Confirmation of collective enhancement and its fadeout in the NLD

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It is now a very well known fact that the density of nuclear states increases rapidly with excitation energy and soon becomes very large [1]. As a result, the nucleus leaves the discrete region and enters the region of quasi-continuum and continuum. Thus, statistical models are crucial for understanding and estimation of various nuclear phenomena. One of the important ingredients of any statistical model code is the nuclear level density (NLD) defined as the number of nuclear level per unit excitation energy. Along with the intrinsic excitations, the nucleus also displays collective vibration and rotational motion. These collective excitations have significant effect on nuclear level density, in particular, for deformed nuclei and their contribution is defined as the collective enhancement in the NLD. Therefore, the total level density is expressed as $\rho(E^*,J) = \rho_{int}(E^*,J) * K_{coll}$, where $\rho_{int}(E^*,J)$ is the intrinsic single particle level density and K_{coll} is the collective enhancement factor [2]. The exact form and the role of K_{coll} still remains an open question to answer since there has been no systematic experimental information of the enhancement and its fadeout with excitation energy.

Recently the signature of collectivity was observed for several deformed nuclei (^{169}Tm, ^{173}Lu, ^{185}Re) from the neutron evaporation spectra studies [3,4] at VECC. A sharp change in the inverse level density parameter was observed for all the three deformed nuclei in the excitation energy interval of 32-37 MeV, but only a weak effect was observed for the near spherical ^{201}Tl [4]. These experiments suggested the fadeout of the collectivity in the excitation range 14-21 MeV. Therefore, if there is an enhancement and its fadeout in the region 14-21 MeV, then that should be directly evident in both neutron as well as giant dipole resonance (GDR) γ decay spectra.

An extensive experiment was performed at the VECC using the K-130 cyclotron to measure the collective enhancement in the NLD and its fadeout with excitation energy. The highly deformed ^{169}Tm (β~0.3 in the ground state [5]) nucleus was populated at 26.1 MeV excitation energy in the reaction ^{4}He + ^{165}Ho with 28 MeV alpha beams. The critical angular momentum for the reaction was ~ $11\hbar$. The high energy GDR γ-rays were measured at 90^{o} and 125^{o} employing the LAMBDA spectrometer [6]. The array was configured in 7x7 matrix and kept at a distance of 50 cm from the target. The 50-element multiplicity filter [7] was split into two blocks of 25 detectors each and was placed on top and bottom of the scattering chamber at a distance of 4.5 cm from the target to extract the angular momentum of the compound nucleus as well as to get the start trigger for the time of flight (TOF) measurements. The evaporated neutron energy spectra were measured through TOF technique using two liquid scintillator based neutron detectors [8] placed at backward angles 120^{o} and 150^{o} at a distance of 150 cm from the target position. The neutron-γ discrimination was achieved by both pulse shape discrimination (PSD) and TOF. The TOF, PSD and fold spectra obtained during the experiment for the neutron and GDR measurements are shown in Fig. 1.

The neutron and the high energy γ-ray spectra, each measured at two different angles, are shown in Fig 2 (a) and (c), respectively at <J> = 11 +/- 4 which was estimated from the fold spectrum applying GEANT simulation [7]. As can be seen, the two spectra almost overlap which clearly indicates that they have originated from an equilibrated compound nucleus. It is very interesting to note the large yield in the cross section of both GDR γ-ray (16 MeV) and neutron energy spectra (beyond 6 MeV) probing

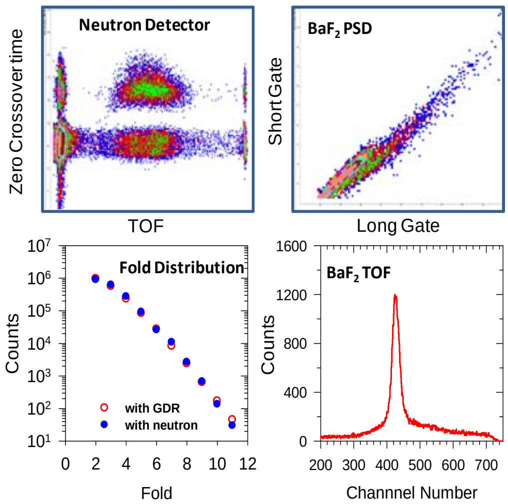

Fig. 1. The experimental PSD and TOF of neutron detector and the BaF_2 detector of the LAMBDA spectrometer. The fold spectrum measured in coincidence with neutron and GDR γ-rays are also shown.

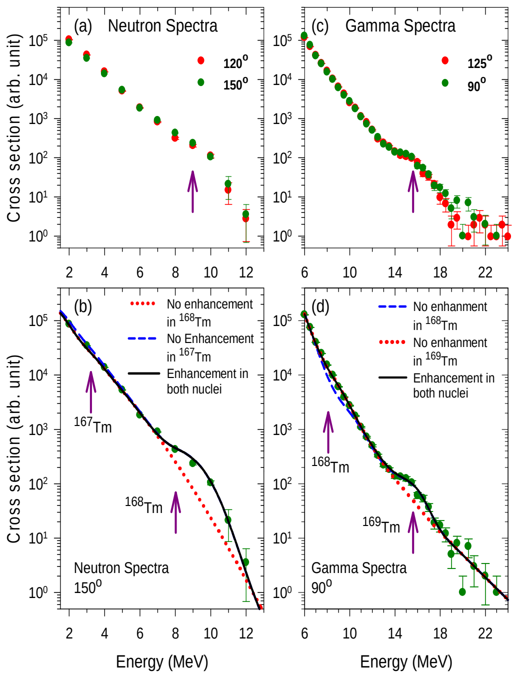

Fig. 2. The neutron (a) and the high energy γ-ray spectra (c) measured at two angles are compared with each other. (b) and (d) The neutron and γ-spectra compared with respective CASCADE calculation. The enhancement in the spectra and the contribution from different nuclei are shown with arrows.

the same excitation energy region in the daughter nuclei ^{169}Tm and ^{168}Tm, respectively. The simultaneous enhancement in both neutron and GDR decay is the direct evidence of the enhancement independent of any model. We mention here that it was not possible to explain the neutron and the GDR spectra with the intrinsic level density used in statistical model code CASCADE based on Fermi gas model. Hence, the K_{coll} (Gaussian distribution) was added to the intrinsic level density to explain the experimental data. The K_{coll} for different Tm nuclei was extracted by simultaneously fitting the GDR and the neutron spectra. The enhancement contribution from different nuclei in the neutron spectra as well as the high energy GDR spectra is shown in Fig 2 with arrows. Interestingly, the extracted GDR parameters were very similar to the ground state values [9], as expected [10], and the estimated deformation from the two GDR peaks was β=0.32. The K_{coll} distribution extracted for ^{169}Tm, ^{168}Tm and ^{167}Tm nuclei (having identical deformations [5]) from the neutron and the GDR data were found to be very similar and the fadeout of the enhancement occurred ~ 14 MeV. Thus, the observation of deformation directly from the GDR and the similar enhancement required in NLD for all the Tm nuclei provides the first direct experimental evidence of the collective enhancement in the NLD. These interesting results as well as how the collective enhancement is reflected through the change in the inverse level density parameter will be presented during the conference.

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