

Neutrino Cross Sections for Shallow Inelastic Scattering at MINERvA

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MINERvA Experiment

- MINERvA is a high statistics ν -A scattering experiment;
- It uses the NuMI beam: neutrino energy peaked at around 6 GeV;
- Interaction vertex in the active tracker region (scintillator);
- MINOS near detector: muon spectrometer (momentum and charge).

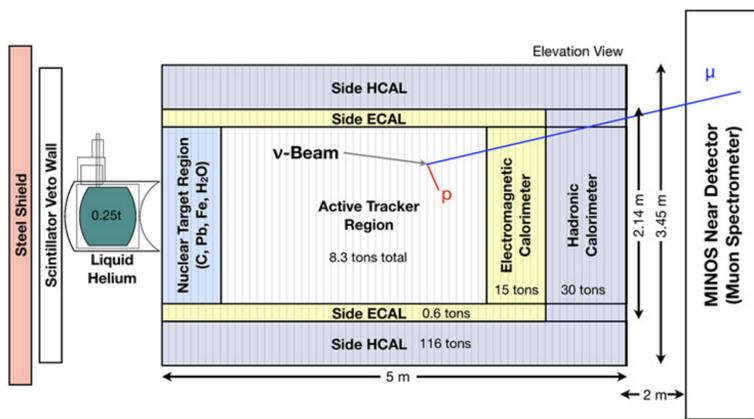


Figure 1: MINERvA detector.

The Shallow Inelastic Scattering Region

The **Shallow Inelastic Scattering (SIS)** region is the transition region between resonant production and deep inelastic scattering processes. Experimentally, SIS is defined in terms of Q^2 as:

- Events with $Q^2 > 0 \text{ GeV}^2/c^2$;
All nonresonant and multi-quark SIS production as well as resonant background
- Events with $Q^2 > 1 \text{ GeV}^2/c^2$;
Emphasizes the multi-quark SIS contribution and reduces the low Q^2 resonant meson background

Moreover, to minimize the resonant pions (Δ), and single-quark DIS events, we restrict the invariant mass of the hadronic system (W_{exp}) to:

$$1.5 < W_{exp} < 2.0 \text{ GeV}/c^2.$$

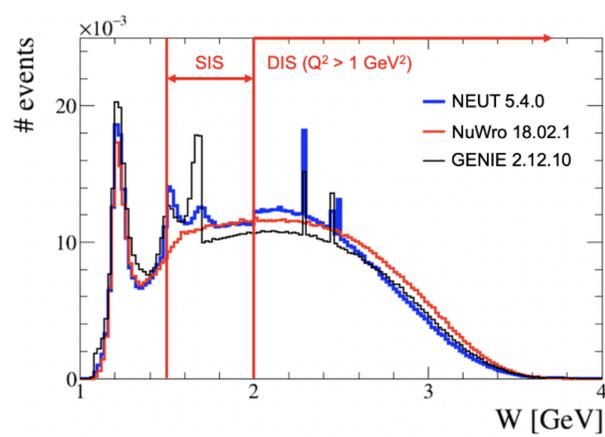


Figure 2: SIS transition region definition at MINERvA. C. Bronner plot [1].

SIS relevance:

- Refinement of models used in neutrino event generators;
- Reduce systematic uncertainty for oscillation experiments (around 50% of events in DUNE will be in the SIS region).

First High-Statistics Measurements

Neutrinos in the SIS signal region are selected from charge-current events with a muon in the final state and hadronic shower limited to:

$$1.5 < W_{reco} < 2.0 \text{ GeV}/c^2.$$

The background is constrained using a χ^2 technique in kinematic regions defined as sidebands (QE, RES, DIS). After removing the background, the SIS sample has:

- 383,494 events for $Q^2 > 0 \text{ GeV}^2/c^2$;
- 93,410 events for $Q^2 > 1 \text{ GeV}^2/c^2$.

Neutrino SIS cross section:

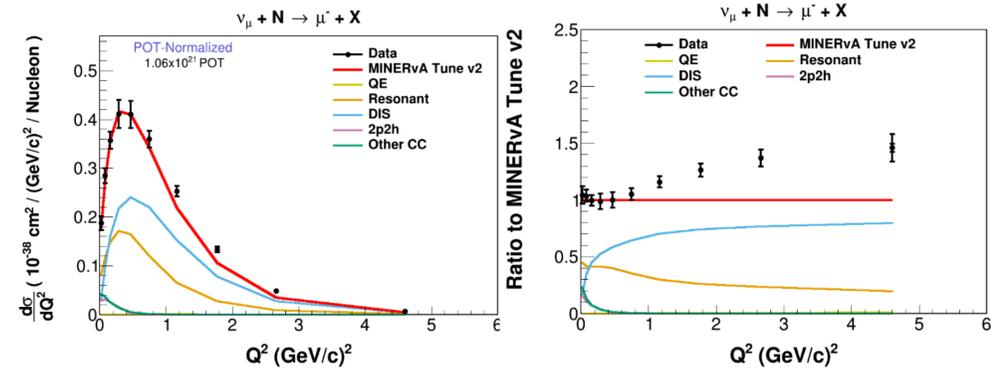


Figure 3: Cross section.

Figure 4: Ratio.

The kinematic breakdown is in terms of GENIE interaction modes, which might not be the best ingredients to describe or tune the SIS region.

Model Comparisons:

- Among the simulation programs tested, none of them describe the data across the full kinematic region;
- NEUT matches the data at high Q^2 as well as NuWro;

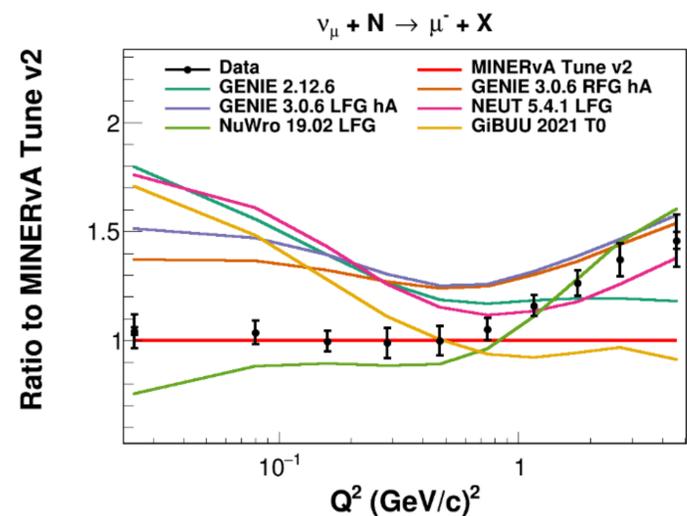


Figure 5: Model Comparison.

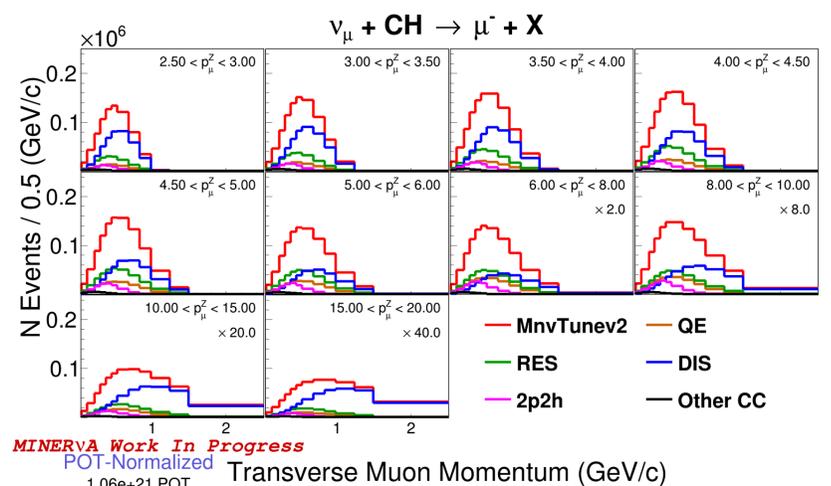
More details in the SIS talk at NuINT24 [2], and in the upcoming SIS paper containing both neutrino AND antineutrino measurements as function of many variables!

Summary and Prospects

- The first high-statistics neutrino cross section measurement for the specific shallow inelastic scattering (SIS) region was presented;
- Discrepancies between measurements and neutrino generator predictions have been observed.

Prospects

Two-dimensional cross section measurements as a function of muon variables, Bjorken-x and Q^2 .



[1] C. Bronner, Generators for the SIS/DIS region, arXiv: 1608.02716 (2016);
[2] A. Sánchez, SIS Interactions in MINERvA, NuINT24;