Effect of nuclear dissipation on the pre scission neutron multiplicities

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Introduction

The study on the heavy ion fusion fission dynamics is essential to explore the synthesis of super heavy elements. The equilibrated compound nuclei formed in a heavy ion induced reaction may end up as evaporation residue (ER) or it may either undergo fission. In addition, the composite system may break up fission like fragments before the complete equilibration known as quasi fission (QF) [1]. There are several tools to identify these reaction mechanisms such as measurement of ER cross section, mass angular distribution of fission fragments, and pre scission neutron multiplicity. Since QF is expected to take place before the fusion fission time scale, the overall neutron yield should be lower than the neutron yield associated with fusion fission [2]. There are different models to explain the observed pre scission neutron multiplicities. The pre scission neutron multiplicities are found to be higher than the statistical model predictions. These excess n_{pre} are used to evaluate the strength of dissipation associated with the fission process.

In the present work, we have performed dynamical model calculations and studied the effect of dissipation on pre scission neutron multiplicities for the reactions $^{19}F + ^{187}Re$ and $^{30}Si + ^{176}Yb$ reactions populating the same compound nucleus ^{206}Po.

Dynamical model Calculations

The dynamical model calculations are performed by the one dimensional Langevin dynamical model for which combined dynamical plus statistical model code is used [3, 4]. Here the dynamical evolution of the compound nucleus is taken into account [5]. The CN may decay via particle emission or fission. The particle emissions such as neutron, proton, and alpha may leave behind evaporation residue. The decay width of particles is accounted for by the Weisskopf formula.

Different choices of dissipation models can be used to explain the observed values of the n_{pre}. In dynamical computations using Langevin equations, the wall plus window friction (WF) and chaotic weighted wall friction (CWWF) [6] are primarily used. The chaos-weighted wall friction model takes into account nuclei that are not completely chaotic, whereas the wall friction model assumes that nucleonic motion is entirely chaotic. In the present study, the CWWF model with spin distribution sampled from systematics as well as from CCFULL calculations is used. Further the calculations with the shape independent constant friction with reduced dissipation β as a free parameter are considered. The reduced dissipation is represented as β and it is expressed in the unit of $MeV/\hbar$.

Results and Discussion

The dynamical calculations of pre scission neutron multiplicity are carried out for the systems $^{19}F + ^{187}Re$ and $^{30}Si + ^{176}Yb$ forming the compound nuclei ^{206}Po. The computations are performed for different dissipation models named as CWWF with spin distribution sampled from systematics, CWWF with spin distribution from CCFULL calculations and shape independent constant friction with parameter β. The results of the calculations for $^{19}F + ^{187}Re$ and $^{30}Si + ^{176}Yb$ reactions are shown in figure 1 and 2 respectively.

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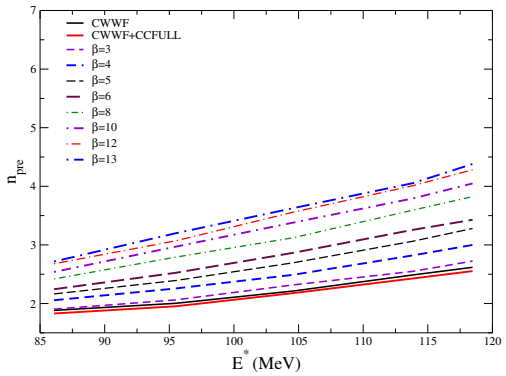

FIG. 1: Variation of pre scission neutron multiplicity with excitation energy for the reaction $^{19}F + ^{187}Re$.

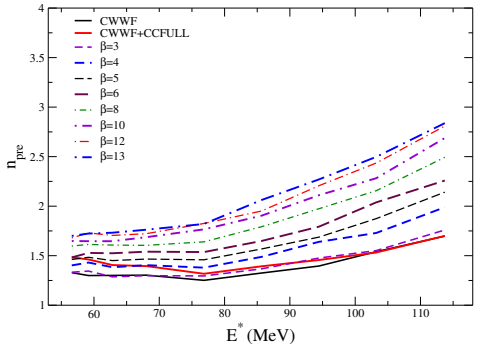

FIG. 2: Variation of pre scission neutron multiplicity with excitation energy for the reaction $^{30}Si + ^{176}Yb$.

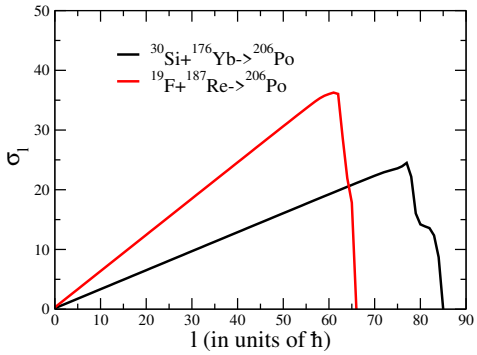

FIG. 3: Fusion l distributions at E*= 100 MeV calculated using the code CCFULL.

TABLE I: The average angular momentum and Q value of the reactions.

Reaction	$< l > (\hbar)$	Q (MeV)
$^{30}Si + ^{176}Yb$	54.19	-59.73
$^{19}F + ^{187}Re$	42.633	-24.51

The pre scission neutron multiplicity for the reaction $^{19}F + ^{187}Re$ is found to be higher than that for $^{30}Si + ^{176}Yb$, due to the higher mass of ^{30}Si, since the compound nucleus gets populated at a higher angular momentum state. As a result, the fission happens quickly, and thereby n_{pre} is getting reduced. The CCFULL calculation of spin distribution for both reactions is plotted in fig. 3, and the average angular momentum of each reaction is listed in table I. Moreover, the pre scission neutron multiplicity is found to increase with excitation energy due to a rise in nuclear temperature. Further, as can be seen from figure 1 and 2, n_{pre} also increases with the dissipation parameter, which is attributed to a longer fission time scale.

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