Giant dipole resonance and shape transitions in ^{144}Sm

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Introduction

The spectrum of Isovector giant dipole resonance commonly termed as GDR could effectively reflect the structure of the nuclear state on which GDR is built. For hot rotating nuclei, GDR serves as a unique probe to obtain the structure information as a function of both temperature (T) and spin (I). The role of thermal fluctuations inherent to finite systems is understood [1] to be quite dominant while calculating the GDR cross-sections. However, at low temperatures microscopic effects (such as shell effects) are expected to be dominant and can overcome the thermal fluctuations [2, 3]. This may lead to survival of sharp structural transitions at higher spins. Hence, it would be interesting to carry out investigations in such cases where better and clear correlations between the GDR cross-sections (or width) and the equilibrium shape of the nucleus. One of the main expected prospect of using recently developed multi detector arrays in combination with multiplicity filters, is the more accurate study of shape transitions in hot rotating nuclei. In the present work, we discuss shape transitions in hot and rotating ^{144}Sm which could be observed through GDR.

Theoretical framework

The GDR observables are related to the nuclear free energy surface, through a rotating anisotropic harmonic oscillator model with separable dipole-dipole interaction [4], with the inclusion of thermal shape fluctuations. For shape calculations we follow the Nilsson-Strutinsky (NS) method extended to high spin and temperature [1,2]. The total free energy ($F_{\rm TOT}$) at fixed deformation is calculated using the expression

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

The angular velocity ω is tuned to obtain the desired spin given by

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

$E_{\rm LDM}$ is the liquid-drop energy corresponding to a triaxially deformed nucleus (with deformation parameters β and γ) and $\Im_{rig}$ is the rigid-body moment of inertia. The shell corrections (δF^{ω},δI) are obtained with exact temperature and spin dependence.

The GDR cross-sections are averaged out by integrating over a Boltzman factor involving the deformation energies using the relation [2]

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

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

Results

The potential energy surfaces (PES) of ^{144}Sm are shown in Fig. 1, where we can see the transition from near spherical shape at lower angular momenta to highly deformed shapes at higher angular momenta. This transition is seen at both the temperatures considered. It is interesting to see that at $T = 1$ MeV and $I = 50\hbar$ the PES exhibits the γ-softness

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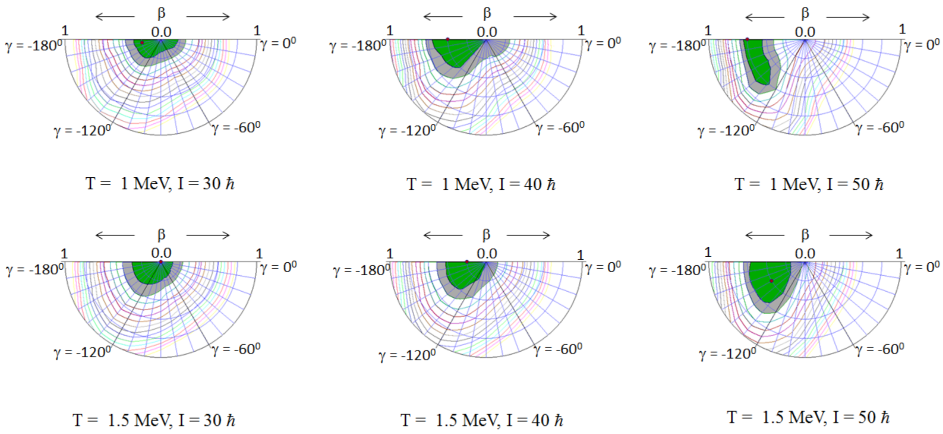

FIG. 1: The potential energy surfaces of the nucleus ^{144}Sm at different temperatures (T) and angular momenta (I). The contour line spacing is 0.5 MeV. The equilibrium shape is represented by a filled circle and the first two minima are shaded.

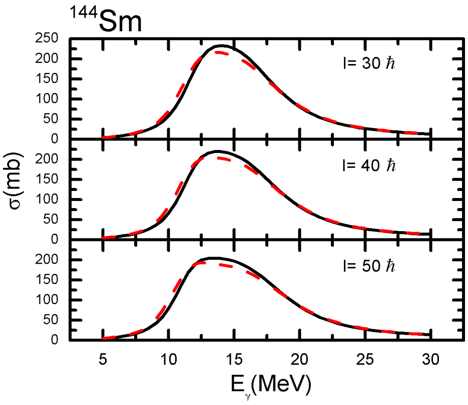

FIG. 2: Dependence of GDR cross sections on temperature (T) and angular momentum (I), in ^{144}Sm. $T = 1$ MeV and $T = 1.5$ MeV correspond to black solid line and red dashed line, respectively.

with a rigid β-value. This minimum spreads over the β-space as we increase the temperature. The calculated GDR cross-sections corresponding to the PES are shown in Fig. 2. We could see the increase in the width as a function of spin which arises from three factors *viz*, 1) Coriolis splitting of GDR components, 2) increase in deformation and 3) the spread in the minimum energy surface (γ-softness). Though it is difficult to disentangle these factors, our calculations suggest that the second factor is dominating and the role of γ-softness could be more clearly understood at lower temperatures.

Conclusion

It will be interesting to measure the GDR spectrum of rotating ^{144}Sm at lower temperatures where the effects of γ-softness and shape transitions could be seen.

References

[1] P. Arumugam, G. Shanmugam and S.K. Patra, Phys. Rev. C **69**, 054313 (2004).

[2] P. Arumugam, A. Ganga Deb and S.K. Patra, Eur. Phys. J. A **25**, 199 (2005).

[3] P. Arumugam, A. Ganga Deb and S.K. Patra, Eur. Phys. Lett. **70**, 313 (2005).

[4] G. Shanmugam, M. Thiagasundaram, Phys. Rev. C **39**, 1623 (1989).