Measurement of Neutrino Flux from Neutrino-Electron Elastic Scattering

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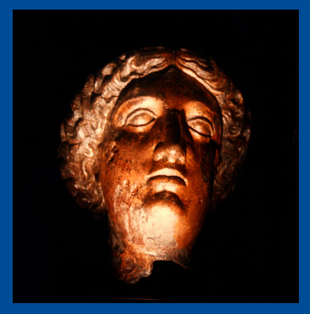
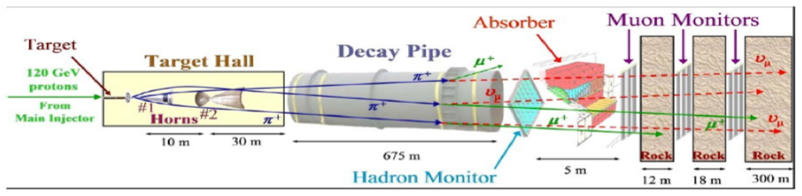


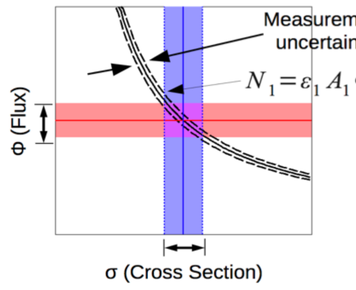
NuMI Beamline:

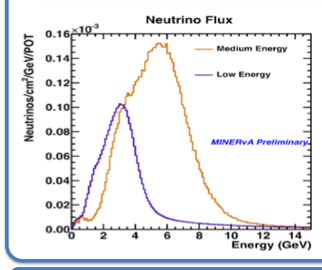


MINERvA

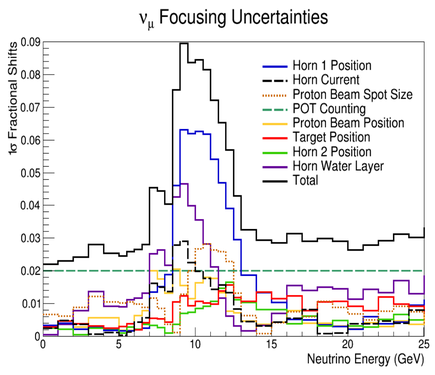
$$\sigma = \frac{N}{\varepsilon A \Phi}$$

Flux uncertainty goes into the cross-section uncertainty

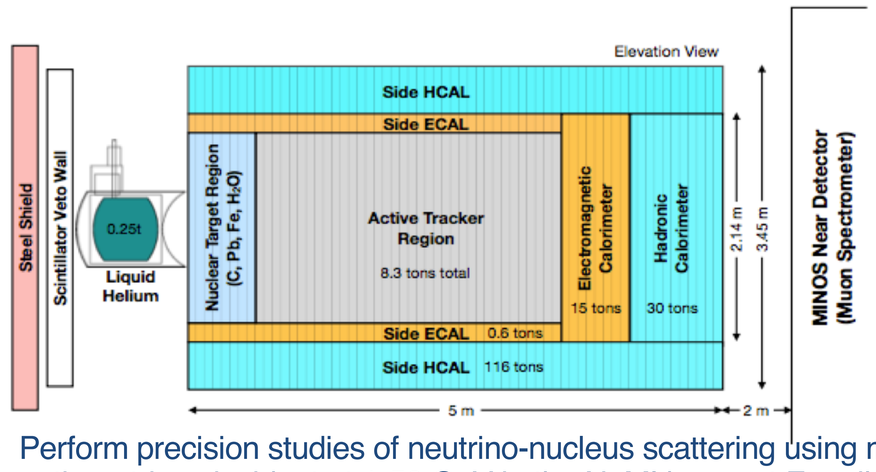


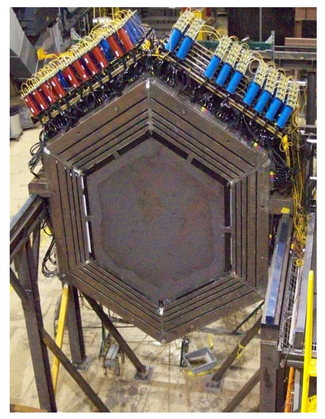


Source of Flux Uncertainties:
Beam Focusing Uncertainties
Hadron production uncertainties



MINERvA Detector



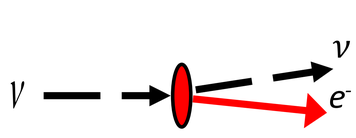


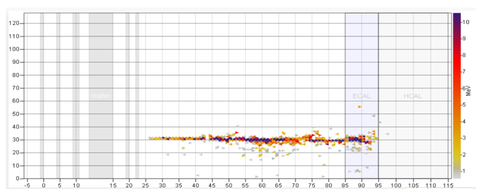
- Perform precision studies of neutrino-nucleus scattering using muon neutrinos and anti-neutrinos incident at 1-50 GeV in the NuMI beam at Fermilab. .
- Finely segmented scintillator

Constrain Flux with in-situ measurement: ν–e scattering

- Theory well predicted by the standard model of particle physics.
- Caveat: Tiny cross section (~1/2000 compare to vN scattering) .
- Signal in MINERvA is a single electron moving in the beam direction

$\nu_\mu + e \rightarrow \nu_\mu + e$
$\nu_e + e \rightarrow \nu_e + e$
$\bar{\nu}_\mu + e \rightarrow \bar{\nu}_\mu + e$
$\bar{\nu}_e + e \rightarrow \bar{\nu}_e + e$





Methodology :

Bayesian Theorem: $P(H \mid x) \propto \pi(H)\, P(x \mid H)$

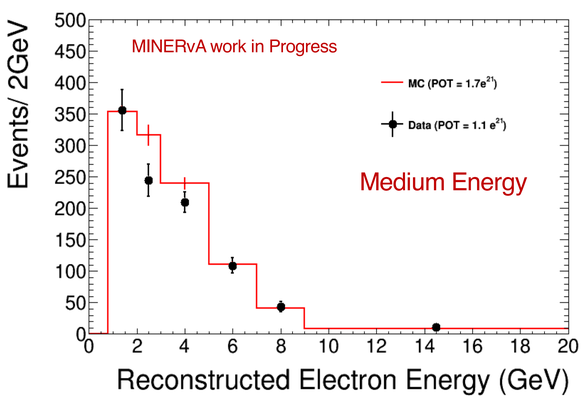
The probability of a flux model (M) given the observed electron energy spectrum ($N\nu e \rightarrow \nu e$) is proportional to the a priori probability of that model (π(M)) and the probability of the electron energy spectrum given the model.

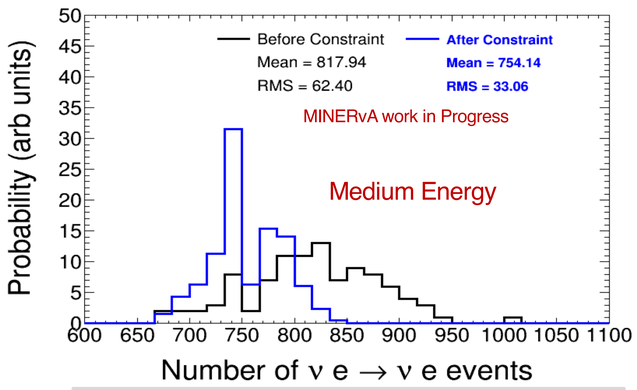
$$P(M \mid N\nu e \rightarrow \nu e) \propto \pi(M)\, P(N\nu e \rightarrow \nu e \mid M)$$

$$P(N\nu e \rightarrow \nu e \mid M) = \frac{1}{(2\pi)^{K/2}} \frac{1}{|\Sigma|_N^{1/2}} e^{-\frac{1}{2}(N-M)^T \Sigma_N^{-1} (N-M)}$$

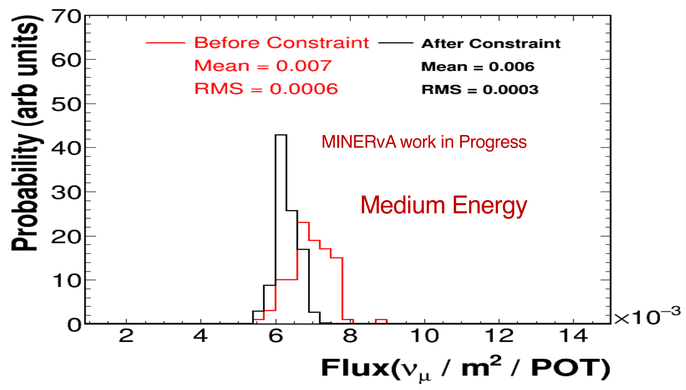
K : no: of bins in the electron energy spectrum; N(M) : vector representing the bin content of that spectrum in data (predicted by model M); Σ_N: total data covariance matrix describing all uncertainties on N.

Results:

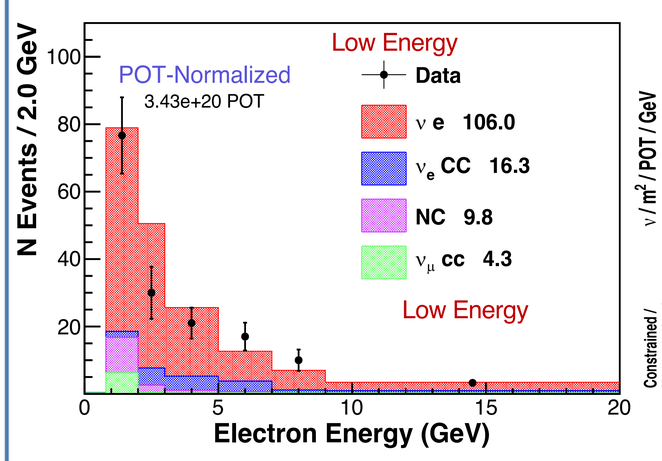


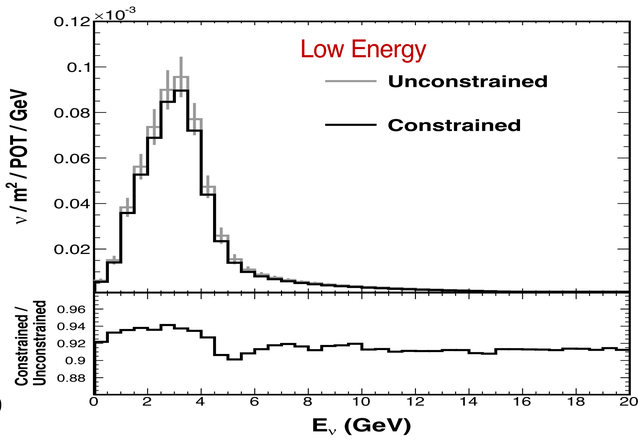


The probability distribution (black) of the predicted total number of neutrino-electron scattering events in the simulation and the modified probability distribution (blue) given the observed electron energy spectrum

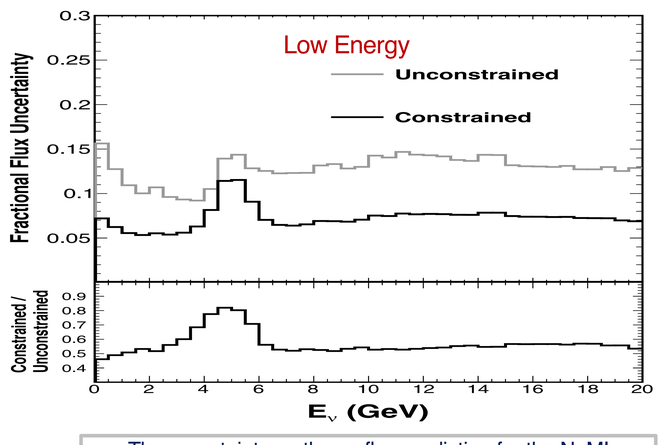


The probability distribution (red) of the predicted neutrino flux and the modified probability distribution (black) given the observed electron energy spectrum.





The ν_μ flux prediction for the NuMI beamline, before (gray) and after (black) the neutrino-electron scattering flux constraint



The uncertainty on the ν_μ flux prediction for the NuMI beamline, before (gray) and after (black) the neutrino-electron scattering flux constraint

Conclusion

- More statistics for ME ~ 800 events
- In the process of finalizing systematics. Significantly lower systematic uncertainties.
- Flux constraint ongoing, changes flux uncertainty from about 8% to 6% in the focusing peak
- Proof of principle for future experiments
- Stay tuned for final results soon

References:

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