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Entrance channel systematics of pre-scission neutron multiplicities

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Abstract. Statistical model analysis has been performed for the available neutron multiplicity (ν_{pre}) data in the literature. Larger ν_{pre} values for more symmetric reactions have been observed in comparison with asymmetric reactions forming the same compound nucleus, in most cases. A reverse trend has also been noticed in a few cases. A systematic entrance channel dependence of fission timescale is brought out in this work. Fission timescales calculated using the experimental ν_{pre} values fall into two distinct groups according to the entrance channel mass asymmetry of the reaction with respect to the Businaro-Gallone critical mass asymmetry. The difference in the delay between these two groups ranges between 20 and 100 zs, which is larger than that reported in some cases.

1 Introduction

Nuclear fission [1, 2] is a clear example for the large-scale collective re-arrangement of nuclear matter. A fundamental feature of the fission process is the dissipation of collective energy. Even though the role of dissipation in fission was proposed in the early days of fission discovery [3], the success of Bohr-Wheeler theory [2] shadowed its acceptance. Clear experimental signature of dissipation in fission was observed in the early 1980s [4], when measured pre-scission neutron multiplicities were observed to be much larger than the Bohr-Wheeler predictions. Dissipation increases the fission timescales and thereby suppresses fission with respect to particle evaporation during the transition of the compound nucleus (CN) from the ground state deformation to the scission point.

Different experimental probes have been used to study the role of dissipation in fission and fission timescales, such as pre-scission particles (charged particles and neutrons) [5–10], giant dipole resonance (GDR) [11, 12] gamma multiplicities and evaporation residues (ER) [13–16]. In all these cases, the experimental observables could not be explained by a model assuming the Bohr-Wheeler fission width, indicating the dynamic nature of the fission process [3, 5, 13, 17–31].

Among these probes, pre-scission neutron multiplicity (ν_{pre}) is one of the most efficient probes to understand the fusion-fission timescales [5, 6, 32, 33]. Neutrons may be evaporated from the compound system itself before fission or from the fission fragments after scission. However the neutrons from these different origins may be clearly separated using their respective kinematics. Larger yields of ν_{pre} compared with other probes such as pre-scission charged particles or GDR gammas ensure better statistics and thus lower uncertainities in the derived quantities. Further, the analysis of the charged-particle multiplicities requires the deformation dependence of the Coulomb barrier and particle binding energies, which are often model-dependent.

Several ν_{pre} measurements have been reported in the literature [29, 30] populating the same CN using different entrance channels. The fission timescale or viscosity associated with fission have been extracted from these measurements. The analysis of neutron multipicity results has been performed using a combined dynamical-statistical model [34] in some cases, where the time evolution of the system is followed in terms of the Langevin equations. A rather simple approach is to treat the problem in a statistical model [5, 31].

Despite a considerable amount of data available and the number of efforts [31, 35–37] made over the years, a common systematics could not be achieved for the neutron multiplicity data, and hence for the derived quantities. Saxena *et al.* [37] reported a formation delay depending on the entrance channel mass asymmetry (α) relative to the Businaro-Gallone (BG) critical mass asymmetry (α_{BG}) [38]. However the systematics of Baba *et al.* [39] contradicted the above observation as they could not notice any discernible relationship between BG point and the magnitude of the dissipation coefficient. The empirical

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