FACULTY OF SCIENCES

DEPARTMENT OF PHYSICS AND ASTRONOMY

NEUTRINO-NUCLEUS SCATTERING IN GHENT

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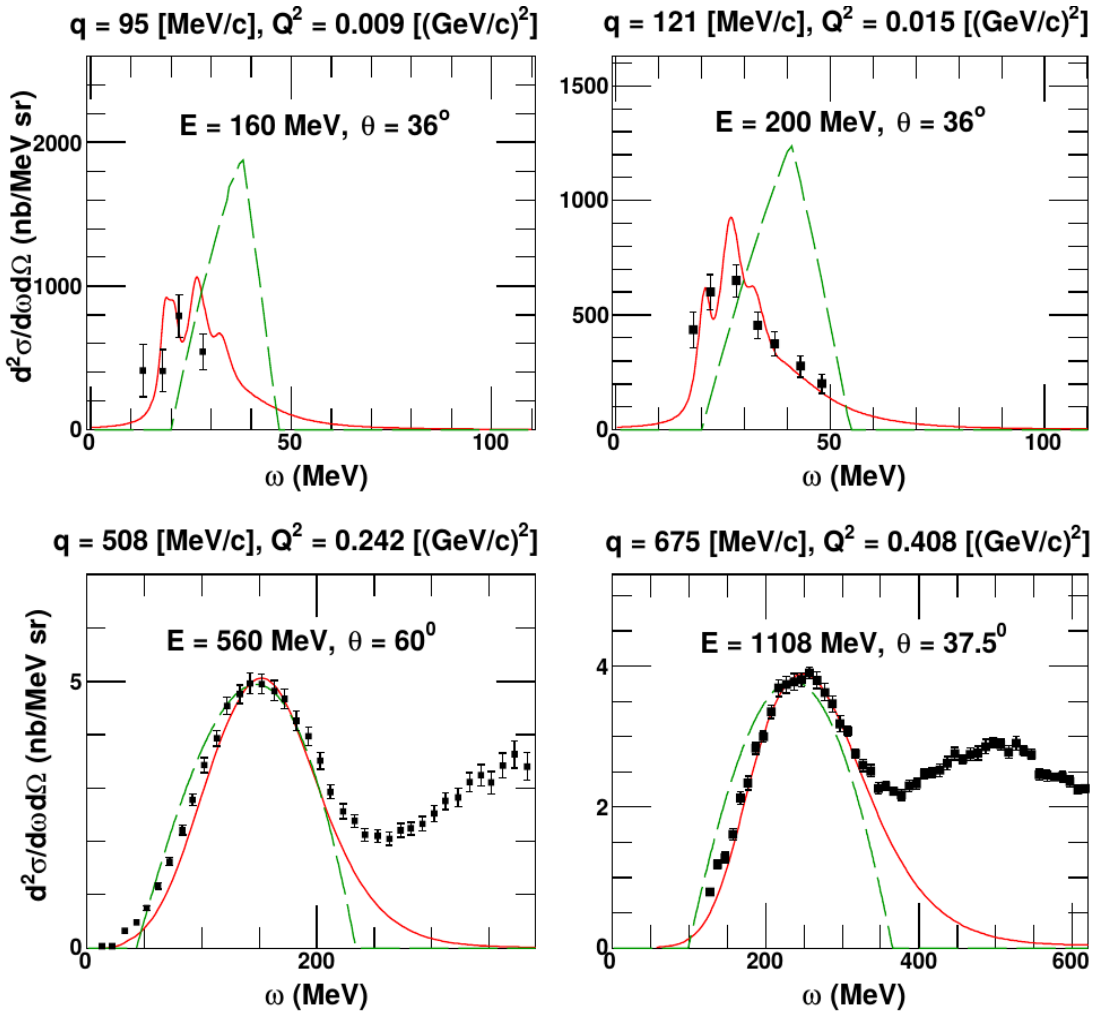
BriX

Hartree-Fock vs Fermi-Gas



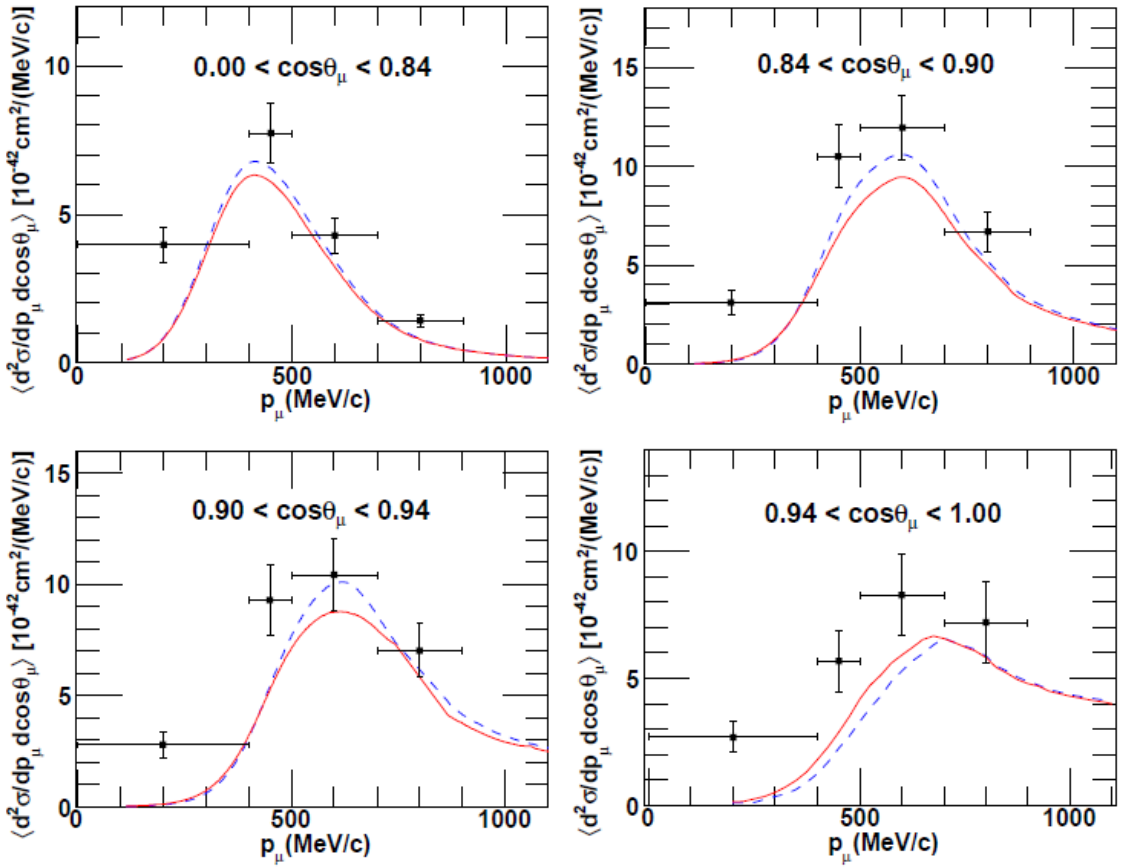
I. QE 1p1h : Hartree-Fock mean-field

- Starting point : mean-field nucleus with Hartree-Fock single-particle wave functions
- Skyrme SkE2 force used to build the potential
- Binding and Pauli blocking naturally included
- Relativized
- Coulomb corrections for the outgoing lepton

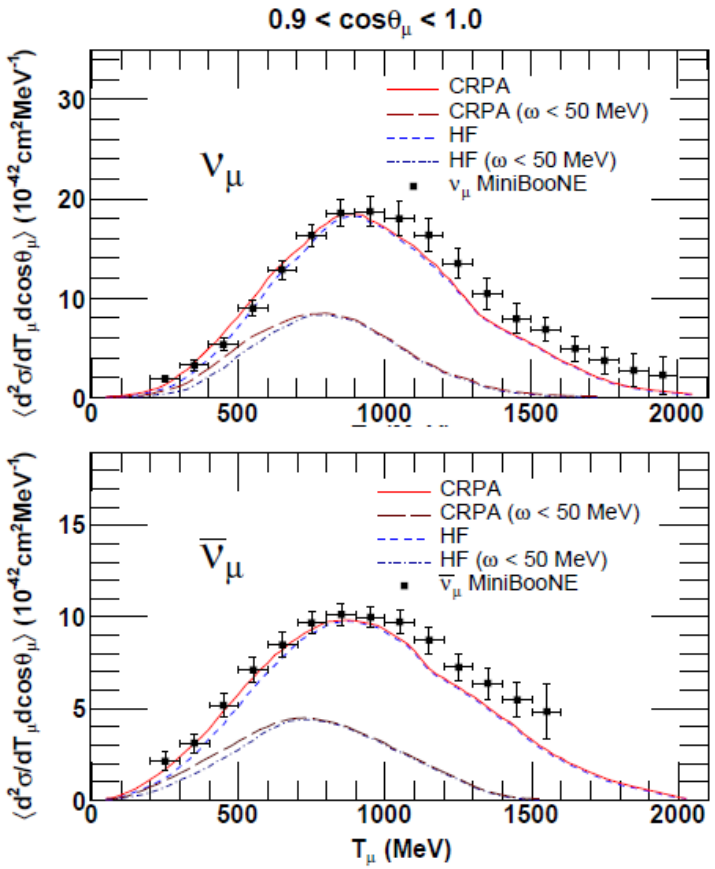
II. Long-range correlations : Continuum RPA

- Green's function approach
- Skyrme SkE2 residual interaction
- self-consistent calculations
- Especially suited for the description of low-excitation energies, forward scattering

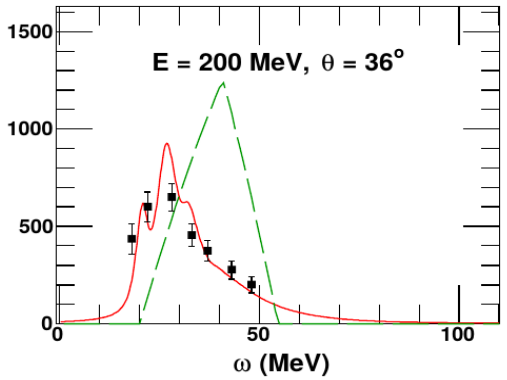
T2K ν_μ



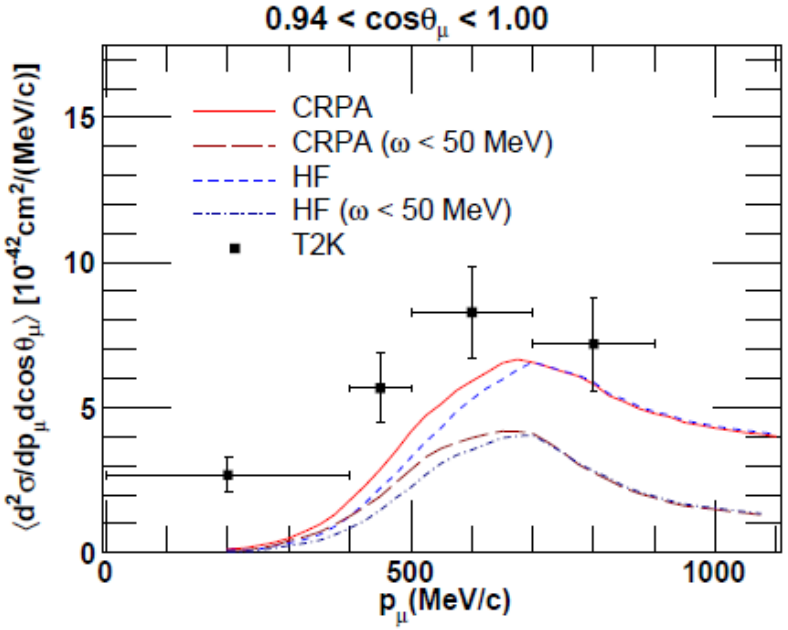
MiniBooNE



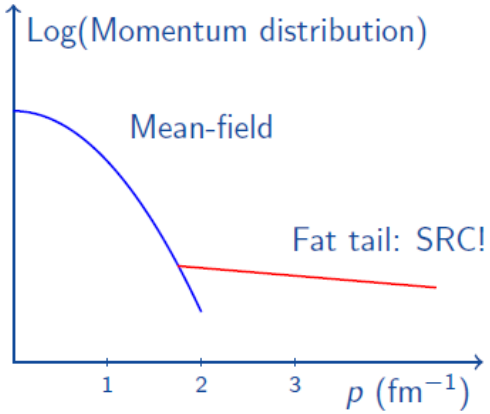
- HF-CRPA calculations provide extra strength for forward scattering arising from low-energy excitations
- This might affect CCQE neutrino cross sections as measured by MiniBooNe and T2K
- **Most of the strength from w<50 MeV.**



T2K



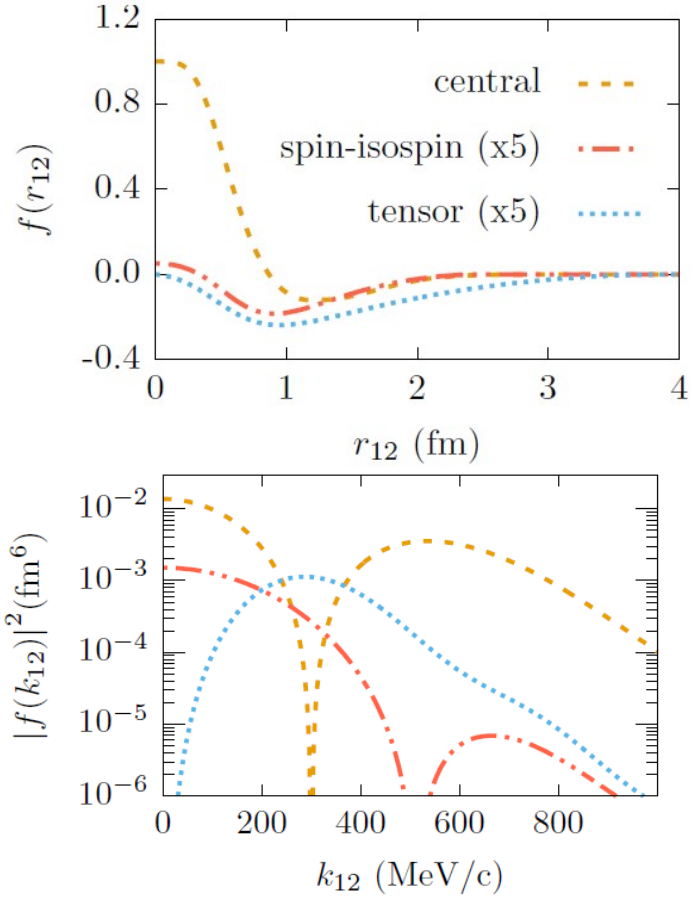
III. Short-range correlations in 1p1h and 2p2h

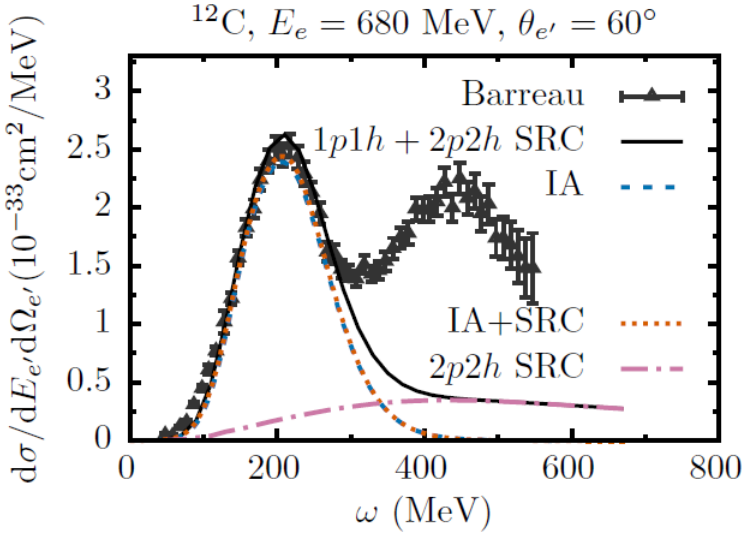


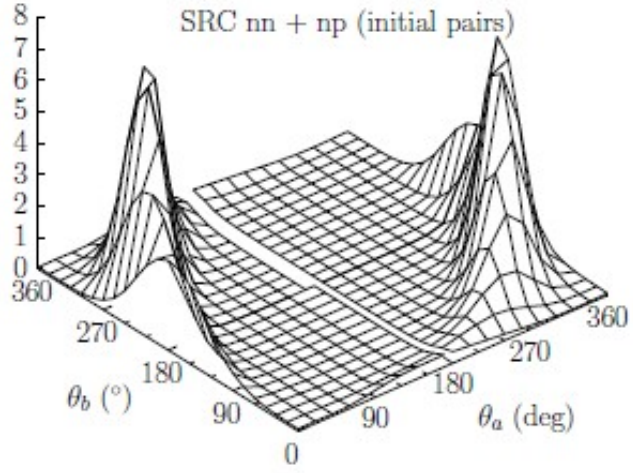
$$|\Psi\rangle = \frac{1}{\sqrt{\mathcal{N}}}\hat{\mathcal{G}}|\Phi\rangle \qquad \text{with} \qquad \hat{\mathcal{G}} \approx \hat{\mathcal{S}}\left(\prod_{i<j}^{A}\left[1+\hat{l}(i,j)\right]\right)$$

$$\hat{l}(i,j) = -\,g_c(r_{ij}) + f_{\sigma\tau}(r_{ij})\,(\vec{\sigma}_i\cdot\vec{\sigma}_j)\,(\vec{\tau}_i\cdot\vec{\tau}_j) + f_{t\tau}(r_{ij})\hat{S}_{ij}\,(\vec{\tau}_i\cdot\vec{\tau}_j)\,,$$

Shifting the complexity induced by correlations from the wave functions to the operators



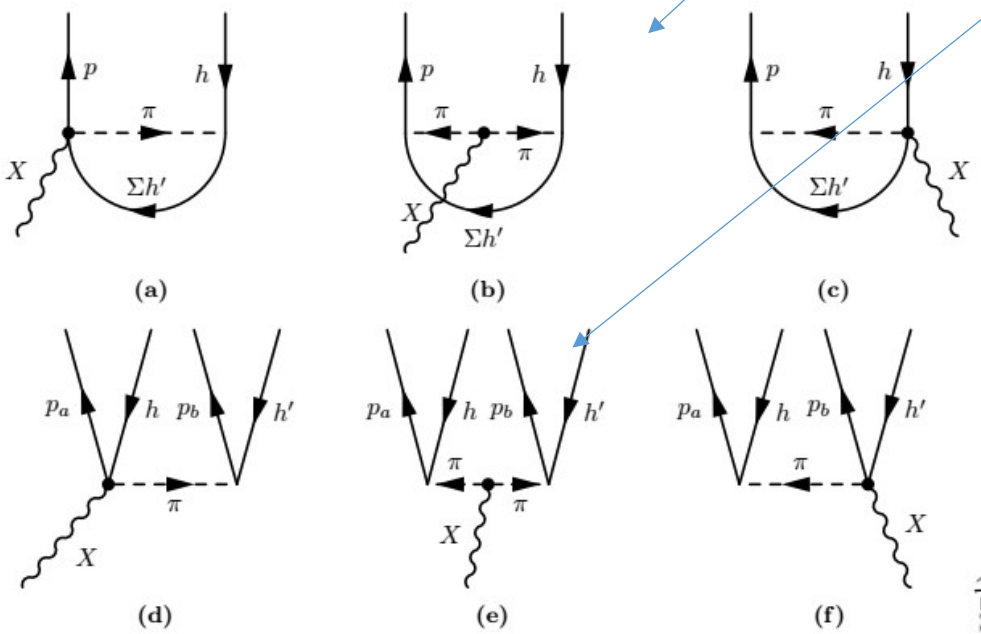




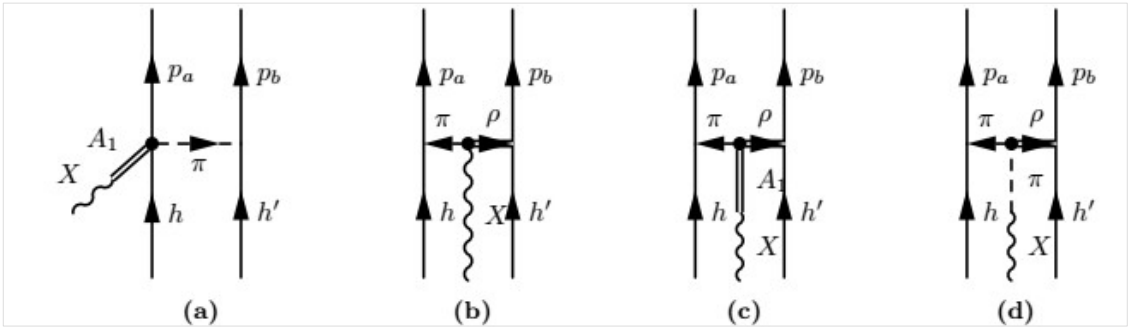
- SRC affect 1- and 2-nucleon knockout processes

Figure 4.5: The ^{12}C($\nu_\mu, \mu^- N_a N_b$) cross section (N_a = p, N_b = p′, n) at ϵ_{ν_μ} = 750 MeV, ϵ_μ = 550 MeV, θ_μ = 15° and T_p = 50 MeV for in-plane kinematics.

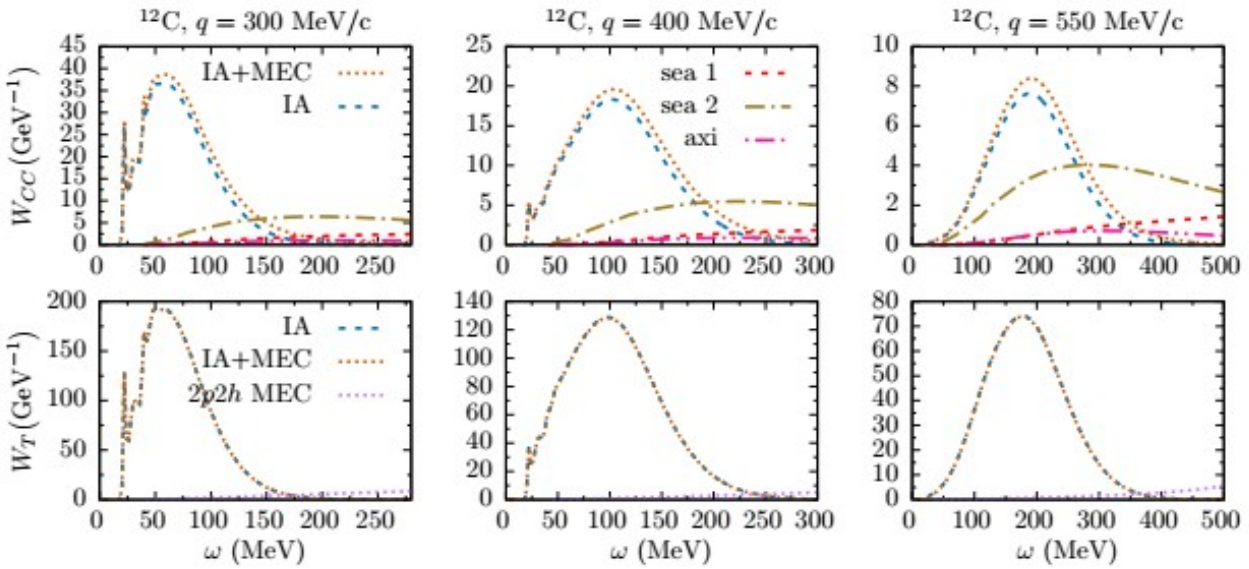
III. MEC in 1p1h and 2p2h



Axial contributions :



$$\widehat{\rho}_A^{[2],\mathrm{axi}}(\boldsymbol{q}) = \frac{i}{g_A}\left(\frac{f_{\pi NN}}{m_\pi}\right)^2 (\boldsymbol{I}_V)\left(F_\pi(q_2^2)\,\Gamma_\pi^2(q_2^2)\frac{\boldsymbol{\sigma}_2\cdot\boldsymbol{q}_2}{q_2^2+m_\pi^2} - F_\pi(q_1^2)\,\Gamma_\pi^2(q_1^2)\frac{\boldsymbol{\sigma}_1\cdot\boldsymbol{q}_1}{q_1^2+m_\pi^2}\right)$$



(a) The 1p1h and 2p2h responses. The three expressions of the axial current are compared in the CC response. The seagull and pion-in-flight contribution are included in the T response.

Near future: Comparison with neutrino data

Future: Including delta-current

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IV. Pion Production

Novelty of our work. We are working on two research lines which complement each other.

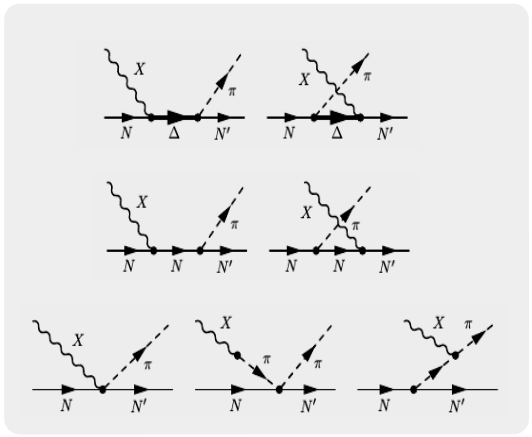
PRESENT

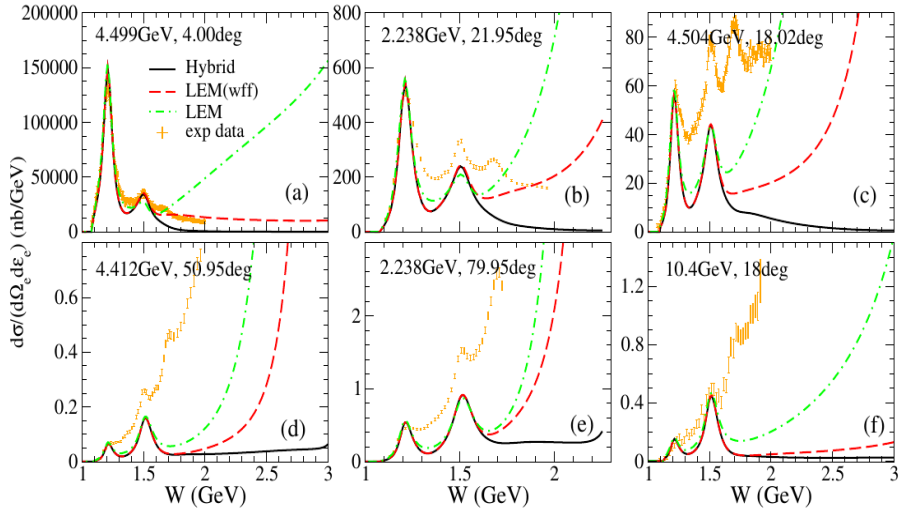
- **Single-pion production off the nucleon:** Low-energy models present a pathological behavior at high invariant masses (W).

We propose a way of extending the low energy model to the high W regime: Regge Theory.
Very shortly, the approach consists in replacing the Feynman propagators by the Regge propagators

$$\frac{1}{t-m_\pi^2} \longrightarrow \frac{\pi\alpha'_\pi}{\sin[\pi\alpha_\pi(t)]}$$

Valencia model PRD 76 (2007) 033005



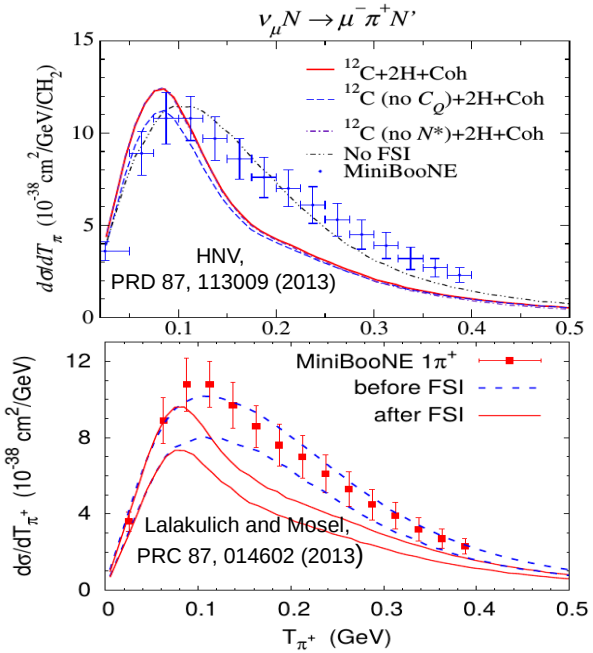


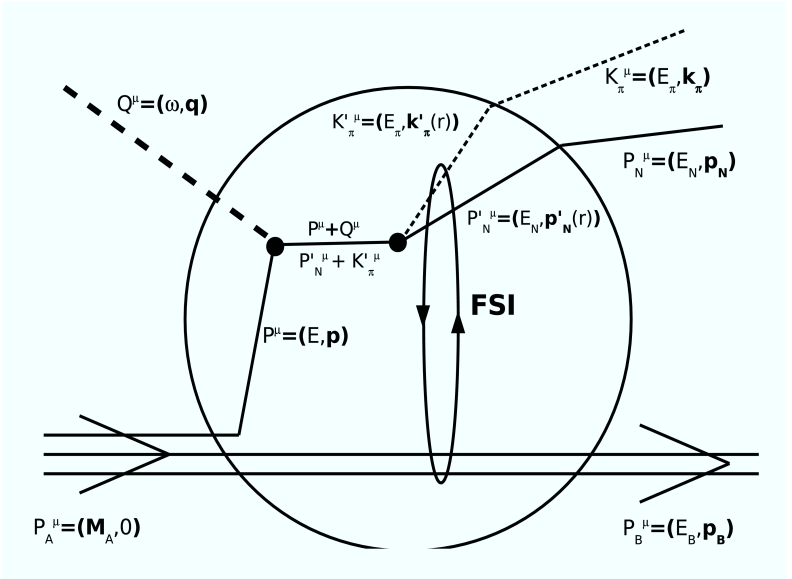
NEAR FUTURE

- **Single-pion production off the nucleus:** Problem with the the FSI.

We want to integrate the previous single-nucleon model with a completely relativistic and *quantum-mechanical description* of the initail and final-state of the hadrons (pion and nucleon):

- ✗ Relativistic Mean-Field model (RMF)
- ✗ Relativistic Multiple Scattering Glauber (RMSGA)





IV. Pion Production

I. Single-pion production on nucleons

Electroweak single-pion production off the nucleon: from threshold to high invariant masses

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[2] *Center for Neutrino Physics, Virginia Tech, Blacksburg, Virginia 24061, USA*

(Dated: December 15, 2016)

Purpose: Our goal is to develop a model for electroweak single-pion production off the nucleon, which is applicable to the entire energy range of interest for present and future accelerator-based neutrino-oscillation experiments.

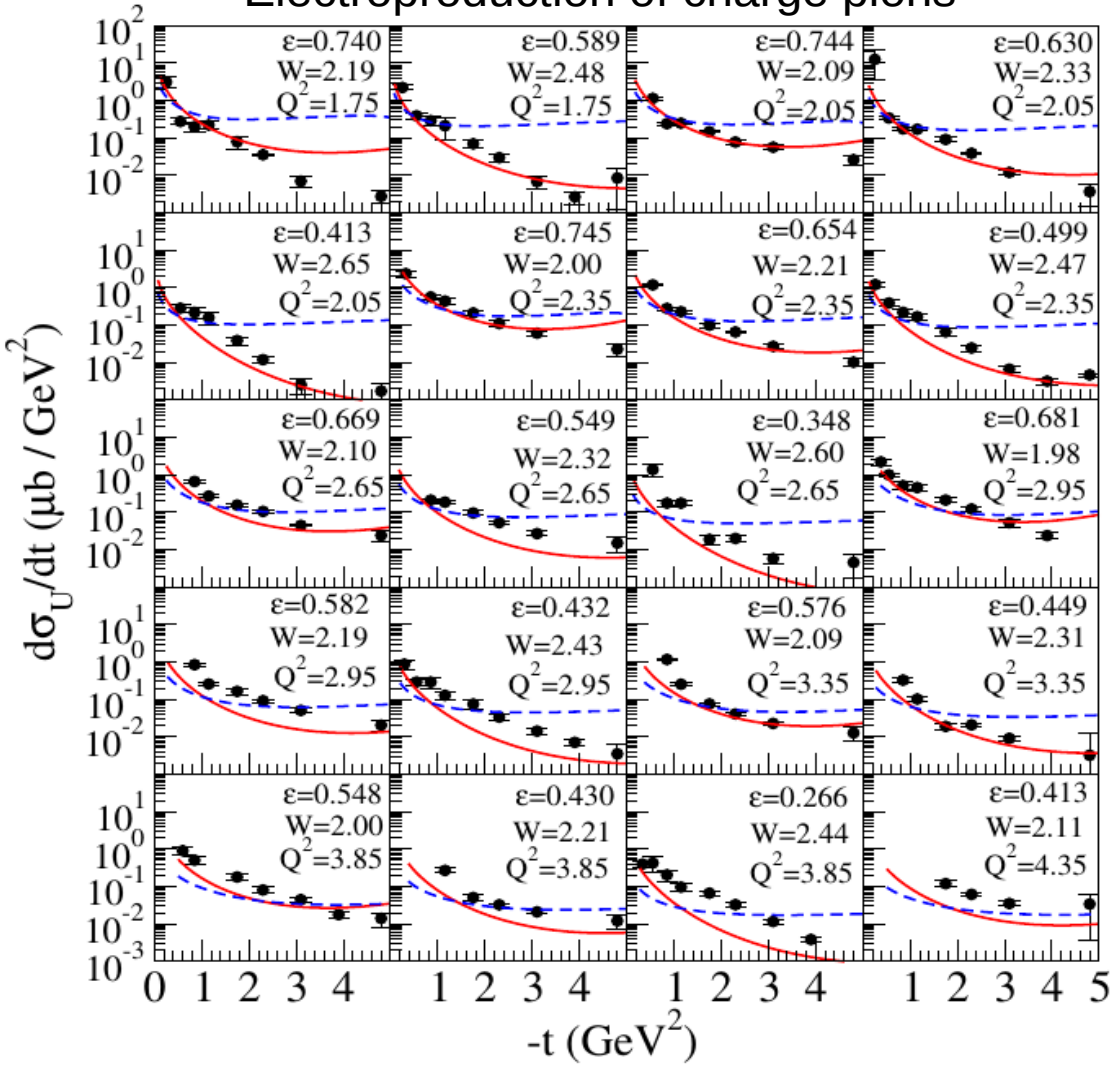
arXiv:1612.05511

December 2016

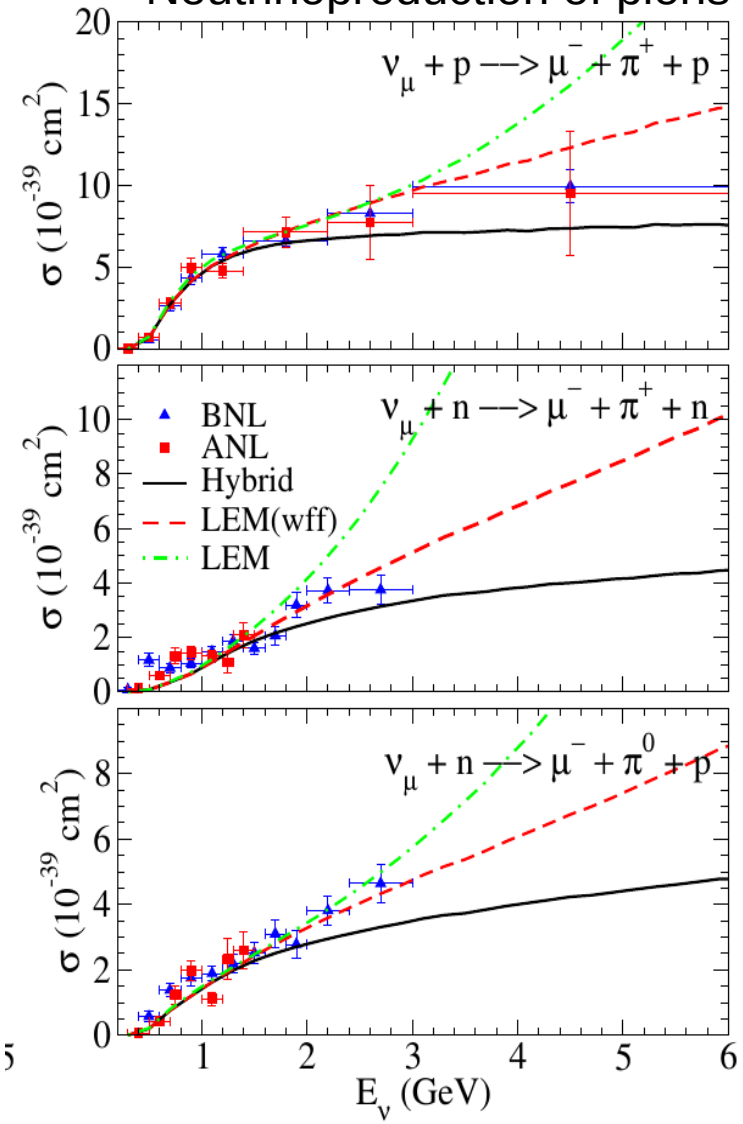
IV. Pion Production

I. Single-pion production on nucleons

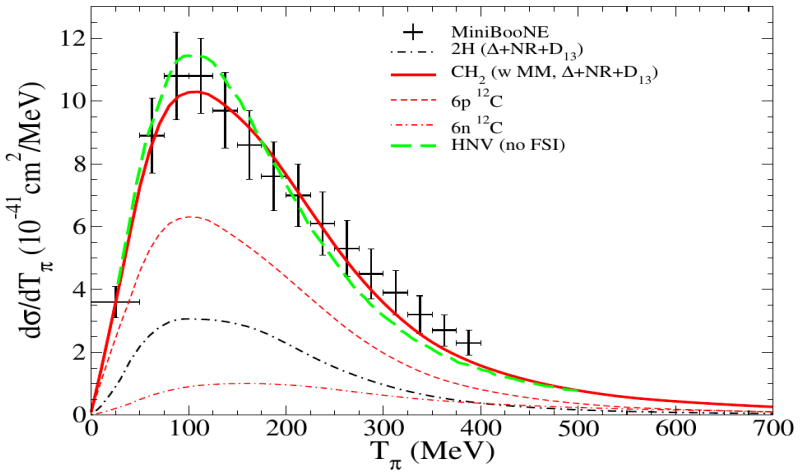
Electroproduction of charge pions



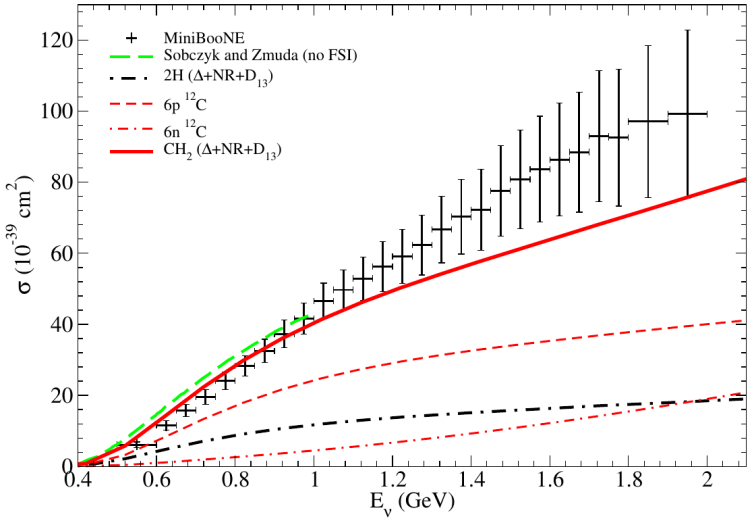
Neutrinoproduction of pions

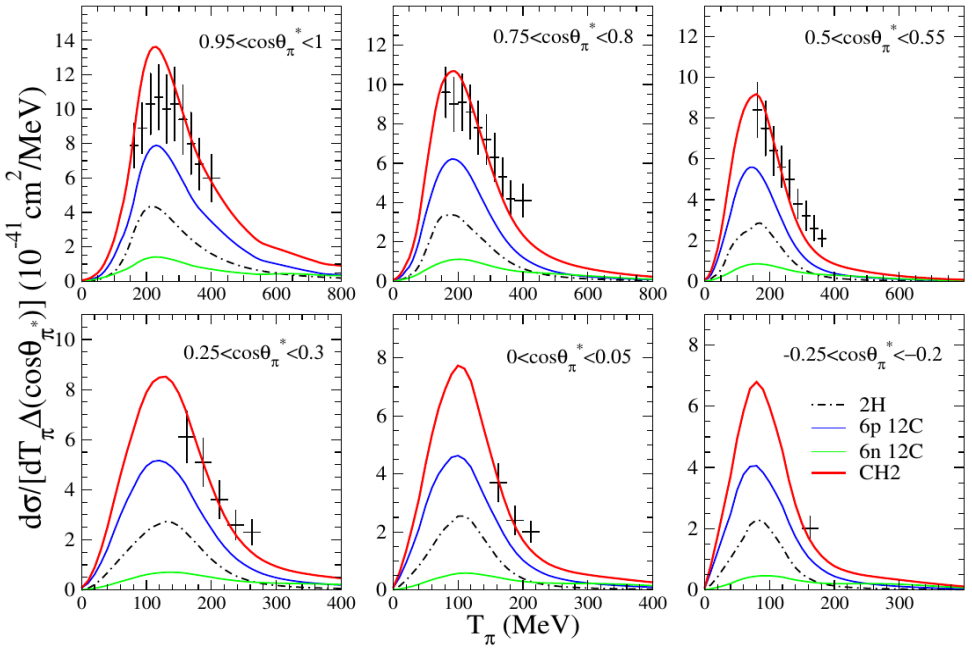


IV. Pion Production



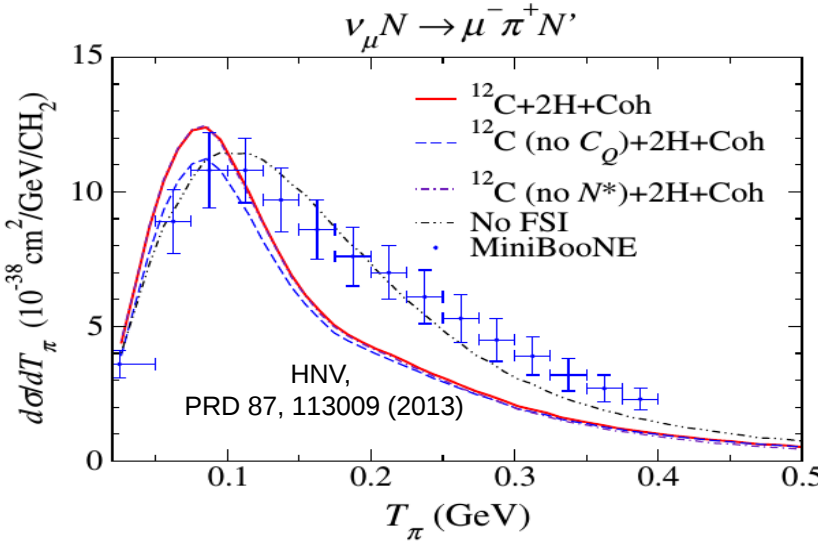
I. Single-pion production on nucleus

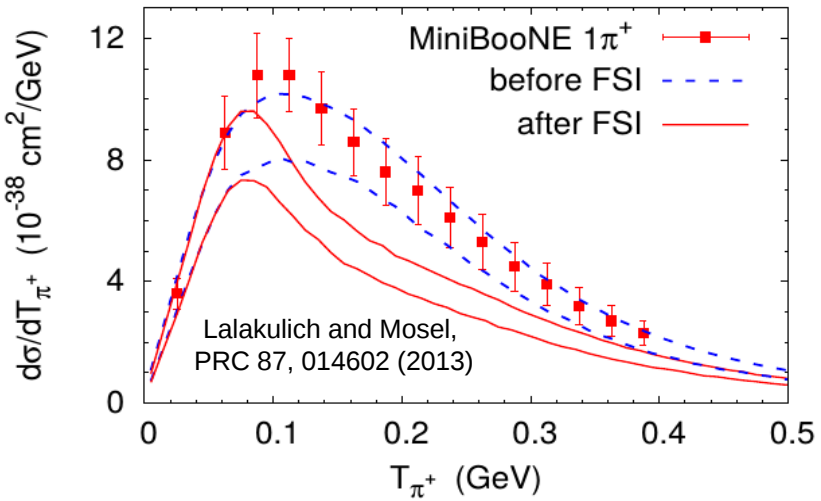




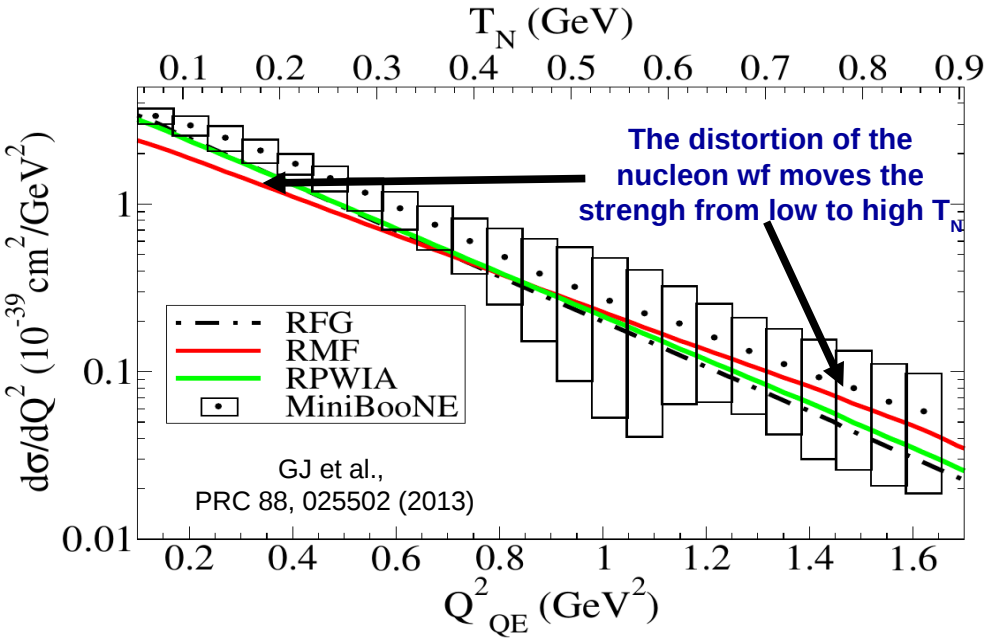
FSI not implemented yet!

IV. Pion Production





Pion production



Neutral-current QE scattering