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Event Categorization in Nuclear Emulsion of E373 Experiment

Khin Than Tint*

Abstract

KEK-PS E373, a hybrid emulsion experiment, was performed using a separated K^- meson beam of momentum 1.66GeV/c at High Energy Accelerator Research Organization (KEK) proton synchrotron (PS). The purpose of this experiment is to study S= -2 nuclei produced via Ξ^- hyperon captured at rest in nuclear emulsion with ten time larger statistics than the previous experiment (E176). Tracks of the Ξ^- hyperon candidates were searched for and traced in the emulsion using a newly-developed automatic track scanning system. We have analyzed nearly 90% of the total emulsion by automatic and semiautomatic scanning methods. We have found 7 double-Λ hypernucleus events, 2 twinΛ-hypernuclei events and 33 single-Λ hypernucleus events.

Key words: KEK, double-Λ hypernucleus, twin Λ–hypernuclei

Introduction

The experimental purpose was to study nuclei with two units of strangeness (S = -2), i.e, double- Λ hypernucleus, twin Λ–hypernuclei, and the *H*-dibaryon, produced via Ξ^- hyperon capture at rest in the emulsion with ten time statistics than those of the previous experiment. In this experiment, Ξ^- hyperons produced in a diamond target via quasi-free (K^-, K^+) reactions. The Ξ^- hyperons were brought to rest, captured by nucleus and could form compound nucleus with S = -2 in the emulsion. At the decay of the nucleus, a double-Λ hypernucleus, twinΛ–hypernuclei, single-Λ hypernucleus or *H*- dibaryon (if exist) is emitted.

The existence of double -Λ hypernucleus is very interesting because it gives valuable information on Λ–Λ interaction and is deeply related to nuclear system with double strangeness (S=-2 system) such as Ξ^- hypernucleus and an H-particle. In the 20th century, double-Λ hypernucleus events were reported by three experimental groups with nuclear emulsion. In 1963, Danysz *et al.* reported an event of the sequential weak decay of a double-Λ hypernucleus (Danysz,1963). In 1966, the event reported by Prowse claimed that a ${}^{6}_{\Lambda\Lambda}\mathrm{He}$ nucleus was uniquely identified in

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the emulsion. However, for this event, only the schematic drawing was given and measured angles were not presented in the literature. In 1980's, an emulsion counter hybrid experiment, the E176 experiment was carried out at the KEK 12GeV Proton Synchrotron (KEK-PS) to study double strangeness nuclei. They confirmed the existence of a double-Λ hypernucleus in nearly 80 events of Ξ^- hyperon capture at rest. Unfortunately, identification of the nuclear species of the double-Λ hypernucleus was not unique. An interpretation is a ${}^{10}_{\Lambda\Lambda}\mathrm{Be}$ nucleus and another one is a ${}^{13}_{\Lambda\Lambda}\mathrm{B}$ nucleus [Aoki, 1991].

In E373 experiment, we have detected 7 double-Λ hypernu- cleus and 2 twin Λ–hypernuclei events. Among them, "NAGARA event" was uniquely identified as sequential weak decay of a ${}^{6}_{\Lambda\Lambda}\mathrm{He}$ nucleus [Takahashi, 2001]. E373 experiment reported the analysis of two twin Λ-hypernuclei events. In this paper, event categorization in nuclear emulsion is presented.

Nuclear Emulsion

The emulsion was the key detector to observe the production and the decay of the S= -2 nuclear system. Total one hundred stacks made of 69 liters emulsion gel were used. Each stack was composed of eleven (for first ten stacks) or twelve (for the rest stacks) plates with the area of 250×245 mm^2. Fig.(1) represents the constitution of the emulsion stack. Each emulsion stack was named "module". Each plate was made by coating Fuji ET-7C or ET-7D emulsion gel on both sides of an acrylic or polystyrene film.

One stack of emulsion is composed of one thin plate (plate#1) and ten or eleven thick plates (plate#2~ pl#11or #12). The most upstream plate (thin plate) with 70 μm or 100 μm thick emulsion on both sides of 200 μm base worked for the connection of Ξ^- hyperon tracks from the SciFi-Bundle detector to the emulsion. Each of the thick plate has 500 μm thick emulsion on both sides of a 50 μm or 40μm thick base. The thick plates were used for the production and analysis of the S=-2 system by Ξ^- hyperon captured reaction in emulsion. Photographs of thin type and thick type nuclear emulsion plates are shown in Fig.(2). The emulsion gel was Fuji ET-7C and Fuji ET-7D, which were developed by Fuji-film and Gifu University. The composition of the emulsion is listed in Table (1).

All emulsion plates were prepared in Gifu University. Emulsion gel was poured on one side of the plastic films in the area of $510\times515\ \text{mm}^2$. They were dried in a drying cabinet which moved emulsion plates automatically so that they were dried uniformly. After drying the emulsion gel on one side, gel was poured on the other side of the plates and dried in the same manner. Then, the emulsion plates were dried again with lower humidity (60% R.H). Finally, each of the emulsion plates was divided to four plates with the size of $245\times250\ \text{mm}^2$.

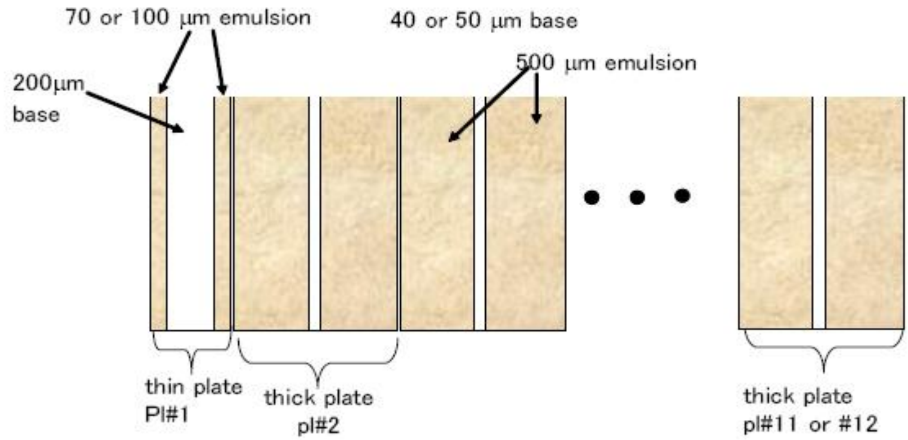
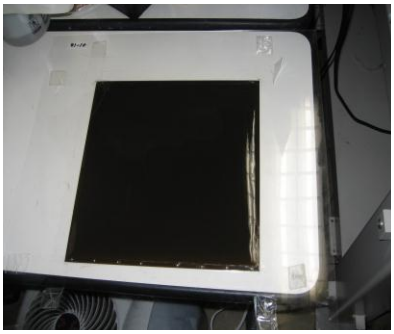


Fig.(1) Constitution of a stack of emulsion (side view).

(a)



(b)

Fig. (2) Photographs nuclear emulsion plates (a) thin type (b) thick type

Table (1). The composition of the Fuji ET-7C and Fuji ET-7D emulsion.

material	**weight ratio(%)**	**mol ratio(%)**
I	0.3	0.06
Ag	45.4	11.2
Br	33.4	11.1
S	0.2	0.2
O	6.8	11.3
N	3.1	5.9
C	9.3	20.6
H	1.5	40.0

Emulsion Scanning Method

Ξ^- hyperon tracks were searched for in the thin type plate (Pl#1) automatically under the guidance of the position and angles predicted by the SciFi-bundle detector. The automatic system was controlled by a personal computer equipped with an image processing board, motor-control board, parallel I/O board, and D/A board. The photograph of the system is shown in Fig. (3). Before the automatic scanning, the surface of the thin plate was wiped by tissue with ethyl-alcohol. For setting the emulsion plate on the microscope stage, four side of the plate was fixed by cellophane tape on acrylic plate with the thickness of 1mm.

A Ξ^- hyperon track was searched for in $900 \times 900\,\mu\text{m}^2$ area typically around the predicted position in the thin-type emulsion plate. The searching angle region (tanθ) was ± 0.1 around the predicted angle. Tracks having the predicted angle were searched for in the emulsion plate of the upstream side. Once a track was found in the upstream, a track with a same angle was searched for at the corresponding position in the downstream emulsion. If a track was found in both sides of the emulsion of the plate, it was accepted as a track candidate Ξ^- hyperon. More than one candidate track can be found for each prediction by the SciFi-Bundle. The candidate tracks in the plate#1 were checked by human eyes.

The low momentum Ξ^- hyperon tracks are deflected by the multiple scattering, so the efficiency of the automatic track-finding system is not sufficiently high in thick type emulsion plates. Therefore, the scanning result was checked individually by human eyes. The scanning method in thick type emulsion (pl #2 ~ pl#11 or pl #12) is called 'semi-automatic scanning'. The preparations for 'semi-automatic scanning' are of the same manners in the case of the thin plate. In the following of the Ξ^- hyperon track in pl#2, we used the position and angle data obtained in Pl#1 and checked by eyes to avoid miss tracing by the system. Ξ^- candidate tracks were scanned and traced emulsion sheet by sheet to those stopping points using the semiautomatic scanning system.

Fig. (3). A photograph of the microscope system

Event Categorization

We categorized the followed tracks according to their topologies at the end points, as follows.

σ-stop: The traced track was dizzy due to multiple scattering near the stopping point and came to rest with the emission of at least one charged-particle. Four categories of σ− stop according to their vertices are shown in Fig.(4).

ρ-stop: There are no evaporation tracks at the end point of dizzy track. This is also a candidate for Ξ^- hyperon capture event, however it is not easy to clarify the event due to Ξ^- hyperon capture without Auger electron emission. A schematic drawing of the ρ stop event is shown in Fig. (5).

decay: A thin track is emitted at the end of a straight track. The event is assigned as the decay of the Ξ^- hyperon into a π^- meson (visible) and a Λ hyperon (invisible). A schematic drawing of one of the decay events is shown in Fig. (6).

beam interaction: Reaction of a beam particle on emulsion nuclei. The traced track is straight and reaches a reaction vertex and associates with a beam track. A beam track can be identified as a thin track almost perpendicular to the emulsion plate. A schematic drawing of beam interaction is shown in Fig. (7).

secondary interaction: The traced particle track is straight and reaches the reaction vertex without any beam-like tracks. The event is categorized to secondary interaction, in-flight interaction with emulsion nuclei. If the vertex a thick and dizzy track accompanies, it could be stop of a Ξ^- hyperon produced via the (K^-, K^+) reaction in the emulsion stack. In that case, the traced track can be a fragment with high momentum emitted from the Ξ^- hyperon capture point or decay of hypernucleus. A schematic drawing of secondary interaction is shown in Fig. (8).

other: Other than above categories is named as other event. For example, if a traced track is dizzy and comes to rest, from which one charged particle track is emitted(~600 μm), and that charged particle decay again into a thin track (eg. $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ event). A schematic drawing of one of the $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ events is shown in Fig. (9).

lost: The followed track could not be detected on the surface of the following plate.

lost in base: The traced track was lost in 40 or 50 μm thick base.

through: The traced track left from the bottom plate emulsion without any interaction.

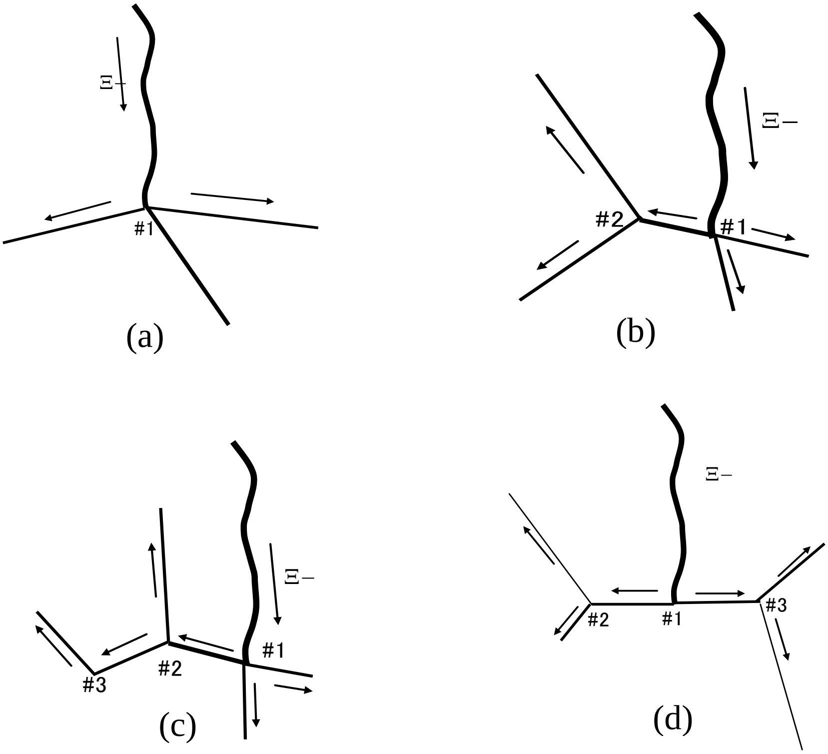


Fig. (4). Schematic drawing of σ−stop events, (a) σ−stop with No-Hyper(one vertex), (b) σ−stop with Single-Λ Hypernucleus (two vertices) (c) σ−stop with Double-Λ hypernucleus (three vertices) (d) σ−stop with Twin Λ-hypernuclei (three vertices).

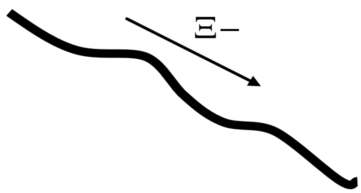


Fig. (5). A schematic drawing of ρ stop event

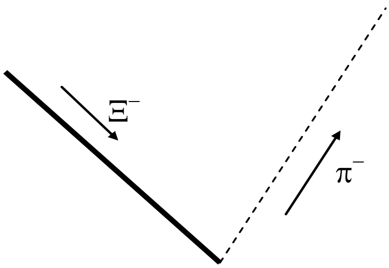


Fig. (6). A schematic drawing of decay event

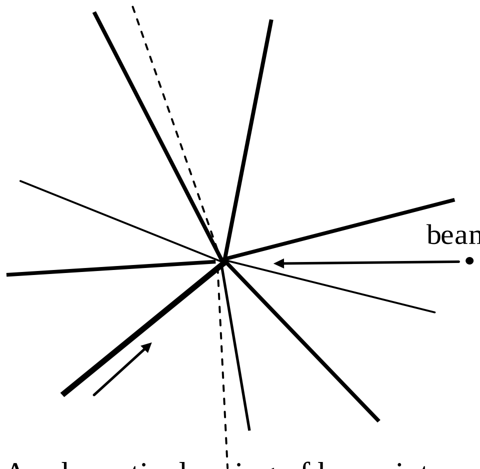


Fig. (7). A schematic drawing of beam interaction

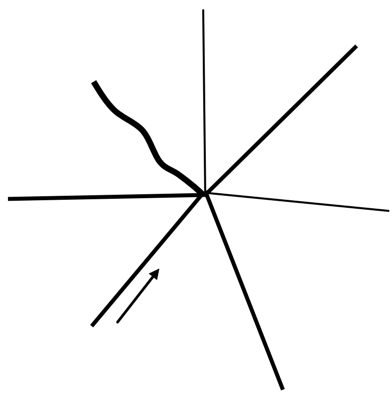


Fig. (8). A schematic drawing of secondary interaction

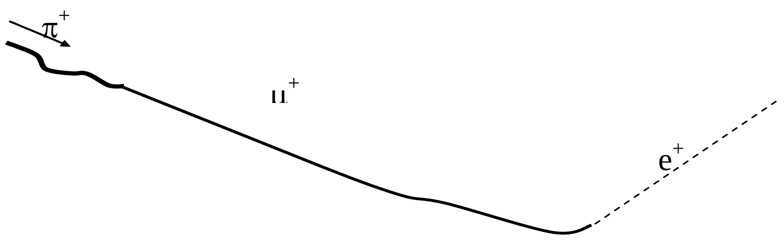


Fig. (9). A schematic drawing of $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ event

Scanning Results

The scanning result of nearly 90% data of total emulsion is described in Table (2). We have found seven double- Λ hypernucleus events and two twin Λ- hypernuclei events and 33 single Λ hypernucleus events. Photographs of one of the double- Λ hypernucleus events, twin Λ-hypernuclei events and 33 single Λ hypernucleus events are described in Fig.(10), (11) and (12), respectively.

Table (2) Result of the categorization of the vertices

# of Mod.	**88**
# of event	14383
# of pred.	24190
# of tracks	48396
σ- stop	1080
ρ-stop	15684
through	19448
decay	1011
Single-Λ Hypernucleus	33
Twin Λ-hypernuclei	2
Double-Λ hypernucleus	7

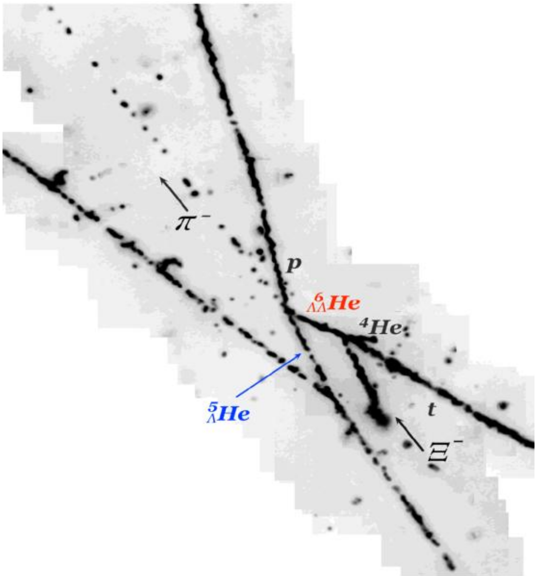


Fig.(10) Photograph of double-Λ hypernucleus event

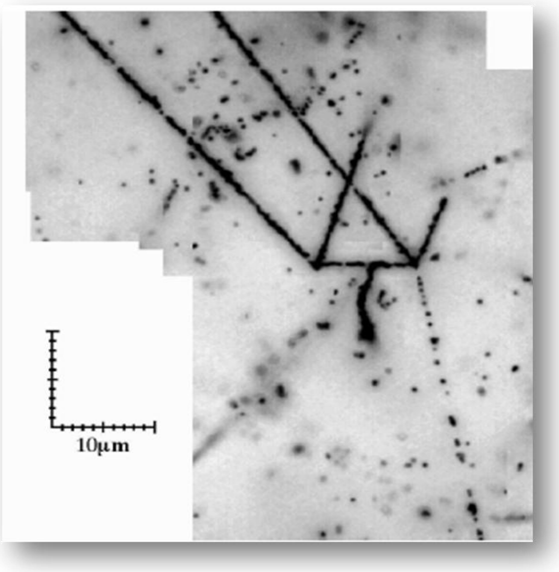


Fig.(11) Photograph of Twin Λ-hypernuclei event

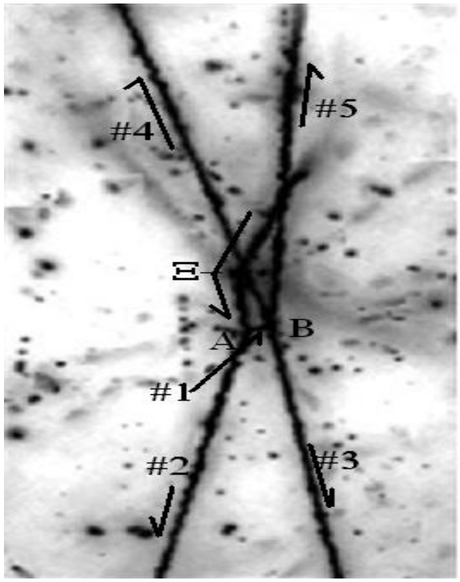


Fig.(12) Photograph of Single-Λ Hypernucleus event

Discussion and Conclusion

We have categorized the follow tracks according to their topologies at the end point for nearly 90% data of total emulsion of E373 experiment.The results are shown in Table (2). The photograph of one of the double- Λ hypernucleus events is shown in Fig. (10). Double- Λ hypernucleus event has three vertices. One vertex is the stopping point of Ξ^- hyperon or emission point of double- Λ hypernucleus and another two vertices are decay points of double- Λ hypernucleus and single Λ hypernucleus, respectively. When we found like that event, we named Double- Λ hypernucleus event. The existence of double -Λ hypernucleus is of very interest because it gives valuable information on Λ−Λ interaction and is deeply related to (S = -2) nuclear system.

One of the photographs of twin Λ- hypernuclei events is expressed in Fig. (11). Twin Λ- hypernuclei event also has three vertices. Form the stopping point of Ξ^- hyperon, two single Λ hypernuclei were emitted back to back. Then, single Λ hypernuclei decay into other particles at their vertices. Until now, we have found 2 twin Λ- hypernuclei events. The binding energy of a Ξ^- hyperon in the Ξ^- nuclear or atomic state can be measured by the observation of a twin Λ-hypernuclei event. The information of the Ξ^--N interaction can be obtained from the measurements of B_{Ξ^-}.

A photograph of single Λ hypernucleus event found in E373 experiment is shown in Fig. (12). Single Λ hypernucleus event has two vertices, Λ hypernucleus production point and decay point. In E373 experiment, we have found 33 single Λ hypernucleus events.

Event categorization in nuclear emulsion is very important fundamental work for event analysis. It also depends on reliability of scanner.

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References

Aoki S. *et.al.* (1991) . Direct Observation of Sequential Weak Decay of a Double Λ Hypernucleus, Progress of Theoretical Physics, 85(6), 1287-1298.

Danysz, M. *et al.* (1963). The Identification of a Double Hyperfragment, Nuclear Physics, 49, 121-132.

Prowse, D. J. (1966). ${}^{6}_{\Lambda\Lambda}\mathrm{He}$ Double Hyperfragment, Physical Review Letters, 17, 782.

Takahashi, H. *et al.* (2001) .Observation of a ${}^{6}_{\Lambda\Lambda}\mathrm{He}$ Double Hypernucleus, Physical Review Letters, 87(21), 212502-1.