# Study of pre-scission neutron multiplicity as a probe of shell closure effect on fission of $^{208, 210}$Po

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## Introduction

Studies on the nature and magnitude of nuclear dissipation have emerged as a topic of considerable interest in recent years. It is now well established that dissipation causes delay of the fission process with respect to the statistical picture of compound nucleus decay. Dissipation has an impact on many experimental observables like pre-scission particle multiplicities, fission probability and mass-energy distribution of fission fragments. Neutron emission that acts as a clock to measure the fission time scale, has proved to be very useful in investigating the mechanism of nuclear fission [1]. This is because neutrons are emitted in succession from a hot compound nucleus till it fissions and thus the pre-scission neutron multiplicity becomes a measure of the time scale of fission. Presently, the dissipation effect in fusion-fission process is well established. The excess in multiplicities with respect to statistical model predictions indicates the presence of a dynamic hindrance to fission. Recently, Singh *et al.* and Sandal *et al.* studied the effect of shell closure on nuclear dissipation by neutron multiplicity measurements [2-4]. With the same motivation to study the effect of shell closure on nuclear dissipation, we have performed statistical model calculations for $^{208,210}$Po populated by $^{16,18}$O+ $^{192}$Os in the excitation energy range of 65.23 MeV to 91.74 MeV and 88.1 MeV to 91 MeV respectively. Experimental data on pre-scission neutron multiplicity is available in the literature for $^{208,210}$Po [1]. In the present paper we are comparing the results obtained from statistical model calculations with the experimental results to see the isotopic and excitation energy dependence of the dissipation strength. We have performed the Bohr-Wheeler and Kramers' calculations for $^{208,210}$Po by both including and excluding shell effects in level density parameter and the fission barrier and the results are reported in this paper.

## Statistical Model Analysis

In the framework of statistical model, emission of neutrons, protons, $\alpha$'s, and giant dipole resonance (GDR) $\gamma$ rays are considered along with fission as the possible decay channels of a compound nucleus. The fission width where effect of dissipation is included is given by [5]:

$$\Gamma_k = \frac{\hbar\omega_g}{2\pi}\exp\left(-V_B/T\right)\left\{\sqrt{1+\left(\frac{\beta}{2\omega_s}\right)^2}-\frac{\beta}{2\omega_s}\right\} \quad (1)$$

where $\beta$ is the reduced dissipation coefficient, $\omega_g$ and $\omega_s$ are the local harmonic oscillator frequencies at the ground state and saddle point. For $\beta$=0, the above expression reduces to the following form of Bohr-Wheeler fission width [6]:

$$\Gamma_{BW} = \frac{\hbar\omega_g}{2\pi}\exp\left(-V_B/T\right) \quad (2)$$

The fission barrier and the nuclear temperature is denoted by $V_B$ and T respectively. The nuclear potential is obtained from the finite range liquid drop model (FRLDM). The level density parameter used in the present work is taken from the work of Ignatyuk *et al.* [7], which takes into account the nuclear shell structure at low excitation energies and is given as:

$$a(E^*) = a\left(1+\frac{f(E^*)}{E^*}\delta M\right) \quad (3)$$

where $f(E^*) = 1 - e^{E^*/E_D}$ . Here, $a$ is the level density parameter and $E_D$ determines the rate at which the shell effects disappear at high excitation energy and $\delta M$ is the shell correction in the LDM masses, i.e. $\delta M = M_{experimental} - M_{LDM}$ .

The shell-corrected temperature dependent fission barrier is given by:

$$V_B(T) = V_{LDM} - \delta M e^{E^*/E_D} \quad (4)$$

where $V_{LDM}$ is the fission barrier from the finite-range rotating LDM potential & $E^*$ is the CN excitation energy. A particular decay channel is selected by performing Monte-Carlo sampling between all the particles and $\gamma$ emission widths.

## Results and Discussion

Upper panel of Fig.1 shows the results of calculations for pre-scission neutron multiplicity with no shell effects in level density parameter and barrier height for $^{208,210}$Po and lower panel shows the results with inclusion of shell effects

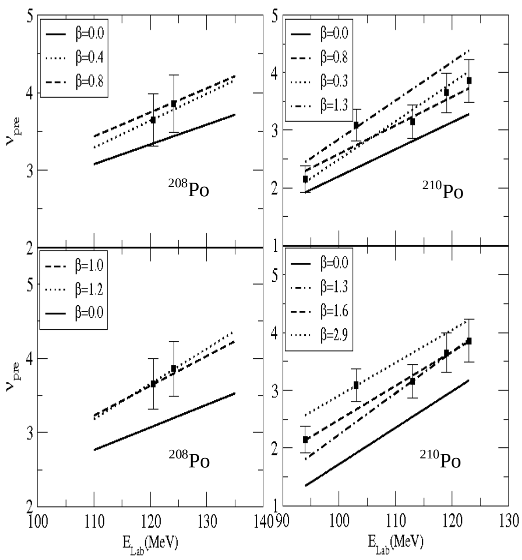


**Fig. 1** Experimental pre-scission neutron multiplicities (filled squares) along with statistical model calculation results for $^{208,\,210}$Po

in both. The comparison of calculated pre-scission neutron multiplicities with the experimental values clearly shows that the predictions using Bohr-Wheeler fission width considerably underestimate the pre-scission neutron multiplicity at all the energies. It is also observed that the experimental values at all the energies cannot be reproduced by a single value of β. However, the calculations which take into consideration Kramers' fission width are in well agreement with the experimental data.

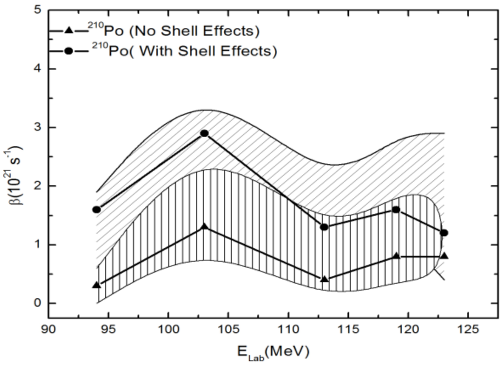


**Fig. 2** The best fit value of β obtained for $^{210}$Po

Fig.2 shows the lab energy dependence of best fit β value for $^{210}$Po where the shaded areas represent the uncertainty in β with the experimental error in $\nu_{pre}$. We first note in this figure that the inclusion of shell effects in the calculation results in higher values for best-fit β. Inclusion of shell effects affects both the particle/ γ decay widths (due to change in level density parameter) and also the fission width (due to change in both fission barrier and level density parameter). Consequently the relative strength of the fission width with respect to the other decay channels changes which results in a higher value for β to fit the experimental data. It is further interesting to note in this figure that the β values for the above two cases tend to merge to a common value at higher excitation energies which is a consequence of reduced shell effects at higher excitations.

Lastly, we observe that the best fit β values at high excitation energies for $^{208}$Po and $^{210}$Po are very close for both the cases. This indicates that shell effects on β, if any, are small at high excitation energies.

## References

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