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EFFECT OF THE PARTICLE-PARTICLE INTERACTION ON THE GAMOW-TELLER β^+-DECAY IN SPHERICAL NUCLEI

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Влияние взаимодействия в канале частица-частица на гамов-теллеровский β^+-распад в сферических ядрах

В приближении хаотических фаз с учетом остаточных сепарабельных взаимодействий в каналах частица-частица и частица-дырка вычислены ft-величины гамов-теллеровских β^+-распадов ядер ^{152}Yb, ^{150}Er, ^{148,146}Dy и ^{96}Pd. При фиксированном отношении констант частично-частичного и частично-дырочного взаимодействий получено согласие с экспериментально определенными значениями ft для $|G_A/G_V| = 1$. Показано, что из расчетов вероятностей β-распадов ядер, удаленных от полосы стабильности, нельзя сделать вывод о величине перенормировки аксиально-векторной константы G_A слабого взаимодействия.

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Effect of the Particle-Particle Interaction on the Gamow-Teller β^+-Decay in Spherical Nuclei

In RPA approximation, taking account of residual separable interactions in the particle-hole and particle-particle channels, ft-values for the Gamow-Teller β^+-decays of ^{152}Yb, ^{150}Er, ^{148,146}Dy and ^{96}Pd are calculated. At a fixed constant ratio of the particle-particle and particle-hole interaction agreement with experimentally determined ft-values for $|G_A/G_V| = 1$ is obtained. It is shown that from the calculations of probabilities of β-decays of nuclei far from stability one cannot conclude on the renormalisation of the axial-vector constant G_A of the weak interaction.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

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Advances in describing some characteristics of collective low-lying states within the interacting boson model[1], that takes into account particle-particle interactions, entailed studies of the role of particle-particle interactions. Taking interactions in the particle-hole and particle-particle channels into account simultaneously allows one to fit the description of the two-neutrino double ß-decay with the experiment[2]. This letter is devoted to the description of the Gamow-Teller β^+-decay of even spherical nuclei in the RPA taking into account interactions between quasiparticles in the particle-particle and particle-hole channels.

The QPNM Hamiltonian[3] contains particle-hole and particle-particle interactions between quasiparticles. From the general formulae of the model one can easily derive equations for the energies and wave functions of the Gamow-Teller 1^+ states in the RPA with particle-particle and particle-hole charge-exchange interactions with the constants G_1^{01} and $\varkappa_1^{01}$, respectively. The creation operator of the charge-exchange phonon is written in the form

$$\Omega_i^+ = \sum_{j_p, j_n} \{ \psi^i_{j_p j_n} A^+(j_p j_n ; 10) + \varphi^i_{j_p j_n} A(j_p j_n ; 10) \},$$

where

$$A^+(j_p j_n ; 10) = \sum_{m_p, m_n} \langle j_p m_p j_n m_n | 10 \rangle \alpha^+_{j_p m_p} \alpha^+_{j_n m_n} .$$

Here α^+_{jm} is the quasiparticle creation operator, $j_p m_p$ ($j_n m_n$) are quantum numbers of proton (neutron) single-particle states, i = 1, 2, 3,... is the root number of the relevant secular equation.

The matrix element of the β^+-decay of the ground state of the doubly even nucleus with the wave function Ψ_0 into the one-phonon 1^+state of the doubly odd nucleus with the wave function $\Omega_i^+ \Psi_0$ is

$$(\Psi_0^* \Omega_i H_\beta^1 \Psi_0) = \sum_{j_p j_n} \langle j_n \| \Gamma_\beta \| j_p \rangle (\psi^i_{j_p j_n} v_{j_p} u_{j_n} + \varphi^i_{j_p j_n} u_{j_p} v_{j_n}),$$

where $\langle j_n \| \Gamma_\beta \| j_p \rangle$ is the single-particle Gamow-Teller matrix element, u_j and v_j are the coefficients of the Bogolubov canonical transformation. The inclusion of the particle-particle interaction alongside with the particle-hole interaction leads to the increase of $\varphi^i_{j_p j_n}$ for the lowest states. Since the signs of the functions $\psi^i_{j_p j_n}$ and $\varphi^i_{j_p j_n}$ are opposite, the increase in the absolute value of the particle-particle interaction constant leads to the suppression of the β^+ transition probabilities.

The results of calculations of $\log \tilde{ft}$ for the β^+ transitions to the lowest 1^+ states of neutron-deficit nuclei calculated in the RPA and the relevant experimental sum values of $\log \tilde{ft}$, defined as

$$(\tilde{ft})^{-1} = \sum_K (ft)_K^{-1}$$

of refs. /5-9/ are shown in the table. The same single-particle energies and wave functions of the Saxon-Woods potential and the pairing constants were used in the calculations as in ref. /4/. The value of $|\varkappa_1^{01} A|$ is 1.5 times as large as the value used in ref. /4/ when studying nuclei of the stability zone. The constants of the particle-particle interaction $G_1^{01} = -0.2\varkappa_1^{01}$ were used in the calculations. With increasing constant one can suppress twice the strength of ß-transitions to the low-lying states without violating the applicability conditions for the RPA.

Table. Values of $\log \tilde{ft}$ for β^+-transitions from $0^+_{g.s.}$ to 1^+ states

β^+-transition	$\log \tilde{ft}$ (experiment)	$\log \tilde{ft}$ (calculation) $G_1^{01} = -0.2\varkappa_1^{01}$	$G_1^{01} = 0$
^{152}Yb - ^{152}Tm	3.4	3.5	3.1
^{150}Er - ^{150}Ho	3.6	3.5	3.2
^{148}Dy - ^{148}Tb	3.9	3.7	3.4
^{146}Dy - ^{146}Tb	3.8	3.8	3.3
^{96}Pd - ^{96}Rh	3.3	3.3	3.0

In more detail we consider the results of calculations of β^+-decay in ^{148}Dy. In comparison with the independent particle model the inclusion of the particle-hole interaction results in a 2.65 decrease of the total β^+-transition strength. The inclusion of the particle-particle interaction gives an additional twice suppression. At $G_1^{01} = -0.21\varkappa_1^{01}$ we get $\log \tilde{ft}=3.9$ that coincides with the experimental value. With increasing G_1^{01} the total ß-transition strength decreases on retention of the relevant sum rule.

We have calculated the matrix elements of the two-neutrino double β^--decay for ^{128,130}Te at $G_1^{01} = -0.2\varkappa_1^{01}$ that are in agreement with ref. /2/ and the experimental value. The necessity of taking into account the interaction in the particle-particle channel to suppress the strength of the two-neutrino double β-decay is confirmed in ref. /10/.

In describing ß-decays of nuclei far from stability, the axial-vector constant G_A of a weak interaction is renormalised. In order to obtain an agreement with the experimental ft-values, it has been assumed in refs. /5,6/ that $|G_A/G_V| = 0.6-0.8$ and in ref. /11/ that $|G_A/G_V| = 0.7-1.0$. Our calculations are performed with $|G_A/G_V| = 1$. The $\tilde{ft}$-values, that are in agreement with the experiment, have been obtained for $|G_A/G_V| = 1.25$ with increasing G_1^{01} by 3%. Therefore, one cannot conclude on the renormalisation of the axial-vector constant G_A of the weak interaction from the calculations of β^+-decays of nuclei far from stability.

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