New Neutrino Source for the Study of Solar Neutrino Physics in the Vacuum-matter Oscillation Transition Region [1]

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One of open issues related to the vacuum-matter oscillation transition region in the solar neutrino physics is the determination of electron-neutrino survival probability $P(\nu_e \rightarrow \nu_e)$ in that region, which is also closely related to the questions such as existence of sterile neutrinos and/or non-standard neutrino interactions (NSI), roles of CNO cycle in the Sun (metallicity problem), etc.

In this work [1], we propose a new artificial accelerator-based electron-neutrino source for experiments of the vacuum-matter oscillation transition region. By adjusting incident proton energy, we can produce a specific unstable isotope as an efficient electron-neutrino source. Unstable isotope, ^{27}Si, is our main neutrino source, which can be produced through ^{27}Al(p,n)^{27}Si reaction and emits electron-neutrinos through radioactive decay processes. In this case, the neutrinos can have an energy range, $0 < E_\nu < 5$ MeV, corresponding to the transition region.

Productions of ^{27}Si through p+^{27}Al reaction are simulated by using GEANT4 code [2] with JENDL-4.0/HE data [3]. Incident proton energy is chosen to be 15 MeV due to the following reasons. (1) There exist only limited numbers of experimental data in the EXFOR database. (2) By choosing this energy, we can suppress productions of unnecessary unstable isotopes (^{23}Mg, ^{25}Al, ^{26}Si, etc.) which can emit ν_e or $\bar{\nu}_e$ backgrounds. A schematic diagram of the target geometry is drawn in Fig. 1. For a 15 MeV proton beam with 10 mA, 3.55×10^{13} ^{27}Si per second (^{27}Si/s) in the ^{27}Al target are expected.

Reaction rates with respect to the neutrino energy generated for the neutrino source are plotted in Fig. 2. For both ^{37}Cl and ^{71}Ga, neutrinos having the continuous energy ($E_{th} < E_{\nu_e} \lesssim 3.79$ MeV) and monoenergies (3.97 MeV and 4.813 MeV) interact with the isotopes. Contributions of the neutrino with two mono-energies are marginal. Consequently, we can obtain the reaction rates or flux-averaged cross sections for both ^{37}Cl(ν_e,e$^-$)^{37}Ar and ^{71}Ga(ν_e,e$^-$)^{71}Ge reactions in the neutrino energy region less than ~3.79 MeV. This energy region is close to the vacuum-matter oscillation transition region in the solar neutrino physics. One can see that widths of energy distributions of reaction rates for deuteron targets are more narrow than those for both ^{37}Cl and ^{71}Ga because of the reaction thresholds. With this feature, we can also have a chance to obtain reaction rates or energy averaged cross sections for ^{2}H(ν_e,e$^-$pp) and ^{2}H(ν_e,$\nu_e$np) reactions with narrow neutrino energy region. This is a unique feature in the present work because most experimental data were obtained by using neutrino sources from pion decay where the neutrino has broad energy region 0 ~ 55 MeV.

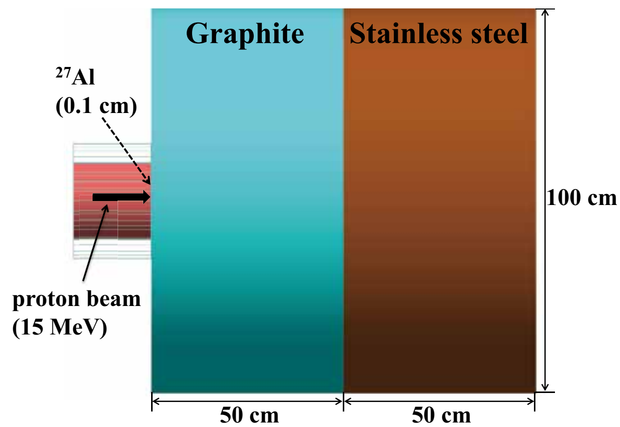

Figure 1: Schematic diagram of the ^{27}Si production target geometry.

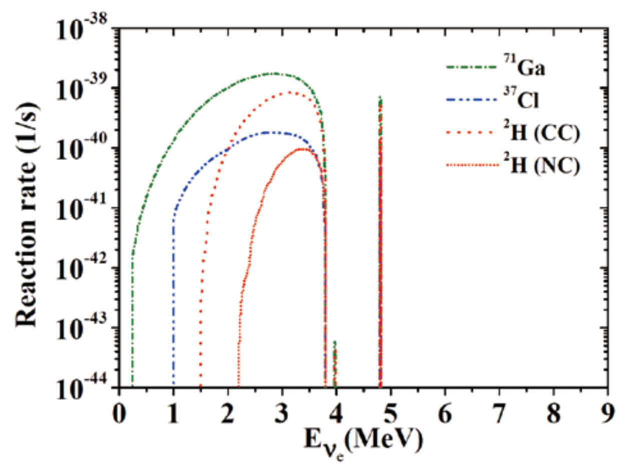

Figure 2: Reaction rates via ^{37}Cl(ν_e,e$^-$)^{37}Ar, ^{71}Ga(ν_e,e$^-$)^{71}Ge, ^{2}H(ν_e,e$^-$pp) and ^{2}H(ν_e,$\nu_e$np) reactions. The neutrinos are generated from decay of ^{27}Si which are produced by the 15 MeV and 10 mA proton beam on a ^{27}Al target.

References

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[2] Agostinelli, S., et al.: 2003, *Nucl. Instrum. Meth. A*, **506**, 250.
[3] JENDL-4.0/HE, http://wwwndc.jaea.go.jp/index.html.