Gamma-ray spectroscopy of hypernuclei – recent results and prospect at J-PARC

Hirokazu Tamura[1]

[1] Department of Physics, Tohoku University

The technique of precision gamma-ray spectroscopy for hypernuclei was developed in late 1990s [1] and a series of experiments were carried out at KEK-PS and BNL-AGS until the mid-2000s [2]. Those experiments revealed detailed structure of various p-shell Λ hypernuclei and provided valuable data to determine the spin-dependent ΛN interaction strengths.

Recently, hypernuclear gamma-ray spectroscopy has just been resumed at J-PARC; we have carried out an experiment (J-PARC E13) [3] to study ${}^{4}_{\Lambda}$He and ${}^{19}_{\Lambda}$F. Those hypernuclei were produced via the (K^-,π^-) reaction at 1.5 GeV/c with ^{4}He target (liquid helium) and at 1.8 GeV/c with ^{19}F target (liquid CF_4), employing the K1.8 beam line and the SKS spectrometer. γ rays emitted from those hypernuclei were detected with a newly-developed germanium (Ge) detector array, Hyperball-J. This array is equipped with low-temperature mechanically-cooled Ge detectors [4], each of which is surrounded by fast background-suppression counters made of PWO scintillator. The experiment was successfully performed in April and June of 2015.

The ${}^{4}_{\Lambda}$He γ-ray spectrum after the Doppler-shift correction clearly exhibits a peak at 1406$\pm$2$\pm$2 keV, which is unambiguously assigned as the ${}^{4}_{\Lambda}$He($1^+ \to 0^+$) $M1$ transition between the ground-state doublet. This energy is much larger than that of the corresponding transition of the mirror hypernuclei, ${}^{4}_{\Lambda}$H($1^+ \to 0^+$), 1.09 ± 0.02 MeV, which clearly confirms existence of charge symmetry breaking (CSB) effect in Λ hypernuclei [5]. We also observed γ rays from ${}^{19}_{\Lambda}$F, which will provide us with information of the effective ΛN interaction in sd-shell hypernuclei.

In the next step, we will precisely measure the $B(M1)$ value for the ${}^{7}_{\Lambda}$Li ground-state doublet and extract Λ's g-factor in a nucleus [3]. We are also planning to study other sd-shell hypernuclei to investigate impurity effects. Another important subject is the measurement of the $E1(p_\Lambda \to s_\Lambda)$ transitions in heavy hypernuclei such as ${}^{89}_{\Lambda}$Y and ${}^{208}_{\Lambda}$Pb, which will provide us with the Λ single particle orbit energies and allow us to investigate possible effects of the ΛNN three-body interaction that is essential to solve the "hyperon puzzle" in neutron stars.

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