Fission timescale from Langevin dynamical model

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Introduction

Fission timescale [1, 2] of the heavy ion collision reactions are measured from the pre-scission multiplicities(neutron, charged particles and the $\gamma-$rays from the GDR) and the mass-angle distribution(MAD) of the fission fragments. These nuclear techniques predict the fission timescales in the order of $10^{-21}s$ to $10^{-20}s$ referred as the short-lifetime component. However, these techniques have some limitations like the pre-scission multiplicities are model dependent and the MAD only predicts the quasi-fission timescales. Recently, the model independent methods like crystal blocking measurements (atomic techniques) predict the very long fission timescales in the order of $\sim 10^{-18}s$ referred as a long-lifetime component. Theoretically, Gontchar and his co-workers [3] calculated the fission timescales from the combined two dimensional dynamical and statistical model with the one-body wall and window friction for different strength factors $\kappa_{red} = 0$ to 1. Their calculations agree with the experimental data at the large $\kappa_{red} = 0.6$ value. In this work, the fission timescales are calculated from the one dimensional (1D) Langevin dynamical model for larger time period.

The 1D Langevin dynamical model and the other details can be found in Ref. [4]. In this work, the reduced dissipation parameter β is considered as a free parameter. In this study, an ensemble of large number of events (2.5×10^6) is considered and for each event, the evolution of the Langevin trajectory for the time $t = 10^{-2} - 10^4$ with a time step $t = 0.001\hbar/MeV$ is considered. The Langevin fission width is defined as $\Gamma_L(t) = \hbar R(t)$. While the fission rate $R(t)$ is calculated for each time step, there are fluctuations. Hence, the time averaging is done over the time step Δt. The Langevin fission time calculated is given as $\tau_f = \hbar/\Gamma_L$.

Results and discussions

The pre-scission neutron multiplicities and the fission timescales were studied in [2], for the $^{16}O +^{208} Pb$ reaction at the lab energy $E_{lab} = 287$ MeV is considered in this present study for which the pre-scission neutron multiplicities are calculated using the 1D Langevin dynamical model for the different reduced friction parameter $\beta = 0.5, 1, 2,$ and 3 MeV/$\hbar$. The pre-scission neutron multiplicities ν_{pre} are plotted as a function of reduced friction parameter β in Fig. 1. For the $\beta = 1$ MeV/$\hbar$, the experimental $\nu_{pre} = 6.9 \pm 0.3$ agrees very well with the calculated ones. In Fig. 2(a) and 2(b), the count of pre-scission neutron

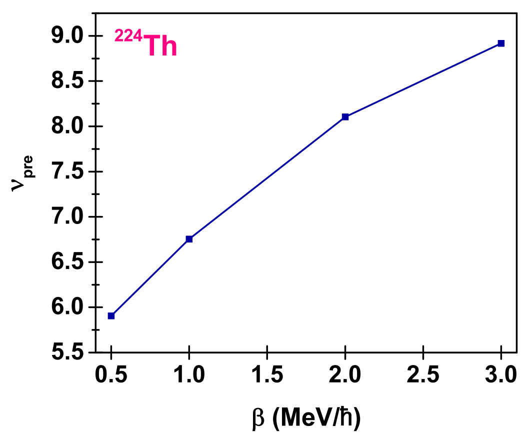

FIG. 1: Pre-scission neutron multiplicities ν_{pre} are plotted as a function of β $(MeV/\hbar)$ for ^{224}Th.

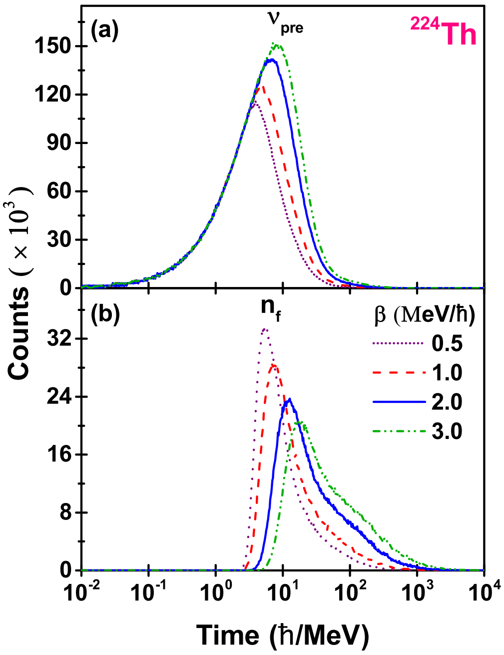

FIG. 2: Pre-scission neutron and fission events as a function of logarithmic time of ^{224}Th for the β.

multiplicity events and the fission events are depicted as a function of time. From Fig. 2(a), all the pre-scission neutron counts are slowly increasing with the time for all β values up-to most probable values and falls to zero for the time region 10 to 100$\hbar$/MeV. However, the most probable number of events is increased with the β; since the higher value of β, the Langevin trajectory spent more time in between ground and saddle region and the emissions of pre-scission neutron from the compound nucleus(CN) are higher. From Fig. 2(b), the fission events start at a much later time compared with pre-scission neutron events time; this is due to the fact that the fission starts after the formation of the CN. Further, for all the values of β, the fission events has the longer tail. As the β value increases, the count for most probable fission events decreases and the count for the fission events increases at later time. After the emission of the large value of ν_{pre}, the excitation energy of the CN is reduced and the probability for

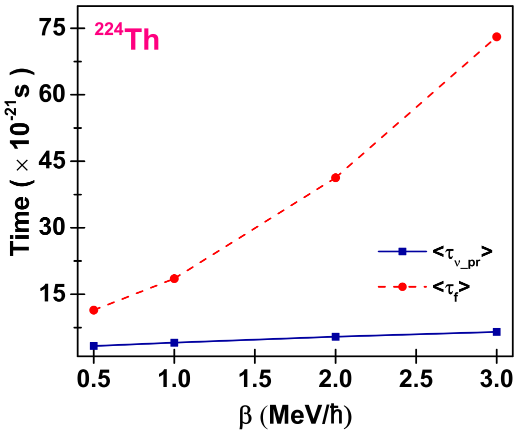

FIG. 3: Average fission and pre-scission neutron lifetimes are plotted as a function of β for ^{224}Th.

the fission is increased with the time. In Fig. 3, the average fission lifetimes, $< \tau_{\nu_{pre}} >$ inferred from the ν_{pre} and the fission lifetime $< \tau_f >$ inferred from the Γ_L for the different β values are shown. The $< \tau_{\nu_{pre}} >$ is linearly increasing with the β and the $< \tau_f >$ is rapidly increasing with the β. For all β values the fission timescales inferred from the ν_{pre} are of the order of $10^{-21}s$. The actual fission time $< \tau_f >$ are of the order of $10^{-20}s$. This difference arises due to the longer-lifetime fission events.

In summary, we show by using 1D Langevin dynamical model that the pre-scission neutron multiplicities is not a suitable probe to determine the fission time scale. The time scale for the pre-scission neutrons is an order of magnitude smaller then the fission time scale.

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