Study of Jacobi shape transition in α cluster and non-α cluster nuclei

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The Jacobi shape transition, an abrupt change of nuclear shape from non-collectively rotating oblate to collectively rotating triaxial/prolate, has been a topic of contemporary interest in nuclear structure physics. The onset of Jacobi transition in nuclei has been seen via the Giant Dipole Resonance (GDR) γ-rays characterized by a narrow low energy component around E $\sim$ 10 MeV along with broader components in the high energy region (E > 15 MeV) [1–3]. The peak around E$\sim$10 MeV arises due to the Coriolis splitting of the GDR vibration along the most elongated axis of the highly deformed nuclei. However, this type of shape transition has only been observed in A $\sim$ 50 mass region [1–3]. On the other hand, there are indications of large deformation in atomic nuclei owing to cluster formation at higher J and excitation energy [4]. The occurrence of such large deformation in light α-like systems are either due to quassi-molecular resonances or due to nuclear orbiting phenomena [4]. Recently, no Jacobi shape transition was observed in ^{32}S for J>J$_c$ and this was attributed to the α cluster structure of the nucleus [2]. It is therefore highly imperative to look for the Jacobi shape transition in α cluster and non-α cluster nuclei, in order to understand the role played by α clustering in nuclear reaction dynamics. In this work, we report the measurement of high energy γ-ray spectra for α cluster ^{28}Si and non-α cluster ^{31}P nuclei.

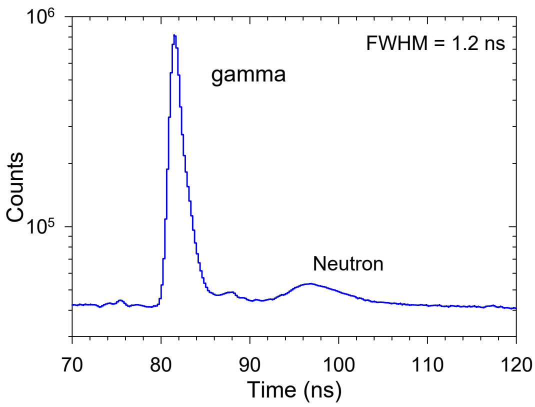

FIG. 1: A typical time-of-flight spectrum for the central detector in the reaction ^{16}O+^{12}C.

The experiments were performed using the pulsed beams of ^{16}O and ^{19}F from Pelletron Linac Facility (PLF), Mumbai bombarding ^{12}C target (400 μg/cm^2) at energies of 125 and 127 MeV populating the ^{28}Si (α cluster) and ^{31}P (non-α cluster), respectively. The maximum angular momentum for fusion for both the reactions was $\sim$ 22 $\hbar$ which is higher the critical angular momentum (J$_c$) predicted for Jacobi shape transition ($\sim$ 18 $\hbar$). The experimetnal setup and electronics are described in detail in Ref. [5]. The high energy γ-rays in the region of 5-30 MeV were measured in an array of seven closely packed hexagonal BaF$_2$ detectors (each 20 cm long with face-

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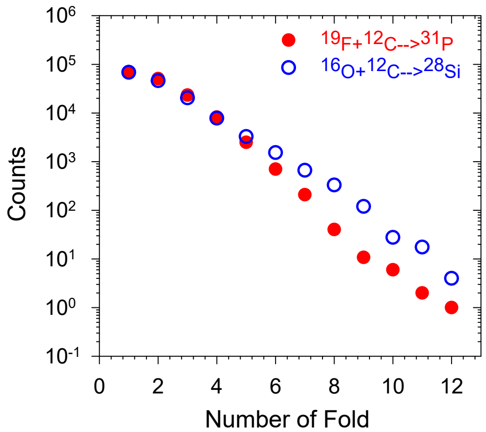

FIG. 2: The energy gated (E_γ=10-25 MeV) multiplicity fold distribution.

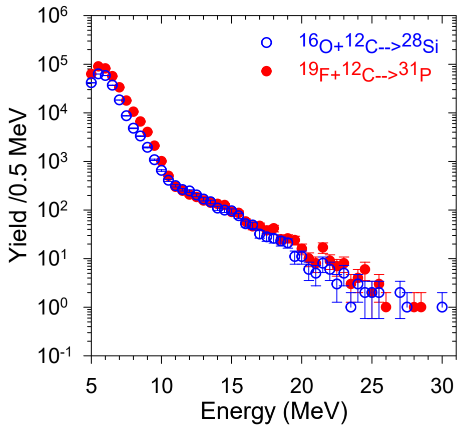

FIG. 3: High energy γ-ray spectra for fold F≥5.

to-face distance of 9 cm), surrounded by an annular plastic shield for cosmic muon veto. The angular momentum information was derived from fold distribution measured in a 14-element BGO multiplicity filter arranged in a castle geometry, surrounding the target. The efficiency of the multiplicity array at 662 keV is estimated to be ∼60%. The time-of-flight (TOF) technique was used to separate the neutrons and γ-rays. A typical TOF spectrum for the central detector is shown in the Fig 1. The pile-up rejection in BaF_2 was achieved by pulse shape discrimination using long (2 μs) and short (200 ns) gate widths for charge integration in QDC. Data was recorded using CAMAC based acquisition-cum analysis software LAMPS [6].

The BaF_2 detectors were calibrated using laboratory standard low energy γ ray sources ^{60}Co, ^{241}Am-^{9}Be and ^{239}Pu-^{13}C and extrapolated linearly up to the high energy. The gain of the BaF_2 detectors were periodically checked during the experiment and was found to be stable within 1%. The beam induced background was also monitored using a blank target frame during the experiment. Data was collected for each reaction for an incident charge of ∼ 0.7 pmC. Preliminary data analysis is carried out to generate fold gated high energy γ-ray spectra for events corresponding to $\gamma-$ prompt in TOF window after suitable chance correction.

The high energy γ gated fold distribution for both reactions are shown in Fig. 2. Significant differences are observed at fold F>6, with α cluster like nuclei having wider distribution. The high energy γ-ray spectra of ^{28}Si and ^{31}P are shown in Fig. 3 for F≥5. An enhancement in the low energy region (E<10 MeV) can be seen for ^{31}P, which could be the signature of Jacobi shape transition. The data analysis is in progress and the results will be presented.

Acknowledgments

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