Giant dipole resonance and shape transitions in hot and rotating ^{88}Mo[†]

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The exploration of extremes of nuclear landscape has unraveled several interesting phenomena, leading to a better understanding of the nuclear force. The giant dipole resonance (GDR) has been considered as a unique and powerful tool to investigate the nuclear structure properties at these extreme conditions. The most important experimental observable for the GDR is the cross section (σ) as a function of the photon energy, from which one can extract the centroid energies and the GDR width (Γ). These observables could effectively reflect the structure of the nuclear state on which the GDR is built.

In a recent work,[1)] the GDR γ-rays emitted from highly excited ^{88}Mo nucleus which is formed in the reaction ^{48}Ti + ^{40}Ca, and a number of daughter nuclei created along the cooling path of the compound nucleus were measured. The data analysis indicates the possibility of Γ saturation at higher angular momentum (I) values. In this article, we study the GDR properties of the hot and rotating compound nucleus ^{88}Mo at different excitation energies within the thermal shape fluctuation model (TSFM) built on the microscopic-macroscopic approach for the free energy calculations and a macroscopic approach for the GDR calculations.

We calculate the average GDR cross section of a nucleus with a given Z and N at a given average T ($T_{\rm ave}$) and having a probability distribution for I, as $\sigma_{\rm ave}(T_{\rm ave}) = \frac{\sum_i \sigma(T_{\rm ave}, I_i) C(i)}{\sum_i C(i)}$ where I_i is the spin of the i^{th} step of the statistical decay of the compound nucleus and $C(i)$ are the corresponding spin counts. As the first step, it is very important to analyze, whether the average GDR cross sections $\sigma_{\rm ave}(T_{\rm ave})$ of a nucleus obtained by considering the $T_{\rm ave}$ and the probability distribution of I are similar or not, to the GDR cross sections $\sigma(T_{\rm ave}, I_{\rm ave})$ of a nucleus obtained with the $T_{\rm ave}$ and average I ($I_{\rm ave}$) values obtained from the same probability distributions. The $I_{\rm ave}$ is estimated from the probability distribution of I as, $I_{\rm ave} = \frac{\sum_i I_i C(i)}{\sum_i C(i)}$.

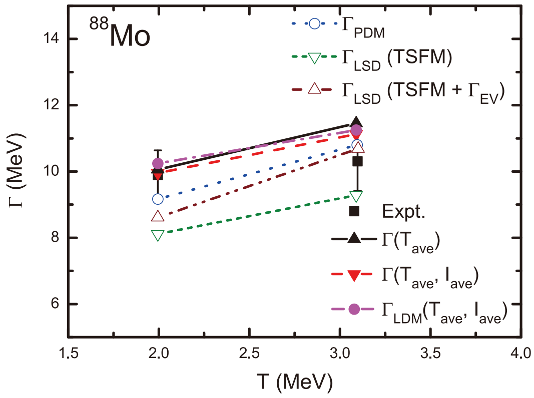

Fig. 1. The GDR width Γ of ^{88}Mo calculated using TSFM at two different excitation energies are plotted as a function of T. The filled upward triangles connected with solid line represent Γ of the final σ [$\Gamma(T_{\rm ave})$], where σ of the daughter nuclei are obtained by considering the $T_{\rm ave}$ and the angular momentum probability distributions. The filled downward triangles connected with dashed line [$\Gamma(T_{\rm ave}, I_{\rm ave})$] and filled circles connected with dash-dotted line [$\Gamma_{\rm LDM}(T_{\rm ave}, I_{\rm ave})$] represent the Γ of the final σ, where σ of the daughter nuclei are obtained by considering the $T_{\rm ave}$ and $I_{\rm ave}$ within the TSFM with free energies obtained from microscopic-macroscopic approach and liquid drop model (LDM), respectively. The experimental results are taken for Ref. 1). The widths obtained within the (Phonon damping model) PDM and Lublin-Strasbourg drop (LSD) model taken from Ref. 1) are also shown with open circles and open triangles. The lines are drawn just to guide the eyes.

An important conclusion from these analysis is that it is not necessary to calculate the theoretical σ at each value of T and I obtained in the probability distribution with their respective weights, instead the σ obtained at the average values of T and I are good enough to compare with the experimental data. In Fig. 1 we compare the Γ of ^{88}Mo calculated using TSFM at two different excitation energies. In the range of $2 \lesssim T \lesssim 3$ MeV, the data suggest a slower increase in the Γ whereas the our results and the PDM suggest a larger increase.

At higher T, as I increases the free energy surfaces shows a gamma-softness before the nucleus undergoes a Jacobi shape transition. Considering the role of enhanced fluctuations at higher T and the Coriolis splitting of GDR components at higher I the GDR width of ^{88}Mo nucleus will not saturate at high T and I.

Reference

1) M. Ciemała *et al.*, Phys. Rev. C **91**, 054313 (2015).

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