On the excitation energy dependence of nuclear level density and damping of shell effect in ^{208}Pb region

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Introduction

The total nuclear level density (NLD) is a fundamental property of the nucleus and is a key input to the statistical model of compound nuclear (CN) decay. The excitation energy (E_X) dependence of the NLD is described by the level density parameter, *'a'*. While on the average *'a'* increases linearly with the mass number of the nucleus, there is a large departure from this behaviour at shell closures. This shell effect on the NLD parameter is expected to decrease asymptotically to its liquid drop value at E_X >50 MeV [1, 2].

Experimental information on such a damping is very limited. It is necessary to access the E_X dependence over as a range of energy, say from 5 to 50 MeV, to observe this effect on the NLD. The effect of shell correction on *'a'* can be seen by comparing the particle spectra in the nuclei both near and away from shell closure. In this work we choose the triton transfer fusion reaction on ^{205}Tl and ^{181}Ta to populate the CN ^{208}Pb and ^{184}W respectively [3] and measure evaporation neutrons by the time-of-flight (TOF) technique.

Experimental details

The experiment was performed at the Mumbai Pelletron Linac Facility (PLF) using a 30 MeV ^{7}Li pulsed beam (∼1.5 nsec width, 9.4 MHz repetition rate) bombarding ^{205}Tl (enriched to >99%) and ^{181}Ta targets of thicknesses 4.7 mg/cm^2 and 3.7 mg/cm^2, respectively. Alpha particles were detected at backward angles (∼150°) in 8 CsI(Tl) detectors

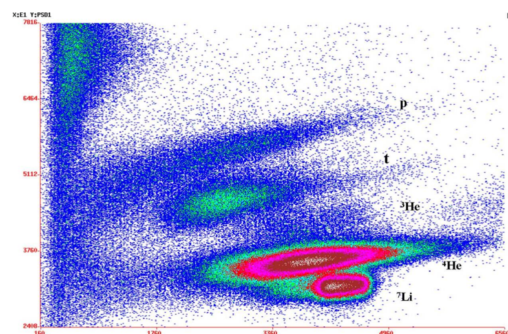

FIG. 1: PSD spectrum in one of CsI(Tl) detector in Ta target shows clear separation of various groups of particles.

of dimensions 2.5 cm×2.5 cm×1 cm (thick) coupled to Si(PIN)photodiodes and identified using pulse shape discrimination (PSD). The energy calibration of these detectors for α-particles was done using the ^{12}C(^{12}C,α)^{20}Ne reaction at E(^{12}C)=24 MeV populating the discrete states in ^{20}Ne. The carbon targets, backed by 1-3 mil thick Ta foils, were placed 23 cm upstream of the centre of the reaction chamber to reduce the kinematic energy spread. Neutrons were detected using a 15 plastic detector array [4] placed at 90° to the beam at a distance of 1 m from the target. The neutron energy was measured using the TOF. The parameters recorded in an event by event mode are:(a) left (T_L) and right (T_R) timing of plastic scintillator with respect to the double filtered RF (RF filtered by both the CsI(Tl) and plastic scintillator) using time to digital converter (TDC), (b) deposited charge from left (Q_L) and right (Q_R) photomultiplier tube(PMT) with charge to digital

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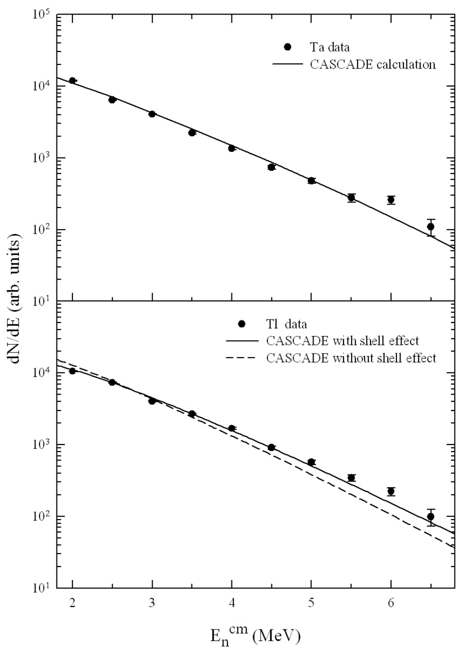

FIG. 2: Neutron evaporation spectra from ^{208}Pb and ^{184}W.

converter(QDC), (c) time of CsI(Tl) detectors with respect to the filtered RF using a TDC, (d) energy of CsI(Tl) detectors and (e) PSD of the CsI detector for particle identification. The time calibration was done using a precision time calibrator. The QDC calibration was done using Compton tagged recoil electrons and various γ-ray sources [4].

Data Analysis

The TOF and position along the length of the plastic scintillator were deduced from T_L and T_R of the plastic detector. The geometric mean charge ($Q_{gm} \propto \sqrt{Q_L Q_R}$) was derived from the left and right PMT charge. This decides the analysis threshold of the neutron TOF spectrum and further used as an input to simulation to obtain the energy dependent efficiency of the plastic detector. The PSD spectrum shows very good separation of various groups of particles. A typical 2D spectrum of the PSD vs energy of CsI(Tl) detector is shown in Fig. 1. The alpha spectrum peaks at 16.9 MeV(FWHM=4.5 MeV) with the ^{205}Tl target and at 16.3 MeV(FWHM=4.2 MeV) with the Ta target. These peaks correspond to α-particles having a beam like velocity ($E_\alpha \simeq \frac{4}{7}E_{7Li}$). Fig. 2 shows the derived neutron energy spectra (using ~0.6% of the data)with Ta and Tl targets. The solid line in the upper panel shows the CASCADE calculation with the asymptotic NLD parameter $\tilde{a}$=A/8. In the lower panel, the dashed curve shows the calculation with the shell effect switched off. The present work, therefore, demonstrates the shell effect in neutron evaporation spectra. Further analysis of the full data and more experiments should reveal the damping of the shell effect with E_X

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