Mirror symmetry breaking in ^{8}He and ^{8}C

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The ^{8}C nucleus is an unbound system beyond the proton drip-line and decays into the ^{4}He+4p five-body states [1]. The mirror nucleus of ^{8}C is ^{8}He, a neutron skin nucleus. It is interesting to examine the mirror symmetry between the proton-rich ^{8}C and the neutron-rich ^{8}He with the isospin $T = 2$ system. We compare the structures of ^{8}He and ^{8}C for their mirror 0^+ states as the five-body decaying states with the α core [2].

We use the cluster-orbital shell model of the ^{4}He+N+N+N+N five-body system, and describe the many-body resonances with the correct boundary conditions using the complex scaling method. We employ the Hamiltonian, the nuclear part of which reproduces the ^{4}He-n scattering data and the ^{6}He energy [3]. We investigate the role of the Coulomb interaction on the spatial properties of ^{8}C in comparison with ^{8}He. For this purpose, we calculate the various radii sizes of ^{8}He and ^{8}C. In this analyses, most of the radii of resonances have imaginary parts that are relatively smaller than the real ones. Hence, we discuss the spatial size of resonances using the real part of the complex radii.

The energies (decay widths) of the $0^+_{1,2}$ states in ^{8}He are -3.22 MeV and 3.07 (3.19) MeV, respectively, measured from the ^{4}He energy. For the $0^+_{1,2}$ states in ^{8}C, 3.32 (0.072) MeV and 8.88 (6.64) MeV, respectively. The RMS radii of the $0^+_{1,2}$ states in ^{8}He and ^{8}C are shown in Fig. 1 for the matter ($R_{\rm m}$), proton (R_p), and neutron (R_n) parts. For the 0^+_1 states, the matter radius of ^{8}C is larger than that of ^{8}He. For the 0^+_2 states, the matter radius of ^{8}C is smaller than that of ^{8}He and this relation is opposite to that observed for the ground states of ^{8}He and ^{8}C. For ^{8}He(0^+_2), the observed large matter radius originates from the large neutron radius. For ^{8}C(0^+_2), the large matter radius is due to the large proton radius, which is smaller than the neutron radius of ^{8}He as shown in Fig. 1 [4].

We conclude that the relation of the spatial properties between ^{8}He and ^{8}C depends on the states, which can be explained from the Coulomb interaction. The Coulomb interaction acts repulsively and shifts the entire energy of ^{8}C upward with respect to the ^{8}He energy. In the ground state of ^{8}C, this repulsion extends the distances between α and a valence proton and between valence protons. On the other hand, the Coulomb interaction makes the barrier above the particle threshold in ^{8}C and the 0^+_2 resonance is affected by this barrier, the effect of which prevents the wave function of valence protons of ^{8}C from extending spatially. In ^{8}He, there is no Coulomb barrier for the four valence neutrons and the neutrons can extend to a large distance in the resonance. This role of the Coulomb interaction leads to the radius of ^{8}C(0^+_2) being smaller than that of ^{8}He(0^+_2).

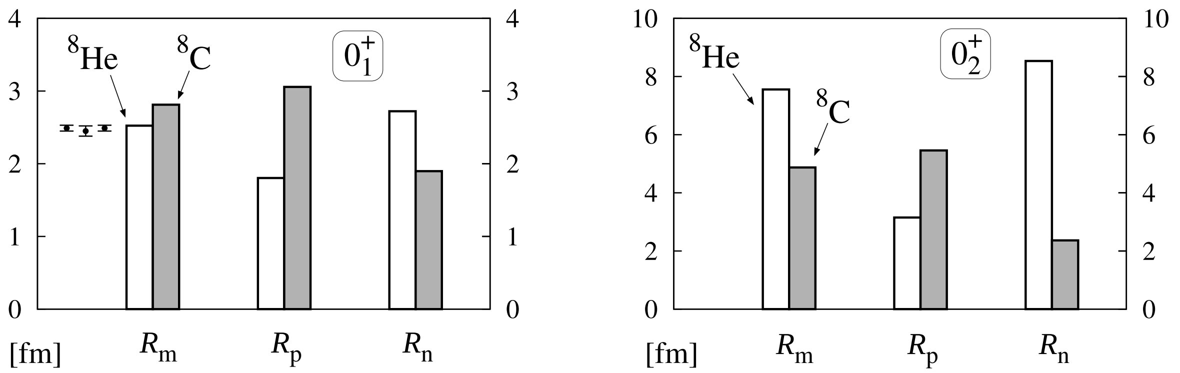

Figure 1: Real parts of matter, proton, and neutron radii of the ground states (left panel) and the 0^+_2 states (right panel) of ^{8}He and ^{8}C in units of fm. Circles with error bars indicate experimental data of the matter radius of ^{8}He.

References

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