Contribution ID: **52** Type: **not specified**

Time-Dependent Generator Coordinate Method for many-particle tunneling

Monday, 16 August 2021 16:30 (15 minutes)

Many-body tunneling is an important phenomenon in many fields of physics and chemistry.
In nuclear physics, tunneling effects appear, e.g., in low-energy fusion reactions, spontanious fission and so on.
The microscopic description of such tunneling effects is one of the major goals of nuclear reaction theory.

The time-dependent Hartree-Fock (TDHF) method, or the time-dependent density functional theory (TDDFT), is one of the most widely used microscopic frameworks for nuclear reactions.
It has been demonstrated that the TDHF successfully describes average behaviors of nuclear reactions such as the energy-angle correlation in heavy-ion deep inelastic collisions[1].
Because it is based on the nucleonic degrees of freedom,
ideally, the TDHF does not contain any empirical parameter for reactions, once static nuclear properties are well investigated.
This feature will be particularly important in applying the framework to unknown regions where experimental studies are difficult,
e.g., reactions of neutron-rich nuclei.

However, it has been known that the TDHF fails to describe tunneling effect. To overcome this problem, we will discuss the
Time-Dependent Generator Coordinate Method (TDGCM)[2-5] approach in this presentation.

In the TDGCM, one assumes that a many-body wave function is given as a superposition of many Slater determinants,
\begin{align}
\Psi(t)=\sum_af_a(t)\Phi_a(t)
\end{align}
where f_a is a weight function and Φ_a is a Slater determinant. %with single-particle wave functions $\{\phi_{ai}\}$.
The index a distinguishes each Slater determinant to one another, and is referred to as a generator coordinate.
The time evolution of the weight functions $f_a(t)$ and the Slater determinants $\Phi_a(t)$
are determined by the time-dependent variational principle.
We have applied this method to collision of an α particle on an external Gaussian barrier in one dimension.
In our calculation, the initial values of the center of mass position and momentum of the α particle
is taken as the generator coordinates.
We obtained the energy dependence of transmission probability.

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Experimental nuclear physics

Theoretical nuclear physics

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Session Classification: Young Scientist Session 1