Prospect of gamma-ray spectrocsopy of ${}^{4}_{\Lambda}$H at J-PARC

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The charge symmetry breaking (CSB) between Λp and Λn has been discussed as unsolved subject in hypernuclear physics. It is based on the large energy differences between ${}^{4}_{\Lambda}$H and ${}^{4}_{\Lambda}$He for both the Λ binding energies (B_Λ) and the energy spacings of the spin doublets $(1^+, 0^+)$ reported in old experiments. The binding energies were measured by nuclear emulsion technique for several times independently then all data suggested large values of $B_\Lambda({}^{4}_{\Lambda}\mathrm{He}) - B_\Lambda({}^{4}_{\Lambda}\mathrm{H})$ to be 0.34 ± 0.12 MeV[1], 0.28 ± 0.07 [2] and 0.34 ± 0.07 MeV[3]. On the other hand, the energy spacings of those doublets were measured by the gamma-ray spectroscopy using NaI scintillation counters. The ${}^{4}_{\Lambda}$H γ-ray energy was reported to be 1.09 ± 0.03 MeV[4], 1.04 ± 0.04 MeV[5] and 1.114 ± 0.030 MeV [6] by several experiments. The ${}^{4}_{\Lambda}$He γ-ray energy was to be 1.15 ± 0.04 MeV [4] by only one experiment with low statistics. In those experiments, the 1^+ states were produced as hyperfragments via stopped K^- absorption. Because of a large recoil velocity ($\beta = 0.05 \sim 0.1$) using the stopped K^- method, γ-ray peaks were Doppler broadened ($\sim$ 100 keV). In addition, the energy resolution of NaI counter is 50 keV(FWHM) at 1 MeV.

Precise measurement for A=4 hypernuclear structures have been long awaited. Recently, two experiments were performed to study this CBS puzzle. One is weak decay π^- spectroscopy of ${}^{4}_{\Lambda}\mathrm{H} \to {}^{4}\mathrm{He} + \pi^-$ using a electron beam at MAMI[7]. Another is a gamma-ray measurement of ${}^{4}\mathrm{He}(1^+ \to 0^+)$ via the ${}^{4}\mathrm{He}(K^-, \pi^-)$ reaction using a Ge detector array, Hyperball-J, at J-PARC (E13). The M1 transition energy of ${}^{4}_{\Lambda}$He was successfully measured with high accuracy thanks to the high resolution of Ge detectors ($\sim$ 5 keV(FWHM)) and the Doppler-shift-correction method by using the information of magnetic spectrometers.

We simulated the gamma-ray spectroscopy of ${}^{4}_{\Lambda}$H for following two reactions assuming at the J-PARC K1.1 beam line. ${}^{4}_{\Lambda}$H is produced (1) directly via the ${}^{4}\mathrm{He}(K^-, \pi^0)$ reaction using $p_K =$ 1.1 GeV/c beam and (2) as secondary hypernucleus (${}^{6}_{\Lambda}\mathrm{Li}^* \to {}^{4}_{\Lambda}\mathrm{H} + d$) via the ${}^{6}\mathrm{Li}(K^-, \pi^-)$ using $p_K < 0.8$ GeV/c at small momentum transfer. The former case, the development of π^0 spectrometer is essential. The latter case, Doppler correction can not be applied thus to improve sensitivity the development of tagging method of ${}^{4}_{\Lambda}$H is essential.

In this paper, the prospect and feasibility of the γ -ray spectroscopy of ${}^{4}_{\Lambda}$H will be presented.

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