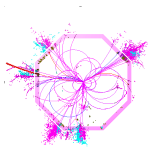# Neutrino Interaction Vertex Reconstruction in the Short Baseline Near Detector (SBND)

New Perspectives 2021

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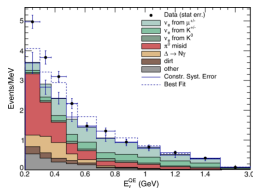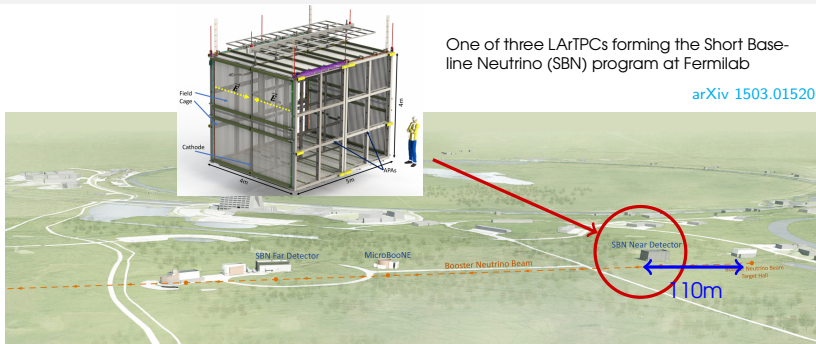h.lay@lancaster.ac.uk

SBND

One of three LArTPCs forming the Short Base-line Neutrino (SBN) program at Fermilab

arXiv 1503.01520

110m

PRL 121, 221801

The primary physics goal of SBN is to investigate the low energy excess seen by the MiniBooNE experiment in its ν_e appearance measurements.

As the nearest of the three detectors to the Booster Neutrino Beam, SBND will observe upwards of 6 million neutrino interactions during its 3 year exposure. This will allow us to pursue a rich cross section measurement program in inclusive and exclusive channels.

LArTPC Operation
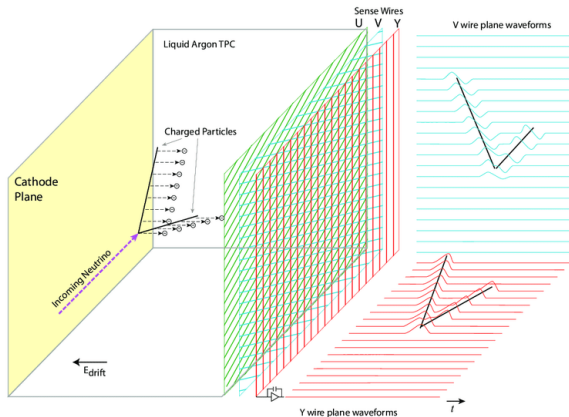
JINST 12 P02017

- LArTPCs use the ionisation of argon atoms to observe charged particles.

- The ionised electrons drift to the anode as a result of an electric field. The anode itself is instrumented with planes of wires aligned in different directions.

- The electronic pulses induced in the wires form the individual 2D hits.

- Reconstruction takes input hits on all three planes and combines them into three dimensional objects utilising the degeneracy between the views.

LArTPCs benefit from fine-grain imaging and significant calorimetric capabilities.

Pandora

U view

V view

W view

3D reconstruction output
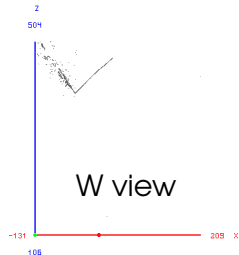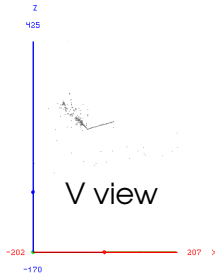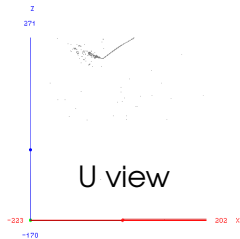
- Detector outputs three 2D images ("wire number vs. time")
- Pandora uses a multi-algorithm approach to incrementally build up a reconstructed event.
- Produces 3D output of tracks, showers, vertices and their hierarchical relationships.
- Pandora is widely used across the liquid argon community (MicroBooNE, DUNE, ProtoDUNE & SBN).
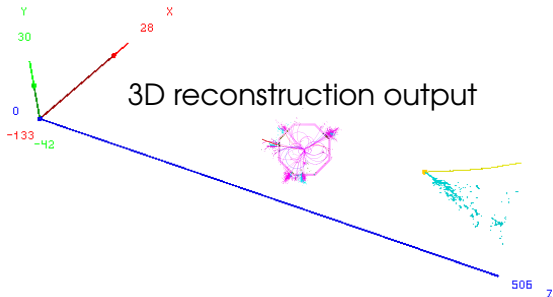
Pandora's Vertex Reconstruction

Vertex reconstruction is a particular challenge in neutrino physics and forms a core component of the Pandora workflow.

2D Clustering

Candidate Creation

Coarse BDT*

Downstream Reconstruction

Precision BDT*

Stage 2: Vertex Selection
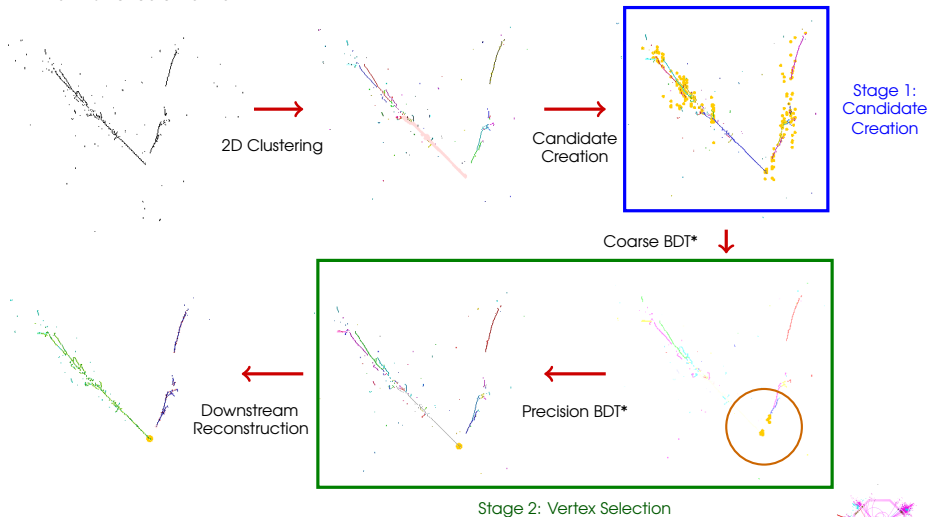
*Boosted Decision Tree

Refinement Algorithm
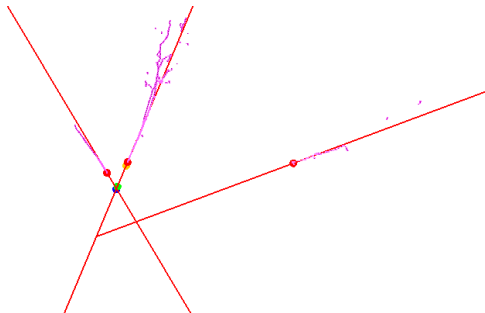
Developed a new algorithm to refine the candidates' positions before the selection stage.

The direction of nearby clusters are used to make precision adjustments to each candidates' position.

- The algorithm takes the initial vertex position (yellow dot) and collects any clusters that pass within 10cm of it (pink hits)

- A principal component analysis is done on all of the clusters to produce a line equation (red lines & dots) representing its direction

- The lines are weighted by their distance to the initial vertex and then solved as a matrix equation to find the least squares best fit point (blue dot) to use as the new vertex position

- ...which moves it nearer to the true vertex (green dot)

Where does this fit in?

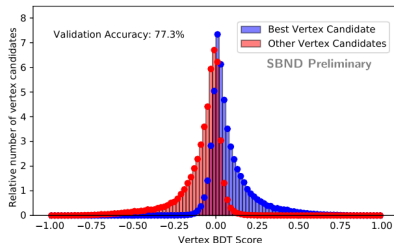Vertex reconstruction is a particular challenge in neutrino physics and forms a core component of the Pandora workflow.
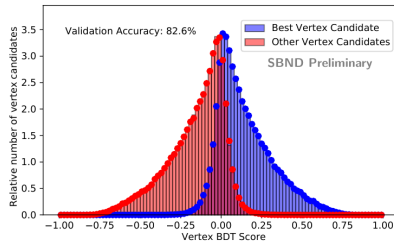

2D Clustering

Candidate Creation

Coarse BDT

Stage 2: Vertex Refinement

Precision BDT

Downstream Reconstruction

Stage 2 3: Vertex Selection
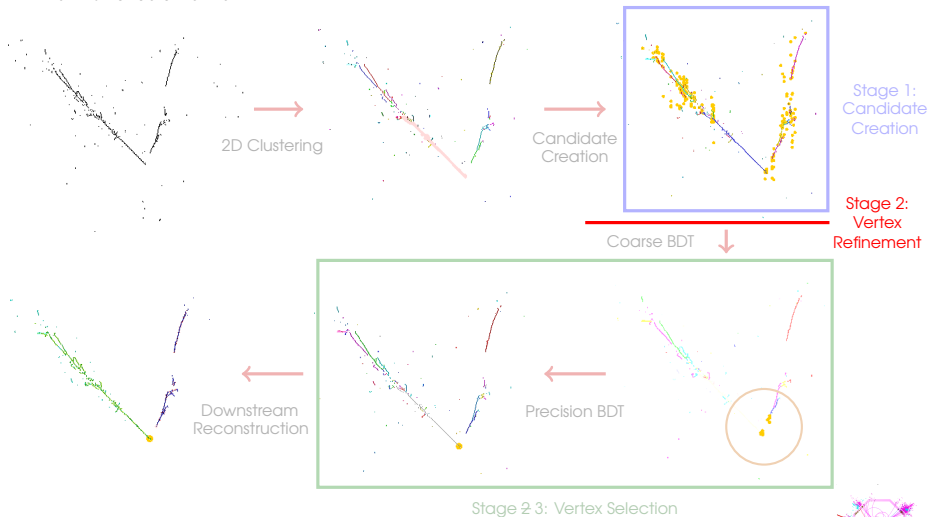
Selection BDT Changes

Also made some changes to the vertex selection algorithm.

– Two boosted decision trees (BDTs) are used to make the selection from the list of candidates.

– First BDT selects the best 10cm region, second BDT selects the best candidate within that region.

– Both operate by making comparing two candidates and selecting the best candidate, the algorithm iterates through all candidates to find the selected vertex.

– New variables added describing the relationship between the two candidates (e.g. the distance between them).

– Other new variables added describing the energy deposition around the vertex candidate.

– Results show a significant improvement in selection of correct vertex candidates (77.3% → 82.6%).

Before Changes

After Changes

Results of Vertex Improvements

SBND Preliminary

Standard Reco

w/ Improvements

	Very Good (<0.5cm)	Good (<1cm)
Standard Reco	51.8%	71.1%
w/ Improvements	65.1%	78.2%

$CC\nu_e$ interactions

CCν_e Events

Distance between true and reconstructed vertex (cm)

Results of Vertex Improvements

SBND Preliminary

Standard Reco

w/ Improvements

	Very Good (<0.5cm)	Good (<1cm)
Standard Reco	54.6%	72.8%
w/ Improvements	68.9%	80.8%

$CC\nu_\mu$ interactions

CCν_μ Events

Distance between true and reconstructed vertex (cm)
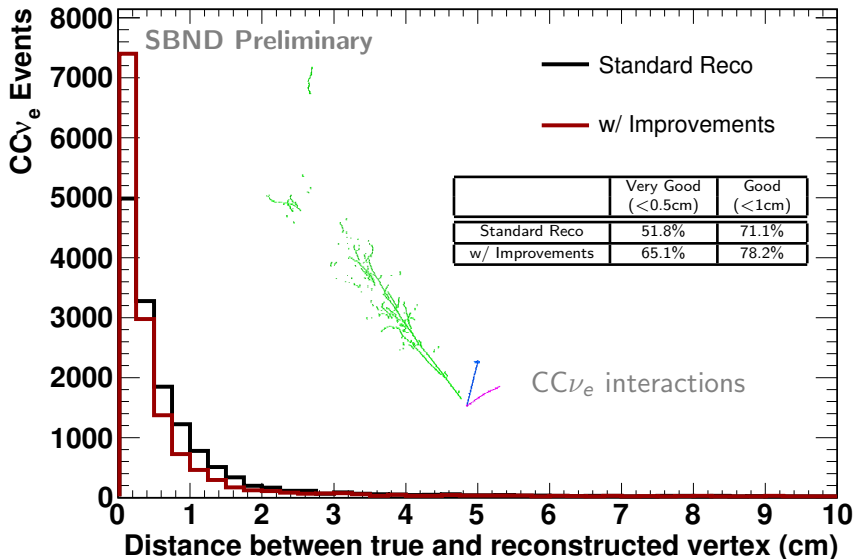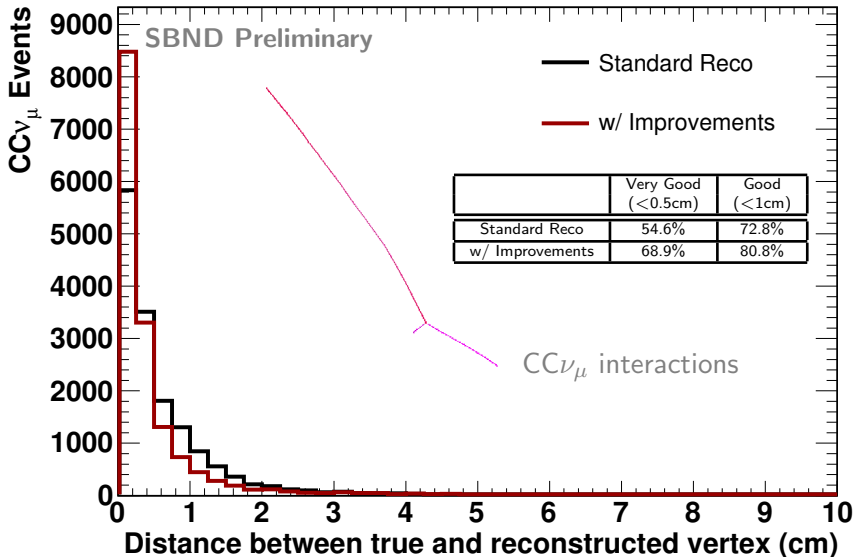
Conclusions

- Accurate vertex reconstruction is a significant challenge in neutrino physics and is core to the Pandora reconstruction workflow.

- Improvements were made to the configuration of the vertex selection BDT algorithm, and an entirely new algorithm was produced for refining the vertex position.

- Large performance gains are seen for both ν_μ and ν_e interaction events as a result of this work.

- These improvements will be available for use across any experiments that utilise the Pandora framework, and work is already ongoing within the DUNE team to retrain their vertex BDT with these updates included.

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