Study of giant dipole resonance in medium heavy mass region

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Giant dipole resonance (GDR) is one of the fundamental modes of excitation in nuclei at finite temperatures. It is also considered a strong experimental probe to study nuclear properties at high excitation energies [1]. The resonance observables, namely, energy centroid could be related to nuclear deformation, and widths could be related to damping mechanism of the resonance. In a compound nucleus (CN), populated using heavy ion fusion reaction, the overall GDR properties are dependent on the coupled effect of spin and temperature. It is an experimental challenge to decouple them and a high efficiency spin spectrometer is required in this job. In a series of experiments, performed at Inter University Accelerator Centre (IUAC), we have studied the GDR observables in CN ^{144}Sm for a temperature range of 1-2 MeV with angular momentum below 60 $\hbar$ to draw a systematic evolution of GDR observables.

The accelerated beam of ^{28}Si were delivered from Pelletron and LINAC facility at IUAC with an energy of 5-7 MeV/nucleon. Self supporting targets of ^{116}Cd (thickness of 1.8-2.0 mg cm^{-2}) were prepared at IUAC target laboratory using rolling technique. γ rays, in the energy range of 5-35 MeV, were measured using high energy gamma ray spectrometer (HIGRASP) in coincidence with the multiplicity of low energy γ rays using 32 element 4π spin spectrometer. The solid angle coverage of spin spectrometer was nearly 90 %. The fold distribution recorded from spin-spectrometer was converted to angular momentum distribution in order to decouple the effect of temperature and spin. Standard NIM electronics were used in these measurements [2] and data acquisition was performed using CANDLE package.

Fold gated high energy γ ray spectra were analysed using statistical model of decay of CN with the help of a modified version of fusion evaporation code CASCADE [3] which incorporates GDR component. The measured spin distributions were supplied to CASCADE for generating theoretical spectra, which was further folded with detector response (simulated using GEANT4) and normalized around 8 MeV with respect to experimental spectrum. Resonance parameters were extracted by comparing the theoretical spectra with measured γ ray spectra and the quality of fit was checked using χ^2 minimization.

Thermal shape fluctuation model calculations (TSFM) [4] were also performed for this nucleus at the extracted spin and temperature values. The free energy (F) was calculated by the Finite Temperature Cranked Nilsson-Strutinsky Method (FTCNSM) where the dependence of shell corrections on temperature (T) and angular momentum (J) were taken into account by a numerical method. The GDR cross-sections at a fixed deformation (β, γ) were calculated in a macroscopic way comprising of an anisotropic harmonic oscillator potential with separable dipole-dipole interaction. The GDR cross-sections obtained by this formalism were compared with experimentally extracted cross-section and were found to be matching within error limits.

The GDR energy centroid is found to be nearly independent of excitation energy for the ^{144}Sm in the measured experimental range. This value is similar to that observed for the ground state of this nucleus. Nuclear deformation showed in increasing trend with angular momentum. It is interesting to discuss the observation of resonance widths with angular momentum and temperature. At any given temperature, the widths remain similar

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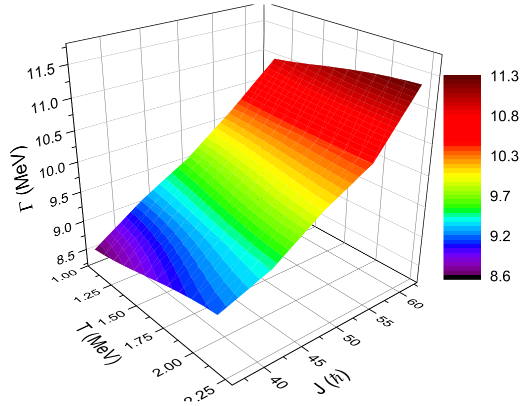

FIG. 1: A contour plot showing GDR widths as a function of angular momentum and temperature.

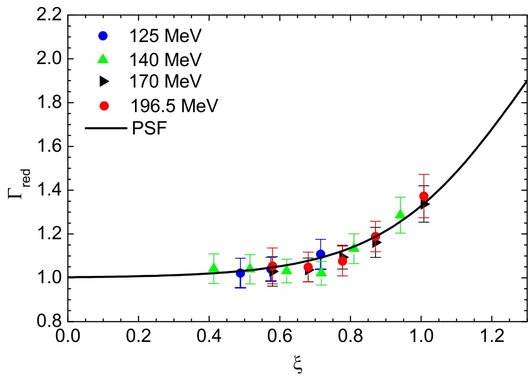

FIG. 2: Reduced GDR widths (Γ_{red}) as a function of reduced angular momentum (ξ = J/A$^{5/6}$) at different excitation energies in CN ^{144}Sm.

till some value of spin, after which the widths increase rapidly [5]. The broadening in widths are due to increasing nuclear deformation and shallowness in potential energy surface (PES). From TSFM calculations, it is found that the area of first minima in PES elongates with increasing angular momentum, which suggests a higher degree of γ softness and shape fluctuations. The increasing shallowness in minima dominates the GDR cross section and thus increases width. This reveals the effect of spin on GDR widths. In case of the effect of temperature, we observed that increase in GDR width is uniform with equal increment in temperature values [6]. The PES calculations also shows similar elongation of surface minima with temperature. This observation suggests that the increase in width could be attributed to the thermal fluctuations induced by increasing T. Finally, the measured widths are consistent with the TSFM calculations for this nucleus in the moderate temperature range of 1-2 MeV.

GDR widths were also compared with a parametrization given by Kusnezov et al. [7]. In this formalism, GDR width is expected to depend weakly on angular momentum till some critical value which is mass dependent. GDR widths were calculated for different temperature values as a function of angular momentum. Experimental resonance widths were also converted to reduced widths which are independent of mass, angular momentum and temperature. Reduced widths as a function of reduced angular momentum were consistent with the universal parametrization (See Fig. 2). Γ_0 parameter used in Kusnezov parametrization was found to be constant as a function of excitation energy in the case of ^{144}Sm nucleus.

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