Isotope identification in nuclear emulsion plate for double-hypernuclear study (isotope track-angle dependence)

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Double-Λ and Ξ hypernuclei, so-called double hyper nuclei, are quite important sources to understand baryon- baryon interaction in a unified manner under $SU(3)_f$ symmetry. Although the Nagara event [1,2] and the Kiso event [3] were the uniquely identified samples for the sequential decay of the double-Λ and Ξ hypernucleus, respectively, knowledge from them has thus far been limited. To systematically study double-strangeness nuclear physics, it is necessary to detect as many uniquely identified double hypernuclei as possible in the emulsion. Therefore, we are going to develop a method for the identification of daughter nuclei from the decay of double hypernuclei by measuring their ionization losses from the viewpoint of track width under a microscope. However, the widths can be changed by the defocusing halo image, which will depend on the track angle in the emulsion, even for the same nucleus. In this report, we will present a preliminary result on the angle dependence of track widths.

Nuclear emulsion sheets (3 × 7 cm^2) were irradiated by 8 nuclear species with charges from one to five, which were ^{1}H, ^{2}H, ^{3}H, ^{3}He, ^{4}He, ^{7}Li, ^{9}Be, and ^{11}B, at RIPS (NP1406-RRC32). Carbon (^{12}C) at 68 MeV/nucleon and 10 pnA was incident on a ^{9}Be target with 0.5-mm thickness. To nominate the secondary nuclides, we utilized wedge-shaped degraders of 962 and 426 mg/cm^2 and iron and/or aluminum plates in front of the emulsion stack. The stacks consist of 6 emulsion sheets, where the sheet size is 30 (x) × 70 (y) × 1 (z) mm^3. The z-direction was at angles (θ) of 0°, 25°, 50°, and 75° with respect to the beam direction (z'). To understand the angle-dependent effect for the width, the stack exposed by ^{1}H was studied.

To measure track widths, we developed a method for image processing with the help of OpenCV24-11. Firstly, we produced a track image consisting of the most focused points in sliced track images taken by moving a 100× objective lens with an 8-bits CCD camera at a pitch of 0.1 μm along the optical axis (z). In Fig. 1 (a), a sliced image is presented. To obtain the most focused point of the track, we applied a Gaussian function for the track illumination of the image along the z direction and obtained the minimum sigma value by fitting with a quadratic function in sigma data, as shown in Fig. 1(b). By summing up those images, the most focused image of a track can be obtained as shown in Fig. 1(c).

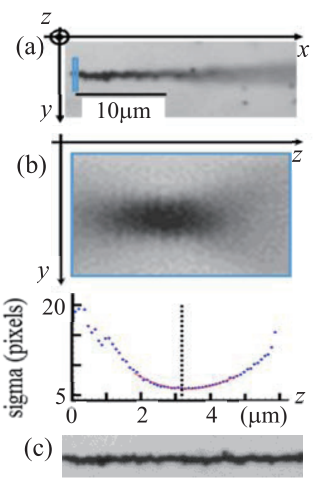

Fig. 1. Process for producing a focused image of the track.

Secondly, we measured the widths along the track as follows. A Gaussian operator is applied to the contrast-enhanced image of Fig.1 (c) to obtain a blurred image with a kernel size of 47 × 47 pixels, where the size of one pixel is 0.080(x) × 0.080(y) μm^2. Each of those images is shown in Fig. 2(a) and (b), respectively. To obtain a uniform background, we produce the image shown in Fig.2 (c) by subtracting Fig. 2(a) from (b). We apply the function $F(x) = A \cdot \tanh(\mathrm{Gauss}(x,\mu,s))$ for the brightness of Fig. 2(c) in each pixel line vertically along the x direction. The width can be obtained as the distance between inflection points of the applied function, as shown in Fig. 2(d).

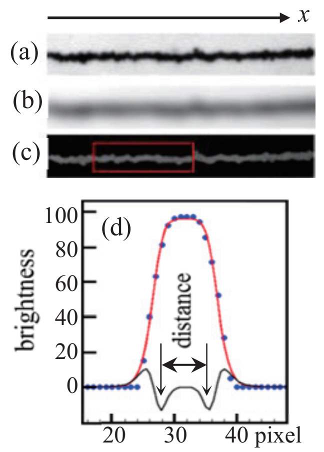

Fig. 2 Process for obtaining track width.

Finally, we set a window with 2-μm range along the track and acquire the minimum track width, so-called *minimum tracking*, to avoid accidental grains associated with the track. The window is shifted by 1 pixel in the range of 10 to 100 μm from the stopping point, and a sample of measured widths is shown in Fig. 3 for the area shown in the box of Fig. 2(c). The dotted line and the solid line are the widths based on the distance between inflection points and for minimum tracking, respectively.

Assuming the track is constructed by many cylinders with the diameter of the width given by the minimum tracking, we obtain the track volume by summing such cylinders. The measured result for track volumes is shown in Fig. 4, for ^{1}H with θ = 0°, 25°, 50°, and 75°. As a preliminary result, we obtained a clear angle dependence ($\log(1/\sin\theta)$) of the track volume measured by our microscope. In the near future, this work should be applied for other nuclides, and the method for their identification with angle dependence will be published.

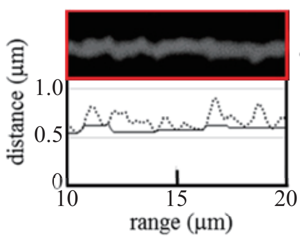

Fig. 3. Minimum tracking.

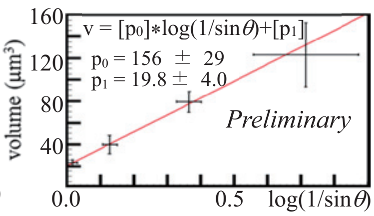

Fig. 4. Angle dependence of volume.

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