Proton and Neutral Pion Identification at ME in MINERvA-Scintillator

$\nu_\mu + N \rightarrow \mu^- + \pi^0 + X$ (no mesons)
Motivation

- Give to MINERvA the first semi-exclusive cross-section analysis with neutral pions at medium energy.

- This result will have much more statistics than what was measured in the low energy beam (O. Altinok et al. Phys.Rev. D96 (2017) no.7, 072003).

- Provide constraints in the cross section in a range of energy as will be seeing for DUNE.
My signal definition:

- The interaction vertex is the start point of a track identify as a muon.
- The interaction vertex must be inside the tracker.
- Final state: $1\mu^- + 1\pi^0 + X$ (no mesons). $\pi^0$ goes out the nucleus.

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Particle Reconstruction
- **Hits**: every interaction.
- **Clusters**: nested set of hits.
- **Prongs**: set of trackable clusters, *useful for muon, charge pion and proton ID*.
- **Photon Candidates**: set of non-trackable clusters, *useful for particle showers studies*.

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Proton Identification

2 Topologies to study:

- 1Track = No Proton Events (Only Muon Track)
- 2Track = With Proton (Muon + Proton)
Proton Score, two methods were used:

1) PID difference = Proton Score - Pion Score.

2) LLR Method (Log Likelihood Ratio).
   - LLR had shown to give a better performance than the dE/dX Tool, specially for fully tracked particle (particle that stop and can be tracked to the end).
   - The LLR PID tool relies on the PDF’s obtained from MC simulation (NIM Paper: Nucl. Inst. and Meth. A743 (2014) 130.)
Neutral Pion Identification

- Look for the available energy to reconstruct the neutral pion.

\[ E_{\text{vis}} = E_{\text{Target}} + E_{\text{Tracker}} + E_{\text{ECal}} + E_{\text{HCal}} \]

- At this stage there is a lot of background that shadowed the initial reconstruction.
Angle Scan
Look over the unused clusters inside to a “cone volume” made around the interaction vertex.
**Found Photon Candidates**
Clusters nested by angle scan:

- Must have at least 2 views in order to ensure a good direction reconstruction.

**Best two Photon Candidates**
Take the best 2 candidates to be EM showers according with the value of the invariant mass.
Cross section versus $M_{p\pi^0}$ for the $p\pi^0$ sample, requiring $T_p > 100$ MeV with $W_{\text{exp}} < 1.8$ GeV. Curves predicted by the reference simulation show that hadronic FSI tends to broaden and mute baryon-resonance structures. In the $\Delta(1232)^+$ region however, the data exhibits a resonance shape that is more pronounced than that predicted by either the GENIE or NuWro generators.

Work in progress

- Extracting and analyzing Blob information by particle type (photon, charge pion, neutral pion, neutron and others): number of clusters, dE/dx, total energy deposited, radiation length, width, number of planes, reconstructed energy, etc.

- Photon Identification.

Summary: neutral pion selection.
Thank you!

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