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 experimentaly 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}B+^{181}Ta, ^{197}Au. Evaporated α-particles were used to access lower excitation energy than CN excitation energy. Neutron spectra were measured in coincidence with evaporated α-particles to study level density parameters of residual nuclei after α evaporation (^{188}Os and ^{204}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}B. Thick targets of ^{181}Ta (2.1 μg/cm^2) and ^{197}Au (2.7 μg/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 ($\pm150°$) for detection of evaporated α-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° - 143°. 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 γ-rays. Neutrons were detected in coincidence with the charged particles, detected at telescope detectors.

Analysis

Experimentally detected α-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}Pt and 11.5 for CN ^{208}Po. α-particle energy gates were applied to obtain the corresponding neutron spectra. It was found that for α-particle energy > 25 MeV, 85% α-particles were first chance alpha i.e. α-particles evaporated from CN. By subtracting the energy of the α-particles and α-particle seperation energy from CN excitation energy, we obtained excitation energies of residual nuclei ^{188}Os and ^{204}Pb.

Results

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

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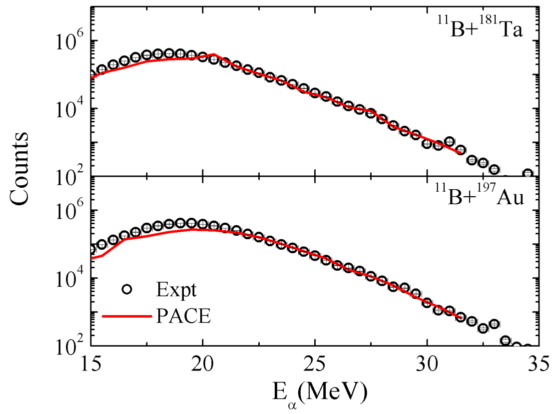

FIG. 1: α-particle spectra for reactions $^{11}B+^{181}Ta,^{197}Au$ along with statistical model predictions shown by lines.

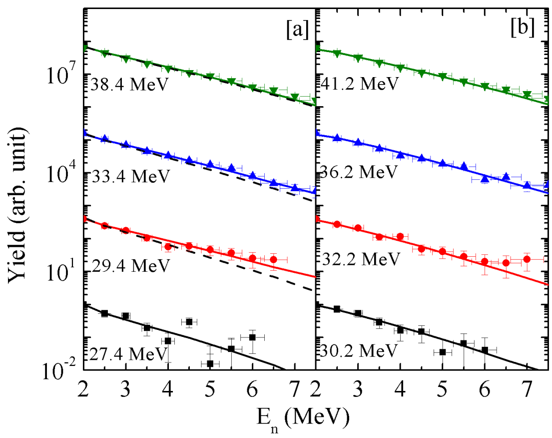

FIG. 2: Evaporated neutron spectra for reactions $^{11}B+^{181}Ta,^{197}Au$. Solid lines show the best fitted neutron spectra calculated usig statistical model code PACE while dashed lines for ^{188}Os show calculations using k that was obtained from α-particle spectra.

were performed using code PACE to fit the neutron spectra considering k as a parameter. It was observed that for ^{204}Pb, value of k did not change over the entire energy range and also agreed within the uncertainty limit with k value obtained from α-particle spectra. For ^{188}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 α-particle spectrum but showed a peak-like structure near 28-36 MeV excitation energy of the ^{188}Os. Similar behavior of k parameter was reported for reactions $^{4}He+^{169}Tm,^{181}Ta$ by Banerjee *et. al.* [5]. Daughter nuclei in case of ^{204}Pb being spherical are not expected to show large enhancement while nuclei ($^{186,187}Os$) produced in decay of ^{188}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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