# Effect of dynamical time on the evaluation of pre-scission neutron multiplicity

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## Introduction

Even today, theoretical modelling of the nuclear fission process is a subject of intense research. Different statistical and dynamical models are used to explain the nuclear fission mechanism. Heavy ion induced fission is a complex phenomenon due to the involvement of many degrees of freedom. Statistical models encompass several approximations, making a bits simple, whereas the dynamical models deal with more realistic real-time evolution of a compound system [1, 2]. In both the variants, excited compound nuclei are considered to form a thermodynamic ensemble that evolves according to its collective driving potential (Helmholtz's free energy) and temperature. Further, stochastic dynamical models presume the collective time-evolution of an excited nucleus to be similar to the motion of a Brownian particle in a heat bath. Moreover, compound nuclei are generally considered to be equilibrated in all degrees of freedom including excitation energy, mass, shape etc. Nuclear dissipation in the stochastic Langevin dynamics can be obtained from the classical wall friction, where intrinsic nucleonic motions are assumed to be fully chaotic. A more realistic calculation can be performed with the chaos-wighted wall friction (CWWF) [3]. All these model considerations affect the fission lifetime and other fission observables as well.

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## Calculation

In the present work, we study the dynamical effects in pre-scission neutron multiplicity ($n_{pre}$) by using a combined dynamical-plus-statistical model code [4] where dynamical evolution is followed with the Langevin equations. We incorporated the possibilities of neutron, proton, $\alpha$, and $\gamma$-ray evaporation at each dynamical time-step. A Monte-Carlo sampling procedure is used for this purpose. We follow the dynamical propagation up to a certain time $t_{dyna}$, after which calculation is switched to the statistical mode. Here, $t_{dyna}$ is tuned as a free parameter and the corresponding $n_{pre}$ values are recorded to understand the effect of dynamical delay as a function of the excitation energy. For the present calculations, CWWF is used. Shell effects in the free-energy profile are accounted from the two centered shell model, and the macroscopic part is calculated from the Yukawa-plus-exponential double-folding interaction.
Here we considered the compound nuclei of different masses and the same compound nucleus produced through different channels, thereby studying the effect of mass asymmetry also.

## Results

The calculated $n_{pre}$ values for different $t_{dyna}$ are plotted in Fig. 1, Fig. 2 as a function of compound nuclear excitation energy $E^*$. In a standard statistical-plus-dyanamical model code $t_{dyna} \sim 100\hbar$/MeV is usually used to deal with the initial dynamical delay. We also found that, for all the reaction channels, $n_{pre}$ becomes almost independent of $t_{dyna}$ when $t_{dyna} \geq 100\hbar$/MeV. Discrepancy between

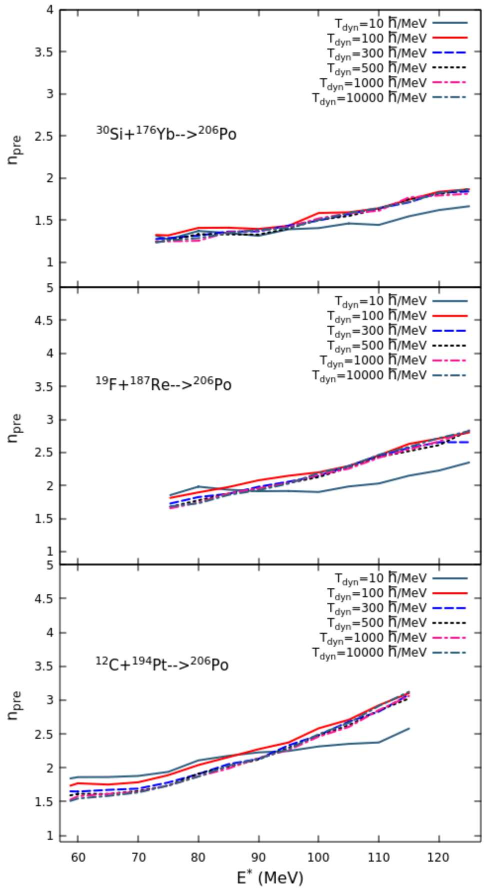


FIG. 1: Variation of pre-scission neutron multiplicity with excitation energy for different dynamical time for compound nucleus $^{206}$Po.

the $t_{dyna} = 10\hbar$/MeV results with that for higher $t_{dyna}$ is more prominent at higher $E^*$ indicating the importance of dynamical delay for larger $E^*$. Moreover, the mismatch is substantial for the heaviest compound system ($^{227}$Np) considered. This is consistent as the dynamical effects are expected to be large for highly fissile systems.

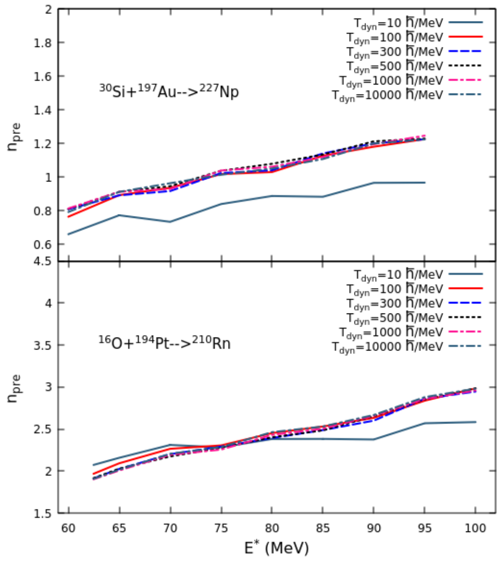


FIG. 2: Variation of pre-scission neutron multiplicity with excitation energy for different dynamical time for compound nucleus $^{227}$Np and $^{210}Rn$.

## Acknowledgments

One of the authors acknowledges the CSIR, Govt. of India for the financial support under the JRF scheme.

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