Quenching factor of Gamow-Teller and spin dipole resonances†

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Spin-isospin excitations provide a unique opportunity to study the spin correlations in nuclei. The Gamow-Teller (GT) transition is the simplest with both spin and isospin transfers by one unit. The next simplest is spin-dipole (SD) excitations, which involve the orbital angular momentum transfer by one unit together with spin and isospin transfer. The quenching of the total GT strength from the model-independent sum rule has prompted theoretical studies of possible mechanisms, ranging from conventional configuration mixing to an admixture of Δ-hole states. Experimental investigations of the (p, n) and (n, p) reactions using the multipole decomposition (MD) technique have identified not only the GT strength but also a considerable amount of broadly distributed $L = 1$ SD strength at excitation energies beyond the GT peak.

We study GT and SD states in four doubly magic nuclei ^{48}Ca, ^{90}Zr, ^{132}Sn, and ^{208}Pb by using the self-consistent Hartree-Fock+random-phase approximation (RPA) model with/without tensor interactions. We adopt the modern energy density functions (EDFs) SAMi and SAMi-T for the theoretical study. The latter has tensor terms determined from Bruckner HF calculations with the AV18 interaction.

The GT strength is shown in Fig. 1 for the t_- channel of ^{48}Ca. The main experimental GT resonance was found experimentally at E_x ∼10 MeV, in addition to a small peak at $E_x = 3$ MeV in ^{48}Ca. The results calculated with SAMi reproduce well the main peak, but the low-energy strength is predicted 1 MeV lower than the experimental one. SAMi-T gives essentially the same results for the main peak, but reproduces better the excitation energy for the small lower energy peak. The integrated GT strength from $E_x = 0 \to 25$ MeV is 15.3, which is 64% of the GT sum rule. The calculated results exhaust almost 100% of the sum rule up to $E_x =$ 20 MeV. The quenching factor for the transition strength is defined as

$$qf = \sum_{E_x=0}^{E_x(max)} B(GT : E_x)_{exp} \Bigg/ \sum_{E_x=0}^{E_x(max)} B(GT)_{cal},$$

where $E_x(max)$ is taken to be 30 MeV in the GT case. The quenching factor $qf = 0.64$ corresponds to a renormalization factor of $q_{RF} = 0.80$ for the GT transition operator to retain the empirical sum rule value.

The calculated SD strength for ^{48}Ca is shown in Fig. 1.

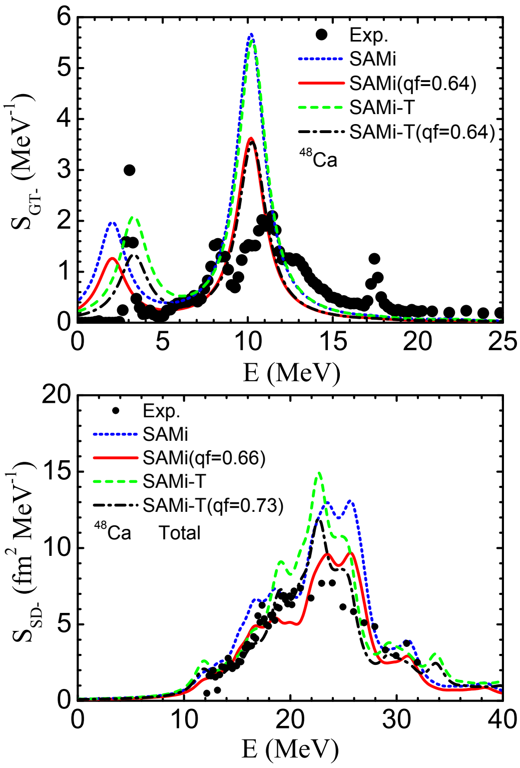

Fig. 1. RPA strength functions of ^{48}Ca for the t_- channel of GT and SD resonances. The solid circles are the experimental data taken from Ref. 1). The short-dotted (short-dashed) and solid (dashed-dotted) lines are the theoretical results without and with a quenching factor given by the SAMi (SAMi-T) EDF, respectively.

The tensor interactions have substantial effects on the SD response, and the effect is different for each multipole. As a net effect, the main peak at E_x ∼23 MeV is shifted to a lower energy by 1 MeV by the tensor effect, which provides a better description of the experimental strength distributions of SD for ^{48}Ca.

The quenching effect is modest for the SD strength. In ^{48}Ca, the qf value is 0.66 (0.73) for the SD with the SAMi (SAMi-T) EDF. In ^{90}Zr, the GT needs $qf = 0.7$, while the SD shows $qf = 0.8$. The feature of quenching is the same for ^{208}Pb; $qf = 0.65$ for the GT and $qf =$ 0.78(0.80) for the SD with the SAMi (SAMi-T) EDF.

In conclusion, the quenching effect is modest for the SD strength with the quenching factor $qf \sim 0.8$ compared with that for GT, for which $qf \sim (0.55 - 0.69)$, which is consistent with the quenching value obtained from the GT beta decay processes in nuclei with $A < 50$. This difference in the effective quenching factors between GT and SD should be implemented in future theoretical studies of double beta decay probabilities.

Reference

1) K. Yako *et al.*, Phys. Rev. Lett. **103**, 012503 (2009) and private communications.

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