Measurement of radiative widths of excited states above the α-decay threshold in ^{12}C

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Excited states in ^{12}C nuclei play a very important role in the nucleosynthesis in the universe. ^{12}C nuclei are synthesized by the triple α reaction as shown in Fig. 1. Firstly, excited states of ^{12}C are produced as 3α resonance states. Most of these excited states immediately decay into three α particles, but a tiny fraction of these excited states decays into the ground state of ^{12}C by emitting γ rays. Normally this process proceeds via the 0^+_2 state (Hoyle states) at $E_x = 7.65$ MeV in ^{12}C. The radiative decay width of the 0^+_2 state is known to be $\Gamma_\gamma = 3.7 \pm 0.5$ meV while the total width for this state is $\Gamma = 8.5 \pm 1.0$ eV [1]. However, at high temperature $T_9 > 1$, the highly excited 3α resonance states such as the 3^-_1 state at $E_x = 9.64$ MeV might play a part of the triple α reaction. The total width of the 3^-_1 state is known to be $\Gamma = 34 \pm 5$ keV [1], but the radiative decay width of this state has not determined.

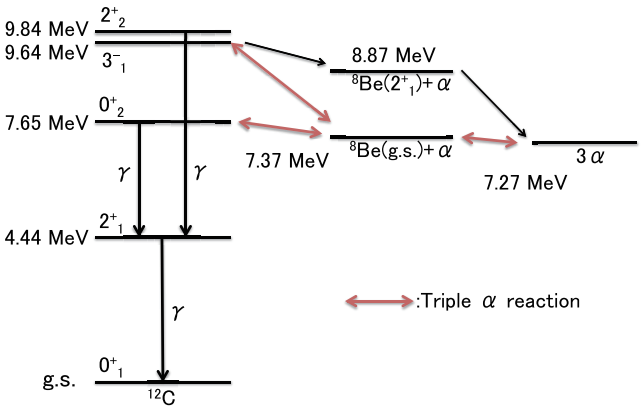

Figure 1: Schematic diagram of the triple α reaction.

We measured the CH_2(^{12}C, ^{12}C*p) reaction at the cyclotron facility in RCNP so as to determine the radiative width. A cryogenic CH_2 target with a thickness of 2 mg/cm^2 was bombarded with a 250-MeV ^{12}C beam. The recoil proton was detected by the Si+CsI telescope in the scattering chamber, and the excitation energy of the scattered ^{12}C was identified by the energy and angle of the recoil proton as shown in Fig. 2(a). The scattered ^{12}C was detected by two plastic scintillators at focal plane of the Grand Raiden spectrometer. The thickness of the scintillators are 1 mm and 10 mm, respectively. The γ-decay events were selected by considering that α can penetrate 1-mm scintillator, but ^{12}C cannot. In principle, the radiative width of the 3^-_1 state should be determined by comparing the number of the γ-decay coincidence events [Fig. 2(b)] with that of the singles events [Fig. 2(a)] exciting the 3^-_1 state. Unfortunately, no γ-decay events of the 3^-_1 state was observed in the present measurement as shown in Fig. 2(b). The upper limit for the radiative width of the 3^-_1 state obtained from this experiment is 132 meV at 68% confidence level despite just 8-hour beam time. We proposed an upgraded experiment (E404) to accumulate more statistics and to improve the signal-to-noise ratio, and now we are preparing for it.

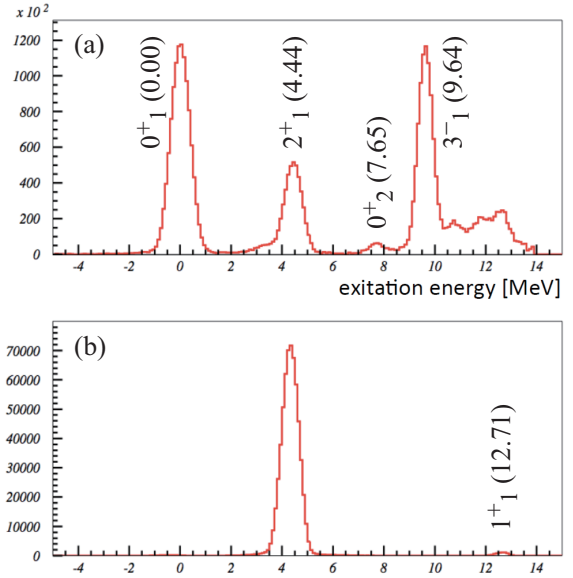

Figure 2: Excitation energy spectra in ^{12}C after the background subtraction.
(a) Singles spectrum measured by the Si+CsI telescope only. (b) Coincidence spectrum measured by the Si+CsI and Grand Raiden focal plane detector.

References

[1] F. Ajzenberg-Selove *et al.*, Nucl. Phys. A **506**, 1 (1990).