Study of hot giant dipole resonance in medium mass nuclei

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Introduction

The isovector giant dipole resonance (IVGDR) is a fundamental high-frequency mode of nuclear collective excitation that decays by emitting γ-rays [1]. Because these γ-rays are minimally affected by nuclear surroundings, it serves as a clean probe for studying hot nuclear systems. The IVGDR can be characterized by three key parameters: centroid energy (E_G), resonance width (Γ_G), and strength (S_G). Among these, the IVGDR width (Γ_G) is particularly significant because it directly relates to various damping mechanisms inside nucleus. Over the past decades, experiments have shown that Γ_G increases with temperature in the range of approximately 1 MeV $\lesssim T \lesssim$ 3 MeV, with some debate over whether it saturates at higher temperatures beyond T >3 MeV. At lower temperatures ($T \lesssim$ 1 MeV), the situation is more complex due to strong microscopic effects, such as pairing correlations and shell effects, which obscure the thermal broadening of Γ_G. Alongside experimental studies, various theoretical models have been developed to explain how Γ_G behaves with temperature. Among these, the classical thermal shape fluctuation model (TSFM) is most popular. However, validating these models requires data over a broad mass range. Most existing experimental data focus on nuclei with $A > 90$ and cover only limited temperature ranges. To address this gap, we conducted an experimental study in mid-mass nuclei. We analyzed high-energy γ-ray spectra from the excited ^{62}Zn compound nucleus, which was populated through light-ion induced fusion reaction, and measured the IVGDR width at different nuclear temperatures. We then compared our findings with TSFM prediction.

Experimental details and data analysis

The experiment was conducted at VECC in Kolkata [3]. Nuclei was populated by bombarding ^{58}Ni target with accelerated alpha beams of energy 28 MeV and 40 MeV from the K-130 RTC. The emitted high-energy γ rays (with energies E_γ >4 MeV) were detected using the LAMBDA high-energy γ-ray spectrometer.

To determine the total energy deposited by γ-rays within the detector volume, nearest-neighbor cluster summing algorithm was employed [2]. Before summing, various unwanted events had to be identified and excluded to isolate the IVGDR bump in 10-25 MeV energy region, which is superimposed on the statistical γ-ray distribution. Major contamination in the high-energy γ-ray spectra, primarily

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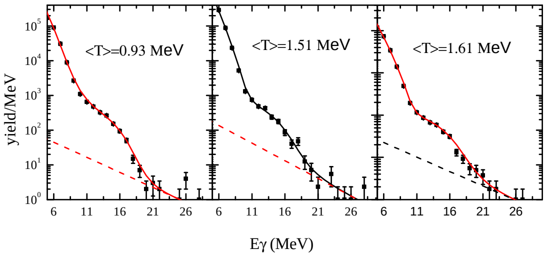

FIG. 1: Measured γ-ray spectra (symbols) from the decay of ^{62}Zn is compared with the statistical model results (red solid lines). The Bremsstrahlung contributions are shown by the red dashed lines.

from neutron background, was identified using time-of-flight technique. Pile-up events were rejected through pulse shape discrimination, and cosmic muon events, which have distinct hit patterns compared to high-energy gamma particles, were effectively identified and eliminated. Events that passed all these checks were considered to be valid.

To extract the IVGDR parameters, measured γ-ray spectra were compared with statistical model calculations in the Hauser-Feshbach formalism using TALYS-1.95 . This model predicts decay through various channels based on excitation energy, with probabilities determined by transmission coefficients (T) and final state level densities. For the decay through γ-ray emission, $T(E_\gamma)$ is related to the energy dependent photon strength function, represented by a standard Lorentzian function:

$$f_{\mathrm{E1}}(E_\gamma) = \frac{2\sigma_{TRK} S_G}{3\pi^3(\hbar c)^2} \frac{E_\gamma \Gamma_G}{(E_\gamma^2 - E_G^2)^2 + E_\gamma^2 \Gamma_G^2}, \tag{1}$$

where Γ_G is the resonance width, E_G is the centroid energy, and S_G is the fraction of the TRK dipole sum rule strength exhausted by the IVGDR. The best-fit values of these parameters were obtained through visual inspection.

Results and discussion

In Fig.1, we compare measured spectra with the best-fit statistical model calculations.

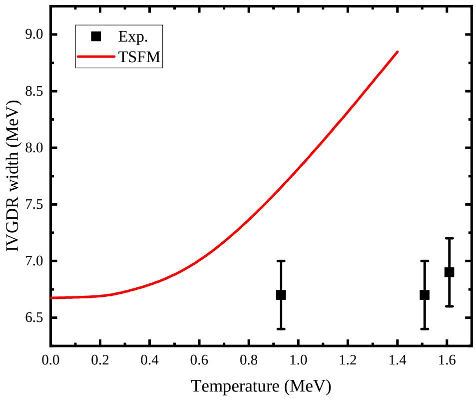

FIG. 2: Variation of the measured IVGDR width with temperature. The solid red line represents the TSFM calculation.

Fig.2 shows the extracted width as a function of temperature, indicating a flat width-temperature behavior, which suggests compactness of the system. The line in Fig.2 represents the TSFM calculation, performed with macroscopic-microscopic potential energy surface, but it fails to account for the low-temperature suppression of Γ_G. This indicates the need for improved models with additional microscopic contributions. Our current results are preliminary, relying on visual fitting of independently varied parameters. A more rigorous approach, such as Bayesian inference, is needed for final results, and this work is ongoing.

References

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