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Development of the triple coincidence method of reaction, gamma-ray, and weak decay in the hypernuclear gamma-ray spectroscopy at J-PARC

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To understand the mechanism of the sizable charge symmetry breaking between ${}^{4}_{\Lambda}$H and ${}^{4}_{\Lambda}$He, we plan to measure the gamma-transition energy of ${}^{4}_{\Lambda}$H ($1^{+}\rightarrow 0^{+}$) with a high-resolution Germanium detector array (Hyperball-J) at J-PARC (E63 experiment). The ${}^{4}_{\Lambda}$H is efficiently produced as hyperfragments from the in-flight ^{7}Li (K^{-},π^{-}) reaction. However, the ${}^{4}_{\Lambda}$H hypernucleus cannot be identified well by the (K^{-},π^{-}) reaction because various hypernuclei are produced as hyperfragments in the reaction. Therefore, for identification of the hypernucleus, we will perform a triple coincidence measurement with the in-flight (K^{-},π^{-}) reaction, gamma-ray, and weak decay for the first time. We measure the monochromatic pion from their two-body weak decay (${}^{4}_{\Lambda}\mathrm{H}\rightarrow{}^{4}\mathrm{He}+\pi^{-}$) with a range counter composed of the multi-layered plastic scintillator (RC) and two layers of hodoscopes measuring pion tracks (TD).

The RC should meet two requirements. First, it is installed inside of the Hyperball-J, where the space is limited and the magnetic field from spectrometers exists. Therefore, it is necessary to optimize the detector geometry and the readout method. The area and the thickness of the counter are designed to be 275 mm × 110 mm and 6 mm × 24 layers, respectively. The readout method using wavelength shifting fibers embedded in the plastic scintillator and connected with MPPCs (multi-pixel photon counter) is adopted. Second, the RC must have a resolution of range measurement enough to distinguish between the pions from the two-body decays of ${}^{4}_{\Lambda}$H and ${}^{3}_{\Lambda}$H with a confidence level of more than 3 sigma. The momentum of pion from ${}^{4}_{\Lambda}$H is 133 MeV/c and that from ${}^{3}_{\Lambda}$H is 114 MeV/c, and the required-energy resolution is 2 MeV for the range difference of 35 mm. The tracking device (TD) has two layers (TD-Y, TD-Z) of strip-shaped plastic scintillators with a 15 mm width, and it is installed in front of the RC.

We fabricated a prototype range counter with a thickness of one-third of the full of detector for E63 and conducted a test experiment at the K1.8 beamline at J-PARC using π^{-} and proton beams. As a result, we found that the prototype had the ability to measure the pion energy accurately enough in the energy region required for E63. Based on the results, we are currently fabricating a whole set of the RC and the TD for the beamtime coming near future. This method will enable gamma-ray spectroscopy of various hyperfragments which cannot be produced by (K^{-},π^{-}) or (π^{+},K^{+}) reactions.

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