entering in the calculation are the coupling constants $\varkappa(\alpha = 0, \lambda, \tau)$ and $G(\alpha = \pm 2, \lambda, \tau)$ which are fixed by fitting the experimental energy of the lowest state of each family of levels.

ii) The calculation of the coupling between the particles (holes) and the vibrational modes, i. e. the calculation of the admixture of 1p-states and 2p−1h states. The coupling strength between the particle (hole) and the vibration is fixed self-consistently by the value of the coupling constants determined in step i).

iii) The calculation of the interaction between the two-phonon states of ^{208}Pb. This interaction is built out of a series of particle-vibration vertices, and consequently the magnitudes of the different matrix elements are fixed self-eonsistently by the values of the coupling strengths obtained in step (ii).

In this way an effective interaction between the elementary modes of excitation as well as composed states is obtained. Particularly, the interaction between the $J^\pi = 0^+$ states was calculated and the results compared with the ^{206}Pb(t, p) and ^{210}Pb(p, t) reaction data [5,8]. The effective interaction between the states of two-phonons with $J_R = 2^+$ in ^{208}Pb is also constructed. Special attention was paid to the states $|2_1^+(^{206}\text{Pb}) \cdot \text{gs}(^{210}\text{Pb}); 2\rangle$ and $|\text{gs}(^{210}\text{Pb}) \cdot 2_1^+(^{210}\text{Pb}); 2\rangle$, and the predictions are compared with the reaction data. For the first time the result provides a clear evidence on the existence of isovector quadrupole mode which dramatically renormalizes (screens) the quadrupole interaction between particles and holes.

The ^{208}Pb(t, p) ^{210}Pb(3^-) reaction is analyzed in the coupled channel Born approximation (CCBA)[4,8]. The competition between the effects of the effective interaction, the effective transfer operator and two-step processes was evidenced.

The (t, p) cross section cannot be explained without accounting for the contributions due to the correlations induced in the ^{208}Pb ground state by the 0^+ pairing vibration and the 3^- particle-hole mode. The inclusion of indirect reaction channels which interfere with the direct one brings the improved results in closer agreement with experiment. The importance of these two effects is due to the collect ivity of the pairing and particle-hole modes in ^{208}Pb and ^{210}Pb, respectively.

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3.4. On the BCS and HFB methods in terms of reduced density matrices

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The basic assumption of the BCS model of spherical nuclei, which are characterized by a large number (10—20) of particles outside the inert core of doubly

closed shells, such as Sn isotopes, is that the ground state of a given nucleus may be described by the function[1] (expressed in the occupation number representation)

$$|\,\mathrm{BCS}\rangle = \prod_{\alpha>0}(u_\alpha + v_\alpha\, s_\alpha\, c_\alpha^+ c_{-\alpha}^+)\,|\,0\rangle, \qquad u_\alpha^2 + v_\alpha^2 = 1. \tag{1}$$

The above function is a mixture of components corresponding to all even systems possible in given orbits

$$|\,\mathrm{BCS}\rangle = \sum_{n=\text{even}} a_n\,|\,\psi_n\rangle, \qquad \sum a_n^2 = 1. \tag{2}$$

where $|\,\psi_n\rangle$ are special seniority zero states of the nucleus with n valence particles.

Thus, the $|\,\mathrm{BCS}\rangle$ function cannot be interpreted as a wave function of the given nucleus with N_0 valence particles. The central idea of this report is that the $|\,\mathrm{BCS}\rangle$ function can be interpreted as a convenient parametrization of the two-body reduced density matrix[2,3]

$$\varrho^{(2)}_{\alpha\beta\gamma\delta} = \langle \mathrm{BCS}\,|\,c_\alpha^+ c_\beta^+ c_\delta c_\gamma\,|\,\mathrm{BCS}\rangle. \tag{3}$$

In fact, this assumption is implicit in the standard BCS model, but there the one-body reduced density matrix is defined independently of (3) as

$$\varrho^{(1)}_{\alpha\beta}(\mathrm{BCS}) = \langle \mathrm{BCS}\,|\,c_\alpha^+ c_\beta\,|\,\mathrm{BCS}\rangle, \tag{4}$$

while it should be more consistently derived from (3) using the exact relation

$$\varrho^{(1)}_{\alpha\beta} = \frac{1}{N_0 - 1}\sum_\gamma \varrho^{(2)}_{\alpha\gamma\beta\gamma} \tag{5}$$

which gives

$$\varrho^{(1)}_{\alpha\beta} = \frac{1}{N_0 - 1}\langle \mathrm{BCS}\,|\,c_\alpha^+ c_\beta\,(N-1)\,|\,\mathrm{BCS}\rangle\,. \tag{6}$$

Taking the trace of relation (6), we arrive at the condition

$$\langle\,\mathrm{BCS}\,|\,N(N-1)\,|\,\mathrm{BCS}\,\rangle = N_0\,(N_0 - 1) \tag{7}$$

instead of the usual BCS condition $N_0 = \langle\,\mathrm{BCS}\,|\,N\,|\,\mathrm{BCS}\,\rangle$.

The above definition of the $\varrho^{(1)}$ matrix leads to some correction terms in the BCS gap equations. Numerical analysis shows that in most cases, when the standard BCS procedure works well, these correction terms do not change the results appreciably. However, for some forces, such as the Gaussian potential of Wigner type, for which the standard BCS procedure completely breaks down giving the unphysical energy much lower than the exact one, the above modification works as well as with other »good« forces. The reasons for this improvement may be traced down by careful analysis of the variational principle.

The more general HFB method can be modified in the same way, but additional problems appear when both neutrons and protons are considered. It seems that instead of the additional condition for the isospin

$$\mathrm{Re}\,\langle \mathrm{HFB}\,|\,T^2\,|\,\mathrm{HFB}\,\rangle = T(T+1), \tag{8}$$

the following (somewhat weaker) condition might turn out more useful

$$\mathrm{Re}\,\langle \mathrm{HFB} \mid N_n N_p \mid \mathrm{HFB} \rangle = N_n N_p. \qquad (9)$$

In describing the excited states by the quasiparticle method based conceptually on ideas of reduced density matrices and transition amplitudes, a very consistent definition of spurious states can be reached which for higher excitations basically differs from the usual one.

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3.5. Investigation of the low energy spectrum in ^{93}Nb*

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3.6. Projection of angular momentum from the generator coordinate wave function

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3.7. Pairing vibrational states in Pb and Sn isotopes**

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3.8. A formula to calculate particle-hole excited states if the two-body density matrix of the ground state is known

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3.9. Three-particle states in the semimicroscopic model

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In nuclei with three particles (holes) away from a single-closed shell or a good subshell, the model of coupling a three-particle (hole) cluster to the quadrupole vibrational field was introduced in order to include the anharmonic structure of the neighbouring even nuclei as well as additional states based on broken and promoted pairs.[1-5] So far this model has been successfully applied to ^{51,53,55}Mn[5], ^{65,67,69}Ga[5], ^{107,109}Ag[5], ^{123,125,127}I[5] and ^{193,195,197,199}Au[1-4]. The success of the model is reflected in reproducing the global structure and the properties of the ground and excited states; this means that the overall agreement with experiment for low lying states is rather good (energy spectra, B(E2) and B(M1) values, electric

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