Presence of delay in fission of ^{210}Po at E* $\sim$ 50 MeV

K. Mahata[1],* S. Kailas[1],† and S. S. Kapoor[1]‡
[1]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*

Recently, we have carried out statistical model analysis for the decay of ^{210}Po* formed in fusion of light (p and α) and heavy (^{12}C and ^{18}O) ions using the same prescriptions for the level density and fission barrier to incorporate shell correction and its damping with excitation energy [1]. It was possible to achieve a consistent description of all the excitation functions using a barrier of 21.8 MeV. However, such a calculation substantially under predicts the measured pre-fission neutron multiplicity data for ^{12}C+^{198}Pt system [2], indicating the presence of fission delay.

Excess neutron emission as compared to the statistical model predictions have been used to determine the fission delay at higher excitation energies [3]. In the present contribution, we have estimated fission delay assuming that these access neutrons arises entirely due to dynamical emission using a Monte Carlo procedure. The mean lifetime of neutron emission (τ_n) at each decay step is estimated from the neutron decay width (Γ_n) from the statistical model. The time distribution of neutron emission is obtained by multiplying τ_n with the negative logarithm of a random number, chosen in the interval between 0 and 1 [4]. The contribution due to dynamical emission is taken as the ratio of the number of neutrons emitted within the dynamical delay time to the total number of cascades. Actually, the dynamical emission of pre-fission neutron can take place from anywhere along the path from equilibrium deformation to scission point. In the present work, fission delay has been estimated under the assumption of dynamical emission taking place either at the equilibrium deformation, at the saddle point or at mean deformation corresponding to saddle-to-scission motion.

In Fig. 1 we have shown the correlation between the fission barrier height and the required fission delay for emission from equilibrium deformation. With the increase of fission barrier height, the predicted number of statistical neutrons decreases and as a result the required fission delay increases. For a fission barrier of 21.8 MeV, which explains all the fission excitation functions [1], the deduced fission delay is $(0.8 \pm 0.1)\times10^{-19}$s. As shown in Fig. 2, a dynamical contribution assuming emission at the equilibrium deformation corresponding to a delay of 0.8×10^{-19}s in addition to the statistical contribution reproduces the measured pre-fission neutron multiplicities well. Even larger fission delay (1.8×10^{-19}s) is required to reproduce the values used in Ref. [5] from the systematics [6].

For saddle point and saddle-to-scission emission the required fission delay to reproduce the measured ν_{pre} data are $(5.6 \pm 1.0)\times10^{-19}$s and $(1.9 \pm 0.3)\times10^{-19}$s, respectively. The excitation energy available at the saddle point is taken as $E^{*}_{s} = E^{*}_{eq} - B_f$, where E^{*}_{eq} and B_f are the excitation energy available at the equilibrium deformation and the height of the fission barrier, respectively. The excitation energy at the scission point is taken as $E^{*}_{sc} = E^{*}_{eq} + Q_{sc}$. The Q-value at scission is calculated as $Q_{sc} = M_{cn} - 2 \times M_f - TKE$, where M_{cn}, M_f and TKE are mass of the compound nucleus, mass of the symmetric fragment and the average kinetic energy released in symmetric fission. The average excitation energy for saddle-to-scission motion is taken as $0.5\times(E^{*}_{s}+E^{*}_{sc})$.

As discussed in Ref. [3], the calculated neutron mean life and hence the extracted fission delay is sensitive to the value of level density parameter. In the above calculation the value of $\tilde{a}$ is assumed to be A/9, which results better reproduction of the experimental

*Electronic address: kmahata@barc.gov.in
†Raja Ramanna Fellow
‡INSA Honorary Scientist

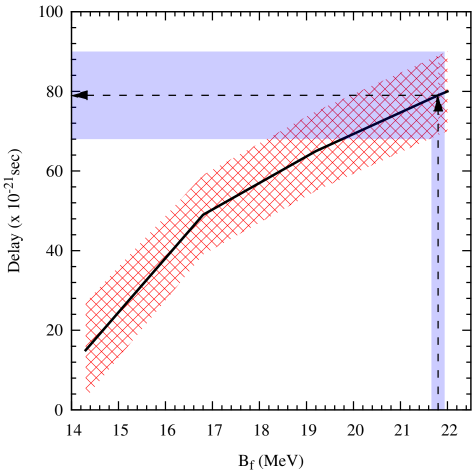

FIG. 1: Correlation between the fission barrier height and the fission delay assuming dynamical emission at equilibrium deformation (continuous line) required to account the excess neutrons as compared to the prediction of the statistical model. The hatched region corresponds to the uncertainty in the measured ν_{pre} data. The shaded region indicate the uncertainty in the fission barrier obtained from the analysis of all the fission excitation functions and the corresponding fission delay.

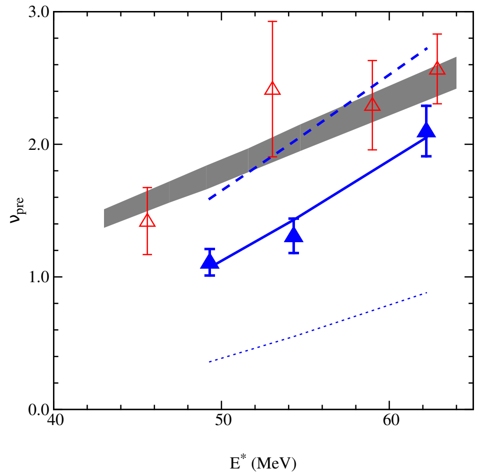

FIG. 2: Experimental pre-fission neutron multiplicity data (filled triangle) [2] is compared with statistical model calculations (blue, doted line) with a fission barrier of 21.8 MeV for ^{12}C + ^{198}Pt system. For comparison pre-fission neutron multiplicity for Z = 82-87 (open triangle) [3] and the systematics (band) [6] are also shown. The (blue) continuous and dashed lines are obtained by adding estimated dynamical neutrons assuming dynamical emission at equilibrium deformation corresponding to a fission delay of 0.8×10^{-19} and 1.8×10^{-19} s to the statistical model predictions, respectively.

partial xn excitation functions [5] and is also within the acceptable range (A/8 to A/9.5) determined from the measured neutron spectrum for a nearby compound nuclei (^{208}Pb) [7]. While the mean lives were calculated with shell corrected level density at equilibrium deformation, no shell correction was employed at the saddle point and for the saddle-to-scission motion.

In summary, simultaneous analysis of the fission excitation functions in light and heavy-ion fusion along with the pre-fission neutron multiplicity data from heavy-ion fusion indicates the presence of fission delay even at excitation energies of 50 MeV. In the above estimate we have not considered contributions from near-scission emission (from a neck region between the two fragments). Presence of near scission neutron emission will reduce the required delay time.

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References

[1] K. Mahata *et al.*, in Proc. Int. Symp. Nucl. Phys., Mumbai (2013), Vol.**58**, p516.
[2] Golda K. S. *et al.*, Nucl. Phys. **A 913** (2013) 157.
[3] D. J. Hinde *et al.*, Phys. Rev. **C 39**, 2268 (1989).
[4] A. Gavron *et al.*, Phys. Rev. C 35, 579 (1987).
[5] K. Mahata *et al.*, Phys. Rev. **C 74** (2006) 041301(R).
[6] H. Baba *et al.*, Jour. of the Phys. Soci. of Japan 66, 998 (1997).
[7] P. C. Rout *et al.*, Phys. Rev. Lett. 110, 062501 (2013).