The effect of level density prescriptions on the understanding of high energy γ-ray spectra

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Giant dipole resonance (GDR) is a prime example of strong collective motion in nucleus providing information on nuclear structure, especially under extreme conditions of nuclear excitation energy (E*) and angular momentum (J) [1]. Measurement of high energy GDR γ-rays (E_γ= 8 - 20 MeV) from the decay of hot compound nucleus (CN) is one of the most important probes to study deformation in excited nuclei [2]. However, to understand the properties of the GDR parameters in excited nuclei, the characterization of the measured high energy γ-rays and its comparison with the predictions of statistical model related to CN decay are absolutely necessary. The acceptability of any statistical model prediction depends on the nuclear level density, which is also the central source of uncertainty in analyzing nuclear reactions and in reliable extraction of the GDR quantities viz. the strength (S), centroid energy (E_{GDR}) and width (Γ_{GDR}). Ideal level density prescription should describe high energy γ-ray spectra by estimating correct level densities starting from lower to higher E* and at different values of J. It should also incorporate shell effects at lower E* which melts at higher E*.

In view of this we have chosen three level density prescriptions viz., Ignatyuk, Smerekin and Tishin (IST) [3], Kataria, Ramamurthy and Kapoor (KRK) [4] and Budtz-Jorgensen and Knitter (BJK) [5]. Although IST is highly popular, the other two have not been tested much in describing high energy γ-ray spectra emitted from excited CN. Previously, Dilg, IST and BJK level density formalisms were compared at A= 110 - 130 over the E* range 58 - 62 MeV and J= 16.9-20ħ by matching experimental high energy γ-ray spectra with CASCADE predictions [6]. They did not find any change of the GDR parameters even after including different level density prescriptions. However, IST was not tested rigorously at different conditions of J and T. In this work [7], the applicability of three different level density prescriptions given by KRK, BJK and IST using experimental high energy γ-ray spectra measured earlier for four nuclei ^{63}Cu [8], ^{97}Tc [9], ^{113}Sb[10] and ^{201}Tl [8] at different excitation energies and angular momenta have been investigated. The results obtained for ^{113}Sb have been discussed in details here.

The experimental high energy γ-ray spectra emitted by the CN ^{113}Sb at E*=122 and 109 MeV for J=49-59ħ are compared with the CASCADE prediction utilizing three different level density models folded with detector response along with an exponential bremsstrahlung component with E_0 as the slope parameter [10]. For all the models, at common beam energy, E_0 is kept fixed as per existing systematics and only the S_{GDR}, Γ_{GDR} and E_{GDR} are varied. For better understanding, the comparison is done in terms of divided linearized GDR plots. Fig. 1 (left pane;) shows the experimental data (open circle) along with IST (continuous line), BJK (dotted-dashed line) and KRK (dashed line) predictions at E*=109 MeV. It was very interesting to find that all the three level density prescriptions could uniformly represent the high energy spectra. However, the extracted GDR centroid energies were very different. The discrepancy is evident in linearized plots shown at different J in Figs. 2. It was observed that IST explains the data really well with E_{GDR}=15.55 MeV consistent with existing systematic [1] of excited state GDR centroid energy (15.1 MeV). However, KRK prescription could explain the data only if E_{GDR} is taken as 17.0-17.3 MeV, much larger than the existing systematics. On the other hand, BJK prescription explains the data with much lower

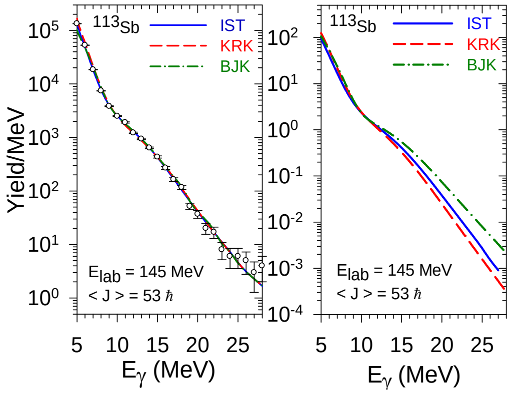

Fig.1. (Left panel): The experimental high energy γ-ray spectrum (open circles with error bars) for ^{113}Sb at projectile energy 145 MeV along with CASCADE predictions exploiting KRK (red dashed line), BJK (green dotted-dashed line) and IST (blue continuous line) level density formalisms. (Right panel): CASCADE outputs of high energy γ-ray spectrum considering the three level density prescriptions for common GDR parameters.

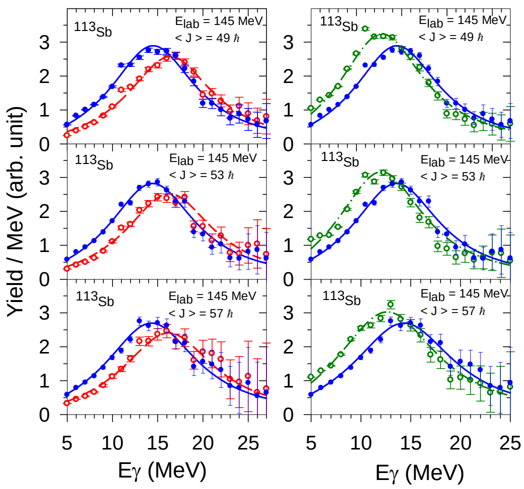

Fig.2. (Left panel): The linearised GDR plots are compared for IST (blue filled circles and continuous lines) and KRK (red open circles and dashed lines) prescription. (Right panel): The linearised GDR plots are compared for IST (blue filled circles and continuous lines) and BJK (green open circles and dot-dashed lines) prescription.

values of E_{GDR}~14.0 MeV. However, their predicted GDR width remains unchanged. Since the inverse level density parameter (k) for IST was not measured, it was taken as 8.0 MeV as per Reisdorf formula. The change of k from 8 to 9 could only alter the centroid energy by 3% and strength by 5%.

The discrepancy in high-energy γ-ray yield is apparent when keeping the GDR parameters same, the CASCADE predicted γ-ray spectrum of ^{113}Sb is compared for three different prescriptions (Fig. 1 right panel). The plots clearly indicate that for the common input parameters KRK predicted γ-ray yield at higher energy side is low compared to other two formalisms. This reduced yield is actually compensated by shifting E_{GDR} at higher energies resulting higher values of E_{GDR}. The reverse phenomenon is seen for BJK prediction thereby yielding lower E_{GDR} values. The proper values of E_{GDR} are highly important for determination of nuclear temperature. It is also important for extracting correct nuclear symmetry energy.

Interestingly, similar results were obtained for ^{113}Sb data at 160 MeV incident energy. Therefore, IST prescription is found to be successful for explaining GDR line shapes in different nuclei with E* and J ranging from lower to higher values. But KRK and BJK cannot explain GDR line shapes and predict E_{GDR} much different from existing systematics. Similar results were obtained for the other nuclei [7] and will be discussed during the symposium.

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