

Wire Cell Toolkit Updates and Status

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SimReco
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Outline

Simulation

Noise Filter

Signal Processing

Toolkit Improvements

LArSoft Integration

Status and Work Needed

WCT Simulation Scope

Overview:

Energy depositions ideal, parameterized line sources or detailed deposition from file (LArG4 dumps: **Brooke**)

Drift physics Fano factor, recombination, absorption, diffusion and related statistics (**Hanyu**)

Response long-range/fine-grained DUNE and μ BooNE 2D Garfield field (**Yichen**) and electronics (**Huchen**) responses.

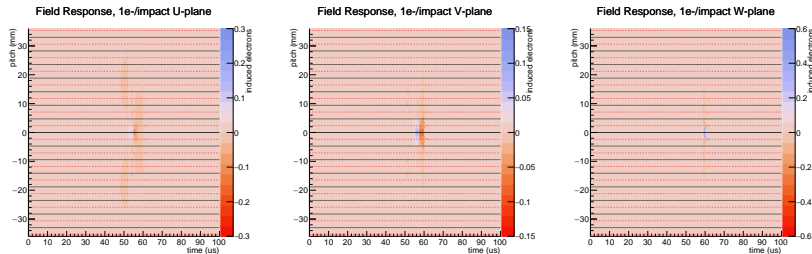
Wire geometry 3D wires from file or parameterized generator.

Convolution $Q_{drift} \otimes R_{field} \otimes R_{elec}$ optimized for RAM and CPU (200 MB max RAM, 20k depos/minute).

Noise empirical μ BooNE (**Jyoti**) and first principle (**Milind/Arbin**) noise models, in development.

Digitizer simple, parameterized linear model.

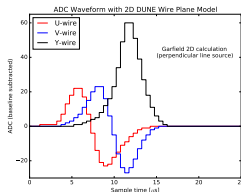
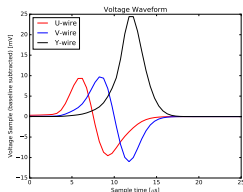
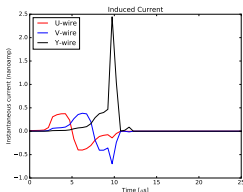
DUNE Field Responses



Induced current of one drifting e^- in impact position vs. time.

- Garfield 2D wire model, 4.71 mm pitch.
- $E_{field} = 500V/cm$, $v_{drift} = 1.6 \text{ mm}/\mu s$.
- 21 wires, $\frac{1}{10}$ pitch drift path impact positions.

Ideal Isochronous Track Response

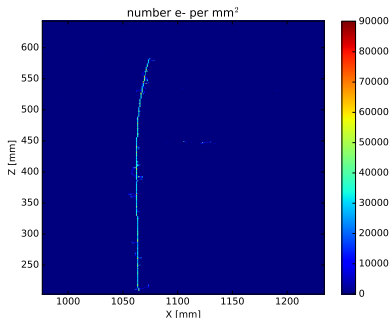


Induced current, amplified and shaped voltage and digitized ADC due to ideal isochronous, MIP track (used: $16k\ e^-/\text{pitch}$).

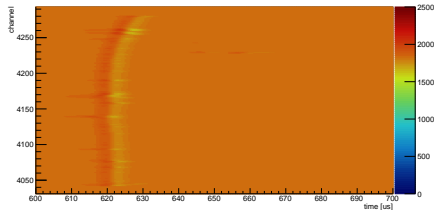
- Ideal line source and R_{field} , R_{elec} and a simple digitizer.
 - Provides simple, understandable case that can be calculated to check normalization.
 - $16,000e^-/\mu s = 2.6\text{ nA}$
 - $16,000e^- \times 14\text{ mV/fC} = 36\text{ mV}$
 - $25\text{ mV} \times 1.2 \times 4096\text{ ADC}/2\text{ V} = 61\text{ V}$
- n.b.: plots happen to use μ BooNE's 1.2 post-FEE gain and MIP e^-/pitch number, but DUNE fields. DUNE normalization is $\sim \frac{5}{3} \times \frac{1}{1.2} = 1.4$ higher.

Tracked muon event

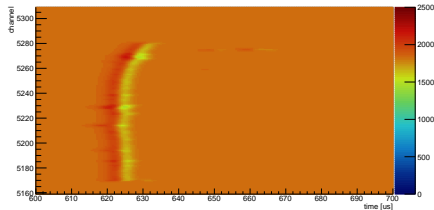
- LArG4 energy depositions dumped to JSON (Brooke)
- ADC waveforms for U/V/W planes
 - Generated pD/SP wires and “wire attachment number” as channel number.
 - Todo: full FEE channel “shuffle”
- True depo points below.



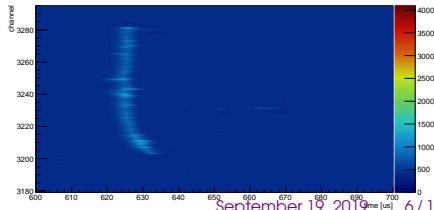
Brett Viren (BNL)



V-Plane



W-Plane



WCT

September 19, 2019

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Software Noise Filter

- Class Interfaces based on per-channel and group-of-channel (coherent) operations.
- Current implementation is rather MicroBooNE-specific.
- Could be a basis for protoDUNE/SP noise filter but depends on what excess noise we actually see.
- **Already integrated into LArSoft** in `larwirecell` using UPS product `wirecell` (providing Wire Cell Toolkit 0.5.2 currently)
 - Integration layer at Module level.
 - Exposes more WCT implementation than ideal.
 - Could clean this up to access WCT Components via Art Tools but this work only pays off if its reused for protoDUNE.

Signal Processing

2D time/wire deconvolution and signal-ROI selections.

- Two filters applied in deconvolution:
 - **Wiener** maximize S/N, used for signal-ROI selection.
 - **Gaussian** preserves charge, produces final signal.
- Signal-ROI uses “tight” and “loose” criteria and both local and neighboring channel info.
- Developed and tested on μ BooNE data.
 - Will be fully applicable to DUNE, others via configuration mods.
 - MicroBooNE paper describing performance is in prep.
- WCT sim with proper response and noise to validate SP.
- Initial implementation in Wire Cell **prototype** codebase.
 - Porting to Toolkit and integration into LArSoft is high priority
 - **Integration into LArSoft driven by paper schedule.** Needed sooner than for protoDUNE.

Toolkit Improvements

- Underlying configuration uses JSON. WCT adds optional support for the **Jsonnet data templating language** to allow for structured configuration.
- Switched from Eigen3 to **FFTW3** for FFTs. Substantial speed up for noise filtering, signal processing and simulation components.
- The **Interface** and **Dynamic Component/Plugin** based design, long existing in WCT, is now being applied pervasively.
- The nascent command line program application, `wire-cell`, is now fully usable to aggregate components into a working application. Eg, run sim:

```
$ wire-cell -c dune/fourdee.jsonnet
```

- Input data/configuration preparation and diagnostic functions available as various Python CLIs, eg **generate wires** or **prepare Garfield responses**:

```
$ wirecell-util make-wires pdsp-wires.json.bz2  
$ wirecell-sigproc convert-garfield dune_4.71.tar.gz \  
    garfield-1d-3planes-2lwires-6impacts-dune-v1.json.bz2
```

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Integration Motivations

WCT has substantial stand-alone functionality exposed by `wire-cell` CLI. However, it is primarily a **toolkit** to be used in other applications

WCT needs LArSoft (the framework) for some critical things:

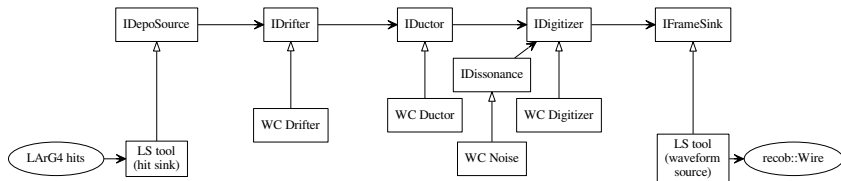
- I/O access to official DUNE file formats.
- Memory-based exchange of data products to/from WCT components and LS modules.

WCT lacks a subset of functionality provided by LArSoft modules:

- Particle interactions and tracking (ie, Geant4/GENIE/etc).
- All the many, alternative reconstruction modules.

Integration Status and Design

- Wire Cell Toolkit built as `wirecell` UPS product (Lynn)
- LS package `larwirecell` holds layers between WCT and LS
- WCT heavily uses **interfaces** and **dynamic components**, similar to recently invented **Art Tool** concept.
- Integrate via Art Tool facade to WCT interface.
→ basic model: “**LArSoft uses Wire Cell tools**”
- Same WCT app component exposed to user as CLI via `wire-cell` (eg, `Fourdee` sim below) will be exposed to LS with a single Tool facade.
- One Tool facade for data conversion at input/output components.



WCT Simulation App with LS Tool facades for input/output components.

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What's left to do?

Areas where help is welcome are in blue.

- Noise filtering
 - Rework to better follow WCT interfaces/components patterns. (bv)
 - [Rework LArSoft integrating to follow Art Tool paradigm](#) (??, or bv)
- Improved detector simulation:
 - Long-range/fine-grained detector response, **done** (Yichen, bv).
 - Normalization and validation, **in progress** (Hanyu, bv).
 - Proper **noise** (Jyoti/Milind/Arbin) and **drift** (Hanyu) models: **in progress**.
 - Implement FEE “channel shuffle” and match numbering convention. (bv)
 - [Integrate WCT sim components into LArSoft](#). **design** (Brian, bv)
- Signal processing
 - Port prototype code into toolkit: **started** (bv, Xin)
 - [Validate signal processing](#) with simulation, develop “truth metrics” (Brooke), understand SP under different signal and noise assumptions.
 - [Integrate WCT sigproc components into LArSoft](#). **design** (Brian, bv)
 - Finish MicroBooNE paper (whole SP team)
- Toolkit infrastructure miscellany
 - Various improvements/cleanups in configuration layer and build/source management. (bv)