

Correcting Undershoot in ProtoDUNE-SP TPC Wire Data

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ProtoDUNE Sim/Reco Meeting

November 7, 2018

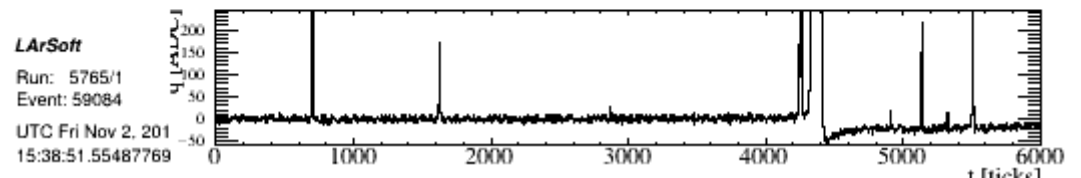
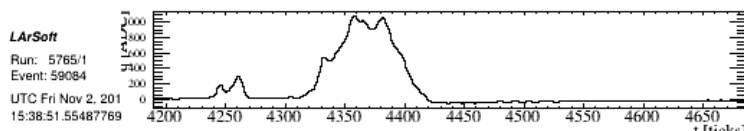
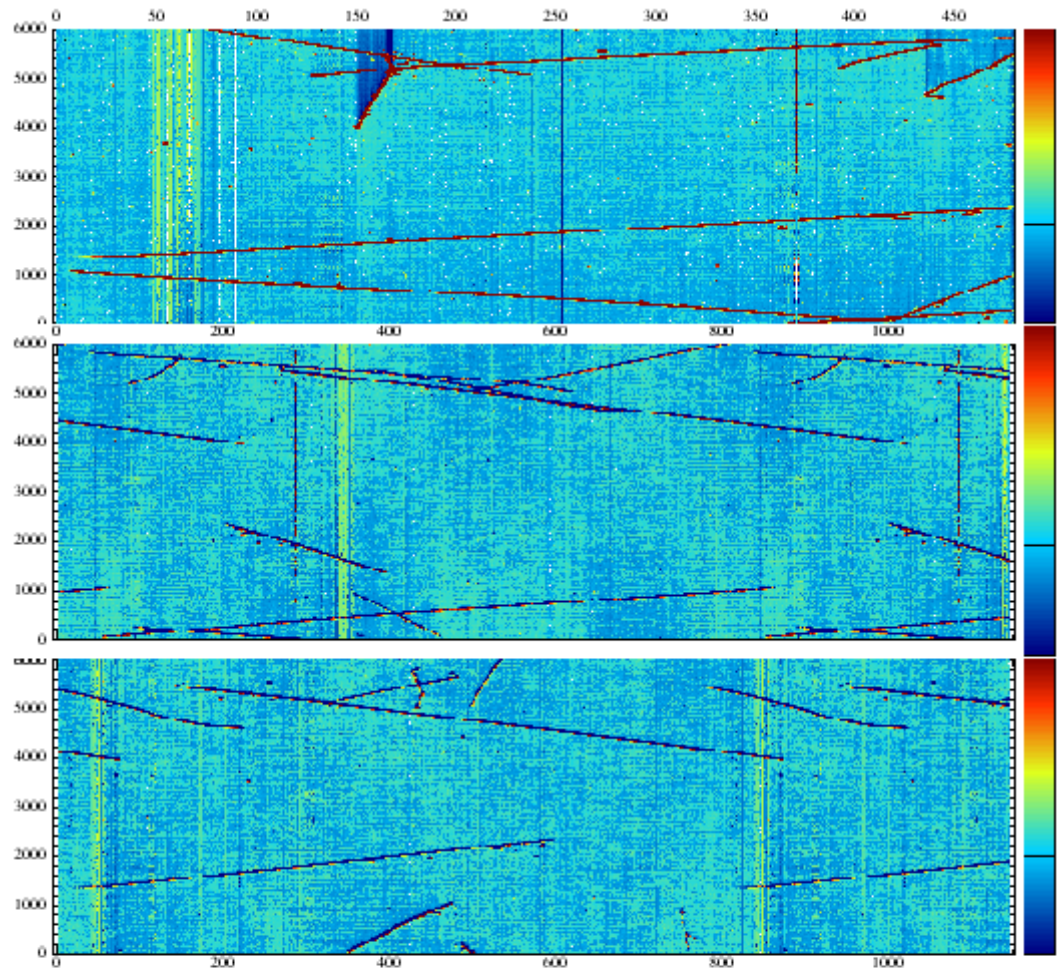
Undershoot in RawADC's

First event I looked at in a recent file has plenty of undershoot on a cosmic-ray track.

Signal peaks at 1000 ADC counts above pedestal for ~30 ticks

Caused by AC coupling in the front end.
Long time constant(s) (~milliseconds)

Wire 155, zoomed in in time,
zoomed out in ADC



MicroBooNE Experience

- Similar undershoot seen in MicroBooNE data with similar front-end electronics.
- Two RC Circuits, each with 1 ms time constant
- Documentation: MicroBooNE Collaboration (R. Acciarri et al) JINST 12 (2017) no.08, P08003. <http://arxiv.org/abs/arXiv:1705.07341>
- Initial strategy – include an RC response function in the signal shaping services.
- Time-domain RC response: $R(t) = \delta(t) - Ae^{-t/\tau}$ (taking $t=0$ as the start time). A is chosen so the total integral is zero.
- Response put in twice – square the FFT amplitude and double the phase.
Some code: <https://github.com/BNLIF/wire-cell-sst/blob/master/src/DatauBooNEFrameDataSource.cxx#L295>
- From Xin and Shanshan: time constant should be 1.1 ms for collection-plane wires and 3.3 ms for induction-plane wires.
- MicroBooNE now uses WireCell for signal processing.

MicroBooNE Example

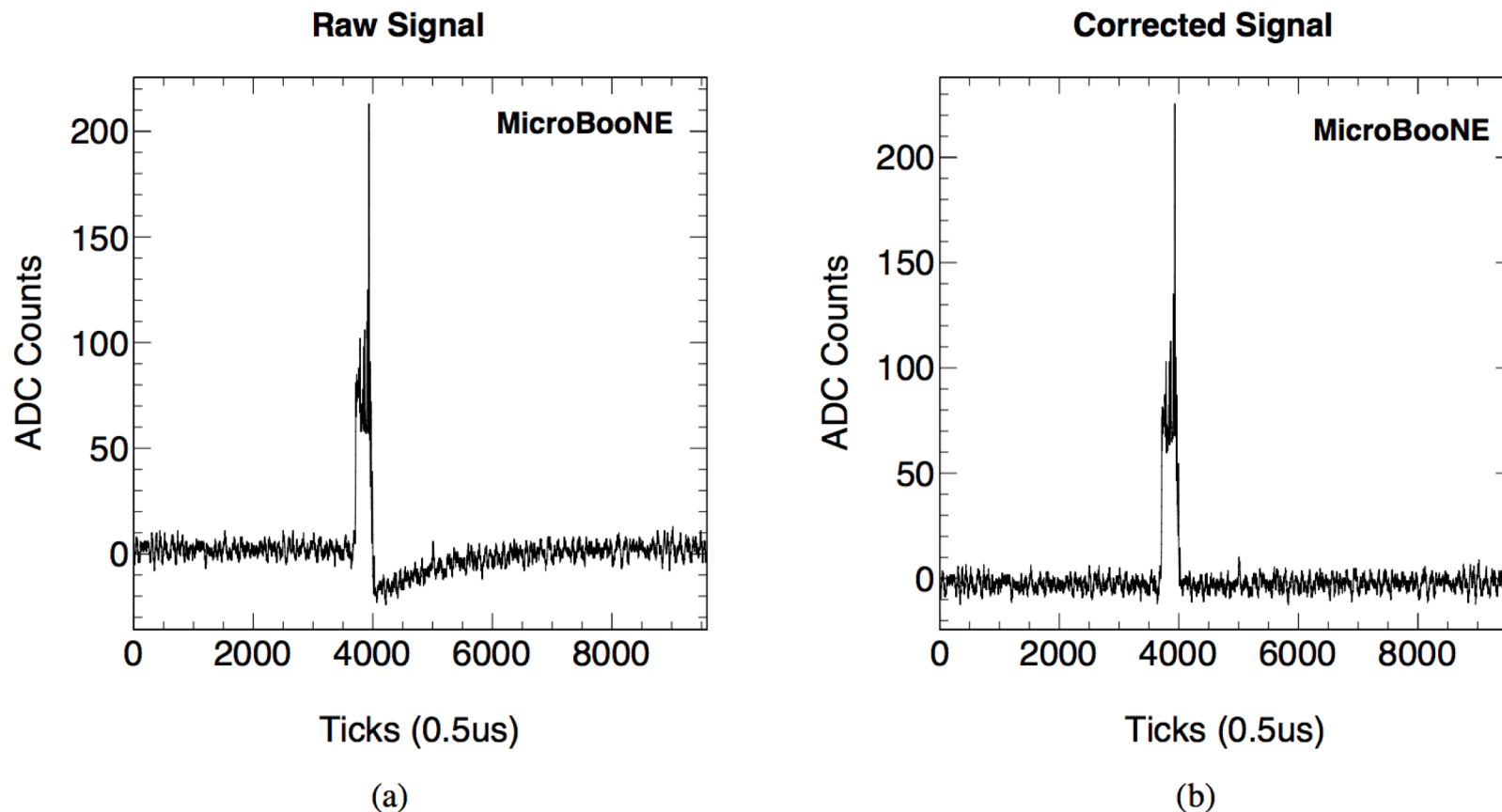


Figure 5. Example Y plane raw signal waveforms from data: (a) before correcting, and (b) after correcting for the RC shaping effect. This signal corresponds to a cosmic muon traveling close to parallel to the collection wires.

JINST 12 (2017) no.08, P08003

Implementation for DUNE

- Also propose two response functions, but tunable amplitudes and time constants.
- DUNE's signal shaping service multiplies the FFT's of each component of the response function so this is equivalent to convoluting the two functions.
- DUNE's signal shaping service also inverts the FFT of the response for simulation and filtering so that effects put in the MC can be filtered out consistently.

- Six functions defined – two per plane

$$R_{ij}(t) = \delta(t) - A_{ij}e^{-t/\tau_{ij}}$$

- $i = U, V, \text{Collection}$
 $j = 1, 2$

- All parameters fcl controllable via fcl. For example:
services.SignalShapingServiceDUNE.CorrectRC: false # turns it all off
services.SignalShapingServiceDUNE.CoIRCTime1: 2.0
services.SignalShapingServiceDUNE.CoIRCFrac1: 0.1
- Default is to turn the correction off (so MC works...)

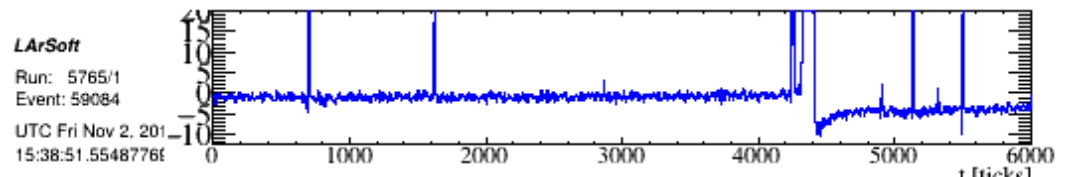
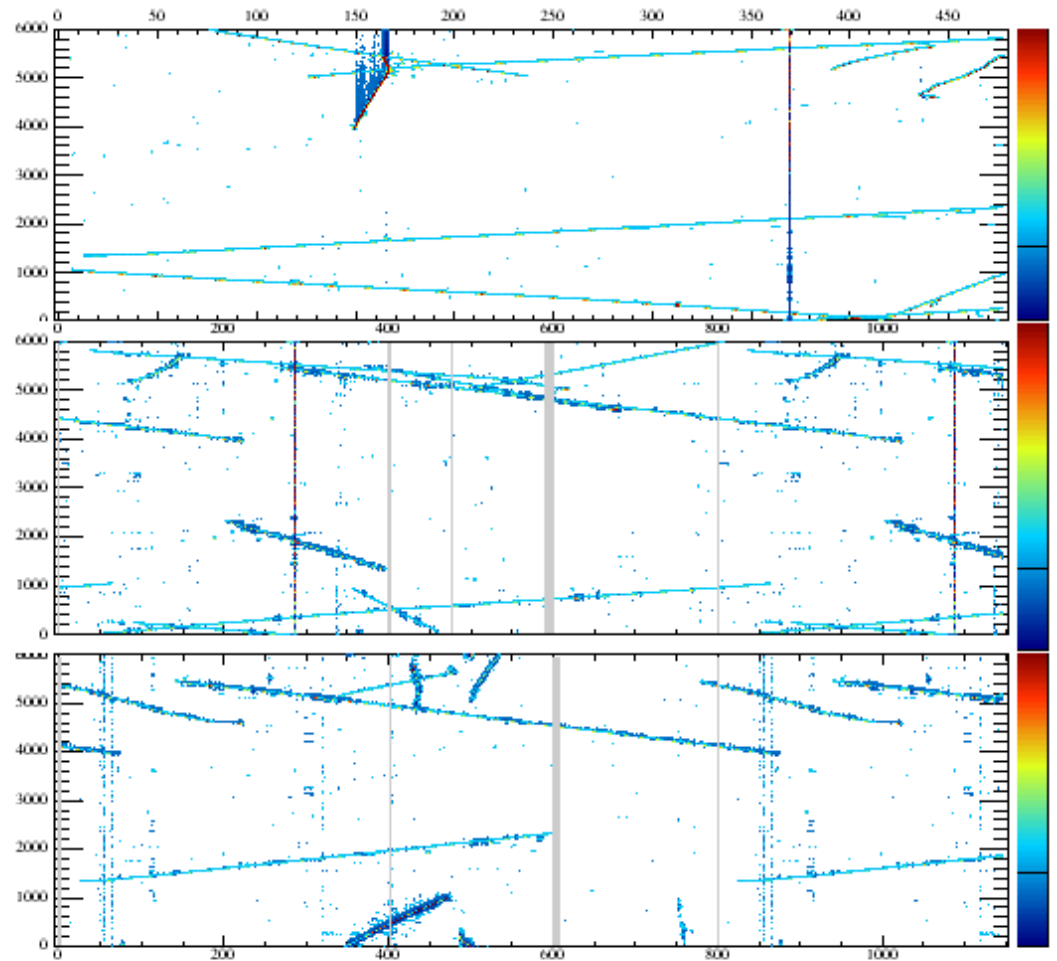
Fixing The Undershoot in Reco

Run
protoDUNE_SP_keepup_decoder_reco.fcl
but with ROI length set to ≥ 6000 in both
directions:

PadHigh = PadLow = 6000

Has all filtering and deconvolution
components except for RC filtering.

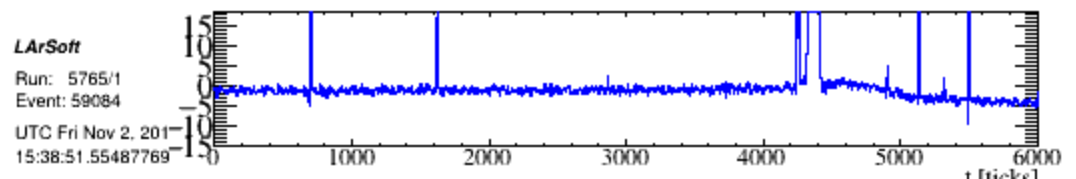
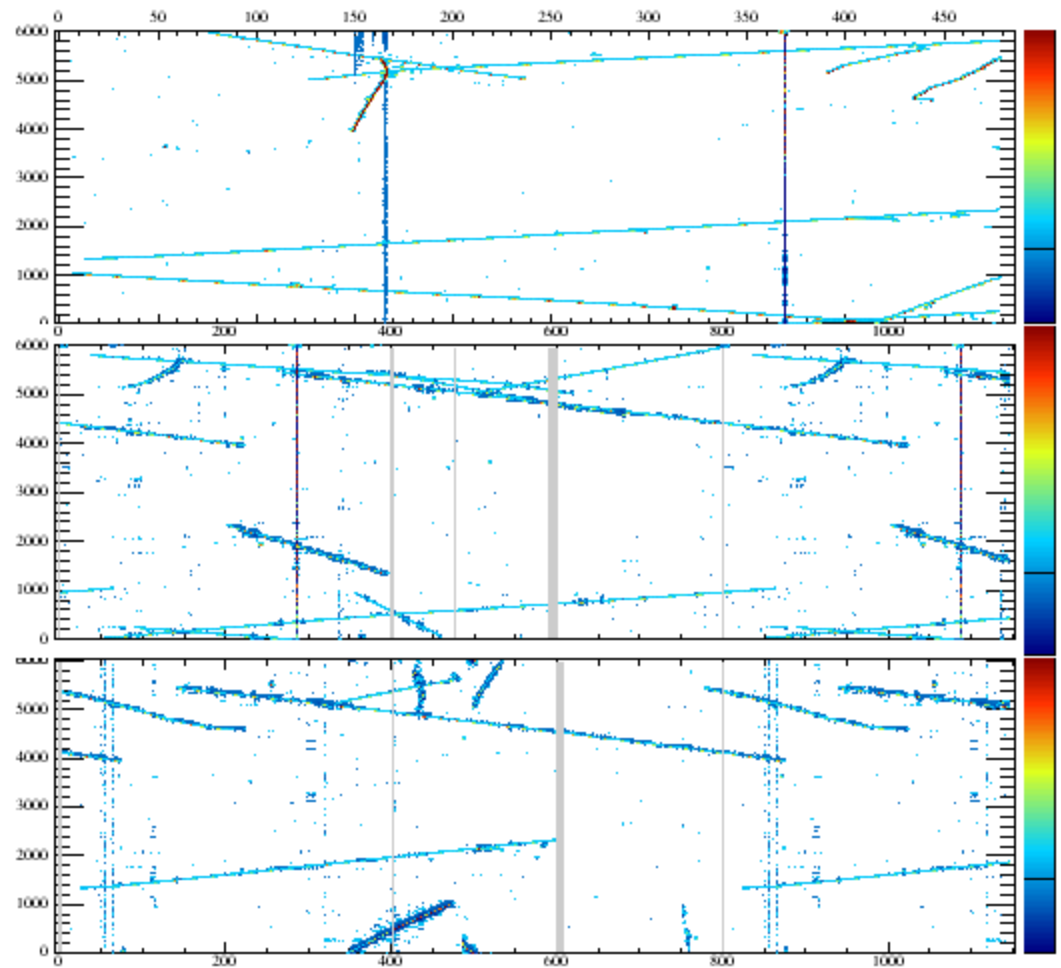
recob::Wire looks a lot like the
raw::RawDigits in the collection plane.



A First Stab at Fixing the Undershoot

Just one component
 $\tau=1.1$ ms,
 $A = 0.4$ of what it
would take for the
response function to
have zero integral

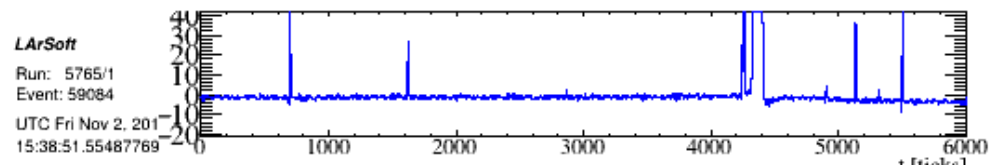
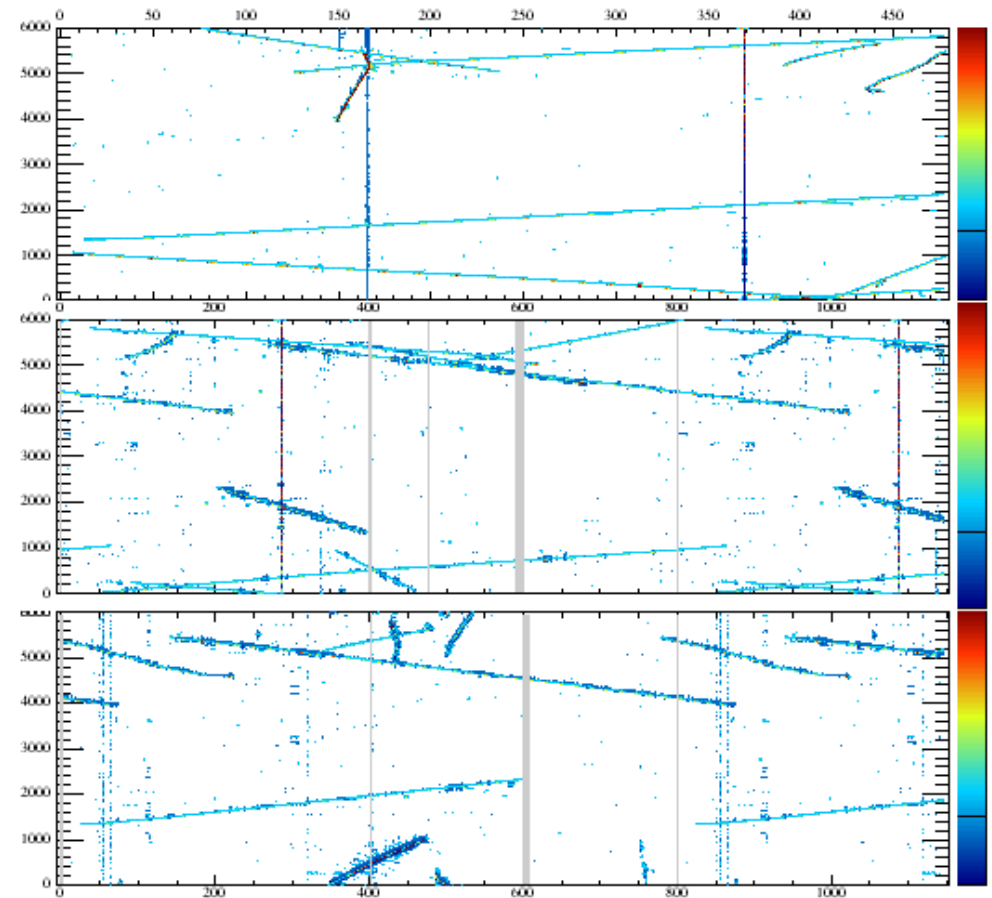
Looks like there is a slower
component!



A Second Stab at Fixing the Undershoot

Just one component
 $\tau=2$ ms,
 $A = 0.4$ of what it
would take for the
response function to
have zero integral

Not slow enough! Looks like
two components with different
times are needed.



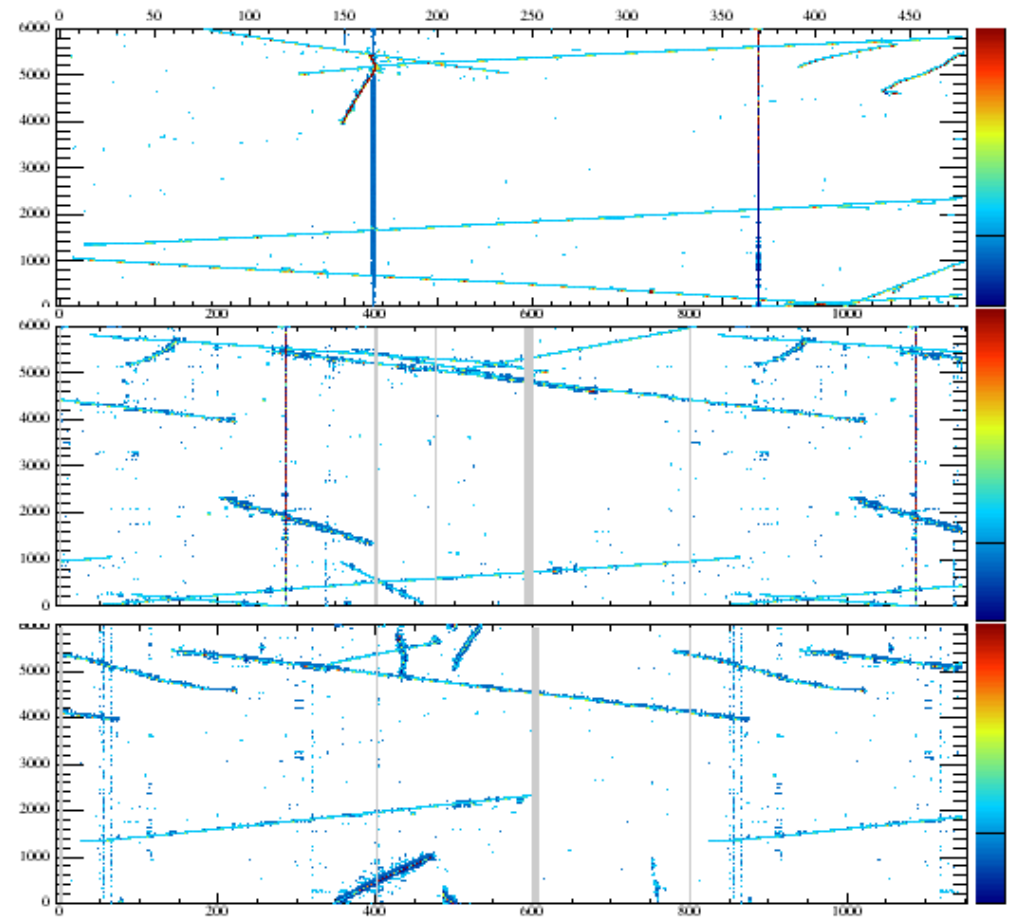
A Third Stab

- 5 ms at 0.9, and 2 ms at 0.1

Zoomed-in scale

Still not perfect. Perhaps need a third component at short time? But much smaller now (2 counts out of 1000).

Most signals on tracks are so small that their undershoot is invisible.



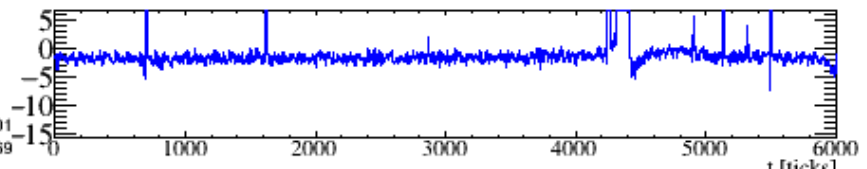
LArSoft

Run: 5765/1

Event: 59084

UTC Fri Nov 2, 201

15:38:51.55487769



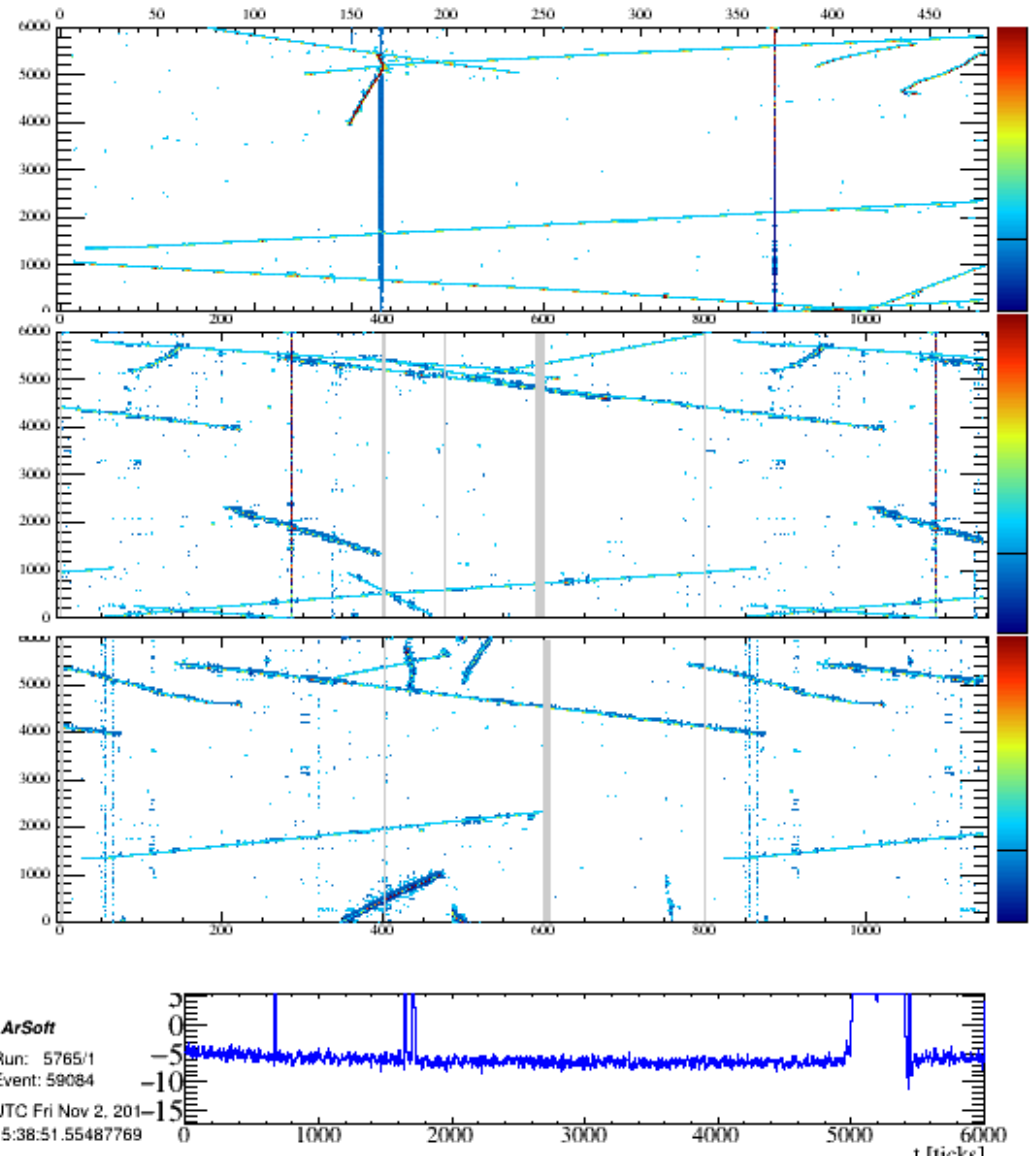
The Vertical Stripe

This has a flat pedestal
in the raw digits.

Rest of filter function removes
zero-frequency component
(pedestal subtraction).

Undershoot after big pulse canceled
the big pulse's contribution to the
ADC sum.

Now that it's been corrected, the
entire rest of the waveform picks
up the difference.

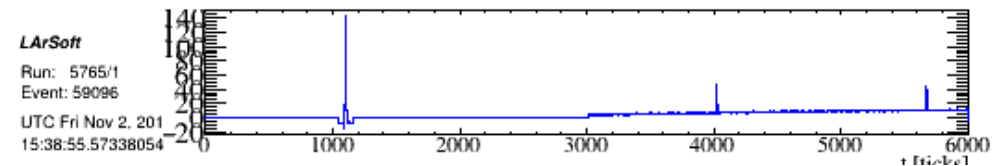
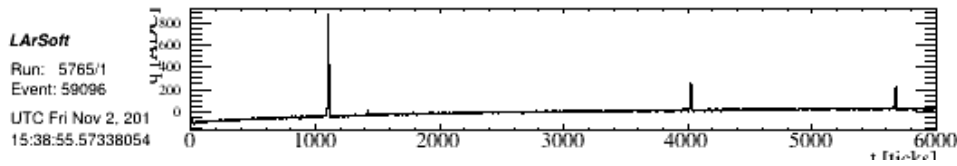
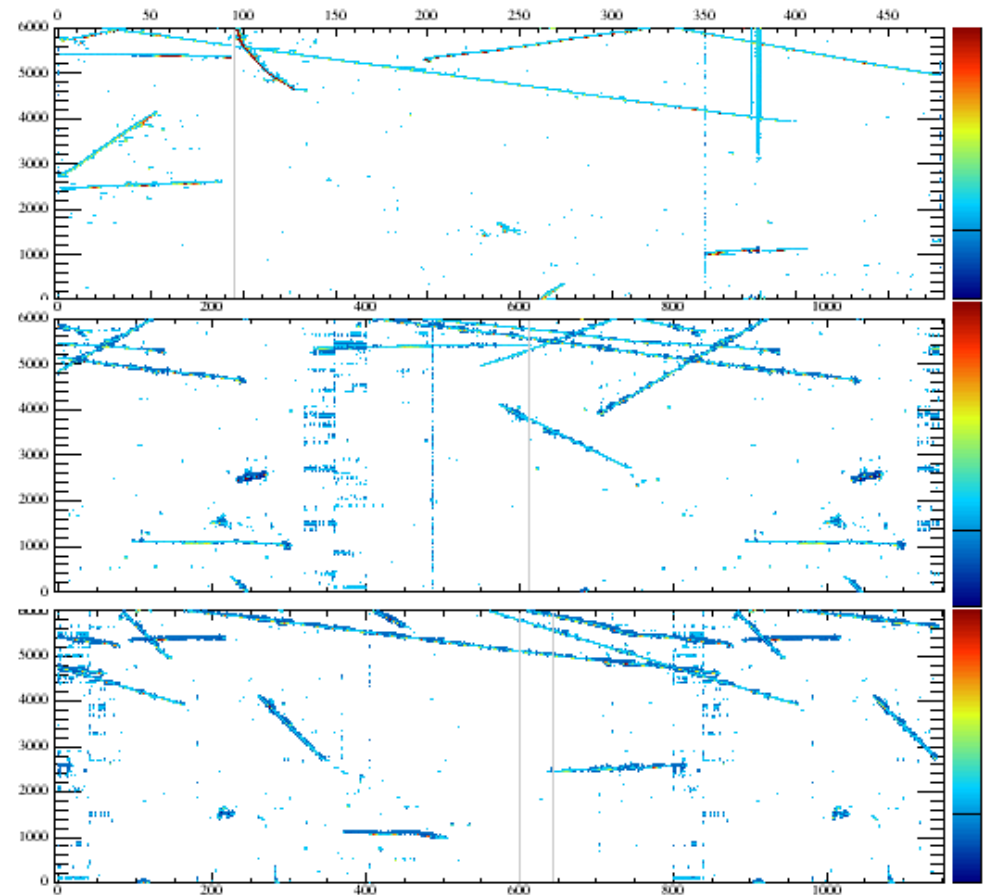
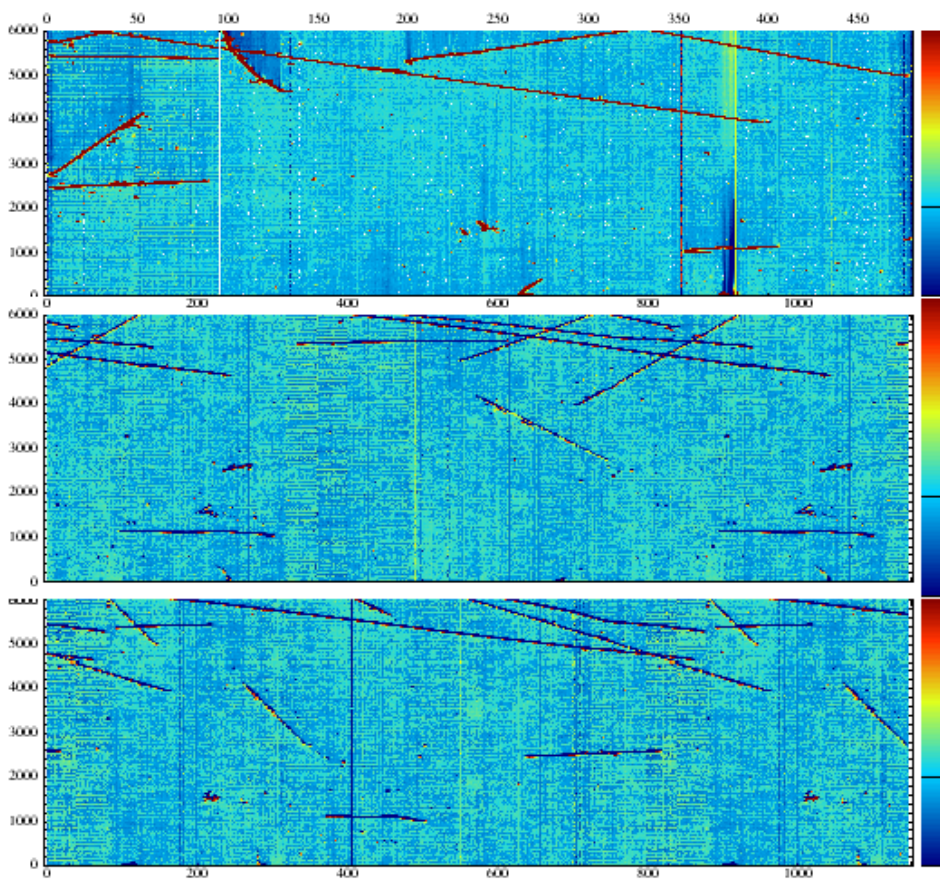


From MicroBooNE

removing this type of distortion. There are certain scenarios where such a correction would fail. For example, if the signal from a vertical cosmic muon arrived just before the 4.8 ms readout time, the recorded data would miss the primary signal that is large and positive, and would only include a long negative tail. Failing to account for this effect would lead to a significant baseline distortion for its few occurrences. Instead, such signals are identified by examining the very low frequency amplitudes and, where identified, the slowly varying baseline under these signals is directly removed in the time domain.

(R. Acciarri et al) JINST 12 (2017) no.08, P08003.

An Example of Pre-Event Charge



A Time-Domain RC fixer

My first attempt was a time-domain undershoot fixer.

Keep a running sum of pedestal-subtracted, undershoot-corrected ADC values.

On each tick, multiply this sum by 0.99955

Add a fraction of this sum ($\times 0.0005$) to the waveform as we go along.

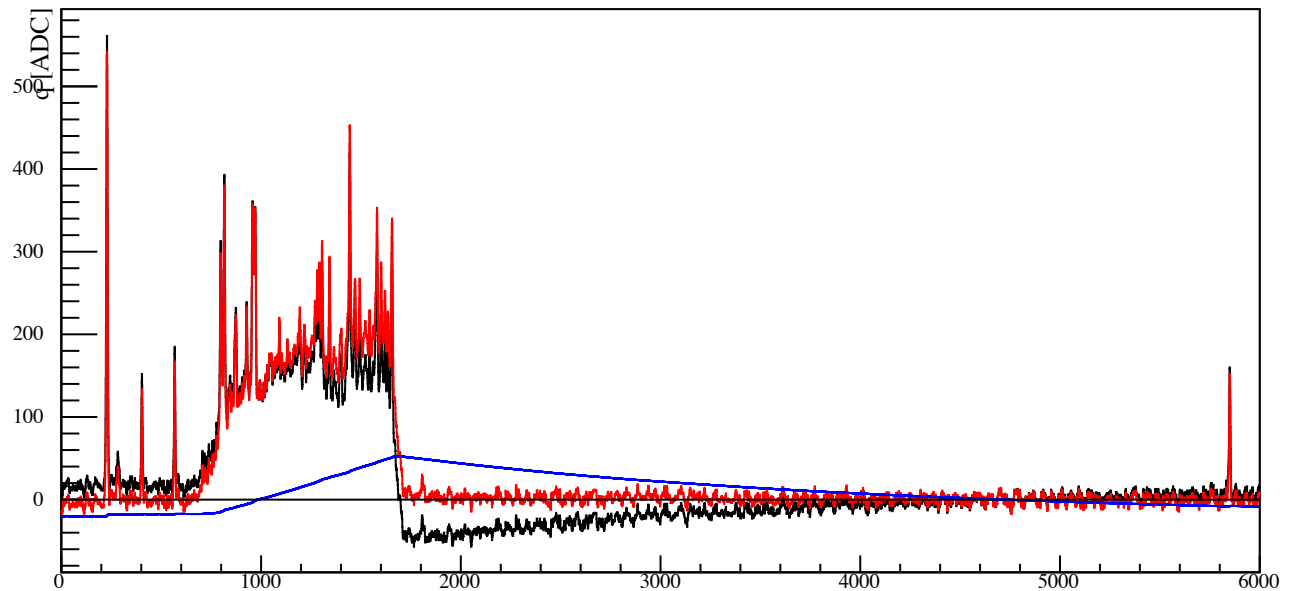
Example:

Black: original
raw digits

Blue: correction

Red: corrected.

Line drawn at 0 to
guide the eye.



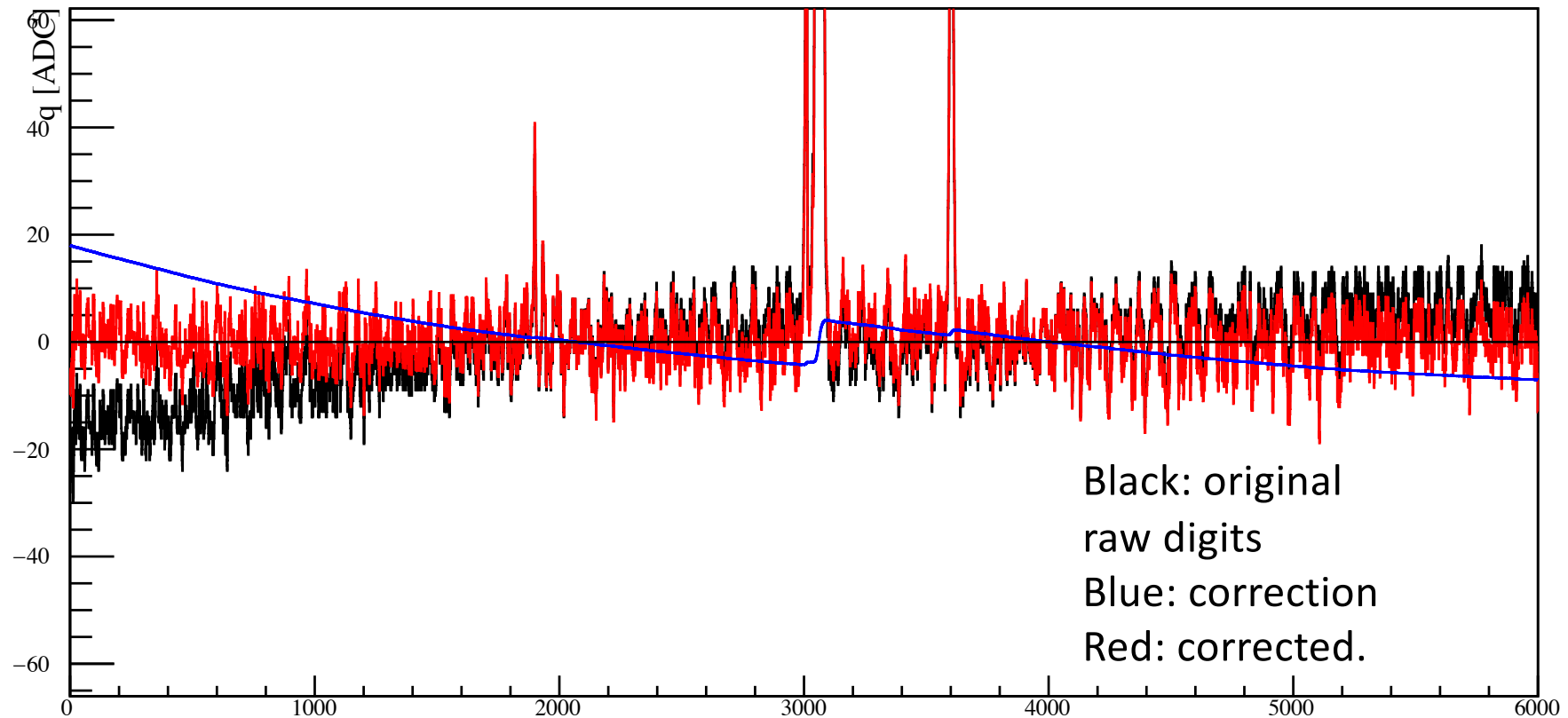
Drawbacks: how do we start it off? Suppose the channel is recovering from undershoot on the first tick from some charge we didn't record?

What's the pedestal? Black curve here has the median subtracted.

May need to fit for two parameters.

I like it better because it's causal (effects don't get corrected before charge arrives).

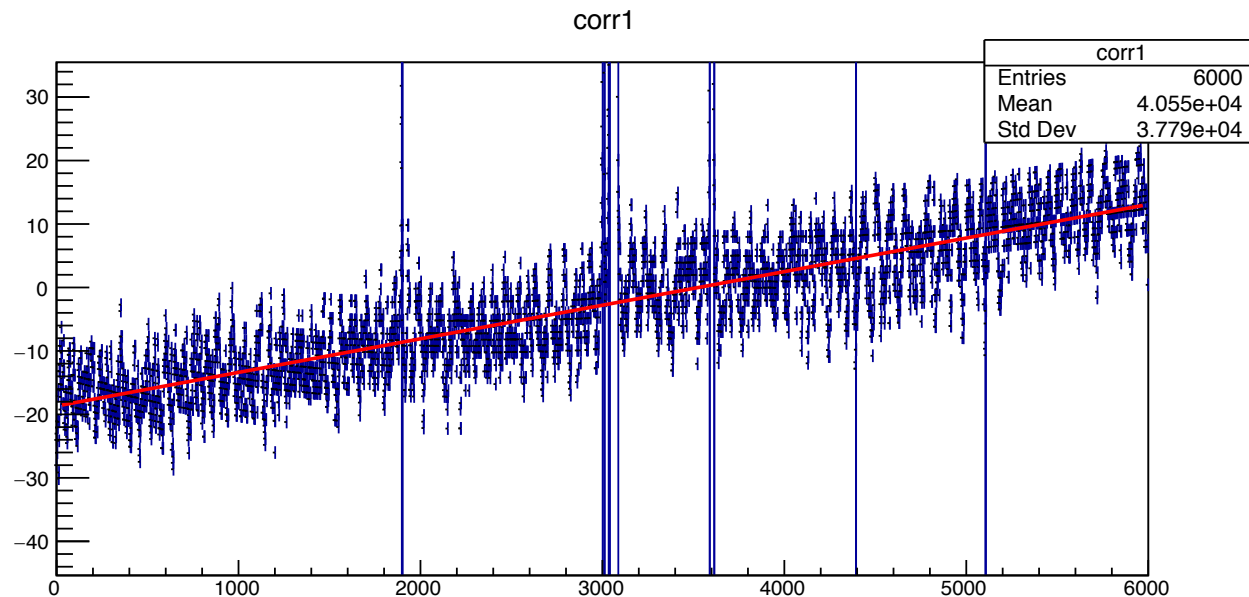
Example with some initial recovery underway when the event starts



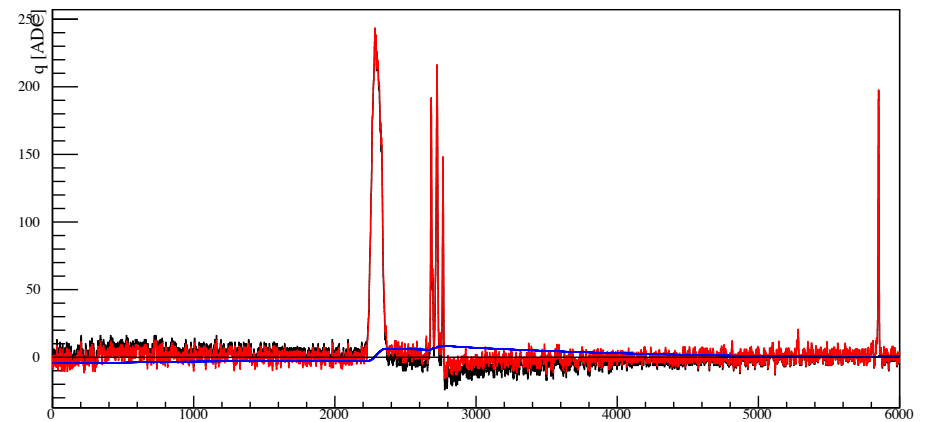
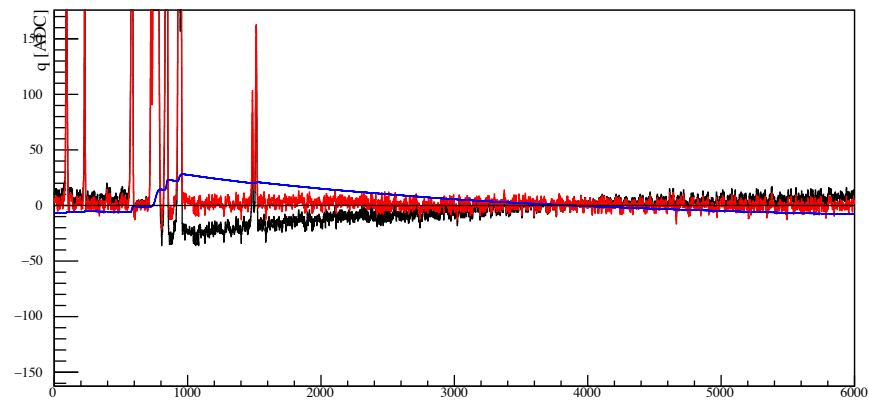
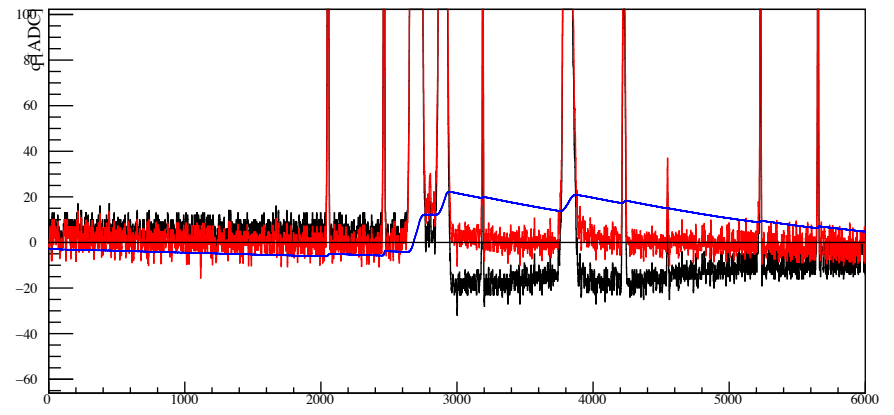
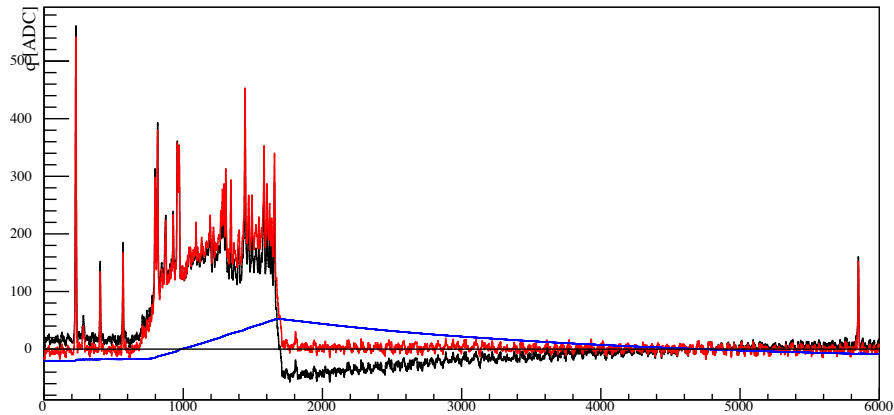
Fitted pedestal and prior charge numbers by hand, optimizing red curve.

Automating the Fit

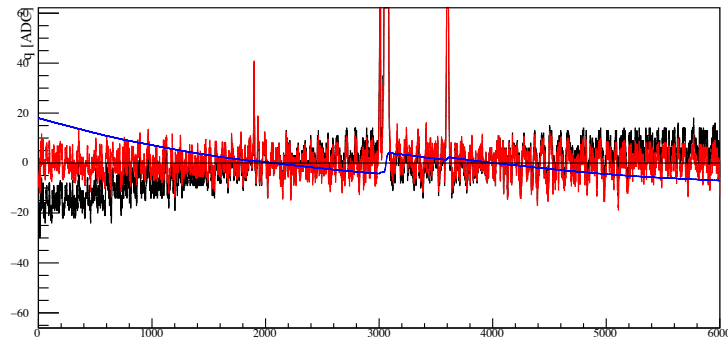
- Correct with no adjustment to pedestal (take median) and zero assumed initial charge.
- Fit a line to the corrected waveform
- Find all ticks more than 20 ADC counts from the line fit and de-weight them (give them errors of ± 1000 ADC counts, all other ticks get an error of 1 ADC count).
- Fit a line again
- Use linear combinations of the slope and intercept to get the pedestal and initial charge.



Automated fit RC corrections



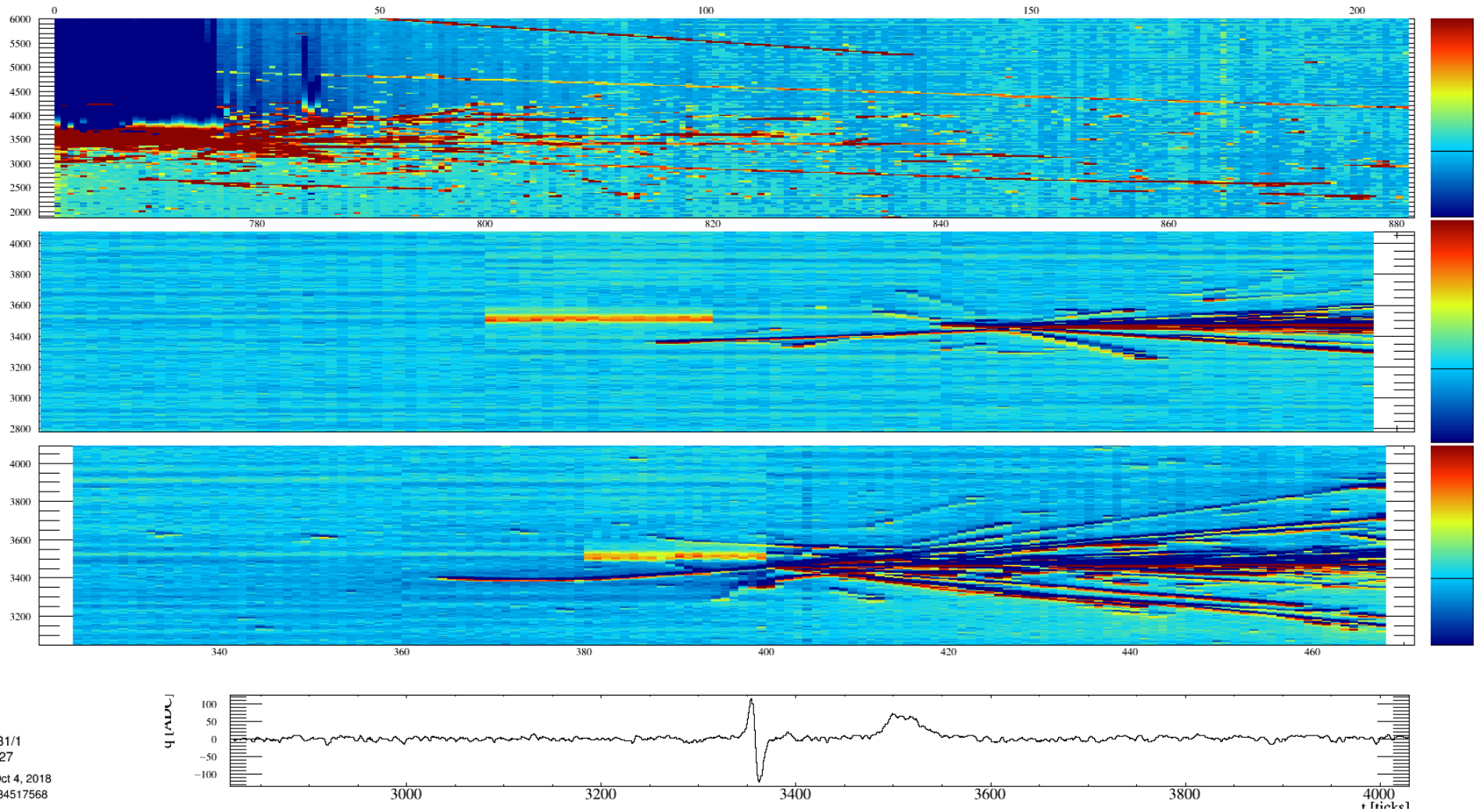
To do:
Make a Tool out of this



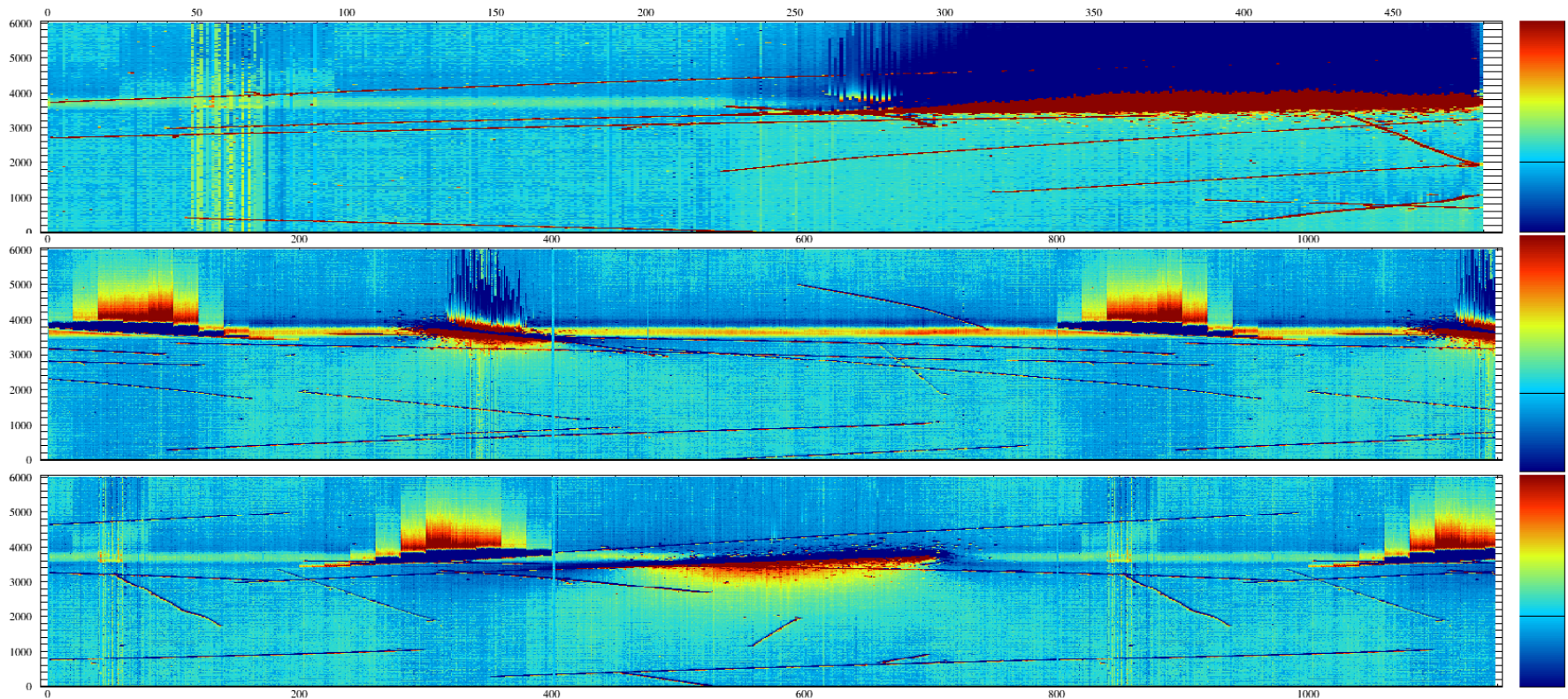
Induction Planes

- Hard to see undershoot in the induction planes.
- Signals are bipolar, and so charge does not integrate.
- Some unipolar signals seen on induction-plane wires but they are artifacts of other effects
 - Saturation ("flatlands")
 - Ghosts (saturation on induction-plane wires on same FEMB)
 - Ledges (very infrequent in induction-plane wires but we've seen them)
- Not clear whether these effects should have undershoot corrected for anyway. But the raw::RaDigits do not tell us what the cause is of each signal so we deconvolute everything the same.
- Naively apply same correction to induction-plane wires as collection-plane wires with the convolution strategy. No correction perhaps is best?

FEMB Ghosting on Induction Plane



Example of Saturation and Ghosting (and ledges on the induction plane)



LArSoft
Run: 5177/1
Event: 600
UTC Thu Oct 11, 2018
14:50:13.792973952

