



# Efficiency and Purity Studies for Charged Pion Semi-Inclusive Muon Neutrino Charged Current Cross-Section in NOvA

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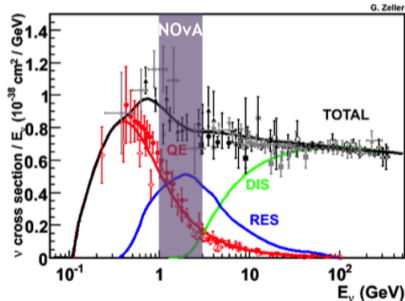
Panjab University, India  
Fermilab  
On behalf of NOvA Collaboration

**APS Meeting**

Columbus, Ohio

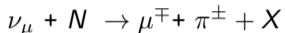
April 15, 2018

- The NOvA Near Detector
  - ▶ 1 km from neutrino production target, having intense rate of neutrino interactions.
  - ▶ Provides a great opportunity to study neutrino-nucleus interactions.
- NOvA with a narrow band beam peaked at 2 GeV, sits in the middle of the energy regime of the T2K, MicroBooNE and MINERvA.
- It can help understand the transition from the  $\Delta$  dominated to the DIS pion production.



J.A. Formaggio and G.P. Zeller, Rev. Mod. Phys., 2012

- Pion Production in  $\nu_\mu$  CC interactions.

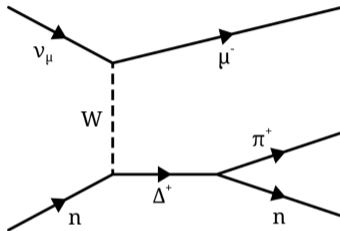


- ▶ Source of systematic uncertainty in neutrino oscillation parameter measurement.
  - ▶ A single charged pion could make the event mimic the CCQE topology.  
Reinteraction  $\rightarrow \pi^+$  absorbed in nucleus  $\rightarrow$  QE like.
  - ▶ Important for correct estimation of the incoming neutrino energy.
- Single Charged Pion cross section measurements on carbon has been reported by the MiniBooNE ([doi:10.1063/1.3274185](https://doi.org/10.1063/1.3274185)) and K2K SciBar detector ([arXiv:0805.0186](https://arxiv.org/abs/0805.0186)), calculated using the ratio of  $CC1\pi^+$  to CCQE.
  - MINERvA has also reported  $CC1\pi^\pm$  cross section measurements ([arXiv:1406.6415](https://arxiv.org/abs/1406.6415)) as a function of charged pion angle and kinetic energy.

- A  $\nu_\mu$  CC interaction having a muon and a well reconstructed single charged pion in the final state.

- ▶ 250 MeV < True Kinetic Energy < 900 MeV.
- ▶ The interaction vertex should be contained in the fiducial volume.

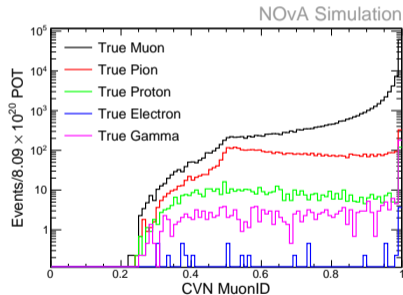
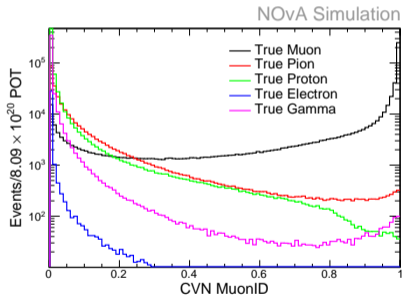
- Using the Near Detector MC simulated data for studying the  $CC1\pi^+$  events

Resonant Production:  $CC1\pi^+$ 

- Event Selection

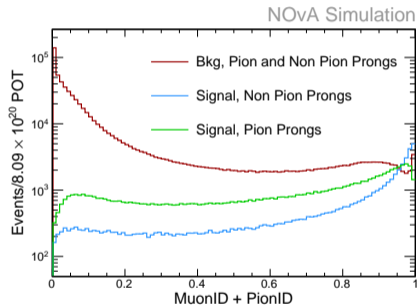
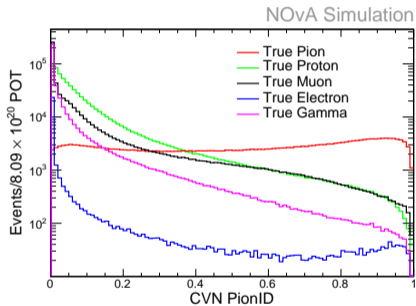
- ▶ All particle trajectories are required to be within the fiducial volume and fully contained inside the active region of the detector.
- ▶ Prong CVN has been used to select the final state particles (Refer to previous NOvA talk by Leo).

- Performance of the Muon CVNID
  - ▶ For all the true particle prongs.
  - ▶ For all those true particle prongs that are most likely to be the muons as per the Muon CVNID.



- Among all the prongs identified as the muon, the one with the highest muon score in the event is selected as the best muon.

- The second non muon prong is considered as the potential pion candidate.



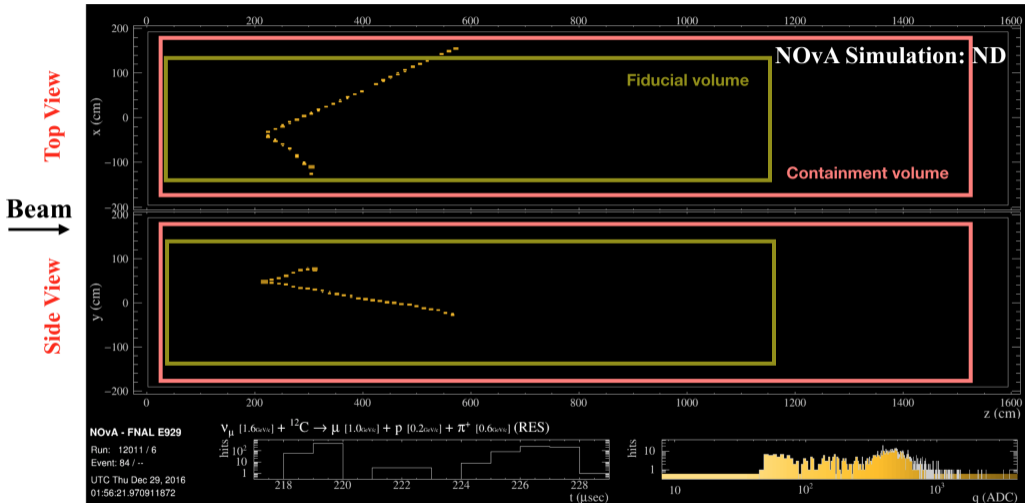
- Pion selection is based on the optimized sum of the pion and the muon score since the pions and the muons look alike a lot.

- Final event selection
  - ▶ The best muon prong is selected as the muon .
  - ▶ The second non muon prong having the sum of the muon and the pion score  $> 0.8$  is selected as the pion.

Selection	Selected	Efficiency (%)	Purity (%)	Background			
				CC Resonance (%)	CC DIS (%)	NC (%)	Coherent (%)
<b>Total</b>	7.16e+07	100	2.7	19.6	64	9.5	0.58
<b>Preselections</b>	5.27e+05	6.9	27.25	36	16.4	16.9	1.5
<b>Muon Selection</b>	3.56e+05	5.6	32.48	48.4	14.1	2.1	1.27
<b>Pion Selection</b>	43,927	1.5	70.3	15.7	10.78	1.2	1.9

- The selected signal has 72.78% events from resonance, 7.5% from coherent and 19.6% from DIS respectively.

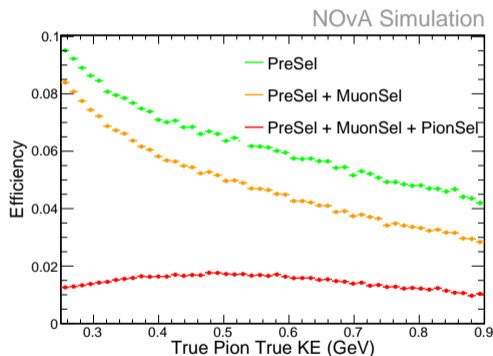
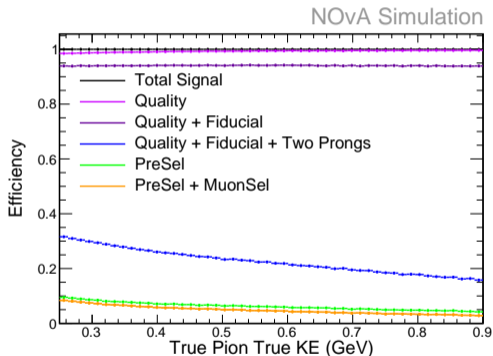
# Simulation of Selected NOvA Event selected



Simulation of a NOvA Near Detector Event

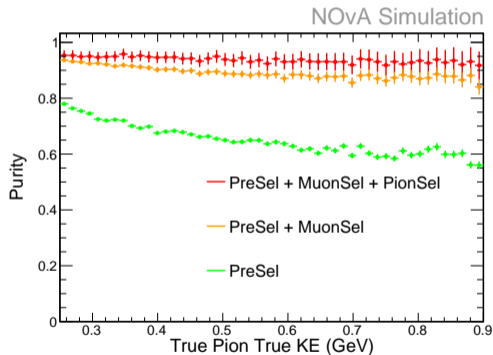
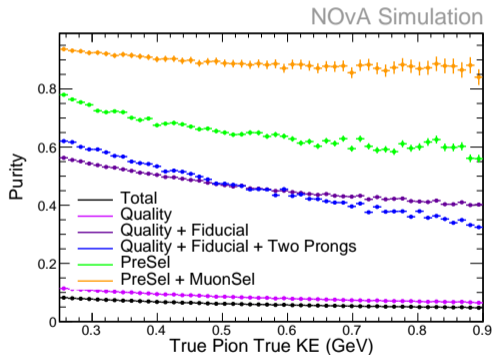


- $\text{Efficiency} = \frac{\text{Number of Selected Signal Events}}{\text{Total number of Signal Events}}$



- The selection efficiency of  $\text{CC1}\pi^+$  sample is 21% and 1.5% with respect to the preselection and the total respectively.

- $\text{Purity} = \frac{\text{Number of Selected Signal Events}}{\text{Total Number of Selected Events}}$



- Applying all the selection cuts, the purity of the selected sample is 93%.

- $CC1\pi^\pm$  measurement has a potential to look at the interactions with low  $W$  (invariant hadronic mass) leading to the improved model of these processes.
- We are planning to have a differential cross section measurement w.r.t to pion kinematics.
- PID for the pion selection has been tuned on MC simulated data. A reconstructed energy cut on the second non muon prong will help reduce the contamination from other particles.
- The total systematics are in the range of 5-15%, investigations are in progress.