Concept clarifications of Wire-Cell simulation and signal processing

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LArSoft Coordination meeting

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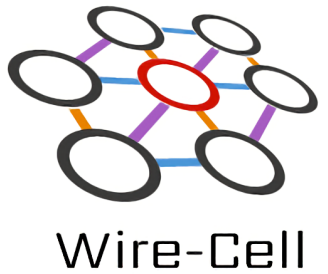
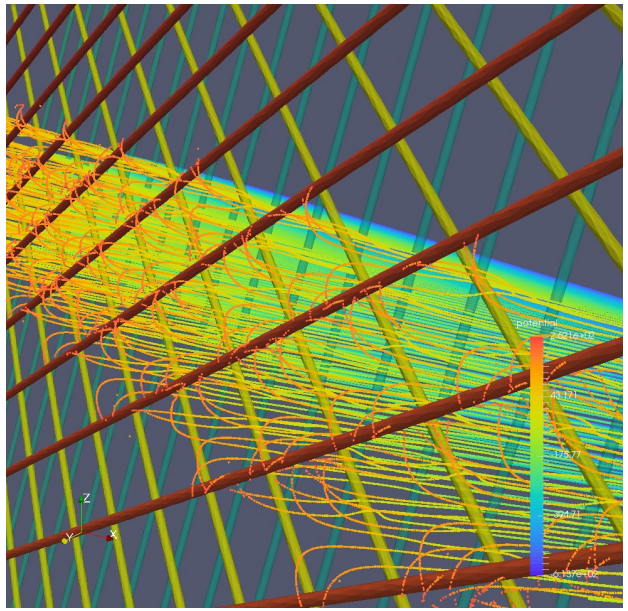


2D-Convolution based LArTPC Simulation/SigProc

$$\text{Ramo's theorem: } i = -q\,\vec{E}_w \cdot \vec{v}_q$$



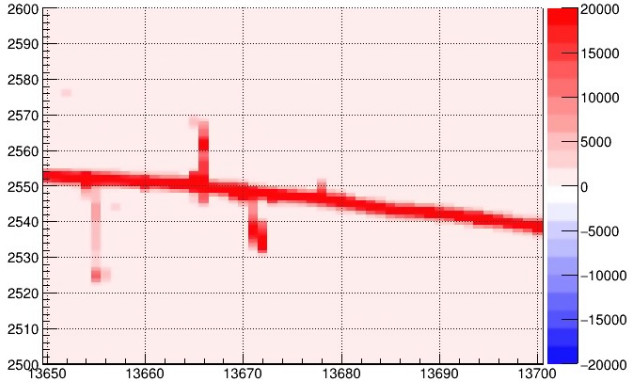
2D: approximate translational symmetry along the wire direction

LArTPC wire-readout measures induced charge ⊗ response

$$M(t', x') = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} R(t, t', x, x') \cdot S(t, x)\, dt dx + N(t', x')$$

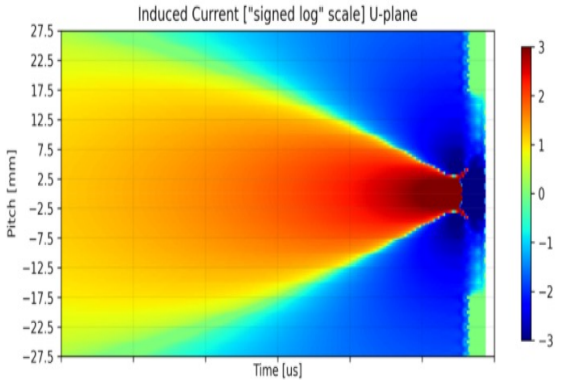
Note: x here is the wire pitch direction NOT the drift direction

Energy depo + drifting + diffusion + rasterization



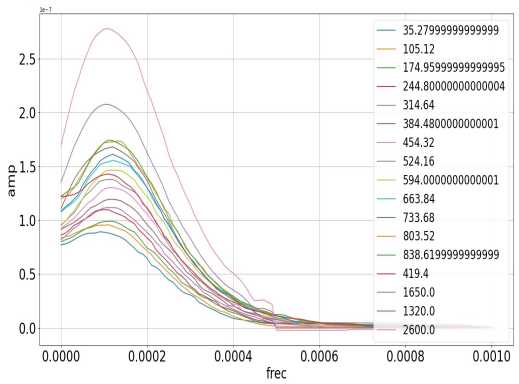
⊗

Long-range and position-dependent field response



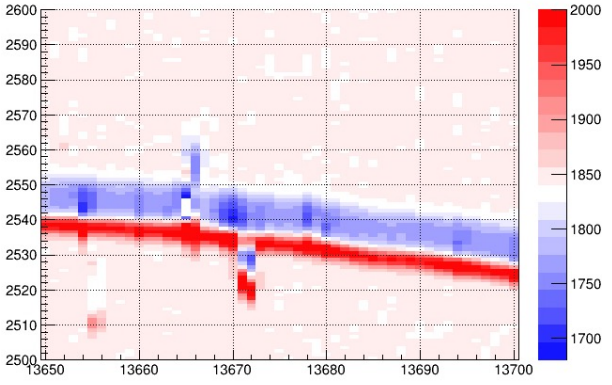
⊕

Noise Spectrum



→

Final Signal

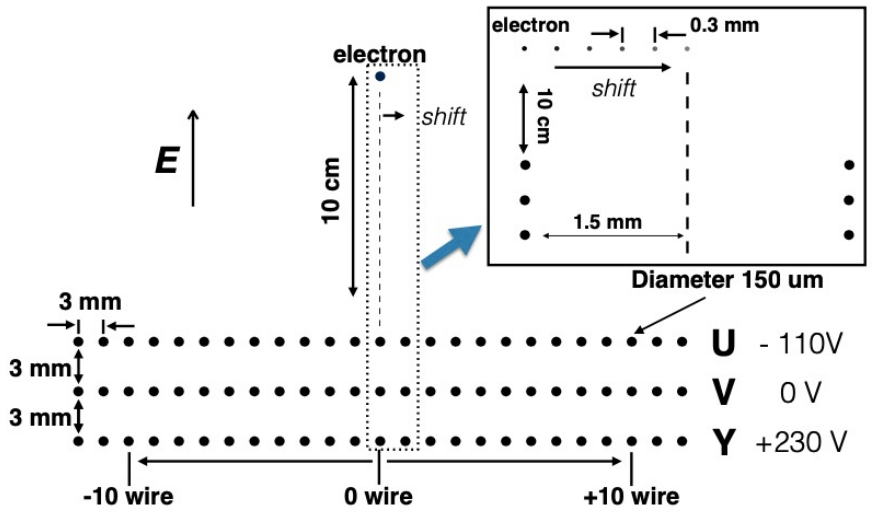


Drift velocity is NOT constant near APAs

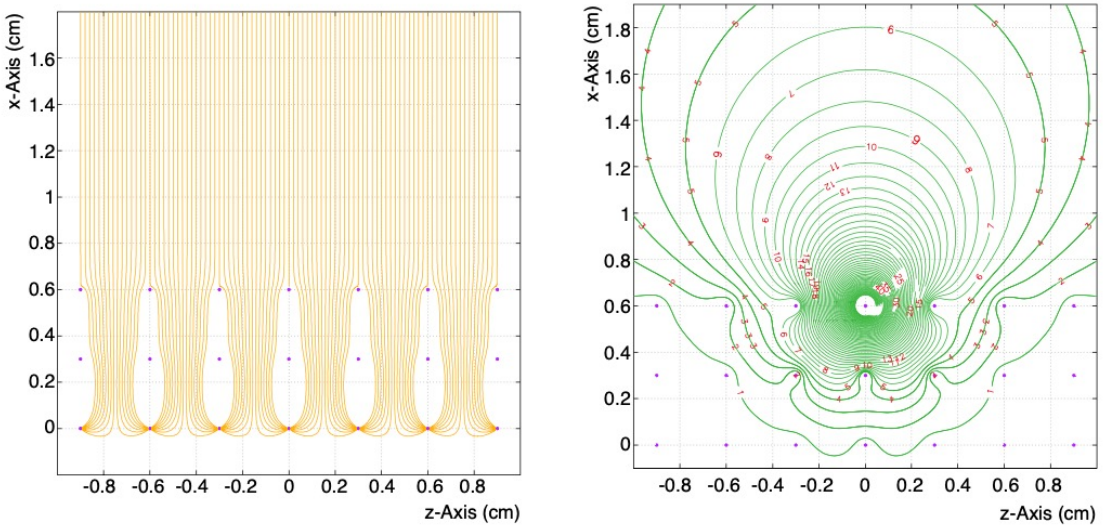
R(t,x) is calculated w.r.t. charge (t,x) distribution at a "response plane"

- 10 cm from collection plane for MircroBooNE and PDSP FR currently used in Wire-Cell
- **drift velocity is NOT constant in this range**
- an effective, constant velocity is calculated
- the effective velocity is used to transport all signals from their times at the response plane to times at the collection plane.

To illustrate response plane arxiv:1802.08709



Garfield Simulation for MicroBooNE, arxiv:1802.08709



(a) Electron drift paths. (b) Weighting potential on a U wire.

[PDSP Field Response]

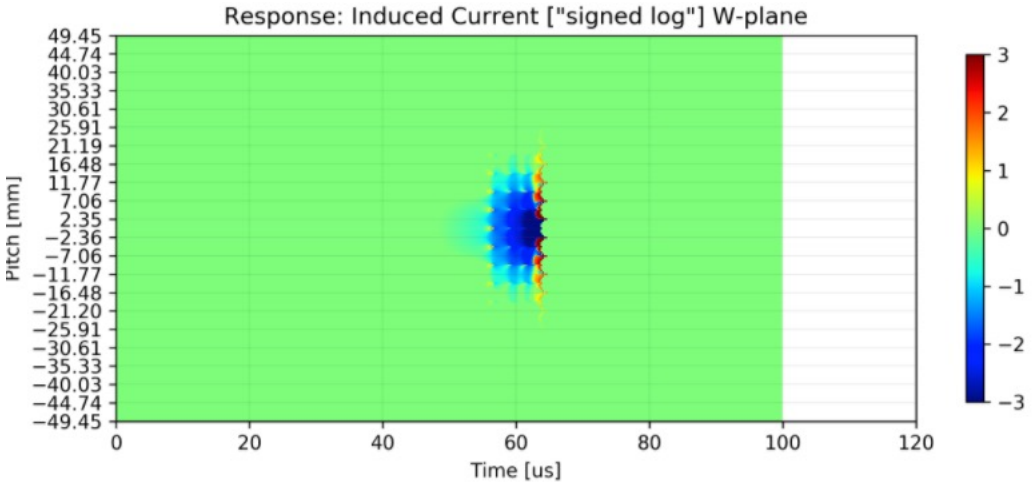
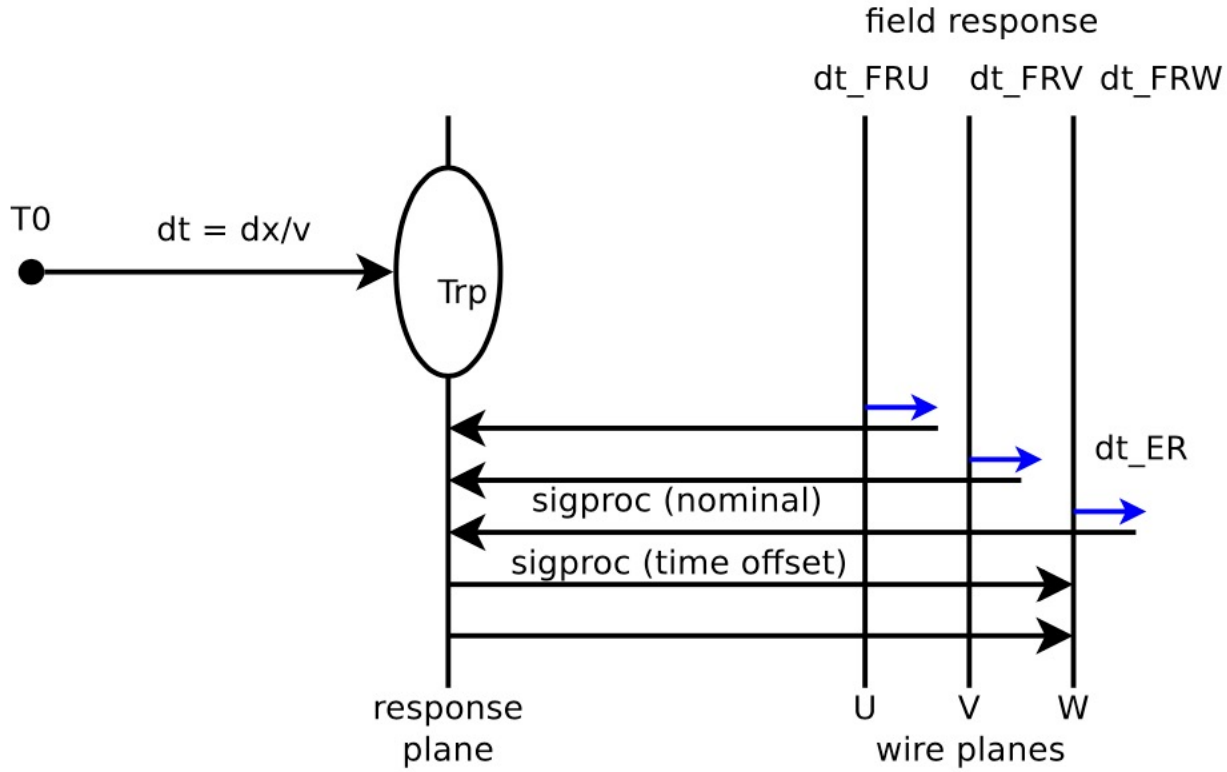


Illustration of Sim/SigProc timings

From B. Viren



$$t_{sim,plane} = t_0 + dx/v + dt_{FR,plane} + dt_{ER}$$

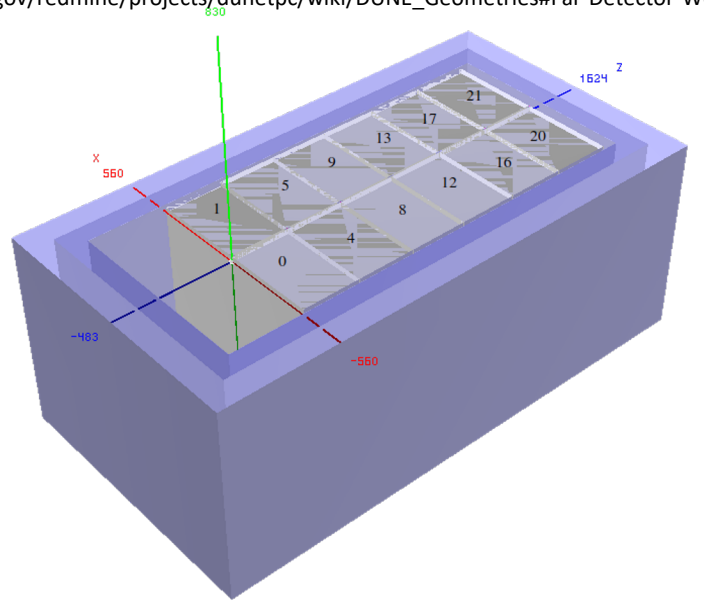
$$\begin{aligned} t_{SigProc} &= t_0 + dx/v + dt_{RP\ to\ Collect.\ Plane} \\ &= t_0 + dx/v + dx_{RP\ to\ Collect.\ Plane}/v_{eff} \end{aligned}$$

Ideal track test using DUNE-FD1x2x6 workspace

```
// between center lines
local apa_cpa = 3.637*wc.m,
local cpa_thick = 50.8*wc.mm,
local apa_w2w = 85.725*wc.mm,
local plane_gap = 4.76*wc.mm,
local apa_g2g = 114.3*wc.mm,
```

response plane: collection + 10cm
= 85.725/2 + 1000 mm
= 1042.8625 mm

https://cdcvs.fnal.gov/redmine/projects/dunetpc/wiki/DUNE_Geometries#Far-Detector-Workspace-1x2x6-Geometry



Wire-Cell APA numbering

X

Upper, Y > 0

1	3	5	7	9	11

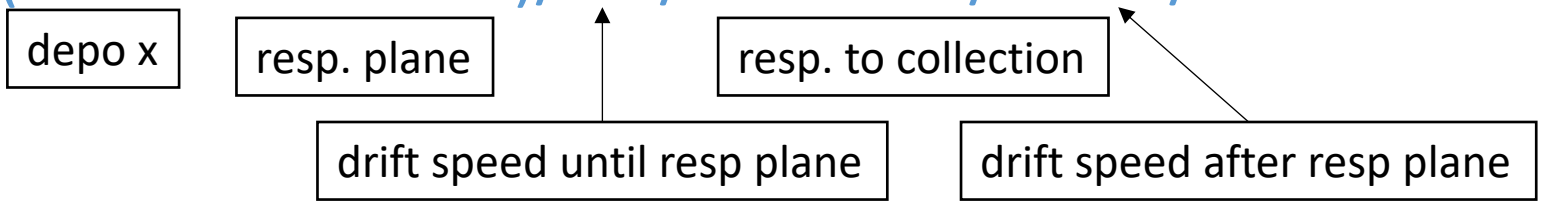
Lower, Y < 0

0	2	4	6	8	10

ideal track test x = 1m, drifting speed = 1.6mm/us

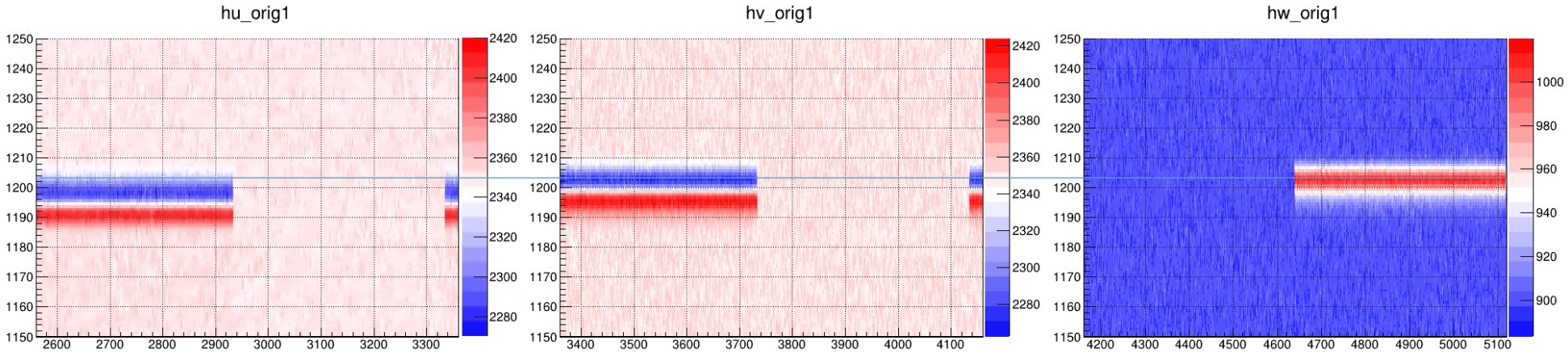
drifting to response plane + response to collection:

(1000 - 142.8625)/1.6/0.5 + 100/1.565/0.5 = 1199.2 ticks

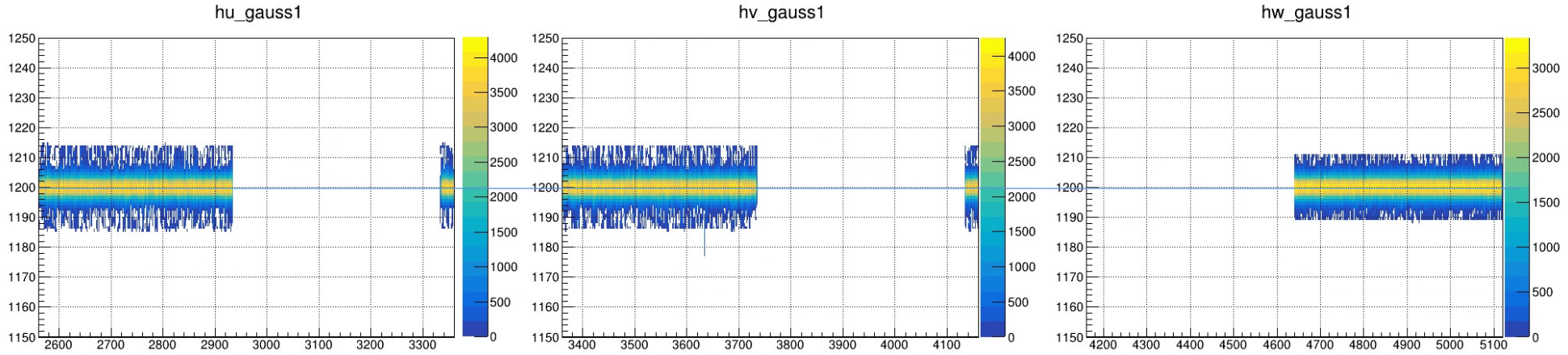


ideal track test x = 1m, drifting speed = 1.6mm/us

WireCell Sim:
raw::RawDigit



Wire-Cell SigProc
recob::Wire

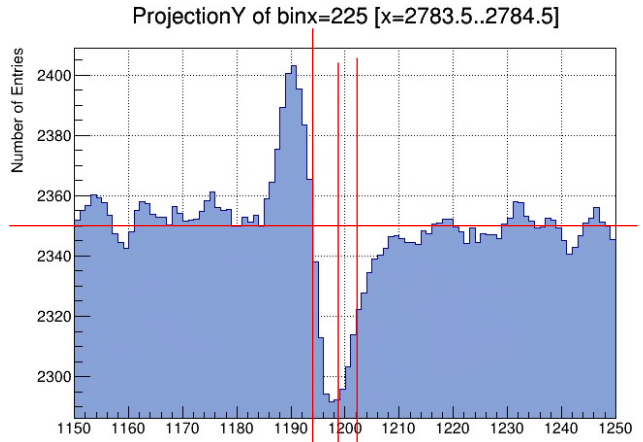


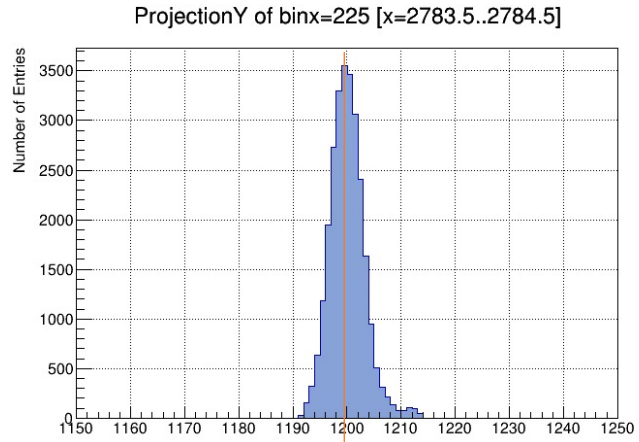
drifting to response plane + response to collection:
(1000 - 142.8625)/1.6/0.5 + 100/1.565/0.5 = 1199.2 ticks

WireCell Sim: **raw::RawDigit**

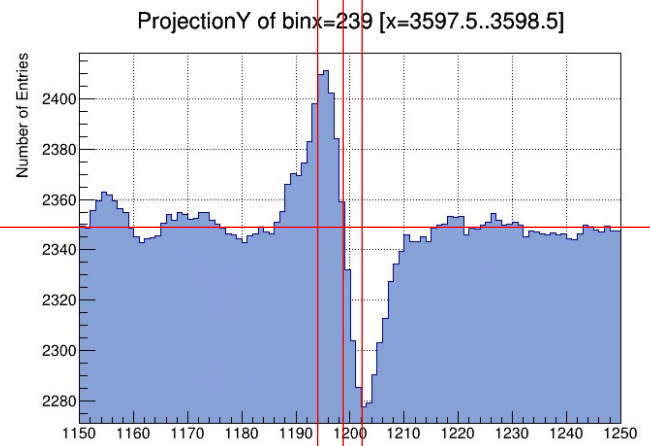
Wire-Cell SigProc **recob::Wire**

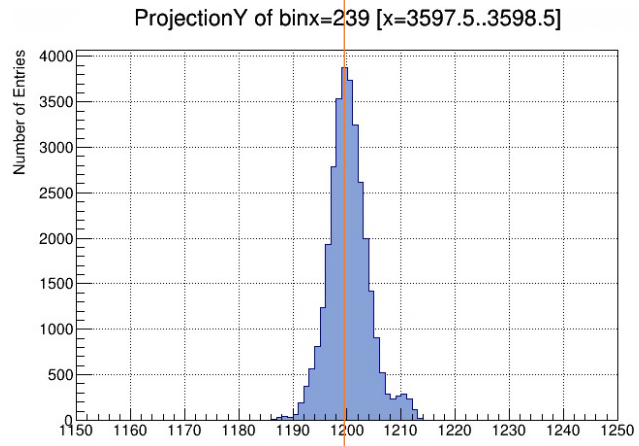
U



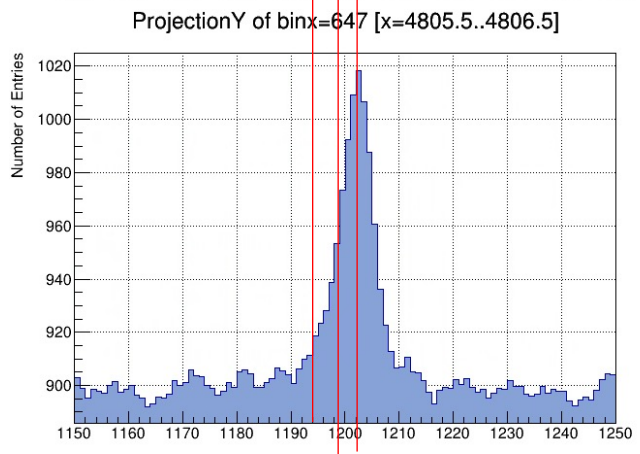


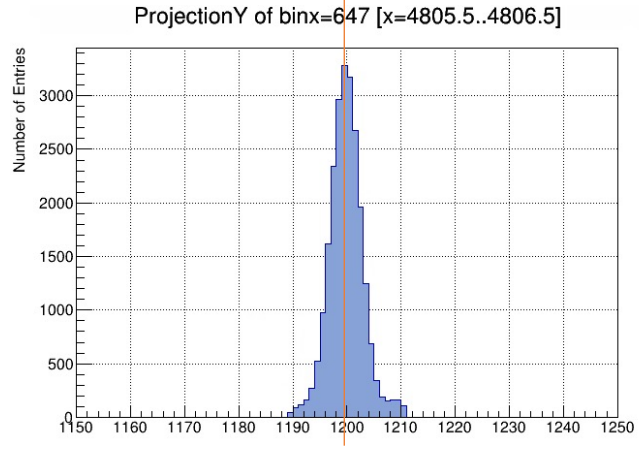
V





W



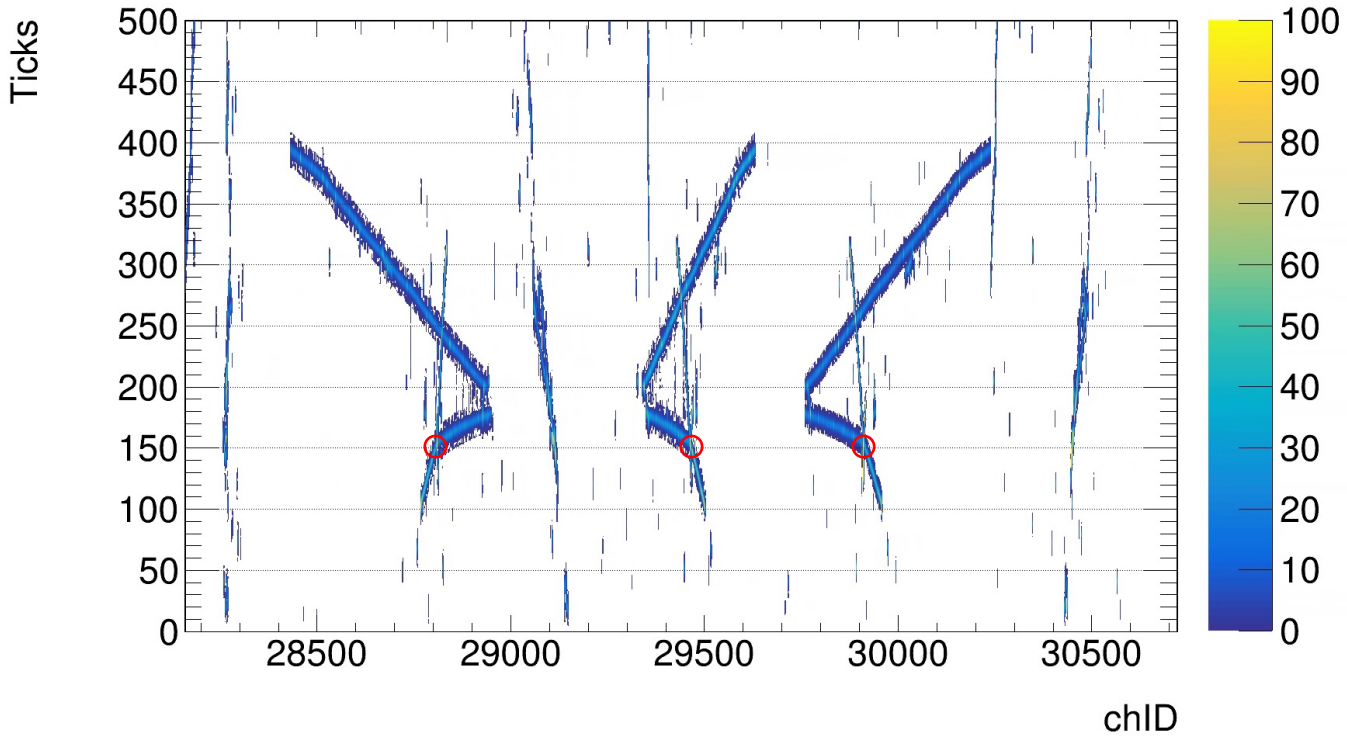


Validation 2: DUNE-FD-1x2x6, Genie + G4

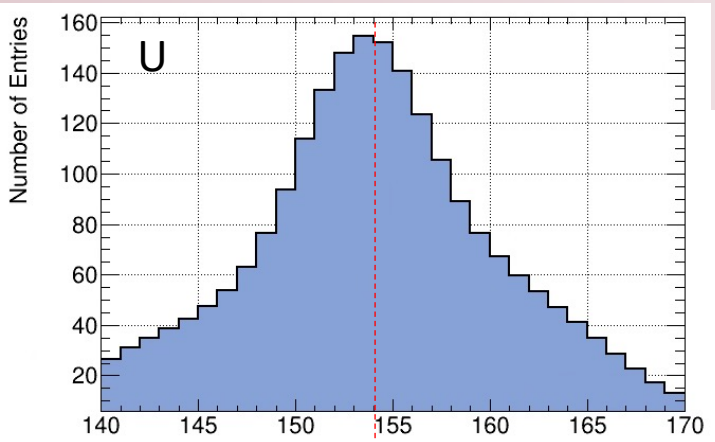
- first event of this file from R. Cross:

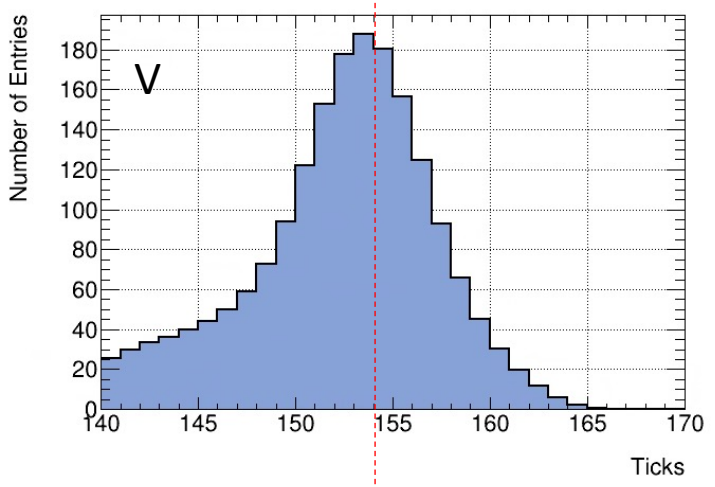
/pnfs/dune/scratch/users/rcross/prod_testing/data/detsim_reco_v09_28_04_mcp12test_prodgenie_nu_dune10kt_1x2x6_24525804_01.root

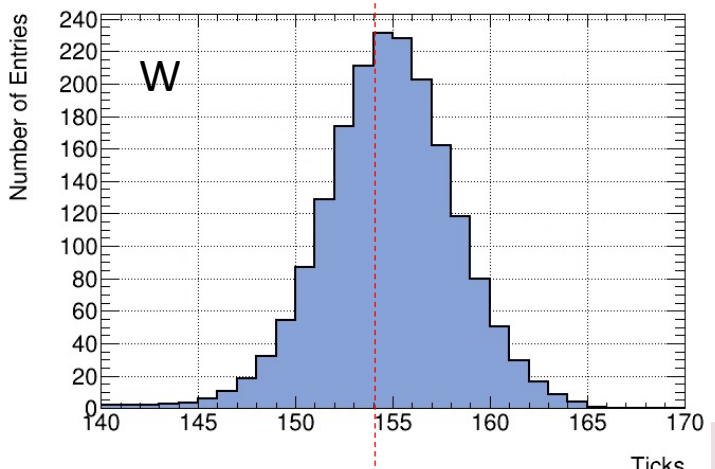
- SigProc results: wclsmcnfsp:gauss, recob::Wire
- Checking a kink (red circle)



U, V, W: 28160, 28960, 29760, 30720



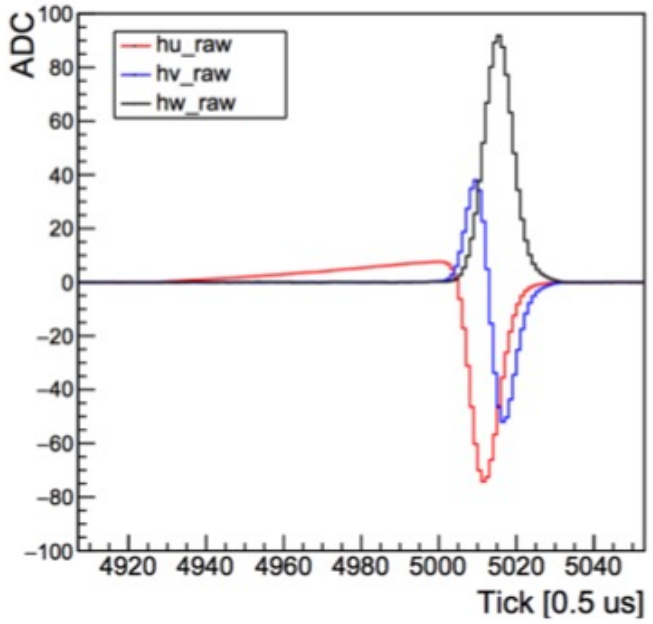


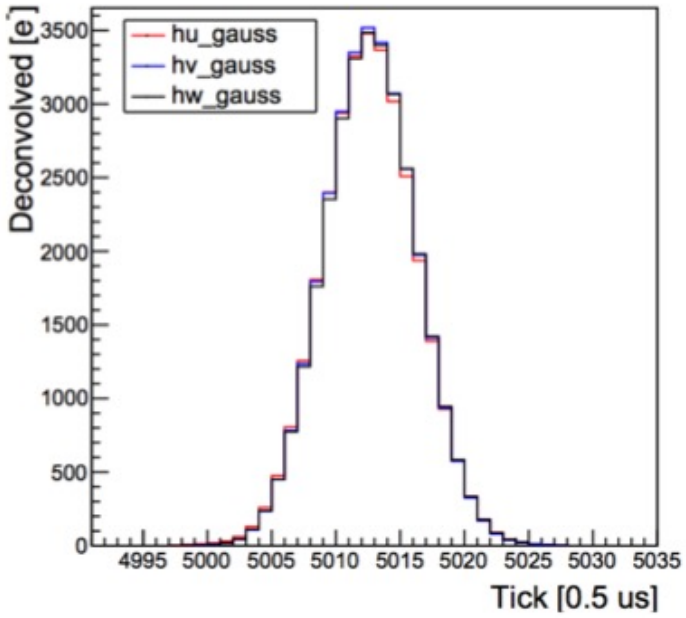


Slide from Hanyu Wei

Inter-plane time offset

- Intrinsically taken into account in the Garfield field response
- See below an ideal isochronous track output





Studies on MicroBooNE - data

arxiv:1804.02583, section 5

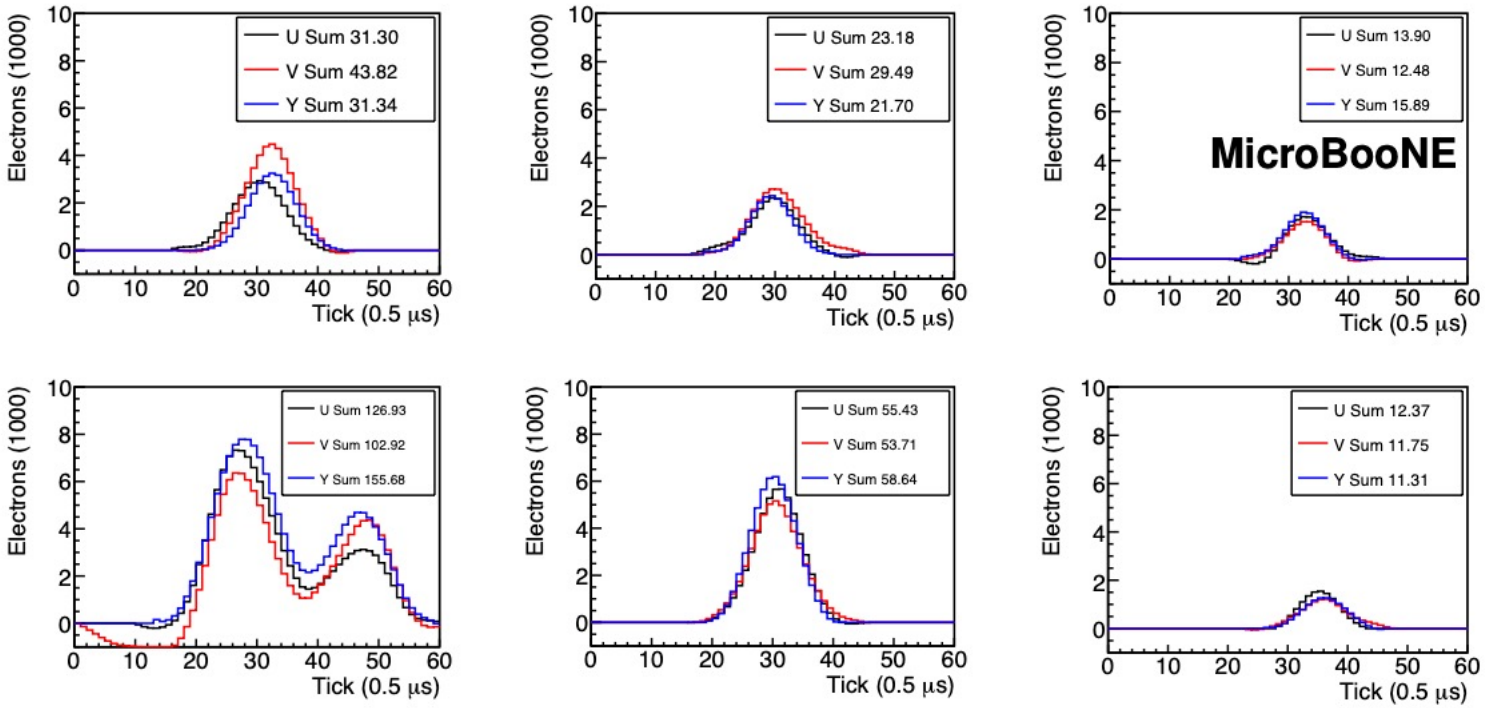


Figure 32: Individual deconvolved ionization charge distributions for a set of selected point sources are shown to demonstrate charge matching across the three wire planes. These distributions are obtained by summing the deconvolved waveforms associated with the extent of charge deposition from each point source (the sum over the range of wires where a signal from the point source can be detected), independently for each plane. The numbers in the legends show the integral of the charge distributions for each plane, with units in thousands of electrons.

Summary

Wire-Cell Signal Processing is a process to extract the original charge t,x distribution at a given plane (collection plane for now)

- the same charge induced current on all wire planes

The drift speed near an APA is NOT constant; Wire-Cell 2D Decon. based SigProc takes the inter-plane time offset into account in a more precise manner and yields good charge matching between planes.