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# DESCRIPTION OF THE GAMOW-TELLER RESONANCES IN DEFORMED NUCLEI

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In recent years the Gamow-Teller (GT) giant resonances and the charge-exchange resonances of the electric type have been observed experimentally in many atomic nuclei /1,2/. Their properties are calculated for several magic nuclei. The charge-exchange resonances can be described within the quasiparticle-phonon nuclear model /3,4/ in the same way as in ref./5/ where the neutron-proton phonons have been introduced to calculate the $T_>$ giant dipole resonance in spherical nuclei. In this paper in the RPA we get an equation for the description of the GT resonances and calculate the strength functions of the (p, n) and (n, p) reactions for some deformed nuclei.

The Hamiltonian of the quasiparticle-phonon nuclear model (QPM) includes the average nuclear field as the Saxon-Woods potential, the pairing interactions, the multipole-multipole and spin-multipole - spin-multipole interactions. A part of the spin-multipole - spin-multipole interaction is taken in the form

$$\kappa_1^{(1)} (t_1^+ t_2^- + t_1^- t_2^+) \vec{\sigma}_1 \vec{\sigma}_2 , \qquad (1)$$

where $\kappa_1^{(1)}$ is the constant of the isovector interaction, $t^{\pm} = t_x \pm i t_y$.

We transform the model Hamiltonian to the same form as in ref./5/. After the Bogolubov transformation we introduce the np -phonon operators

$$\Omega_{\rho\mu i} = \frac{1}{\sqrt{2}} \sum_{rs} \{ \psi_{rs}^{\mu i} A(rs, \mu\rho) - \phi_{rs}^{\mu i} A(rs, \mu -\rho) + \bar{\psi}_{rs}^{\mu i} \bar{A}(rs, \mu\rho) - \bar{\phi}_{rs}^{\mu i} \bar{A}(rs, \mu -\rho) \}, \qquad (2)$$

where

$$A(rs, \mu\rho) = \sum_{\rho'} \delta_{\rho'(K_r - K_s), \rho\mu}\, \alpha_{s -\rho'} \alpha_{r\rho'} ,$$

$$\bar{A}(rs, \mu\rho) = \sum_{\rho'} \delta_{\rho'(K_r + K_s), \rho\mu}\, \alpha_{r\rho'} \alpha_{s -\rho'} ,$$

$\alpha_{r\rho}$ is the quasiparticle absorption operator, r and s denote the quantum numbers of the proton and neutron single-particle states, and $\rho = \pm 1$.

The equations for the energies $\Omega_{\mu i}$ of the np -phonon states in the RPA are

$$F(\Omega_{\mu i}) = (1 - \kappa_1^{(1)} X_1^{\mu i})(1 - \kappa_1^{(1)} X_2^{\mu i}) - (\kappa_1^{(1)} X_{12}^{\mu i})^2 = 0, \qquad (3)$$

where

$$X_1^{\mu i} = \sum_{rs} 4 \{ (f_{rs}^{\mu})^2 + (\bar{f}_{rs}^{\mu})^2 \} \{ \frac{u_r^2 v_s^2}{\epsilon(rs) - \Omega_{\mu i}} + \frac{v_r^2 u_s^2}{\epsilon(rs) + \Omega_{\mu i}} \} , \qquad (4)$$

$$X_2^{\mu i} = \sum_{rs} 4 \{ (f_{rs}^{\mu})^2 + (\bar{f}_{rs}^{\mu})^2 \} \{ \frac{v_r^2 u_s^2}{\epsilon(rs) - \Omega_{\mu i}} + \frac{u_r^2 v_s^2}{\epsilon(rs) + \Omega_{\mu i}} \} , \qquad (4')$$

$$X_{12}^{\mu i} = \sum_{rs} 4 \{ (f_{rs}^{\mu})^2 + (\bar{f}_{rs}^{\mu})^2 \} \{ \frac{1}{\epsilon(rs) - \Omega_{\mu i}} + \frac{1}{\epsilon(rs) + \Omega_{\mu i}} \} u_r v_s v_r u_s , \qquad (5)$$

$\epsilon(rs) = \epsilon(r) + \epsilon(s)$, $\epsilon(r)$ is the quasiparticle energy, $u_r$ and $v_r$ are the Bogolubov transformation coefficients, and the matrix elements have the form $f_{rs}^{\mu} = \langle r\rho | \sigma_{\mu} t^- | s\rho \rangle$, $\bar{f}_{rs}^{\mu} = \langle r\rho | \sigma_{\mu} t^- | s -\rho \rangle$.

Using the strength function method (see refs./3,4/ ) we get the (p, n) and (n, p) strength in the form

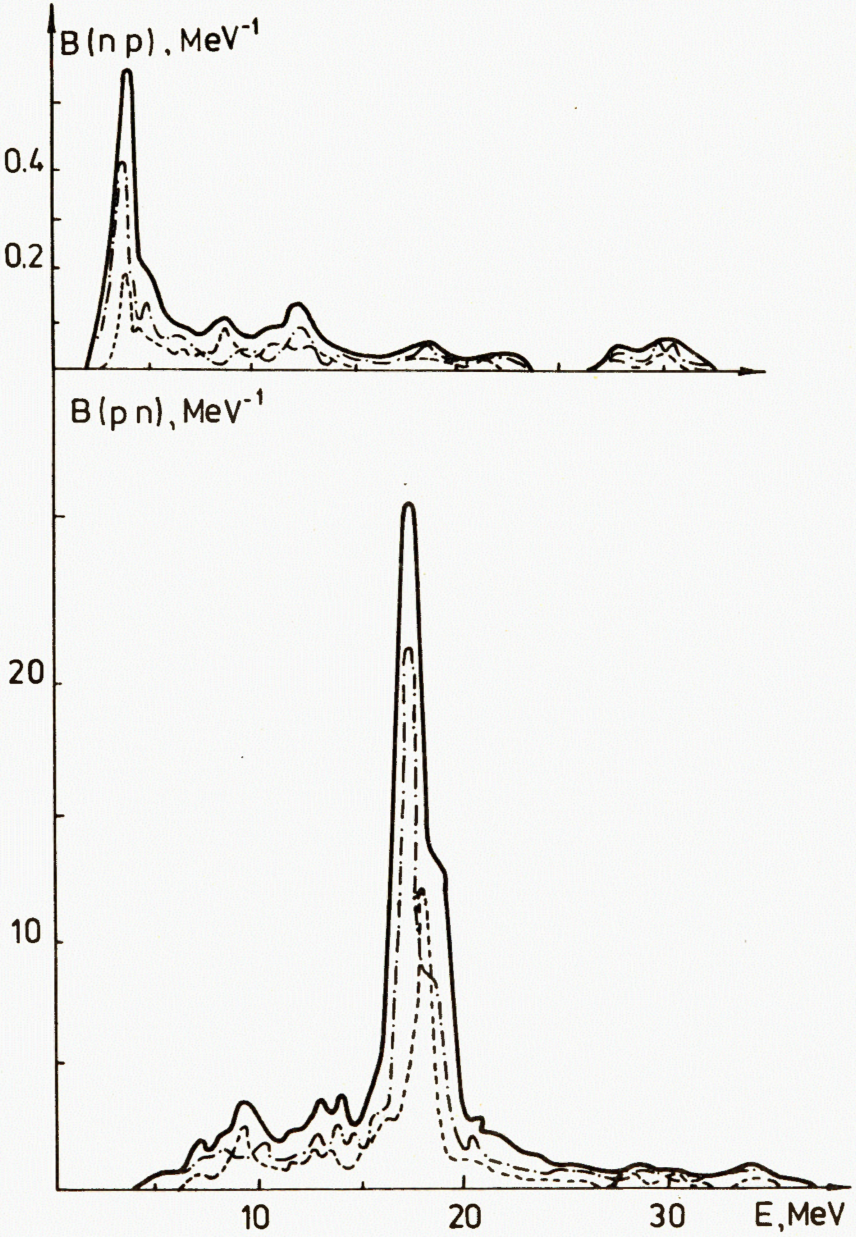
$$B(np) = \frac{1}{\pi} \mathrm{Im} \{ \frac{1 - \kappa_1^{(1)} X_1(z)}{2\kappa_1^{(1)} F(z)} |_{z = \Omega + i\Delta/2} \} , \qquad (6)$$

$$B(pn) = \frac{1}{\pi} \mathrm{Im} \{ \frac{1 - \kappa_1^{(1)} X_2(z)}{2\kappa_1^{(1)} F(z)} |_{z = \Omega + i\Delta/2} \} , \qquad (7)$$

where Δ is the averaging parameter.

The calculations have been performed for $^{162}$Dy, $^{166,168}$Er and $^{238}$U with the largest possible number of single-particle levels. The parameters of the Saxon-Woods potential and the pairing constants are the same as in ref./4/, $\kappa_1^{(1)} = 17/A$ MeV, that is less than the values given in refs./1,2,6/ due to the inclusion of a large number of single-particle states.

By the example of $^{166}$Er we demonstrate the results of calculations given in the figure. It represents the strength functions calculated with $\Delta = 0.5$ MeV of the (n, p) transitions and of the (p, n) transitions with the excitation of the GT resonances. The GT strength is distributed in the region of 5-40 MeV, and the



Strength functions of the (n, p) and (p, n) reaction on $^{166}$Er the dashed line is the strength function with $I^{\pi}K = 1^{+}0$, and the dot-dash line is the strength function with $I^{\pi}K = 1^{+}1$.

GT resonances have a strong maximum at 17.4 MeV with respect to the ground state of the target-nucleus. This maximum is by 0.7 MeV higher than the isobar-analogous states$^{/7/}$ and is close to the experimentally measured value. For $^{168}$Er and $^{162}$Dy the GT maximum is higher by 1.7 and 1.1 MeV than the isobar-analogous state. In the GT strength distribution, one can separate the low-energy part (5-16 MeV), the region of maximum(16-19 MeV) and the high-energy part (19-40 MeV), the contribution of which is 31%, 51%, and 18%, respectively. Such a distribution of strength takes place in all the calculated nuclei. The centroid energy of the low-energy part equals 11.7 MeV, and it is lower by 5.7 MeV than the GT maximum. According to the calculations about 1% of GT strength in $^{168}$Er and $^{238}$U lies at an energy of about 50 MeV. In the deformed nuclei the GT resonance consists of the components with $I^{\pi}K$ equal to $1^{+}0$ and $1^{+}1$, which are splitted by 0.6 MeV for $^{166}$Er and by 0.3 MeV for $^{238}$U. In comparison with the spherical nuclei the GT maximum becomes somewhat broader and a portion of its strength in the low-energy region increases. The (n, p) transition strength is distributed in the region of 2-30 MeV with the centroid energy of 12 MeV for the nuclei in the rate-earth region and of 15 MeV for $^{238}$U. The ratio B(pn)/B(np) for the nuclei of the rare-earth elements is 20 and for $^{238}$U is 57. For the GT transitions there exists a simple sum rule$^{/8/}$:

$$B(pn) - B(np) = 3(N - Z).$$

In our calculations (98-99)% of $3(N - Z)$ is exhausted in all the nuclei.

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Описание гамов-теллеровских резонансов
в деформированных ядрах

В приближении хаотичных фаз рассчитаны силовые функции (p, n) и (n, p) переходов в $^{162}$Dy , $^{166,168}$Er и $^{238}$U. Показано, что максимум ГТР находится при энергии 17-18 МэВ, в нем сосредоточено около 50% его силы. В низкоэнергетической части локализовано около 30% силы ГТР.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

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Description of the Gamow-Teller Resonances
in Deformed Nuclei

The strength functions of the (p, n) and (n, p) reactions for $^{162}$Dy, $^{166,168}$Er and $^{238}$U are calculated in the RPA. The maximum of the Gamow-Teller (GT) resonances is shown to be at 17-18 MeV and it contains about 50% of the GT strength. About 30% of the GT strength is localized in the low-energy part.

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

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