SHELL EFFECTS AND THE NEUTRON EMISSION WITHIN THE MULTI-DIMENSIONAL LANGEVIN MODEL FOR NUCLEAR FISSION

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We solve the Langevin equations for the time evolution of parameters that describe the shape of fissioning system, see [1]. On each integration step, we calculate the probability of neutron emission and estimate whether a neutron would be emitted or not. If yes, we decrease the excitation energy of the nucleus by the neutron separation energy plus the average energy of the emitted neutron, switch to the layer of potential energy surface with a smaller number of neutrons and continue the process of integration. If the trajectory reaches the scission point, we check how many neutrons were emitted along this trajectory. The pre-scission neutron multiplicity M_{pre} is defined by the ratio of the total number of emitted neutrons to the total number of fission trajectories.

Besides M_{pre}, the mass distribution of fission fragments, the distribution of emitted neutrons with respect to the fission stage (deformation of system) and the distribution of emitted neutrons with respect to their energies are calculated.

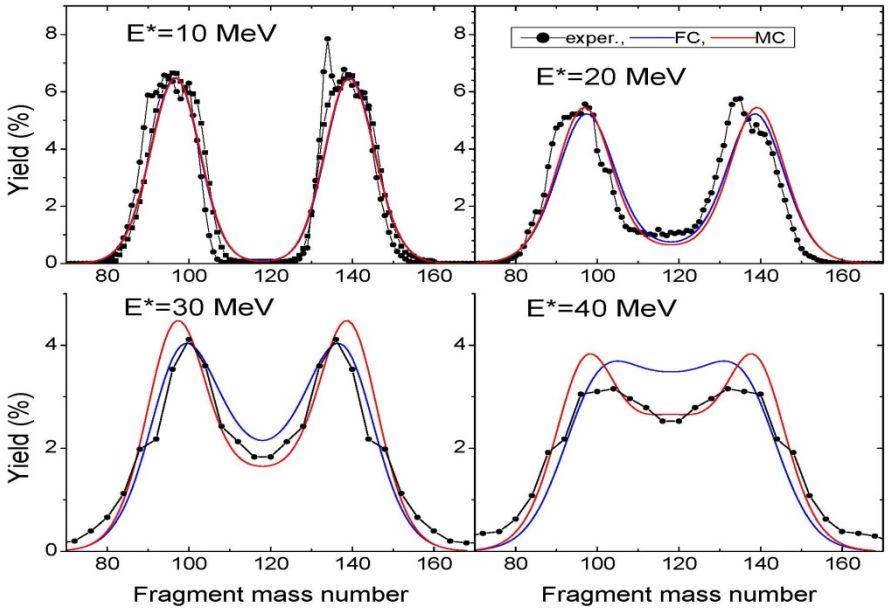

Fig.1. The comparison of the fission fragment mass distributions of the first chance (blue lines) and the multi-chance fission (red lines) of ^{236}U at few values of the initial excitation energy E*. The experimental mass distributions are shown by black lines with dots.

The calculated fission fragment mass distributions reproduce quite well the experimental data, see Fig.1. For the instantaneous emission rate dN/dt, an analytical expression was derived based on the continuity equation and the Fermi-gas model.

The dependence of the number of emitted neutrons on the stage of fission is clarified. At E*=10 MeV, all the neutrons are emitted after the system crosses the fission barrier. For larger excitation energy, a small portion of neutrons is emitted from the potential well around the ground state. The main part of pre-scission neutrons is emitted at larger deformations, between the saddle and scission.

The calculated pre-scission neutron multiplicity is in reasonable agreement with the available experimental data.

The Langevin model developed in the present work is a powerful tool for the investigation of the process of nuclear fission.

1. F.A. Ivanyuk et al. Shell effects and the neutron emission within the multi-dimensional Langevin model for fission 2026. arXiv:2604.19576v2 [nucl-th]. Submitted to Phys. Rev. C.