Giant Dipole Resonance width at very low temperature in near-Pb nuclei

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Introduction

The study of collective motion, in particular Giant Dipole Resonance (GDR), provides a unique probe to explore the evolution of nuclear structure as a function of excitation energy and nuclear spin [1]. In recent decades, the damping mechanism of GDR has been studied extensively as a function of angular momentum (J) and temperature (T). It is now well established that the observed GDR width increases with both J and T [1]. In general, over a wide range of temperature, angular momentum and nuclear mass (A) the increase in GDR width can be explained in the framework of thermal shape fluctuation model (TSFM), in which the shape of the nucleus couples adiabatically to the GDR vibrations [2, 3]. However, there are cases (A~120), where the macroscopic TSFM overestimates the GDR width for T below 1.5 MeV [4, 5]. The suppression of the GDR width at low temperature, in Pb region, has been attributed to strong shell effects, which first have to be dissolved before the width increases with the increase in temperature. The existing experimental GDR width data of ^{208}Pb are to some extent in agreement with the shell effect included TSFM [6]. However, no data point exists below T ~ 1.3 MeV to verify the prediction of the theoretical model where shell effects are expected to be large. Therefore, a systematic experimental study in the low temperature regime for A ~ 200 mass region is required to provide an important test of theoretical model where shell effects are significant. In this paper, we report the measurement of high-energy GDR photons from the decay of excited ^{201}Tl, a near Pb nucleus, using alpha induced fusion reaction at the Variable Energy Cyclotron Centre to investigate the evolution of GDR width at low temperature.

Experimental Details

The hot ^{201}Tl compound nucleus was formed by bombarding ^{4}He beam from the room temperature cyclotron on 2 mg/cm^2 thick ^{197}Au target at 35, 42 and 50 MeV beam energies. The initial excitation energies were 32.7, 39.6 and 47.5 MeV while the critical angular momenta were $14.8\hbar$, $18.3\hbar$ and $21.2\hbar$ respectively for the three incident energies. 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 multiplicity filter [8]. The LAMBDA array, arranged in 7x7 matrix, was kept at a distance of 50 cm from the target and at an angle of 90° with respect to the beam direction. 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 7 cm from the target to extract the angular momentum populated by the compound nucleus as well as to get the start trigger. The neutrons were eliminated from the high energy gamma rays by time of flight technique while the pile up events were rejected using the pulse shape discrimination technique in each detector element.

Results

The high-energy γ-ray spectra were generated in offline analysis after all necessary rejections and using a nearest neighbor summing (cluster) algorithm [7] (Fig 1). The GDR width was extracted from the experimental data by comparing with the predictions from a modified version of the statistical model code CASCADE [9]. In the statistical calculation, the Ignatyuk level density prescription has been used with the asymptotic level density parameter a = A/8.0.

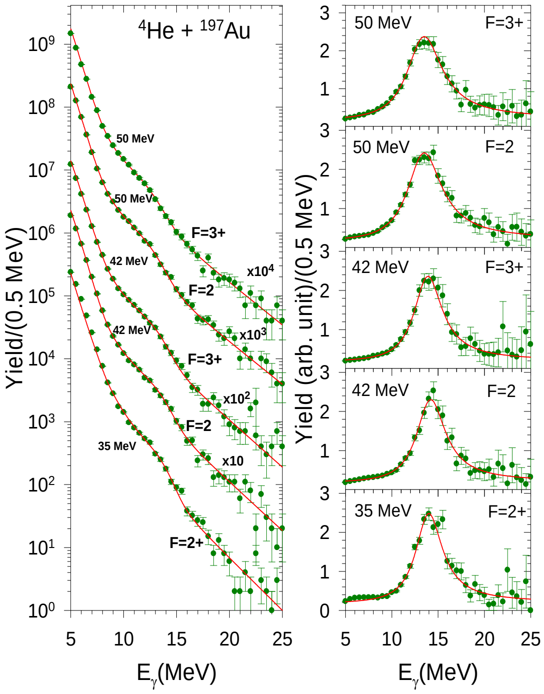

Fig.1. (Left) High-energy gamma spectra (filled circles) for various folds along with CASCADE prediction (continuous line) for different beam energies. (Right) The corresponding linearized GDR plots. Fold 2+ & 3+ represent the data for 2 fold or more and 3 fold or more respectively

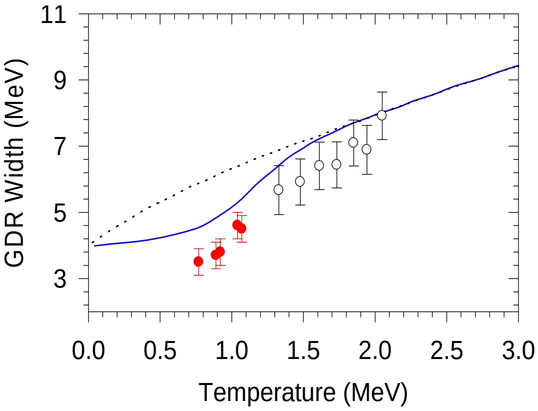

Fig.2. The GDR width plotted as a function of temperature. The filled circles are the data from this work. The open circles represent the data for ^{208}Pb obtained from inelastic scattering [6]. The dotted line and the continuous line correspond to the TSFM calculation without and with shell correction respectively (ref [6]).

The individual experimental folds were mapped onto the angular momentum space using Monte Carlo GEANT3 simulation [8] and the obtained angular momentum distributions were used as inputs in CASCADE calculation. The average temperature was calculated from the initial excitation energy after subtracting the GDR resonance energy and the rotational energy for corresponding fold. The GDR centroid energy did not vary much for different folds and was found to lie between 13.5 ~ 14.0 MeV. The extracted GDR widths from this experiment are shown in Fig 2 along with the previously measured ^{208}Pb data points [3,6]. The results have been compared with the predictions of TSFM [6]. It is evident that the theoretical model fails completely when shell corrections are not included in the calculation (dotted line). However, the measured GDR widths also differ significantly from the shell effect corrected TSFM calculation (continuous line) indicating towards the failure of the adiabatic assumption of TSFM at low temperature. Hence, modifications are required in the existing model to predict the correct evolution of GDR width with temperature. It appears that the suppression of GDR width at low temperature is a general trend independent of shell effects since it has been found to be suppressed in other nuclei also where shell effects are small [3,4,5].

References

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