Study of hot giant dipole resonance in medium mass nuclei

Chandrani Sen[1,2,*] Debasish Mondal[1,2], Gourab Banerjee[2,3], Supriya Mukhopadhyay[1,2], Jhilam Sadhukhan[1,2], Deepak Pandit[1], Surajit Pal[1,2], Sujan Kumar Roy[1,2], Balaram Dey[4], Srijit Bhattacharya[5], A. De[6], Pratap Roy[1,2], T. K. Rana[1,2], Rajkumar Santra[1], and Saumanti Sadhukhan[1,2]
[1] *Physics Group, Variable Energy Cyclotron Centre, 1/AF, Bidhannagar, Kolkata-700064, India.*
[2] *Homi Bhabha National Institute, Anushakti Nagar, Mumbai-400094, India.*
[3] *Saha Institute of Nuclear Physics, Kolkata, 700064, India*
[4] *Department of Physics, Bankura University, Bankura, 722155, India.*
[5] *Department of Physics, Barasat Government College, Barasat, 700124, India. and*
[6] *Department of Physics, Raniganj Girls' College, Raniganj, 713358, India*

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.

*Electronic address: `c.sen@vecc.gov.in`

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

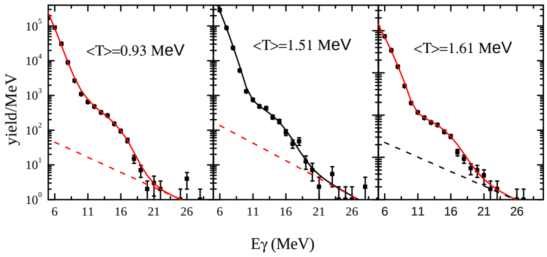

FIG. 1: Measured γ-ray spectra (symbols) from the decay of ^{62}Zn is compared with the statistical model results (red solid lines). The Bremsstrahlung contributions are shown by the red dashed lines.

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:

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

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.

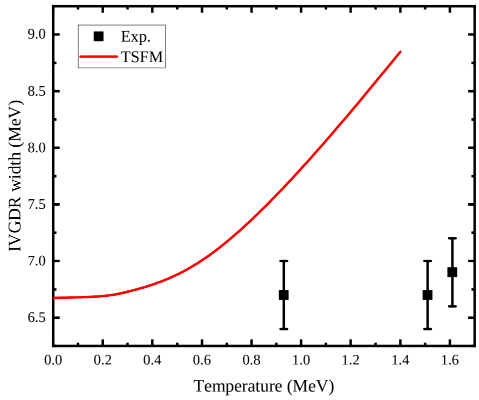

FIG. 2: Variation of the measured IVGDR width with temperature. The solid red line represents the TSFM calculation.

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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