The In-Medium Effects on the Neutrino Reaction in Dense Matter

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Nowadays neutrino scattering becomes one of useful tools for understanding neutrino physics as well as neutrino astrophysics. But most of the scattering data were extracted by the neutrino scattering off target nuclei. Moreover incident neutrino energy ranges from a few MeV to tens of GeV. As well known in other projectiles, we need to understand target nuclear structure probed by the weak interaction. Then it would be very helpful to know from which energy region we have to include the structure effect and how to include it in the analysis of neutrino scattering.

Moreover, strong recent evidence for the modification of nucleon properties in a nuclear medium has been reported using the electromagnetic (EM) nucleon form factors measured in polarized $(\vec{e}, e'\,\vec{p})$ and $(\vec{e}, e'\,\vec{n})$ scattering on some light nuclei [1]. Since the weak form factors also may be affected by the modification of the EM form factors, Since the weak-vector currents and EM currents form iso-vector and vector currents, one might naturally expect that the modification of weak-vector form factors occurs in a similar manner to that of the EM form factors. Refs. [2] explored nuclear structure effects in those data directly using robust nuclear structure and reaction theories in the relativistic framework.

In this work, we report one of the answers regarding the question. In Fig. 1, we show our theoretical total cross sections of neutrino and anti-neutrino scattering off hydrogen and ^{12}C target and compared to the MiniBooNE and NOMAD neutrino data, whose energy ranges are up to about 10^0 and 10^2 GeV, respectively [3]. These results were carried out by the elementary process, i.e. neutrino scattering off a free nucleon, by taking into account the in-medium effect for ^{12}C using the density-dependent form factors estimated by the quark meson coupling (QMC) model [4]. Effects of the in-medium (difference between red and black curves) turn out to be small compared to the experimental error bars. In particular, neutrino scattering above 1 GeV can be properly described by the elementary process, irrespective of neutrino types and their current types. But, below 1 GeV region, it is found that one needs to include nuclear structure as well as Fermi motion of nucleons for the neutrino scattering.

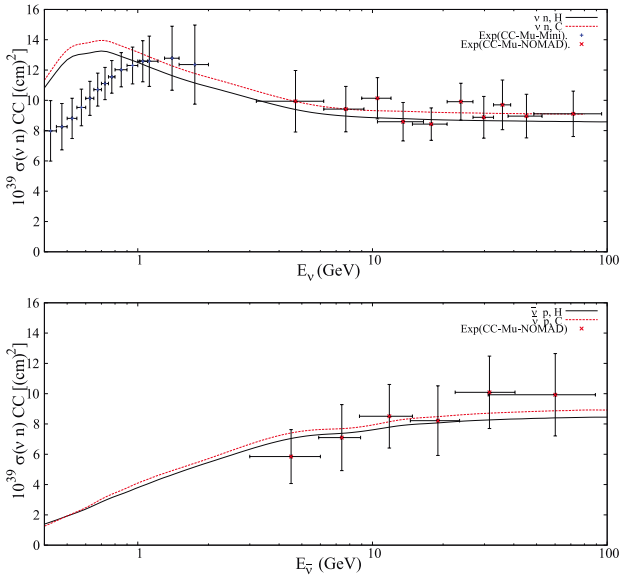

Figure 1: (Color online) Results of $\nu + n \to \mu^- + p$ (upper) and $\overline{\nu} + p \to \mu^+ + n$ (lower) for a nucleon in H and ^{12}C. Results for a free neutron (proton) and neutron (proton) in a carbon target are denoted as solid (black) and dotted (red) curves, respectively. Data are MiniBooNE and NOMAD in Refs. [5] and [6], respectively.

References

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