Status of the Measurement of Neutrino-Electron Elastic Scattering in the NOvA Near Detector

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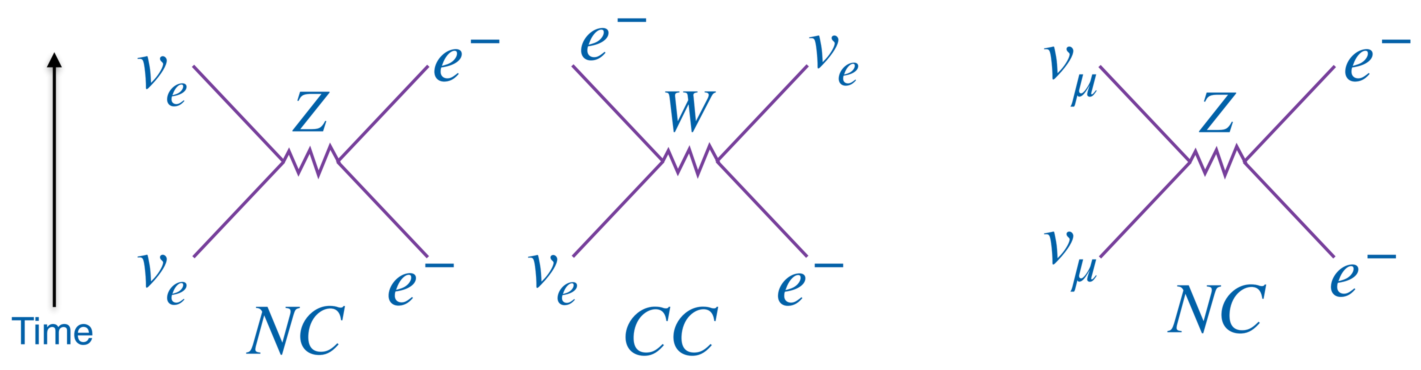
Introduction

$\nu_e + e^- \rightarrow \nu_e + e^-$ $\qquad$ $\nu_\mu + e^- \rightarrow \nu_\mu + e^-$



Neutrino-electron elastic scattering is a leptonic process which exchanges a vector boson to scatter off an electron.
According to the standard model (SM), the cross section has been calculated as a function of the neutrino energy:

$$\sigma^{\nu_l e \rightarrow \nu_l e} \sim 10^{-42}(E_\nu/\text{GeV})\ \text{cm}^2 \qquad \text{(Uncertainty ~ 1\%)}$$

Measuring neutrino-electron scattering is an experimentally challenging task due to the smallness of the scattering cross section.

- Since, there is no hadronic or nuclear uncertainties associate with this process, the neutrino-electron scattering measurement is an important tool to constrain the neutrino flux prediction to reduce the total uncertainty.

NOvA Near Detector

- NOvA (NuMI Off-Axis ν_e Appearance Experiment) is a long-baseline (800 km) neutrino experiment to observes the oscillation of muon neutrinos to electron-neutrinos
- The near detector (ND) has been placed 1 km away from the NuMI target to match 14.6 mrad off axis spectrum at the far detector from the beam
- ND is located 100 m underground at Fermilab

NOvA near detector at Fermilab

- ND is a tracking calorimeter with 300 ton liquid scintillator
- ND has 18,000 channels
- The high rate of neutrino interactions at the ND provides opportunities to make detailed measurements of neutrino-nucleus cross sections

Event Identification

According to the kinematics of $\nu - e$ scattering, the relationship of the scattering angle of electron (θ_e) with the neutrino energy (E_ν) and electron energy (E_e) is: $1 - \cos\theta_e = \dfrac{m_e(1 - T_e/E_\nu)}{E_e}$

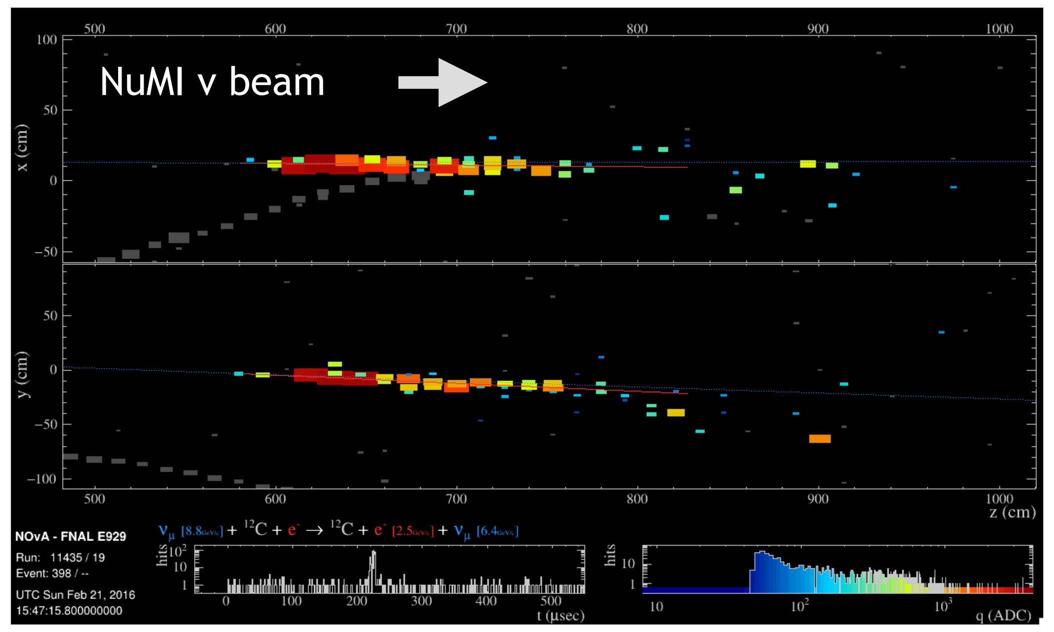
where: T_e : Electron Kinetic Energy .

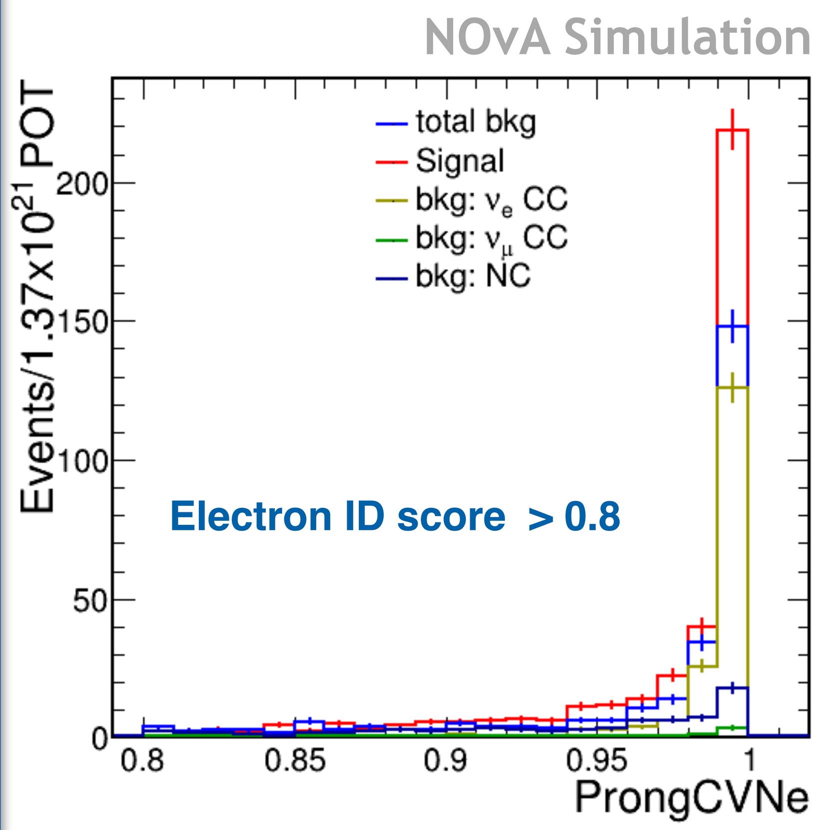
This sets the limits for the signature of the $\nu - e$ as:

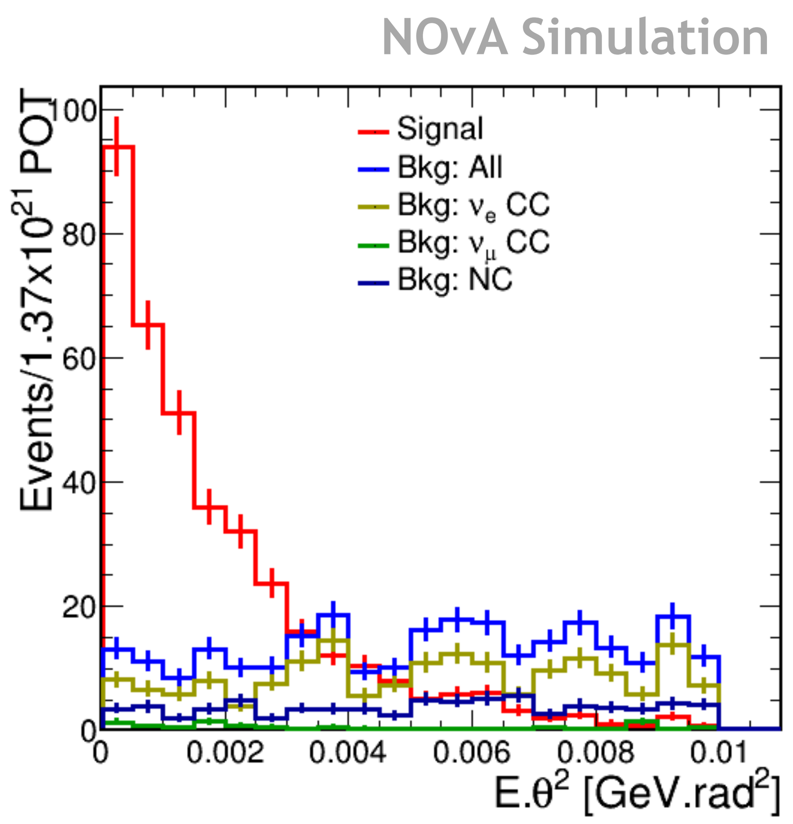
$E_e \cdot \theta_e^2$ to be small ($< 2m_e$)

Therefore, we are searching for events as:

- Very forward going single prong events with small $E_e \cdot \theta_e^2$ peaking around zero
- The Convolutional Visual Network (CVN) score for electron identification should be above 0.8
- Reconstructed hadron energy should be small

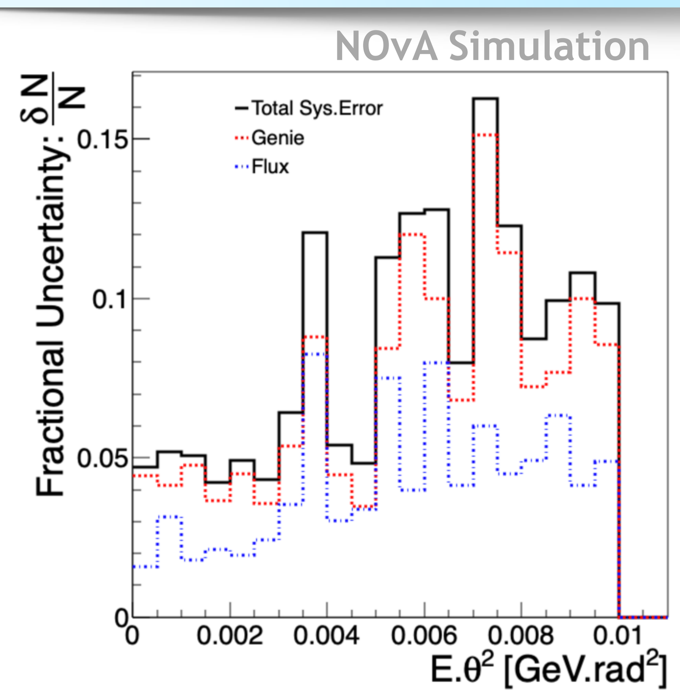


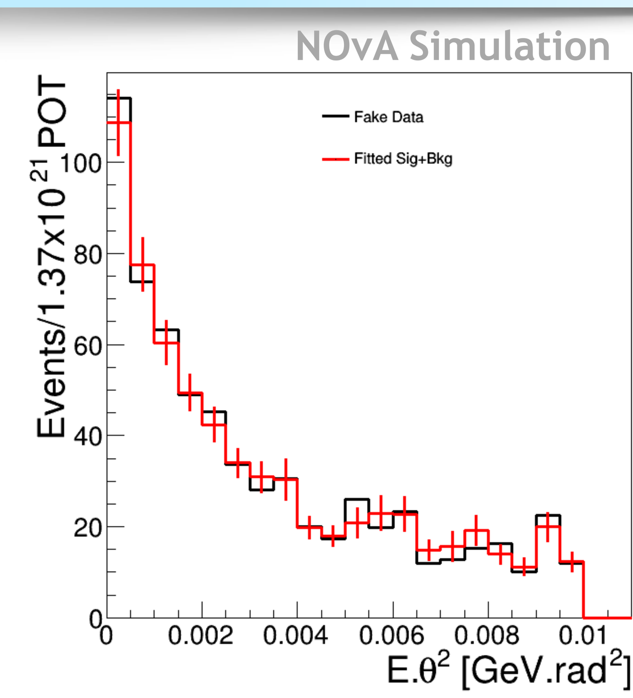




Simulation results of the signal event selection with the breakdown of the background interactions

Uncertainty and Template Fitting



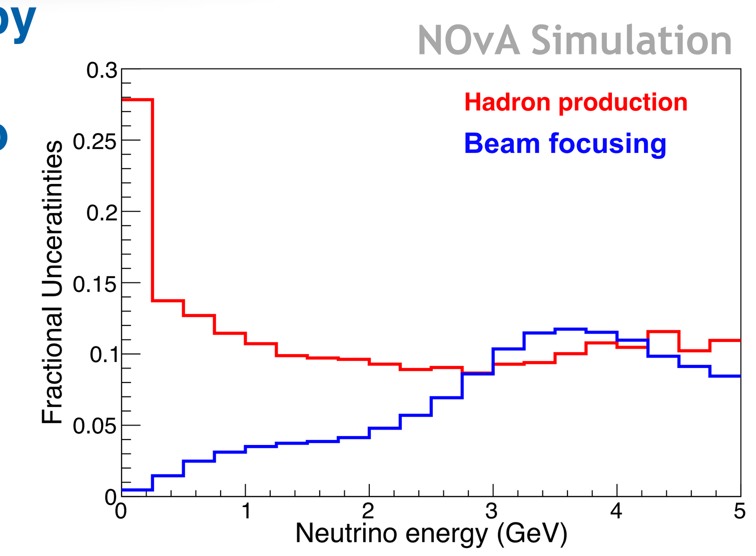


- $\nu - A$ and FSI modeling systematic uncertainty and neutrino flux uncertainties have been taken into account to the total uncertainty calculation
- The detector response uncertainties will be taken into account for the final uncertainty estimations in the future
- A template fitting algorithm has been tested to fit fake data on the total Signal + Background distribution of $E_e \cdot \theta_e^2$
- The fake data for this study has been randomly chosen within the total uncertainty
- The template fitting is performed by using a defined χ^2 with taking account the total covariance matrix (COV) to obtain the normalization factors for the signal (Sig) and the background (Bkg)

$$\chi^2 = \sum \left[\text{Data} - ([0]\,.\,\text{Sig} + [1]\,.\,\text{Bkg})\right)_i \cdot \text{COV}_{ij}^{-1}\left(\text{Data} - ([0]\,.\,\text{Sig} + [1]\,.\,\text{Bkg})\right]_j$$

Conclusion

- A method [1] of applying Bayes theorem by taking account the observations and the model predictions is a possible method to constrain the flux
- Previous studies indicate that the NOvA flux normalization uncertainty can be reduced by at least 40% using neutrino-electron scattering events in the NOvA near detector



- The combined results from the data collected for neutrino and the anti-neutrino modes will be a powerful flux constraint tool
- Also this measurement could be used to constrain new physics such as the magnetic moment of the neutrino

[1] MINERvA Collaboration, "Measurement of neutrino flux from neutrino-electron elastic scattering", *Phys.Rev.D* 93 (2016) 11, 112007

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