Signal Processing Adjustment in PDHD APA1

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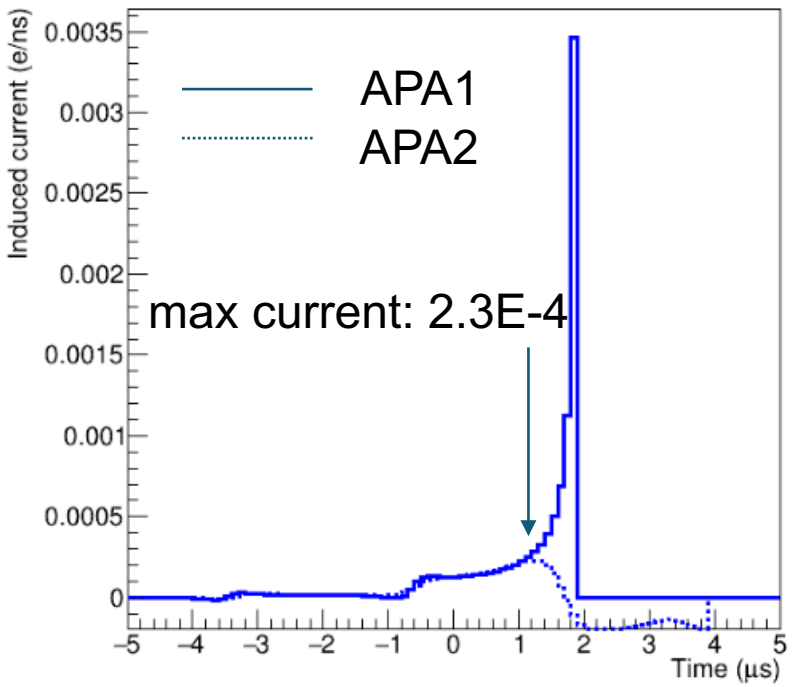
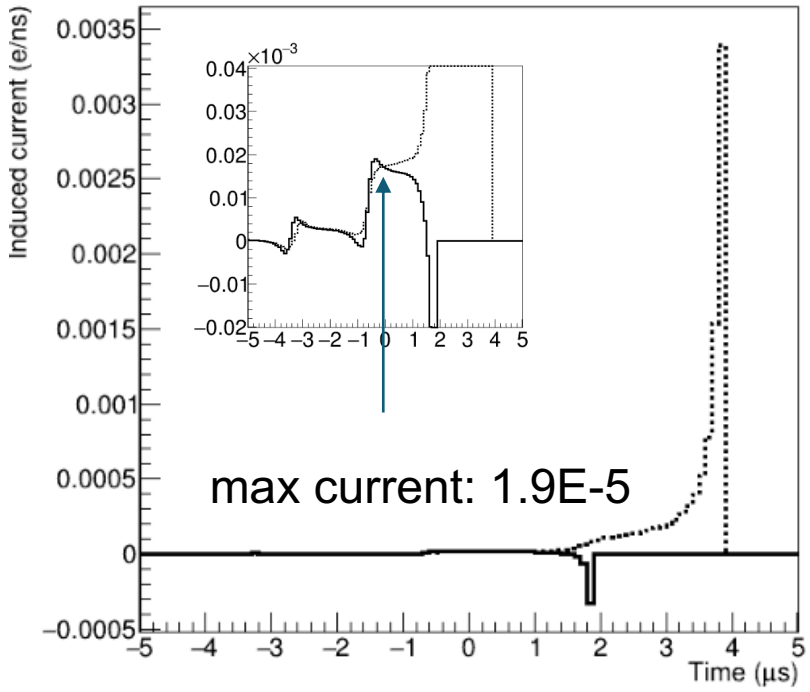
0822

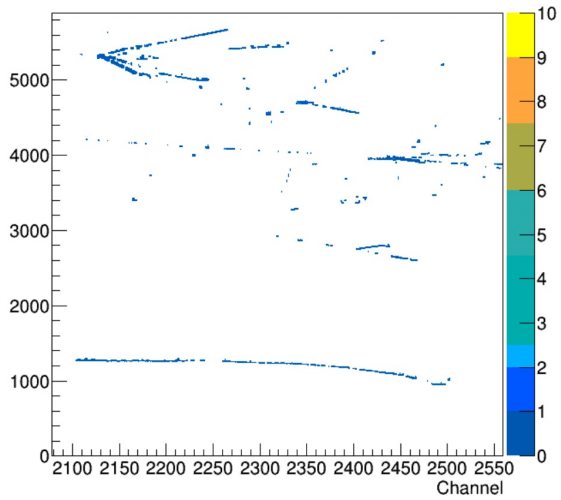
Recap

V plane

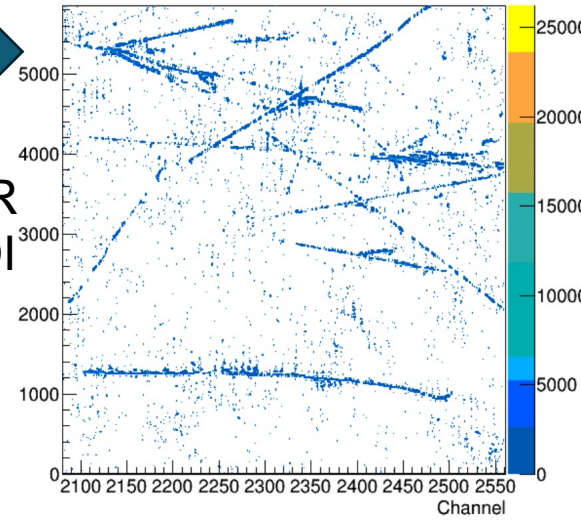


W plane





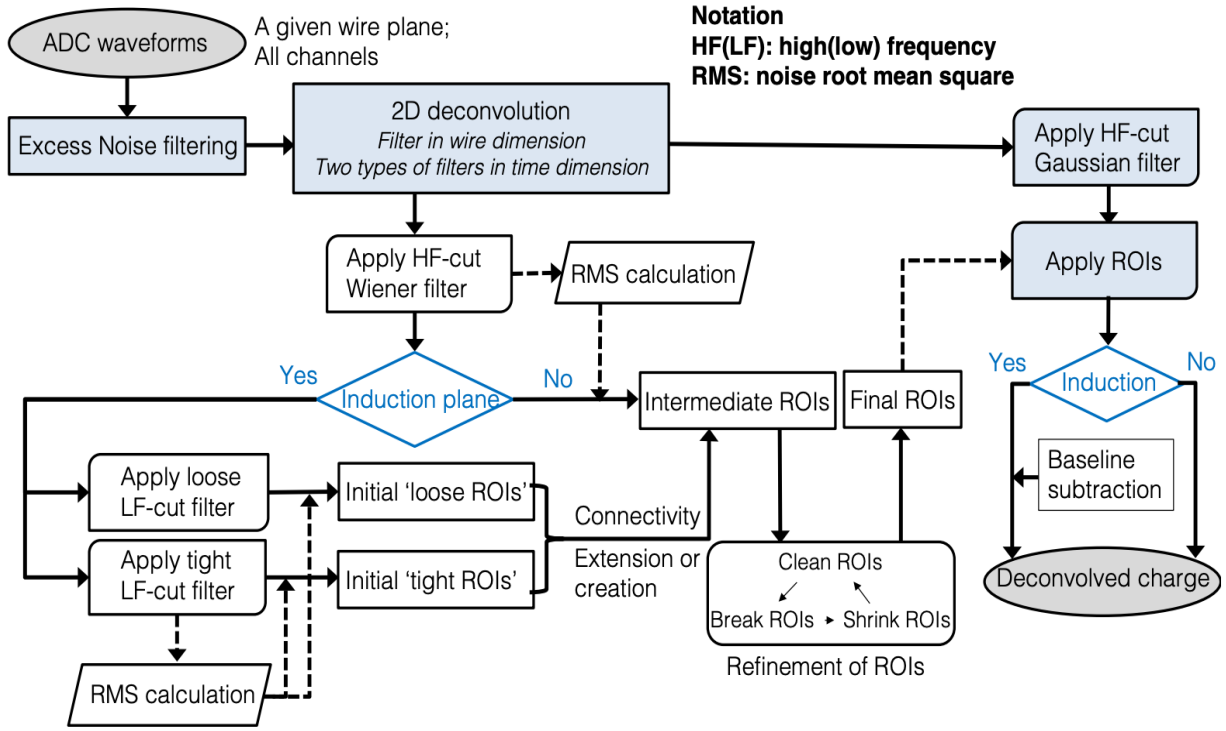
Update FR + tight ROI threshold



- Field response (FR) was recalculated for APA1 (see Wenqiang's talk)
- Signal processing in APA1 improved with a lower ROI thres. (2.5 r.m.s)

Plans for improving SigProc in APA 1

- Recalculate Wiener filter for ROI determination (This work)
  - ➢Need a data-driven noise model
- Correct workflow of induction and collection for APA 1
  - ➢W: induction needs LF-cut filter
- Adjust thresholds for tight/loose ROI and ROI refinement

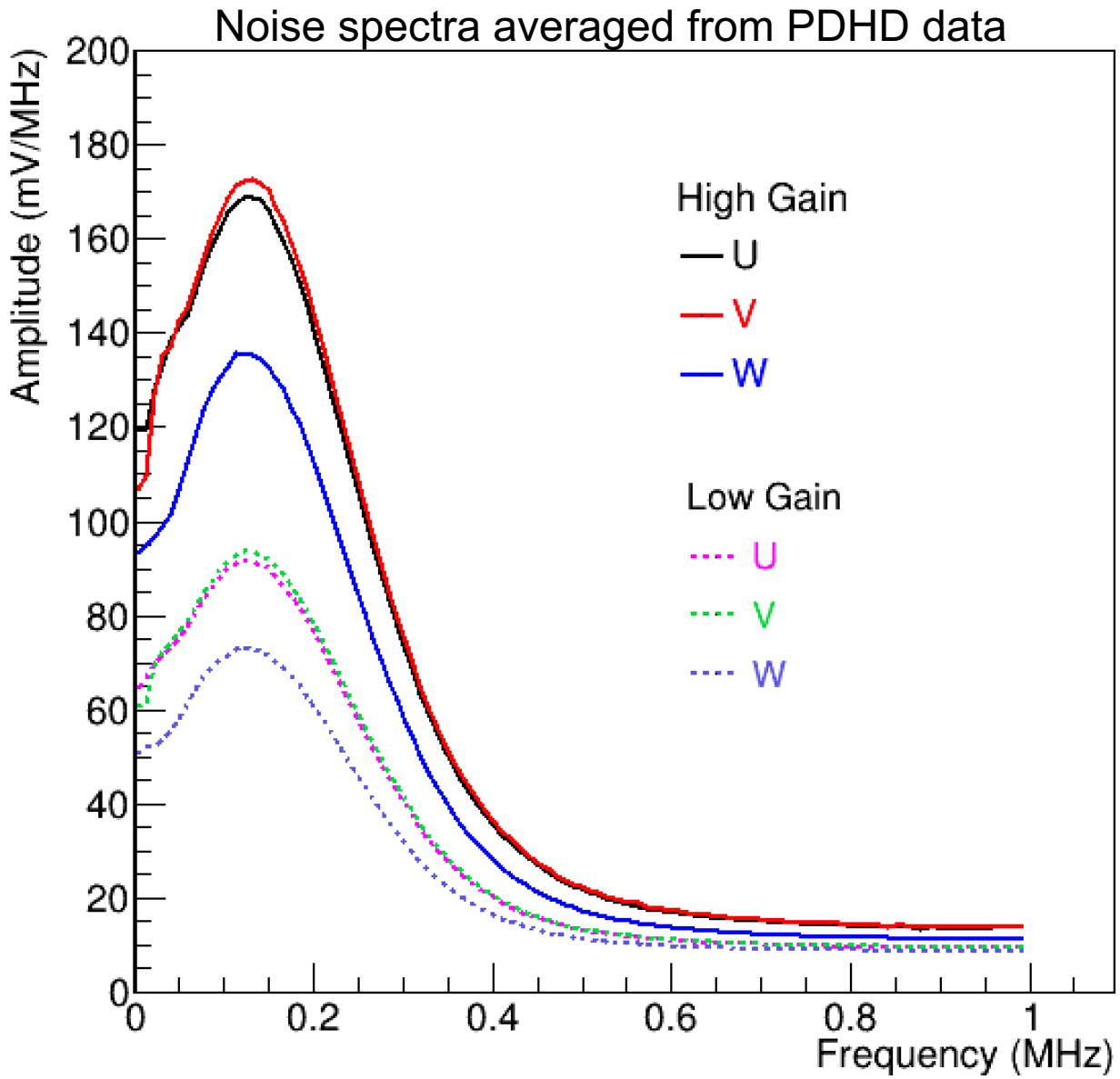


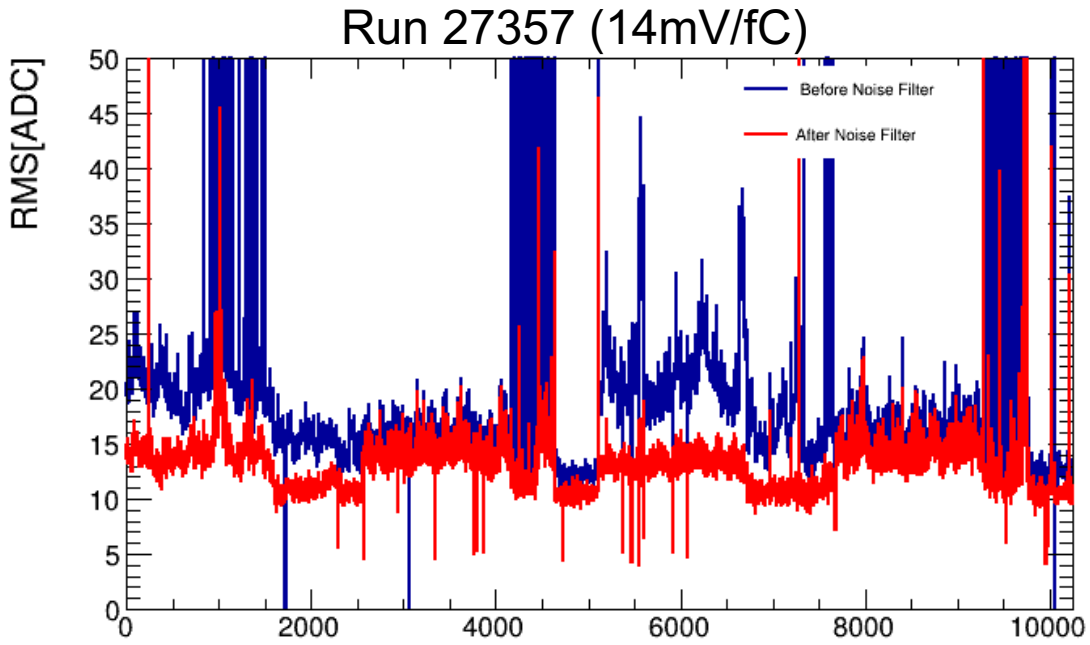
Wire-Cell's SigProc workflow

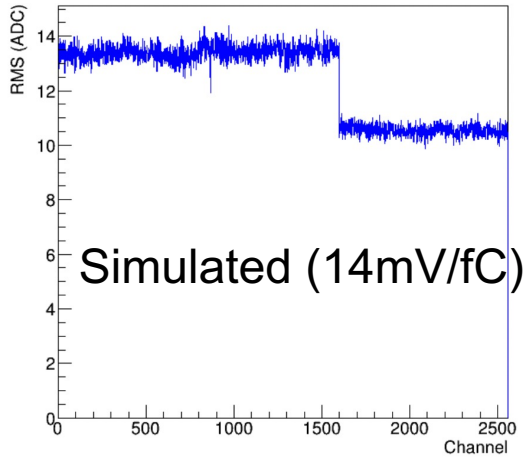
JINST 13 P07006 (2018)

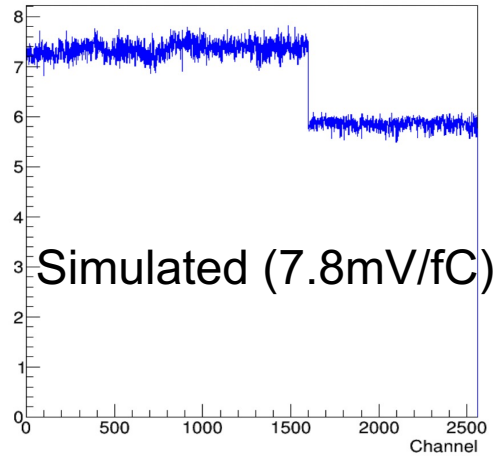
Noise model & Wiener filters

PDHD noise spectra

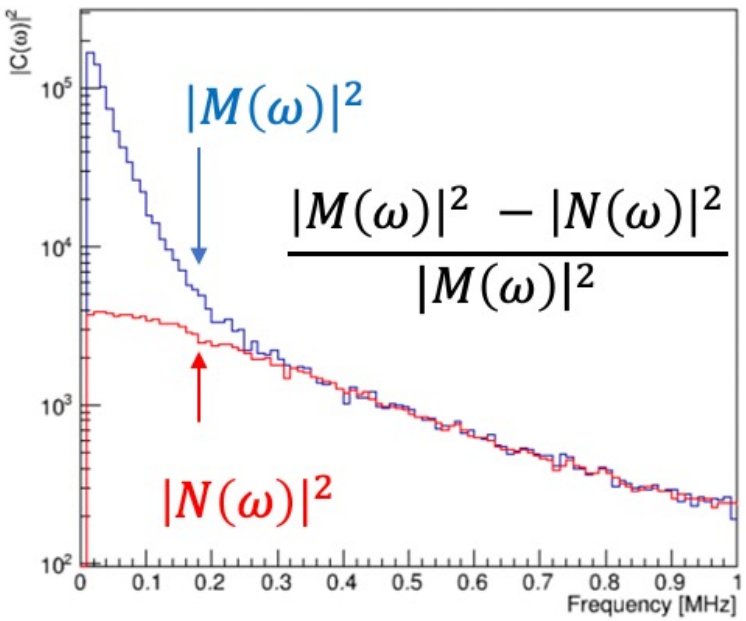




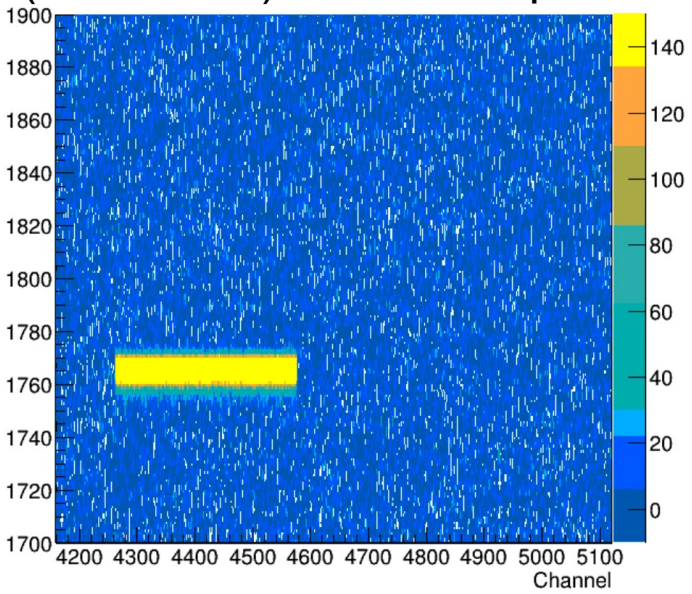




Wiener filter construction example



(Simulation) APA 2 – W plane



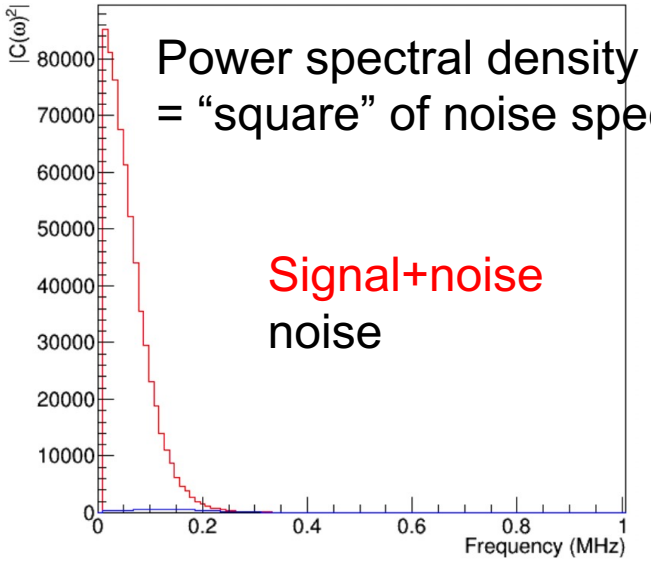
- DL : 6.2 cm2/s
- DT : 16.3 cm2/s
- e lifetime : 50 ms
- drift_speed : 1.565 mm/us
- drift_length: 100 cm

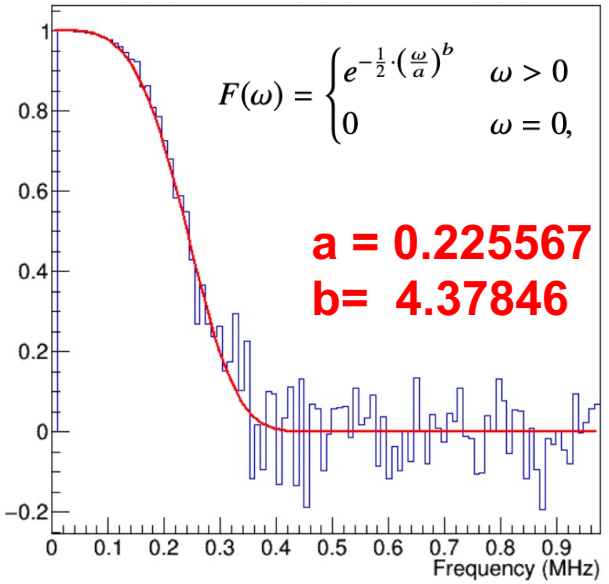
- & 200 ticks readout window

- MIP: 5000e/mm, parallel to plane, perpendicular to wires

A wiener filter minimizes MSE, i.e., maximize S/N.

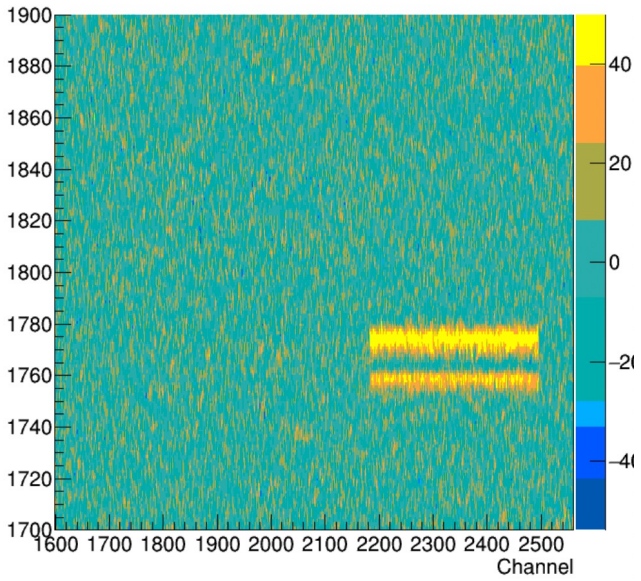
- Wiener filter: determining ROIs,
- Gauss filter: presenting deconvolution charge.

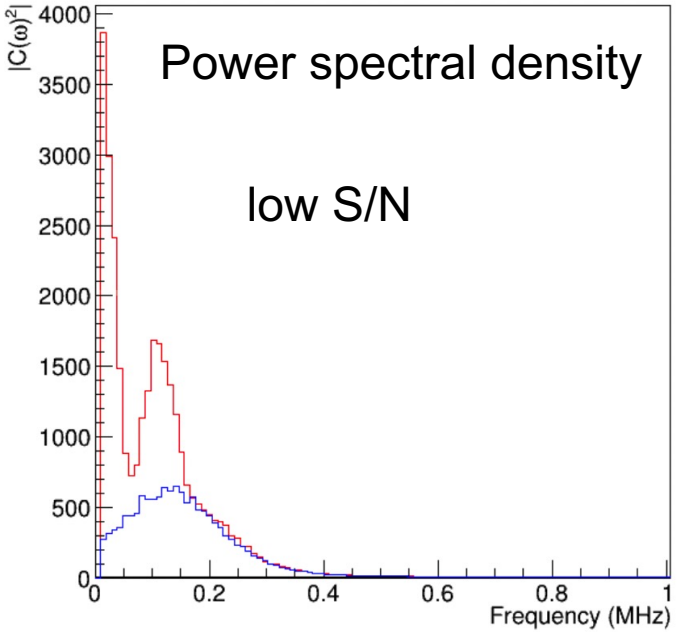


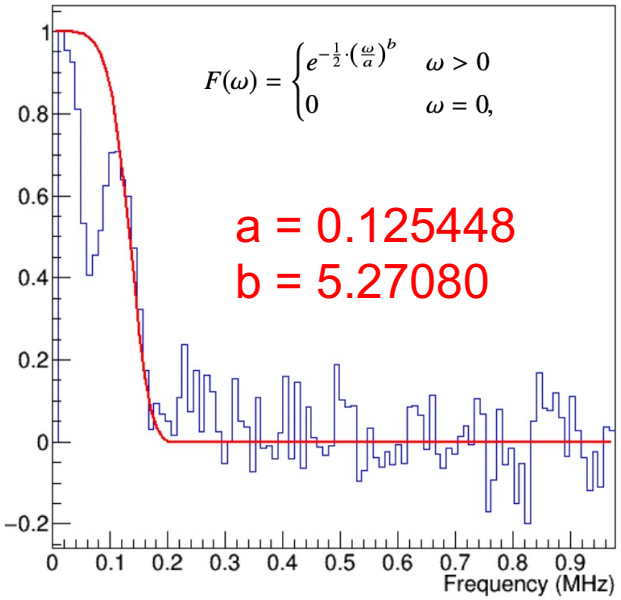


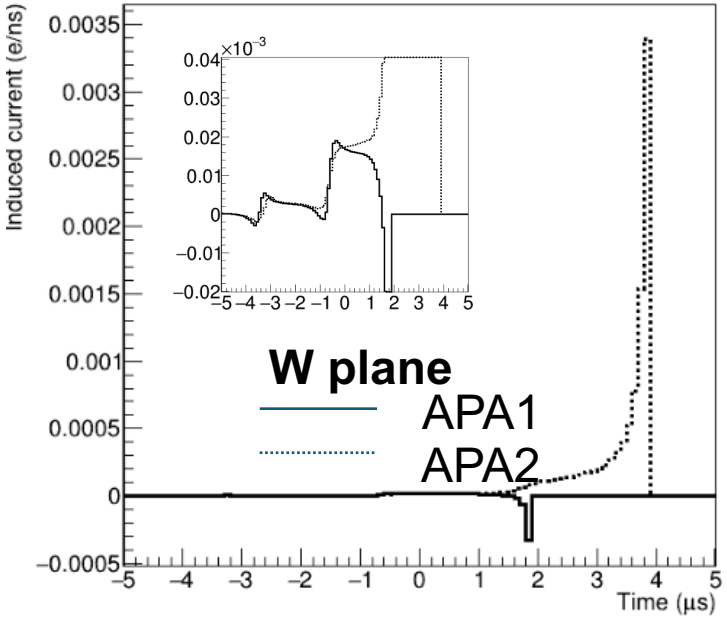
Wiener Filter for APA1; w

(Simulation) APA 1 – W plane





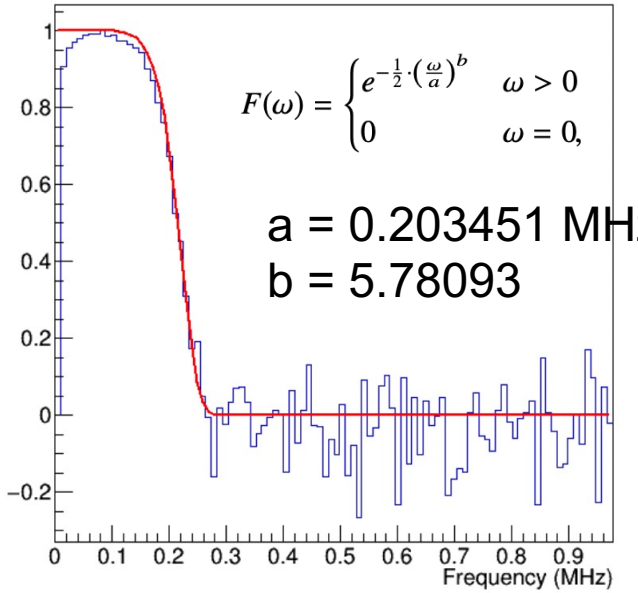




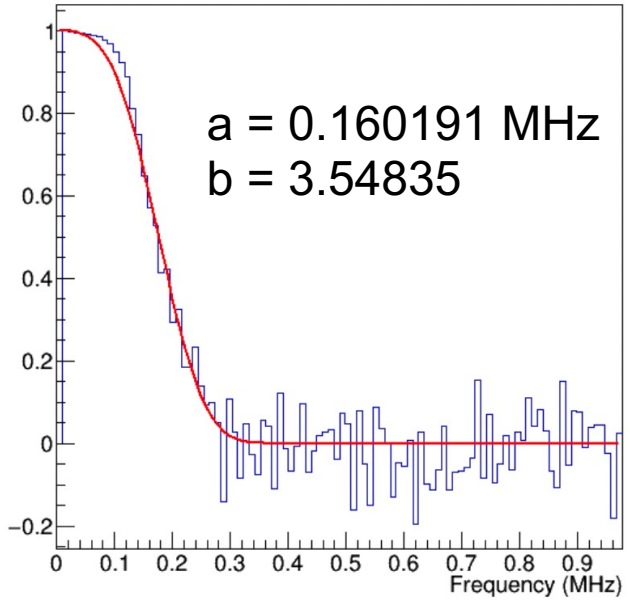
- S/N is low in APA1 W plane
- Also, the induction feature introduces a different shape for power spectral density
  - ➢ **Need more calibration studies**
- A reasonable choice of Wiener filter would be edging at 0.125 MHz, however, it may not provide best result for ROI finding (will discuss later)

Wiener Filter for all planes

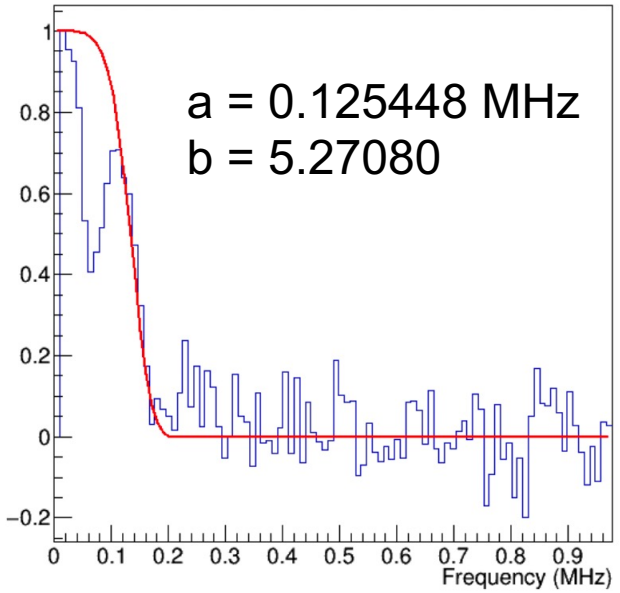
APA1 - U



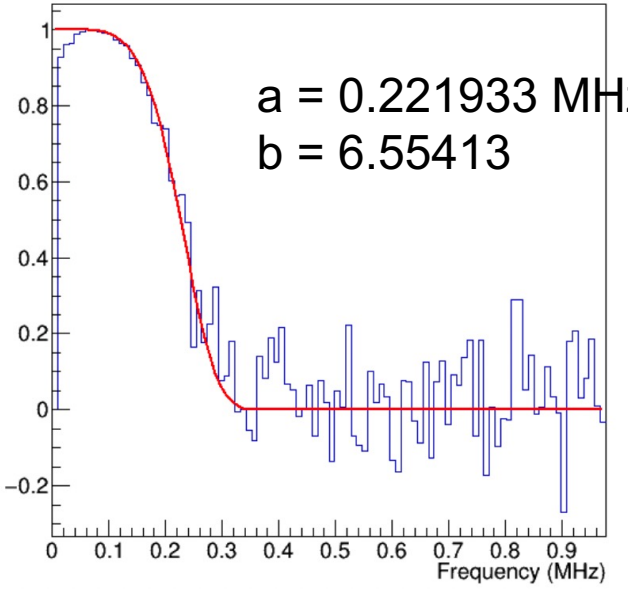
APA1 - V



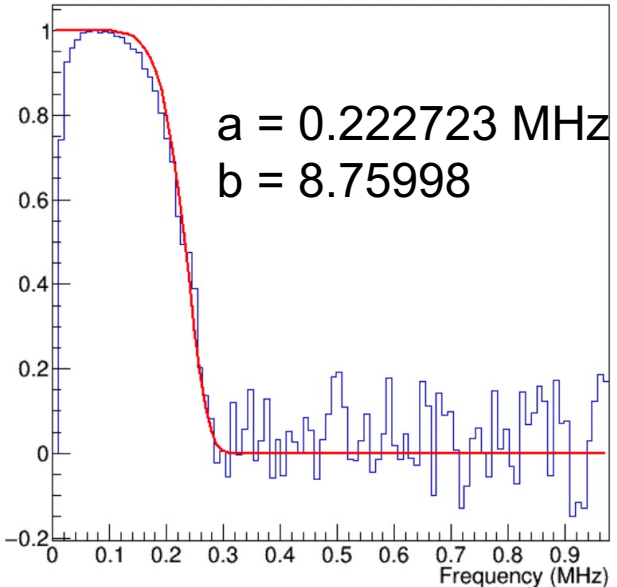
APA1 - W



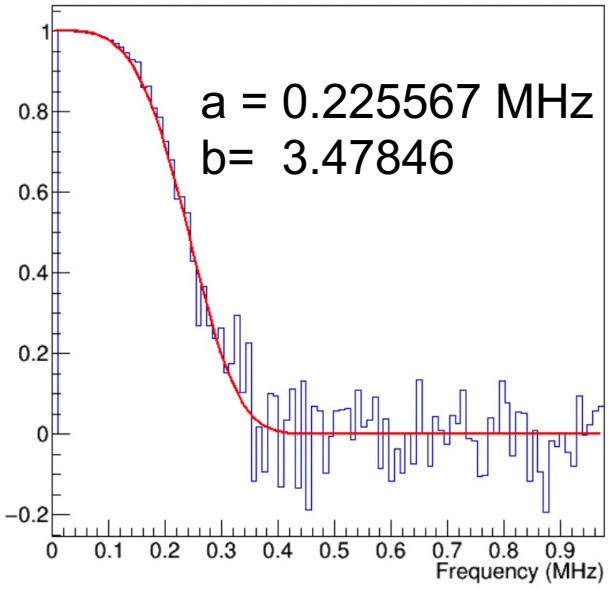
APA2 - U



APA2 - V

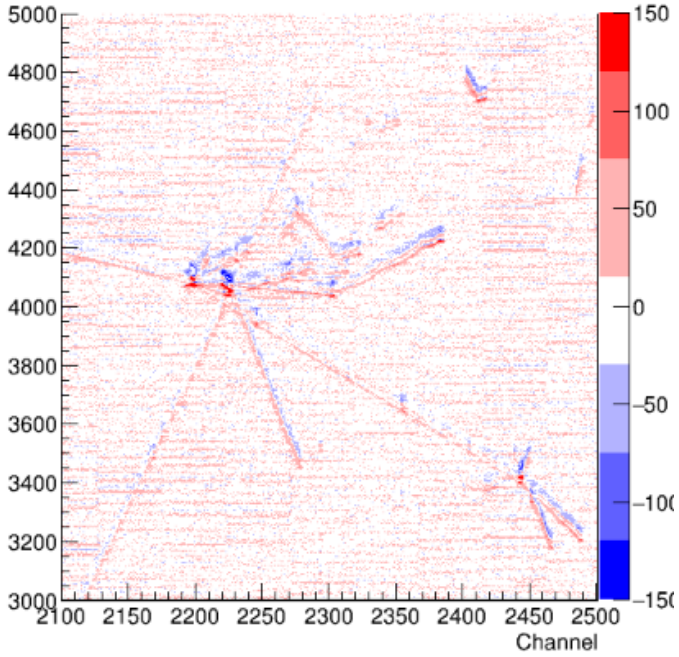


APA2 - W

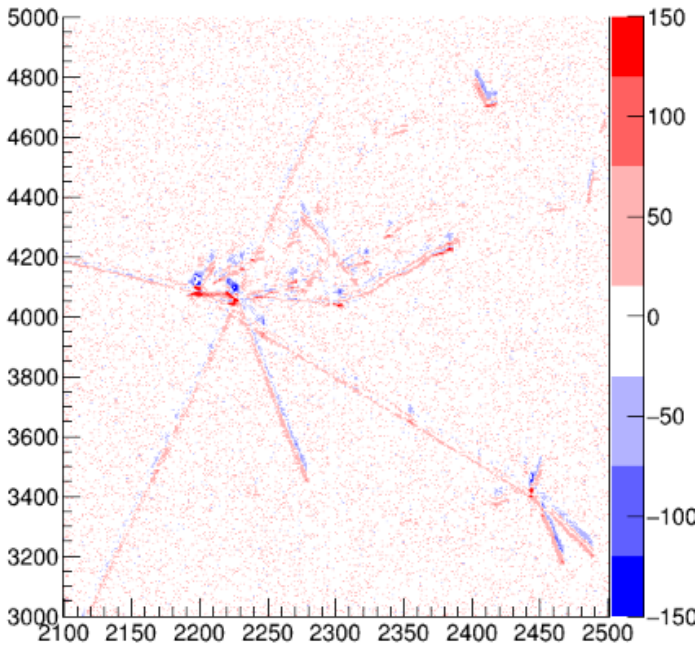


Application of updated Wiener filters

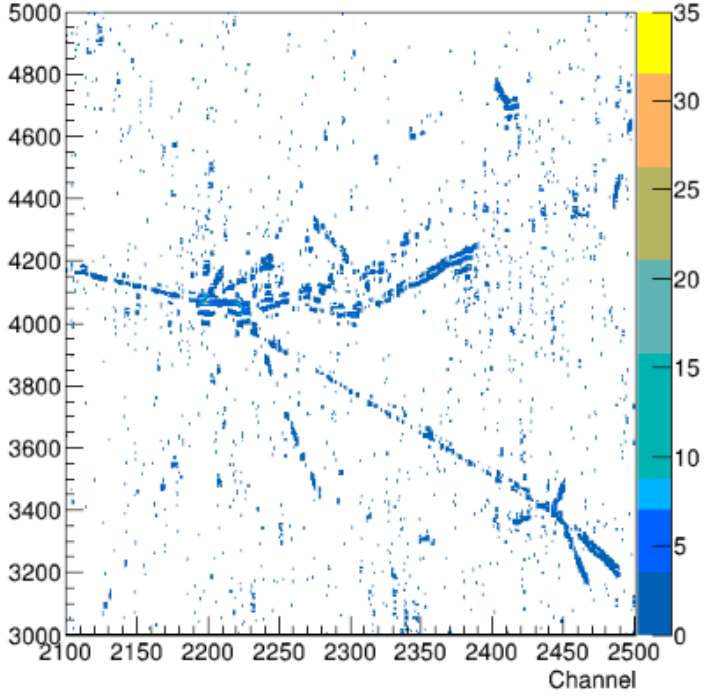
Run 27380 Event 2019
APA 1 - W plane



Raw waveform



Denoised
(CNR by Barnali et al.)



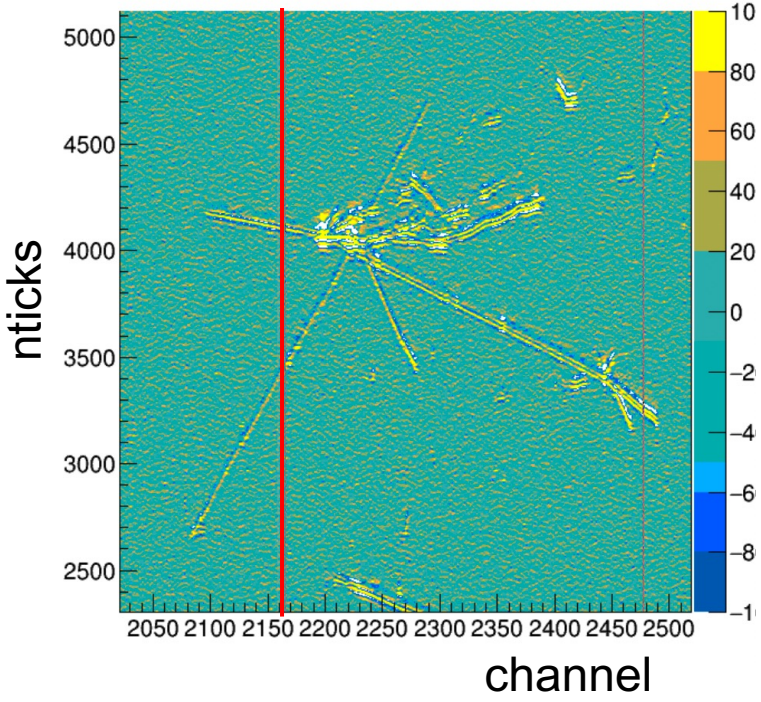
Deconvolution with new field response
(low thres. ROI: 2.5 r.m.s)

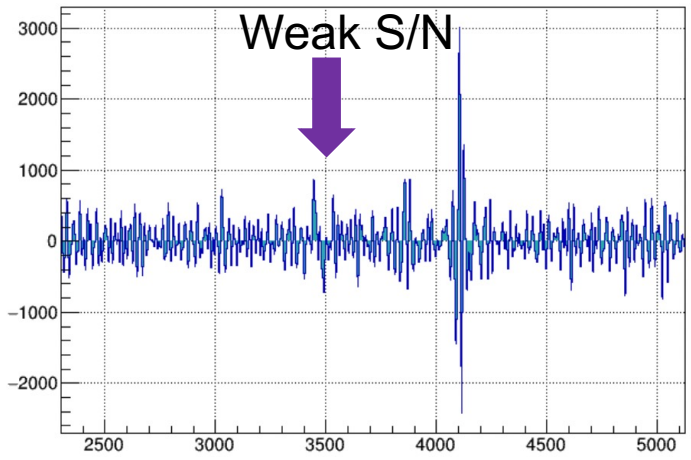
dunereco v09_91_03d00

- A proper treatment of induction (LF-cut filter, loose/tight ROI etc.) helps
- Would a more stringent Wiener filter further improve the result?

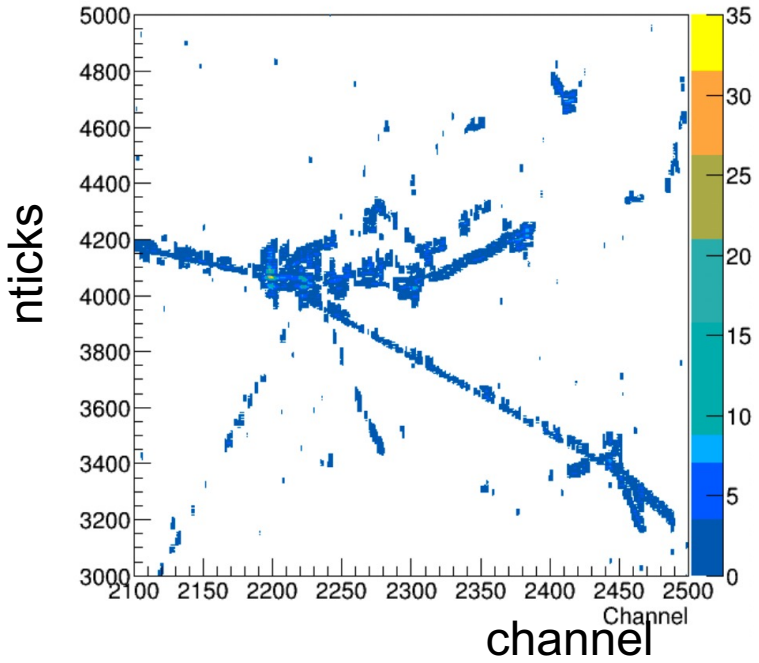
Update Wiener filter for APA1;w

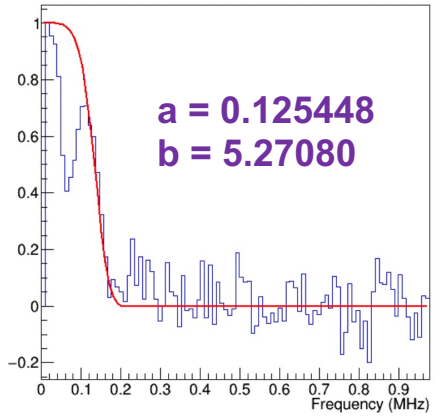
Initial deconvolution result with Wiener filter applied





Final deconvolution charge with ROI determined



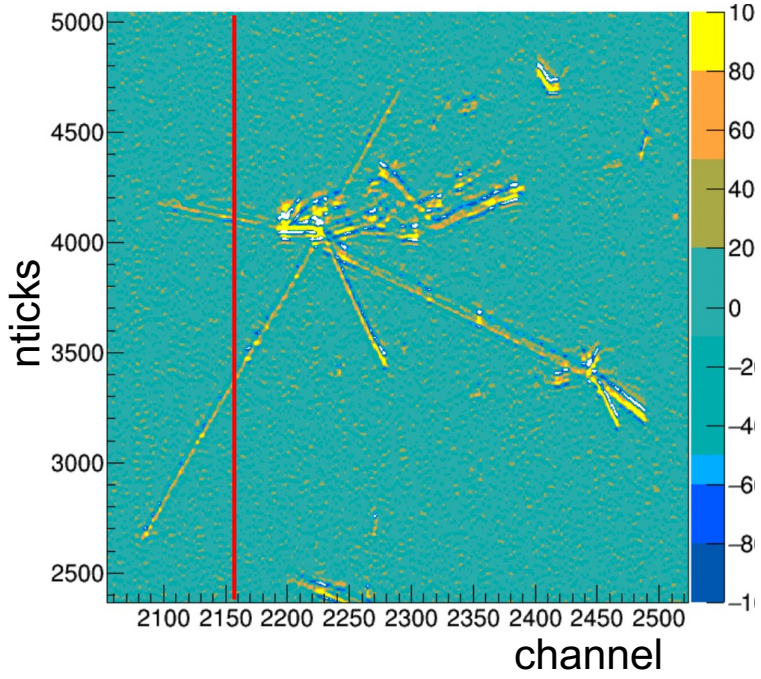


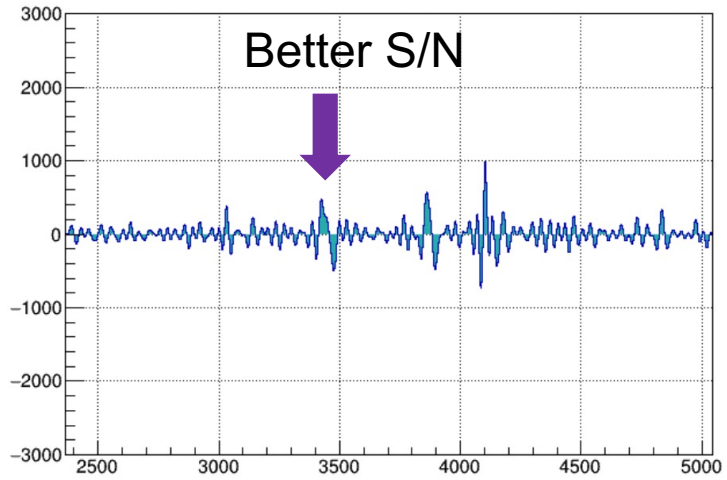
- ROIs will be determined from the deconvolution result with a few threshold cuts, a typical cut is 3 r.m.s.

- Wiener filter can be more stringent to improve the S/N
  - ➢Or reduce the thres cut, but not desired given more noisy result

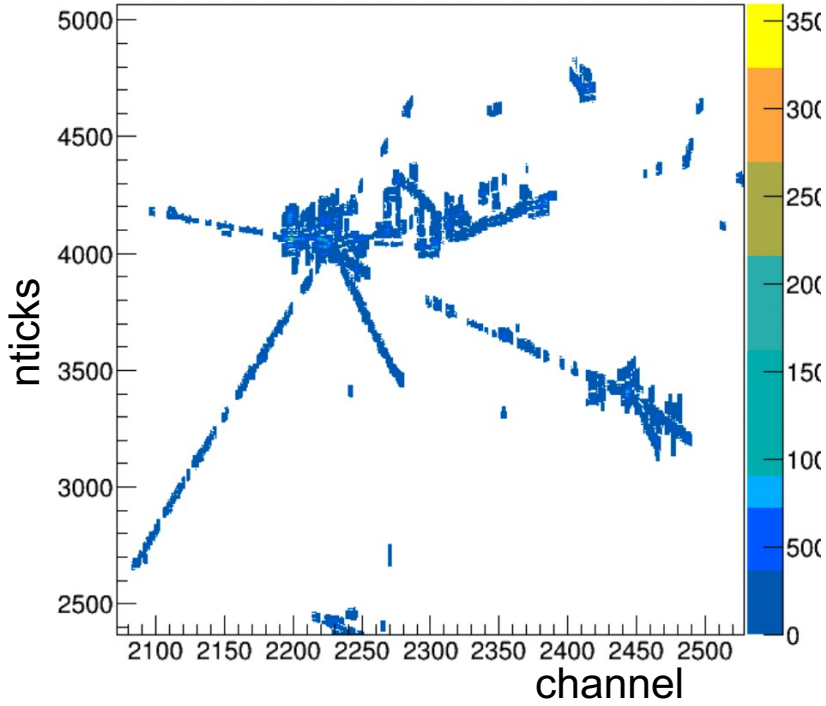
Update Wiener filter for APA1;w

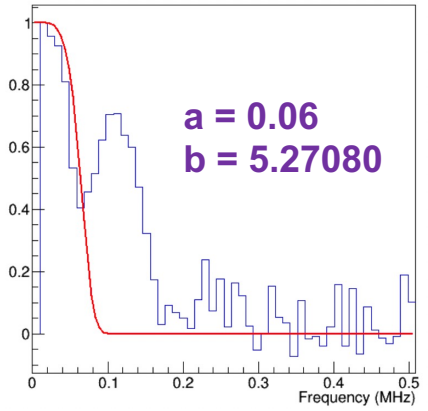
Initial deconvolution result with Wiener filter applied





Final deconvolution charge with ROI determined

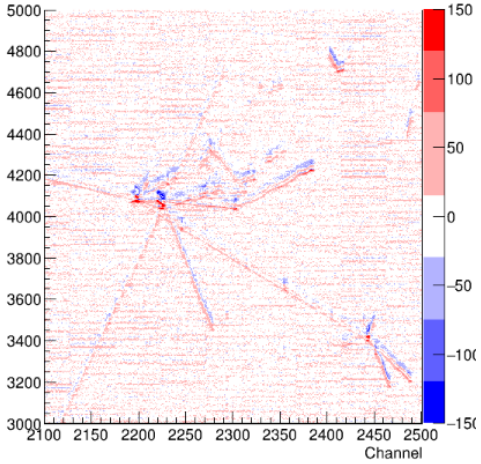




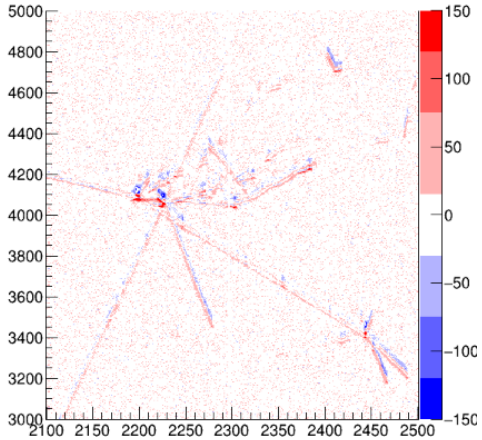
- Result improved although gaps still exist
- Need further study

Application of Wiener filters (cont')

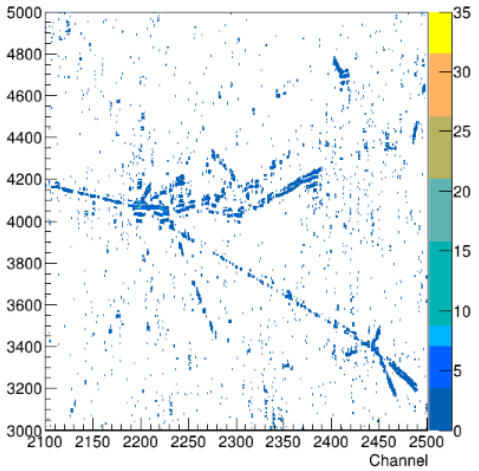
Run 27380 Event 2019
APA 1 - W plane



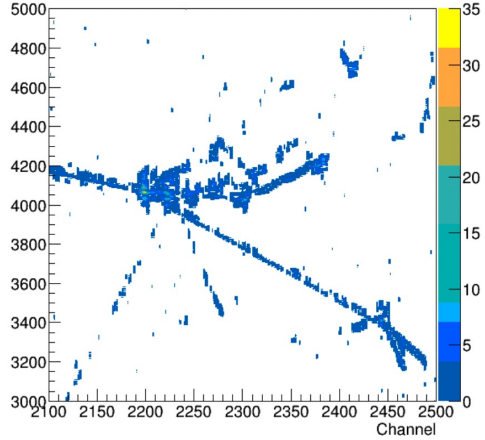
Raw waveform



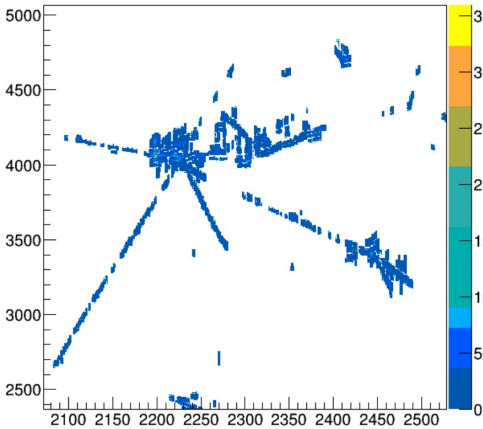
Denoised
(CNR by Barnali et al.)



Deconvolution with new field response (low thres. ROI: 2.5 r.m.s)
dunereco v09_91_03d00



Wiener filter:
a= 0.12 MHz



Wiener filter:
a= 0.06 MHz

- A stringent Wiener filter helps the ROI determination, while more ROI protection needed. May reduce threshold or more advanced tools

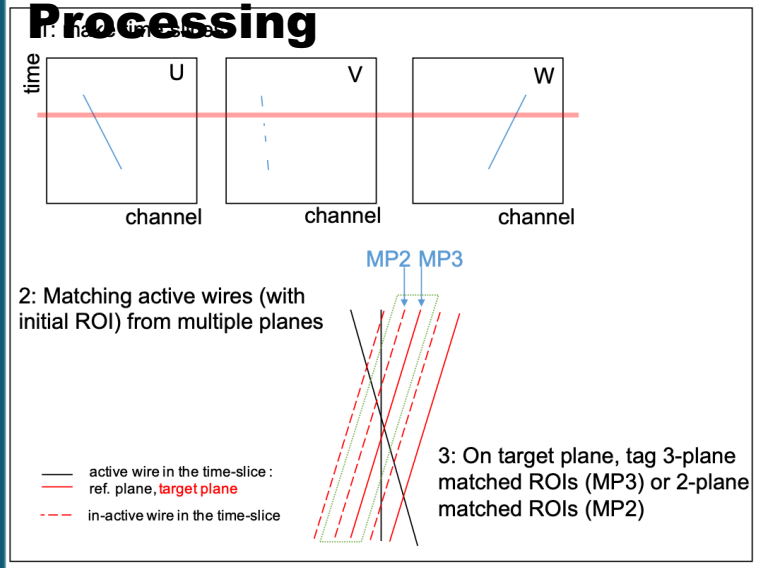
Summary and plan

- We revisited the signal processing chain in Wire-Cell and aim to improve the result, in particular, for APA1 W plane through:
  - Optimize Wiener filters with a data-driven noise model
  - Slightly reduce various thresholds for protecting ROIs given the stringent Wiener filter above
  - May consider more advanced tools such as multi-plane protection and DNN ROI identification (see Sergey's talk at the May colla. mtg.)
- Need more detailed calibration studies to validate the APA1 field response calculation
- Need to understand the SigProc efficiency/bias with simulation

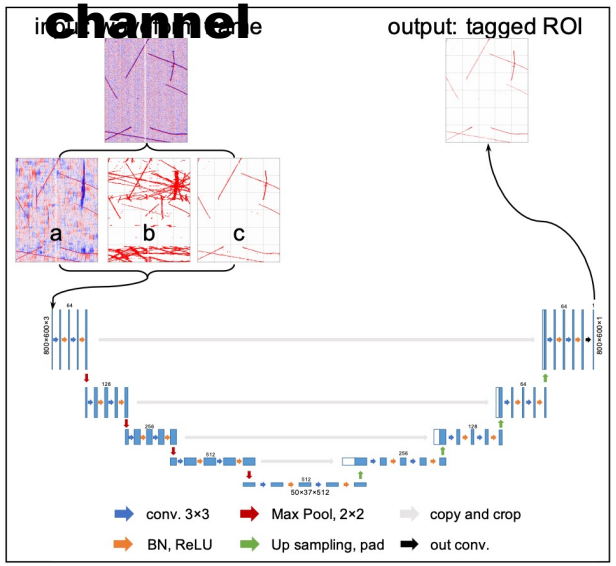
Backup

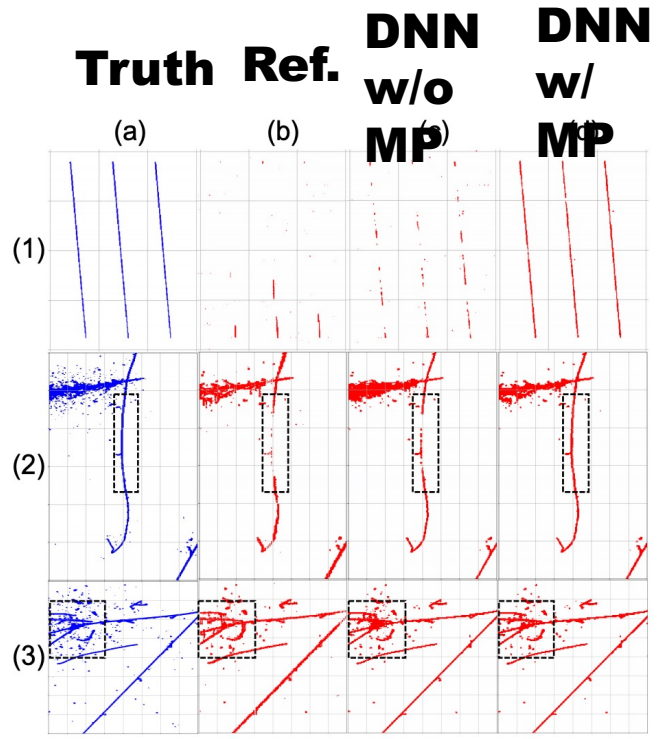
DNN ROI with 3-plane Information

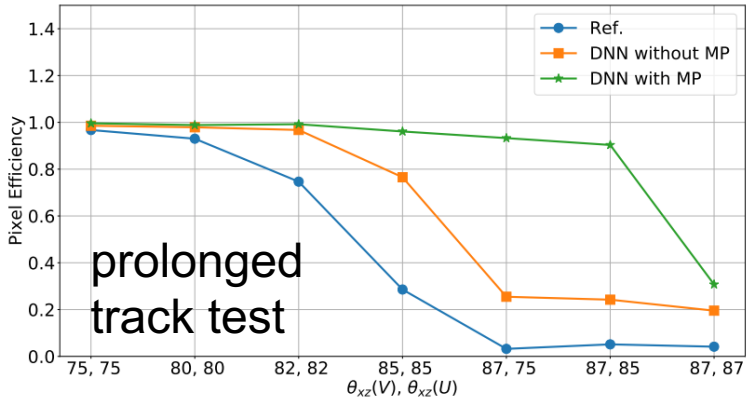
Multi-plane information in Signal Processing



DNN ROI finding with multiple input channel







- Information from other wire planes can be used to protect weak ROIs (e.g., low S/N in prolonged tracks)
- Deep learning technique can further improve the ROI refinement
- **Also see Sergey's talk in the May collaboration meeting**

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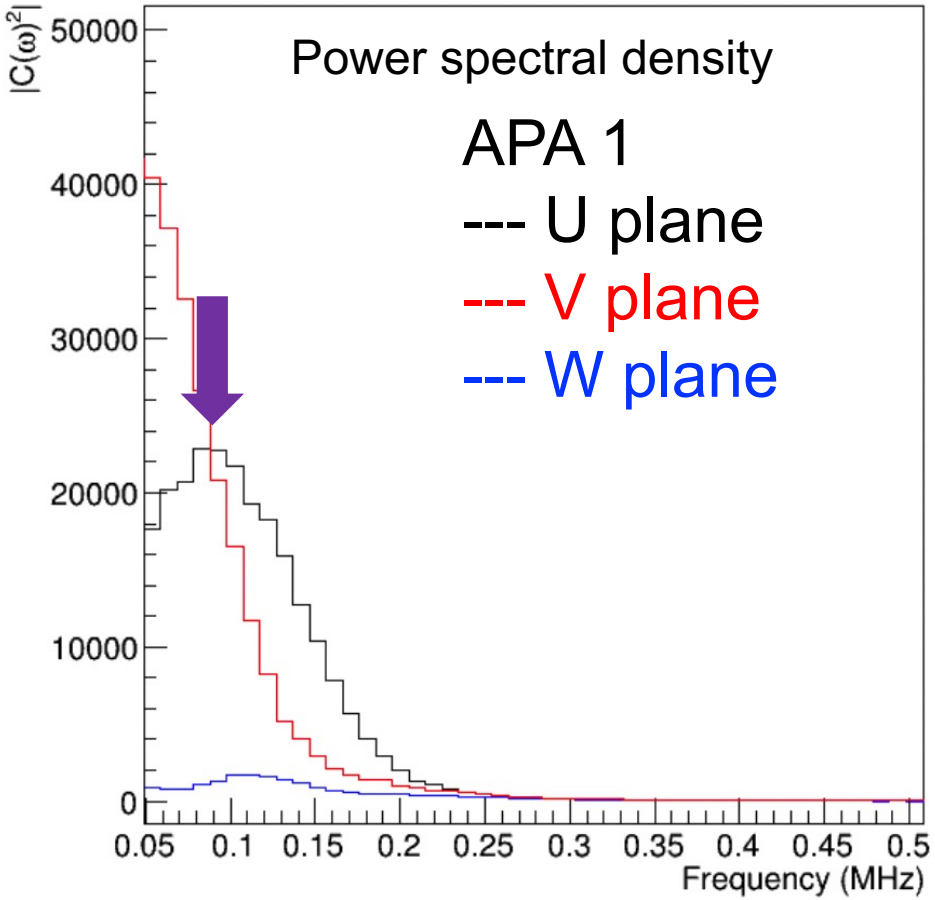
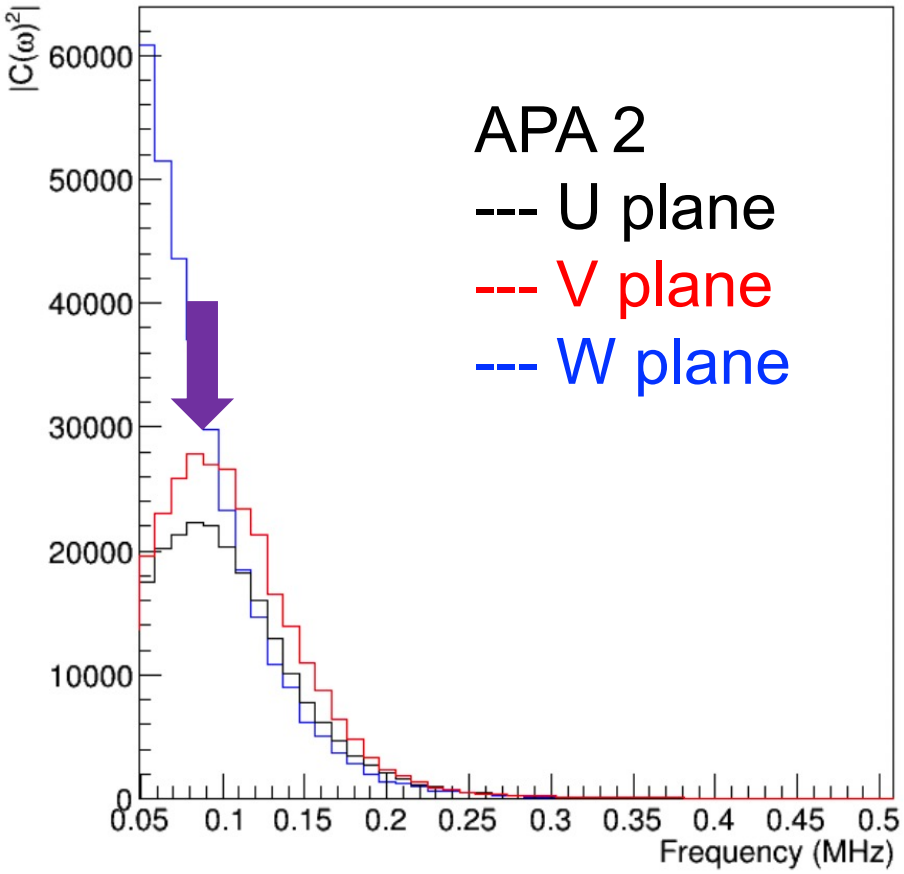
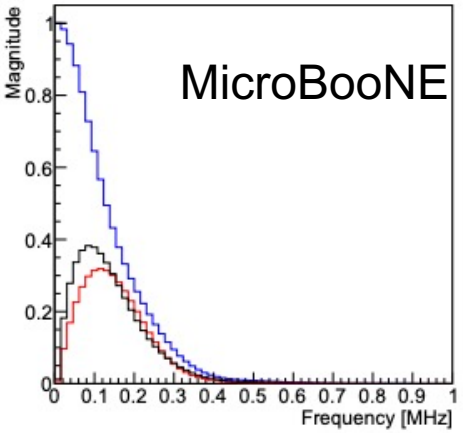
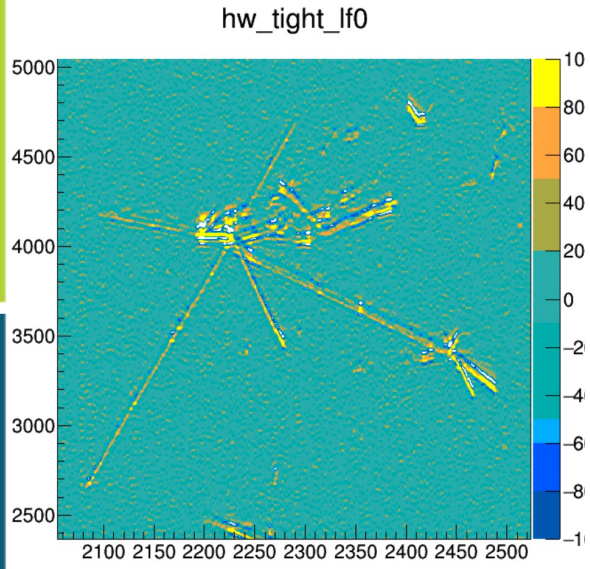


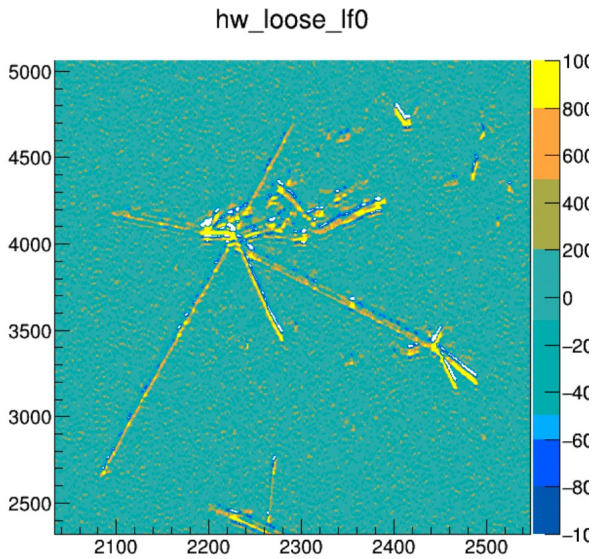


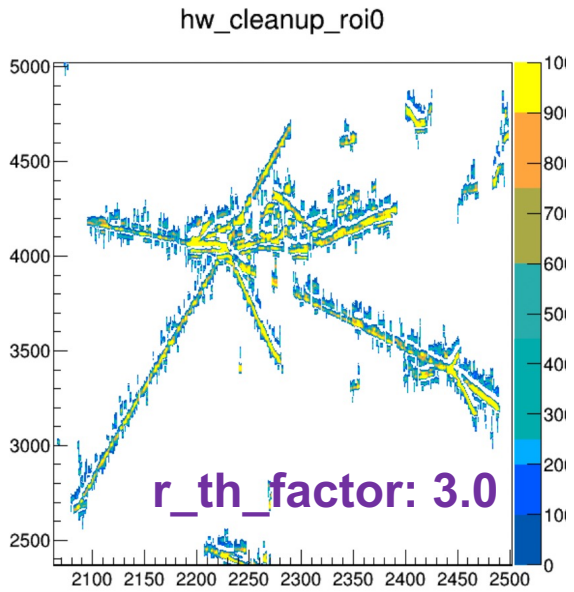
Low Frequency (LF) cut filter: $F(\omega) = 1 - e^{-\left(\frac{\omega}{\tau}\right)^2}$

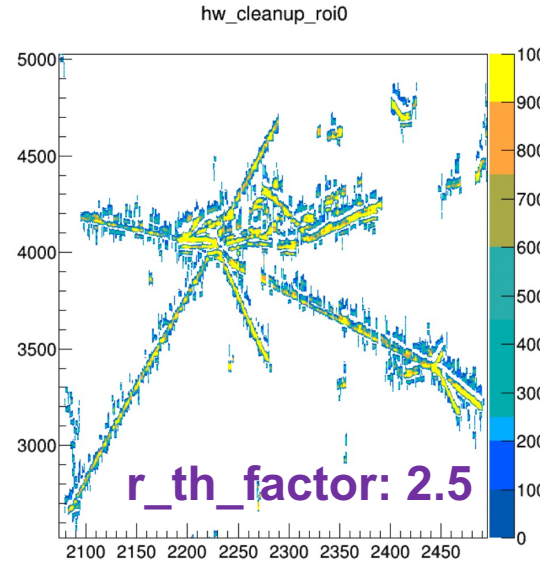
τ (unit of MHz)	Loose_lf	Tight_lf	Tighter_lf
MicroBooNE	0.0025	0.02	0.1
PDHD	0.002	0.016	0.08



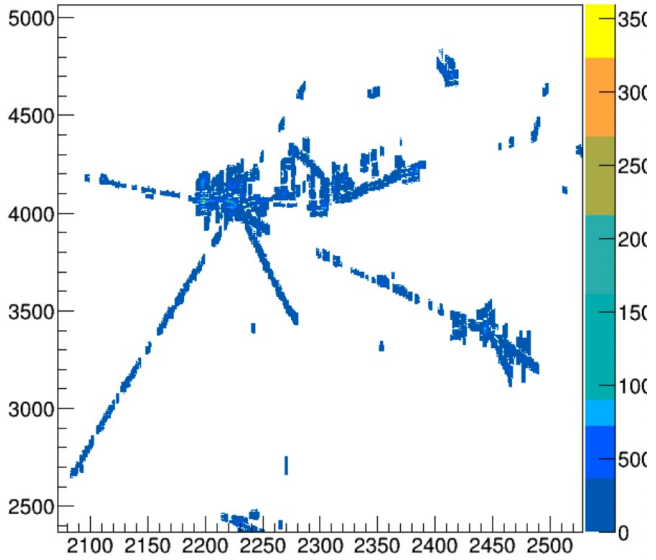




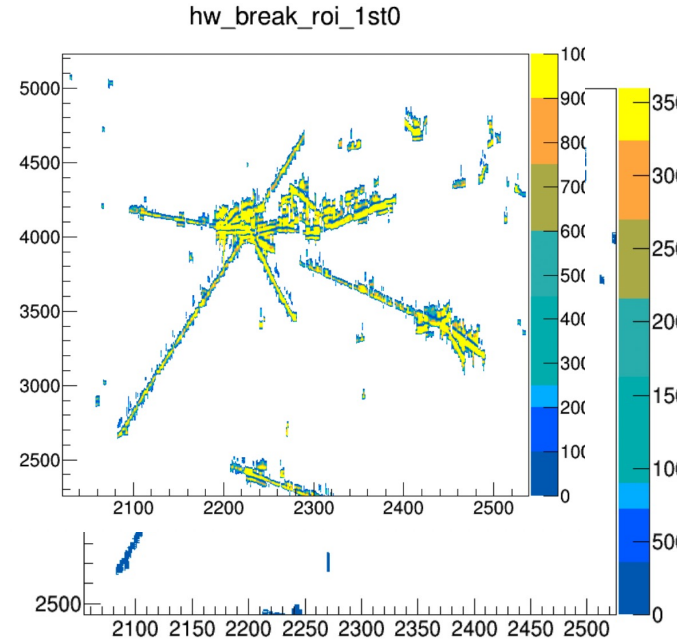




troi_ind_th_factor: 3.0
lroi_th_factor: 3.5
r_th_factor: 3.0



troi_ind_th_factor: 3.0
lroi_th_factor: 3.5
r_th_factor: 2.5



Cleanup ROIs: to ensure bin content inside ROIs is above threshold (r_th_factor=3)

- Loose ROIs are clustered according to connectivity info
- A loose ROI cluster is removed if none of its loose ROIs contain tight ROIs

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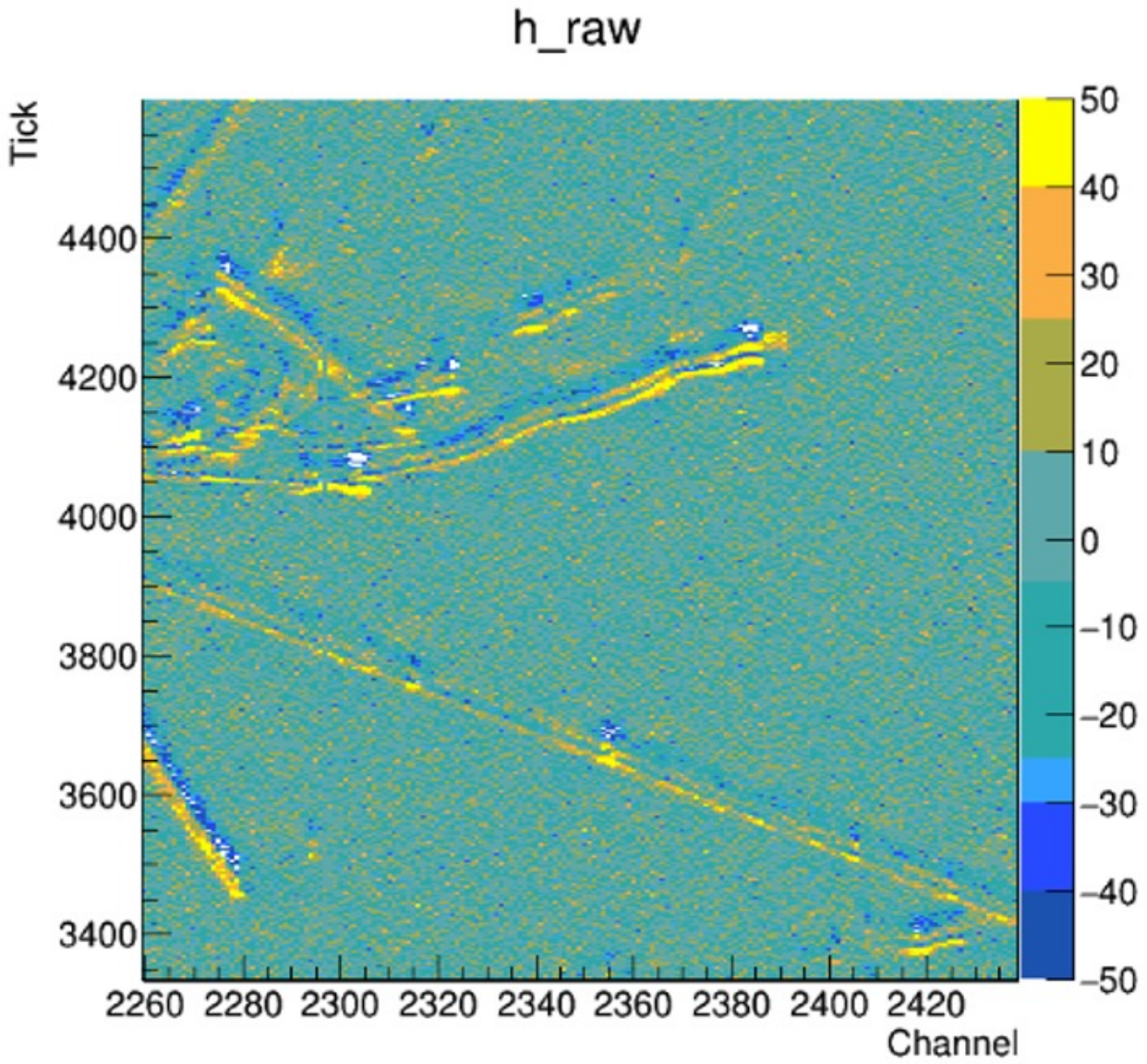
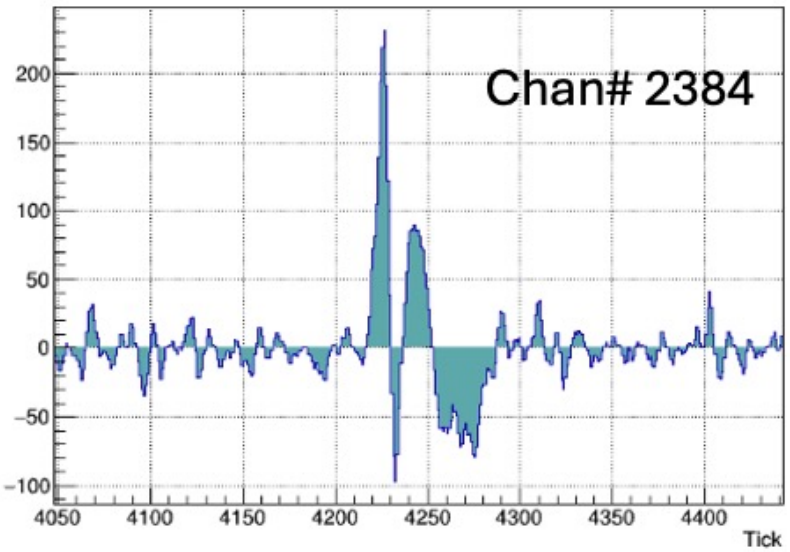


- Double peaks are visible in the real data of APA1 W plane



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