# Measurement of $^{10}$C($\alpha$,$\alpha$') at 75 MeV/u with the MAIKo active target

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Nuclear clustering is an essential aspect of nuclear structures [1]. The clustering correlation also affects the syntheses of elements in the universe [2]. Recent theoretical studies predict that various cluster structures can be formed by excess nucleons in proton or neutron rich unstable nuclei [3]. In this article, we report the preliminary results of the $^{10}$C($\alpha$,$\alpha$') experiment carried out in October 2017 to search for alpha cluster structures in $^{10}$C. By comparing the energy spectra of the mirror system of $^{10}$C and $^{10}$Be, the inner structures of the alpha clusters in these nuclei can be unveiled since the energy shifts between the mirror nuclei reflect the size of the clusters [4].

The experiment was carried out at the EN beam line of the RCNP cyclotron facilities. The setup of the experiment is illustrated in Fig. 1. A $^{10}$C secondary beam at 75 MeV/u was produced from a $^{12}$C primary beam at 96 MeV/u on a 508-mg/cm$^2$ thick $^9$Be target. The intensity of the $^{12}$C beam was 50 pnA. The $^{10}$C beam was separated from the projectile fragments by the two dipole magnets (D1, D2), the 2-mm aluminum degrader at the F1 focal plane and the collimators located at the F2 focal plane. The intensity of the $^{10}$C beam measured by the plastic scintillator at the F3 was 80 kcps and the purity of $^{10}$C was 95%.

The alpha inelastic scattering was measured using the MAIKo active target [5] in which the detection gas of the time projection chamber (TPC) was used also as the target gas. The active target was installed at F3. The chamber was filled with the He(96%)+$CO_2$(4%) mixture gas to provide the helium target. The recoil alpha particles were detected by the TPC to perform the missing mass spectroscopy. High-energy recoil particles which penetrated the TPC were detected by the Si detectors installed at left and right sides of the TPC. In the previous experiment, we used the parallel plate avalanche counters (PPACs) to determine trajectories of the beam particles. However, detection efficiency of the PPACs for the $Z = 6$ particles was low. In the present measurement, we newly developed low-pressure multi-wire drift chambers (MWDCs) to track the beam particles. The MWDCs were operated with the same gas as the TPC. Two slits made from 10-mm thick tungsten were installed between the MWDC and the TPC to limit the horizontal position of the beam. A plastic scintillator with a thickness of 1 mm was used at downstream of the TPC to identify the decay channel of the scattered $^{10}$C from the energy loss.

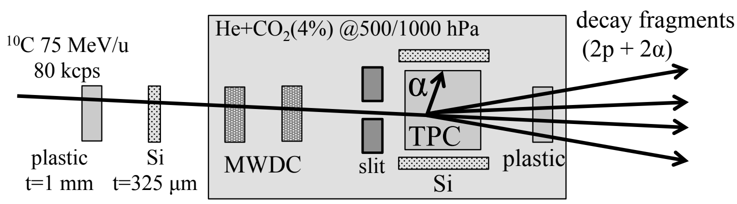


Figure 1: Experimental setup.

The summary of the measurement is shown in Table 1. The TPC was operated with two different gas pressures (500 hPa and 1000 hPa) to cover wider angular acceptance in the center of mass frame. In addition to the measurement with the $^{10}$C beam, we acquired data with a $^{12}$C primary beam to estimate the angular acceptance of the active target by comparing the cross section of the alpha elastic scattering off $^{12}$C with the previous data [6].

Table 1: Summary of the measurement.

| Beam | Intensity | Pressure | Time | Angular acceptance |
|---|---|---|---|---|
| $^{10}$C 75 MeV/u | 80 kcps | 500 hPa | 100 hours | $2.3° < \theta_{CM} < 4.6°$, $7.6° < \theta_{CM}$ |
| $^{10}$C 75 MeV/u | 80 kcps | 1000 hPa | 30 hours | $3.9° < \theta_{CM} < 6.6°$, $9.4° < \theta_{CM}$ |
| $^{12}$C 96 MeV/u | 70 kcps | 500 hPa | 5.8 hours | $1.9° < \theta_{CM} < 3.8°$, $6.4° < \theta_{CM}$ |
| $^{12}$C 96 MeV/u | 70 kcps | 1000 hPa | 3.5 hours | $3.3° < \theta_{CM} < 5.6°$, $7.9° < \theta_{CM}$ |

The detection efficiency of one plane of the first MWDC, as a function of the applied high voltage to the cathode and the potential wires, is shown in Fig. 2. Almost 100% detection efficiency was achieved without any discharge during the measurement, which could not be achieved using the PPACs in the previous experiments. The $^{10}$C beam was tracked by fitting the position of all of the MWDC planes. The residual of the fitting at the X1 plane of the first MWDC is shown in Fig. 3. The position resolution of the MWDC, obtained by fitting the histogram to a Gaussian function, was about 300 $\mu$m in FWHM.

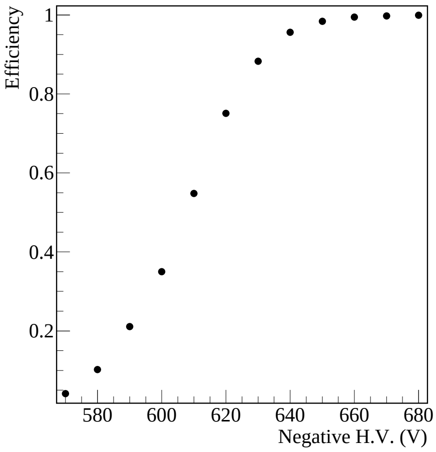


Figure 2: Detection efficiency of one plane of the first MWDC as a function of the high voltage.

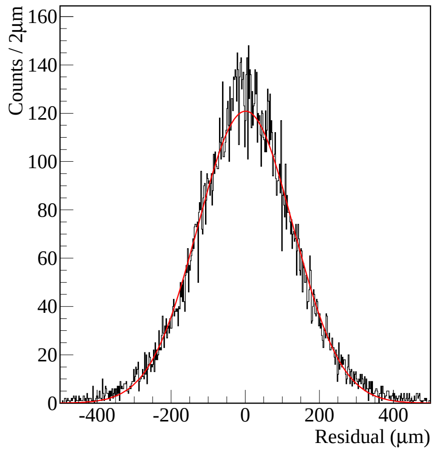


Figure 3: Residual of the $^{10}$C beam tracking at the X1 plane of the first MWDC.

In the online analysis, trajectories of the recoil alpha particles were extracted by eye scan. Figures 4 and 5 show the reconstructed energy and angle of the recoil alpha particles from the online analysis for the $^{12}$C($\alpha$,$\alpha$') and $^{10}$C($\alpha$,$\alpha$') measurements, respectively. The pressure of the TPC gas was 500 hPa. Although these results contain only a few percent of the total statistics and the angular spread of the $^{12}$C and $^{10}$C beams was neglected, clear loci of the elastic scattering can be seen. The detection threshold for the recoil alpha particles was successfully lowered down to 500 keV. The offline analysis is still ongoing. The excitation energy resolution is expected to be improved by taking into account the incident angles of the beams which are determined by the MWDCs.

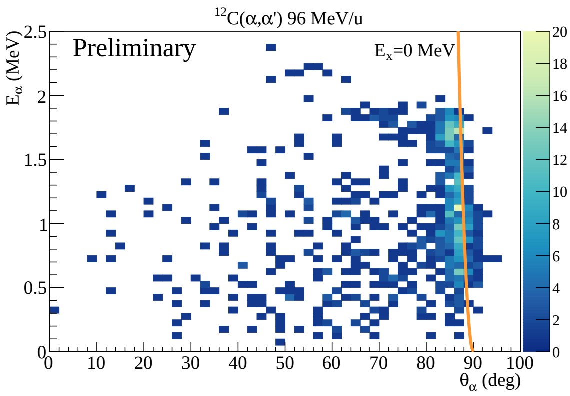


Figure 4: Reconstructed energy versus angle of the recoil alpha particle in $^{12}$C($\alpha$,$\alpha$') at 96 MeV/u.

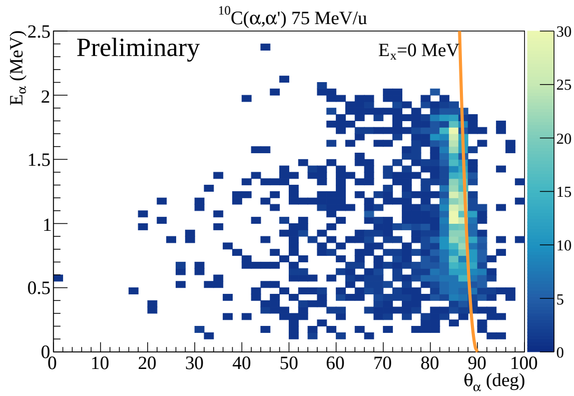


Figure 5: Reconstructed energy versus angle of the recoil alpha particle in $^{10}$C($\alpha$,$\alpha$') at 75 MeV/u.

## References


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