The 29th International Nuclear Physics Conference (INPC 2025)

Contribution ID: **250**

Type: **Contributed Oral Presentation**

Spectroscopic Study of Λ-hypernuclei Using CW Electron Beam at JLab - Overview of the Hypernuclear Experiments at JLab

A primary goal of nuclear physics is to understand the behavior of many-body systems bound by the strong interaction. In contrast, hypernuclear physics aims to extend this understanding, primarily built upon the NN interaction, to include new flavors (strangeness) such as the YN and YY interactions.

One notable example involves the study of neutron stars, massive baryonic objects with a radius of approximately 10 km existing in the universe. With reasonably understood NN and YN interactions, equations of state (EOS) of baryonic systems were hypothesized, and correlations between neutron stars'maximum mass and radius were calculated. However, the EOS with hyperons tends to be softer than the EOS for only nucleons due to additional degrees of freedom. Consequently, the estimated maximum mass of a neutron star containing hyperons is around 1.6 solar masses. Recently, neutron stars with two solar masses have been observed, and the EOS with hyperons could not explain their existence, leading to the so-called "hyperon puzzle". Therefore, an improved understanding of NN, YN and YY interactions, as well as the ΛNN (3B) force at high nuclear density, is necessary and represents an urgent problem in nuclear physics, as emphasized by astrophysicists.

Another intriguing example is the significant charge-symmetry-breaking (CSB) observed in the ΛN interactions, evidenced by the difference in Λ separation energies between the $^{4}_{\Lambda}$He and $^{4}_{\Lambda}$H hypernuclei. While CSB is proven to be small in NN interactions, the origin of this contradiction remains unknown.

Although the CEBAF beam at JLab is essentially built for hadron physics, its unique beam structure, stable beam properties, and high intensity also provide a unique opportunity to carry out high-precision Λ hypernuclear spectroscopy. This can offer stringent information, leading to advances in understanding YN interactions. The crucial absolute Λ single-particle binding energy of the ground state of hypernuclei can only be precisely determined through Jlab experiments using the (e, e'K^+) reaction.

Before the CEBAF 12 GeV upgrade began in 2012, a series of experiments were conducted in both Hall C and A, achieving spectroscopy for several p-shell hypernuclei and demonstrating the capability to achieve the world's best energy resolution (~700 keV FWHM).

This presentation provides an overview of five new experiments that will be consecutively conducted using a single experimental configuration over a two-year period (2028-2029) in Hall C at JLab. Building upon the experimental techniques utilized in the previous Hall C and A experiments, the objective of the new experiments is to achieve high-precision spectroscopy of Λ hypernuclei across a wide mass range, from light (A=6) to heavy (A=208) hypernuclei. The physics goals include:

1. High-precision determination of the binding energy of the ground state of light hypernuclei via decay-pion spectroscopy.
2. Charge symmetry breaking (CSB) studies using p-shell hypernuclei.
3. Investigating the isospin dependence of the three-body ΛNN interaction through the $^{40}_{\Lambda}$K and $^{48}_{\Lambda}$K spectroscopies.
4. Exploring the role of ΛNN interaction in saturated nuclear density through the spectroscopy of $^{208}_{\Lambda}$Tl hypernucleus.
5. Studying the triaxial deformation of nuclei (e.g., ^{26}Mg) using Λ as a probe in hypernuclei (e.g. $^{27}_{\Lambda}$Mg).

Results of these experiments are expected to significantly advance our understanding of ΛN and ΛNN interactions.

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Track Classification: Hadrons in Nuclei