LAr as DUNE ND

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Technical challenges of large LAr TPCs

Large monolithic liquid TPCs present many new technical challenges:

- Cost of failure is high.
- Long drift lengths incur even more potential pitfalls:
  - Requires high purity.
  - Needs high cathode potential that could produce breakdowns: we now know that electrical breakdowns in LAr start at a field of $\simeq 40$ kV cm^{-1}
  - The amount of energy stored in the E-field can cause damage to electronics if discharged.

Would there be a way to mitigate these points?

Technical challenges of large LAr TPCs

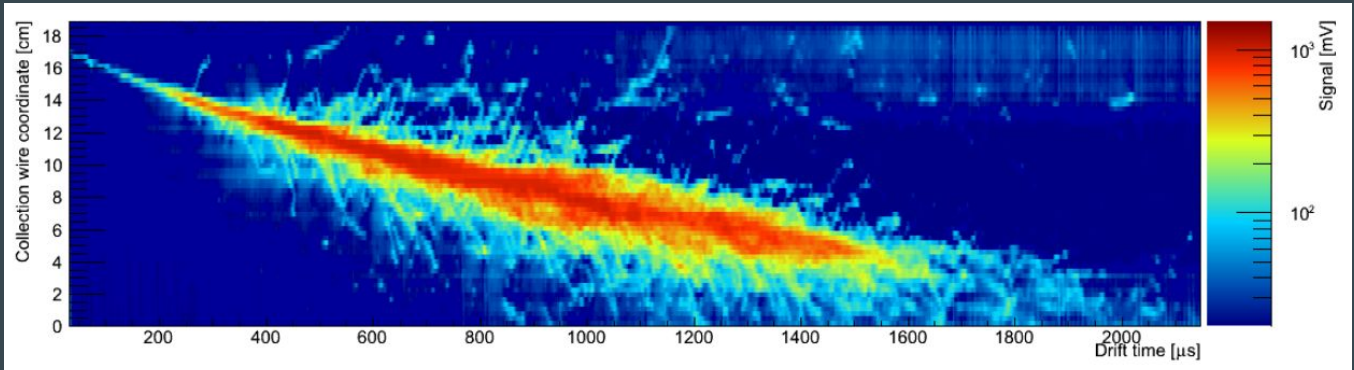
One answer could lie modularity:

- Separate a large volume in independent sub-volumes:
  - Keep drift length in the order of 1 m.
  - Lower space charge accumulation leads to less field distortions.
  - Cathode potential in a more manageable range (~100 kV).
  - Reduce the stored E-field energy.
  - Drift times go down to the order of 0.5 ms and so purity requirements can be relaxed.
  - Potential for individual repairs bringing down the failure costs.

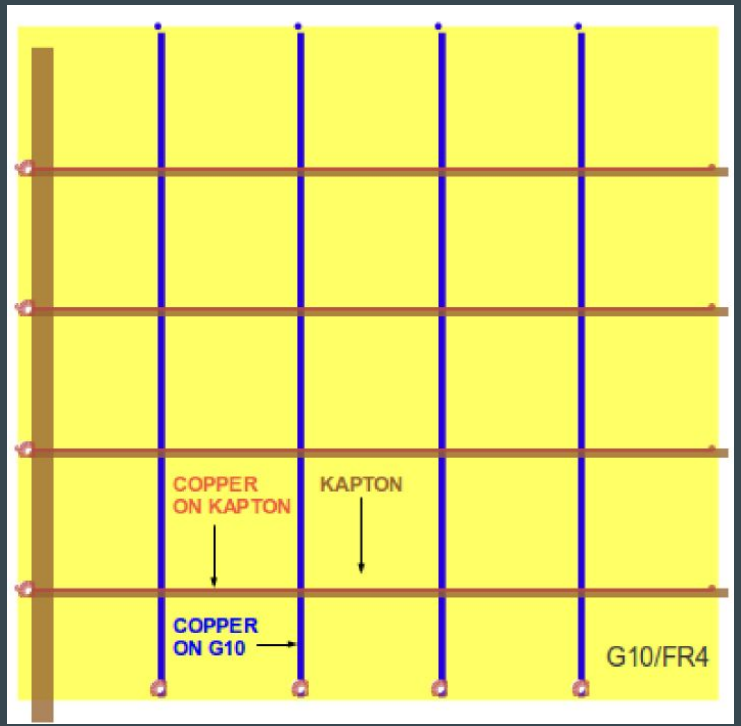
Technical challenges of large LAr TPCs - Readout

Historically (and even in active experiments today) wires were the favored readout approach. They are well understood btu come with drawbacks:

- They are prone to microphonics.
- They only provide projections of X and Y (or U,V,W) and that can induce ambiguities in reconstruction
- Mechanically demanding (like stringing a piano)



A “solid-state” readout



Using kapton and known PCB manufacturing techniques, one can replicate a wire pattern but do away with tensioning and other problems

- Base support is standard G10/FR4.
- Series of copper tracks in one axis.
- Strips of copper coated kapton in the other.

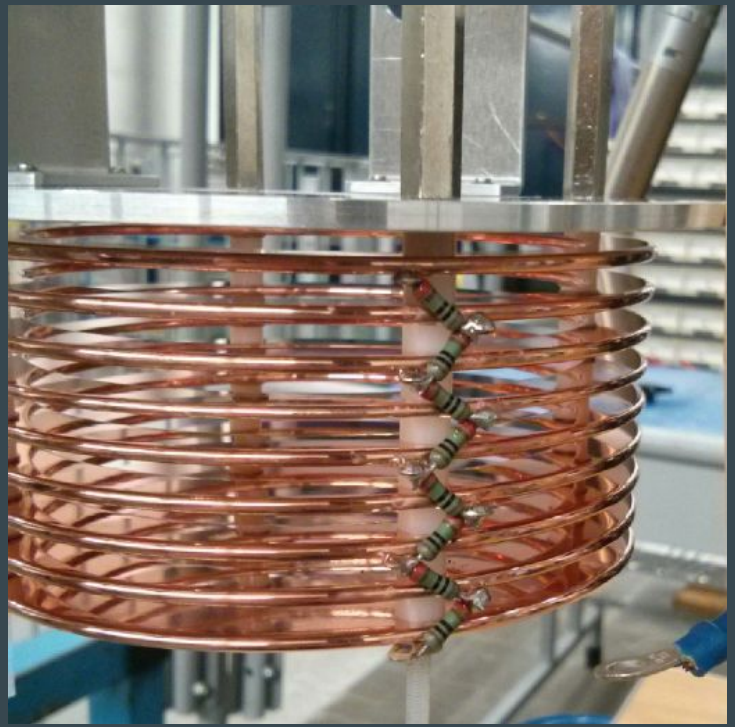
This arrangement boils down to charge sharing between the two wire sets on the PCB.

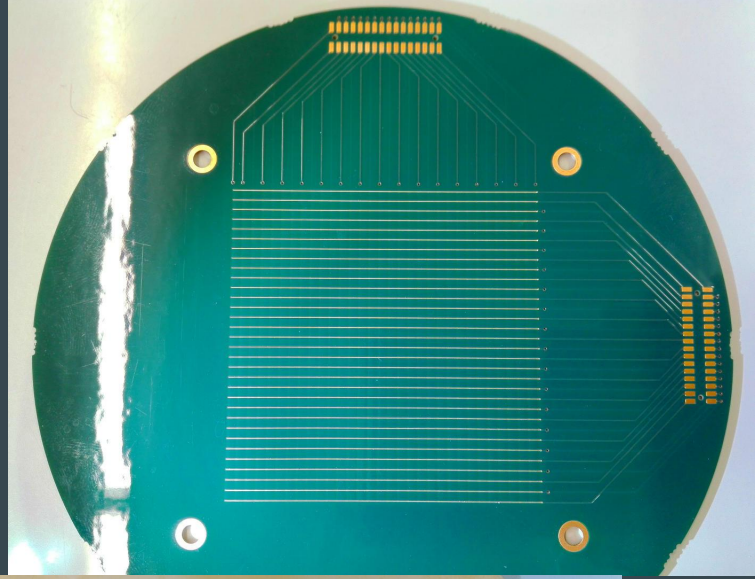
A “solid-state” readout - Prototype

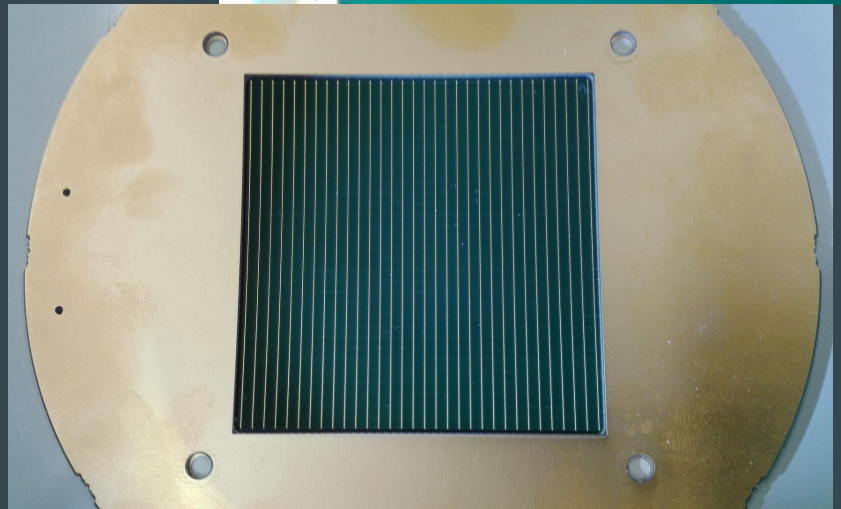
A prototype board stemming from this idea was already built and operated.

- 100 μm wide copper tracks.
- 1.7 mm pitch between tracks.
- 32 tracks on each side of the 50 μm thick flexible PCB.
- The wires on the “back” side work in induction mode
- Main readout electronics being the cold LARASIC preamps from BNL.

A “solid-state” readout - Prototype







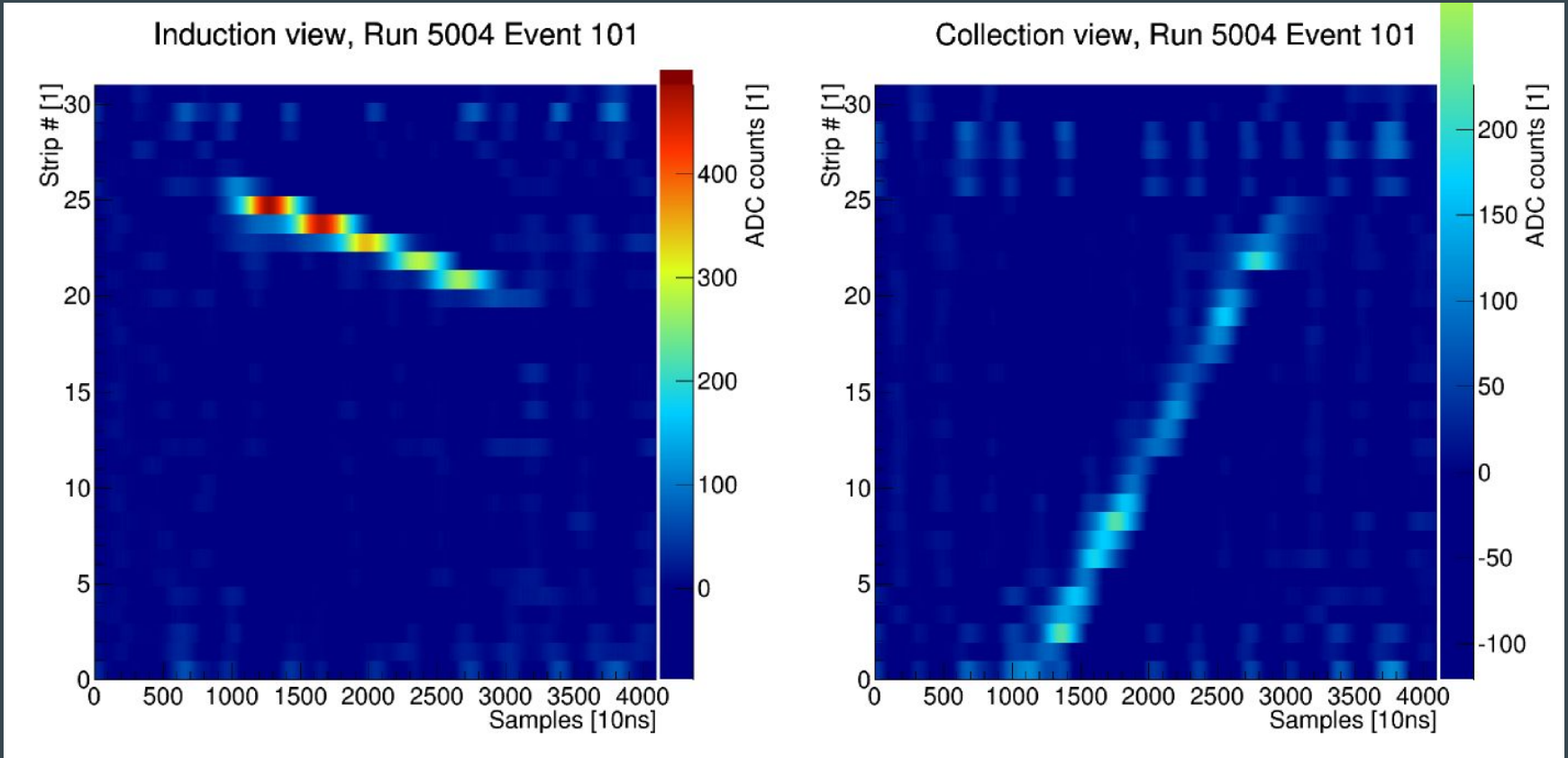
A “solid-state” readout - Prototype

Some facts about the little test cell:

- 46 mm drift length.
- 8 cm in diameter.
- 5kV at the cathode giving a field of ≈1.1 kV cm^{-1} .
- Drift speed of ≈2 mm μs^{-1} .
- Total drift time of ≈ 23 μs.
- Trigger generated either by threshold on wires or by an external muon telescope.

But did it work?

A “solid-state” readout - Prototype



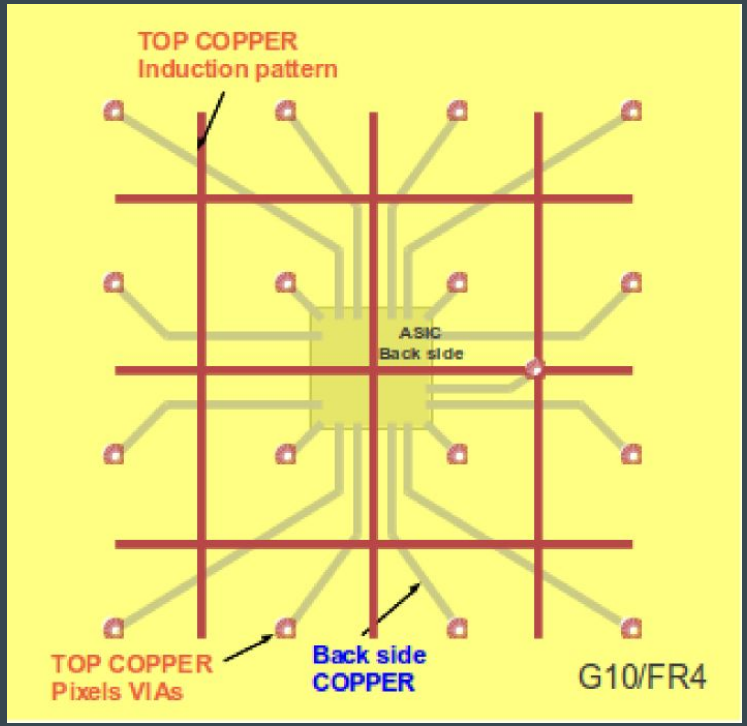
A “solid-state” readout - Prototype

Although plagued by a grounding/noise problem this proof of concept was successful. The positive takeaways are that:

- This is a tough and rugged one-piece readout.
- We used connectors but you could expand the kapton into flat cables and do away with connectors.
- Easy to manufacture in standard PCB industries.

This was still based on wire-like geometry though.

A “solid-state” readout - The Next Prototype



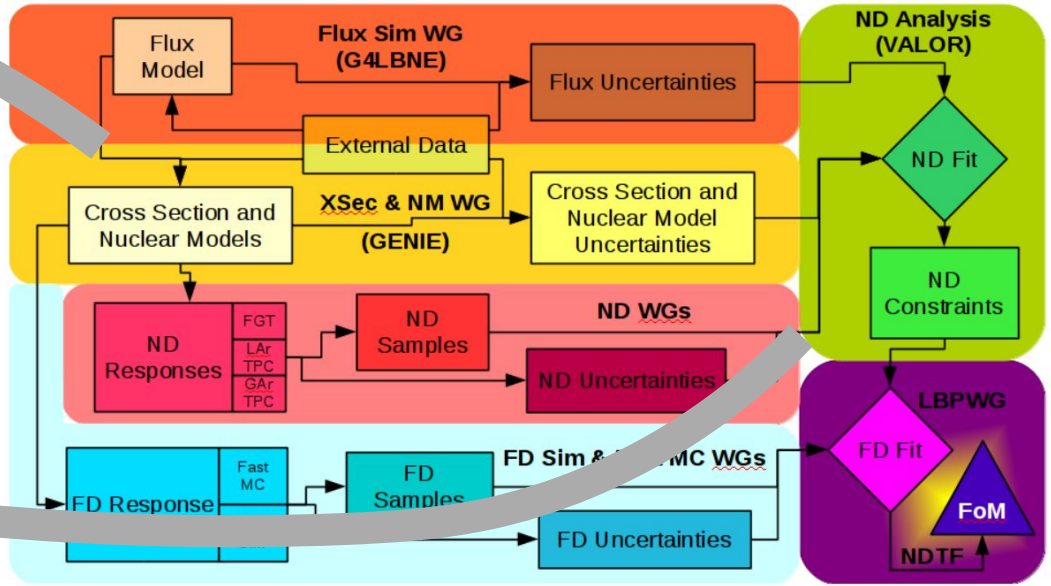
Using regions of interest defined by an induction pattern would do away with the 2D projections of a wire geometry.

- Independent copper trace grids define induction zones.
- Zones are populated by pixels. Every same pixel from every induction zone is read out by a single channel.
- Every induction zone is read out by a channel.
- Pair hit pixels to right zones and reconstruct events directly in 3D.
- Number of pixels scale with the square of readout channels.

Segue to Simulation & Reconstruction Efforts of the LArTPC Option

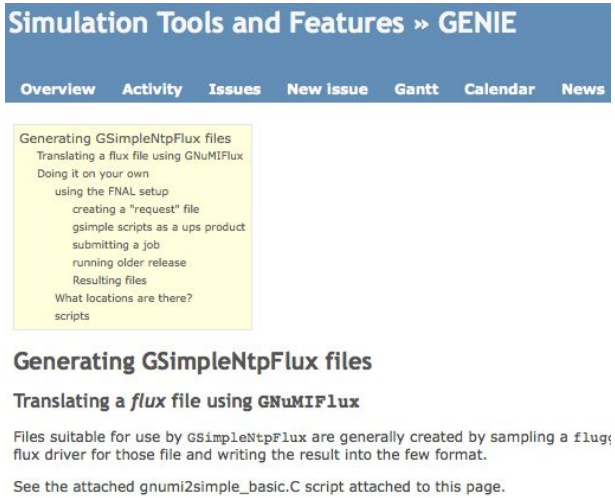
Plan

- Flux files
- Generate events in a LArTPC
- Reconstruct events on some level
- Make outputs
- Short-term plan is to go through each of the steps in a dry run, and later make improvements



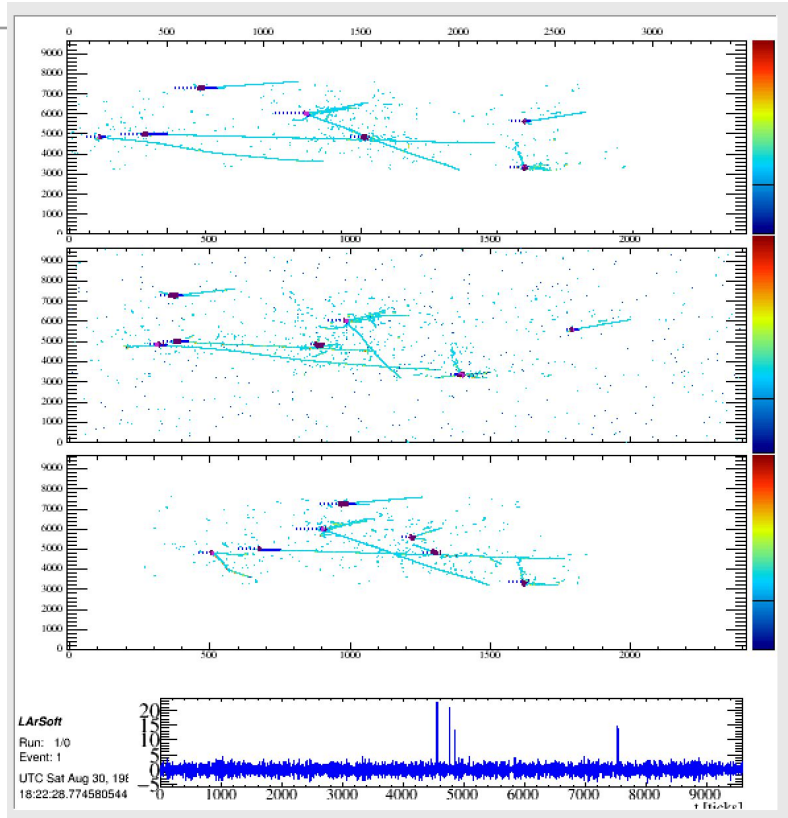
Plan into more Detail & Status

- Laura Fields pointed me to a number of options for Dune flux files
- Flux file format dk2nu is not fully implemented in nutools… yet!
- Robert Hatcher has code to convert dk2nu —> gsimple files
  - gsimple works in NuTools
  - This is working!



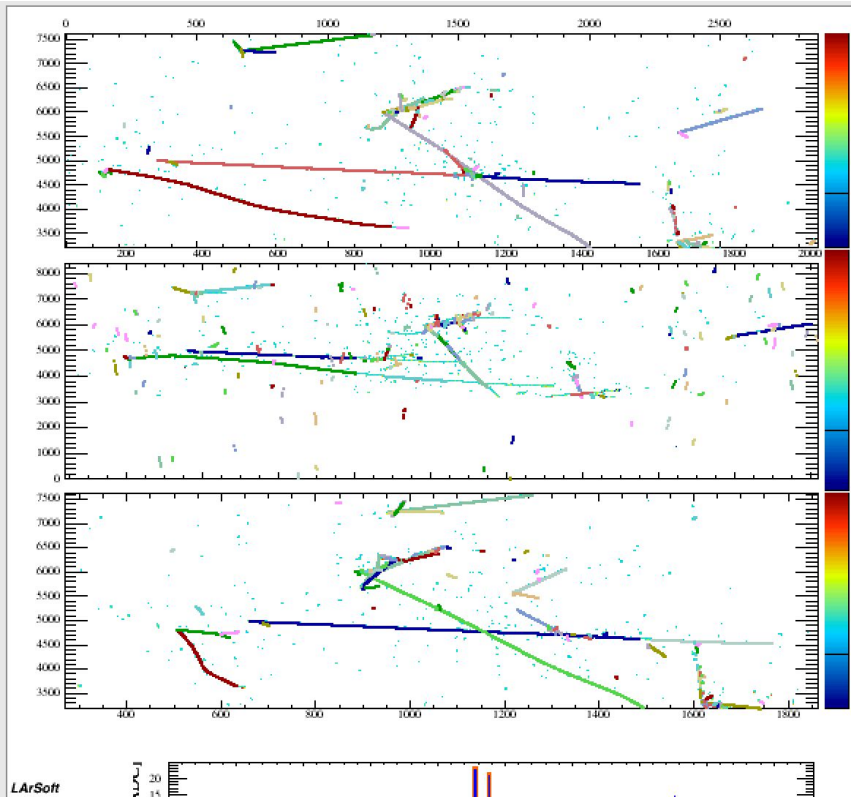
Plan/Status: Generate Events in LArTPC

- Using these flux files, generate events in a LArTPC
  - Using MicroBooNE right now
  - Gen —> prodgenie_bnb_nu_uboone.fcl
    LArG4 —> standard_g4_uboone.fcl
    DetSim —> standard_detsim_uboone.fcl
    CalData —> standard_reco_uboone.fcl
  - Works!



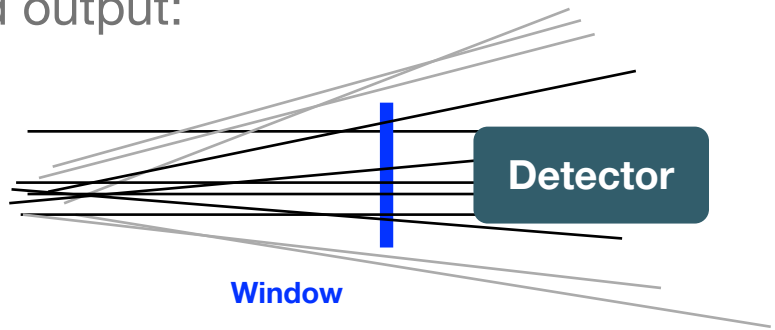
Plan/Status: Reconstruct Events

- Can run reconstruction on the events using:
  - Real reconstruction algorithms:
    - FFT on wires,
      Gauss HitFinder,
      Fuzzy Clustering,
      (tracking could also be run)
  - This is where we currently are



Plans/Future: Flux to Detector

- dk2nu —> gsimple files
- The code makes uses a window in front of the detector to determine what goes into the saved output:



- If the other detector options plan to use nutools + gsimple files, we should use the same files

Plans/Future: Generating Events & Detector Simulation

- For the first pass, generate more events
  - Tested the machinery with an event, now go through and increase it
- Samples for systematics?
- Need to look closely at the configuration files (are the settings what we really want to use?)
- Eventually may consider:
  - Shielding
  - Upstream magnet (are through-going muons an issue?)
  - Detector size (is containment an issue?)
  - Detector optimization/improvement?

Plans/Future: Reconstruction and Outputs

- We are able to use the reconstruction efforts for other experiments in LArSoft
- Will be able to use “cheated” reco shortly
  - Looks at truth information
- Need to use reconstruction that’s comparable to other two groups for a fair comparison
- Need to produce output in a defined format
  - The format is being discussed

Summary

- Status:
  - Can generate and reconstruct events in a LArTPC with the Dune flux
- What is needed for a first pass?
  - Generate more events
  - Define an output format
- What we'll need for a pass that matters:
  - Make sure we are using common flux files & reasonable settings
  - Unbiased reconstruction
  - A first pass at systematics