Isospin effects on the level density of nuclei involved in the decay of $^{139}$Eu


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Nuclear level density is a fundamental quantity for the static and dynamic properties of nuclei and in particular in nuclear astrophysics. Much work has been devoted to study this quantity whose most commonly used expression is based on the Fermi-gas model. At present, the level density has only been studied in nuclei close to the valley of stability and mainly on the neutron-deficient side. Starting from the Bethe work, based on an energy independent level density of single particle states, angular momentum as well as pairing and shell effects have been included in more realistic expressions. In all these studies, isospin effects have been usually neglected, as they are expected to be relatively small for nuclei close to the stability valley, as those produced by stable beams.

In the framework of the Fermi-gas model the isospin effects on the level density can be taken into account including a factor related to the isospin component $T_3$=$(N-Z)/2$ as well as to the density of single-particle states at the Fermi energy and the excitation energy of the system. According to this, the level density is expected to decrease with increasing $|T_3|$.

Recently, the analysis of the level density data for excitation energies below 8 MeV for nuclei with $20 \leq A \leq 70$, three nuclei with $A=100$ and two nuclei with $A=140$ has been carried out comparing different isospin dependences [1]. It has been shown that, compared to the prescription based on the N-Z dependence, a reduction factor of the level density based on the distance from the valley of stability $Z-Z_0$, where $Z_0$ is the Z of the beta stable isotope with the same mass, provides a better description of the data. These predictions, in particular the $Z-Z_0$ dependence, would have strong implications for nuclei far from the stability line. Such effects could be important also in nuclei relatively close to the valley of stability. In particular they could be responsible for the failure of the statistical model in reproducing experimental evaporation particle multiplicity in some reactions.

In this framework, we have undertake the study of the nuclear level density of nuclei produced in the particle decay of the highly excited $^{139}$Eu nucleus. For this system, statistical model calculations predict large differences in the light particle multiplicities when the $Z-Z_0$ dependence is used, with respect to the results obtained with the other prescriptions. To carry on these calculations, a new version of Lilita_N97 has been implemented, with the inclusion of the isospin effects as proposed in Ref. [1], using a standard Fermi-gas level density.

The $^{139}$Eu nucleus was produced by the 180 MeV $^{32}$S + $^{107}$Ag reaction. A $^{32}$S pulsed beam delivered by the XTU-Tandem accelerator of Laboratori Nazionali di Legnaro was impinging on a target of 300$\mu$g/cm$^2$ thickness. We detected the light charged particles emitted in the evaporation channel by the telescopes of the $8\pi$LP apparatus. The evaporation residues were measured by four detectors placed, symmetrically, at forward angles, covering an angular range from 2.5° to 7.5°, each subtending a solid angle of about 0.8 msr. Each of them is composed by a sequence of two parallel plate avalanche counters (PPAC’s) separated by an absorber. Evaporation residues were identified by the Time Of Flight (TOF) technique, taking the stop signal by the first PPAC with respect to the radiofrequency signal of the accelerator. The second PPAC was used as a veto to the elastic scattering events.

From the coincidences between particles and evaporation residues, multiplicity spectra of alpha particles evaporated from the compound nucleus were extracted. Absolute angular multiplicity distributions were obtained by integration of spectra measured in 17 telescopes placed in the vertical plane. The alpha in-plane angular distribution is plotted in Fig.1 as a function of the correlation angle between the particle detector and the up or down PPACs. The alpha out-of-plane angular distribution is plotted in Fig.2 as a function of the detector angle with respect to the beam direction.

In order to fix the value of the maximum angular momentum for the evaporative decay, to be entered in the statistical code, the evaporation residue production cross section for our reaction was measured in a dedicated experiment carried out at LNL. For this purpose the incoming beam was deflected out by an electrostatic separator [2]. Evaporation residues focused at small angles were identified by the Time Of Flight (TOF) technique, taking the stop signal by the first PPAC with respect to the radiofrequency signal of the accelerator. The second PPAC was used as a veto to the elastic scattering events.

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coefficients for spherical nuclei derived by a) fusion systematics (FS), b) Optical Model (OM) and c) Ingoing Wave Boundary Condition Model (IWBCM) were used. To compare calculations with the experimental results, simulated events were filtered by a program which takes into account the response function of the 8πLP apparatus.

Similar calculations were performed using IWBCM transmission coefficients and the level density formulas depending on N-Z and Z - Z₀ with the parameter values extracted by a best fit to experimental data, performed by Al-Quraishi et al.

The angular distributions resulting from such simulations are presented in Fig. 1 and 2 together with experimental data.

![Fig.1 In-Plane Angular Distribution](image1)

In the Figs. 3 and 4 the multiplicity spectra of alpha particles for two detectors placed at forward and backward angles in the in-plane angle distribution, namely at 346° and 201°, respectively, are shown.

As it can be seen, the standard calculation without the introduction of the isospin dependence in the level density parameter better reproduces the experimental data.

Analysis of proton data is in progress.

![Fig.4 Out-of-Plane Alpha Spectra at (Θ = 201°)](image4)

References