

# Semi-inclusive neutrino-nucleus reactions in PWIA

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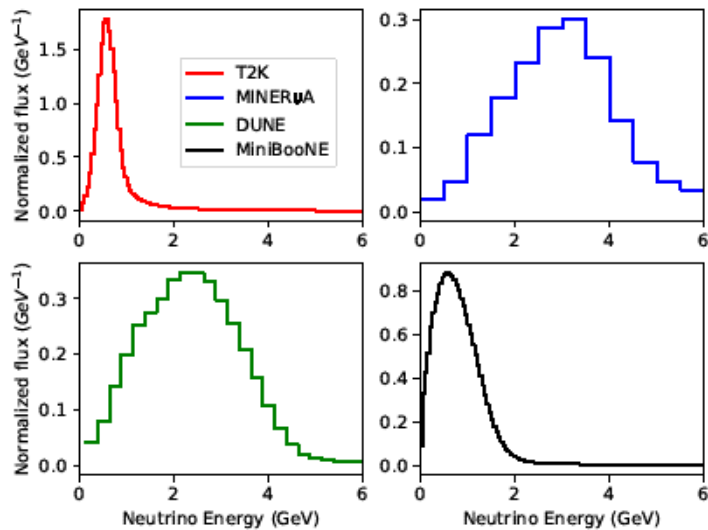
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# Introduction

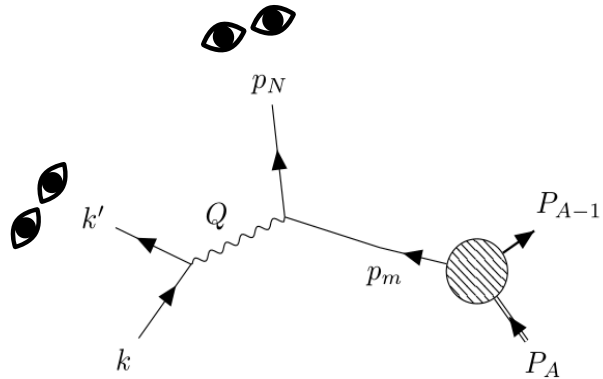
Determination of oscillation parameters requires measuring particles in the final state to reconstruct the neutrino energy.



Until now, most of the studies have focused on inclusive measurements with only one lepton detected in the final state.

One way to improve the neutrino energy reconstruction is measuring more exclusive channels, like the detection in coincidence of one lepton and one hadron in the final state.

# Semi-inclusive $\nu$ -nucleus cross section in PWIA



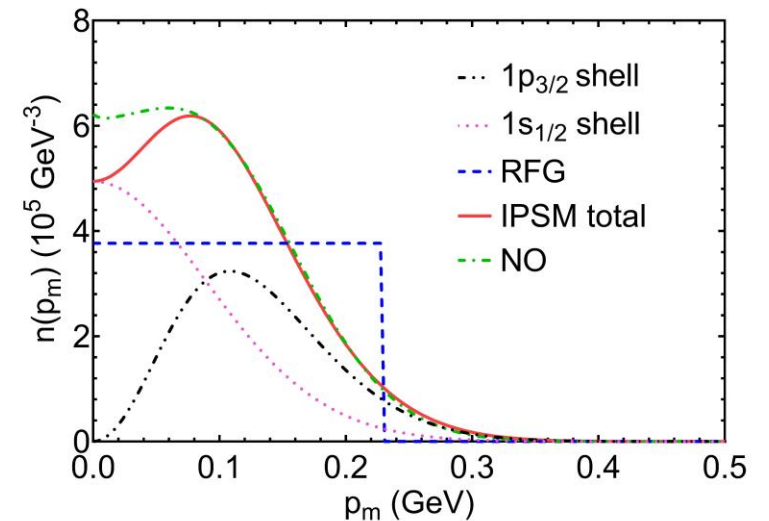
In the impulse approximation, the cross section factorizes in three terms:  
 a kinematic factor, the reduced off-shell single-nucleon cross section and the spectral function

$$\frac{d\sigma}{dk' d \cos \theta_l dp_N d \cos \theta_N^L d \phi_N^L} = \frac{(G_F \cos \theta_c k' p_N)^2 m_N}{8k \varepsilon' E_N (2\pi)^5} v_0 \mathcal{F}_\chi^2 S(p_m, E_m)$$

$$\begin{aligned} v_0 \mathcal{F}_\chi^2 &= 2L_{\mu\nu} \mathcal{H}^{\mu\nu} \\ &= V_{CC} R^{CC} + 2V^{CL} R^{CL} + V_{LL} R^{LL} + V_T R^T \\ &+ V_{TT} R^{TT} + V_{TC} R^{TC} + V_{TL} R^{TL} \\ &- \chi (V_{T'} R^{T'} + V_{TC'} R^{TC'} + V_{TL'} R^{TL'}) \end{aligned}$$

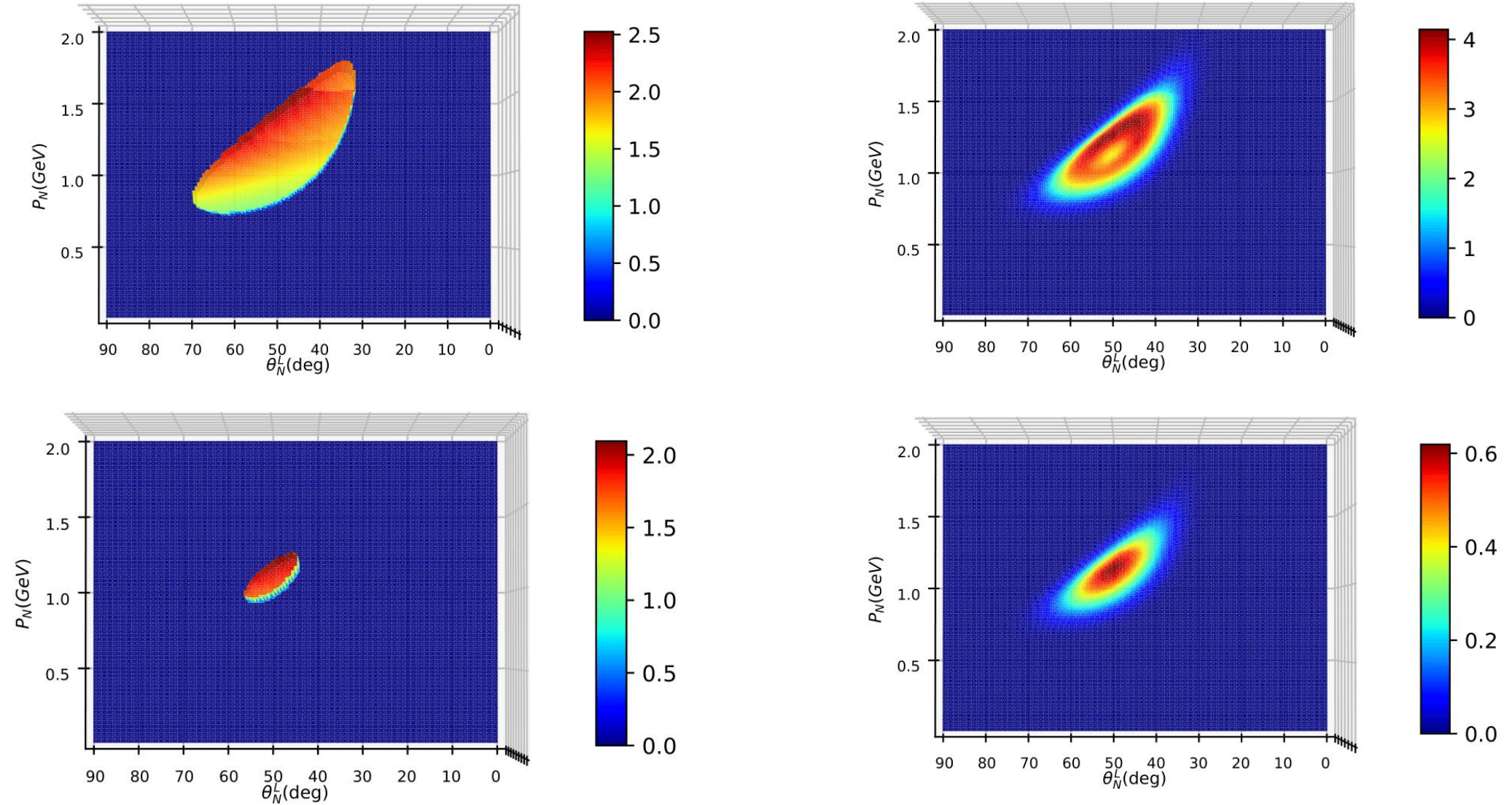
All the responses are analytic in PW approximation!!

$$n(p_m) = \int_0^\infty dE_m S(p_m, E_m) \rightarrow$$

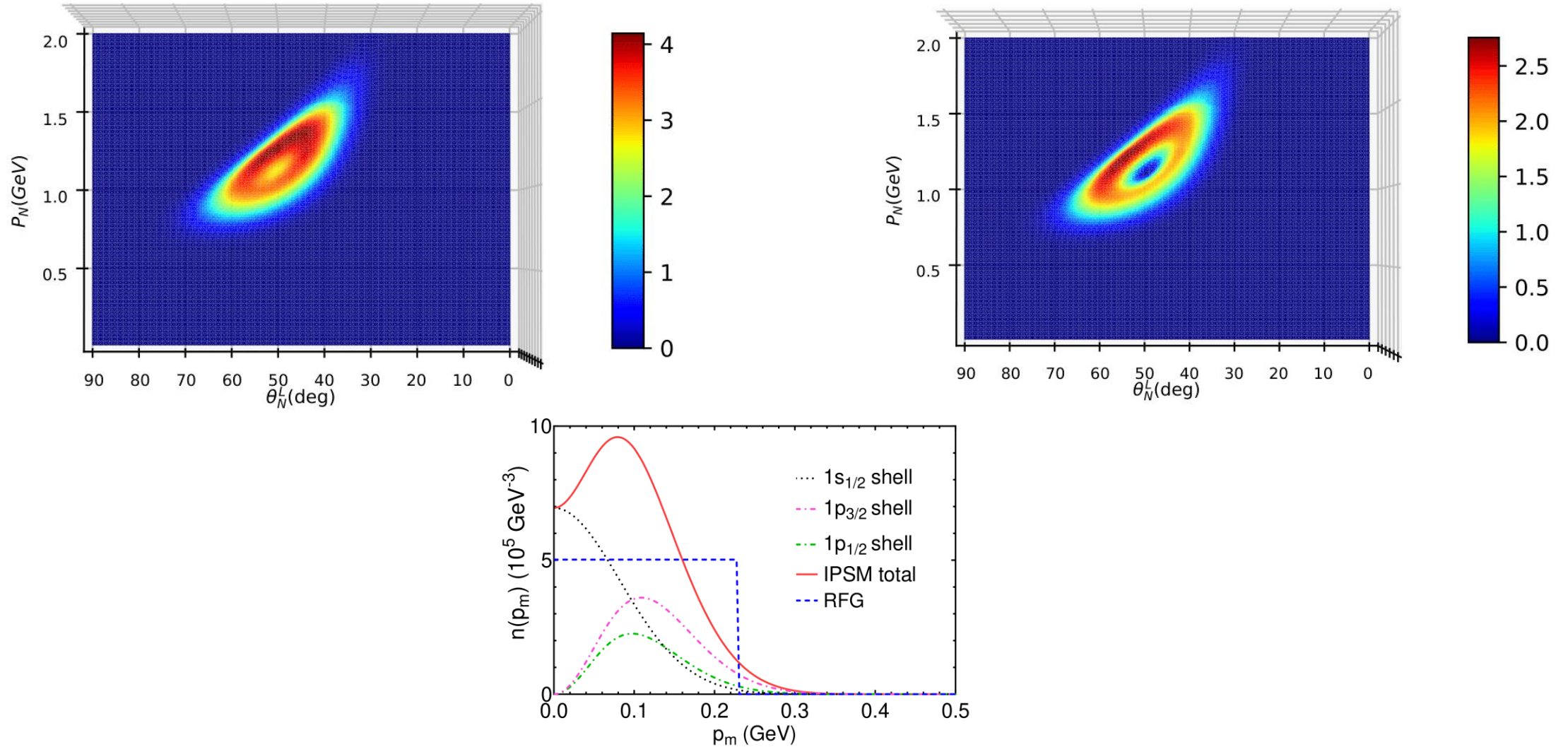


Carbon-12

$\nu_\mu + {}^{16}\text{O}$  DUNE flux,  $k' = 2.0 \text{ GeV}$ ,  $\theta_l = 25^\circ$ ,  $\phi_N^L = 180^\circ$  (top) or  $\phi_N^L = 165^\circ$  (bottom)

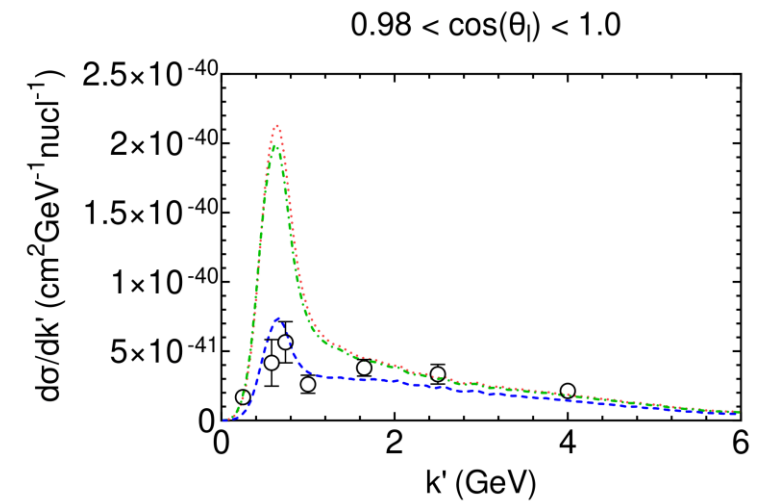
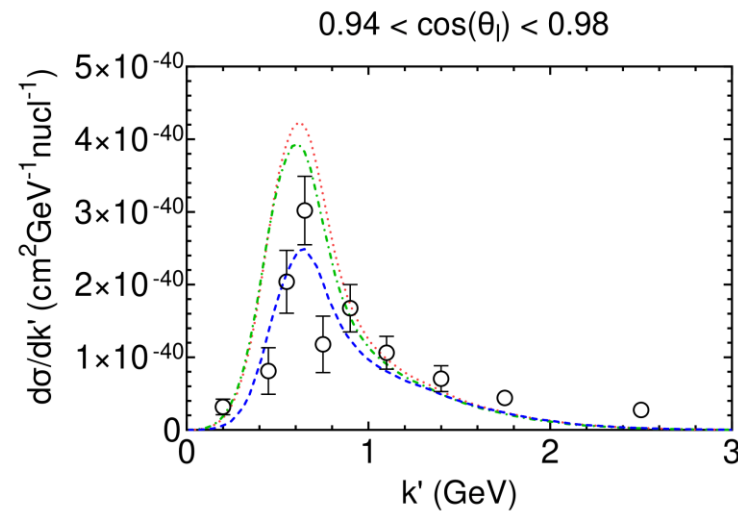
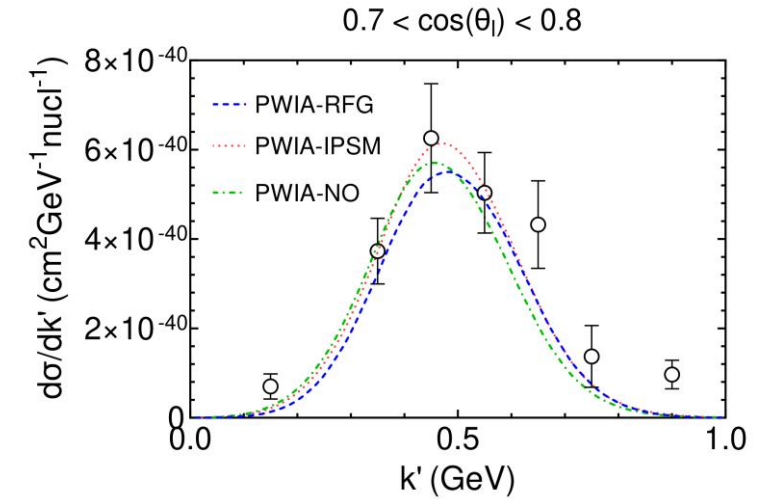
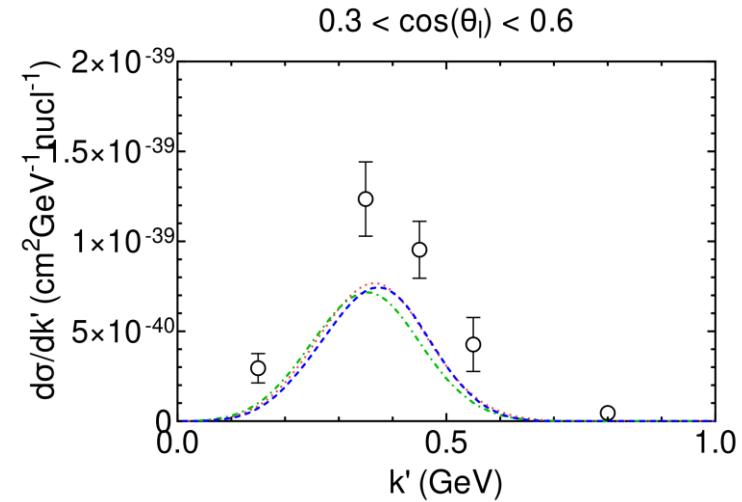


$\nu_\mu + {}^{16}\text{O}$  DUNE flux,  $k' = 2.0 \text{ GeV}$ ,  $\theta_l = 25^\circ$ ,  $\phi_N^L = 180^\circ$ , all shells included (left) and excluding  $1s_{1/2}$  (right)

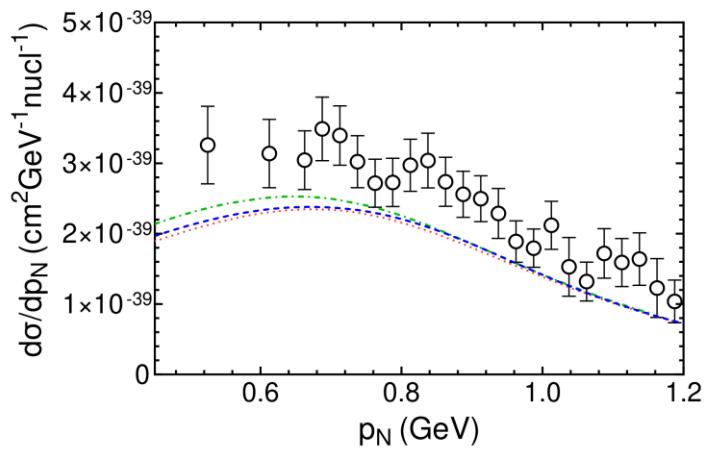
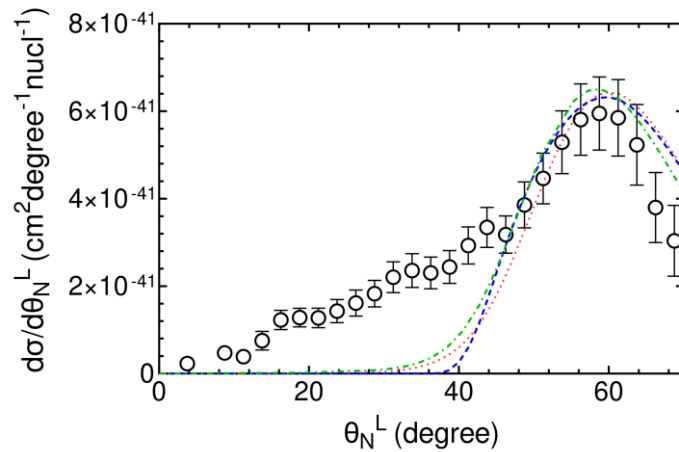
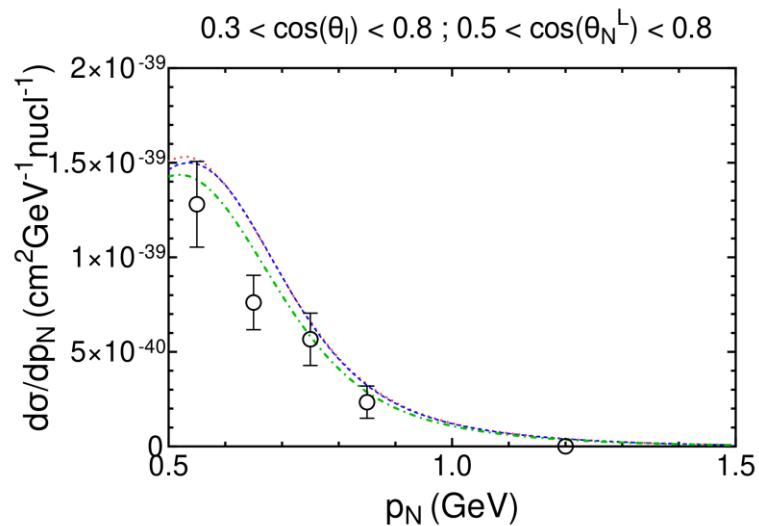
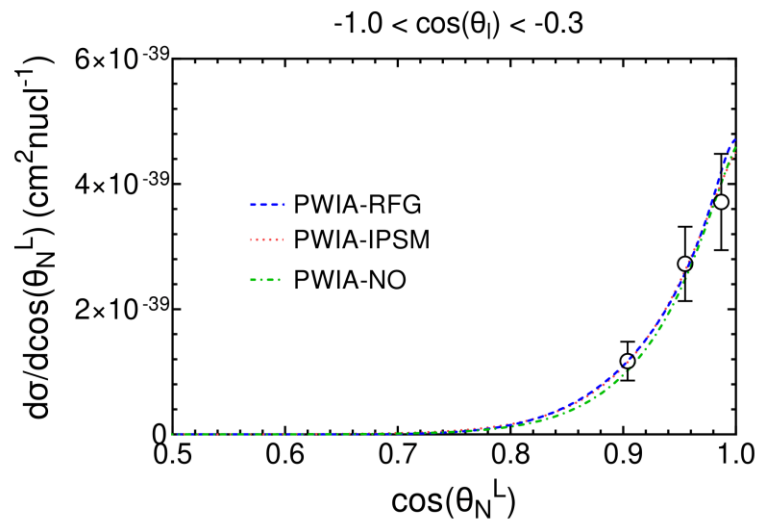


# Comparison with experimental data

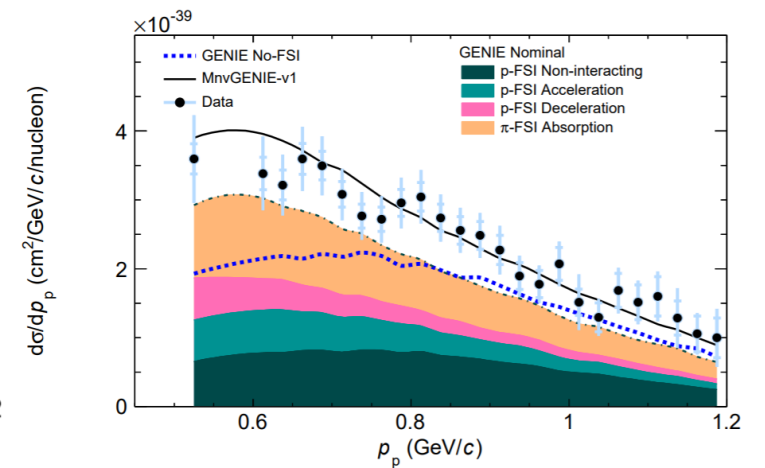
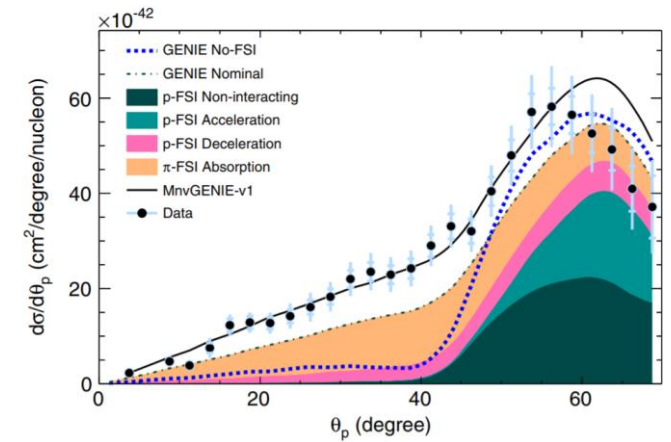
T2K single-differential cross sections as function of final muon momentum without protons with momenta above 0.5 GeV

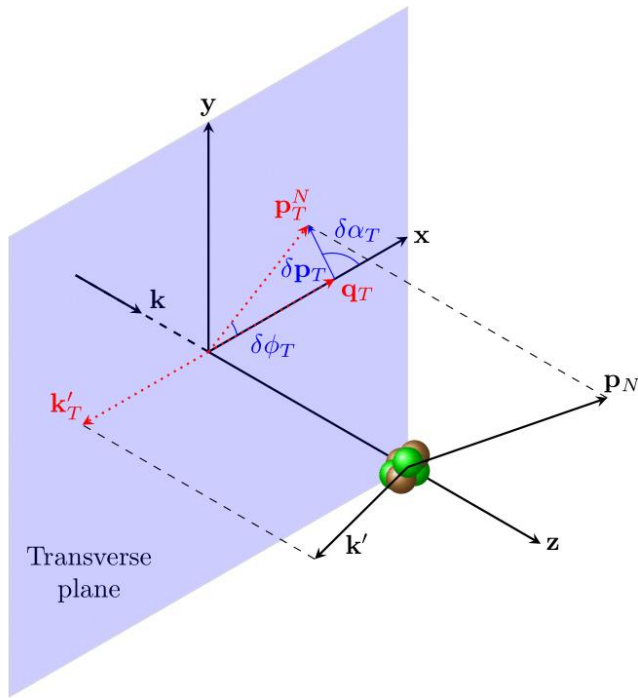


# T2K

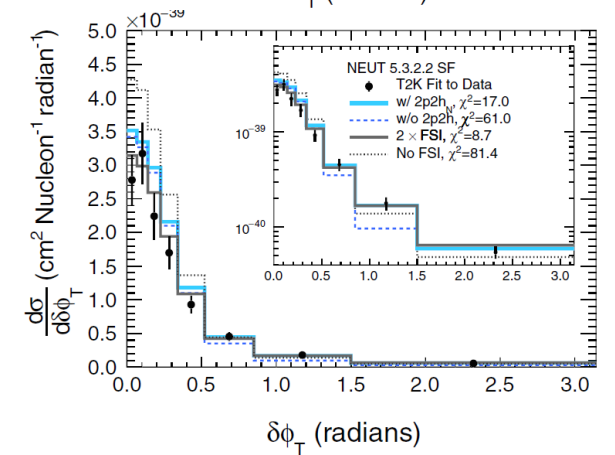
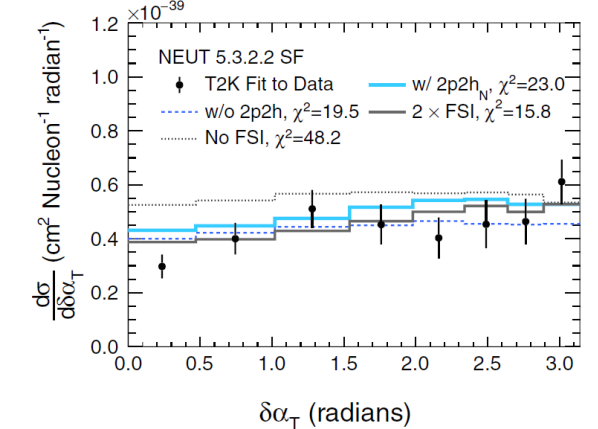
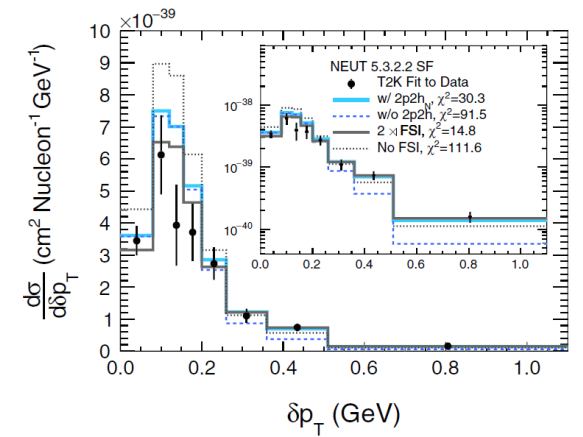
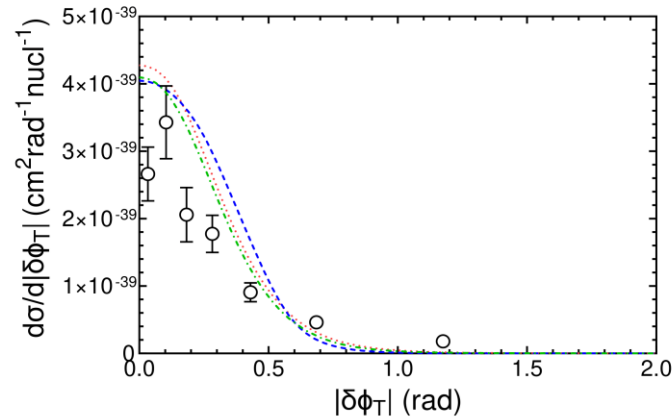
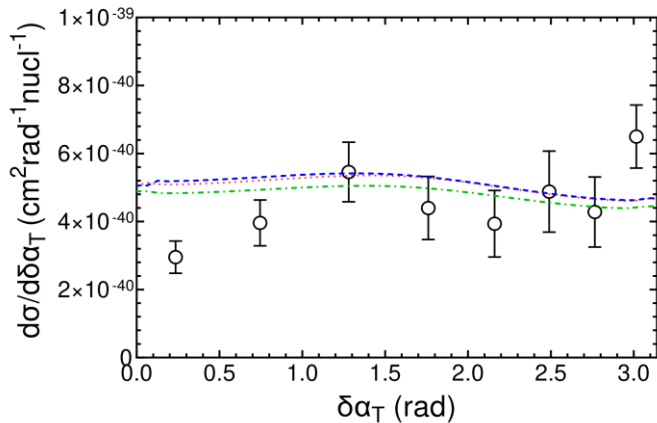
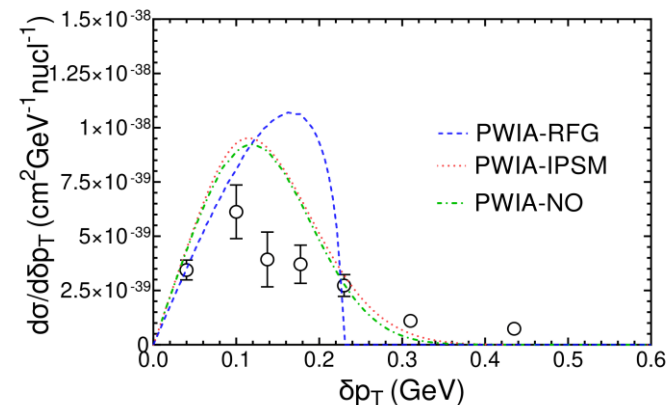


# MINERvA





In PWIA,  $\delta p_T$  is the transverse component of the bound nucleon momentum distribution and  $\delta\alpha_T$  is the angle between the transverse components of the initial nucleon momentum and the transferred momentum, which is expected to be flat in absence of FSI.





# Summary

- Semi-inclusive neutrino-nucleus reactions have been studied from a theoretical point of view within PWIA and the analysis was published in Phys. Rev. C 102, 064626 (2020).
- The analysis of all the available semi-inclusive experimental data with one muon and one proton in the final state within PWIA was submitted to PRD and is available now on <https://arxiv.org/abs/2106.02311>.
- Work is in progress to include FSI and maybe contributions beyond IA (2p2h).

Thanks for you attention!