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Feasibility study for measuring the gamma-decay probability of the 3-1 state in 12C with deuteron inelastic scattering

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The triple alpha (3α) reaction, which produces ^{12}C from ^{4}He, is one of the most important reactions in nucleosynthesis in the universe. In this reaction, resonance states of three α particles are generated as excited states of ^{12}C. In most cases, these states decay back into three α particles, but a tiny fraction of them undergo radiative decay, leading them to the ground state of ^{12}C. Thus, the branching ratio of α-decay and radiative decay in the 3α resonance states is a crucial physical quantity that determines the ^{12}C production rate. At normal stellar temperatures lower than 10^8 K, the 3α reaction mainly proceeds via the 0_2^+ state (Hoyle state), and its radiative-decay probability has been already measured. However, at high temperatures above 10^9 K, high-lying excited states e.g., 3_1^- and 2_2^+ states play an important role. Despite their importance, the radiative-decay probabilities of these high-lying states still remain unmeasured due to the extremely small expected values ranging from 10^{-8} to 10^{-6}. Although we previously measured the radiative-decay probability of the 3_1^- state in ^{12}C by means of proton inelastic scattering with a solid hydrogen target [1], we could not achieve sufficient precision due to significant systematic uncertainty due to background events.
Therefore, we conceived an idea to employ a deuterium target instead of the hydrogen target. Generally, deuterons possess higher separation energies from nuclei than protons. That should be an advantage to kinematically distinguish background events from true events. In this study, we aim to precisely determine the radiative-decay probability of the 3_1^- state in ^{12}C through simultaneous measurement of the scattered ^{12}C and the recoil deuteron, which are emitted from the inelastic deuteron scattering under inverse kinematics conditions. We have already conducted simulation studies to search for optimum experimental conditions. We considered utilizing $\mathrm{TiD_2}$ (deuterated titanium) or solid deuterium as a deuteron target. $\mathrm{TiD_2}$ is much easier to handle than the solid deuterium because it is stable at room temperature and resistant to heating from the beam. However, it was not unclear whether the $\mathrm{TiD_2}$ target was useful for the proposed measurement because its signal-to-noise ratio in the inelastic deuteron scattering was unknown. Therefore, we measured the background rate due to Ti in the $\mathrm{TiD_2}$ target as well as the reaction cross section to excite the 3_1^- state using a 218-MeV ^{12}C beam at CYRIC, Tohoku University. In this talk, we will report the result of the test experiment at CYRIC and our present status.
[1] M. Tsumura et al., Phys. Lett. B 817,136283 (2021).

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