Realistic treatment of nuclear structure in the neutrino-nucleus interaction

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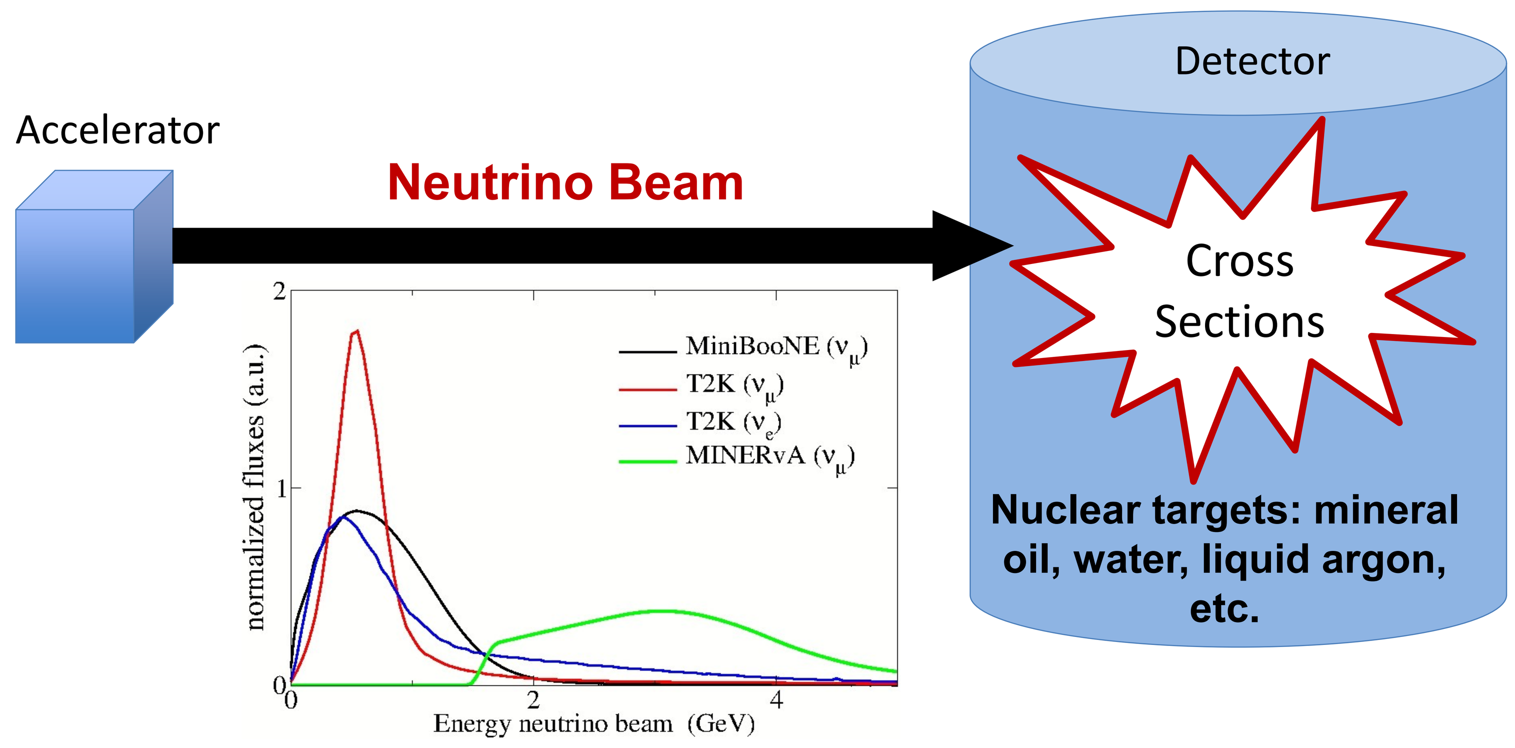
Context: Determination of neutrino oscillation parameters to establish the ν-Standard Model.

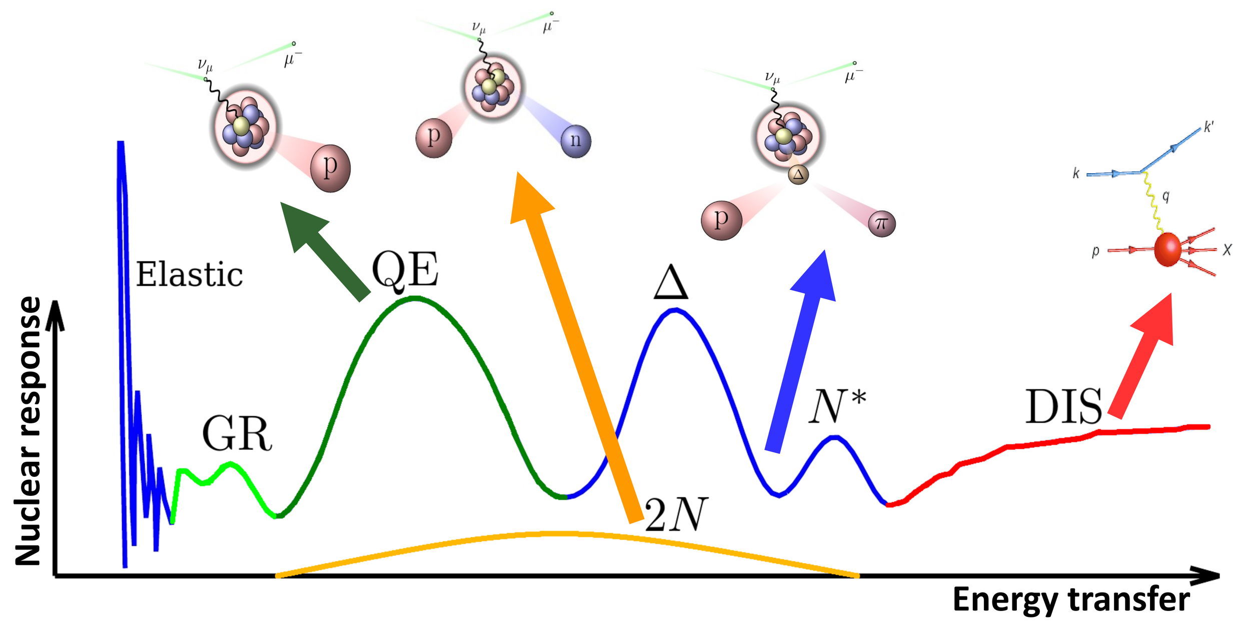
- Both present and future generations of accelerator-based ν-oscillation experiments use nuclei as target material.
- A good understanding of ν-nucleus scattering processes, including **nuclear effects**, is essential to reduce systematic errors in the experimental analyses.
- **Mono-energetic neutrino beams are not available:** we need theoretical models able to describe all possible reaction channels in the wide energy region covered by the neutrino beams.



Our work: Providing a theoretical model for the quasielastic regime including the meson exchange current contribution in the particle-hole channel

Depending on the energy transferred, **different ν-nucleus reaction mechanisms** may occur. In the energy region covered by present and future accelerator-based ν-oscillation experiments, the main reactions contributing the cross section are:

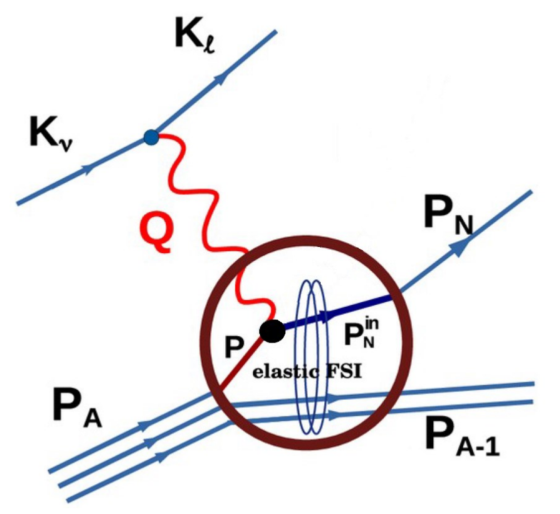
- One-nucleon knockout:
  - Giant resonances.
  - Quasielastic peak.
- Neutrino-induced one-pion production.
- Two-nucleon knockout.
- Deep inelastic scattering.



We focus on the **quasielastic peak:** scattering off a bound nucleon which is knocked out.

The modeling of the scattering process is handled by using two basic and well-founded approximations:

- **Impulse approximation**: the neutrino interacts only with the knockout nucleon in the nucleus.
- **First-order Born approximation**: only one boson is exchanged between the neutrino and the nucleus.



Our model

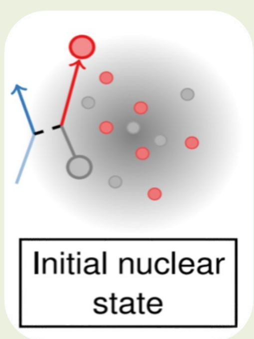
Nuclear dynamics

Mean-field models

- Nucleons are moving in an average potential, independently of one another.
- Binding energies, nuclear structure, etc. are naturally implemented.

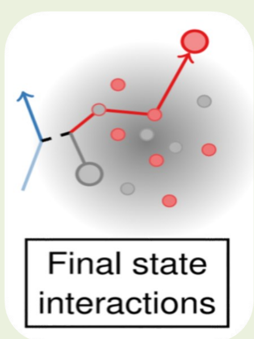
Initial nucleon

- Initial **bound state nucleons** are under the influence of the mean-field potential.
- Described by an **independent particle relativistic mean-field** model.



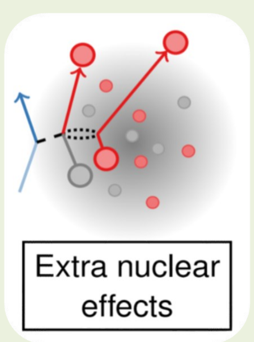
Final nucleon

- Solution of the Dirac equation in the presence of relativistic potentials. **Final-state interactions** are taken into account.
- Variety of potentials. Our choice: **energy-dependent relativistic mean-field**, it preserves orthogonality between initial and final states (Pauli Blocking).



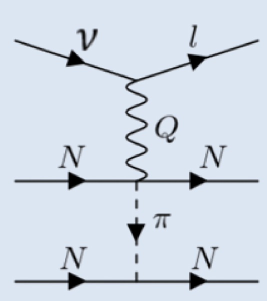
Nucleus

- Shell-model occupations and background due to short-range correlations taken from a realistic spectral function.

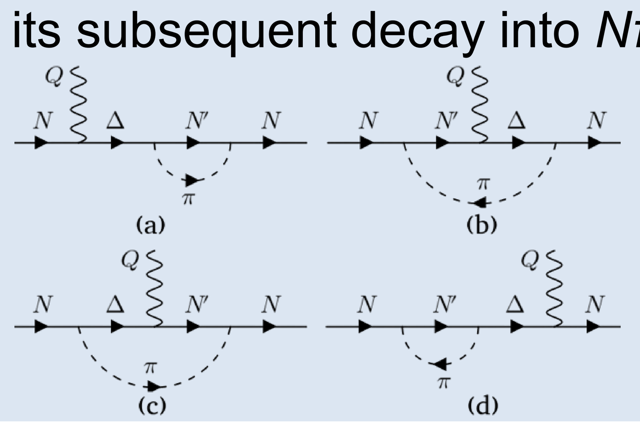


Meson exchange currents

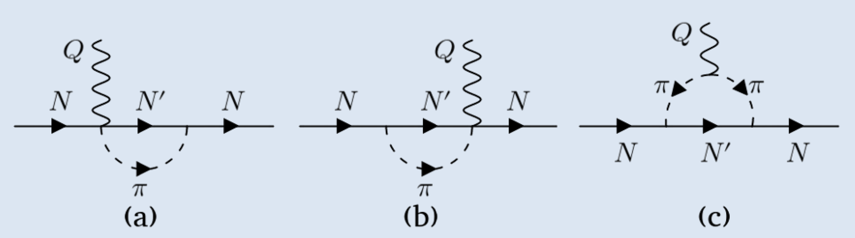
- In the particle-hole channel, apart from the well-known one-body current operator, we include **one-pion exchange effects** by incorporating a **two-body meson exchange current operator**.
- When the particle-hole excitation occurs through a two-body current, one of the outgoing nucleons becomes bound to the nucleus again entering in the hole left by the other. The hadronic final state consists in just a nucleon and a residual nucleus.



- **Delta resonance mechanism**: excitation of the Δ(1232) resonance and its subsequent decay into $N\pi$.



- **Background** contributions deduced from the chiral perturbation theory Lagrangian of the pion-nucleon system.

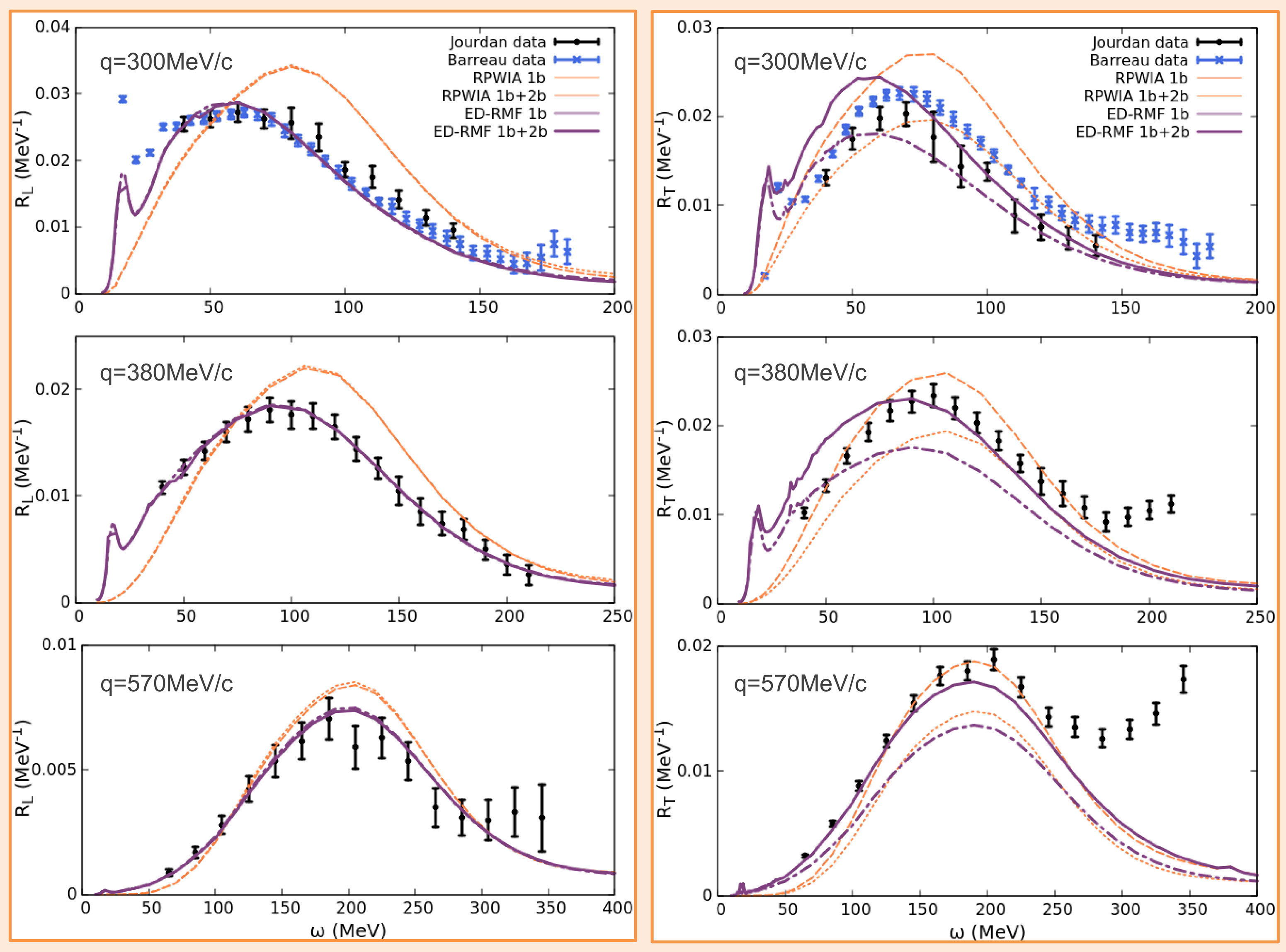


The connection of **electron scattering** experiments with neutrino scattering allows to **scrutiny the available theoretical models** by a first comparison to electron scattering data.

Results

$$\frac{d\sigma}{dE_f d\Omega_f} = \sigma_{Mott}\{v_L(R_p^L + R_n^L) + v_T(R_p^T + R_n^T)\}$$

Electromagnetic inclusive responses of ^{12}C



Electromagnetic inclusive cross section of ^{40}Ca