Recent and planned experiments drive the interest for medium-energy neutrino physics

Electroweak pion production on nucleons and nuclei

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N-Δ transition form factors (1)

The weak production of the Δ on a free nucleon is modeled within a phenomenological form-factor approach. The vector form factors are relatively well known from the conserved current triplet current hypothesis (CNC). A recent fit to electroproduction helicity amplitudes from Rosh and Mainz experiments yields

\[ C_V^0 = \frac{2.14 D_V}{1 + Q^2/4 MeV^2}, \]

\[ C_T^0 = \frac{-1.51 i}{2.14}, \]

\[ C_V^1 = \frac{0.8 D_V}{1 + Q^2/0.76 MeV^2}, \]

with \( D_V = (1 + Q^2/2 M^2) e^{-2} \) the dipole function and \( M = 949 \) MeV.

In the axial vector, a good agreement with BNL data is reached with the parametrization [2]

\[ C_V = 0, C_T = -C_V^1/4 \]

More precise data is urgently needed to resolve the differences between the existing bubble-chamber data sets.

Nuclear model

Adopting the impulse approximation (IA), and writing the nuclear wave functions as an independent-particle model, the involved nuclear current matrix elements can be reduced to a form similar as in the free-nucleon case.

\[ < J_{\text{had}} | \bar{p} s_A | k_0 > = \sum_{\sigma} \langle k_{A1} \sigma | p \bar{s} | k_{A2} \rangle \delta (k_{A2} - k_0), \]

The bosonization spinor is

\[ u_{\delta}(k_0) = \frac{1}{\sqrt{2}} \langle \phi_{\delta}(P - k_0) | \gamma_\mu | s \rangle, \]

where the \( \phi_{\delta}(P) \) are computed in the Hartree approximation to the \( \sigma \rightarrow \omega \) Walcka model [5]. The subscript \( \delta \) refers to a set of quantum numbers specifying a single-particle orbital. This way, we naturally incorporate

\( \sqrt{V} \)

Form factor

\( \sqrt{W} \)

Nuclear binding effects

\( \sqrt{P} \)

Pauli exclusion principle

This approach is known as the relativistic plane-wave impulse approximation (RPWIA).

\[ \nu + A \rightarrow l + (A-1) + N + \pi \]

\[ \Delta \text{ medium modifications} \]

As the Δ is created in the nuclear medium, its mass and width need to be modified with respect to their free values. In the calculation of Δ(γ, nπ) and Δ(γ, pπ) cross sections, the recipe [6]

\[ M_{\Delta} \rightarrow M_{\Delta} + 30 \text{ MeV}, \]

\[ \Gamma \rightarrow \Gamma + 30 \text{ MeV}, \]

leads to a fine agreement with data in the energy regime where the reaction is dominated by Δ creation.

OUTLOOK

Starting from the eightfold exclusive cross section

\[ \sigma^{\nu + A \rightarrow l + (A - 1) + N + \pi} \]

our framework aims at a large flexibility in calculating various observables, related to both inclusive and exclusive measurements with a pion, a nucleon, or both in the final state.

However, as a prerequisite to study exclusive channels, the RPWIA pion distributions must be corrected for final-state interaction (FSI) effects.

As a next step, we plan to compute FSI effects. For fast pions, this can be achieved in a relativistic and quark-size-favored Glashow approach, whereas for low-energy pions and nucleons, one has to resort to Monte-Carlo techniques. In this sense, our RPWIA results serve as the starting point from where the final hadronic states are propagated through the medium.

Other extensions to our model include

- Study the role of background terms in Δ scattering
- Extension to the second-resonance region

References