Measurement of rotational enhancement in the nuclear level density in mass A∼160

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Introduction

The level density is a fundamental property of the atomic nucleus and an important physical quantity for the calculations of reaction rates relevant to nuclear astrophysics, nuclear reactors and spallation neutron sources. The nuclear level density (NLD) rapidly increases with increasing excitation energy (E_X) as $e^{2\sqrt{aE_X}}$, 'a' is the NLD parameter. In general, the NLD depends on E_X and angular momentum (J), parity, number of nucleons (A) and also on the microscopic properties such as pairing, shell effect and collective degrees of freedom such as rotation and vibration. The shell effect on the NLD and its damping with E_X has been inferred from an exclusive measurement of the neutron spectrum in ^{208}Pb region [1]. The influence of collective rotational motion leads to a significant increase in the total NLD as predicted by Bjornholm, Bohr and Motelson [2]. The total level density is given by $\rho_{tot} = \rho_{int} K_{coll}$, ρ_{int} is the intrinsic level density and $K_{coll} = K_{rot} K_{vib}$ is the collective enhancement factor due to rotational (K_{rot}) and vibrational (K_{vib}) motion [2]. The enhancement factor is ∼3 at E_X=8 MeV for deformed nuclei in A∼160 and 240 region [3]. The collective enhancement of the nuclear level density is predicted to be damped out with E_X. However the experimental observation on the washing out of collectivity with E_X through the NLD measurement is scarce. Recent measurement claims to observe the direct evidence on the fadeout of the collectivity with E_X [4]. More measurements are required in the deformed nuclei to investigate the critical energy and damping factor for the fading out of the collectivity.

The aim of the present measurement is to study of the rotational enhancement of the nuclear level density(NLD) in ^{161}Dy and its damping with excitation energy. The statistical model analysis of the measured neutron spectra from strongly deformed ^{162}Dy (β=0.341) will reveal the damping of rotational enhancement with the excitation energy. One possible method to populate ^{162}Dy is via break-up followed by fusion/transfer in ^{7}Li-induced reaction on ^{159}Tb target. Neutron spectra are measured from the excited ^{162}Dy nucleus in coincidence with the outgoing alpha particles using similar experimental techniques as in Ref. [1] but with more advanced detector system.

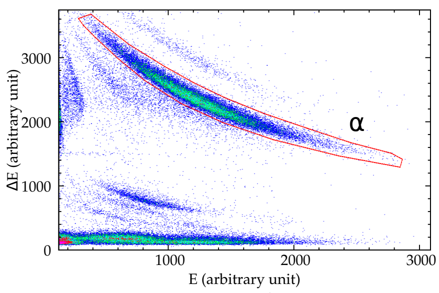

FIG. 1: Two dimensional ΔE-E spectrum for identification of alpha particles.

Experimental details:

The experiment was carried out by bombarding 27 MeV pulsed ^{7}Li beam on a 3 mg/cm^{2} thick, self supporting ^{159}Tb target at the BARC-TIFR Pelletron-LINAC facility, Mumbai. Two ΔE-E silicon strip detector telescopes (each dimension 5 cm×5 cm) placed at a distance of ∼7 cm from target and

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a mean angle ±150°, have been used to detect charged particles. The thickness of ΔE and E detectors were 50 μm and 1.5 mm respectively. Each of detector has 16 strips and have an angular coverage ∼35°. An array of 15 liquid scintillation (LS) detector(EJ301) was used to measure neutron energy by time of flight techniques(TOF). Each scintillation detector (5 inch diameter and 2 inch long cylindrical shape) was coupled to a 5 inch diameter fast PMT for signal readouts. The detectors were kept at a distance of 70 cm from the target covering an angular range 58.3° to 143.3° with a angular separation of 16° among the detectors. Both TOF and pulse shape discrimination (PSD) technique have been used for unambiguous selection of neutron events. The neutrons were measured in coincidence with the charged particles and data were stored in list mode using VME based data acquisition system. The TOF information of each LS with respect to the pulsed beam filtered by the charged particles, PSD, pulse height information of the liquid scintillator, energy signals from each strips of ΔE and E detectors and two beam timing(Tb) with respect with ΔE and E detectors were recorded in each events. The calibration of TOF was done with a precision time calibrator, pulse height calibration was done by measuring the Compton edge using ^{137}Cs and ^{22}Na sources. The energy calibration of ΔE and E detectors was done measuring discrete alpha energies from ^{229}Th sources.

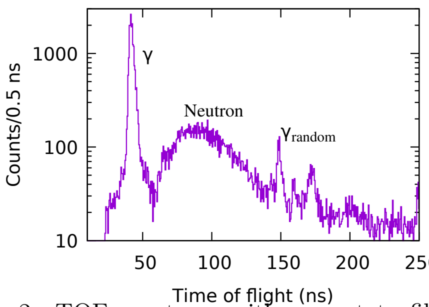

FIG. 2: TOF spectrum with respect to filtered pulsed beam gated by alpha particles in ΔE-E spectrum

Analysis and results:

A typical two dimensional ΔE-E spectrum for particle identification is shown in Fig. 1.

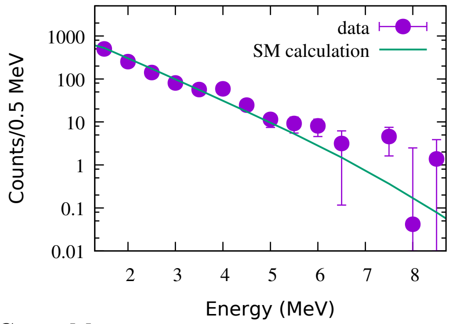

FIG. 3: Measure neutron evaporation spectrum and its comparison with statistical model(SM) calculation.

It shows that alpha particles are clearly separated from other charged particles. Fig.2 shows the TOF spectrum derived with appropriate gates in alpha particles and beam timing (Tb). The continuum neutrons are well separated from the prompt γ rays while second peak (γ_{random}) is due to random coincidence with second beam burst. For E_α=12.5-14 MeV, the derived neutron spectrum from the TOF spectrum and its comparison with the SM calculation including rotational enhancement of NLD are shown in Fig.3.

Summary and conclusion

The strongly deformed nucleus ^{162}Dy has been populated at E_X ∼ 19-24 MeV via the breakup-fusion/transfer reaction. The exclusive measurement of neutron spectra has been made in coincidence with the alpha particles. The statistical model analysis of the measured neutron spectra invoking collective nuclear level density will reveal the fading out of the collectivity with E_X.

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