Investigation of odd-even effect in giant dipole resonance width in medium mass nuclei

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Introduction

Study of isovector giant dipole resonance (IVGDR) at finite temperature and increasing angular momentum is one of the most effective tools to know the structural details of excited nuclei. Over the last several years, numerous experiments have been performed to study the temperature and angular momentum dependence of IVGDR width [1]. In parallel, different theoretical models are proposed to extract IVGDR width and understand the role of thermal and pairing fluctuations in the damping mechanism of IVGDR. Statistical thermal shape fluctuation model (TSFM) [2] is one of the successful theoretical framework that explains the temperature dependence of IVGDR width. In TSFM, it is assumed that, at finite temperature, shape of a nucleus fluctuates around its equilibrium shape. Usually, such vibrations are assumed to be adiabatic in nature, i.e., the time scale for shape fluctuation is much larger than the damping of GDR vibration. An improved version of TSFM with self consistent inputs is reported recently [3]. It predicts a better reproduction of the temperature dependence of IVGDR width. Since the collective dynamics associated with GDR is strongly correlated to the underlying nucleonic motions, it would be an interesting study to investigate whether any odd-even effects influences the IVGDR width. In the present work, we calculated IVGDR width of ^{63}Cu and ^{64}Ni by employing the TSFM with self-consistent nuclear energy density functional inputs. Here, we have restricted ourselves to one dimensional calculation of GDR width.

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Calculations

The GDR line-shape can be represented by a Lorentzian distribution function given by,

$$\mathcal{F} = C_n \frac{NZ}{A} \sum_{\{x_i\}} \frac{\left(E^* \ \Gamma_{x_i}\right)^2}{\left(E^{*2} - E_{x_i}^2\right)^2 + \left(E^* \Gamma_{x_i}\right)^2}, \tag{1}$$

where N, Z, and A represent neutron, proton and mass numbers of the nucleus, respectively. The sum in eq.(1) is performed over the three body fixed principle axes of a deformed configuration. For the IVGDR parameters, we consider the following expressions,

$$\begin{aligned} E_{x_i} &= E_0 \exp\left[-\sqrt{\frac{5}{4\pi}}\beta \cos\left(\gamma - \frac{2\pi}{3} i\right)\right] \\ \Gamma_{x_i} &= \Gamma_0 \left(\frac{E_0}{E_{x_i}}\right)^{1.6} \end{aligned} \tag{2}$$

where, $E_0 = 18.0A^{-1/3} + 25.0A^{-1/6}$ and Γ_0 is the GDR width for spherical shape of the nuclei, which has been taken as 7.3 MeV for both nuclei. For shape fluctuations around the equilibrium shape, we usually consider β and γ as independent coordinates. The resultant distribution function is obtained by performing weighted average over the (β, γ) surface, and is given by

$$\langle \mathcal{O} \rangle = \frac{\int_\beta \int_\gamma D[\beta,\gamma] \ P(\beta,\gamma) \ \mathcal{O}}{\int_\beta \int_\gamma D[\beta,\gamma] \ P(\beta,\gamma)}, \tag{3}$$

$P(\beta, \gamma)$ being the thermal probability to attain a particular shape with (β, γ), and it is

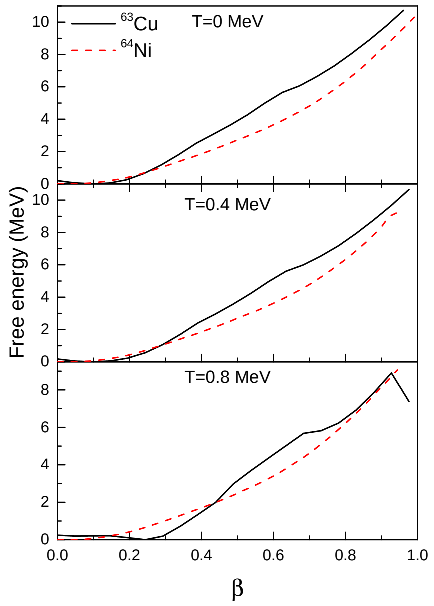

FIG. 1: β dependence of free energy curves for ^{63}Cu and ^{64}Ni at different temperature calculated using the SkM* parameters of the Skyrme energy density functional.

given by,

$$P(\beta, \gamma) \propto \exp\left(-\frac{F(\beta, \gamma, T) - F_0}{T}\right), \quad (4)$$

here, F is the free energy and detailed calculations can be found in Ref [3]. In the present calculation we restrict to $\gamma = 0$, i.e., only axially symmetric shapes.

Results and Conclusion

In the present investigation, we have calculated the free energy curves of ^{64}Ni and ^{63}Cu microscopically at different temperatures by solving the finite temperature Hartree-Fock-Bogoliubov (FT-HFB) equation. Axially symmetric DFT solver HFBTHO is used for this purpose. Odd particle number has been handled by blocking the quasi-particle states. Helmholtz free energy curves have been shown in Fig. 1 for both the nuclei against the deformation β at different temperatures. It can be seen that free energy curve of ^{63}Cu is relatively steeper than the other nucleus. Moreover, it has prolate deformation at the ground-state. In Fig. 2, calculated IVGDR widths for the two nuclei are compared along with the experimental data of ^{63}Cu [4]. Clearly, calculated results overestimates the measured width. The reason behind this discrepancy is that, at low temperature $T < 1.5$ MeV, pairing fluctuations play an important role. More details will be discussed during the symposium. It has been shown in a recent work [5] that the incorporation of pairing fluctuations is an efficient way to reproduce the low temperature behaviour of IVGDR width. Moreover, for the present calculations, we have considered only axially symmetric shapes to contribute in the broadening of the GDR lineshape. A two dimensional calculation incorporating pairing fluctuations at low temperature is under progress.

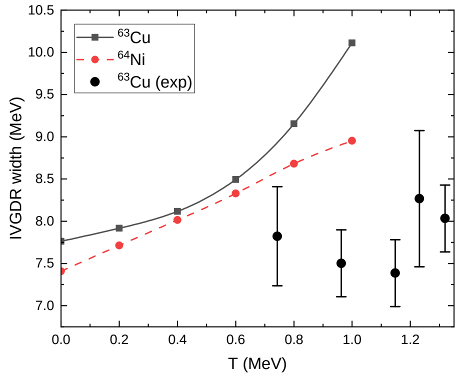

FIG. 2: IVGDR width from present calculation along with experimental data.

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