# Monte Carlo shell model and its applications to exotic nuclei

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The nuclear shell model is one of the most basic models in the nuclear structure. It has been quite successful in describing the low-lying nuclear properties in the *sd* shell region in the 1980s and also in the *pf* shell region in the last 1990s to 2000s. However, since the dimension of the shell-model Hamiltonian matrix is expanding for heavier nuclei, it is very hard to further extend the region covered by the shell model. The Monte Carlo shell model (MCSM) has been developed since 1996 in order to relax this computational difficulty [1]. In this talk, we will present basic concepts of the MCSM and its applications to the neutron-rich nuclei around N=20 [2]. We will also discuss the evolution of the shell structure in exotic nuclei due to the nuclear force.

The MCSM aims to represent the very complex shell-model wave function with a small number of elaborately selected many-body basis states. In most cases, we use a deformed Slater determinant with parity and total angular momentum projection as the basis state. We generate candidates for the basis state stochastically with the auxiliary Monte Carlo method, and choose the one that makes the total energy as low as possible. It has turned out that this method works quite well in realistic systems such as the full *pf* shell calculation in $^{56}$Ni.

The MCSM has been applied to the neutron-rich N=20 region. This region is famous for the disappearance of the N=20 magic number. To study the disappearance by using the shell model, not only the *sd* shell but also part of the *pf* shell must be included as the valence shell. This calculation involves a very large Hamiltonian matrix, and the MCSM has indeed been able to resolve this problem. From this calculation, we have succeeded in drawing how the shell structure evolves in this region. Namely, the neutron $0d_{3/2}$ orbit must be very sharply lowered from oxygen (Z=8) to silicon (Z=14) to account for the structure of this region in a unified framework. This sharp shell evolution is driven by strong proton-neutron monopole interaction between $0d_{5/2}$ and $0d_{3/2}$. This phenomenological finding has been supported by the tensor-force driven shell evolution [3] proposed several years after this study. We are now heading for the description of exotic nuclei with the tensor force fully included. We will also show some recent results in the N=28 region, focusing upon the change of the spin-orbit splitting in going from the LS closure to the jj closure and its effect on the observables [4].

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