Study of α-cluster structure in ^{22}Mg

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The study of the α-cluster structure in a nucleus is one of the most important subjects in nuclear physics. In the case of self-conjugate $4N$ nuclei, it is well known that the energy levels with large α-reduced widths form the rotational bands, which indicates the molecular-like cluster structures of the nuclei. The α-cluster structure of rare isotopes is, however, still poorly understood especially for $N < Z$ proton-rich nuclei.

As pointed out by Dufour and Descouvemont,[1)] the proton-rich radionuclide ^{22}Mg is expected to show an α-cluster structure. The ^{22}Mg nucleus (^{18}Ne + α system) was investigated using the generator coordinate method (GCM), which obtained results indicating the expected doubling cluster states with $J^{\pi} = 1^-$ and 3^- at the energy range of $12 < E_x < 13$ MeV. However, the energy levels were not clearly observed in the follow-up experiment performed by Goldberg et al.[2)]

The elastic scattering of ^{18}Ne(α,α)^{18}Ne was measured in the inverse kinematics at the Center for Nuclear Study Radioactive Ion Beam Separator (CRIB) of the RIKEN Nishina Center in September 2016 for 10 days. A thick target method was adopted so that a wide energy range of ^{22}Mg nuclei could be scanned. A beam of rare isotope ^{18}Ne was produced by the ^{3}He(^{16}O, ^{18}Ne)n reaction using the primary ^{16}O beam from the AVF cyclotron ($E_{beam} = 8.0$ MeV/u). The ^{3}He gas target density was 1.54 mg/cm^2. The typical secondary beam intensity was about 3×10^5 particles per second during the runs. The ^{18}Ne with a beam energy of ~ 50 MeV impinged on the 470 Torr of the ^{4}He gas target at the final focal plane. The energy levels of ^{22}Mg up to $E_x \sim 18$ MeV were observed.

Recoiling α particles were measured by two ΔE-E silicon detector telescopes located 430 mm downstream from the target entrance window, which enabled α-particle identification using the standard energy loss technique. No significant contamination from other light charged particles was found. A background run with an 87-Torr Ar gas target was performed to see if the observed α particles originated from the desired reactions. Figure 1 shows a typical α energy spectrum. The black and red lines indicate the α energy spectra for the ^{4}He and Ar gas targets, respectively. Relative counts are shown in the figure for comparison.

A detailed calibration and energy reconstruction will be performed to determine the precise α energy spectrum. The experimental excitation function of the ^{18}Ne + α system will be extracted and compared with the theoretical R-matrix calculation.[3)] The properties of populated energy levels such as excitation energies, spins, parities, and the α-reduced widths will be constrained for the α cluster structure information.

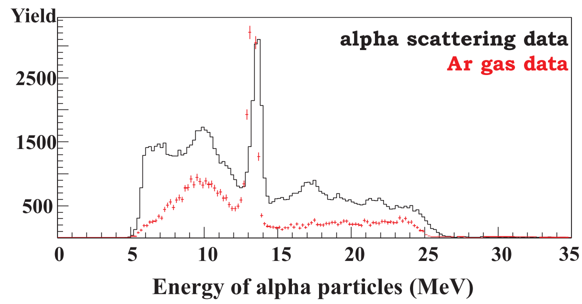

Fig. 1. Typical α spectrum. The black (red) line indicates the ^{4}He (Ar) gas run. All data were normalized by beam intensity. The strong peak near 13 MeV represents leaky α particles that originated at the production target chamber.

References
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