HYPERNUCLEAR EXPERIMENTS IN HALL C

HISTORY AND RESULTS

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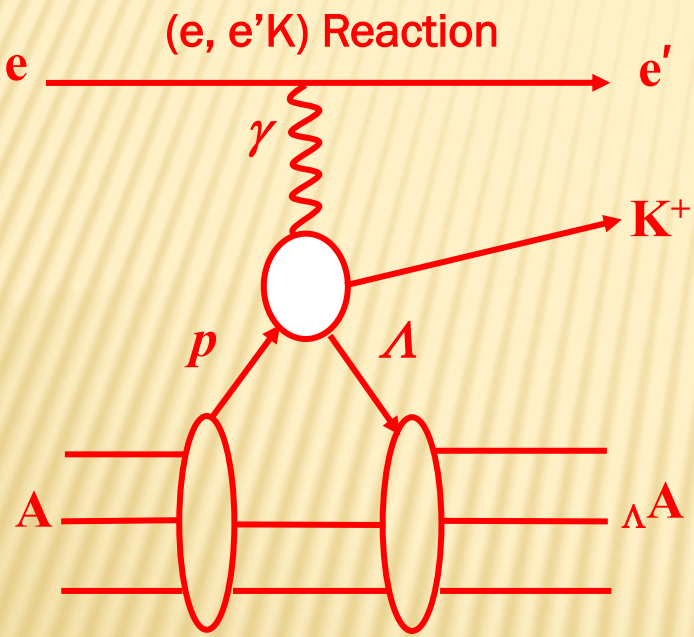
GOAL OF THE HALL C PROGRAM

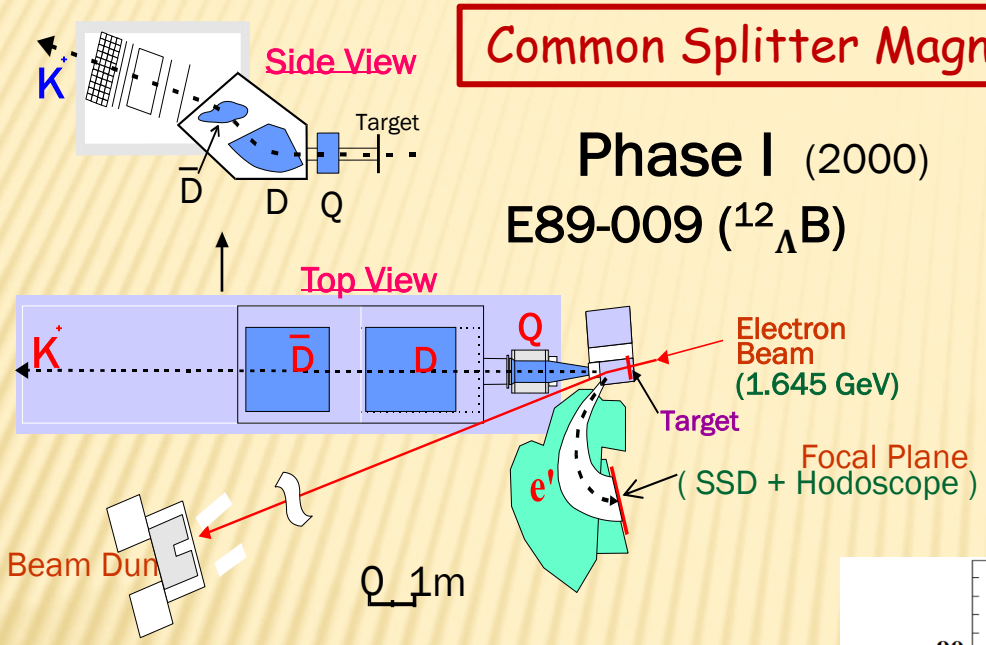
High precision ($\delta E \leq 1\ MeV\ FWHM$) mass spectroscopy of neutron Λ-hypernuclei featured by deeply bound states with both unnatural and natural parities



- Precision measurement of e' and K^+
- Small forward angles: Optimizing virtual photon flux rate and production cross section of Λ and 3-momentum transfer to Λ
- Short orbit for the kaon spectrometer, optimizing the survival rate of the short-lived kaons
- Wide momentum acceptance for K^+, precise absolute missing mass calibration by the $p(e,e'K^+)\Lambda\&\Sigma^0$ reaction

Hall C Technique: Common Splitter and later the "Tilt Method"

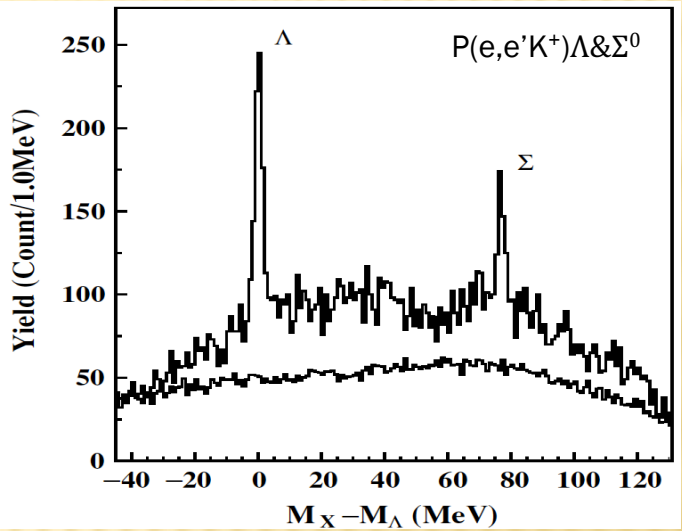
HALL C EXPERIMENTS IN CEBAF 6GEV ERA

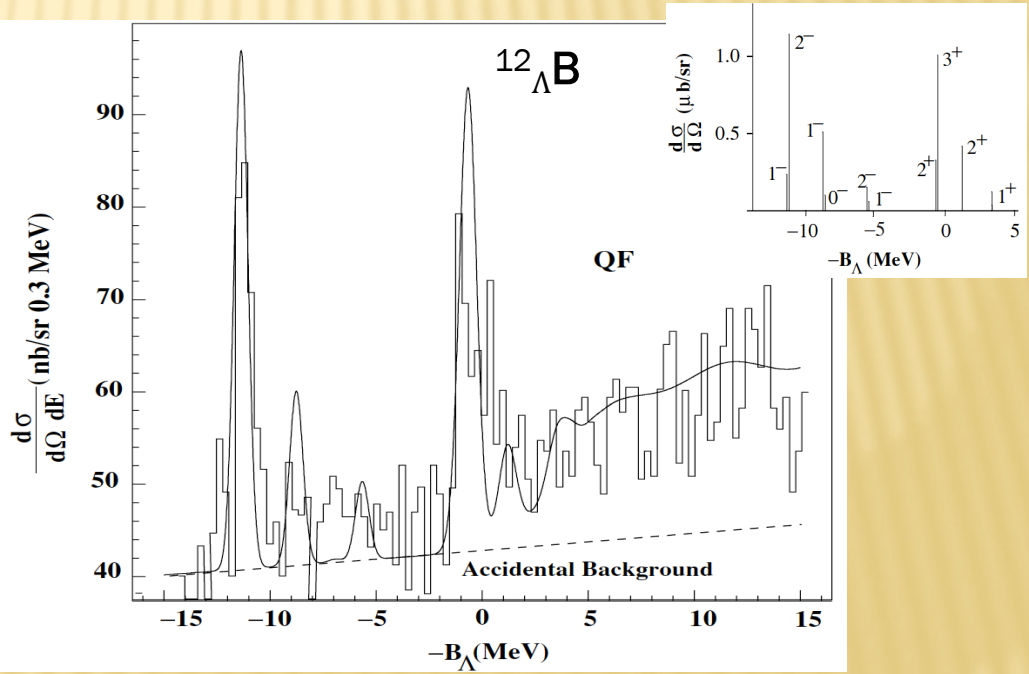


Common Splitter Magnet

Phase I (2000)

E89-009 ($^{12}_{\Lambda}$B)

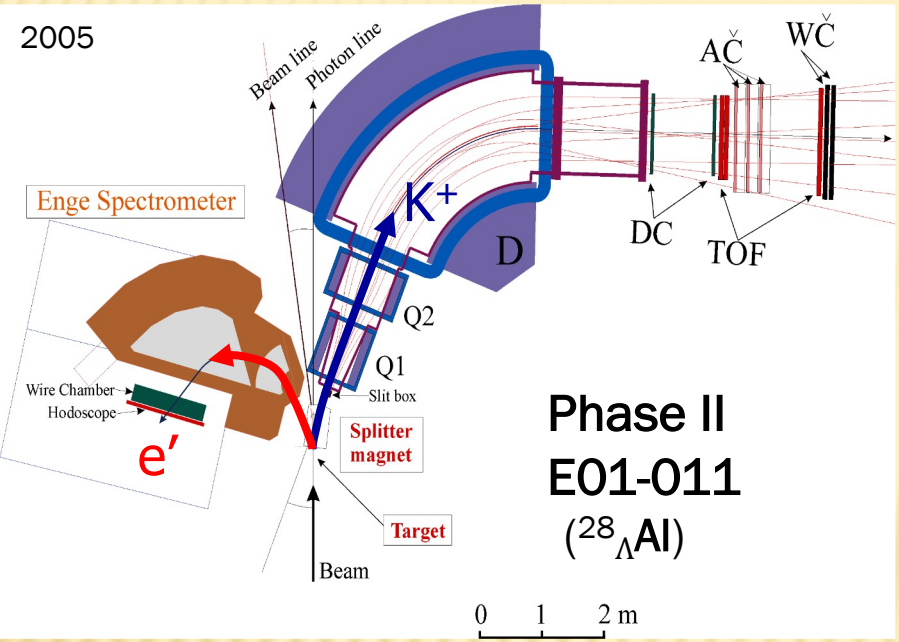


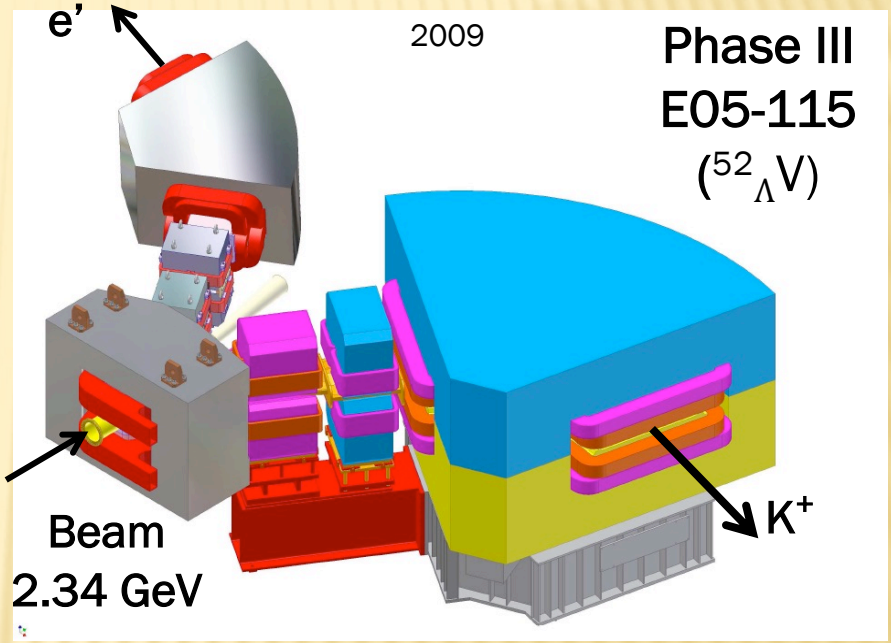


- Zero degree e' tagging
- High e' single rate
- Low beam luminosity
- High accidental rate
- Low yield rate
- A first important milestone for hypernuclear physics with electro-production

HALL C EXPERIMENTS IN CEBAF 6GEV ERA

"Tilt" Method to Avoid Bremsstrahlung and Moller Electrons



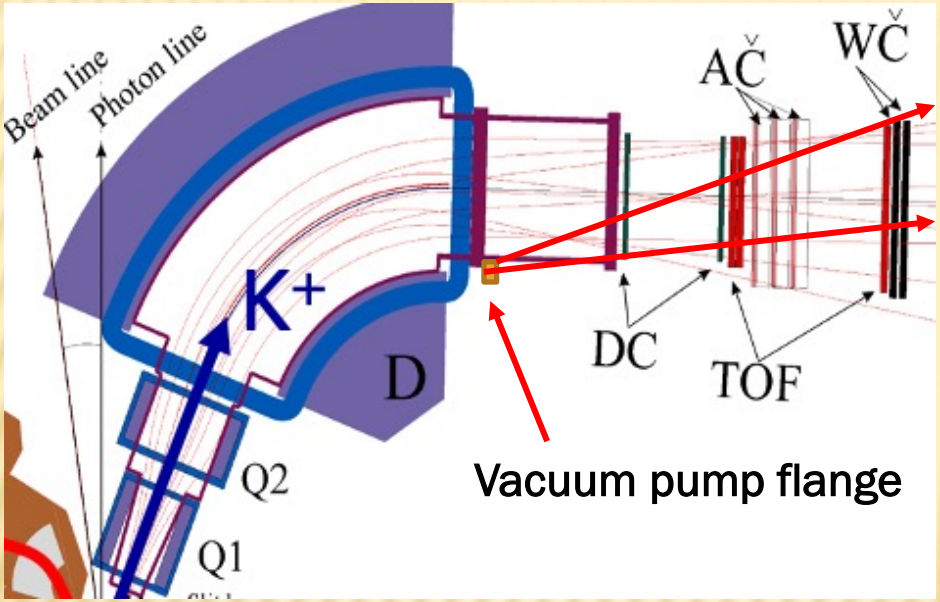


- New HKS spectrometer → large $\Delta\Omega$
- Tilted Enge spectrometer → Reduce e' single rate by a factor of 10^{-5}
- High beam luminosity
- Accidental rate improves 4 times
- Possible studies beyond p shell

- New Splitter magnet and new HES spectrometer → larger $\Delta\Omega$
- Further improves accidental rate
- Further improves resolution and accuracy
- Possible studies beyond A > 50

HALL C EXPERIMENTS IN CEBAF 6GEV ERA

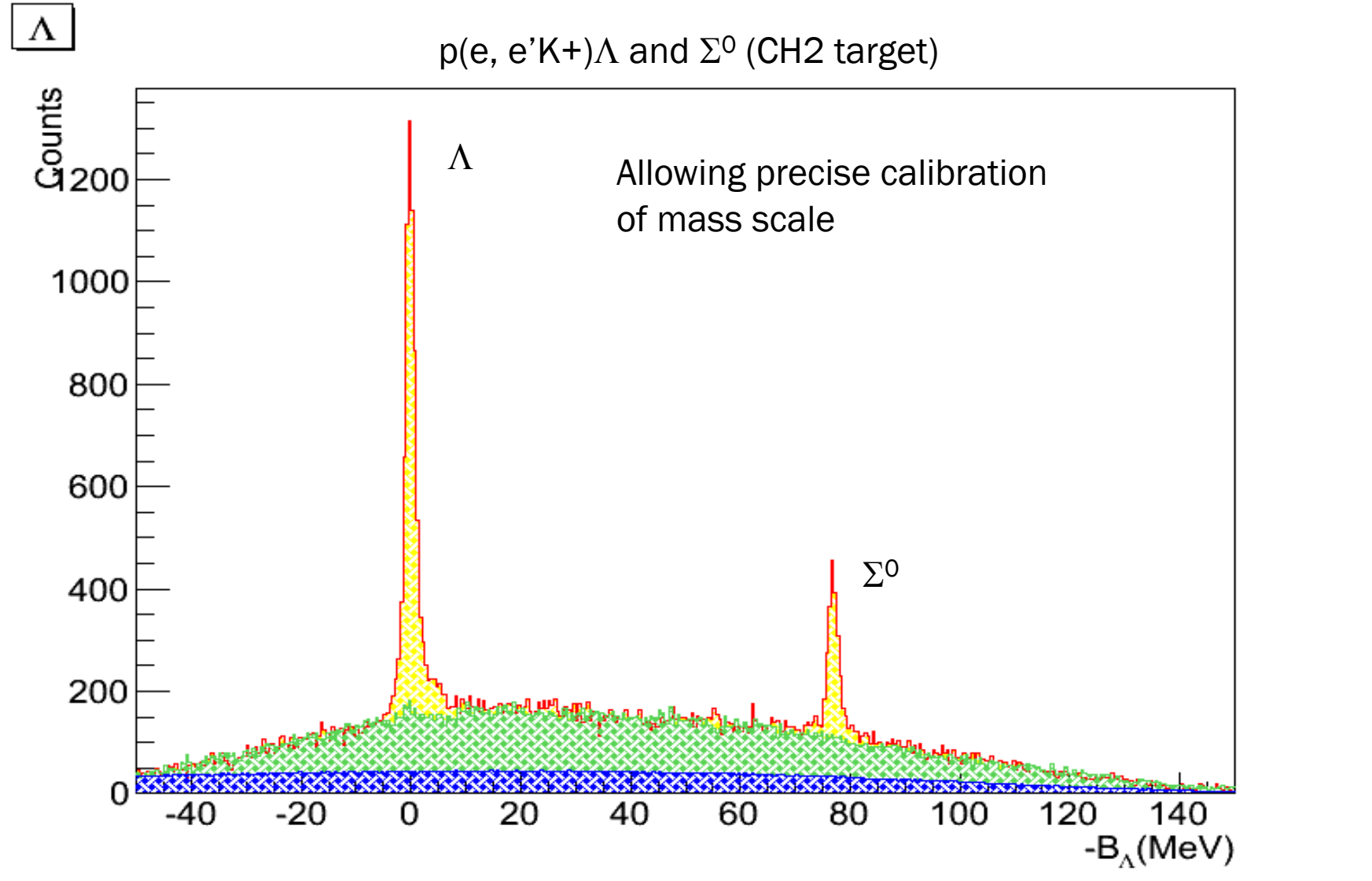
Problem encountered by Phase II and III experiments



- Common Splitter allowed forwardly emitted positrons to enter HKS
- Low momentum positrons showered at the vacuum flange on the vacuum extension box
- Shower produced background particles with very high rate
- It caused high trigger rate and high accidental rate

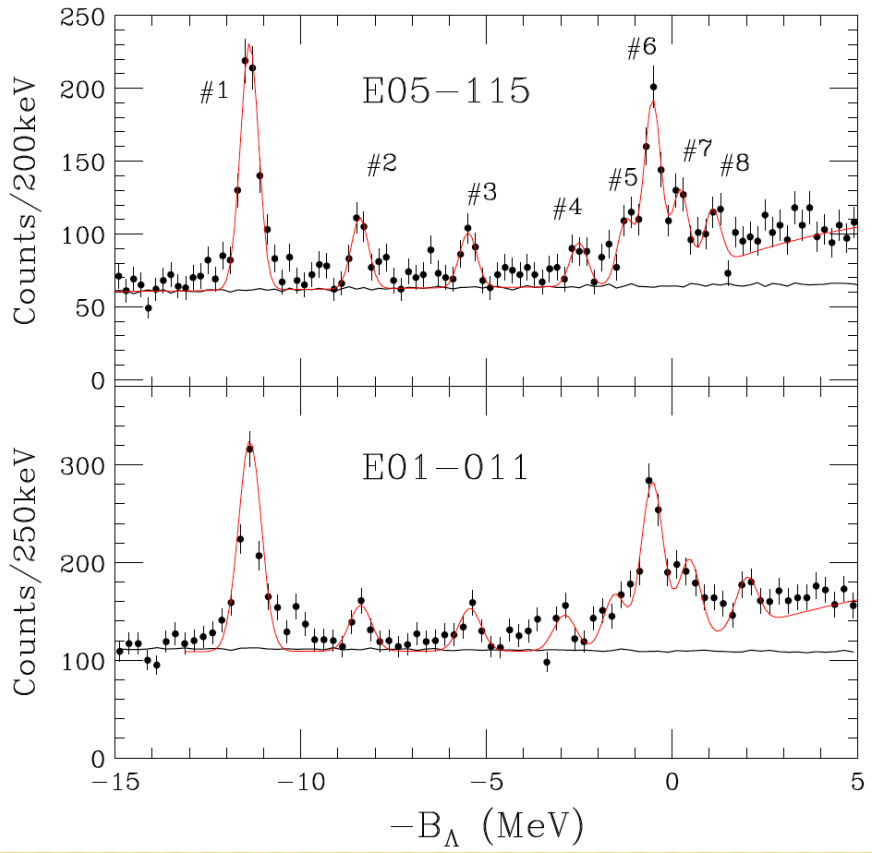
Nevertheless, the experiments were able to produce new Λ hypernuclear spectroscopy which were never produced with good precision

HIGH LIGHTS FOR PHASE II&III EXPERIMENTS



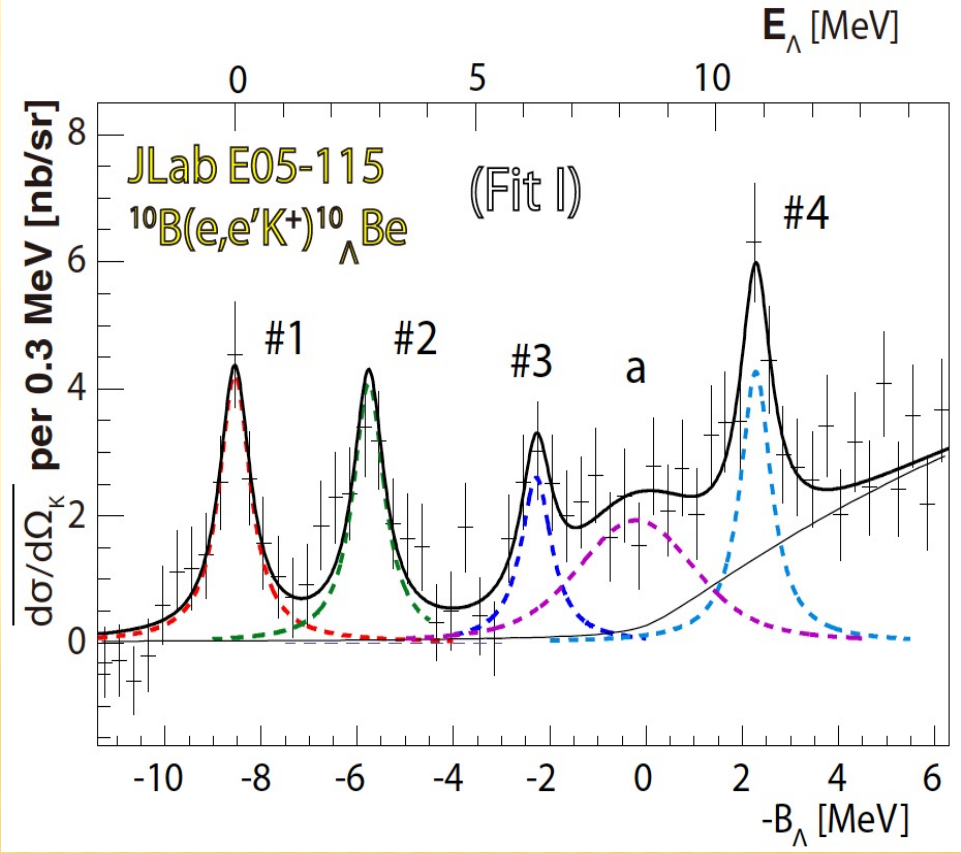
HIGH LIGHTS FOR PHASE II&III EXPERIMENTS

Improved $^{12}{}_{\Lambda}$B spectroscopy



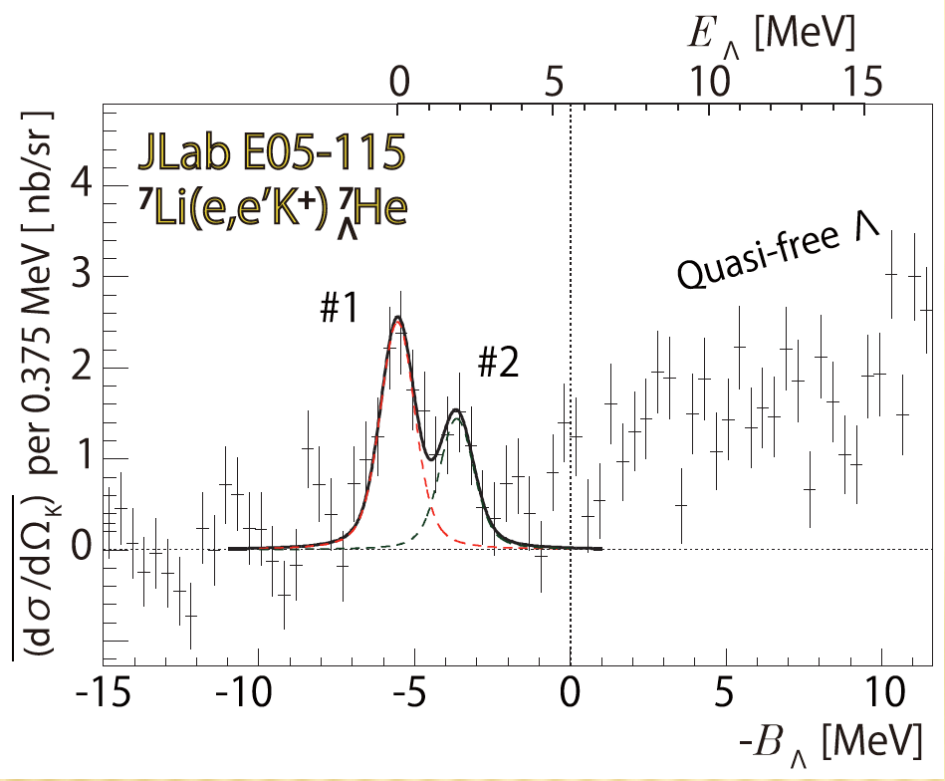
Resolution ≈ 600 keV FWHM

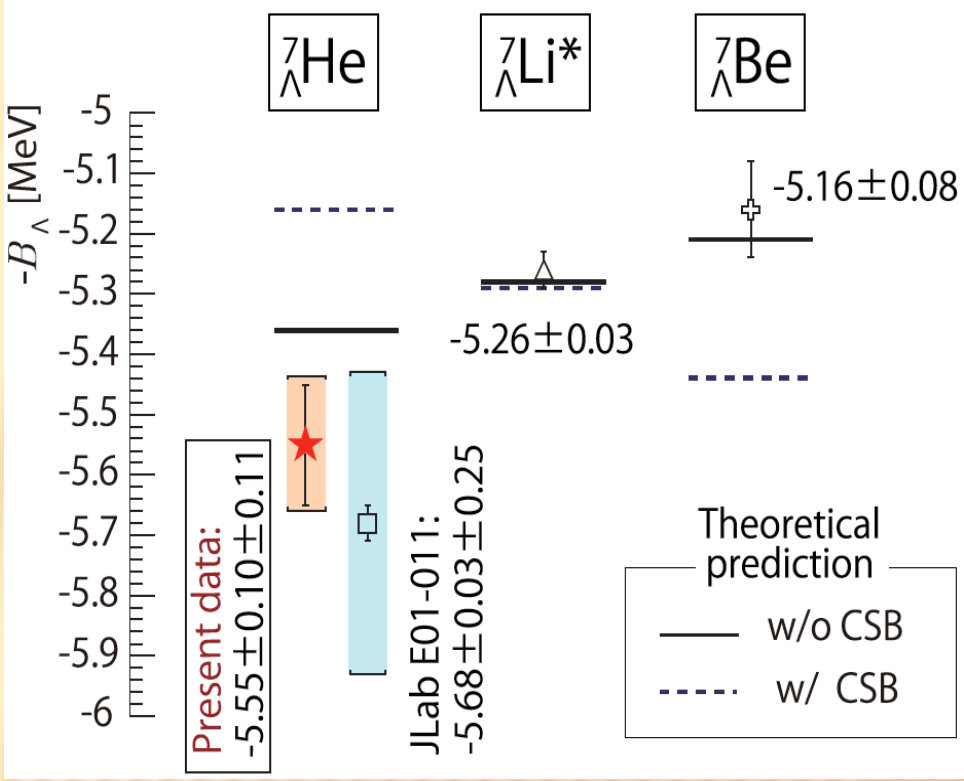
First measured $^{10}{}_{\Lambda}$Be spectroscopy



Resolution ≈ 800 keV FWHM

HIGH LIGHTS FOR PHASE II&III EXPERIMENTS

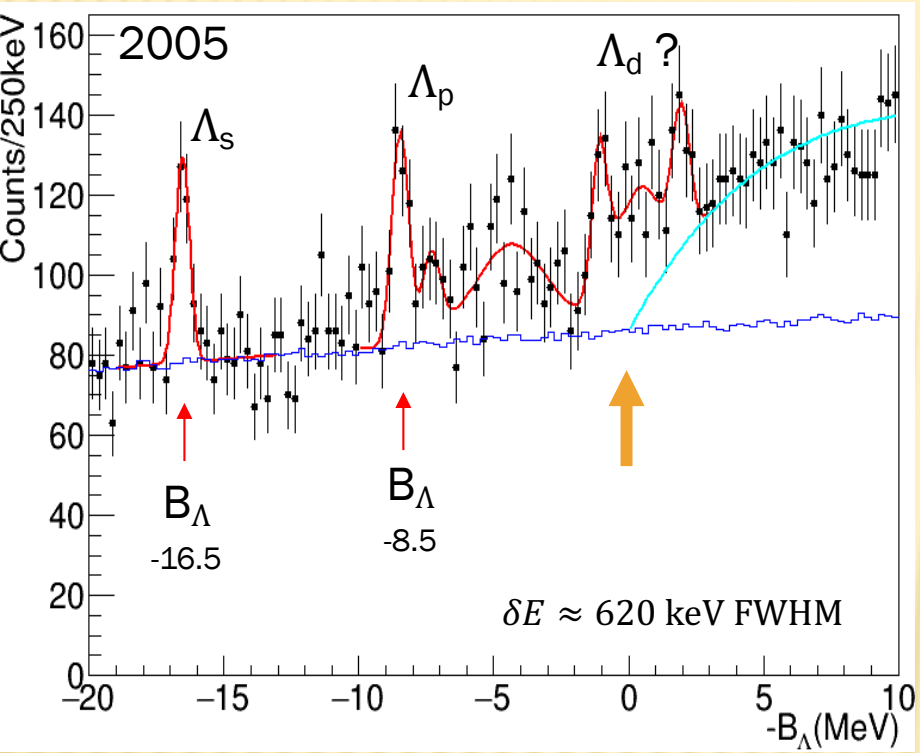




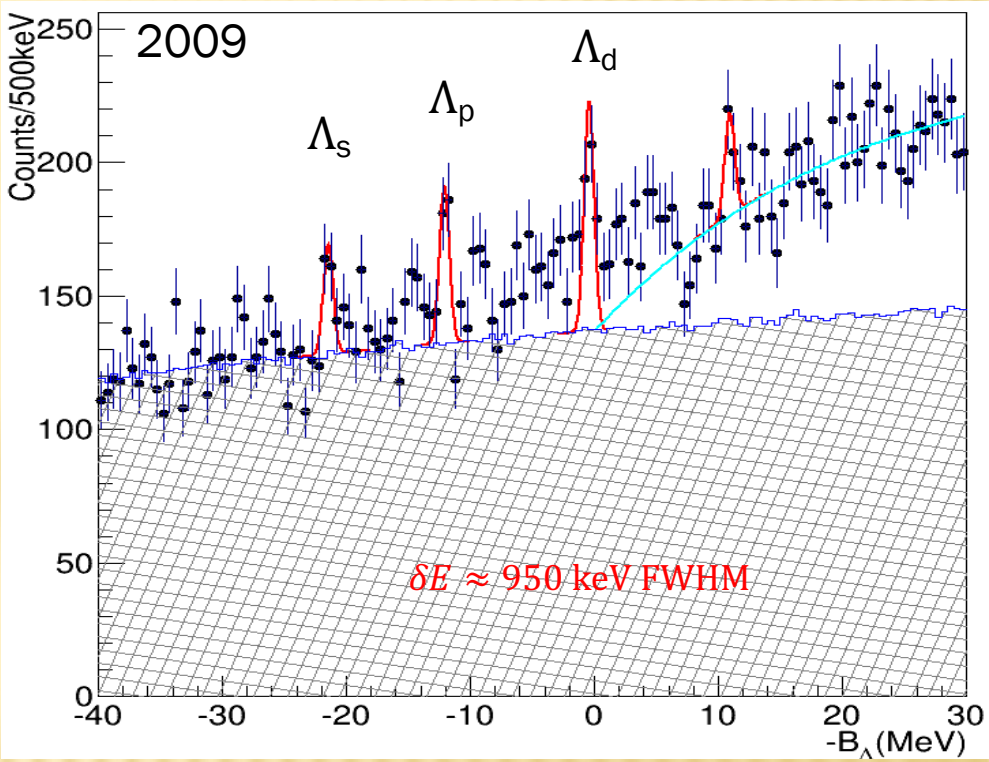
Allowing Charge Symmetry Breaking study using A = 7 (proton and neutron rich) hypernuclei

HIGH LIGHTS FOR PHASE II&III EXPERIMENTS

$^{28}{}_{\Lambda}$Al, the primary HYP for E01-011



$^{52}{}_{\Lambda}$V, the primary HYP for E05-115



- High positron rate in HKS caused high accidental rate
- Poorer S/B ratio and resolution than expected
- Forced to run with low beam current, that resulted low statistics
- These results are not published

PEER REVIEWED JOURNAL PUBLICATIONS

- T. Miyoshi, *et al.,* "High Resolution Spectroscopy of the $^{12}{}_{\Lambda}$B Hpernucleus Produced by the (e,e'K^{+}) Reaction", Phys. Rev. Lett. Vol. **90** , No. **23**, 232502 (2003).
- L. Yuan, *et al.,* "Hypernuclear spectroscopy using the (e,e'K^{+}) reaction", Phys. Rev. C, Vol. **73**, 044607 (2006).
- O. Hashimoto, *et al.,* "Hypernuclear Spectroscopy at JLab Hall C", Nuclear Physics A **835** 121-128 (2010).
- S.N. Nakamura, *et al.,* "Observation of the $_{\Lambda}{}^{7}$He Hypernucleus by the (e, e′K^{+}) Reaction", Phys. Rev. Lett. **110**, 012502 (2013).
- T. Gogami, *et al.,* "Bucking coil implementation on PMT for active canceling of magnetic field", Nucl. Instr. and Meth. in Physics Research A **729** 816-824 (2013).
- L. Tang, *et al.,* "Experiments with the High Resolution Kaon Spectrometer at Jlab Hall C and the new spectroscopy of $^{12}{}_{\Lambda}$B hypernuclei", Phys. Rev. C **90**, 034320 (2014).
- T. Gogami, *et al.,* "High resolution spectroscopic study of $^{10}{}_{\Lambda}$Be", Phys. Rev. C **93**, 034314 (2016).
- T. Gogami, *et al.,* "Spectroscopy of the neutron-rich hypernucleus $^{7}{}_{\Lambda}$He from electron scattering", Phys. Rev. C **94**, 021302 (R) (2016).
- X. Qiu, *et al.,* "Direct measurements of the lifetime of medium-heavy hypernuclei", Nuclear Physics A **973** 116-148 (2018).
- T. Gogami, *et al.,* "Experimental techniques and performance of *Λ*-hypernuclear spectroscopy with the $(e, e'K^{+})$ reaction", Nucl. Instr. and Meth., A **900** 69-83 (2018).
- T. Gogami, *et al.,* "Spectroscopy of A=9 hyperlithium with the (e, e′K^{+}) reaction", Phys. Rev. C 103, L041301 (2021).

SUMMARY

- Hypernuclear Physics is an important part of nuclear physics.
- The previous Hall C experiments successfully achieved high precision in terms of missing mass resolution and absolute binding energy.
- However, they suffered poor S/A ratio that affected the outcome for the two primary hypernuclear systems: ${}^{28}_{\Lambda}$Al and ${}^{52}_{\Lambda}$V.
- The new experiments in Hall C will be more successful with the new configuration.