Reactions on ^{40}Ar involving solar neutrinos and neutrinos from core-collapsing supernovae

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Neutrino (ν) reactions on ^{40}Ar were of astrophysical importance because the reactions are used to detect the solar ν emitted from ^{8}B via the pp-chains in the sun through the liquid argon time projection chamber (LArTPC) in the ICARUS (Imaging of Cosmic and Rare Underground Signals) [1]. Since the maximum energy of the solar ν is thought to be about 17 MeV in the standard solar model, the ν reactions are sensitive to discrete energy states of ^{40}Ar. The Q-value for the ^{40}Ar(ν_e, e^-)^{40}K* reaction is 1.50 MeV while it is 7.48 MeV for the ^{40}Ar($\bar{\nu}_e$, e^+)^{40}Cl* reaction. Therefore, ^{40}Ar($\bar{\nu}_e$, e^+)^{40}Cl* reactions might be kinematically disfavored in the low energy ν such as solar ν's. In this respect, ^{40}Ar was claimed to effectively distinguish the ν_e and $\bar{\nu}_e$ emitted from the sun.

Recently, Ref. [1] revised previous work by focusing on the possible detection of ν oscillation of supernova (SN) ν's. The ν's from the SN explosion can give valuable information about the ν properties, because they traverse regions of dense matter in the exploding star where matter enhanced oscillations take place.

Since ν energies from the SN explosion are expected to be higher than the solar ν [2], one needs to consider the contributions from higher multi-pole transitions. Moreover $\nu(\bar{\nu})$ energies and flux emitted from the core collapsing SN explosion are believed to be peaked from a few to tens of MeV energy region [2]. Therefore, the $\nu(\bar{\nu})$-induced reactions on ^{40}Ar are sensitive to the higher excited states of the nucleus beyond nucleon thresholds, which eventually decay to lower energy states with the emission of some particles.

Here we report more advanced results [3] based on the QRPA calculation for $\nu(\bar{\nu})$-^{40}Ar reactions by solar and SN ν's, whose energy ranges are considered up to 30 and 80 MeV region, respectively. In particular, we focus on roles of higher excited states around 20 MeV although they are not verified at the experiments. Our results decrease the cross sections of ^{40}Ar(ν_e, e^-)^{40}K* reaction about 3.5 times and increase about twice those of ^{40}Ar($\bar{\nu}_e$, e^+)^{40}Cl* reaction compared to the previous calculations [1]. Consequently, the expected 12 times difference between the reactions at E_ν= 80 MeV is drastically reduced about twice, as shown in Fig. 1 [3].

Other related ν-reactions on ^{40}Ar target through charged and neutral currents are shown in Fig. 2.

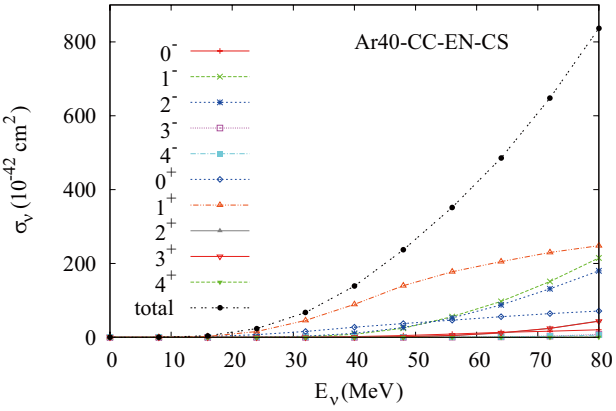

Figure 1: (Color online) Cross sections by CC current, ^{40}Ar(ν_e, e^-)^{40}K*, for solar and SN ν's.

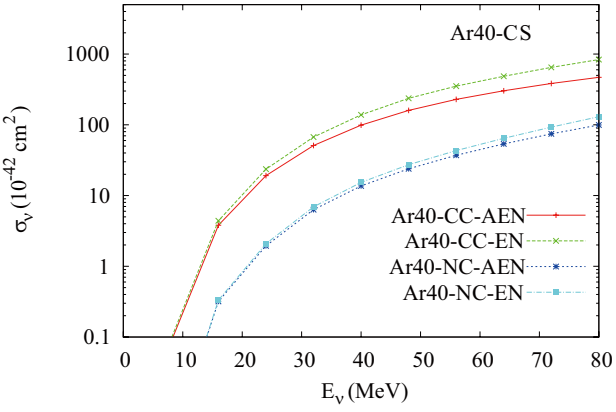

Figure 2: (Color online) Comparison of cross sections for relevant ν reactions on ^{40}Ar for SN ν's.

References

[1] Gil-Botella, I., Rubbia, A.: 2003, *J. Cosmol. Astropart. Phys.*, **10**, 009.
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[3] Cheoun, M.-K., Ha, E., Kajino, T.: 2011, *Phys. Rev. C*, **83**, 028801.