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Scanning systems for searching double strangeness nuclei in nuclear emulsion

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Scanning systems for detecting double Lambda hypernucler events in nuclear emulsion plates with high statistics are presented. The systems are complexes of optical microscopes and computers to provide fast emulsion scanning and image recognition for vertex-like objects. We recently introduced a two-stage process of vertex detection to exclude misdetected objects. The method can be expected to reduce conventional eye-check works and increase search speed for double Lambda hypernuclear event.

KEYWORDS: Double Lambda Hypernucleus, Nuclear emulsion

1. Introduction

Double Λ hypernucleus is one of the most important subjects to investigate baryon-baryon interaction. The mass measurement of double Λ hypernuclei is a unique experimental approach to obtain the information about the Λ-Λ interaction, which is the doorway to understand the hyperon-hyperon interaction. The first double Λ hypernucleus was observed in a nuclear emulsion plate exposed by cosmic ray [1]. In KEK-PS E176, the existence of the double Λ hypernucleus was confirmed among nearly 80 Ξ^- hyperon stopping events [2]. In KEK-PS E373, seven events of double Λ hypernuclei were detected among several hundreds' Ξ^- hyperon stopping events [3].

Nuclear emulsion plate has been the most suitable detector to study double Λ hypernucleus. It is a photographic film, which records the tracks of charged particles. After photographic development, the tracks are observed as sequences of black dots or lines in the emulsion layer through an optical microscope with high accuracy of sub micro meters. The production and the chain decays of double Λ hypernuclei can be visible by fine spatial resolution of the emulsion. A double Λ hypernuclear event shall be seen like a branch, which consists of several black tracks and three vertices as shown in Fig. 1.

2. New searching method for double Λ hypernucleus

2.1 The hybrid emulsion method and Overall scanning method

A new searching method is being developed to increase the statistics of double Λ hypernuclei in the emulsion. By using the new method named Overall scanning, we search characteristic features which consist of three vertices with image processing [4,5].

The previous experiments about double Λ hypernuclei were performed with the hybrid emulsion method. In this method, firstly, electric particle detectors tag quasi-free '*p*'(K^-,K^+)Ξ^- interactions. Secondly, we follow the tracks of the Ξ^- hyperons in stacked emulsion plates. This method was the best way to reach double Λ hypernuclei with minimal emulsion observation. However, the tagging efficiency of a K^+ meson by the spectrometer is estimated as about 30%. Besides, '*n*'(K^-,K^0) Ξ^- reactions are not triggered. We aim to detect such un-triggered, latent double Λ hypernuclear events in the emulsion with another approach.

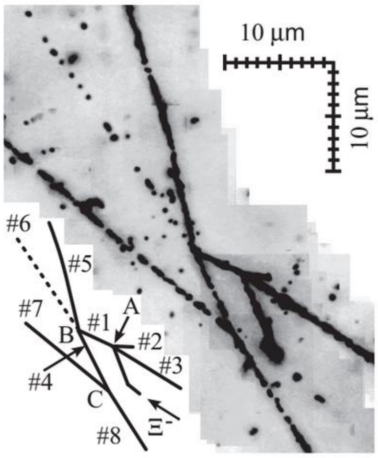

Fig. 1. A micrograph and a schematic drawing of a typical double Λ hypernuclear event named Nagara event. Double Λ hypernuclear event has a characteristic feature which consists of three vertices.

2.2 Image taking and image processing

We have been developing an optical microscope as shown in Fig. 2 to scan the entire volume of thick-type and large-sized emulsion plates. Computer-controlled motors drive the large microscope-stage. A high-speed and -resolution camera takes micrographs of the tracks through 20x objective lens. The dimension of the field of view is 1140 x 200 μm^2. This relatively wide field of view is reasonable in terms of scanning speed.

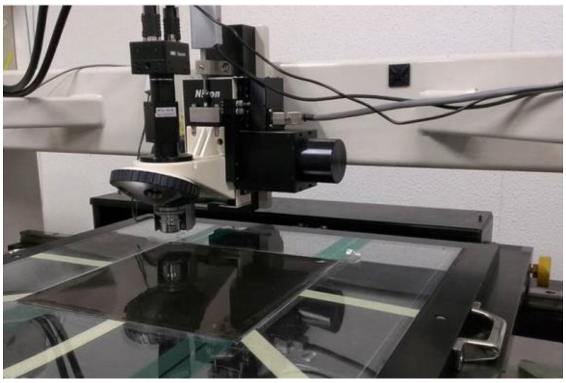

Fig. 2. A dedicated optical microscope to scan the entire volume of thick-type and large-sized emulsion plates.

Besides, we have been developing an image processing to pick up vertex-like shapes. The image processing performs high-pass filtering, binary thresholding and line detection to micrographs. Finally, this image processing selects clusters of lines situated radially as vertex candidates. There are about 20 parameters of the series of image processing. These parameters are tuned to detect some alpha decay events and typical double Λ hypernucleus such as Nagara event [6,7] and Kiso event [8]. This scanning system which is a complex of computer and the microscope was named as "Vertex picker".

By this primary image processing, $3\text{x}10^3$ objects were selected in 10 x 10 x 0.9 mm^3 volumes of an emulsion plate of the E373 experiment. We previously applied eye-check work to screen them. The screening speed is about 2.5 x 10^3 events per hour. Among them, 58.4 +- 0.4% of the objects were not vertex i.e., miss-recognition of cross tracks. 32.8 +- 0.3% were hadronic interactions between a beam particle and a nucleus in the emulsion layer. Others were alpha decay event and black object which is not attributable to nuclear interaction on the surface of the emulsion. The fraction of 2-vertex-events was 0.3%.

2.3 Secondary selection

The secondary image taking by a 50x lens is applied to the selected objects. A schematic view of the two-stage process is described in Fig. 3. By the 50x objective lens, the dimension of the field of view is 130 x 110 μm^2 and the resolution is 0.26 μm per pixel. This resolution, which is twice higher than the optics for the primary image taking is suitable to discriminate between cross track and vertex.

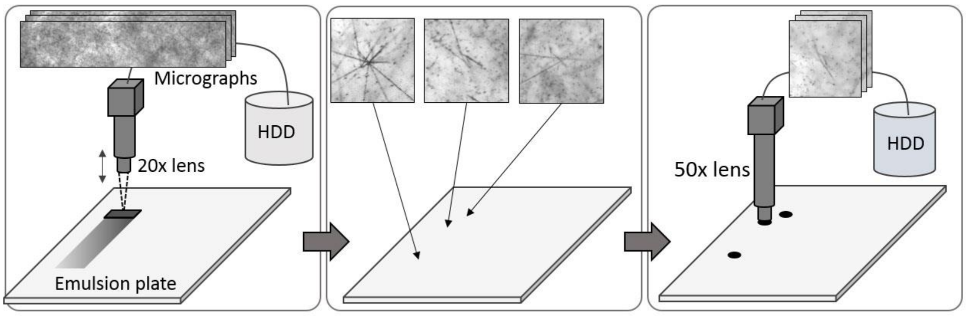

Fig. 3. A schematic drawing of the primary and secondary selection for vertex-like objects in an emulsion plate. Left: The primary image taking under a 20x objective lens. Middle: detected objects via the primary selection. Right: The secondary image taking for each object to discriminate vertex and non-vertex under a 50x lens.

We launched a scanning software for the secondary image taking. This software takes cross-sectional micrographs for each object detected by the primary selection. The locations of the scanning points are calibrated by "grid-marks" printed on the emulsion plates in every 1 cm^2. The accuracy of position is 5.7 μm, therefore the target object shall be located around the center of the field of view. The speed of image taking is 8 events per minute. The scanning system continues the task of image taking for about 6 hours for $3\text{x}10^3$ candidates in 10 x 10 x 0.9 mm^3 volumes.

The secondary image processing is applied for the micrographs. Several cross-sectional micrographs which is equivalent to 30 μm thickness of the emulsion layer are projected onto a superimposed image to make an appropriate focal depth. The procedure is almost the same to the primary process. The parameters of the secondary process are optimized to detect alpha decay events and typical double Λ hypernucleus.

After the secondary process, the surviving ratios for one-vertex and cross track events were 83.1 +- 6.1% and 37.4 +- 1.8%, respectively. The total event number was reduced to 44.7 +- 1.8%. This two-stage process seems to be effective to discriminate cross track without eye-check work. Currently, we have been investigating the detection efficiency of multi-vertex events by this two-stage process.

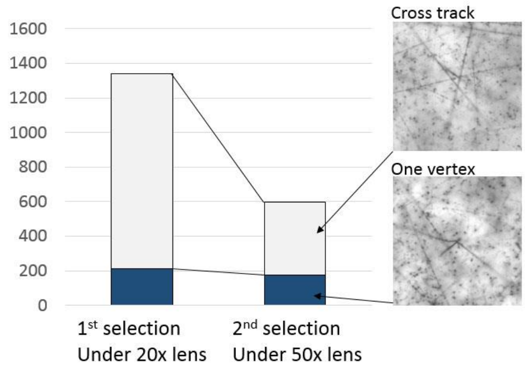

Fig. 4. The number of events of one vertex and cross track events for the primary and secondary selection in a volume of an emulsion plate.

3. Conclusion

We have been developing a new scanning system named “Vertex picker” to search for double Λ hypernuclear events in nuclear emulsion plates. An image process picks up vertex-like shapes from micrographs of the emulsion. Vertex selection is performed via two-stage process, i.e., primary selection of 20x image and secondary selection of 50x image. The two-stage process is able to exclude misdetected objects effectively. Therefore, this method can be expected to reduce conventional eye-check works and increase search speed for double Λ hypernuclear event.

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