ProtoDUNE TPC pulser data

ProtoDUNE simulation and reconstruction

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Introduction

December pulser data

- Internal (ASIC) and external (FEMB) pulsers
- HV off and on
- 16 or 17 amplitude setting for each
  - A = (1), 2, 3, 4, …, 30, (35), (40), (50)
  - Q = A ×(3.43 fC) = A × (21.4 ke) ≈ A MIP
- Standard preamp setting (14 mV/fC, 2 us)
  - Some data also at 0.5 us

Analysis

- Processed December external pulser, HV off data
- ROI's found with AdcThresholdSignalFinder
  - Threshold of 100 or 600 ADC counts
- Data processed using AdcRoiViewer
  - Each ROI fit to CE response function
  - Histogram ROI area and fitted height and width
  - Channel summary histograms of mean and truncated RMS of area, height

Pulser signals

Cold electronics provide the option to inject pulses

- At regular intervals, injected voltage is raised and then lowered
  - Controlled with 6-bit DAC ➔ 64 levels
  - Fairly linear with step size V_{step} = 18.75 mV
- Capacitively coupled to preamp input
  - C = 183 fF
- Voltage change corresponds to fast charge collection
  - Step size is Q_S = (183 fF) × (18.75 mV) = 3.43 fC = 21.4 ke
  - This is about 1 MIP
    - Prefer something smaller?

Signal may be generated in either of two places

- Internal: signal generated in the preamp ASIC
  - Input voltage has significant offset that varies from ASIC to ASIC
  - Variations are a large fraction of the step size
- External: signal generated on the FEMB
  - Little or no offset, i.e. for DAC setting A, Q = A × Q_{step}

Amplifier and ADC response

Data studied here was taken with nominal protoDUNE settings

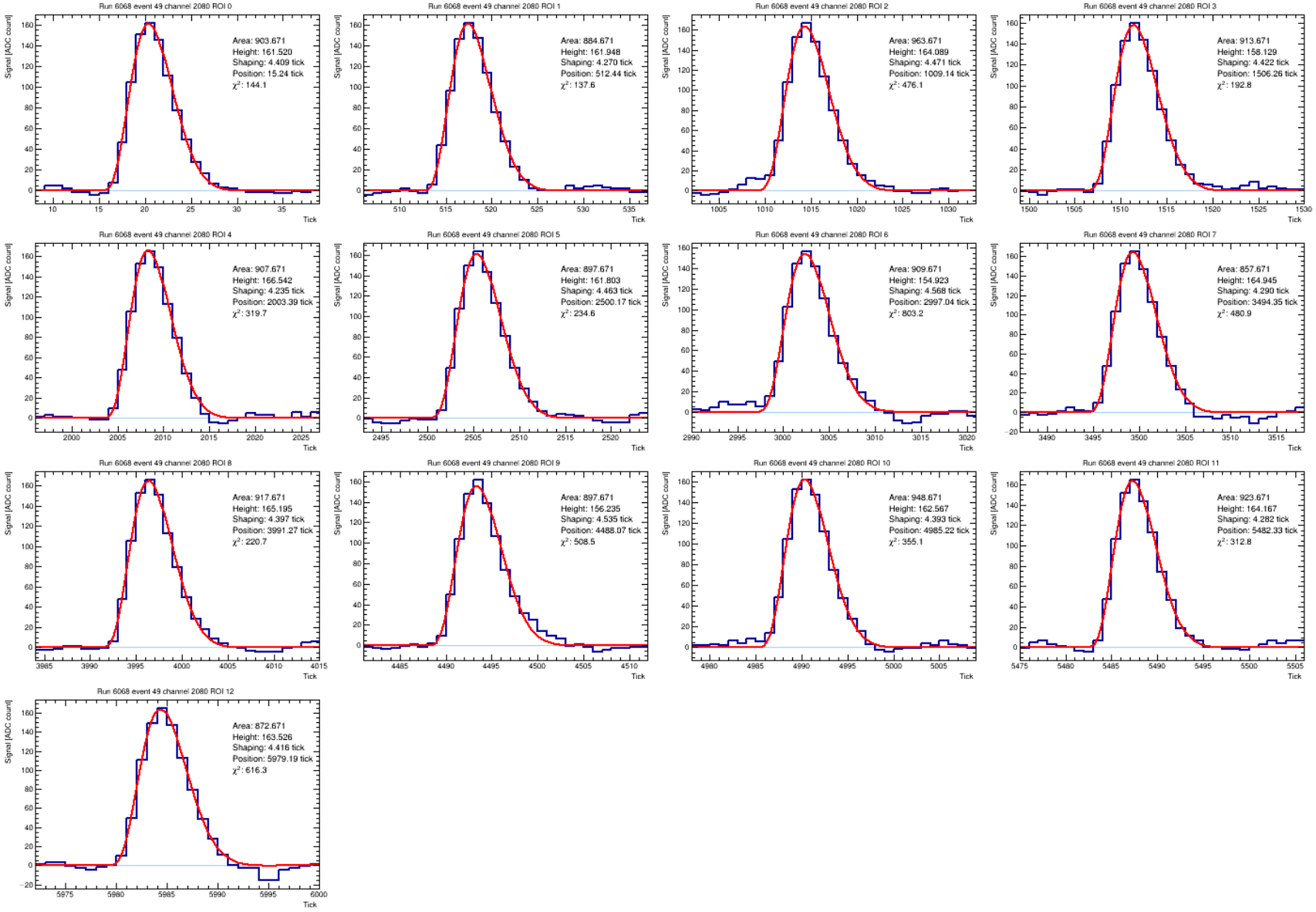
- Amplifier gain is 14 mV/fC
  - I.e. for pulser setting A, V = A×(48 fC)
- Nominal shaping time is 2.0 μs
- Amplifier baseline set at 900 mV (middle of 1.8 V range)
  - For both collection and induction channels
  - Former to combat the “ledge effect”
  - Expect signal reach amplifier rails (.e. start to clip, saturate) at ±900 mV
    - I.e. A = ±19

ADC response is about (3 ADC count)/mV with 12 bit output

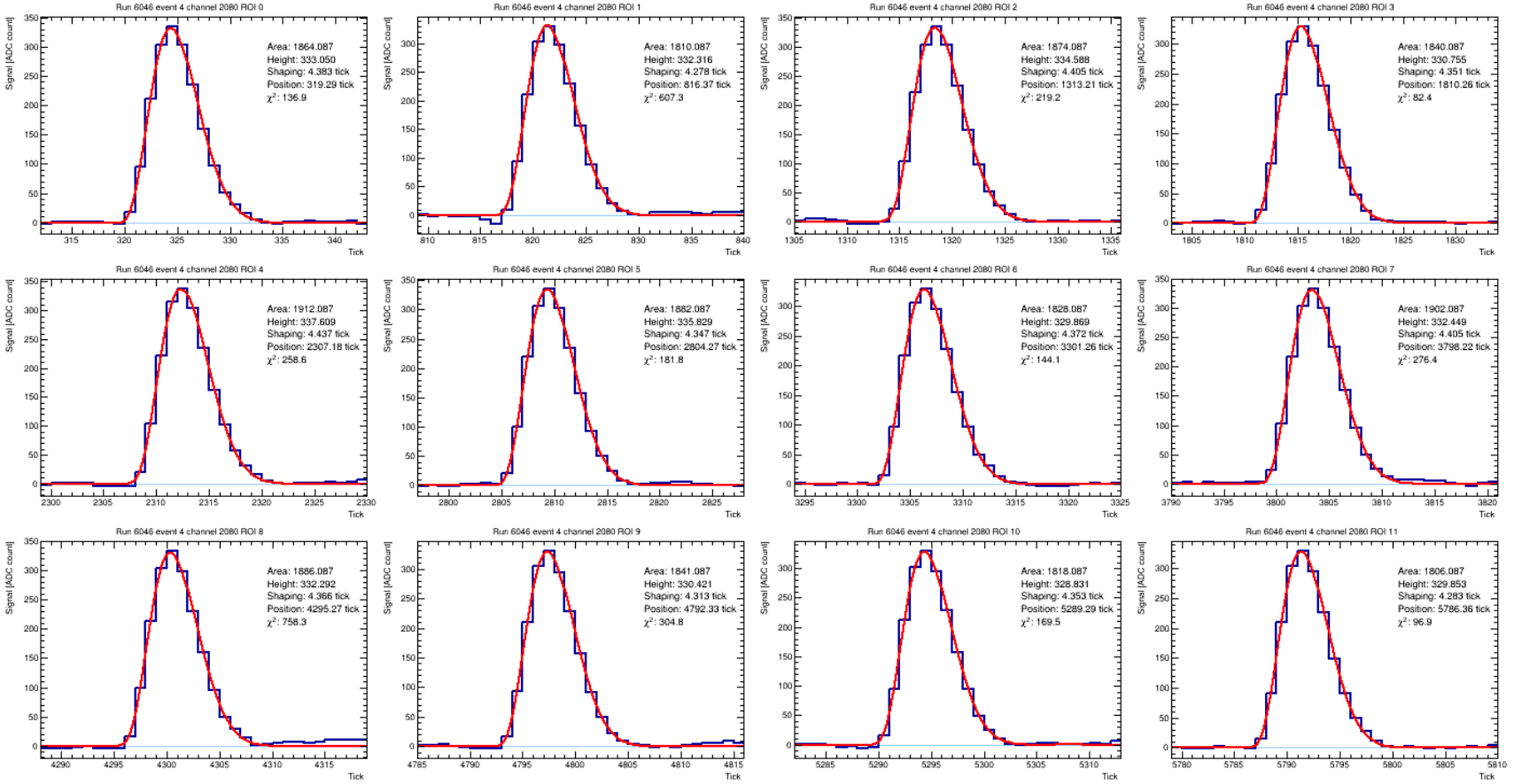
- Significant (10%) channel to channel variation
- For pulser setting A, expect about A×(145 ADC counts)
- Pedestal set around 900 ADC counts for the collection channels
  - Positive saturation at 3200 (ADC counts), i.e 1100 mV, A = 22.1
  - Negative saturation at 900 (ADC counts), i.e. 300 mV, A = 6.2

ROI waveforms with low threshold

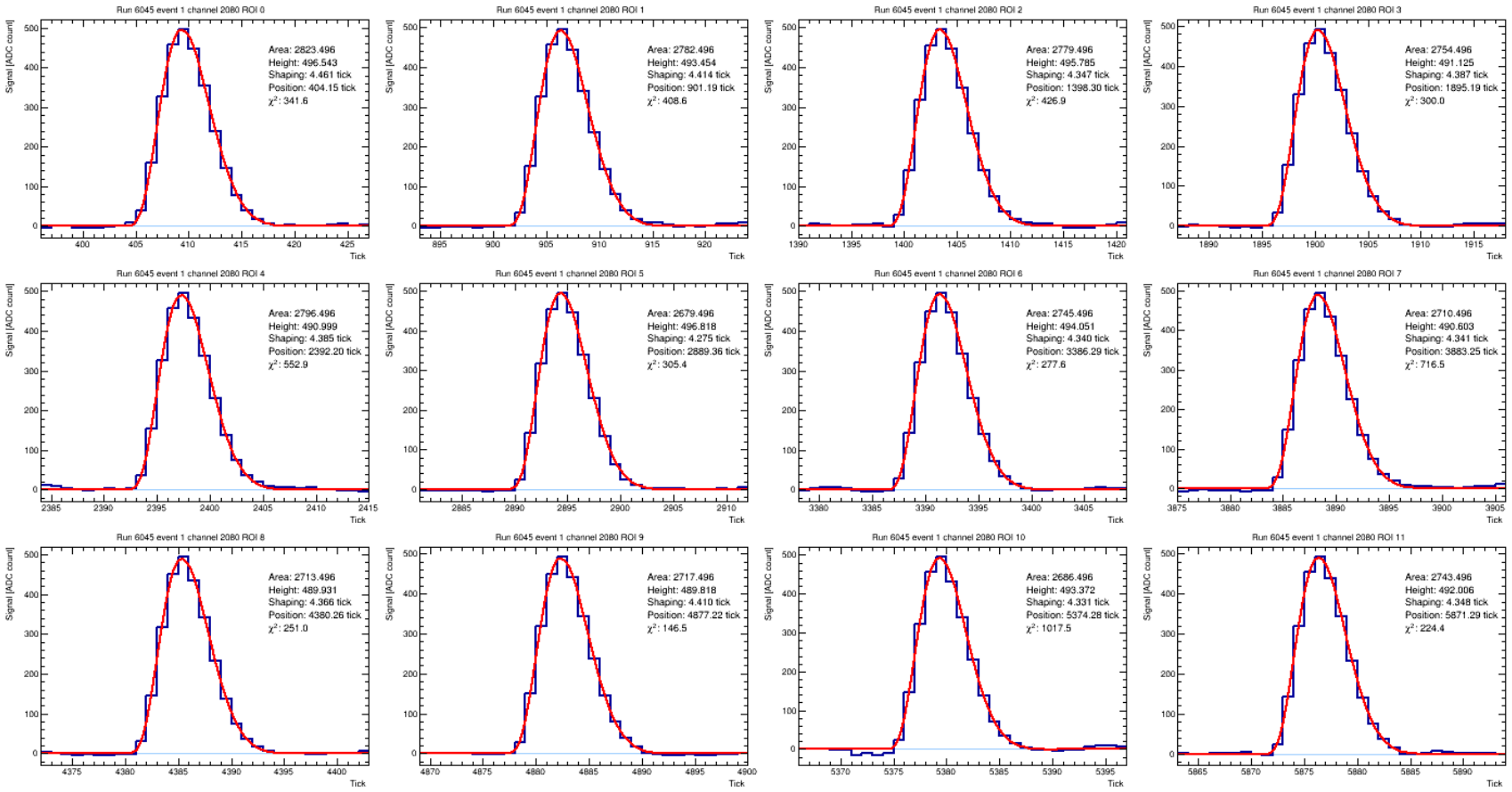
A=1


Run 6068 event 49 channel 2080 ROI 0
Area: 903.671
Height: 161.520
Shaping: 4.409 tick
Position: 15.24 tick
χ²: 144.1
Run 6068 event 49 channel 2080 ROI 1
Area: 884.671
Height: 161.948
Shaping: 4.270 tick
Position: 512.44 tick
χ²: 137.6
Run 6068 event 49 channel 2080 ROI 2
Area: 963.671
Height: 164.089
Shaping: 4.471 tick
Position: 1009.14 tick
χ²: 476.1
Run 6068 event 49 channel 2080 ROI 3
Area: 913.671
Height: 158.129
Shaping: 4.422 tick
Position: 1506.26 tick
χ²: 192.8
Run 6068 event 49 channel 2080 ROI 4
Area: 907.671
Height: 166.542
Shaping: 4.235 tick
Position: 2003.39 tick
χ²: 319.7
Run 6068 event 49 channel 2080 ROI 5
Area: 897.671
Height: 161.803
Shaping: 4.463 tick
Position: 2500.17 tick
χ²: 234.6
Run 6068 event 49 channel 2080 ROI 6
Area: 909.671
Height: 154.923
Shaping: 4.568 tick
Position: 2997.04 tick
χ²: 803.2
Run 6068 event 49 channel 2080 ROI 7
Area: 857.671
Height: 164.945
Shaping: 4.290 tick
Position: 3494.35 tick
χ²: 480.9
Run 6068 event 49 channel 2080 ROI 8
Area: 917.671
Height: 165.195
Shaping: 4.397 tick
Position: 3991.27 tick
χ²: 220.7
Run 6068 event 49 channel 2080 ROI 9
Area: 897.671
Height: 156.235
Shaping: 4.535 tick
Position: 4488.07 tick
χ²: 508.5
Run 6068 event 49 channel 2080 ROI 10
Area: 948.671
Height: 162.567
Shaping: 4.393 tick
Position: 4985.22 tick
χ²: 355.1
Run 6068 event 49 channel 2080 ROI 11
Area: 923.671
Height: 164.167
Shaping: 4.282 tick
Position: 5482.33 tick
χ²: 312.8
Run 6068 event 49 channel 2080 ROI 12
Area: 872.671
Height: 163.526
Shaping: 4.416 tick
Position: 5979.19 tick
χ²: 616.3
Signal [ADC count]
Tick

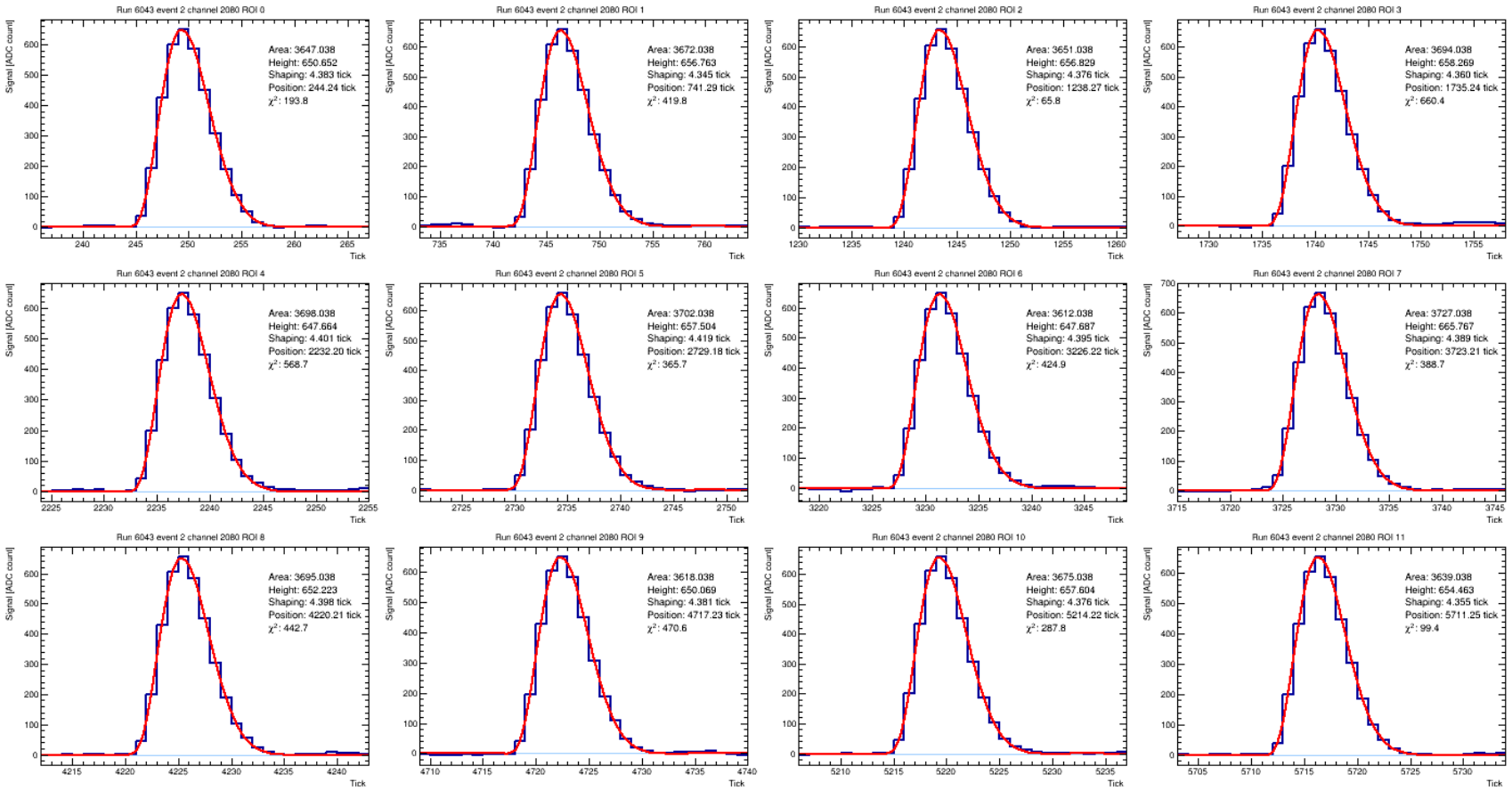
A=2


Run 6046 event 4 channel 2080 ROI 0
Area: 1864.087
Height: 333.050
Shaping: 4.383 tick
Position: 319.29 tick
χ²: 136.9
Run 6046 event 4 channel 2080 ROI 1
Area: 1810.087
Height: 332.316
Shaping: 4.278 tick
Position: 816.37 tick
χ²: 607.3
Run 6046 event 4 channel 2080 ROI 2
Area: 1874.087
Height: 334.588
Shaping: 4.405 tick
Position: 1313.21 tick
χ²: 219.2
Run 6046 event 4 channel 2080 ROI 3
Area: 1840.087
Height: 330.755
Shaping: 4.351 tick
Position: 1810.26 tick
χ²: 82.4
Run 6046 event 4 channel 2080 ROI 4
Area: 1912.087
Height: 337.609
Shaping: 4.437 tick
Position: 2307.18 tick
χ²: 258.6
Run 6046 event 4 channel 2080 ROI 5
Area: 1882.087
Height: 335.829
Shaping: 4.347 tick
Position: 2804.27 tick
χ²: 181.8
Run 6046 event 4 channel 2080 ROI 6
Area: 1828.087
Height: 329.869
Shaping: 4.372 tick
Position: 3301.26 tick
χ²: 144.1
Run 6046 event 4 channel 2080 ROI 7
Area: 1902.087
Height: 332.449
Shaping: 4.405 tick
Position: 3798.22 tick
χ²: 276.4
Run 6046 event 4 channel 2080 ROI 8
Area: 1886.087
Height: 332.292
Shaping: 4.366 tick
Position: 4295.27 tick
χ²: 758.3
Run 6046 event 4 channel 2080 ROI 9
Area: 1841.087
Height: 330.421
Shaping: 4.313 tick
Position: 4792.33 tick
χ²: 304.8
Run 6046 event 4 channel 2080 ROI 10
Area: 1818.087
Height: 328.831
Shaping: 4.353 tick
Position: 5289.29 tick
χ²: 169.5
Run 6046 event 4 channel 2080 ROI 11
Area: 1806.087
Height: 329.853
Shaping: 4.283 tick
Position: 5786.36 tick
χ²: 96.9
Signal [ADC count]
Tick

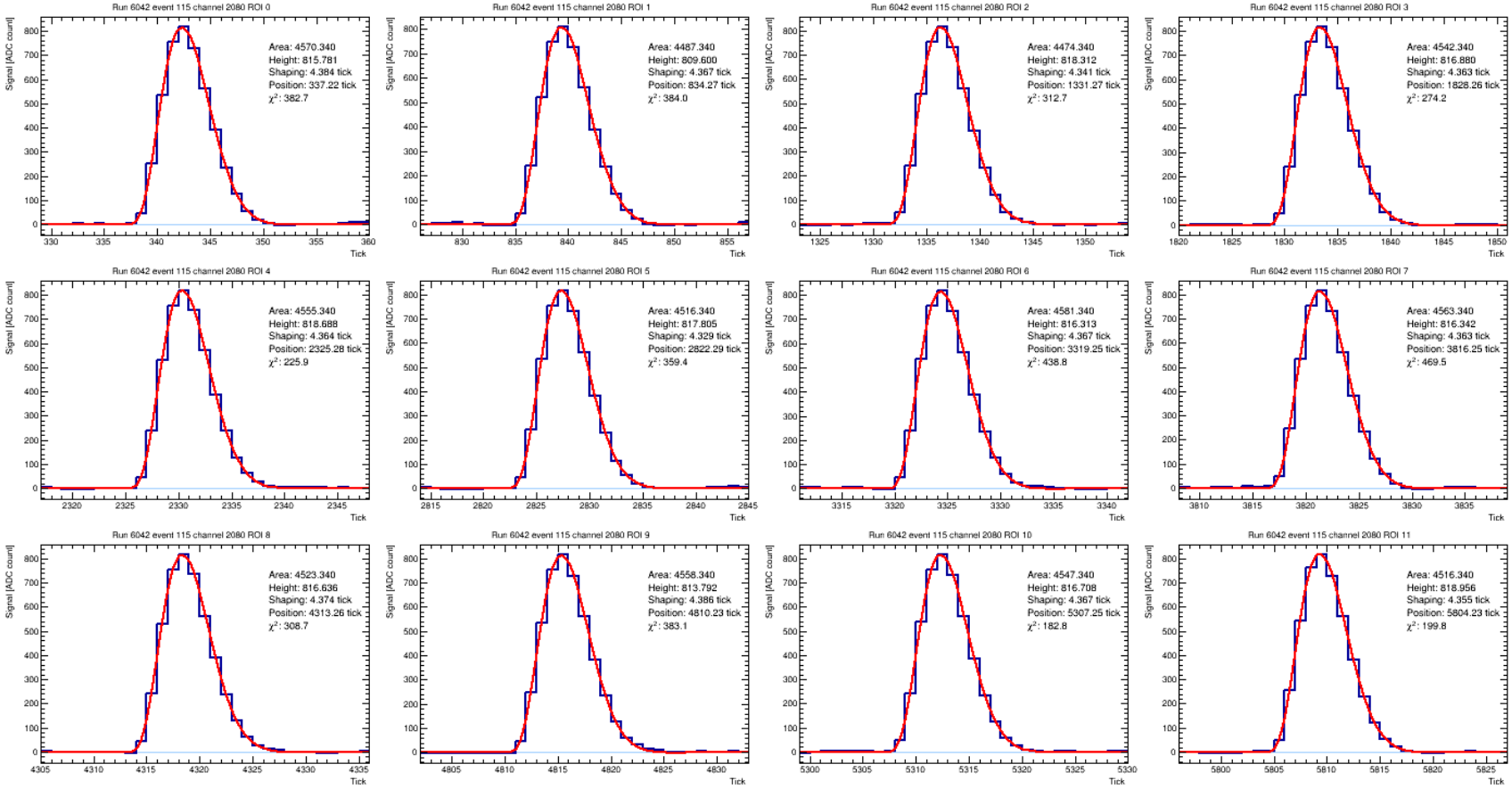
A=3


Run 6045 event 1 channel 2080 ROI 0
Area: 2823.496
Height: 496.543
Shaping: 4.461 tick
Position: 404.15 tick
χ²: 341.6
Run 6045 event 1 channel 2080 ROI 1
Area: 2782.496
Height: 493.454
Shaping: 4.414 tick
Position: 901.19 tick
χ²: 408.6
Run 6045 event 1 channel 2080 ROI 2
Area: 2779.496
Height: 495.785
Shaping: 4.347 tick
Position: 1398.30 tick
χ²: 426.9
Run 6045 event 1 channel 2080 ROI 3
Area: 2754.496
Height: 491.125
Shaping: 4.387 tick
Position: 1895.19 tick
χ²: 300.0
Run 6045 event 1 channel 2080 ROI 4
Area: 2796.496
Height: 490.999
Shaping: 4.385 tick
Position: 2392.20 tick
χ²: 552.9
Run 6045 event 1 channel 2080 ROI 5
Area: 2679.496
Height: 496.818
Shaping: 4.275 tick
Position: 2889.36 tick
χ²: 305.4
Run 6045 event 1 channel 2080 ROI 6
Area: 2745.496
Height: 494.051
Shaping: 4.340 tick
Position: 3386.29 tick
χ²: 277.6
Run 6045 event 1 channel 2080 ROI 7
Area: 2710.496
Height: 490.603
Shaping: 4.341 tick
Position: 3883.25 tick
χ²: 716.5
Run 6045 event 1 channel 2080 ROI 8
Area: 2713.496
Height: 489.931
Shaping: 4.366 tick
Position: 4380.26 tick
χ²: 251.0
Run 6045 event 1 channel 2080 ROI 9
Area: 2717.496
Height: 489.818
Shaping: 4.410 tick
Position: 4877.22 tick
χ²: 146.5
Run 6045 event 1 channel 2080 ROI 10
Area: 2686.496
Height: 493.372
Shaping: 4.331 tick
Position: 5374.28 tick
χ²: 1017.5
Run 6045 event 1 channel 2080 ROI 11
Area: 2743.496
Height: 492.006
Shaping: 4.348 tick
Position: 5871.29 tick
χ²: 224.4
Signal [ADC count]
Tick

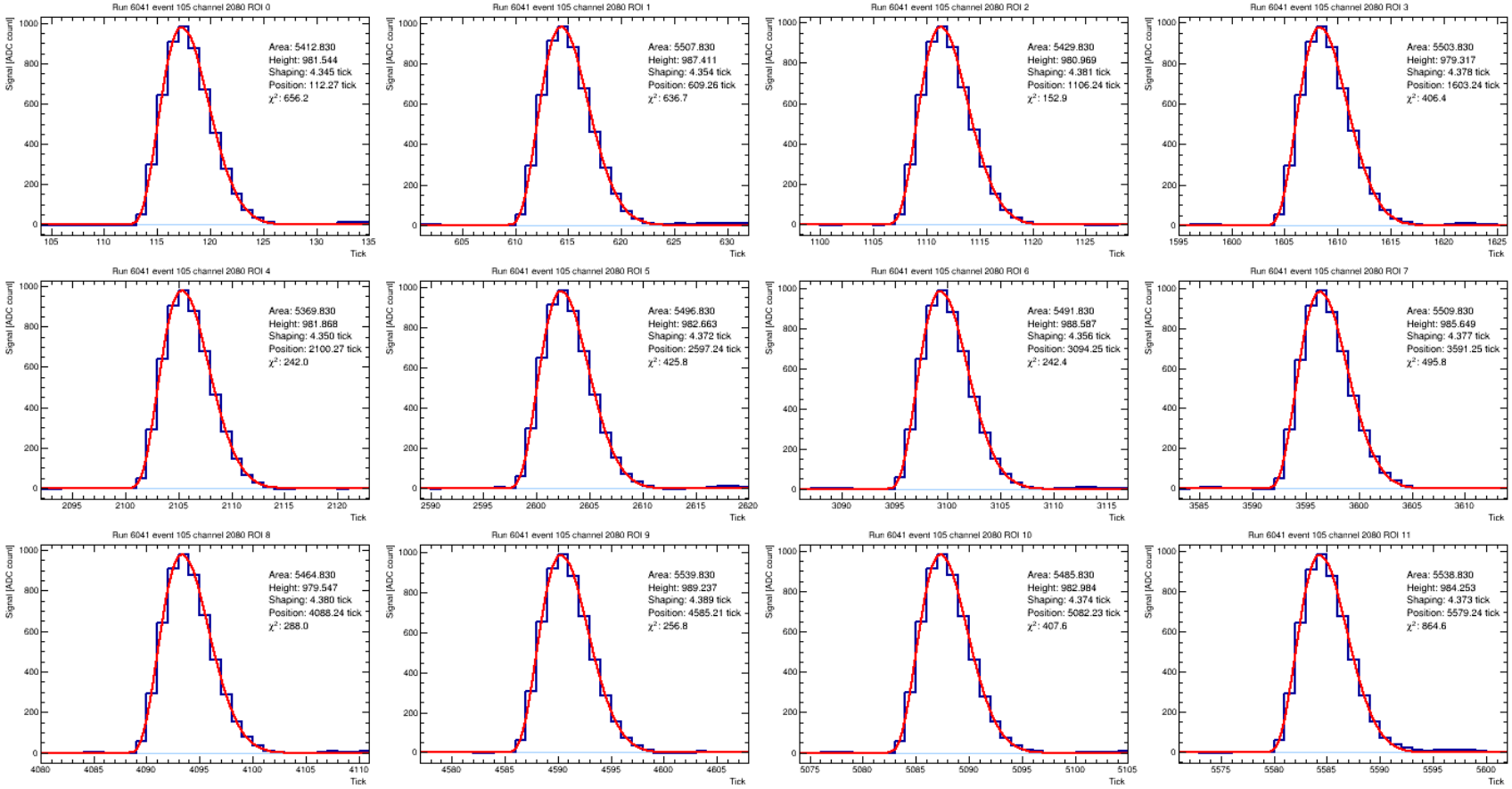
A=4


Run 6043 event 2 channel 2080 ROI 0
Area: 3647.038
Height: 650.652
Shaping: 4.383 tick
Position: 244.24 tick
χ²: 193.8
Run 6043 event 2 channel 2080 ROI 1
Area: 3672.038
Height: 656.763
Shaping: 4.345 tick
Position: 741.29 tick
χ²: 419.8
Run 6043 event 2 channel 2080 ROI 2
Area: 3651.038
Height: 656.829
Shaping: 4.376 tick
Position: 1238.27 tick
χ²: 65.8
Run 6043 event 2 channel 2080 ROI 3
Area: 3694.038
Height: 658.269
Shaping: 4.360 tick
Position: 1735.24 tick
χ²: 660.4
Run 6043 event 2 channel 2080 ROI 4
Area: 3698.038
Height: 647.664
Shaping: 4.401 tick
Position: 2232.20 tick
χ²: 568.7
Run 6043 event 2 channel 2080 ROI 5
Area: 3702.038
Height: 657.504
Shaping: 4.419 tick
Position: 2729.18 tick
χ²: 365.7
Run 6043 event 2 channel 2080 ROI 6
Area: 3612.038
Height: 647.687
Shaping: 4.395 tick
Position: 3226.22 tick
χ²: 424.9
Run 6043 event 2 channel 2080 ROI 7
Area: 3727.038
Height: 665.767
Shaping: 4.389 tick
Position: 3723.21 tick
χ²: 388.7
Run 6043 event 2 channel 2080 ROI 8
Area: 3695.038
Height: 652.223
Shaping: 4.398 tick
Position: 4220.21 tick
χ²: 442.7
Run 6043 event 2 channel 2080 ROI 9
Area: 3618.038
Height: 650.069
Shaping: 4.381 tick
Position: 4717.23 tick
χ²: 470.6
Run 6043 event 2 channel 2080 ROI 10
Area: 3675.038
Height: 657.604
Shaping: 4.376 tick
Position: 5214.22 tick
χ²: 287.8
Run 6043 event 2 channel 2080 ROI 11
Area: 3639.038
Height: 654.463
Shaping: 4.355 tick
Position: 5711.25 tick
χ²: 99.4
Signal [ADC count]
Tick

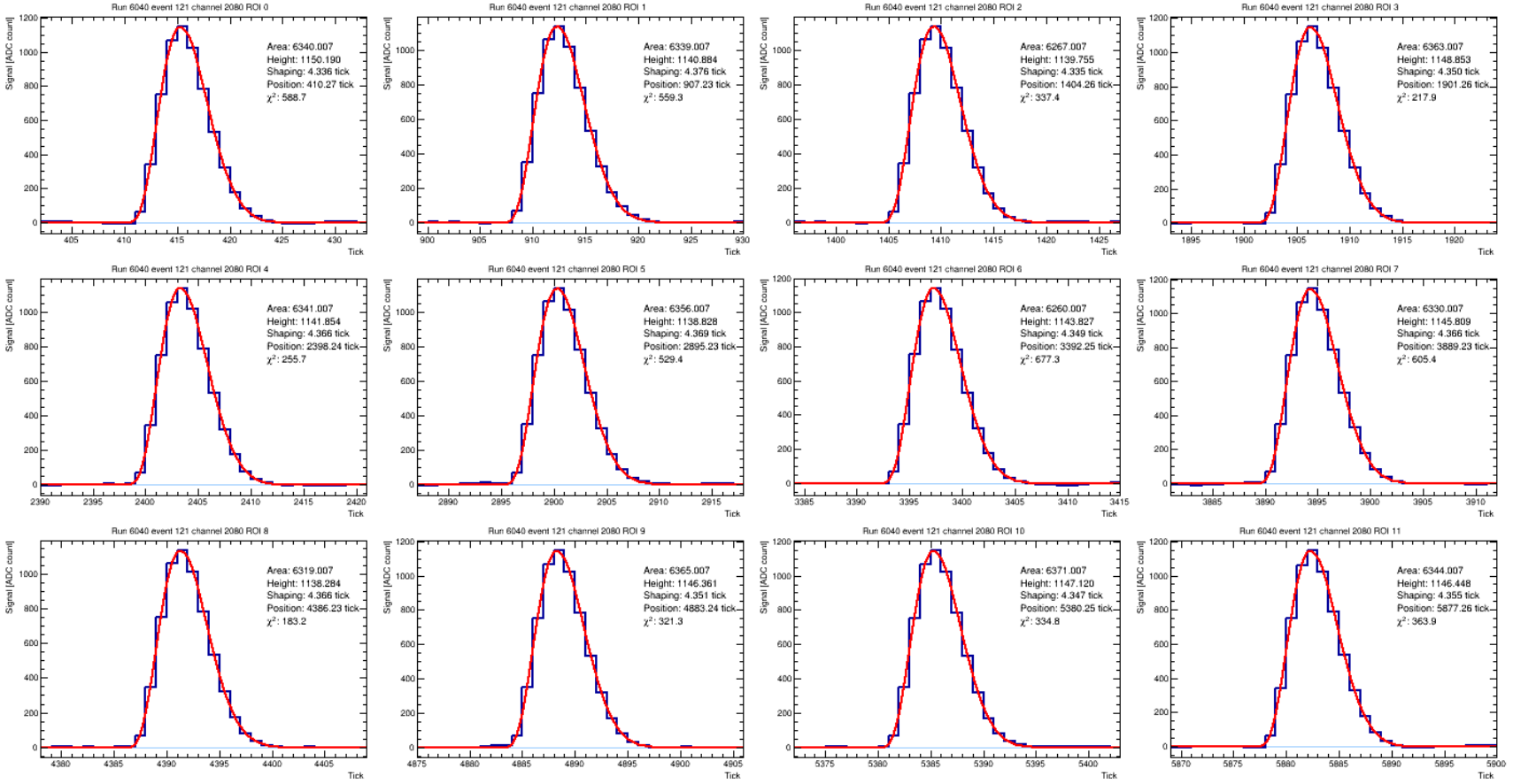
A=5


Run 6042 event 115 channel 2080 ROI 0
Area: 4570.340
Height: 815.781
Shaping: 4.384 tick
Position: 337.22 tick
χ²: 382.7
Run 6042 event 115 channel 2080 ROI 1
Area: 4487.340
Height: 809.600
Shaping: 4.367 tick
Position: 834.27 tick
χ²: 384.0
Run 6042 event 115 channel 2080 ROI 2
Area: 4474.340
Height: 818.312
Shaping: 4.341 tick
Position: 1331.27 tick
χ²: 312.7
Run 6042 event 115 channel 2080 ROI 3
Area: 4542.340
Height: 816.880
Shaping: 4.363 tick
Position: 1828.26 tick
χ²: 274.2
Run 6042 event 115 channel 2080 ROI 4
Area: 4555.340
Height: 818.688
Shaping: 4.364 tick
Position: 2325.28 tick
χ²: 225.9
Run 6042 event 115 channel 2080 ROI 5
Area: 4516.340
Height: 817.805
Shaping: 4.329 tick
Position: 2822.29 tick
χ²: 359.4
Run 6042 event 115 channel 2080 ROI 6
Area: 4581.340
Height: 816.313
Shaping: 4.367 tick
Position: 3319.25 tick
χ²: 438.8
Run 6042 event 115 channel 2080 ROI 7
Area: 4563.340
Height: 816.342
Shaping: 4.363 tick
Position: 3816.25 tick
χ²: 469.5
Run 6042 event 115 channel 2080 ROI 8
Area: 4523.340
Height: 816.636
Shaping: 4.374 tick
Position: 4313.26 tick
χ²: 308.7
Run 6042 event 115 channel 2080 ROI 9
Area: 4558.340
Height: 813.792
Shaping: 4.386 tick
Position: 4810.23 tick
χ²: 383.1
Run 6042 event 115 channel 2080 ROI 10
Area: 4547.340
Height: 816.708
Shaping: 4.367 tick
Position: 5307.25 tick
χ²: 182.8
Run 6042 event 115 channel 2080 ROI 11
Area: 4516.340
Height: 818.956
Shaping: 4.355 tick
Position: 5804.23 tick
χ²: 199.8
Signal [ADC count]
Tick

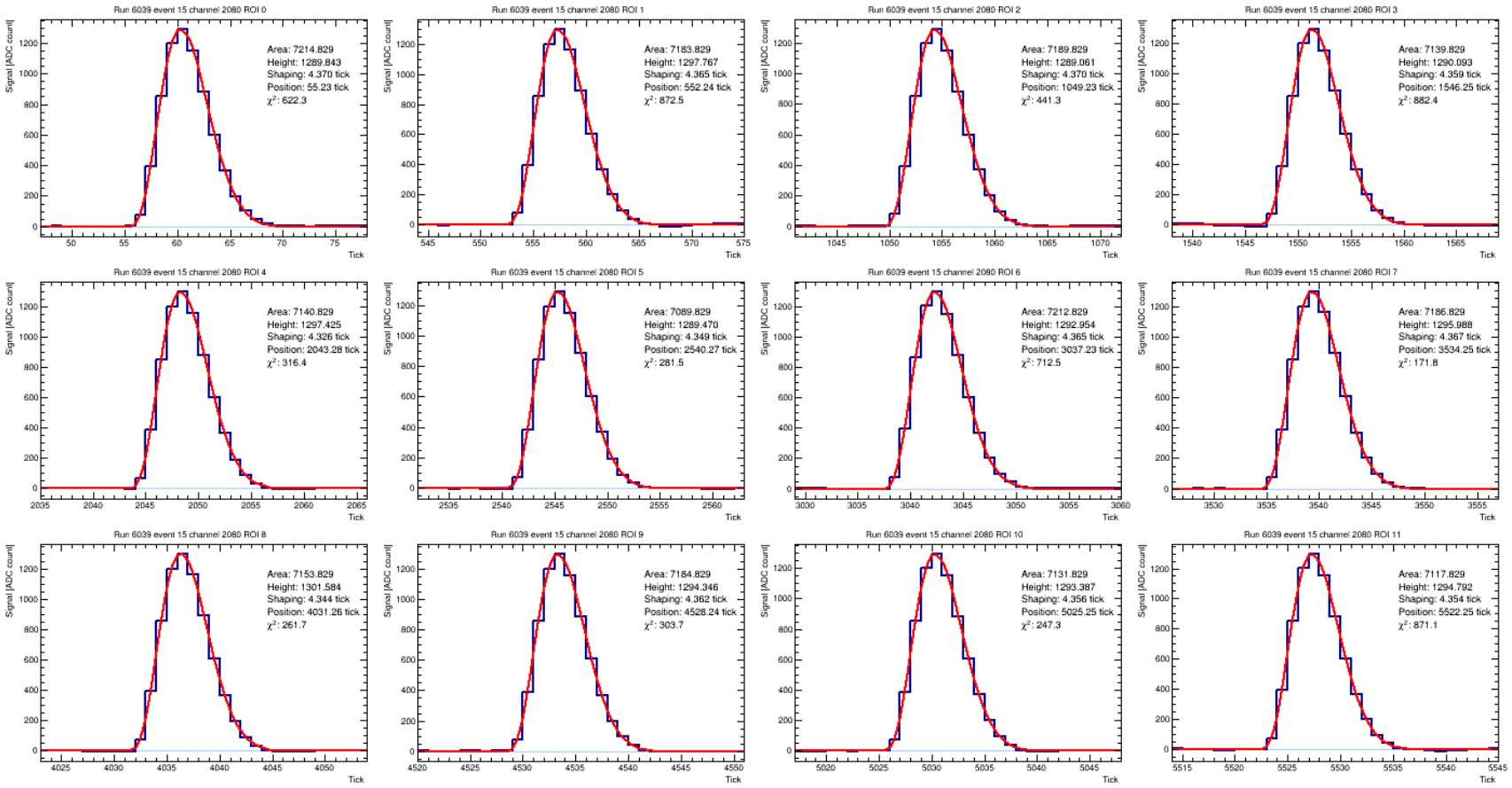
A=6


Run 6041 event 105 channel 2080 ROI 0
Area: 5412.830
Height: 981.544
Shaping: 4.345 tick
Position: 112.27 tick
χ²: 656.2
Run 6041 event 105 channel 2080 ROI 1
Area: 5507.830
Height: 987.411
Shaping: 4.354 tick
Position: 609.26 tick
χ²: 636.7
Run 6041 event 105 channel 2080 ROI 2
Area: 5429.830
Height: 980.969
Shaping: 4.381 tick
Position: 1106.24 tick
χ²: 152.9
Run 6041 event 105 channel 2080 ROI 3
Area: 5503.830
Height: 979.317
Shaping: 4.378 tick
Position: 1603.24 tick
χ²: 406.4
Run 6041 event 105 channel 2080 ROI 4
Area: 5369.830
Height: 981.868
Shaping: 4.350 tick
Position: 2100.27 tick
χ²: 242.0
Run 6041 event 105 channel 2080 ROI 5
Area: 5496.830
Height: 982.663
Shaping: 4.372 tick
Position: 2597.24 tick
χ²: 425.8
Run 6041 event 105 channel 2080 ROI 6
Area: 5491.830
Height: 988.587
Shaping: 4.356 tick
Position: 3094.25 tick
χ²: 242.4
Run 6041 event 105 channel 2080 ROI 7
Area: 5509.830
Height: 985.649
Shaping: 4.377 tick
Position: 3591.25 tick
χ²: 495.8
Run 6041 event 105 channel 2080 ROI 8
Area: 5464.830
Height: 979.547
Shaping: 4.380 tick
Position: 4088.24 tick
χ²: 288.0
Run 6041 event 105 channel 2080 ROI 9
Area: 5539.830
Height: 989.237
Shaping: 4.389 tick
Position: 4585.21 tick
χ²: 256.8
Run 6041 event 105 channel 2080 ROI 10
Area: 5485.830
Height: 982.984
Shaping: 4.374 tick
Position: 5082.23 tick
χ²: 407.6
Run 6041 event 105 channel 2080 ROI 11
Area: 5538.830
Height: 984.253
Shaping: 4.373 tick
Position: 5579.24 tick
χ²: 864.6
Signal [ADC count]
Tick

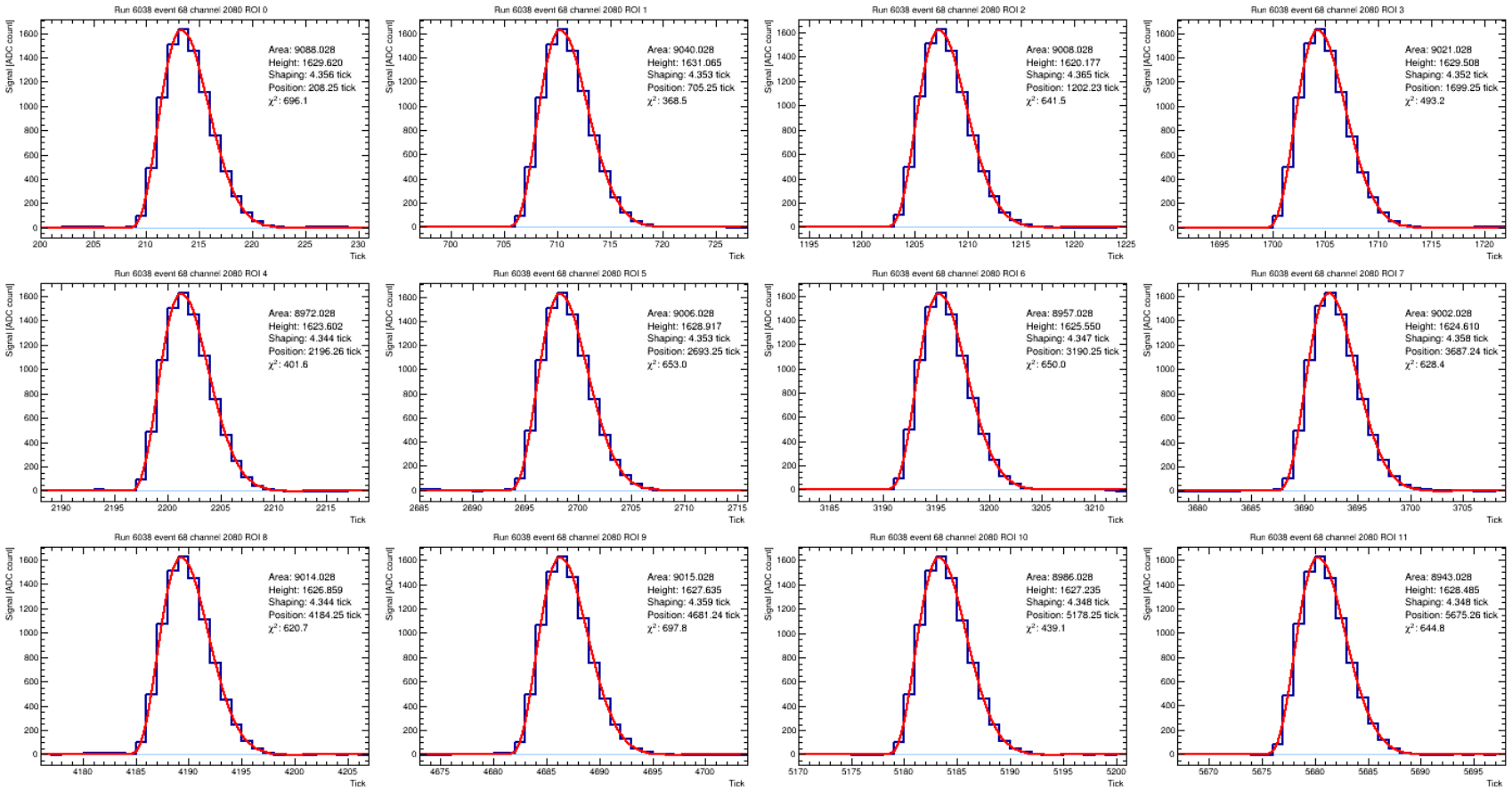
A=7


Run 6040 event 121 channel 2080 ROI 0
Area: 6340.007
Height: 1150.190
Shaping: 4.336 tick
Position: 410.27 tick
χ²: 588.7
Run 6040 event 121 channel 2080 ROI 1
Area: 6339.007
Height: 1140.884
Shaping: 4.376 tick
Position: 907.23 tick
χ²: 559.3
Run 6040 event 121 channel 2080 ROI 2
Area: 6267.007
Height: 1139.755
Shaping: 4.335 tick
Position: 1404.26 tick
χ²: 337.4
Run 6040 event 121 channel 2080 ROI 3
Area: 6363.007
Height: 1148.853
Shaping: 4.350 tick
Position: 1901.26 tick
χ²: 217.9
Run 6040 event 121 channel 2080 ROI 4
Area: 6341.007
Height: 1141.854
Shaping: 4.366 tick
Position: 2398.24 tick
χ²: 255.7
Run 6040 event 121 channel 2080 ROI 5
Area: 6356.007
Height: 1138.828
Shaping: 4.369 tick
Position: 2895.23 tick
χ²: 529.4
Run 6040 event 121 channel 2080 ROI 6
Area: 6260.007
Height: 1143.827
Shaping: 4.349 tick
Position: 3392.25 tick
χ²: 677.3
Run 6040 event 121 channel 2080 ROI 7
Area: 6330.007
Height: 1145.809
Shaping: 4.366 tick
Position: 3889.23 tick
χ²: 605.4
Run 6040 event 121 channel 2080 ROI 8
Area: 6319.007
Height: 1138.284
Shaping: 4.366 tick
Position: 4386.23 tick
χ²: 183.2
Run 6040 event 121 channel 2080 ROI 9
Area: 6365.007
Height: 1146.361
Shaping: 4.351 tick
Position: 4883.24 tick
χ²: 321.3
Run 6040 event 121 channel 2080 ROI 10
Area: 6371.007
Height: 1147.120
Shaping: 4.347 tick
Position: 5380.25 tick
χ²: 334.8
Run 6040 event 121 channel 2080 ROI 11
Area: 6344.007
Height: 1146.448
Shaping: 4.355 tick
Position: 5877.26 tick
χ²: 363.9
Signal [ADC count]
Tick

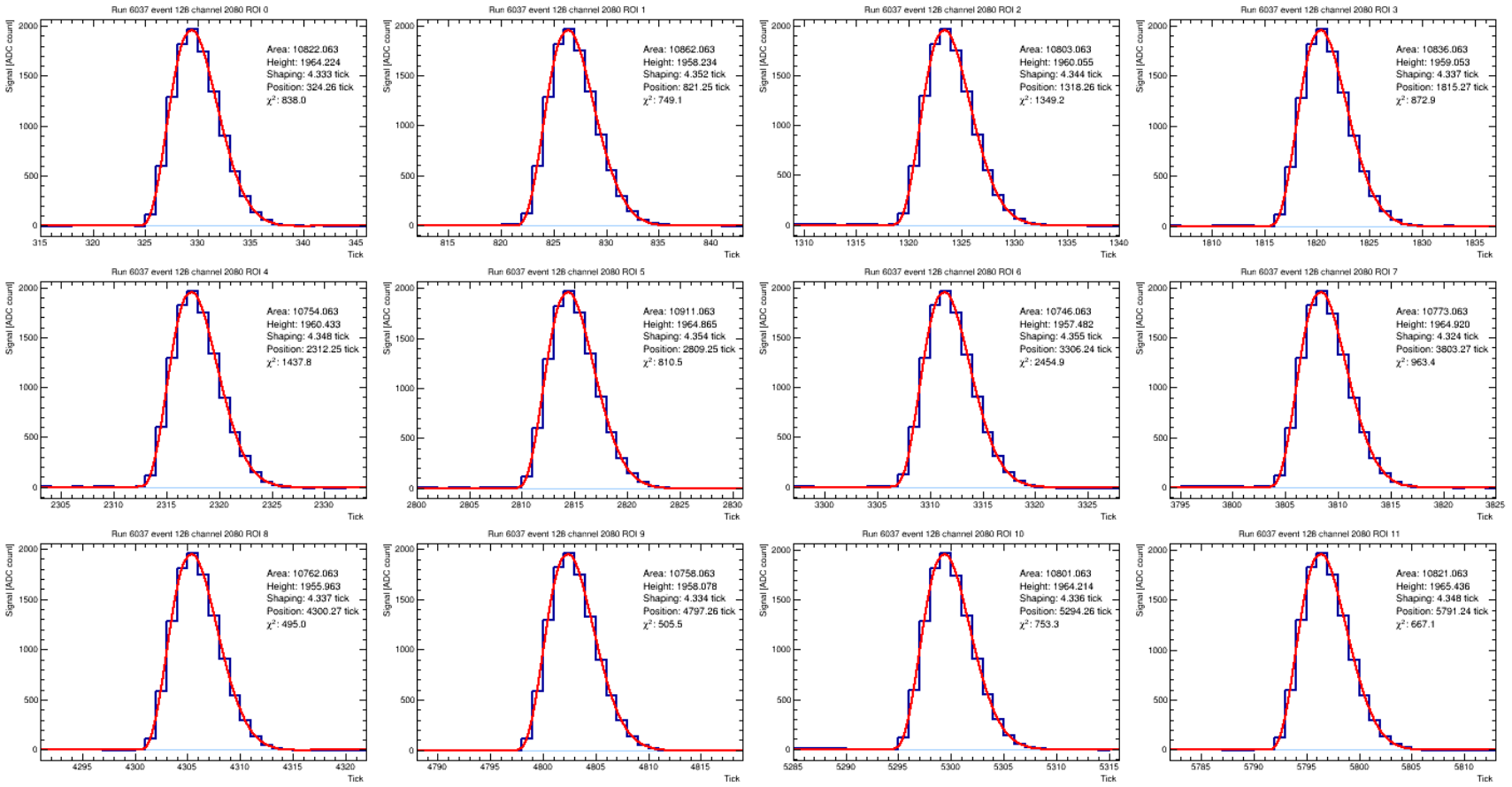
A=8


Run 6039 event 15 channel 2080 ROI 0
Area: 7214.829
Height: 1289.843
Shaping: 4.370 tick
Position: 55.23 tick
χ²: 622.3
Run 6039 event 15 channel 2080 ROI 1
Area: 7183.829
Height: 1297.767
Shaping: 4.365 tick
Position: 552.24 tick
χ²: 872.5
Run 6039 event 15 channel 2080 ROI 2
Area: 7189.829
Height: 1289.061
Shaping: 4.370 tick
Position: 1049.23 tick
χ²: 441.3
Run 6039 event 15 channel 2080 ROI 3
Area: 7139.829
Height: 1290.093
Shaping: 4.359 tick
Position: 1546.25 tick
χ²: 882.4
Run 6039 event 15 channel 2080 ROI 4
Area: 7140.829
Height: 1297.425
Shaping: 4.326 tick
Position: 2043.28 tick
χ²: 316.4
Run 6039 event 15 channel 2080 ROI 5
Area: 7089.829
Height: 1289.470
Shaping: 4.349 tick
Position: 2540.27 tick
χ²: 281.5
Run 6039 event 15 channel 2080 ROI 6
Area: 7212.829
Height: 1292.954
Shaping: 4.365 tick
Position: 3037.23 tick
χ²: 712.5
Run 6039 event 15 channel 2080 ROI 7
Area: 7186.829
Height: 1295.988
Shaping: 4.367 tick
Position: 3534.25 tick
χ²: 171.8
Run 6039 event 15 channel 2080 ROI 8
Area: 7153.829
Height: 1301.584
Shaping: 4.344 tick
Position: 4031.26 tick
χ²: 261.7
Run 6039 event 15 channel 2080 ROI 9
Area: 7184.829
Height: 1294.346
Shaping: 4.362 tick
Position: 4528.24 tick
χ²: 303.7
Run 6039 event 15 channel 2080 ROI 10
Area: 7131.829
Height: 1293.387
Shaping: 4.356 tick
Position: 5025.25 tick
χ²: 247.3
Run 6039 event 15 channel 2080 ROI 11
Area: 7117.829
Height: 1294.792
Shaping: 4.354 tick
Position: 5522.25 tick
χ²: 871.1
Signal [ADC count]
Tick

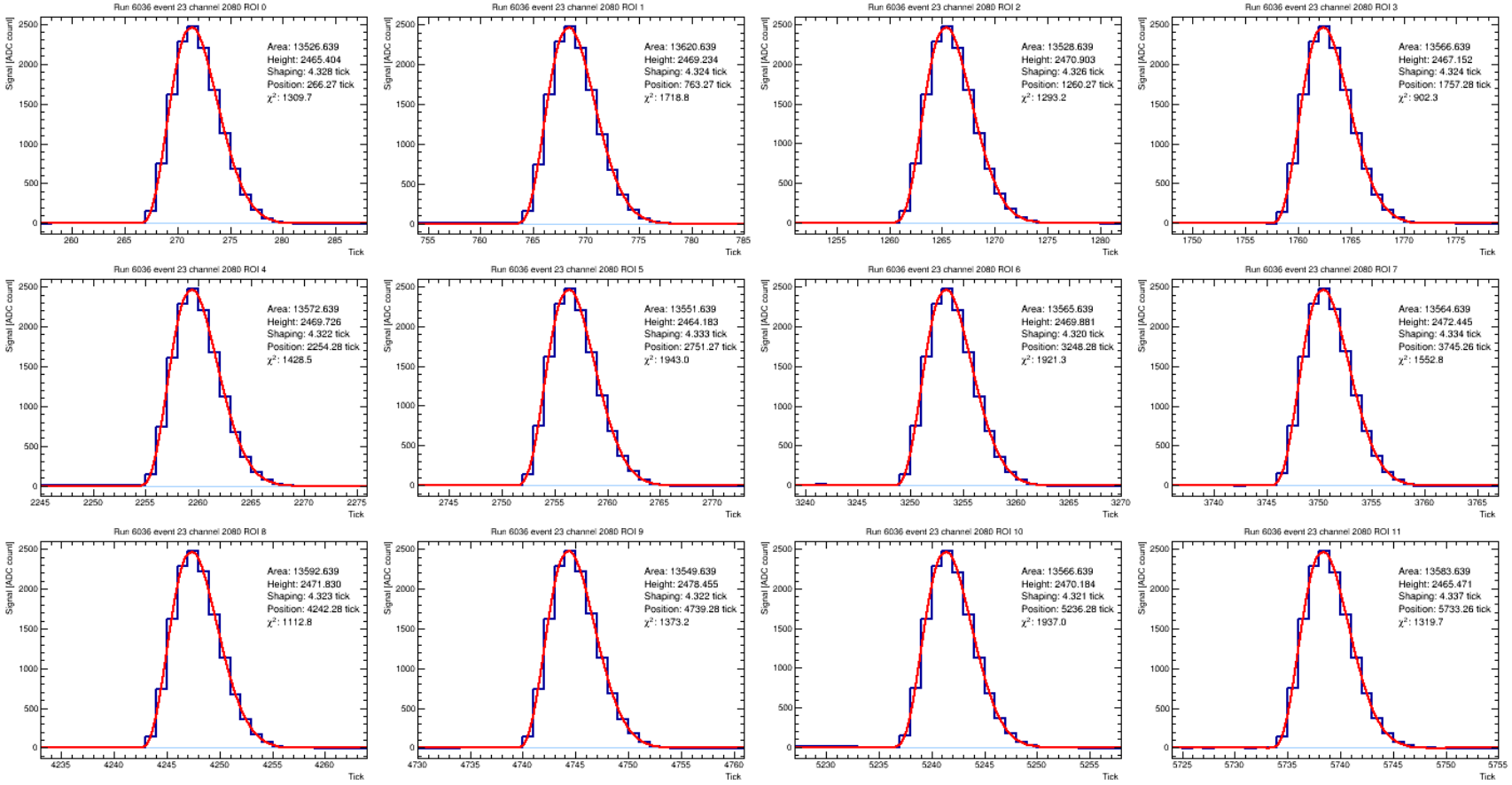
A=10


Run 6038 event 68 channel 2080 ROI 0
Area: 9088.028
Height: 1629.620
Shaping: 4.356 tick
Position: 208.25 tick
χ²: 696.1
Run 6038 event 68 channel 2080 ROI 1
Area: 9040.028
Height: 1631.065
Shaping: 4.353 tick
Position: 705.25 tick
χ²: 368.5
Run 6038 event 68 channel 2080 ROI 2
Area: 9008.028
Height: 1620.177
Shaping: 4.365 tick
Position: 1202.23 tick
χ²: 641.5
Run 6038 event 68 channel 2080 ROI 3
Area: 9021.028
Height: 1629.508
Shaping: 4.352 tick
Position: 1699.25 tick
χ²: 493.2
Run 6038 event 68 channel 2080 ROI 4
Area: 8972.028
Height: 1623.602
Shaping: 4.344 tick
Position: 2196.26 tick
χ²: 401.6
Run 6038 event 68 channel 2080 ROI 5
Area: 9006.028
Height: 1628.917
Shaping: 4.353 tick
Position: 2693.25 tick
χ²: 653.0
Run 6038 event 68 channel 2080 ROI 6
Area: 8957.028
Height: 1625.550
Shaping: 4.347 tick
Position: 3190.25 tick
χ²: 650.0
Run 6038 event 68 channel 2080 ROI 7
Area: 9002.028
Height: 1624.610
Shaping: 4.358 tick
Position: 3687.24 tick
χ²: 628.4
Run 6038 event 68 channel 2080 ROI 8
Area: 9014.028
Height: 1626.859
Shaping: 4.344 tick
Position: 4184.25 tick
χ²: 620.7
Run 6038 event 68 channel 2080 ROI 9
Area: 9015.028
Height: 1627.635
Shaping: 4.359 tick
Position: 4681.24 tick
χ²: 697.8
Run 6038 event 68 channel 2080 ROI 10
Area: 8986.028
Height: 1627.235
Shaping: 4.348 tick
Position: 5178.25 tick
χ²: 439.1
Run 6038 event 68 channel 2080 ROI 11
Area: 8943.028
Height: 1628.485
Shaping: 4.348 tick
Position: 5675.26 tick
χ²: 644.8
Signal [ADC count]
Tick

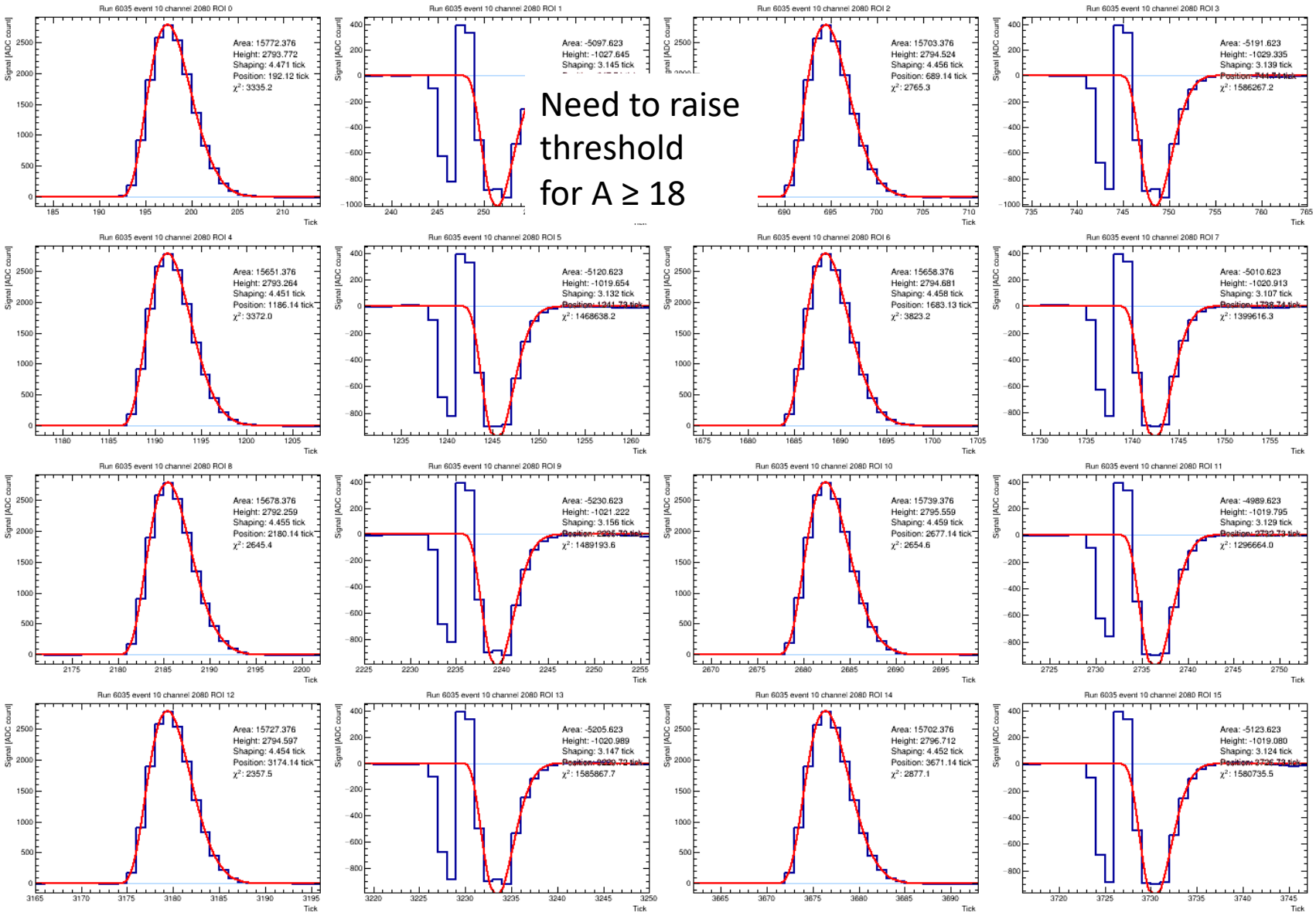
A=12


Run 6037 event 126 channel 2080 ROI 0
Area: 10822.063
Height: 1964.224
Shaping: 4.333 tick
Position: 324.26 tick
χ²: 838.0
Run 6037 event 126 channel 2080 ROI 1
Area: 10862.063
Height: 1958.234
Shaping: 4.352 tick
Position: 821.25 tick
χ²: 749.1
Run 6037 event 126 channel 2080 ROI 2
Area: 10803.063
Height: 1960.055
Shaping: 4.344 tick
Position: 1318.26 tick
χ²: 1349.2
Run 6037 event 126 channel 2080 ROI 3
Area: 10836.063
Height: 1959.053
Shaping: 4.337 tick
Position: 1815.27 tick
χ²: 872.9
Run 6037 event 126 channel 2080 ROI 4
Area: 10754.063
Height: 1960.433
Shaping: 4.348 tick
Position: 2312.25 tick
χ²: 1437.8
Run 6037 event 126 channel 2080 ROI 5
Area: 10911.063
Height: 1964.865
Shaping: 4.354 tick
Position: 2809.25 tick
χ²: 810.5
Run 6037 event 126 channel 2080 ROI 6
Area: 10746.063
Height: 1957.482
Shaping: 4.355 tick
Position: 3306.24 tick
χ²: 2454.9
Run 6037 event 126 channel 2080 ROI 7
Area: 10773.063
Height: 1964.920
Shaping: 4.324 tick
Position: 3803.27 tick
χ²: 963.4
Run 6037 event 126 channel 2080 ROI 8
Area: 10762.063
Height: 1955.963
Shaping: 4.337 tick
Position: 4300.27 tick
χ²: 495.0
Run 6037 event 126 channel 2080 ROI 9
Area: 10758.063
Height: 1958.078
Shaping: 4.334 tick
Position: 4797.26 tick
χ²: 505.5
Run 6037 event 126 channel 2080 ROI 10
Area: 10801.063
Height: 1964.214
Shaping: 4.336 tick
Position: 5294.26 tick
χ²: 753.3
Run 6037 event 126 channel 2080 ROI 11
Area: 10821.063
Height: 1965.436
Shaping: 4.348 tick
Position: 5791.24 tick
χ²: 667.1
Signal [ADC count]
Tick

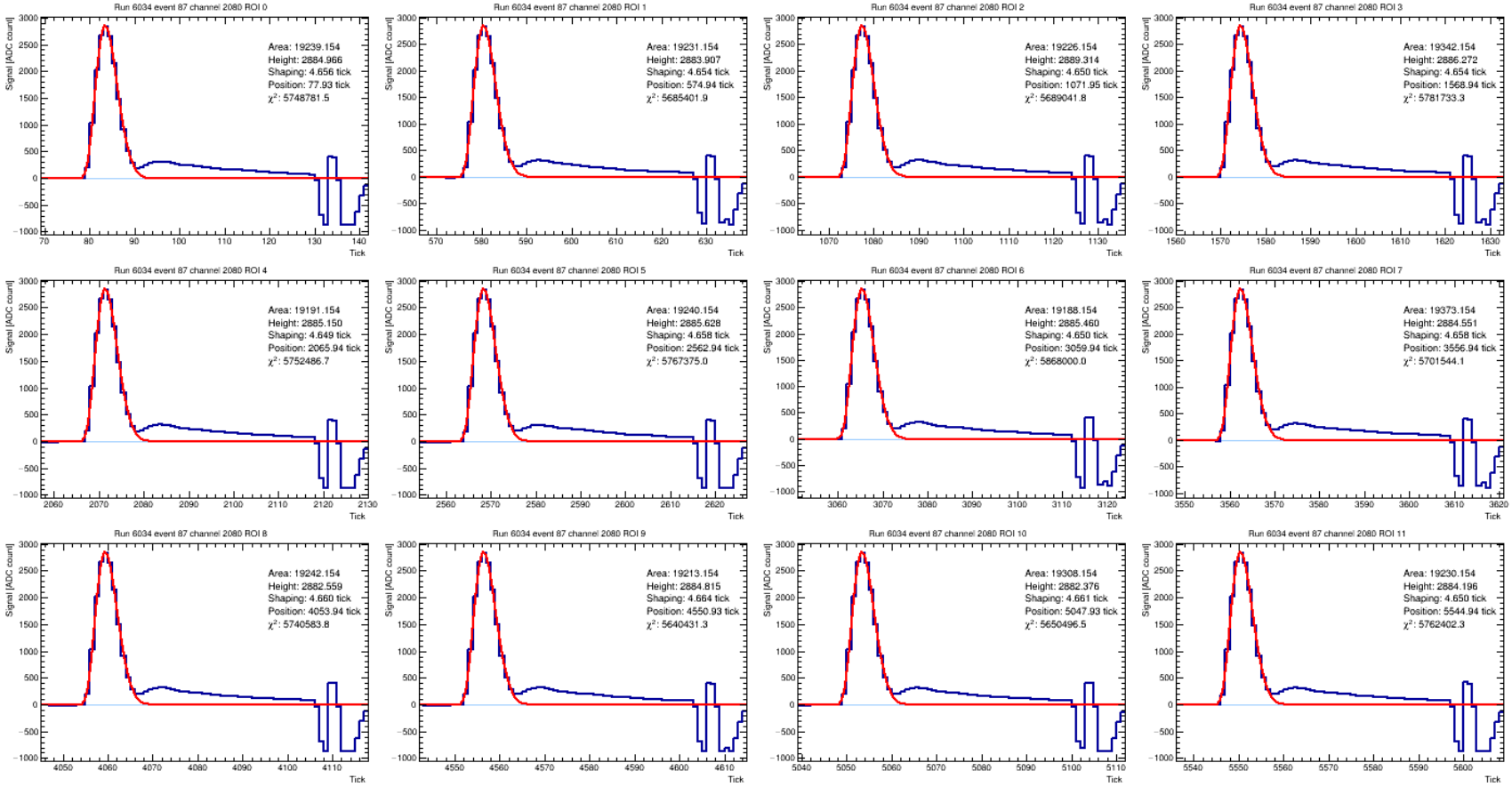
A=15


Run 6036 event 23 channel 2080 ROI 0
Area: 13526.639
Height: 2465.404
Shaping: 4.328 tick
Position: 266.27 tick
χ²: 1309.7
Run 6036 event 23 channel 2080 ROI 1
Area: 13620.639
Height: 2469.234
Shaping: 4.324 tick
Position: 763.27 tick
χ²: 1718.8
Run 6036 event 23 channel 2080 ROI 2
Area: 13528.639
Height: 2470.903
Shaping: 4.326 tick
Position: 1260.27 tick
χ²: 1293.2
Run 6036 event 23 channel 2080 ROI 3
Area: 13566.639
Height: 2467.152
Shaping: 4.324 tick
Position: 1757.28 tick
χ²: 902.3
Run 6036 event 23 channel 2080 ROI 4
Area: 13572.639
Height: 2469.726
Shaping: 4.322 tick
Position: 2254.28 tick
χ²: 1428.5
Run 6036 event 23 channel 2080 ROI 5
Area: 13551.639
Height: 2464.183
Shaping: 4.333 tick
Position: 2751.27 tick
χ²: 1943.0
Run 6036 event 23 channel 2080 ROI 6
Area: 13565.639
Height: 2469.881
Shaping: 4.320 tick
Position: 3248.28 tick
χ²: 1921.3
Run 6036 event 23 channel 2080 ROI 7
Area: 13564.639
Height: 2472.445
Shaping: 4.334 tick
Position: 3745.26 tick
χ²: 1552.8
Run 6036 event 23 channel 2080 ROI 8
Area: 13592.639
Height: 2471.830
Shaping: 4.323 tick
Position: 4242.28 tick
χ²: 1112.8
Run 6036 event 23 channel 2080 ROI 9
Area: 13549.639
Height: 2478.455
Shaping: 4.322 tick
Position: 4739.28 tick
χ²: 1373.2
Run 6036 event 23 channel 2080 ROI 10
Area: 13566.639
Height: 2470.184
Shaping: 4.321 tick
Position: 5236.28 tick
χ²: 1937.0
Run 6036 event 23 channel 2080 ROI 11
Area: 13583.639
Height: 2465.471
Shaping: 4.337 tick
Position: 5733.26 tick
χ²: 1319.7
Signal [ADC count]
Tick

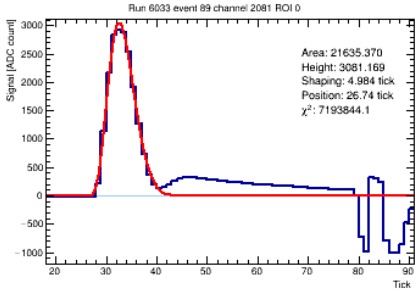
A=18

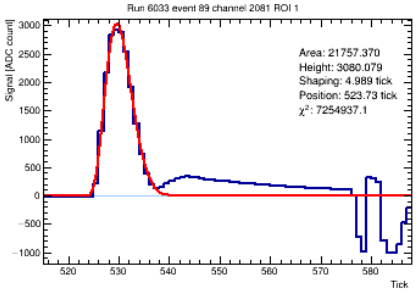

Run 6035 event 10 channel 2080 ROI 0
Area: 15772.376
Height: 2793.772
Shaping: 4.471 tick
Position: 192.12 tick
χ²: 3335.2
Run 6035 event 10 channel 2080 ROI 1
Area: -5097.623
Height: -1027.645
Shaping: 3.145 tick
Run 6035 event 10 channel 2080 ROI 2
Area: 15703.376
Height: 2794.524
Shaping: 4.456 tick
Position: 689.14 tick
χ²: 2765.3
Run 6035 event 10 channel 2080 ROI 3
Area: -5191.623
Height: -1029.335
Shaping: 3.139 tick
χ²: 1586267.2
Need to raise threshold for A ≥ 18
Run 6035 event 10 channel 2080 ROI 4
Area: 15651.376
Height: 2793.264
Shaping: 4.451 tick
Position: 1186.14 tick
χ²: 3372.0
Run 6035 event 10 channel 2080 ROI 5
Area: -5120.623
Height: -1019.654
Shaping: 3.132 tick
χ²: 1468638.2
Run 6035 event 10 channel 2080 ROI 6
Area: 15658.376
Height: 2794.681
Shaping: 4.458 tick
Position: 1683.13 tick
χ²: 3823.2
Run 6035 event 10 channel 2080 ROI 7
Area: -5010.623
Height: -1020.913
Shaping: 3.107 tick
χ²: 1399616.3
Run 6035 event 10 channel 2080 ROI 8
Area: 15678.376
Height: 2792.259
Shaping: 4.455 tick
Position: 2180.14 tick
χ²: 2645.4
Run 6035 event 10 channel 2080 ROI 9
Area: -5230.623
Height: -1021.222
Shaping: 3.156 tick
χ²: 1489193.6
Run 6035 event 10 channel 2080 ROI 10
Area: 15739.376
Height: 2795.559
Shaping: 4.459 tick
Position: 2677.14 tick
χ²: 2654.6
Run 6035 event 10 channel 2080 ROI 11
Area: -4989.623
Height: -1019.795
Shaping: 3.129 tick
χ²: 1296664.0
Run 6035 event 10 channel 2080 ROI 12
Area: 15727.376
Height: 2794.597
Shaping: 4.454 tick
Position: 3174.14 tick
χ²: 2357.5
Run 6035 event 10 channel 2080 ROI 13
Area: -5205.623
Height: -1020.989
Shaping: 3.147 tick
χ²: 1585867.7
Run 6035 event 10 channel 2080 ROI 14
Area: 15702.376
Height: 2796.712
Shaping: 4.452 tick
Position: 3671.14 tick
χ²: 2877.1
Run 6035 event 10 channel 2080 ROI 15
Area: -5123.623
Height: -1019.080
Shaping: 3.124 tick
χ²: 1580735.5
Signal [ADC count]
Tick

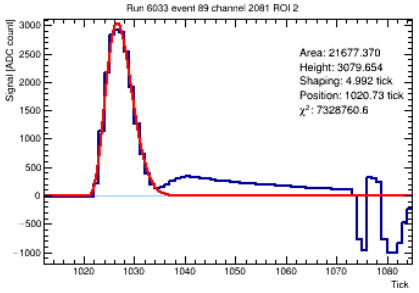
A=21

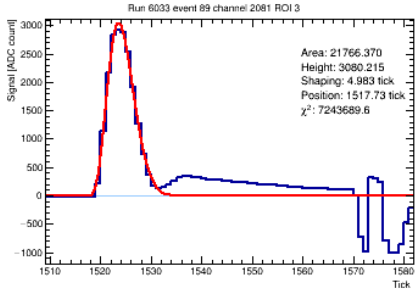

Run 6034 event 87 channel 2080 ROI 0
Area: 19239.154
Height: 2884.966
Shaping: 4.656 tick
Position: 77.93 tick
χ²: 5748781.5
Run 6034 event 87 channel 2080 ROI 1
Area: 19231.154
Height: 2883.907
Shaping: 4.654 tick
Position: 574.94 tick
χ²: 5685401.9
Run 6034 event 87 channel 2080 ROI 2
Area: 19226.154
Height: 2889.314
Shaping: 4.650 tick
Position: 1071.95 tick
χ²: 5689041.8
Run 6034 event 87 channel 2080 ROI 3
Area: 19342.154
Height: 2886.272
Shaping: 4.654 tick
Position: 1568.94 tick
χ²: 5781733.3
Run 6034 event 87 channel 2080 ROI 4
Area: 19191.154
Height: 2885.150
Shaping: 4.649 tick
Position: 2065.94 tick
χ²: 5752486.7
Run 6034 event 87 channel 2080 ROI 5
Area: 19240.154
Height: 2885.628
Shaping: 4.658 tick
Position: 2562.94 tick
χ²: 5767375.0
Run 6034 event 87 channel 2080 ROI 6
Area: 19188.154
Height: 2885.460
Shaping: 4.650 tick
Position: 3059.94 tick
χ²: 5868000.0
Run 6034 event 87 channel 2080 ROI 7
Area: 19373.154
Height: 2884.551
Shaping: 4.658 tick
Position: 3556.94 tick
χ²: 5701544.1
Run 6034 event 87 channel 2080 ROI 8
Area: 19242.154
Height: 2882.559
Shaping: 4.660 tick
Position: 4053.94 tick
χ²: 5740583.8
Run 6034 event 87 channel 2080 ROI 9
Area: 19213.154
Height: 2884.815
Shaping: 4.664 tick
Position: 4550.93 tick
χ²: 5640431.3
Run 6034 event 87 channel 2080 ROI 10
Area: 19308.154
Height: 2882.376
Shaping: 4.661 tick
Position: 5047.93 tick
χ²: 5650496.5
Run 6034 event 87 channel 2080 ROI 11
Area: 19230.154
Height: 2884.196
Shaping: 4.650 tick
Position: 5544.94 tick
χ²: 5762402.3
Signal [ADC count]
Tick

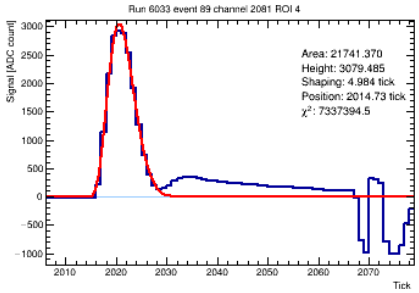
A=25

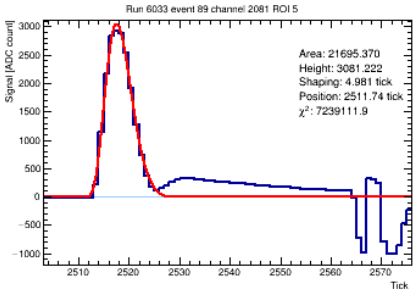

Run 6033 event 89 channel 2081 ROI 0
Area: 21635.370
Height: 3081.169
Shaping: 4.984 tick
Position: 26.74 tick
χ²: 7193844.1
Signal [ADC count]
Tick

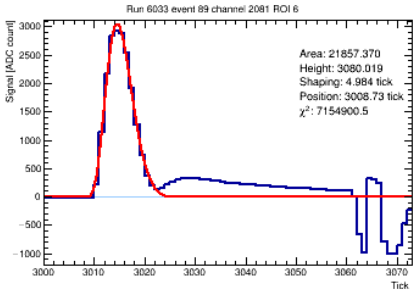

Run 6033 event 89 channel 2081 ROI 1
Area: 21757.370
Height: 3080.079
Shaping: 4.989 tick
Position: 523.73 tick
χ²: 7254937.1
Signal [ADC count]
Tick

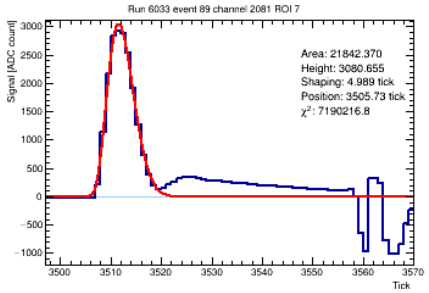

Run 6033 event 89 channel 2081 ROI 2
Area: 21677.370
Height: 3079.654
Shaping: 4.992 tick
Position: 1020.73 tick
χ²: 7328760.6
Signal [ADC count]
Tick

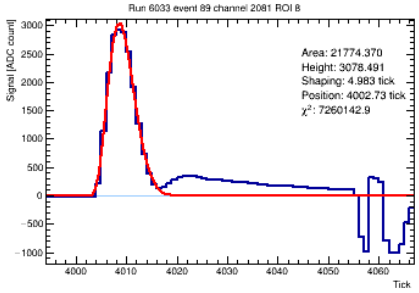

Run 6033 event 89 channel 2081 ROI 3
Area: 21766.370
Height: 3080.215
Shaping: 4.983 tick
Position: 1517.73 tick
χ²: 7243689.6
Signal [ADC count]
Tick

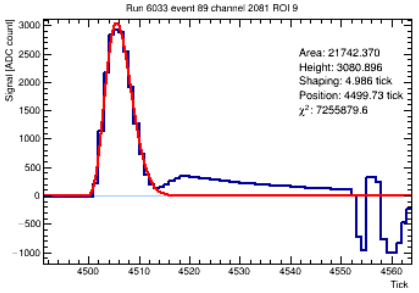

Run 6033 event 89 channel 2081 ROI 4
Area: 21741.370
Height: 3079.485
Shaping: 4.984 tick
Position: 2014.73 tick
χ²: 7337394.5
Signal [ADC count]
Tick

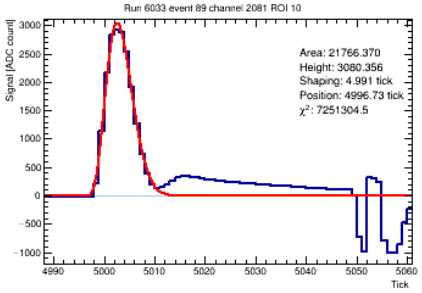

Run 6033 event 89 channel 2081 ROI 5
Area: 21695.370
Height: 3081.222
Shaping: 4.981 tick
Position: 2511.74 tick
χ²: 7239111.9
Signal [ADC count]
Tick

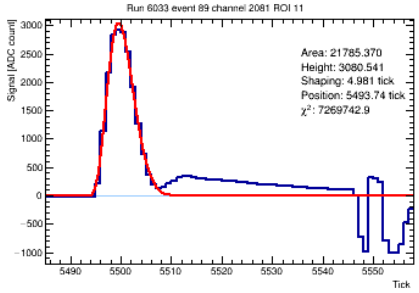

Run 6033 event 89 channel 2081 ROI 6
Area: 21857.370
Height: 3080.019
Shaping: 4.984 tick
Position: 3008.73 tick
χ²: 7154900.5
Signal [ADC count]
Tick

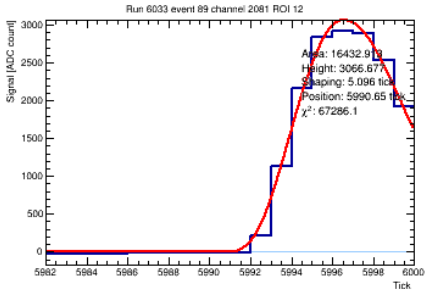

Run 6033 event 89 channel 2081 ROI 7
Area: 21842.370
Height: 3080.655
Shaping: 4.989 tick
Position: 3505.73 tick
χ²: 7190216.8
Signal [ADC count]
Tick


Run 6033 event 89 channel 2081 ROI 8
Area: 21774.370
Height: 3078.491
Shaping: 4.983 tick
Position: 4002.73 tick
χ²: 7260142.9
Signal [ADC count]
Tick

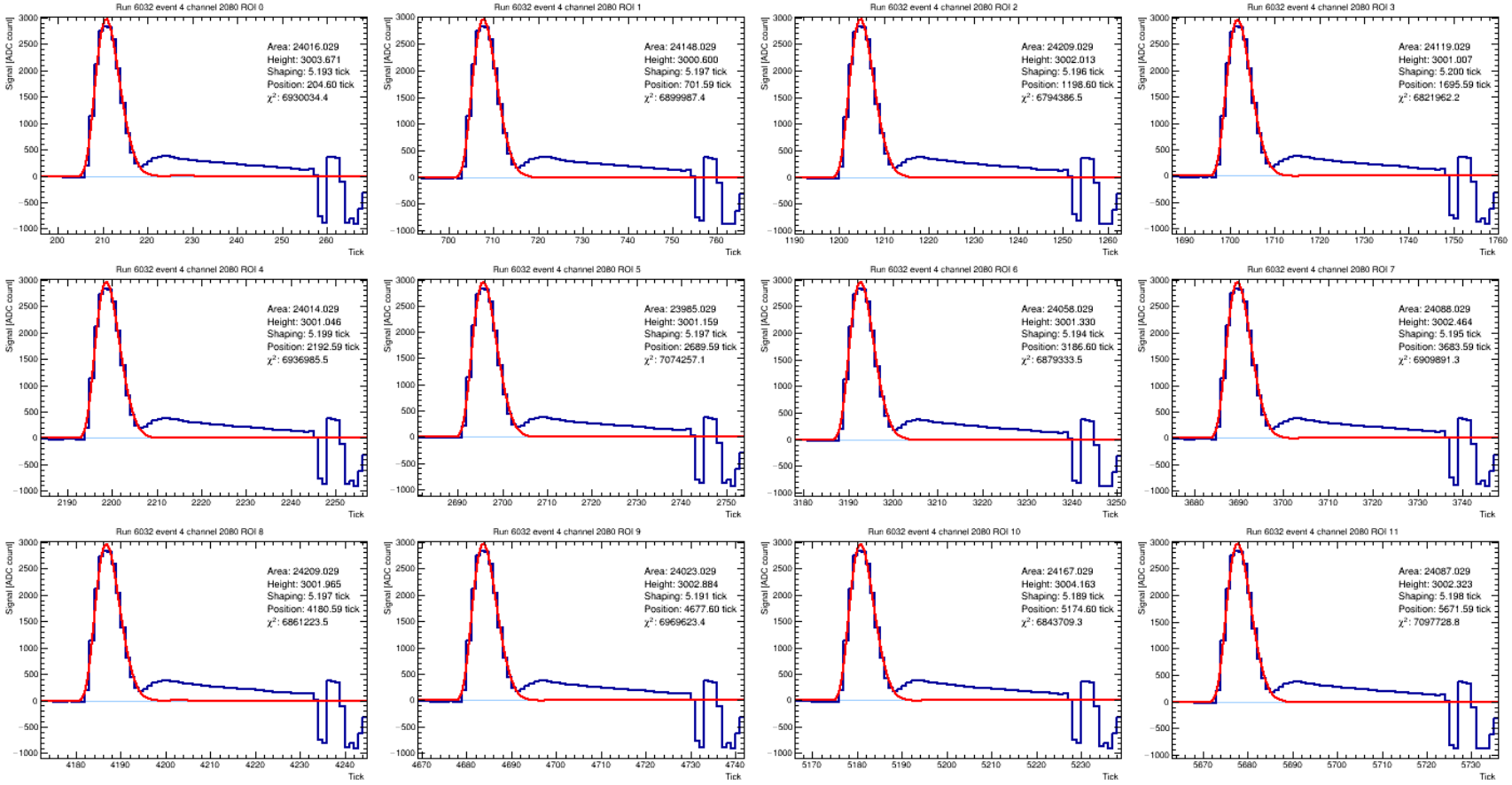

Run 6033 event 89 channel 2081 ROI 9
Area: 21742.370
Height: 3080.896
Shaping: 4.986 tick
Position: 4499.73 tick
χ²: 7255879.6
Signal [ADC count]
Tick


Run 6033 event 89 channel 2081 ROI 10
Area: 21766.370
Height: 3080.356
Shaping: 4.991 tick
Position: 4996.73 tick
χ²: 7251304.5
Signal [ADC count]
Tick


Run 6033 event 89 channel 2081 ROI 11
Area: 21785.370
Height: 3080.541
Shaping: 4.981 tick
Position: 5493.74 tick
χ²: 7269742.9
Signal [ADC count]
Tick

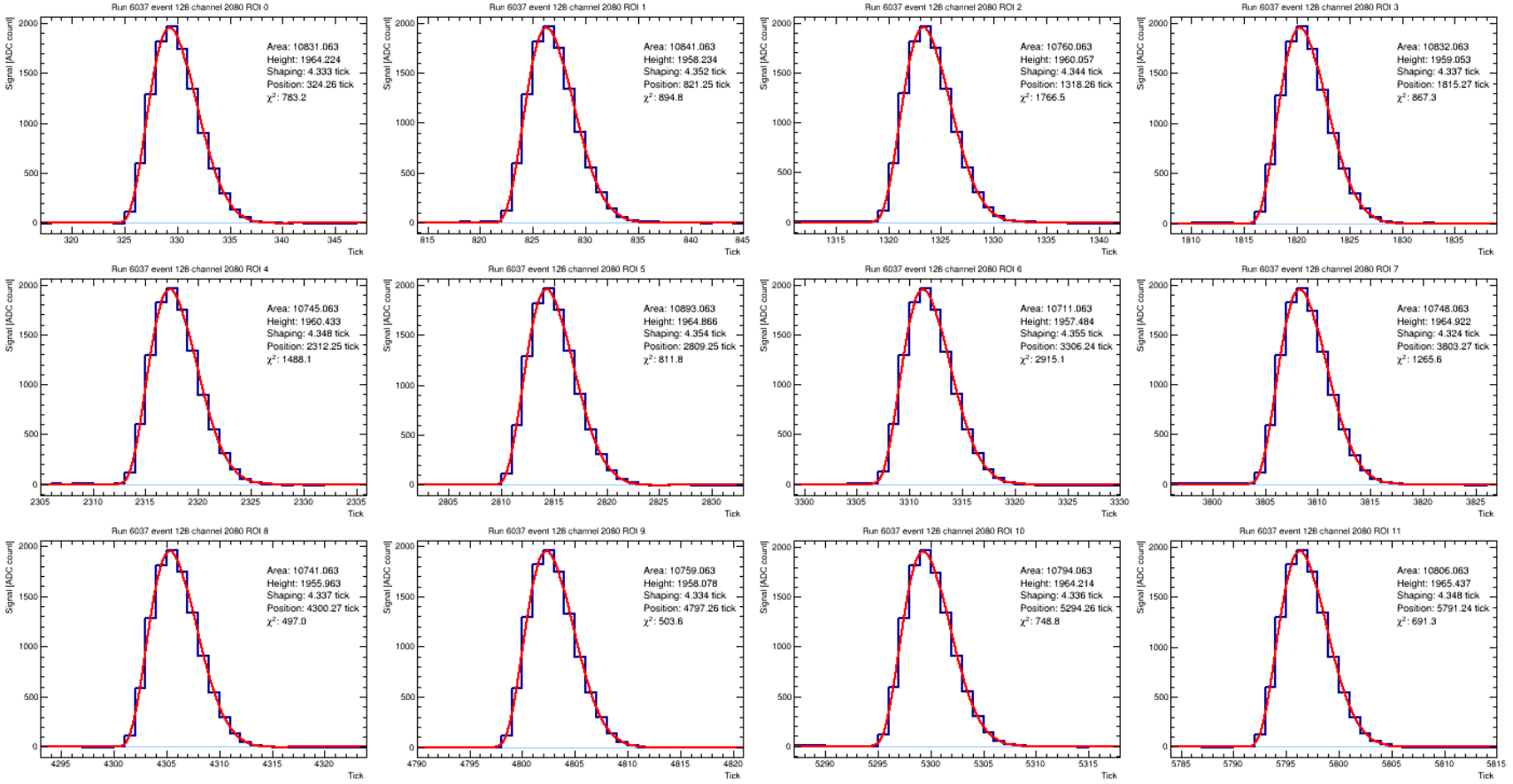

Run 6033 event 89 channel 2081 ROI 12
Area: 16432.910
Height: 3066.677
Shaping: 5.096 tick
Position: 5990.65 tick
χ²: 67286.1
Signal [ADC count]
Tick

A=30

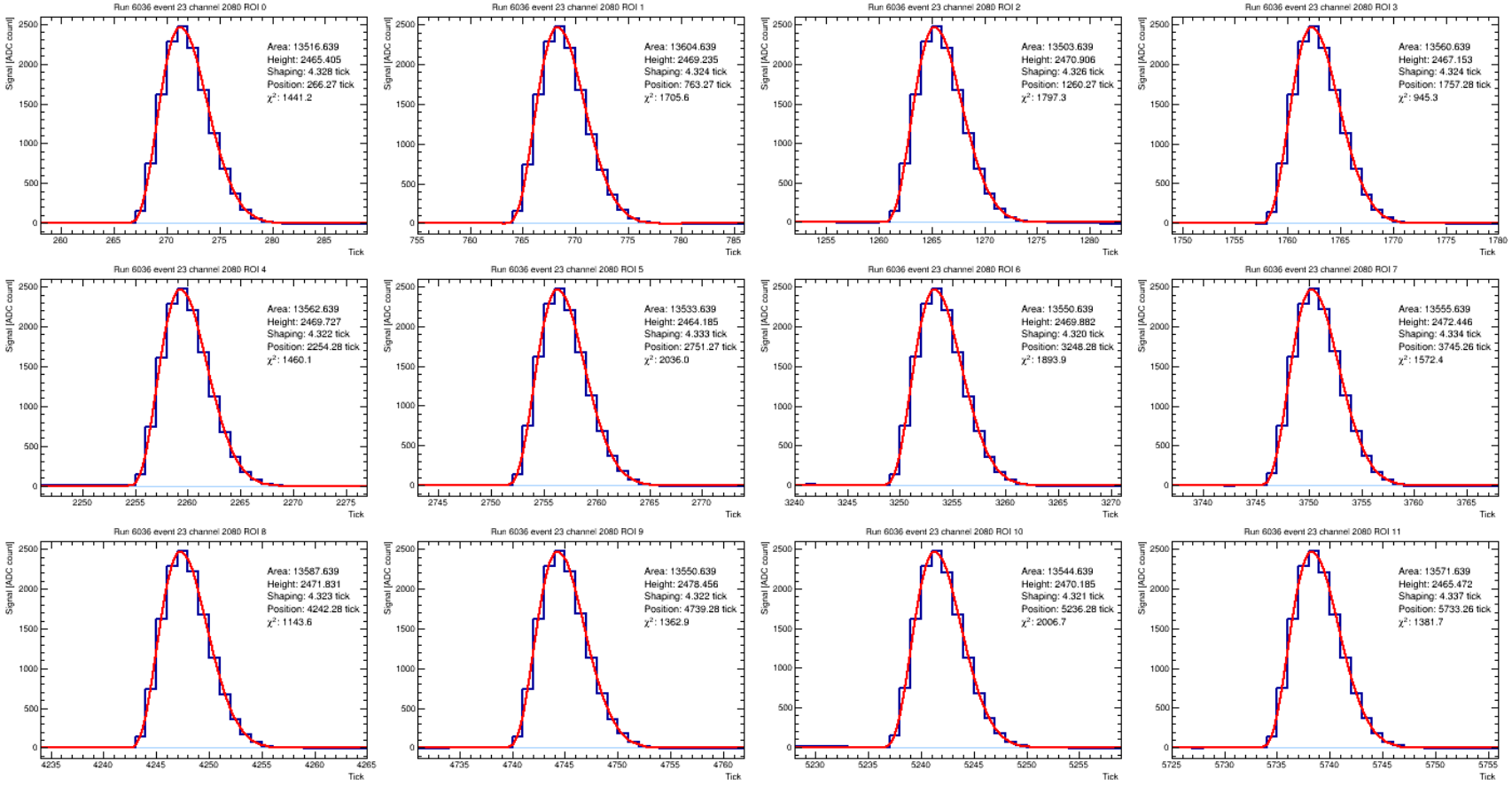

Run 6032 event 4 channel 2080 ROI 0
Area: 24016.029
Height: 3003.671
Shaping: 5.193 tick
Position: 204.60 tick
χ²: 6930034.4
Run 6032 event 4 channel 2080 ROI 1
Area: 24148.029
Height: 3000.600
Shaping: 5.197 tick
Position: 701.59 tick
χ²: 6899987.4
Run 6032 event 4 channel 2080 ROI 2
Area: 24209.029
Height: 3002.013
Shaping: 5.196 tick
Position: 1198.60 tick
χ²: 6794386.5
Run 6032 event 4 channel 2080 ROI 3
Area: 24119.029
Height: 3001.007
Shaping: 5.200 tick
Position: 1695.59 tick
χ²: 6821962.2
Run 6032 event 4 channel 2080 ROI 4
Area: 24014.029
Height: 3001.046
Shaping: 5.199 tick
Position: 2192.59 tick
χ²: 6936985.5
Run 6032 event 4 channel 2080 ROI 5
Area: 23985.029
Height: 3001.159
Shaping: 5.197 tick
Position: 2689.59 tick
χ²: 7074257.1
Run 6032 event 4 channel 2080 ROI 6
Area: 24058.029
Height: 3001.330
Shaping: 5.194 tick
Position: 3186.60 tick
χ²: 6879333.5
Run 6032 event 4 channel 2080 ROI 7
Area: 24088.029
Height: 3002.464
Shaping: 5.195 tick
Position: 3683.59 tick
χ²: 6909891.3
Run 6032 event 4 channel 2080 ROI 8
Area: 24209.029
Height: 3001.965
Shaping: 5.197 tick
Position: 4180.59 tick
χ²: 6861223.5
Run 6032 event 4 channel 2080 ROI 9
Area: 24023.029
Height: 3002.884
Shaping: 5.191 tick
Position: 4677.60 tick
χ²: 6969623.4
Run 6032 event 4 channel 2080 ROI 10
Area: 24167.029
Height: 3004.163
Shaping: 5.189 tick
Position: 5174.60 tick
χ²: 6843709.3
Run 6032 event 4 channel 2080 ROI 11
Area: 24087.029
Height: 3002.323
Shaping: 5.198 tick
Position: 5671.59 tick
χ²: 7097728.8
Signal [ADC count]
Tick

ROI waveforms with high threshold

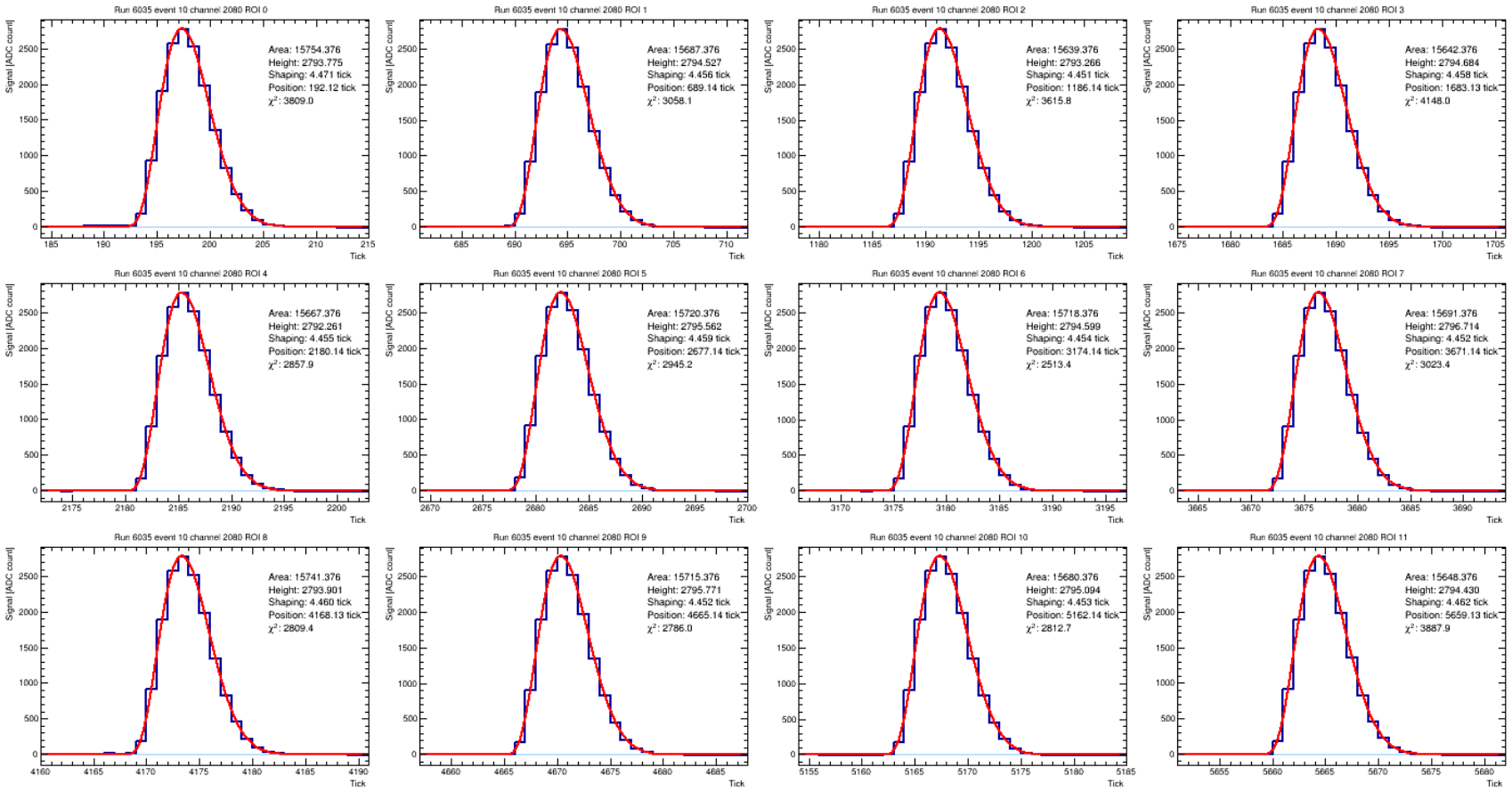
A=12


Run 6037 event 126 channel 2080 ROI 0
Area: 10831.063
Height: 1964.224
Shaping: 4.333 tick
Position: 324.26 tick
χ²: 783.2
Run 6037 event 126 channel 2080 ROI 1
Area: 10841.063
Height: 1958.234
Shaping: 4.352 tick
Position: 821.25 tick
χ²: 894.8
Run 6037 event 126 channel 2080 ROI 2
Area: 10760.063
Height: 1960.057
Shaping: 4.344 tick
Position: 1318.26 tick
χ²: 1766.5
Run 6037 event 126 channel 2080 ROI 3
Area: 10832.063
Height: 1959.053
Shaping: 4.337 tick
Position: 1815.27 tick
χ²: 867.3
Run 6037 event 126 channel 2080 ROI 4
Area: 10745.063
Height: 1960.433
Shaping: 4.348 tick
Position: 2312.25 tick
χ²: 1488.1
Run 6037 event 126 channel 2080 ROI 5
Area: 10893.063
Height: 1964.866
Shaping: 4.354 tick
Position: 2809.25 tick
χ²: 811.8
Run 6037 event 126 channel 2080 ROI 6
Area: 10711.063
Height: 1957.484
Shaping: 4.355 tick
Position: 3306.24 tick
χ²: 2915.1
Run 6037 event 126 channel 2080 ROI 7
Area: 10748.063
Height: 1964.922
Shaping: 4.324 tick
Position: 3803.27 tick
χ²: 1265.6
Run 6037 event 126 channel 2080 ROI 8
Area: 10741.063
Height: 1955.963
Shaping: 4.337 tick
Position: 4300.27 tick
χ²: 497.0
Run 6037 event 126 channel 2080 ROI 9
Area: 10759.063
Height: 1958.078
Shaping: 4.334 tick
Position: 4797.26 tick
χ²: 503.6
Run 6037 event 126 channel 2080 ROI 10
Area: 10794.063
Height: 1964.214
Shaping: 4.336 tick
Position: 5294.26 tick
χ²: 748.8
Run 6037 event 126 channel 2080 ROI 11
Area: 10806.063
Height: 1965.437
Shaping: 4.348 tick
Position: 5791.24 tick
χ²: 691.3
Signal [ADC count]
Tick

A=15

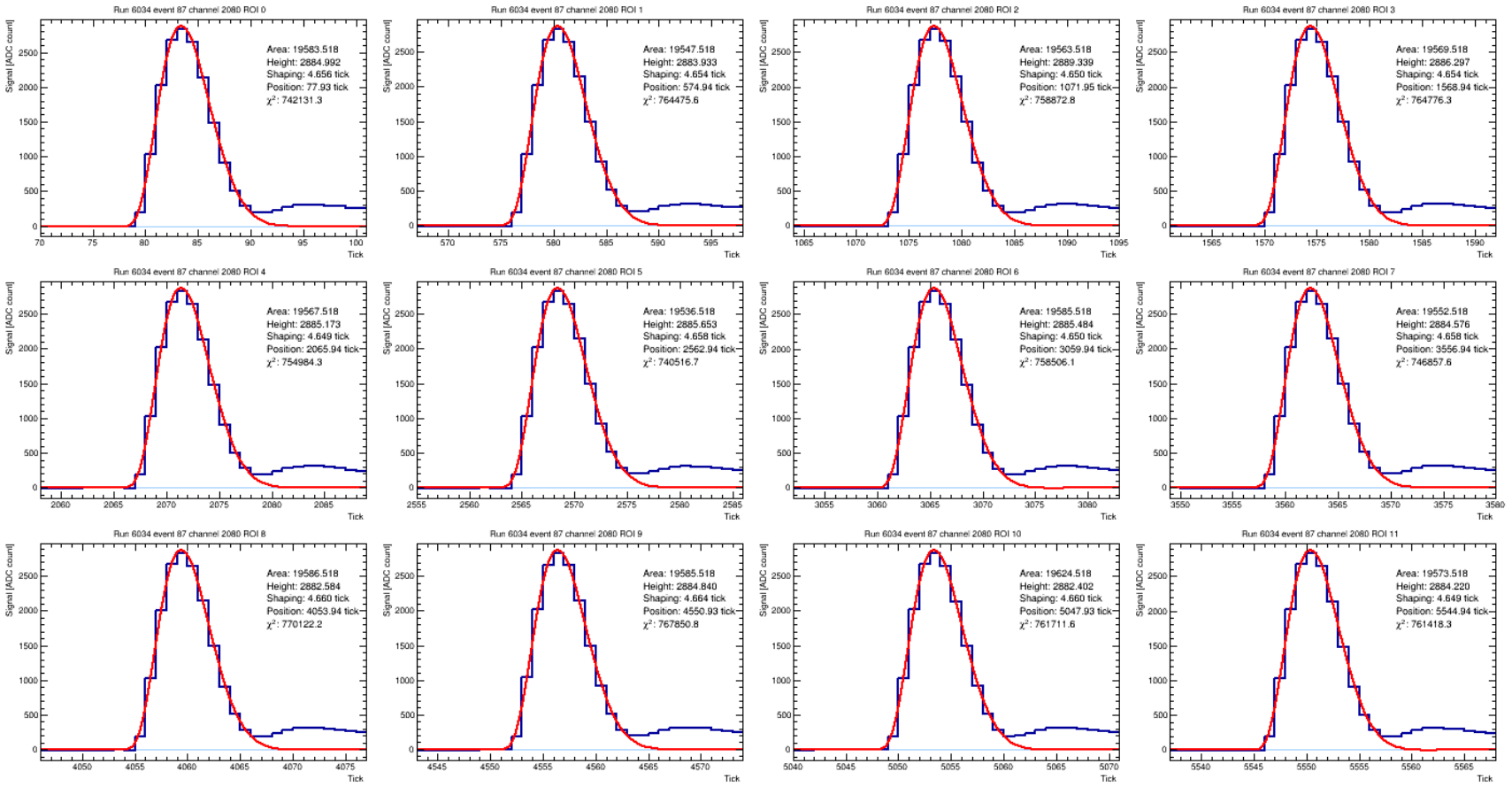

Run 6036 event 23 channel 2080 ROI 0
Area: 13516.639
Height: 2465.405
Shaping: 4.328 tick
Position: 266.27 tick
χ²: 1441.2
Run 6036 event 23 channel 2080 ROI 1
Area: 13604.639
Height: 2469.235
Shaping: 4.324 tick
Position: 763.27 tick
χ²: 1705.6
Run 6036 event 23 channel 2080 ROI 2
Area: 13503.639
Height: 2470.906
Shaping: 4.326 tick
Position: 1260.27 tick
χ²: 1797.3
Run 6036 event 23 channel 2080 ROI 3
Area: 13560.639
Height: 2467.153
Shaping: 4.324 tick
Position: 1757.28 tick
χ²: 945.3
Run 6036 event 23 channel 2080 ROI 4
Area: 13562.639
Height: 2469.727
Shaping: 4.322 tick
Position: 2254.28 tick
χ²: 1460.1
Run 6036 event 23 channel 2080 ROI 5
Area: 13533.639
Height: 2464.185
Shaping: 4.333 tick
Position: 2751.27 tick
χ²: 2036.0
Run 6036 event 23 channel 2080 ROI 6
Area: 13550.639
Height: 2469.882
Shaping: 4.320 tick
Position: 3248.28 tick
χ²: 1893.9
Run 6036 event 23 channel 2080 ROI 7
Area: 13555.639
Height: 2472.446
Shaping: 4.334 tick
Position: 3745.26 tick
χ²: 1572.4
Run 6036 event 23 channel 2080 ROI 8
Area: 13587.639
Height: 2471.831
Shaping: 4.323 tick
Position: 4242.28 tick
χ²: 1143.6
Run 6036 event 23 channel 2080 ROI 9
Area: 13550.639
Height: 2478.456
Shaping: 4.322 tick
Position: 4739.28 tick
χ²: 1362.9
Run 6036 event 23 channel 2080 ROI 10
Area: 13544.639
Height: 2470.185
Shaping: 4.321 tick
Position: 5236.28 tick
χ²: 2006.7
Run 6036 event 23 channel 2080 ROI 11
Area: 13571.639
Height: 2465.472
Shaping: 4.337 tick
Position: 5733.26 tick
χ²: 1381.7
Signal [ADC count]
Tick

A=18



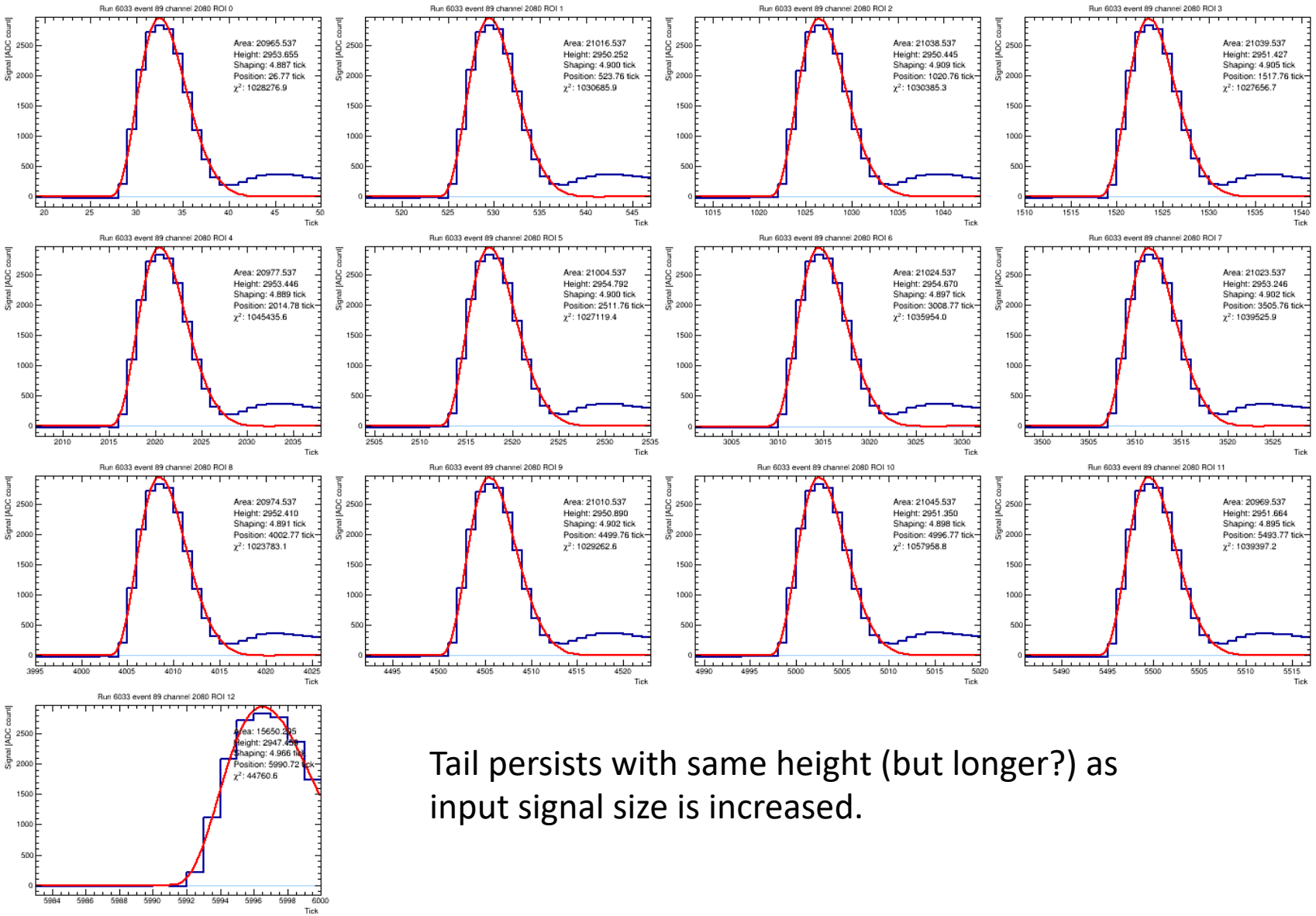
Signals starting to clip, i.e. flatten on top.
Amplifier is starting to saturate.
Data taken with offset of 900 mV.

A=21



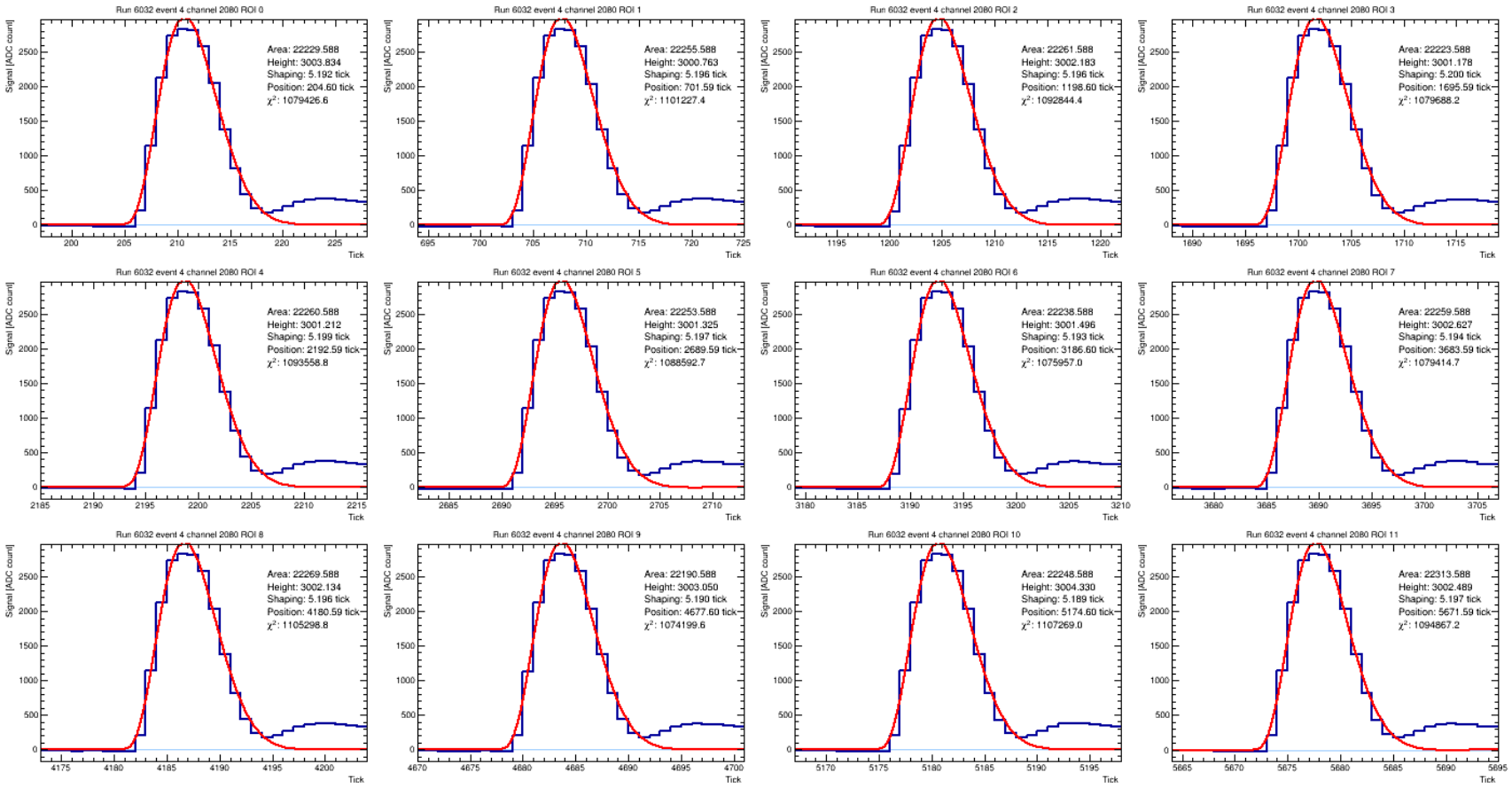
Tail appears at about 120% of saturation.
Height is about 300 ADC counts = 2 MIPs.

A=25



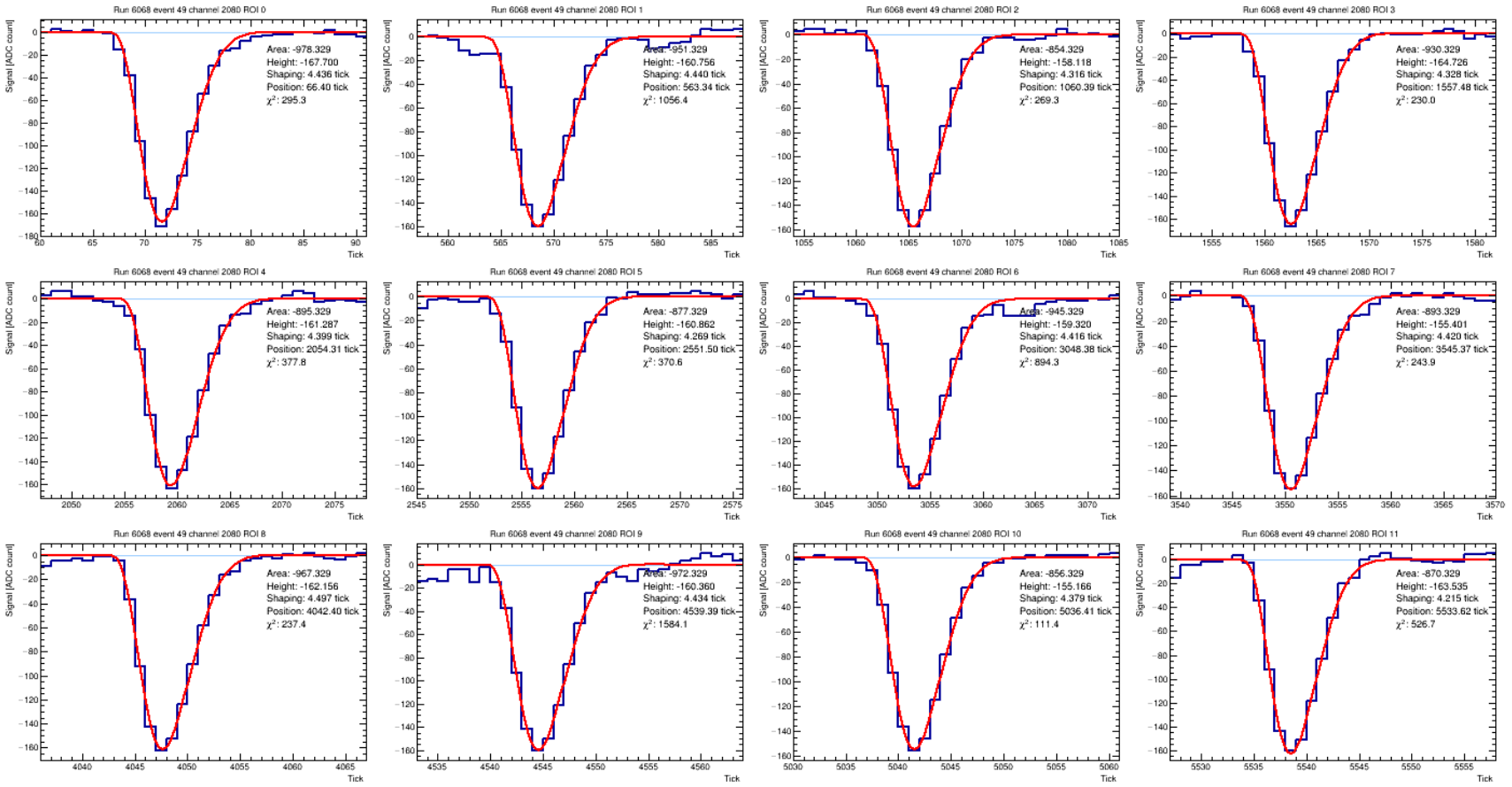
Tail persists with same height (but longer?) as input signal size is increased.

A=30

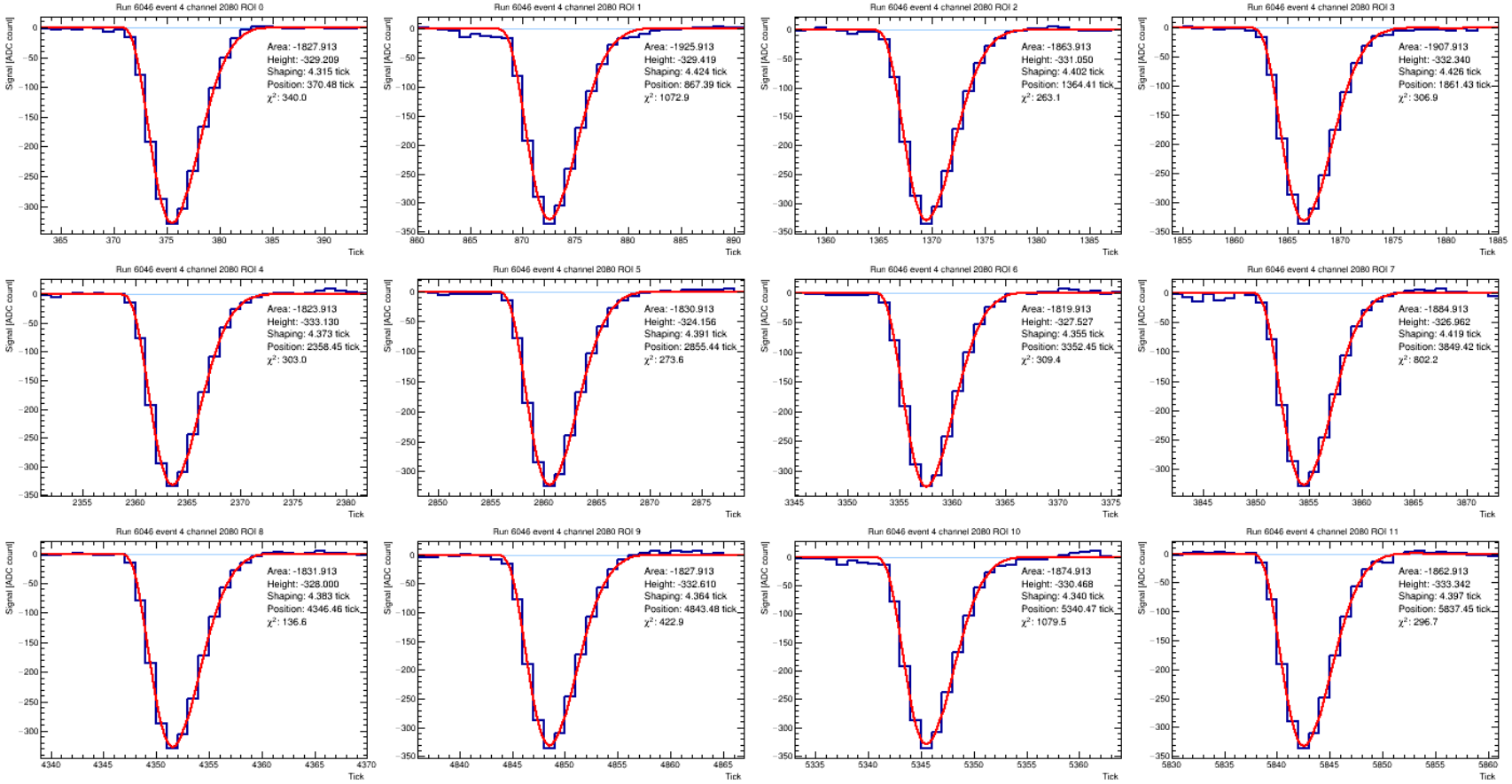

Run 6032 event 4 channel 2080 ROI 0
Area: 22229.588
Height: 3003.834
Shaping: 5.192 tick
Position: 204.60 tick
χ²: 1079426.6
Run 6032 event 4 channel 2080 ROI 1
Area: 22255.588
Height: 3000.763
Shaping: 5.196 tick
Position: 701.59 tick
χ²: 1101227.4
Run 6032 event 4 channel 2080 ROI 2
Area: 22261.588
Height: 3002.183
Shaping: 5.196 tick
Position: 1198.60 tick
χ²: 1092844.4
Run 6032 event 4 channel 2080 ROI 3
Area: 22223.588
Height: 3001.178
Shaping: 5.200 tick
Position: 1695.59 tick
χ²: 1079688.2
Run 6032 event 4 channel 2080 ROI 4
Area: 22260.588
Height: 3001.212
Shaping: 5.199 tick
Position: 2192.59 tick
χ²: 1093558.8
Run 6032 event 4 channel 2080 ROI 5
Area: 22253.588
Height: 3001.325
Shaping: 5.197 tick
Position: 2689.59 tick
χ²: 1088592.7
Run 6032 event 4 channel 2080 ROI 6
Area: 22238.588
Height: 3001.496
Shaping: 5.193 tick
Position: 3186.60 tick
χ²: 1075957.0
Run 6032 event 4 channel 2080 ROI 7
Area: 22259.588
Height: 3002.627
Shaping: 5.194 tick
Position: 3683.59 tick
χ²: 1079414.7
Run 6032 event 4 channel 2080 ROI 8
Area: 22269.588
Height: 3002.134
Shaping: 5.196 tick
Position: 4180.59 tick
χ²: 1105298.8
Run 6032 event 4 channel 2080 ROI 9
Area: 22190.588
Height: 3003.050
Shaping: 5.190 tick
Position: 4677.60 tick
χ²: 1074199.6
Run 6032 event 4 channel 2080 ROI 10
Area: 22248.588
Height: 3004.330
Shaping: 5.189 tick
Position: 5174.60 tick
χ²: 1107269.0
Run 6032 event 4 channel 2080 ROI 11
Area: 22313.588
Height: 3002.489
Shaping: 5.197 tick
Position: 5671.59 tick
χ²: 1094867.2
Signal [ADC count]
Tick

Negative ROI waveforms

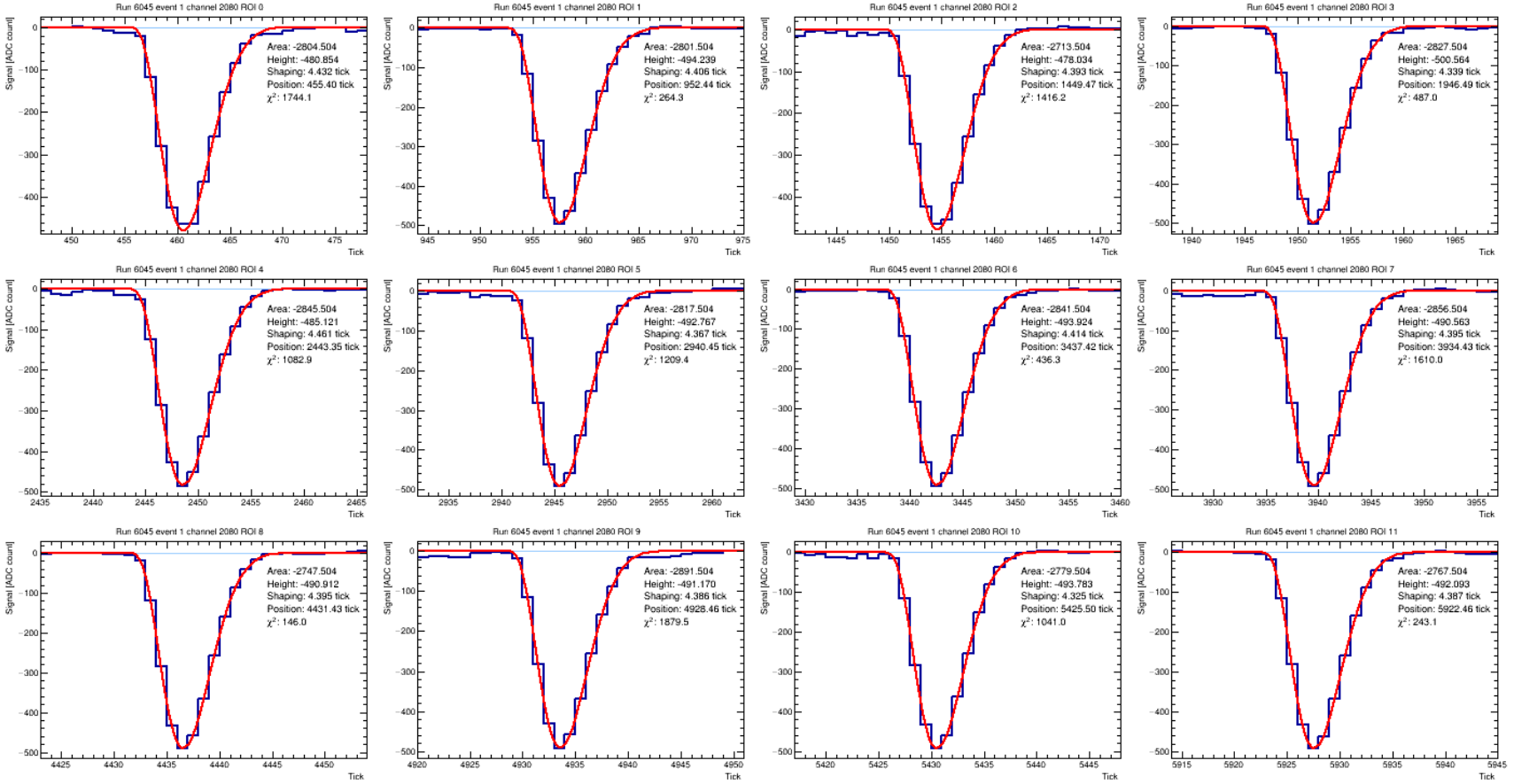
A=-1


Run 6068 event 49 channel 2080 ROI 0
Area: -978.329
Height: -167.700
Shaping: 4.436 tick
Position: 66.40 tick
χ²: 295.3
Run 6068 event 49 channel 2080 ROI 1
Area: -951.329
Height: -160.756
Shaping: 4.440 tick
Position: 563.34 tick
χ²: 1056.4
Run 6068 event 49 channel 2080 ROI 2
Area: -854.329
Height: -158.118
Shaping: 4.316 tick
Position: 1060.39 tick
χ²: 269.3
Run 6068 event 49 channel 2080 ROI 3
Area: -930.329
Height: -164.726
Shaping: 4.328 tick
Position: 1557.48 tick
χ²: 230.0
Run 6068 event 49 channel 2080 ROI 4
Area: -895.329
Height: -161.287
Shaping: 4.399 tick
Position: 2054.31 tick
χ²: 377.8
Run 6068 event 49 channel 2080 ROI 5
Area: -877.329
Height: -160.862
Shaping: 4.269 tick
Position: 2551.50 tick
χ²: 370.6
Run 6068 event 49 channel 2080 ROI 6
Area: -945.329
Height: -159.320
Shaping: 4.416 tick
Position: 3048.38 tick
χ²: 894.3
Run 6068 event 49 channel 2080 ROI 7
Area: -893.329
Height: -155.401
Shaping: 4.420 tick
Position: 3545.37 tick
χ²: 243.9
Run 6068 event 49 channel 2080 ROI 8
Area: -967.329
Height: -162.156
Shaping: 4.497 tick
Position: 4042.40 tick
χ²: 237.4
Run 6068 event 49 channel 2080 ROI 9
Area: -972.329
Height: -160.360
Shaping: 4.434 tick
Position: 4539.39 tick
χ²: 1584.1
Run 6068 event 49 channel 2080 ROI 10
Area: -856.329
Height: -155.166
Shaping: 4.379 tick
Position: 5036.41 tick
χ²: 111.4
Run 6068 event 49 channel 2080 ROI 11
Area: -870.329
Height: -163.535
Shaping: 4.215 tick
Position: 5533.62 tick
χ²: 526.7
Signal [ADC count]
Tick

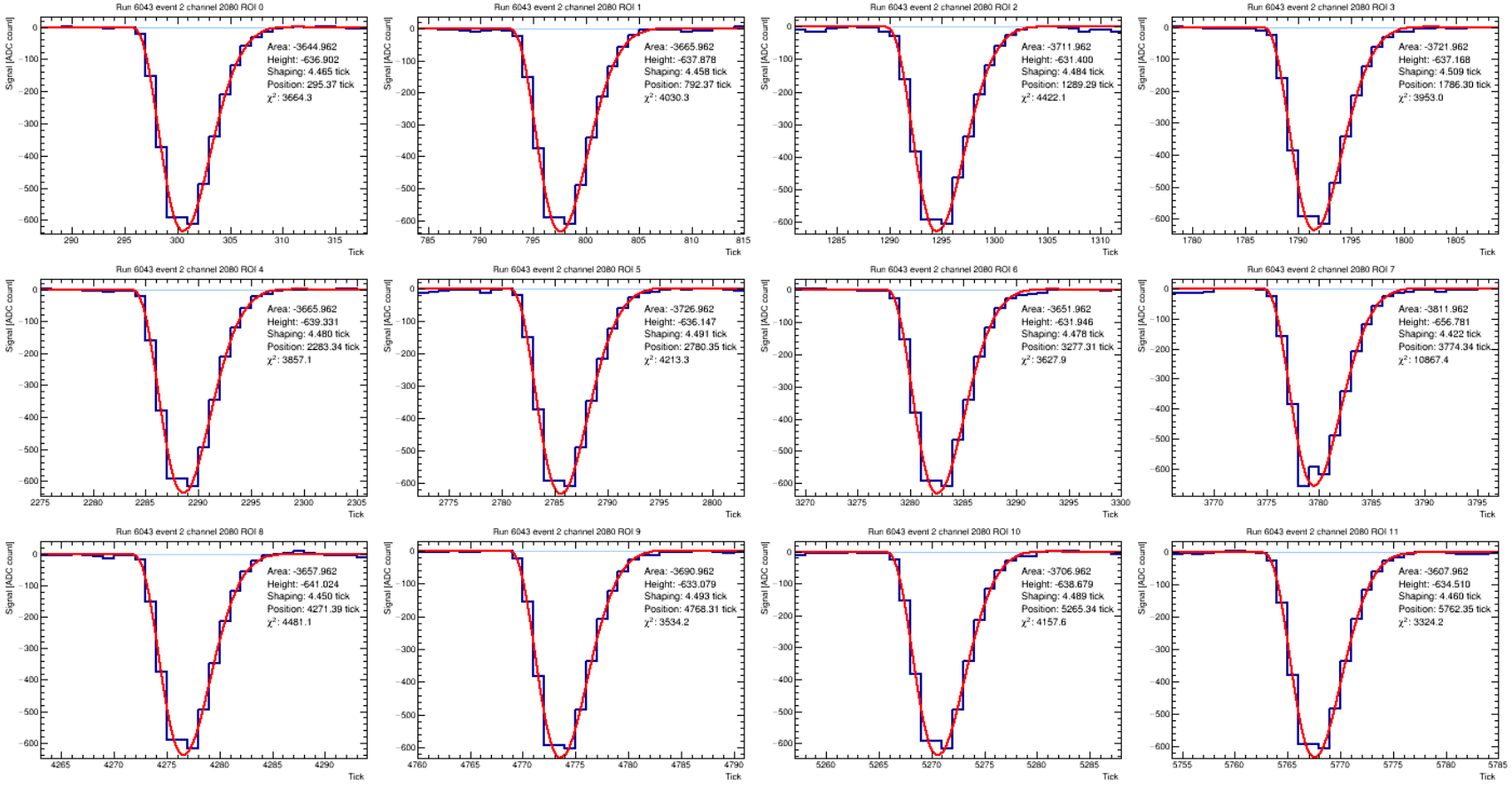
A=-2


Run 6046 event 4 channel 2080 ROI 0
Area: -1827.913
Height: -329.209
Shaping: 4.315 tick
Position: 370.48 tick
χ²: 340.0
Run 6046 event 4 channel 2080 ROI 1
Area: -1925.913
Height: -329.419
Shaping: 4.424 tick
Position: 867.39 tick
χ²: 1072.9
Run 6046 event 4 channel 2080 ROI 2
Area: -1863.913
Height: -331.050
Shaping: 4.402 tick
Position: 1364.41 tick
χ²: 263.1
Run 6046 event 4 channel 2080 ROI 3
Area: -1907.913
Height: -332.340
Shaping: 4.426 tick
Position: 1861.43 tick
χ²: 306.9
Run 6046 event 4 channel 2080 ROI 4
Area: -1823.913
Height: -333.130
Shaping: 4.373 tick
Position: 2358.45 tick
χ²: 303.0
Run 6046 event 4 channel 2080 ROI 5
Area: -1830.913
Height: -324.156
Shaping: 4.391 tick
Position: 2855.44 tick
χ²: 273.6
Run 6046 event 4 channel 2080 ROI 6
Area: -1819.913
Height: -327.527
Shaping: 4.355 tick
Position: 3352.45 tick
χ²: 309.4
Run 6046 event 4 channel 2080 ROI 7
Area: -1884.913
Height: -326.962
Shaping: 4.419 tick
Position: 3849.42 tick
χ²: 802.2
Run 6046 event 4 channel 2080 ROI 8
Area: -1831.913
Height: -328.000
Shaping: 4.383 tick
Position: 4346.46 tick
χ²: 136.6
Run 6046 event 4 channel 2080 ROI 9
Area: -1827.913
Height: -332.610
Shaping: 4.364 tick
Position: 4843.48 tick
χ²: 422.9
Run 6046 event 4 channel 2080 ROI 10
Area: -1874.913
Height: -330.468
Shaping: 4.340 tick
Position: 5340.47 tick
χ²: 1079.5
Run 6046 event 4 channel 2080 ROI 11
Area: -1862.913
Height: -333.342
Shaping: 4.397 tick
Position: 5837.45 tick
χ²: 296.7
Signal [ADC count]
Tick

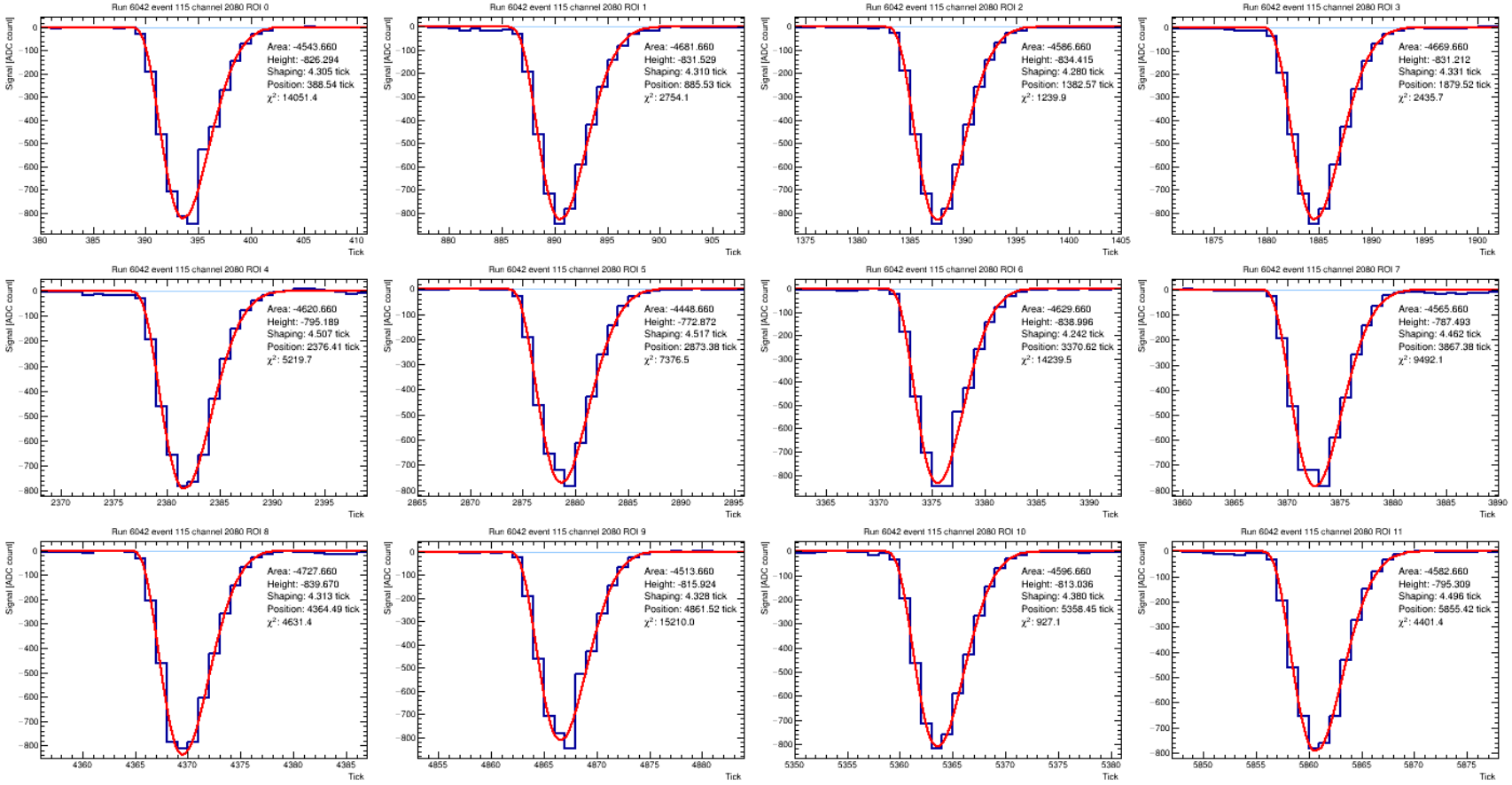
A=-3


Run 6045 event 1 channel 2080 ROI 0
Area: -2804.504
Height: -480.854
Shaping: 4.432 tick
Position: 455.40 tick
χ²: 1744.1
Run 6045 event 1 channel 2080 ROI 1
Area: -2801.504
Height: -494.239
Shaping: 4.406 tick
Position: 952.44 tick
χ²: 264.3
Run 6045 event 1 channel 2080 ROI 2
Area: -2713.504
Height: -478.034
Shaping: 4.393 tick
Position: 1449.47 tick
χ²: 1416.2
Run 6045 event 1 channel 2080 ROI 3
Area: -2827.504
Height: -500.564
Shaping: 4.339 tick
Position: 1946.49 tick
χ²: 487.0
Run 6045 event 1 channel 2080 ROI 4
Area: -2845.504
Height: -485.121
Shaping: 4.461 tick
Position: 2443.35 tick
χ²: 1082.9
Run 6045 event 1 channel 2080 ROI 5
Area: -2817.504
Height: -492.767
Shaping: 4.367 tick
Position: 2940.45 tick
χ²: 1209.4
Run 6045 event 1 channel 2080 ROI 6
Area: -2841.504
Height: -493.924
Shaping: 4.414 tick
Position: 3437.42 tick
χ²: 436.3
Run 6045 event 1 channel 2080 ROI 7
Area: -2856.504
Height: -490.563
Shaping: 4.395 tick
Position: 3934.43 tick
χ²: 1610.0
Run 6045 event 1 channel 2080 ROI 8
Area: -2747.504
Height: -490.912
Shaping: 4.395 tick
Position: 4431.43 tick
χ²: 146.0
Run 6045 event 1 channel 2080 ROI 9
Area: -2891.504
Height: -491.170
Shaping: 4.386 tick
Position: 4928.46 tick
χ²: 1879.5
Run 6045 event 1 channel 2080 ROI 10
Area: -2779.504
Height: -493.783
Shaping: 4.325 tick
Position: 5425.50 tick
χ²: 1041.0
Run 6045 event 1 channel 2080 ROI 11
Area: -2767.504
Height: -492.093
Shaping: 4.387 tick
Position: 5922.46 tick
χ²: 243.1
Signal [ADC count]
Tick

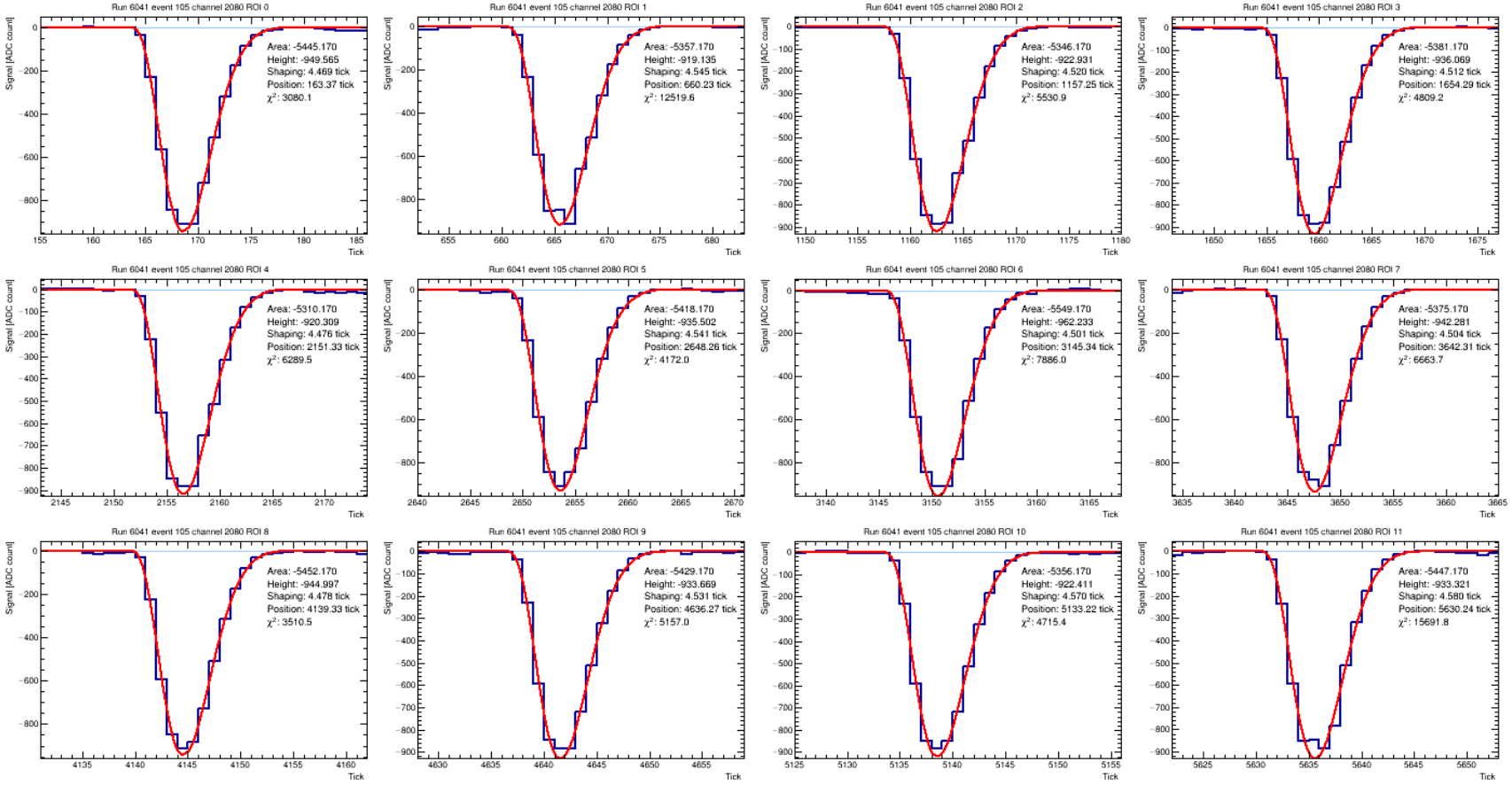
A=-4


Run 6043 event 2 channel 2080 ROI 0
Area: -3644.962
Height: -636.902
Shaping: 4.465 tick
Position: 295.37 tick
χ²: 3664.3
Run 6043 event 2 channel 2080 ROI 1
Area: -3665.962
Height: -637.878
Shaping: 4.458 tick
Position: 792.37 tick
χ²: 4030.3
Run 6043 event 2 channel 2080 ROI 2
Area: -3711.962
Height: -631.400
Shaping: 4.484 tick
Position: 1289.29 tick
χ²: 4422.1
Run 6043 event 2 channel 2080 ROI 3
Area: -3721.962
Height: -637.168
Shaping: 4.509 tick
Position: 1786.30 tick
χ²: 3953.0
Run 6043 event 2 channel 2080 ROI 4
Area: -3665.962
Height: -639.331
Shaping: 4.480 tick
Position: 2283.34 tick
χ²: 3857.1
Run 6043 event 2 channel 2080 ROI 5
Area: -3726.962
Height: -636.147
Shaping: 4.491 tick
Position: 2780.35 tick
χ²: 4213.3
Run 6043 event 2 channel 2080 ROI 6
Area: -3651.962
Height: -631.946
Shaping: 4.478 tick
Position: 3277.31 tick
χ²: 3627.9
Run 6043 event 2 channel 2080 ROI 7
Area: -3811.962
Height: -656.781
Shaping: 4.422 tick
Position: 3774.34 tick
χ²: 10867.4
Run 6043 event 2 channel 2080 ROI 8
Area: -3657.962
Height: -641.024
Shaping: 4.450 tick
Position: 4271.39 tick
χ²: 4481.1
Run 6043 event 2 channel 2080 ROI 9
Area: -3690.962
Height: -633.079
Shaping: 4.493 tick
Position: 4768.31 tick
χ²: 3534.2
Run 6043 event 2 channel 2080 ROI 10
Area: -3706.962
Height: -638.679
Shaping: 4.489 tick
Position: 5265.34 tick
χ²: 4157.6
Run 6043 event 2 channel 2080 ROI 11
Area: -3607.962
Height: -634.510
Shaping: 4.460 tick
Position: 5762.35 tick
χ²: 3324.2
Signal [ADC count]
Tick

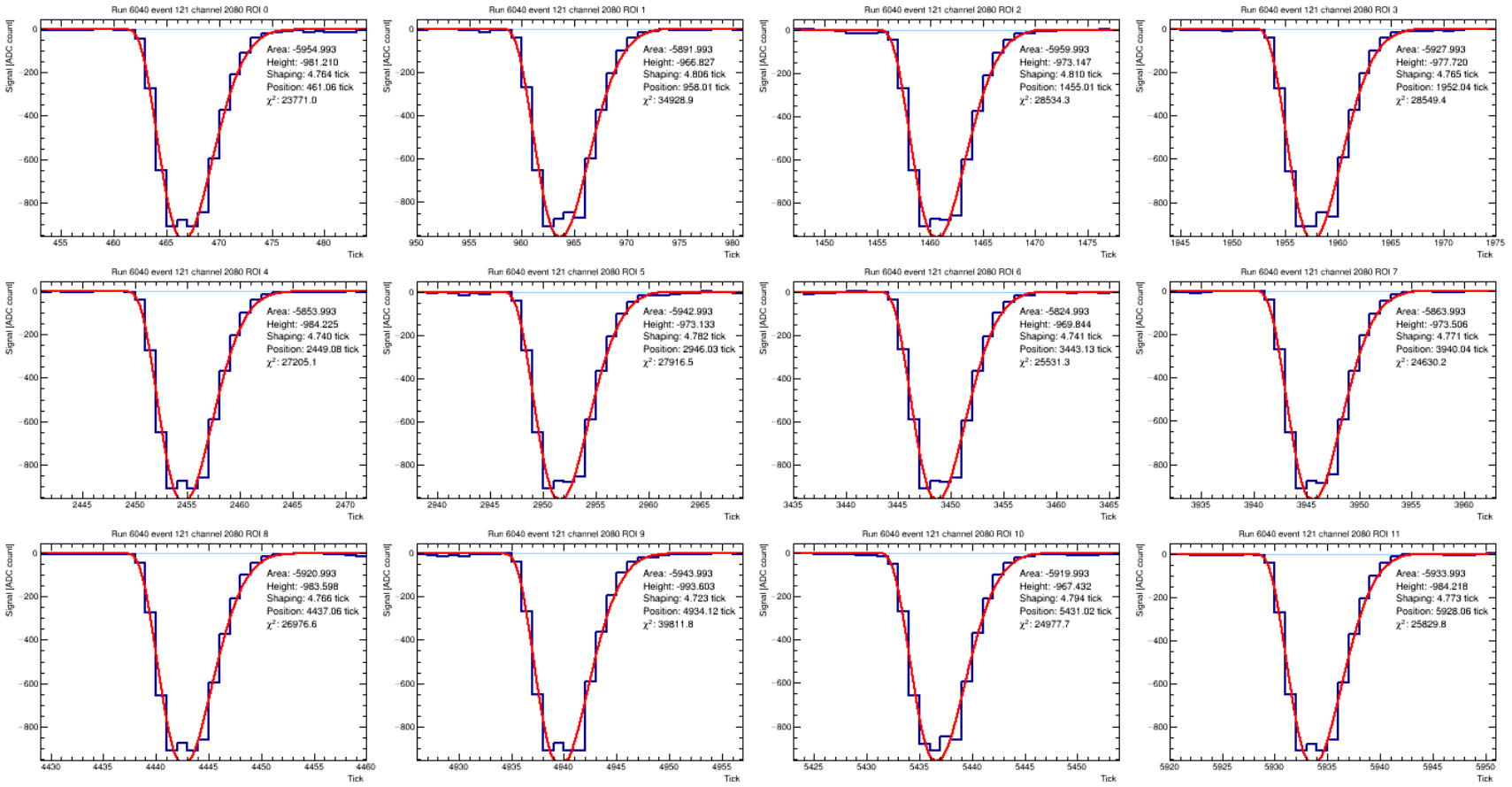
A=-5


Run 6042 event 115 channel 2080 ROI 0
Area: -4543.660
Height: -826.294
Shaping: 4.305 tick
Position: 388.54 tick
χ²: 14051.4
Run 6042 event 115 channel 2080 ROI 1
Area: -4681.660
Height: -831.529
Shaping: 4.310 tick
Position: 885.53 tick
χ²: 2754.1
Run 6042 event 115 channel 2080 ROI 2
Area: -4586.660
Height: -834.415
Shaping: 4.280 tick
Position: 1382.57 tick
χ²: 1239.9
Run 6042 event 115 channel 2080 ROI 3
Area: -4669.660
Height: -831.212
Shaping: 4.331 tick
Position: 1879.52 tick
χ²: 2435.7
Run 6042 event 115 channel 2080 ROI 4
Area: -4620.660
Height: -795.189
Shaping: 4.507 tick
Position: 2376.41 tick
χ²: 5219.7
Run 6042 event 115 channel 2080 ROI 5
Area: -4448.660
Height: -772.872
Shaping: 4.517 tick
Position: 2873.38 tick
χ²: 7376.5
Run 6042 event 115 channel 2080 ROI 6
Area: -4629.660
Height: -838.996
Shaping: 4.242 tick
Position: 3370.62 tick
χ²: 14239.5
Run 6042 event 115 channel 2080 ROI 7
Area: -4565.660
Height: -787.493
Shaping: 4.462 tick
Position: 3867.38 tick
χ²: 9492.1
Run 6042 event 115 channel 2080 ROI 8
Area: -4727.660
Height: -839.670
Shaping: 4.313 tick
Position: 4364.49 tick
χ²: 4631.4
Run 6042 event 115 channel 2080 ROI 9
Area: -4513.660
Height: -815.924
Shaping: 4.328 tick
Position: 4861.52 tick
χ²: 15210.0
Run 6042 event 115 channel 2080 ROI 10
Area: -4596.660
Height: -813.036
Shaping: 4.380 tick
Position: 5358.45 tick
χ²: 927.1
Run 6042 event 115 channel 2080 ROI 11
Area: -4582.660
Height: -795.309
Shaping: 4.496 tick
Position: 5855.42 tick
χ²: 4401.4
Signal [ADC count]
Tick

A=-6

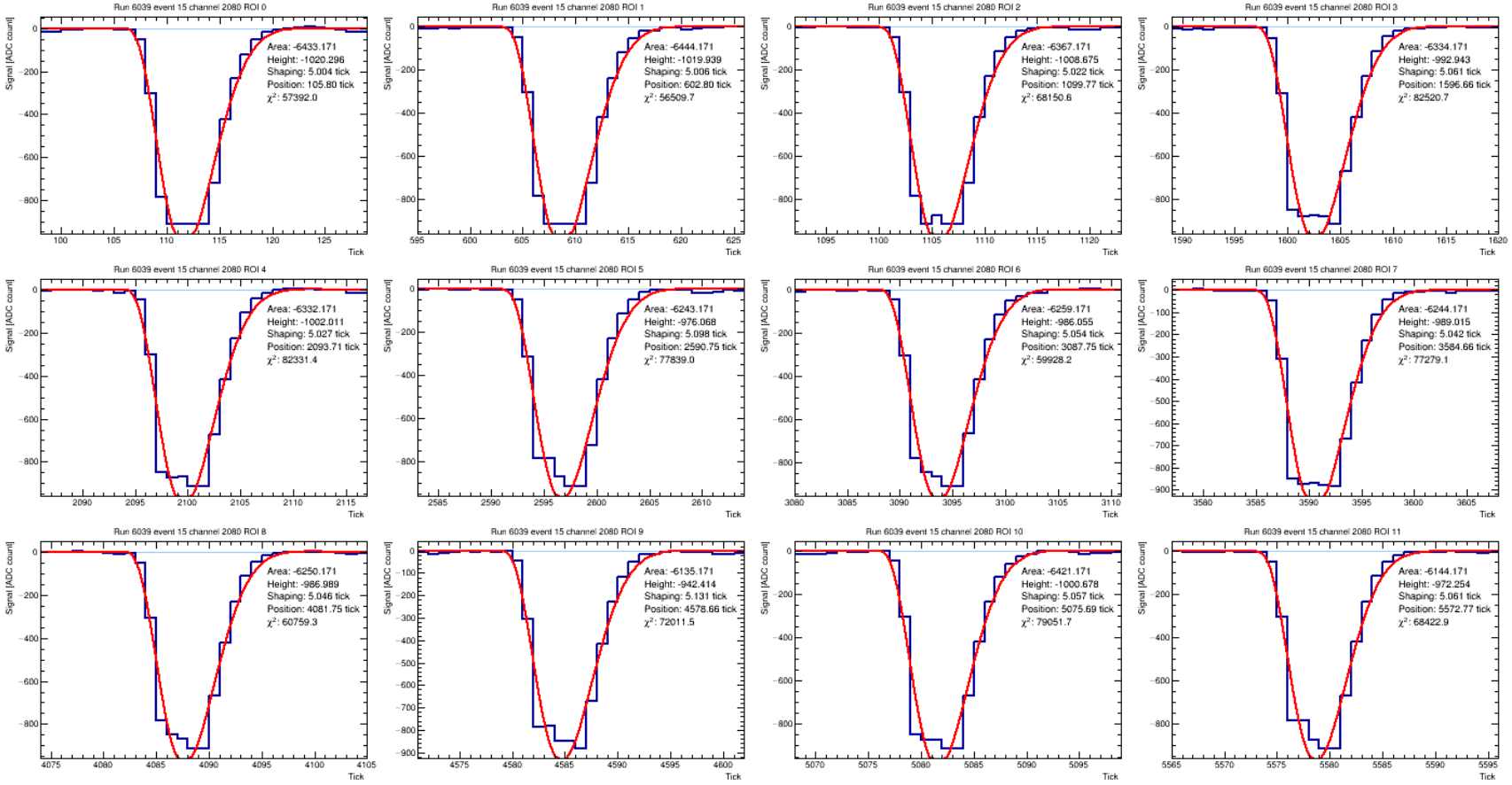

Run 6041 event 105 channel 2080 ROI 0
Area: -5445.170
Height: -949.565
Shaping: 4.469 tick
Position: 163.37 tick
χ²: 3080.1
Run 6041 event 105 channel 2080 ROI 1
Area: -5357.170
Height: -919.135
Shaping: 4.545 tick
Position: 660.23 tick
χ²: 12519.6
Run 6041 event 105 channel 2080 ROI 2
Area: -5346.170
Height: -922.931
Shaping: 4.520 tick
Position: 1157.25 tick
χ²: 5530.9
Run 6041 event 105 channel 2080 ROI 3
Area: -5381.170
Height: -936.069
Shaping: 4.512 tick
Position: 1654.29 tick
χ²: 4809.2
Run 6041 event 105 channel 2080 ROI 4
Area: -5310.170
Height: -920.309
Shaping: 4.476 tick
Position: 2151.33 tick
χ²: 6289.5
Run 6041 event 105 channel 2080 ROI 5
Area: -5418.170
Height: -935.502
Shaping: 4.541 tick
Position: 2648.26 tick
χ²: 4172.0
Run 6041 event 105 channel 2080 ROI 6
Area: -5549.170
Height: -962.233
Shaping: 4.501 tick
Position: 3145.34 tick
χ²: 7886.0
Run 6041 event 105 channel 2080 ROI 7
Area: -5375.170
Height: -942.281
Shaping: 4.504 tick
Position: 3642.31 tick
χ²: 6663.7
Run 6041 event 105 channel 2080 ROI 8
Area: -5452.170
Height: -944.997
Shaping: 4.478 tick
Position: 4139.33 tick
χ²: 3510.5
Run 6041 event 105 channel 2080 ROI 9
Area: -5429.170
Height: -933.669
Shaping: 4.531 tick
Position: 4636.27 tick
χ²: 5157.0
Run 6041 event 105 channel 2080 ROI 10
Area: -5356.170
Height: -922.411
Shaping: 4.570 tick
Position: 5133.22 tick
χ²: 4715.4
Run 6041 event 105 channel 2080 ROI 11
Area: -5447.170
Height: -933.321
Shaping: 4.580 tick
Position: 5630.24 tick
χ²: 15691.8
Signal [ADC count]
Tick

A=-7

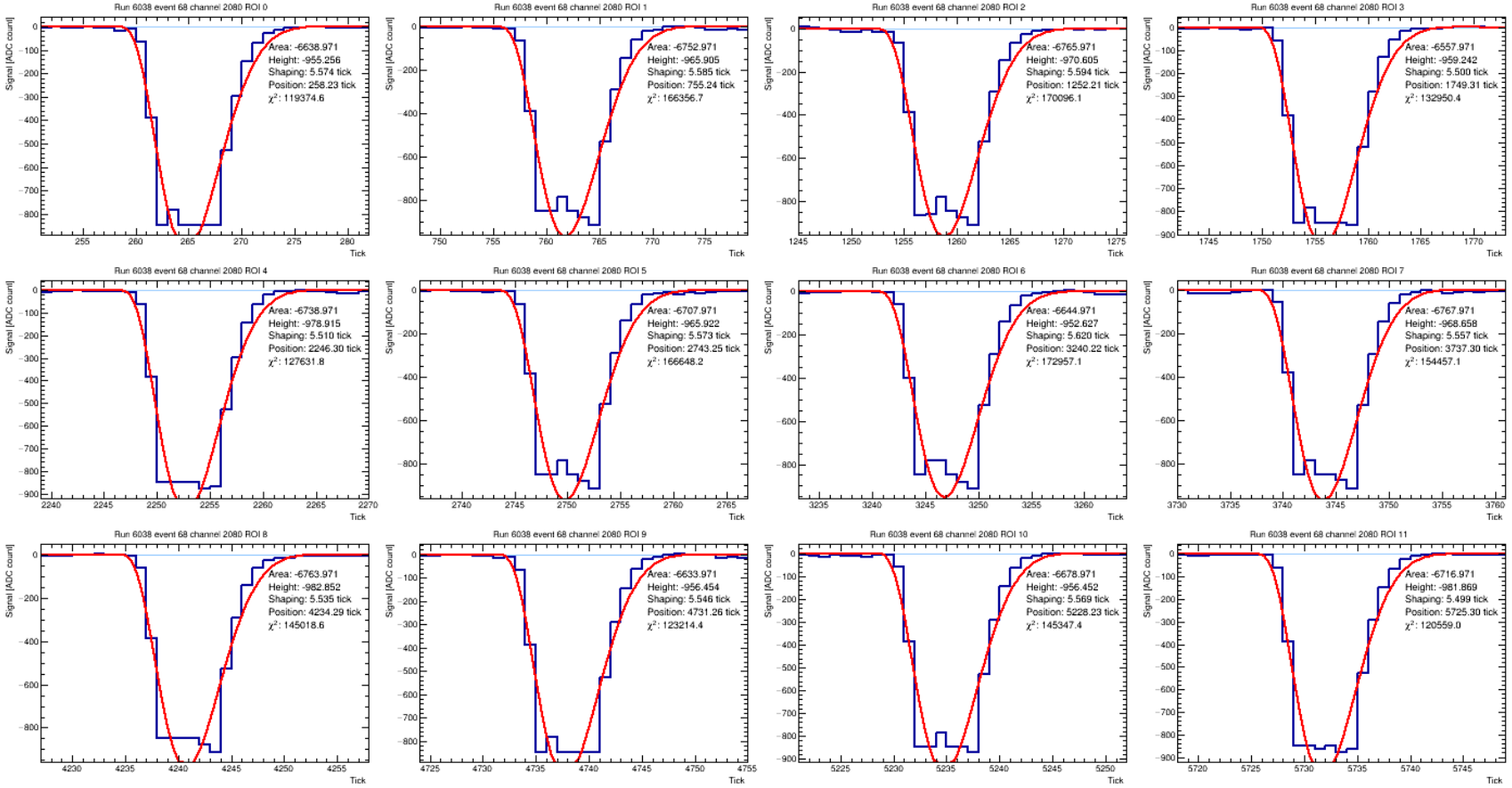


Signals starting to clip.
This is ADC rather than amplifier saturation.

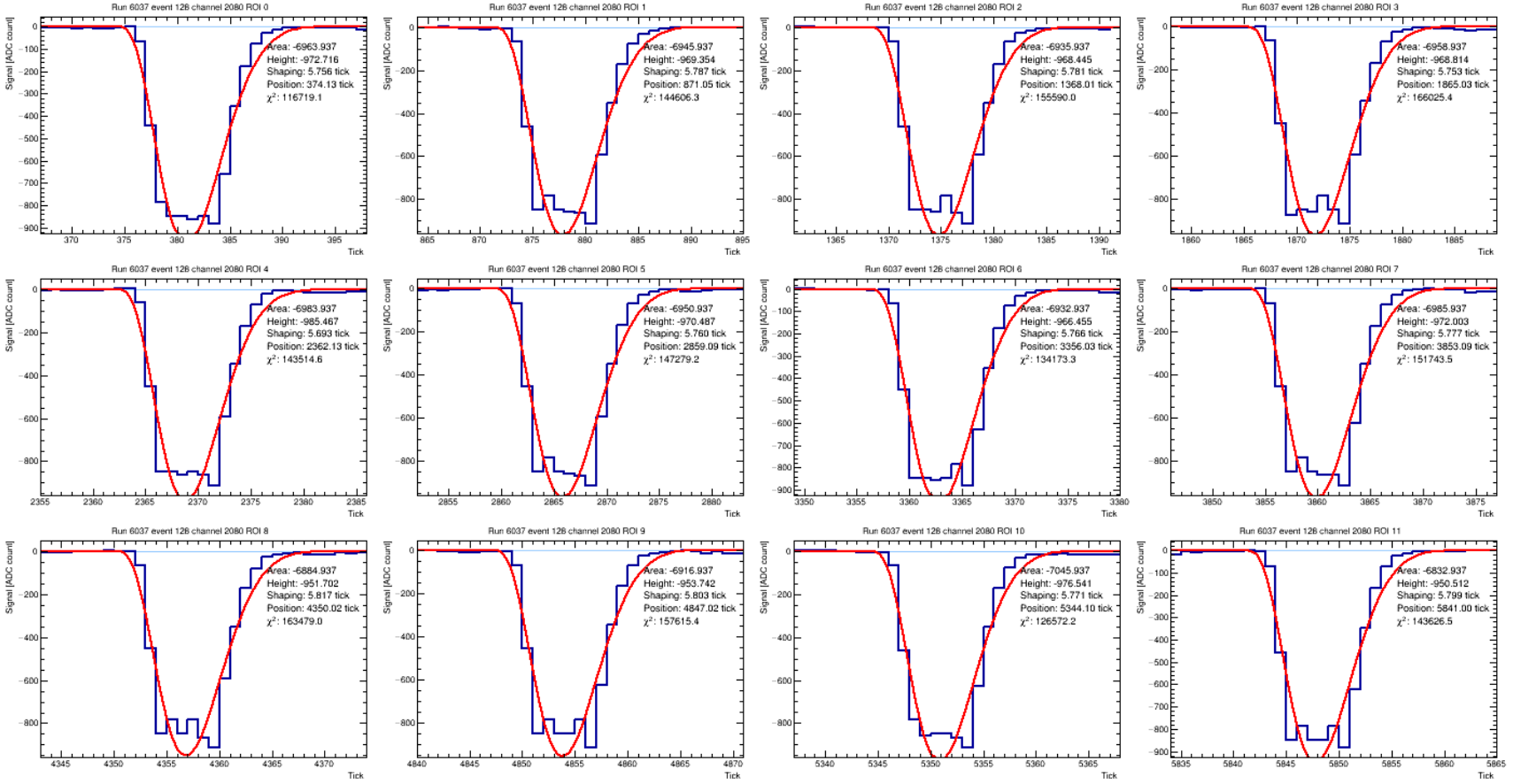
A=-8


Run 6039 event 15 channel 2080 ROI 0
Area: -6433.171
Height: -1020.296
Shaping: 5.004 tick
Position: 105.80 tick
χ²: 57392.0
Run 6039 event 15 channel 2080 ROI 1
Area: -6444.171
Height: -1019.939
Shaping: 5.006 tick
Position: 602.80 tick
χ²: 56509.7
Run 6039 event 15 channel 2080 ROI 2
Area: -6367.171
Height: -1008.675
Shaping: 5.022 tick
Position: 1099.77 tick
χ²: 68150.6
Run 6039 event 15 channel 2080 ROI 3
Area: -6334.171
Height: -992.943
Shaping: 5.061 tick
Position: 1596.66 tick
χ²: 82520.7
Run 6039 event 15 channel 2080 ROI 4
Area: -6332.171
Height: -1002.011
Shaping: 5.027 tick
Position: 2093.71 tick
χ²: 82331.4
Run 6039 event 15 channel 2080 ROI 5
Area: -6243.171
Height: -976.068
Shaping: 5.098 tick
Position: 2590.75 tick
χ²: 77839.0
Run 6039 event 15 channel 2080 ROI 6
Area: -6259.171
Height: -986.055
Shaping: 5.054 tick
Position: 3087.75 tick
χ²: 59928.2
Run 6039 event 15 channel 2080 ROI 7
Area: -6244.171
Height: -989.015
Shaping: 5.042 tick
Position: 3584.66 tick
χ²: 77279.1
Run 6039 event 15 channel 2080 ROI 8
Area: -6250.171
Height: -986.989
Shaping: 5.046 tick
Position: 4081.75 tick
χ²: 60759.3
Run 6039 event 15 channel 2080 ROI 9
Area: -6135.171
Height: -942.414
Shaping: 5.131 tick
Position: 4578.66 tick
χ²: 72011.5
Run 6039 event 15 channel 2080 ROI 10
Area: -6421.171
Height: -1000.678
Shaping: 5.057 tick
Position: 5075.69 tick
χ²: 79051.7
Run 6039 event 15 channel 2080 ROI 11
Area: -6144.171
Height: -972.254
Shaping: 5.061 tick
Position: 5572.77 tick
χ²: 68422.9
Signal [ADC count]
Tick

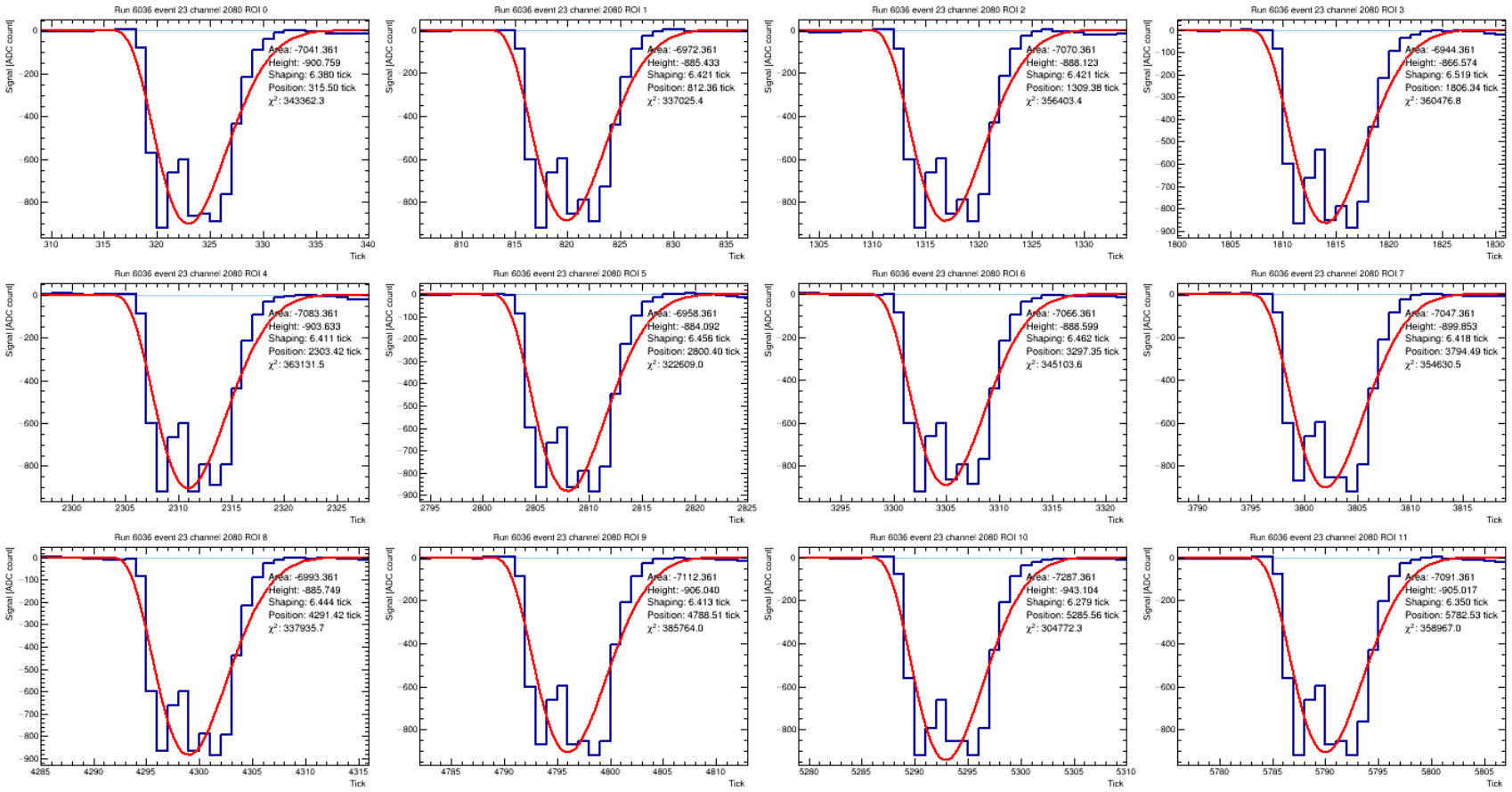
A=-10


Run 6038 event 68 channel 2080 ROI 0
Area: -6638.971
Height: -955.256
Shaping: 5.574 tick
Position: 258.23 tick
χ²: 119374.6
Run 6038 event 68 channel 2080 ROI 1
Area: -6752.971
Height: -965.905
Shaping: 5.585 tick
Position: 755.24 tick
χ²: 166356.7
Run 6038 event 68 channel 2080 ROI 2
Area: -6765.971
Height: -970.605
Shaping: 5.594 tick
Position: 1252.21 tick
χ²: 170096.1
Run 6038 event 68 channel 2080 ROI 3
Area: -6557.971
Height: -959.242
Shaping: 5.500 tick
Position: 1749.31 tick
χ²: 132950.4
Run 6038 event 68 channel 2080 ROI 4
Area: -6738.971
Height: -978.915
Shaping: 5.510 tick
Position: 2246.30 tick
χ²: 127631.8
Run 6038 event 68 channel 2080 ROI 5
Area: -6707.971
Height: -965.922
Shaping: 5.573 tick
Position: 2743.25 tick
χ²: 166648.2
Run 6038 event 68 channel 2080 ROI 6
Area: -6644.971
Height: -952.627
Shaping: 5.620 tick
Position: 3240.22 tick
χ²: 172957.1
Run 6038 event 68 channel 2080 ROI 7
Area: -6767.971
Height: -968.658
Shaping: 5.557 tick
Position: 3737.30 tick
χ²: 154457.1
Run 6038 event 68 channel 2080 ROI 8
Area: -6763.971
Height: -982.852
Shaping: 5.535 tick
Position: 4234.29 tick
χ²: 145018.6
Run 6038 event 68 channel 2080 ROI 9
Area: -6633.971
Height: -956.454
Shaping: 5.546 tick
Position: 4731.26 tick
χ²: 123214.4
Run 6038 event 68 channel 2080 ROI 10
Area: -6678.971
Height: -956.452
Shaping: 5.569 tick
Position: 5228.23 tick
χ²: 145347.4
Run 6038 event 68 channel 2080 ROI 11
Area: -6716.971
Height: -981.869
Shaping: 5.499 tick
Position: 5725.30 tick
χ²: 120559.0
Signal [ADC count]
Tick

A=-12

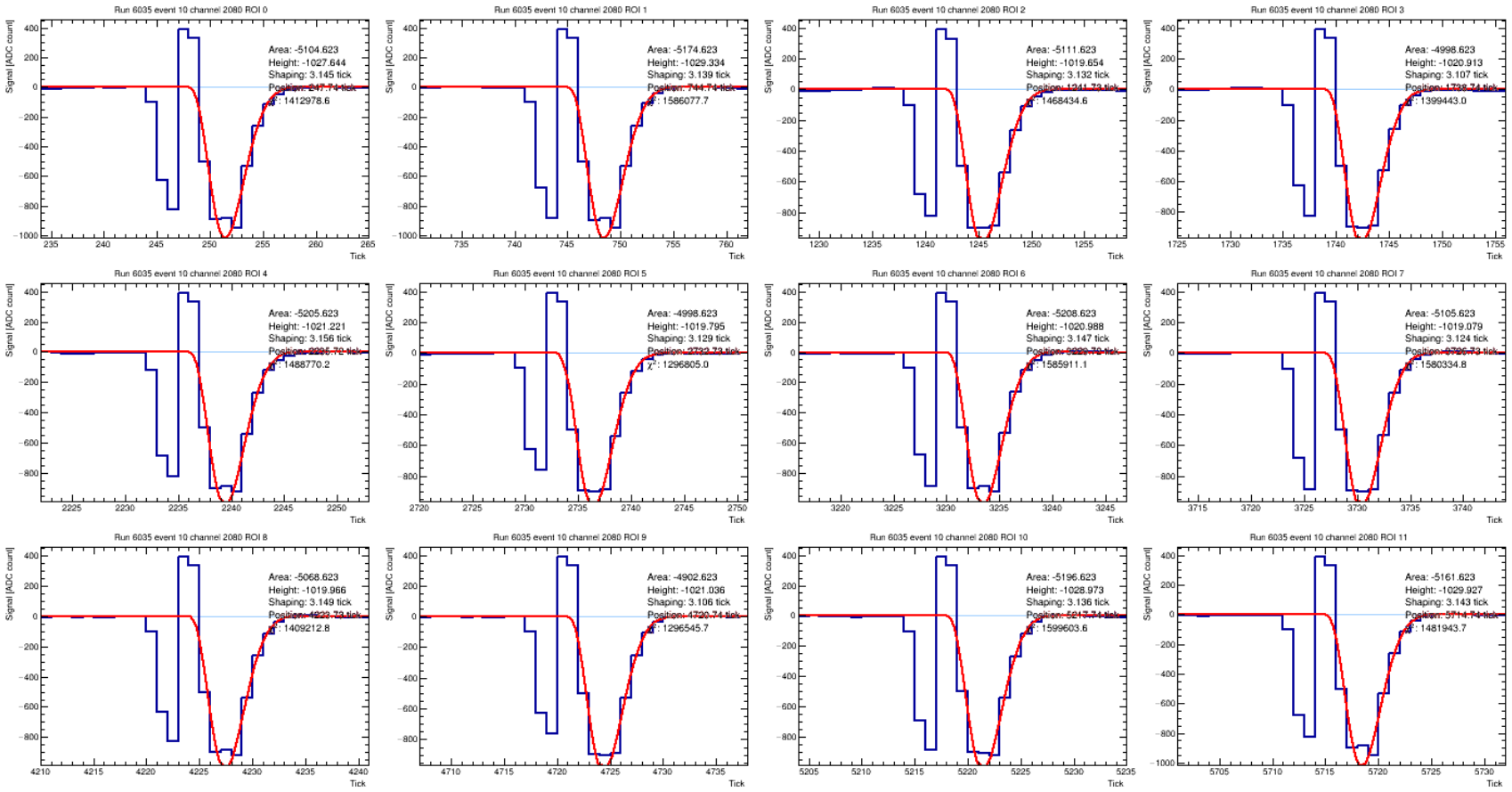

Run 6037 event 126 channel 2080 ROI 0
Area: -6963.937
Height: -972.716
Shaping: 5.756 tick
Position: 374.13 tick
χ²: 116719.1
Run 6037 event 126 channel 2080 ROI 1
Area: -6945.937
Height: -969.354
Shaping: 5.787 tick
Position: 871.05 tick
χ²: 144606.3
Run 6037 event 126 channel 2080 ROI 2
Area: -6935.937
Height: -968.445
Shaping: 5.781 tick
Position: 1368.01 tick
χ²: 155590.0
Run 6037 event 126 channel 2080 ROI 3
Area: -6958.937
Height: -968.814
Shaping: 5.753 tick
Position: 1865.03 tick
χ²: 166025.4
Run 6037 event 126 channel 2080 ROI 4
Area: -6983.937
Height: -985.467
Shaping: 5.693 tick
Position: 2362.13 tick
χ²: 143514.6
Run 6037 event 126 channel 2080 ROI 5
Area: -6950.937
Height: -970.487
Shaping: 5.760 tick
Position: 2859.09 tick
χ²: 147279.2
Run 6037 event 126 channel 2080 ROI 6
Area: -6932.937
Height: -966.455
Shaping: 5.766 tick
Position: 3356.03 tick
χ²: 134173.3
Run 6037 event 126 channel 2080 ROI 7
Area: -6985.937
Height: -972.003
Shaping: 5.777 tick
Position: 3853.09 tick
χ²: 151743.5
Run 6037 event 126 channel 2080 ROI 8
Area: -6884.937
Height: -951.702
Shaping: 5.817 tick
Position: 4350.02 tick
χ²: 163479.0
Run 6037 event 126 channel 2080 ROI 9
Area: -6916.937
Height: -953.742
Shaping: 5.803 tick
Position: 4847.02 tick
χ²: 157615.4
Run 6037 event 126 channel 2080 ROI 10
Area: -7045.937
Height: -976.541
Shaping: 5.771 tick
Position: 5344.10 tick
χ²: 126572.2
Run 6037 event 126 channel 2080 ROI 11
Area: -6832.937
Height: -950.512
Shaping: 5.799 tick
Position: 5841.00 tick
χ²: 143626.5
Signal [ADC count]
Tick

A=-15



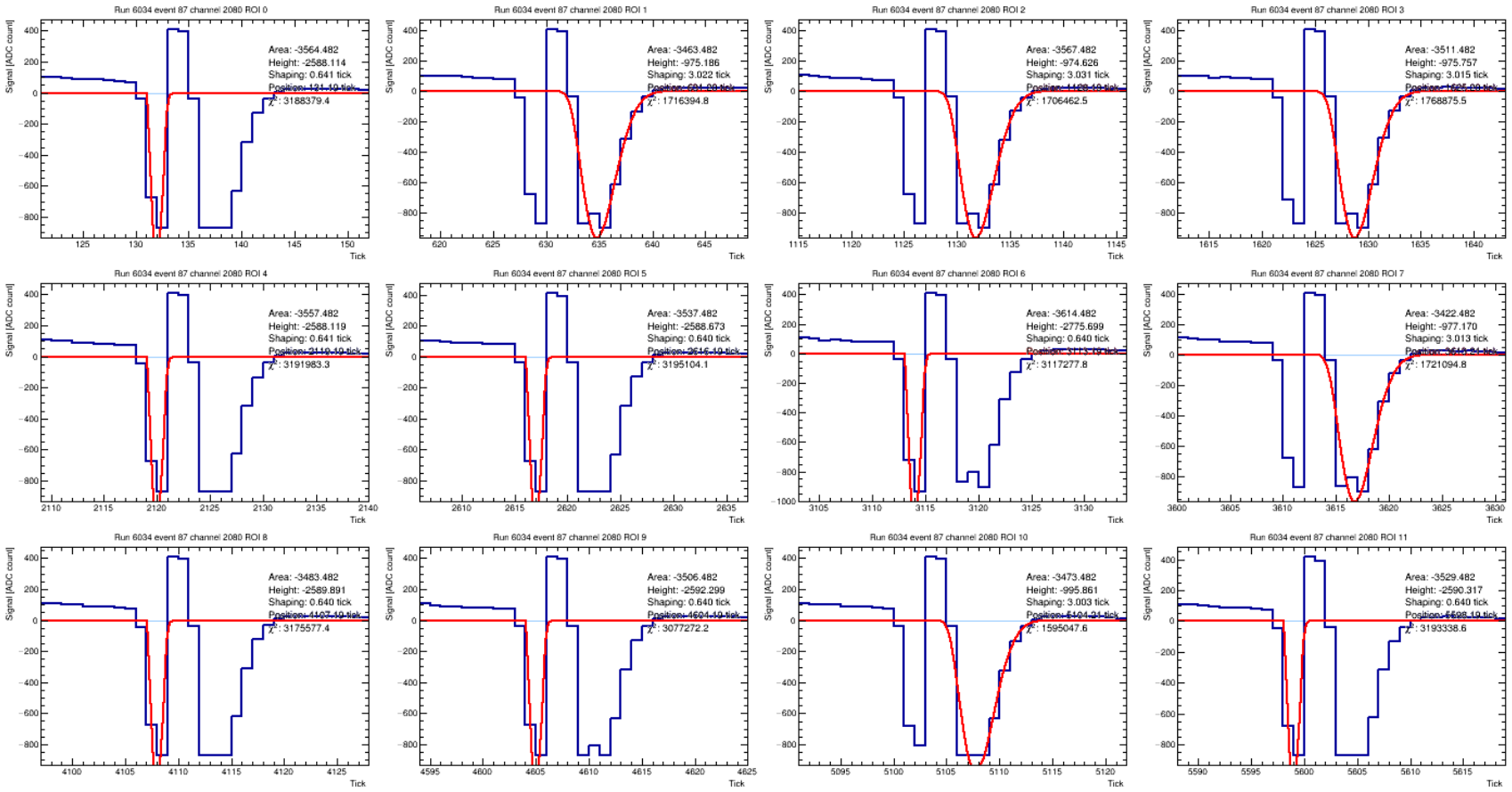
ADC response starting to show “rollback”—signals below the ADC range appear in range.

A=-18

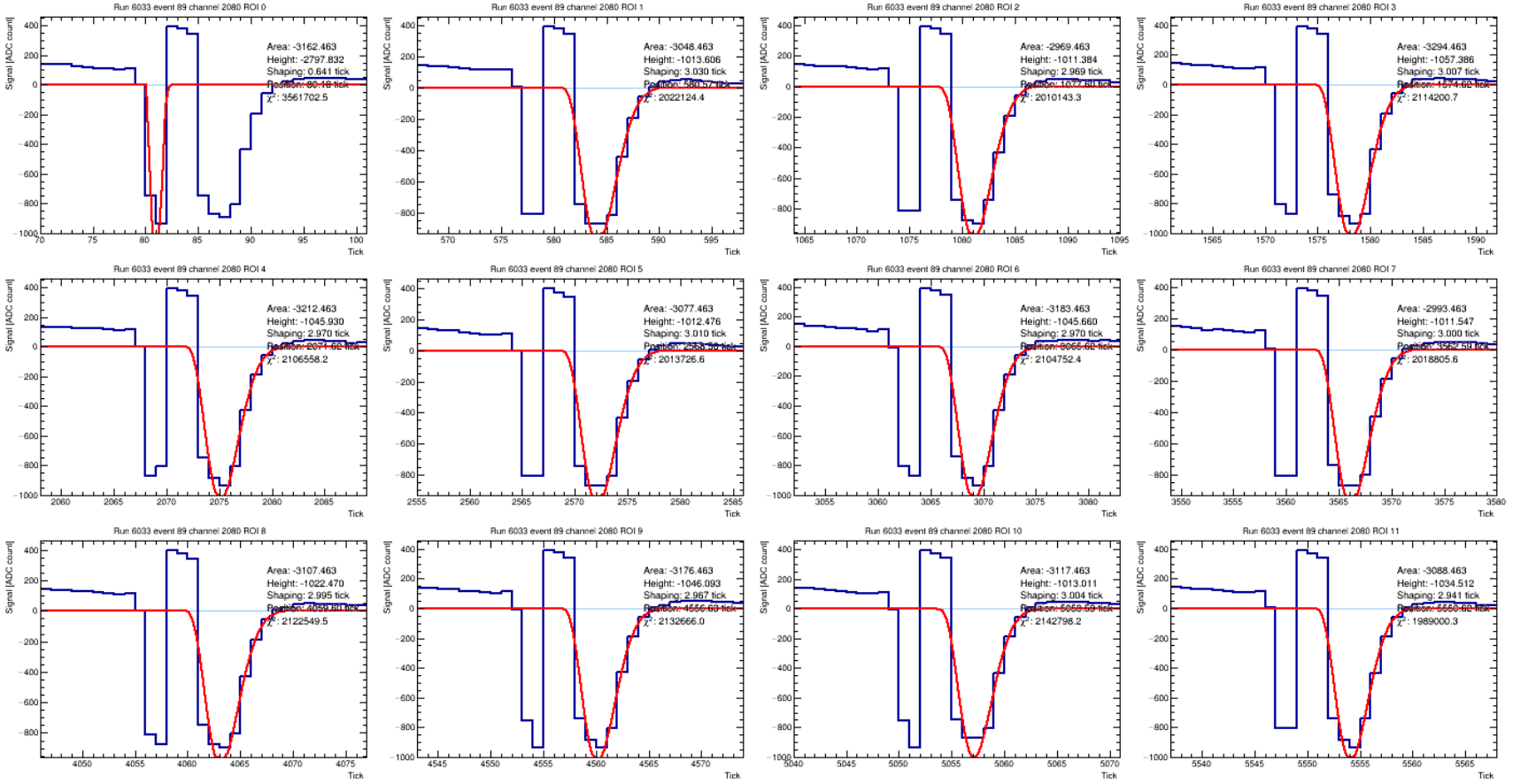


Here and beyond, the rollback is huge—past the pedestal to about +400 ADC counts, i.e. +3 MIPs.

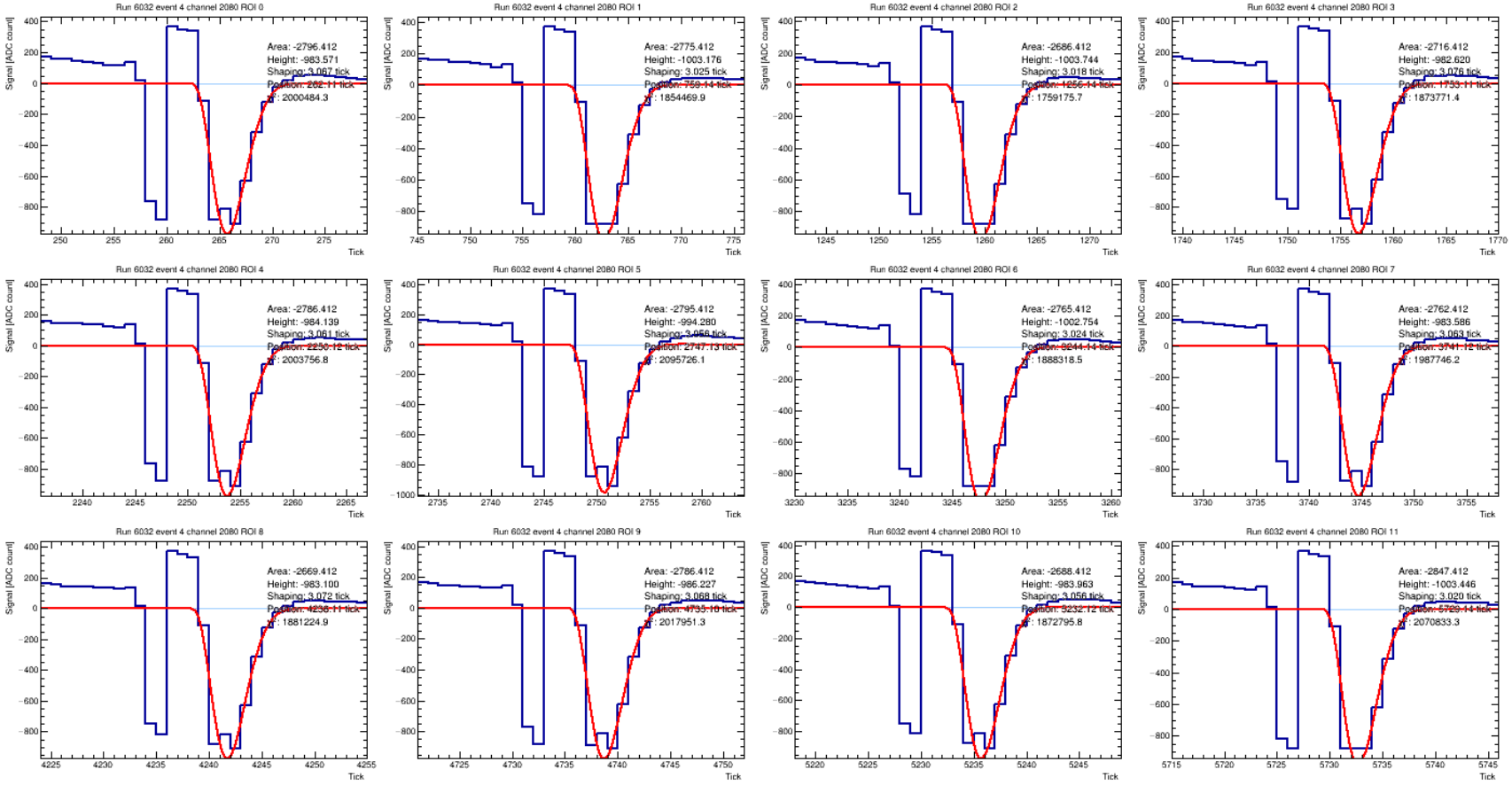
A=-21


Run 6034 event 87 channel 2080 ROI 0
Area: -3564.482
Height: -2588.114
Shaping: 0.641 tick
Run 6034 event 87 channel 2080 ROI 1
Area: -3463.482
Height: -975.186
Shaping: 3.022 tick
Run 6034 event 87 channel 2080 ROI 2
Area: -3567.482
Height: -974.626
Shaping: 3.031 tick
Run 6034 event 87 channel 2080 ROI 3
Area: -3511.482
Height: -975.757
Shaping: 3.015 tick
Run 6034 event 87 channel 2080 ROI 4
Area: -3557.482
Height: -2588.119
Shaping: 0.641 tick
Run 6034 event 87 channel 2080 ROI 5
Area: -3537.482
Height: -2588.673
Shaping: 0.640 tick
Run 6034 event 87 channel 2080 ROI 6
Area: -3614.482
Height: -2775.699
Shaping: 0.640 tick
Run 6034 event 87 channel 2080 ROI 7
Area: -3422.482
Height: -977.170
Shaping: 3.013 tick
Run 6034 event 87 channel 2080 ROI 8
Area: -3483.482
Height: -2589.891
Shaping: 0.640 tick
Run 6034 event 87 channel 2080 ROI 9
Area: -3506.482
Height: -2592.299
Shaping: 0.640 tick
Run 6034 event 87 channel 2080 ROI 10
Area: -3473.482
Height: -995.861
Shaping: 3.003 tick
Run 6034 event 87 channel 2080 ROI 11
Area: -3529.482
Height: -2590.317
Shaping: 0.640 tick
Signal [ADC count]
Tick

A=-25


Run 6033 event 89 channel 2080 ROI 0
Area: -3162.463
Height: -2797.832
Shaping: 0.641 tick
Position: 80.18 tick
χ²: 3561702.5
Run 6033 event 89 channel 2080 ROI 1
Area: -3048.463
Height: -1013.606
Shaping: 3.030 tick
Position: 581.57 tick
χ²: 2022124.4
Run 6033 event 89 channel 2080 ROI 2
Area: -2969.463
Height: -1011.384
Shaping: 2.969 tick
Position: 1072.80 tick
χ²: 2010143.3
Run 6033 event 89 channel 2080 ROI 3
Area: -3294.463
Height: -1057.386
Shaping: 3.007 tick
Position: 1574.60 tick
χ²: 2114200.7
Run 6033 event 89 channel 2080 ROI 4
Area: -3212.463
Height: -1045.930
Shaping: 2.970 tick
Position: 2071.68 tick
χ²: 2106558.2
Run 6033 event 89 channel 2080 ROI 5
Area: -3077.463
Height: -1012.476
Shaping: 3.010 tick
Position: 2568.36 tick
χ²: 2013726.6
Run 6033 event 89 channel 2080 ROI 6
Area: -3183.463
Height: -1045.660
Shaping: 2.970 tick
Position: 3065.68 tick
χ²: 2104752.4
Run 6033 event 89 channel 2080 ROI 7
Area: -2993.463
Height: -1011.547
Shaping: 3.000 tick
Position: 3562.58 tick
χ²: 2018805.6
Run 6033 event 89 channel 2080 ROI 8
Area: -3107.463
Height: -1022.470
Shaping: 2.995 tick
Position: 4059.80 tick
χ²: 2122549.5
Run 6033 event 89 channel 2080 ROI 9
Area: -3176.463
Height: -1046.093
Shaping: 2.967 tick
Position: 4556.68 tick
χ²: 2132666.0
Run 6033 event 89 channel 2080 ROI 10
Area: -3117.463
Height: -1013.011
Shaping: 3.004 tick
Position: 5053.59 tick
χ²: 2142798.2
Run 6033 event 89 channel 2080 ROI 11
Area: -3088.463
Height: -1034.512
Shaping: 2.941 tick
Position: 5550.62 tick
χ²: 1989000.3
Signal [ADC count]
Tick

A=-30


Run 6032 event 4 channel 2080 ROI 0
Area: -2796.412
Height: -983.571
Shaping: 3.067 tick
Position: 262.11 tick
χ²: 2000484.3
Run 6032 event 4 channel 2080 ROI 1
Area: -2775.412
Height: -1003.176
Shaping: 3.025 tick
Position: 759.14 tick
χ²: 1854469.9
Run 6032 event 4 channel 2080 ROI 2
Area: -2686.412
Height: -1003.744
Shaping: 3.018 tick
Position: 1256.14 tick
χ²: 1759175.7
Run 6032 event 4 channel 2080 ROI 3
Area: -2716.412
Height: -982.620
Shaping: 3.076 tick
Position: 1753.11 tick
χ²: 1873771.4
Run 6032 event 4 channel 2080 ROI 4
Area: -2786.412
Height: -984.139
Shaping: 3.061 tick
Position: 2250.12 tick
χ²: 2003756.8
Run 6032 event 4 channel 2080 ROI 5
Area: -2795.412
Height: -994.280
Shaping: 3.056 tick
Position: 2747.13 tick
χ²: 2095726.1
Run 6032 event 4 channel 2080 ROI 6
Area: -2765.412
Height: -1002.754
Shaping: 3.024 tick
Position: 3244.14 tick
χ²: 1888318.5
Run 6032 event 4 channel 2080 ROI 7
Area: -2762.412
Height: -983.586
Shaping: 3.063 tick
Position: 3741.12 tick
χ²: 1987746.2
Run 6032 event 4 channel 2080 ROI 8
Area: -2669.412
Height: -983.100
Shaping: 3.072 tick
Position: 4238.11 tick
χ²: 1881224.9
Run 6032 event 4 channel 2080 ROI 9
Area: -2786.412
Height: -986.227
Shaping: 3.068 tick
Position: 4735.10 tick
χ²: 2017951.3
Run 6032 event 4 channel 2080 ROI 10
Area: -2688.412
Height: -983.963
Shaping: 3.056 tick
Position: 5232.12 tick
χ²: 1872795.8
Run 6032 event 4 channel 2080 ROI 11
Area: -2847.412
Height: -1003.446
Shaping: 3.020 tick
Position: 5729.14 tick
χ²: 2070833.3
Signal [ADC count]
Tick

Combining pulses

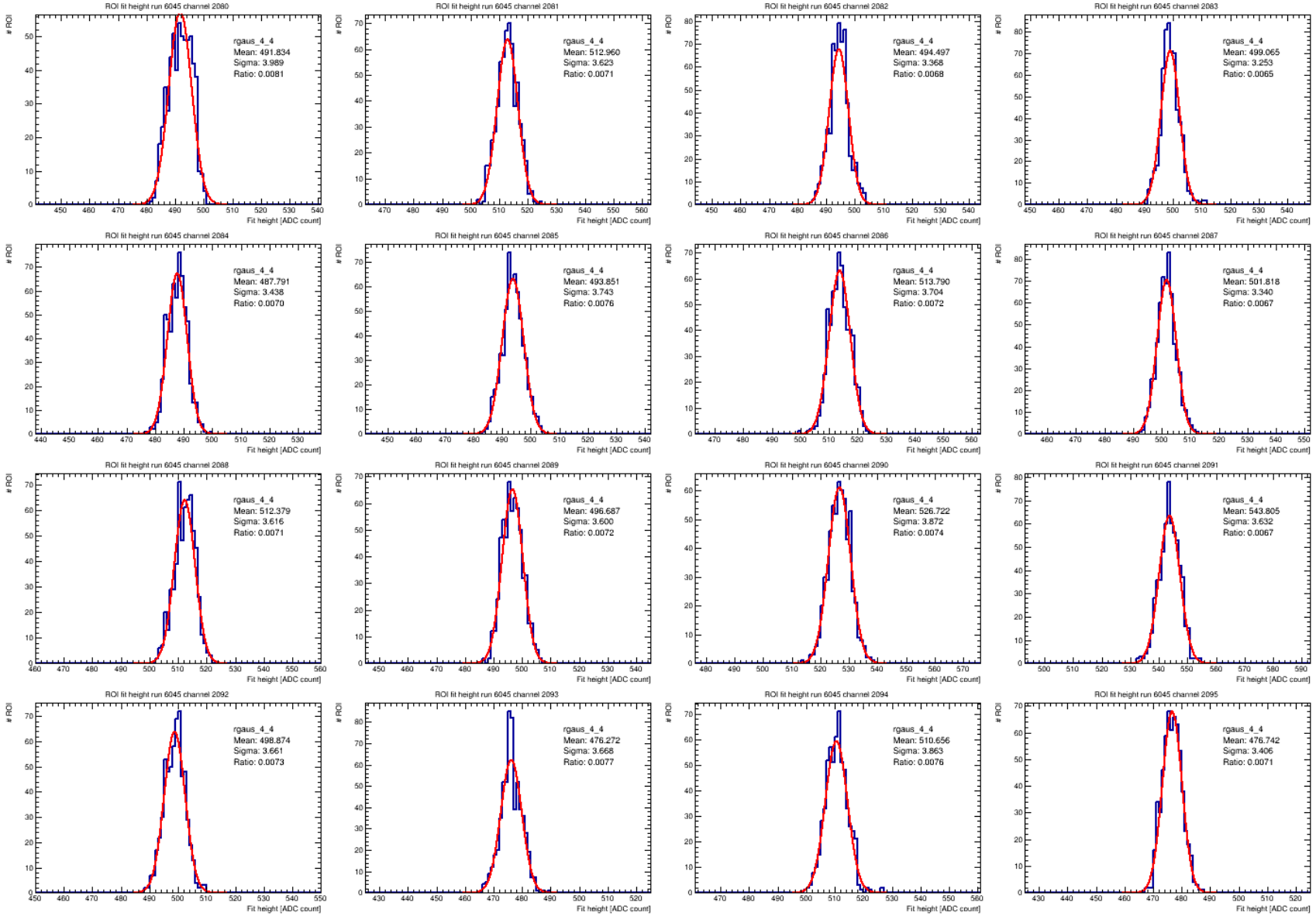
Preceding pulses are fit with CE response function

- Three fitted params: height, shaping time and position (time)
  - Also have chi-square, DOF, etc.
- For a given run, we expect the same height and shaping for all pulses and expect to find pulses at regular intervals

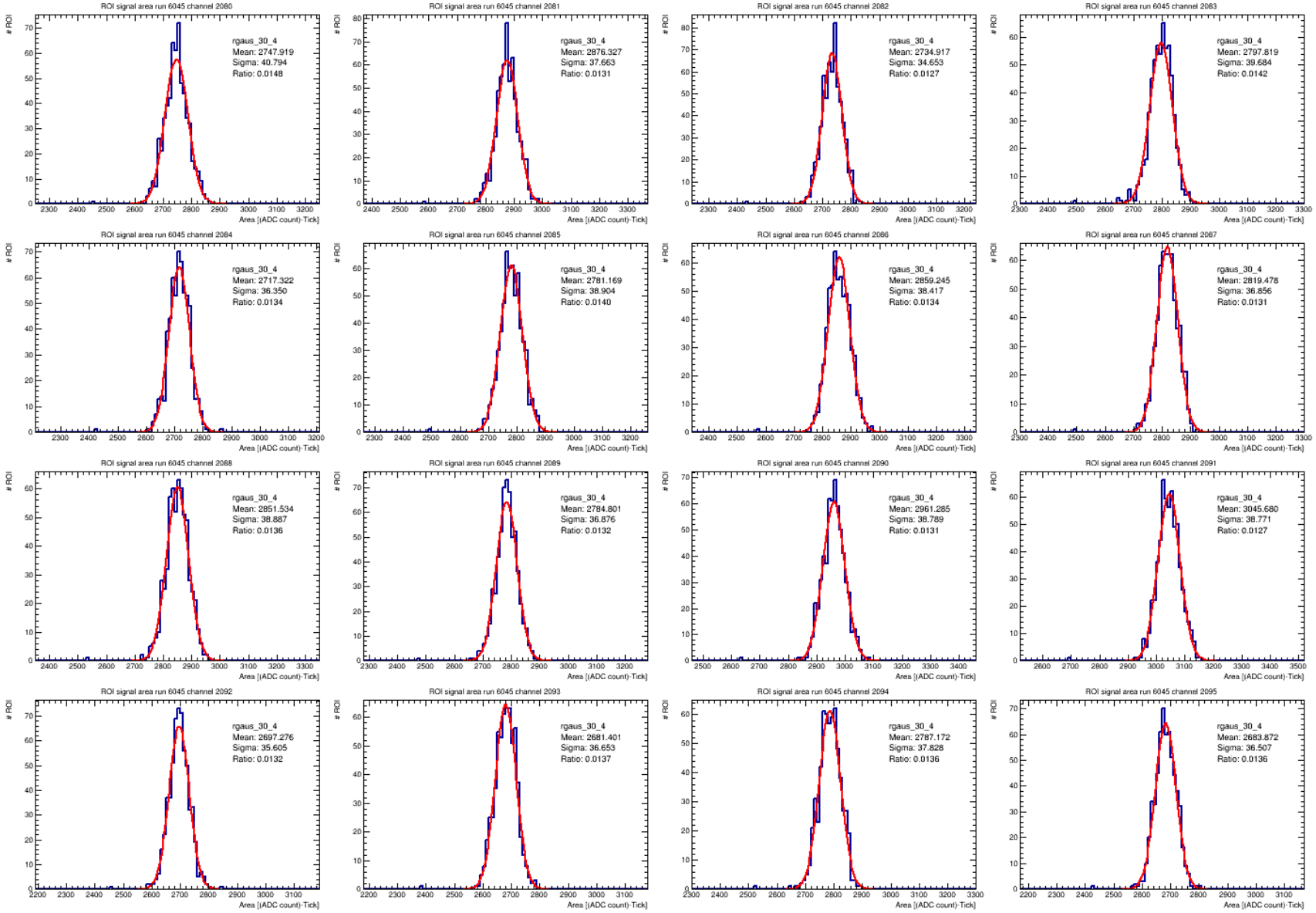
Summary histograms

- AdcRoiViewer makes summary histograms
- One entry per pulse for any of the pulse fit parameters
  - Can also histogram other metrics
    - E.g. pulse area used for calibration
- Summary histograms can be fit
  - With gaussian or truncated RMS (Dec protoDUNE sim/reco mtg)
  - Result of fit is a mean and RMS/sigma
- Many examples of summary histograms may be found at
  - http://internal.dunescience.org/people/dladams/protodune/data/pulser/sums/
  - Follow links to sign/threshold, run, and plot type (hfh=height, hsa=area)

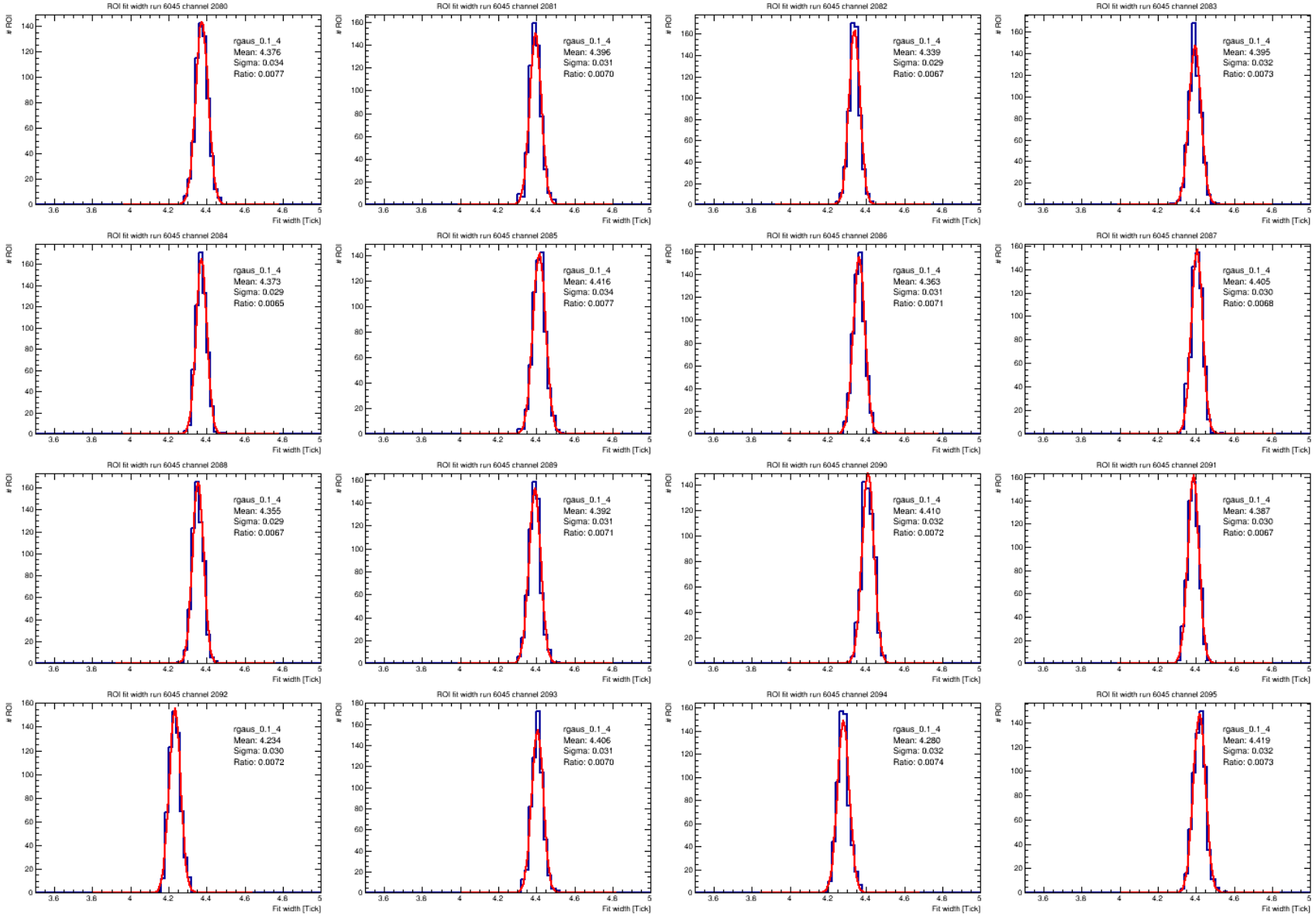
Example fitted height summaries



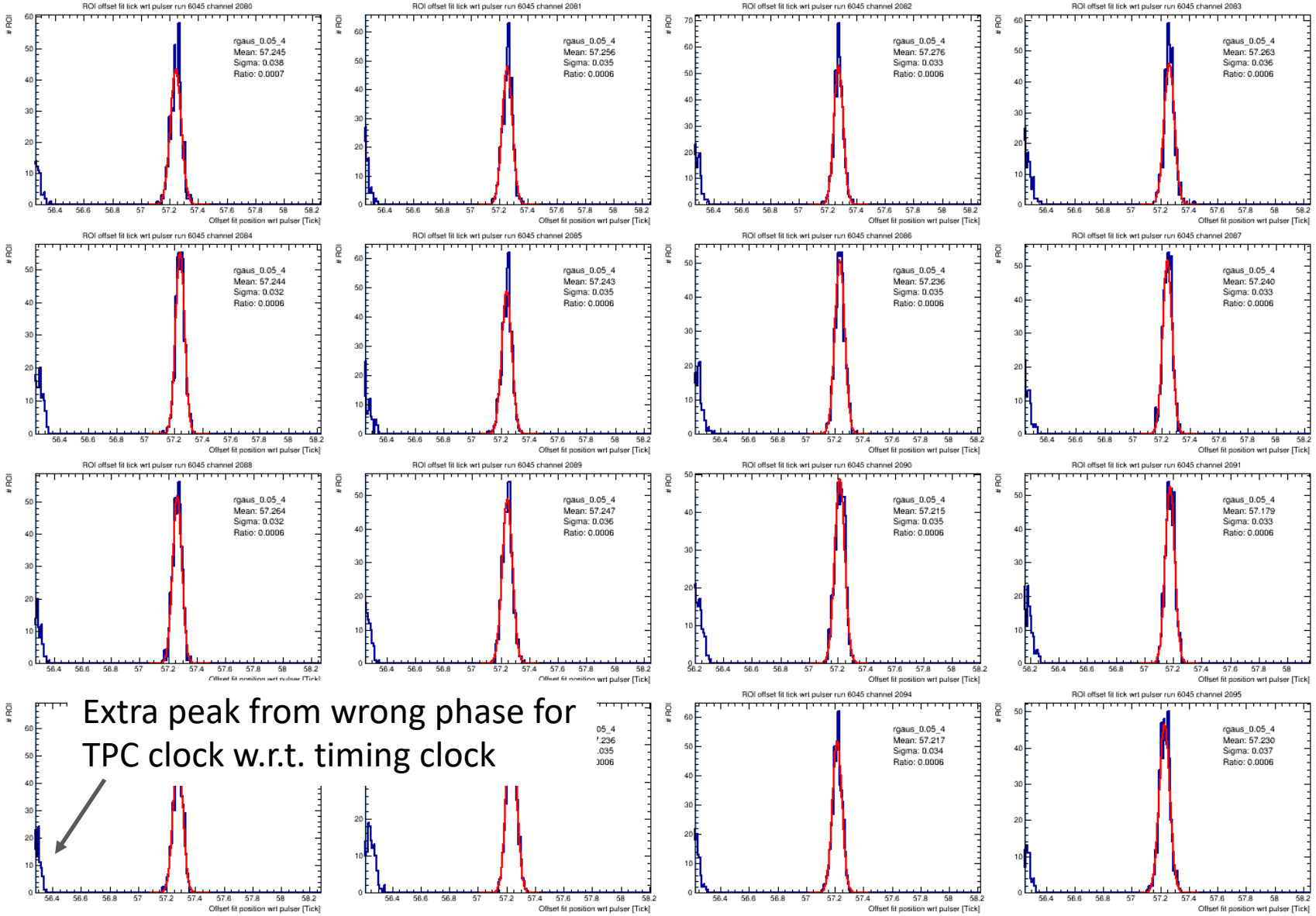
Example fitted area summaries



Example fitted shaping summaries

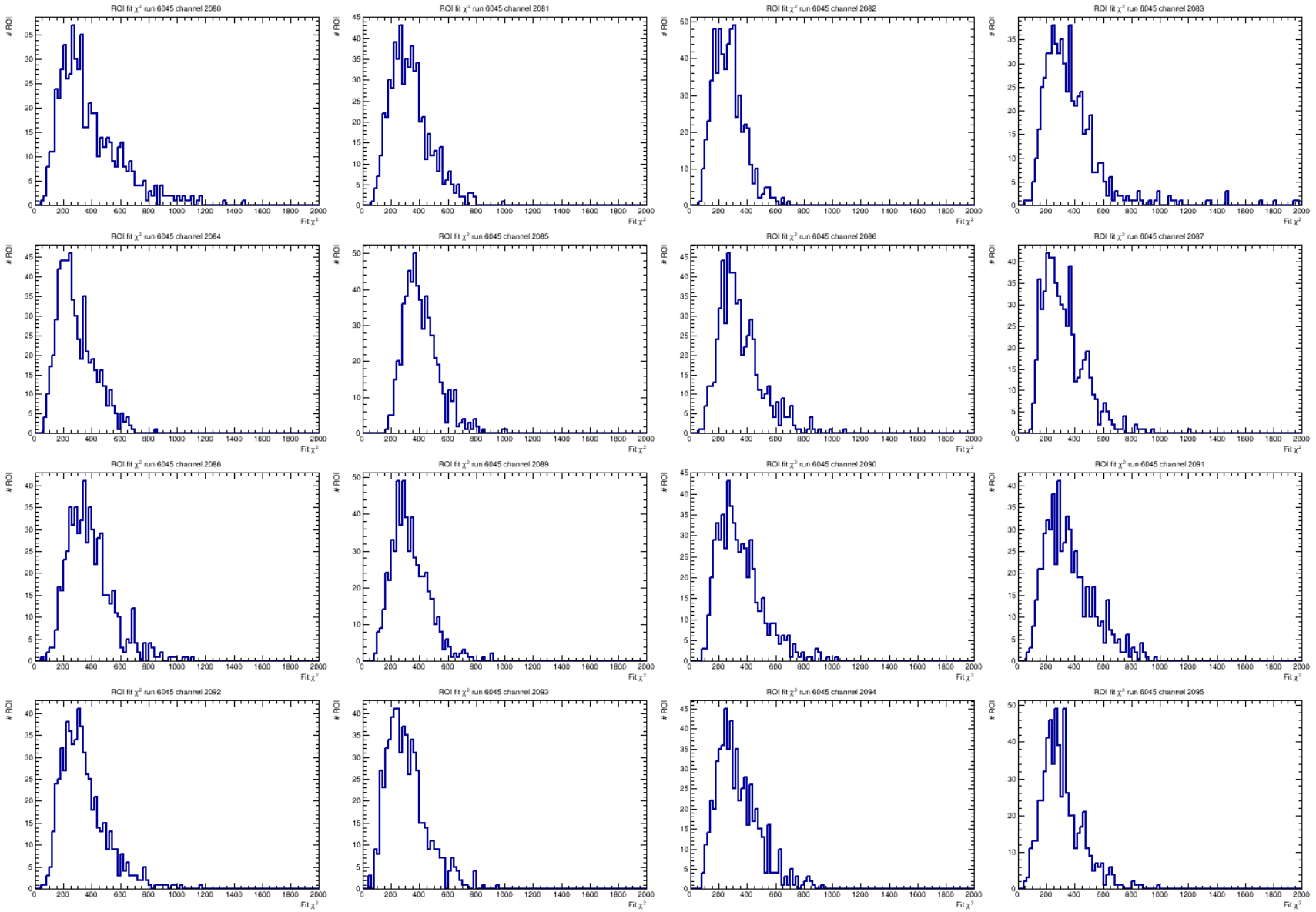


Example fitted position/time summaries



Extra peak from wrong phase for TPC clock w.r.t. timing clock

Example fit chi-square summaries



Combining pulse summaries

I have many summary histograms

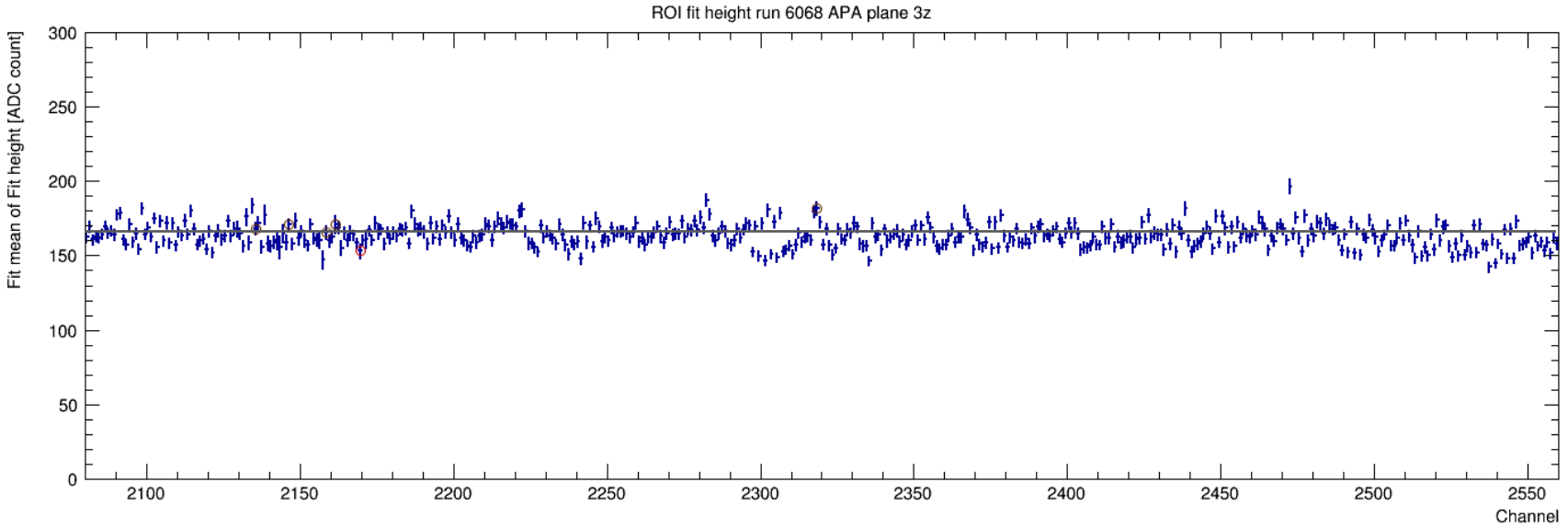
- Examples on preceding pages
- For one variable and one collection plane:
  - (2 charge signs) (16 pulser settings) (480 channels) = 15k plots

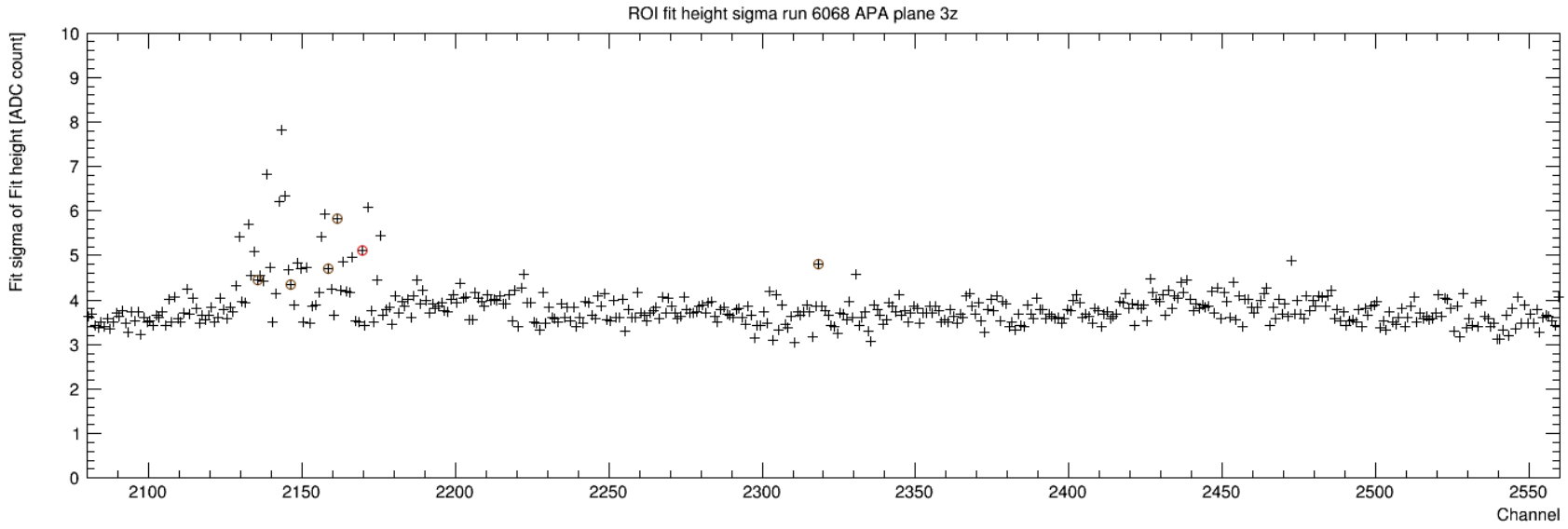
Channel summary plots

- Extract a feature, e.g. the mean, from each summary plot
  - When mean is shown, error bars are the corresponding sigma/RMS
  - Actual error on mean is sqrt(N) = 20 times smaller
- Plot feature vs. channel for each sign and pulser setting
  - Pulser setting denote by A
  - Value is roughly in MIPs
- Some of these plots follow
  - For the December pulser data
  - External pulser and HV off

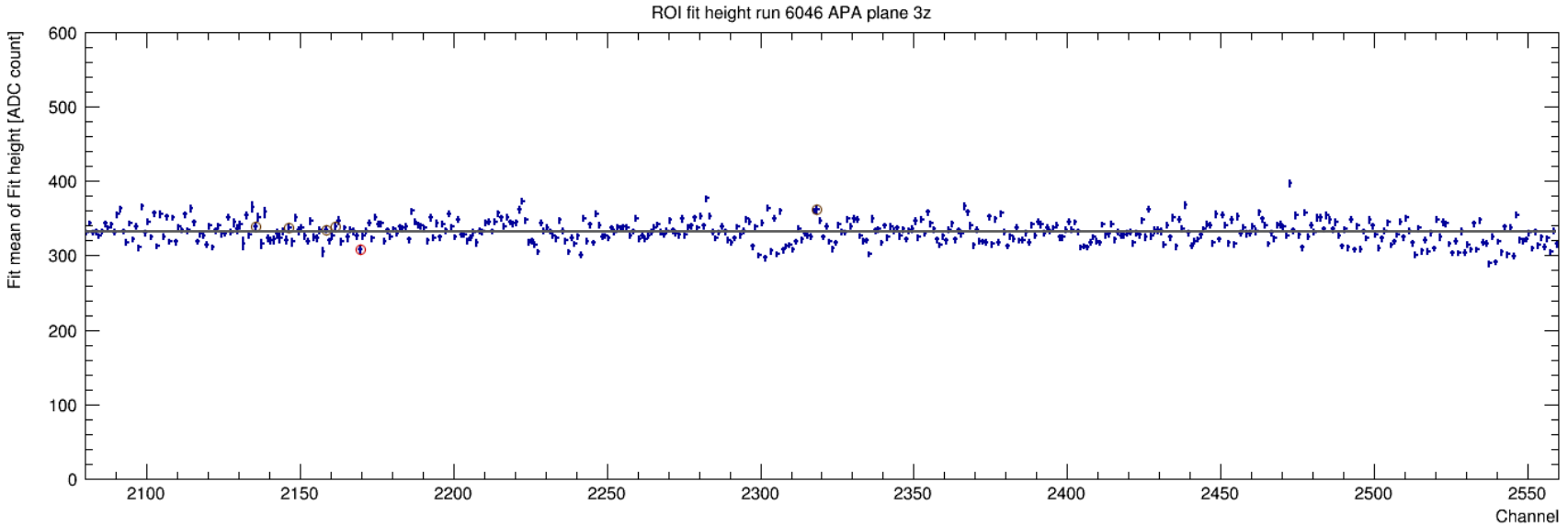
ROI fitted heights

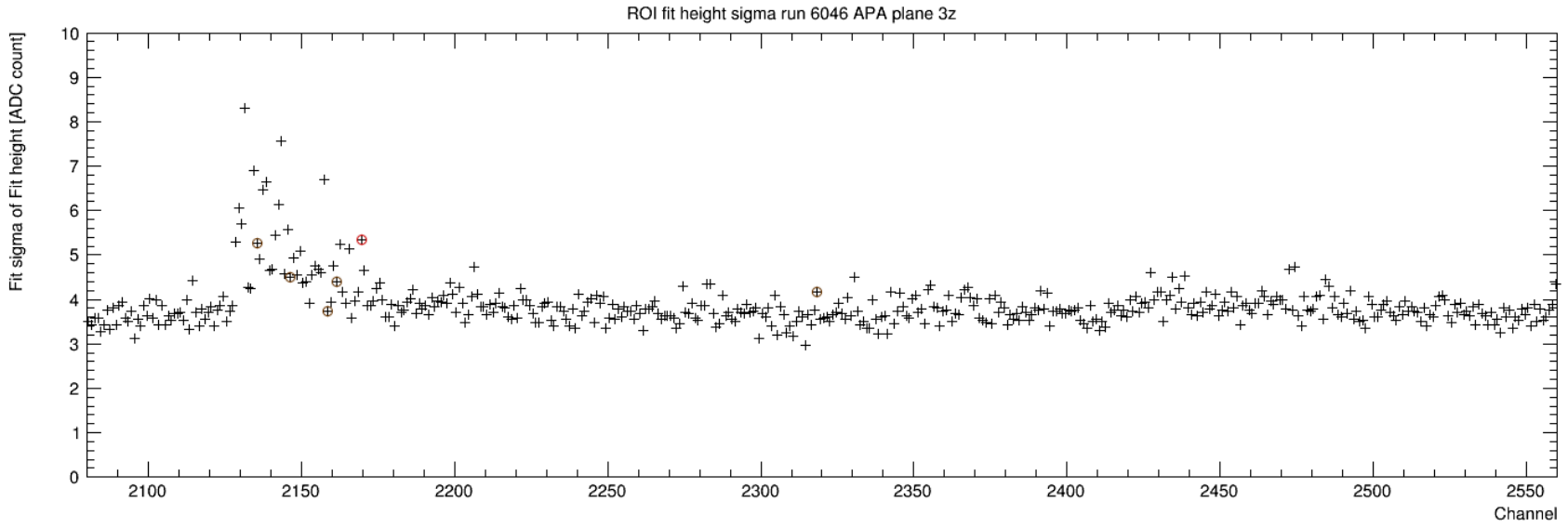
A=1 Fitted height



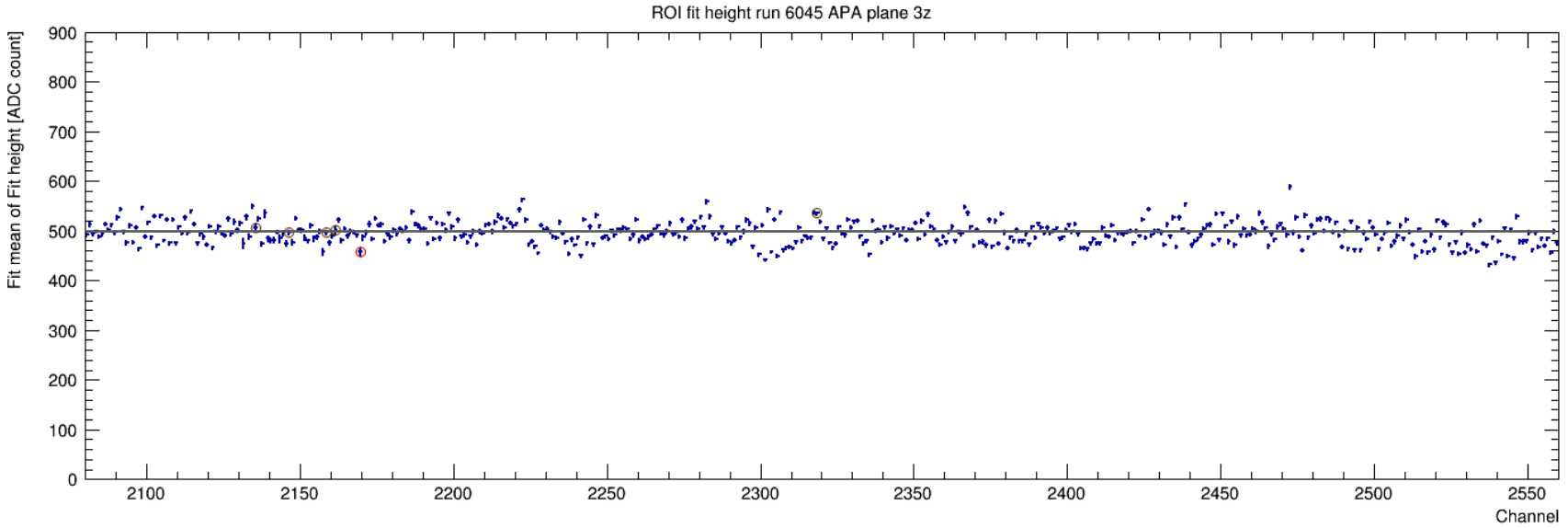


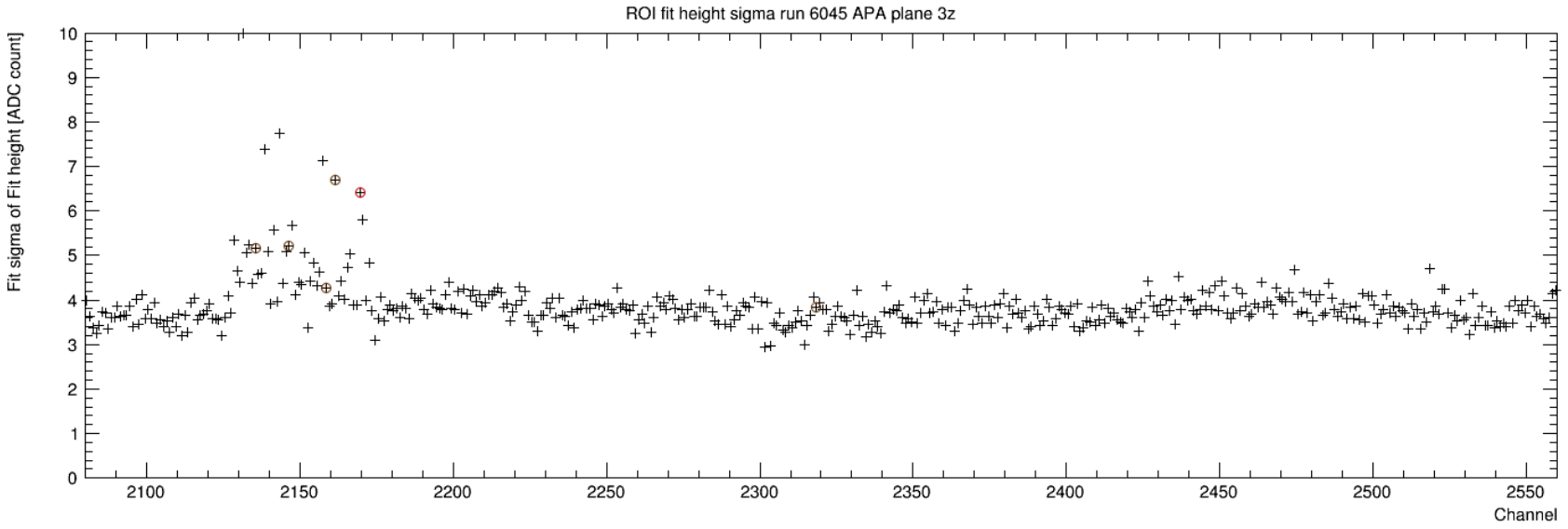
A=2 Fitted height



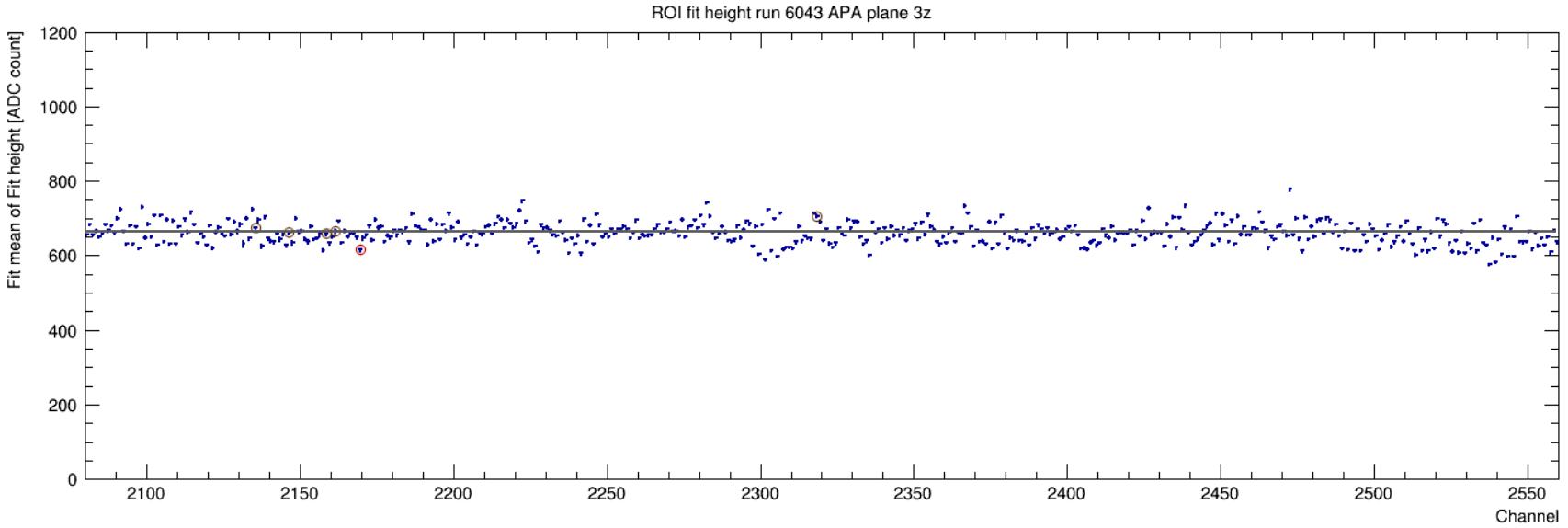


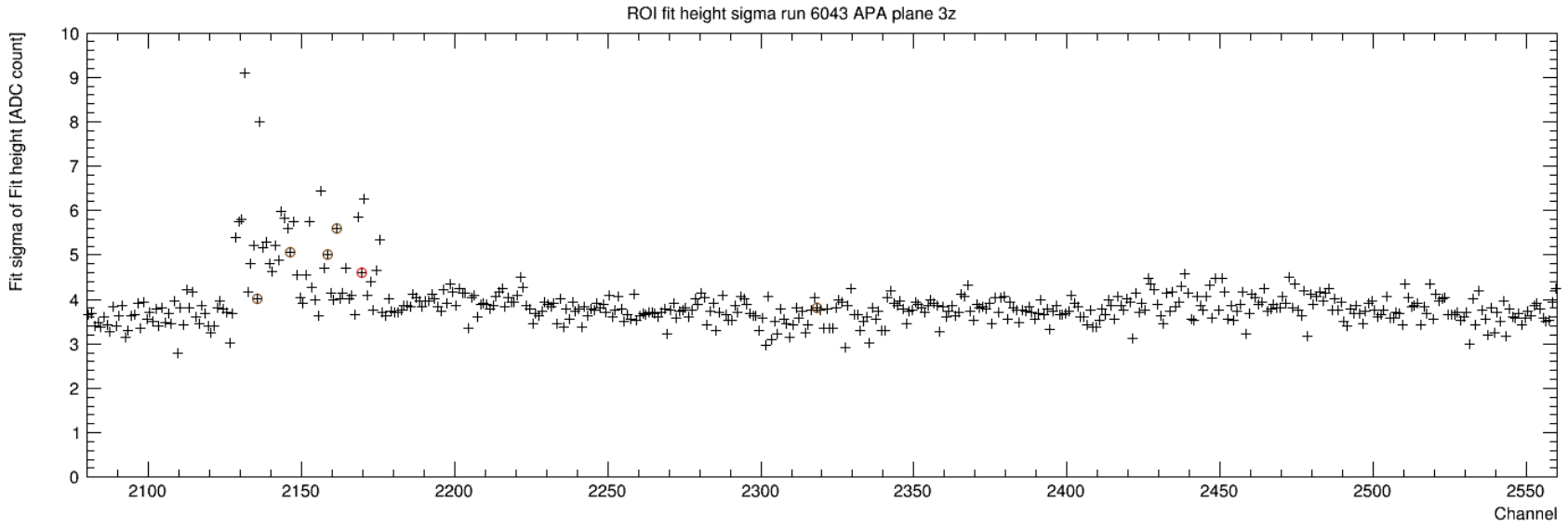
A=3 Fitted height



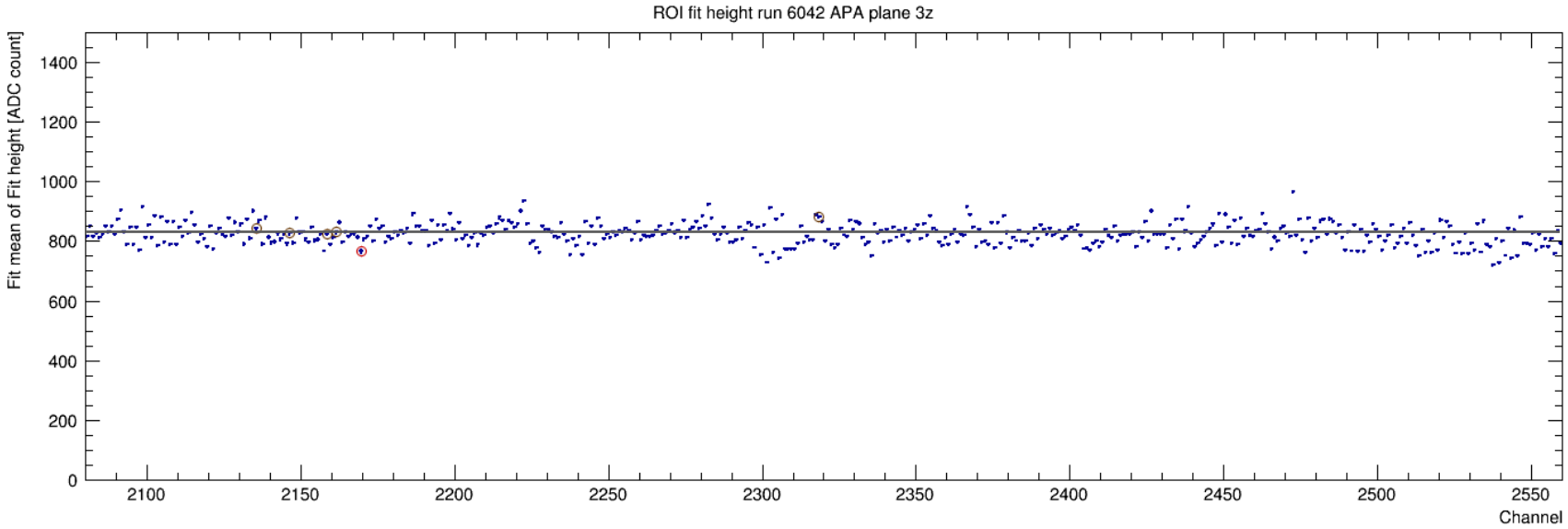


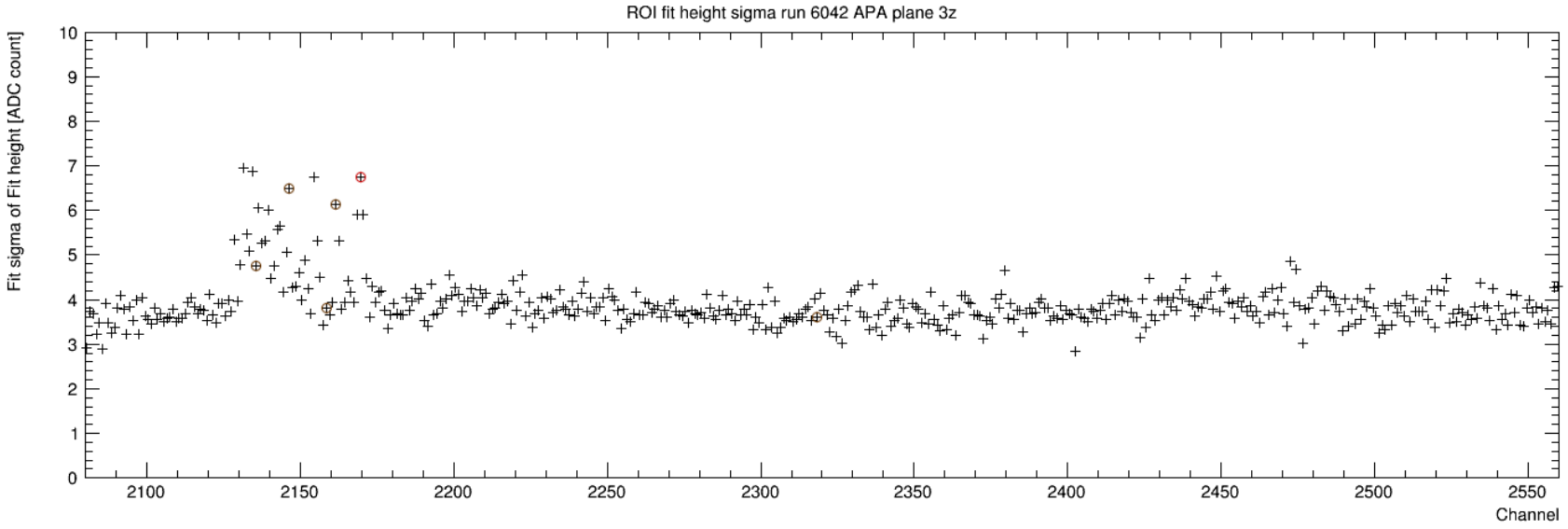
A=4 Fitted height



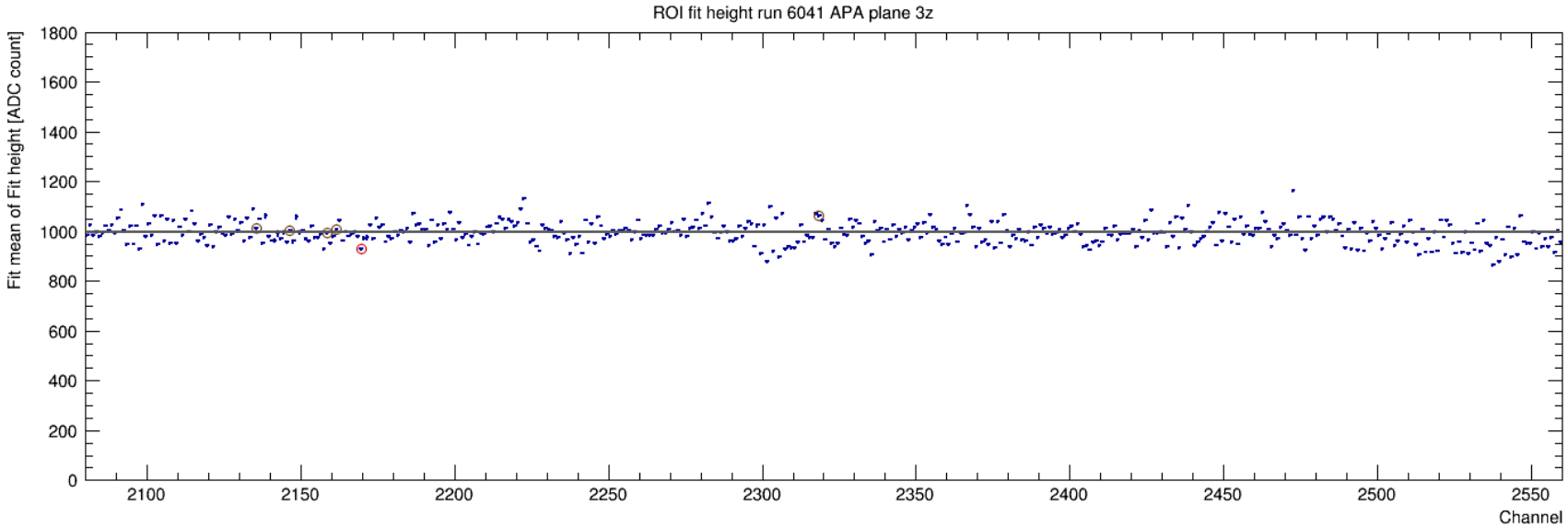


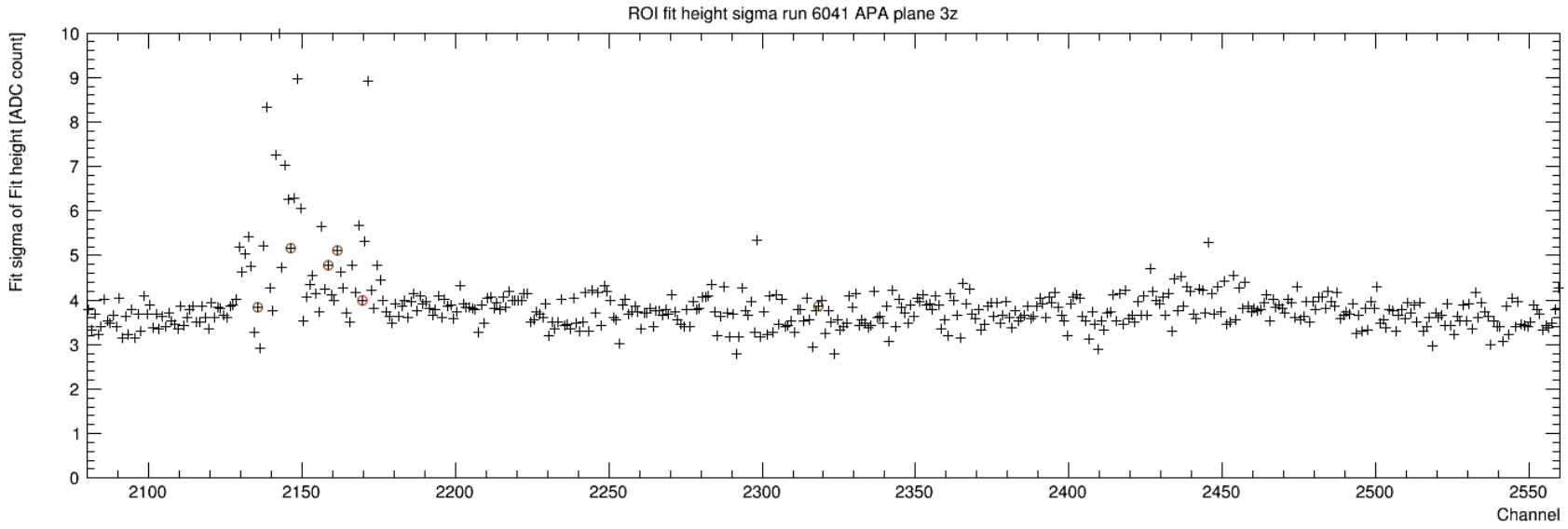
A=5 Fitted height



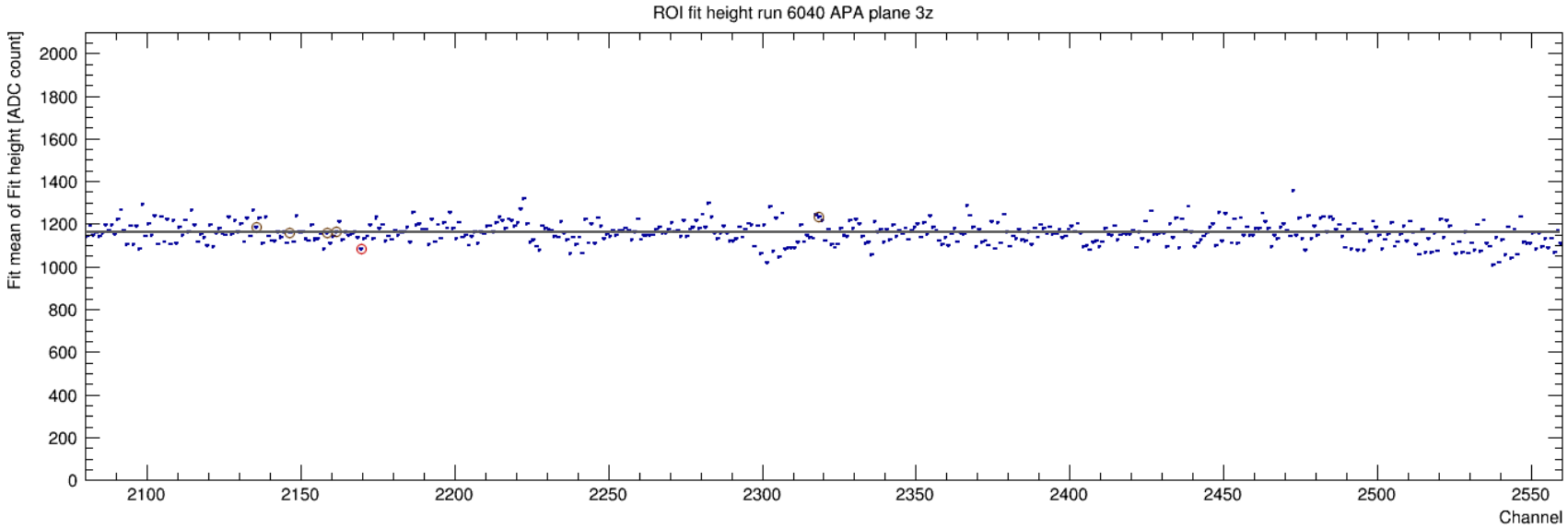


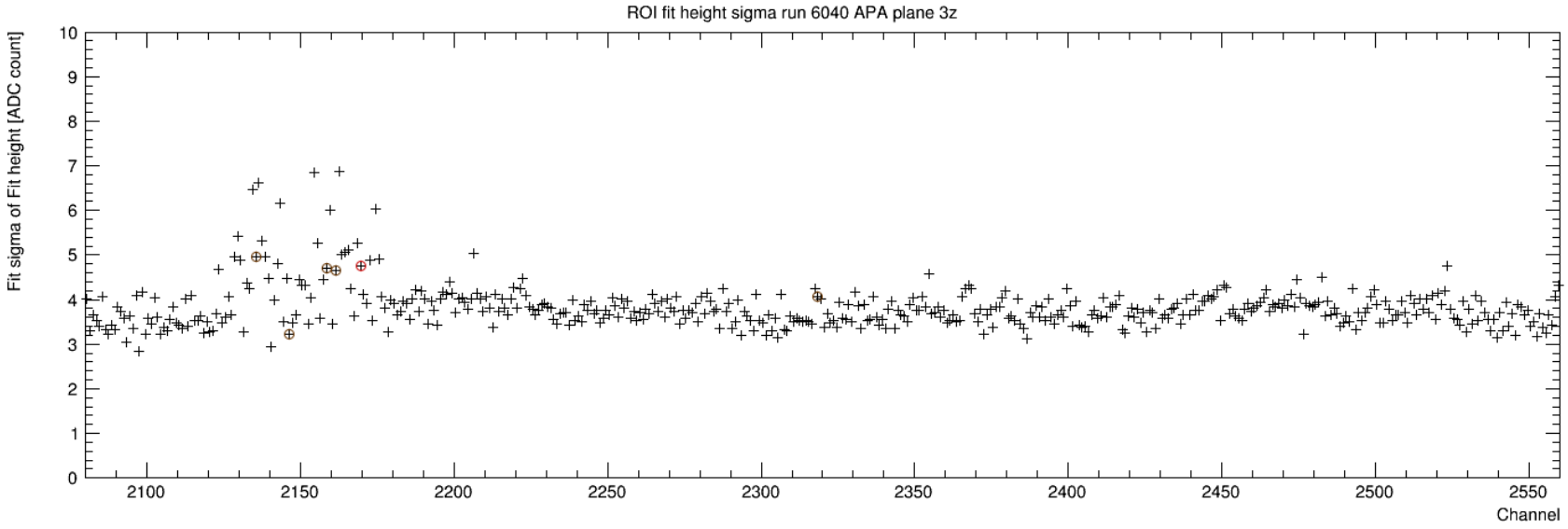
A=6 Fitted height



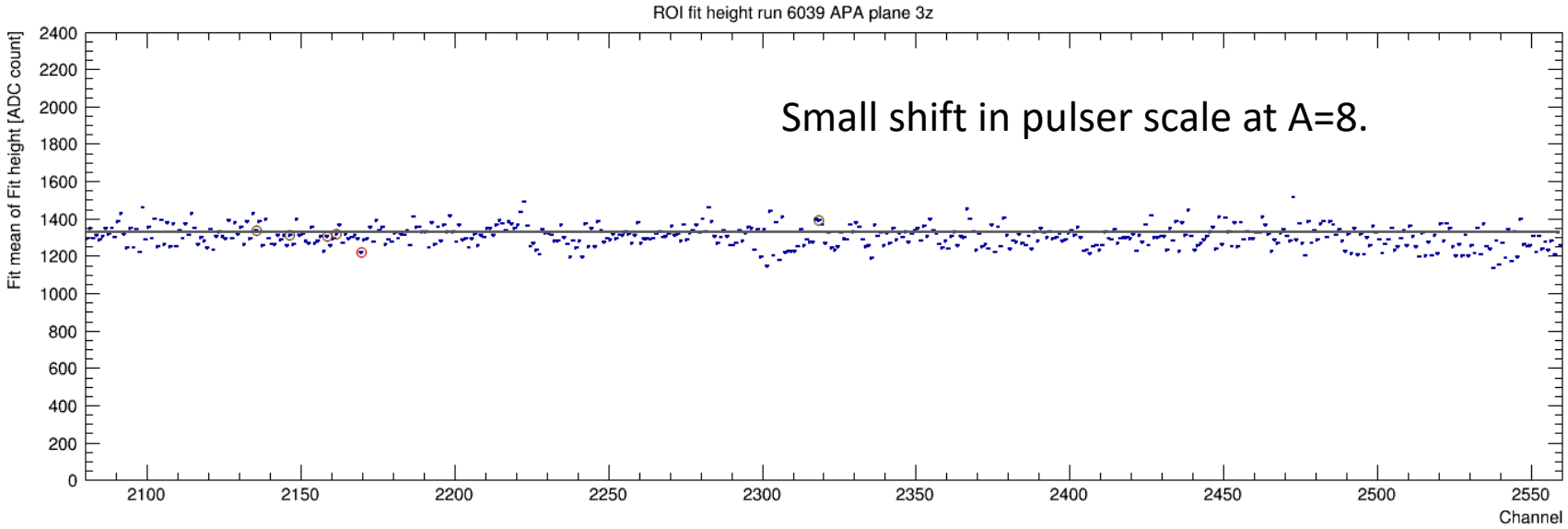


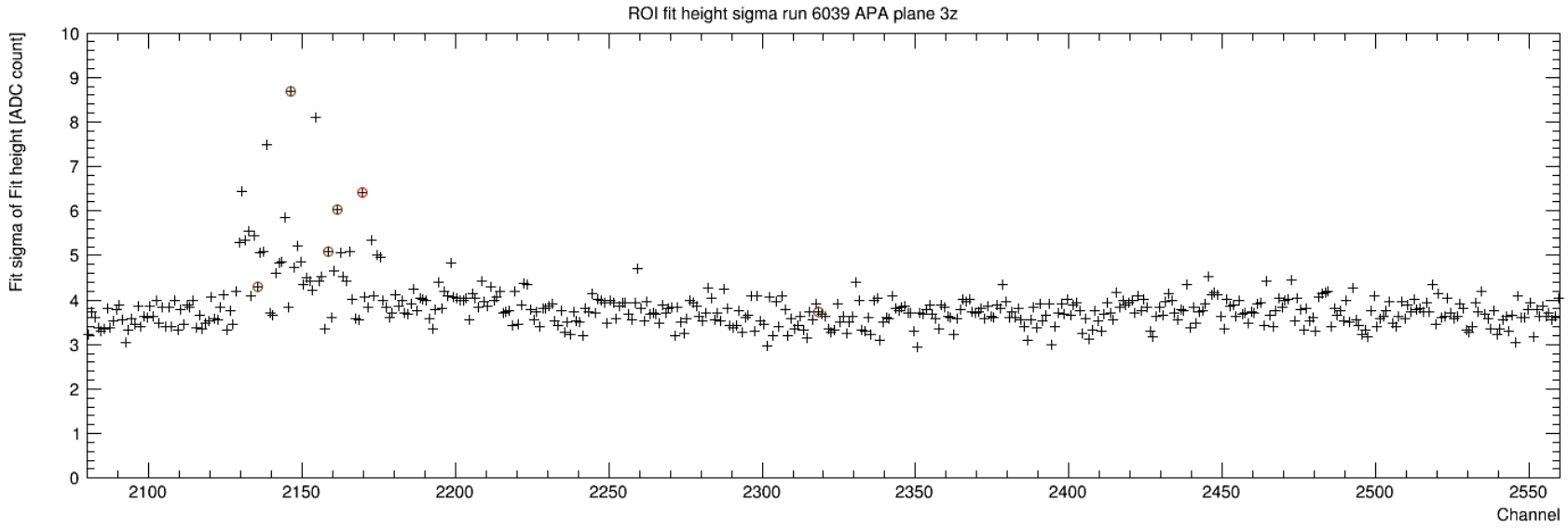
A=7 Fitted height



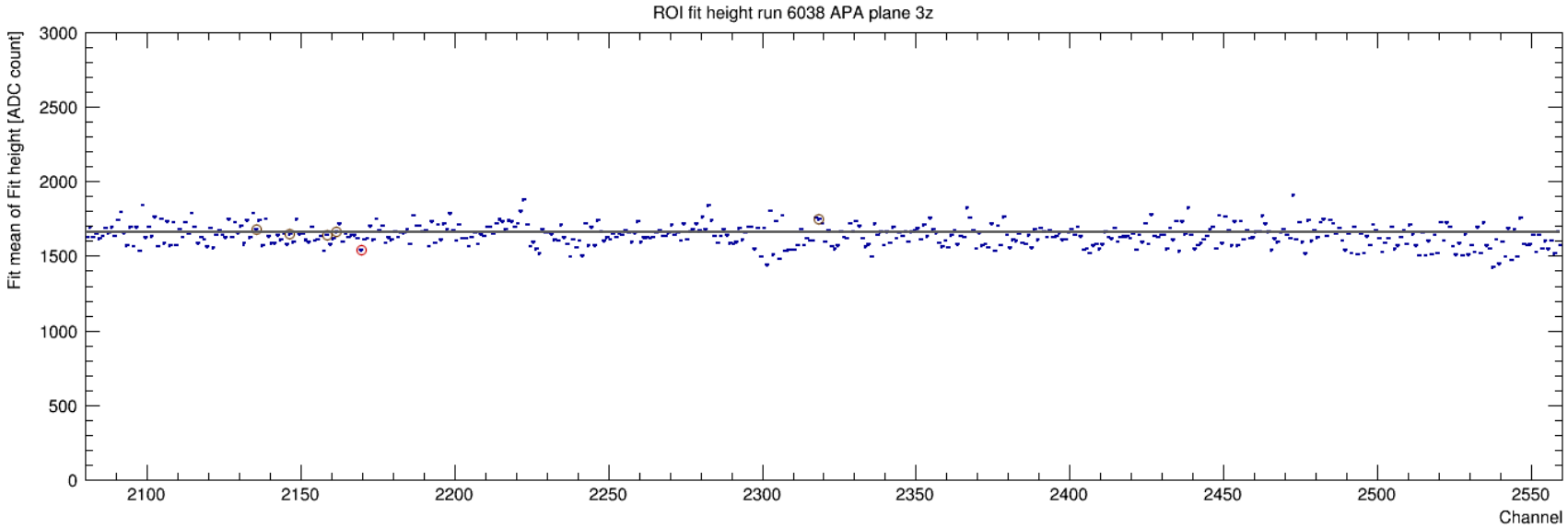


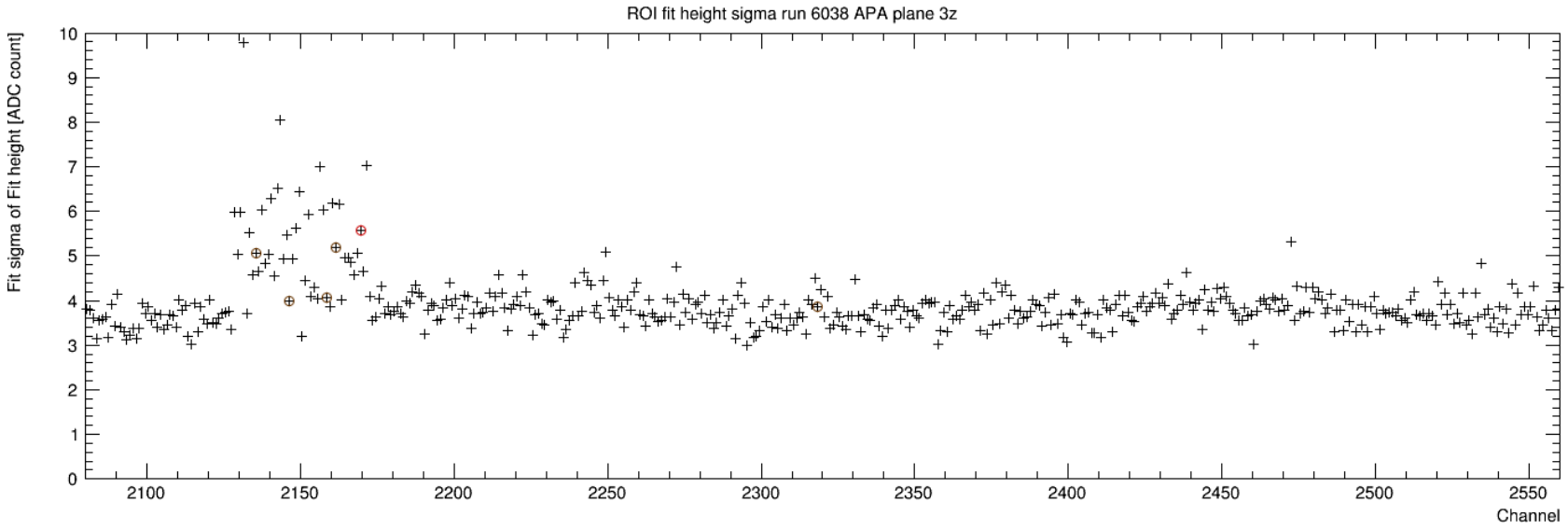
A=8 Fitted height



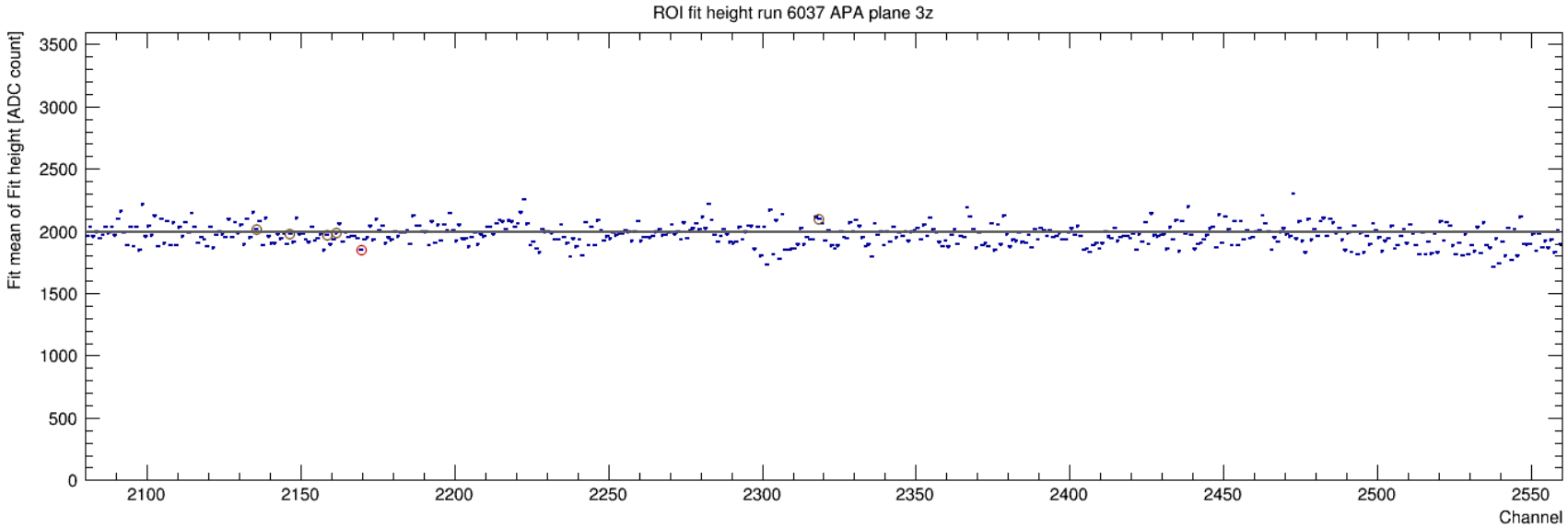


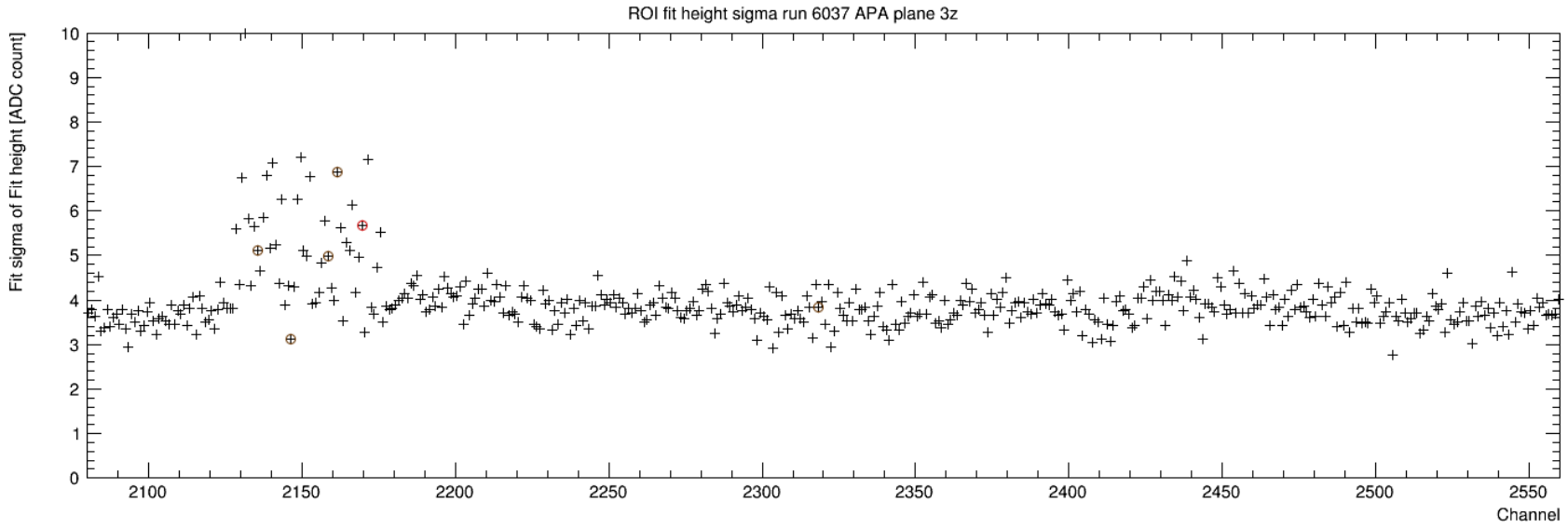
A=10 Fitted height



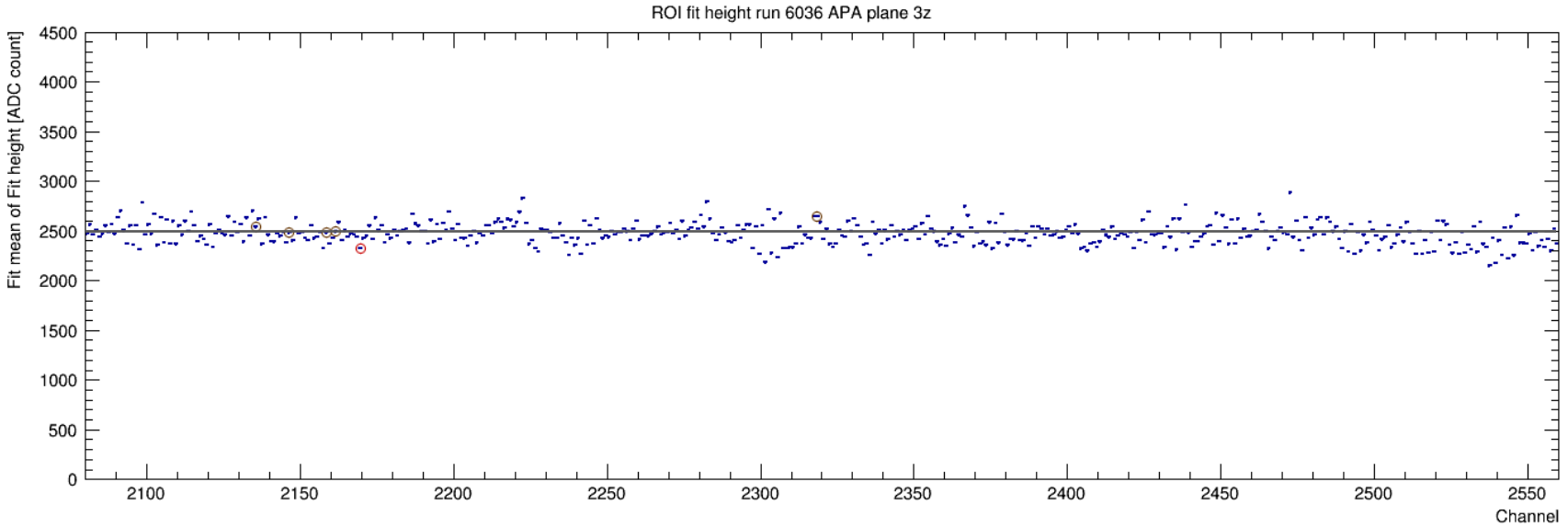


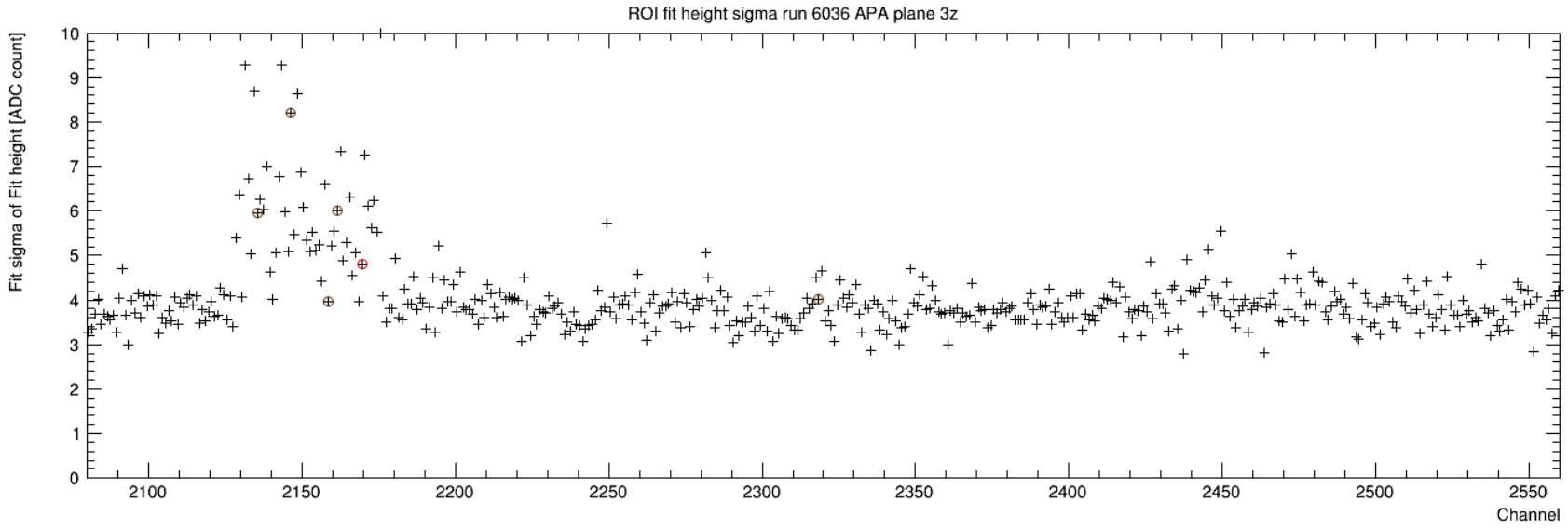
A=12 Fitted height



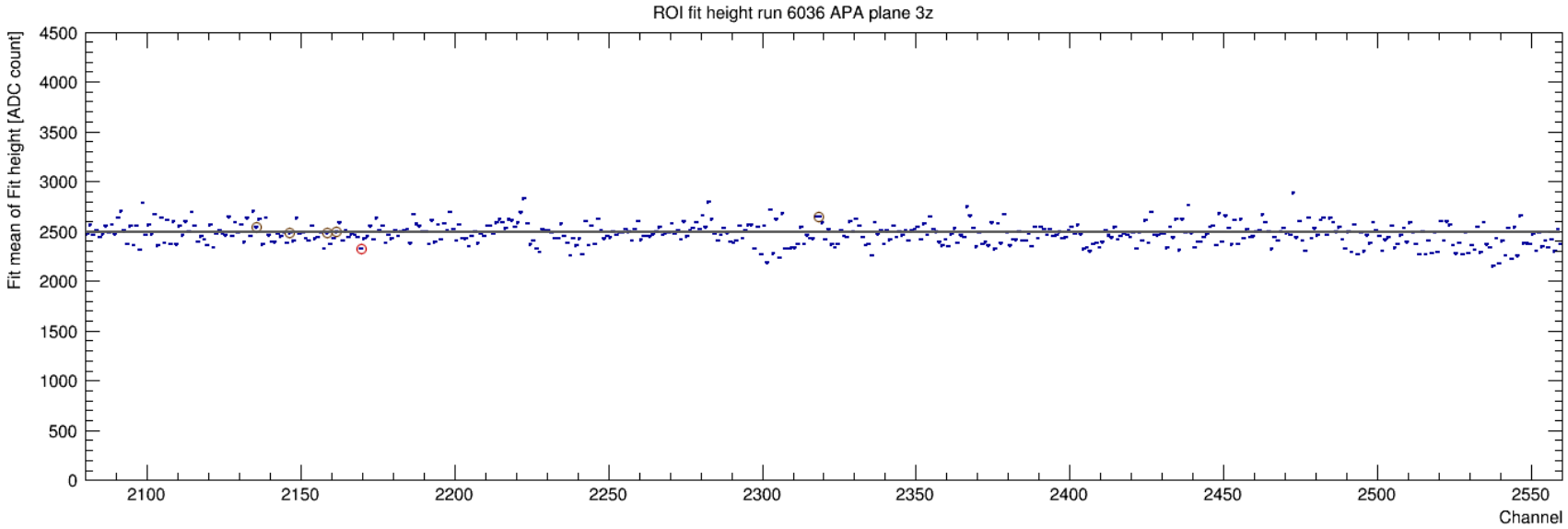


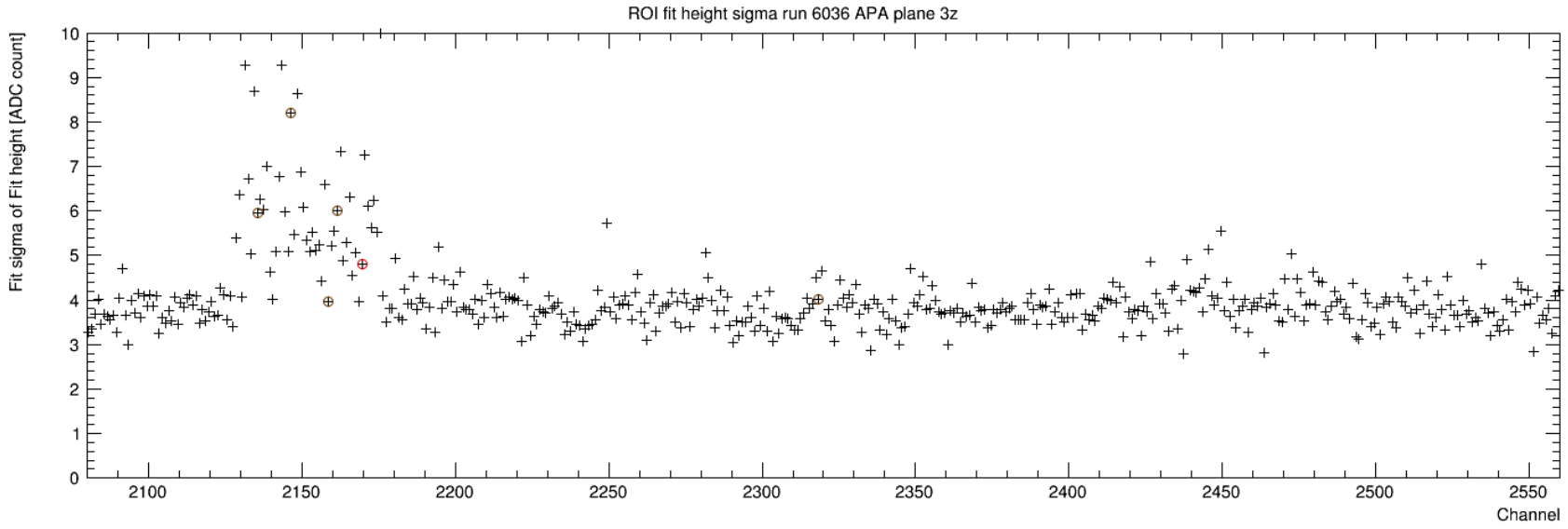
A=15 Fitted height (low threshold)



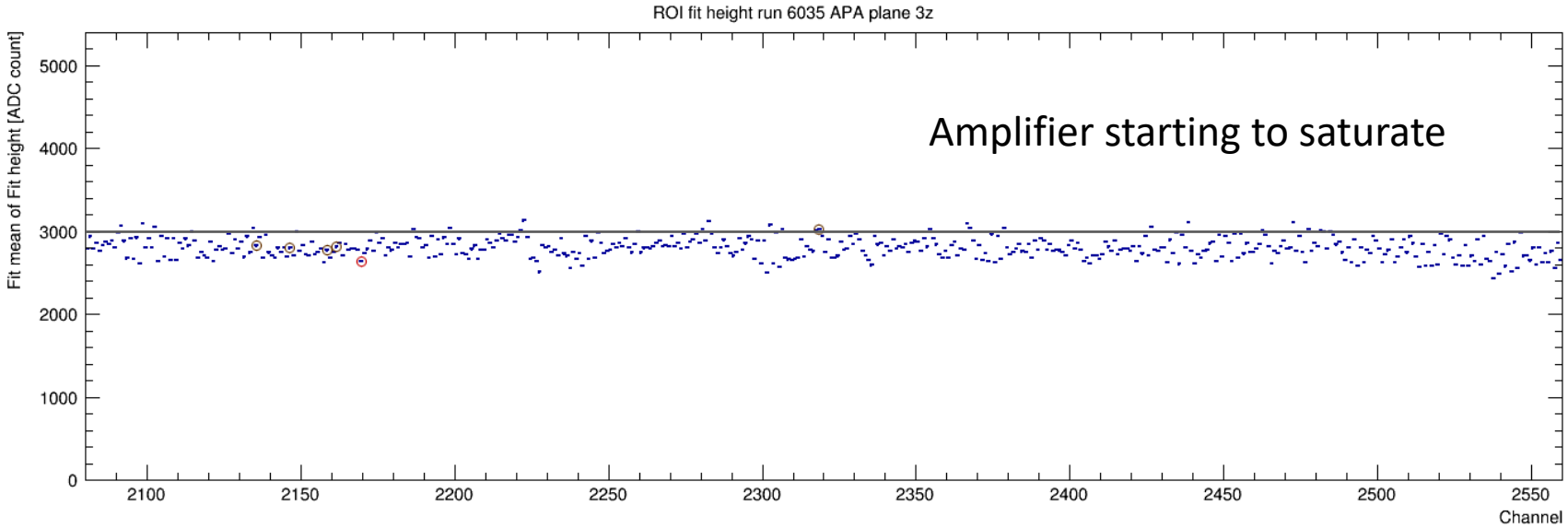


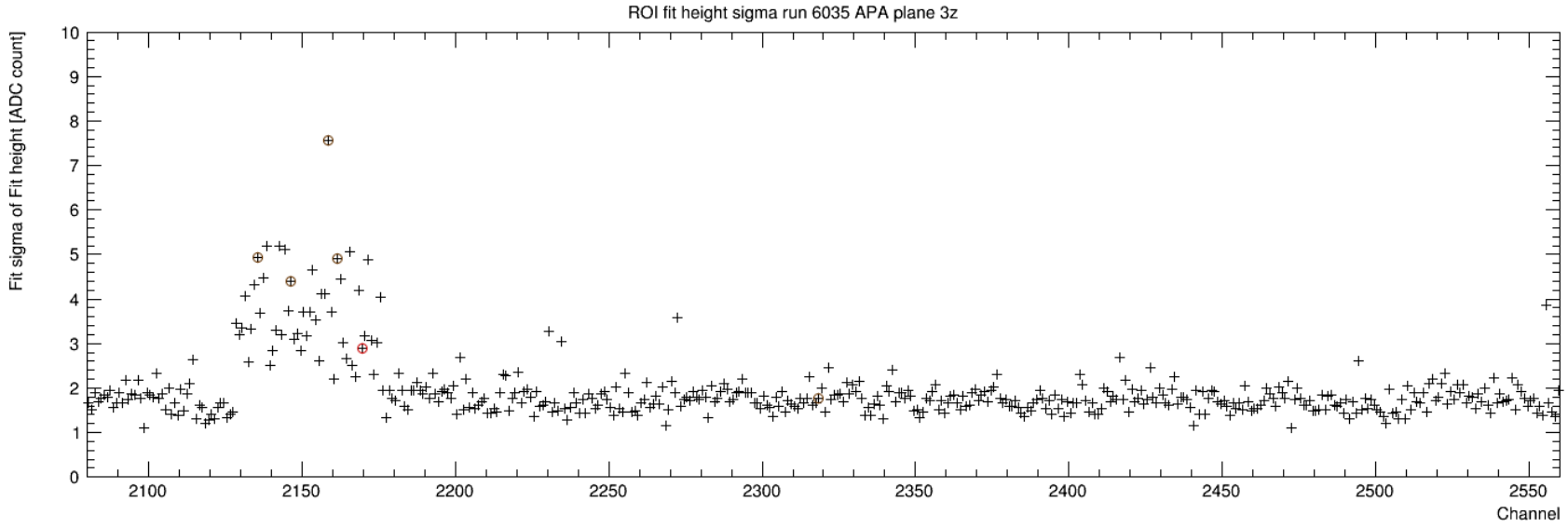
A=15 Fitted height (high threshold)



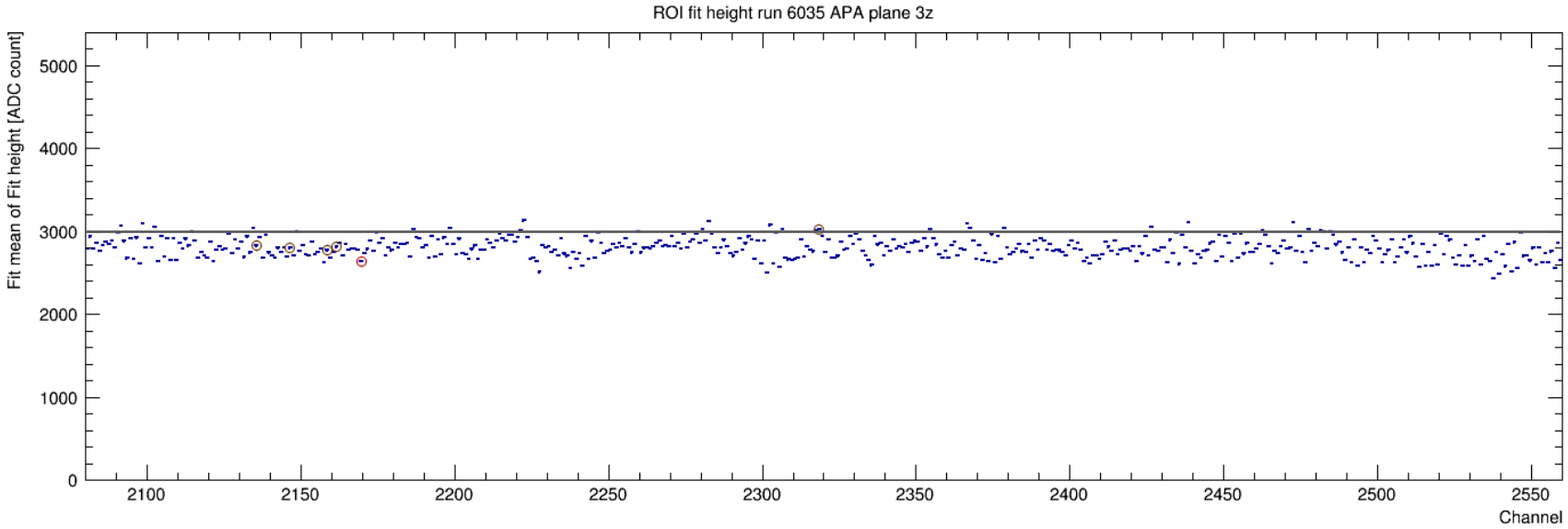


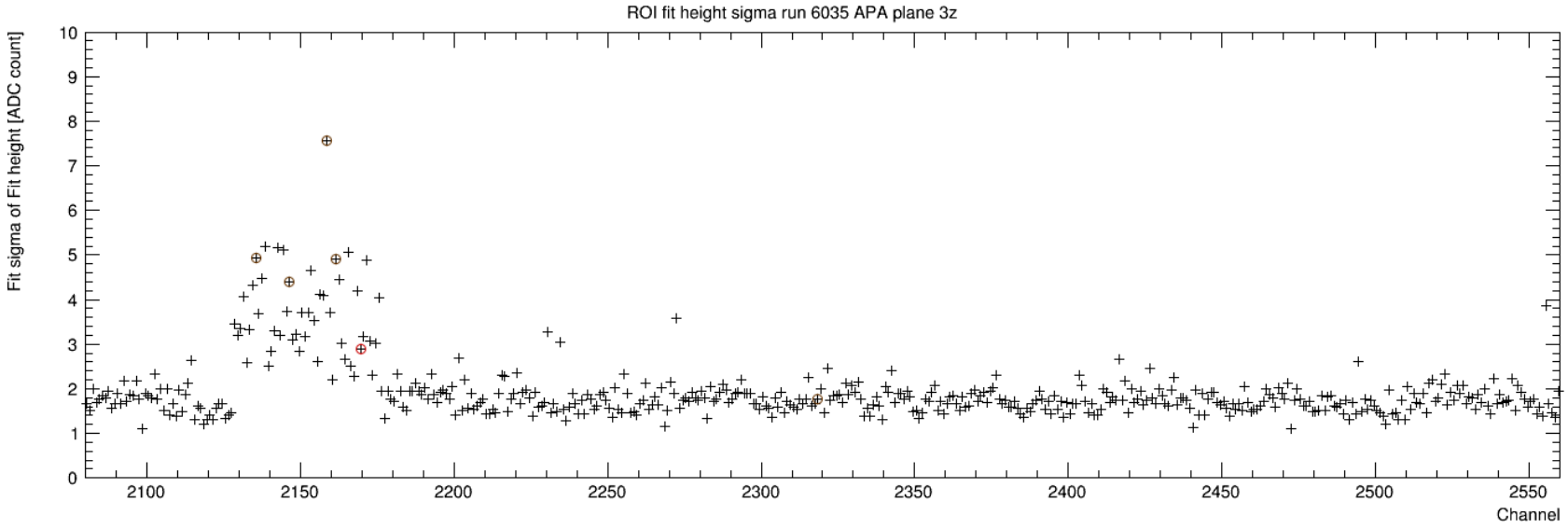
A=18 Fitted height (low threshold)



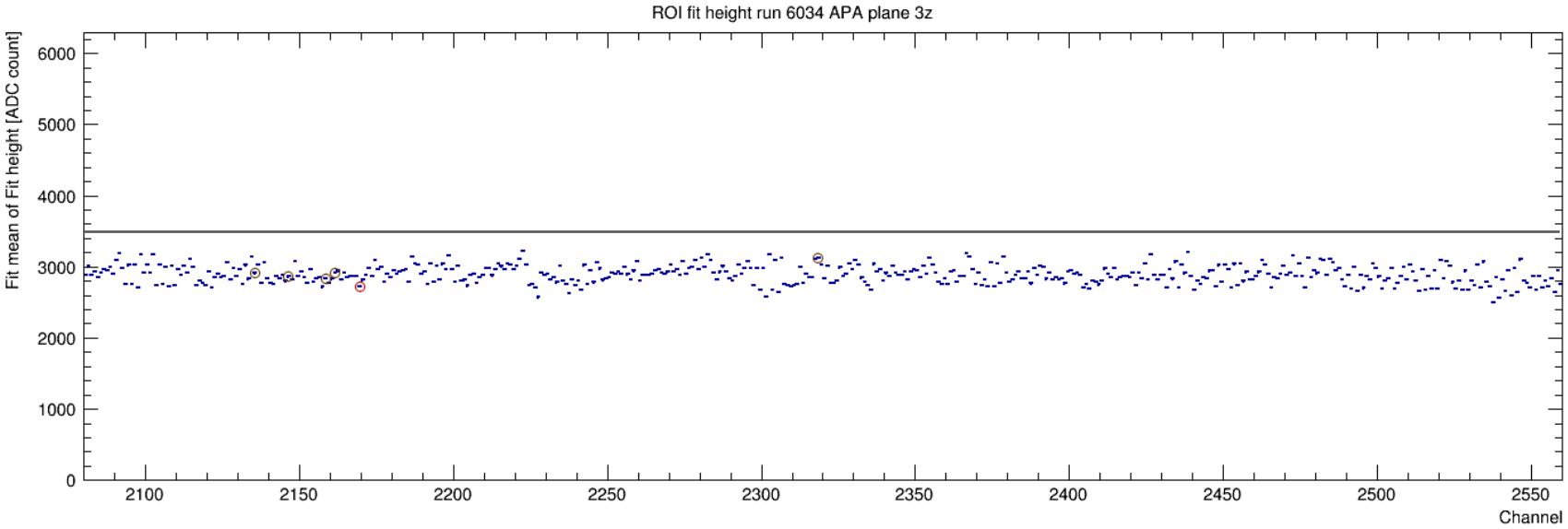


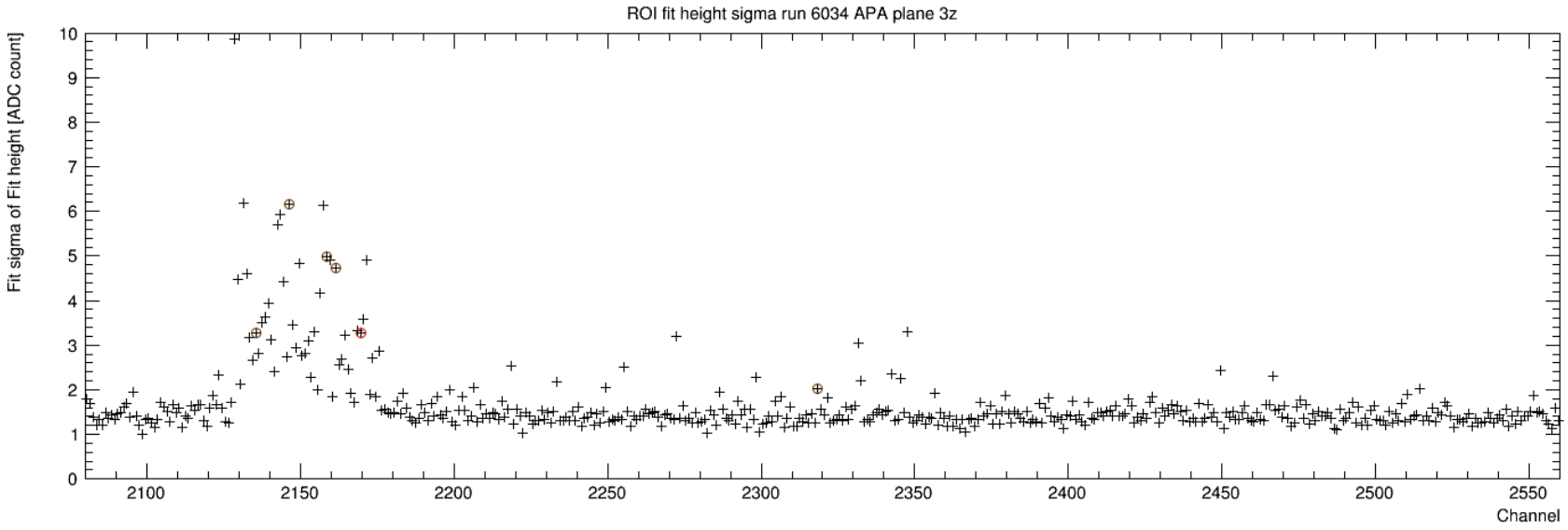
A=18 Fitted height (high threshold)



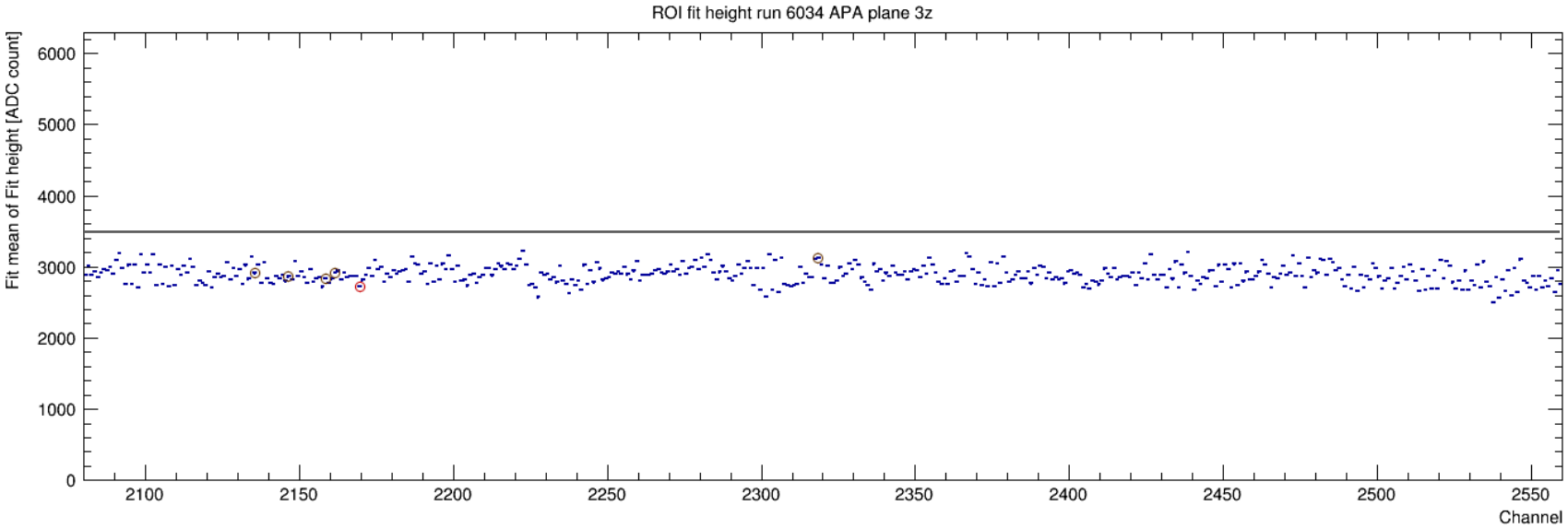


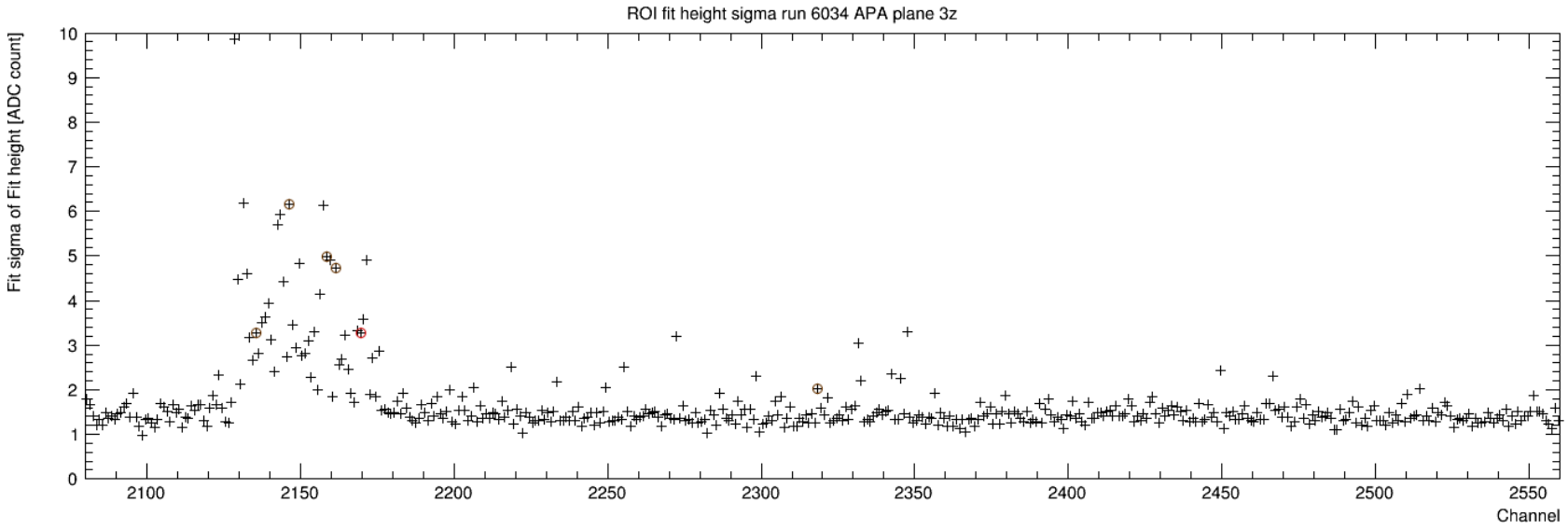
A=21 Fitted height (low threshold)



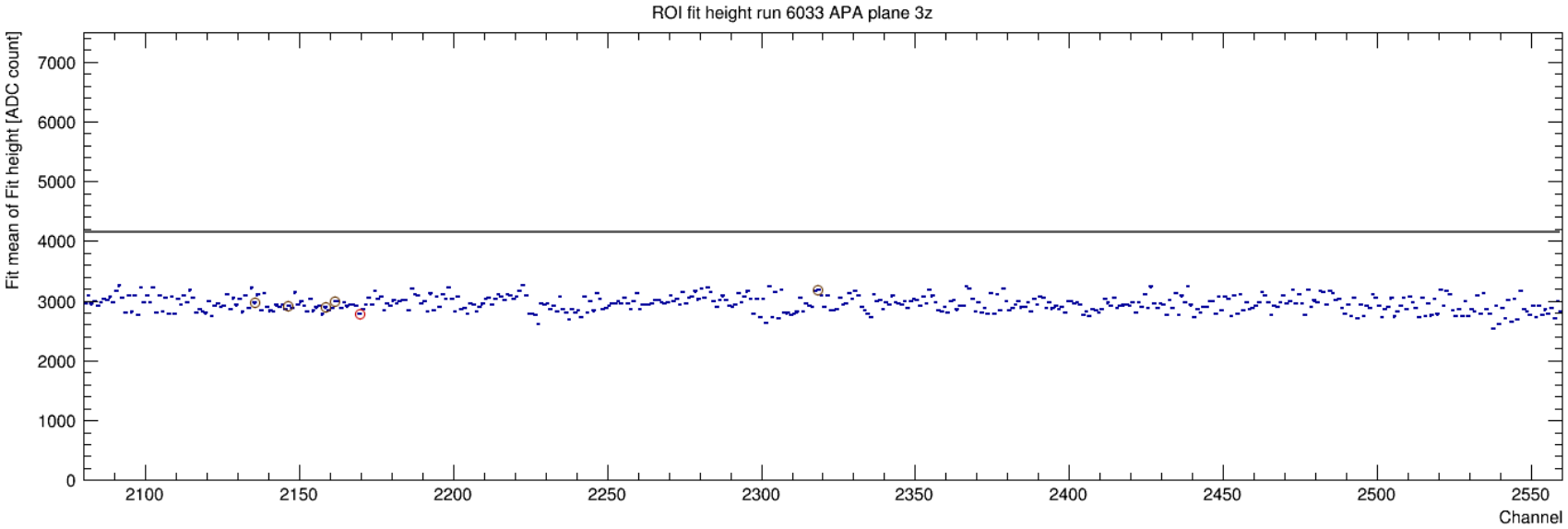


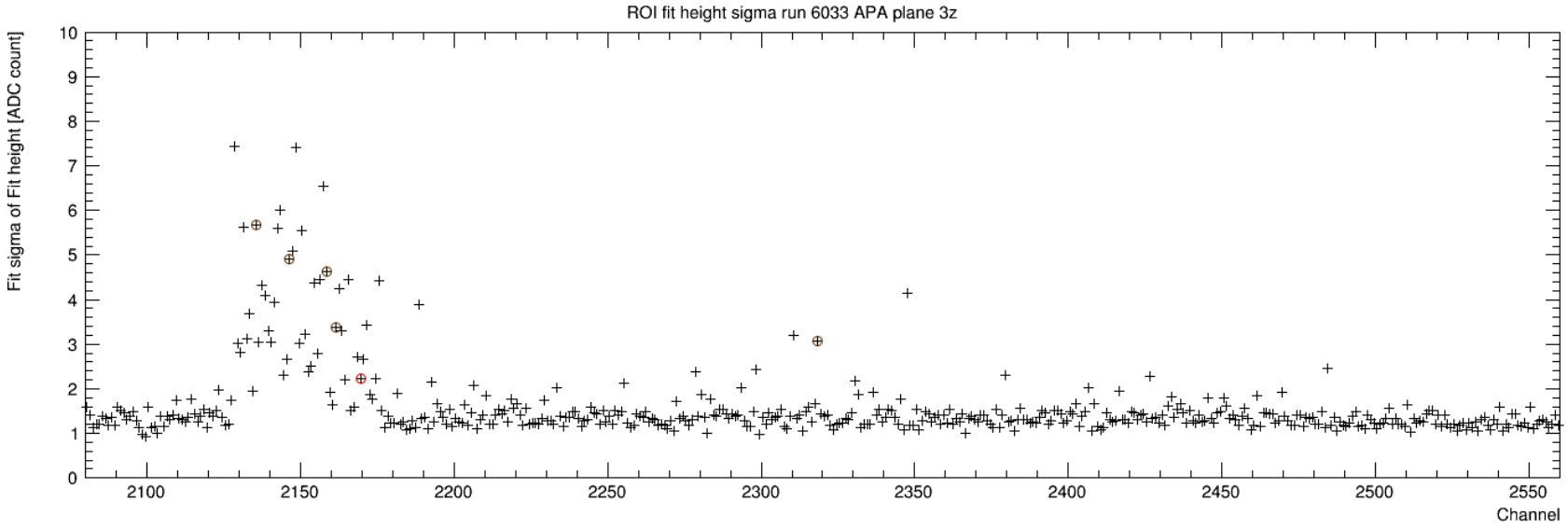
A=21 Fitted height (high threshold)



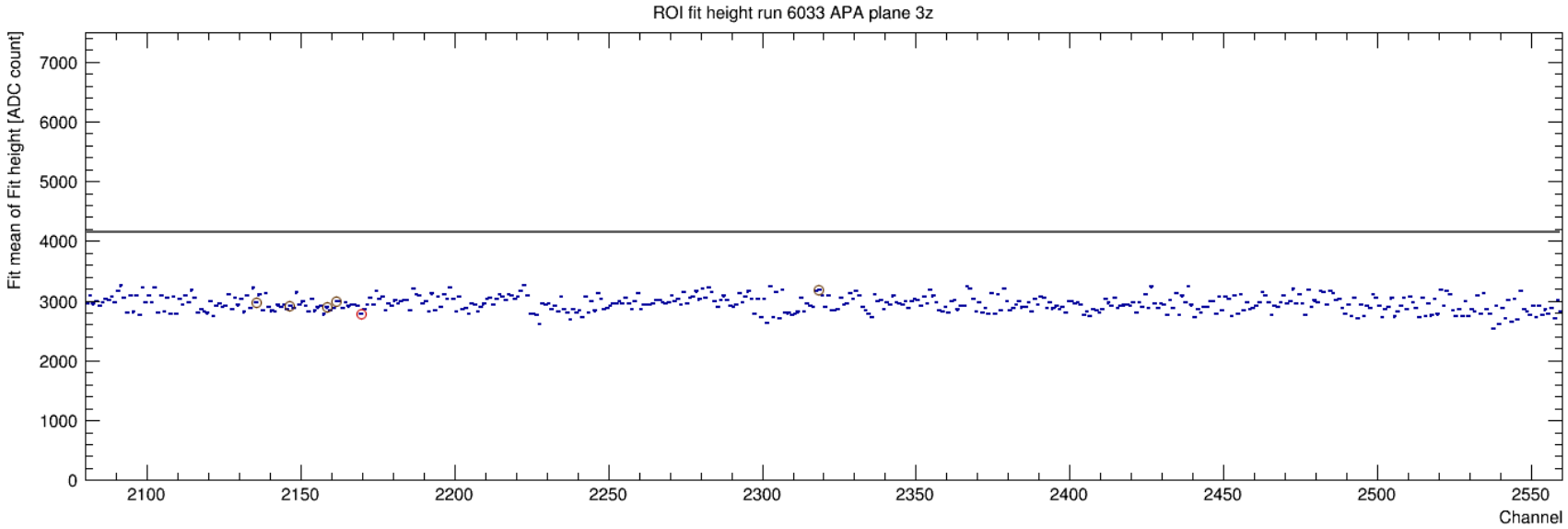


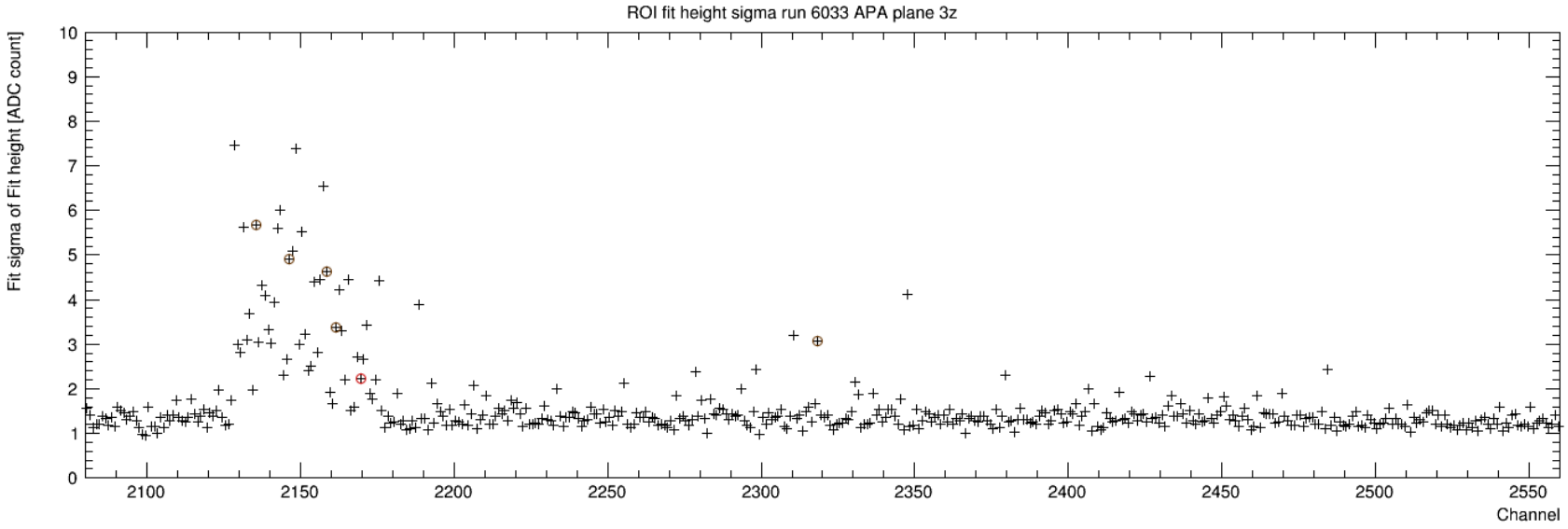
A=25 Fitted height (low threshold)



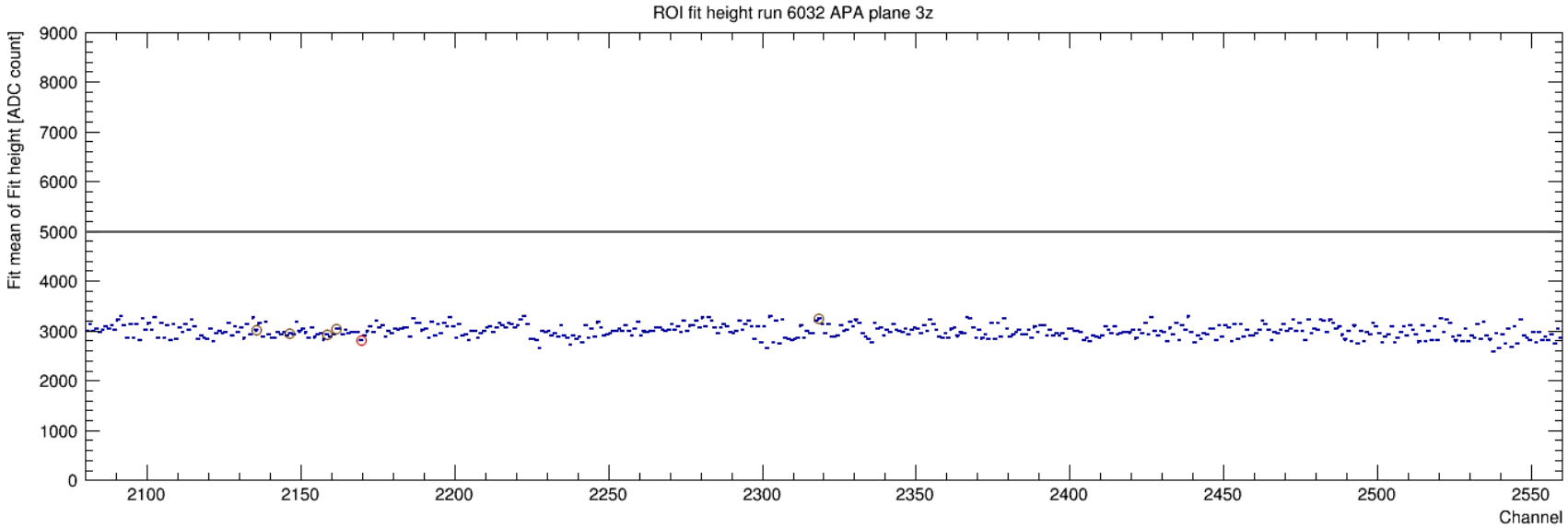


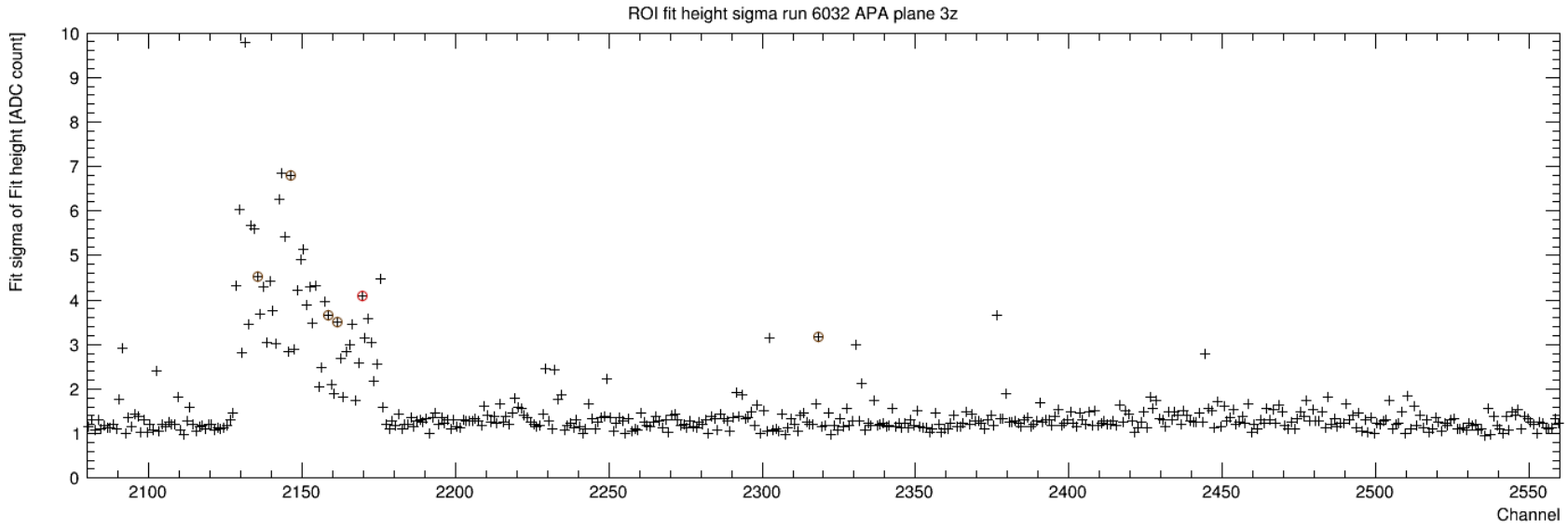
A=25 Fitted height (high threshold)



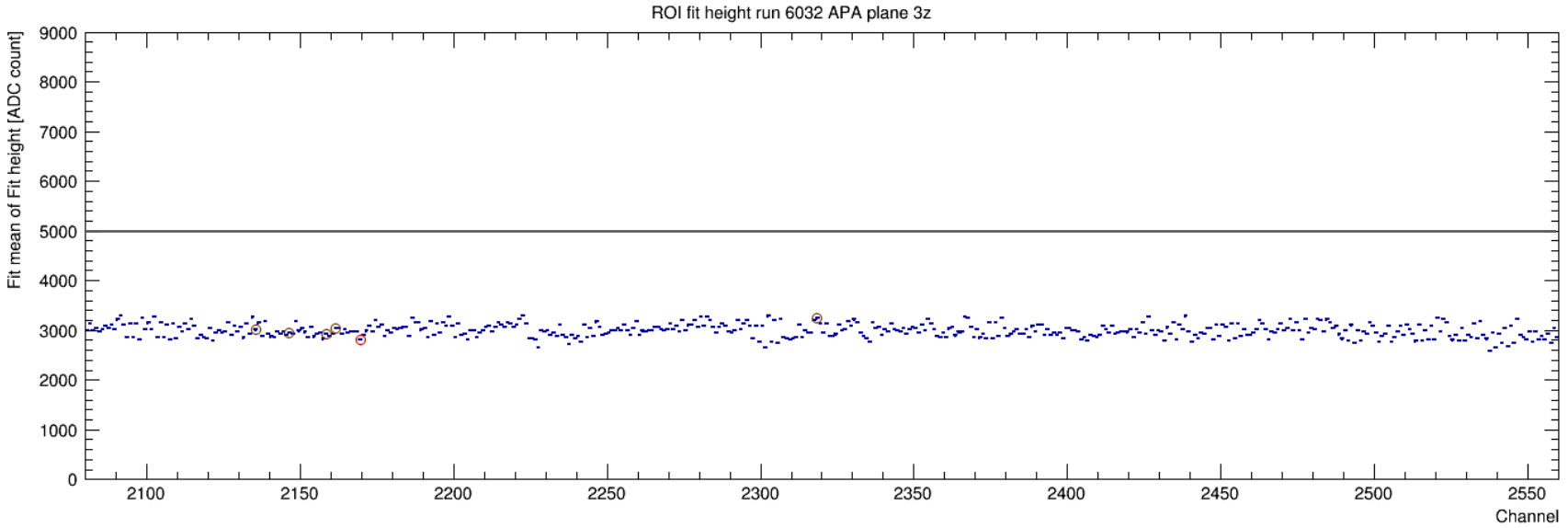


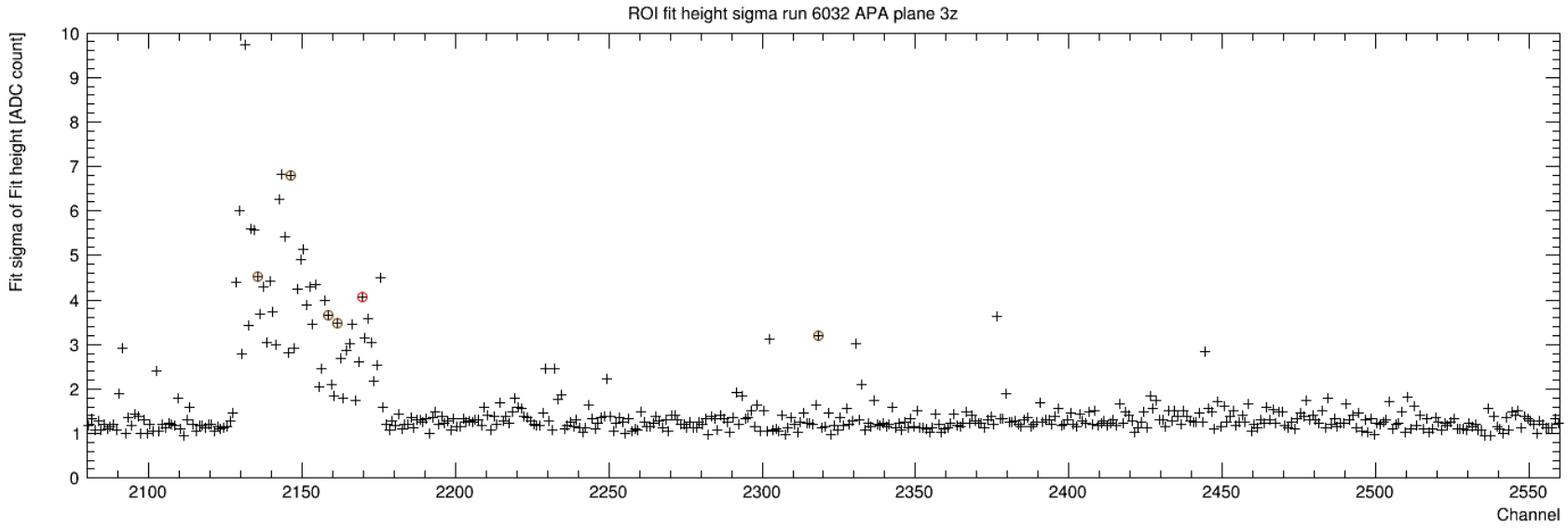
A=30 Fitted height (low threshold)





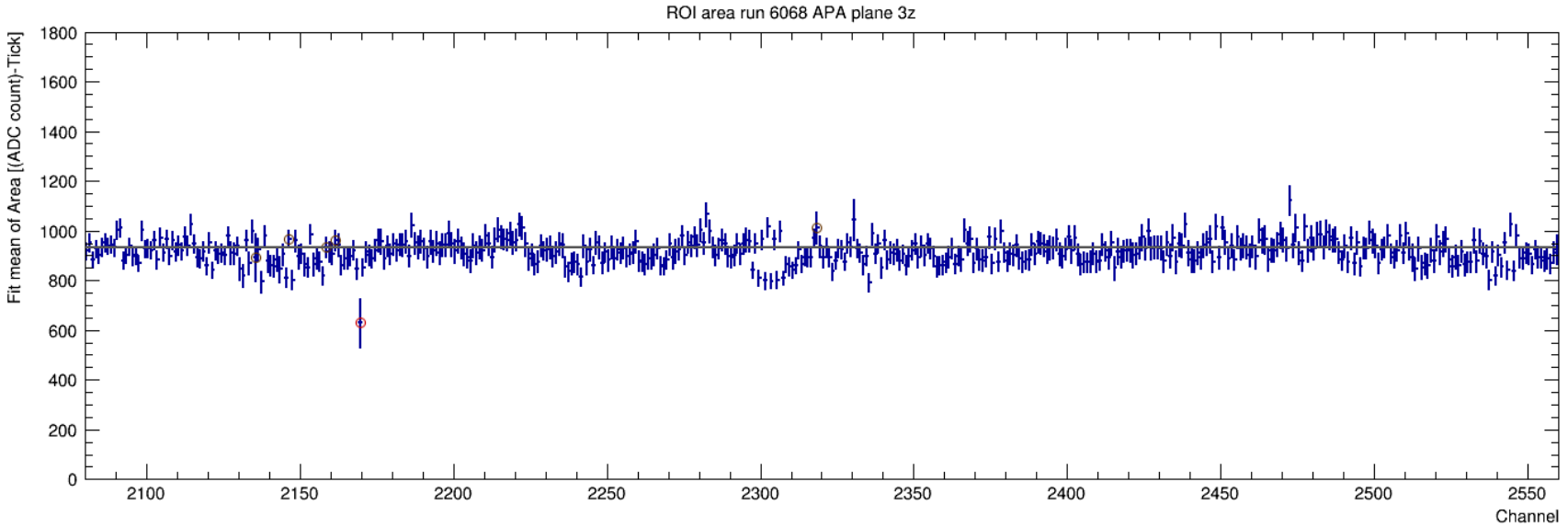
A=30 Fitted height (high threshold)

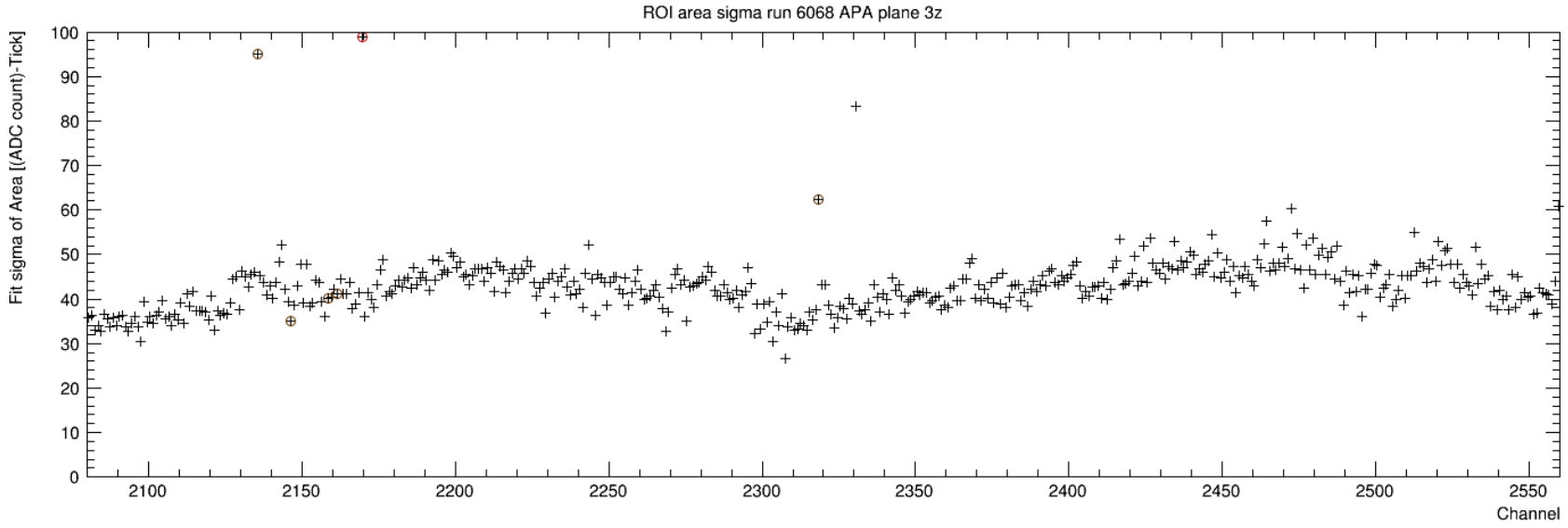




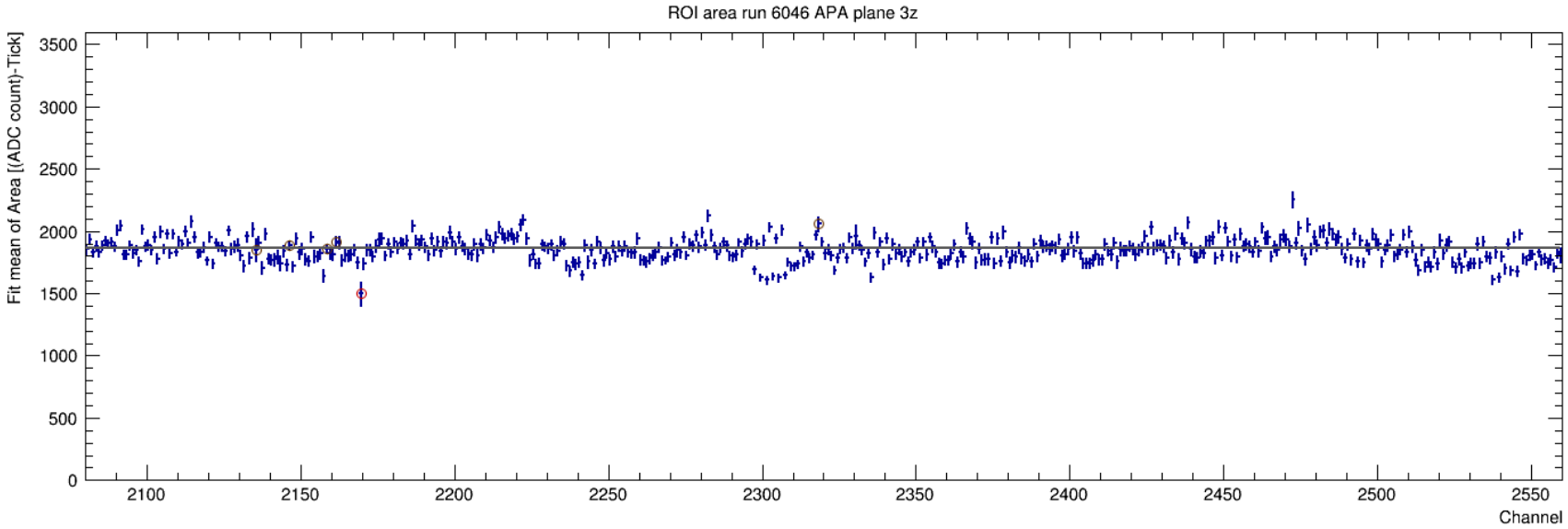
ROI areas

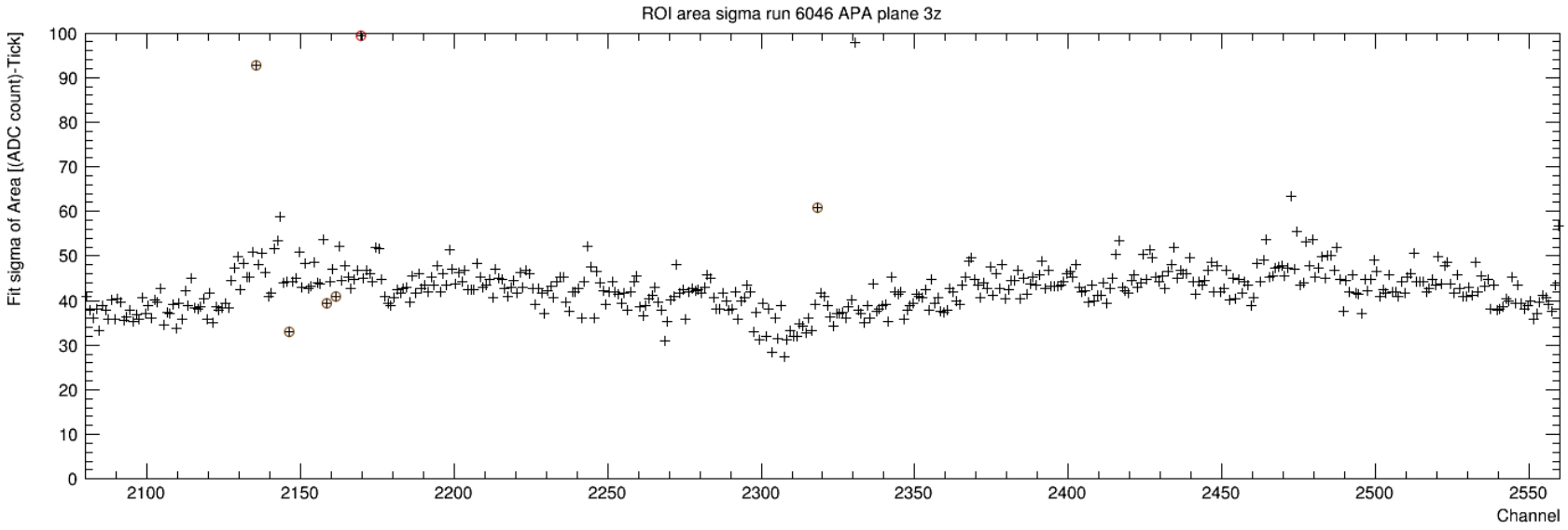
A=1 ROI area


ROI area run 6068 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
Channel

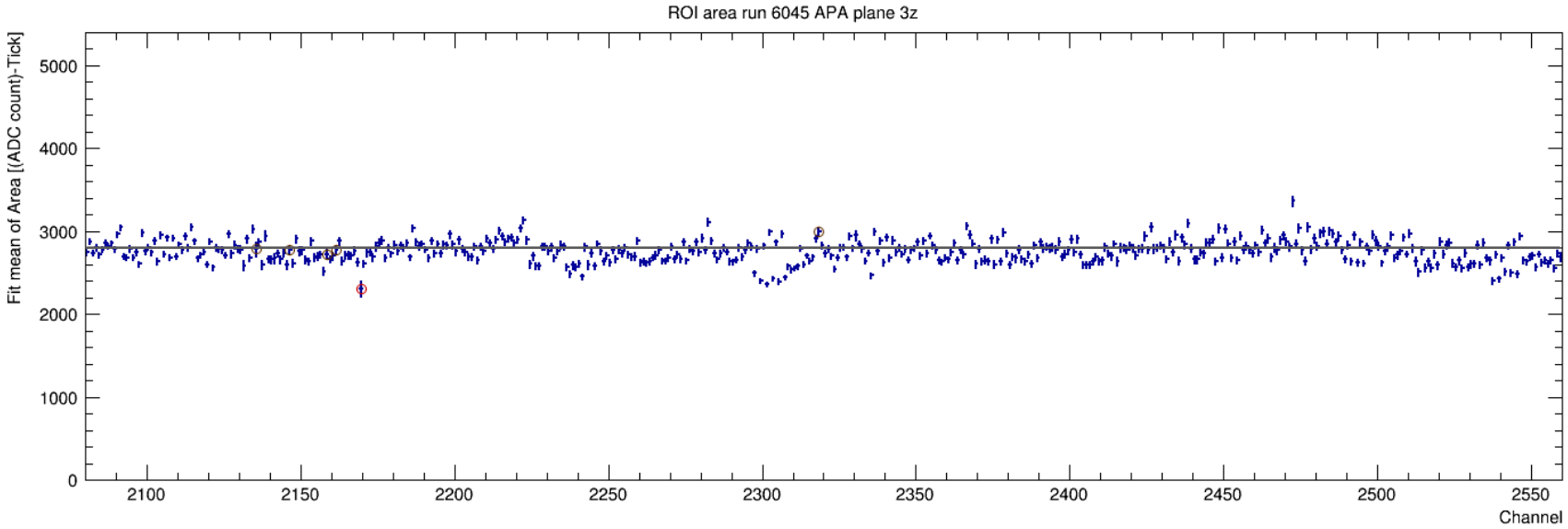

ROI area sigma run 6068 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
Channel

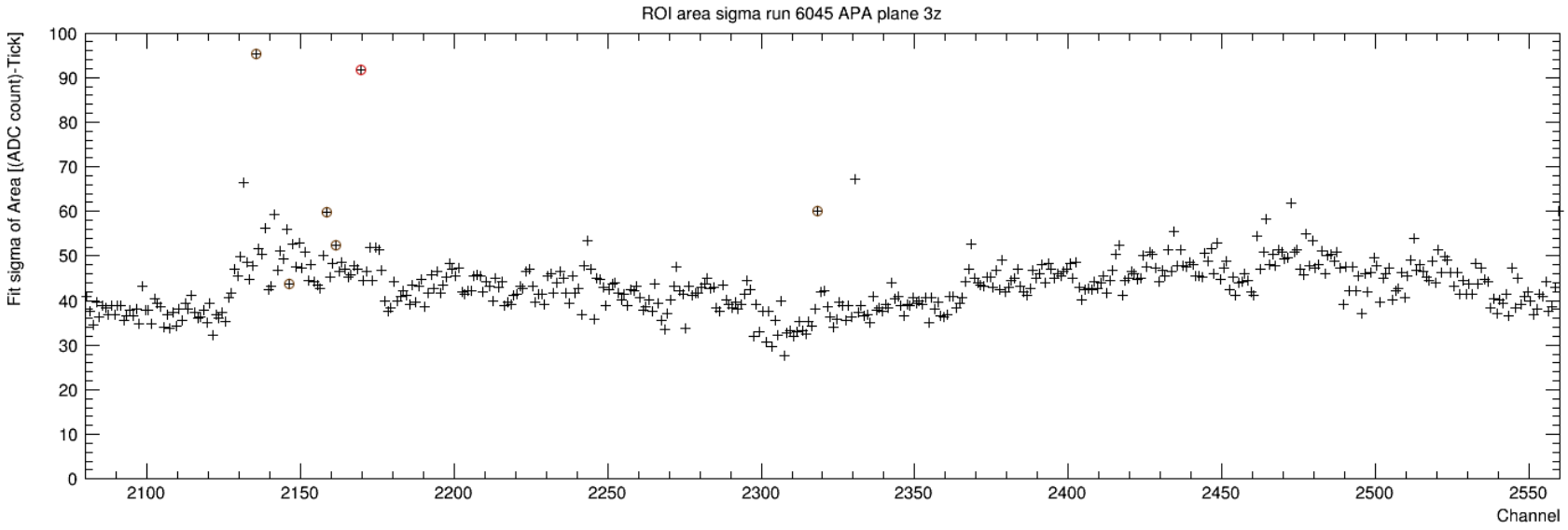
A=2 ROI area


ROI area run 6046 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
3500
3000
2500
2000
1500
1000
500
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

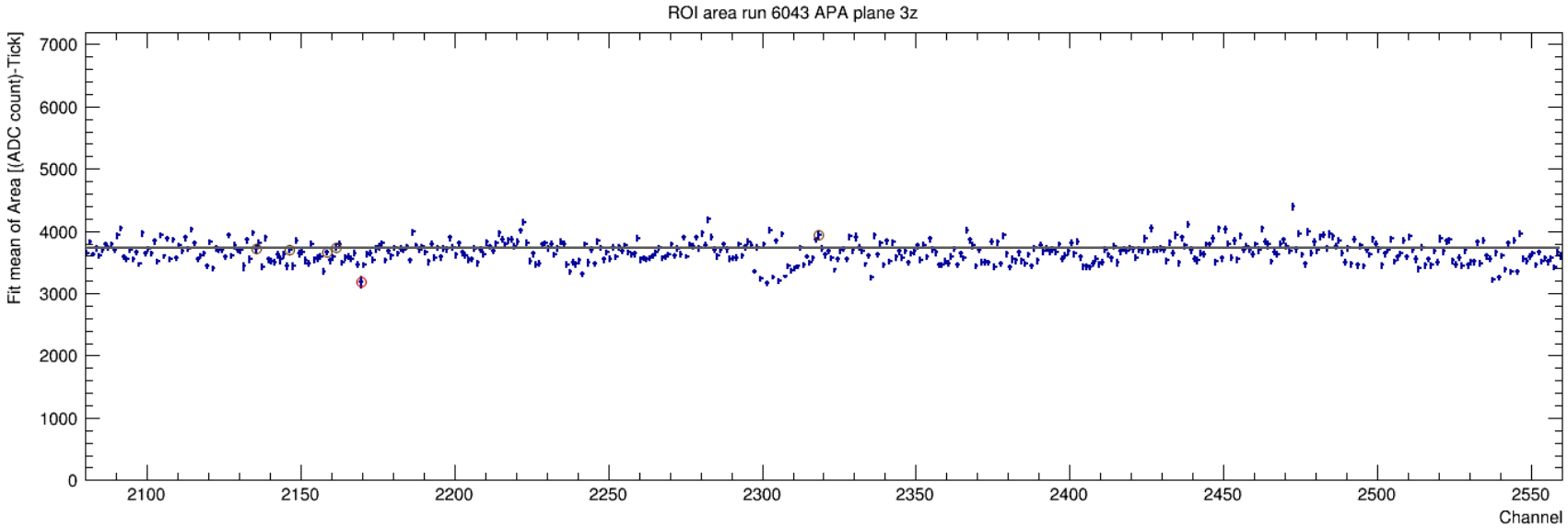

ROI area sigma run 6046 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

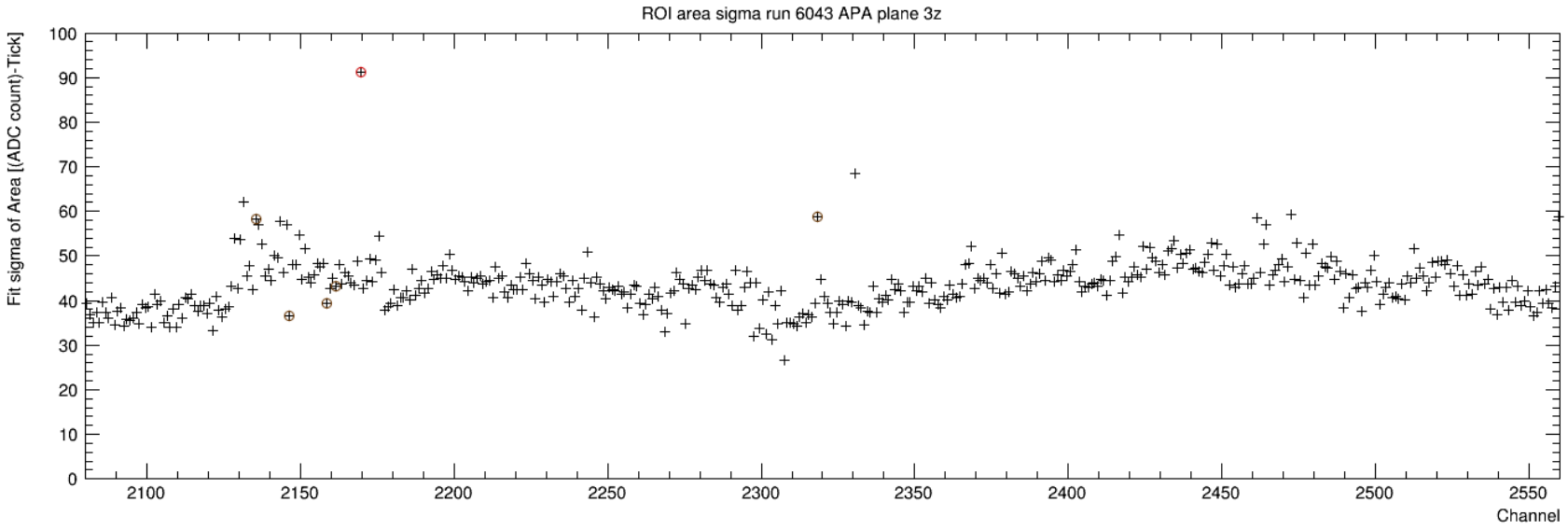
A=3 ROI area


ROI area run 6045 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
5000
4000
3000
2000
1000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

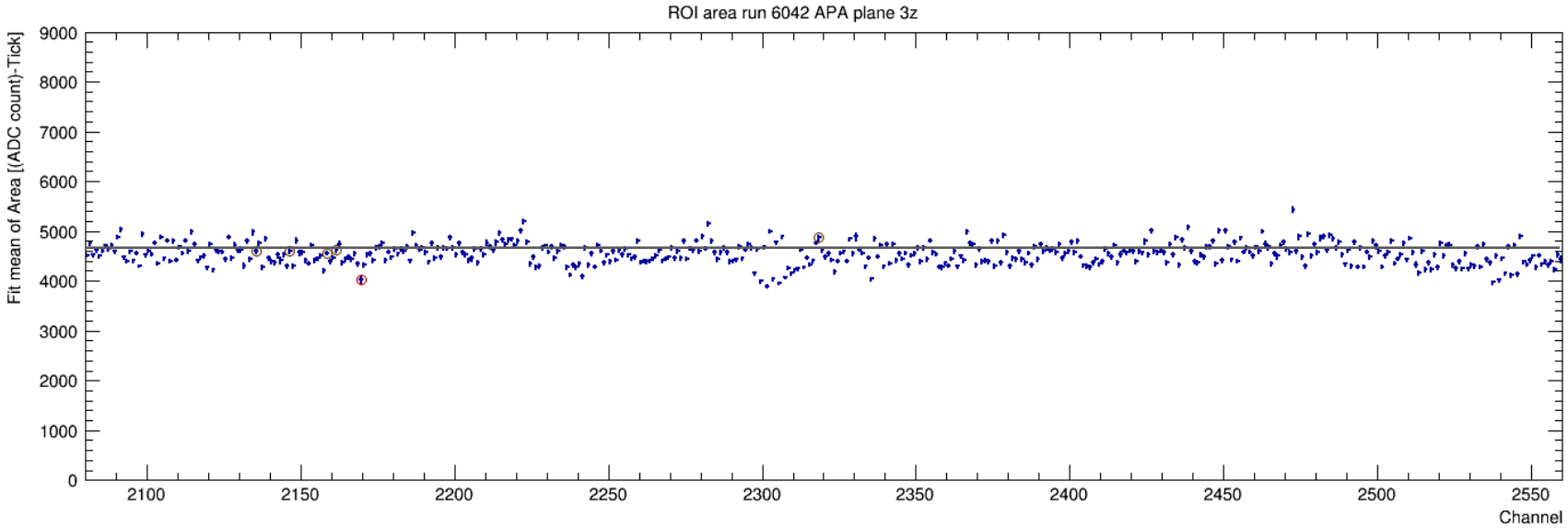

ROI area sigma run 6045 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

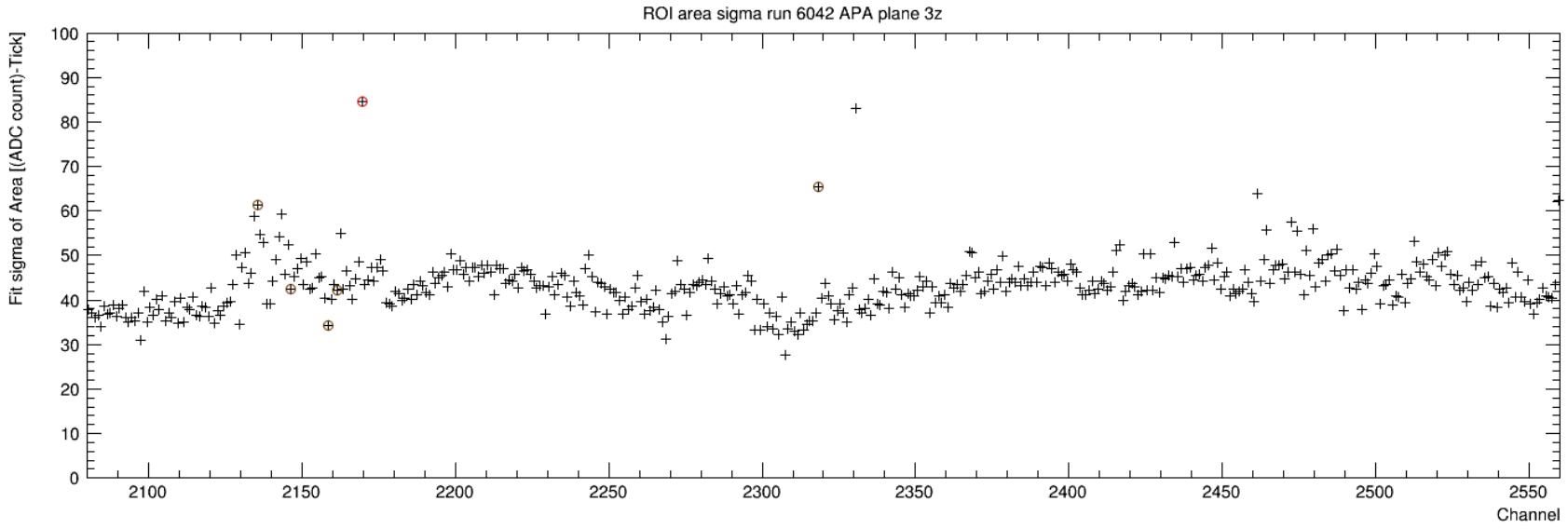
A=4 ROI area


ROI area run 6043 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
7000
6000
5000
4000
3000
2000
1000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

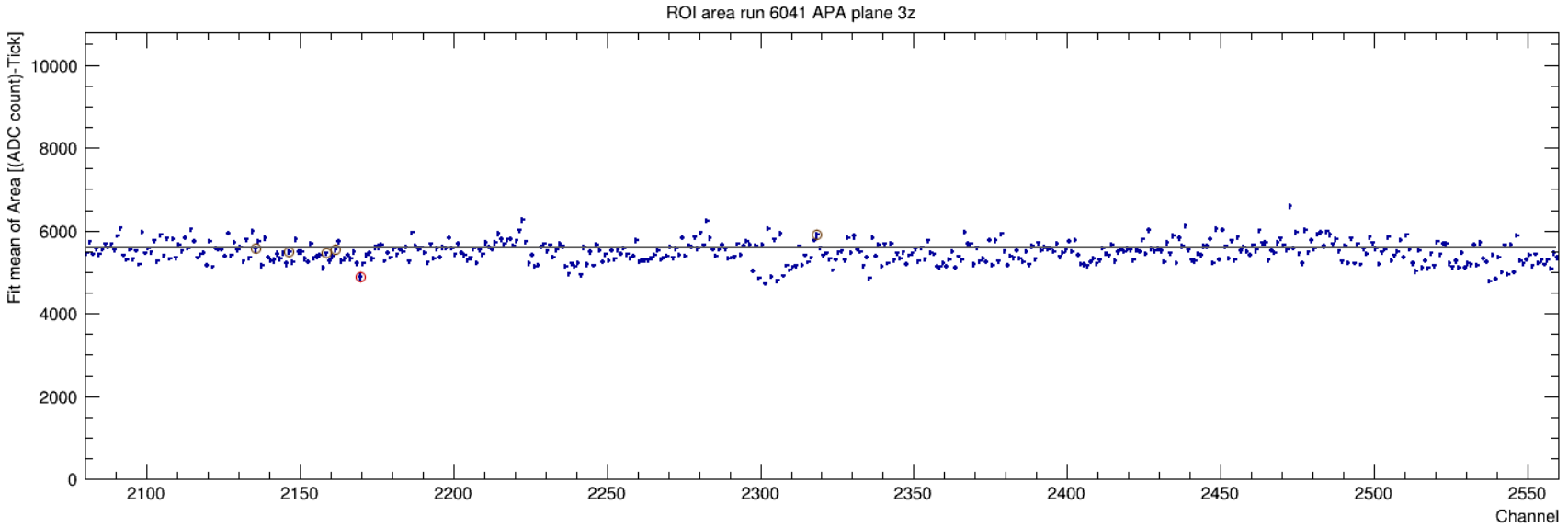

ROI area sigma run 6043 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

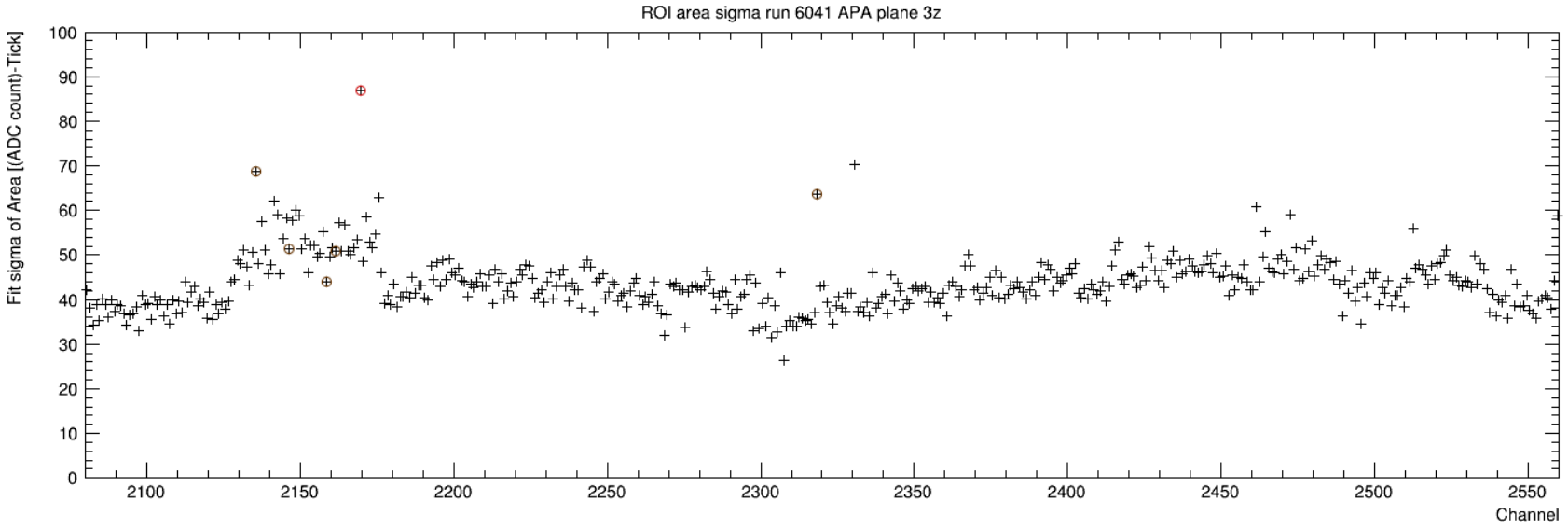
A=5 ROI area


ROI area run 6042 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

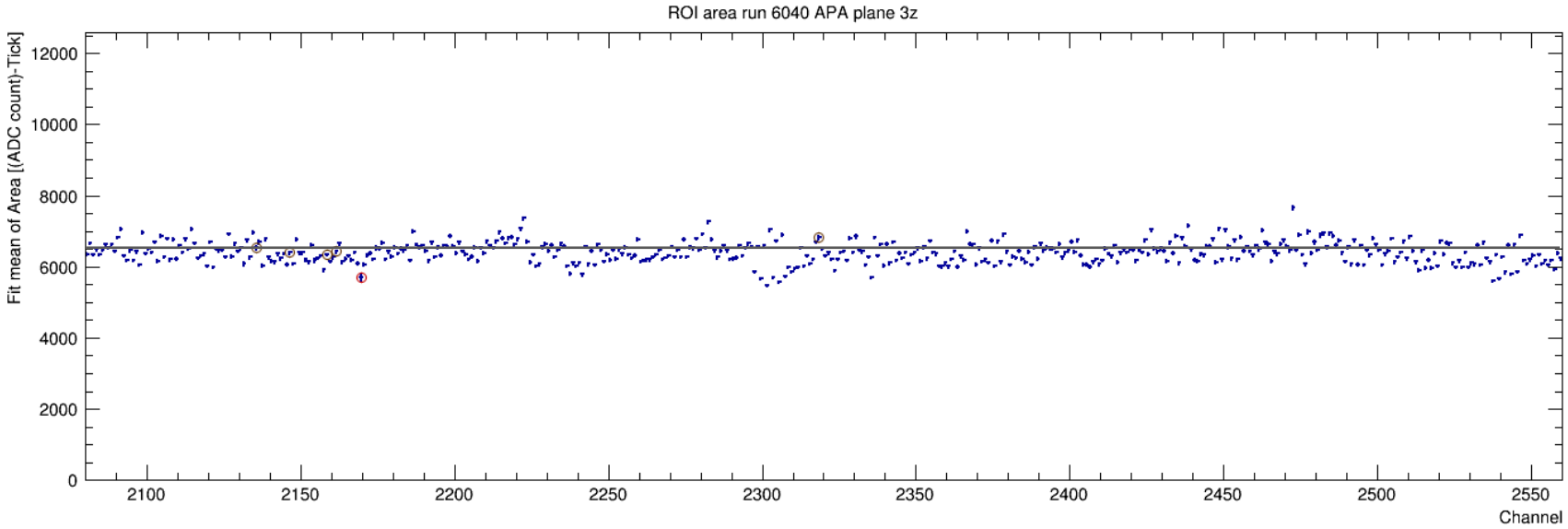

ROI area sigma run 6042 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

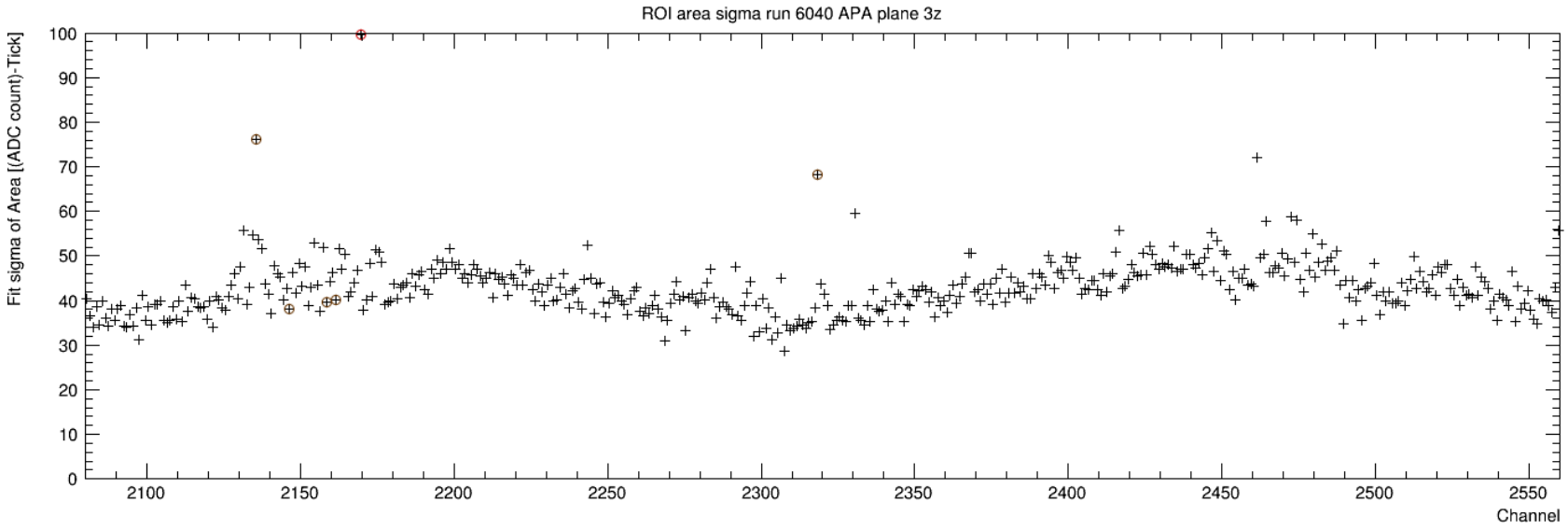
A=6 ROI area


ROI area run 6041 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
10000
8000
6000
4000
2000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

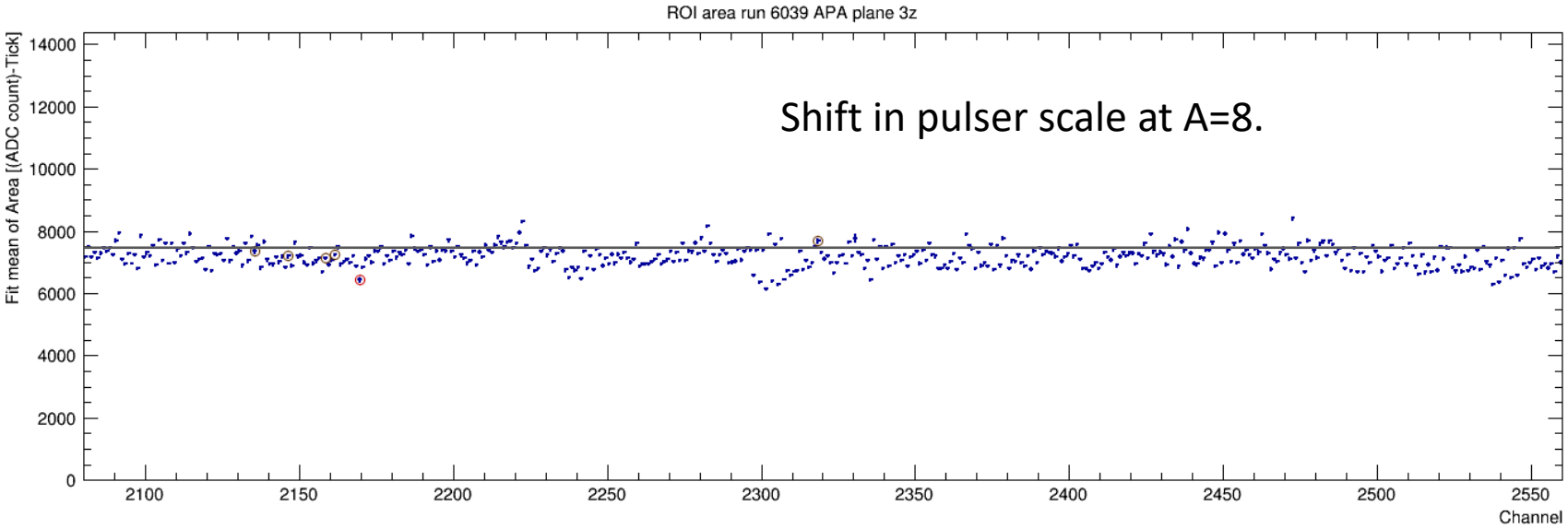

ROI area sigma run 6041 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

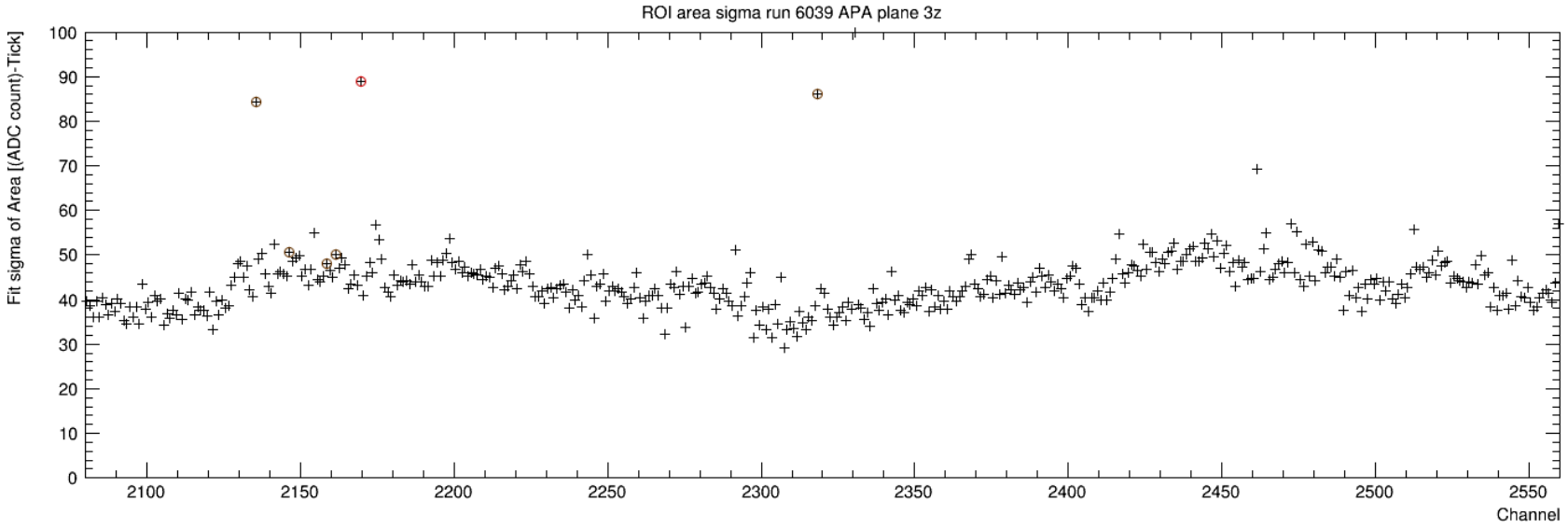
A=7 ROI area


ROI area run 6040 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
0
2000
4000
6000
8000
10000
12000
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

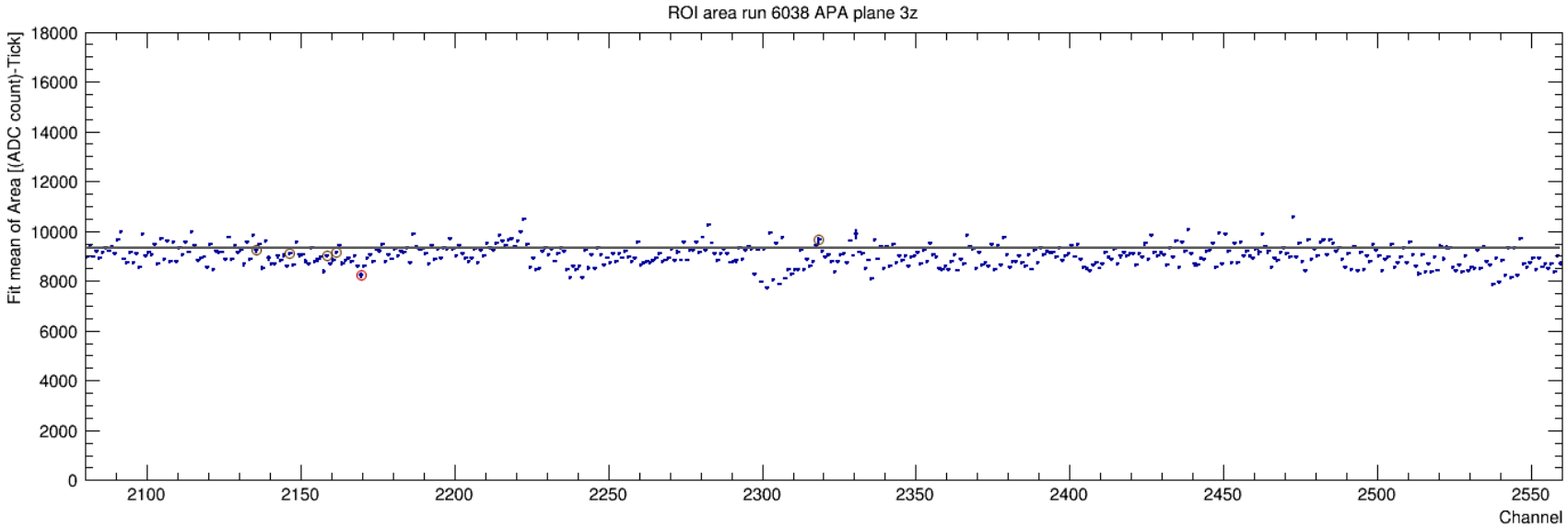

ROI area sigma run 6040 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
0
10
20
30
40
50
60
70
80
90
100
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

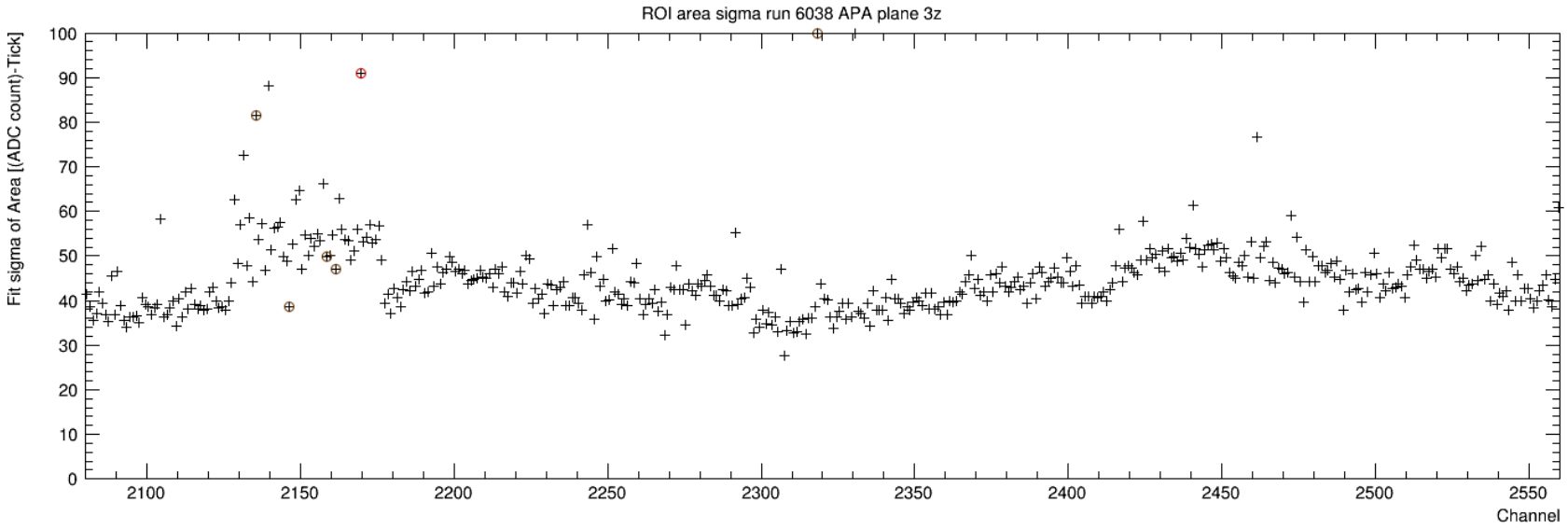
A=8 ROI area


ROI area run 6039 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
Shift in pulser scale at A=8.
Channel

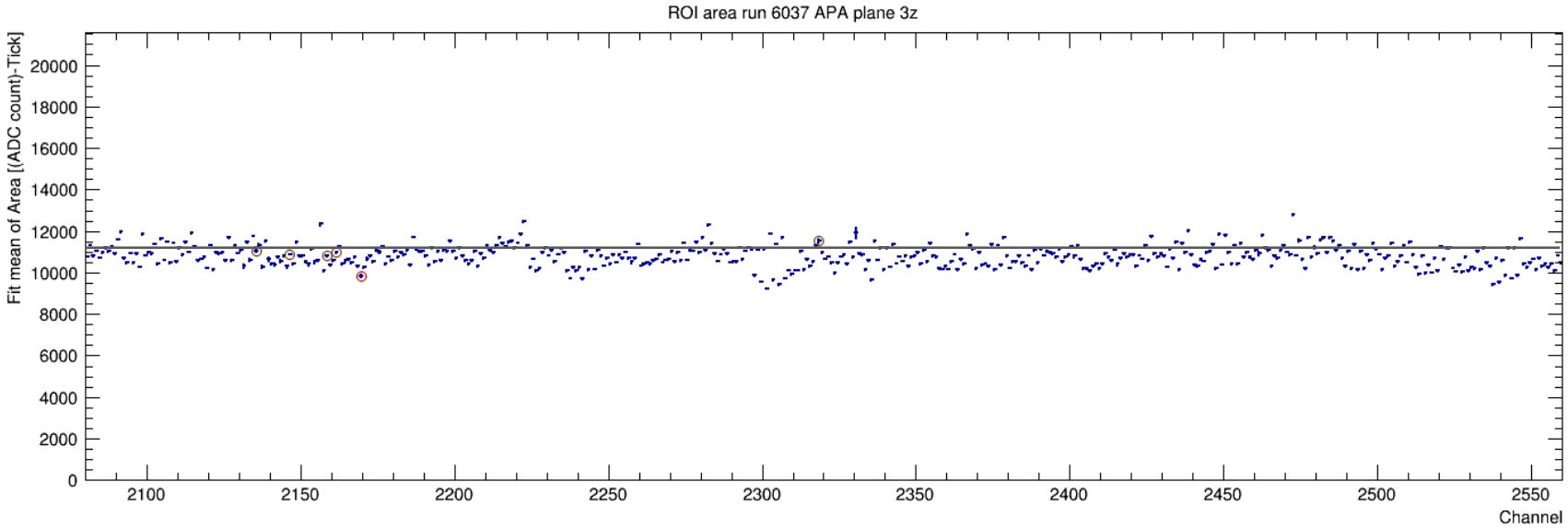

ROI area sigma run 6039 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
Channel

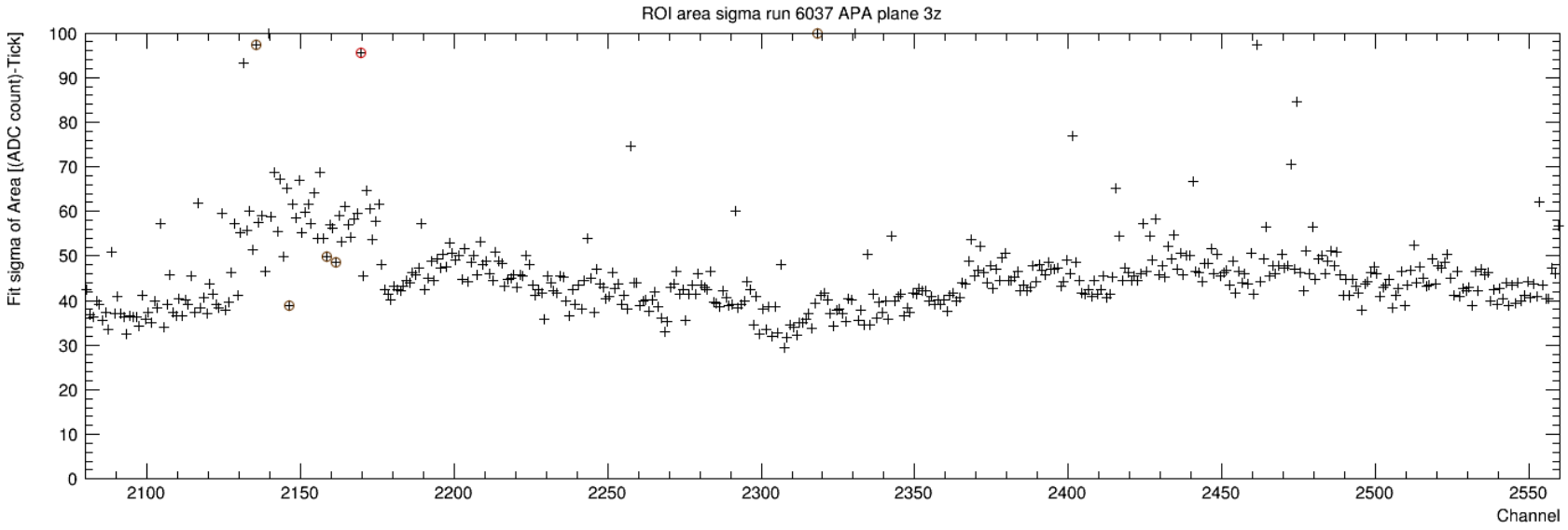
A=10 ROI area


ROI area run 6038 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

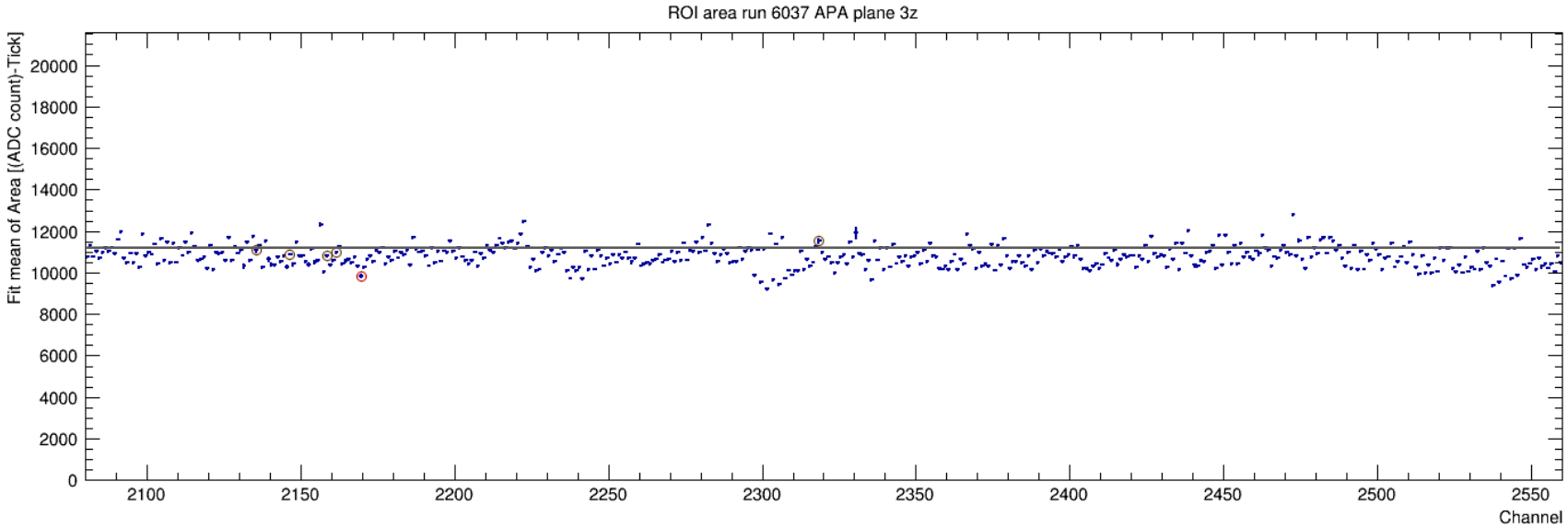

ROI area sigma run 6038 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

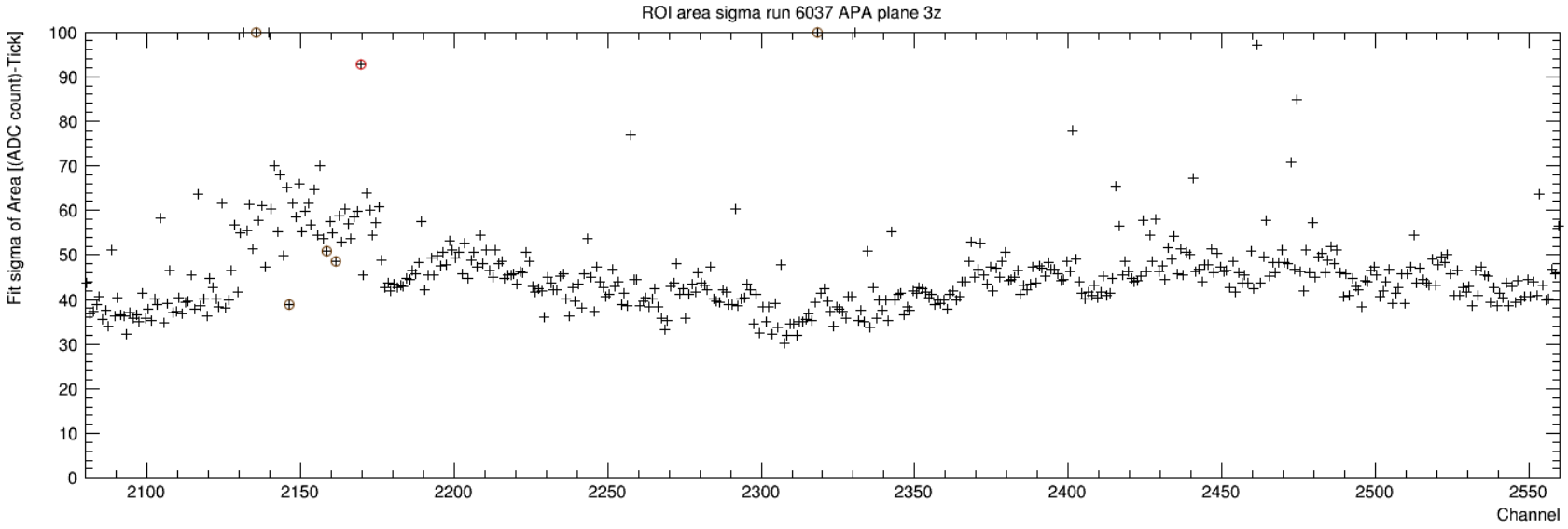
A=12 ROI area (low threshold)



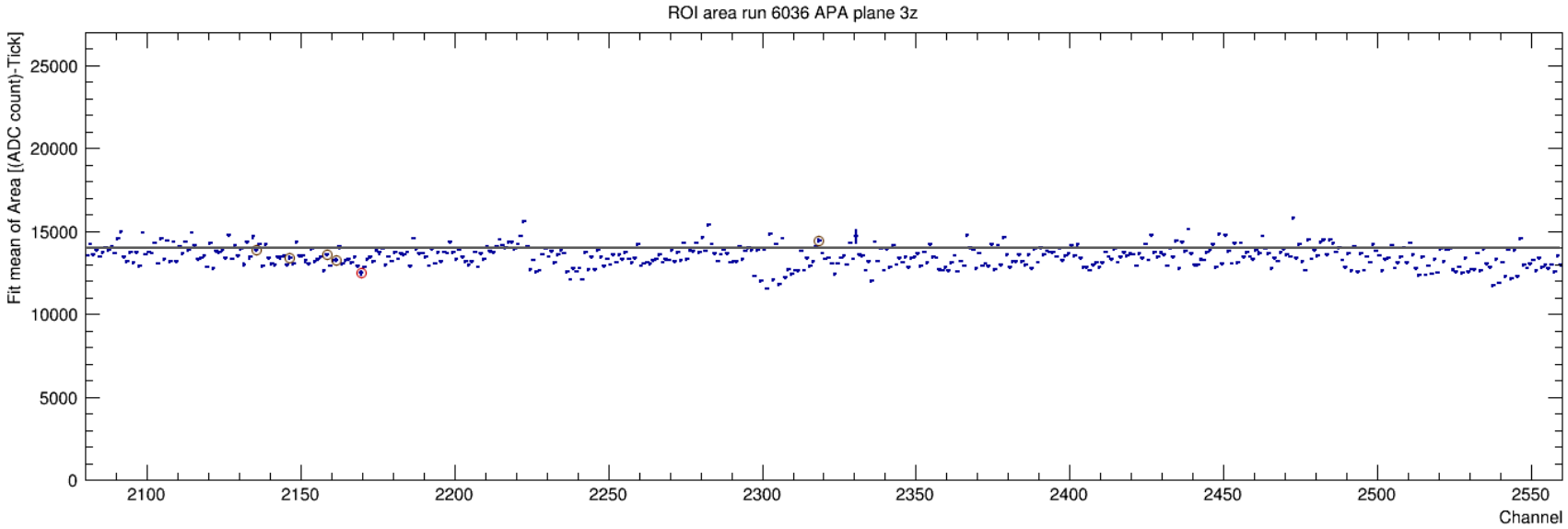


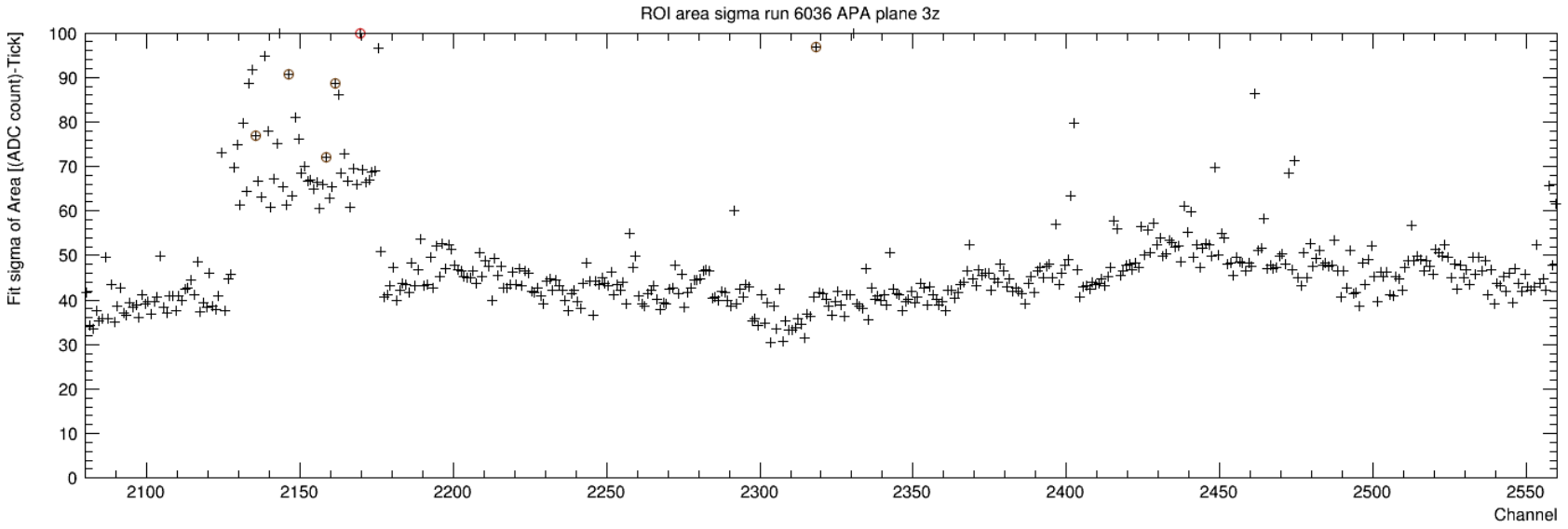
A=12 ROI area (high threshold)



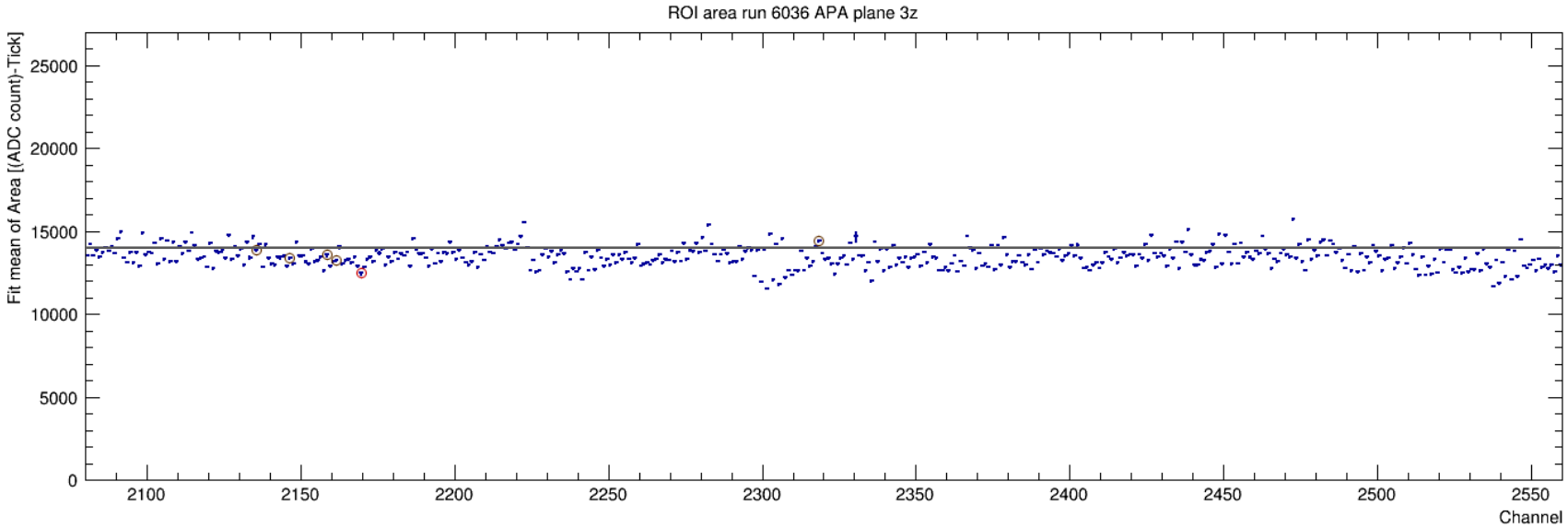


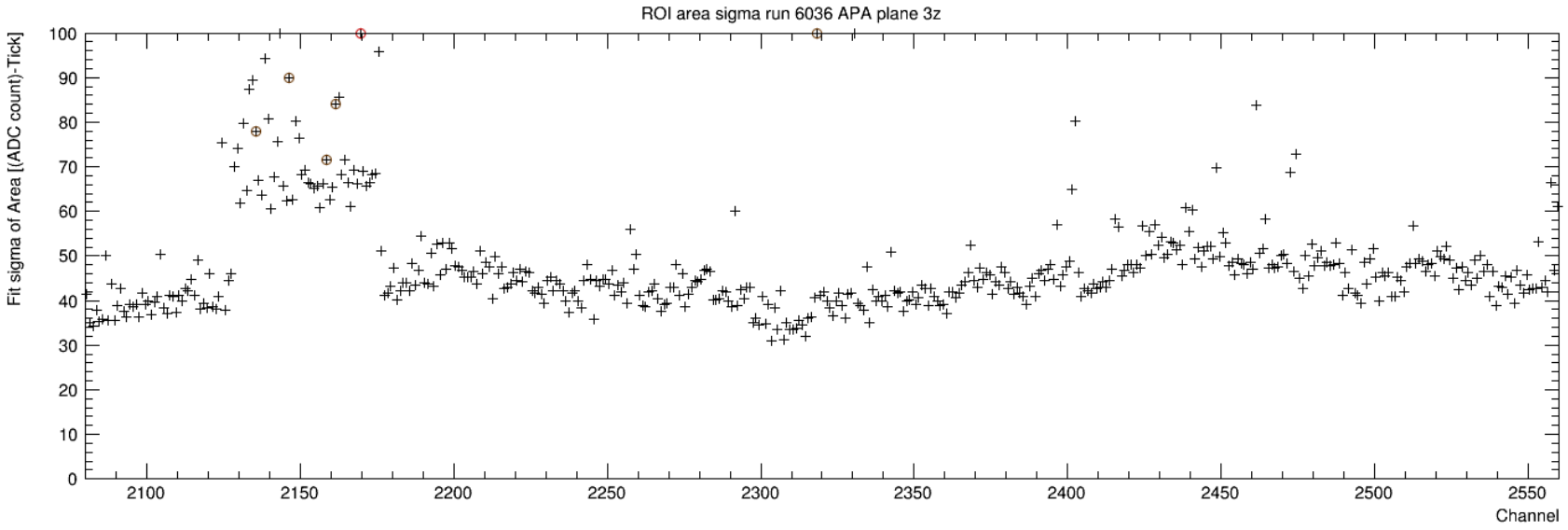
A=15 ROI area (low threshold)



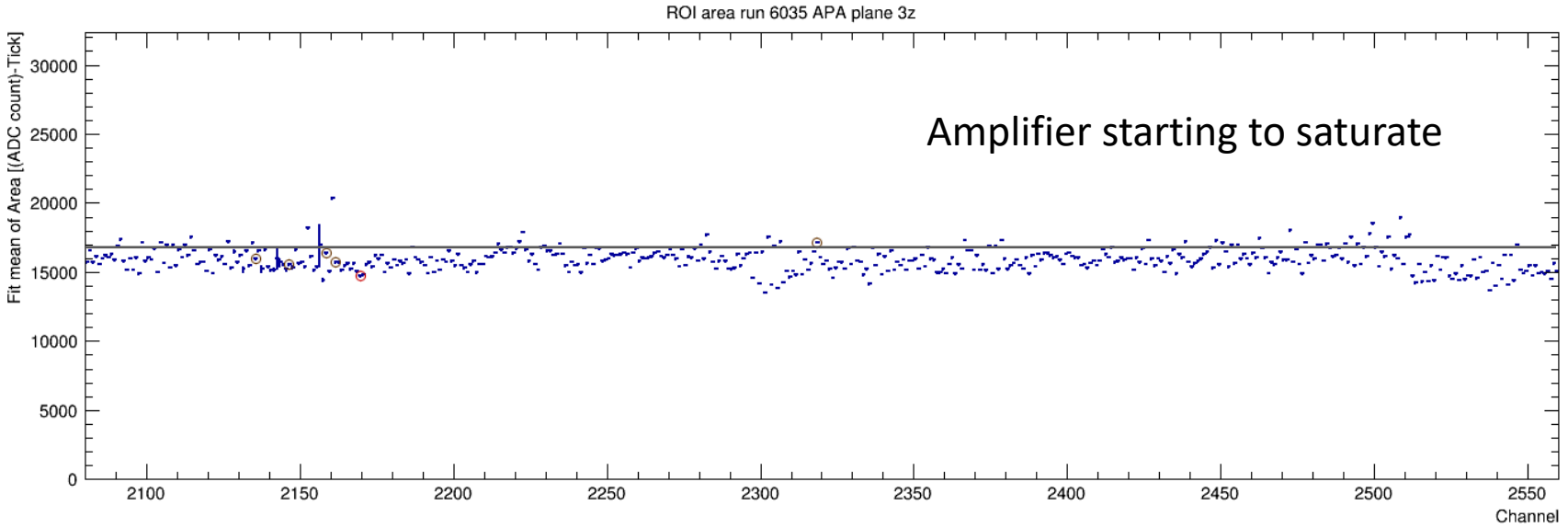


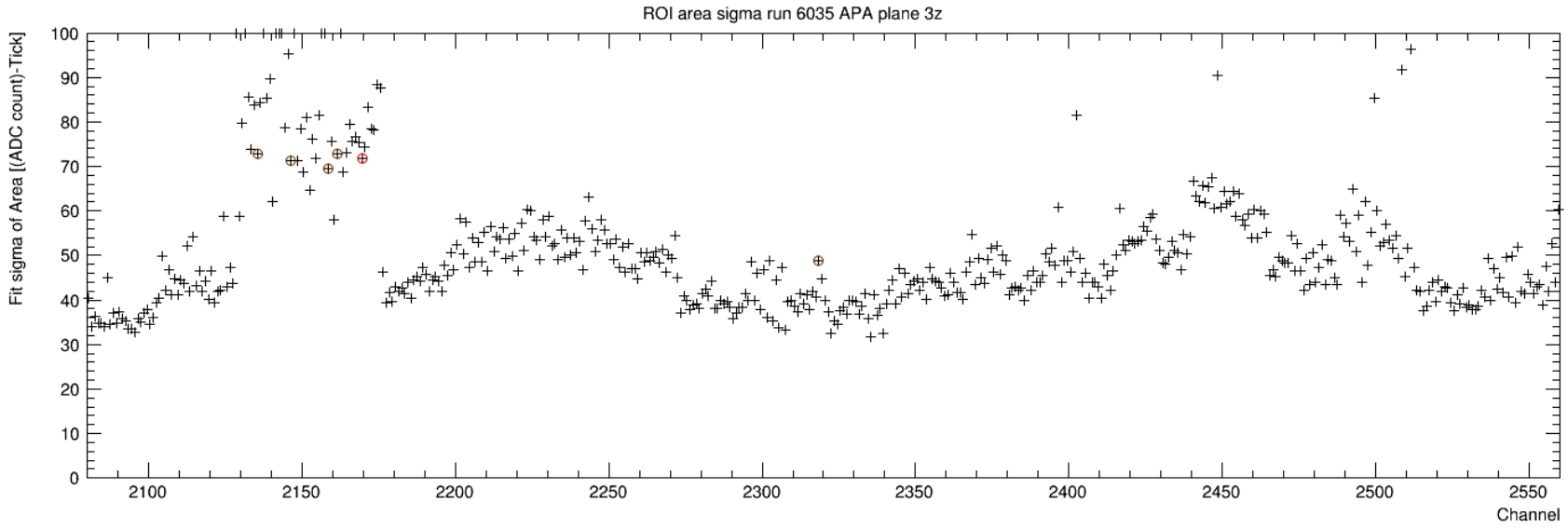
A=15 ROI area (high threshold)



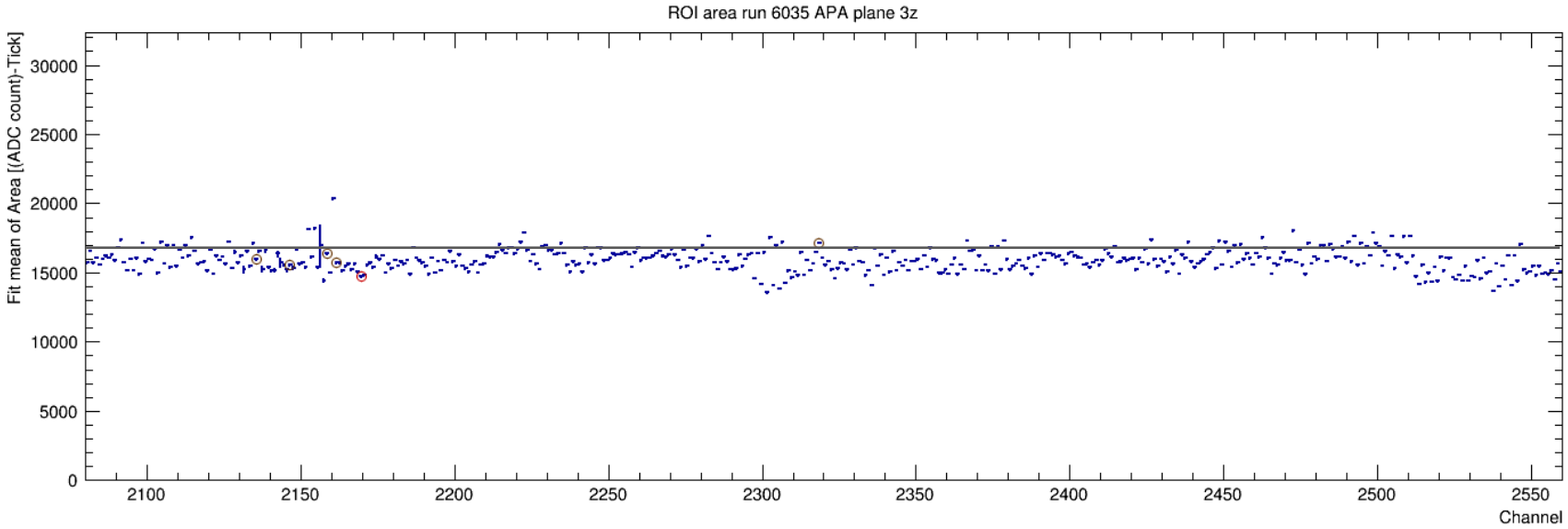


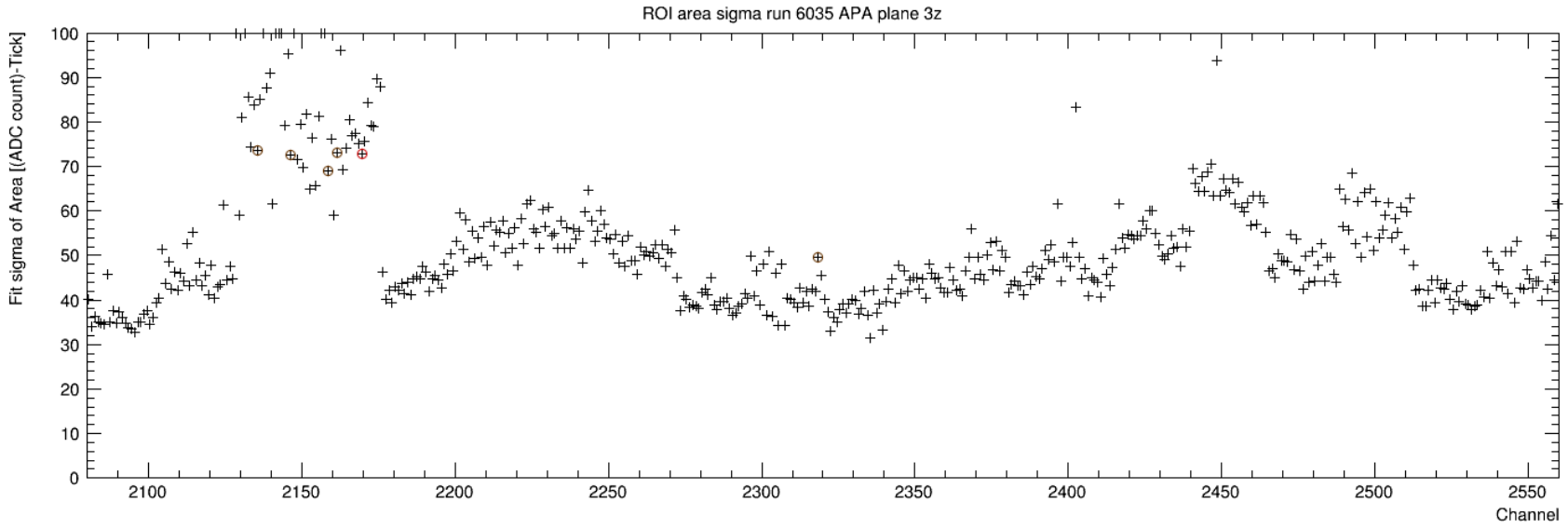
A=18 ROI area (low threshold)



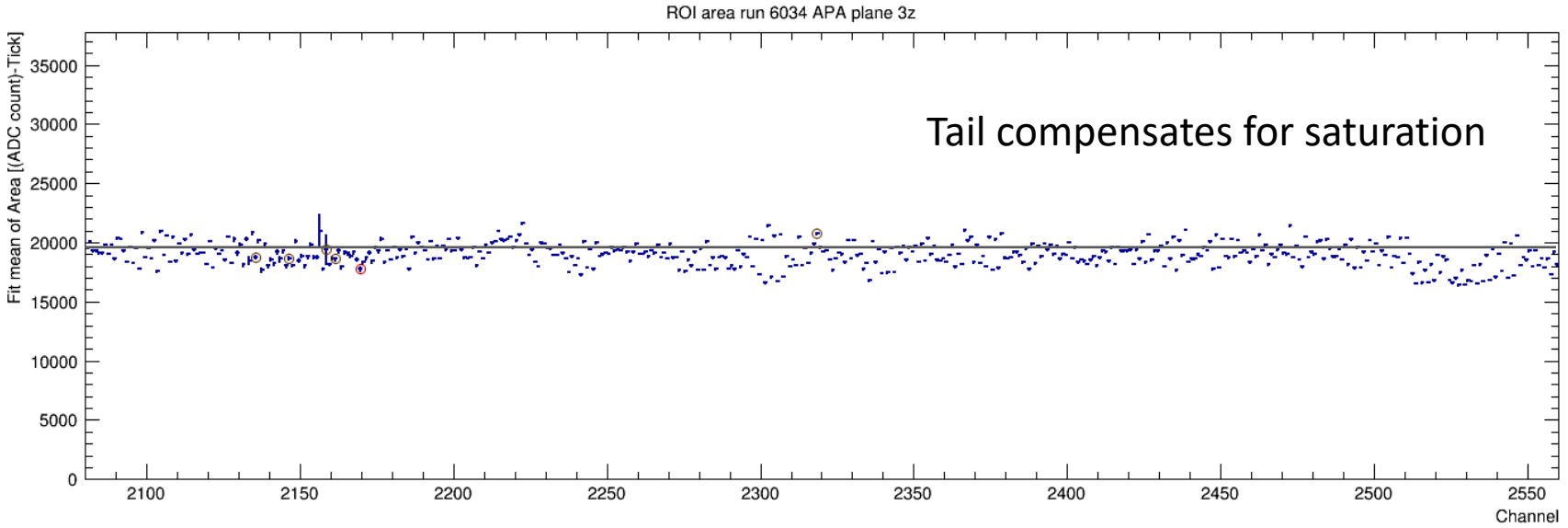


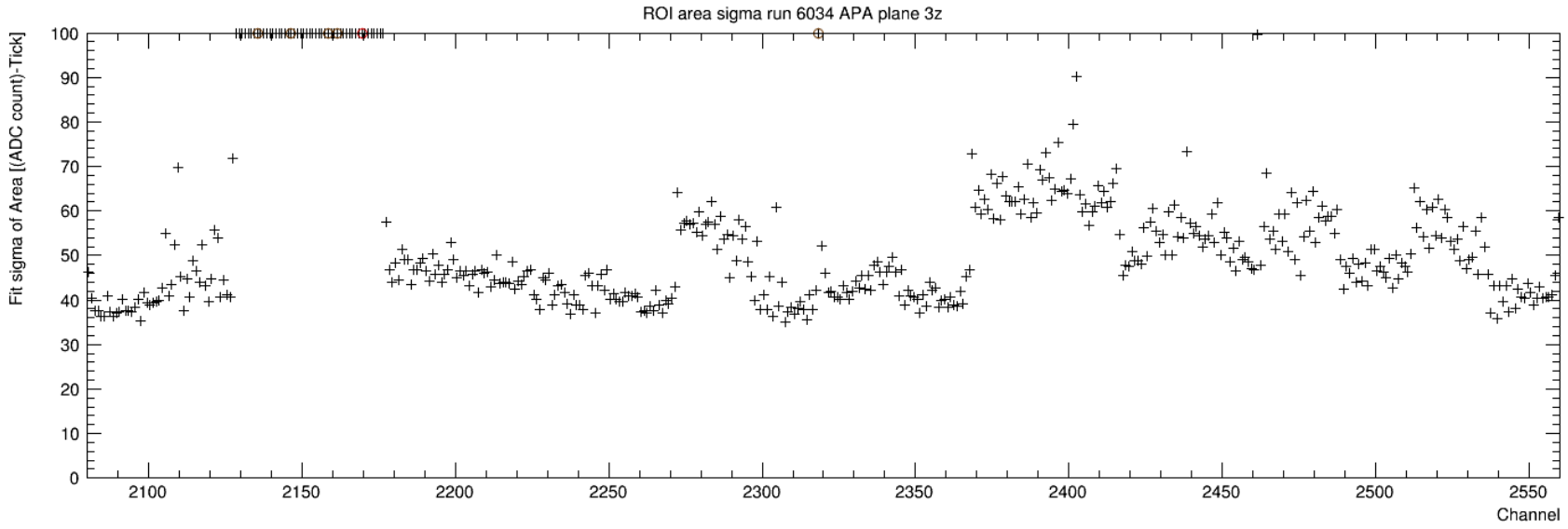
A=18 ROI area (high threshold)



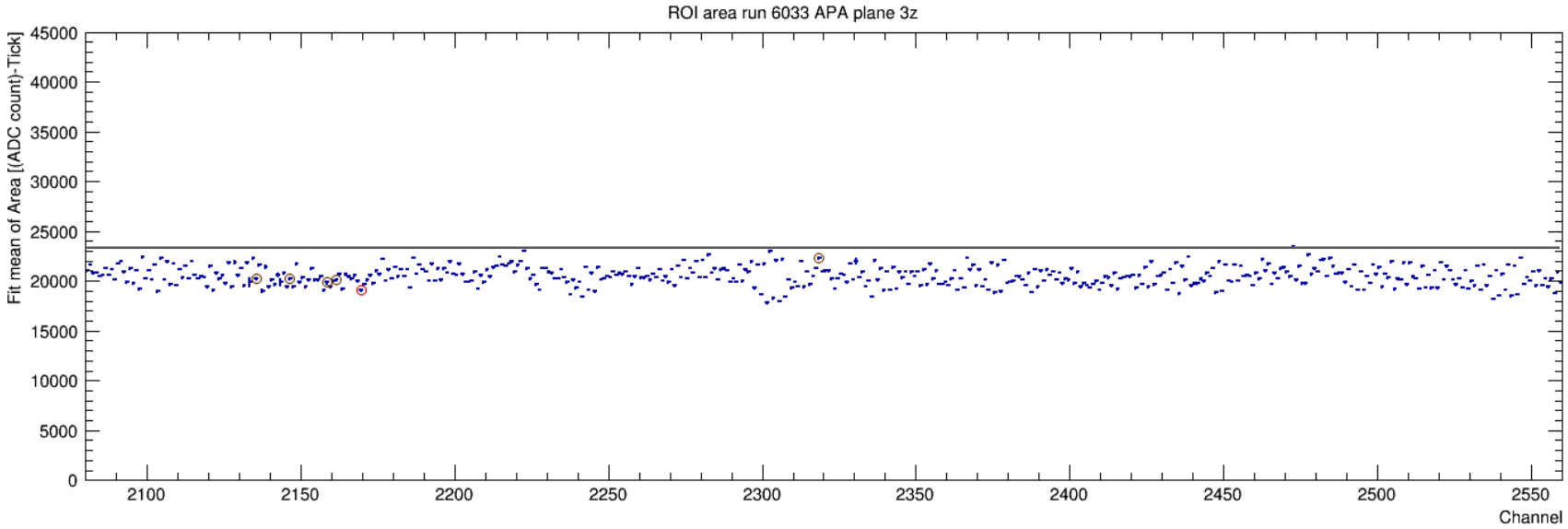


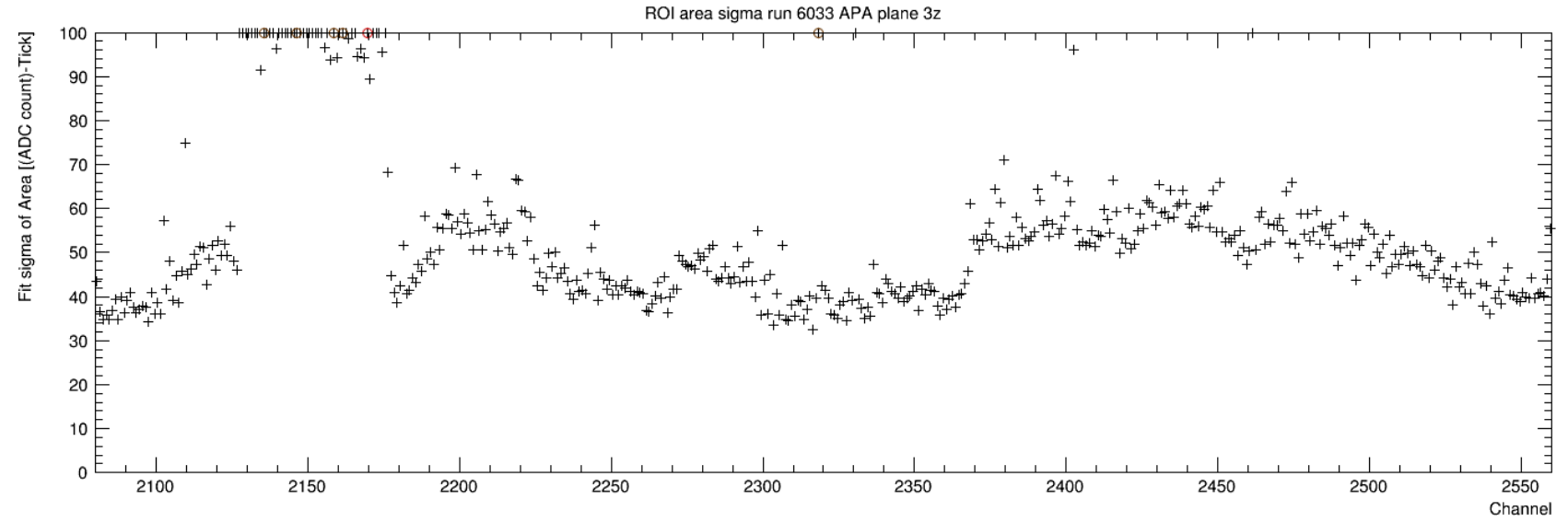
A=21 ROI area (high threshold)



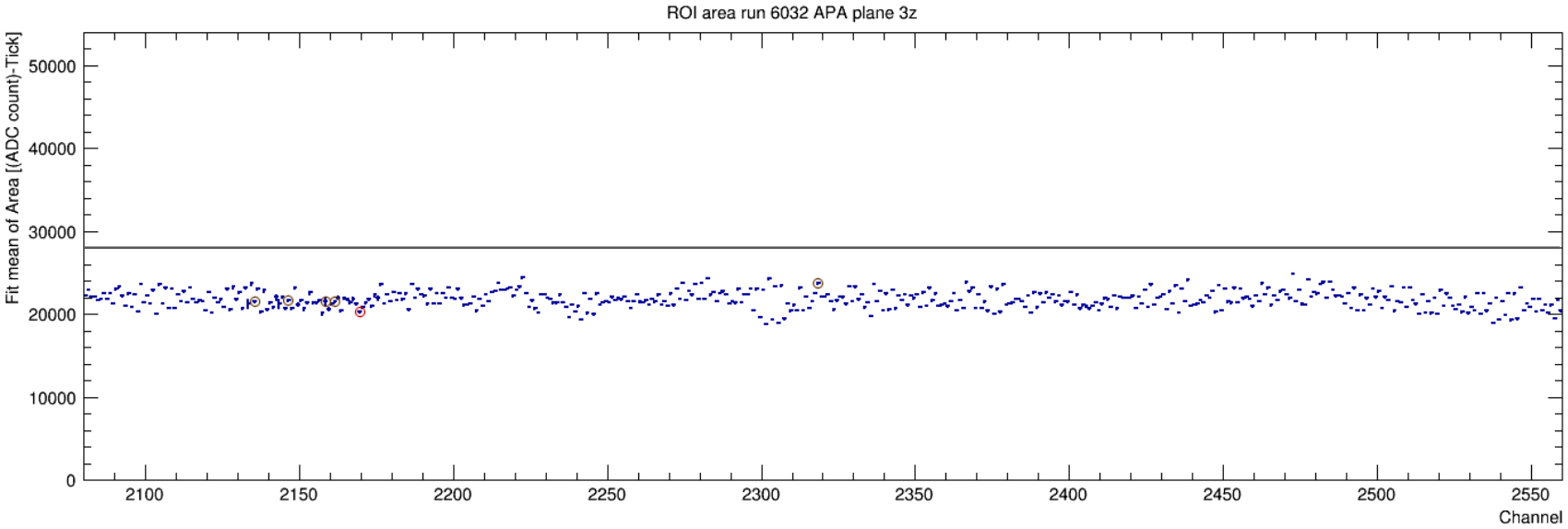


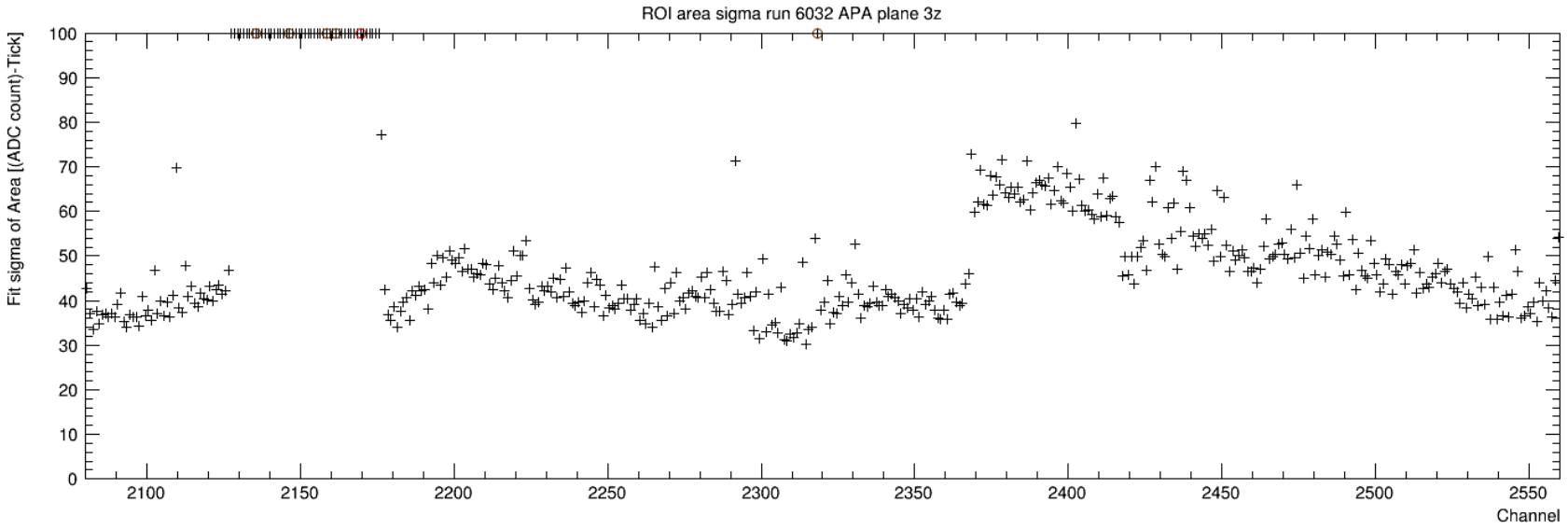
A=25 ROI area (high threshold)





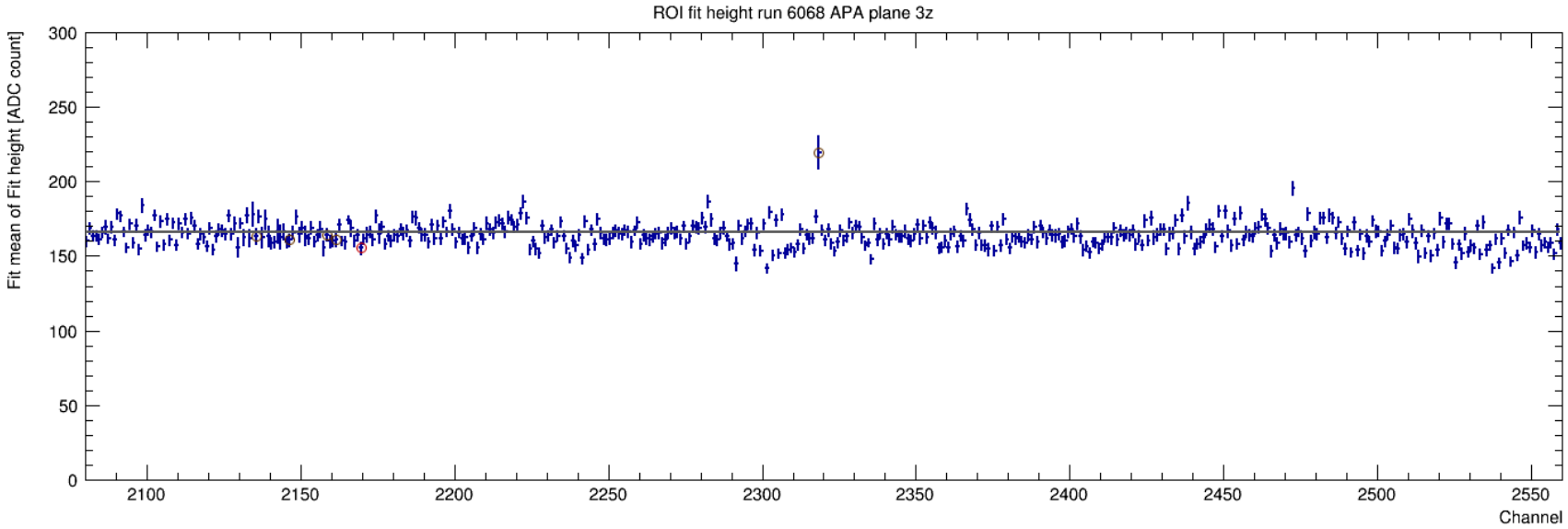
A=30 ROI area (high threshold)

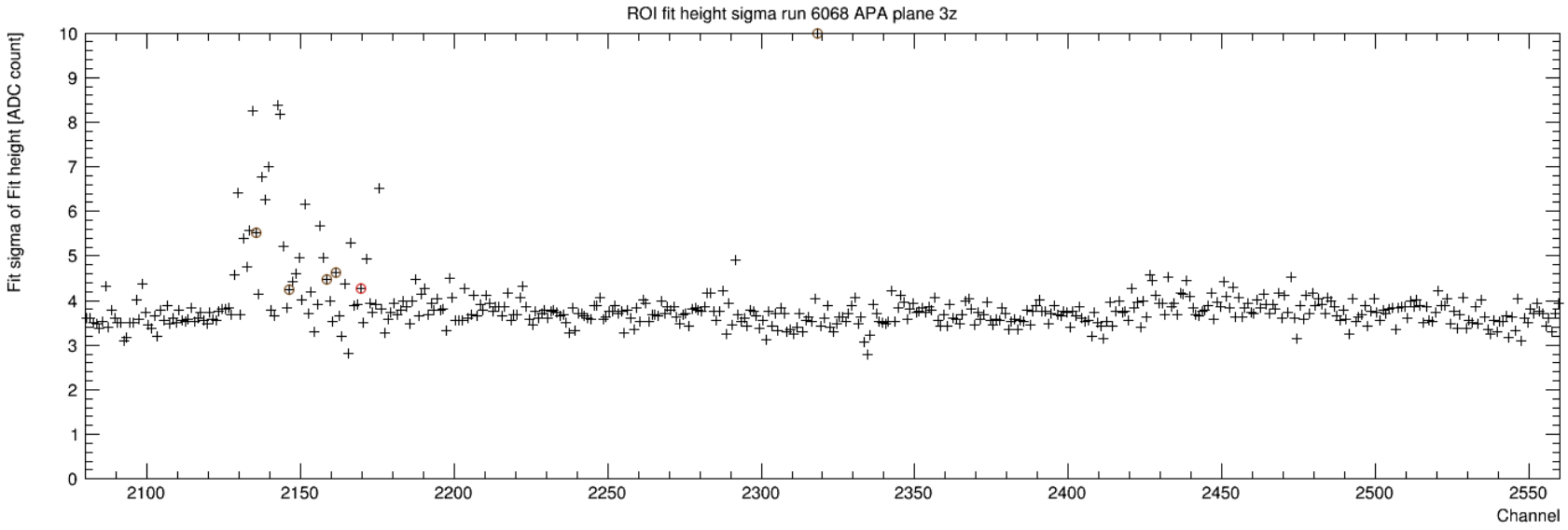




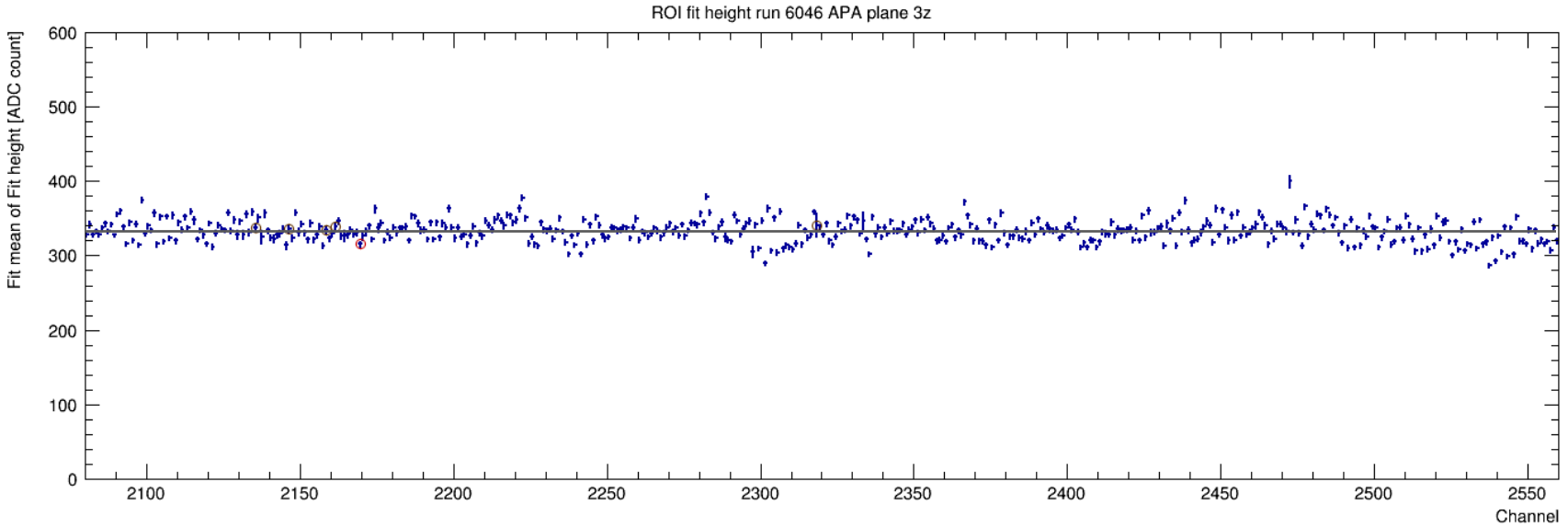
Negative ROI fitted heights

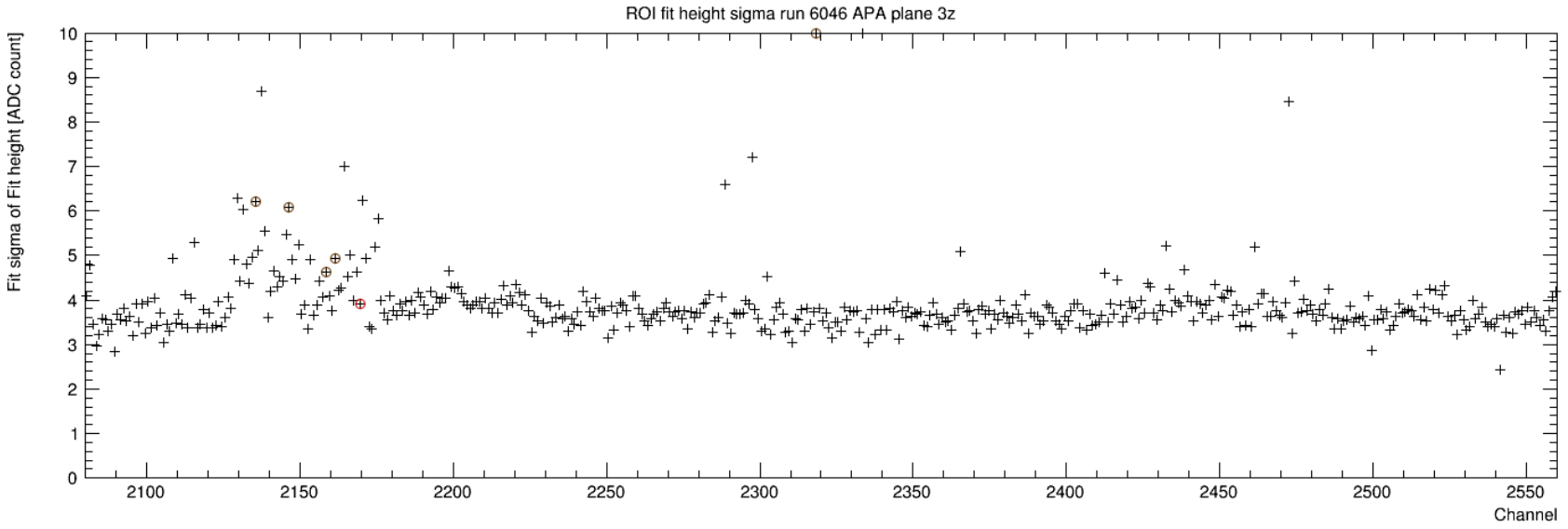
A=-1 fitted height



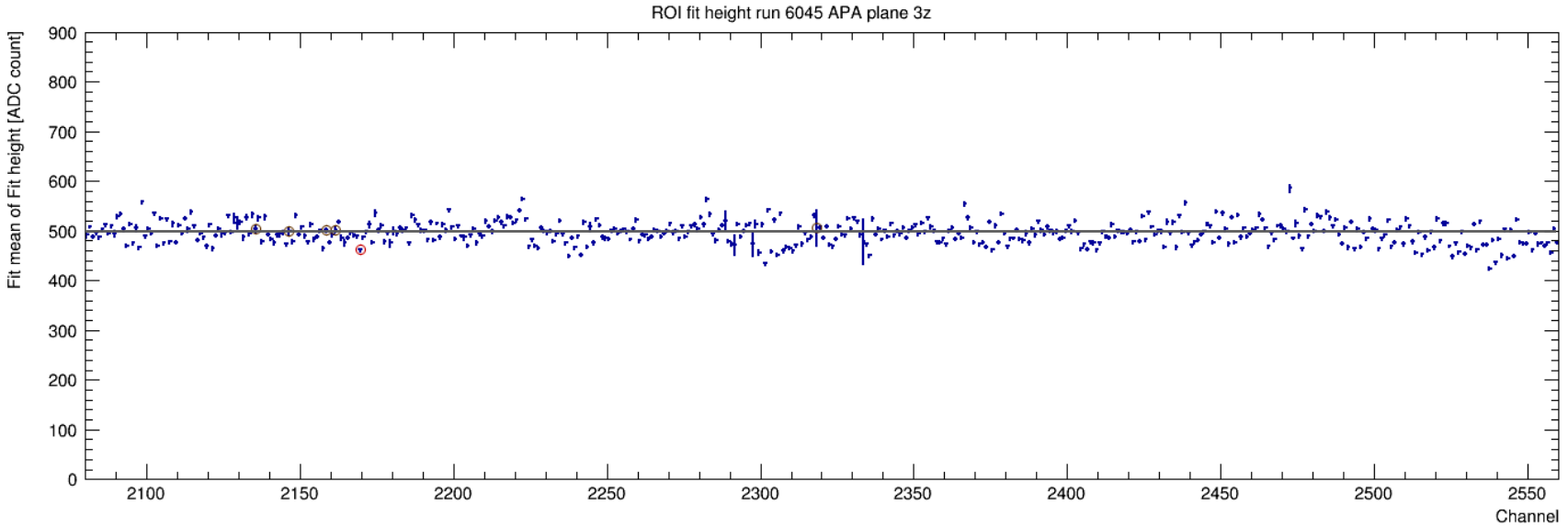


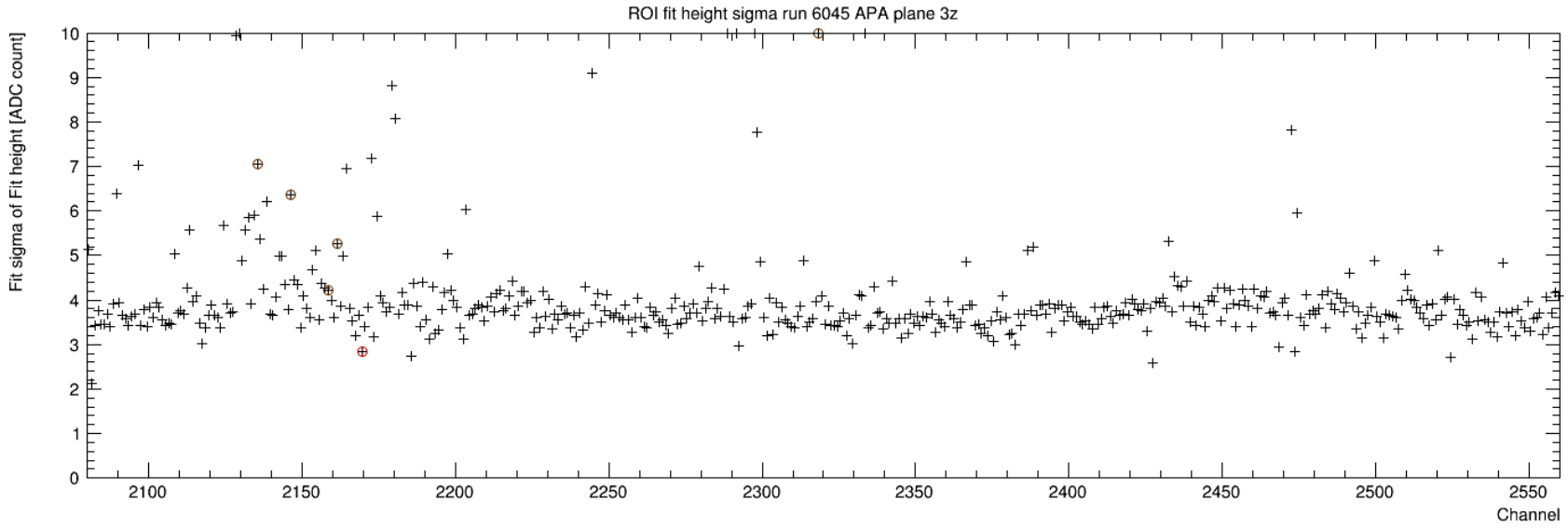
A=-2 fitted height



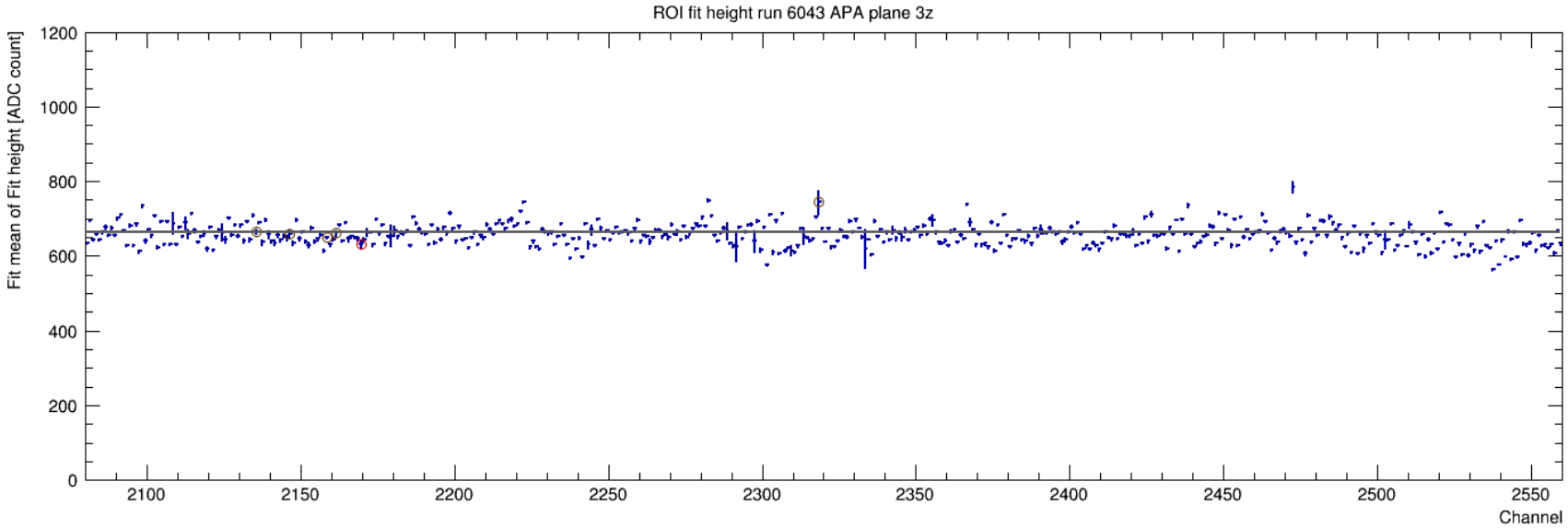


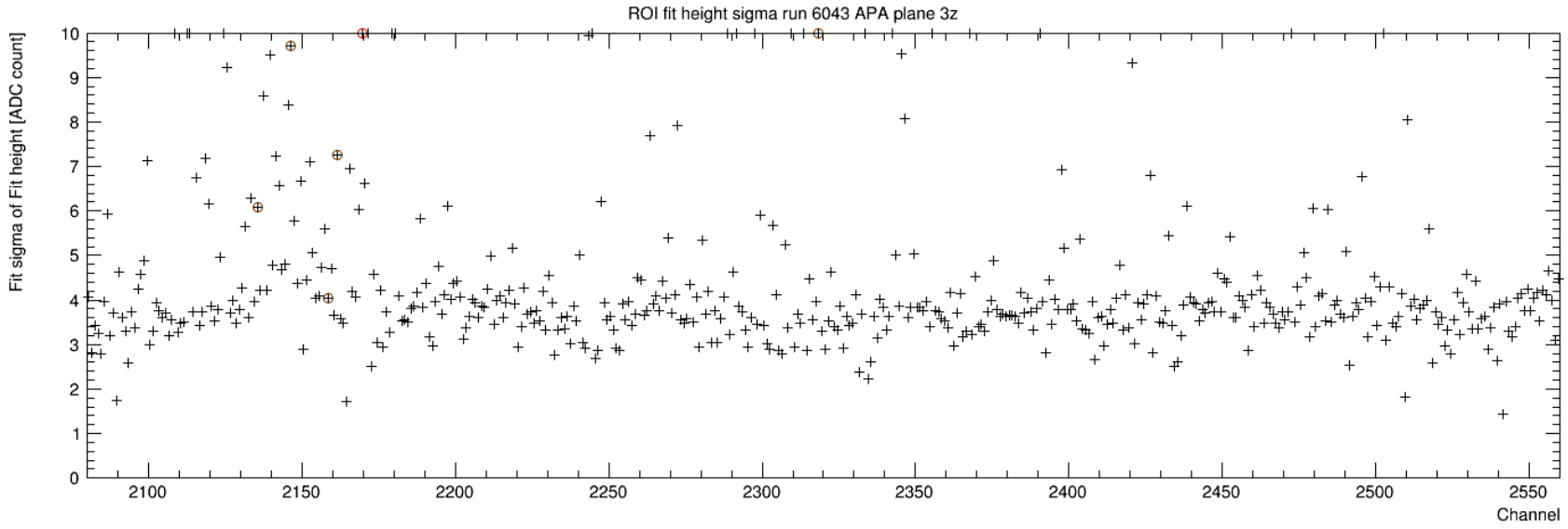
A=-3 fitted height



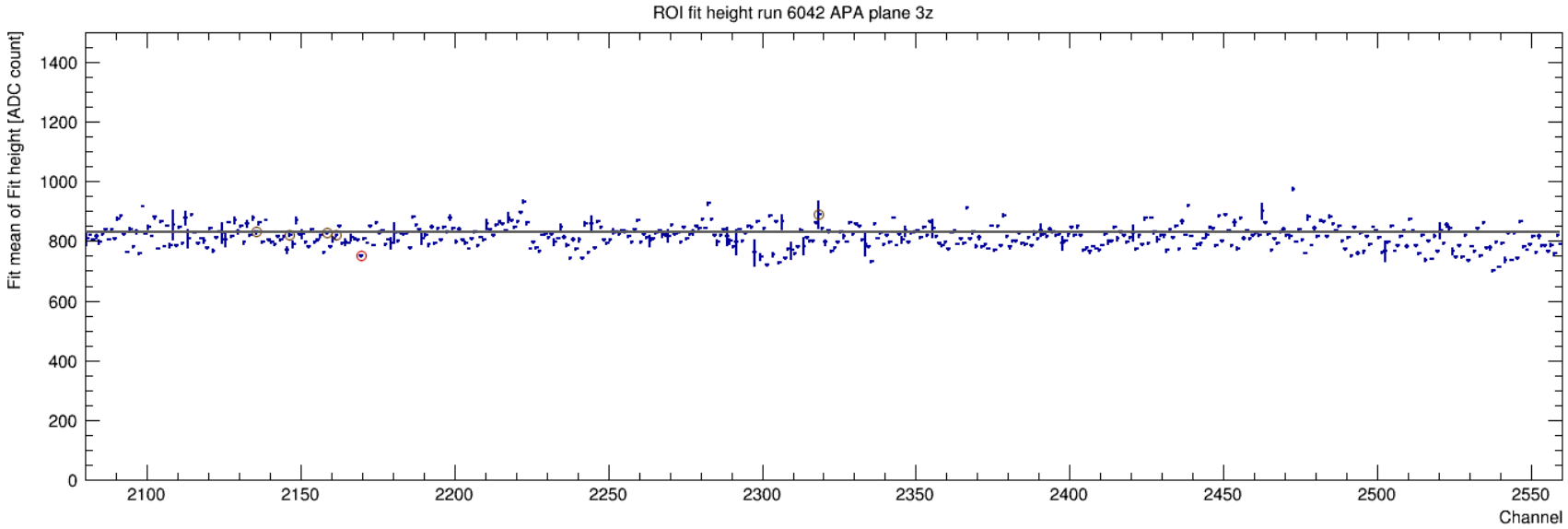


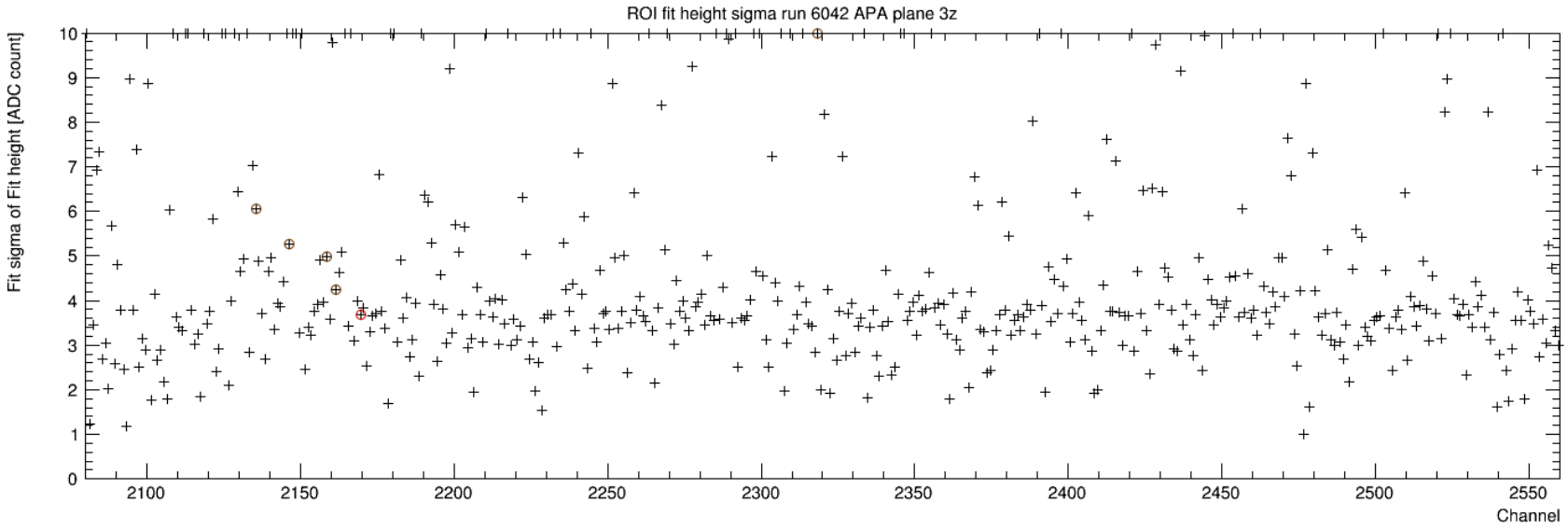
A=-4 fitted height



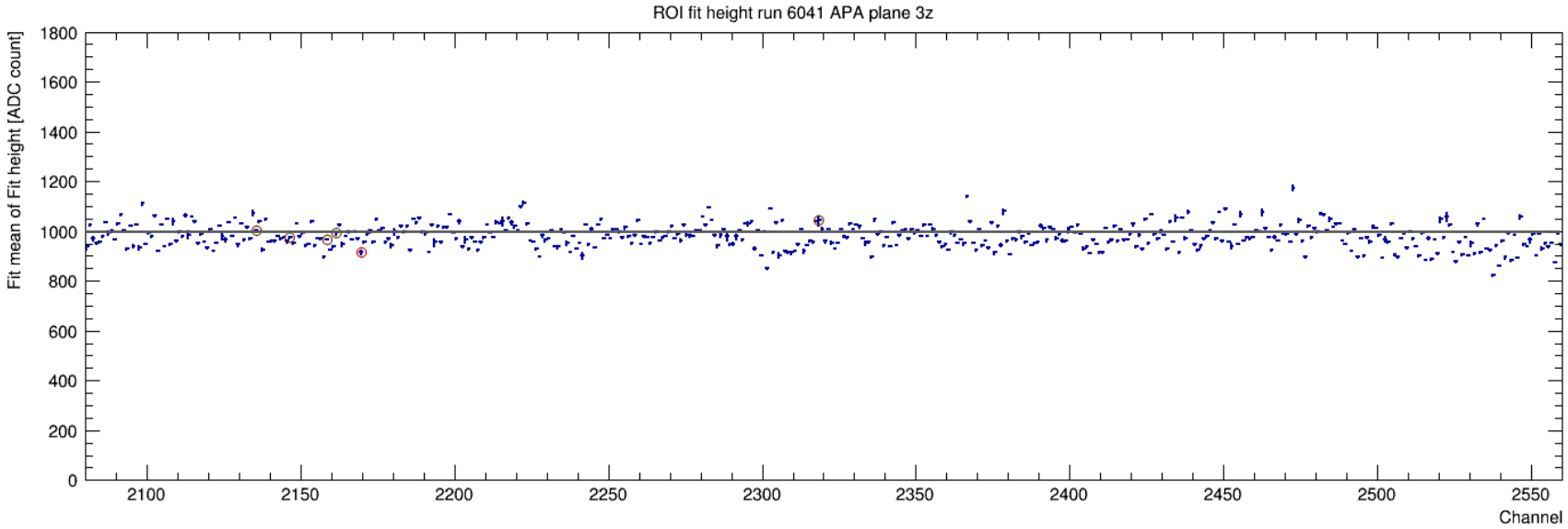


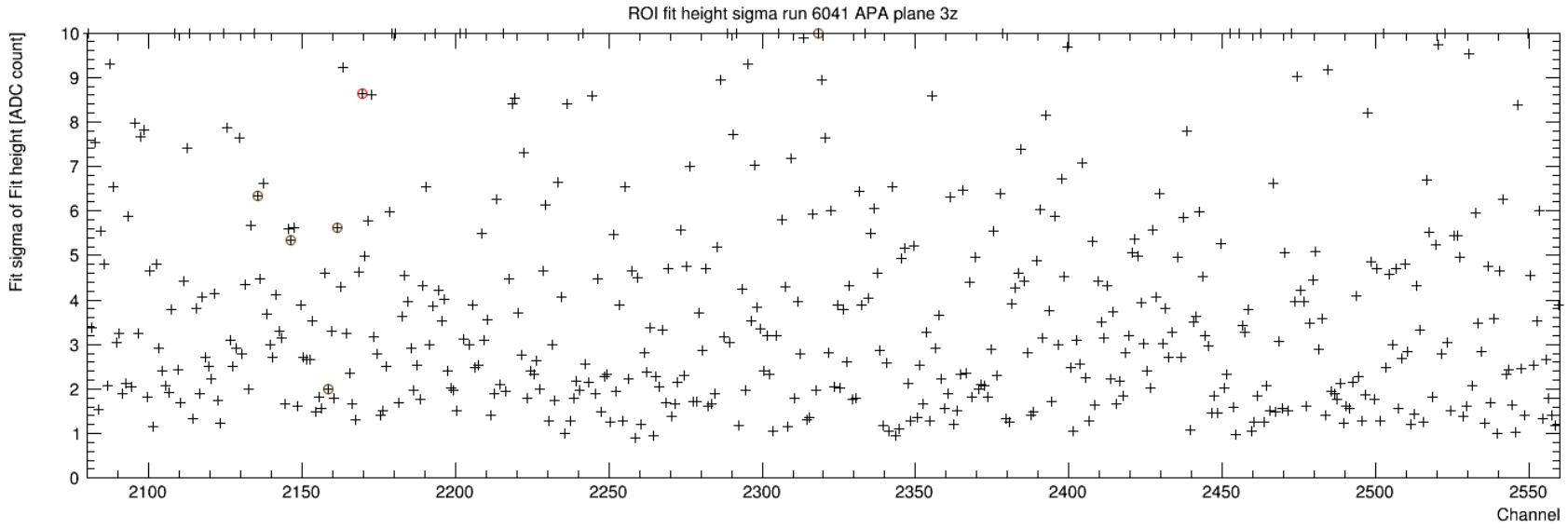
A=-5 fitted height



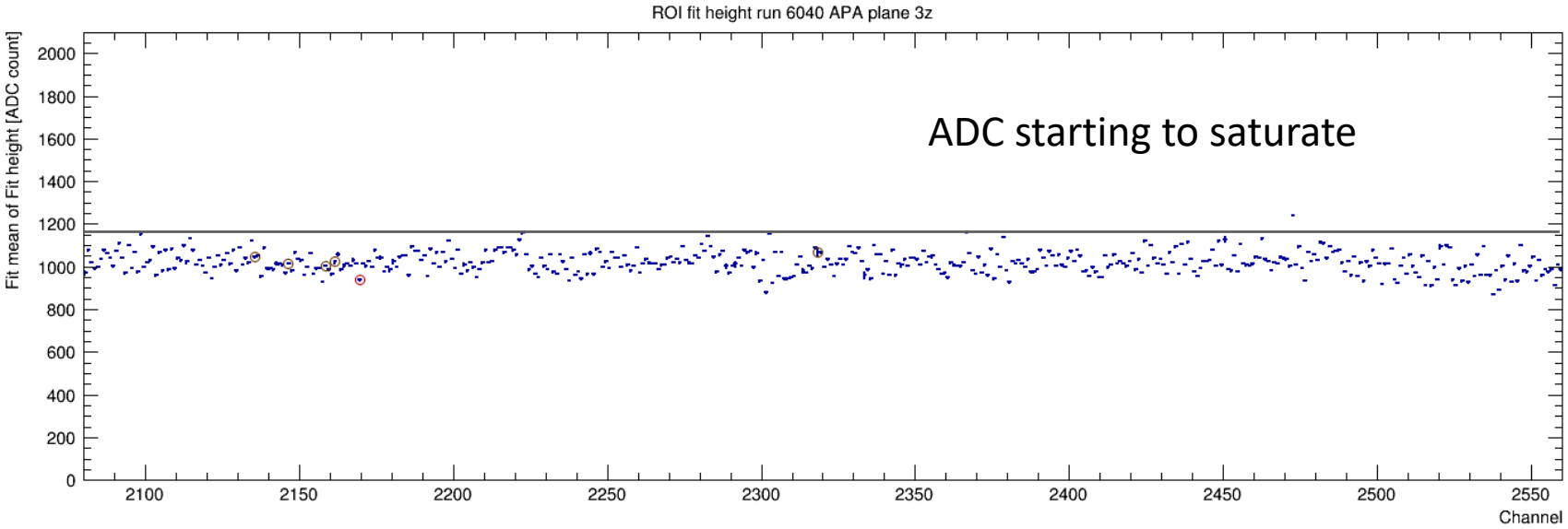


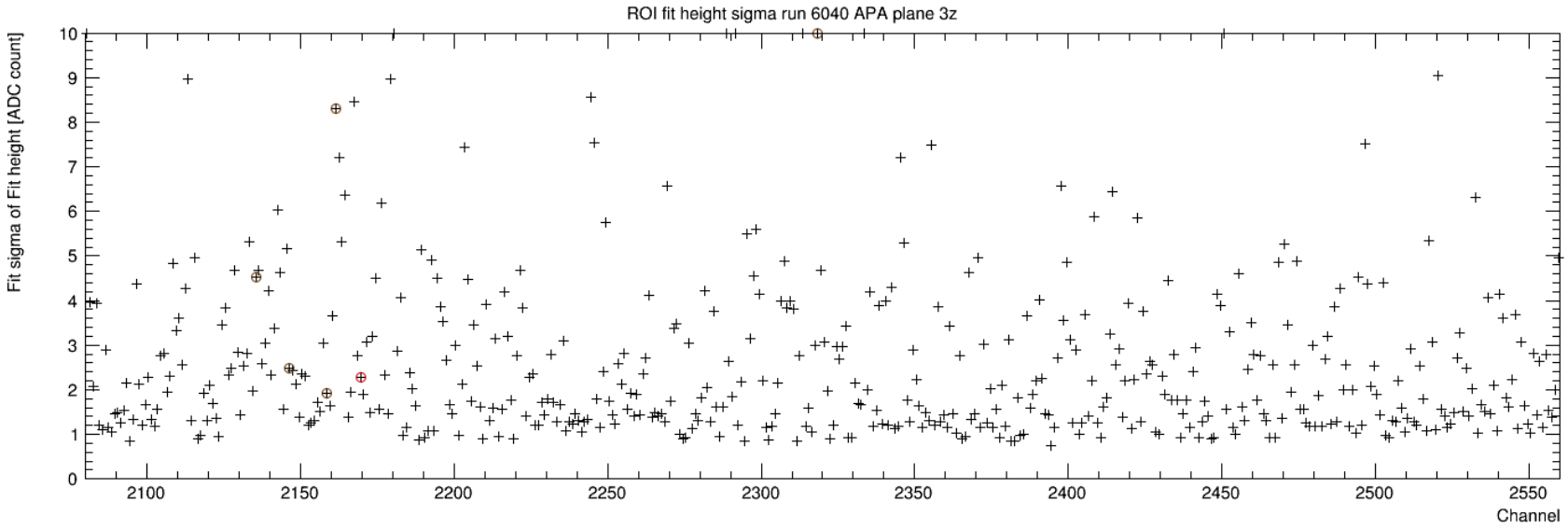
A=-6 fitted height



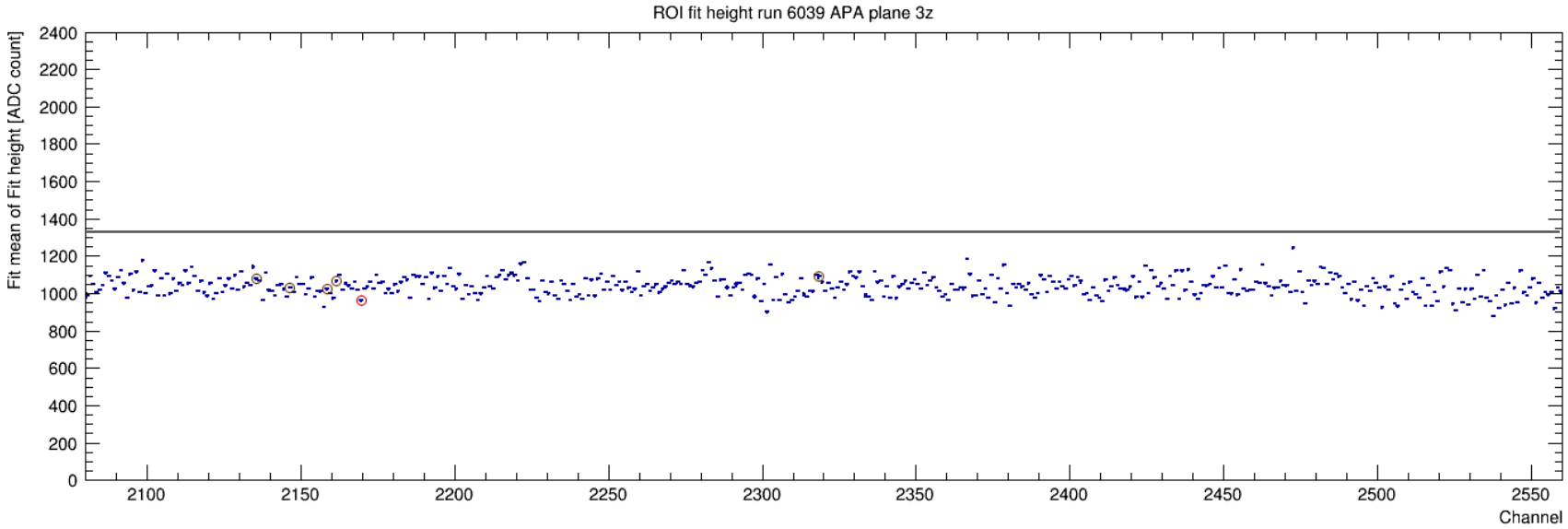


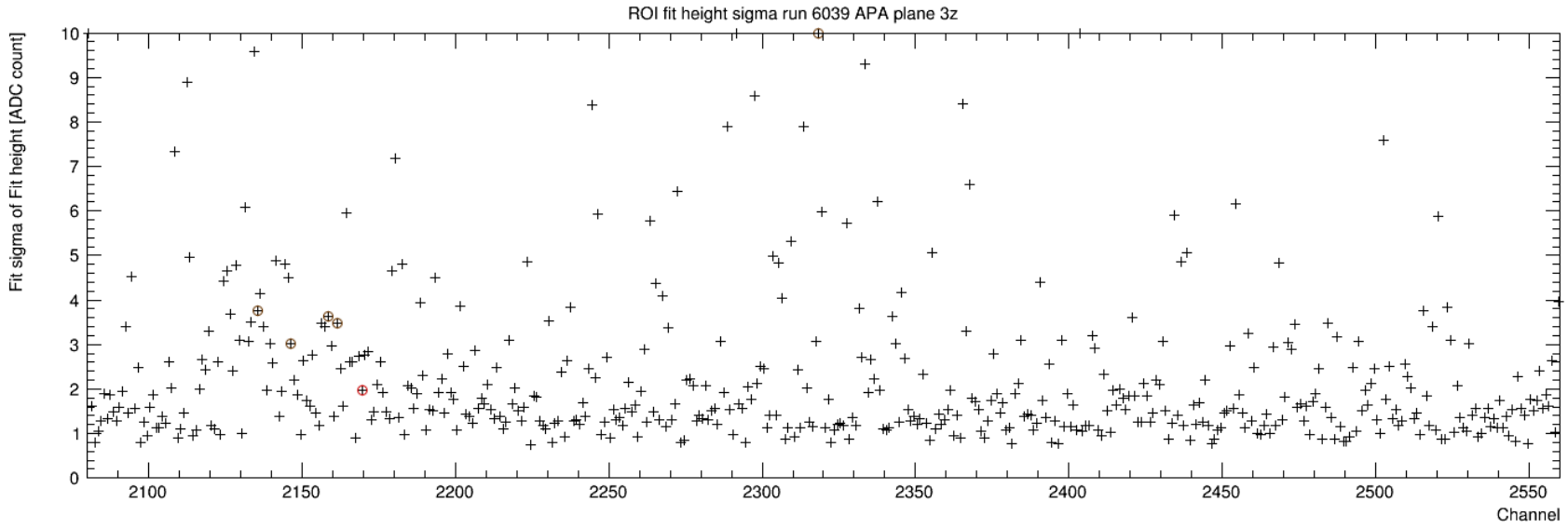
A=-7 fitted height



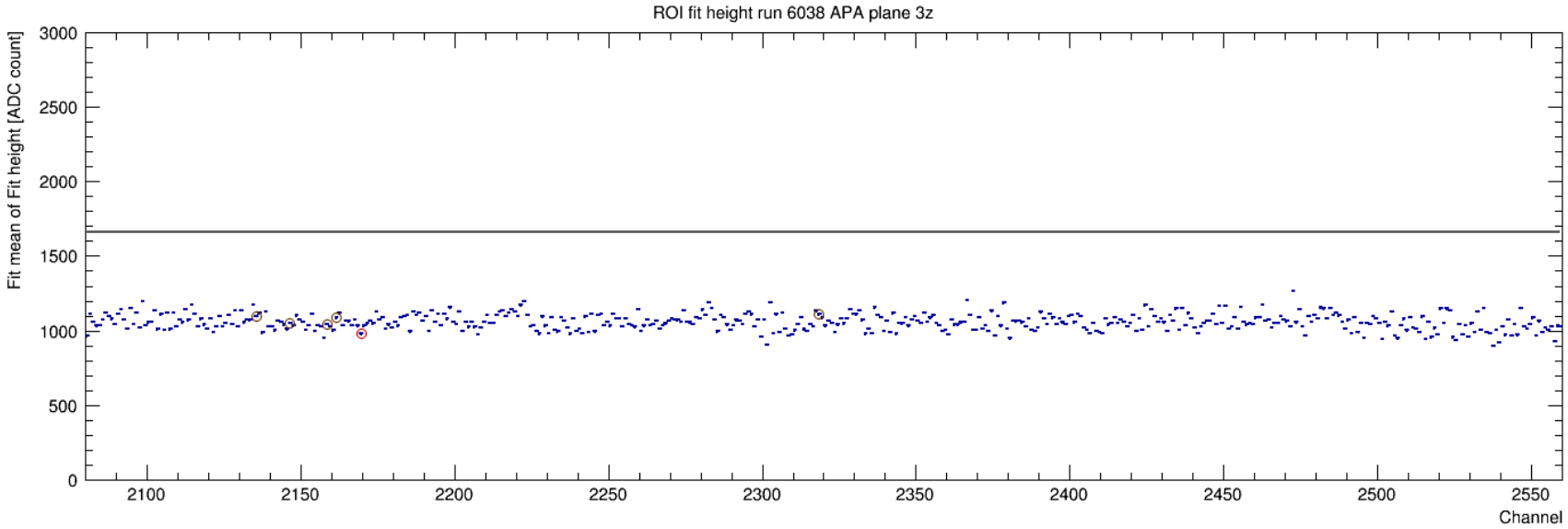


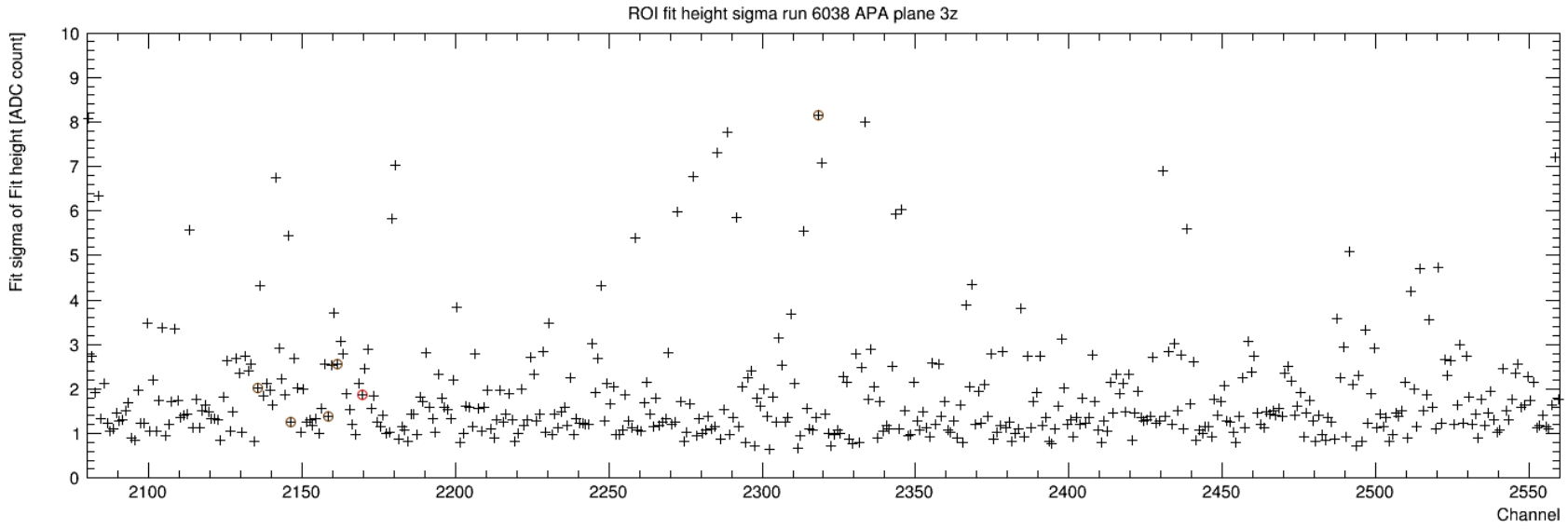
A=-8 fitted height



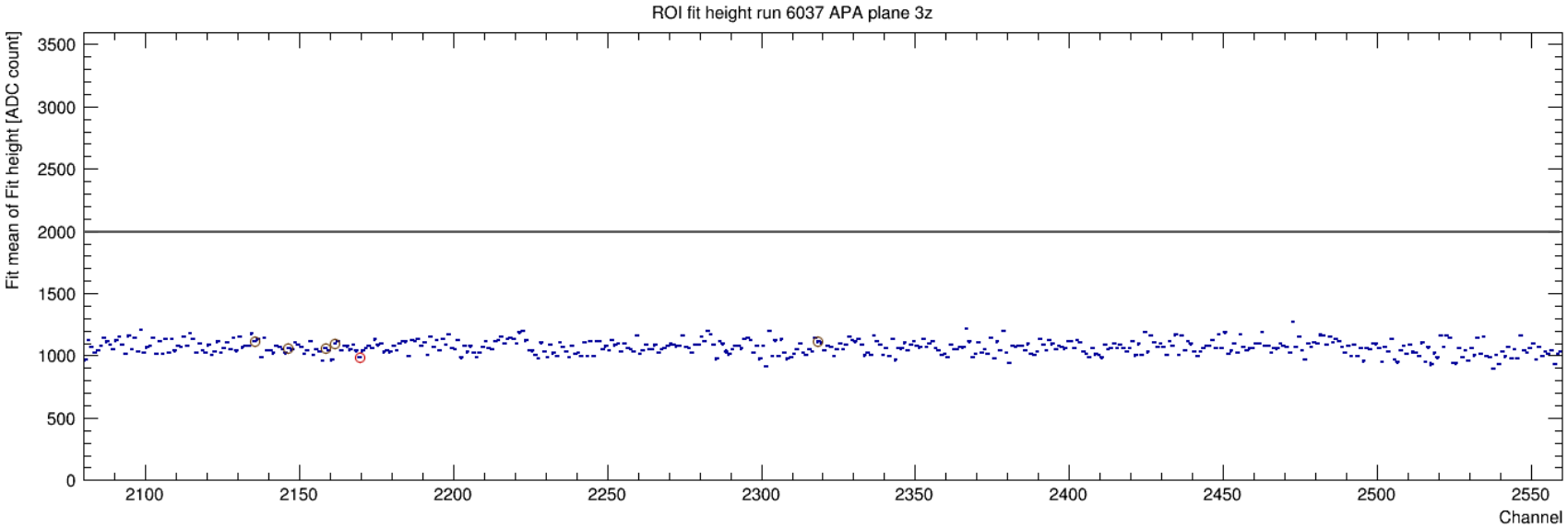


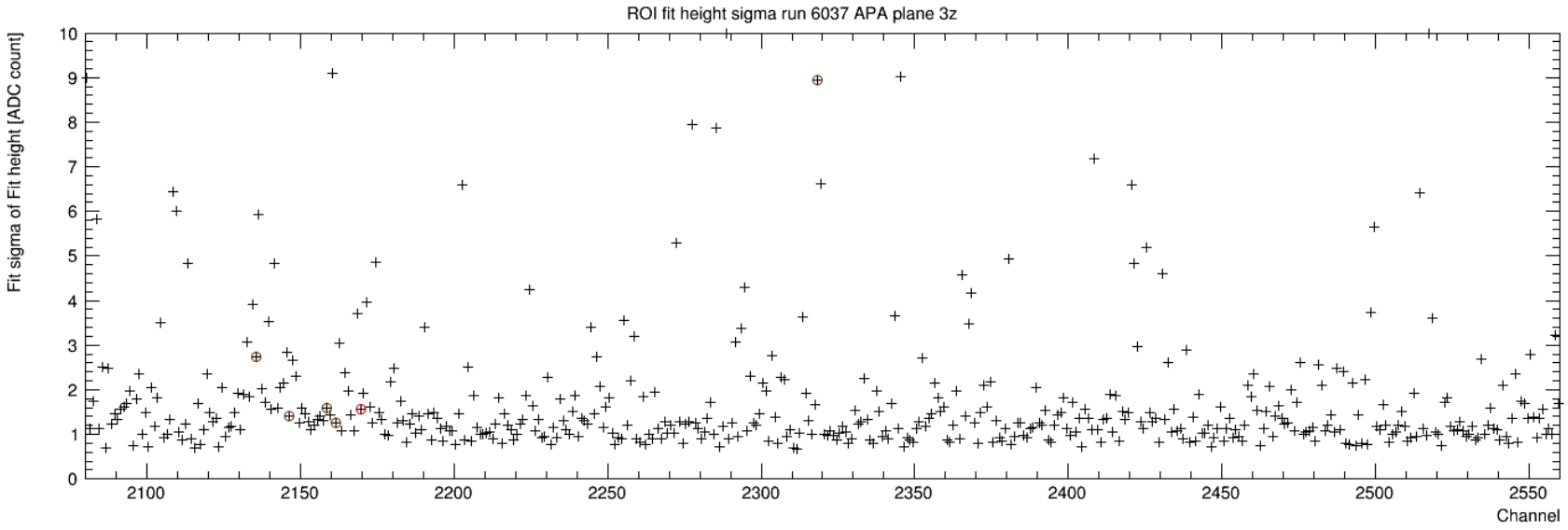
A=-10 fitted height





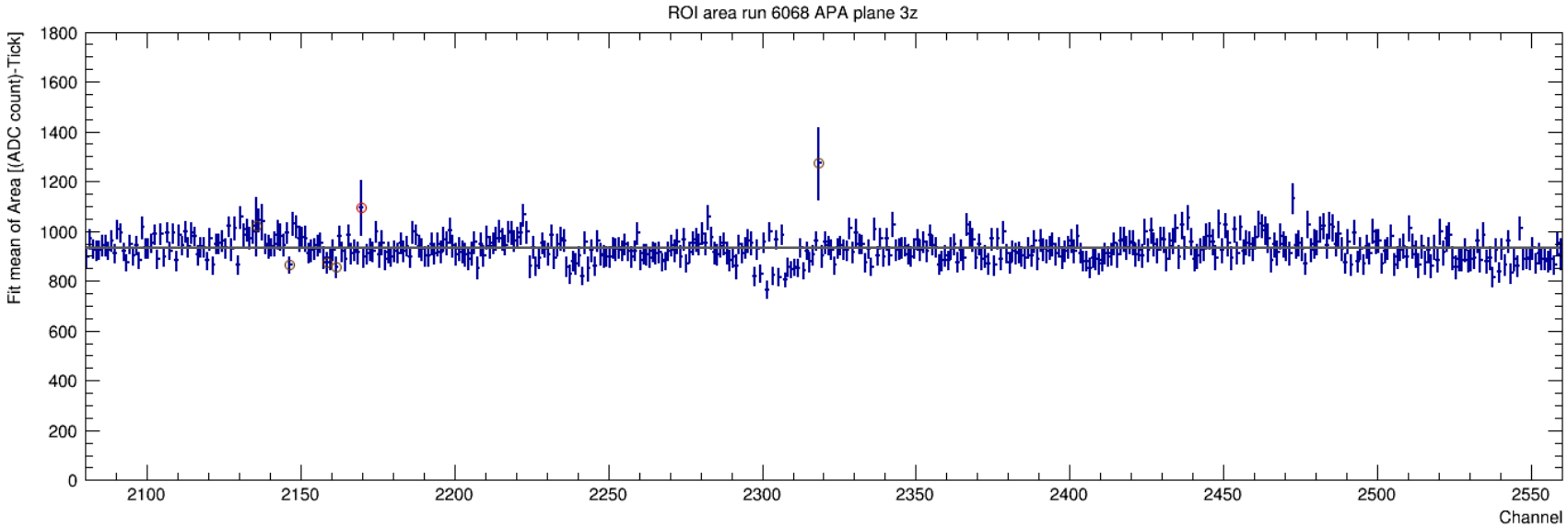
A=-12 fitted height

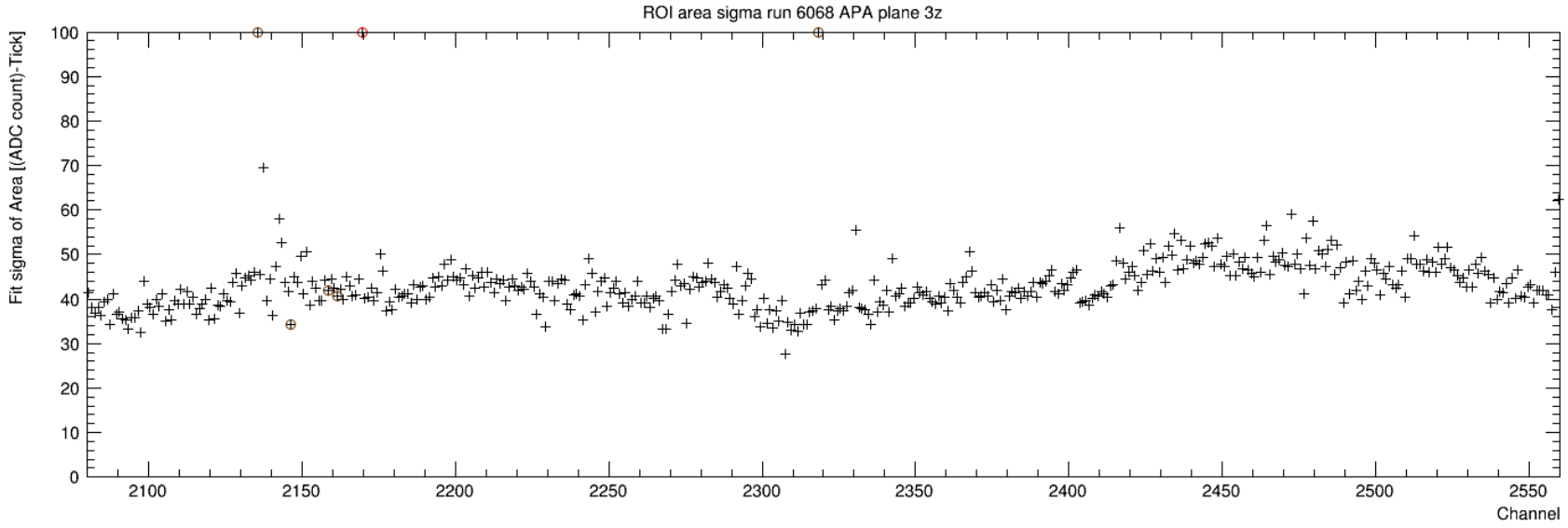




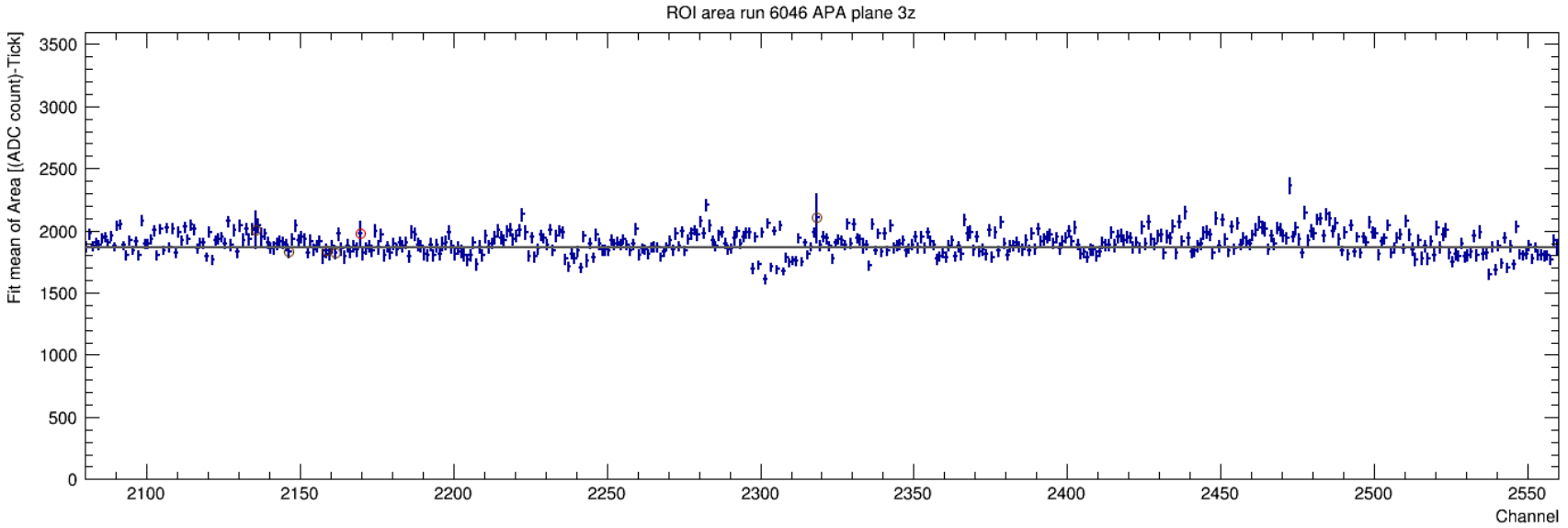
Negative ROI areas

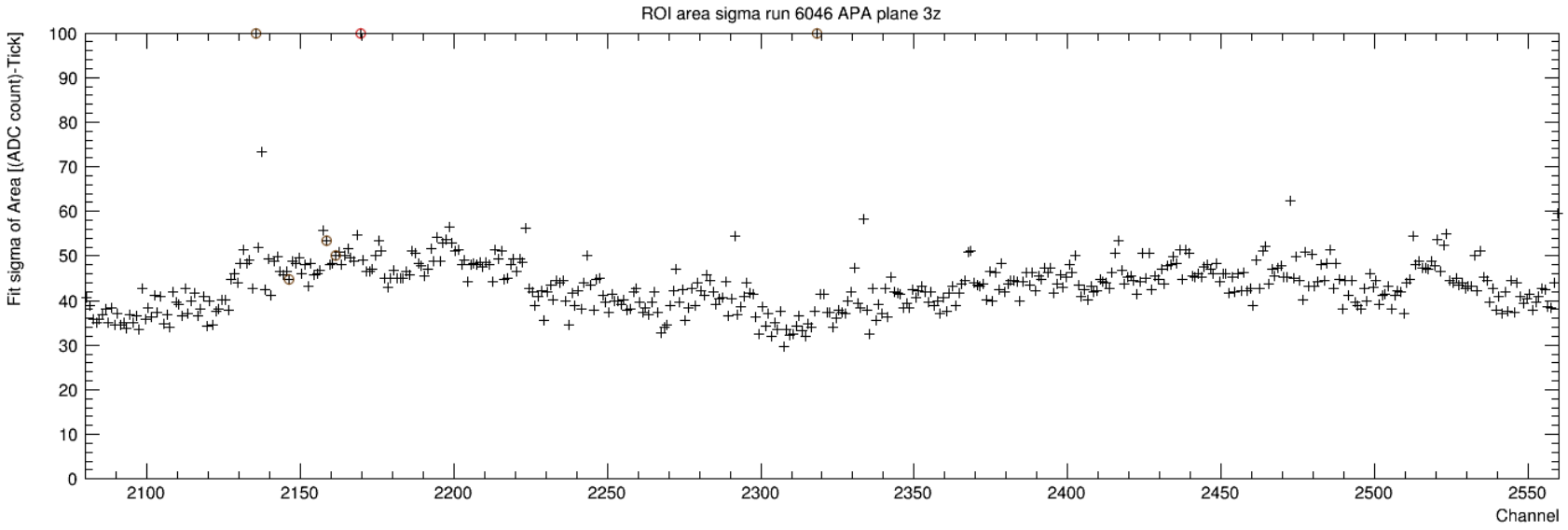
A=-1 ROI area


ROI area run 6068 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
Channel

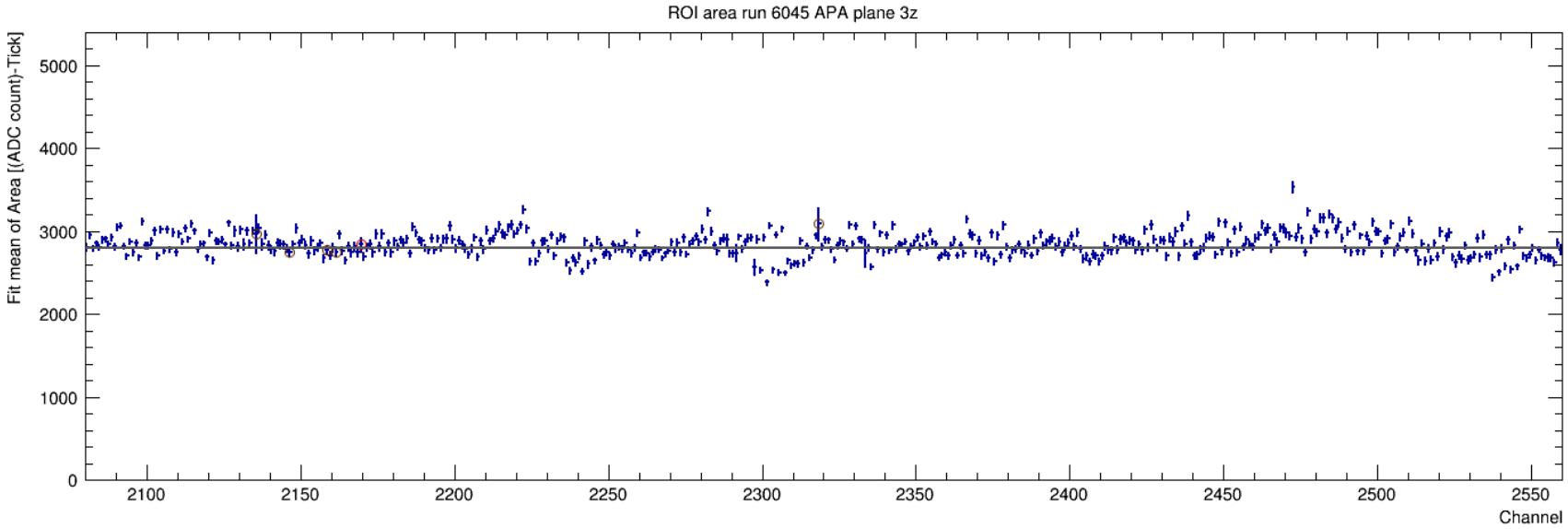

ROI area sigma run 6068 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
Channel

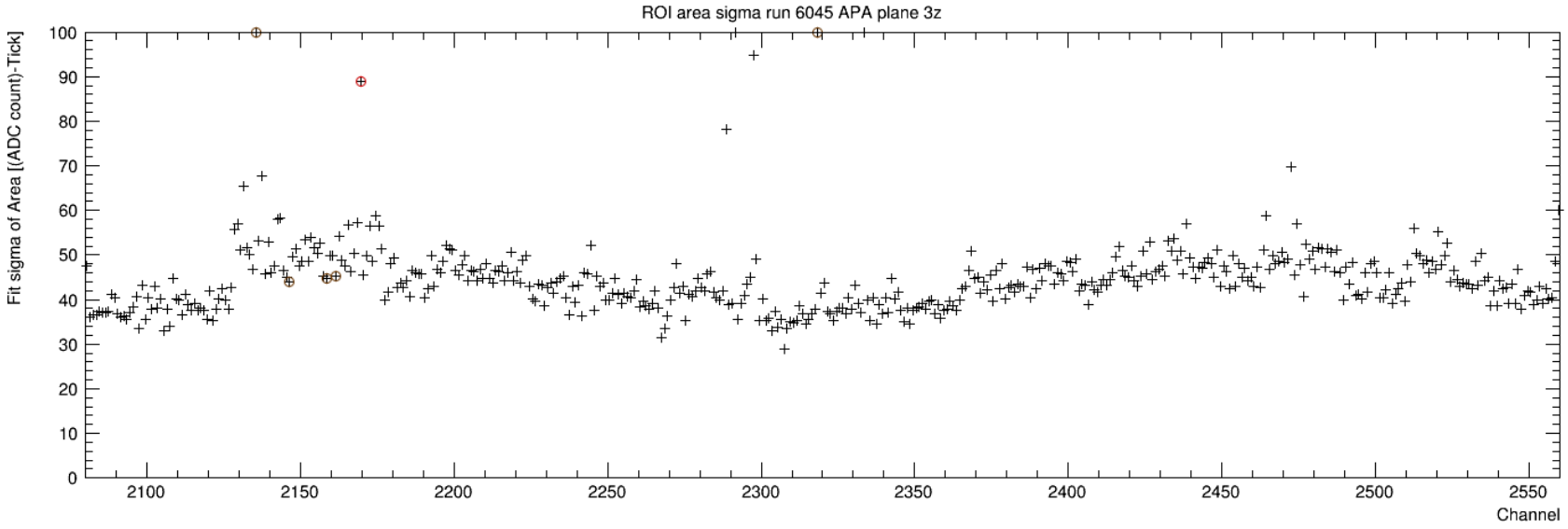
A=-2 ROI area


ROI area run 6046 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
3500
3000
2500
2000
1500
1000
500
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

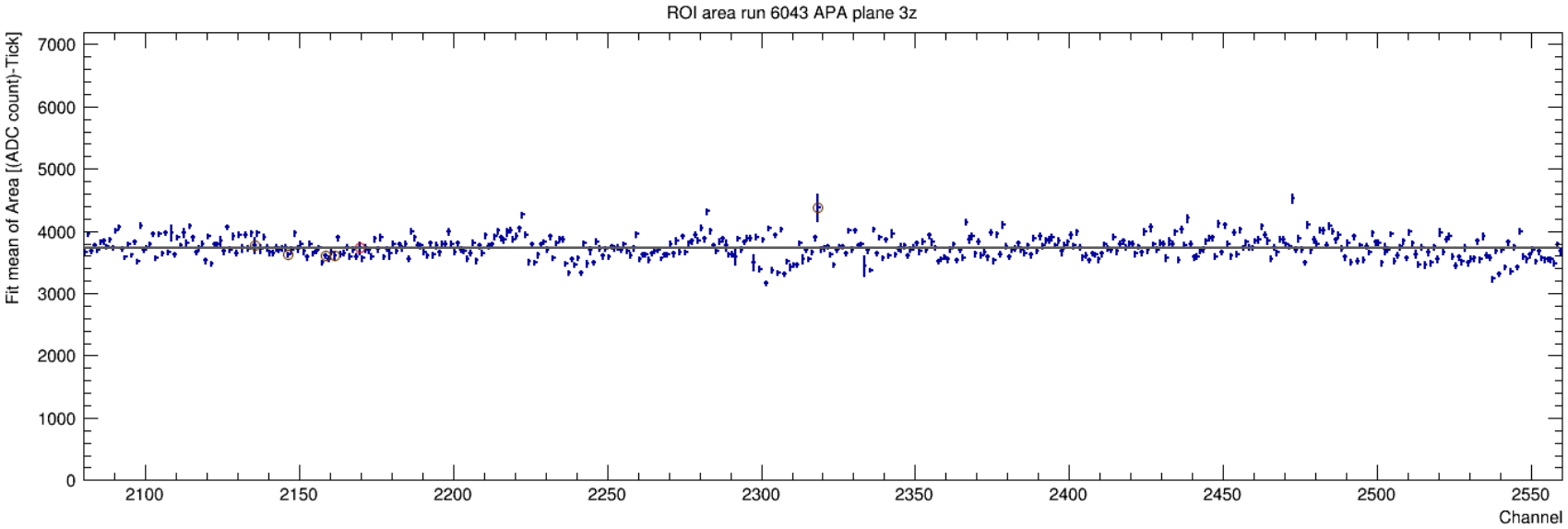

ROI area sigma run 6046 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

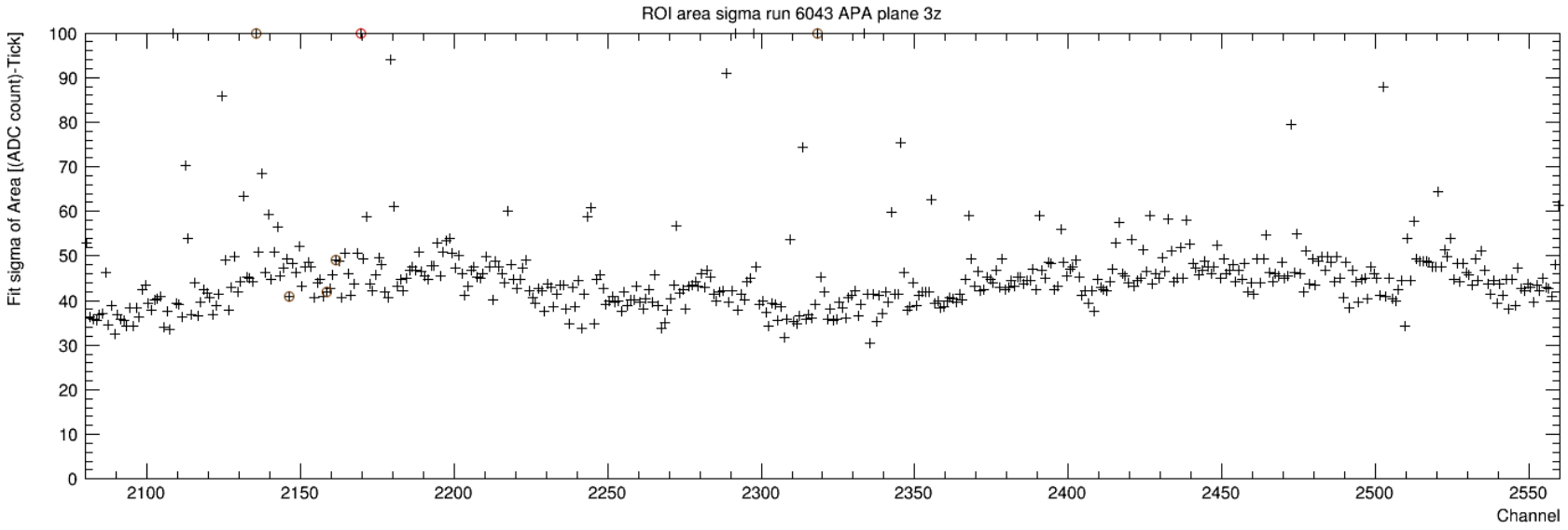
A=-3 ROI area


ROI area run 6045 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
5000
4000
3000
2000
1000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

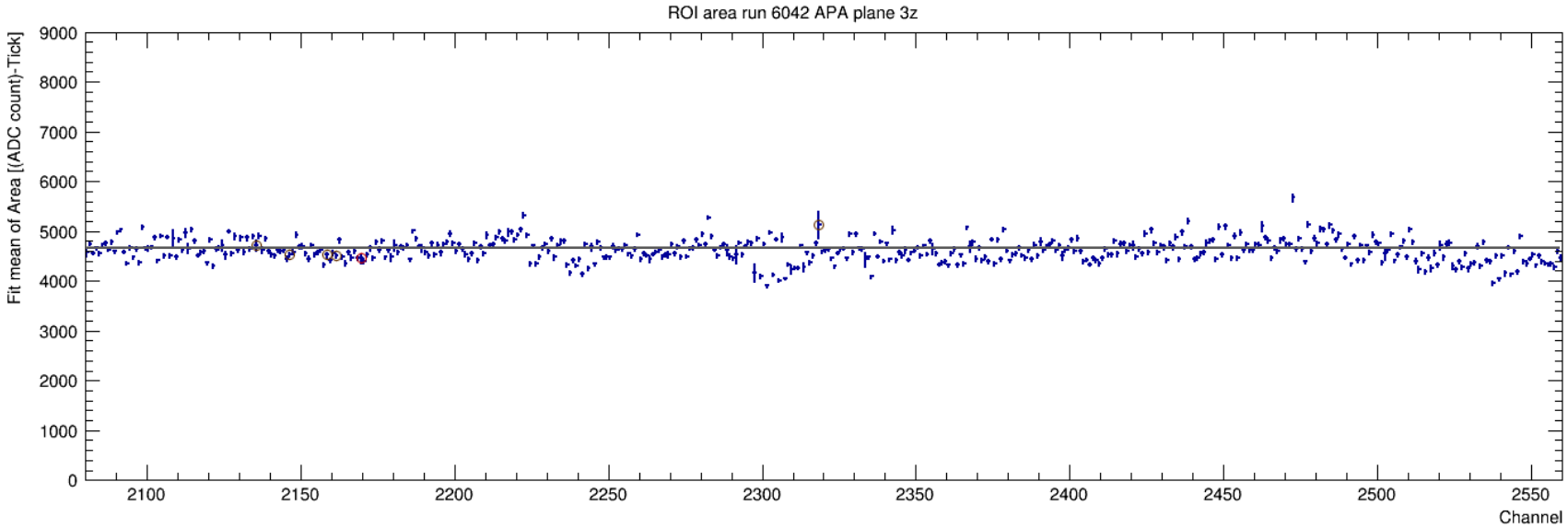

ROI area sigma run 6045 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

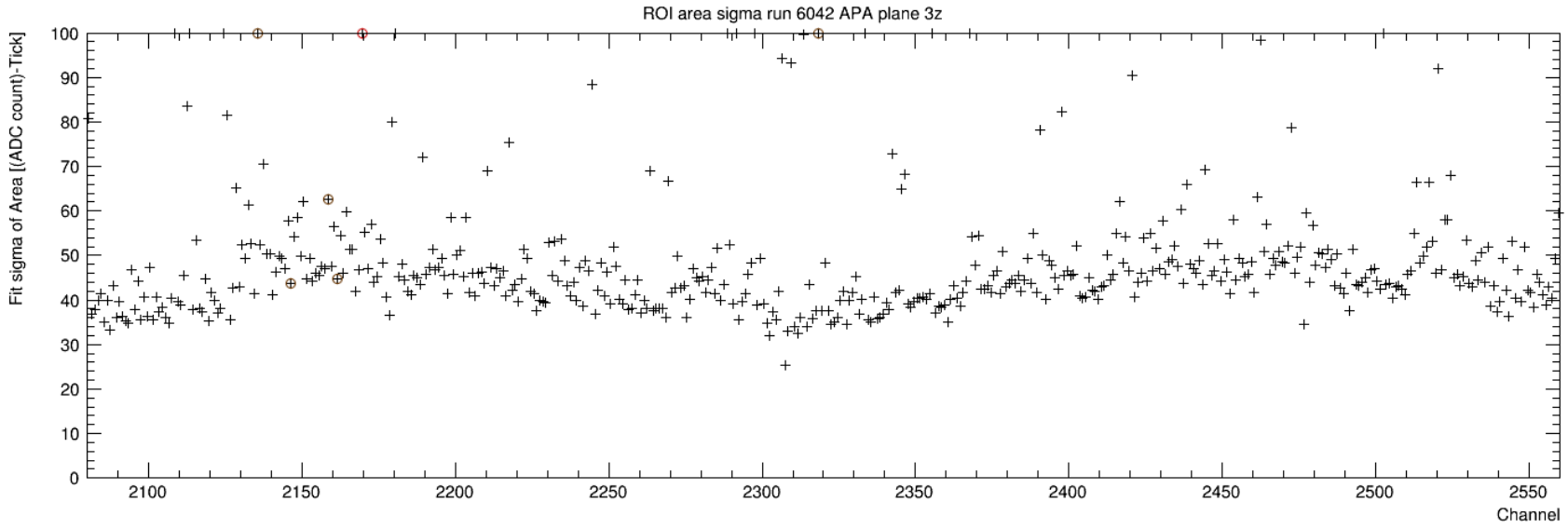
A=-4 ROI area


ROI area run 6043 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
7000
6000
5000
4000
3000
2000
1000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

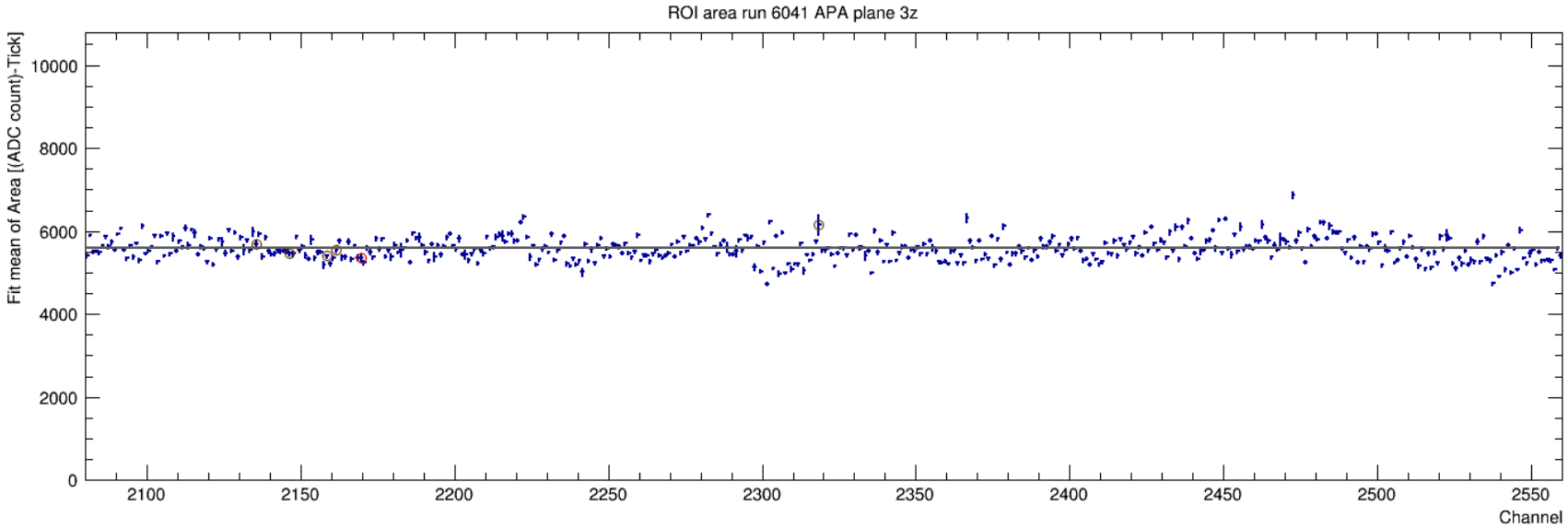

ROI area sigma run 6043 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

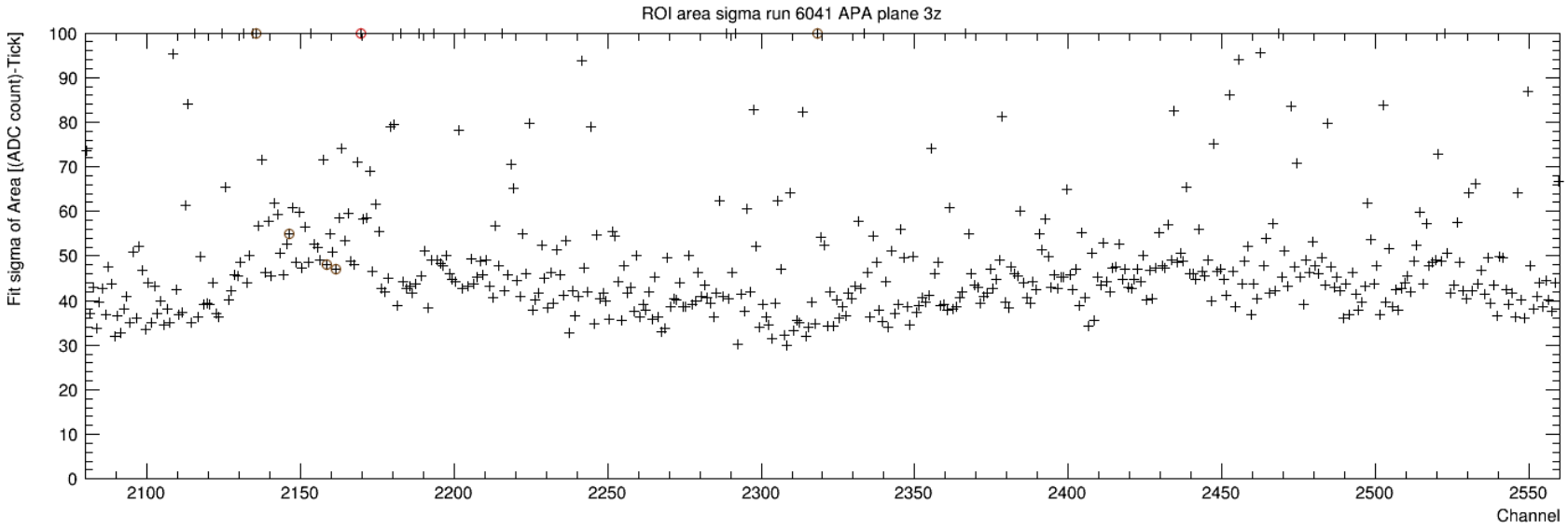
A=-5 ROI area


ROI area run 6042 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

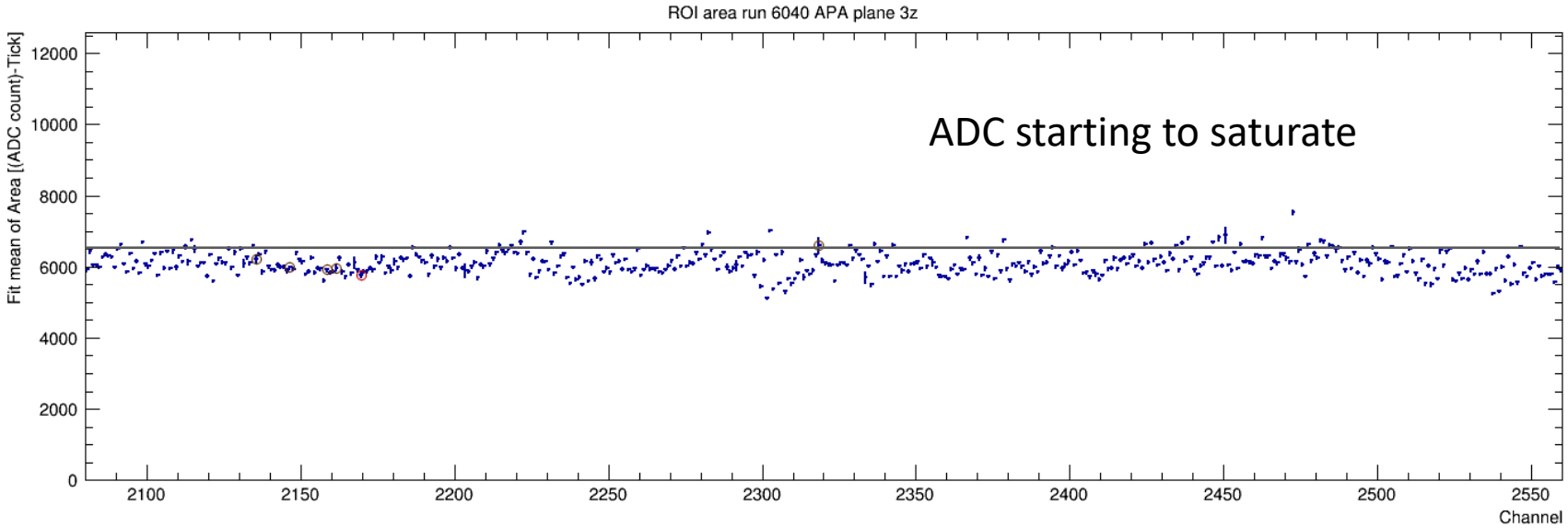

ROI area sigma run 6042 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

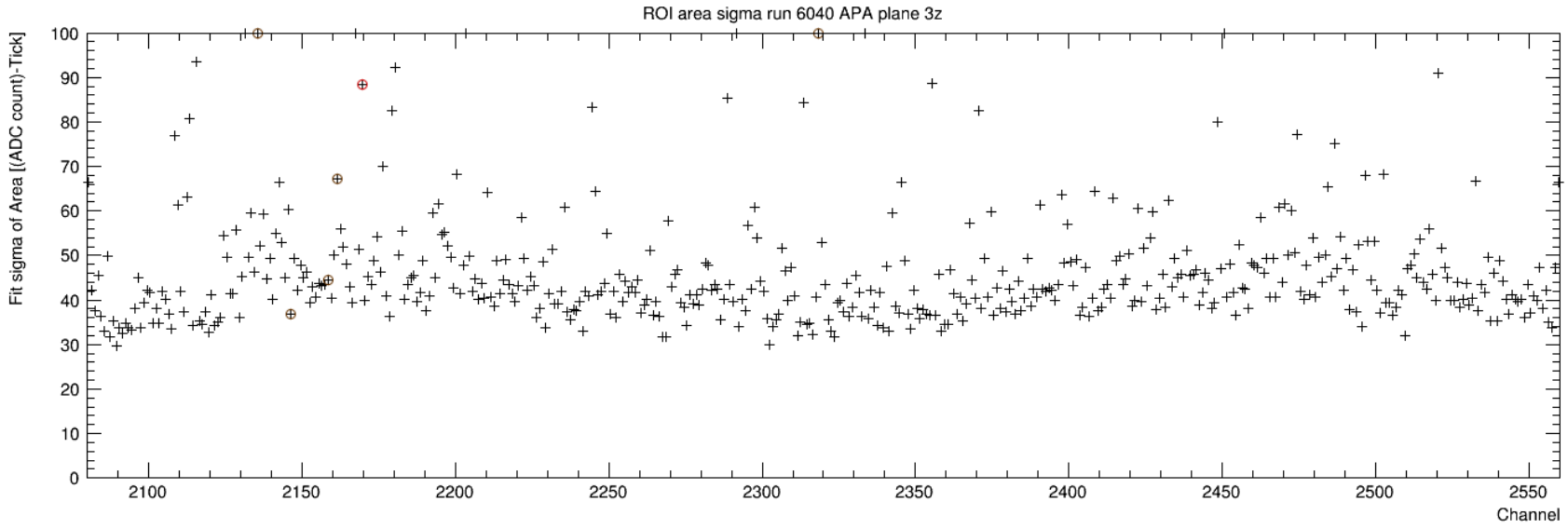
A=-6 ROI area


ROI area run 6041 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
10000
8000
6000
4000
2000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

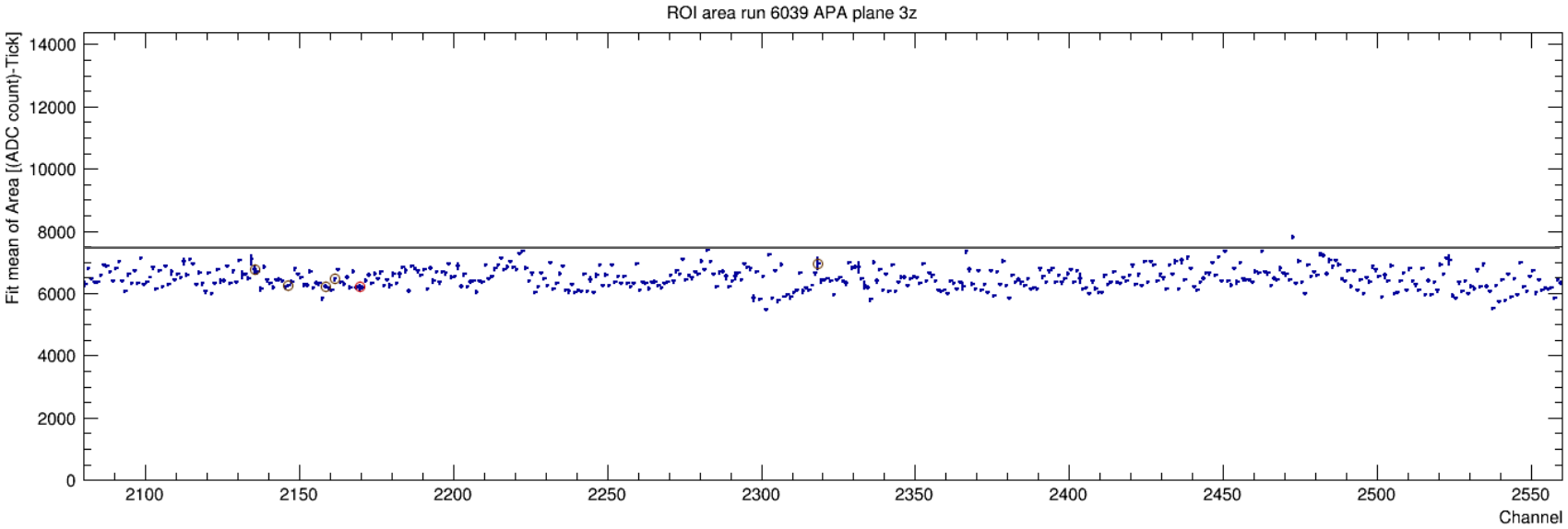

ROI area sigma run 6041 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

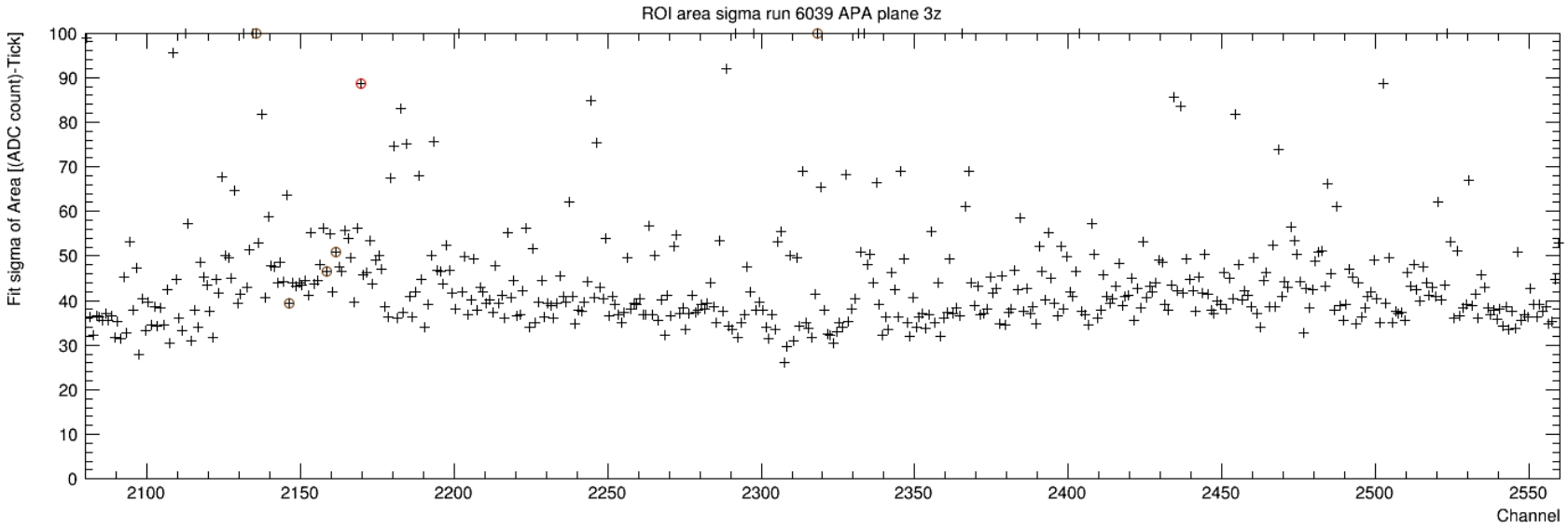
A=-7 ROI area


ROI area run 6040 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
ADC starting to saturate
Channel

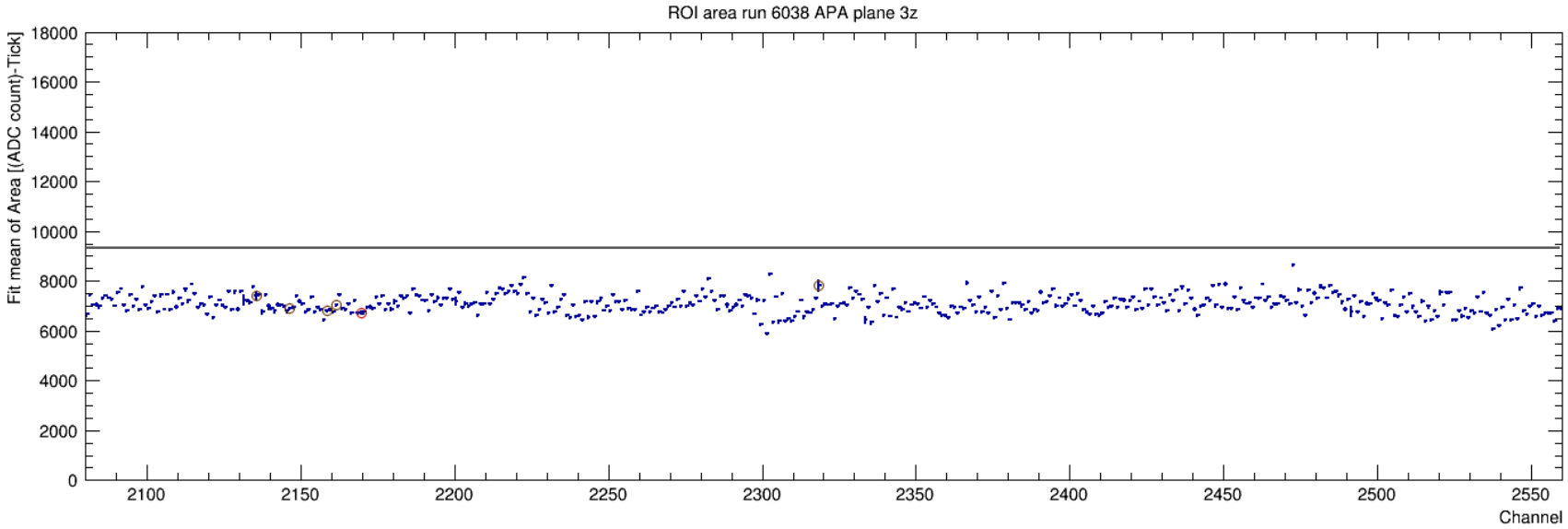

ROI area sigma run 6040 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
Channel

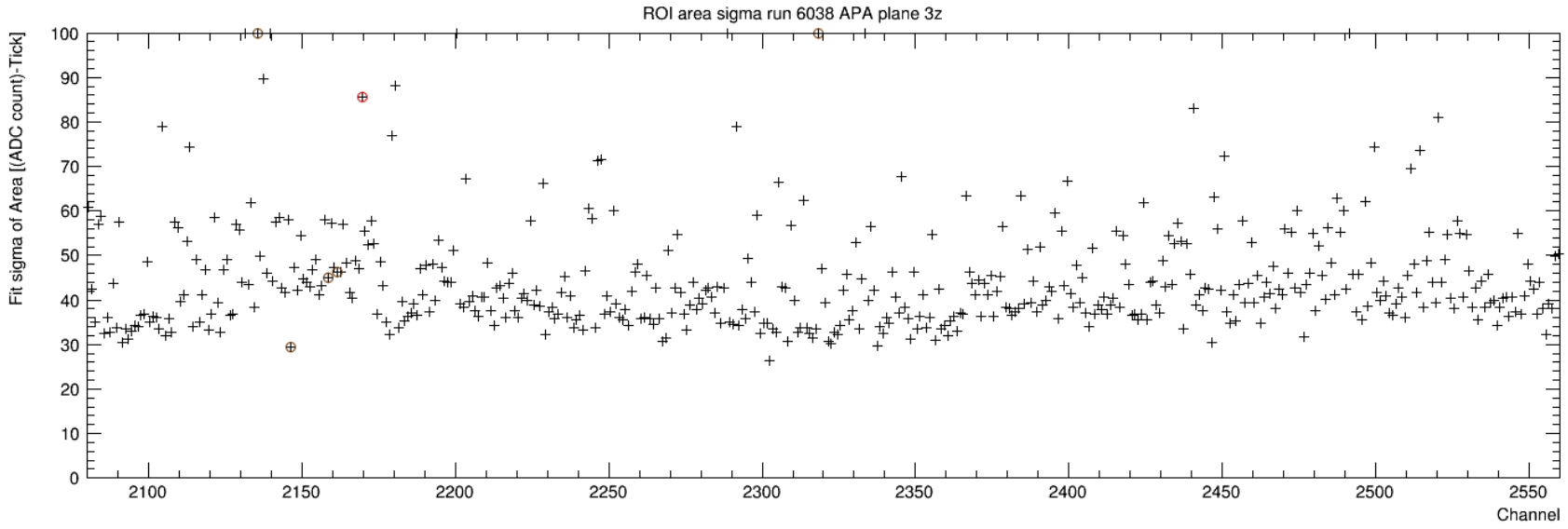
A=-8 ROI area


ROI area run 6039 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
14000
12000
10000
8000
6000
4000
2000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

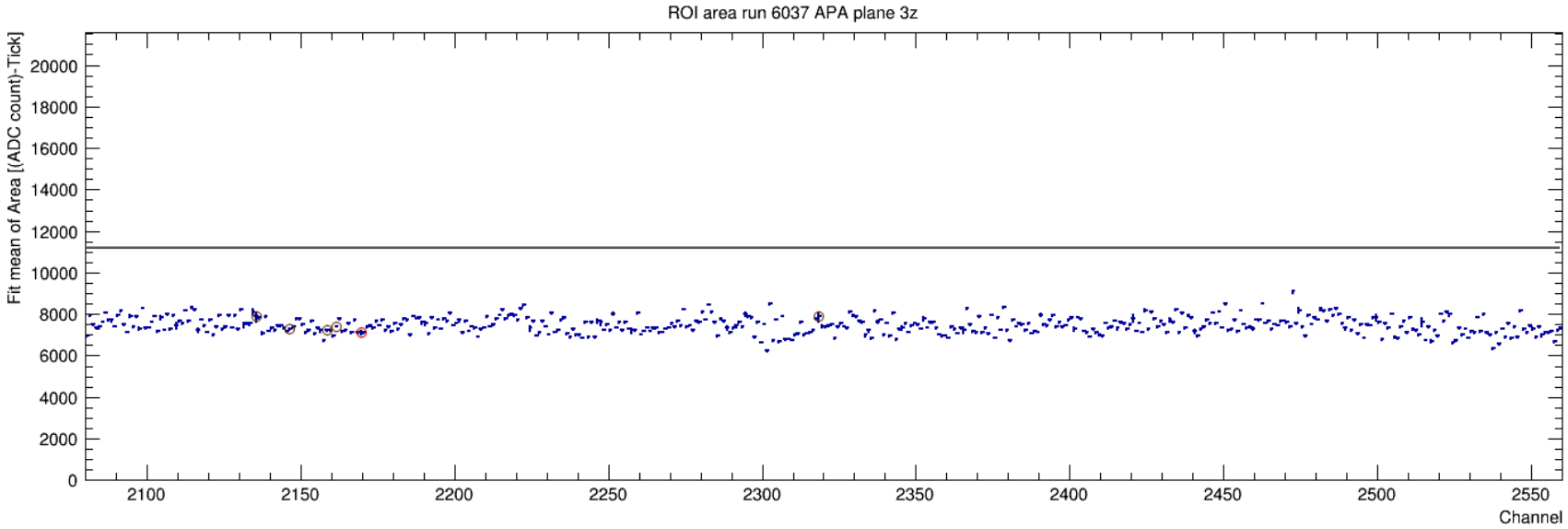

ROI area sigma run 6039 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

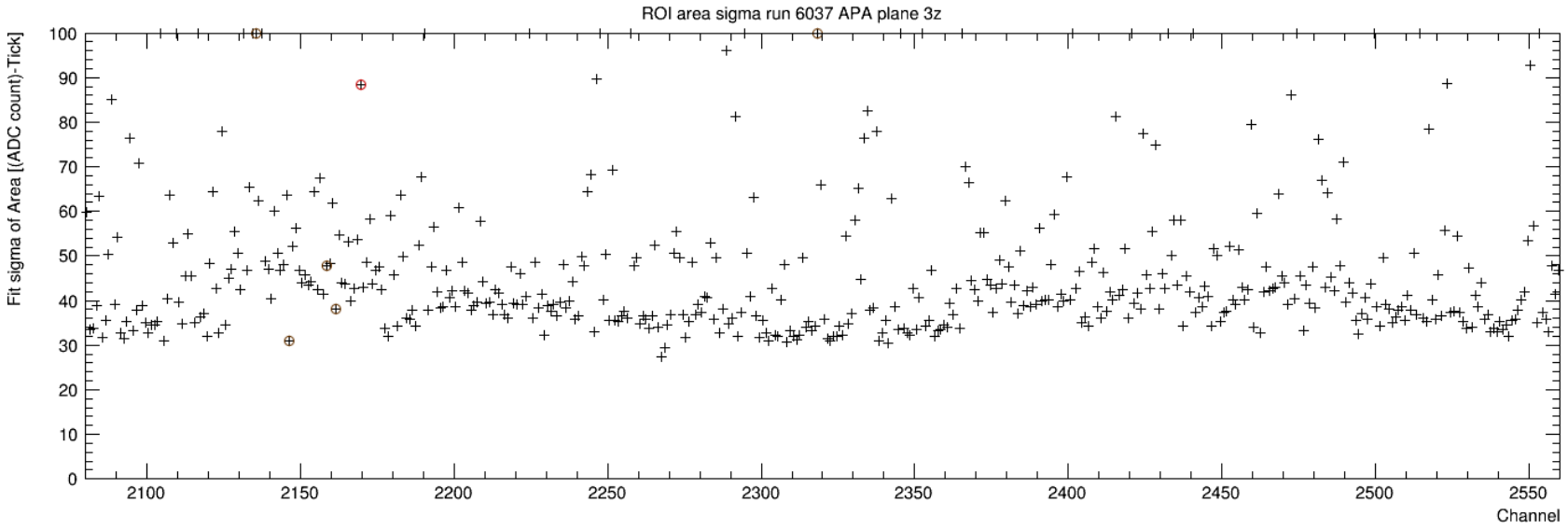
A=-10 ROI area


ROI area run 6038 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

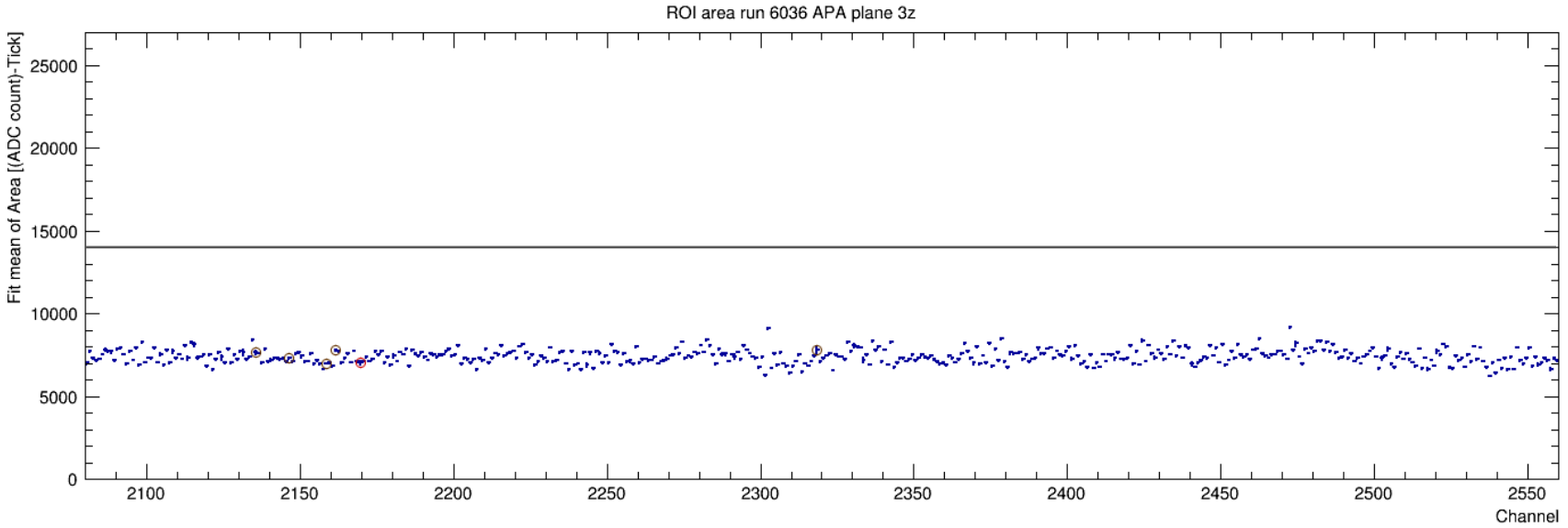

ROI area sigma run 6038 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

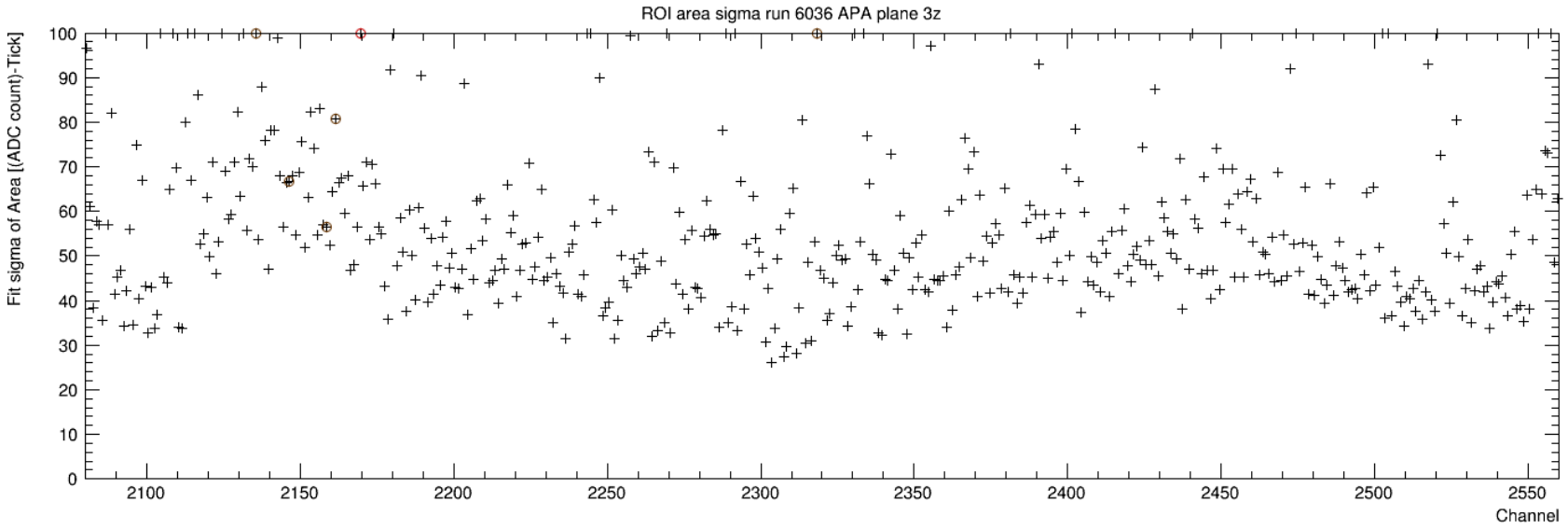
A=-12 ROI area


ROI area run 6037 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

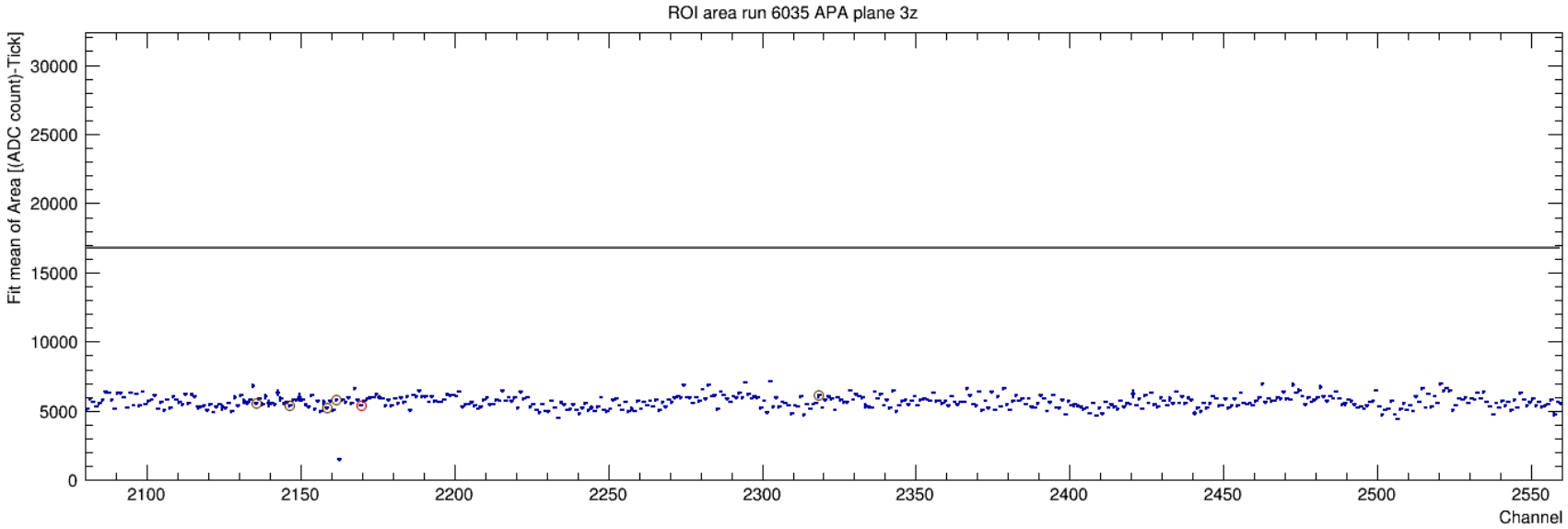

ROI area sigma run 6037 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

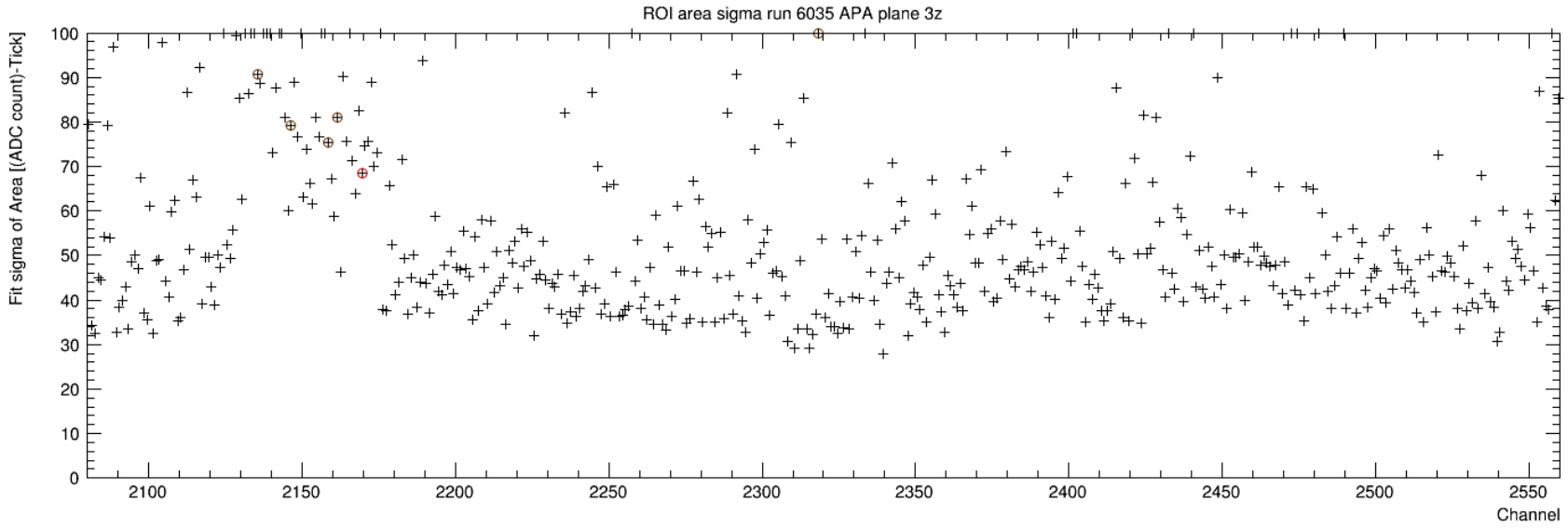
A=-15 ROI area


ROI area run 6036 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
25000
20000
15000
10000
5000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel


ROI area sigma run 6036 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

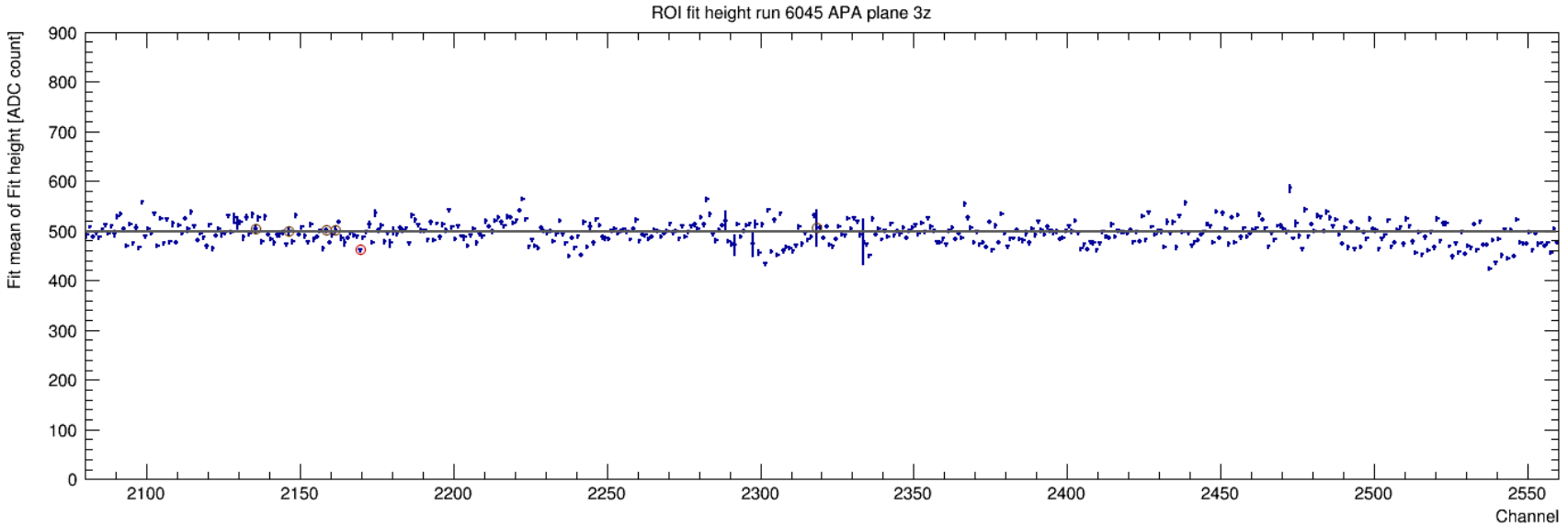
A=-18 ROI area

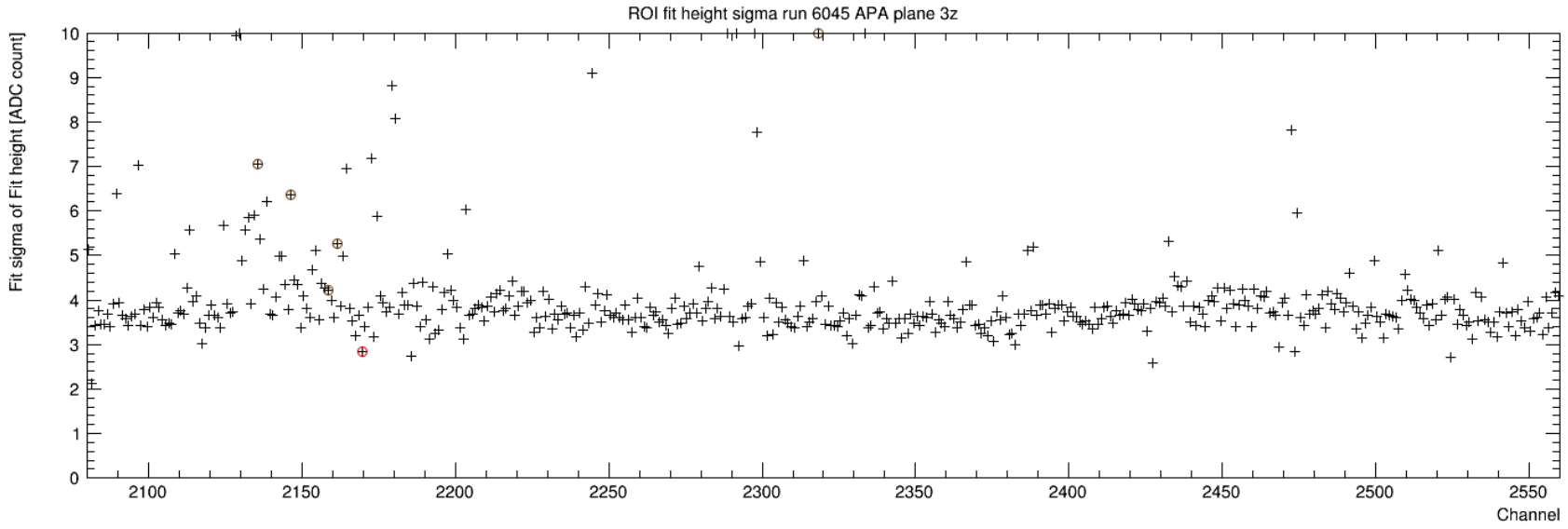

ROI area run 6035 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
30000
25000
20000
15000
10000
5000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel


ROI area sigma run 6035 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

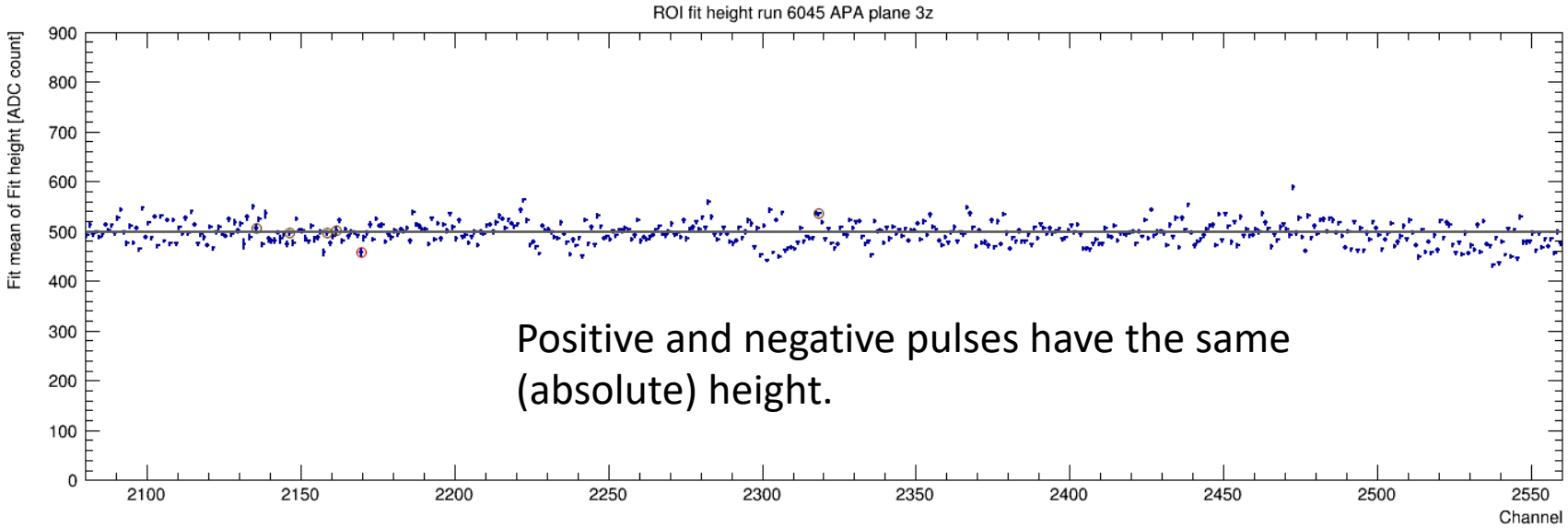
Compare positive and negative pulses

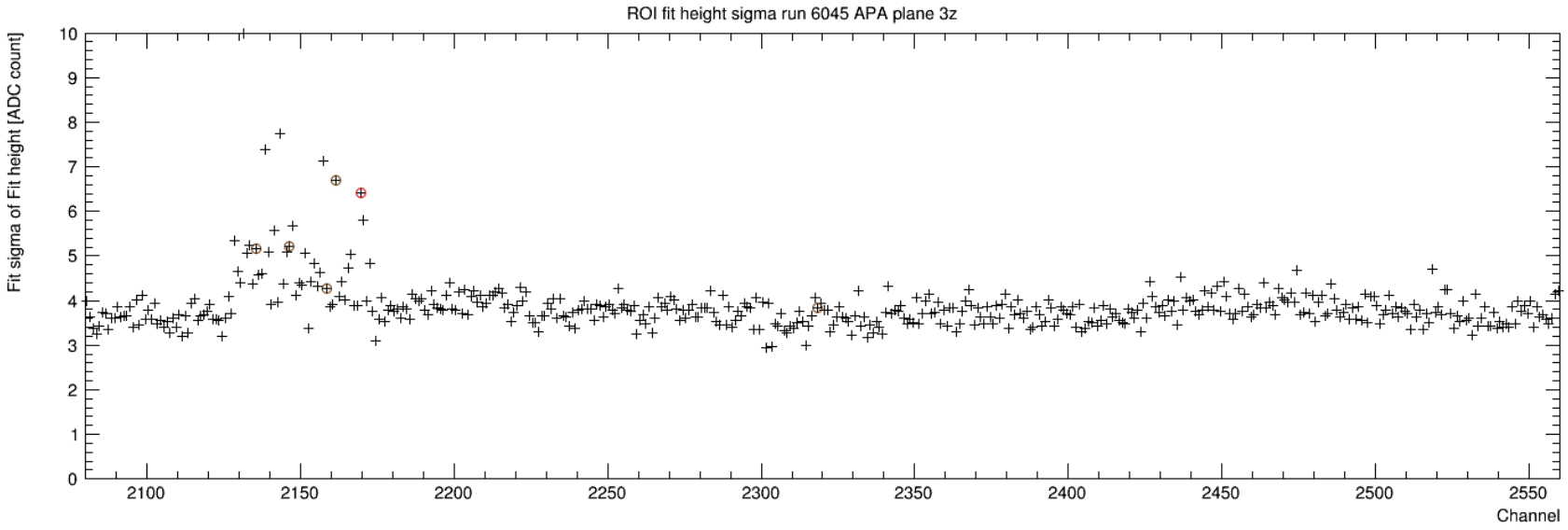
A=-3 fitted height



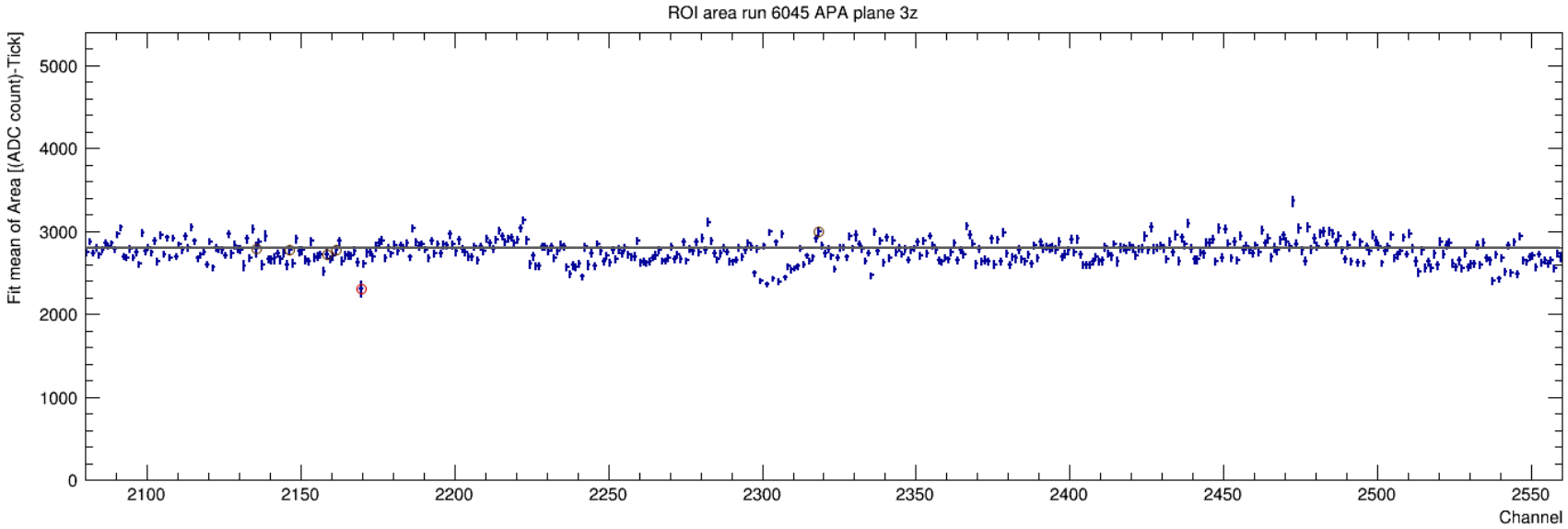


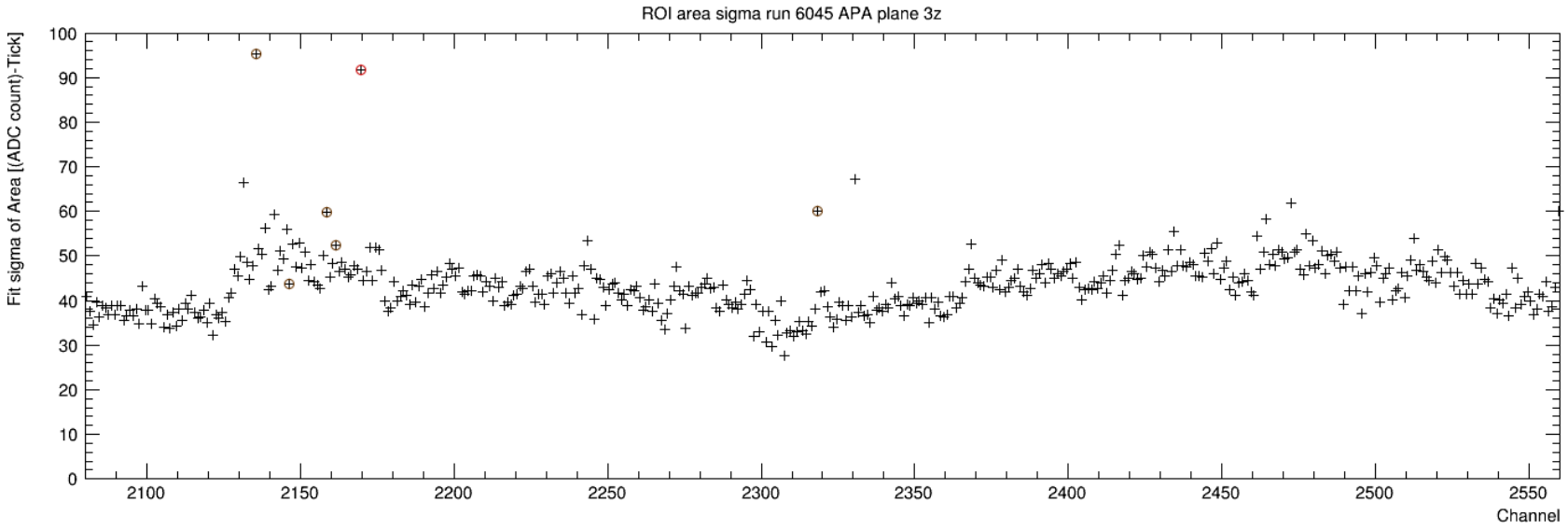
A=3 Fitted height



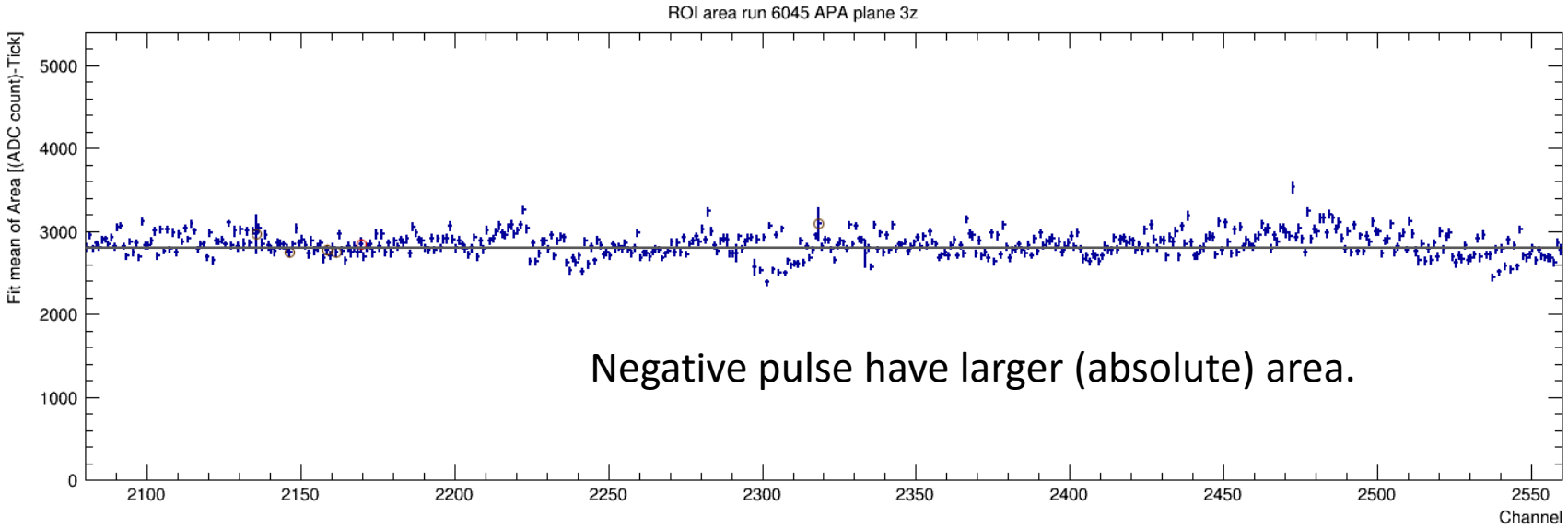


A=3 ROI area

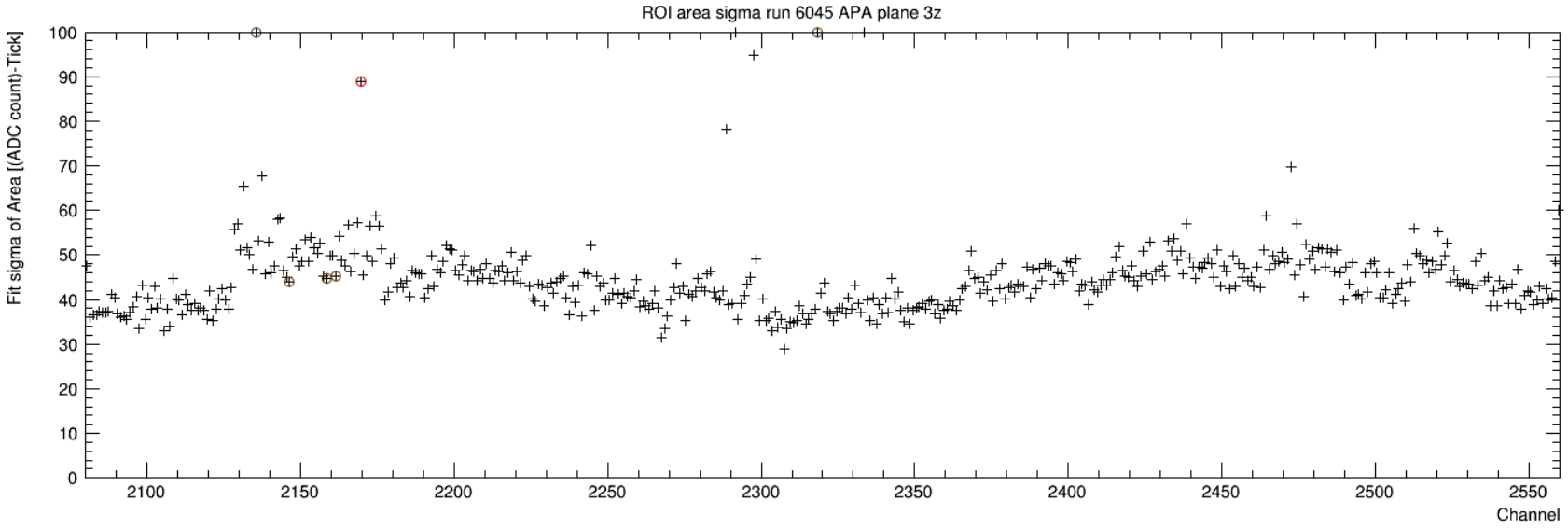

ROI area run 6045 APA plane 3z
Fit mean of Area [(ADC count)-Tick]
5000
4000
3000
2000
1000
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel


ROI area sigma run 6045 APA plane 3z
Fit sigma of Area [(ADC count)-Tick]
100
90
80
70
60
50
40
30
20
10
0
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
Channel

A=-3 ROI area

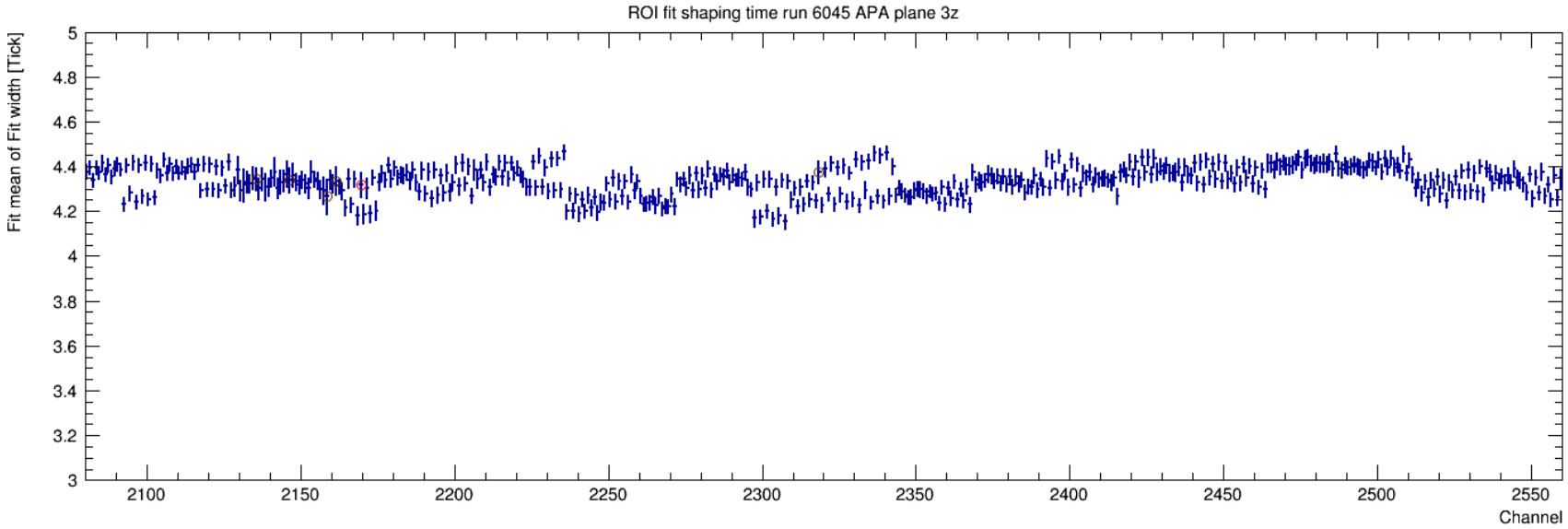


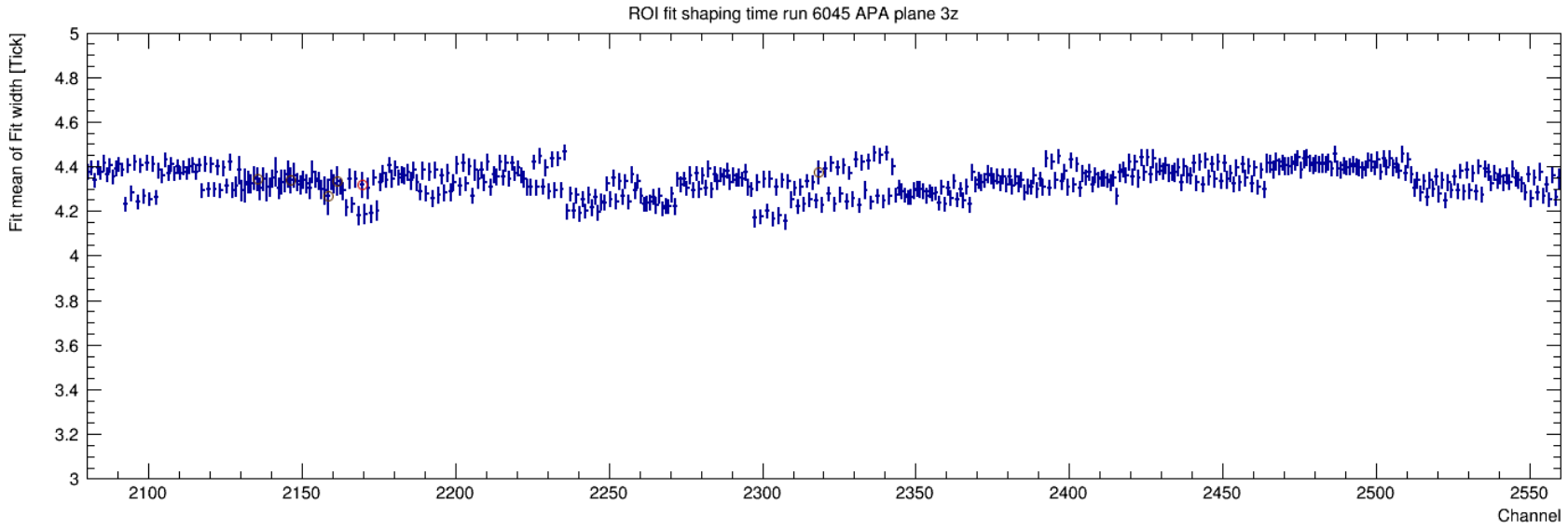
Negative pulse have larger (absolute) area.



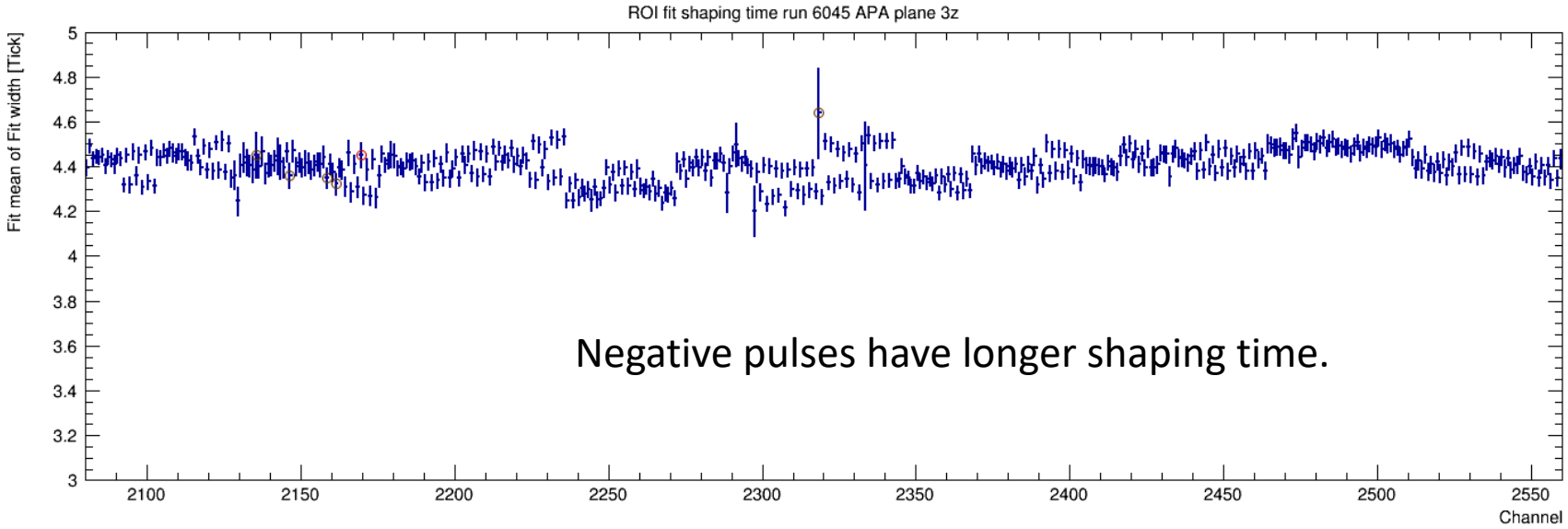
Shaping times

A=3 positive pulses

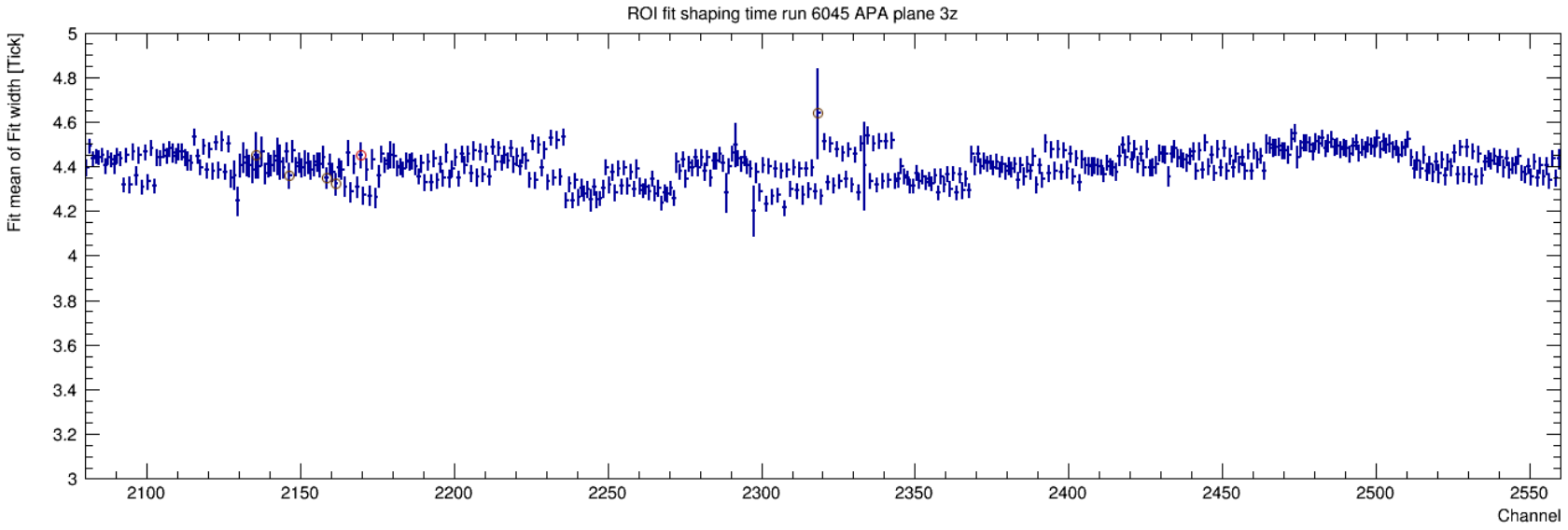




A=3 negative pulses



Negative pulses have longer shaping time.



Comments on CE performance

Some observed features for collection signals

- Positive pulser signals start to saturate (clip) at A = 18
  - This is from amplifier, not ADC
  - About what we expect for the 900 mV baseline
- For A ≥ 21, positive signals develop a tail
  - Height is 300 ADC counts, 2 MIP
- For negative signals, saturation sets in at A = -7
  - Presumably due to ADC
- For A ≤ -18, pulses have bounce back—region in middle of signal jumps up to +400 ADC counts (3 MIP)
- Negative pulses have few percent longer shaping time than positive
- Negative pulses have same absolute height but larger absolute area than positive pulses
  - Presumably due to the longer shaping
- Signal height drops by a couple percent at A=8
  - Presumably the pulser

Combining runs

Combining runs: Introduction

Combine runs to see height or area vs. A

- Calibration of CE response
- E.g. slope gives the gain

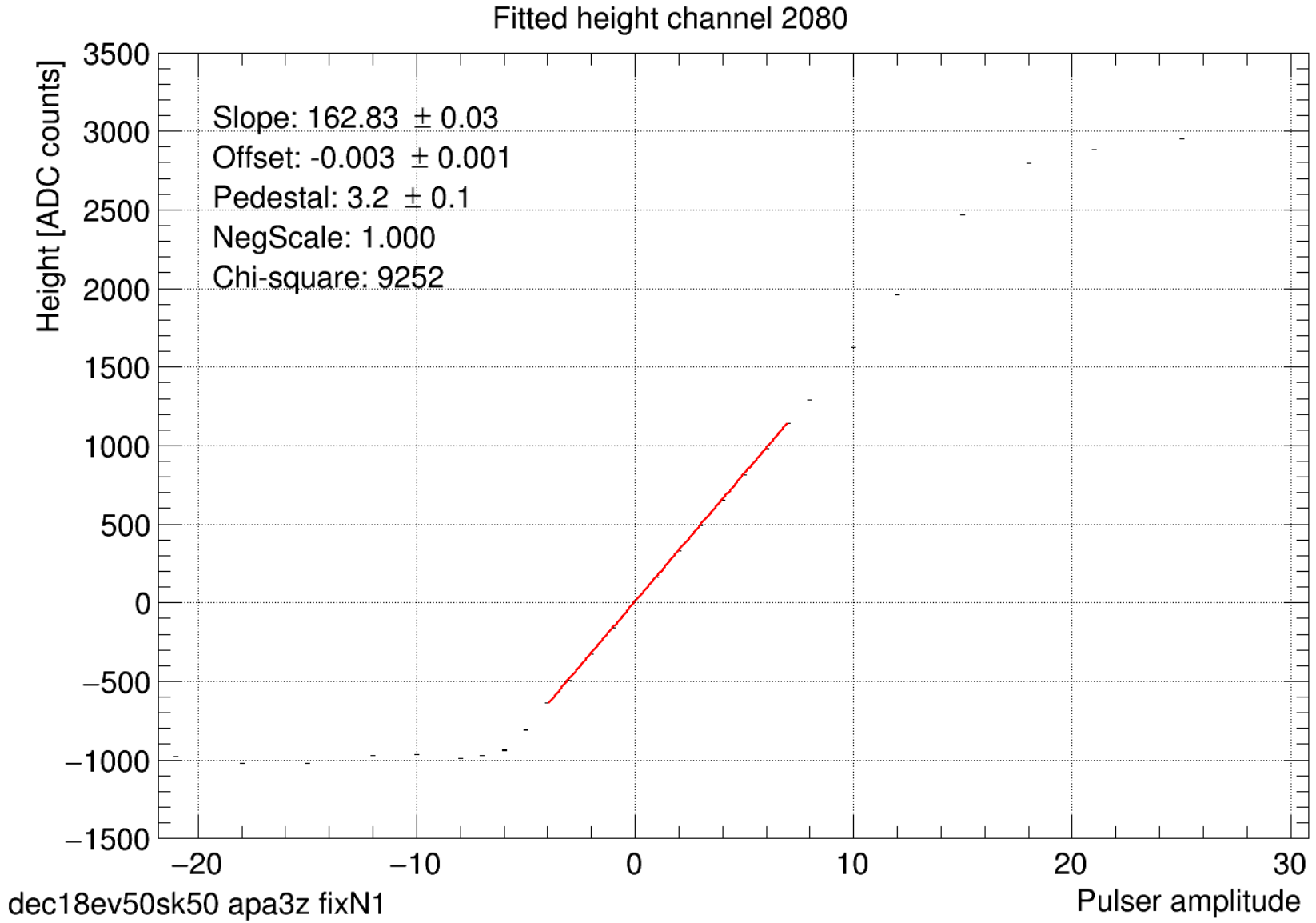
Error on height/area can be RMS or RMS/sqrt(N)

- Plots here use the latter

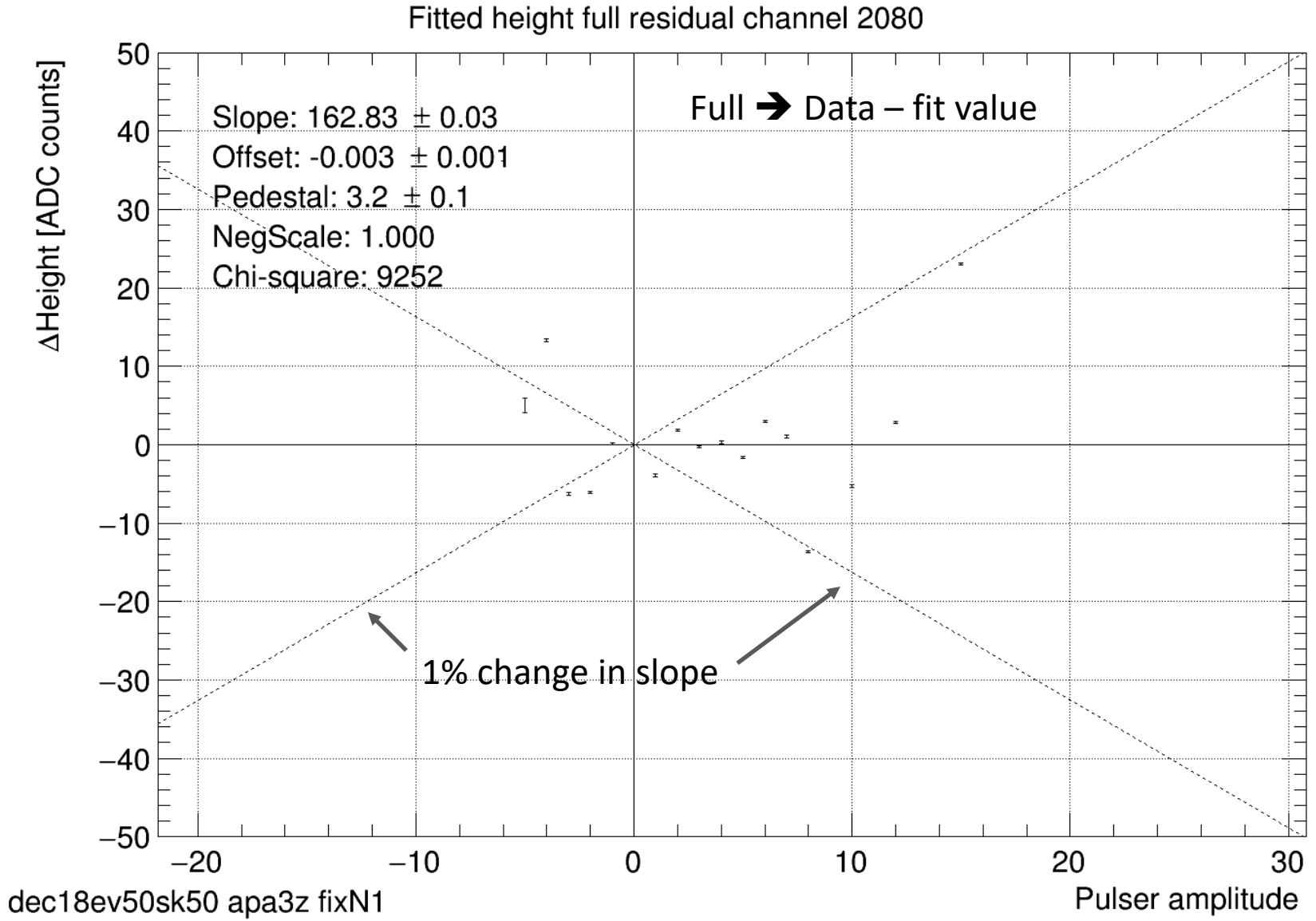
Standard fit function has four parameters

- Slope is d(Adc count)/dA
- Offset is charge offset for pulser: $Q = \text{Offset} + A \times Q_{step}$
  - Essential for studying internal pulser data
- Pedestal is offset for height/area
- NegScale is scale factor for negative charge measurements
- A couple example plots follow
- More to come…

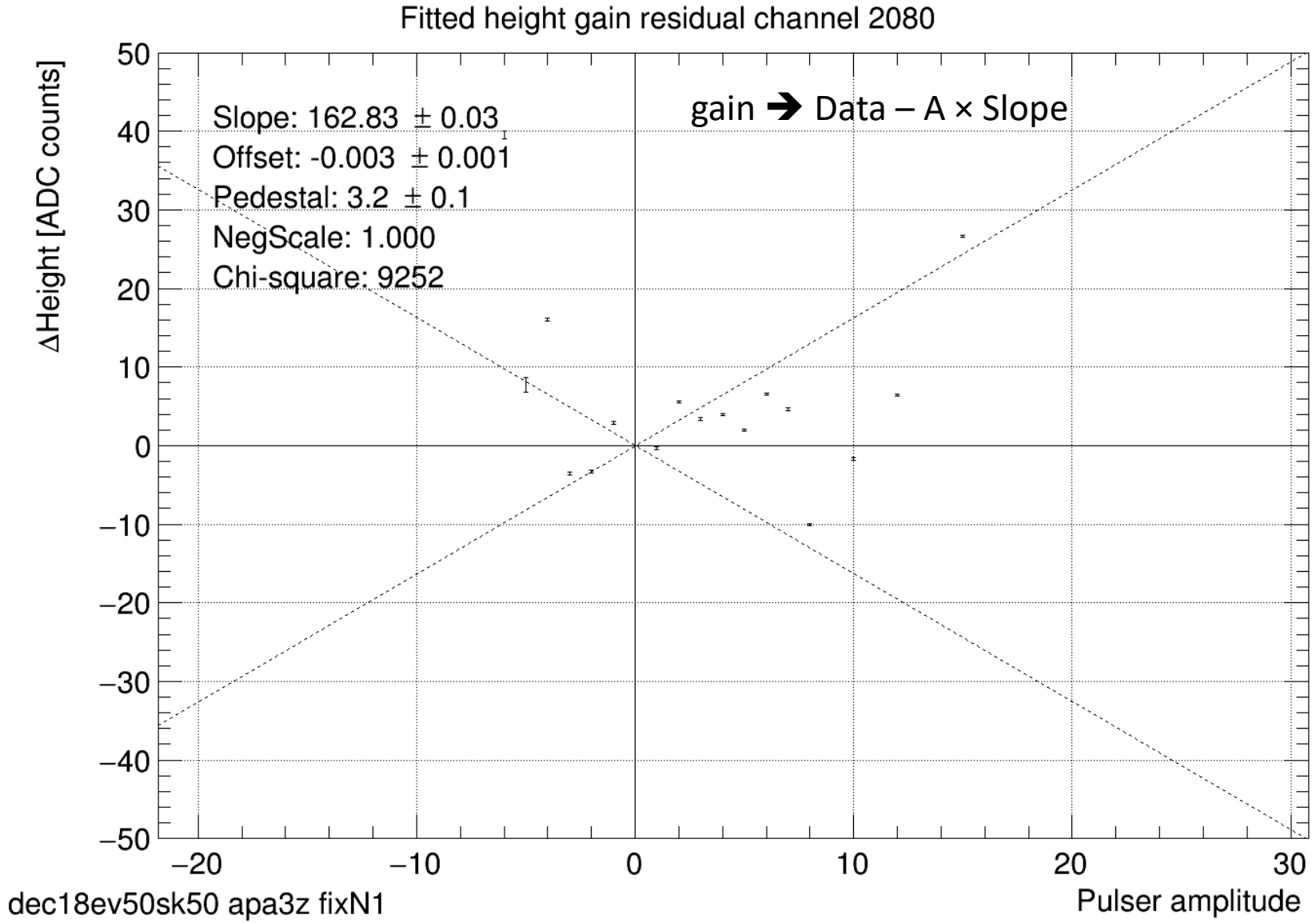
Example fit


Fitted height channel 2080
Slope: 162.83 ± 0.03
Offset: -0.003 ± 0.001
Pedestal: 3.2 ± 0.1
NegScale: 1.000
Chi-square: 9252
Height [ADC counts]
3500
3000
2500
2000
1500
1000
500
0
−500
−1000
−1500
−20
−10
0
10
20
30
dec18ev50sk50 apa3z fixN1
Pulser amplitude

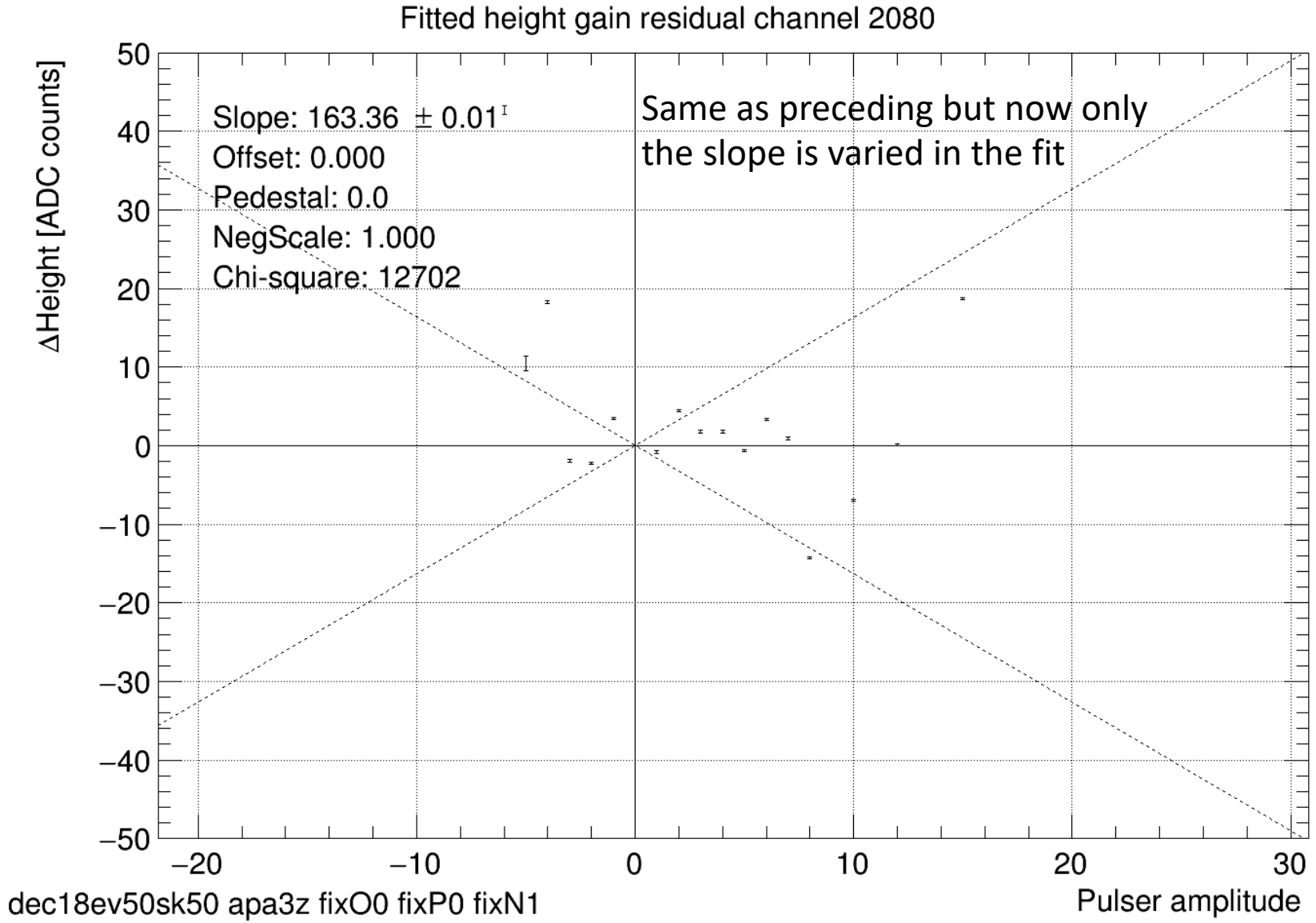
Example fit full residual



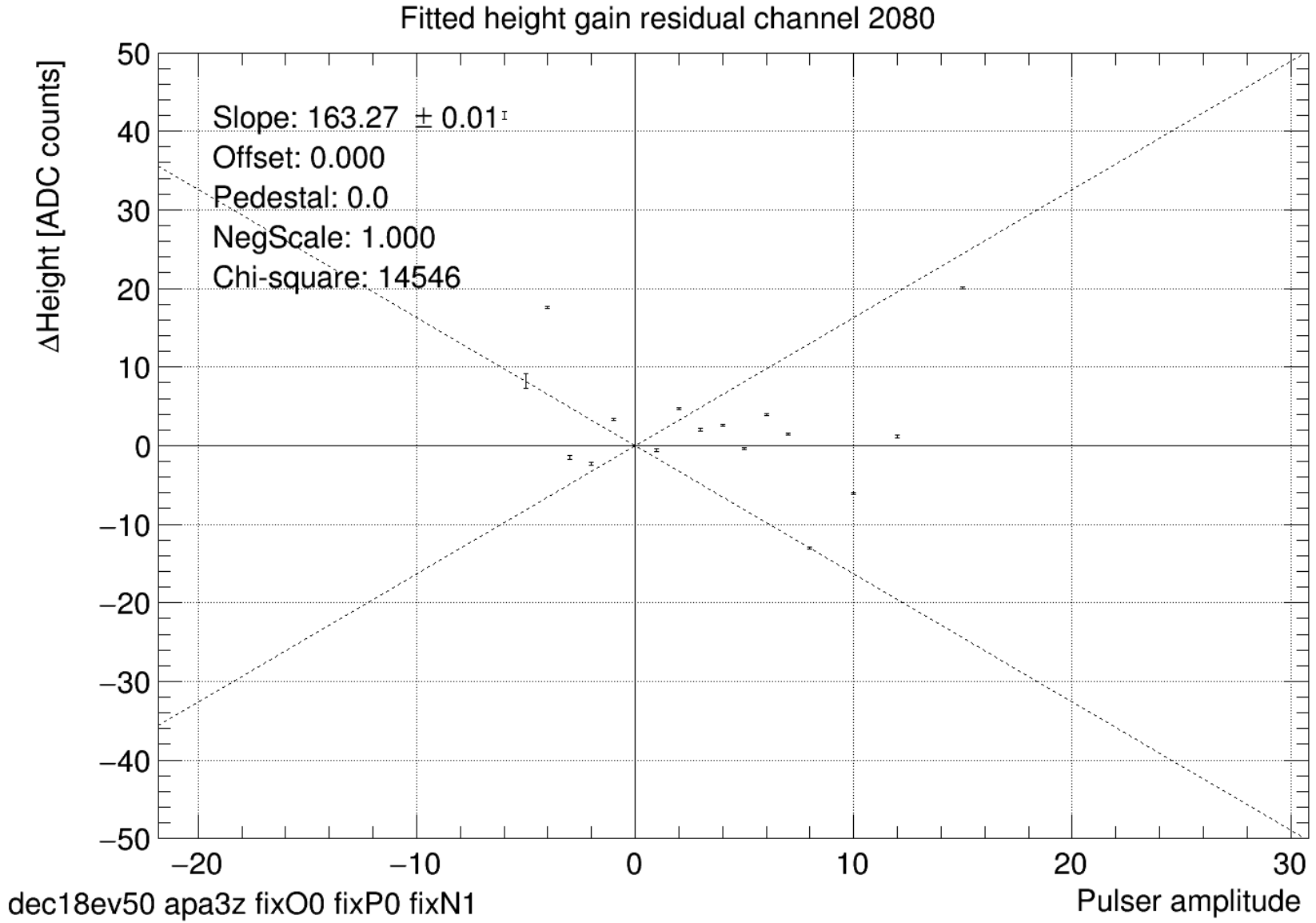
Example fit gain residual



Example different fit full residual



Same with different data



Fit comments

Fit quality is not good

- I.e. chi-squares around 10,000
- Can see problem by eye in point-to-point variation
- Plot with different 50 events shows variation is not statistical
- Presumably real non-linearity in ADC response
  - Variation is a few ADC counts
- Can use the pulser data to measure non-linearity
  - But need much better illumination than here
  - Especially if non-linearity is from sticky codes
- Illumination can be improved
  - Adding other gain settings
  - Use points along waveforms
  - Offset pulse w.r.t. TPC clock (in combination with preceding)
- However note size nonlinearity is a few ADC counts
  - I.e. similar to the ADC noise level
  - So don’t expect nonlinearity to seriously degrade resolution

Calibration

An important product of pulser analysis is calibration

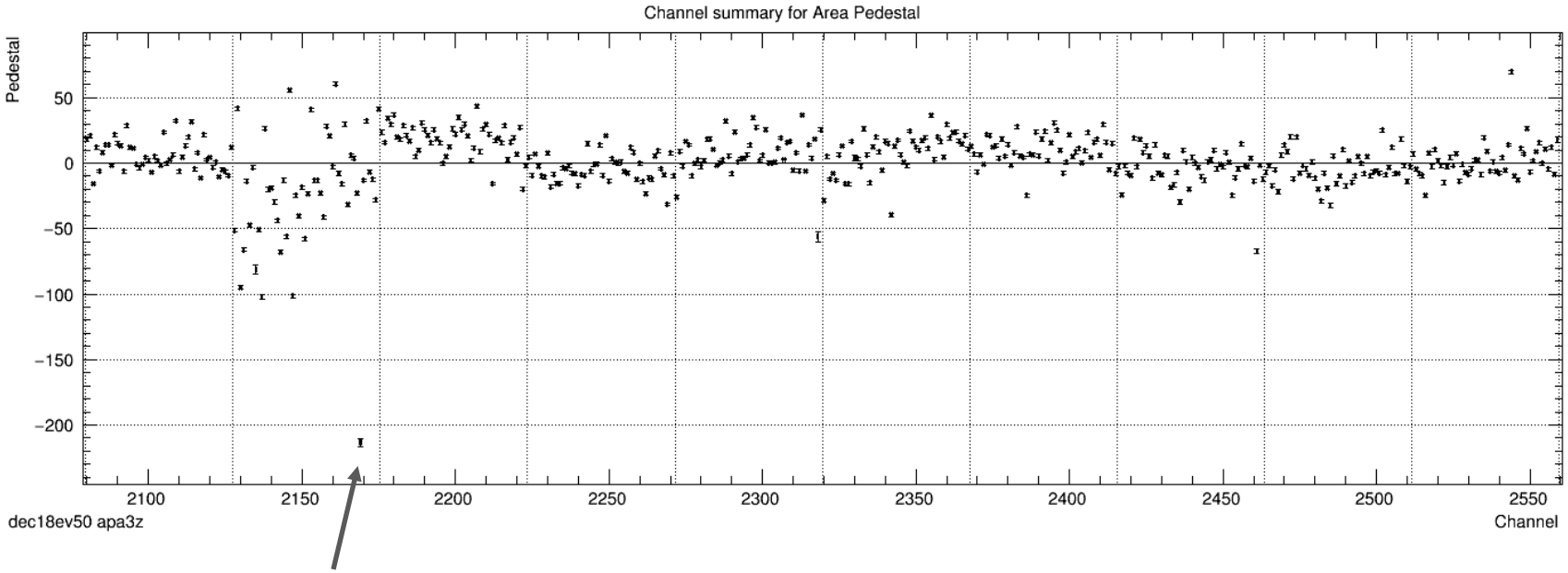
- To begin, gain calibration (i.e. deferring nonlinearity corrections)
- Can calibrate height or area
  - Height useful for fast (or at least uniform shape) signals
    - Like the pulser
  - But physics signals are smeared by varying track angle, charge diffusion and ionization rate (dE/dx)
  - So calibrate area gain, i.e. charge per ADC-tick
  - Still plan to apply calibration to each ADC sample

Area calibration channel summary plots follow

- First the nuisance parameters (all but Slope) with all varied
- The the Slope (= 1/gain) varying different combinations

Nuisance parameters

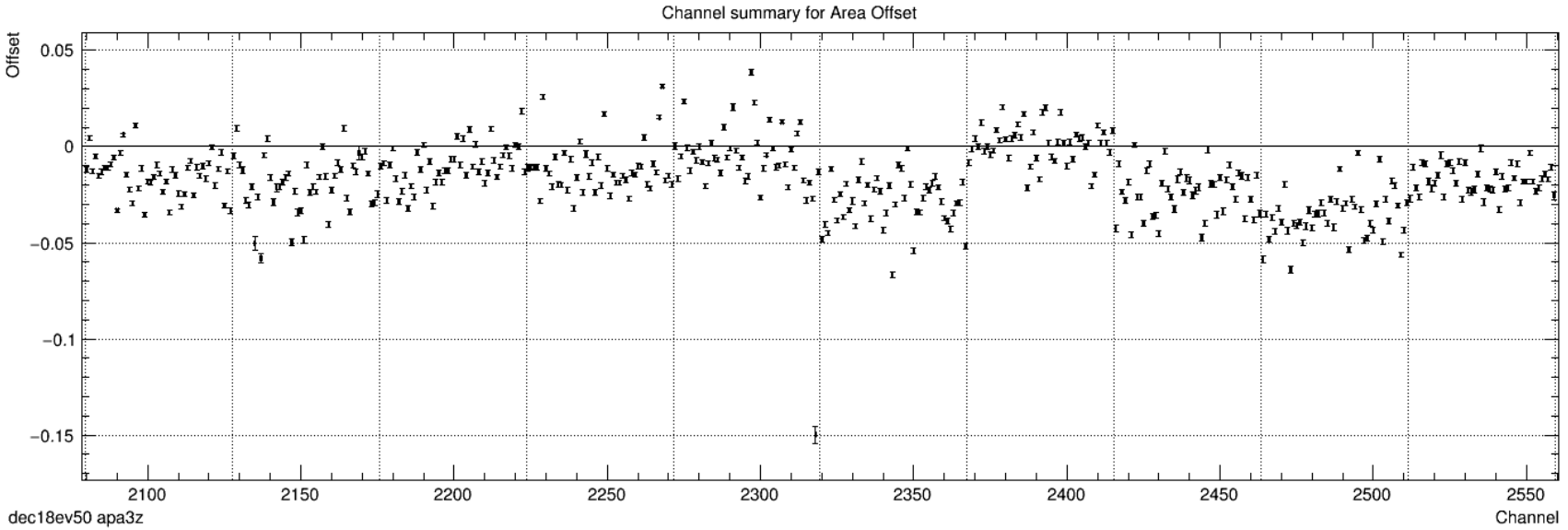
Pedestal fits



Known bad channel

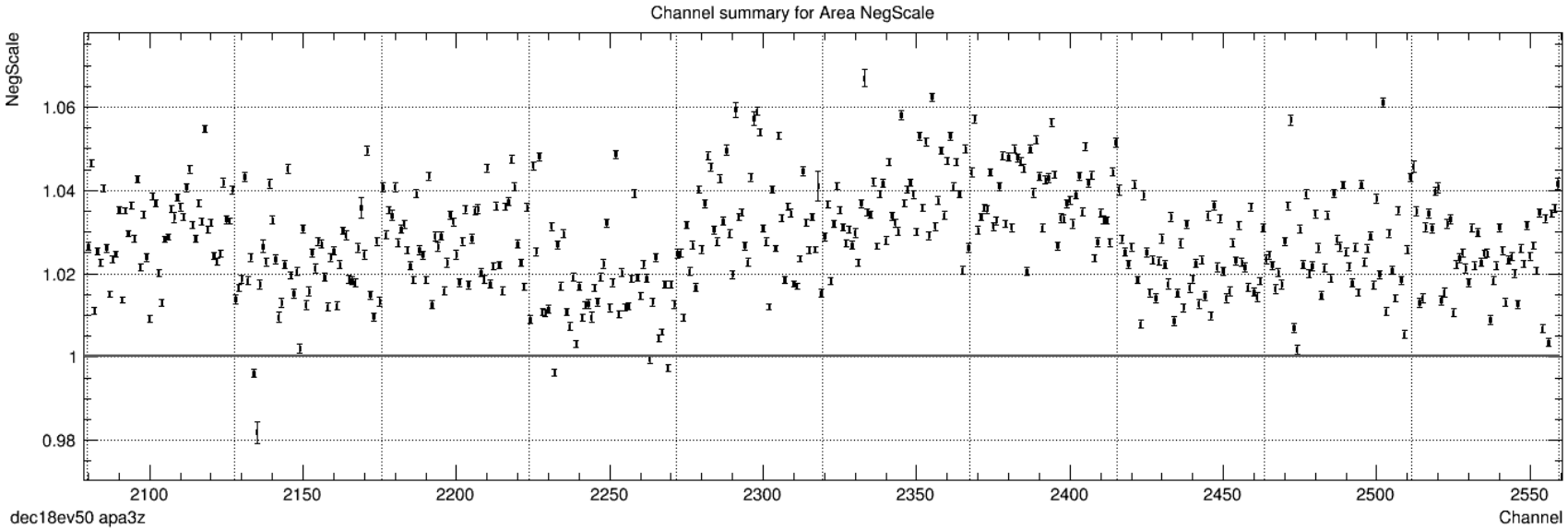
Area is integrated over 30 ADC bins. So Area Pedestal of 30 corresponds to ADC pedestal of 1.

Offset



Looks like there might be real (but small) offset in the pulser signals. Values tend to cluster for each FEMB.

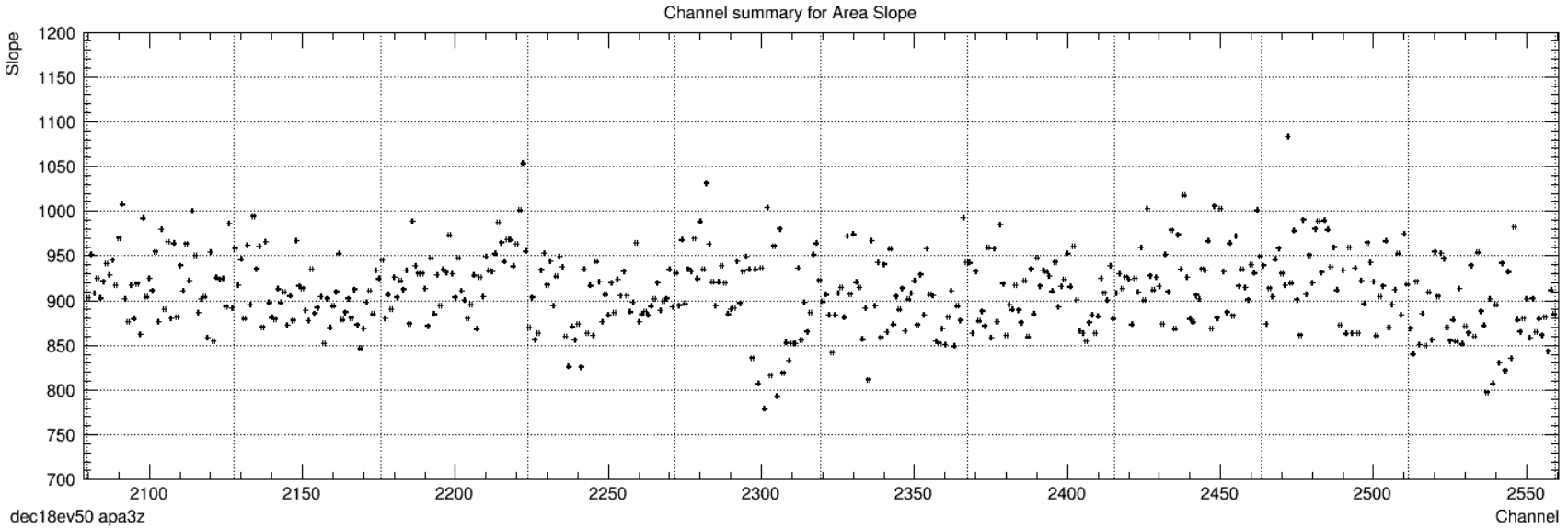
NegScale



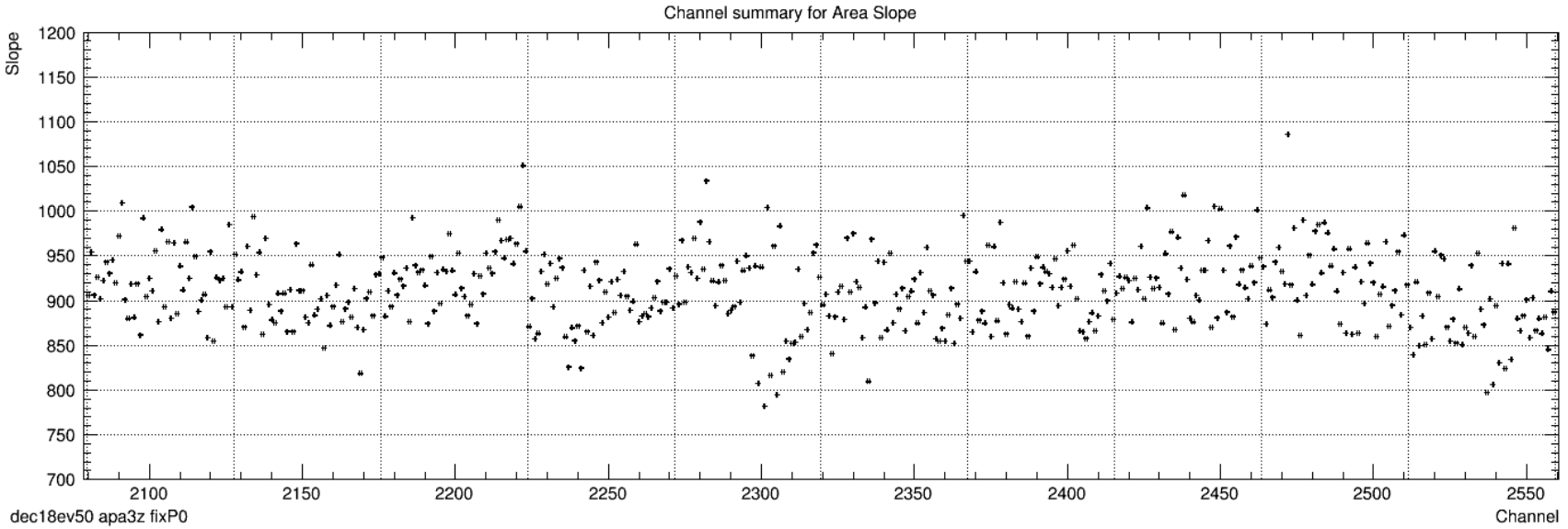
As we say earlier, negative signal do have slightly larger area than their positive counterparts.

Slope (= 1/gain)

All parameters varied

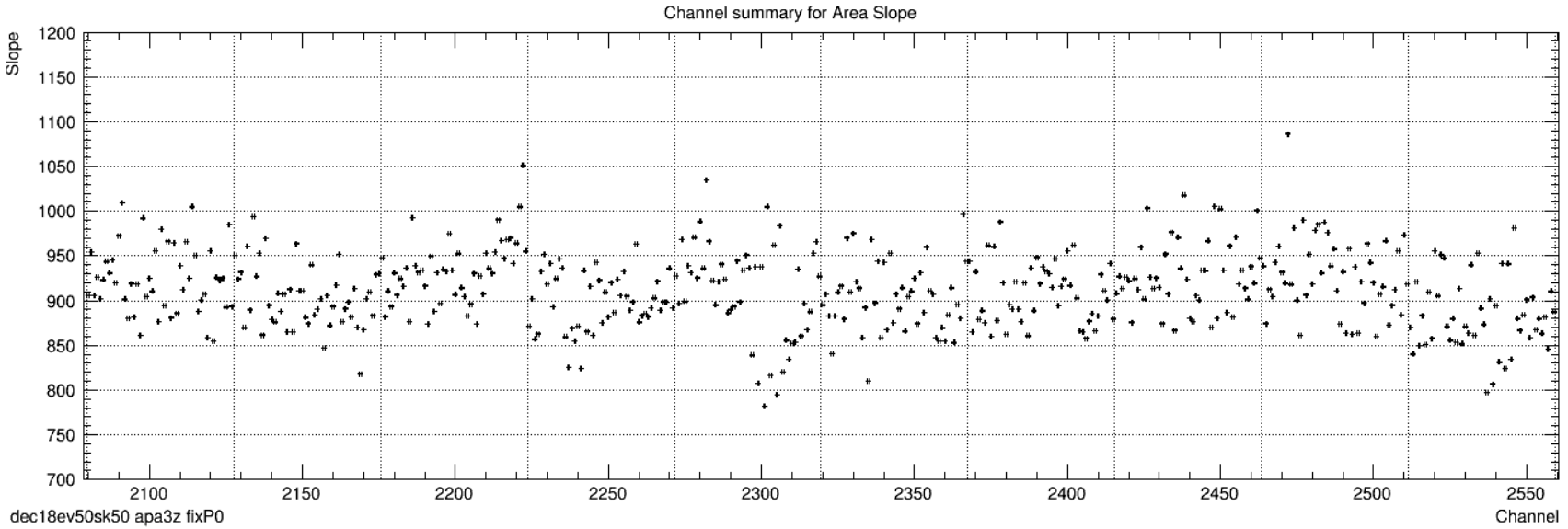


Fix pedestal=0

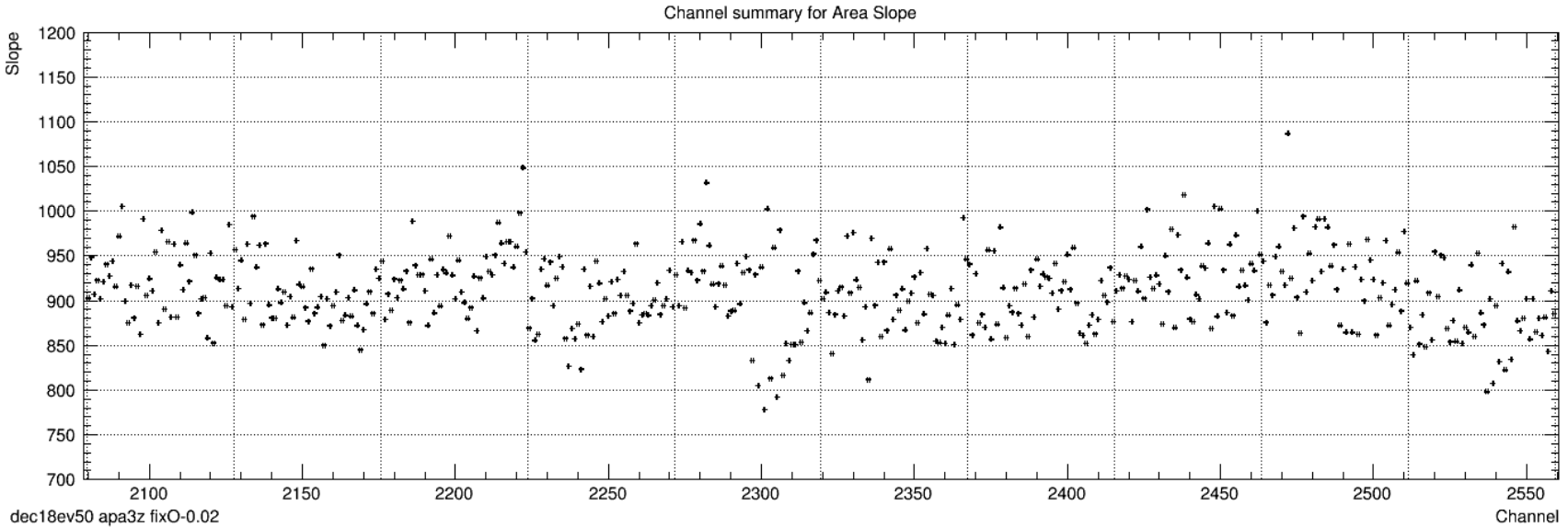


Use this for calibration?

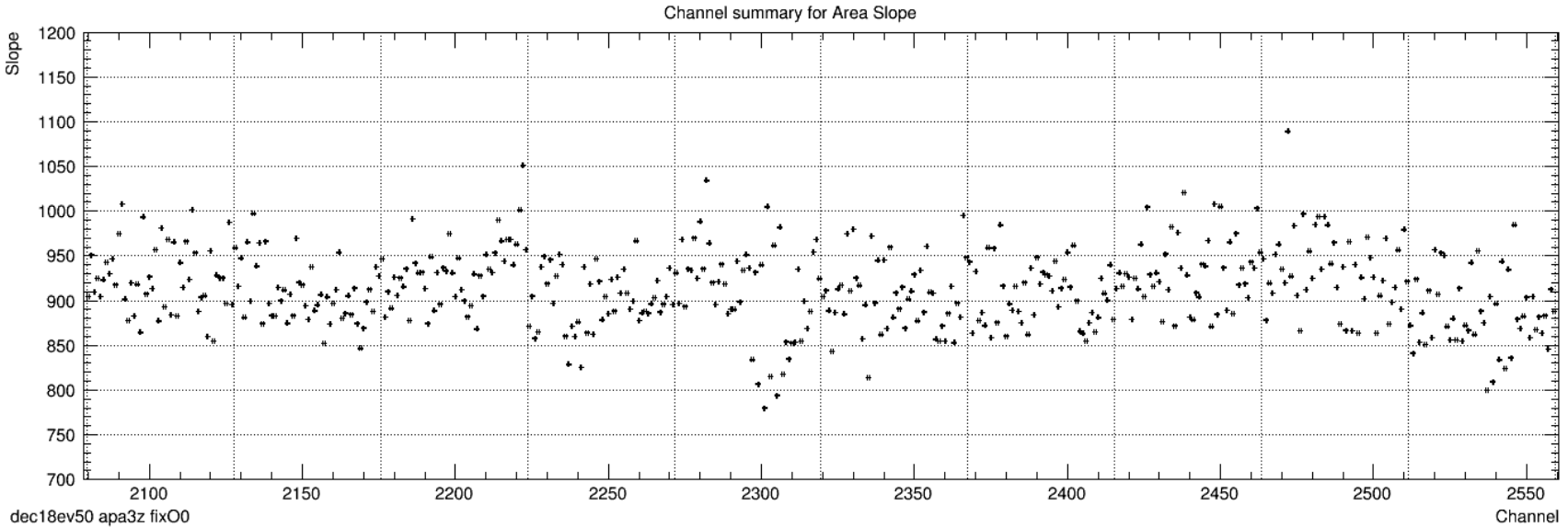
Fix pedestal=0 for different set of events



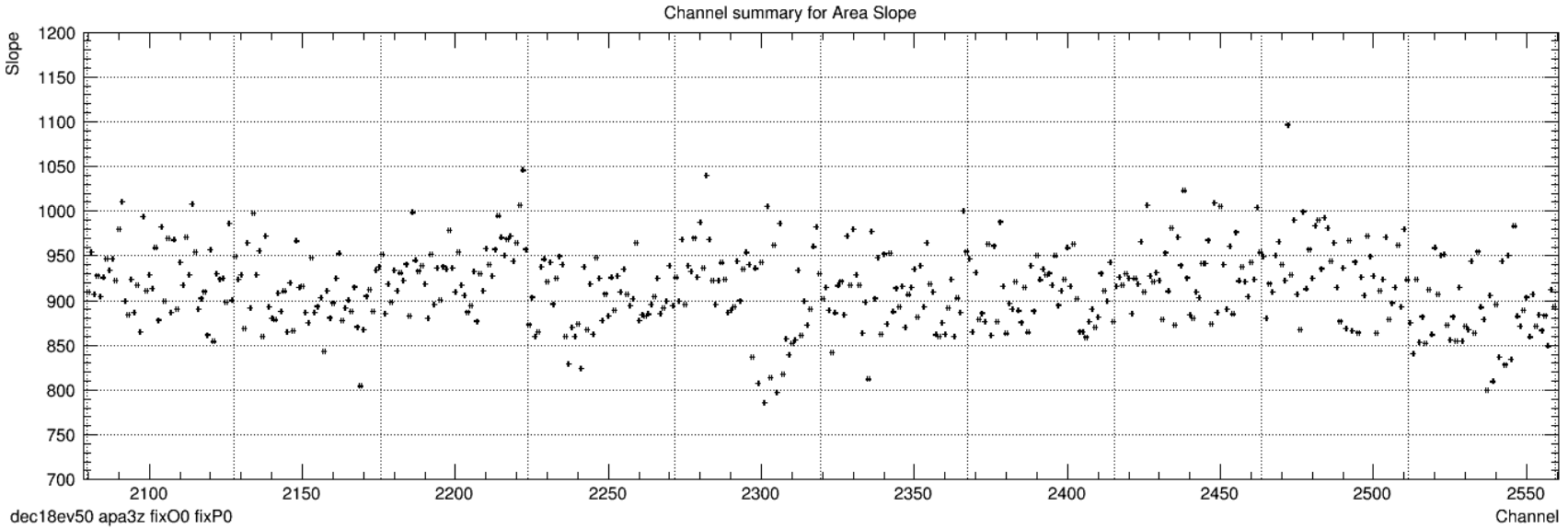
Fix Offset=-0.02



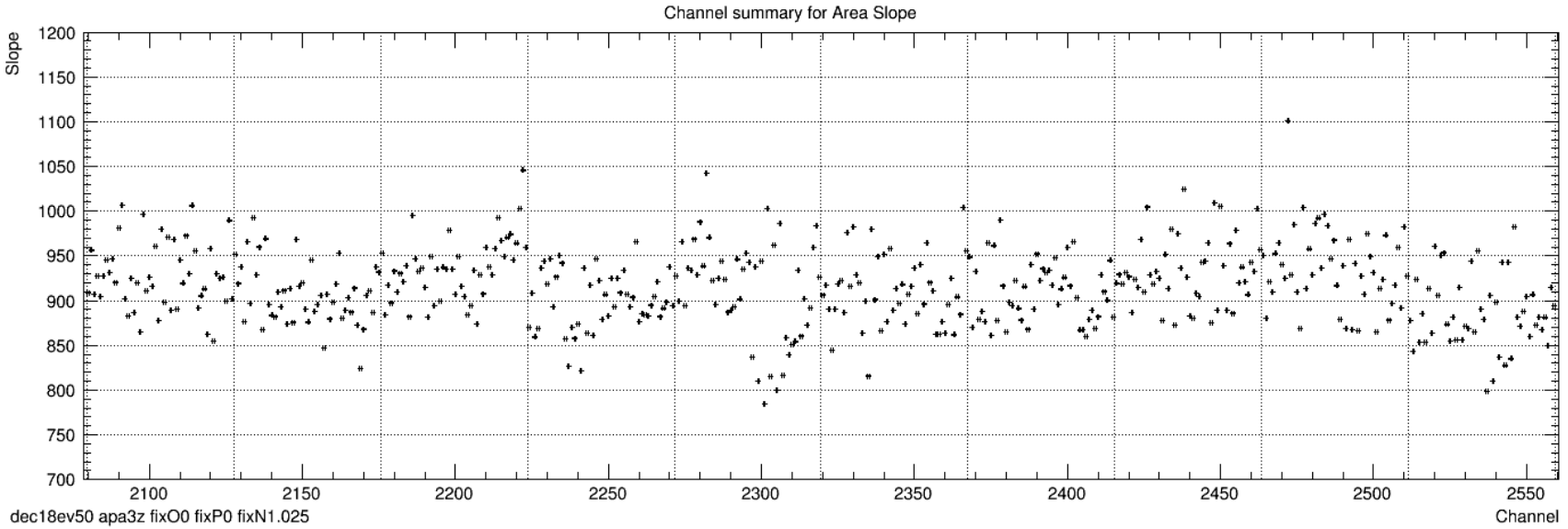
Fix Offset=0


Channel summary for Area Slope
Slope
1200
1150
1100
1050
1000
950
900
850
800
750
700
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
dec18ev50 apa3z fixO0
Channel

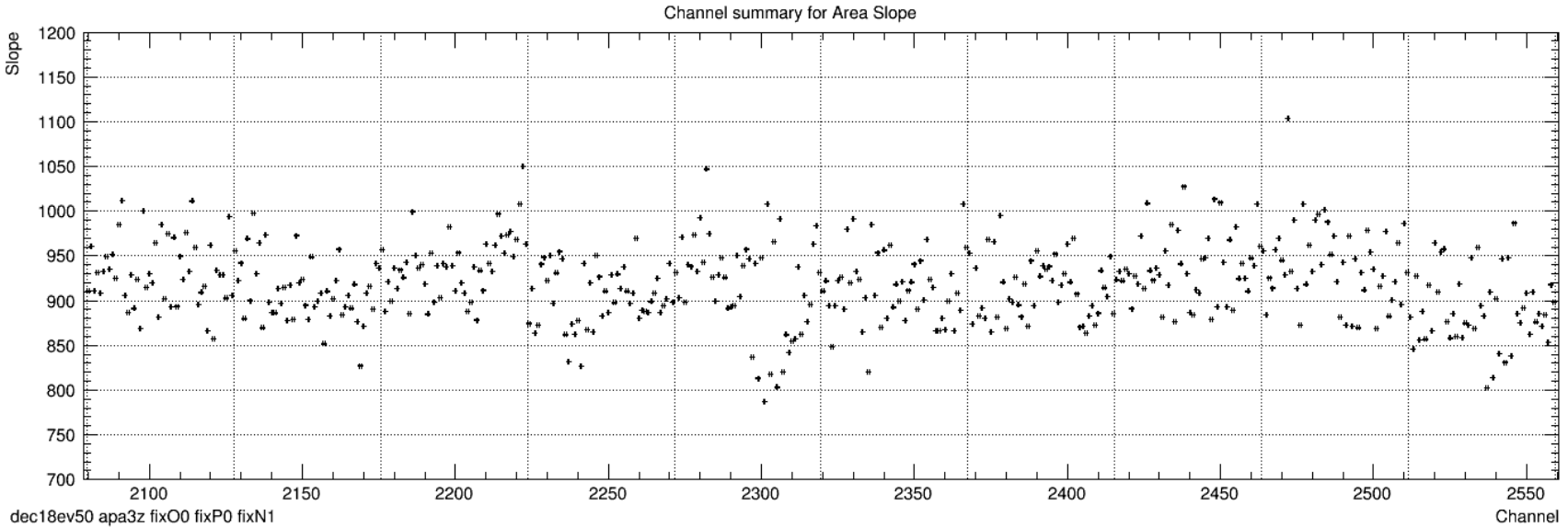
Fix Offset=0 and Pedestal=0



Fix Offset=0, Pedestal=0 and NegScale=1.025



Fix Offset=0, Pedestal=0 and NegScale=1 (wrong)



Calibration comments

Nuisance parameters are small but significant

- Pedestal ≤ 30 ➔ ADC pedestal offset ≤ 1
  - May be able to use pulser to refine pedestal evaluation
- Offset ≈ -0.02
  - Real offset in the pulser?
  - There is a obvious, much larger offset with the internal pulser
- NegScale ≈ 1.025
  - Negative pulses are really longer
  - Should we apply this factor when pedestal-subtracted ADC count is negative?

Gain fits

- Only small variation with sensible fitting options
- Probably any of these are OK for calibration

Calibration proposal

For now, use fit with pedestal fixed to zero

- I.e. so we use the pedestals as evaluated in physics data
- Quickly generate calibration for use in data processing
  - I.e. for each channel
    - Gain
    - Positive and negative shaping times
    - Min and max limits for good signals
      - » Below/above, samples are flagged as underflow/overflow

Possible future developments

- Use pulser data to evaluate pedestals or study current pedestal algorithm
- Scale negative pulses by negative/positive shaping times
- Assign a pulser offset for each FEMB by averaging its fitted values

Calibration tool and units

Calibration will be carried out by new ADC channel tool

- Input is raw ADC count
- Output is the floating array samples and int array flags
  - Each sample is gain×(raw – pedestal)
- Replace the current trivial calibration adcSampleFiller

What units do we want for the calibration?

- Do want area calibration so units are charge per (ADC count)-tick?
  - For collection, sum bins to get the charge for an ROI
- Which unit for charge?
  - fC, e, ke, …
  - Or average/nominal ADC ≈ 23 e, i.e. close to current values
  - My vote is for ke