Pion production contribution to 0π final states

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Working group specifics

Neutrino data to probe “quasielastic and dip” region response are necessarily contaminated with pion production where the pion is absorbed or otherwise “stuck” inside the nucleus and does not appear in the final state

Work goals

- understand specifically how the convolution of primary pion production processes and FSI models in different generators results in different predictions.
- Compare primary production models without FSI
- To what extent is the difference in the primary production model versus being in the FSI?
- Can we identify specific kinematic regions with differences between models?
- Are there approaches or tests that could improve the reliability of this prediction in generators?

Where are we?

- Behind schedule
  - Limited participation in the discussion
  - Overlap
- Yet we have learned something

- We have plots and contributions from
  - GENIE
  - NuWro

- Group discussion document
  - https://docs.google.com/document/d/1NmU6xE9zb5laqFk5VmpwIDFdh5gK2JJxkYm0-twG7jw/edit?usp=sharing

GENIE

- MiniBooNE CCQE datasets (neutrino and anti-neutrinos)
- T2K ND280 CC0pi dataset

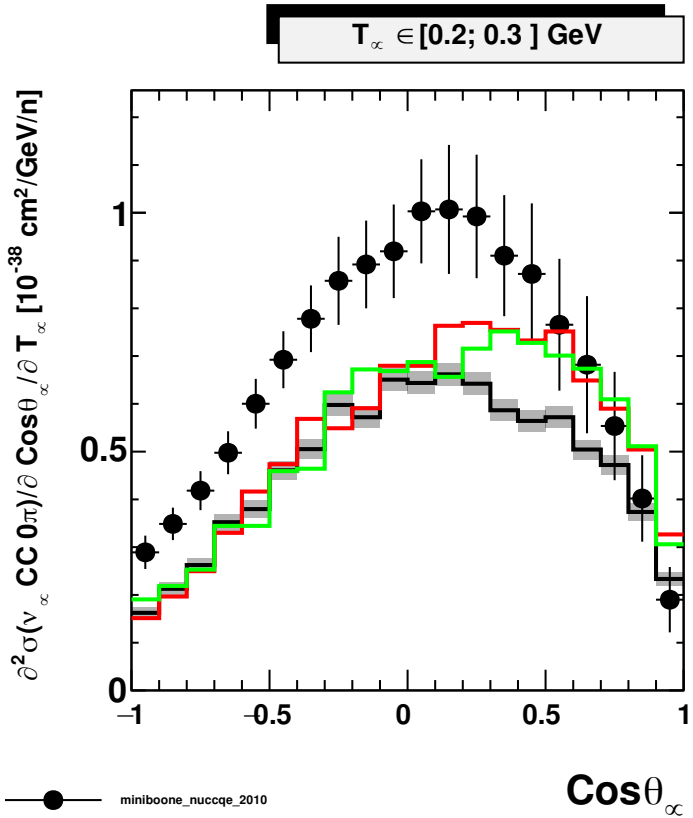
- Two different FSI algorithms
  - hA – most popular
  - hN – full cascade, Oset paper inputs
  - They corresponds to different tunes in v3 Scheme

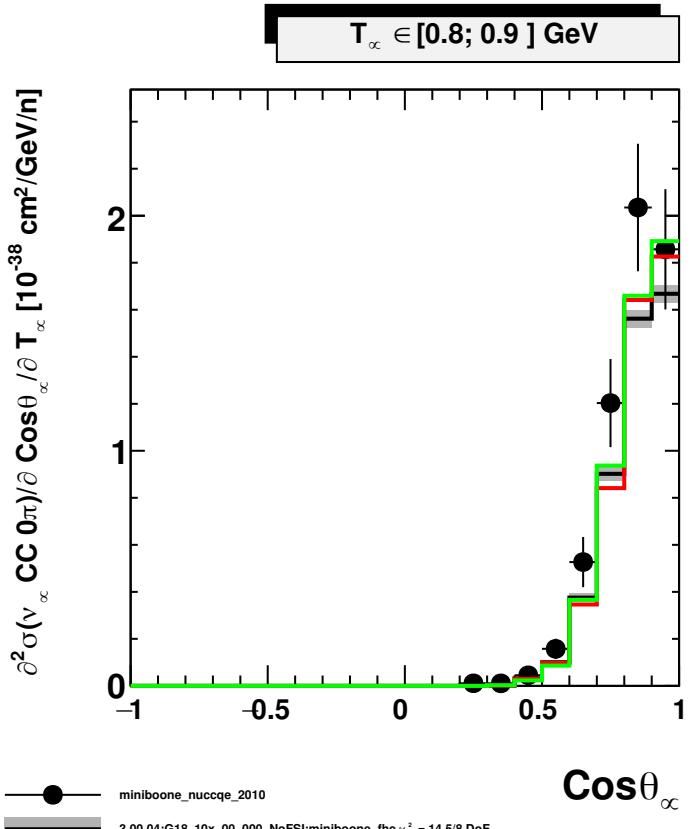
- Explored the effect of both
  - On two different tunes on different tunes
  - They are the same configurations: CCQE and 2p2h - Nieves, RES - Berger Sehgal, Nuclear model – LFG
    - G18_10x_00_000 – un-tuned
    - G18_10x_02_11a – tuned with respect to old bubble chamber to avoid pion production over-counting

GENIE – takeaway messages

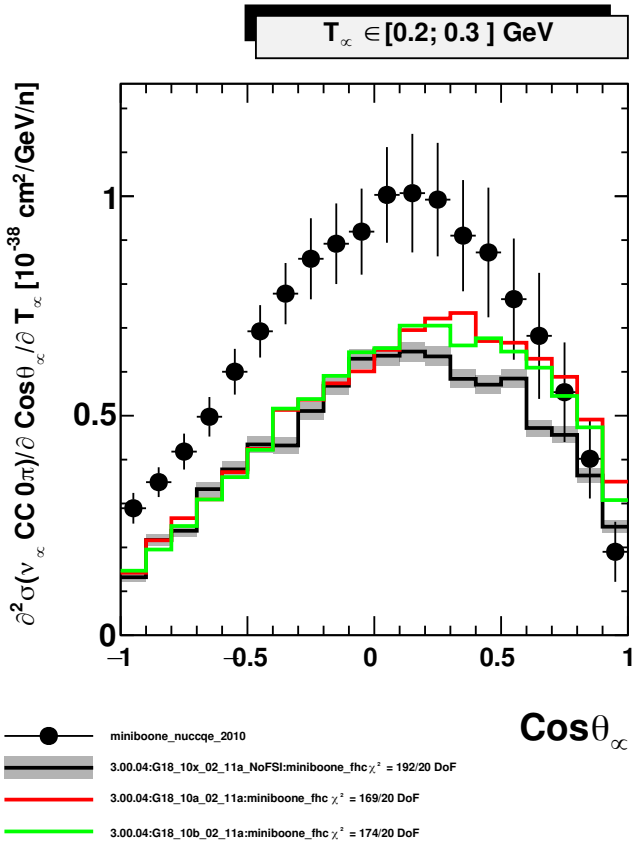
- FSI effect contribution only on low muon-momentum region
  - $p_\mu < 600$ MeV
- The contributions leads to a distortion of the symmetry with respect to cos theta of the distributions
  - Contribution significant (distinguishable) only on neutrino data
- In the p_μ , cosθ space, no different behaviour of hA or hN

GENIE – plots – v3.00.04 - G18_10x_00_000





GENIE – plots – v3.00.04 - G18_10x_02_11a

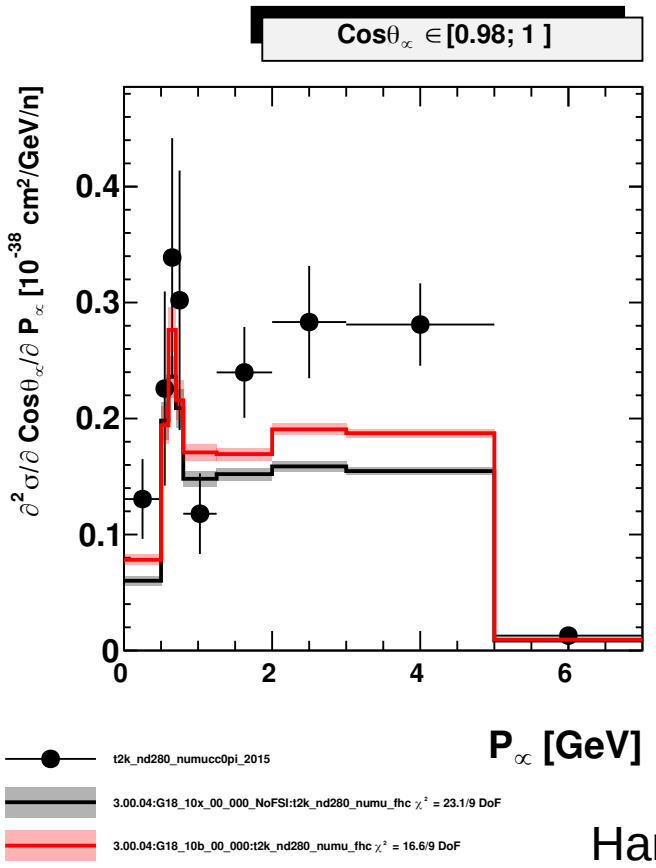


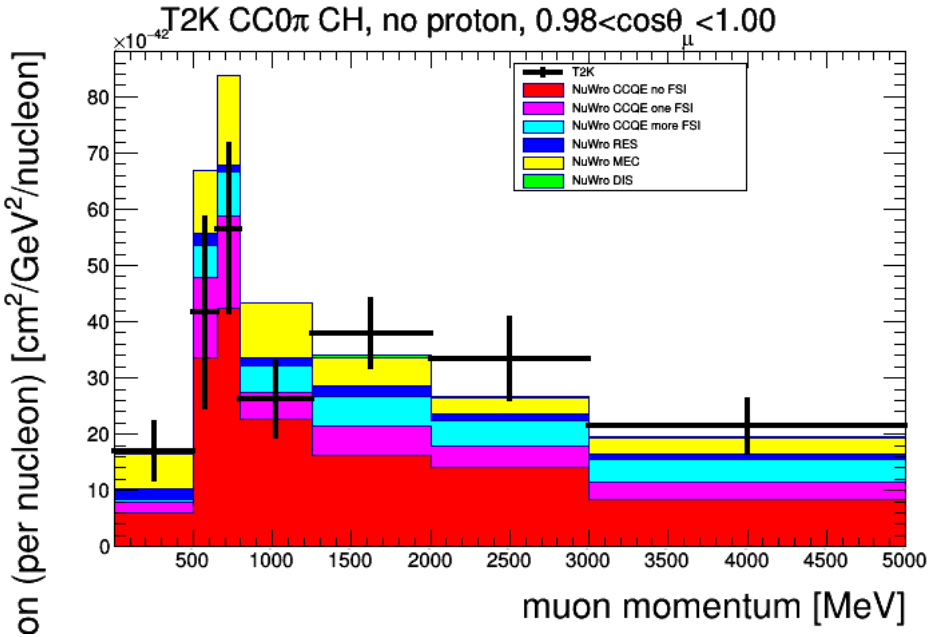
- The effect of the tuning is a reduction of the contribution
- Consequence of the reduction of RES production

NuWro

- Version 18.02
- Model configuration
  - LFG for CCQE
  - Nieves' 2p2h
  - RES: Delta resonance + background added incoherently
  - FSI: cascade
    - Pions treated accordingly to Oset paper

GENIE vs NuWro





Handle with care these plots, I still don't understand them

Ideas to work on

- Double differential cross-section (p,theta) (pt,pl) at the nucleon level
  - or other variables:
    - energy transfer and momentum transfer for a given neutrino energy or for a given neutrino flux
  - Separated by 1p1h and 2p2h
- Nucleon fermi momentum as it is in the MC
- Final state proton and neutron momentum at nucleon level (before FSI)
  - Again separated between 1p1h and 2p2h
- Differential cross sections of transverse variables for 1-proton+1-muon events
  - versus something else that experiments can measure, or versus neutrino energy?
  - (again maybe for 1p1h and 2p2h separately)
- Joining forces with FSI working group: a number of common areas were identified and no much man power in our WG

Issues

- Theory inputs for FSI are kind of weak
  - At least I didn’t receive any
  - And a number of theorists are in the

- Essentially no participation in the discussion
  - Apart from Debbie and Jan
  - For sure not all the topics will be covered
    - We have generated events, we need to see what kind of analyses in 2 days :-)