Non-Markovian Langevin Dynamics of Nuclear Fermi Liquid Drop

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One of the important features of the nuclear large amplitude dynamics is its dissipative character or, the presence of the time irreversible energy flow from the collective degrees of freedom to the nucleonic ones. On the other hand, the experimental observation of the finite variance of the kinetic energy of the fission fragments manifests the fact that fluctuations have to be also associated with the collective variables. Both the dissipation and the fluctuations can be described by the introduction of the friction and random forces connected to each other by the fluctuation-dissipation theorem. In this respect, the Fokker-Planck or Langevin approaches can be used to study the nuclear large scale dynamics (nuclear fission, heavy ion collisions, etc.) [1].

We study the influence of the memory effects on some precission characteristics of the fissioning nucleus. Starting from the collisional kinetic equation with a random force we derive the memory-dependent Langevin equation of motion for the nuclear shape parameter. Considering a spheroidal nucleus, the nuclear shape is parametrized by the parameter $q$ of the total elongation and the collective potential energy in the region from the barrier to the scission point is approximated by an inverted oscillator. The position of the nuclear scission $q_{sc}$ is defined from the difference of 28 MeV in the potential energy between the saddle $q_f$ and scission $q_{sc}$ points for the nucleus $^{236}$U. Solving the generalized Langevin equation, we have obtained analytical expressions for the mean value $\langle E_{kin}\rangle$ and the variance $\sigma^2(E_{kin})$ of the collective kinetic energy. We have found that both quantities $\langle E_{kin}\rangle$ and $\sigma^2(E_{kin})$ are sensitive to the variations of the saddle-to-scission time $t_{sc}$, arising from the random force contribution to the equation of motion. We have also studied the pre-scission kinetic energy, $\langle E_{kin,ps}\rangle$, of the fissioning nucleus assuming that $\langle E_{kin,ps}\rangle$ is given by the kinetic energy $\langle E_{kin,ps}\rangle$ at $t = t_{sc}$, where the saddle-to-scission time $t_{sc}$ is obtained in the absence of the random force. The results of numerical calculations within our non-Markovian Langevin-like approach provide smaller values of $\langle E_{kin,ps}\rangle$ and $\sigma^2(E_{kin,ps})$ than those obtained within the traditional Markovian Langevin approach. The lowering of the values of $\langle E_{kin,ps}\rangle$ and $\sigma^2(E_{kin,ps})$ for the non-Markovian dynamics can be explained as a result of the presence of the additional elastic force coming from the memory integral in the equation of motion for shape variable $q$. The memory integral (retarded force) is split into the dissipative friction and time-reversible elastic forces [2]. The latter is caused by the Fermi-surface distortion and acts against the adiabatic force, slowing down the descent from the barrier. This phenomena reflects itself in the lowering of the mean values and the fluctuations of the velocity at the scission point and leads to the lowering of $\langle E_{kin,ps}\rangle$ and $\sigma^2(E_{kin,ps})$.