Contribution ID: **93** Type: **Oral Contribution**

Study of light hypernuclei in Europe: the hypertriton and nnΛ puzzles

Thursday, 27 October 2022 16:15 (20 minutes)

The current understanding of the light hypernuclei, sub-atomic nuclei with strangeness, is challenged and studied in detail by several European research groups and collaborations [1, 2, 3, 4, 5].
In recent years, hypernuclear studies performed using high-energy heavy ion beams have reported unexpected results on the three-body hypernuclear state $^{3}_{\Lambda}$H, named the hypertriton. Its shorter lifetime [3, 6, 7, 8, 9, 5, 10] and larger binding energy [11] than the accepted understanding has created a puzzling situation for its theoretical description, the so-called "hypertriton puzzle". Additionally the possible neutral bound state of a Λ hyperon with two neutrons, nnΛ [12] has questioned our comprehension of the formation of light hypernuclei bound or resonance state. 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 heavy ion beams at $2A$GeV on a fixed carbon target with the WASA detector system and the Fragment separator FRS at GSI [4]. The WASA-FRS experimental campaign was performed during the first quarter of 2022, and the data analyses are in progress.

Additionally, our collaboration between CSIC and RIKEN search and identify with machine learning techniques hypernuclei present in the nuclear emulsions irradiated by kaon beams in the J-PARC E07 experiment [13]. At the moment, we focus on measuring the hypertriton binding energy at the world's best precision [4]. We have already uniquely identified events associated with its decay, and the determination of the binding energy is underway.

A quick overview of the European efforts in the study of hypernuclei will be given before focusing on the experimental study of the light hypernuclei in the WASA-FRS HypHI experiment. The measurement of the lifetime of $^{3}_{\Lambda}$H and $^{4}_{\Lambda}$H is the first goal of the experiment. The possible observation of the nnΛ state is the second part of the WASA-FRS research program. Details of the experiment and preliminary results will be discussed. The measurement of the hypertriton binding energy in the nuclear emulsion analysis will also be reported to exhibit the European participation in tackling the second aspect of the hypertriton puzzle. The future perspectives will then conclude this contribution.

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Session Classification: P9 Few-Body Systems

Track Classification: P9 Few-Body Systems