Warsaw, September 3, 2020

Tunneling of a few interacting ultra-cold atoms to open space

Summary of the doctoral thesis

In this work I theoretically analyze the dynamics of quantum tunneling through a classically forbidden region, focusing on a one-dimensional system of a few strongly correlated particles, tunneling from a potential well into open space. This research was motivated by the modern experiments in atomic physics, studying the dynamical properties of ultracold gases. Therefore, I consider a typical scenario where the particles are initially prepared inside a harmonic well, which is then suddenly opened from one side so that the particles can tunnel into open space. By means of an exact numerical simulation, I directly analyze the system dynamics from the point of view of physical observables that allow to distinguish between various decay channels (sequential tunneling, pair tunneling, trimer tunneling etc.) and determine their relative participation in the decay of the initial state. In order to make the description as complete as possible, I consider particles with different statistics (bosons or fermions) as well as interactions with varying ranges.

The most significant thesis of this work is that the dominant decay mechanism changes abruptly as the interaction strength crosses certain critical values. These changes are reflected in experimentally measurable quantities, such as the decay rate of the initial state, or the momentum distributions of the emitted particles. I demonstrate that by tuning the parameters of the problem it is possible to modify the dynamical properties of the tunneling particles, and conversely, by measuring these properties, it is possible to precisely determine the experimental parameters. From this point of view, though the work is purely theoretical, its results can be significant to experiments. Specifically, they can open a way to a better understanding of the dynamics of tunneling systems, and to exerting greater experimental control over such systems.

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