Solar Neutrino Responses of ^{176}Yb and ^{160}Gd

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The combined results of solar neutrino measurements from Kamiokande and from Gallex and Sage are inconsistent with the standard solar model to explain the burning process based on the P-P chain and CNO cycle. If the Kamiokande results are taken as a measurement of the ^{8}B neutrinos and the Gallex and Sage results taken as a measurement of the integrated flux including *pp*, ^{7}Be, and ^{8}B neutrinos, the low integrated flux measured by Gallex and Sage implies a negligible flux of ^{7}Be neutrinos. This is, however, inconsistent with the solar energy cycle, since ^{8}B is created in a minor branch of the ^{7}Be decay. This problem has led to the speculation that the electron neutrinos from the ^{7}Be decay are highly converted through flavor changing (neutrino oscillation) in their flight from the reaction site in the sun to the detector on earth [1, 2, 3]. The most important piece of information lacking is a direct measurement of the electron neutrino flux from the sun at the energy corresponding to the ^{7}Be decay neutrinos.

A low-threshold, real time, flavor specific scheme for detecting solar neutrinos based on the Gamow-Teller transitions for the ^{176}Yb(ν,e$^-$)^{176}Lu and ^{160}Gd(ν,e$^-$)^{160}Tb processes has been proposed by Ragahavan [4]. He pointed out that absorption events of *pp* and ^{7}Be solar neutrinos can be identified by a delayed coincidence between the prompt electron from the GT transition followed by the γ-decay of the excited state. He also proposes to construct a new solar-neutrino detector LENCSE (Low Energy Capture Spectrometric Experiment) [5] using Yb or Gd-loaded scintillation-counters, which make a real-time spectroscopy of solar *pp* and ^{7}Be neutrinos possible.

To determine the differential sensitivity for *pp* and ^{7}Be neutrinos, it is very important to know the B(GT) values for the 1^+ states excited by the ^{176}Yb$(\nu, e^-)^{176}$Lu and ^{160}Gd$(\nu, e^-)^{160}$Tb reactions, independently. We therefore measured a high resolution (^{3}He,t) spectra at zero degrees using a ^{3}He beam at 450 MeV to complement the (p, n) measurements. The (^{3}He,t) reaction at 450 MeV has already been demonstrated to be useful in getting the B(GT) values. Since the full Fermi strength B(F)=N–Z is exhausted by the IAS, the B(GT) values can be relatively precisely obtained from the singles (^{3}He,t) spectra on ^{176}Yb and ^{160}Gd by using the relative ratio of the excitation strengths of 1^+ states and the IAS [7].

In the present experiment, the spectrometer Grand Raiden was set at $\theta = 0°$ with the solid angle of $\Delta\Omega = 1.6$ msr. Both the incident ^{3}He^{++} beam and the reaction products entered into the spectrometer set at 0°. The ^{3}He^{++} beam with its lower magnetic rigidity was bent

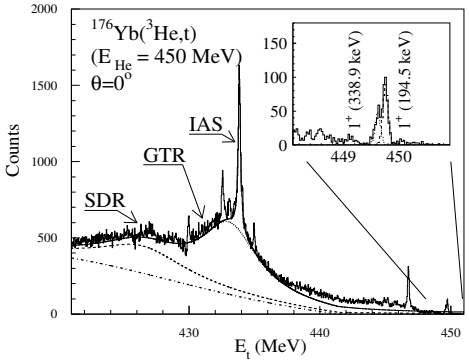

Figure 1: Triton-particle energy spectrum from the ^{176}Yb(^{3}He,t) reaction at 0° taken with a ^{3}He beam of 150 MeV/A. A sharp IAS peak and two broad bumps corresponding to a Gamow-Teller resonance and a spin dipole resonance are observed. The global structure of the spectrum are fitted by assuming an underlying continuum due to quisi-free scattering. Discrete states in the low excitation energy are displayed in the expanded spectrum.

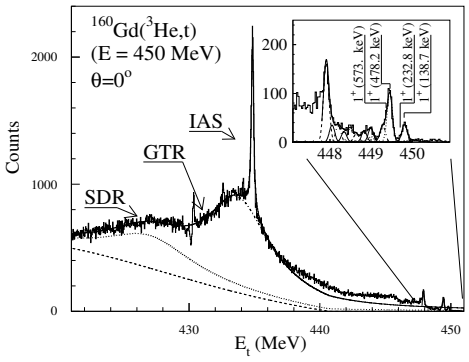

Figure 2: Triton-particle energy spectrum from the ^{160}Gd(^{3}He,t) reaction at 0° taken with a ^{3}He beam of 150 MeV/A. A sharp IAS peak and two broad bumps corresponding to a Gamow-Teller resonance and a spin dipole resonance are observed. The global structure of the spectrum are fitted by assuming an underlying continuum due to quasi-free scattering. Discrete states in the low excitation energy are displayed in the expanded spectrum.

inward and stopped at the internal Faraday cup in the first dipole (D1) magnet. Particles were identified in the focal-plane detector system by measuring the energy loss signals in three plastic scintillators. In order to reduce the events due to the (^{3}He$^+$,t) reaction in the plastic scintillator at the focal plane, which were not rejected by using two 5 mm and 10 mm scintillation counters in the previous experiment, we used three plastic scintillation counters with thicknesses of 1 mm, 5 mm and 10 mm, respectively. In order to achieve a high energy resolution around 100 keV, we installed a new energy defining slit in the beam transport system from the K=400 MeV ring cyclotron to the target position. The image defining slit was put at the BV2-WN position. In addition, the dispersion matching between the beam line and the spectrometer was applied.

An overall energy resolution of ΔE ~100 keV for the final-state spectrum was achieved by using the dispersive-mode beam transportation and the energy-defining slits in the beam line.

Figs. 1 and 2 shows the (^{3}He,t) spectra taken at $\theta = 0°$. Several discrete 1^+ levels are resolved thanks to the present resolution. The detailed analyses are now in progress.

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