Study of giant dipole resonance in ^{152}Gd

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Introduction

For the study of nuclear properties at finite temperature (T) and angular momentum (I), the giant dipole resonance (GDR) has been proved to be a unique probe. The GDR can be realized as a collective mode of excitation of nuclei caused by the out-of-phase oscillations between the proton and neutron fluids under the influence of the electromagnetic field induced by the emitted/absorbed photon. In a macroscopic approach the GDR is coupled to the shape of the nuclei whereas the microscopic approaches couple the GDR to particle-hole, particle-particle and hole-hole excitations. The thermal shape fluctuation model (TSFM) based on the macroscopic approach is one among the most successful models to explain several GDR observations in hot and rotating nuclei [1–3]. Recently, a new theoretical framework has been developed to study the hot nuclei with proper treatment of pairing and its fluctuations along with the thermal shape fluctuations [4]. In the present work, we discuss the TSFM results in hot and rotating ^{152}Gd along with the GDR widths obtained from different phenomenological formulae.

Theoretical framework

The TSFM describes the measured GDR observable through an average over the probable quadrupole shapes. The GDR cross-sections σ are averaged with the weights given by the Boltzman factor involving the deformation energies using the relation [1]

$$\langle \mathcal{O} \rangle_{\beta,\gamma} = \frac{\int_\beta \int_\gamma \mathcal{D}[\alpha] e^{-F_{\rm TOT}(T,I;\beta,\gamma)/T} \Im_{\rm TOT}^{-3/2} \mathcal{O}}{\int_\beta \int_\gamma \mathcal{D}[\alpha] e^{-F_{\rm TOT}(T,I;\beta,\gamma)/T} \Im_{\rm TOT}^{-3/2}} ,$$

where $\Im_{\rm TOT} = \Im_{rig}\omega + \delta\Im$ and the volume element $\mathcal{D}[\alpha] = \beta^4 |\sin 3\gamma|\ d\beta\ d\gamma$.

$$F_{\rm TOT} = E_{\rm LDM} + \sum_{p,n} \delta F^\omega + \frac{1}{2}\omega(I_{\rm TOT} + \sum_{p,n} \delta I) .$$

$E_{\rm LDM}$ is the liquid-drop energy corresponding to a triaxially deformed nucleus. δF^ω and δI are the shell corrections obtained with exact temperature and spin dependence. ω is the angular velocity tuned to obtain the desired spin given by

$$I_{\rm TOT} = \Im_{rig}\omega + \delta I ,$$

and $\Im_{rig}$ is the rigid-body moment of inertia. The nuclear shapes are related to the GDR observables using a macroscopic model comprising an anisotropic harmonic oscillator potential with a separable dipole-dipole interaction [1].

Results

The TSFM results at different values of T and I are compared with the experimental data reported in Ref. [5]. The results are presented in Fig. 1. The theoretical GDR cross sections are in agreement with the experimental data. The experimental data in the higher energy region is quite scattered. These scattered data with large errors in the high energy region tend to yield a larger experimental GDR width.

We have also compared the experimental GDR widths with the values obtained with the phenomenological scaling formula (PSF) [6] and the critical temperature formula (CTF) [7] along with the TSFM results. The results are presented in Table 1. The TSFM results suggest a lower GDR width for this nucleus at different T and I values. The PSF also fails to explain the experimental widths, where the ground state GDR width is assumed to be

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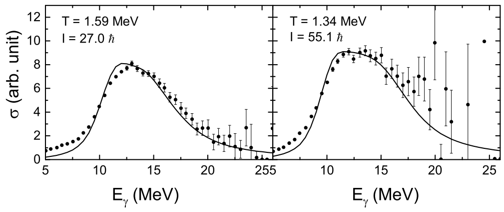

FIG. 1: The GDR experimental cross sections (filled circles) of ^{152}Gd taken from Ref. [5], are compared with the TSFM results (solid lines) at different values of temperature (T) and angular momentum (I).

TABLE I: The experimental GDR widths (Γ_{expt}) in ^{152}Gd at different temperature (T) and angular momentum (I) are compared with the GDR widths calculated with TSFM (Γ_{TSFM}), the GDR widths obtained using phenomenological scaling formula Γ_{PSF} and critical temperature formula Γ_{CTF}.

T (MeV)	I ($\hbar$)	Γ_{expt} (MeV)	Γ_{TSFM} (MeV)	Γ_{PSF} (MeV)	Γ_{CTF} (MeV)
1.34	55.1	10.1±0.5	8.7	9.2	9.5
1.59	27.0	8.5±0.3	7.4	8.7	8.8
1.64	56.5	11.7±0.8	9.1	9.9	10.9
1.91	13.3	9.5±0.5	7.4	9.1	9.6

$\Gamma_0 = 3.8$ MeV and all other parameters are fitted in a global way. The CTF with two adjustable parametrs, is able to explain the widths much better than PSF. A larger Γ_0 of 5.7 MeV is used to explain the experimental widths. The success of CTF in explaining the widths in an empirical manner shall not be considered as a validation of the extracted widths, as the reliable information lies within the GDR cross sections [8].

Conclusion

The TSFM GDR cross sections are in good agreement with the experimental data and points out that reproducing the GDR widths with empirical formulae could conceal the information contained in the cross sections.

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