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

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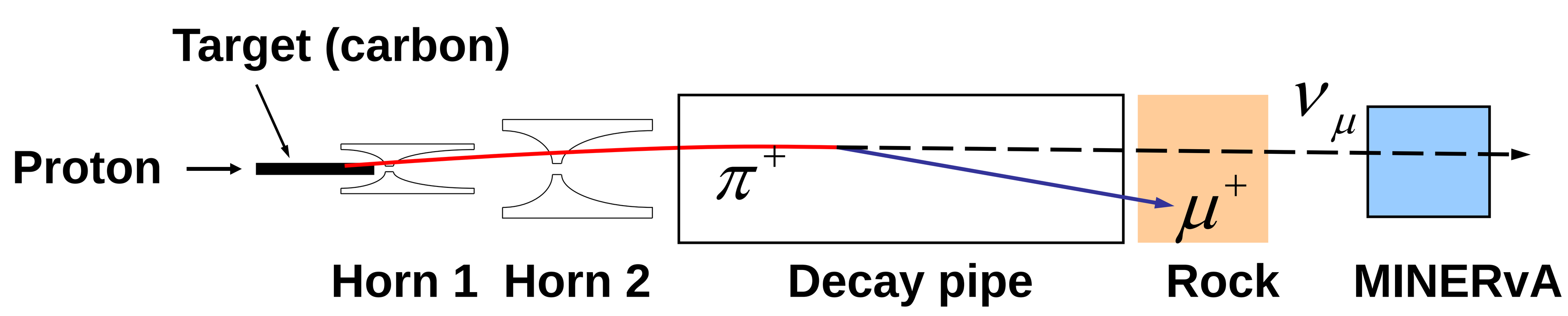
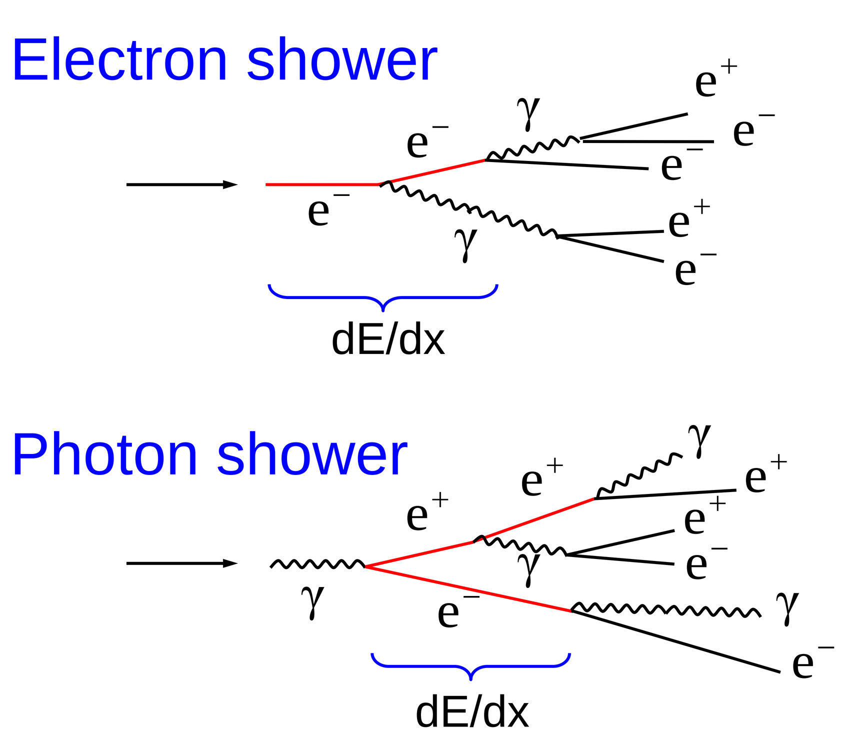
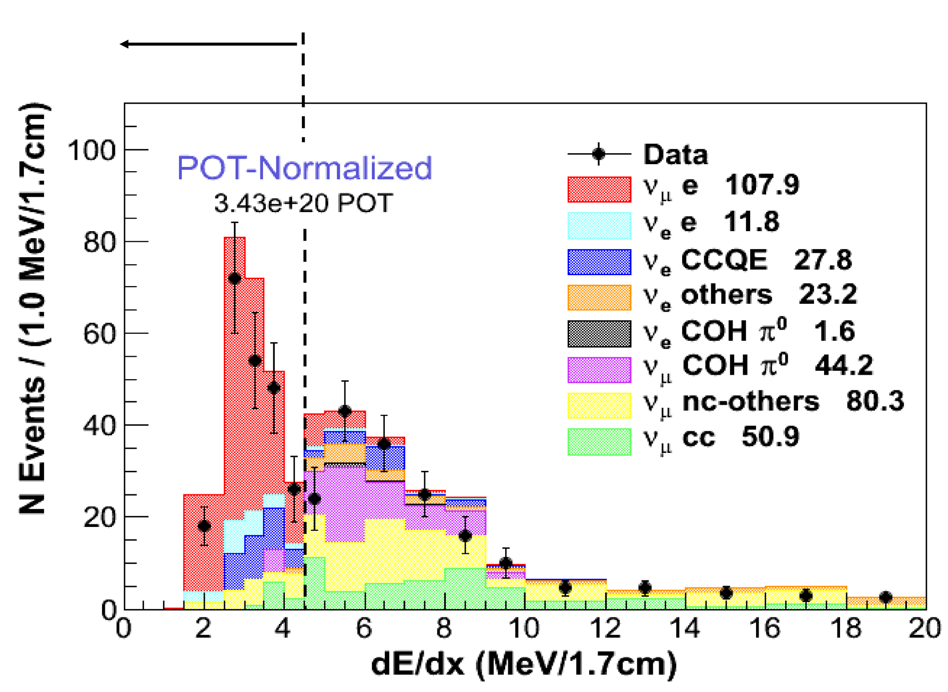
Introduction



- 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
- ν-e scattering provides a direct measurement of flux

Photon Rejection

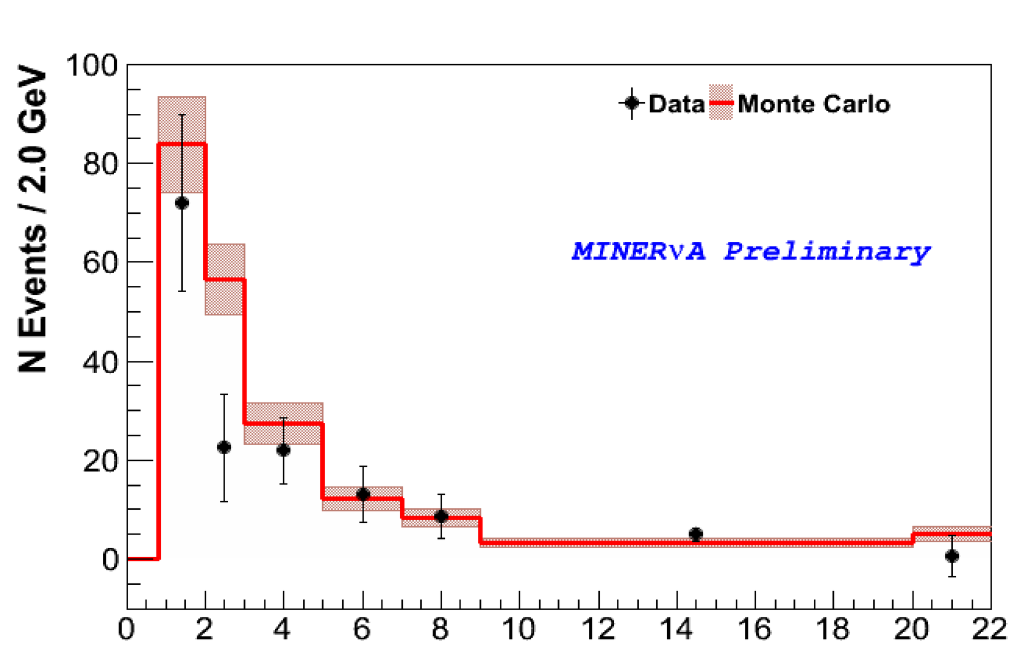




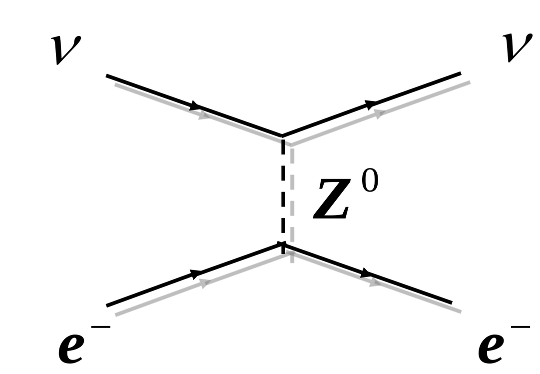
- When one of the photons from π^0 decay is not observed, it mimics the signal events
- Photon-induced electromagnetic shower has twice dE/dx (energy loss per length) at the beginning of the shower than electron-induced shower

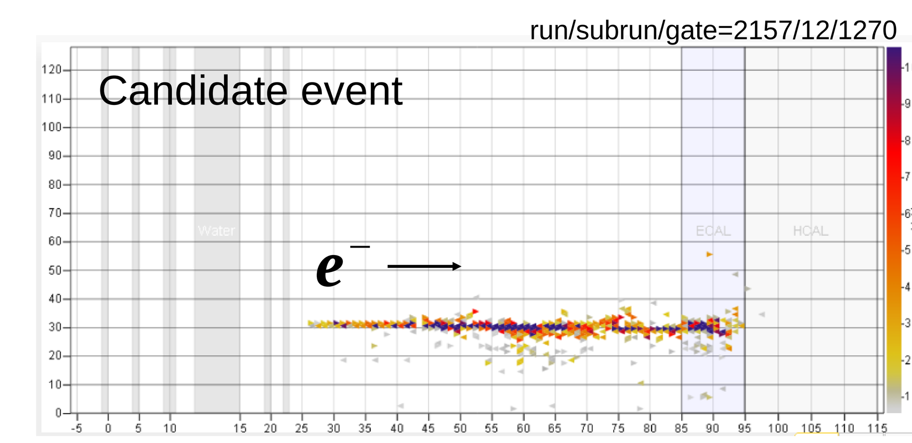
Result

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



ν-e Scattering

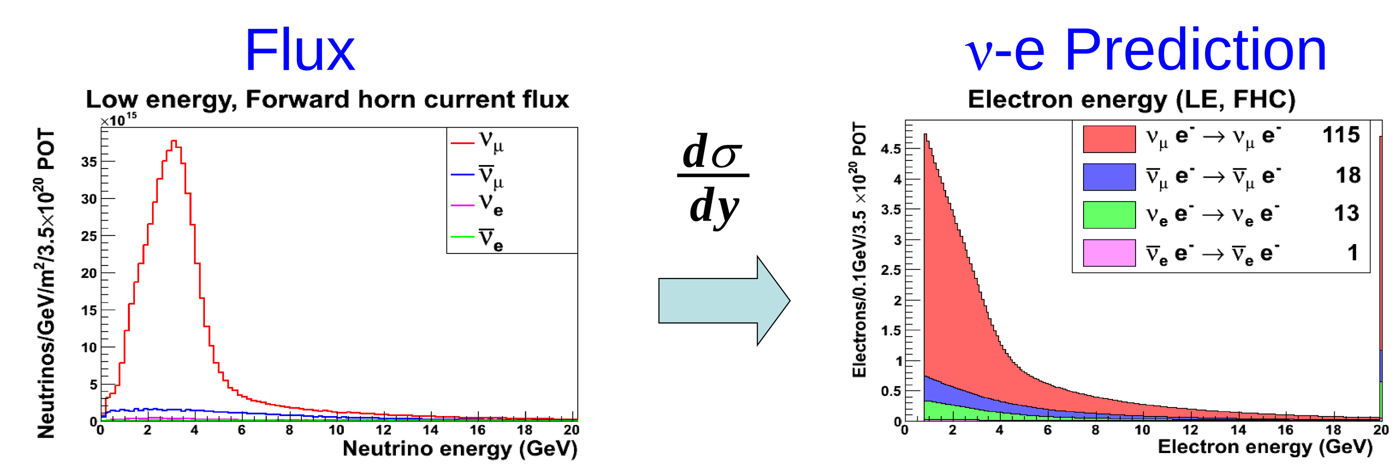




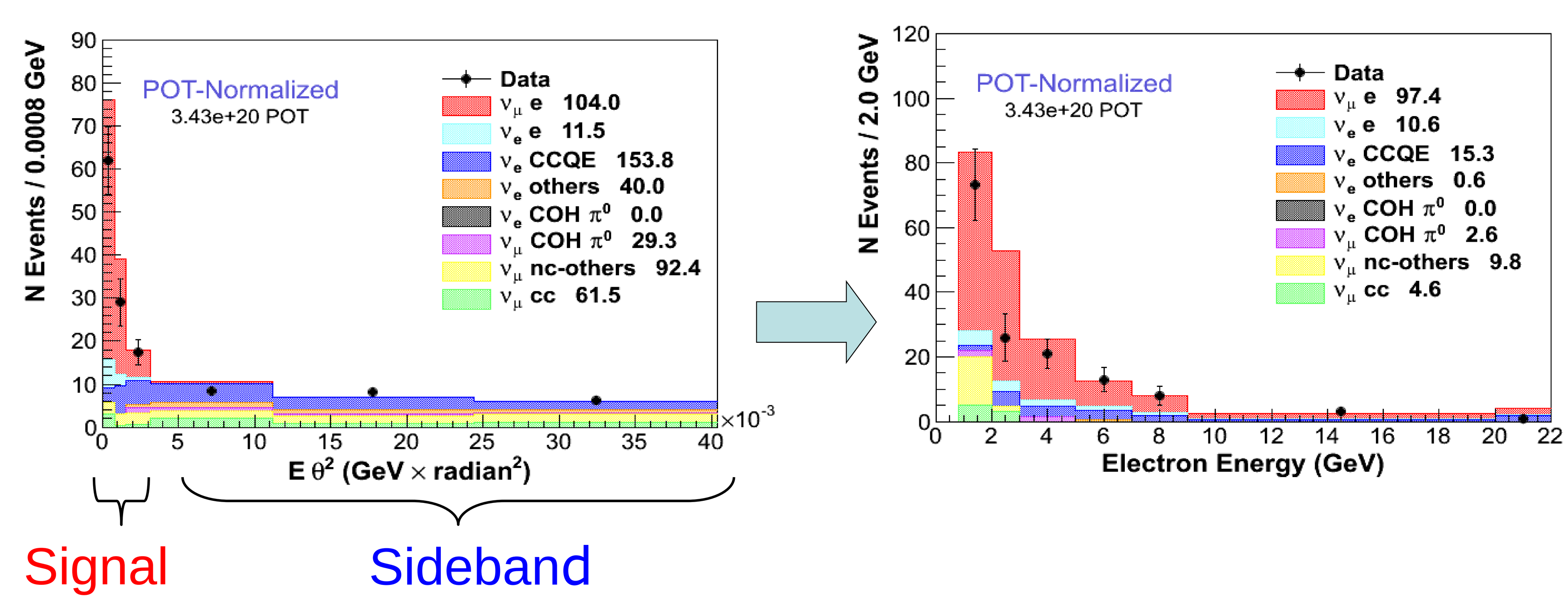
- ν-e scattering is a point-like scattering that is well-understood in electroweak theory to 1% accuracy

$$\frac{d\sigma(\nu_\mu e^- \to \nu_\mu e^-)}{dy} = \frac{G_F{}^2 m_e E_\nu}{2\pi}\left[\left(\frac{1}{2}-\sin^2\theta_W\right)^2 + \sin^4\theta_W (1-y)^2\right] \quad \text{where } y = \frac{E_e}{E_\nu}$$

G_F and θ_W: well-known electroweak parameters



Forward Electron Selection



- Kinematics constraint $\boxed{E\theta^2 < 2m_e}$

  where E : electron energy, θ : electron angle w.r.t neutrino

- $E\theta^2$ 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

Conclusion

- ν-e scattering provides an independent flux measurement for ν-nucleon cross-section normalization
- Uncertainty on ν-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