New Pandora code for multi-TPC reconstruction.

(Slides adapted from Pandora talk at last week's DUNE collaboration meeting)

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LArSoft meeting

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Introduction

- **A number of Pandora developments are converging:**
  - ➢ Treatment of multiple TPCs for DUNE & ProtoDUNE [AB]. (larpandoracontent, larpandora, dunetpc)
  - ➢ Machine learning approach to vertex selection [Jack Anthony]. (larpandoracontent, uboonecode, dunetpc)
  - ➢ Machine learning approach to track/shower ID [Lorena Escudero]. (larpandoracontent, uboonecode, dunetpc)
  - ➢ And more …

❑ **I'm first up!**

- ➢ My set of feature branches "blake_multidrift" in larpandoracontent, larpandora and dunetpc are ready to go into develop please.
- ➢ These implement some strategies for multi-TPC reconstruction in DUNE and ProtoDUNE (and SBND).

Multi-TPC Reconstruction

- **New code contains the following strands of work:**

(1) Global coordinate systems for reconstructing neutrino interactions or single particles in multi-TPC detectors.

➢ larpandora (mainly "LArPandoraInterface" package).

(2) Stitching algorithms for connecting cosmic-ray muon tracks across APA or CPA boundaries.

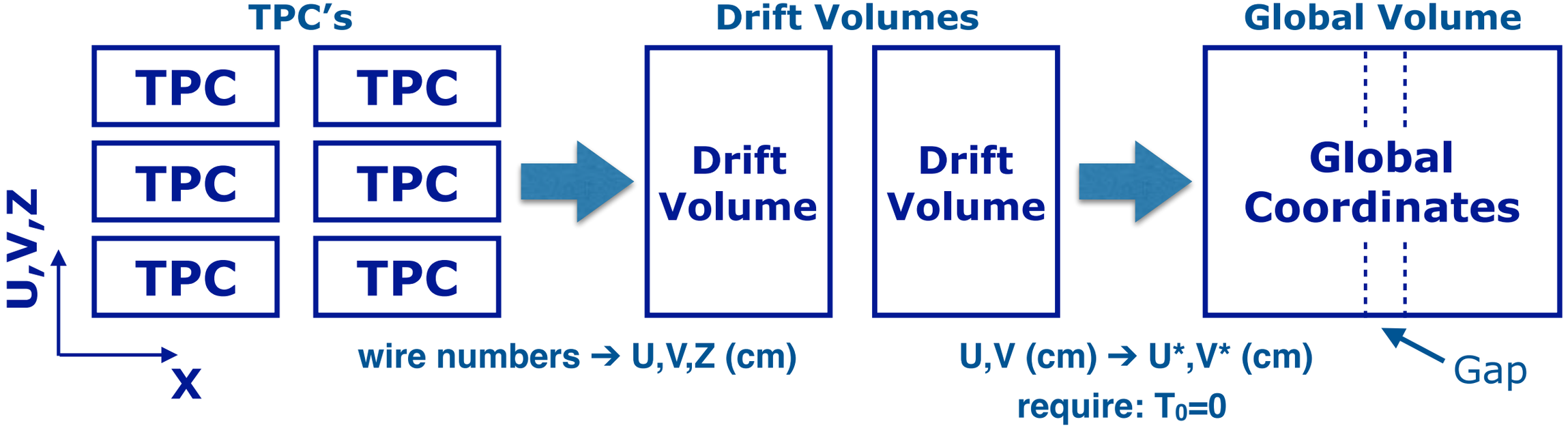
➢ larpandoracontent

(3) Implementation .fcl and .xml settings for DUNE and ProtoDUNE.

➢ dunetpc ("DUNEPandora" package).

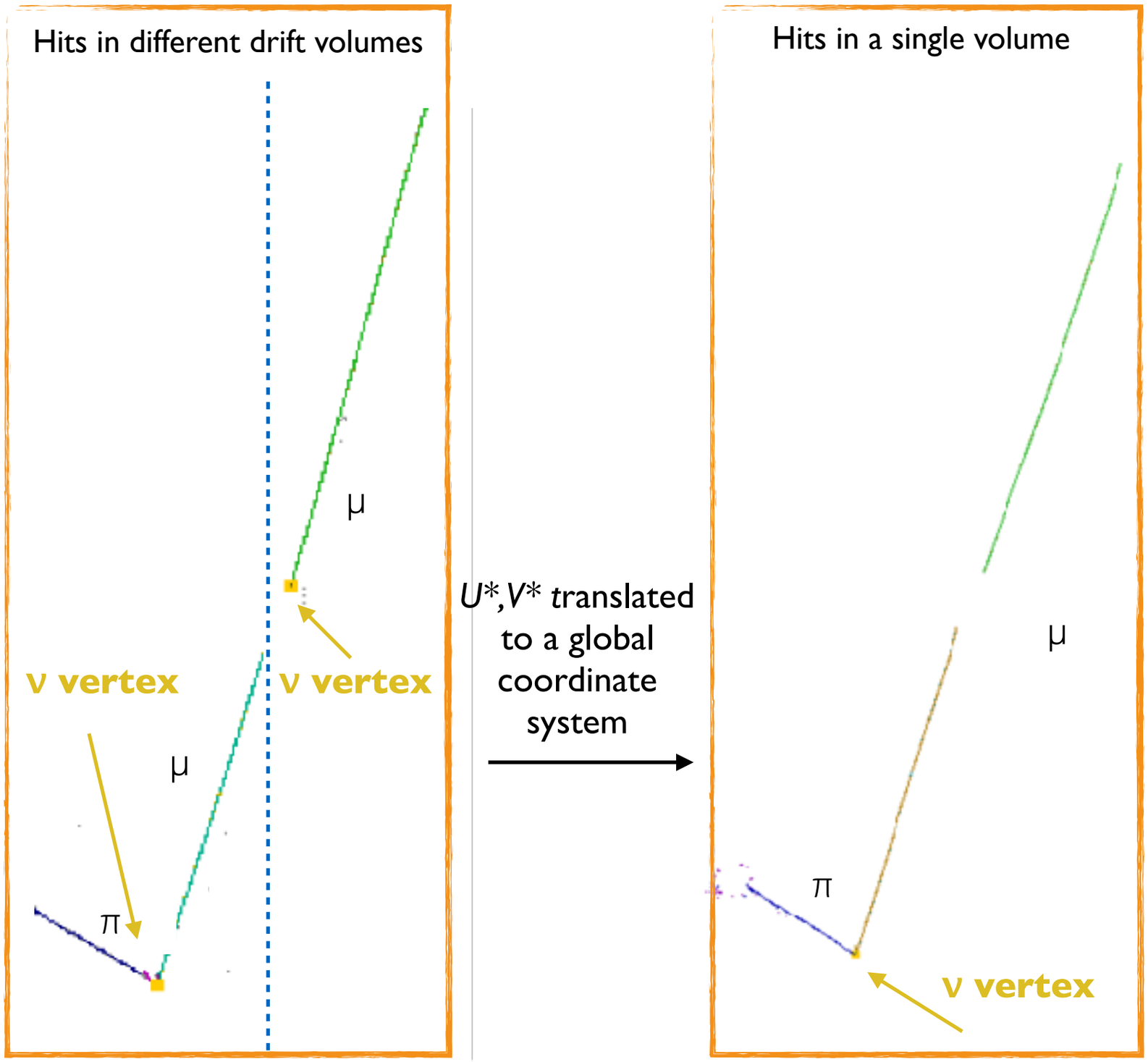
Global Coordinates

- **Reconstruction of LAr-TPC images in multi-TPC detectors is a very difficult jigsaw puzzle!**
- **To simplify the problem, can exploit the common wire angles of every TPC in DUNE and ProtoDUNE to define common coordinate systems:**



- **Have coded up these coordinate systems in larpandora:**
  - ➢ This should enable us to adapt our MicroBooNE-style algorithms for use in DUNE and ProtoDUNE.

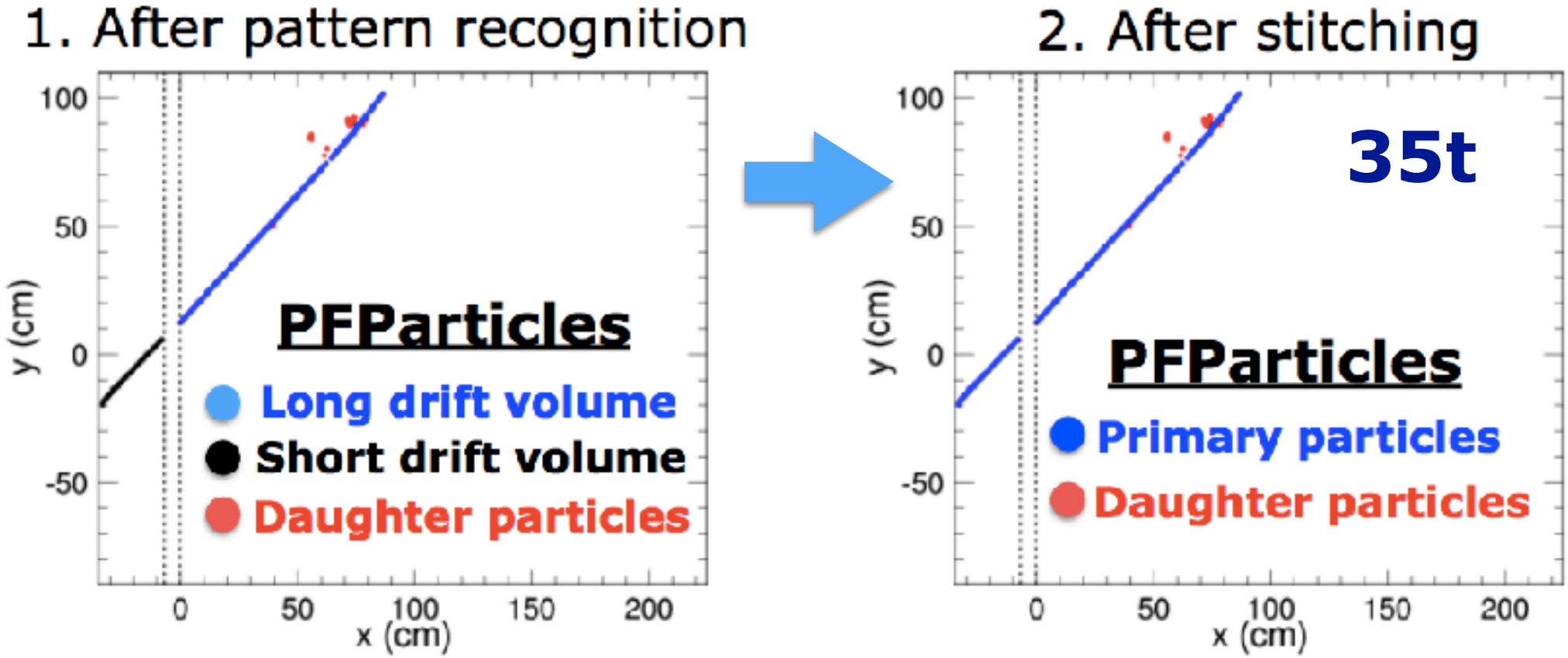
Global Coordinates



- With a single drift volume, neutrino reconstruction is less of a jigsaw puzzle!
- Should be much easier to reconstruct neutrino interactions without the need for complicated stitching.
- Note: will need to deal with a few complications:
  - ➢ Gaps between APA or CPA frames.
  - ➢ Space charge.
  - ➢ Anything else?
- New larpandora code will enable us to explore this strategy.

Particle Stitching

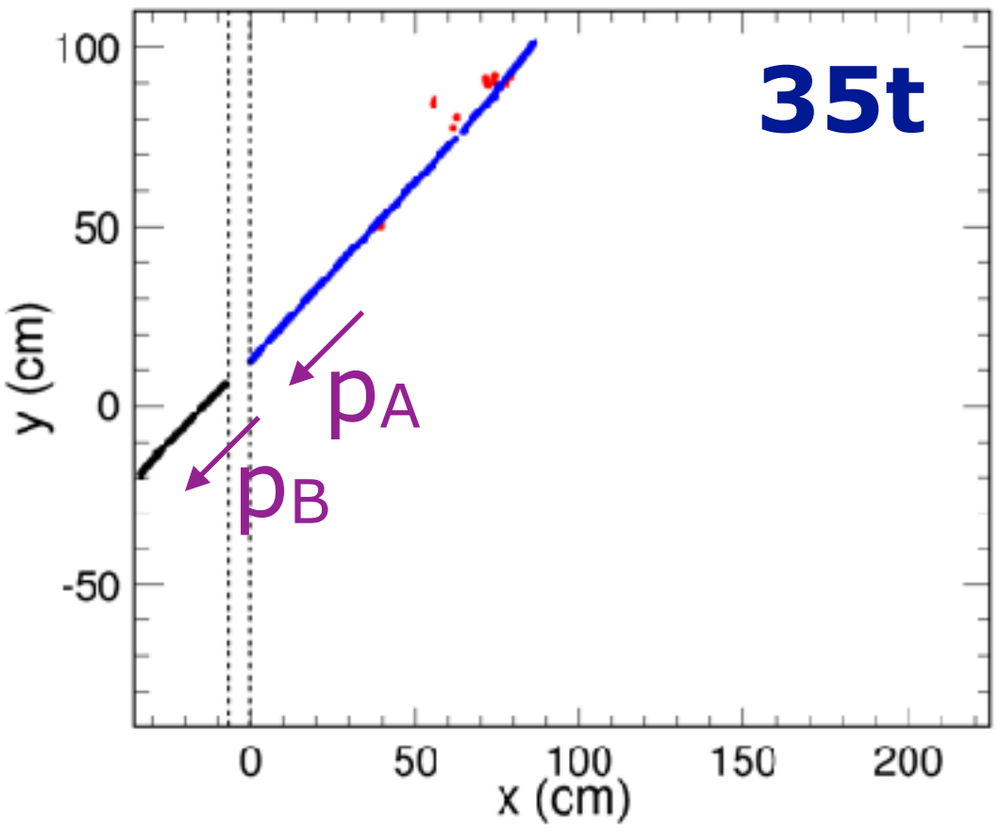
- **Previously wrote LArSoft module "PFParticleStitcher" to stitch together PFParticle objects in the DUNE 35t detector.**
  - ➢ This stitched together track-like PFParticles across mid-plane.
  - ➢ Also determined T_0 based on x-position offset between tracks.



- **Have now adapted module for ProtoDUNE and absorbed code into larpandoracontent framework (to use available tools).**

Particle Stitching

- **Particle-stitching algorithm is based on reconstructed 3D hits associated with each track-like PFParticle.**

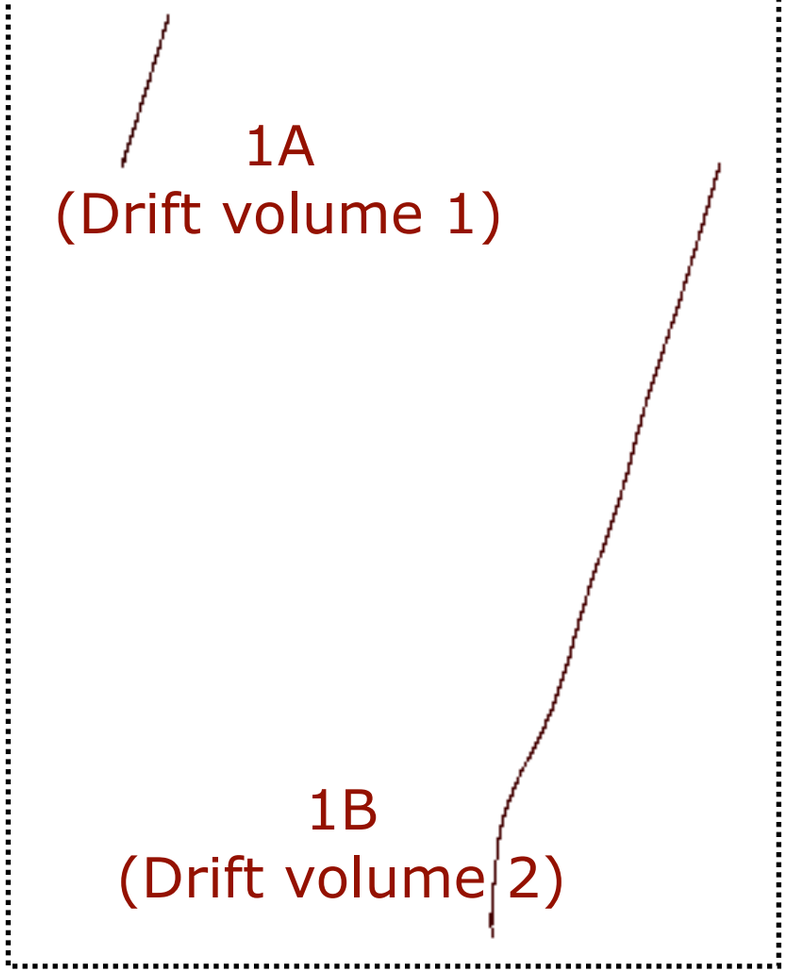


- **Stitching procedure:**
  1. Track-fitting: Apply sliding linear fits to each 3D track.
  2. Track-matching: Use Y-Z pointing information to match trajectories across boundaries, and resolve any ambiguities.
  3. T_0-correction: Use X offset to determine T_0 of matched tracks, and shift tracks such that they line up in drift coordinate.
  4. Track-stitching: Stitch together matched and T_0-corrected tracks.

- **The output objects and associations written to LArSoft after stitching are the same as those without any stitching.**
  - ➢ However, in addition, **T0 objects** and **Track-T0** associations are saved for each stitched track.

Particle Stitching

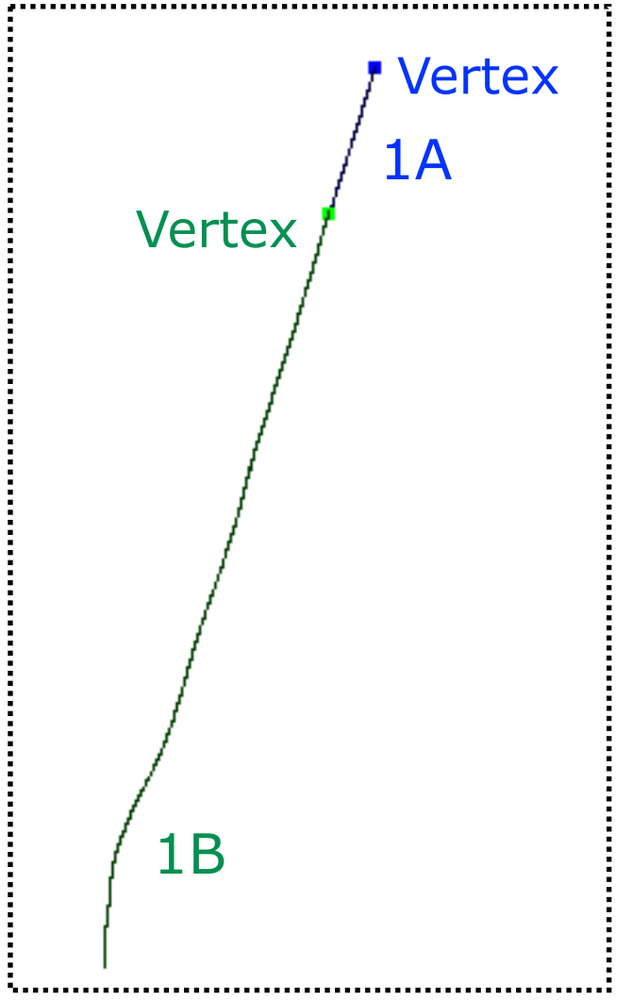
Matched tracks



Use pointing information to match tracks across mid-plane boundary.

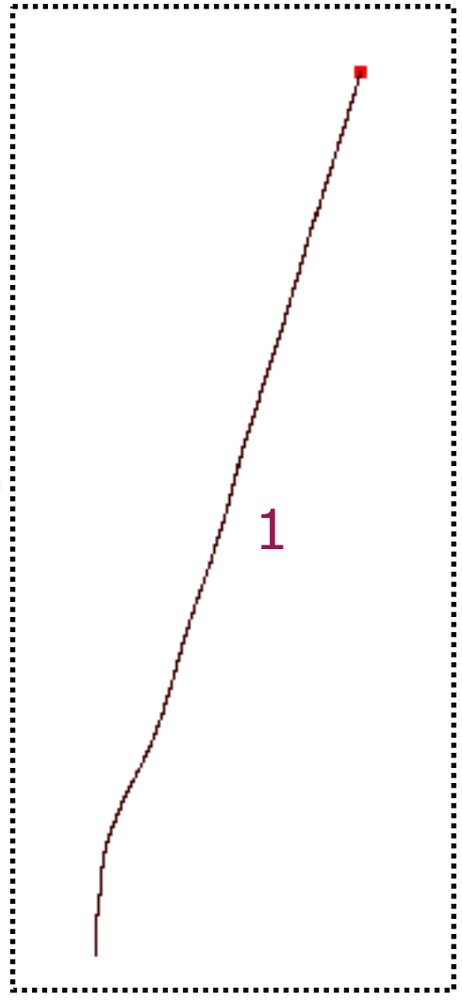
(resolve any ambiguities - but these are very rare!)

T_0 correction



Apply T_0 correction to reconstructed **3D objects***, such that the matched tracks form a single continuous trajectory.

Stitched track



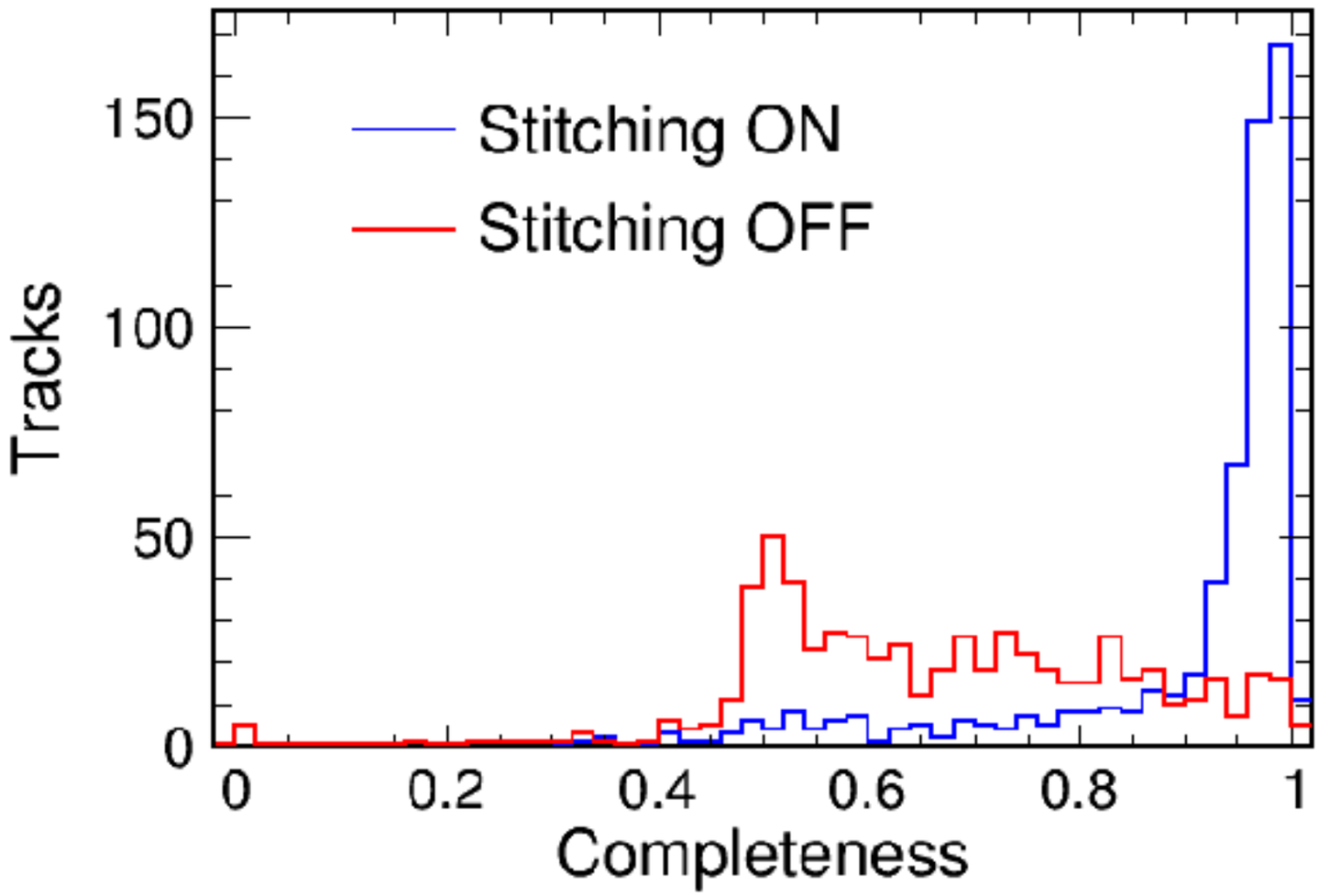
Stitch together tracks to form a single PFParticle object

*Note: this means that 2D hits will be displaced from stitched 3D track.

Particle Stitching

- Assess performance by studying "completeness" metric for a sample of approximately 500 true tracks that cross the mid-plane in ProtoDUNE:

$$\text{completeness} = \frac{\text{number of 2D hits in best-matched reconstructed track}}{\text{number of 2D hits associated with true track}}$$



- Can see that stitching algorithm produces a significant improvement!

Big Picture

- **Currently developing "two-pass" strategy for pattern recognition in ProtoDUNE similar to that of MicroBooNE.**
- **"multidrift" feature branches will fill a couple of important gaps, and will also support pattern recognition for DUNE.**

Input: disambiguated 2D hits

Cosmic Pass:

Pandora cosmic-ray reconstruction

(a) Reconstruct each drift volume separately ← **Use drift volumes here**

(b) Stitch together drift volumes ← **Run stitching**

Cosmic-ray background removal ← **Apply LArSoft cosmic tagging**

"Neutrino" Pass:

Pandora single-particle reconstruction ← **Use global volume here**