Isotope identification in nuclear emulsion plate for double-hypernuclear study

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Double-Λ hypernuclei and twin single-Λ hypernuclei are quite important objects, since they give us the Λ-Λ and Ξ-N interaction. In the KEK-E373 experiment, only the NAGARA event was uniquely identified as a ${}_{\Lambda\Lambda}{}^{6}$He among seven events in nuclear emulsion, and the Λ-Λ interaction is found to be weakly attractive in the s-shell double-Λ hypernucleus.[1), 2)] To understand the Λ-Λ and Ξ-N interaction in a unified way up to the p-shell nuclei, it is necessary to uniquely identify as many nuclides as possible. For such detection, we find that the recognition of daughter particles from the decay of the double-Λ hypernucleus is key issues. It can be very useful for ionization-loss measurement, which will be reflected in particle-track thickness or width in the emulsion. Although the relation between energy losses, dE/dx, and their ranges has been calibrated by specific a rays with monochromatic energies of natural radioisotopes in the emulsion, we have no experience in recognizing the relation between particle track widths and their charges.

To develop a particle-identification (PID) method, fully stripped particles of ^{1}H, ^{2}H, ^{3}H, ^{3}He, ^{4}He, ^{7}Li, ^{9}Be and ^{11}B were exposed to the emulsion. Those particles were produced as fragments of the ^{12}C beam with an energy of 70 AMeV and intensity of 10 pnA at the ^{9}Be target (t = 0.5 mm). Wedge-shaped degraders made of Al with a thickness of 962 mg/cm^2 and 426 mg/cm^2 were used to degrade the particle energies. Additionally, Al and Fe degraders, which were combined with several thickness plates, were installed to get suitable particle energies for stopping in the emulsion in front of the emulsion stack.

An emulsion stack had a size of 3×7 cm^2 and a thickness of 6 mm, and was exposed to one particle with a density of nearly 10^4 particles/cm^2. To obtain the parameter for calibrating a track haloes depending on the incident angle θ, all emulsion stacks were exposed with angles of $\theta = 0^o$, 25^o, 50^o, 75^o. We exposed ^{1}H horizontally ($\theta = 90^o$) to all emulsion plates as a baseline of track width, which depends on the optical and photographic development conditions on plate by plate of the emulsion.

The raw image taken with a CCD camera attached to an optical microscope is shown in Fig.1 a). Based on this image a), the blurred image of b) by Gaussian kernel was obtained. By subtracting the blurred image b) from the raw image a), an image of c) with a uniform background was obtained. In this image c), the track width was defined as the distance between two inflection points, which were obtained from the brightness distribution by using the fitting function, $F{=}A{*}\tanh(\mathrm{Gauss}(x,\mu,\sigma))$. We assumed a track to be made of many cylinders with a thickness of 1 μm, and obtained the track volume as collection of cylinders.

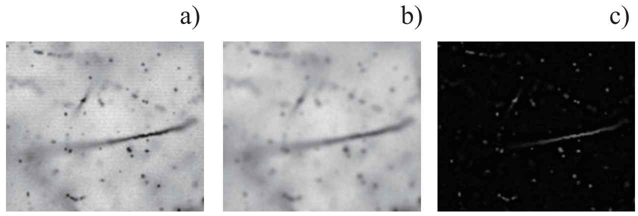

Fig. 1. Process to obtain track width with uniform background from a) to c).

The volumes of five nuclides ($\theta = 75^o$) were obtained along the track between 10 μm and 100 μm from the stopping point. Since the track width becomes narrow near the stopping point, we omitted the track volume around there. Two large volumes, which would suddenly appear, were removed among the ten cylinders, and the average volume in an interval of 10 μm was obtained from the eight cylinders. The preliminary result on the volume ratios for the five nuclides of ^{1}H, ^{4}He, ^{7}Li, ^{9}Be and ^{11}B corresponding to horizontally exposed ^{1}H ($\theta = 90^o$) is shown in Fig. 2. Although the recognition for the different charged particles seems good around 100 μm in three standard deviations, it is quite necessary to develop the analysis in the region near the stopping point. Data fluctuation around there causes worse convergence in a more short range region.

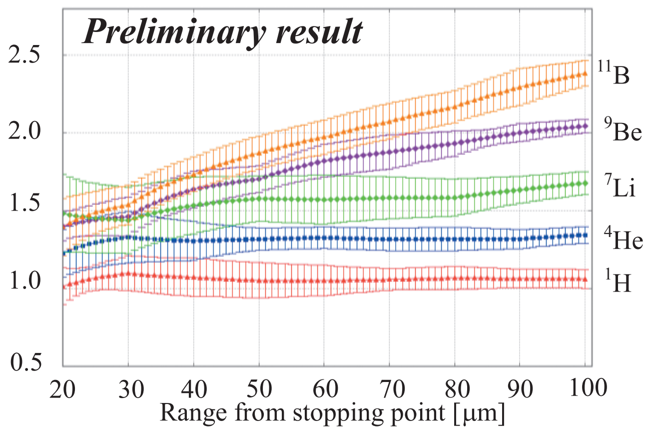

Fig. 2. Volume ratio for each nuclides ($\theta = 75^o$) to ^{1}H ($\theta = 90^o$) .

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