The NOvA detectors are made from planes of extruded PVC cells. Each cell is 4 cm x 6 cm x 5 cm (shown at the right) for the far detector, and 4 cm x 6 cm x 4 m for the near detector. These cells are read out at one end from a fiber connected to an avalanche photo diode. The planes alternate between being horizontally and vertically oriented to provide 3D tracking of particles in the detector.

Our reconstruction algorithms are designed to take position, time, and charge information from cell hits and construct interaction vertices and particle tracks.

**Step 1: Event Separation**

The first step in our reconstruction is to separate hits into groups that represent independent physics events (cosmic rays or neutrino interactions.) This is done by applying a density-based clustering technique based off of an algorithm called DBSCAN.

For each pair of hits in the detector, we compute a "neighbor score" based on how closely related they are. This computed score takes into account both the spatial and temporal separation of the hits. Next, hits with good scores are grouped together using an expanding clustering algorithm. All other hits not associated with a hit group are then labeled as "noise."

**Examples:**

- The plot above was made from simulated cosmic ray events.
- Average hit group completeness: Average hit group purity: 0.9552

The above plot was made from simulated cosmic ray events.

**Examples:**

- The blue X is the reconstructed vertex.
- Shown above are all hits within 500 μsec, sorted by time. This is data taken during a time when the far detector was not yet fully instrumented.

**Step 2a: Vertexting**

The next step in reconstructing an event is to determine the location of the neutrino interaction vertex. One approach to event reconstruction is to identify the largest horizontal plane of hits that are associated with a single vertex. The NOvA tracker can easily follow long tracks through the detector.

**Examples:**

- A: Event data (cosmic ray neutrons)
- B: Simulated high energy νCC event

**Step 2b: Tracking**

No alternate reconstruction path is to create particle tracks immediately after the event separation. This method is employed primarily for the purpose of tracking muons (used in the νe CC disappearance analysis) and uses a algorithm based on a Kalman filter.

**Examples:**

- C: Simulated high energy νCC event
- D: Simulated low energy νCC event

**Step 3a: Clustering**

The next step in reconstructing a neutrino event is to create "prongs." A prong is a cluster of hits associated with a single particle and has both a start point and a direction associated with it.

To create prongs, sort hits in a physics slice or represented as energy deposition at an angle with respect to the previously produced vertex. Hits are then clustered through a 2D angular space using a k-means clustering algorithm [see example plot of the near right]. Hits are allowed to have membership in multiple clusters and a cluster can be as small as a single hit to account for small neutrino deposits.

Clustering is done in each 2D detector view separately and are then matched between views by applying a k-δ algorithm to the energy profiles (see example plot at the far right.) These final 3D prongs serve as input to advanced tracking and particle identification algorithms.

**Examples:**

- Above: Example of angular distribution of hits around the vertex within a 2D view. Major prongs show up as spikes in this plot.
- Above Right: Example of 6.5 test prongs made when matching the energy profile for prongs in each view.

**Step 3b: Performance:**

Performance is based off of the completeness of the prong that matches the primary lepton.

- For νe CC, ave. completeness = 0.98
  - For QE, 0.96 (for non-QE)
- For νe CC, ave. completeness = 0.93
  - For QE, 0.98 (for non-QE)

Further Information on NOvA:

- Poster: Event reconstruction with the NOvA Far Detector
- Michael Baird – mibaird@indiana.edu
- for the NOVA Collaboration

**Examples:**

- Above: Tracks are drawn as colored dashed lines. Tracks of the same color are matched between each view.
- Below: The tracker can easily follow long muon tracks through multiple layers to provide good muon energy resolution.