Study of angular momentum gated light-particle evaporation spectra in ^{4}He + ^{93}Nb and ^{4}He + ^{58}Ni reactions.

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Study of evaporation spectra of particles emitted from an excited compound nucleus gives useful information about the nuclear level density (NLD). The knowledge of NLD in turn can provide an interesting test of microscopic approaches of nuclear structure. Moreover nuclear level densities are important ingredient in the statistical model calculations of nuclear cross sections. It is important and interesting to understand the dependence of NLD on some key parameters such as excitation energy (temperature) and angular momentum. In recent years there have been reviewed interests [1-4] in understanding the angular momentum *(J)* dependence of NLD. Although a few experimental and theoretical studies have been performed in the past, no conclusive picture of variation of NLD with *'J'* was obtained from these studies. In order to understand the angular momentum dependence of NLD in a systematic manner we have carried out measurement of angular momentum gated light particle (n, p, and α) evaporation spectra in ^{4}He + ^{93}Nb and ^{4}He + ^{58}Ni systems.

The experiment was performed with 35 MeV ^{4}He beam from the VECC K-130 cyclotron facility, using self-supporting foils of ^{93}Nb and ^{58}Ni (thicknesses ~1 mg/cm^2). To detect and identify the charged particles emitted during the compound nuclear evaporation process, a 3-element detector telescope consisting of a 50μm single-sided silicon strip detector (16 channels), 500μm double-sided silicon strip detector (16 X 16 channels) and two CsI(Tl) crystals (thickness 4 cm) at the back was mounted at the mean angle of 147^0 covering an angular range of ±17.5^0. Four liquid-scintillator (BC501A) detectors were mounted at the back angles to detect the emitted neutrons. In the present experiment, populated angular momentums were recorded by measuring the γ-multiplicity using a 50 element BaF_2 based low energy γ-ray filter array. Data from the neutron and the charge particle detectors were recorded in coincidence with γ- multiplicity in event by event mode. Fig.1 shows the schematic of the typical experimental setup used in this experiment. The fold (defined as the number of γ detector fired simultaneously) gated *α*-particle, proton, and neutron kinetic energy spectra were measured to study the angular momentum dependence of NLD.

The angular momentum distributions for different folds were obtained by converting the measured γ-fold distribution, using the Monte Carlo simulation technique based on GEANT3 toolkit [5]. The theoretical neutron, proton and α-particle energy spectra were calculated using the statistical model code CASCADE [6], with the extracted angular momentum distributions for different folds as the input.

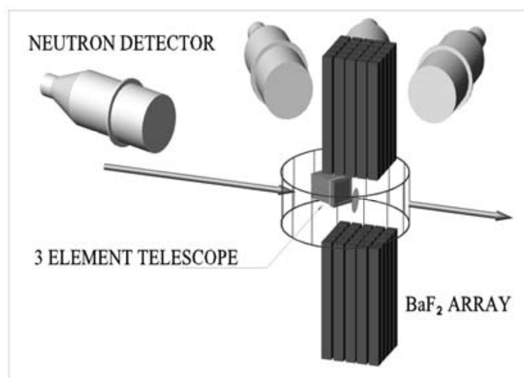

Fig.1 A typical experimental setup

The experimental neutron, proton, and α-particle energy spectra for ^{4}He + ^{93}Nb system, along-with the corresponding CASCADE fits have been shown in Fig.2. The shape of the kinetic energy spectra were mostly determined by the value of the level density parameter *(a)*. In the calculation the inverse level density parameter *'k'* (*k = A/a,* where A is the mass number) was varied to get the best fit to the experimental data, while for other statistical model parameters, default values were taken. The extracted values of the inverse level density parameters for different angular momentum regions as obtained by fitting the neutron (k_n), proton (k_p), and α-particle (k_α) data are given in TABLE:I and II for $^{4}He + ^{93}Nb$ and $^{4}He + ^{58}Ni$ systems respectively.

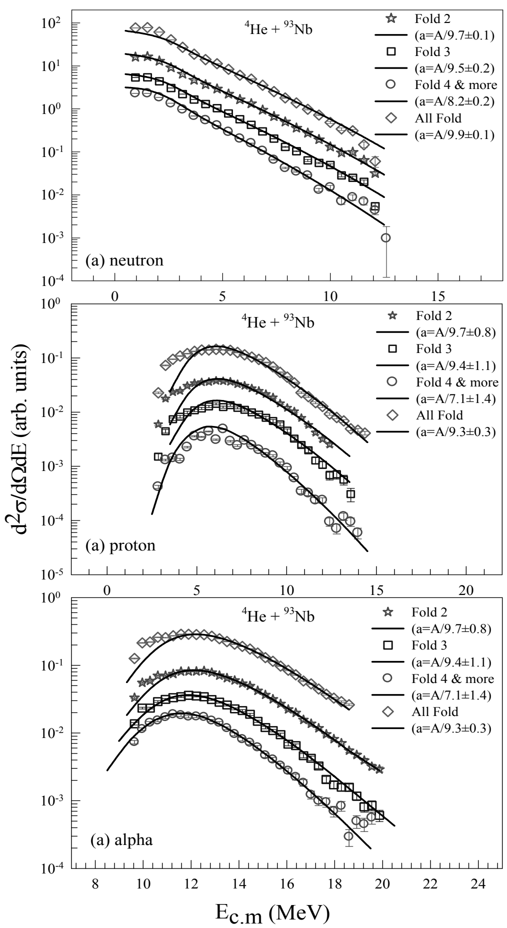

Fig. 2: Experimental (a) neutron, (b) proton, and (c) α-particle energy spectra along-with the CASCADE fits for different folds in case of $^{4}He + ^{93}Nb$ system.

From TABLE: I and II it can be observed that the values of inverse level density parameters (k) decrease with the increase in angular momentum for both the systems. The decreases of *'k'* with increasing *'J'* were observed from the analysis of all the (major) light particle spectra consistently. This implies increase of nuclear level density at higher *'J'* values. The observed variation of *'k'* with *'J'* is in accordance with the observation of Ref. [1]. However with increasing angular momentum, increasing trends as well as constant nature of *'k'* were observed in Ref. [2] and Ref. [3] respectively.

TABLE: I & II

Extracted values of inverse level density parameters for different folds

[I] $^{4}He + ^{93}Nb$ system

Fold (Avg. ang. Mom.)	k_n (neutron)	k_p (proton)	k_α (alpha)
Fold 2 (15.7 ħ)	9.7 ± 0.1	9.7 ± 0.8	10.4 ± 0.5
Fold 3 (18.8 ħ)	9.7 ± 0.8	9.4 ± 1.1	8.4 ± 0.6
Fold 4 (22.5 ħ)	8.2 ± 0.2	7.1 ± 1.4	6.0 ± 0.7

[II] $^{4}He + ^{58}Ni$ system

Fold (Avg. ang. Mom.)	k_n (neutron)	k_p (proton)	k_α (alpha)
Fold 2 (13.5 ħ)	8.0 ± 0.5	9.3 ± 0.2	8.0 ± 0.4
Fold 3 (15.8 ħ)	7.0 ± 0.7	8.8 ± 0.4	6.5 ± 0.5
Fold 4 (18.8 ħ)	6.0 ± 0.8	8.2 ± 0.5	5.6 ± 0.7

The present observation on the variation of NLD with *'J'* could not be accounted by any known nuclear effects such as 'shell effect' or 'collective enhancement' for the present systems. Microscopic calculations and further investigations will be useful in understanding the phenomenon in more detail.

References

[1] K. Banerjee et. al, Phys Rev. **C 85**, 064310 (2012).
[2] Y. K. Gupta et. al, Phys. Rev. **C 78**, 054609 (2008), and references therein.
[3] Y. K. Gupta, et. al, Phys. Rev. **C 80**, 054611 (2009).
[4] M Aggarwal et. al, Phys. Rev. C **81**, 047302 (2010).
[5] K. Bannerjee et. al, Proceedings of the DAE symp. On Nucl. Phys 55 (2010) 324.
[6] F. Puhlhofer, Nucl. Phys. **A 280** (1977) 267.