Decay dynamics of the unbound ^{25}O and ^{26}O nuclei[†]

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We study the ground and excited resonance states in ^{26}O with a three-body model by taking into account the coupling to the continuum. The main aim of our study is to extract the di-neutron correlations and the halo nature of the ground state of ^{26}O from the two-neutron decay spectrum with updated empirical inputs for the model Hamiltonian. In the present ^{24}O $+n+n$ three-body model, the neutron-core potential as well as the strength of the pairing interaction between the valence neutrons is calibrated using new experimental data from Ref. 1 and the calculations performed in Refs. 2 are refined. With the same model input, we also discuss the structure of the excited 2^+ resonance state.

We discuss the first 2^+ state in ^{26}O. One of the most important findings in the recent experiment reported in Ref. 1 is a clear second peak at $E = 1.28^{+0.11}_{-0.08}$ MeV, which is likely attributed to the 2^+ state. Because of the pairing interaction between the valence neutrons, the energy of the 2^+ state is slightly shifted towards lower energies from the unperturbed energy, whereas the energy shift is much larger for the 0^+ state due to the larger overlap between the wave functions of the two neutrons in the three-body model. The 2^+ peak appears at 1.282 MeV, which agrees perfectly with the experimental data, as shown in Table 1.

While we achieve an excellent agreement with the experimental data for the energy of the 2^+ state, it is striking that most theoretical calculations performed so far overestimate the energy. We summarize other results in Table I together with the energy of the $3/2^+$ state in ^{25}O for each calculation. The 2^+ state should certainly appear at an energy slightly lower than the unperturbed state, as long as the three-body structure is reasonable. In this sense, the ab-initio calculation with chiral NN and $3N$ interactions shows the opposite trend, and the shell model (SM) calculations, except for the continuum SM calculations of Ref. 4 and Ref. 5, seem to overestimate the correlation.

We next discuss the angular correlation of the emitted neutrons from the ground state of ^{26}O. Figure 1 shows the angular distributions thus obtained. In the absence of the correlation between the valence neutrons, the angular distribution is symmetric with respect to $\theta_{12} = \pi/2$ (see the dotted line). On the other hand, in the presence of the interaction between the valence neutrons, the angular distribution becomes highly asymmetric, with an enhancement of the back-to-back emission,[2,7] as shown by the solid line. This is a natural consequence of the dineutron correlation in the momentum space, which has an opposite trend to the correlation in the coordinate space; the di-neutron correlation has a strong peak at the small correlation angle in the coordinate space and Heisenberg's uncertainty principle converts the backward correlations in the momentum space.

Table 1. Comparison of the energies of the $3/2^+$ state of ^{25}O and the 2^+ state of ^{26}O obtained with several methods. These values, given in units of MeV, are measured from the thresholds.

Method	^{25}O ($3/2^+$)	^{26}O (2^+)	Ref.
Shell model (USDA)	1.301	1.9	3)
Shell model (USDB)	1.303	2.1	3)
chiral NN + 3N	0.742	1.64	3)
continuum SM	1.002	1.8	4)
continuum-coupled SM	0.86	1.66	5)
3-body model	?	1.6	6)
3-body model	0.749 (input)	1.282	this work
Experiment	0.749 (10)	$1.28^{+0.11}_{-0.08}$	1)

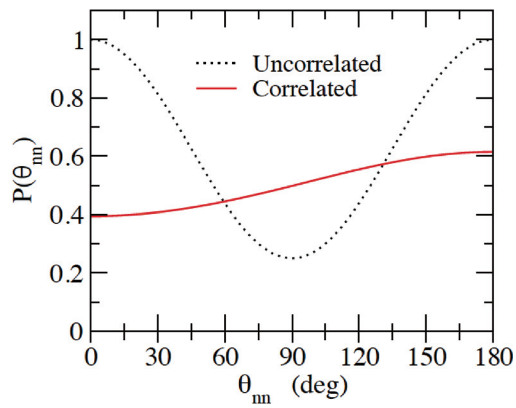

Fig. 1. (Color online) Angular correlations between the emitted neutrons from the two-neutron decay of ^{26}O. The solid and dotted lines show the correlated and uncorrelated distributions, respectively.

References

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