Investigation of spatial manifestation of α clusters in ^{16}O via α-transfer reactions

T. Fukui[1], Y. Kanada-En'yo[2], K. Ogata[3,4], T. Suhara[5], and Y. Taniguchi[6]

[1] *Istituto Nazionale di Fisica Nucleare, Sezione di Napoli, Napoli 80126, Italy*

[2] *Department of Physics, Kyoto University, Kyoto 606-8502, Japan*

[2] *Research Center for Nuclear Physics, Osaka University, Ibaraki, Osaka 567-0047, Japan*

[2] *Department of Physics, Osaka City University, Osaka 558-8585, Japan*

[2] *Matsue College of Technology, Matsue, Shimane 690-8518, Japan*

[2] *Department of Information Engineering, National Institute of Technology, Kagawa College, Mitoyo, Kagawa 769-1192, Japan*

Recently, five-body calculations of ^{16}O based on the ^{12}C + $ppnn$ configuration was carried out [1] and suggested that the α-particle distribution in the 0_1^+ and 0_2^+ states is qualitatively different from that predicted by the conventional orthogonality condition model (OCM) [2, 3] assuming an inert α particle plus ^{12}C configuration. As shown in Fig. 1, the surface peaks of the α probabilities computed by the five-body model (5BM) are shifted out-ward in both states, compared to those by the OCM. Here the horizontal axis r is the relative distance between ^{12}C and α. We have investigated how the significant change of the α distribution is observed on α-transfer cross sections. To this end, the α-transfer reactions ^{12}C(^{6}Li, d)^{16}O at two incident energies, 42.1 MeV [4] and 48.2 MeV [5] have been analyzed by the distorted-wave Born approximation (DWBA). The detail of the numerical calculations are reported in Ref. [6].

Figure 2 shows the α-transfer cross sections as a function of the deuteron emitting angle θ, calculated by the DWBA. The solid and dashed lines correspond to the results adopting the wave function computed by the OCM and 5BM, respectively. Regarding the 0_1^+ state as shown in Fig. 2(a), the cross section at the forward angles, say $\theta \lesssim 30°$, obtained with the 5BM wave function has the diffraction pattern consistent with that of the measured data at both incident energies, $\varepsilon_1 = 42.1$ MeV and $\varepsilon_2 = 48.2$ MeV. In contrast, the OCM fails to account for the behavior of the measured cross section of the 0_1^+ state. This indicates that the α-cluster breaking described in the 5BM is essential to explain the 0_1^+-cross section.

As regards the 0_2^+ state, however, the 5BM cannot explain the first and second peaks of the cross section, as well as the dip between those. Instead, the behavior of the cross section at forward angles obtained with the OCM coincides well with the experimental one. This may be due to the excitation of ^{12}C, which is taken into account in the OCM, while the 5BM ignores it.

In Ref. [6] we have introduced a phenomenological potential model with respect to the ^{12}C-α system, in order to investigate the correspondence between the surface peak of the α distribution and the transfer-cross section at forward angles. As a result of the potential-model analysis, we have found that the ratio of the first and second peaks of the cross section reflects the surface-peak position of the α distribution, and thus, we have estimated that the α-cluster structure of the 0_1^+ and 0_2^+ states manifests itself at $r \sim 4$ fm and $r \sim 4.5$ fm, respectively.

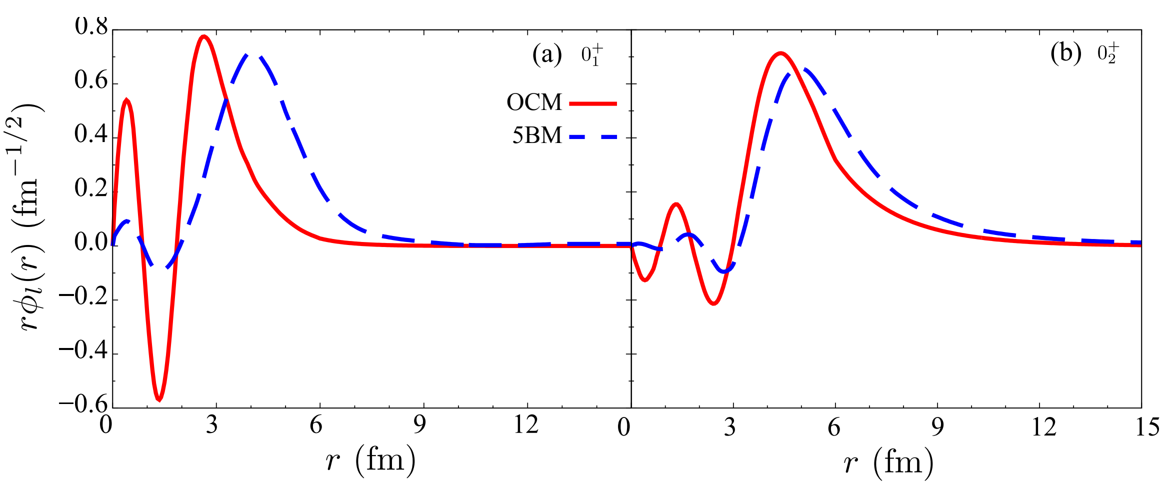

Figure 1: The α-particle distribution computed by the OCM (solid line) and the 5BM (dashed line) in the (a) 0_1^+ and (b) 0_2^+ states. The amplitudes are normalized to be unity.

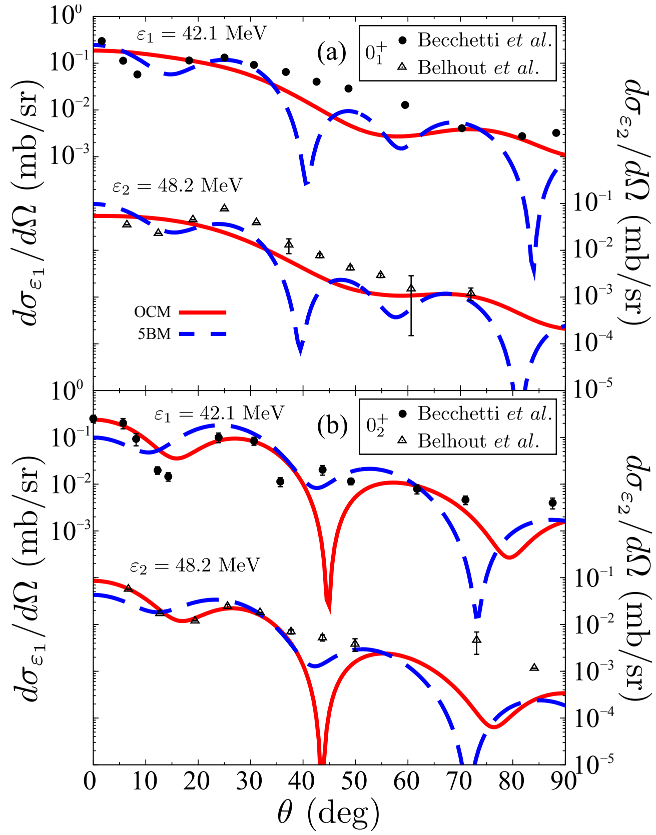

Figure 2: The comparison of the calculated cross sections of $^{12}\mathrm{C}(^6\mathrm{Li}, d)^{16}\mathrm{O}$ as a function of the deuteron emitting angle θ with the measured data at $\varepsilon_1 = 42.1$ MeV [4] and $\varepsilon_2 = 48.2$ MeV [5], for the (a) 0_1^+ state and (b) 0_2^+ state. The solid and dashed lines are obtained by employing the OCM- and 5BM-wave functions, respectively.

References

[1] W. Horiuchi and Y. Suzuki, Phys. Rev. C **89**, 011304 (2014).

[2] Y. Suzuki, Prog. Theor. Phys. **55**, 1751 (1976).

[3] Y. Suzuki, Prog. Theor. Phys. **56**, 111 (1976).

[4] F. D. Becchetti, J. Jänecke, and C. E. Thorn, Nucl. Phys. A **305**, 313 (1978).

[5] A. Belhout *et al.*, Nucl. Phys. A **793**, 178 (2007).

[6] T. Fukui, Y. Kanada-En'yo, K. Ogata, T. Suhara, and Y. Taniguchi, Nucl. Phys. A **983**, 38 (2019).