

Experimental Study of the Λ - n Interaction in the $\gamma d \rightarrow K^+ \Lambda n$ Reaction



NSTAR 2026

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Introduction



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ΛN interaction

The ΛN interaction is a fundamental ingredient of hypernuclear physics.

Charge symmetry implies:

$$V_{\Lambda p} = V_{\Lambda n}$$

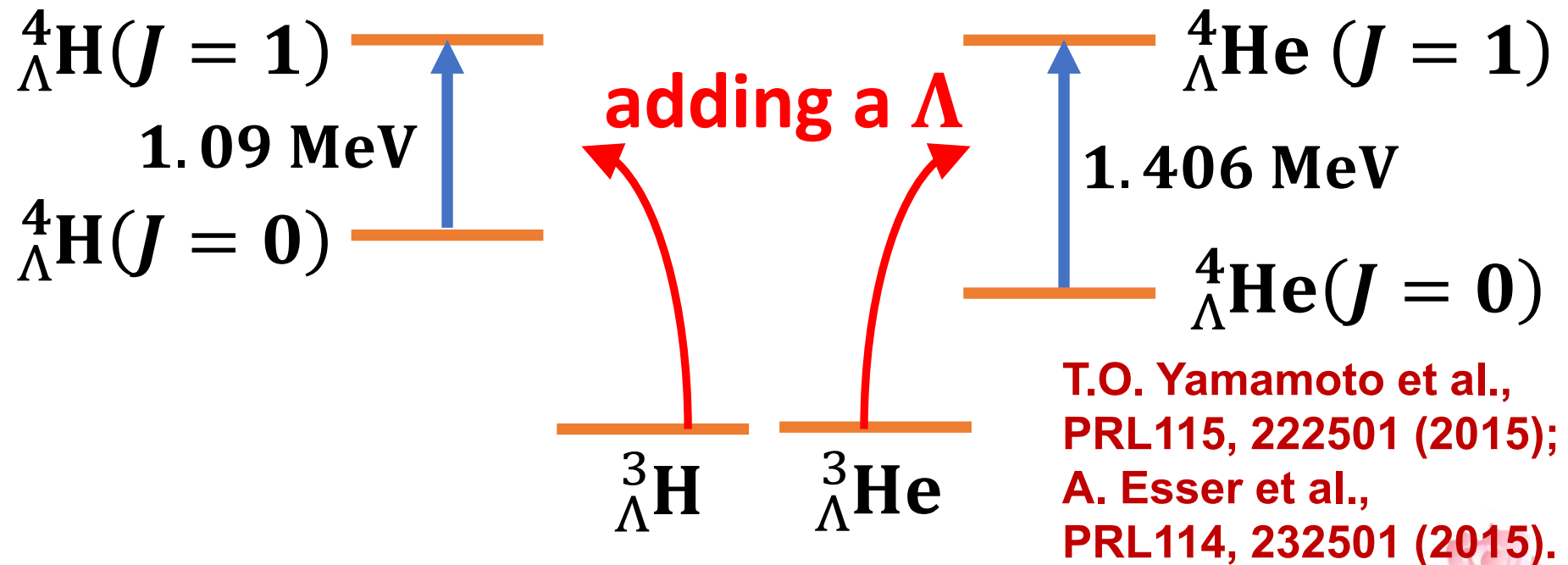
Charge symmetry breaking (CSB) has been observed in the $A = 4$ mirror hypernuclei





${}^4_{\Lambda}\text{H}$ and ${}^4_{\Lambda}\text{He}$

0.3-MeV difference of excitation energies between ${}^4_{\Lambda}\text{H}$ and ${}^4_{\Lambda}\text{He}$



How different are the Λp and Λn interactions?

J. Haidenbauer, U.-G. Meißner, A. Nogga,
Eur. Phys. J. A 56, 91 (2020).

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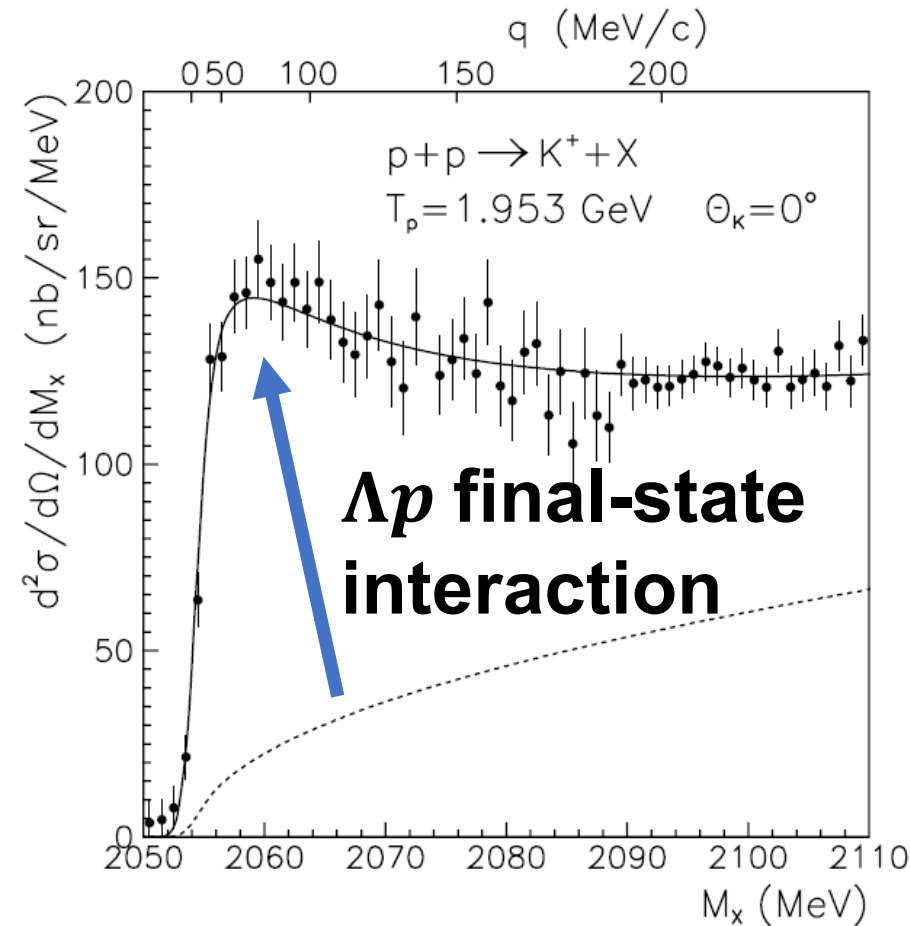
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Λp interaction

The Λp scattering length was determined



from $pp \rightarrow K^+(\Lambda p)$ at
 $P_p = 2.735 \text{ GeV}/c$,

$\theta_K = 0^\circ$

M_X spectrum for
 $p(p, K^+)X$ gives

$$\bar{a} = 2.43^{+0.16}_{-0.17} \text{ fm}$$

$$\bar{r} = 2.21^{+0.16}_{-0.16} \text{ fm}$$

HIRES Collaboration,
Phys. Lett. B 687, 31 (2010).



Direct Λp scattering becomes possible



How to study the Λn interaction

Several reaction have been proposed to study the Λn interaction.

1. $K^- d \rightarrow \Lambda n \gamma$

W.R. Gibbs, S.A. Coon, H.K. Han, and B.F. Gibson,
PRC61, 064003 (2000).

2. $K^- d \rightarrow \pi^0 \Lambda n$ and $\pi^- \Lambda p$

direct comparison is possible between
 Λn and Λp

Y. Iizawa, D. Jido, T. Ishikawa, PRC106, 045201 (2022);
S. Yasunaga, D. Jido, T. Ishikawa, PRC112, 015208 (2025).

3. $\gamma d \rightarrow K^+ \Lambda n$

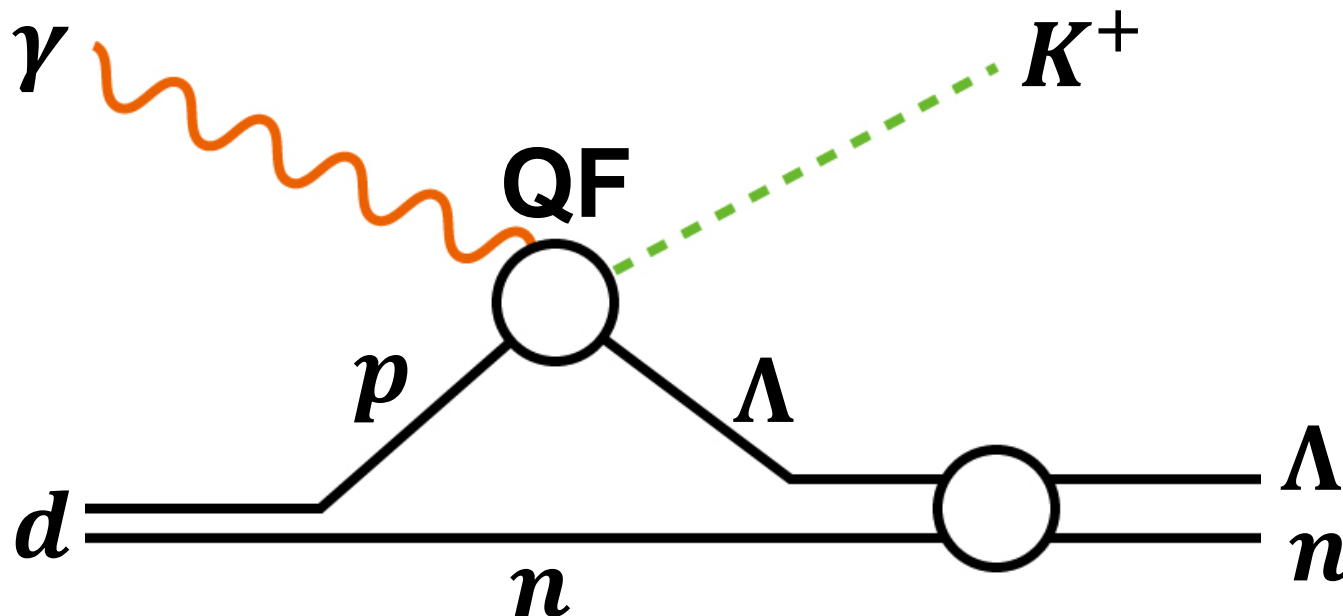
H. Yamamura, K. Miyagawa *et al.*, PRC61, 014001 (1999).





$$\gamma d \rightarrow K^+ \Lambda n$$

Λn final-state interaction (FSI) in $\gamma d \rightarrow K^+ \Lambda n$, where quasi-free (QF) $\gamma p' \rightarrow K^+ \Lambda$ is expected to take place



Λn FSI is expected to enhance the $M_{\Lambda n}$ spectrum near the Λn threshold





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Experiment

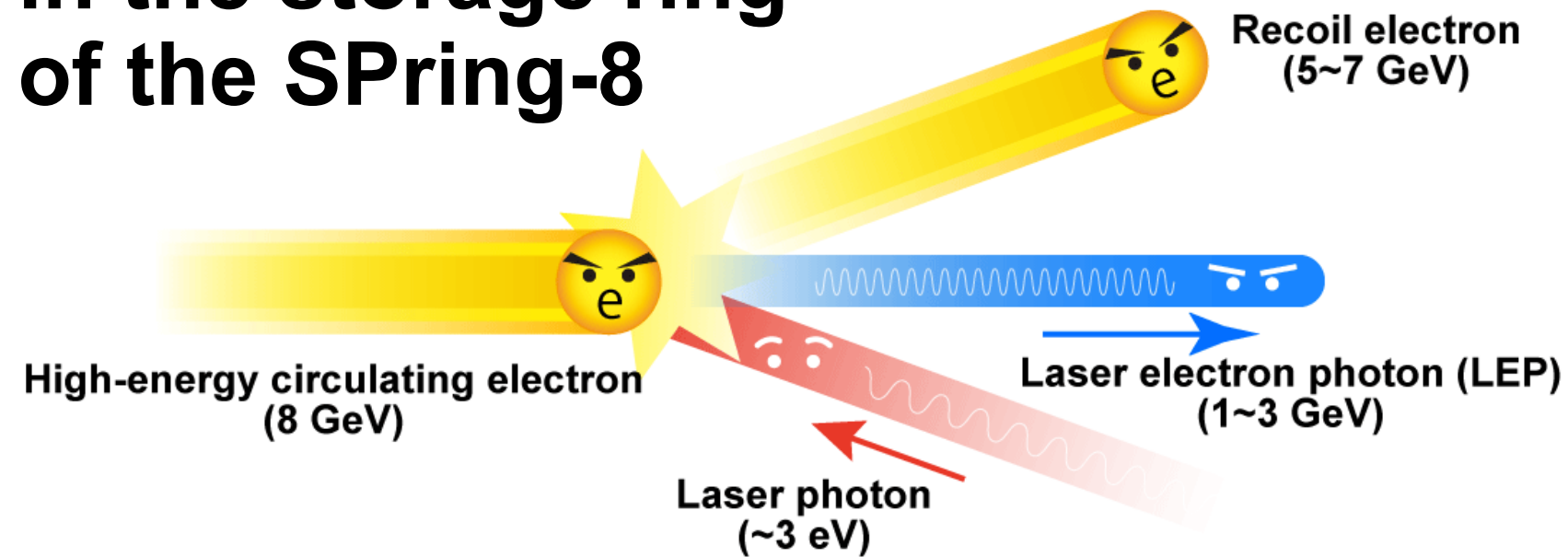


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LEPS facility at SPring-8

At the LEPS facility, we use **the laser electron photon (LEP) beam**, which is generated by Compton scattering from laser photons and circulating electrons in the storage ring of the SPring-8



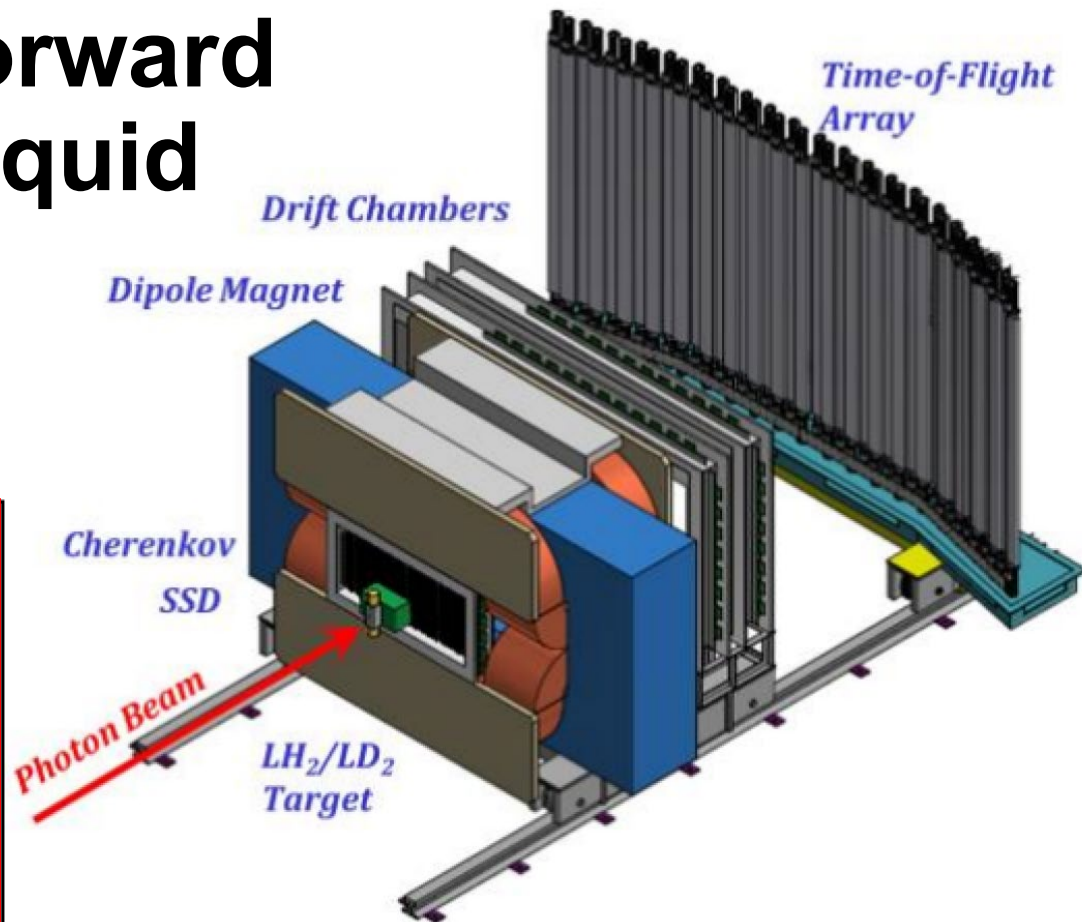
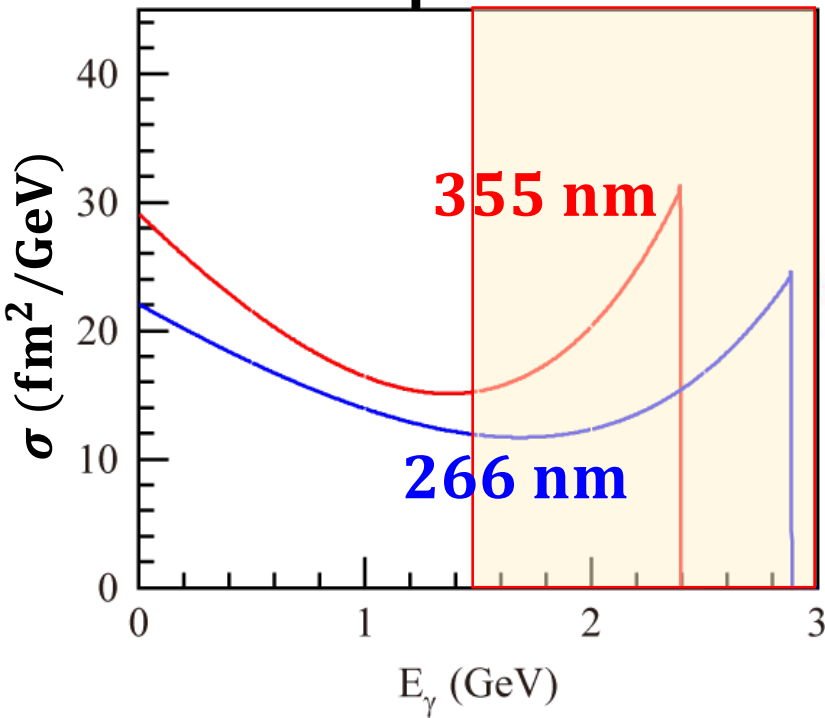


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LEPS facility at SPring-8

K^+ detection at forward angles from the liquid deuterium target

Energy distribution of incident photons



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Analysis



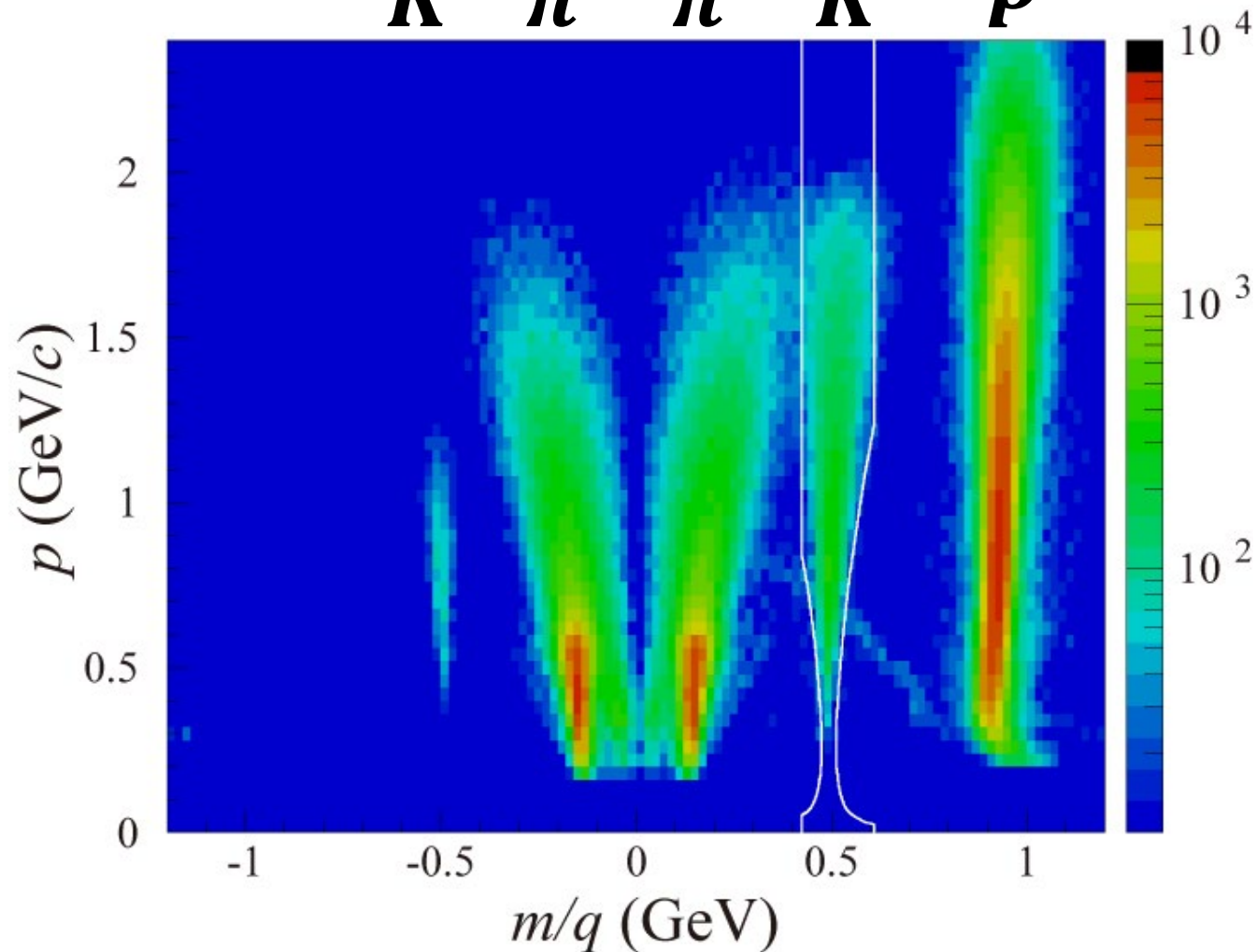


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Particle ID

K^+ detection

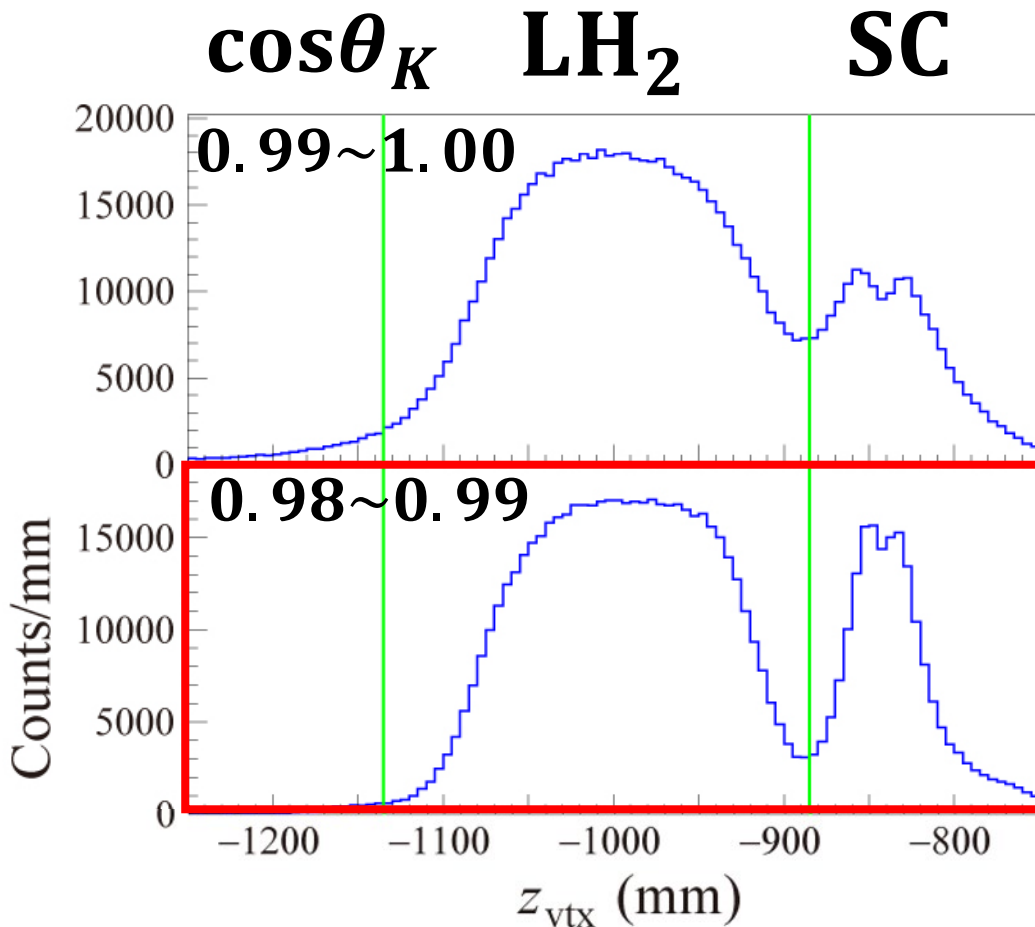
$K^- \quad \pi^- \quad \pi^+ \quad K^+ \quad p$



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Vertex selection



**Vertex resolution
deteriorates at
forward angles**

Selection criteria

$$\cos\theta_K < 0.99$$

$$z_{\text{vtx}} \in [-1135, -885) \text{ mm}$$





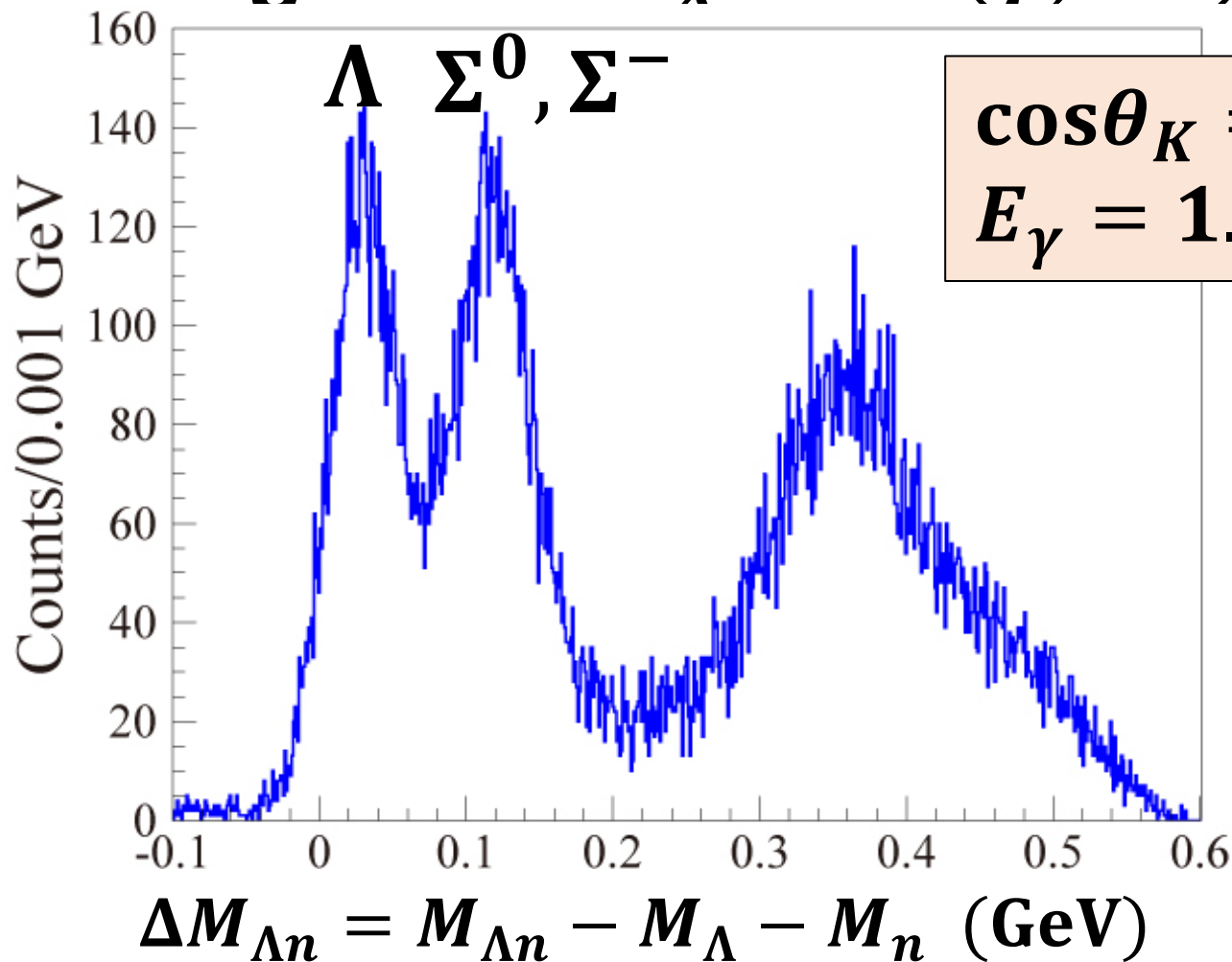
Preliminary Results





Λn invariant mass distributions

Λn invariant mass $M_{\Lambda n}$ is given by the missing mass M_X for $d(\gamma, K^+)X$



$$\cos\theta_K = 0.98 \sim 0.99$$
$$E_\gamma = 1.6 \sim 1.7 \text{ GeV}$$





Λn invariant mass distributions

$\gamma p \rightarrow K^+ \Lambda$ data

relatively well-established below $W \simeq 2.0 \text{ GeV}$ ($E_\gamma \simeq 1.66 \text{ GeV}$) T. Mart, Prog. Theor. Exp. Phys. 2019, 069101 (2019).

Quasifree $\gamma p' \rightarrow K^+ \Lambda$ and $K^+ \Sigma^0$ data are produced from the CLAS data

M. Sumihama et al., Phys. Rev. C 73, 035214 (2006)
R. Bradford et al., Phys. Rev. C 73, 035202 (2006)

Λn final-state interaction

$$\text{FSI factor} \sim \left\{ 1 + \left(\frac{p}{-\frac{1}{a} + \frac{1}{2} r p^2} \right)^2 \right\}^{-1}$$



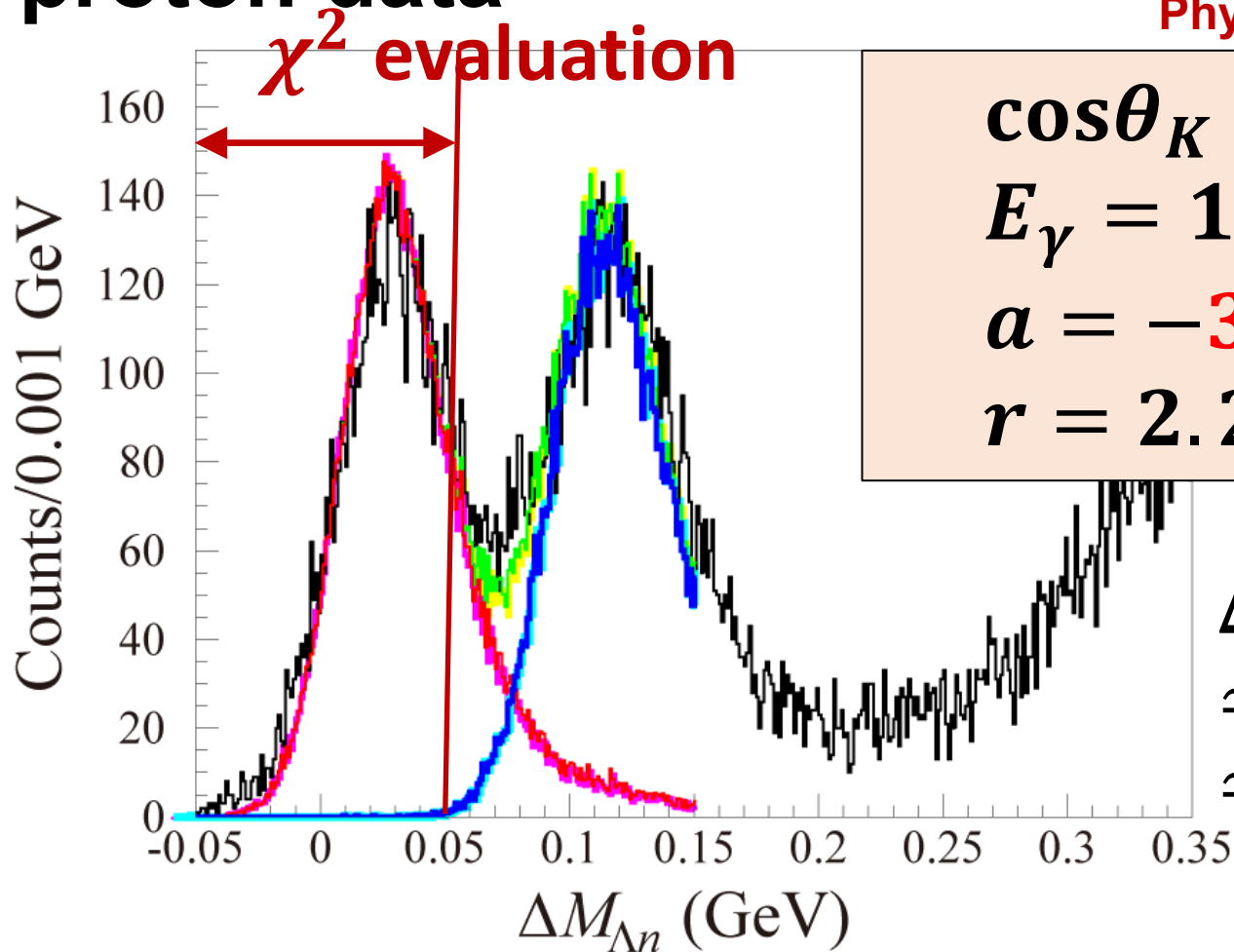


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Λn invariant mass distributions

Quasifree $\gamma p' \rightarrow K^+ \Lambda$ and $K^+ \Sigma^0$ from the proton data

R. Bradford *et al.*,
Phys. Rev. C 73, 035202 (2006).



$$\cos\theta_K = 0.98 \sim 0.99$$

$$E_\gamma = 1.6 \sim 1.7 \text{ GeV}$$

$$a = -3.0, -1.0 \text{ fm}$$

$$r = 2.21 \text{ fm } (\Lambda p)$$

$$\Delta M_{\Lambda n}$$

$$\simeq 77.0 \text{ MeV } (\Sigma^0 n)$$

$$\simeq 80.5 \text{ MeV } (\Sigma^- p)$$

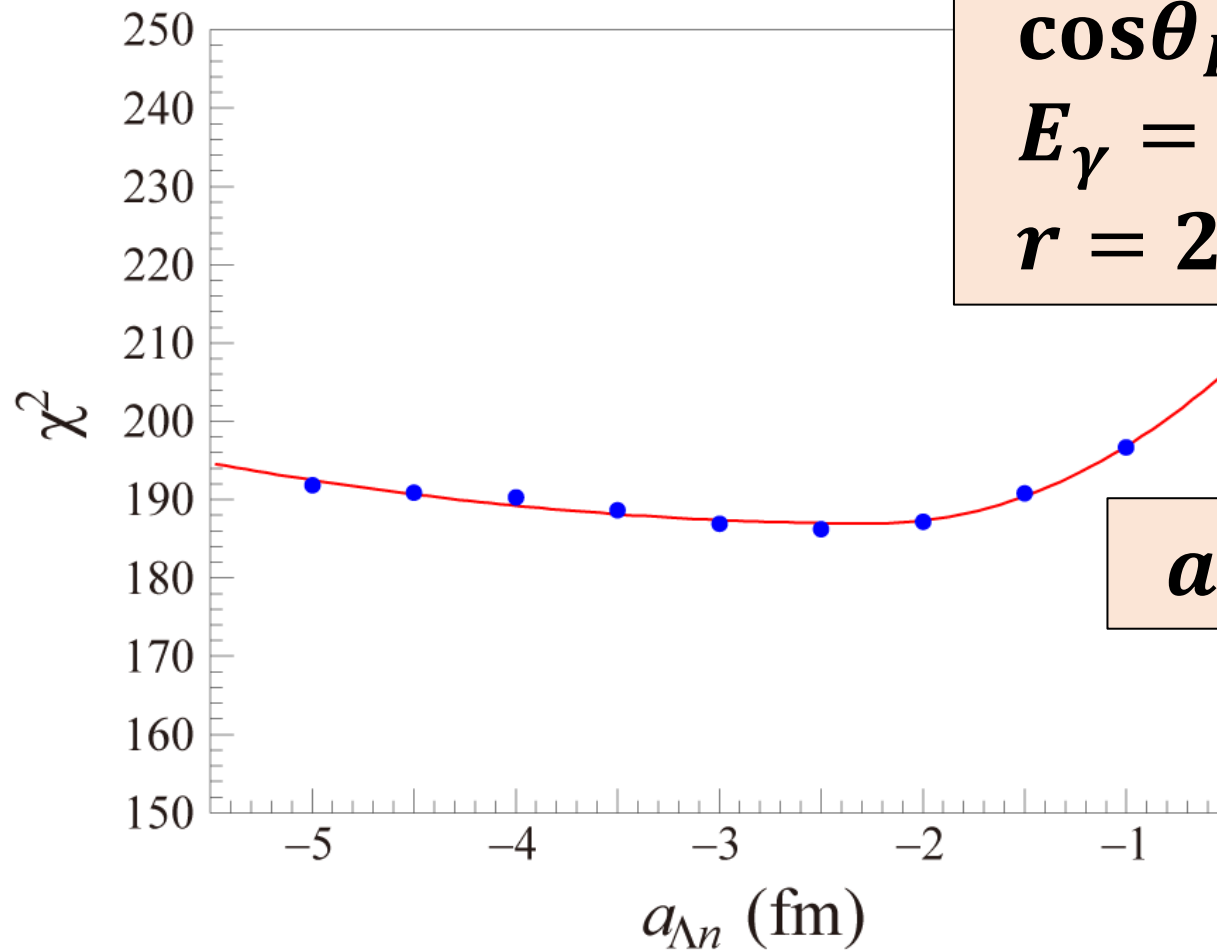


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Λn scattering length



$\cos\theta_K = 0.98 \sim 0.99$,
 $E_\gamma = 1.6 \sim 1.7$ GeV
 $r = 2.21$ fm (Λp)

$$a = -2.2_{-1.2}^{+0.4} \text{ fm}$$

Errors correspond
to $\Delta\chi^2 = 1$

$$a = -2.7_{-1.5}^{+0.4} \text{ fm for } E_\gamma = 1.5 \sim 1.6 \text{ GeV}$$





Summary





Summary

- We measured differential cross sections for inclusive K^+ photoproduction from the deuteron with K^+ detection at forward angles
- A small excess over the quasifree contribution is seen in the low-relative-energy region
- A preliminary fit suggests a spin-averaged Λn scattering length: $a \sim -2.5$ fm
- More reliable elementary $\gamma N \rightarrow K^+ Y$ inputs are needed
- Three-body calculations are needed.

