Supernova-, Solar- and Reactor-Neutrino Detection and Precise Theoretical Calculation of Neutrino Capture Cross Section on ^{13}C [1]

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The natural abundance of ^{13}C is 1.07 % in carbon isotopes. As the threshold for charged-current reactions on ^{12}C is slightly more than 13 MeV, ^{13}C is an attractive target to detect very low-energy neutrinos. The background is from supernova and ^{8}B solar neutrinos. In scintillator-based experiments, ^{13}C may be useful to sort out uxes of various avors from supernovae.

A new shell-model Hamiltonian for p-shell nuclei, SFO [2], is used to evaluate neutrino cross sections on ^{13}C. With this new Hamiltonian the magnetic properties of p-shell nuclei are considerably improved compared to conventional Hamiltonians such as Cohen-Kurath (CK) Hamiltonian [3]. Here, we study neutrino-nucleus reactions, which are induced mainly by excitations of Gamow-Teller and spin-dipole states as well as isobaric analog states. The SFO Hamiltonian, which was constructed for use in the p-sd shell configurations including up to 2–3 $\hbar\omega$ excitations, can describe well the magnetic moments of p-shell nuclei systematically and Gamow-Teller (GT) transitions in ^{12}C and ^{14}C with a small quenching for spin g-factor and axial-vector coupling constant: i.e., $g_A^{eff}/g_A = g_s^{eff}/g_s = 0.95$. In case of CK, where configuration space is restricted to within p-shell, a large quenching factor of $g_A^{eff}/g_A = 0.69$ is used. The exclusive cross sections, ^{12}C (ν_e, e^-) ^{12}N ($1^+_{g.s.}$), obtained by shell-model calculations with SFO and CK are are shown in Fig. 1 together with the experimental values. The SFO is found to reproduce the experimental values very well. The cross sections for SFO are enhanced compared with those for CK.

The charged-current cross sections leading to various states in the daughter ^{13}N and the neutral-current cross sections leading to various states in the daughter ^{13}C are obtained with the use of SFO [1]. Simple polynomial fits to those cross sections are also provided for quick estimates of the reaction rates (see Ref. [1]). In Fig. 2, cross sections induced by Gamow-Teller and isobaric analog transitions are compared between SFO and CK. The SFO give larger cross sections compared with CK [4].

One possible application of these cross sections could be to search for electron neutrino appearance in the reactor antineutrino ux and determine the mass hierarchy [5], being free from supernova and solar neutrino background. Ideally one would like to be as close to the reactors as possible much like experiments searching for the neutrino magnetic moment. However, in this case reactor neutrino ux uncertainties can be sizable. This is also true for the energy-integrated count rate, which is between 5.2 and 13.0 MeV. One possible way to reduce such uncertainties is to use much more abundant electron antineutrinos to estimate the reactor flux. This can be achieved using neutral-current scattering.

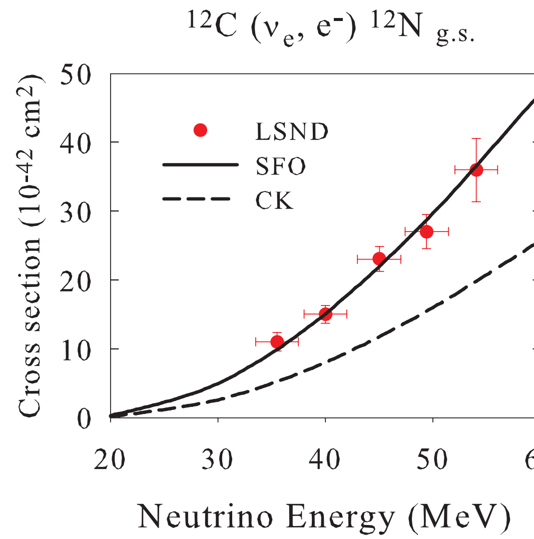

Figure 1: The exclusive cross sections for ^{12}C (ν_e, e^-) ^{12}N ($1^+_{g.s.}$) in shell-model calculations with SFO and CK.

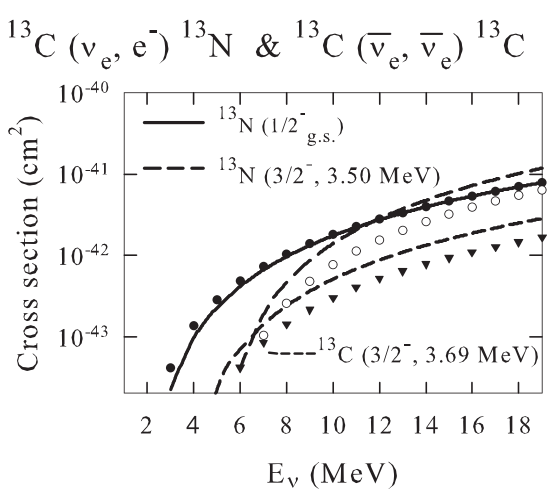

Figure 2: Calculated charged-current cross sections for ^{13}C (ν_e, e^-)^{13}N to the ground ($1/2^-$) and $3/2^-$ (3.502 MeV) states and neutral-current cross sections for ^{13}C ($\overline{\nu}_e$, $\overline{\nu}_e$')^{13}C to $3/2^-$ (3.685 MeV) state with SFO. Calculations with CK are indicated by circles anf triangles.

References

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