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MASTER

A CONTRIBUTION TO THE QUASI-PARTICLE
DESCRIPTION OF SPHERICAL NUCLEI

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ABSTRACT

A central force with only the singlet component is used to solve the BCS-Baranger equations for some single-closed 82-neutron nuclei and the resulting wave functions are in turn used to calculate some excited levels of even-even nuclei. The roles of the quasiparticle residual terms are studied and within Tamm-Dancoff approximation (TDA) certain conditions are found to be necessary for the theory to agree with the experimental trends of the energy spectra, the enhanced $2+ \rightarrow 0+$ ground state and retarded $4+ \rightarrow 2+$ transitions. For the quasiparticle interactions in TDA, a triplet force as strong as the singlet seems to be needed. A rough estimate of the lowest order ground state correlation is made for the enhanced $2+ \rightarrow 0+$ transition, and the contribution appears to be negligible.

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Berkeley, California, U.S.A.Description of the Problem.

In a spirit similar to that of Arvieu et al [1], the BCS plus Tamm-Dancoff Approximation (TDA) are applied to some single-closed 82-neutron nuclei, with special attention on Ce^{140} . Of interest are the level spectra of $J > 0$ states, the largely enhanced first $2+ \rightarrow 0+$ (ground state) transition, the large retardation of $4+$ to $2+$ transition and the gyromagnetic ratio of the $4+$ state in Ce^{140} . Except for $0+$ states which require an extended method [1], TDA seems to be sufficient.

(a) The single particle (shell model) levels are taken, in MeV, as $1g_{7/2}(0.)$, $2d_{5/2}(1.00)$, $2d_{3/2}(2.88)$, $1h_{11/2}(2.18)$, and $3s_{1/2}(3.20)$.

(b) The BCS-Baranger equations [3] are solved with the pairing matrix elements computed with $V_{SE} = -37.8$ MeV, r_0 (= range) = $1.73F$, and $V_{TO} = 0$. The strength is adjusted to fit the odd-even mass differences.

(c) The TDA equation is solved for $J > 0$ states with the unperturbed wave functions as given by the results of (b). A strong attractive V_{TO} ($\approx V_{SE}$) is found to be needed to fit the ground-to- $2+$ and $2+$ -to- $4+$ relative spacings.

(d) The $B(E2)$ values for the $2+ \rightarrow 0+$ and $4+ \rightarrow 2+$ transitions are computed in TDA. The relevant transition matrix elements are

$$| \langle 0+ | M(E2) | 2+ \rangle | = \sqrt{5} \left| \sum_{a \geq b} \langle a || e r^2 Y_2 || b \rangle (u_a v_b + v_a u_b) C_{ab2} \delta_{\kappa 2} \delta_{\mu - m} \right| \quad (1)$$

and

$$| \langle 2+ | M(E2) | 4+ \rangle | = \left| \sum_{a \geq b} \sum_{a' \geq b'} (-)^{j_a + j_{b'}} C_{ab2} C_{a'b'4} P(ab; a'b') \right| \quad (2)$$

$$((a' || e r^2 Y_2 || a) W(42aa'; 2b') (u_a u_{a'} - v_a v_{a'}) \delta_{bb'}) | \delta_{\mu, -(m+m')}$$

where C_{ab2} and $C_{a'b'4}$ are 2+ and 4+ wave function amplitudes respectively, W is the Racah coefficient, and $P(ab; a'b')$ arranges the quantity in curly bracket so that all possible combination of $aba'b'$ obtains without changing the positions for the primed and unprimed labels.

The large enhancement of $B(E2; 2+ \rightarrow 0+)$ implies that the individual term in the sum of Eq. (1) contributes coherently. If one chooses the configuration (ab) such that $\langle a || e r^2 Y_2 || b \rangle = \eta |\langle a || e r^2 Y_2 || b \rangle|$, then C_{ab2} should be of the same sign in order to make the entire terms coherent. This condition favors a large V_{TO}/V_{GE} value. On the other hand, the interference in the contributions in Eq. (2) due to the configuration mixing, combined with retardation factor [Racah coefficient and $(u-v)$ factor], is expected to reduce the matrix element [Eq. (2)] considerably. The effect of the ground state correlation on the $B(E2; 2+ \rightarrow 0+)$ was also examined by introducing four-quasi-particle states into the ground state, and the result seems to indicate that the contribution is negligible.

(e) The TDA wave functions are used to compute the magnetic g factors of 4+ states. Around Ce^{140} (which is the only nucleus whose moment has been measured), the g factors for $g_{7/2}$ and $d_{5/2}$ are taken from neighboring odd-A nuclei, whereas the rest are just Schmidt values. The results do not depend on u and v factors, and hence may give a sensitive test for the configuration mixing computed in (c).

Comparison with Experiments.

The spectra of $2+$, $3+$, and $4+$ states are given in Fig. 1 for some of the nuclei around Ce^{140} for which experimental results are more or less known. The radial wave function is the usual harmonic oscillator type with oscillator parameter $\nu^{-1/2} = 2,283\text{F}$. We varied the $V_{\text{TO}}/V_{\text{SE}}$ around unity to fit the data.

The $B(E2)$ values for $2+ \rightarrow 0+$ transition are experimentally known for Ba^{138} , Ce^{140} , and Nd^{142} . In the single particle unit $[B(E2)_{\text{sp}}]$, the theoretical results (for $V_{\text{TO}}/V_{\text{SE}} = 1.0$) are 11, 13, and 16 respectively, compared with experiments 14, 17, and 15. The present experimental knowledge of $4+ \rightarrow 2+$ $E2$ transition is scarce; compare the theoretical value of $1/28$ to the experimental value of $1/17$ for Ce^{140} . The later results are very sensitive to the components of the wave function, but at least the qualitative retardation is understood here.

The most recent magnetic g factor measurement for $4+$ in Ce^{140} reports [4] $g_{4+}(\text{Ce}^{140}) = 0.95 \pm 0.10$ and our result $g = 0.92$ compares well with the experiment. In the quasi-particle configuration, such an agreement implies a dominant $(g_{7/2}^2)$ configuration with other components mixed in. A variation of $V_{\text{TO}}/V_{\text{SE}}$ shows again the V_{TO} should be sufficiently attractive.

REFERENCES

- [1] R. Arvieu, E. Baranger, M. Veneroni, M. Baranger, and V. Gillet, Phys. Letters 4, 119 (1963).
- [2] S. T. Belyaev, Kgl. Danske Videnskab. Selskab, Mat.-Fys. Medd. 31, No. 11 (1959).
- [3] M. Baranger, Phys. Rev. 120, 957 (1960).
- [4] M. Schmorak, H. Wilson, P. Catti, and L. Grodzins, to be published in Phys. Rev.

FIGURE CAPTION

1. Level spectra for $J\pi = 2+, 3+, 4+$. The far right entry in parenthesis corresponds to the dominant component of the wave function.

Fig. 1

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