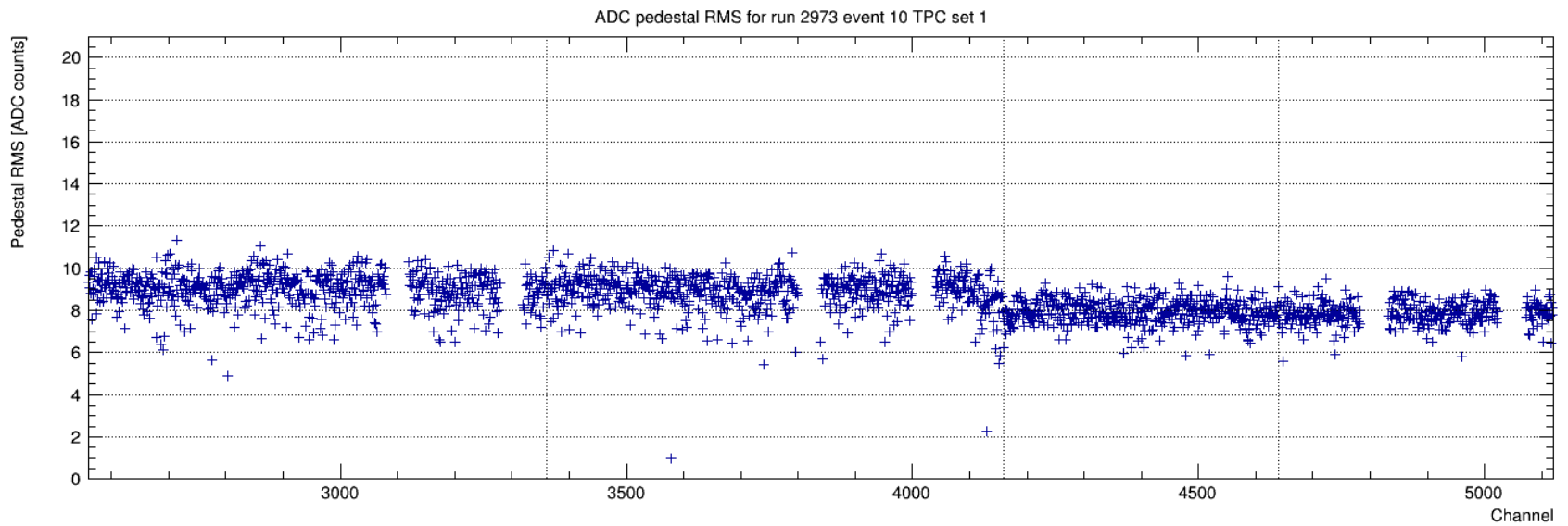
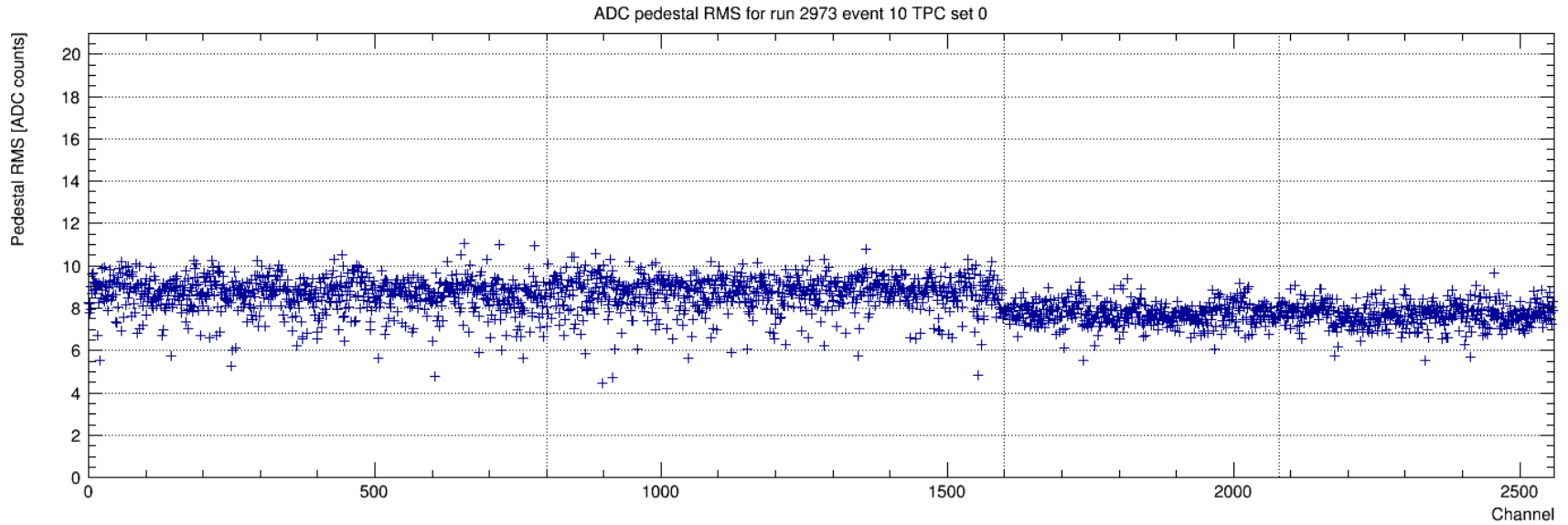


Pedestals 8/21 DAC=2

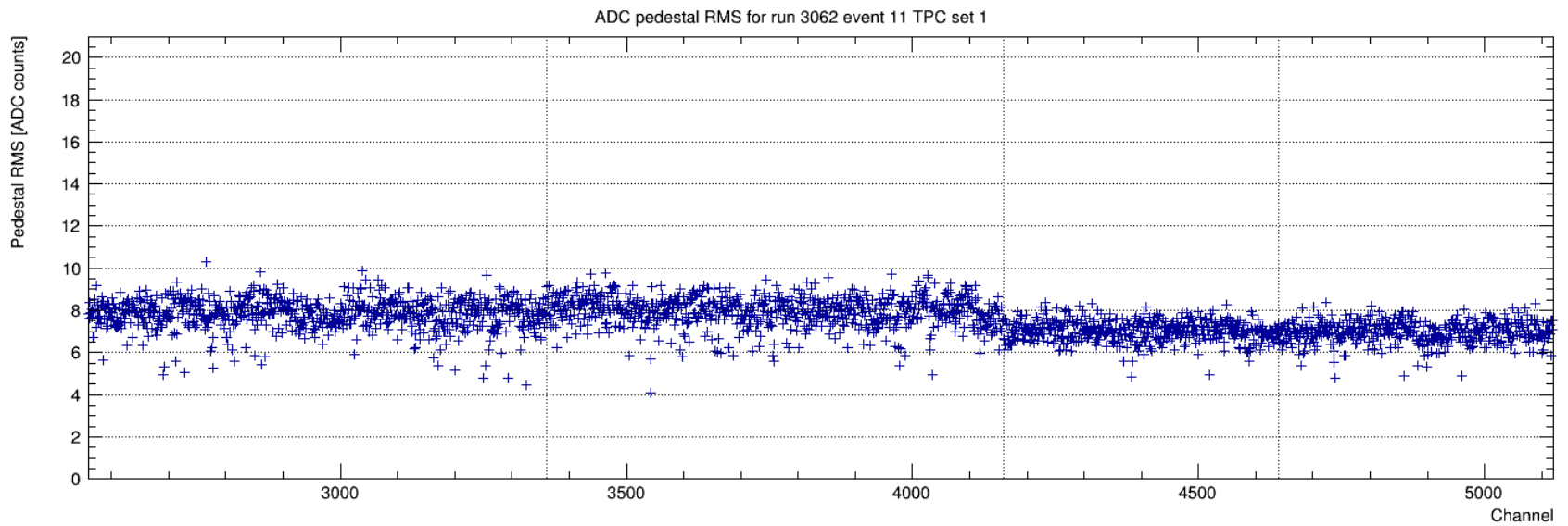
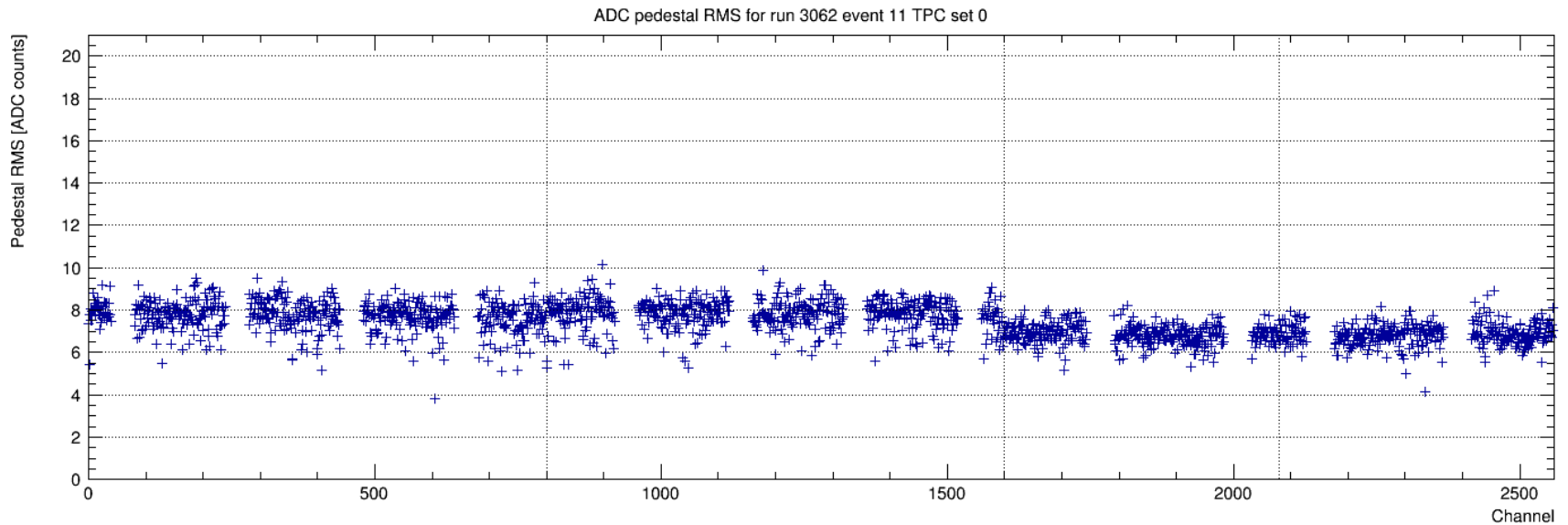


Noise

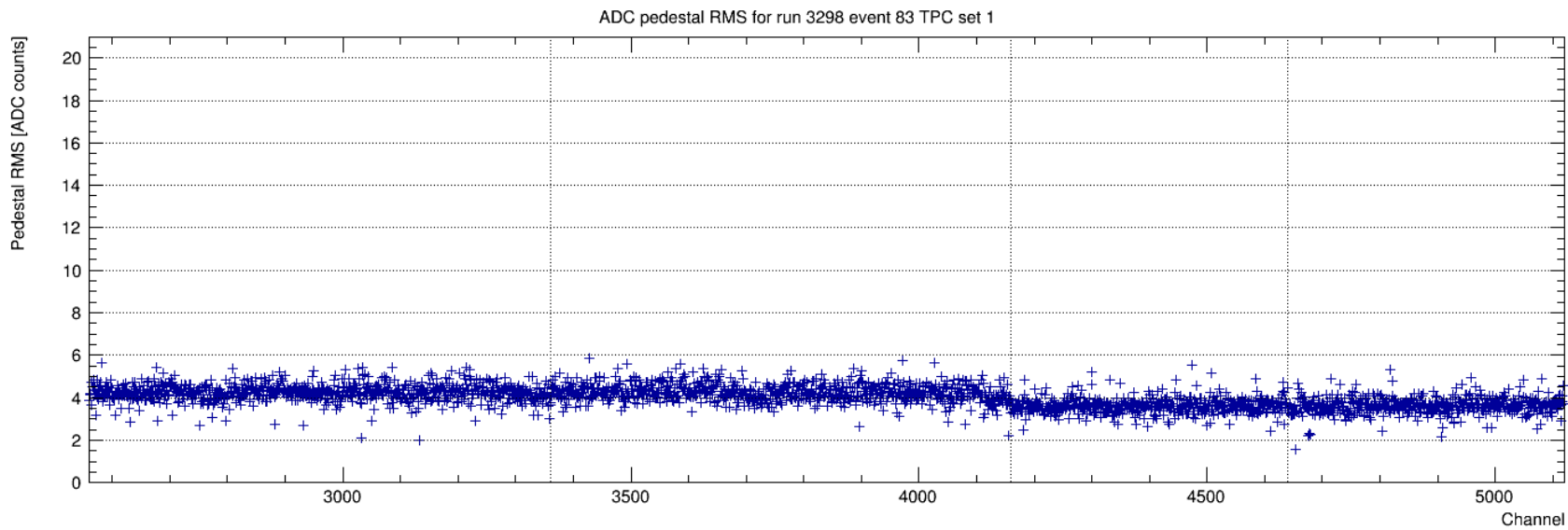
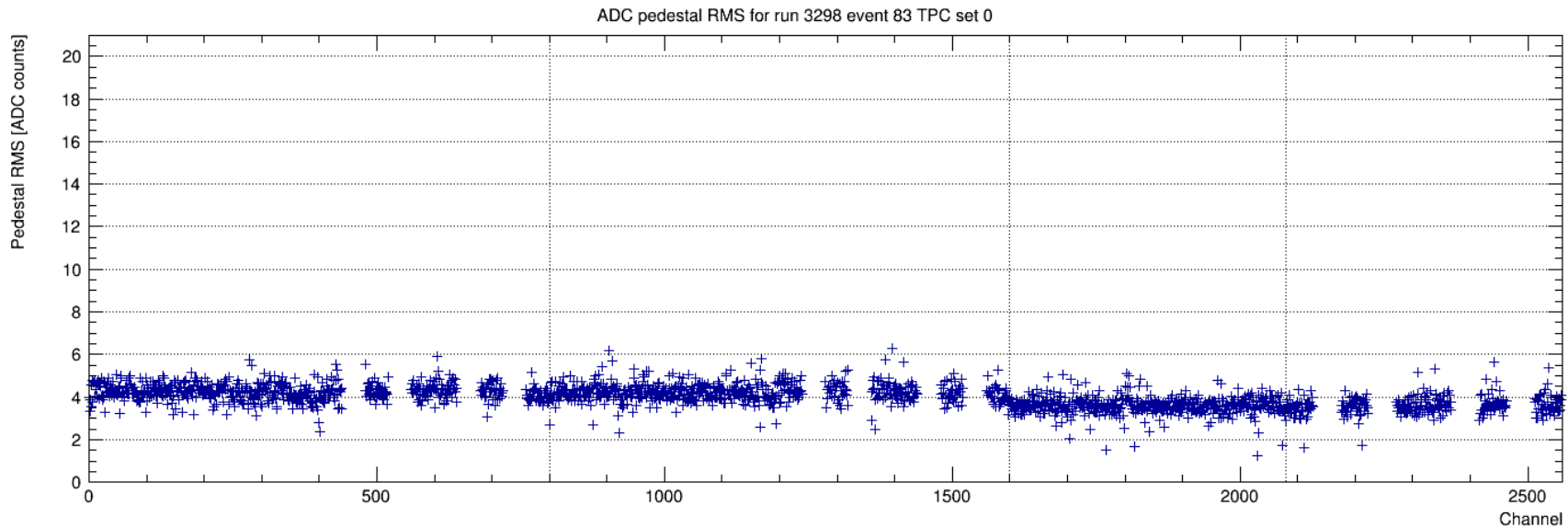
Pedestal noise 8/1



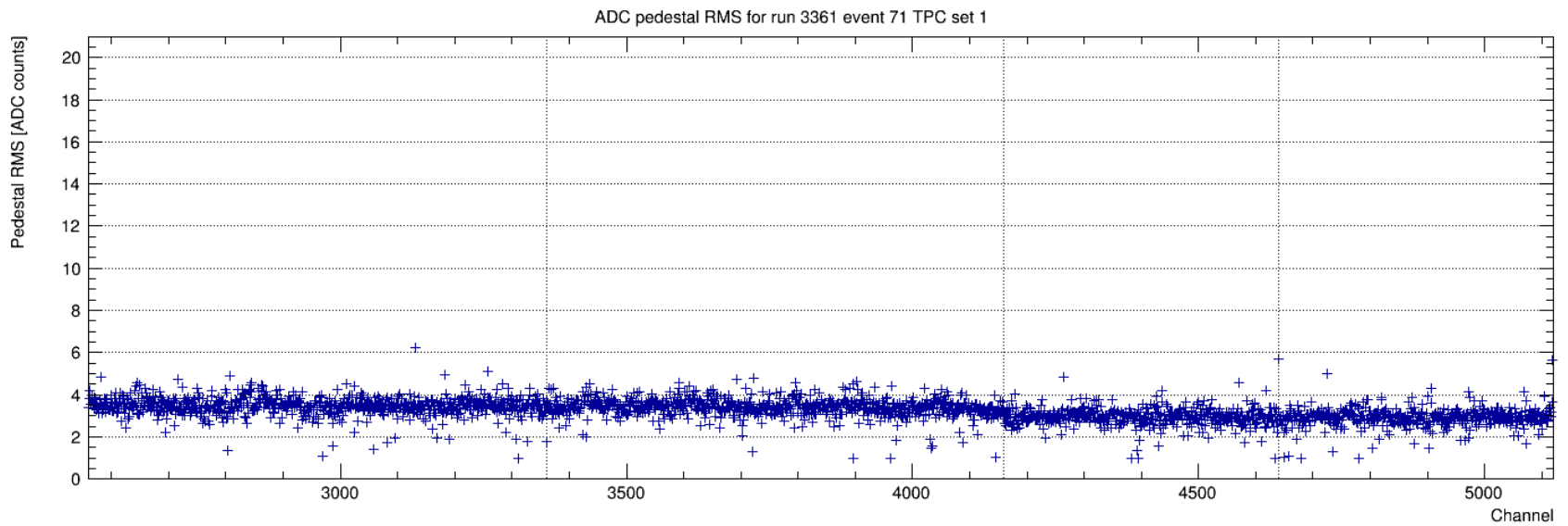
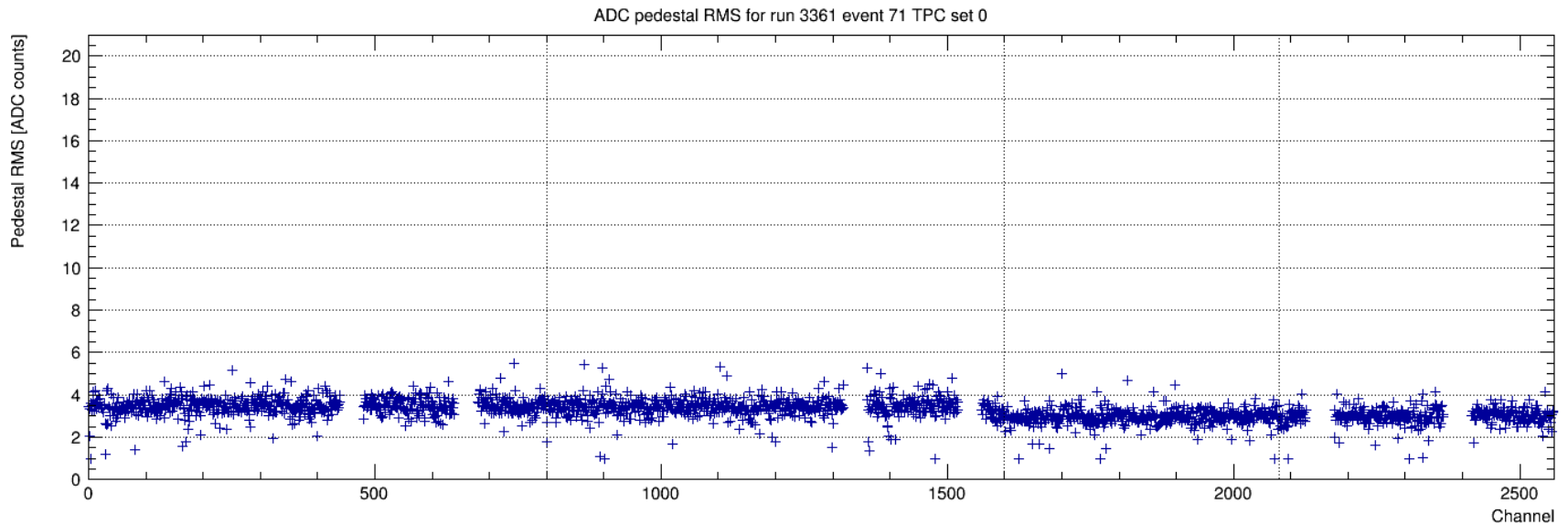
Pedestal noise 8/3, pulser DAC=5



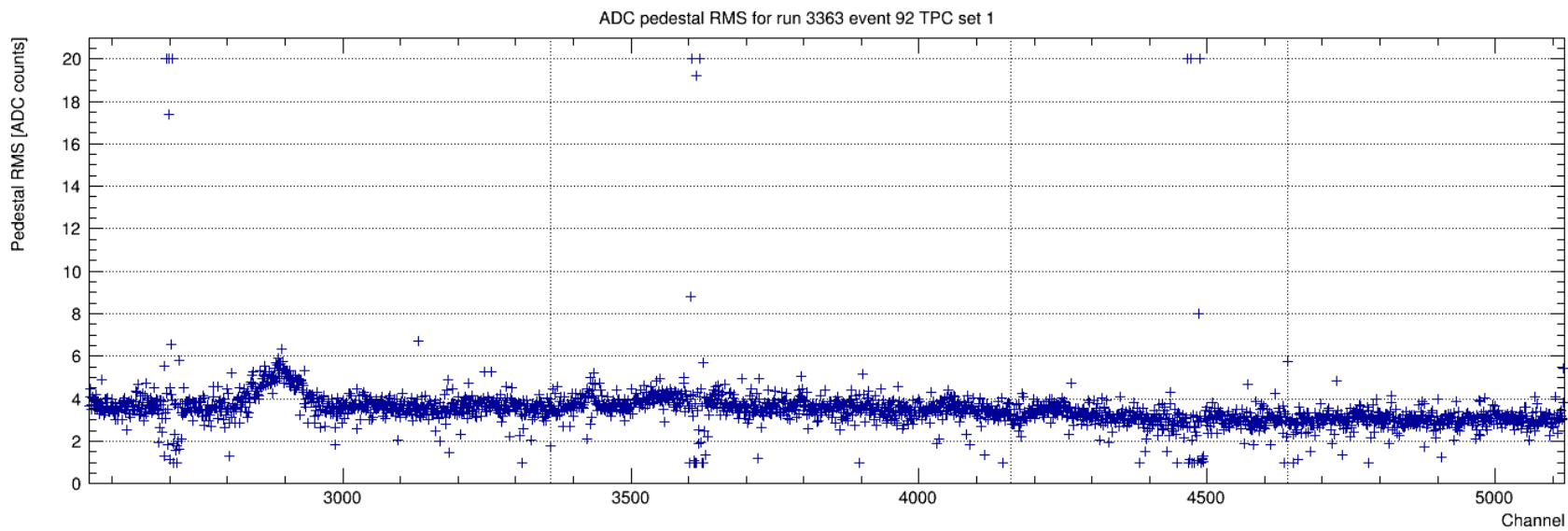
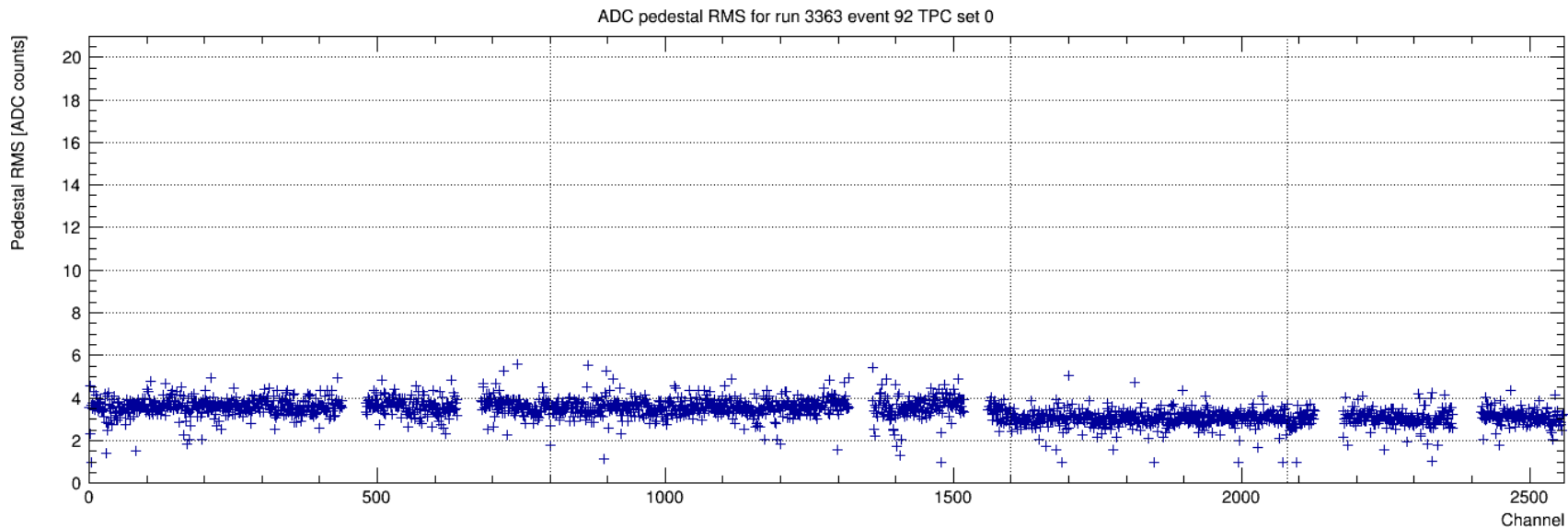
Pedestal noise 8/13



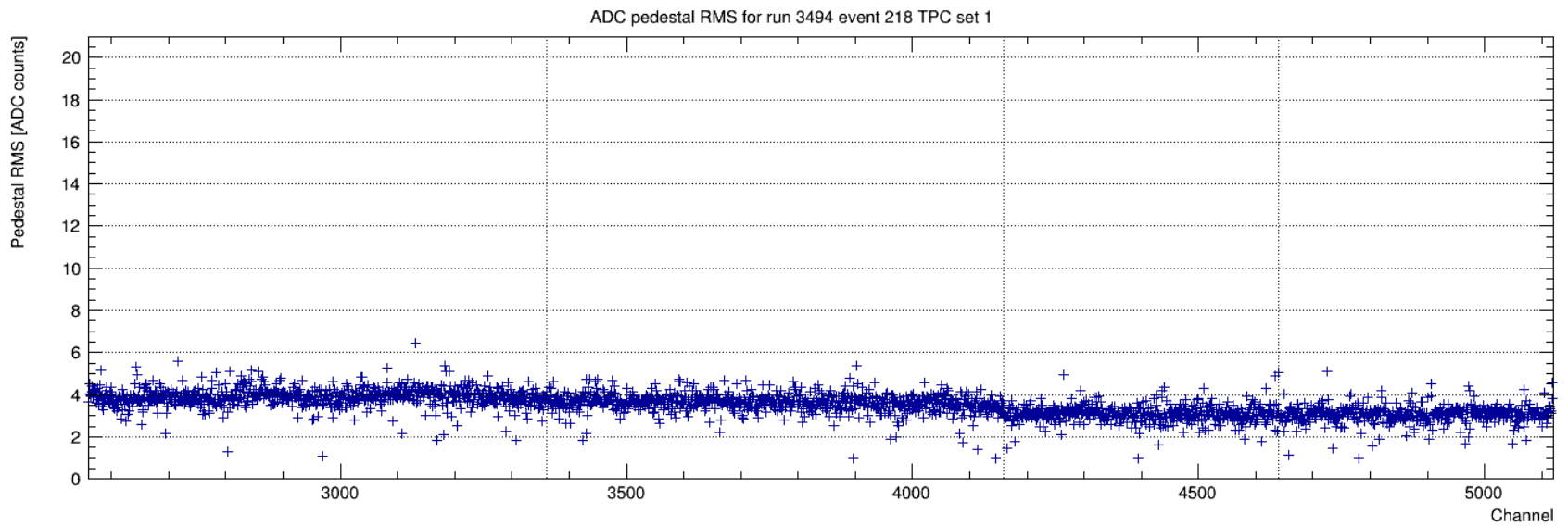
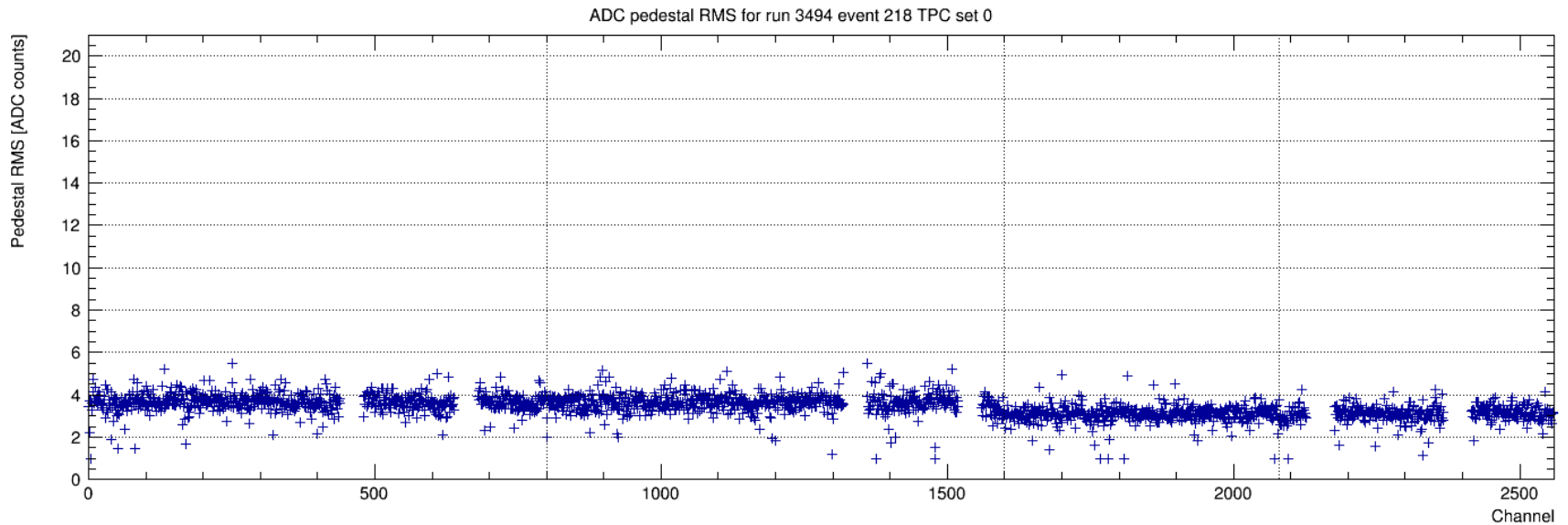
Pedestal noise 8/14



Pedestal noise 8/14, pulser DAC=5

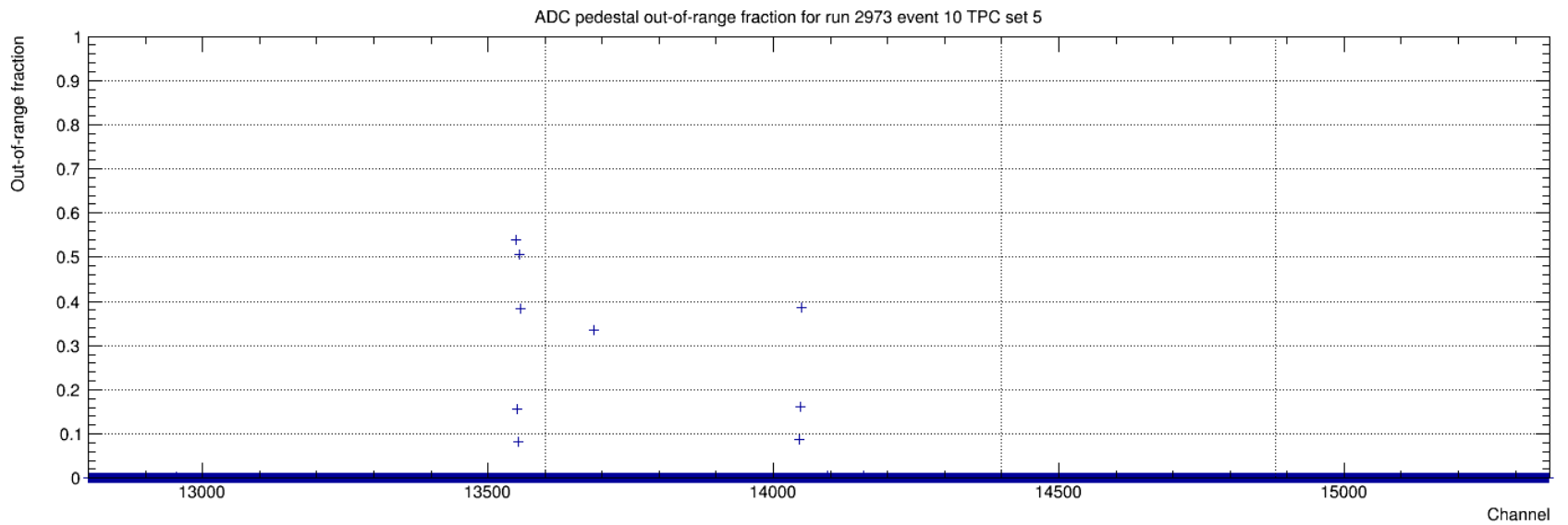
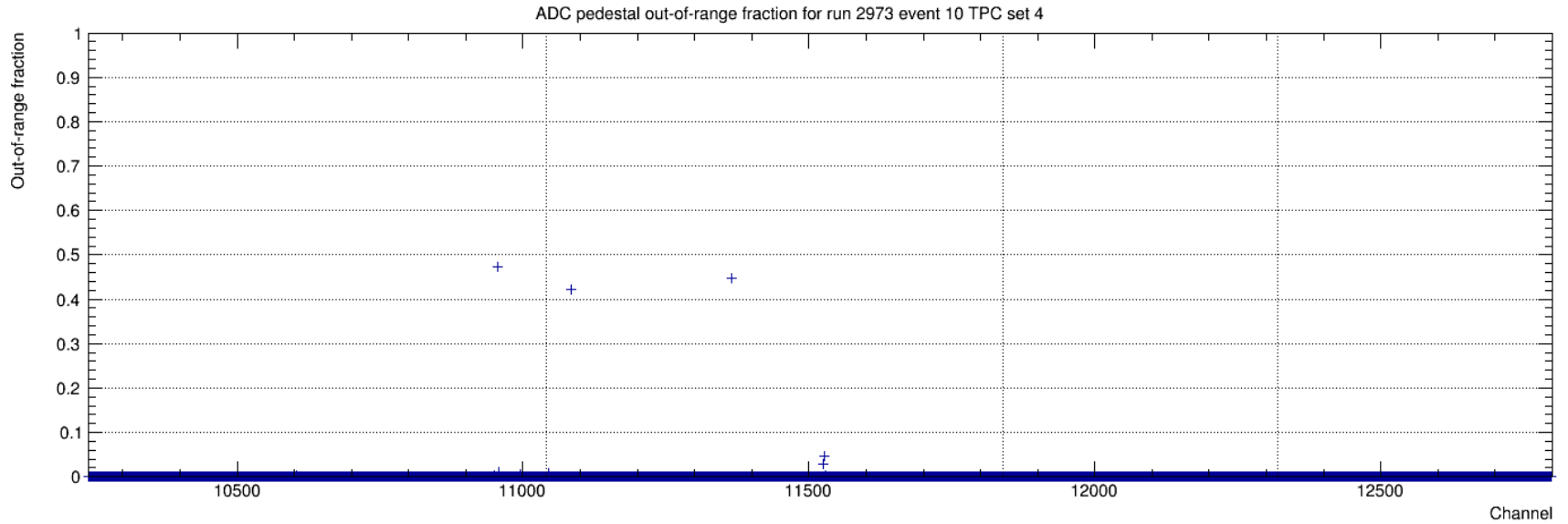


Pedestal noise 8/21, pulser DAC=2

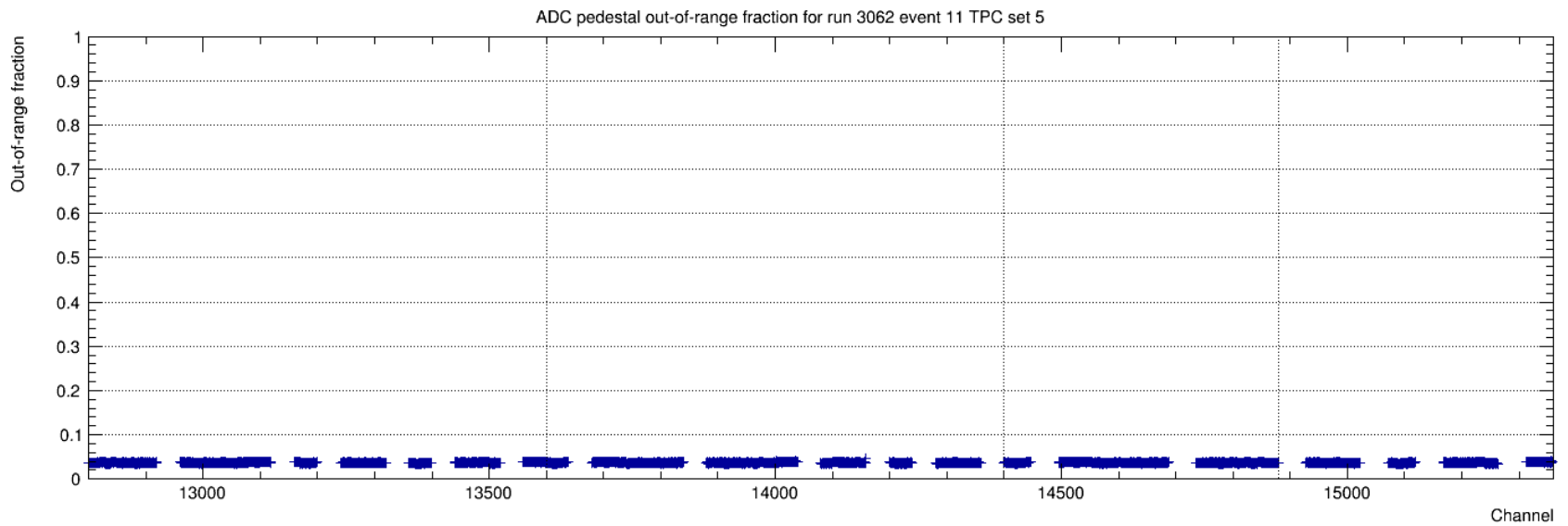
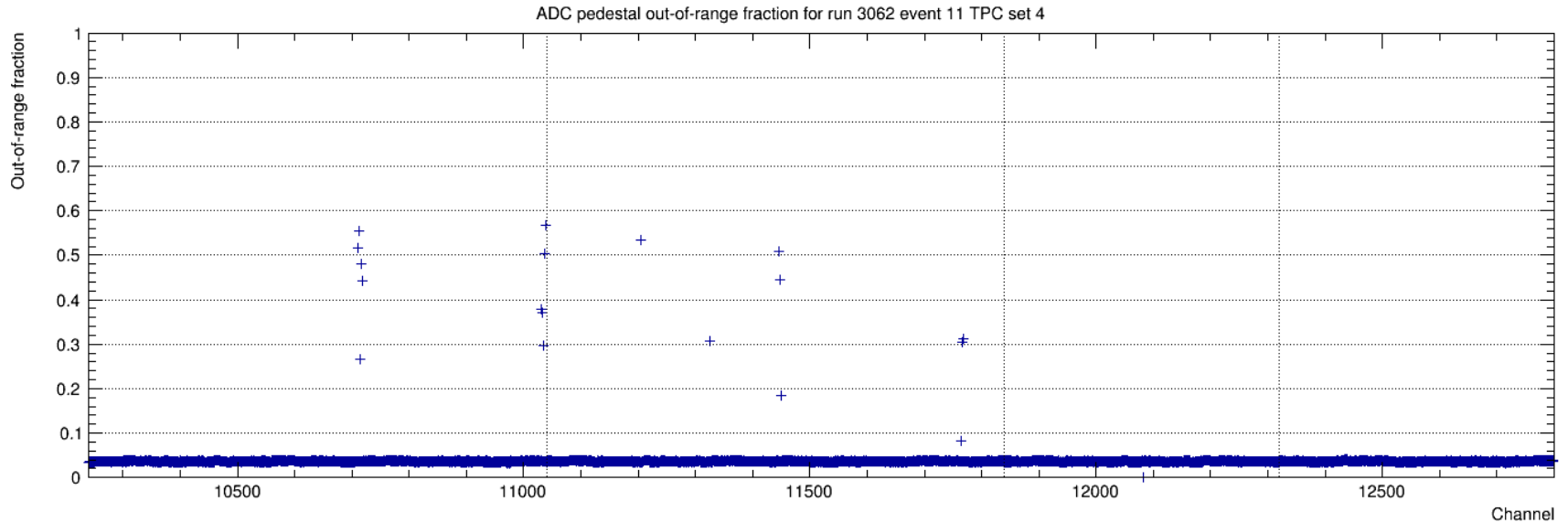


Out of range fractions

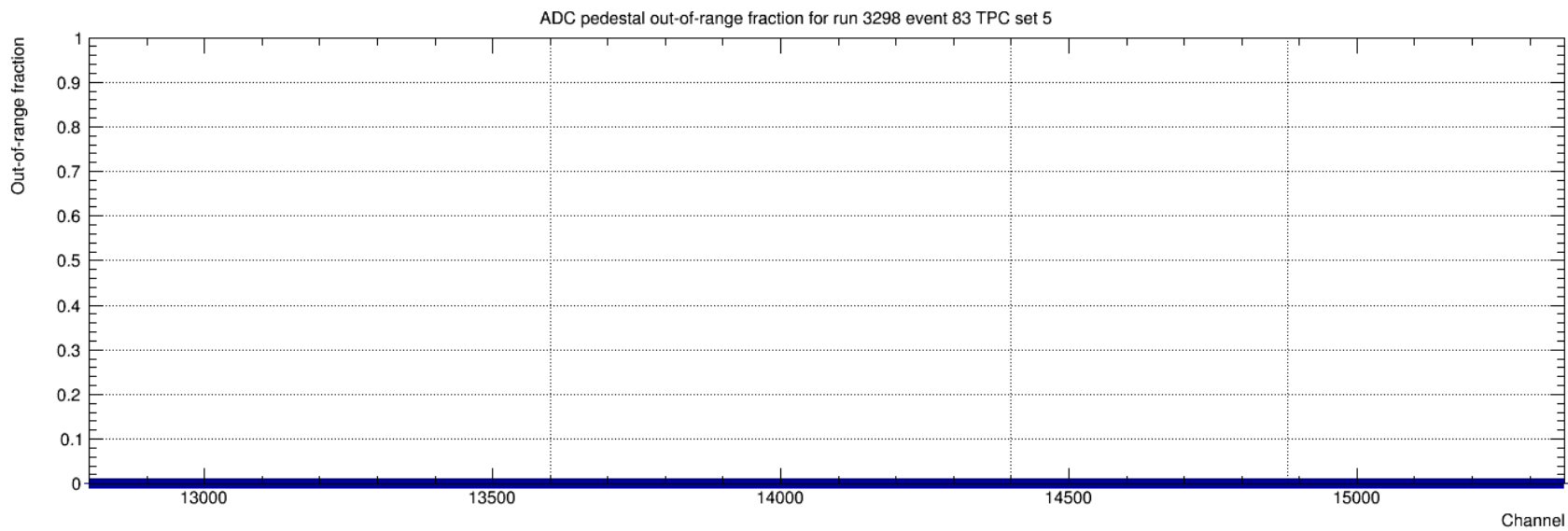
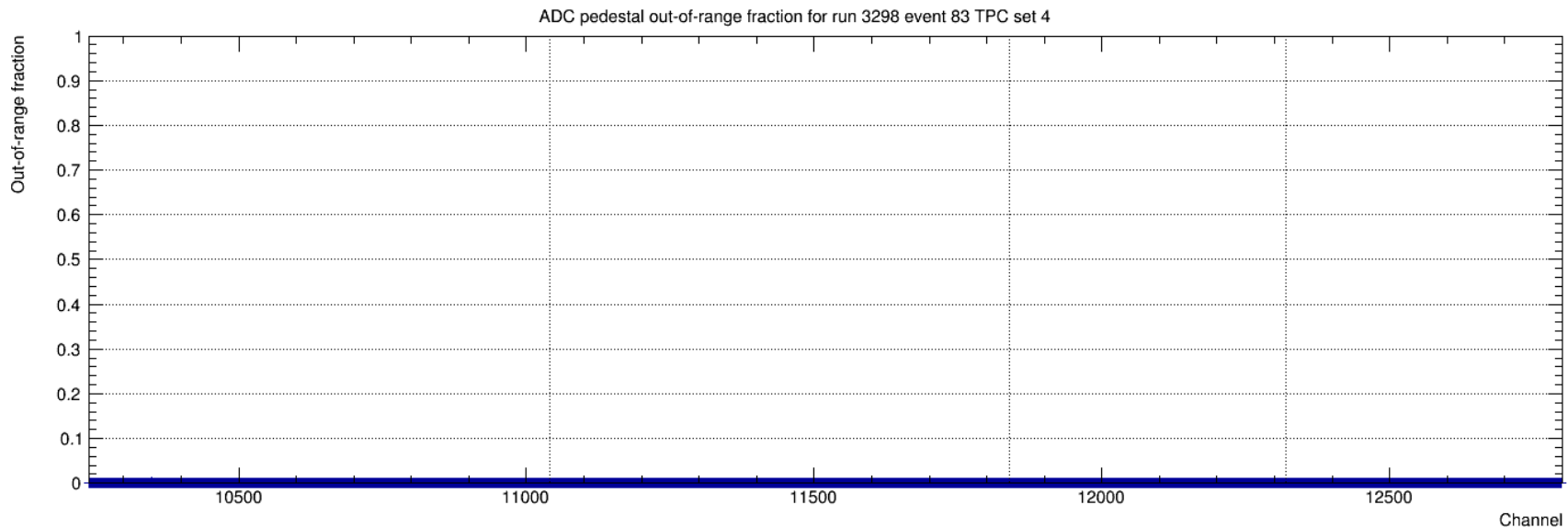
OORF 8/1



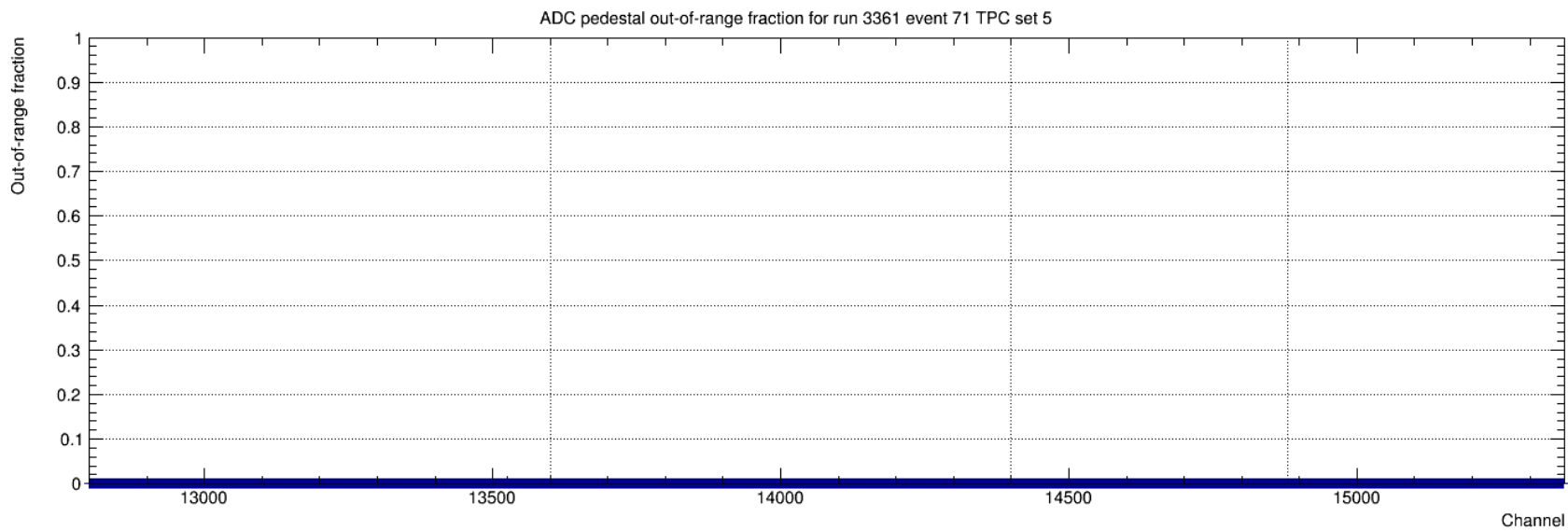
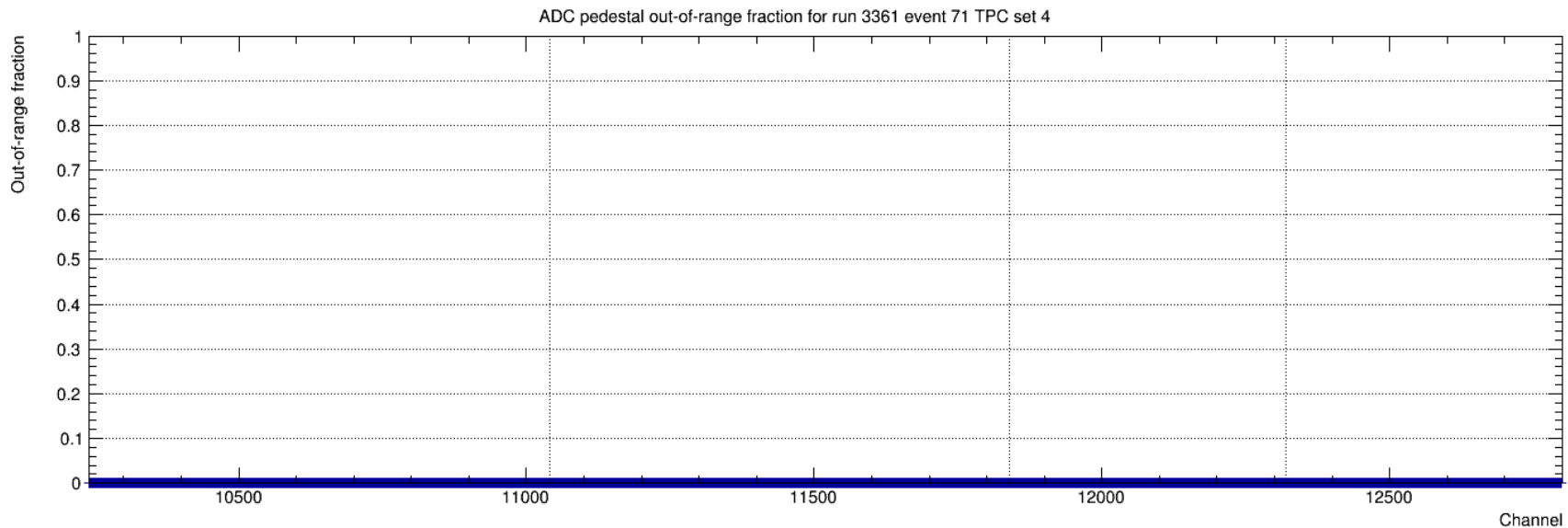
OORF 8/3, pulser DAC=5



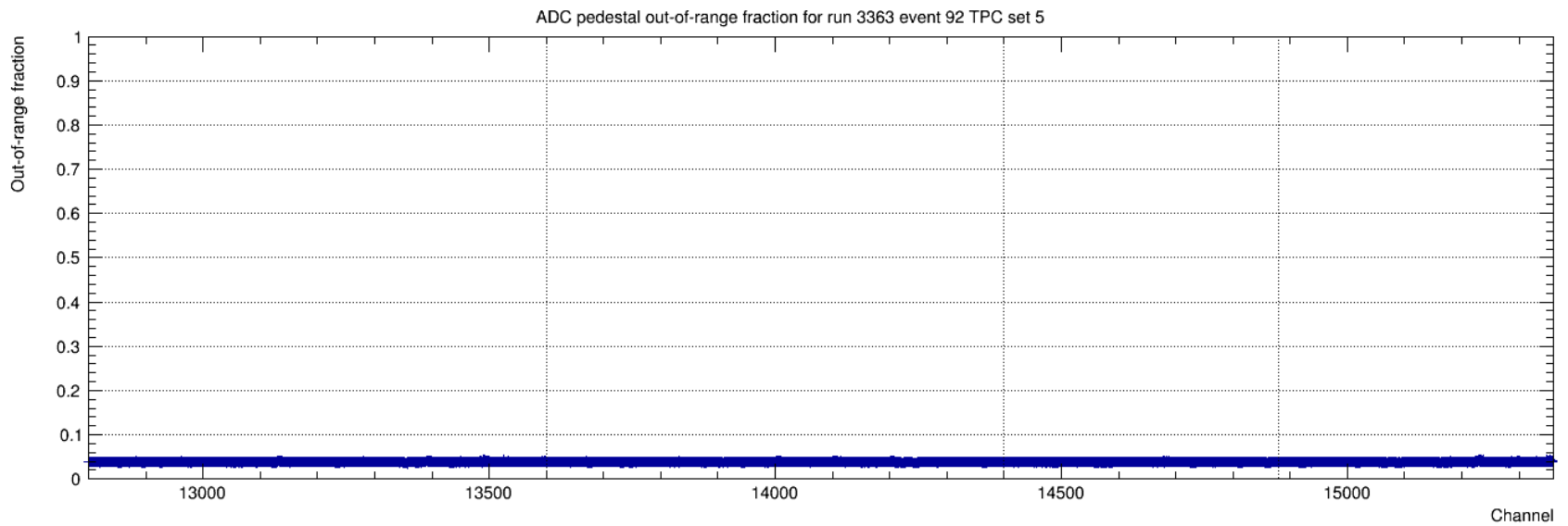
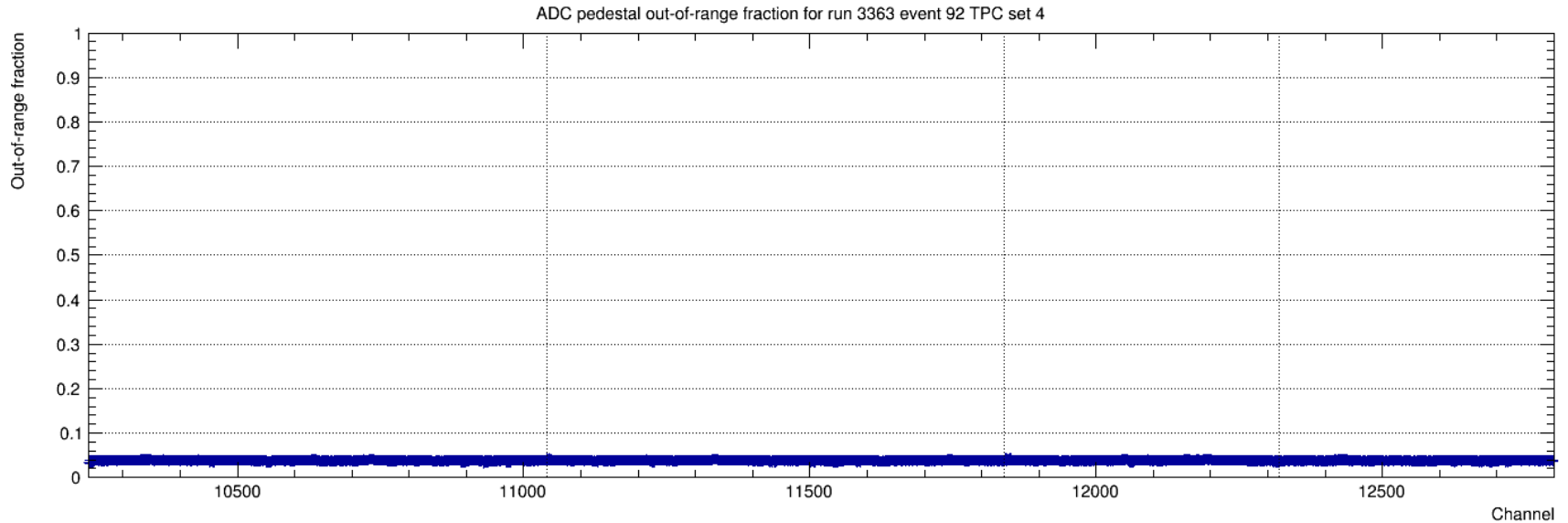
OORF 8/13



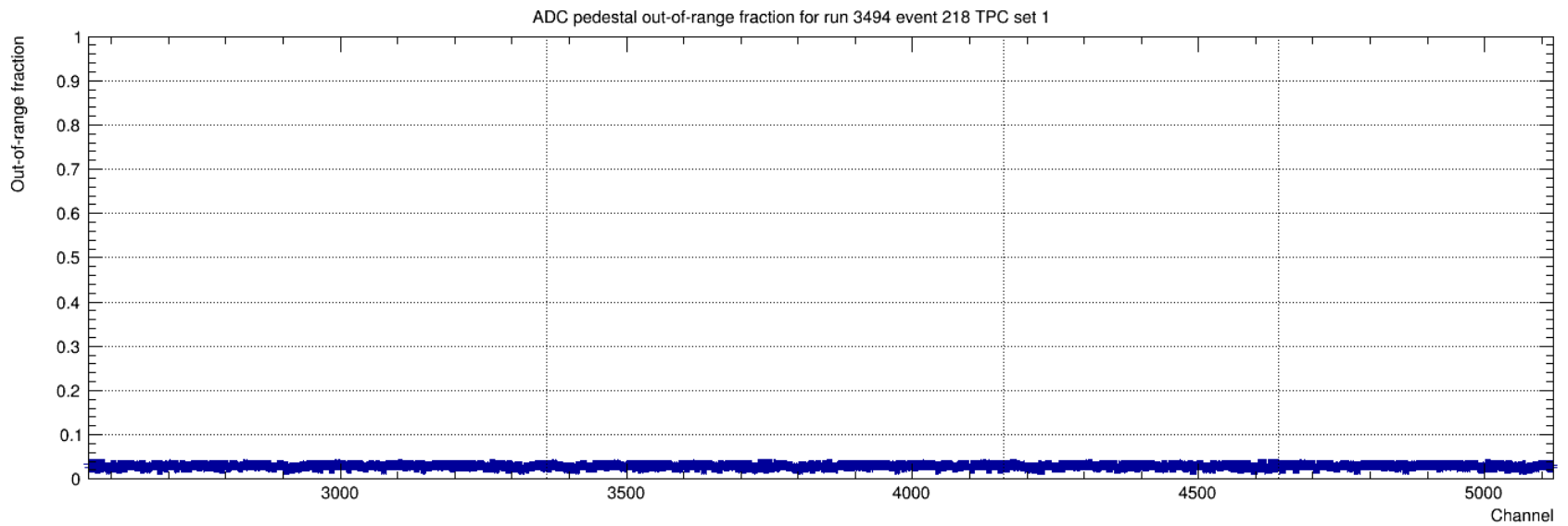
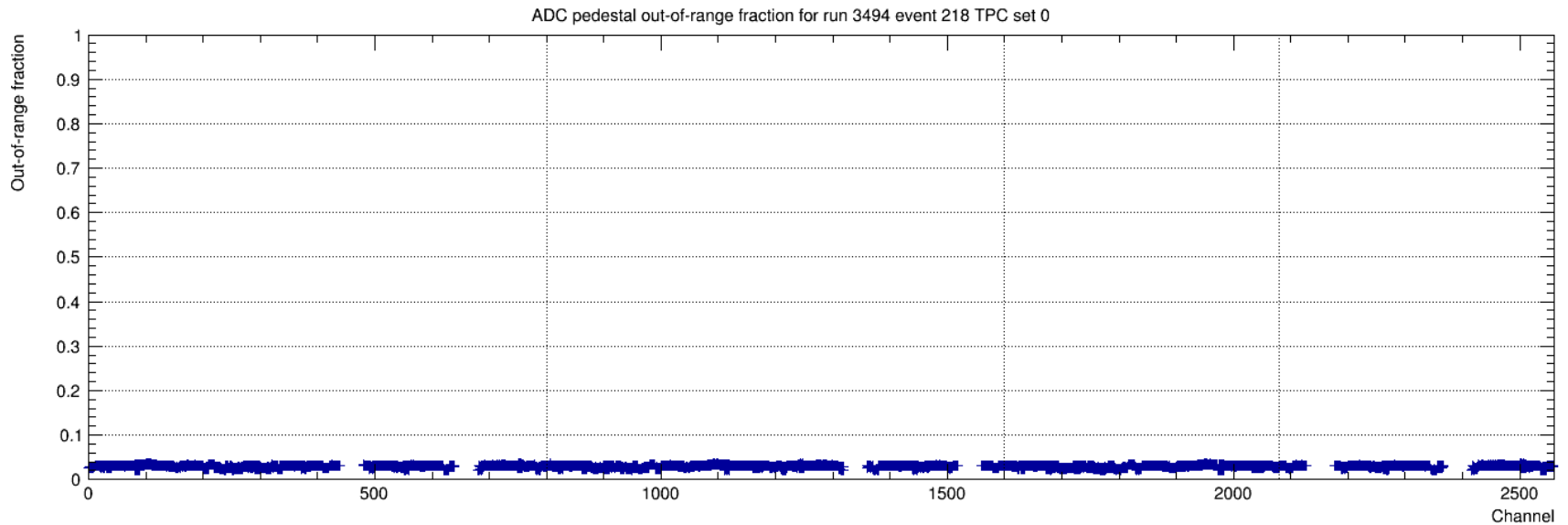
OORF 8/14



OORF 8/14, pulser DAC=5

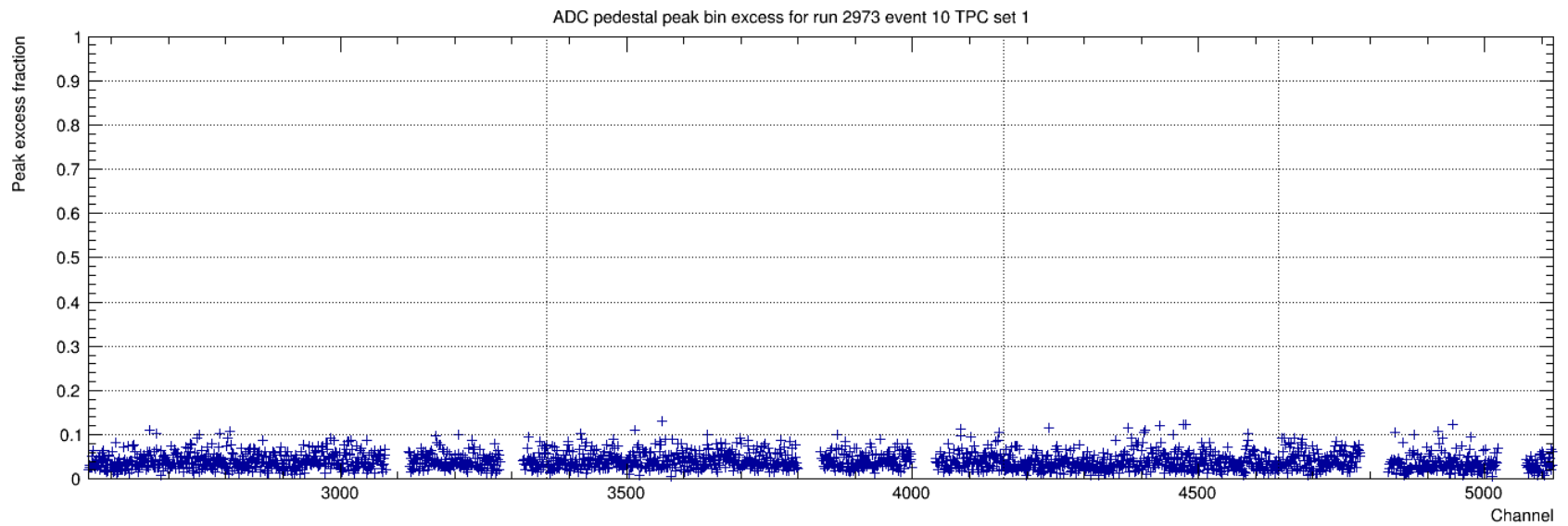
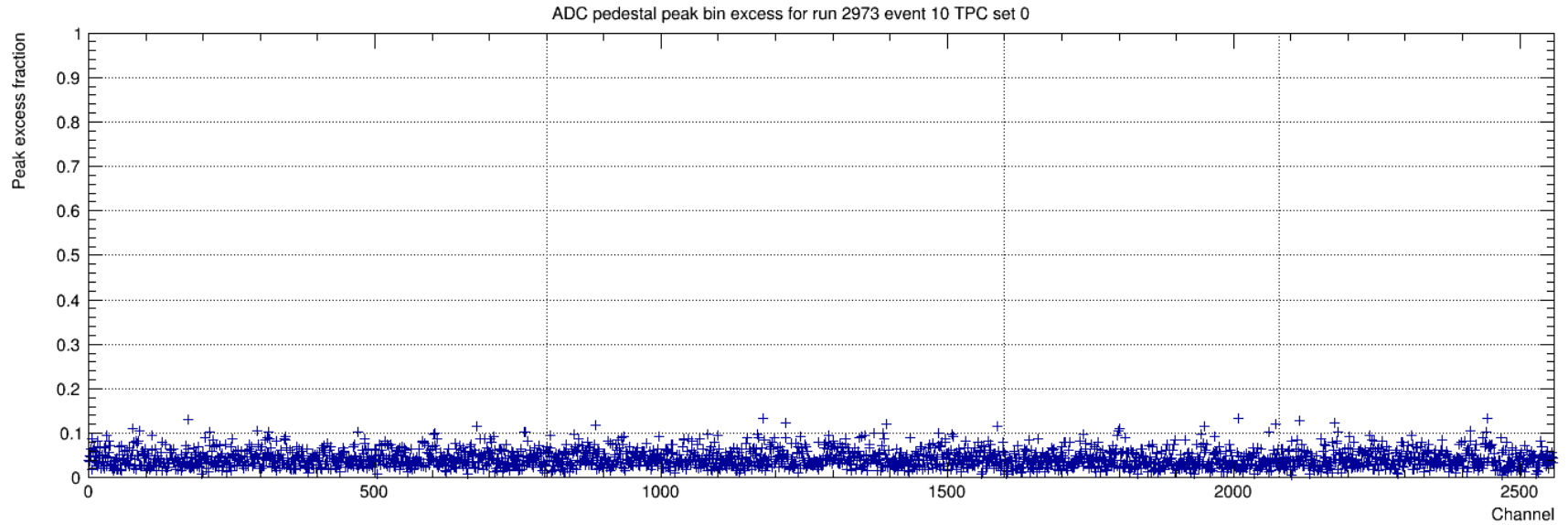


OORF 8/21, pulser DAC=2

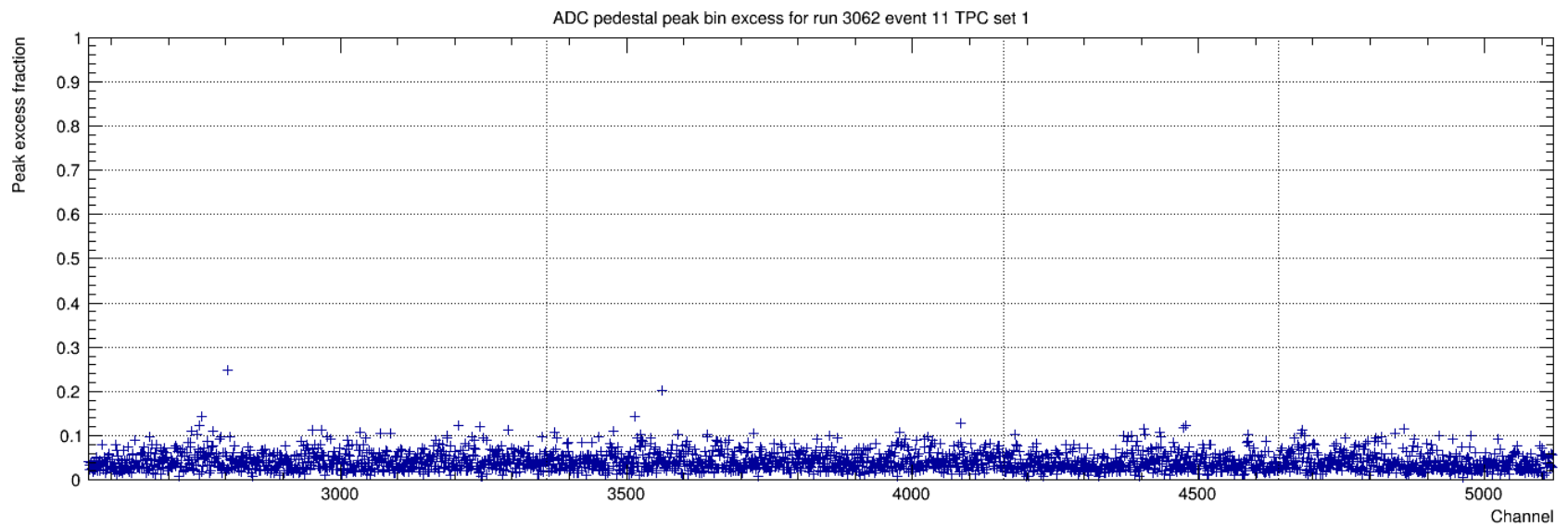
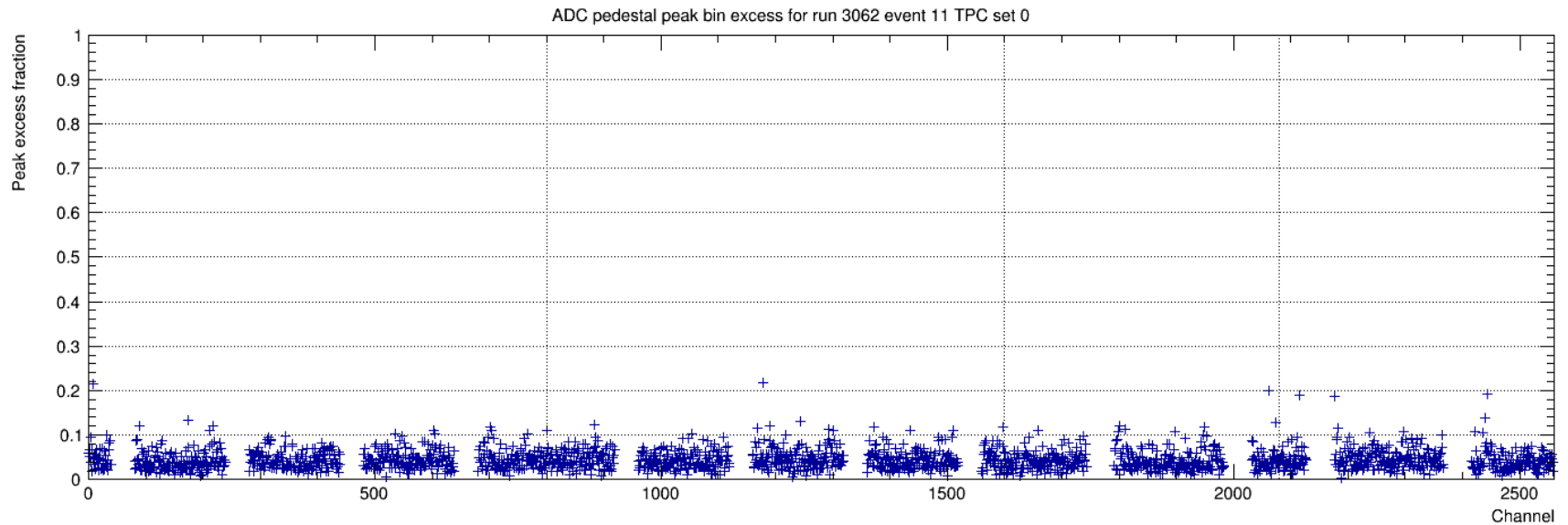


Peak bin excess (sticky codes)

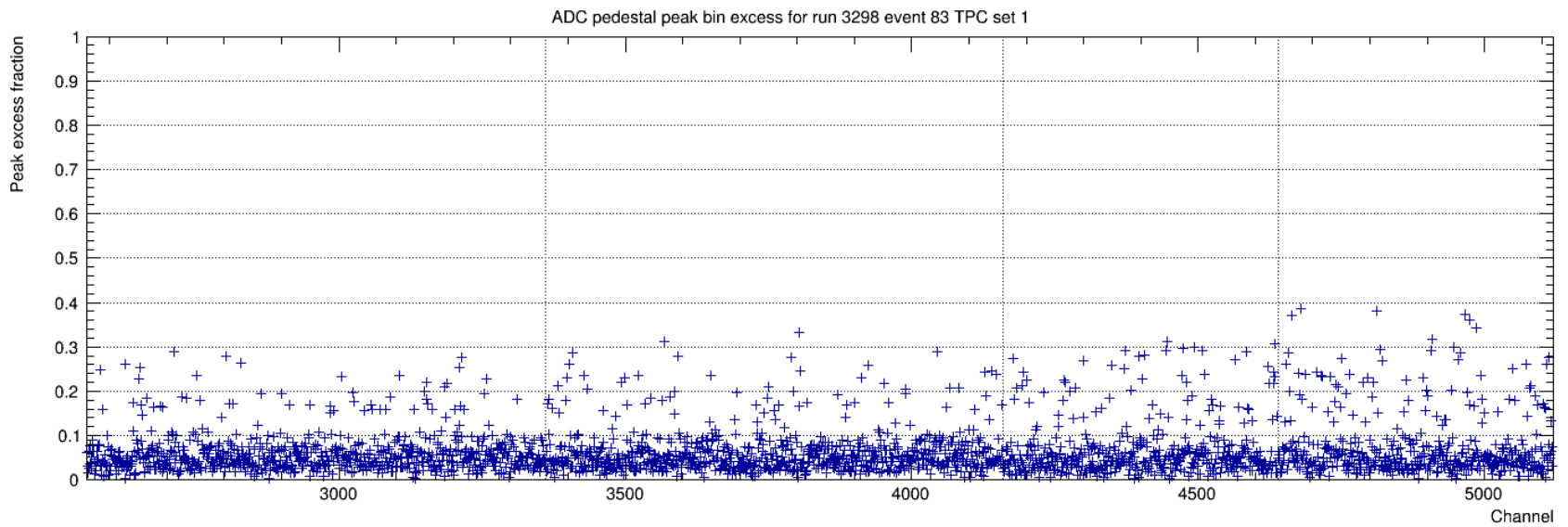
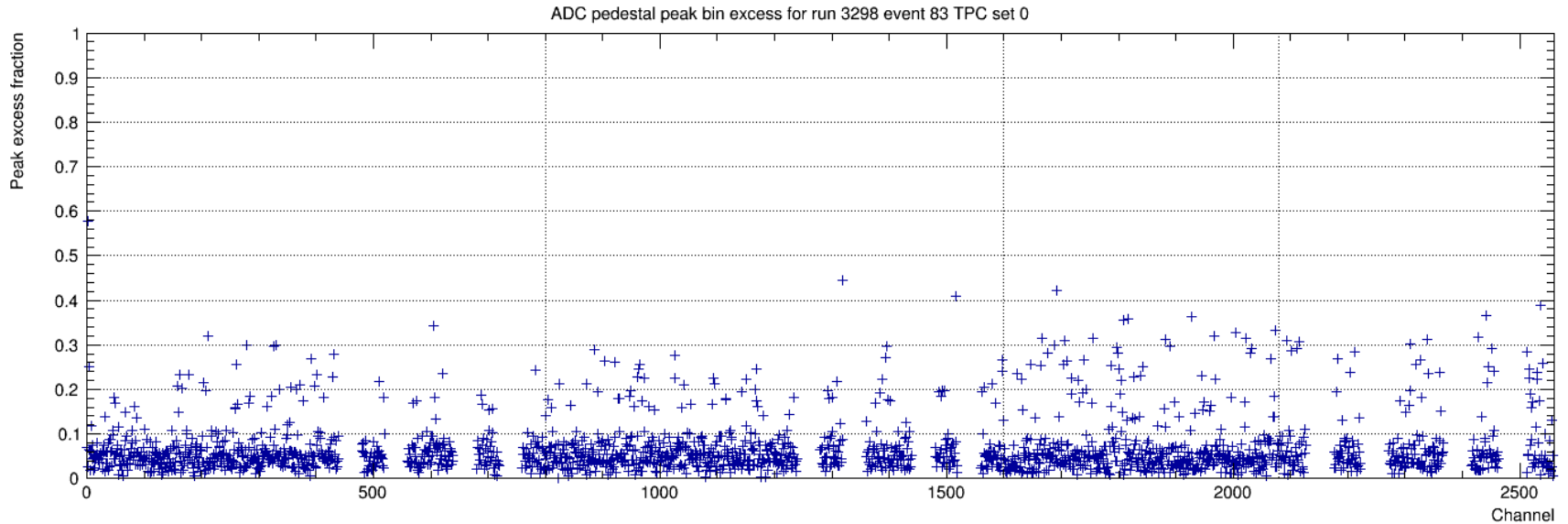
Peak bin excess 8/1



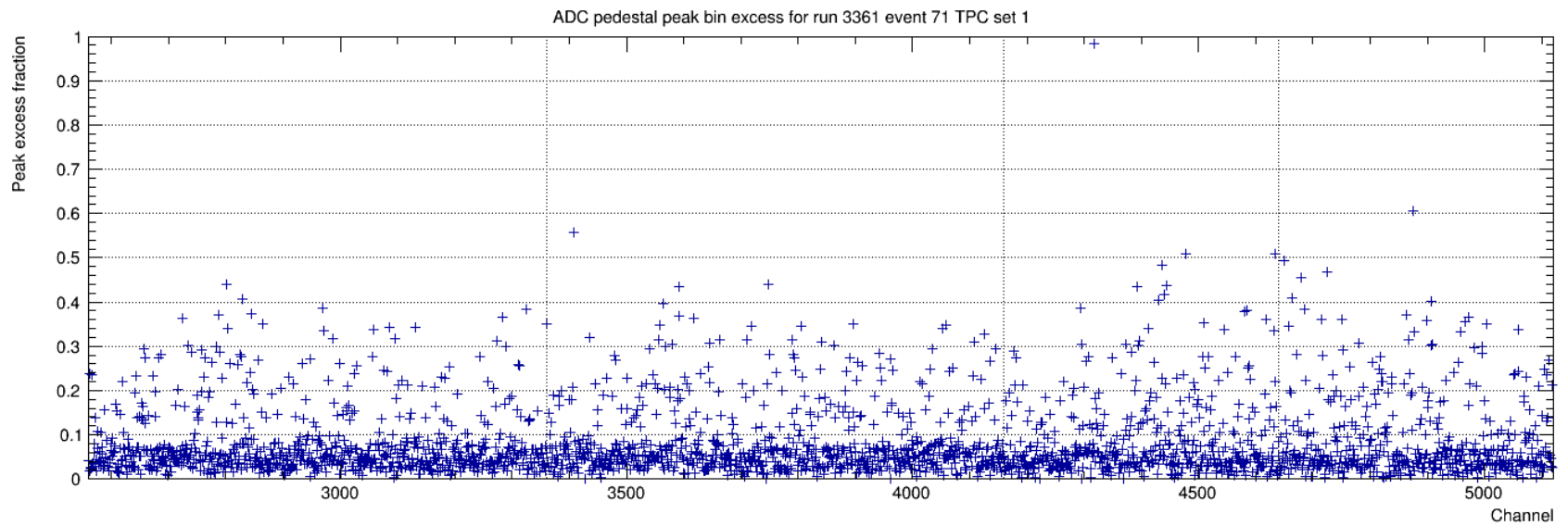
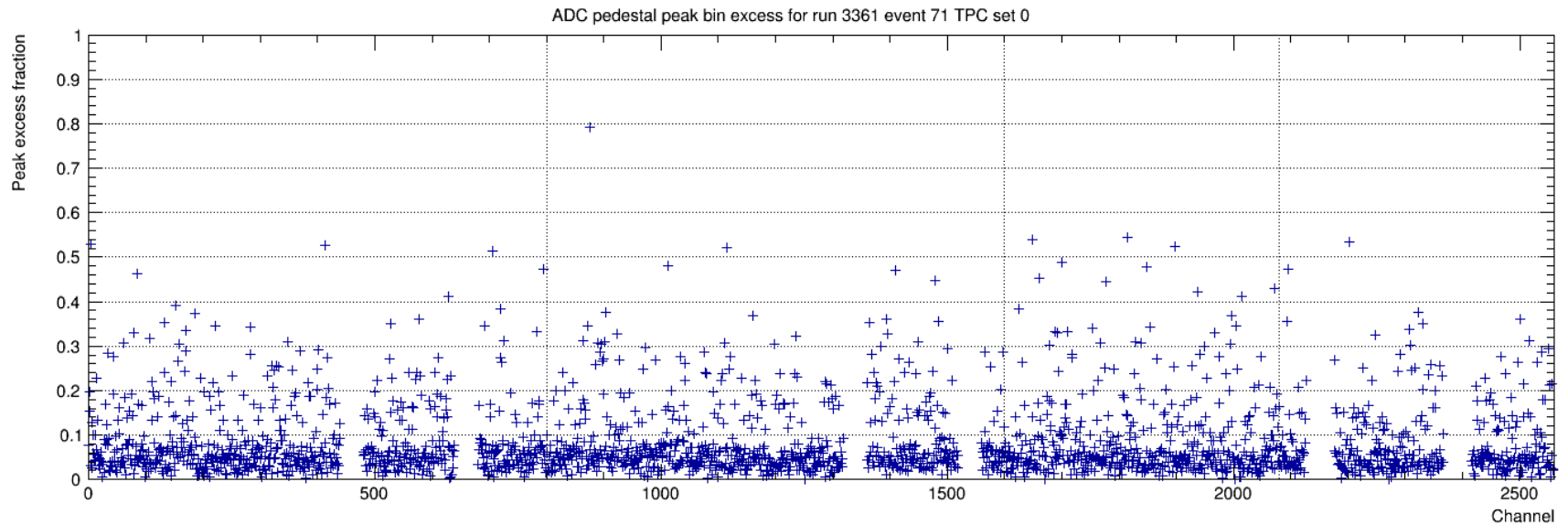
Peak bin excess 8/3, pulser DAC=5



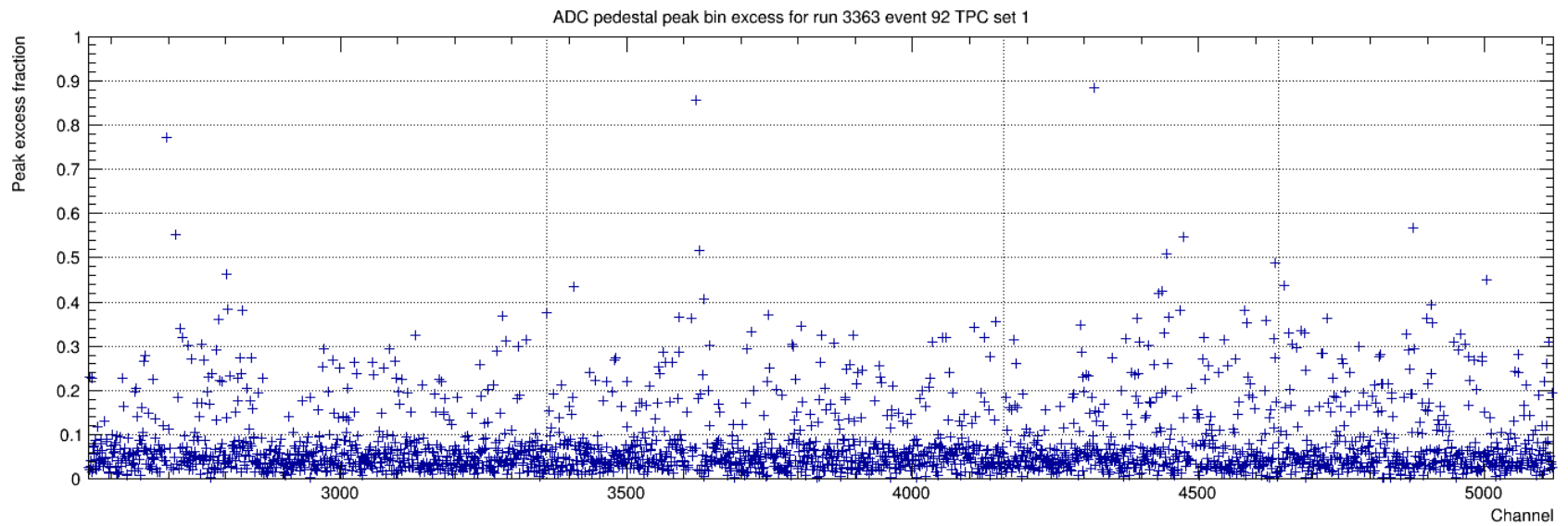
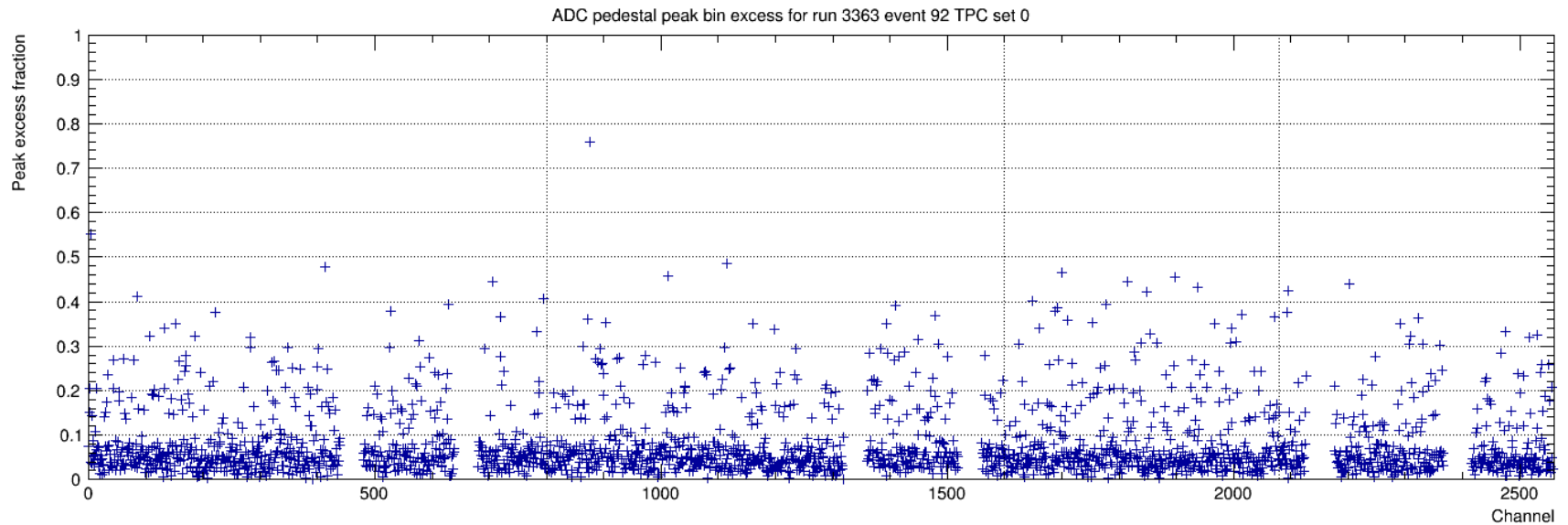
Peak bin excess 8/13



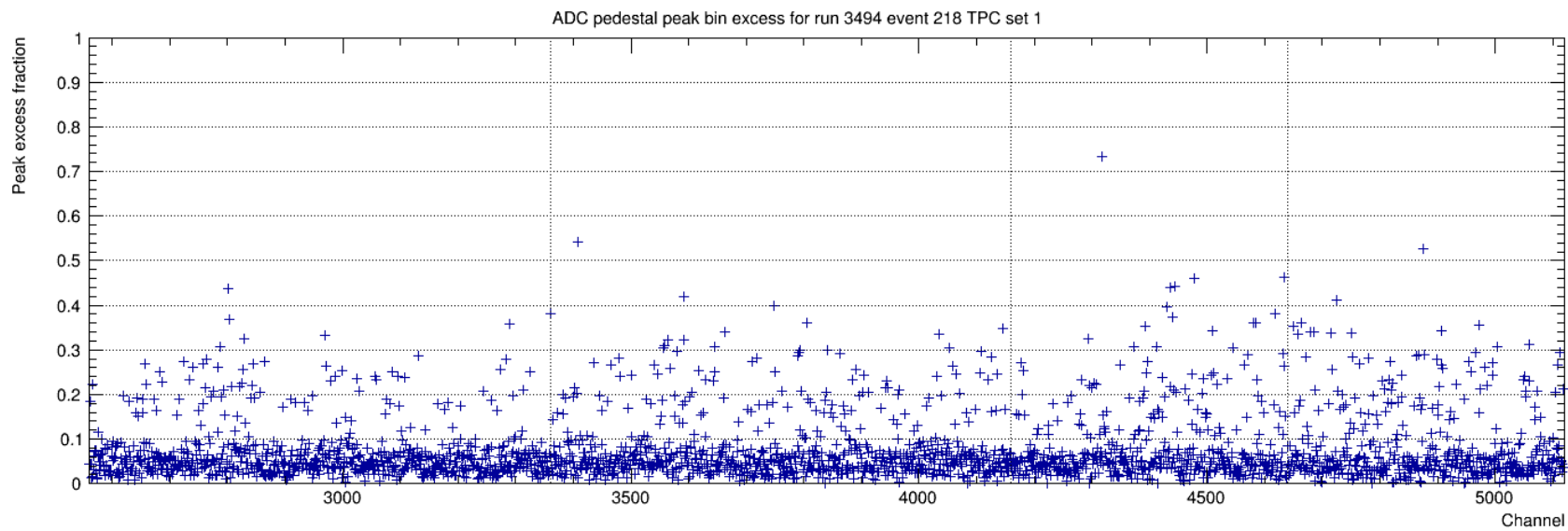
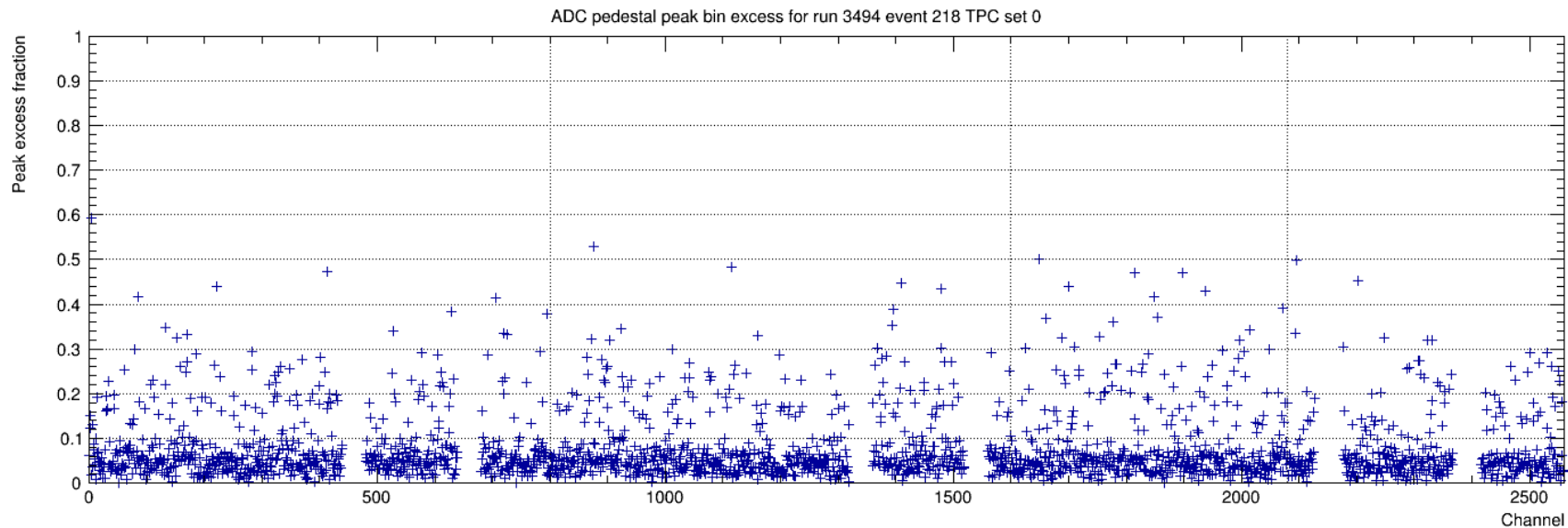
Peak bin excess 8/14



Peak bin excess 8/14, pulser DAC=5



Peak bin excess 8/23, DAC=2



Pedestal analysis comments

Preceding plot show

- Pedestal changed a little early on but looks very stable over last week
- Pedestal noise dropping
 - 8/1 was 8-10 ADC counts
 - Now is 3.5-4 ADC counts (500-600 e)
- Early saw a few channels with large OORF but no more
- Sticky codes increased early on but now stable
 - But what will happen when LAr hits the electronics?
 -

Tickmod analysis

Like to assess CE performance over full ADC range

- Pedestals cover a very limited range
 - And may have been adjusted if they hit a bad spot
- ADC performance was studied during testing with voltage ramps covering the full ADC range
 - But ADCs were not mounted in FEMBs
 - Hoping performance will be better now
 - No option for voltage ramp in FEMBs
- But (due to shaping) test pulser samples about 10 voltages
 - Different for each pulser DAC setting
 - Can also vary the time offset of the pulses to sample a different set

Make use of tickmod distributions

- Tickmod == tick modulus pulser period, i.e. $\text{Tick} \% 497$ (current setting)
- Look at distribution of ADC signals for each tickmod
 - As for pedestal, expect narrow peaks
- Need to combine events to get sufficient stats

Event synchronization

To combine events, we need synchronization

- I.e. need to know the number of TPC ticks between events
 - Modulus 497 is good enough
- We could (should?) fit the waveforms for each event and channel
 - But this could be slow

2 MHz counters

- There are 16-bit (not much) TPC counters in the data that are (or should be) used to align channel-tick frames of data
- We can and should check these for consistency when building larsoft view of raw data and extract a count for tick 0
 - Assuming all channels are aligned
- But 16 bits is only 32 ms and probably not possible to align with only the 1-second precision time stamp
- However, there is a 64 bit, 50 MHz timing counter
 - The TPC timing is derived from this

Event synchronization (2)

50 MHz timing counter

- The 2 MHz TPC count (N_{TPC}) can be derived from the timing count (N_{tim}) but there is a phase offset N_0 :

$$N_{\text{TPC}} = (N_{\text{tim}} + N_0)/25$$

where N_0 is one of the values $\{0, 1, 2, \dots, 24\}$

- Wrong value for N_0 means count can be off by one tick depending on the event phase $\varphi = N_{\text{tim}}\%25$
- Early data showed this works fairly well w/ different N_0 for each FEMB
- This was fixed and now the same N_0 applies to the full detector

Checking synchronization

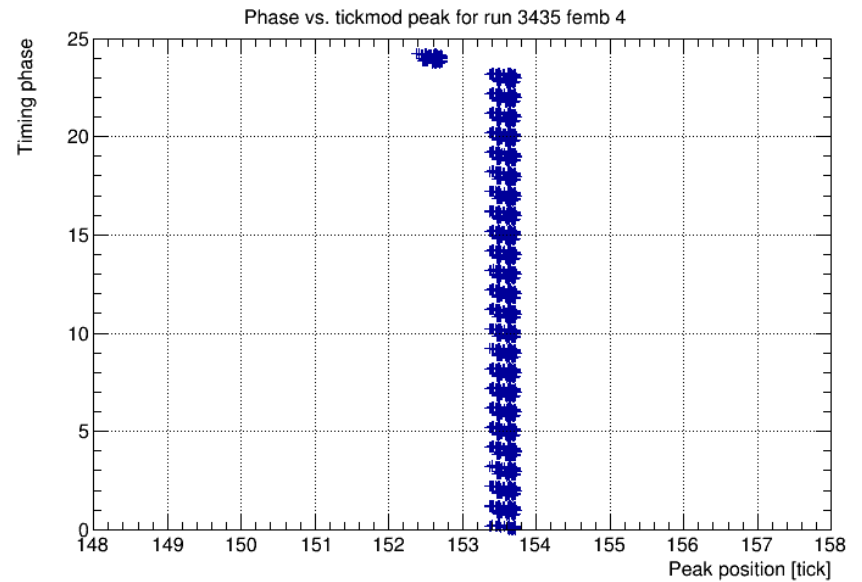
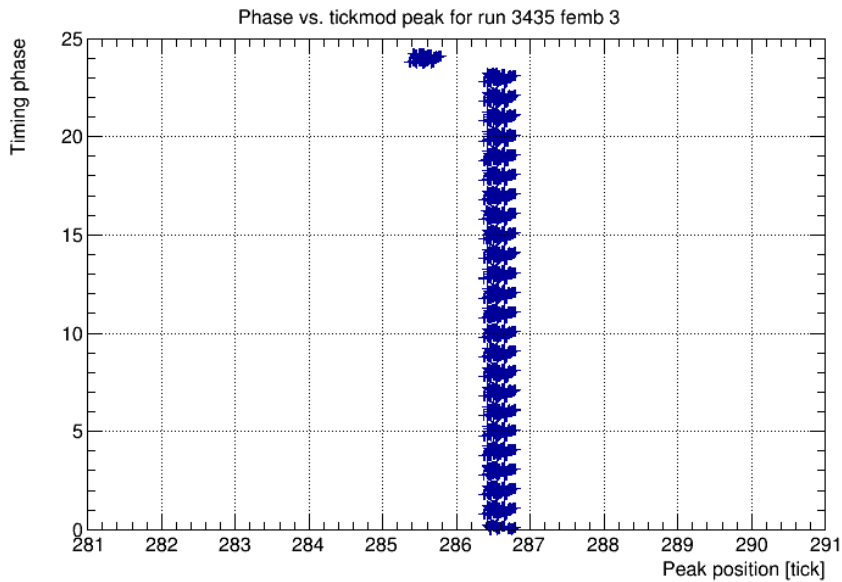
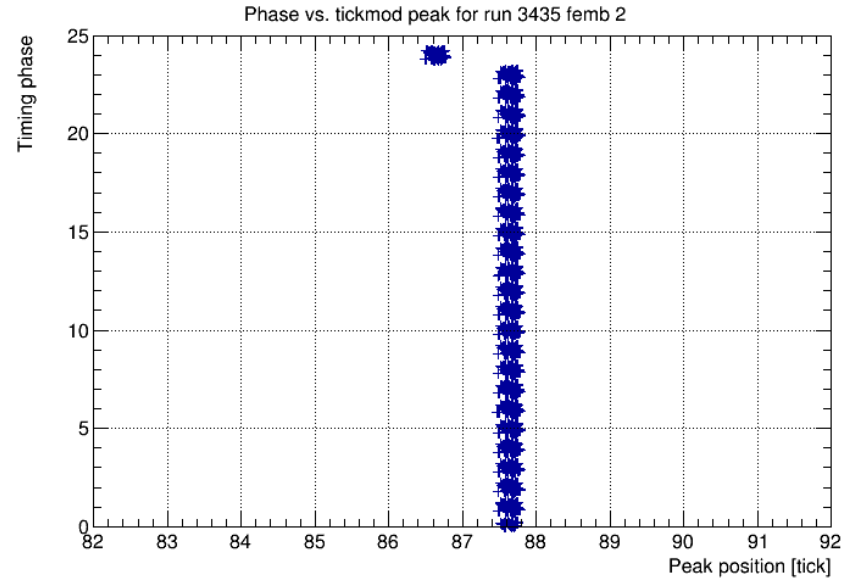
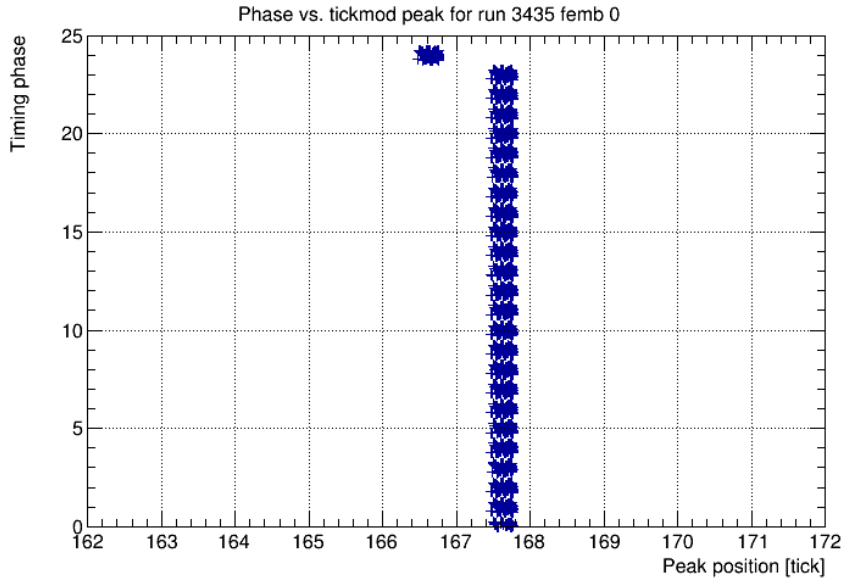
- To check timing, tickmods are collected for each event and the mean of each is used to construct a waveform
- Three-point interpolation is then used to find maximum (positive peak)
- Distribution of the peak position vs. event phase

Event synchronization (3)

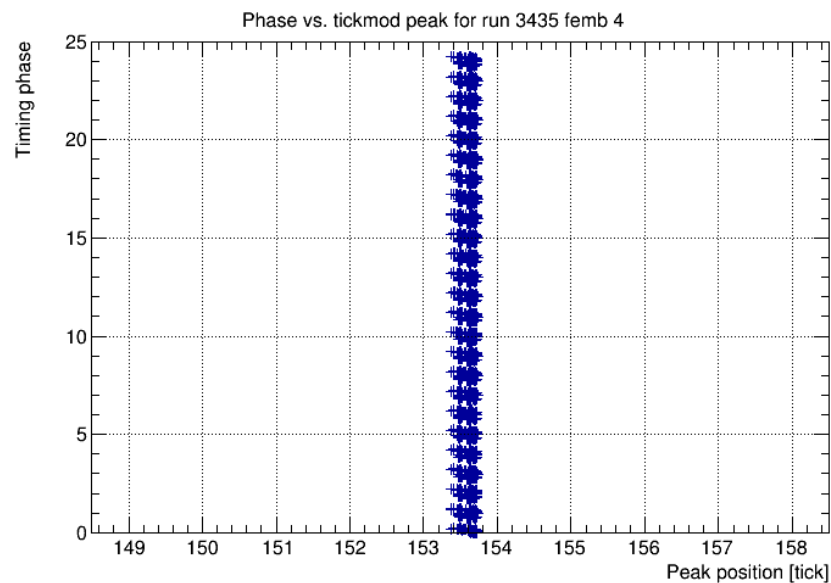
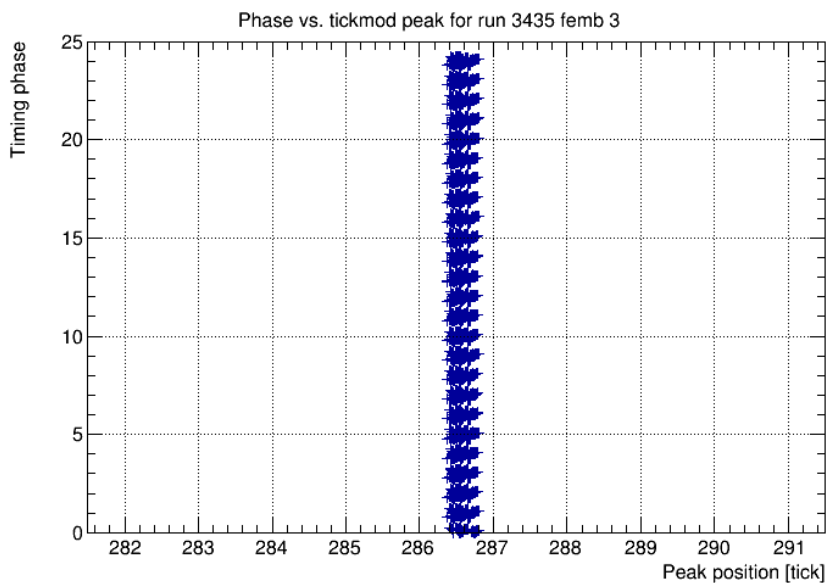
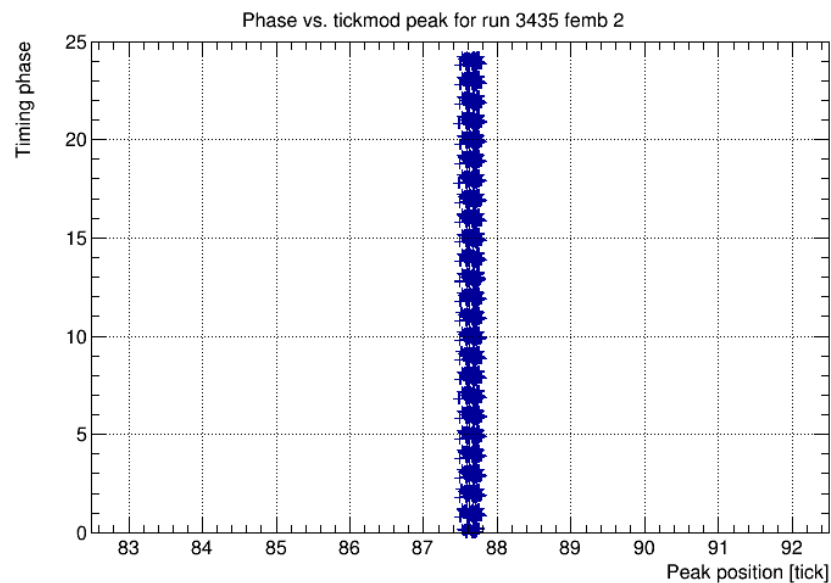
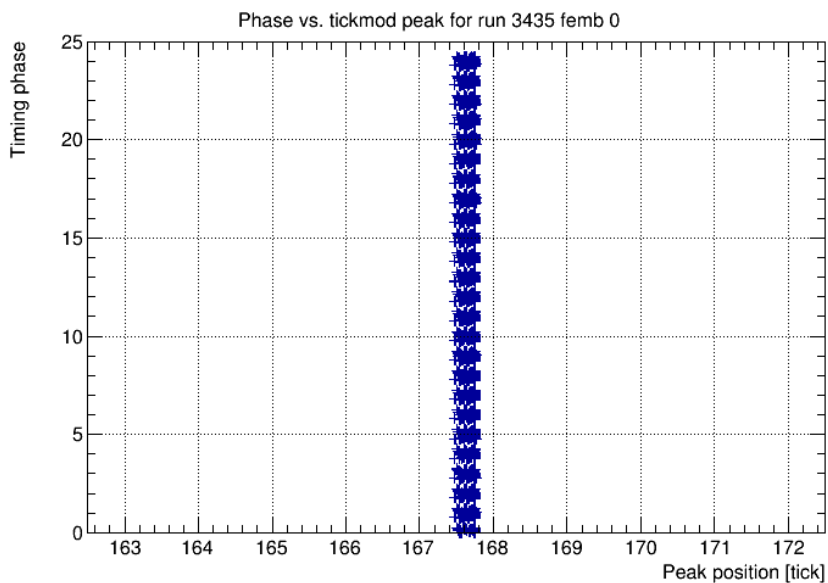
Timing phase vs. tickmod peak plots are available

- All FEMBs now seen have the same phase offset
- Following pages have examples with $N_0=0$ and $N_0=1$
- Full set of TPS0 (APA3) plots for this run at
 - <http://home.fnal.gov/~dladams/protodune/tickmodPhaseFemb/tps0/run003435/plots.html>
 - <http://home.fnal.gov/~dladams/protodune/tickmodPhaseFemb/tmphase01/tps0/run003435/plots.html>
- Plots for other APAs and runs at
<http://home.fnal.gov/~dladams/protodune/tickmodPhaseFemb>

Timing phase vs. tm peak: 8/17 DAC=8 $N_0=0$



Timing phase vs. tm peak: 8/17 DAC=8 $N_0=1$

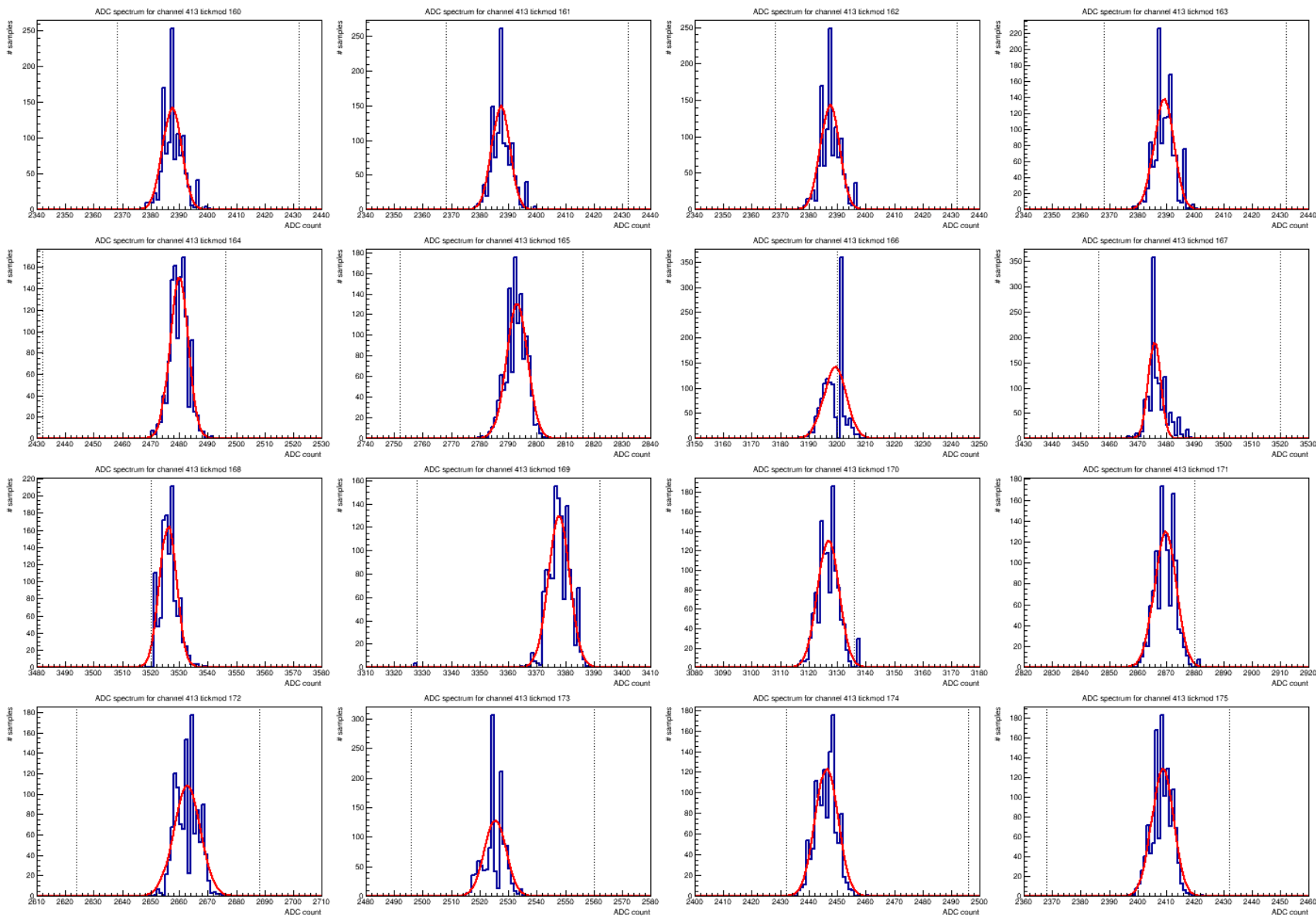


Tickmod distributions

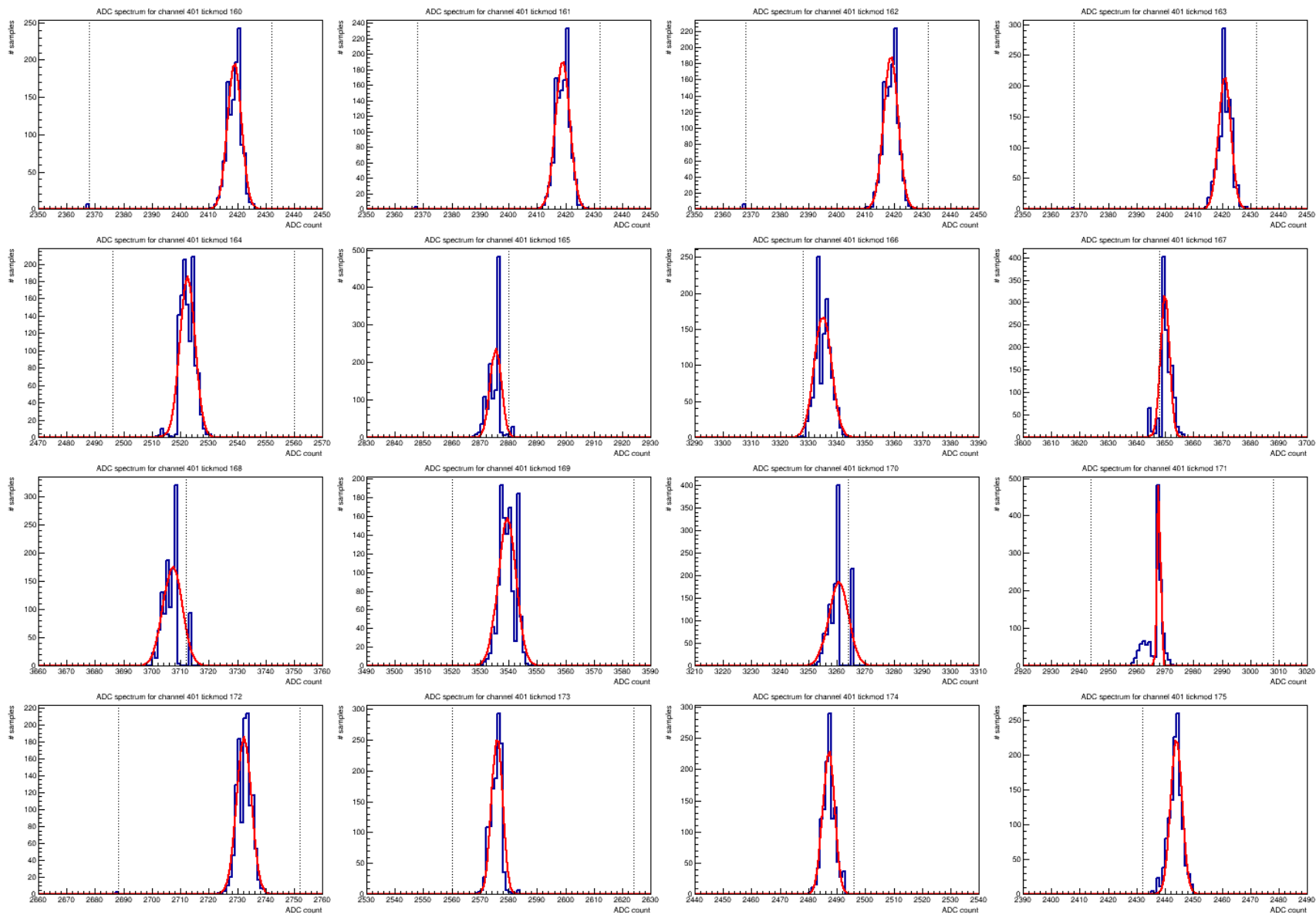
Following pages show some example tickmod distributions

- Plots are the “max” distributions, those near the maximum signal
 - One page for each channel shows 16 or 497 distributions
 - Most of the distributions not shown are at the pedestal
 - There is another set for the negative pulse

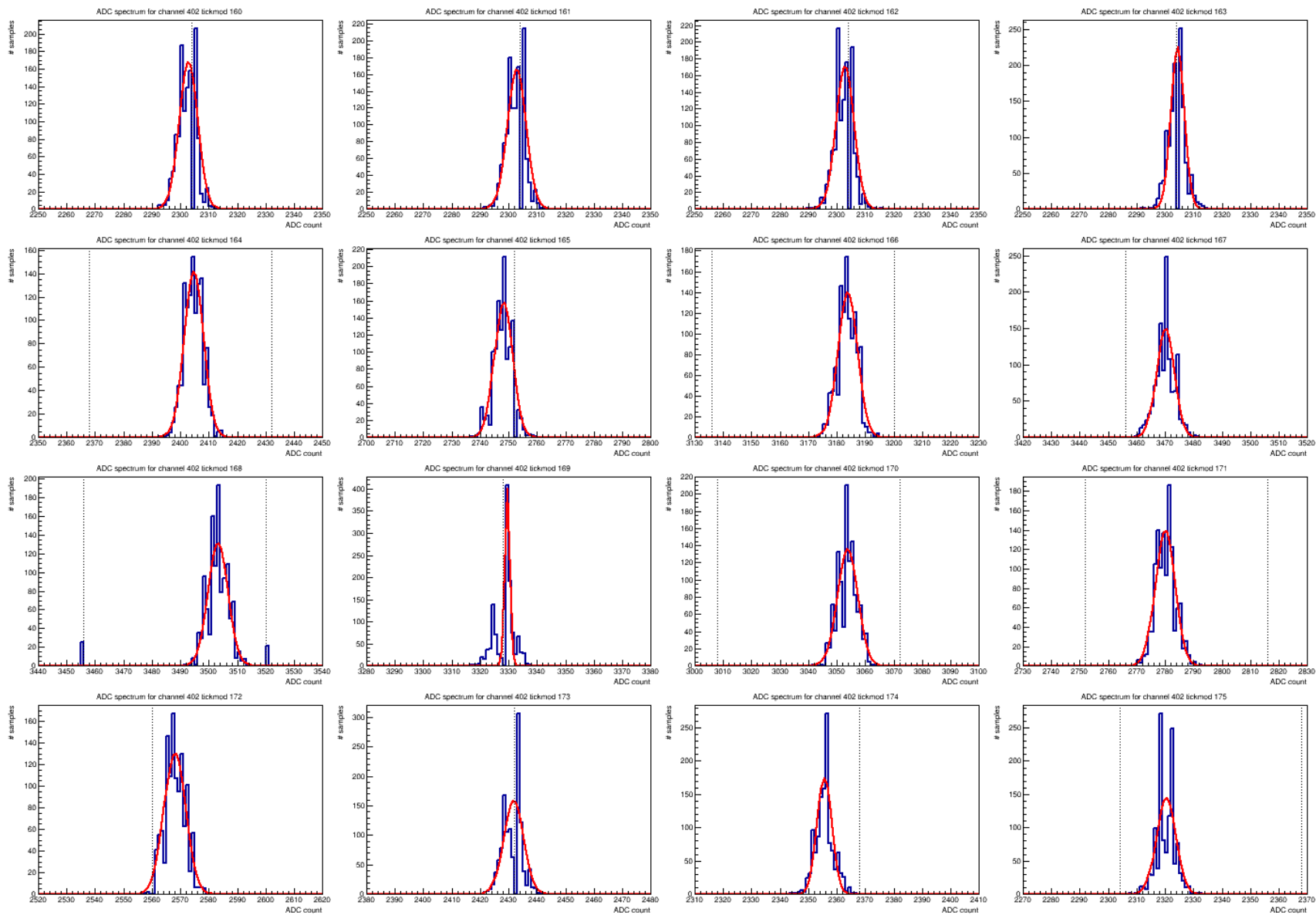
Tickmod dists 8/21 DAC=8 channel 400



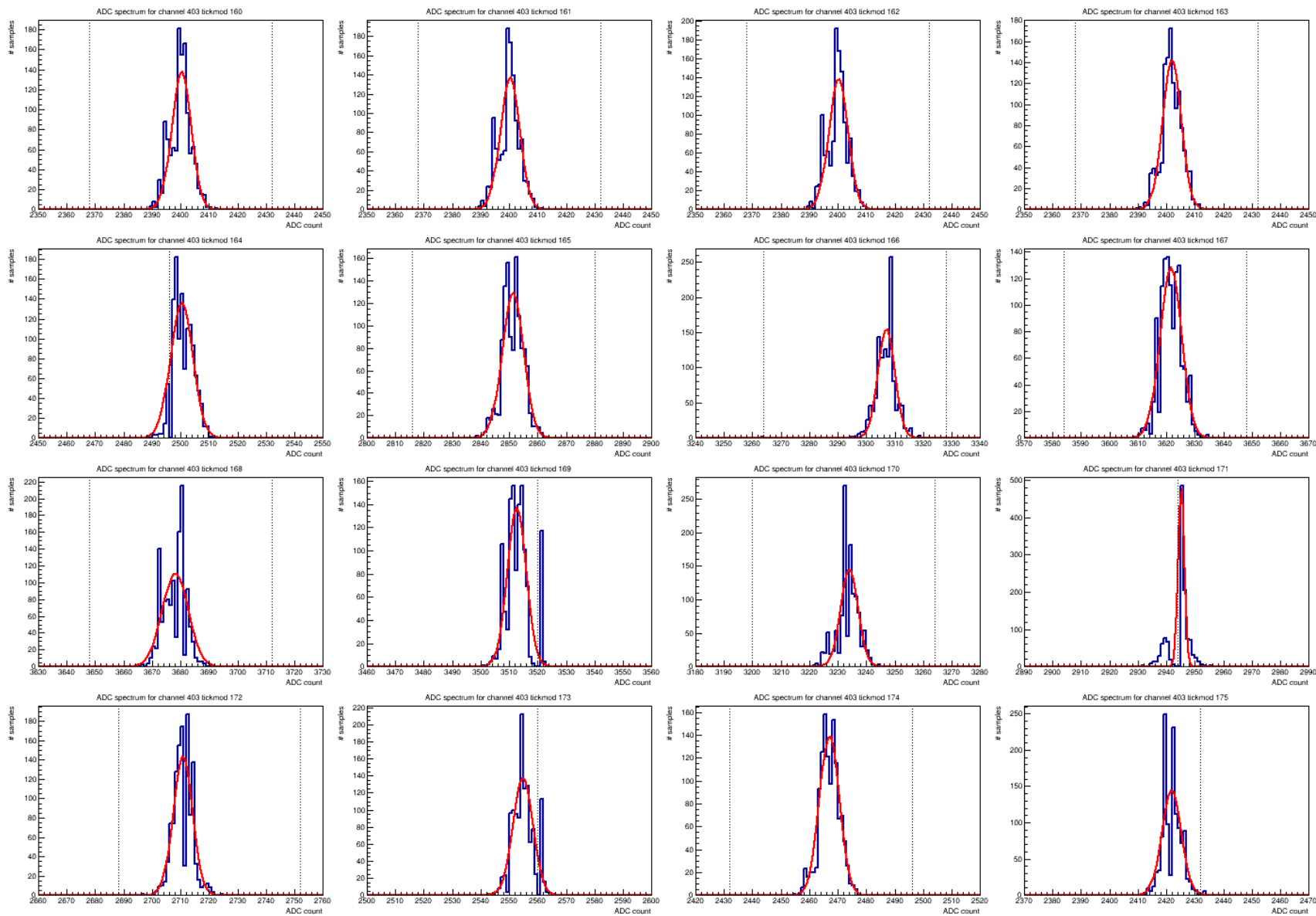
Tickmod dists 8/21 DAC=8 channel 401



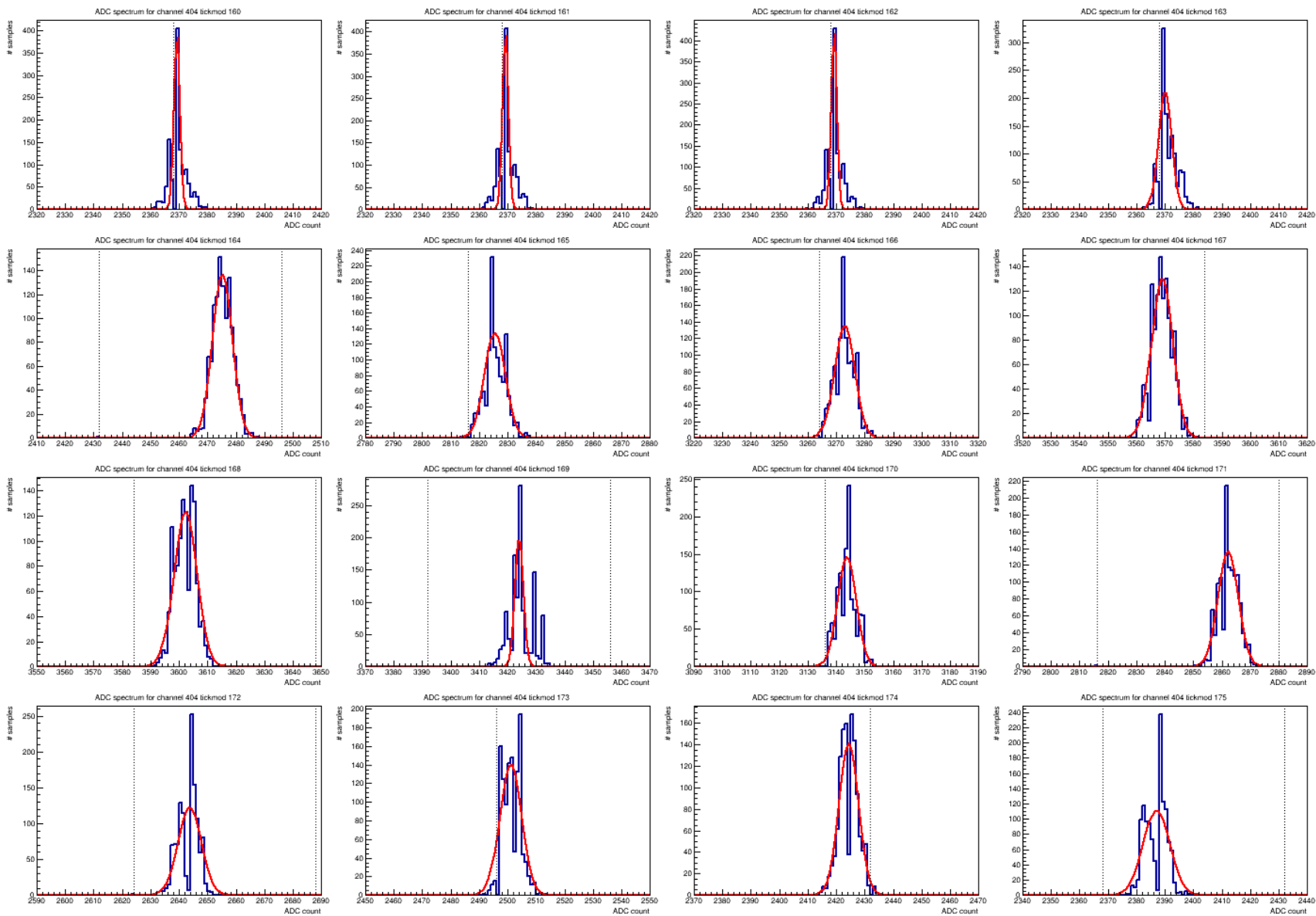
Tickmod dists 8/21 DAC=8 channel 402



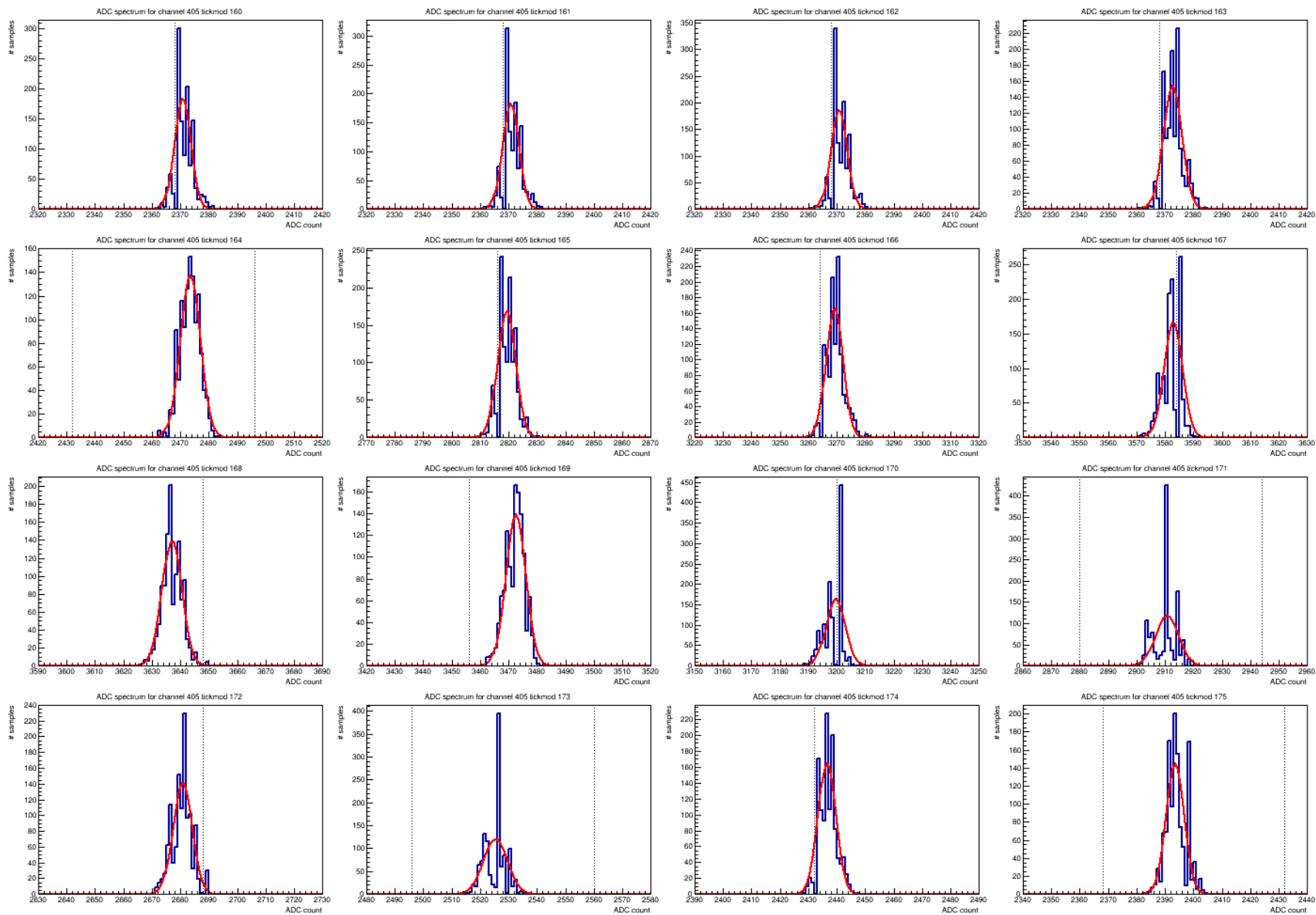
Tickmod dists 8/21 DAC=8 channel 403



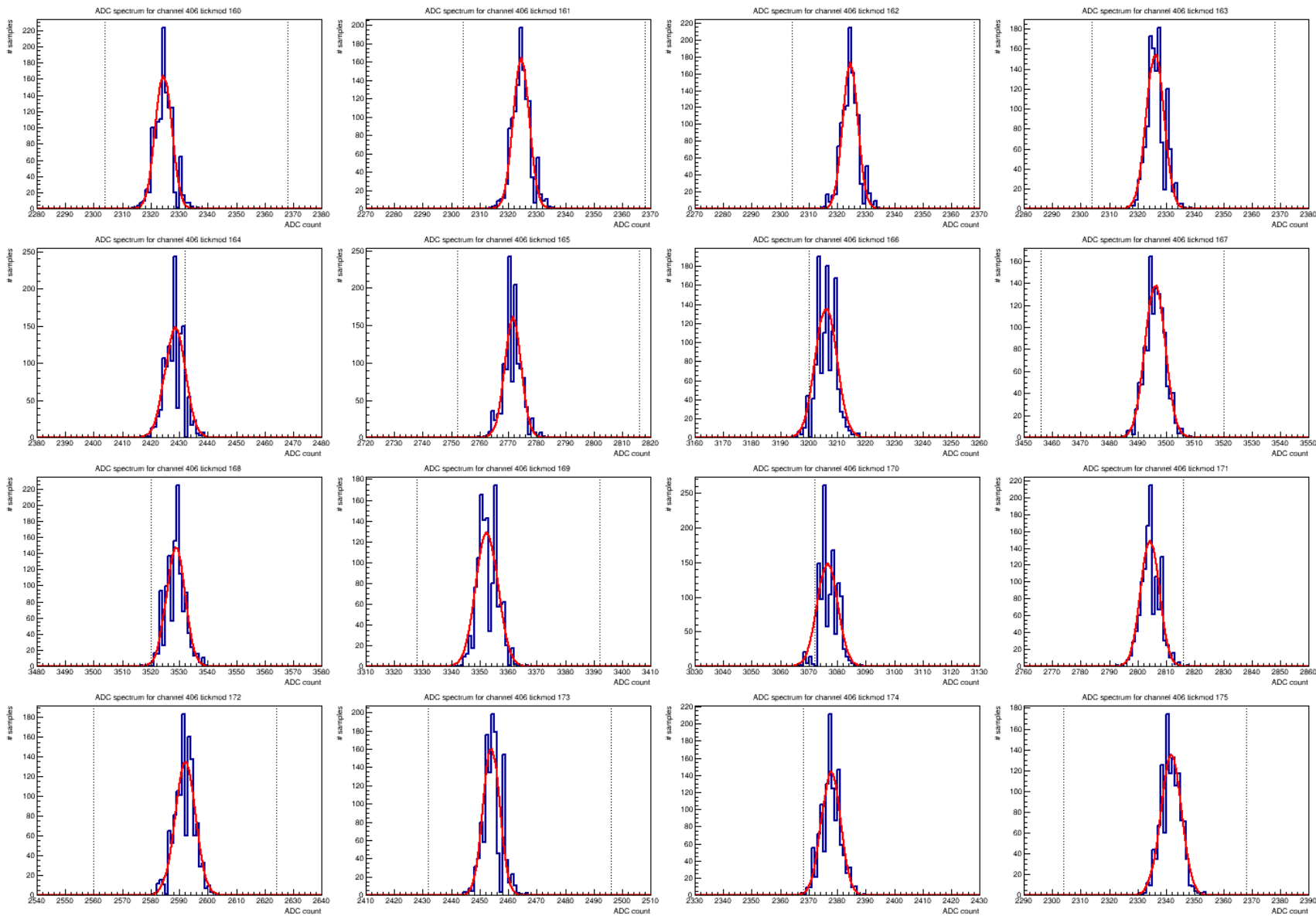
Tickmod dists 8/21 DAC=8 channel 404



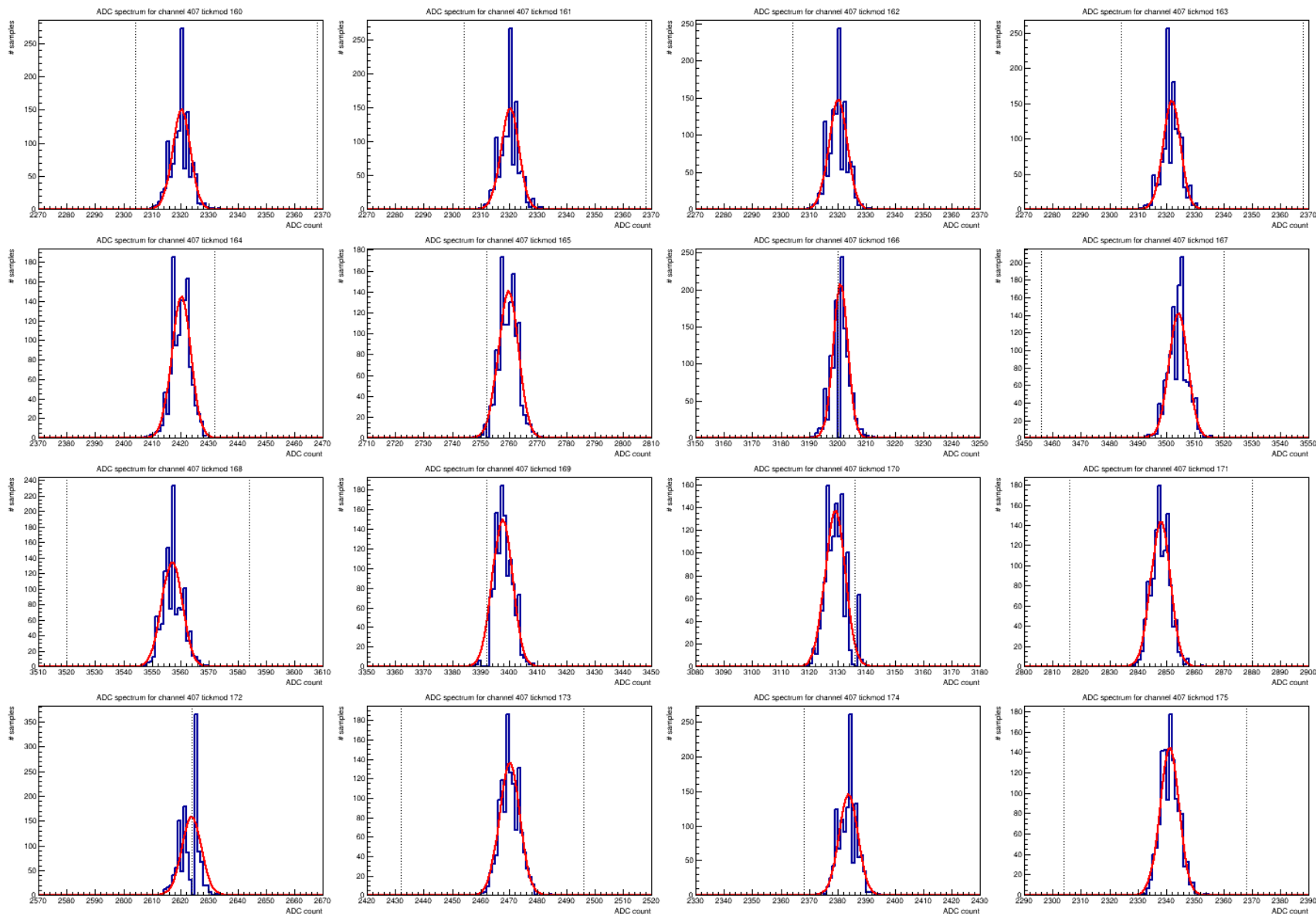
Tickmod dists 8/21 DAC=8 channel 405



Tickmod dists 8/21 DAC=8 channel 406



Tickmod dists 8/21 DAC=8 channel 407



Comments on tickmod distributions

A few plots shown here

- 8 of 15k channels
- 16 of 497 tickmods (but half the interesting ones)

Fitting needs a bit of work

- Min value for sigma to avoid settling on a spike

Sticky codes

- Some are evident but don't seem to skew distributions
- Se what happens when LAr reaches the top...

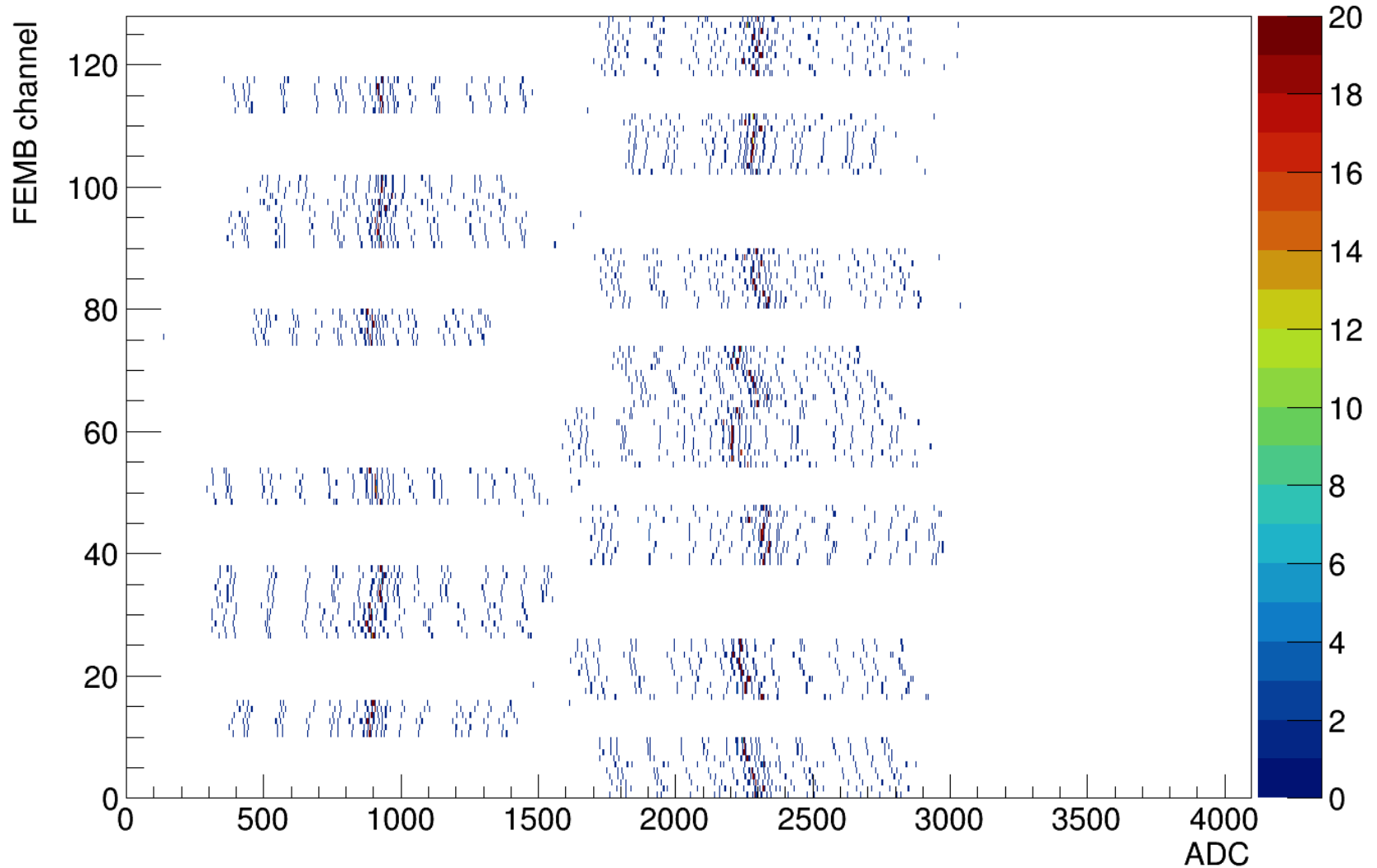
Tickmod summary plots

Need summary views

- Want to view performance for 4k bins in 15k channels
 - Resolution of 3-4 ADC counts provides some smearing
 - Rebinning ADC by 4 or 8 still leaves 1000 or 500 ADC merged bins
 - Include one FEMB or one detector plane in each plot to get a manageable # channels
- First look at illumination—do we have at tickmod in each bin?
 - Following plots shows illumination for a few runs
 - Bins are one channel by 4 ADC bins
 - Nice sampling but not much coverage
 - About 2%/(DAC setting) away from pedestal
- To increase coverage:
 - Multiple DAC settings: 1, 2, ..., 20 (and beyond?)
 - Shift pulses by fractions of a tick
- With coverage, look at performance in channel-ADC space
 - Charge resolution, sticky code metrics, calibration nonlinearity

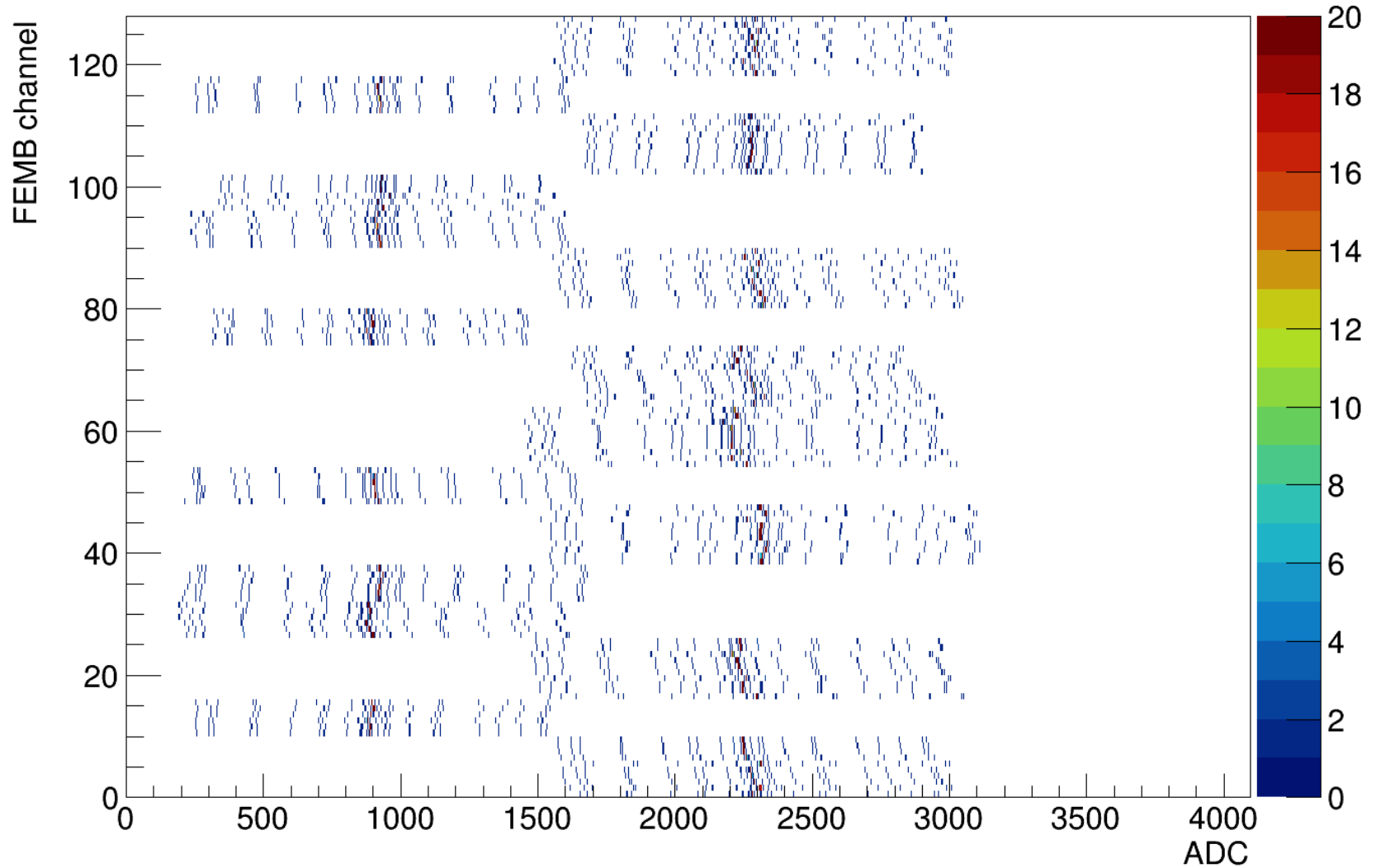
DAC=4

Illumination for run 3255



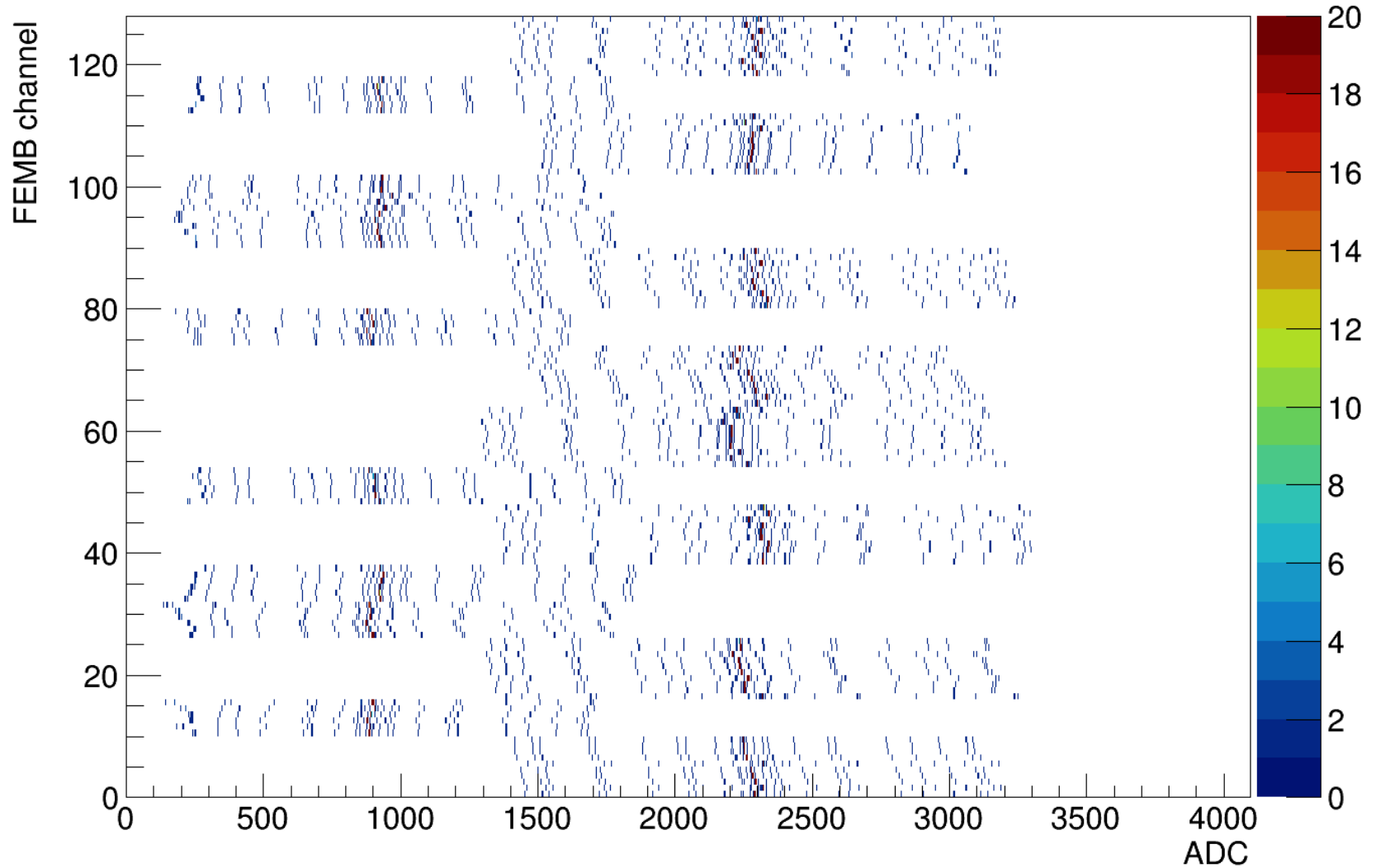
DAC=5

Illumination for run 3289



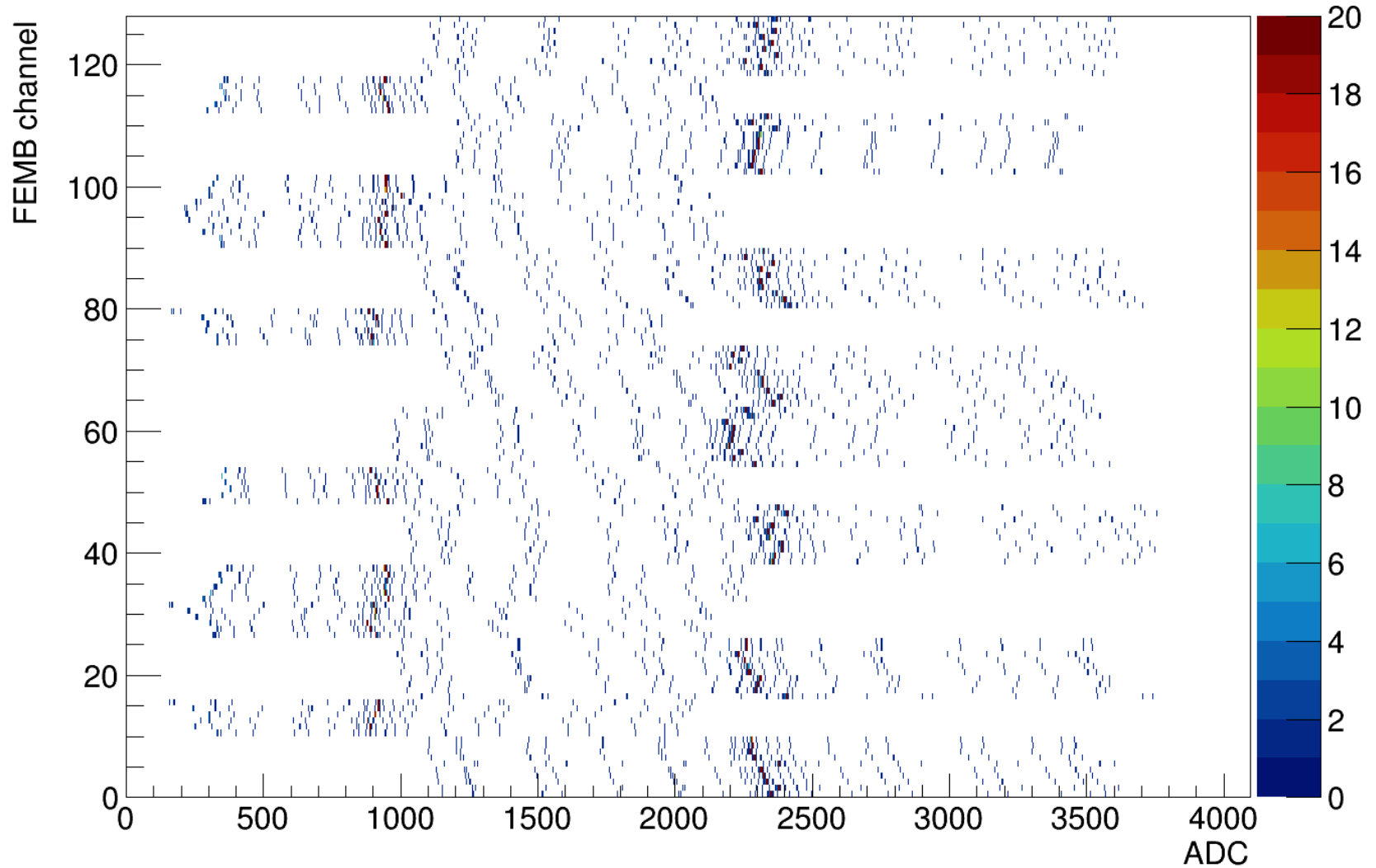
DAC=6

Illumination for run 3256



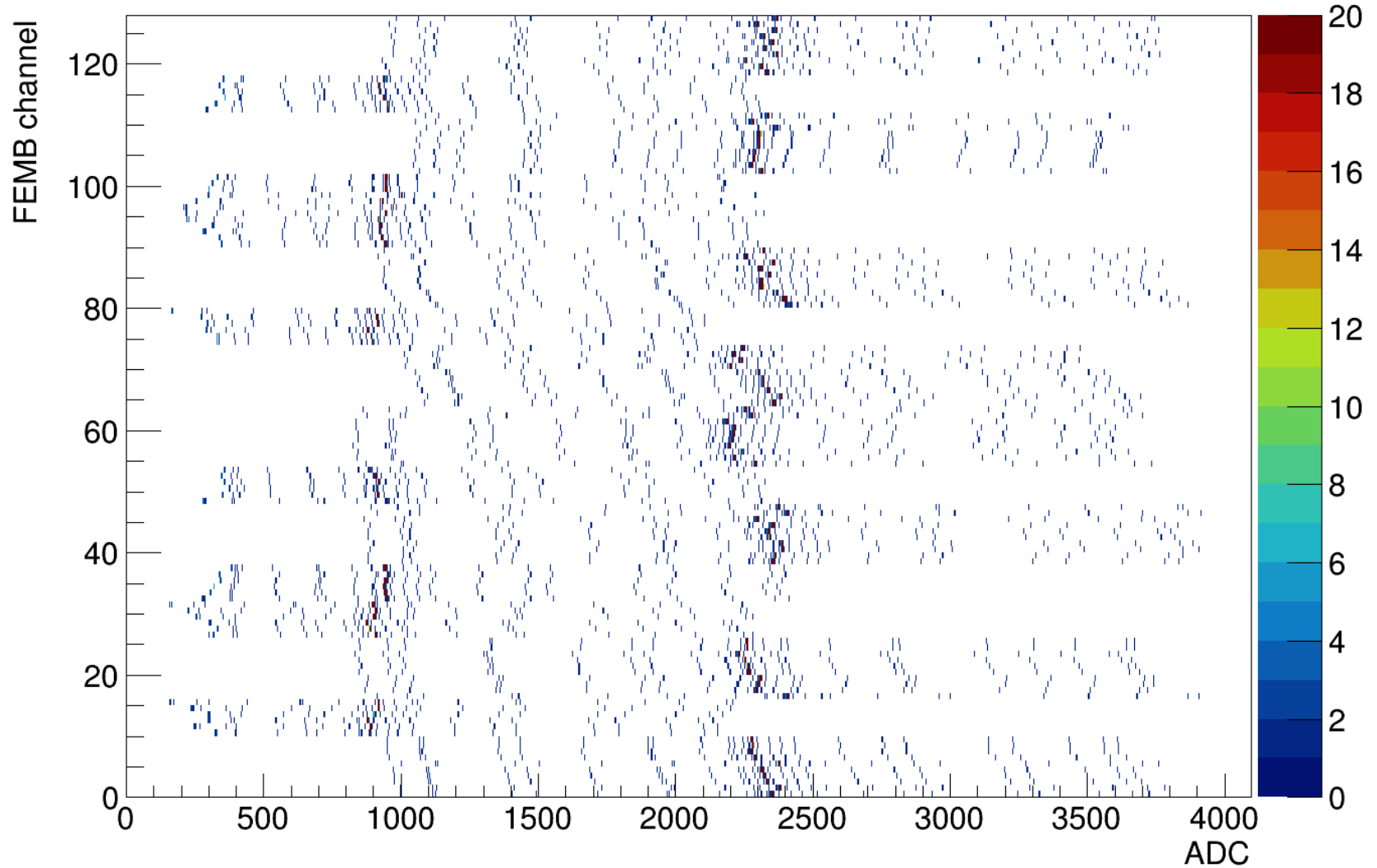
DAC=8

Illumination for run 3435



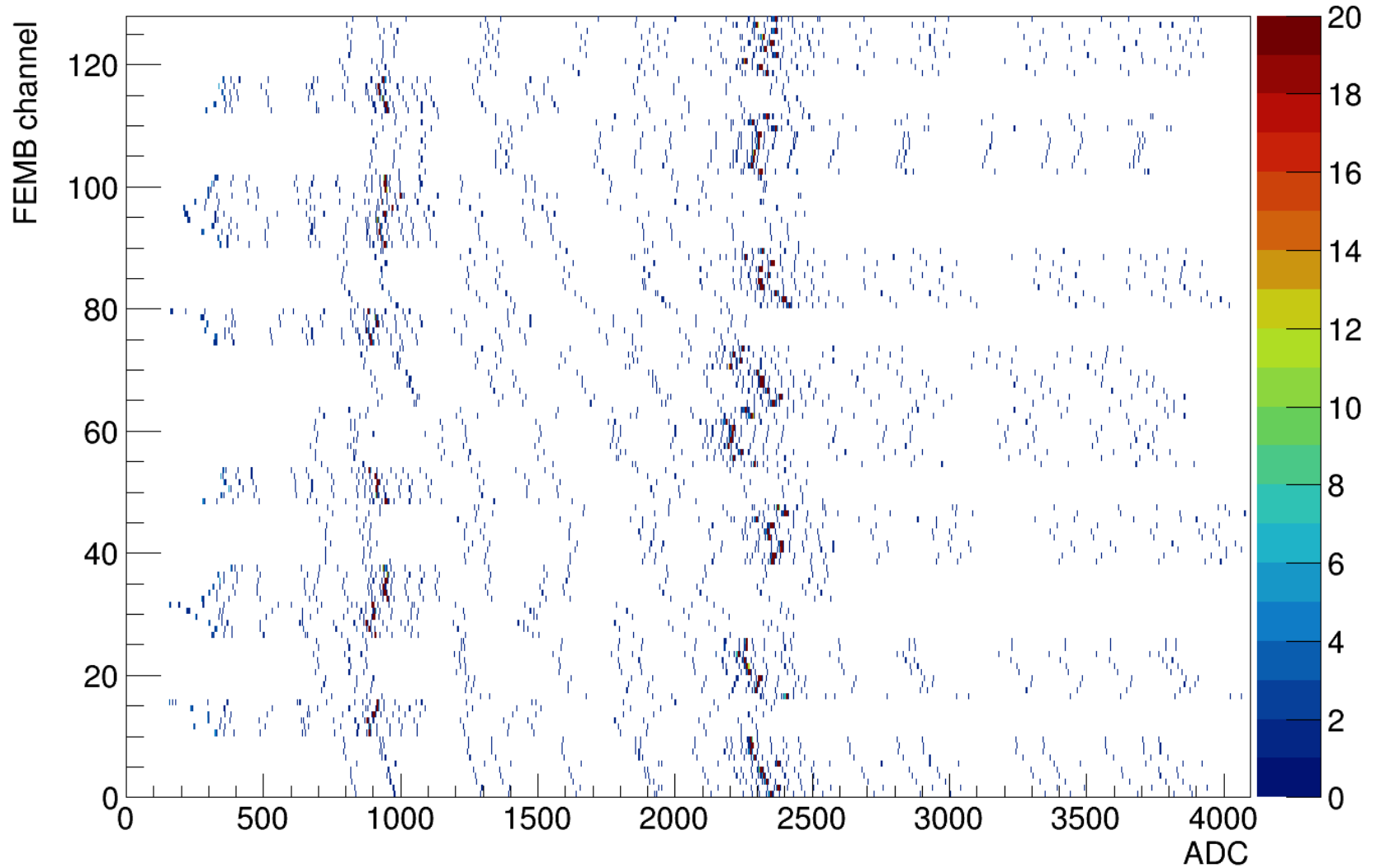
DAC=9

Illumination for run 3436



DAC=10

Illumination for run 3438



DAC 4-6, 8-10

Illumination for Aug 10-17

