

Checking Hit Reconstruction

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ProtoDUNE DRA

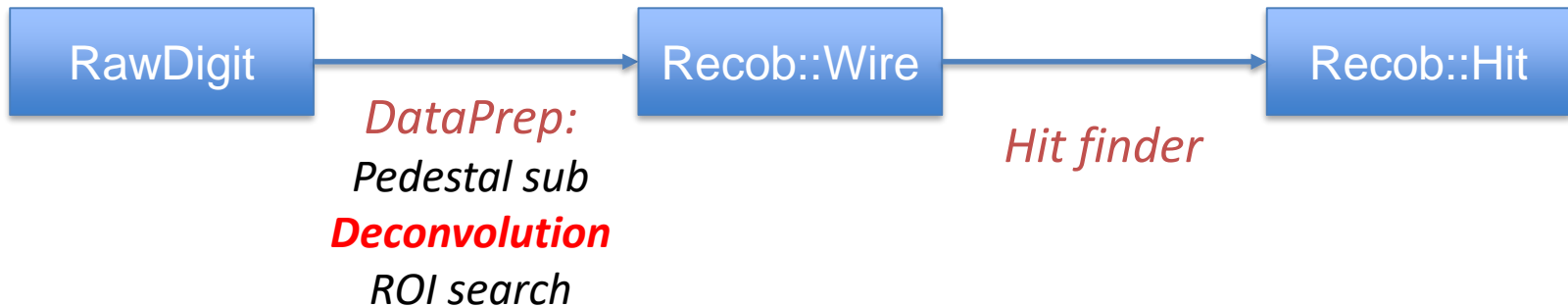
26/02/2020

Introduction

- We have been using the “DPRawHitFinder” for hit reconstruction
 - Fits asymmetric waveform to the raw data
- Try to use GausHitFinder for ProtoDUNE DP
 - This is the standard DUNE hit finder also used in ProtoDUNE SP
 - Appears to give better [track reconstruction efficiency](#) (E. Chardonnet DRA 12/02)
- Will only look at properties of reconstructed hit charge ~ integral of hit shape == integral of the raw waveform

Deconvolution

- The hit reco process:



- Need to run deconvolution to shape the raw waveform signals to be fitted by GausHitFinder (assume that collected charge follows a Gaussian distribution after diffusion)
 - There is no existing simulation of the exact field response in the CRP induction gap for the anode electrode geometry
 - So only deconvolution is that of the electronics response

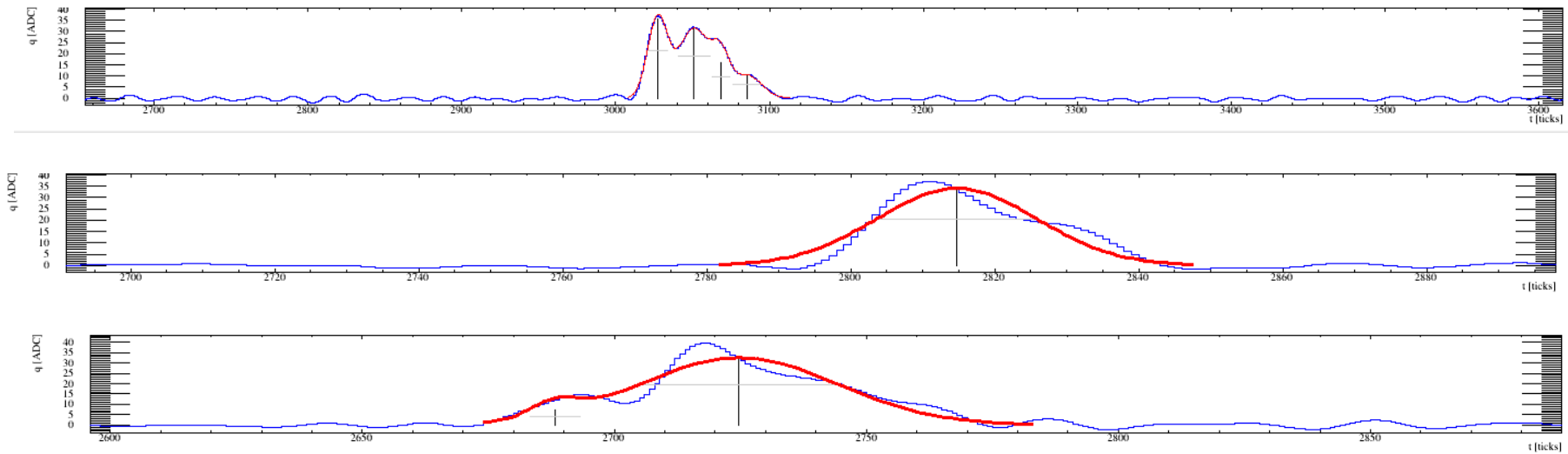
Signal normalization (~ charge)

- Response function integral is normalized to 1, so as to remove shape only in deconvolution
- Check charge reconstruction results from hit finder and integral of the raw waveform (basically a raw hit finder) in a hit ROI

Ideally the two should be the same

- Use summedADC from reconstructed hits as a measure of charge
- This ADCsum is the sum of recob::Wire samples in the window hit→StartTick to hit→EndTick
- It is the same for all hits in the multi-hit group returned by GausHitFinder

Hit charge



Charge is calculated as the integral of the Gaussians

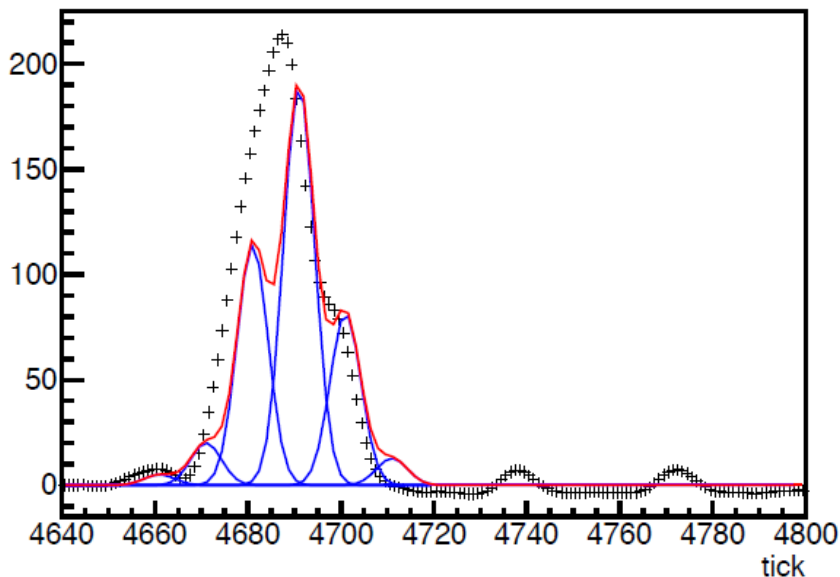
- Often the multi-gauss fit may not be necessarily a good approximation to the recob::Wire signals → can bias charge estimation
- The time profile however is well covered by the hit finder so the total integral of recob::Wire in the multi-hit group, ADCsum, should be ok

A caveat

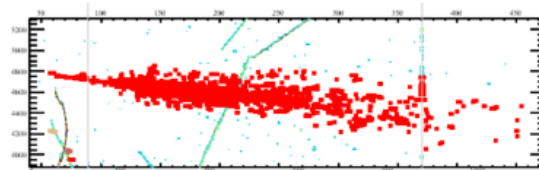
Charge Integral

From Aaron's [presentation](#) at 12/02 DRA

ch 2196



raw::RawDigit, raw waveform
recob::Wire wire, (after signal processing) Signal processing “smear” the waveform (expected)
recob::Hit hit (hitpdune), we use hit information to do patten recognition and to get charge from reco object (shower)



recob::Hit multiplicity 6

Integral of the gaussian hits (summedADC) = 3544.07

Integral of the waveform (recob::wire) = 4296.29

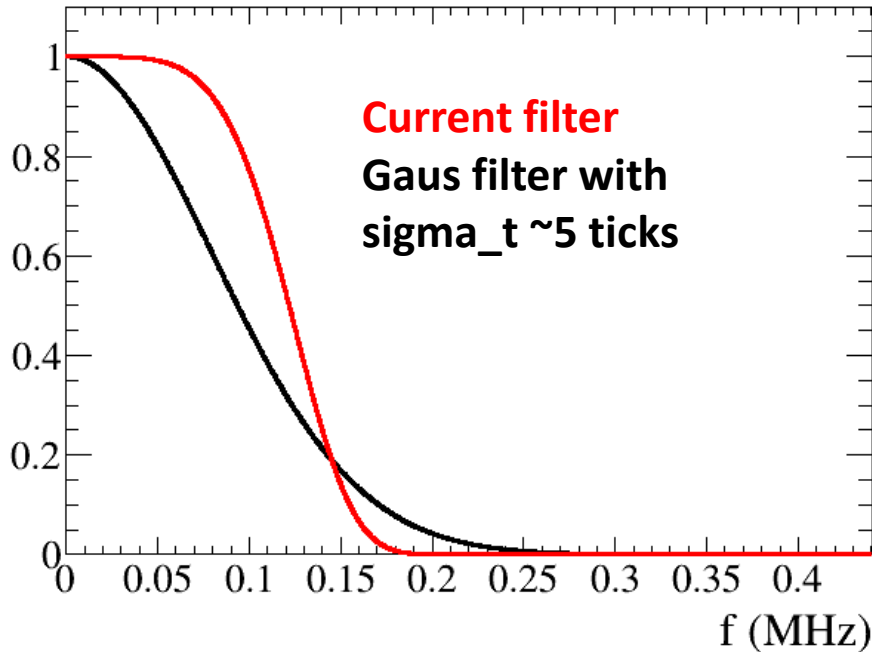
Deficit = 17.5%

Filter function and DeconNorm

- Started with the what has been defined for DP in its signal service

```
dunefddphase_signalshapingervice:
{
  AreaNorm: 35.64 # in units (ADC x us) / fC
  ADCpermV: 1.0 # ADC conversion factor (not used at the moment)
  AmpENC: 1000.0 # noise in electrons from TDR
  DeconNorm: 200
  ShapeFunc: "[0]/([0]-[1]) * ( exp(-(x)/[0]) - exp(-(x)/[1]) )"
  ShapeFuncParams: [1.0, 4.5]
  RespSamplingPeriod: 400. # in nano second
  ColFilter: "[0]*exp(-1.2*(((x-[1])/[2])^2)^[3])"
  ColFilterParams: [ 1.0, 0.0, 0.136, 2.5 ]
```

Filter functions

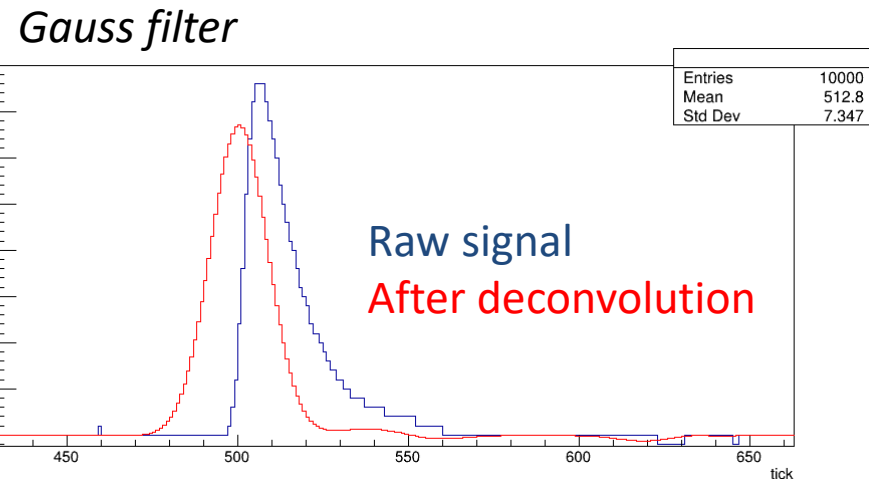
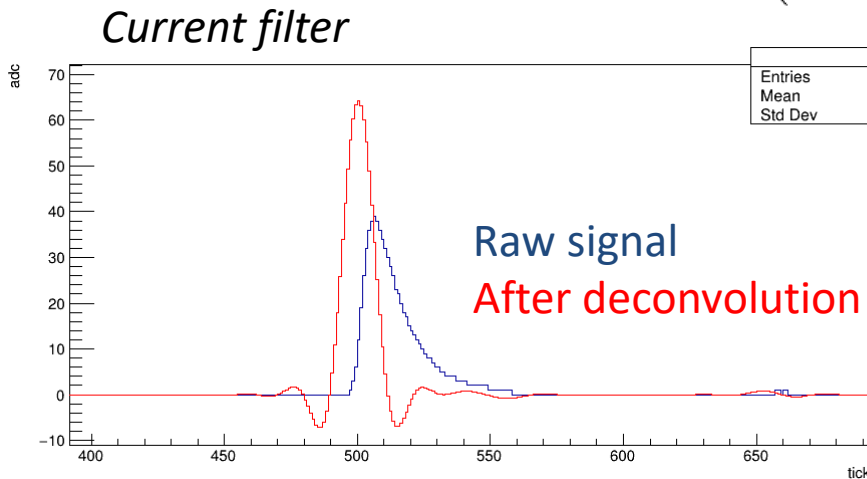


- Gaussian filter gives a better response after deconvolution (no ringing artefacts)
- Also used for ProtoDUNE SP

For 5 tick width (averaged), $\sigma_f \sim 0.08$

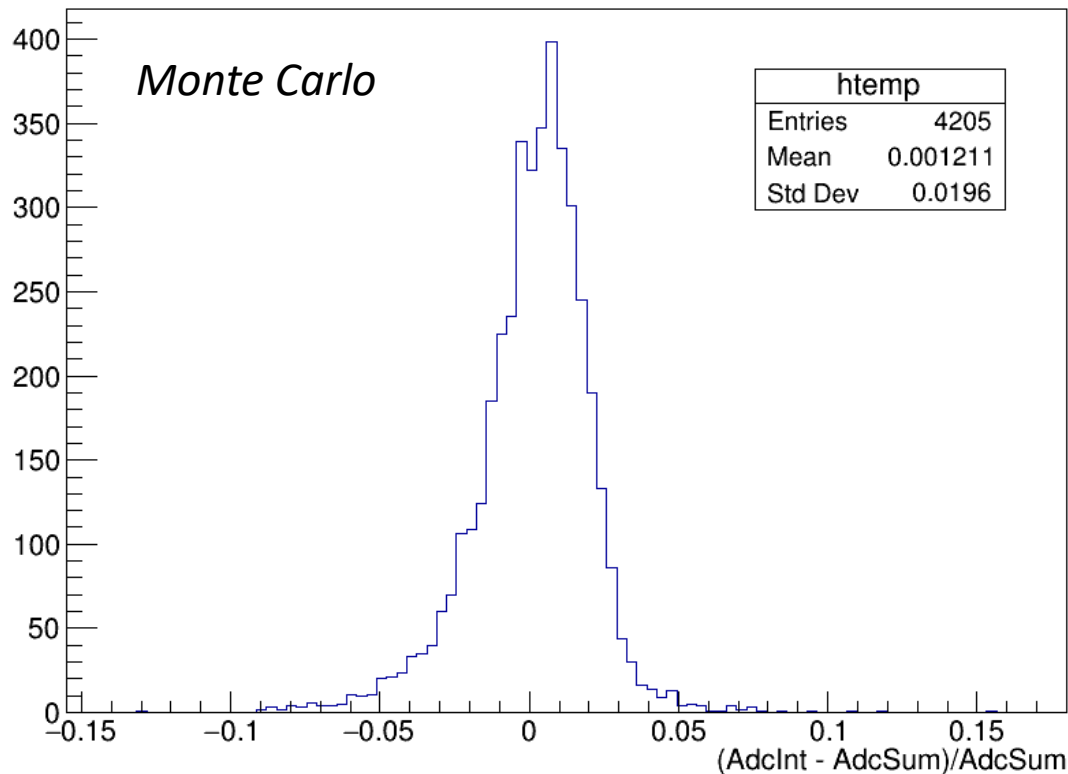
```
ColFilter: "(x>0.0)*gaus"  
ColFilterParams: [ 1.0, 0.0, 0.08 ]
```

Can be tuned a bit as a function of noise



Hit charge from fit (Gaus filter)

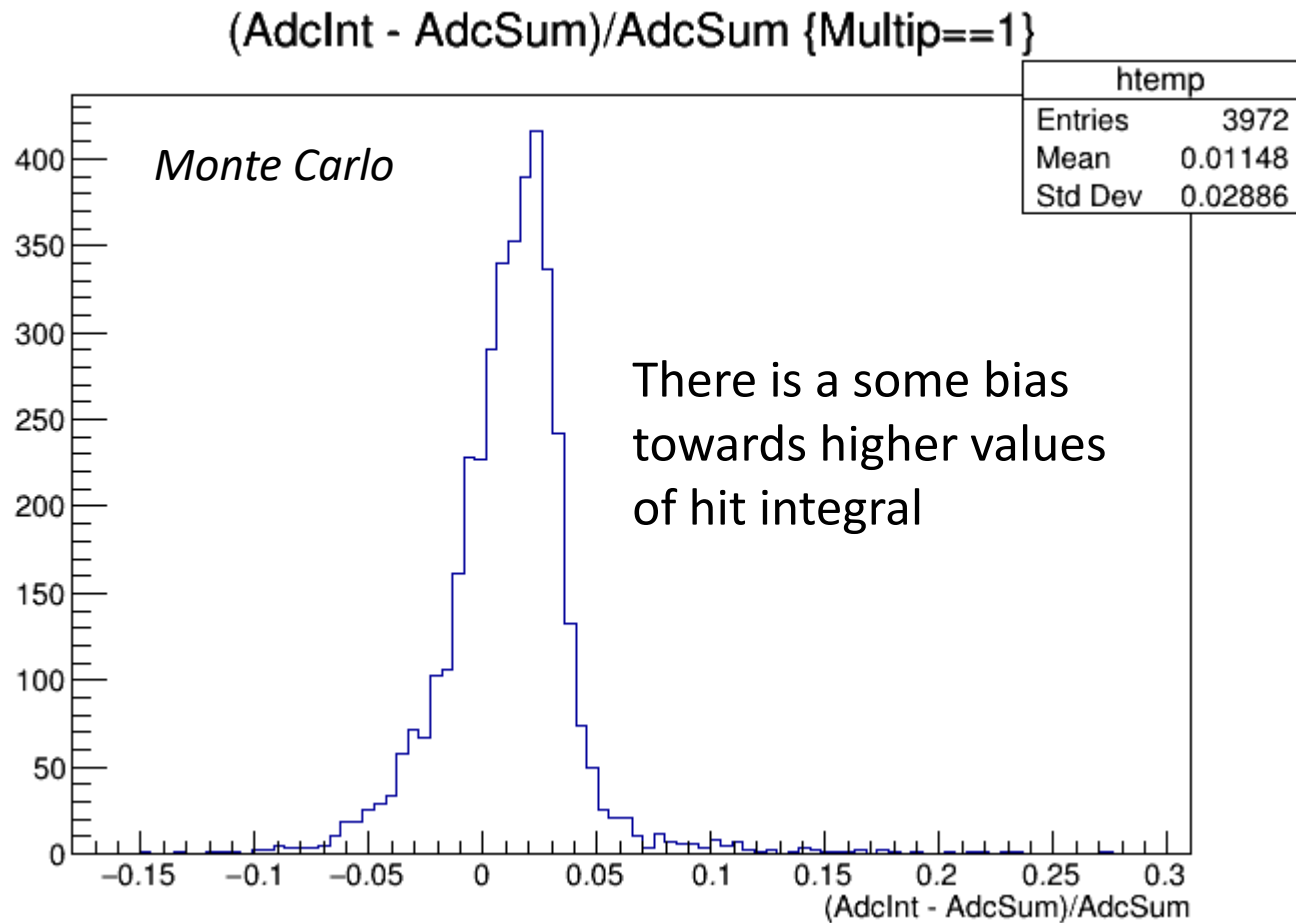
$(\text{AdcInt} - \text{AdcSum})/\text{AdcSum} \{\text{Multip}==1\}$



A measure of how well the Gaussian approximates deconvoluted signal

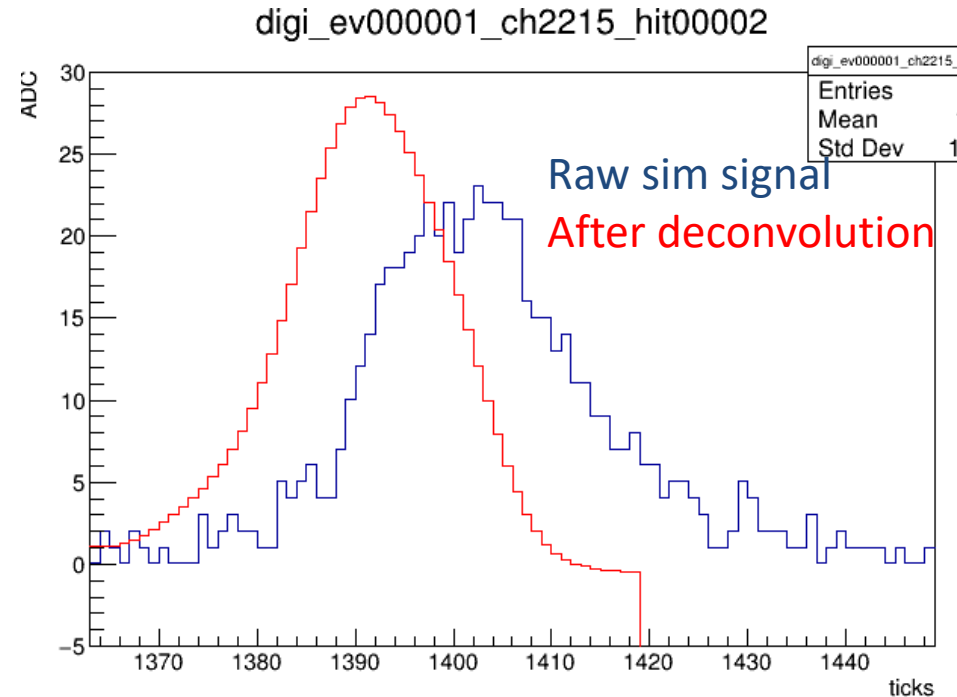
Only single hits (multiplicity 1 hits) are selected here

Hit charge from fit (old filter function)



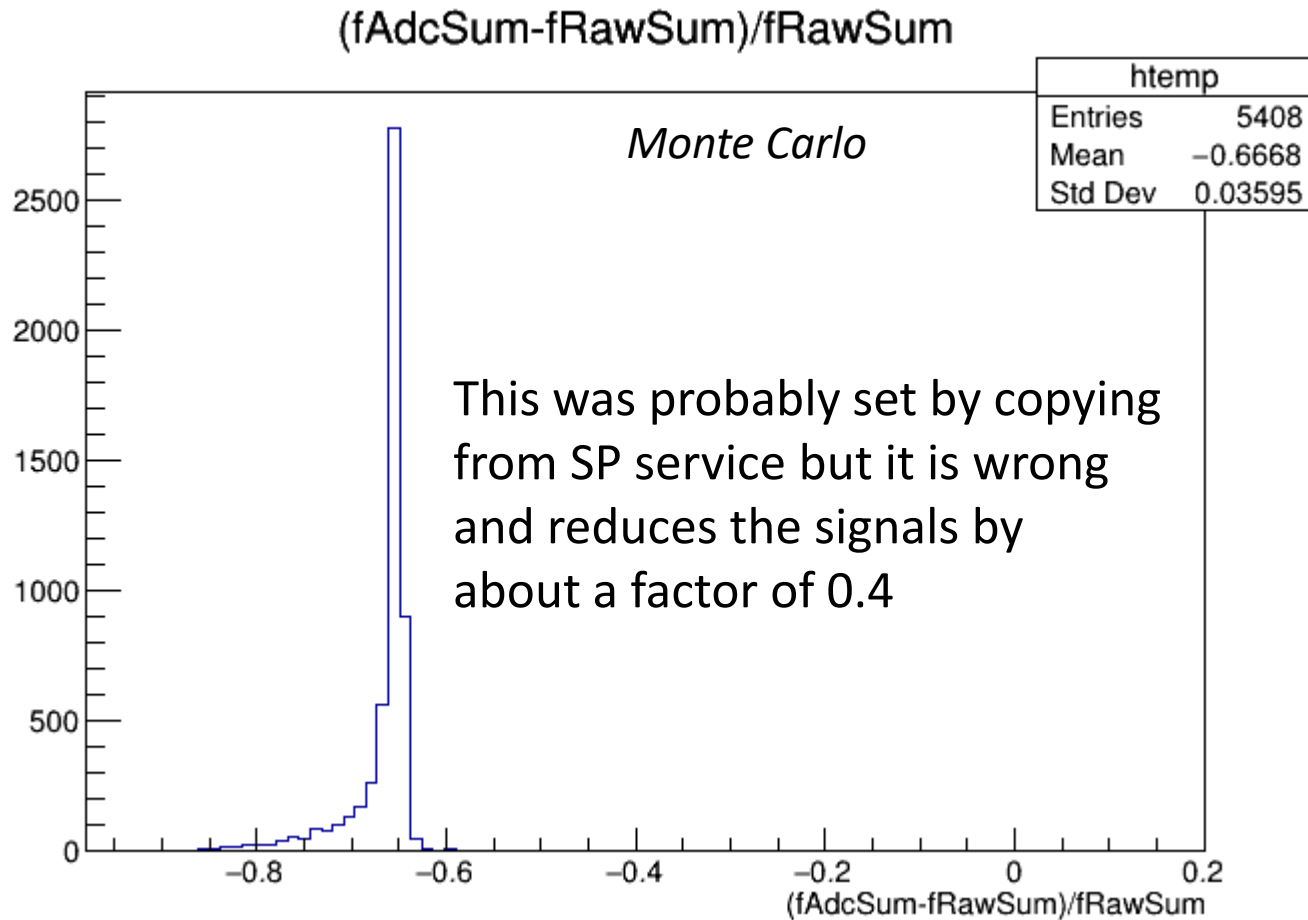
Checking hit normalization

- Check how well ADCSum reconstructed after running GausHitFinder on the deconvoluted signals matches the integral of the raw waveform
- The sum over the raw waveform is calculated by integrating in the time window given by the hit group + 30 tick padding at the end
- Skip if the next hit group start within 2x this padded region
- Use 200 ticks before hit to compute the pedestal (so require there are no hits before in that time window)

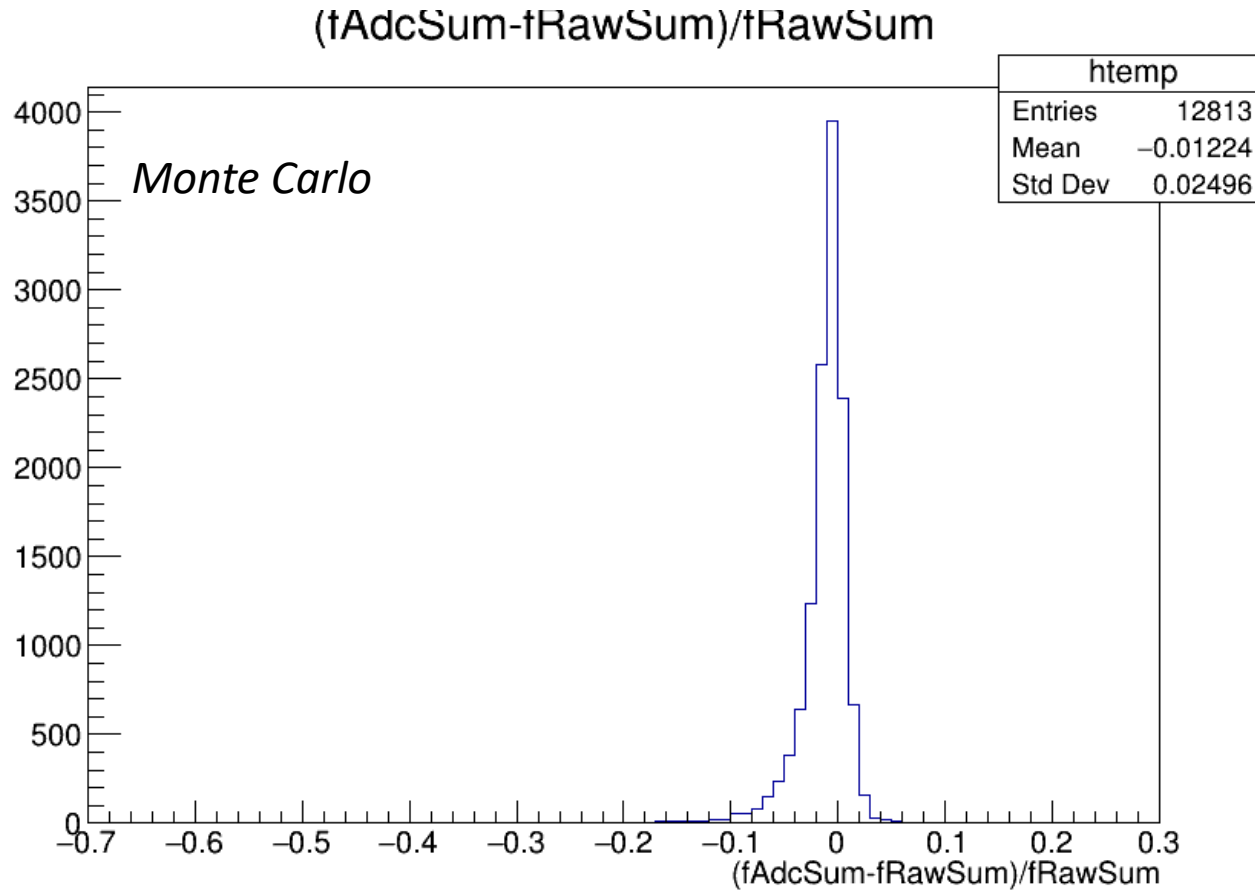


Wrong DeconNorm

services.SignalShapingServiceDUNEDPhase.DeconNorm: 200

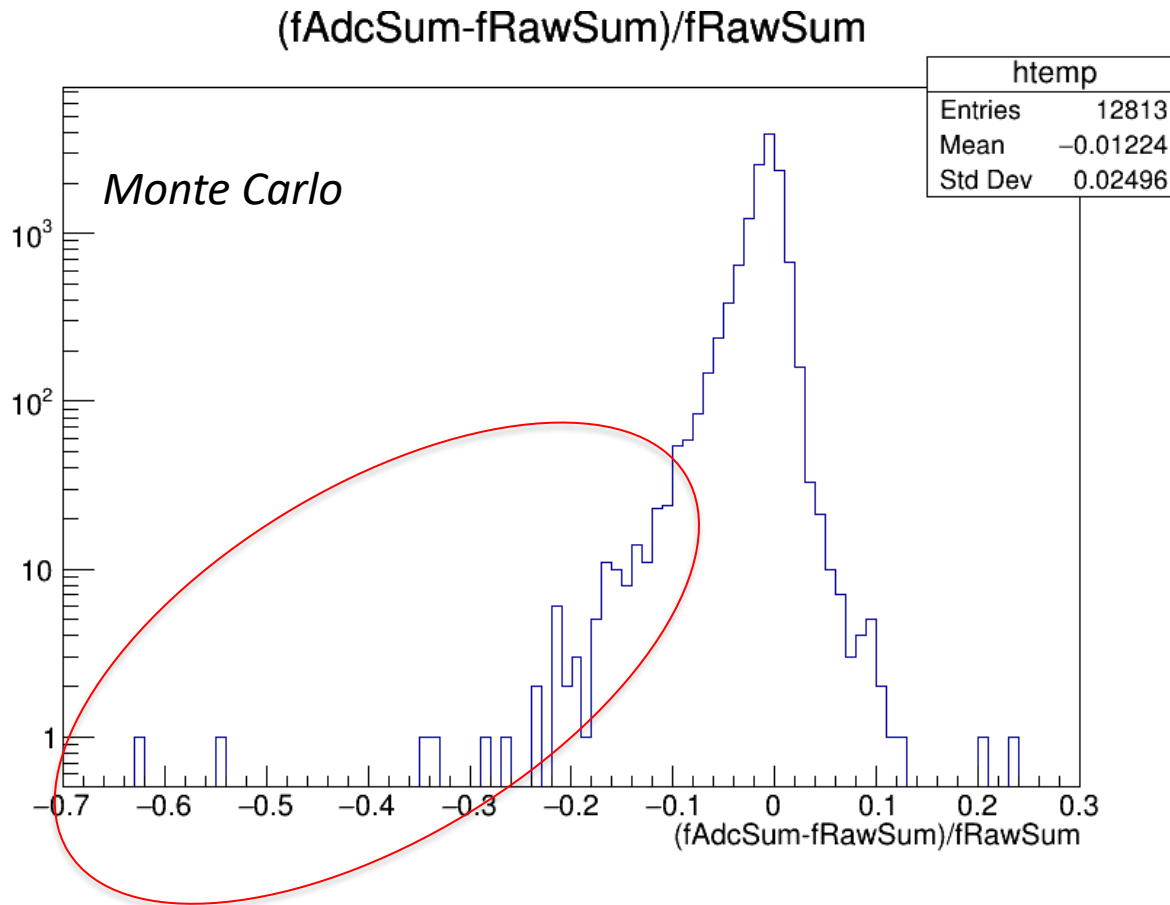


DeconNorm fixed



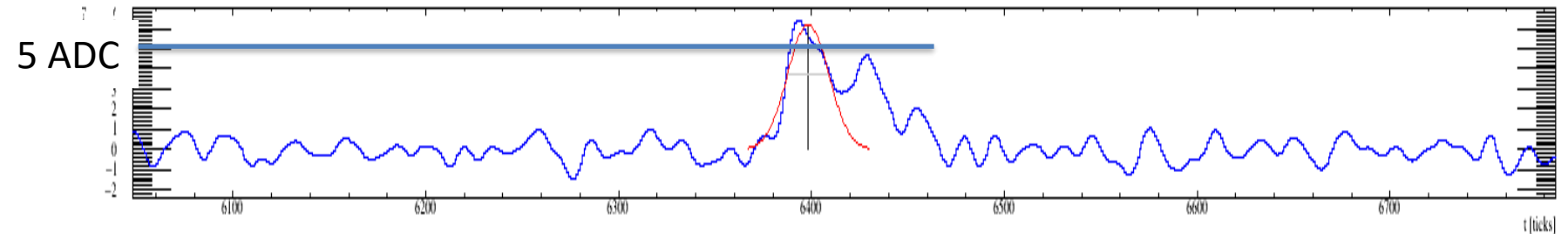
The response function integral should be normalized to 1 to remove only the shape contribution in deconvolution → DeconNorm = 70 to match the response calibration factor

Fraction difference on log scale



A tail with hits showing much lower ADCSum than what it should

Missing charge

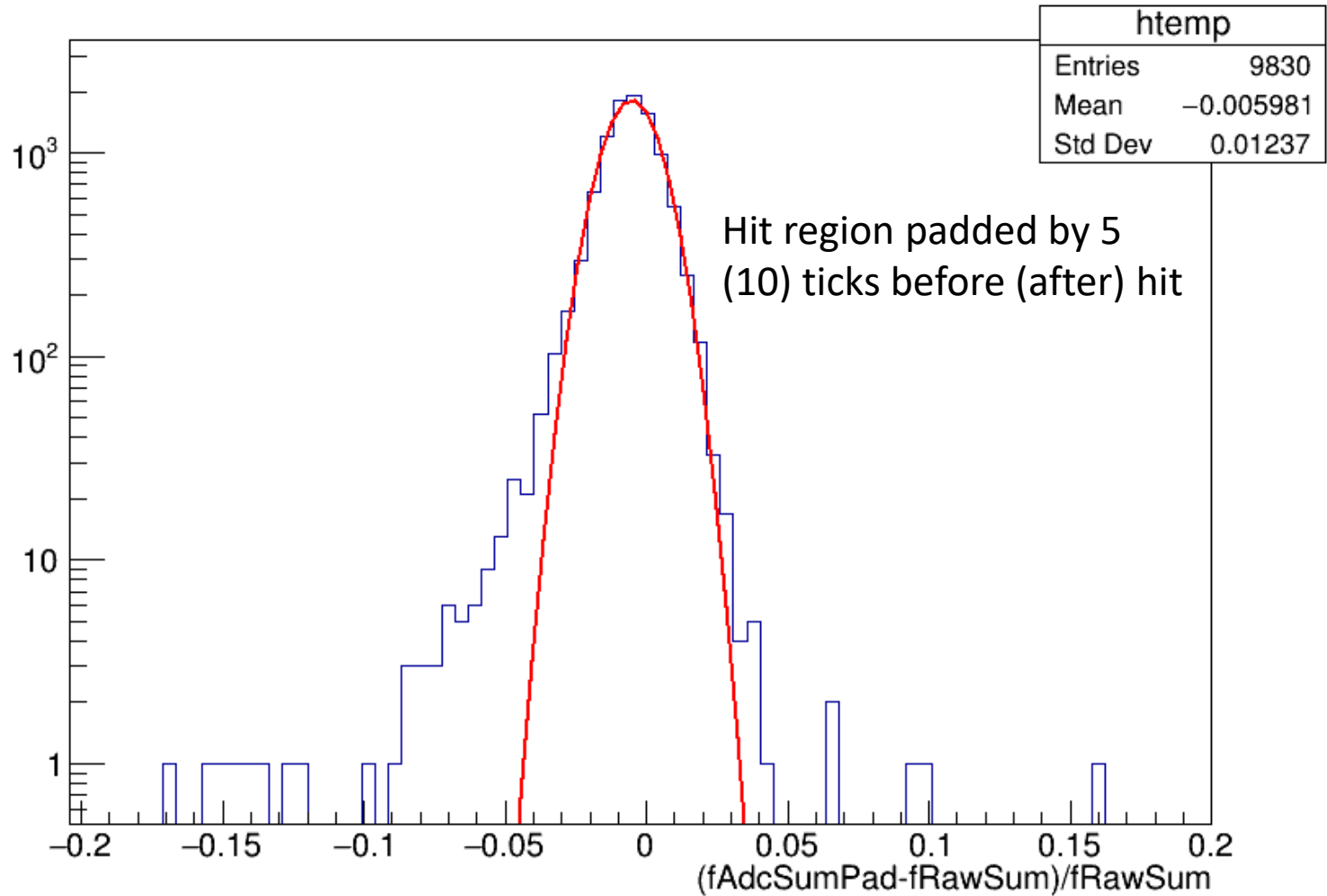


The tail where the charge from the hit is missing is due to the fact that the signal falls below threshold of 5ADC set for these tests

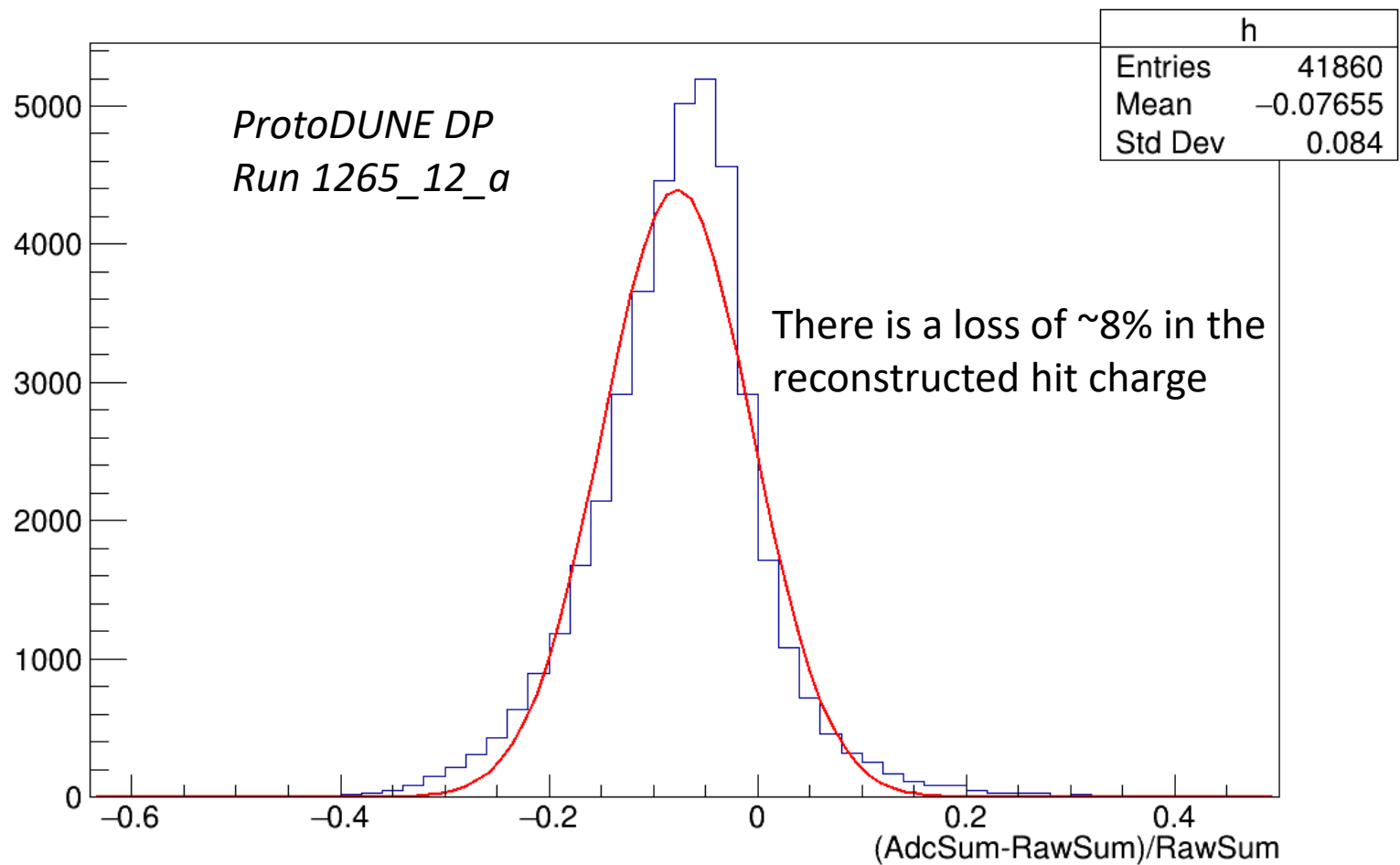
Can increasing the integration window on `recob::wire`

Fraction difference: hit peak > 10 ADC

$(fAdcSumPad - fRawSum) / fRawSum$ {fPeak > 10}

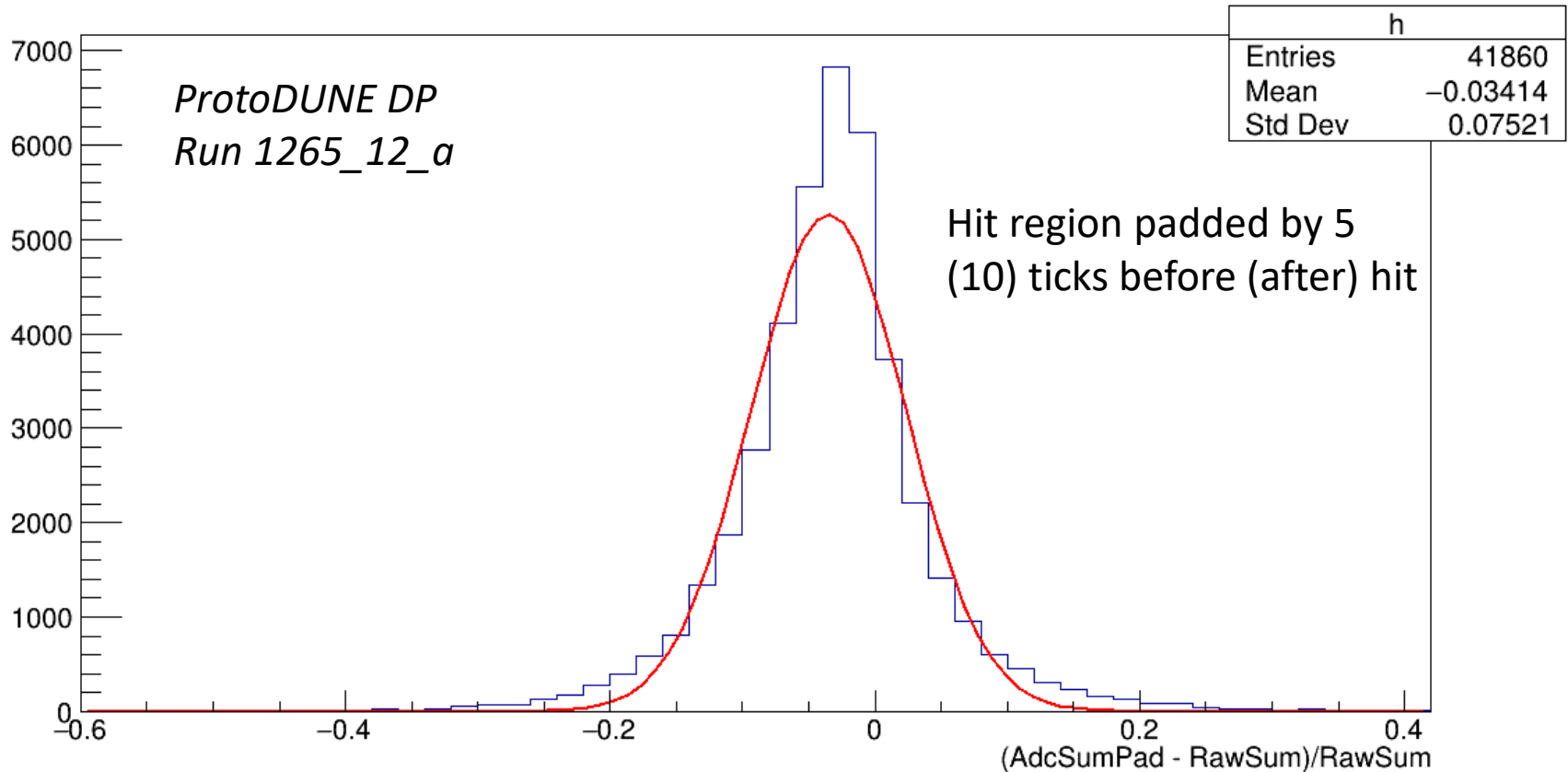


Data comparison: GausHitFinder

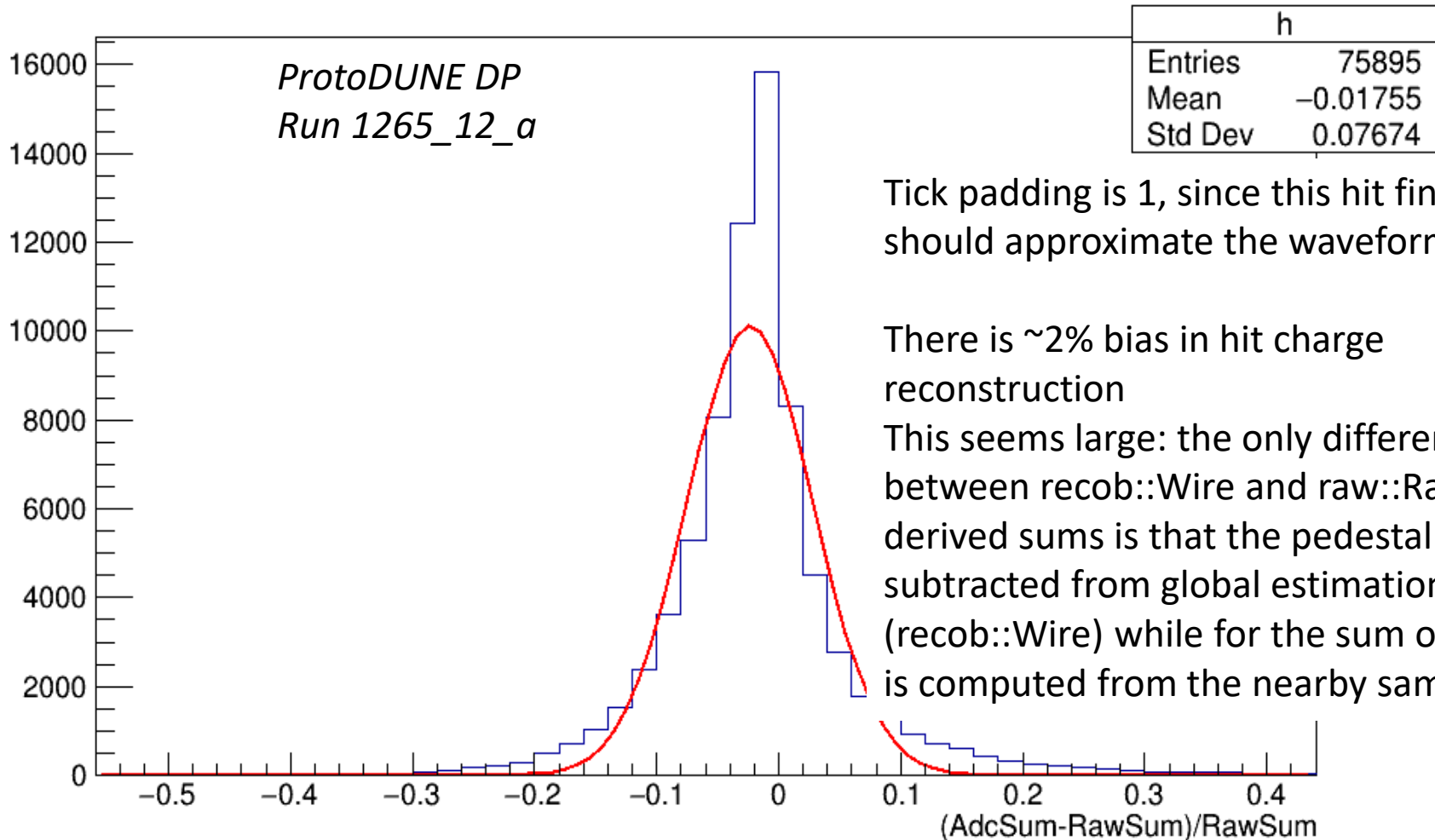


I am checking now how the response function from CRP pulser runs matches that measured in the lab

Data comparison: GausHitFinder



DPRawHitFinder



Tick padding is 1, since this hit finder should approximate the waveform

There is ~2% bias in hit charge reconstruction

This seems large: the only difference between `recob::Wire` and `raw::RawDigit` derived sums is that the pedestal is subtracted from global estimation (`recob::Wire`) while for the sum of digits it is computed from the nearby samples

Hit Multiplicity Treatment

DPRAWHIT: the ADCsum is split between hits in a group as well as StartTick and EndTick

```
Hit #79: Channel 389 View = 3 Signal type = 1 Wire = C:0 T:0 P:0 W:389
StartTick = 9186 EndTick = 9260 PeakTime = 9214.29 +/- 0.09 RMS = 22.56
Amplitude = 14.74 +/- 1.00 Integral = 859.48 +/- 8.00 ADCsum = 595.27 Multiplicity = 0 of 2

Hit #80: Channel 389 View = 3 Signal type = 1 Wire = C:0 T:0 P:0 W:389
StartTick = 9261 EndTick = 9356 PeakTime = 9303.73 +/- 1.06 RMS = 22.56
Amplitude = 10.74 +/- 1.00 Integral = 420.18 +/- 8.00 ADCsum = 483.75 Multiplicity = 1 of 2
```

GAUSHIT: StartTick and EndTick and consequently ADCsum are the same for multi-hit groups

```
Hit #0: Channel 5 View = 3 Signal type = 1 Wire = C:0 T:0 P:0 W:5
StartTick = 4603 EndTick = 4724 PeakTime = 4636.28 +/- 0.06 RMS = 5.99
Amplitude = 42.91 +/- 0.46 Integral = 644.24 +/- 0.13 ADCsum = 3209.16 Multiplicity = 0 of 2

Hit #1: Channel 5 View = 3 Signal type = 1 Wire = C:0 T:0 P:0 W:5
StartTick = 4603 EndTick = 4724 PeakTime = 4659.67 +/- 0.20 RMS = 24.53
Amplitude = 41.87 +/- 0.23 Integral = 2536.98 +/- 0.13 ADCsum = 3209.16 Multiplicity = 1 of 2
```

Inconsistent definitions in reconstructed quantities cause bad problems in the analyses

Better hit integral normalization?

- The total charge from the integral of the recob::Wire samples within the multi-hit (single) time window: **hit**→**summedADC()**
- The charge of each hit (**hit**→**Integral()**) is from integral of the hit function (Gaussian) → if summed over multi-hits can differ from the total **ADCSum**
- Partition this total charge between hits in a multi-hit group based on the relative weight of each hit:

$$Q_{Hit_i} = \frac{w_{Hit_i}}{\sum w_{Hit_j}} Q_{Tot}$$

$$\text{E.g., } w_{Hit} = A\sigma\sqrt{2\pi}$$

- Even if the shape is not exactly right, the sum of all hit integral should explicitly conserve the total sum

In summary

- The quality of hit charge reconstruction should be a good first metric to check hit reconstruction
- Some fixes to be committed to the DP signal service for the deconvolution (Gauss filter + corrected DeconNorm)
- Investigating the bias in reconstructed hit charge in gaushitfinder after deconvolution: checking the shape of the response in the CRP pulser test runs
- There is an inconsistency in the definitions of **ADCsum** and **startTick** and **endTick** of the hit window between *gaushitfinder* and *dprawhitfinder* for multi-hit groups