Onset of exotic shape in ^{31}P

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Introduction

The isovector giant dipole resonance (GDR) is an out-of-phase collective oscillation of proton and neutron fluids in the nucleus. The short lifetime of the GDR makes it an excellent probe to investigate the properties of the nucleus at high temperature (*T*) and angular momentum (*J*). The GDR energy is inversely related to the length of the axis along which the oscillation occurs and thus the GDR line shape provides the information regarding the shape and deformation of the nucleus [1].

At high temperatures (T > 1.5 MeV), the shell-effect vanishes and the nucleus behaves as a charged liquid drop. Such a system prefers a non-collective oblate (rotation axis coincides with the symmetry axis) shape at moderate spins. Above a critical angular momentum [2], the nucleus is expected to undergo an abrupt shape transition from a non-collective oblate to a triaxial or collective prolate (rotation axis is perpendicular to the symmetry axis) shape with a large deformation (quadrupole deformation parameter $\beta > 0.4$). This is called the Jacobi shape transition which is also observed in rotating gravitational systems [3]. For light mass nuclei, the critical angular momentum for Jacobi shape transition is below the angular momentum at which fission barrier vanishes. This type of shape transition, therefore, is mainly observed in light mass systems [4-9]. The main signature of the Jacobi shape transition is the appearance of a sharp peak at around E_γ ~ 10 MeV along with a broad peak at around E_γ ~ 25 MeV in the high energy γ-ray spectrum observed from the decay of the GDR. The peak at E_γ ~ 10 MeV appears due to the Coriolis splitting of the lowest GDR component arising due to the vibration along the longest axis of the deformed prolate or triaxial shape.

The Jacobi shape transition has recently been observed in ^{31}P [9]. The compound nucleus was populated at E^* ~ 72 MeV and J ~ 22 $\hbar$ by bombarding ^{19}F beam on ^{12}C. A peak was observed around E_γ ~ 9 MeV which was attributed to the Jacobi shape transition in the nucleus. However, when the same nucleus was populated at low angular momentum (up to 16$\hbar$, highest excitation energy was ~ 46 MeV) by using ^{4}He beam on ^{27}Al target, the high-energy γ-ray spectra could be well explained with a single Lorentzian line shape with peak at E_γ ~ 17.5 MeV [10]. This calls for a measurement at still higher excitation and angular momentum to observe the possible onset of exotic shapes and its evolution in this light mass system.

Experimental details

The experiment was performed at the Variable Energy Cyclotron Centre (VECC), Kolkata. ^{4}He beam of energy E_{lab} = 50 MeV from the K-130 cyclotron was bombarded on a self-supporting ^{27}Al target producing the ^{31}P compound nucleus at an initial excitation energy of ~ 53 MeV. The high energy γ rays were measured by using a part of the LAMBDA spectrometer [11]. 49 BaF_2 scintillators were arranged in a 7×7 matrix and placed at a distance of 50 cm from the target position at an angle of 90^o with respect to the beam axis. A 50-element multiplicity filter [12], divided in two parts of 25 detectors each and placed on top and bottom of the target chamber in 5×5 matrix at adistance of ~ 5 cm from the target, was utilized for the

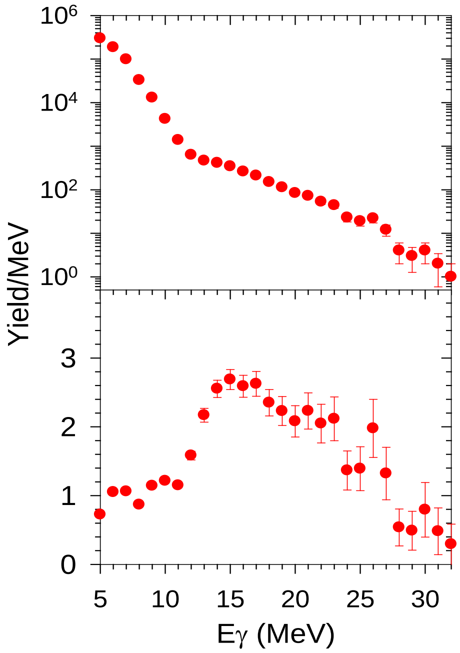

Fig. 1. Measured high-energy γ-ray spectrum (top panel) along with the divided plot (bottom panel).

measurement of angular momentum populated as well as to take start trigger for time of flight (TOF) measurements. The time spectrum of the cyclotron radio frequency (RF) was recorded with respect to the multiplicity filter to further ensure the selection of beam related events. The evaporated neutrons were also measured, in coincidence with the multiplicity γ rays, by using a liquid scintillator based fast neutron detector [13] for the extraction of nuclear level density.

Data analysis and inferences

The high-energy γ-ray spectrum was reconstructed using the cluster summing technique [11]. The neutron backgrounds and the pile-up events were rejected by taking the prompt time gate and pulse shape discrimination (PSD) gate in each BaF_2 scintillator of the LAMBDA array, respectively. The neutron TOF spectrum were converted to neutron energy spectrum taking the prompt peak as the time reference. The n-γ discrimination was achieved using both PSD and TOF techniques. The top panel of fig 1. shows a high-energy γ-ray spectrum originated from the decay of the GDR in ^{31}P . It is observed that the γ-ray strength is distributed towards higher energy with an additional peak around 23 MeV. The peak becomes clearer in the divided plot (bottom panel) obtained by dividing the high-energy spectrum with an exponential γ-ray spectrum along with a bremsstrahlung component. The exponential γ-ray spectrum was calculated by using the statistical model code CASCADE [14] without incorporating the GDR strength function but a constant dipole strength of 0.2 Weisskopf unit. The appearance of the peak around 23 MeV could be due to the onset of a highly deformed shape similar to that observed in refs. [4,5].

In summary, the high-energy γ-ray spectrum from the decay of GDR was measured for ^{31}P at an excitation energy of 53 MeV, along with the evaporated neutrons and γ-ray multiplicity. The preliminary analysis shows the appearance of a deformed shape. The detailed statistical model analysis is in progress and will be presented during the symposium.

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