

Fine structure in giant resonances

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The decay of Giant Resonances (GRs) serves as a key illustration of how a coherent collective excitation transitions into chaotic motion of internal degrees-of-freedom within fermionic quantum many-body systems [1]. However, a comprehensive understanding of the decay widths remains elusive. Several experimental investigations into the origin of damping mechanisms of GRs in nuclei across the period table have been carried out at the iThemba LABS South Africa, using the state-of-the-art K600 magnetic spectrometer. It has been demonstrated that the primary mechanism driving the observed fine structure varies for different resonances. The fragmentation of elementary one-particle one-hole (1p-1h) excitations, known as Landau damping, appears to be the primary contributor to the distribution of Isovector Giant Dipole Resonance (IVGDR) strength, which gives rise to the fine structure [2]. In the case of the Isoscalar Giant Quadrupole Resonance (ISGQR) in the medium- and heavy-mass region, the decay is influenced by coupling to 2p-2h and many-particle many-hole (np-nh) states, which contributes to the spreading width. This indicates that there is a connection with the low-lying surface vibrations [3]. For the Isoscalar Giant Monopole Resonance (ISGMR), Landau damping is significant in the medium-mass region, whereas since the spreading width rises with the mass number, it plays a major role in heavy nuclei [4]. This study aims to provide a more detailed analysis of the fine structure of ISGMR, selecting the well-known spherical nuclei ⁵⁸Ni, ⁹⁰Zr, ¹²⁰Sn, and ²⁰⁸Pb as the subjects of investigation.

From a theoretical perspective, traditional approaches for fine-structure analysis of the ISGMR involve the Random Phase Approximation (RPA) using the Skyrme Energy Density Functional (EDF), as well as its quasi-particle variant (QRPA) for open-shell nuclei; see, e.g., [5,6]. The study of the ISGMR distribution involves taking into account a coupling between the simple 1p-1h excitations and more complicated configurations [5-7]. Our analysis, which incorporates Phonon-Phonon Coupling (PPC), accurately captures the gross structure of the ISGMR across various mass regions [4,7]. The effects of PPC lead to a redistribution of the main monopole strength to lower energy states and into higher energy tail. In particular, the PPC predictions of the fine structure of the ISGMR in ⁵⁸Ni, ⁹⁰Zr, ¹²⁰Sn, and ²⁰⁸Pb are in good agreement with the fine structure which is extracted from experimental data analysis [4,8]. More specifically, the substantial impact of octupole vibrations on the damping of the ISGMR and ISGQR in ²⁰⁸Pb has been highlighted [8].

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