Status of the
Muon Neutrino Charged-Current Zero Mesons Cross Section at the NOvA Near Detector

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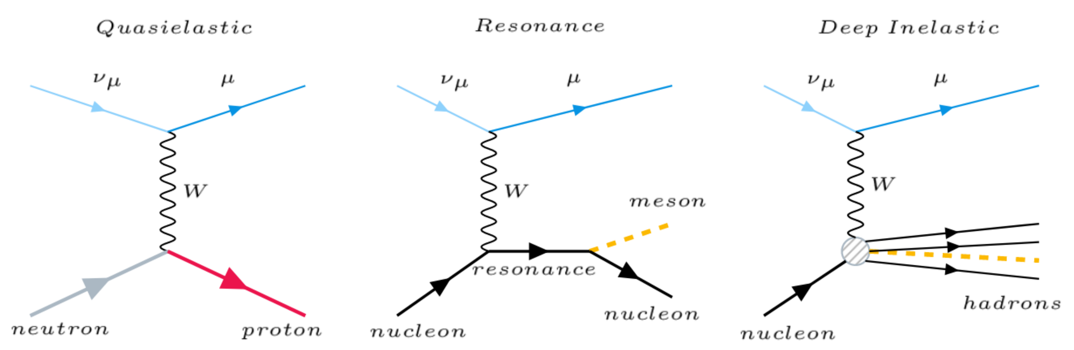
Why ν_μCC Zero Mesons?

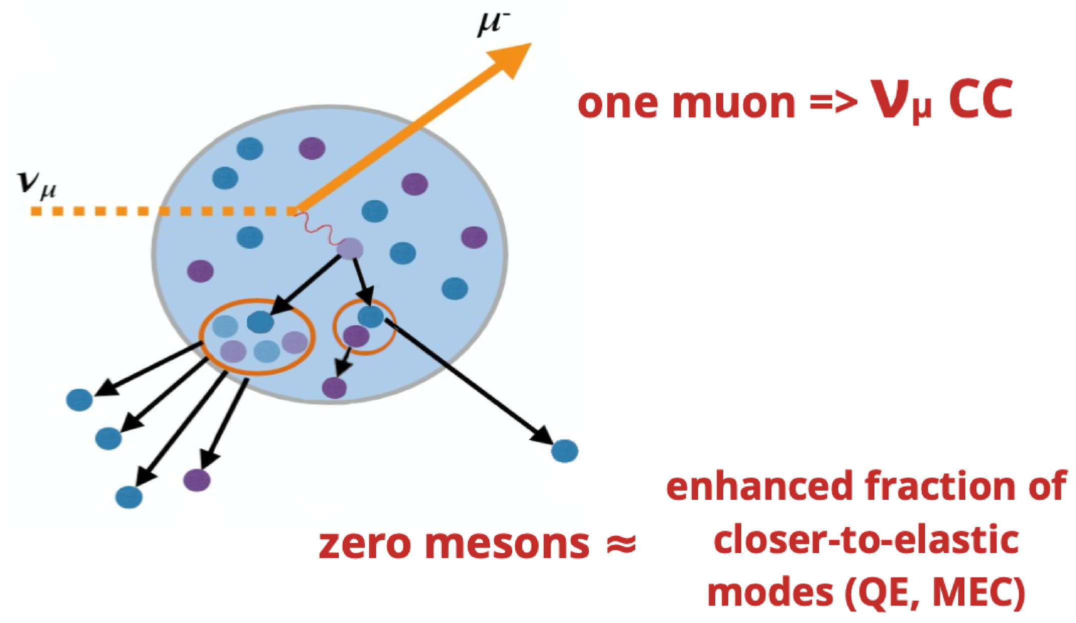
Solving **open questions in neutrino physics** requires understanding their **interactions**. Some typical muon neutrino charged-current (CC) interactions:



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

- Only partially known initial state
- Scattering off multiple, correlated nucleons
- Intranuclear re-scattering

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

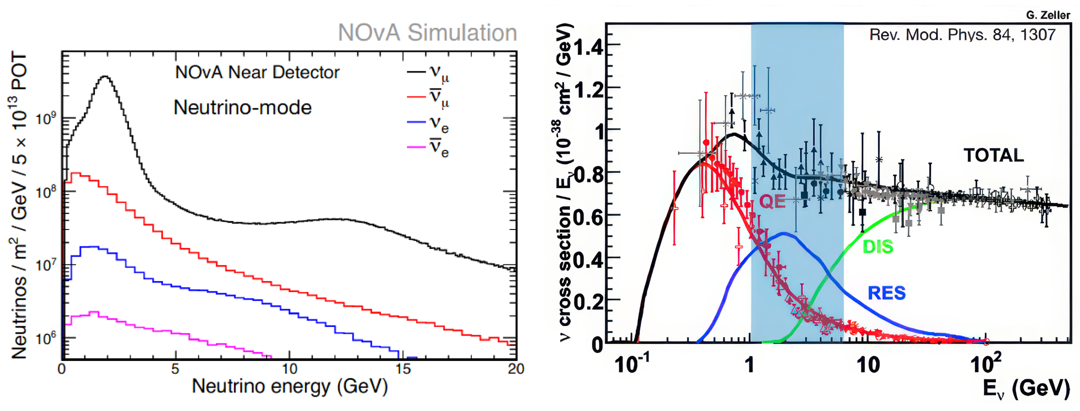


ν_μCC Zero Mesons

- Enhances **quasielastic** and **multinucleon** interactions
- Probes nucleon **weak-interaction structure**
- Handle for **constraining nuclear models**
- **Goal:** differential cross section in muon kinematics.
- **The future:** cross section ratios; dissecting the hadronic component (e.g. proton multiplicity)

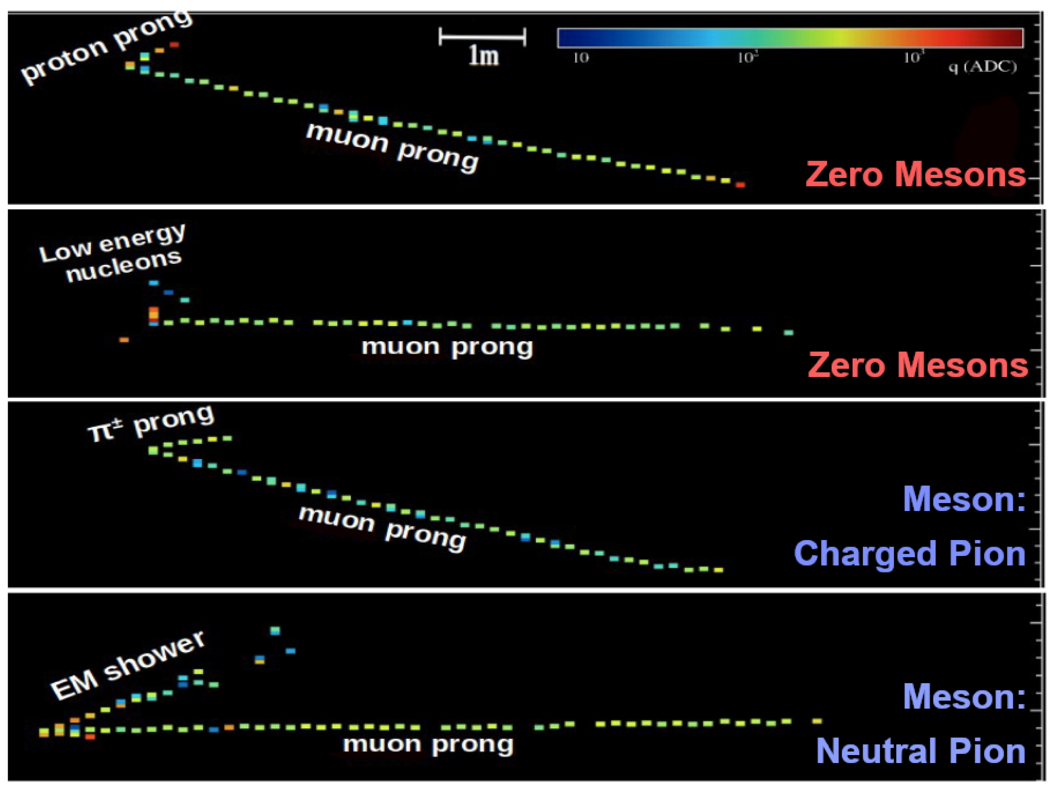
Why at the NOvA Near Detector?

- NOvA is a **long-baseline accelerator neutrino** experiment at Fermilab with **two functionally identical** detectors (77% CH, 16% Cl, 6% TiO_2)
- The **Near Detector** receives a **high intensity, high purity beam** in a **dynamic energy region** with several interaction modes



How does ν_μCC Zero Mesons look?

- 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**

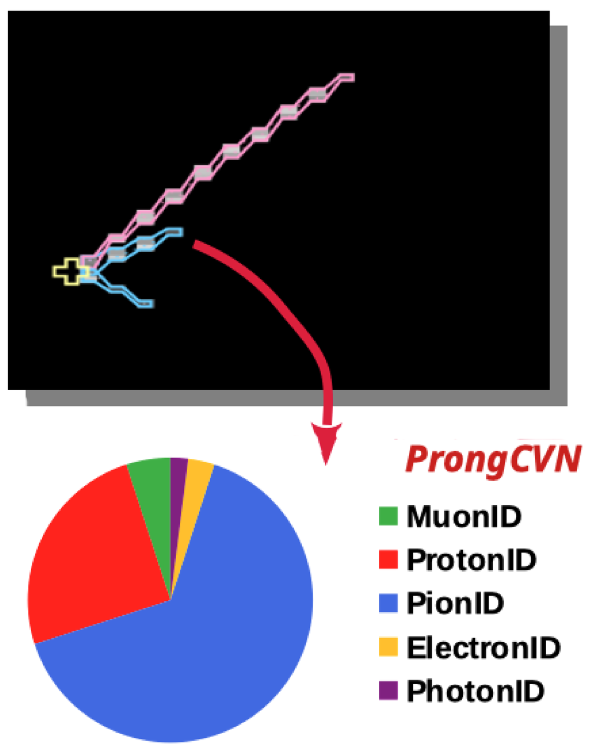


Need a tool to identify prongs by how they look like in the detector

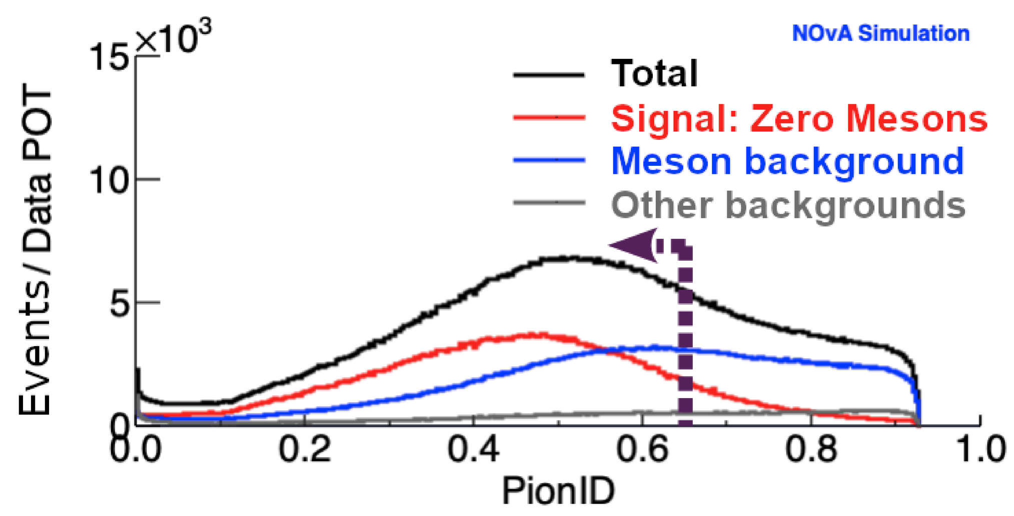
How to select ν_μCC Zero Mesons?

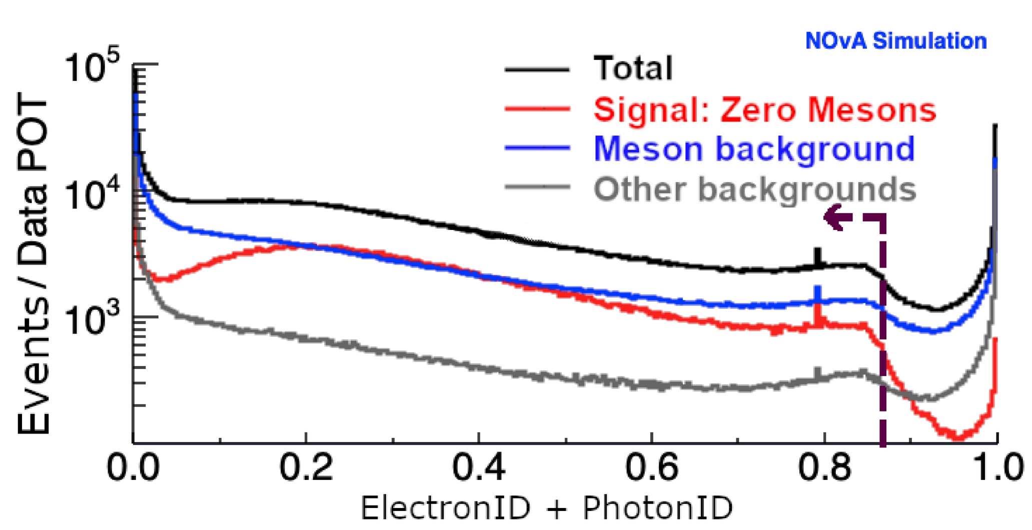
ProngCVN

- **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

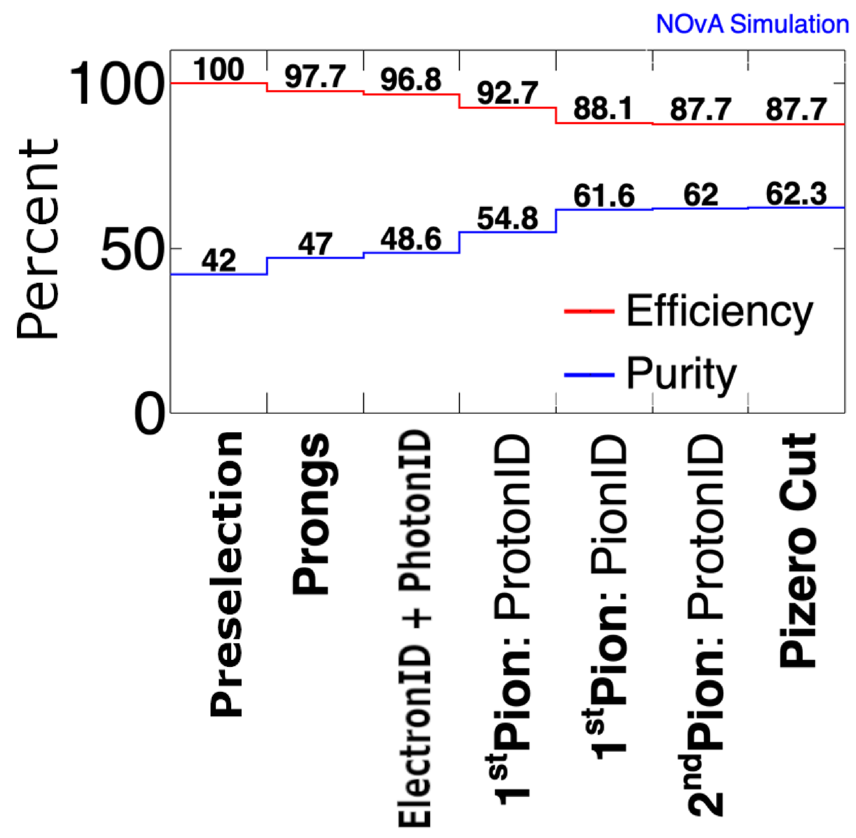


- **Application:** for each prong in the event, provides five particle ID scores



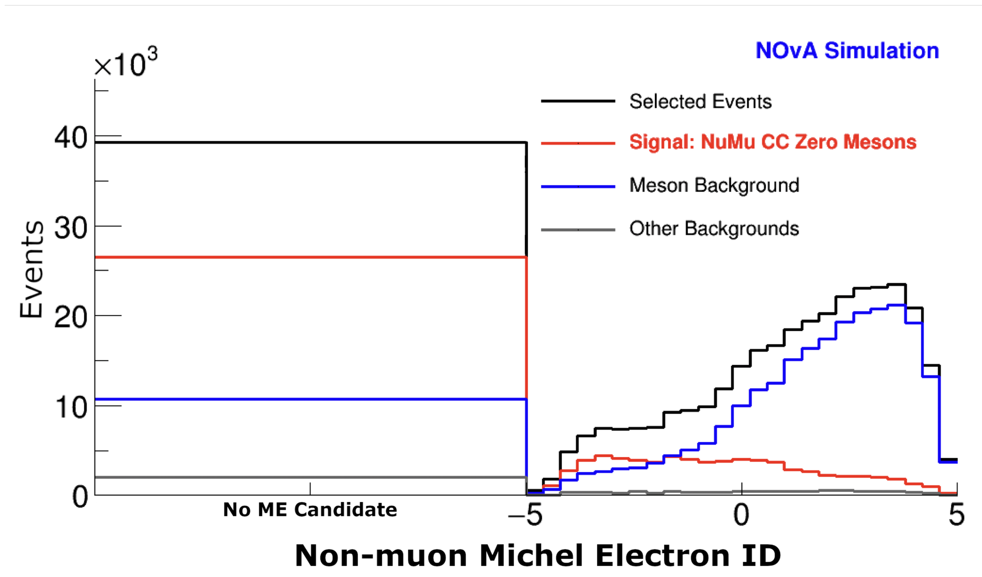


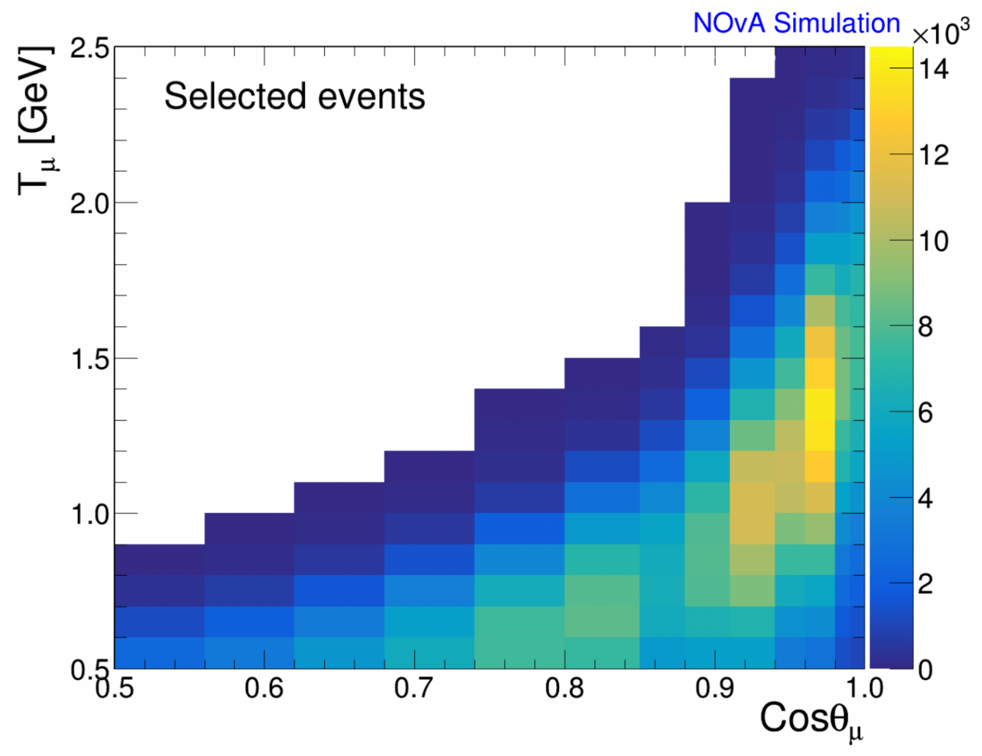
Selection Summary



In progress: *Template Fitting*

- The signal is finally extracted by **fitting a linear combination** of simulated **signal and background templates** to the selected data events.
- Templates in a **Michel Electron ID** variable display shape differences due to positive pions
- Fit is done **simultaneously** over all of the muon kinematics bins





The cross section will then be computed as:

$$\left[\frac{d^2\sigma}{dT_\mu \, d\cos\theta_\mu}\right]_{ij} = \frac{U_{\text{Reco}\to\text{True}}\left[N_{\text{Signal, fit}}\right]}{\Phi_{\text{flux}}\epsilon_{\text{eff}}N_{\text{targets}}\Delta T_\mu \Delta\cos\theta_\mu}$$

Summary

ν_μCC Zero Mesons is a **signal defined experimentally** which is valuable for studying **nuclear effects** and **reducing systematic uncertainties** in neutrino experiments

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