Update of deconvolution module in duneopdet (LArSoft/DUNE)

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Deconvolution

- Implemented multiple options for deconvolution
  1. + Wiener filter
  2. + Gaussian filter
  3. Without filter

- Applied in frequency domain, after FFT

- Additional Gaussian filter after deconvolution

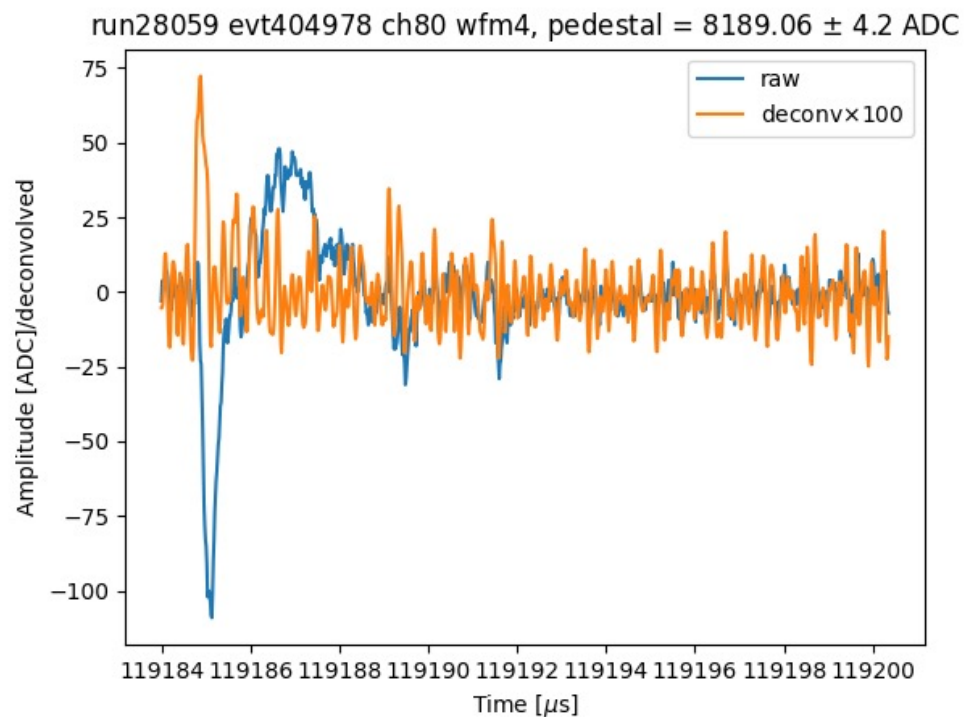# Noise filters – my understanding

Wiener

- Finds frequencies where noise dominates over signal and suppresses them

Gaussian

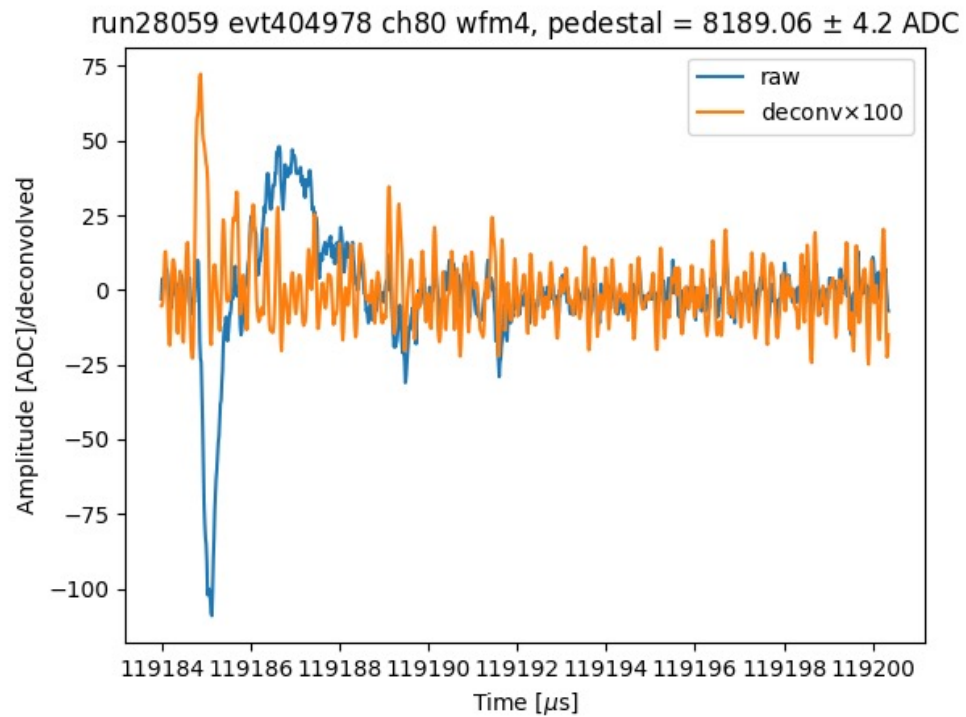- Simple smoothing – averages neighbouring samples, adding gaussian weight
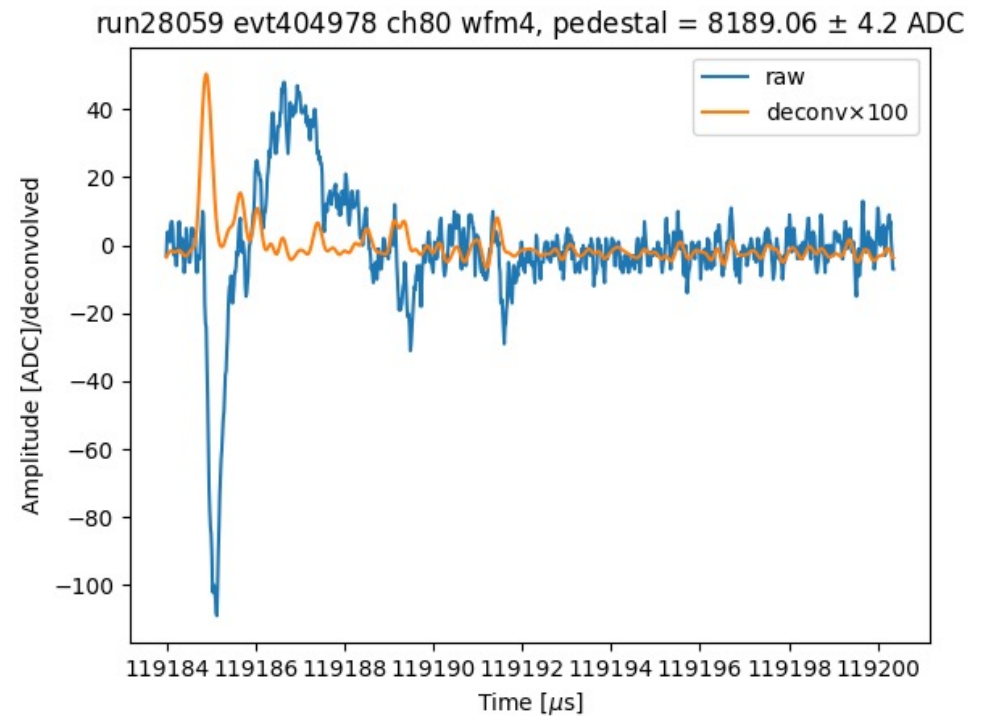
Example

Wiener filter

run28059 evt404978 ch80 wfm4, pedestal = 8189.06 ± 4.2 ADC

- Noise is large
- 4.5 ADC RMS white noise used for the filter
- Does not work so well

Example

Wiener filter

Wiener filter + Gaussian postfilter

run28059 evt404978 ch80 wfm4, pedestal = 8189.06 ± 4.2 ADC

run28059 evt404978 ch80 wfm4, pedestal = 8189.06 ± 4.2 ADC

Example

Wiener filter

run28059 evt404978 ch80 wfm4, pedestal = 8189.06 ± 4.2 ADC

Gaussian filter

run28059 evt404978 ch80 wfm4, pedestal = 8189.06 ± 4.2 ADC
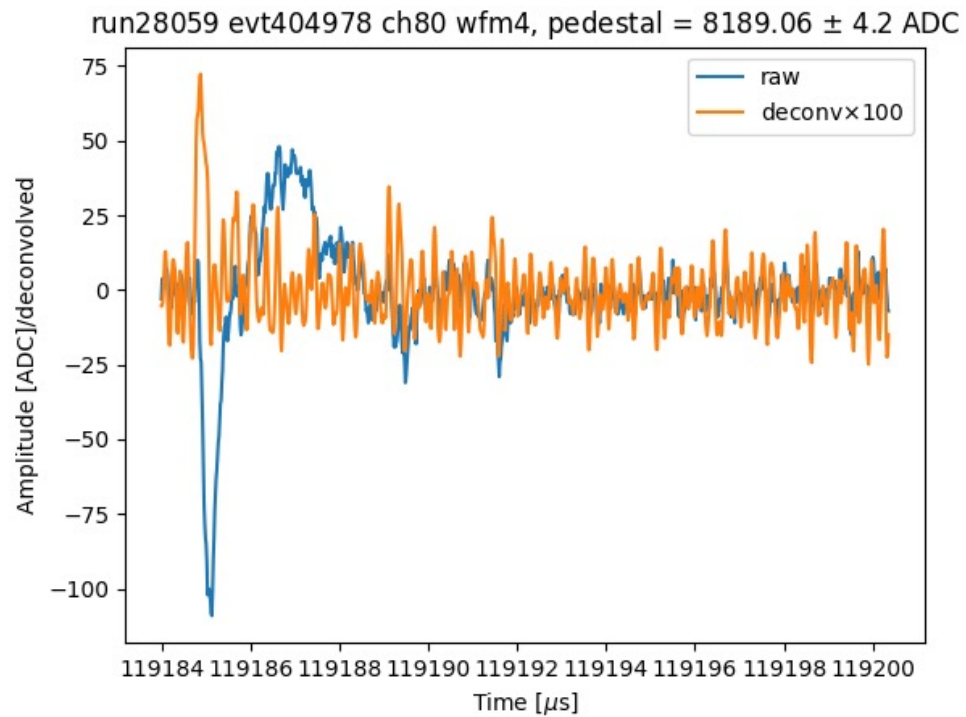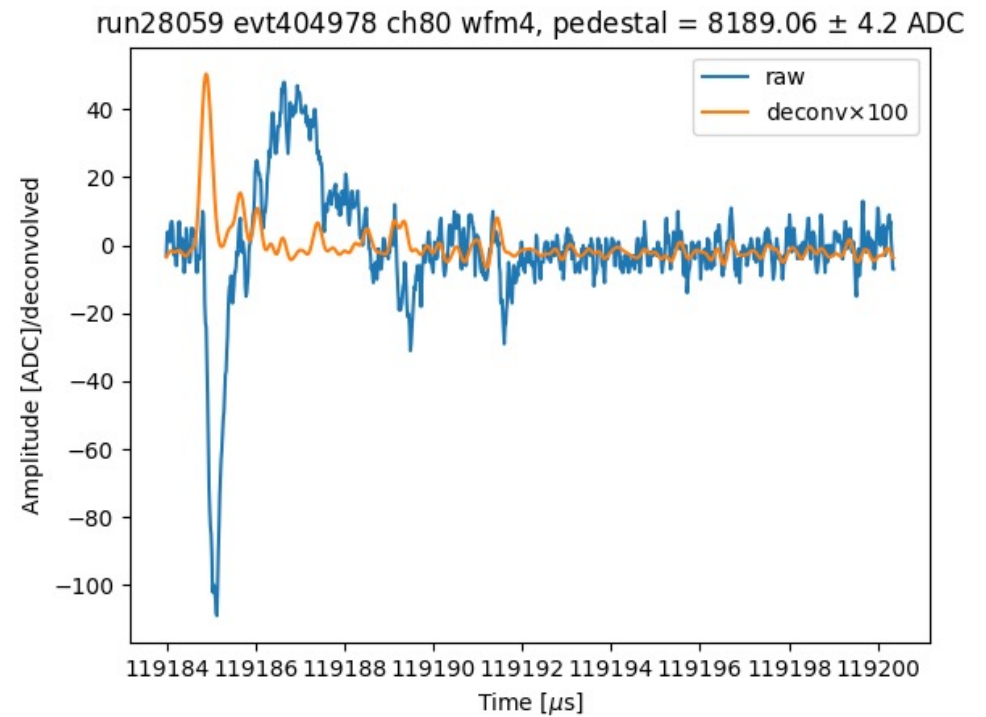
Example – Gaussian filter

run28059 evt404978 ch80 wfm4, pedestal = 8189.06 ± 4.2 ADC
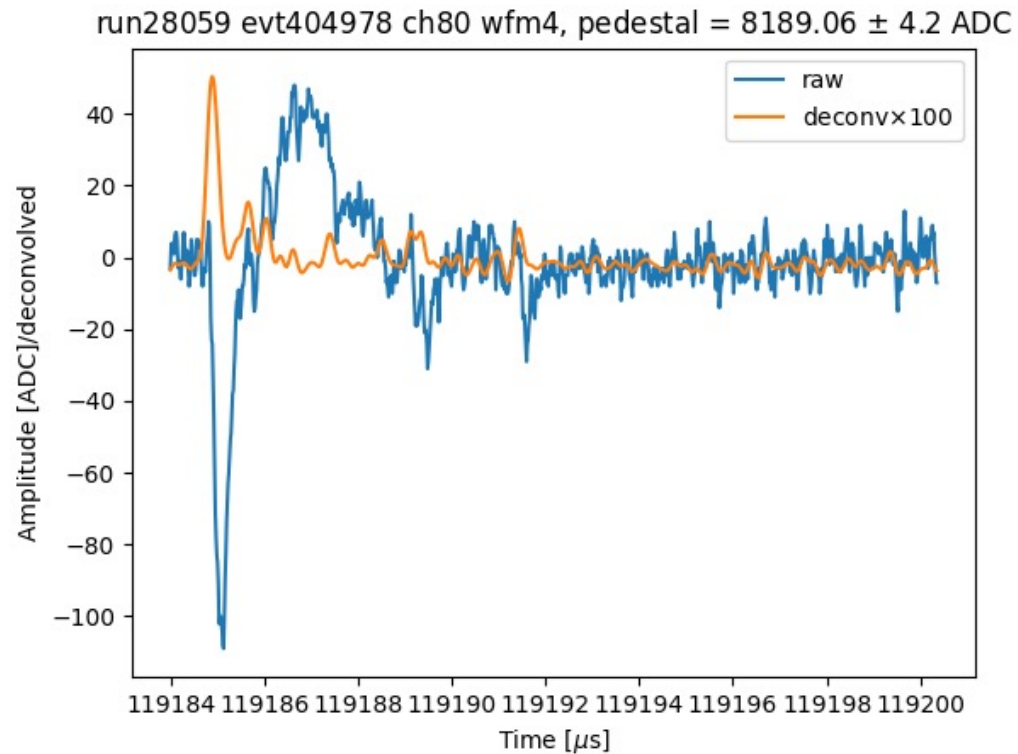
- Same as Wiener + Gaussian
- => Wiener noise filter has no effect now
- Not sure why

Main new features

- Can take more than one SPE template

- Uses noise templates

- Can ignore channels

SPE templates

- Used for deconvolution
- Average SPE amplitude per time tick
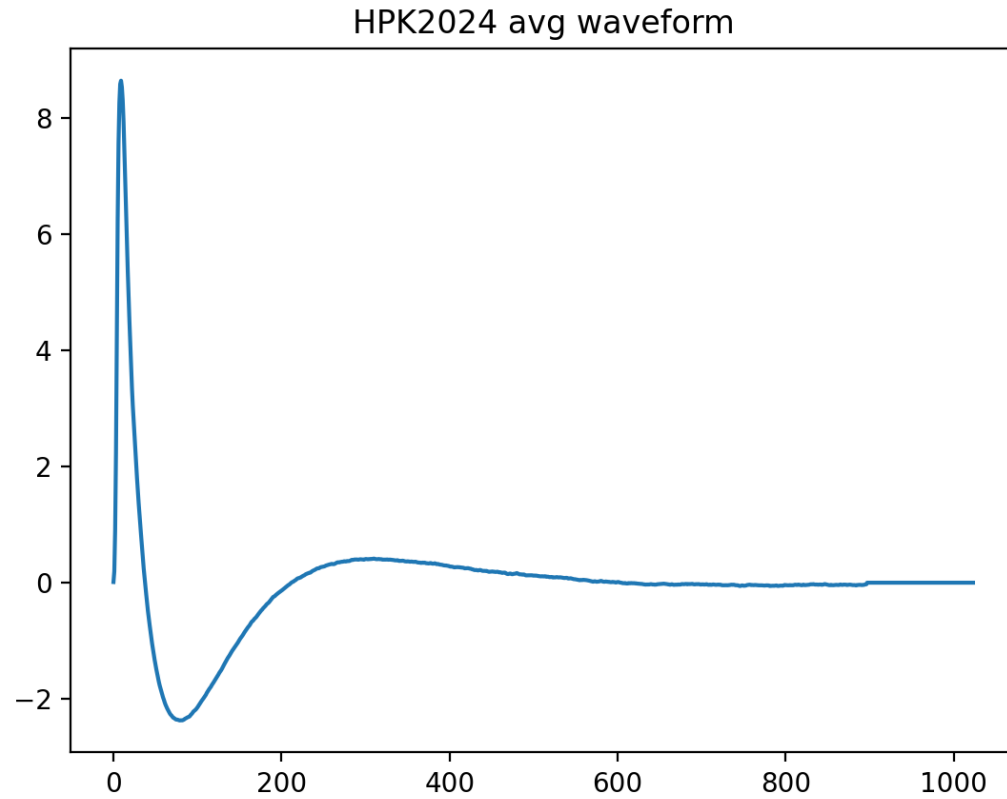- Text files
- Can configure multiple:

```
DigiDataFiles: ["input1.txt", "intpu2.txt", ...]
```

- Files looked up from FW_SEARCH_PATH
- Need channel-to-template map:

```
TemplateMapChannels:  [0,1,2,…] # all channels to deconvolve
TemplateMapTemplates: [0,0,1,…] # index in DigiDataFiles list
```

SPE template for an HPK channel

HPK2024 avg waveform

Noise templates

- Used in Wiener filter
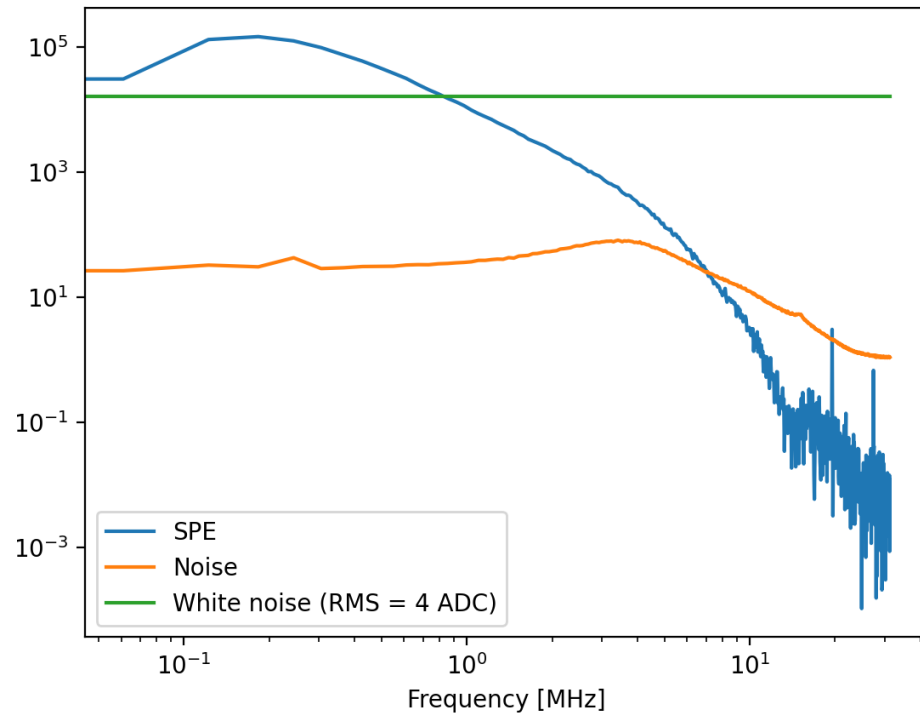- Expected input power spectral density:

$$\mathtt{abs(FFT(waveform))}^2$$

- Same system as with SPE templates
- Configurables:

```
NoiseTemplateFiles:        [] # list of file names
NoiseTemplateMapChannels:  [] # channels to map to templates
NoiseTemplateMapTemplates: [] # index in NoiseTemplateFiles
```

Comparison of SPE and noise spectra

- Currently assumed white noise much higher than measured noise

- Still, no effect in the deconvolution?

- Do we understand normalisation of the templates?

- Need to tune parameters or are there bugs?

Ignore channels

- Channels can be completely ignored in deconvolution

  IgnoreChannels: [0,1,2,…]

- Leads to possible mismatch between number of raw input (raw::OpDetWaveform) and output deconvolved (recob::OpWaveform) waveforms

- Added associations product: keeps track of which reco wfm came from which raw wfm

Technical instructions

DUNE LArSoft deconvolution module

Located in duneopdet/OpticalDetector/Deconvolution

DUNE repository

- https://github.com/dune/duneopdet

My fork

- https://github.com/vpec0/duneopdet

Pull request submitted

- https://github.com/DUNE/duneopdet/pull/61

Module content

Main code

- duneopdet/OpticalDetector/Deconvolution/Deconvolution_module.cc

Main configuration blocks (PROLOG) in

- duneopdet/OpticalDetector/Deconvolution/Deconvolution.fcl

Run configuration for PD HD data

- duneopdet/OpticalDetector/Deconvolution/protodunehd_deconvolution_run.fcl

Supporting configuration

dune_opdet_channels.fcl

- Channel-to-template maps

- Ignored channels
    - Dead
    - Noisy

Setup your SL7 environment

```
APPTAINER=/cvmfs/oasis.opensciencegrid.org/mis/apptainer/current/bin/apptainer
CONTAINER=/cvmfs/singularity.opensciencegrid.org/fermilab/fnal-dev-sl7:latest
BINDINGS=/cvmfs,/opt,/run/user,/tmp,/etc/hostname,/etc/hosts,/etc/krb5.conf
$APPTAINER shell -e --shell=/bin/bash -B $BINDINGS --env
SSH_AUTH_SOCK=$HOME/.ssh/ssh_auth_sock --ipc --pid $CONTAINER
# note that env setting for SSH_AUTH_SOCK needed for ssh agent forwarding passed
on into the apptainer

source /cvmfs/dune.opensciencegrid.org/products/dune/setup_dune.sh
VERSION=v09_92_00d00
QUALS=e26:prof
setup dunesw $VERSION -q $QUALS
```

Build your local version

Changes not yet on cvmfs => setup local products from my fork

```
mkdir dev ; cd dev
mrb n
source localProducts_*/setup # always needed
cd srcs
git clone git@github.com:vpec0/duneopdet.git
cd duneopdet ; git checkout vpec/deconv_template_by_channel; cd ..
mrb uc # update CMakeLists.txt with duneopdet
mrbsetenv
mrb i -j 10  # build and install; '-j 10' if you have 10 cores available
```

Run

To run, repeat the setup on slide 'Setup your SL7 environment'

In your dev directory

```
source localProducts*/setup
mrbslp
```

You are ready to run over data (make sure you have valid voms_proxy):

```
INPUTFILE=root://xrootd.echo.stfc.ac.uk:1094/dune:/protodune/RSE/hd-protodune-det-
reco/66/3e/np04hd_raw_run028059_1633_dataflow2_datawriter_0_20240719T045856_reco_stage1_reco
_stage2_20240719T114708_keepup.root
```

```
lar -c protodunehd_deconvolution_run.fcl -n 1 $INPUTFILE -o output.root -T
waveform_hists.root
```