Recent progresses in studies of fission of pre-actinide nuclei

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Understanding fission of a nucleus, particularly in the pre-actinide region, continues to be a challenging problem. Fission process involves drastic rearrangements in nuclei, where both statistical and dynamical features, governed by the delicate interplay between the macroscopic (liquid drop) aspects and the quantal (shell) effects, are exhibited. Study of fission has relevance in studies related to superheavy elements, stellar nucleosynthesis, and nuclear energy applications. Currently, much effort is on to model and understand both the statistical and dynamical aspects of fission. In both the cases, shell correction and its evolution with excitation energy and deformation plays a important role.

Accurate knowledge of the fission barrier is very essential not only for understanding fission process but also related applications. Several authors have pointed out that the cumulative fission probability in the heavy-ion induced reaction with excitation energy (E*) in the range 40 to 60 MeV is not sensitive to the correlated variation of the statistical model (SM) parameters, namely the fission barrier (B_f) and the ratio of the level density parameter at the saddle point to that at the equilibrium deformation (a_f/a_n) [1, 2]. The pre-fission neutron multiplicity (ν_{pre}) or the fission chance distribution was found to be sensitive to the above correlated variation in the SM parameters. Simultaneous SM fitting of the experimental fission excitation functions and the ν_{pre} values in ^{12}C+^{198}Pt results much smaller value of the fission barrier (∼11 MeV) as compared to that (∼22 MeV) extracted from the light-ion (p, α) induced fission excitation functions [2–4]. The light-ion induced fission measurement extends down to much lower excitation energy (E*∼25 MeV) and thus more sensitive to the fission barrier. The SM calculation with the fission barrier determined from the light-ion data under predicts the measured ν_{pre} data. Significantly large dynamical delay is required if one assumes that the the entire excess ν_{pre} as compared to SM prediction is due to dynamical emission [4].

Recently, we have extracted the fission chance distributions and the ν_{pre} values from the experimental excitation functions in the light-ion induced fission of the neighbouring Po isotopes [5]. The ν_{pre} extracted from the excitation functions corresponds to the pre-saddle emission only and is in excellent agreement with the SM predictions, which accounts for the low-energy light-ion fission data. This indicates that the pre-saddle dynamics is not important in this energy range for this mass region. The ν_{pre} determined from the experimental fission excitation functions are much smaller than those extracted from the experimental neutron spectra. This reveals that there is a significant contribution from post-saddle emission to the ν_{pre} determined from the neutron spectra. The saddle point being extremely deformed, the saddle to scission motion in this mass region is expected to be fast and not expected to contribute significantly to the ν_{pre}. This implies that there is a significant contribution from near scission neutron emission in the ν_{pre} determined from the neutron spectra.

Recent observation of asymmetric mass distribution in β-delayed fission of proton rich ^{180}Hg [6] has brought new excitements in this field. Asymmetric mass division in fission of actinides is believed to be due to the

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strong shell correction in the heavier fragment. Predominantly symmetric mass distributions were observed in the fission of pre-actinide nuclei suggesting that the dominance of the liquid drop behavior in this mass region. Both from the liquid drop aspect as well as shell correction in the fragments, ^{180}Hg was expected to undergo symmetric fission. However, the measured fragment mass distributions in low-energy fission of ^{180}Hg was found to be asymmetric. The result is understood in terms of relatively small shell correction that causes the saddle point to be mass asymmetric but do not survive up to the scission point [6]. This has highlighted the importance of understanding the structure effects (shell correction) near the saddle point and dynamics of the saddle to scission region in determining the fragment mass distribution.

Few heavy-ion experiments [7–9] have already reported the observation of asymmetric mass distribution in fission of nuclei near the proton-rich ^{180}Hg at excitation energies $\sim$30 MeV above the saddle point. Further investigations are required/planned to study the role of N/Z, excitation energy and dynamics in influencing the fission fragment mass distribution in this mass region. This talk will summarize the recent progresses in this field.

References

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