Temperature evolution of GDR width in very light nucleus

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Introduction

The isovector giant dipole resonance (IVGDR), an out of phase oscillation of protons and neutrons, built on the highly excited states of atomic nuclei is an excellent tool to study the atomic nuclei at extreme conditions. It is a highly damped motion and releases its energy by the emission of high energy γ-rays of Lorentzian shape characterized by its strength, peak position and width. In recent years, a major experimental [1, 2] and theoretical [3–5] efforts have been devoted towards the understanding of the damping mechanism contributing to the IVGDR width at low temperatures. However, the main focus of these investigations has been the heavy and medium heavy nuclei where the GDR strength remains well concentrated. The light nuclei, where the GDR is characterized by its own prominent specific features [6] have rarely been investigated and no experimental data exists for GDR built on excited states in A $<$ 40 nuclei. This motivated us to have a precise and systematic measurement of GDR width in ^{31}P as a function of temperature, which will provide a stringent testing ground for different microscopic [3, 4] and macroscopic models [5, 7].

Experimental details

The experiment was performed at Variable Energy Cyclotron Centre (VECC), Kolkata. A self-supporting 7.1 mg/cm^2 thick ^{27}Al target was bombarded with α-beam at three different energies 28, 35 and 42 MeV to produce the compound nucleus (CN) ^{31}P at the excitation energies of 34.1, 40.2 and 46.2 MeV, respectively. The high energy γ-ray spectra from the decay of IVGDR were measured using a part of the LAMBDA spectrometer [8] arranged in a 7×7 matrix and placed at a distance of 50 cm from the target at an angle of 90° with respect to the beam axis. The spectrometer was surrounded by a 10 cm thick passive lead shield to block the γ-ray backgrounds. A 50 element multiplicity filter, divided in two parts of 25 detectors each and placed on top and bottom of the target chamber in 5×5 matrix at a distance of 5 cm from the target, was utilized for precise measurement of angular momentum populated as well as to take start trigger for time of flight (TOF) measurements. The data were acquired using a VME based data acquisition system. Only those events for which at least one from both the top and bottom multiplicity filter fired in coincidence with one of the detectors of LAMBDA spectrometer above a threshold of $\sim$ 4.0 MeV were recorded. The time spectrum of the cyclotron radio frequency (RF) was also recorded with respect to the multiplicity filter to further ensure the selec-

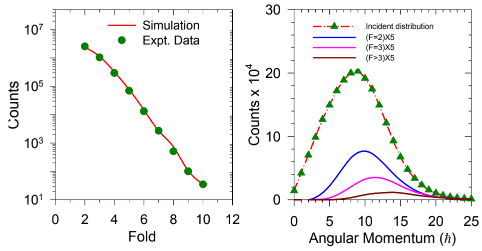

FIG. 1: a) Experimental fold distribution (green filled circles) at beam energy 42 MeV along with the simulation (red line), b) angular momentum distribution for different folds along with the incident distribution (dot-dashed line with symbols).

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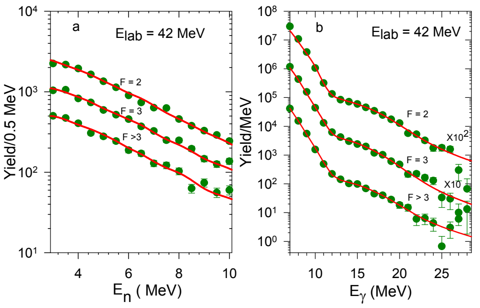

FIG. 2: The neutron energy spectra (a) and the high energy γ-ray spectra (b) along with best fit CASCADE spectra at E* = 46.2 MeV.

tion of beam related events. The evaporated neutron energy spectra were measured, in coincidence with the multiplicity γ-rays, using a liquid scintillator based neutron TOF detector. It was placed at the backward angle of 150° and at a distance of 150 cm from the target. The angular distribution of the high energy γ-rays was performed at 42 MeV beam energy to estimate the bremsstrahlung component.

Data analysis and inferences

The high energy γ-ray spectra corresponding to different multiplicity folds were reconstructed using cluster summing technique [8] in which each detector was required to satisfy the condition of prompt time gate and pulse shape discrimination (PSD) gate. The selection of prompt time gate and PSD gate ensures the rejection of neutron and pile-up events, respectively. The neutron TOF spectra were converted to neutron energy spectra taking the prompt peak as time reference. The $n - \gamma$ discrimination was done using PSD technique comprising of TOF and zero crossover time (ZCT). The experimentally measured fold distribution was mapped into angular momentum space using a realistic technique [9]. The experimental fold distributions along with the simulated one are shown in Fig 1a. and the selected angular momentum phase space for different folds are shown in Fig 1b. Using the simulated angular momentum phase space in the modified version of the statistical model code CASCADE [10], the nuclear level density (NLD) parameters at different angular momenta were extracted by comparing the CASCADE neutron spectra (after correcting for detector efficiency) with the experimental ones (Fig 2a) for precise determination of nuclear temperature as well as to put a vital constraint in the analysis of high-energy γ-ray spectra. The IVGDR parameters were extracted by comparing the CASCADE high energy γ-ray spectra (after folding with the detector response function) with the experimental ones (Fig 2b). The preliminary results shows that the IVGDR energy remains constant with temperature and the width remains nearly constant at nearly the ground state value upto a temperature of 1.7 MeV and increases thereafter. However, it is highly suppressed as compared to the thermal shape fluctuation model (TSFM) calculations [7]. These interesting results will be discussed in detail during the symposium.

References

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