Role of saddle-to-scission dynamics in fission fragment mass distribution

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Fission fragment mass distribution (FFMD) is an important tool to distinguish the complete fusion events from the non-compound events like quasi-fission, deep inelastic collision etc. Statistical model calculations have been applied successfully in the past [1] to calculate the FFMD of thermal neutron induced fission . But, in case of heavy-ion induces fusion-fission reactions, dynamical models are more appropriate because of the presence of nuclear dissipation. In the present calculation, using Langevin dynamical equations, we show the effect of dissipation in FFMD during the journey of the compound nucleus (CN) from saddle to scission configuration.

We use two-dimensional Langevin equation in (c, α) coordinates [2] where c is elongation and the mass asymmetry parameter α determines the ratio of masses of the future fragments. The Langevin equations are solved to get the asymmetry coordinate distribution at both the saddle and scission configurations. In this calculation the potential energy $V(c, \alpha)$ is obtained from the finite-range rotating liquid drop model [3]. We make the Werner-Wheeler approximation for incompressible irrotational flow to calculate the inverse of collective inertia tensor m_{ij}^{-1}. For the friction tensor γ_{ij}, the one-body model for nuclear dissipation is used and can be written as [2]

$$\gamma_{ij} = \gamma_{ij}^{wall+window} + \gamma_{ij}^{asym} \quad (1)$$

where the first part includes the usual wall-plus-window dissipation and the second part

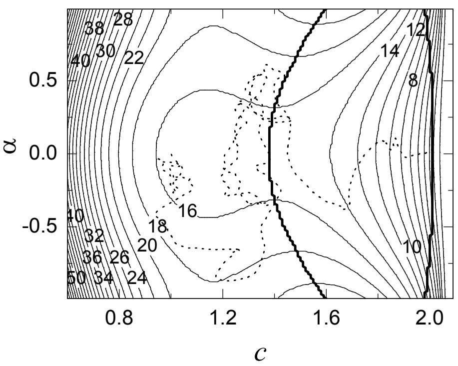

FIG. 1: $V(c, \alpha)$ contours in MeV. The saddle-ridge and the scission line are shown by thick lines. The dashed line is a typical trajectory which undergoes fission.

is the dissipation associated with the time-rate of change of mass asymmetry degree of freedom. To investigate the role of γ_{ij}^{asym} in FFMD, we have done two sets of calculation, one with γ_{ij}^{asym} and another without γ_{ij}^{asym} in γ_{ij}.

The contour plot of $V(c, \alpha)$ for the compound nucleus ^{224}Th is shown in Fig.1 for the compound nuclear spin (ℓ) equal to $60\hbar$. Both of inertia and friction are 2×2 symmetric matrices. The inertia inverse and the dissipation tensor components are plotted as contours in Fig.2 and Fig.3 respectively. Calculations are done for ^{224}Th using the above mentioned inputs and a shape dependent level density parameter prescribed by Ignatyuk *et al.* The FFMDs are generated for three different values of ℓ at a initial temperature of 2 MeV. As shown in Fig.1, the trajectories cross the saddle-ridge many times before they reach the scission line. For the fissioning tra-

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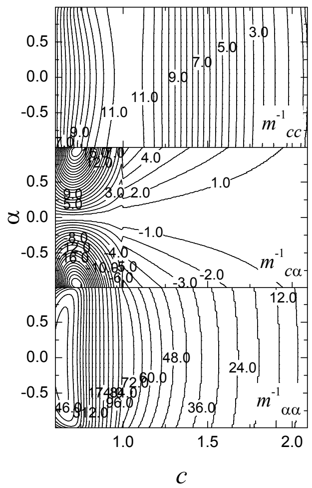

FIG. 2: m_{ij}^{-1} contours for ^{224}Th in $10^{-3}MeV/\hbar^2$.

jectories, only the mass asymmetry coordinate of the last crossing of the saddle-ridge is recorded. In this way, we obtain the dis-

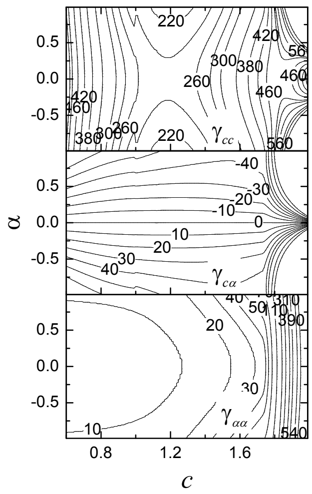

FIG. 3: γ_{ij} contours for ^{224}Th in unit of $\hbar$.

tribution of future fragments at saddle corresponding to each FFMD as shown in Fig.4 for $\ell = 60\hbar$. The mass variance (σ_m^2) for different ℓ is plotted in Fig.5. It is evident from this figure that up to saddle γ_{ij}^{asym} does not affect σ_m^2. But it has a major contribution to build up the mass dispersion during the passage from saddle to scission. Without this

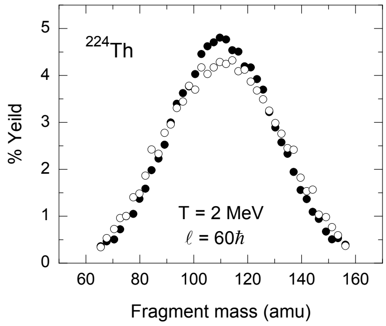

FIG. 4: Mass distribution at saddle (open circle) and scission (filled circle).

term in dissipation, σ_m^2 decreases substantially after saddle because of the funnel shape of the potential profile. The variance however does not change much with the γ_{ij}^{asym} term in Eq.1.

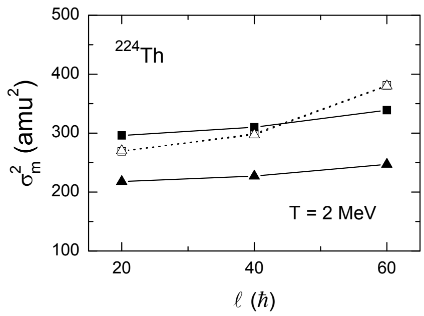

FIG. 5: σ_m^2 as a function of ℓ at saddle (open symbols) and scission (filled symbols). Square and triangular symbols are calculations with and without γ_{ij}^{asym} respectively. Lines are drawn to guide the eye.

We therefore conclude that the saddle to scission dynamics plays a major role in the FFMD of heavy nuclei.

References

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[3] K. T. R. Davies *et al.*, Phys. Rev. C **13**, 2385 (1976).