APA 7 analysis

BNL DUNE

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Introduction

Data taken with APA 7 in the coldbox

- New APA with electronics (for now) like those used in protoDUNE
- Data taken both cold (306 K) and cold (164 K)
- Data taken Oct 23 – Nov 13, 2019
- For run details, see log summary:
  - https://docs.google.com/spreadsheets/d/1QOdzk1xNTc7-KXrpiMoUMLn1dNTxSLOGaX4eHR7c6DA/edit#gid=0

More plots

- Event displays, DFT power and more:
  - https://internal.dunescience.org/people/dladams/protodune/data/coldbox
- Calibration results:
  - https://internal.dunescience.org/people/dladams/protodune/calibrations

Geometry

Each APA has four wire planes

- Two induction planes with wrapped wires
  - Outer u plane: channels 0-799
  - Inner v plane: channels 800-1599
- One collection plane on each side. For beam right and APA7:
  - Cryostat side c plane: channels 1600-2079
  - Drift side z plane: channels 2080-2559

ProtoDUNE geometry and cabling is described here:

- https://wiki.dunescience.org/wiki/ProtoDUNE_geometry
- APA 7 c/z naming is as if it were installed beam right
- Use dunetpc command to get channel numbers for a FEMB, e.g.
  - pdChannelRange –d apa7 CR
  - where CR = apa7, femb703x, femb703u14, …

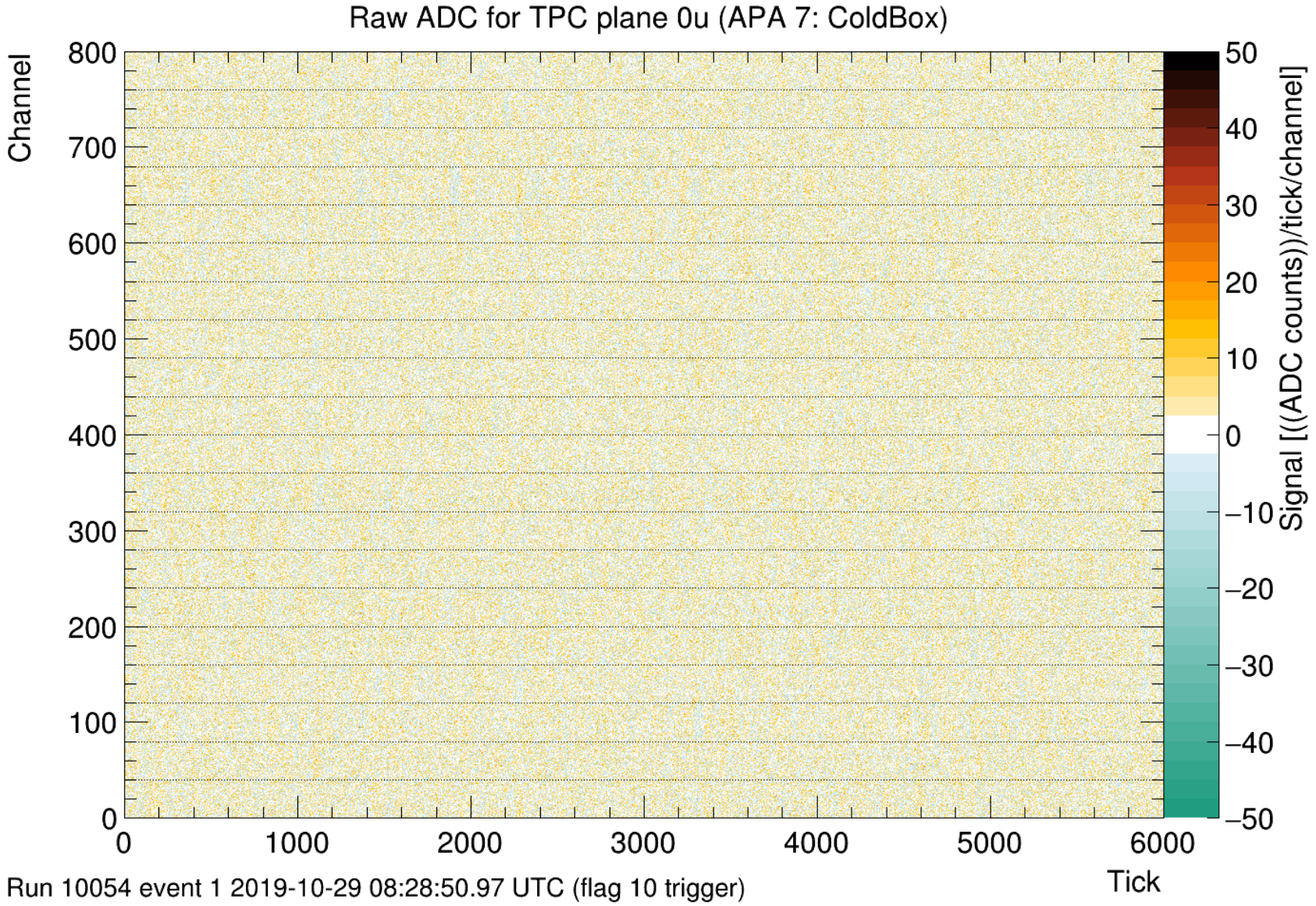
Some of the runs analyzed

Runs of interest:

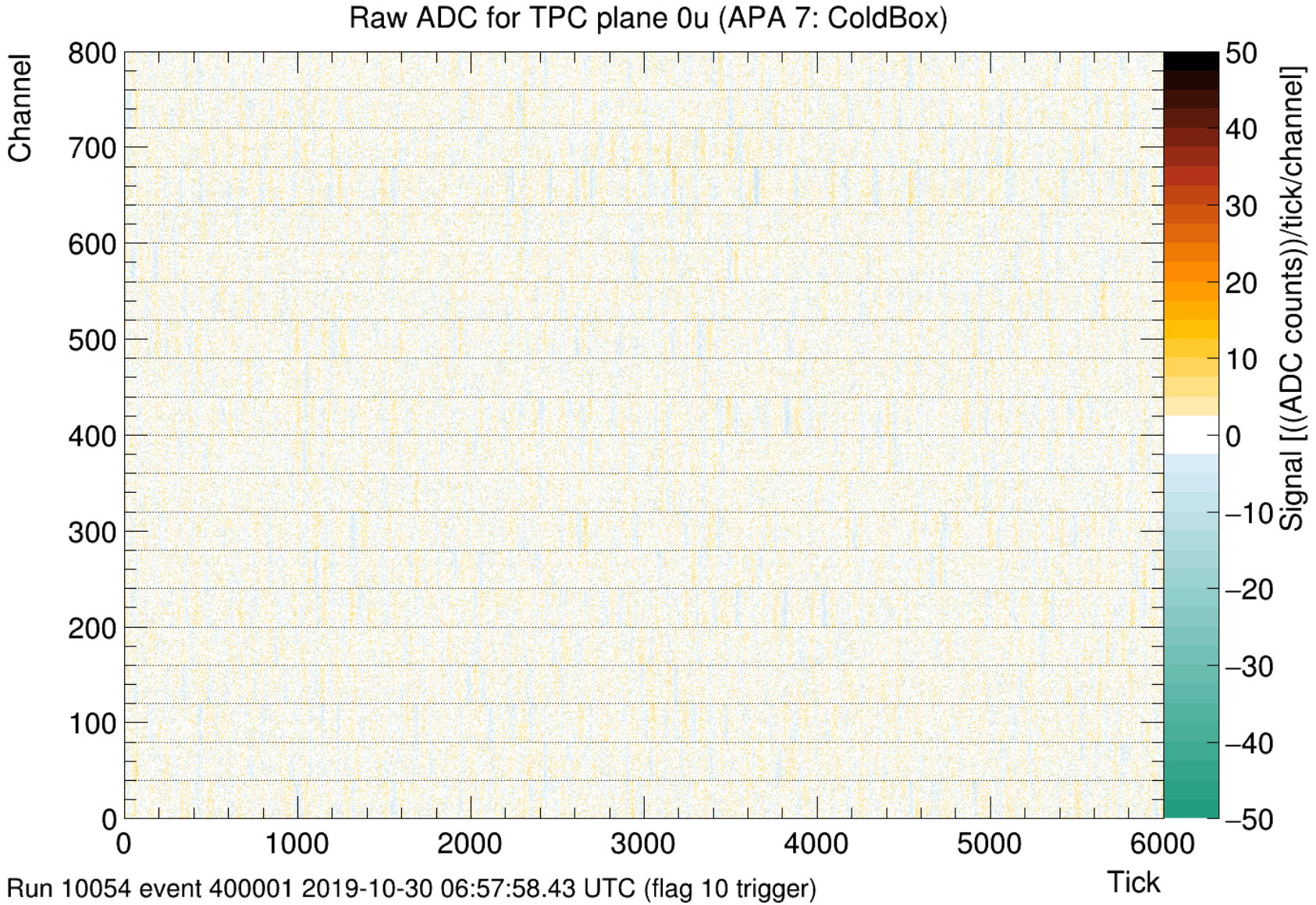
Run	Temp	Bias	Window (ms)
9914	warm	off	3
10054	warm->cold	off	3
10130	cold	off	3
10158	cold	on	3
10180	cold	on	100
10256	cold	half	100
10289	cold	low	100
10290	cold	low	100

Event displays

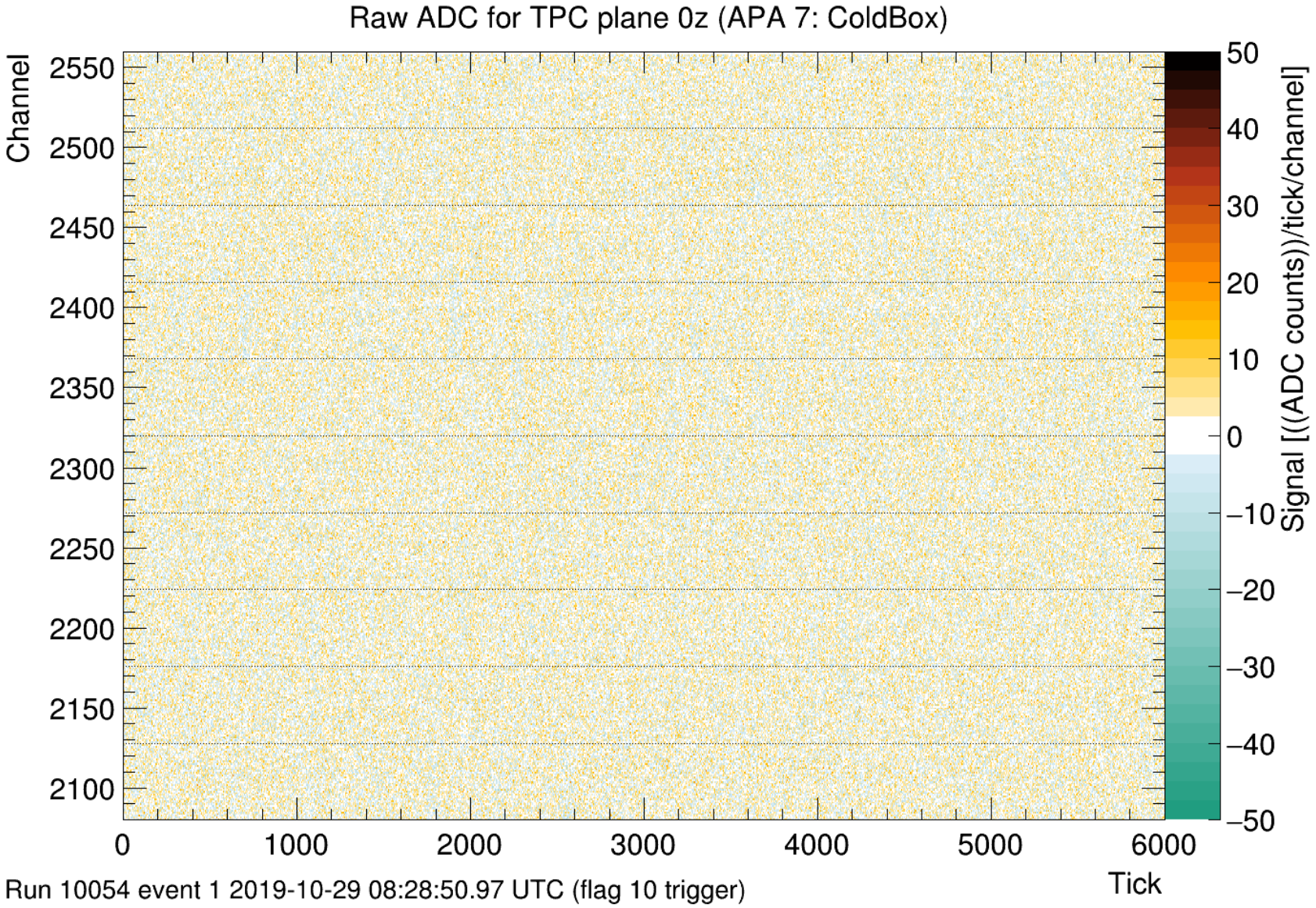
APA 7u warm


Raw ADC for TPC plane 0u (APA 7: ColdBox)
Channel
800
700
600
500
400
300
200
100
0
0
1000
2000
3000
4000
5000
6000
Tick
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 10054 event 1 2019-10-29 08:28:50.97 UTC (flag 10 trigger)

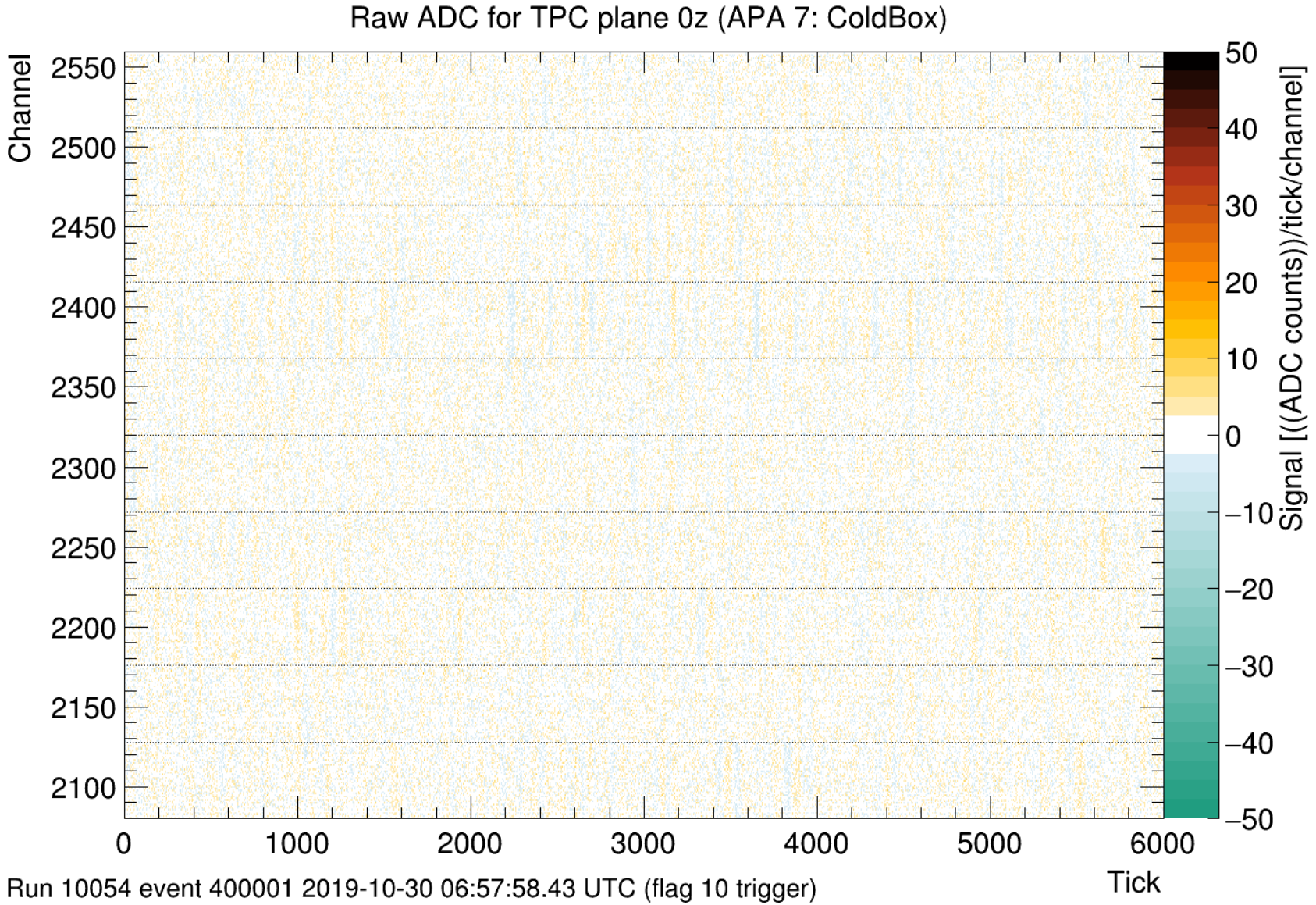
APA 7u cold


Raw ADC for TPC plane 0u (APA 7: ColdBox)
Channel
800
700
600
500
400
300
200
100
0
0
1000
2000
3000
4000
5000
6000
Tick
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 10054 event 400001 2019-10-30 06:57:58.43 UTC (flag 10 trigger)

APA 7z warm


Raw ADC for TPC plane 0z (APA 7: ColdBox)
Channel
2550
2500
2450
2400
2350
2300
2250
2200
2150
2100
0
1000
2000
3000
4000
5000
6000
Tick
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 10054 event 1 2019-10-29 08:28:50.97 UTC (flag 10 trigger)

APA 7z cold


Raw ADC for TPC plane 0z (APA 7: ColdBox)
Channel
2550
2500
2450
2400
2350
2300
2250
2200
2150
2100
0
1000
2000
3000
4000
5000
6000
Tick
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 10054 event 400001 2019-10-30 06:57:58.43 UTC (flag 10 trigger)

Bad channels

Bad channels

Broken wire connections

- These are identified by having very low noise
- Warm found channel 2558 as broken
- Later (cold) found also channel 2058

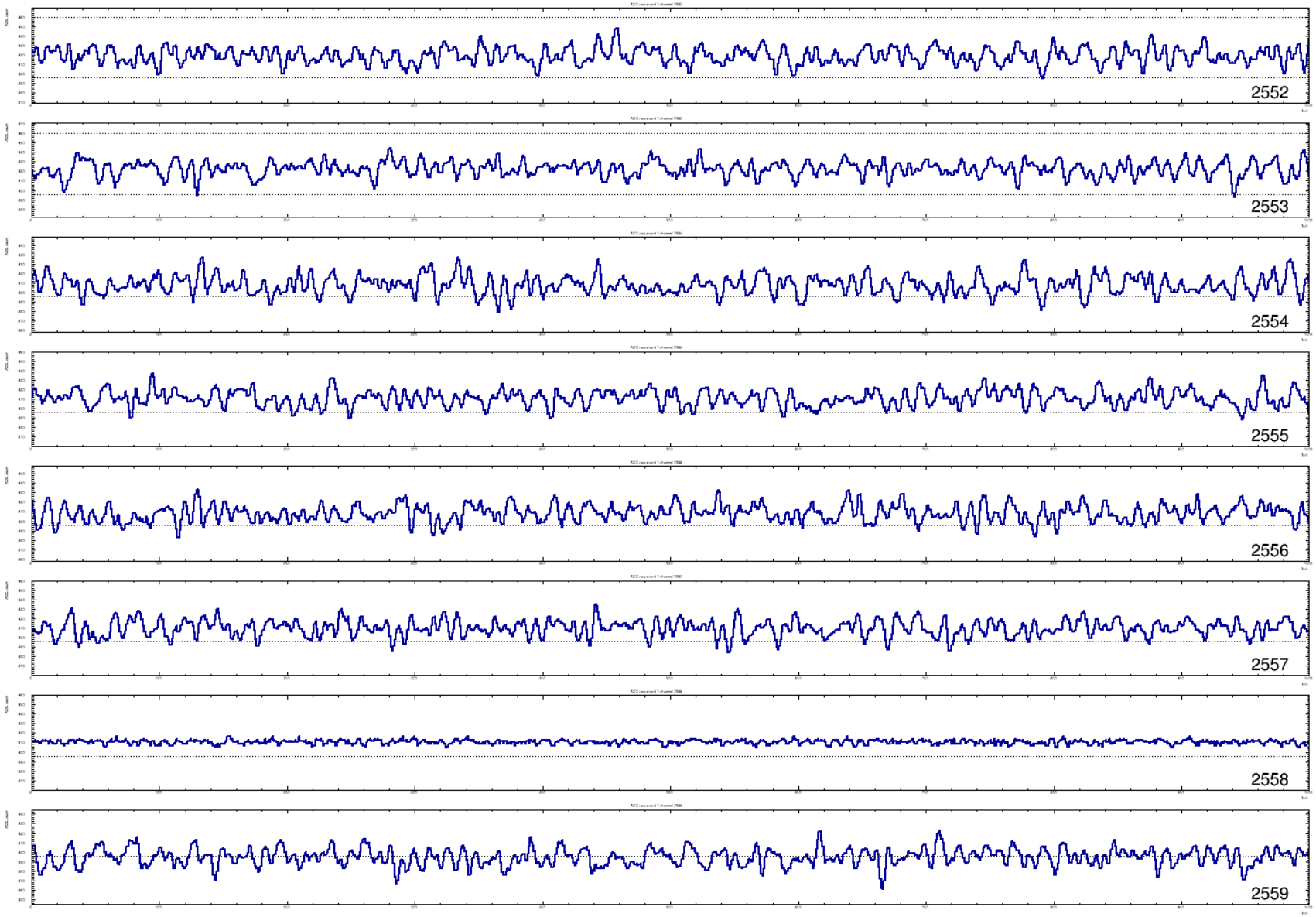
Dropped bits (?)

- Warm found a few channels where much or all of the signal appeared below 300 ADC counts: 1085, 1285, 1325, 1405
- Cold showed problems in different channels: 1050, 1052, (1900, 1902, 1904, 1906, 1908, 1910)

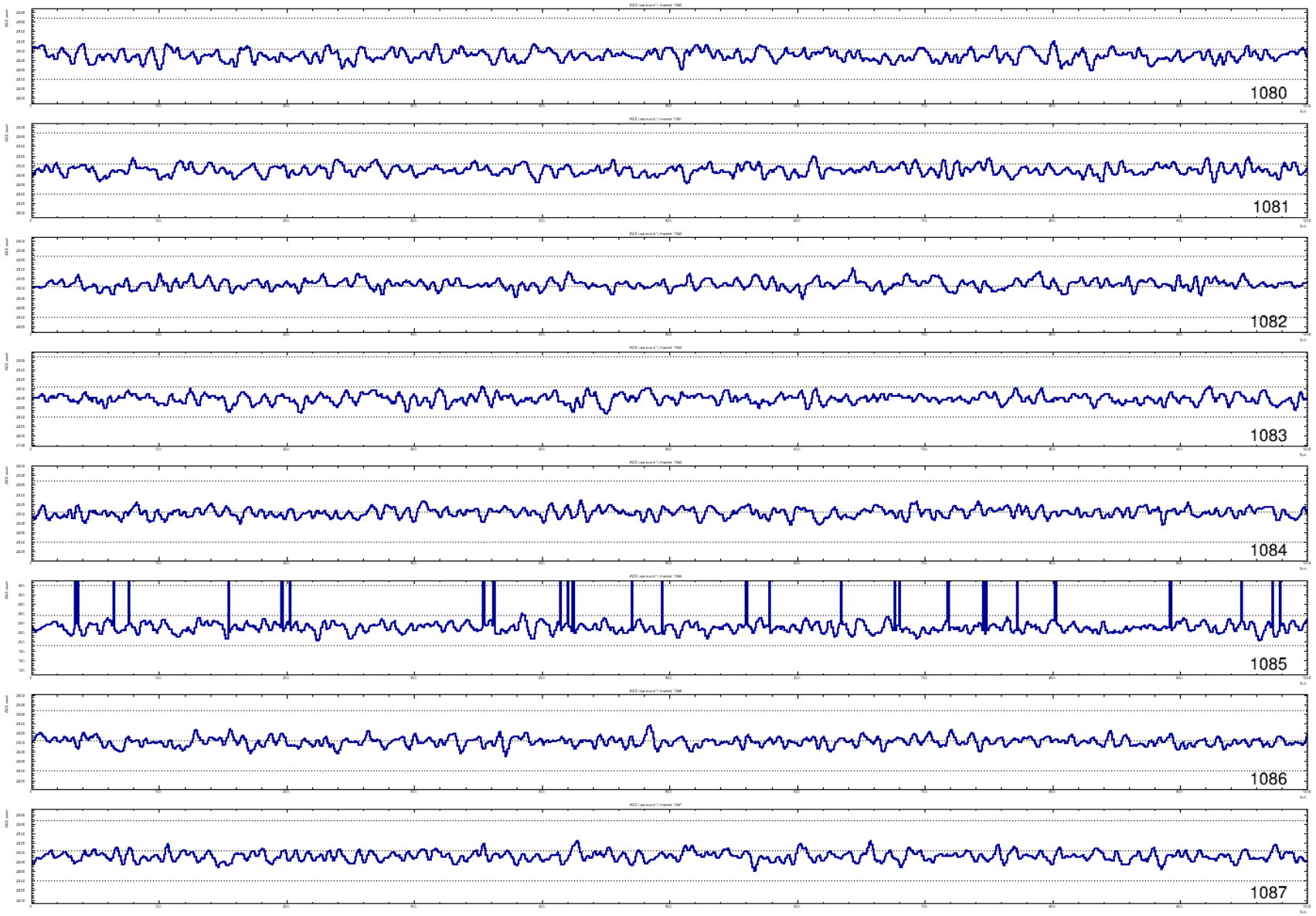
Bad channels are flagged in dunetpc

- In the channel status service
- Separate configurations for warm and cold

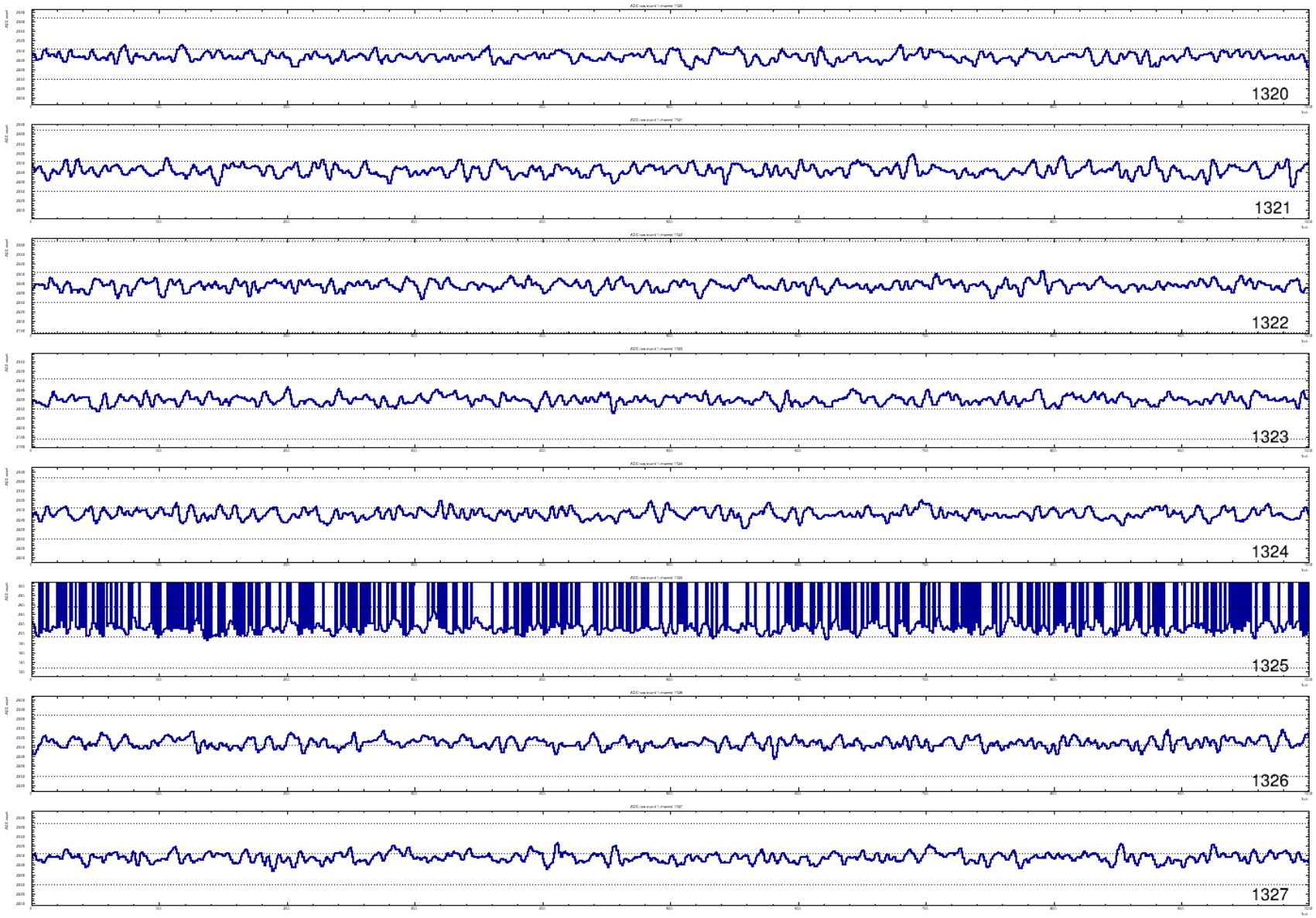
Waveforms for run 9914 (warm)



Warm run 9914



Warm run 9914



Sticky codes

Sticky code search

Looked in pedestal region for sticky codes

- Warm found 147 channels, 10 jumping to the low range
- Cold found 26 channels, one with two sticky codes

Mitigation

- Separate configurations for warm and cold can be used to flag sticky codes
- Mitigation tool can then be used to interpolate over these

DFT power spectra

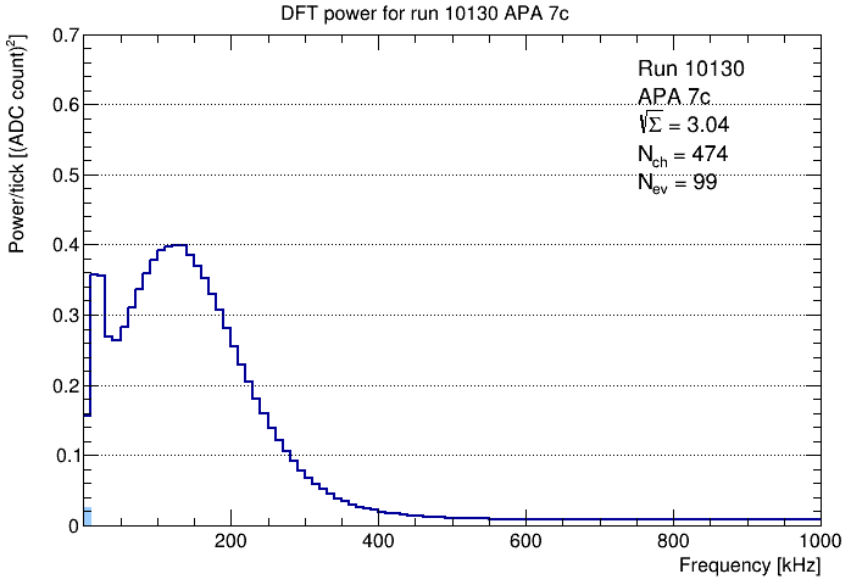
DFT power spectra are obtained

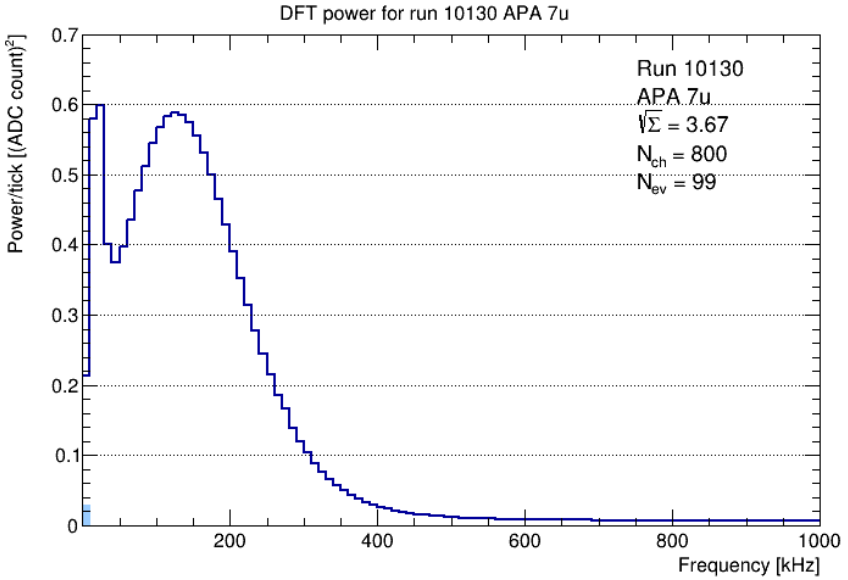
- To see which frequencies contribute to the observed noise
  - As always for DFT, there is aliasing
  - E.g. 200 kHz includes 1.8 MHz, 2.2 MHz, 3.8 MHz, …
- Normalized so sum over all frequencies is equal to the average power per tick in each plane—approximately (4 ADC count)2
- Plots here are an average over approximates 100 events
- Use data with 100 ms readout window
  - Frequency binning is 10 Hz
  - 100k bins in full spectrum
- Histogram binning is typically coarser
  - When rebinned, zero frequency is shown separately (solid bar)

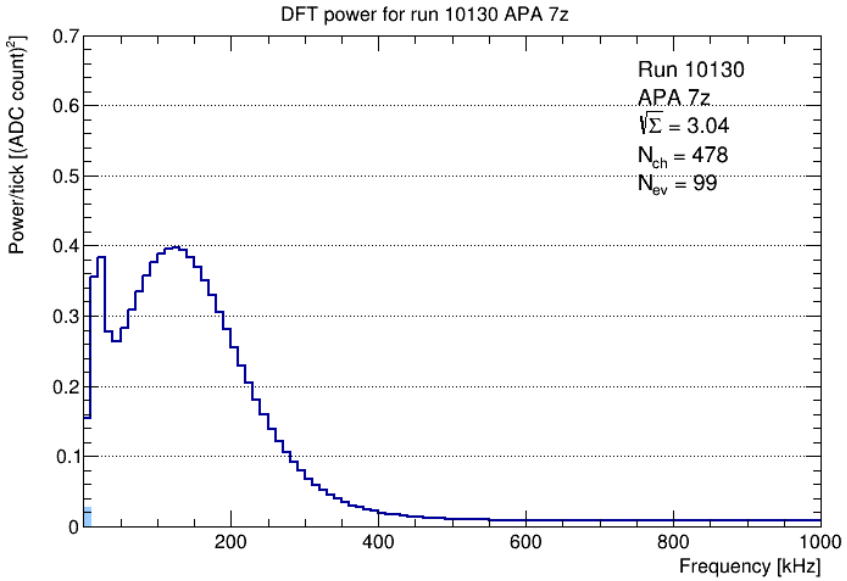
Plots here all start at frequency zero and include

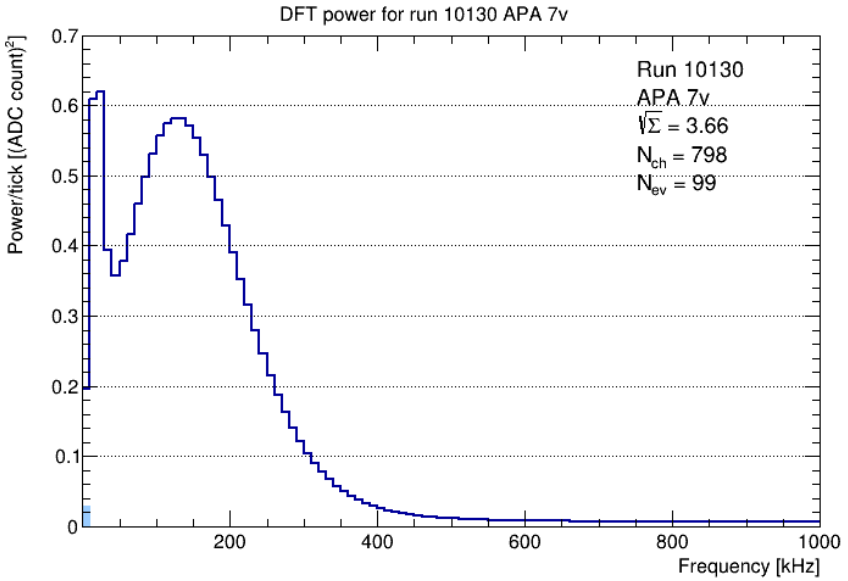
- Full range, I.e. up to 1 MHz with rebinning of 1000
- Up to 100 and 10 kHz with rebinning of 100 and 10
- First 10 kHz with no rebinning
- Plots show for no, (very) low, half and full wire bias

Cold, bias off: full frequency range

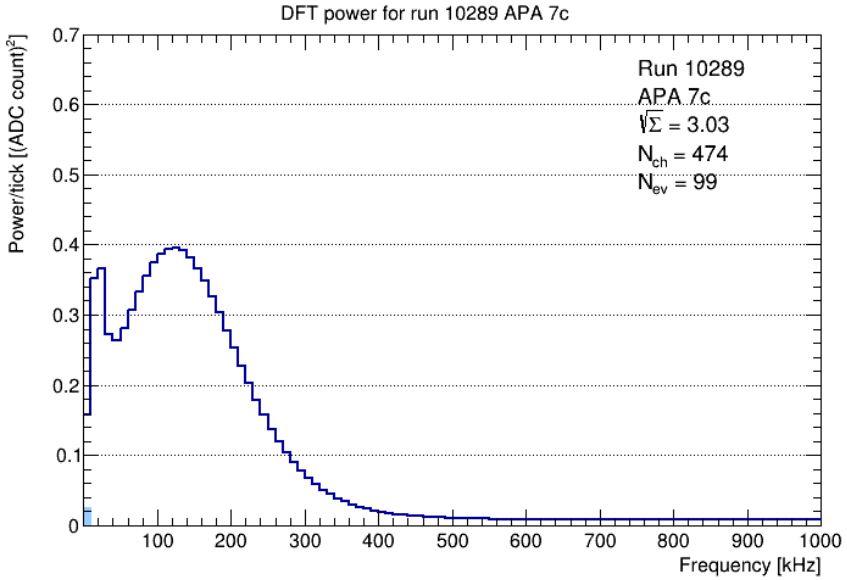


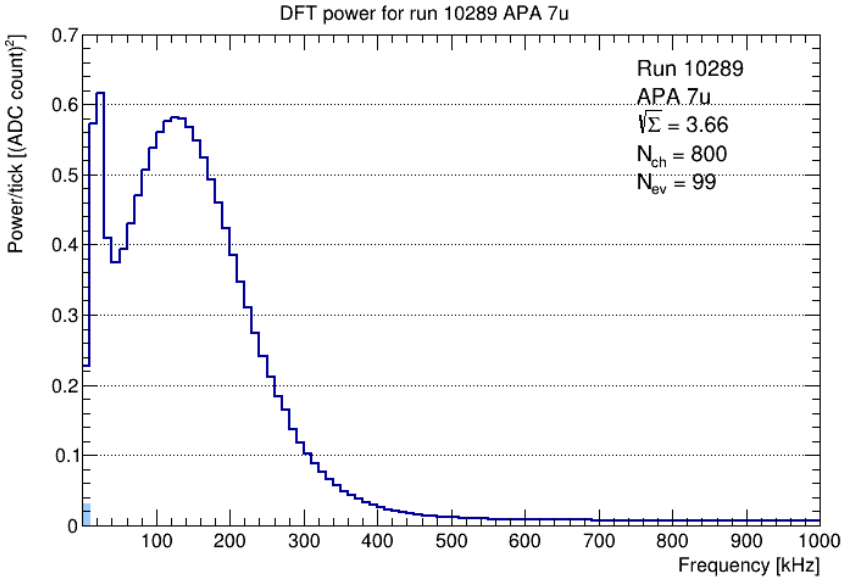


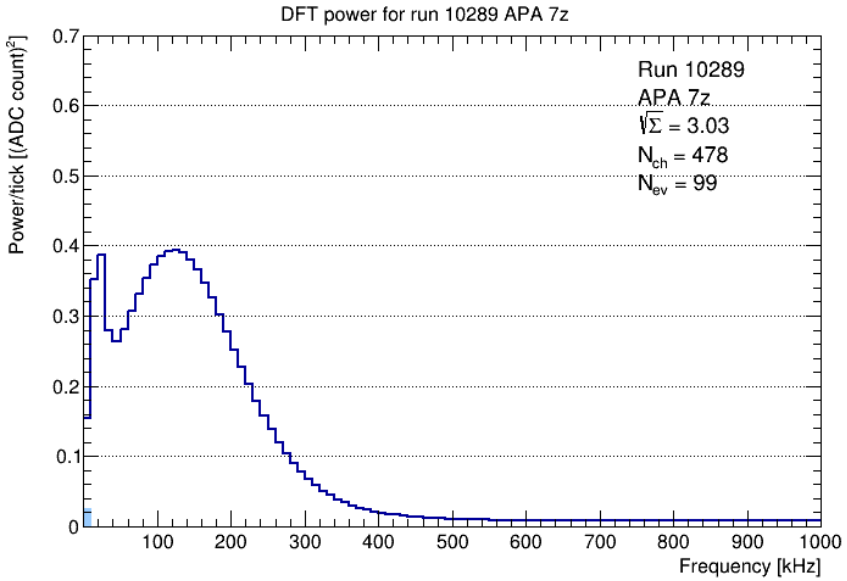


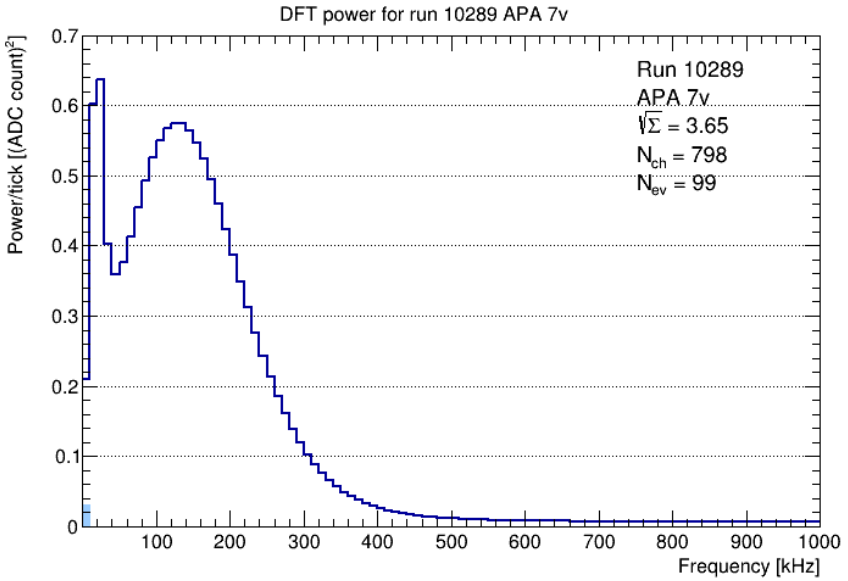


Cold, bias low: full frequency range

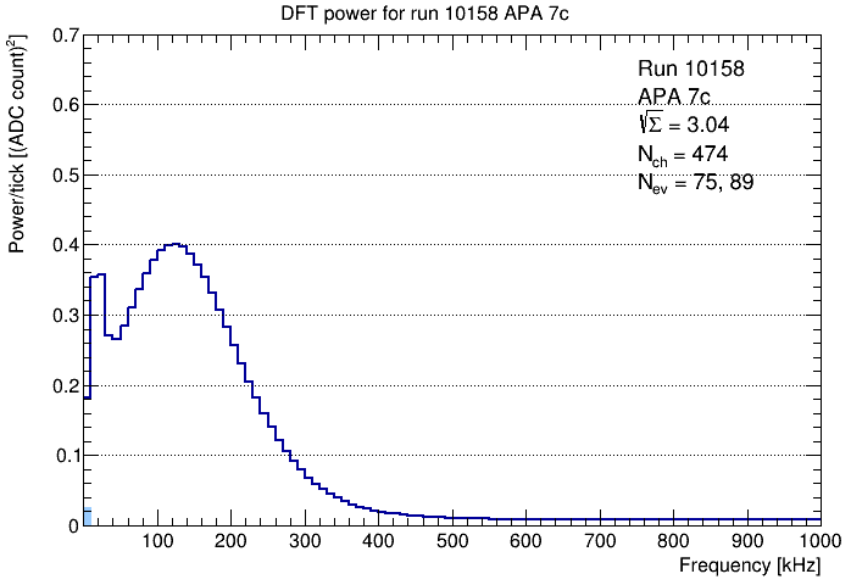


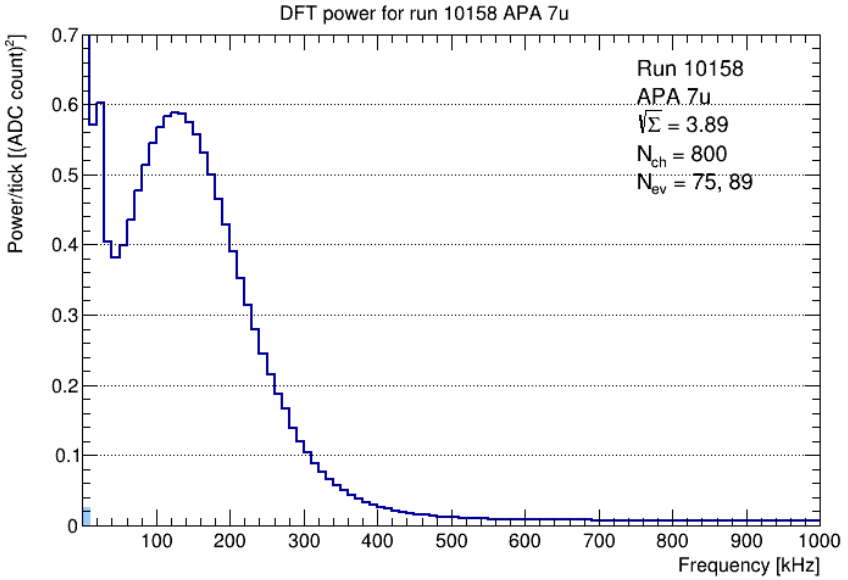


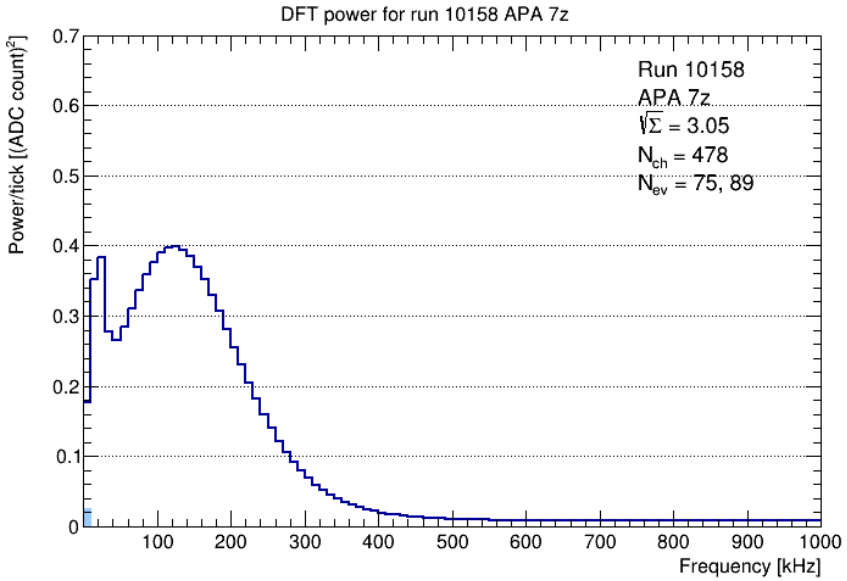


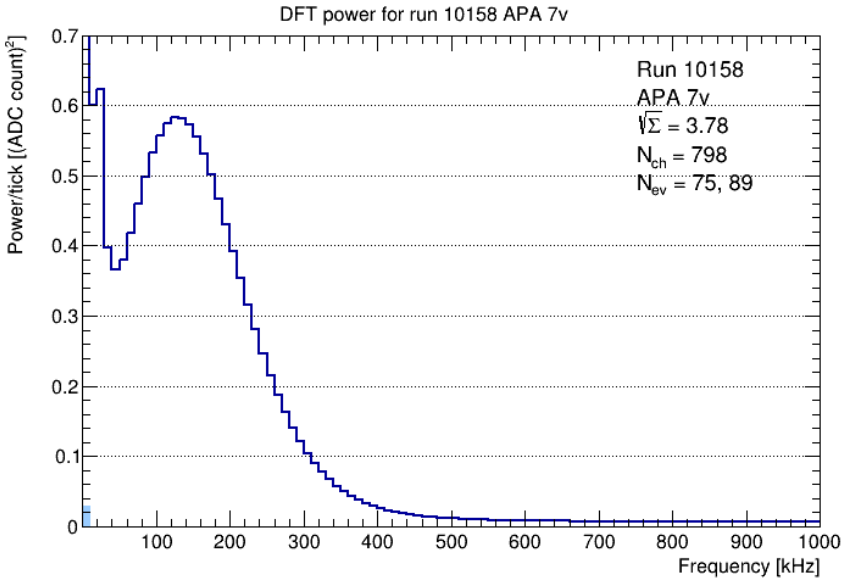


Cold, bias on: full frequency range

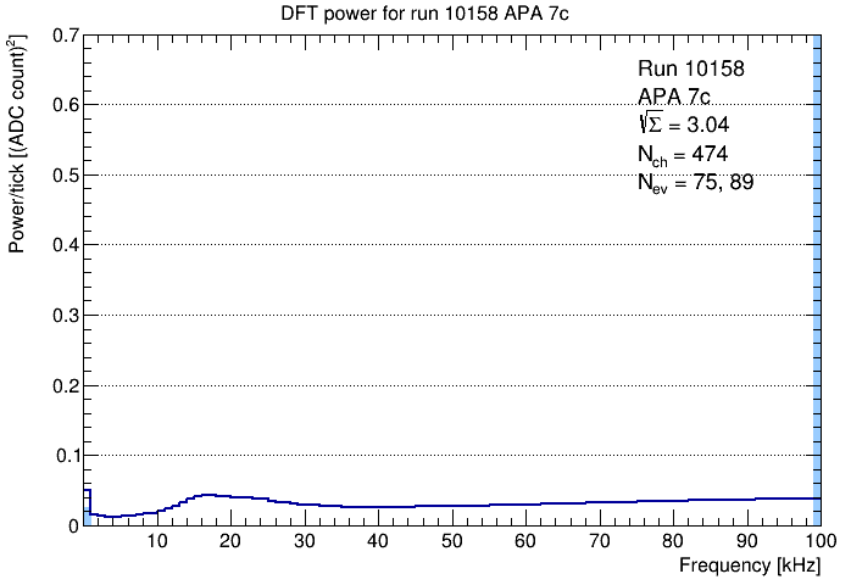


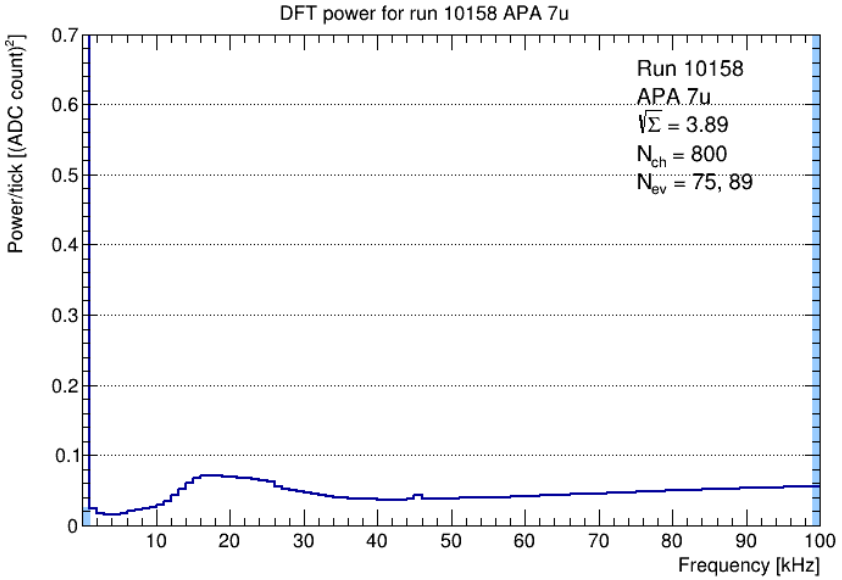


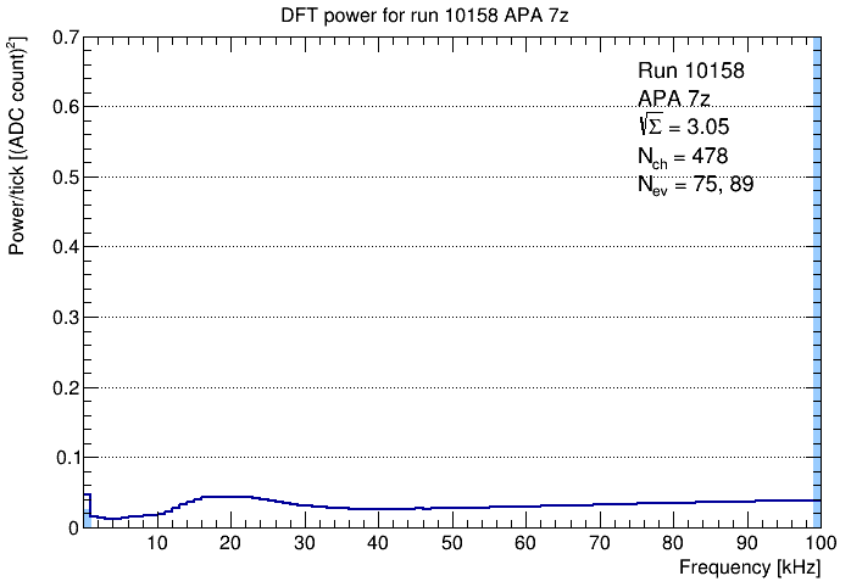


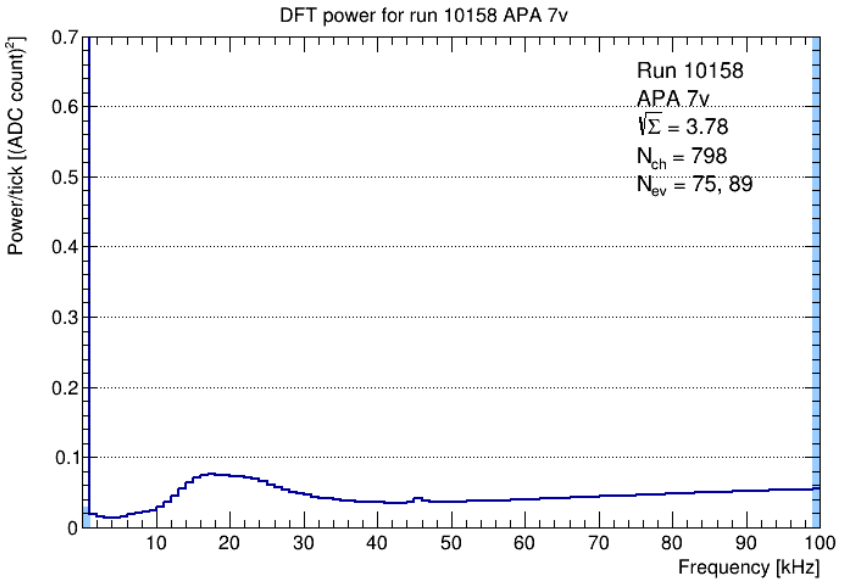


Cold, bias on: (0, 100) kHz

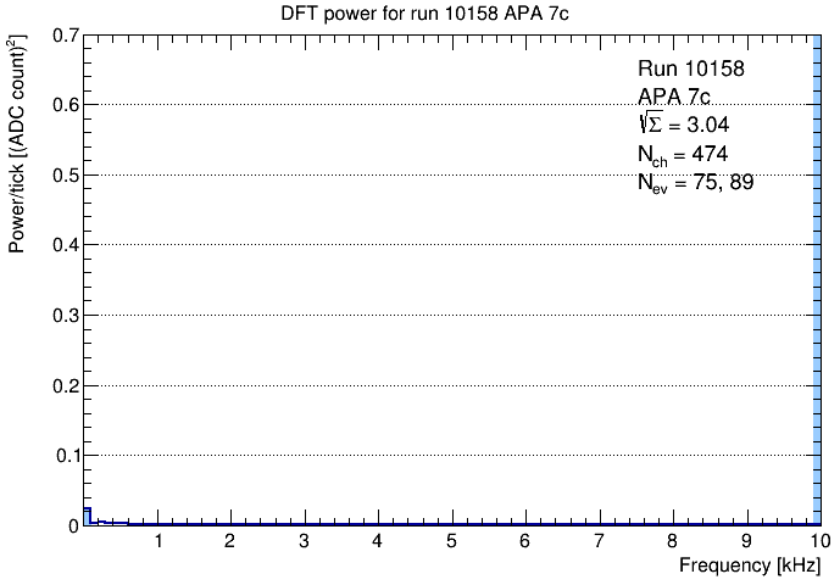


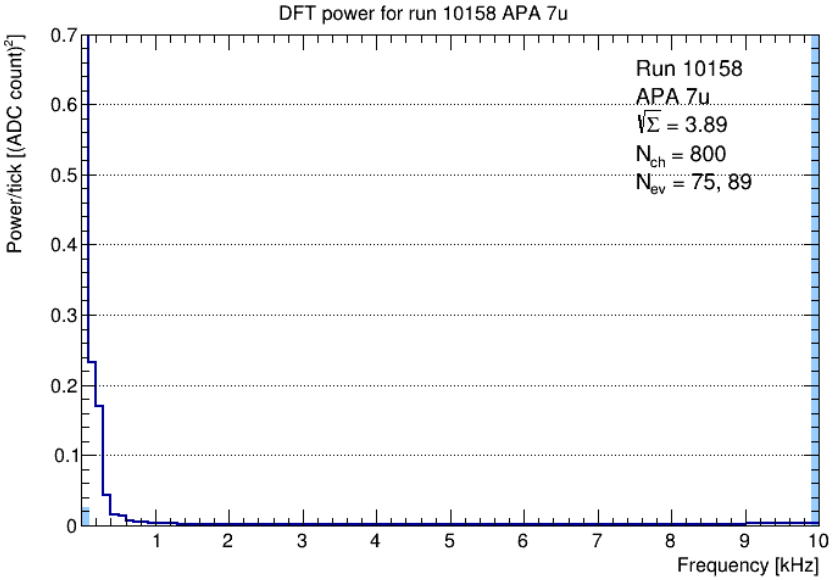


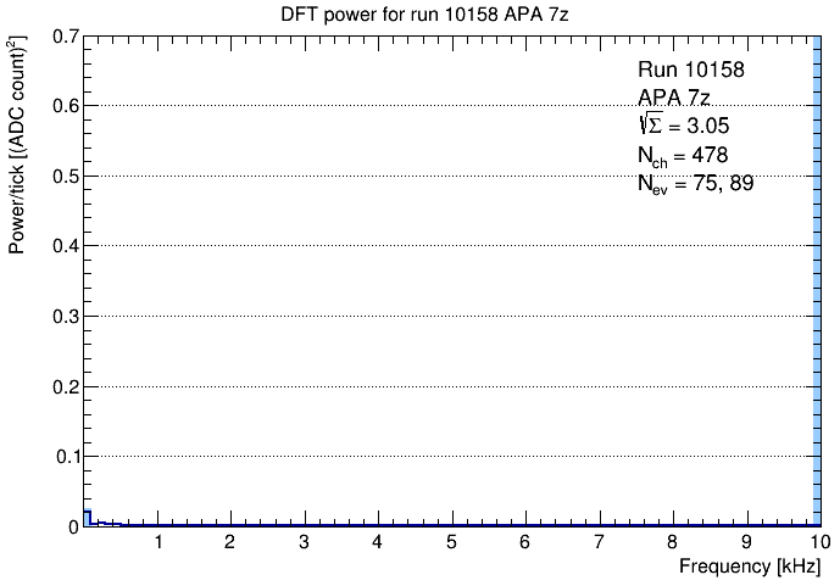


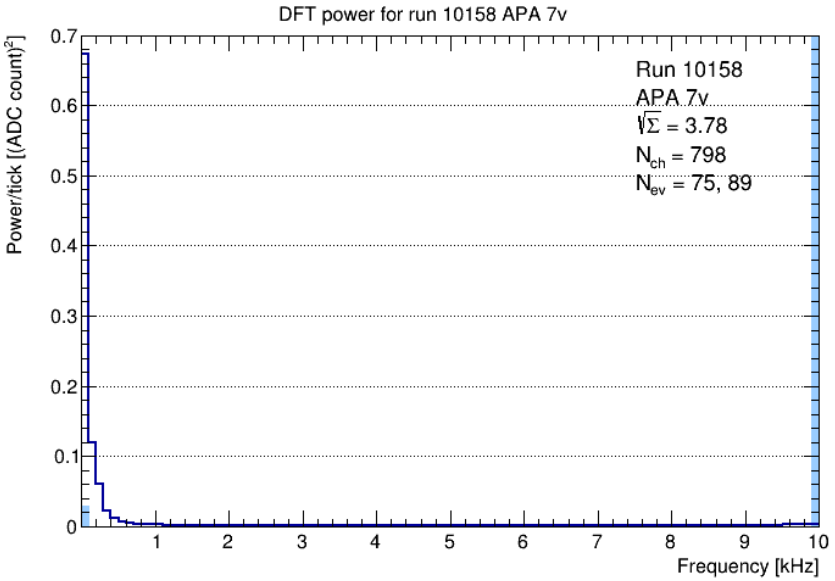


Cold, bias on: (0, 10) kHz

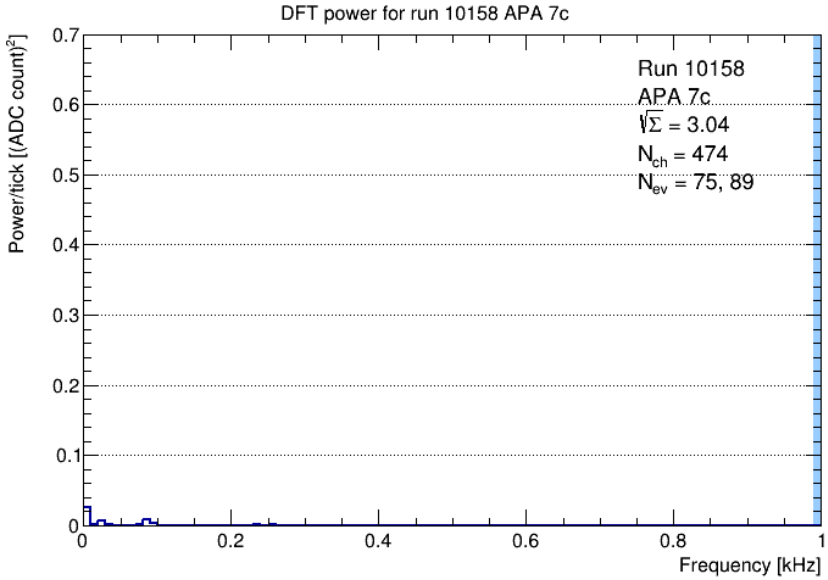


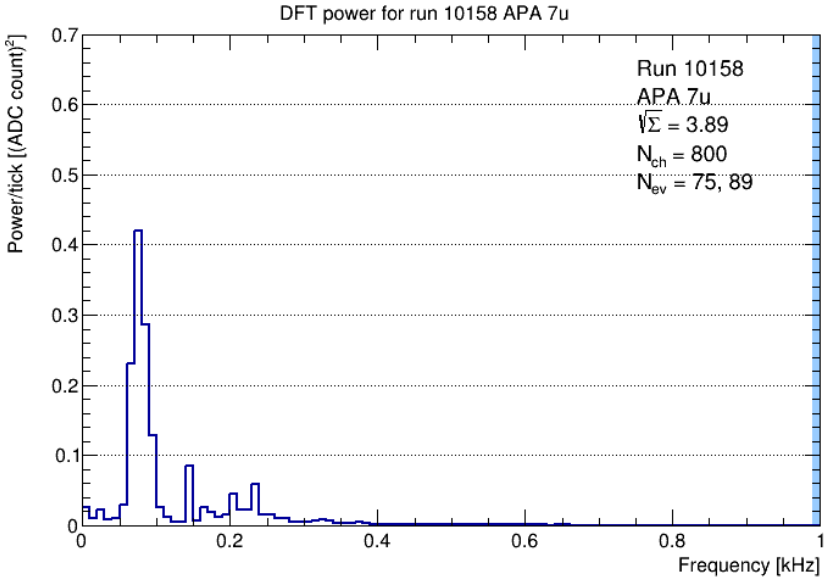


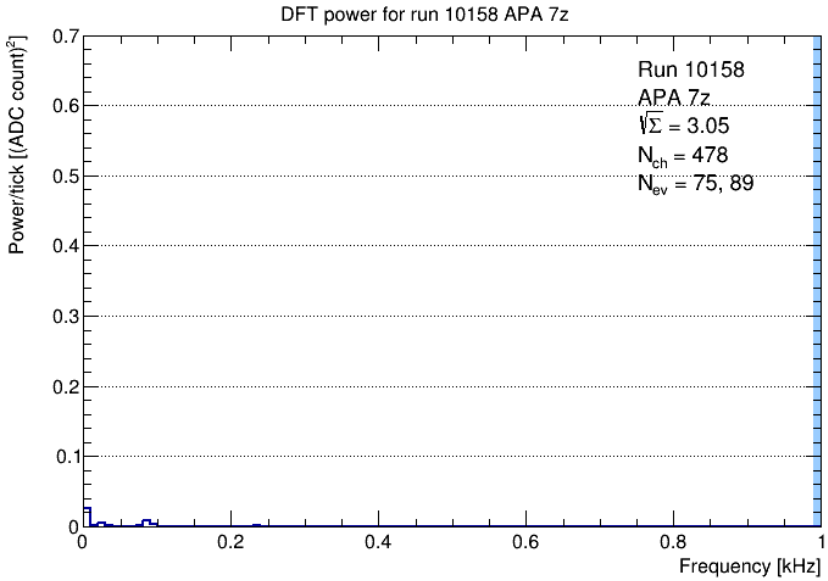


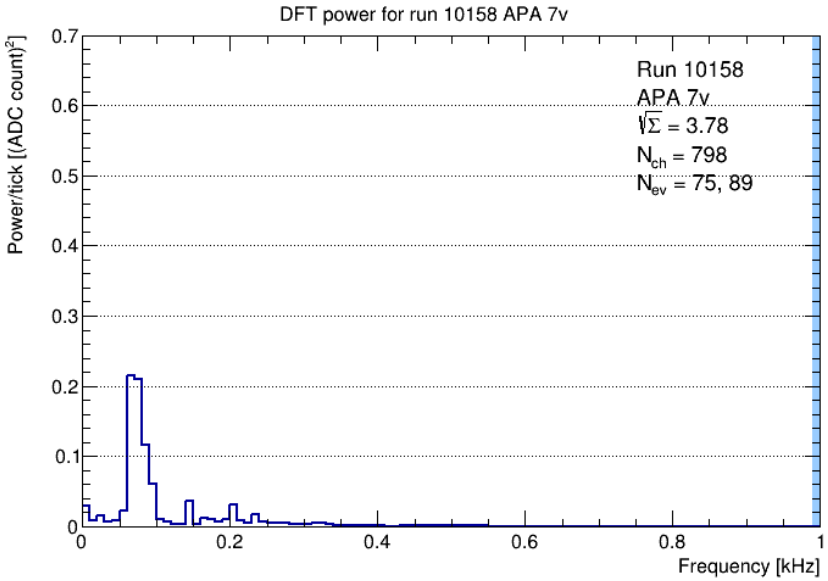


Cold, bias on: (0, 1) kHz

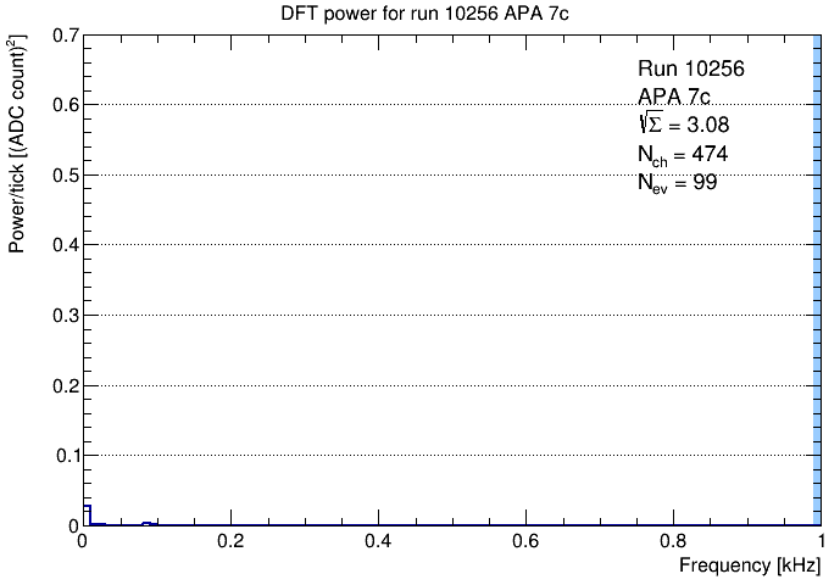


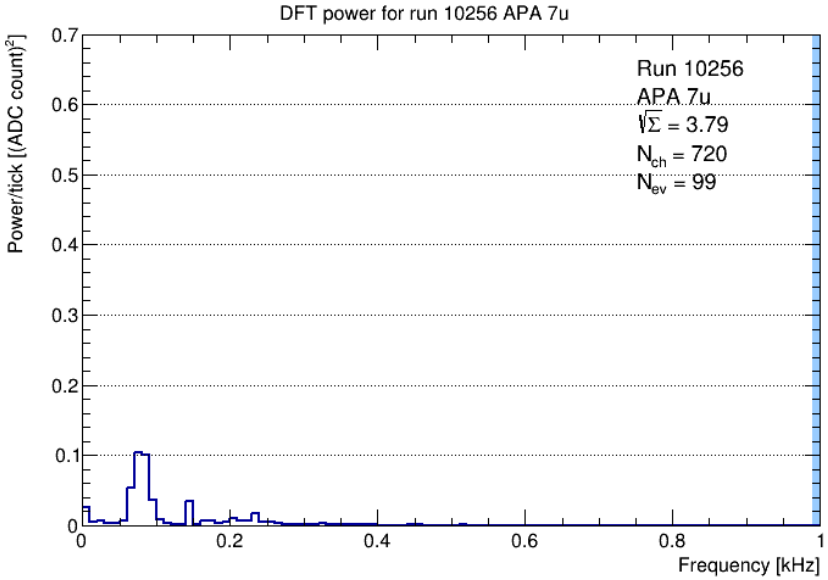


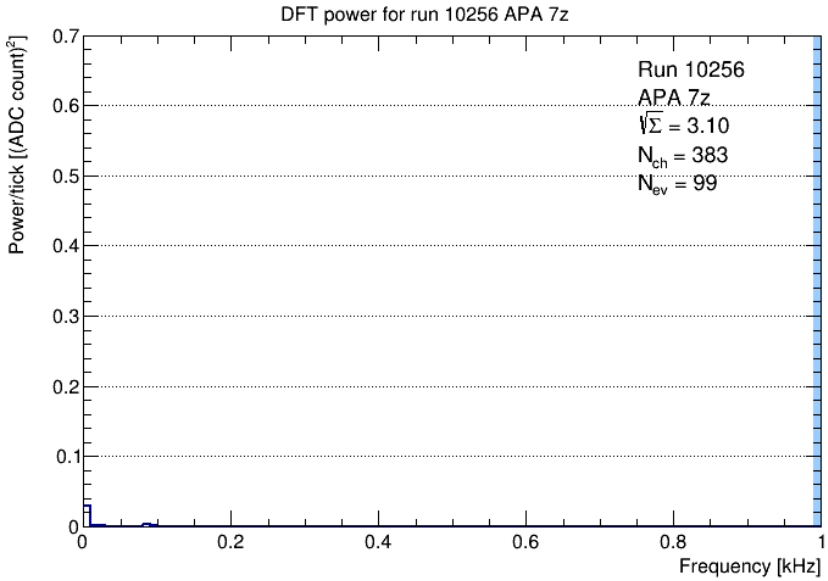


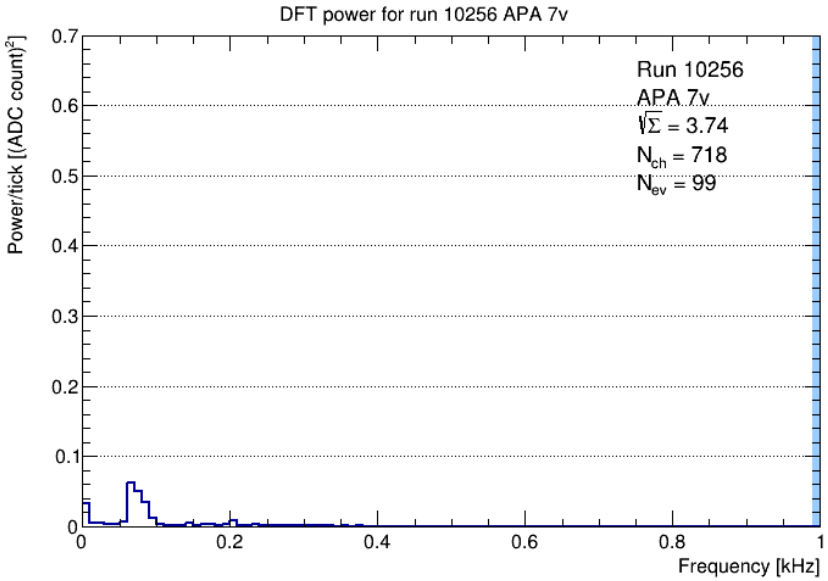


Cold, half bias: (0, 1) kHz

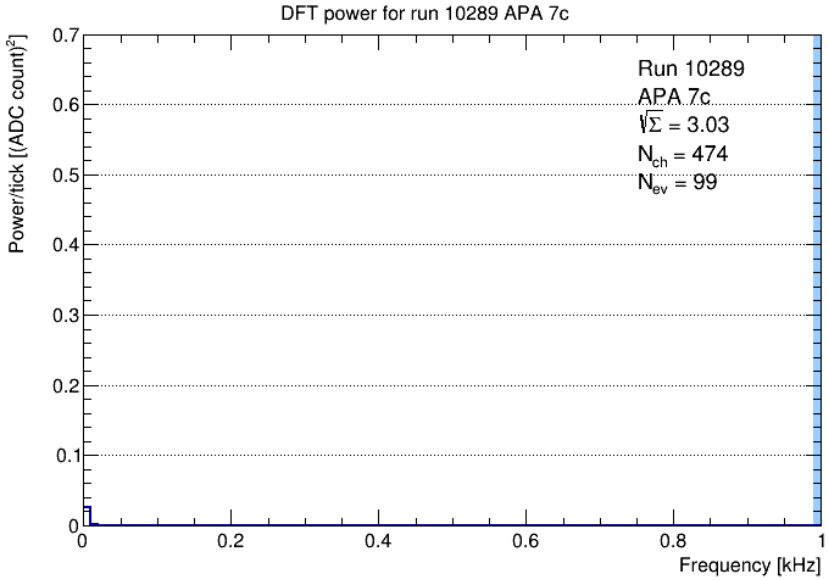


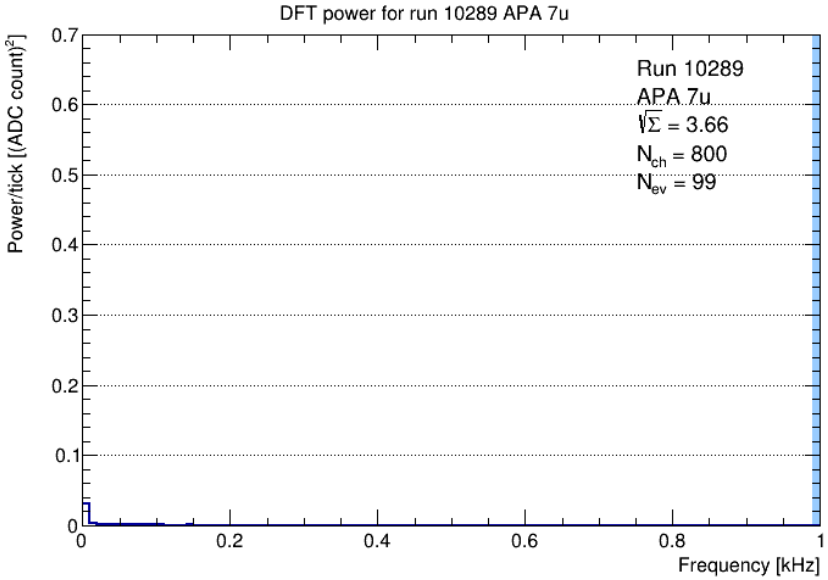


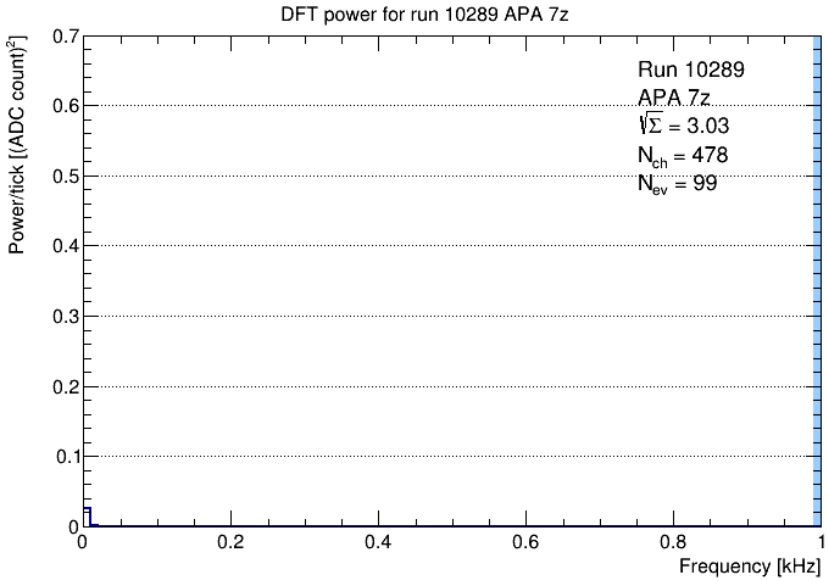


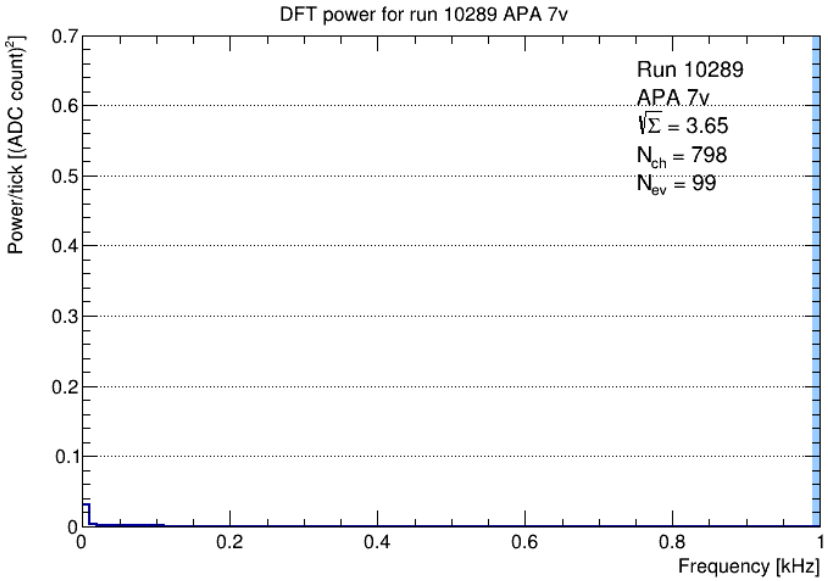


Cold, low bias: (0, 1) kHz

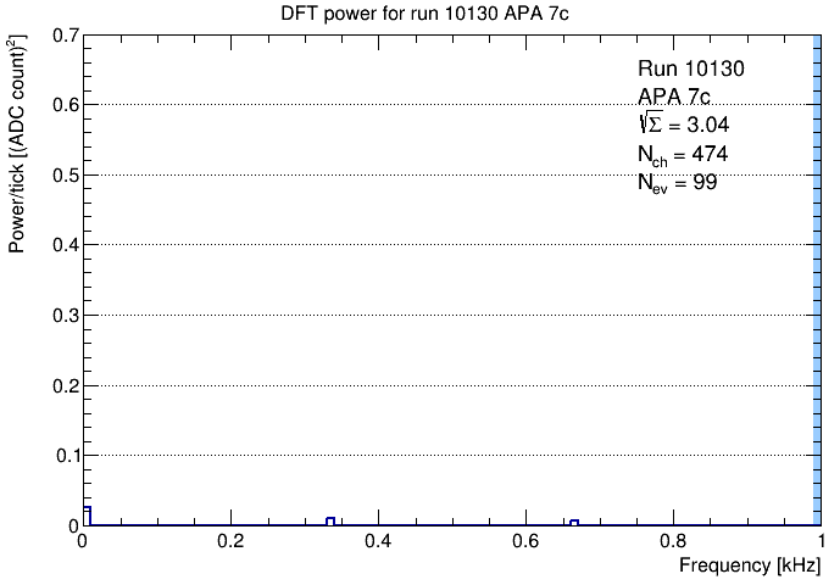


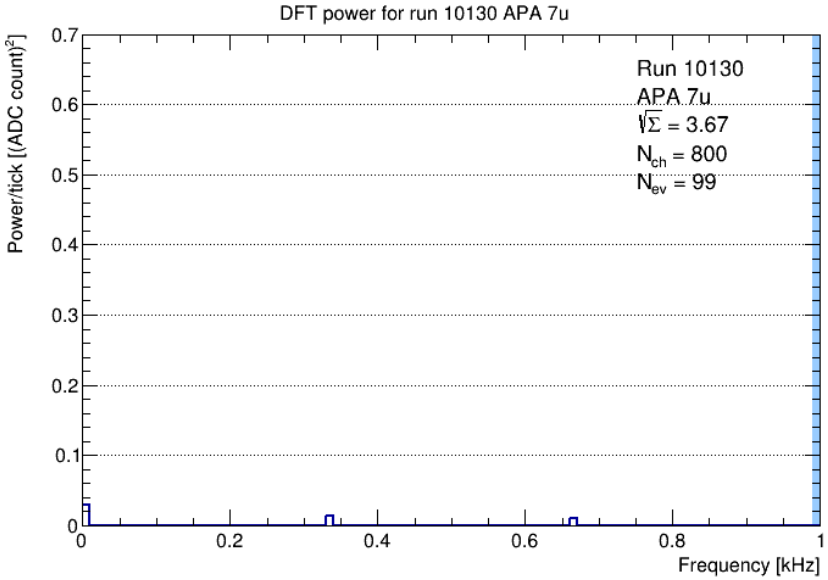


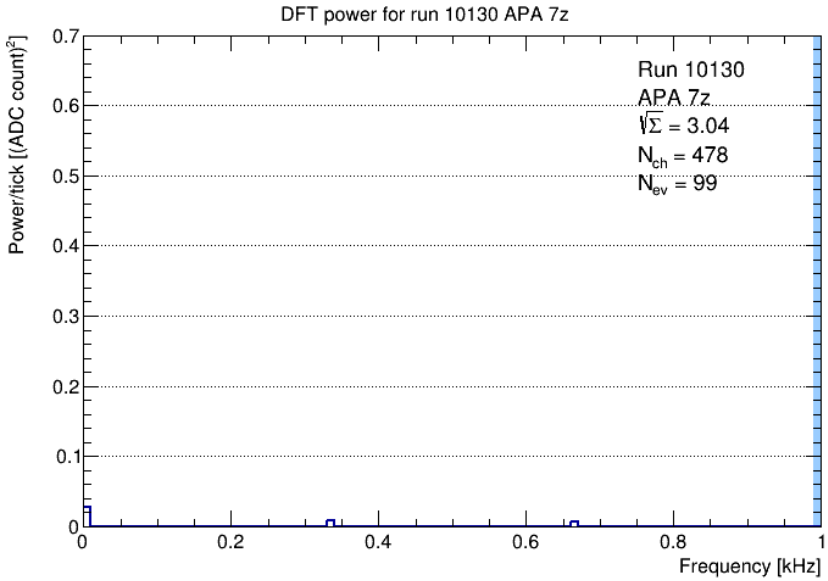


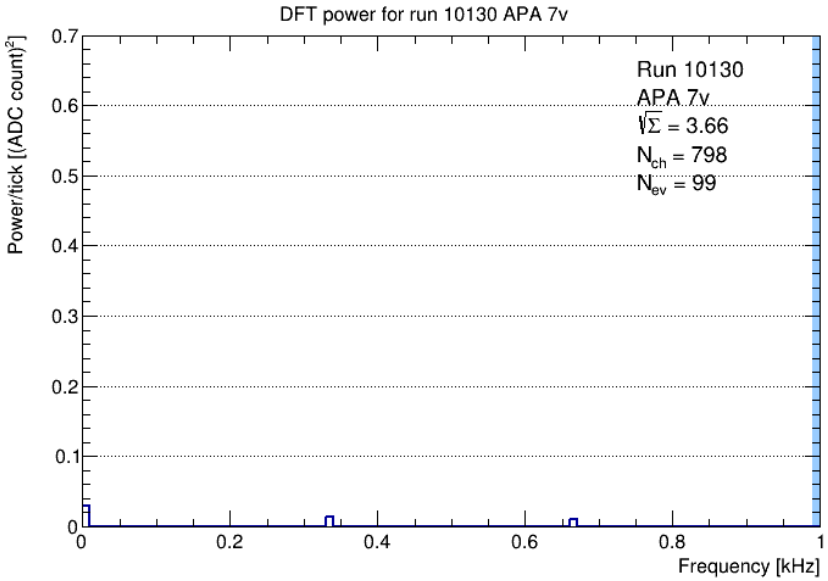


Cold, no bias: (0, 1) kHz









Comments on DFT power

Some features of preceding spectra

- Noise is low: 3.0/3.9 ADC counts for collection/induction
- Most of the power is always in the broad peak centered at 130 kHz
- Second much weaker broad peak at 20 kHz
- With bias on, there is a narrow peak at 70 Hz
  - And other noise up to about 300 Hz
  - Considerable channel to channel variation in this low frequency noise
    - Not shown here—see individual plots, e.g. at
    - https://internal.dunescience.org/people/dladams/protodune/data/coldbox/dft/run010158/event000001-001000/apa7u_001khzNoOffset_lin/plots.html

Charge calibration

Charge calibration

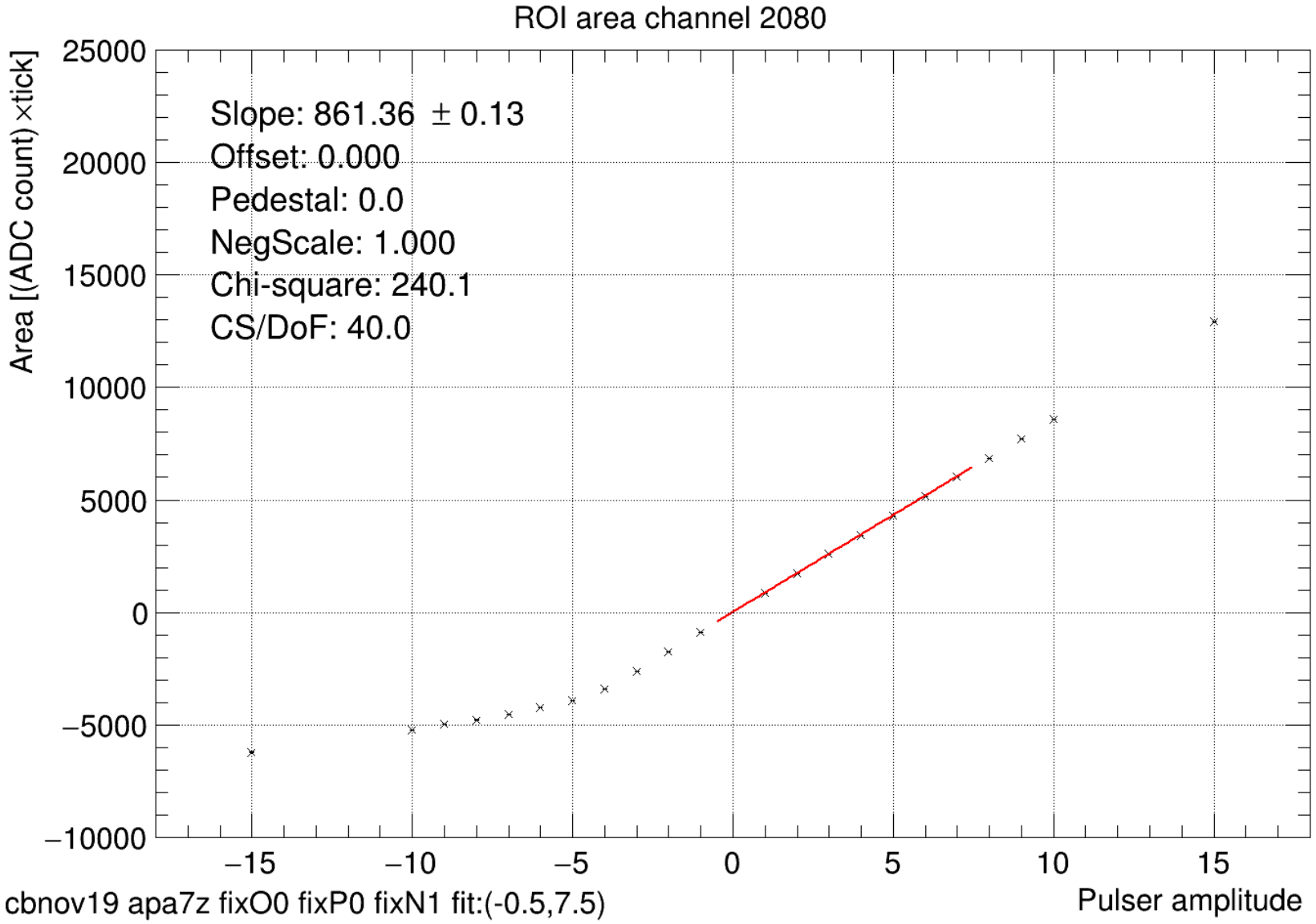
Charge calibration done with CE pulser

- Positive pulses with pulser settings of 1, 2, …, 7 used in calibration
- Step size is about 21.4 ke (about 1 MIP) from circuit
- Procedure described in DUNE-doc-15523
- Note this is an *area* calibration: sum over ticks in a calibrated pulse give the total charge

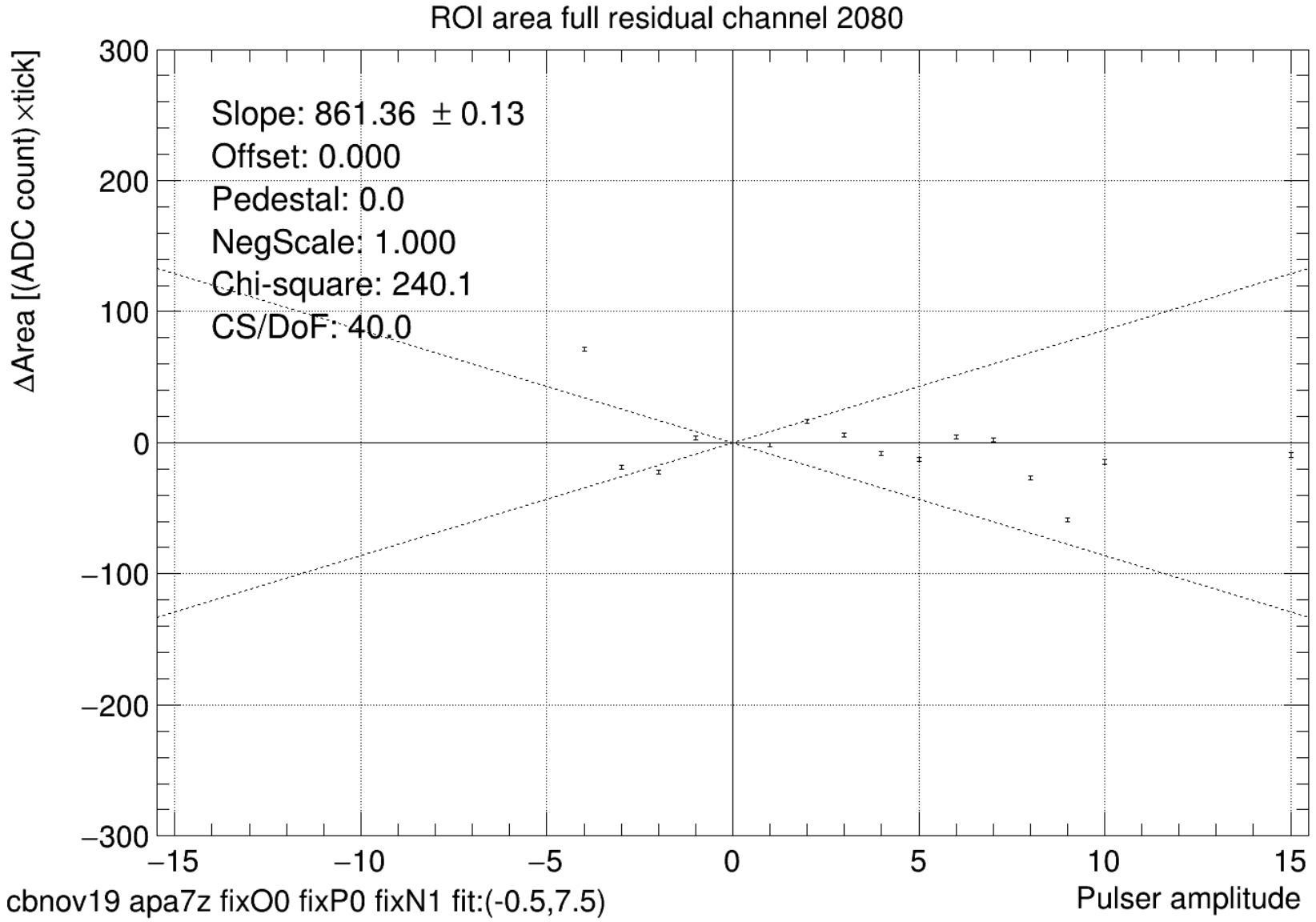
Calibrations

- Calibrations done both warm and cold
- For preamp at 14 mV/fC gain and shaping 2 µs
  - Pulser data available at other settings
- Calibrations are in dunetpc, e.g. for cold
  - tools.adcSampleCalibration.GainTool: "areaGain_cbnov19"
- Typical response and residual plots follow
  - Residual = measured minus calibrated area vs. pulser setting
- Residuals (and more) for all channels available at
  - Cold: https://internal.dunescience.org/people/dladams/protodune/calibrations/cbnov19/
  - Warm: https://internal.dunescience.org/people/dladams/protodune/calibrations/cbwnov19/

Example area vs. pulser setting



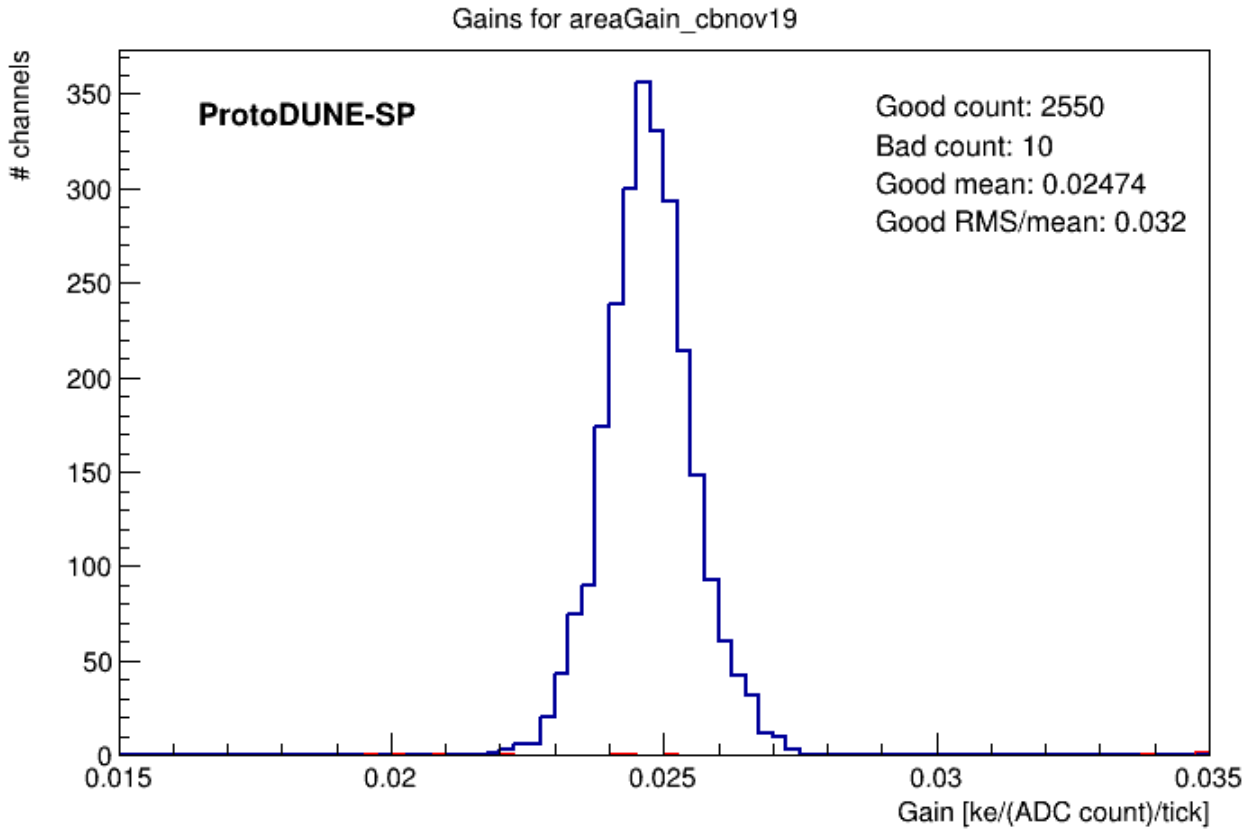
Example residual vs. pulser setting



Gain distribution

Plots show distribution of gains

- For all good channels
- As expected, near 25 e/(ADC count)/tick



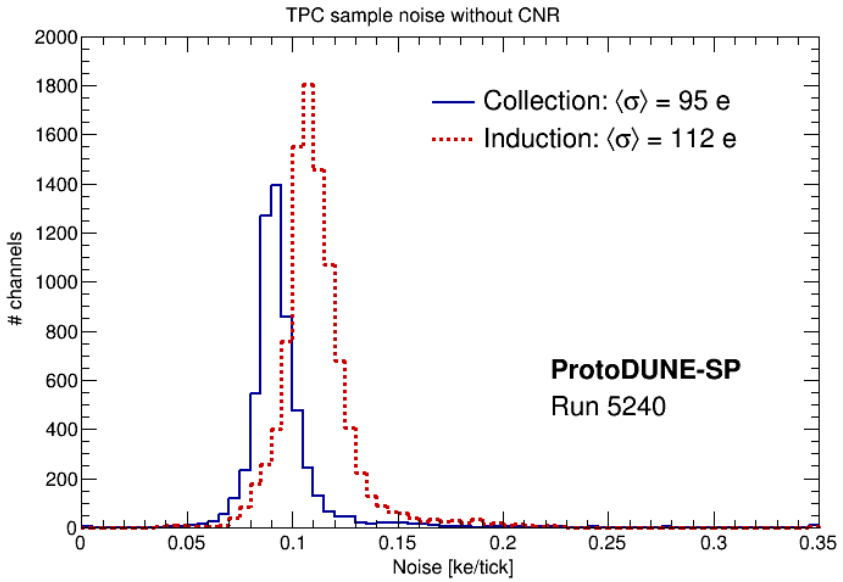
Noise summary

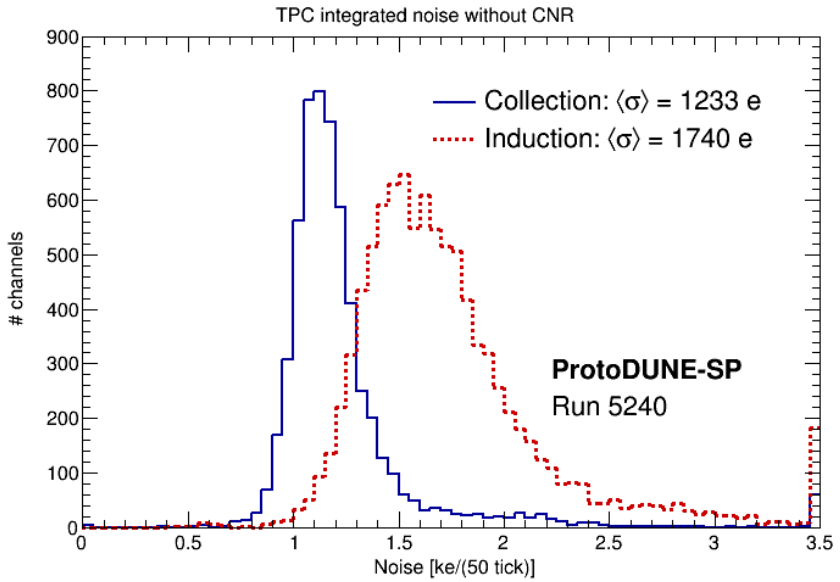
Noise plots

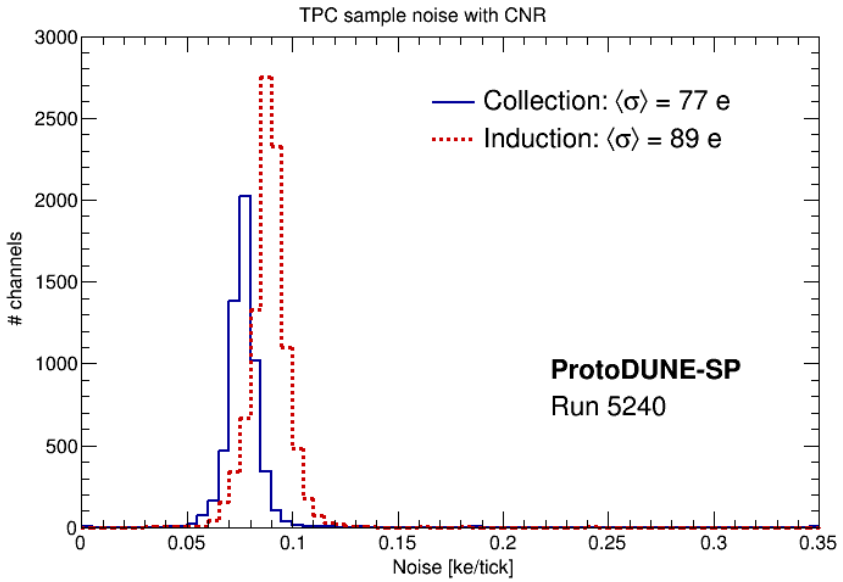
Noise summary plots are generated

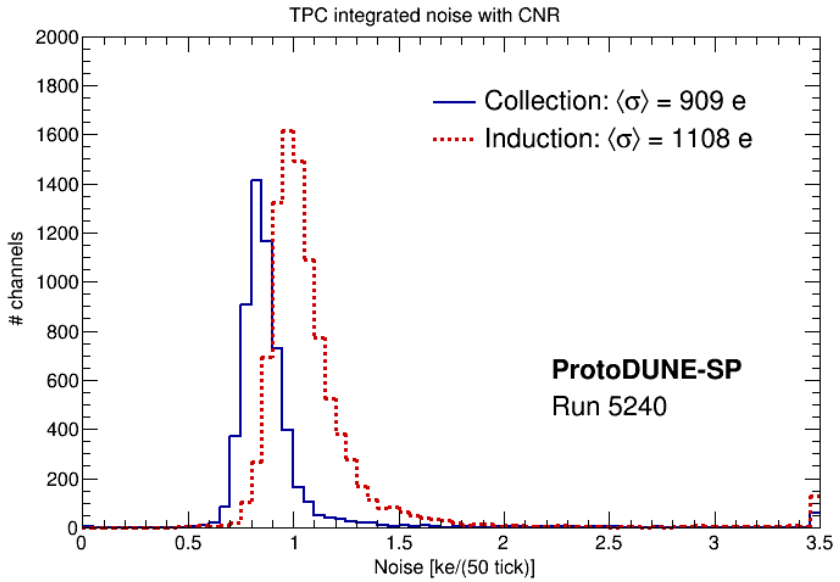
- Data are calibrated as described earlier
- Evaluate noise as RMS for two cases
  - Sample noise is single tick
  - Integrated noise is 50 contiguous ticks
    - Approximate region used to estimate charge (left)
    - Good estimate of our best uncertainty in charge/channel for a track (right)
- Show results after SC mitigation (little effect)
  - before (top) and
  - after (bottom) correlated noise removal
- Similar plot for protoDUNE shown first
- Plots include all good channels (those not flagged as bad)
  - Separate distributions for collection and induction channels

ProtoDUNE noise: quiet run

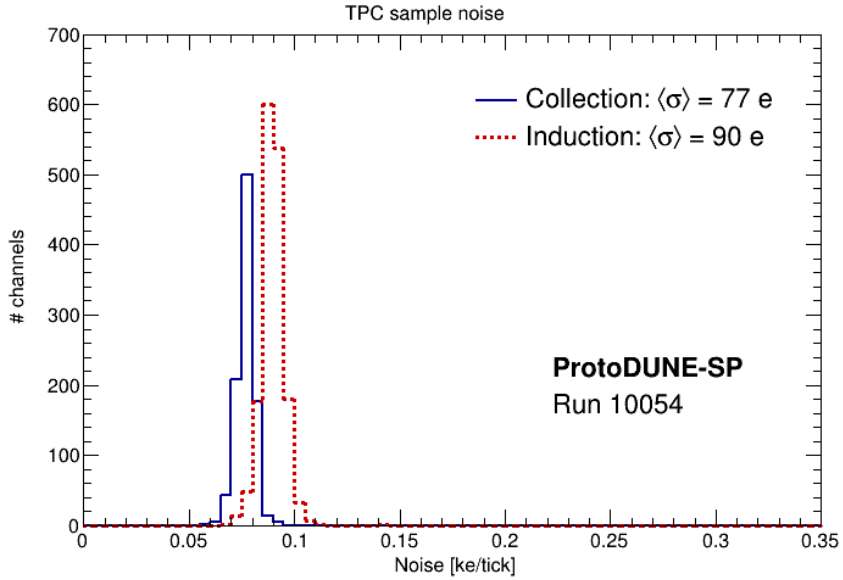


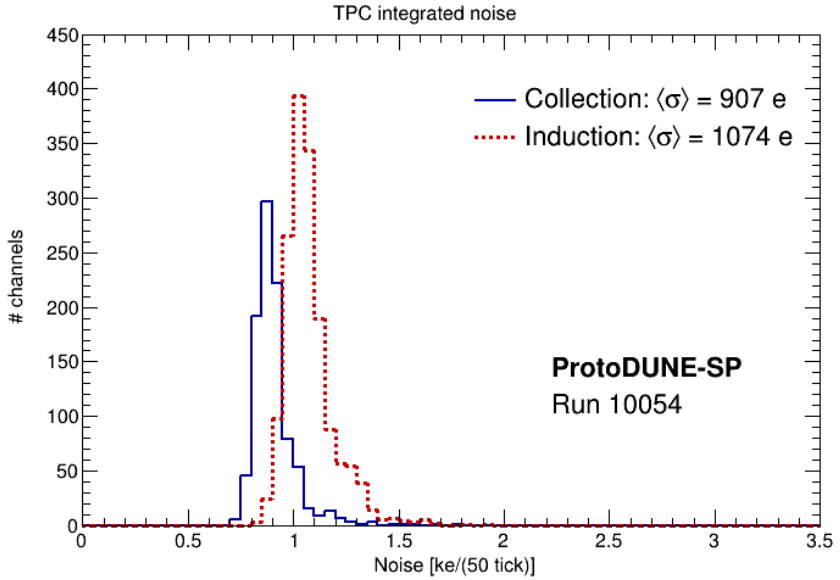


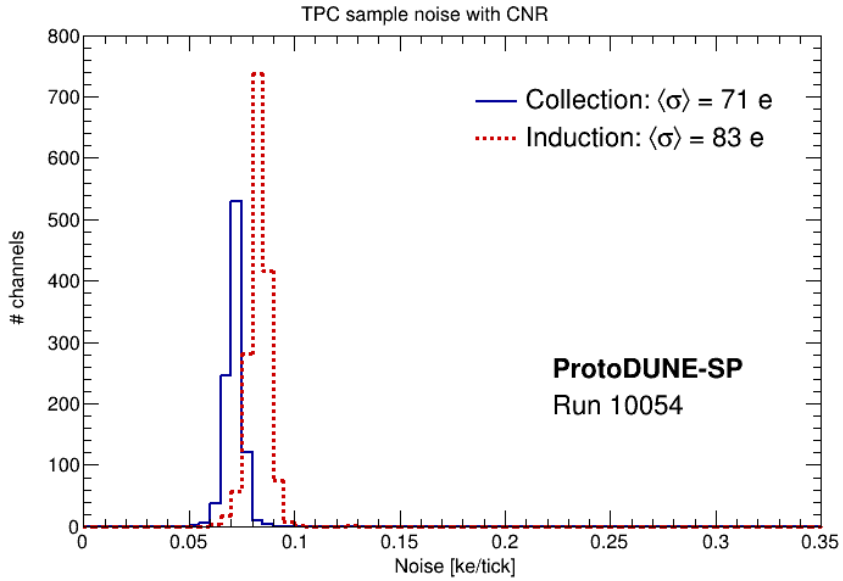


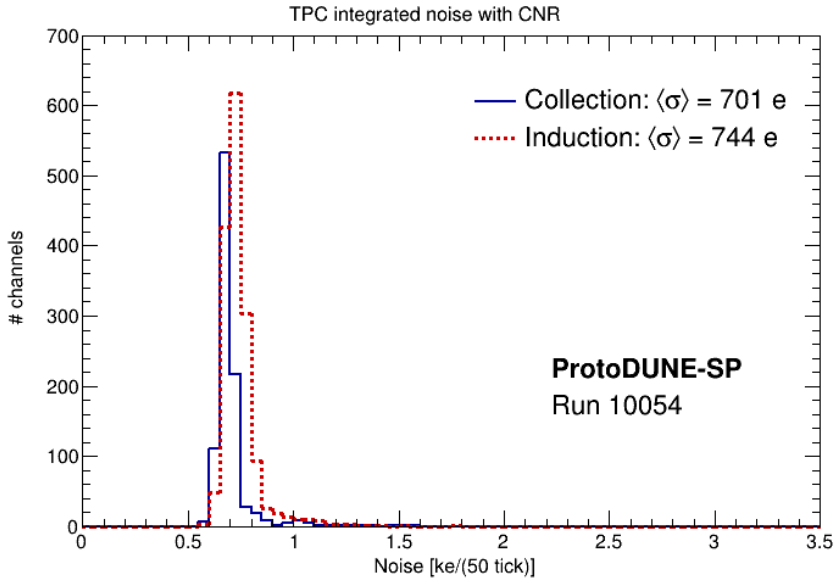


APA 7 noise: cold, bias voltage off

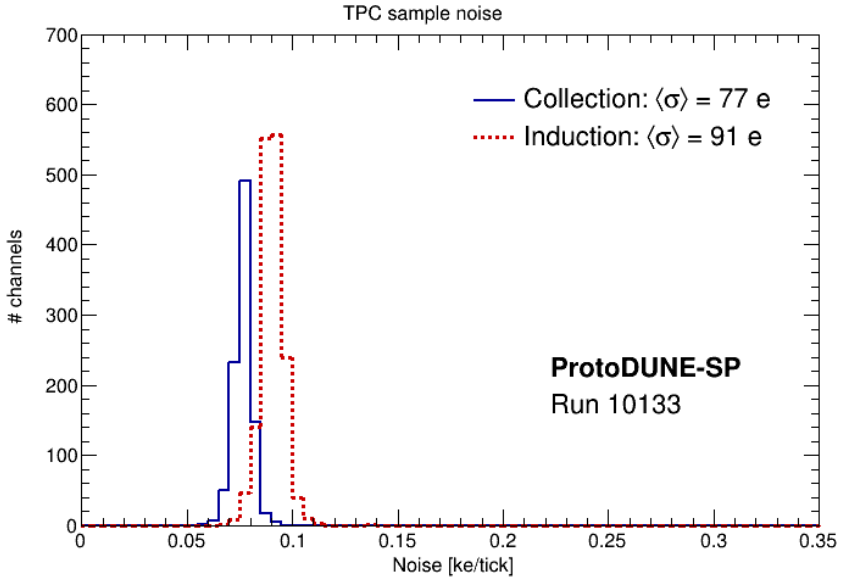


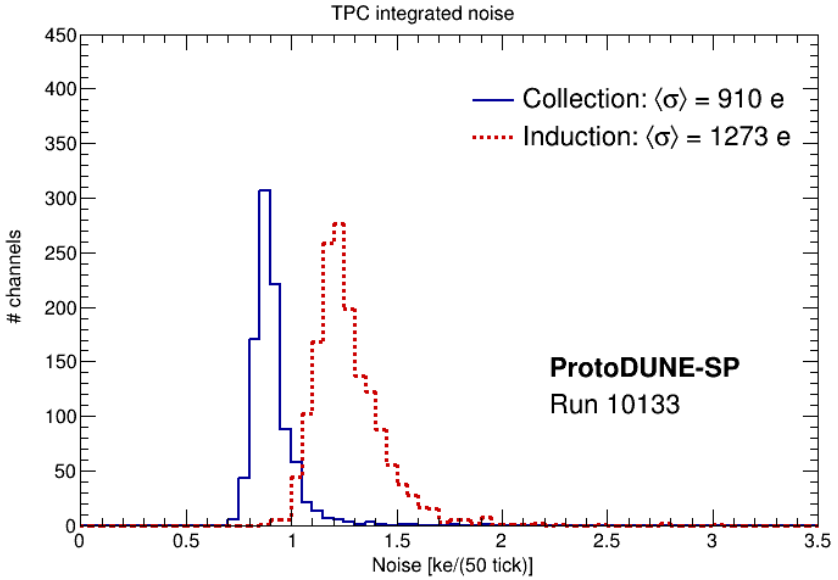


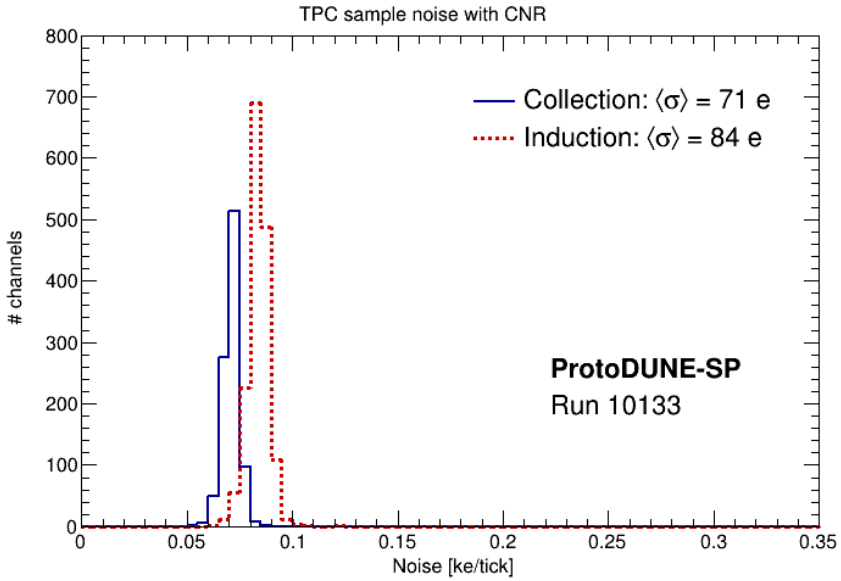


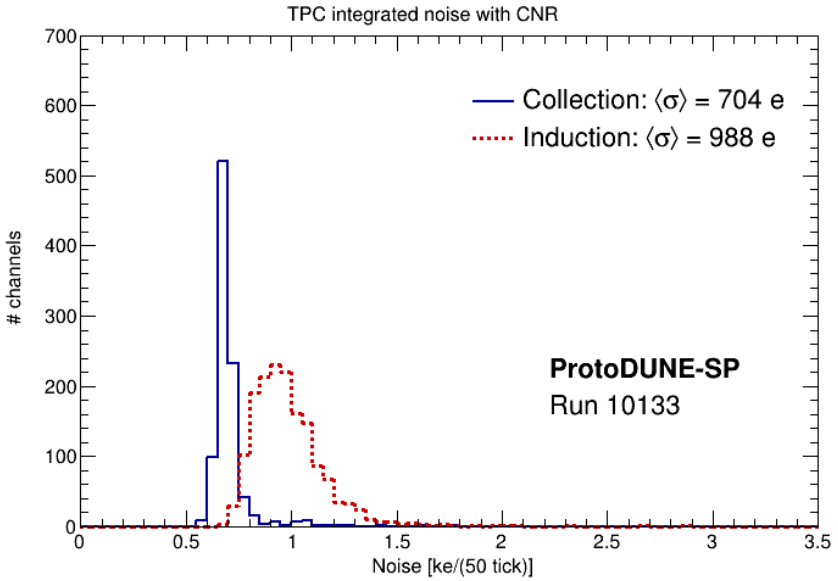


APA 7 noise: cold, bias voltage on









ENC

Noise is often specified by ENC

- This is the RMS of a charge measurement based on peak height
  - Peak are is used in the calibration here
  - Appropriate for charge collection much faster than the sampling time
    - Nominal 2 μs, actual 2.2 μs with channel-to-channel variation
- CE response function gives A/h = 1.269 τ_{shap} = 5.58
  - This describes the pulser data well
- So ENC before/after correlated noise removal is
  - Collection: 430/400 e
  - Induction: 510/470 e

Extras

Results and plots here from

- dunetpc
- protodune-adc-calib (dladams in github)
- Scripts in ~dladams/dev/dudev02/np04-proc/oct2019/apa7