Isotope identification in nuclear emulsion plate for double-hypernulcear study[†]

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Double hypernulcei such as double-Λ and Ξ hypernuclei provide information about Λ-Λ and Ξ-N interactions, which are important to understand the inner structure of a neutron star. We have only two reliable information from the NAGARA[1,2] and KISO[3,4] events in the E373 experiment. Other events are not uniquely identified for the production and decay processes owing to the remaining possible interpretations. The charge identification method is a key technique to understand the multi-strangeness system.

To develop the method, we exposed eight nuclides (^{1}H, ^{2}H, ^{3}H, ^{3}He, ^{4}He, ^{7}Li, ^{9}Be, and ^{11}B) to a nuclear emulsion at RIPS. To study the halo effect in the finite focal depth of objective lens, the exposed angle θ perpendicular to the emulsion surface was set to be $\theta \approx 25°$, 50°, and 75°.

To recognize the charge of the particle, we measured the track width and estimated the track volume that reflect the energy-losses. Raw images were taken by microscope with a 100× objective lens and an 8 bits CCD camera. A focused image, as shown in Fig. 1(a), consists of the most focused layers of raw images. Figure 1(b) is illustrated according to the following equation, $B_{\text{out}} = 255 \times (B_{\text{in}} - B_{\text{min}})/(B_{\text{max}} - B_{\text{min}})$, where B_{in}, B_{max}, and B_{min} are the brightness of each pixel, maximum, and minimum brightness in Fig. 1(a), respectively. B_{in} was enhanced to B_{out}. Figure 1(c) was illustrated by applying an algorithm called "difference of Gaussian" to Fig. 1(b). Then, a uniform background image was obtained by subtracting Fig. 1(b) from 1(c), as shown in Fig. 1(d). We measured the brightness perpendicular to the track in the Fig. 1(d) and defined the track width as a distance between two inflection points, which were obtained by applying a fitting function, $f = a \times \tanh(\text{gauss}(x, \mu, \sigma))$, to the data in Fig. 1(e).

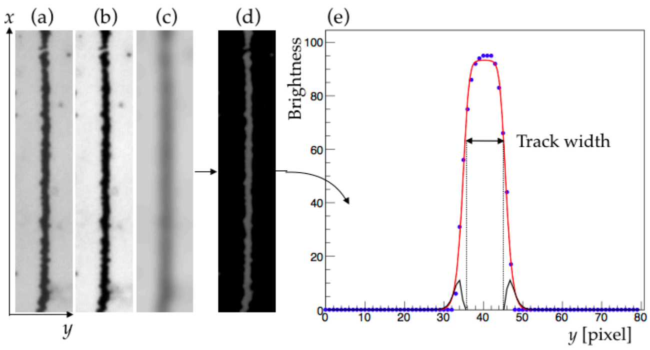

Fig. 1. Image processing method to obtain track width.

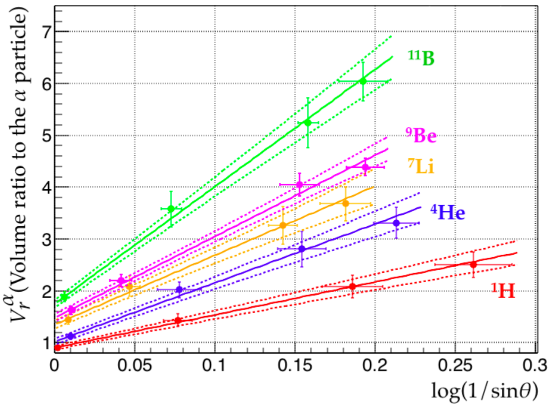

Fig. 2. V_r^α of each nucleus to α particle as a function of log(1/sinθ).

The track width depends on the photographic development. As a calibration source, we used α particles which have monochromatic kinetic energy emitted from natural isotope ^{212}Po in the emulsion. We obtained the calibration function of $v^\alpha(d)$ with 68 α-particles, where v^α is the average track volume of an α-particle at depth d from the emulsion surface.

The widths were measured for every 1 μm cell along the track. Because the depths of the measured cells changed along the track, a volume ratio V_r^α to normalize the α-particle for each nucleus was obtained for measured volume V_i in ith cell as $V_r^\alpha = \sum_{i=1}^{90} V_i / \sum_{i=1}^{90} v^\alpha(d_i)$, where d_i is the depth of the ith cell. We put 200 tracks together at four areas for each nucleus in the exposed emulsion and fitted them according to log(1/sinθ), where we set log(1/sinθ) to be ξ, as angle dependence of the volume ratio, $V_r^\alpha(\xi)$, to the volume of the α particle, as shown in Fig. 2.

To confirm the utility of the above method, it was applied to one track of a Ξ hypernucleus candidate detected in the E373 experiment. The nucleus of this track is known as ^{3}H or ^{6}He by kinematical analysis. Their V_r^α can be estimated by the data points of ^{1}H and ^{4}He. Thus, we concluded that the nucleus would be a ^{6}He nucleus with a likelihood ratio of 0.9.

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