Iceberg analysis with dataprep: Noise and SNR

Iceberg analysis

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Introduction

I continue look at Iceberg data

- Results plots posted at dedicated Iceberg link:
  - https://internal.dunescience.org/people/dladams/protodune/iceberg/data/index.html

Today look more at time dependence of noise

- Run-to-run variation of noise averaged over all wires
- Noise summaries and DFT spectra for low, typical and high noise

And estimates of SNR

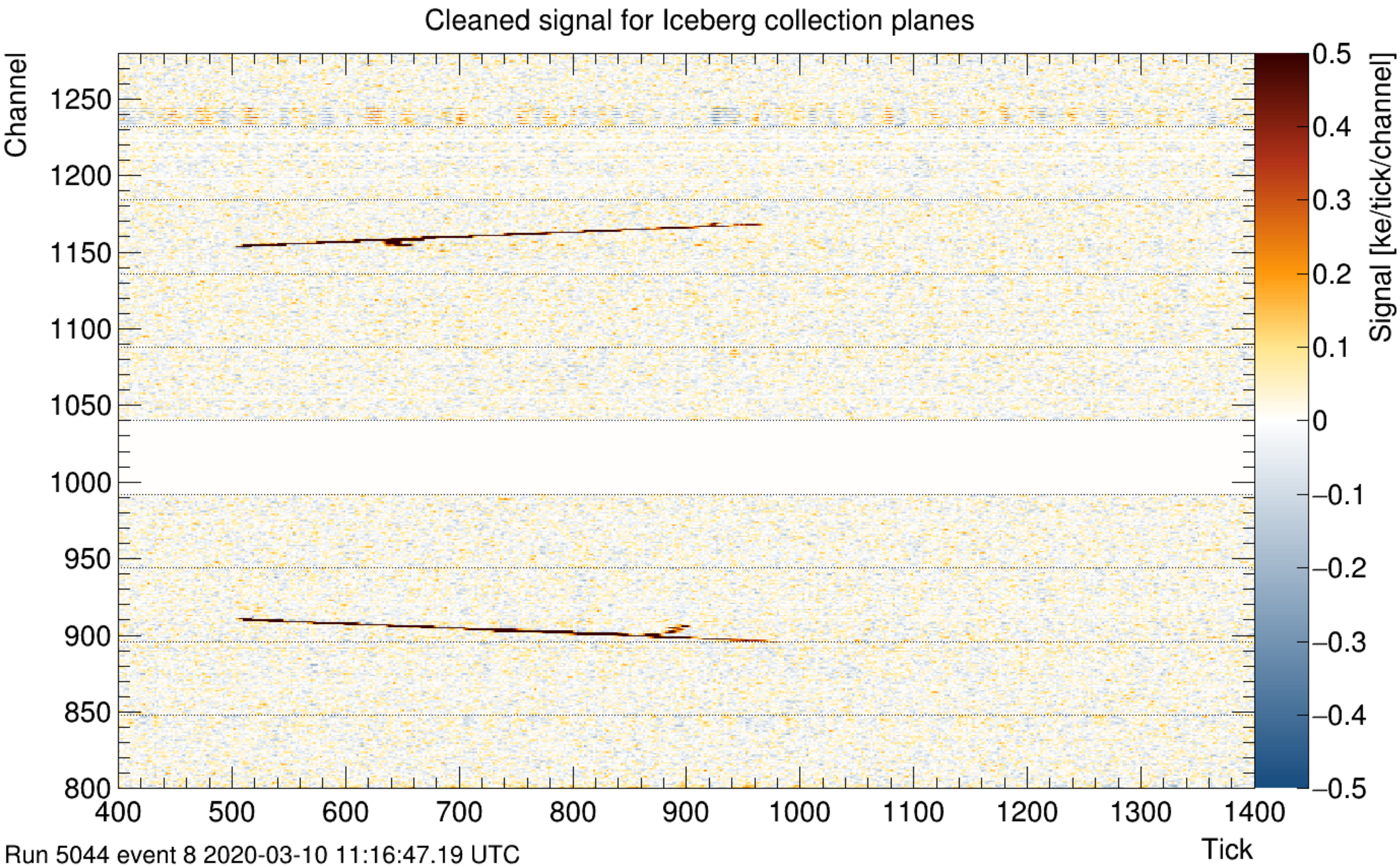
Noise evaluation procedure

Noise evaluation

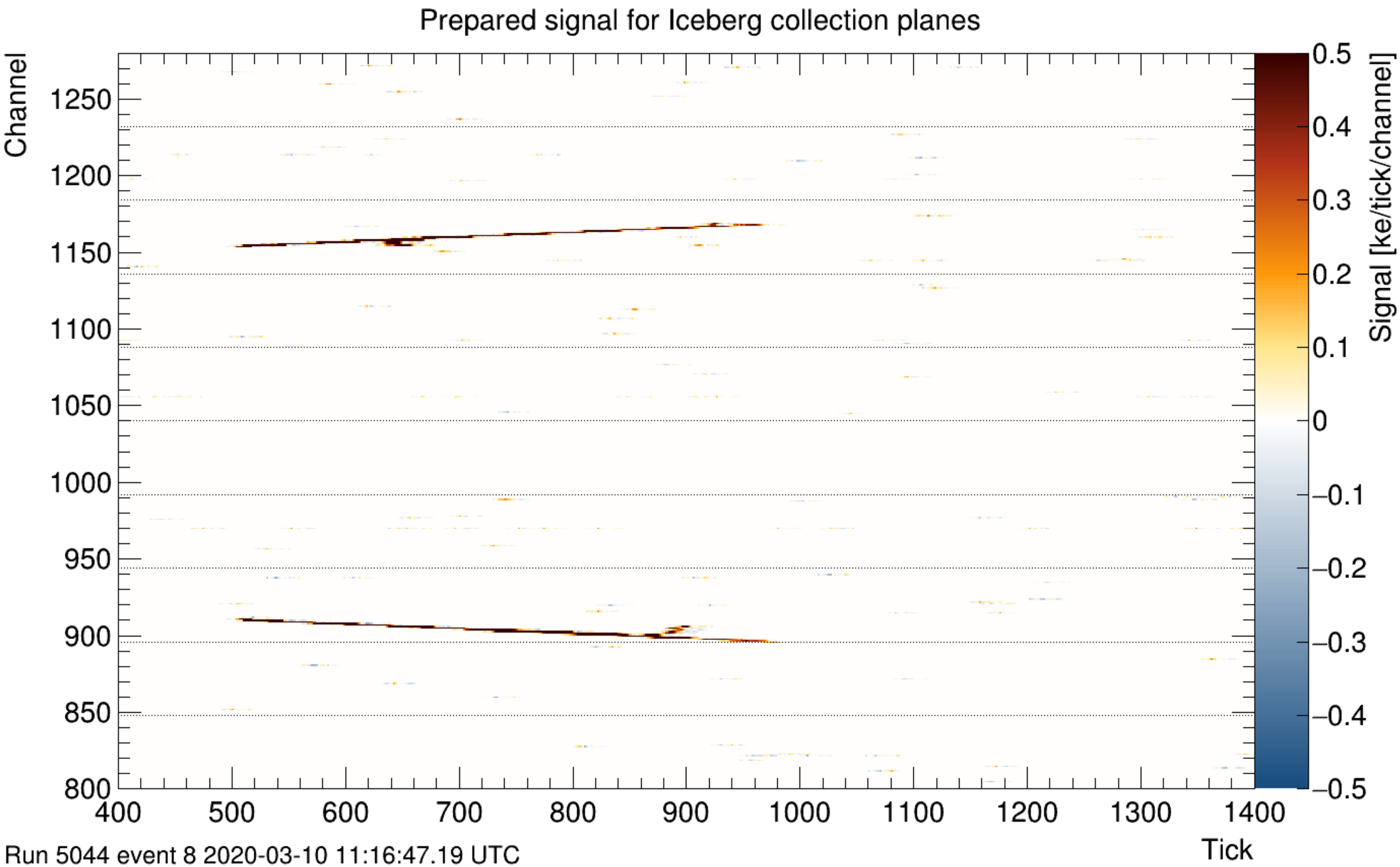
How noise is measured

- Quick summary—see previous talks for more details
- Data preparation similar to protoDUNE
  - Identified sticky codes are flagged
  - Pedestal evaluated for each channel each event
  - Sticky codes mitigated (replace with interpolated values)
  - Tails (from amp-ADC AC coupling) are removed
  - Coherent noise removal (CNR) is applied
    - Subtracting median in each FEMB-plane (I think)
    - Noise results shown with and without CNR
- Signal-free regions selected
  - Dynamic threshold signal finder used to identify ROIs
    - Ticks inside ROIs are flagged as signal
  - Blocks of 1000 ticks w/o signal are identified
- Noise is defined as RMS over not-ROI ticks
- DFT power is evaluated us the signal-free 1000-tick blocks

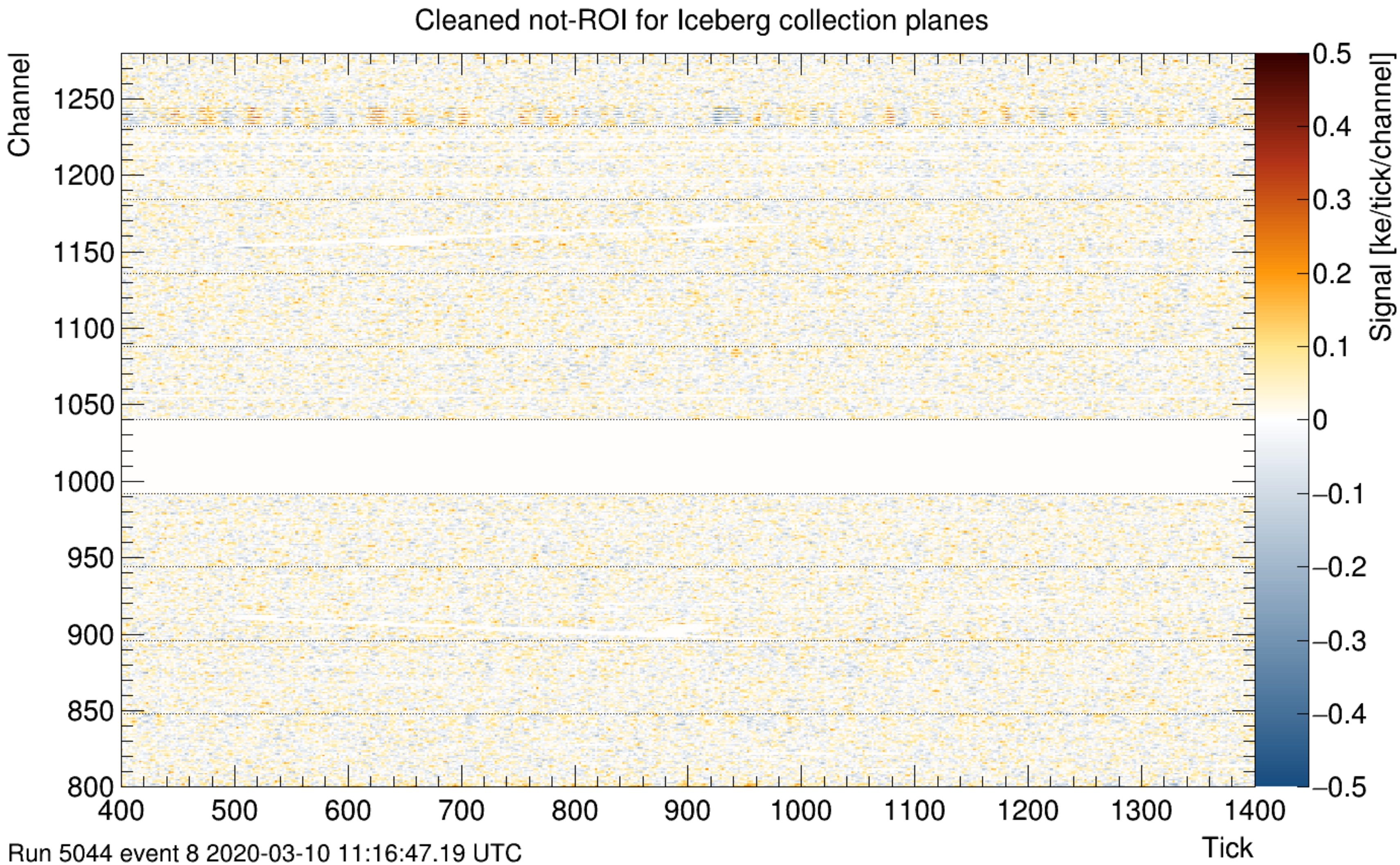
Example waveform after dataprep



After signal finding



Noise ticks (i.e. inverting signal finding)



Noise summary

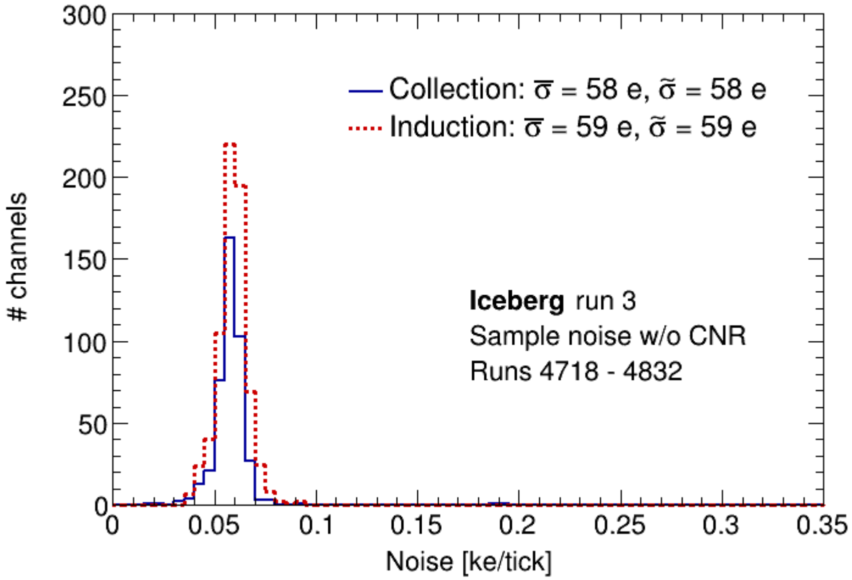
Noise summary plots

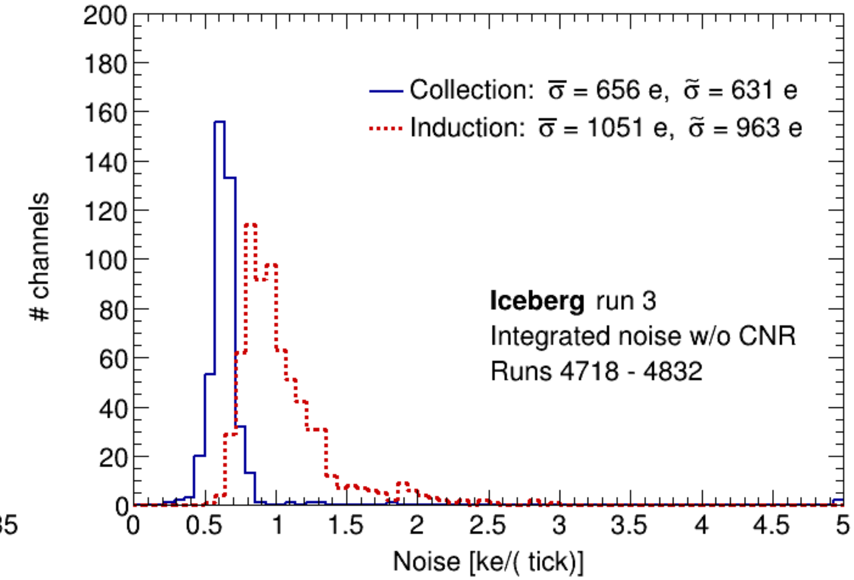
- Noise = RMS in signal-free regions
  - Sample noise = individual samples
  - Integrated noise = sums over 50 ticks
    - To approximate physics charge measurements
    - MIP deposit is 20-30 ke
- Eight curves with mean and median (new) are shown
  - Before and after CNR (top, bottom)
  - Sample and integrated (left, right)
  - Collection and induction (blue, red)
- One entry for each channel
  - Excluding channels flagged bad (134) or noisy (26)

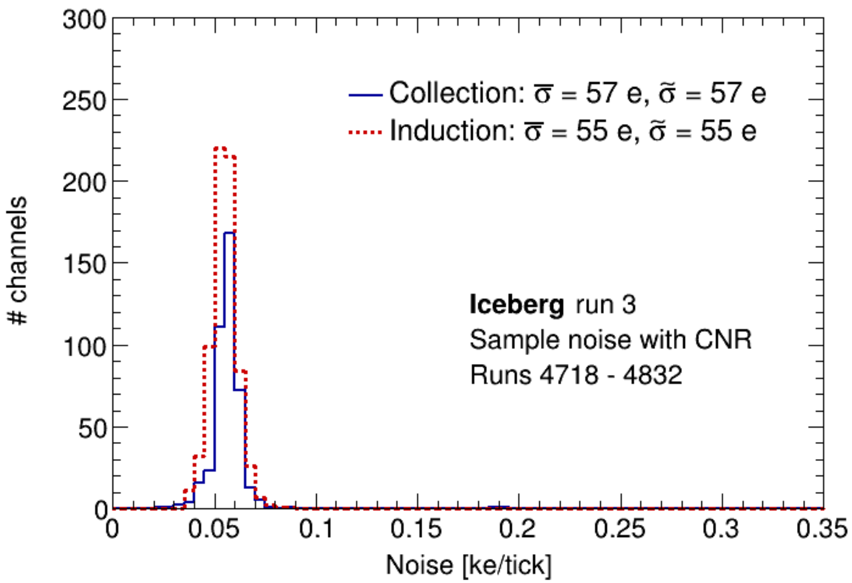
Summary for full run period on following page

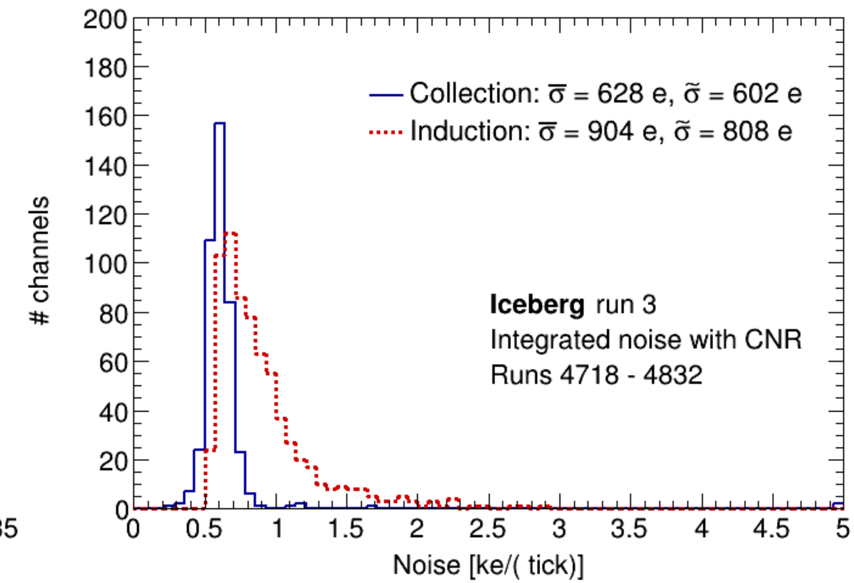
- Sample noise looks good
- Integrated induction is very broad
- Integrated collection and induction have tails

Early runs (4718 – 4832)



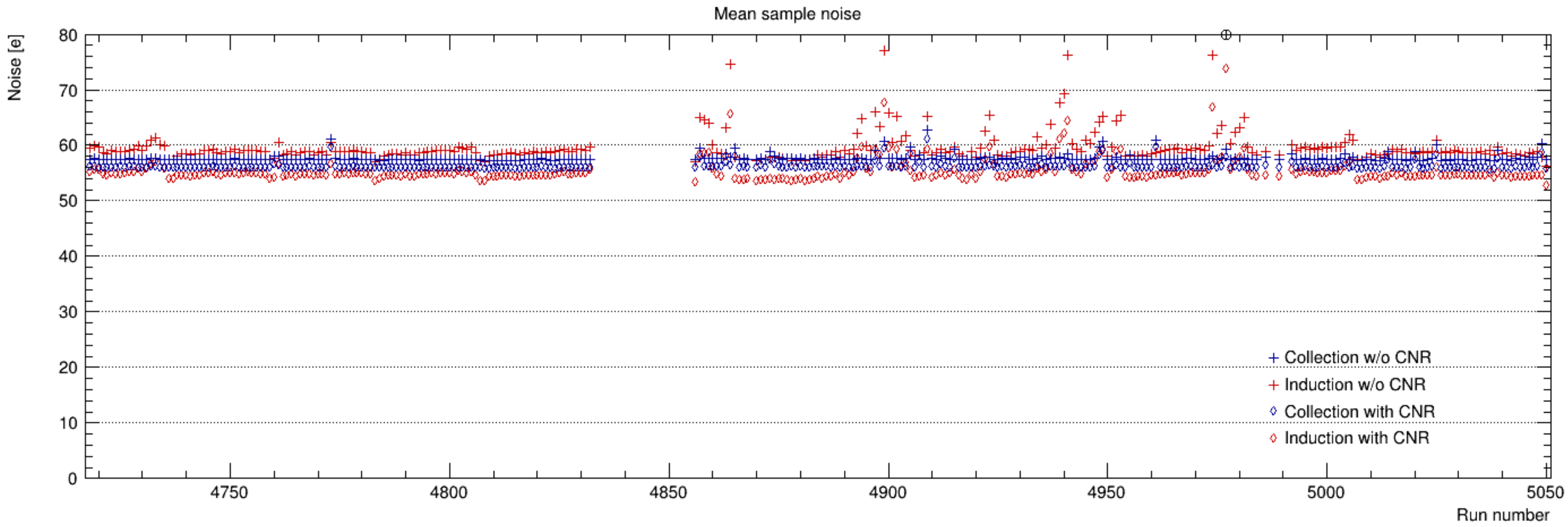


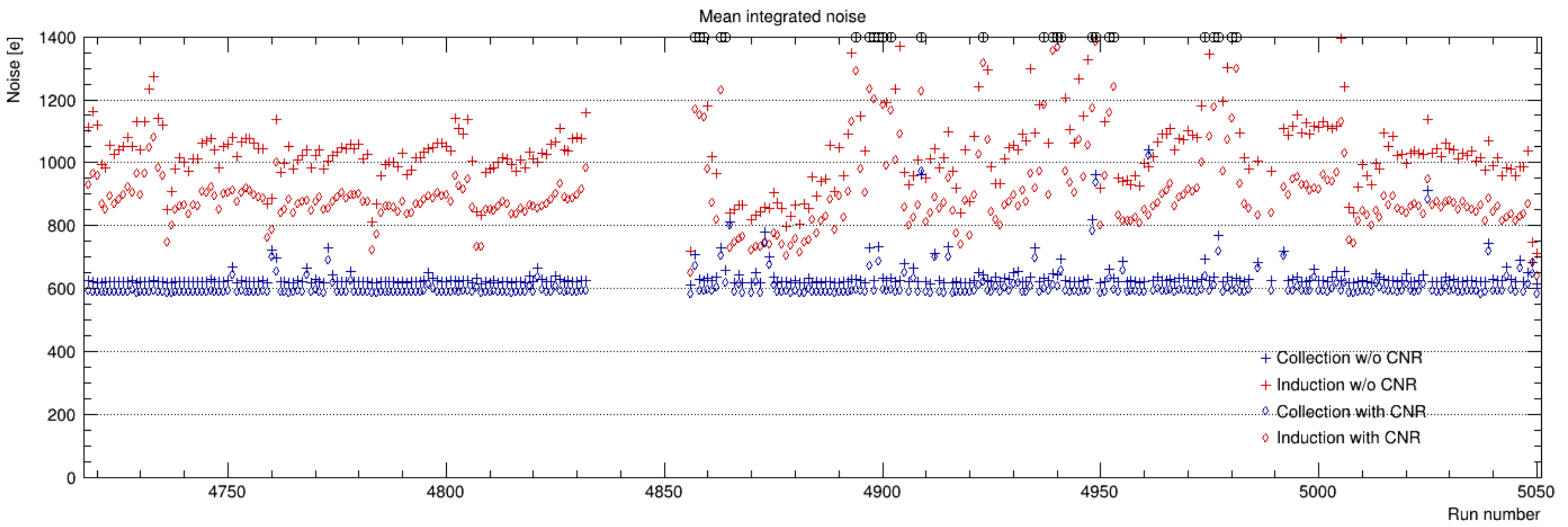




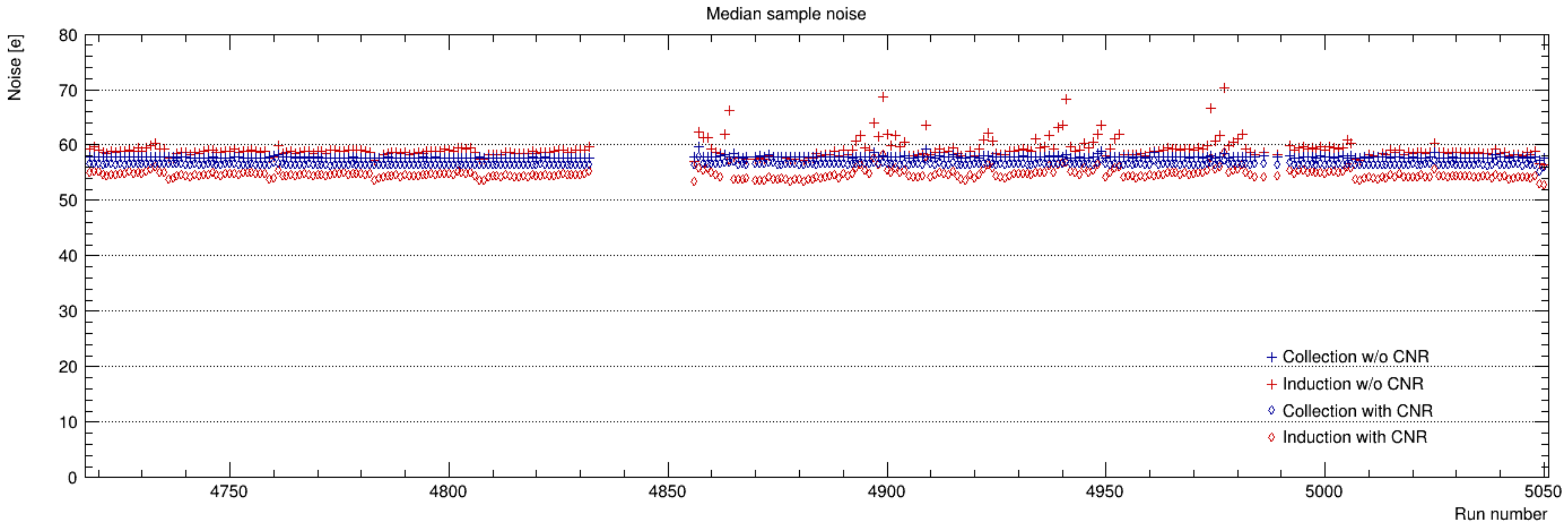
Noise vs. run

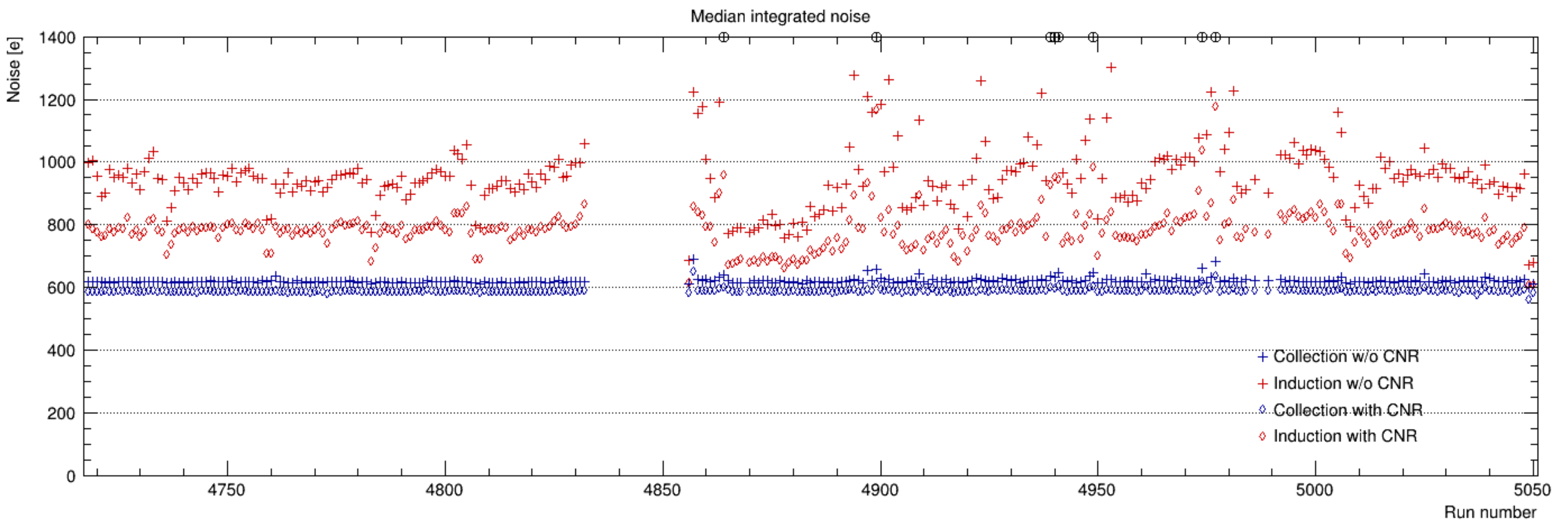
Mean noise vs. run



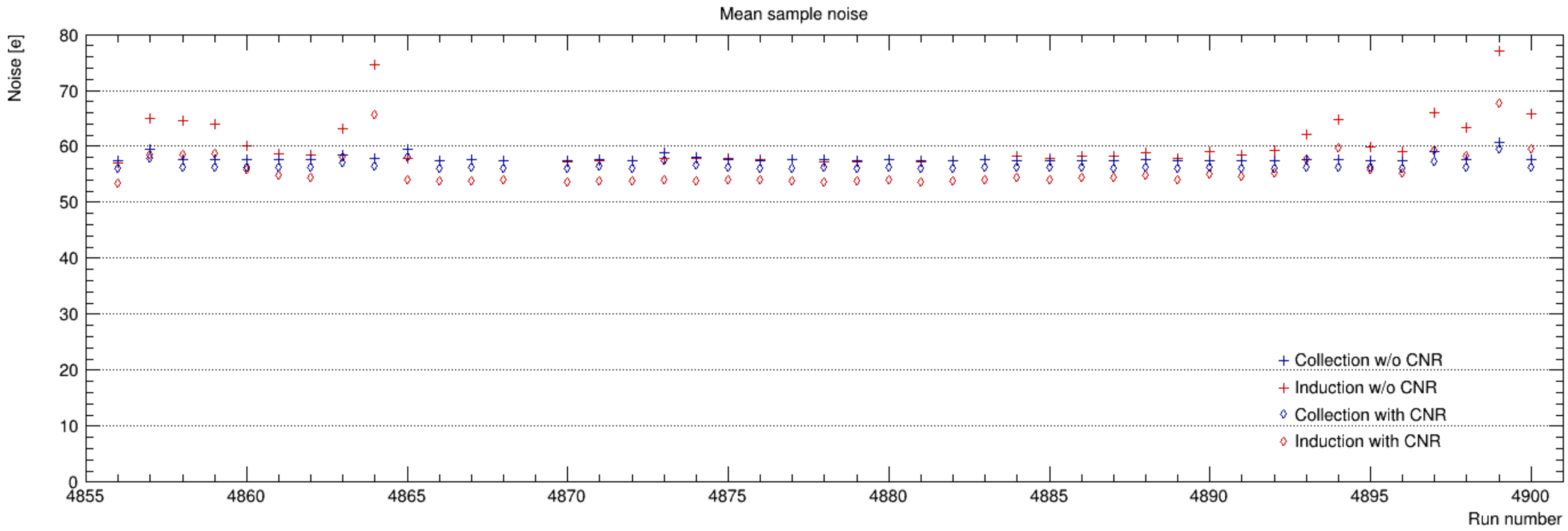


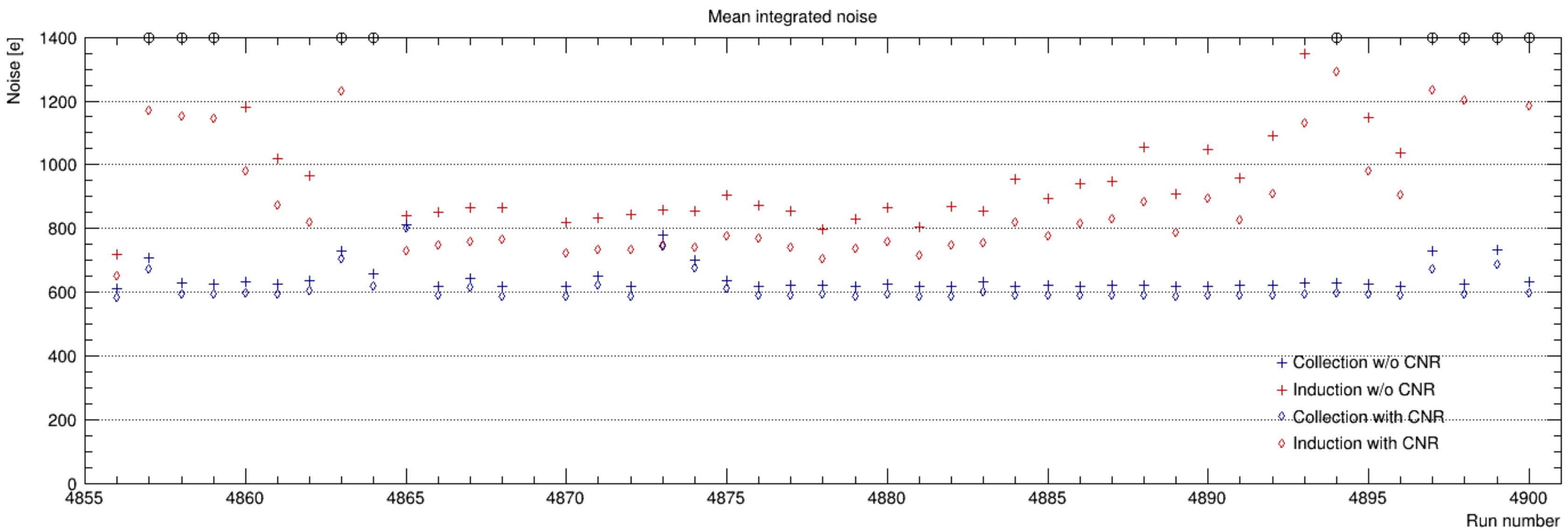
Median noise vs. run



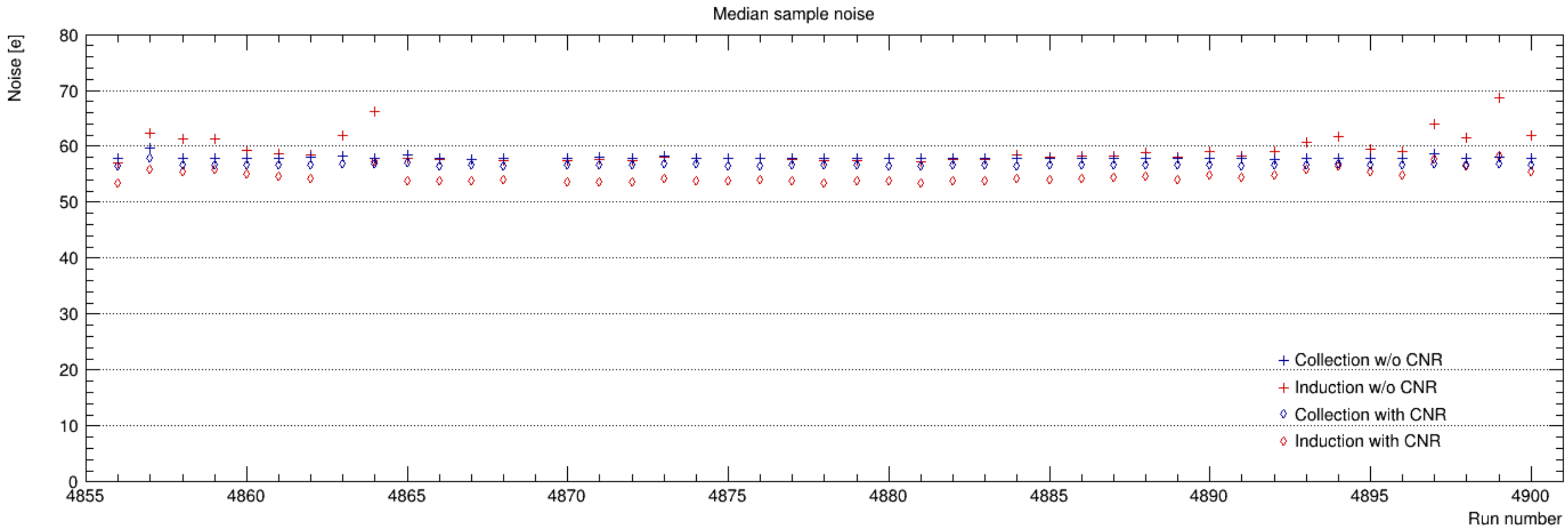


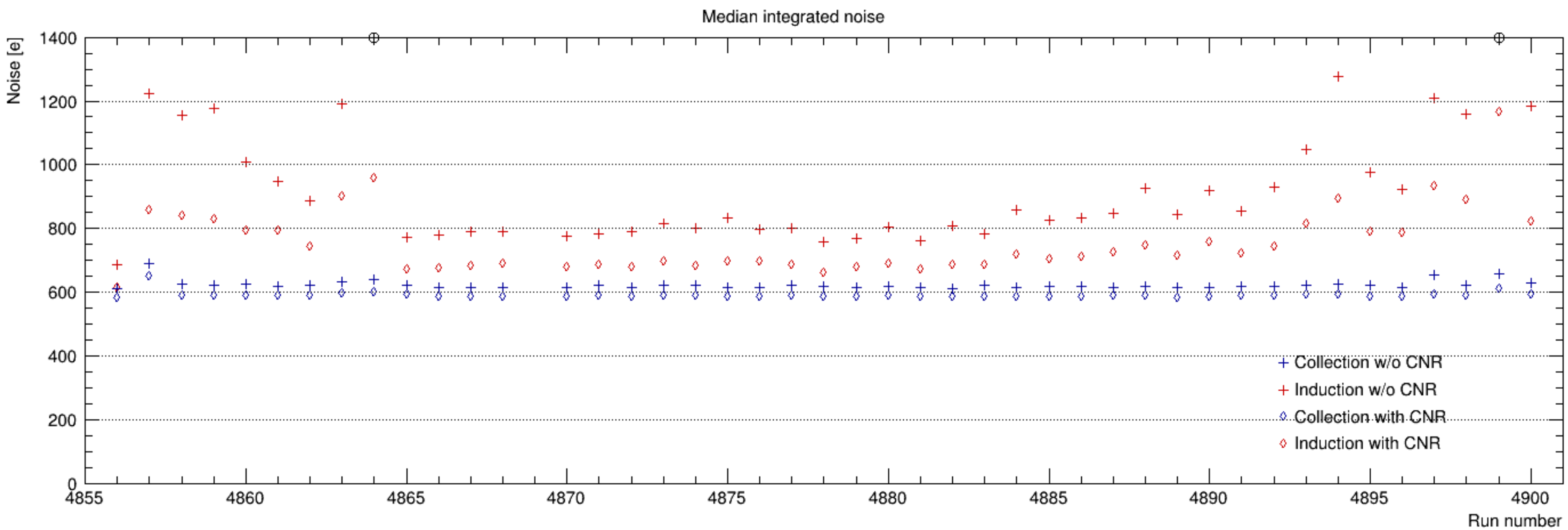
Zoomed mean noise vs. run





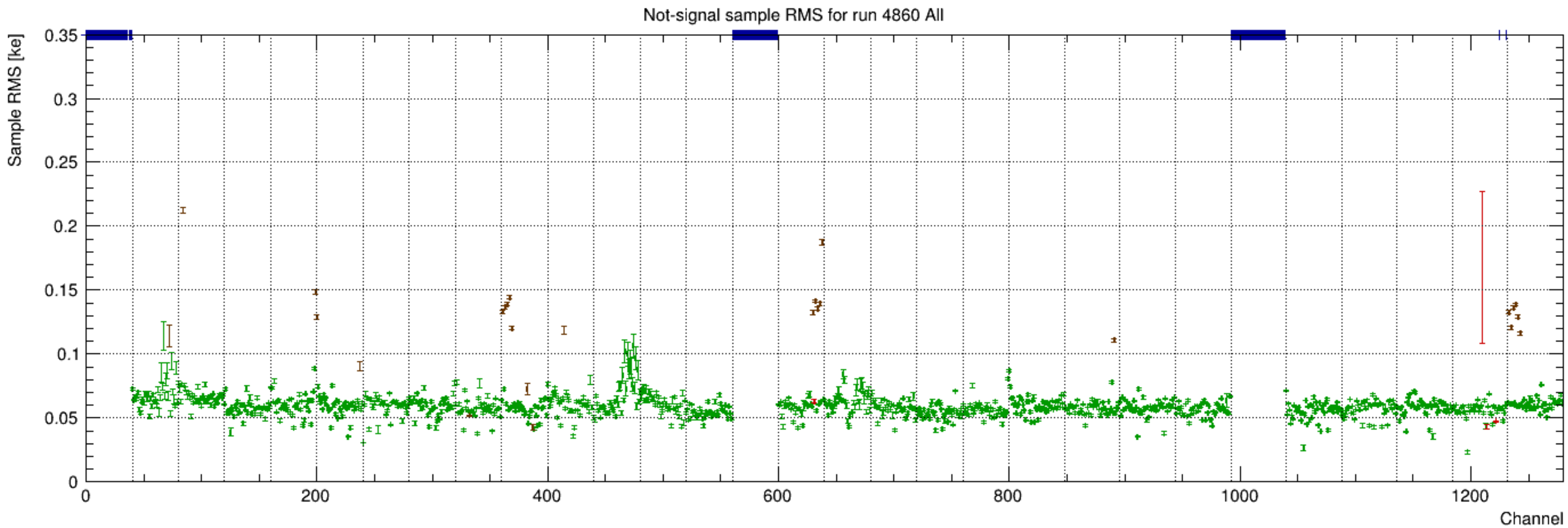
Zoomed median noise vs. run



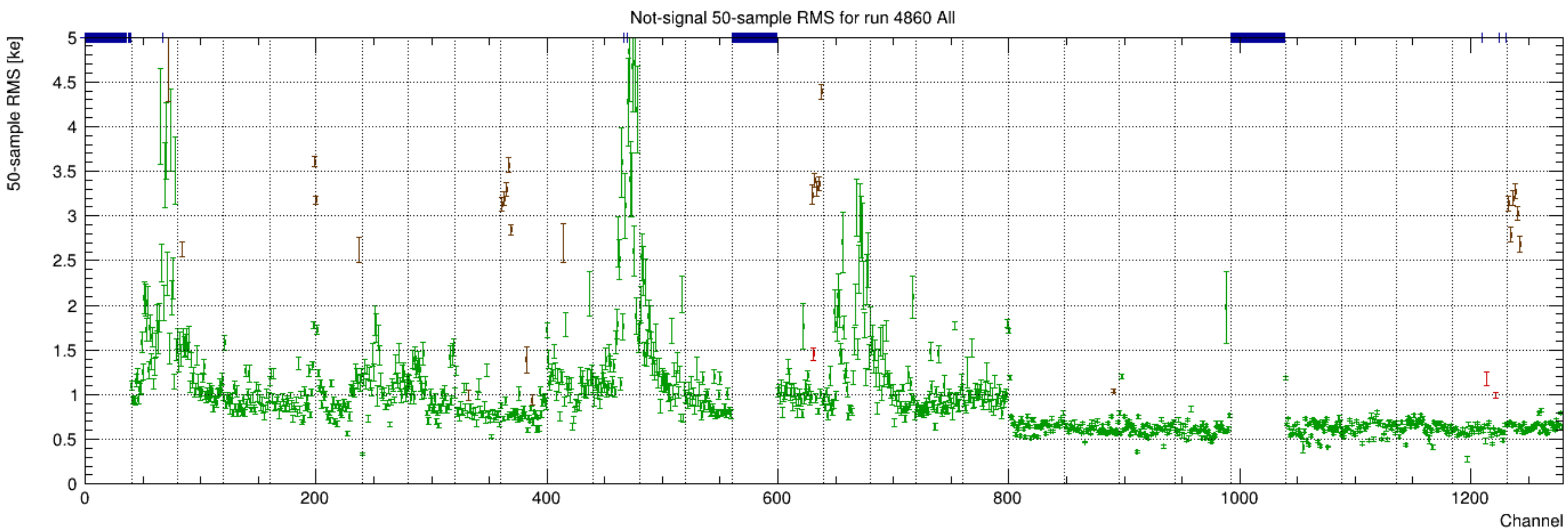


Noise w/o CNR vs. channel by run

4860

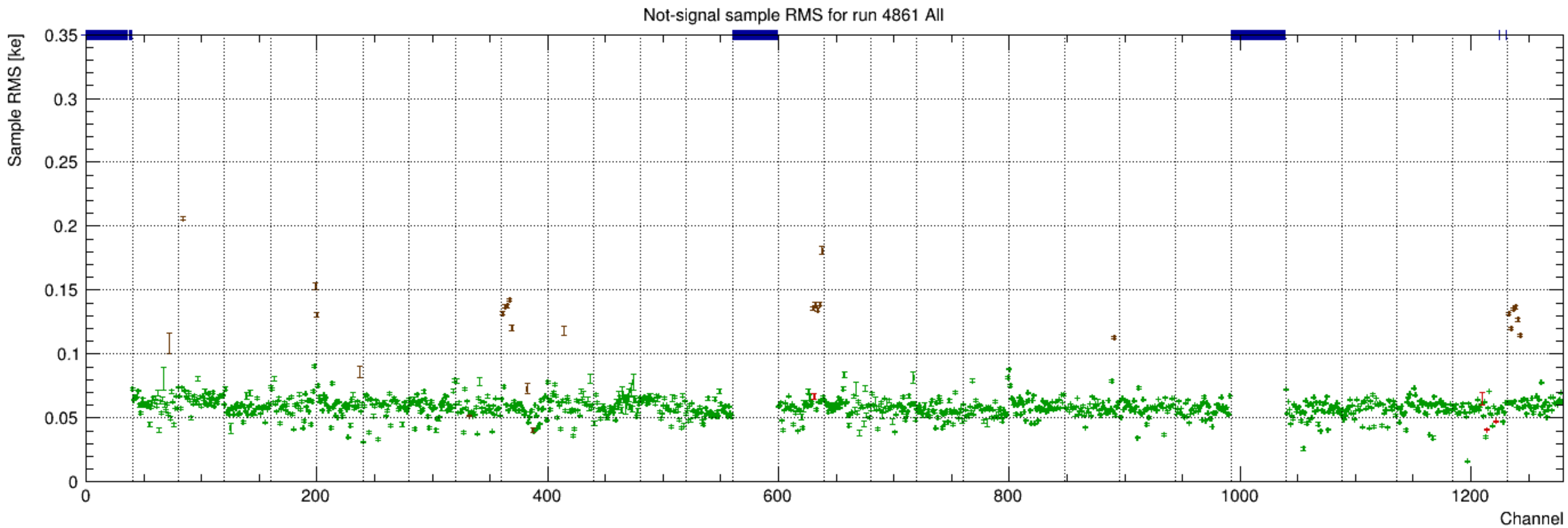


Not-signal sample RMS for run 4860 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel



Not-signal 50-sample RMS for run 4860 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4861



Not-signal sample RMS for run 4861 All
Sample RMS [ke]
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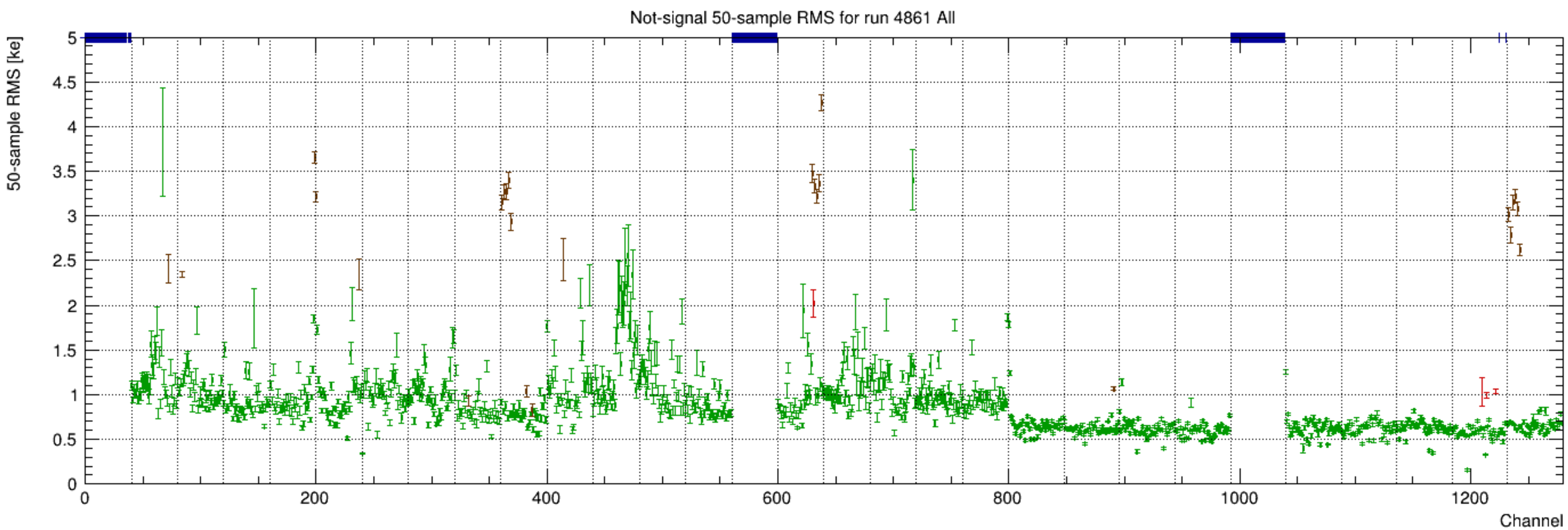
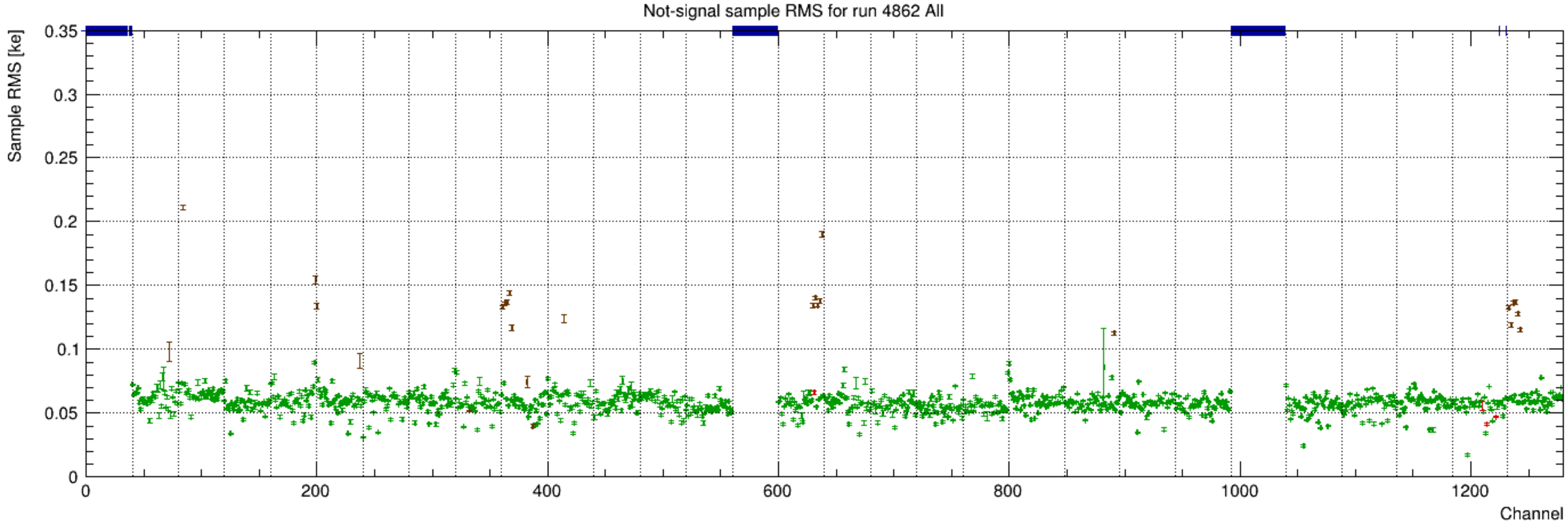
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel

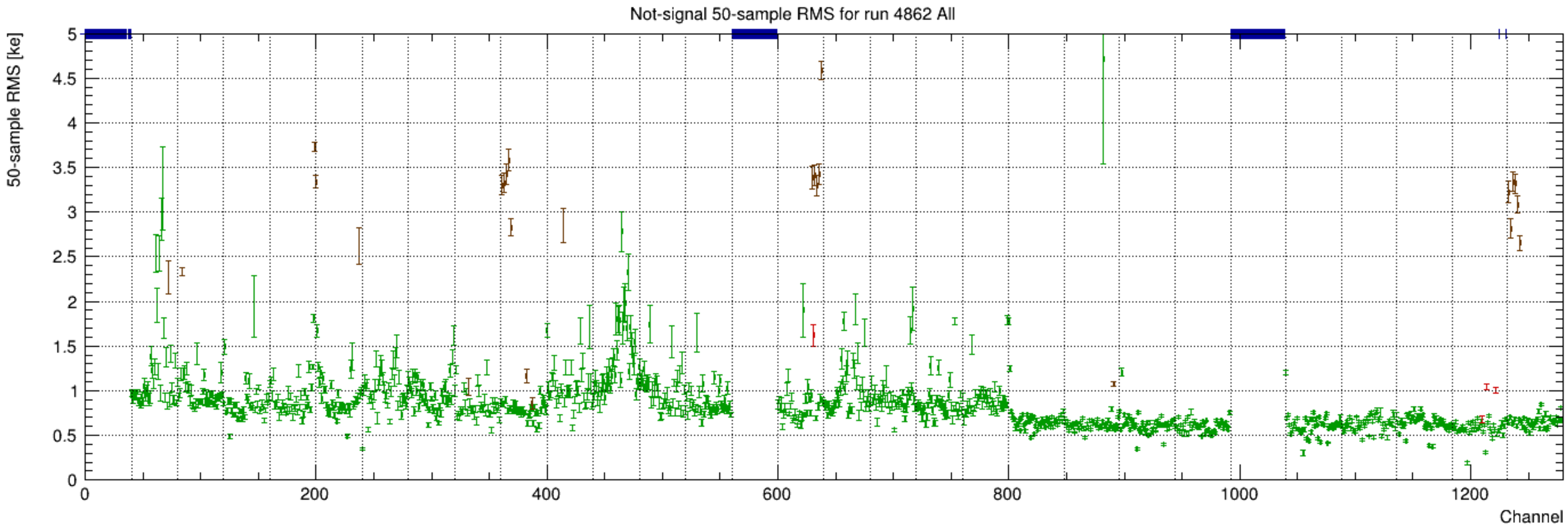


Not-signal 50-sample RMS for run 4861 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4862

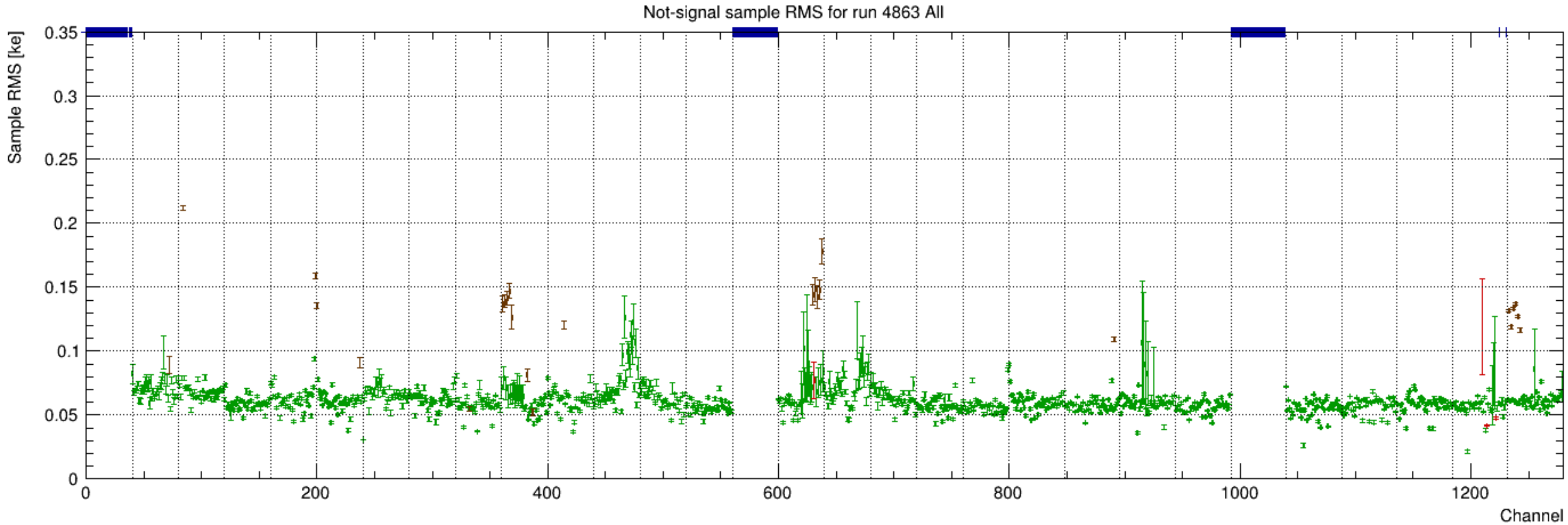


Not-signal sample RMS for run 4862 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel

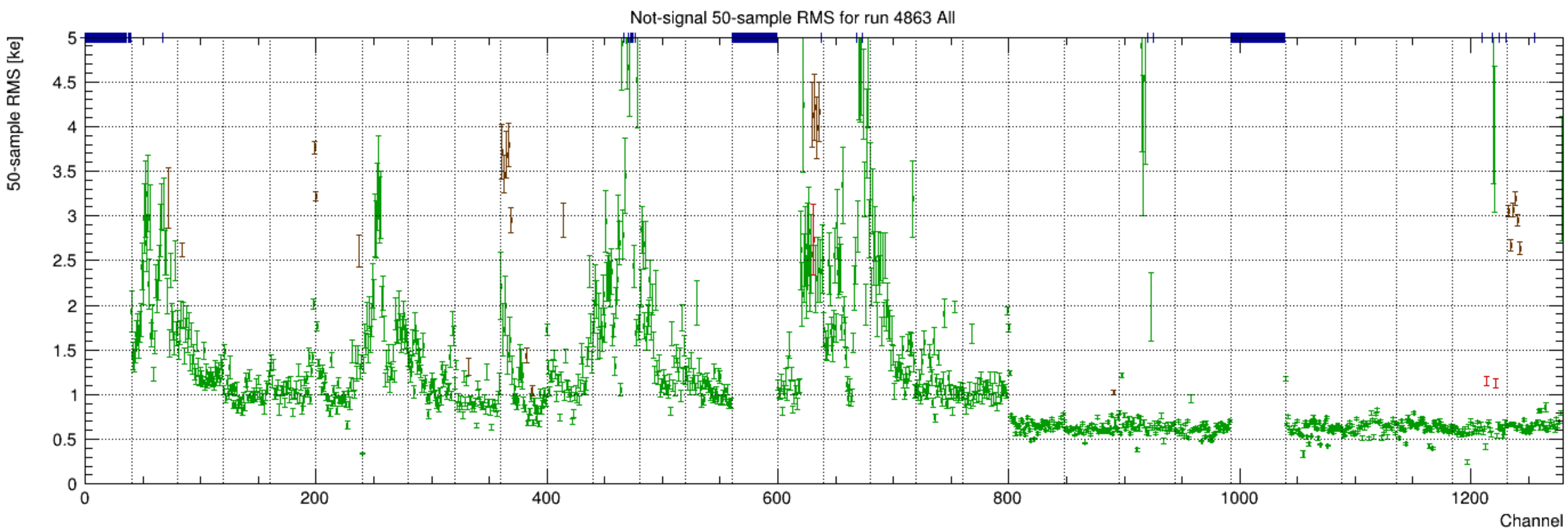


Not-signal 50-sample RMS for run 4862 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4863

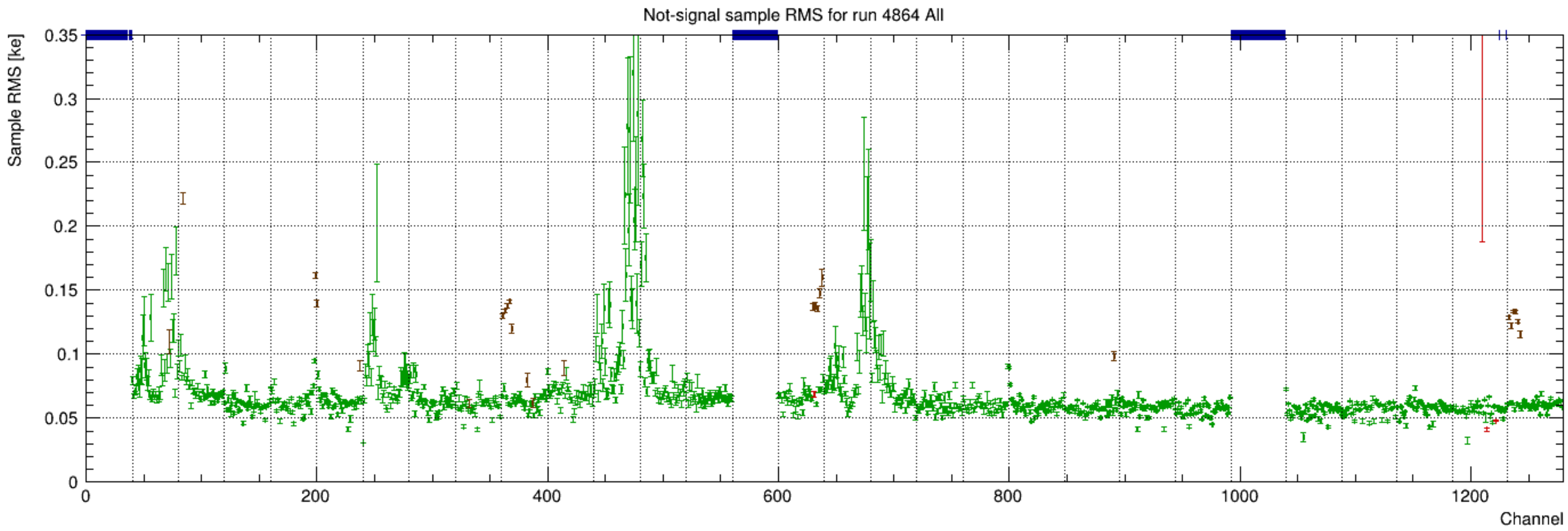


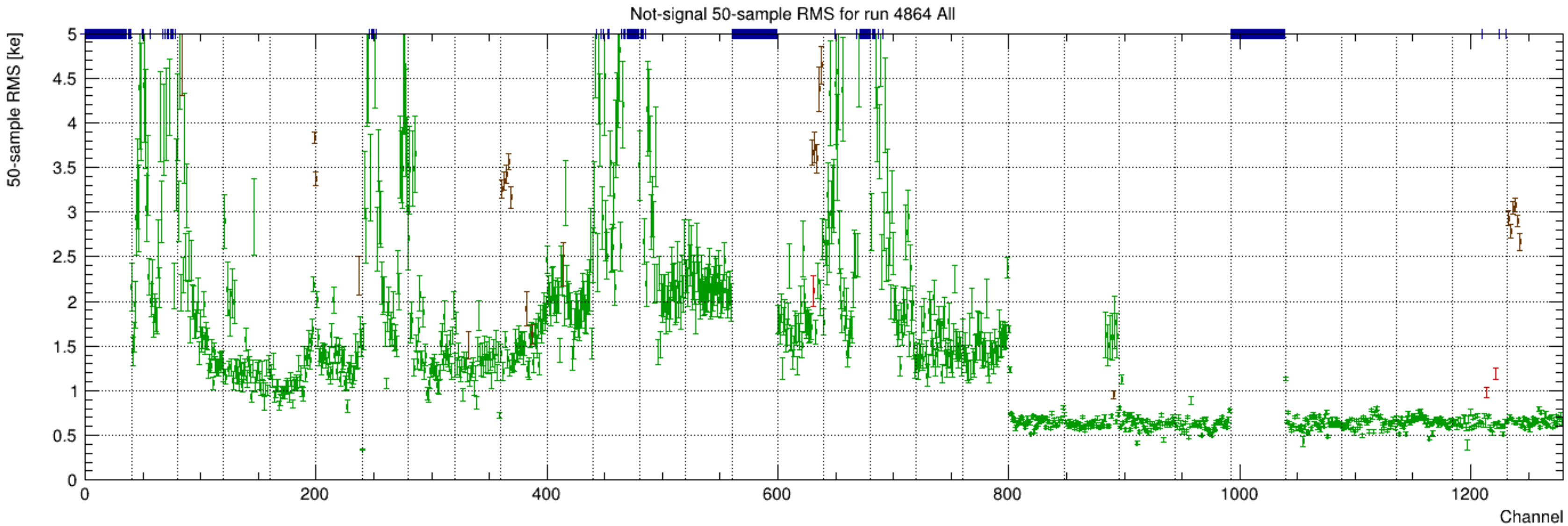
Not-signal sample RMS for run 4863 All
Sample RMS [ke]
Channel



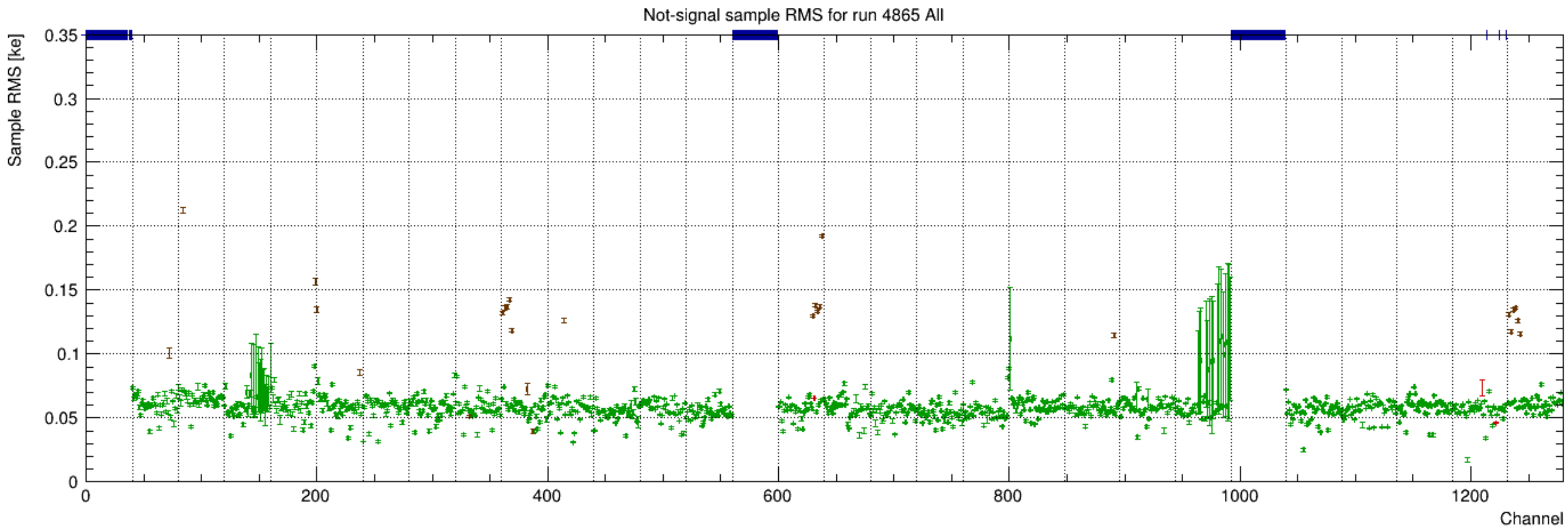
Not-signal 50-sample RMS for run 4863 All
50-sample RMS [ke]
Channel

4864

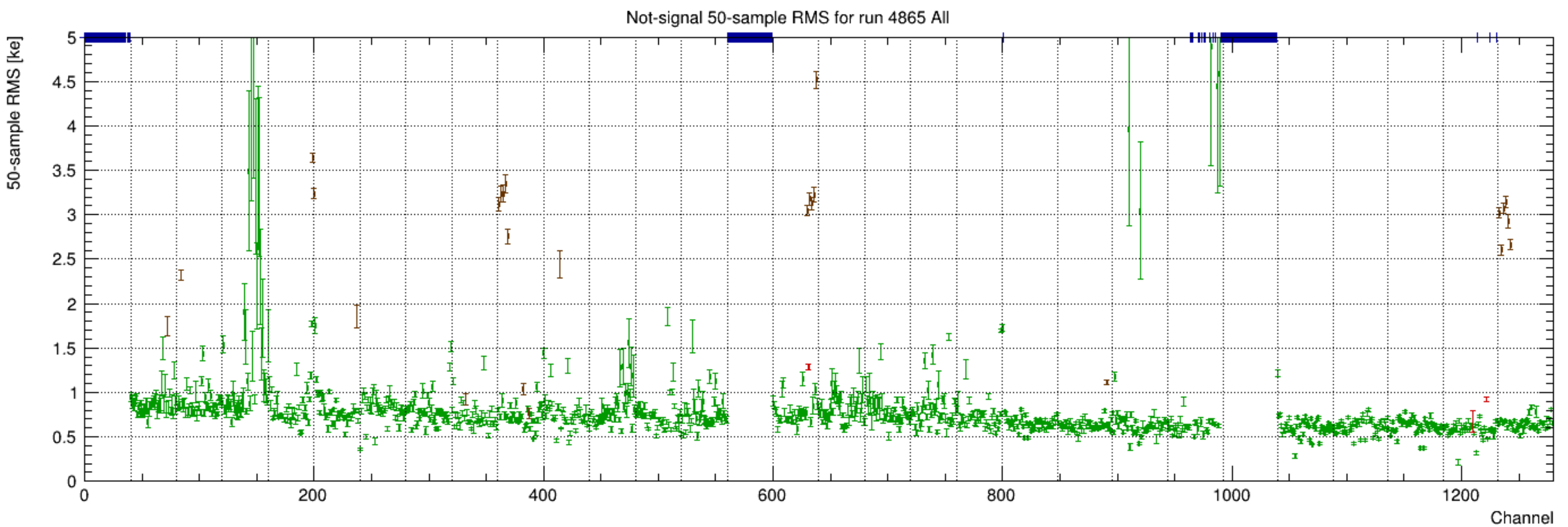

Not-signal sample RMS for run 4864 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel


Not-signal 50-sample RMS for run 4864 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4865



Not-signal sample RMS for run 4865 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel



Not-signal 50-sample RMS for run 4865 All
50-sample RMS [ke]
5
4.5
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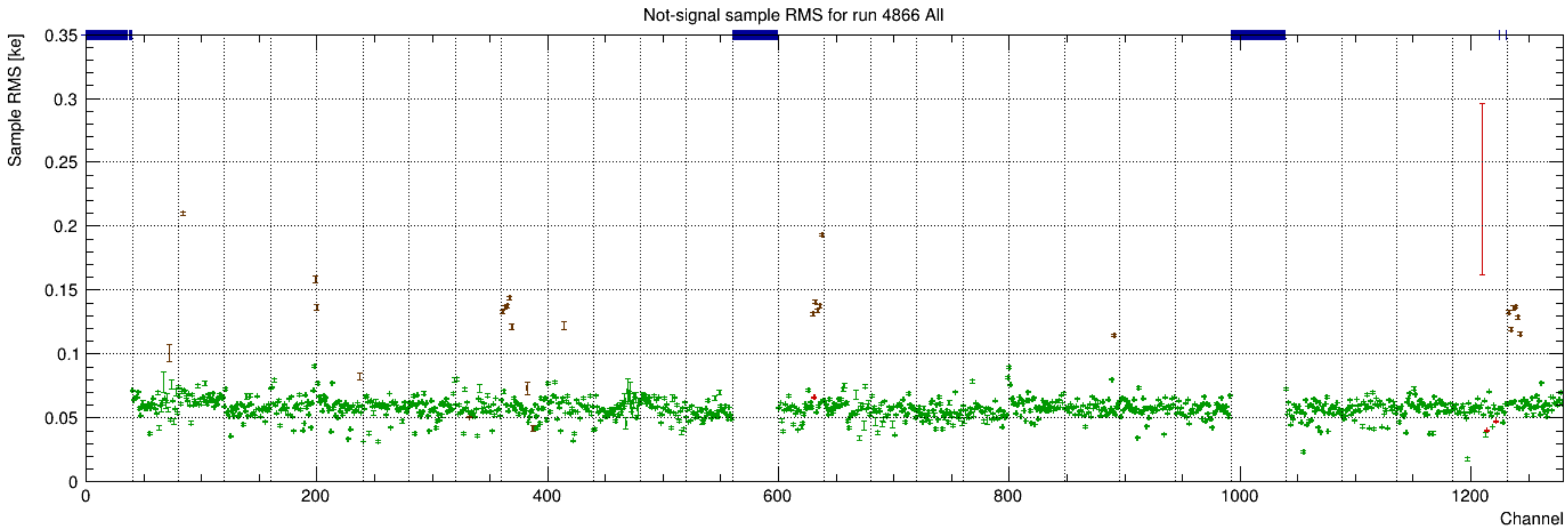
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4866



Not-signal sample RMS for run 4866 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
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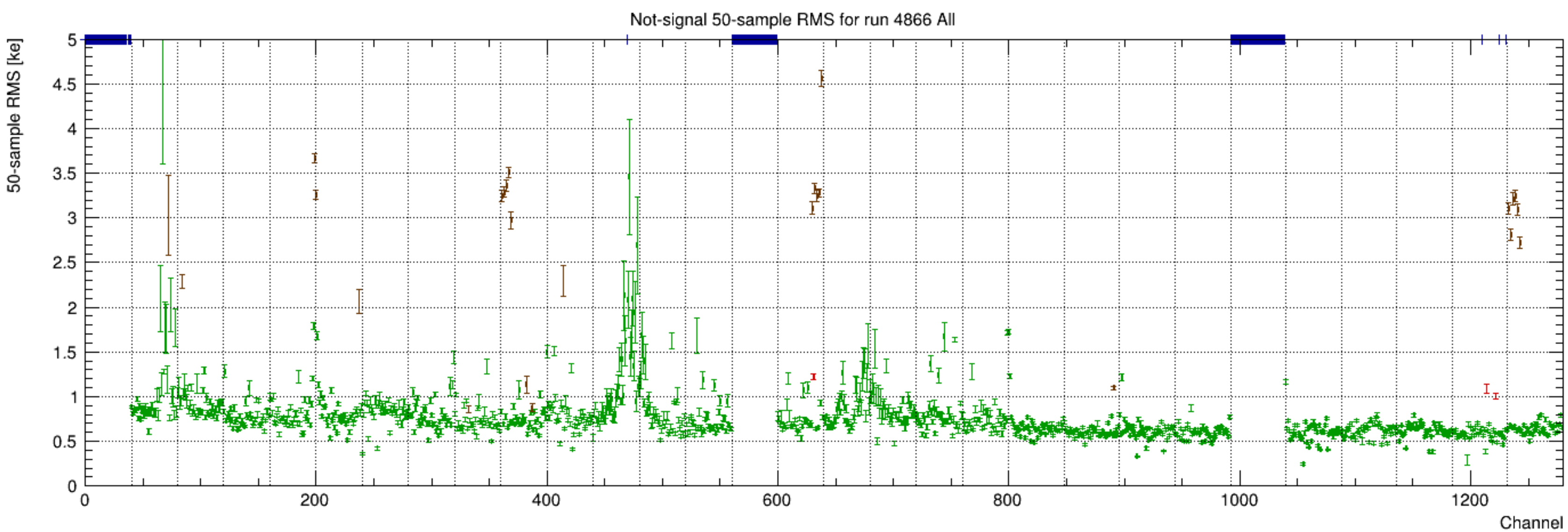
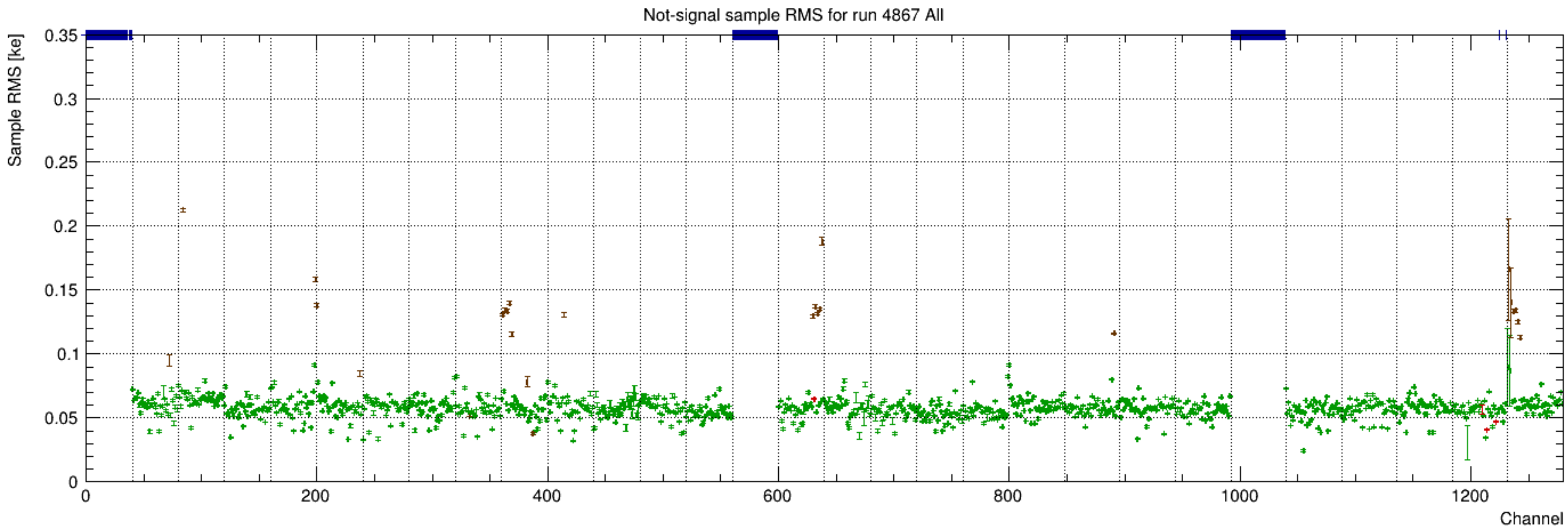
0
200
400
600
800
1000
1200
Channel

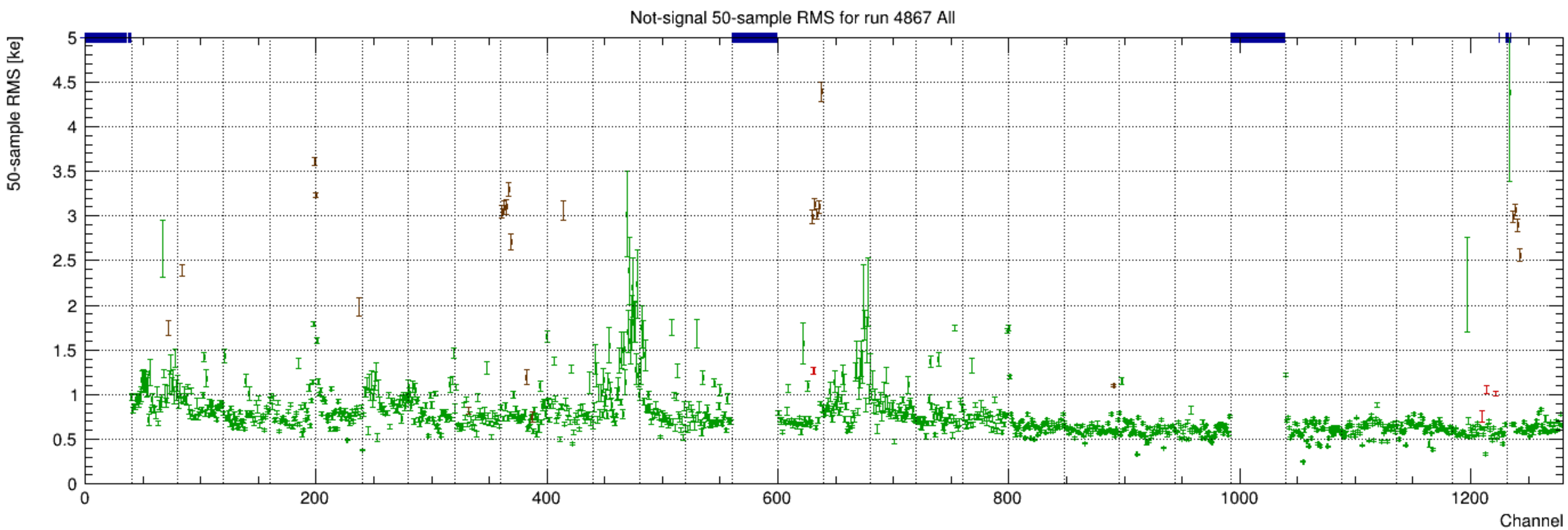


Not-signal 50-sample RMS for run 4866 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4867

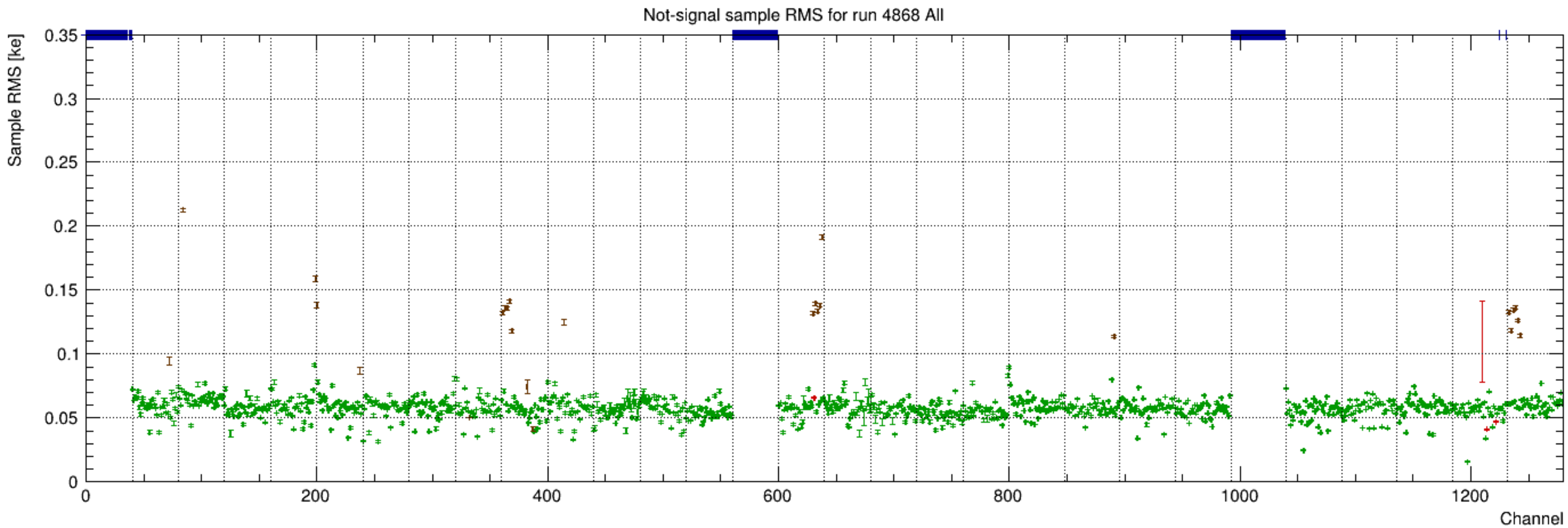


Not-signal sample RMS for run 4867 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel



Not-signal 50-sample RMS for run 4867 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4868


Not-signal sample RMS for run 4868 All
Sample RMS [ke]
0.35
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0.25
0.2
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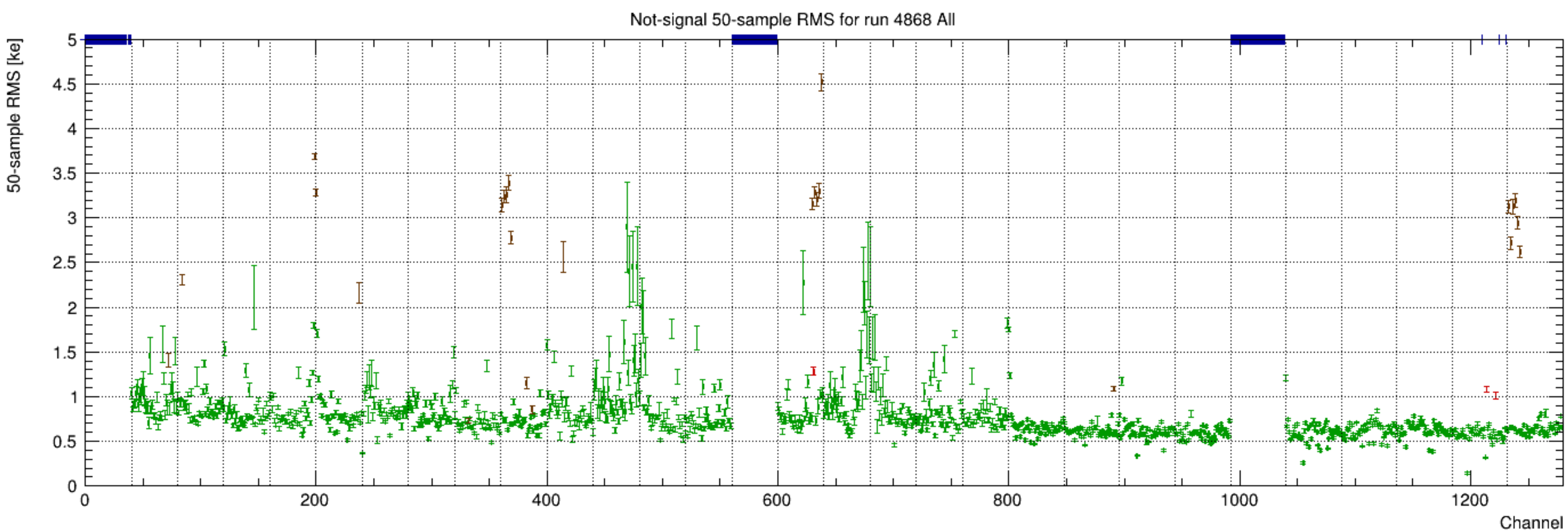
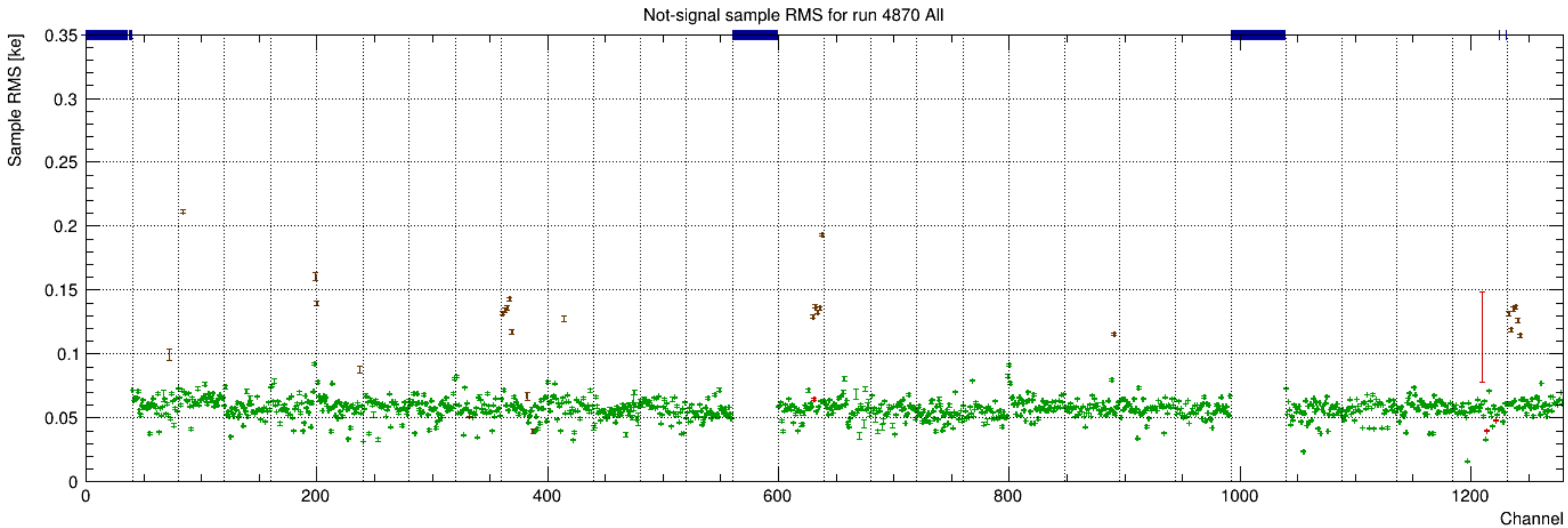
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel


Not-signal 50-sample RMS for run 4868 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4870



Not-signal sample RMS for run 4870 All
Sample RMS [ke]
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0.2
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0.1
0.05
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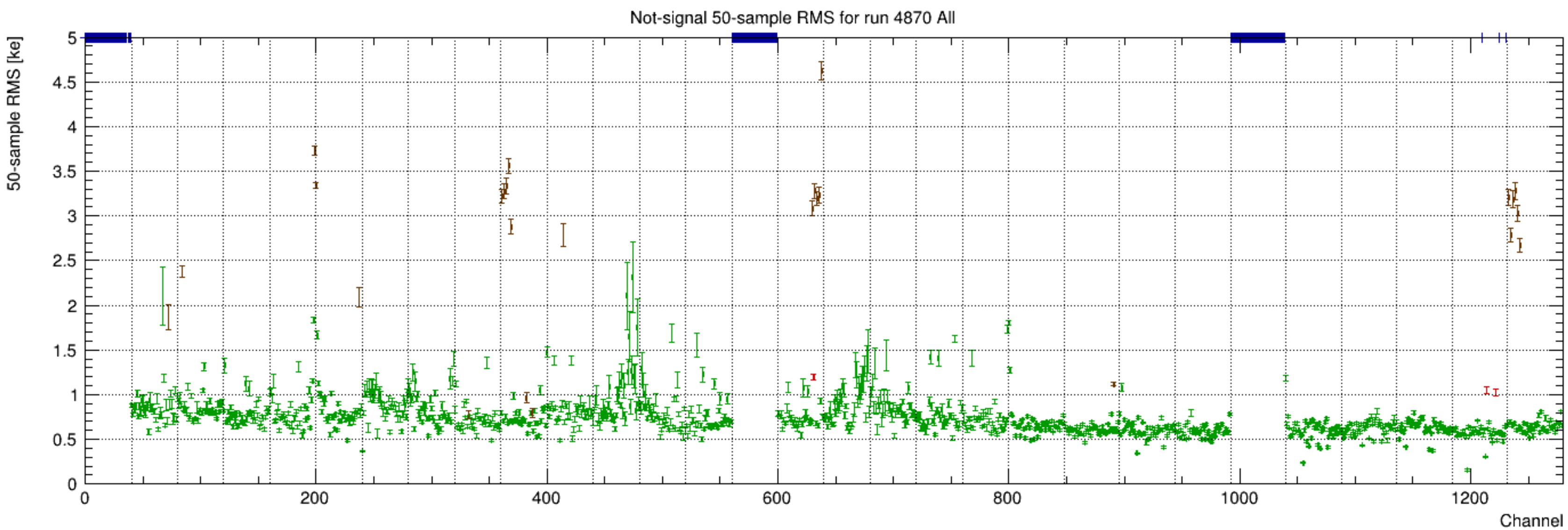
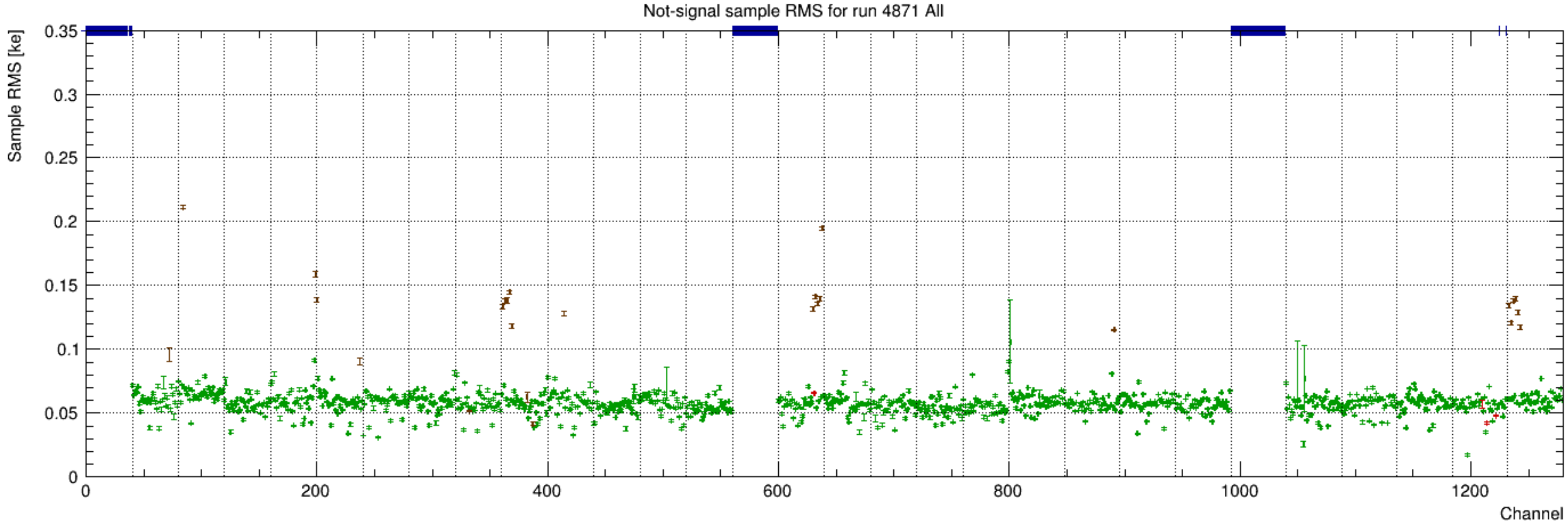
0
200
400
600
800
1000
1200
Channel



Not-signal 50-sample RMS for run 4870 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4871



Not-signal sample RMS for run 4871 All
Sample RMS [ke]
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0.2
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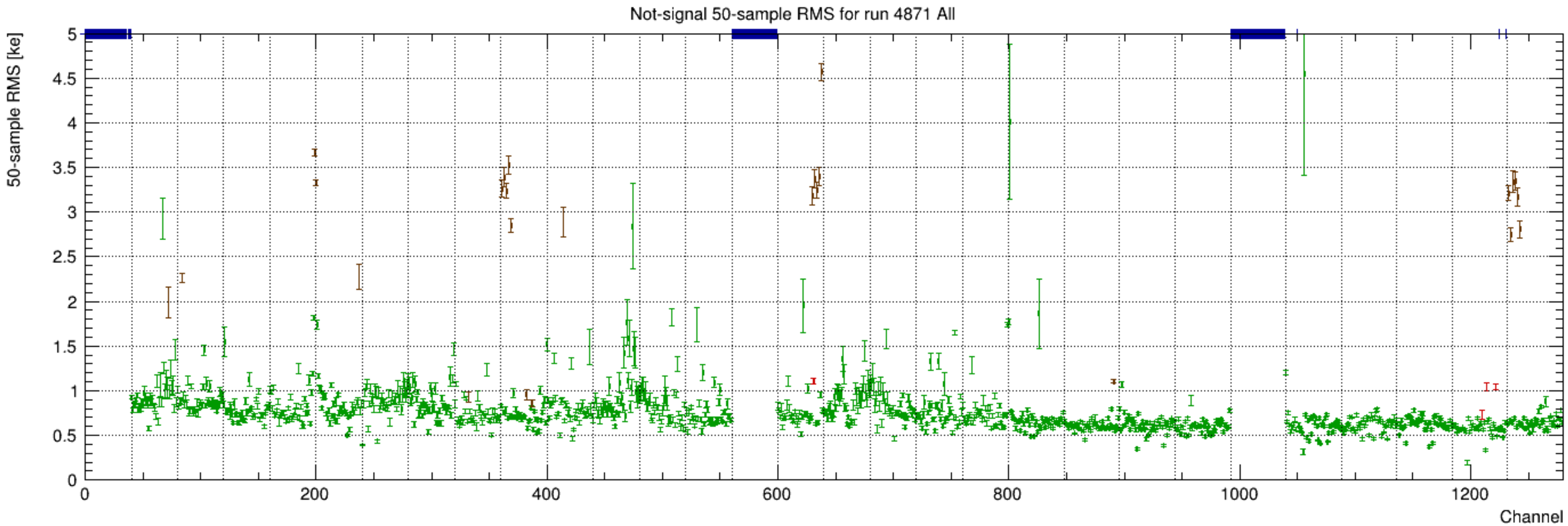
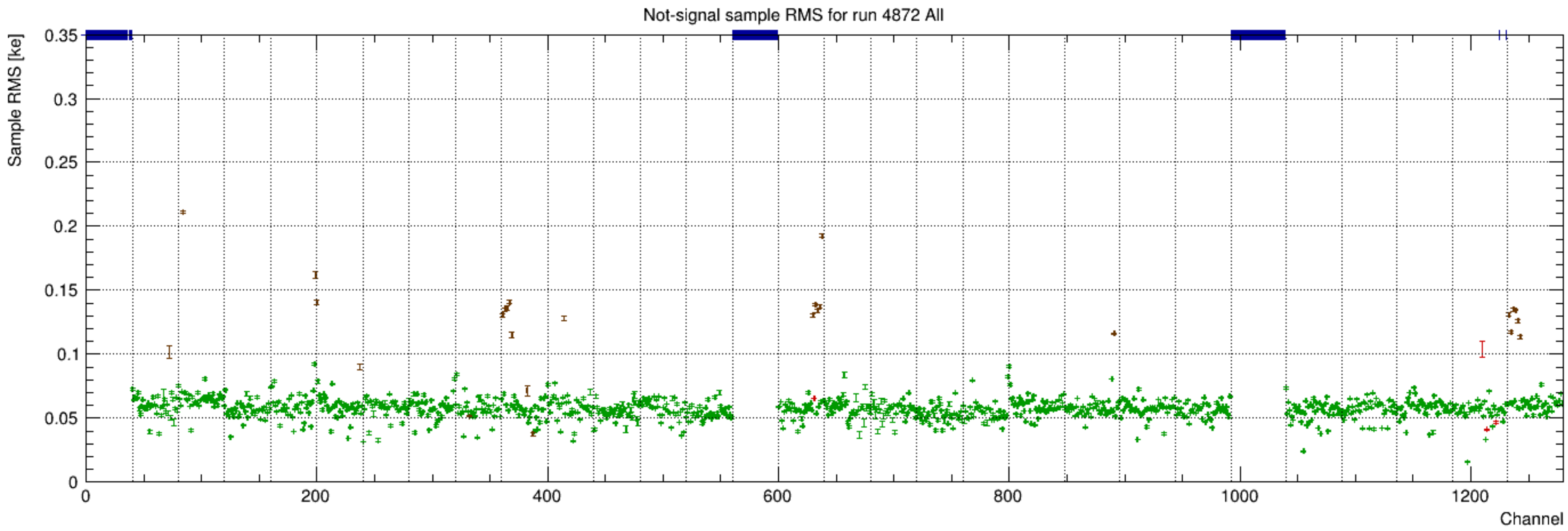
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel



Not-signal 50-sample RMS for run 4871 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4872



Not-signal sample RMS for run 4872 All
Sample RMS [ke]
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0.3
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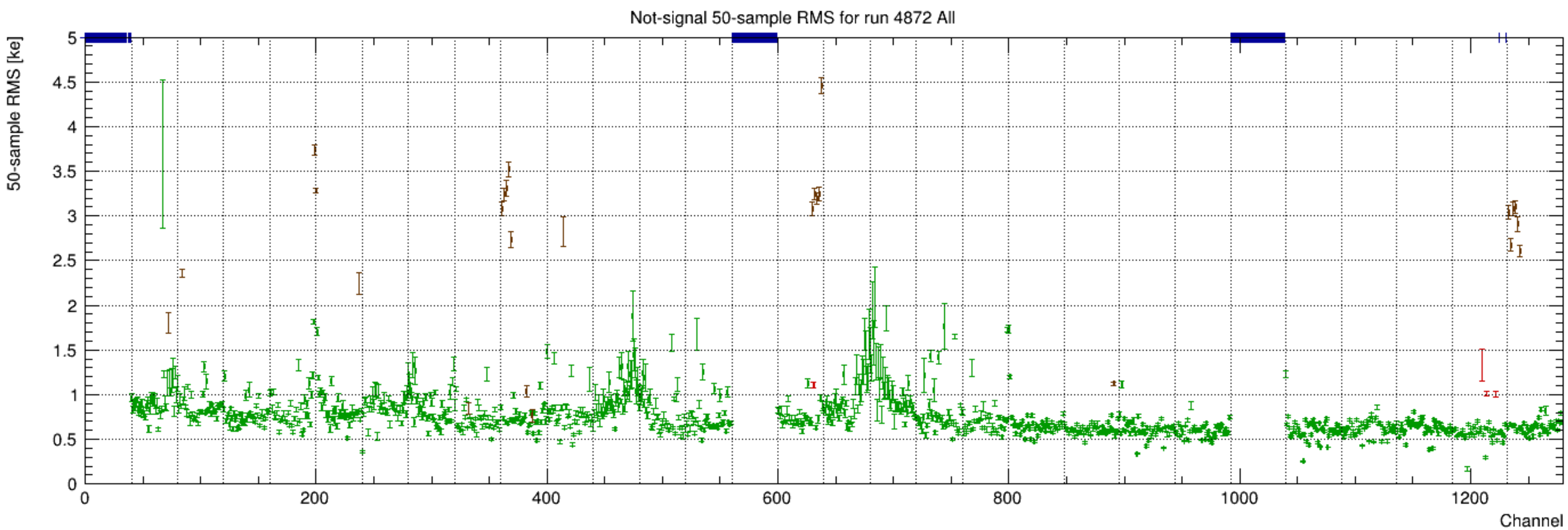
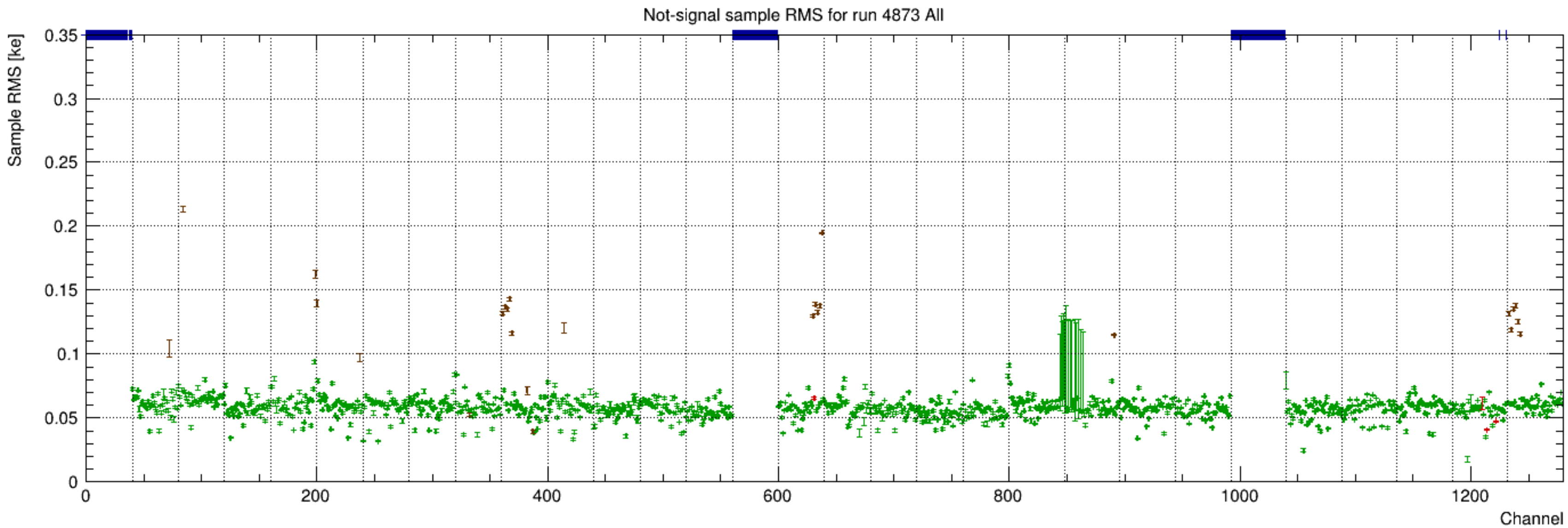
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel



Not-signal 50-sample RMS for run 4872 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4873



Not-signal sample RMS for run 4873 All
Sample RMS [ke]
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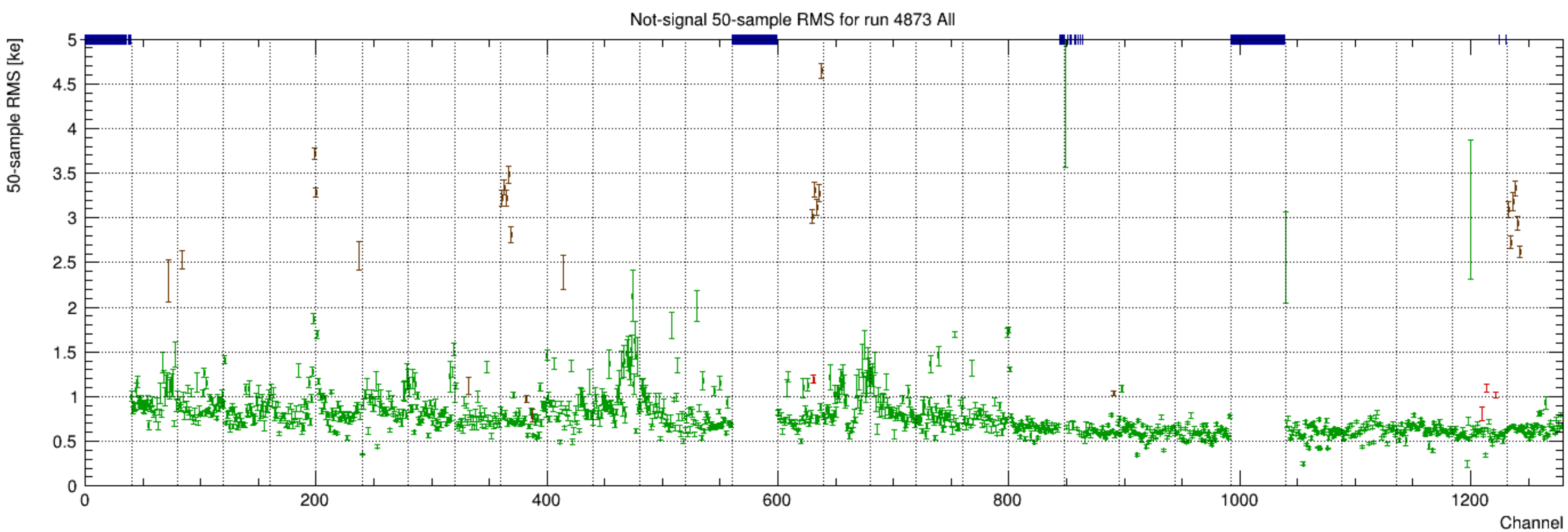
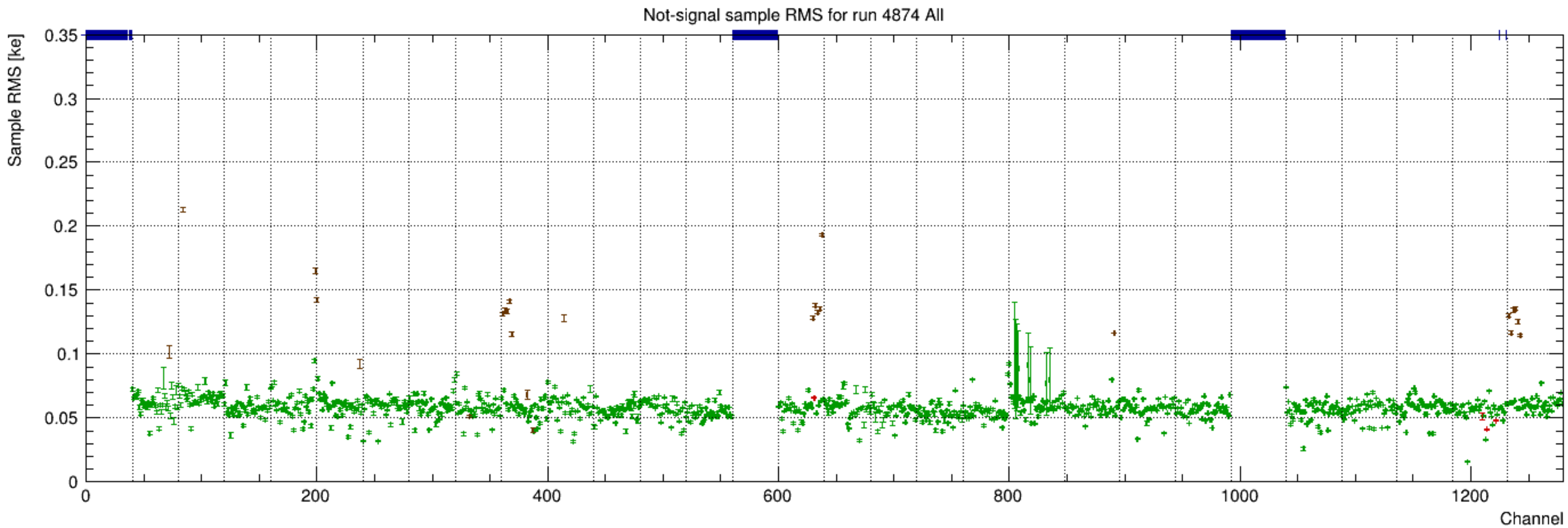
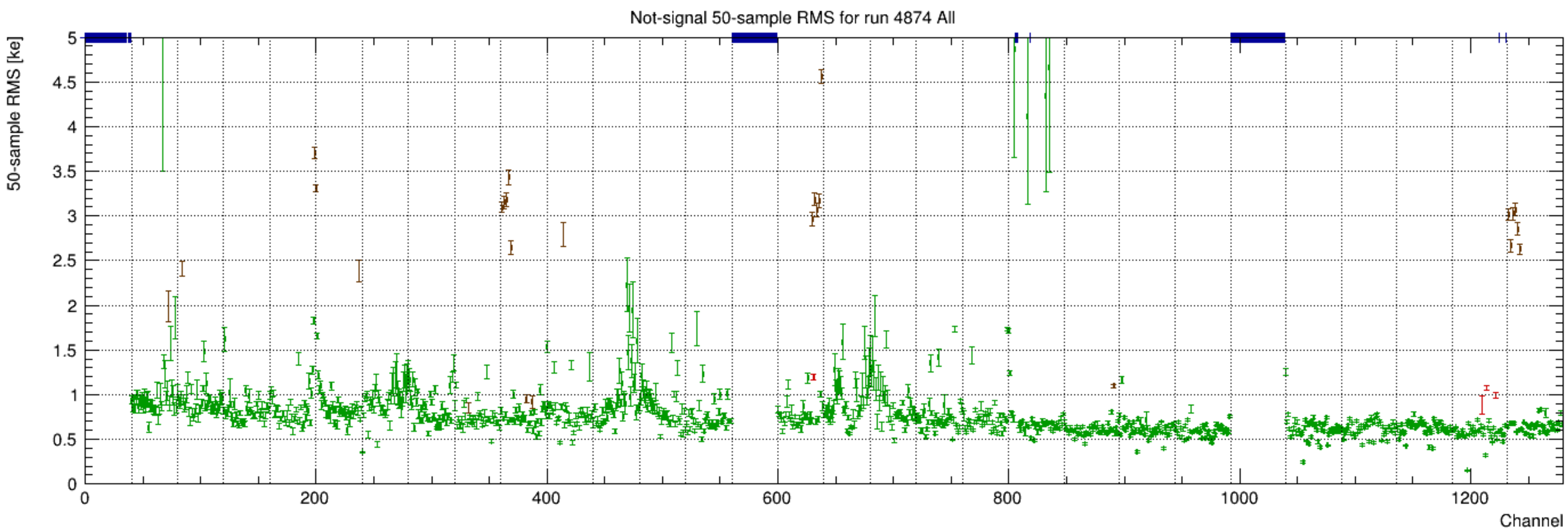
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel



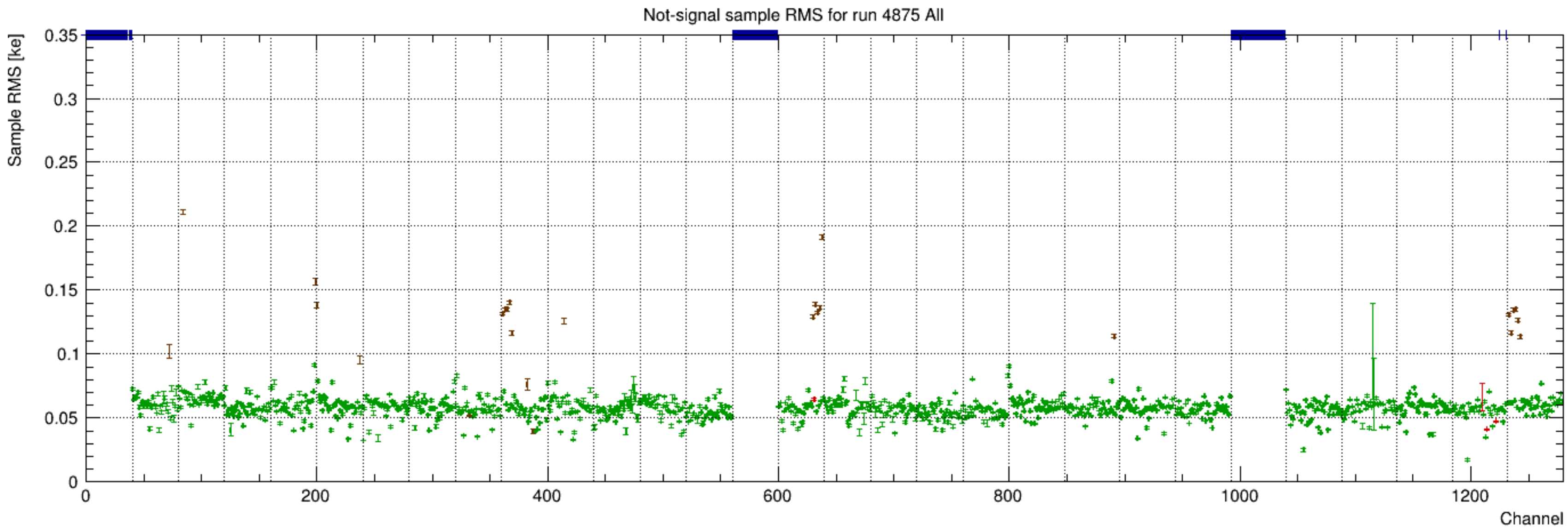
Not-signal 50-sample RMS for run 4873 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4874


Not-signal sample RMS for run 4874 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel


Not-signal 50-sample RMS for run 4874 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4875


Not-signal sample RMS for run 4875 All
Sample RMS [ke]
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0.3
0.25
0.2
0.15
0.1
0.05
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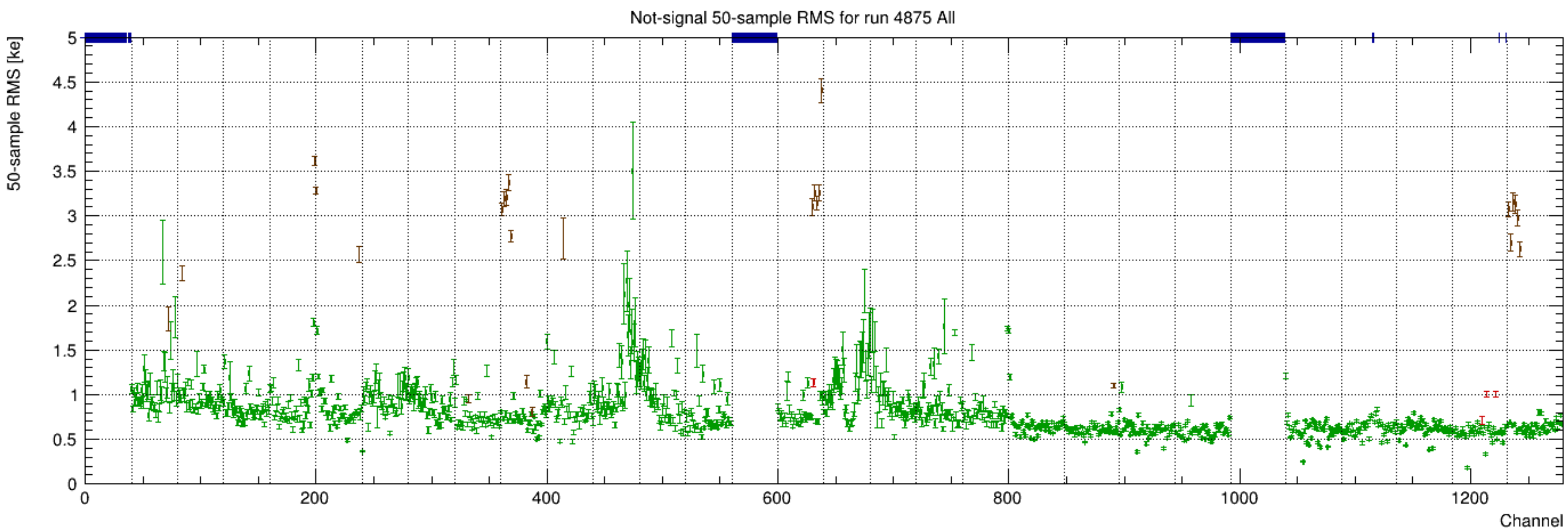
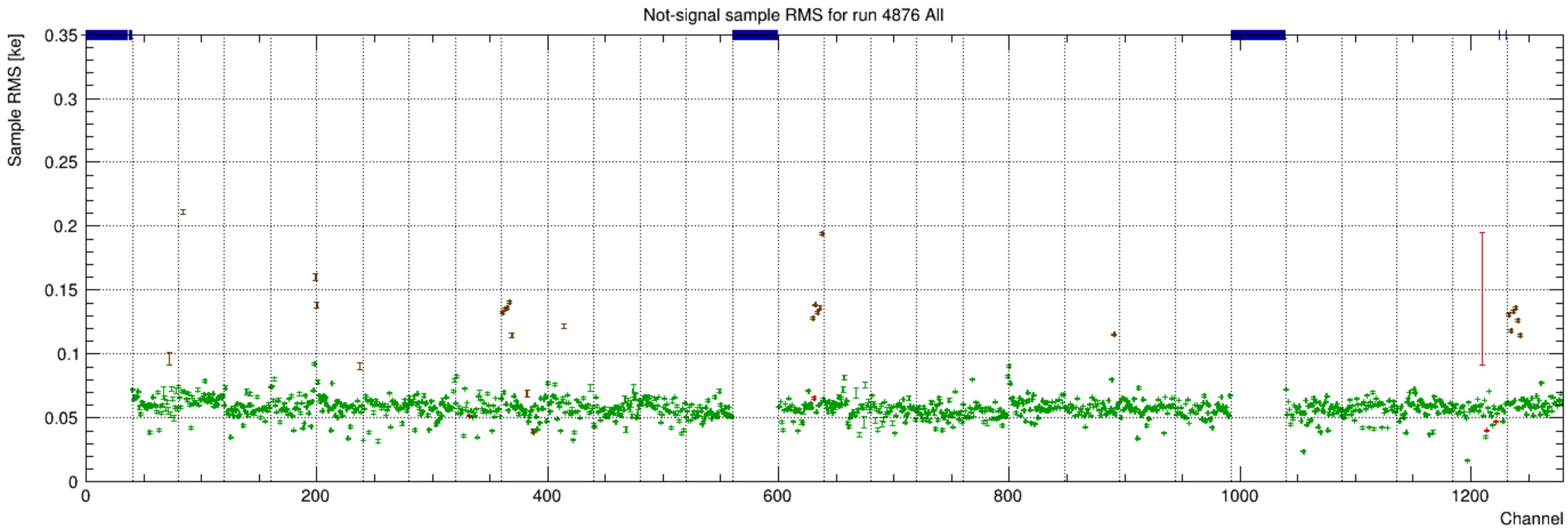
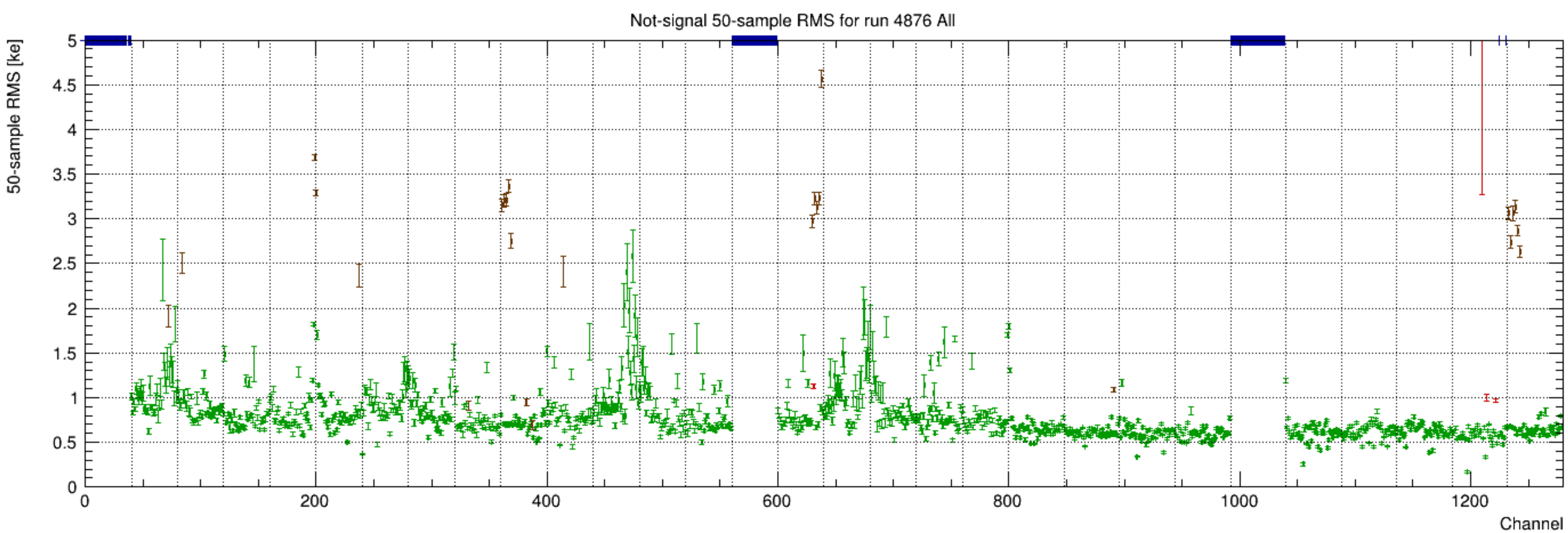
0
200
400
600
800
1000
1200
Channel


Not-signal 50-sample RMS for run 4875 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4876

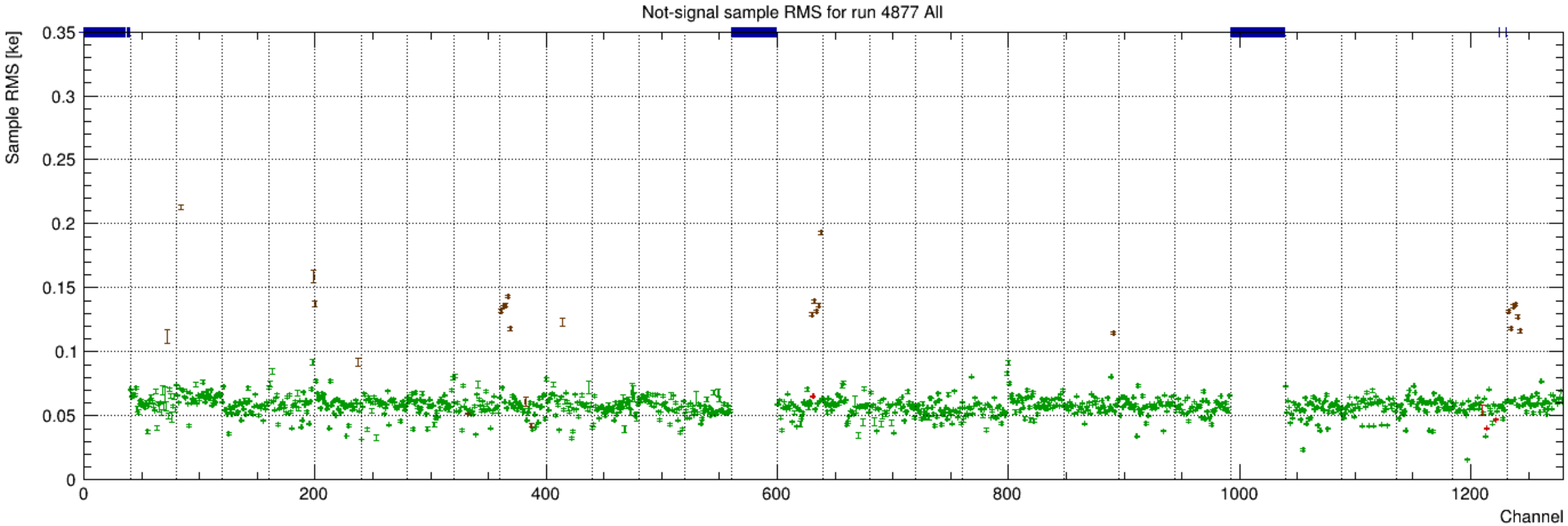


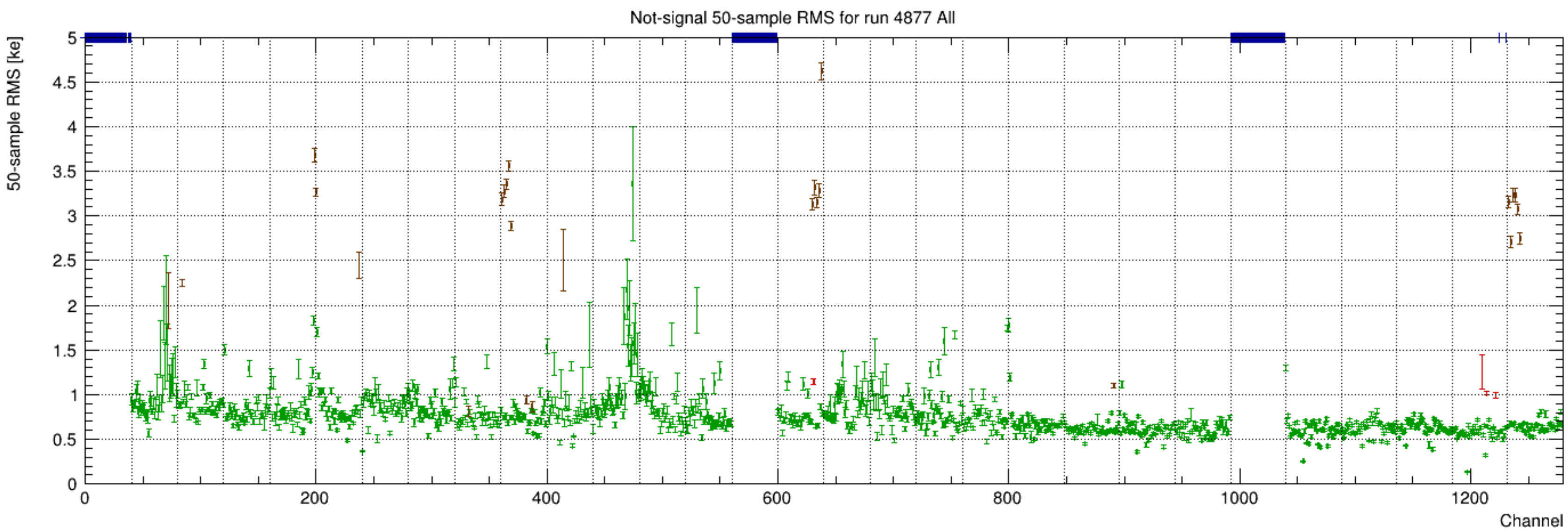
Not-signal sample RMS for run 4876 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel



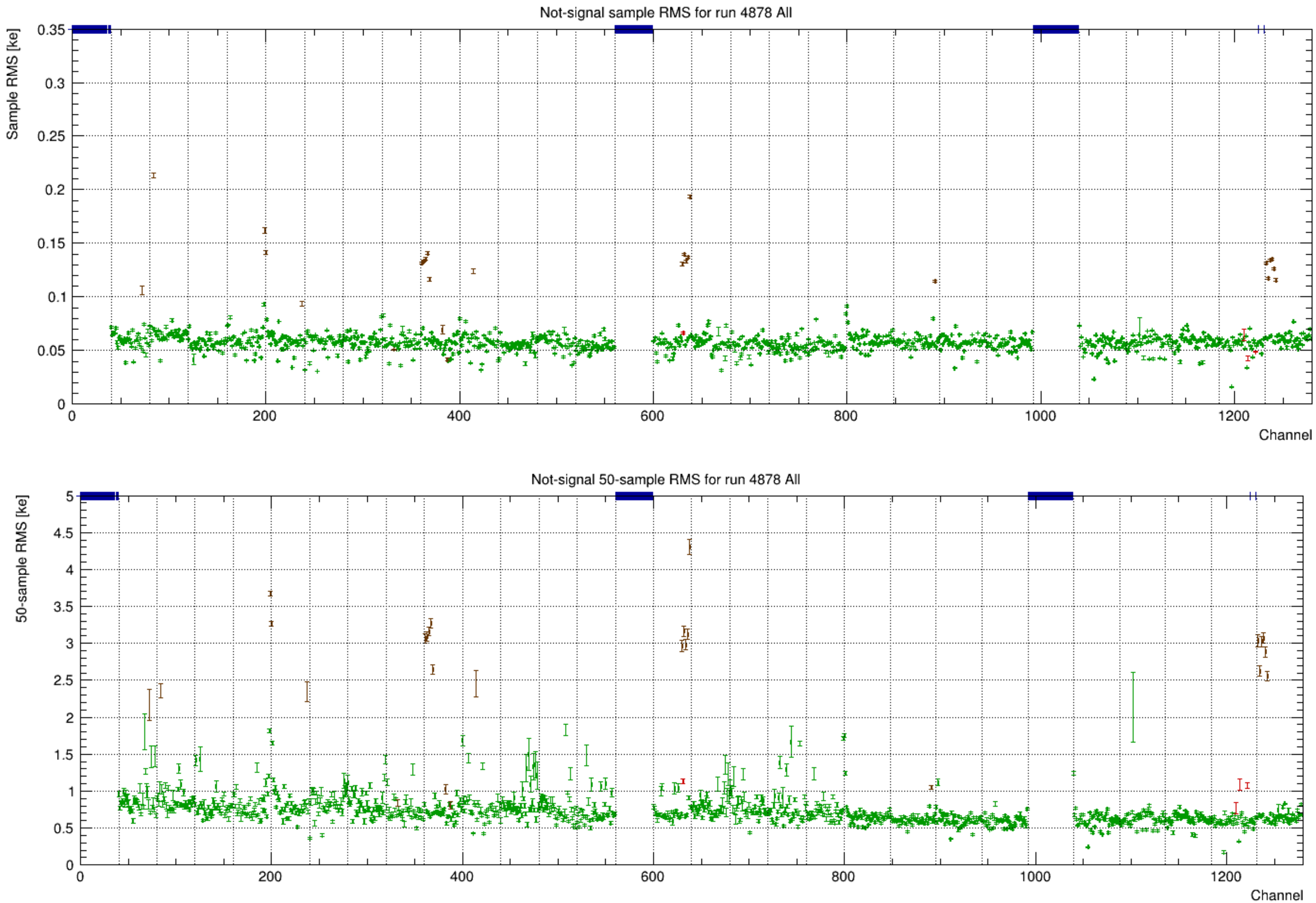
Not-signal 50-sample RMS for run 4876 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4877


Not-signal sample RMS for run 4877 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel

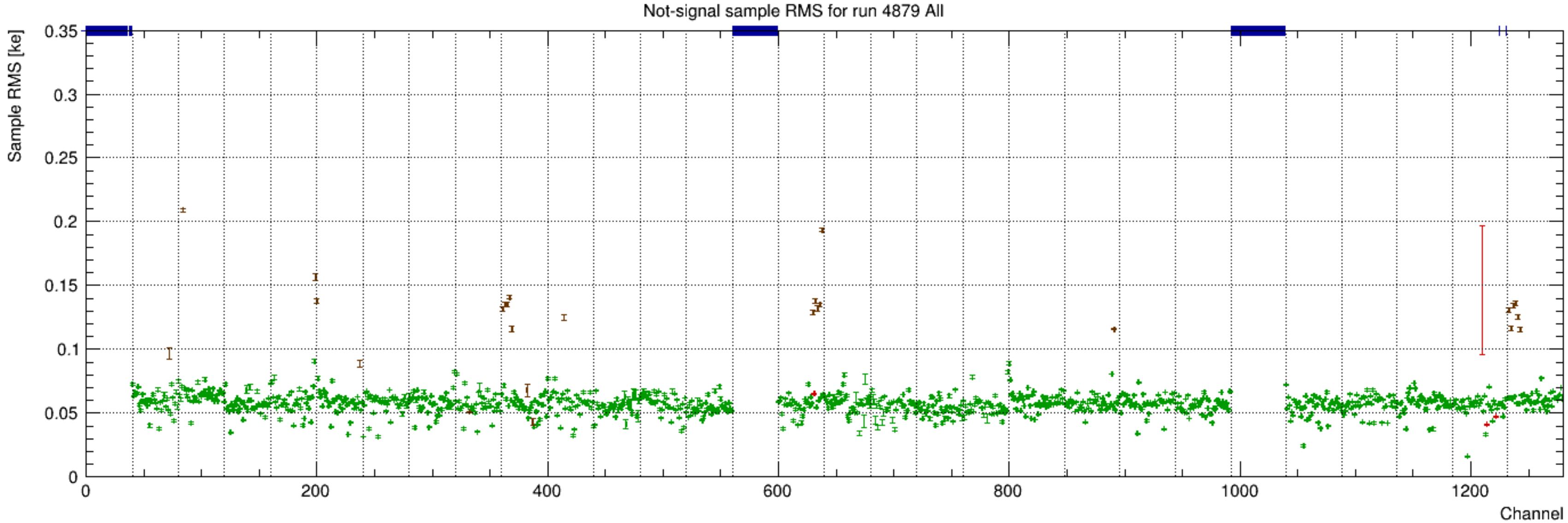

Not-signal 50-sample RMS for run 4877 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

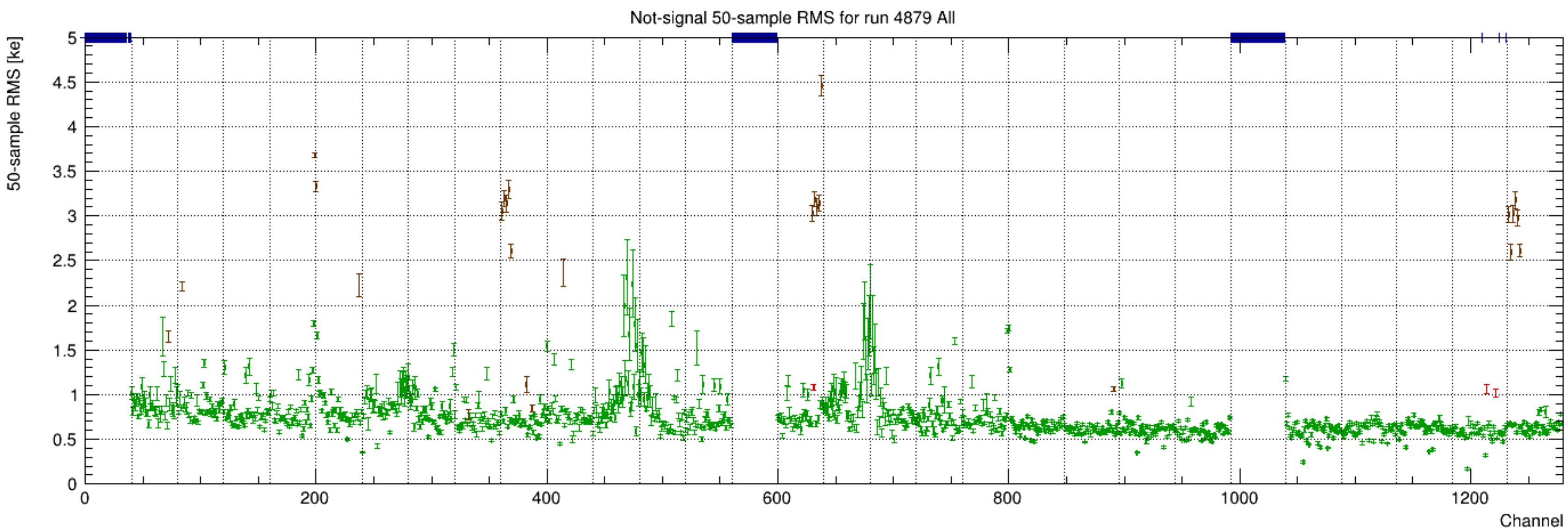
4878



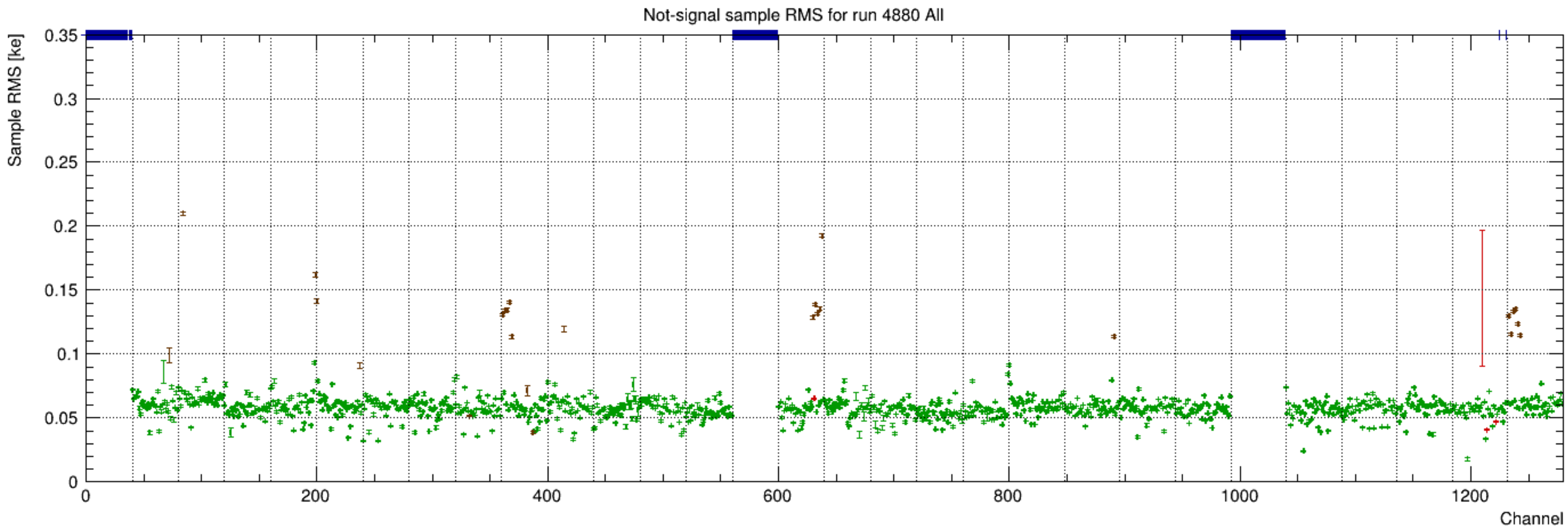
Not-signal sample RMS for run 4878 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel
Not-signal 50-sample RMS for run 4878 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4879

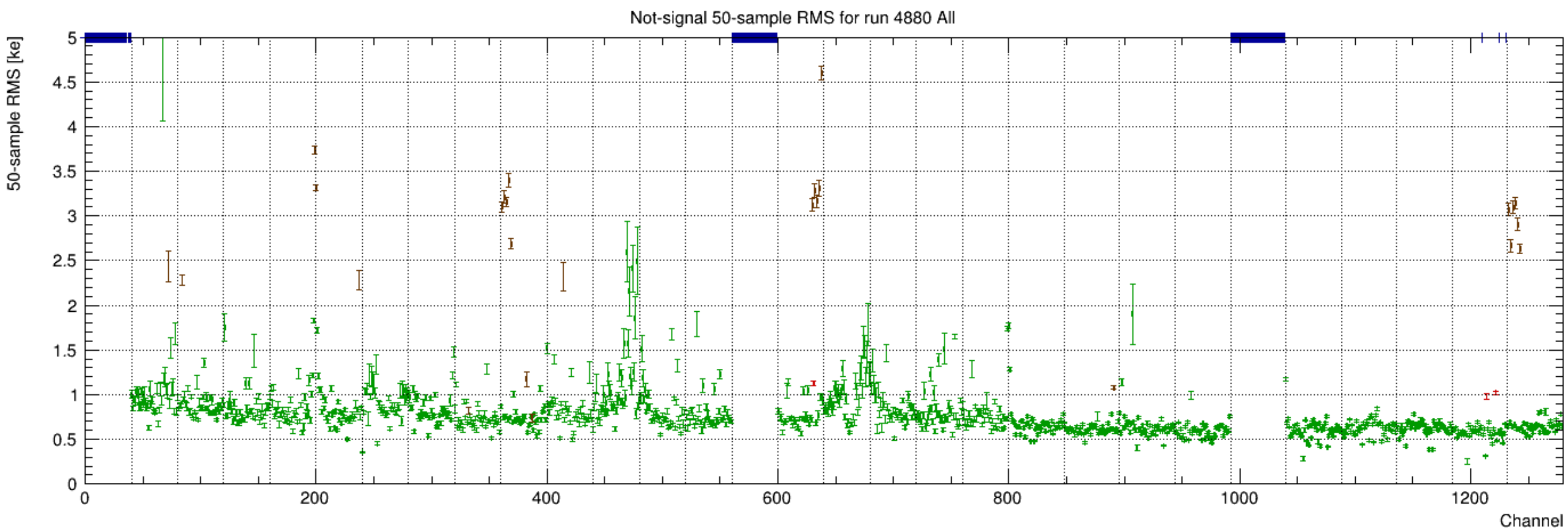

Not-signal sample RMS for run 4879 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel


Not-signal 50-sample RMS for run 4879 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4880

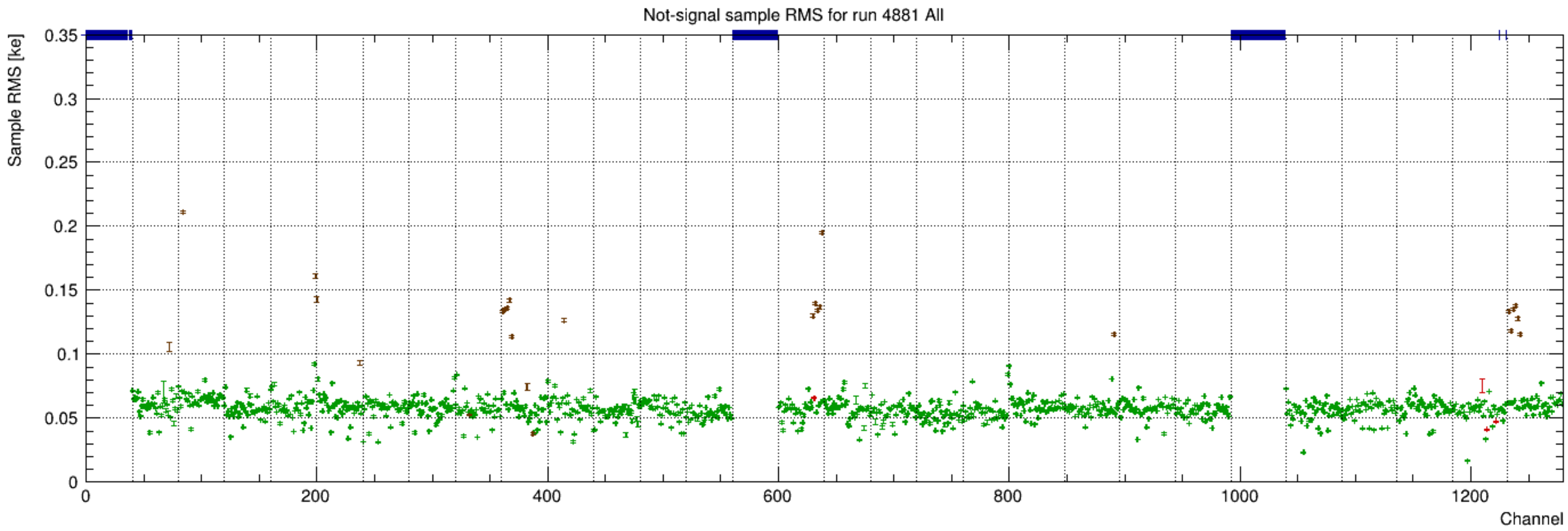


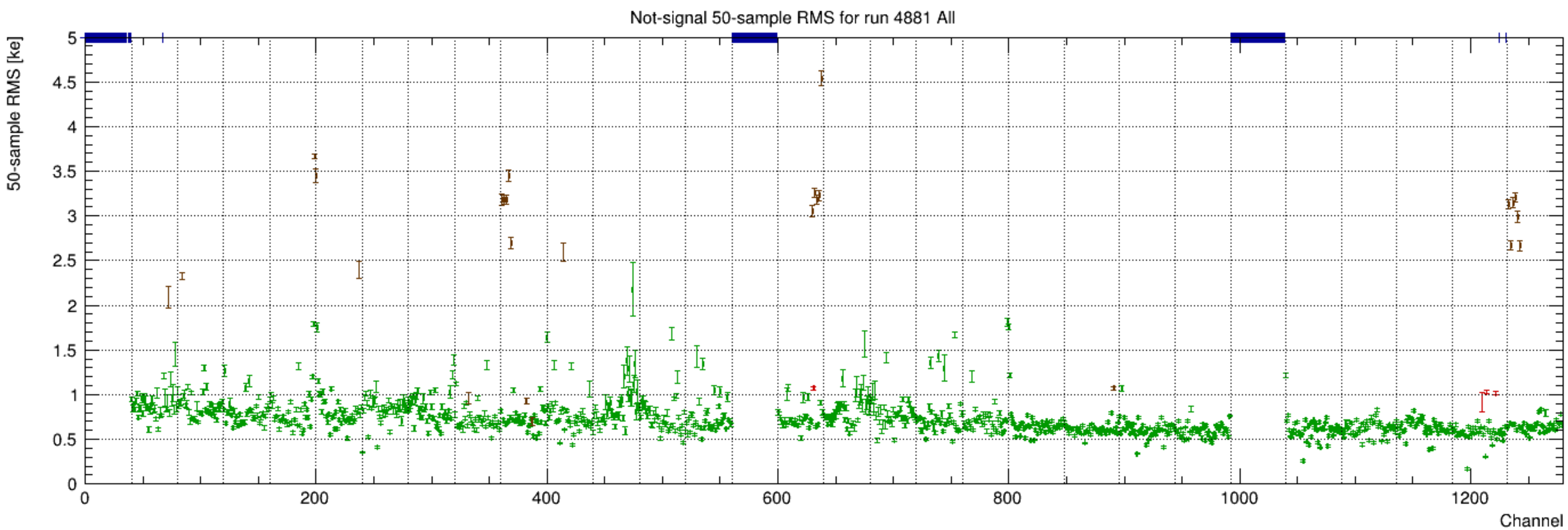
Not-signal sample RMS for run 4880 All
Sample RMS [ke]
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0
200
400
600
800
1000
1200
Channel



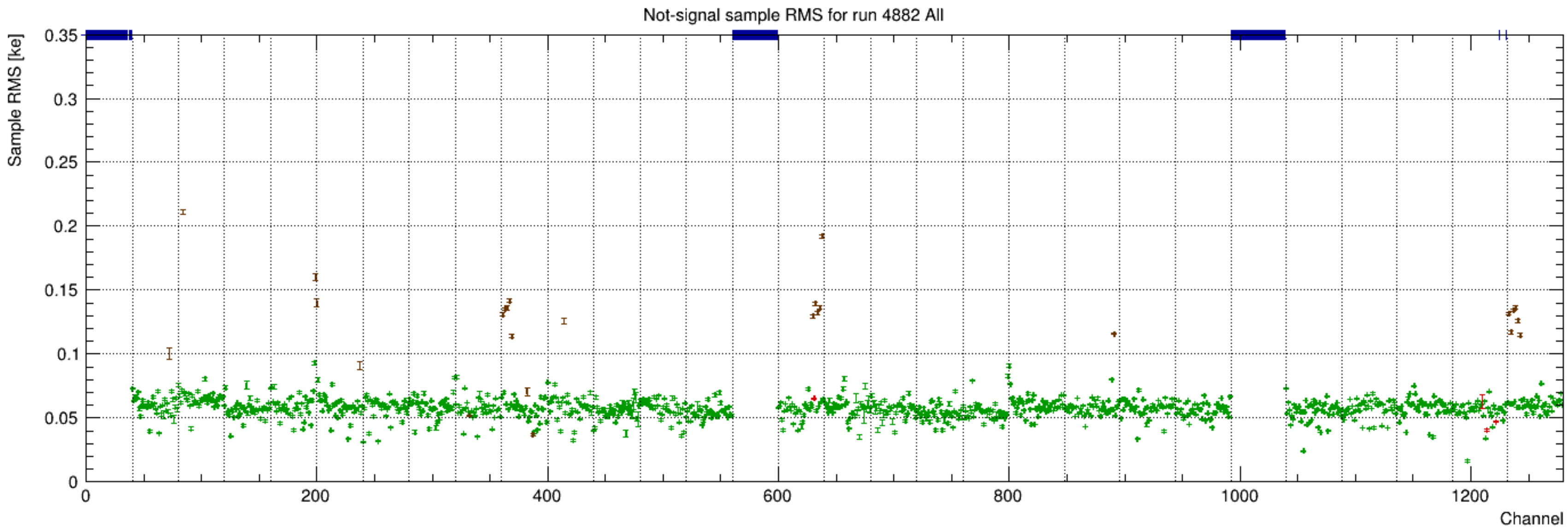
Not-signal 50-sample RMS for run 4880 All
50-sample RMS [ke]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
200
400
600
800
1000
1200
Channel

4881

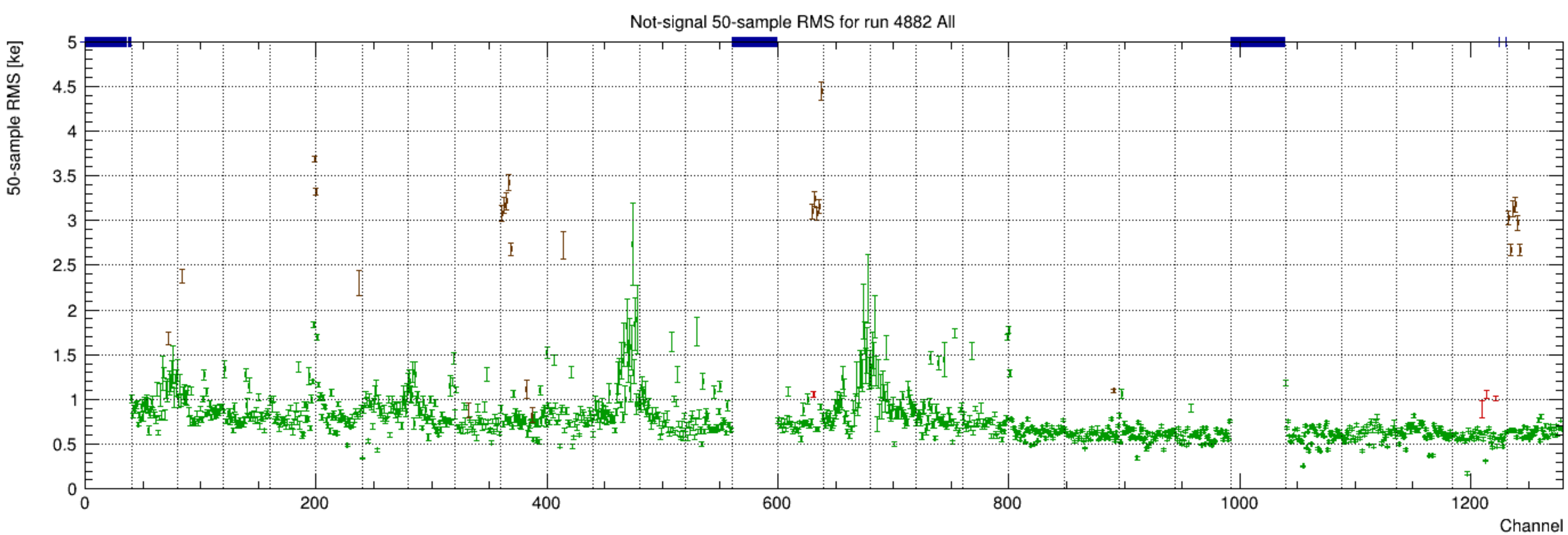

Not-signal sample RMS for run 4881 All
Sample RMS [ke]
0 0.05 0.1 0.15 0.2 0.25 0.3 0.35
0 200 400 600 800 1000 1200
Channel


Not-signal 50-sample RMS for run 4881 All
50-sample RMS [ke]
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
0 200 400 600 800 1000 1200
Channel

4882

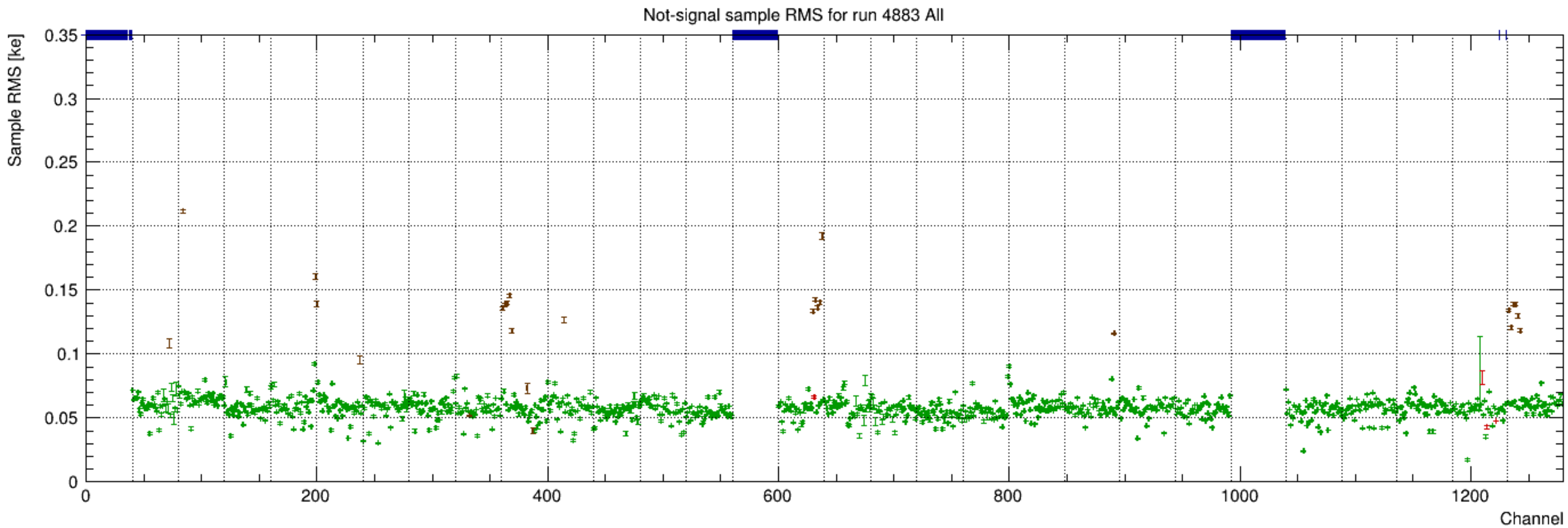


Not-signal sample RMS for run 4882 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel

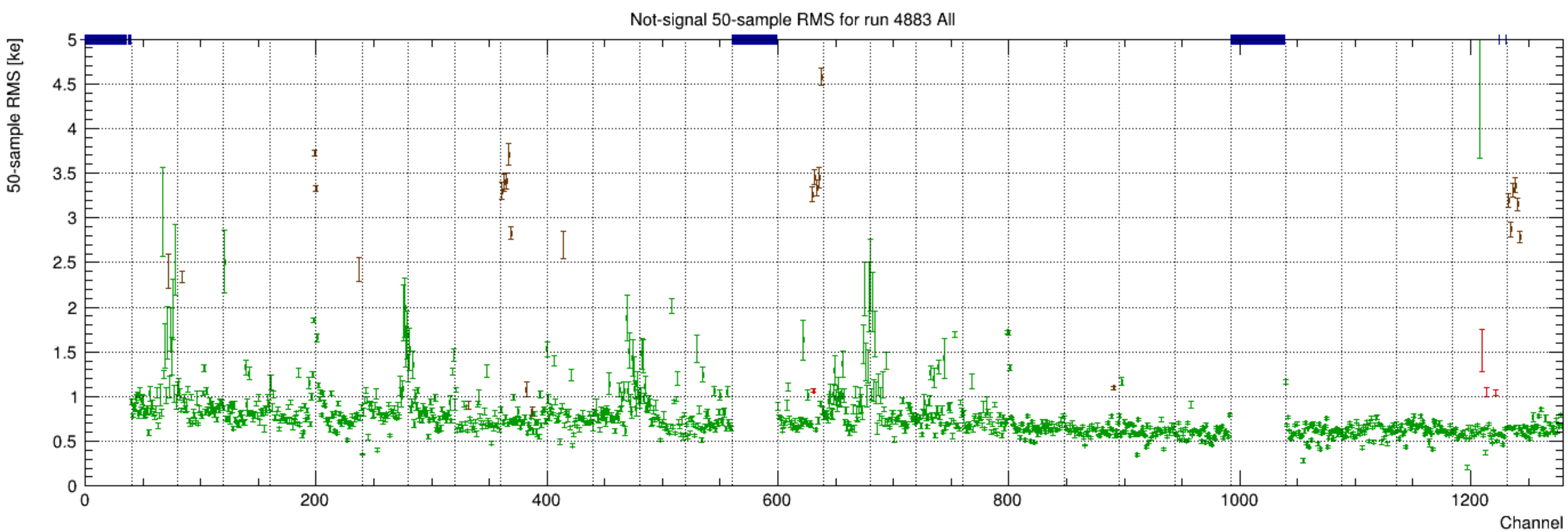


Not-signal 50-sample RMS for run 4882 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4883

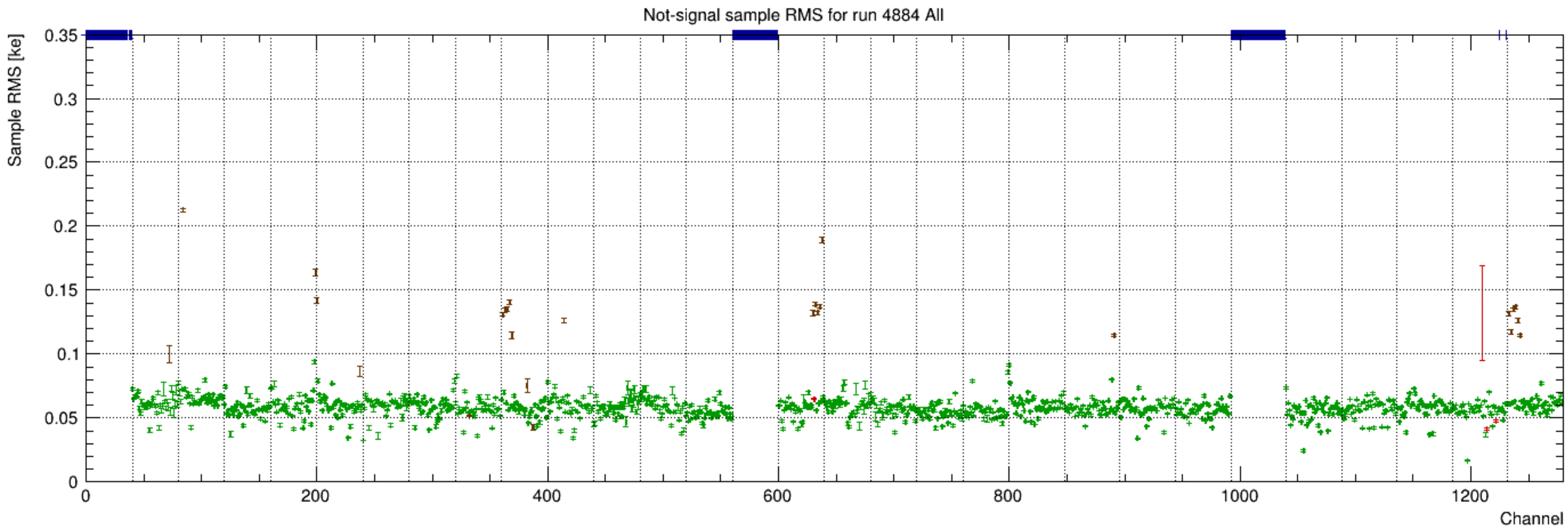


Not-signal sample RMS for run 4883 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel

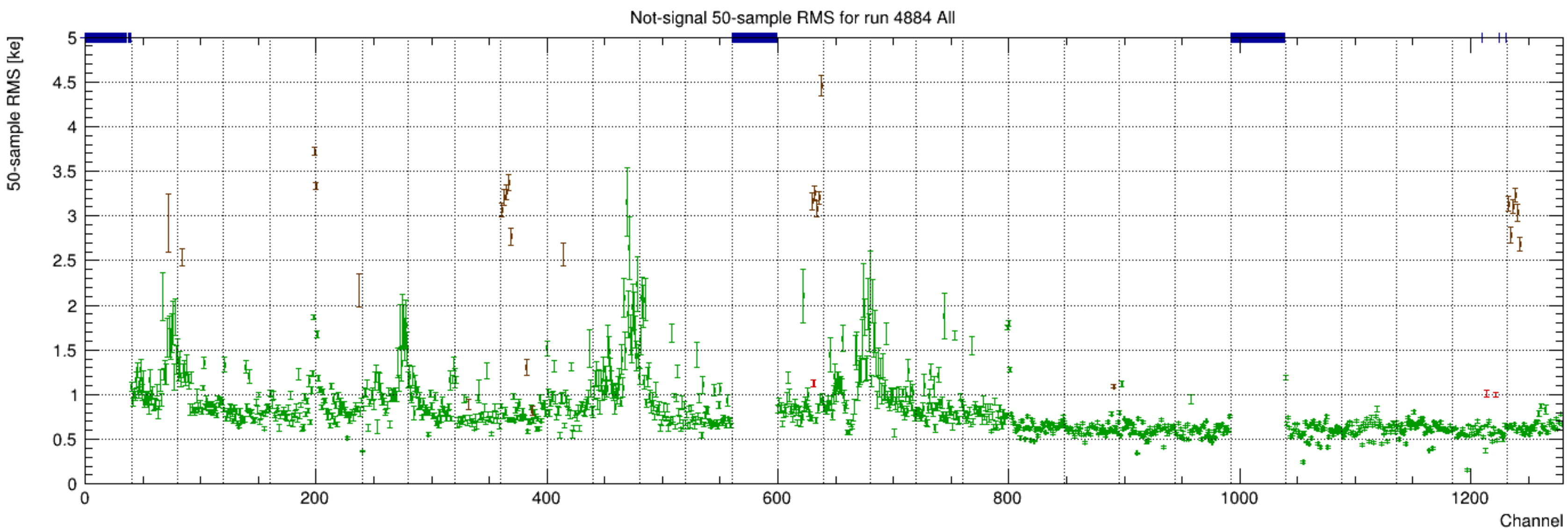


Not-signal 50-sample RMS for run 4883 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4884

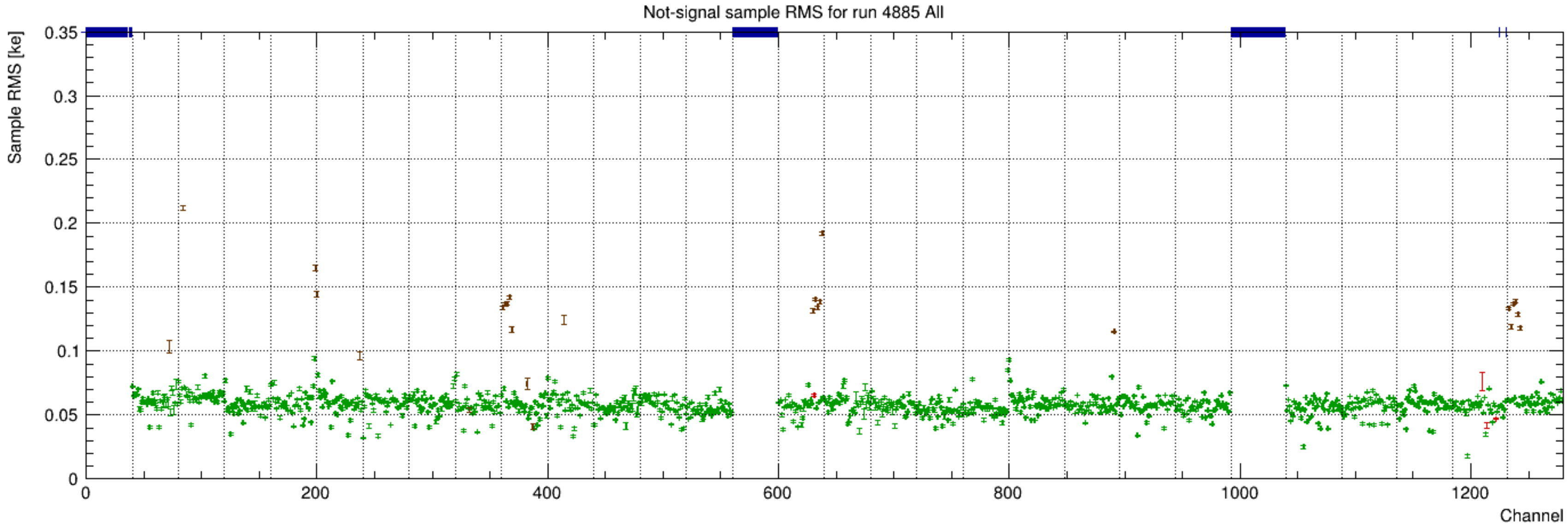


Not-signal sample RMS for run 4884 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel

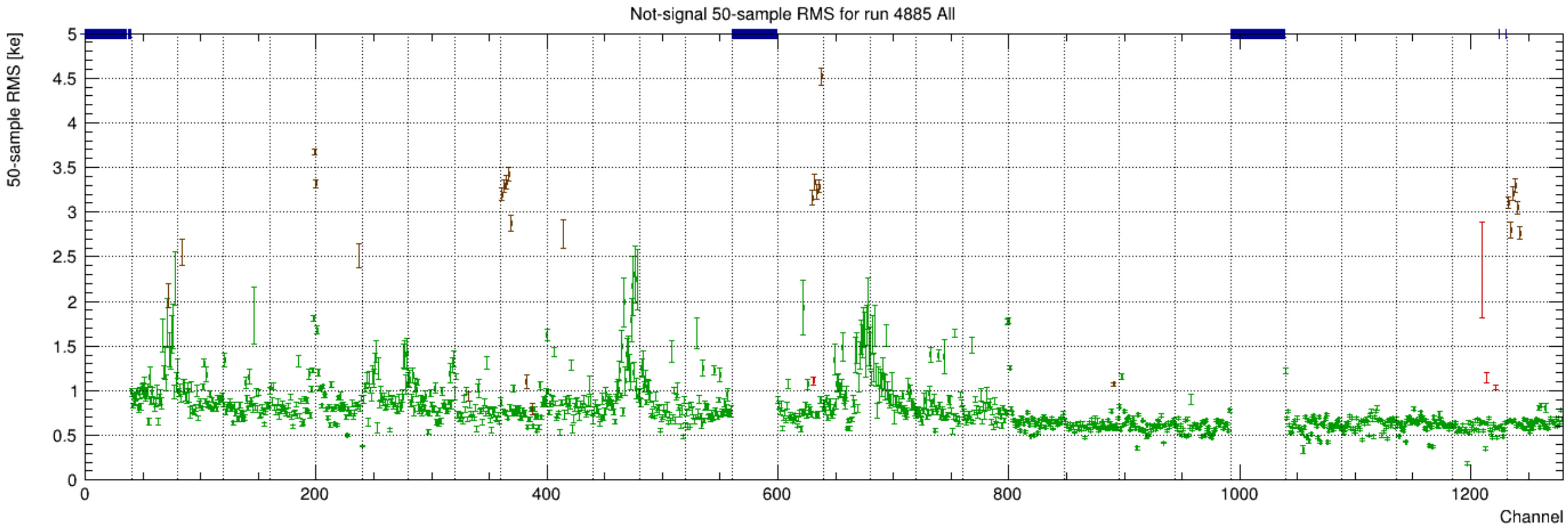


Not-signal 50-sample RMS for run 4884 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4885

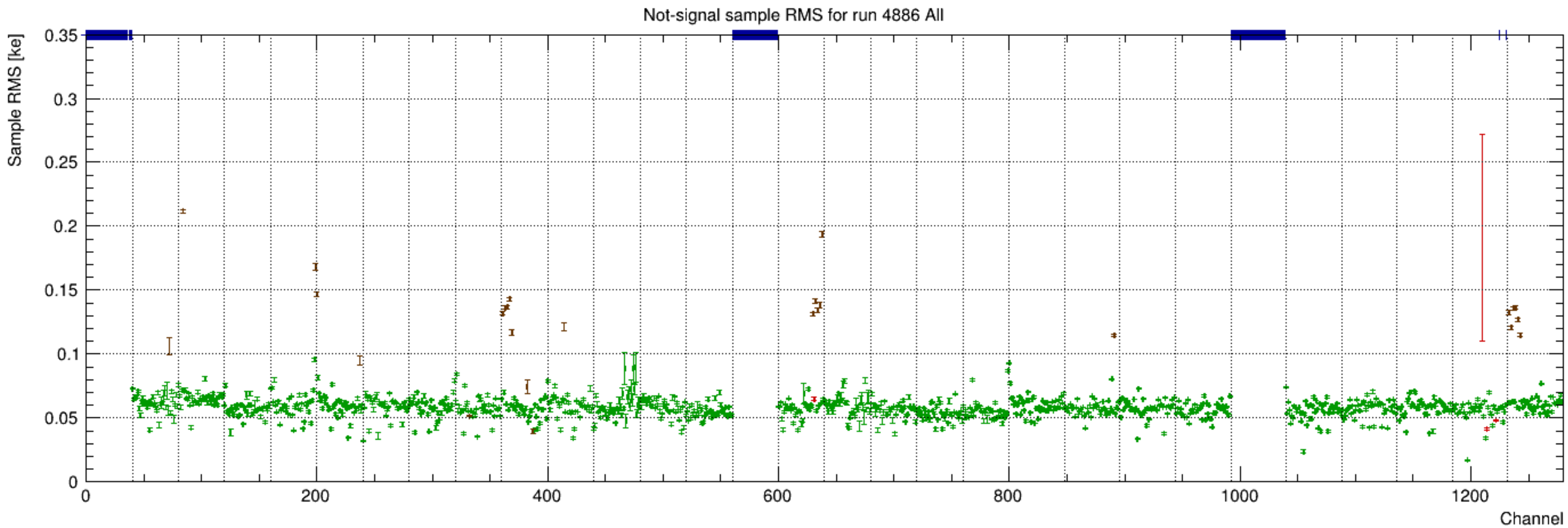


Not-signal sample RMS for run 4885 All
Sample RMS [ke]
Channel

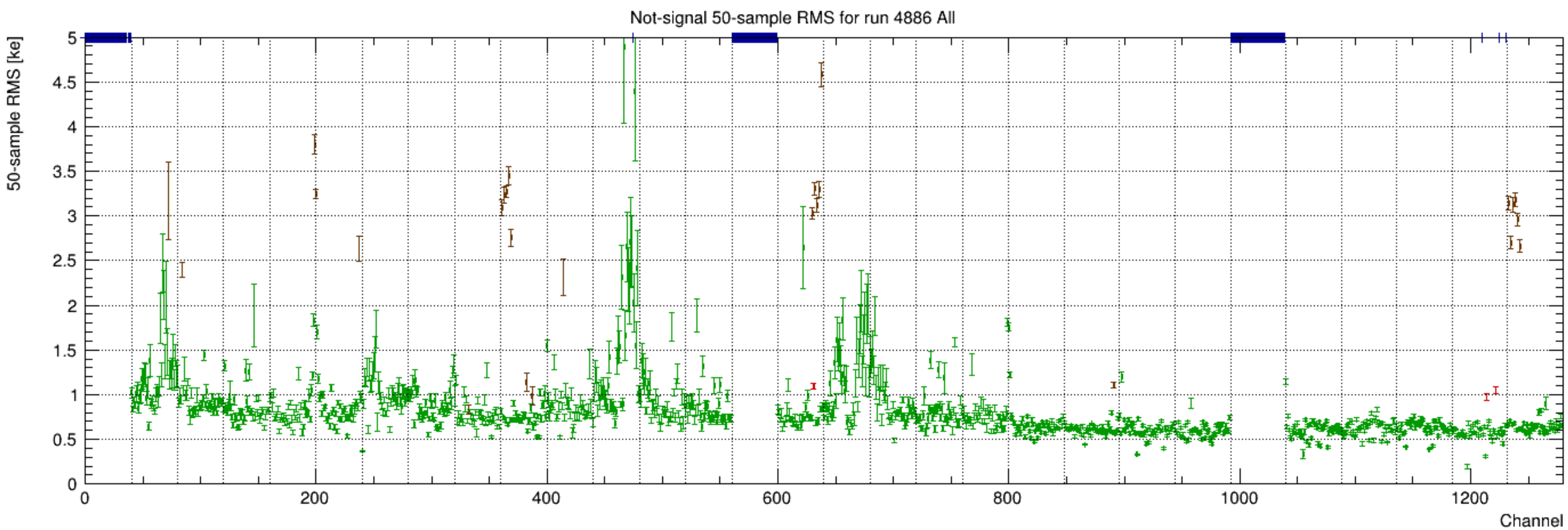


Not-signal 50-sample RMS for run 4885 All
50-sample RMS [ke]
Channel

4886

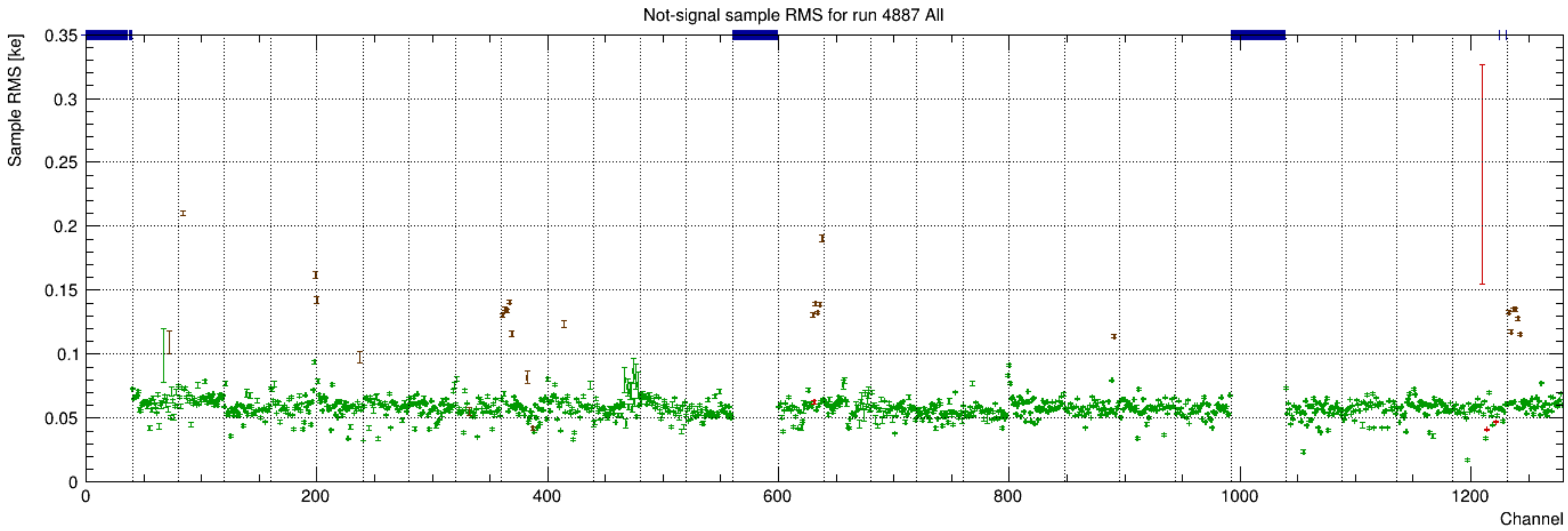


Not-signal sample RMS for run 4886 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel

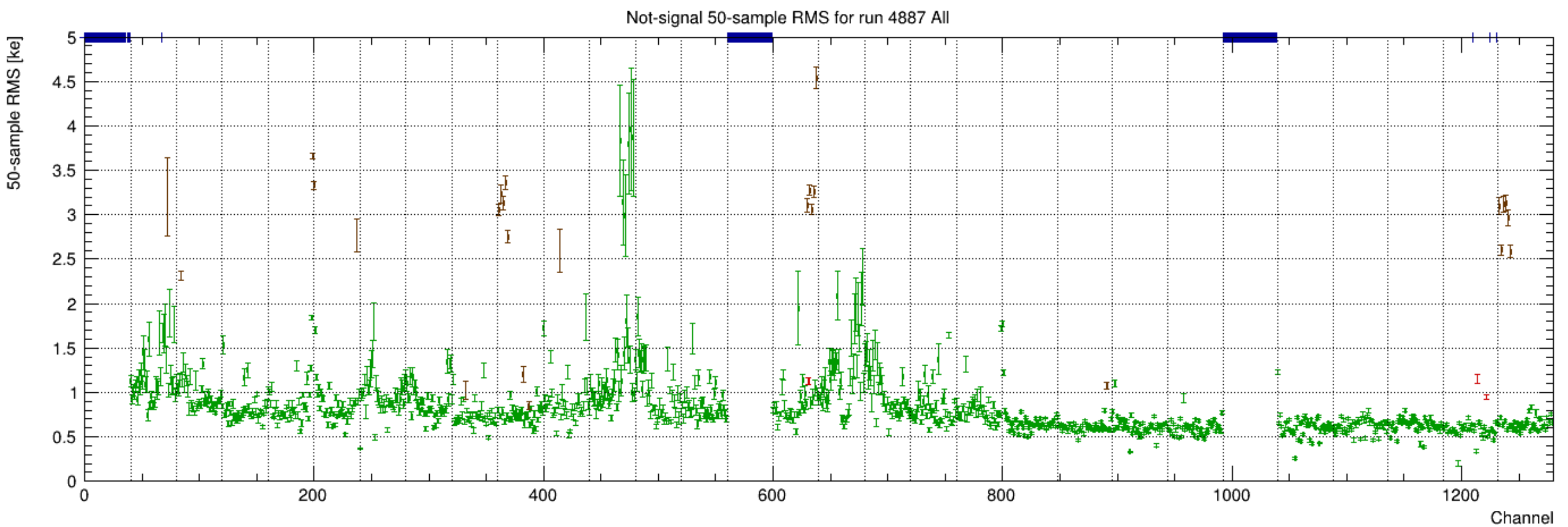


Not-signal 50-sample RMS for run 4886 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4887

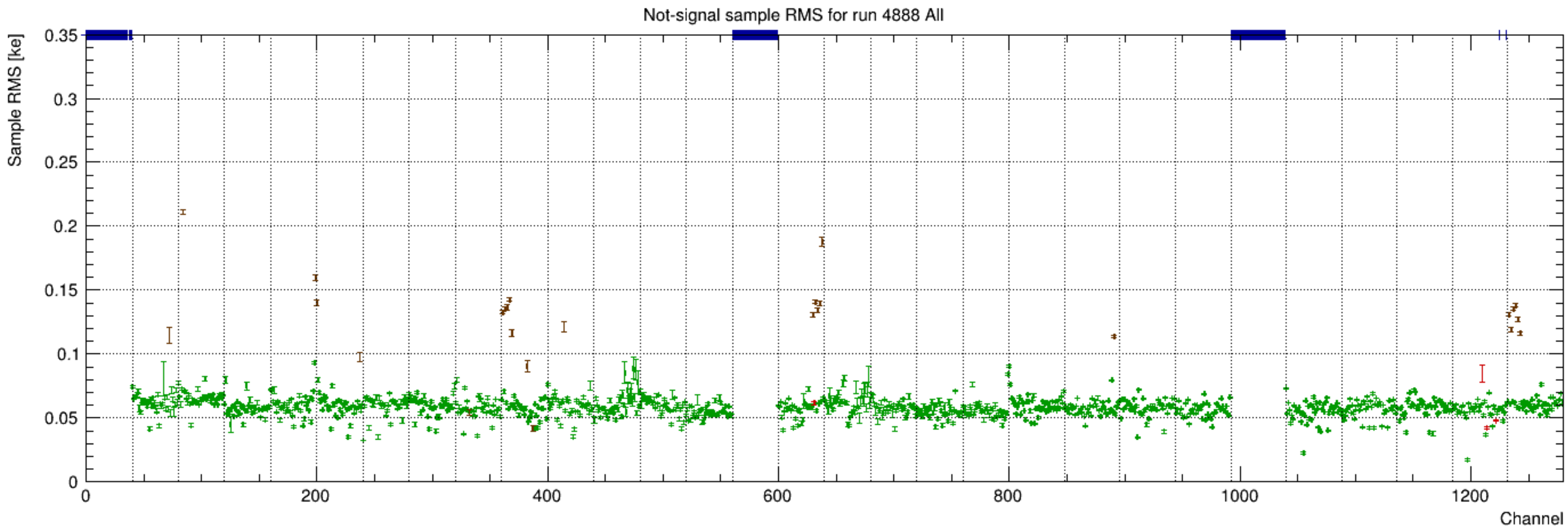


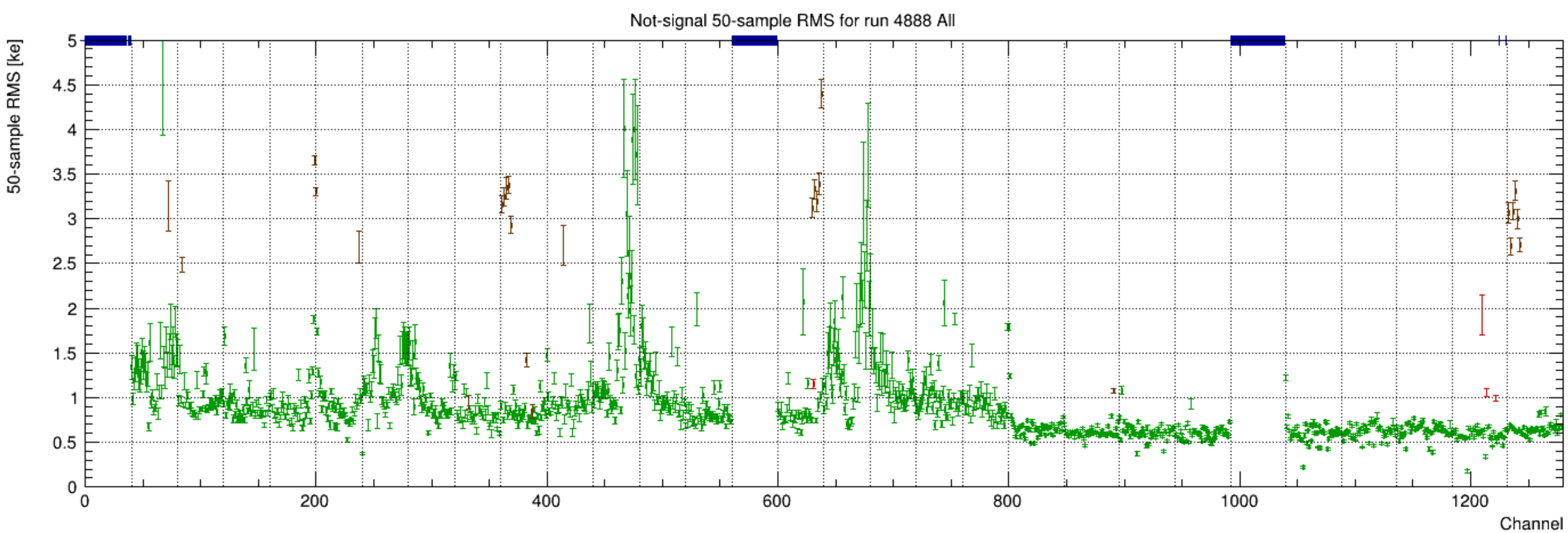
Not-signal sample RMS for run 4887 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel



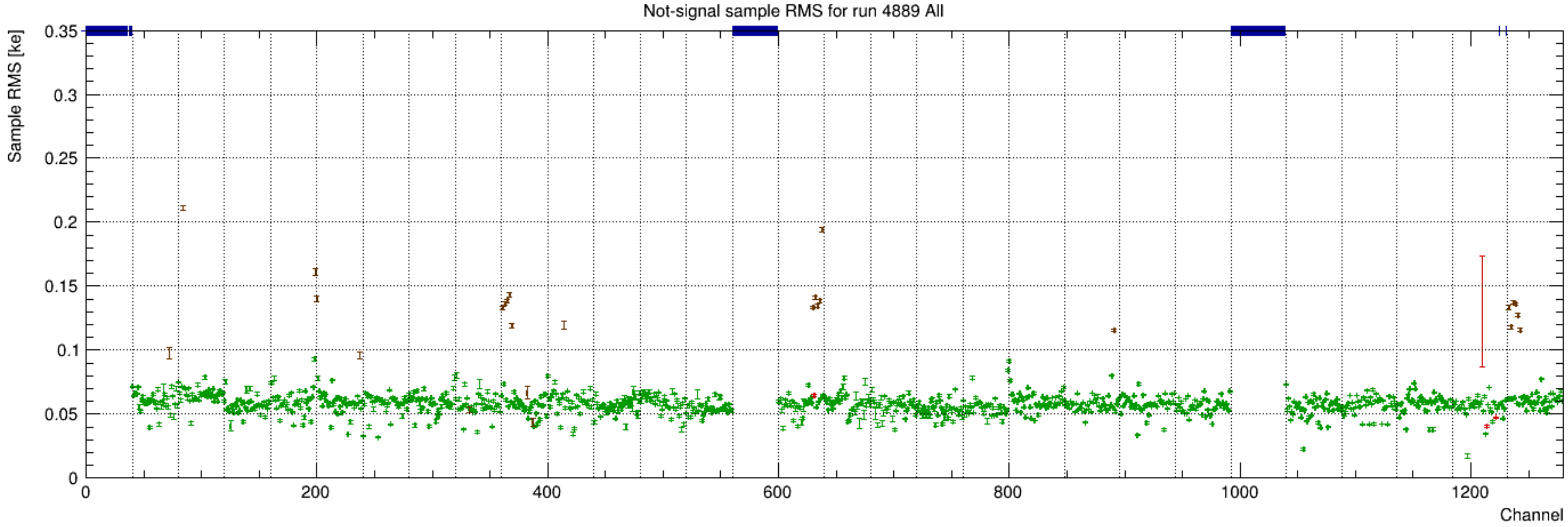
Not-signal 50-sample RMS for run 4887 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

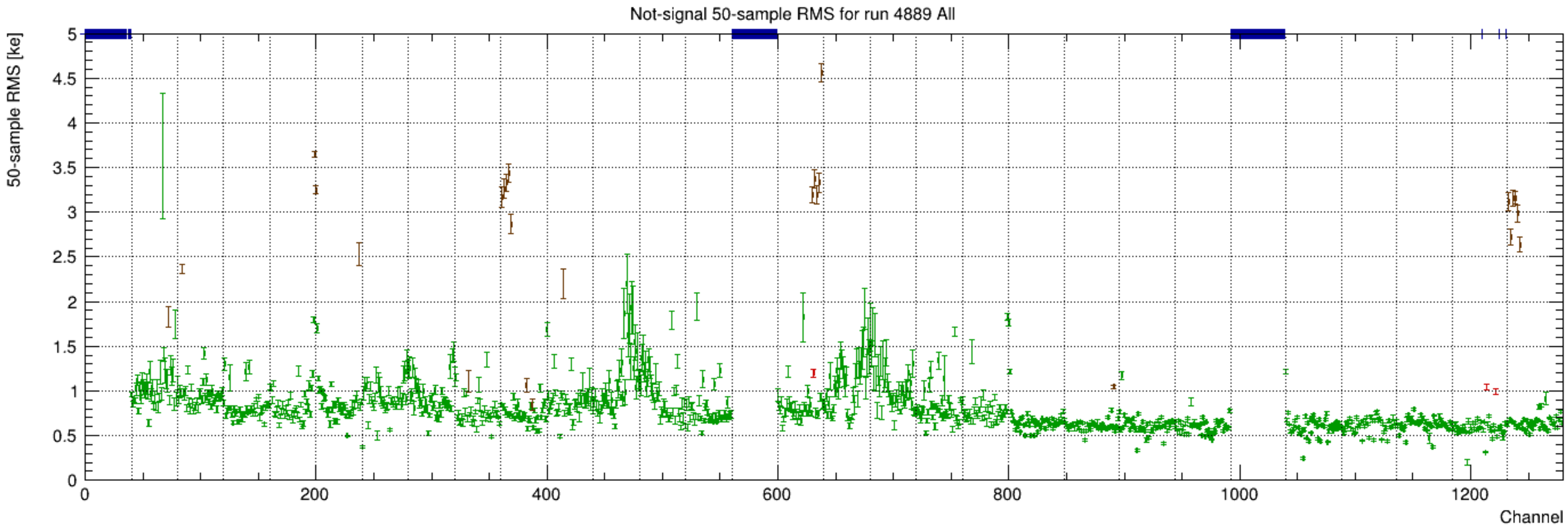
4888


Not-signal sample RMS for run 4888 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel

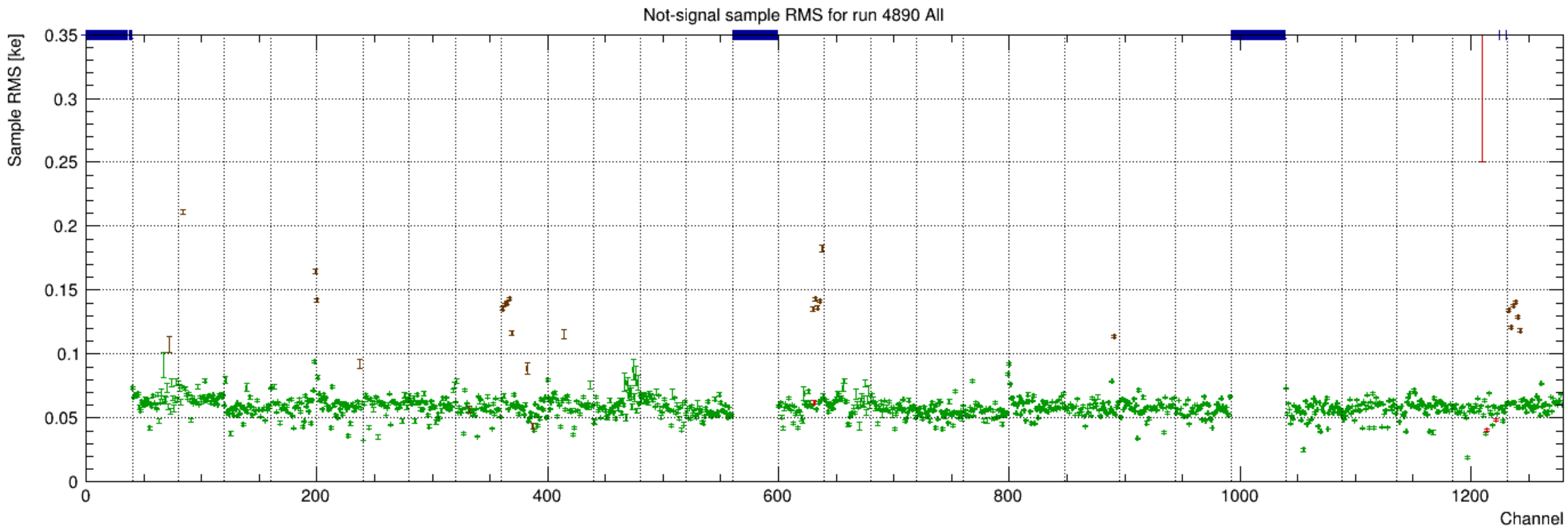

Not-signal 50-sample RMS for run 4888 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4889

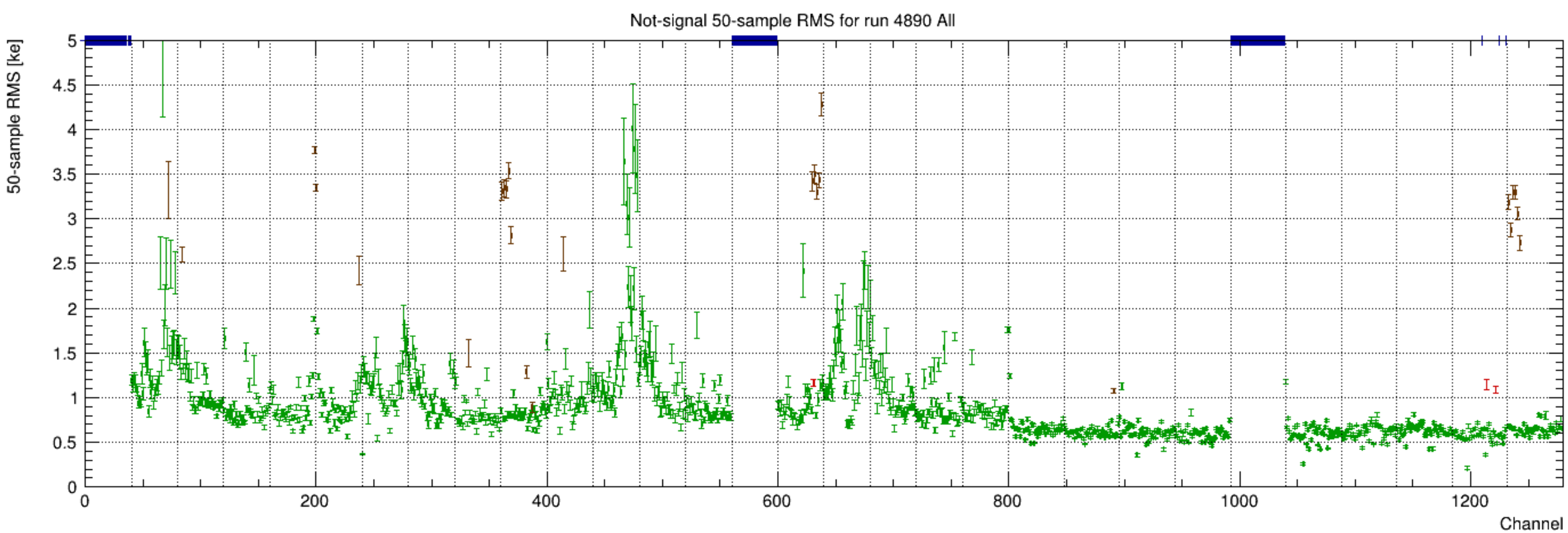

Not-signal sample RMS for run 4889 All
Sample RMS [ke]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
200
400
600
800
1000
1200
Channel


Not-signal 50-sample RMS for run 4889 All
50-sample RMS [ke]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
Channel

4890



Not-signal sample RMS for run 4890 All
Sample RMS [ke]
Channel

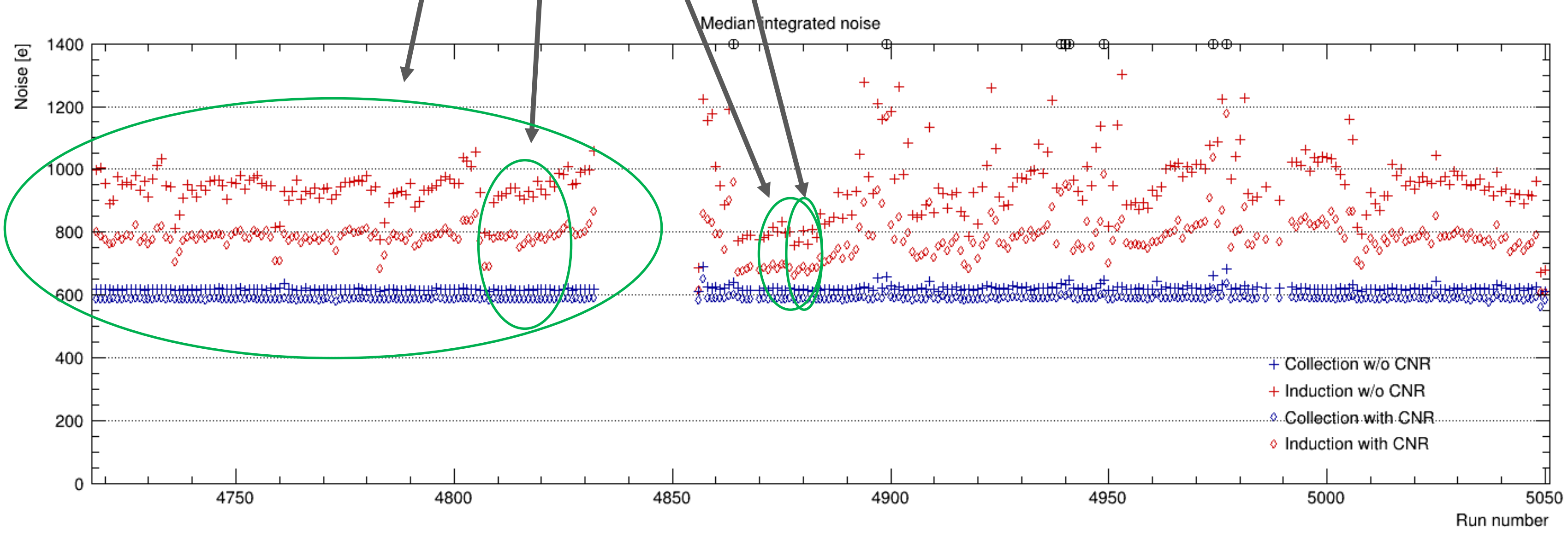


Not-signal 50-sample RMS for run 4890 All
50-sample RMS [ke]
Channel

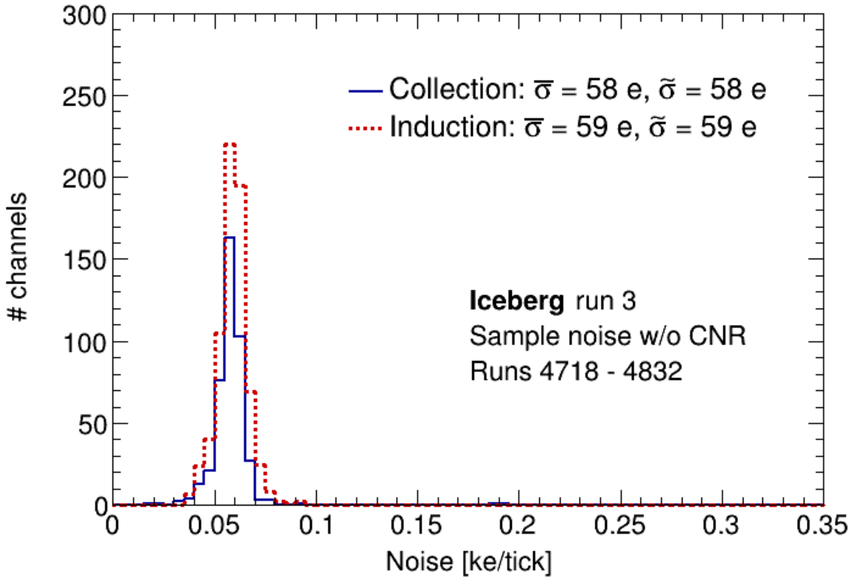
Noise summary selections

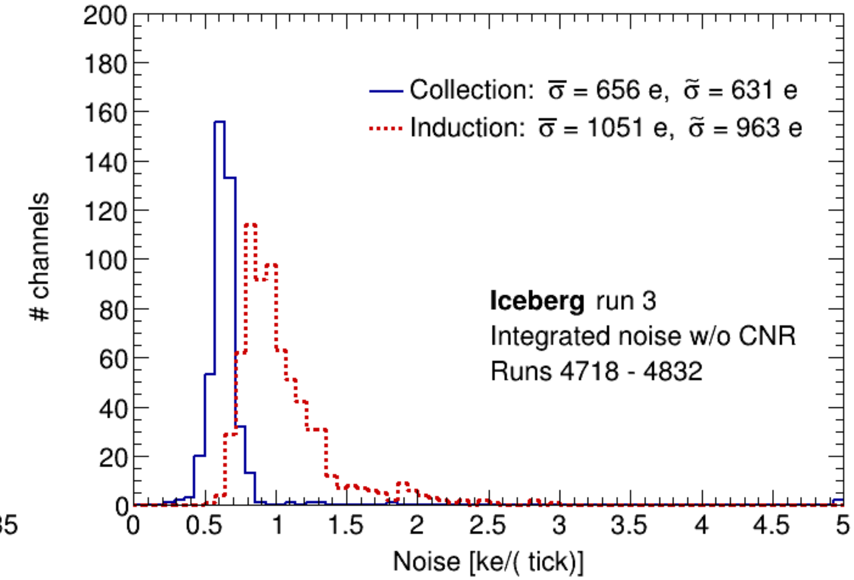
Want noise summary values

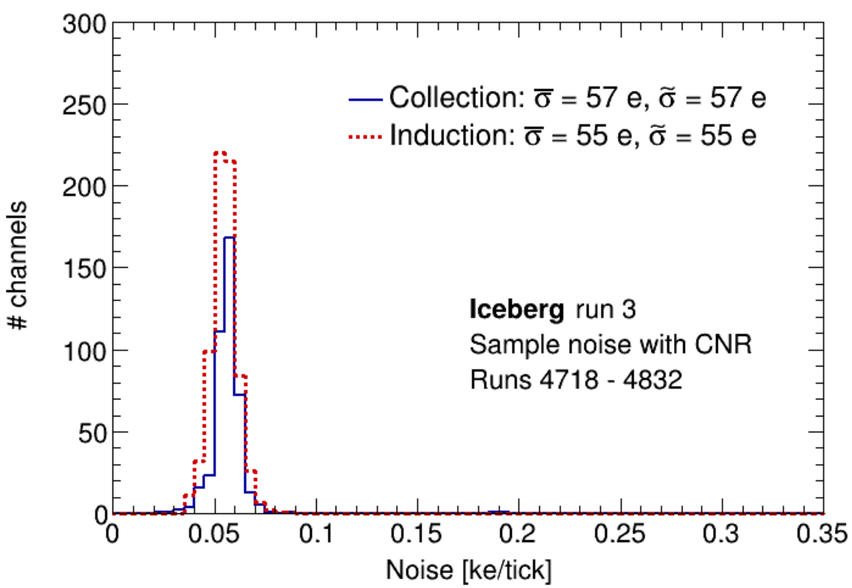
- For collection, induction with and w/o CNR
- Look at some run periods
    - First period (4718 -4832)
    - Typical: runs 4809 – 4823 (much of the data looks like this)
    - Quiet: runs 4865 – 4885
    - Very quiet: runs 4877 - 4882

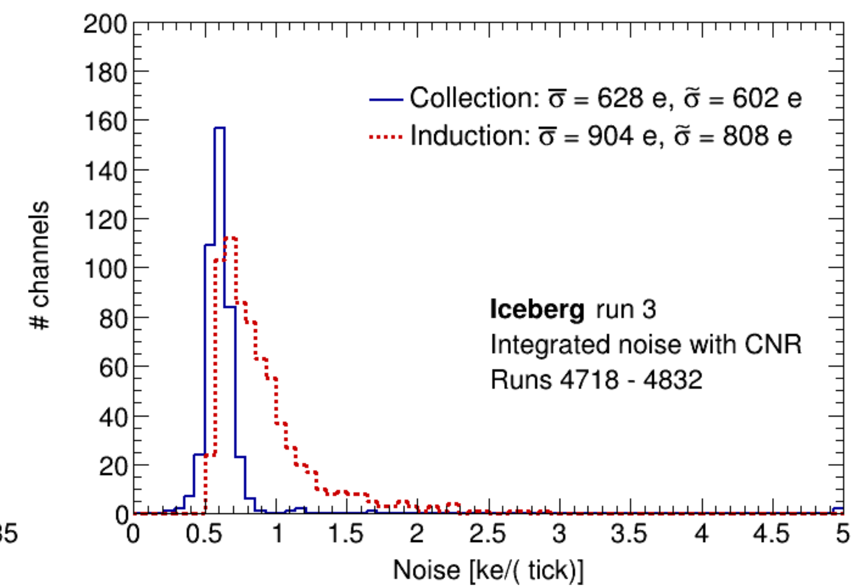


First period (4718 – 4832)

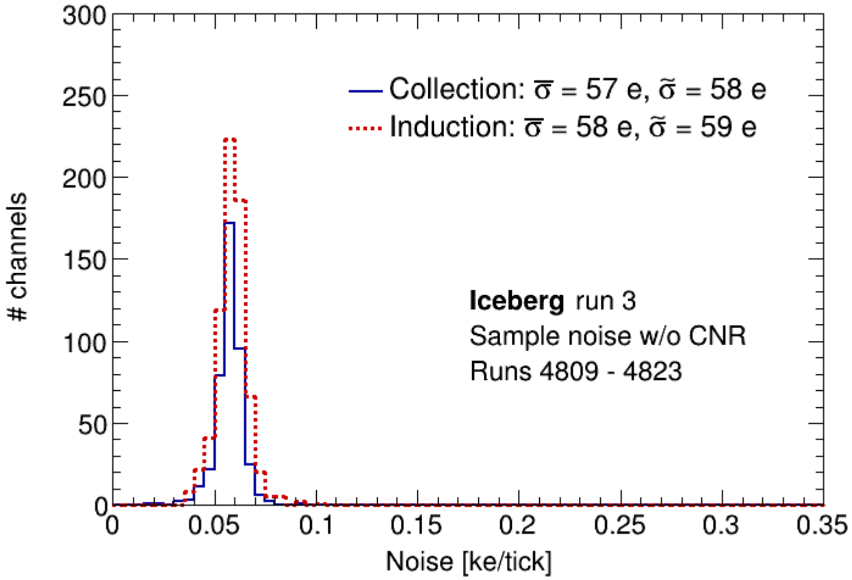


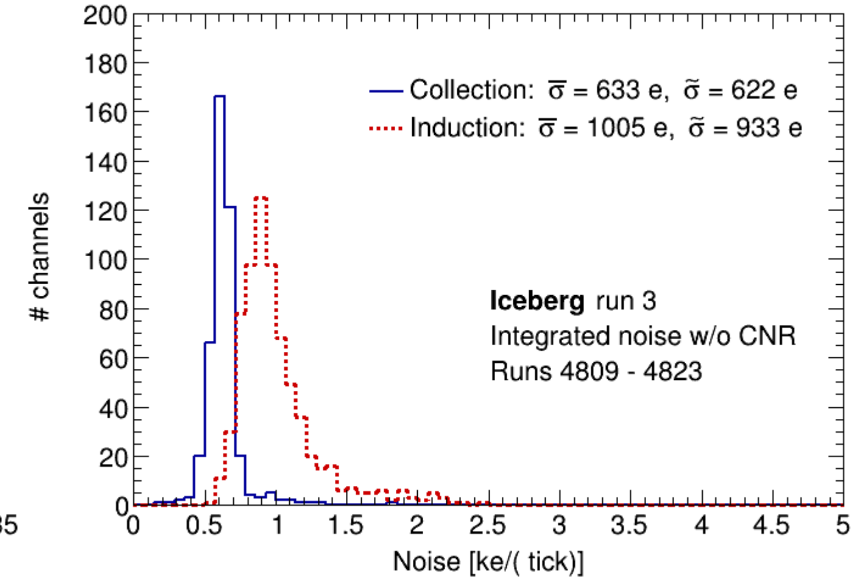


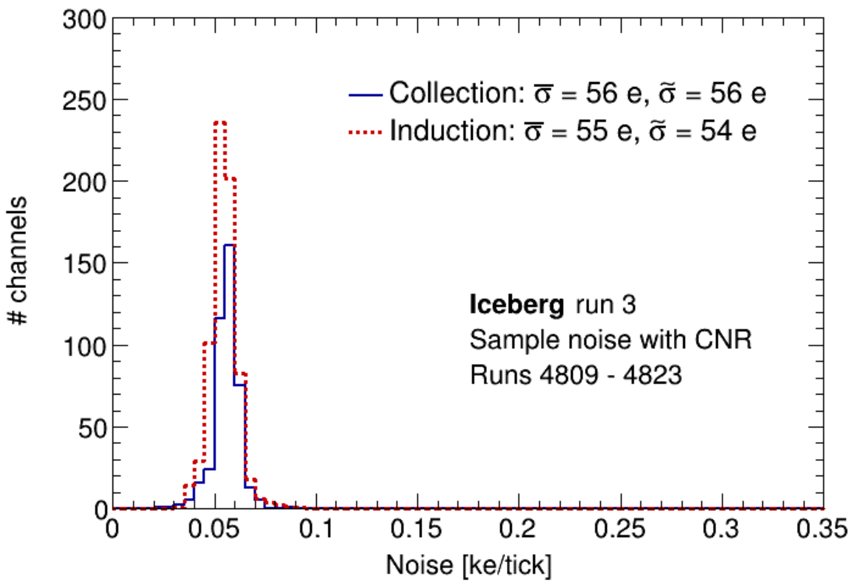


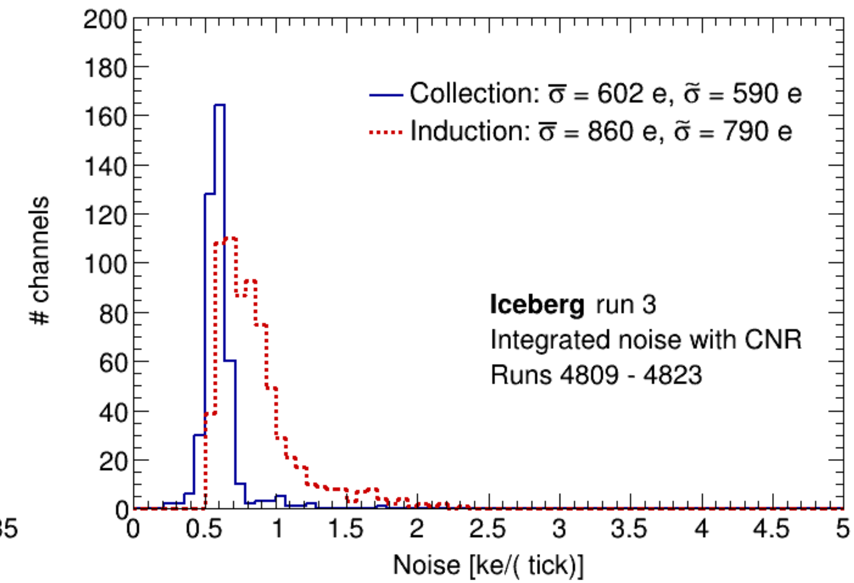


Typical (4809 – 4823)

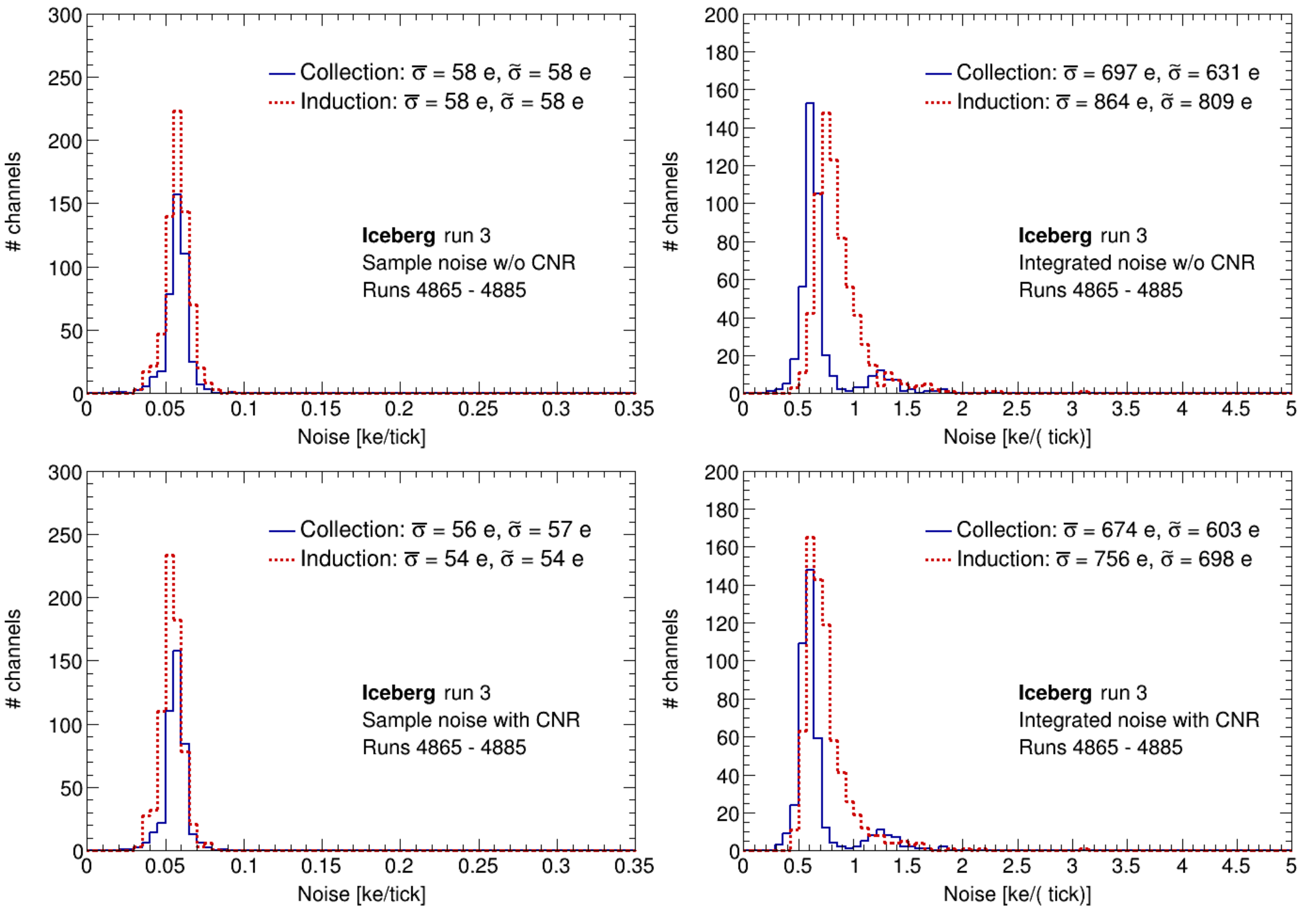




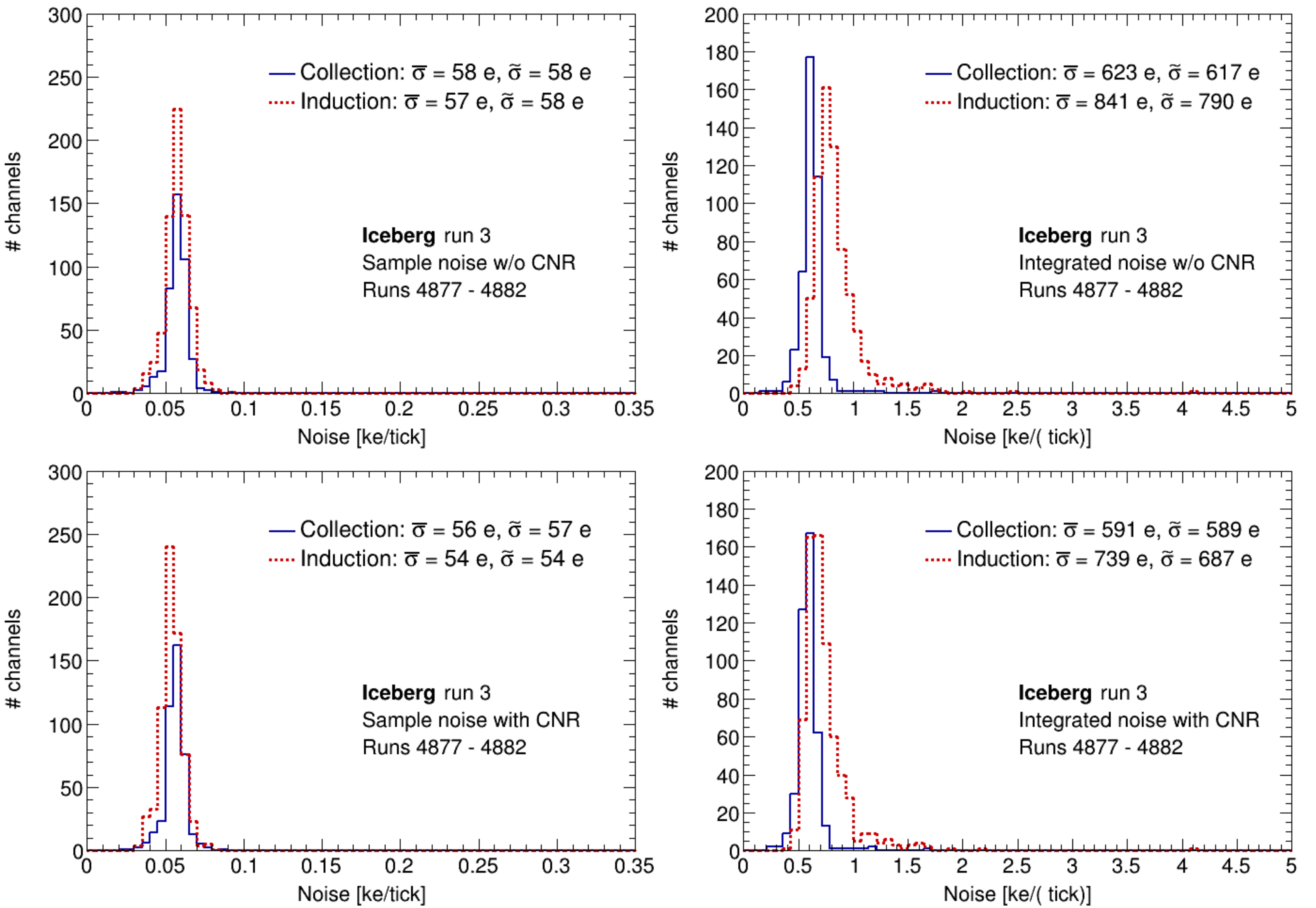




Quiet (4865 – 4885)



Very quiet (4877 – 4882)



Noise summary medians

		Sample noise [e]			
	CNR	**All**	**Typical**	**Quiet**	**V. quiet**
Collection	no	58	58	58	58
	yes	57	56	57	57
Induction	no	59	59	58	58
	yes	55	54	54	54

		Integrated noise [e]			
	CNR	**All**	**Typical**	**Quiet**	**V. quiet**
Collection	no	630	620	630	620
	yes	600	590	600	590
Induction	no	930	930	810	790
	yes	790	790	700	690

Noise comments

Preceding is direct measurement of collection noise

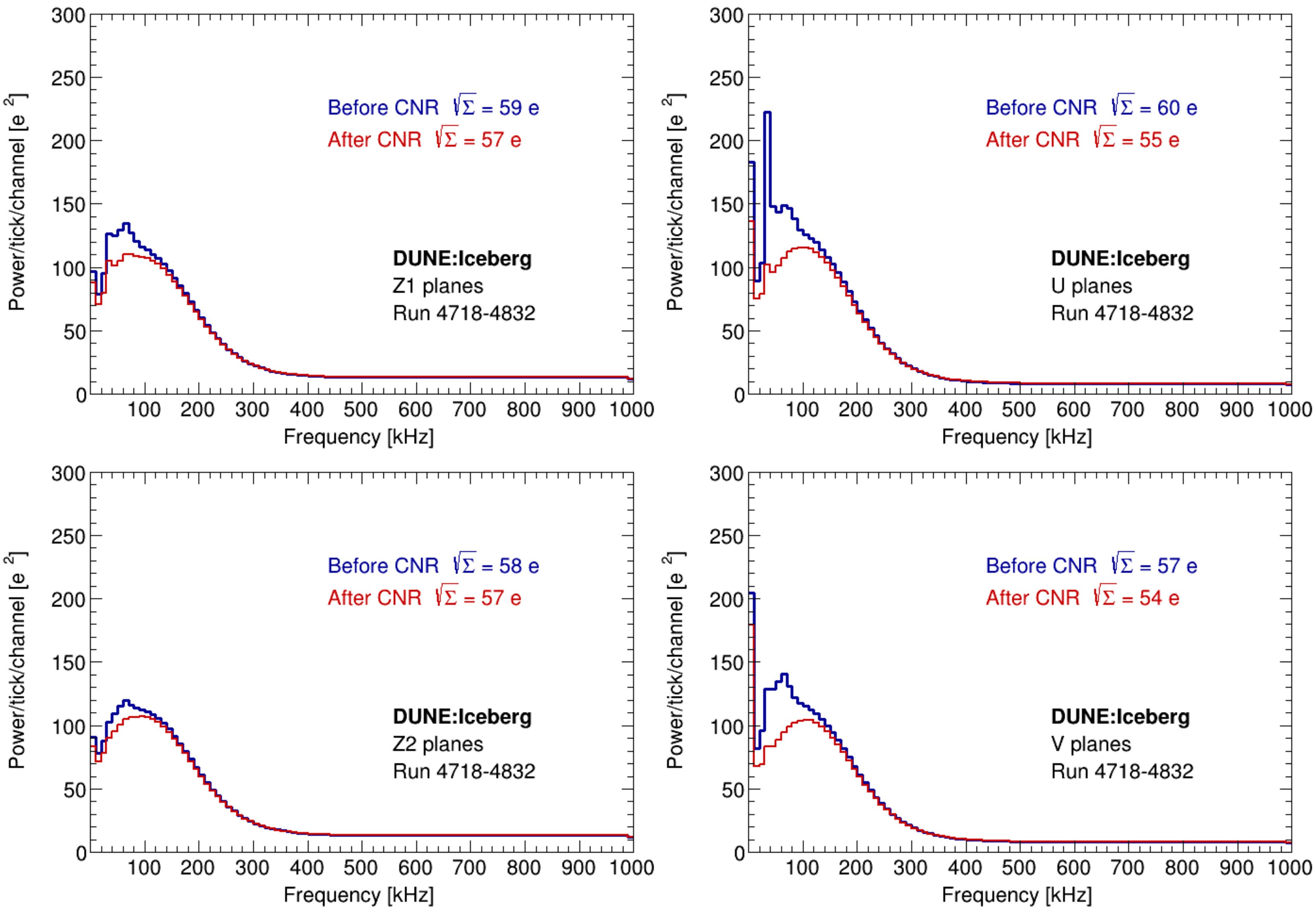
- Sample noise: 58 → 57 e (before → after CNR)
  - CNR = coherent noise removal
  - ENC = 5.58 × (sample noise): 320 → 320 e
    - Dune doc 15523
- Integrated noise: 620 → 590 e
  - Expect this uncertainty for charge measurements
    - Deconvolution should not change it
  - protoDUNE values are 1250, 920 e

Corresponding results for induction planes

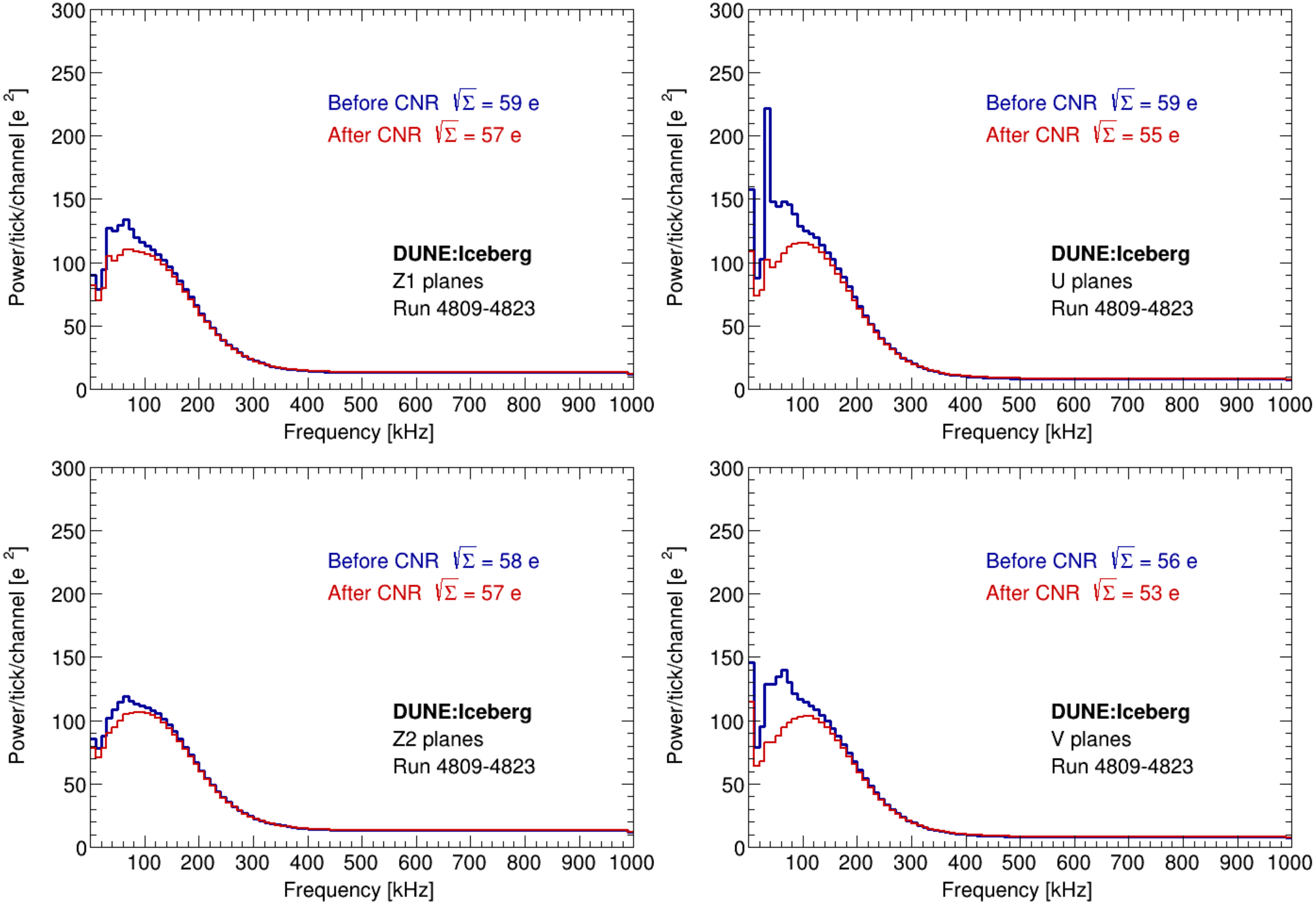
- Sample: 58 → 54 e
  - ENC: 320 → 300 e
- Integrated: 790 → 690 e
  - Deconvolution ➔ much larger uncertainty on charge measurements
    - To be determined

DFT power

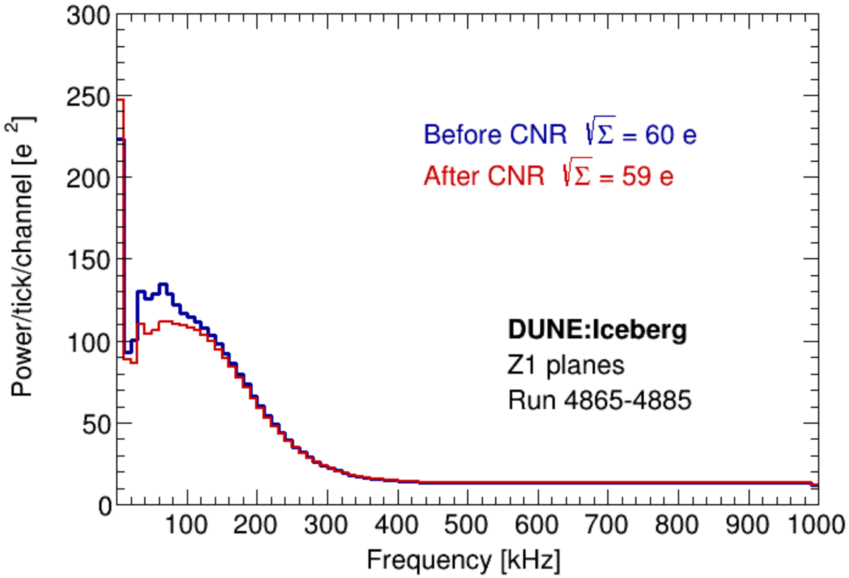
First period (4718-4832)

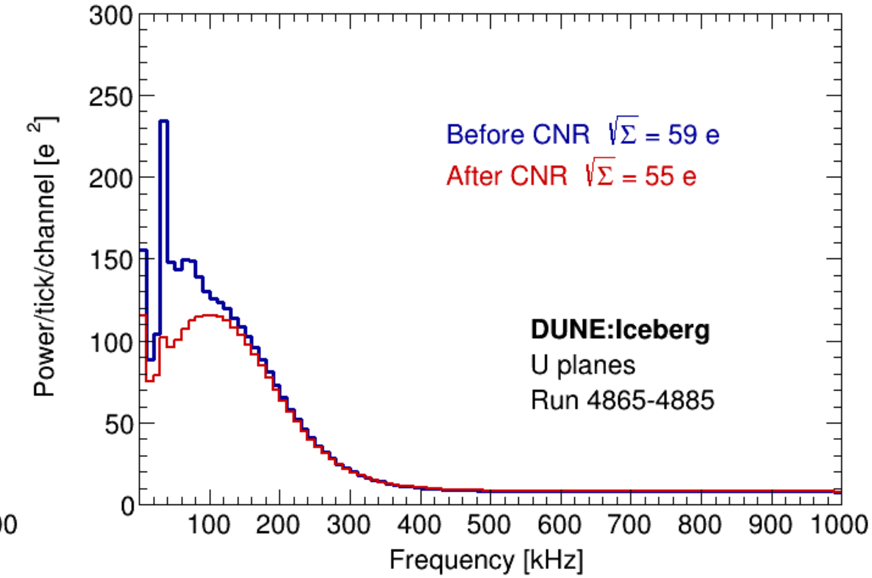


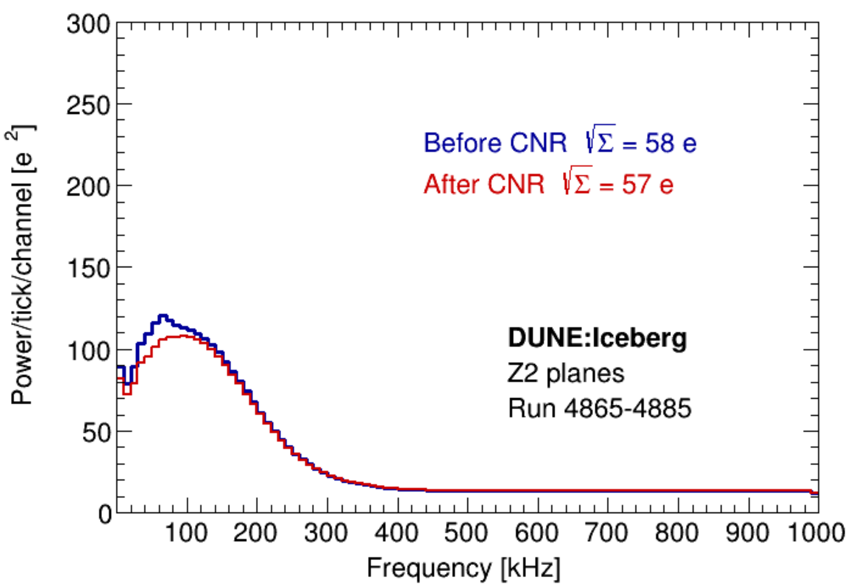
Typical (4809-4823)

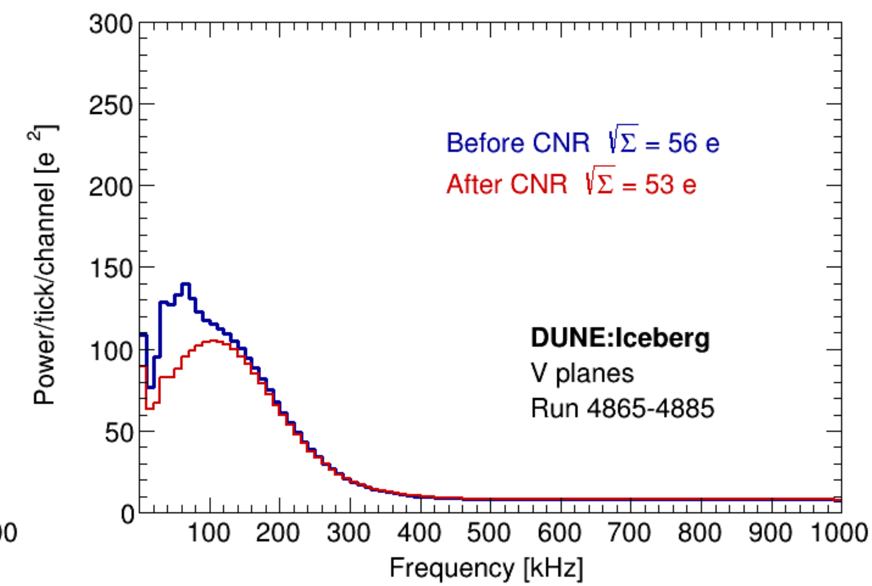


Quiet (4865-4885)

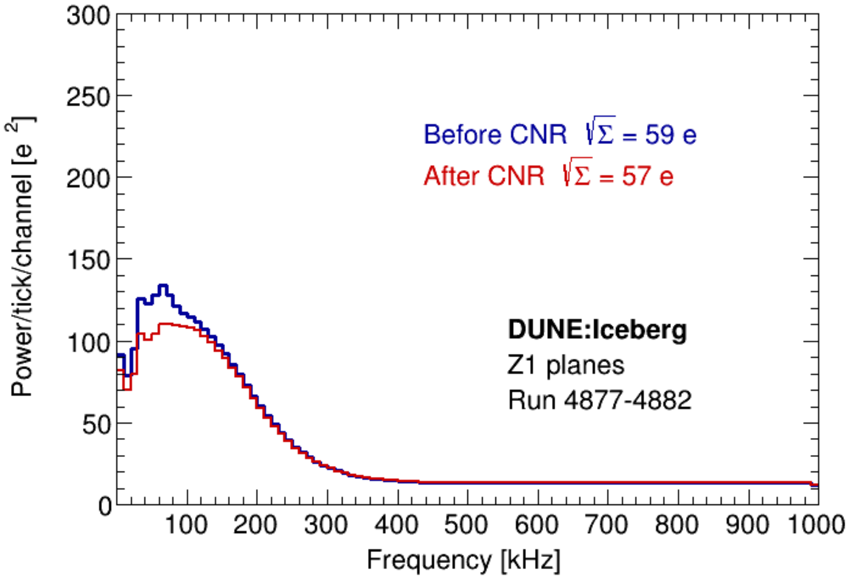


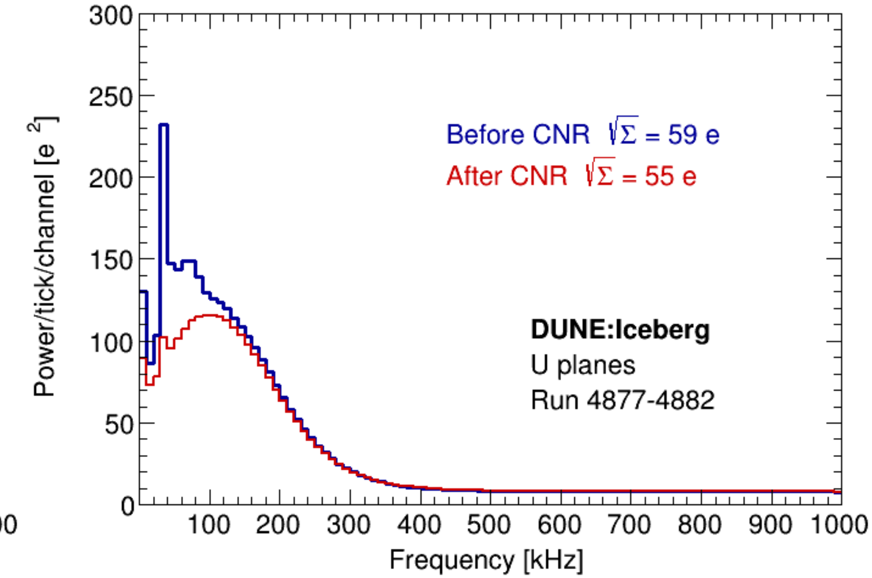


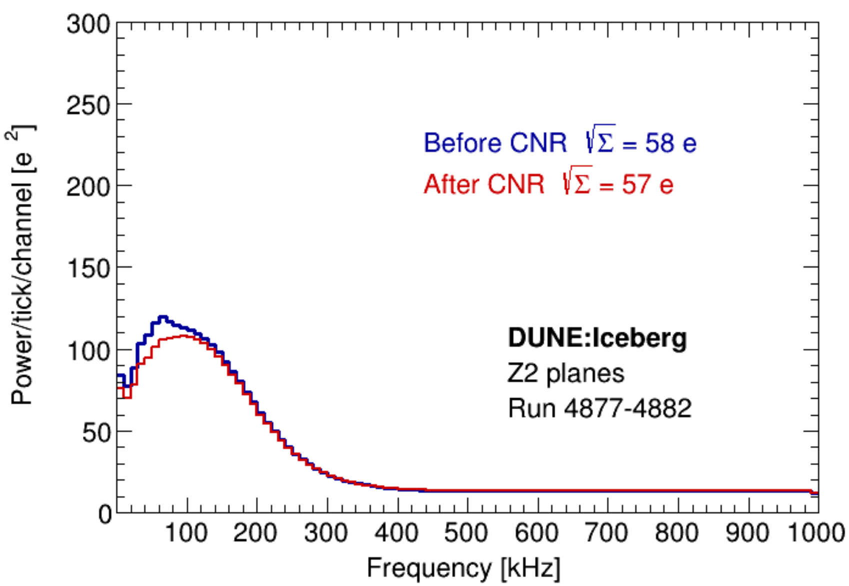


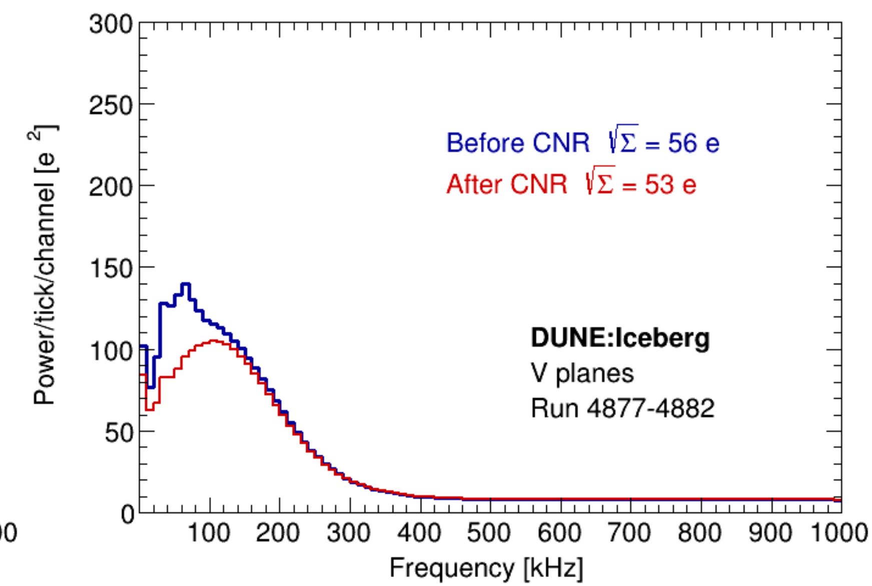


Very quiet (4877-4882)

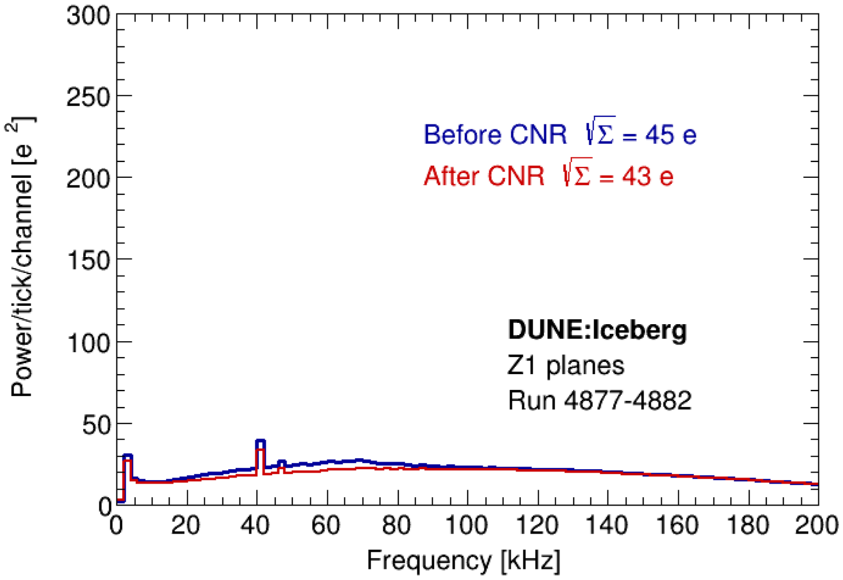


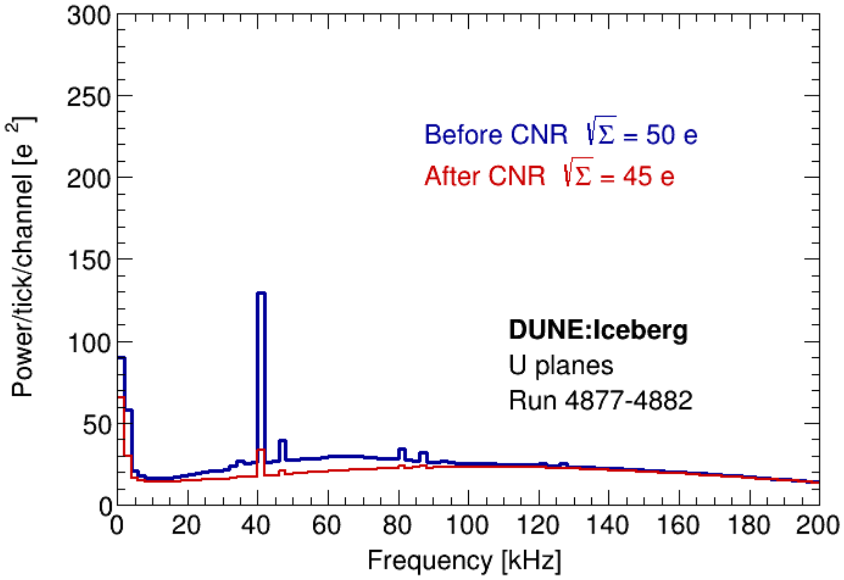


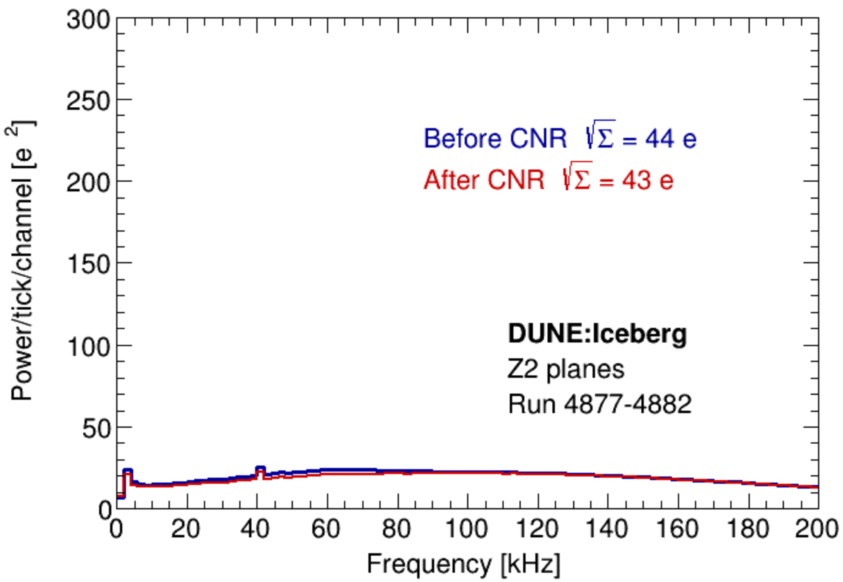


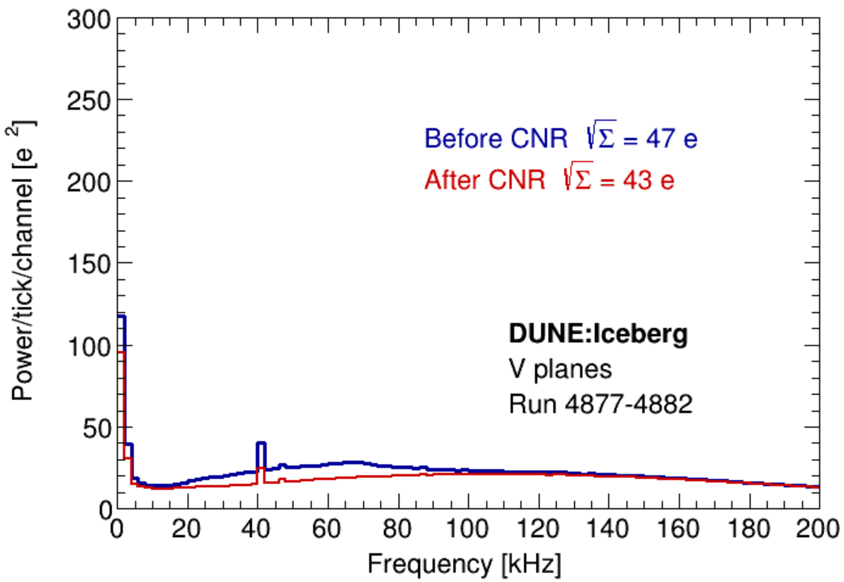


Very quiet (4877-4882) zoomed









Signal to noise (SNR)

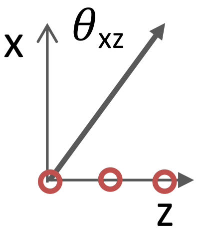
Signal to noise

Reported difficult to repeat protoDUNE SNR study

- Wanwei, Tingjun talk May 21
- Because tracks typically deposit charge on few wires
  - I.e. $\theta_{xz} \approx 0$ deg
- But we expect signal height similar to that for $\theta_{xz} \approx 90$
  - See following slides
  - Need a different analysis to pull this out
- And there are quite a few tracks (1 in 10 events?) where track is not quite perpendicular
  - Charge is distributed over 20+ wires
  - Amenable to traditional analysis?
  - Example plot follows

Perpendicular tracks

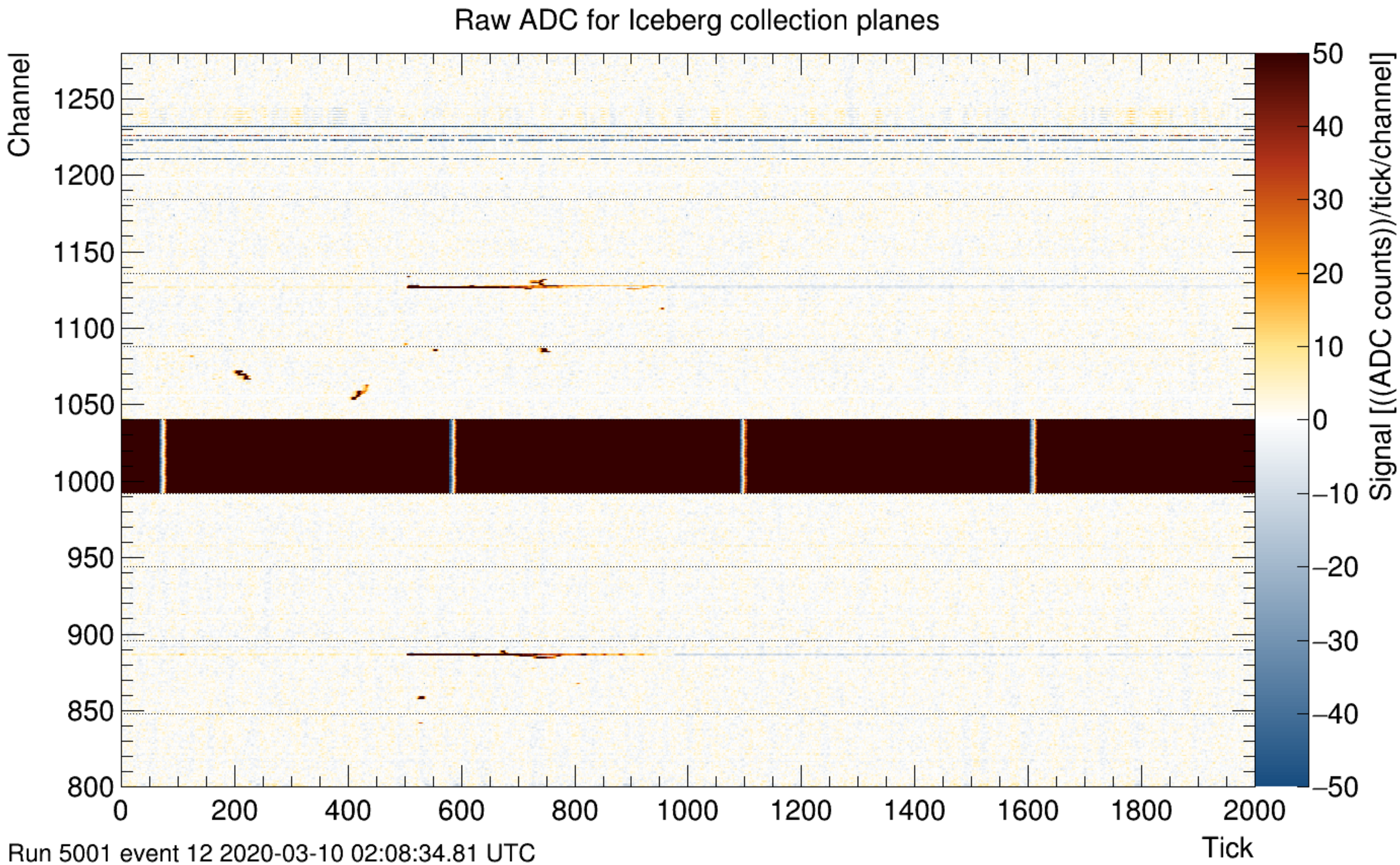
Tracks perpendicular to wire plane



Expected signal for $\theta_{xz} \approx 0$

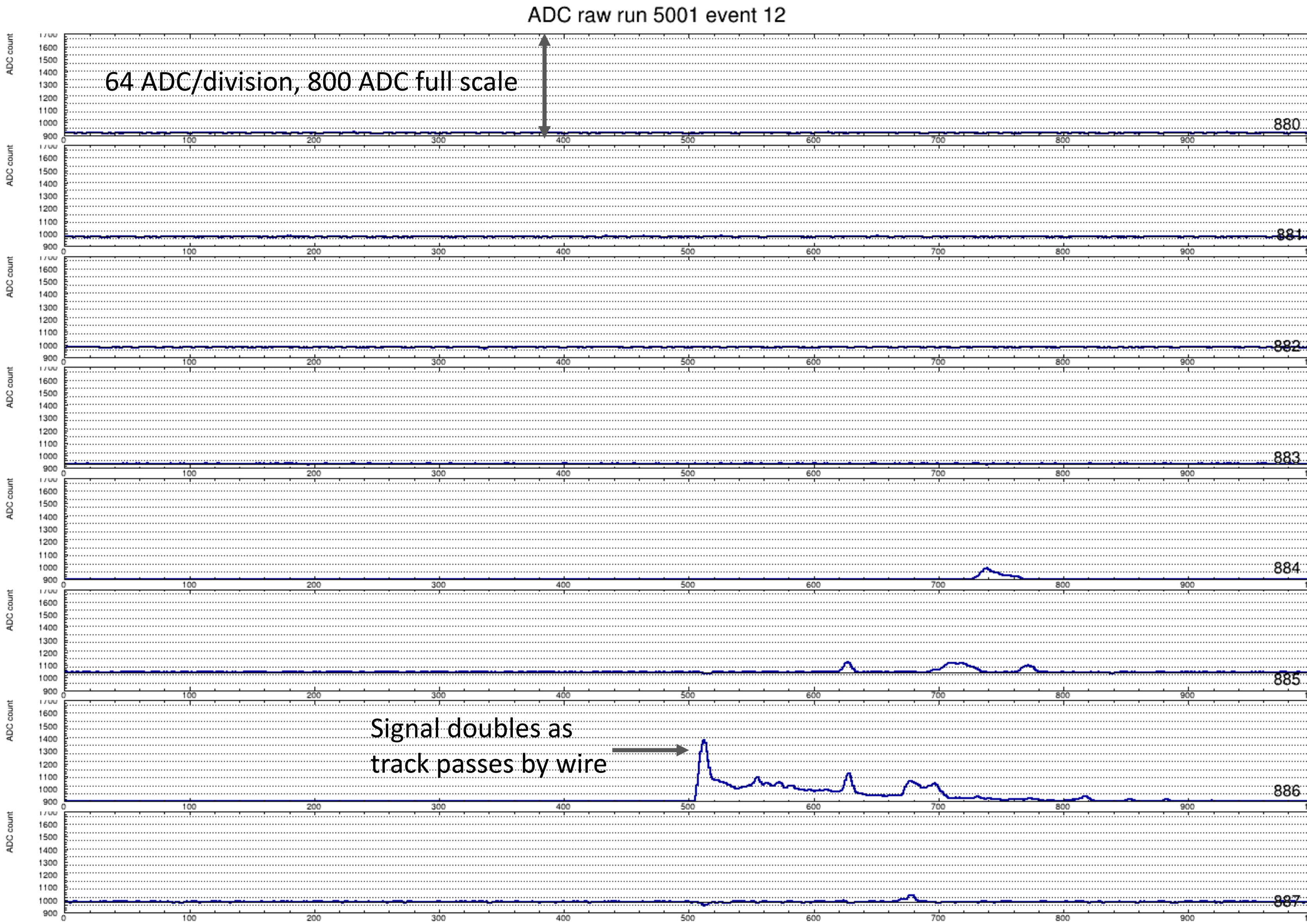
- I.e. track perpendicular to wire plane
- MIP produces 62 ke/cm after recombination
  - Smearing from shaping, diffusion have little effect on these tracks
    - As long as signal does not migrate to neighboring wire
  - Attenuated by electron lifetime
  - Boosted by $1/\cos(\theta_{zy})$ (Small effect with out trigger)
- Drift speed 1.6 mm/μs = 0.8 mm/tick ➔ 5.0 ke/tick
  - Sample noise of 0.06 ke ➔ SNR = 85
- CE response 40 ADC/ke ➔ 200 ADC/tick
  - Examples follows
- Observed waveforms are not flat
  - Exponential decrease with drift time due to electron lifetime
  - Bumps in spectra from delta rays--expect 20% signal in deltas
  - Signal is doubled where track passes by collection wire
  - Many example follow

5001-12

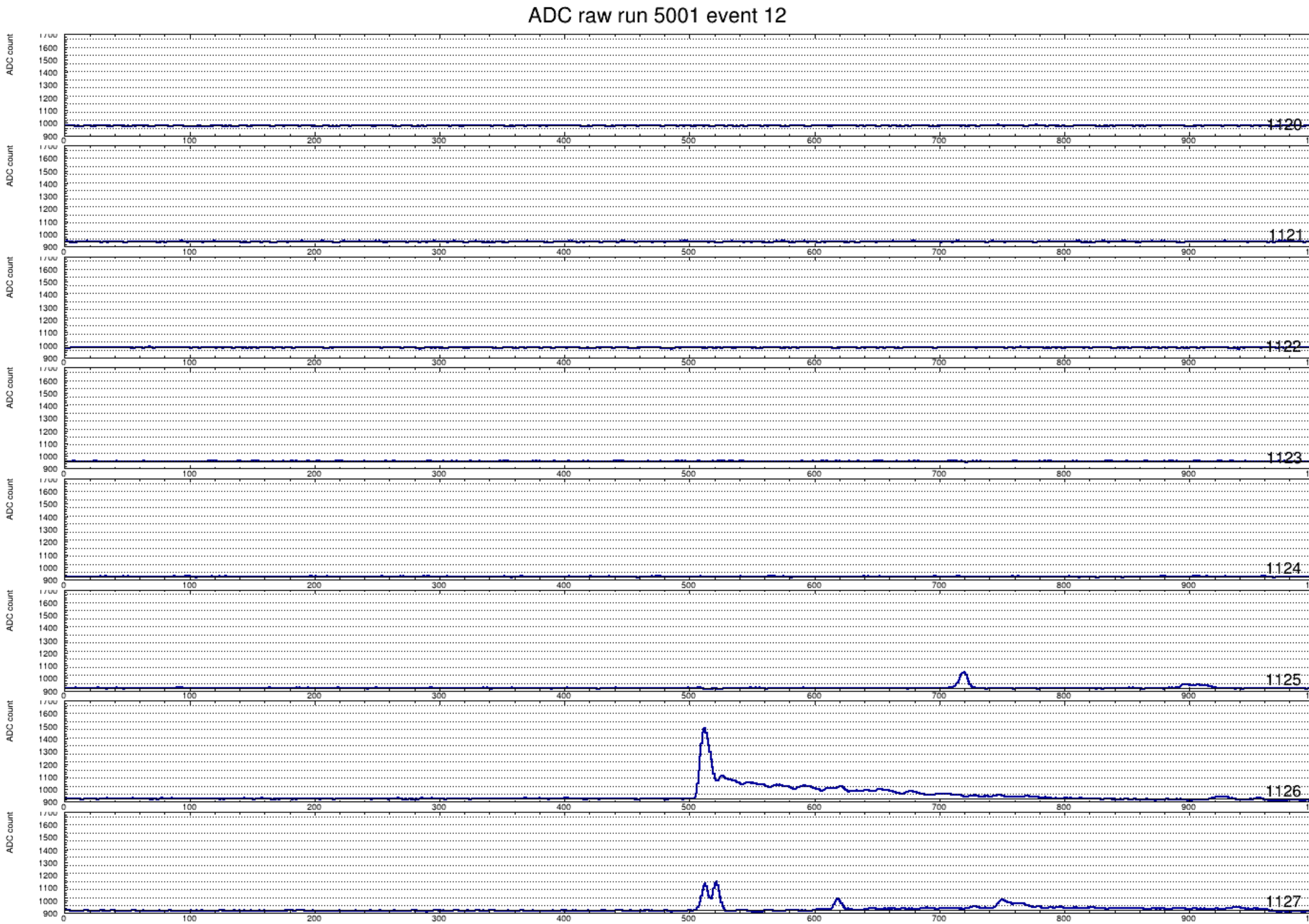


Raw ADC for Iceberg collection planes
Channel
1250
1200
1150
1100
1050
1000
950
900
850
800
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Tick
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 5001 event 12 2020-03-10 02:08:34.81 UTC

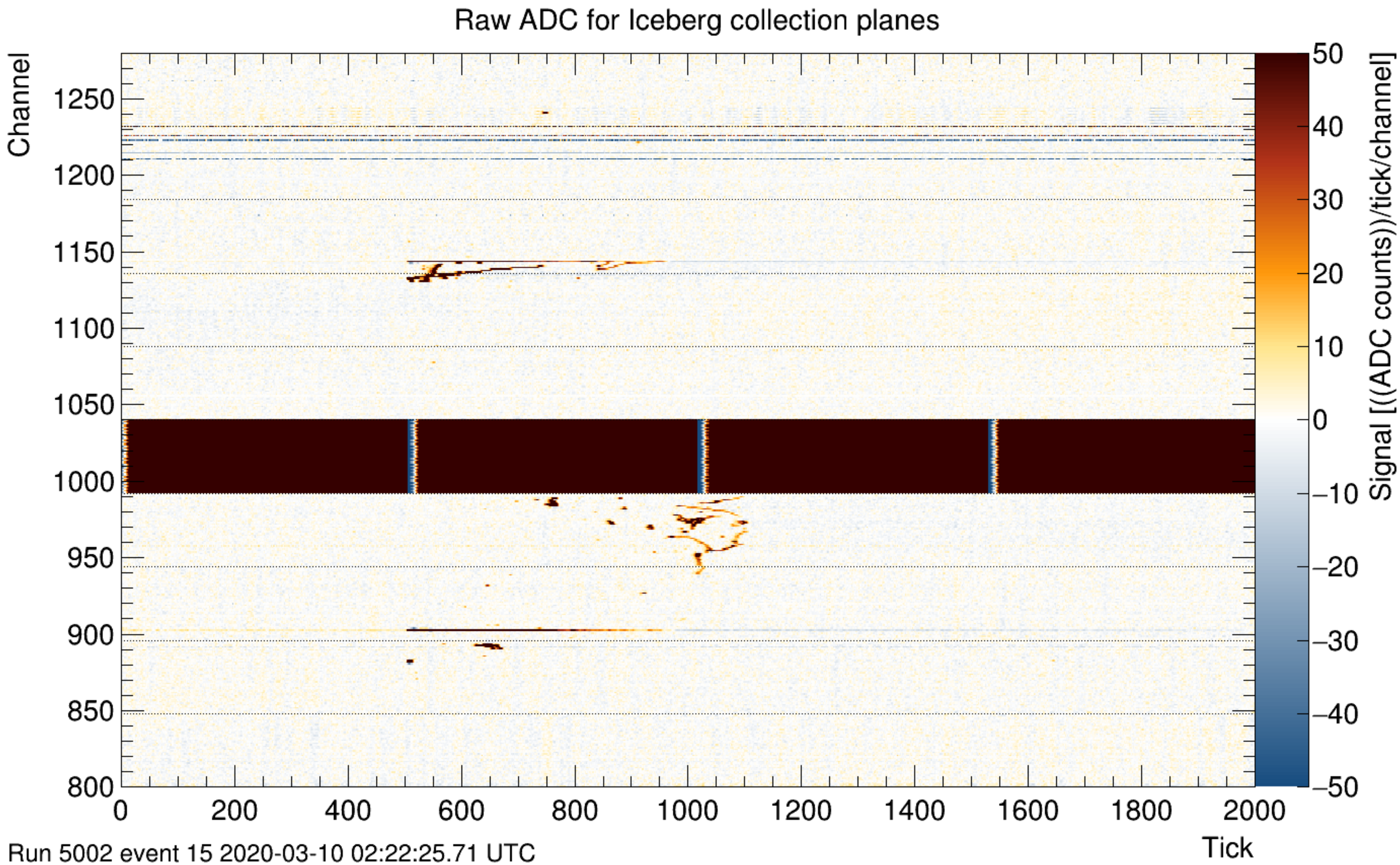
5001-12 z1


ADC raw run 5001 event 12
64 ADC/division, 800 ADC full scale
Signal doubles as
track passes by wire
ADC count
880
881
882
883
884
885
886
887

5001-12 z2

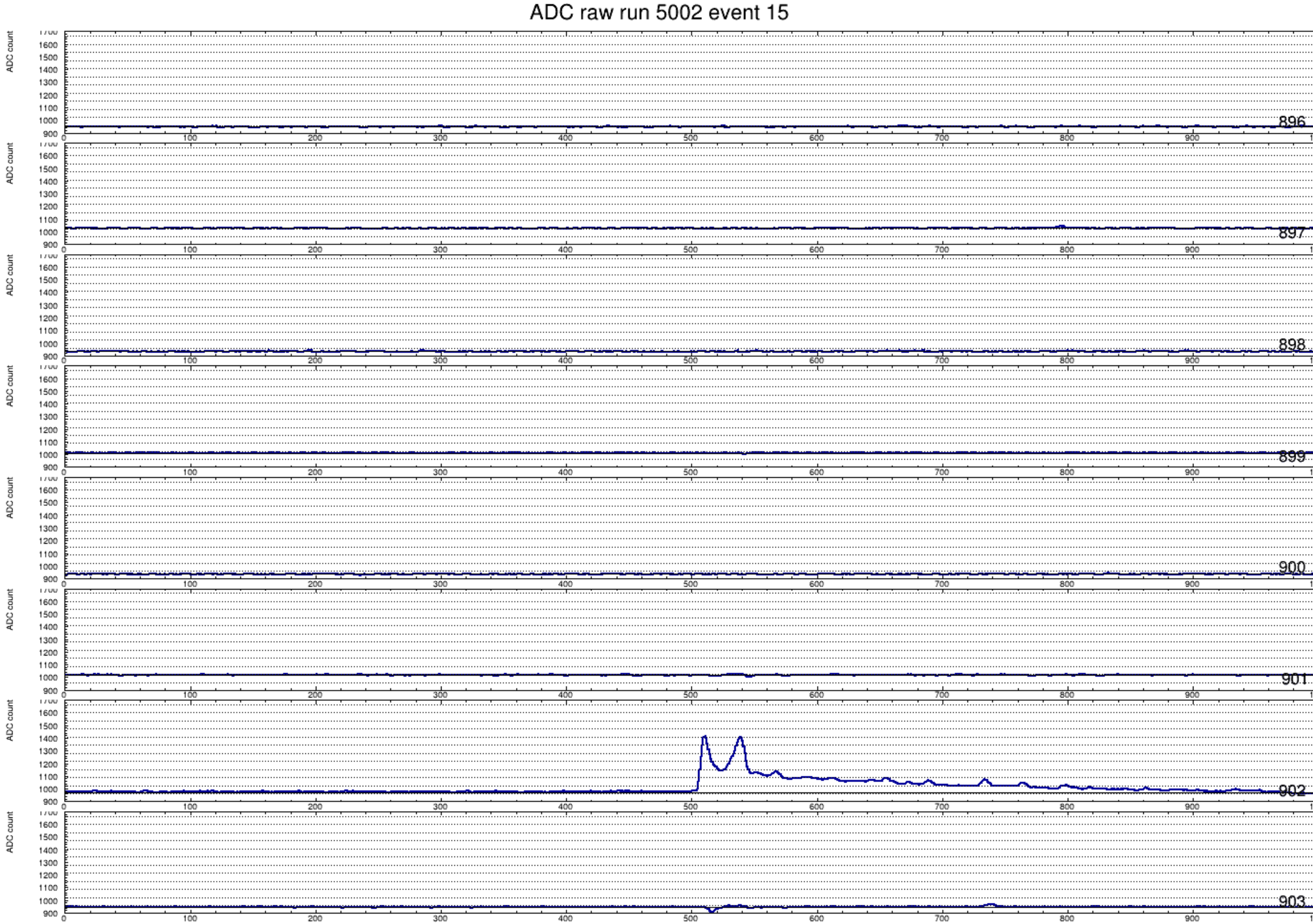

ADC raw run 5001 event 12
ADC count
1120
1121
1122
1123
1124
1125
1126
1127

5001-15

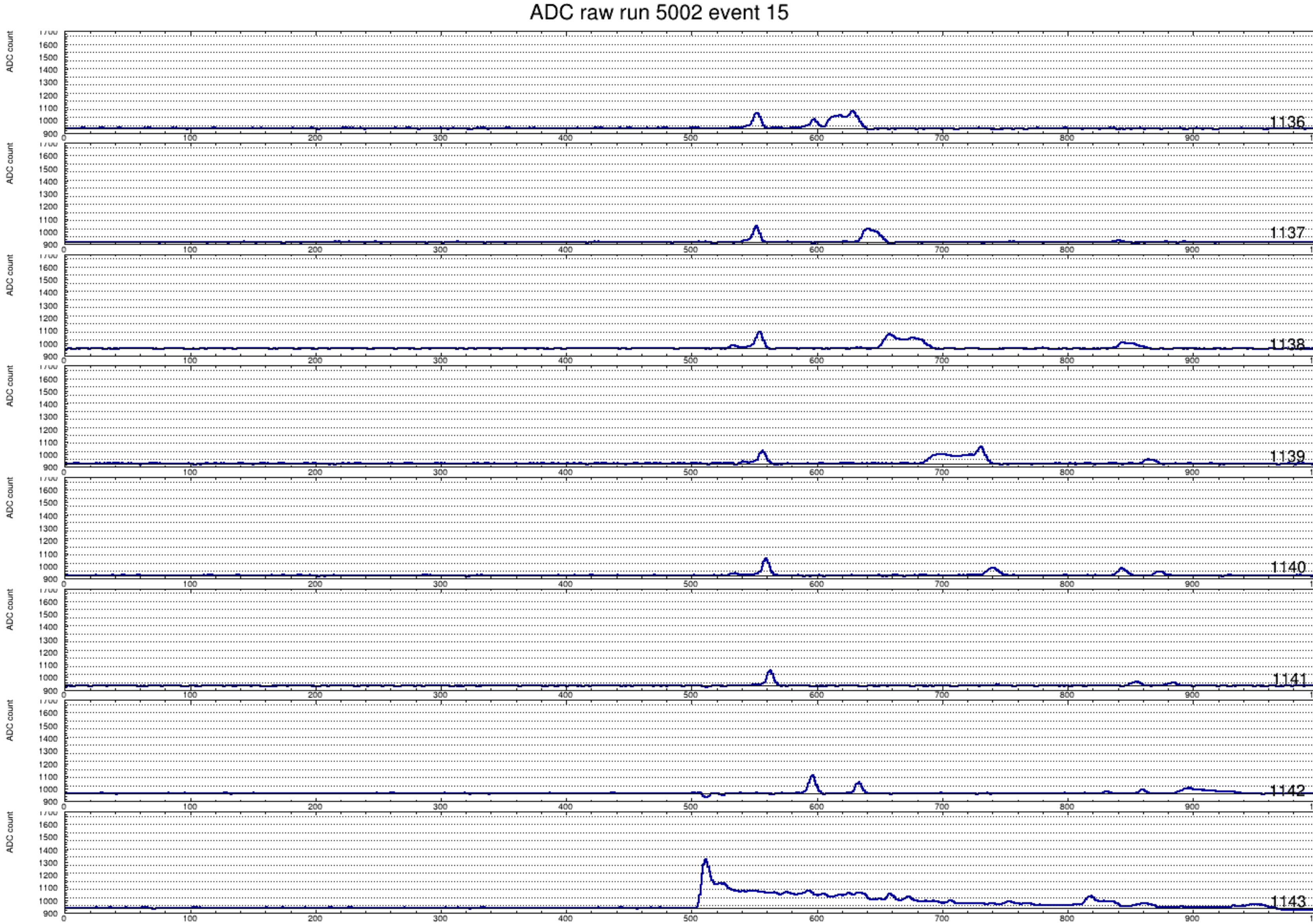


Raw ADC for Iceberg collection planes
Channel
1250
1200
1150
1100
1050
1000
950
900
850
800
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Tick
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 5002 event 15 2020-03-10 02:22:25.71 UTC

5001-15 z1

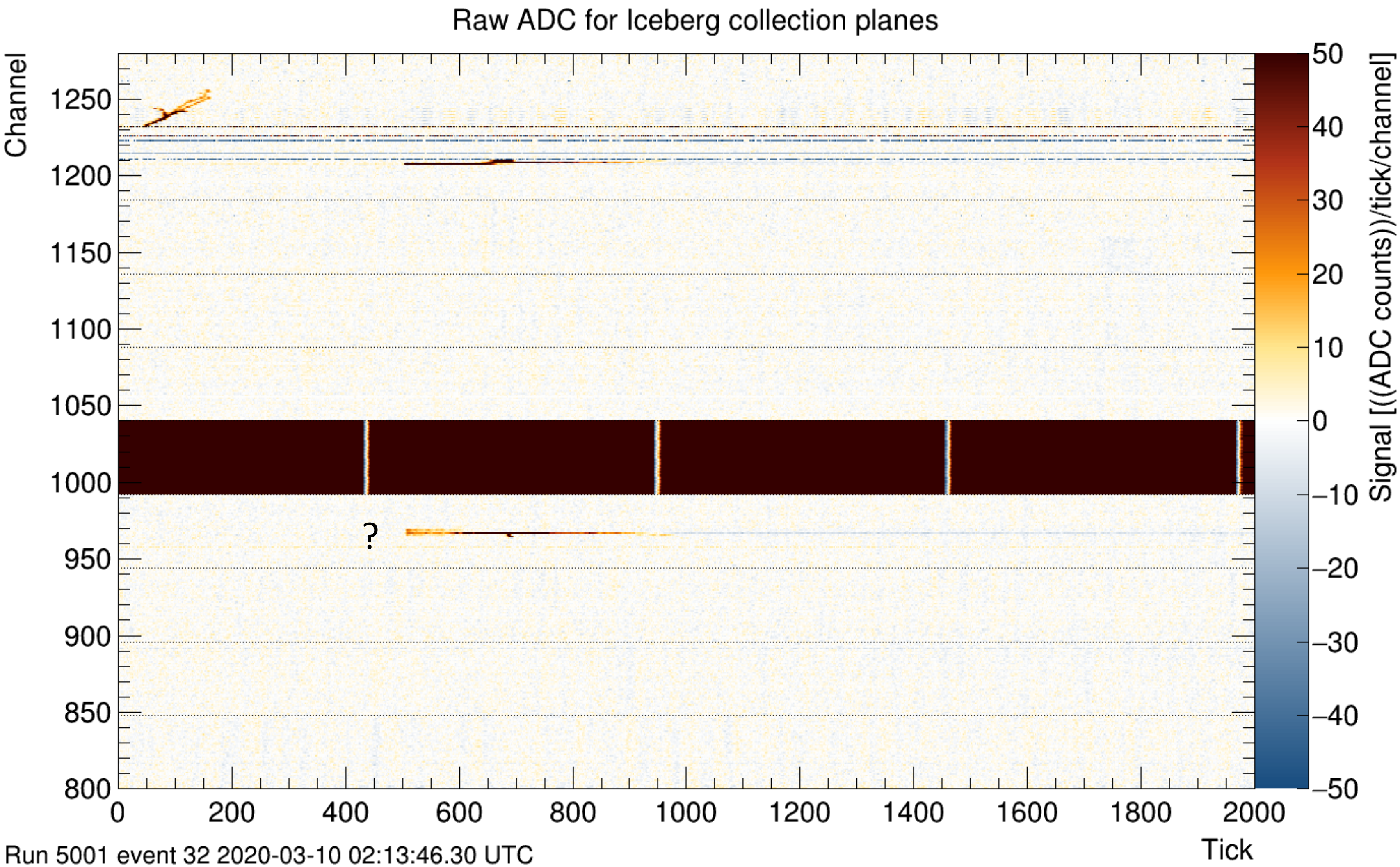

ADC raw run 5002 event 15
ADC count
896
897
898
899
900
901
902
903

5001-15 z2



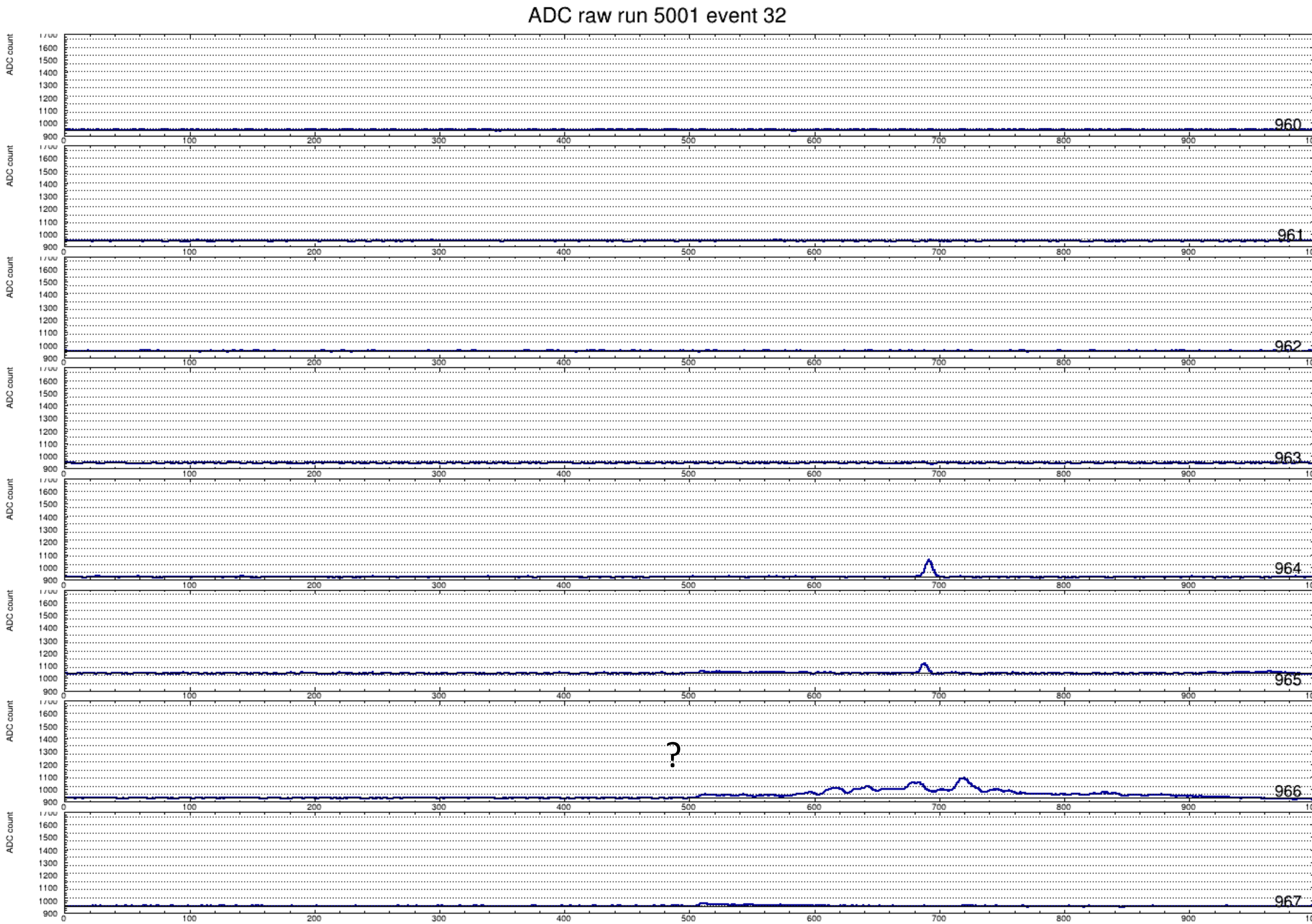
ADC raw run 5002 event 15
ADC count
1136
1137
1138
1139
1140
1141
1142
1143

5001-32

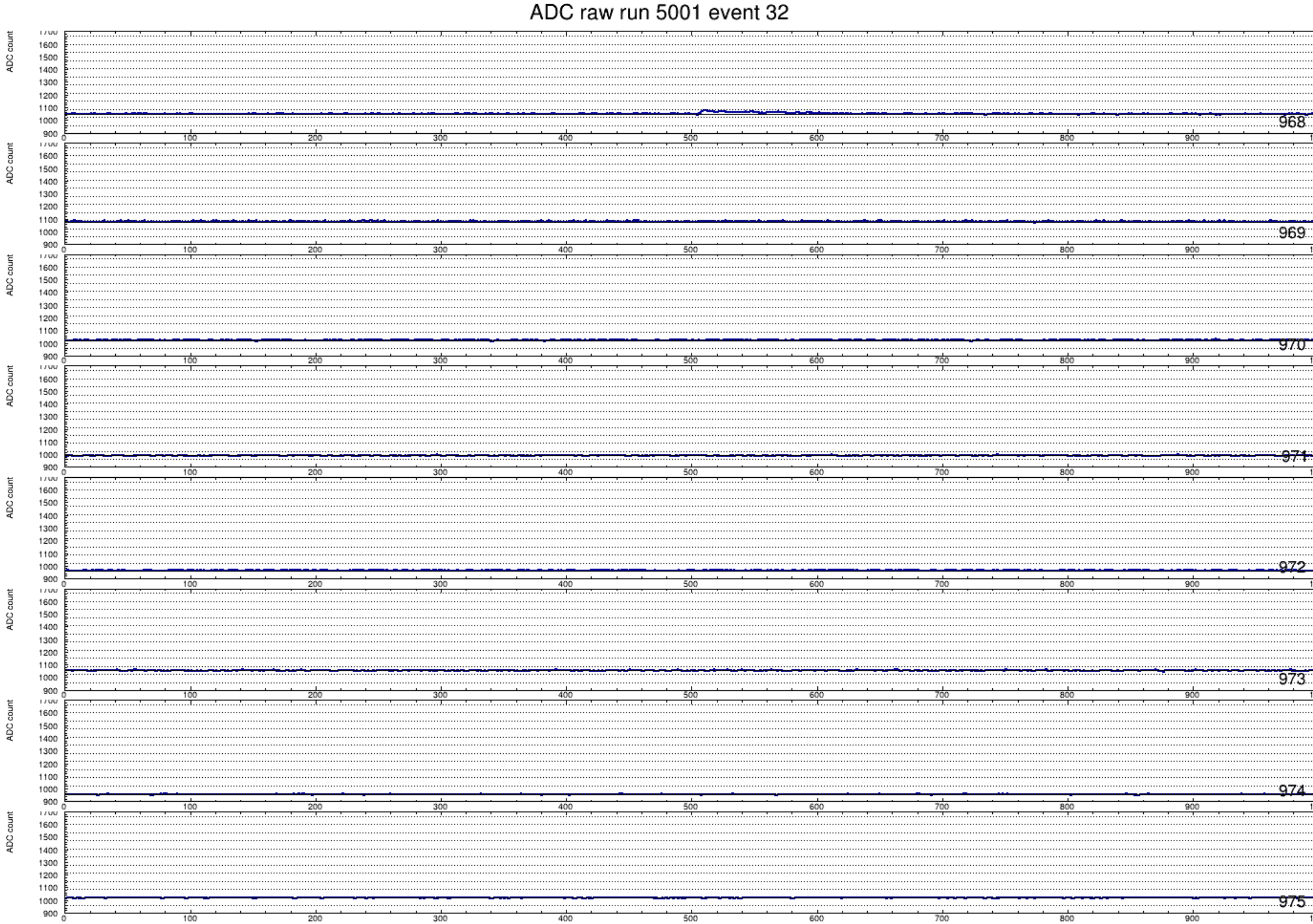


Raw ADC for Iceberg collection planes
Channel
1250
1200
1150
1100
1050
1000
950
900
850
800
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Tick
?
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 5001 event 32 2020-03-10 02:13:46.30 UTC

5001-32 z1

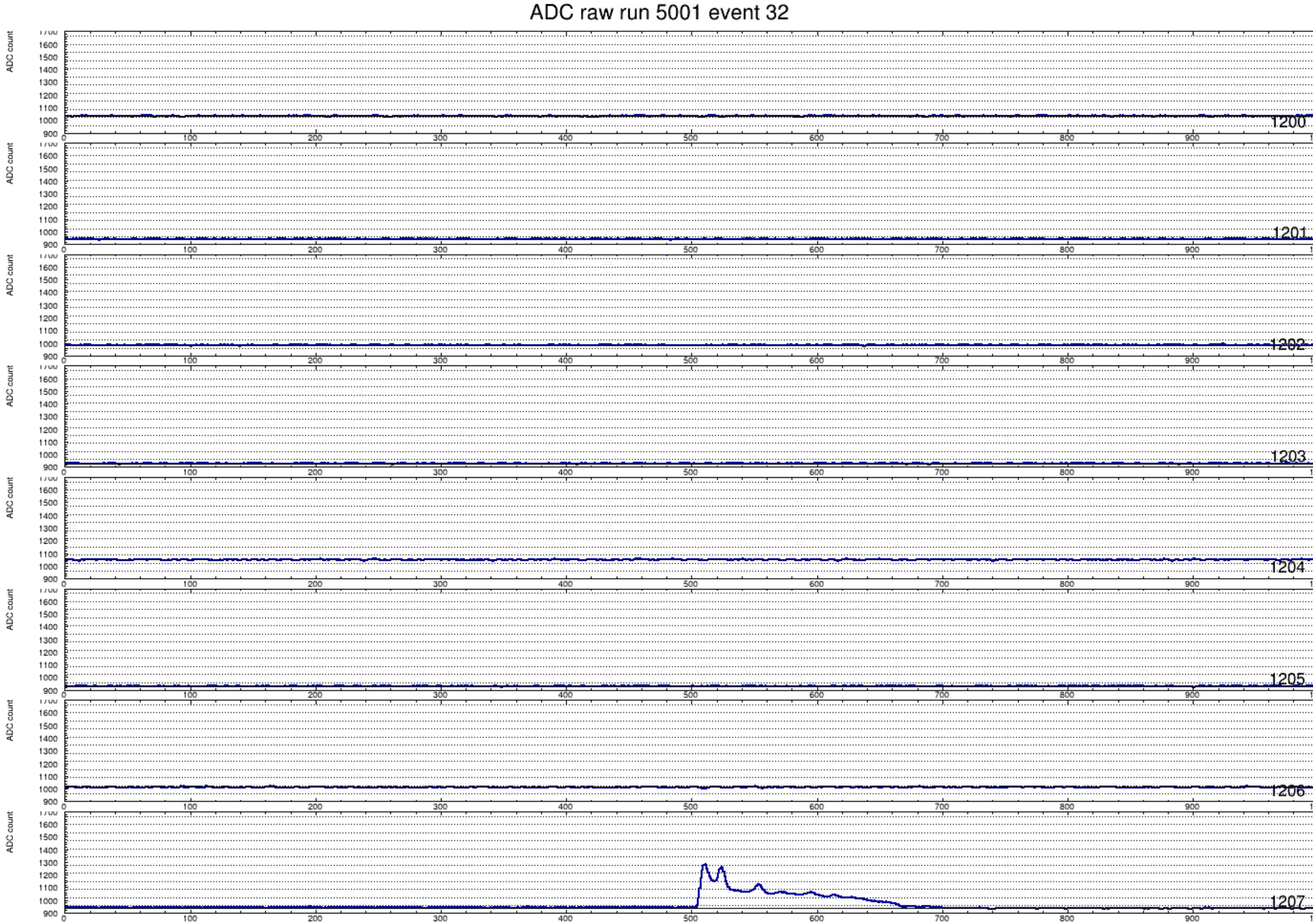

ADC raw run 5001 event 32
ADC count
1700
1600
1500
1400
1300
1200
1100
1000
900
0
100
200
300
400
500
600
700
800
900
1000
960
961
962
963
964
965
966
967
?

5001-32 z1

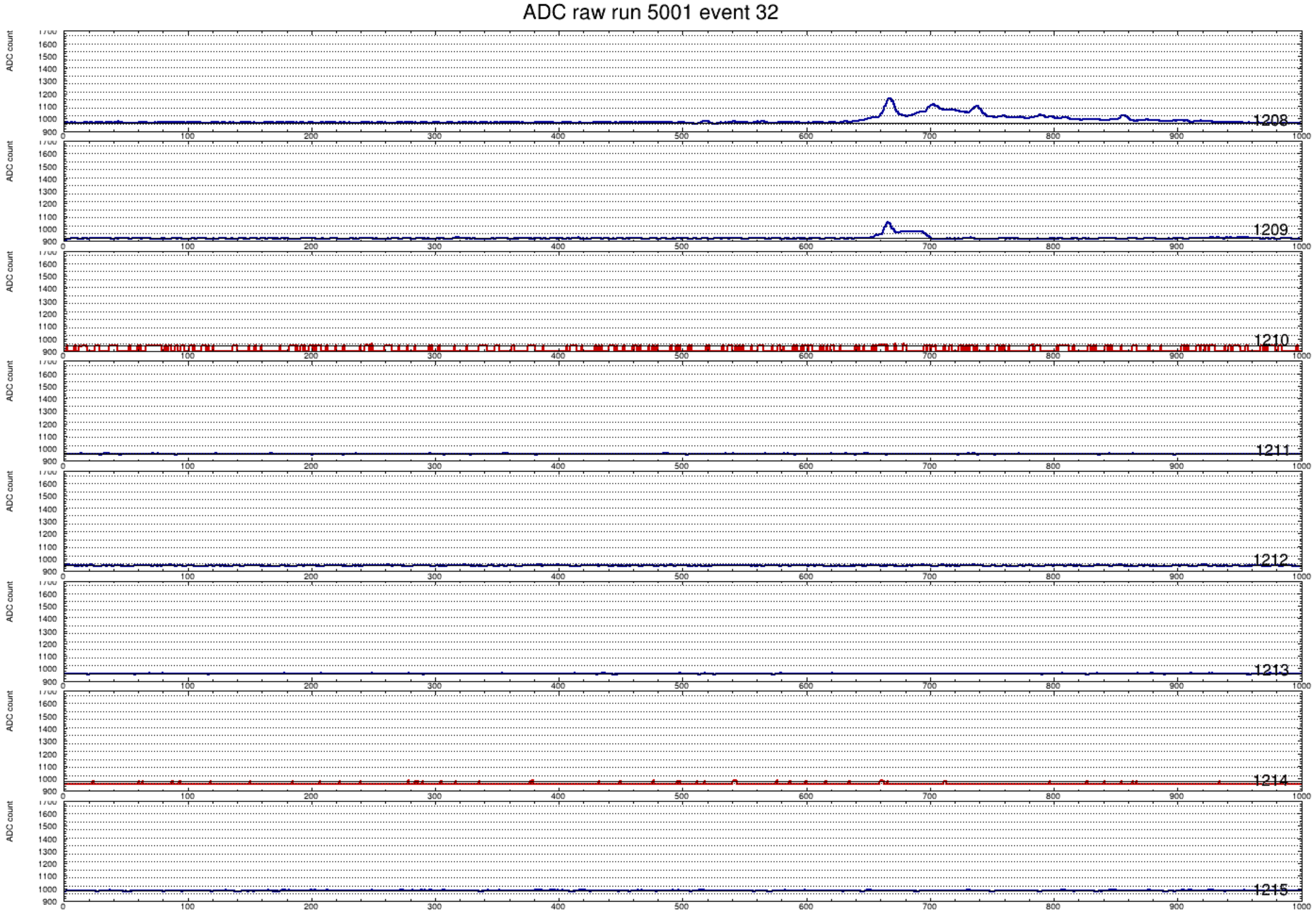


ADC raw run 5001 event 32
ADC count
968
969
970
971
972
973
974
975

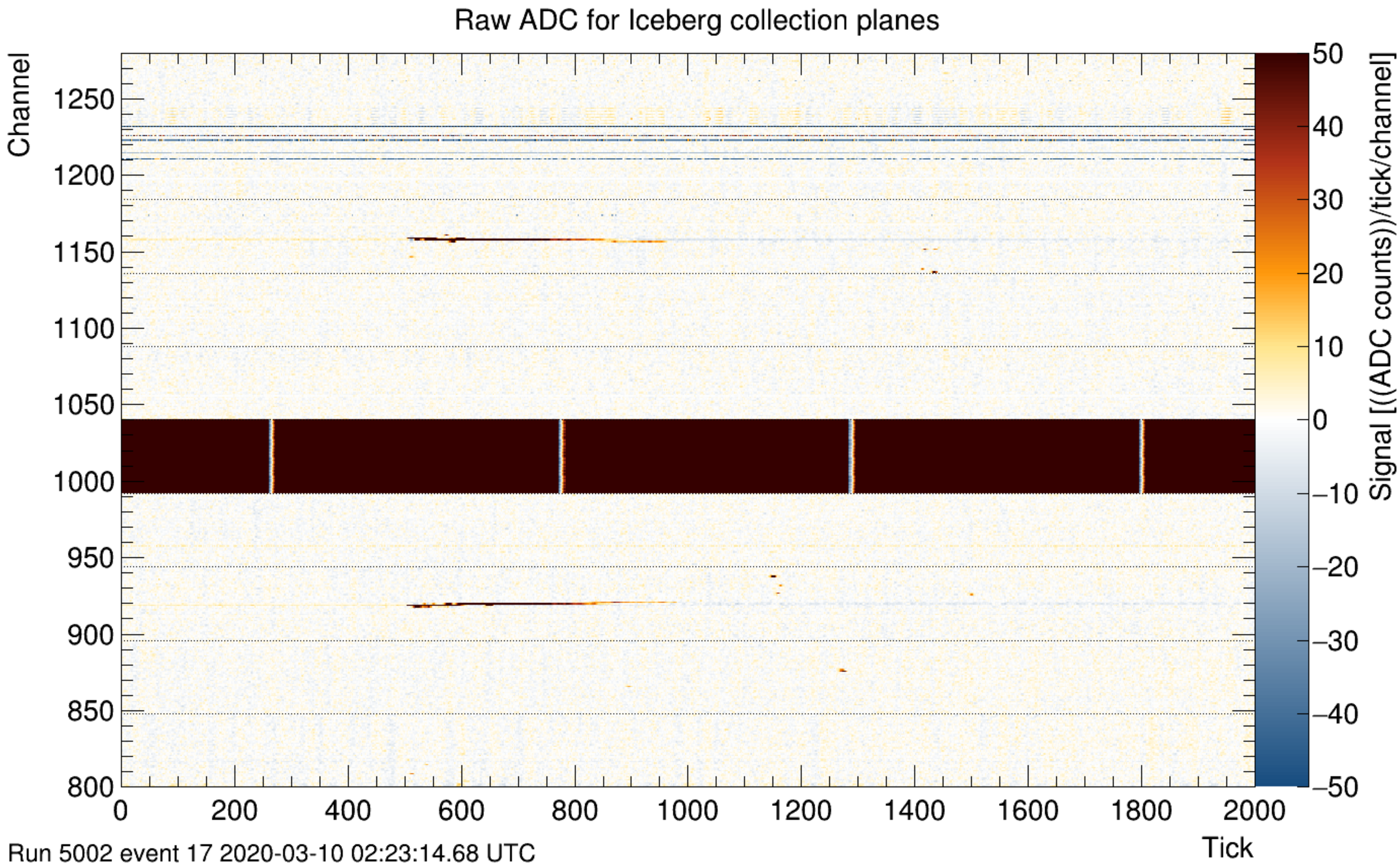
5001-32 z2


ADC raw run 5001 event 32
ADC count
1200
1201
1202
1203
1204
1205
1206
1207

5001-32 z2

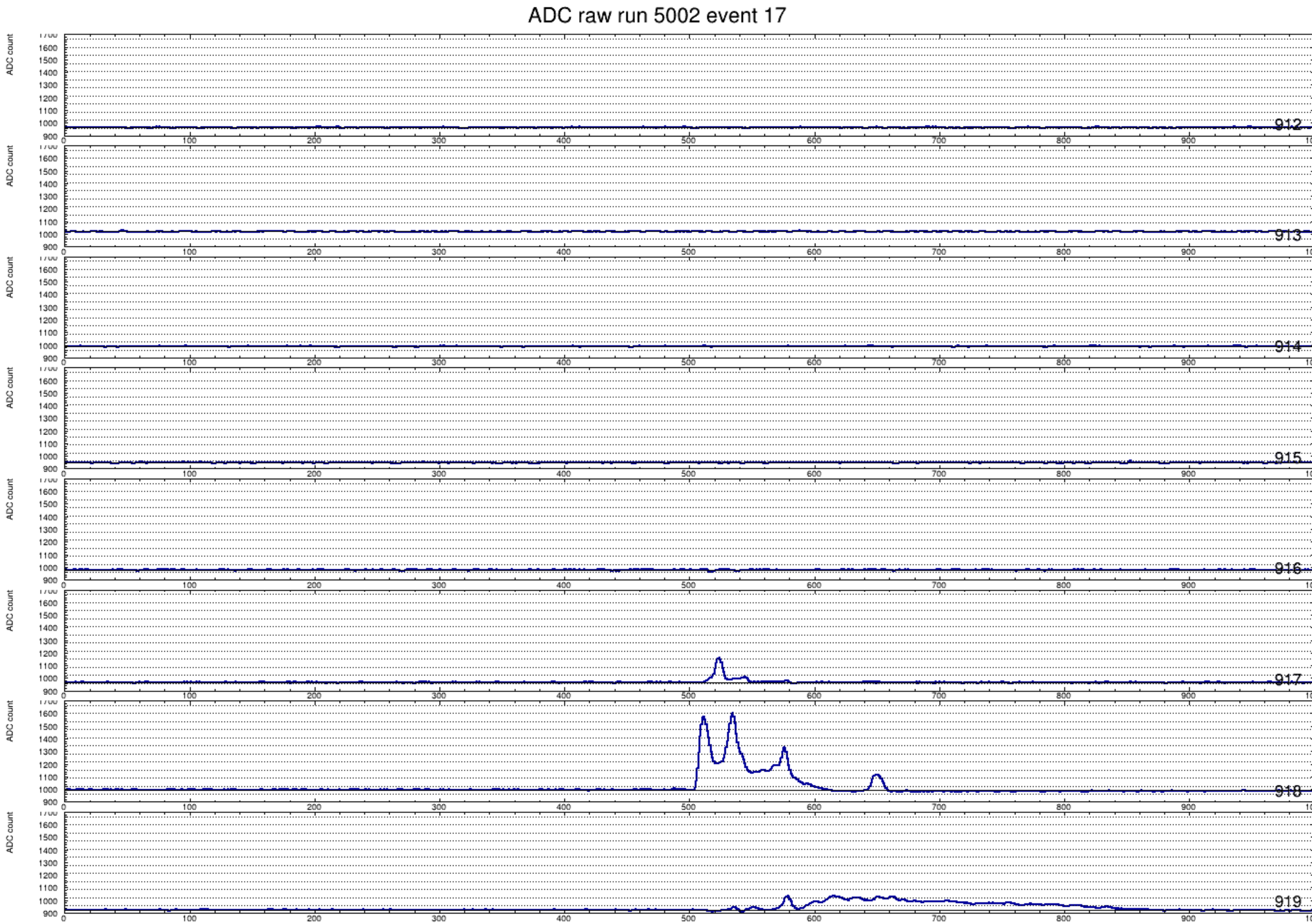

ADC raw run 5001 event 32
ADC count
1208
1209
1210
1211
1212
1213
1214
1215

5002-17

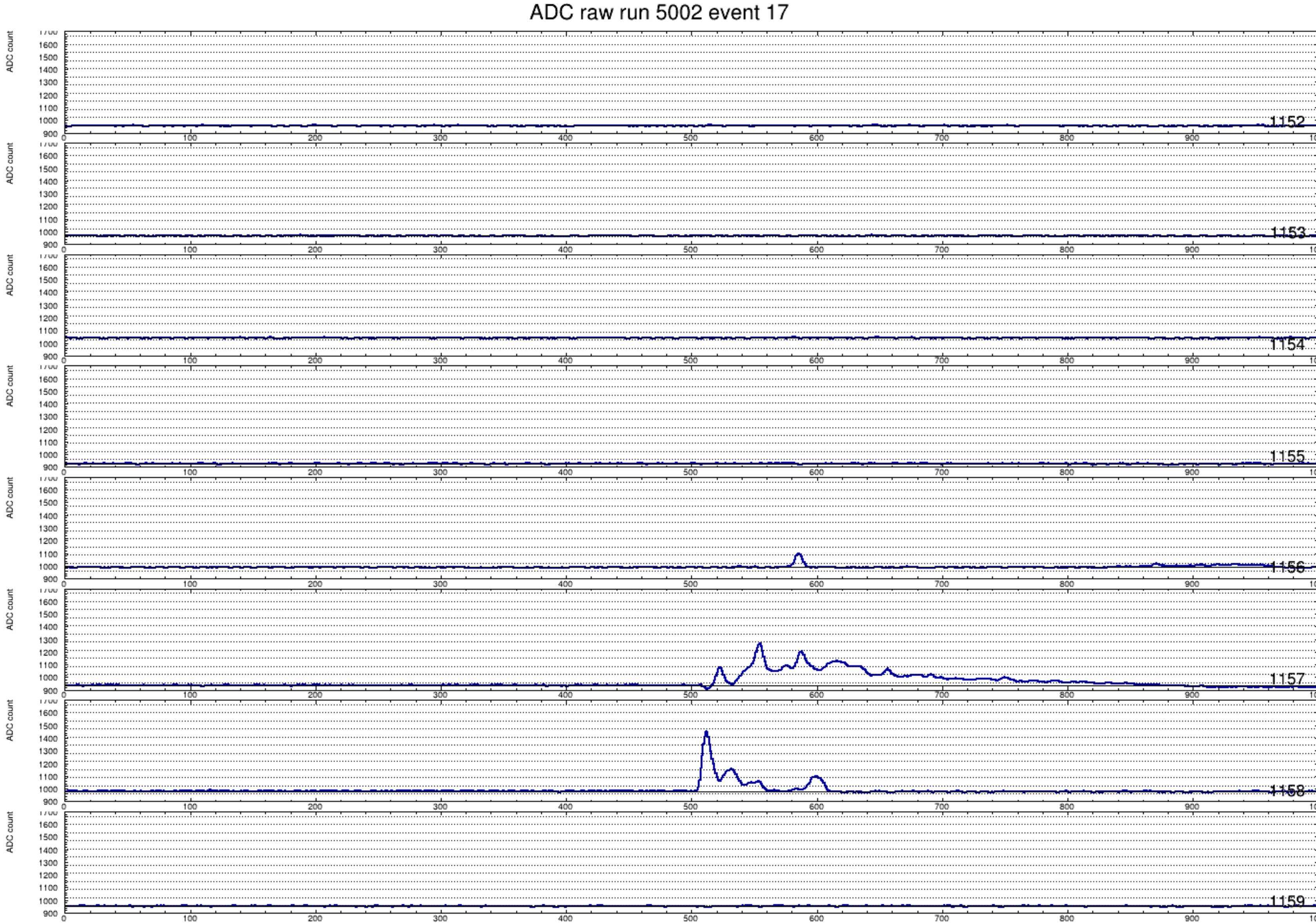


Raw ADC for Iceberg collection planes
Channel
1250
1200
1150
1100
1050
1000
950
900
850
800
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Tick
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 5002 event 17 2020-03-10 02:23:14.68 UTC

5002-17 z1

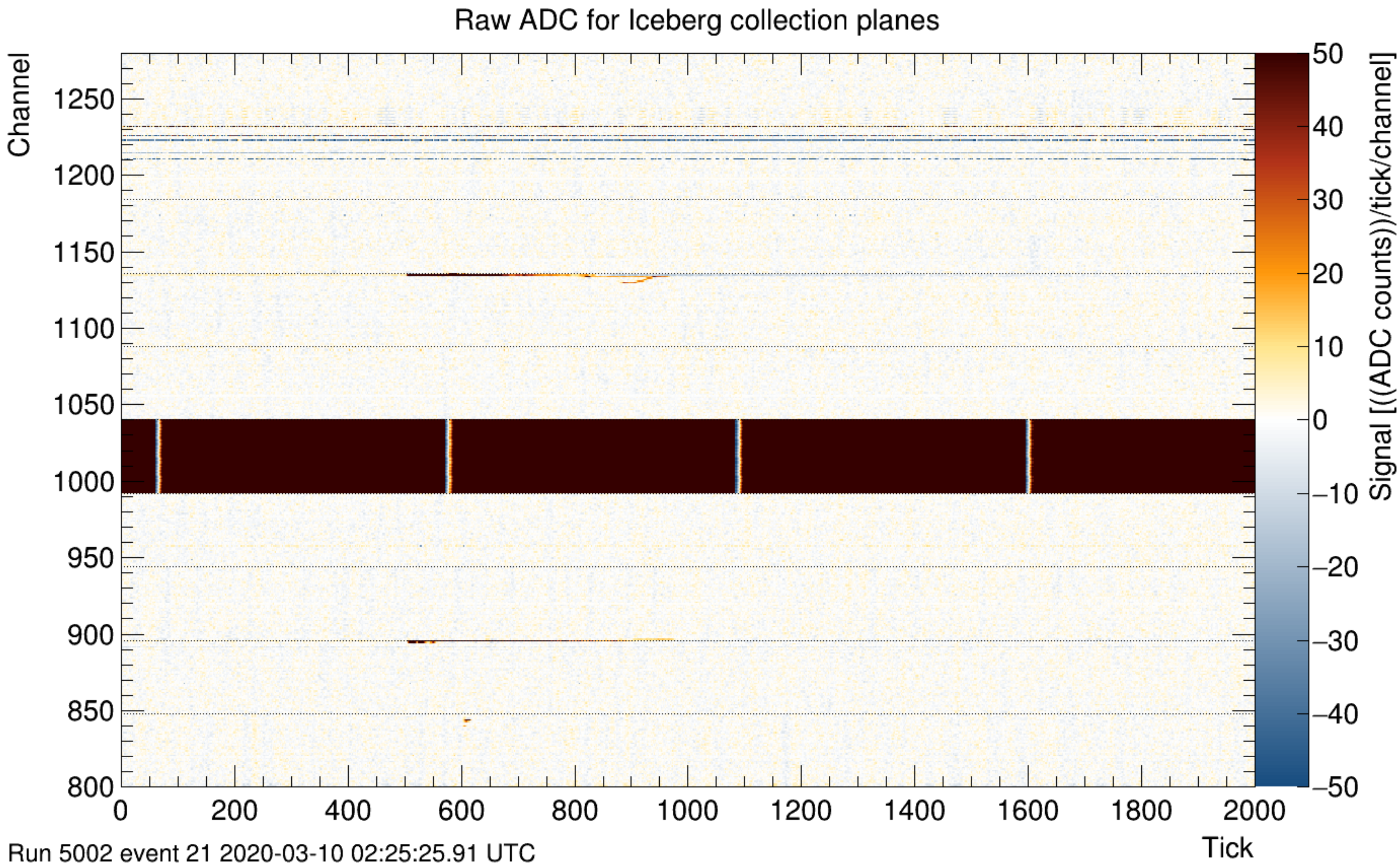

ADC raw run 5002 event 17
ADC count
912
913
914
915
916
917
918
919

5002-17 z2



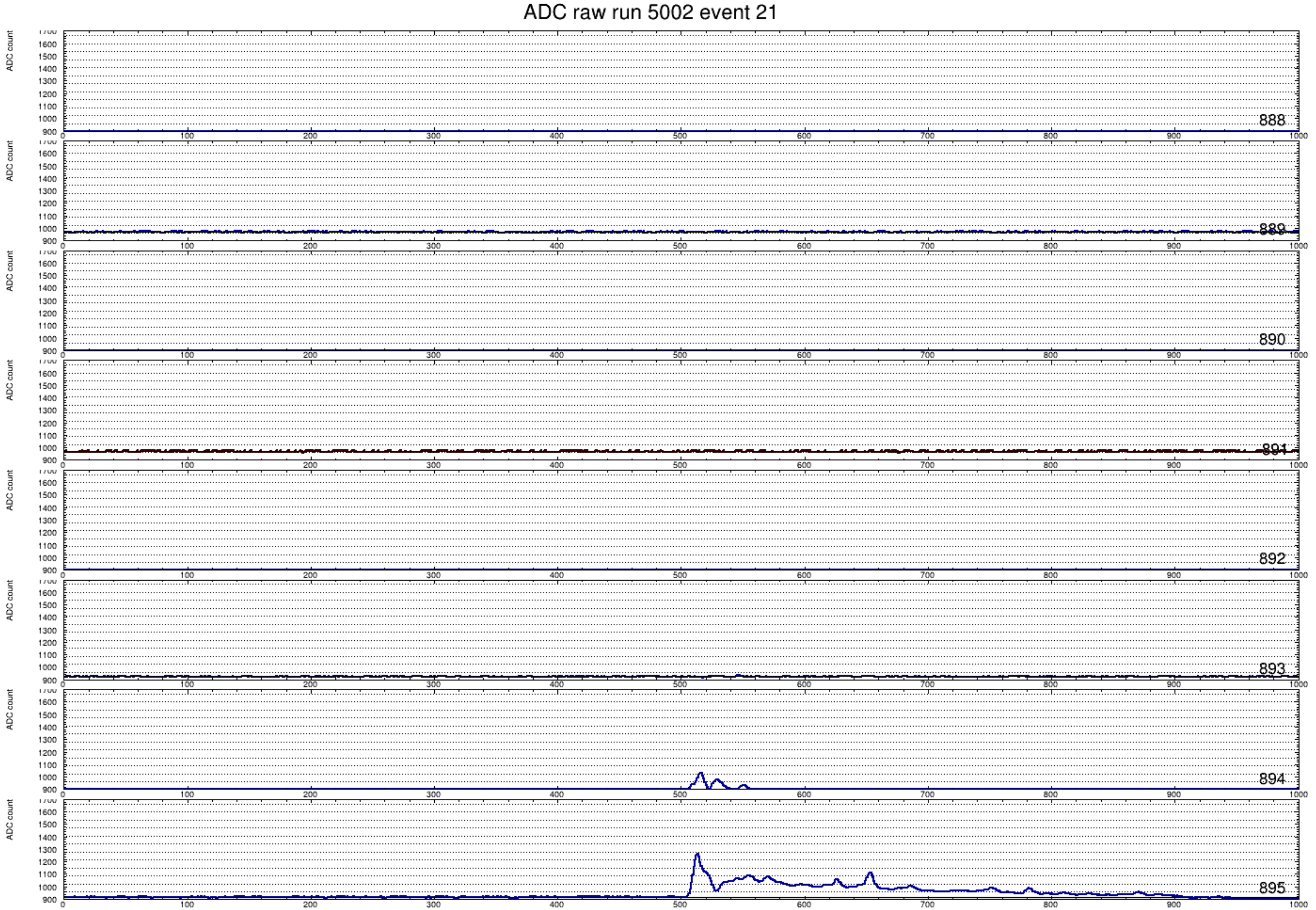
ADC raw run 5002 event 17
ADC count
1152
1153
1154
1155
1156
1157
1158
1159

5002-21



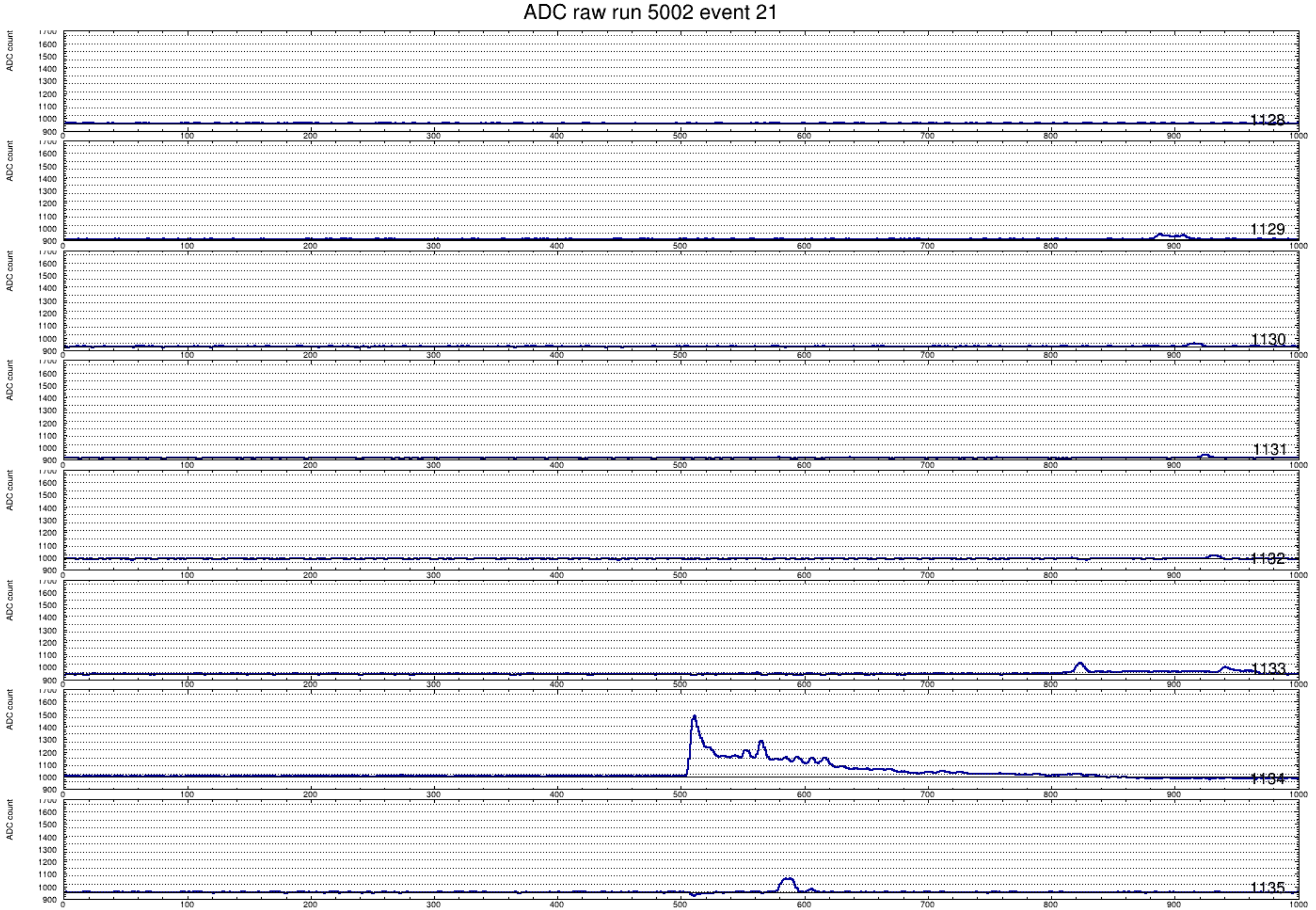
Raw ADC for Iceberg collection planes
Channel
1250
1200
1150
1100
1050
1000
950
900
850
800
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Tick
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 5002 event 21 2020-03-10 02:25:25.91 UTC

5002-21 z1



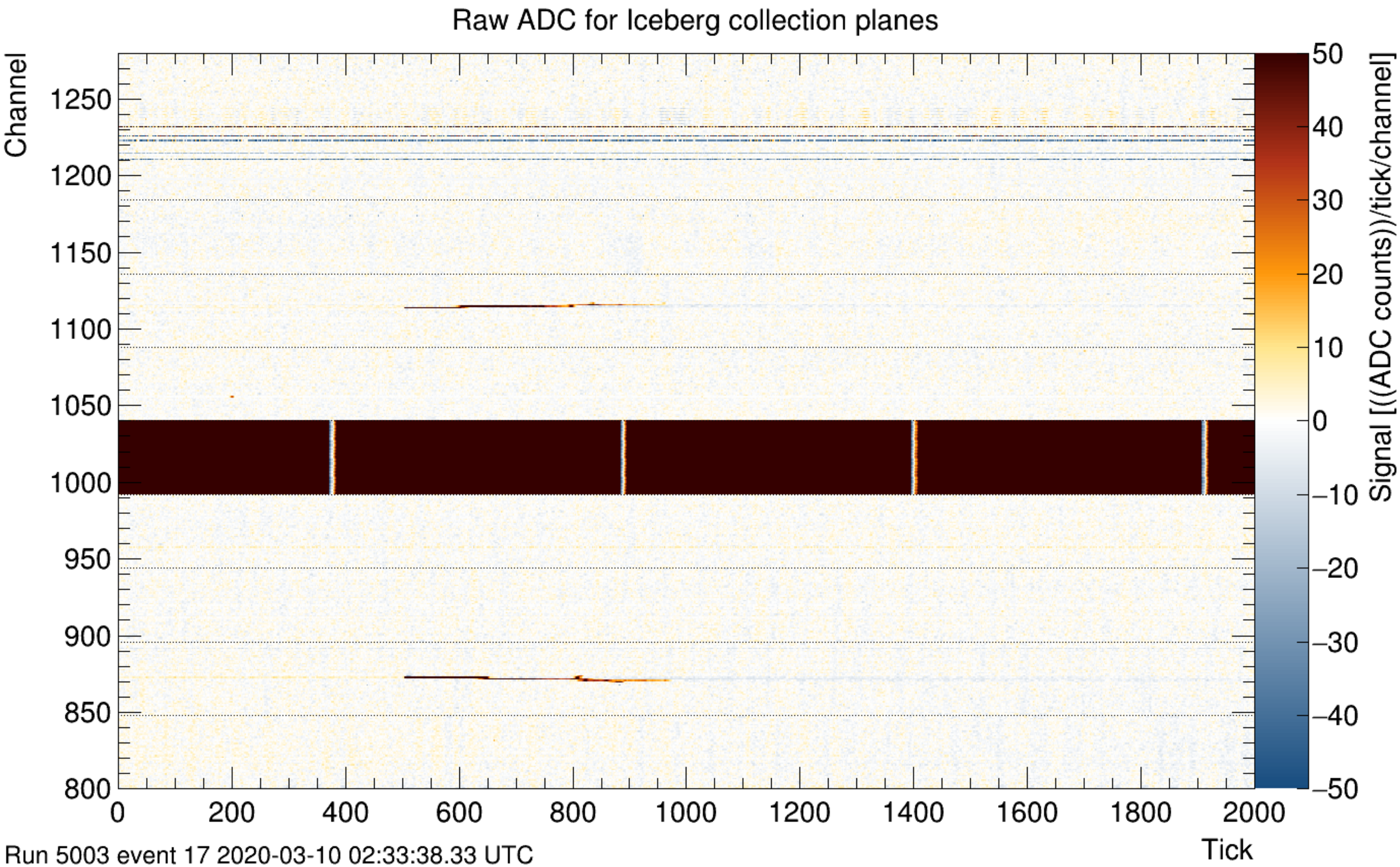
ADC raw run 5002 event 21
ADC count
888
889
890
891
892
893
894
895

5002-21 z2



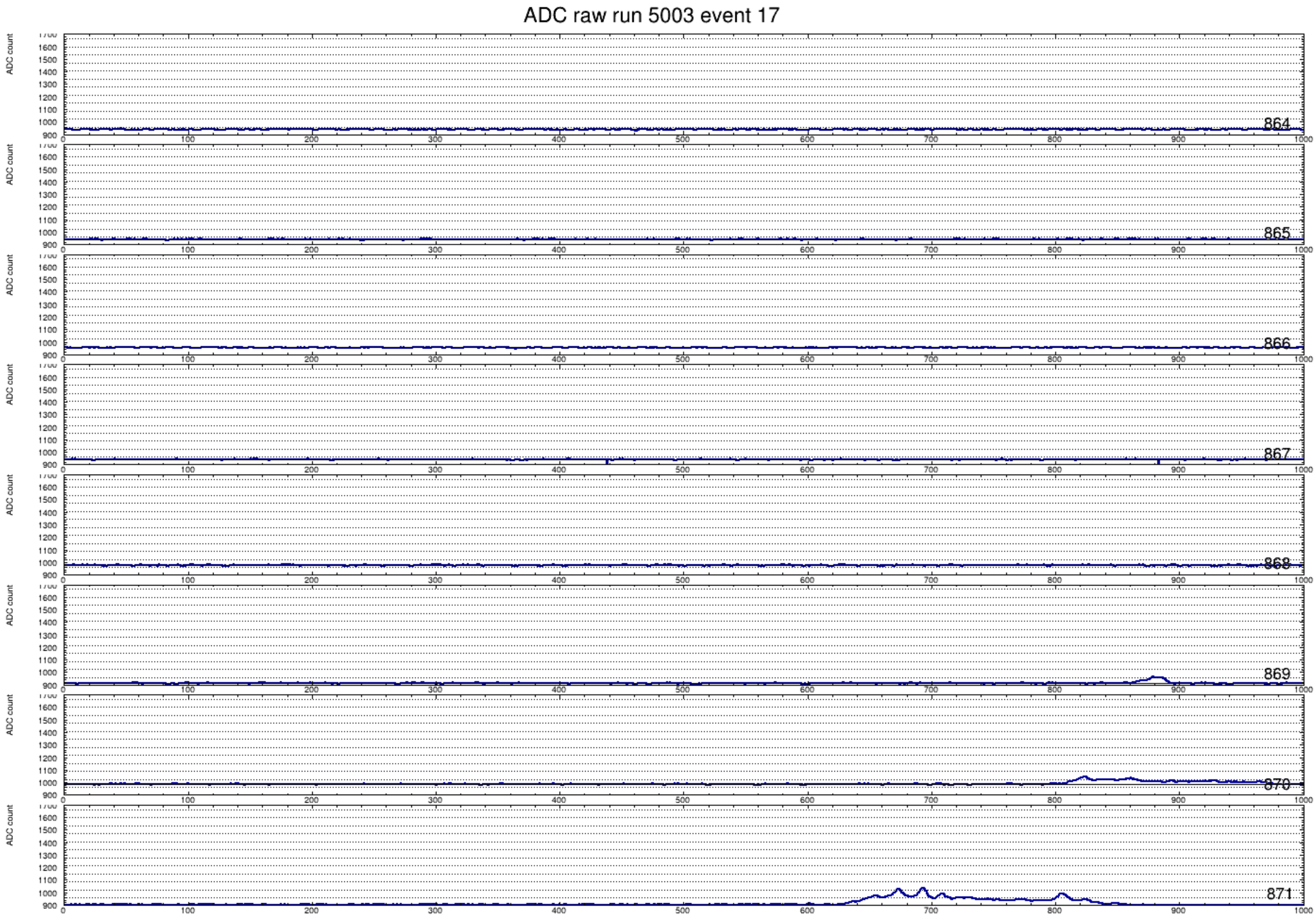
ADC raw run 5002 event 21
ADC count
1128
1129
1130
1131
1132
1133
1134
1135

5003-17



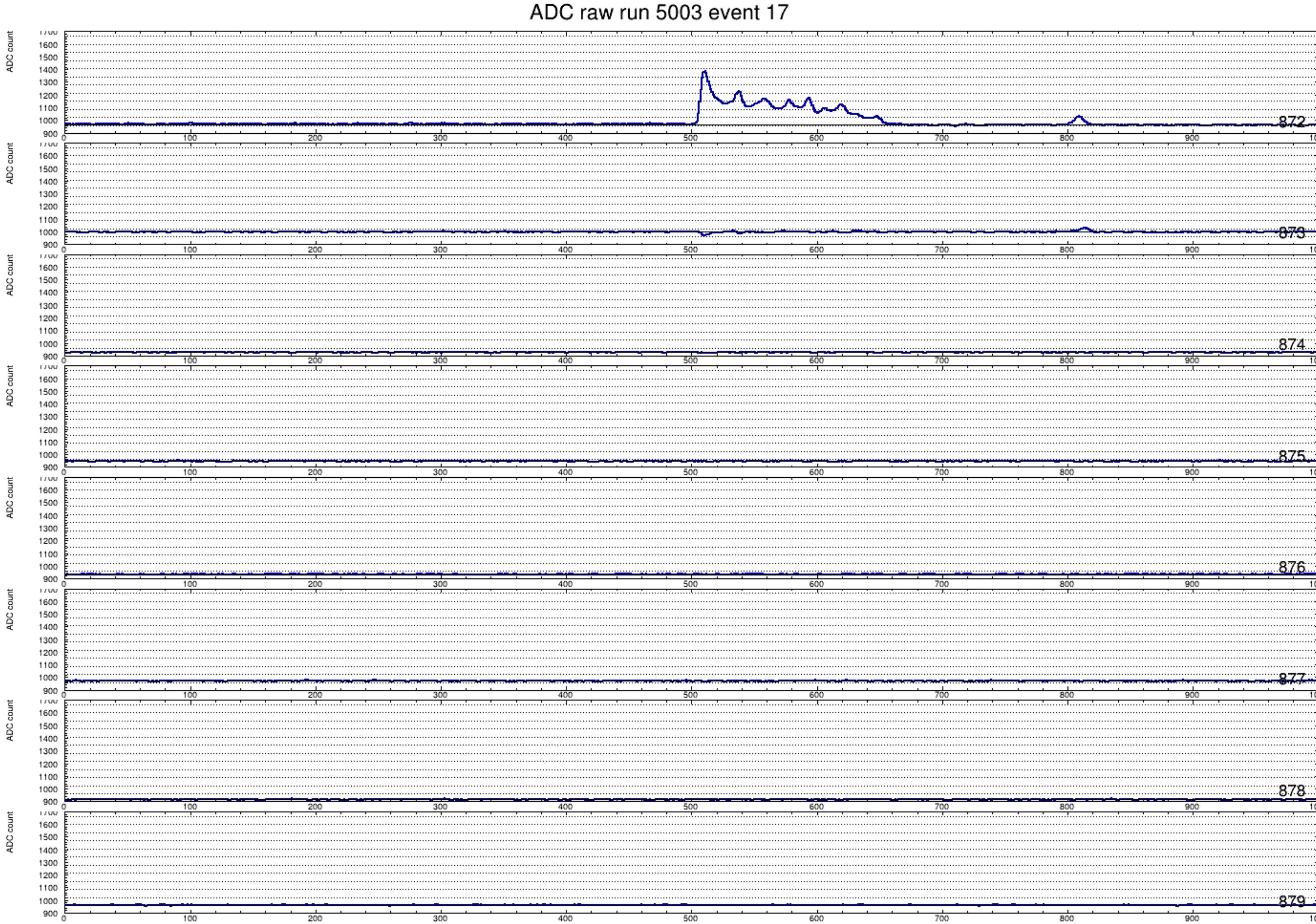
Raw ADC for Iceberg collection planes
Channel
1250
1200
1150
1100
1050
1000
950
900
850
800
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Tick
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 5003 event 17 2020-03-10 02:33:38.33 UTC

5003-17 z1

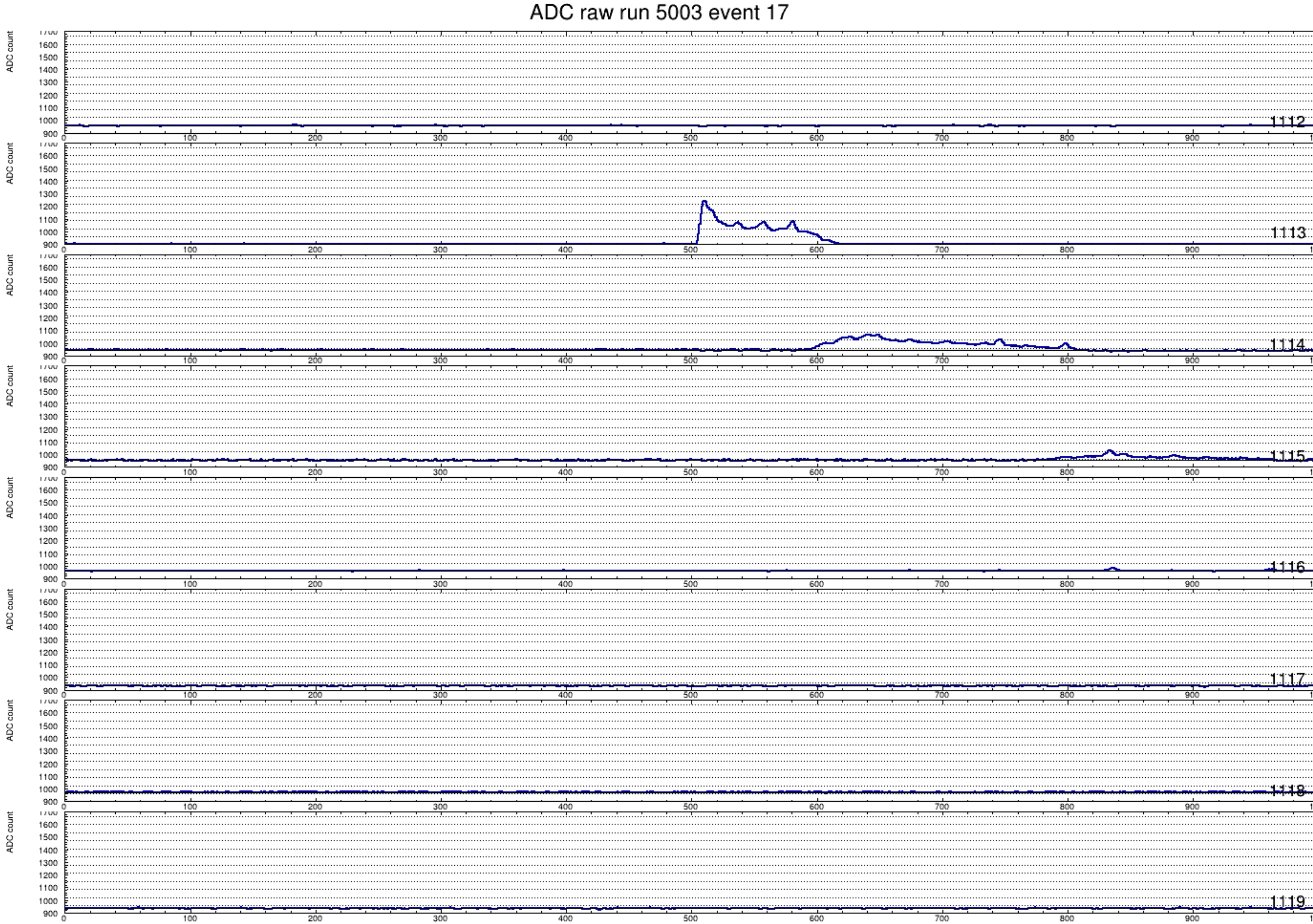


ADC raw run 5003 event 17
ADC count
864
865
866
867
868
869
870
871

5003-17 z1


ADC raw run 5003 event 17
ADC count
872
873
874
875
876
877
878
879

5003-17 z2



ADC raw run 5003 event 17
ADC count
1112
1113
1114
1115
1116
1117
1118
1119

Comments on perpendicular tracks

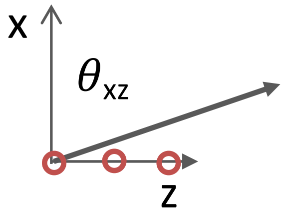
We do observe large signals

- Height around 200 – 250 ADC counts
  - After correcting (by eye) for electron lifetime and doubling of signal near collection wire
- Prediction was 200 ADC counts without accounting for vertical angle
  - I.e. signal is enhanced by $1/\cos(\theta_{xy})$
  - Trigger counters are at 25 deg (near horizontal)
  - ➔ enhancement is 1.09, i.e. expect 220 ADC
  - Consistent

Non-perpendicular tracks

Tracks not perpendicular to wire plane

Standard MIP signal: $\theta_{xz} \approx 90$ deg

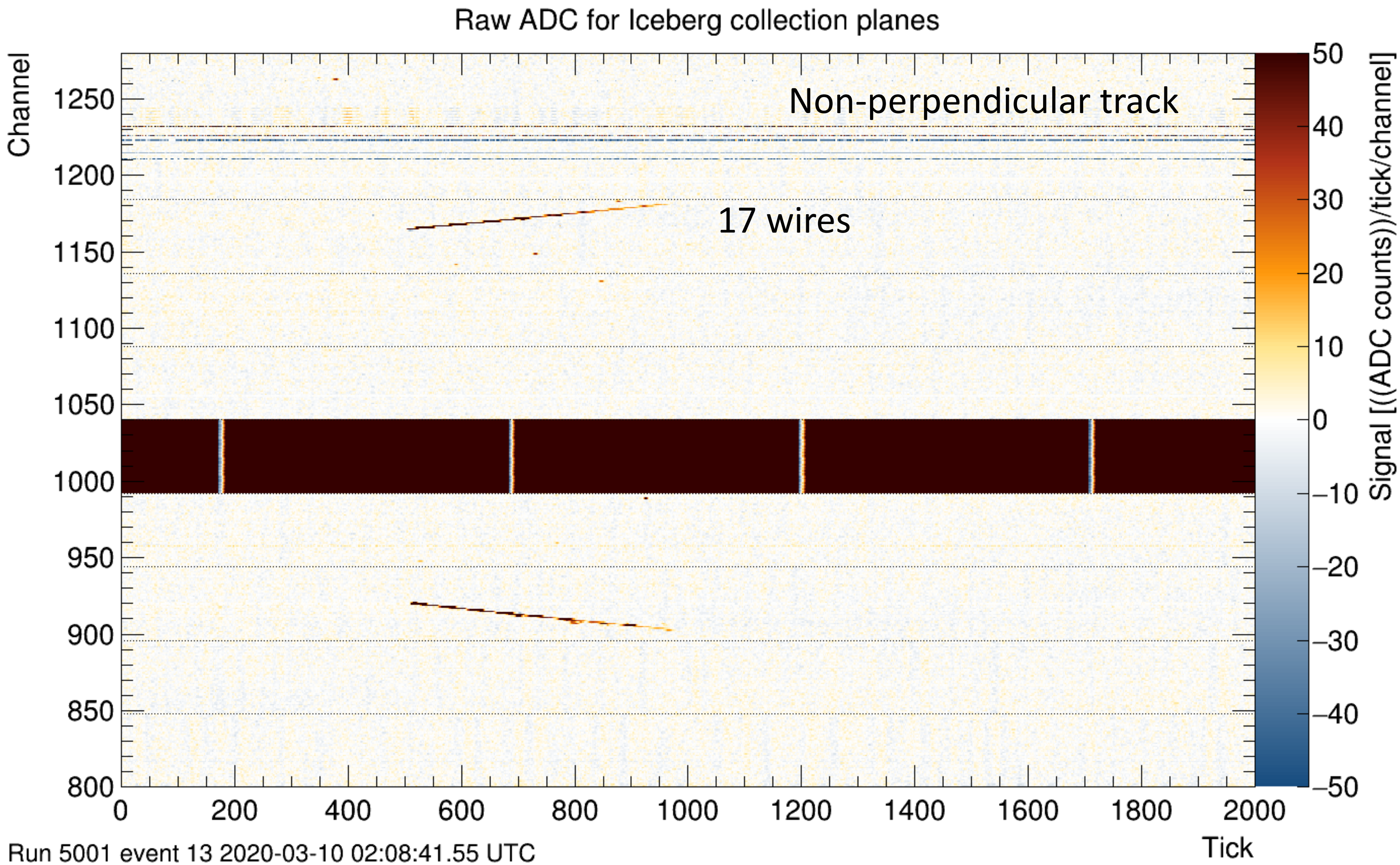


- I.e. nearly parallel to wire plane
- Integrated charge/wire is (4.8 mm) (62 ke/cm) = 30 ke
  - For track in horizontal plane
- Peak height is area/5.58 from shaping
  - plus smearing due to path lengths and diffusion
  - ➔ Peak height $\lesssim$ 5 ke = 200 ADC
- I.e. height is about the same as perpendicular tracks

Trigger counters accept $|\theta_{xz}| \lesssim 25$ deg

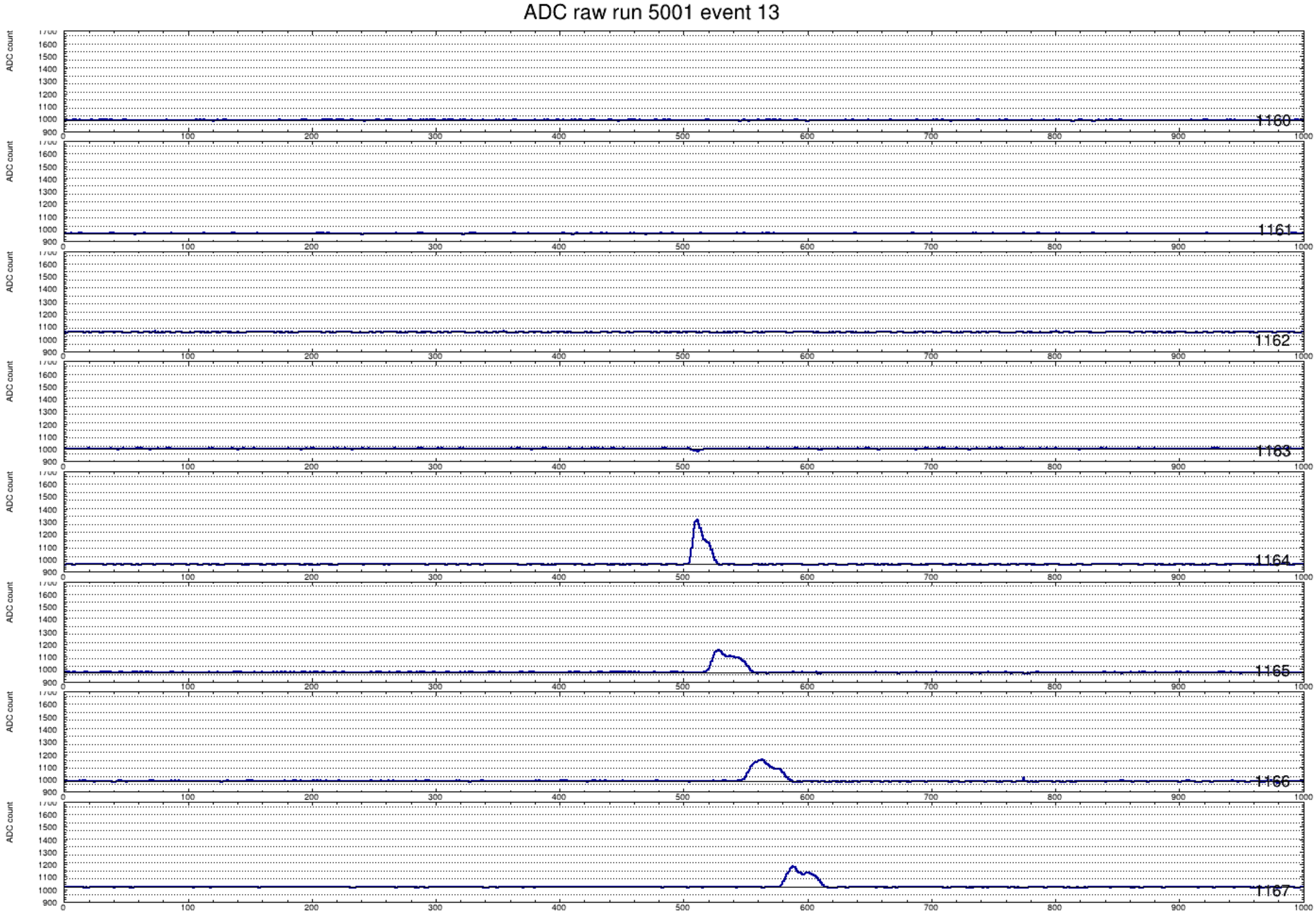
- Far from parallel but there are some tracks significantly away from the perpendicular
- Tracks cross fewer than 30 wires on either side of APA
  - Maybe 20-30 wires are enough for protoDUNE-like SNR study?
- Following pages show a few tracks away from perpendicular

5001-13

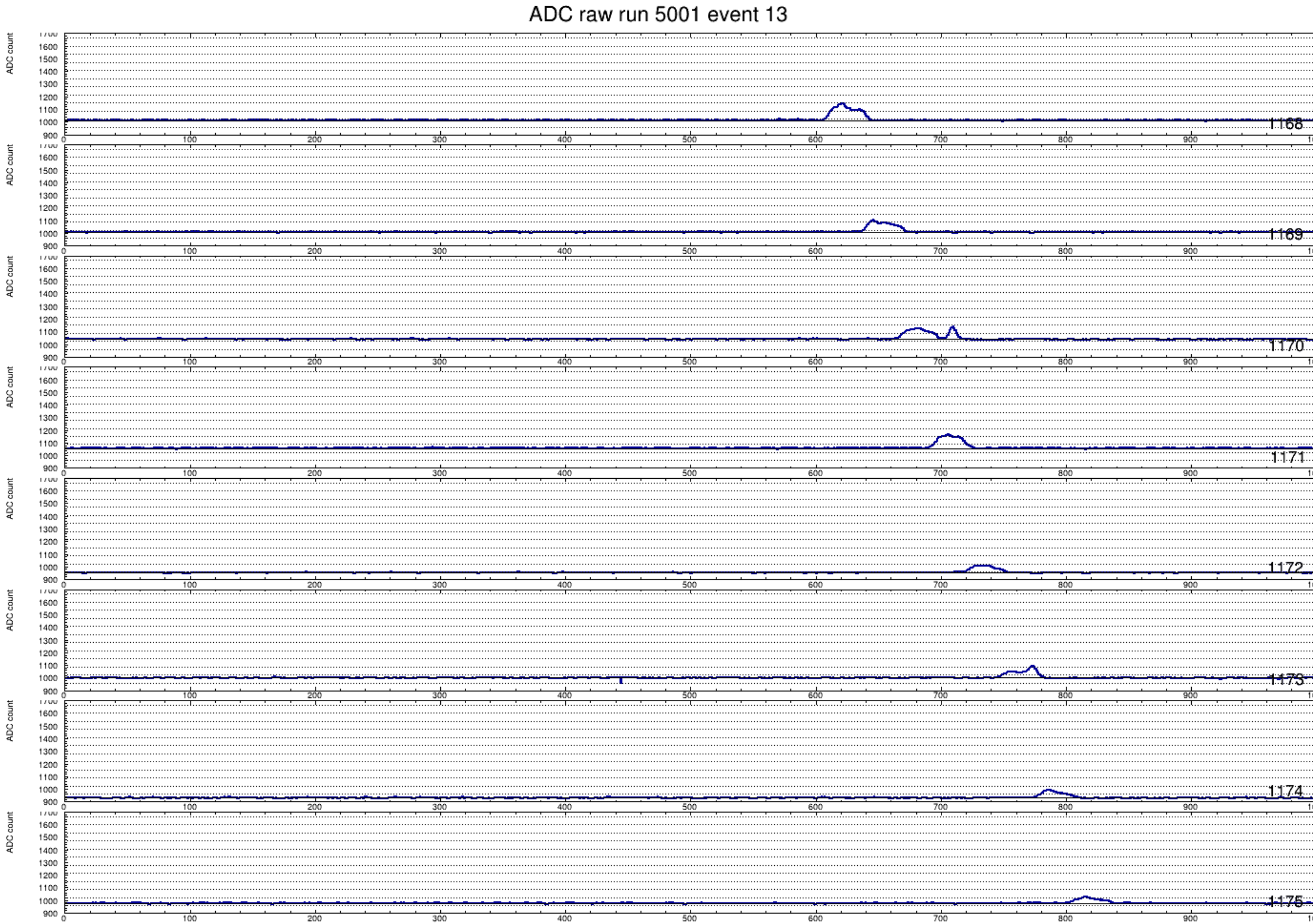


Raw ADC for Iceberg collection planes
Channel
1250
1200
1150
1100
1050
1000
950
900
850
800
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Tick
Non-perpendicular track
17 wires
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 5001 event 13 2020-03-10 02:08:41.55 UTC

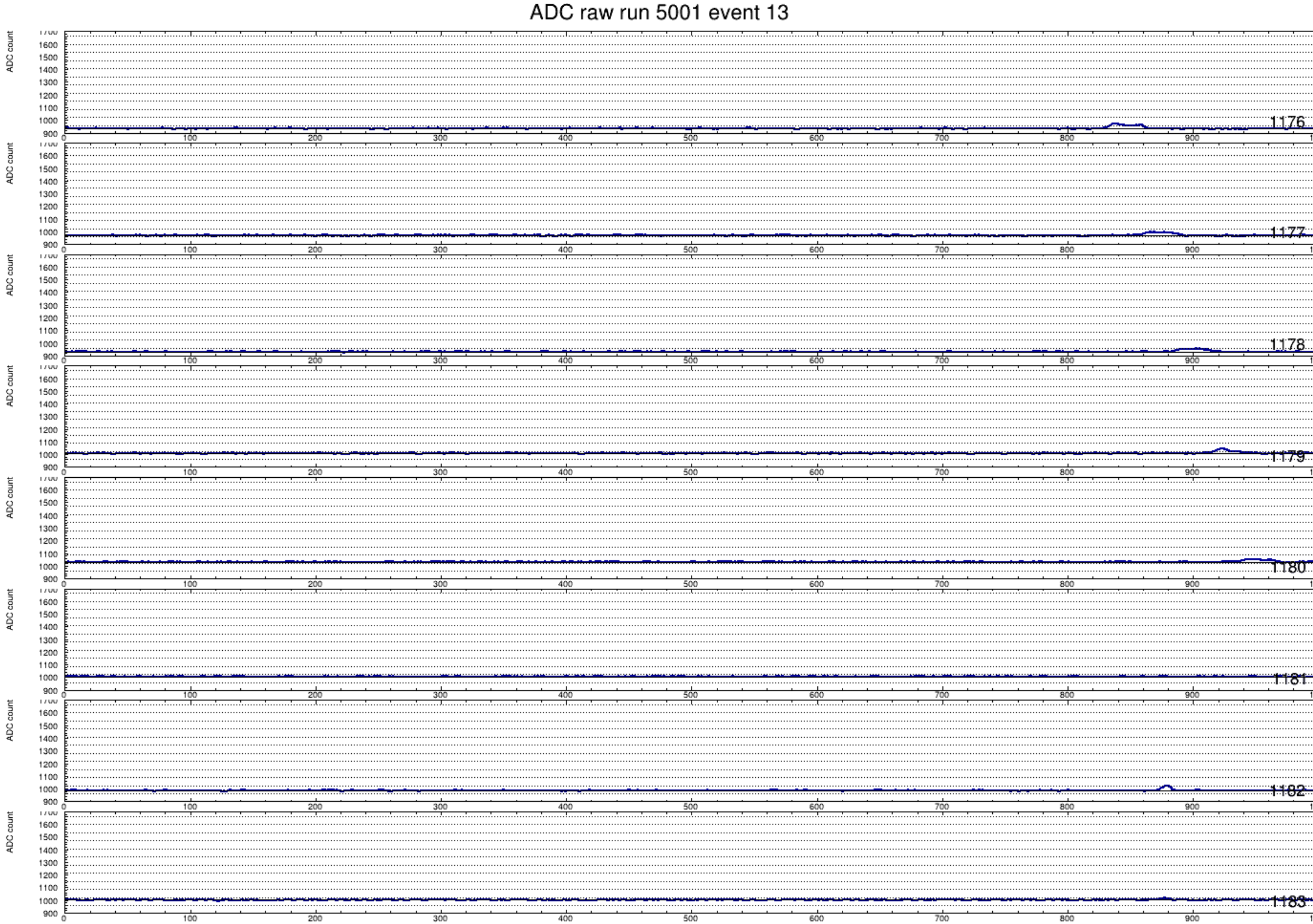
5001-13 z1


ADC raw run 5001 event 13
ADC count
1160
1161
1162
1163
1164
1165
1166
1167

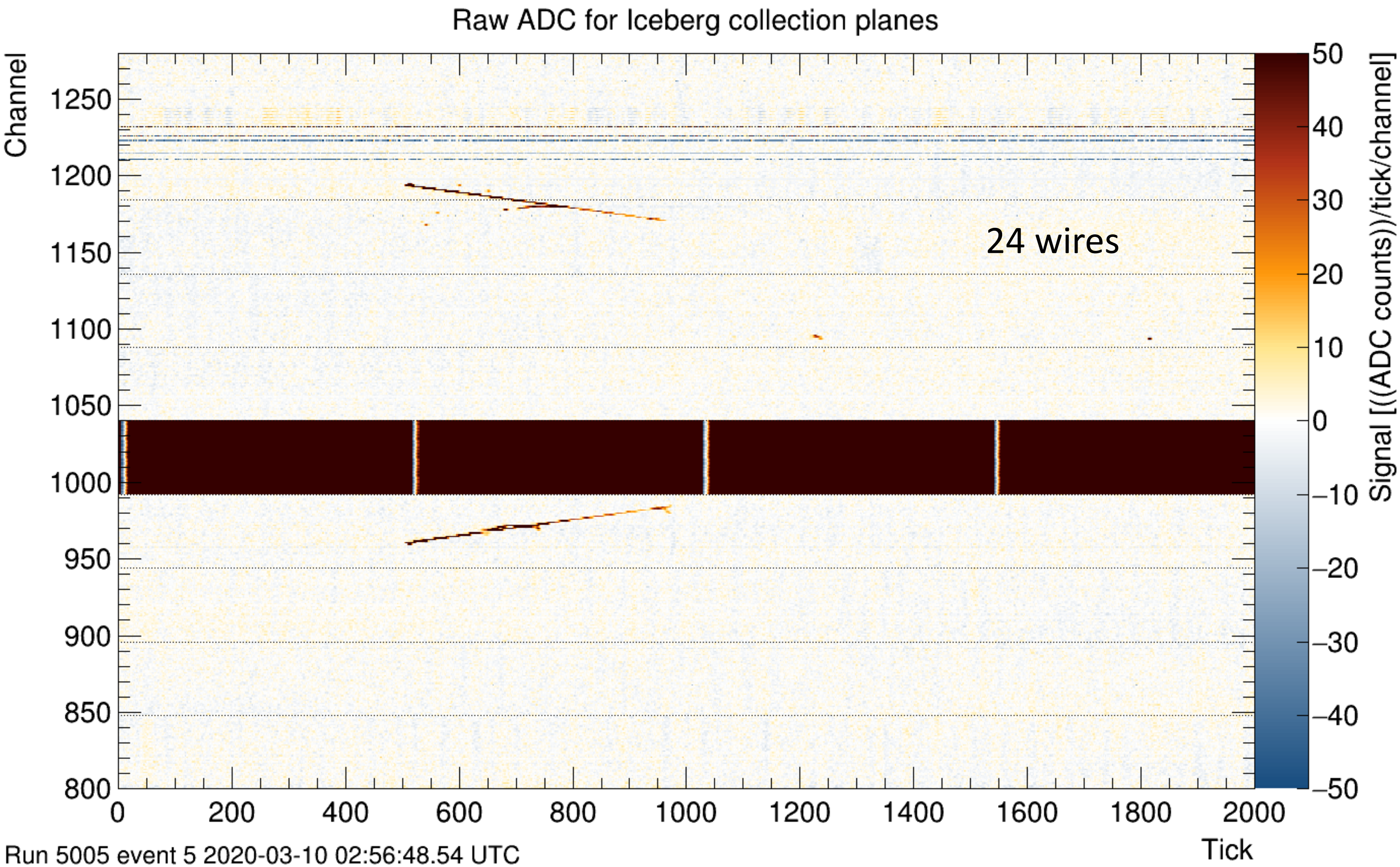
5001-13 z1


ADC raw run 5001 event 13
ADC count
1168
1169
1170
1171
1172
1173
1174
1175

5001-13 z1

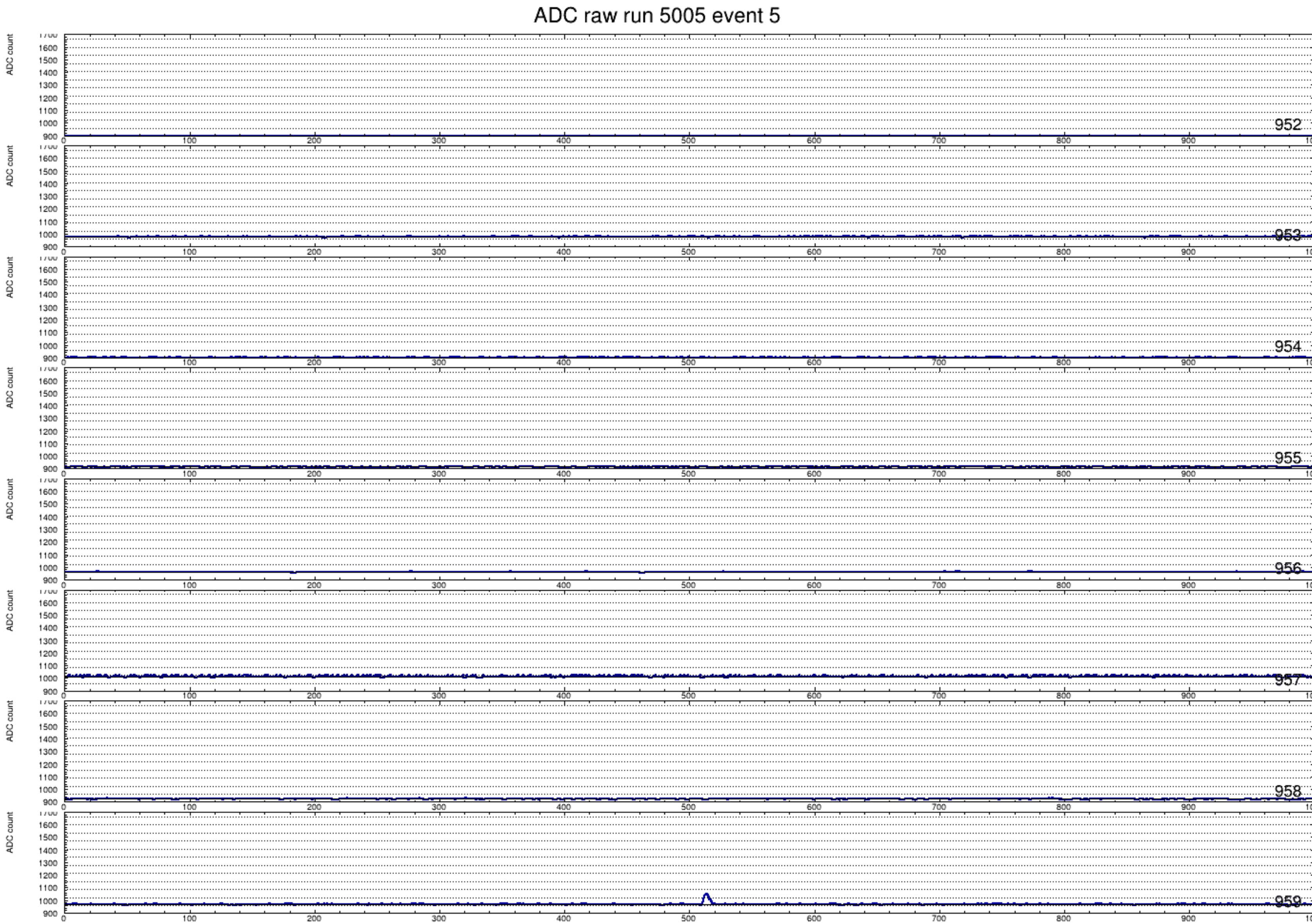

ADC raw run 5001 event 13
ADC count
1176
1177
1178
1179
1180
1181
1182
1183

5005-5



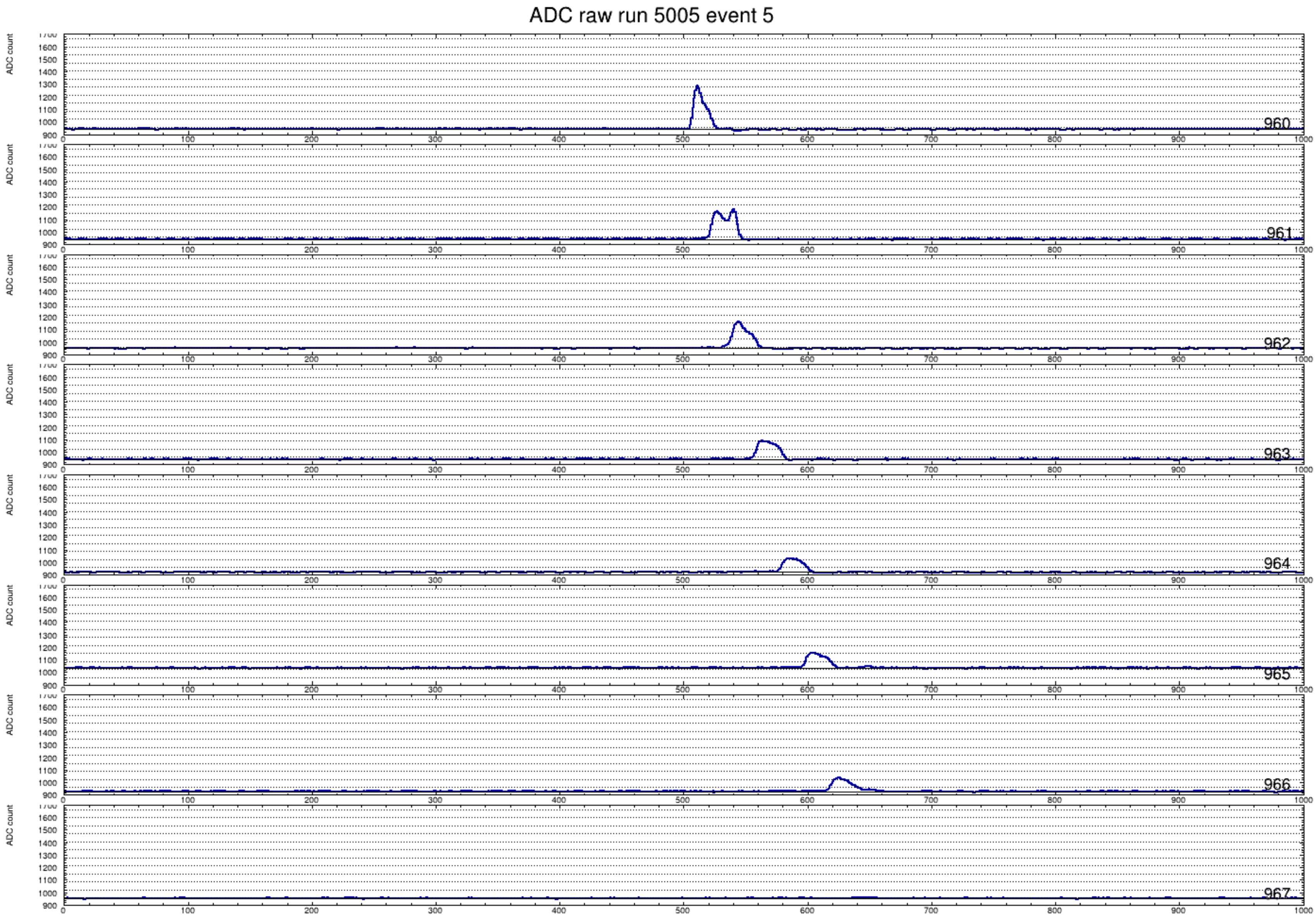
Raw ADC for Iceberg collection planes
Channel
1250
1200
1150
1100
1050
1000
950
900
850
800
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Tick
24 wires
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 5005 event 5 2020-03-10 02:56:48.54 UTC

5005-5 z1

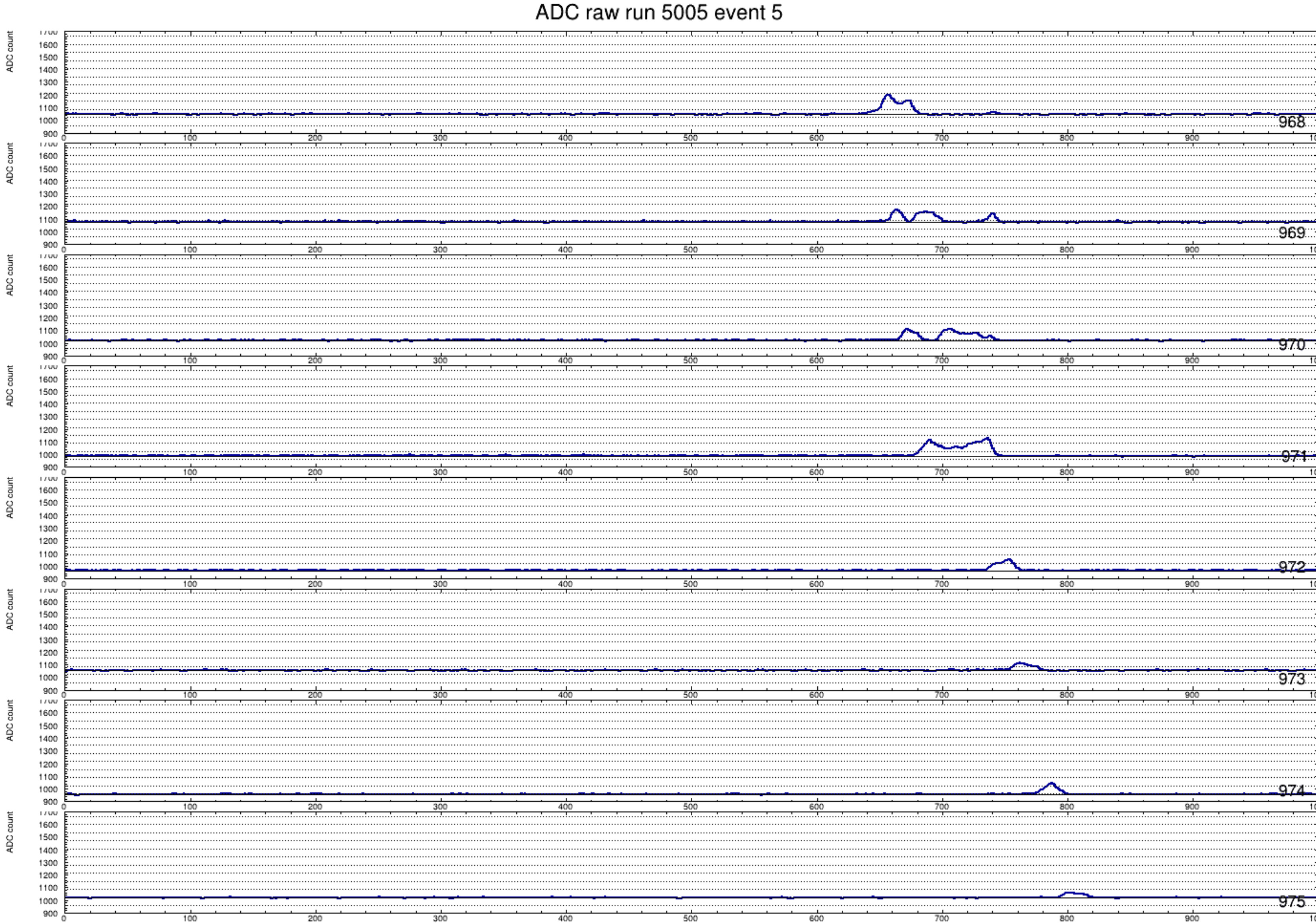


ADC raw run 5005 event 5
ADC count
952
953
954
955
956
957
958
959

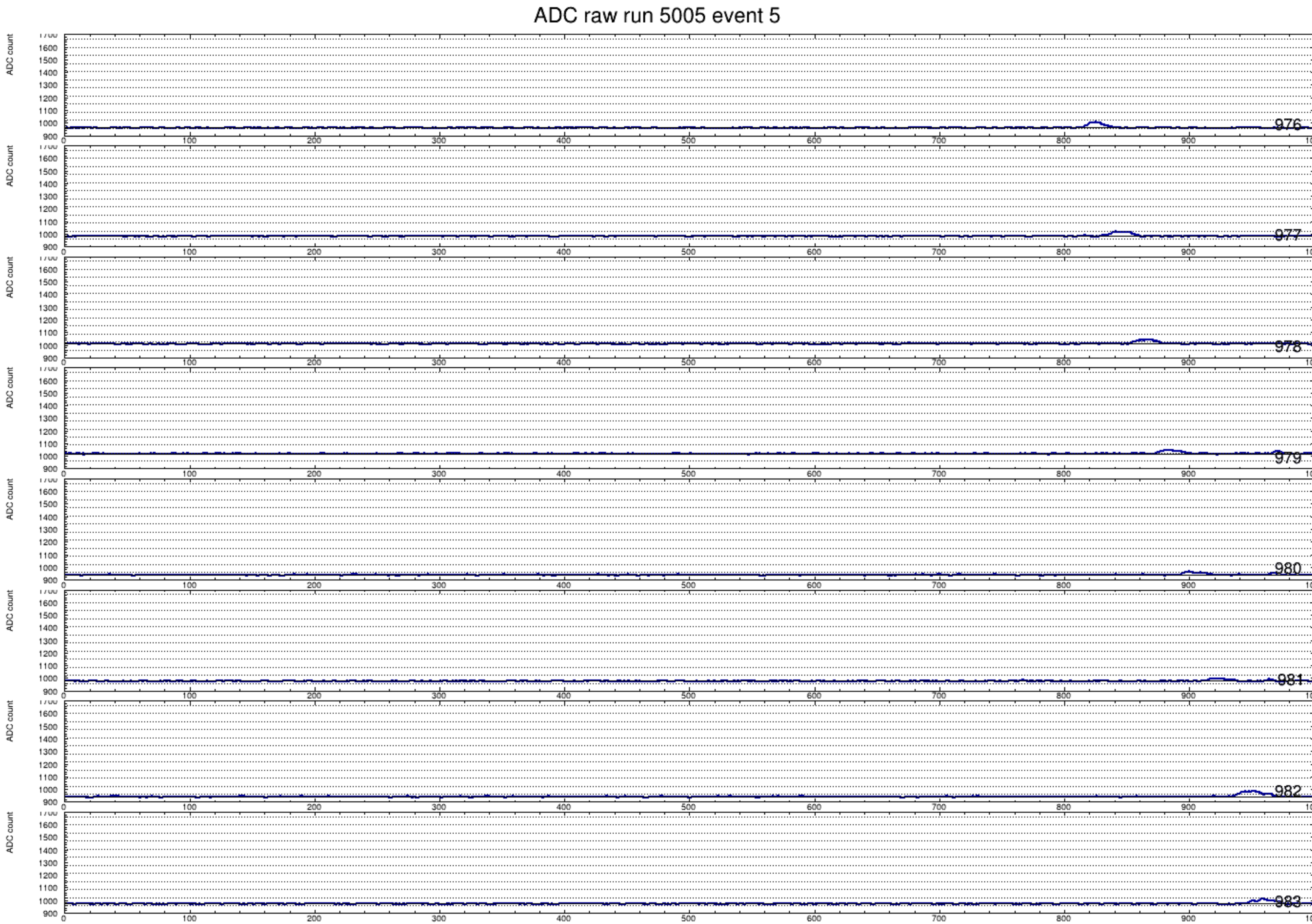
5005-5 z1


ADC raw run 5005 event 5
ADC count
960
961
962
963
964
965
966
967

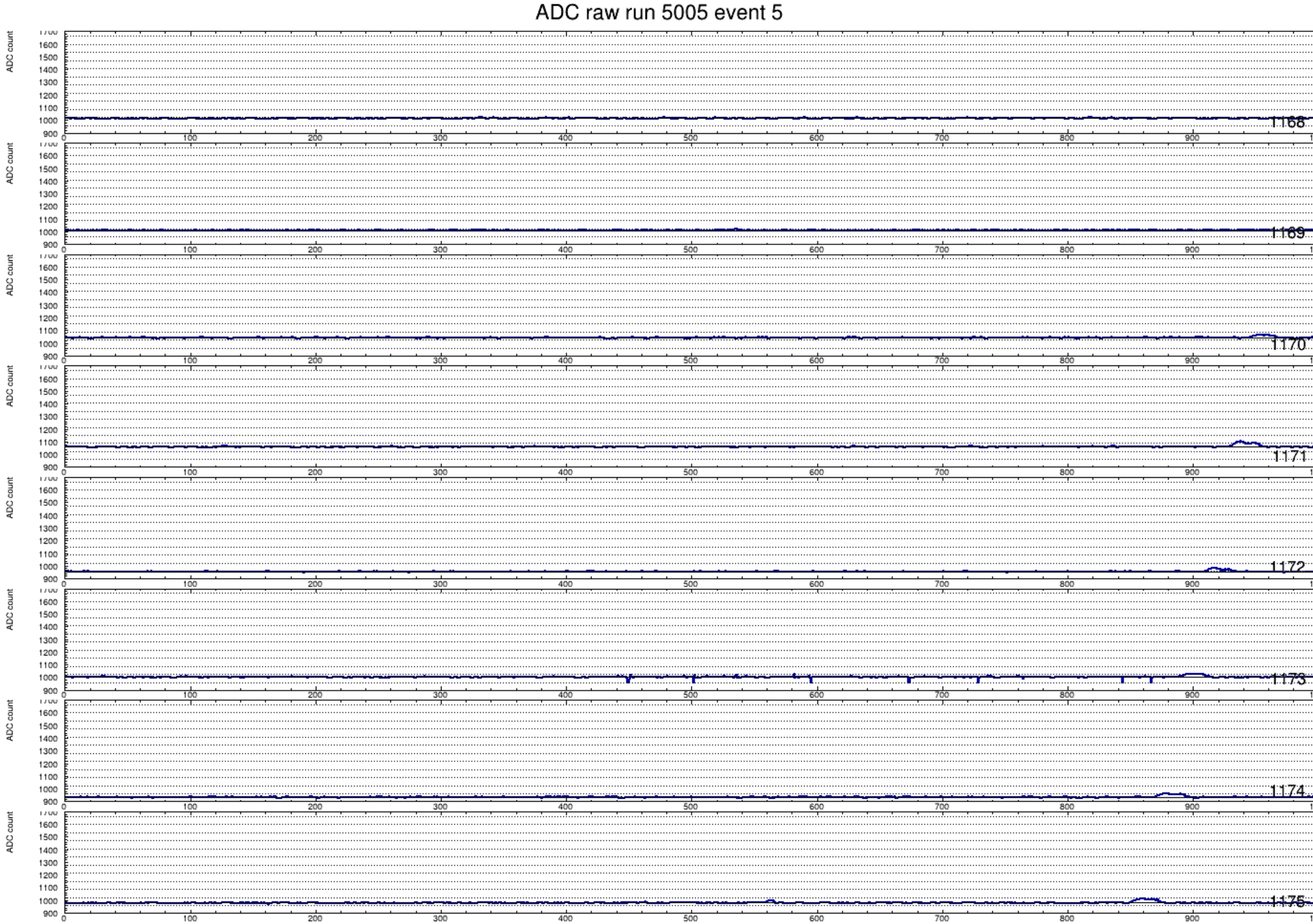
5005-5 z1


ADC raw run 5005 event 5
ADC count
968
969
970
971
972
973
974
975

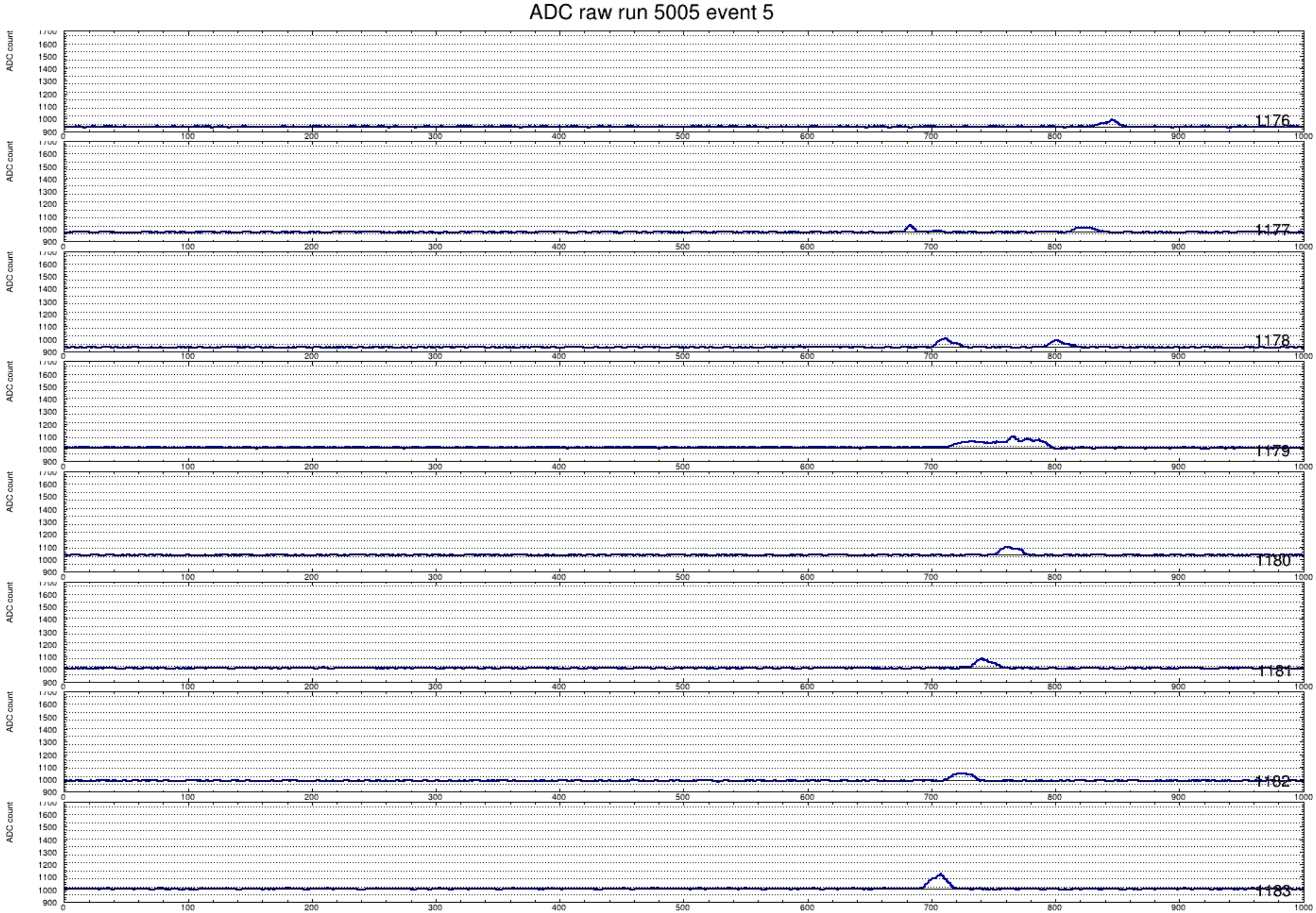
5005-5 z1


ADC raw run 5005 event 5
ADC count
900
1000
1100
1200
1300
1400
1500
1600
1700
0
100
200
300
400
500
600
700
800
900
1000
976
977
978
979
980
981
982
983

5005-5 z2

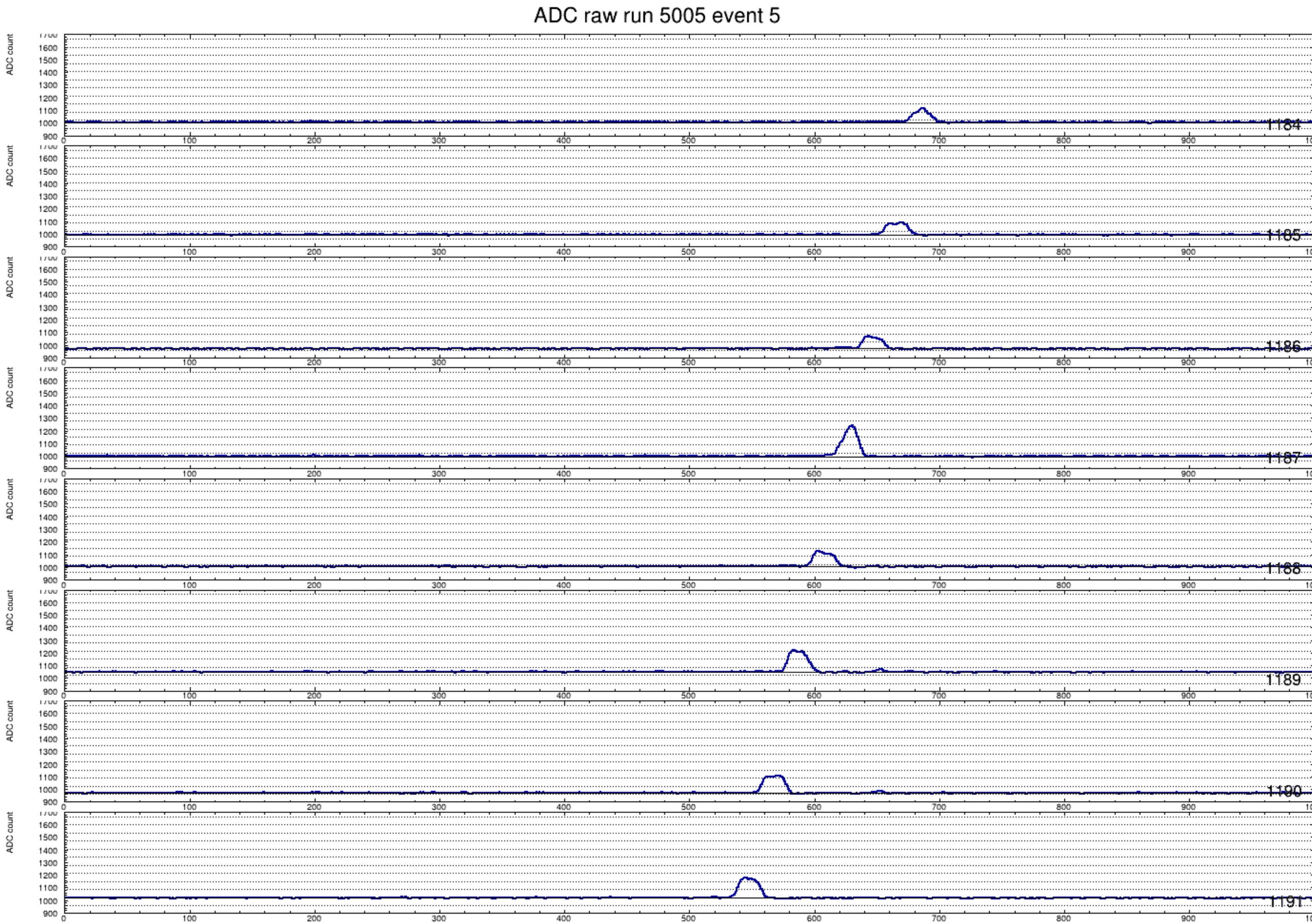

ADC raw run 5005 event 5
ADC count
1168
1169
1170
1171
1172
1173
1174
1175

5005-5 z2

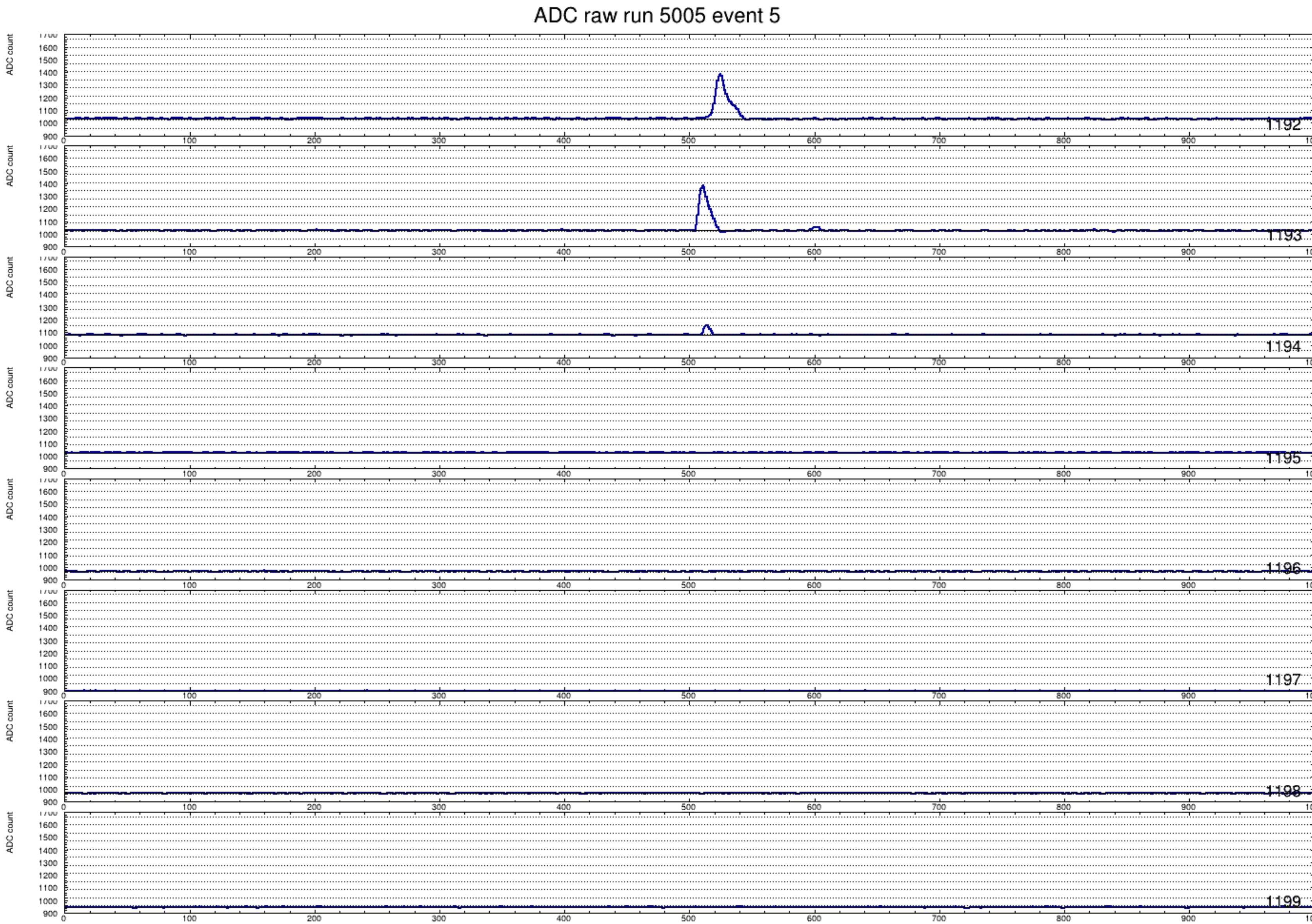


ADC raw run 5005 event 5
ADC count
1176
1177
1178
1179
1180
1181
1182
1183

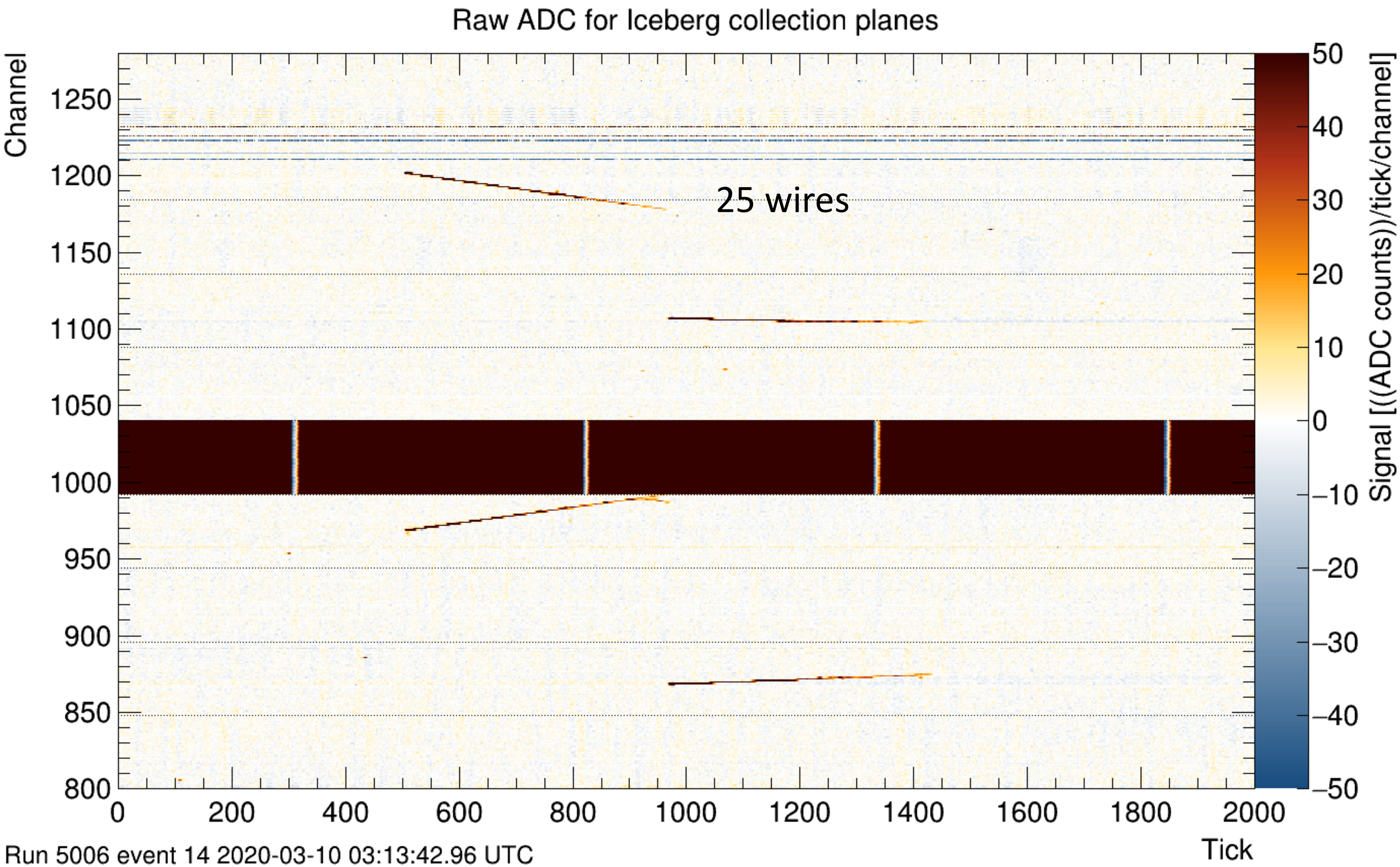
5005-5 z2


ADC raw run 5005 event 5
ADC count
1184
1185
1186
1187
1188
1189
1190
1191

5005-5 z2

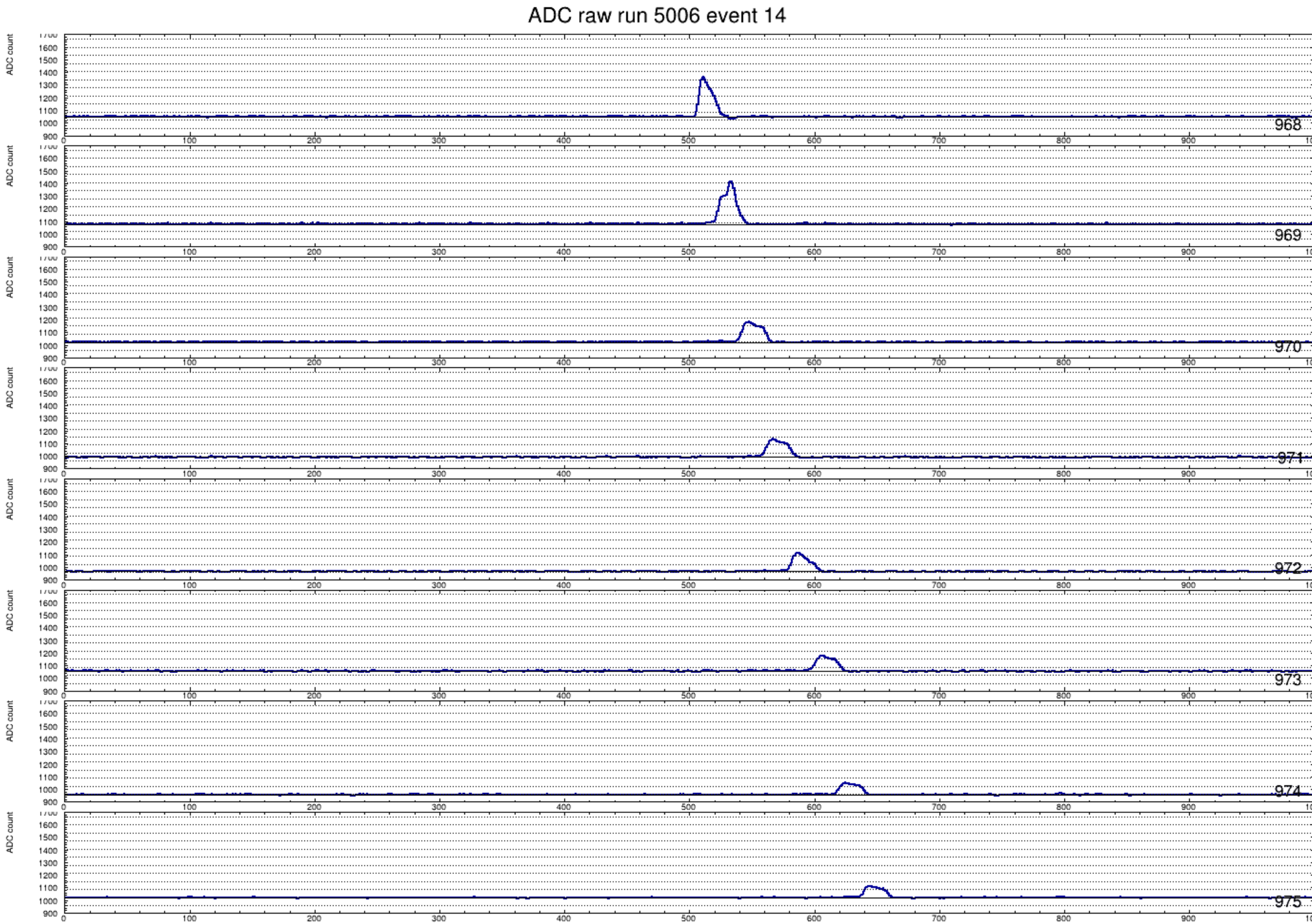

ADC raw run 5005 event 5
ADC count
1192
1193
1194
1195
1196
1197
1198
1199

5006-14

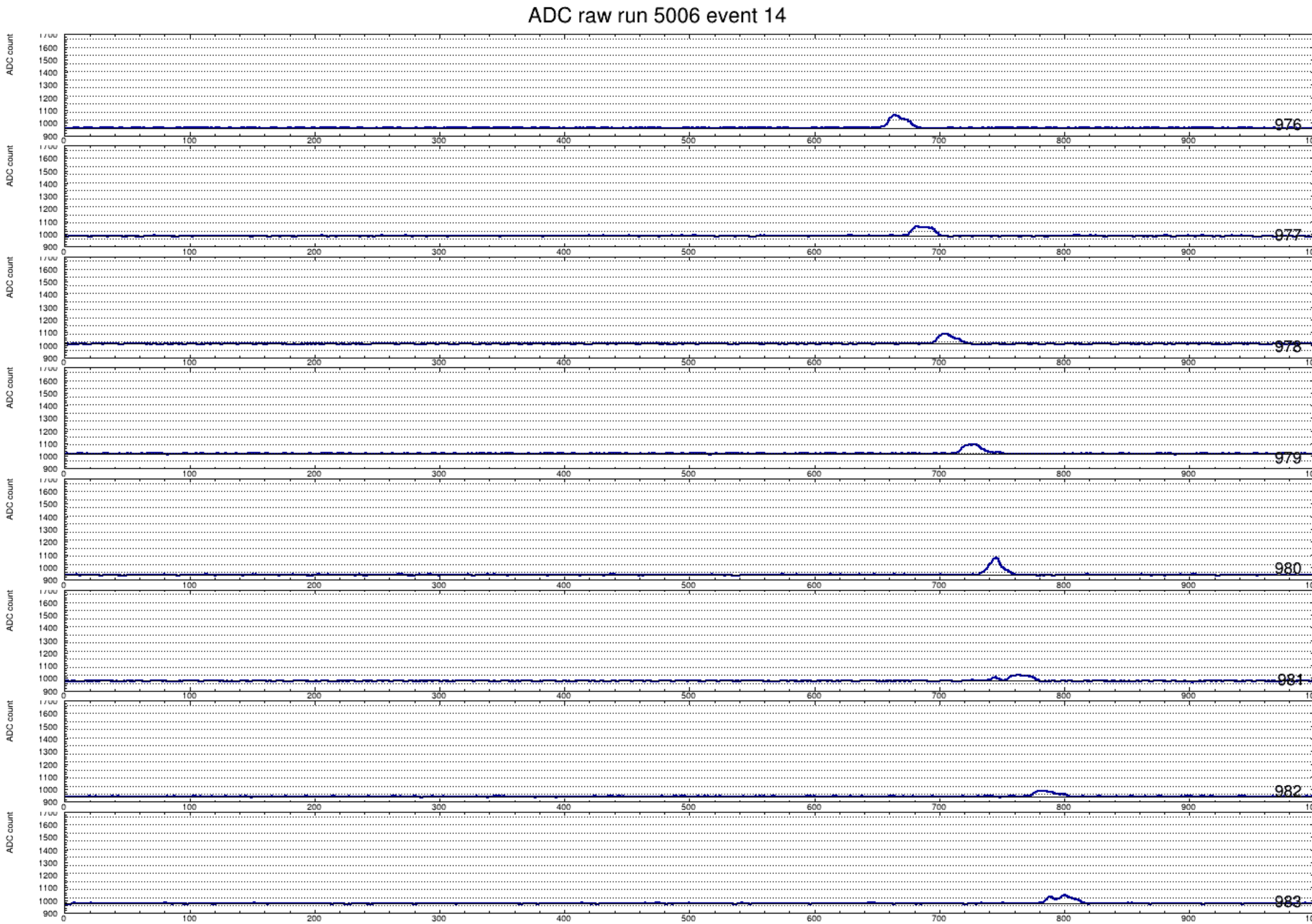


Raw ADC for Iceberg collection planes
Channel
1250
1200
1150
1100
1050
1000
950
900
850
800
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Tick
25 wires
50
40
30
20
10
0
−10
−20
−30
−40
−50
Signal [((ADC counts))/tick/channel]
Run 5006 event 14 2020-03-10 03:13:42.96 UTC

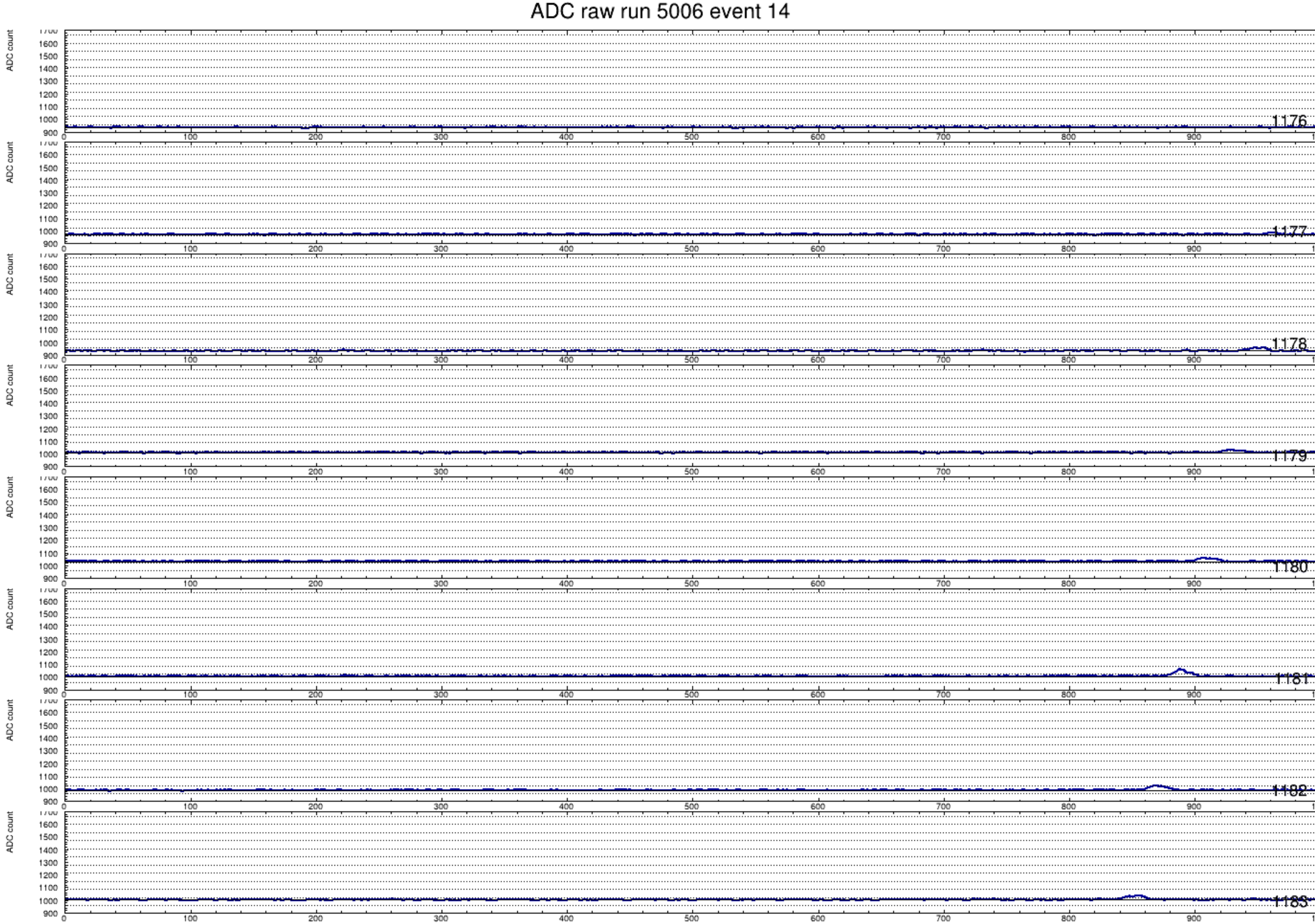
5006-14 z1


ADC raw run 5006 event 14
ADC count
968
969
970
971
972
973
974
975

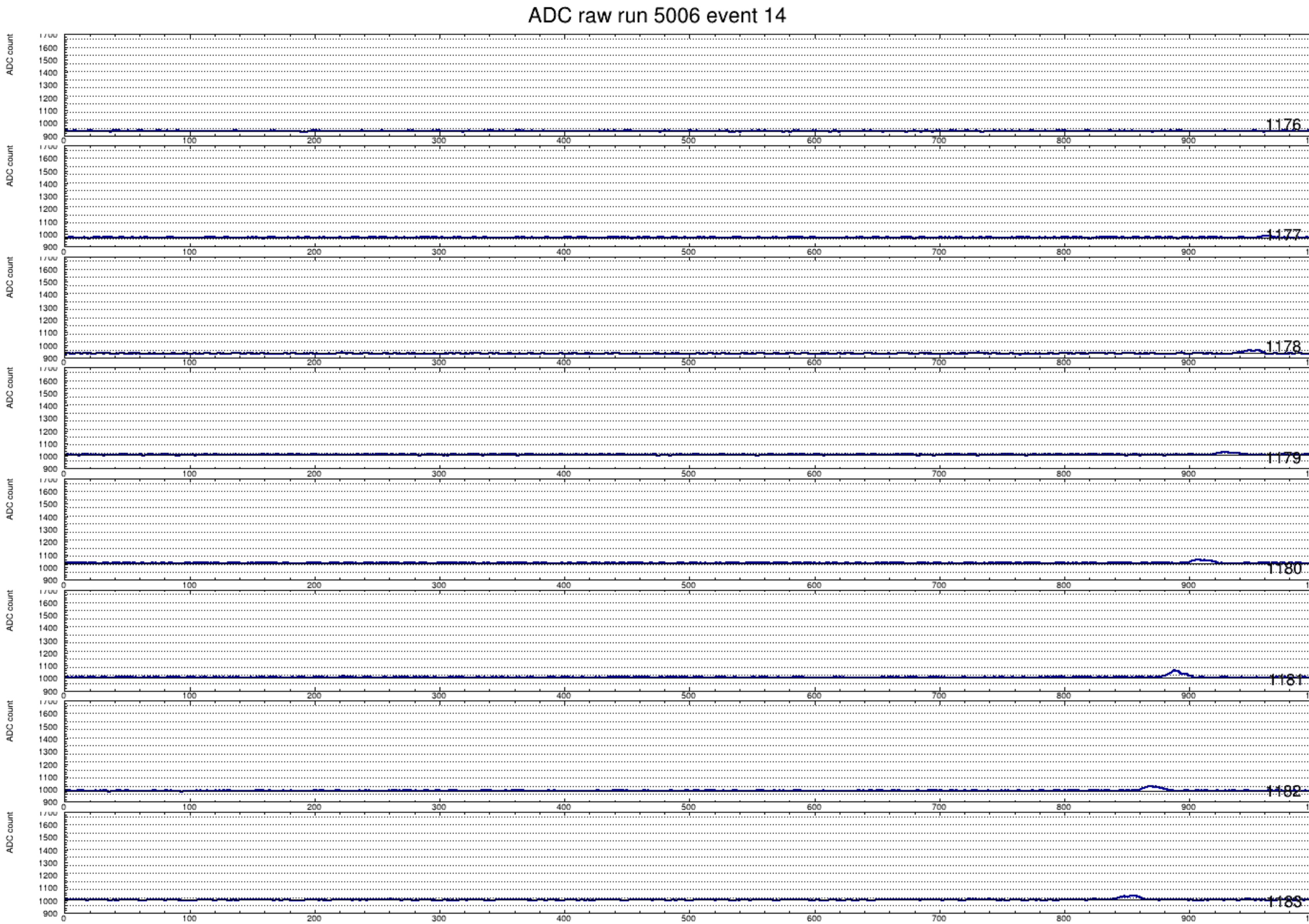
5006-14 z1


ADC raw run 5006 event 14
ADC count
976
977
978
979
980
981
982
983

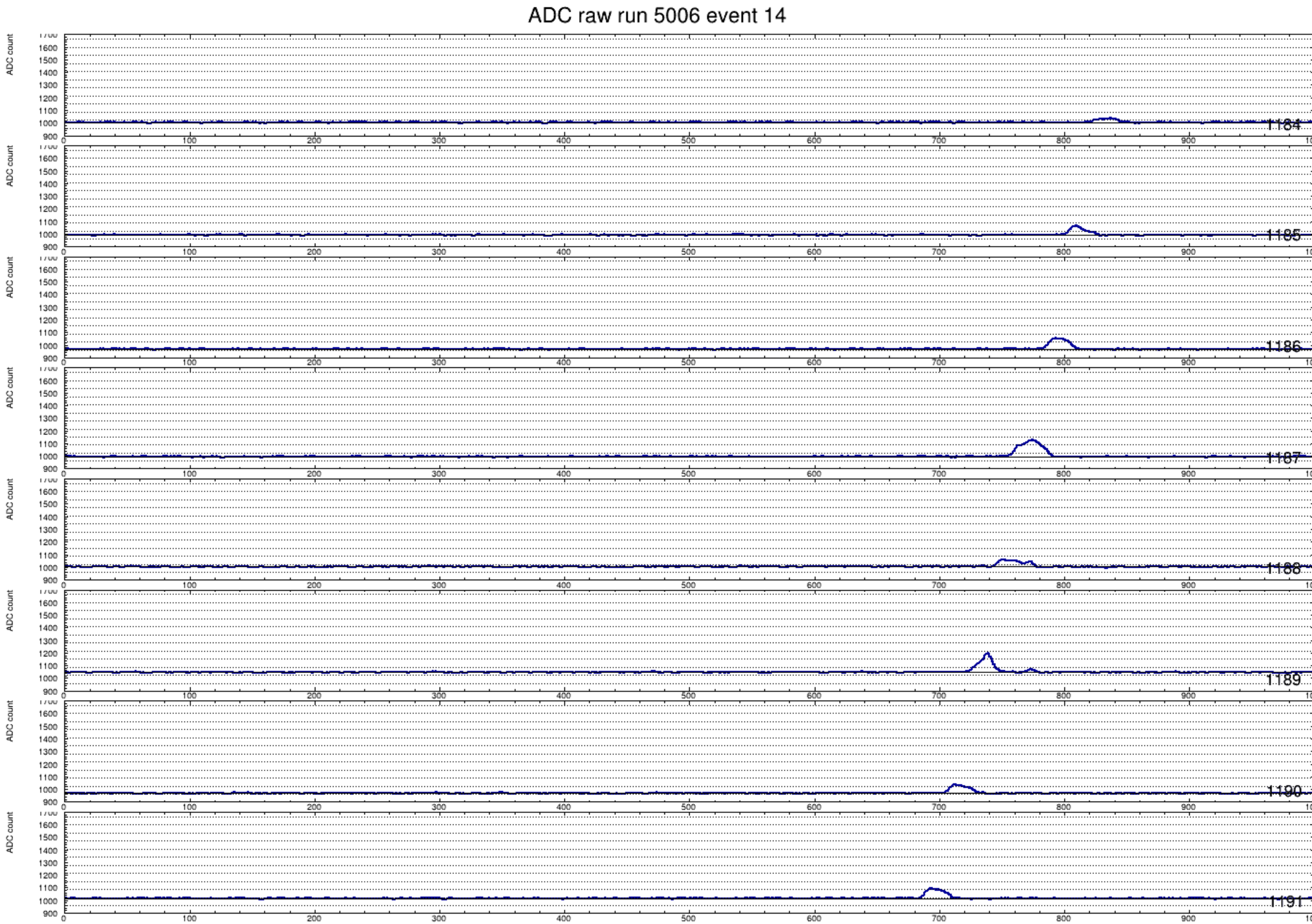
5006-14 z1


ADC raw run 5006 event 14
ADC count
1176
1177
1178
1179
1180
1181
1182
1183

5006-14 z2

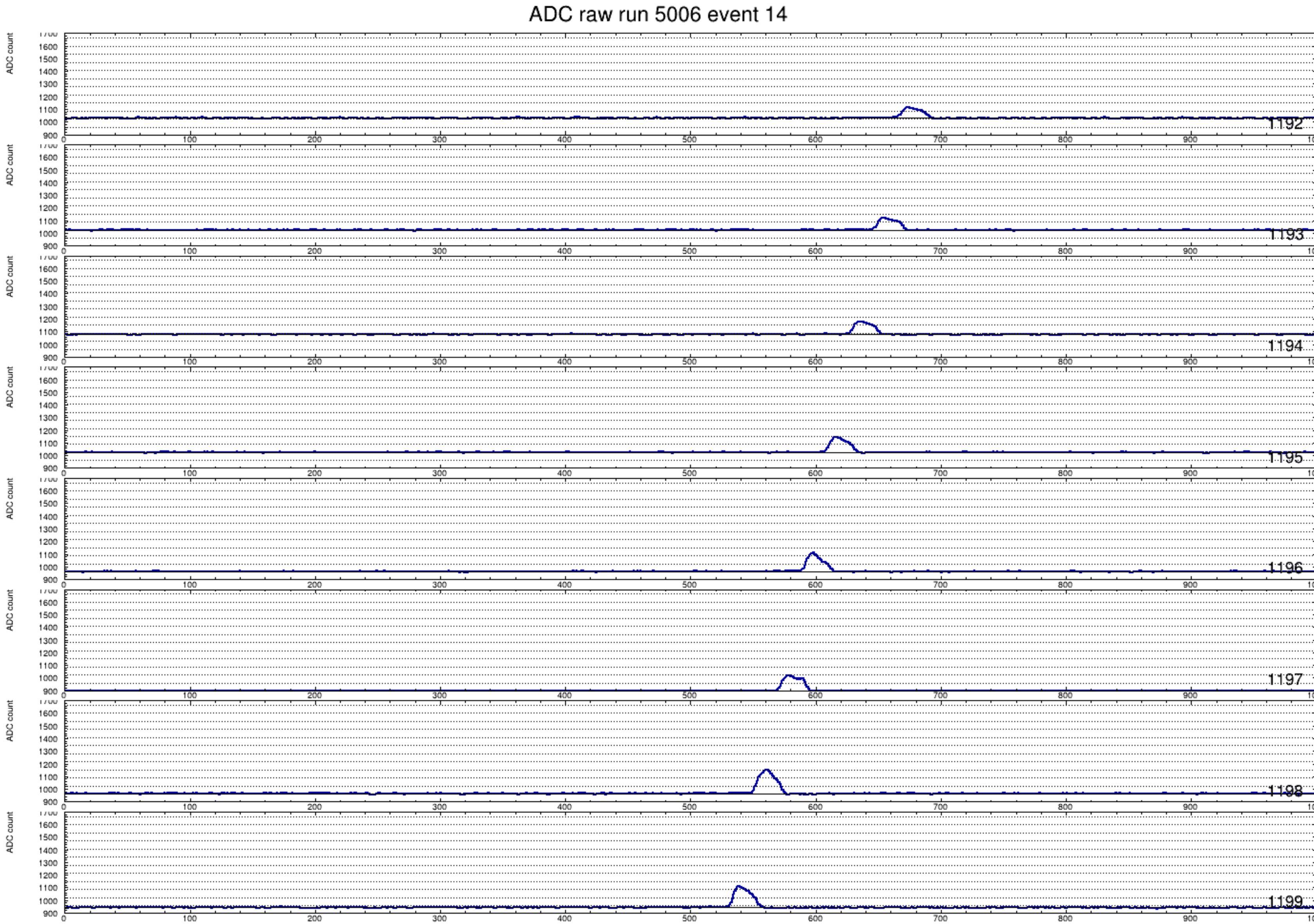

ADC raw run 5006 event 14
ADC count
1176
1177
1178
1179
1180
1181
1182
1183

5006-14 z2

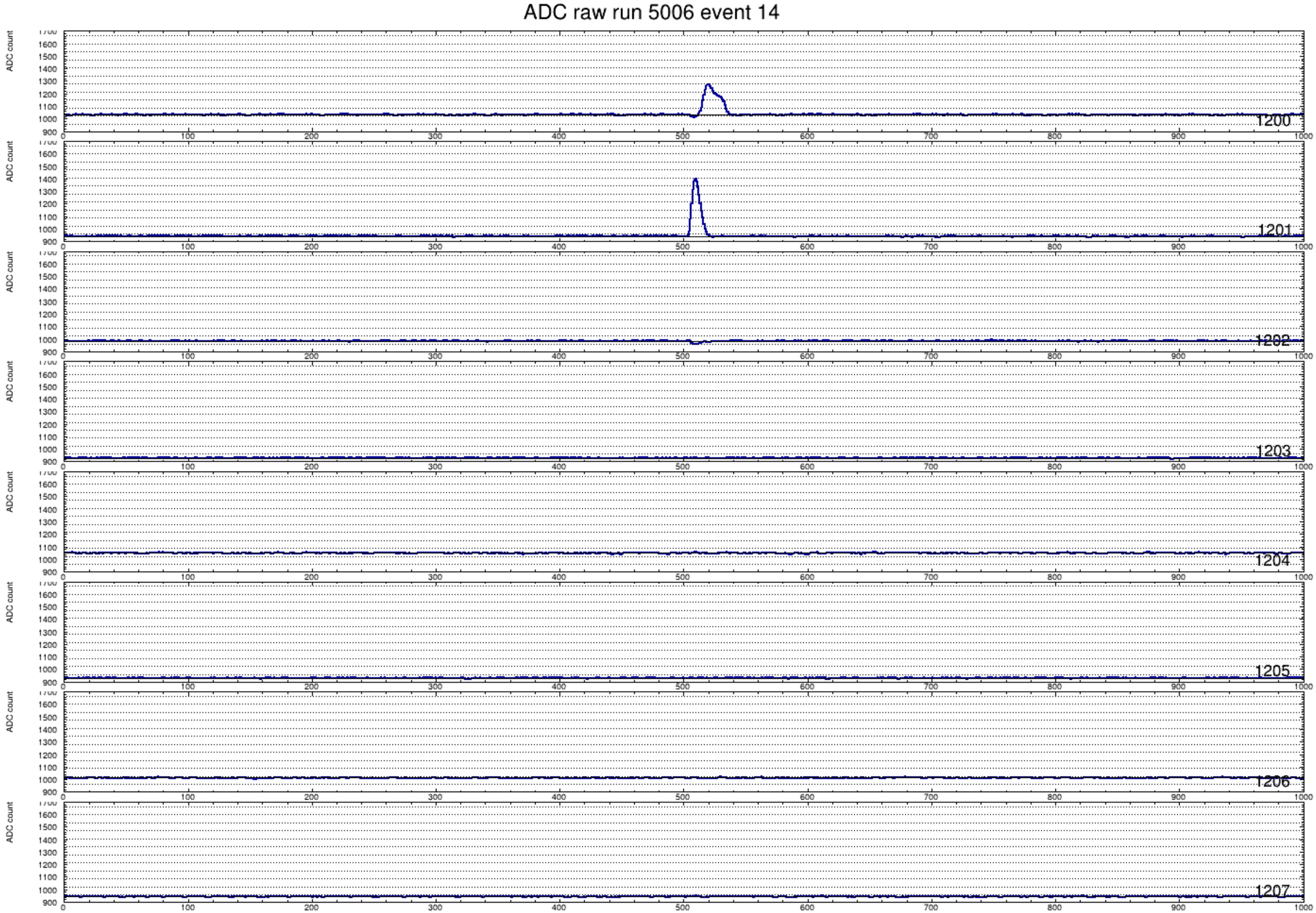


ADC raw run 5006 event 14
ADC count
1184
1185
1186
1187
1188
1189
1190
1191

5006-14 z2


ADC raw run 5006 event 14
ADC count
1192
1193
1194
1195
1196
1197
1198
1199

5006-14 z2


ADC raw run 5006 event 14
ADC count
1200
1201
1202
1203
1204
1205
1206
1207

Conclusions

Summary noise levels presented

- Sample and integrated; before/after CNR, collection/induction
- And for various run periods
- Sample noise $\lesssim$ 58 e (ENC 320 e)
- Integrated noise before → after CNR
  - Collection: 620 → 590 e
  - Induction 790 → 690 e
  - Both are medians for “very quiet” run period

Calibration scale check

- Signals from perpendicular tracks have the expected ADC signal height ➔ our calibration scale is roughly correct
- Height SNR for perpendicular tracks is around 85
  - Expect about the same for parallel tracks
- Area SNR for parallel tracks is (30 ke)/(600 e) = 50
- All before degradation from lifetime

Next

What might I/we do next?

- ~~Charge calibration~~
- ~~Identify sticky codes~~
- Tune reconstruction sequence
  - ~~Use the above (calibrate, mitigate SC)~~
  - ~~Check tail removal (fix if needed)~~
  - Timing mitigation?
  - ~~Check noise removal~~
  - Deconvolution
- Noise studies
  - ~~Sample and integrated estimates before deconvolution~~
  - ~~DFTs for each view~~
  - ~~Same combining many runs~~
  - ~~Same after removing noisy channels~~
  - Same after deconvolution
  - Remove event channels with overflows

Extras

Track angles from Wanwei

Trigger counter geometry (Shekhar)

Analysis code packages

Still more noise summary groups

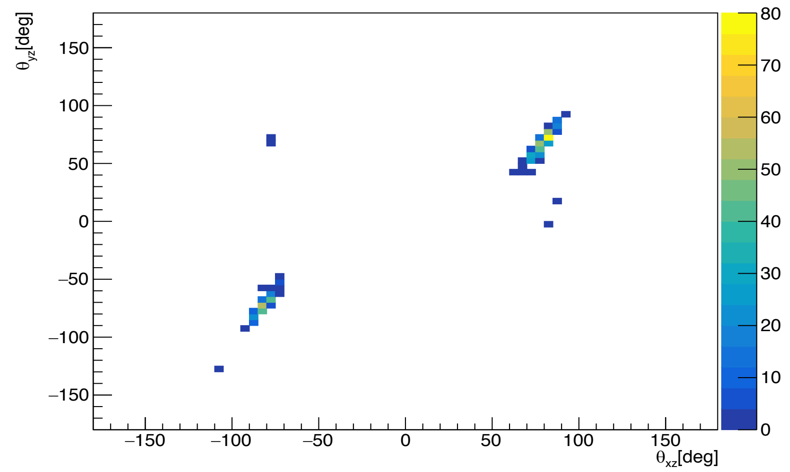
Analysis code

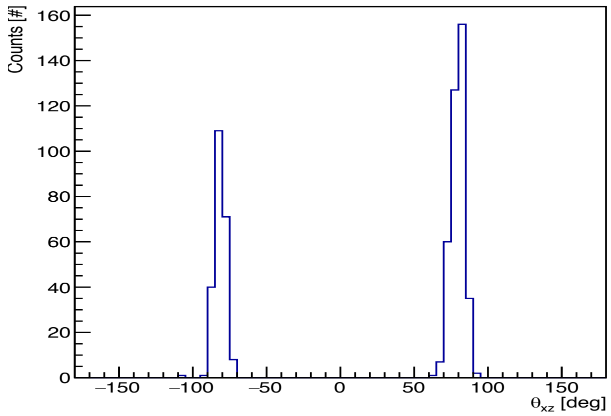
Run groups

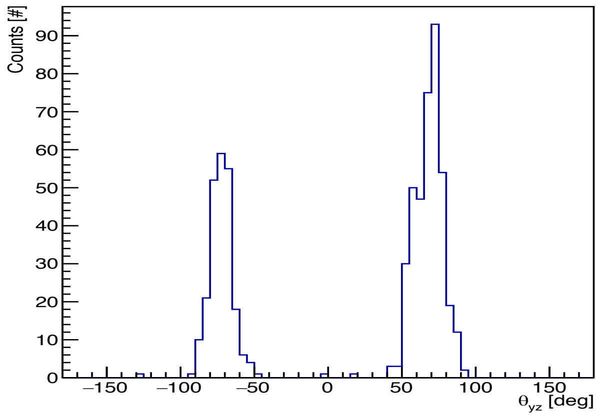
Track angles from Wanwei

Today's Topics—Track Angle

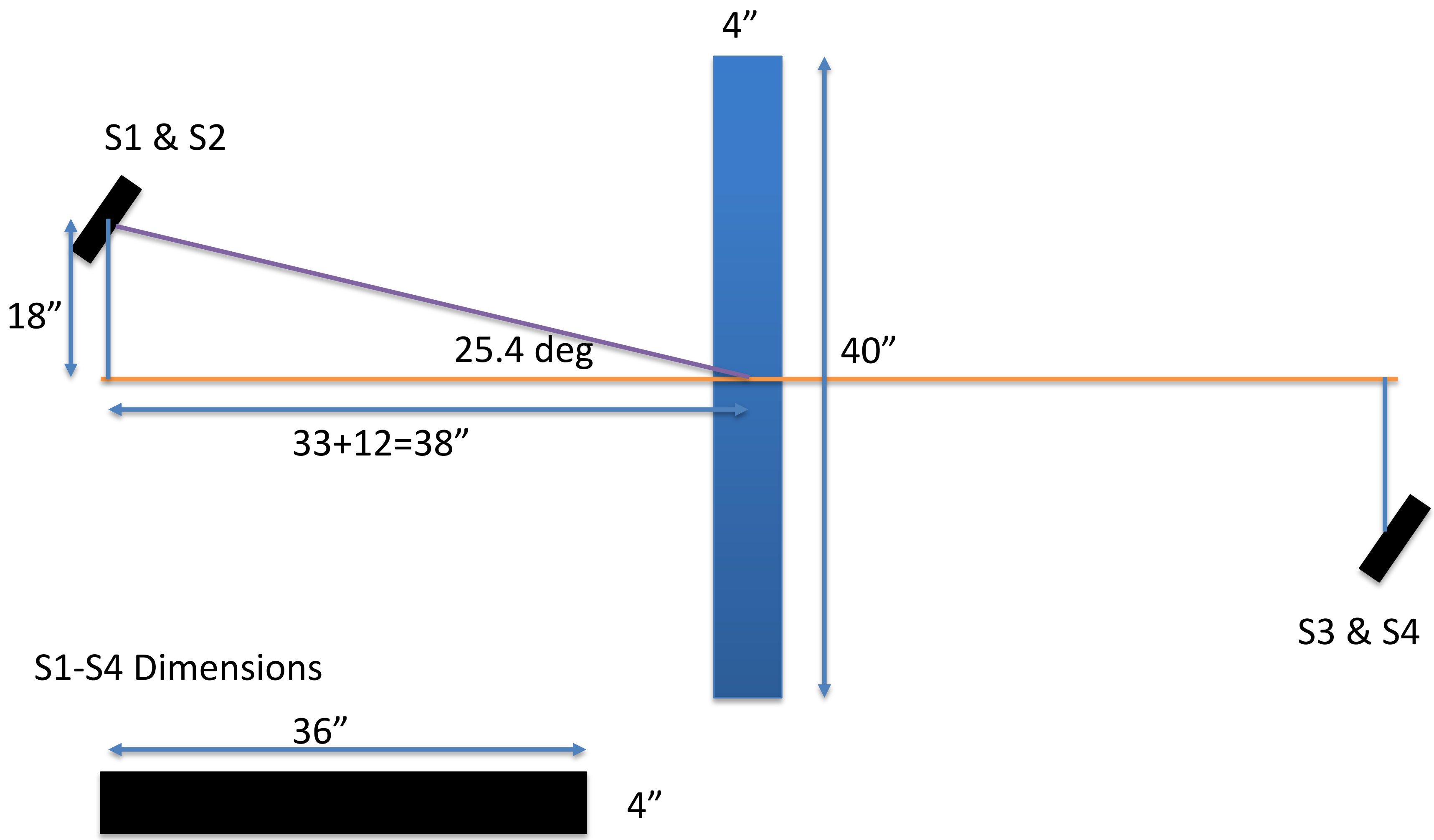
- Most of tracks are close to the drift direction
- Many of tracks are also close to wire direction



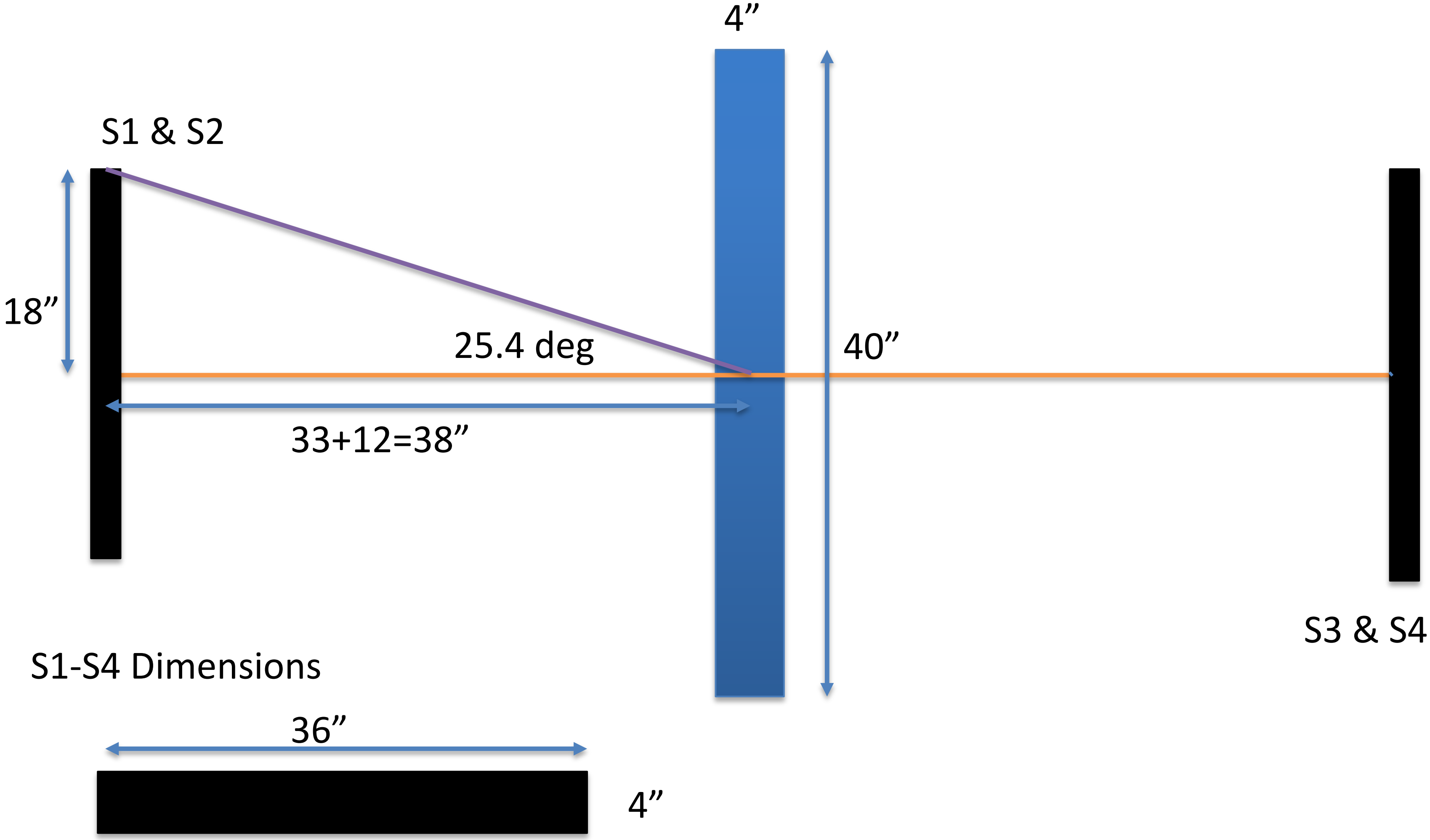




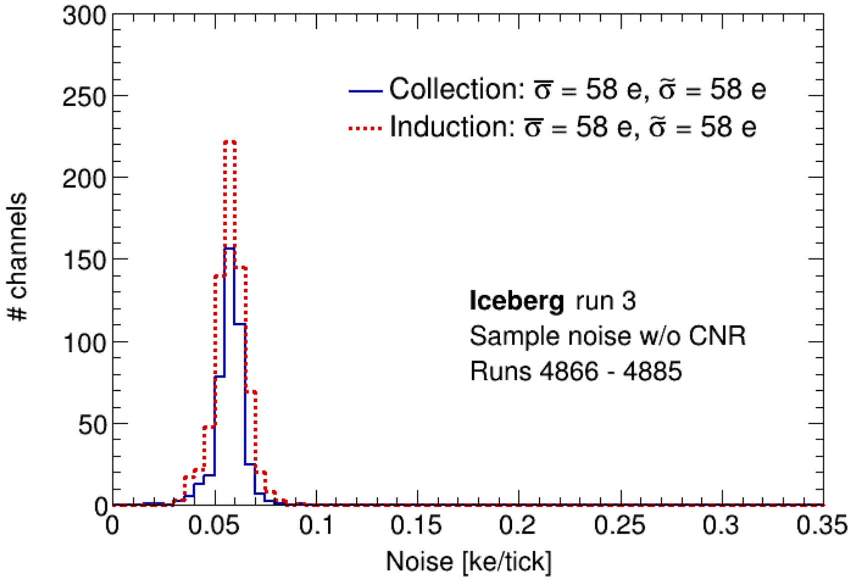
CRT Vertical Angle

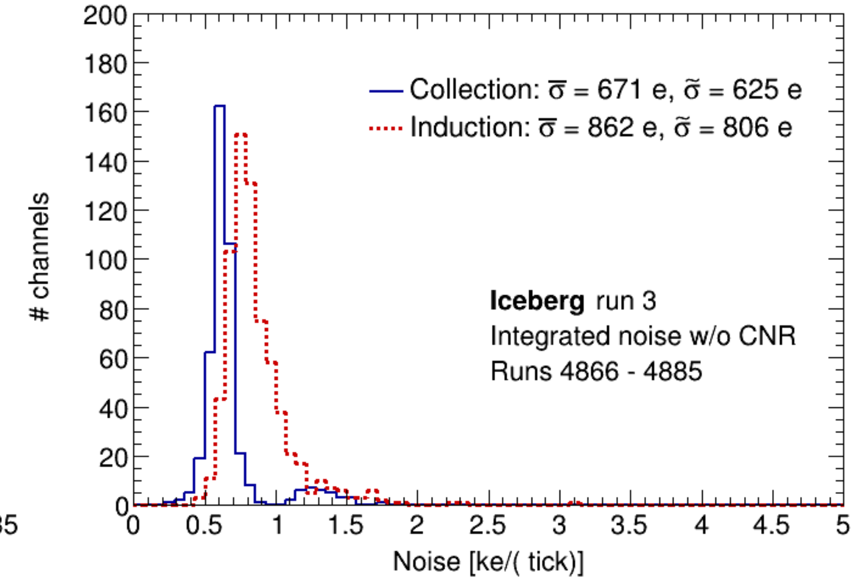


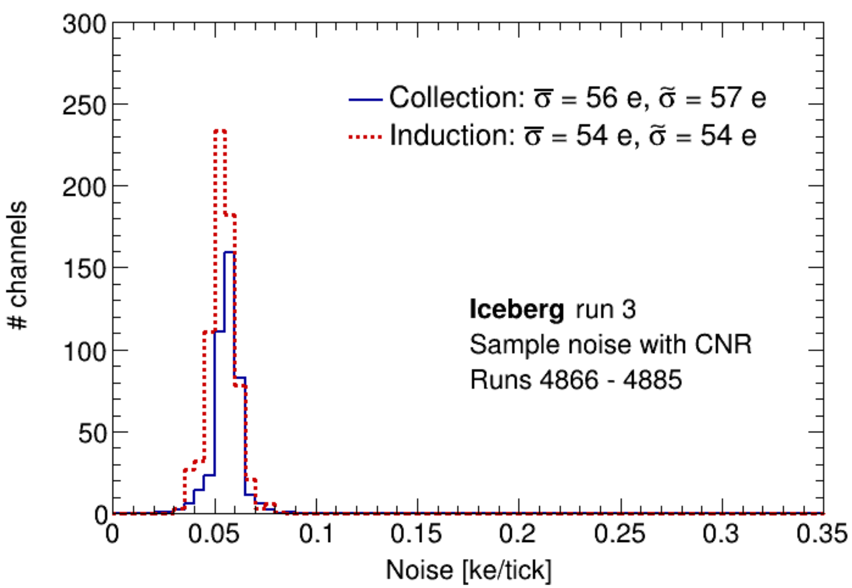
CRT Horizonal Angle

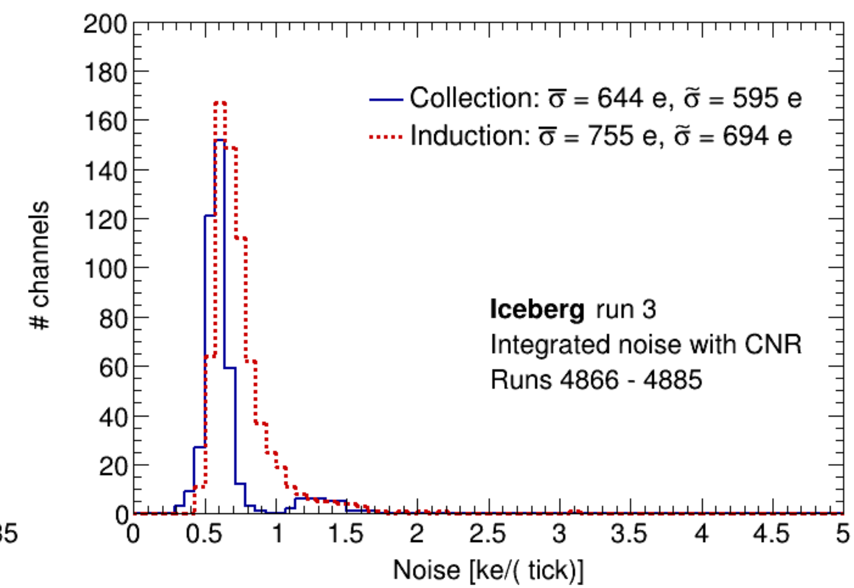


Quiet 2 (4866 – 4885)

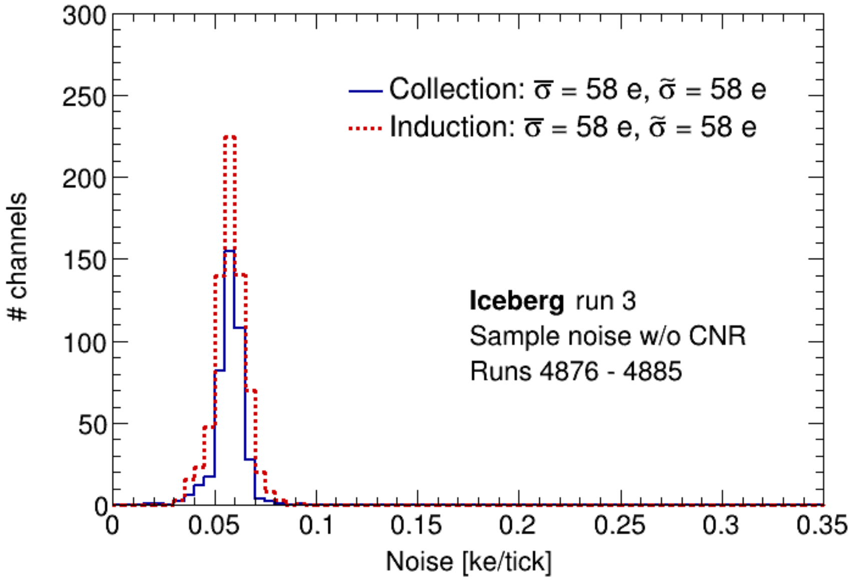


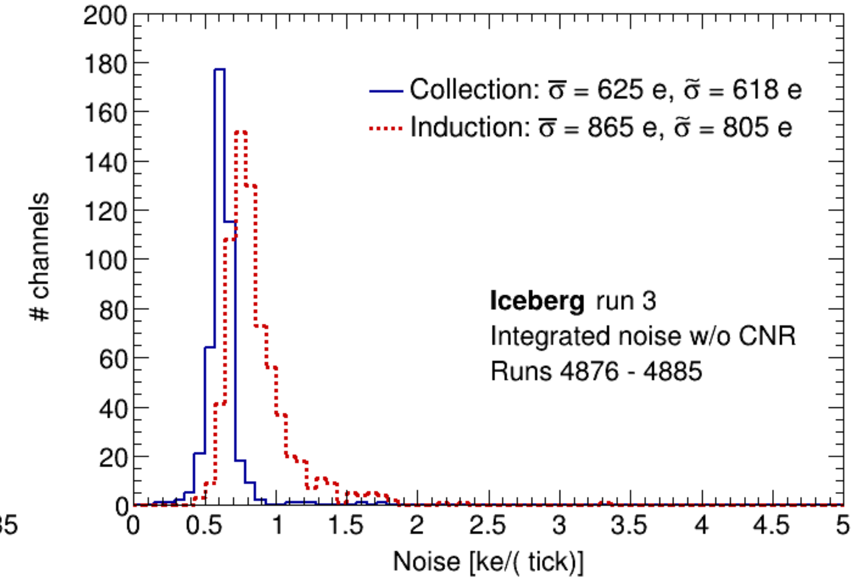


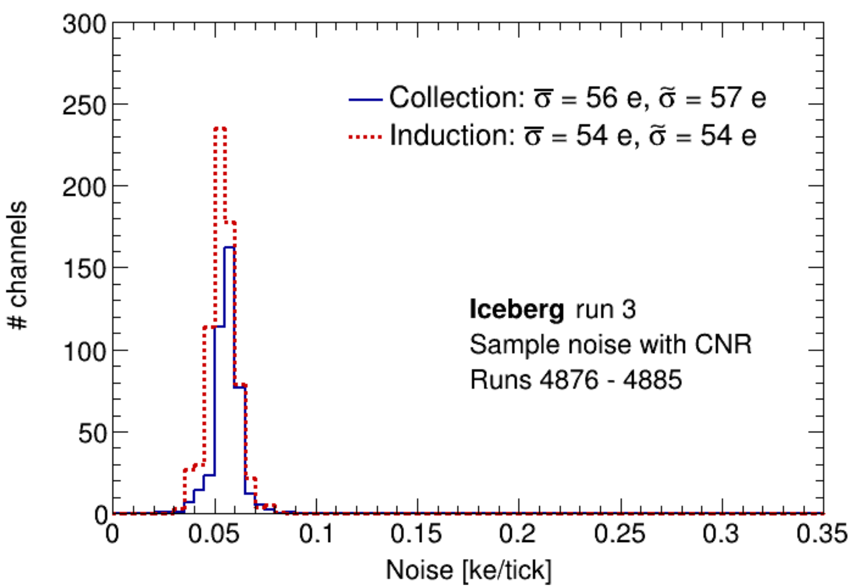


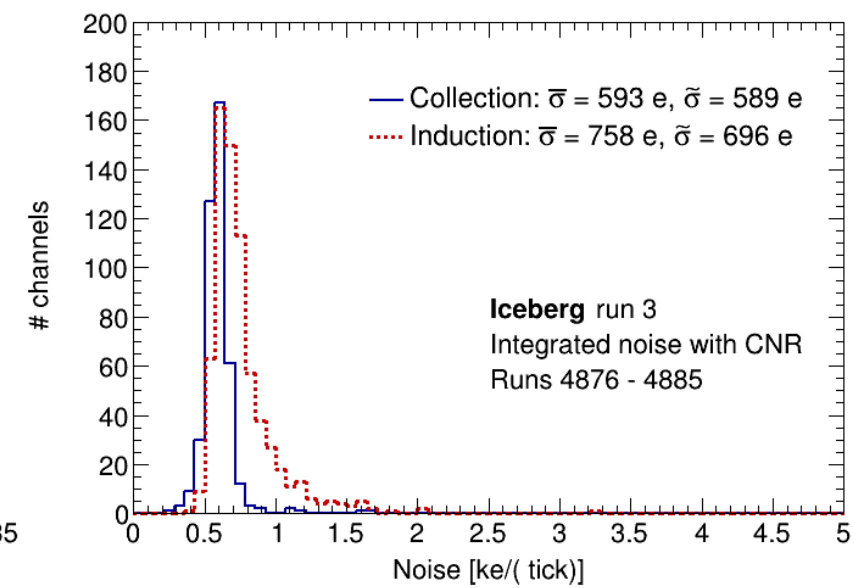


Quiet 3 (4876 – 4885)









Analysis code

I have been migrating my analysis scripts into github

- A series of small (and so quick to build) cmake projects
- For my use but available to all
- Happy to get feedback and have others create similar

Current projects

- myproj is a toy example showing the conventions:
  - Script “build” to build and install the project
  - Cmake examples to build utility libraries, art services and root dictionaries, and to install headers, fcl and python
  - https://github.com/dladams/myproj/blob/master/README.md
- duneproc is my base level project
  - Script duneproc is a wrapper for running lar jobs
  - Fcl file for protoDUNE and (new) Iceberg
  - https://github.com/dladams/duneproc/blob/master/README.md
    - Note link to Iceberg tutorial
- dunececalib has charge calibration code
- dunenoise has code for noise studies and DFT

Run groups

Iceberg Run 3 run grouping
David Adams
May 5, 2020

Run range	Configuration
3366 3382	Initial CRT (cosmic trigger) configuration. 15 deg?
3384 3466	Final CRT. 15 deg?
3467 3611	Cosmics with CRT at 15 deg
3616 3626	TPC off
3627 3695	Cosmics with CRT at 15 deg?
3696 3839	Cosmics with CRT at 15 deg
3870 3874	TPC off
3875 4430	Cosmics with CRT at 15 deg?
4431 4480	Cosmics with CRT at 15 deg
4481 4507	Pulser runs
4508 4530	Cosmics with CRT at 15 deg
4531 4658	TPC off
4679 4698	Pulser runs
4699 4699	Pulser DAC=0 (cosmic0, random trigger?)
4700 4703	Pulser runs (pulser)
4704 4705	Pulser DAC=0 (pulser0)
4710 4711	Pulser runs
4714 4717	Pulser DAC=0 (pulser0)

Begin stable running

4718 4860	New 60 deg CRT (cosmic trigger) with S4
4861 5050	New 60 deg CRT w/o S4
5060 5108	Investigation of timing fragment
5109 5112	Random trigger with g=4.7.
5113 5132	Pulser with g=4.7
5133 5153	Pulser with g=7.8
5154 5174	Pulser with g=25
5175 5195	Pulser with s=0.5
5196 5222	Pulser with s=1.0
5223 5243	Pulser with s=3.0
5244 5264	Pulser with b=200 mV
5265 5285	Pulser with b=200/900 mV
5286 5306	Pulser with s=0.5
5307 5327	Pulser with l=1000 pA
5328-5348	Pulser with AC coupling
5349-5359	Cosmics vary settings run to run

4504, 4699, 5109 taken without cosmic trigger and TPC on.