ProtoDUNE TPC data: Charge resolution with pulser data

ProtoDUNE sim/reco

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Introduction

Pulser data is useful for performance evaluation

- Same FE charge injected at regular intervals
- Amplifier and ADC same as for charge collected from TPC

Performance metrics

- Local charge resolution
  - E.g. RMS of measured charge for many pulses
    - For each channel and
    - For multiple charge injection levels (~ 1, 2, 3, … MIPs)
- Non-linearity in charge measurements
  - E.g. look at mean response for different charge injection levels
  - Complicated by non-linearity of pulser levels but may be able to use the fact that the same pulser signal is seen by all channels in an ASIC or FEMB
- Tails in charge measurements
  - E.g. how often pulse measurement is N-sigma from mean

Important for studying reco algorithms

- How are above metrics affected by pedestal evaluation, noise removal, ADC mitigation, undershoot correction, deconvolution, etc?

Calibration

Results here make use of calibrated data

- Calibration from pulser data presented here last month
- Calibration is linear: Q = gain × (ADC – pedestal)

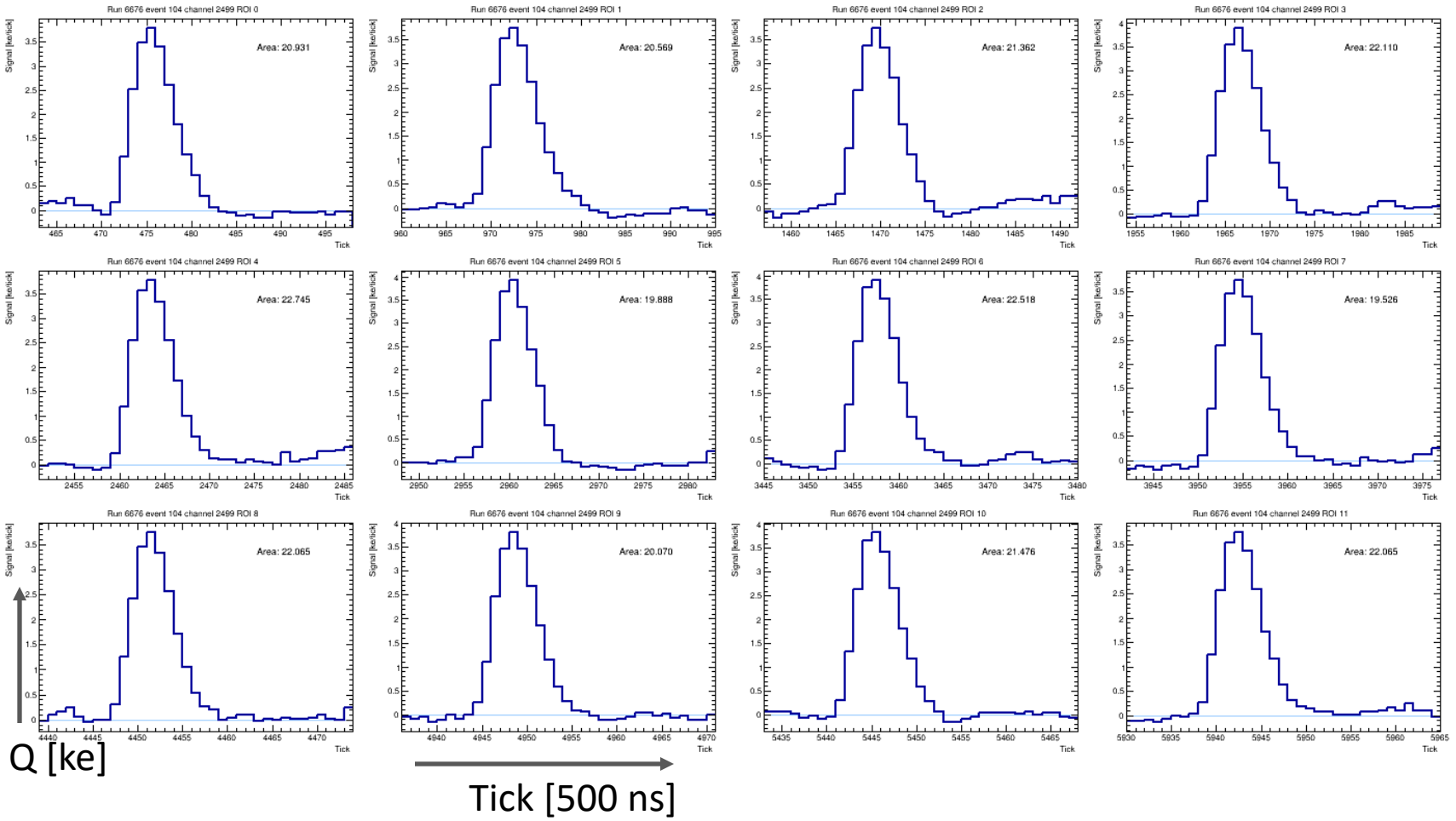
Example pulses

- Plot on following page shows pulses at lowest pulser gain setting
  - I.e. pulse charge is around 21 ke (about 1 MIP)

Simple ROI algorithm

- Signals found with a (single-tick) threshold of 2.0 ke
- Retain 10 ticks before and 20 ticks after any tick above this threshold
  - Could be narrower for pulser signals but want to mimic TPC data
- ROI charge is the integral over this range
  - Presumably can do better with CE response function fit but we cannot use that with TPC data

Example signals from pulser



Calibrated pulses from run 6676. Pulser gain setting 1.

Study with HV off

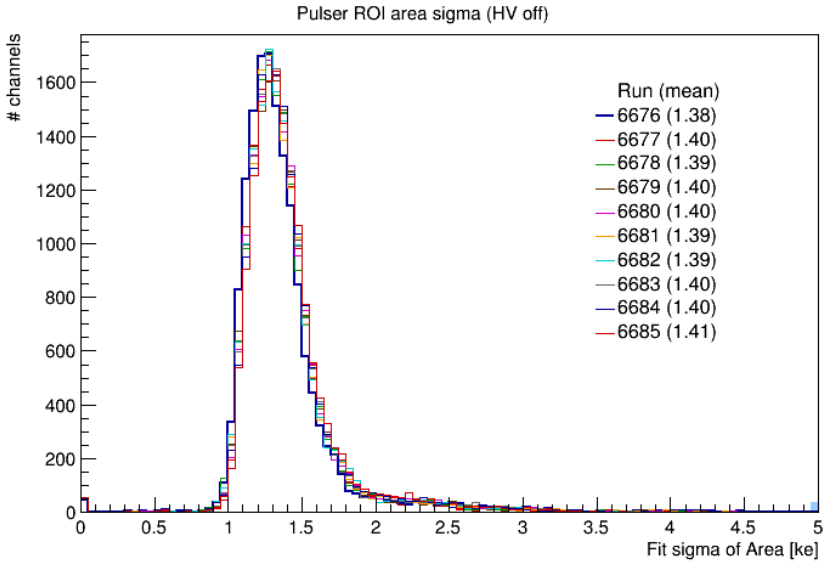
Start with data taken with HV off

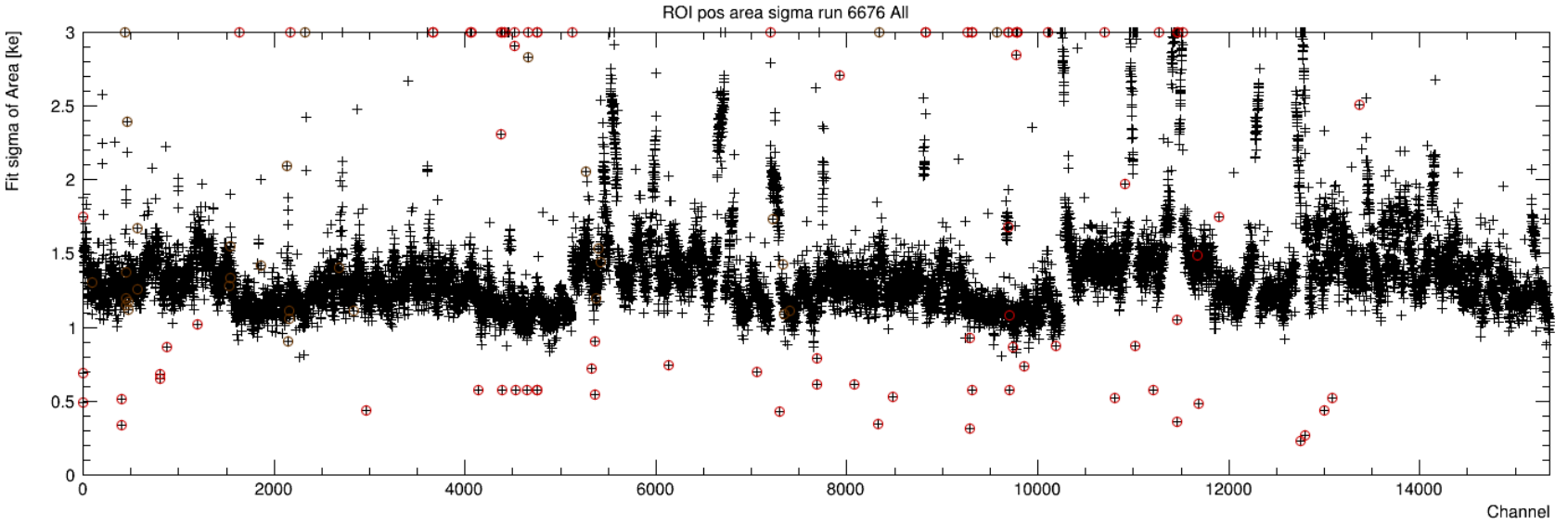
- Bias voltage is also off
- TPC signals are still seen but much less than with HV on
- Runs 6676 – 6691
  - Pulser settings 1-10
- Analysis
  - Process the first 50 events for each run (~600 pulses each channel)
    - Results shown with and without ADC mitigation
  - ROI area as described earlier
  - Histogram the area for each channel in each run
  - Evaluate the RMS for each histogram retaining entries within ±4×RMS

Results with HV off, ADC mitigation off

Plots show some results

- Right: distribution of ROI area sigma for all channels
  - For each pulser setting (1-10)
- Below: ROI area sigma vs. channel for pulser setting 1
- Charge resolution is 1.2 – 1.3 ke
- A few regions (FEMBs?) are significantly worse

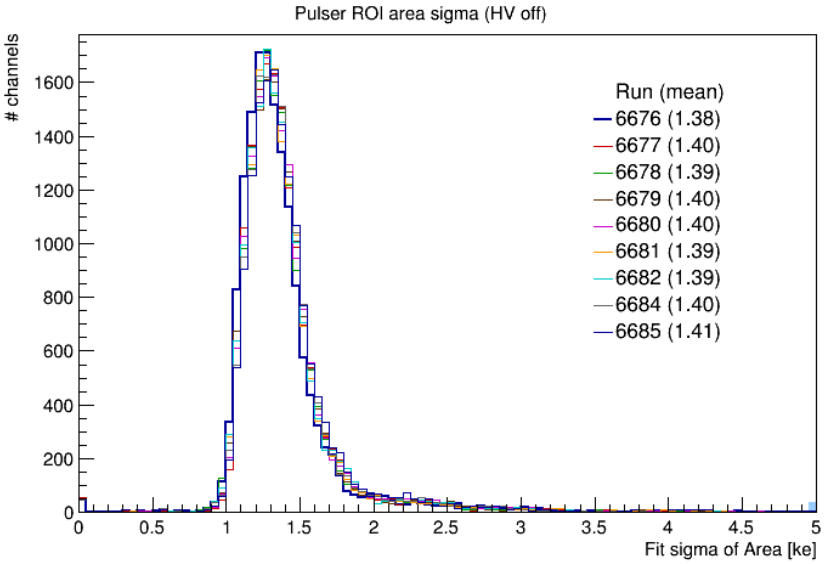


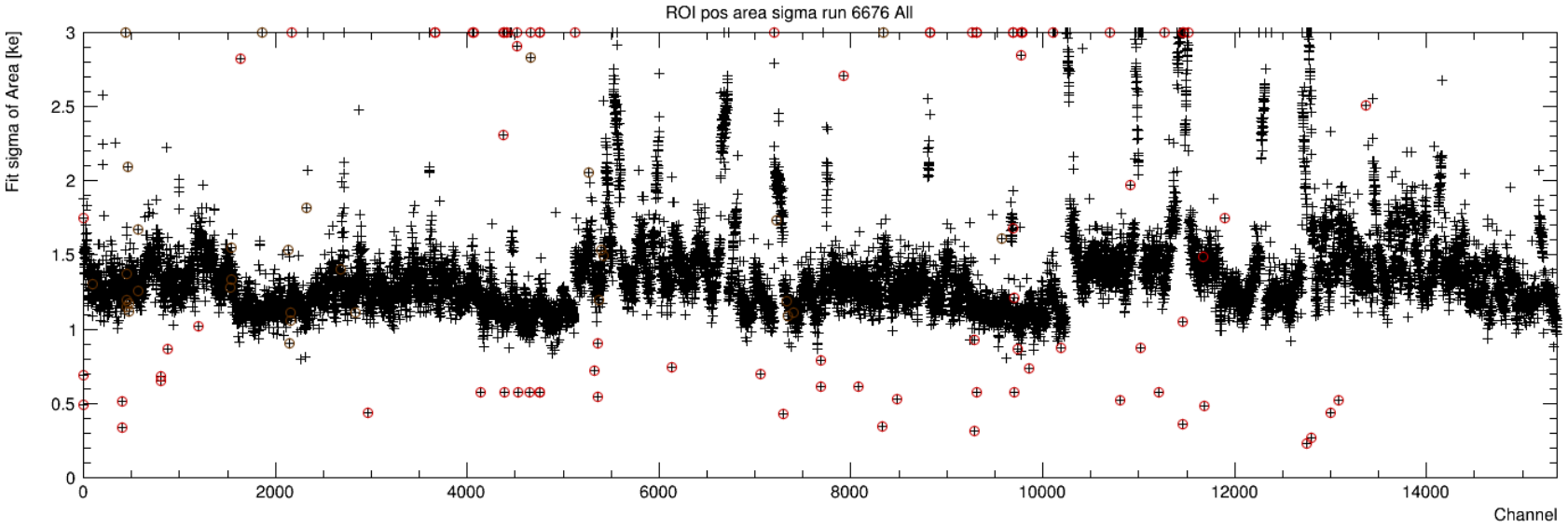


Results with HV off, ADC mitigation on

Results with ADC mitigation

- Same plots as preceding page
- A few channels are improved significantly

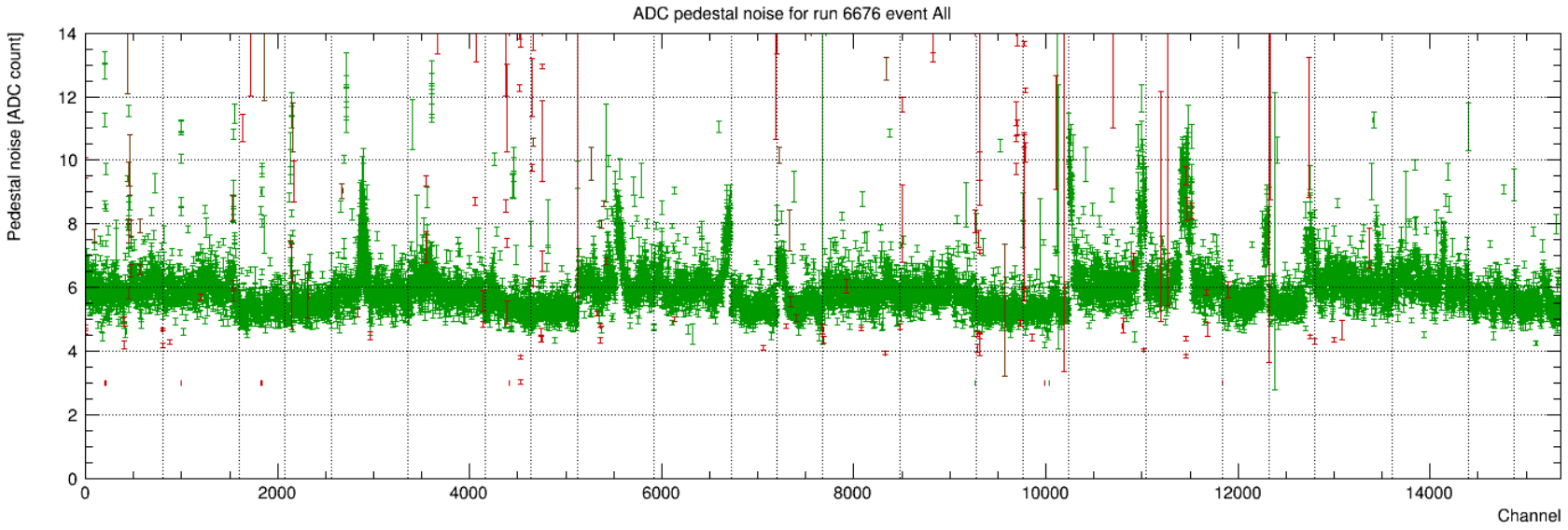




Noise

Plot below shows ADC pedestal noise vs. channel

- Comparing with preceding, we see that most of the tail in ROI resolution comes from noisy channels
- Noise has a bigger effect in noisy channels
  - Extra noise is time coherent (lower frequency)
  - I.e. does not cancel out when we integrate to get ROI area
- Might be able to improve ROI area with better (e.g. local) pedestal or with noise removal



Summary/conclusions

Charge resolution for ROIs is 1.2 – 1.3 ke

- Lower value for collection planes (we should add this plot)

Tail of 5-10% significantly above this value

- Few channels are fixed by ADC mitigation
  - Nice to demonstrate this makes things better (and not worse)
- Most of the tail is from noisier channels
  - ROI magnifies the effect of the noise
  - ➔ noise is coherent (low frequency)
  - Can we improve this with better pedestal or with noise removal?

Extras

Tickmod vs channel