Brief Update on Signal Processing for ProtoDUNE-SP

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ProtoDUNE-SP DRA Meeting

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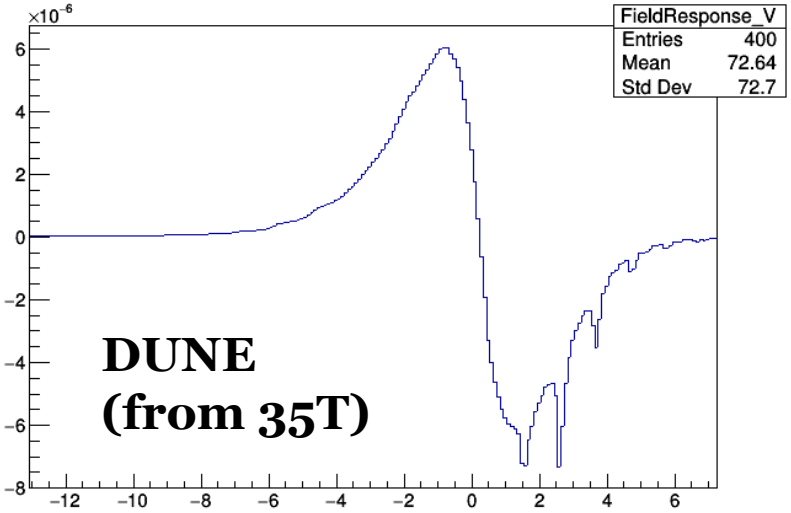
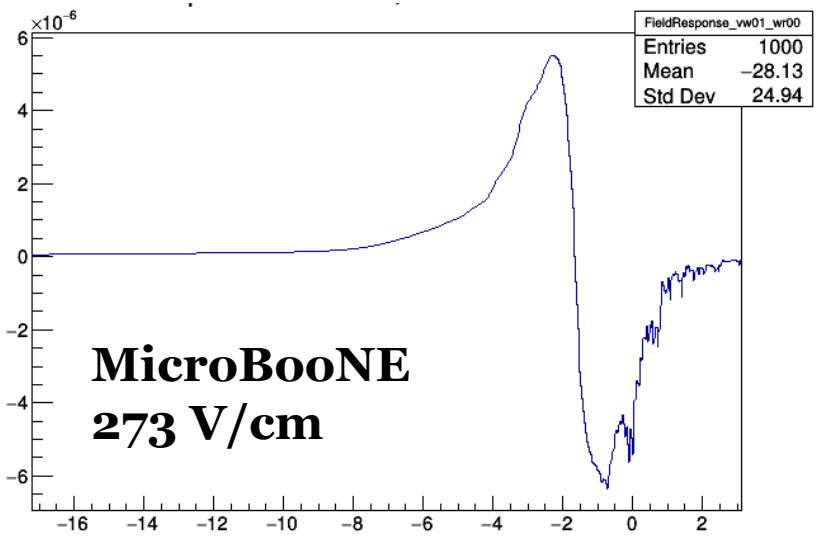
Introduction

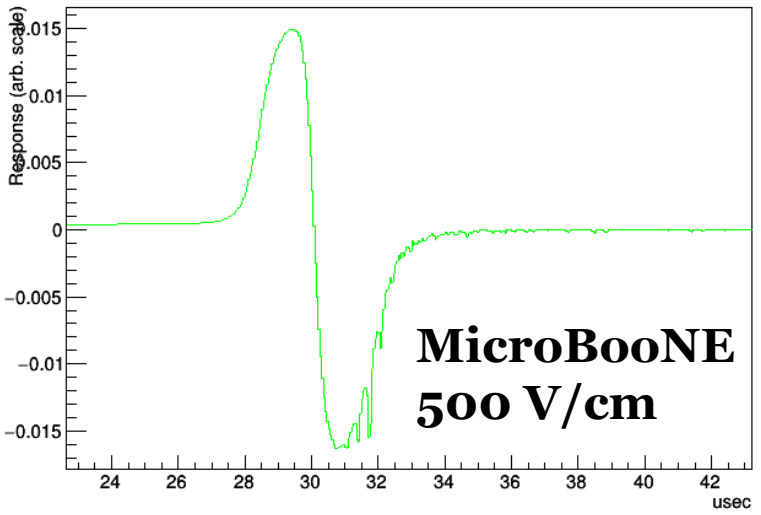
- Brief look today at signal processing for ProtoDUNE-SP
- Two main topics:
  - Wire field response
  - Deconvolution filter
- Work very preliminary but feedback here could be useful to further investigation

Field Response Comp.

- ProtoDUNE simulation currently using 35T wire field responses
- Compare to MicroBooNE
  - Seems similar to 273 V/cm…
  - Need to change for 500 V/cm

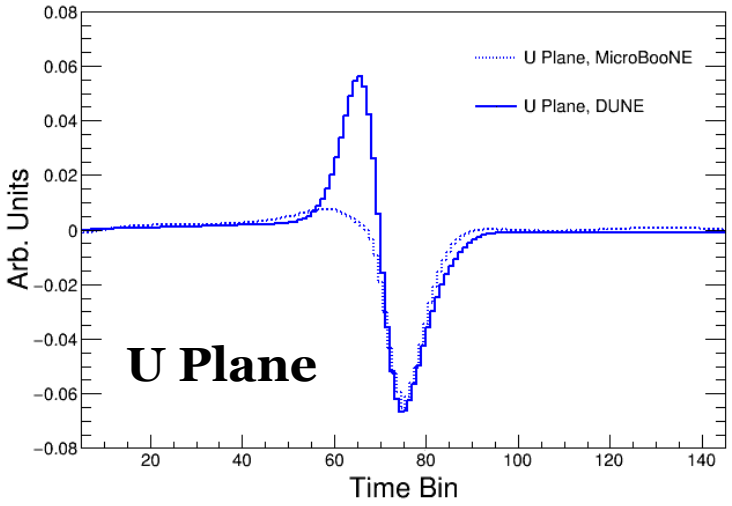


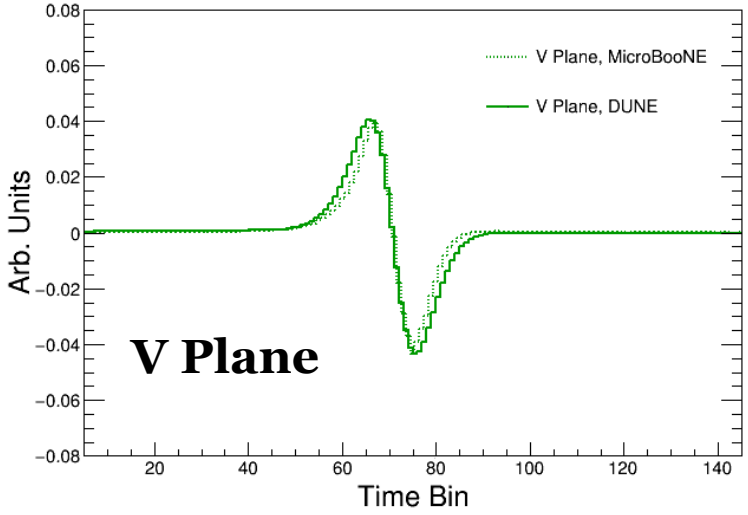


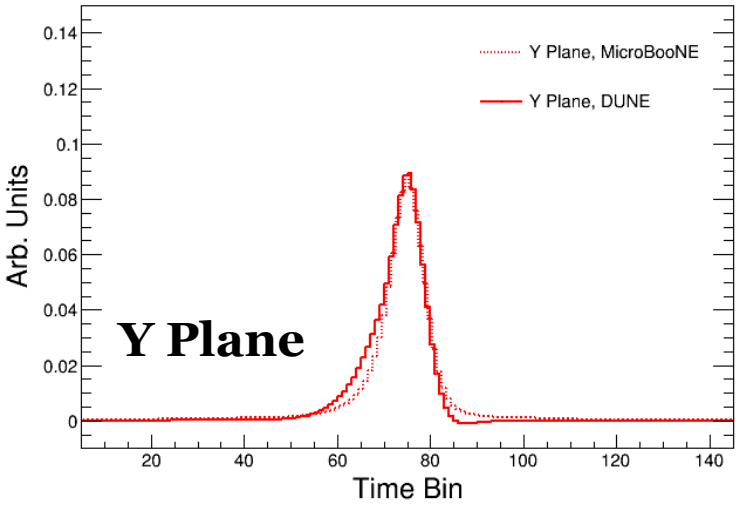


Field Response Comp.

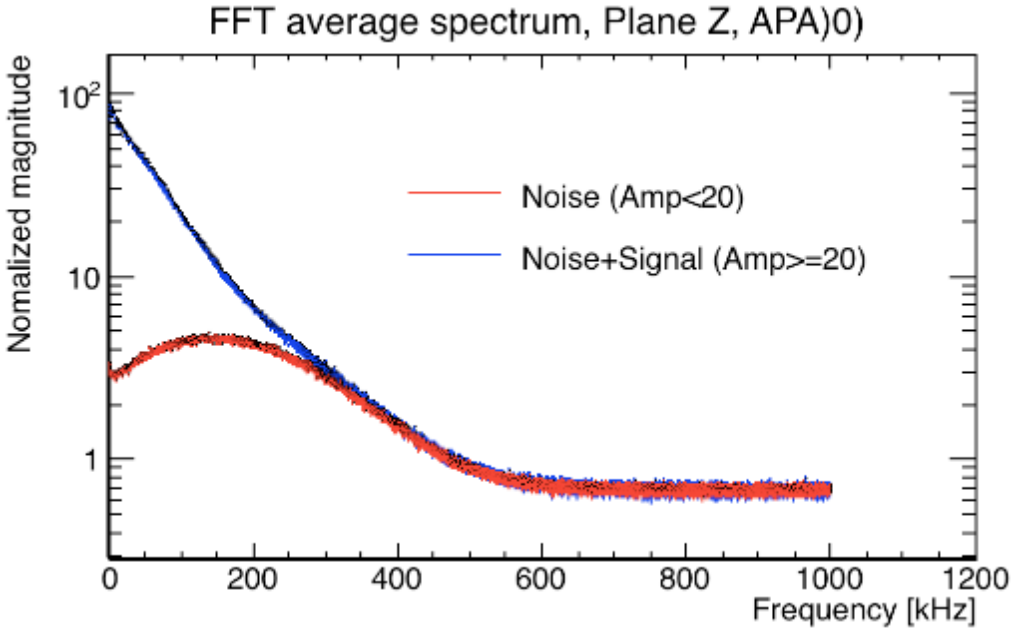
- Compare DUNE and MicroBooNE, full responses (field and electronics)
- Fix max signal amplitude in comparison
- Very similar shape, but MicroBooNE at 273 V/cm…







Considerations with Noise



New Data-Driven Noise Model from Jingbo/Mike

- So what if signal response is incorrect? Remove same response in deconvolution.
  - Noise complicates things – leads to different optimal shape of **deconvolution filter**
  - Also need this to be correct to study raw waveforms
  - And of course, data will be different than MC…

Deconvolution Filter

- Below is Gaussian deconvolution filter being tested – same as MicroBooNE:

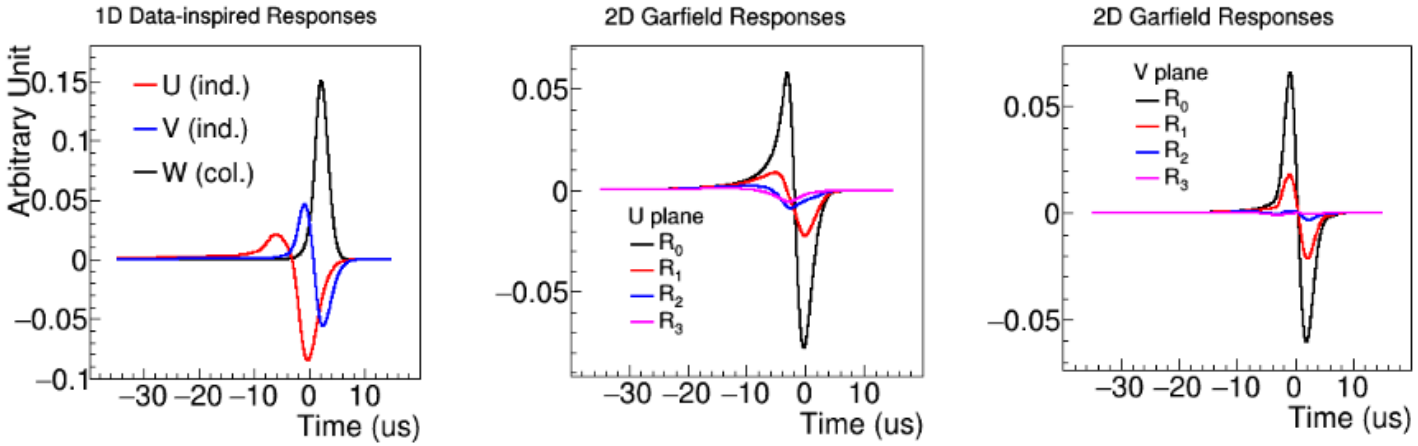
```
services.SignalShapingServiceDUNE.ColFilter:       "(x>0.0)*gaus"
services.SignalShapingServiceDUNE.ColFilterParams: [ 1.0, 0.0, 0.1 ]
services.SignalShapingServiceDUNE.IndUFilter:       "(x>0.0)*gaus"
services.SignalShapingServiceDUNE.IndUFilterParams: [ 1.0, 0.0, 0.1 ]
services.SignalShapingServiceDUNE.IndVFilter:       "(x>0.0)*gaus"
services.SignalShapingServiceDUNE.IndVFilterParams: [ 1.0, 0.0, 0.1 ]
```

- Given that electronics shaping time is same (2 μs), thus noise, and current field response being used for DUNE is very similar to MicroBooNE (?), could use above filter immediately with current field response
- But should change field response to 500 V/cm
  - … and correspondingly, the deconvolution filter

BACKUP SLIDES

MicroBooNE SP Public Note

- MicroBooNE has released public note documenting signal processing techniques useful for LArTPC experiments
  - See public note here: **MICROBOONE-NOTE-1017-PUB**
- This note describes 2D deconvolution technique
  - Technique improved since public note – paper forthcoming
  - Nature of detector response different than current assumption that only closest wire matters (see below figure)
  - Worst for MicroBooNE (3 mm spacing), still important for PD-SP



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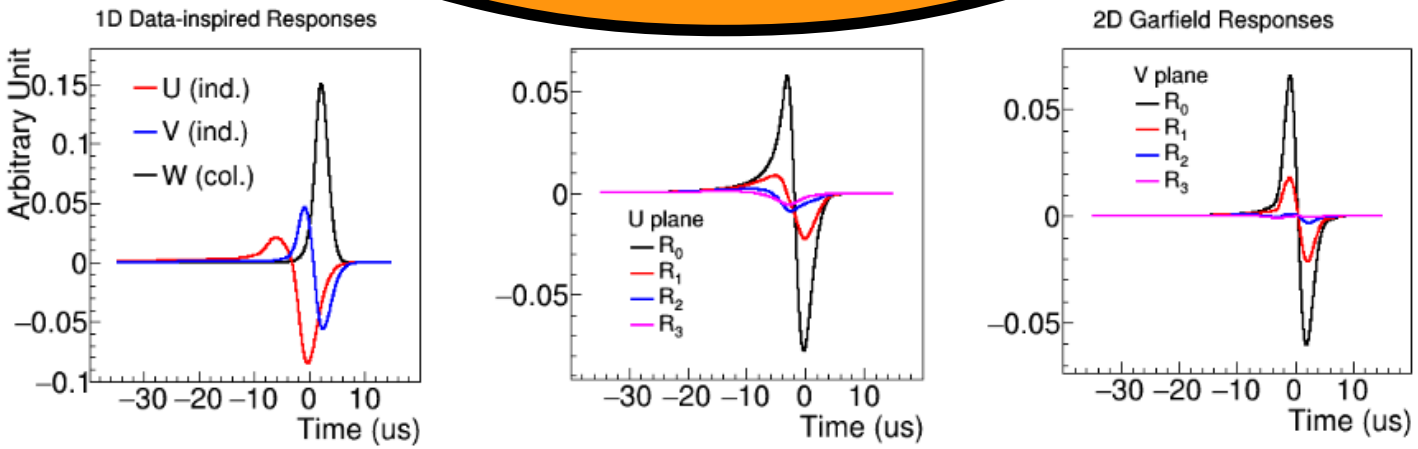
  - Worst fo… portant for PD-SP

See Backup Slides For 2D Deconvolution Examples at MicroBooNE

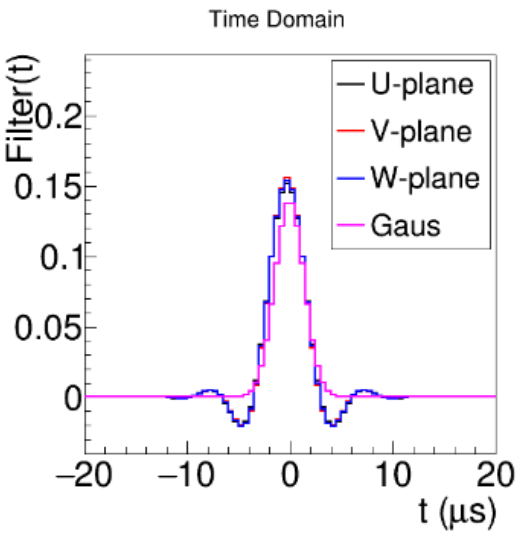


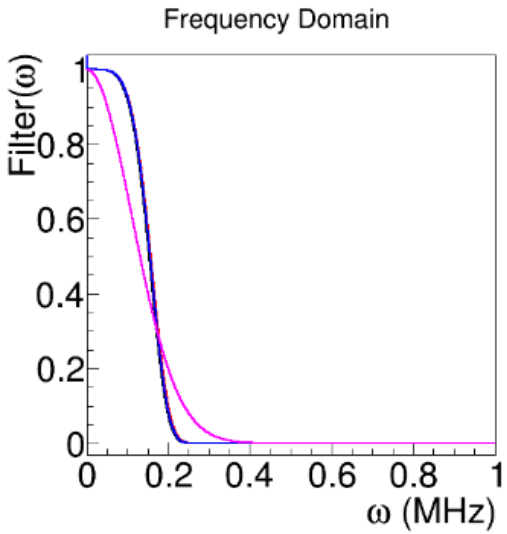
Signal Processing Concepts

- Also detailed in the note is the importance of a deconvolution filter – prevents noise blow-up when dividing out response

Deconvolution → $S(\omega) = \frac{M(\omega)}{R(\omega)} \cdot F(\omega)$ | $F(\omega) = \frac{S^2(\omega)}{S^2(\omega) + N^2(\omega)}$ ← **Wiener Filter**

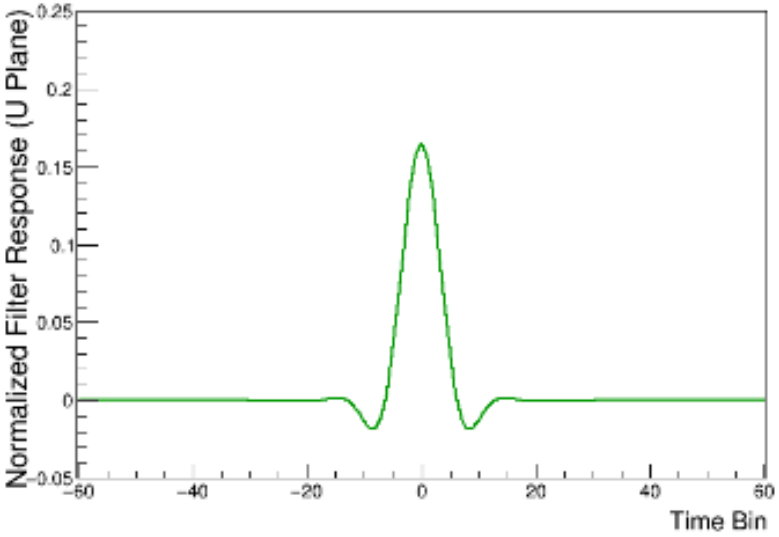
- Wiener filter gives optimal peak-to-peak separation, but we are fitting to Gaussians (GaussHitFinder) → problems!

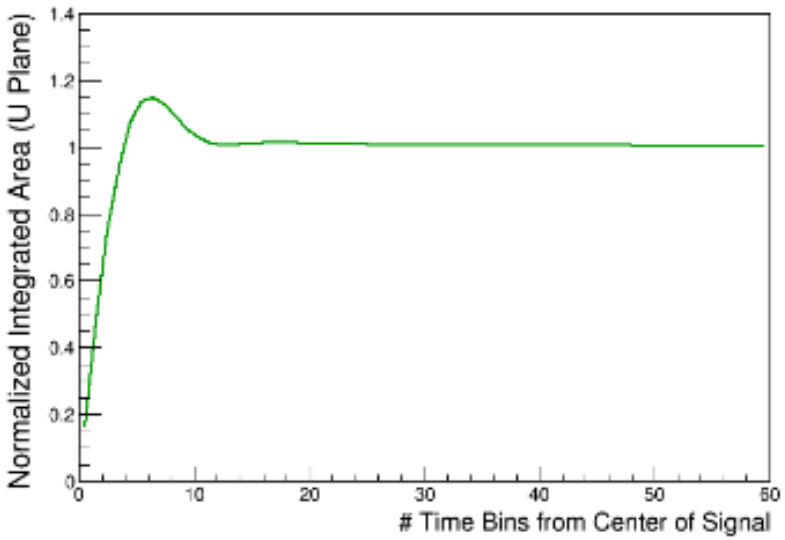




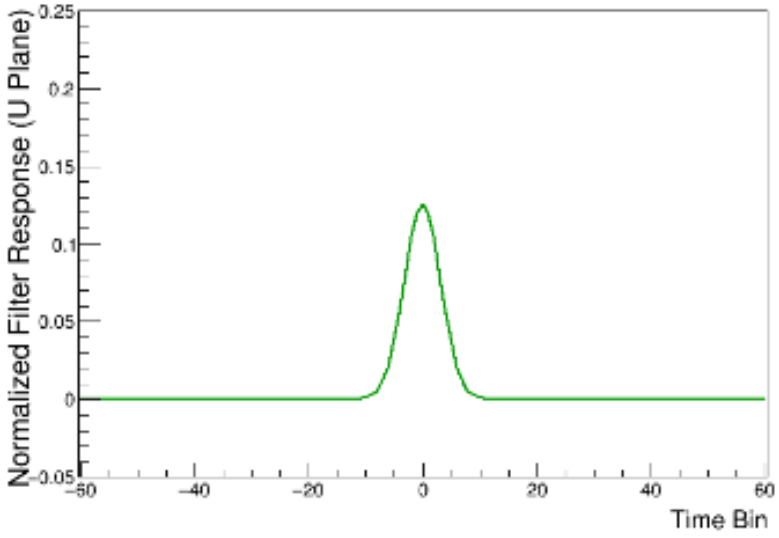
MicroBooNE U Plane

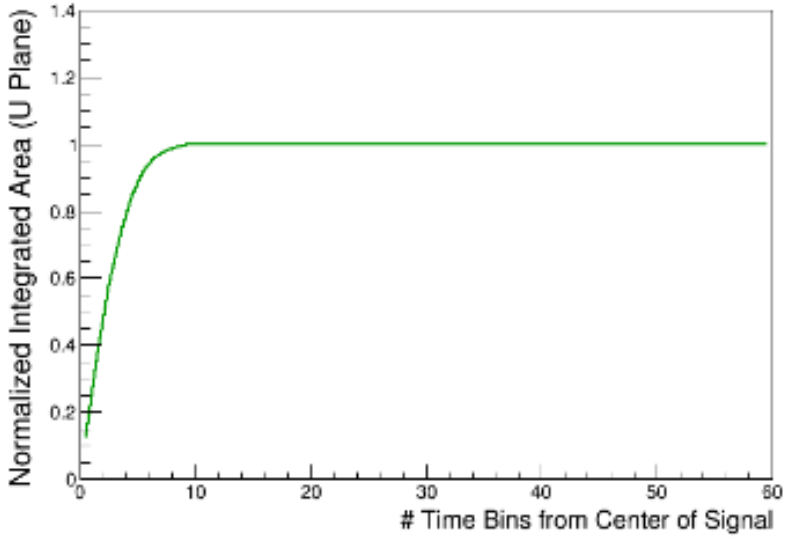
Wiener Filter





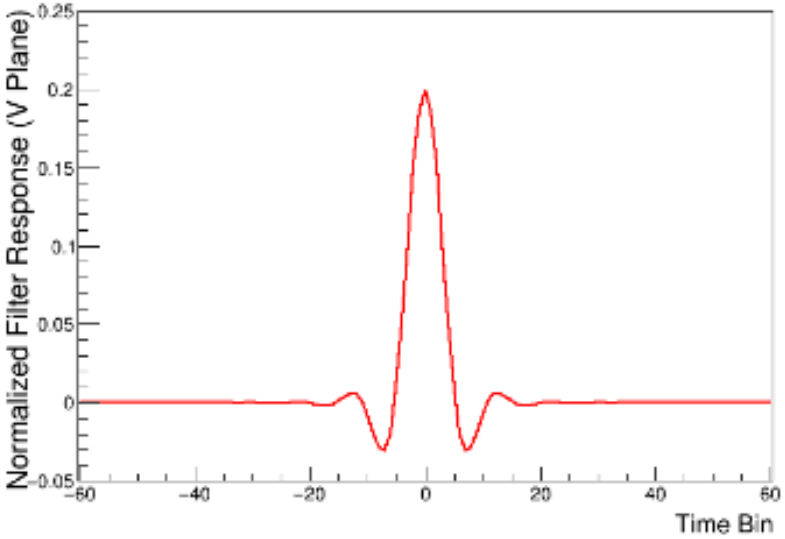
Gaussian Filter

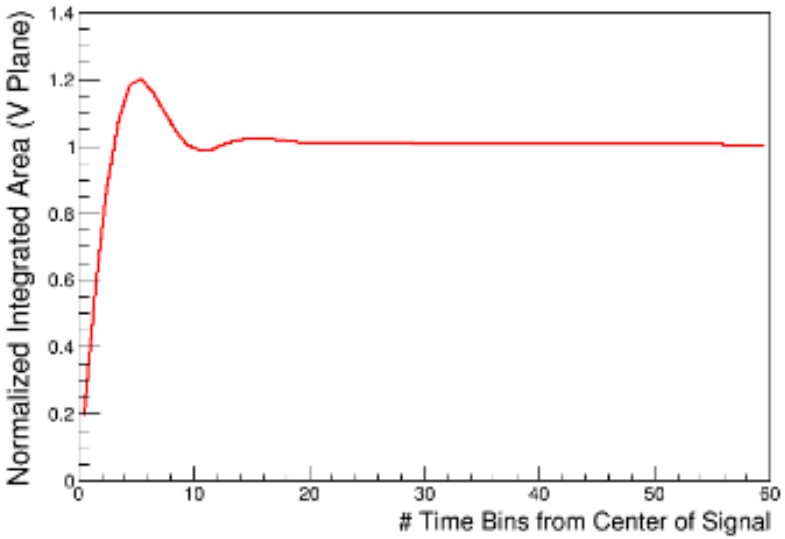




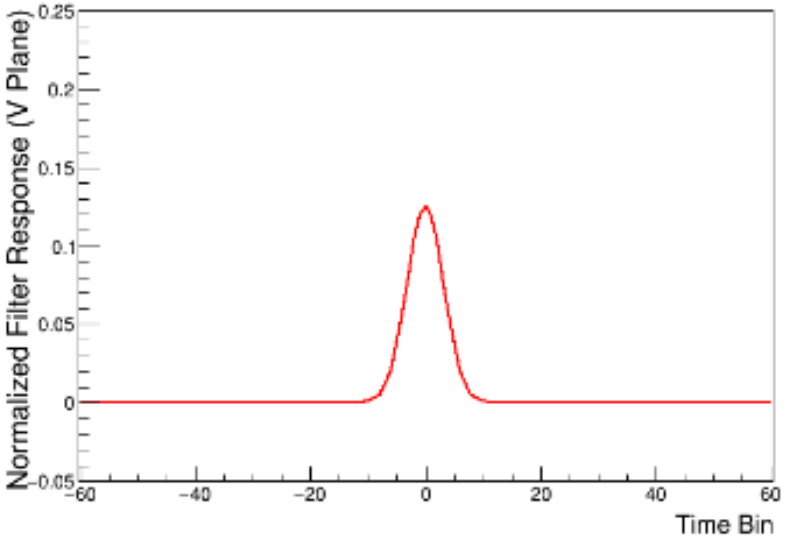
MicroBooNE V Plane

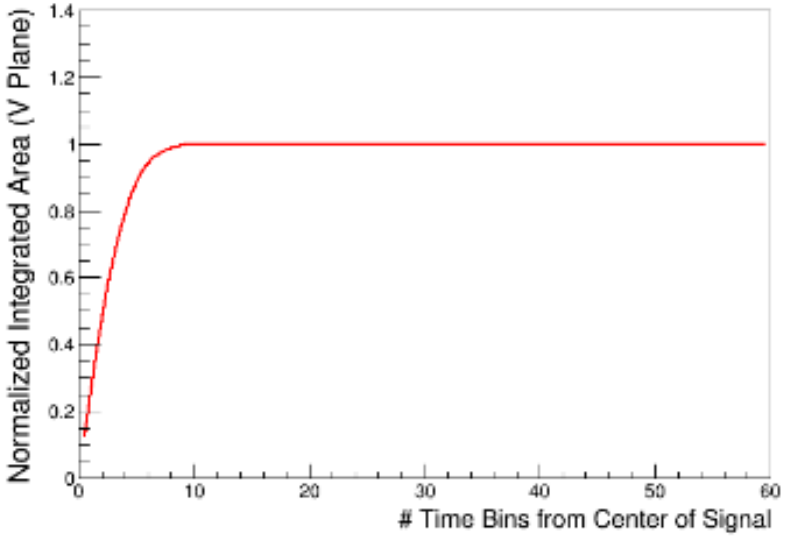
Wiener Filter





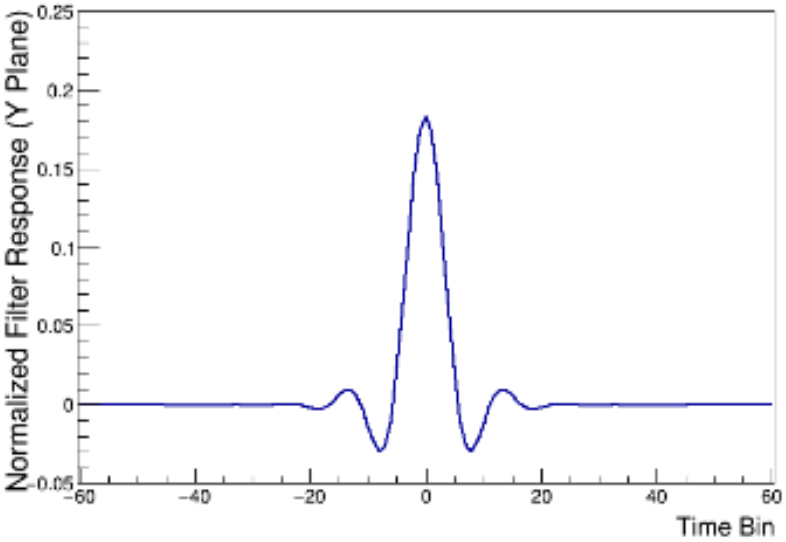
Gaussian Filter

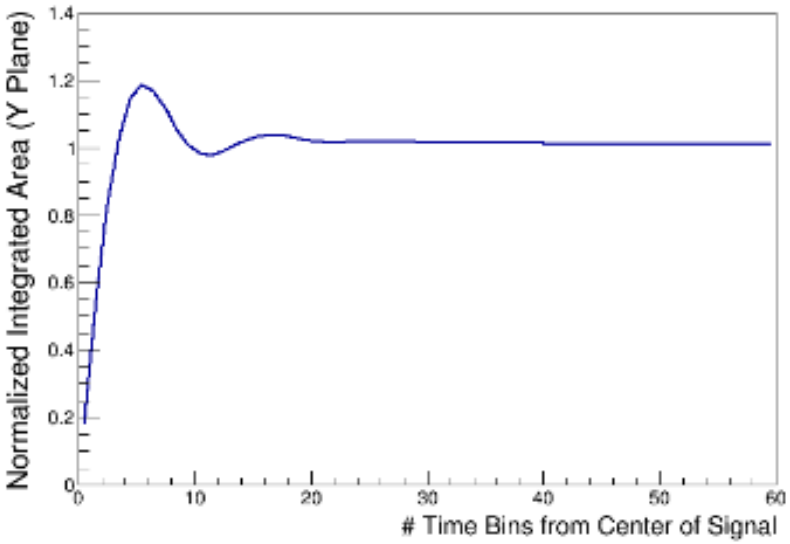




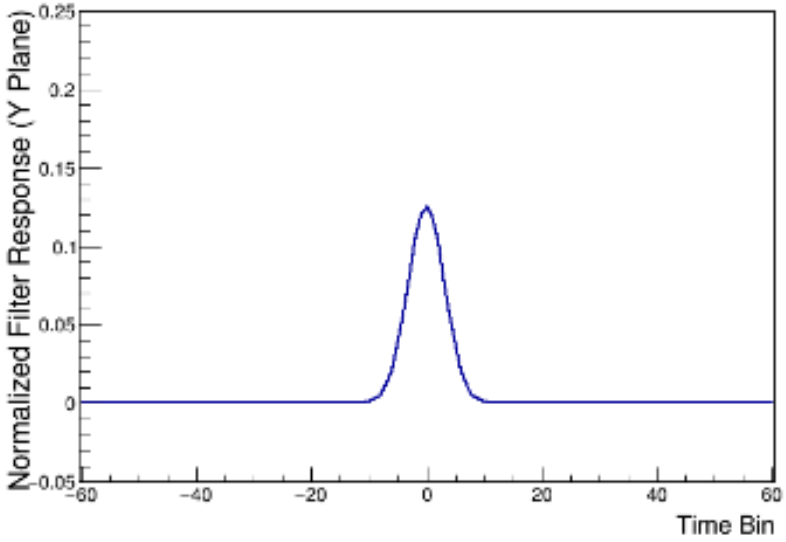
MicroBooNE Y Plane

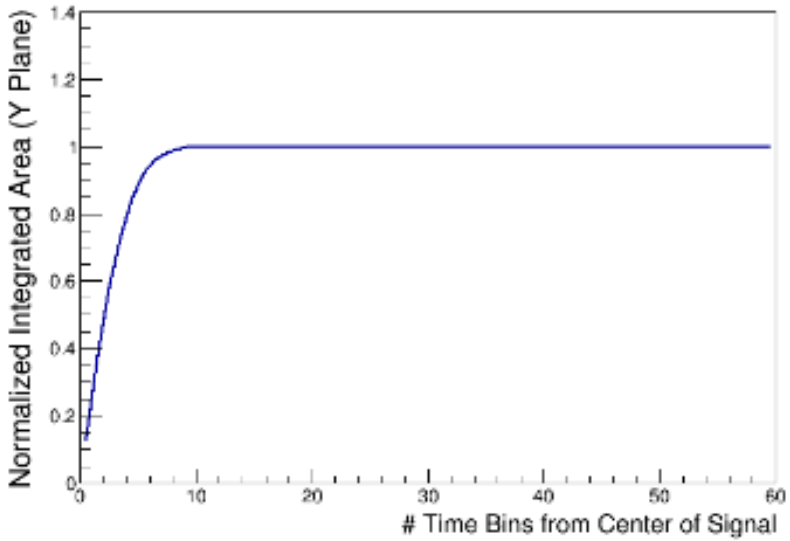
Wiener Filter





Gaussian Filter





Discussion

- If fitting post-deconvolution signal with Gaussians (GaussHitFinder), would overestimate charge with Wiener filter (peaks of integral plots) – for MicroBooNE (273 V/cm):
  - **U Plane**: overestimate charge by **~14%**
  - **V Plane**: overestimate charge by **~19%**
  - **Y Plane**: overestimate charge by **~18%**
- Advantages of Gaussian filter:
  - Minimal bias charge extraction when using Gaussian fits
  - Better goodness of fit
  - Uniformity of dQ/dx vs. angle of track w.r.t. anode plane
  - No noise hits from “side bumps” associated with Wiener signal
- Simple to switch in code (.fcl file parameters)
  - First need to study/optimize for ProtoDUNE-SP