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

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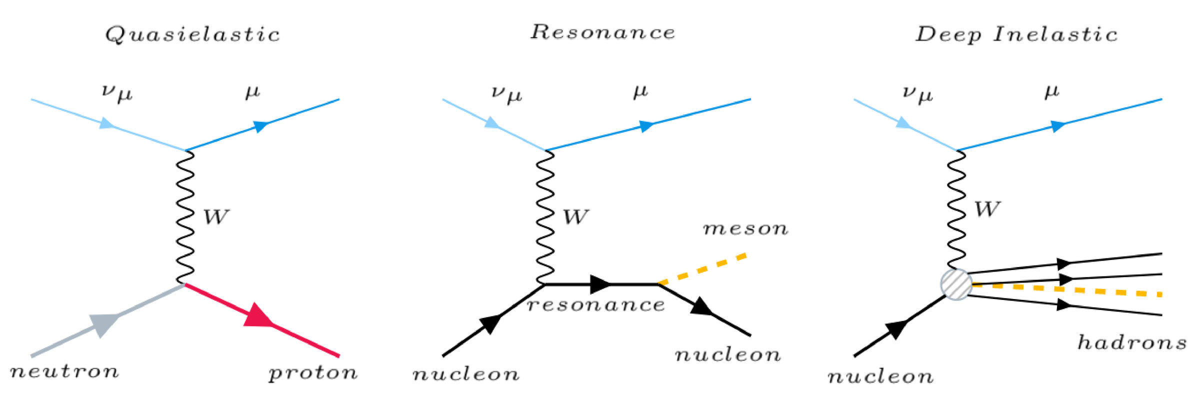
Why ν_μCC Zero Mesons?

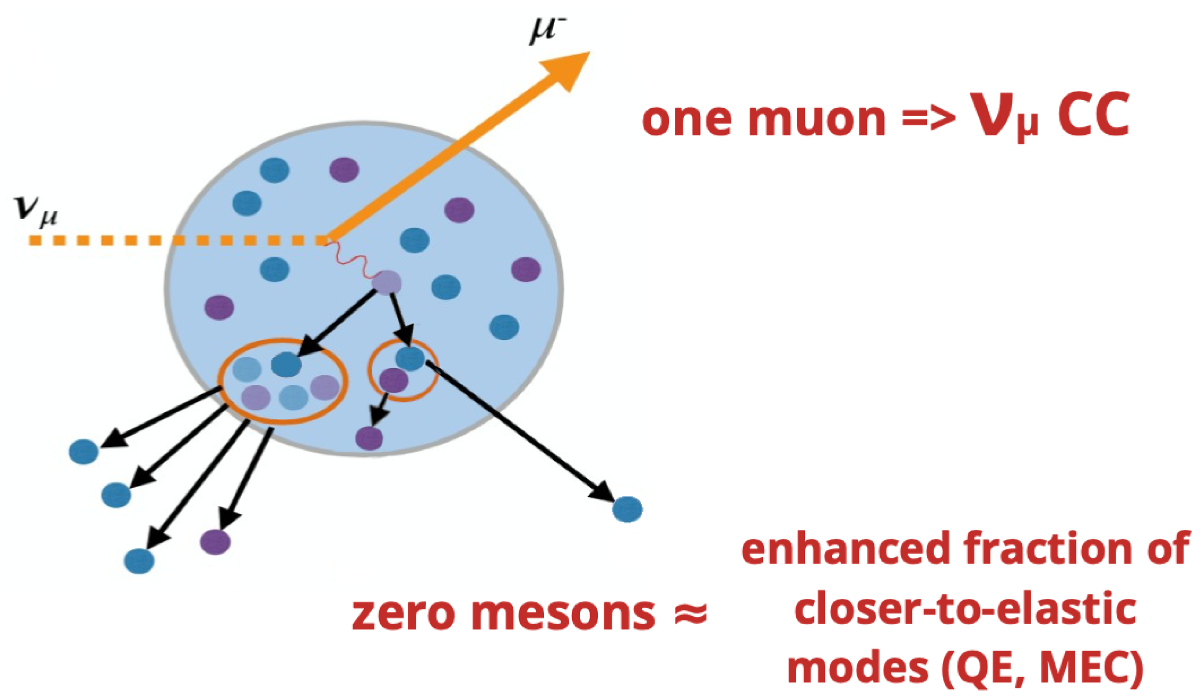
Solving **open questions in neutrino physics** requires understanding their **interactions**. Some typical muon neutrino charged-current (CC) interactions, from closer-to-elastic to more inelastic:



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

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

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

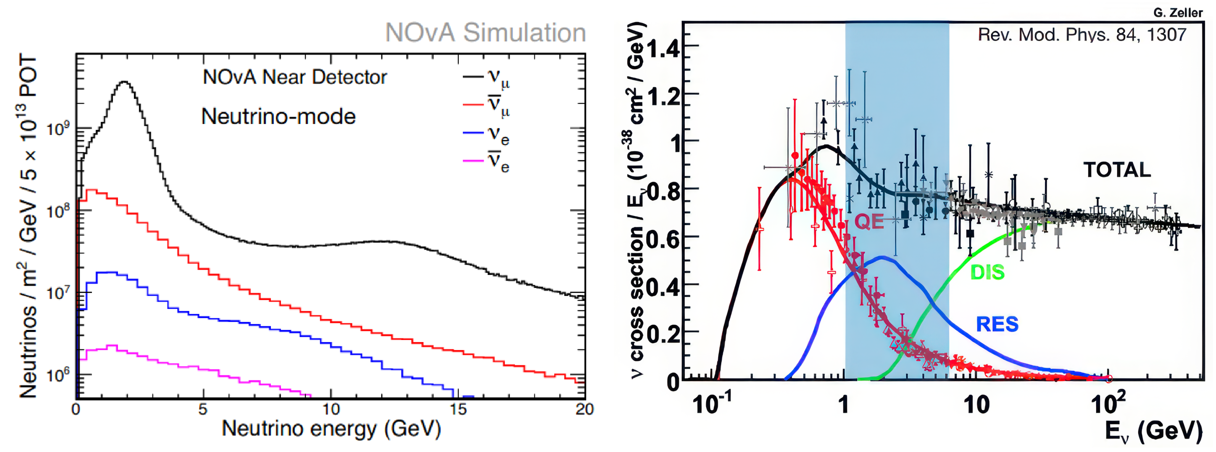


ν_μCC Zero Mesons

- Especially sensitive to **quasielastic** and **multinucleon** interactions
- Probes **weak-interaction structure of nucleons**
- Handle for **constraining nuclear models**
- **The deliverable:** differential cross section with respect muon kinematics.
- **The future:** cross section ratios; dissecting the hadronic component (e.g. proton multiplicity)

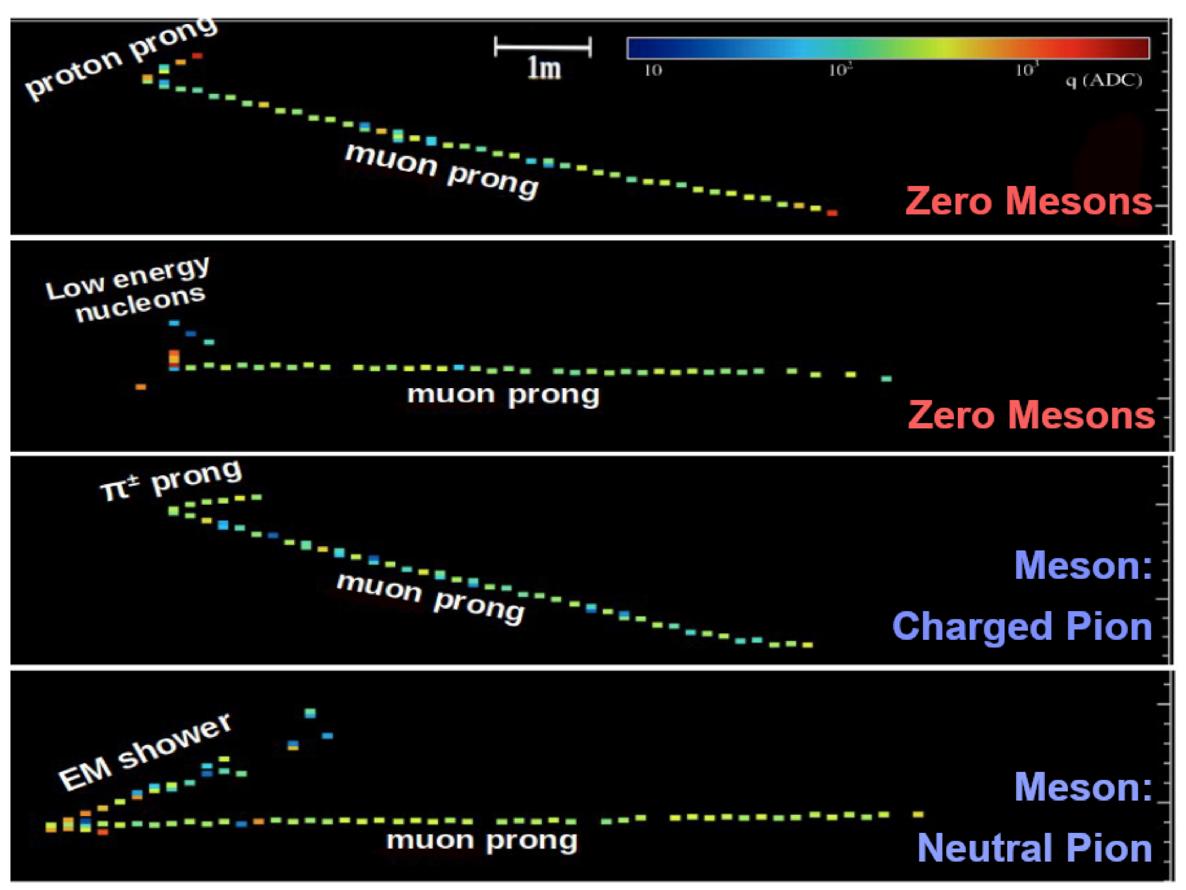
Why at the NOvA Near Detector?

- NOvA is a **long-baseline accelerator neutrino** experiment at Fermilab, 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 interaction 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?

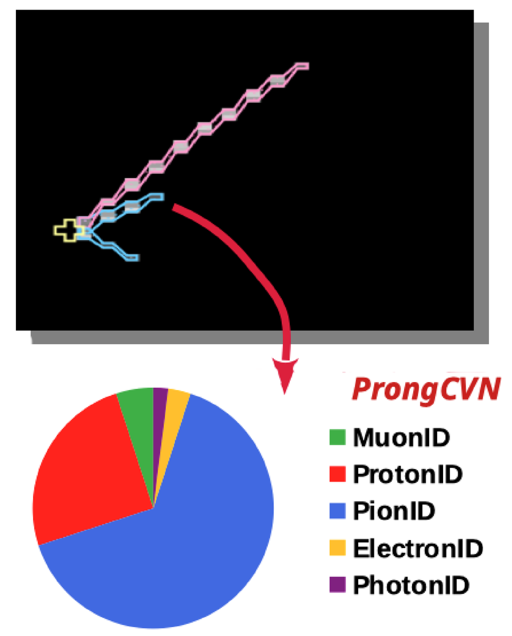
- NOvA reconstructs particles using ***prongs***: directional energy deposits
- **Muons** make **long**, clean prongs
- **Protons** and **pions** make **shorter** prongs
- **Proton** prongs usually end with a **Bragg peak**



How to select ν_μCC Zero Mesons?

ProngCVN

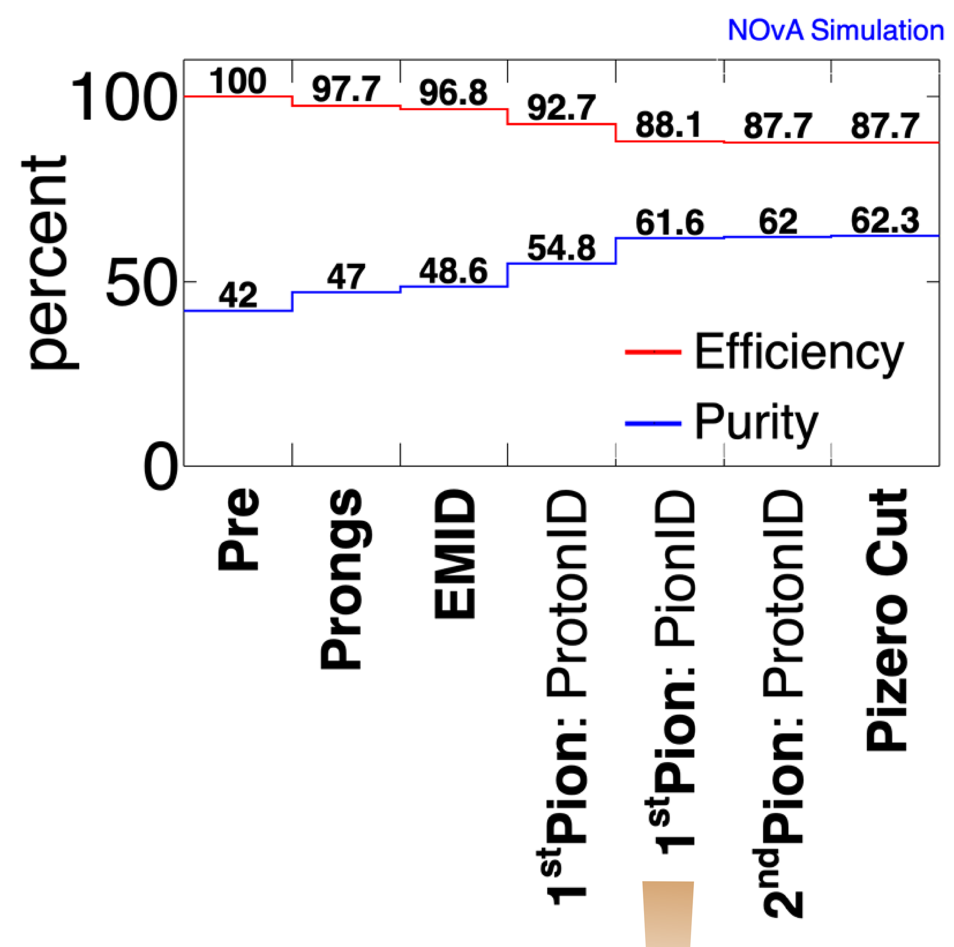
- **Convolutional Neural Network:** Takes pictures of prongs and applies convolution layers to extractfeatures
- **Training:** individual uniformly simulated particles of 5 classes: muon, proton, pion, electron and photon
- **Application:** for each prong in the event, provides five particle ID scores

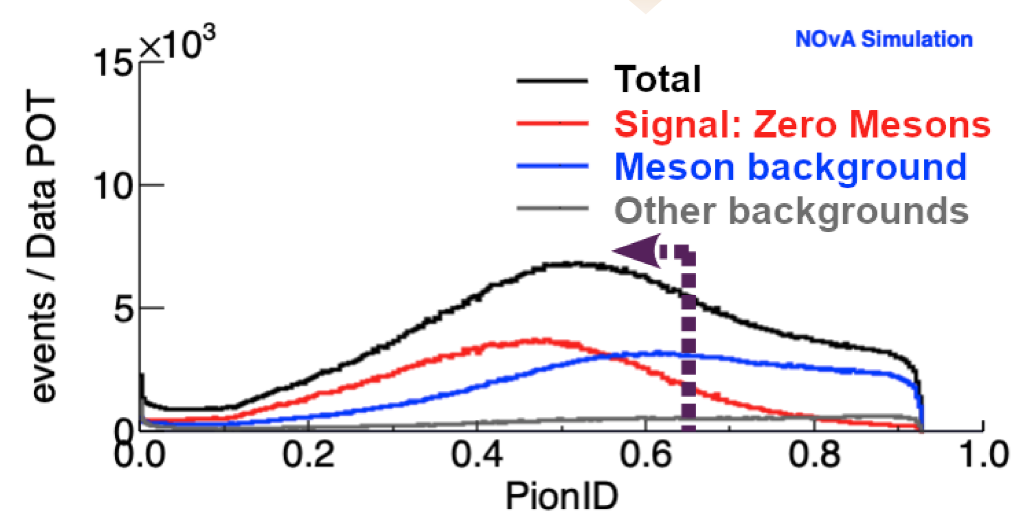


Neutral Pion Analysis Selection

Reversed, to reject neutral pions.

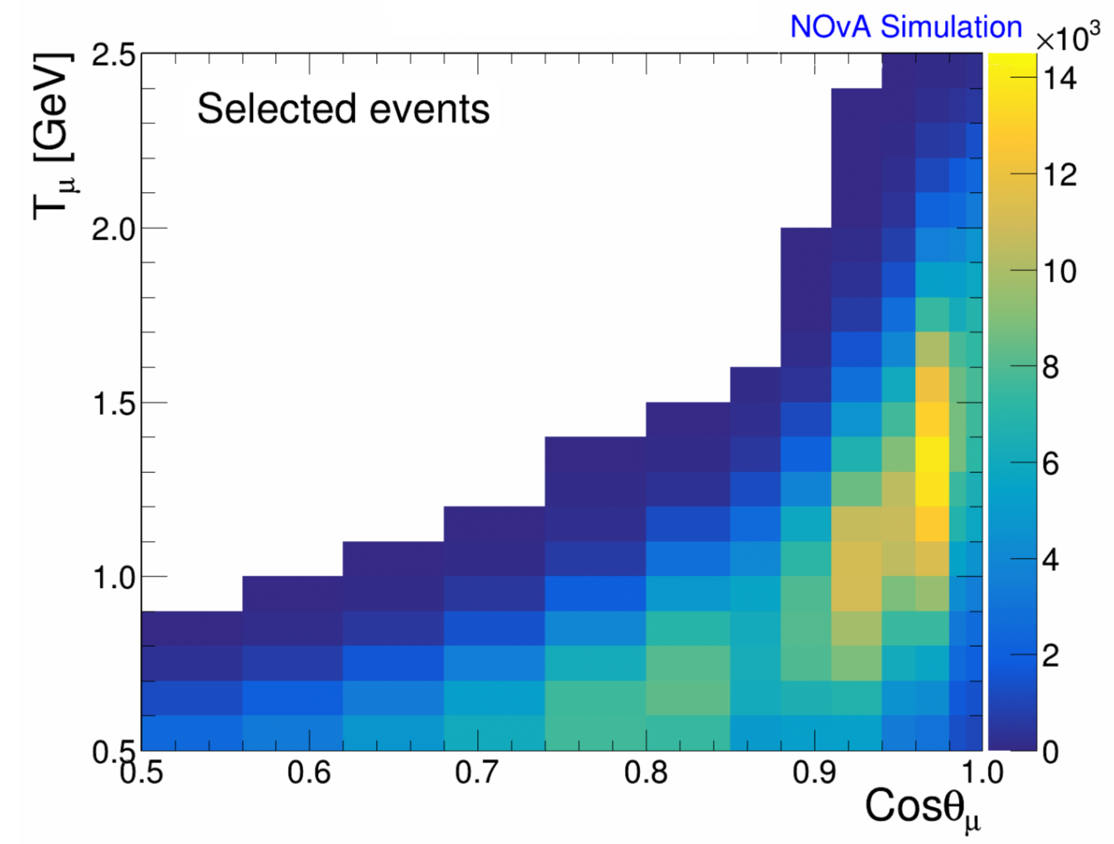
Selection Highlights

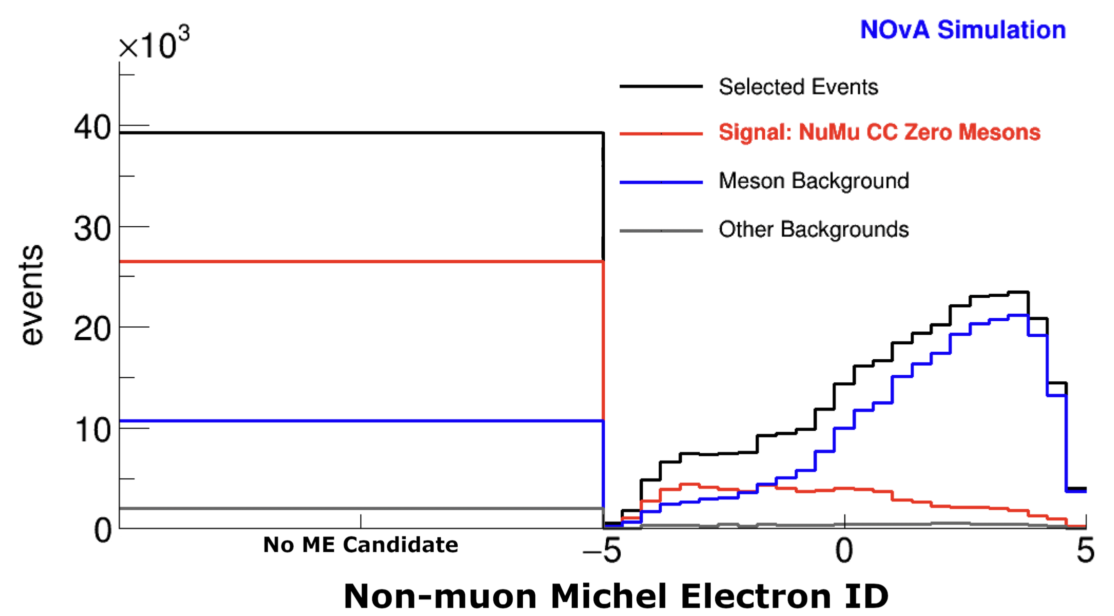




In progress: Template Fitting

- 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 charged pions
- Fitis done **simultaneously** over all ofthe muon kinematics bins





The cross section will then be computed as:

$$\frac{d\sigma}{dT_\mu\, d\cos\theta_\mu} = \frac{U_{\mathrm{Reco}\rightarrow\mathrm{True}} \times N_{\mathrm{Signal,\ fit}}}{\langle\Phi_{\mathrm{flux}}\rangle \times \epsilon_{\mathrm{eff}} \times N_{\mathrm{targets}} \times \Delta T_\mu \times \Delta\cos\theta_\mu}$$

Summary

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

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