# Study of cluster states in $^{11}$B and $^{13}$C via ($\alpha$,$\alpha$') reaction

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The alpha particle cluster is one of the important concepts in the nuclear structure. Alpha cluster states in self-conjugate 4N nuclei are expected to emerge near the $\alpha$-decay threshold as shown in the Ikeda diagram [1]. For example, it has been suggested that the 7.65-MeV $0_2^+$ state in $^{12}$C has a 3$\alpha$ configuration [2]. This state locates at 0.39 MeV above the 3$\alpha$-decay threshold energy.

Recently, it was found that the $3/2_3^-$ state at $E_x = 8.56$ MeV in $^{11}$B is not described by the shell model calculation in the measurement of the Gamow-Teller and spin-flip $M1$ strength [3]. The $3/2_3^-$ state, which locates 100-keV below the $\alpha$-decay threshold, is expected to be a cluster state. Milin and Oertzen proposed that the $1/2_2^-$ state ($E_x = 8.86$ MeV) and the $1/2_2^+$ state ($E_x = 10.996$ MeV) in $^{13}$C are 3$\alpha$ cluster states with one excess neutron which acts as a covalent particle. The influence of such excess particles and holes in the cluster states can be examined by comparing of the cluster state in $^{12}$C with those in $^{13}$C and $^{11}$B.

In order to investigate their structure, we measured the angular distribution of cross sections for the $\alpha$-inelastic scattering from $^{11}$B, $^{13}$C, and $^{nat}$C at forward angles of $\theta = 0^\circ - 19.4^\circ$. The experiment was performed by using a 400-MeV alpha beam at RCNP. The alpha particles scattered from the target were momentum analyzed by the magnetic spectrometer Grand Raiden (GR). To eliminate the background caused by the elastic scattering from hydrogenous contaminants in the target, the recoil proton counter was installed in the scattering chamber. The background events from hydrogen can be tagged by the counter which detected recoil protons from the $\alpha + p$ scattering. The detailed explanation for the recoil counter is given in Ref. [5].

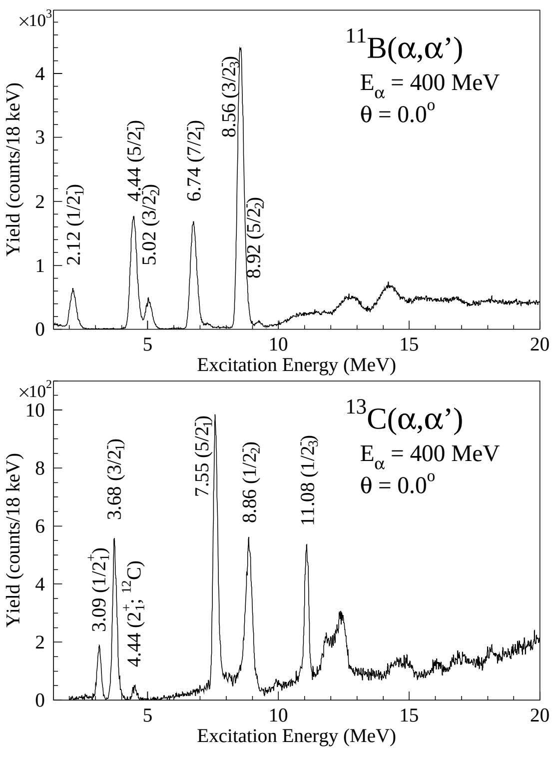


Figure 1: Energy spectra for $^{11}$B($\alpha$,$\alpha$') and $^{13}$C($\alpha$,$\alpha$') reactions at 0°

In the 0° measurement, the primary beam passed though the GR and was stopped in a Faraday cup placed 12-m downstream from the focal plane. The beam duct was usually placed at the high momentum side of the focal plane detectors to lead the beam to the Faraday cup. Therefore the momentum acceptance was geometrically restricted to $E_x \geq 6$ MeV. In the present experiment, a beam stopper was installed in front of the focal plane detectors to measure the low-lying states with $E_x \leq 6$ MeV. Fig.1 shows the excitation energy spectra for the $^{11}$B($\alpha$,$\alpha$') and $^{13}$C($\alpha$,$\alpha$') reactions measured at 0° by using the beam stopper. The first excited state in $^{11}$B at the very low excitation energy of 2.12 MeV was successfully measured.

The angular distribution will be compared with the distorted-wave-impulse-approximation calculations to obtain the transition strengths and to study the cluster structures in $^{11}$B and $^{13}$C. The results will be reported elsewhere soon.

## References

[1] K. Ikeda *et al.* Prog. Theor. Physi. Suppl. Extra Number p. 464 (1968).

[2] H. Morinaga, Phys. Rev. **101**, 254 (1956).

[3] T. Kawabata *et al.* , Phys. Rev. C **70**, 034318 (2004).

[4] M. Milin *et al.* , Eur. Phys. J. A **14**, 295 (2002).

[5] Y. Sasamoto *et al.* , in this Annual Report.