Hunting double hypernuclei in photographic emulsion: J-PARC E07

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Double Λ hypernuclei and Ξ hypernuclei shown in Fig. 1, collectively called “double hypernuclei”, have come to play important roles in hadron nuclear physics as valuable information sources of baryon-baryon interaction. Baryon-baryon interaction is essential for our understanding of the hierarchical structure of matter from quarks to nuclei. However, up to now Λ-Λ and Ξ-nucleon interactions still have many unknown aspects. There are only a few ways to obtain information on Λ-Λ and Ξ-nucleon interactions, and mass measurements of double hypernuclei are one of them.

The most effective method to investigate double hypernuclei is an event-by-event analysis with photographic emulsion sheets, so called “emulsion”. Emulsion visualizes tracks of charged particles with sub-μm resolution. The production and decays of double hypernuclei can be seen under an optical microscope and be discriminated against other huge background.

To find double hypernuclei effectively, we employ the so-called "Hybrid emulsion method" [1], which is a combination of electrical detectors and emulsion. The procedure is as follows. Firstly, a K^- beam provided from an accelerator is irradiated to a target made of diamond. In the target, Ξ^- particles are produced via $'p'(K^-, K^+)\Xi^-$ reaction, where 'p' is a proton bound inside a carbon nucleus. The Ξ^-s go into the emulsion through a SSD (Silicon Strip Detector) which is located between the target and the emulsion module. Some Ξ^-s travel through the emulsion by losing kinetic energy and stop, where, finally, some Ξ^-s are captured by the surrounding nuclei. A Ξ hypernuclei is formed if the Ξ^- is bound in a deep enough orbit by the Ξ-nucleon interaction. Moreover, a double hypernucleus is formed if the 2 Λs converted from Ξ^- are bound on the same nucleus. The Ξ^- tracks are searched based on the SSD prediction and followed in emulsion with an advanced image recognition technique.

J-PARC E07, an experiment for double hypernuclei with the Hybrid emulsion method, is designed to detect 10 times higher statistics of double hypernuclei compared to the past experiments [2-4]. So far, only 2 double hypernuclei events, Nagara and Kiso event, are identified without ambiguity [1,5]. However, a larger variety of double hypernuclear nuclides are necessary for a systematic validation of the Λ-Λ and Ξ-nucleon interactions. For this purpose, we designed the experiment to obtain one hundred double hypenuclei and nearly ten clearly identified double hypernuclear nuclides. Furthermore, another goal of this experiment is the first observation of Ξ atom X-ray with a Ge detector array with surrounding emulsion. We measure the X-ray energy with about 0.2 keV accuracy and use this information to reconstruct Ξ-nucleon interaction. Although the background is huge, we expect it to be strongly suppressed by selecting Ξ^- stop events in emulsion.

Beam exposure of J-PARC E07 has been completed at the K1.8 beamline in the J-PARC hadron facility in 2017. Totally 118 modules, containing 1.5k emulsion sheets, were used. Photographic developing of all emulsion sheets has been completed at Gifu Univ., after which they are presently being analysed with dedicated microscope systems at JAEA and Gifu Univ. The time to scan one emulsion module is about one week with a microscope system. 10^4 Ξ^- stop events will be obtained according to our yield. We plan to finish the main part of emulsion scanning within FY2018.

So far, about 10 double hypernuclear events have been observed in nearly ten percent of total statistics. Figure 3 shows a typical double Λ nucleus event. The production and sequential decay of the double Λ hypernucleus shown as red points are clearly seen. Even though we were not able to identify this event uniquely, we expect unambiguous events to be found in near future.

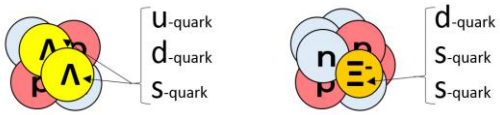

Fig.1 Double Λ hypernucleus and Ξ hypernucleus. Red and blue circle represent proton and neutron, respectively.

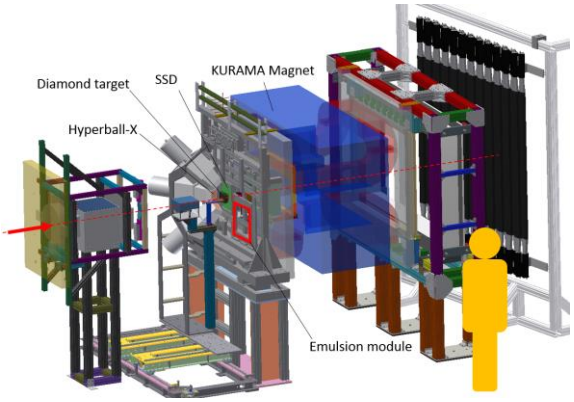

Fig.2 Experimental apparatus of J-PARC E07.

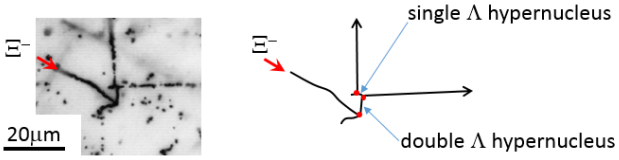

Fig.3 A typical double Λ nucleus event found in E07 experiment.

References

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