# Time-Dependent Hartree-Fock Theory and Its Extensions for Low-Energy Nuclear Reactions: Recent Progress

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Low-energy nuclear reactions at around the Coulomb barrier offer unique opportunity to study a variety of non-equilibrium nuclear dynamics, such as energy dissipation, nucleon transfer, shape evolution, fusion, and so on. Besides the fundamental interest into the underlying reaction mechanism, it possesses substantial importance as a means for producing new, neutron-rich, heavy and superheavy nuclei, whose properties are crucial to figure out the detailed scenario of the r-process nucleosynthesis. Furthermore, the effect of pairing correlations in nuclear dynamics has rarely been investigated to date, in spite of the known great importance of the pairing in nuclear structure studies.

In this talk, recent applications of microscopic dynamic approaches, known as time-dependent Hartree-Fock (TDHF) theory and its various extensions will be discussed. (See, e.g., [1] for a recent review of TDHF.)

In recent studies (see, e.g., [2]), it has been shown that TDHF can reasonably describe quasifission dynamics in collisions of heavy nuclei. However, in the case of superheavy element (SHE) synthesis, the compound-nucleus formation after capture due to the thermal fluctuation of nuclear shapes is out of reach of the TDHF description. To evaluate the evaporation-residue formation probability, a novel approach that combines TDHF with a Langevin model has been developed (TDHF+Langevin [3]). In the latter approach, the entrance-channel dynamics are described microscopically within TDHF, which provides the initial condition for the diffusion process over the inner barrier. Implications of the TDHF+Langevin approach when applied to hot fusion reactions to synthesize the element 120 (i.e., $^{48}$Ca+$^{254,257}$Fm, $^{51}$V+$^{249}$Bk, and $^{54}$Cr+$^{248}$Cm) [3] will be discussed.

There is a well-known drawback of the standard TDHF approach, where the width of fragment mass distribution is severely underestimated as compared with experimental data. Recently, it has been shown that one can overcome the drawback by incorporating one-body fluctuations into the description by the time-dependent random phase approximation (TDRPA) [4] or the stochastic mean-field approach [5]. This progress opens a door for the prediction of unstable nucleus productions far away from the stability. Applications of those extended approaches for the production of neutron-rich (super)heavy nuclei will be discussed.

Last but not least, pairing correlations are of significant importance in nuclear dynamics at low energies. Novel phenomena associated with pairing in low-energy nuclear reactions [6] as well as interior of neutron stars [7] will be discussed.

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## References

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