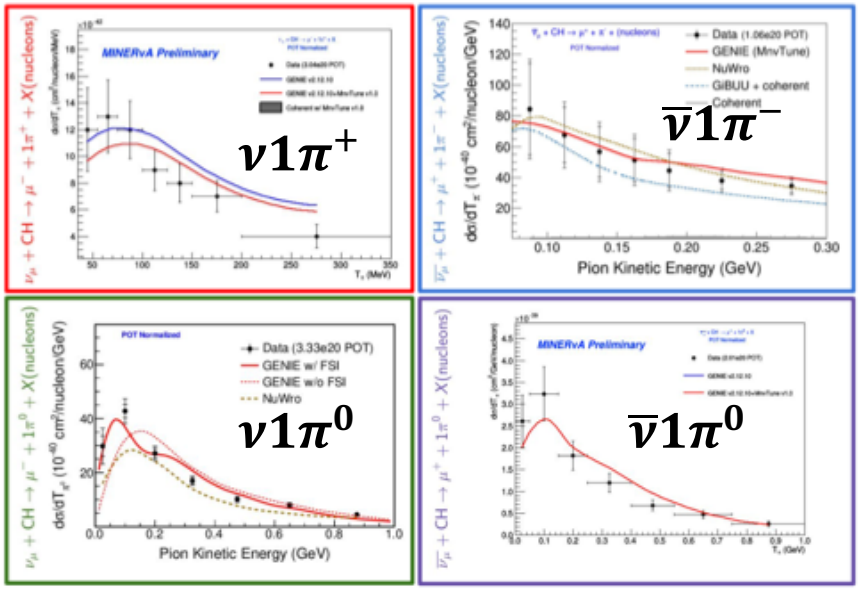
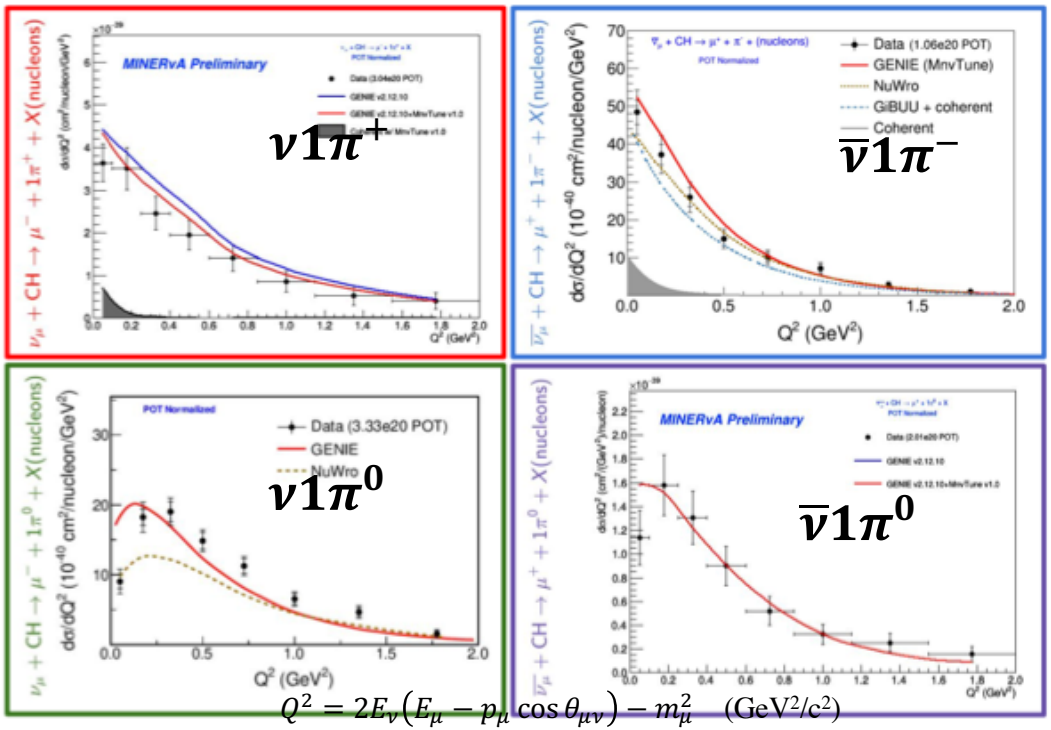
# MINERvA's Four Charged-Current Single Pion Channels in $T_\pi$ and $Q^2$




Pion Kinetic Energy (GeV)

- MINERvA tuned GENIE 2.12.x reasonable description

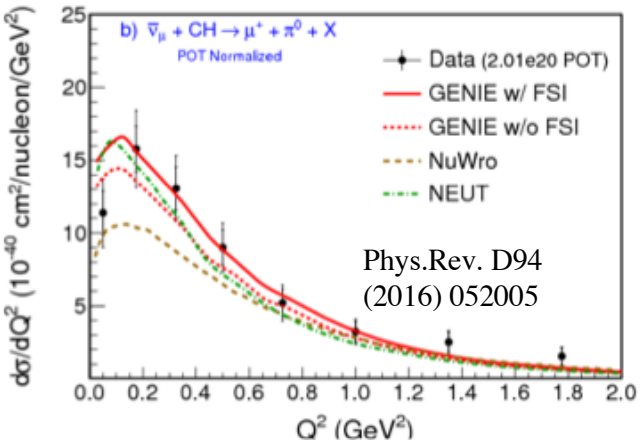
- Obvious neutral pion low $Q^2$ suppression.

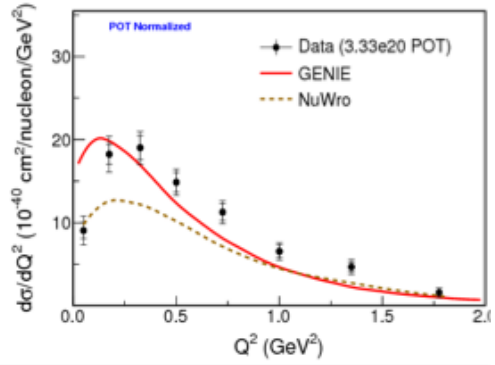



$Q^2 = 2E_\nu(E_\mu - p_\mu \cos\theta_{\mu\nu}) - m_\mu^2$ (GeV$^2$/c$^2$)

# Pion production observations

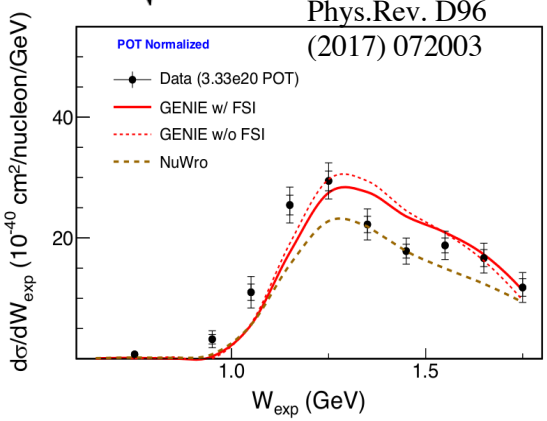
- MINERvA: deficit of pion production at low $Q^2$ in several channels.
  - MINOS also sees a low $Q^2$ suppression in "resonance region".
  - New Nuclear Effect?

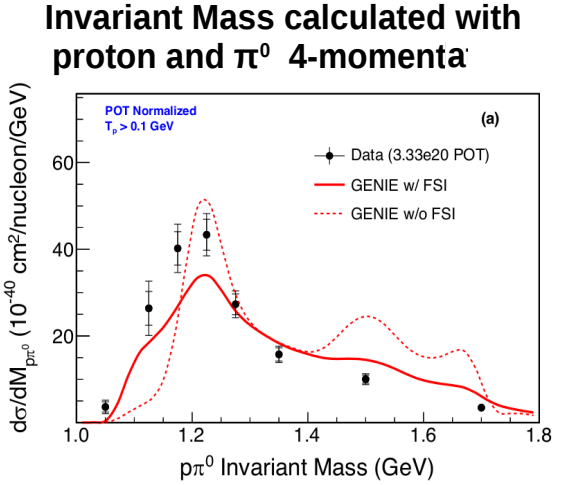



- MINERvA: shift W to slightly lower values:
  - shift in the Δ(1232) peak?
  - FSI induced?
  - resonant-non resonant interference absent from model?

$$W_{exp} = \sqrt{m_n^2 + 2m_n(E_\nu - E_\mu) - Q^2}$$



# MINERvA Needs -

- We are in the midst of analyzing our "6 GeV" (ME) sample of events concentrating on higher W phenomena. So we need:
  - Explanation of additional "2p2h" needed to fit "QE + Delta" results
  - Explanation for low-$Q^2$ suppression of neutral single pion states.
  - Calculations of 2p2h for pion production.
  - Work on ν-nucleus pion production above the Delta.
  - Alternative FSI models?
  - Better understanding of Duality in ν-nucleus interactions.
  - Work on low-Q corrections to ν-nucleus QCD (higher twist, target mass).
  - An improved ν-nucleus DIS model.