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HYPERNUCLEAR SPECTROSCOPY WITH ELECTRON BEAM AT JLab HALL C

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Hypernuclear spectroscopy with electron beam at JLab Hall C has been studied since 2000. The first experiment, JLab E89-009, demonstrated the possibility of the $(e, e'K^+)$ reaction for hypernuclear spectroscopy by achieving an energy resolution of better than 1 MeV (FWHM). The second experiment, JLab E01-011 employed a newly constructed high resolution kaon spectrometer and introduced a vertically tilted electron arm setup to avoid electrons from bremsstrahlung and Moeller scattering. The setup allowed us to have 10 times yield rate and 4 times better signal to accidental ratio with expected energy resolution of 400 keV (FWHM). The third experiment, JLab E05-115 will be performed in 2009 with employing newly constructed high resolution electron spectrometer and a new charge-separation magnet. With the fully customized third generation experimental setup, we can study a variety of targets up to medium-heavy ones such as ^{52}Cr.

Keywords: Strangeness, hypernucleus, electroproduction, JLab.

1. Introduction

Hypernuclear spectroscopy with the $(e, e'K^+)$ reaction provides unique information on strangeness nuclear physics not accessible with mesonic reactions. However, the study had been hampered by experimental difficulties such as requirement of high duty factor electron beam, much smaller cross section than those of mesonic reactions, background electrons from associated with bremsstrahlung and Moeller scattering, and necessity to measure both electrons and kaons at very forward angles.

2. First Generation Experiment - E89-009

By overcoming these experimental difficulties and with the use of CW electron beam from CEBAF accelerator (Continuous Electron Beam Accelerator Facility) of Jefferson Lab (JLab), the first hypernuclear spectroscopy experiment using the $(e, e'K^+)$ reaction was successfully carried out at JLab Hall C in the spring of 2000 by the E89-009 collaboration[1].[2] The obtained energy resolution was 900 keV (FWHM), the best resolution by reaction spectroscopy at that time.

3. Second Generation Experiment - E01-011

Although the first experiment was successful, it suffered from high background rate of up to 200 MHz from bremsstrahlung at electron arm. This was due to the experimental setup that detects scattered electrons at 0 degree (zero-degree tagging method). Moreover, missing mass resolution was limited by the resolution of SOS spectrometer, used as kaon arm. Thus, the second generation experiment, E01-011, was proposed.[3] The schematic drawing of the HKS spectrometer system is shown in Ref.[4] The major changes in the setup are follows.

- Electron arm is tilted with respect to the splitter dispersion plane
- Kaon arm is replaced by newly constructed high resolution kaon spectrometer (HKS)

The former, so-called "tilt-method", avoids background electrons from bremsstrahlung and Moeller scattering by taking advantage of that the electrons from bremsstrahlung are more forward peaked than that associated with the virtual photon. With the setup, much higher beam current (up to 30 μA) and thicker target (100 mg/cm^2) can be used with much lower electron arm singles rate (< 10 MHz).

The latter, the HKS was newly constructed for the hypernuclear spectroscopy at the JLab Hall C. It is designed to have a momentum resolution of 2×10^{-4} FWHM and large solid angle of 16 msr (w/splitter), which is twice better momentum resolution and four times larger acceptance than the SOS.

The experiment was performed in the summer of 2005. The results shown here are all preliminary and accidental coincidence events are not subtracted. In particular, absolute scale and linearity of missing mass are under finalization process.

Fig. 1 shows preliminary missing mass spectrum of $CH_x(e, e'K^+)$ reaction. The two peaks correspond to production of Λ and Σ^0. Optics

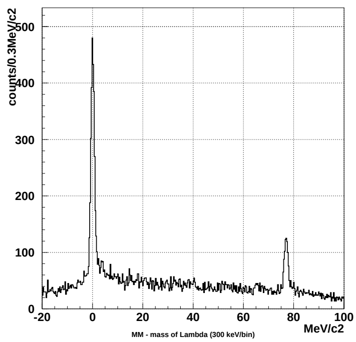

Fig. 1. Preliminary missing mass spectrum of the $(e, e'K^+)$ reaction on a CH_x target. The two peaks correspond to production of Λ and Σ^0. Optics of the electron arm and the kaon arm were calibrated using known hyperon masses.

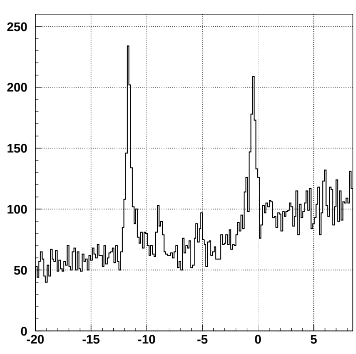

Fig. 2. Preliminary missing mass spectrum of the $^{12}C(e, e'K^+)$ reaction. Accidental coincidence is not subtracted. Two prominent peaks correspond to s_Λ and p_Λ states of $^{12}_{\Lambda}B$ and between two peaks several peaks correspond to core excited states are observed.

of the electron arm and the kaon arm were calibrated using known hyperon masses. Fig. 2 shows preliminary missing mass spectrum of the $^{12}C(e, e'K^+)$ reaction. Two prominent peaks correspond to s_Λ and p_Λ states of $^{12}_{\Lambda}B$ and between two peaks several peaks correspond to core excited states are observed. Fig. 3 shows preliminary missing mass spectrum of the $^{7}Li(e, e'K^+)$ reaction. Single prominent peak near -5 MeV corresponds to s_Λ state of $^{7}_{\Lambda}He$. Fig. 4 shows preliminary missing mass spectrum of the $^{28}Si(e, e'K^+)$ reaction. Three prominent peaks correspond to s_Λ, p_Λ, and d_Λ states of $^{28}_{\Lambda}Al$.

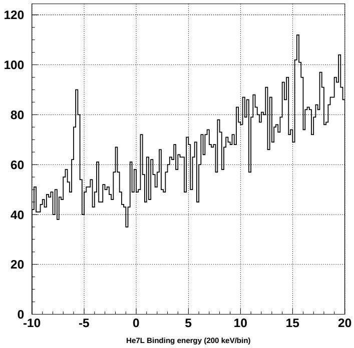

Fig. 3. Preliminary missing mass spectrum of the ^{7}Li$(e, e'K^{+})$ reaction. Accidental coincidence is not subtracted. Single prominent peak near -5 MeV corresponds to s_{Λ} state of $^{7}_{\Lambda}$He.

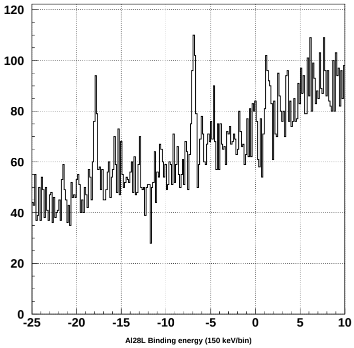

Fig. 4. Preliminary missing mass spectrum of the ^{28}Si$(e, e'K^{+})$ reaction. Accidental coincidence is not subtracted. Three prominent peaks correspond to s_{Λ}, p_{Λ}, and d_{Λ} states $^{28}_{\Lambda}$Al.

4. Third Generation Experiment - E05-115

The third generation experiment, E05-115 was proposed as a natural extension of E01-011 experiment[5] and will be performed in the summer of 2009. Major improvements of the experimental setup can be summarized as:

(1) Introduction of a newly constructed high resolution electron spectrometer (HES) as an electron arm.
(2) Introduction of a new charge-separation magnet (Splitter), fully cus-

tomized for hypernuclear experiment with the HKS and the HES at Hall C.

By introducing the HES and the Splitter, we are able to perform precision hypernuclear spectroscopy in the wide mass region, up to around $A = 50$.

5. Summary

At JLab Hall C, a series of hypernuclear spectroscopy using the $(e, e'K^+)$ reaction has been performed. The evolution of the hypernuclear program at JLab Hall C is summarized in Table 1. The first experiment proved that the $(e, e'K^+)$ hypernuclear spectroscopy is possible. Then, the second experiment established the experimental technique. Finally, in the third experiment we will be able to perform precision hypernuclear spectroscopy in the wide mass region using spectrometer system fully optimized to the $(e, e'K^+)$ hypernuclear spectroscopy.

Table 1. Evolution of $(e, e'K^+)$ hypernuclear spectroscopy at JLab Hall C.

	2000	2005	2009
	E89-009	E01-011	E05-115
Configuration	SOS+ENGE +Splitter	HKS+ENGE +Splitter	HKS+HES New Splitter
Beam intensity (μA)	0.66	24	30-100
on ^{12}C thickness (mg/cm^2)	22	100	100
Hypernuclear yield ($^{12}_{\Lambda}$B$_{gr}$/h)	0.9	10	>40-100
Resolution (keV) FWHM	750	400-500	[300-400]
Beam energy (GeV)	1.7-1.8	1.850	2.344
p_K (central : GeV/c)	1.2	1.2	1.2
p_e (central : GeV/c)	0.3	0.3	0.7-1.0
θ_K (degree)	0-7	1-13	1-13
θ_e (degree)	0	4.5	6.5
		HKS+Tilt	HKS+Tilt+HES

[ ] expected

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