Effects of shell, *K*-orientation and CELD on particle multiplicities

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Statistical model (SM) has been used extensively to interpret data from fusion-fission reactions [1–3]. A recent upgradation of our SM [4] could reproduce the evaporation residue (ER) cross sections ($\sigma_{\rm ER}$), fission cross sections ($\sigma_{\rm fiss}$) and pre-scission neutron multiplicities ($\nu_{\rm pre}$) of the asymmetric reactions populating compound nuclei (CN) of mass upto $A_{\rm CN} \sim 200$. Comparison of more observables *e.g.* charged particle multiplicities, with SM predictions would strengthen our earlier findings. Beyond the evident limit of a static description of a dynamical process, incorporation of a certain amount of dissipation in fission in an SM would allow more particles to evaporate before the CN fissions. With zero dissipation (or zero delay), the SM used to underestimate $\nu_{\rm pre}$ and overestimate pre-scission proton and α-particle multiplicities ($\pi_{\rm pre}$ and $\alpha_{\rm pre}$, respectively), revealing that these mismatches do not belong to a common origin [7]. Although, a certain value of time delay can reproduce the $\nu_{\rm pre}$, it fails in case of $\pi_{\rm pre}$ and $\alpha_{\rm pre}$. Moreover, particle multiplicities in fission and ER channels ($\nu_{\rm ER}$, $\pi_{\rm ER}$ and $\alpha_{\rm ER}$) are not reproduced simultaneously [7, 8]. As particle multiplicities in the ER channels are insensitive to saddle-to-scission dynamics, it can be used as a tool for reliable estimation of SM parameters.

Here, we have compared the particle multiplicities in fission and ER channels of ^{32}S+^{126}Te [9–11], ^{19}F+^{159}Tb [12, 13], ^{19}F+^{181}Ta [12, 14–16], ^{28}Si+^{175}Lu [17], ^{16}O+^{197}Au [12, 14, 18, 19] and ^{16}O+^{208}Pb [20] (whichever are available in literature) with our updated SM model code VECSTAT [4]. The model takes into account shell effects in both level density (LD) and fission barrier ($B_{\rm f}$), orientation degree of freedom ($K_{\rm or}$), collective enhancement in level density (CELD) and a suitable value of the reduced dissipation coefficient (β). Assuming a fast equilibration of the $K_{\rm or}$ (projection of the total angular momentum J on the nuclear symmetry axis), the fission width has been modified as prescribed by Lestone [5]. The effect of CELD is incorporated in the present calculation following the work of Zagrebaev *et al.* [6] where a smooth transition from a vibrational enhancement ($K_{\rm vib}$) to a rotational enhancement ($K_{\rm rot}$) has been considered. More details about the model can be found elsewhere [3]. Results with both $\beta = 0$ and $\beta \neq 0$ are presented in Fig. 1 and Fig. 2 along with data.

It can be seen in the figures that particle multiplicities measured in coincidence with ERs have reasonably good agreement with model predictions. This ensures correct branching of total events into ER and fission channels in the model. The fact, that the model reproduces multiplicities of very asymmetric reactions only up to $A_{\rm CN} \sim 200$, is in agreement with our earlier findings [4]. More measurements of $\pi_{\rm pre}$, $\alpha_{\rm pre}$, $\nu_{\rm ER}$, $\pi_{\rm ER}$ and $\alpha_{\rm ER}$ are necessary to have a better understanding of the underlying physics and refinement of the model.

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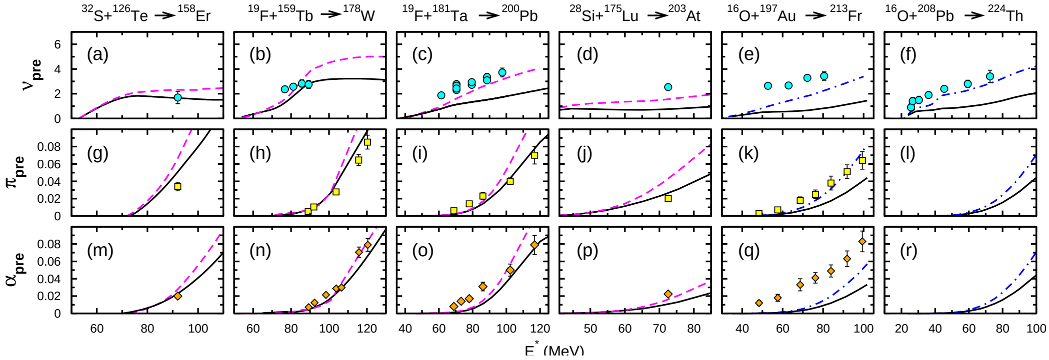

FIG. 1: Measured and calculated $\nu_{\rm pre}$, $\pi_{\rm pre}$ and $\alpha_{\rm pre}$ for ^{32}S+^{126}Te [9, 10], ^{19}F+^{159}Tb [12, 13], ^{19}F+^{181}Ta [12, 14], ^{28}Si+^{175}Lu [17], ^{16}O+^{197}Au [12, 14] and ^{16}O+^{208}Pb [20]. Continuous (black) lines represent SM predictions with inclusion of shell effects in both $B_{\rm f}$ and LD, $K_{\rm or}$ and CELD. Dashed (magenta) and dash-dotted (blue) lines show results with $\beta = 2 \times 10^{21}$ s^{-1} and $\beta = 3 \times 10^{21}$ s^{-1}, respectively, in addition to the aforementioned effects.

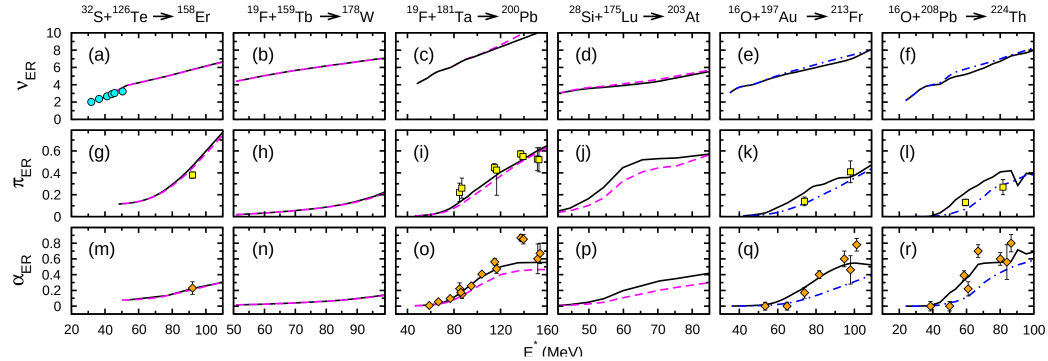

FIG. 2: Measured and calculated $\nu_{\rm ER}$, $\pi_{\rm ER}$ and $\alpha_{\rm ER}$ for ^{32}S+^{126}Te [10, 11], ^{19}F+^{159}Tb, ^{19}F+^{181}Ta [15, 16], ^{28}Si+^{175}Lu, ^{16}O+^{197}Au [18, 19] and ^{16}O+^{208}Pb [18, 19]. Data points shown in panel (a) are for ^{12}C+^{144}Sm [11]. Legends are same as in Fig. 1.

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