Status of the Inclusive $\nu_e$ Charged Current Cross-Section Measurement in the NOvA Near Detector

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New Perspectives
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Motivation

- Precision is becoming more important to the results of long baseline neutrino programs, with experiments looking to reduce uncertainties to the percent level.

- Improving on the existing measurements of neutrino cross sections will play an important role in improving the precision of oscillation analyses and will influence future experiments.

- The inclusive $\nu_e$ charged current (CC) cross-section is a basic measurement that can be used to directly tune simulations for the oscillation analysis.
There are few electron neutrino cross-section measurements at the GeV scale.
Electron Neutrino flux is a small percent of the total flux, with a broad energy spectrum.
Cross-Section Measurement

The NOvA Near Detector (ND) provides an excellent opportunity for the measurement of various neutrino interactions.

\[
\sigma_k = \frac{\sum_j U_{kj} \left( N_j^{sel} - N_j^{bkg} \right)}{T \Phi \varepsilon_k}
\]

- \(N_j^{sel}\) is the number of selected data events
- \(N_j^{bkg}\) is the number of background events
- \(U\) is an unfolding matrix to unfolded to true space from reconstructed space
- \(\Phi\) is the integrated neutrino flux
- \(T\) is the total number of nucleons in the target
- \(\varepsilon\) is the total event selection efficiency
Neutrino Interactions in the NOvA Detector

Simulated Events With 2 GeV Neutrino Energy
Event Selection

- A number of cuts are used to select a sample of electron neutrino events
- The final selection is made using a technique based on deep learning to select $\nu_e$ CC events
  - Events are classified based on topology:
    - $\nu_\mu$ CC events can be identified by the presence of long straight tracks
    - $\nu_e$ CC events can be identified through the presence of a shorter, wider shower
    - NC events lack a charged lepton in the final state and tend to only have activity from the nuclear recoil system
  - A series of image processing transformations are used to extract features that can be used to distinguish these different types of events
  - Convolutional Visual Network (CVN)
Event Selection
Efficiency and Purity

- Signal = $\nu_e$ CC, Background = All other interactions
- Defining figure of merit (F.O.M.) as $\frac{\text{Signal}}{\sqrt{\text{Signal} + \text{Background}}}$
- Maximum value of the F.O.M. is found at requiring $\text{CVN} > 0.85$
Event Selection

- Events with CVN > 0.85 are selected as candidate $\nu_e$ CC events
- All other interaction types are defined as backgrounds

### Expected Event Fraction From Simulation

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Fraction(%)</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\nu_e$ CC</td>
<td>51.2</td>
<td>10,446.70</td>
</tr>
<tr>
<td>Anti-$\nu_e$ CC</td>
<td>4.4</td>
<td>904.66</td>
</tr>
<tr>
<td>$\nu_\mu$ CC</td>
<td>21.1</td>
<td>4,316.67</td>
</tr>
<tr>
<td>NC</td>
<td>23.0</td>
<td>4,691.16</td>
</tr>
<tr>
<td>Other</td>
<td>0.18</td>
<td>37.67</td>
</tr>
</tbody>
</table>
There are two major contributions to the background in the signal region, $\bar{\nu}_\mu$ CC and NC.

We are going to constrain the background components using a sideband to our signal region.

The sideband will have high statistics and should be background dominated.

This will use a data-driven technique of fitting the background components to the data in the region to get an estimate of the amount of background in the signal region.

The determination of the background component will be done in Leading Prong E - Remaining Slice Energy space to give more information on the measurable components.
Markers show the mean and error bands show RMS of each slice of Reconstructed - True neutrino energy (electron angle) with respect to true neutrino energy (electron angle).

The predicted energy resolution is ~400 MeV averaged over the entire sample from 1 to 3 GeV in true Neutrino Energy.

The predicted angular resolution is ~4° averaged over the region shown in true electron angle.
Muon Removed Sample

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Muon Removed Sample

- Calculate the efficiency of PID selection from the MRE sample in Data and MC

- Calculate the correction of the efficiency of the electron neutrino signal by comparing the Data and MC efficiencies of the selection using leading prong kinematics
The NOvA ND provides an excellent opportunity to measure the inclusive $\nu_e$ charged current (CC) cross-section.

We have done studies on resolution, background estimation, energy reconstruction, etc.

The expected uncertainty on the measurement should be $\sim 14\%$.

Aiming to have results later this year.