Hypernuclear Physics --Recent Results and Future Prospects--

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The most important mission of the nuclear physics today is to elucidate the origin and the evolution of matter in the universe, by answering the basic questions how the elementary particles (quarks) are combined to form hadrons (nucleons), and how the hadrons are combined and form various atomic nuclei and also neutron stars. Although ordinary matter (nuclei) is made of up and down quarks, strange quarks play particularly important roles to approach these problems. For example, the origin of the nuclear force, particularly of its short range properties, is not understood well but expected to be described by quark-gluon picture. Quark models as well as lattice QCD calculations for baryon-baryon (BB) interactions predict characteristic features in the short range part of the BB interactions with strangeness (hyperon-nucleon and hyperon-hyperon interactions) completely different from those of the nuclear force without strangeness.

We have investigated various types of hypernuclei, nuclear systems containing hyperons such as Λ, Σ, and Ξ particles. By using K^- and π^+ meson beams we have investigated precise structure of various p-shell Λ hypernuclei via gamma-ray spectroscopy. Detailed structure data of hypernuclei allow us to extract valuable information on the ΛN interaction. In our recent experiment at J-PARC we observed gamma-rays from ${}^{4}_{\Lambda}$He and ${}^{19}_{\Lambda}$F, and determined their level schemes. The ${}^{4}_{\Lambda}$He result confirmed the existence of a quite large effect of charge symmetry breaking (CSB) in □ hypernucleus which was suggested in 1960s but cannot be theoretically understood yet. Recent precise data on production and decay of Λ hypernuclei have been also taken at MAMI, DAΦNE, and Jefferson Laboratory, giving further hints to elucidate the origin of the CSB effect in hypernuclei.

Experimental data on "doubly strange" nuclei are also being accumulated at J-PARC. We have observed deeply-bound Ξ-nuclear systems from emulsion experiments, clearly indicating for the first time that the ΞN interaction is attractive. Several new samples of ΛΛ hypernuclei have also been observed, providing quantitative information on the attractive ΛΛ interaction.

Such studies provide key information to understand BB interactions based on quark-gluon picture, and then to clarify extremely high density matter in neutron stars where hyperons are naively expected to exist stably. In future we are planning to extend the hadron facility at J-PARC for further investigation on BB and 3-body BBB interactions with strangeness in order to reveal unknown high-density matter in the core of neutron stars.