Update of noise filtering in protoDUNE

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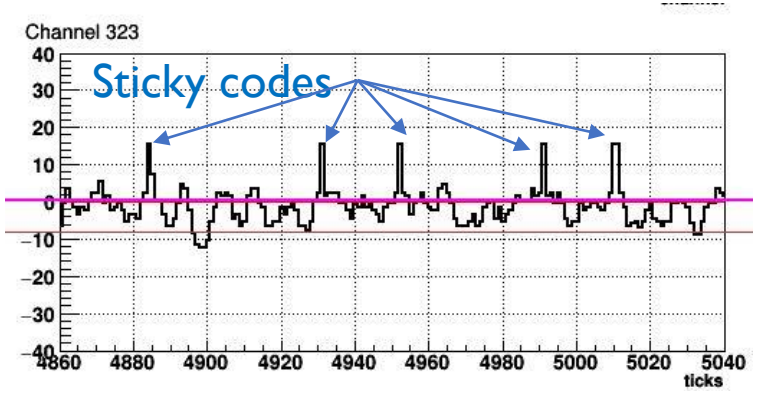
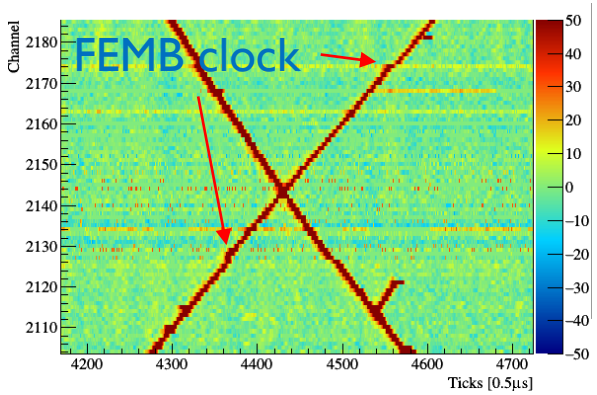
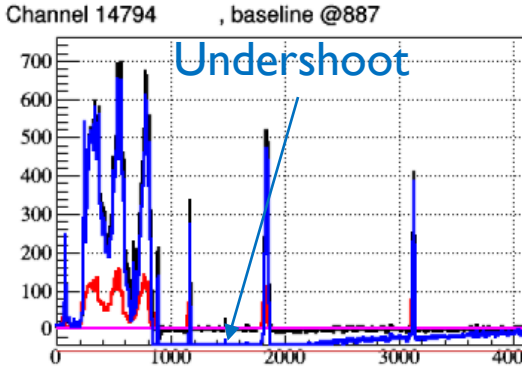
Overview of the noise filtering

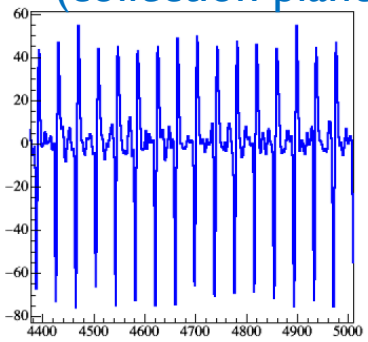
- Noise filtering (NF) is a key step towards a high-quality signal processing (SP)

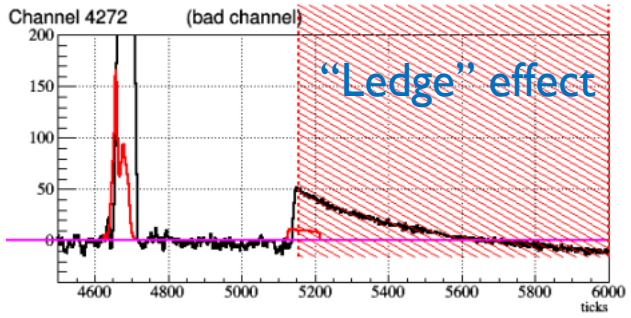




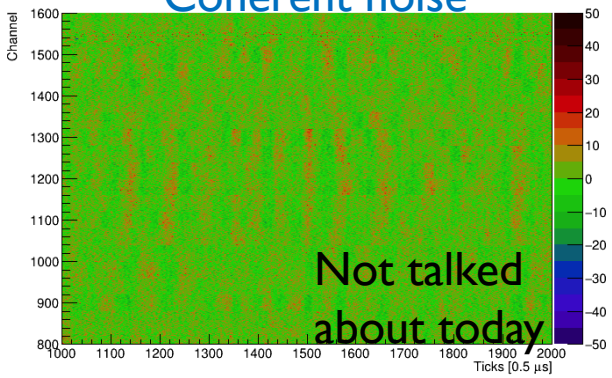


"50kHz" noise (collection plane)





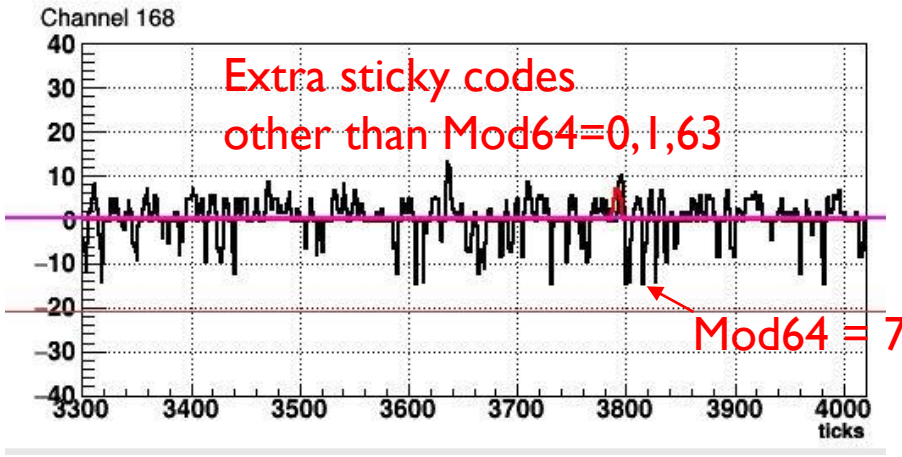
Coherent noise



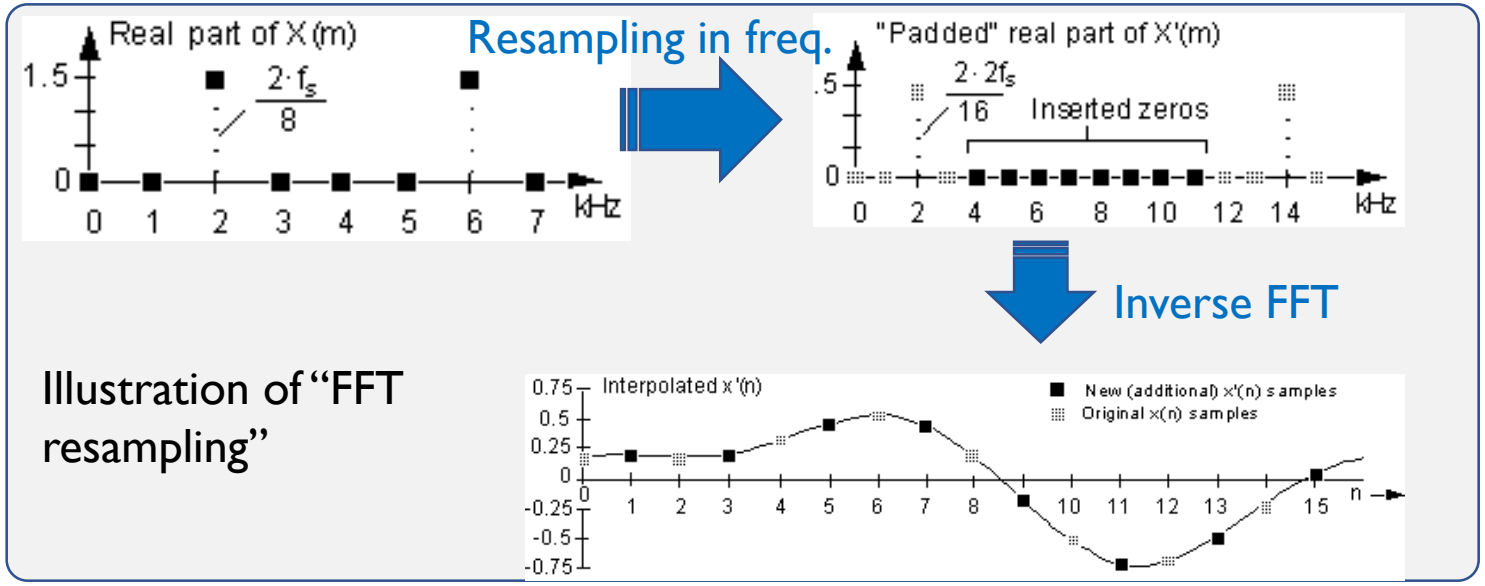
- Recently, revisited the performance of noise filtering
- Some problems, some new ideas, …
- Towards a high-quality NF soon

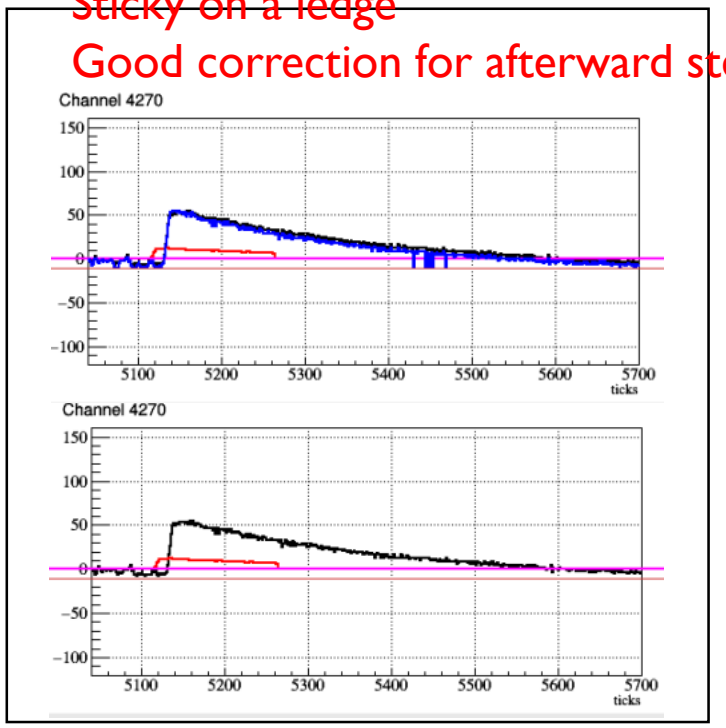
Also see prev. analyses by 1) David, 2) Wenqiang

Sticky codes mitigation

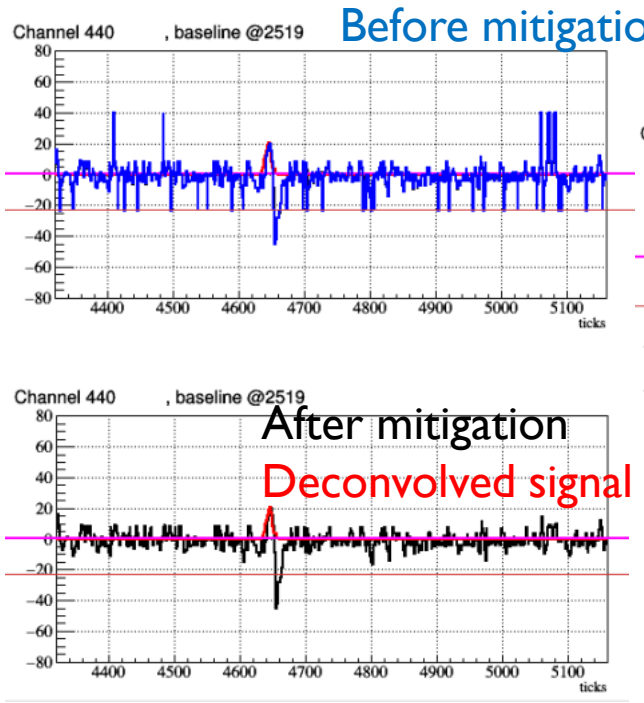


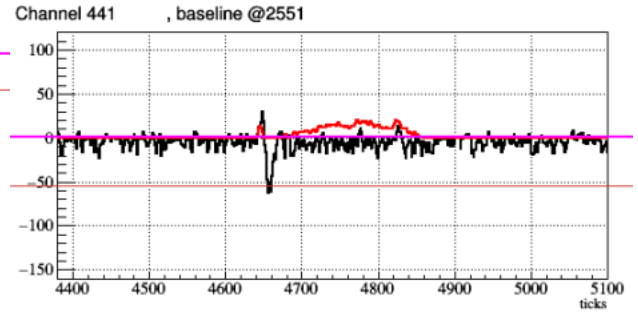
- Apply correction
  - "noise-like": linear interpolation + FFT resampling
  - "signal-like": FFT resampling
    - Peak value > 15 ADC, nearby (+/- 1 tick) > 2*RMS
- Some additional sticky codes need to be deal with





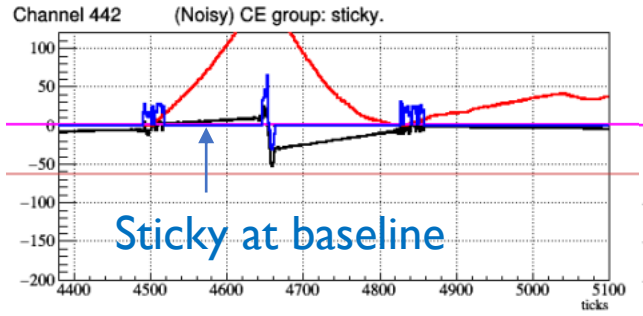
An example of sticky code mitigation

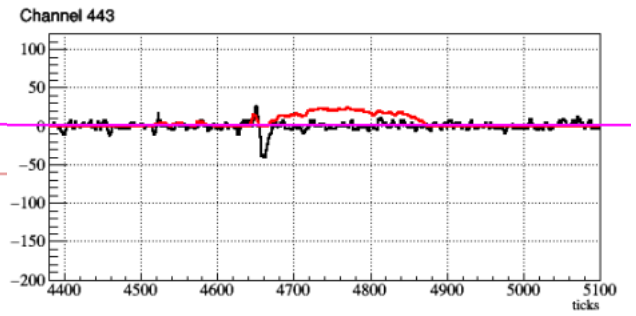




Deconvolved charge from adjacent channels:

- "2D" deconvolution





An extreme sticky channel, an artificial "bipolar" shape after interpolation
=> fake charge

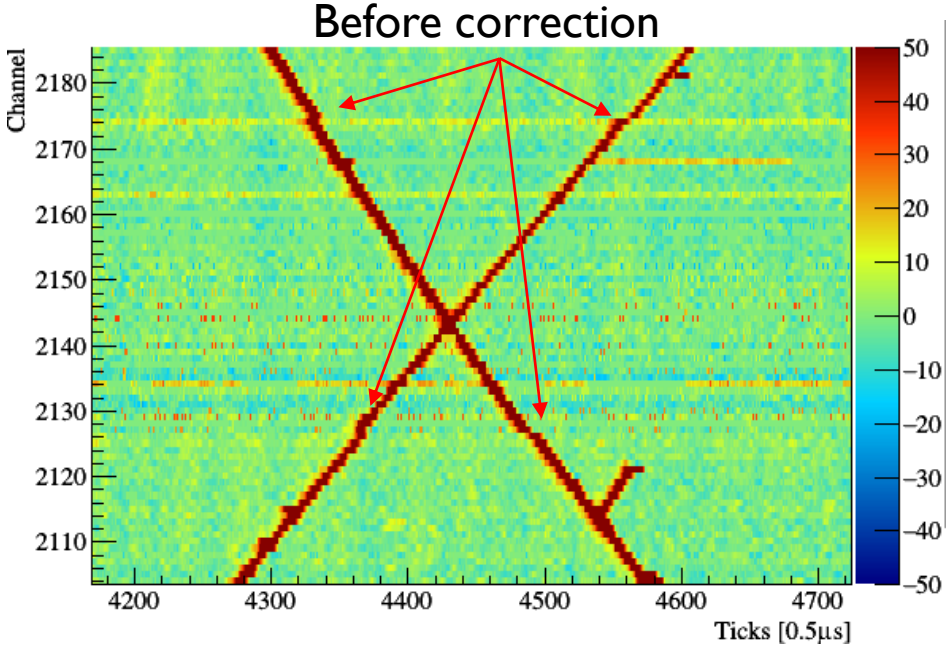
- Need more detailed evaluation
  - Exclude very sticky channels / time regions for SP
  - Any over-correction for SP?

Also see David & Tom's talk for resampling in time domain

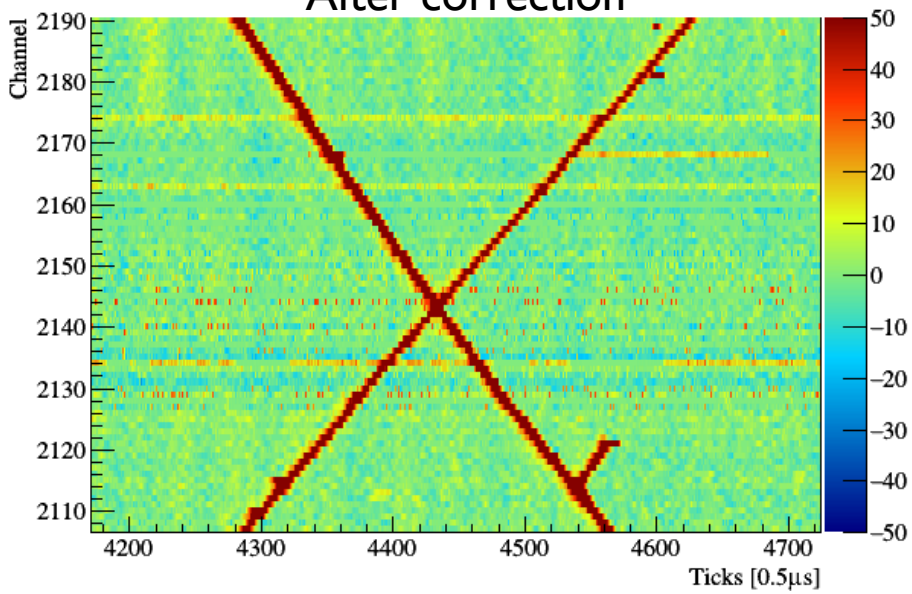
FEMB 302 clock

- 128 channels in FEMB 302 is "slower" than others
- The FFT resampling approach also works here
  - Extend 5996 samples => 6000 samples in freq. domain

Before correction



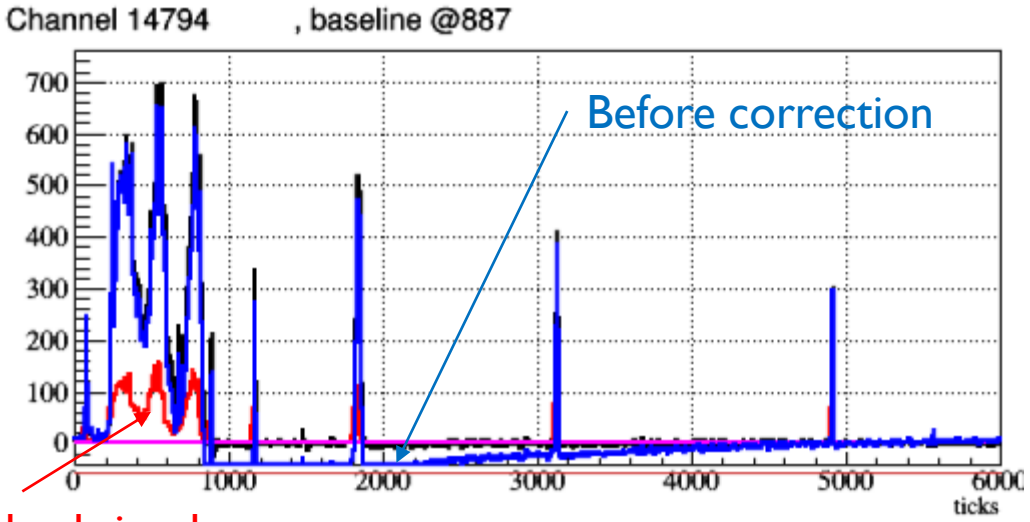
After correction

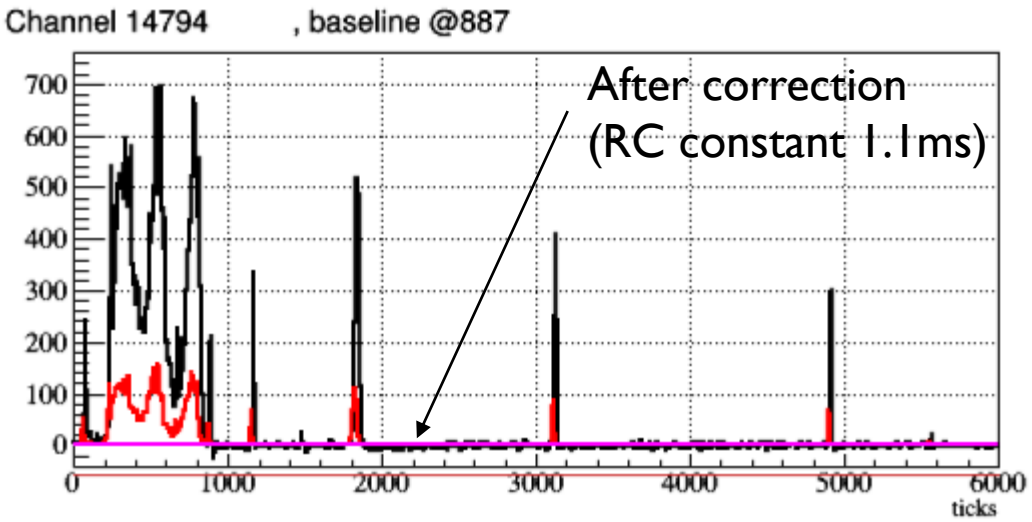


Also see Tom's time-domain RC fixer

Undershoot correction (i)

Run 5424 Event 10447





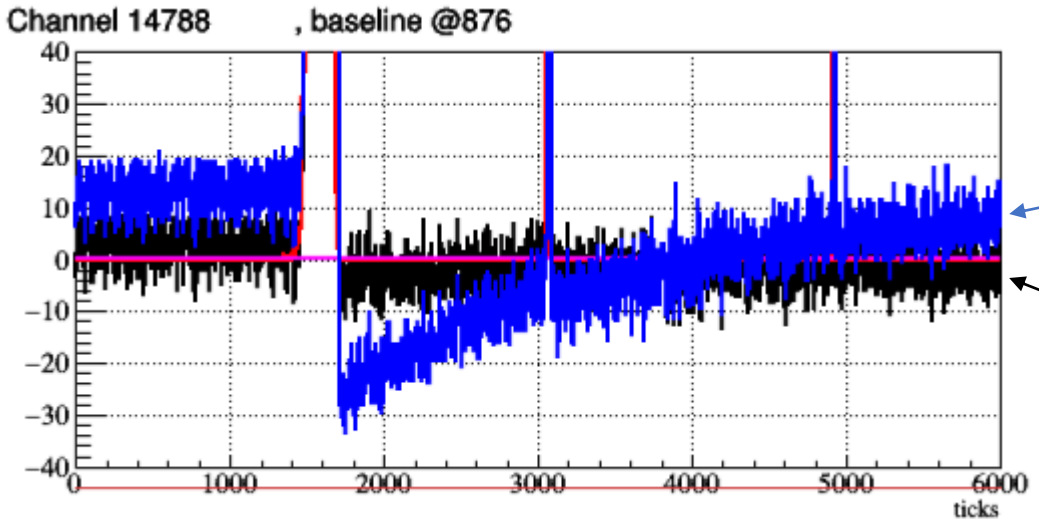
- Undershoot can be successfully removed by deconvolving the RC response (~ 1.1ms) in frequency domain via FFT

$$R(t) = \delta(t) - Ae^{-t/\tau}$$

τ = 1.1 ms (collection)

τ = 3.3 ms (induction)

Undershoot correction: another example

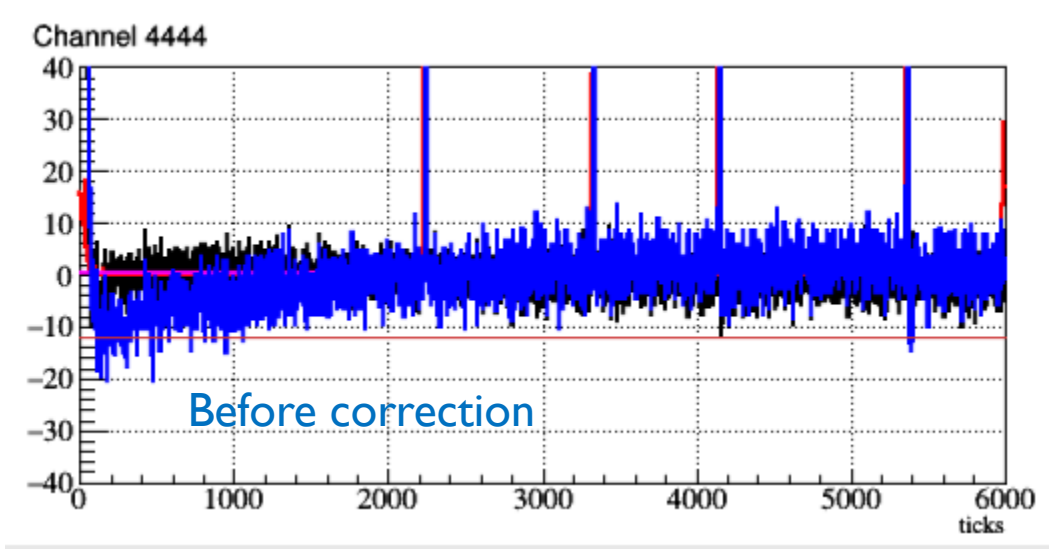


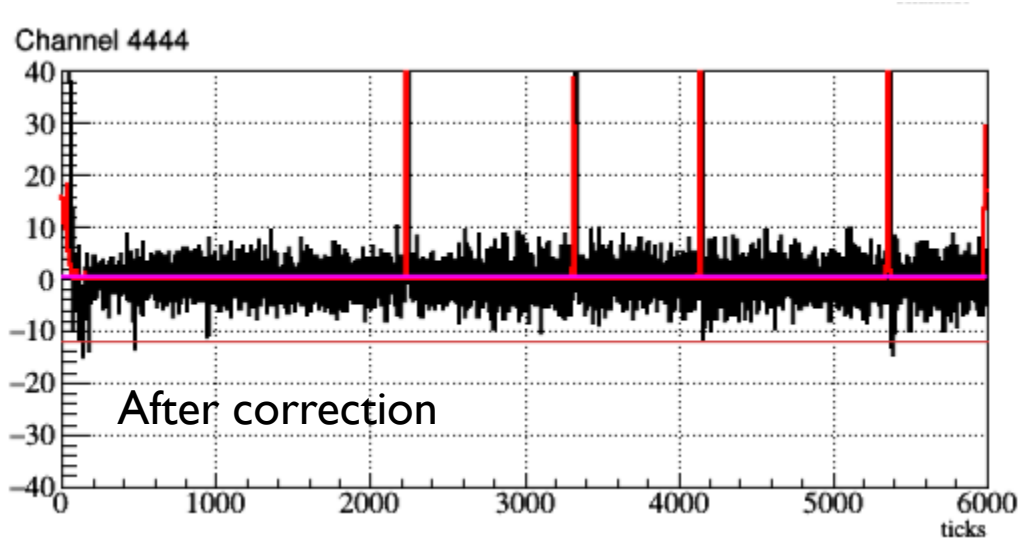
Raw waveform

After deconvolving RC response

- Another example

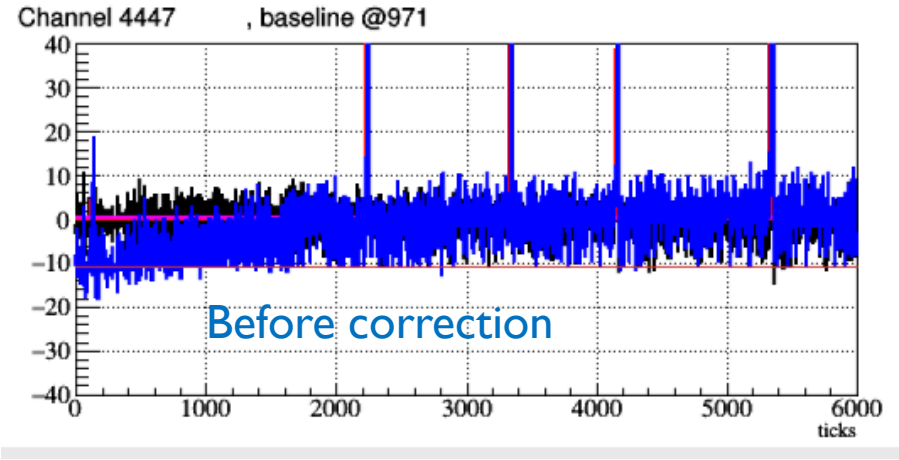
Undershoot correction (ii)

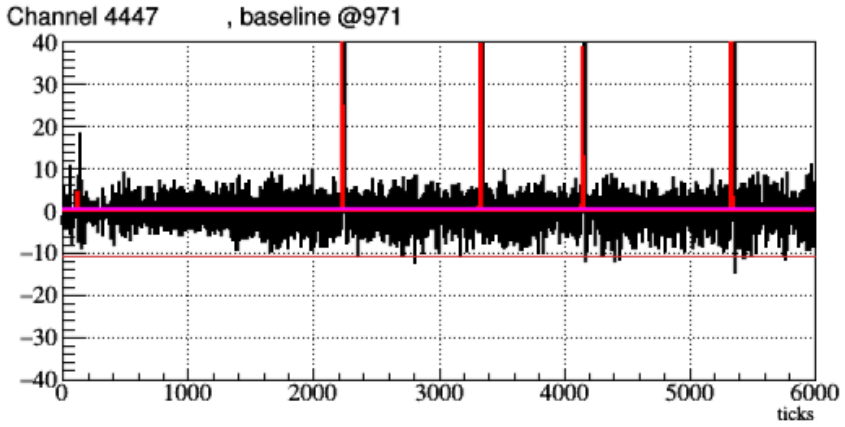




- In case that a large signal happens right before the readout window ("partial RC"), an adaptive baseline correction (linear) is applied

Undershoot correction (ii): another example

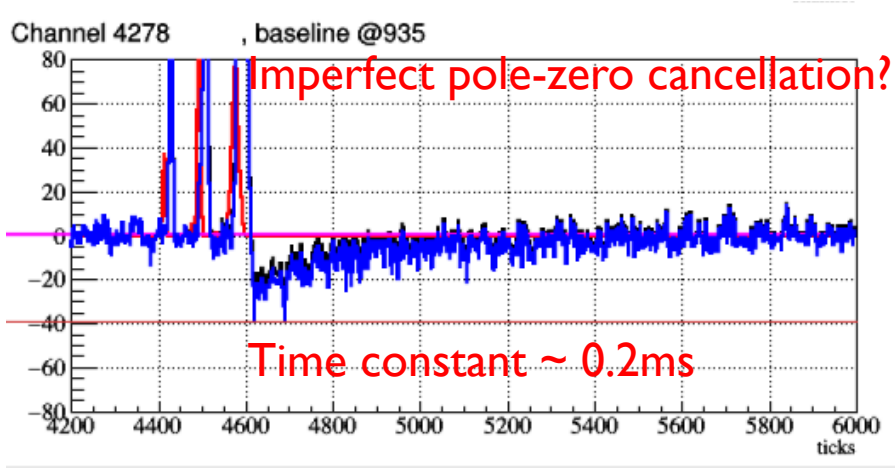


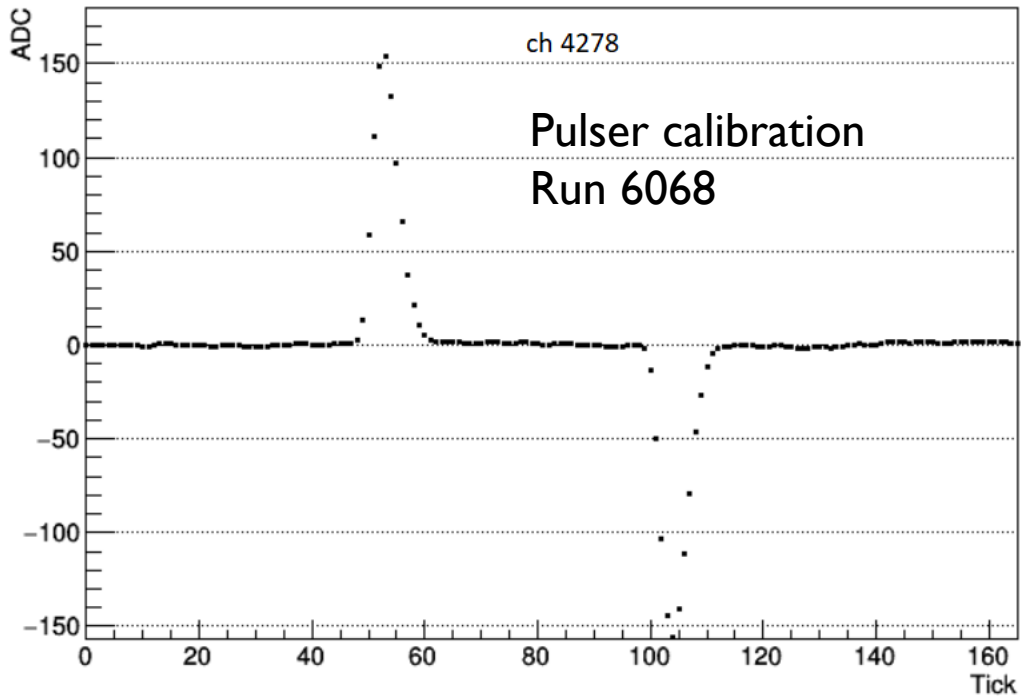


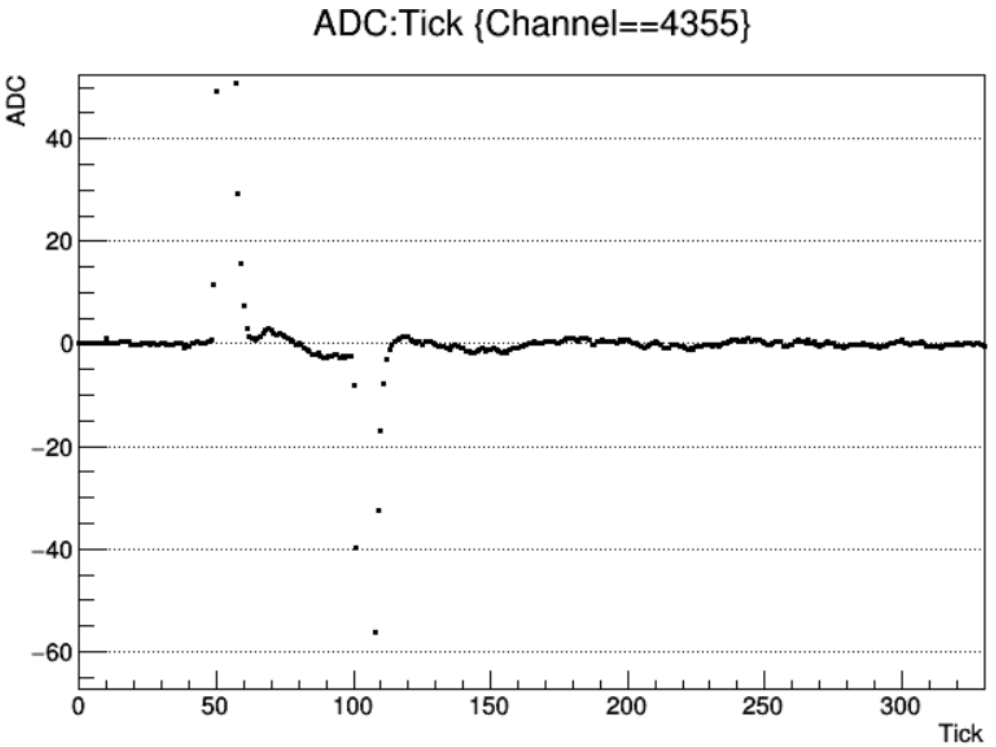
- Another example of "partial RC" correction

Imperfect electronics response

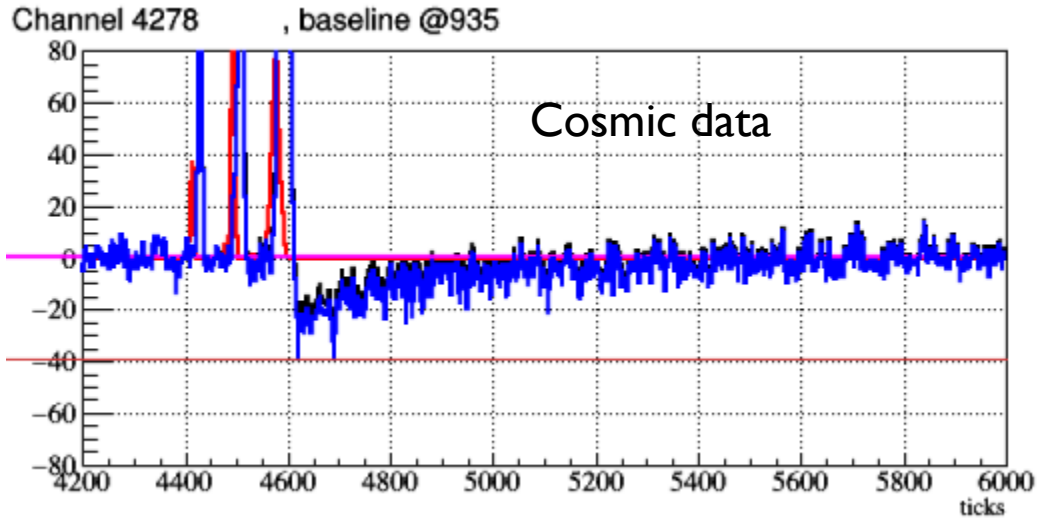
- The RC correction works well, however, still observed some imperfect electronics response even after small signals
  - Imperfect pole-zero cancellation?
- A dedicated calibration could help if indeed an electronics response issue
  - Current pulser data: too short distance between the positive and the negative pulses
- Need more samples for a conclusion

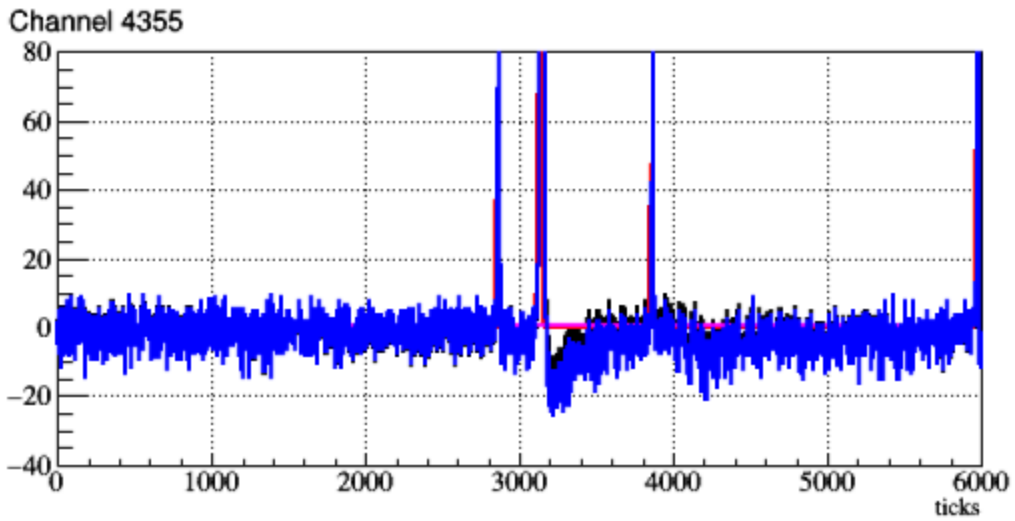






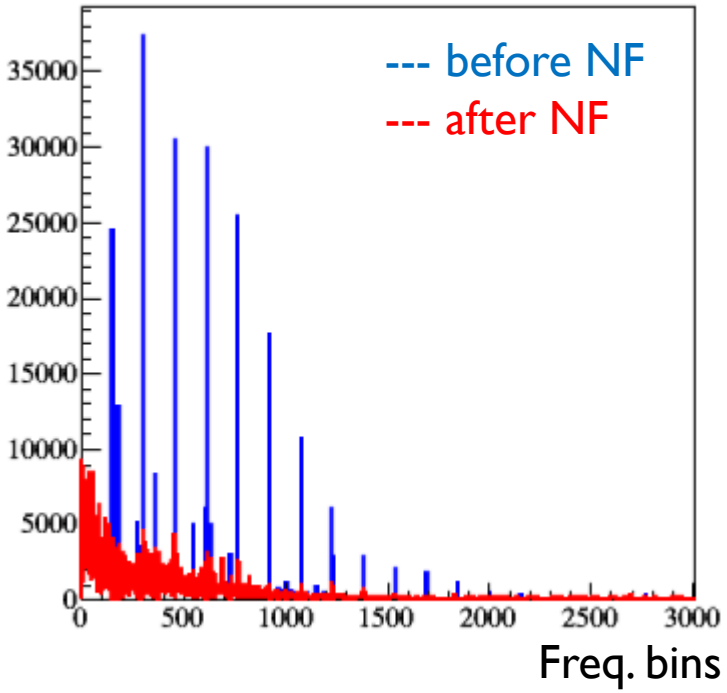
Seems to be not consistent?

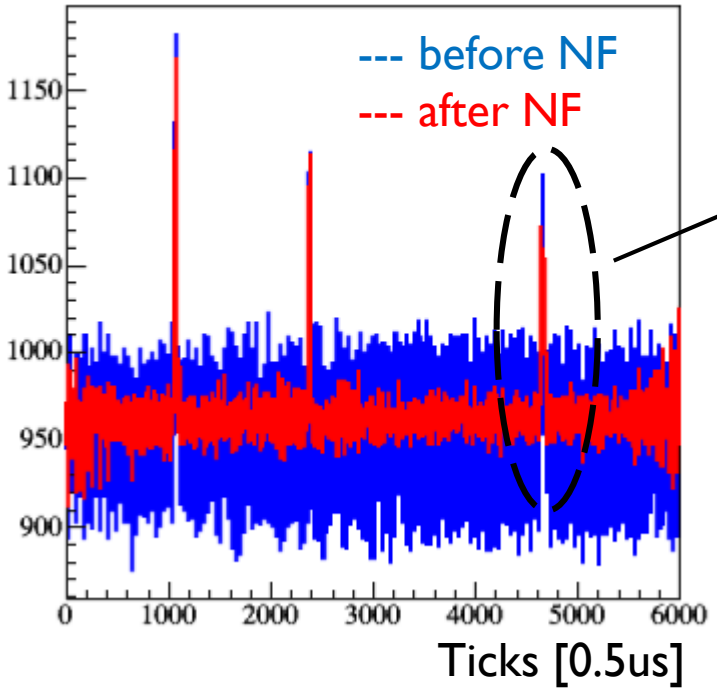


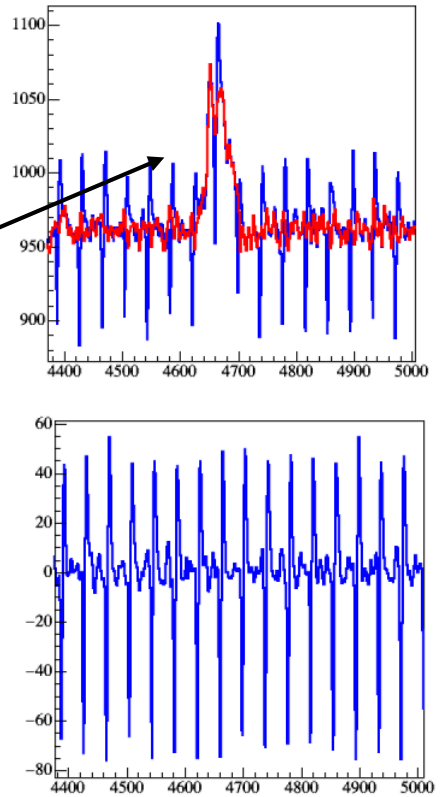


Also see previous analysis by Carlos: 1 2

"50 kHz" noise in some collection channels







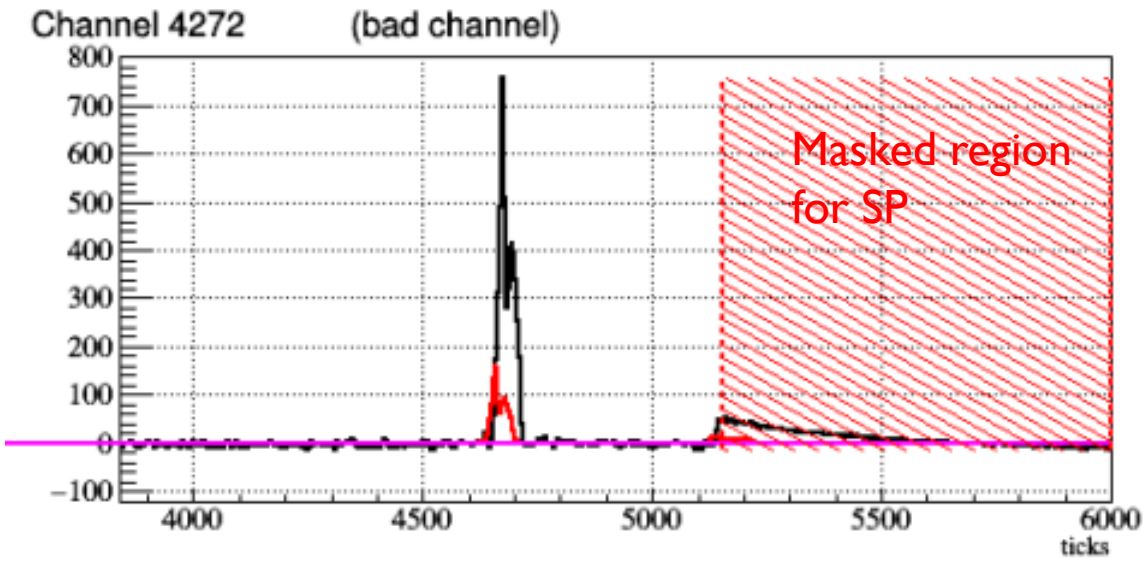
Filtered noise component

Looks reasonable!

- An automated spike filtering is implemented
  - Zero-out extreme outliers of each sub-region in frequency domain

Also see previous analysis

Mask for "ledge" region



- The bad region of the identified "ledge" will be masked and ignored in the SP
- Still need some tuning for the range

Summary

- Noise filtering are revisited and the general performance are good
- Still need more detailed evaluation/hand scan for sticky code, ledge, undershoot, etc.
  - Imperfect response shape in some channels
  - Calibration pulser data could be helpful
- Before we tune the SP algorithm, a solid performance of NF is necessary