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# Deep learning techniques in the study of the hypertriton puzzle

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Recent experiments with high-energy heavy ion beams challenge the current understanding of light hypernuclei (sub-atomic nuclei exhibiting strangeness), particularly the hypertriton [1,2,3,4,5,6,7,8]. This perplexing situation, known as the "hypertriton puzzle," is the focal point of our European-Japanese collaboration between CSIC – Spain, GSI-FAIR – Germany and RIKEN – Japan within the Super-FRS Experiment Collaboration and the Emulsion-ML collaboration. Employing deep learning techniques, our groundbreaking research addresses this puzzle through two distinct experiments [9]. The first involves studying hypernuclear states using heavy ion beams, where a Graph Neural Network aids in track finding, crucial for the ongoing data analysis [10]. Simultaneously, the second experiment focuses on identifying hypernuclei in nuclear emulsions irradiated by kaon beams, utilizing Mask R-CNN for object detection [11]. These efforts aim to achieve world-leading precision in measuring hypertriton lifetime and binding energy.

In the first experiment, the WASA-FRS experiment of Super-FRS Experiment Collaboration, conducted with heavy ion beams at 2 GeV/u on a fixed carbon target at GSI-FAIR, the WASA detector system and Fragment separator FRS were employed during the first quarter of 2022 [9]. The Graph Neural Network model plays a pivotal role in overcoming the challenges associated with induced reactions, particularly in the track finding procedure, given the large combinatorial background in the forward direction. Preliminary analyses with the Graph Neural Network model that we have developed demonstrate its high efficacy in finding track candidates and in estimating particle momentum and charge, providing promising insights into the hypertriton observation [10].

In the second experiment, we, the Emulsion-ML collaboration, lead the search and identification of hypernuclei with AI in nuclear emulsions irradiated by kaon beams at the J-PARC E07 experiment [12]. To efficiently analyze a substantial amount of image data, we introduced Mask R-CNN model for object detection [11]. Overcoming the scarcity of training data for rare hypernuclear events, a generative adversarial network (GAN) model was developed using Geant4 simulation data and real background images of nuclear emulsions [11]. The ongoing analysis has already led to the unique identification of events associated with hypertriton decay, and the measurement of the hypertriton binding energy is in progress [9].

This contribution will present a comprehensive approach to addressing the hypertriton puzzle via deep learning methods, offering significant contributions to the field of hypernuclei research.

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