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OBSERVATION OF A SINGLE-STRANGENESS HYPERNUCLEUS EVENT IN KEK-PS E 373 EXPERIMNT

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Abstract

A single-Λ hypernucleus event is kinematically analyzed in this research paper. The analyzed event was observed in KEK-PS E373 experiment. In this research work, a single-Λ hypernucleus was produced by the direct process of hypernuclei studies. From the experimental studies, ranges of tracks #1, #2, #3, #4 and #5 are 40.10 ± 0.30 μm, 414.93 ± 0.48 μm, 9.11 ± 0.03 μm, 9.47 ± 0.15 μm and 10800.90 ± 0.00 μm. By using these ranges, Q-value, total kinetic energy, reconstructed mass and mass difference are calculated. We checked conservation laws so that 167 decay modes are obtained. All negative Q-values are neglected as the first step of our analysis. Furthermore, comparison of Q-value and visible energy released are performed and then mass of single-Λ hypernucleus is calculated. Finally, we have obtained 13 decay modes. According to our calculated results, only two decay modes, ${}^{6}_{\Lambda}\mathrm{Li} \rightarrow \mathrm{p} + {}^{4}_{2}\mathrm{He} + \mathrm{p} + \pi^{-}$ and ${}^{6}_{\Lambda}\mathrm{Li} \rightarrow \mathrm{p} + \mathrm{p} + {}^{4}_{2}\mathrm{He} + \pi^{-}$ are possible with the same single-strangeness hypernucleus. Due to the percentage of mass difference, ${}^{6}_{\Lambda}\mathrm{Li} \rightarrow \mathrm{p} + \mathrm{p} + {}^{4}_{2}\mathrm{He} + \pi^{-}$ is more acceptable between the most possible two decay modes. Q-value and total kinetic energy or visible energy released of ${}^{6}_{\Lambda}\mathrm{Li}$ are 35.27 ± 0.00 MeV and 35.25 ± 0.06 MeV. The mass difference of the single-Λ hypernucleus is 0.019 MeV/c^2. According to our calculating results, a single-Λ hypernucleus was identified as a ${}^{6}_{\Lambda}\mathrm{Li}$ hypernucleus.

Keywords: Single-strangeness, Single-Λ hypernucleus, nuclear emulsion, relativistic kinematics, range-energy relation

Introduction

Strangeness nuclear physics introduces "strangeness" quantum number into nuclear systems. In 1953, Gell-Mann, Nakano and Nishijima introduced a strangeness quantum number conserved under the strong interaction in order to explain the behaviour of the strange particles. Almost simultaneously the first strange hypernucleus event formed by a Λ hyperon bound to a nuclear fragment was observed by Danysz and Pniewski in nuclear emulsions exposed to cosmic rays.

Hyperons or strange particles are special class of baryons heavier than nucleons and consisting one or more strange quarks. A Λ hyperon consists of one up quark "u", one down quark "d" and one strange quark "s". So, the nuclear system which contains a Λ hyperon is called the single-strangeness hypernuclear system. Hyperons have the life time of the order of 10^{-10} s and they decay weakly while their formation time is in the order of 10^{-23} s which is typical for strong interaction. Their decay time is very much greater than that of their formation. Because of this strange property, the hyperons along with the K mesons are called strange particles. Being baryons, all hyperons are fermions. That is, they have half-integer spin and obey Fermi-Dirac statistics.

According to the recent data of Particle Data Group (PDG), the hyperons are classified into four main groups such as lambda (Λ), sigma (Σ), Xi (Ξ), omega (Ω). In the family of hyperons, Λ particle is the lightest particle, and it can stay in contact with nucleons inside nuclei and form hypernuclei. It carry zero charge and its mass is 1115.683 ± 0.006 MeV. It can stay in contact with protons and neutrons because its mass is nearly equal to that of protons and neutrons. Hypernuclei are produced by two processes in nuclear emulsion. One is the direct production of Λ hyperon(s)

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and another process is the production of Λ hyperon via the Ξ^- atom. Λ hyperons are directly produced when K^- is bombarded the proton or Ξ^- atom. But, the production of Λ hyperon via the Ξ^- atom, when K^- is bombarded the proton of target nucleus, Ξ^- hyperon is emitted. Λ hyperon is produced from the decay of the emitted Ξ^- hyperon. In this research work, the analyzed single-Λ hypernucleus event was produced by the direct process called the direct production of Λ hyperons. The analyzed event was observed in KEK-PS E373 experiment.

Strangeness nuclear physics extends our knowledge on nuclear and hadron many-body system regarding hypernuclei, hyperon-nucleons systems and hyperon-hyperon systems. Hypernuclei studies are performed with the aim of investigating the hyperon-nucleon (Y-N) and hyperon-hyperon (Y-Y) interactions in theoretical approach. Otherwise, it is to understand the baron-baron (B-B) interactions in a uniform way. The nucleon-nucleon (N-N) interaction (nuclear force) is phenomenologically well known, but the physical understanding of the N-N interaction has not been achieved yet.

Baryon-baryon (B-B) interaction was expected to extend the nuclear force by adding the strangeness quantum number. For the experimental approach, nuclei with strangeness can be plotted in the three-dimensional nuclear chart. The knowledge of the (Y-N) and (Y-Y) interactions is essential to understand high-density nuclear matter in neutron stars where strangeness is expected to appear.

KEK-PS E373 Experiment

Experimental Procedure

The hybrid-emulsion experiment KEK-PS E373 was performed using a 1.66 GeV/c K^- beam at the K2 beam line of the proton synchrotron facility at KEK. In this experiment, (K^-, K^+) reactions were identified by a beam-line spectrometer for incoming K^- particles and a KURAMA spectrometer for outgoing K^+. Ξ^- hyperons which were produced from the quasi-free p (K^-, K^+) Ξ^- reaction were detected by a scintillating microfiber bundle detector (SciFi-Bundle), and then entered a stack of emulsion plates. This experiment was designed to observe ten times more stopping Ξ^- hyperons in the emulsion than the previous experiment KEK-PS E176.To optimize the stopping rate in the emulsion, density of the target material should be high to decelerate the Ξ^- hyperons in the target and size of the target should be also optimized. An emulsion stack consisted of a thin emulsion plate located upstream followed by eleven thick emulsion plates. The thin plate had 70 µm thickness emulsion gel on both sides of a 200 µm thickness emulsion acrylic base film, and each thick plate had 500 µm thickness emulsion gel on both sides of a 500 µm thickness acrylic film. The schematic diagram of the experimental setup of KEK-PS E373 is shown in figure 2.

The positions and angles of the Ξ^- hyperons at the surface of the first emulsion thin plate were provided. The tracks of Ξ^- hyperons detected with the SciFi-Bundle detector which was sandwiched between the diamond target and the emulsion stack measured the position and angle of each Ξ^- hyperons were identified under a microscope, and then followed the tracks to their end points in the nuclear emulsion thin plate. The production of a double-Λ hypernucleus and its decay were searched for around the end points. Scintillating fiber (SciFi) detector, U-Block and D-block, were placed both upstream and downstream of the emulsion stack.

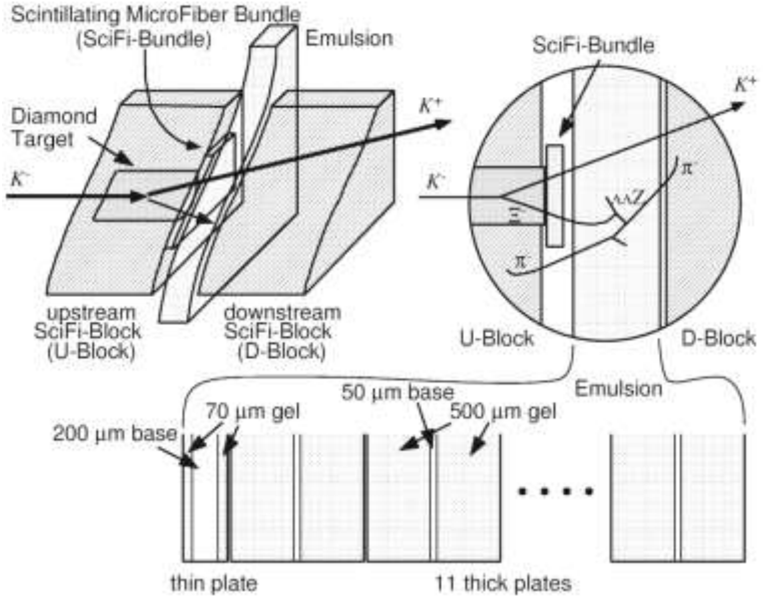


Figure 1 Schematic view of the experimental set-up of KEK-PS E373 experiment

Present Research of Single-Λ Hypernucleus Event

The analyzed event is detected in nuclear emulsion of KEE-PS E373 experiment. Nuclear emulsion is a three dimensional photographic plate and can be recorded as a photograph in which the tracks of charged particles are taken photographs. The analyzed event is identified as a single-Λ hypernucleus event which has a $^{6}_{\Lambda}\mathrm{Li}$ hypernucleus and its decay species of protons, helium and pi-minus meson.

Aim

The analyzed event is performed with the aims of supporting for theoretical and experimental studies. Our analysis supports the nuclear forces (B-B interactions) for theoretical approach and extension of 3-D nuclear chart for experimental studies.

Overall Scanning Method

In the previous method, hybrid emulsion method, the number of double hypernuclei strongly depends on the detection efficiency of K^+ mesons by KURAMA spectrometer system. The overall scanning method is well known that the topology with three vertices is shown at the production and decay of double hypernuclei. The aim of intending to use the overall scanning method is to obtain ten times more double hypernuclei than that by hybrid emulsion method. Ξ^- hyperons are also produced via some other process such as n (K^-, K^0) Ξ^-, where K^0 mesons are not tagged by KURAMA spectrometer.

The overall scanning system was developed with fast image taking of the emulsion in the whole area and image processing to search for three vertices. In this system consists of an objective lens (×50) and a CCD camera (100Hz), where the image size is 120 × 100 μm^2. Four million images were taken in the emulsion of the KEK-PS E373 experiment, and then the events with at least one vertex were searched. When this system was developed, 1000 times faster scanning speed than that of the previous system was obtained. The α decay vertices of uranium and thorium series for calibration of the range-energy relation were detected by a new method, called overall scanning of the full emulsion volume. During test operations of this method, a twin single-hypernuclei event was found among about 8 million pictures taken in a volume of 1.46 cm^3 emulsion exposed in the KEK-PS E373 experiment. By using this method, the KISO event was found in this experiment.

Event Description

The analyzed event is observed in KEK-PS E373 experiment. In the analyzed event, a Λ hyperon is produced by the direct process of beam interaction. A single-Λ hypernucleus (track #1) is produced at production point A and four charged particles (tracks #2, #3, #4 and #5) are emitted from the decay of single-Λ hypernucleus #1 at point B. This event has two vertex points; “A” which is the production vertex of track #1 and “B” which is the decay vertex of it. Therefore, the particle of track #1 can be identified as single-Λ hypernucleus. The photograph and schematic diagram are shown in figure 2.

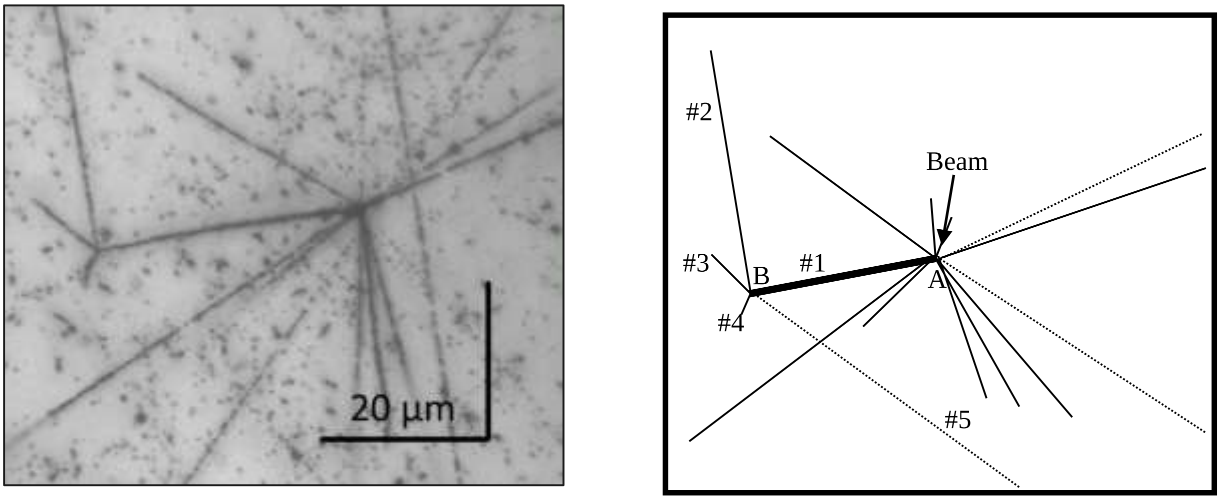


Figure 2 Photograph and Schematic diagram of analyzed single-Λ hypernucleus event

According to experimental results, ranges and position angles of single-Λ hypernucleus and its decay species are summarized in table 1.

Table 1 Ranges and position angles of tracks #1, #2, #3, #4 and #5

Track (#)	Range (μm)	θ (degree)	ϕ (degree)
#1	40.10 ± 0.30	52.69 ± 3.09	97.91 ± 2.61
#2	414.93 ± 0.48	111.28 ± 4.70	189.19 ± 5.12
#3	9.11 ± 0.03	76.71 ± 1.82	232.51 ± 4.30
#4	9.47 ± 0.15	321.25 ± 2.70	121.03 ± 4.31
#5	>10800.90	67.19 ± 4.71	43.29 ± 2.11

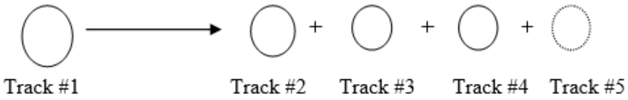
Choosing Possible Decay Modes

To choose the possible decay mode, we firstly checked the conservation laws which are charge, baryon number, lepton number and strangeness number**.** Moreover, mesonic or non-mesonic decay have to be considered. According to grain density and ionization measurements of experimental results, charged particle track #5 is a pi-minus meson. Therefore, non-mesonic decay was not considered at decay point B. According to visible structure and decay topology of the analyzed single-Λ hypernucleus event, a single-Λ hypernucleus (#1) decayed into only four charged particles (#2, #3, #4 and #5). After checking the conservation laws, 167 decay modes of all possible decay modes are obtained with pi-minus meson emission.

Track #1 → charged particles (#2, #3 and #4) + pi-minus meson (1)

Calculation of Q-value, Visible Energy and Kinetic Energy of Decay Pro of Single-Λ Hypernucleus

The Q-value of the reaction is defined as the difference between the sum of the masses of the initial and final states.



$$Q\ (\mathrm{MeV}) = [M(\text{track \#1}) - \{M(\text{track \#2}) + M(\text{track \#3}) + M(\text{track \#4}) + M(\text{track \#5})\}]c^2 \qquad (2)$$

At decay point B, Q-values of all possible decay modes are calculated. If Q-value is positive, the reaction is energetically possible. This reaction can be called exoergic reaction. If Q-value is negative, the reaction is not energetically possible. This reaction can be called endoergic reaction. First of particle identification steps, all negative Q-values are rejected from 167 decay modes. Only 12 decay modes of all possible decay modes are neglected because of negative Q-values. So, we have to consider only 155 decay modes which are positive Q-values to analyze our research work. In this research paper, visible energy released of 155 decay modes are calculated by using equation 3. The visible energy released is the sum of kinetic energies of emitted charged particles.

$$E_{vis} = KE\ (\text{track \#2}) + KE\ (\text{track \#3}) + KE\ (\text{track \#4}) + KE\ (\text{track \#5}) \qquad (3)$$

Table 2 Kinetic energy of single-Λ hypernuclei and emitted charged particles

No	Decay Mode					KE of Charged Particles				
	Track #1	Track #2	Track #3	Track #4	Track #5	Track #1	Track #2	Track #3	Track #4	Track #5
1	${}^{4}_{\Lambda}\mathrm{He}$	d	p	p	π^-	3.180	10.818	0.734	0.754	23.647
2	${}^{4}_{\Lambda}\mathrm{He}$	p	d	p	π^-	3.180	8.173	0.883	0.754	23.647
3	${}^{4}_{\Lambda}\mathrm{He}$	p	p	d	π^-	3.180	8.173	0.734	0.910	23.647
4	${}^{6}_{\Lambda}\mathrm{Li}$	p	${}^{4}_{2}\mathrm{He}$	p	π^-	3.553	8.173	2.613	0.754	23.647
5	${}^{6}_{\Lambda}\mathrm{Li}$	p	p	${}^{4}_{2}\mathrm{He}$	π^-	3.553	8.173	0.734	2.699	23.647
6	${}^{7}_{\Lambda}\mathrm{Li}$	d	${}^{4}_{2}\mathrm{He}$	p	π^-	3.696	10.818	2.613	0.754	23.647
7	${}^{7}_{\Lambda}\mathrm{Li}$	d	p	${}^{4}_{2}\mathrm{He}$	π^-	3.696	10.818	0.734	2.699	23.647
8	${}^{7}_{\Lambda}\mathrm{Li}$	p	${}^{4}_{2}\mathrm{He}$	d	π^-	3.696	8.173	2.613	0.910	23.647
9	${}^{7}_{\Lambda}\mathrm{Li}$	p	d	${}^{4}_{2}\mathrm{He}$	π^-	3.696	8.173	0.883	2.699	23.647
10	${}^{8}_{\Lambda}\mathrm{Li}$	p	t	${}^{4}_{2}\mathrm{He}$	π^-	3.818	8.173	0.959	2.699	23.647
11	${}^{8}_{\Lambda}\mathrm{Li}$	p	${}^{4}_{2}\mathrm{He}$	t	π^-	3.818	8.173	2.613	0.991	23.647
12	${}^{8}_{\Lambda}\mathrm{Be}$	p	${}^{3}_{2}\mathrm{He}$	${}^{4}_{2}\mathrm{He}$	π^-	3.818	8.173	2.474	2.699	23.647
13	${}^{8}_{\Lambda}\mathrm{Be}$	p	${}^{4}_{2}\mathrm{He}$	${}^{3}_{2}\mathrm{He}$	π^-	3.818	8.173	2.613	2.550	23.647

Kinetic energy of decay products of single-Λ hypernucleus is obtained by using range-energy software package. For example, Kinetic energies of charged particles are obtained by using the range-energy software package as presented in table 2.

Table 3 The Most Possible Mesonic decay modes with Q-value and E_{vis} comparison

No.	Decay mode	Q-value (MeV)	E_{vis} (MeV)
1	${}^{4}_{\Lambda}He \rightarrow d + p + p + \pi^{-}$	29.887±0.058	35.953±0.025
2	${}^{4}_{\Lambda}He \rightarrow p + d + p + \pi^{-}$	29.887±0.058	33.457±0.024
3	${}^{4}_{\Lambda}He \rightarrow p + p + d + \pi^{-}$	29.887±0.058	33.464±0.026
4	${}^{6}_{\Lambda}Li \rightarrow p + {}^{4}_{2}He + p + \pi^{-}$	**35.272±0.000**	**35.187±0.030**
5	${}^{6}_{\Lambda}Li \rightarrow p + p + {}^{4}_{2}He + \pi^{-}$	**35.272±0.000**	**35.253±0.061**
6	${}^{7}_{\Lambda}Li \rightarrow d + {}^{4}_{2}He + p + \pi^{-}$	30.272±0.058	37.832±0.033
7	${}^{7}_{\Lambda}Li \rightarrow d + p + {}^{4}_{2}He + \pi^{-}$	30.272±0.058	37.898±0.063
8	${}^{7}_{\Lambda}Li \rightarrow p + {}^{4}_{2}He + d + \pi^{-}$	30.272±0.058	35.343±0.034
9	${}^{7}_{\Lambda}Li \rightarrow p + d + {}^{4}_{2}He + \pi^{-}$	30.272±0.058	35.402±0.062
10	${}^{8}_{\Lambda}Li \rightarrow p + t + {}^{4}_{2}He + \pi^{-}$	28.514±0.058	35.478±0.062
11	${}^{8}_{\Lambda}Li \rightarrow p + {}^{4}_{2}He + t + \pi^{-}$	28.514±0.058	35.424±0.036
12	${}^{8}_{\Lambda}Be \rightarrow p + {}^{3}_{2}He + {}^{4}_{2}He + \pi^{-}$	29.365±0.071	36.993±0.067
13	${}^{8}_{\Lambda}Be \rightarrow p + {}^{4}_{2}He + {}^{3}_{2}He + \pi^{-}$	29.365±0.071	36.983±0.063

To choose the most probable decay modes, the visible energy released (E_{vis}) must be calculated.The total kinetic energy of emitted charged particles, E_{vis}, should be comparable with Q-value of the selected decay mode.

Mass of Single-Λ Hypernucleus

The reconstruction of the analyzed event was performed at point B by comparing the calculated masses and known masses of single-Λ hypernuclei for all possible decay modes.

Table 4 Calculated masses and known experimental masses of analyzed single-Λ hypernuclei

No.	**Decay Mode**	**Known Experimental Mass (#1) (MeV)**	**Calculated Mass (#1) (MeV)**
1	${}^{4}_{\Lambda}\mathrm{He} \rightarrow d + p + p + \pi^{-}$	3921.642±0.058	3927.708±0.025
2	${}^{4}_{\Lambda}\mathrm{He} \rightarrow p + d + p + \pi^{-}$	3921.642±0.058	3925.212±0.024
3	${}^{4}_{\Lambda}\mathrm{He} \rightarrow p + p + d + \pi^{-}$	3921.642±0.058	3925.219±0.026
4	${}^{6}_{\Lambda}\mathrm{Li} \rightarrow p + {}^{4}_{2}\mathrm{He} + p + \pi^{-}$	**5778.807 ± 0.000**	**5778.722 ± 0.030**
5	${}^{6}_{\Lambda}\mathrm{Li} \rightarrow p + p + {}^{4}_{2}\mathrm{He} + \pi^{-}$	**5778.807 ± 0.000**	**5778.788 ± 0.061**
6	${}^{7}_{\Lambda}\mathrm{Li} \rightarrow d + {}^{4}_{2}\mathrm{He} + p + \pi^{-}$	6711.61±0.058	6718.715±0.033
7	${}^{7}_{\Lambda}\mathrm{Li} \rightarrow d + p + {}^{4}_{2}\mathrm{He} + \pi^{-}$	6711.61±0.058	6718.781±0.063
8	${}^{7}_{\Lambda}\mathrm{Li} \rightarrow p + {}^{4}_{2}\mathrm{He} + d + \pi^{-}$	6711.61±0.058	6716.226±0.034
9	${}^{7}_{\Lambda}\mathrm{Li} \rightarrow p + d + {}^{4}_{2}\mathrm{He} + \pi^{-}$	6711.61±0.058	6716.285±0.062
10	${}^{8}_{\Lambda}\mathrm{Li} \rightarrow p + t + {}^{4}_{2}\mathrm{He} + \pi^{-}$	7642.712±0.058	7649.676±0.062
11	${}^{8}_{\Lambda}\mathrm{Li} \rightarrow p + {}^{4}_{2}\mathrm{He} + t + \pi^{-}$	7642.712±0.058	7649.622±0.036
12	${}^{8}_{\Lambda}\mathrm{Be} \rightarrow p + {}^{3}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He} + \pi^{-}$	7643.023±0.071	7650.651±0.067
13	${}^{8}_{\Lambda}\mathrm{Be} \rightarrow p + {}^{4}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} + \pi^{-}$	7643.023±0.071	7650.641±0.063

We assumed that a single-Λ hypernucleus (track #1) at rest decays into charged particles. The mass of a single-Λ hypernucleus was calculated from kinetic energy values of its decay products.

In our calculation, the masses of single-Λ hypernuclei are also calculated and compared with known experimental masses of these hypernuciei by using the followig formula.

$$M(\#1) = M(\#2) + M(\#3) + M(\#4) + M(\#5) + KE(\#2) + KE(\#3) + KE(\#4) + KE(\#5) \qquad (4)$$

Identification of Single-Λ Hypernucleus

The analyzed event has been identified as a single-Λ hypernucleus according to decay topology and its visible structure. Then, Q-values of all possible decay modes are calculated and negative Q-values are neglected. From all decay modes, only positive Q-values are considered to identify the most possible decay modes. To do this, the main performances of identification are to compare the Q-value and visible energy released and to evaluate calculated mass of a single-Λ hypernucleus and known experimental mass of the accepted event.

After completing our analysis, 13 decay modes are acceptable among the 155 decay modes. But, only two decay modes, ${}^{6}_{\Lambda}\mathrm{Li} \rightarrow p + {}^{4}_{2}\mathrm{He} + p + \pi^{-}$ and ${}^{6}_{\Lambda}\mathrm{Li} \rightarrow p + p + {}^{4}_{2}\mathrm{He} + \pi^{-}$ **,** are the most acceptable decay modes. Therefore, the other 142 decay modes are not comparable not only with Q-values and visible energy released but also with calculated mass and known experimental mass. The results of accepted decay modes are summarized in table 4.

Results and Discussions

Detecting with overall scanning method, the analyzed event which was observed in KEK-PS E 373 experiment has been identified as a single-Λ hypernucleus event according to decay topology. In this research paper, kinematical analysis based on relativity theory is performed. In this analyzed event, the beam line with momentum of 1.67 GeV/c was accelerated and charged particles are produced at point A including a single-strangeness hypernucleus in nuclear emulsion. Our analysis is started at point B because the analysis on a hypernucleus can be performed only if physical properties of decay products of a hypernucleus are studied by using the relativistic kinematic.

At point B, the single-Λ hypernucleus of track #1 decays into four charged particles tracks #2, #3, #4 and #5. The charged particle track #1 is identified as pi-minus meson according to ionization measurement and grain density observation. So, only the mesonic decay is considered and the non-mesonic decay is neglected.

Moreover, Q-values and visible energy released are compared. The comparable values and positive Q-values are accepted. Performing the kinematical analysis, only two decay modes, ${}^{6}_{\Lambda}\mathrm{Li} \rightarrow \mathrm{p} + {}^{4}_{2}\mathrm{He} + \mathrm{p} + \pi^{-}$ and ${}^{6}_{\Lambda}\mathrm{Li} \rightarrow \mathrm{p} + \mathrm{p} + {}^{4}_{2}\mathrm{He} + \pi^{-}$, are possible with the highest possibility. Finally, the decay mode of ${}^{6}_{\Lambda}\mathrm{Li} \rightarrow \mathrm{p} + \mathrm{p} + {}^{4}_{2}\mathrm{He} + \pi^{-}$ is accepted as the mass difference value on which the ΔM (%) value is 0.000329 is the smallest among the most possible decay modes.

If all charged particles are emitted as decay products, the calculated masses of single-Λ hypernucleus should be equal to known mass. If neutral particles exist in decay products, the calculated masses of single-Λ hypernucleus should be less than known mass. In our results, the calculated masses of the accepted decay modes are nearly equal to known experimental mass because only charged particles are emitted.

According to those assumptions, it is found that the possible species of single-Λ hypernuclei is ${}^{6}_{\Lambda}\mathrm{Li}$ and the charged particle decay products are possible to be protons, helium and pi-minus meson. The values of mass differences are shown in table 5 illustrating with percentages.

Table 5 Mass differences and percentages for each decay mode

No.	Decay Mode	ΔM (MeV)	ΔM (%)	Remark
1	${}^{4}_{\Lambda}\mathrm{He} \rightarrow d + p + p + \pi^{-}$	-6.066	-0.15468	Rejected
2	${}^{4}_{\Lambda}\mathrm{He} \rightarrow p + d + p + \pi^{-}$	-3.57	-0.09103	Rejected
3	${}^{4}_{\Lambda}\mathrm{He} \rightarrow p + p + d + \pi^{-}$	-3.577	-0.09121	Rejected
4	${}^{6}_{\Lambda}\mathrm{Li} \rightarrow p + {}^{4}_{2}\mathrm{He} + p + \pi^{-}$	0.085	0.001471	Rejected
5	${}^{6}_{\Lambda}\mathrm{Li} \rightarrow p + p + {}^{4}_{2}\mathrm{He} + \pi^{-}$	0.019	0.000329	Acceptable
6	${}^{7}_{\Lambda}\mathrm{Li} \rightarrow d + {}^{4}_{2}\mathrm{He} + p + \pi^{-}$	-7.105	-0.10586	Rejected
7	${}^{7}_{\Lambda}\mathrm{Li} \rightarrow d + p + {}^{4}_{2}\mathrm{He} + \pi^{-}$	-7.171	-0.10684	Rejected
8	${}^{7}_{\Lambda}\mathrm{Li} \rightarrow p + {}^{4}_{2}\mathrm{He} + d + \pi^{-}$	-4.616	-0.06878	Rejected
9	${}^{7}_{\Lambda}\mathrm{Li} \rightarrow p + d + {}^{4}_{2}\mathrm{He} + \pi^{-}$	-4.675	-0.06966	Rejected
8	${}^{7}_{\Lambda}\mathrm{Li} \rightarrow p + {}^{4}_{2}\mathrm{He} + d + \pi^{-}$	-4.616	-0.06878	Rejected
9	${}^{7}_{\Lambda}\mathrm{Li} \rightarrow p + d + {}^{4}_{2}\mathrm{He} + \pi^{-}$	-4.675	-0.06966	Rejected
10	${}^{8}_{\Lambda}\mathrm{Li} \rightarrow p + t + {}^{4}_{2}\mathrm{He} + \pi^{-}$	-6.964	-0.09112	Rejected
11	${}^{8}_{\Lambda}\mathrm{Li} \rightarrow p + {}^{4}_{2}\mathrm{He} + t + \pi^{-}$	-6.91	-0.09041	Rejected
12	${}^{8}_{\Lambda}\mathrm{Be} \rightarrow p + {}^{3}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He} + \pi^{-}$	-7.628	-0.0998	Rejected
13	${}^{8}_{\Lambda}\mathrm{Be} \rightarrow p + {}^{4}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} + \pi^{-}$	-7.618	-0.09967	Rejected

Conclusion

A single-strangeness hypernucleus observed in KEK-PS E373 experiment is kinematically analyzed in this research work. In this analyzed event a single-Λ hypernucleus decays into four charged particles including pi-minus meson. According to our calculated results, Q-value and total kinetic energy or visible energy released of ${}^{6}_{\Lambda}\mathrm{Li}$ are 35.27 ± 0.00 MeV and 35.25 ± 0.06 MeV and its calculated mass and known experimental mass of ${}^{6}_{\Lambda}\mathrm{Li}$ are 5778.788MeV and 5778.807 MeV while the mass difference percent is 0.000329. According to those results, it is found that the possible species of single-Λ hypernuclei is ${}^{6}_{\Lambda}\mathrm{Li}$ and the charged particle decay products are possible to be protons, helium and pi-minus meson.

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