Status of the muon neutrino charged-current zero mesons cross section measurement in the NOvA near detector

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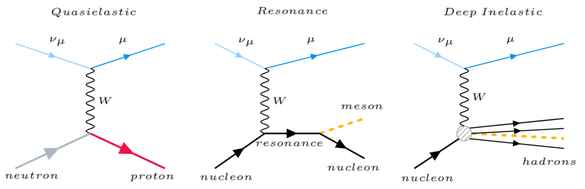
Why ν_μCC Zero Mesons?

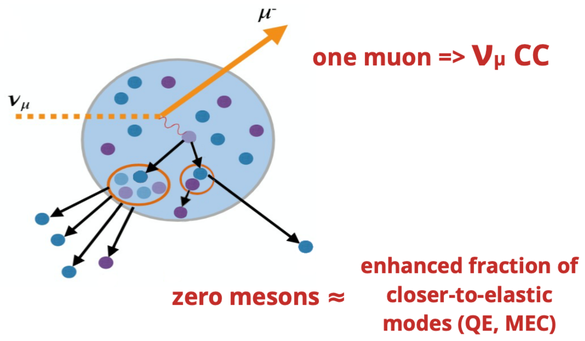
Solving **open questions in neutrino physics** requires understanding their **interactions**. Some typical muon neutrino charged-current (CC) interactions, from closer-to-elastic to more inelastic:



More elastic interactions are **easier to fully reconstruct**. However, the **nuclear environment** often blurs the underlying interactions:

- Partially known initial state
- Scattering off multiple correlated nucleons
- Intranuclear re-scattering

Alternatively, we can measure a **final state**:

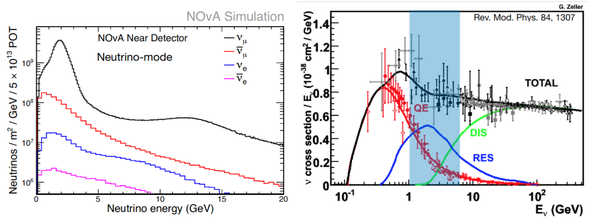


ν_μCC Zero Mesons

- Especially sensitive to **quasielastic** and **multinucleon** interactions
- Probes **weak-interaction structure of nucleons**
- Handle for **constraining nuclear models**
- **The deliverable:** differential cross sections with respect to final state particle kinematics

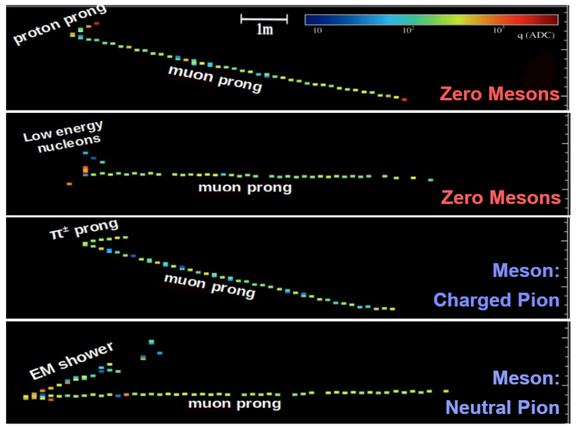
Why at the NOvA Near Detector?

- NOvA is a **long-baseline accelerator neutrino** experiment at Fermilab, comprising **two functionally identical** liquid scintillator tracking calorimeters (77% hydrocarbon, 16% Chlorine, 6% TiO_2)
- The **Near Detector** receives a **high intensity, high purity beam** in a **dynamic energy region** with several interaction modes, making it an excellent laboratory for cross sections.
- Great potential to contribute to **joint fits** with experiments at other neutrino energies and atomic number ranges



What does ν_μCC Zero Mesons look like?

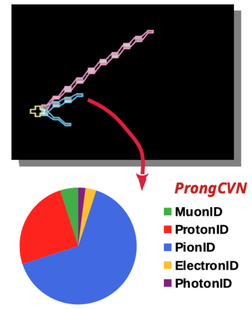
- NOvA reconstructs particles using ***prongs***: directional energy deposits
- **Muons** make **long**, clean prongs
- **Protons** and **pions** make **shorter** prongs
- **Proton** prongs usually end with a **Bragg peak**



How to select ν_μCC Zero Mesons?

ProngCVN

- Convolutional Neural Network: Takes pictures of prongs and applies convolution layers to extract features
- Training: individual uniformly simulated particles of 5 classes: muon, proton, pion, electron and photon
- Application: for each prong in the event, provides five particle ID scores



Michel Electron ID

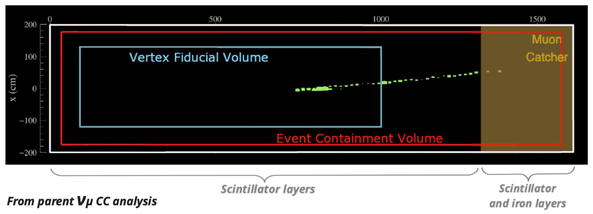
Log-likelihood identifier: takes small energy deposits and evaluates size, timing and distance to other prongs

Neutral Pion Analysis Selection

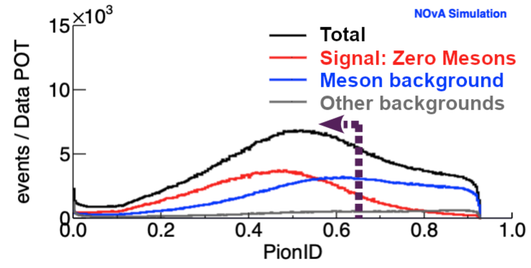
Reversed, to reject neutral pions. See poster by Fan Gao.

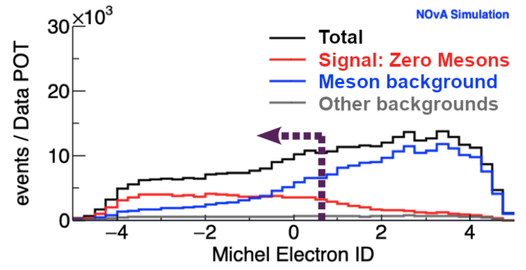
Selection Overview

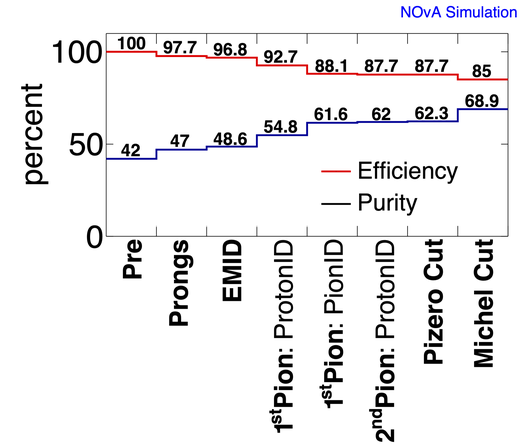
1. Preselection
   Vertex in fiducial volume, prong containment, data quality
2. Find a muon
   Longest prong longer than 5m OR the prong with highest MuonID
3. Reject events with mesons
   - Charged pions: PionID, ProtonID, Michel Electron ID
   - Neutral Pions: EMID, neutral pion analysis selection



Selection Highlights







Summary

- ν_μCC Zero Mesons is an **experimentally defined signal** valuable for studying **nuclear effects** and **reducing systematic uncertainties** in neutrino experiments
- Upcoming: background constraining with **sidebands**, **unfolding** and studies of **systematic uncertainties**.

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