Verification of the critical behavior of the Giant Dipole Resonance width in A ≈ 100 mass region

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Introduction

During the last few decades it has become clear that the giant dipole resonance (GDR), built on excited states, is a very good experimental tool to study the nuclear properties at extreme conditions. However, the GDR width which gives the damping information of the nuclear medium, is not yet fully understood at low temperature for the entire mass regions and remains a puzzling topic. The measured GDR widths were well explained by the Thermal Shape Fluctuation Model (TSFM) [1, 2] for T > 1.5 MeV. But, at low temperature T < 1.5 MeV TSFM completely fails to explain the experimental results even after incorporating shell correction. Recently, in our previous work, a new model has been proposed for a better understanding of the GDR width systematics for the entire range of mass, angular momentum (J) and temperature (T) named as Critical Temperature included Fluctuation Model (CTFM) [1]. It has been argued that the GDR vibration itself induces a quadrupole moment causing the nuclear shape to fluctuate even at T=0 MeV. Hence, the competition between β_{GDR} (deformation due to GDR) and $\Delta\beta$, due to thermal fluctuations, should lead to a critical temperature (T_c) in the increase of the GDR width. In other words, the GDR width should remain constant at the ground state value [3] below T_c and the increase of the GDR width should be evident experimentally only when the thermal fluctuations become larger than the intrinsic GDR fluctuation [1]. It has also been shown that the critical temperature and the deformation induced by the GDR vibration both follow a 1/A dependence. Although, the CTFM gave an excellent description of the GDR widths for ^{63}Cu, ^{119}Sb and ^{208}Pb at low T, the critical behaviour requires further investigation in other mass region at low temperature in order to be used universally. In this paper, we report on the experimental measurement of the high-energy γ-rays from ^{97}Tc to investigate the critical behaviour of the GDR width in the low temperature region (0.8-1.5 MeV).

Experimental Details & Analysis

The hot ^{97}Tc compound nucleus was populated at 29.3, 36, 43 & 50.4 MeV excitation energies by bombarding 30, 35 42 & 50 MeV alpha beams, respectively, on 1 mg/cm^2 thick target of ^{93}Nb. The high-energy photons from GDR decay were measured using the LAMBDA [4] spectrometer. The array was arranged in 7x7 matrix and placed at distance of 50 cm from the target at an angle of 90^0 to the beam direction. Along with the LAMBDA spectrometer, a 50-element gamma multiplicity [5] filter was used to estimate the angular momentum populated in

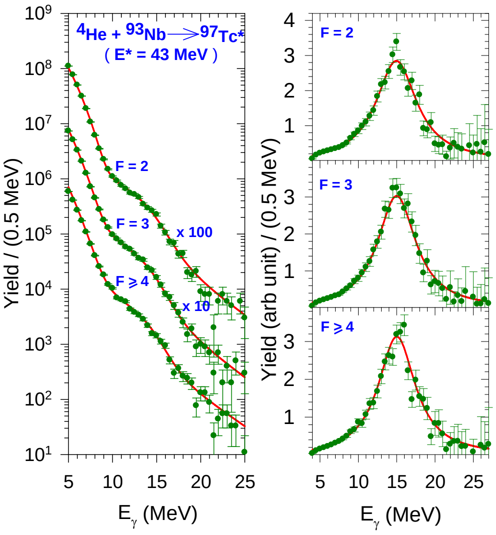

Fig.1. (Left panel) Experimental γ-energy spectrum along with CASCADE prediction (Right panel) Linearized GDR strength function.

the compound nucleus as well as to get the start trigger for time of flight (TOF) measurement. The filter was split into two blocks of 25 detectors each in staggered castle type geometry and was placed above and below the scattering chamber at a distance of 3 cm from the target. The pulse shape discrimination (PSD) technique was applied to reject the pile up events while TOF was used to separate the neutrons from the high-energy gamma rays. Since, the nuclear level density (NLD) parameter is an important ingredient for statistical calculations, the evaporation neutron spectrum was also measured employing a liquid organic scintillator (BC501A) [6] based neutron detector to extract the NLD parameter.

The high-energy γ-ray spectra were generated in off line analysis after all necessary rejections using the cluster summing technique (Fig.1). The data were compared with a modified version of the statistical model code CASCADE [7] to extract the GDR parameters. The level density prescription of Ignatyuk et al., [8] was used with the asymptotic level density parameter as extracted from the neutron evaporation spectrum. The individual experimental folds were mapped onto the angular momentum space applying the technique based on Monte Carlo GEANT4 simulation [5] and used as input in CASCADE. The high-energy γ-ray spectra for E_{lab} = 42 MeV are shown in Fig. 1 along with the linearized GDR lineshapes for different folds.

Results & Discussions

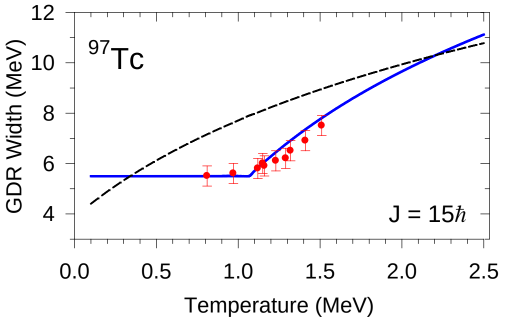

Fig.2. Temperature dependence of GDR width. Dotted line correspondence to TSFM calculations, where as continuous line is for CTFM predictions. Filled circles are the experimental data points.

Since the γ-emission from GDR decay takes place at different steps of the compound nuclear decay process, the average temperature was estimated by weighing over the daughter nuclei for the γ-emission in the GDR region. The measured GDR widths in the low temperature range of 0.8 - 1.5 MeV in the present study are shown in Fig 3 as function of T. The data are also compared with the predictions of the theoretical models of TSFM (dashed line) and CTFM (continuous line). It is evident that the temperature dependence of the GDR width determined from this experiment differs substantially from the adiabatic TSFM at low temperature and suggests that the calculations overestimate the influence of shape fluctuations at low temperature. On the other hand, the CTFM better explains the trend of the data at this low temperature range. Moreover, it can also be seen that the GDR width is constant at the ground state value (Γ_0 = 5.5 MeV) clearly pointing towards the critical behaviour and increases after T = 1.08 MeV consistent with the CTFM predictions (T_c = 0.7 + 37.5/A). The ground state GDR width was calculated using the ground state deformation (β = 0.134) [9] and spreading width parametrization $\Gamma_s = 0.05E_{GDR}^{1.6}$ for each Lorentzian. Hence, the excellent match between the experimental data and the CTFM clearly suggests that the experimental GDR widths are not suppressed rather TSFM overpredicts the GDR width at low temperature since it does not take into account the intrinsic GDR fluctuation induced by the GDR quadrupole moment. Details will be presented during the conference.

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