Collective enhancement in nuclear level density of ^{72}Ga from particle-gamma coincidence measurement

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Introduction

Nuclear level density (NLD) plays an important role as one of the key ingredients in the reaction codes commonly used in basic and applied nuclear science research works. NLD is one of the major sources of uncertainties in the calculation of astrophysical reaction cross-section or reaction rate that is used in the modeling of stellar evolution and nucleosynthesis[1]. On the other hand, the collective enhancement [2,3] in the NLD still remains an elusive topic due to the lack of proper experimental techniques of extracting level densities. The collective enhancement present in the NLD, especially at separation energy, could have a significant effect on the particle capture cross-sections. Therefore, an accurate description of NLD by using a reliable experimental technique is essential to constrain the NLD in estimating the astrophysical reaction Cross-section as precisely as possible.

In this work, we have measured the gamma-gated evaporated protons coming from the nucleus ^{73}Ge, populated in the reaction ^{9}Be(^{64}Ni, pnγ)^{71}Ga and ^{9}Be(^{64}Ni, p2nγ)^{70}Ga.The gamma gated proton spectra, thus obtained, are utilized to extract the NLD experimentally in the range of excitation energy – 5-20 MeV.

Experimental details and analysis

The ^{9}Be beam of 30 MeV (current 5 nA) was used from BARC-TIFR Pelletron Linac Facility, Mumbai, on a self-supporting ^{64}Ni target of thickness 500 μg/cm^2 . The outgoing protons were detected using CsI(Tl) detectors with angle of coverage from 22° to 67°. The 14 Compton-suppressed Clover detectors were used to detect the de-exiting discrete γ-rays coming from the residual nuclei. XIA-LLC based digital data acquisition system was used to store the time-stamp data in list mode. Multi parameter time

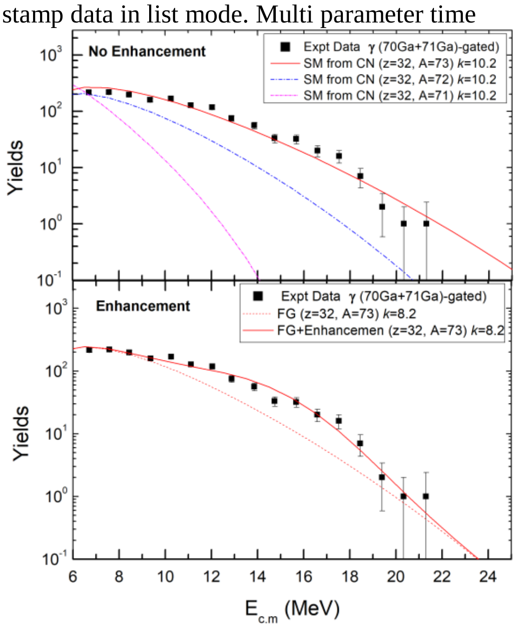

Fig. 1 Symbols with error bars represent the experimental data of γ-gated proton spectra. Solid line represents the statistical model (SM) prediction with contributions from pn (blue - dashed) and p2n (purple-dashed) channels.

stamped based Coincidence Search program (MARCOS) [4] was used to construct the p-γ matrix. From this matrix, proton yield spectra were extracted gated by characteristic 154, 187, 198 keV γ-rays of ^{70}Ga[5] and 488 keV of ^{71}Ga [6] corresponding to *p2n* and *pn* evaporation channels, respectively. Finally, all the γ-gated proton spectra are added to visualize the shape of the final proton spectrum with higher statistics as shown in Fig. 1.

Results and Discussions

The proton spectrum gated by γ-rays were compared with statistical model calculation using CASCADE [7] code with Fermi gas (FG) model [8] prescription of NLD, as shown in Fig. 1. It is found that the statistical model calculation reasonable explain the experimental data considering (p,n) and (p, 2n) channels with the inverse level density parameter k = 10.8 +/-0.4 MeV, (upper panel in Fig.1) ensuring the first chance evaporation of protons from the CN. However, the obtained k-value is not matched with its systematic value (~ 8) [2,3]. The collective enhancement in the NLD due to the deformation of ^{72}Ga (β_2 ~ -0.207[9]) could be a possible reason for such large value of k. Therefore in order to explain the experimental data, the intrinsic NLD was multiplied by an energy-dependent empirical enhancement factor [3] written as

$$K_{coll} = 1 + C * \exp[-(U - E_{cr})^2/2\sigma^2]$$

where C, E_{cr} and σ are the magnitude, peak and width of the enhancement factor, respectively. Including the enhancement factor in the NLD, the SM calculation better describes the experimental spectrum with the value of k=8.3±0.3 MeV, as shown in Fig. 2 (Lower Panel). The parameters of the enhancement factor are C=2±0.5, E_{cr}=15.5±0.3 MeV and σ=2.4±0.2 MeV. The deformation of 72Ga has been calculated from E_{cr} and σ parameters and found to be β_2 ~ -0.2, which is close to the reported value [9]. Furthermore, the γ-gated best fitted proton spectrum has been utilized to extract the NLD of ^{72}Ga by using the same approach as discussed in our previous works [11]. The NLD has now been compared with the level density obtained from RIPL and compared with the constant temperature (CT) model. The CT model parameters of T=1.0 MeV and E_0=2.9 MeV (close to the systematics for ^{72}Ga [10]) describe the present data well up to 12 MeV excitation energy as well as the low energy RIPL-3 data and NLD data at S_n. In the present NLD data, the enhancement with respective to FG model, is observed around 8 to 17 MeV excitation energy region.

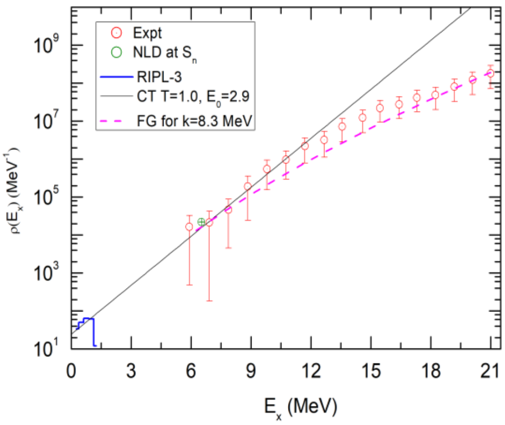

Fig. 2 Open symbol represents the experimental NLD function of excitation energy that are compare with RIPL-3 data and NLD at S_n.

The dashed line in Fig.2 shows the FG model prediction for NLD as a function of energy with k=8.2 MeV.

The present NLD could be used to estimate the ^{71}Ga(n, γ)^{72}Ga cross-section and will be discussed in details in the conference.

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