Wire-Cell Signal Processing Directional Metrics (spdir)

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`spdir` - SP metrics as a function of track direction

*`spdir` provides a **standard calculator** of **efficiency, bias and resolution** of Wire-Cell **signal processing** as a function of **track direction**.*

- Motivation
- Calculation overview
- Results on PDSP
- Running the process
- Future work

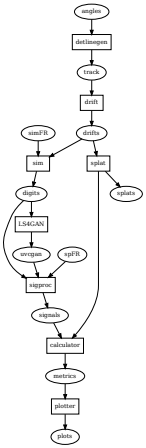
Motivation for an `spdir` process

A few needs from different areas happened to coincide:

- People started to reimplement MicroBooNE SP-1 paper's "money plot" figure 30 to new detectors.
- Production of this plot in a "standard" way for multiple detectors and across different WCT software versions was seen as a very strong regression test.
- The final LS4GAN LDRD paper using LArTPC needs some "physics level" comparisons between nominal simulation and UVCGAN-translated and the `spdir` metrics are a very good match for that.

Though each of these adds its own complexity, they are largely overlapping and so a unified, general approach has been pursued.

spdir process overview



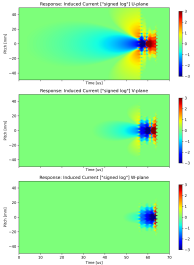
- Generate **depos** from **ideal line tracks** at **different angles**.
- Apply **drift** and **splat** with proper smearing to get “SP truth denominator”.
- Apply **FR** + **sim** (signal+noise) to **drift** to get **digits**.
- Translate **nominal** digits with LS4GAN to get **uvcgan** digits.
- Apply **FR** + **sigproc** both types of digits get **signals**.
- Compare **splat** to **signals** to form **metrics** for given **plane and track angle**.
- Collect **metrics** across a configuration and make the “money plot”.

← conceptual DAG, actual DAG for one track angle ↓



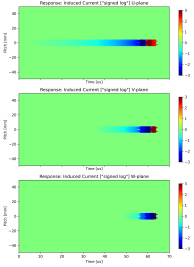
Three field responses

FR usage:	detector	sigproc
real nature	3D	2D
mock nature	2D	q1D
unnaturally ideal	2D	2D
very unnaturally ideal	q1D	q1D



q1D is **intentionally degraded** from 2D: zero all but central wire region.

- FR variation still exists across the central wire region, thus “q” for “quasi”.
- Consider `spdir` metrics using **mock nature** as a **proxy** for **real nature**.
- Historically we consider **unnaturally ideal** FR pairings.
- Cover all combos of q1D/2D, 2×2 multiplier to number of jobs.



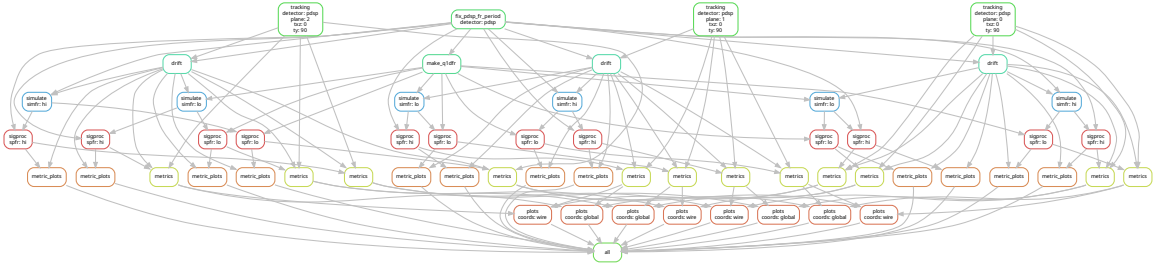
Extra requirements for LS4GAN

LS4GAN translates sim-q1D $\rightarrow$ sim-2D$'$ as a **proxy** for translating sim-2D $\rightarrow$ det-3D$'$.

- Manually export ADC frames from `spdir` to UVCGAN environment.
- UVCGAN does **cross translation** (q1D $\leftrightarrow$ 2D).
- Import translated ADC frames back to `spdir`.
- For each translated FR, SP with either FR applied.

Results in another 2×2 multiplier of `spdir` variants.

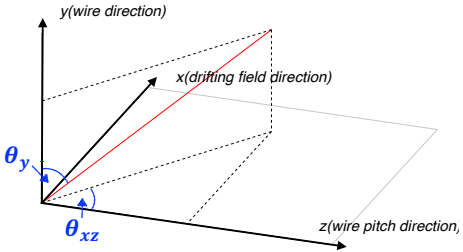
Single track, no LS4GAN `spdir` sub-DAG



just for reference

Extend MicroBooNE SP-1 paper's track direction angle convention

- MB defines angles in the "global" coordinate system.
  - Coincident with the W-plane coordinate system.
- MB uses same track for metrics from all 3 planes.
  - U/V's wire-track angle different than W's.
- `spdir` also defines track angles in each wire plane coordinate system.
  - Calculates metrics using both conventions.



(b) Definition of two angles, θ_{xz} and θ_y.

Can configure any angles, but default to MB's choice:

- $\theta_y = 90°$ always (though it is possible to vary this).
- $\theta_{xz} \in \{0, 1, 3, 5, 10, 20, 30, 45, 60, 75, 80, 82, 84, 89\}°$.

Result plots

Two basic types of sets of plots:

- Metrics vs track angle in global or wire-plane coordinates.
- Several detailed metrics plots for a given track angle and wire-plane coordinate system.

Both have subtypes depending on sim/SP FRs

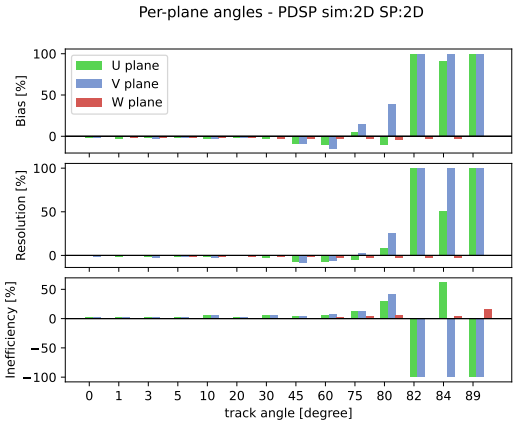
- “mock reality” (sim-2D/sp-q1D) vs “unnaturally ideal” (sim-2D/sp-2D)

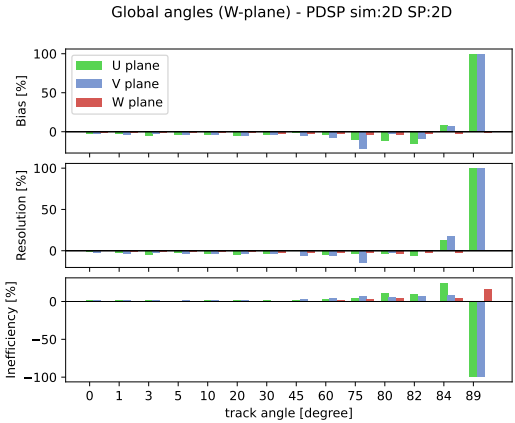
Current set of plots are all for ProtoDUNE-SP.

- “unnaturally ideal” and “global coordinates” is equivalent to MB “money plot”

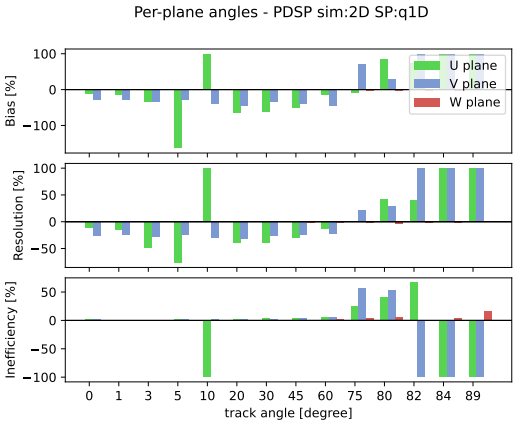
Some examples $\longrightarrow$

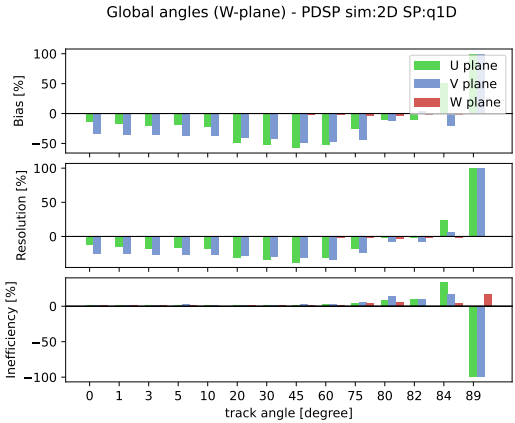
Unnaturally ideal: sim-2D, sp-2D



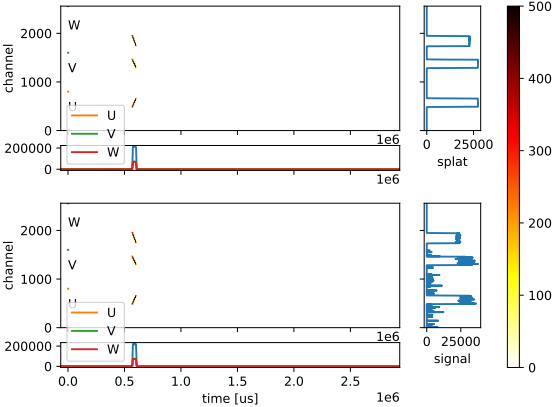


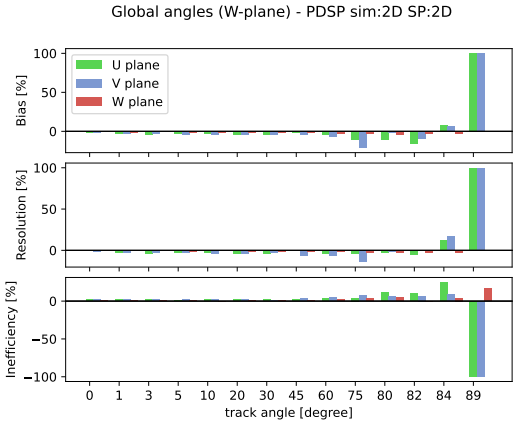
Mock reality: sim-2D, sp-q1D



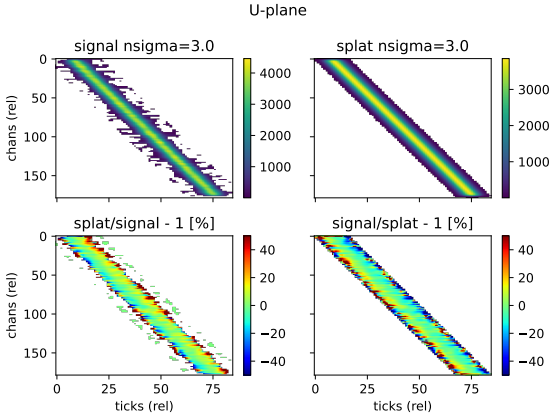


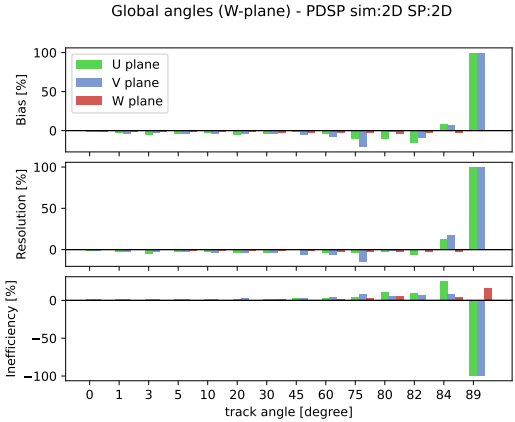
Unnaturally ideal: sim-2D, sp-2D, 3° global angles - details



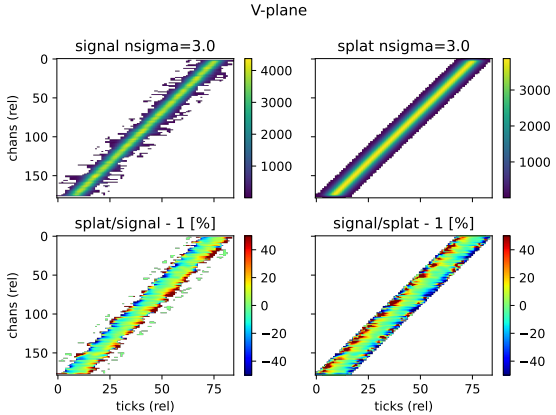


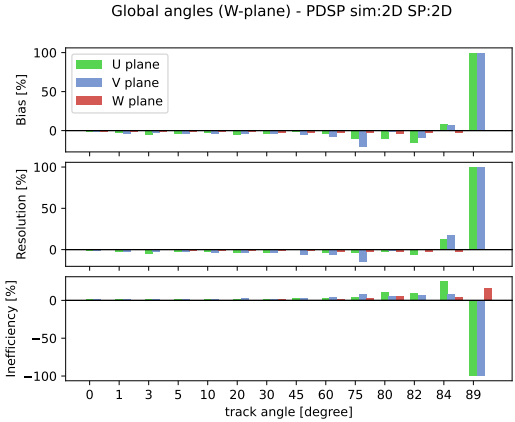
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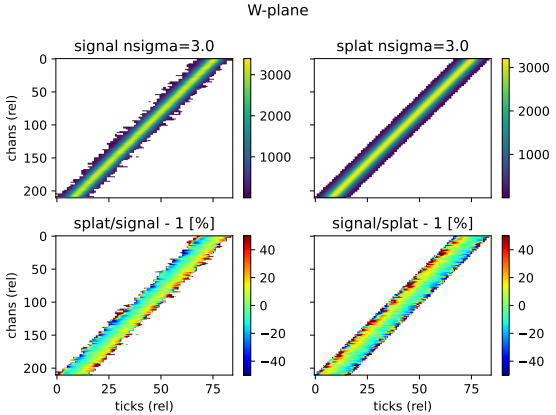


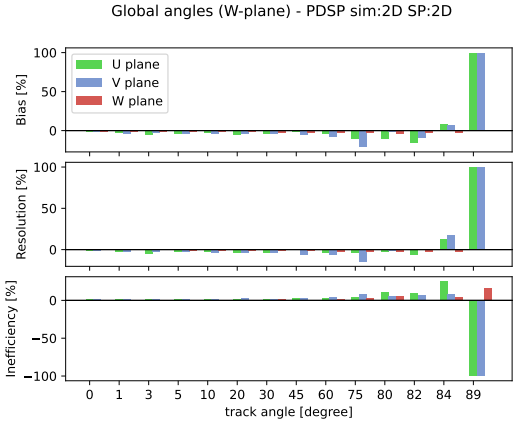
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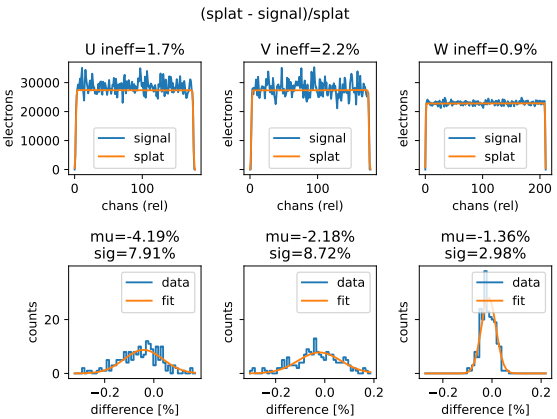


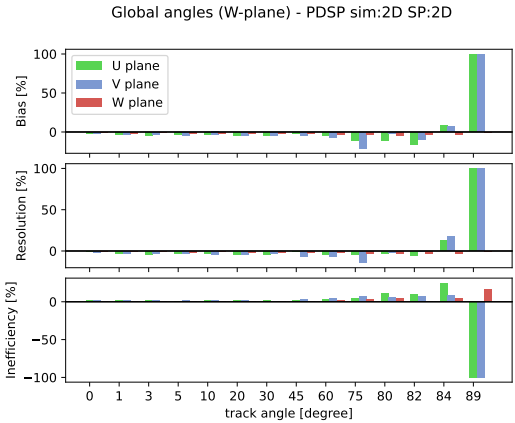
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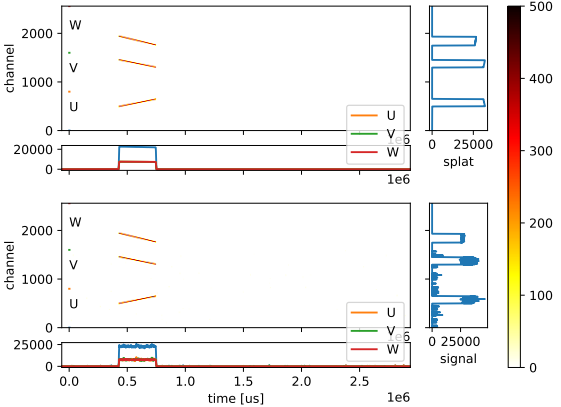


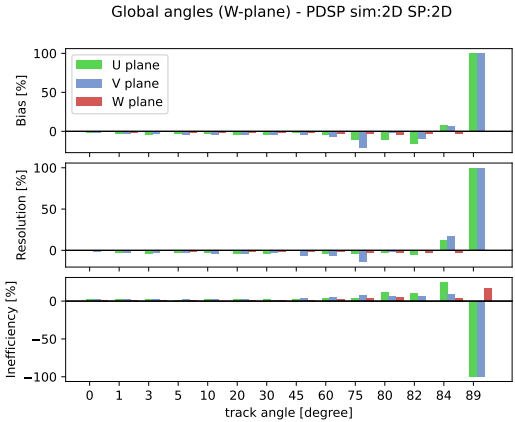
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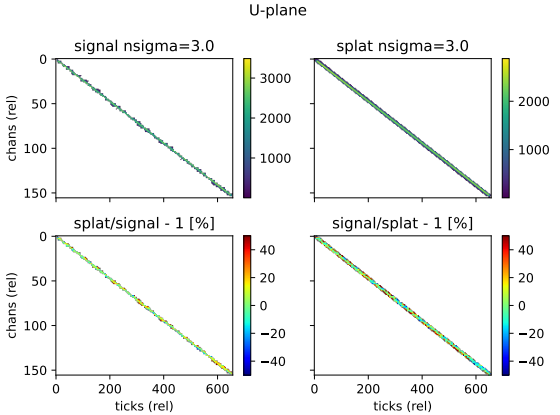


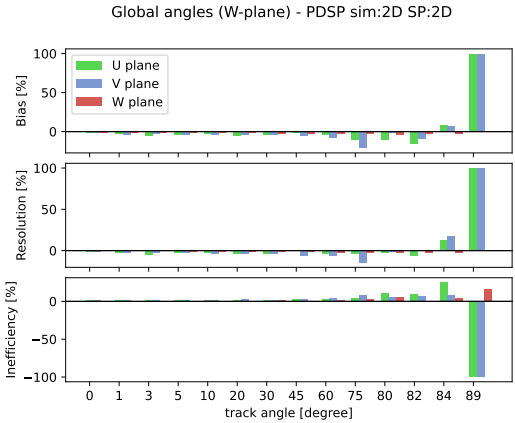
Unnaturally ideal: sim-2D, sp-2D, 30° global angles - details



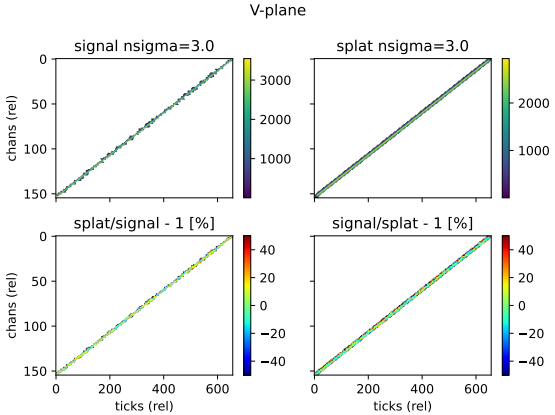


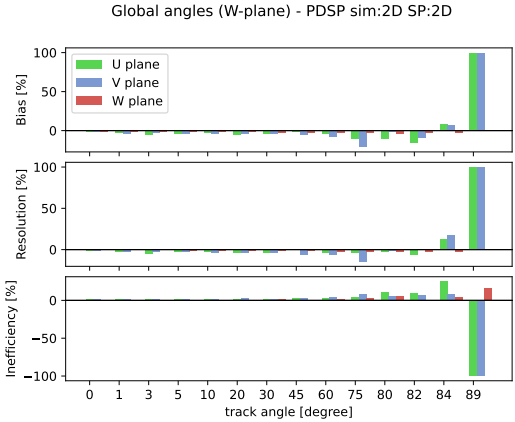
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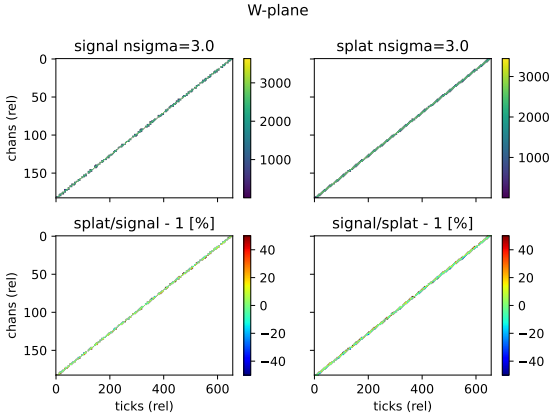


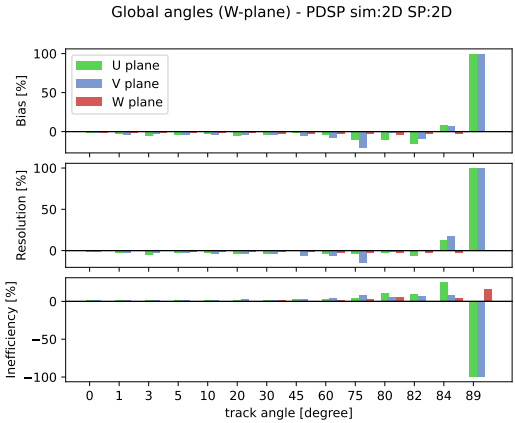
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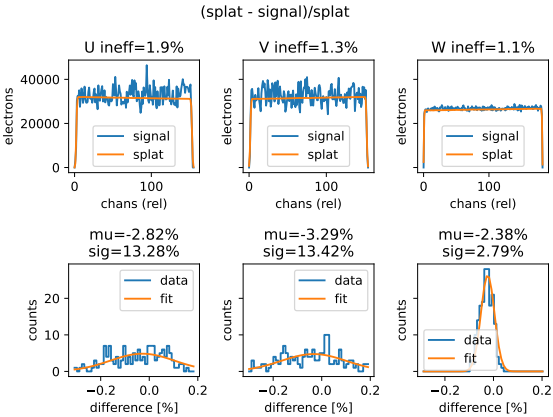


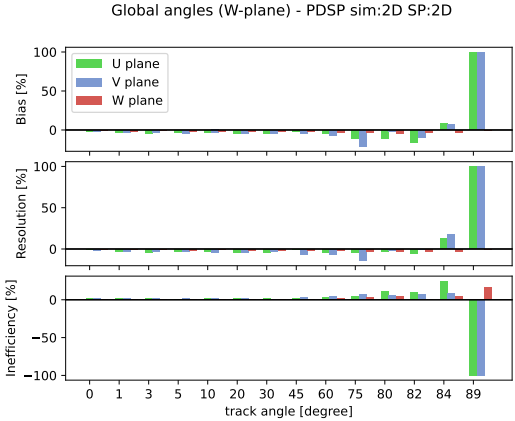
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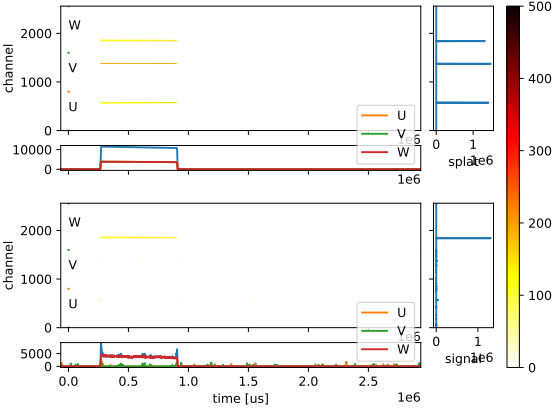


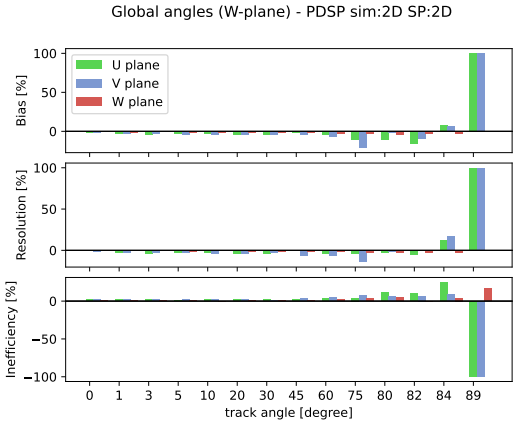
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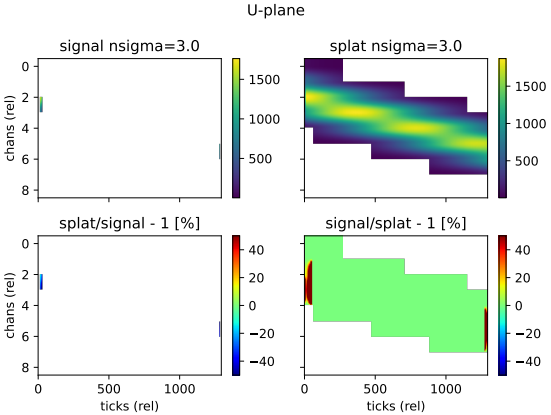


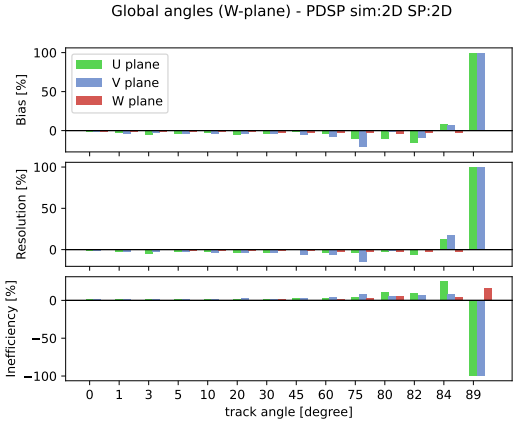
Unnaturally ideal: sim-2D, sp-2D, 89° global angles - details



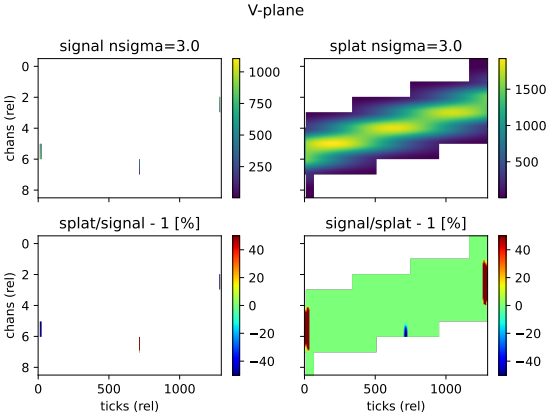


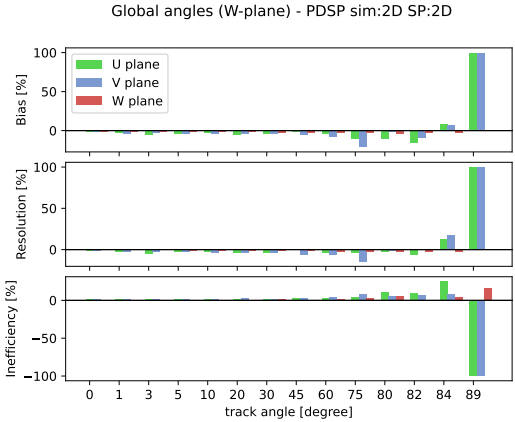
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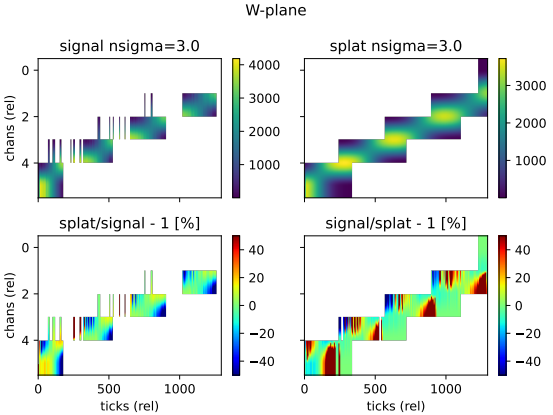


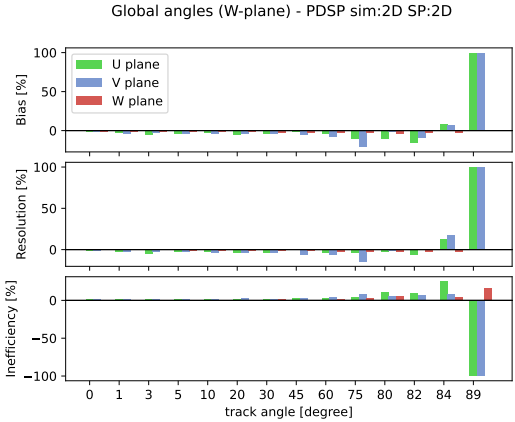
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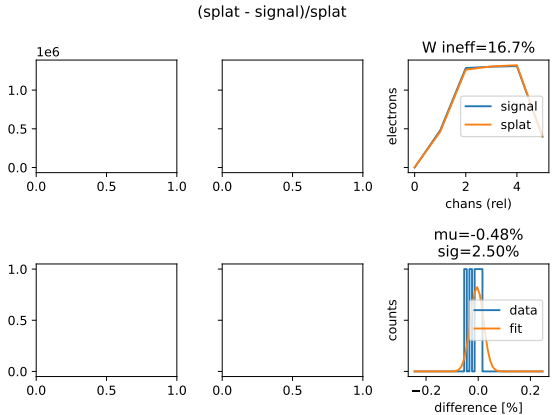


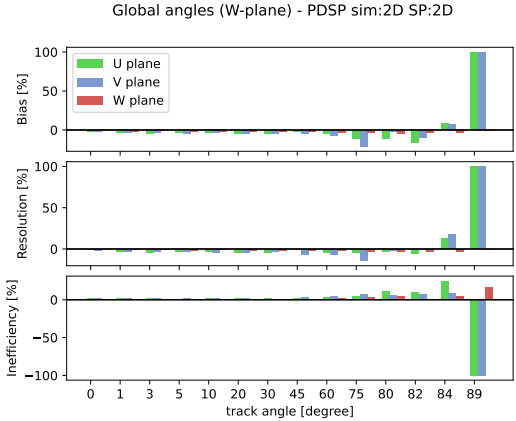
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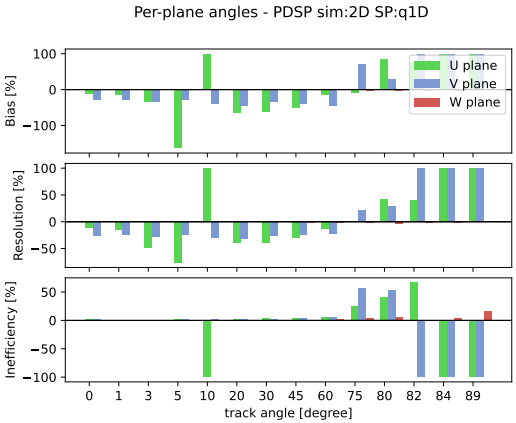


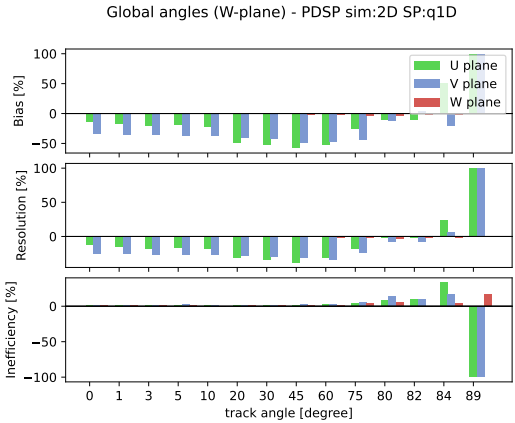
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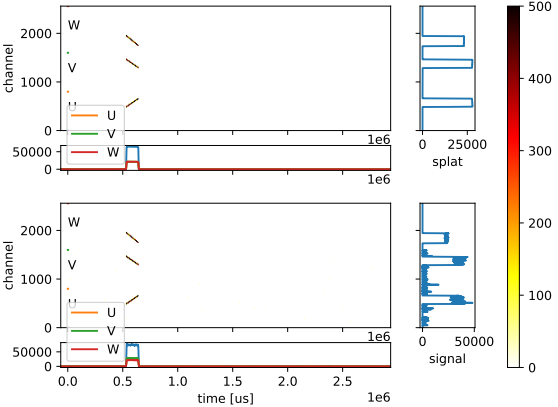


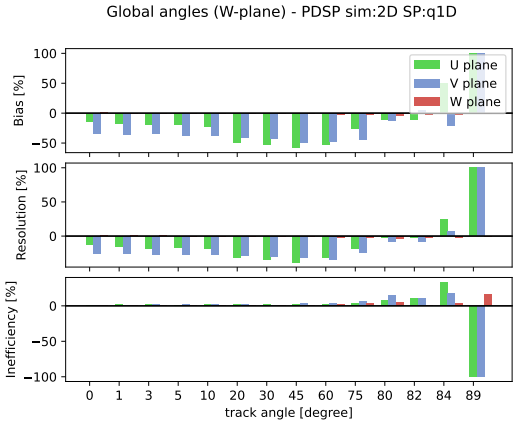
Mock reality: sim-2D, sp-q1D (repeated)



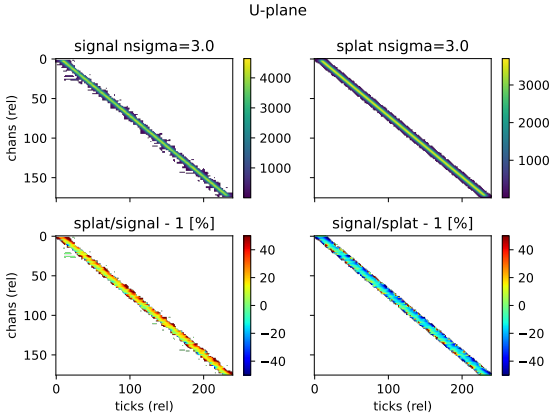


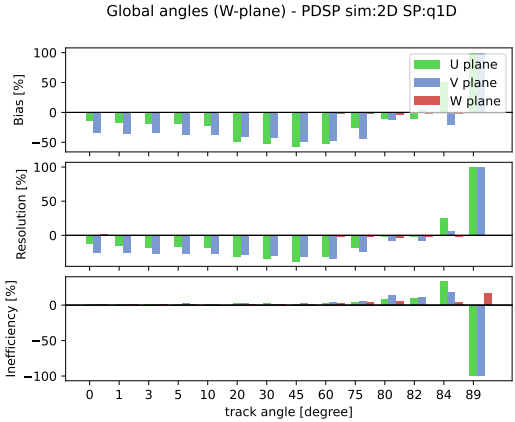
Mock reality: sim-2D, sp-q1D, 10° global angles - details



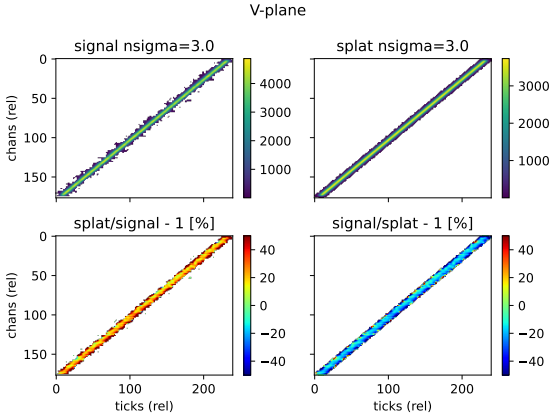


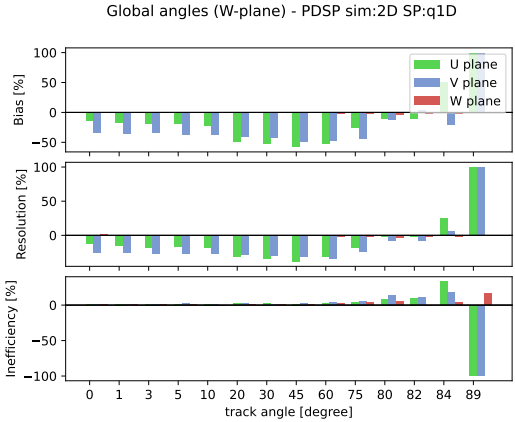
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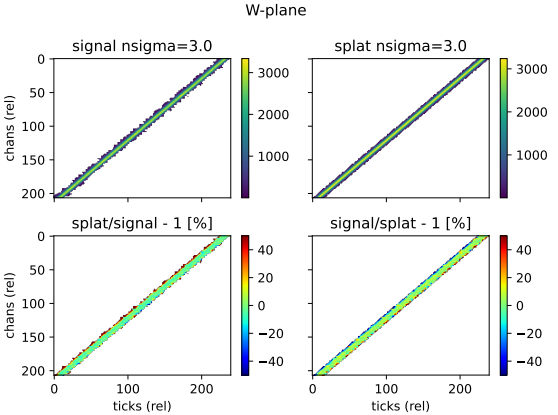


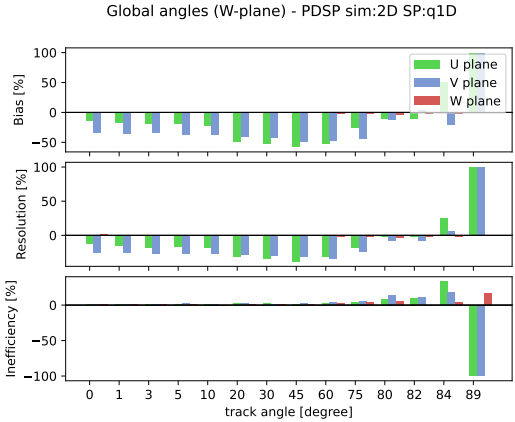
Mock reality: sim-2D, sp-q1D, 10° global angles - details



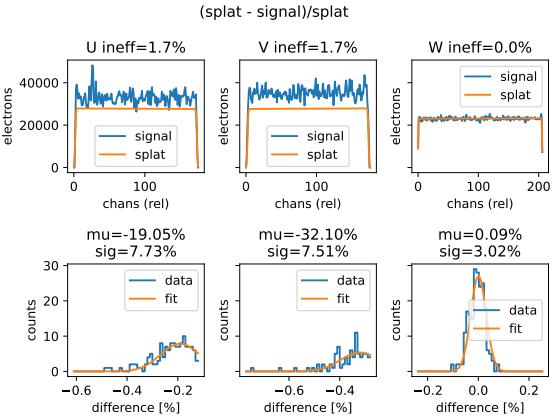


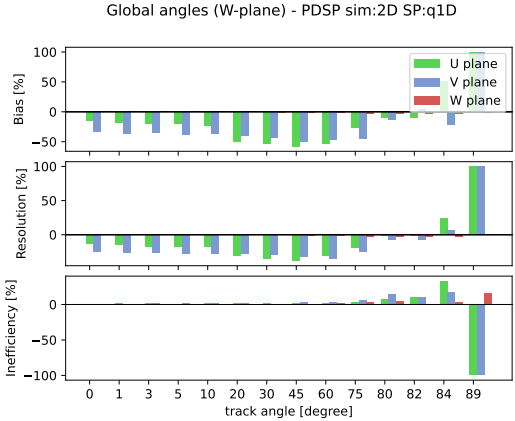
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Running spdir

```
cd /path/to/wire-cell-python
pip install -e .
pip install snakemake

# for convenience to find "spdir"
PATH=/path/to/wire-cell-toolkit/test/scripts:$PATH

spdir --directory spdir all
ls spdir/ | wc -l
1060
```

LS4GAN translation

LS4GAN UVCGAN-translations are optional and require external processing.

```
tar -cvf spdir-pdsp-digits.tar spdir/pdsp-digits-sim*.npz
```

Send `spdir-pdsp-digits.tar` to Dmitrii for UVCGAN-translation and receive results, unpack and complete the `spdir` DAG execution.

```
tar -C spdir -xf translations-from-dmitrii.tar
spdir --directory spdir ls4gan
```

Programs used by `spdir`

`spdir` is a Snakemake file using:

- `wirecell-gen detlinegen` generate tracks vs angle (Dmitrii).
- `wirecell-sigproc frzero` construct degraded q1d FR.
- `wirecell-test ssss-metrics` write JSON metric file for each track/variant.
- `wirecell-test plot-metrics` plot set of JSON metric files.
- `wirecell-test plot-ssss` metric detailed plots
- `wire-cell -c omnijob.jsonnet` a generic, do-all job driven by CLI args
  - requires detector support in `cfg/layers/` scheme (pdsp and uboone so far).

Future work

With PDSP

- Check sign convention with MB SP-1 metrics.
- Switch from Gaussian fit μ/σ to avg/RMS stats to avoid fit failures.
- Splat extra smearing is from a "Morse analysis" assuming only 2D sim/SP FR.
  - Should repeat with mixed 2×2 sim/SP FRs.

With MicroBooNE

- Apply to `uboone`, which has existing `omnijob.jsonnet` config support.
- Make quantitative comparison with MB SP-1 plot.

Other detectors

- Develop WCT configuration and run on SBND, PDHD/PDVD, DUNEFD, etc.
  - Likely I need help from detector/WCT experts.