Evidence for the second 2^+ state at $E_x \sim 10$ MeV in ^{12}C

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The ^{12}C nucleus is well investigated nuclei in the entirely nuclear chart. However, there are still many unanswered questions concerning the nuclear structure of this nucleus. Among them, a famous question has been addressed for the multipolarity of the broad level at E_x=10.3 MeV. In Ref. [1], this state has been tentatively assigned to be 0^+. According to the 3-α RGM calculation by Kamimura [2], there should be a 2^+ level at E_x∼10 MeV as a 2^+ member of a β band beginning the 7.654 MeV 0_2^+ level in ^{12}C, since the coupling strength for the $0_2^+ \rightarrow 2_2^+$ transition were 25 times larger than that for the g.s$\rightarrow 2_1^+$ transition. These states has been predicted to be the molecule-like states consisting of three α-particles. Motivated these theoretical predictions, the KVI group tried to find the 2^+ state at E_x∼10 MeV. However, no conclusive result has been obtained yet [3].

To determine the multipolarity of this state, we measured the cross sections in these excitation energy regions for ^{12}C and carried out the multipole decomposition analysis (MDA). The experiment was performed under Program Number E200 in RCNP with 386 MeV α particles using the GRAND RAIDEN spectrometer. The details of the experimental setup and procedure are described in Ref. [4].

The angular distributions were obtained at angles from 0° to 10° for each 0.25 MeV bin in the excitation energy of 10 MeV region. A special care was paid to keep the energy resolution of the beam stable. The energy resolution was less than 200 keV through all the runs. Figure 1 shows the energy spectra at $\theta_{c.m.}$=0.9° and 5.1°, where the differential cross sections of states for L=0 and L=2 are the first maximum, respectively. The cross section in 10 MeV regions remained at $\theta_{c.m.}$=5.1° where the angular distribution of the L=0 component showed the minimum according to the DWBA calculation. This was direct evidence for existing the other strength in addition to the L=0 strength.

In inelastic α scattering, the angular distributions are characterized by the transferred angular momentum L, and only the natural parity states are excited. Thus, MDA was applied to identify the multipolarity of this state. The DWBA calculations were carried out in the framework of the single-folding model with a density-dependent effective N-α interaction [5] and the collective transition densities [6, 7] to obtain the angular distributions for various multipole components.

Figure 2 shows the results of MDA in the excitation energy region from 9.5 MeV to 10.5 MeV. Figure 2-(a) and (b) show angular distributions summed two bins, respectively. Although the strong 3_1^- state at E_x=9.641 MeV was contained in Fig. 2-(a), both of Fig. 2-(a) and (b) clearly show the L=2 component exists. Figure 3 shows the energy spectra at $\theta_{c.m.}$=0.9° and 5.1° classified into the L=0,1,2,3 components. As shown in Fig. 3-(a), there was the broad 0_3^+ state at E_x=10.0±0.3 MeV with the width of 2.7±0.3 MeV. In Fig. 3-(b),

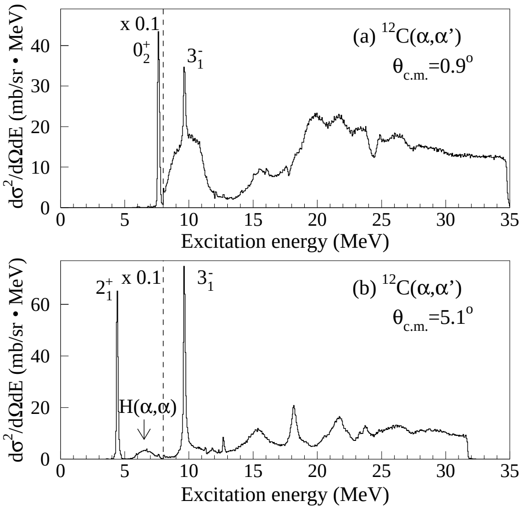

Figure 1: Energy spectra of ^{12}C(α,α').

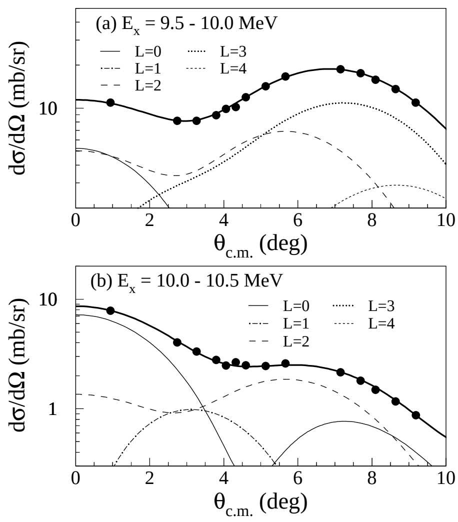

Figure 2: Cross sections for the excitation energy region from 9.5 MeV to 10.5 MeV.

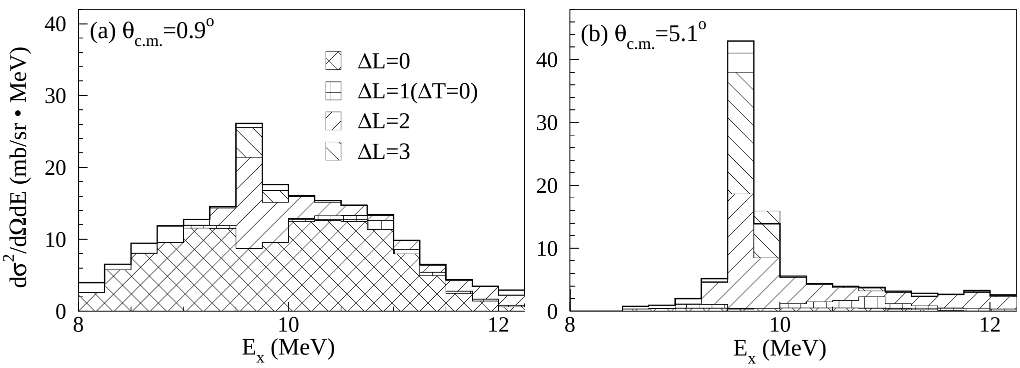

Figure 3: The result for the multipole decomposition analysis. (a) $\theta_{c.m.}$=0.9°; (b)$\theta_{c.m.}$=5.1°.

we could clearly find the 2_2^+ state submerged in the broad 0_3^+ state.

References

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