TPC electronics calibration with pulser in cold box data

BNL DUNE

David Adams
BNL

June 20, 2018

Introduction

I look at APA data from CERN

- Data available at CERN and FNAL
    - https://wiki.dunescience.org/wiki/Accessing_ProtoDUNE-SP_Cold_Box_Test_Data_in_LArSoft
- Single APA in a cold box
    - Expect to find 2560 channels: 20 FEMB × 128 chan/FEMB
    - For APA5 testing, 12/20 FEMBs have data → 1536 channels
- Some data taken with pulser
    - DAC = 1, 2, …, 10 (See following page)
- Use this data to calibrate the TPC electronics
    - I.e. convert ADC count to input charge

Pulser

Pulser

- DAC used induce voltage shift V_{in} at input to preamp
  - (As does a moving charge in the vicinity of an anode wire)
  - Voltage shifted up and then back down periodically
  - Rising and falling edges inject charge

- With known input capacitance C, the charge injection is $Q_{in} = C\, V_{in}$
  - DAC setting of P = 0, 1, 2,…, 63 should give $V_{in} = P\, V_{step}$

    ➔ $Q_{in} = P\, Q_{step}$ where

    $Q_{step} = C\, V_{step}$ = (183 fF) (18.75 mV) = 3.43 fC = 21.4 ke
- Two options for the pulser
  - Internal: DAC is on the preamp ASIC
  - External: DAC on the FEMB

P = 1 is about 1 MIP

- APA5 data taken with internal pulser
  - Behavior does not follow the above ideal
  - There is a channel-dependent offset: $V_{in} = V_{off} + P\, V_{step}$ for P > 1
  - P = 1 has additional channel dependence
  - Ignore P = 1 and, for P > 1, assume $Q_{in} = Q_{off} + P\, Q_{step}$

Analysis procedure

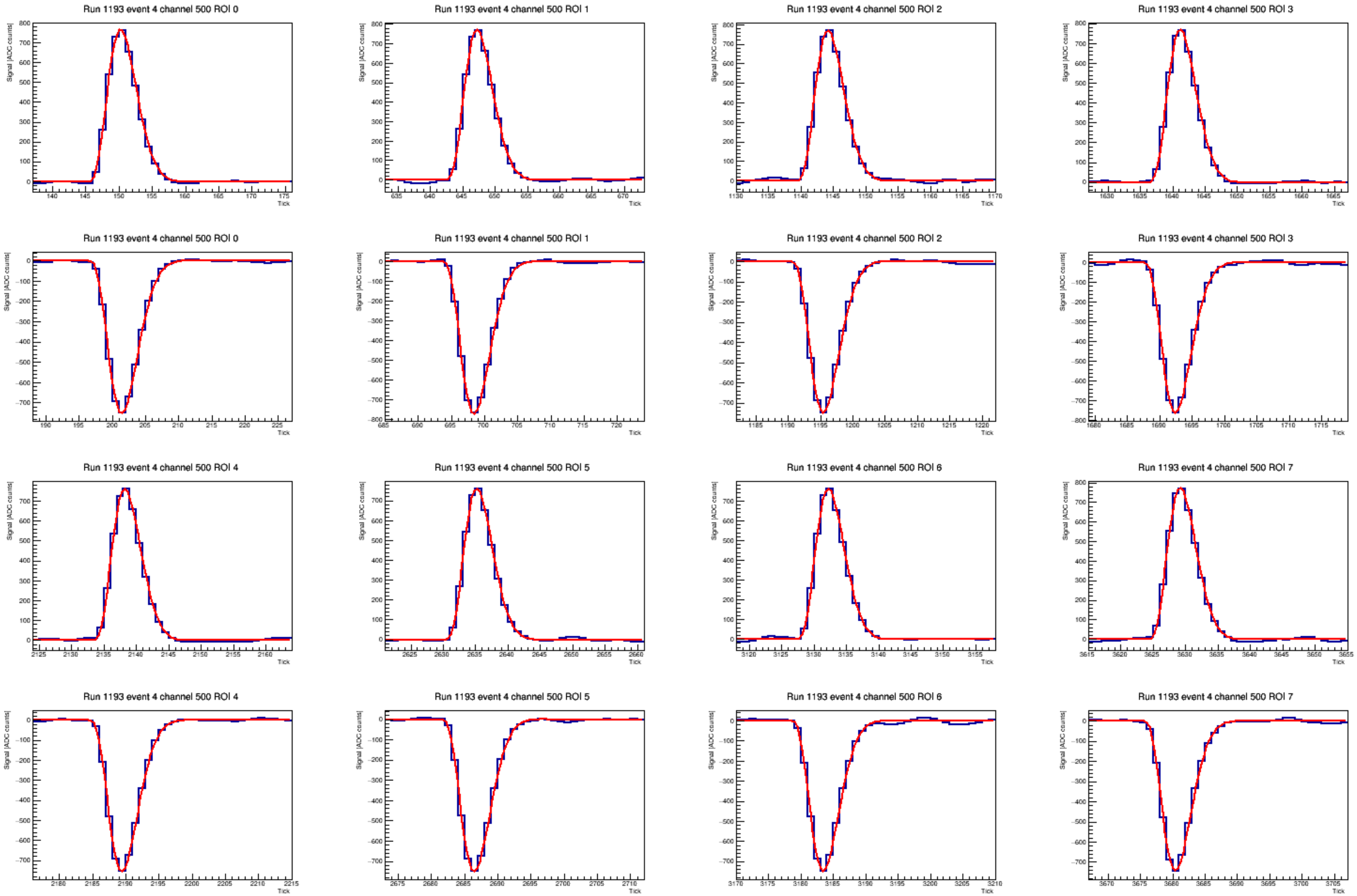
For each channel and pulser setting

- Evaluate and subtract pedestal
- Find ROIs
  - ROI = region of interest, range of ticks where signal appear
  - One ROI should be one pulse, i.e. a step up or down in the input voltage
  - Simple threshold algorithm is sufficient to find these pulses which are well above the noise level
- Process ROIs
  - Separate analysis for positive and negative signals
  - Fit each ROI with coldelec function
    - Vary height, shaping time and position in fit
  - Create summary histograms with the mean values of
    - height
    - shaping time
    - chi-square
    - chi-square/DOF
- Sample fcl in appendix (uses Tool-based data prep)

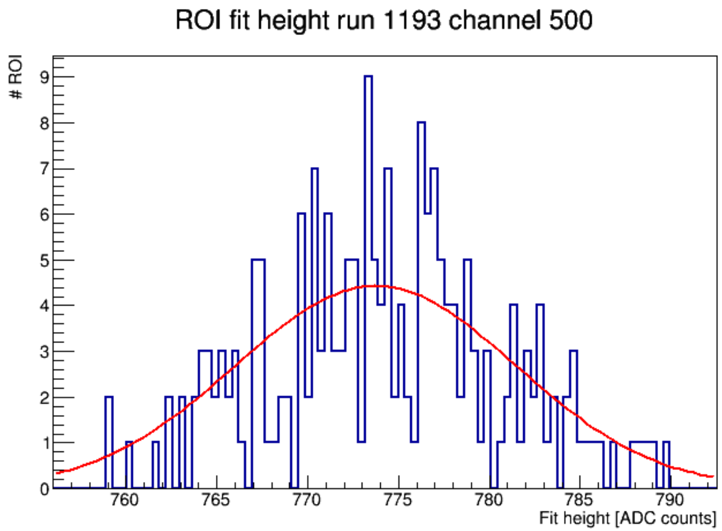
Evaluate gain for each channel

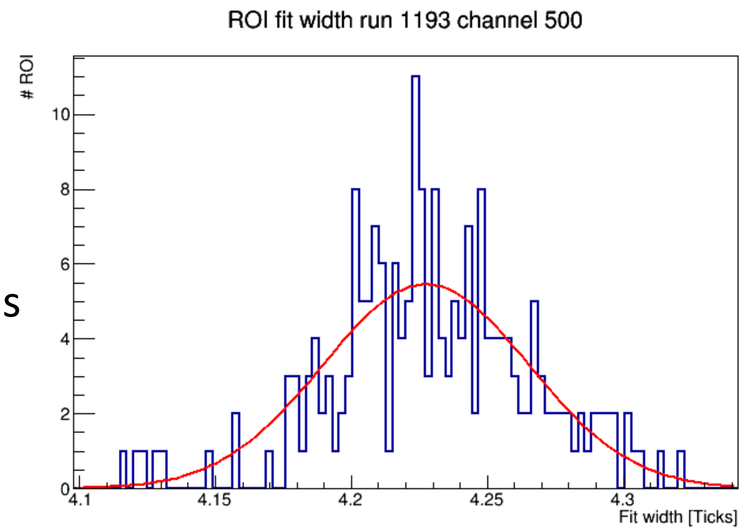
- Using observed height distributions for multiple pulser settings

Example ROI fits (run 1193, pulser=3)

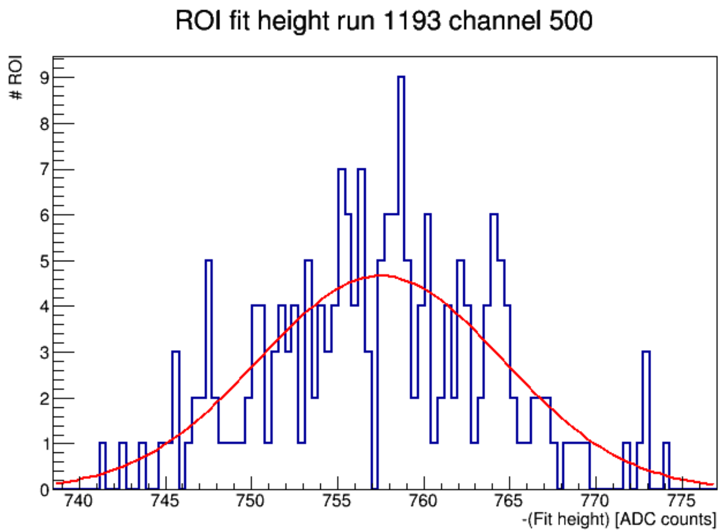


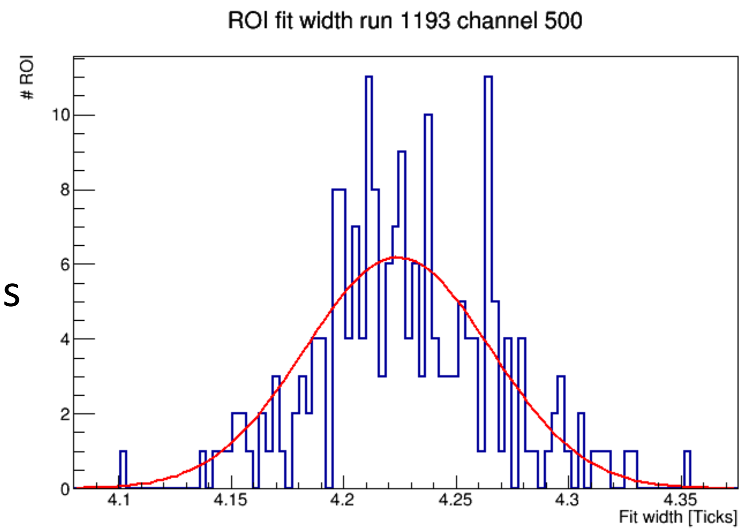
Example summary height and shaping (1/1200)





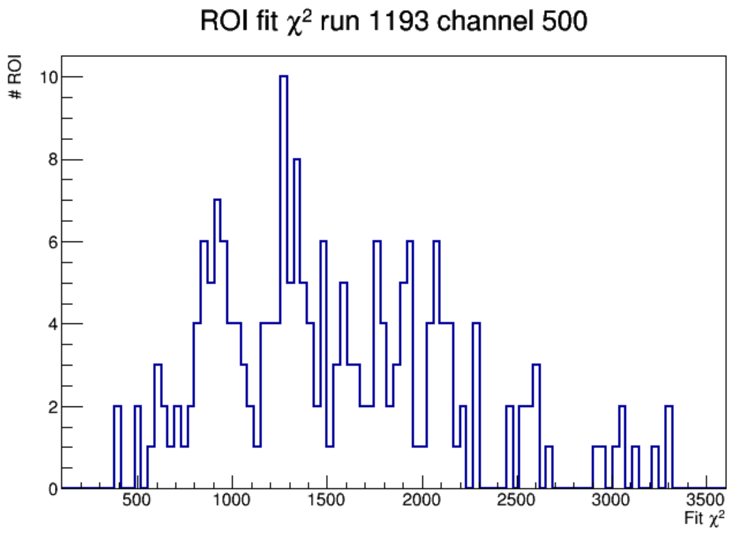
Pos. pulses

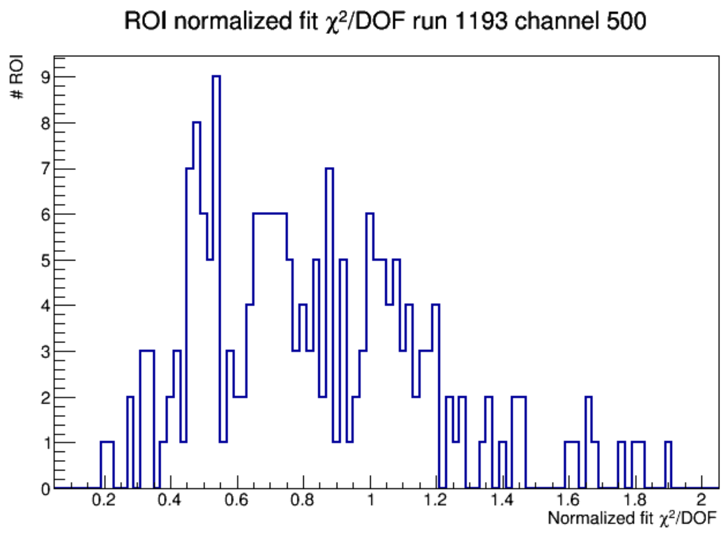


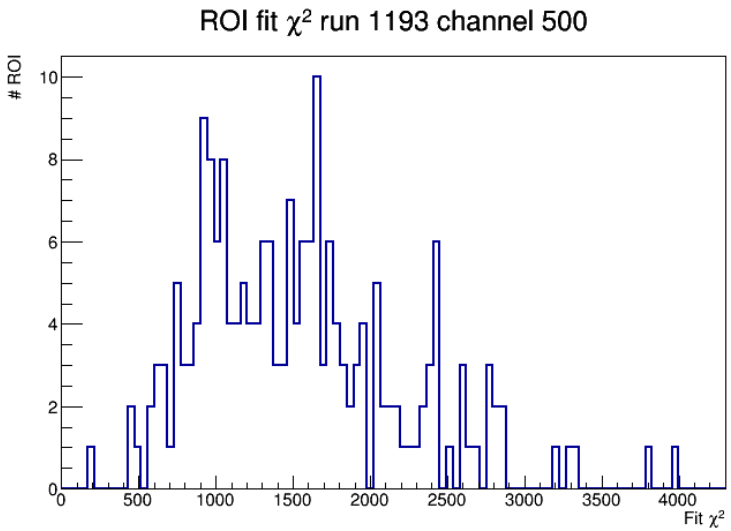


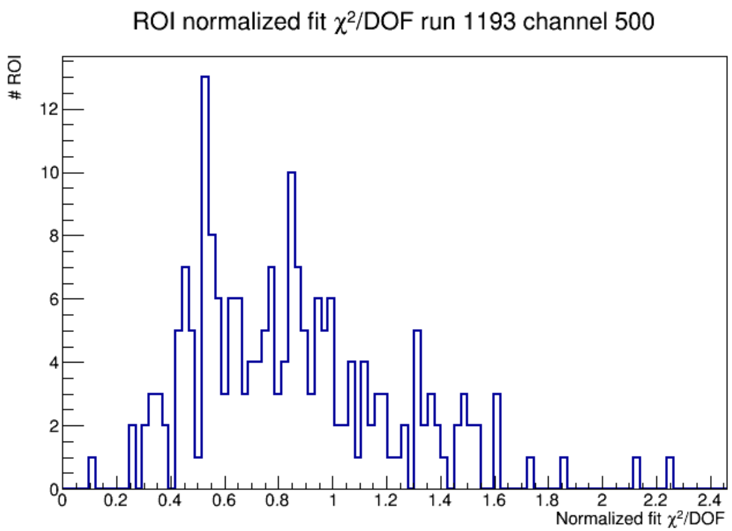
Neg. pulses

Example summary chi-square (1/1200)







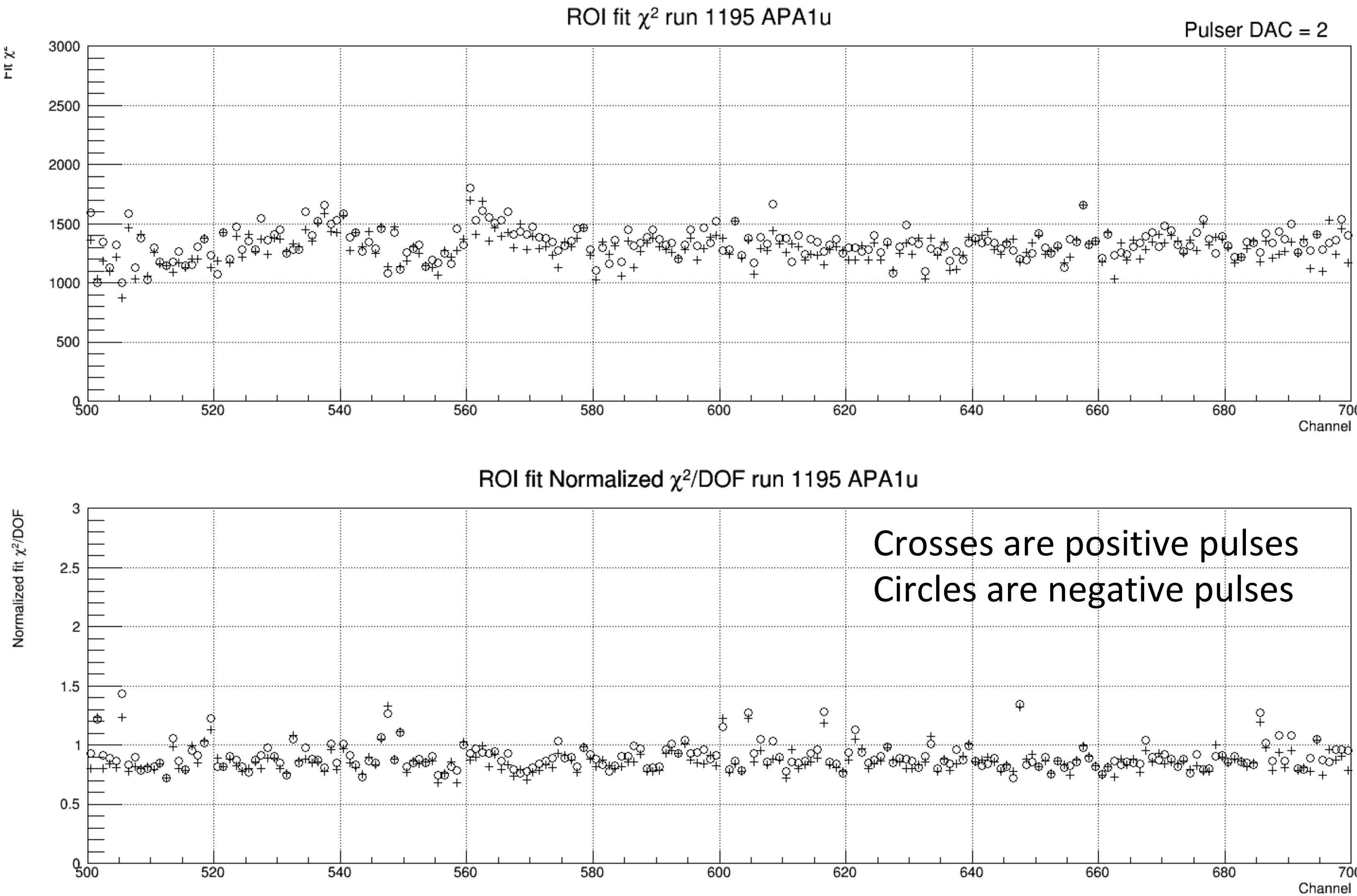


Pulse fit quality

Following slides show fit quality for 200 channels

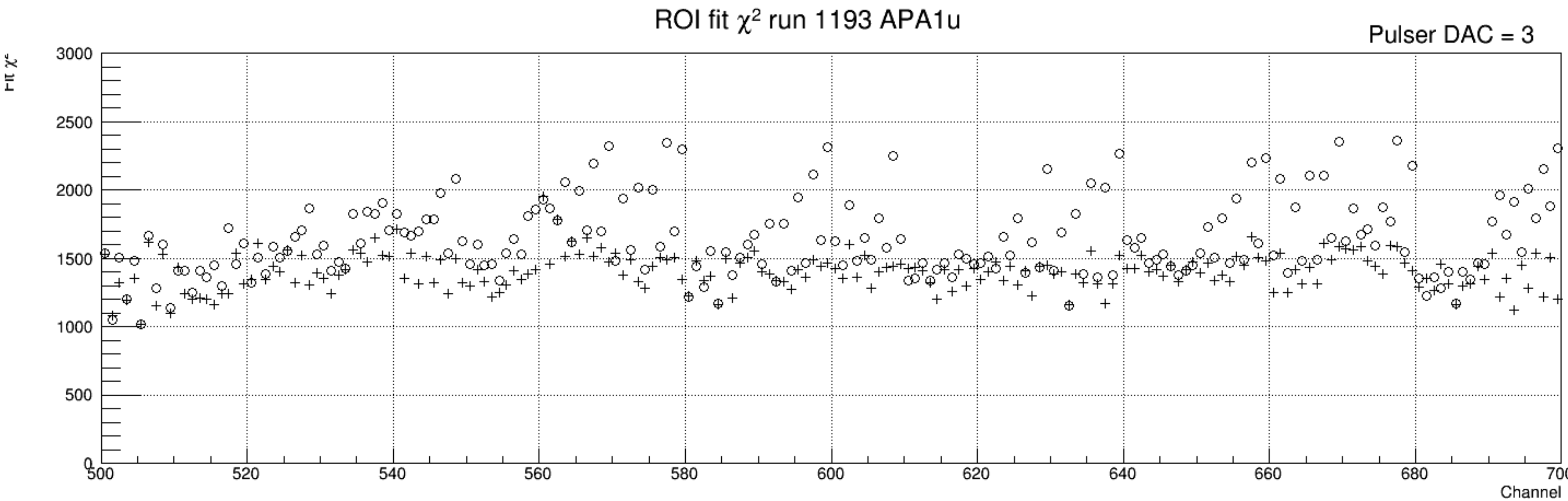
- Mean value from distributions like those on previous page
- For the 7 different DAC settings
- Two plots
  - Raw chi-square (from fit without errors)
  - Normalized chi-square dividing by DOF and using the pedestal RMS as the uncertainty for each ADC bin
- Results very good for positive pulses
  - Corrected mean chi-square/DOF is close to one except at the highest DAC setting where saturation (clipping) is evident by eye
- Negative pulse quality degrades as DAC setting is increased
  - Not clear why this is

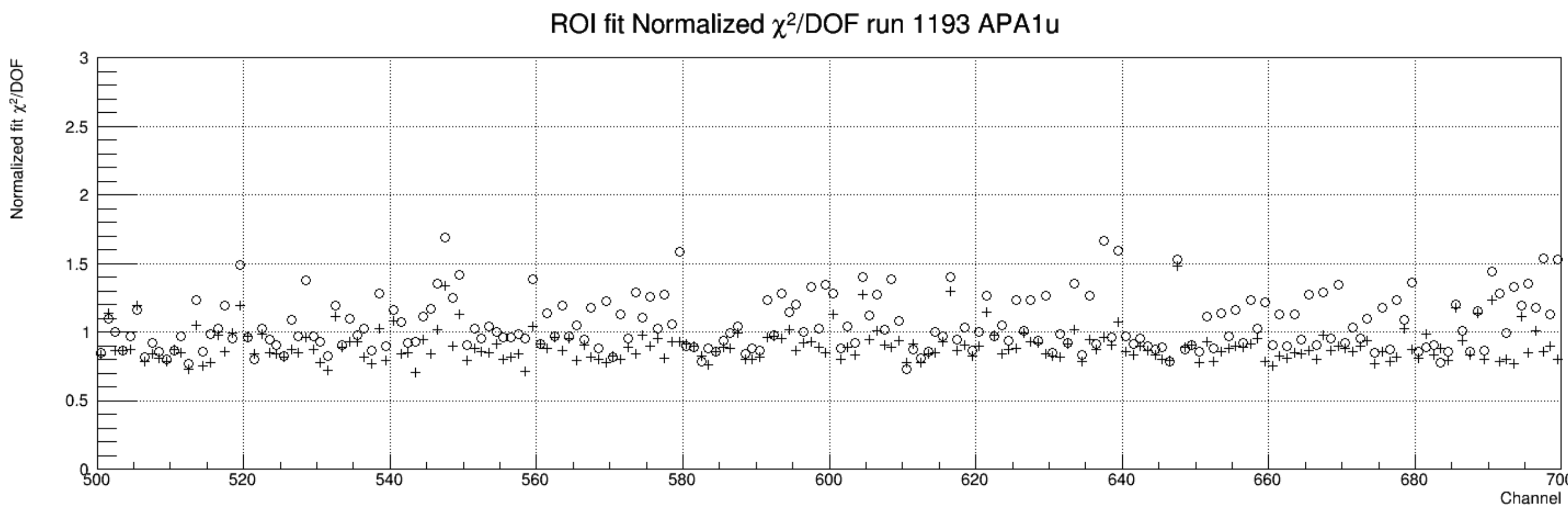
Fit quality for DAC = 2



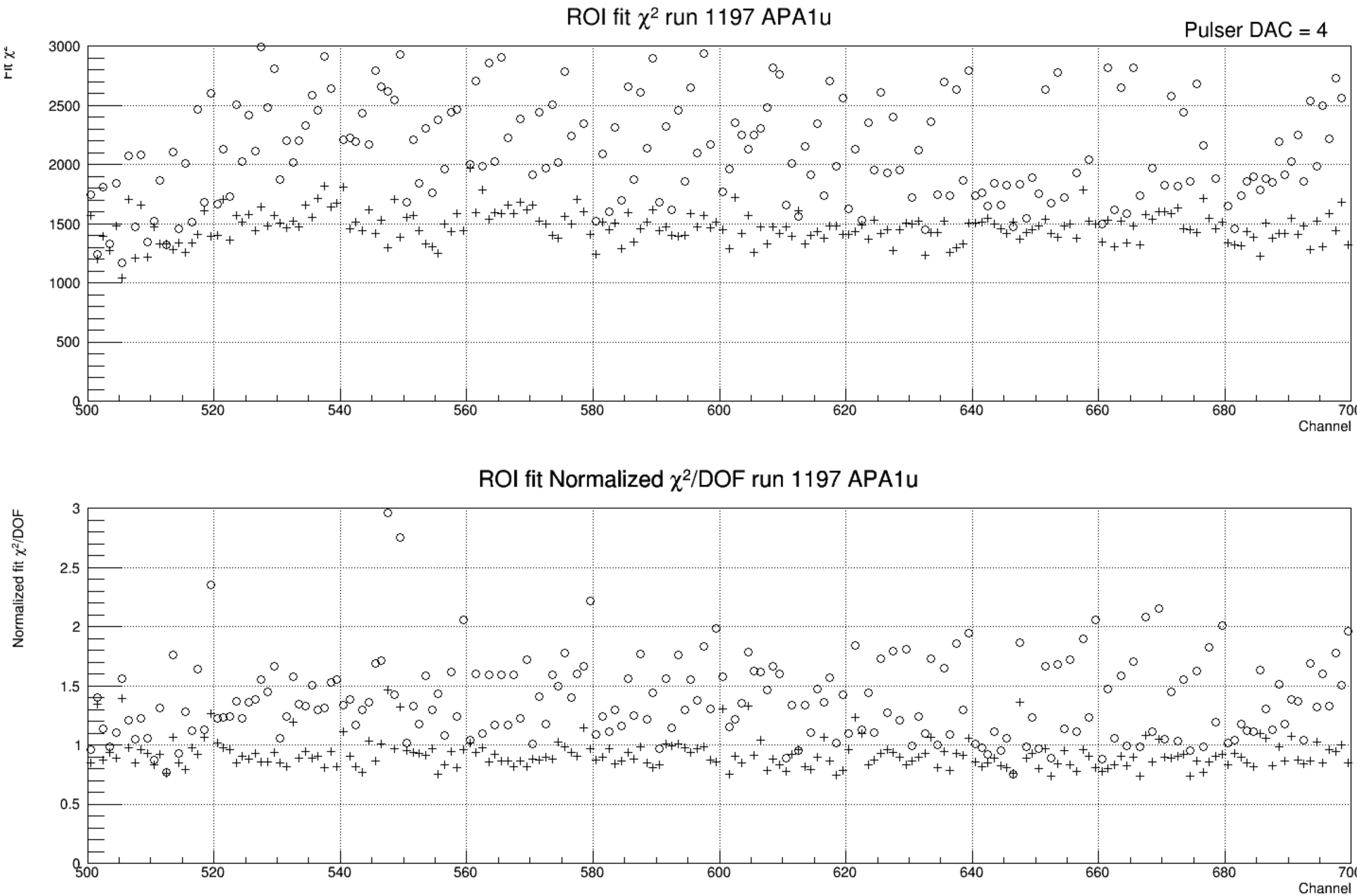
Crosses are positive pulses
Circles are negative pulses

Fit quality for DAC = 3

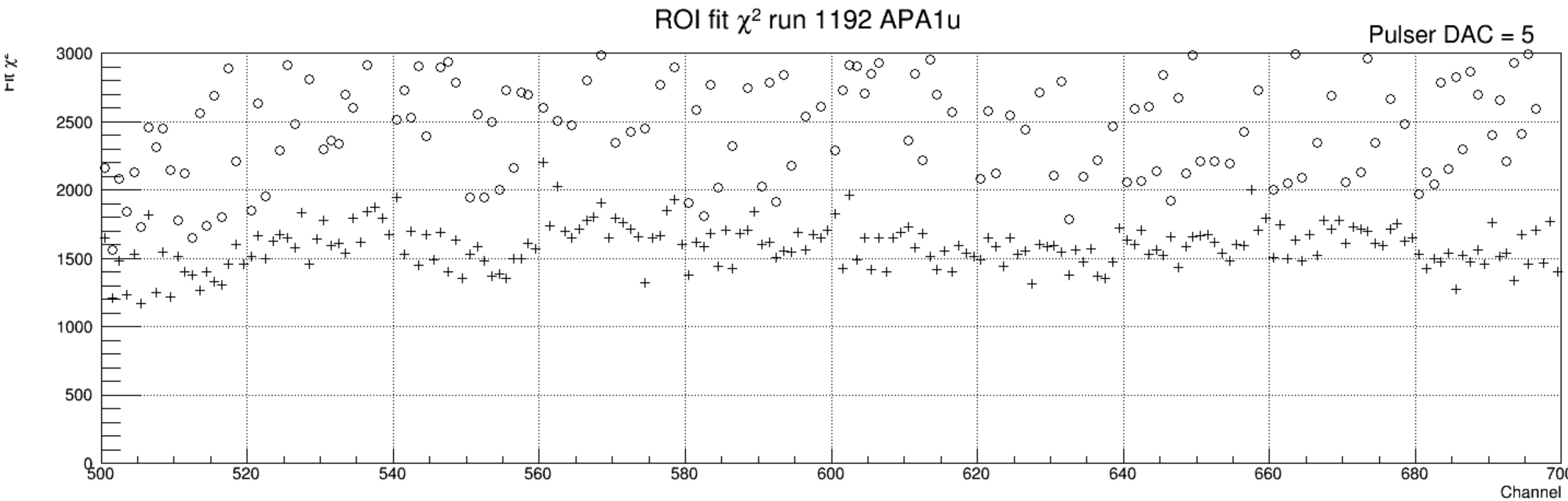


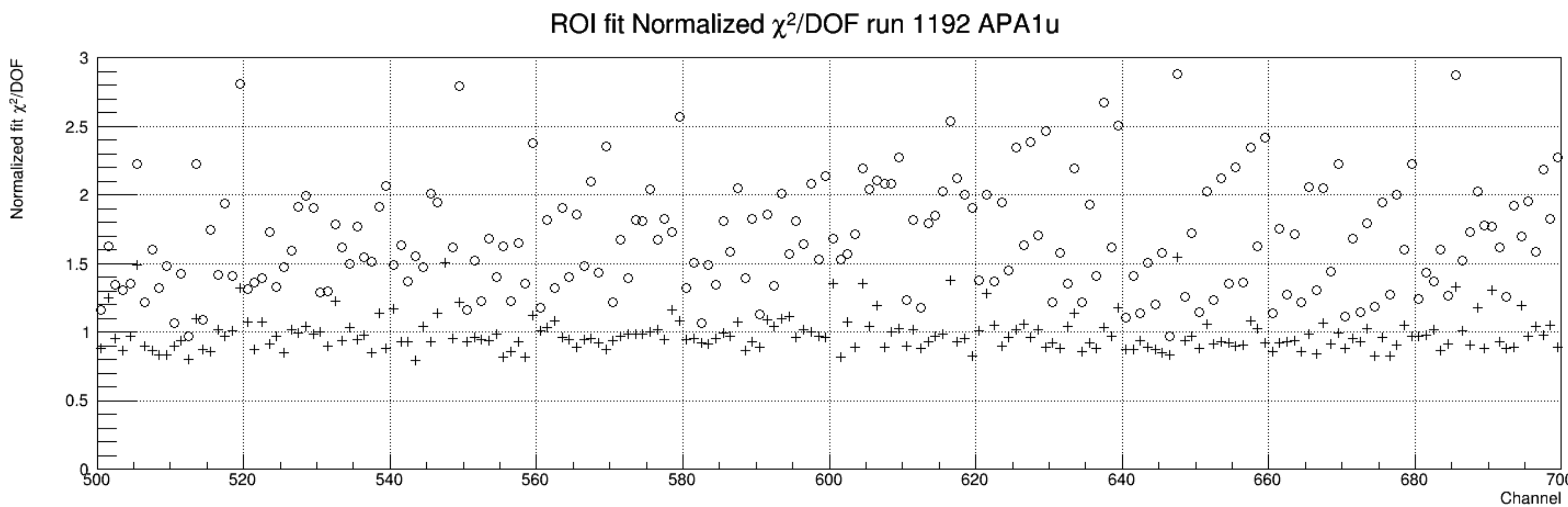


Fit quality for DAC = 4

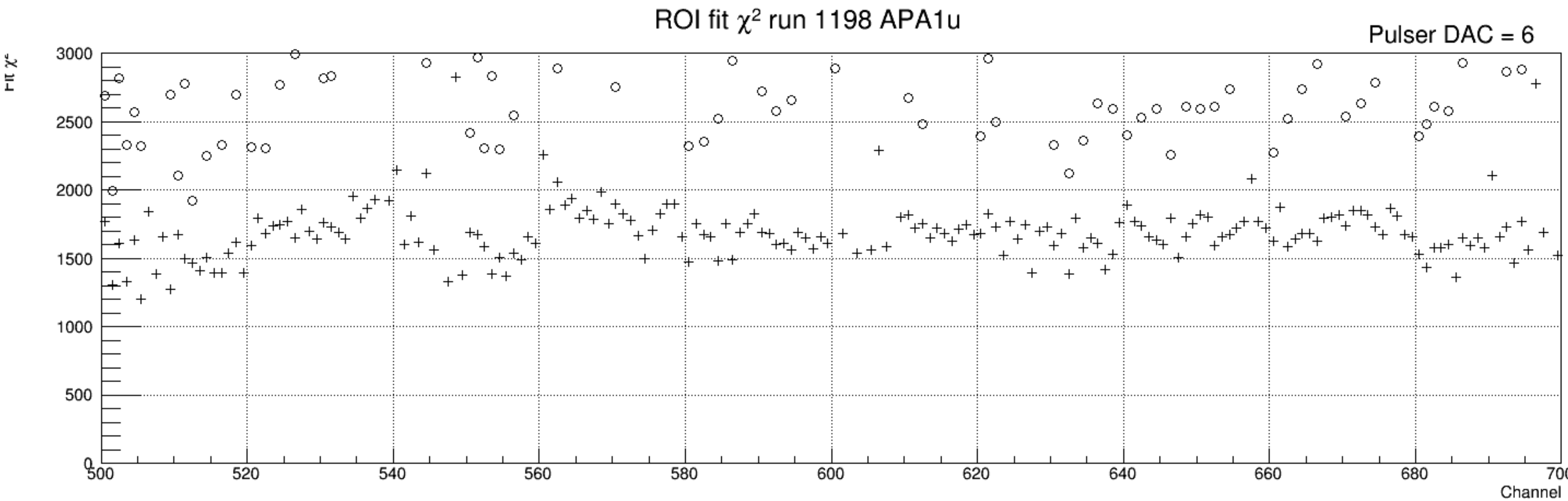


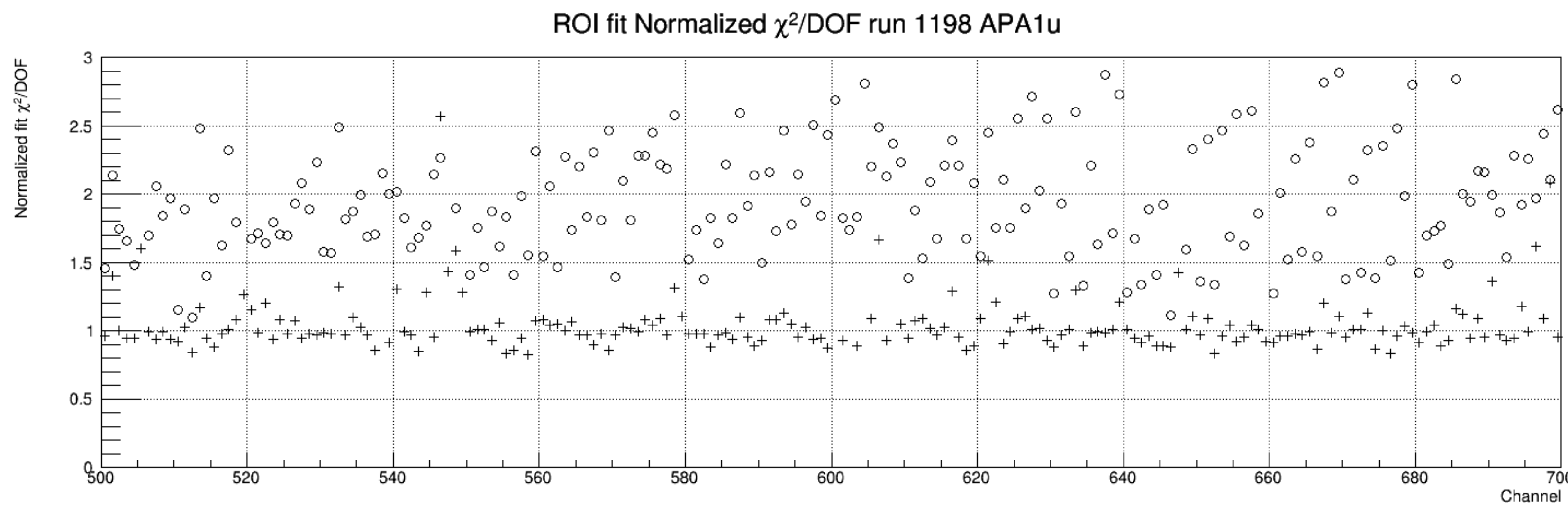
Fit quality for DAC = 5



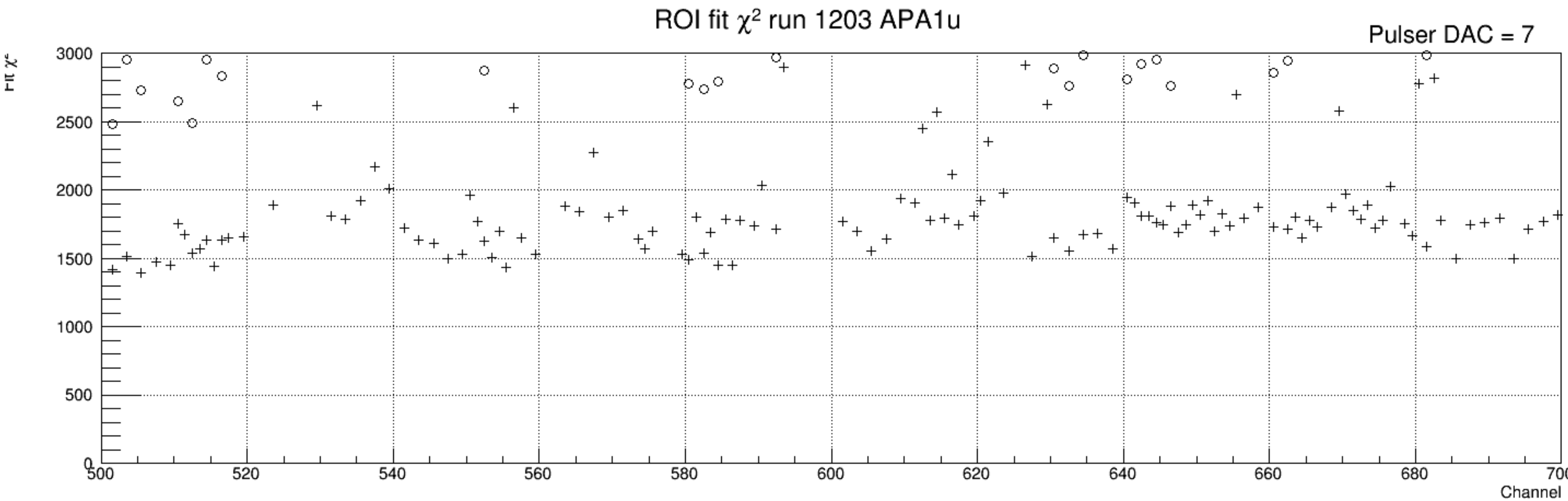


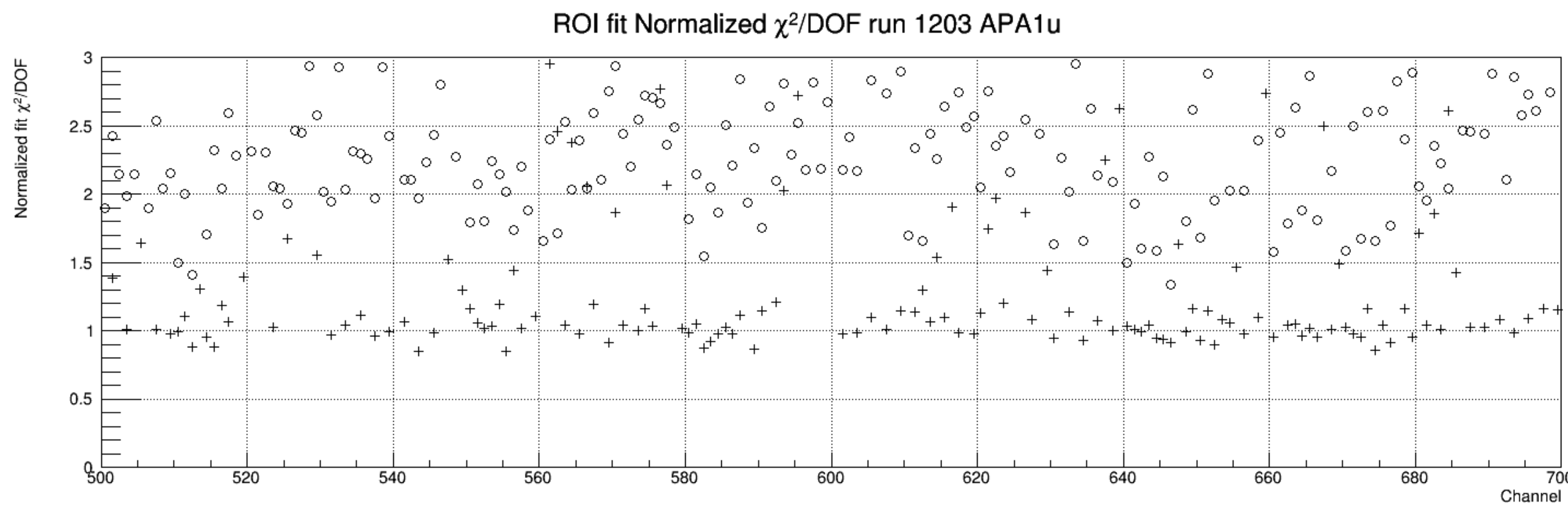
Fit quality for DAC = 6





Fit quality for DAC = 7





Gain evaluation

Use pulser data to measure gains

- I.e. ADC count out for a given input charge
  - Input charge follows from the height of the pulser voltage step
- Using preceding model for input charge, expect (ADC − pedestal)

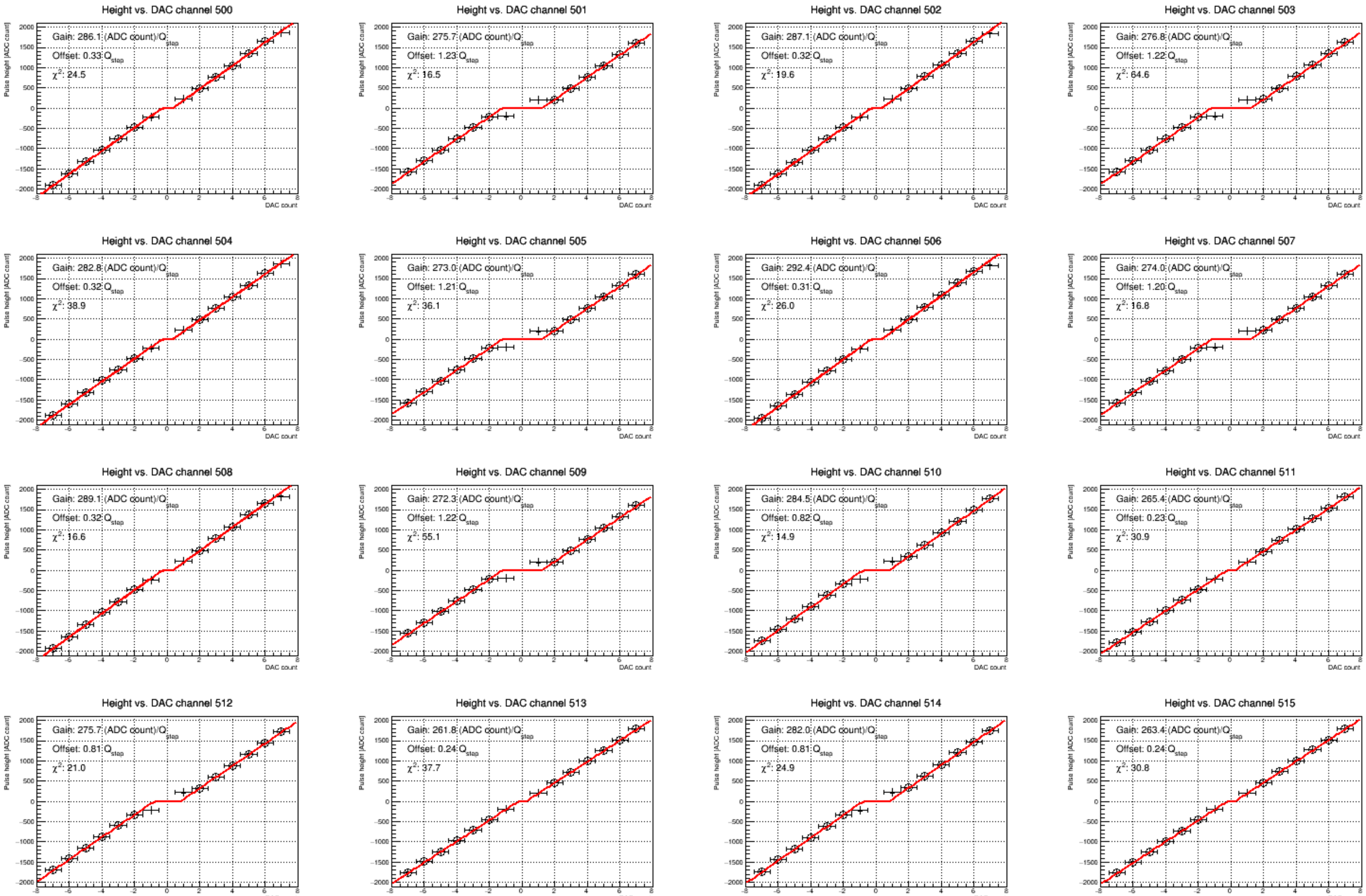
  $A = g\ Qin$

  $= g\ (Q_{off} + P\ Q_{step})$

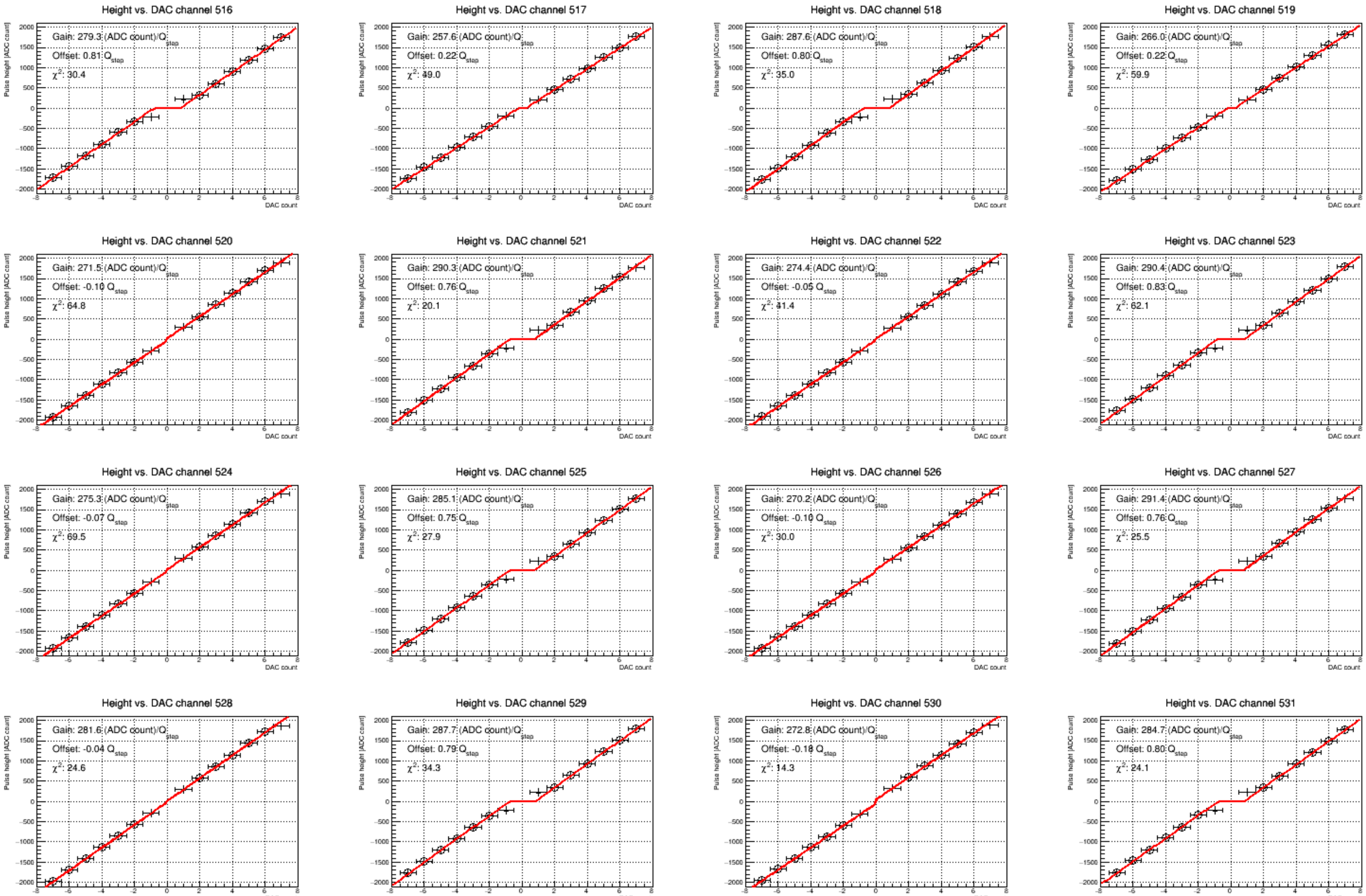
  $= S\ (P + P_{off})\ Q_{step}\ g$

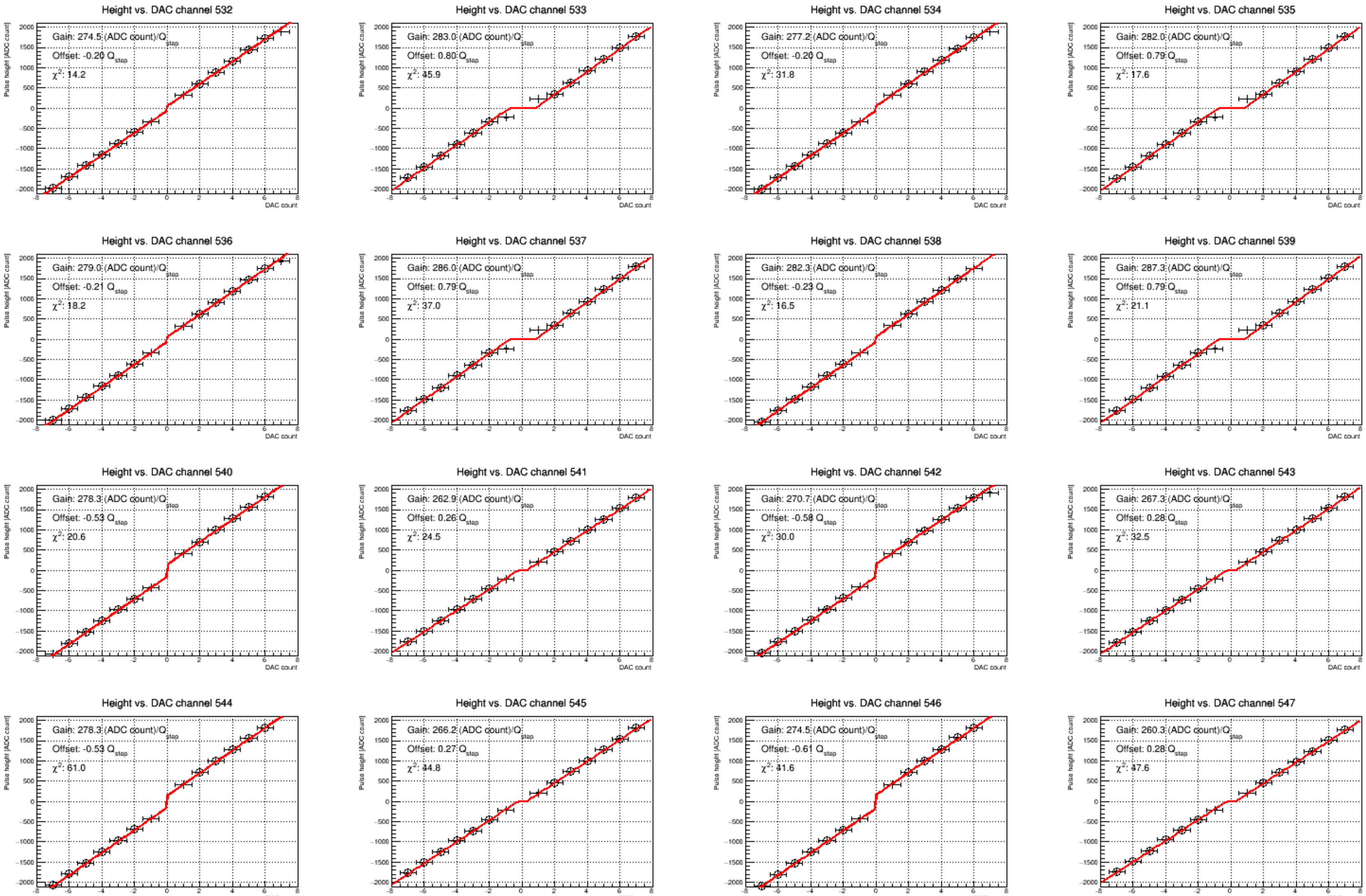
  where S = +1 for the rising edges and -1 for the falling edges
- Fit for g (and Poff) using measured A for P = 2, 3, …
  - Stop when pulse saturates (amplifier or ADC)
  - Larger values of P may identify limits of ADC range
- A is the mean of the height for DAC setting P
  - RMS of this is used as error in A for the fit

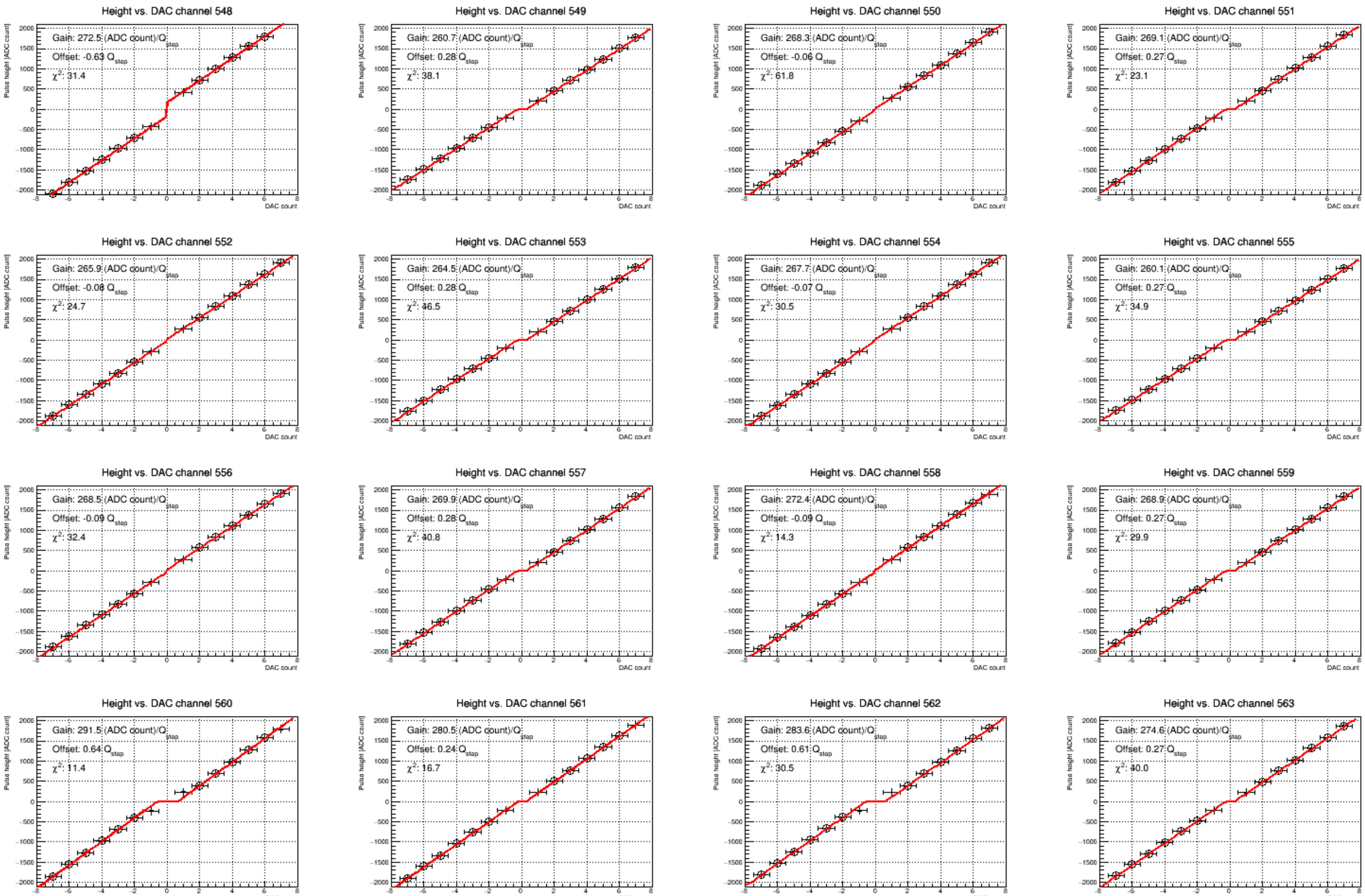
Gain fits

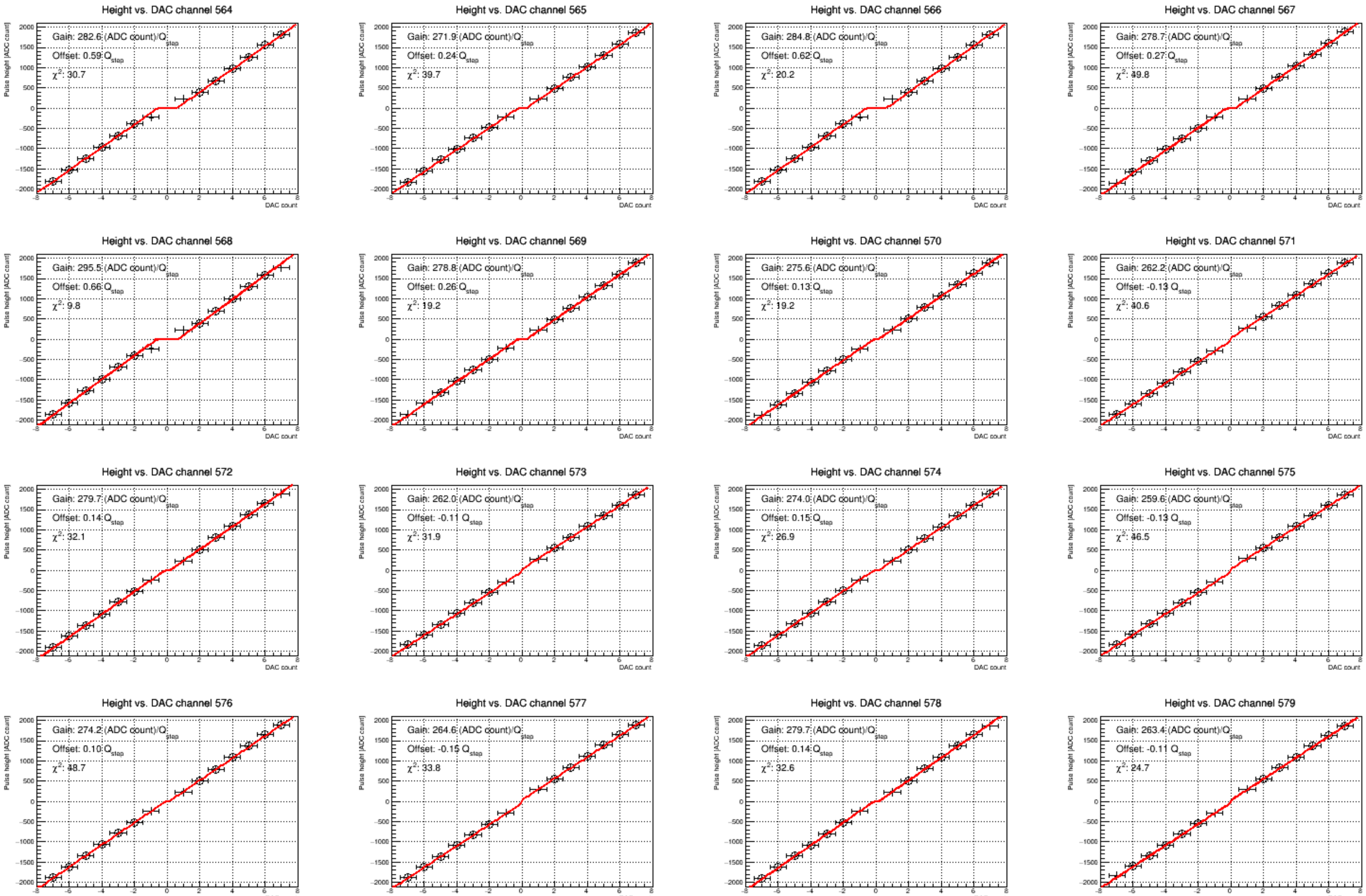


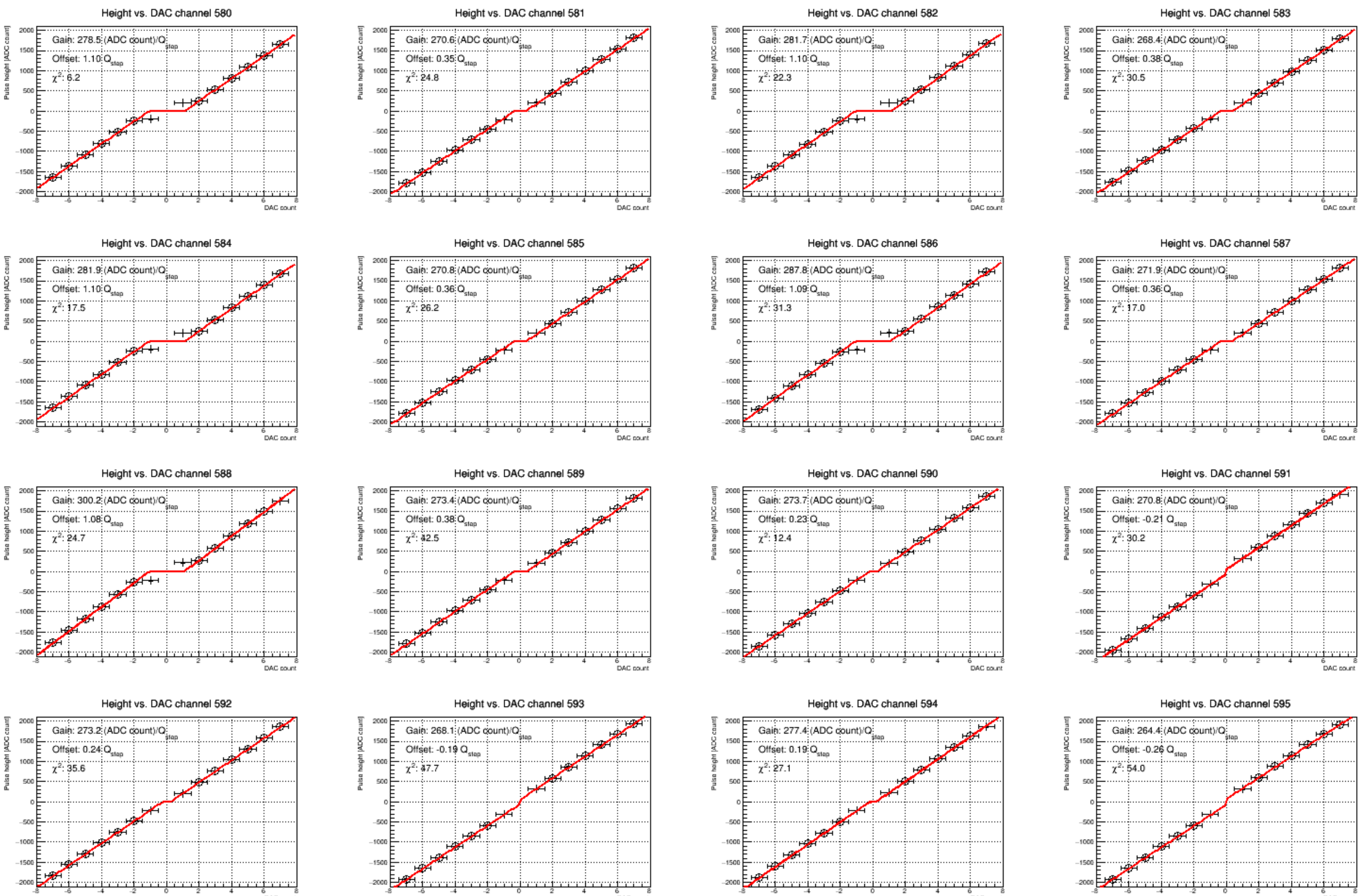
Height vs. DAC channel 500
Gain: 286.1 (ADC count)/Qstep
Offset: 0.33 Qstep
χ2: 24.5
Height vs. DAC channel 501
Gain: 275.7 (ADC count)/Qstep
Offset: 1.23 Qstep
χ2: 16.5
Height vs. DAC channel 502
Gain: 287.1 (ADC count)/Qstep
Offset: 0.32 Qstep
χ2: 19.6
Height vs. DAC channel 503
Gain: 276.8 (ADC count)/Qstep
Offset: 1.22 Qstep
χ2: 64.6
Height vs. DAC channel 504
Gain: 282.8 (ADC count)/Qstep
Offset: 0.32 Qstep
χ2: 38.9
Height vs. DAC channel 505
Gain: 273.0 (ADC count)/Qstep
Offset: 1.21 Qstep
χ2: 36.1
Height vs. DAC channel 506
Gain: 292.4 (ADC count)/Qstep
Offset: 0.31 Qstep
χ2: 26.0
Height vs. DAC channel 507
Gain: 274.0 (ADC count)/Qstep
Offset: 1.20 Qstep
χ2: 16.8
Height vs. DAC channel 508
Gain: 289.1 (ADC count)/Qstep
Offset: 0.32 Qstep
χ2: 16.6
Height vs. DAC channel 509
Gain: 272.3 (ADC count)/Qstep
Offset: 1.22 Qstep
χ2: 55.1
Height vs. DAC channel 510
Gain: 284.5 (ADC count)/Qstep
Offset: 0.82 Qstep
χ2: 14.9
Height vs. DAC channel 511
Gain: 265.4 (ADC count)/Qstep
Offset: 0.23 Qstep
χ2: 30.9
Height vs. DAC channel 512
Gain: 275.7 (ADC count)/Qstep
Offset: 0.81 Qstep
χ2: 21.0
Height vs. DAC channel 513
Gain: 261.8 (ADC count)/Qstep
Offset: 0.24 Qstep
χ2: 37.7
Height vs. DAC channel 514
Gain: 282.0 (ADC count)/Qstep
Offset: 0.81 Qstep
χ2: 24.9
Height vs. DAC channel 515
Gain: 263.4 (ADC count)/Qstep
Offset: 0.24 Qstep
χ2: 30.8
Pulse height [ADC count]
DAC count


Height vs. DAC channel 516
Gain: 279.3 (ADC count)/Q_{step}
Offset: 0.81 Q_{step}
χ^2: 30.4
Height vs. DAC channel 517
Gain: 257.6 (ADC count)/Q_{step}
Offset: 0.22 Q_{step}
χ^2: 49.0
Height vs. DAC channel 518
Gain: 287.6 (ADC count)/Q_{step}
Offset: 0.80 Q_{step}
χ^2: 35.0
Height vs. DAC channel 519
Gain: 266.0 (ADC count)/Q_{step}
Offset: 0.22 Q_{step}
χ^2: 59.9
Height vs. DAC channel 520
Gain: 271.5 (ADC count)/Q_{step}
Offset: -0.10 Q_{step}
χ^2: 64.8
Height vs. DAC channel 521
Gain: 290.3 (ADC count)/Q_{step}
Offset: 0.76 Q_{step}
χ^2: 20.1
Height vs. DAC channel 522
Gain: 274.4 (ADC count)/Q_{step}
Offset: -0.05 Q_{step}
χ^2: 41.4
Height vs. DAC channel 523
Gain: 290.4 (ADC count)/Q_{step}
Offset: 0.83 Q_{step}
χ^2: 62.1
Height vs. DAC channel 524
Gain: 275.3 (ADC count)/Q_{step}
Offset: -0.07 Q_{step}
χ^2: 69.5
Height vs. DAC channel 525
Gain: 285.1 (ADC count)/Q_{step}
Offset: 0.75 Q_{step}
χ^2: 27.9
Height vs. DAC channel 526
Gain: 270.2 (ADC count)/Q_{step}
Offset: -0.10 Q_{step}
χ^2: 30.0
Height vs. DAC channel 527
Gain: 291.4 (ADC count)/Q_{step}
Offset: 0.76 Q_{step}
χ^2: 25.5
Height vs. DAC channel 528
Gain: 281.6 (ADC count)/Q_{step}
Offset: -0.04 Q_{step}
χ^2: 24.6
Height vs. DAC channel 529
Gain: 287.7 (ADC count)/Q_{step}
Offset: 0.79 Q_{step}
χ^2: 34.3
Height vs. DAC channel 530
Gain: 272.8 (ADC count)/Q_{step}
Offset: -0.18 Q_{step}
χ^2: 14.3
Height vs. DAC channel 531
Gain: 284.7 (ADC count)/Q_{step}
Offset: 0.80 Q_{step}
χ^2: 24.1
Pulse height [ADC count]
DAC count

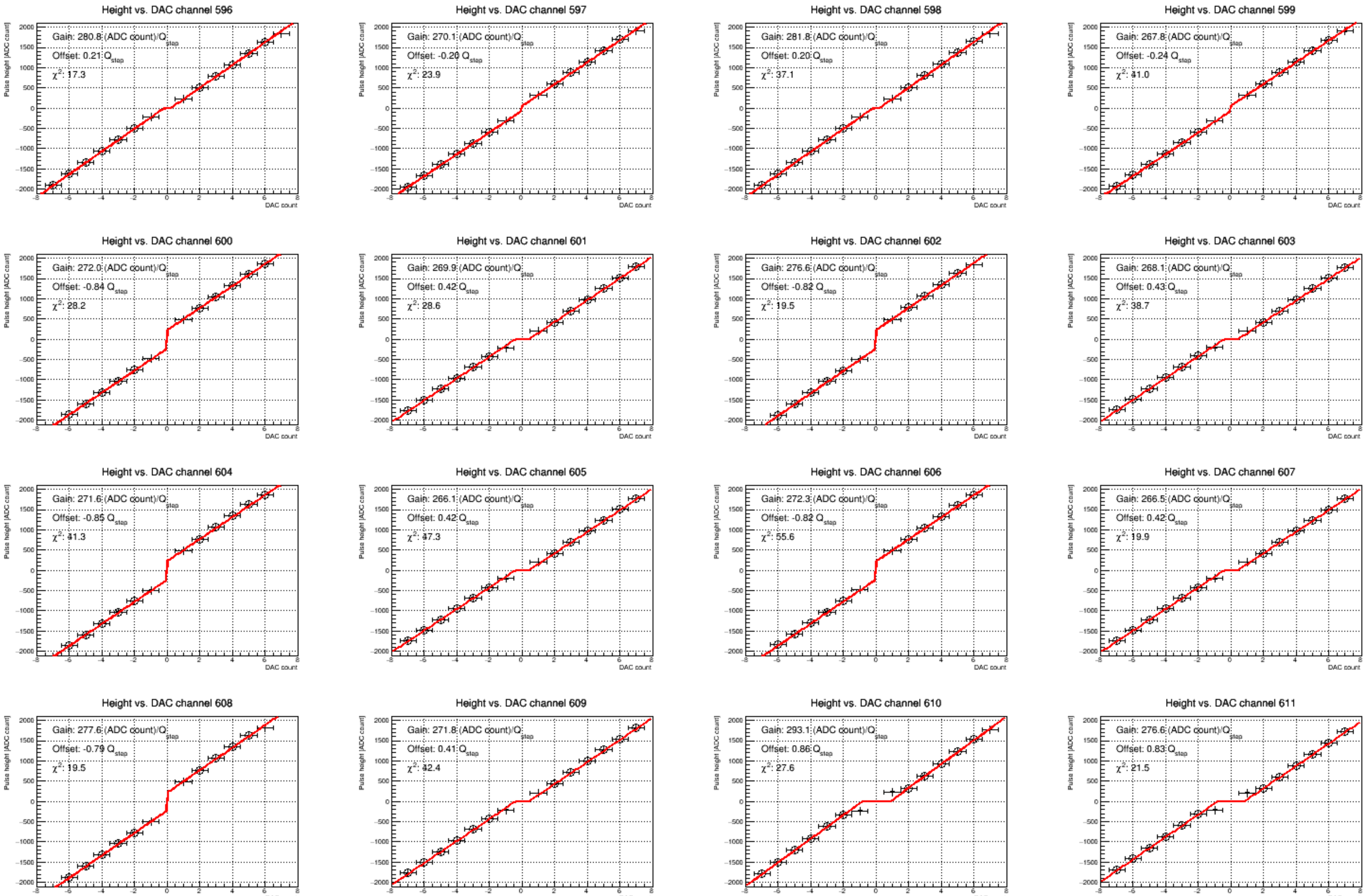

Height vs. DAC channel 532
Gain: 274.5 (ADC count)/Q_step
Offset: -0.20 Q_step
χ²: 14.2
Height vs. DAC channel 533
Gain: 283.0 (ADC count)/Q_step
Offset: 0.80 Q_step
χ²: 45.9
Height vs. DAC channel 534
Gain: 277.2 (ADC count)/Q_step
Offset: -0.20 Q_step
χ²: 31.8
Height vs. DAC channel 535
Gain: 282.0 (ADC count)/Q_step
Offset: 0.79 Q_step
χ²: 17.6
Height vs. DAC channel 536
Gain: 279.0 (ADC count)/Q_step
Offset: -0.21 Q_step
χ²: 18.2
Height vs. DAC channel 537
Gain: 286.0 (ADC count)/Q_step
Offset: 0.79 Q_step
χ²: 37.0
Height vs. DAC channel 538
Gain: 282.3 (ADC count)/Q_step
Offset: -0.23 Q_step
χ²: 16.5
Height vs. DAC channel 539
Gain: 287.3 (ADC count)/Q_step
Offset: 0.79 Q_step
χ²: 21.1
Height vs. DAC channel 540
Gain: 278.3 (ADC count)/Q_step
Offset: -0.53 Q_step
χ²: 20.6
Height vs. DAC channel 541
Gain: 262.9 (ADC count)/Q_step
Offset: 0.26 Q_step
χ²: 24.5
Height vs. DAC channel 542
Gain: 270.7 (ADC count)/Q_step
Offset: -0.58 Q_step
χ²: 30.0
Height vs. DAC channel 543
Gain: 267.3 (ADC count)/Q_step
Offset: 0.28 Q_step
χ²: 32.5
Height vs. DAC channel 544
Gain: 278.3 (ADC count)/Q_step
Offset: -0.53 Q_step
χ²: 61.0
Height vs. DAC channel 545
Gain: 266.2 (ADC count)/Q_step
Offset: 0.27 Q_step
χ²: 44.8
Height vs. DAC channel 546
Gain: 274.5 (ADC count)/Q_step
Offset: -0.61 Q_step
χ²: 41.6
Height vs. DAC channel 547
Gain: 260.3 (ADC count)/Q_step
Offset: 0.28 Q_step
χ²: 47.6
Pulse height [ADC count]
DAC count


Height vs. DAC channel 548
Gain: 272.5 (ADC count)/Q_step
Offset: -0.63 Q_step
χ²: 31.4
Height vs. DAC channel 549
Gain: 260.7 (ADC count)/Q_step
Offset: 0.28 Q_step
χ²: 38.1
Height vs. DAC channel 550
Gain: 268.3 (ADC count)/Q_step
Offset: -0.06 Q_step
χ²: 61.8
Height vs. DAC channel 551
Gain: 269.1 (ADC count)/Q_step
Offset: 0.27 Q_step
χ²: 23.1
Height vs. DAC channel 552
Gain: 265.9 (ADC count)/Q_step
Offset: -0.08 Q_step
χ²: 24.7
Height vs. DAC channel 553
Gain: 264.5 (ADC count)/Q_step
Offset: 0.28 Q_step
χ²: 46.5
Height vs. DAC channel 554
Gain: 267.7 (ADC count)/Q_step
Offset: -0.07 Q_step
χ²: 30.5
Height vs. DAC channel 555
Gain: 260.1 (ADC count)/Q_step
Offset: 0.27 Q_step
χ²: 34.9
Height vs. DAC channel 556
Gain: 268.5 (ADC count)/Q_step
Offset: -0.09 Q_step
χ²: 32.4
Height vs. DAC channel 557
Gain: 269.9 (ADC count)/Q_step
Offset: 0.28 Q_step
χ²: 40.8
Height vs. DAC channel 558
Gain: 272.4 (ADC count)/Q_step
Offset: -0.09 Q_step
χ²: 14.3
Height vs. DAC channel 559
Gain: 268.9 (ADC count)/Q_step
Offset: 0.27 Q_step
χ²: 29.9
Height vs. DAC channel 560
Gain: 291.5 (ADC count)/Q_step
Offset: 0.64 Q_step
χ²: 11.4
Height vs. DAC channel 561
Gain: 280.5 (ADC count)/Q_step
Offset: 0.24 Q_step
χ²: 16.7
Height vs. DAC channel 562
Gain: 283.6 (ADC count)/Q_step
Offset: 0.61 Q_step
χ²: 30.5
Height vs. DAC channel 563
Gain: 274.6 (ADC count)/Q_step
Offset: 0.27 Q_step
χ²: 40.0
Pulse height [ADC count]
DAC count

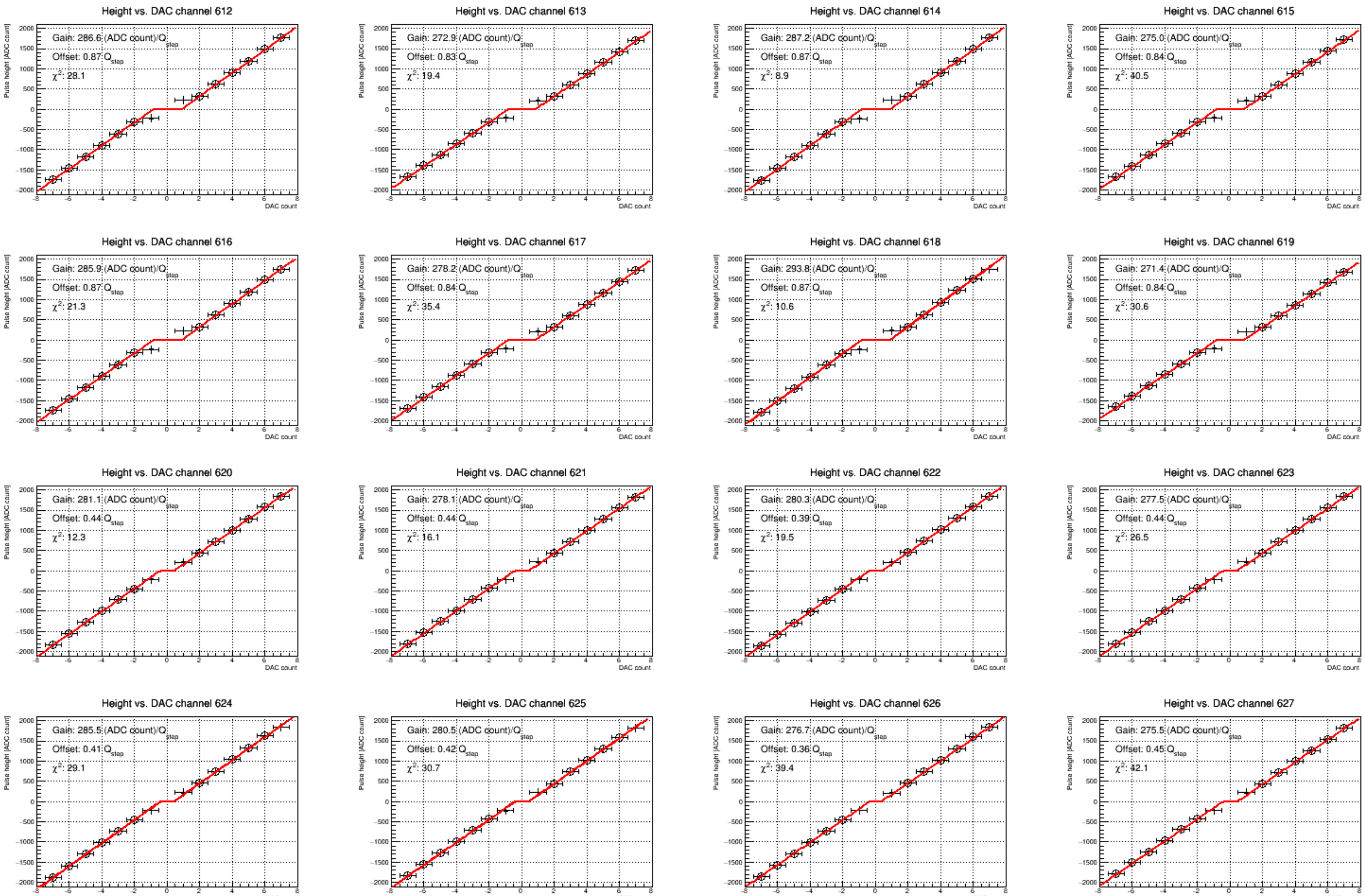

Height vs. DAC channel 564
Gain: 282.6 (ADC count)/Q_step
Offset: 0.59 Q_step
χ2: 30.7
Height vs. DAC channel 565
Gain: 271.9 (ADC count)/Q_step
Offset: 0.24 Q_step
χ2: 39.7
Height vs. DAC channel 566
Gain: 284.8 (ADC count)/Q_step
Offset: 0.62 Q_step
χ2: 20.2
Height vs. DAC channel 567
Gain: 278.7 (ADC count)/Q_step
Offset: 0.27 Q_step
χ2: 49.8
Height vs. DAC channel 568
Gain: 295.5 (ADC count)/Q_step
Offset: 0.66 Q_step
χ2: 9.8
Height vs. DAC channel 569
Gain: 278.8 (ADC count)/Q_step
Offset: 0.26 Q_step
χ2: 19.2
Height vs. DAC channel 570
Gain: 275.6 (ADC count)/Q_step
Offset: 0.13 Q_step
χ2: 19.2
Height vs. DAC channel 571
Gain: 262.2 (ADC count)/Q_step
Offset: -0.13 Q_step
χ2: 40.6
Height vs. DAC channel 572
Gain: 279.7 (ADC count)/Q_step
Offset: 0.14 Q_step
χ2: 32.1
Height vs. DAC channel 573
Gain: 262.0 (ADC count)/Q_step
Offset: -0.11 Q_step
χ2: 31.9
Height vs. DAC channel 574
Gain: 274.0 (ADC count)/Q_step
Offset: 0.15 Q_step
χ2: 26.9
Height vs. DAC channel 575
Gain: 259.6 (ADC count)/Q_step
Offset: -0.13 Q_step
χ2: 46.5
Height vs. DAC channel 576
Gain: 274.2 (ADC count)/Q_step
Offset: 0.10 Q_step
χ2: 48.7
Height vs. DAC channel 577
Gain: 264.6 (ADC count)/Q_step
Offset: -0.15 Q_step
χ2: 33.8
Height vs. DAC channel 578
Gain: 279.7 (ADC count)/Q_step
Offset: 0.14 Q_step
χ2: 32.6
Height vs. DAC channel 579
Gain: 263.4 (ADC count)/Q_step
Offset: -0.11 Q_step
χ2: 24.7
Pulse height [ADC count]
DAC count



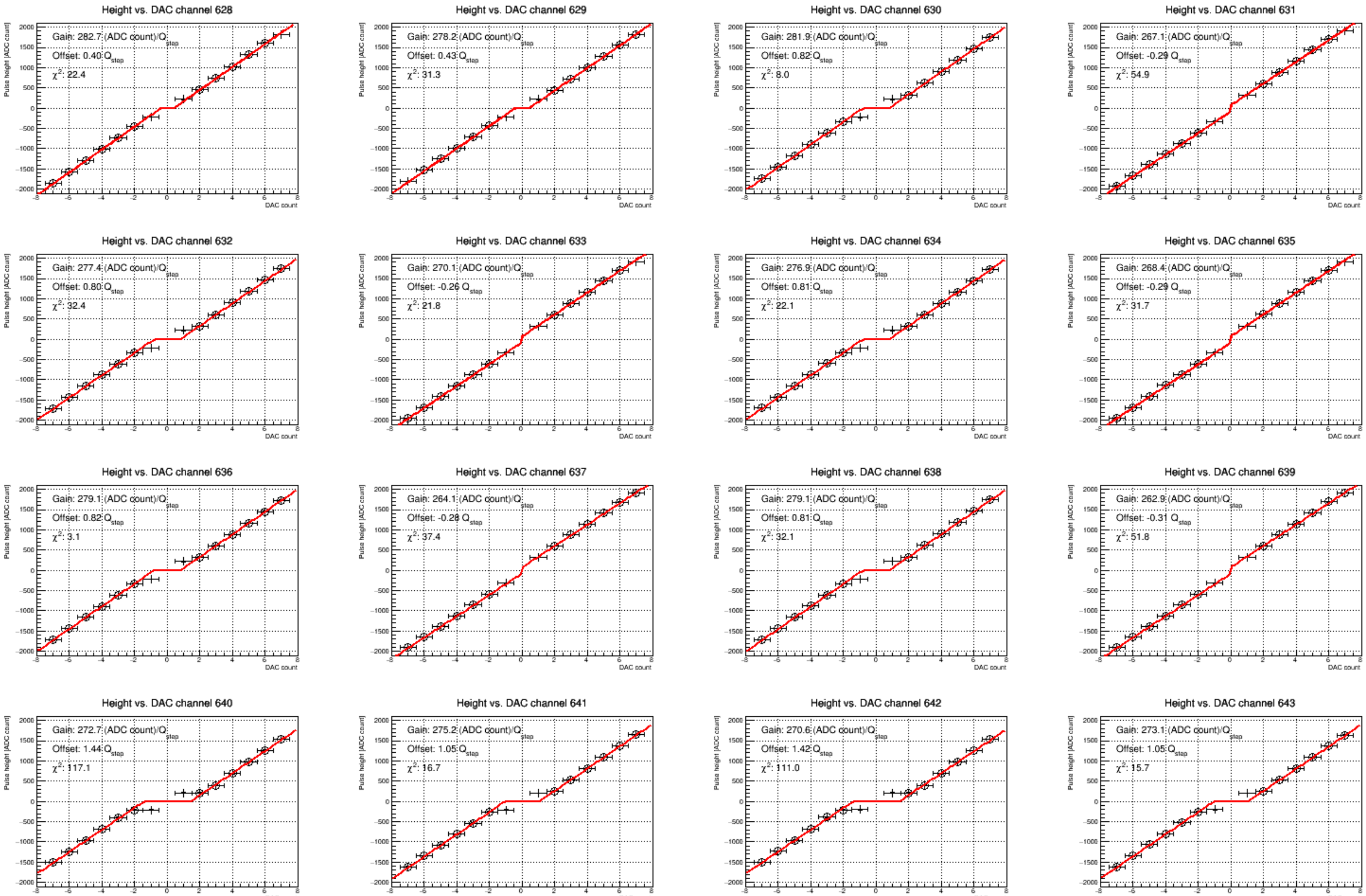
Height vs. DAC channel 580
Gain: 278.5 (ADC count)/Q$_{step}$
Offset: 1.10 Q$_{step}$
χ^2: 6.2
Height vs. DAC channel 581
Gain: 270.6 (ADC count)/Q$_{step}$
Offset: 0.35 Q$_{step}$
χ^2: 24.8
Height vs. DAC channel 582
Gain: 281.7 (ADC count)/Q$_{step}$
Offset: 1.10 Q$_{step}$
χ^2: 22.3
Height vs. DAC channel 583
Gain: 268.4 (ADC count)/Q$_{step}$
Offset: 0.38 Q$_{step}$
χ^2: 30.5
Height vs. DAC channel 584
Gain: 281.9 (ADC count)/Q$_{step}$
Offset: 1.10 Q$_{step}$
χ^2: 17.5
Height vs. DAC channel 585
Gain: 270.8 (ADC count)/Q$_{step}$
Offset: 0.36 Q$_{step}$
χ^2: 26.2
Height vs. DAC channel 586
Gain: 287.8 (ADC count)/Q$_{step}$
Offset: 1.09 Q$_{step}$
χ^2: 31.3
Height vs. DAC channel 587
Gain: 271.9 (ADC count)/Q$_{step}$
Offset: 0.36 Q$_{step}$
χ^2: 17.0
Height vs. DAC channel 588
Gain: 300.2 (ADC count)/Q$_{step}$
Offset: 1.08 Q$_{step}$
χ^2: 24.7
Height vs. DAC channel 589
Gain: 273.4 (ADC count)/Q$_{step}$
Offset: 0.38 Q$_{step}$
χ^2: 42.5
Height vs. DAC channel 590
Gain: 273.7 (ADC count)/Q$_{step}$
Offset: 0.23 Q$_{step}$
χ^2: 12.4
Height vs. DAC channel 591
Gain: 270.8 (ADC count)/Q$_{step}$
Offset: -0.21 Q$_{step}$
χ^2: 30.2
Height vs. DAC channel 592
Gain: 273.2 (ADC count)/Q$_{step}$
Offset: 0.24 Q$_{step}$
χ^2: 35.6
Height vs. DAC channel 593
Gain: 268.1 (ADC count)/Q$_{step}$
Offset: -0.19 Q$_{step}$
χ^2: 47.7
Height vs. DAC channel 594
Gain: 277.4 (ADC count)/Q$_{step}$
Offset: 0.19 Q$_{step}$
χ^2: 27.1
Height vs. DAC channel 595
Gain: 264.4 (ADC count)/Q$_{step}$
Offset: -0.26 Q$_{step}$
χ^2: 54.0
Pulse height [ADC count]
DAC count

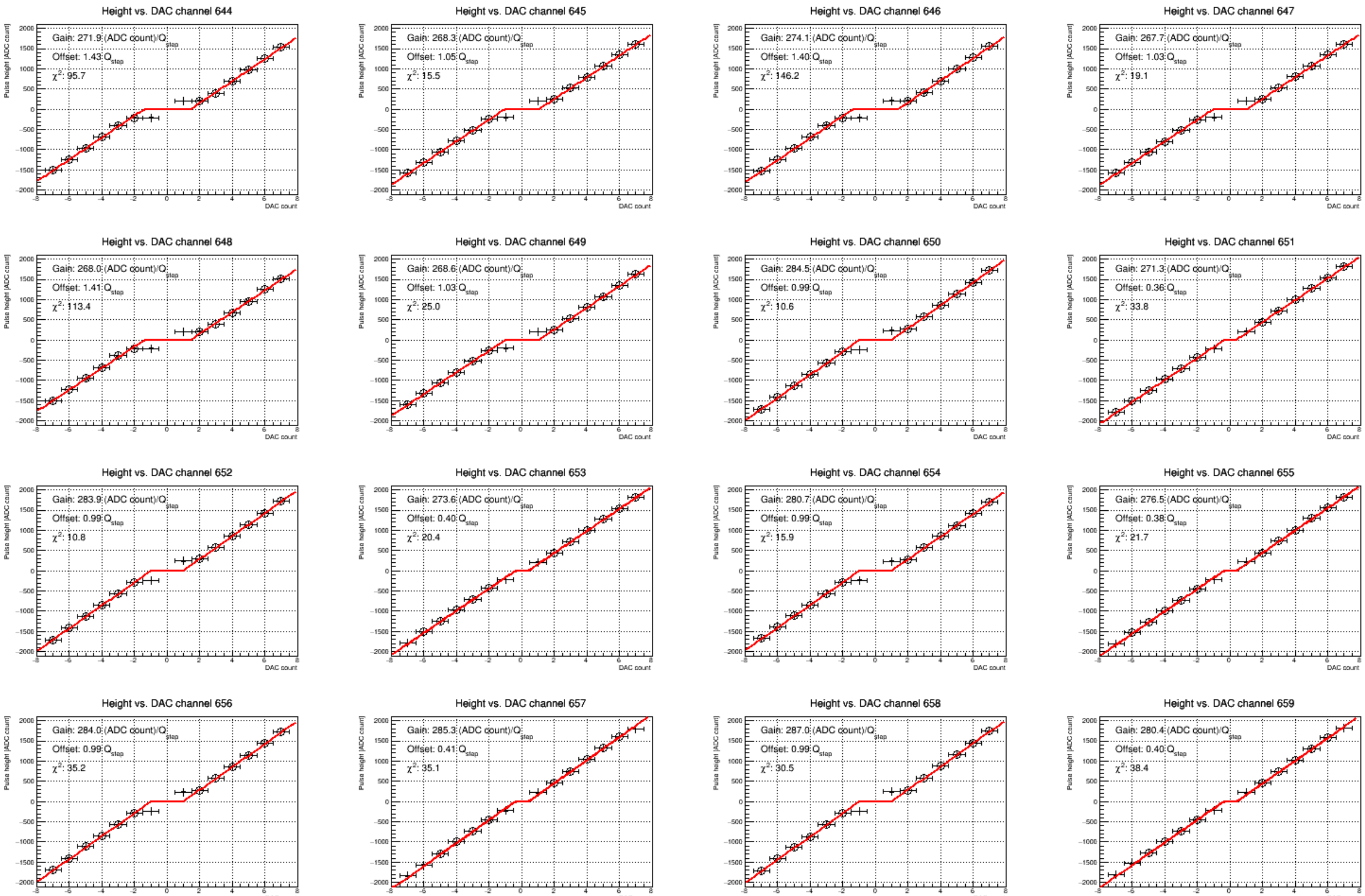


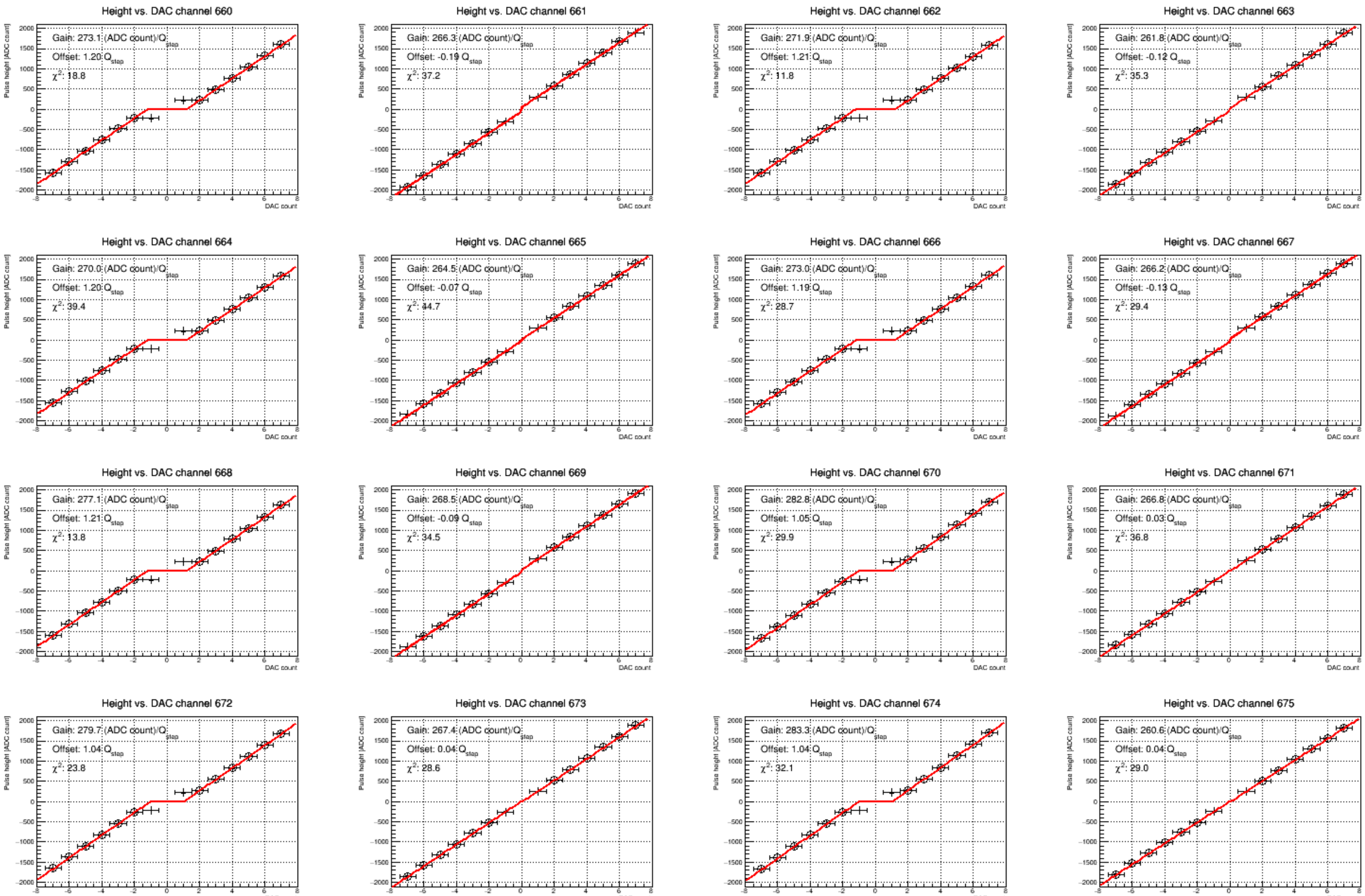
Height vs. DAC channel 596
Gain: 280.8 (ADC count)/Q_{step}
Offset: 0.21 Q_{step}
χ^2: 17.3
Height vs. DAC channel 597
Gain: 270.1 (ADC count)/Q_{step}
Offset: -0.20 Q_{step}
χ^2: 23.9
Height vs. DAC channel 598
Gain: 281.8 (ADC count)/Q_{step}
Offset: 0.20 Q_{step}
χ^2: 37.1
Height vs. DAC channel 599
Gain: 267.8 (ADC count)/Q_{step}
Offset: -0.24 Q_{step}
χ^2: 41.0
Height vs. DAC channel 600
Gain: 272.0 (ADC count)/Q_{step}
Offset: -0.84 Q_{step}
χ^2: 28.2
Height vs. DAC channel 601
Gain: 269.9 (ADC count)/Q_{step}
Offset: 0.42 Q_{step}
χ^2: 28.6
Height vs. DAC channel 602
Gain: 276.6 (ADC count)/Q_{step}
Offset: -0.82 Q_{step}
χ^2: 19.5
Height vs. DAC channel 603
Gain: 268.1 (ADC count)/Q_{step}
Offset: 0.43 Q_{step}
χ^2: 38.7
Height vs. DAC channel 604
Gain: 271.6 (ADC count)/Q_{step}
Offset: -0.85 Q_{step}
χ^2: 41.3
Height vs. DAC channel 605
Gain: 266.1 (ADC count)/Q_{step}
Offset: 0.42 Q_{step}
χ^2: 47.3
Height vs. DAC channel 606
Gain: 272.3 (ADC count)/Q_{step}
Offset: -0.82 Q_{step}
χ^2: 55.6
Height vs. DAC channel 607
Gain: 266.5 (ADC count)/Q_{step}
Offset: 0.42 Q_{step}
χ^2: 19.9
Height vs. DAC channel 608
Gain: 277.6 (ADC count)/Q_{step}
Offset: -0.79 Q_{step}
χ^2: 19.5
Height vs. DAC channel 609
Gain: 271.8 (ADC count)/Q_{step}
Offset: 0.41 Q_{step}
χ^2: 42.4
Height vs. DAC channel 610
Gain: 293.1 (ADC count)/Q_{step}
Offset: 0.86 Q_{step}
χ^2: 27.6
Height vs. DAC channel 611
Gain: 276.6 (ADC count)/Q_{step}
Offset: 0.83 Q_{step}
χ^2: 21.5
Pulse height [ADC count]
DAC count



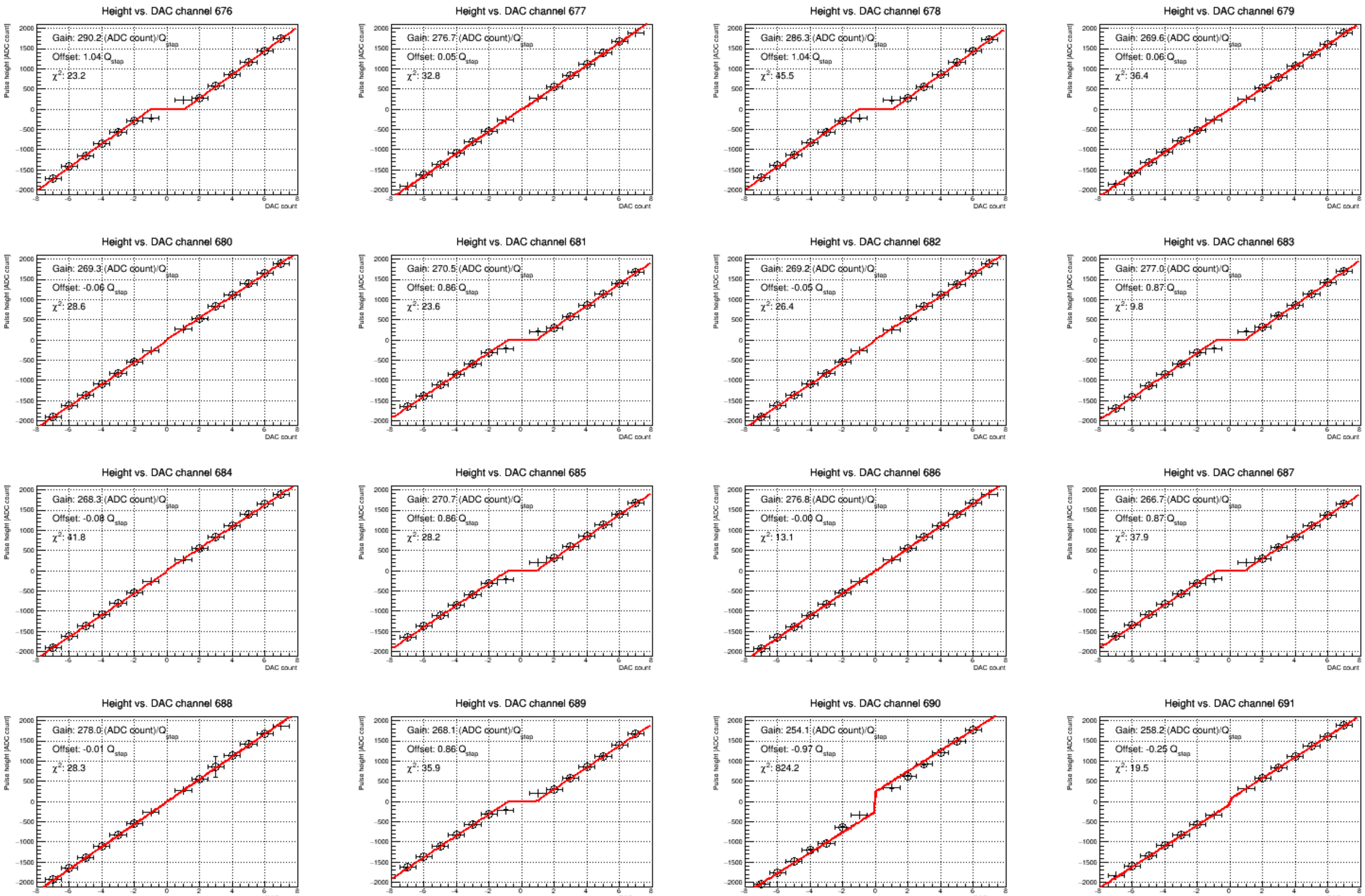
Height vs. DAC channel 612
Gain: 286.6 (ADC count)/Q_{step}
Offset: 0.87 Q_{step}
χ^2: 28.1
Height vs. DAC channel 613
Gain: 272.9 (ADC count)/Q_{step}
Offset: 0.83 Q_{step}
χ^2: 19.4
Height vs. DAC channel 614
Gain: 287.2 (ADC count)/Q_{step}
Offset: 0.87 Q_{step}
χ^2: 8.9
Height vs. DAC channel 615
Gain: 275.0 (ADC count)/Q_{step}
Offset: 0.84 Q_{step}
χ^2: 40.5
Height vs. DAC channel 616
Gain: 285.9 (ADC count)/Q_{step}
Offset: 0.87 Q_{step}
χ^2: 21.3
Height vs. DAC channel 617
Gain: 278.2 (ADC count)/Q_{step}
Offset: 0.84 Q_{step}
χ^2: 35.4
Height vs. DAC channel 618
Gain: 293.8 (ADC count)/Q_{step}
Offset: 0.87 Q_{step}
χ^2: 10.6
Height vs. DAC channel 619
Gain: 271.4 (ADC count)/Q_{step}
Offset: 0.84 Q_{step}
χ^2: 30.6
Height vs. DAC channel 620
Gain: 281.1 (ADC count)/Q_{step}
Offset: 0.44 Q_{step}
χ^2: 12.3
Height vs. DAC channel 621
Gain: 278.1 (ADC count)/Q_{step}
Offset: 0.44 Q_{step}
χ^2: 16.1
Height vs. DAC channel 622
Gain: 280.3 (ADC count)/Q_{step}
Offset: 0.39 Q_{step}
χ^2: 19.5
Height vs. DAC channel 623
Gain: 277.5 (ADC count)/Q_{step}
Offset: 0.44 Q_{step}
χ^2: 26.5
Height vs. DAC channel 624
Gain: 285.5 (ADC count)/Q_{step}
Offset: 0.41 Q_{step}
χ^2: 29.1
Height vs. DAC channel 625
Gain: 280.5 (ADC count)/Q_{step}
Offset: 0.42 Q_{step}
χ^2: 30.7
Height vs. DAC channel 626
Gain: 276.7 (ADC count)/Q_{step}
Offset: 0.36 Q_{step}
χ^2: 39.4
Height vs. DAC channel 627
Gain: 275.5 (ADC count)/Q_{step}
Offset: 0.45 Q_{step}
χ^2: 42.1
Pulse height [ADC count]
DAC count

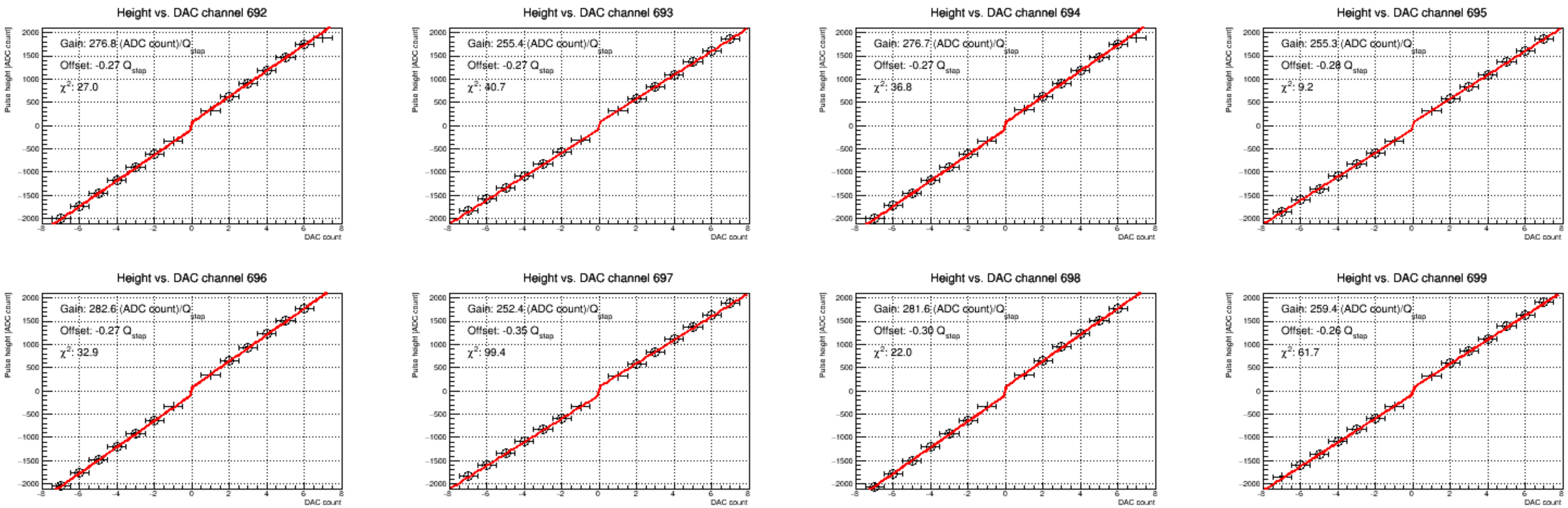

Height vs. DAC channel 628
Gain: 282.7 (ADC count)/Q_step
Offset: 0.40 Q_step
χ²: 22.4
Height vs. DAC channel 629
Gain: 278.2 (ADC count)/Q_step
Offset: 0.43 Q_step
χ²: 31.3
Height vs. DAC channel 630
Gain: 281.9 (ADC count)/Q_step
Offset: 0.82 Q_step
χ²: 8.0
Height vs. DAC channel 631
Gain: 267.1 (ADC count)/Q_step
Offset: -0.29 Q_step
χ²: 54.9
Height vs. DAC channel 632
Gain: 277.4 (ADC count)/Q_step
Offset: 0.80 Q_step
χ²: 32.4
Height vs. DAC channel 633
Gain: 270.1 (ADC count)/Q_step
Offset: -0.26 Q_step
χ²: 21.8
Height vs. DAC channel 634
Gain: 276.9 (ADC count)/Q_step
Offset: 0.81 Q_step
χ²: 22.1
Height vs. DAC channel 635
Gain: 268.4 (ADC count)/Q_step
Offset: -0.29 Q_step
χ²: 31.7
Height vs. DAC channel 636
Gain: 279.1 (ADC count)/Q_step
Offset: 0.82 Q_step
χ²: 3.1
Height vs. DAC channel 637
Gain: 264.1 (ADC count)/Q_step
Offset: -0.28 Q_step
χ²: 37.4
Height vs. DAC channel 638
Gain: 279.1 (ADC count)/Q_step
Offset: 0.81 Q_step
χ²: 32.1
Height vs. DAC channel 639
Gain: 262.9 (ADC count)/Q_step
Offset: -0.31 Q_step
χ²: 51.8
Height vs. DAC channel 640
Gain: 272.7 (ADC count)/Q_step
Offset: 1.44 Q_step
χ²: 117.1
Height vs. DAC channel 641
Gain: 275.2 (ADC count)/Q_step
Offset: 1.05 Q_step
χ²: 16.7
Height vs. DAC channel 642
Gain: 270.6 (ADC count)/Q_step
Offset: 1.42 Q_step
χ²: 111.0
Height vs. DAC channel 643
Gain: 273.1 (ADC count)/Q_step
Offset: 1.05 Q_step
χ²: 15.7
Pulse height [ADC count]
DAC count


Height vs. DAC channel 644
Gain: 271.9 (ADC count)/Q_step
Offset: 1.43 Q_step
χ²: 95.7
Height vs. DAC channel 645
Gain: 268.3 (ADC count)/Q_step
Offset: 1.05 Q_step
χ²: 15.5
Height vs. DAC channel 646
Gain: 274.1 (ADC count)/Q_step
Offset: 1.40 Q_step
χ²: 146.2
Height vs. DAC channel 647
Gain: 267.7 (ADC count)/Q_step
Offset: 1.03 Q_step
χ²: 19.1
Height vs. DAC channel 648
Gain: 268.0 (ADC count)/Q_step
Offset: 1.41 Q_step
χ²: 113.4
Height vs. DAC channel 649
Gain: 268.6 (ADC count)/Q_step
Offset: 1.03 Q_step
χ²: 25.0
Height vs. DAC channel 650
Gain: 284.5 (ADC count)/Q_step
Offset: 0.99 Q_step
χ²: 10.6
Height vs. DAC channel 651
Gain: 271.3 (ADC count)/Q_step
Offset: 0.36 Q_step
χ²: 33.8
Height vs. DAC channel 652
Gain: 283.9 (ADC count)/Q_step
Offset: 0.99 Q_step
χ²: 10.8
Height vs. DAC channel 653
Gain: 273.6 (ADC count)/Q_step
Offset: 0.40 Q_step
χ²: 20.4
Height vs. DAC channel 654
Gain: 280.7 (ADC count)/Q_step
Offset: 0.99 Q_step
χ²: 15.9
Height vs. DAC channel 655
Gain: 276.5 (ADC count)/Q_step
Offset: 0.38 Q_step
χ²: 21.7
Height vs. DAC channel 656
Gain: 284.0 (ADC count)/Q_step
Offset: 0.99 Q_step
χ²: 35.2
Height vs. DAC channel 657
Gain: 285.3 (ADC count)/Q_step
Offset: 0.41 Q_step
χ²: 35.1
Height vs. DAC channel 658
Gain: 287.0 (ADC count)/Q_step
Offset: 0.99 Q_step
χ²: 30.5
Height vs. DAC channel 659
Gain: 280.4 (ADC count)/Q_step
Offset: 0.40 Q_step
χ²: 38.4
Pulse height [ADC count]
DAC count



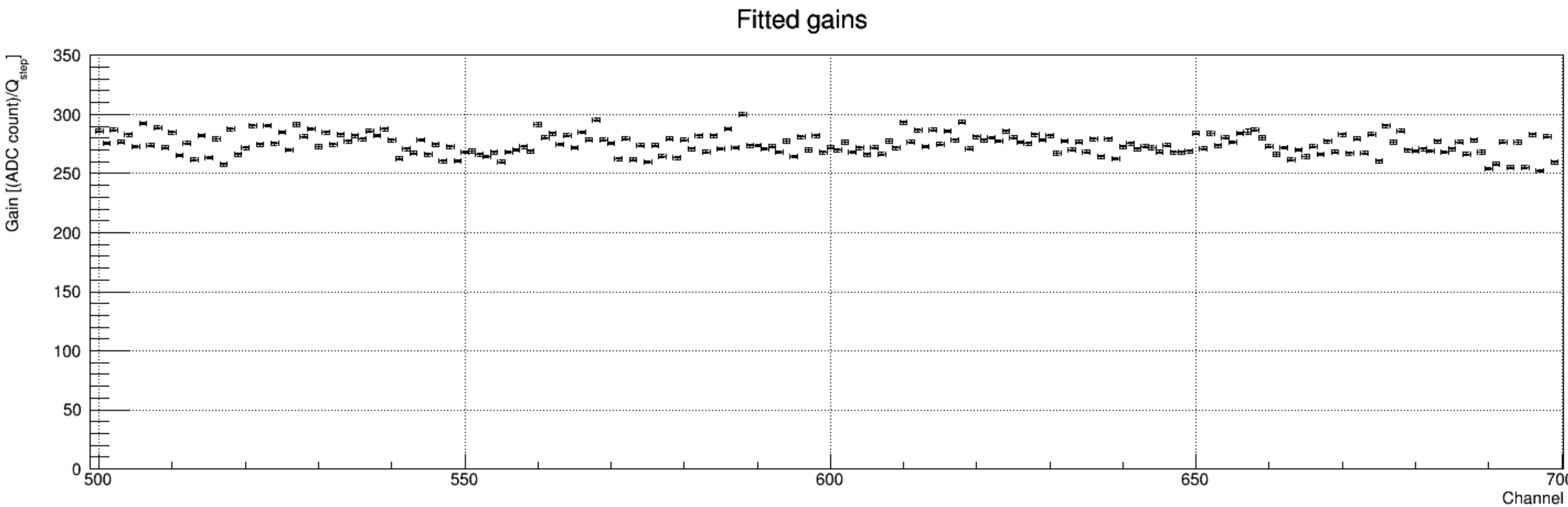
Height vs. DAC channel 660
Gain: 273.1 (ADC count)/Q_step
Offset: 1.20 Q_step
χ²: 18.8
Height vs. DAC channel 661
Gain: 266.3 (ADC count)/Q_step
Offset: -0.19 Q_step
χ²: 37.2
Height vs. DAC channel 662
Gain: 271.9 (ADC count)/Q_step
Offset: 1.21 Q_step
χ²: 11.8
Height vs. DAC channel 663
Gain: 261.8 (ADC count)/Q_step
Offset: -0.12 Q_step
χ²: 35.3
Height vs. DAC channel 664
Gain: 270.0 (ADC count)/Q_step
Offset: 1.20 Q_step
χ²: 39.4
Height vs. DAC channel 665
Gain: 264.5 (ADC count)/Q_step
Offset: -0.07 Q_step
χ²: 44.7
Height vs. DAC channel 666
Gain: 273.0 (ADC count)/Q_step
Offset: 1.19 Q_step
χ²: 28.7
Height vs. DAC channel 667
Gain: 266.2 (ADC count)/Q_step
Offset: -0.13 Q_step
χ²: 29.4
Height vs. DAC channel 668
Gain: 277.1 (ADC count)/Q_step
Offset: 1.21 Q_step
χ²: 13.8
Height vs. DAC channel 669
Gain: 268.5 (ADC count)/Q_step
Offset: -0.09 Q_step
χ²: 34.5
Height vs. DAC channel 670
Gain: 282.8 (ADC count)/Q_step
Offset: 1.05 Q_step
χ²: 29.9
Height vs. DAC channel 671
Gain: 266.8 (ADC count)/Q_step
Offset: 0.03 Q_step
χ²: 36.8
Height vs. DAC channel 672
Gain: 279.7 (ADC count)/Q_step
Offset: 1.04 Q_step
χ²: 23.8
Height vs. DAC channel 673
Gain: 267.4 (ADC count)/Q_step
Offset: 0.04 Q_step
χ²: 28.6
Height vs. DAC channel 674
Gain: 283.3 (ADC count)/Q_step
Offset: 1.04 Q_step
χ²: 32.1
Height vs. DAC channel 675
Gain: 260.6 (ADC count)/Q_step
Offset: 0.04 Q_step
χ²: 29.0
Pulse height [ADC count]
DAC count

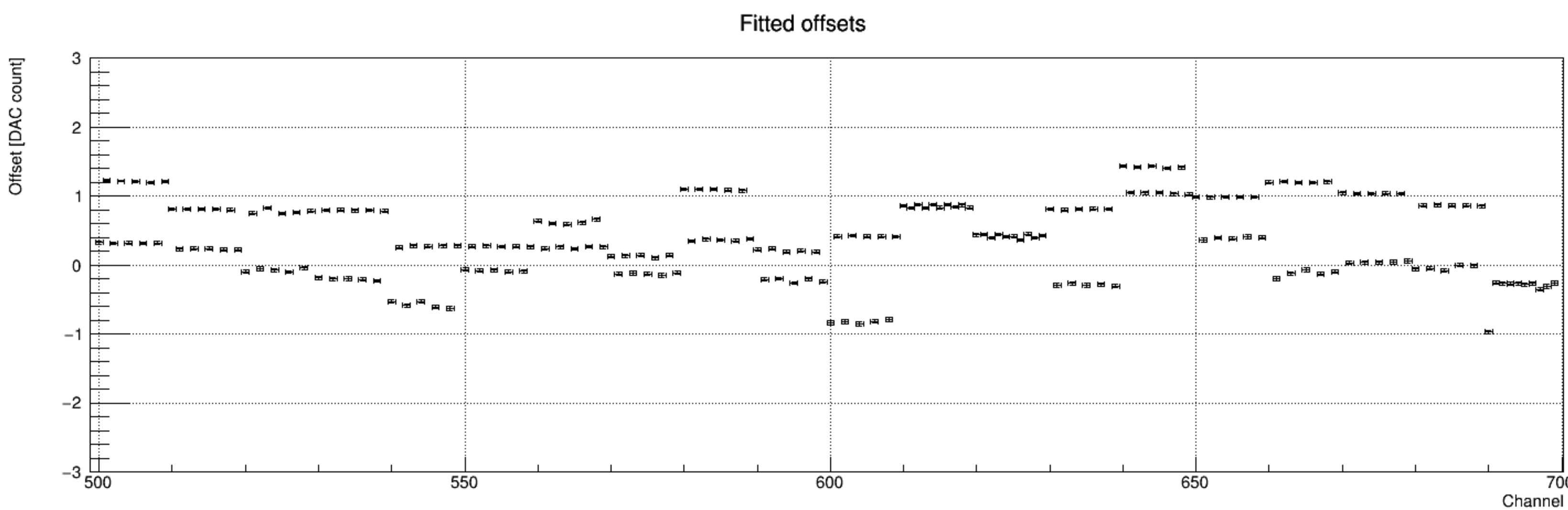

Height vs. DAC channel 676
Gain: 290.2 (ADC count)/Qstep
Offset: 1.04 Qstep
χ2: 23.2
Height vs. DAC channel 677
Gain: 276.7 (ADC count)/Qstep
Offset: 0.05 Qstep
χ2: 32.8
Height vs. DAC channel 678
Gain: 286.3 (ADC count)/Qstep
Offset: 1.04 Qstep
χ2: 45.5
Height vs. DAC channel 679
Gain: 269.6 (ADC count)/Qstep
Offset: 0.06 Qstep
χ2: 36.4
Height vs. DAC channel 680
Gain: 269.3 (ADC count)/Qstep
Offset: -0.06 Qstep
χ2: 28.6
Height vs. DAC channel 681
Gain: 270.5 (ADC count)/Qstep
Offset: 0.86 Qstep
χ2: 23.6
Height vs. DAC channel 682
Gain: 269.2 (ADC count)/Qstep
Offset: -0.05 Qstep
χ2: 26.4
Height vs. DAC channel 683
Gain: 277.0 (ADC count)/Qstep
Offset: 0.87 Qstep
χ2: 9.8
Height vs. DAC channel 684
Gain: 268.3 (ADC count)/Qstep
Offset: -0.08 Qstep
χ2: 41.8
Height vs. DAC channel 685
Gain: 270.7 (ADC count)/Qstep
Offset: 0.86 Qstep
χ2: 28.2
Height vs. DAC channel 686
Gain: 276.8 (ADC count)/Qstep
Offset: -0.00 Qstep
χ2: 13.1
Height vs. DAC channel 687
Gain: 266.7 (ADC count)/Qstep
Offset: 0.87 Qstep
χ2: 37.9
Height vs. DAC channel 688
Gain: 278.0 (ADC count)/Qstep
Offset: -0.01 Qstep
χ2: 28.3
Height vs. DAC channel 689
Gain: 268.1 (ADC count)/Qstep
Offset: 0.86 Qstep
χ2: 35.9
Height vs. DAC channel 690
Gain: 254.1 (ADC count)/Qstep
Offset: -0.97 Qstep
χ2: 824.2
Height vs. DAC channel 691
Gain: 258.2 (ADC count)/Qstep
Offset: -0.25 Qstep
χ2: 19.5



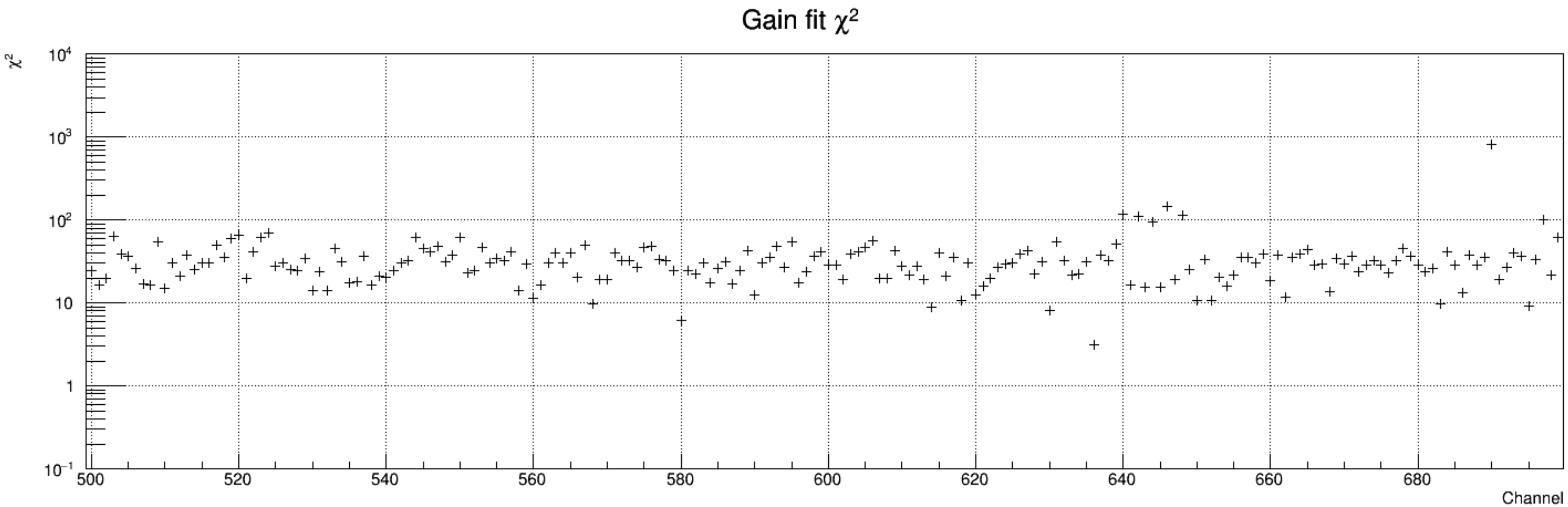
Height vs. DAC channel 692
Gain: 276.8 (ADC count)/Q step
Offset: -0.27 Q step
χ2: 27.0
Height vs. DAC channel 693
Gain: 255.4 (ADC count)/Q step
Offset: -0.27 Q step
χ2: 40.7
Height vs. DAC channel 694
Gain: 276.7 (ADC count)/Q step
Offset: -0.27 Q step
χ2: 36.8
Height vs. DAC channel 695
Gain: 255.3 (ADC count)/Q step
Offset: -0.28 Q step
χ2: 9.2
Height vs. DAC channel 696
Gain: 282.6 (ADC count)/Q step
Offset: -0.27 Q step
χ2: 32.9
Height vs. DAC channel 697
Gain: 252.4 (ADC count)/Q step
Offset: -0.35 Q step
χ2: 99.4
Height vs. DAC channel 698
Gain: 281.6 (ADC count)/Q step
Offset: -0.30 Q step
χ2: 22.0
Height vs. DAC channel 699
Gain: 259.4 (ADC count)/Q step
Offset: -0.26 Q step
χ2: 61.7
Pulse height [ADC count]
DAC count

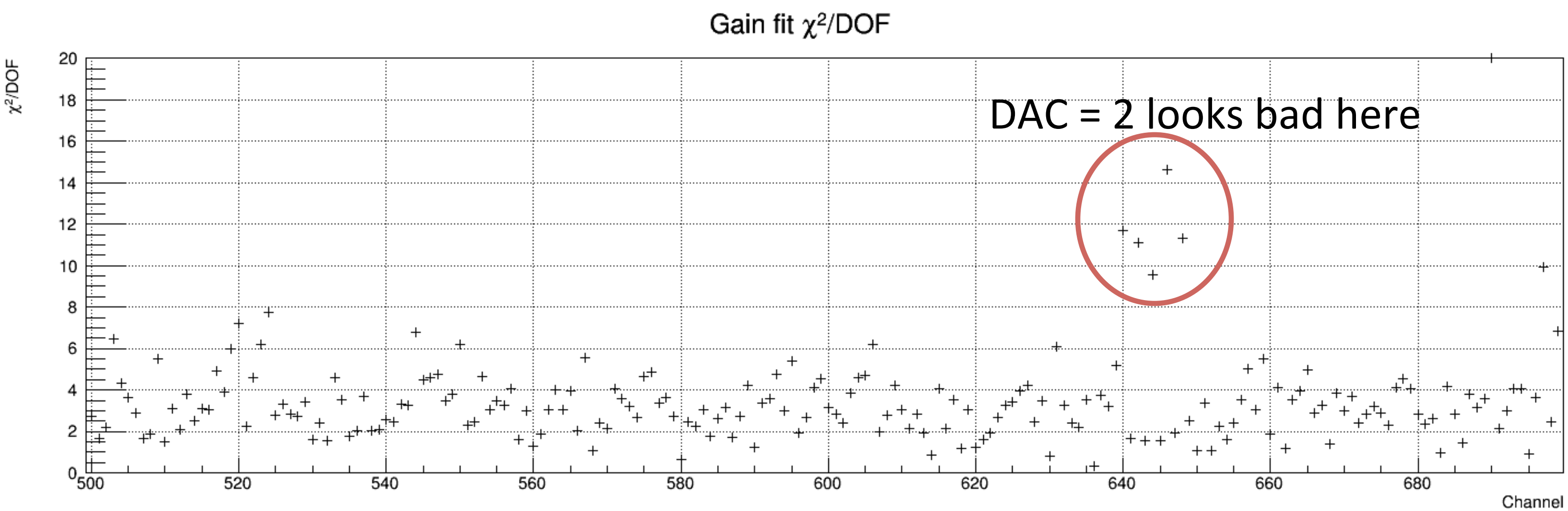
Gain and offset fits results vs. channel



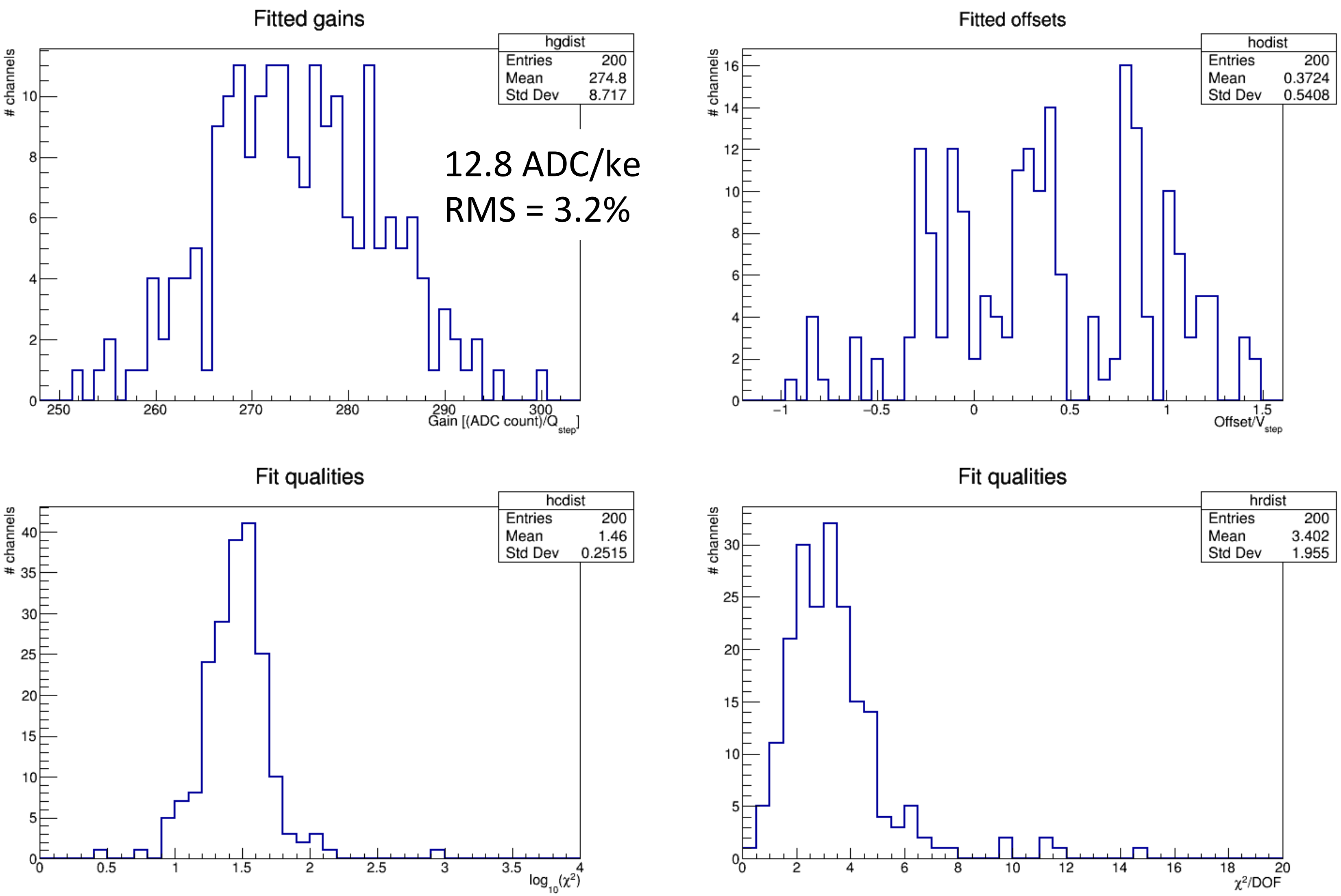


Fit quality vs. channel





Fit distributions (channels 500-699)



Summary/conclusions

Pulser data used to obtain TPC electronics calibration

- The gain, (input charge)/(ADC count), for each channel
  - So far for 200 induction channels
  - Data taken with preamp gain of 25 mV/fC and 2 μs shaping
  - Result is an average gain of 78 e/(ADC count) with σ = 3.2%
- Pedestal was evaluated first (see earlier talks)
- Gain is an average over a broad range of the ADC
  - More work needed to correct for non-linearity or get response in the single MIP region
  - Pulses alone give only coarse calibration
  - But may be able to use points on the pulse waveform to go finer

Above is a pulse height calibration

- Valid for isolated signal with charge collection time << 2 μs
- I think we want a pulse area calibration—right?
  - Straightforward to obtain this from pulser data
- A bit more channel-to-channel variation because shaping time varies

Future

Study few % of channels with poor fits

Look at remaining channels in APA 5

- The other 1336 channels
- Including collection with different pedestal location

Area calibration?

Calibrate

- Put gains in calibration tool and validate

Search each channel for sticky ADC codes

- Determine extent of the problem
  - Use pulser data to determine implication with and without mitigation
- Most of the data is is in the pedestal region and we can do a thorough characterization there
- Use samples along the pulse waveform to examine other regions
  - Vary pulser DAC and offset to illuminate most of the ADC range
  - Good fit quality suggests this will work well for the positive pulses
  - Like to understand why fit quality degrades for negative pulses at high DAC settings

Extras

Data prep service configuration

```
RawDigitPrepService: {
    service_provider: ToolBasedRawDigitPrepService
    LogLevel: 3
    DoWires: false
    AdcChannelToolNames: [
      "digitReader",
      "adcPedestalFit",
      "pdapa_adcChannelPedestalRmsPlotter",
      "adcSampleFiller",
      "adcThresholdSignalFinder",
      "adcRoiFitterPos”,
      "adcRoiFitterNeg"
    ]
}
```

Extract raw data and pedestal from raw::RawDigit

Find pedestals

Display RMS

Subtract pedestal, trivial calibration

Find ROIs

Process ROIs

Configuration of ROI processing tool (obsolete)

```
tools.adcRoiFitterPos: @local::tools.adcRoiFitter
tools.adcRoiFitterPos.LogLevel: 2
tools.adcRoiFitterPos.SigThresh: 100.0
tools.adcRoiFitterPos.RoiHistOpt: 1
tools.adcRoiFitterPos.FitOpt: 1
tools.adcRoiFitterPos.RoiRootFileName: "roiroipos.root"
tools.adcRoiFitterPos.SumRootFileName: "roisumpos.root"
tools.adcRoiFitterPos.ChanSumRootFileName: "roichanpos.root"
tools.adcRoiFitterPos.SumHists: [
  {var:fitHeight    name:"hfh_ch%0CHAN%"     title:"ROI fit height channel %CHAN%"                  nbin:100 xmin:100  xmax:5     fit:gaus},
  {var:fitHeight    name:"hfhw_ch%0CHAN%"    title:"ROI fit height channel %CHAN%"                  nbin:100 xmin:0    xmax:0     fit:gaus},
  {var:fitWidth     name:"hfw_ch%0CHAN%"     title:"ROI fit width channel %CHAN%"                   nbin:100 xmin:4.0  xmax:4.5   fit:gaus},
  {var:fitWidth     name:"hfww_ch%0CHAN%"    title:"ROI fit width channel %CHAN%"                   nbin:100 xmin:0.0  xmax:0.0           },
  {var:fitPosition  name:"hfp_ch%0CHAN%"     title:"ROI fit position channel %CHAN%"                nbin:100 xmin:0.0  xmax:10000         },
  {var:fitTickRem   name:"hfr_ch%0CHAN%"     title:"ROI fit position remainder channel %CHAN%"      nbin:100 xmin:-0.5 xmax:0.5   fit:gaus},
  {var:fitPeriodRem name:"hftw_ch%0CHAN%"    title:"ROI fit period remainder channel %CHAN%"        nbin:500 xmin:-250 xmax:250           },
  {var:fitChiSquare name:"hfcsw_ch%0CHAN%"   title:"ROI fit #chi^{2} channel %CHAN%"                nbin:100 xmin:0.0  xmax:0.0           },
  {var:fitCSNormDof name:"hfcsndw_ch%0CHAN%" title:"ROI normalized fit #chi^{2}/DOF channel %CHAN%" nbin:100 xmin:0.0  xmax:0.0           }
]
tools.adcRoiFitterPos.ChannelRanges: [
  {name:apa1u begin:0 end:800 label:"APA1u"}
]
tools.adcRoiFitterPos.ChanSumHists: [
  {name:"hcsHeight_%CRNAME%"    title:"ROI fit height run %RUN% %CRLABEL%"                  valHist:"hfh_ch%0CHAN%"     valType:fitMean
cr:apa1u},
  {name:"hcsShaping_%CRNAME%"   title:"ROI fit shaping time run %RUN% %CRLABEL%"            valHist:"hfw_ch%0CHAN%"     valType:fitMean
cr:apa1u},
  {name:"hcsChiSquare_%CRNAME%" title:"ROI fit #chi^{2} run %RUN% %CRLABEL%"                valHist:"hfcsw_ch%0CHAN%"   valType:mean
cr:apa1u},
  {name:"hcsCSNormDof_%CRNAME%" title:"ROI fit Normalized #chi^{2}/DOF run %RUN% %CRLABEL%" valHist:"hfcsndw_ch%0CHAN%" valType:mean
cr:apa1u}
]
```

Fit with coldelec function

Output root files

Summary histograms

Channel summary histograms