Computational nuclear physics

Mysteries of neutrinos: Neutrinoless double beta decay

Neutrino is still a mysterious elementary particle. We do not know how large its mass is, and whether the neutrino is its own anti-neutrino (Majorana particle). The observation of the neutrinoless double beta decay (Fig. 1a) may solve these mysteries. However, to quantify the neutrino mass, we need the accurate nuclear matrix elements associated with this process. This is a challenge for the most reliable calculation.

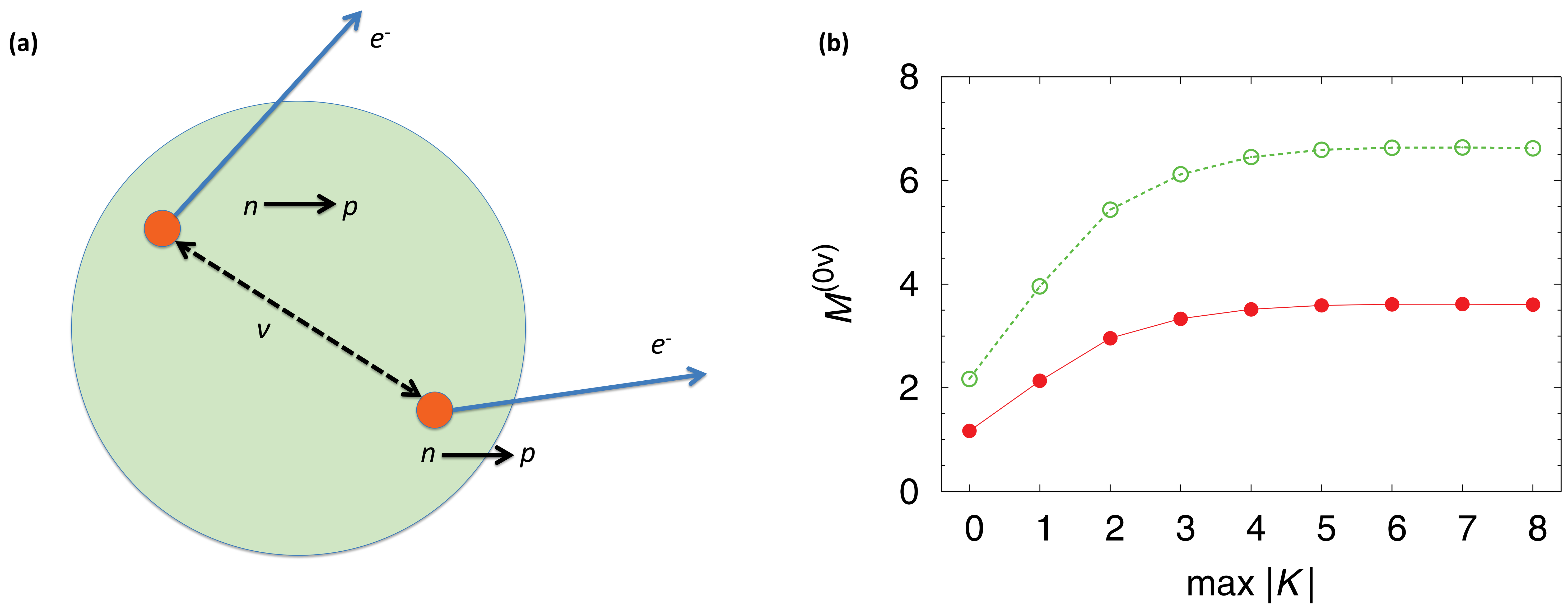

Fig. 1a: Neutrinoless double beta decay (0*vββ*) process. Neutrino is emitted from one of the neutron and absorbed by the other.
Fig. 1b: Calculated nuclear matrix elements for ^{150}Nd --> ^{150}Sm 0*vββ*. The horizontal axis indicates the quantum number of the vibrational modes included in the calculation. It shows, for the first time, that the convergence is achieved.

Fusion hindrance problem

Nuclear fusion reaction is the fuel burning for the stars to shine in the sky. All the heavy elements in the universe are supposed to be produced in the steller burning and explosions. Nuclear physicists observed that the fusion is extremely hindered for synthesis of very heavy elements, which is called “fusion hindrance problem”. Its microscopic mechanism is studied with the time-dependent density-functional calculation for the fusion reaction, to solve this mystery.

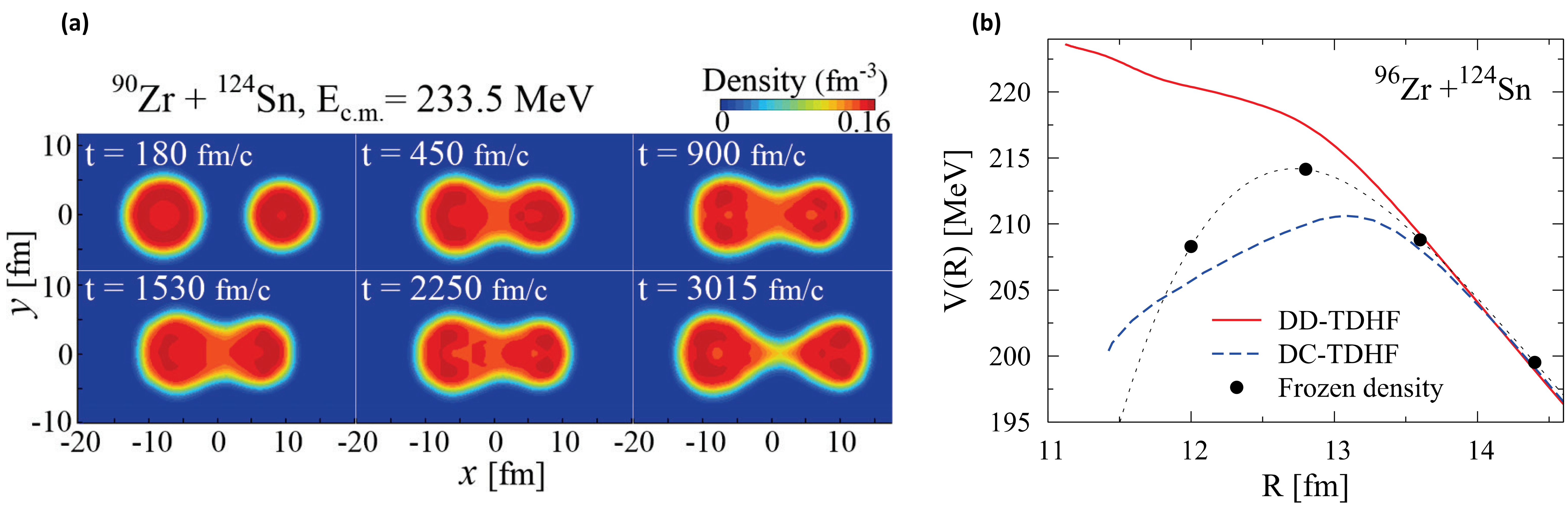

Fig. 2: TDDFT simulation studies for fusion reaction to synthesize the thorium nucleus (*Z*=90). The fusion fails and the quasi-fission process takes place (Fig. 2a). Potential as a function of the internuclear distance *R* is derived from the simulation (Fig. 2b). The rising potential at smaller *R* (red line) is a cause of the hindrance.