Role of Collectivity in Nuclear Level Density at A∼150 Mass Region

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I. INTRODUCTION

Nuclear level density (NLD) represents the number of energy levels available to a nucleus at a given excitation energy, providing insight into the internal structure and statistical behavior of the nucleus. It plays a crucial role in the different areas of nuclear science such as nuclear astrophysics, reactor technology, etc. Several studies have done to investigate the dependence of the NLD parameter "a" on the key factors such as excitation energy, angular momentum, ground state deformation, isospin, etc. The present study focuses on the effects of ground state deformation and isospin on the level density parameter.

In nuclei with significant ground state deformation, the collective rotational and vibrational states couple with single-particle states, leading to an enhancement in NLD beyond its single-particle value [1]. However, at higher excitation energies, this enhancement diminishes, and the NLD returns to its single-particle nature. Previous research, including our earlier work in the A∼180 mass region, has provided direct evidence of this fade-out of collective enhancement in deformed nuclei [2].

Additionally, NLD is influenced by isospin. Al-Quraishi [3] proposed an empirical formula for the asymptotic NLD parameter:

$$\tilde{a} = \alpha A/exp[\gamma(Z - Z_0)^2] \quad (1)$$

suggesting a (Z−Z_0) dependence. Here Z_0 corresponds to the β-stable isobar, while γ and α are constants. Our previous studies [5, 6] indicated that this (Z−Z_0) dependency effectively explains the evaporated neutron energy spectra in the A∼120 mass region.

An experiment was performed to investigate the NLD of different Gd isotopes through neutron evaporation measurement from the ^{4}He + ^{144,150,154}Sm reactions. In the present paper the results of ^{157}Gd is presented. The nucleus ^{157}Gd is axially deformed and is expected to exhibit collective enhancement. For ^{157}Gd, (N−Z) = 29 and $|Z - Z_0| = 1.28$, hence isospin effects are also expected to play a significant role. The comparison of different Gd isotopes will be discussed during the symposium.

II. EXPERIMENTAL DETAILS

The experiment was conducted with K-130 cyclotron at VECC. Three different isotopically enriched samarium (^{144,150,154}Sm) targets having thickness 5.7mg/cm^{2}, 7.7mg/cm^{2}, and 12.2mg/cm^{2} were used. Eight 5"×5" liquid scintillator based neutron detectors were placed at angles in the range 45° to 150° with respect to the outgoing beam direction.

III. RESULTS AND DISCUSSION

The neutron kinetic energy spectra for the ^{4}He+^{154}Sm reaction, derived from the corresponding time-of-flight (TOF) spectra, are shown in Fig. 1. The experimental data was analyzed and fitted using the statistical model code TALYS-v1.96, where the asymptotic value of the NLD parameter was considered as defined in equation (1). The parameter α was the only free variable adjusted to

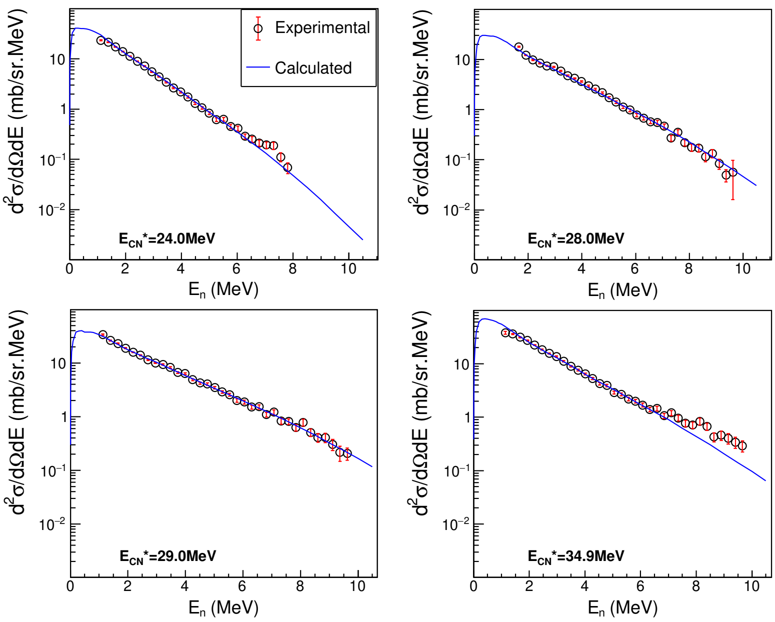

FIG. 1: Neutron energy spectra from the ^{4}He + ^{154}Sm reaction measured at 150° for different beam energies

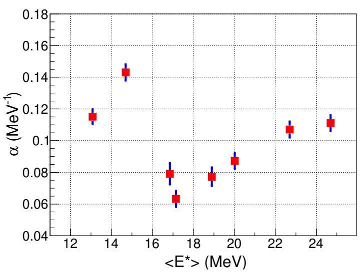

FIG. 2: Variation of fitted parameter α with average excitation energy

fit the experimental data, as it largely determines the overall slope of the neutron energy spectra. The calculated spectra, using the optimally fitted α, show good agreement with the experimental results, as demonstrated in Fig. 1.

It is observed that the shape of the neutron energy spectra is highly sensitive to the NLD, and consequently to the parameter α. The optimum α values were obtained by fitting the experimental neutron spectra using the χ^2 minimization method within the range $2 \leq E_n \leq 8$ MeV. These values were plotted as a function of the average residue excitation energy ($\langle E^* \rangle = E^*_{\rm CN} - S_n - E_{\rm rot} - \langle E_n \rangle$), as shown in Fig. 2. A sharp change in α is observed at $\langle E^* \rangle \sim 17$ MeV. The decrease in α value at this point can be linked to the fade-out of collectivity around $\langle E^* \rangle \sim 17$ MeV, a trend also observed previously [2]. Afterward, α increases monotonically with excitation energy, the microscopic origin of this behavior is being investigated.

References

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