Hypernuclear γ-ray spectroscopy via the Hyperball2 array

T. Koike, Y. Fujii, O. Hashimoto, S. Kinoshita, Y. Ma, Y. Miura, S. Nakamura, H. Tamura and M. Ukai
Department of Physics, Tohoku University

Atomic nuclei consist of a number of protons and neutrons. When one of the constituent nucleons is replaced by a hyperon, a hypernucleus is formed. Hyperons such as Λ and Σ are different types of particle from nucleons in that they have non-zero strangeness quantum number. The inclusion of strangeness in nuclear medium offers an unique laboratory for deepening our understanding of nuclear force not limited to nucleon-nucleon but extended to hyperon-nucleon and hyperon-hyperon interaction. Until recently, detailed structural investigations of hypernuclei had only been a dream due to the experimental challenge such studies pose. However, the high resolution γ-ray spectroscopy of hypernuclei became a reality with a development and construction of the germanium (Ge) detector array, Hyperball. Thus far, precise structures of several Λ hypernuclei have been identified from which strengths of spin-dependent interaction between a Λ and a nucleon are experimentally determined. A reduction in size of a bulk nuclear matter (core) in the hypernucleus ${}^{7}_{\Lambda}$Li has also been observed experimentally confirming the glue like presence of a hyperon that is not affected by Pauli principle.

Based on the success of a series of Hyperball experiments, an upgrading of Hyperball has been undertaken. The new array, Hyperball2, houses six Clover-type detectors, which are segmented into four Ge crystals, plus 14 single-crystal Ge detectors. Each detector is surrounded by BGO scintillator counters for a reduction of backgrounds in γ-ray spectrum by vetoing contaminated events. The photo-peak detection efficiency of Hyperball2 is nearly doubled from that of the previous array. The first experiment with this array, in conjunction with Superconducting Kaon Spectrometer (SKS), is scheduled at the KEK beam facility to perform γ-ray spectroscopy of ${}^{12}_{\Lambda}$C and ${}^{11}_{\Lambda}$B using the (π^+, K^+) reaction on ^{12}C target. In this experiment, one of the main goals is to measure a lifetime of $7/2^+$ state in ${}^{11}_{\Lambda}$B, which is selectively produced via one proton emission decay of ${}^{12}_{\Lambda}$C(2^+). The measured lifetime, by means of Doppler shift attenuation method, determines the reduced transition probability of the ${}^{11}_{\Lambda}$B($7/2^+ \rightarrow 5/2^+$) Λ-spin-flip M1 transition (B(M1;$7/2^+ \rightarrow 5/2^+$)). Properties of a Λ particle in free space may change in nuclear matter and the magnetic moment is one of them. The measurement of the B(M1;$7/2^+ \rightarrow 5/2^+$) value will provide a quantitative account for the change of the magnetic moment of a Λ if at all.

More expansive and systematic studies of various hypernuclei via the γ-ray spectroscopy are planned in the future with high intensity beams provided by 50-GeV Proton Synchrotron at Japan Proton Accelerator Research Complex (J-PARC), currently under construction. The beams with an intensity $\sim$10 to $\sim$100 times of that achievable at the present will be available for the hypernuclear experiments. Thus a dramatic increase in counting rates of Ge detectors is anticipated and a much faster data-readout system for these detectors is being developed.