Nuclear level density and its dependence on angular momentum and ground state deformation

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Nuclear level density (NLD) is one of the important ingredients of any statistical model code. Although NLD has been extensively studied over the years, still today there are many open questions. Nuclear level density depends on excitation energy, angular momentum, isospin and parity. There is also significant dependence on nuclear structure of both single particle (shell) and collective natures. Our recent result on the role of angular momentum and collectivity on nuclear level density is presented below. Angular momentum dependence of nuclear level density is generally incorporated through spin dependence of rotational energy. In another approach, the spin dependence is introduced in the total level density by a multiplicative Gaussian function, where the width of the Gaussian is determined by the temperature-dependent spin cutoff factor σ. At high excitation energy (i.e., for $E^* >> E$rot) these two approaches become equivalent. In both of these approaches, the spin dependence in NLD has been incorporated independently and there is no additional dependence of the level density parameter on angular momentum. These prescriptions have been tested mostly with the inclusive particle spectra and found to be reasonable to explain the experimental data. However exclusive experimental data are rare to check the validity of above phenomenological prescription. In recent years, we made a series of exclusive measurements, in which neutron and charged particle energy spectra were measured at backward angles in coincidence with gamma ray fold (multiplicity) for ^{119}Sb*(^{4}He + ^{115}In), ^{97}Tc*(^{4}He + ^{93}Nb) and ^{62}Zn*(^{4}He + ^{58}Ni) compound nucleus. Experimental data have been compared with the statistical model calculation. The available prescription of angular momentum dependence could not explain the data, additional dependence of angular momentum in the form of nuclear level density parameter was used to explain the measured data [1, 2].

For the nuclei with appreciable ground-state deformations, it has been conjectured by Ignatyuk *et al.* [3] that, at low excitation energies, there should be collective enhancement of NLD due to the coupling of the rotational as well as the vibrational degrees of freedom with the single particle degrees of freedom. The enhanced level density $\rho(E^*, J)$ may be expressed as $\rho(E^*, J) = \rho_{int}(E^*, J)K_{coll}(E^*)$, ρ_{int} being the single particle level density and K_{coll} the collective enhancement factor. To explore the signature of collectivity, an in beam experiment has been performed, in which neutron evaporation spectra at backward angles from ^{201}Tl* (^{4}He + ^{197}Au), ^{185}Re* (^{4}He + ^{181}Ta), and ^{169}Tm* (^{4}He + ^{165}Ho) compound nuclei, having different ground-state deformations, have been measured at two excitation energies ($E^* \sim 37$ and 26 MeV). Statistical model analysis of the experimental data was carried out. The values of the inverse level density parameter ($k = A/\tilde{a}$), extracted at these excitations as obtained from the statistical model fits, are observed to decrease substantially at the lower excitation energy (~26 MeV) for nuclei having large ground-state deformation (residues of ^{185}Re* and ^{169}Tm*), whereas for near-spherical nuclei (residues of ^{201}Tl*), the k value remains unchanged at the two energies. The above observation suggests that there has been a relative enhancement in nuclear level density at lower excitation energy for the first two systems, whereas for the third system no such variation has been observed. The nature of variation as seen above may be directly linked with the deformation of the respective systems. The ground state deformations of the dominant daughter nuclei produced in ^{4}He + ^{165}Ho (β_2 ~0.284 for ^{166,167}Tm) and ^{4}He + ^{181}Ta (β_2 ~0.24 for ^{182,183}Re) reactions are significantly higher than those produced in ^{4}He + ^{197}Au reaction (β_2 ~ 0.044 for ^{198,199}Tl). The collective enhancement factors calculated using relation described in ref [4] for these systems indicate that there should be appreciable collective enhancement in the two deformed systems (K_{coll} ~ 80) as compared to the nearly spherical third system (K_{coll} ~ 1). So the observed variation of inverse level density parameter with excitation energy for the deformed systems is clearly a signature of collectivity induced enhancement of the level density, which is absent in case of nearly spherical system (^{4}He + ^{197}Au) [5].

References

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