NuWro - neutrino Monte Carlo event generator

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Abstract

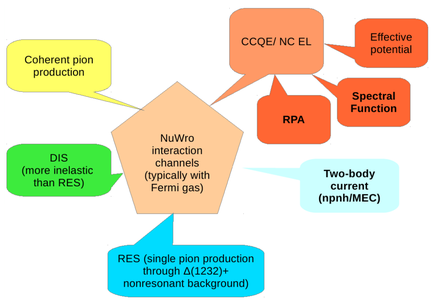
NuWro Monte Carlo event generator is described and then used in investigation of MEC events.

NuWro

NuWro is a Monte Carlo neutrino event generator under development at Wrocław University since $\sim$ 2006 [1].

- Open source code, repository at https://github.com/NuWro/nuwro
- Covers energy range from $\sim$ 100 MeV to TeV region.
- Flux and detector interfaces allow for a use in neutrino experiments.

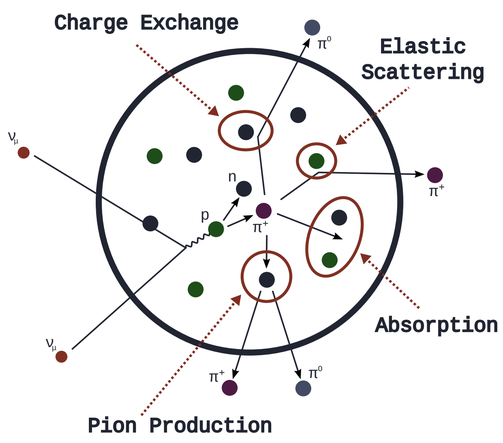
NuWro physics models



- QEL: $\nu_l\, n \to l^-\, p$
- RES, $W \leq 1.6$ GeV: mostly single pion production via $\nu_l\, N \to l^-\, \Delta\, N'$, $\quad \Delta \to \pi\, N''$
- DIS, $W > 1.6$ GeV
- COH: coherent pion production

NuWro FSI model

The basic picture is that of impulse approximation. Neutrino-nucleus scattering is a two-step process. Primary interaction on quasifree nucleons is followed by hadron rescatterings.



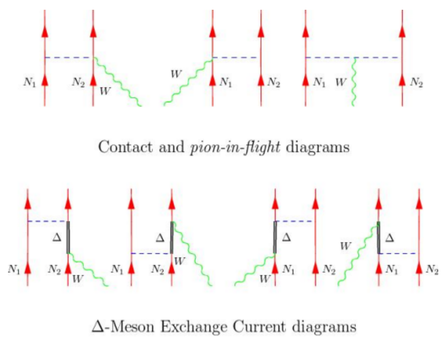
How pion cascade may change final state particles.

- A critical ingredient to compare to experimental data.
- NuWro includes FSI effects for pions and nucleons.

a) Pion rescatterings (and absorption) described by Oset et al model [2]

b) Nucleon rescatterings described by Pandharipande-Pieper model [3]. Nucleon-nucleon correlations effects will be included.

MEC mechanism

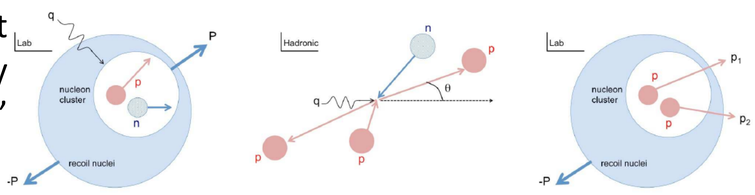


In case of neutrino nucleus scattering interaction can occur on nucleon-nucleon pairs via two body current mechanism.
Ab initio computations for electron scattering show that the mechanism must be include to describe quasi-elastic peak region.

NuWro MEC model

Contribution to lepton inclusive cross section taken from Valencia model [4]

Hadronic part described by "phase space" model [5].

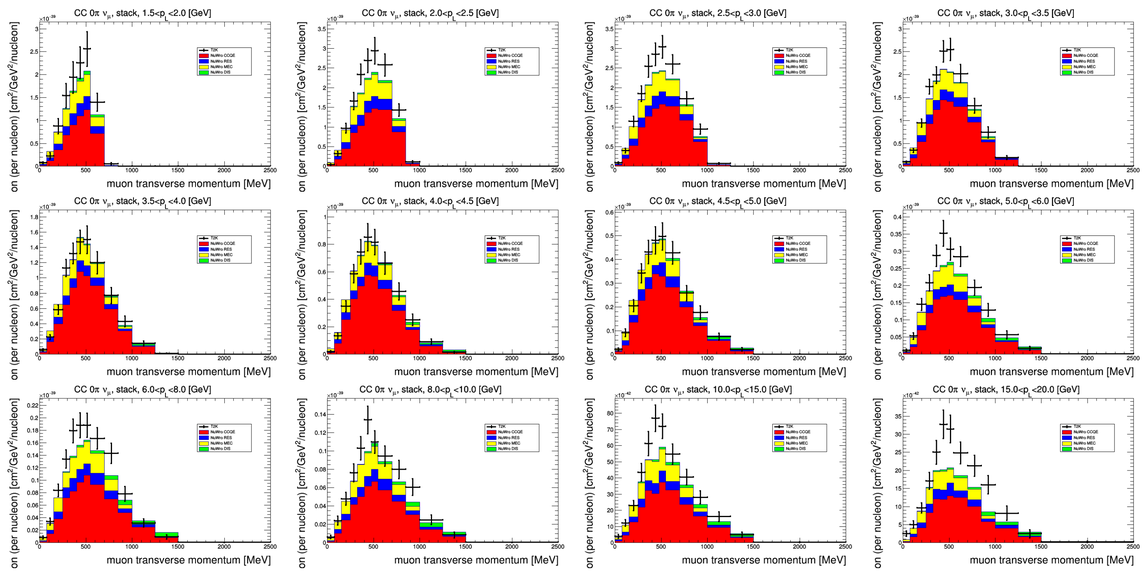


Uniform distribution of nucleons in the center of mass frame.

A search for MEC events

MEC events are supposed to be a significant fraction of CC0π events with a signal defined as no pions and arbitrary number of nucleons in the final state.

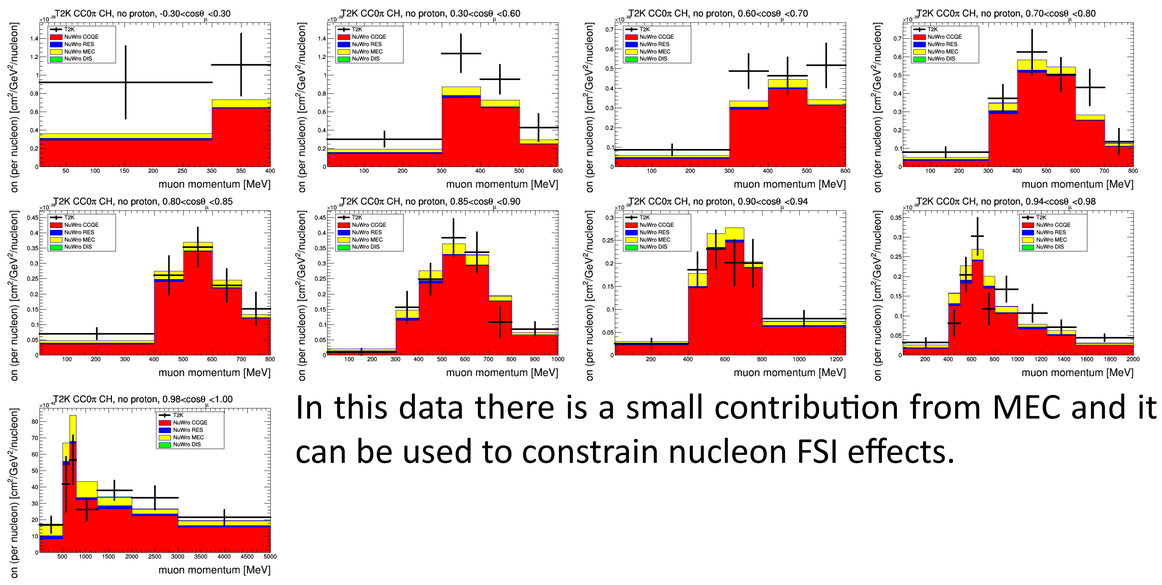
Example: MINERvA experiment results [6].



One may try to learn about MEC contribution from CC0π data from MINERvA, T2K, ν_μ and $\overline{\nu}_\mu$ measurements, but there is a lot of ambiguity.

Proton observables

It seems necessary to study proton observables. Example: T2K measurement of CC0π without a proton in an acceptance region [7].



In this data there is a small contribution from MEC and it can be used to constrain nucleon FSI effects.

Final remarks

- A lot of interest in MEC contribution to overall cross section
- Theoretical models predictions are quite different.
- There is a lot of new neutrino scattering data, also with proton detection, one must use MC generator to analyze results and learn about the MEC contribution.

References

[1] T. Golan, C. Juszczak, Jan T. Sobczyk, Phys.Rev. C86 (2012) 015505.

[2] L. L. Salcedo, E. Oset, M. J. Vicente-Vacas, and C. Garcia-Recio, Nucl. Phys. A484 (1988) 557.

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[4] J. Nieves, I. Ruiz Simo, and M. J. Vicente Vacas, Phys. Rev. C83 (2011) 045501.

[5] J.T. Sobczyk, Phys.Rev. C86 (2012) 015504; a figure - credit to T. Katori.

[6] D. Ruterbories [MINERvA], a presentation at NuInt2016, Toronto.

[7] T2K collaboration, arXiv:1802.05078 [hep-ex]