Refactoring Wire-Cell Electron Drift Simulation for protoDUNE-SP

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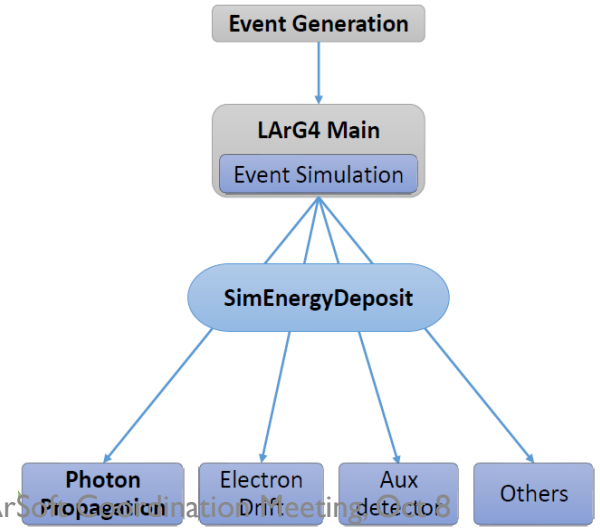
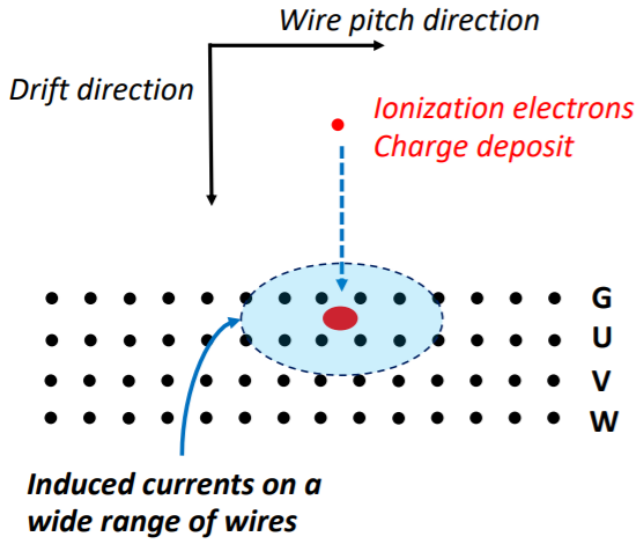
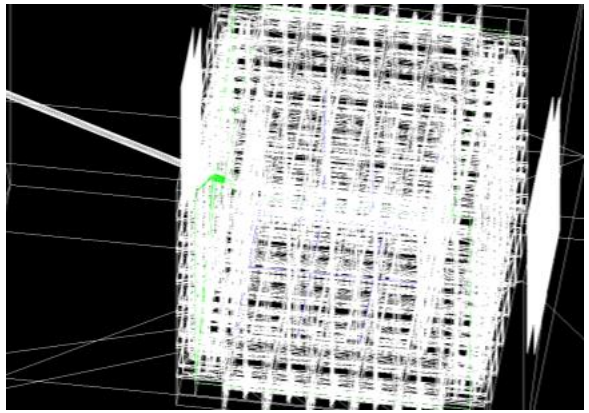
ProtoDUNE-SP simulation task force

- Aim at two major updates
  - Refactored larg4 simulation (David Rivera, UPenn)
  - WireCell electron drift simulation (Wenqiang Gu, BNL)
- Other subsystems
  - Optical detector simulation (Wei Mu, FNAL)
  - CRT simulation (Richie Diurba, U Minnesota)

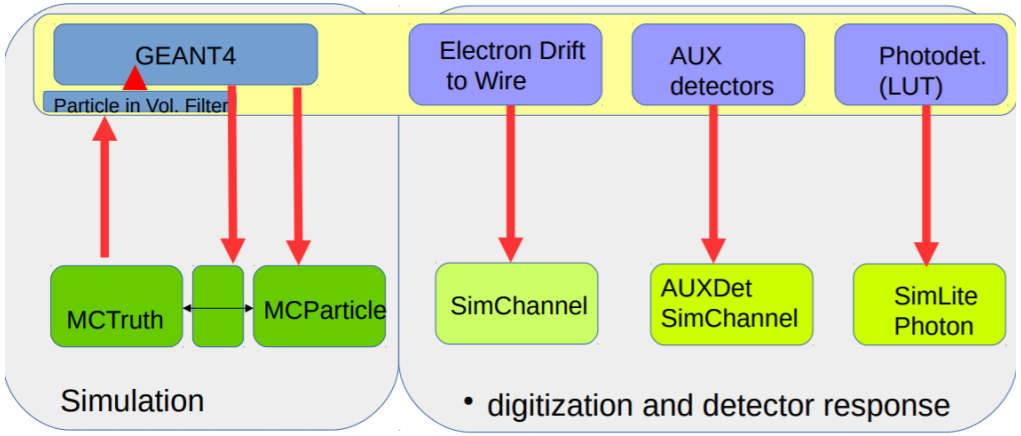




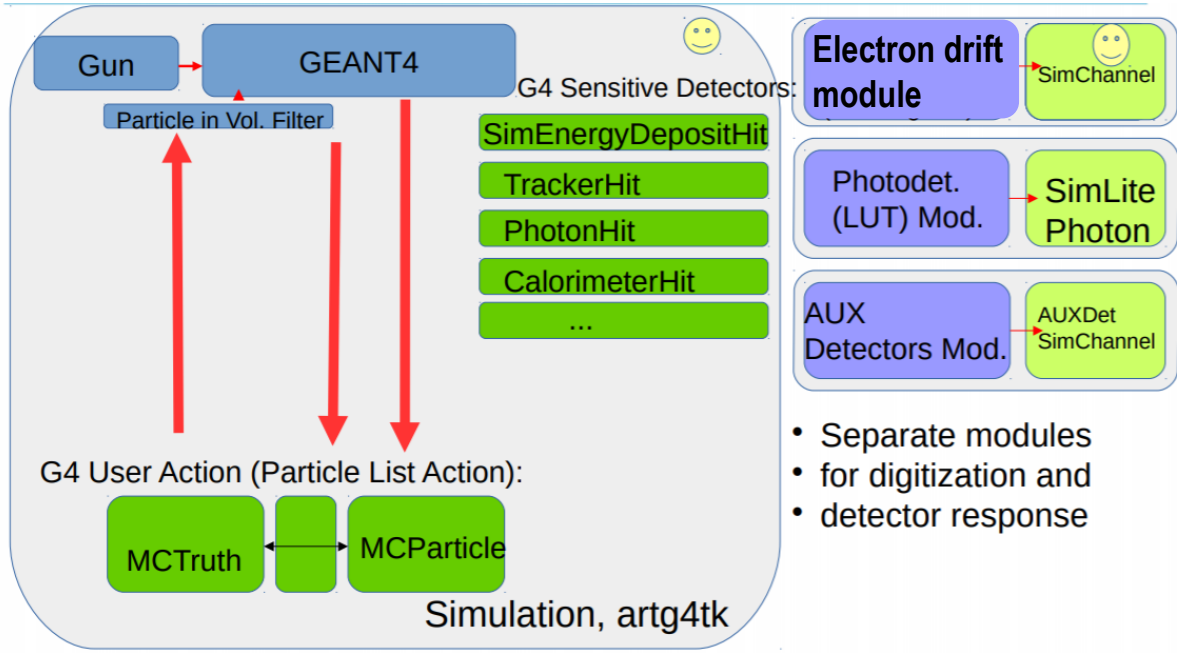


Refactored framework (Hanz et al.)

Current (**larsim/LArG4**)



Refactored (**larg4**)



More readings about refactored simulation larg4:

[Hanz Wenzel] https://indico.fnal.gov/event/18681/session/6/contribution/61/material/slides/0.pdf

[David Rivera] https://indico.fnal.gov/event/21037/contribution/2/material/slides/0.pdf

WireCell Electron Drift Simulation

- Long-range induction effect → field response (2D effect: time, wire)
- Diffusion, lifetime, etc.

Overview of Wire-Cell simulation

$$\textbf{ADC Wavform} = (\boldsymbol{Depo} \circledast \boldsymbol{Drifter} \circledast \boldsymbol{Ductor} + \boldsymbol{Noise}) \times \boldsymbol{Digitizer}$$

One charge depo
(x, y, z, t0, # of electrons)

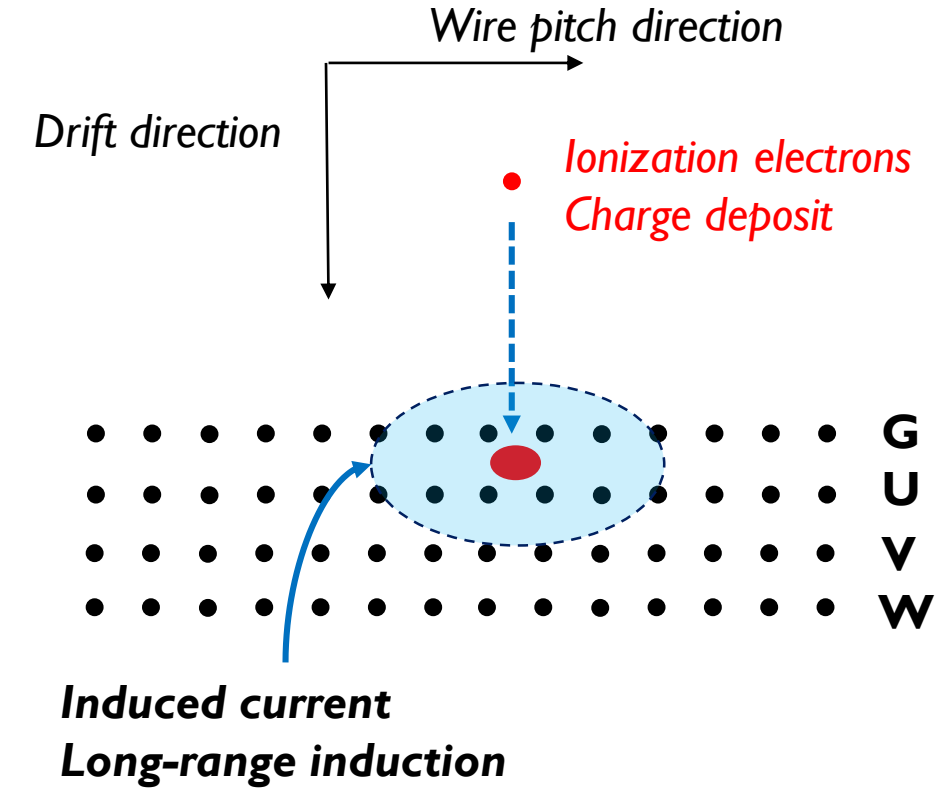
Data-driven input + analytic method

✓Field response (pre-calculated 2D Garfield calculation)
✓Pre-amplifier electronic response (gain, shaping)
✓Additional response (AC coupling)

Kernel:

$$[Gaus(t) \cdot Gaus(x)] \otimes field(x,t) \otimes Preamp\ (t) \otimes RC(t)$$

✓ Ionized electron absorption (electron lifetime in LAr)
✓ Gaussian diffusion (longitudinal / transverse)
✓ Fluctuation (for each gird of the discretized 2D Gaussian cloud)



DUNE collaboration meeting, May 2019

Refactoring *larwirecell*

- From μBooNE to protoDUNE: 1 APA → 6 APAs

```
private:
WireCell::IDepo::pointer m_depo;
// WireCell::IAnodePlane::pointer m_anode;
std::vector<WireCell::IAnodePlane::pointer> m_anodes; // multiple volumes
WireCell::IRandom::pointer m_rng;
```

```
for (auto anode: m_anodes) {
for(auto face : anode->faces()){
  auto boundbox = face->sensitive();
  if(!boundbox.inside(depo->pos())) continue;
```

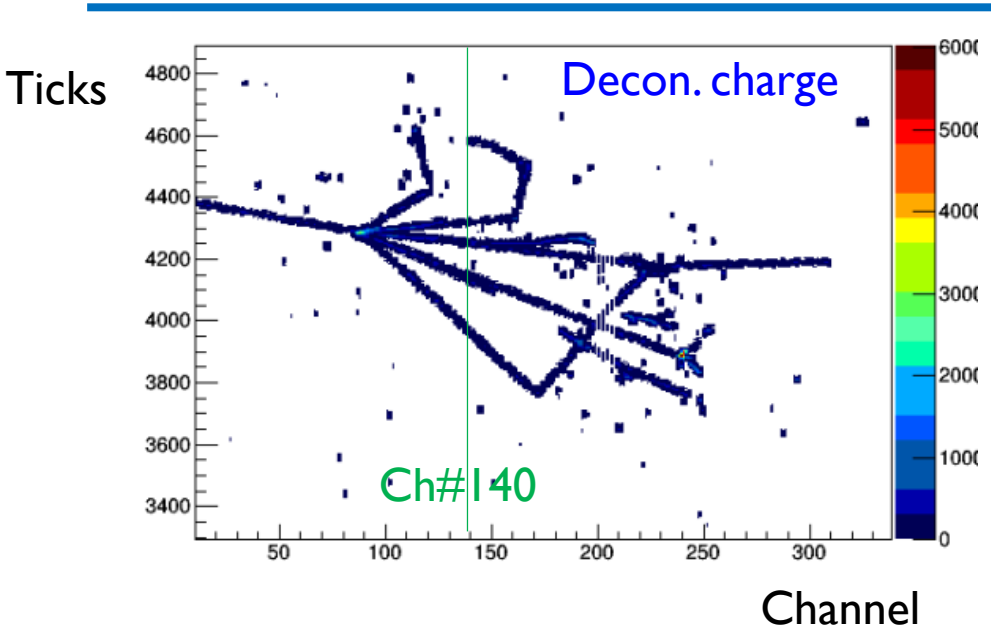
- Fix some hard-coded geometry from μBooNE

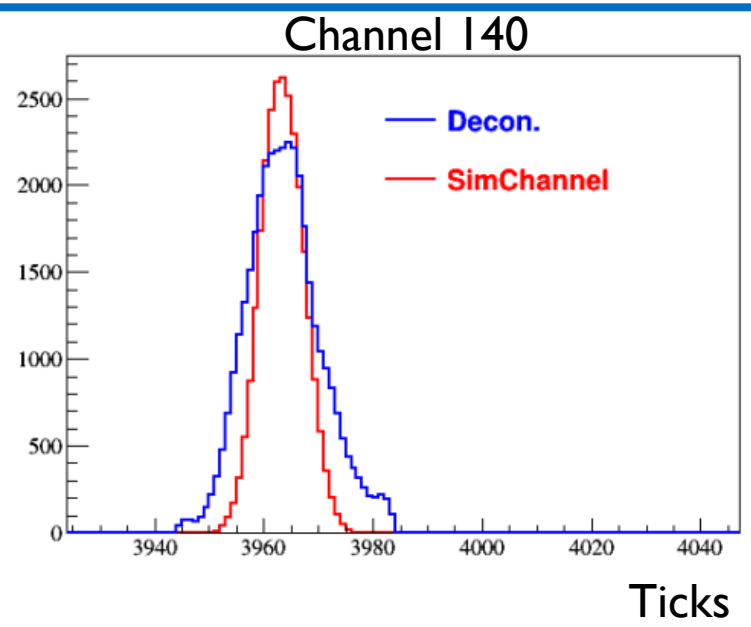
```
SimChannelSink::SimChannelSink()
  : m_depo(nullptr)
{
  m_mapSC.clear();
  uboone_u = new Pimpos(2400, -3598.5, 3598.5, Point(0,sin(Pi/6),cos(Pi/6)), Point(0,cos(5*Pi/6),sin(5*Pi/6)), Point(94,9.7,5184.98), 1);
  uboone_v = new Pimpos(2400, -3598.5, 3598.5, Point(0,sin(5*Pi/6),cos(5*Pi/6)), Point(0,cos(Pi/6),sin(Pi/6)), Point(94,9.7,5184.98), 1);
  uboone_y = new Pimpos(3456, -5182.5, 5182.5, Point(0,1,0), Point(0,0,1), Point(94,9.7,5184.98), 1);
}

int plane = -1;
for(Pimpos* pimpos : {uboone_u, uboone_v, uboone_y}){
  plane++;
```

```
for (auto plane : face->planes()) {
  const Pimpos* pimpos = plane->pimpos();
```

Geometry from gdml

MC backtracking: SimChannel

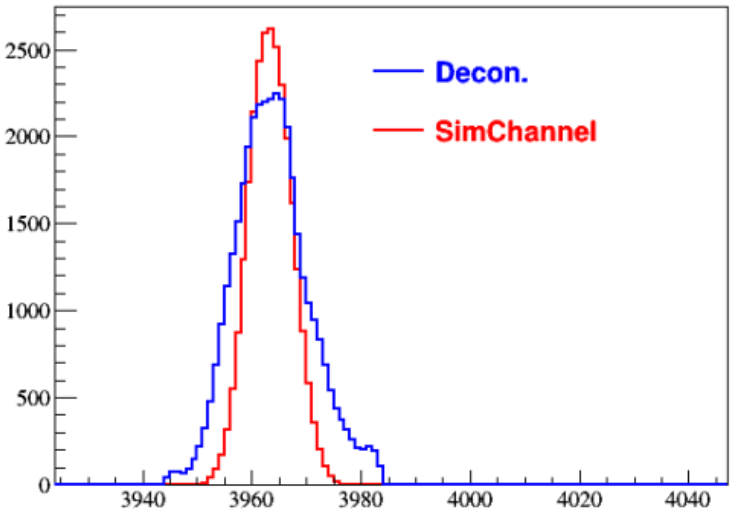


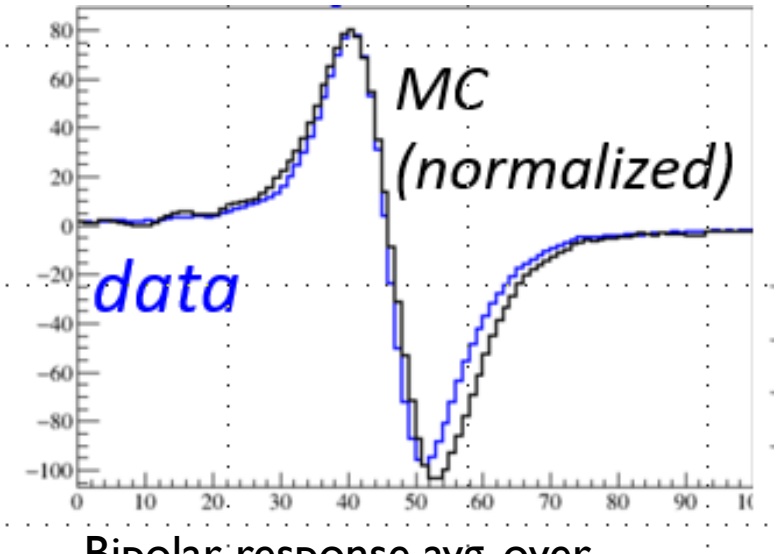


- SimChannel: energy depo. from all G4 tracks saved separately in time - per channel
- Time alignment: decon. vs SimChannel
- Charge width: extra smearing from signal processing (expected)

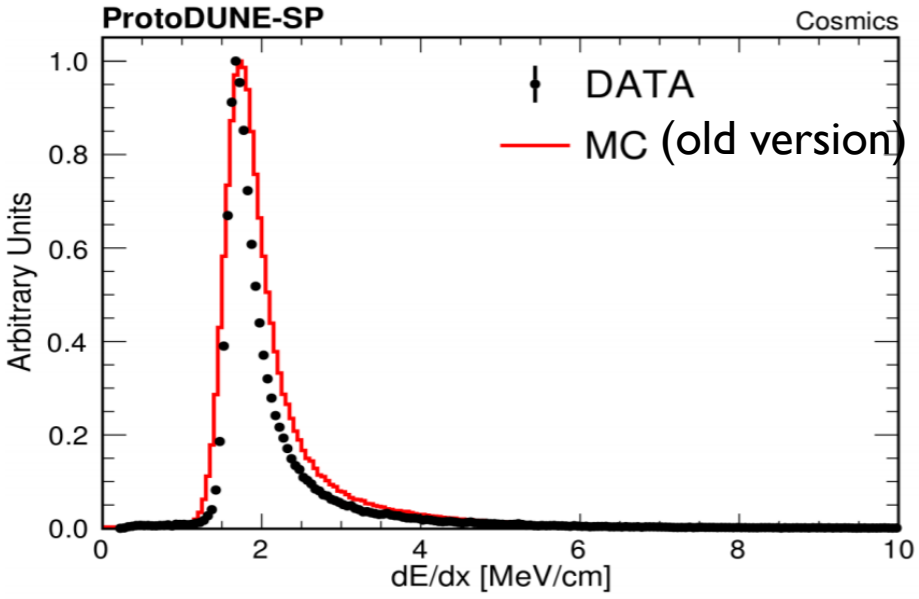
Next step

- Add extra smearing in "SimChannel" (optional)
- Validate field response: data vs. MC
- Improve agreement in dE/dx: data vs. MC





Bipolar response avg. over channels in a cosmic dataset (Wenqiang et al.)



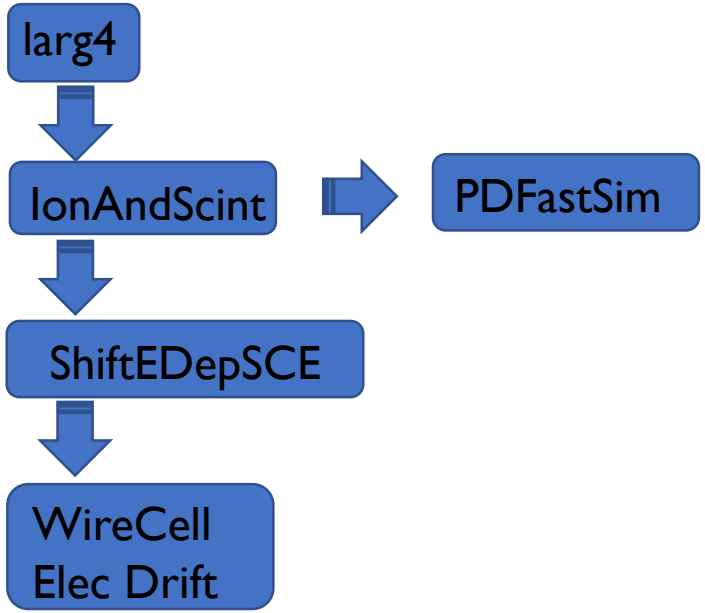
Stopping muon (Ajib et al.)

Fhicl's

- Base version: larsoft v08_31_01
- Feature branches

  dunetpc @ feature/wgu_refact
  lardataobj @ feature/muve_pdsim_refactor
  larsim @ feature/muve_pdsim_refactor
  larg4 @ feature/muve_pdsim_refactor
  larwirecell @ feature/muve_pdsim_refactor @ feature/wgu_refact

- Usage:
  - lar -c **gen_protoDune_muon_1GeV_mono.fcl** -n 1 -o gen.root
  - lar -c **protoDUNE_refactored_g4.fcl** -n 1 gen.root -o g4.root
  - lar -c **wcls-sim-drift-simchannel.fcl** -n 1 g4.root -o detsim.root
  - lar -c **protoDUNE_refactored_reco.fcl** -n 1 detsim.root -o reco.root



Summary

- Generalized wirecell module to perform electron drift simulation
- SimChannel's time offset is perfectly matched with the deconvolved charge
- Need some improvement in field response and dE/dx