Splat: True Signal Waveforms

`DepoFluxSplat` vs `DepoTransform + OmnibusSigProc`

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Topics

- Introduce **splat algorithm** as a “true” approximation to “sim+SP”.
- Estimate **excess smearing** in “sim+SP” using fits to “morse” track pattern.
- Compare **splat and sim+SP** w/out and w/ excess smearing using a “diagonal” track.

Splat

A **splat** is a kind of **true signal frame**.

- It closely resembles the **reco signal frame** from SP.
- Produced simply and directly from depos.
- Lacks noise, field and electronics response and ADC truncation.
- No convolution / filter / deconvolution round trip.
- Allows arbitrary additional Gaussian smearing and time offsets (becoming < 100 % "true").

Mechanically, one can replace the usual subgraph:

`[DepoTransform]` $\rightarrow$ (`[NoiseFilter]` $\rightarrow$) `[OmnibusSigProc]`

with a singular splat node:

`[DepoFluxSplat]`

Splat construction

Start with the depos drifted to the **response plane** as normal.

- Drift them on a little further to the **collection plane**.
- Apply **optional, extra per-plane, per-dimension smearing** to each depo.
  - $\sigma_{long,tran}^{U,V,W}$ added in quadrature to native depo Gaussian extent.
- Construct **patch of charge** for each depo and each plane
  - Patch aligns to wire plane pitch vs tick grid.
  - Use `GaussianDiffusion` to do heavy lifting just like full sim.
- Project patch onto each wire's **channel** to make a **trace**.
- Apply **optional, arbitrary time offsets** to the frame and traces.

Splat smearing

Sources of smearing

SP **depo diffusion**, SP low-pass filter, mismatch between sim/SP FRs, ADC truncation, …

splat **depo diffusion**, configured **extra** smearing

When to add extra smearing to make SP "match" splat?

- Signal efficiency/bias metrics need matching "numerator" and "denominator".
- Train DNNROI on "true ROIs" that closely resemble what SP would/should produce.

When to not add extra smearing?

- Train new DNN to remove SP's additional smearing, make more realistic signals.

How to match splat and SP signal shapes

Find values for the smear parameters: $\sigma_{long,tran}^{U,V,W}$.

Method: calculation / exclusive

Assume main source of extra smearing is SP low-pass time and wire filters.

- Fit filters to Gaussians, use the fit sigmas as smear parameter values.
- Ignores some sources of smearing (eg sim conv. vs pitch SP decon. binning).

Method: simulate / inclusive

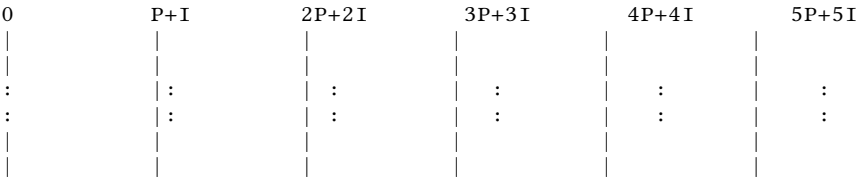
Place point-depos (no diffusion) at response plane, run sim+SP.

- Collect output signals, fit to Gaussian, take sigmas.
- Includes all sources of smearing in sim+SP, no understanding of relative source strengths.

Will show an example of this one.

Introduce the “morse” depo pattern

Legend: P = 25 pitches, I = 0.1 pitch impact position, “|” = wires, “:” = depos.

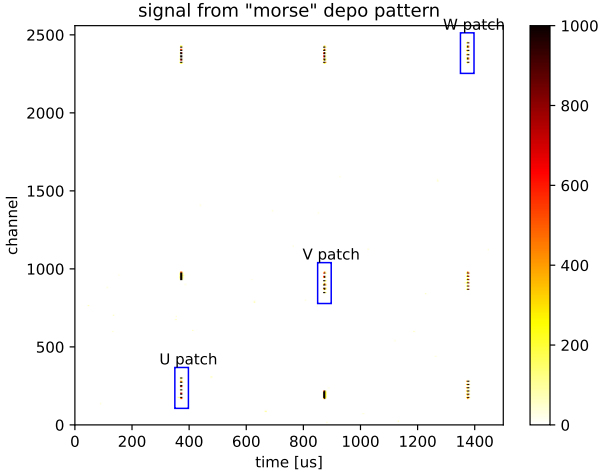


An **array of small tracks** in the response plane “target” each wire plane

- Tracks are **parallel to the wires** of the plane they “target”.
- Tracks have **fixed separation** so their FR do not overlap in pitch.
- Tracks **progressive separation** so each lands on a different FR impact position.
- Arrays of tracks have **times** so their FR+ER do not overlap in time.

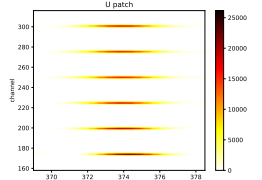
It is named “morse” as in “Morse code”….

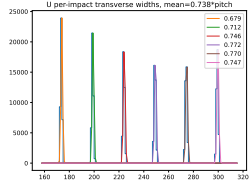
A frame view of “morse” pattern.

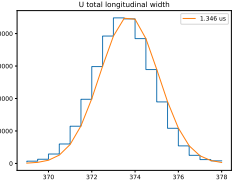


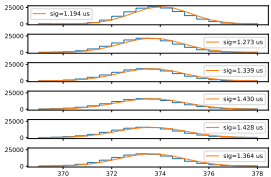
Using “morse” pattern sim+SP

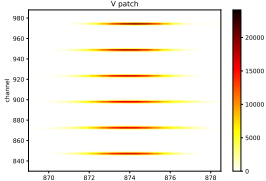
- Generate depos, run through sim+SP, write out frame.
- Select `{U,V,W}` patch
- Form **total waveform** summing patch along channel, find **total peak**.
- Form **channel waveforms** at tick **total peak**. Find each **channel peak**.
- Form **tick waveforms** at each **channel peak**. Find **tick peak**.
- Around each **peak** fit a Gaussian model.

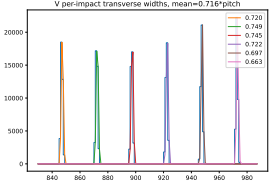

U patch
channel
time [us]

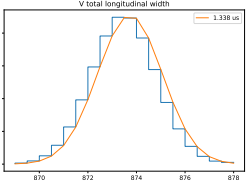

U per-impact transverse widths, mean=0.738*pitch
0.679
0.712
0.746
0.772
0.770
0.747
channel

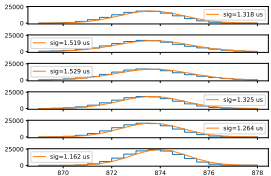

U total longitudinal width
1.346 us
time [us]

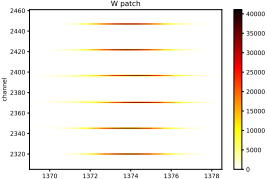

U per impact longitudinal widths, mean=1.346 us
sig=1.194 us
sig=1.273 us
sig=1.339 us
sig=1.430 us
sig=1.428 us
sig=1.364 us
time [us]

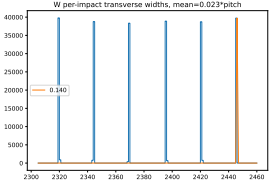

V patch
channel
time [us]

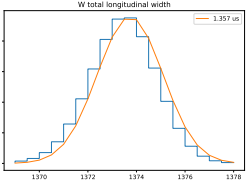

V per-impact transverse widths, mean=0.716*pitch
0.720
0.749
0.745
0.722
0.697
0.663
channel

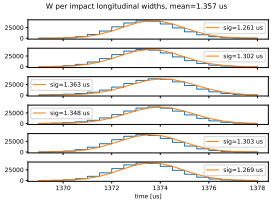

V total longitudinal width
1.338 us
time [us]


V per impact longitudinal widths, mean=1.338 us
sig=1.318 us
sig=1.519 us
sig=1.529 us
sig=1.325 us
sig=1.264 us
sig=1.162 us
time [us]


W patch
channel
time [us]


W per-impact transverse widths, mean=0.023*pitch
0.140
channel


W total longitudinal width
1.357 us
time [us]


W per impact longitudinal widths, mean=1.357 us
sig=1.261 us
sig=1.302 us
sig=1.363 us
sig=1.348 us
sig=1.303 us
sig=1.269 us
time [us]

Summary from “morse” analysis

The sim+SP apparently adds this amount of additional smearing:

plane	tick	pitch
U	2.692	0.738
V	2.675	0.716
Z	2.714	0.140

Units are `[tick]` and `[pitch]`.

To get these numbers as config chunk for `DepoFluxSplat`:

```
$ wirecell-gen morse-splat -o splat-params.json tmp-morse/peaks.json
```

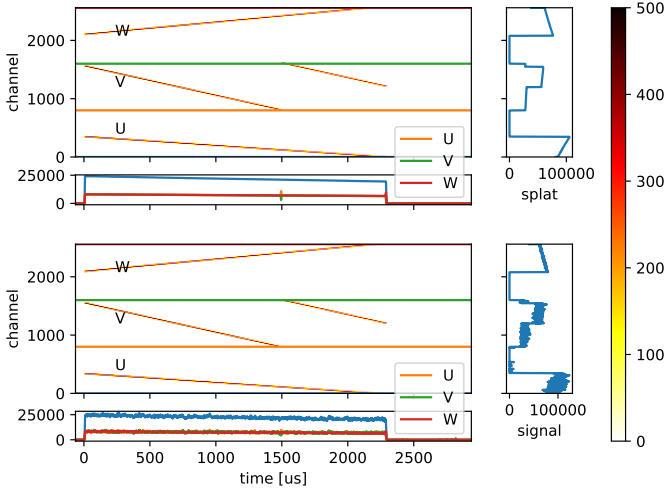
Introduce the “diagonal” pattern

A single, ideal, minimum-ionizing line track running **diagonally** between opposite corners of one anode plane face’s sensitive volume.

- Run both splat and sim+SP.
- Check timing, positioning, charge and shape of signals.

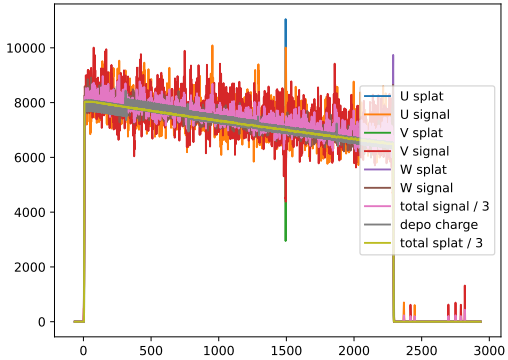
First look at **unsmeared splat case** then look at **smeared case** using “morse” numbers.

Splat and sim+SP overview



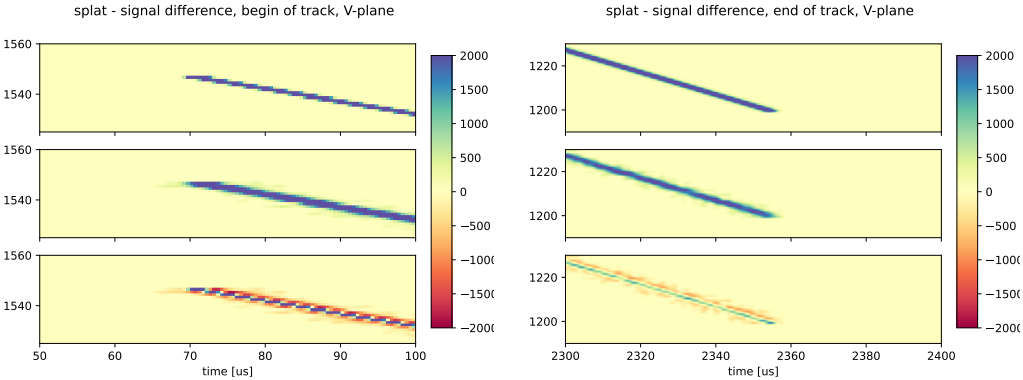
- Top is splat, bottom is sim+SP.
- channel and tick profiles.
- Electron absorption reduces charge over
- Good time, position and charge match.
- Note small splat “blips” at 1500 us.
  - Wrong wire ID?

Check charge



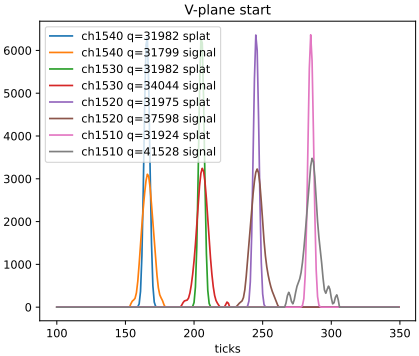
- Depos, splat and sim+SP signals by plane and total.
- Depo line has artifacts due to beating between steps and tick binnings.
- The “U/V splat blip” at 1500 us is seen.

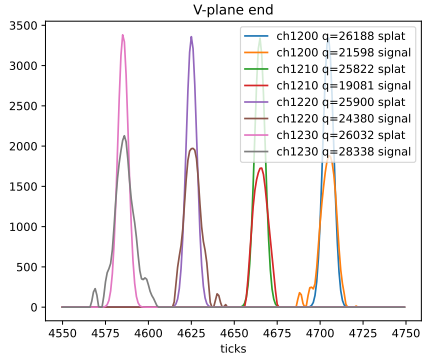
Unsmeared differences at track ends



- Good position and timing match.
- Charge is way off. Splat is more narrow and dense than sim+SP.

A look at some V-plane channels near track endpoints



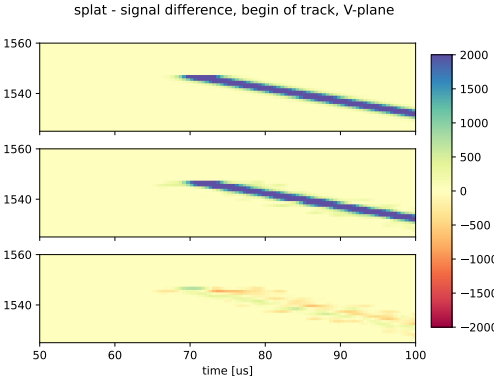


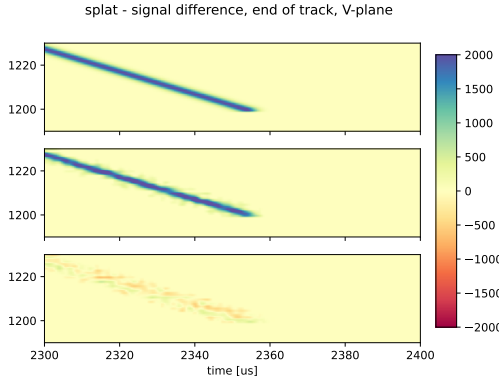
- Well aligned in time.
- Shapes are way off. Splat is more narrow and dense than sim+SP.
- Sim+SP has features near the base that will never be in splat. Likely induced by noise.

Add extra smearing.

Now, rerun "diagonal" track but configure `DepoFluxSplat` *with the additional smearing found by the "morse" analysis.*

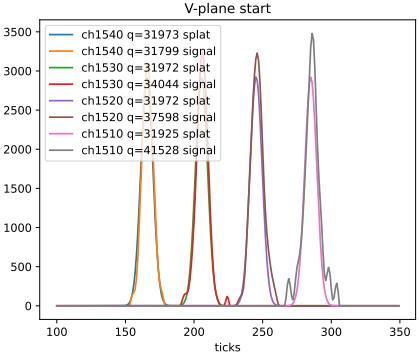
Differences at track ends with extra smearing

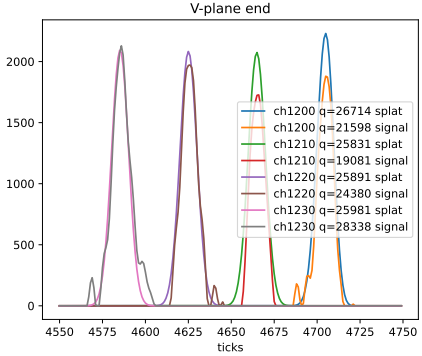




- Difference much reduced.

V-plane channels near track endpoints with extra smearing





- Time alignment retained. Shapes much closer.
- Splat sometimes larger/smaller than sim+SP. Due to fluctuationions?

Summary

- Splat provides a kind of “true signal”.
- With suitable extra smearing we may approximate that added by sim+SP.
- The “morse” depo pattern and software can measure the extra smearing.
- This allows splat to come close to matching sim+SP.
- Sim+SP has features unmatched by splat, especially near base (probably noise).
- What’s going on at 1500 us

Some entries to the software used to make this presentation

Morse

```
$ WCT_BATS_TMPDIR=$(pwd)/tmp-morse bats ./test/test/test-morse-pdsp.bats
$ wirecell-gen morse-splat -o splat-params.org tmp-morse/peaks.json
```

Diagonal

```
$ WCT_BATS_TMPDIR=$(pwd)/tmp-diag bats ./test/test/test-ssss-pdsp.bats
```

Todo

Parts of these tests are **pdsp-only**, need to generalize to **uboone**, **sbnd**, etc.