2p2h

In GiBUU

With

Kai Gallmeister

2p2h: Electron induced

- 2p2h (since 2016), assume purely transverse
  - electrons

$$\frac{\mathrm{d}^2\sigma^{2p2h}}{\mathrm{d}\Omega \mathrm{d}E'} = \frac{8\alpha^2}{Q^4} E'^2 \cos^2\frac{\theta}{2}\left(\frac{Q^2}{2\mathbf{q}^2} + \tan^2\frac{\theta}{2}\right) W_1^e(Q^2,\omega)$$

$$W_1^e = G_M^2 \frac{\omega^2}{\mathbf{q}^2} R_T^e$$

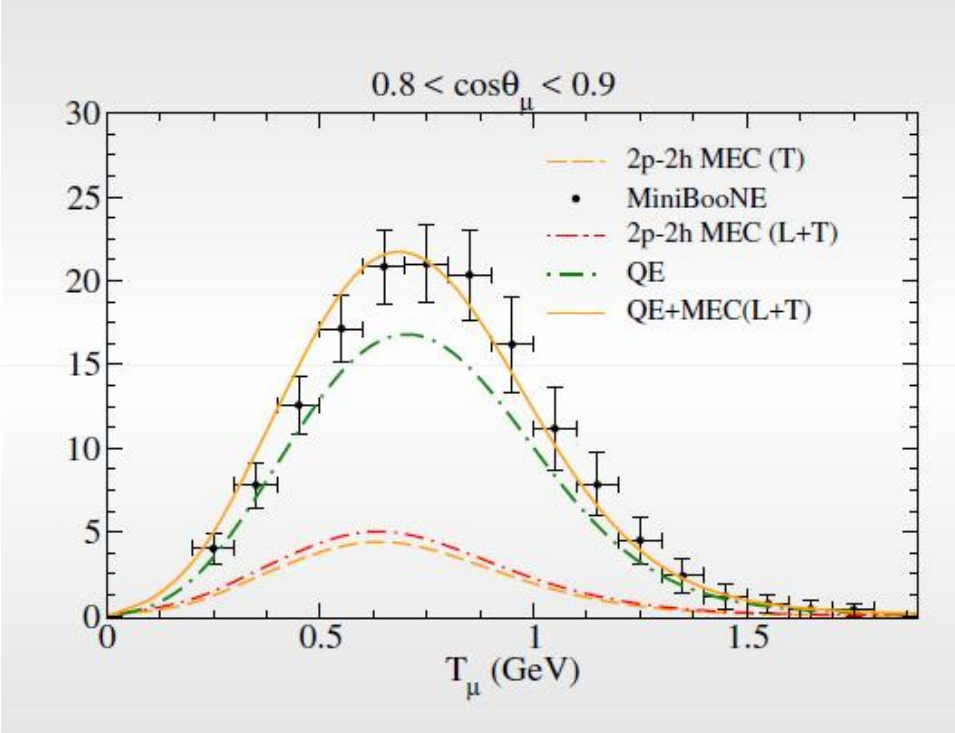
R = reduced transverse response

- W1 determined from data in a wide kinematical range:

  $0 < W < 3.2$ GeV, $0.2 < Q^2 < 5$ GeV^2

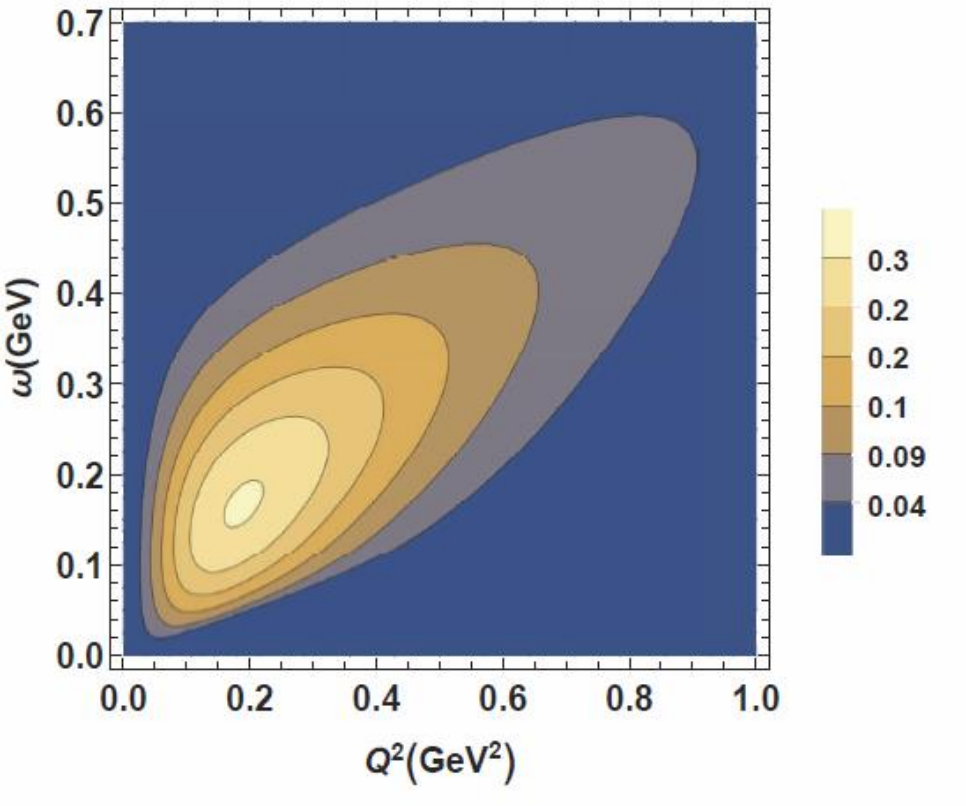
Includes not only MEC, but also src, nuclear correlations, RPA, …

Scaling + 2p2h



J. Caballero:
SUSAv2 for QE
2p2h from microscopic calculation: note that it is nearly perfectly transverse (as assumed in GiBUU)

Structure Function W_1 (Bosted/Christy)



Parametrized in wide kinematical range for electrons:

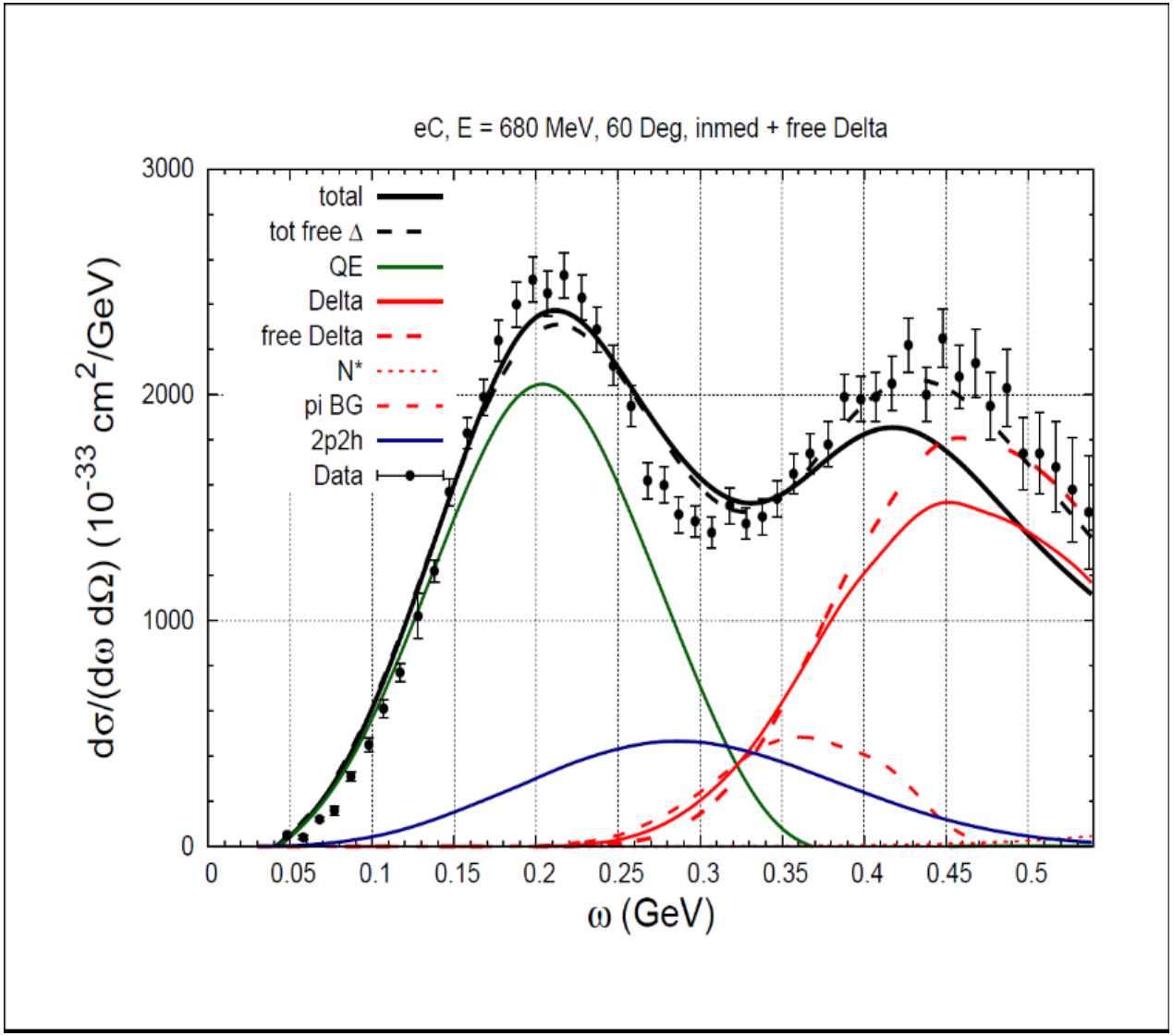
$0 < W < 3.2$ GeV, $0.2 < Q^2 < 5$ GeV^2

Problem at $Q^2 = 0$

As an empirical fit it contains implicitly:

src, MEC, nucleon correlations …., not just MEC

2p2h: Electron induced



2p2h: Neutrino induced

$$\frac{\mathrm{d}^2\sigma^{2p2h}}{\mathrm{d}\Omega \mathrm{d}E'} = \frac{G^2}{2\pi^2} E'^2 \cos^2\frac{\theta}{2} \left[2W_1^\nu \left(\frac{Q^2}{2\mathbf{q}^2} + \tan^2\frac{\theta}{2} \right) \mp W_3^\nu \frac{E+E'}{M} \tan^2\frac{\theta}{2} \right]$$

Purely transverse

Walecka, O'Connell, Donnelly, Walecka (1972); connects electron response with neutrino response:

$$W_1^\nu = \left(G_M^2 \frac{\omega^2}{\mathbf{q}^2} + G_A^2 \right) R_T^e \, 2(\mathcal{T}+1)$$

$\mathcal{T}$ = isospin or target nucleus

Now assume:

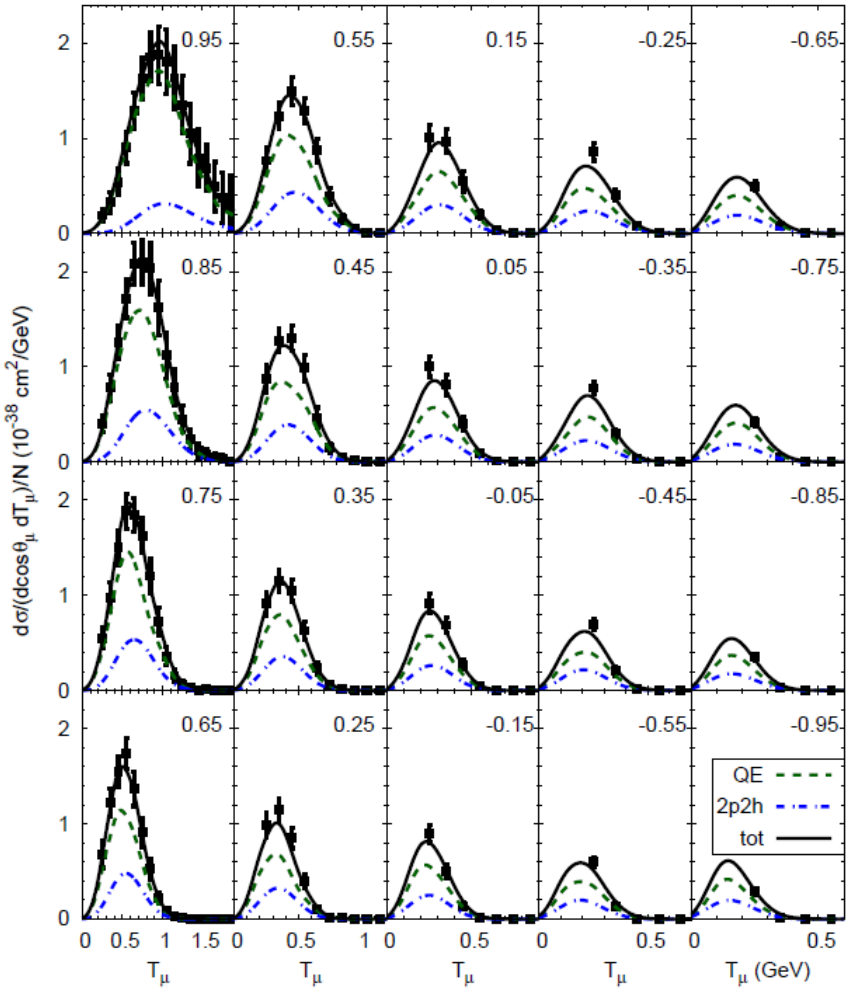
- longitudinal current negligable in W_3
- Neutrinos populate isobaric analogues of electron-excitations

$$W_3^\nu = 2 G_A G_M \, R_T^e \, 2(\mathcal{T}+1)$$

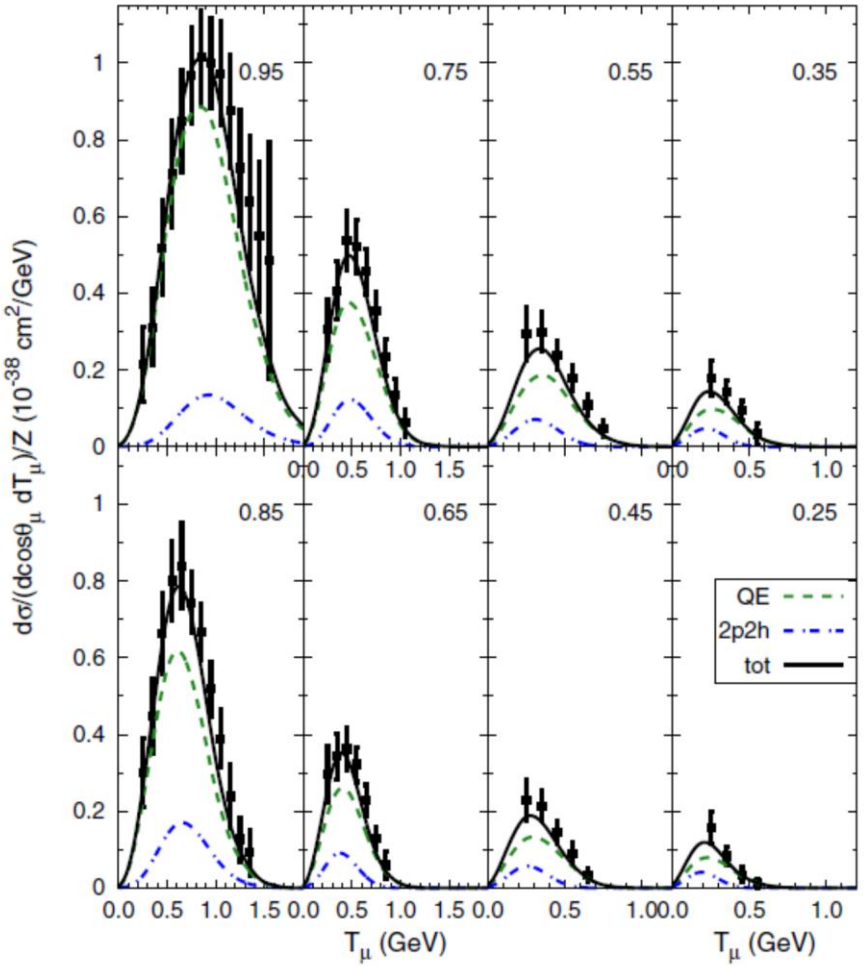
Same expressions used by Ericsson, Delorme (1985), Martini et al (2009 - ..)

MiniBooNE 0pion = QE + 2p2h

neutrinos

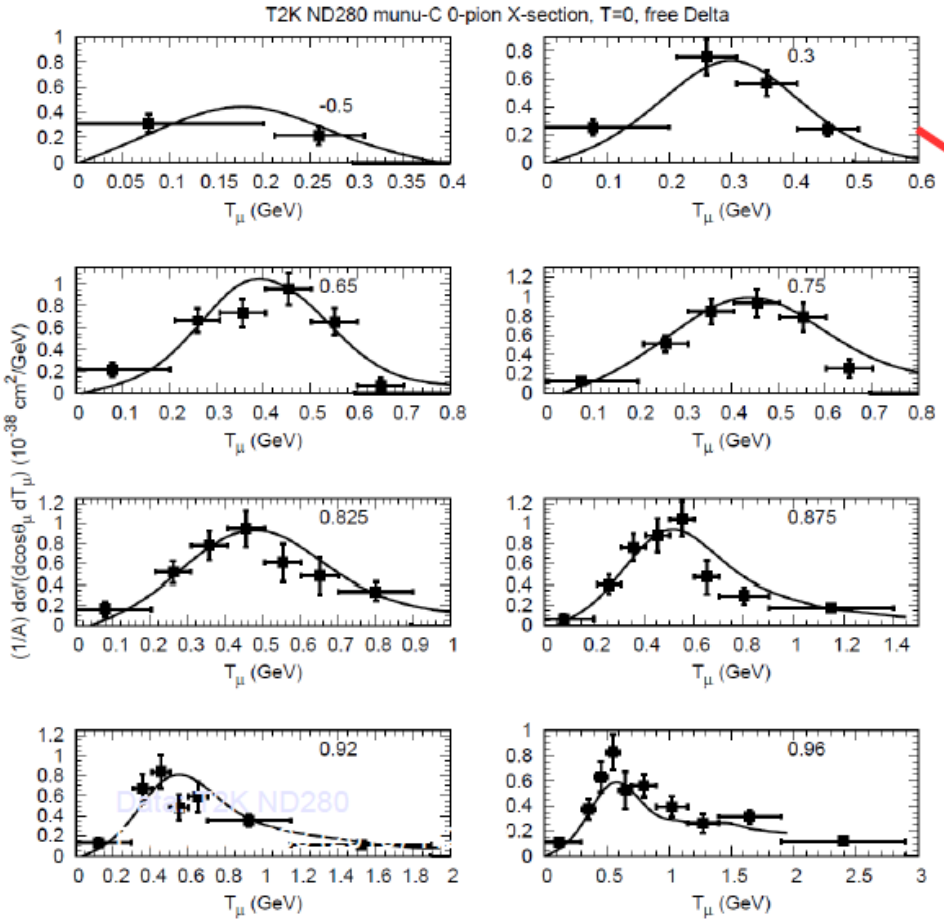


antineutrinos

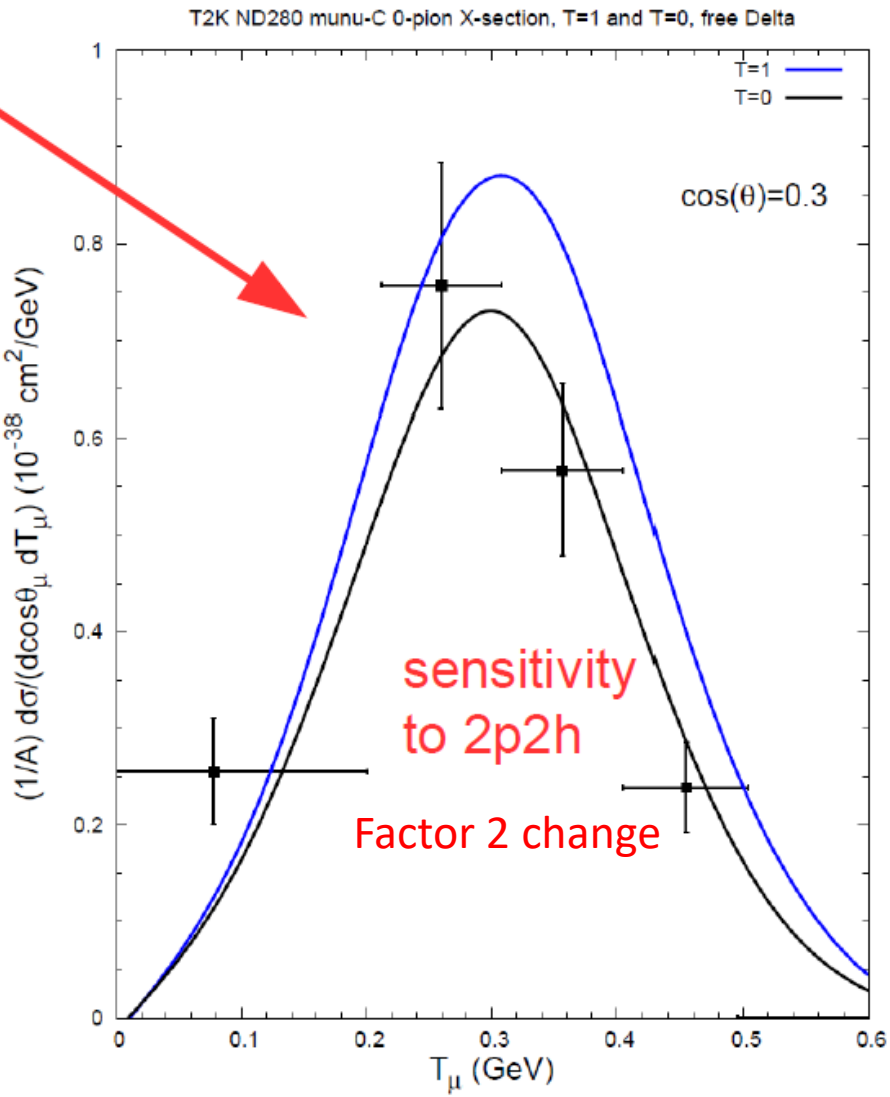


No flux correction!

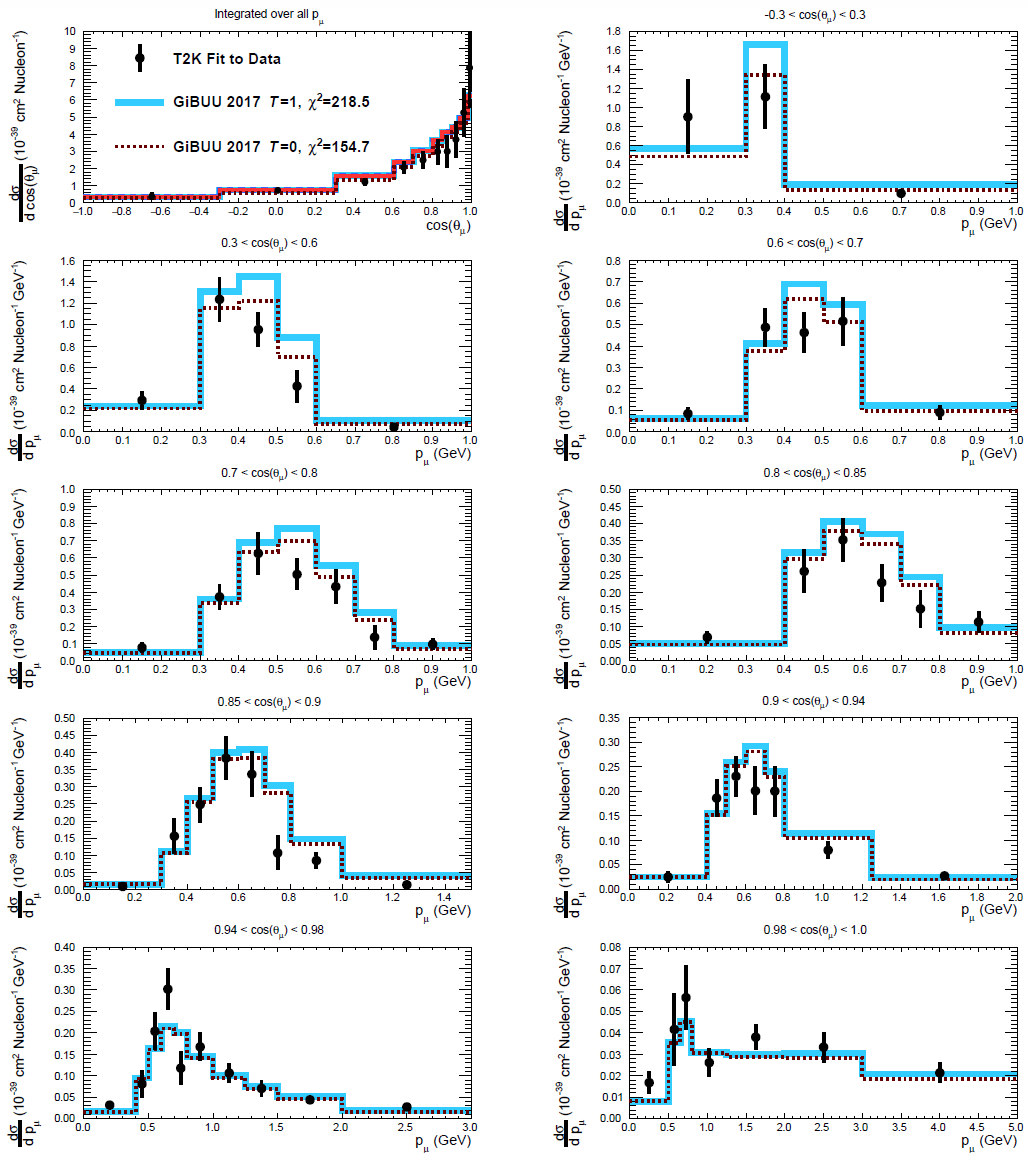
T2K 0pion = QE + 2p2h + stuck pions



Data: T2K ND280
Phys.Rev. D93 (2016) 112012



T2K 0pion = QE + 2p2h + π reabsorb



Dolan et al,
arXiv 1804.09488

Propagation of 2p2h events

So far, only inclusive X-sections, but for event generation need the 2 outgoing nucleons
from initial neutrino-2p2h interaction

- Choose initial nucleons with random momenta inside the Fermi sea, but at same location (short range assumption)

- Choose isospin according to simple combinatorics (no special weight for pn vs nn ..)

- Go to cm-system of 2 nucleons after absorption of momentum transfer q:

  $P_{cm} = p_1 + p_2 + q = 0$

- In that cm system populate final nucleon states according to phase space (somewhat complicated because potential is momentum-dependent!)

- Propagate these two nucleons as usual, with all fsi (potential and collisions)

Summary

1. 2p2h for electrons works by construction

2. Just one structure function describes neutrinos and antineutrinos. This structure function is available in a simple parametrization.