Proton and Neutral Pion Identification at ME in MINERvA-Scintillator

$$\nu_\mu + N \longrightarrow \mu^- + \pi^0 + X \text{ (no mesons)}$$

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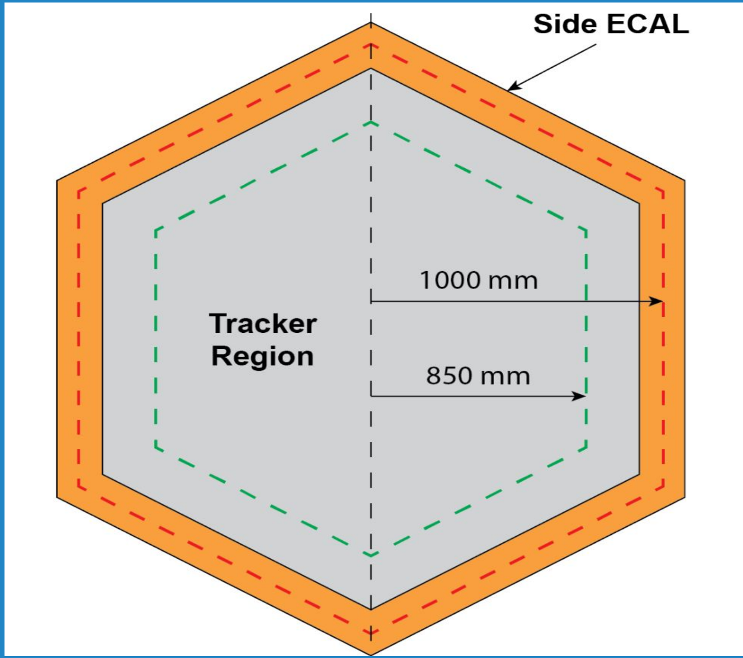
Motivation

- 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 μ^- + 1π^0 + X (no mesons).** *π^0 goes out the nucleus.*



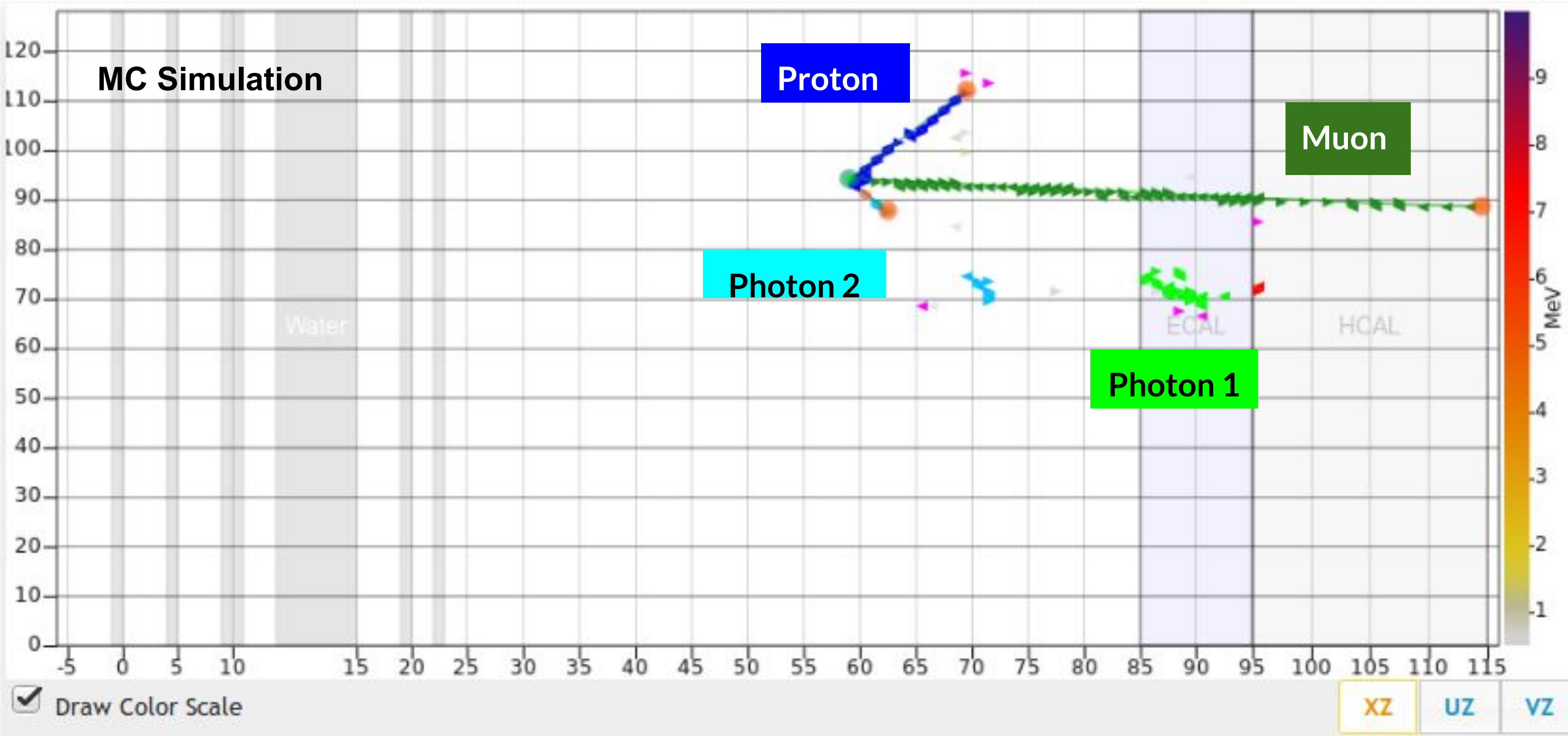
$$\nu_\mu + N \longrightarrow \mu^- + \pi^0 + X \text{ (no mesons)}$$

a) π^0 goes out the nucleus.

b) π^+ exchange charge inside the nucleus $\rightarrow$ π^0 goes out the nucleus.

c) π^0 is absorbed inside the nucleus.

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.

Proton Identification

2 Topologies to study:

- 1Track = No Proton Events (Only Muon Track)
- 2Track = With Proton (Muon + Proton)

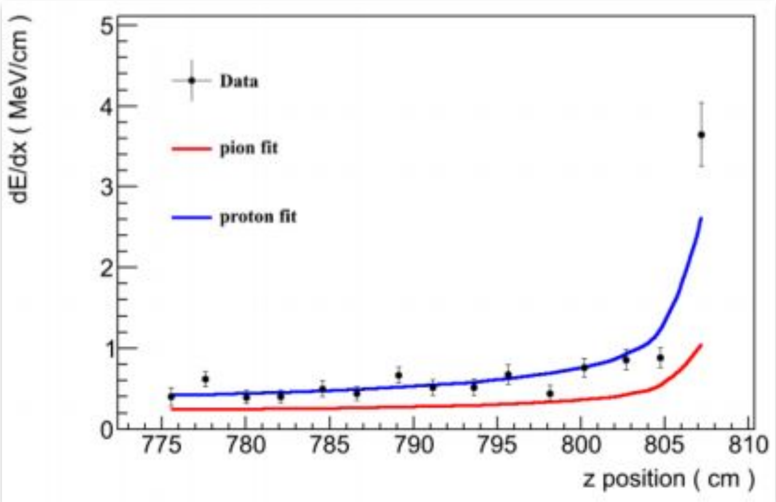
Proton Score, two methods were used :

1) PID difference = Proton Score - Pion Score.

2) LLR Method (Log Likelihood Ratio).

- LLR had show 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.)

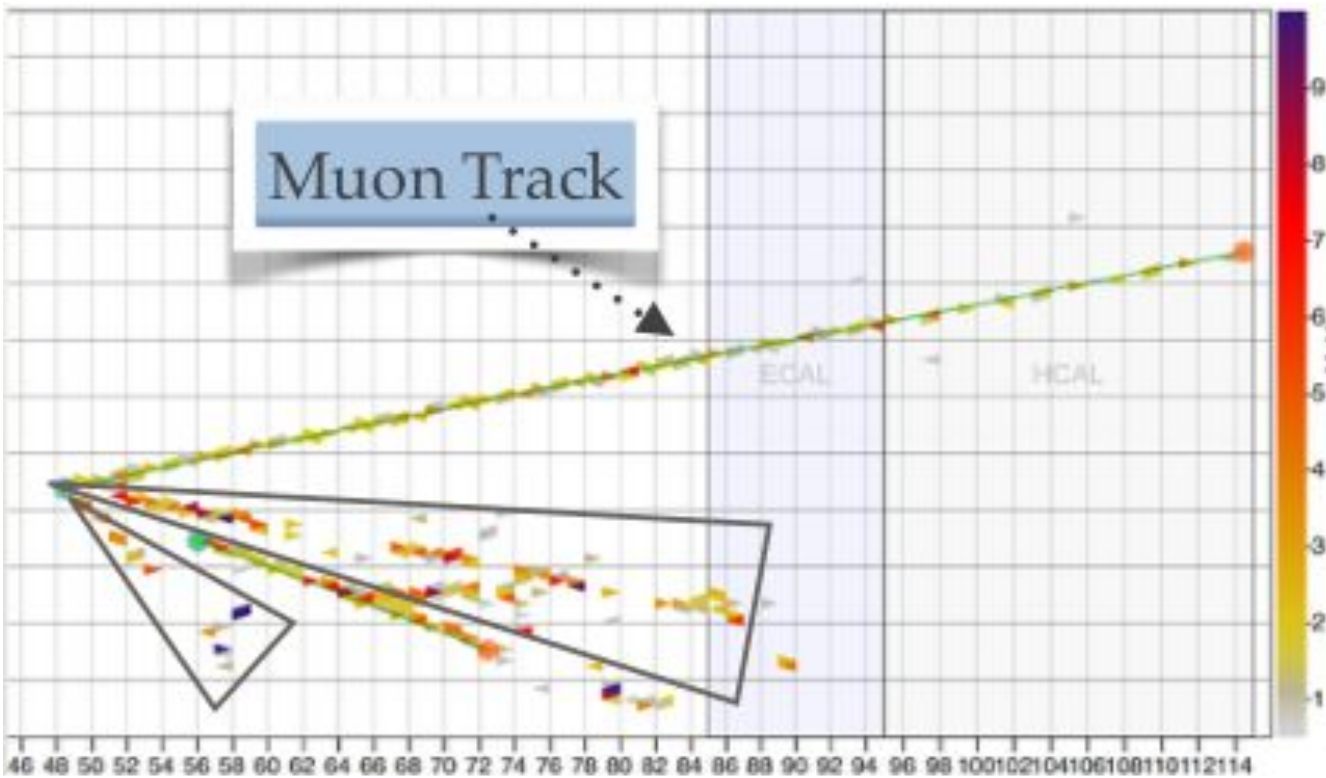


Neutral Pion Identification

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

$$E_{vis} = E_{Target} + E_{Tracker} + E_{ECal} + E_{HCal}$$

- At this stage there is a lot of background that shadowed the initial reconstruction.



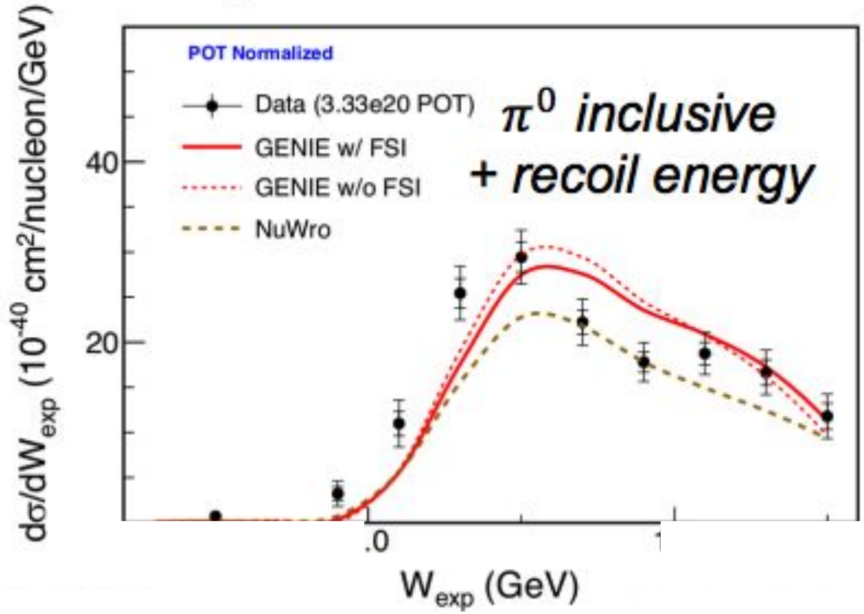
Angle Scan
Look over the unused clusters inside to a “cone volume” made around the interaction vertex.

Found Photon Candidates
Clusters nested by angle scan:

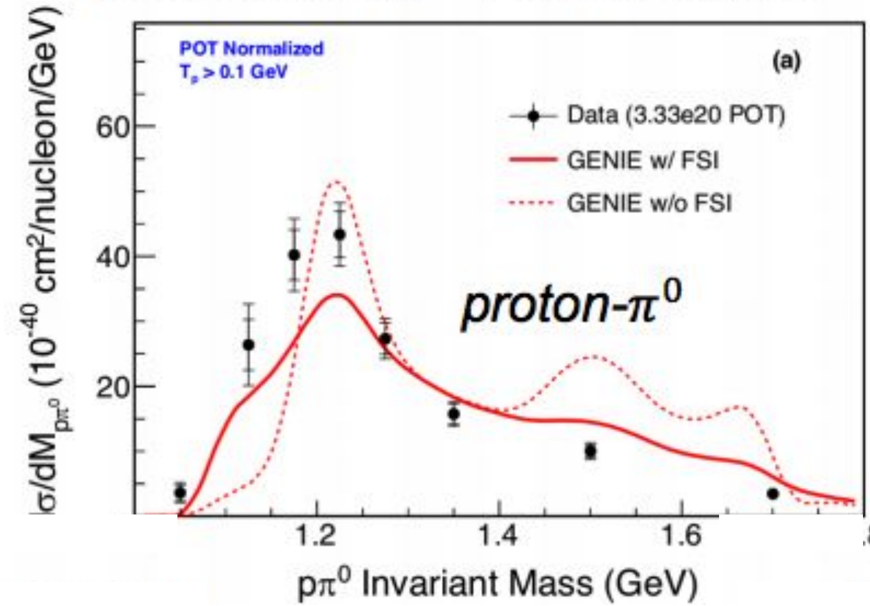
- ➔ Must have at least 2 views in order to ensure a good direction reconstruction. .

Best two Photon Candidates
Take the best 2 candidates to be EM showers according with the value of the invariant mass.

$$W_{exp} = \sqrt{m_n^2 + 2m_n(E_\nu - E_\mu) - Q^2}$$



Invariant Mass calculated with proton and π^0 4-momentums



Ref. O. Altinok et al. Phys.Rev. D96 (2017) no.7, 072003 .

Cross section versus $M_{p\pi0}$ for the $p\pi^0$ sample, requiring T_p > 100 MeV with W_{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.

Active Guatemala Volcanoes: Agua, Fuego, Acatenango and Pacaya. (Foto: NASA, April 2018)

Thank you!

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