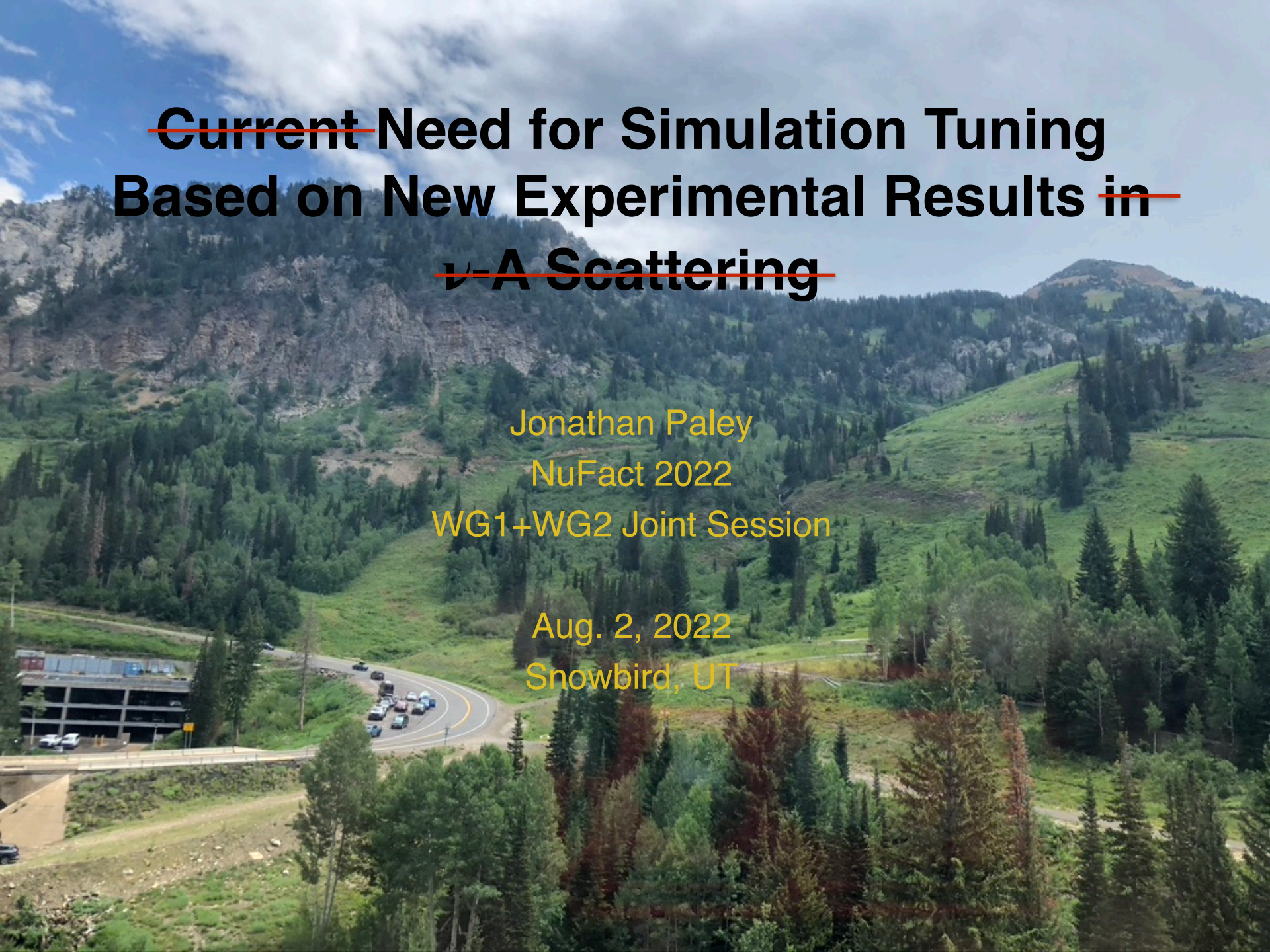


~~Current~~ Need for Simulation Tuning Based on New Experimental Results ~~in ν-A Scattering~~

Jonathan Paley

NuFact 2022

WG1+WG2 Joint Session

Aug. 2, 2022

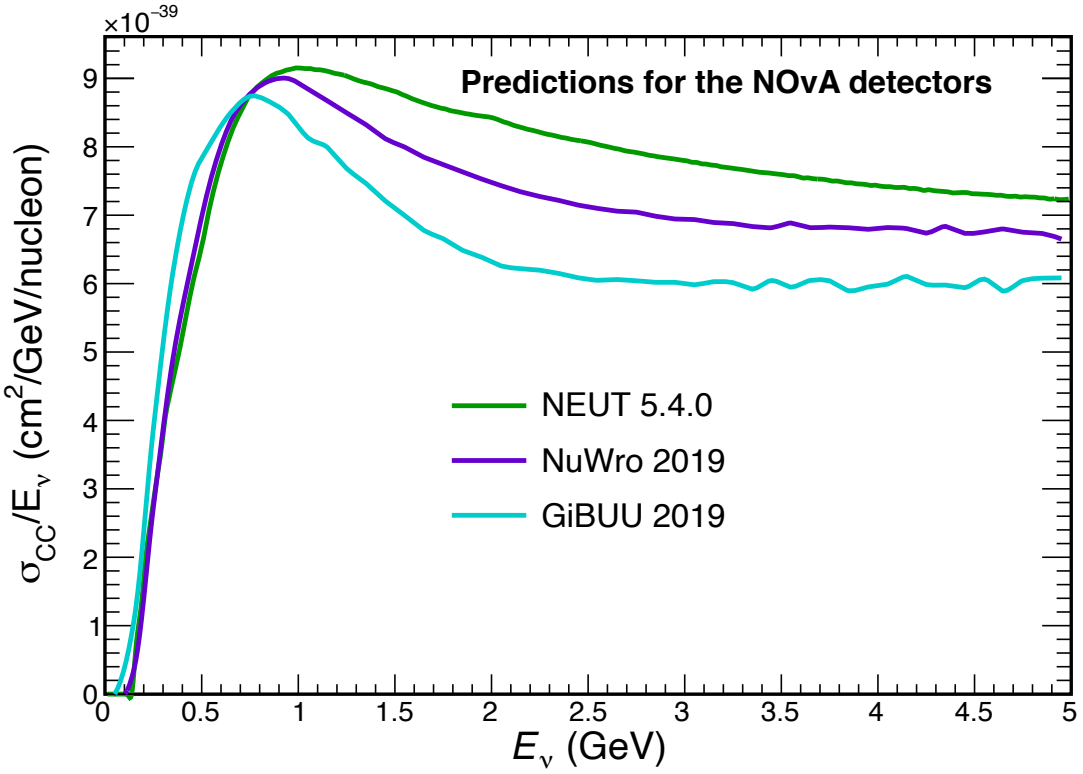
Snowbird, UT

Outline

- A few examples of data-simulation differences
- Some thoughts (only a few rants, I promise)
- Discussion!

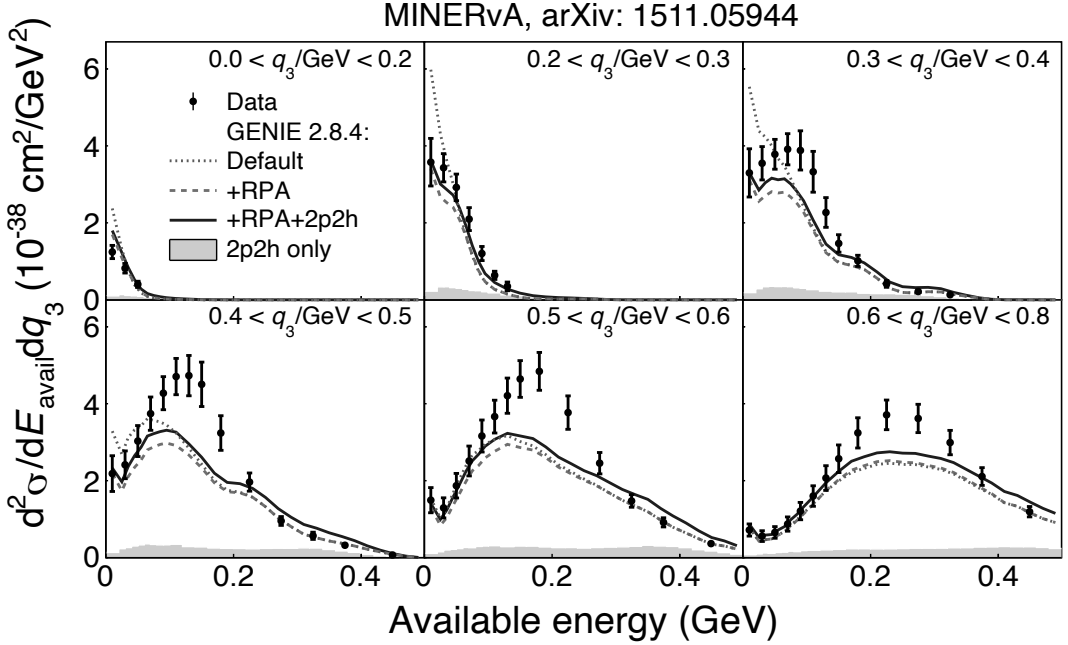
Generator Inconsistency

- Before I even show any data, it should be pointed out that there are already very large differences between generators!
- A clear indication that we have a way to go to tune the models that go into these inclusive predictions.

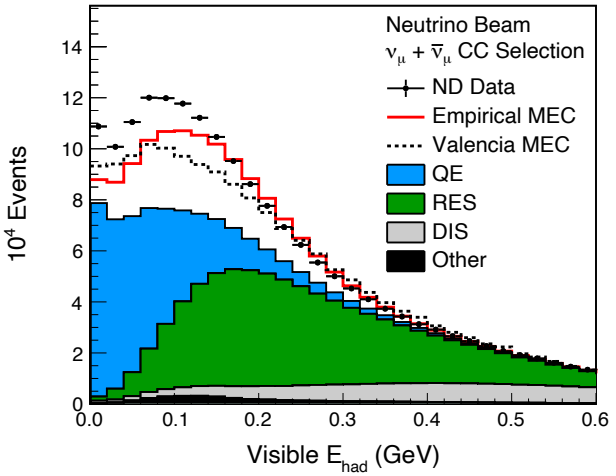


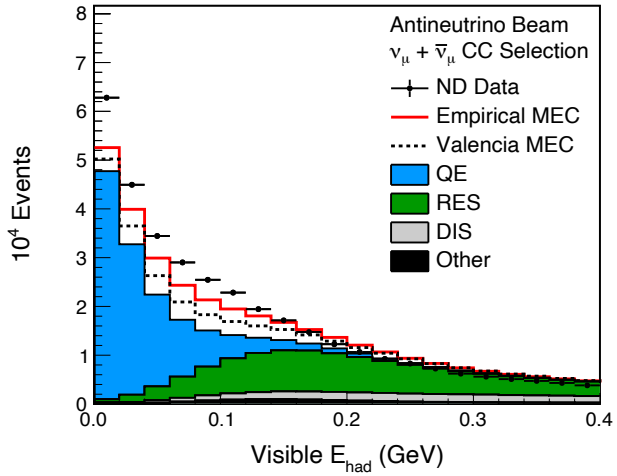
The "2p2h" Saga

MINERvA, arXiv: 1511.05944



NOvA, arXiv: 2006.08727

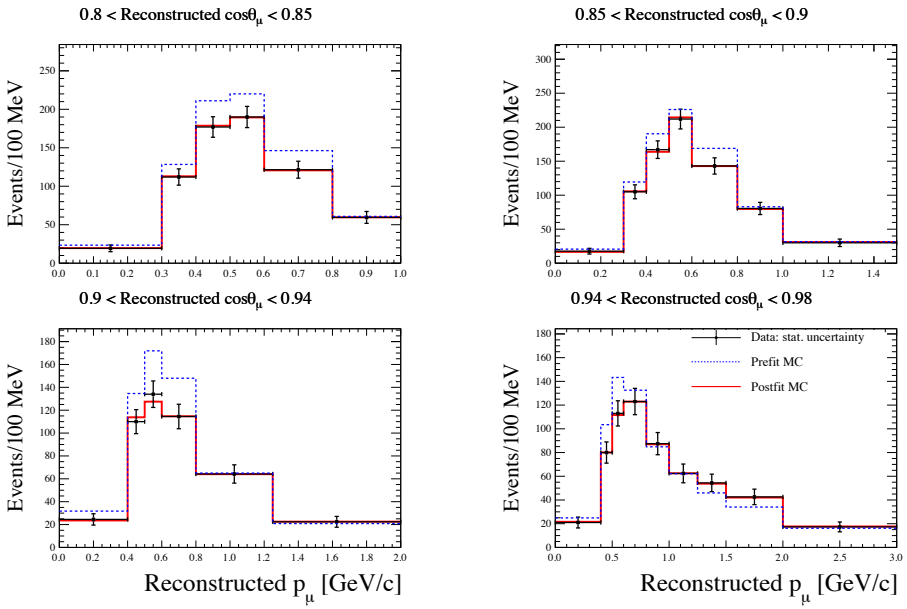




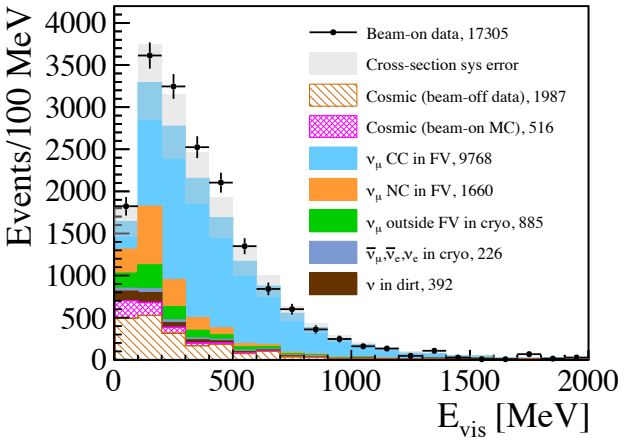
- MINERvA and NOvA both have shown very large discrepancies between data and MC. None of the 2p2h models come close, and none of the generators come close.

The "2p2h" Saga

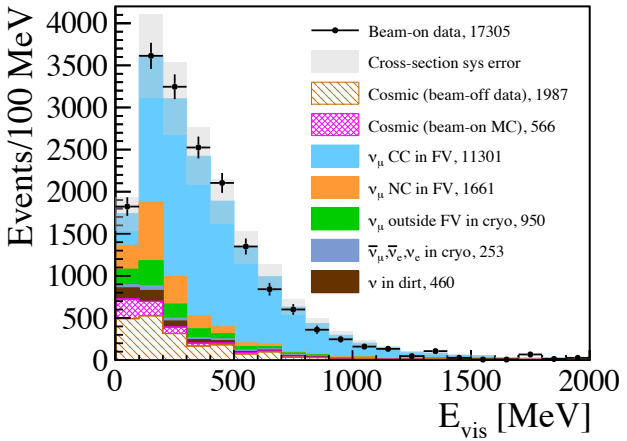
T2K, arXiv:2002.09323



MicroBooNE, arXiv:2110.14028



(a) Simulated neutrino interactions predicted by GENIE v3.0.6 G18_10a_02_11a

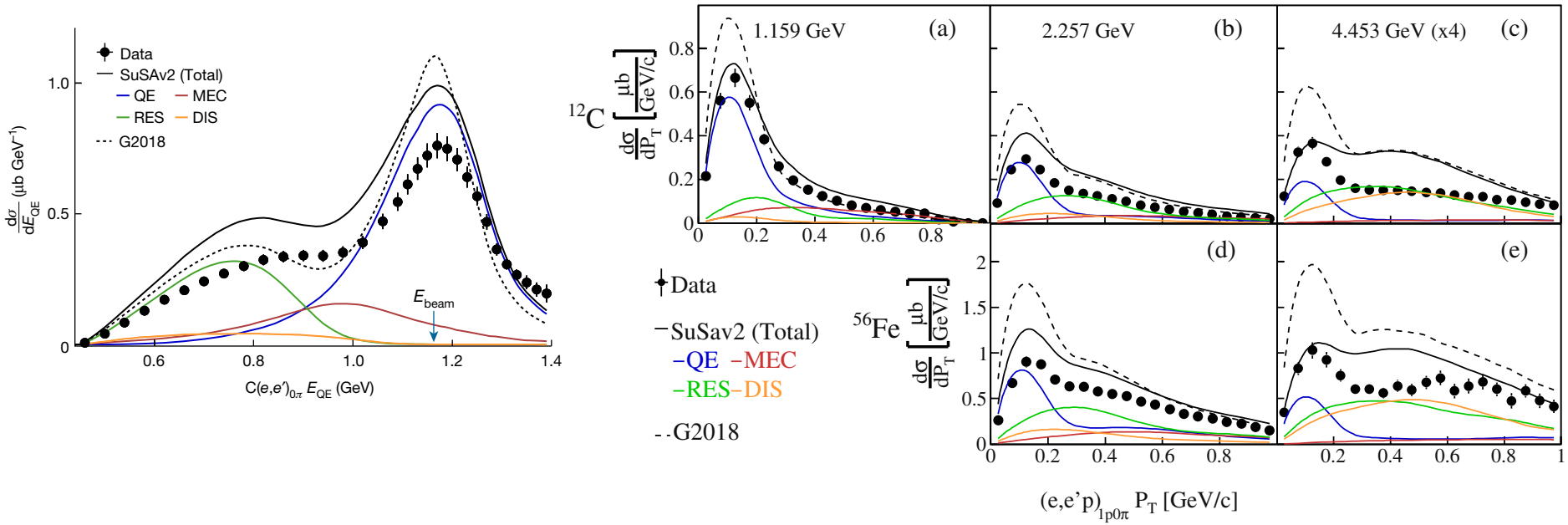


- MINERvA and NOvA both have shown very large discrepancies between data and MC. None of the 2p2h models come close, and none of the generators come close.
- Both T2K and MicroBooNE are able to tune (fit) their MC to data using reasonable (physics-motivated) parameters. Their 0π measurements are not off by the ~2x implied by MINERvA and NOvA.

Fermilab

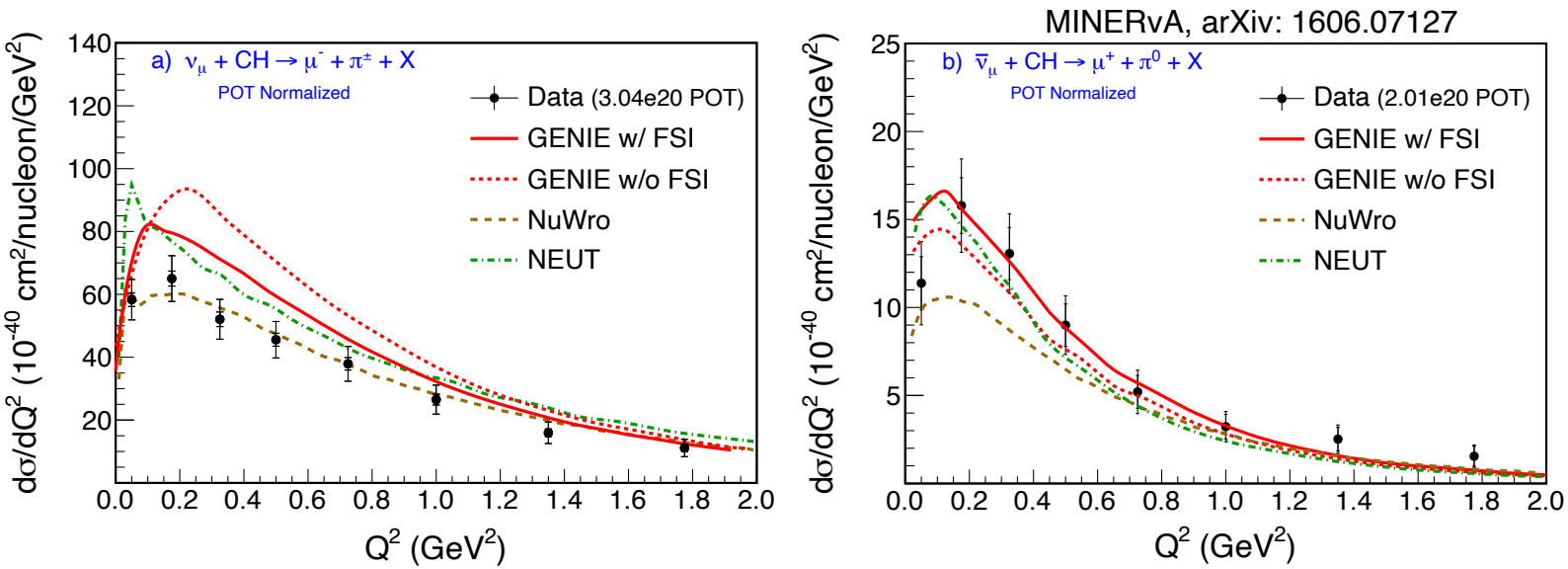
Electron scattering measurements

M. Khachatryan et al, Nature Vol 599, 25 Nov. 2021



- The e4nu collaboration has shown that the vector component of the 0π predictions at lepton energies of a few GeV are way off.
- Further tuning is clearly needed!

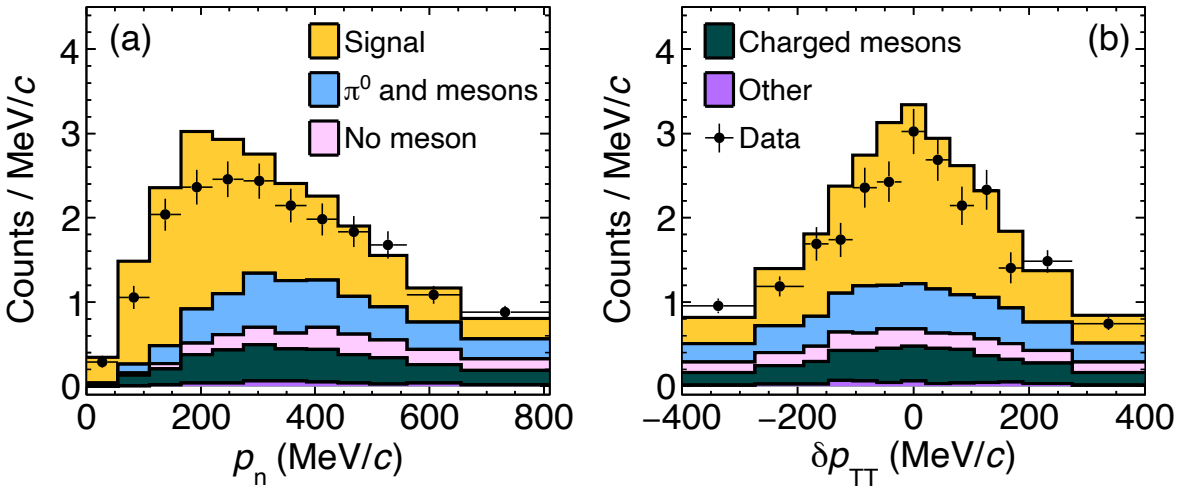
Single-pion results

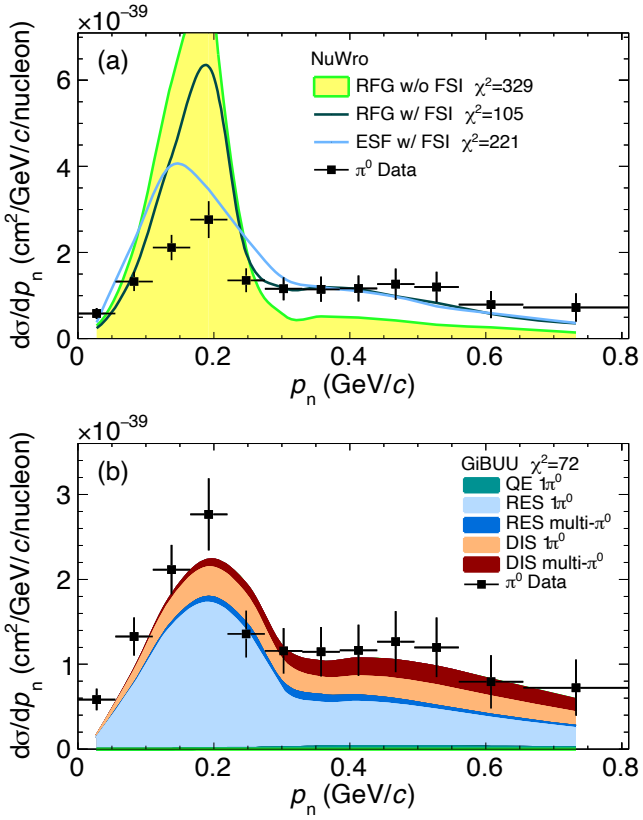


- Most interactions in the NOvA and DUNE detectors involve pions.
- FSI effects are significant and must be accounted for!
- MINERvA results show that, again, we have a way to go in our predictions.

Single-pion results

MINERvA, arXiv: 2002.05812





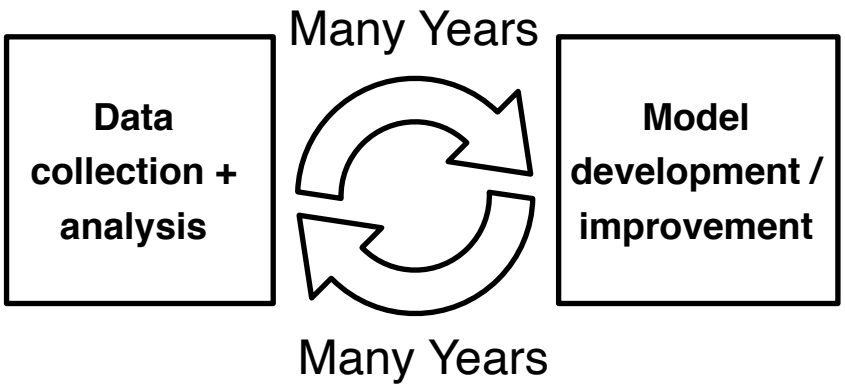
- Most interactions in the NOvA and DUNE detectors involve pions.
- FSI effects are significant and must be accounted for!
- MINERvA results show that, again, we have a way to go in our predictions.

Thoughts

- We will likely need to “tune” our predictions for a very long time to come. Note, GEANT has been doing this for **decades**!
- Ideally, one would only tune specific processes. But we don’t measure specific processes, we measure final states. Disentangling specific processes from final state measurements is often not possible, especially in neutrino physics. DUNE is trying to address this with it’s ND design, but the lack of knowledge of the initial state of an interaction still makes this quite challenging.
- It is very important to understand that some tunes, especially those that are done when there is a huge disagreement between data and prediction, are a pragmatic approach to deal with a major problem. No one is claiming that the tunes represent an actual model. But until we see better agreement between data and predictions, we’re kinda stuck.
- To improve our models and have very robust (and perhaps not overly conservative) systematic uncertainties, we need improved coordination and cooperation between experimentalists and theorists, and particle and nuclear physicists. Please consider joining or engaging with NuSTEC (Neutrino Scattering Theory-Experiment Collaboration) to work on these important topics.

Thoughts

- Currently (or soon-to-be) operating neutrino- and electron-scattering experiments [will] have a wealth of data, and we will see many data releases in the coming years.
- Surely we will be continuing to tune our predictions based on these data.
- DUNE is designing a highly capable near detector that should allow us to constrain many (most) of the issues we have thought of.
- But I will not be surprised if we see something [important] in the ND that we won't have great handles on.
- It is really important that we have robust uncertainties, driven by theory.
- Independent data sets are also very useful… so far, I don't see anything realistic on the time scale of DUNE Phase 1.
- The data-driven model-improvement cycle is extremely long, often on the time-scale of of a decade. DUNE would really benefit if we can get started _now_ on getting high-quality nu+Ar xsec data at energies at and above the Resonance. (Note: the 2x2 demonstrator at FNAL is likely insufficient.)



Thoughts

- We often focus on nu+A cross section uncertainties.
- We should not forget that hadron+A cross section uncertainties are critical too!
  - Modeling of secondary interactions (typically done via Geant) is important for event selection efficiency calculations and hadron energy reconstruction.
  - We rely on these cross-sections to predict the flux.
- I personally feel like our community treats hadron+A cross sections as “someone else’s problem”. May of us take Geant for granted.
- We should be very skeptical of how well Geant models charged pion and neutron scattering, and we need robust uncertainties for these processes.
- If we truly want to do precision neutrino physics, we need better hadron-scattering and hadron-production measurements across a broad range of energies and nuclear targets.

Discussion?