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Studies of hypernuclei with the WASA-FRS setup, nuclear emulsions and machine learning

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Studies of hypernuclei, subatomic bound systems with at least one hyperon, have been contributing for understanding the fundamental baryonic interactions as well as the nature of dense nuclear matters. Hypernuclei can also reveal nature of ordinary sub-atomic nuclei by using a hyperon as a prove or/and an impurity in nuclei. Hypernuclei have already been studied for almost seven decades in reactions involving cosmic rays and with meson- and electron-beams. In recent years, hypernuclear studies can also be performed by using energetic heavy ion beams, and some of these experiments have revealed unexpected results on three-body hypernuclear states, i.e., shorter lifetime [1-7] and larger binding energy [8] of the lightest hypernucleus, the hypertriton, than what was formerly determined and the unprecedented bound state with a Lambda hyperon with two neutrons [9]. These results have initiated several ongoing experimental programs all over the world to study these three-body hypernuclear states precisely. We are studying those light hypernuclear states by employing different approaches from the other experiments. We employ heavy ion beams on fixed nuclear targets with the WASA detector and the Fragment separator FRS at GSI (the WASA-FRS project) in Germany for measuring their lifetime precisely [10]. The experiment was already performed in the first quarter of 2022, and the data analyses are in progress. We also analyze the entire volume of the nuclear emulsion irradiated by kaon beams in the J-PARC E07 experiment [11, 12, 13] in order to measure their binding energies at the world best precision [10]. We have already uniquely identified events associated with the production and decays of the hypertriton, and the binding energy of the hypertriton is to be determined. We also search events of other single-strangeness hypernuclei and double-strangeness hypernuclei in the E07 emulsion to understand the nature of Lambda-nucleon, Lambda-Lambda and Xi-nucleon interactions. We are using Machine Learning techniques for all our projects with heavy ion beams and nuclear emulsions [10]. These projects will be extended at FAIR in Germany, HIAF in China and J-PARC in Japan.

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Collaboration

WASA-FRS, Super-FRS Experiment

Primary author: SAITO, Takehiko (RIKEN and GSI Darmstadt)

Presenter: SAITO, Takehiko (RIKEN and GSI Darmstadt)

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