Measurement of Giant Dipole Resonance width at very low temperature in near-Sn nuclei

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Introduction

The study of hot giant dipole resonance (GDR) has been a very successful tool in nuclear structure physics for last few decades. The damping mechanism of the GDR as a function of temperature (T) and angular momentum (J) has been of particular interest in this field. While the main features are understood, the temperature dependence of GDR width in ^{120}Sn and nearby nuclides is still incomplete due to scarcity of experimental data followed by the inconsistency of existing successful theoretical models at low T (<1.5MeV) [1,2]. Low temperature GDR width measurements are experimentally very challenging due to difficulties in achieving low excitation energies and only one data point exists so far below T=1.2 MeV. Heavy ion reactions are not suitable due to the presence of coulomb barrier in entrance channels and are always associated with broad J distributions. In inelastic scattering experiments, the excitation energy windows are uncertain to about 10 MeV and hence the estimated temperatures are less precise. In general, at higher T (>1.5MeV) the GDR widths are well explained in terms of the adiabatic thermal shape fluctuation model (TSFM) [3,4] but this model completely fails to explain the suppression of GDR width at low temperatures , even after incorporating the shell corrections. Therefore, a systematic experimental study of the GDR width in this temperature region is essential in order to understand the suppression of the strong damping mechanism of the collective dipole oscillations in hot nuclei. In this paper we report the first investigation of GDR width in the temperature range 1–1.2 MeV for A~120 mass region through alpha capture reactions.

Experimental Details

The experiment was performed at VECC using 35 MeV alpha beam from K130 Cyclotron. Self supporting, 1mg/cm^2 thick ^{115}In target was bombarded to populate ^{119}Sb at 36.19 MeV excitation energy. The high-energy photons were detected employing the LAMBDA [5] spectrometer arranged in a 7 x 7 matrix. The detector array was positioned at a distance of 50 cm from the target and at an angle of 90º with respect to the beam axis. The same measurement was repeated at two more angles i.e. 55º and 125º. Along with the spectrometer, a 50-element multiplicity filter [6] was used to extract the angular momentum populated by the compound nucleus as well as to get the start trigger for time-of-flight (TOF) measurements. The filter was split into two blocks of 25 detectors each and was placed on the top and bottom of a specially designed scattering chamber at a distance of 5 cm from the target in staggered castle type geometry. Time-of-flight technique was used to eliminate neutrons, while the pulse shape discrimination (PSD) was adopted to reject pile-up events for the individual detector elements. Apart from the photon detectors, liquid scintillator (BC501A) based neutron time-of-flight detectors [7] were also employed to detect the evaporated neutrons in order to extract angular momentum gated nuclear level density parameters.

Results

The high-energy γ–ray spectra were generated for various folds after all necessary rejections and compared with a modified version of the statistical model code CASCADE [8]. The high-energy gamma-spectra (measured at 90º) and the corresponding linearized GDR lineshapes are shown in Fig.1 along with the CASCADE predictions. The individual experimental folds were mapped onto the angular momentum space using a realistic approach [6] based on the Monte Carlo GEANT3 simulation. The obtained spin distributions for different fold were used as inputs in the CASCADE. The level density parameter ($\tilde{a}$=A/k MeV^{-1}) which is crucial for CASCADE calculation was extracted from the neutron evaporation spectra [9].

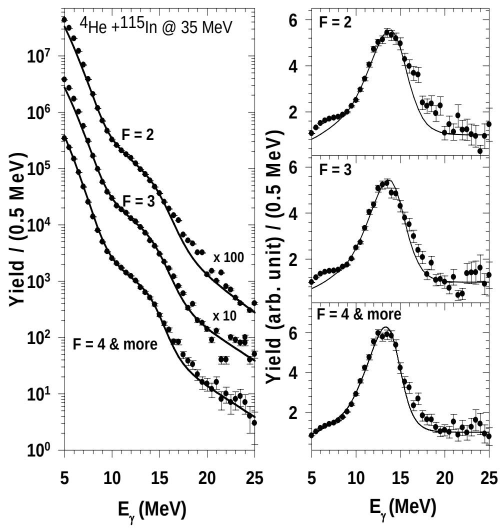

Fig.1. (Left) High energy gamma spectra (filled circles) for various folds along with CASCADE prediction (continuous line). (Right) The corresponding linearized GDR plots.

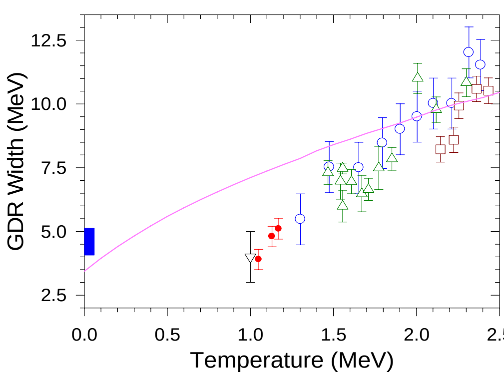

Fig.2. Comparison of data and theory for ^{120}Sn region. The filled circles are from this work and open symbols from [3] and references therein. Solid line corresponds to TSFM calculation while the rectangle represents the range of width measured for the ground state (T = 0 MeV).

The average angular momentum value, temperature, GDR width and level density parameter ($\tilde{a}$) for different folds are given in Table-1. The GDR centroid energy was taken as ~15 MeV. The extracted GDR widths are plotted as a function of temperature along with data from earlier works and compared with TSFM predication (Fig.2). From figure it is evident that the GDR widths (Γ_{gdr}) measured in this experiment differ significantly at low temperatures from adiabatic TSFM calculation (solid line). The measured GDR width is also consistent with the previous measurement at T = 1 MeV in ^{120}Sn. A further systematic study is underway to study the width below 1 MeV and above 1.25 MeV in order to achieve precise data set at low temperatures. This systematic study is very essential to propose a new model or to make necessary modifications of existing ones in order to predict the correct variation of the GDR widths from very low to high temperatures uniformly.

Table 1. The extracted parameters of this experiment

Fold	<J> ($\hbar$)	T (MeV)	Γ_{gdr} (MeV)	$\tilde{a}$ (MeV^{-1})
2	12.2	1.17	5.1 ± 0.3	A/8.5
3	15.1	1.13	4.8 ± 0.3	A/8.5
4+	20.1	1.03	3.9 ± 0.3	A/7.9

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