

MiniBooNE/MINERvA comparisons

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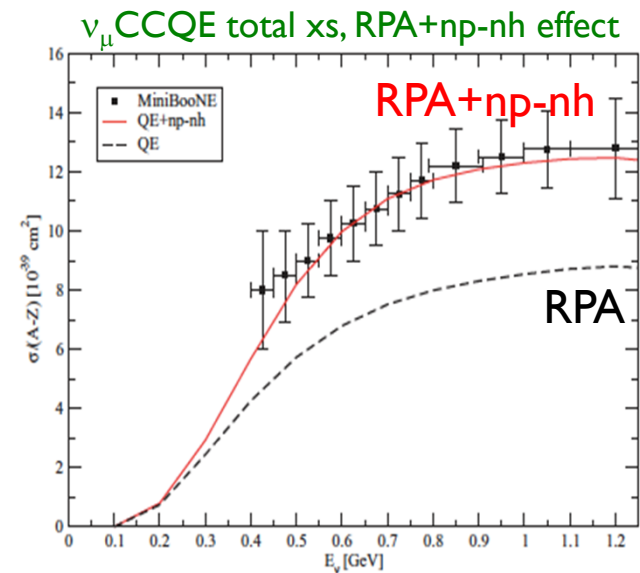
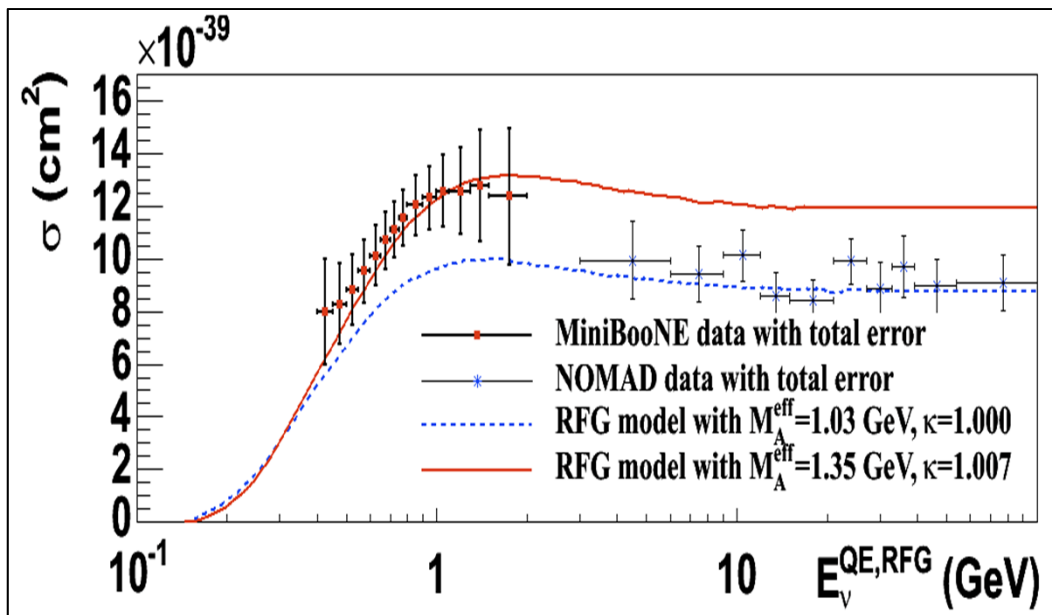
- large-scale differences
- 1pi production
- QE interaction

Outward differences

- ▶ MiniBoone used CH₂, mineral oil Cerenkov
 - ▶ BNB beam $E_\nu \sim 1$ GeV well understood
 - ▶ Some hadron detection
 - ▶ Excellent statistics (unprecedented)
- ▶ MINERvA uses scintillator, 95% CH
 - ▶ NUmI beam $\langle E_n \rangle \sim 4$ GeV still being studied
 - ▶ Very good hadron detection
 - ▶ 1st measurements largely statistics limited, emphasize shape measurements.

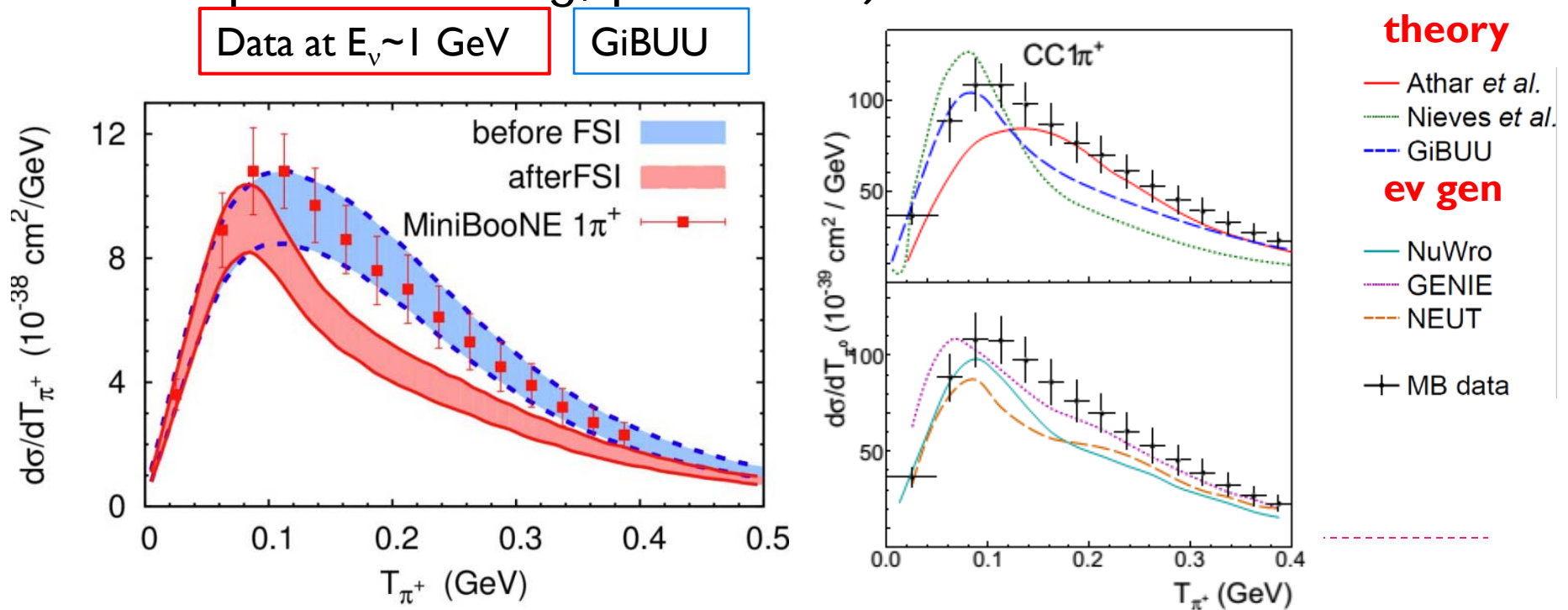
QE Puzzle

- ▶ What is QE in detector → QE-like
- ▶ Most data based on muon detection with suppression of pion events
- ▶ Suggestion of MEC changed things a lot, usually included in QE-like definition.
- ▶ Is MiniBooNE (1-track) incompatible with NOMAD (2-track)?



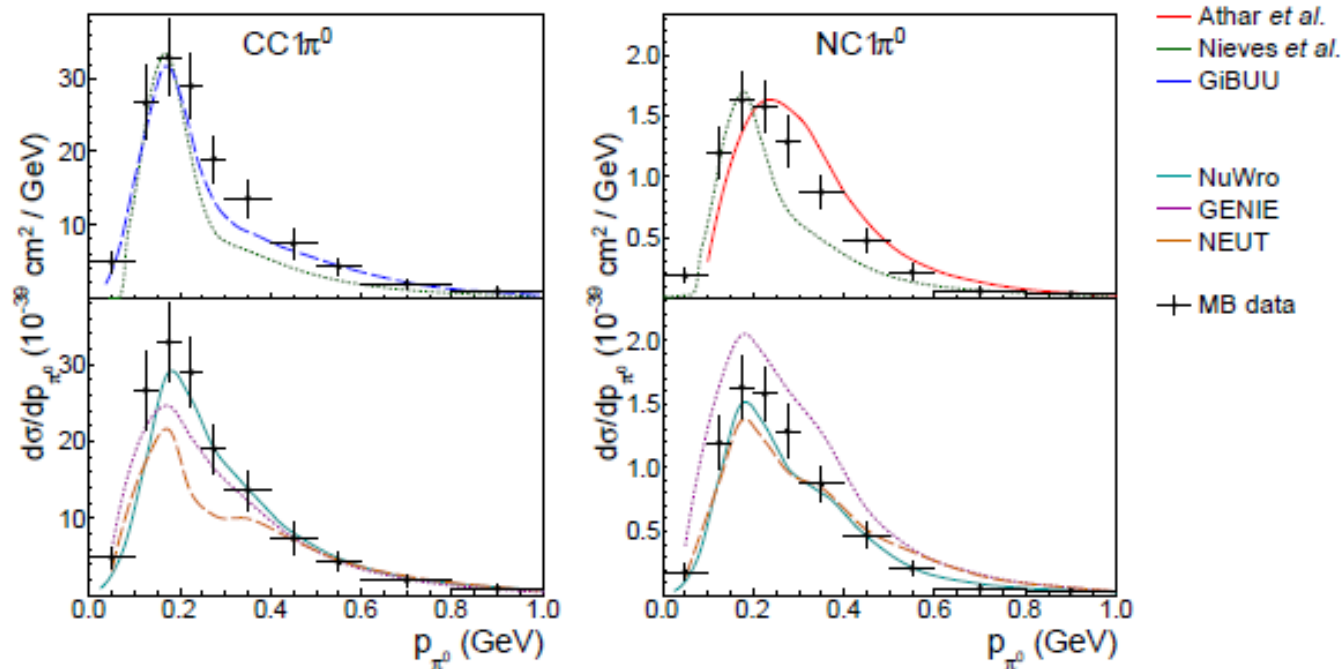
1pi Puzzle

- ▶ Started with MiniBooNE data at NUINT12 (P. Rodriguez)
- ▶ π^+ kinetic energy extremely useful (link to pion dynamics)
- ▶ Best calcs (Salamanca-Valencia, GiBBU) have strong shape disagreement with data. (medium corrections, pion FSI from pion scattering, production)



1pi puzzle, cont.

- ▶ No calculation is in good agreement with MiniBooNE.
- ▶ Event generators tend to have small deviations in shape or normalization.
- ▶ Similar problems in π^0 production.



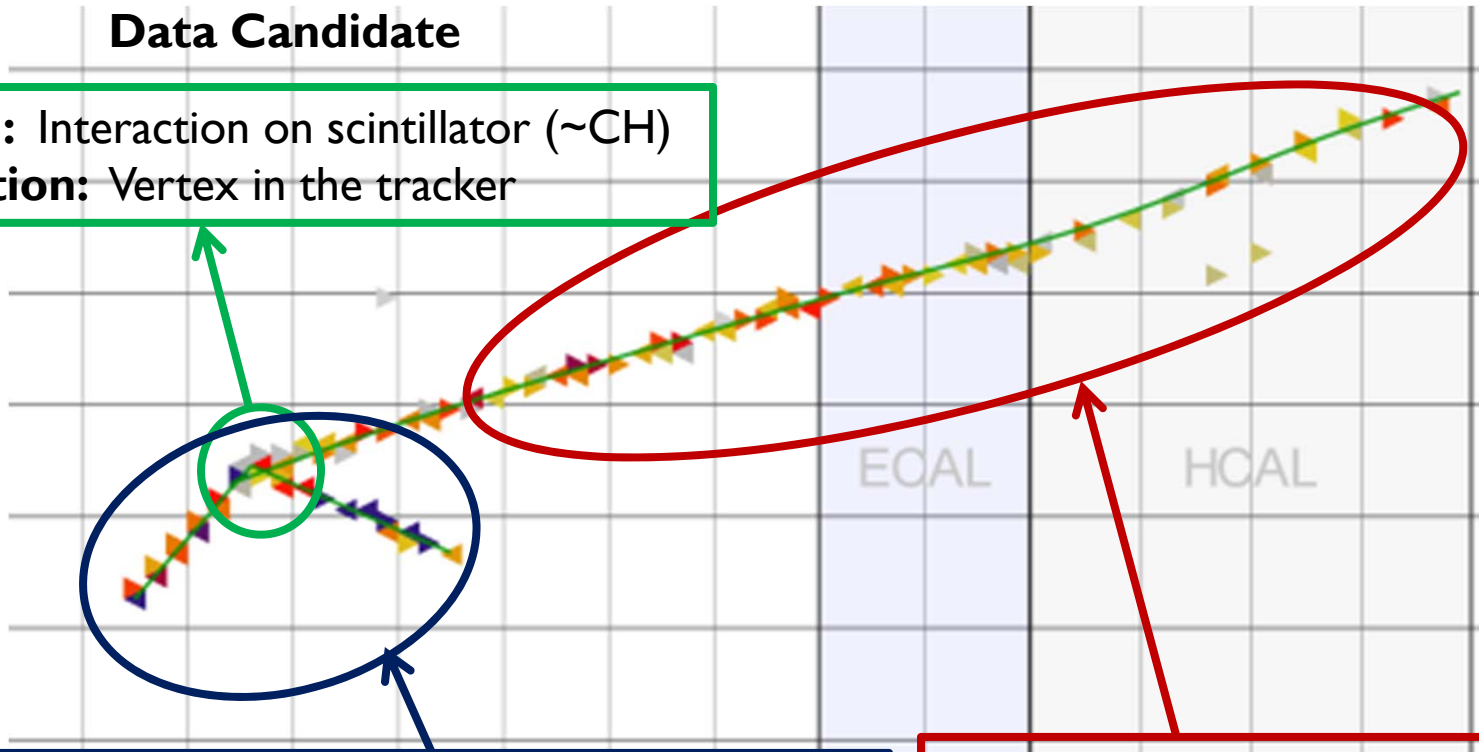
MINERvA data (B. Eberly PhD)

- ▶ Track and identify pions
 - ▶ Low efficiency, but accurate tracking
 - ▶ Michel tag focuses on π^+ !
 - ▶ Use $W < 1.4$ GeV cut to get better comparison with MiniBooNE (focus on Δ production and 1pi)

Need to detect a pion+muon in plastic

Data Candidate

Signal: Interaction on scintillator (\sim CH)
Selection: Vertex in the tracker

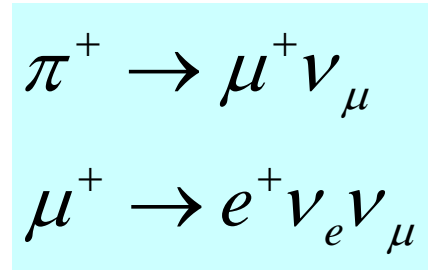
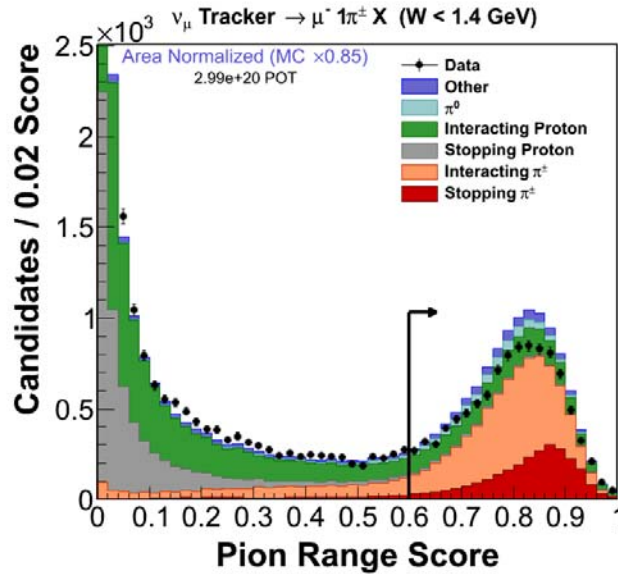
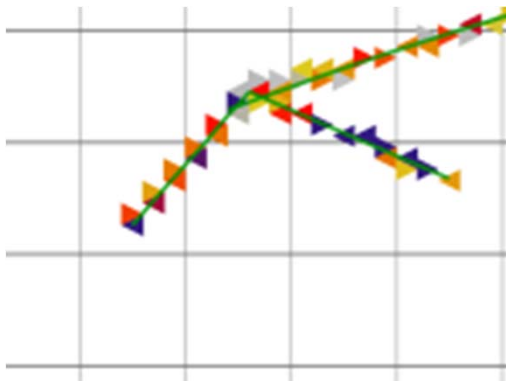


Signal: Exactly one charged pion in the final state
Selection: 1-2 non-muon tracks at the primary vertex

Signal: CC muon neutrino interaction
Selection: Muon track that is matched with the correct charge sign in MINOS

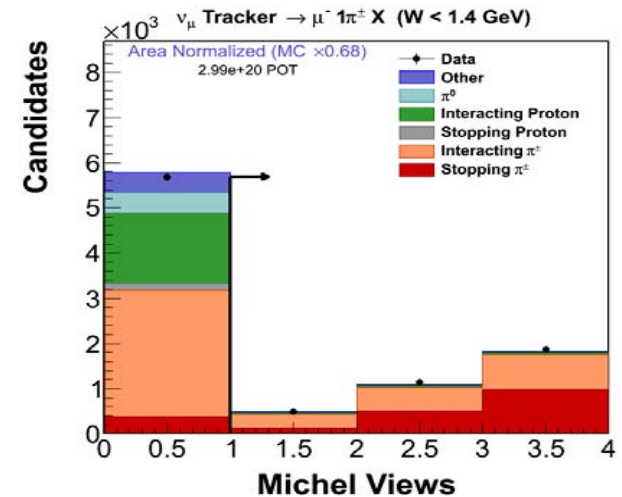
Signal Definition & Event Selection

Score = $\chi^2(\text{pion}) - \chi^2(\text{proton})$ via dE/dx.



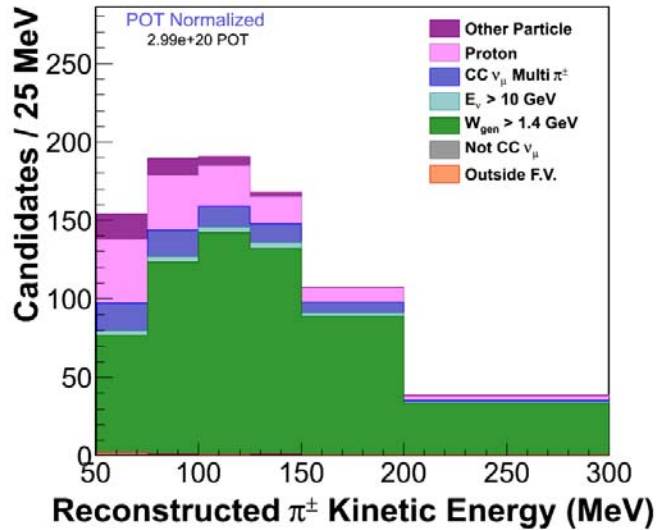
Signal: Exactly one charged pion in the final state

Selection: 1-2 non-muon tracks at the primary vertex, 1 reconstructed pion candidate

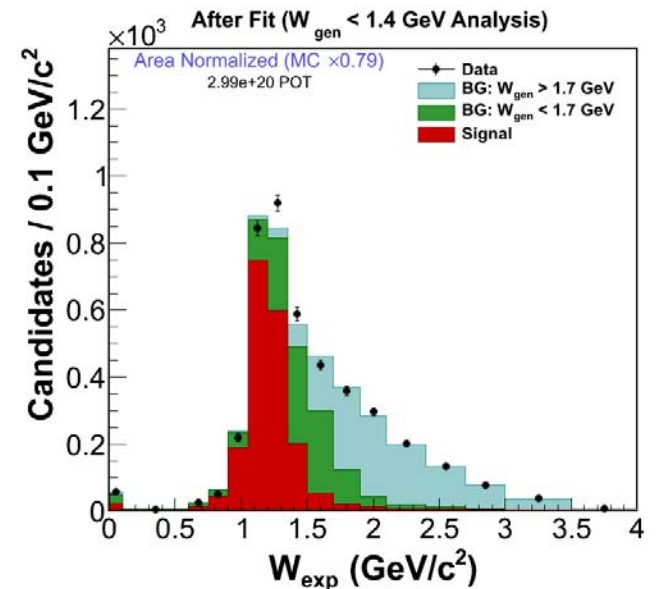
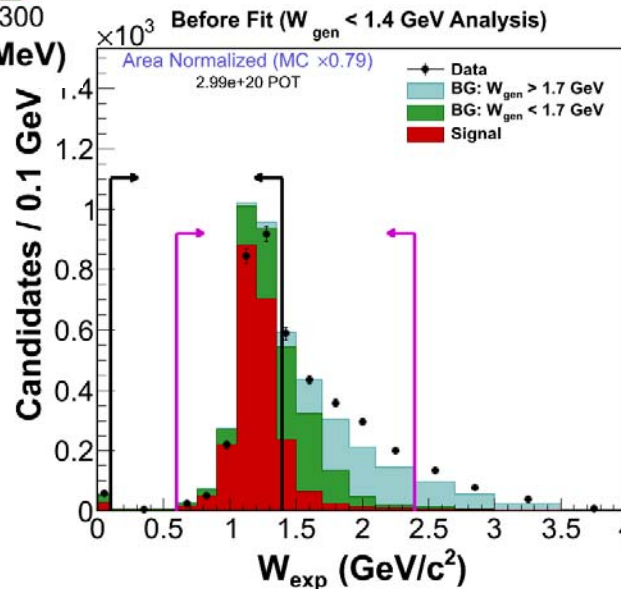


Background constraint

ν_μ Tracker $\rightarrow \mu^- 1\pi^\pm X$ ($W < 1.4$ GeV) Background Prediction

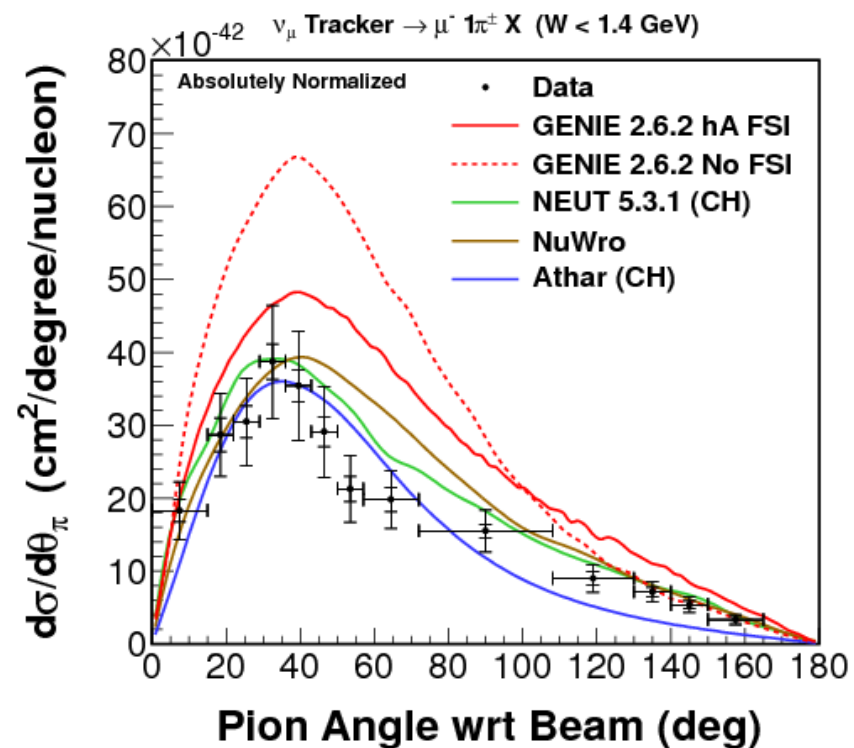
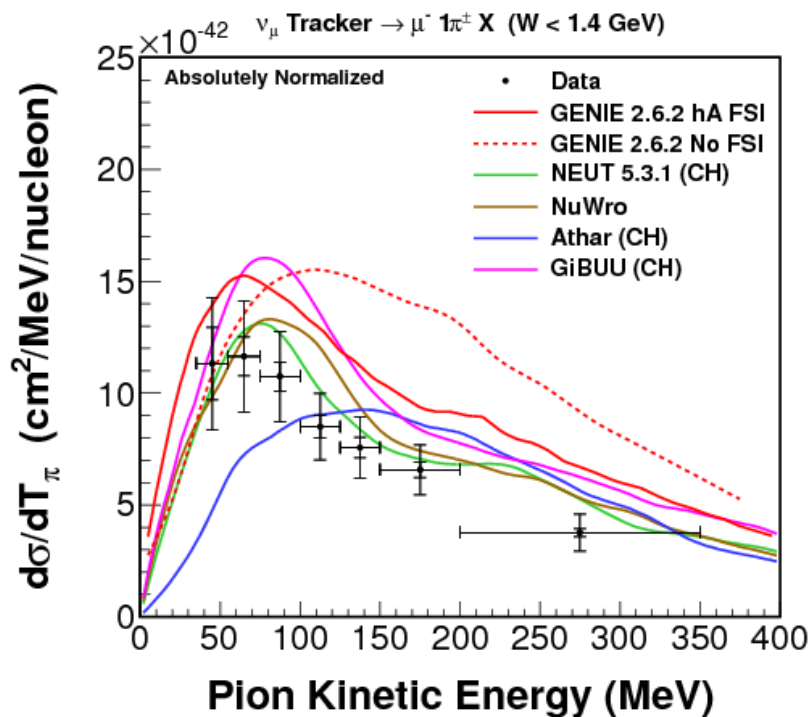


- **Largest background:** $W_{\text{true}} > 1.4$ GeV **~17%** of sample
- Fit the shape of the data W_{exp} distribution to signal and background templates.
- Use the fit results to adjust the background prediction. Reduces model-dependence!



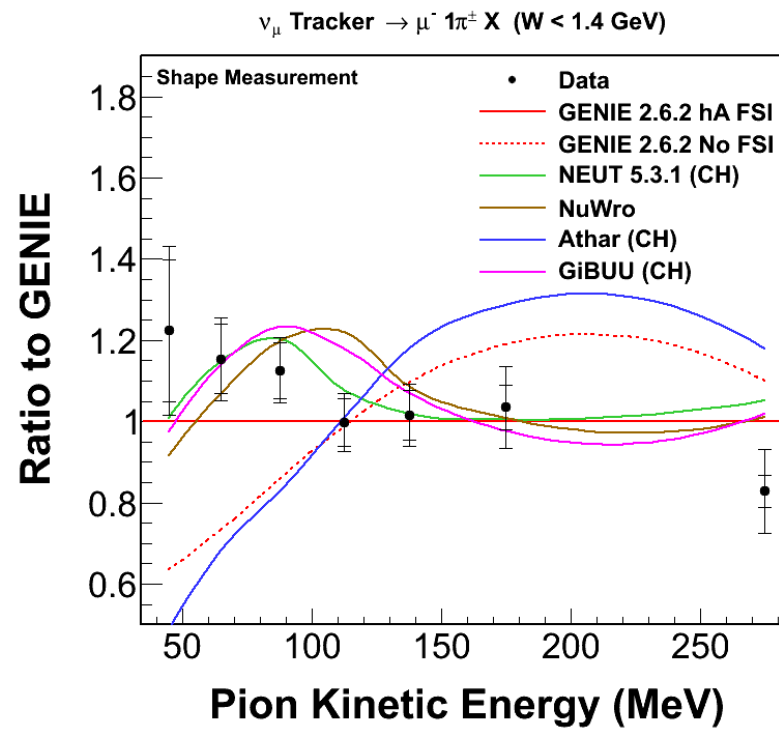
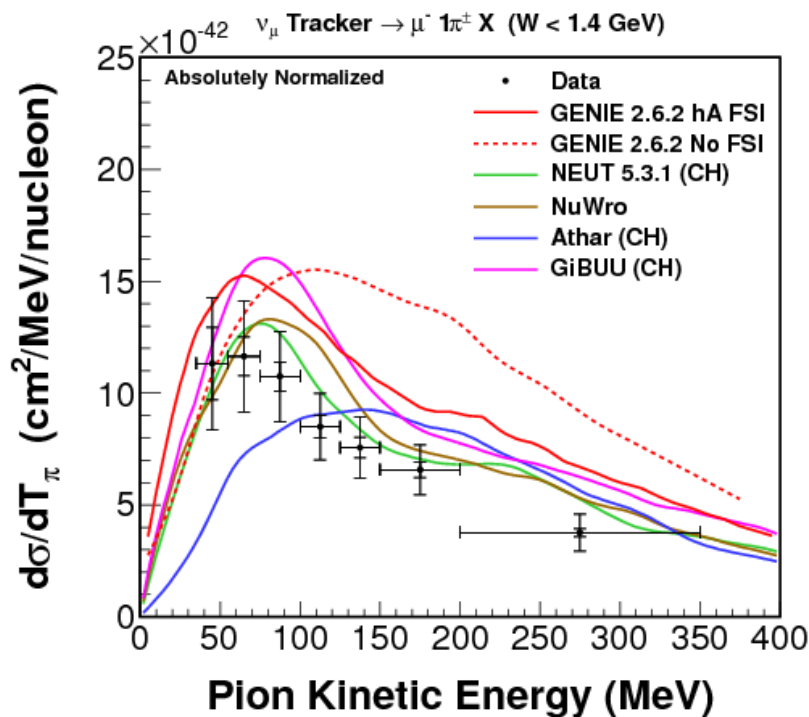
Absolute cross section- model comparisons

- ▶ Many calcs available (Valencia not applicable)
- ▶ Add angle info, π^+ KE still the best test (θ complementary)
- ▶ Wow, story has changed!



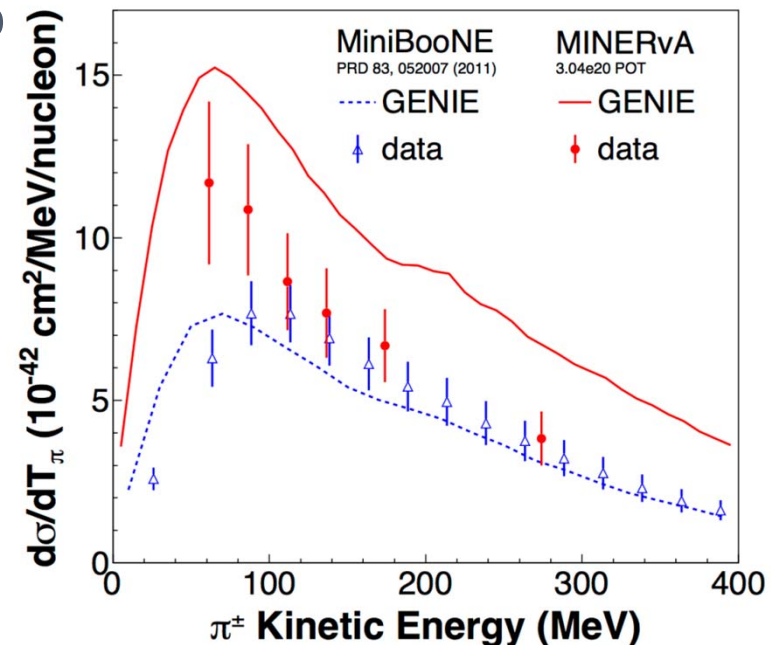
More MINERvA (no dips anywhere!)

- ▶ NuWro and NEUT agree very well with magnitude/shape
- ▶ Athar, GENIE noFSI have wrong FSI
- ▶ GENIE and GiBUU have ~right shape wrong magnitude.



MiniBooNE vs. MINERvA

- ▶ Put them on same graph
 - ▶ Each has final state with $1\pi^+$, dominated by Delta.
- ▶ Energies very different (~ 1 GeV vs. ~ 4 GeV)
 - ▶ Nonres likely different
 - ▶ Q2 perhaps different (form factor)
- ▶ MINERvA must be larger because xs grows with En.
 - ▶ Definition slightly different
 - ▶ MB – $1\mu, 1\pi^+$, no other mesons
 - ▶ Min – $1\mu, 1\pi^+$, other hadrons
 - ▶ Cuts are different, $\sim 25\%$

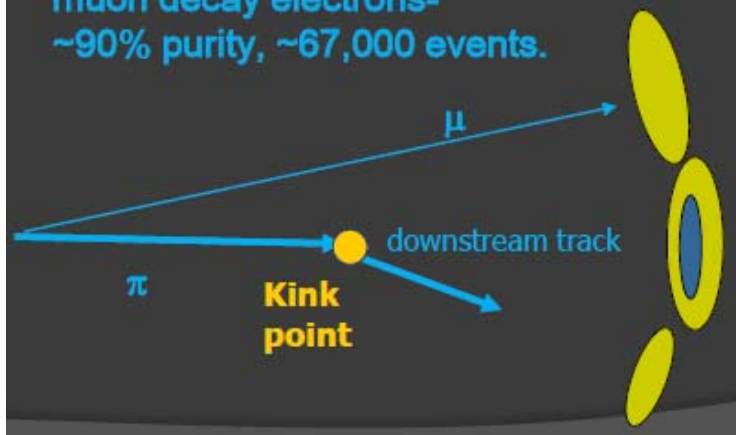


MiniBooNE - event selection

- ▶ Very complementary to Minerva
- ▶ Mostly interactions
- ▶ Cut at $W < 1.35$ GeV and correct.
- ▶ GENIE: 25% of events at $W > 1.4$ GeV

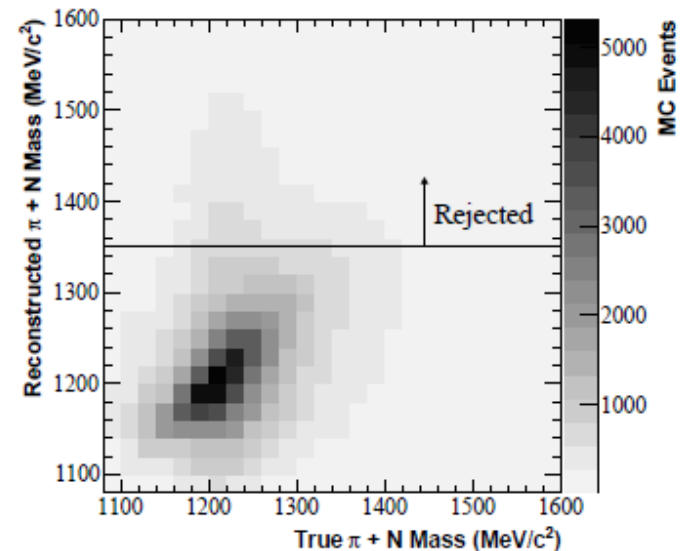
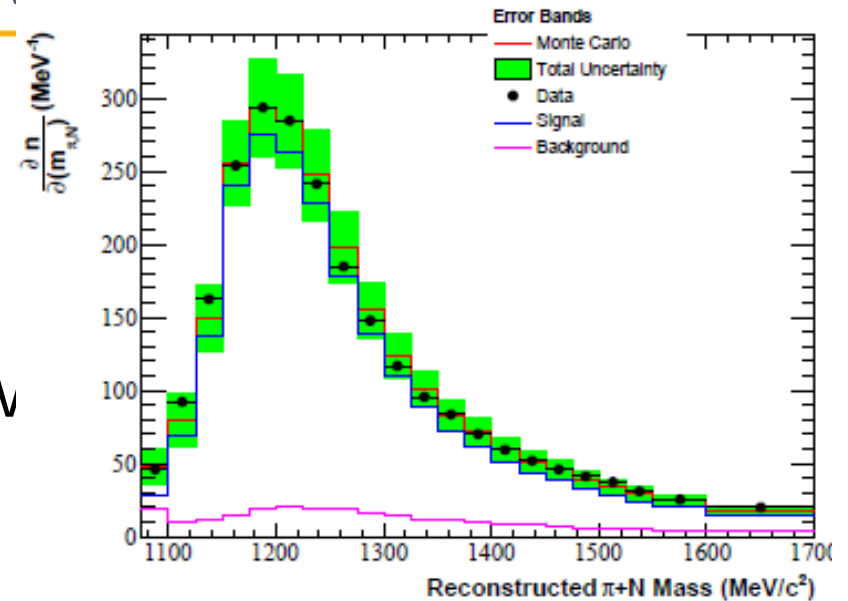
Reconstruction:

- π^+ undergoes hadron interactions results in kinked tracks.
- 3 rings - μ and kinked π^+
- events are tagged by two stopped muon decay electrons - ~90% purity, ~67,000 events.



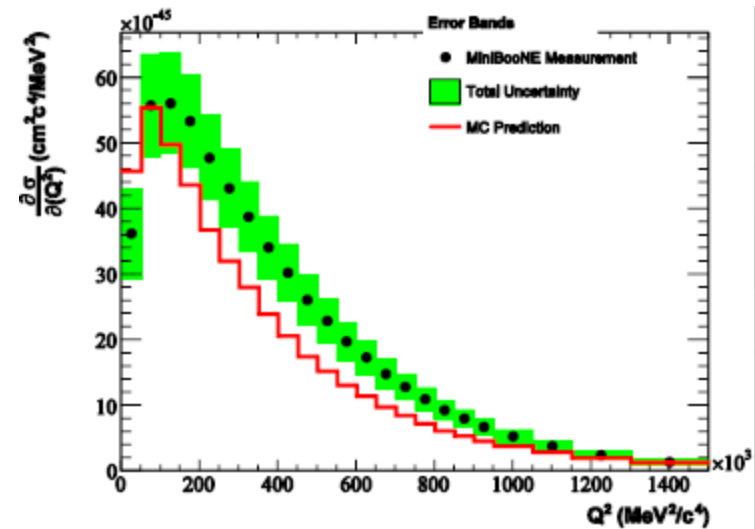
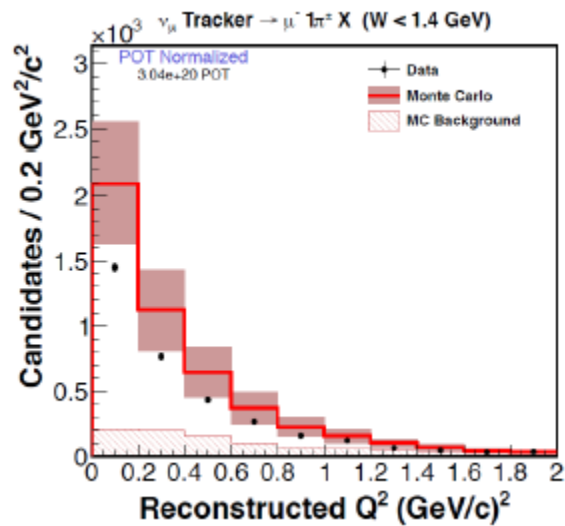
▶ 13

MicroBox



Q² detail

- ▶ Not very different



What are conclusions?

- ▶ Neither data shows a dip, effect of Δ absorption filled in
- ▶ Comparisons with theory (GiBUU) different for MiniBooNE (dip) and MINERvA (magnitude).
- ▶ No calculation gets both data sets correct.
- ▶ Despite 25% correction, there still appears to be normalization issue?

What about QE?

- ▶ Magnitude matters there, source of need for MEC!
- ▶ Looks like problem there, too. Plots later.

