First production of ^{10}Be beam at CRIB and ^{10}Be+α resonant elastic scattering

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α-cluster states are known to occur in many nuclei, including isotopes of the carbon nucleus. Among the α-cluster states, linear-chain cluster states have been considered as exotic and of interest for a long time. Although there have been many theoretical investigations, no clear experimental evidence has been obtained for such states thus far.

By performing an antisymmetrized molecular dynamics (AMD) calculation, Suhara and En'yo[1,2] obtained a band (0_5^+, 2_6^+, 4_6^+) that could be explained as linear-chain cluster levels of ^{14}C. It was predicted that these levels appear a few MeV or more above the ^{10}B+α threshold, unlike the prolate bands in the study of Oertzen et al.[3] The investigation[2] shows that the AMD wave function has a configuration in which two α particles and two neutrons are located close to each other, while the remaining α particle is relatively faraway. This implies that states having such a linear-chain configuration could be accessed from the ^{10}Be+α channel.

The aims of the present work are 1) to search for a linear-chain configuration via ^{10}Be+α resonant scattering, and 2) to determine the resonant parameters of the high excited states (13-18 MeV) of ^{14}C, which are still mostly unknown, in order to elucidate on the cluster-band structure. The experimental method is similar to that used in previous studies.[4,5]

The study was conducted at the low-energy radioactive-isotope (RI) beam separator CRIB. The ^{10}Be beam at CRIB was first produced on January 17-19, 2014. Using a 5.57 MeV/u primary ^{11}B beam from the AVF cyclotron and a 500-Torr cryogenic deuterium target, ^{10}Be particles were produced via the ^{11}B(d, ^{3}He)^{10}Be reaction in inverse kinematics. The 4^+ charge state was selected using the D1 dipole magnet of CRIB. The produced ^{10}Be^{4+} beam was contaminated with a small amount of ^{10}B^{4+}, which was mostly excluded by inserting a 0.7 μm-thick Mylar film as a charge stripper at the F1 focal plane. The highest ^{10}Be beam production rate was 2×10^4 pps at the final focal plane (F3). The beam energy was 3.51 MeV/u before reaching parallel-plate avalanche counters (PPACs) installed for the beam monitoring.

We also performed a test measurement of α resonant scattering using a chamber filled with helium gas at 760 Torr, which served as the target for elastic scattering. The chamber had a window covered with a 25 μm-thick Mylar film at the beam entrance. A pair of silicon detectors, which had thicknesses of 20 μm and 480 μm, were placed in the gas-filled chamber, consisting of a "ΔE-E" telescope. The telescope was located at 482 mm from the Mylar entrance window, exactly in the direction of the beam axis. The energy of the beam degraded and the beam was stopped by the thick gas target and α particles originating from elastic scatterings reached the telescope. The energy spectrum of the α particles exhibited several peaks, as shown in Fig. 1. In principle, α-cluster like resonances including theoretically predicted ones should be observed as peaks in the present measurement. In particular, two distinct peaks that likely correspond to resonances in ^{14}C are observed at excitation energies of 14.3 MeV and 16 MeV; however, the resonant features of those are yet to be investigated. The peak at the highest energy of approximately 17 MeV could be due to background events arising from impurities in the ^{10}Be beam and should be eliminated in the main run.

In summary, we successfully produced a ^{10}Be beam at CRIB for the first time and also showed that the resonant scattering measurement is feasible. The actual measurement for 7.5 days will be performed in 2015.

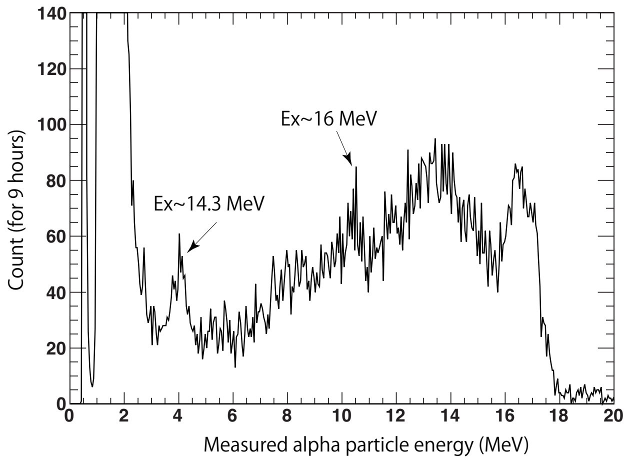

Fig. 1. Energy spectrum of α particles. The data were accumulated for 9 hours.

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