Project Title:

Structure and dynamics of nuclear large amplitude collective motion

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Time-dependent Hartree-Fock (TDHF) theory, proposed by Dirac in 1930, has been extensively applied to the studies of fusion excitation function, giant resonance, fission, deep-inelastic scattering, and nuclear molecular resonances. It provides, from a fully microscopic point of view, the dynamical foundation of such large amplitude collective motion. The main approximation of TDHF theory is that the many-body wave function is treated as the independent particle state at any time. Hence, TDHF theory includes only one-body dissipation of energy from collective kinetic energy into internal degrees of freedom. It is treated exactly in the mean-field theory because Pauli principal prevents nucleon-nucleon collision during time evolution. The energy dissipation caused by the collision of nucleon with mean-field potential and nucleon transfer between two colliding partners plays an important role in low-energy deep-inelastic scattering and heavy-ion fusion reaction.

In most TDHF calculations, the tensor force was neglected due to the numerical complexity. Although the effect of tensor force has been extensively studied in the nuclear structure properties and collective excitation, there is quite few studies of the tensor effect on heavy-ion collision including fusion reaction and deep-inelastic collision. Due to the present situation, our study aims at investigating the effect of tensor force on heavy-ion collisions in the framework of self-consistent TDHF theory. We first formulated the energy density functional with tensor force in a fully microscopic way and then realized them in the numerical codes. We also did many numerical calculations to make the careful check on the numerical accuracy by using RICC systems. We solve TDHF equation in three-dimensional coordinate space and the numerical codes are parallized with message passing interface (MPI).

The full three dimensional TDHF calculations will shed light on more realistic dynamics in heavy ion collisions. However the numerical calculations are quite time-consuming, especially for the TDHF calculations including tensor force. The high speed and available CPU cores of MPI parallization in RICC system provided essential support for the studies of the research project.

In the past year, our study mainly focused on the following three respects. First, the effect of tensor force and spin-orbit force on the dissipation dynamics has been investigated in deep-inelastic collisions for the system $^{16}O+^{16}O$. This system is the most frequently studied in earlier TDHF calculation. Our results are compared extensively with the earlier calculations. Since tensor force and spin-orbit force have the same dynamical effect despite of different origin, we estimate the ratio between tensor and spin-orbit effects. Second, the shell evolution of tensor effects on heavy-ion collision has been working and we obtained some preliminary results. We analyzed the adiabatic single particle states with boost-invariant TDHF theory to clarify the tensor effect on the evolution of single-particle states. Third is the study of tensor effects on fusion cross sections. We found the different parameters of tensor force have significant influence on the fusion cross section. At present, all of these studies mainly focused on the light systems.

In the next usage term, I will continue my present research project along the above three directions. The systematic studies will be done from light to heavy systems. All these studies need a lot of numerical calculations and RICC system will provide essential and important supports to these numerical calculation.