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Spreading widths of giant monopole resonance in the lead region: Random matrix approach

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The general idea on Giant Resonance (GR) decay properties as a consequence of the coupling of high-lying modes with the lowest collective vibrational modes [1–4] requires further development in light of discussion on the role of order and disorder (chaos) in nuclei [5, 6]. We recall, however, that the analysis of spreading widths, associated with the cascade of couplings and their fragmentations due to these couplings (cf. [7–10]), is a real challenge for nuclear structure theory. Nowadays, most successful attempts in this direction are restricted by the consideration of the microscopic coupling between one-phonon and two-particle-two-hole ($2p-2h$) or two-phonon configurations (see, e.g., discussion in [11–17]).

In this paper we suggest the alternative approach, based on ideas of the Random Matrix Theory (RMT) [18, 19], which enables us to count effectively the problem of the hierarchy at the description of spreading widths. To provide a detailed overview of our approach we consider only spherical or near-spherical nuclei around ^{208}Pb and focus our attention on the spreading width of Giant Monopole Resonances (GMRs). To demonstrate the validity of our approach we compare the results of: i) the microscopic calculations, based on the coupling between one-phonon and two-phonon configurations, so called phonon-phonon coupling (PPC); ii) the random matrix approach based on the one-phonon approximation; iii) available experimental data for ^{204,206,208}Pb nuclei.

To carry out the item i) we employ the modern development of the quasiparticle-phonon model, where the single-particle spectrum and the residual interaction are determined making use of the Skyrme interaction without any further adjustments [20]. By means of the finite rank separable approximation [21, 22] for the residual interaction we perform the calculations within the quasiparticle random phase approximation (QRPA) in very large two-quasiparticle spaces. To construct wave functions of the excited 0^+ states up to 20 MeV we take into account all two-phonon terms that are built from the phonons of different multipolarities $\lambda^\pi = 0^+, 1^-, 2^+, 3^-, 4^+$, coupled to 0^+ state (see details in [23, 17, 24]). Following the basic ideas of the quasiparticle-phonon model [4], the Hamiltonian is then diagonalized in a space spanned by states composed of one and two phonons coupled by means of the microscopic coupling matrix elements (see details in [20, 25]). In the item ii) the statistical description of the GMR fragmentation is based on ideas from the RMT [26, 27]. Namely, the one-phonon states are generated by means of the QRPA calculations, while the coupling matrix elements between the one-phonon and two-phonon states are replaced by random matrix elements of the Gaussian Orthogonal Ensemble type. Within the framework of our approach the two-phonon model space is decomposed on two subspaces that are differently coupled to the QRPA states. On the larger energy scale the gross structure and structure effects of the GMRs are defined; that includes the random coupling to surface vibrations of a few strongest coupling matrix elements. On the smaller energy scale there is the random coupling to surface vibrations of a majority (small) matrix elements. This coupling is particularly responsible for the fine structure of the strength function in the energy region around the GMR.

To illustrate the quality of our approach, all numerical calculations have been done on the basis of the Skyrme forces SLy4 [28, 29]. Switching on the strong as well as the week interactions, with the chosen values $\sigma_1 = 600$ keV and $\sigma_2 = 30$ keV, the RMT results are in a quite good agreement with those of the PPC (see Fig. 1). It is notable that the strength distribution of the GMR, obtained in this case, is rather close to the experimental distribution [30]. The remarkable agreement between the results of the PPC and the RMT calcula-

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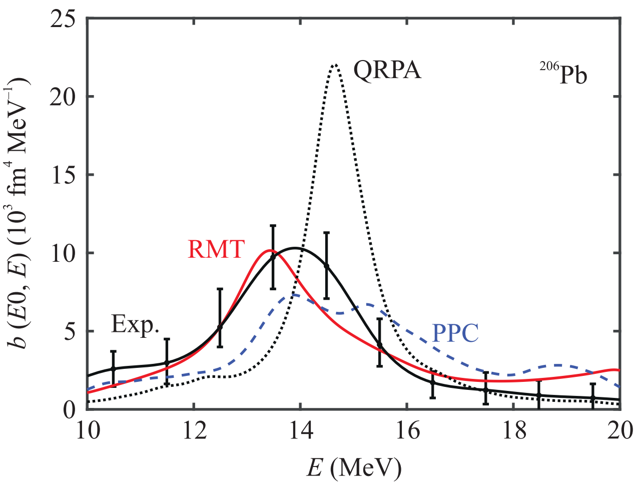

Fig. 1. (Color online) The monopole transition strength $b(E0, E)$ versus the transition energy E in the case of ^{206}Pb. The results, obtained by means of: i) the two-scale RMT approach are connected by (red) solid line; ii) the microscopic PPC calculations are connected by (blue) dashed line; iii) the QRPA approach are connected by (black) dotted line. For a comparison the experimental data [30] shown by (black) squares with error bars, smoothly interpolated, are connected by (black) thin line

tions for the GMR strength distribution of ^{204,206,208}Pb confirms the vitality and validity of our approach.

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