Direct Measurement of the NuMI Flux with Neutrino-Electron Scattering in MINERvA

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Introduction

• Flux prediction is important for MINERvA's absolute cross-section measurement
• Future precision neutrino oscillation experiment requires low uncertainty on flux prediction
• Flux has large uncertainty due to poor knowledge of hadron production
• Use of external data is useful but it can't handle all the uncertainties
• $\nu$-$e$ scattering provides a direct measurement of flux

$\nu$-$e$ Scattering

- $\nu$-$e$ scattering is a point-like scattering that is well-understood in electroweak theory to 1% accuracy

$$d\sigma(\nu_e \rightarrow e^-) = \frac{G_F^2 m_e E_e}{2\pi} \left[ \frac{1}{2} \sin^2 \theta_W \sin^2 \theta_W (1-y)^2 \right]$$

where $y = E_e / E_\nu$.

Phonon Rejection

- When one of the photons from $\pi^0$ decay is not observed, it mimics the signal events
- Photon-induced electromagnetic shower has twice $dE/dx$ (energy loss per length) at the beginning of the shower than electron-induced shower

Photon shower

Forward Electron Selection

- Kinematics constraint $E\theta^2 < 2m_e$
- $E\theta^2$ would be much larger for events where the target is a nucleon
- Clean separation of signal using $E\theta^2$ cut
- Good angular resolution (0.3 degree) is critical to use $E\theta^2$ cut
- Data-driven background prediction tuning is used to handle the uncertainty of predicted background

Result

- Measured $\nu$-$e$ scattering events
  - $123.8 \pm 17.0$ (stat) $\pm 9.1$ (sys) .... Total uncertainty: 15%
- Prediction from Simulation
  - $147.5 \pm 22.9$ (flux) .................Flux uncertainty: 15.5%
- $\nu$-$e$ scattering provides an independent constraint with similar uncertainty to current flux prediction

Conclusion

- $\nu$-$e$ scattering provides an independent flux measurement for $\nu$-nucleon cross-section normalization
- Uncertainty on $\nu$-$e$ based flux measurement in Low Energy beam is 15%
- In Medium Energy run, estimate a 7% uncertainty on total flux
- This technique could be used in future higher intensity experiments like NOvA and LBNE to provide a precise flux measurement