Effects of two particle-two hole configurations and tensor force on β decay of magic nuclei†

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A nuclear β decay is a weak interaction process, which plays a significant role in the neutron capture process of stellar nucleosynthesis. With the development of radioactive ion-beam facilities, important advances and improvements in nuclear β decay half-life measurement have been achieved in recent years.

Quasi-particle random phase approximation (QRPA) model can be applied to calculate the β decay half-lives of all nuclei in the whole nuclear chart. However, in the QRPA approach, low-lying 1^+ Gamow-Teller (GT) states of daughter nuclei are often predicted either at high energy or with much small strength, and consequently, the estimated half-lives become longer than the experimental data.

To overcome the deficiency of QRPA, we adopt the subtracted second RPA (SSRPA) model, which include both the 1p-1h and 2p-2h configurations, for the study of β decay half-lives. The SSRPA model has been applied to study collective excitations and GT giant resonances (GTGR) of several magic and semi-magic nuclei successfully.1) Recently, tensor force was introduced in the SSRPA calculations and found to play an important role to reproduce experimental excitation energies and GTGR strengths.2)

The beta decays of nuclei in this study are dominated by the GT strength defined by

$$B^{GT^{\pm}}_{1^+_n} = |\langle 1^+_n || \hat{O}^{\pm}_{GT} || 0 \rangle|^2, \tag{1}$$

where $\hat{O}^{\pm}_{GT} = \sum_{i=1}^{A} \sigma(i) t_{\pm}(i)$ and $|1^+_n\rangle$ is the n-th $J^{\pi} = 1^+$ state. Then, the GT-type β decay half-life can be calculated as

$$T_{1/2} = D/g_A^2 \sum_n B^{GT^-}_{1^+_n} f_0(Z, A, \omega_n), \tag{2}$$

where $D = 6163.4 \pm 3.8$ s, $f_0(Z, A, \omega_n)$ is the integrated phase factor and ω_n is the excitation energy of the n-th GT state. A quenched value $g_A \equiv G_A/G_V = 1.0$ is adopted for the ratio of the axial-vector and vector coupling constants.

Figure 1 shows results adopting six energy density functionals (EDFs), *i.e.* SGII, SAMi, SAMi-T, SIII, SLy5 and SkM*, which describe well the GTGRs of closed shell nuclei including ^{132}Sn. In the RPA calculations, calculated half-lives are much longer than the experimental values and become infinite for ^{132}Sn, and also for ^{68}Ni except when using SIII, SLy5, and SkM*. Compared with the RPA model, the inclusion of the 2p-2h configurations in the SSRPA model can reduce systematically the lifetimes of β decay of the four nuclei. Particularly, it accelerates the β decay rates of ^{34}Si and ^{78}Ni by approximately two order of magnitude, and also produces finite half-lives for long-life nuclei ^{132}Sn and ^{68}Ni.

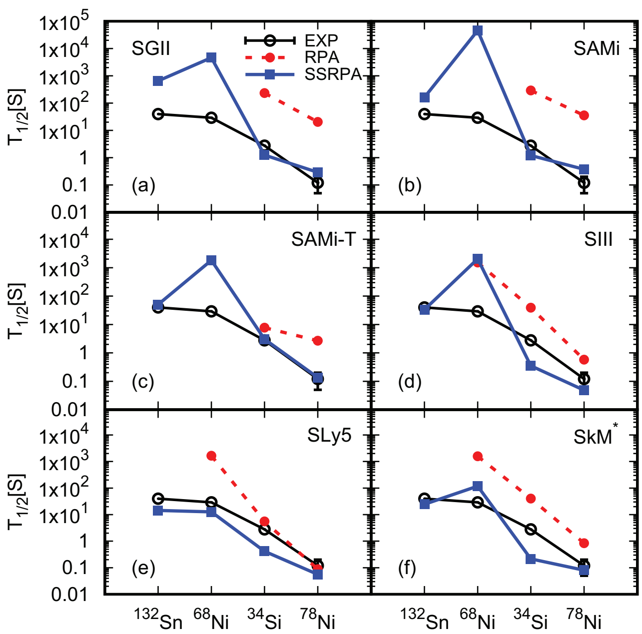

Fig. 1. β decay half-lives of ^{132}Sn, ^{68}Ni, ^{34}Si, and ^{78}Ni calculated using the RPA and SSRPA models, respectively, in comparisons with experimental values. The experimental data are shown as black empty circles. The RPA results for some nuclei are infinite andnot shown in the figure.

The effects of the tensor force inclusion in the SSRPA are studied by using SAMi-T and SGII + T. The SAMi-T results show that the tensor force accelerates the β decay rates of ^{132}Sn and ^{68}Ni by approximately 5 times, whereas it increase the half-life of ^{34}Si significantly. In the results of SGII + T, the effect of the tensor force is mainly observed on ^{68}Ni, whose decay rate is accelerated by approximately two order of magnitude.

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