Pion Measurements With Advanced Decay Electron Reconstruction at MINERvA

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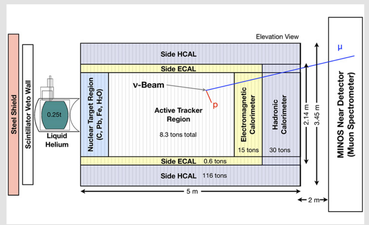
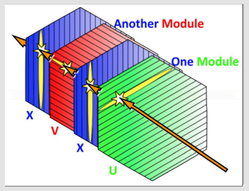
Introduction to MINERvA Experiment

The MINERvA detector is:

- A multi-purpose segmented neutrino detector with XUV oriented modules for 3-D tracking

ν_μ → ν_μ ν_μ



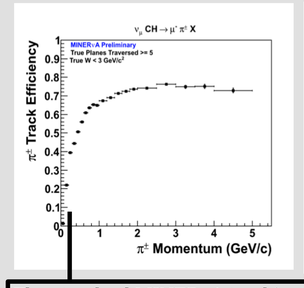


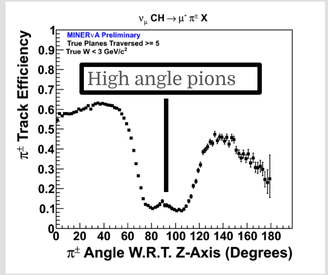
X, U (+ 60 °), and V (- 60 °) oriented planes designed for 3D tracking!

- Designed to measure neutrino cross-sections in different nuclei
- Based at FNAL on the path of the NUMI beamline.
- Measures neutrinos in the 1-10 GeV range with high precision.
- Has very fine timing (3.0 ns) and spatial (3.1 mm) resolution to probe the nuclear environment[1].

Motivation

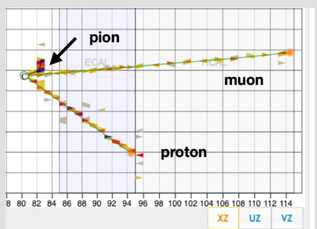
- Pion re-scattering can complicate track reconstruction.
- Tracking efficiency is almost zero at lower pion momenta and drops significantly at high angles approaching 90 degrees.[2]





The standard MINERvA tracking is less ideal for pion momenta less than ~150 MeV/c (or KE = 75 MeV)

- Low momentum pions: not enough energy deposits for tracking methods.
- High angle pions: limited to a single plane, no 3D information
- Michel electrons can be used to probe the above kinematic regions.



Tracking Michel (decay) Electrons

$\pi^+ \rightarrow \mu^+ + \nu_\mu$

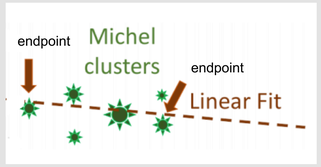
Pion decays into a muon that doesn't track in the detector.

$e^+ + \nu_e + \overline{\nu}_\mu$

Muons decays to e^+ (and neutrinos) at a later time. e^+ interacts in detector and leaves a signal in a later time slice.

MINERvA's new Michel electron reconstruction:

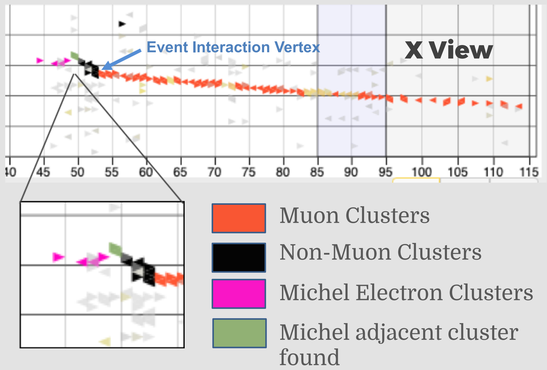
- Identifies high quality decay electron candidates with fine spatial information.
- Michel electron candidates are required to have at least 4 clusters in at least 2 separate views.
- Applies a linear fit to the Michel energy clusters.
- Information about the fit, slope, and end points is stored.



Identifying π^+ Events

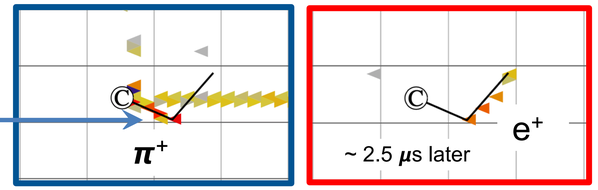
Using Michel Electron reconstruction, some pion kinematics can be reconstructed.

These measurements are used to select pion events.



Tag Michel electrons near interaction vertex in at least 2 views. If that fails, continue to following:

- Scan all non-muon energy clusters in the event (black),
- Find the closest view with energy clusters (green) adjacent to the Michel electron (pink).
- Store clusters least two views are less than 90 mm to the Michel endpoint, The clusters are tagged as a pion candidate.



Event Selection

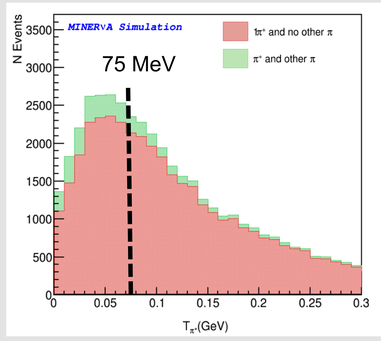
- Using the NuMI Medium Energy Neutrino Beam
- MC POT = 4.07516e+20

Event has: $\nu_\mu + N \rightarrow \mu + N' + \pi^+$

- A muon track matched in the MINOS detector.
- A good quality tracked Michel electron candidate
- Michel electron candidate must have at least 2 adjacent views in time with the primary event interaction

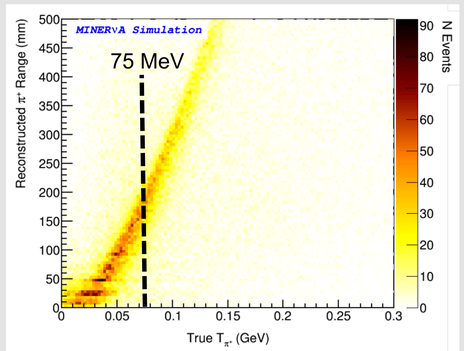
Results

The new methods are yielding higher statistics for pion selection close to the vertex and below the tracking threshold of 75 MeV.



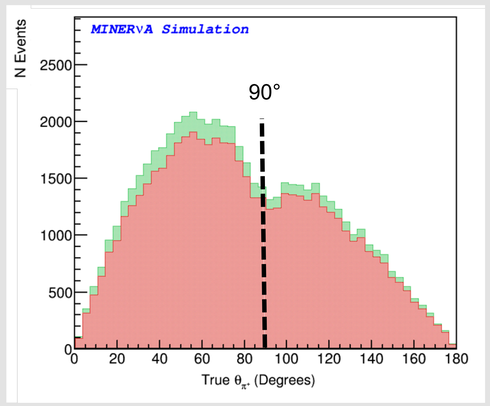
Pion range is between the event vertex and the 3-D inferred point of the Michel-adjacent pion candidate clusters (or interaction vertex position).

$$\sqrt{(x_{adj} - x_{vtx})^2 + (y_{adj} - y_{vtx})^2 + (z_{adj} - z_{vtx})^2}$$

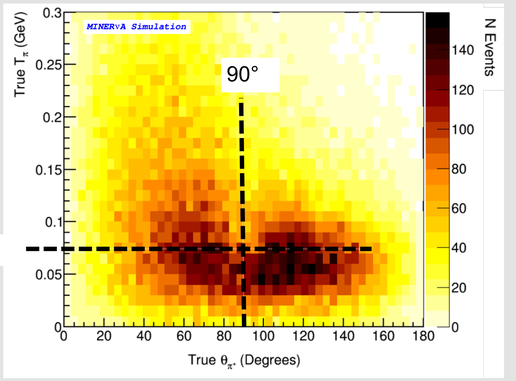


Results II

True angle with respect to the detector Z-axis is shown below.



We are seeing higher statistics in kinematic regions that are difficult to probe through standard tracking methods.



Conclusions

- The new reconstruction methods prove promising statistics for new analyses
- Using the pion event selection from this work a semi-inclusive low recoil analysis can be conducted with low energy pions (stay tuned!)
- Has potential to improve background identification for oscillation events

Resources

1. L. Aliaga et al. *Design, calibration, and performance of the MINERvA detector.* https://doi.org/10.1016/j.nima.2013.12.053
2. B M. Eberly. Characterization of Final State Interaction Strength in Plastic Scintillator by Muon-Neutrino Charged Current Charged Pion Production. PhD thesis, Pittsburgh U., 2014.

Acknowledgements

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