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# Development of cryogenic hydrogen gas target and estimation of background for a measurement of neutron inelastic scattering in $^{12}$C

The triple alpha process is a set of reactions, which produces $^{12}$C from three alpha particles in stellar nucleosynthesis. The $0_2^+$ resonance of $^{12}$C, known as the Hoyle state, plays an important role in that process. The Hoyle state de-excites to the ground state of $^{12}$C with low probability by mainly radiative de-excitations under typical stellar conditions. In a hot and dense environment such as supernovae, the triple alpha reaction rate can be enhanced by neutron upscattering. In the neutron upscattering, the excited state decays into the bound states by giving its excitation energy to neutrons instead of radiative de-excitation. We plan to measure a cross section of the inverse reaction, expressed in $^{12}\mathrm{C}(\mathrm{n},\mathrm{n}')$, near the reaction threshold energy to determine the enhancement factor of the triple alpha reaction rate. In this study, we have been developing a monoenergetic 10 MeV neutron source with $^{1}$H($^{13}$C, n)$^{13}$N reaction.

In order to obtain a high-intensity neutron beam, we developed a cryogenic hydrogen gas target with a GM refrigerator. We have already conducted a performance test of the new target at RARiS in Tohoku University. In the test, we measured the produced neutron intensity and the energy spectrum using the time of flight method. The cooled gas target improved the neutron intensity and the signal-to-noise ratio. However, we found an unexpected double-peak structure in the neutron spectrum. To understand the unexpected peak structure, we estimated the neutron spectrum using cross section data of $^{13}$C(p, n) reaction from literature. We confirmed that the structure comes from the variation of the cross section against the incident energy.

In the measurement of $^{12}\mathrm{C}(\mathrm{n},\mathrm{n}')$, we will detect the scattered neutron with liquid scintillators. To eliminate the neutron background which is incident to the detectors directly from the neutron-production target, a collimator is necessary. We estimated the required collimator thickness with Monte Carlo simulations and we confirmed the background intensity with a newly designed collimator.

We will report the current status of the neutron inelastic scattering experiment including the development of the cryogenic hydrogen target and background reduction.

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