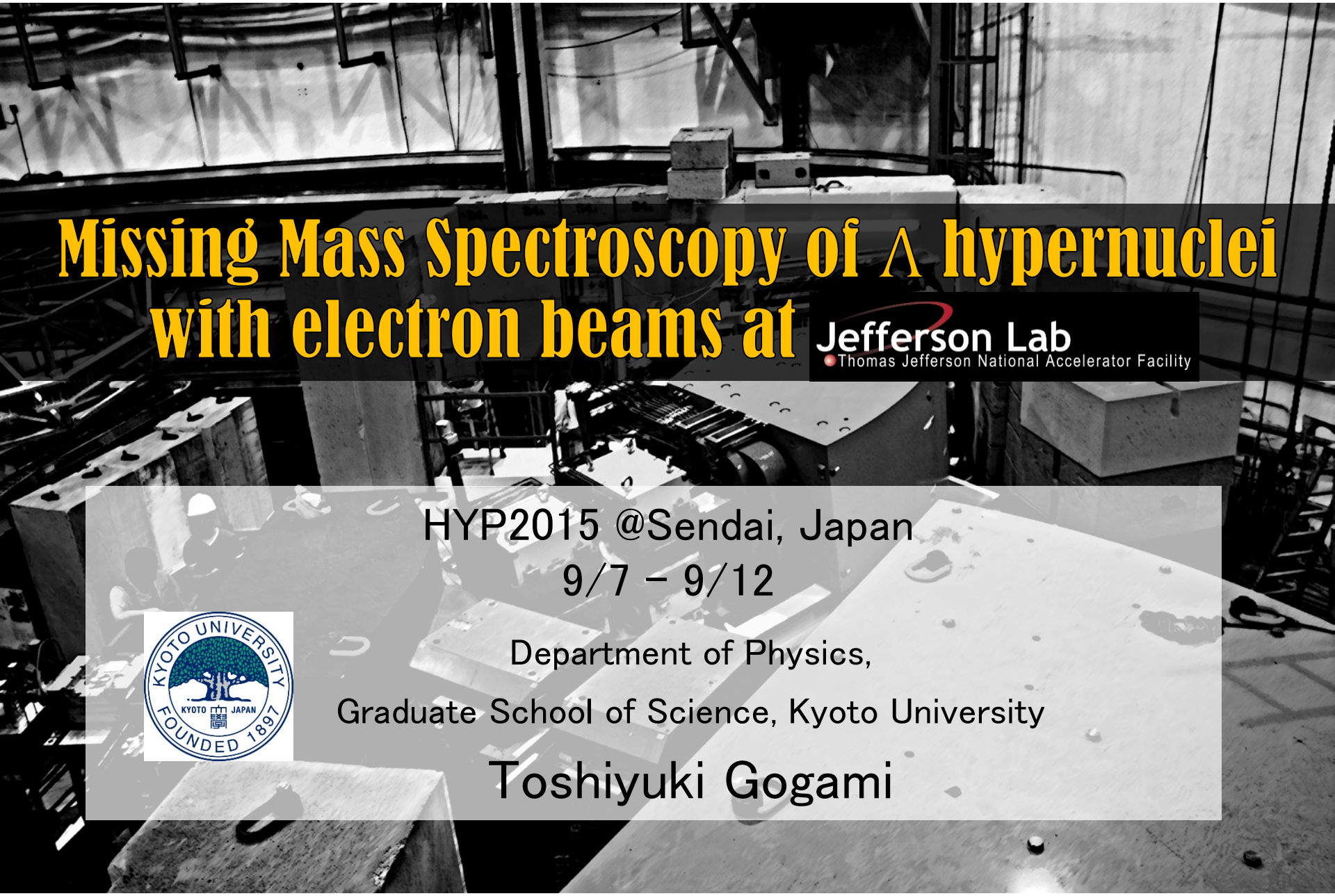

Missing Mass Spectroscopy of Λ hypernuclei with electron beams at Jefferson Lab

Thomas Jefferson National Accelerator Facility

HYP2015 @Sendai, Japan

9/7 – 9/12

Department of Physics,

Graduate School of Science, Kyoto University

Toshiyuki Gogami

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- Introduction
  - $\boldsymbol{\Delta B_{\Lambda}^{mirror}}$ in p-shell hypernuclei
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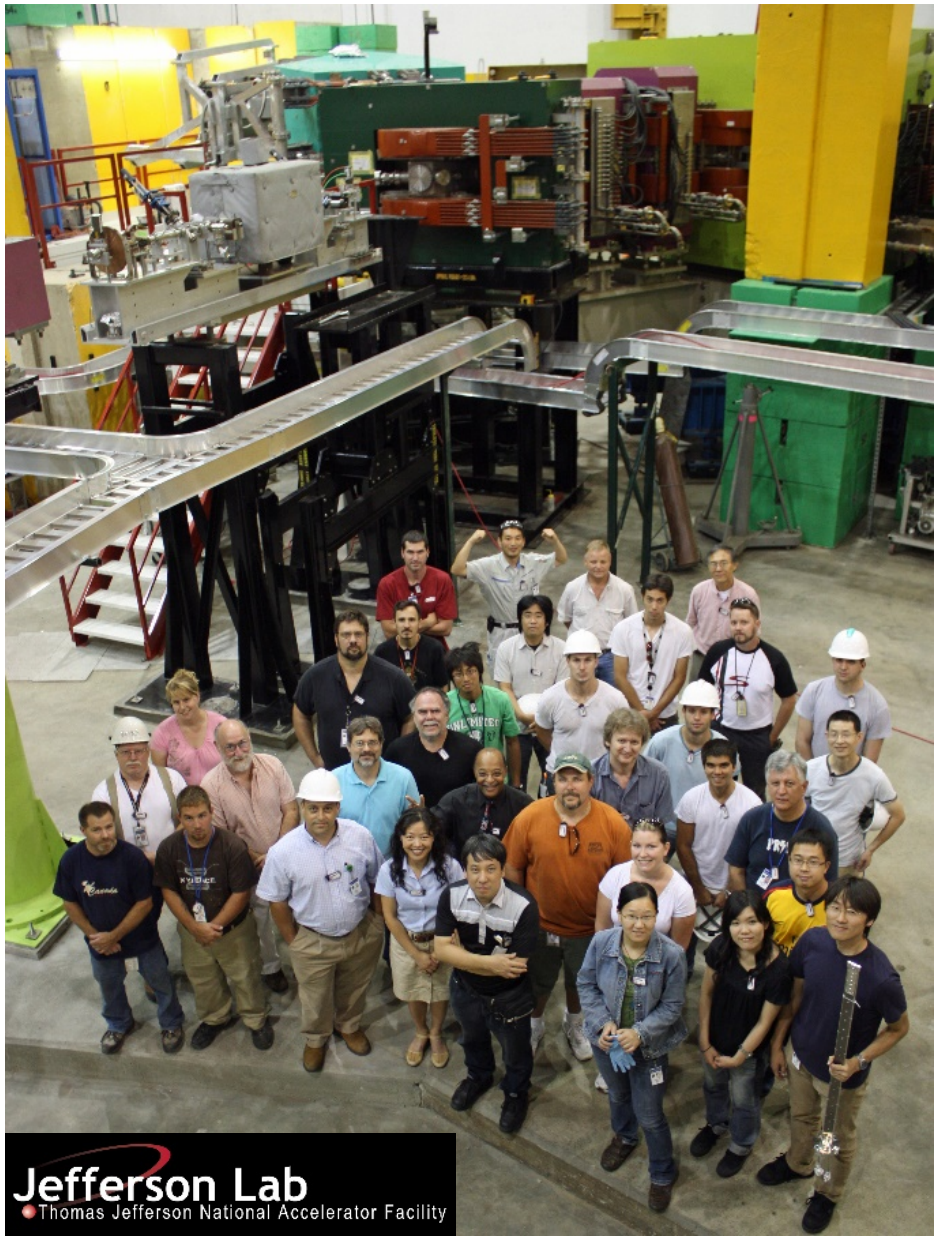

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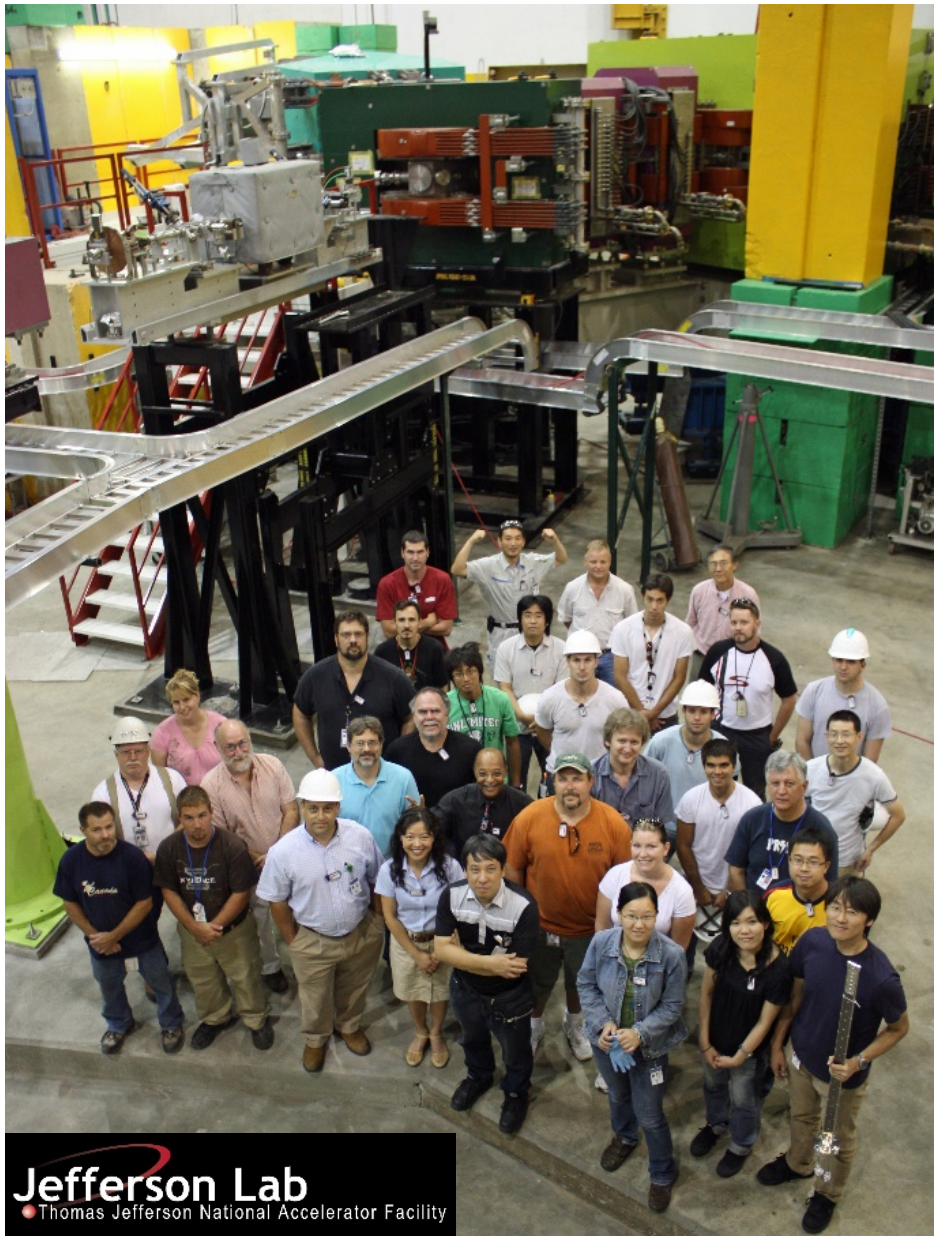

A Role of the (e,e' K^+) Experiment

Experiment	Energy Resolution (FWHM) [keV]	B_Λ accuracy [keV]	Mass Number (So far)
Emulsion	–	≲ 200	≤ 16
(K^-, π^-), (π^+,K^+)	≳ 1000	≲ 1000	≤ 209
γ –ray	A few	–	≤ 19
(e,e' K^+)	≅ 500	≲ 200	≤ 52
Decay– π	≅ 100	≲ 200	A=4

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⟹ Comparing B_Λ of isotopic mirror hypernuclei up to p–shell region.

⟹ ΛN CSB effect in p–shell hypernclei.

ΔB_Λ of isotopic mirror pairs (g.s.)

Mirror pairs	$\Delta B_\Lambda^{theor.}$ [MeV]	Experiment	$\Delta B_\Lambda^{exp.}$ [MeV]
${}^{4}_{\Lambda}\mathrm{He} - {}^{4}_{\Lambda}\mathrm{H}$	$+0.226$[1]	Emul. - Emul.	$+0.35 \pm 0.06$
		Emul. - MAMI	$+0.27 \pm 0.10$
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		Emul. - *JLab_2009*	*NEW*
${}^{12}_{\Lambda}\mathrm{C} - {}^{12}_{\Lambda}\mathrm{B}$		Emul. - Emul.	-0.61 ± 0.20
		Emul. - Other_(e,e'K^+)	Consistent with above
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[1] A.Gal, PLB 744, 352 (2015)

[2] E.Hiyama *et al.*, PRC 80, 054321 (2009), w/o CSB

[3] E.Hiyama and Y.Yamamoto., PTP 128, 1 (2012), w/o CSB

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Large CSB in A=12 ?

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THIS TALK

New ΔB_Λ (${}^{12}_{\Lambda}\mathrm{C} - {}^{12}_{\Lambda}\mathrm{B}$)

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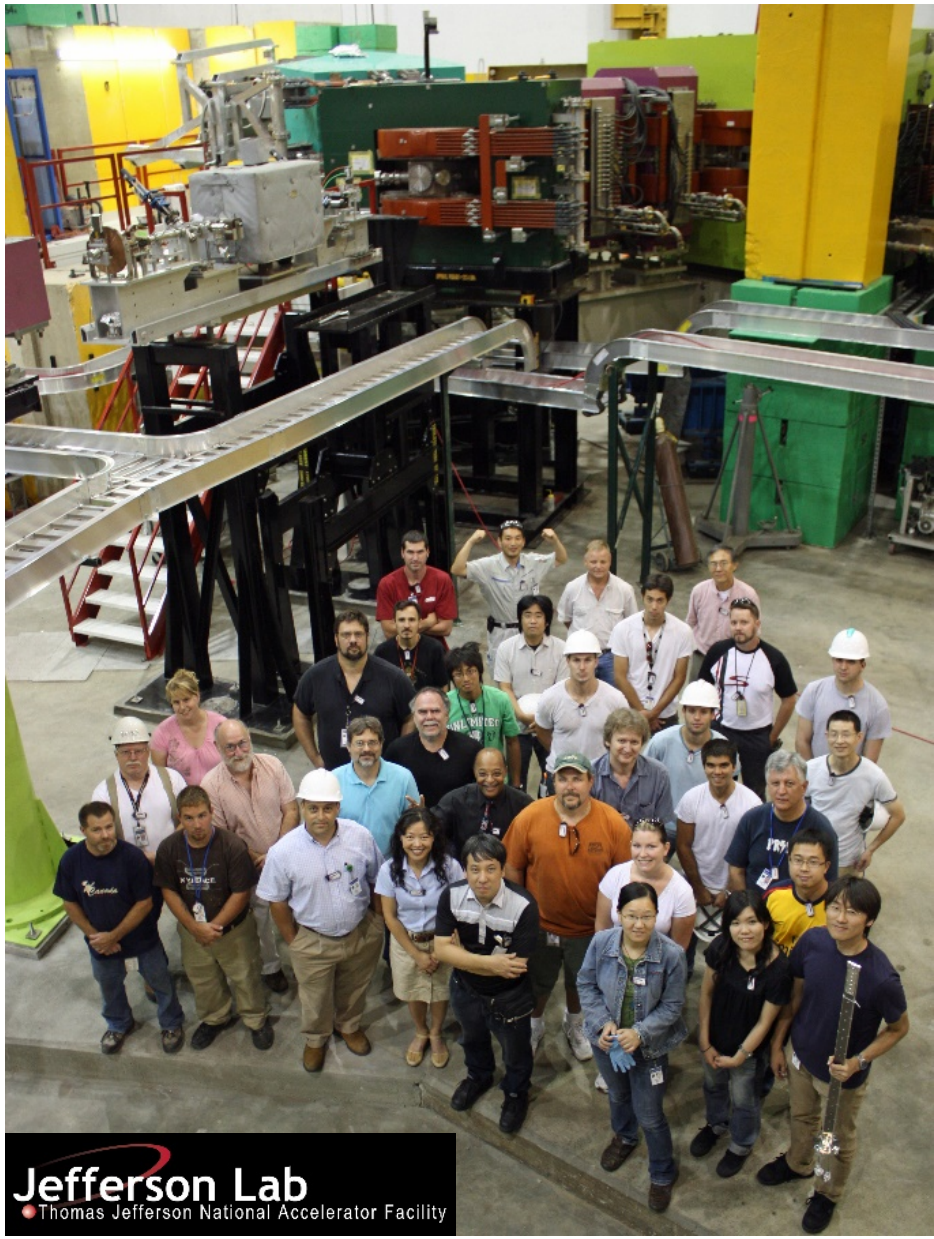


Missing mass spectroscopy

$$^{A}Z\,(e,e'K^{+})\,^{A}_{\Lambda}(Z-1)$$

CEBAF CEBAF Measure

$$M_{HYP}^{2} = (E_e + M_t - E_K - E_{e'})^2 - (\boldsymbol{p}_e - \boldsymbol{p}_K - \boldsymbol{p}_{e'})^2$$

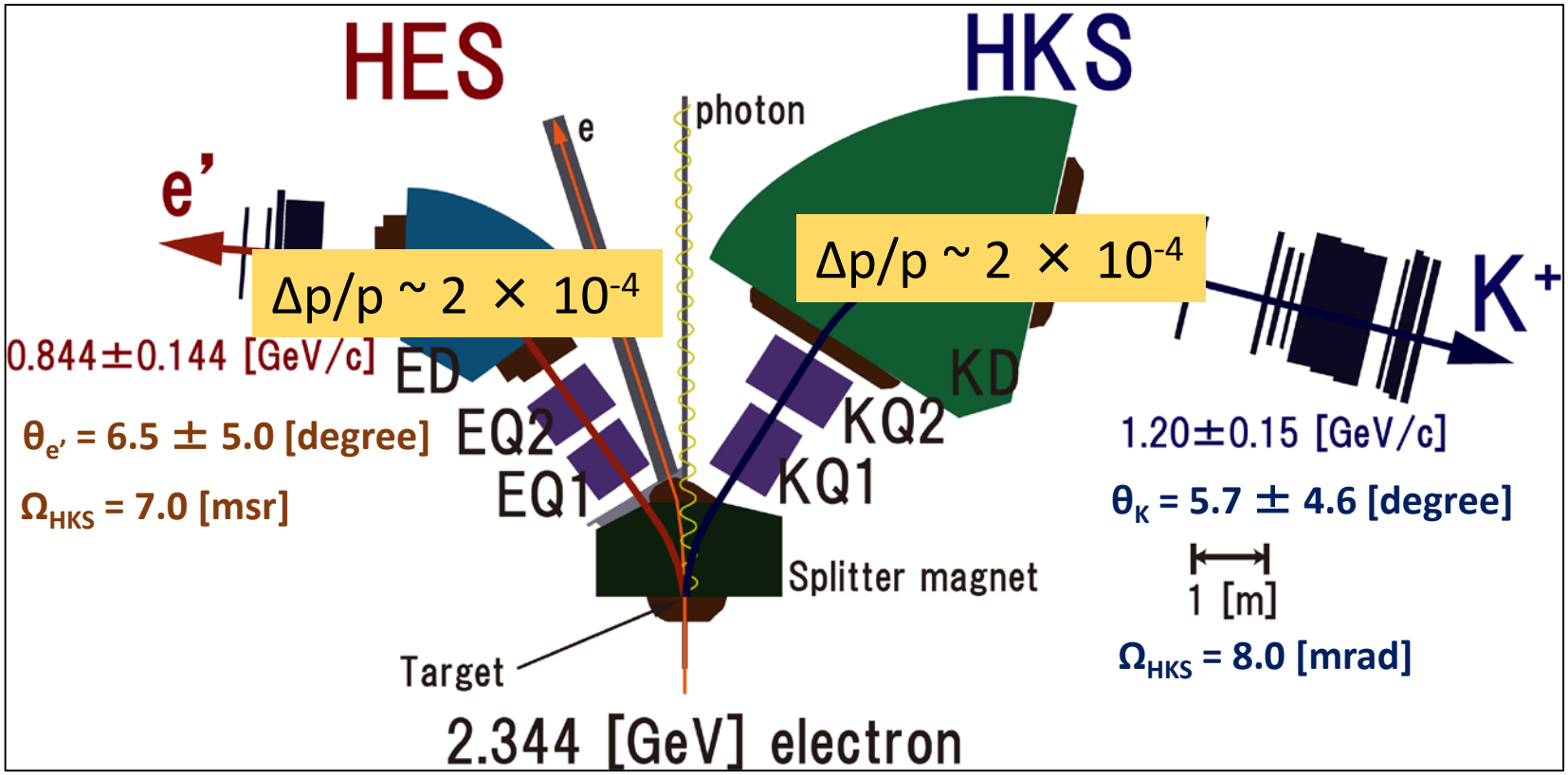
Known

$$-B_\Lambda = M_{HYP} - M_\Lambda - M_{core}$$

(Λ's binding energy)

Experimental setup (JLab E05-115)

Jefferson Lab
Thomas Jefferson National Accelerator Facility



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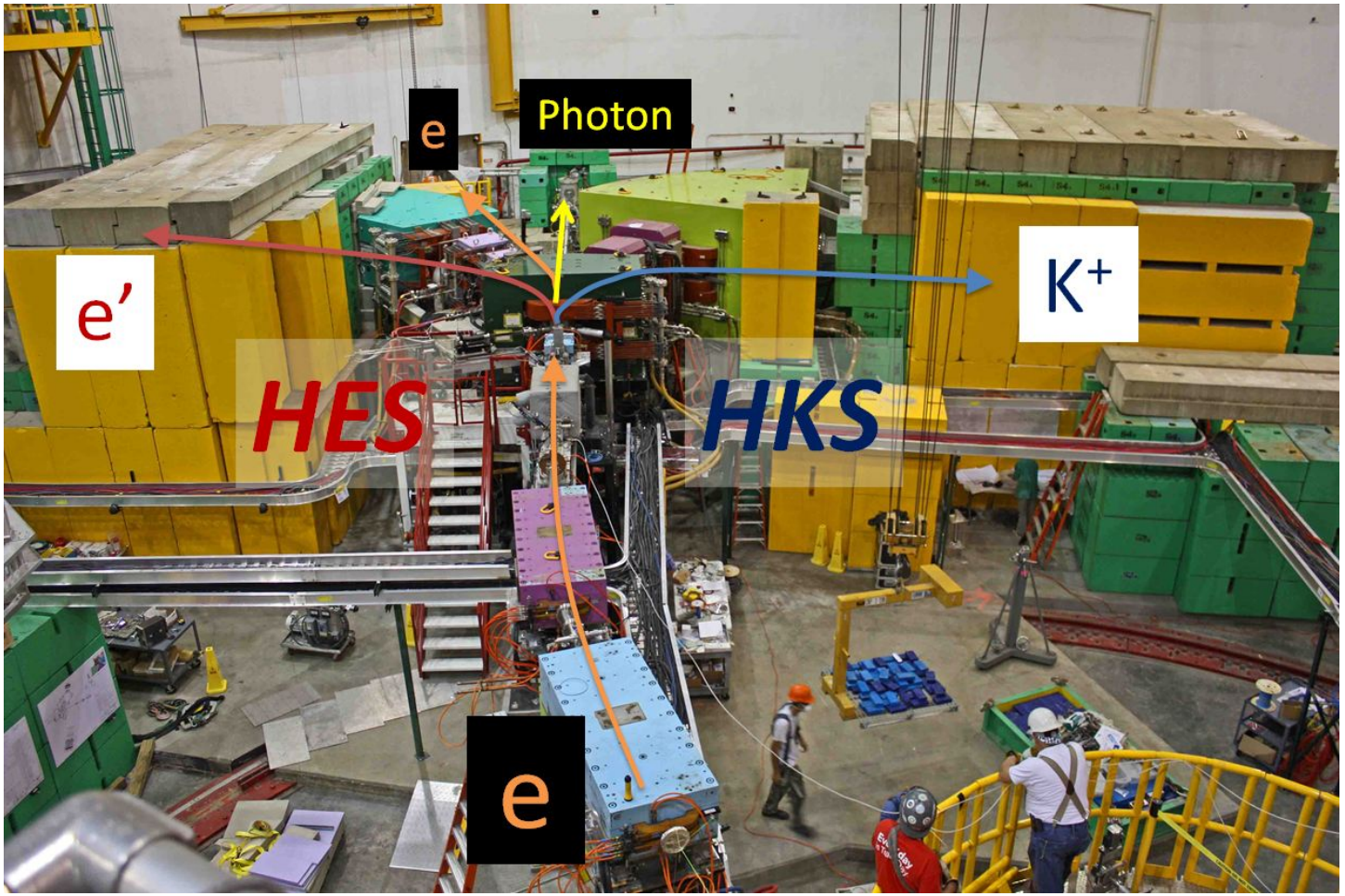

Data summary (JLab E05-115)

(August - November in 2009)

Target ([mg/cm^2])	Hypernucleus Hyperon	Nominal beam current [μA]	Run time [h]	Total incident charge [C] (Number of incident e^-)
CH_2 (450)	Λ, Σ^0, $^{12}_{\Lambda}$B	2.0	39	0.28 (0.17×10^{19})
H_2O (500)	Λ, Σ^0, $^{16}_{\Lambda}$N	2.5	21	0.20 (0.12×10^{19})
^{7}Li (208)	$^{7}_{\Lambda}$He	35	42	4.84 (3.0×10^{19})
^{9}Be (188)	$^{9}_{\Lambda}$Li	40	39	5.33 (3.3×10^{19})
^{10}B (56)	$^{10}_{\Lambda}$Be	40	45	6.25 (3.9×10^{19})
^{12}C (88)	$^{12}_{\Lambda}$B	20, 35	55	5.73 (3.6×10^{19})
^{52}Cr (154)	$^{52}_{\Lambda}$V	7.5	230	6.35 (4.0×10^{19})

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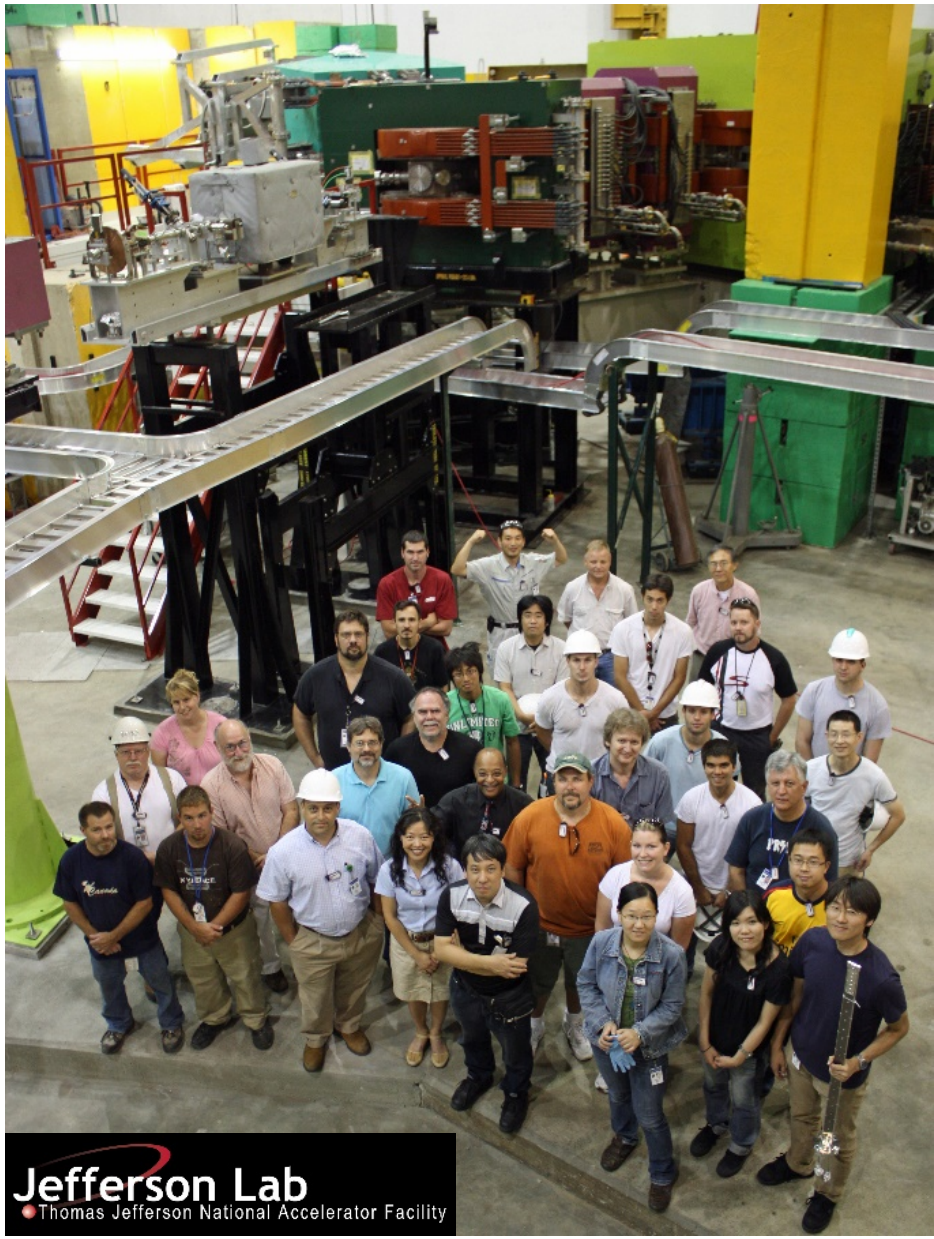
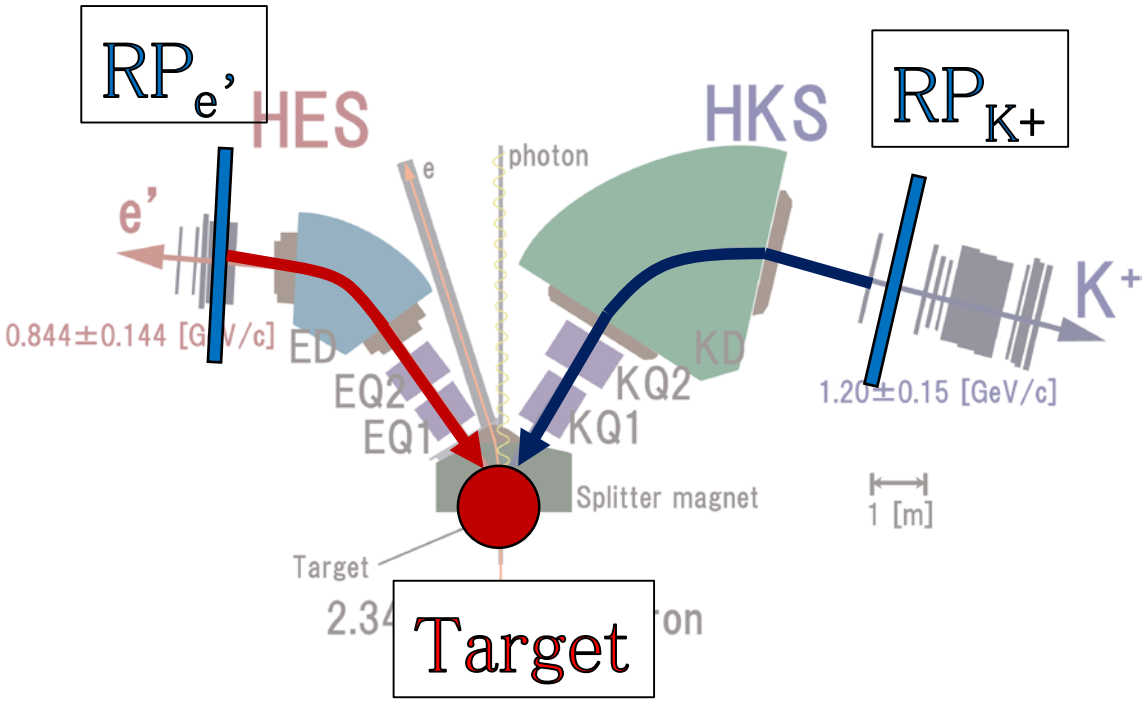


Missing Mass Reconstruction using Backward Transfer Matrices



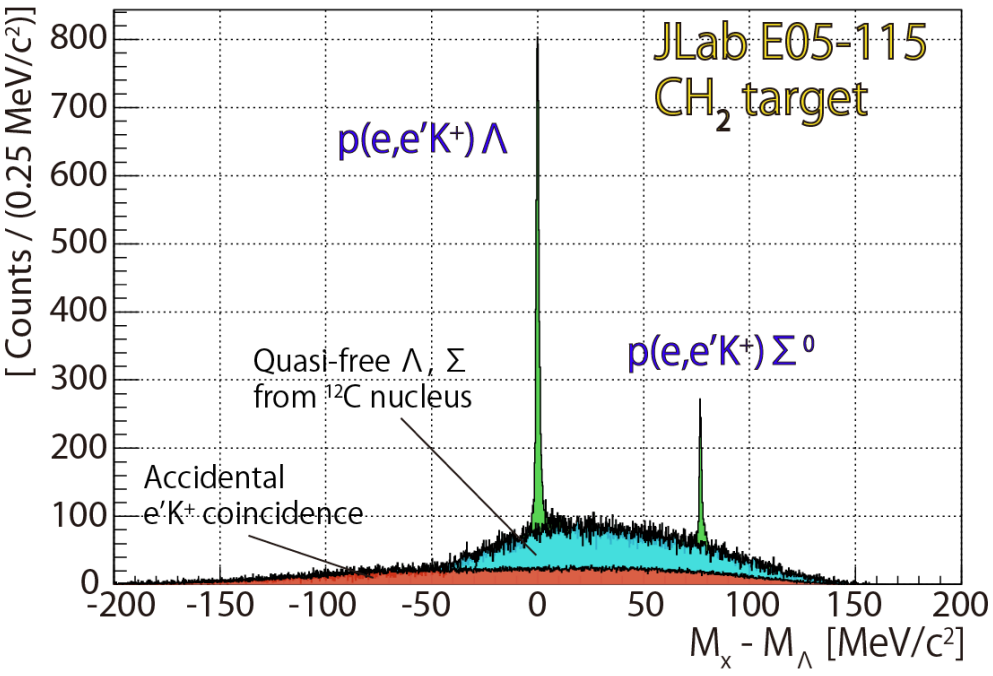
Positions, angles
@Reference plane

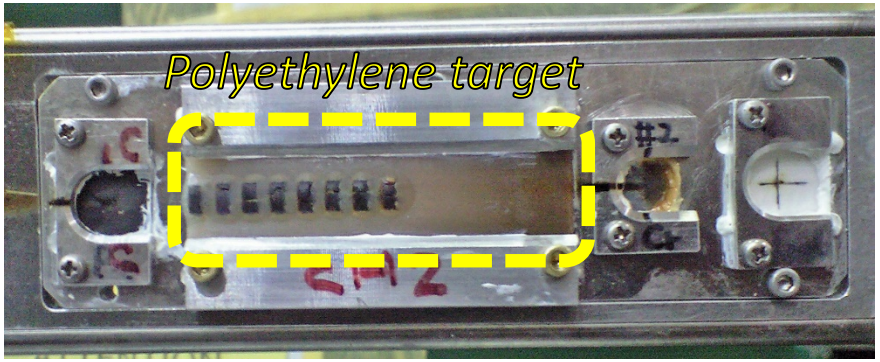
6th order Backward Transfer Matrices

Momentum vectors
@Target

Missing Mass, M_H

Energy Scale Calibration
= Backward Transfer Matrix Optimization





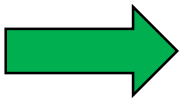
PDG values

(K. Nakamura et al., Journal of Physics G 37, 075021, 2010)

Λ : 1115.683 ± 0.006 MeV

Σ^0 : 1192.642 ± 0.024 MeV

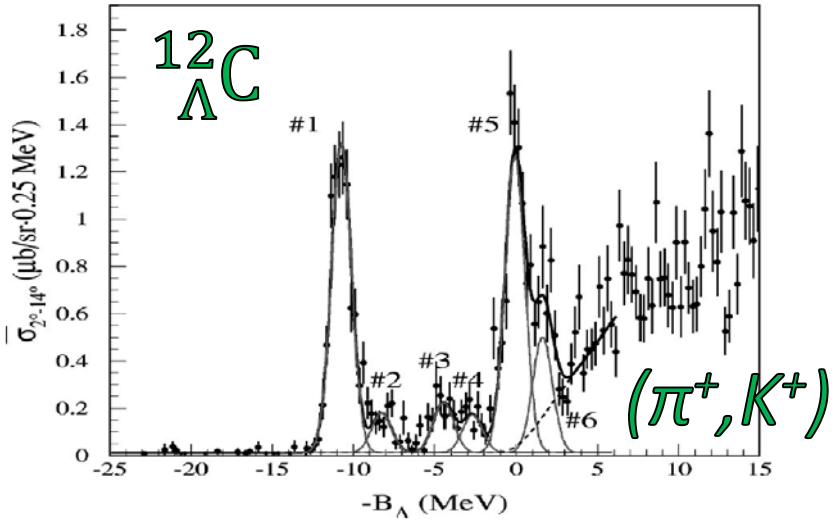
Full modeled
Monte Carlo Sim.



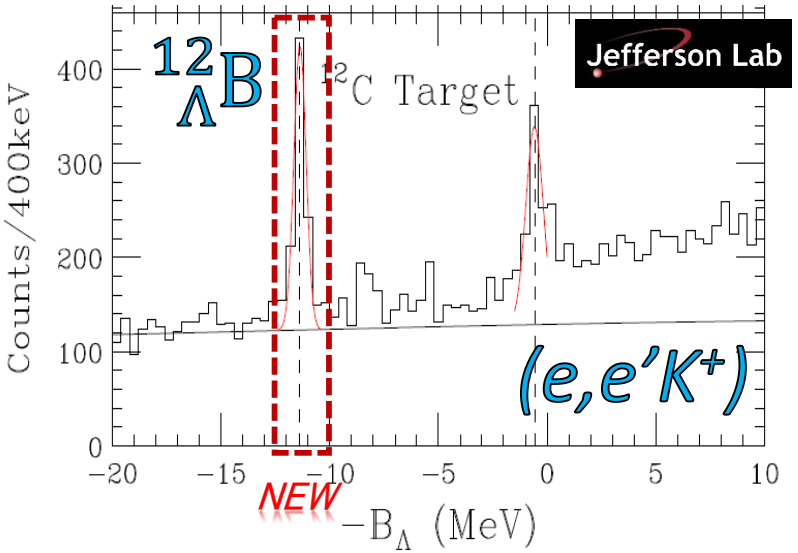
Sys. Error = 0.11 MeV

A result of $^{12}_{\Lambda}$B comparing with $^{12}_{\Lambda}$C

H. Hotchi et al., PRC 64, 044302 (2001)



L.Tang et al., PRC 90, 034320 (2014)



Hypernucleus	Experiment	B_Λ [MeV]	$\Delta B_\Lambda(^{12}_{\Lambda}\mathrm{C} - ^{12}_{\Lambda}\mathrm{B})$ [MeV]
$^{12}_{\Lambda}$C	Emulsion	$10.76 \pm 0.19^{*1)}$	
$^{12}_{\Lambda}$B	Emulsion	$11.37 \pm 0.06^{*1)}$	-0.61 ± 0.20
	JLab_2009	$11.529 \pm 0.025^{*2)}$ NEW	-0.77 ± 0.19

*1) Systematic error = 0.04 MeV

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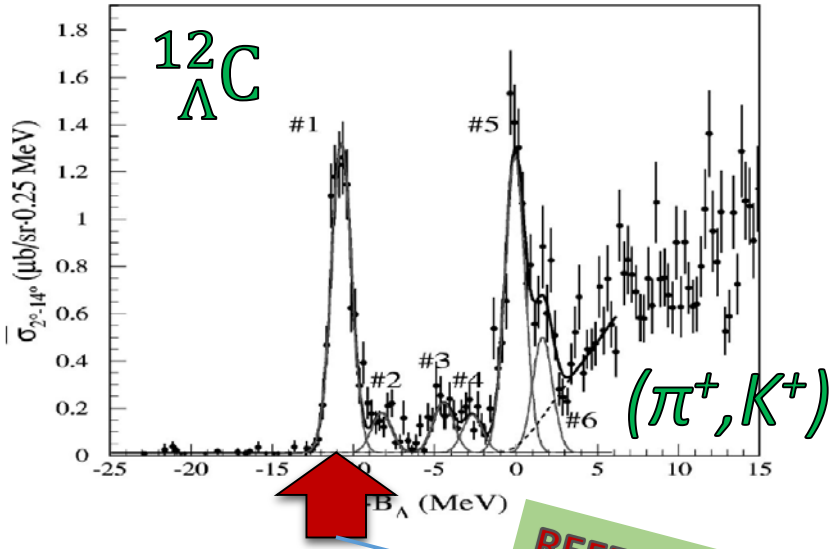

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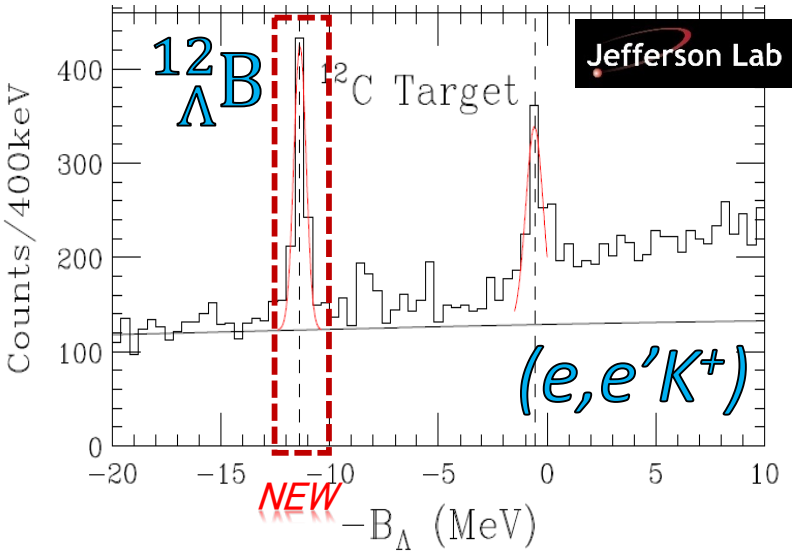

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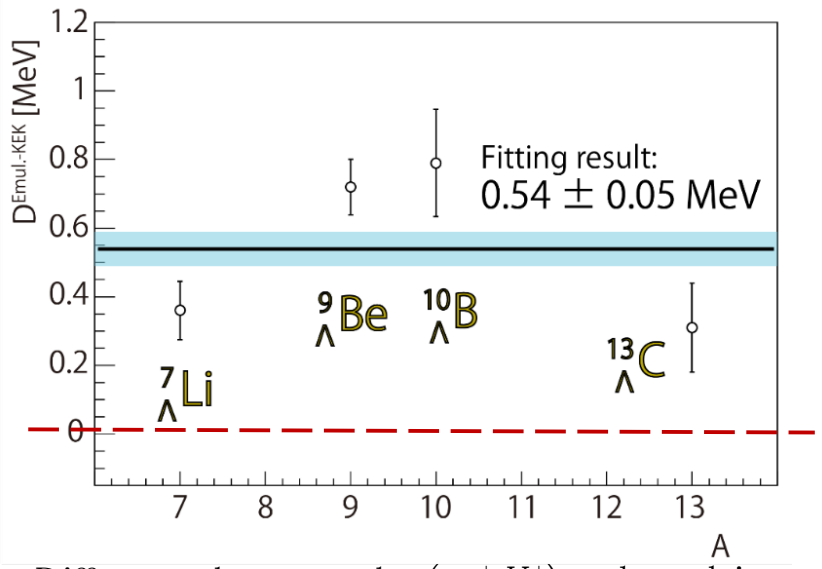

Difference between the (π^+,K^+) and emulsion exp.

Indicates that
the reported $B_{\Lambda}({}^{12}_{\Lambda}\mathrm{C})$
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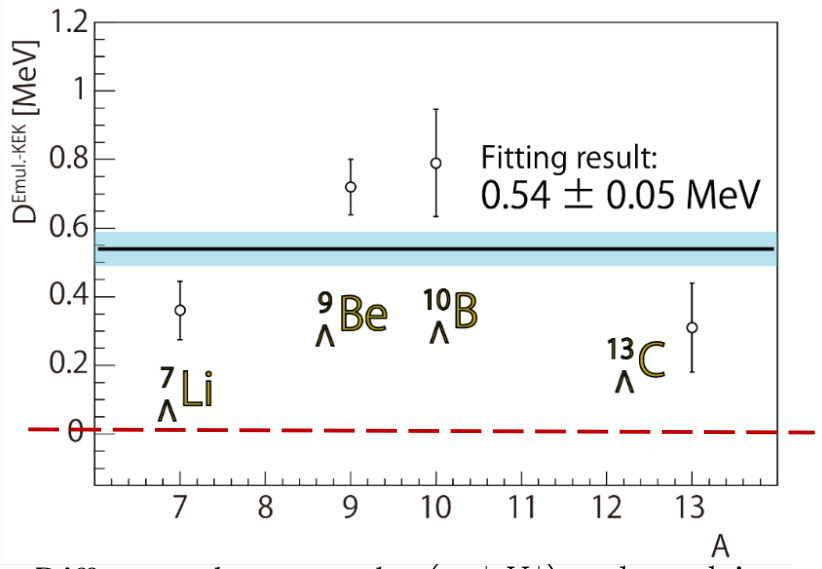

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Support small CSB in A=12

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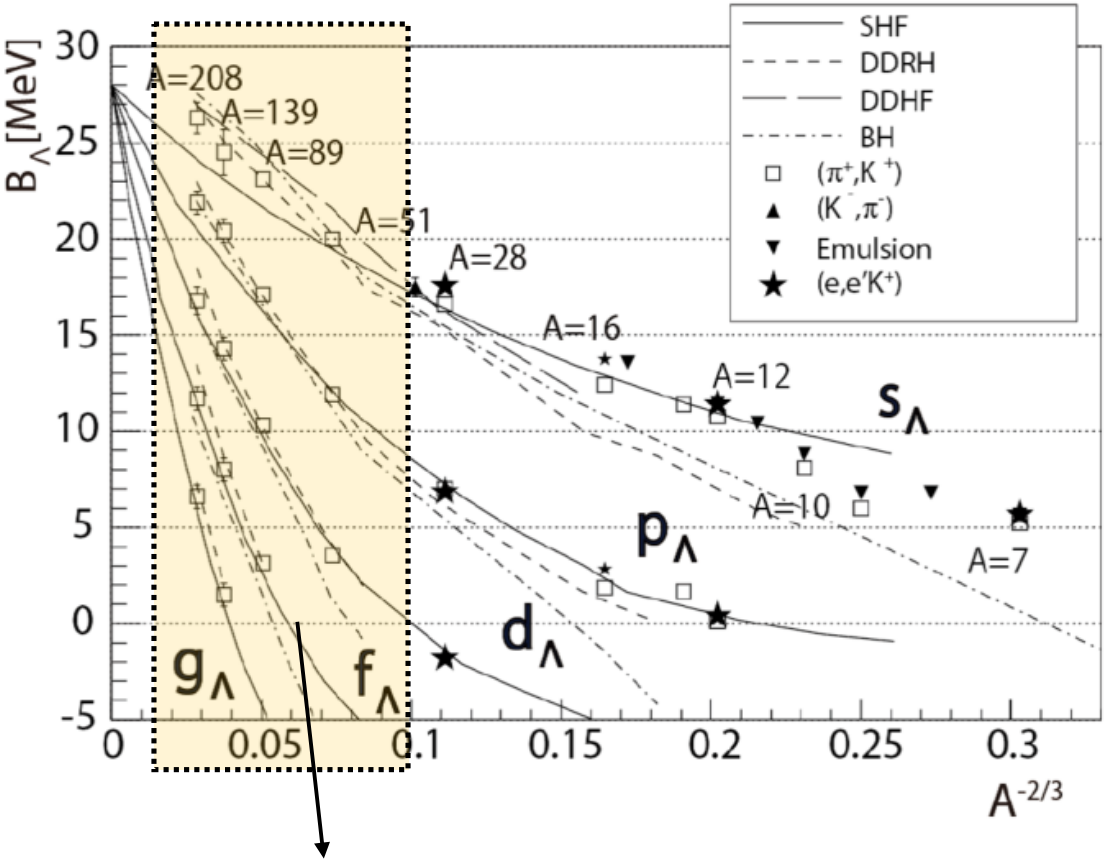
Necessity of B_Λ measurement in medium to heavy mass region



Only the (π^+,K^+) data

These data have to be shifted by ～0.54 MeV ?

Only the (e,e'K^+) can confirm the B_Λ in medium to heavy mass region.

- ✓ Analysis of ${}^{52}_{\Lambda}V$
- ✓ Future experiment

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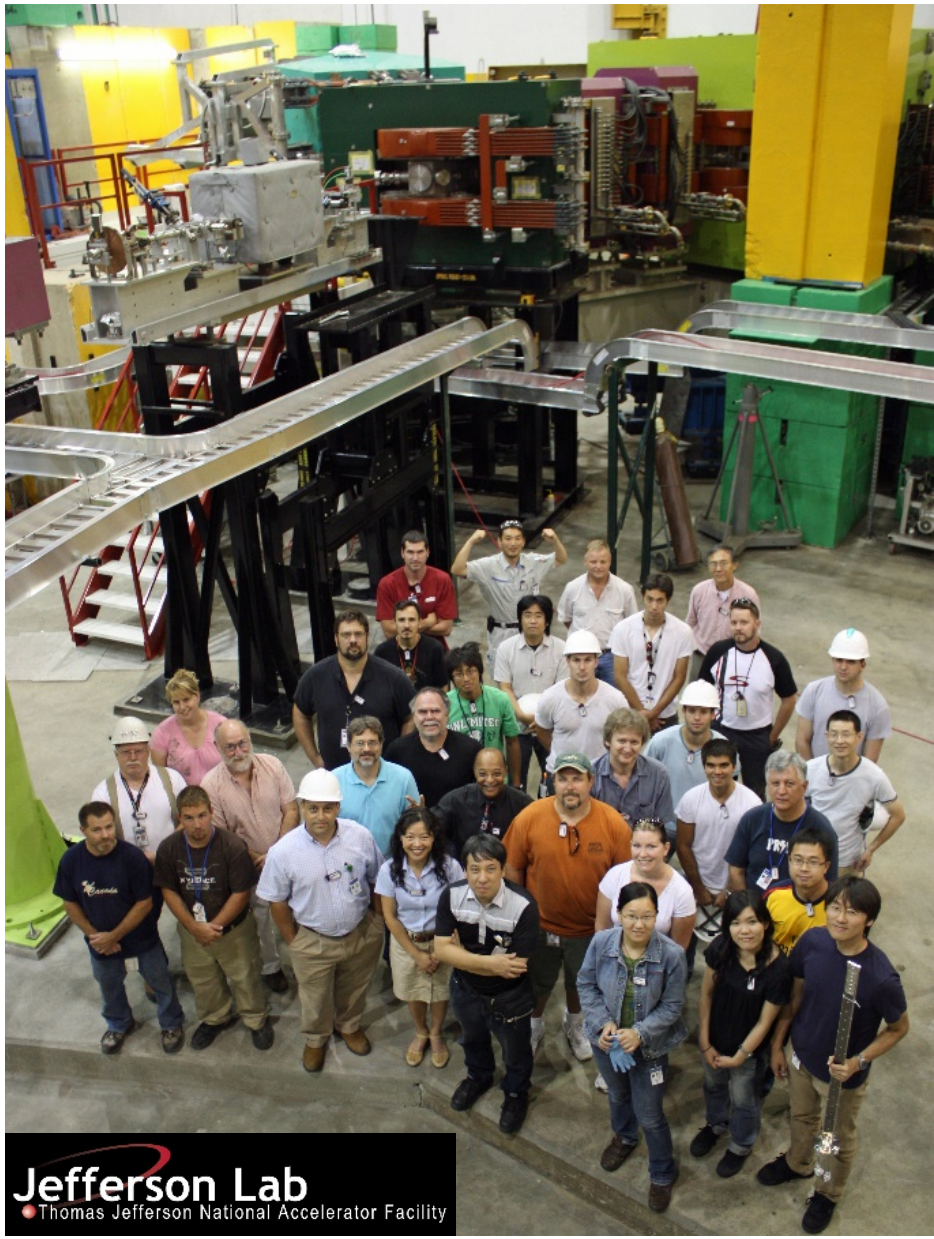
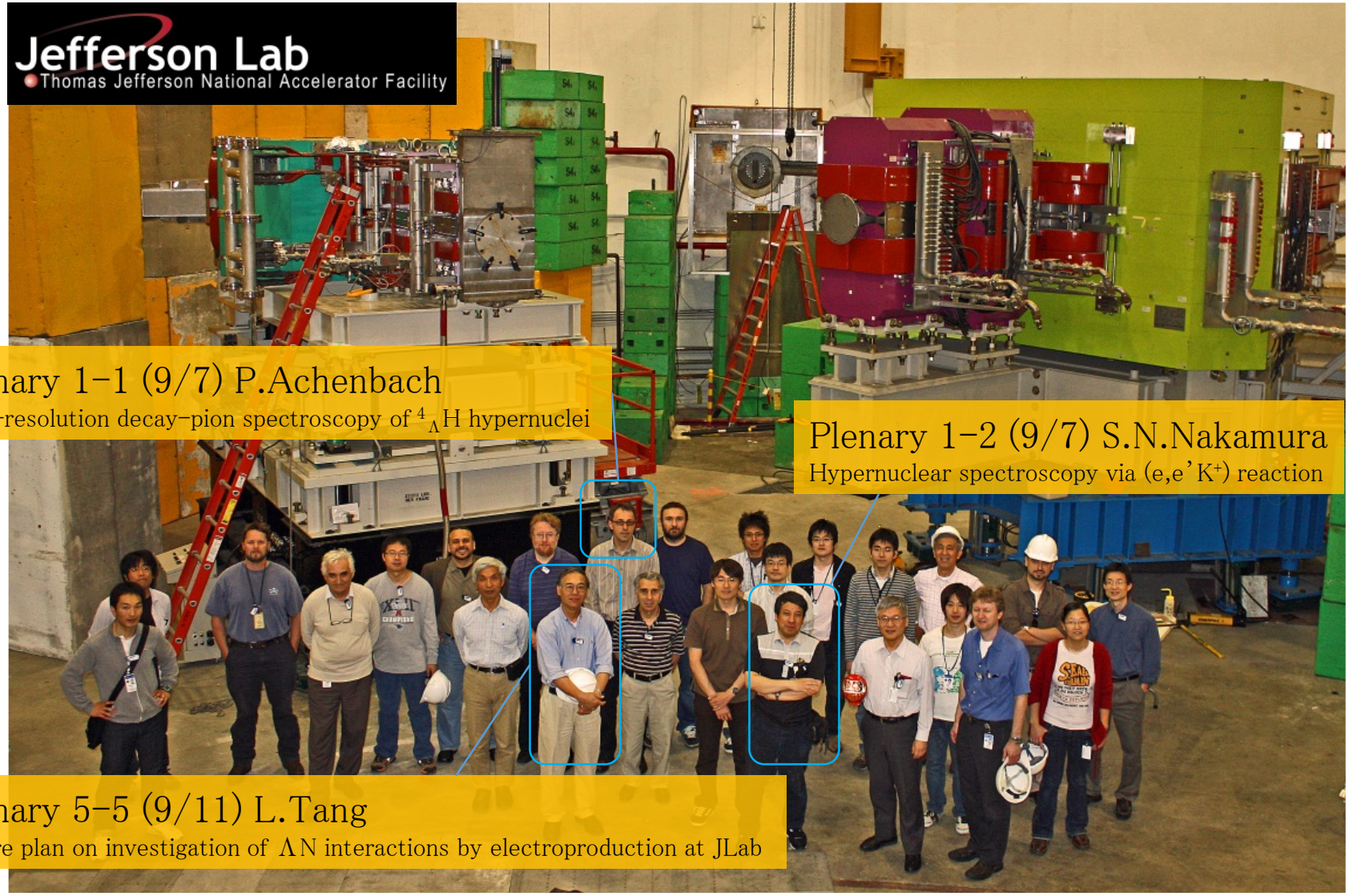


Summary

- In 2009, electroproduction of Λ hypernuclei was performed measuring ${}^{7}_{\Lambda}\mathrm{He}$, ${}^{9}_{\Lambda}\mathrm{Li}$, ${}^{10}_{\Lambda}\mathrm{Be}$, ${}^{12}_{\Lambda}\mathrm{B}$ and ${}^{52}_{\Lambda}\mathrm{V}$ at Jefferson Lab (JLab E05-115).

- Large ΔB_{Λ} for A=12 isotopic mirror hypernuclei was also observed with new ${}^{12}_{\Lambda}\mathrm{B}$ data ($\Delta B_{\Lambda} = -0.77 \pm 0.19$ MeV).
  - Indication of the 0.54 MeV shift on the reported $B_{\Lambda}({}^{12}_{\Lambda}\mathrm{C})$
    - $\Delta B_{\Lambda} = -0.23 \pm 0.19$ MeV → Small CSB in A=12
    - Do all data in medium to heavy mass region need this correction ?
      → Have to be confirmed by the (e,e'K^{+}) experiment.

Thank you for your attention



Plenary 1-1 (9/7) P.Achenbach
High-resolution decay-pion spectroscopy of $^{4}_{\Lambda}$H hypernuclei

Plenary 1-2 (9/7) S.N.Nakamura
Hypernuclear spectroscopy via (e,e'K^{+}) reaction

Plenary 5-5 (9/11) L.Tang
Future plan on investigation of ΛN interactions by electroproduction at JLab