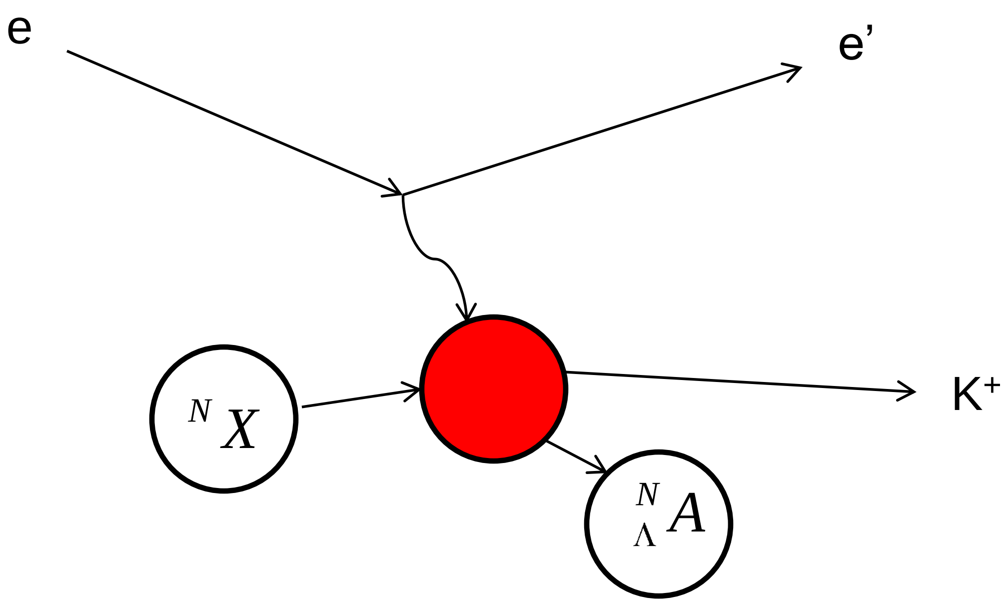
E94-107 Hypernuclear Spectroscopy Experiment Status



John J. LeRose

for the E94107 Collaboration

Electroproduction of Hypernuclei

• Hypernuclear physics accesses information on the nature of the force between nucleons and strange baryons. The nucleus provides a unique laboratory for studying this interaction.

- **i.e. the Λ-N interaction**

• The characteristics of the JLab electron beam, together with those of the experimental equipment, offer a unique opportunity to study hypernuclear spectroscopy via electromagnetic induced reactions.

- **A new experimental approach: alternative to the hadronic induced reactions studied previously.**

• E94-107 has completed its measurements, performing high-resolution hypernuclear spectroscopy on light (p-shell) targets

E94107 COLLABORATION

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$^{16}O(e,e'K^{+})^{16}{}_{\Lambda}N$

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

$^{9}Be(e,e'K^{+})^{9}{}_{\Lambda}Li$

$H(e,e'K^{+})\Lambda,\Sigma^{0}$

E_{beam} = 4.016, 3.777, 3.656 GeV

P_e= 1.80, 1.57, 1.44 GeV/c **P_k= 1.96 GeV/c**

$\theta_e = \theta_K = 6$

$W \sim 2.2$ GeV $Q^2 \sim 0.07$ (GeV/c)^2

Beam current : $\leq$100 μA Target thickness : ~100 mg/cm^2

Counting Rates ~ **0.1 – 10 counts/peak/hour**

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

Results published: M.Iodice et al., Phys. Rev. Lett. E052501, 99 (2007).

PHYSICAL REVIEW LETTERS

An experiment measuring electroproduction of hypernuclei has been performed in hall A at Jefferson Lab on a ^{12}C target. In order to increase counting rates and provide unambiguous kaon identification two superconducting septum magnets and a ring imaging Cherenkov detector were added to the hall A standard equipment. An unprecedented energy resolution of less than 700 keV FWHM has been achieved. Thus, the observed $^{12}_{\Lambda}$B spectrum shows for the first time identifiable strength in the core-excited region between the ground-state *s*-wave Λ peak and the 11 MeV *p*-wave Λ peak.

DOI:

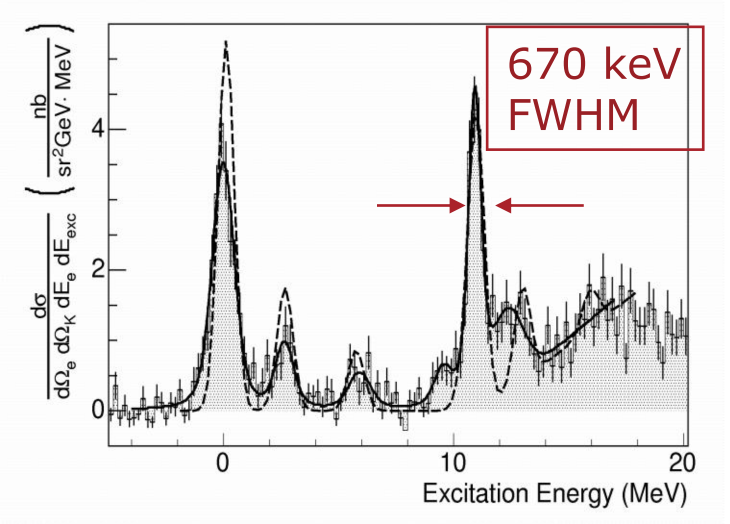
PACS numbers: 21.80.+a, 21.60.Cs, 25.30.Rw, 27.20.+n

Hypernuclear Spectrum of $^{12}{}_{\Lambda}B$

Experimental data			
Position (MeV)	Width (FWHM, MeV)	SNR	Cross section (nb/sr^2/GeV)
0.0 ± 0.03	1.15 ± 0.18	19.7	$4.48 \pm 0.29(\text{stat}) \pm 0.63(\text{syst})$
2.65 ± 0.10	0.95 ± 0.43	7.0	$0.75 \pm 0.16(\text{stat}) \pm 0.15(\text{syst})$
5.92 ± 0.13	1.13 ± 0.29	5.3	$0.45 \pm 0.13(\text{stat}) \pm 0.09(\text{syst})$
9.54 ± 0.16	0.93 ± 0.46	4.4	$0.63 \pm 0.20(\text{stat}) \pm 0.13(\text{syst})$
10.93 ± 0.03	0.67 ± 0.15	20.0	$3.42 \pm 0.50(\text{stat}) \pm 0.55(\text{syst})$
12.36 ± 0.13	1.58 ± 0.29	7.3	$1.19 \pm 0.36(\text{stat}) \pm 0.35(\text{syst})$

Narrowest peak is doublet at 10.93 MeV
⇒ experiment resolution < 700 keV

G.S. width is 1150 keV; an unresolved doublet?
What would separation be between two 670 keV peaks? ⇒ ~650 keV (theory predicts only 140)



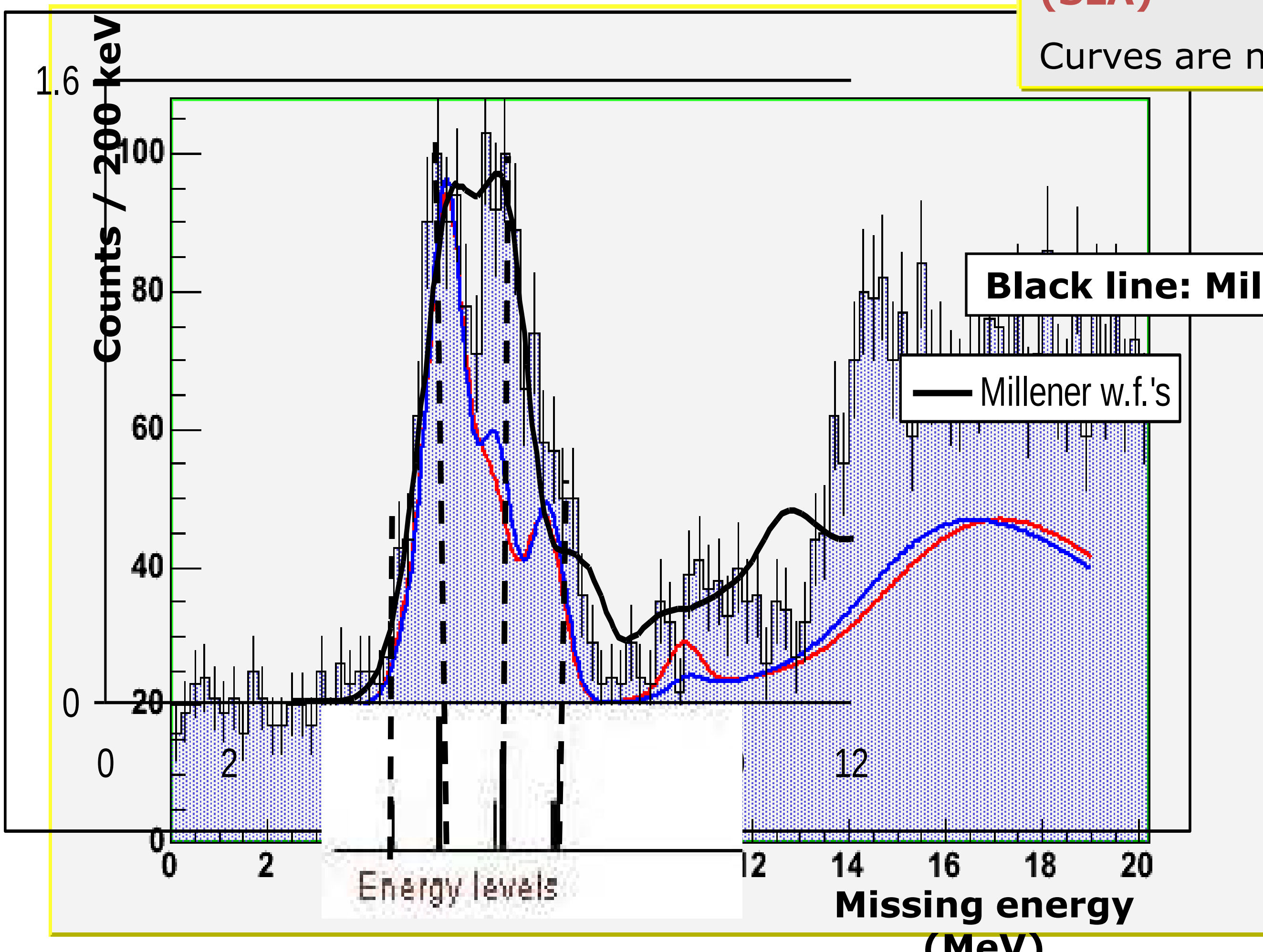
Very Preliminary Analysis of ^{9}Be(e,e'K^{+})$^{9}{}_{\Lambda}$Li

Red line: Benhold-Mart (K MAID)

Blue line: Saghai Saclay-Lyon (SLA)

Curves are normalized on g.s. peak.

Black line: Millener wave function



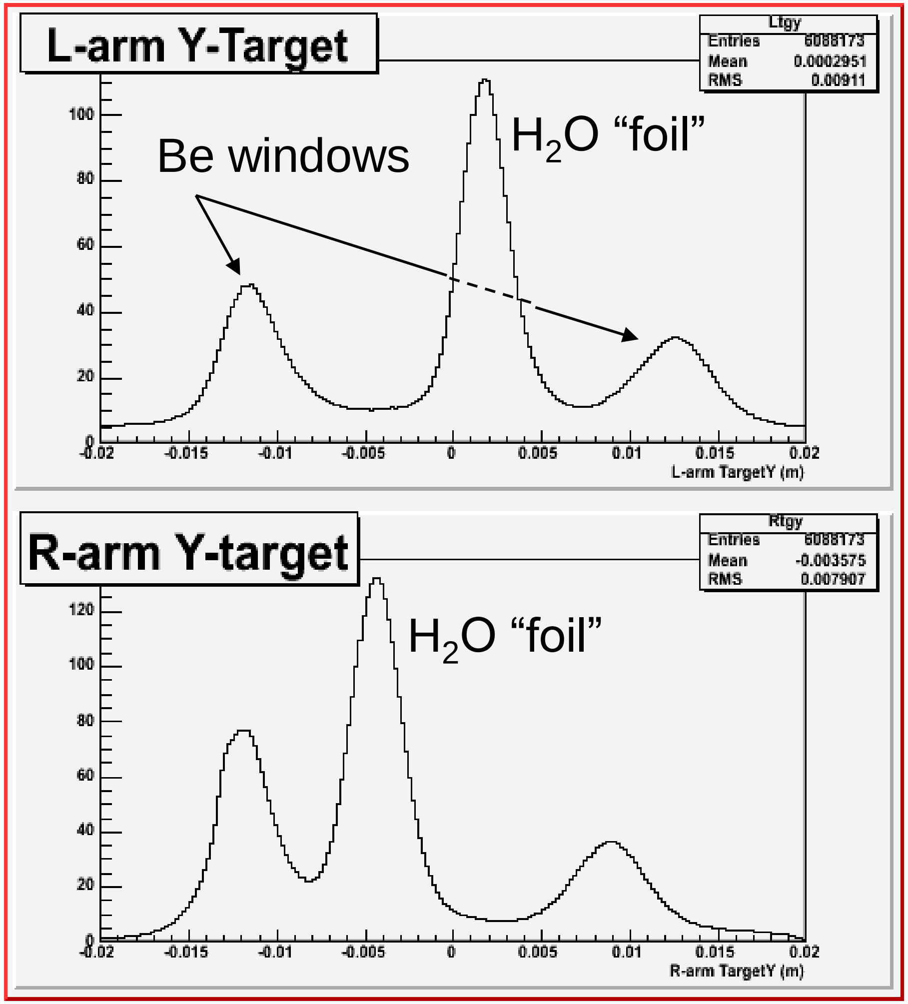
Results from the WATERFALL target

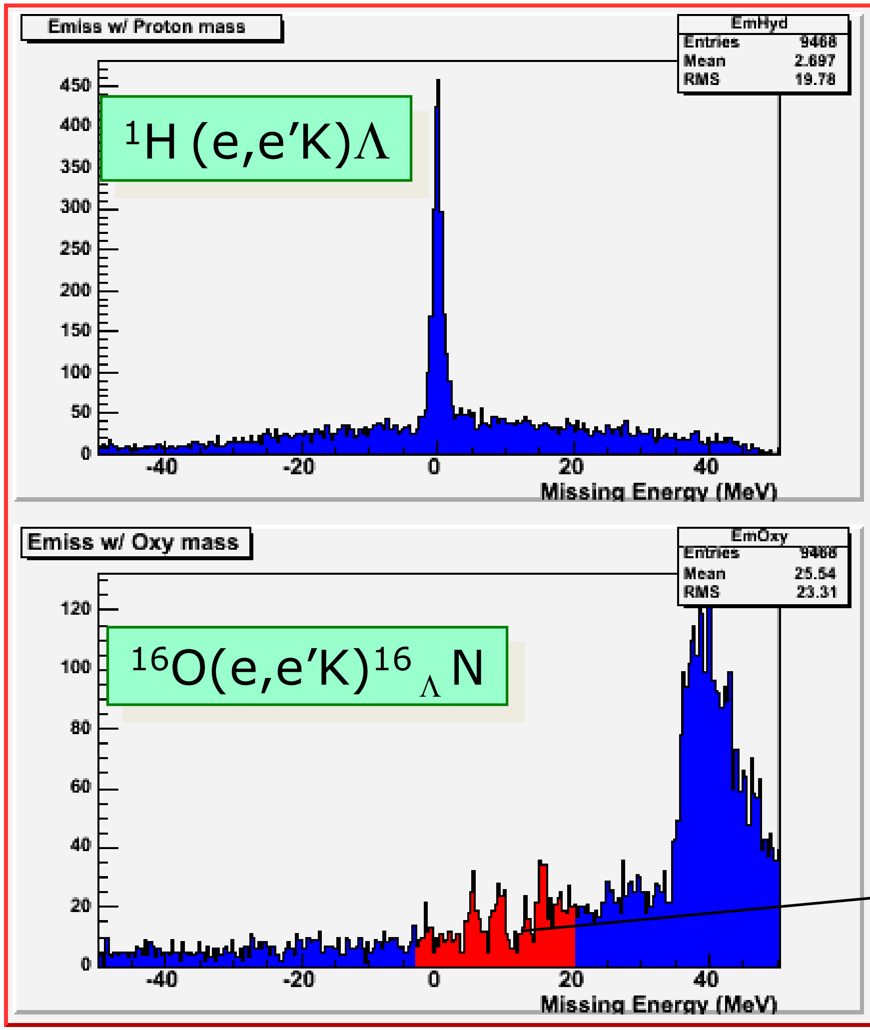
$^{16}O(e,e'K^+)^{16}{}_{\Lambda}N$

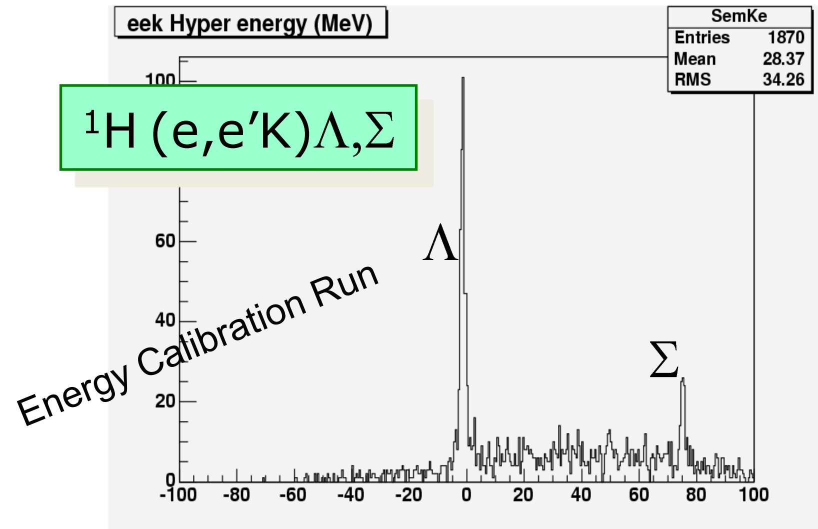
$H(e,e'K^+)\Lambda,\Sigma^0$

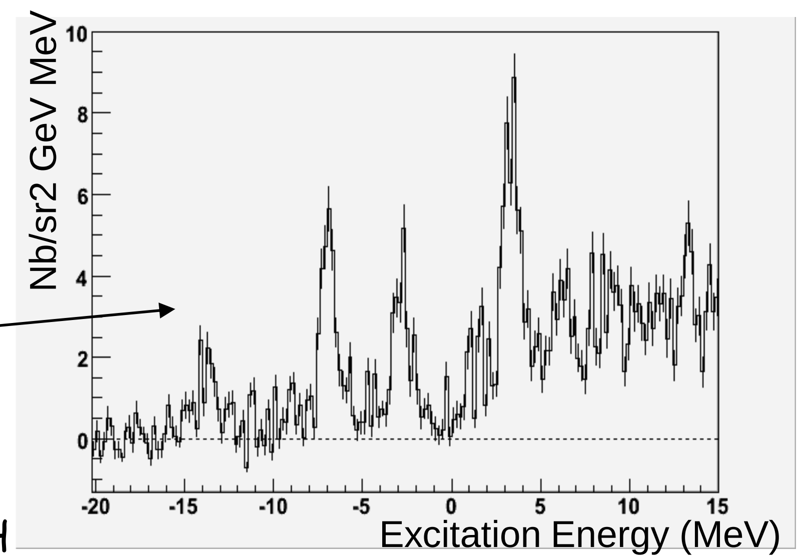
Waterfall target allows energy-scale calibration
of ^{16}**O**(e,e′K)$^{16}{}_{\Lambda}$**N**
by ^{1}**H**(e,e′K)Λ (peak at binding energy = 0)

the waterfall target: provides ^{16}O and H targets



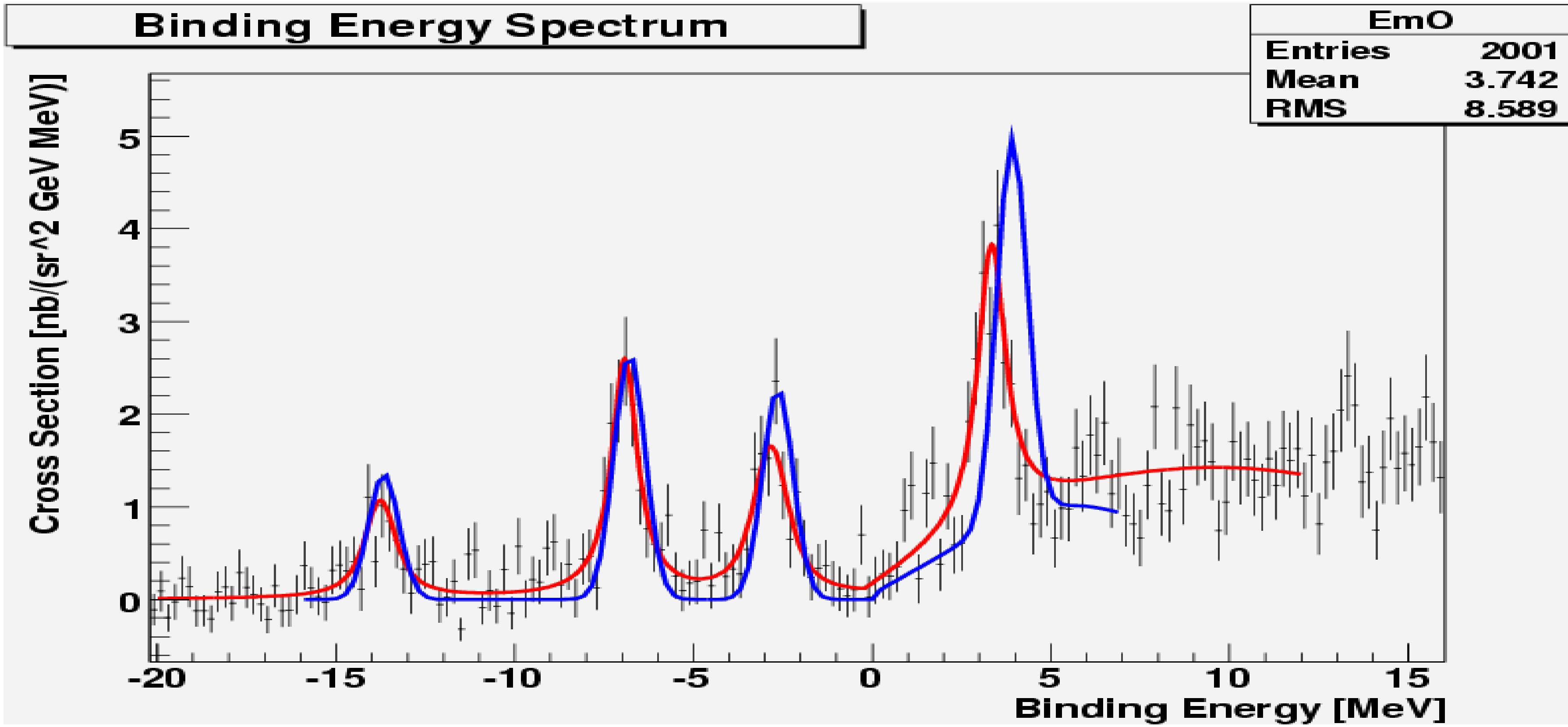






- Water thickness from elastic cross section on H
- Excellent determination of the missing mass scale using the Λ & Σ peaks

Hypernuclear Spectrum of $^{16}{}_{\Lambda}N$



Peak Search : Identified 4 regions with excess counts above background

- Fit to the data (red line): Fit 4 regions with 4 Voigt functions $\Rightarrow$ $X^2{}_{/ndf} = 1.19$
- Theoretical model (blue line)

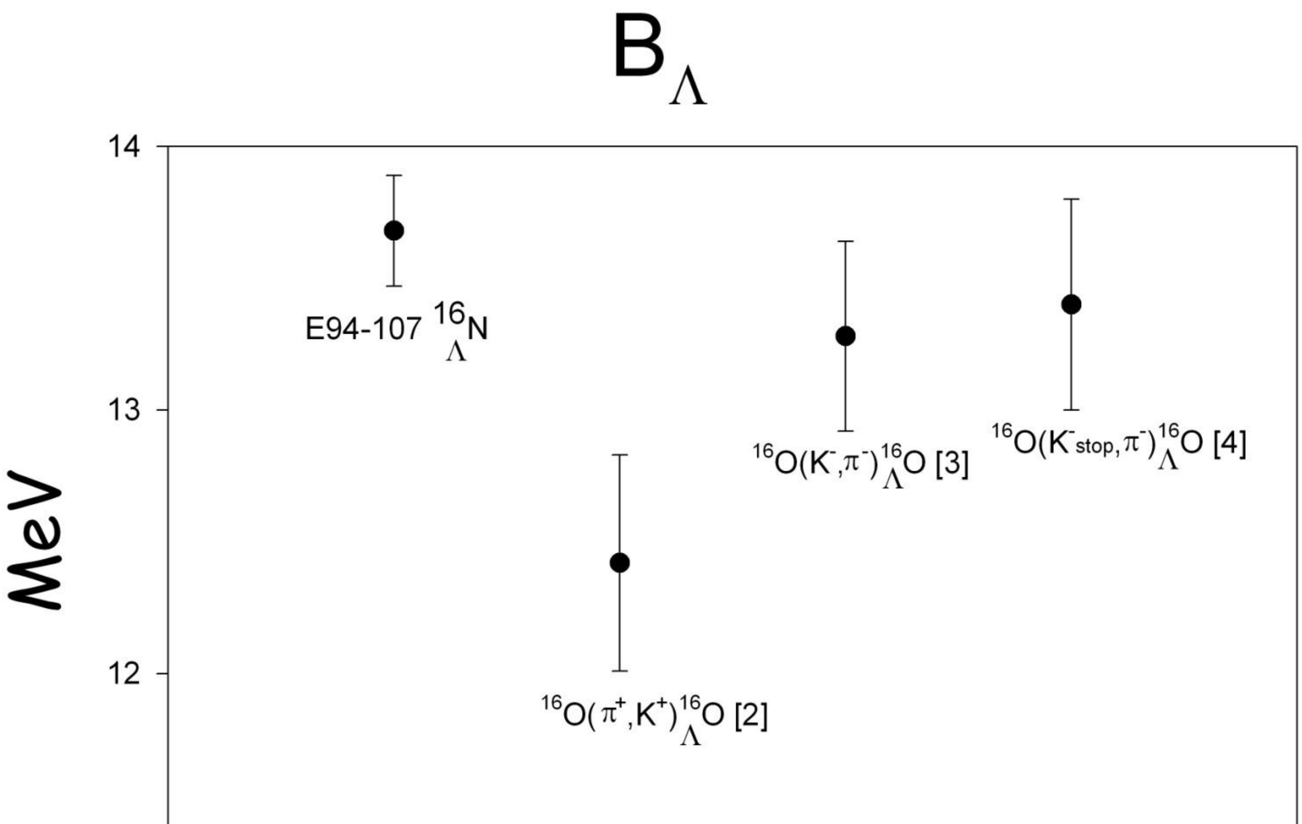
Summary of fitting and Theoretical calculation

E_x/E_Λ (MeV)	Width (FWHM, MeV)	Cross section $(nb/sr^2/GeV)$	E_x (MeV)	Wave function	J^π	Cross section $(nb/sr^2/GeV)$
$0.0/13.68 \pm 0.16$	1.71	1.46 ± 0.29	0.00	$p_{1/2}^{-1} \otimes s_{1/2\Lambda}$	0^-	0.002
			0.03	$p_{1/2}^{-1} \otimes s_{1/2\Lambda}$	1^-	1.45
6.76 ± 0.06	0.88	3.16 ± 0.63	6.71	$p_{3/2}^{-1} \otimes s_{1/2\Lambda}$	1^-	0.80
			6.93	$p_{3/2}^{-1} \otimes s_{1/2\Lambda}$	2^-	2.11
10.81 ± 0.07	0.99	2.11 ± 0.42	11.00	$p_{1/2}^{-1} \otimes p_{3/2\Lambda}$	2^+	1.82
			11.07	$p_{1/2}^{-1} \otimes p_{1/2\Lambda}$	1^+	0.62
17.01 ± 0.07	1.00	3.44 ± 0.69	17.56	$p_{3/2}^{-1} \otimes p_{1/2\Lambda}$	2^+	2.10
			17.57	$p_{3/2}^{-1} \otimes p_{3/2\Lambda}$	3^+	2.26

Theory Particulars:

- DWIA
- Saclay-Lyon model for elementary production
- YNG interaction adjusted to reproduce the spectra of ${}^{16}_{\Lambda}O$ and ${}^{15}_{\Lambda}O$
- The ground state of ${}^{16}O$ is assumed to be a simple closed shell
- The shell-model wave functions for ${}^{16}_{\Lambda}N$ are computed in a simple particle-hole model space.

The four pronounced peaks in the spectrum are reproduced in the shell-model calculation but there is non-negligible discrepancy in absolute cross sections and position for the fourth peak.



[2] O. Hashimoto, H. Tamura, Part Nucl Phys 57, 564 (2006)

[3] private communication from D. H. Davis, D. N. Dovee, fit of data from Phys Lett B 79, 157 (1978)

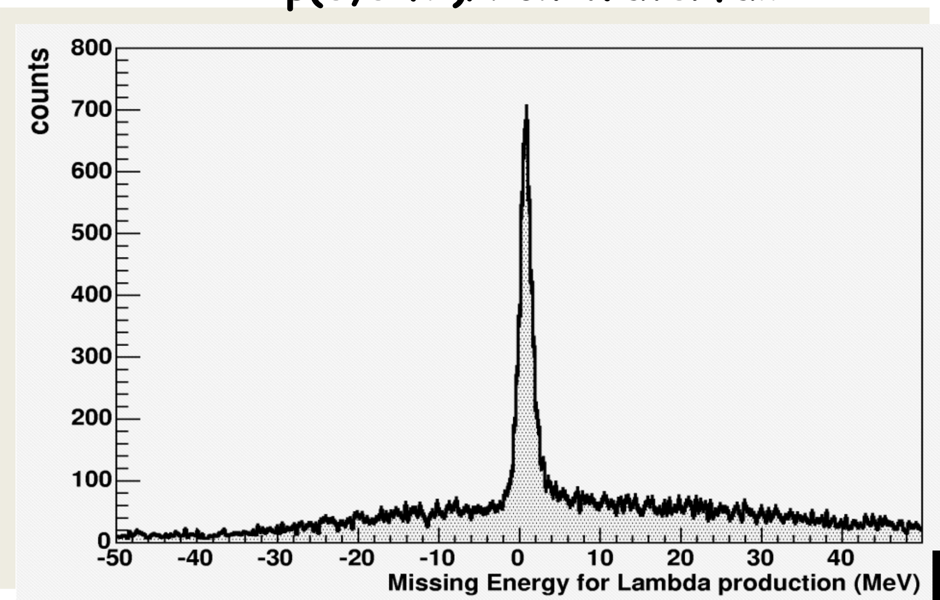
[4] private communication from H. Tamura, erratum on Prog Theor Phys Suppl 117, 1 (1994)

- Binding Energy B_Λ=13.68 ± 0.16 (stat) ± 0.05 (sys) MeV
Measured for the first time with this level of accuracy
- With hadronic probes calibration is performed by comparing to ^{12}C, where the binding energy is well known.
  - But, Involves comparison with different targets
different equipment ⇨ larger systematic errors

Difference expected with respect to mirror nucleus: 400 – 500 keV (M. Sotona)

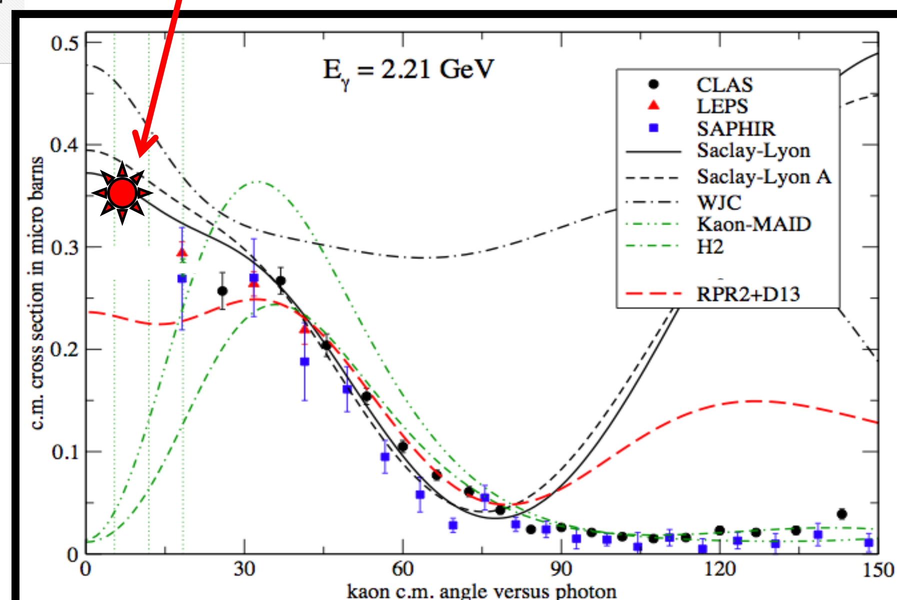
Results on H target – The p(e,e'K)Λ Cross Section

p(e,e'K+)Λ on Waterfall



Work on normalizations, acceptances, efficiencies still underway. Estimate ~1 month till reportable results.

Thesis work of Armando Acha (FIU)



Summary

- Carbon results are published
  - M.Iodice et al., Phys. Rev. Lett. E052501, 99 (2007)
- Oxygen results are about to be published
  - PRL circulating
- Beryllium work has just started
- Elementary production analysis is underway
  - Expect results soon
- Ultimately there will be an archival paper on the whole business
  - All targets, magnets, RICH, Waterfall, …