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The Alignment Method of The Emulsion Plates for Ξ^-Hyperon Tracking on J-PARC E07

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In the J-PARC E07 experiment, we will search for double Λ hypernuclei. Double Λ hypernuclei are produced via capture reaction of Ξ^- hyperons in nuclear emulsion sheet. Tracks of Ξ^- hyperons are followed with a newly developed automated track following system. A technique for position alignment of adjacent emulsion sheets has been developed by using pattern matching of beam tracks within 1μm at 10^{-5} error rate.

KEYWORDS: J-PARC E07 experiment, Double Λ hypernuclei, Emulsion, Automatic tracking, Beam pattern matching

1. Introduction

In the J-PARC E07 experiment, it is planned to detect double Λ hypernuclei with 10 times higher statistics than the previous experiment, KEK-PS E373. Double Λ hypernuclei are produced via capture reaction of Ξ^- hyperons by nuclei in nuclear emulsion, where the Ξ^- hyperons are produced by quasi-free 'p'(K^-, K^+) Ξ^- reaction in a diamond target located upstream of the emulsion sheets. To avoid time-consuming job by human, candidate tracks of Ξ^- hyperons can be followed with a newly developed automated tracking system.

An emulsion stack consists of 12 emulsion plates with 0.5mm thick emulsion coated on both sides of a thin polystyrene film. For the success of the automated tracking of Ξ^- hyperons, accurate plate-by-plate alignment of the emulsion plats is an essential task.

2. Parameter Tuning of Beam Pattern Matching

2.1 Required Conditions for Pattern Matching

Technique of precise plate-by-plate position alignment has been developed with pattern matching of beam tracks which were recorded in emulsion plates. When there are more than 100 spots of the beams in one view of microscope (110×130 μm^2), it determines successful connection of the track satisfying the following three conditions. First, it is required that all the 740 test samples of track connection must be correctly connected. Second, in J-PARC E07 it is necessary that the probability of mistaken track

connection to be less than 10^{-5}. Third, the position accuracy of alignment between plate-by-plate is less than 1 μm.

2.2 Beam Pattern Matching

Beam pattern matching is composed of three steps. The first step is perpendicular track recognition from cross-sectional micrographs. Secondly, (x, y) differences between each beam spot on one plate and all beam spots on the next plate (Fig.1 left) are plotted for a round-robin fashion (Fig.1 center). In this plot, data aggregate as a 2D peak at the (x,y) position, which gives the (x,y) offset between the two plates (Fig. 1 right). Finally, the significance of the 2D peak is evaluated from a probability that the peak is produced from random background around the peak.

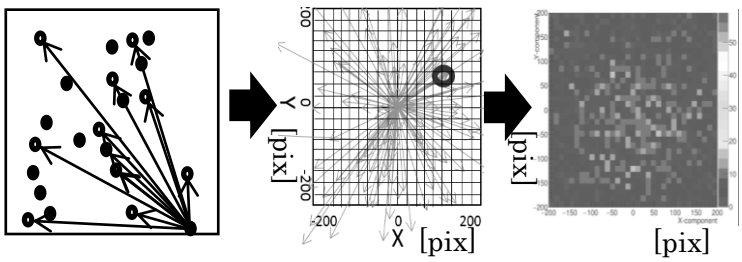

Fig. 1. Technique of pattern matching

2.3 Optimization and Performance

The image samples of 740 connections are collected for optimization. Fig. 2 is the distribution of the probability, P, that the detected peak is produced from random background, which corresponds to the probability of misconnection. Then it was compared with the average of the histogram for various parameter combinations. The optimized beam pattern matching efficiency and the position accuracy of alignment were evaluated. Fig. 2 shows that the tracks can be correctly connected with the efficiency of 100% because there is no sample that is stochastically below $-\mathrm{Log}_{10}(P) = 5$, the probability for one misconnection out of the total connections in E07 ($\sim 10^5$). Alignment accuracies are found to be 0.82 μm and 0.57 μm in x and y projection, respectively.

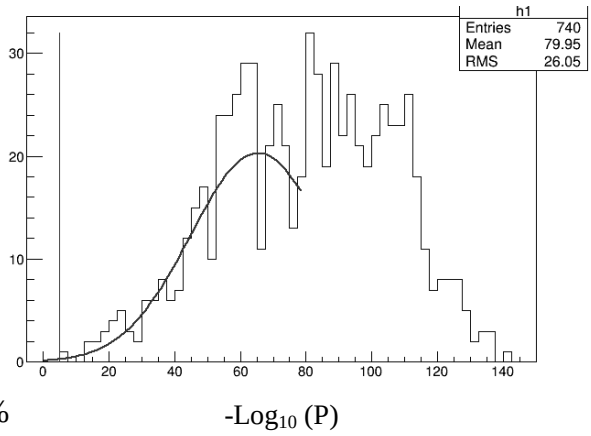

Fig.2. Probability of misconnection, P, plotted in log scale for 740 connection samples.

3. Conclusion

We have developed a method for beam pattern matching between the emulsion plates. The alignment accuracies are 0.82 μm and 0.57 μm. The position accuracy of alignment between plate-by-plate could be less than 1 μm in full area of the emulsion plate with a size of 23×23 cm^2. The results fulfil the three conditions and indicate sufficient performance for the automatic track following for J-PARC E07.