New Neutrino-Nucleus Reaction Cross Sections at Solar, Reactor and Supernova Neutrino Energies

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Remarkable improvements in the evaluations of neutrino-nucleus reaction cross sections are obtained based on new shell-model Hamiltonians at solar, reactor and supernova neutrino energies. New shell-model Hamiltonians can successfully describe spin responses in nuclei and explain shell evolutions toward drip-lines. A common feature of the new intearctions is that they have proper tensor components.

A new shell-model Hamiltonian for p-shell nuclei, SFO[1], which proved to be quite successful in the evaluation of the ν-^{12}C cross sections [2,3], is used to evaluate charged- and neutral-current neutrino cross sections on ^{13}C leading to low-lying states in ^{13}N and ^{13}C [3]. ^{13}C is an attractive target for detecting very low energy neutrinos as it is free from the contamination of ^{12}C at $E_\nu \leq 13$ MeV. A knowledge of these cross sections would help scintillator-based searches for low-energy electron neutrinos in environments dominated by the electron antineutrinos, such as nuclear reactors.

A new shell-model Hamiltonian for pf-shell nuclei, GXPF1J, is shown to reproduce well ν-^{56}Fe cross section for DAR neutrinos [4]. It describes also well the Gamow-Teller (GT) strengths in Ni isotopes, in particular ^{56}Ni [5, 6]. Neutral-current reactions on ^{56}Ni are evaluated, and proton-emission cross sections are found to be enhanced due to a large spreading of the GT strength and lead to enhanced production of ^{55}Mn element in supernova explosions in population III stars [5].

Gamow-Teller (GT) strength in ^{40}Ar is studied by shell-model calculations with monopole-based universal interaction [7], which has tensor components of π+ρ-meson exchanges. Calculated GT strength is found to be consistent with the experimental (p, n) reaction data. Cross sections for the charged-current reaction, ^{40}Ar (ν_e, e^-) ^{40}K, are evaluated by a hybrid model, where contributions from the GT and IA transitions are obtained by shell-model calculations while other multipoles are treated by RPA. A better evaluation of the cross section for the GT contributions has been achieved [8]. An enhancement of the cross section for solar neutrinos from ^{8}B is found compared to previous calculations. An accurate knowledge of the cross section is important for the studies of supernova neutrinos and neutrino oscillations. Implications on the effects of neutrino oscillations will be discussed.

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