Simultaneous microscopic description of nuclear level density and radiative strength function †

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According to the rules of quantum mechanics, the atomic nucleus has discrete energy levels. As the excitation energy increases, the level spacing decreases rapidly so that the levels become densely crowded. In this condition dealing with individual nuclear levels becomes impractical. Instead, it is meaningful and convenient to consider the average properties of nuclear excitations in terms of the nuclear level density (NLD) and radiative strength function (RSF). The former, introduced by Hans Bethe 80 years ago, is the number of excited levels per unit of excitation energy. The latter, proposed by Blatt and Weisskopf 64 years ago, describes the emission probability of high-energy γ-rays, which is expressed in terms of the average reduced partial radiation of γ-rays per unit energy interval.

These two quantities are indispensable ingredients in astrophysical nucleosynthesis, including the calculations of reaction rates in cosmos and production of elements, as well as in technology such as nuclear energy production and transmutation of nuclear waste. Therefore, the study of these quantities has been one of the most important topics in nuclear physics. This study has gained impetus in 2000 after the experimentalists of Oslo university proposed a method to simultaneously extract both the NLD and RSF from the primary γ-decay spectrum obtained in a single compound nuclear reaction experiment (Fig. 1). This method, however, suffers from the normalisation uncertainties.

Given the importance of the NLD and RSF, it is imperative to have a consistent theoretical basis to understand these quantities. Nonetheless, a unified theory capable of simultaneously and microscopically describing both the NLD and RSF has been absent so far.

In the present work, we propose for the very first time a microscopic approach, which is able to describe simultaneously the nuclear level density and radiative γ-ray strength function. This approach used the exact solutions of the pairing problem to construct the partition function to calculate the NLD and thermal pairing gap at finite temperature. The latter is included in the phonon damping model[1] to calculate the RSF. The good agreement between the results obtained within this approach and the experimental data for NLD and RSF in ^{170,171,172}Yb (Fig. 1) has shown

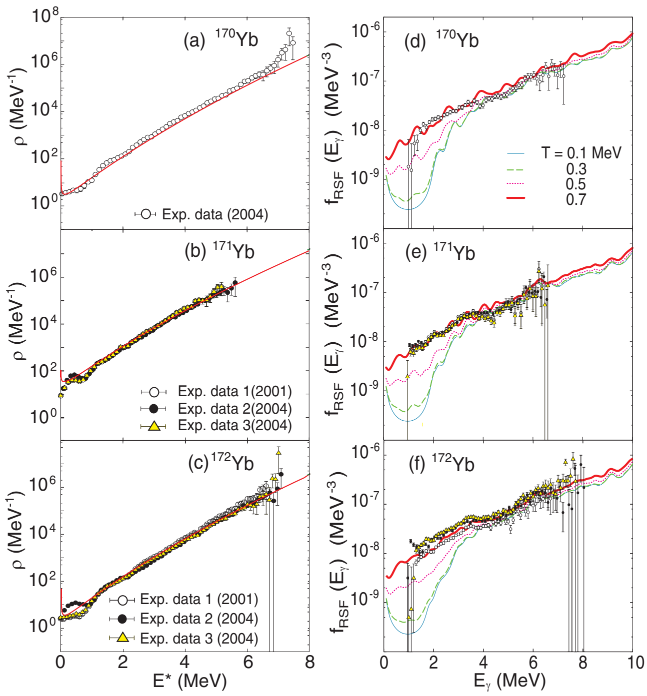

Fig. 1. NLD [(a) – (c)] as functions of excitation energy and RSF [(d) – (f)] as functions of γ-ray energy at different temperatures T, predicted by the present approach, in comparison with the experimental data for ytterbium isotopes ^{170,171,172}Yb.

that exact thermal pairing is indeed very important for the description of both NLD and RSF in the low and intermediate region of excitation and γ-ray energies. Moreover, to have a good description of the RSF the microscopic strength function with the temperature-dependent width for the giant resonances should be used instead of the Brink-Axel hypothesis. The merits of this approach are its microscopic nature and the use of only the parameters taken over from previous calculations. It does not consume much computing time either as the calculation takes less than five minutes even for a heavy nucleus, and therefore can be performed on a PC.

Reference

1) N. Dinh Dang, A. Arima, Phys. Rev. Lett. **80**, 4145 (1998); N.D. Dang, A. Arima, Nucl. Phys. A **636**, 427 (1998).

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