Resonances of ^{7}He using the complex scaling method

T. Myo[1], K. Katō[2] and K. Ikeda[3]
[1] *Research Center for Nuclear Physics (RCNP), Osaka University, Ibaraki, Osaka 567-0047, Japan,*
[2] *Division of Physics, Graduate School of Science, Hokkaido University, Sapporo 060-0810, Japan,*
[3] *RIKEN Nishina Center, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan.*

Development of the radioactive beam experiments provides us with much information of the unstable nuclei far from the stability. Recently, many experiments of ^{7}He, the unbound nuclei, have been reported[1, 2, 3, 4, 5, 6]. However, there are still found contradictions in the observed energy levels and the excited states are not settled for their spins and energies. The ^{7}He excited states are experimentally suggested to appear as two or three particle resonances above the ^{4}He+3n threshold energy, because the subsystem ^{6}He is a Borromean nucleus and breaks up easily into ^{4}He+n+n.

Theoretically, when we discuss the structures of the ^{7}He resonances, it is important to describe the many-body decay properties concerned with subsystems consistently, in which the subsystems also have their particular decay widths such as ^{5}He+2n channels. This condition was not emphasized so far in the studies of ^{7}He. The ^{7}He resonant spectroscopy is desired to be investigated with the appropriate treatments of the decay properties concerned with ^{5,6}He.

The purpose of this theoretical study is to carry out the resonance spectroscopy of ^{7}He with the simultaneous descriptions of ^{5,6}He imposing the accurate boundary conditions of many-body decays. Here, we employ the cluster orbital shell model of the four-body ^{4}He+n+n+n system under the orthogonality condition model, in which the open channel effects for the ^{6}He+n, ^{5}He+2n and ^{4}He+3n decays are taken into account explicitly. We describe the many-body resonances under the correct boundary conditions for these decay channels using the complex scaling method. We employ the Hamiltonian, which reproduces the ^{4}He-n scattering data and the ^{6}He energies, shown in Fig. 1[7].

As a result, we found five resonances of ^{7}He shown in Fig. 1, which are dominantly described by the p shell configurations and the small contributions come from the sd shell. The ground and the $5/2^-$ states are reproduced well, while the slight overbinding is seen for the ground state by 0.2 keV in comparison with the experiments. The $3/2^-_2$ state is predicted very close to the $5/2^-$ state in Fig. 2. The $1/2^-$ state is also predicted as a four-body resonance with a low excitation energy having a relatively large decay width of around 2 MeV. We further investigate the spectroscopic factors (S factors) of the ^{6}He-n component for ^{7}He resonances[7], which are useful to understand the coupling between ^{6}He and the additional neutron in ^{7}He. It is found that the ^{6}He(2^+_1) state contributes largely in the several states of ^{7}He. For the ground state, the S factors of the ^{6}He(0^+_1)-n and ^{6}He(2^+_1)-n components are obtained as $0.75 + i0.10$ and $1.51 - i0.40$, respectively.

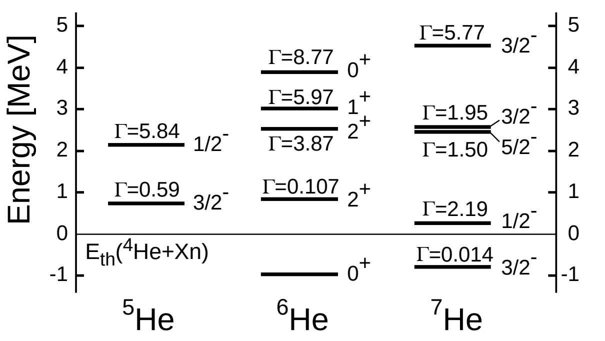

Figure 1: Energies and decay widths of the ^{5,6,7}He states measured from the ^{4}He+Xn threshold ($X = 1, 2, 3$).

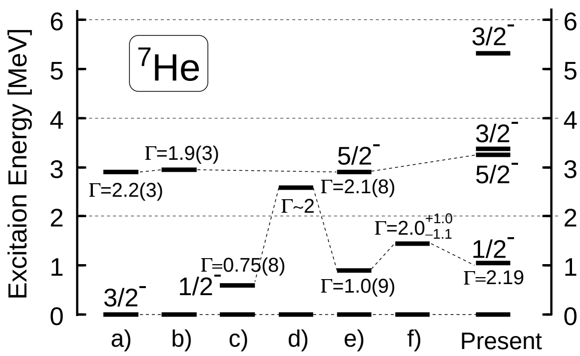

Figure 2: Excitation spectra of ^{7}He in comparison with the experiments (a)[1], b)[2], c)[3], d)[4], e)[5], f)[6]).

References

[1] A. A. Korsheninnikov et al., Phys. Rev. Lett. **82**, 3581 (1999).
[2] G. Bohlen et al., Phys. Rev. C**64**, 024312 (2001).
[3] M. Meister et al., Phys. Rev. Lett. **88**, 102501 (2002).
[4] A. H. Wuosmaa et al., Phys. Rev. C **72**, 061301 (2005).
[5] F. Skaza et al., Phys. Rev. C **73**,044301 (2006).
[6] N. Ryezayeva et al., Phys. Lett. B**639**, 623 (2006).
[7] T. Myo, K. Katō and K. Ikeda, Phys. Rev. C**76**, 054309 (2007).