**Motivation**

**Why a time-dependent approach?**

Central nuclear reactions, such as those involving fusion or multifragmentation, as well as other nuclear processes, like fission, involve sequences of events. These phenomena cannot be easily cast in a stationary framework and are naturally described in a time-dependent approach. Such an approach can also be employed to study the ground-state properties of finite nuclei.

**Why a Green’s Functions approach?**

A description in terms of Green’s Functions (GF) is fully quantal (unlike Boltzmann-type approaches) and can accommodate the effects of correlations both in the initial state and in the time evolution. In addition, the one-body GF gives access to all the one-body properties of the system (one-body density, response, etc) as well as to the total energy of the system.

**Kadanoff-Baym equations**

The dynamical evolution of the correlation functions:

\[ i\hbar \frac{\partial}{\partial t} \varphi^{\pi}(t', t') = -\left( \Sigma_F(i\hbar \omega) \varphi^{\pi}(t', t') \right) \]

with \( \varphi^{\pi}(t', t) \) is given, under very general assumptions, by the Kadanoff-Baym (KB) equations [1]:

\[
\begin{aligned}
\left\{ \frac{\partial}{\partial t} + \frac{\Sigma_F}{2m} \right\} \varphi^{\pi}(t', t') &= \int d^3x \Sigma_F(t, t') \varphi^{\pi}(t', t') \\
+ \frac{\partial}{\partial t} \int d^3x \Sigma_F(t, t') \varphi^{\pi}(t', t') &+ \int d^3x \Sigma_F(t, t') \varphi^{\pi}(t', t') \\
\left\{ -\frac{\partial}{\partial t} + \frac{\Sigma_F}{2m} \right\} \varphi^{\pi}(t', t') &= \int d^3x \Sigma_F(t, t') \varphi^{\pi}(t', t') \\
+ \frac{\partial}{\partial t} \int d^3x \Sigma_F(t, t') \varphi^{\pi}(t', t') &+ \int d^3x \Sigma_F(t, t') \varphi^{\pi}(t', t')
\end{aligned}
\]

These complex integro-differential equations:

- Account for interaction effects via the self-energy \( \Sigma \), which can be systematically improved to describe different many-body effects, including various types of correlations.
- Preserve local and global conservation laws, provided that \( \Sigma \) is of a “conserving” type [2].
- Incorporate the duration of collisions via the memory effects associated to the time integrals in the rhs.
- Avoid any presumption related to the quasiparticle limit.
- Can be extended to include initial state correlations beyond the mean-field approximation [3].

**Mean-field approximation**

The first benchmark calculation includes the following ingredients [4]:

1. One inhomogeneous spatial dimension (slabs)
2. Instantaneous zero-range mean-field self-energy
3. Time evolution implemented via the Split Operator Method
4. The results are equivalent to Time-Dependent Hartree-Fock

**Correlated approximation**

The time evolution in the correlated approach is more difficult to implement due to the presence of memory effects. To solve the KB equations optimally, one must take profit of the symmetries of the correlation functions [5]:

\[ G(t', t) = \left[ G(t, t') \right]^* \]

Our current effort is focused on studying the time evolution of 1D slabs with a self-energy computed in the direct Born approximation:

\[ \Sigma_F(p, p', t, t') = \int d^3x d^3y d^3z V(p_x - p'_x, p_y - p'_y, p_z - p'_z) G_z(t', t) \]

which is the simplest conserving approximation beyond the mean-field. We will use it as a benchmark to assess the effect of correlations on the time evolution of 1D systems.

**Future work**

- Set up a full code for the time evolution of a strongly interacting quantum many-body system in 1D.
- Study possible approximations and extend the code to 2D & 3D.
- Understand the role of the non-diagonal elements of the density matrix.
- Clarify the effect of correlations in the time evolution (thermalization, decoherence, etc).
- Test different possibilities for correlated initial states.
- Improve interactions and self-energies.

**Bibliography**