Contribution of tensor forces to formation of Gamow-Teller Resonance and its overtone in closed-shell parent nuclei

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A mean-field and interaction in the particle-hole (p-h) channel are the input quantities for any RPA-based approach to describing Gamow-Teller Resonance and its overtone — Isovector Giant Spin-Monopole Resonance in the $\beta^{(-)}$ -channel (GTR and IVGSMR$^{(-)}$, respectively). The recent example of such an approach is given in Ref. [1], where main properties of mentioned resonances in ^{208}Bi are described within the continuum-RPA-based semimicroscopic p-h dispersive optical model. A realistic partially self-consistent phenomenological mean field and Landau-Migdal p-h interaction have been used in this study. Provided that dimensionless strength g' of the spin-isospin part of the mentioned interaction is adjusted to reproduce in calculations of the GT strength function the observable GTR energy, the calculated IVGSMR$^{(-)}$ energy is found to be less (on about 3 MeV) than respective experimental value. In the present study, we attempt to resolve this puzzle by taking into account tensor forces, which lead to mixing 1^+ spin-monopole and spin-quadrupole excitations. In applying to describing GT strength distribution, tensor forces have been considered in Ref. [2]. Mentioned mixing takes place due to both the spin-orbit term in a mean field (so-called nonsymmetric or non-diagonal approximation in RPA-based approaches employing central forces [3] and non-central (tensor) forces. Using the mentioned continuum-RPA-based analysis of Ref. [1] as a starting point, we resolved the above-described puzzle related to evaluation of the IVGSMR$^{(-)}$ energy by taking tensor forces into account. As expected, the strength parameter of the spin-isospin part of non-central forces g'_T is found to be less than the Landau-Migdal parameter g'.

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2. A. P. Severyukhin and H. Sagawa, Prog. Theor. Exp. Phys. 103D03 (2013).
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External field (probing operator)

$$V^{(-)}_{JLSM}(\mathbf{r}) = V^{(-)}_{JLS}(r)\,T_{JLSM}(\mathbf{n}),\quad J=1,\; S=1,\; L=0,\; L=2$$

$$\tilde{V}^{(-)}_{J=1,L=0,S=1}(r) = \begin{cases} V_{GT} = 1 \\ V_{SM}(r) = r^2 - \eta \end{cases}$$

$$T_{JLSM}(\mathbf{n}) = \sum_{m\mu} \langle Lm, S\mu | JM \rangle Y_{Lm} \cdot \boldsymbol{\sigma}_{S,M}$$

$$T_{J=1,L=0,S=1,M} = Y_{00} \cdot \boldsymbol{\sigma}_{1,M}$$

Effective field

$$\tilde{V}^{(-)}_{J=1,M}(\mathbf{r},\omega) = \tilde{V}^{(-)}_{J=1,L=0,S=1}(r,\omega)\,T_{J=1,L=0,S=1,M}(\mathbf{n}) + \tilde{V}^{(-)}_{J=1,L=2,S=1}(r,\omega)\,T_{J=1,L=2,S=1,M}(\mathbf{n})$$

Set of eqs. for the radial effective fields:

$$\tilde{V}^{(-)}_{J,L=0,S}(r,\omega) = V^{(-)}_{J,L=0,S}(r) + \frac{2G'}{r^2}\int_0^\infty A^{(-)}_{J;L=0,L=0,S,S}(r,r',\omega)\tilde{V}^{(-)}_{J,L=0,S}(r',\omega)\,dr' + \frac{2G'}{r^2}\int_0^\infty A^{(-)}_{J;L=0,L=2,S,S}(r,r',\omega)\tilde{V}^{(-)}_{J,L=2,S}(r',\omega)\,dr'$$

$$\tilde{V}^{(-)}_{J,L=2,S}(r,\omega) = \frac{2G'}{r^2}\int_0^\infty A^{(-)}_{J;L=2,L=0,S,S}(r,r',\omega)\tilde{V}^{(-)}_{J,L=0,S}(r',\omega)\,dr' + \frac{2G'}{r^2}\int_0^\infty A^{(-)}_{J;L=2,L=2,S,S}(r,r',\omega)\tilde{V}^{(-)}_{J,L=2,S}(r',\omega)\,dr'$$

$$A^{(-)}_{J;L=0,L=2,S,S}(r,r',\omega) = \sum_{(\pi),\nu} n_\nu t^{J,L=0,S}_{(\pi)(\nu)} t^{J,L=2,S}_{(\pi)(\nu)} \chi_\nu(r)\chi_\nu(r')\,g_{(\pi)}(r,r',E=E_\nu+\omega) + \sum_{(\nu),\pi} n_\pi t^{J,L=0,S}_{(\nu)(\pi)} t^{J,L=2,S}_{(\nu)(\pi)} \chi_\pi(r)\chi_\pi(r')\,g_{(\nu)}(r,r',E=E_\pi-\omega)$$

$$t_{(\nu)(\lambda)} = \frac{\langle j_\nu l_\nu \| T_{JLS} \| j_\lambda l_\lambda \rangle}{\sqrt{2J+1}}$$

Polarizability

$$P^{(-)}\left(\left[\tilde{V}^{(-)}_{J,L=0,S}\right],\omega\right) = \int_0^\infty\int_0^\infty V^{(-)}_{J,L=0,S}(r)\left\{A^{(-)}_{J;L=0,L=0,S,S}(r,r',\omega)\tilde{V}^{(-)}_{J,L=0,S}(r',\omega) + A^{(-)}_{J;L=0,L=2,S,S}(r,r',\omega)\tilde{V}^{(-)}_{J,L=2,S}(r',\omega)\right\}dr\,dr'$$

Strength function

$$S\left(\left[\tilde{V}^{(-)}_{J,L=0,S}\right],\omega\right) = -\frac{1}{\pi}\operatorname{Im} P^{(-)}\left(\left[\tilde{V}^{(-)}_{J,L=0,S}\right],\omega\right)$$