Production of nuclear emulsion mixed with Lithium and Boron to confirm the ground state of the Xi hypernucleus

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Introduction

Understanding the nuclear force under SU(3) symmetry is a key issue not only for nuclear physics but also for understanding the structure of neutron stars. To date, approximately 50 doubly-strange hypernuclei have been detected in experiments. These results indicate that the s-wave interaction of $\Lambda\Lambda$ is weakly attractive, Ξ hypernuclei exist, and the Ξ-N interaction is attractive. However, specific experimental challenges remain unresolved.

In the Ξ^--^{14}N system (${}^{15}_{\Xi}$C), we found a deeply bound state of Ξ^- about 6 MeV, and several theories predicted its state to be a ground state. Another theory, however, claimed that Ξ^- did not bind ^{14}N with nuclear force, but it just shows the atomic binding as $\Xi^- + {}^{14}N \Rightarrow \Xi^0 + {}^{14}C + 6.2$ MeV ($\Xi^- p \Rightarrow \Xi^0 n$). Furthermore, the number of candidate events for Ξ hypernuclei was 4, 7 and 1 for ^{12}C, ^{14}N, and ^{16}O, respectively, despite the mol ratio for ^{12}C, ^{14}N, and ^{16}O in the emulsion being 0.55 : 0.16 : 0.29, respectively. In the case of Ξ^--^{14}N system, the Ξ hypernucleus of ${}^{15}_{\Xi}$C is α-cluster. Thus, the emulsion doped with ^{7}Li and ^{11}B is beneficial for not appearing $\Xi^- p \Rightarrow \Xi^0 n$, and producing α-cluster Ξ hypernuclei such as ${}^{8}_{\Xi}$He and ${}^{12}_{\Xi}$Be, where it may be possible to measure the ground state and compare production rate among Ξ hypernuclei with core nuclei of He, Be, B, C, and N. Then we can understand ΞN interaction more deeply.

With doping of ^{7}Li, it may be possible to detect the reaction of $\Xi^- + {}^{7}Li \Rightarrow {}^{8}_{\Xi}He \Rightarrow {}^{5}_{\Lambda\Lambda}H + {}^{3}H$. The nucleus of ${}^{5}_{\Lambda\Lambda}$H is very sensitive to $\Lambda\Lambda$-ΞN coupling effect. If the coupling effect is strong, many ${}^{8}_{\Xi}$He must decay to ${}^{5}_{\Lambda\Lambda}$H, and if it is not strong, ${}^{8}_{\Xi}$He may decay into two single-Λ hypernuclei like ${}^{4}_{\Lambda}H + {}^{4}_{\Lambda}H$ or ${}^{5}_{\Lambda}H + {}^{3}_{\Lambda}H$. This decay pattern gives us the strength of $\Lambda\Lambda$-ΞN coupling effect, which is valuable information for the content of Strangeness in a neutron star.

Experimental Procedures

There is prior research, as shown in Figure 1[1]. In Figure 1 a) and b), a neutron was captured by a ^{6}Li and ^{10}B nucleus、respectively. In both cases, the number of developed grains is low for low-energy charged particles, making it impossible to record tracks of minimum-ionising charged particles, such as π^-'s from the decay of hypernuclei. Especially in b), a powder interrupts checking the precise topology around the neutron capture point. The production and decay of doubly-strange hypernuclei occur on a scale of a few microns.

We will develop the nuclear-emulsion gel with ^{7}Li and ^{11}B, which should satisfy the following conditions;

(1) To not pose a problem for observation under an optical microscope, ^{7}Li and ^{11}B compounds disperse at the molecular level to such an extent.

(2) The compound must be doped to yield approximately 7% molar ratio (equivalent to ^{14}N) of ^{7}Li and ^{11}B within the emulsion sheet.

(3) Even when the proportion of AgBr, the major player in making a latent image, is reduced, it retains sensitivity to the minimum-ionising particles.

Up to now, we are planning to use $Na_2B_{10}O_{16}\cdot 10H_2O$, $LiNO_3$, $LiBF_4$, $NH_4B_5O_8\cdot 4H_2O$, and so on, as the ^{7}Li and ^{11}B compounds.

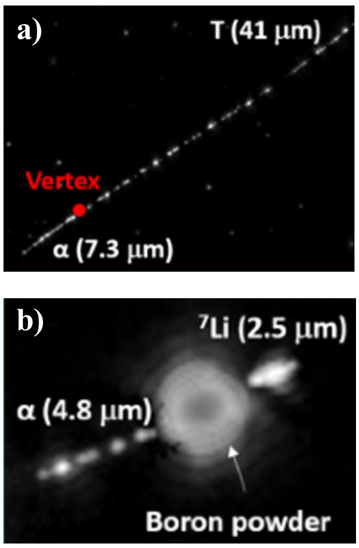

Figure 1 Reactions with a neutron,
a) $n + {}^{6}Li \rightarrow \alpha + T + 4.78$ MeV,
b) $n + {}^{10}B \rightarrow \alpha + {}^{7}Li + 2.31$ MeV.

Outlook

We are hopeful that young researchers will yield new insights with the use of the nuclear emulsion developed in this project. The expenses for this project have been applied for under the JSPS Grant from the fiscal year 2026.

Reference

[1] Akamatsu, Shiraisi, et al., The Japan Soc. of Appl. Phys.//[Featured Lecture Press Releases] 2022. Sep. 14.