Investigation of isospin effect on the nuclear level density parameter in $A \sim 130$ mass region

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Introduction

Nuclear level density play a significant role in modern nuclear reaction codes used for reaction cross section calculation in the areas of basic nuclear physics, nuclear technology, astrophysics, and for the evaluation of nuclear data. Numerous theoretical and experimental efforts have been made to investigate nuclear level density (NLD) as a function of excitation energy [1], angular momentum [2], nuclear shell structure [3], isospin dependence[4] and other factors. The most commonly used theoretical expression for NLD was proposed by Bethe [5], who derived it by modeling the nucleus as a non-interacting Fermi gas.

$$\rho(E_X) = \frac{\sqrt{\pi}}{12}\frac{\exp\left(2\sqrt{aE_X}\right)}{a^{1/4}E_X^{5/4}}, \qquad (1)$$

where E_X is the excitation energy of the nucleus and a, is the NLD parameter which is related to the single particle level density $g(\epsilon_F)$ at the Fermi energy ϵ_F. This parameter is given by the simple expression $a = A/K$, where A is the nucleon number and K is a inverse-level-density parameter. Various refinement have been incorporated since its introduction, to include the angular momentum, shell structure, pairing, and collective effect. One major issues that still needs to be addressed is the dependence of NLD on the neutron(N)-proton(Z) asymmetry which is commonly measured in term of the isospin projection $(N - Z)$. Experimental information about the NLD parameter, a, at excitation energies above the neutron separation can be obtained from the slope of evaporated particle spectra from heavy ion fusion reactions. In our last measurement [4], it was observed that the inverse-level density parameter, K, is appreciably higher for a neutron-rich excited nucleus in comparison to the similarly excited nucleus but neutron-deficient. As a continuation, in the present work, we investigate the isospin dependent inverse-level-density parameter, K, for two residues nuclei, ^{125,131}La populated via ^{35}Cl + ^{94,100}Mo reactions with compound nuclear excitation energy (E_{ex}^{CN}) in the range of 64-83 MeV.

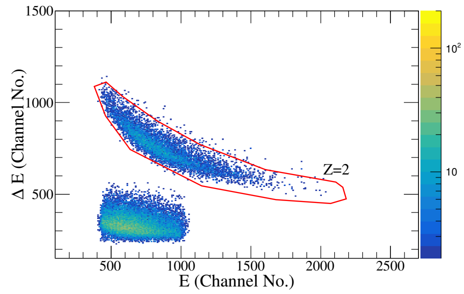

FIG. 1: A typical correlation plot of ΔE versus E corresponding to the particles detected in Silicon surface barrier detector telescope mounted at 158° for ^{35}Cl + ^{100}Mo reaction at beam energy 140.1 MeV.

Experimental Details and Data Analysis

The experiment was performed using ^{35}Cl beam from BARC-TIFR Pelletron Linac accelerator facility at Mumbai. ^{35}Cl beam of varying energies bombarded on isotopically enriched (95%>) and self-supporting foils of ^{94}Mo and ^{100}Mo of the thickness 1.8 mg/cm^2 and 1.0 mg/cm^2, respectively. ^{35}Cl beam with energies of 161.5 MeV and 179.1 MeV was used to populate the compound nucleus ^{129}Pr at excitation energies 64.5 MeV and 80.1 MeV, respectively, via ^{35}Cl + ^{94}Mo reaction. Similarly, ^{35}Cl beam with energies of 140.1 MeV

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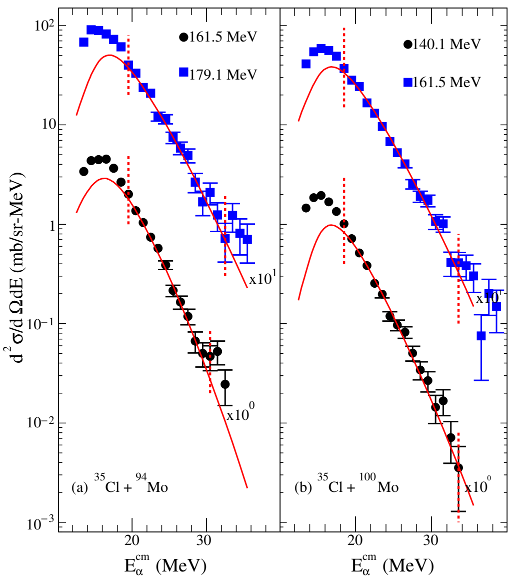

FIG. 2: α-particle energy spectra at different energies in c.m. frame (a) for ^{35}Cl + ^{94}Mo reaction and (b) for ^{35}Cl + ^{100}Mo reaction. The lines represents the best fitted statistical model calculation (using CASCADE code). The individual spectra have been scaled appropriately for better visualization.

and 161.5 MeV was employed to populate the compound nucleus ^{135}Pr at excitation energies 66.5 MeV and 82.5 MeV, respectively, using ^{35}Cl + ^{100}Mo reaction. Charge particles were detected using $\Delta E - E$ silicon surface barrier (SSB) telescopes, mounted in the backward hemisphere of Charge Particle Detector Array (CPDA) at laboratory angles of 138°, 148°, and 158°. Two SSB detectors with each having solid angle of $\sim$ 0.30 msr were placed at $\pm 20^o$ for Rutherford normalization purpose. SSB telescopes were energy calibrated using ^{229}Th radioactive source. Particle identification in SSB telescope was achieved using partial energy loss technique. Fig.(1) shows a two dimensional plot of ΔE versus E acquired in one of the telescope, which clearly separate the alpha particles. α-particle yields spectra were extracted out from ΔE versus E plot (Z=2) for different angles. The α-particle energy spectra, thus obtained were converted to center-of-mass (c.m.) frame using the standard Jacobian transformation. The c.m. spectra of different laboratory angles overlapped very well, indicating dominant yields of α particle

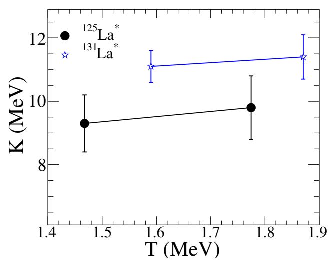

FIG. 3: Inverse level-density parameter as a function of temperature with solid line connecting the data point.

is from compound nucleus evaporation. The most backward angle (158°) telescope's data was used for further analysis. The center-of-mass (c.m.) α-particle spectrum at each beam energy was compared with statistical model calculations using CASCADE code for ^{35}Cl + ^{94,100}Mo reactions. The inverse level density parameter, K, was kept as a free parameter to obtain a best fit using χ^2 minimization technique. The χ^2 minimization was performed in the α-particle kinetic energy region above 18.5 MeV as marked by two vertical line in Fig.(2). Experimental α-particle energy spectra along with best fitted CASCADE calculations are shown in Fig.(2) for both the compound nuclear system at different beam energies. An average nuclear temperature, T, was calculate at each beam energy by using the recipe discussed in [4].

Results and Discussions

The best fitted inverse-level density parameter, K are plotted as a function of nuclear temperature, T, as shown in Fig.(3). It is observed that K value is higher for neutron-rich nucleus (^{131}La) compared to neutron-deficient nucleus (^{125}La). This observed preliminary results are consisted with our earlier measurements [4].

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