The second generation hypernuclear spectroscopy at JLab Hall C

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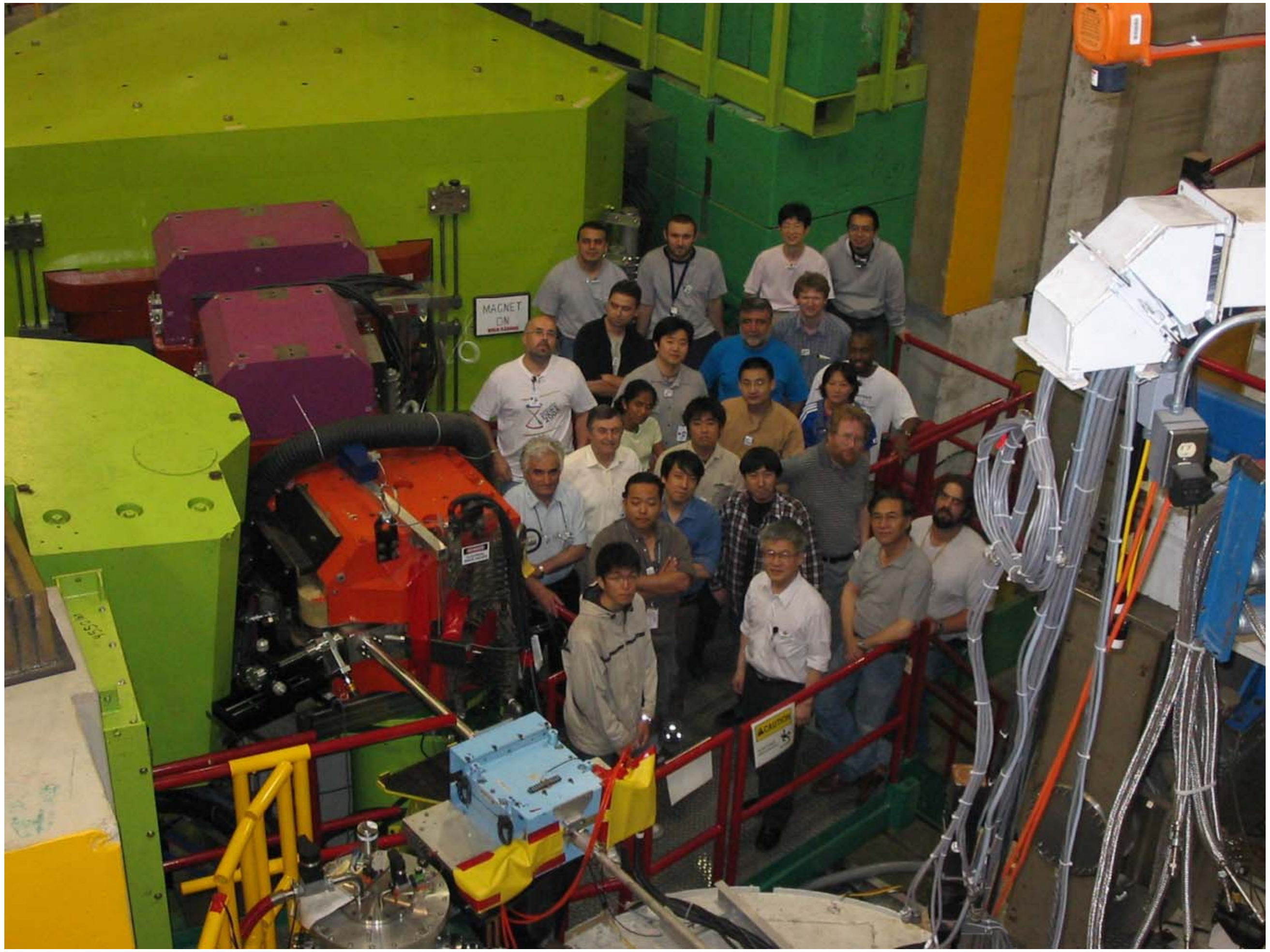
Tohoku University

For JLab E01-011 collaboration



Collaborators near target region of E01-011 experiment setup (Spring, 2005)

Hyp X Conference, Sep. 17, 2009

Motivation of the experiment

Investigate fine structures of various Λ hypernuclei by the $(e,e'K^+)$ reaction

- $^{7}Li(e,e'K^+)^{7}_{\Lambda}He$; Neutron rich hypernucleus
  - Precision determination of hypernuclear mass
  - ΛN-ΣN coupling, CSB effect in A=7 iso-triplet

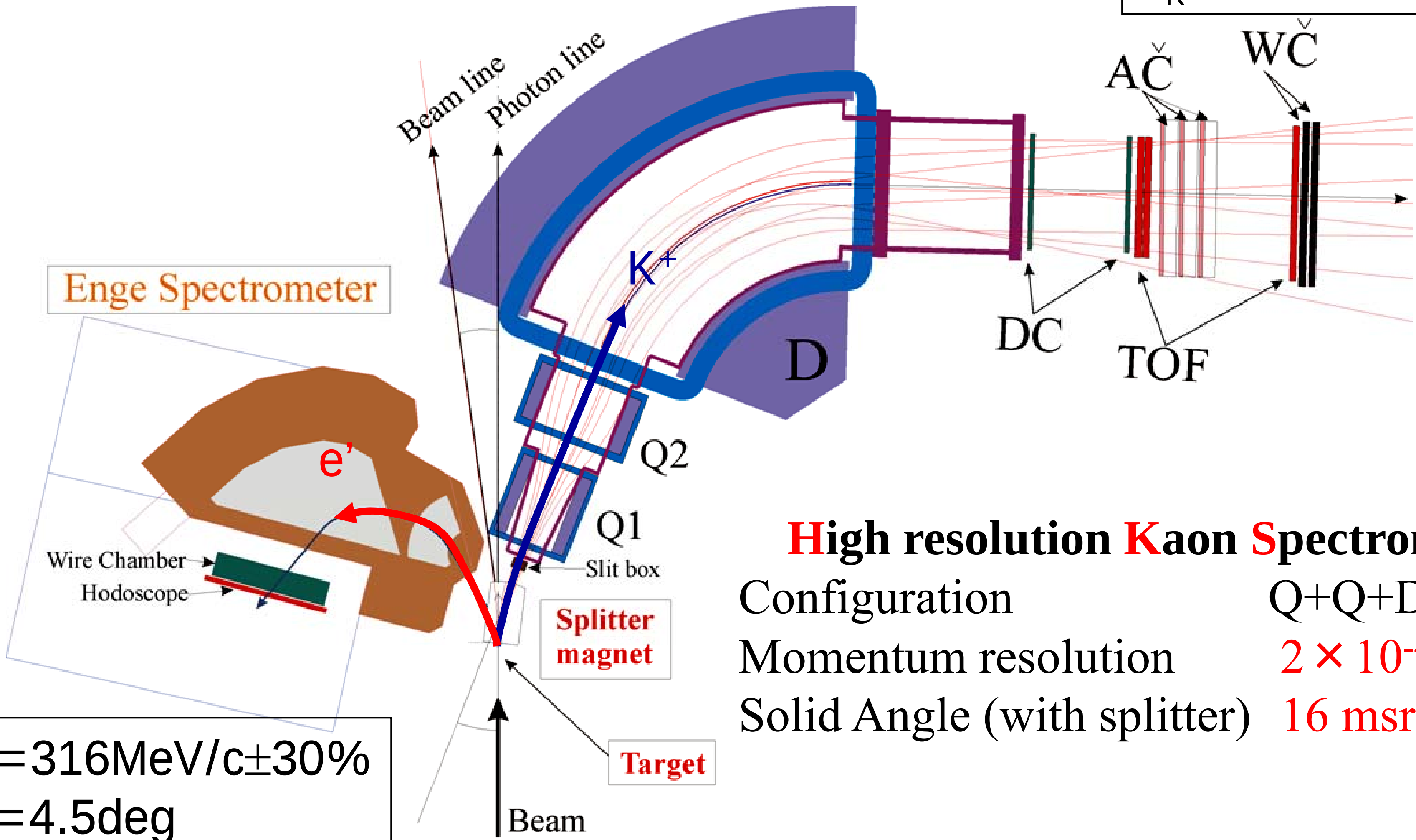
- $^{28}Si(e,e'K^+)^{28}_{\Lambda}Al$
  - First challenge to study beyond the p-shell region
  - Mean field aspect of Λ hypernuclei

- $^{12}C(e,e'K^+)^{12}_{\Lambda}B$; Mirror-symmetric to $^{12}_{\Lambda}C$ @ (π^+,K^+))
  - Fine structure of p-shell hypernucleus

- $CH_2(e,e'K^+)\Lambda,\Sigma$; For calibration

Experimental setup of JLab E01-011

p_K=1.2GeV/c±12.5%
θ_K=2 to 13 deg.



High resolution Kaon Spectrometer

Configuration	Q+Q+D
Momentum resolution	2×10^{-4} (FWHM)
Solid Angle (with splitter)	16 msr

$p_{e'}$=316MeV/c±30%
$\theta_{e'}$=4.5deg

e 1.85 GeV
<30μA

0 1 2 m

→ $E_{\gamma*}$=1.5GeV, $-Q^2$~0.01GeV^2

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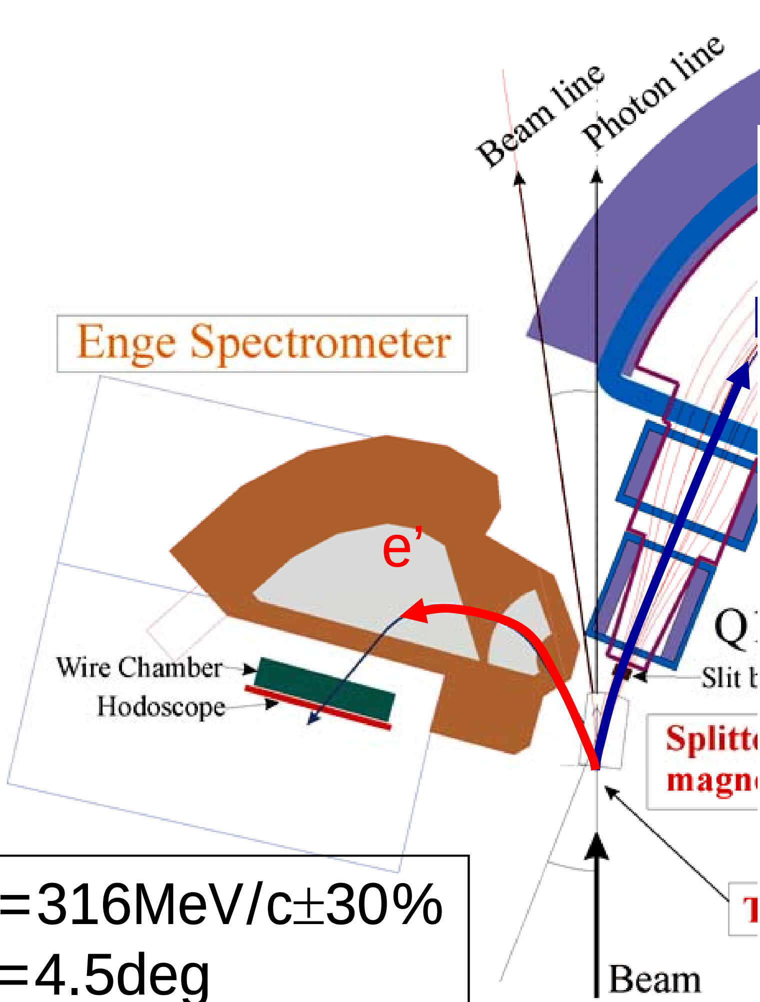

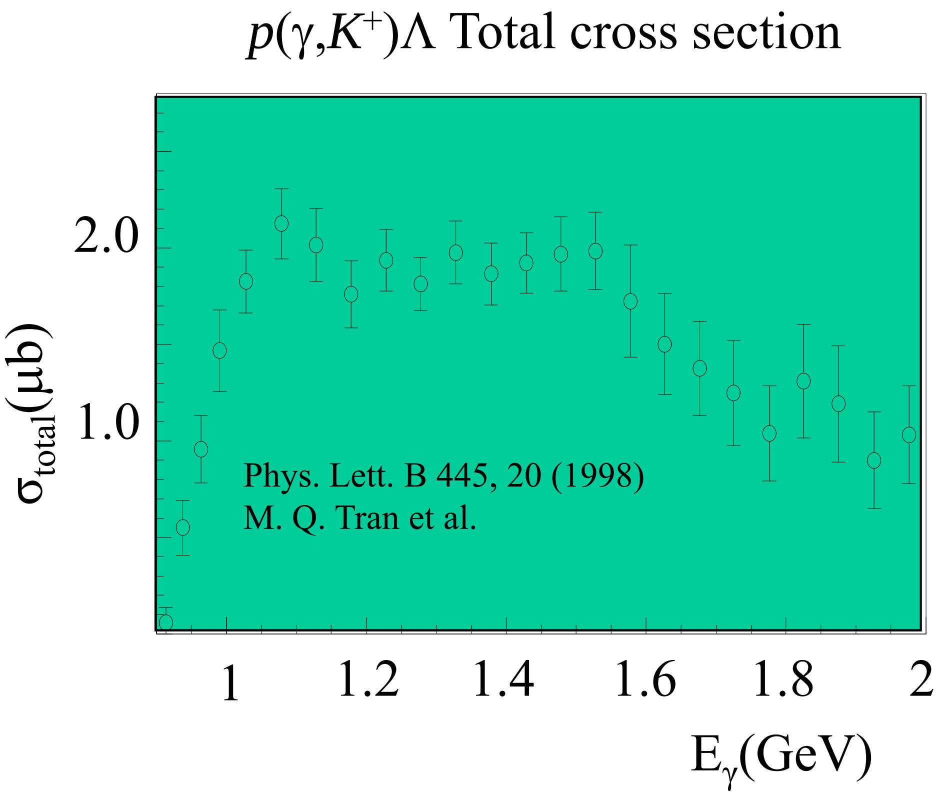

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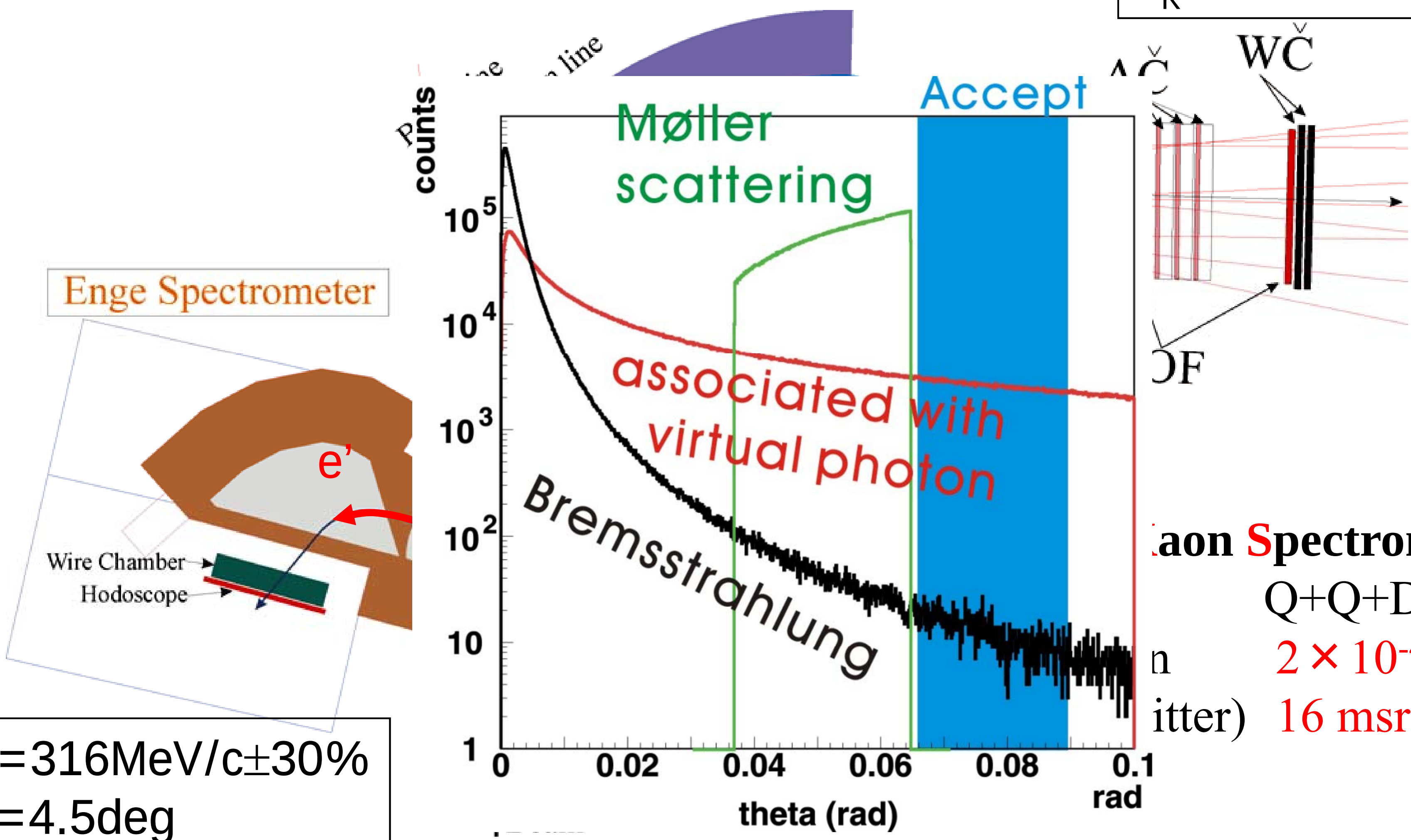

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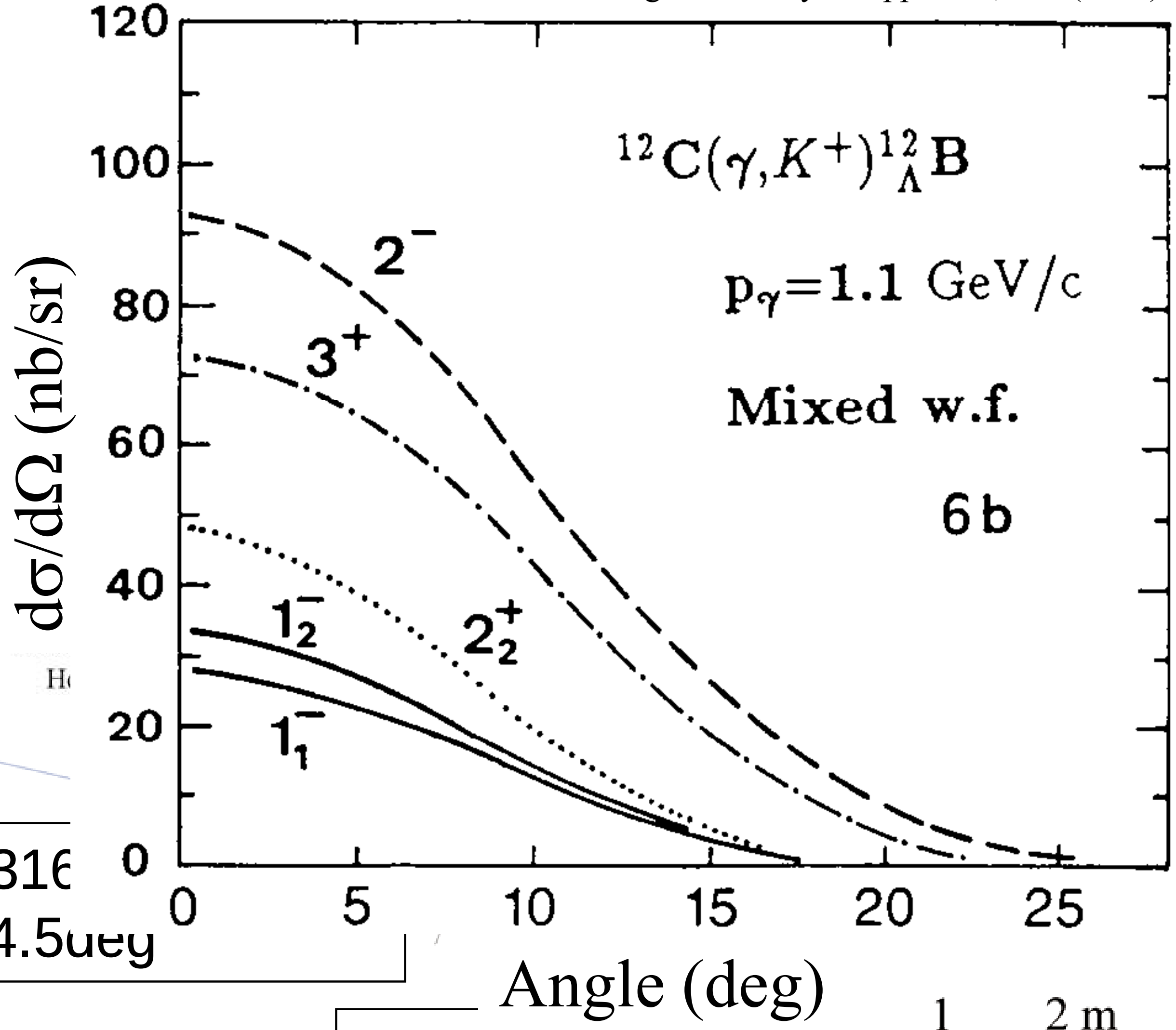
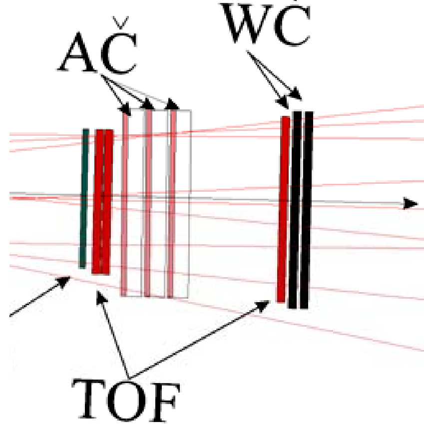
T.Motoba et al.
Prog. Theo. Phys. Suppl. 117, 123 (1994)





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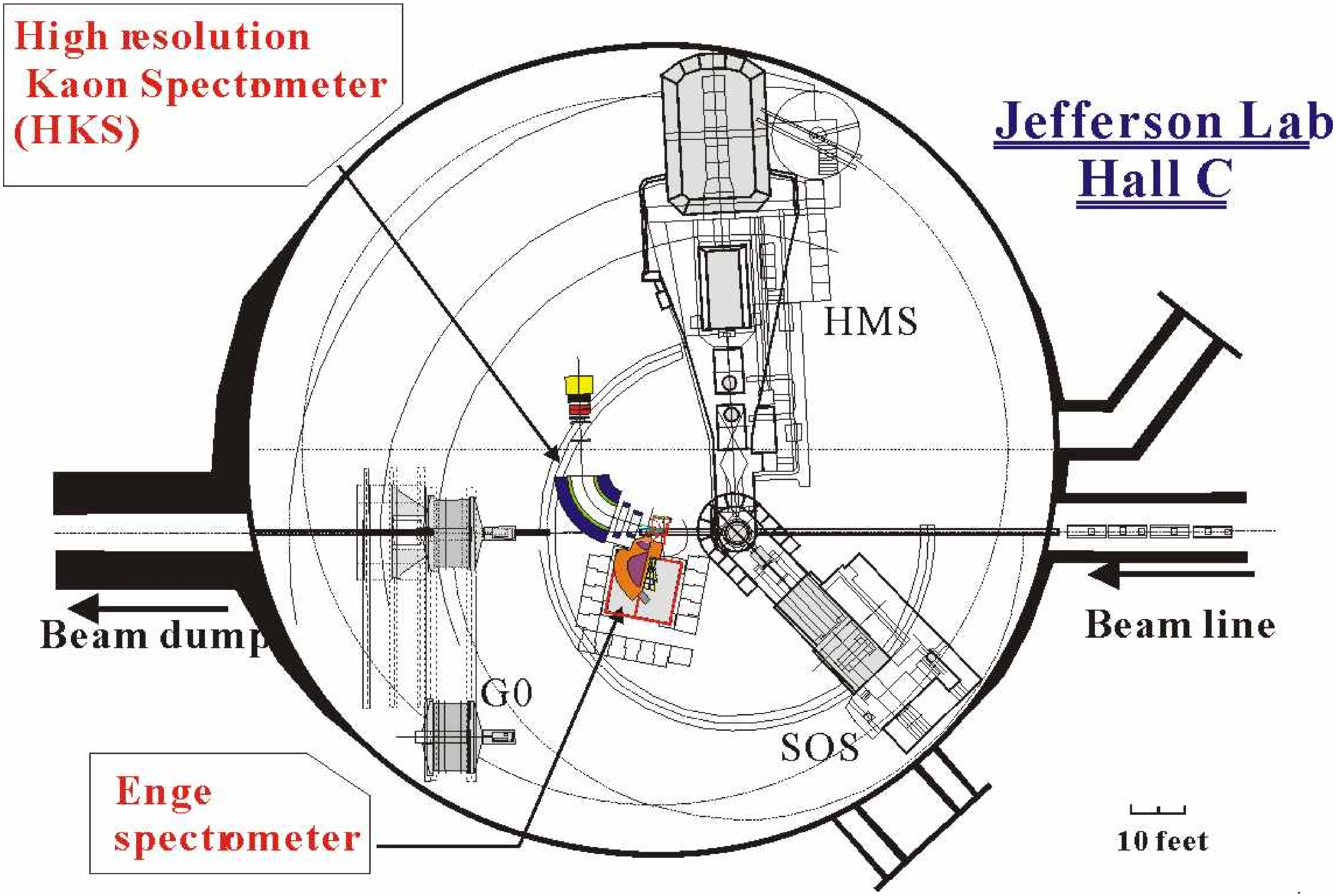


Looking downstream from upstream

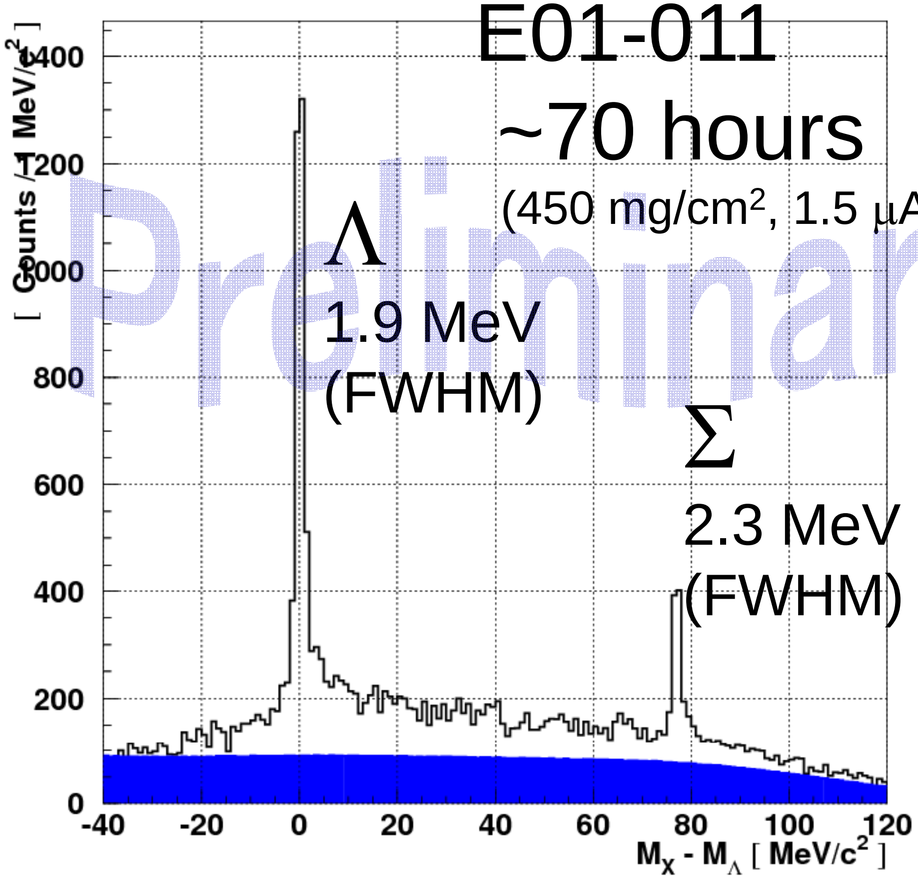
Calibration data : $CH_2(e,e'K^+)\Lambda,\Sigma^0$

Absolute mass scale can be determined by Λ and Σ masses

E01-011

~70 hours

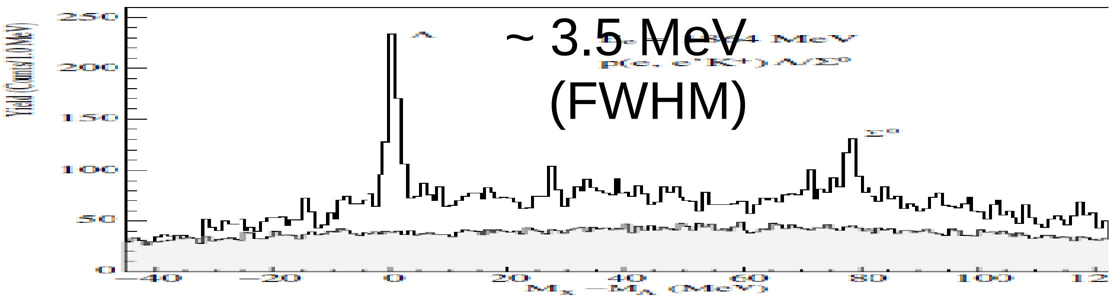
(450 mg/cm^2, 1.5 μA)



c.f. E89-009, 183 hours

(8.8 mg/cm^2, 0.5 or 1.0 μA)

T. Miyoshi *et al*.,
Phys. Rev. Lett. **90**, 232502(2003)



Better resolution and statistics

Estimation of systematic errors on,

- **Absolute mass scale**
- **Cross sections**

due to uncertainty in optics calibration.

Tune optics of both arm w/ known masses (Λ, Σ, ...) → Missing Mass spectra

Iteration

\+

The same tuning on Monte Carlo simulation data with artificially altered optics (Not knowing the answer)

Obtained systematic errors

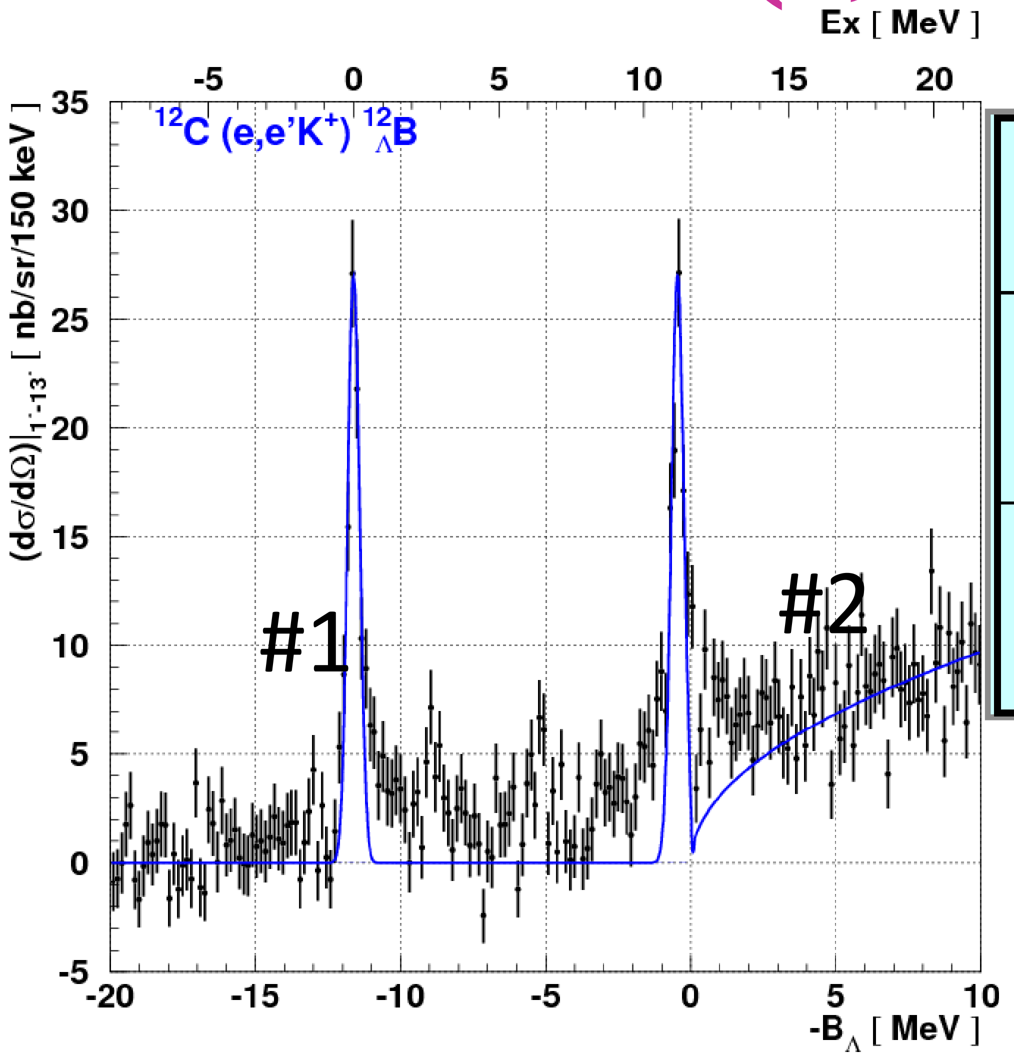
1. Absolute mass scale

- for major peaks (S/N > 1),
  binding energy < 100 keV
- for core excited states (S/N < 1),
  binding energy < 400 keV

2. Cross section

Target	Thickness	N_γ	$d\Omega$	ε_{total}	*Tune (S/N>1)*		Total
^{7}Li	5%						23%
^{12}C	2%	**22%**	1%	3%	5%		22%
^{28}Si	5%						23%

$^{12}C(e,e'K^+)^{12}{}_{\Lambda}B$



ID	Ex [MeV]	$-B_{\Lambda}$ [MeV]	Cross section [nb/sr]
#1	0	-11.6±0.1 (*stat.*) ±0.1 (*sys.*)	89±7 (*stat.*) ±19 (*sys.*)
#2	11.2±0.1 (*stat.*) ±0.1 (*sys.*)	-0.5±0.1 (*stat.*) ±0.1 (*sys.*)	98±7 (*stat.*) ± 22 (*sys.*)

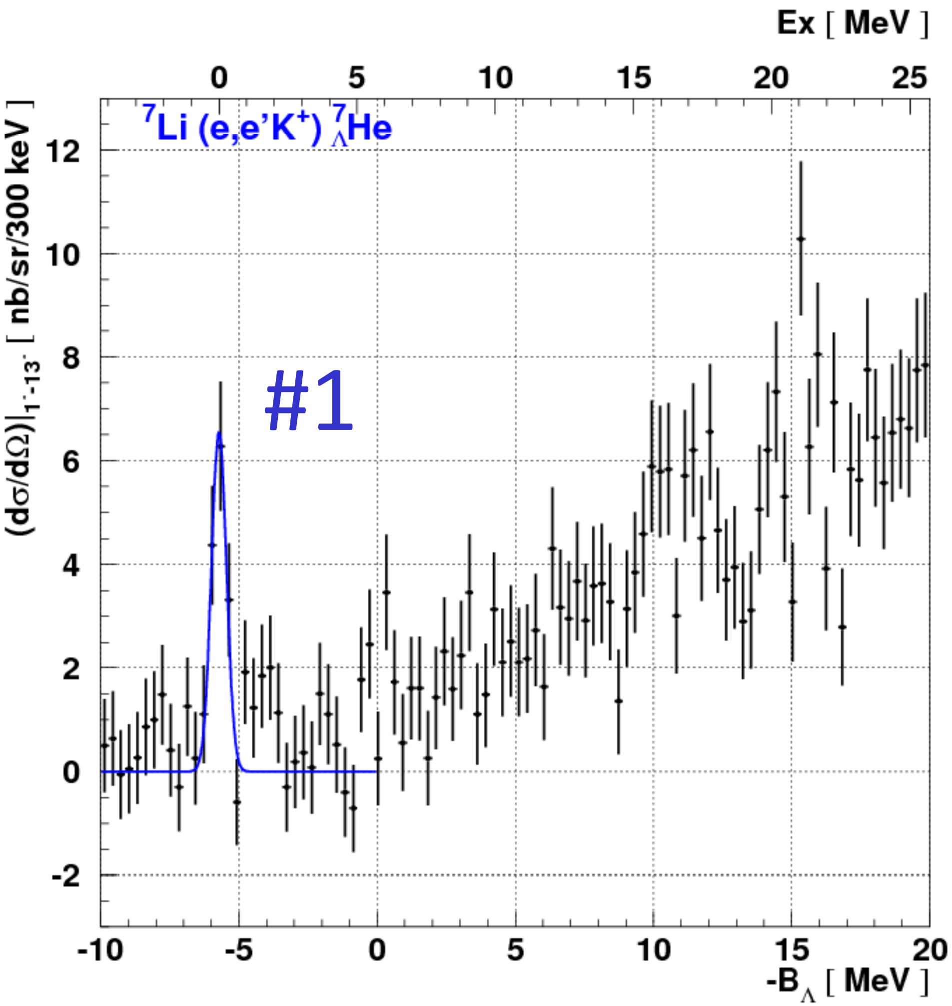
- $^{12}{}_{\Lambda}B$ g.s. doublet resolution: 470 keV FWHM
- 8 counts/h for g.s. doublet

Data taking : ~30 hours w/ 30 μA

Model Calculation by Sotona *et. al.*
(1.3 < Eγ < 1.6 GeV, 1 < θ_K < 13 deg.)

J^{π}	Ex [MeV]	Cross section [nb/sr]		
		SLA	C4	KMAID
1^-	0	19.7	22.8	20.7
2^-	0.14	65.7	82.0	43.0
2^+	10.99	48.3	56.9	38.0
3^+	11.06	75.3	107.3	68.5

^{7}Li(e,e'K^{+})$^{7}_{\Lambda}$He (Preliminary)



Resolution : ~510 keV (FWHM) for g.s.
Data taking : ~30 hours w/ 30 μA

Present result

ID	$-B_{\Lambda}$ [MeV]	Cross section [nb/sr]
#1	-5.7±0.2 (*stat.*) ±0.2 (*sys.*)	15±3 (*stat.*) ±3 (*sys.*)

Theoretical calculation

Binding energy: Hiyama w/o CSB

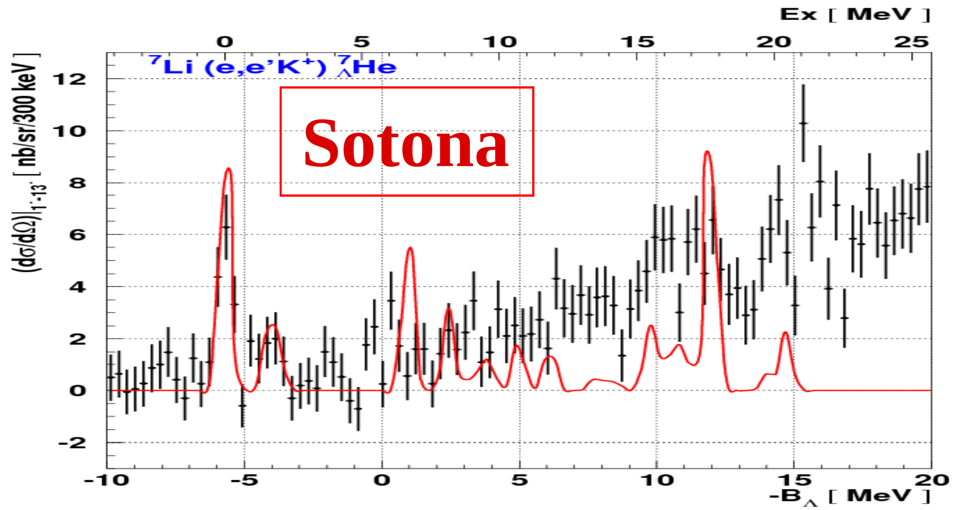
Cross section: Sotona *et.al.*

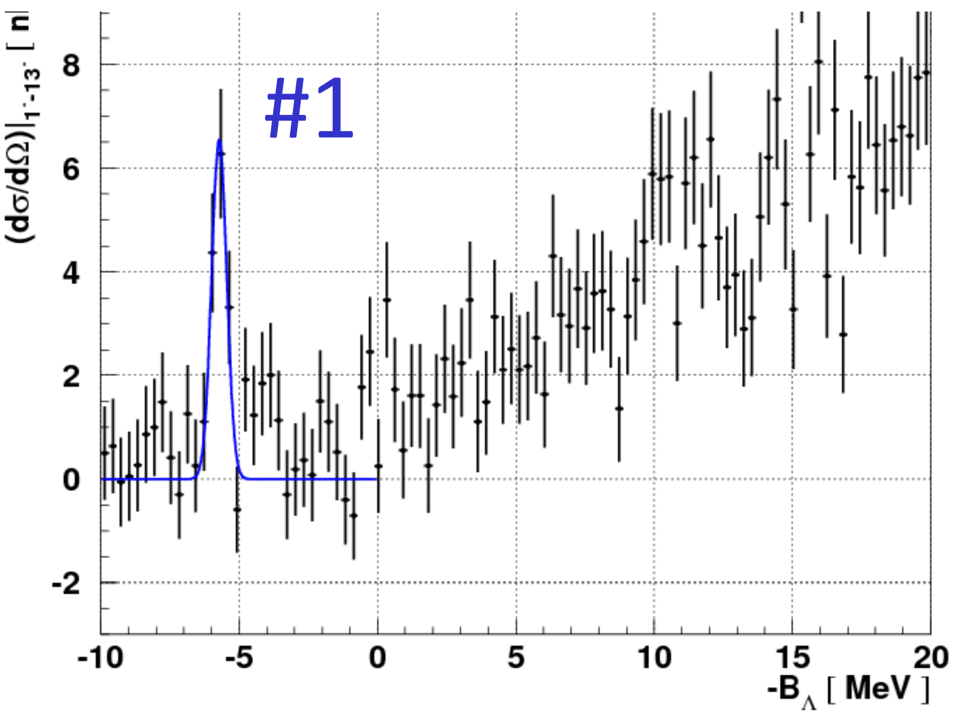
(1.3 < Eγ < 1.6 GeV, 1 < θ_K < 13 deg.)

J^{π}	$-B_{\Lambda}$ [MeV]	Cross section [nb/sr]		
		SLA	C4	KMAID
$1/2^{+}$	-5.36	13.2	16.2	9.7

Hiyama Sotona

^{7}Li(e,e'K^{+})$^{7}_{\Lambda}$He (Preliminary)





Resolution : ~510 keV (FWHM) for g.s.
Data taking : ~30 hours w/ 30 μA

Present result

ID	$-B_{\Lambda}$ [MeV]	Cross section [nb/sr]
#1	-5.7±0.2 (*stat.*) ±0.2 (*sys.*)	15±3 (*stat.*) ±3 (*sys.*)

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Binding energy: Hiyama w/o CSB

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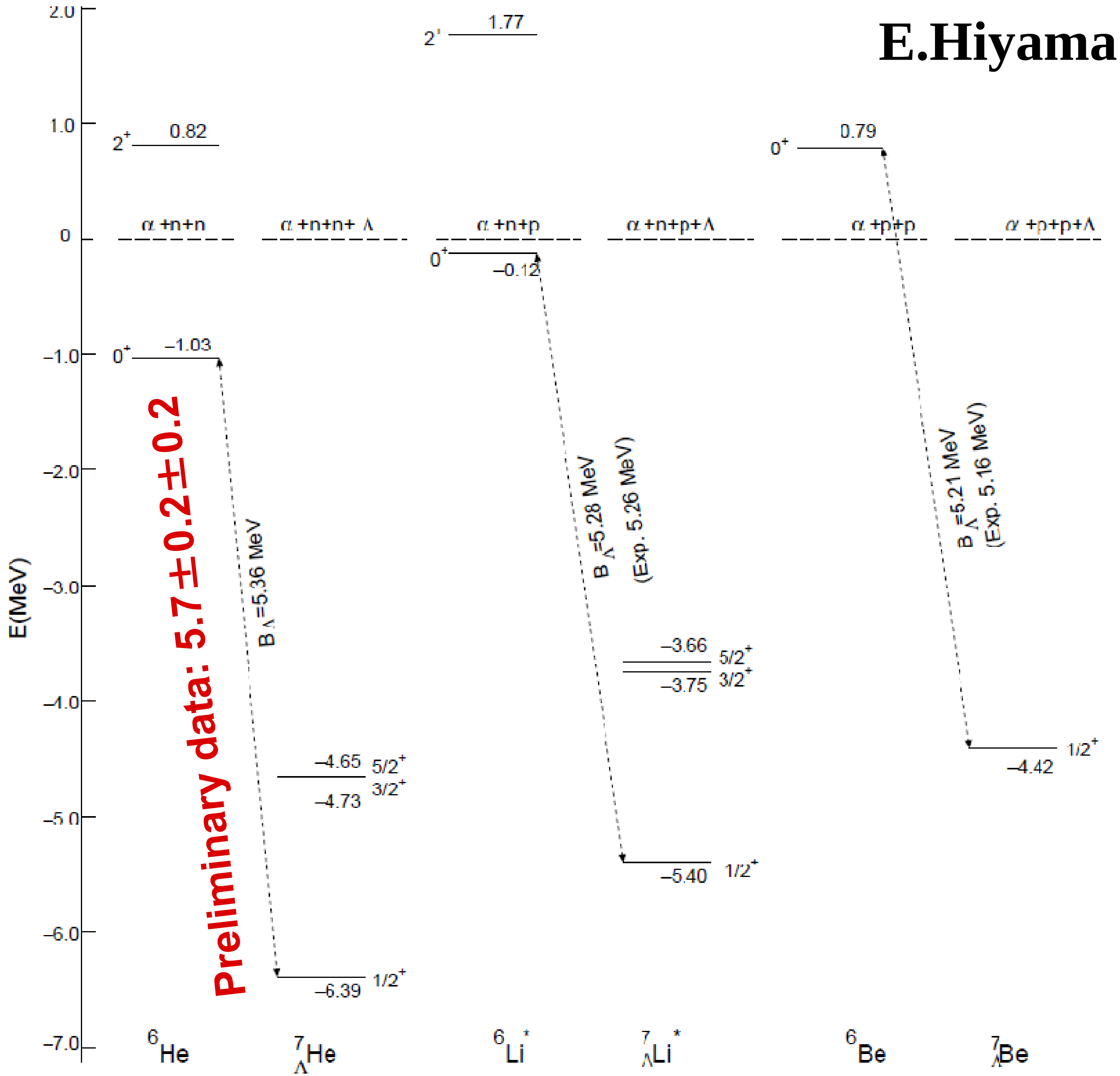
(1.3 < Eγ < 1.6 GeV, 1 < θ_K < 13 deg.)

J^{π}	$-B_{\Lambda}$ [MeV]	Cross section [nb/sr]		
		SLA	C4	KMAID
$1/2^{+}$	-5.36	13.2	16.2	9.7

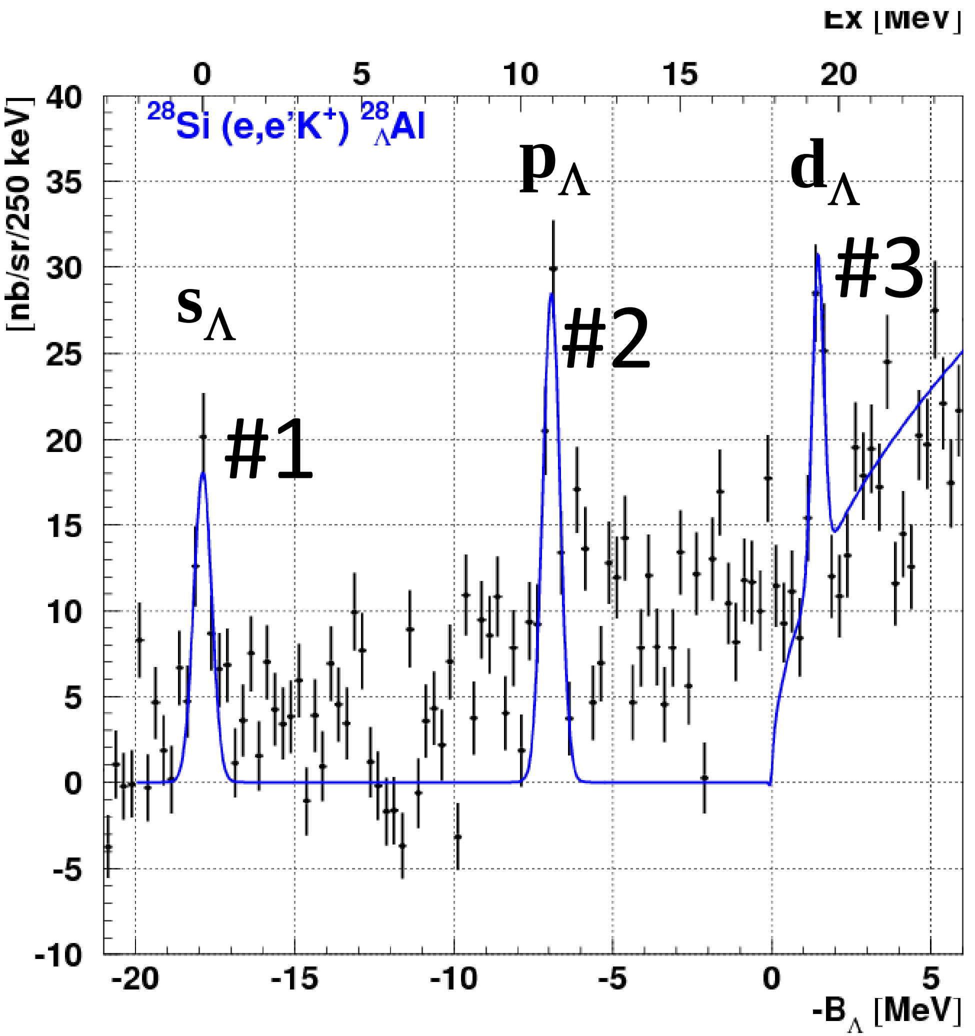
Hiyama   Sotona

Comparison with 4-body calc.

E.Hiyama w/o CSB



$^{28}Si(e,e'K^+)^{28}{}_{\Lambda}Al$ (preliminary)



Resolution : ~520 keV (FWHM) for g.s.
Data taking : ~30 hours w/ 30 μA

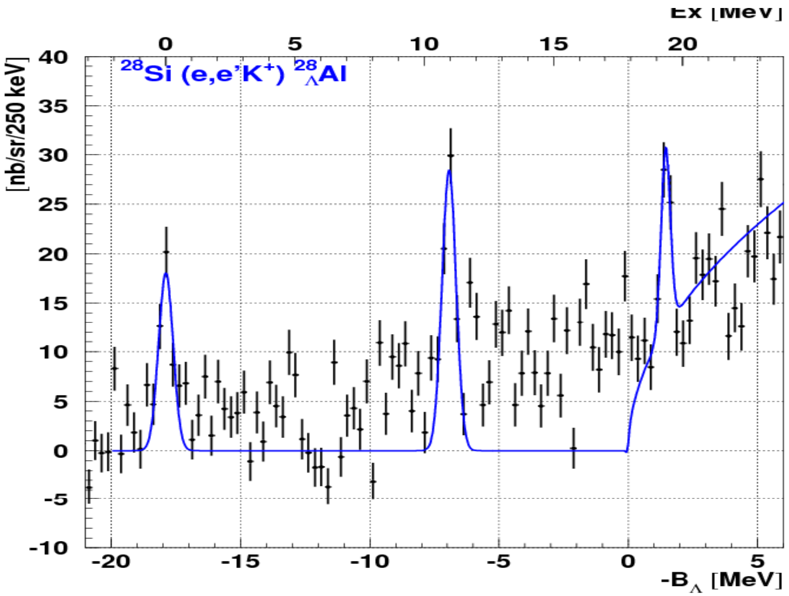
Present Result

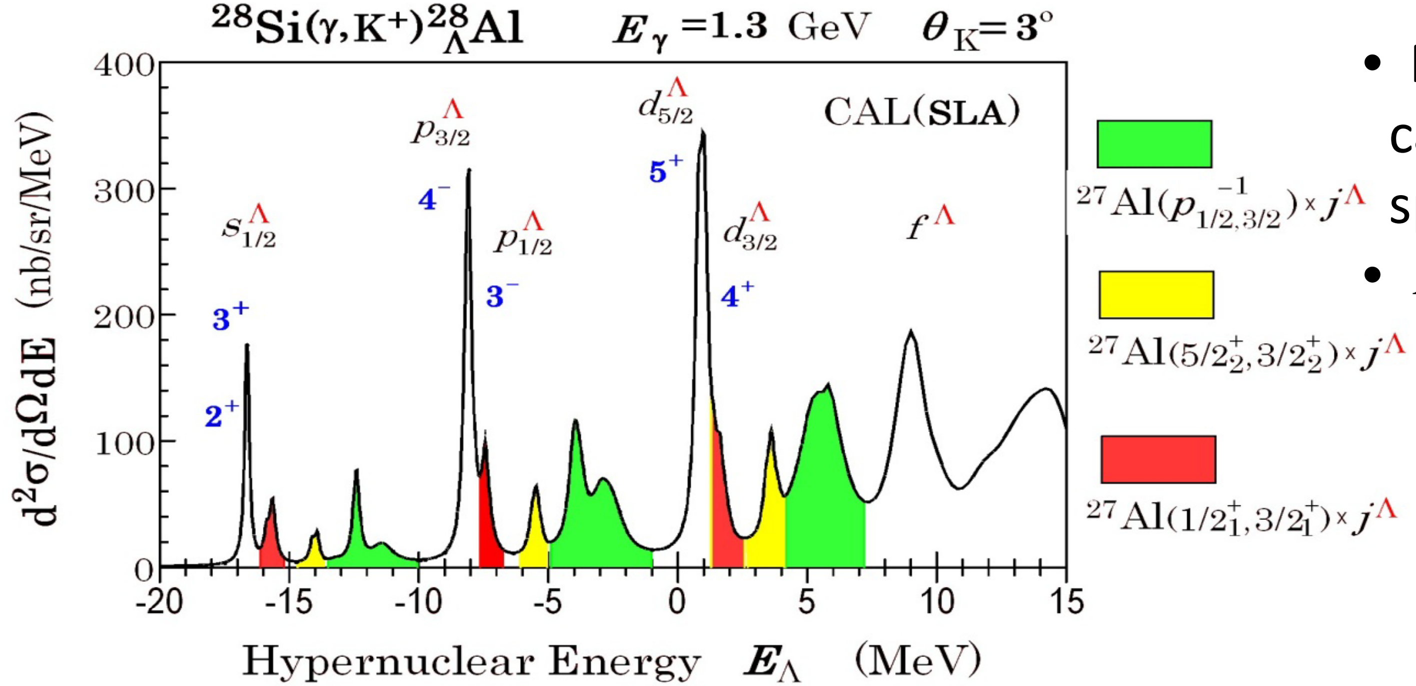
ID	Ex [MeV]	$-B_{\Lambda}$ [MeV]	Cross section [nb/sr]
#1	0	-17.9 ±0.1 (*stat.*) ±0.3 (*sys.*)	51 ±10 (*stat.*) ±12 (*sys.*)
#2	11.0 ±0.1 (*stat.*) ±0.3 (*sys.*)	-6.9 ±0.1 (*stat.*) ±0.3 (*sys.*)	78 ±13 (*stat.*) ± 18 (*sys.*)
#3	19.3 ±0.1 (*stat.*) ±0.3 (*sys.*)	1.4 ±0.1 (*stat.*) ±0.3 (*sys.*)	33 ±7 (*stat.*) ± 8 (*sys.*)

Theoretical calculation by Sotona *et. al.*
($1.3 < E\gamma < 1.6$ GeV, $1 < \theta_K < 13$ deg.)

J^{π}	Ex [MeV]	Cross section [nb/sr]		
		SLA	C4	KMAID
$2^+, 3^+$	0	92.1	112.7	71.76
4^-	9.42	134.9	167.7	117.5
3^-	9.67	91.3	109.1	58.5
4^+	17.6	148.4	184.7	135.1
5^+	17.9	139.1	167.1	89.9

Comparison with Motoba’s calc.





Major peak series : $[^{27}\mathrm{Al}(5/2^+_1) \times j^\Lambda]_J$ with $j^\Lambda = s, p, d, \ldots$

- Full shell model calculation in the $[s^4p^{12}(sd)^{12}]$ space
- ΛN interaction ND

Summary

2^{nd} generation precision hypernuclear spectroscopy by the $(e,e'K^+)$ reaction in JLab Hall C was performed in 2005, with

- installing the new kaon spectrometer (HKS)
- adopting so-called "tilt" geometry for the electron spectrometer.

Resolution as good as ~500 keV(FWHM) and yield rate of 7-8 counts/hr for the $^{12}_{\Lambda}B$ ground state doublet were realized.

Preliminary spectra of $^{28}_{\Lambda}Al$ and $^{7}_{\Lambda}He$ are presented, and compared with calculated spectra.

3^{rd} generation experiment ongoing