Three-body model calculation of the $2^+$ state in $^{26}$O$^+$

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We discuss the $2^+$ state of $^{26}$O using a three-body model of $^{24}$O+n+n system with full account of the continuum. The decay energy spectrum for a given angular momentum $I$ can be evaluated as

$$\frac{dP_I}{dE} = \sum_k |\langle \Psi_k^{(I)} | \Phi_{ref}^{(I)} \rangle|^2 \delta(E - E_k),$$  \hspace{1cm} (1)

where $\Psi_k^{(I)}$ is a solution of the three-body model Hamiltonian with angular momentum $I$ and energy $E_k$, and $\Phi_{ref}^{(I)}$ is the wave function for a reference state with the same angular momentum. For a reference state we use the uncorrelated state of $^{22}$F with the neutron $[1d_{3/2} \otimes 1d_{3/2}]^{[1]}(I=0')$, configuration, which is dominant in the ground state of $^{22}$F.

With a contact interaction, the continuum effects on the decay energy spectrum can be taken into account in terms of the Green’s function. Notice that Eq. (1) can be expressed as

$$\frac{dP_I}{dE} = -\frac{1}{\pi} \sum_k (\Phi_{ref}^{(I)} | G^{(I)}(E) | \Phi_{ref}^{(I)}) \frac{1}{(E_k - E - i\eta)^2},$$  \hspace{1cm} (2)

where $\Delta$ denotes the imaginary part and $\eta$ is an infinitesimal number and $G^{(I)}(E)$ is the correlated Greens's function. The correlated Greens's function will be constructed using the unperturbed Green’s function.

The upper panel of Fig. 1 shows the decay energy spectrum of $^{26}$O for $I = 0$ (dashed line) and $I = 2$ (solid line). For presentation purposes, we set $\eta$ in Eq. (2) to be a finite value, i.e., $\eta = 0.21$ MeV$^{-1}$. For comparison, we also show the spectrum for the uncorrelated case with a dotted line, which gives the same spectrum both for $I = 0$ and $I = 2$. For the uncorrelated case, the spectrum has a peak at $E = 1.54$ MeV, which is twice the single-particle resonance energy, 0.77 MeV. With the pairing interaction between the valence neutrons, the peak energy shifts towards lower energies. The energy shift $\Delta E$ is larger in $I = 0$ than in $I = 2$, i.e., the peak in the spectrum appears at $E = 0.148$ MeV ($\Delta E = -1.392$ MeV) for $I = 0$ and at $E = 1.354$ MeV ($\Delta E = -0.186$ MeV) for $I = 2$.

We have shown that the $2^+$ state appears at approximately $E = 1.35$ MeV. This $2^+$ energy is close to, but slightly smaller than, the unperturbed energy, $E = 1.54$ MeV, and thus the energy shift from the unperturbed energy is much smaller than the energy shift for the $0^+$ state. We have argued that this is a typical spectrum well understood by the single-$j$ model with the pairing residual interaction. Many shell model calculations such as the ab initio$^3$ and USDA and USDB$^4$ calculations have predicted the excitation energy of the $2^+$ state in $^{26}$O in the opposite trend, i.e., they have predicted a higher energy than the unperturbed energy. The energy of the $2^+$ state needs to be urgently confirmed experimentally$^5$ in order to clarify the validity of nuclear models and effective interactions in nuclei on and beyond the neutron drip-line.

References

5) Y.Kondo and T.Nakamura, private communications.