Ambiguity in choosing potential energy surface in the interpretation of fission of A∼200 at intermediate excitation energy

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The potential energy surface is an important ingredient in both the statistical and dynamical interpretation of fission. In general the potential energy has a macroscopic (liquid drop) part and a microscopic (shell correction) part. Even though lots of progress has taken place in the understanding of fission process, there are ambiguities in the theoretical model studies. Use of purely liquid drop deformation energy along with the experimental mass, as might be the case in Ref [1] and many other works, amounts to lowering of the whole surface with the same microscopic corrections as that at the equilibrium deformation, rather than having no microscopic corrections (see Fig. 1).

In order to highlight the sensitivity of the fission observables to the potential energy surface, we have carried out statistical model calculations with three different options (see Fig. 1): a. liquid drop mass (M_{LD}) and liquid drop fission barrier (B_{LD}), b. experimental mass ($M_{exp} = M_{LD} + \Delta_n$) along with a damping of the shell correction at the ground state (Δ_n) with excitation energy and shell corrected fission barrier ($B_{LD} - \Delta_n$), c. experimental mass and liquid drop fission barrier.

The calculations have been carried out using the statistical model code PACE [2]. The value of the level density parameter ($\tilde{a_n}$) is taken as A/9. The ratio of the level density parameter at the saddle deformation to that at the equilibrium deformation ($\tilde{a_f}/\tilde{a_n}$) is taken as 1.015. Shell corrections at the ground state (Δ_n) are taken from Ref. [3]. The angular momentum dependent macroscopic (liquid drop) part of the fission barrier ($B_{mac}(J)$) and $E_{rot}(J)$ are taken from the Rotating Finite Range Model (RFRM) [4]. The RFRM values of fission barriers have been scaled by a factor 1.05 for all the option.

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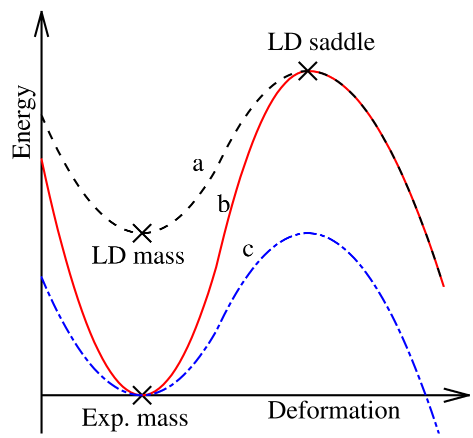

FIG. 1: (Color online) A schematic representation of the potential energy as a function of deformation in mass A ∼ 200. Different reference surfaces used in the statistical model calculations are marked as a, b, c.

As can be seen from the Fig. 2, statistical model calculation with option ‘a’ reproduces both the experimental fission probabilities and the prefission neutron multiplicity (ν_{pre}) data [5–7]. Calculation with option ‘b’ reproduces the experimental fission probabilities. However, it fails to reproduce the experimental ν_{pre} data. Calculation with option ‘c’ over predicts both the experimental fission probabilities and ν_{pre} data. However, they are found to be in good agreement with the results obtained from the advanced 4D Langevin dynamical calculation [1], which also overpredicts both the experimental fission probabilities and ν_{pre} data. Good agreement between the results of the dynamical calculation [1] and the present statistical model with similar values of the fission barrier and level density parameters indicates that the dynamical contribution in the results of the dynamical calculation [1] was not significant. It was observed in Ref. [8], both the heavy-ion and light-ion induced fission excitation function for the compound nucleus ^{210}Po could be simultaneously explained using the op-

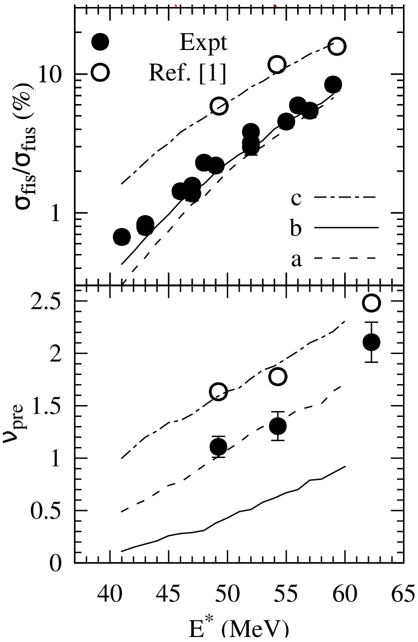

FIG. 2: Statistical model predictions for fission and prefission neutron multiplicity with different options of potential energy surface are compared with the experimental data [5–7] and the prediction of the advanced 4D Langevin code [1].

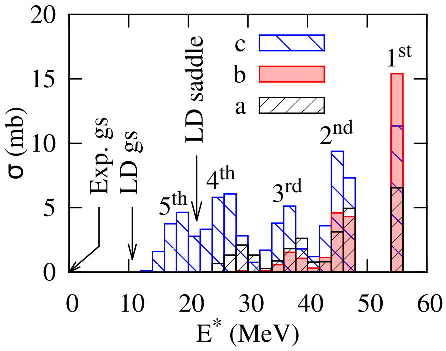

FIG. 3: (Color online) Statistical model predictions of excitation energy of the nuclei undergoing fission arising from the decay of compound nuclei with same excitation energy (55 MeV) after one or more neutron emission for ^{12}C+^{198}Pt system with different options for the potential energy surface (see text).

tion ‘b’ only. However, it fails to reproduce the experimental neutron multiplicity data. It was concluded that the experimental ν_{pre} data may have contribution from non-statistical processes and the experimental ν_{pre} data should not be used in statistical model to determine the fission barrier.

In case of option ‘c’, fission occurs even at energies below the liquid drop saddle point resulting in higher ν_{pre} as compared to the other options (see Fig 3). It should be mentioned here that the present statistical model calculation do not consider barrier tunneling. The level density at equilibrium deformation falls off slowly with decrease in excitation energy when a realistic continuous damping of shell effect is considered (option ‘b’) as compared to complete washing out of shell effect (option ‘a’). Hence, as excitation energy reduces, neutron emission is more favoured over fission in option ‘b’ as compared to that in option ‘a’ leading to lower ν_{pre} with option ‘b’.

In summary, we have investigated the sensitivity of fission observable to the different potential energy surfaces frequently used in literature. The option ‘c’ (experimental mass and purely liquid drop deformation energy), which might have been used in Ref. [1] and by many others, is incorrect and should not be used. Even though the option ‘a’ is applicable at high energies, it is difficult to constrain the model parameters and the conclusion drawn from such a analysis can be ambiguous. The option ‘b’, which is more realistic and accurate, should be used in the analysis to have more accurate knowledge about fission.

References

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