Prong Formation in NOvA Reconstruction Pipeline

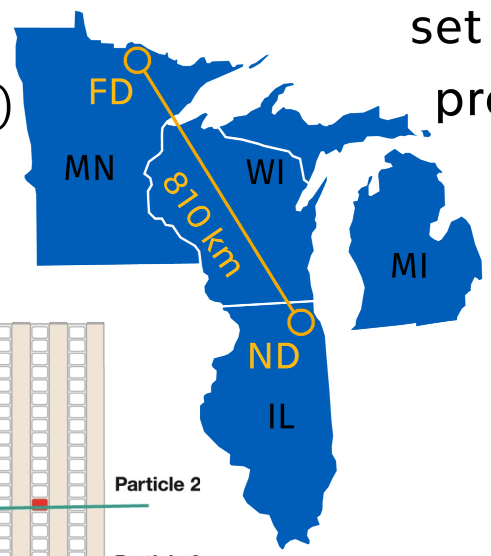
ACAT, 11-15 March 2019
Saas-Fee, Switzerland

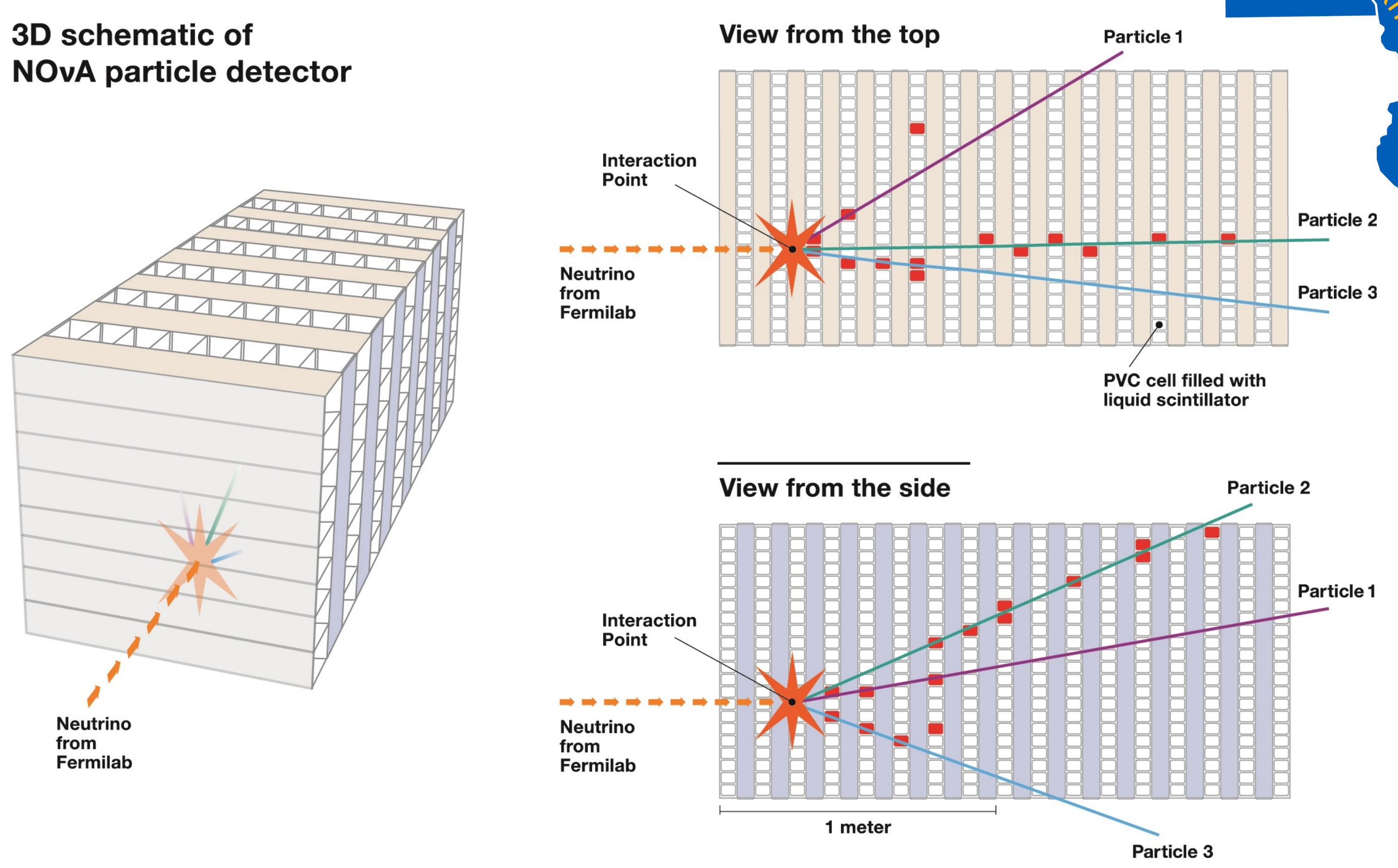
Petr Bouř, Václav Kůs
on behalf of the NOvA collaboration

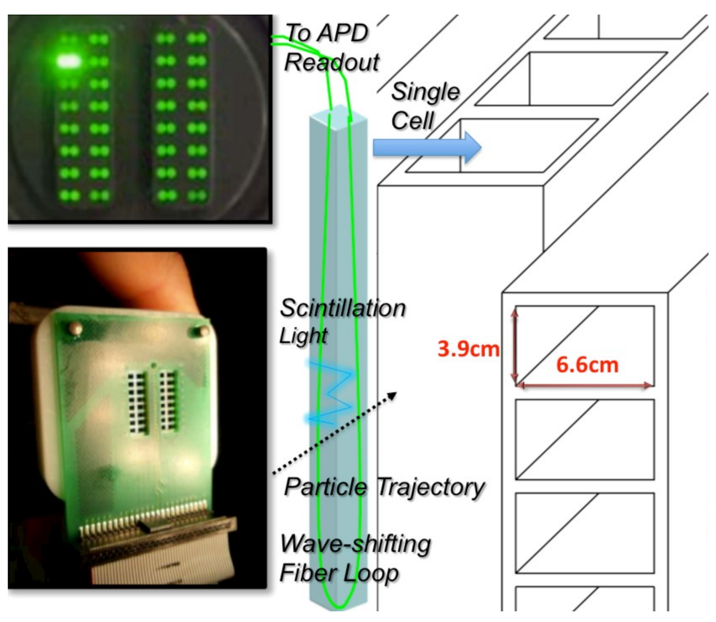
Faculty of Nuclear Sciences and Physical Engineering
Czech Technical University in Prague

NOvA Experiment

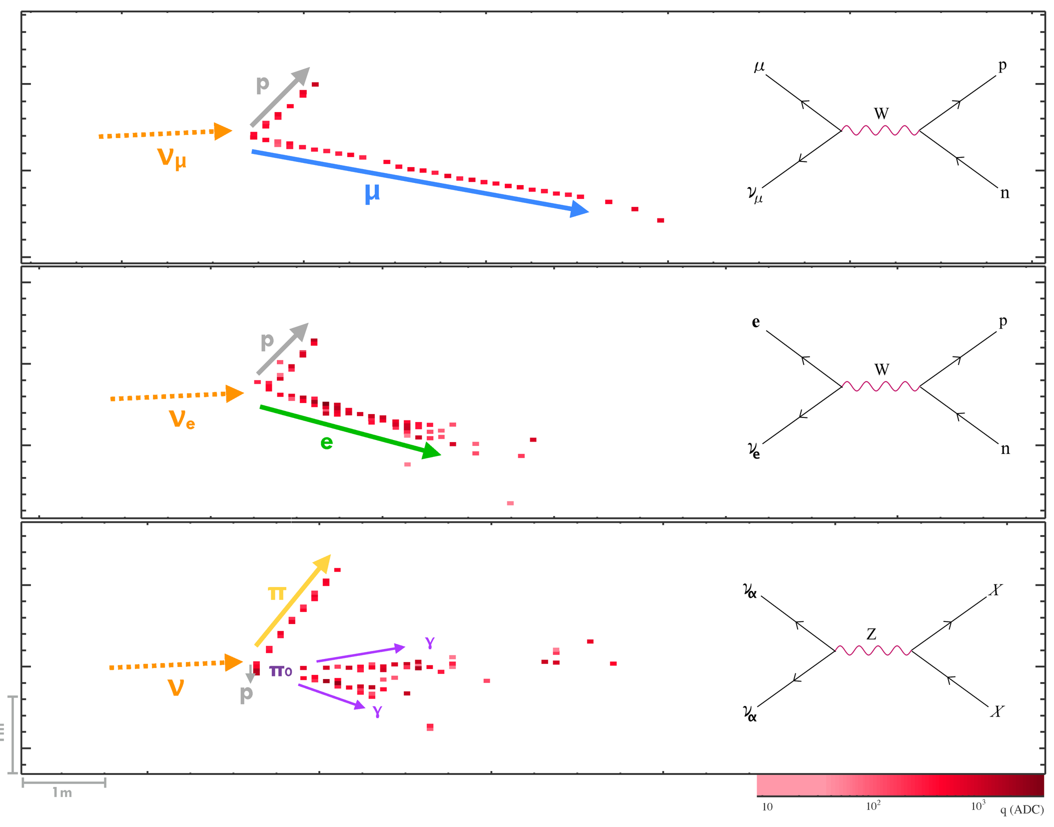
The NOvA (NuMI Off-axis ν_e Appearance) **long-baseline neutrino oscillations experiment** is devoted to studying neutrino mass hierarchy, CP violation and neutrino oscillation parameters. Neutrinos travel 810 km through the Earth from a 300 ton Near Detector (ND) in Fermilab to a 14 kiloton Far Detector (FD).







The structure of NOvA detectors.

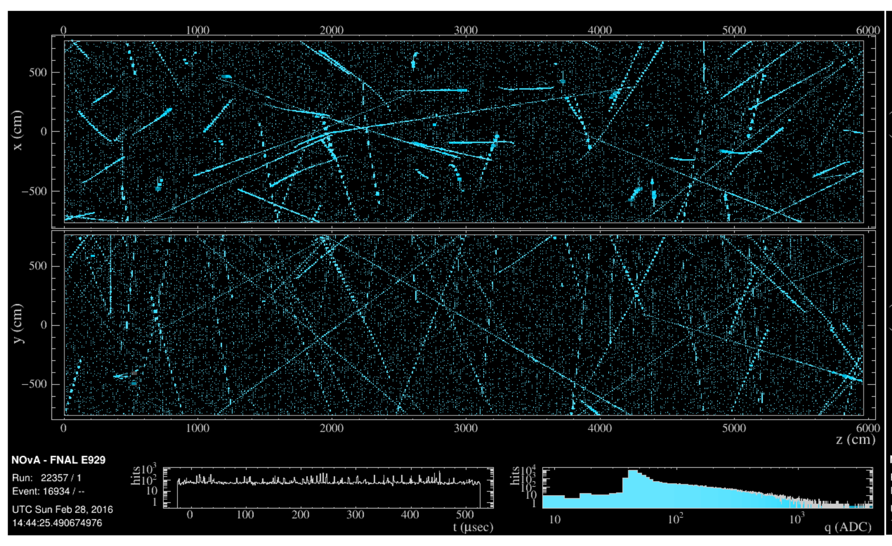


Example neutrino event topologies in ND.

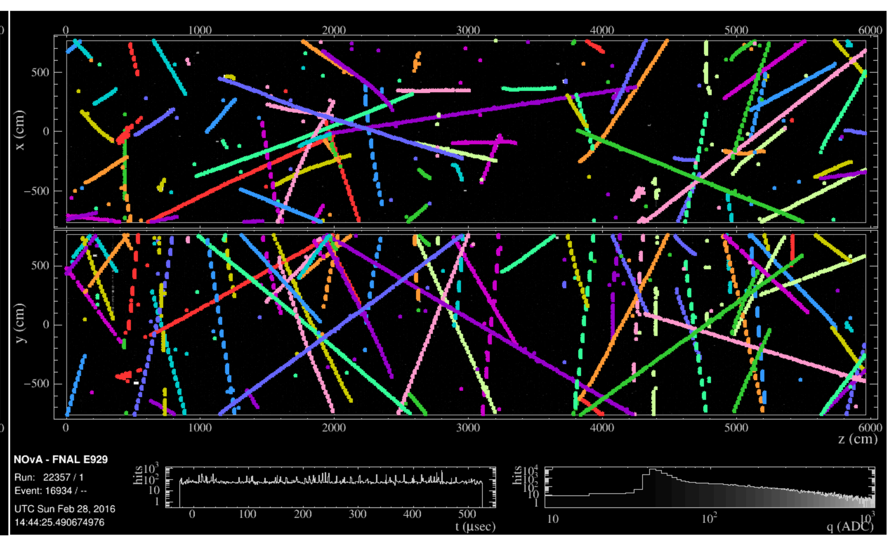
1. Physics Events Clustering

Density-Based Spatial Clustering of Applications with Noise (**DBSCAN**) algorithm is grouping together the hits that are close in space and time. Within DBSCAN, we use following distance metric:

$$\epsilon = \left(\frac{|\Delta T| - |\Delta \vec{r}|/c}{T_{res}}\right)^2 + \left(\frac{\Delta Z}{D_{pen}}\right)^2 + \left(\frac{\Delta X \text{or} Y}{D_{pen}}\right)^2$$



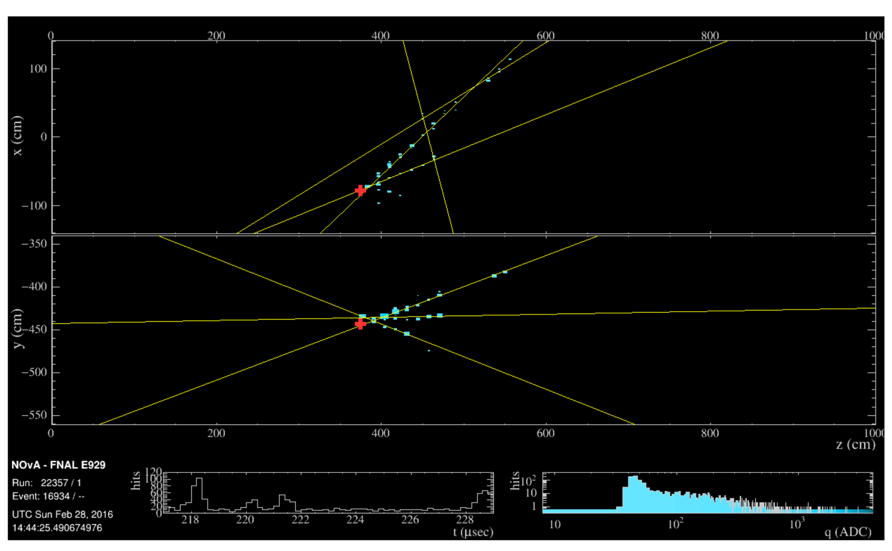
An example of cosmic ray distribution throughout the 550 μs time window.



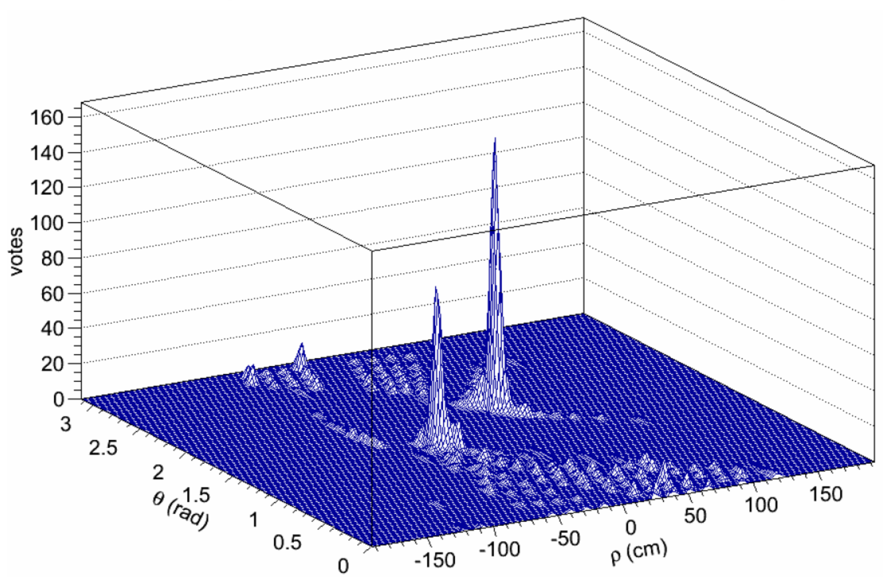
The reconstructed events ("slices") are drawn with different colours in FD.

2. Vertex Positioning

Using **Hough transform**, we detect 2D lines in order to determine event's vertex candidates. Additional fits are used to optimise the true vertex position.



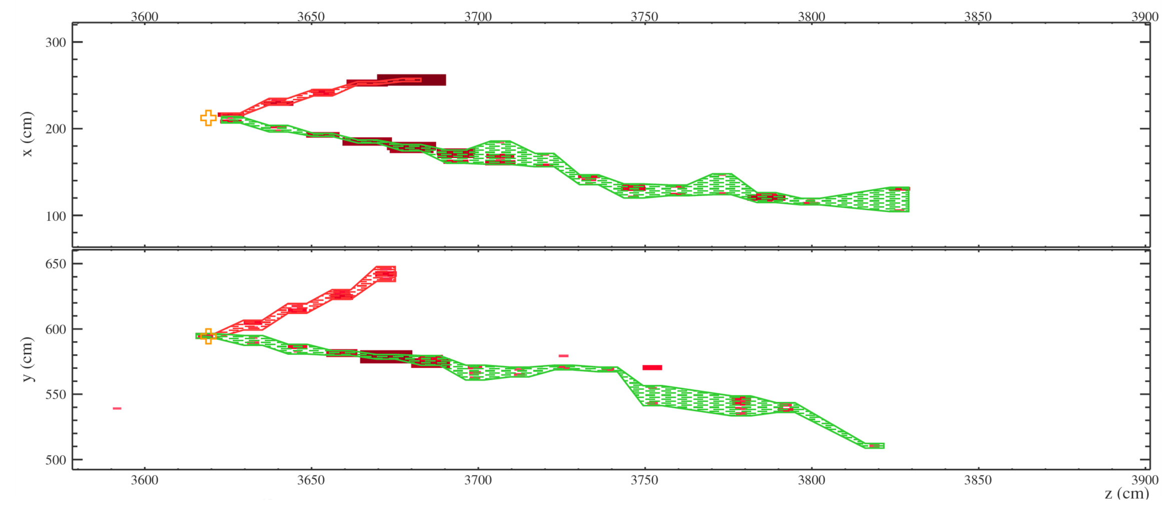
An example of the Hough lines (yellow) and the reconstructed vertex (red cross).



An example of an image projection into Hough space. A line in the image corresponds to a point in Hough space.

3. Prong Formation

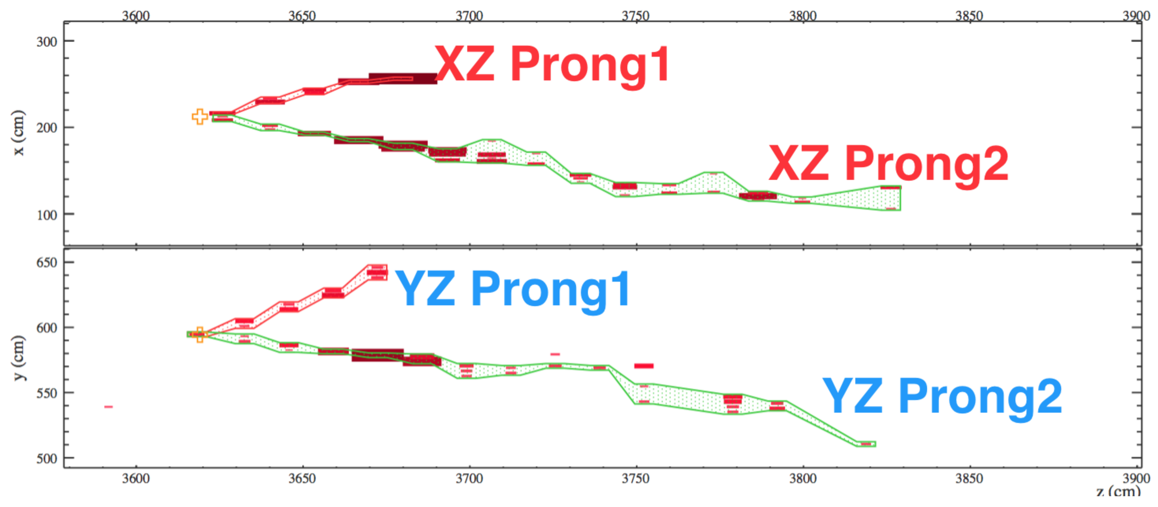
Utilising **Fuzzy *k*-means clustering** algorithm, we cluster all the hits in a 1D angular space around the vertex for each view separately. This yields a set of 2D **"prongs"** for each view *XZ*, *YZ* of the NOvA detector. So far, the 2D prongs in *XZ* and *YZ* planes are not matched.



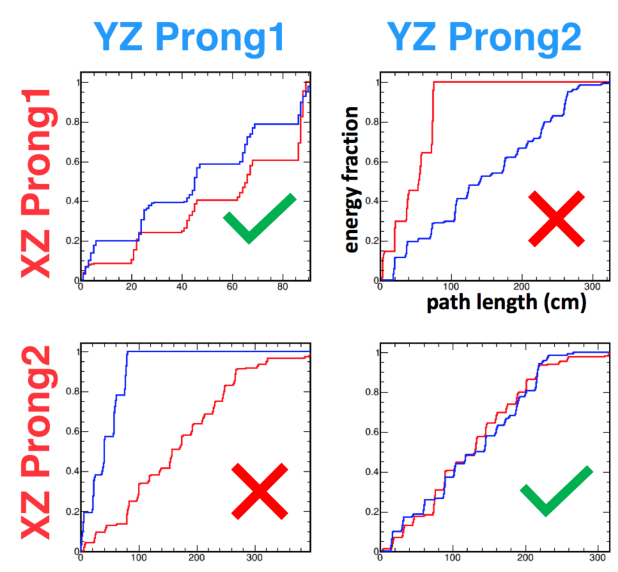
An example of individual 2D prongs determined by 1D angular Fuzzy *k*-means clustering.

4. Prong Matching

The last critical step, which precedes 3D prongs creation, is a matching of the *XZ* prongs with the corresponding *YZ* prongs. In order to obtain reliable combinations, we take into account the **cumulative energy profile** of a prong. We then compare the cumulative energy profiles between *XZ*, *YZ* views.



The individual 2D prongs in each *XZ*, *YZ* view are ready for the matching in order to form 3D prongs.



Comparison of 2D prong cumulative energy profiles.

For path length *s*, the best match for a prong is determined via the **Kuiper metric** (the two-sample Kuiper test statistic):

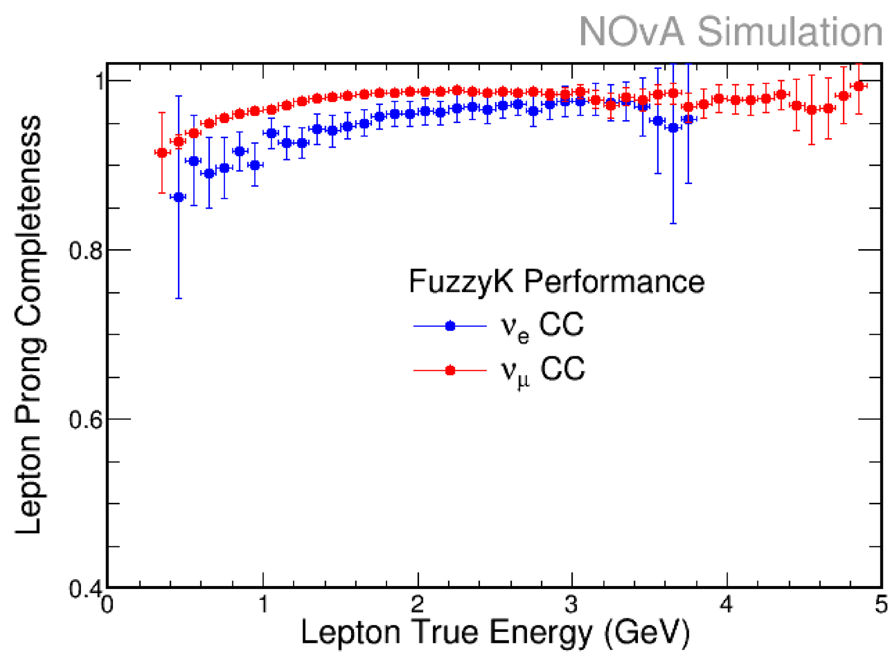
$$K = D^+ + D^-$$
$$D^+ = max\left(E^{XZ}(s) - E^{YZ}(s)\right)$$
$$D^- = max\left(E^{YZ}(s) - E^{XZ}(s)\right)$$

The best matching prong combination is selected to form a proper 3D prong. Furthermore, we may perform a **statistical two-sample homogeneity test** in order to eventually reject an uncomplying prong combination even though it achieved the lowest value of the Kuiper metric. This may obviously be the case when 2D prongs in one view overlap in the second view.

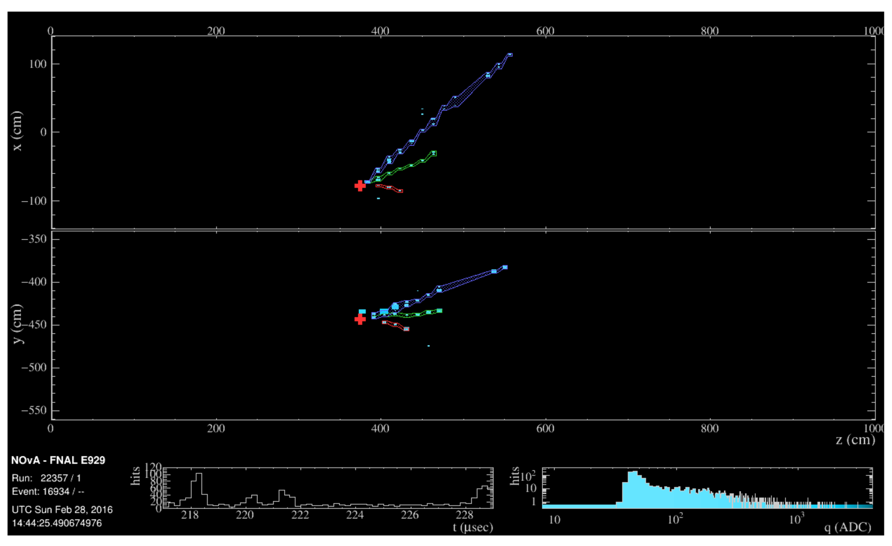
5. Reconstruction Performance

We calculate a **completeness** score to determine the performance of 3D prong formation. This is calculated using the following equation:

$$completeness = \frac{\text{primary prong visible energy}}{\text{primary lepton true visible energy}}$$



Average completeness as a function of primary lepton true energy (Monte Carlo simulation at the FD).



An example of the final reconstructed vertex with matched 2D prongs.

petr.bour@fjfi.cvut.cz

http://novaexperiment.fnal.gov