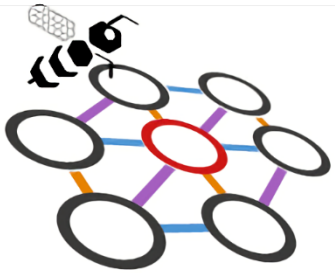
DEEP UNDERGROUND NEUTRINO EXPERIMENT

Multi-plane Signal Processing for Prolonged Tracks

Haiwang Yu (BNL)
for the Wire-Cell team
Oct. 30, 2019



BROOKHAVEN NATIONAL LABORATORY

Brief review of Signal Processing in Wire-Cell

Extract S using 2D deconvolution

$$M(t',x') = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} R(t,t',x,x')\cdot S(t,x)dtdx$$

$$S(\omega_t,\omega_x) = \frac{M(\omega_t,\omega_x)}{R(\omega_t,\omega_x)}$$

Filters in frequency domains used to suppress noise

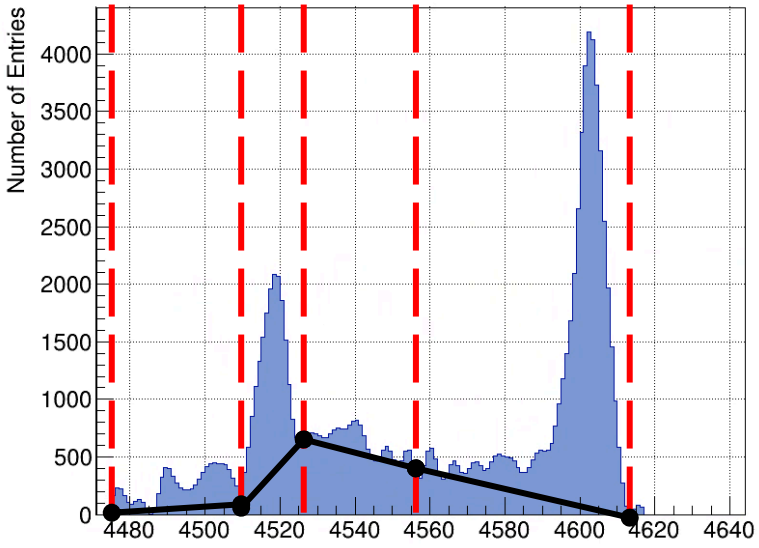
- electronic
- LF noise due to field response shape

Further, back to time (space) domain, ROIs (region of interests) are used to further remove background noise

- e.g. “BreakROI” is used to further reduce local LF noise

Refer to *JINST 13 P07006 (2018)*

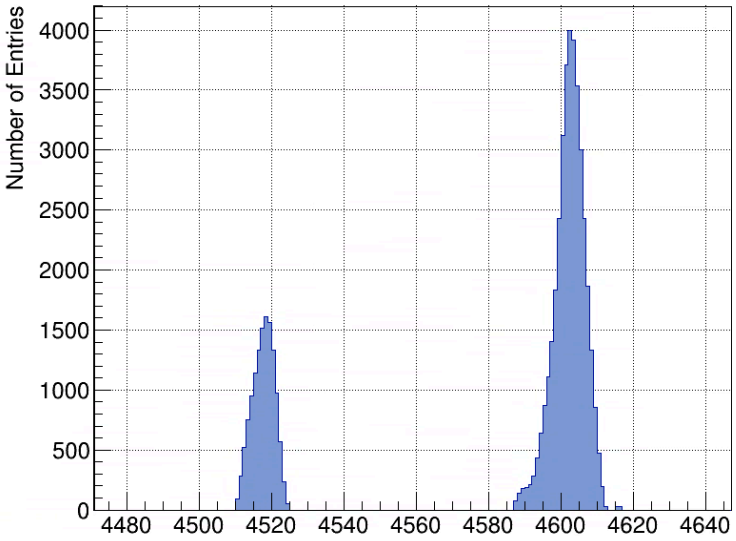
deconvoluted waveform
Peak/valley finding
Baseline subtraction



BreakROI

- Baseline subtraction
- thresholding

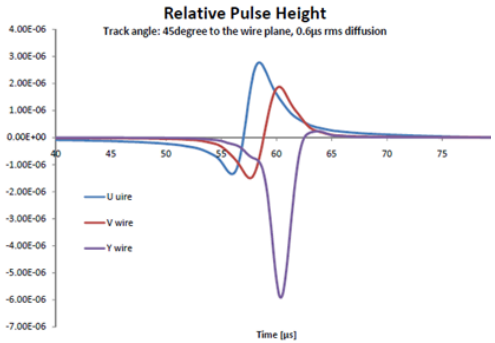
SP result



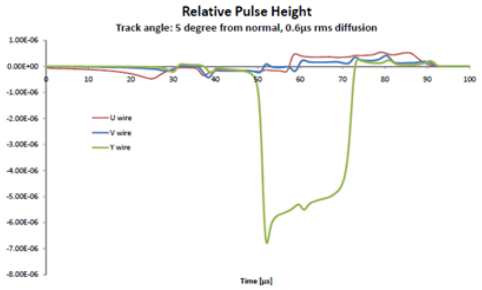
prolonged tracks

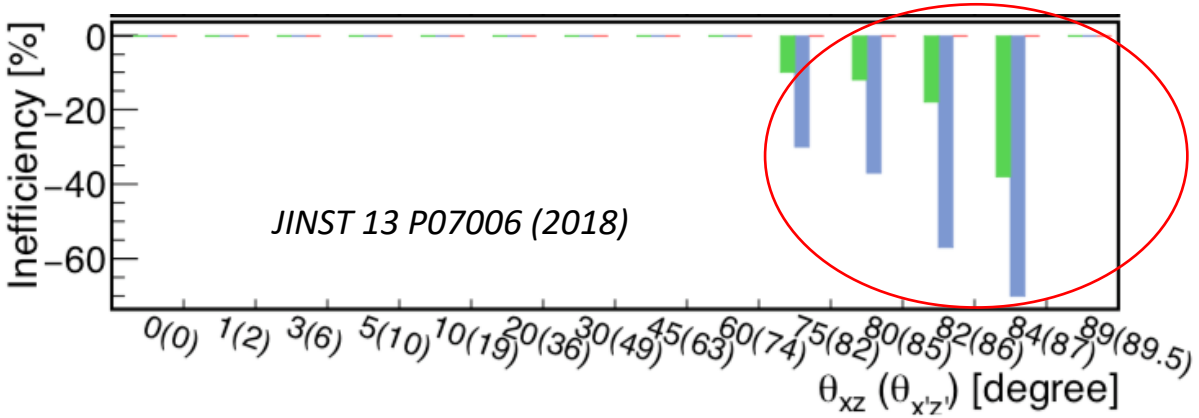
- Due to the bipolar shape of induction plane field response, if a track is near perpendicular to the wire-pitch direction from the wire-pitch-drift projection view, similar charge would hit a same wire repletely causing signal to cancel – prolonged tracks
- After deconvolution, prolonged tracks also show as low frequency signals which could be removed by the "BreakROI" step

45 degrees

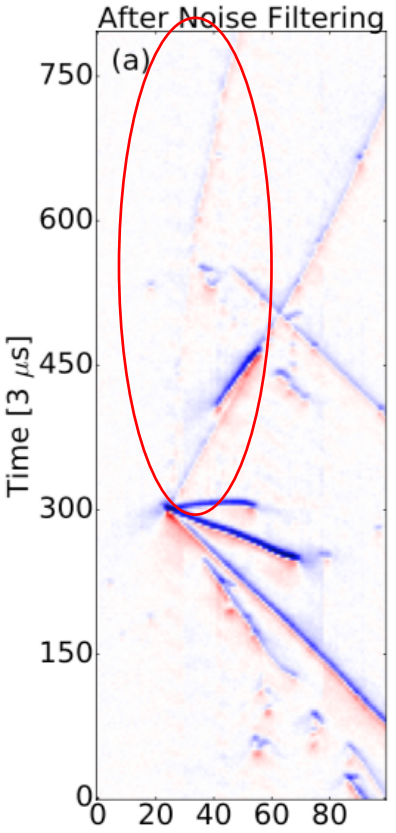


85 degrees





JINST 13 P07006 (2018)

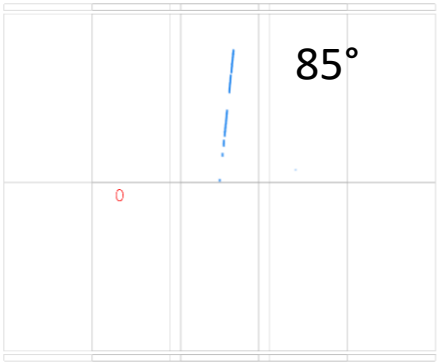


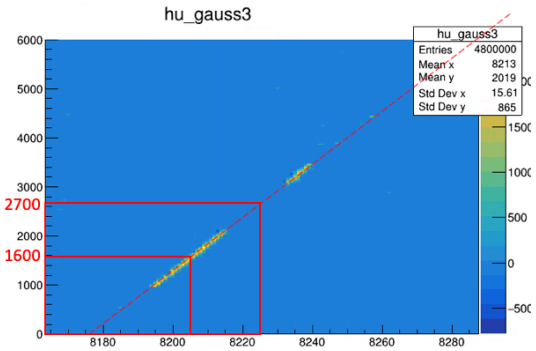
JINST 13 P07006 (2018)

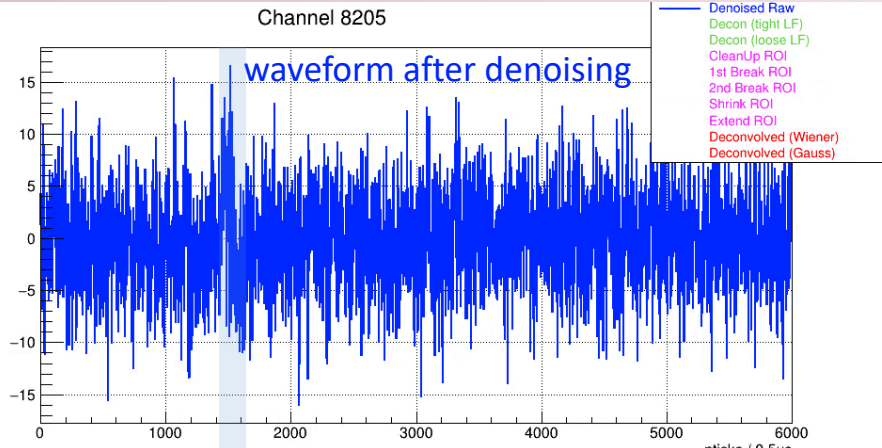
Lost in `BreakROI`

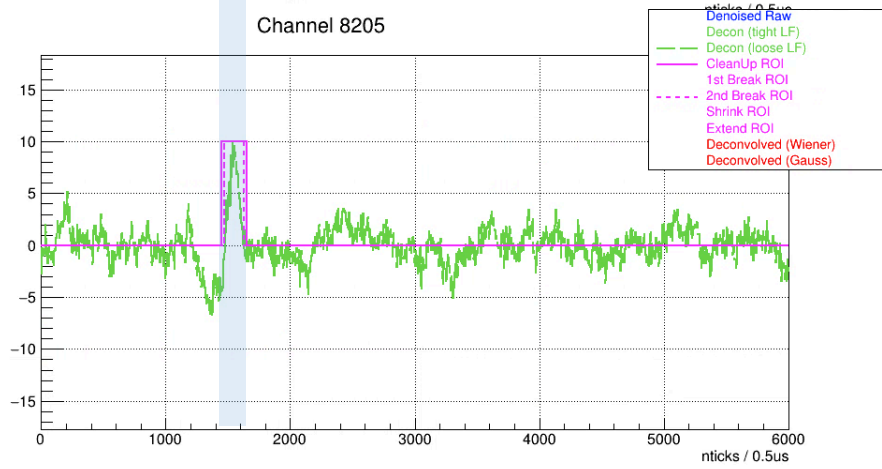
- Weak signal in raw waveform
- With proper filter, signal could be enhanced after 2D deconvolution
- Due to the LF nature of the signal, some of the ROIs are lost after 'BreakROI' step

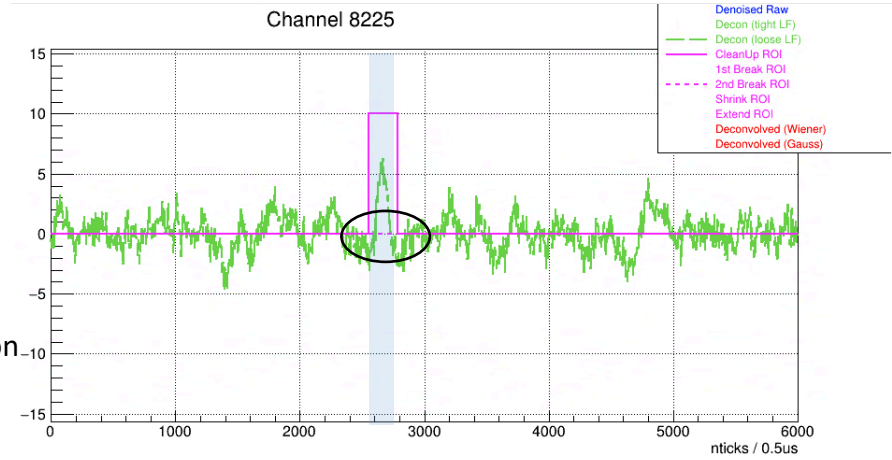
prolonged track-sim









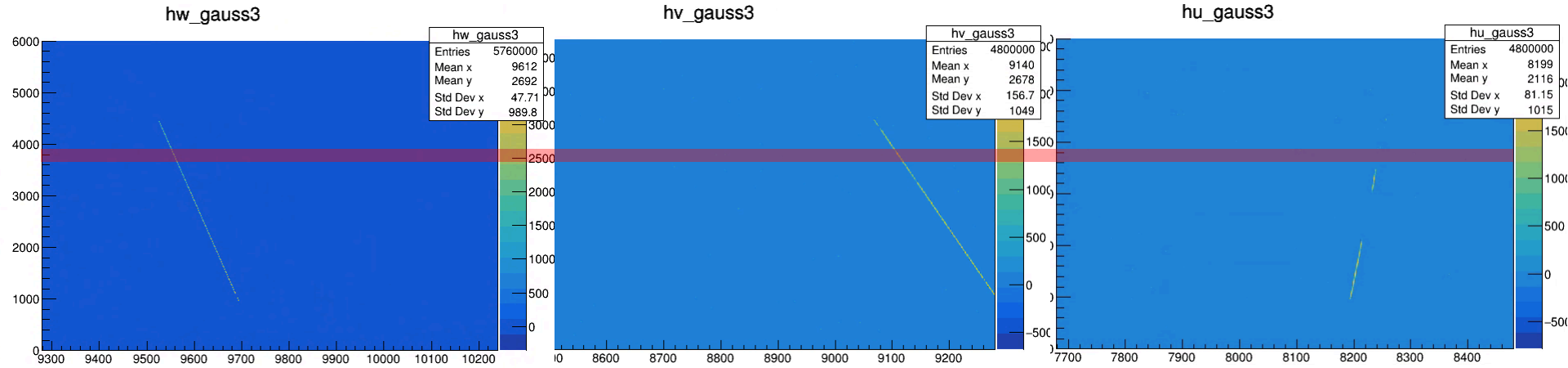


Used Wenqiang's OScope tools in this exploration
https://github.com/BNLIF/Magnify-protodune/tree/master/test_feature/oscope

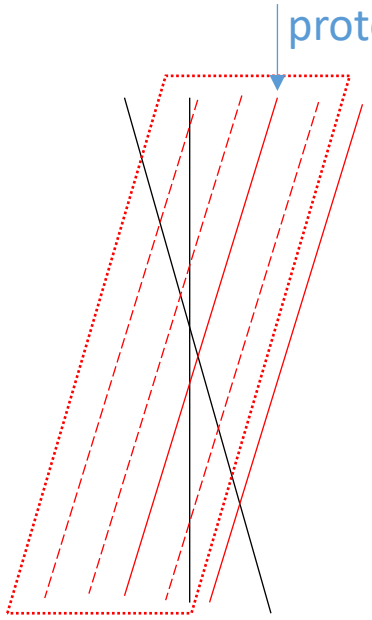
Using multi-plane information in SP

proposed by Xin Qian

1, make time slices



2, Matching active (with ROI) wires in multiple planes



active wire in the time-slice :
ref. plane, target plane

in-active wire in the time-slice

3, mark matched ROIs as ‘protected’

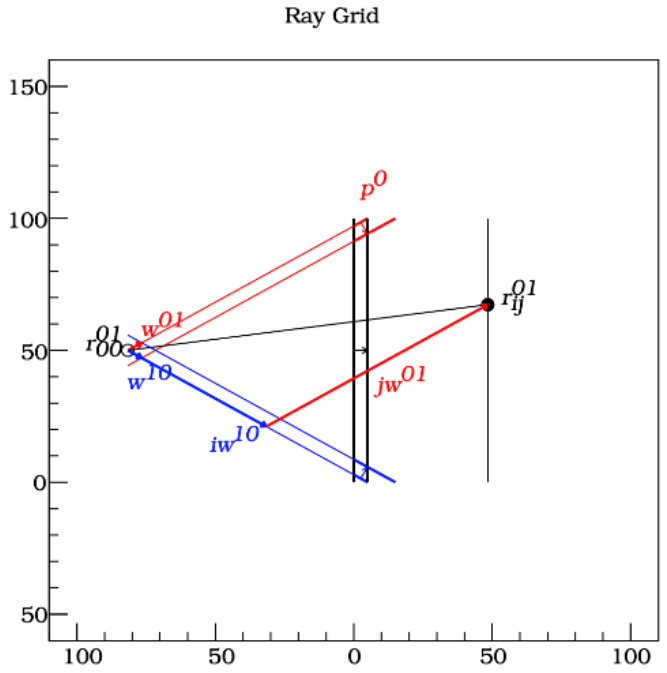
RayGrid Projection

One key algorithms is the projection algorithm – RayGrid Projection by Brett Viren (BNL)
https://github.com/WireCell/wire-cell-docs/blob/master/presentations/updates/20190321/latexmk-out/img.pdf

*Combining two 1-D ray grids form a **regular 2D grid**, may provide a **non-orthogonal coordinate system**.*

Each ray grid is one "layer".

- p^l relative **pitch vector** for layer l.
- c^l the **origin point** (center of **ray0**) for layer l.
- r_{ij}^{lm} a **crossing point** of ray i from layer l and ray j from layer m.
- w^{lm} relative **displacement vector** for layer l connecting crossing points of neighboring layer-m rays on a ray of layer l.



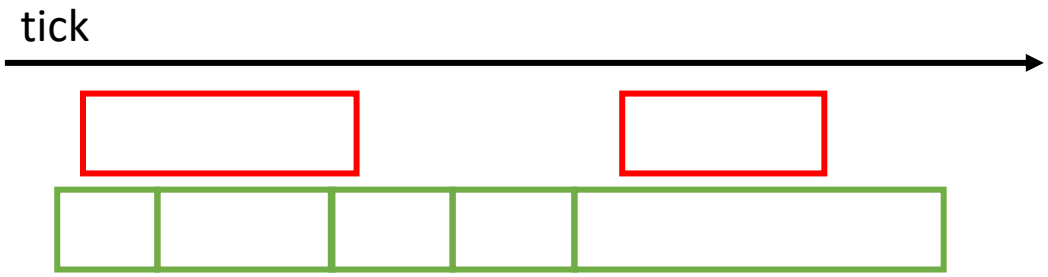
Given vectors p^l, c^l and tensor w^{lm} for **two layers** and one explicitly calculated crossing point r_{00}^{lm} the tensor of **all other crossing points** r_{ij}^{lm} is trivial:

$$r_{ij}^{lm} = r_{00}^{lm} + jw^{lm} + iw^{ml}$$

Using multi-plane info in ‘BreakROI’

Instead of protecting whole ROI, consider using finer time-slice-wise information in the BreakROI step

- Bookkeeping of which time zones are protected
- Consider that information when performing ‘baseline subtraction’ in ‘BreakROI’



MP: mp-protection zones

BreakROI: single plane valleys from peak finding

Tried strategies:

Baseline subtraction
Keep original waveform

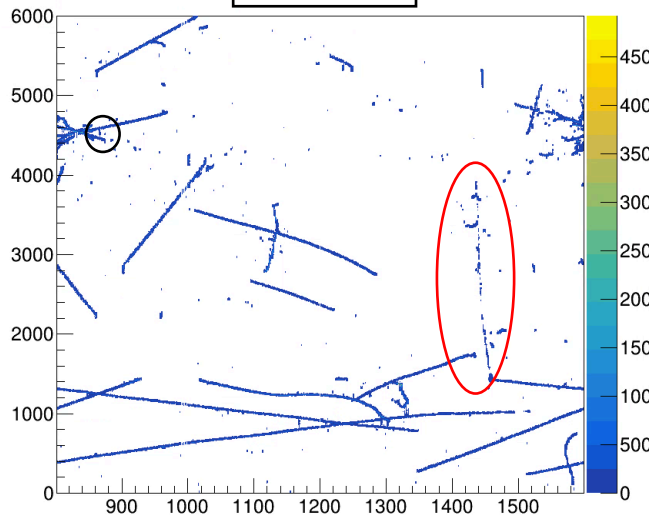
any overlap - still too noisy

mid (~peak) in zone - current best

Multi-plane Signal Processing (mp-sp) – current result

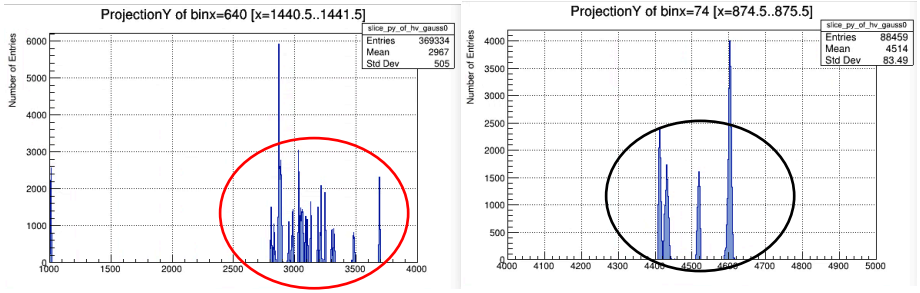
Low frequency (LF) signal and LF noise could be separated using multi-plane information

no mp-sp

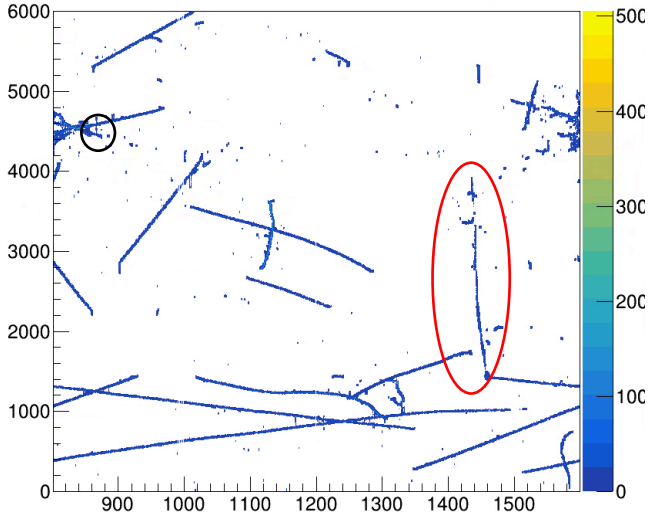


LF signal

LF noise

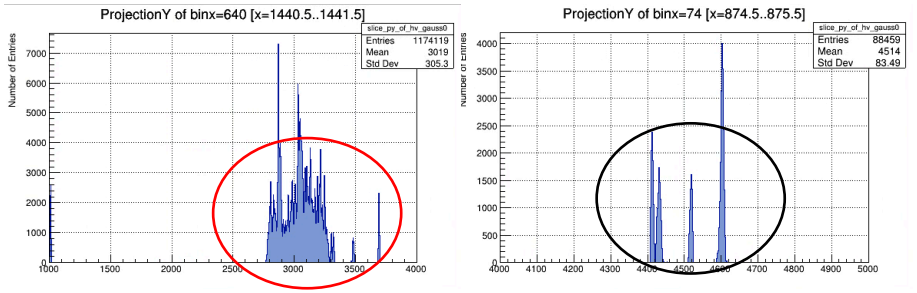


mp-sp



LF signal

LF noise



Summary

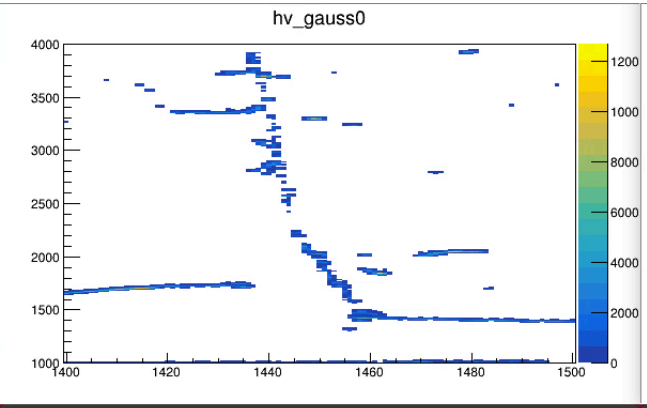
- Multi-plane SP was inspired by Wire-Cell 3D imaging - using more raw information
  - utilizing the redundency of planes
  - preserve the signal as SP stage
- Looks promising in distinguishing low frequency signal and noise

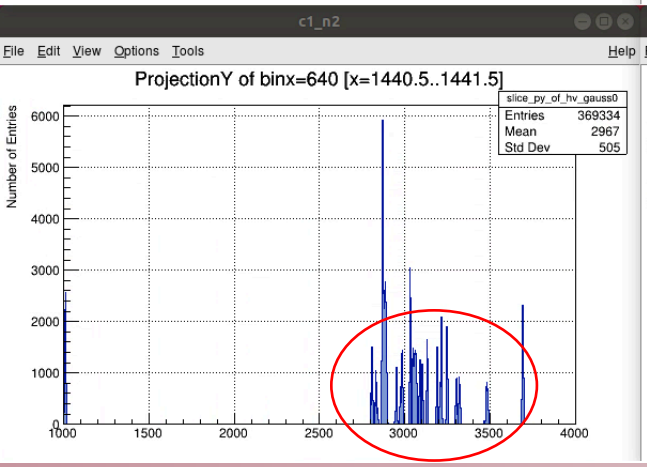
Next

- More failure mode analysis using data
  - remove extra noise
- Systematic evaluation using simulation
- Implementation optimization for speed
- Suggestions?

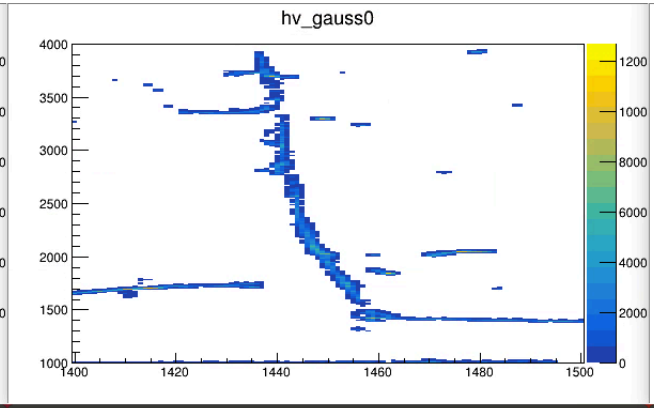
True LF signal survived

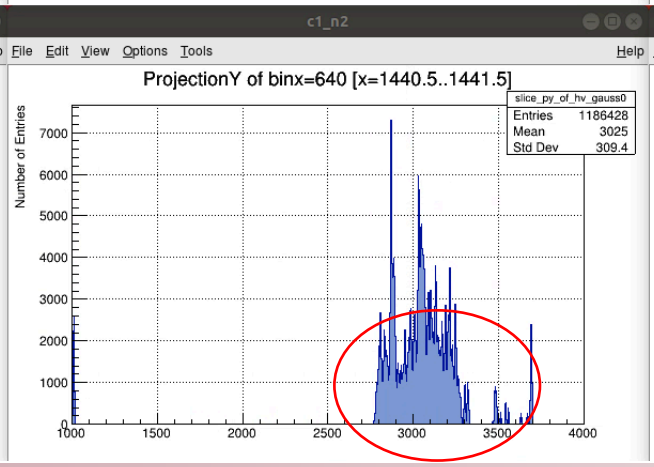
no protection - baseline



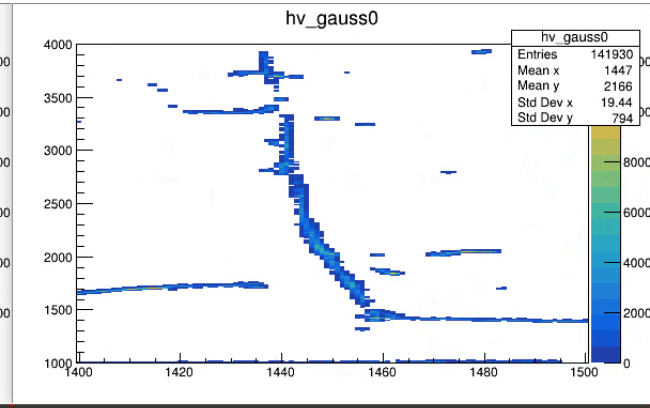


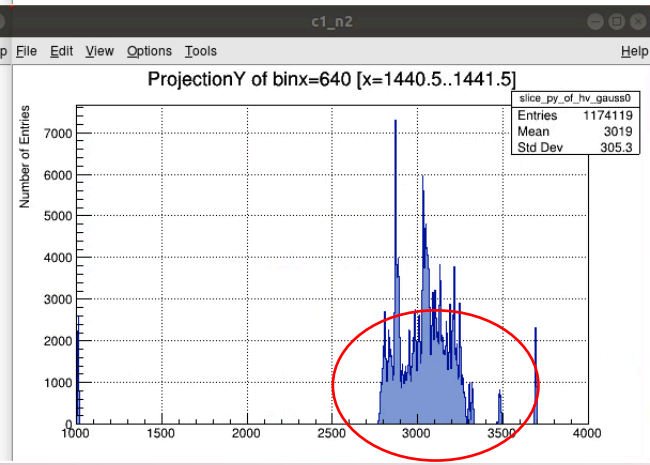
whole ROI protection - PR3





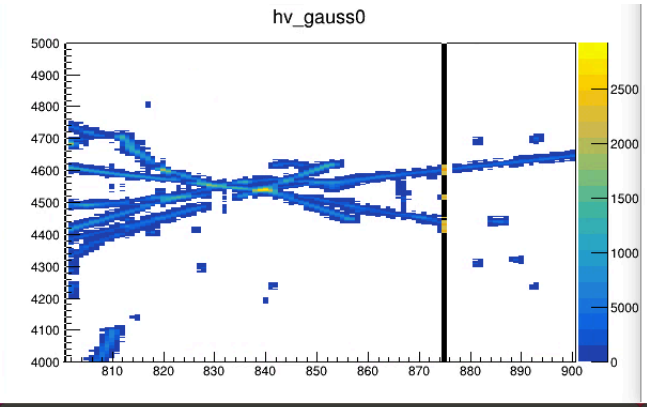
slice-wise protection - current dev

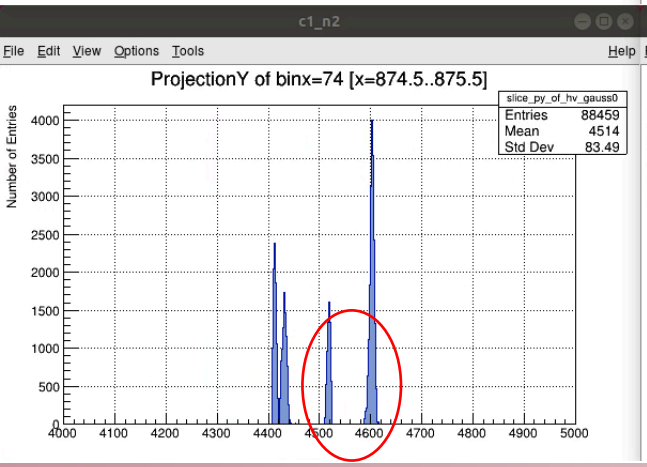




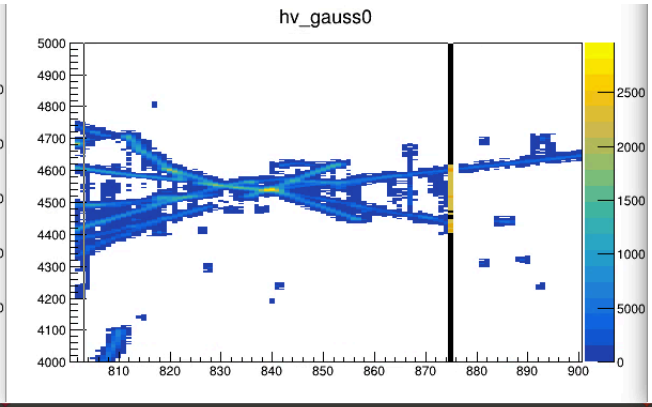
False LF signal (noise) removed

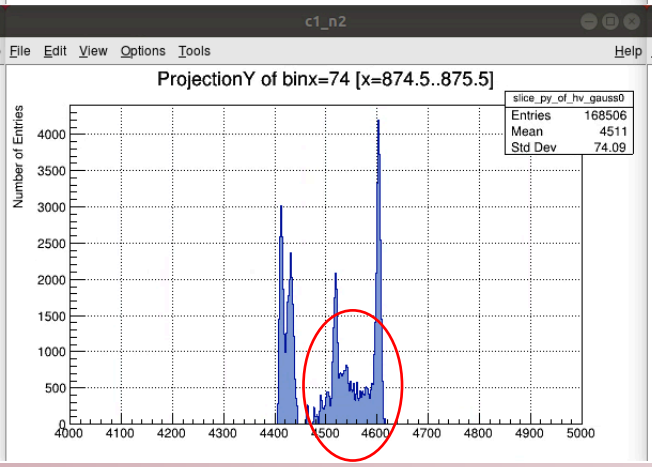
no protection - baseline





whole ROI protection - PR3





slice-wise protection - current dev