Missing mass spectroscopy on carbon isotopes beyond proton drip-line

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The ^{8}C nucleus is one of the most proton rich nuclei existing outside of the proton drip-line. While the mass of the ground state and decay modes of ^{8}C[1–4] has been known, the energy and the spin-parity of the excited states have never been measured. Therefore, we investigated the excited states of ^{8}C by using missing mass spectroscopy, which enabled us to search for the unbound nuclei ^{8}C unbiasedly with respect to three-body, four-body, and five-body decay[4].

The experiment was performed at the RIPS facility[5] in RIKEN. A 70 MeV/nucleon ^{12}C primary beam with an intensity of 200 pnA bombarded a ^{9}Be production target with a thickness of 0.5 mm. A 50 MeV/nucleon ^{10}C secondary beam was produced via projectile fragmentation and distributed to a reaction chamber located downstream of the second achromatic plane (F3) of RIPS. Particle identification of the secondary beam was carried out on event by event basis using the time of flight and energy loss, which were measured by two plastic scintillators placed at the first achromatic plane (F2) and F3 of RIPS. Two parallel plate avalanche counters (PPACs)[6] placed at F3 and double PPACs in the reaction chamber were used to measure and adjust the beam position. We obtained the pure ^{10}C beam with an intensity of about 2×10^5 Hz.

The secondary ^{10}C beam was injected into a cryogenic H_2 gas target (CRYPTA)[7]. Temperature and pressure of the H_2 gas were kept around 30 K and 0.4 MPa, respectively. The H_2 gas was sandwiched by two 10-μm-thick Havar[8] foils. The diameter and thickness of the target cell were 30 and 1 mm, respectively.

Recoil deuterons and tritons from the reaction were detected by silicon detectors called a RIKEN telescope[9] and a Dubna telescope, respectively. The double-sided strip detector (DSSD) of the RIKEN telescope was installed at 120.5 mm downstream from the target. The Dubna telescope, which was installed downstream of the RIKEN telescope, consisted of 1-mm-thick DSSD and 16 trapezoid 25-mm-thick CsI(Tl) scintillators with photo-multiplier readouts. The DSSD has 16 sectors in front and 16 rings at the back. The DSSD is circular with a 28 mm ϕ hole, and the active radius ranges from 33 to 84 mm. The DSSD was placed at 300 mm from the target, followed by the CsI(Tl) scintillators at 5-mm intervals. The polar angular coverage of the Dubna telescope is about $3.0° \leq \theta \leq 8.0°$ in a laboratory frame.

Four plastic scintillators were installed at 0 degree, downstream of Dubna telescope. The first two scintillators were used to stop the ^{10}C beam. They identified $Z = 4$ and $Z = 6$ particles from the reactions. The following two scintillators were used as the stopper and separator for lighter particles such as α particles and protons produced by the reactions. Therefore, we selected these scintillators with thicknesses of 2, 5, 2, and 15 mm from upstream.

Trigger sources of the data acquisition were the RIKEN telescope $\otimes$ beam, the Dubna telescope $\otimes$ beam, and the down-scaled beam. Data were taken for 31 hours under the condition with H_2 gas, and 11 hours without H_2 gas.

In the online analysis, the recoil deuterons and tritons detected by the Dubna telescope were well identified. From the energy information of these recoil particles, the excitation energy of ^{8}C and ^{9}C will be deduced by the missing mass method. A detailed analysis is now in progress.

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