Effect of doubly closed shells on nuclear level density through neutron TOF measurements in the ^{208}Pb region

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Introduction

Preliminary results on neutron time of flight measurements in ^{7}Li induced reactions on ^{205}Tl and ^{181}Ta targets, made in coincidence with alpha particles, have been reported earlier [1]. The aim of these measurements was to identify clearly, the effect of nuclear shell closure on the nuclear level density (NLD). The latter is a key input to the statistical model (SM) of compound nuclear decay. The NLD increases steeply with excitation energy (E_X) as $e^{2\sqrt{aE_X}}$, where *'a'* is the NLD parameter. On the average a increases linearly with the mass number (A). However at doubly closed shells it shows dips and is expected to approach the liquid drop value at excitation energies of ∼ 40 MeV[2].

In our studies, the triton transfer induced fusion reaction populated ^{208}Pb and ^{184}W at an E_X of 20-24 MeV. After one neutron evaporation, final states with E_X between 4-15 MeV were populated. At these low excitation energies the shell effects should be prominent for the Pb nuclei and small for the W nuclei. In

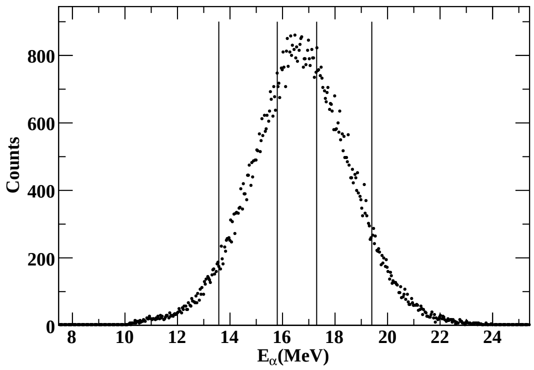

FIG. 1: Alpha spectrum in ^{7}Li+ ^{205}Tl system at E(^{7}Li) = 30 MeV. The vertical lines define the energy bins for which neutron TOF spectra were extracted.

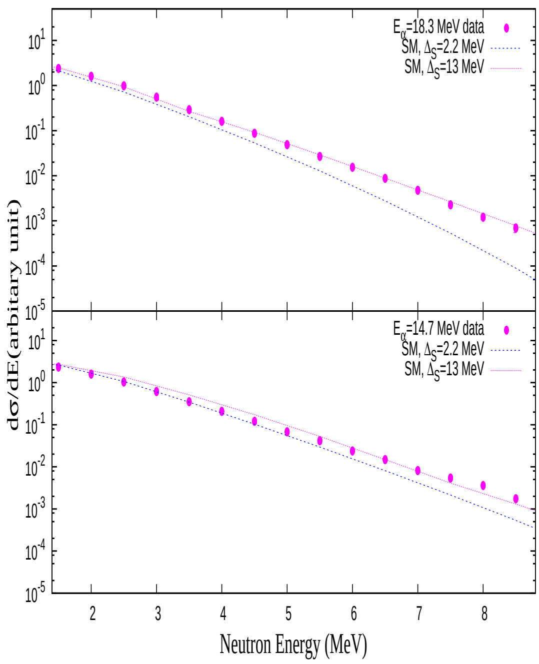

FIG. 2: Measured neutron spectra on ^{205}Tl target and statistical model (SM) calculations at two extreme alpha energies which corresponds to excitation energies ∼ 24 and 20 MeV respectively.

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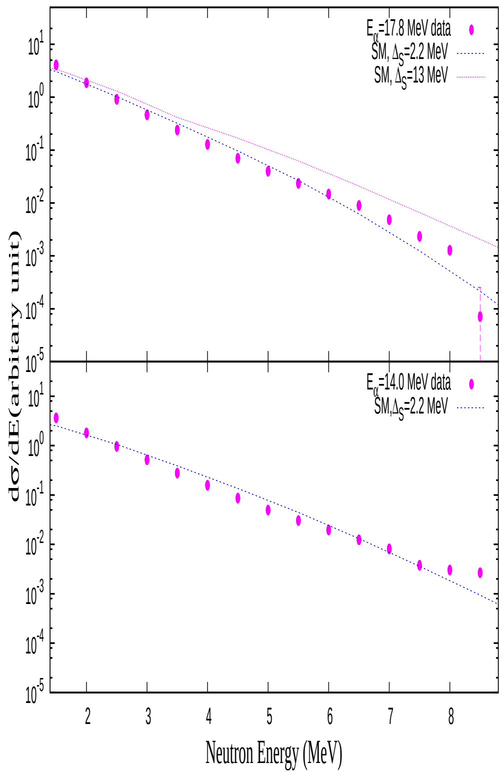

FIG. 3: As in Fig. 2 for ^{181}Ta target.

this paper we report the analysis of the full data for both the targets extracting the neutron spectra upto about 9 MeV.

Experimental results

The reactions (^{7}Li,α) on ^{205}Tl and ^{181}Ta targets were used to populate ^{208}Pb and ^{184}W compound nuclei, respectively. This was guided by the large triton transfer/break-up fusion probablity in ^{7}Li induced reactions in this mass region [3, 4]. Neutron time of flight (TOF) spectra were measured, in coincidence with α-particles, with a 1 m^2 array of plastic scintillator detectors [1]. The energy spectra of neutrons were derived from the TOF data for three energy bins of the alpha particles for each target. The alpha spectrum for the ^{205}Tl target is shown in Fig. 1. The measured neutron spectra are seen to be harder with decreasing alpha energy (corresponding to increase in E$_X$).

The spectra for the Tl target are shown in Fig. 2. The SM calculation was done using the code CASCADE [5] with the NLD prescription for a [6],

$$a = \tilde{a}[1 - \frac{\Delta_S}{U}(1 - e^{-\gamma U})]$$

where U is the energy available for intrinsic excitation. An asymptotic value of the NLD parameter $\tilde{a}$ of A/8 was used. It is clear from the plot that a shell correction energy (Δ_S) of 13 MeV fits the data while Δ_S of 2.2 MeV does not. A similar plot for the Ta target is shown in Fig. 3. Here, the CASCADE calculation with Δ_S = 2.2 MeV fits the data. In all these, the damping factor γ=0.054 MeV^{-1} was used. The above comparison of data and SM calculations shows that the effect of shell closure on the level density has been experimentally observed in the Pb region. Future experiments using liquid scintillator detectors with pulse shape discrimination and still better statistics should pin down the E$_X$ dependence of the shell effect for which almost no experimental data exist. In addition, an angular distribution of neutrons is necessary to estimate the contribution of possible non-compound processes.

References

[1] P C Rout et al., Proc. of DAE Symp. on Nuclear Physics, Vol.**54**, 392 (2009).

[2] V S Ramamurthy, S.K. Kataria and S S. Kapoor, Phys. Rev. Lett. **25**, 386 (1970).

[3] A Shrivastava, FUSION11, to be published in EPJ Web.

[4] M Dasgupta et al., Phys. Rev. C **70**, 024606 (2004).

[5] F Puhlhofer, Nucl. phys. A **280**, 268 (1980).

[6] A V Ignatyuk, G.N. Smirenkin and A.S. Tishin, Sov. J. Phys. **21**, 255 (1975).