GAMOW-TELLER BETA DECAY IN SPHERICAL ODD-MASS NUCLEI
- QUADRUPOLE-QUADRUPOLE CORRELATION AND $\sigma\cdot\sigma\ \tau\cdot\tau$ CORRELATION -

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Recently, a new microscopic theory of spherical odd mass nuclei which introduce a new kind of fermion type collective excitation mode i.e. "dressed" three-quasi-particle (3QP) mode has been proposed |1,2|. So far, the analysis of excitation spectra and electromagnetic properties of the low-lying states has been restricted within the framework of the pairing plus quadrupole force (P+QQ̊) model |3,4|. However, for the estimation of beta decay probabilities, it may be necessary to take into account the effect of the correlation arising from the charge exchange proton-neutron (CEPN) interaction specific to beta decay.

In order to take into account this CEPN correlation explicitly,

1) the dressed 3QP mode should be extended to include the corresponding correlation amplitudes, and

2) the shell model space should be extended to include the neutron excess core.

Thus in this treatment, the CEPN correlation will manifest itself as one of the collective excitations which has high excitation energy and it corresponds to the usual charge exchange core polarization |5,6,7|.

The extended dressed 3QP (ED3QP) mode is obtained by adding the following terms to the original mode Y^{+}_{nI} defined by Eq. (2.1) of ref. |4|,

$$\frac{1}{\sqrt{2}} \sum_{\mu_1\mu_2\gamma} \phi^{(V)}_{nI}(\mu_1\mu_2:\gamma)\ \mathbb{P}(\mu_1\mu_2)\ \frac{1}{\sqrt{2}} : \{a^{\dagger}_{\mu_1} a_{\tilde{\mu}_2} + a_{\tilde{\mu}_1} a^{\dagger}_{\mu_2}\} : a_{\tilde{\gamma}}$$

$$+ \sum_{\mu\nu\gamma(m\neq n)} \phi^{(VI)}_{nI}(\mu\gamma;\nu)\, a^{\dagger}_{\nu} a_{\tilde{\mu}} a_{\tilde{\gamma}}$$

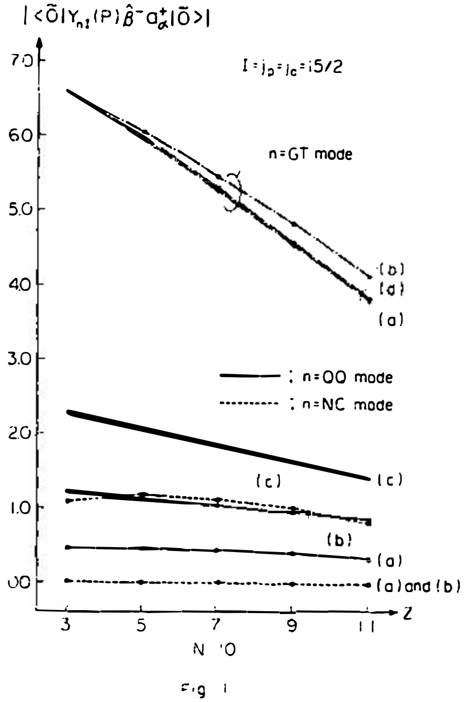

Fig.1. The TME $\langle\tilde{0}|Y_{nI}(P)\hat{\beta}^{-}a_{\alpha}^{+}|\tilde{0}\rangle$ of the electron decay operator in the case of $I=j_p=j_a=15/2$, where $a_{\alpha}^{+}|\tilde{0}\rangle$ is the 1QP state in the neutron odd (Z-1,N+1) nucleus and $Y_{nI}^{+}(P)|\tilde{0}\rangle$ is the ED3QP state in the proton odd (Z,N) nucleus. (a)∿(d) in the figure stand for the following sets of the force strength parameters χ_G and χ_Q with which the equation of motion is solved: (a) $\chi_G=0.54$, $\chi_Q=100$, (b) $\chi_G=0.12$, $\chi_Q=100$, (c) $\chi_G=0.0$, $\chi_Q=100$, (d) $\chi_G=0.54$, $\chi_Q=0.0$. Here, the parameter χ_Q is related to the QQ force strength χ_{QQ} through $\chi_{QQ} = \chi_Q b^{-4}A^{-5/3}$, where b^2 is the harmonic-oscillator range parameter and is taken to be $1.0\ A^{1/3}$. Throughout the calculation, 1QP energy and the mass number are fixed to 1 MeV and 100, respectively.

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where we used the same notation as ref. |4|. By solving the equation of motion for the ED3QP, we can explicitly treat the QQ correlation and the CEPN correlation on an equal footing. Thus we can examine the effects of (and interrelation between) the CEPN correlation and the QQ correlation to beta decay between low-lying states.

In this report we investigate the characteristics

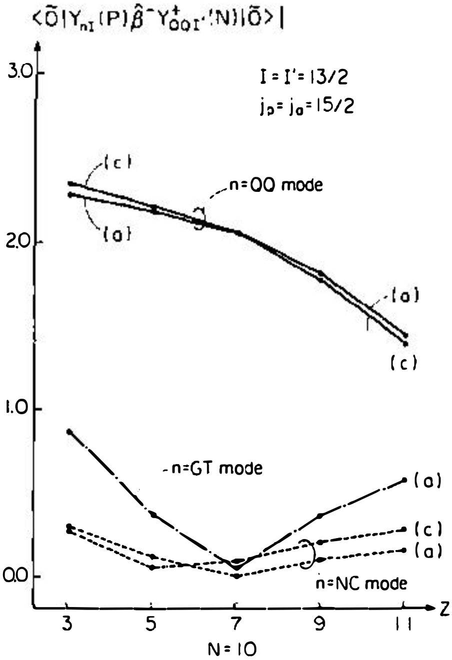

Fig. 2

Fig.2.The TME $\langle\tilde{O}|Y_{nI}(P)\hat{\beta}^- Y^+_{QQI'}(N)|\tilde{O}\rangle$ in the case of $j_p=j_a=15/2$ and $I=I'=13/2$, where $Y^+_{QQI'}(N)|\tilde{O}\rangle$ is the QQ state in the neutron odd (Z-1,N+1) nucleus and $Y^+_{nI}(P)|\tilde{O}\rangle$ is the ED3QP state in the proton odd (Z,N) nucleus. The force parameter set (a) and (c) in the figure are the same as those in fig. 1.

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of this ED3QP mode in the simple model, that is, protons in j_p-shell and neutrons in j_a-shell interacting with P+QQ+ $\sigma\cdot\sigma$ $\tau\cdot\tau$ force.

The ED3QP mode can be expressed with six special correlation amplitudes in this simple model and the eigenvalue equation has three physical solutions for every total spin I.

We found, as expected, that the excitation energy of the lowest solution which we shall call QQ mode is not sensitive to the strength χ_G of the $\sigma\cdot\sigma$ $\tau\cdot\tau$ force, and that of the highest energy solution (GT mode) is not sensitive to the strength χ_{QQ} of the QQ force. The excitation energy of the remaining solution (NC mode) is always close to the unperturbed 3QP energy and is sensitive neither to χ_G nor to χ_{QQ}. Fig. 1 shows the transition matrix element (TME) of the electron decay operator between neutron 1QP mode and proton odd ED3QP modes with $I=j_p$. We can see that the TME between 1QP and the GT mode is not sensitive to χ_{QQ}, but the TME between 1QP and the

QQ mode is quite sensitive to χ_G, i.e. the beta transition intensity of the QQ mode reduces rapidly as the increase of χ_G. --(A) This makes a clear contrast to the excitation energy of the QQ mode which is found to be insensitive to the change of χ_G. We can say that the QQ mode has lost its intensity by the presence of the GT mode (the core polarization effect to the low-lying collective excitation mode).

As for the coupling effect between the ED3QP modes and 1QP mode, we found that the magnitude of the mixing of the GT mode in the 1QP state is about the same as that of the usual core polarization treatment, but that of the QQ mode is about half as large as that given by the phonon-quasi-particle coupling (PQC) model. --(B)

As the results of (A) and (B), the contribution of the QQ mode to the non-l-forbidden decay is greatly reduced compared to that of the PQC model |6| and the importance of the contribution of the GT mode (in the usual treatment, the contribution of the core polarization itself) increases relatively.

Next, the TME of the electron decay operator between the QQ mode and the three kinds of ED3QP modes is shown in fig. 2, where the QQ mode in neutron odd nucleus and the ED3QP modes in proton odd nucleus have the total spin j_a-1 and j_p-1, respectively. We can see that the TME between the QQ modes is larger than the other two and quite insensitive to the variation of χ_G. Thus the l-forbidden decay of the low-lying collective state (the main component of which is the QQ mode) to the single particle state is expected to be mainly determined by the contribution of the QQ modes which mix in the single particle state, in the situations where the TME between the QQ mode in the collective state and 1QP mode in the single particle state can be neglected. In this case the effect of the CEPN correlation is expected to be negligibly small.

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