Dynamical coupled-channels study of neutrino-induced meson production reactions on nucleon at forward-angle limit

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Since the breakthrough measurements of neutrino mixing angle θ_{13}, the main issue of the neutrino physics has been shifting to determining leptonic CP phase and neutrino mass hierarchy. For making a progress towards this direction by analyzing data from the next-generation long-baseline and atmospheric experiments, neutrino-nucleon and neutrino-nucleus scattering cross sections need to be understood within 10% or better accuracy for the relevant neutrino energy region from sub GeV to a few GeV, and $Q^2 \leq 4$ (GeV/c)^2. This kinematic region covers neutrino-nucleus interactions of different characteristics, namely, the quasi-elastic (QE), resonant (RES), and deep-inelastic scatterings (DIS) (left panel of Fig. 1). Thus a combination of different expertise is necessary to tackle the problem. This motivates theorists and experimentalists to get together to organize a new collaboration, e.g., see Ref. [1].

Here we are concerned with the RES region which covers the $\Delta(1232)$ peak and, through the second and third resonance regions, up to the region overlapping with the DIS region. In order to describe the neutrino-induced reactions in the whole RES region, the reaction model has to take into account the coupled-channels effects and satisfy unitarity for the multichannel reactions. However, such a model for the neutrino-nucleon reactions has not been developed so far.

In this context, our recent development of a dynamical coupled-channels (DCC) model is quite encouraging [2]. Our DCC model is based on a comprehensive analysis of $\pi N, \gamma N \to \pi N, \eta N, K\Lambda, K\Sigma$ reactions in the RES region, taking account of the coupled-channels unitarity including the $\pi\pi N$ channel. An extension of the DCC model to the neutrino reaction is fairly straightforward.

As a first step toward accomplishing such an extension of our DCC model to the weak interaction sector, we made a computation of the neutrino-induced meson production cross sections at the forward angle limit, which is characterized by the structure function F_2 at $Q^2 = 0$, by invoking the PCAC hypothesis [3]. The resulting F_2 function is presented in the middle and right panels of Fig. 1. Here we remark that the contributions of $\nu N \to lKY$, $\nu N \to l\eta N$, and $\nu N \to l\pi\pi N$ are, for the first time, estimated with a multichannel reaction model that has been rather extensively tested by the data of πN and γN reactions in the RES region.

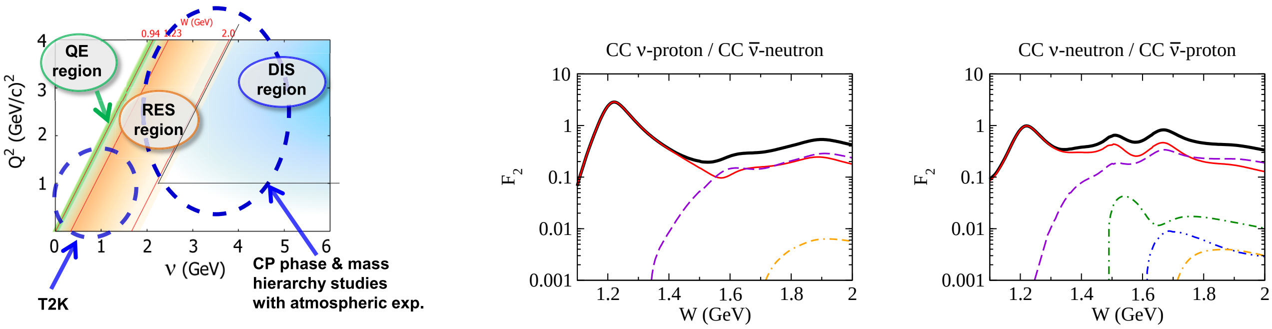

Figure 1: [Left panel] Kinematic region relevant to the neutrino-parameter searches in the future neutrino-oscillation experiments. [Middle and right panels] W-dependence of the F_2 structure function for $\nu N \to lX$ ($X = \pi N, \pi\pi N, \eta N, K\Lambda, K\Sigma$) at the limit $Q^2 \to 0$, plotted for W from the 1π-production threshold up to 2 GeV. (Thick solid curves) total contribution; (thin solid) contribution from $X = \pi N$ only; (dashed) $X = \pi\pi N$ only; (dashed-dotted) $X = \eta N$ only; (dashed-two-dotted) $X = K\Lambda$ only; (two-dashed-dotted) $X = K\Sigma$ only.

References

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