Single pion production in NEUT

Yoshinari Hayato
(Kamioka, ICRR, UTokyo)

Single pi production updates
by P. Rodriguez and A. Bercellie
Pion interactions in nucleus updates
by P. de Perio and R. Tacik

Single pion production via resonance in NEUT

Use the model by Rein and Sehgal

- Code to calculate the helicity amplitude
  Provided by the authors
- Calculation of the cross-section ($d\sigma/dq^2dW$)
  Follow the formula in the publications

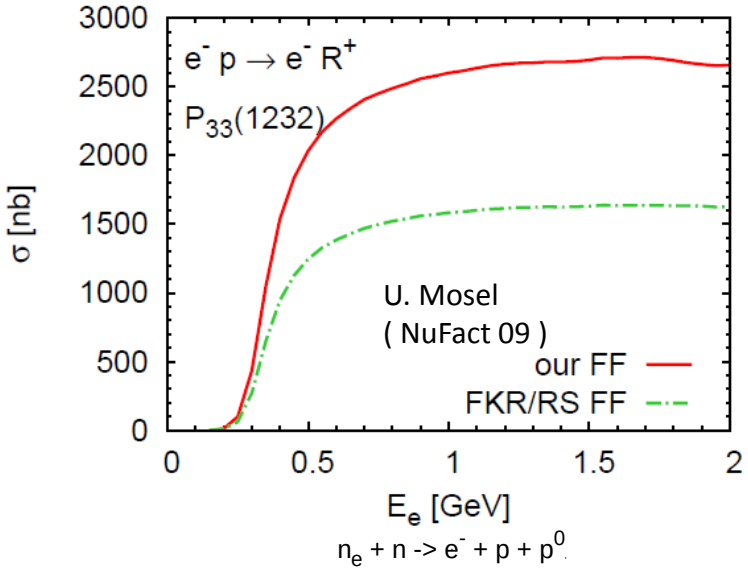
  Add helicity amplitudes as proposed in the original article
  to take into account the interference of the resonances

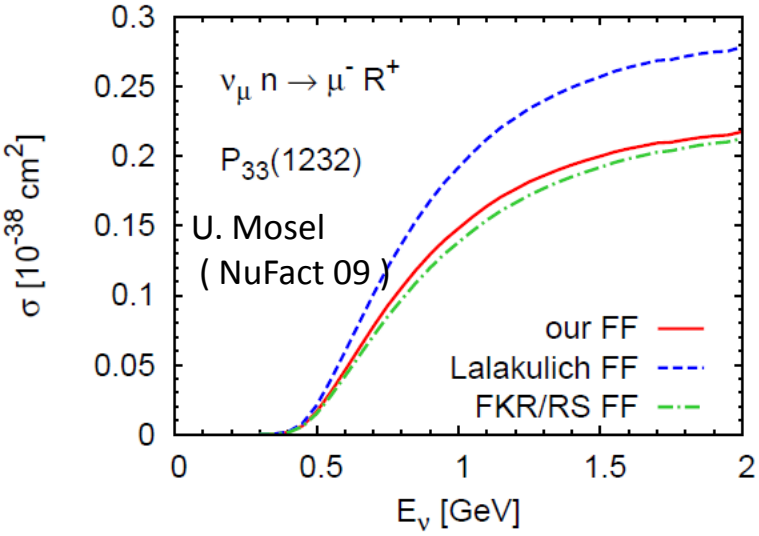
- Lepton mass corrections by the same authors
  have been included
- Two form factors are implemented
  Original form factor by Rein & Sehgal
  $M_A = 1.21$ GeV/c^2 was chosen
  Revised form factor by K.M. Graczyk and J.T. Sobczyk
  (explained later)

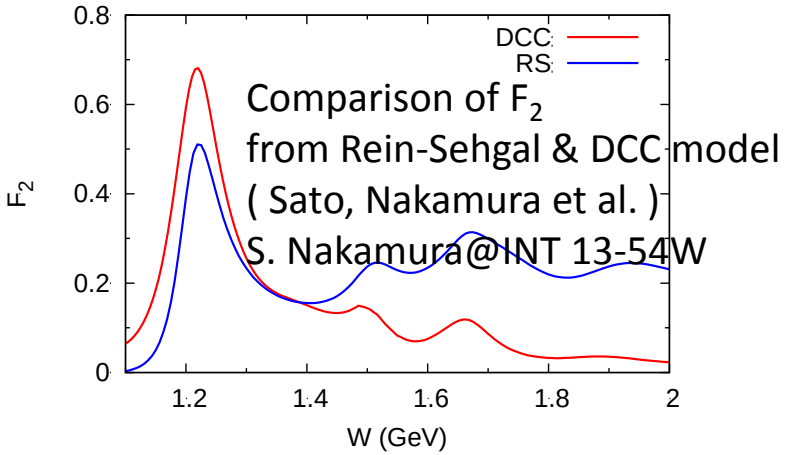
Single pion production via resonance in NEUT

Known issue in the Rein-Sehgal model

electro-pion production cross-section
can not reproduce data if we use the vector part







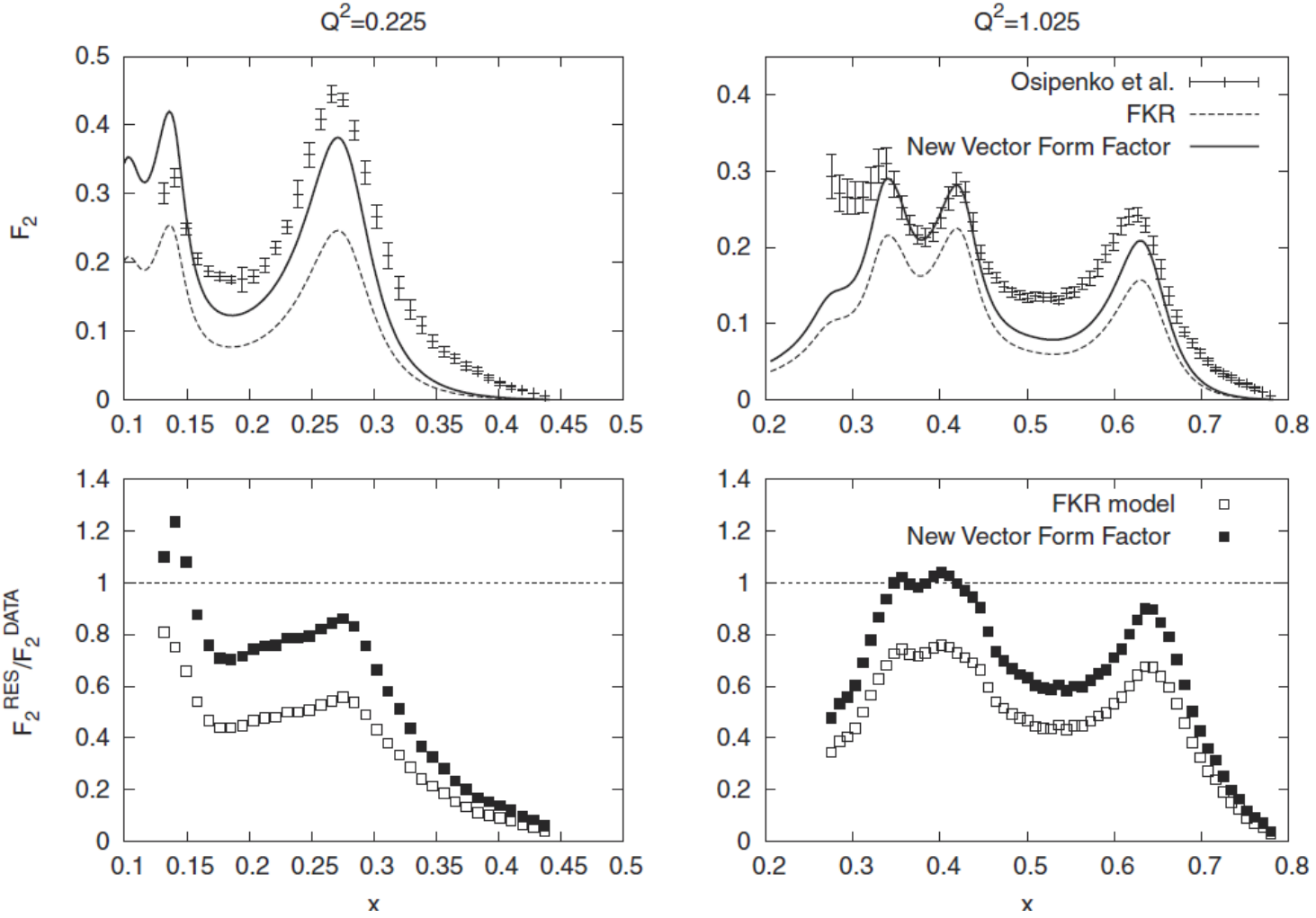
Comparison of F_2
from Rein-Sehgal & DCC model
(Sato, Nakamura et al.)
S. Nakamura@INT 13-54W

Interestingly, results for neutrino agrees pretty well.
(Including axial current component makes the cross-section similar.)

Single pion production via resonance in NEUT

Attempts to improve the vector form factor in Rein-Sehgal model

Prescription by K.M. Graczyk and J.T. Sobczyk
Phys.Rev.D 77,053001 (2008)

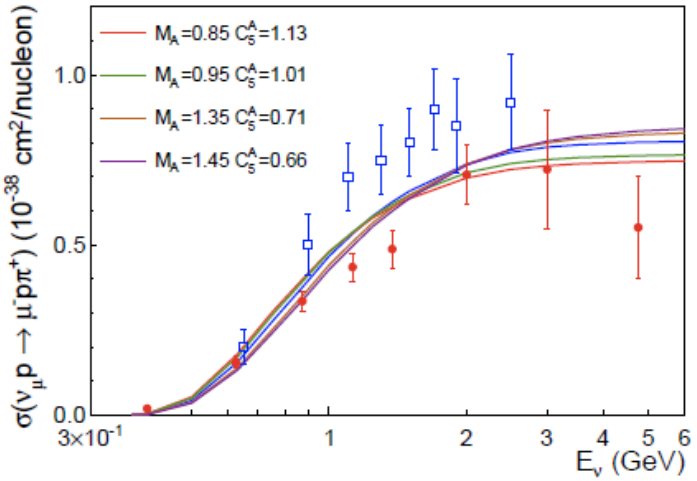


Single pion production via resonance in NEUT

Parametrization

Parameters were fit with
the bubble chamber data
(ANL & BNL)

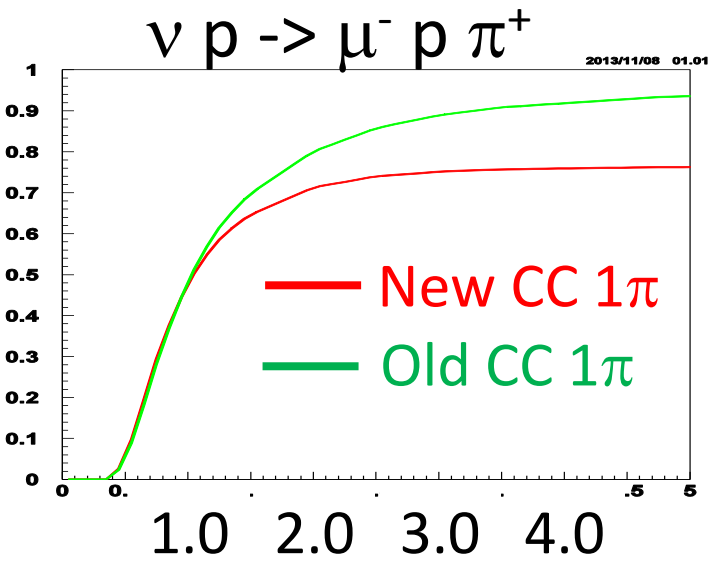
- Best fit: $M_A^{\mathrm{res}} = 0.95,\ C_5^A(0) = 1.01$
non-resonant background
scale factor = 1.3



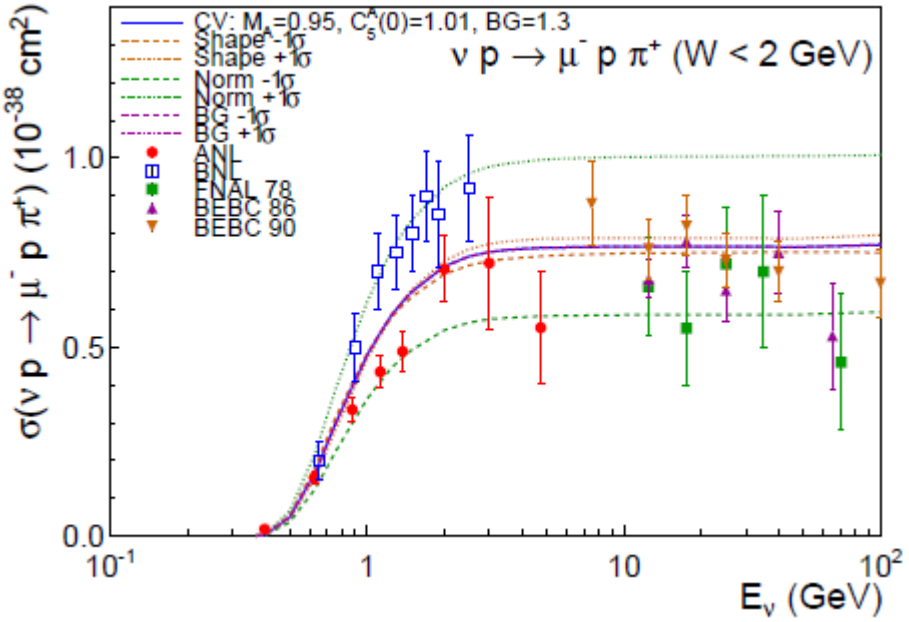
Samples from the curve: nearly const

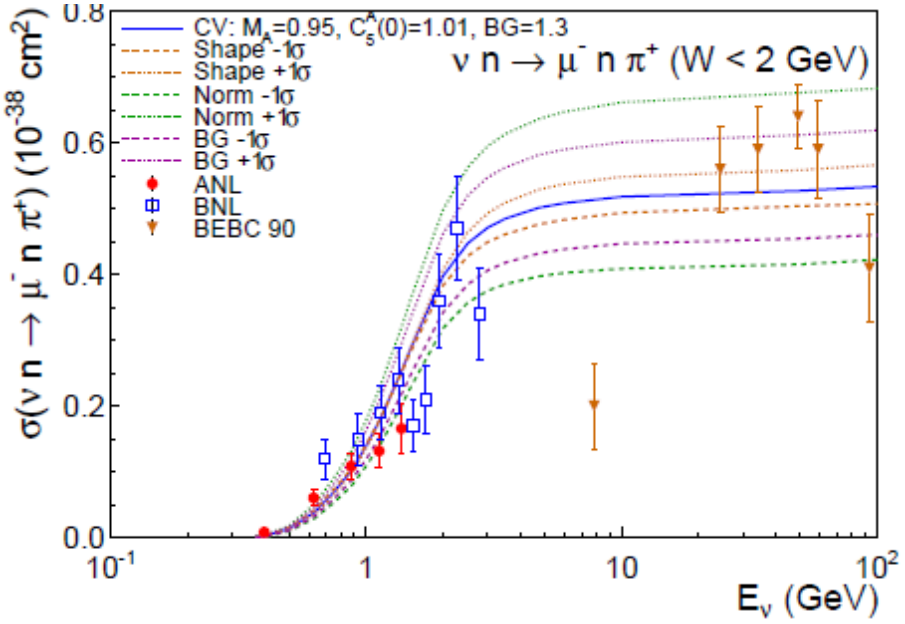
- Parameters in nucleon model:
  - $C_5^A(0)$ Value of axial FF at $Q^2 = 0$. Main effect is normalization of total xsec
  - M_A^{res} Mass parameter in axial FF. Affects both shape of $\mathrm{d}\sigma/\mathrm{d}Q^2$ and overall normalization.
  - BG Scale of $J = 1/2$ nonresonant background terms
- Try to reparametrize $(M_A^{\mathrm{res}}, C_5^A(0))$ into (shape, norm) for convenience

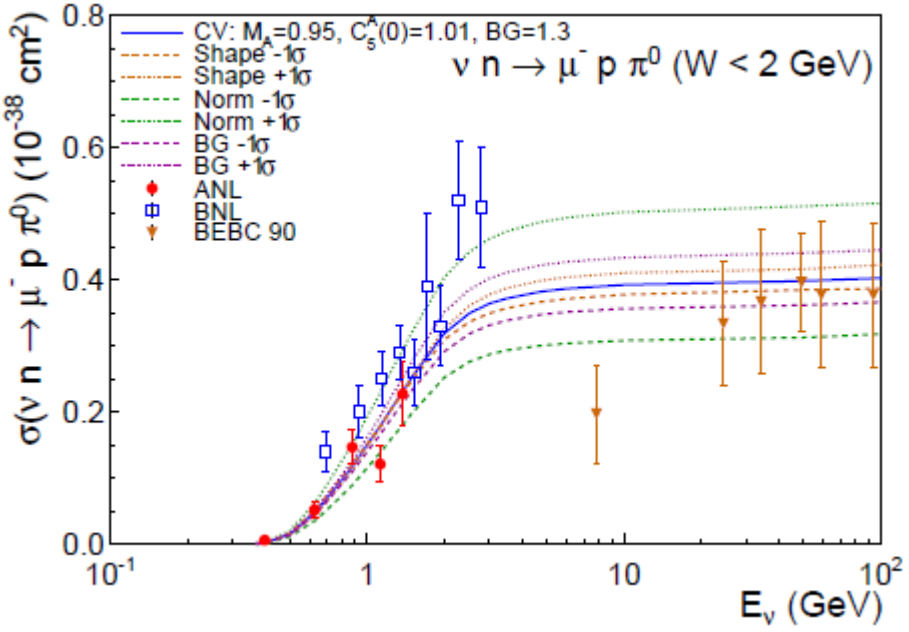
Single pion production via resonance in NEUT



Cross-section comparison (new vs old)







Single pion production via resonance in NEUT

For the interaction in nucleus,
initial interactions are modified

- Pauli-blocking effect is taken into account
  Momentum of nucleon after the decay of delta
  has to be larger than the Fermi surface momentum.
  (2 ~ 3 % of the interactions are prohibited.)
- Pion-less delta decay has been implemented
  20% of the delta are assumed to be absorbed.

$$\nu\ N \rightarrow l\ \Delta$$

$$\Delta\ N\ N \rightarrow N\ N$$

~ no pion is produced but lepton and nucleon are ejected
for the interaction in nucleus.

*) Recently, meson exchange current interaction
was independently added
and ***this feature has been turned off by default***
in the latest release.

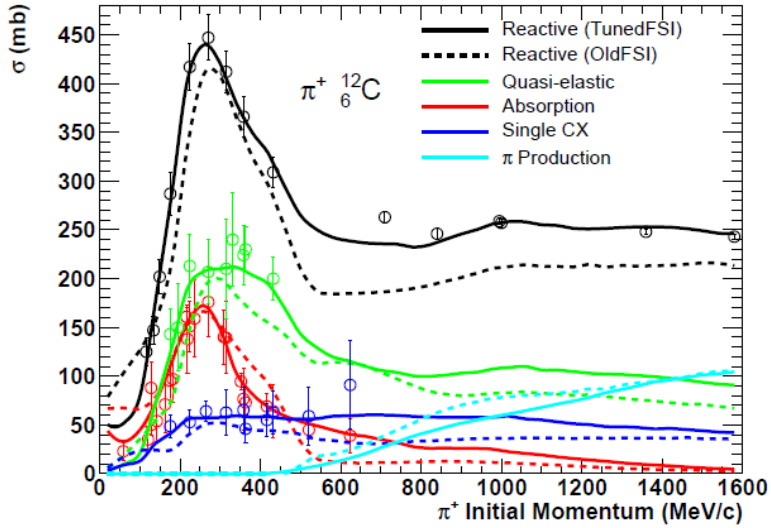
Single pion production via resonance in NEUT

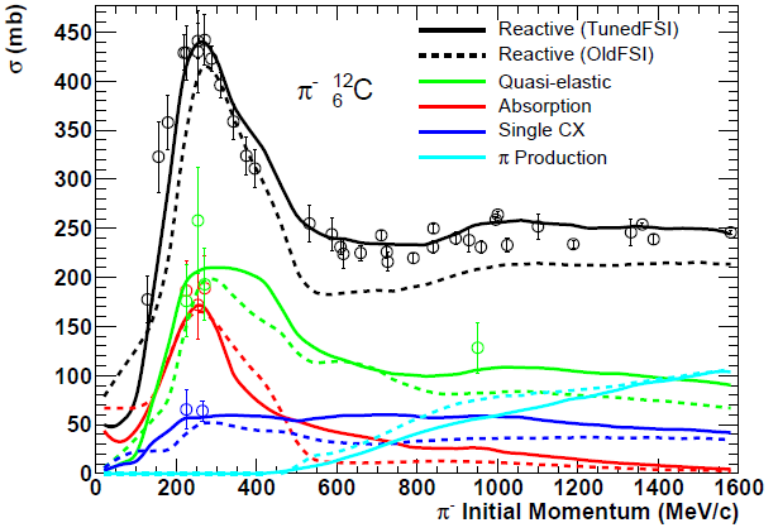
Pion interactions in nucleus, which change the observables.

- Simulated with the cascade model
- Simulated interactions
  - inelastic scattering
    - incl. charge exchange & particle production ($\pi N \rightarrow \pi \pi N$)
  - absorption
- Interaction probability ~ Mean free paths
  - P_π < 500 MeV/c
    - Density dependent mean free path
      - Originally from E. Oset et. al. model
      - Scaled by fitting the π A scattering data
  - P_π > 500 MeV/c
    - Density independent mean free path
      - π-N scattering data + π A scattering data
- Kinematics determination
  - π N phase shift analysis with medium correction (R. Seki et al.)

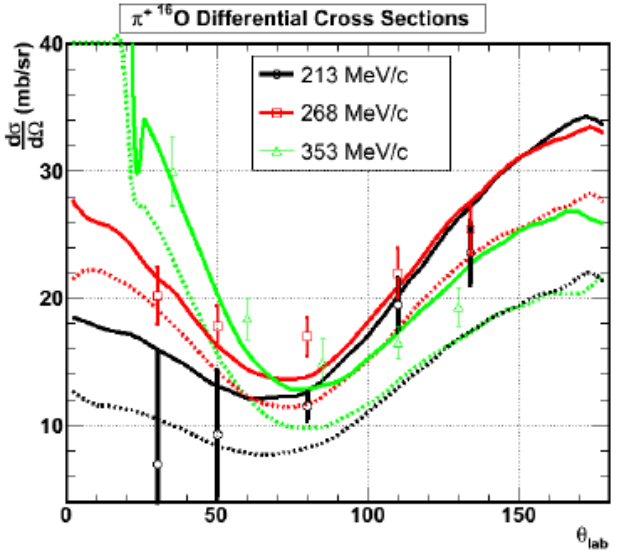
Single pion production via resonance in NEUT

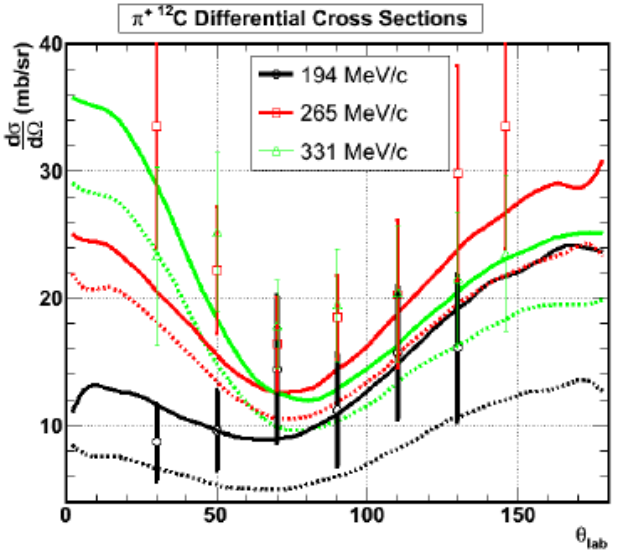
π Carbon scattering interaction cross-sections





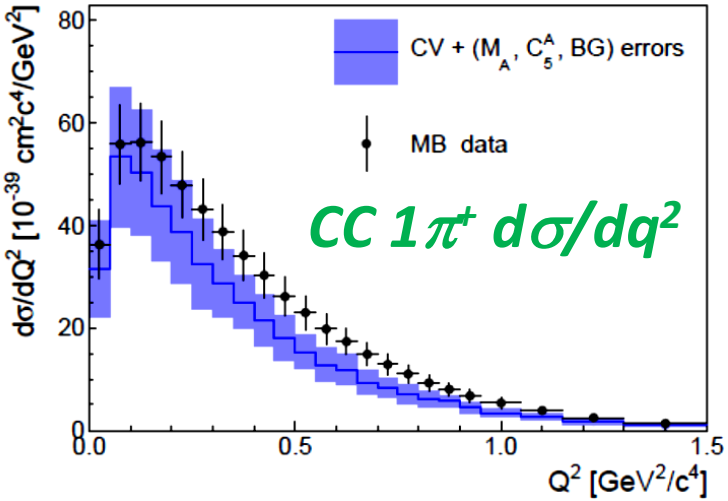
π^+ Oxygen scattering differential cross-sections



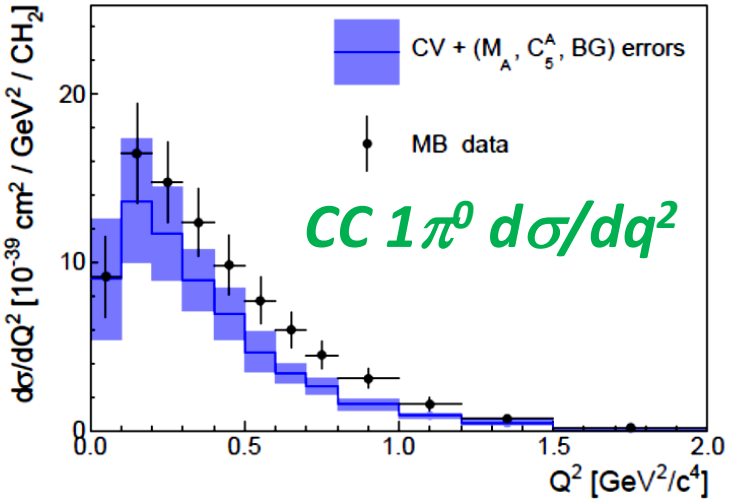


Single pion production via resonance in NEUT

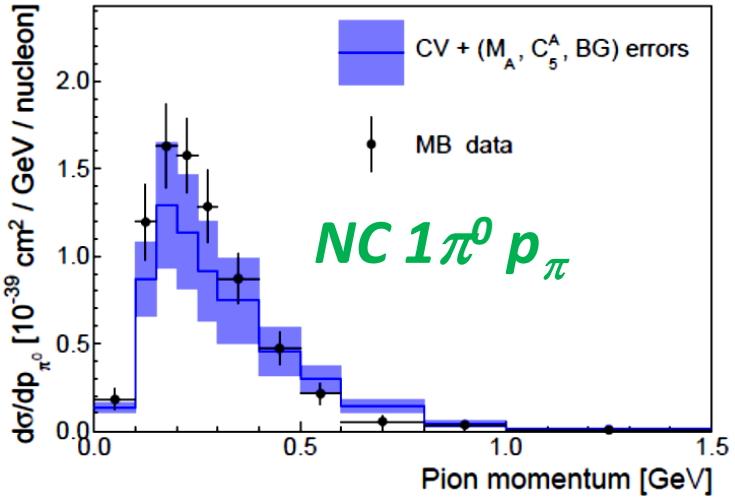
Comparisons with data from MiniBooNE



(a) MiniBooNE CC1π^+



(b) MiniBooNE CC1π^0

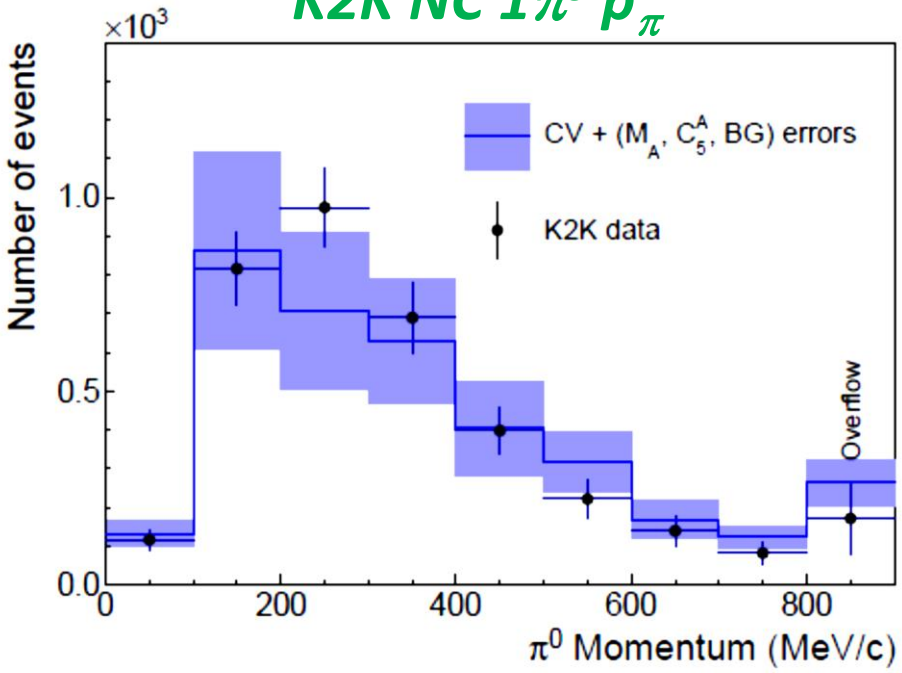


(c) MiniBooNE NC1π^0

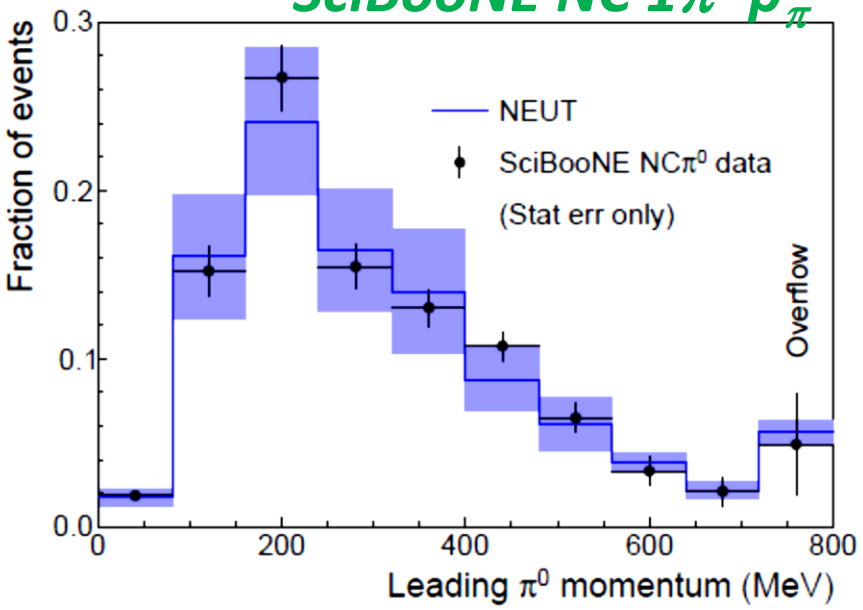
Single pion production via resonance in NEUT

Comparisons with data
from K2K and SciBooNE

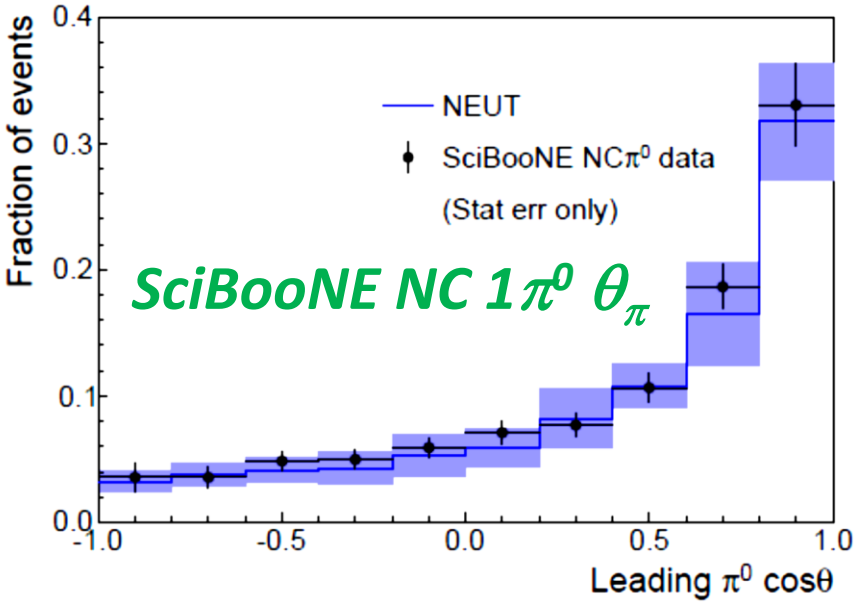
K2K NC 1π^0 p_π



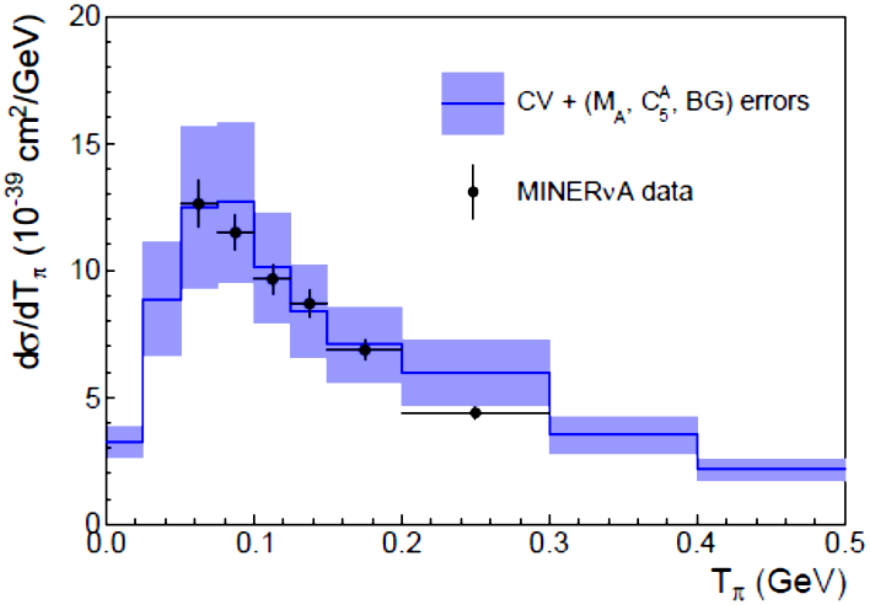
SciBooNE NC 1π^0 p_π

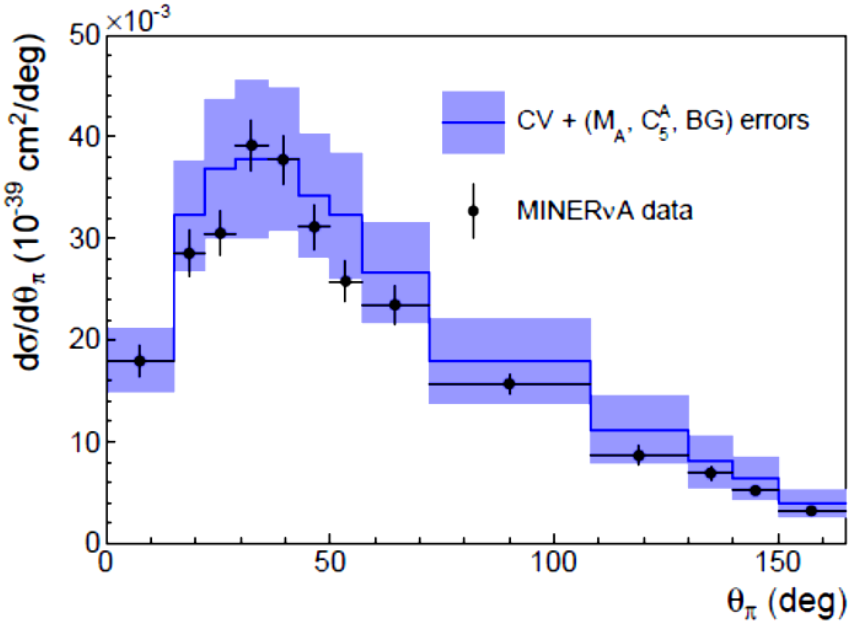


SciBooNE NC 1π^0 θ_π



Single pion production via resonance in NEUT

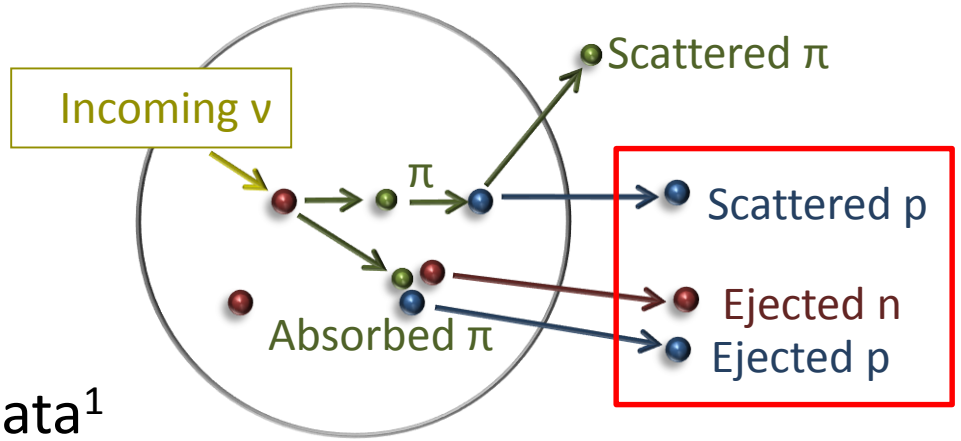




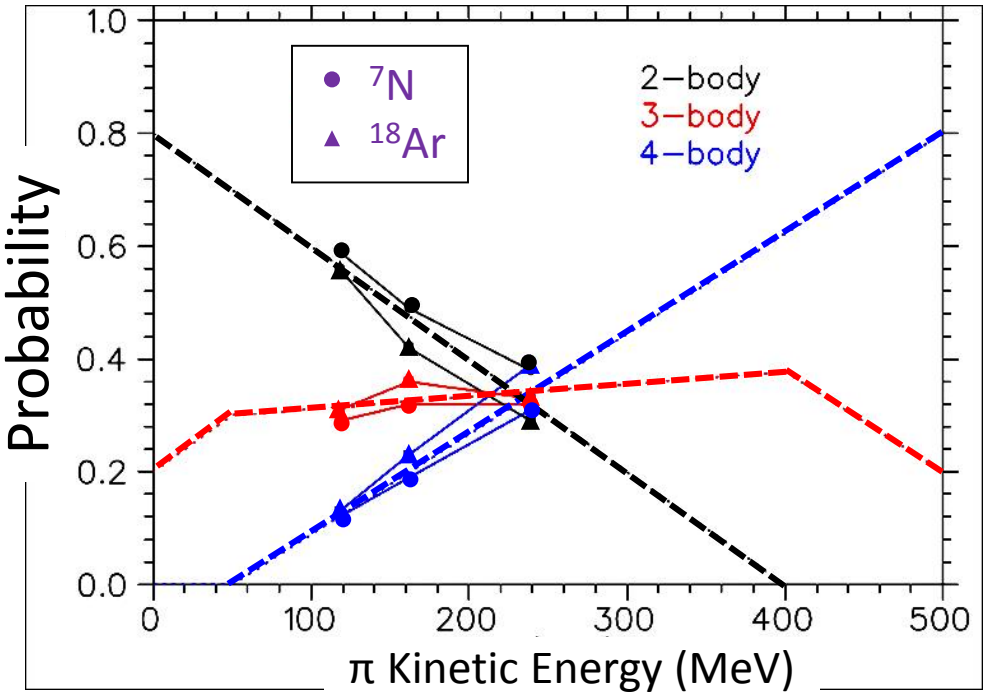
Data points are from the results presented by B. Eberly titled
“Probing Nuclear Physics with Neutrino Pion Production at MINERvA”
(Joint Experimental-Theoretical Seminar at Fermilab, Feb. 7 2014)

Single pion production via resonance in NEUT

Nucleon emission after π absorption



- # of nucleon emitted after π absorption
  Based on the experimental data[1]
- Momentum of nucleons for 2 body decay
  : measurements[2]
  Other cases
  : Isotropically



[1] Rowntree *et al*. Phys. Rev. C60 (99) 054610
[2] Ritchie, Phys. Rev. C 44, 533

(P. de Perio / R. Tacik)