Study of Nuclear Level Density at A∼150 Mass Region

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Nuclear level density (NLD) is an important quantity to determine the statistical decay rate in nuclear reactions. Several studies have been done on NLD to study its dependency on various parameters of atomic nuclei, like excitation energy (E^*) [1], angular momentum [1, 2], ground state deformation (β_2) [3, 4], isospin [5, 6], etc. Fermi (FG) model proposed by Bethe [7], is widely used description of NLD. This model assumes that the neucleons behave like non-interacting Fermi gas and the energy levels are equidistant. However this model is not sufficient to explain most of the measured data. So, several phenomenological corrections are imposed on the model parameters to include the effect of pairing, shell structure, etc. Studies have shown that the ground state deformed nuclei shows enhancement in NLD due to collective excitations [3, 4]. Quantitatively, it is defined in terms of enhamcement factors. The nuclear level density $\rho(E^*, J)$ at excitation energy E^* and angular momentum J is expressed as $\rho(E^*, J) = \rho_{int}(E^*, J)K_{coll}(E^*)$ [8], where $\rho_{int}(E^*, J)$ is the intrinsic single particle level density from FG model and K_{coll} is total enhancement factor. K_{coll} can be described as $K_{rot}K_{vib}$; where K_{rot} and K_{vib} are the rotational and vibrational enhancement factors, respectively. In the present study different isotopes of Gd nuclei are considered, among them ^{153}Gd and ^{157}Gd are the axially deformed and are expected to show the collective enhancement. On the other hand ^{147}Gd is spherical and no rotational enhancement is expected.

Since these isotopes have widely different neutron numbers, so isospin may also affect the NLD values. The emperical form of isospin dependent NLD parameter "a" was proposed by Al-Quraishi et al.[9] which seemed to be valid from our previous experiments at 120 mass region [5, 6]. According to Al-Quraishi NLD parameter can be defined as

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

where γ is a constant, and Z_0 is the atomic number of the most stable isobar situated at the bottom of the mass parabola. So NLD parameter depends on neutron(N) and proton number(Z) and not only on mass number(A) as considered in the FG model. According to Eq.1, NLD parameter is maximum for the nuclei with Z=Z_0 and it decreases if the Z is away from Z_0. The purpose of the present work is to study NLD from neutron evaporation spectra over a wide range of excitation energy for different Gd nuclei. Table I shows the different parameters of the Gd isotopes which can be formed as major residue in the ^{4}He + ^{144,150,154}Sm reactions.

Isotopes of Gd	N	N-Z	Z_0	Z-Z_0	β_2
^{147}Gd	83	19	61.59	2.40	-0.044
^{153}Gd	89	25	63.81	0.18	0.215
^{157}Gd	93	29	65.28	-1.28	0.271

TABLE I: Isospin and ground state quadrupole deformation parameter β_2 for different Gd isotopes.

Present work will also help to understand the sensitivity of NLD on two key factors, ground state deformation and isospin.

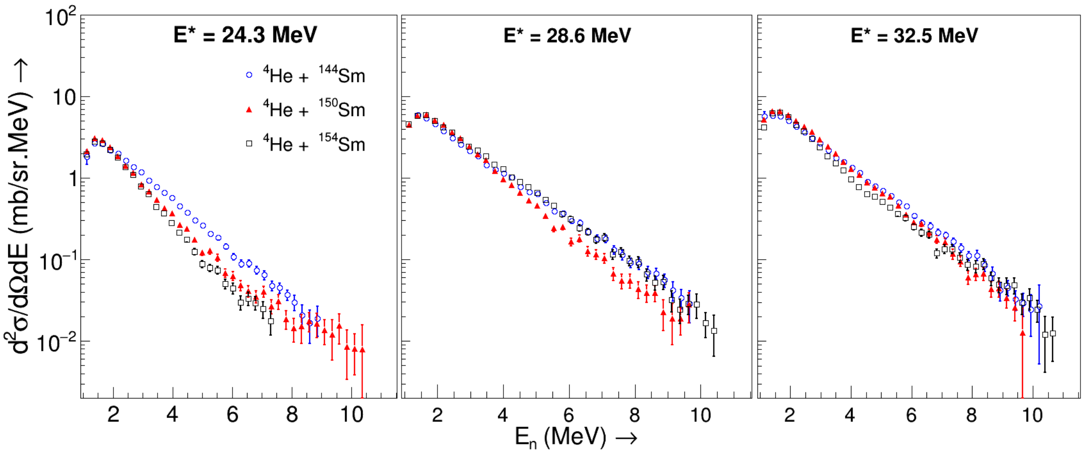

FIG. 1: Neutron energy spectra from the ^{4}He + ^{144,150,154}Sm reactions measured at 150°

Neutron spectra of ^{147,153,157}Gd were measured in the backward angle (150°) for ^{4}He+^{144,150,154}Sm reactions for the beam energy range 26-42 MeV.

The experiment was conducted using K-130 room-temperature Cyclotron situated at VECC. Three different isotopically enriched samarium (^{144,150,154}Sm) targets having thickness 5.7 mg/cm$^{\mathbf{2}}$, 7.7 mg/cm$^{\mathbf{2}}$, and 12.2 mg/cm$^{\mathbf{2}}$ 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. They were positioned at a distance of 1.5m from the target centre.

The neutron energy spectrum was determined by the Time of Flight (TOF) technique. Start signal for TOF measurements was generated by the BaF_2 multiplicity detector array. Neutron and gamma-ray discrimination was achieved using both the TOF and the Zero Cross Over (ZCO) technique.

Neutron spectra at 150° was considered for the analysis, where the contribution of pre-equilibrium component is the minimum (see Fig.1). Neutron energy spectra corresponding to the deformed residues ^{153}Gd and ^{157}Gd, show a change in the slope with the increase in beam energy. However, the spectra correspond to the spherical ^{147}Gd exhibit the least amount of variation in slope. At E*=32.5 MeV, slope of the neutron energy spectra corresponding to deformed ^{153}Gd and ^{157}Gd matches with the spherical ^{147}Gd. Since the slope of the neutron spectra is directly related to NLD, hence a change in NLD is expected for the deformed nuclei with the increase in energy. To obtain the information of NLD, the statistical model analysis using TALYS code is now being done. More details will be discussed during the symposium.

References

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