The influence of thermal fluctuation on the nuclear shape at low temperatures via the GDR γ-rays

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It is now well known that the temperature (T) and angular momentum (J) have amazing effects on the nuclear shape [1,2,3]. At low T, most nuclei have deformed ground state owing to the quantum shell effects arising due to the nucleon-nucleon interactions. However, if the temperature is raised, then the thermal excitations weaken these shell effects and the equilibrium shape of a non-rotating nucleus becomes spherical. In the case of a hot rotating nucleus, one expects an oblate spheroid rotating about its symmetry axis. One of the main probes to study this shape transition as function of T is the gamma decay from the giant dipole resonance (GDR). The decay of GDR occurs on a time scale which is very short and thus probes the condition prevailing at that time. Most importantly, the GDR couples directly with the nuclear shape degrees of freedom and an investigation of its strength function, along with angular distribution, gives a direct access to the nuclear deformation [1]. Recently, it has been seen that the effect of thermal fluctuations have almost no effect on the apparent GDR width below a critical temperature (T_c) (T ~ 1 MeV) [4,5,6]. Macroscopically it is interpreted due to the GDR induced quadrupole moment while microscopically it is explained by taking into account the fluctuations in the pairing field. Thus, it will be an intriguing study to probe the shape of a highly deformed nucleus just below and above the critical point to examine whether thermal fluctuations indeed have no role below the critical temperature.

An extensive experiment was performed at the Variable Energy Cyclotron Centre (VECC) using the alpha beams from the K-130 cyclotron to study the melting of shell effects and interplay of thermal fluctuations on the nuclear deformation. The highly deformed ^{169}Tm (β~0.3 in the ground state) nucleus was populated at two different excitation energies 26.1 and 35 MeV in the reaction ^{4}He + ^{165}Ho with 28 and 37 MeV alpha beams, respectively. The critical angular momenta for the two reactions were $12\hbar$ and $17\hbar$. These incident energies were chosen so that the nucleus is populated both below and above but close to the critical temperature. The decay photons from the GDR were measured employing the LAMBDA spectrometer [7] in coincidence with low energy discrete γ-rays, measured using the 50-element gamma multiplicity filter [8]. The LAMBDA array, arranged in 7x7 matrix, was kept at a distance of 50 cm from the target. The high energy γ-ray spectrum was measured at two different angles of 90° and 125° to extract the angular anisotropy coefficient (a_2). The multiplicity filter was split in two blocks of 25 detectors each and was placed on top and bottom of the scattering chamber at a distance of 5 cm from the target to extract the angular momentum of the compound nucleus as well as to get the start trigger. The neutrons were eliminated from the high energy γ-rays by time of flight technique while the pile up events were rejected using the pulse shape discrimination technique in each detector element. The high-energy γ-ray spectra were generated in offline analysis after all necessary rejections and using a nearest neighbor summing (cluster) algorithm [7]. The GDR parameters were extracted from the experimental data by comparing with the predictions from a modified version of the statistical model code CASCADE. In the statistical model calculation, the Ignatyuk level density prescription has been used with the asymptotic level density parameter a = A/9.0. The individual experimental folds were mapped onto the angular momentum space using Monte

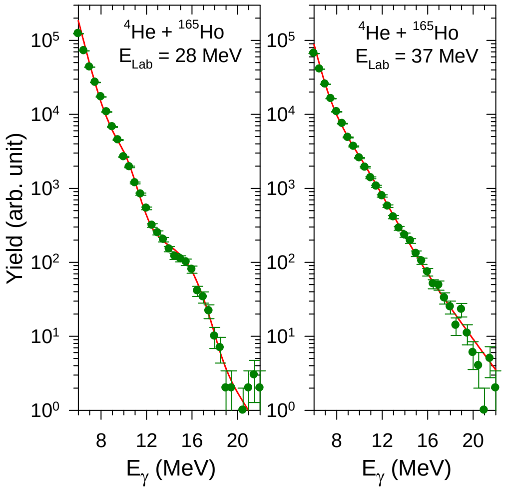

Fig. 1. The high energy γ-ray spectra (symbols) at two incident energies are shown with the statistical model CASCADE calculation plus bremsstrahlung component (solid line).

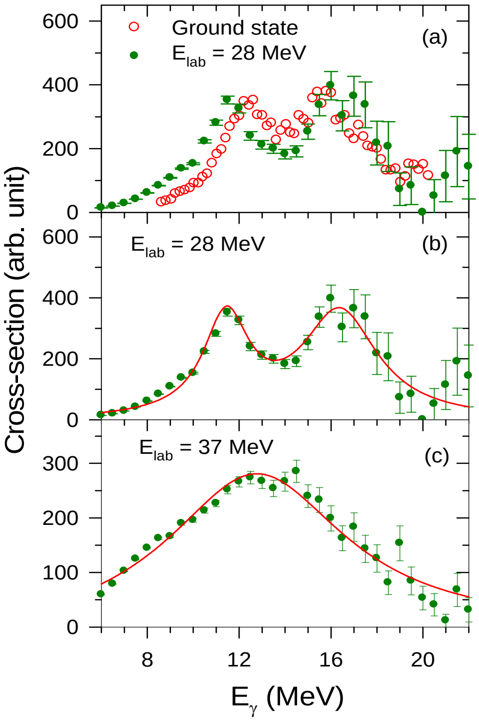

Fig. 2. (a) The experimental GDR strength function at E_{lab} =28 MeV along with the available ground state data of ^{170}Yb [10] (same ground state deformation as ^{169}Tm). (b) and (c) The linearized GDR along with the corresponding best fit GDR lineshape used in CASCADE calculation at 28 MeV and 37 MeV incident energies, respectively.

Carlo GEANT3 simulation [8] and the obtained angular momentum distributions were used as inputs in CASCADE calculation. The average temperatures, calculated from the initial excitation energies after subtracting the GDR resonance energy and the rotational energy for the corresponding J, were 0.8 MeV and 1.04 MeV whereas the T_c is 0.92 MeV for ^{169}Tm. The high energy gamma ray spectra along with the CASCADE calculation plus bremsstrahlung for the two incident energies are shown in Fig.1. The linearised GDR spectra are shown in Fig 2.

Recently, the shape transition as a function of T was studied theoretically for ^{169}Tm [9]. It was observed that the shape of ^{169}Tm at 0.8 MeV and 1.0 MeV was nearly same since the thermal fluctuations do not change drastically for this small variation in T. However, the experimental data present a completely different picture. A two component Lorentzian is observed at lower T (just below T_c) having the characteristics of a highly deformed prolate shape similar to the ground state GDR strength function (Fig. 2a). On the other hand a single Lorentzian strength function is observed at higher T (just above T_c) highlighting the effect of thermal fluctuations. The angular distribution study reveals that the nucleus has a prolate shape with similar deformations at both the excitation energies. These interesting results, along with the theoretical calculations, will be presented and explained during the conference

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