



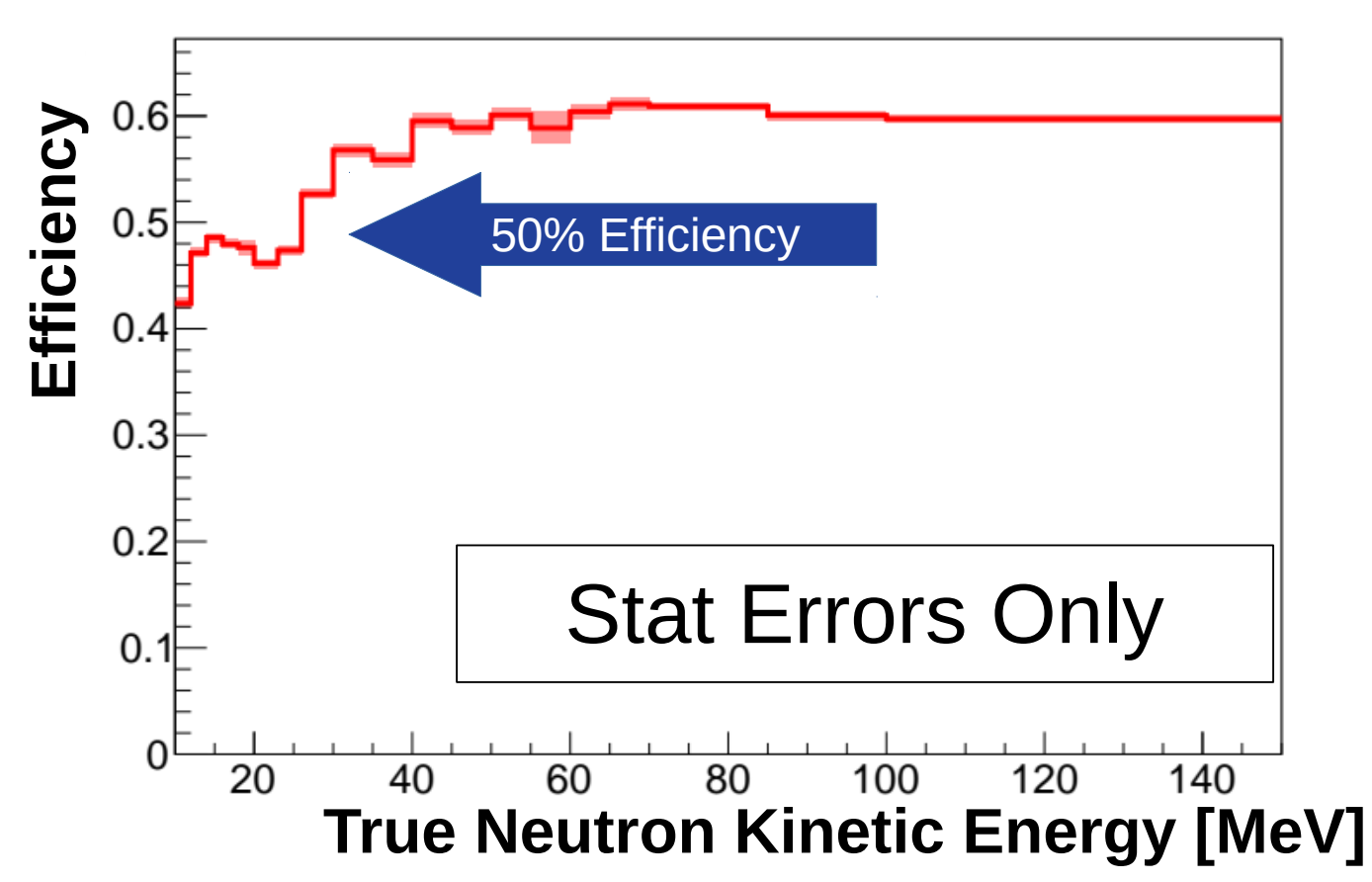
Measuring the Multi-Neutron Antineutrino Cross Section at Low Charged Hadron Energy in MINERvA

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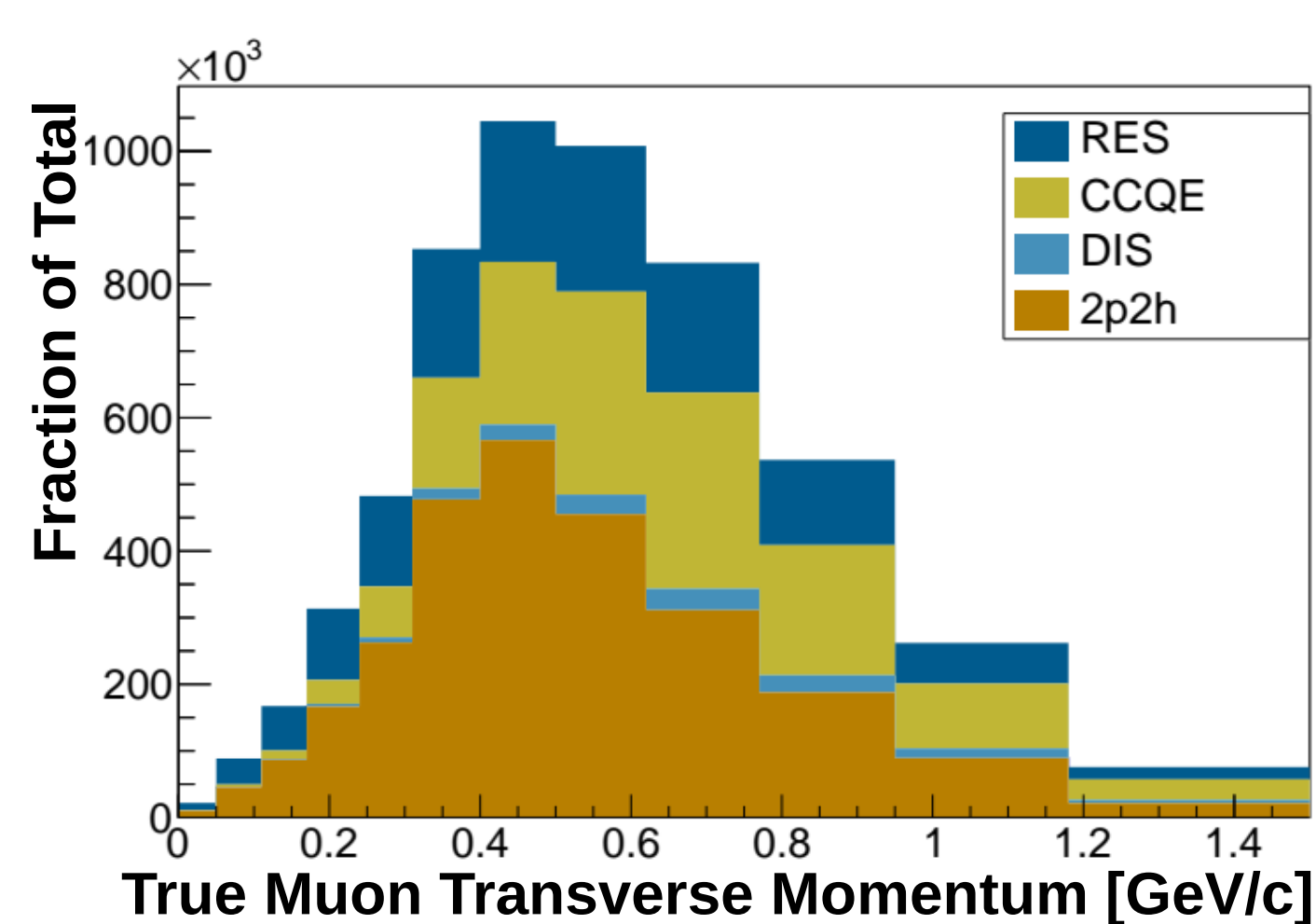
#1 Neutrons from Antineutrinos

- **Neutrons** are an important source of **energy reconstruction** bias for oscillation experiments
- **MINERvA** can detect neutrons efficiently^[1]
- Multi-neutron cross section: **2p2h**- and **FSI**-rich^[2]

Neutron Detection Efficiency

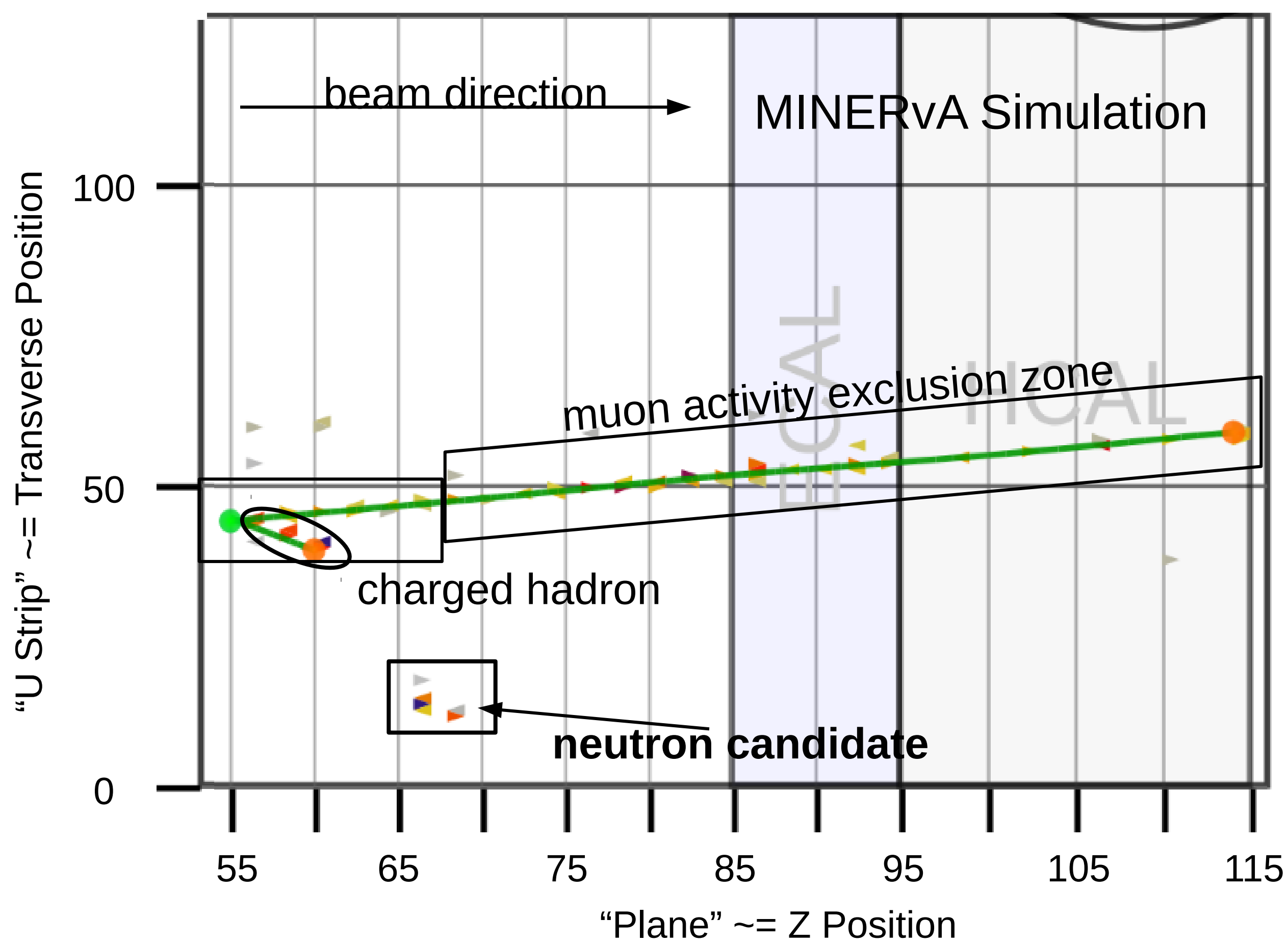


Interaction Channels



#2 Neutron Counting in MINERvA

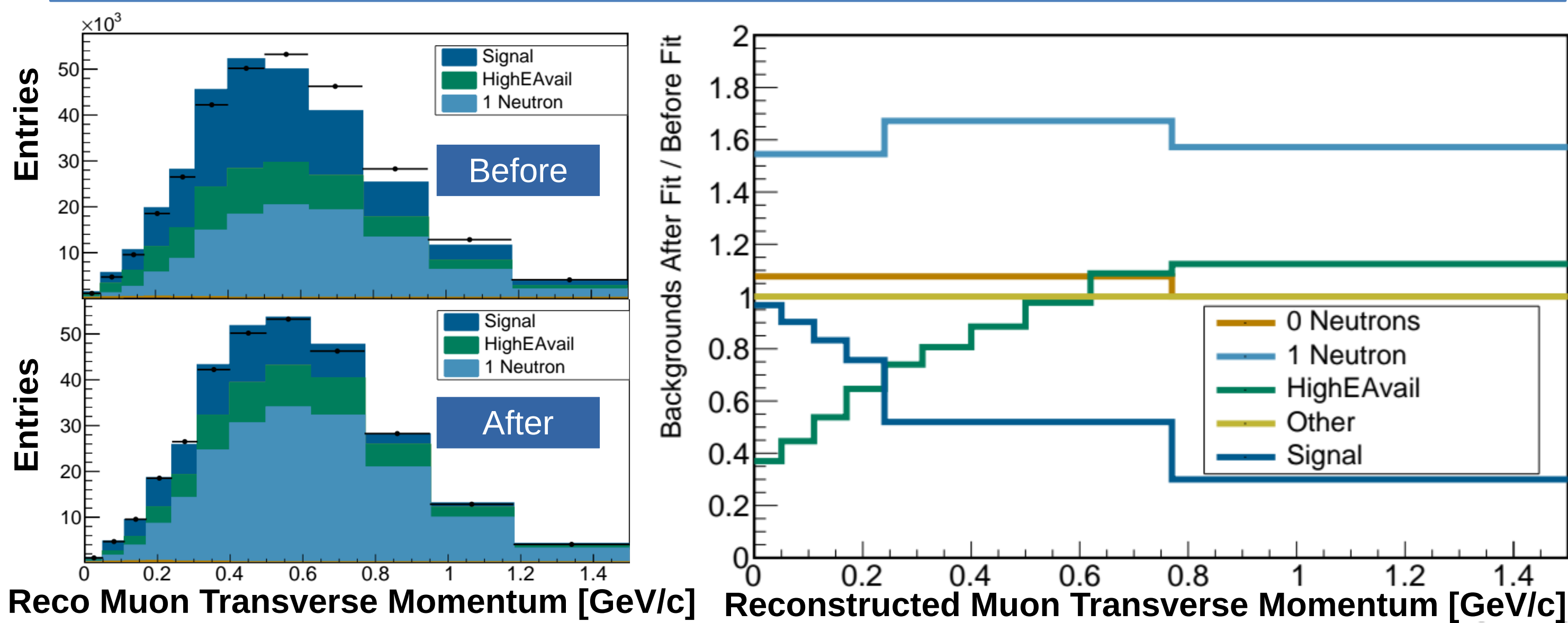
- MINERvA sees neutrons primarily by their **inelastic scatters**
- Primarily **protons**
- Some photons at low neutron energy
- Rarely see nuclear fragments
- Neutron candidates must be:
 - Away from **muon**
 - **> 1.5 MeV** energy
 - Not connected to **vertex**



MINOS ND

#3 Background Constraint

- Leading backgrounds to multi-neutron interactions:
 - **1 Neutron**: mostly antineutrino QE-like
 - **High E_{avail}**: energy mis-reconstructed for pions
- Sideband fits resemble trends in past MINERvA publications

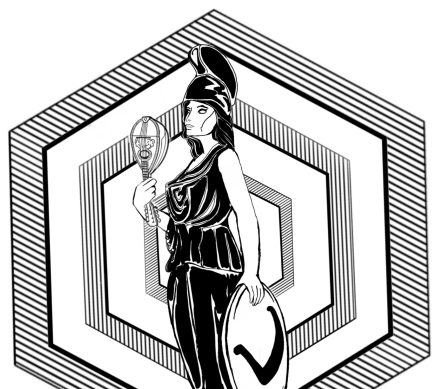


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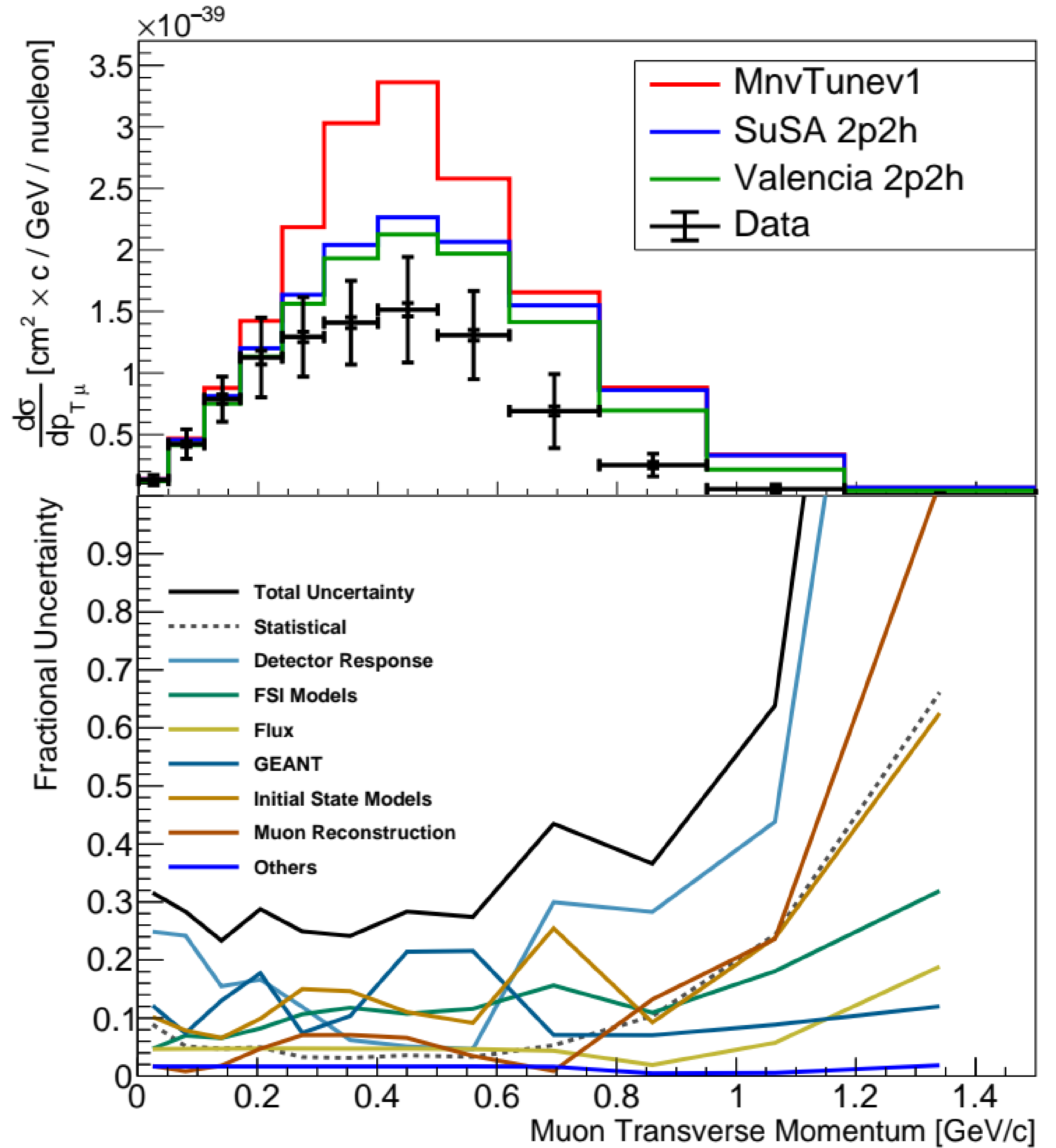
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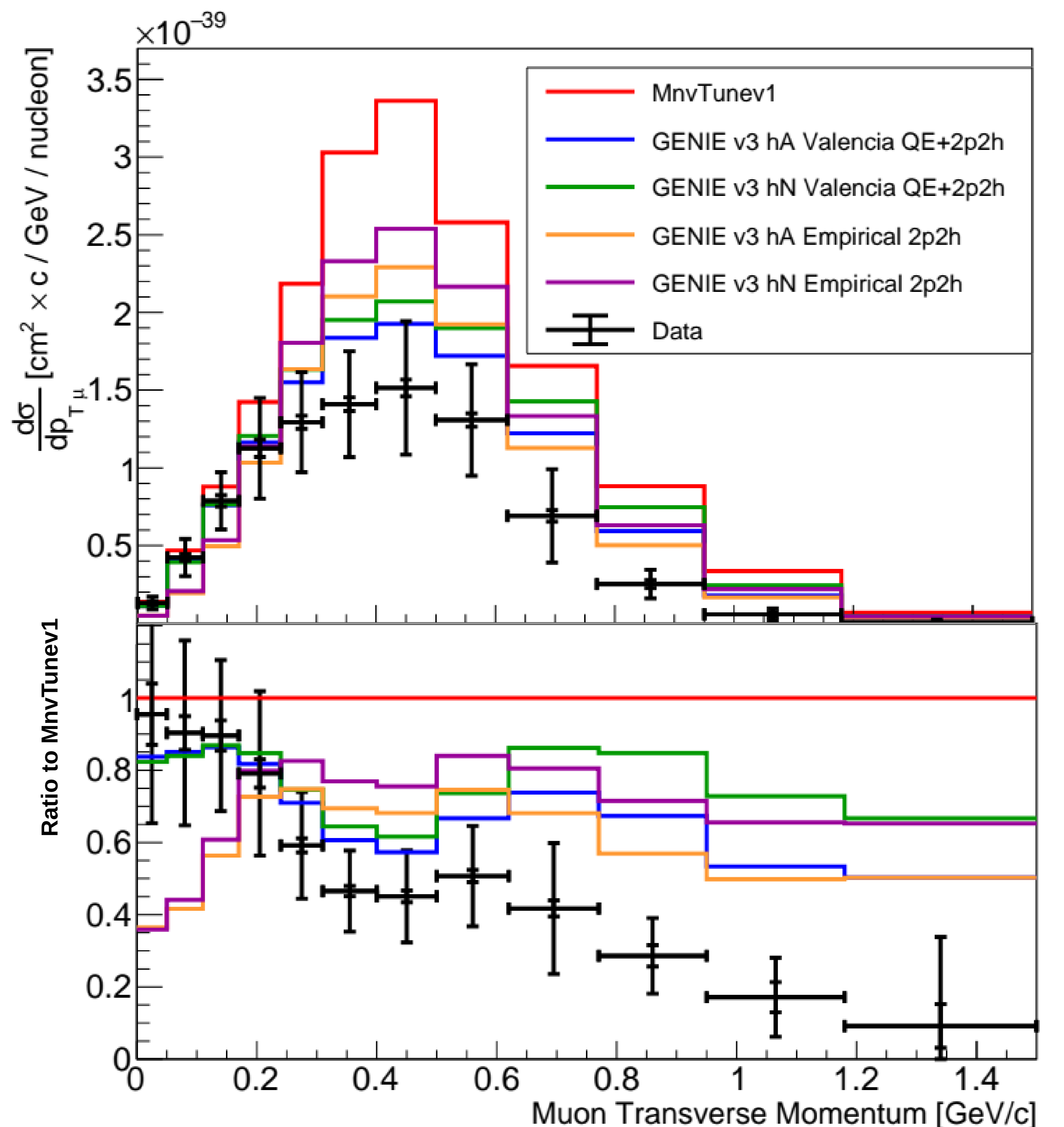
#4 Cross Section

- Cross section for **2+ neutrons** at $E_{avail} < 100$ MeV
- Data prefers models without dedicated **2p2h** tune
- Uncertainties dominated by GEANT **neutron modeling**^[3]



#5 GENIE v3 Comparisons

- **2 2p2h** models^{[4][5][6]}:
- Empirical: different data from MnvTunev1
- Nieves = Valencia
- High momentum tail driven by **FSI**, not 2p2h



#6 Conclusions

- Neutron production sensitive to **2p2h** and **FSI**
- Extracted differential cross section for model comparisons
- Many leading models do not agree