

## Collective enhancement of nuclear level density

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### Introduction

Collective enhancement of level density has been studied theoretically for a long time [1, 2], however experimentally only a few evidences are there. First experimental evidence was found by Jhungans *et al.* [3] in an experiment of heavy nucleus fragmentation. Later, evaporated particle spectra measurements did not find any signature of enhancement [4]. In a few recent studies neutron spectra evaporated from compound nucleus (CN) at excitation energy 25 – 40 MeV showed signature of fade out [5, 6] but the shape of the enhancement is still to be obtained experimentally. We have measured neutron spectra for reactions  $^{11}\text{B}+^{181}\text{Ta}$ ,  $^{197}\text{Au}$ . Evaporated  $\alpha$ -particles were used to access lower excitation energy than CN excitation energy. Neutron spectra were measured in coincidence with evaporated  $\alpha$ -particles to study level density parameters of residual nuclei after  $\alpha$  evaporation ( $^{188}\text{Os}$  and  $^{204}\text{Pb}$ ) in the excitation energy range 27 – 41 MeV to look for the signature of fade out of collective enhancement.

### Experiment

The experiment was carried out at TIFR pelletron facility using pulsed beam of  $^{11}\text{B}$ . Thick targets of  $^{181}\text{Ta}$  ( $2.1 \mu\text{g}/\text{cm}^2$ ) and  $^{197}\text{Au}$  ( $2.7 \mu\text{g}/\text{cm}^2$ ) were bombarded at energies 61.5 and 63.0 MeV, respectively. Two telescope detectors, consisting of silicon strip detectors

were placed at backward angles ( $\pm 150^\circ$ ) for detection of evaporated  $\alpha$ -particles. Neutrons were detected with the help of 15 liquid scintillator detectors placed at a distance of 72.5 cm from the target covering angular range  $58^\circ - 143^\circ$ . Time of flight of neutrons were recorded with respect to beam RF signal to obtain energy. Pulse shape discrimination technique was exploited to separate neutrons from  $\gamma$ -rays. Neutrons were detected in coincidence with the charged particles, detected at telescope detectors.

### Analysis

Experimentally detected  $\alpha$ -particle spectra were compared with statistical model predictions (using code PACE) and best fits were obtained by changing level density parameter  $a$  shown in Fig. 1. Inverse level density parameters ( $k = A/a$ ,  $A$  being mass of nuclei) that fitted the experimental data were 10.5 for CN  $^{192}\text{Pt}$  and 11.5 for CN  $^{208}\text{Po}$ .  $\alpha$ -particle energy gates were applied to obtain the corresponding neutron spectra. It was found that for  $\alpha$ -particle energy  $> 25$  MeV, 85%  $\alpha$ -particles were first chance alpha i.e.  $\alpha$ -particles evaporated from CN. By subtracting the energy of the  $\alpha$ -particles and  $\alpha$ -particle separation energy from CN excitation energy, we obtained excitation energies of residual nuclei  $^{188}\text{Os}$  and  $^{204}\text{Pb}$ .

### Results

Neutron spectra, evaporated from residual nuclei at different excitation energies are shown in Fig.2. Statistical model calculations

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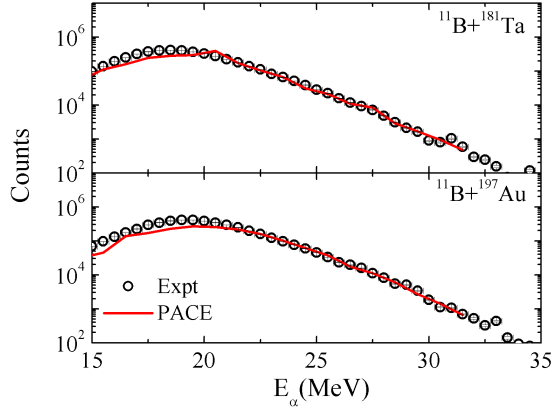


FIG. 1:  $\alpha$ -particle spectra for reactions  $^{11}\text{B}+^{181}\text{Ta}$ ,  $^{197}\text{Au}$  along with statistical model predictions shown by lines.

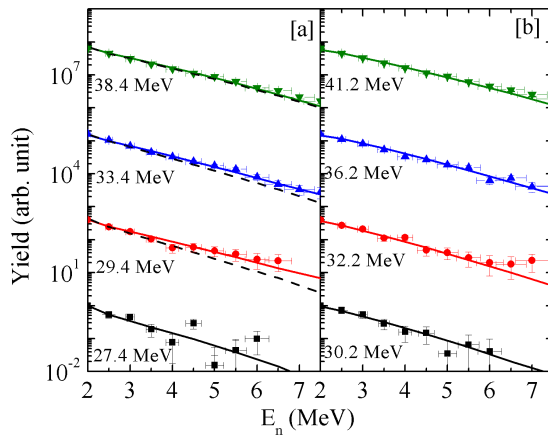


FIG. 2: Evaporated neutron spectra for reactions  $^{11}\text{B}+^{181}\text{Ta}$ ,  $^{197}\text{Au}$ . Solid lines show the best fitted neutron spectra calculated using statistical model code PACE while dashed lines for  $^{188}\text{Os}$  show calculations using  $k$  that was obtained from  $\alpha$ -particle spectra.

were performed using code PACE to fit the

neutron spectra considering  $k$  as a parameter. It was observed that for  $^{204}\text{Pb}$ , value of  $k$  did not change over the entire energy range and also agreed within the uncertainty limit with  $k$  value obtained from  $\alpha$ -particle spectra. For  $^{188}\text{Os}$ , similar  $k$  value could not explain all the  $n$  spectra (shown by dashed lines in Fig. 2[a]). At highest energy the value was comparable with that obtained from  $\alpha$ -particle spectrum but showed a peak-like structure near 28-36 MeV excitation energy of the  $^{188}\text{Os}$ . Similar behavior of  $k$  parameter was reported for reactions  $^4\text{He}+^{169}\text{Tm}$ ,  $^{181}\text{Ta}$  by Banerjee *et. al.* [5]. Daughter nuclei in case of  $^{204}\text{Pb}$  being spherical are not expected to show large enhancement while nuclei ( $^{186,187}\text{Os}$ ) produced in decay of  $^{188}\text{Os}$  are highly deformed that causes large rotational enhancement in low energy. Fade out of enhancement changes the evaporated neutron spectra that causes unusual structure in  $k$  distribution. We have extracted the enhancement factor as a function of energy by fitting the neutron spectra.

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