2025 Summer Hall A/C Collaboration Meeting

Electro-production of hypernuclear spectroscopy with high precision in wide mass range

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June 18, 2025

KYOTO UNIVERSITY

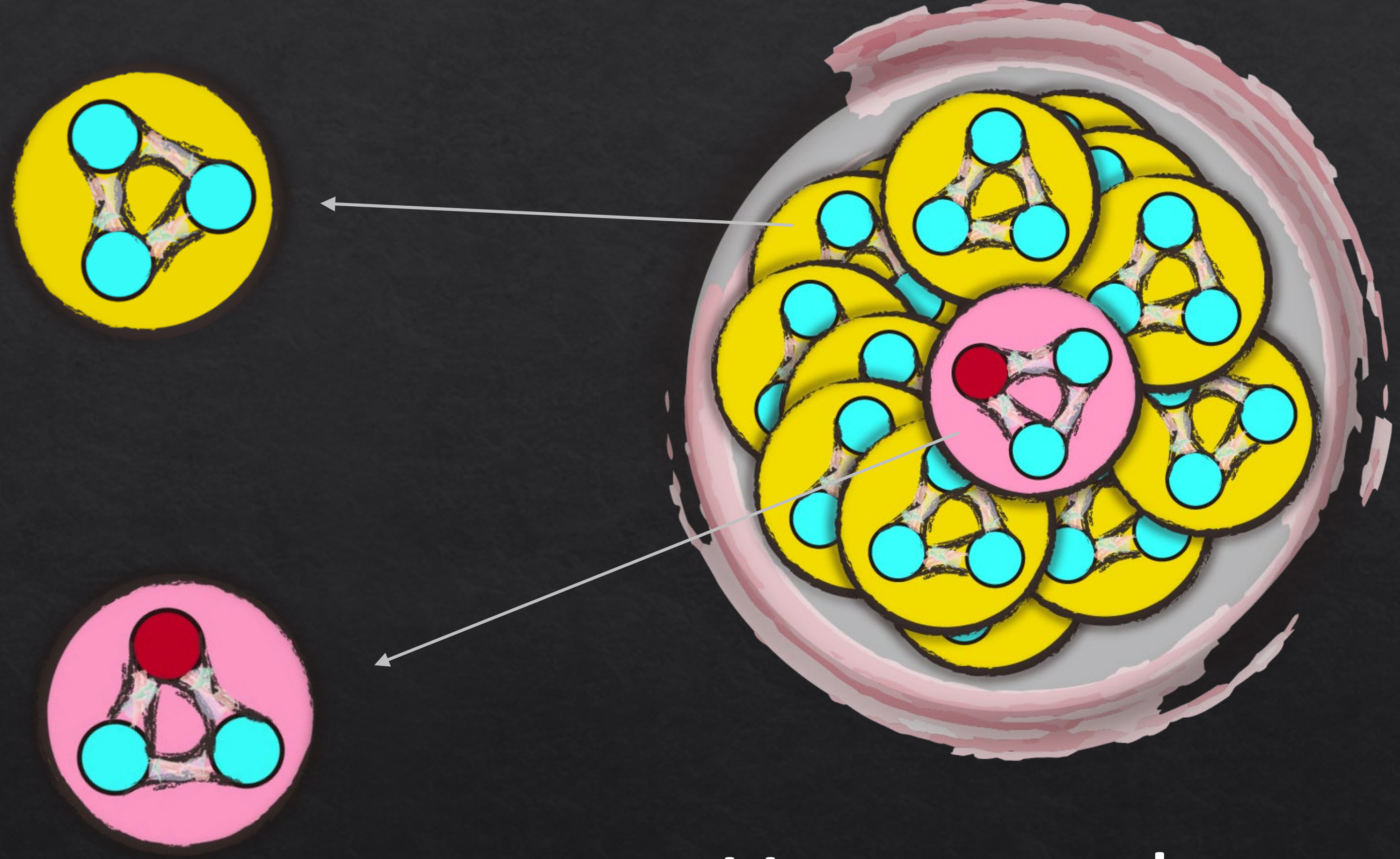
Hypernucleus

Nucleon

only up, down quarks

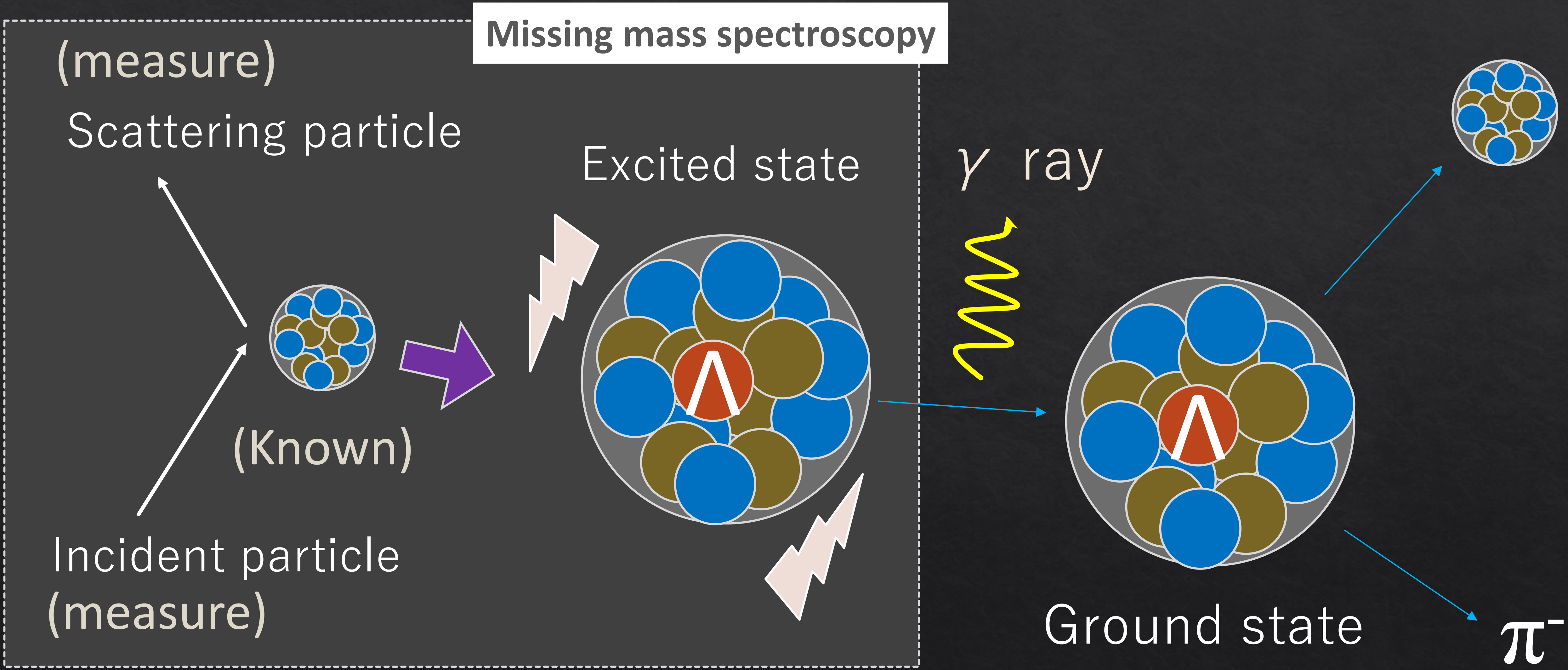
Hyperon

(u, d +) strange (s) quark

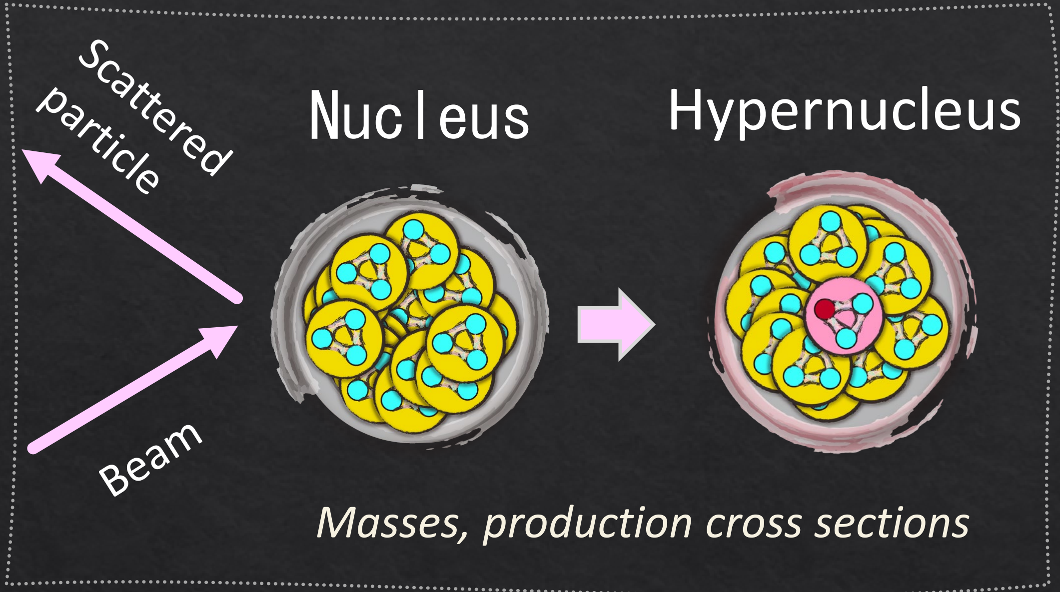


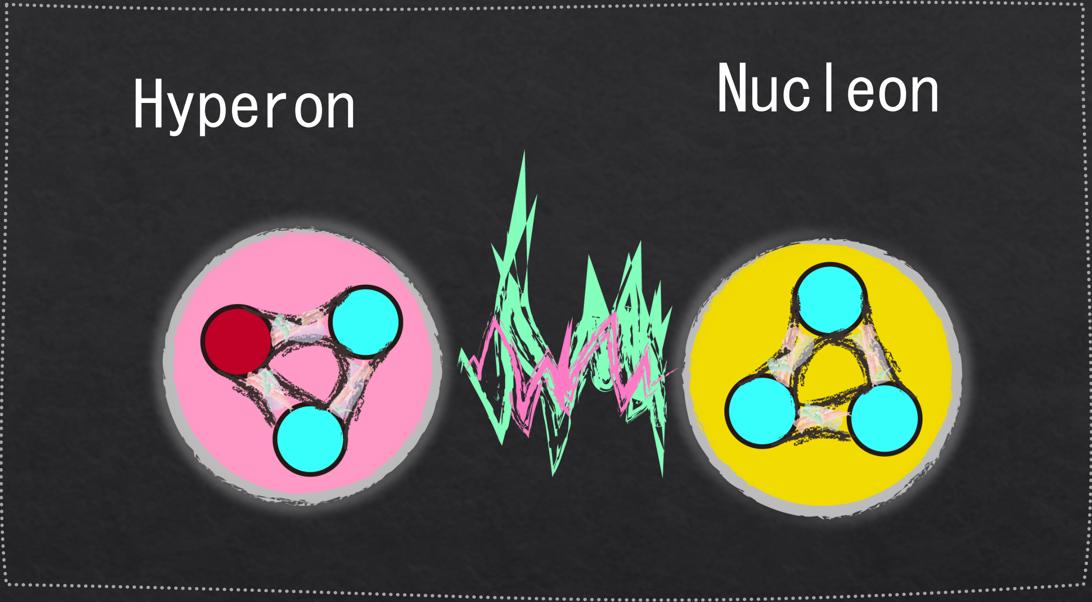
Hypernucleus

The mass at the moment of production



Baryon interaction study through hypernuclei



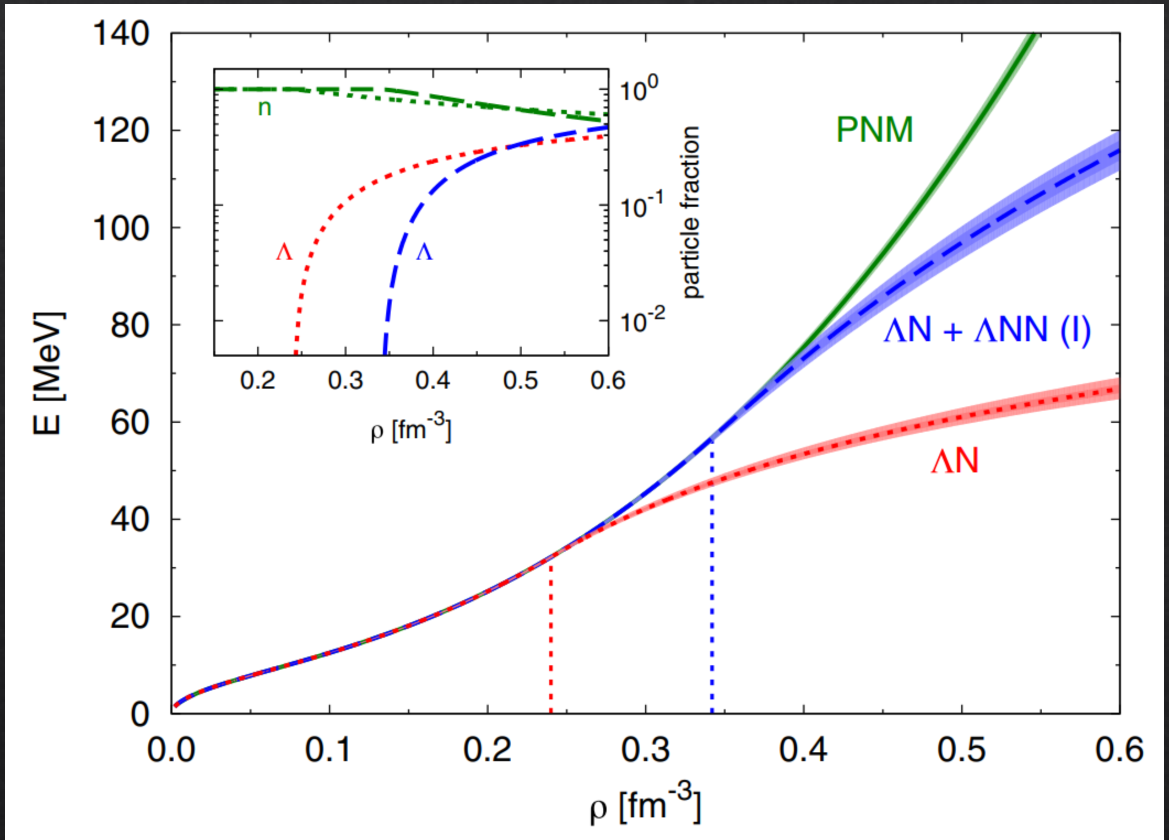


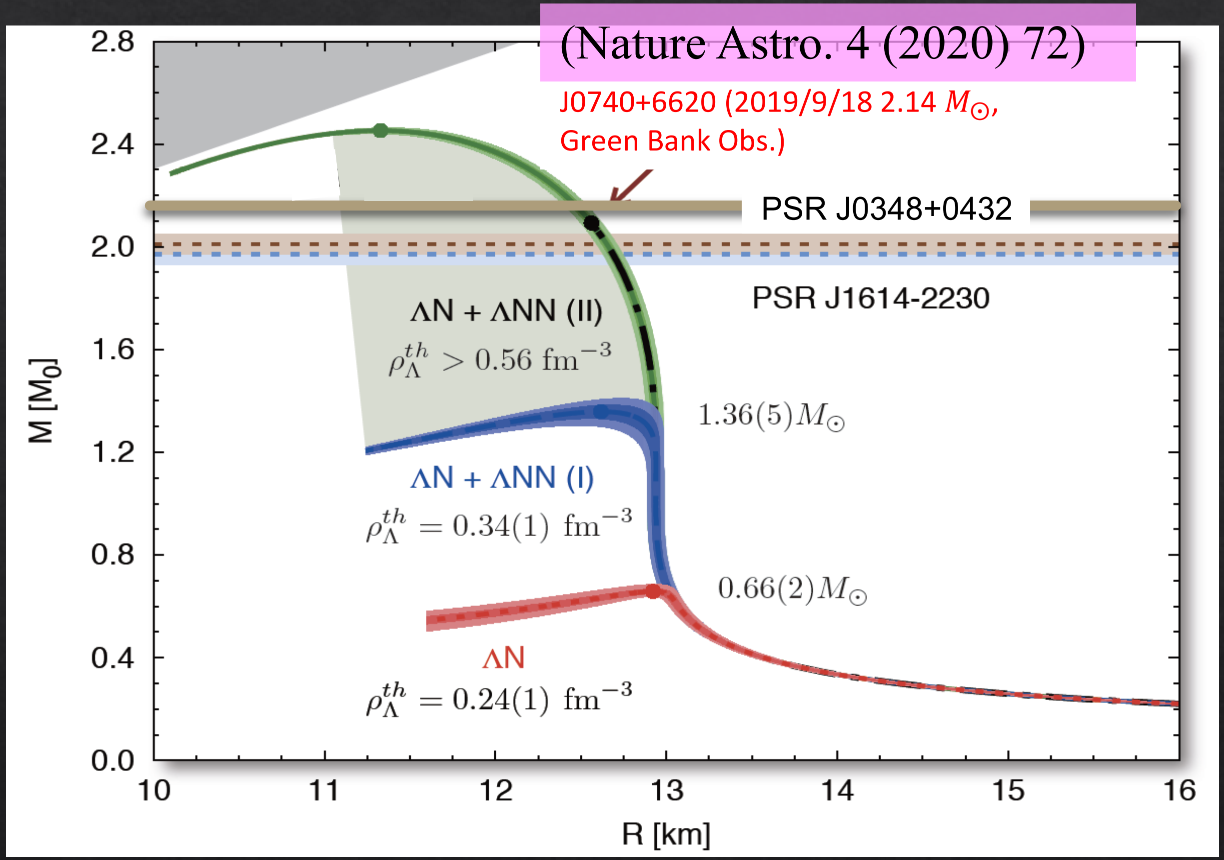
→ Hyperon(Y)-nucleon(N) interaction

→ More general baryon-baryon interaction

Hyperons in neutron stars

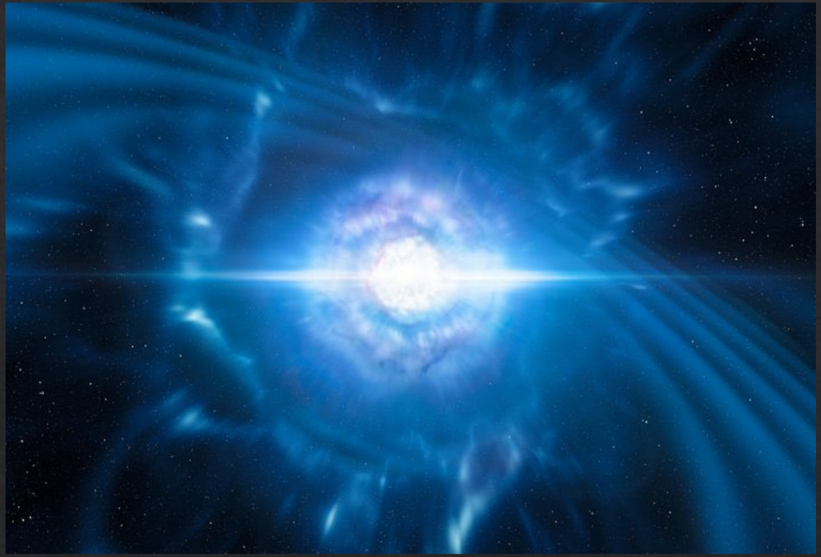
D. Lonardoni et al., Phys. Rev. Lett. 114, 092301 (2015)





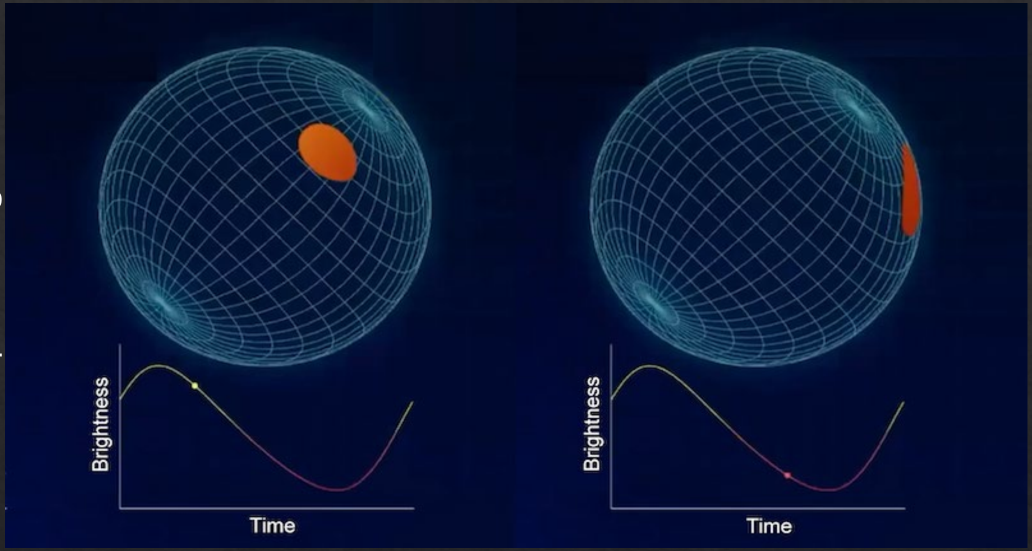
➔ Multi-body force may play an important role

New astronomical observations



CC4.0 ESO/L. Calçada/M. Kornmesser

Gravitation Wave from neutron star mergers
LIGO/Virgo PRL **119**, 161101 (2017)



Goddard Space Flight Center

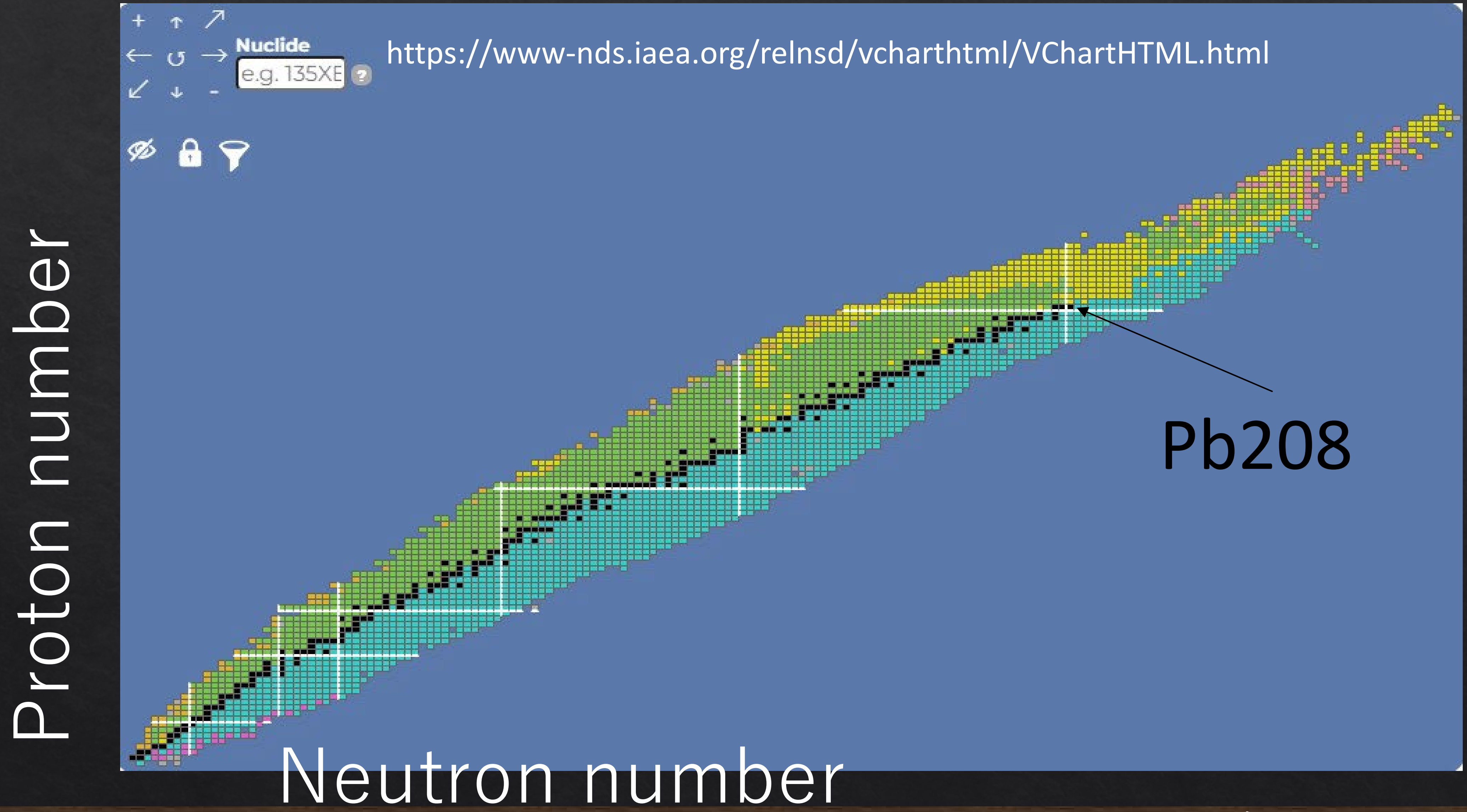
NICER : NS x-ray hot spot measurement
Physics 14, 64 (Apr. 29, 2021)

Macroscopic features of NS : Tidal deformability, masses and radii

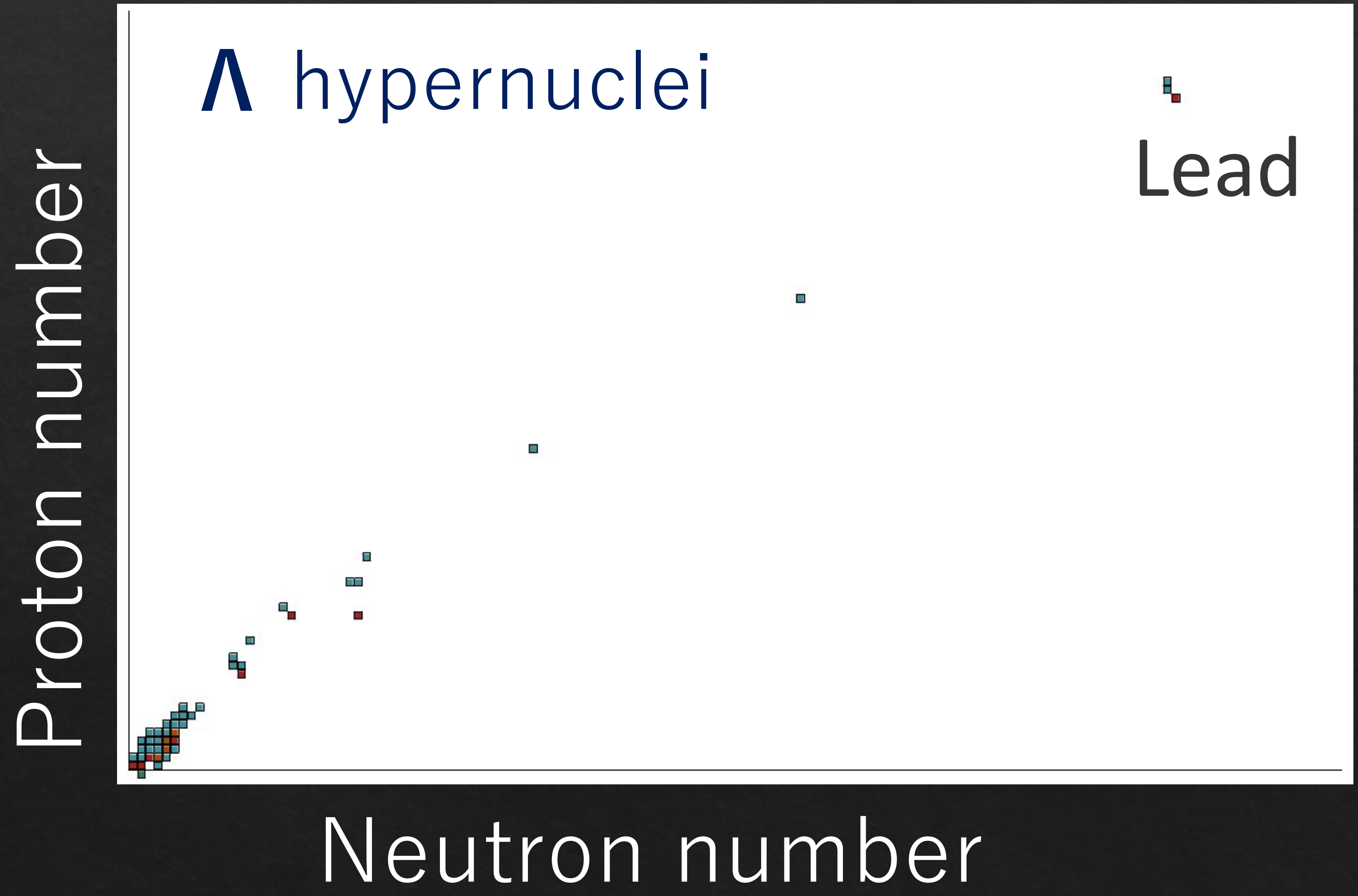
vs.

Microscopic investigation of NS: Inner composition → HYPERNUCLEAR SPECTROSCOPY

Nuclear chart (strangeness = 0 floor)



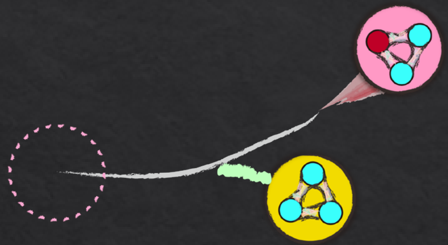
Hypernuclear chart (strangeness $= \mathbf{-1}$ floor)

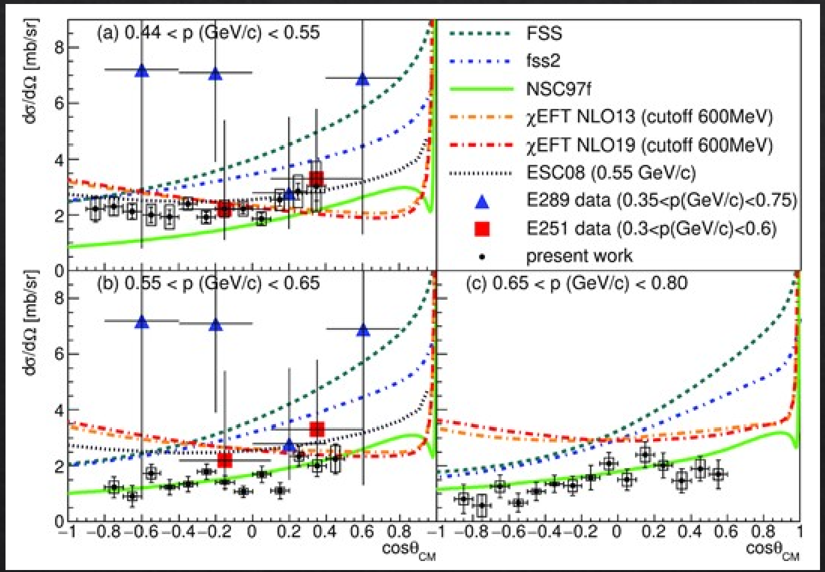


Data is scarce
➔ Lots of unknowns

YN/YY interaction study

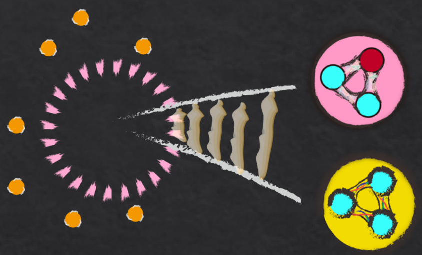
Scattering experiments

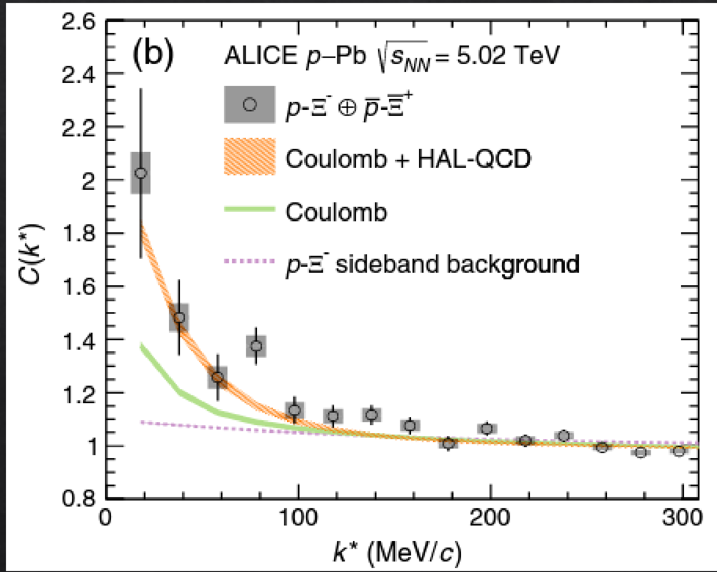




T. Nanamura et al., PTEP 2022, 9, 093D01 (2022)

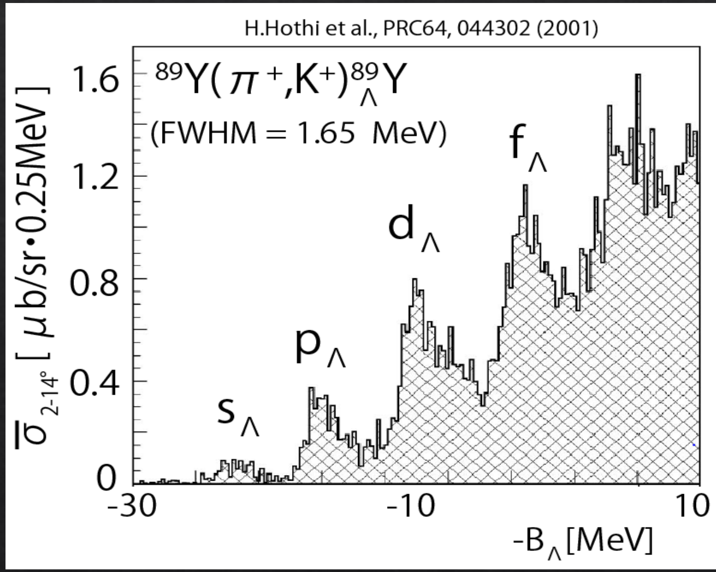
Femtoscopy





S. Acharya et al., Phys. Rev. Lett. 123, 112002 (2019)

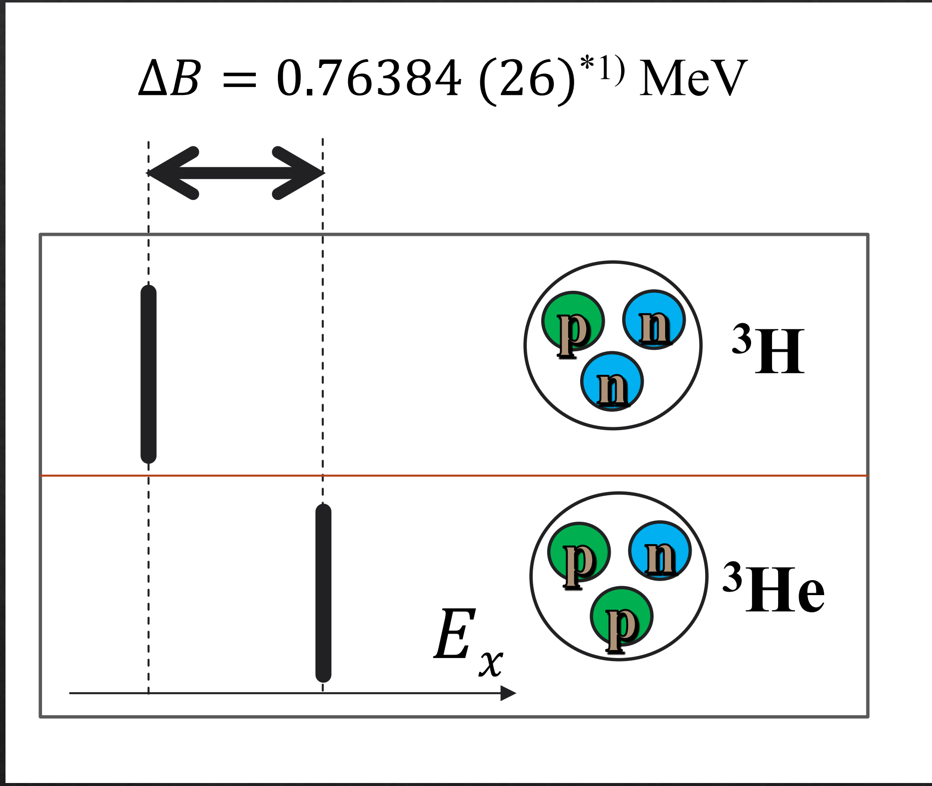
Hypernuclear spectroscopy



H. Hotchi et al., Phys. Rev. C 64, 044302 (2001)

Charge Symmetry Breaking (CSB), the mystery

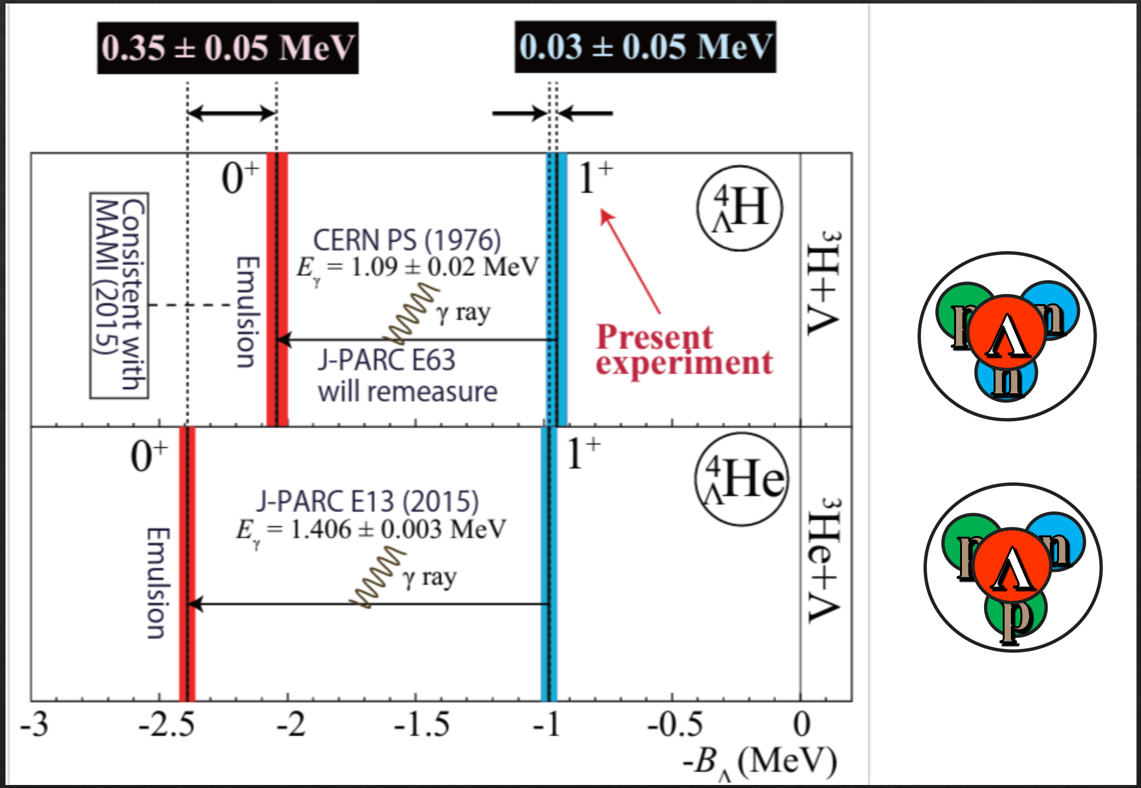
*1) J.H.E.Mattauch *et al.*, *Nucl. Pys.* **67**, 1 (1965).



81 keV after Coulomb correction

[R.A.Brandenburg, S.A.Coon *et al.*, *NPA***294**, 305 (1978)]

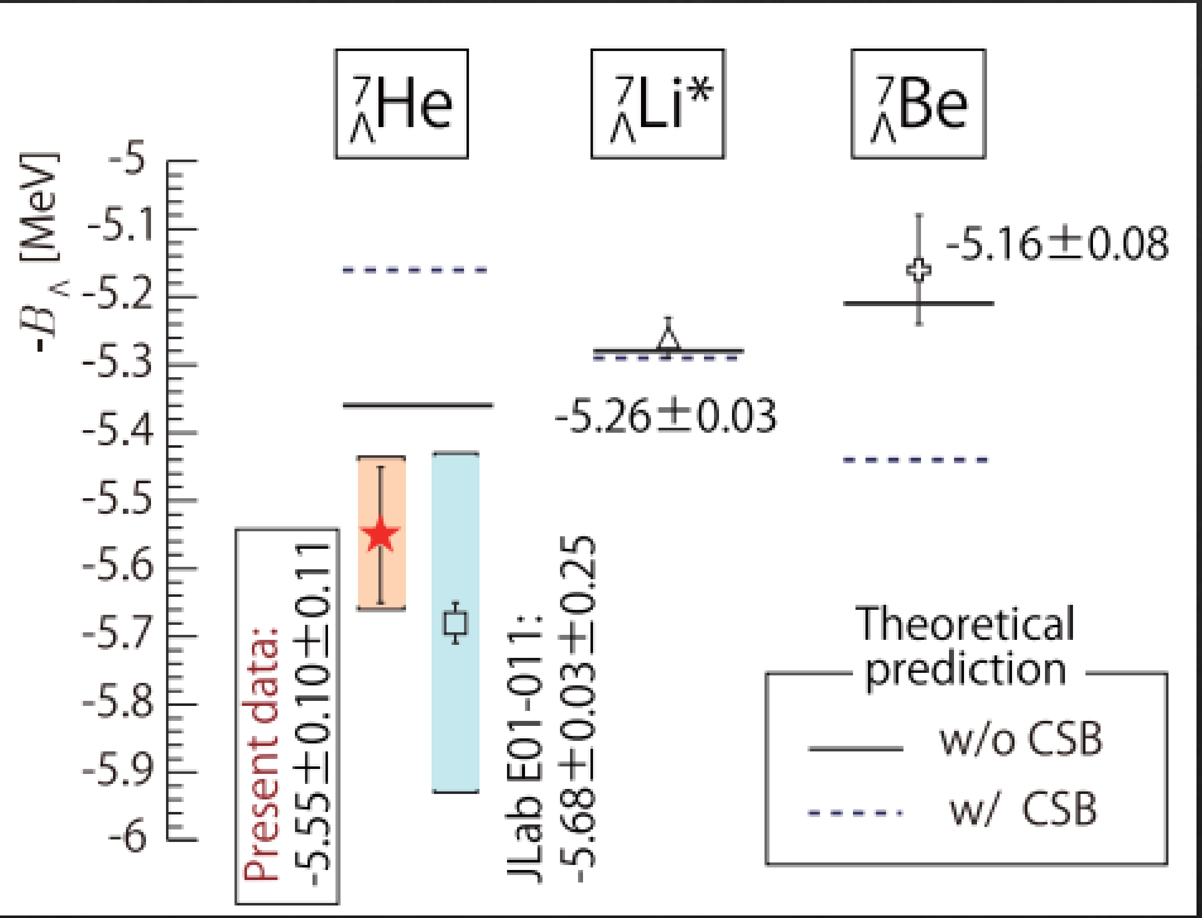
Figure from proposal of JLab E12-19-002



~400 KeV after Coulomb correction

➡ **5 times larger CSB than NN interaction!**

Previous study of CSB effect for A = 7 at JLab



TG et al., PRC 94, 021302(R) (2016)

E. Hiyama et al., PRC80, 054321 (2009)

Phenomenological CSB potential

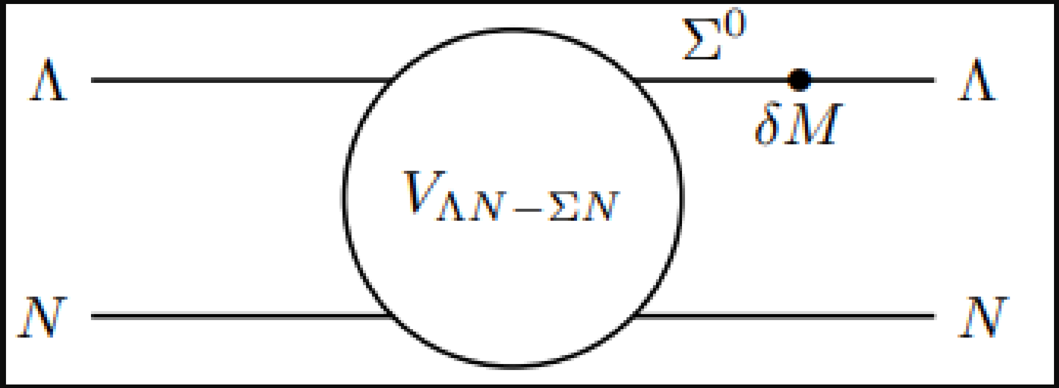
$$V^{\mathrm{CSB}}_{\Lambda N}(r) = -\frac{\tau_z}{2}\left[\frac{1+P_r}{2}\left(v_0^{\mathrm{even,CSB}} + \boldsymbol{\sigma}_\Lambda\cdot\boldsymbol{\sigma}_N v^{\mathrm{even,CSB}}_{\sigma_\Lambda\cdot\sigma_N}\right)e^{-\beta_{\mathrm{even}}r^2} + \frac{1-P_r}{2}\left(v_0^{\mathrm{odd,CSB}} + \boldsymbol{\sigma}_\Lambda\cdot\boldsymbol{\sigma}_N v^{\mathrm{odd,CSB}}_{\sigma_\Lambda\cdot\sigma_N}\right)e^{-\beta_{\mathrm{odd}}r^2}\right],$$

Parameters were adjusted
to reproduce the binding energies of
$^{4}_{\Lambda}$He, $^{4}_{\Lambda}$H, $^{8}_{\Lambda}$Li, $^{8}_{\Lambda}$Be hypernuclei

The calc. w/o the CSB potential is more consistent with the data.
The origin of CSB is more complex?

ΛN-ΣN coupling effect

A. Gal and D. Gazda, J. Phys.: Conf. Ser. 966 012006 (2018)



Charge symmetric ΛN-ΣN

±1

$$\langle N\Lambda|V_{\mathrm{CSB}}|N\Lambda\rangle = \boxed{-0.0297}\,\tau_{Nz}\,\frac{1}{\sqrt{3}}\,\boxed{\langle N\Sigma|V_{\mathrm{CS}}|N\Lambda\rangle}$$

ΛΣ mixing matrix element

A = 4 CS average	LO	LO [22]	NLO [22]	Exp. (Fig. 1)
$B_\Lambda^{J=0}$	$2.37^{+0.20}_{-0.13}$	2.5 ± 0.1	$1.53^{+0.08}_{-0.06}$	2.27 ± 0.09
$B_\Lambda^{J=1}$	$1.08^{+0.58}_{-0.47}$	$1.4^{+0.5}_{-0.4}$	$0.83^{+0.07}_{-0.10}$	1.03 ± 0.09
$E_x(0^+_{\mathrm{g.s.}}\rightarrow1^+_{\mathrm{exc}})$	1.29 ± 0.38	1.05 ± 0.25	0.71 ± 0.04	1.25 ± 0.02

w/o CSB

Mirror hypernuclear data for p-shell systems

Energies in keV

Isomultiplet	${}^{4}_{\Lambda}\mathrm{He}-{}^{4}_{\Lambda}\mathrm{H}$	${}^{7}_{\Lambda}\mathrm{Be}-{}^{7}_{\Lambda}\mathrm{Li}^{*}$	${}^{7}_{\Lambda}\mathrm{Li}^{*}-{}^{7}_{\Lambda}\mathrm{He}$	${}^{8}_{\Lambda}\mathrm{Be}-{}^{8}_{\Lambda}\mathrm{Li}$	${}^{9}_{\Lambda}\mathrm{B}-{}^{9}_{\Lambda}\mathrm{Li}$	${}^{10}_{\Lambda}\mathrm{B}-{}^{10}_{\Lambda}\mathrm{Be}^{*}$
Shell model (Gal *et al.*)	+226	−17	−28	+49	−54	−136
Cluster model (Hiyama *et al.*)		+150	+130			+20
No-core shell model (Le *et al.*)	+238	−35	−16	+143		
Experiment	$+233 \pm 92$	-100 ± 90	-20 ± 230	$+40 \pm 60$	-210 ± 220	-220 ± 250

A. Gal, and D. Gazda, Jour. Phys.: Conf. Ser. 966, 012006 (2018)
E. Hiyama et al., Prog. Theor. Phys. 128, 105 (2012).
H. Le et al., Phys. Rev. C 107, 24002 (2023)

大強度陽子加速器施設 J-PARC Japan Proton Accelerator Research Complex

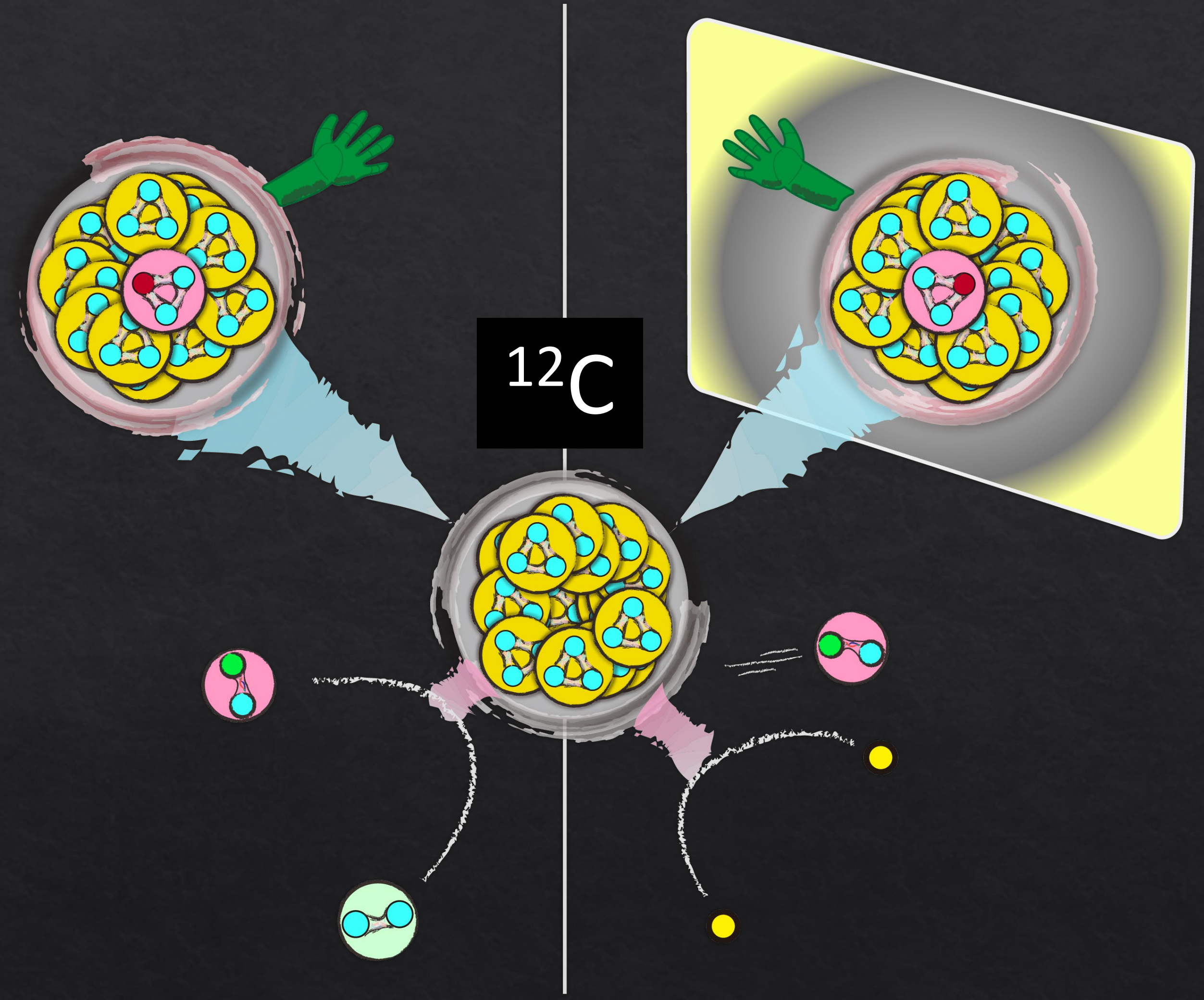
Jefferson Lab Thomas Jefferson National Accelerator Facility

Existing data accuracy is not sufficient for CSB study (ΔB_{diff} > 200 keV)

→ **ΔB_{diff}〜100 keV for A = 6, 7, 9, 10, 11, 12**

Mirror Hypernuclear Study

$^{12}_{\Lambda}\mathrm{C}$



$^{12}_{\Lambda}\mathrm{B}$

大強度陽子加速器施設 J-PARC Japan Proton Accelerator Research Complex

(π^+, K^+)

n→Λ

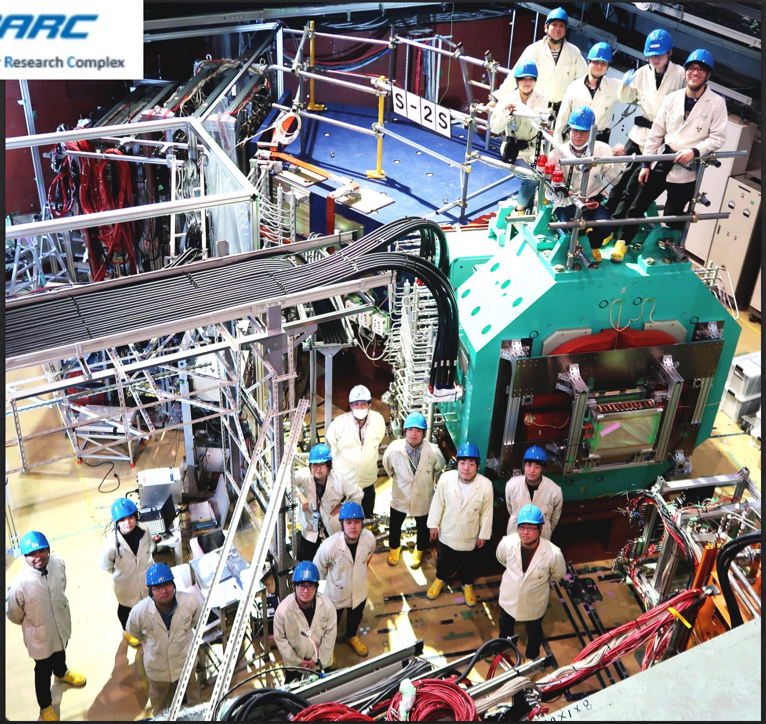
Jefferson Lab Thomas Jefferson National Accelerator Facility

$(e, e'K^+)$

p→Λ

Missing mass spectroscopy for Λ hypernuclei

TG et al., EPJ Web Conf. 271, 11002 (2022)



S-2S (2025～)

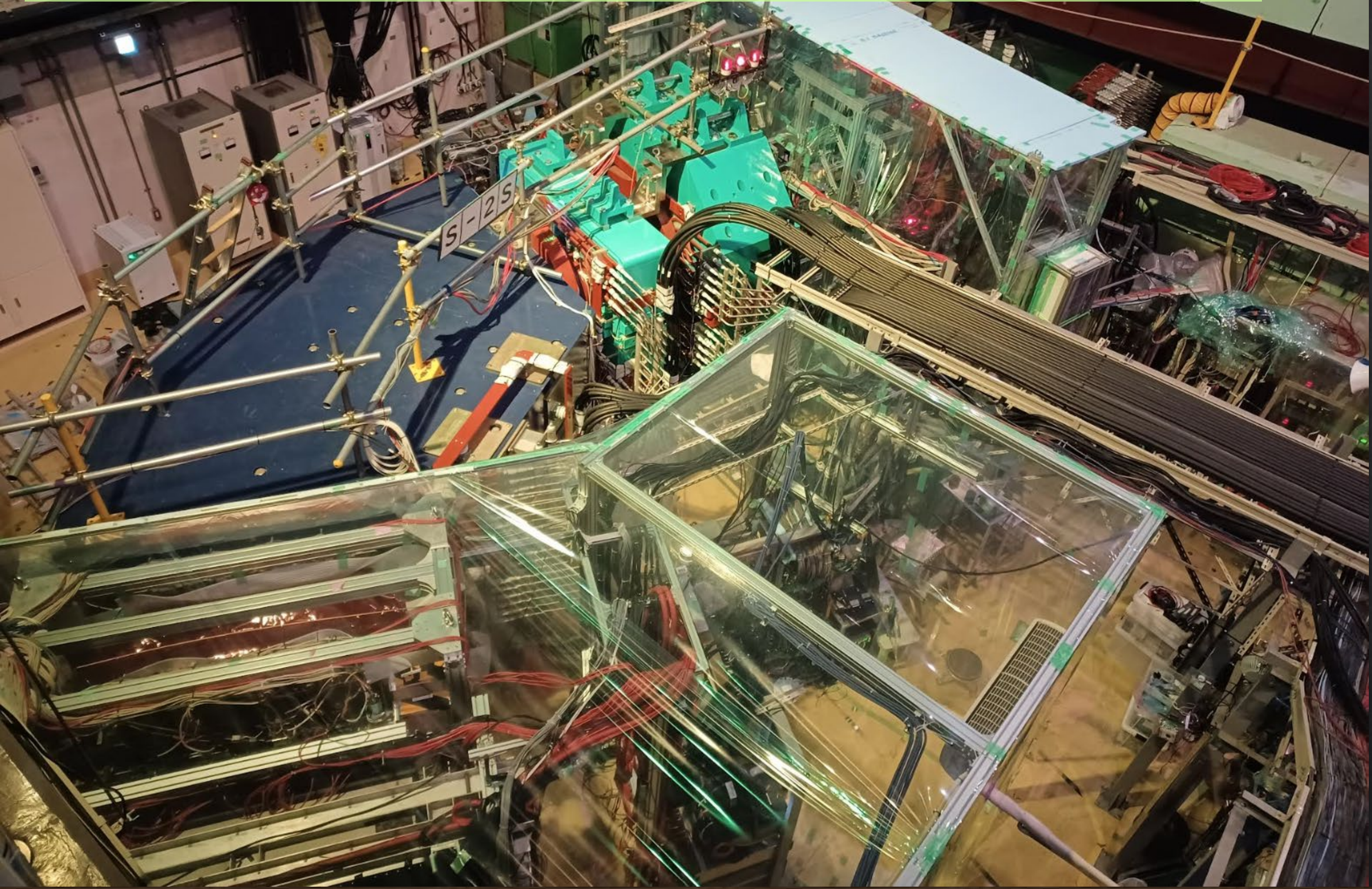
Λ: A = 7, 10, 12

Ξ: A = 12, 7

HES-HKS (2027～)

Λ: A = 6, 9, 11, 12, 27, 40, 48, 208

The first experiment with S-2S

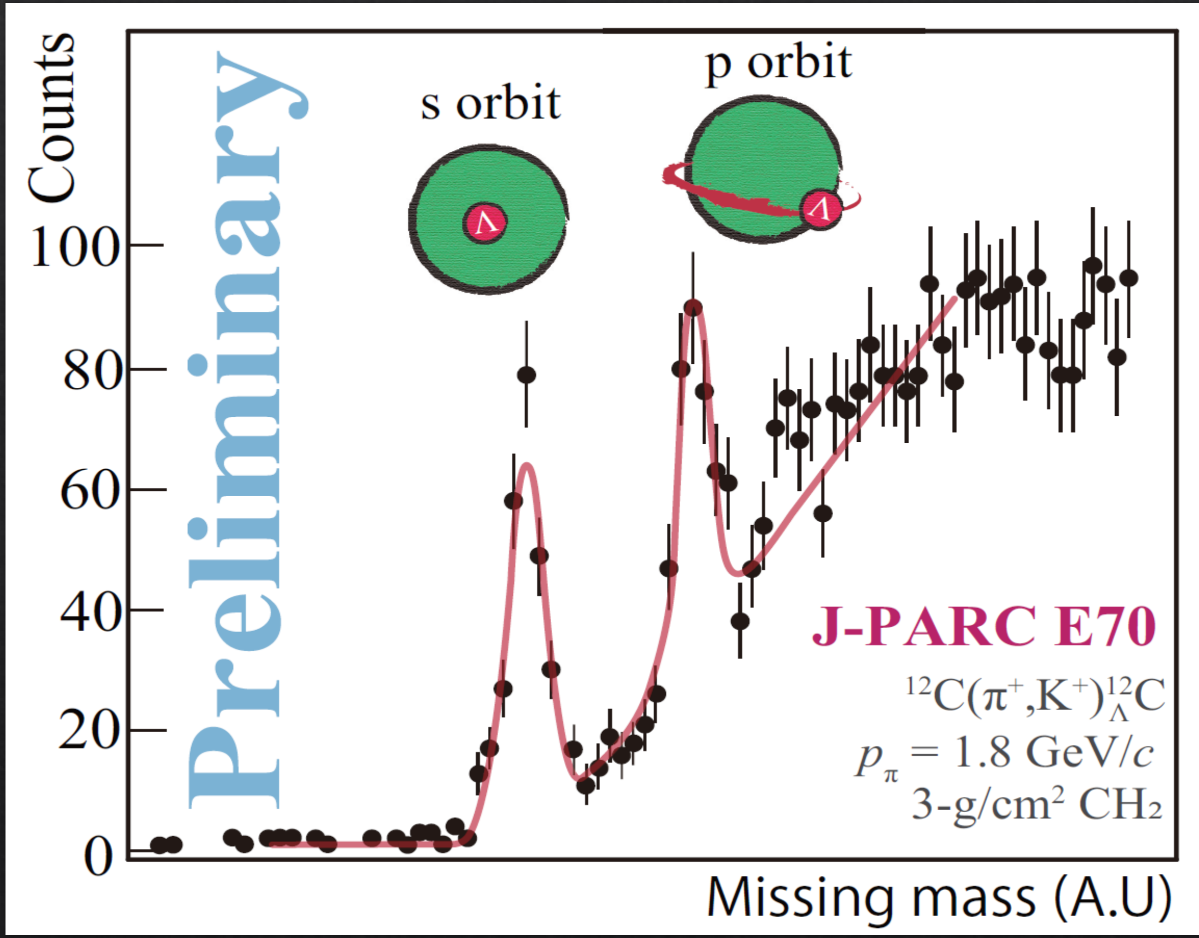


J-PARC E70 experiment
(Ξ hypernuclear spectroscopy)

2023.6 commissioning
2024.4—6 commissioning
2025.1—2 comm. + calib.
2025.4—5 Physics data

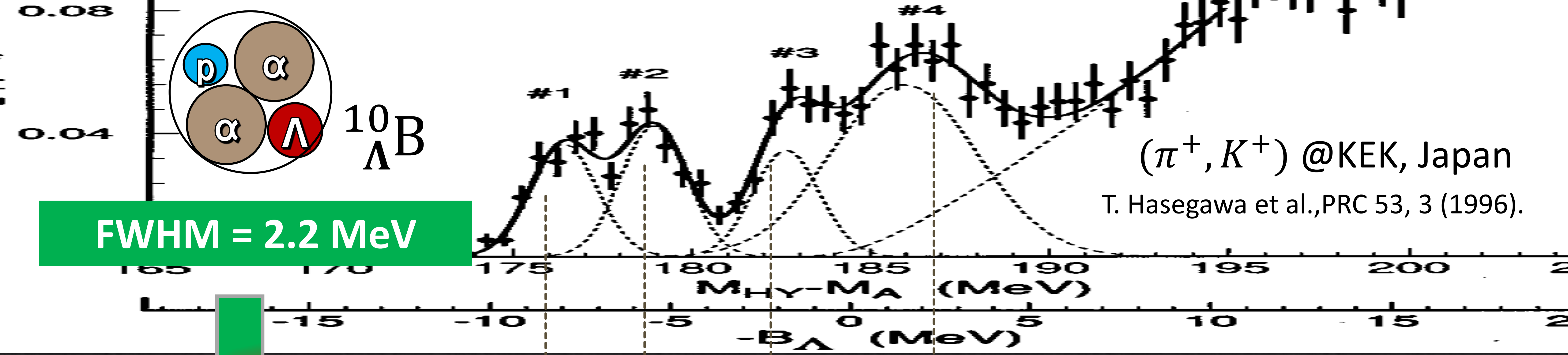
0.9M K^-/spill
(K:π = 3.3)

Preliminary (π^+,K^+) data



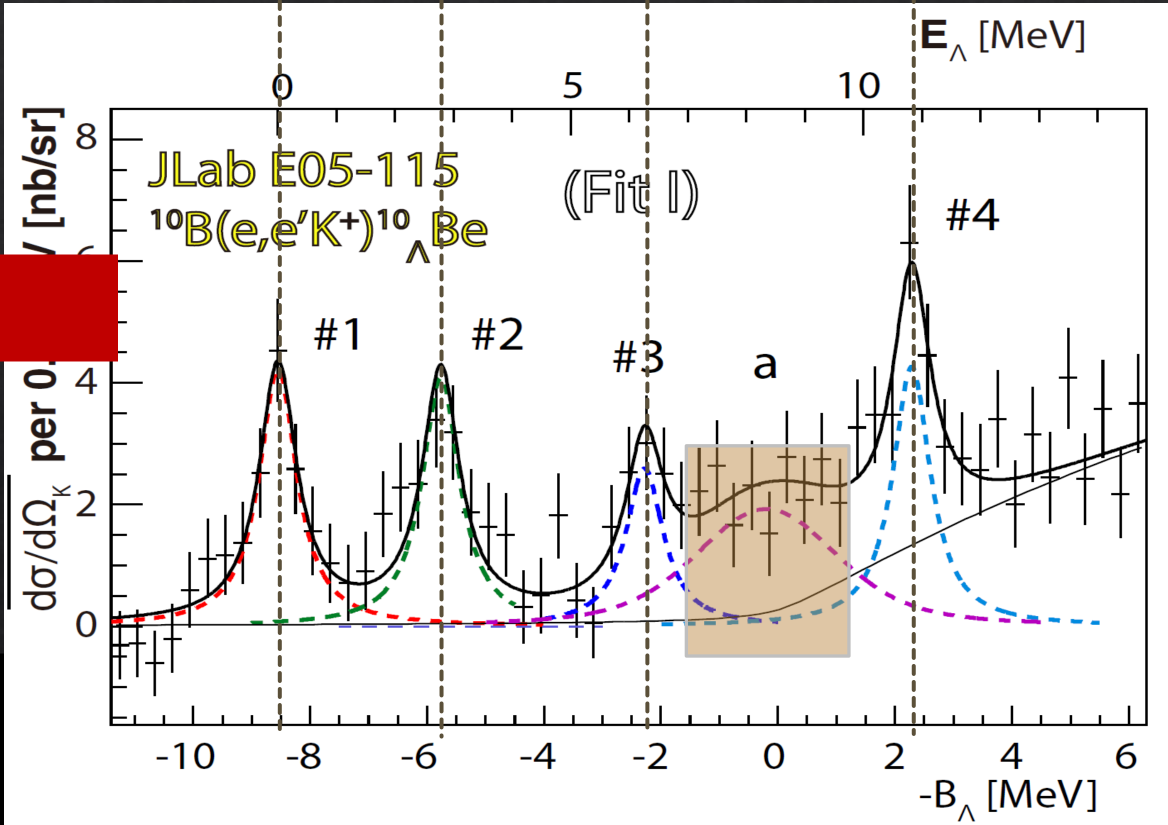
High resolution spectroscopy by π beam which is **complementary with JLab experiments** is promising

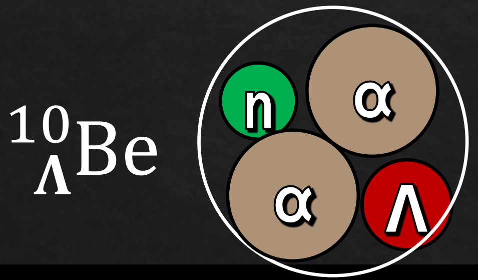
➔ Opened new era for studying CSB / isospin dependent interaction!



FWHM = 2.2 MeV

FWHM = 0.8 MeV





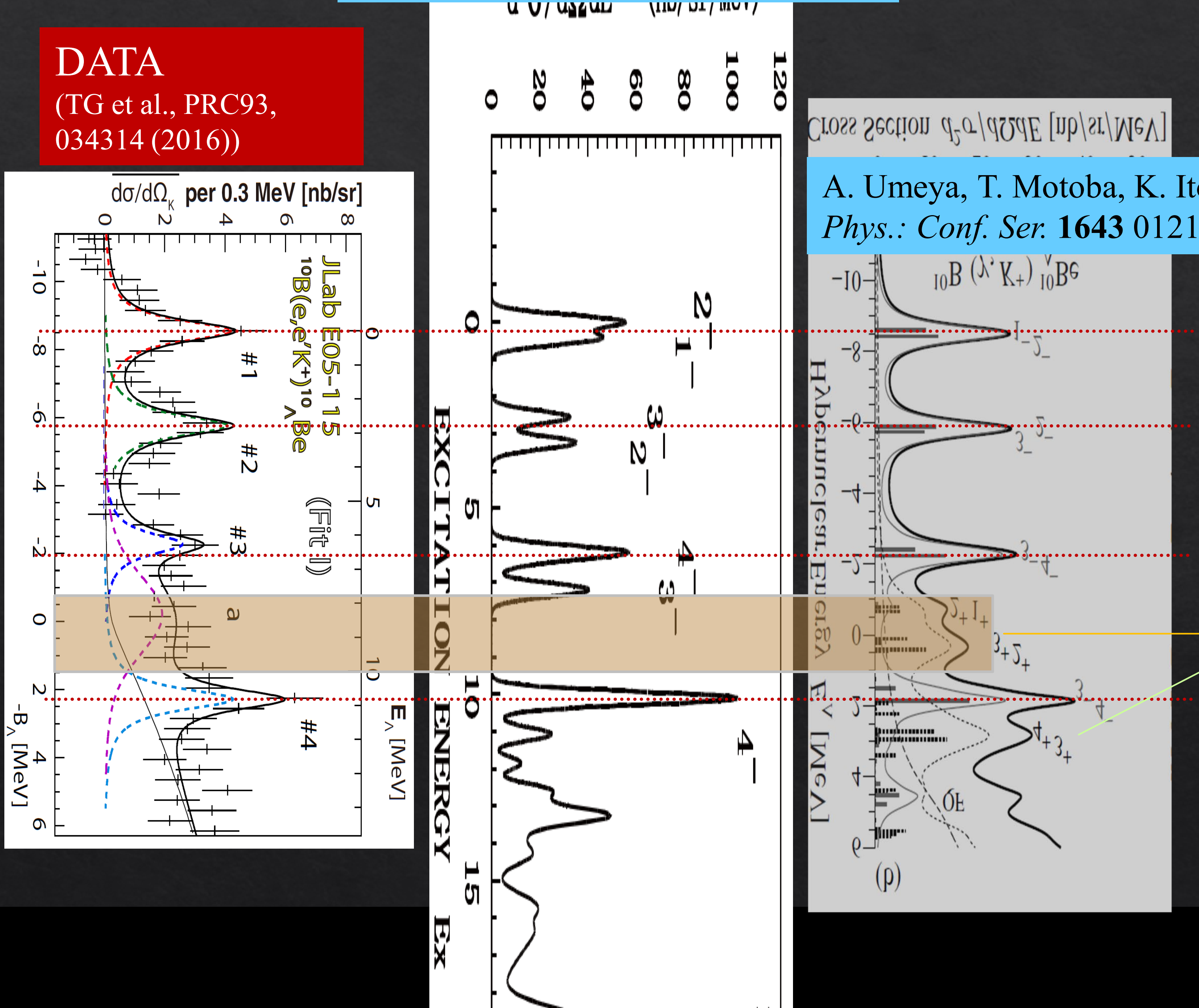
TG et al.,
PRC 93, 034314 (2016).

New finding from improved precision

DATA
(TG et al., PRC93, 034314 (2016))

T. Motoba, P. Bydzovsky, M. Sotona, K. Itonaga, PTP Suppl. 185 (2010)

A. Umeya, T. Motoba, K. Itonaga, *J. Phys.: Conf. Ser.* **1643** 012110 (2020)



$J_C^- \otimes s_\Lambda$

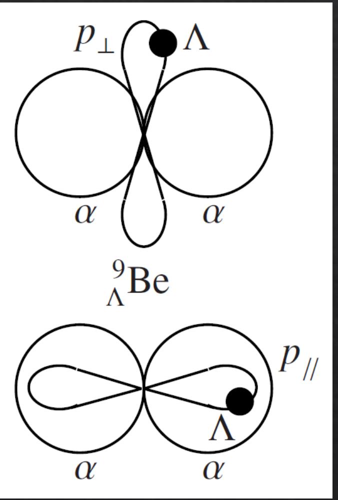
$J_C^- \otimes s_\Lambda$

$J_C^- \otimes s_\Lambda$

$J_C^- \otimes s_\Lambda$

$J_C^- \otimes p_\Lambda$

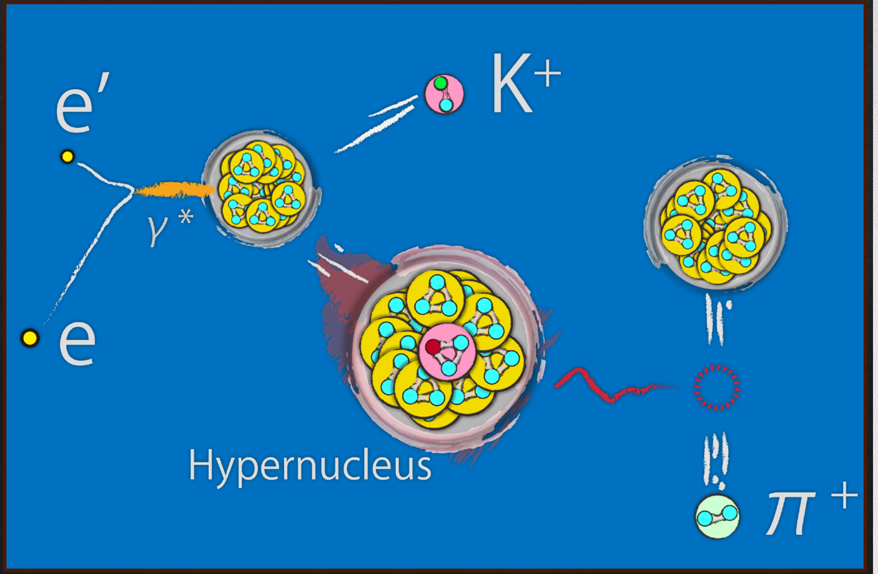
α - α structure splits p$_\Lambda$ state

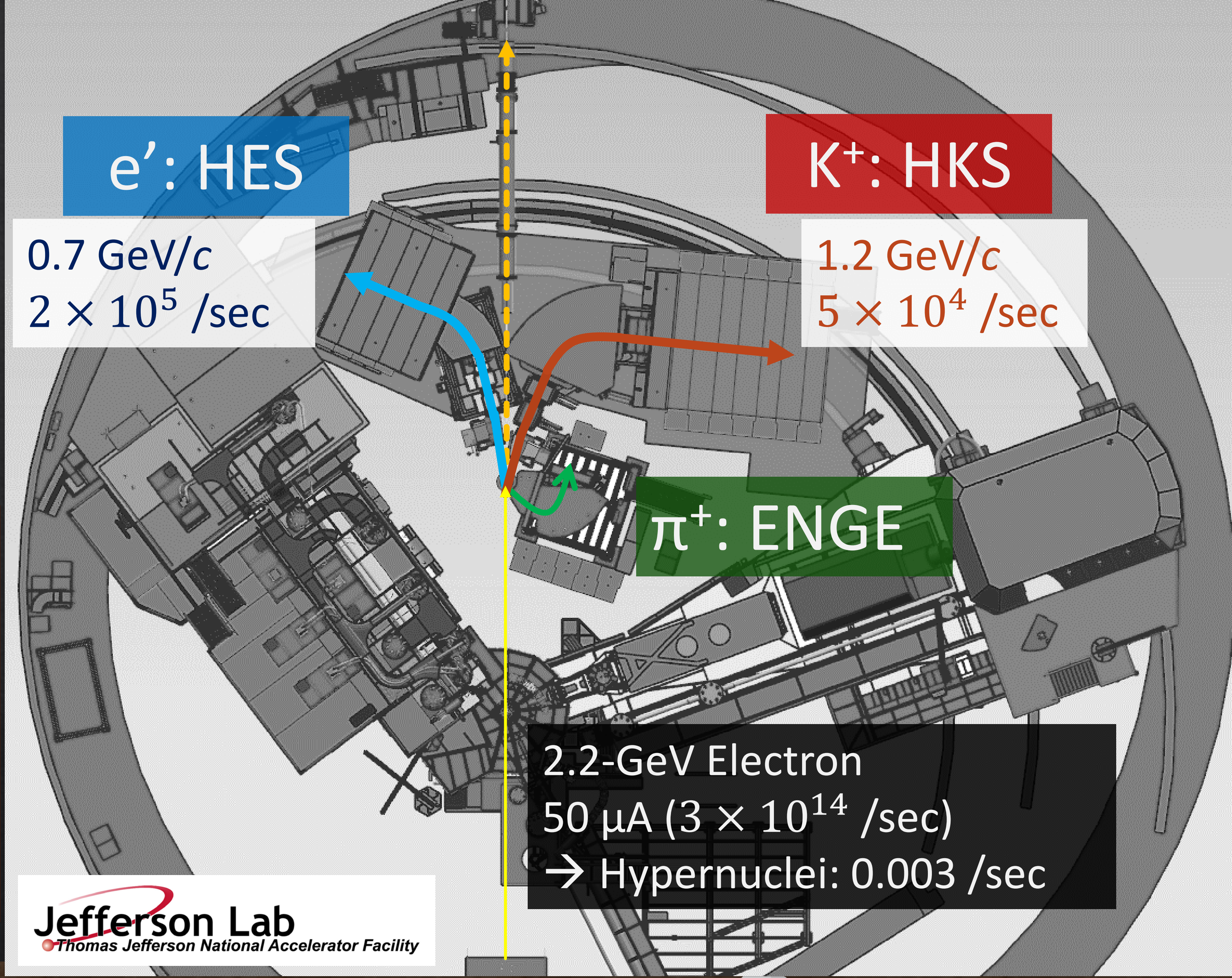


c.f.)
A. Umeya, T. Motoba, K. Itonaga, EPJ Web Conf. 271, 01010 (2022)

New experiment at JLab Hall-C (2027～)

- High resolution: 0.6 MeV FWHM
- High accuracy: 0.07 MeV
- Wide mass number: A = 6—208





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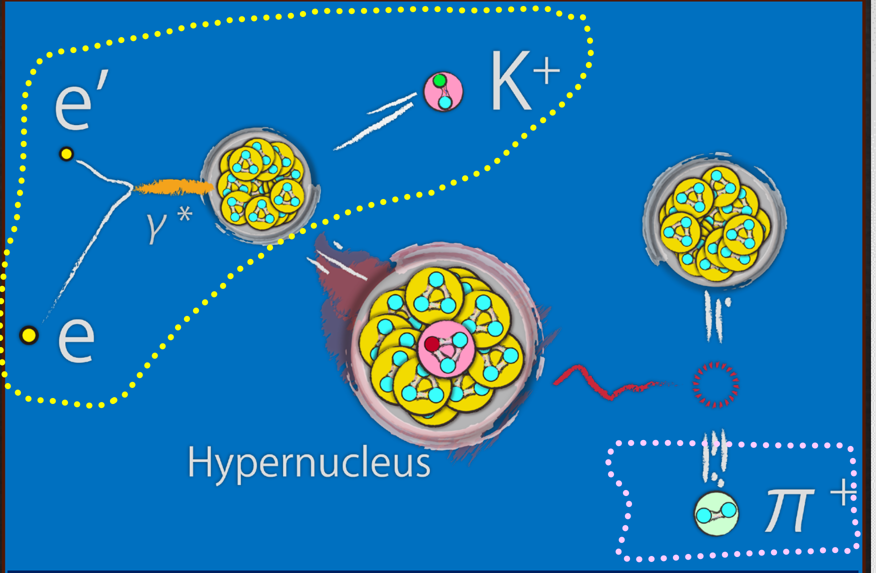
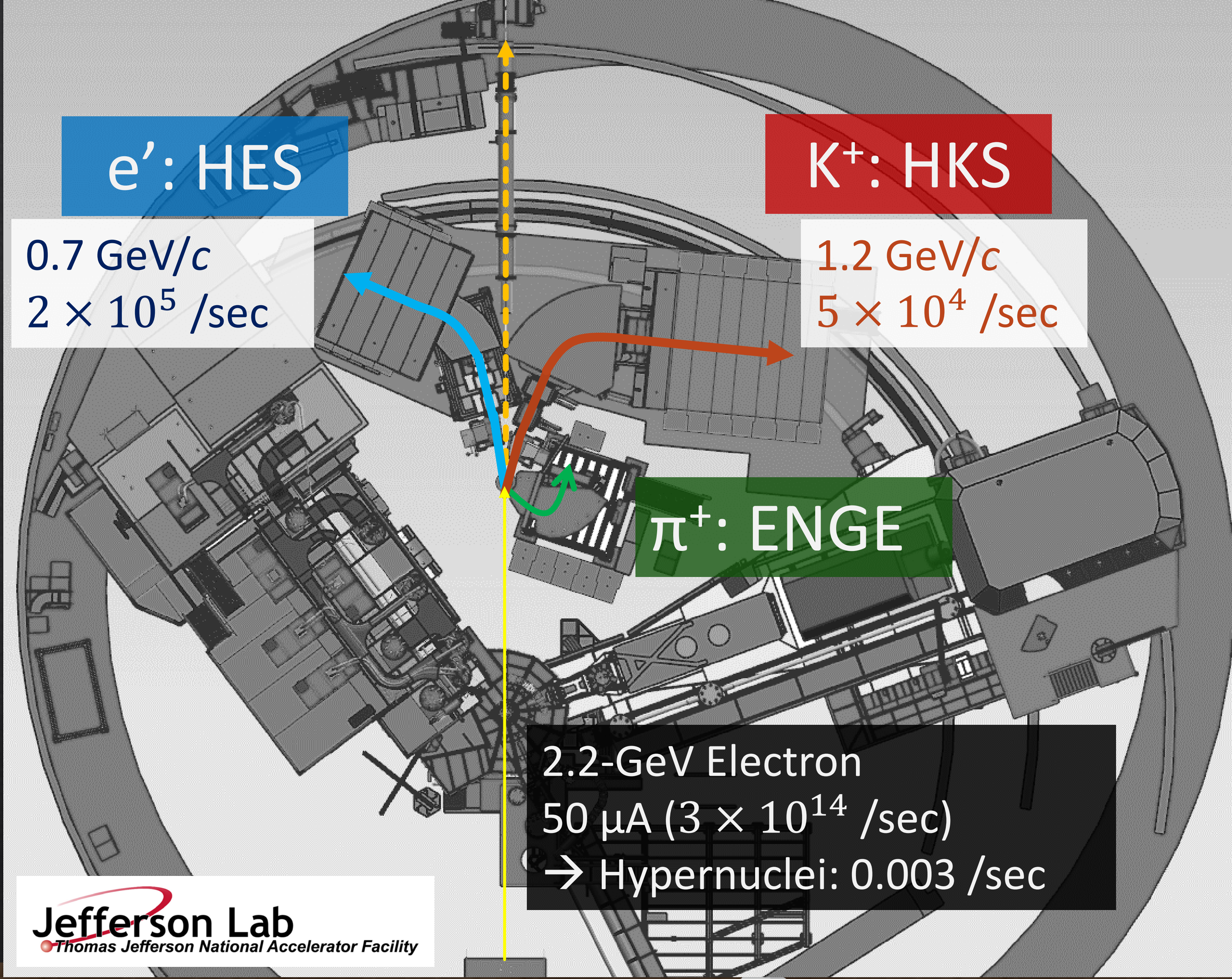
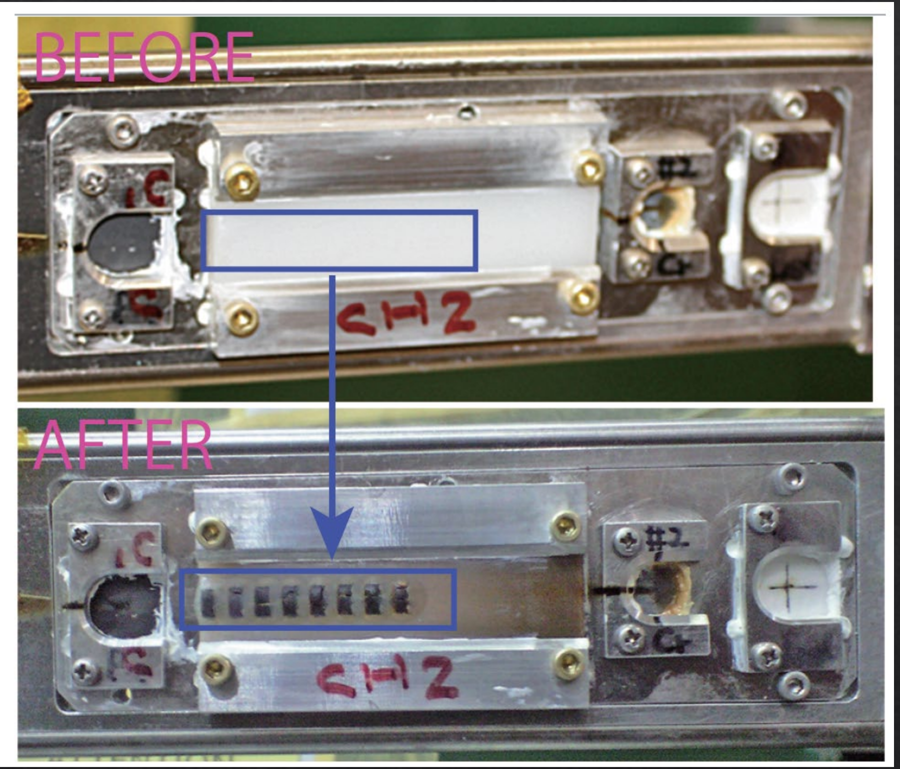


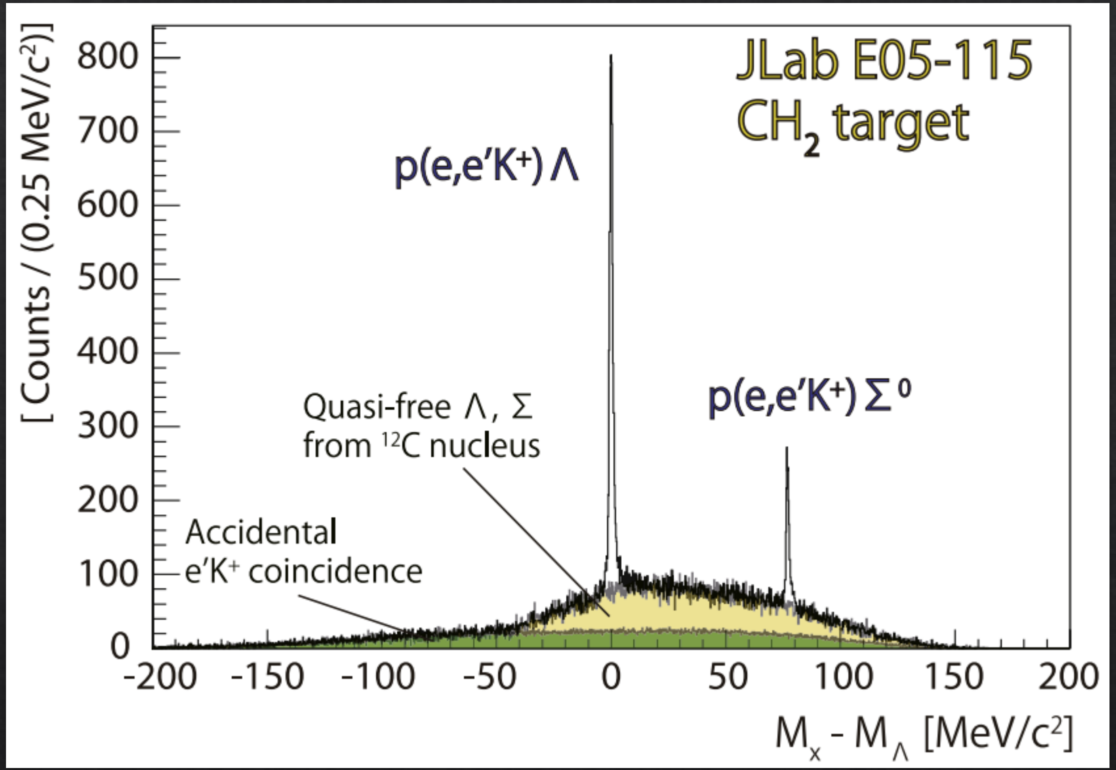
Missing mass + Decay pion spectroscopy



Energy Calibration (example from JLab E05-115)



TG et al., NIMA 900, 69—83 (2018)



➔ High accuracy spectroscopy is passible

Approved Hypernuclear Experiments (proposed by JLab Hypernuclear Collaboration)

① E12-15-008 → ${}^{40}_{\Lambda}$K、${}^{48}_{\Lambda}$K
"Isospin dependence of ΛN interaction"

② E12-19-002 → ${}^{3}_{\Lambda}$H、${}^{4}_{\Lambda}$H
"Hypertriton puzzle, s-shell CSB"

③ E12-20-013 → ${}^{208}_{\Lambda}$Tl
"ΛNN three body force"

④ E12-24-004 → ${}^{6}_{\Lambda}$He、${}^{9}_{\Lambda}$Li、${}^{11}_{\Lambda}$Be
"p-shell CSB"

⑤ E12-24-011 → ${}^{27}_{\Lambda}$Mg
" Search for triaxially deformation states in ^{26}Mg"

⑥ Run group experiment (E12-15-008A): Decay-pion spectroscopy

Approved Hypernuclear Experiments (proposed by JLab Hypernuclear Collaboration)

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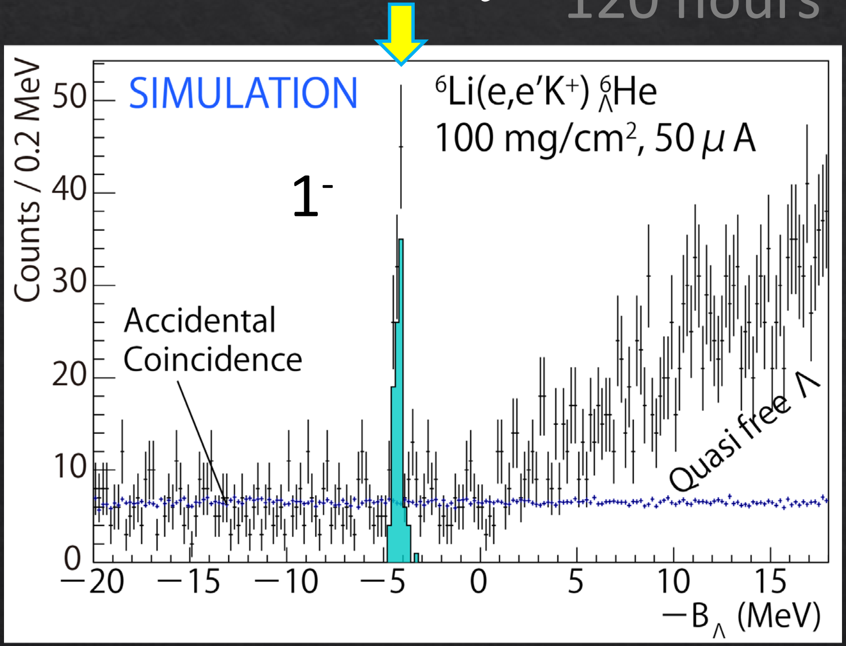
"p-shell CSB"

⑤ E12-24-011 → ${}^{27}_{\Lambda}\mathrm{Mg}$
" Search for triaxially deformation states in ${}^{26}\mathrm{Mg}$"

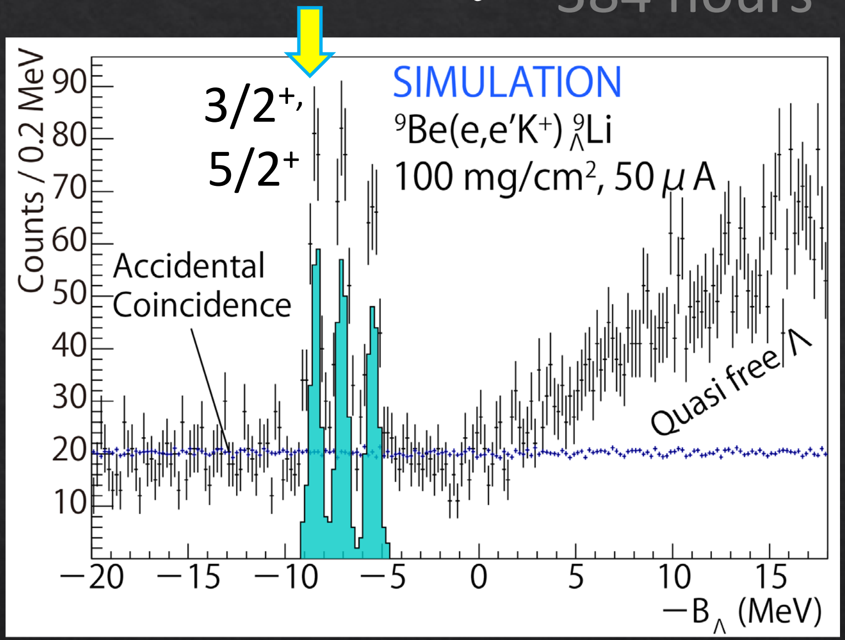
Will be performed from 2027~

Expected Spectra (JLab E12-24-004)

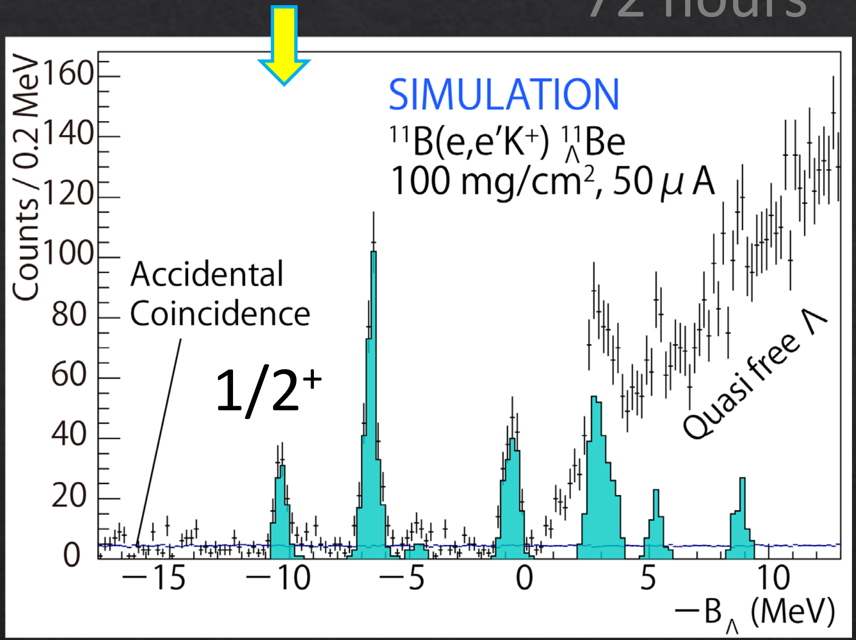
for CSB study 120 hours



for CSB study 384 hours



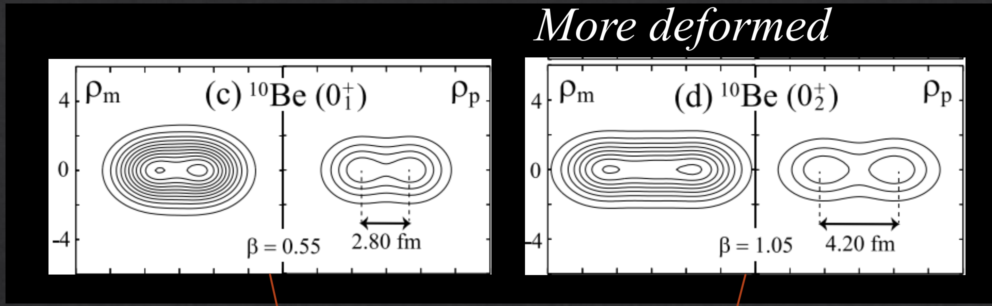
for CSB study 72 hours



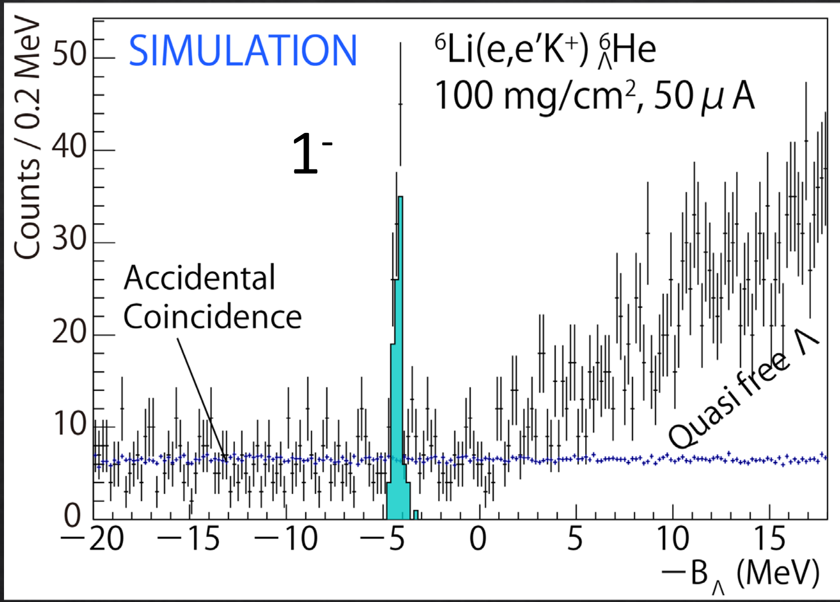
Total accuracy:

$$\left|\Delta B_{\Lambda}^{\text{total}}\right| = \sqrt{\left(\Delta B_{\Lambda}^{\text{stat.}}\right)^2 + \left(\Delta B_{\Lambda}^{\text{sys.}}\right)^2} \leq \textbf{70 keV}$$

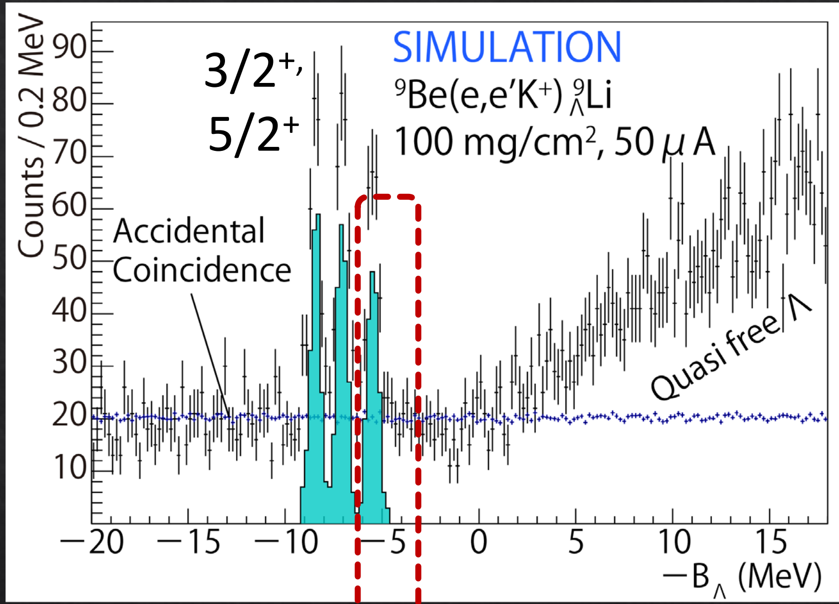
Expected Spectra



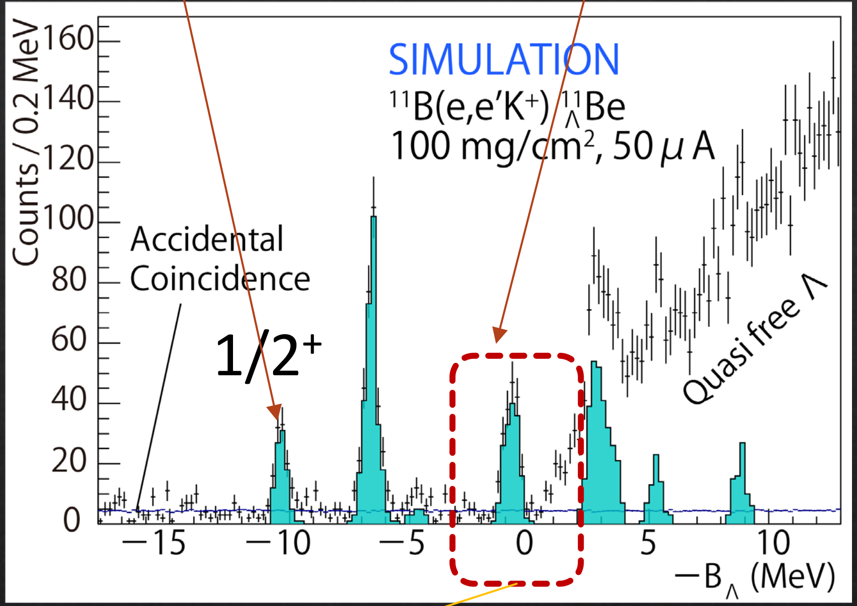
120 hours



384 hours



72 hours



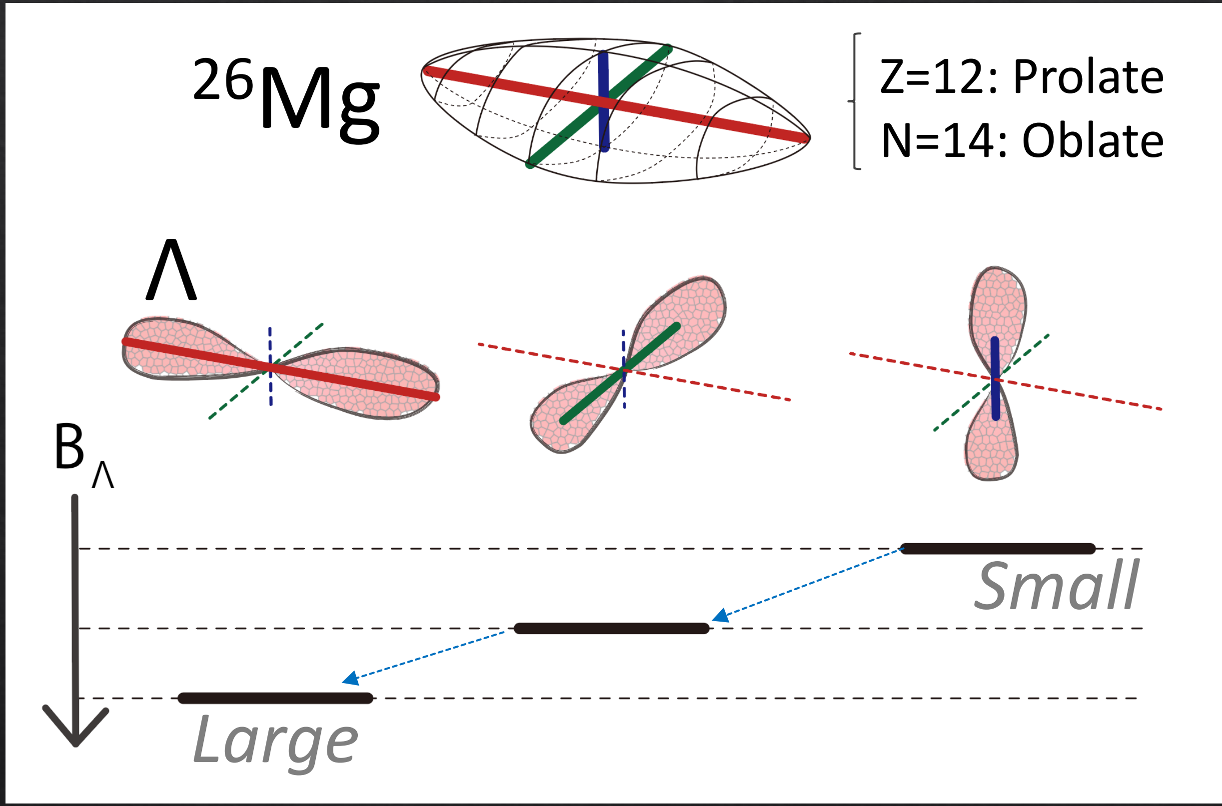
Total accuracy:
$\left|\Delta B_\Lambda^{\mathrm{total}}\right| \leq$ **70 keV**

c.f.) TG et al., PRC 103, L041301 (2021)

Cluster / deformation structures

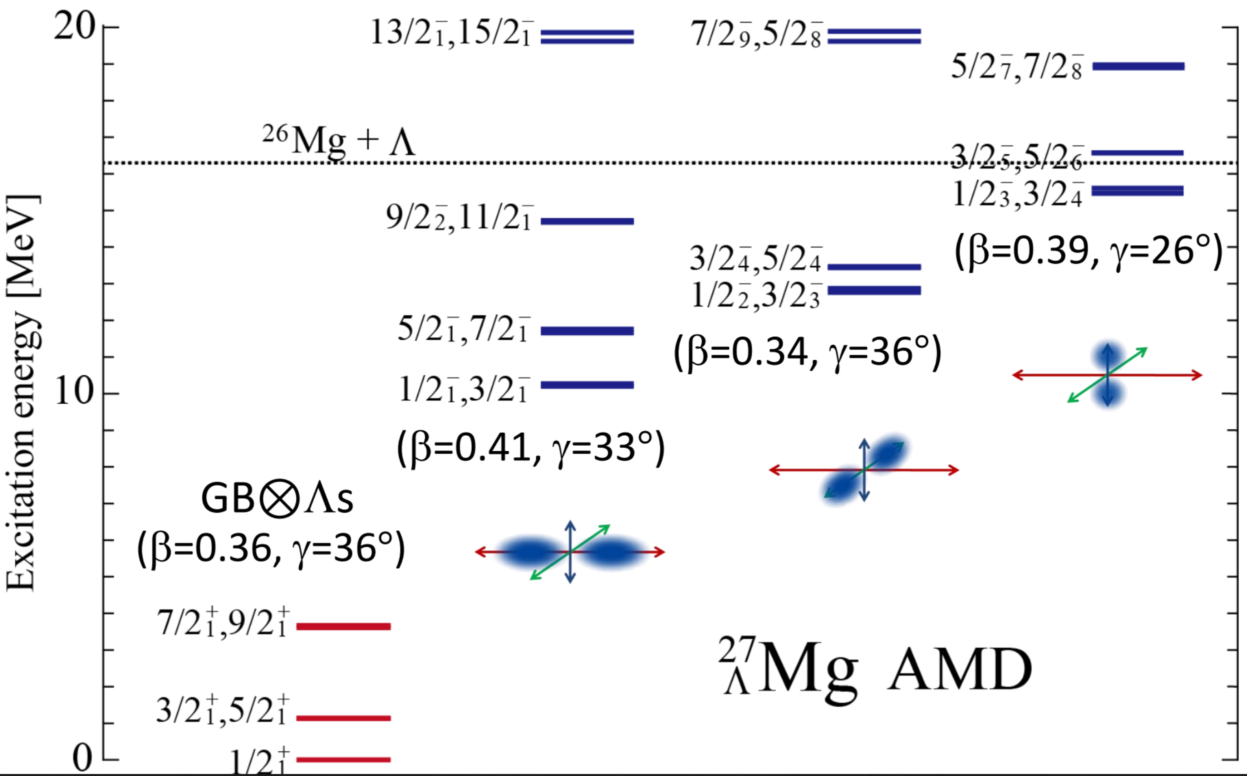
M. Isaka et al., PRC 92, 044326 (2015)

$^{27}\mathrm{Al}(e,e'K^+)^{27}_{\Lambda}\mathrm{Mg}$ (JLab E12-24-011)



Anti-molecular dynamics (AMD) calculation

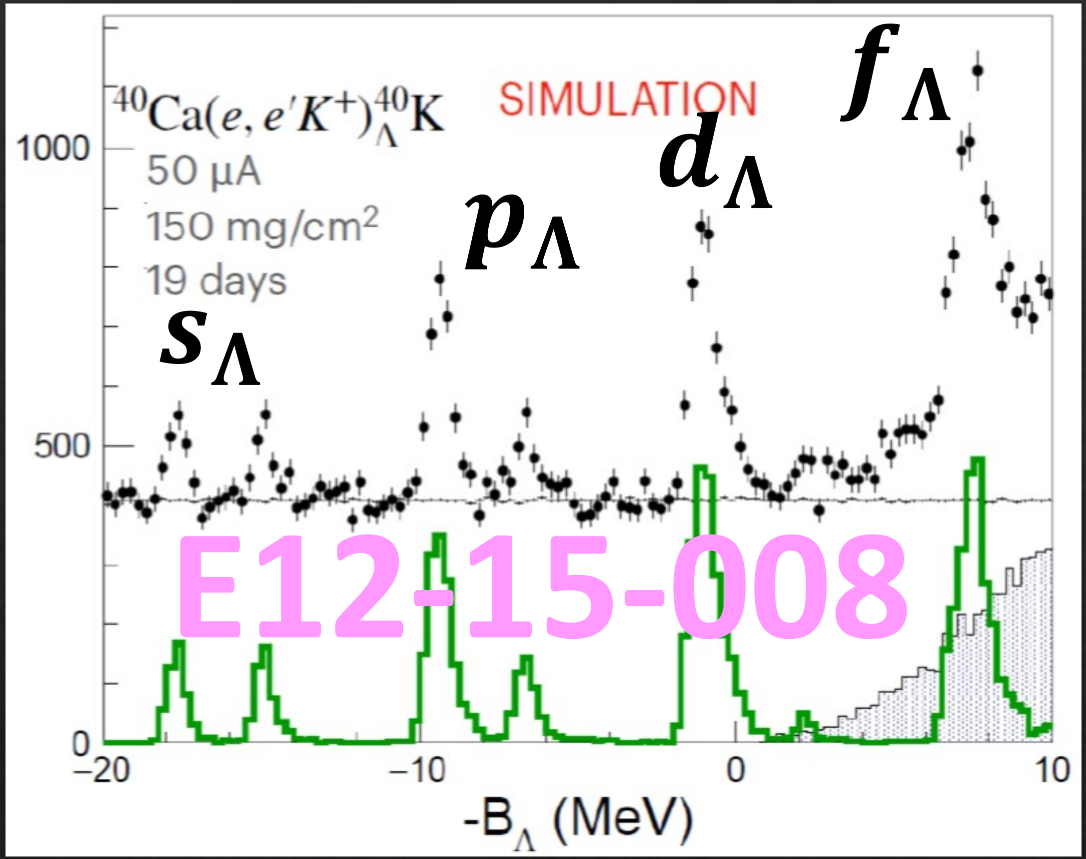
Presentation by M. Isaka (2023); https://indico.jlab.org/event/705/



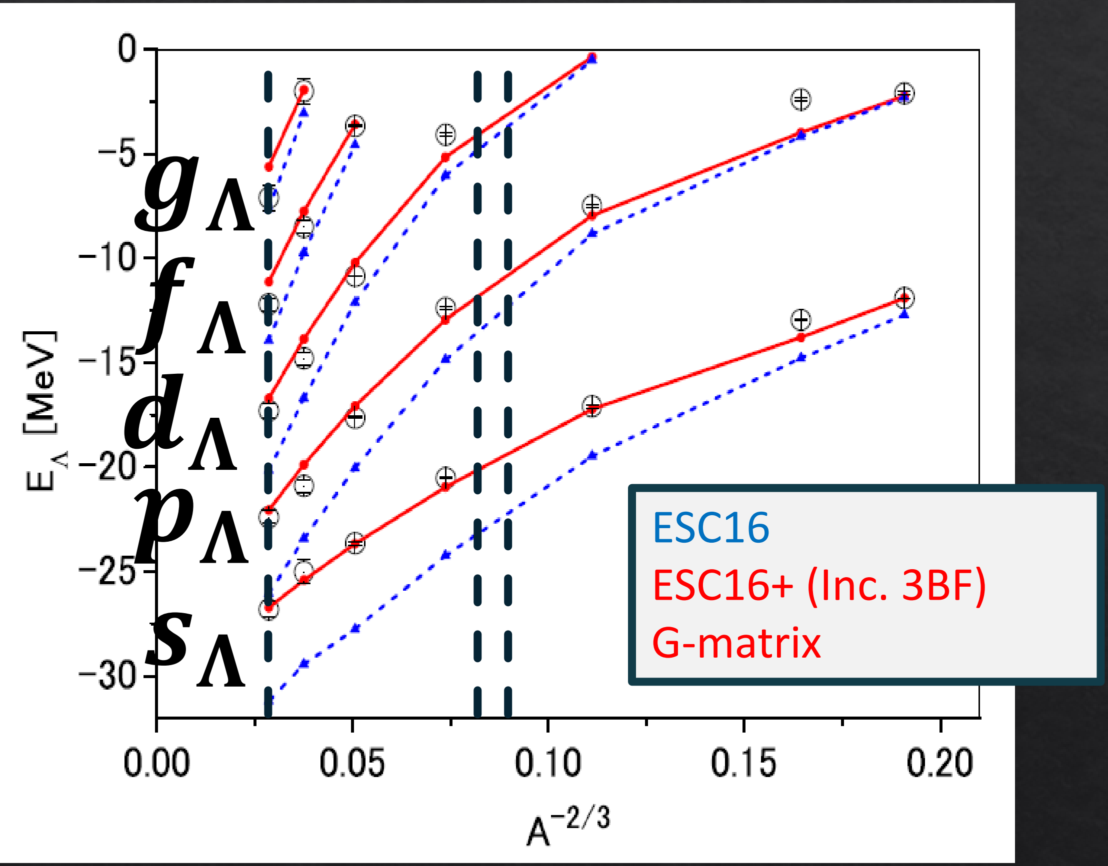
$^{26}\mathrm{Mg} \times p_{\Lambda}$ ➔ Probing triaxially deformation

High accuracy experiment → 3-body force study

Expected spectrum based on Geant4 simulation



M.M. Nagels et al., PRC 99 (2019) 044003.



Missing mass spectroscopy with the world best accuracy $|\Delta B_\Lambda| \leq 100$ keV

New information for 3-body force

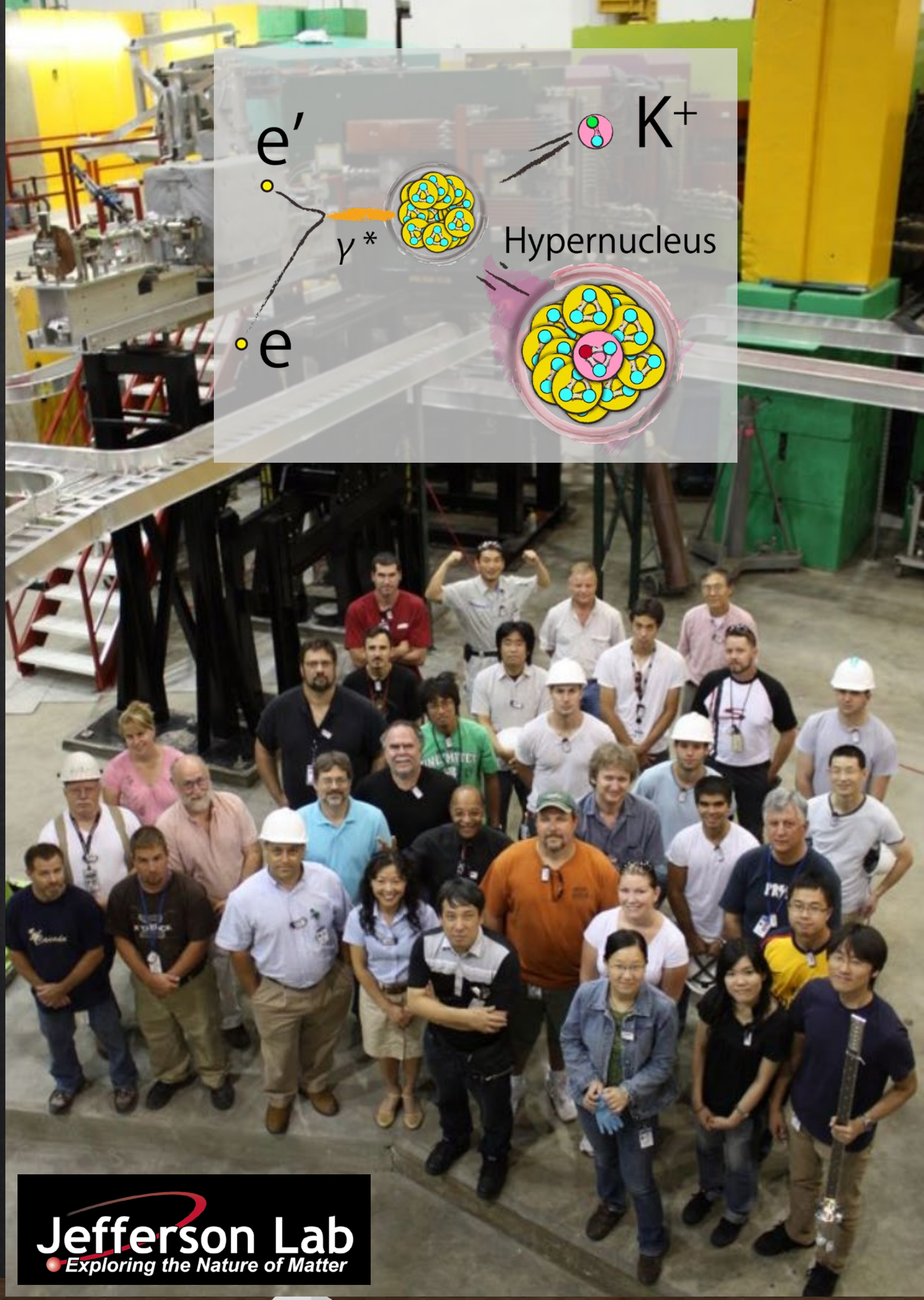
Summary

Λ hypernuclear spectroscopy

- Baryon interaction (YN, YNN)

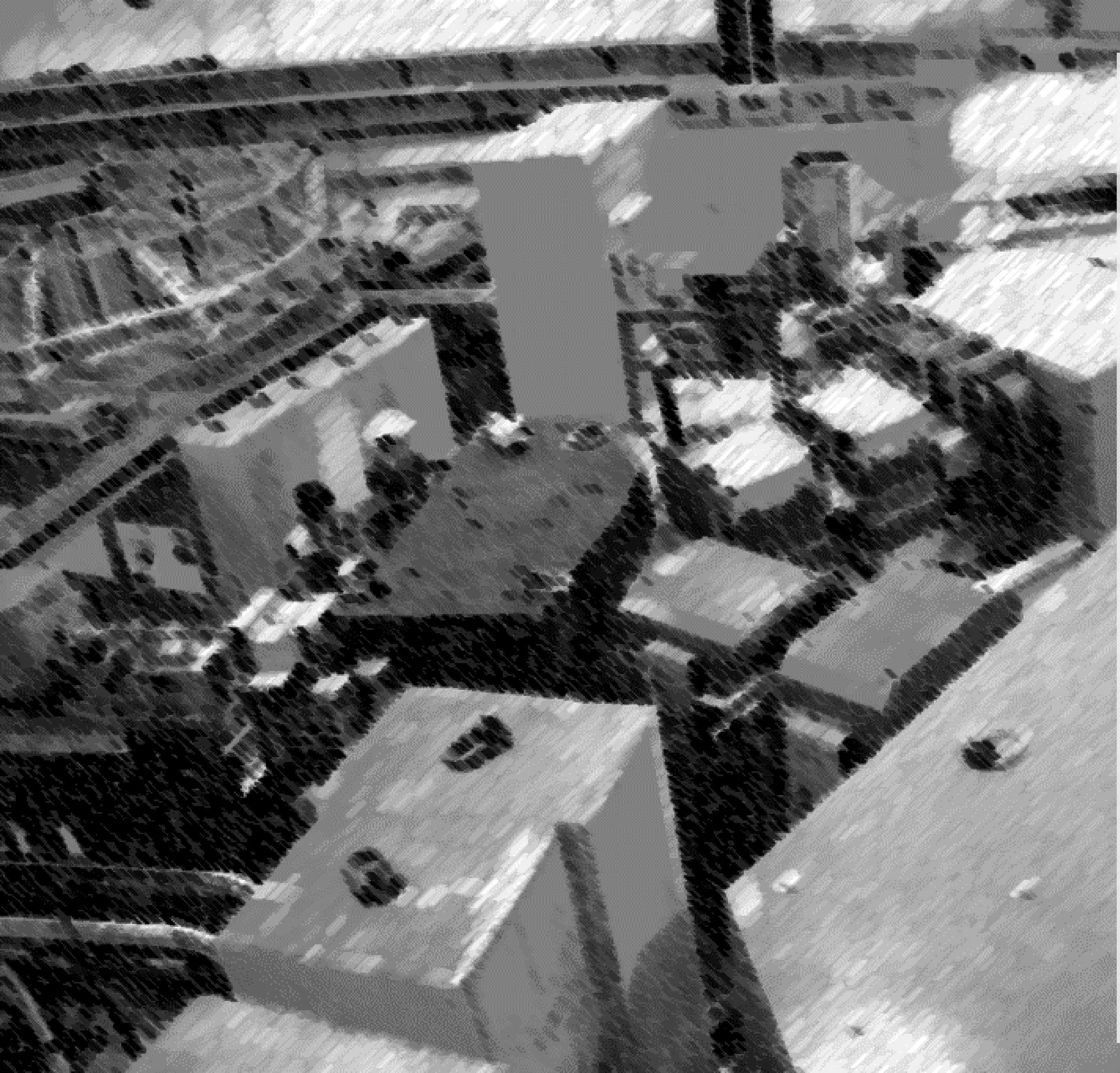
JLab Hypernuclear Collaboration

- (e,e' K^{+}) reaction → High resolution/accuracy spectroscopy
- The method was established at JLab
- Future experiment (${}^{3}_{\Lambda}\mathrm{H}$, ${}^{4}_{\Lambda}\mathrm{H}$, ${}^{6}_{\Lambda}\mathrm{He}$, ${}^{11}_{\Lambda}\mathrm{Be}$, ${}^{27}_{\Lambda}\mathrm{Mg}$, ${}^{40}_{\Lambda}\mathrm{K}$, ${}^{48}_{\Lambda}\mathrm{K}$, ${}^{208}_{\Lambda}\mathrm{Tl}$)
  - hypertriton puzzle (biding energy vs. lifetime) **2027～**
  - Charge symmetry breaking
  - (Triaxially) deformation
  - ΛN−ΣN coupling
  - iso-spin dependence of ΛNN force



Thank you for your attention

JLab Hypernuclear Collaboration Meeting 2025 (May 2025, JLab)
https://indico.jlab.org/event/931/



Hall A

- K. Okuyama et al., PRC 110, 025203 (2024)
- B. Pandey et al., PRC 105, L051001 (2022)
- K.N. Suzuki et al., PTEP 2022, 1, 013D01 (2022)
- F. Garibaldi et al., PRC 99, 054309 (2019)
- G. M. Urciuoli et al., PRC 91, 034308 (2015)
- F. Cusanno et al., PRL 103, 202501 (2009)
- G. M. Urciuoli et al., NIMA612, 56—68 (2009)
- M. Iodice et al., PRL 99, 052501 (2007)

Hall C

- TG et al., PRC 103, L041301 (2021)
- TG et al., NIMA 900, 69—83 (2018)
- TG et al., PRC 94, 021302(R) (2016)
- TG et al., PRC 93, 034314 (2016)
- Y. Fujii et al., NIMA795, 351—363 (2015)
- L. Tang et al., PRC 90, 034320 (2014)
- S.N. Nakamura et al., PRL 110, 012502 (2013)
- TG et al., NIMA 729, 816—824 (2013)
- L. Yuan et al., PRC 73, 044607 (2006)
- T. Miyoshi et al., PRL 90, 232502 (2003)

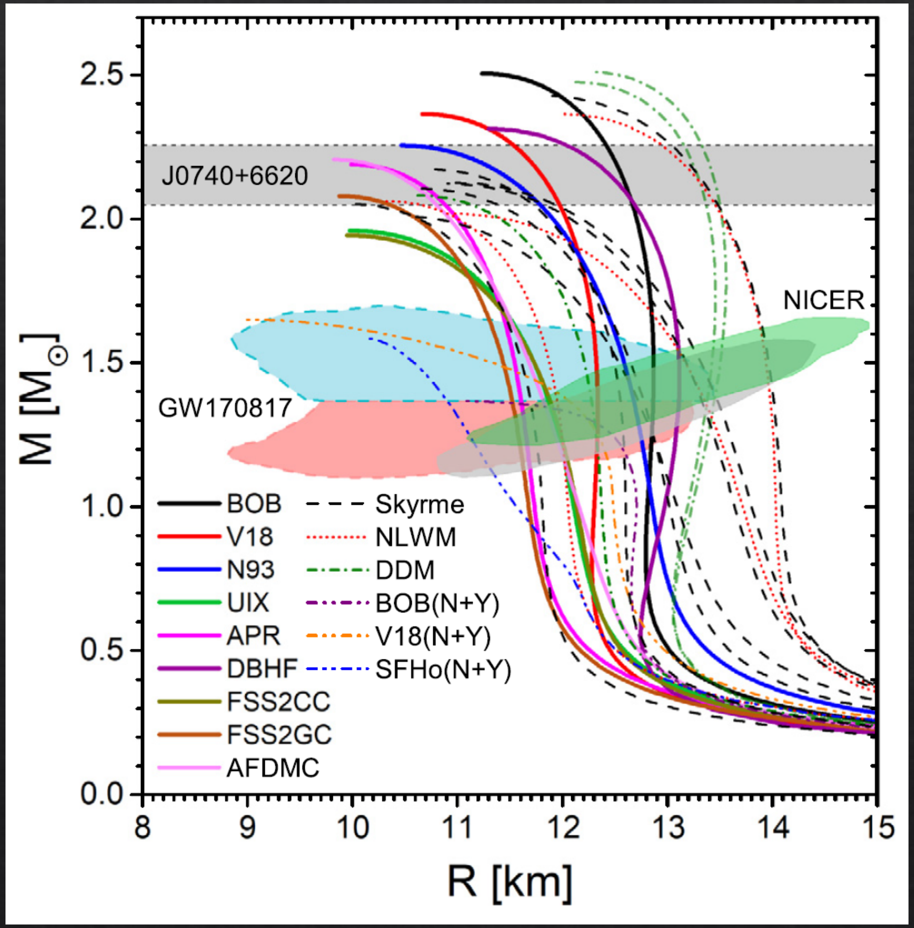
Experimental parameters for the next JLab Experiment (2027-)

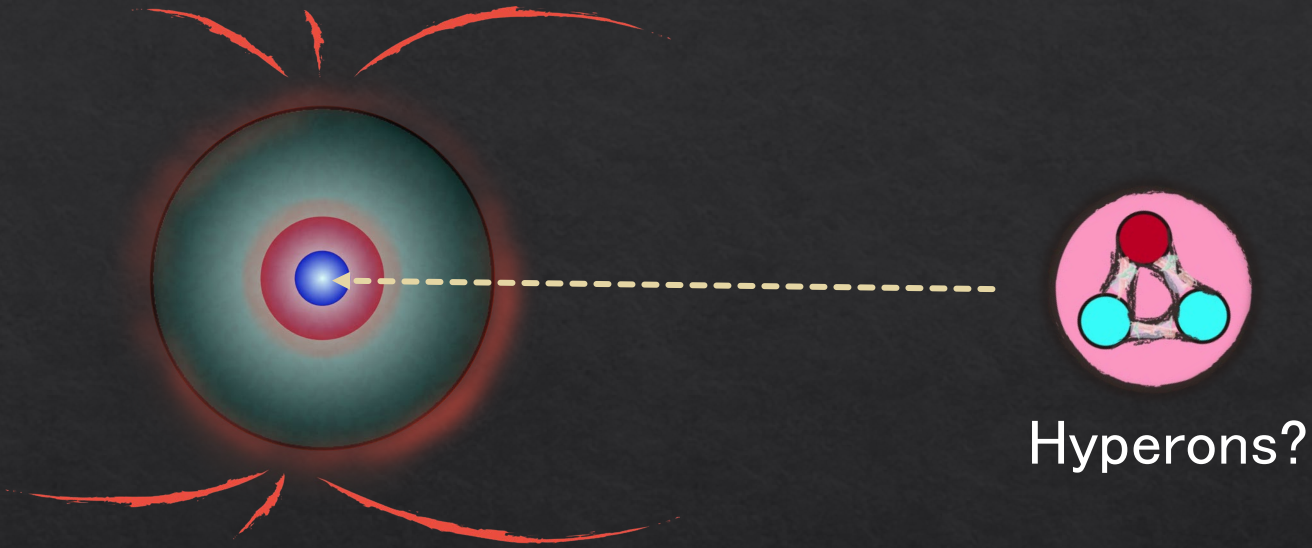
TABLE II. Summary of the kinematics parameters in the proposed experiment.

Item		Value
Beam (e)	Energy (/GeV)	2.24
	(Required) energy spread and drift	1×10^{-4} (FWHM)
PCS + HES (e')	Central momentum $p_{e'}^{\mathrm{cent.}}$ [/(GeV/c)]	0.74
	Central angle $\theta_{ee'}^{\mathrm{cent.}}$	8.5°
	Solid angle acceptance $\Omega_{e'}$ (/msr) (at $p_{e'}^{\mathrm{cent.}}$)	3.4
	Momentum resolution $\Delta p_{e'}/p_{e'}$	4.4×10^{-4} (FWHM)
PCS + HKS (K^+)	Central momentum $p_{K^+}^{\mathrm{cent.}}$ [/(GeV/c)]	1.20
	Central angle $\theta_{eK^+}^{\mathrm{cent.}}$	11.5°
	Solid angle acceptance Ω_{K^+} (/msr) (at $p_{K^+}^{\mathrm{cent.}}$)	7.0
	Momentum resolution $\Delta p_{K^+}/p_{K^+}$	2.9×10^{-4} (FWHM)
$p(e, e'K^+)\Lambda$	$\sqrt{s} = W$ (/GeV)	1.912
	Q^2 [/(GeV/c)^2]	0.036
	K^+ scattering angle wrt virtual photon, $\theta_{\gamma^* K^+}$	7.35°
	ϵ	0.59
	ϵ_L	0.0096

New constrains from astronomical observations

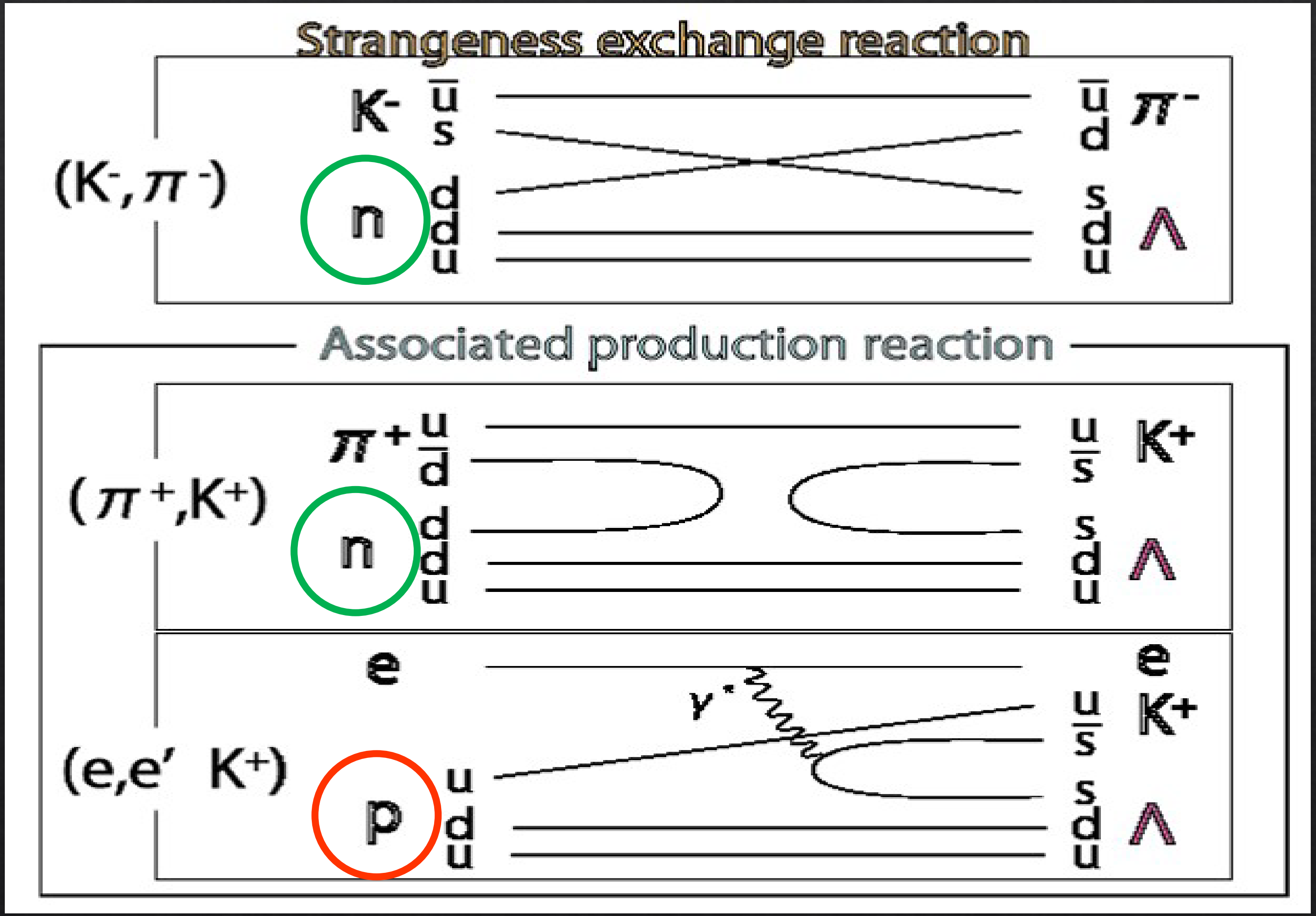
C.F. Burgio et al. Prog. Part. Nucl. Phys 120 (2021) 103879.





Microscopic study (← nuclear/hypernuclear research) has become more important as the macroscopic study is in great progress

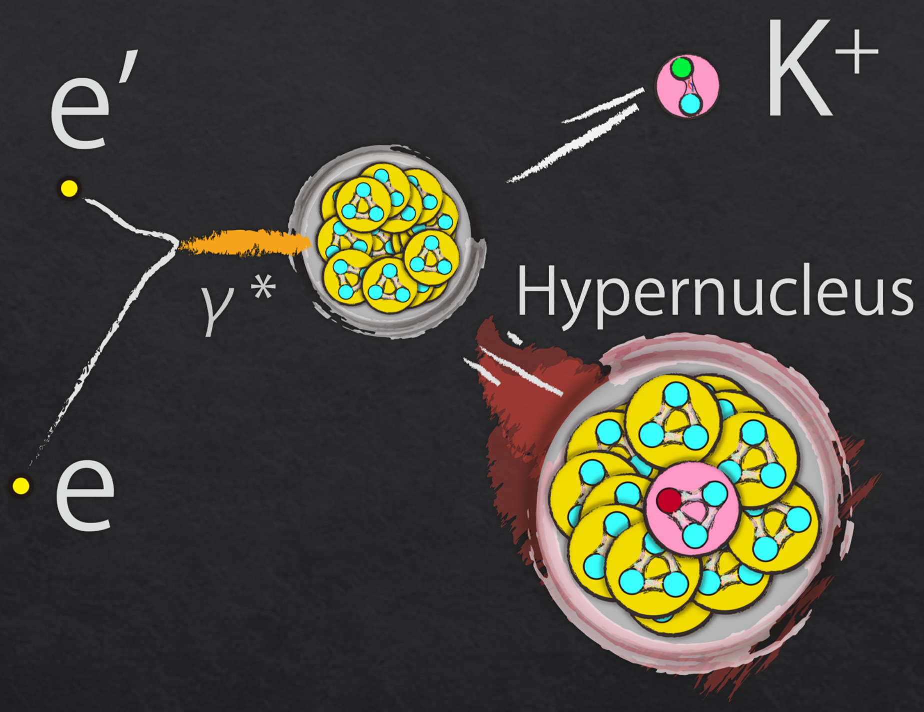
Reactions used at J-PARC and JLab



Hadron Beams
@J-PARC, Japan

Electron Beams
@JLab, US

Missing-mass spectroscopy at JLab



$$M_H = \sqrt{(E_e + M_T - E_{e'} - E_K)^2 - \left(\vec{P_e} - \vec{P_{e'}} - \vec{P_K}\right)^2}$$

To be measured

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

Electro-production

- Better understanding of reaction GOOD
- Small cross section Bad
- Larger noise as Z gets larger Bad

Primary beam

- High precision / small emittance GOOD
- High intensity → thin target GOOD
  (→ High energy resolution)

Virtual photo production

→ Large spin flip amplitude GOOD Bad

p → Λ

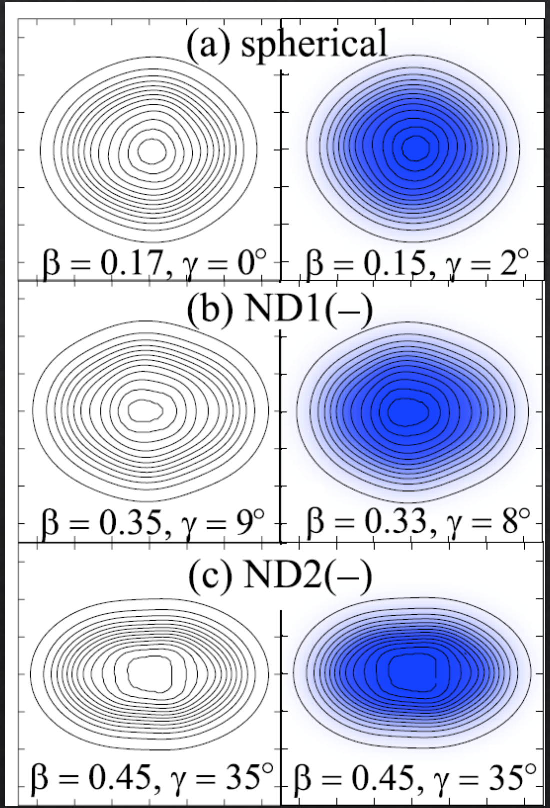
GOOD

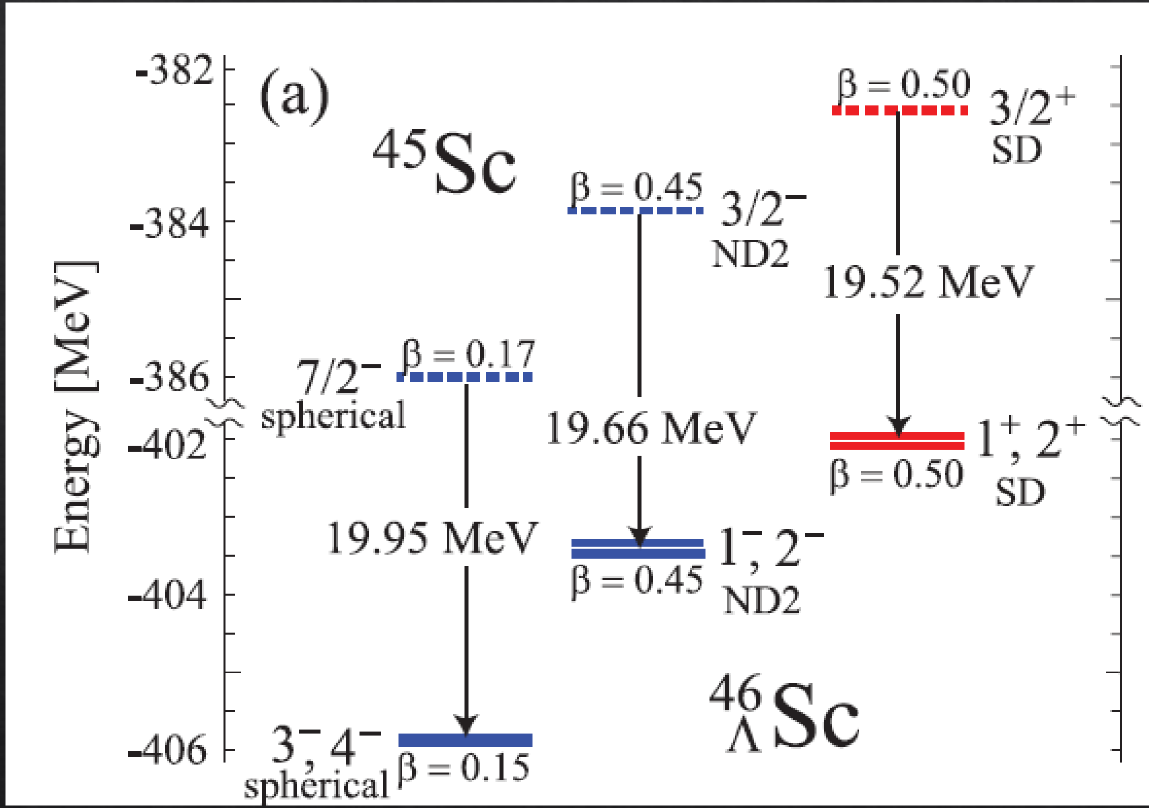
→ Good calibration with proton target

→ Mirror Hypernuclear study GOOD

$^{46}\mathrm{Ti}(e,e'K^+)^{46}_{\Lambda}\mathrm{Sc}$

M. Isaka et al., PRC **89**, 024310 (2014)

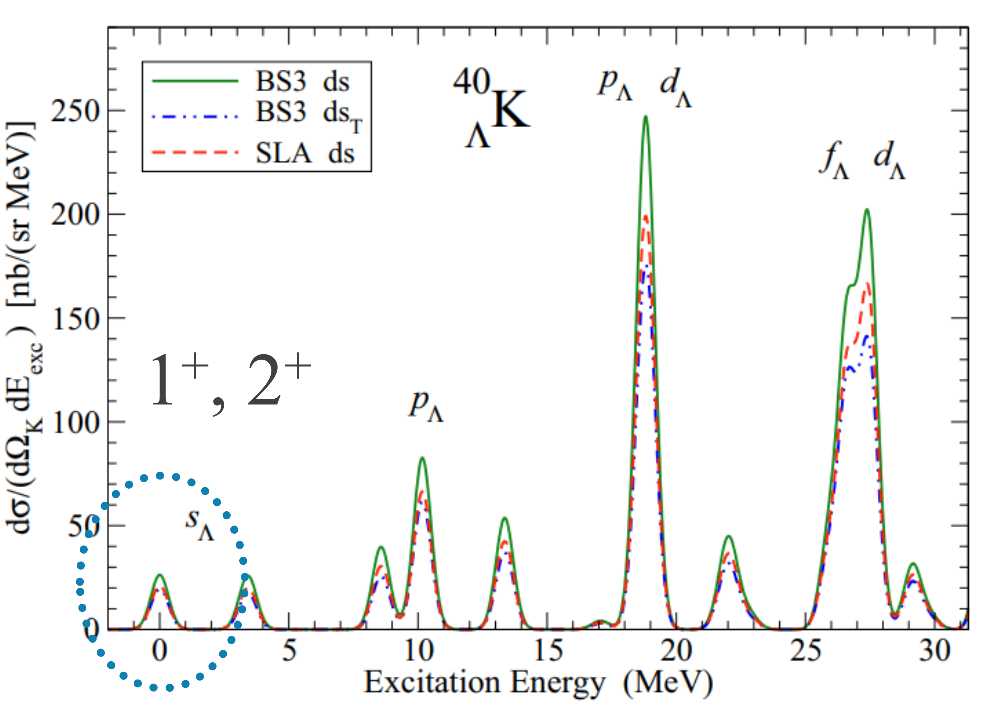




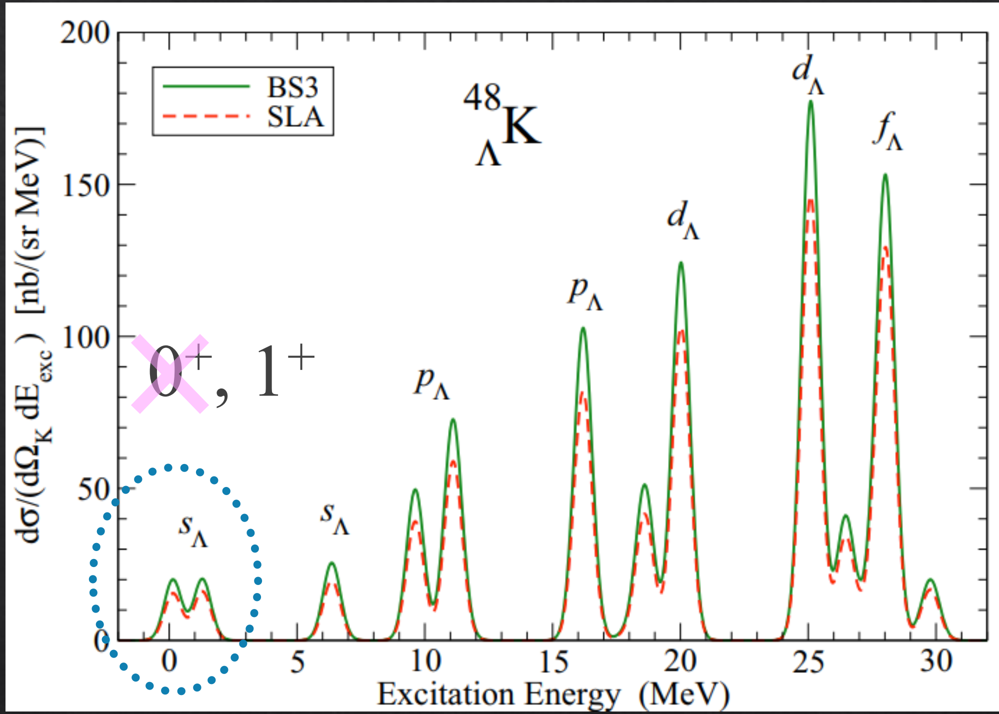
Less bound as the core is more deformed due to smaller overlap between core and Λ

Comparison between ${}^{40}_{\Lambda}$K and ${}^{48}_{\Lambda}$K

P. Bydžovský et al., PRC **108**, 024615 (2023)



E_x (MeV)	J^P	s.p. states p	s.p. states Λ	Cross sections SLA	Cross sections BS3
0.000	1^+	$0d_{3/2}$	$0s_{1/2}$	4.47	7.55
0.004	2^+	$0d_{3/2}$	$0s_{1/2}$	13.43	14.84
3.417	1^+	$1s_{1/2}$	$0s_{1/2}$	17.02	21.77
8.570	3^+	$0d_{5/2}$	$0s_{1/2}$	17.34	24.53



E_x (MeV)	J^P	s.p. states p	s.p. states Λ	Cross sections SLA	Cross sections BS3
0.148	1^+	$1s_{1/2}$	$0s_{1/2}$	13.14	16.80
1.294	1^+	$0d_{3/2}$	$0s_{1/2}$	3.41	5.67
1.297	2^+	$0d_{3/2}$	$0s_{1/2}$	10.30	11.52
6.359	3^+	$0d_{5/2}$	$0s_{1/2}$	11.14	15.61

0^+ : negligible

✓ HRS-HRS @ Hall A
✓ Tritium target
✓ (e,e'K$^+$)
✓ Oct—Nov 2018

Recent related paper
→ K. Okuyama et al., PRC 110, 025203 (2024)

PTEP Progress of Theoretical and Experimental Physics JPS The Physical Society of Japan

The cross-section measurement for the ^{3}H(e, $e'K^+$)$nn\Lambda$ reaction

K N Suzuki, T Gogami, B Pandey, K Itabashi, S Nagao, K Okuyama, S N Nakamura, L Tang, D Abrams, T Akiyama, D Androic, K Aniol, C Ayerbe Gayoso, J Bane, S Barcus, J Barrow, V Bellini, H Bhatt, D Bhetuwal, D Biswas, A Camsonne, J Castellanos, J-P Chen, J Chen, S Covrig, D Chrisman, R Cruz-Torres, R Das, E Fuchey, K Gnanvo, F Garibaldi, T Gautam, J Gomez, P Gueye, T J Hague, O Hansen, W Henry, F Hauenstein, D W Higinbotham, C E Hyde, M Kaneta, C Keppel, T Kutz, N Lashley-Colthirst, S Li, H Liu, J Mammei, P Markowitz, R E McClellan, F Meddi, D Meekins, R Michaels, M Mihovilovič, A Moyer, D Nguyen, M Nycz, V Owen, C Palatchi, S Park, T Petkovic, S Premathilake, P E Reimer, J Reinhold, S Riordan, V Rodriguez, C Samanta, S N Santiesteban, B Sawatzky, S Širca, K Slifer, T Su, Y Tian, Y Toyama, K Uehara, G M Urciuoli, D Votaw, J Williamson, B Wojtsekhowski, S A Wood, B Yale, Z Ye, J Zhang, X Zheng

Progress of Theoretical and Experimental Physics, Volume 2022, Issue 1, January 2022, 013D01, https://doi.org/10.1093/ptep/ptab158

Published: 06 December 2021 **Article history ▾**

https://doi.org/10.1093/ptep/ptab158 *(see also here)*

PHYSICAL REVIEW C
covering nuclear physics

Letter

Spectroscopic study of a possible Λnn resonance and a pair of ΣNN states using the $(e, e'K^+)$ reaction with a tritium target

B. Pandey[1], L. Tang[1,2,*], T. Gogami[3,4], K. N. Suzuki[4], K. Itabashi[3], S. Nagao[3], K. Okuyama[3], S. N. Nakamura[3], D. Abrams[5], I. R. Afnan[6], T. Akiyama[3], D. Androic[7], K. Aniol[8], T. Averett[9], C. Ayerbe Gayoso[9], J. Bane[10], S. Barcus[9], J. Barrow[10], V. Bellini[11], H. Bhatt[12], D. Bhetuwal[12], D. Biswas[1], A. Camsonne[2], J. Castellanos[13], J-P. Chen[2], J. Chen[9], S. Covrig[2], D. Chrisman[14,15], R. Cruz-Torres[16], R. Das[17], E. Fuchey[18], C. Gal[5], B. F. Gibson[19], K. Gnanvo[5], F. Garibaldi[11,20], T. Gautam[1], J. Gomez[2], P. Gueye[1], T. J. Hague[21], O. Hansen[2], W. Henry[2], F. Hauenstein[22], D. W. Higinbotham[2], C. Hyde[22], M. Kaneta[3], C. Keppel[2], T. Kutz[17], N. Lashley-Colthirst[1], S. Li[23,24], H. Liu[25], J. Mammei[26], P. Markowitz[13], R. E. McClellan[2], F. Meddi[11], D. Meekins[2], R. Michaels[2], M. Mihovilovič[27,28,29], A. Moyer[30], D. Nguyen[16,31], M. Nycz[21], V. Owen[9], C. Palatchi[5], S. Park[17], T. Petkovic[7], S. Premathilake[5], P. E. Reimer[32], J. Reinhold[13], S. Riordan[32], V. Rodriguez[33], C. Samanta[34], S. N. Santiesteban[23], B. Sawatzky[2], S. Širca[27,28], K. Slifer[23], T. Su[21], Y. Tian[35], Y. Toyama[3], K. Uehara[3], G. M. Urciuoli[11], D. Votaw[14,15], J. Williamson[36], B. Wojtsekhowski[2], S. Wood[2], B. Yale[23], Z. Ye[32], J. Zhang[5], and X. Zheng[5] (Hall A Collaboration)

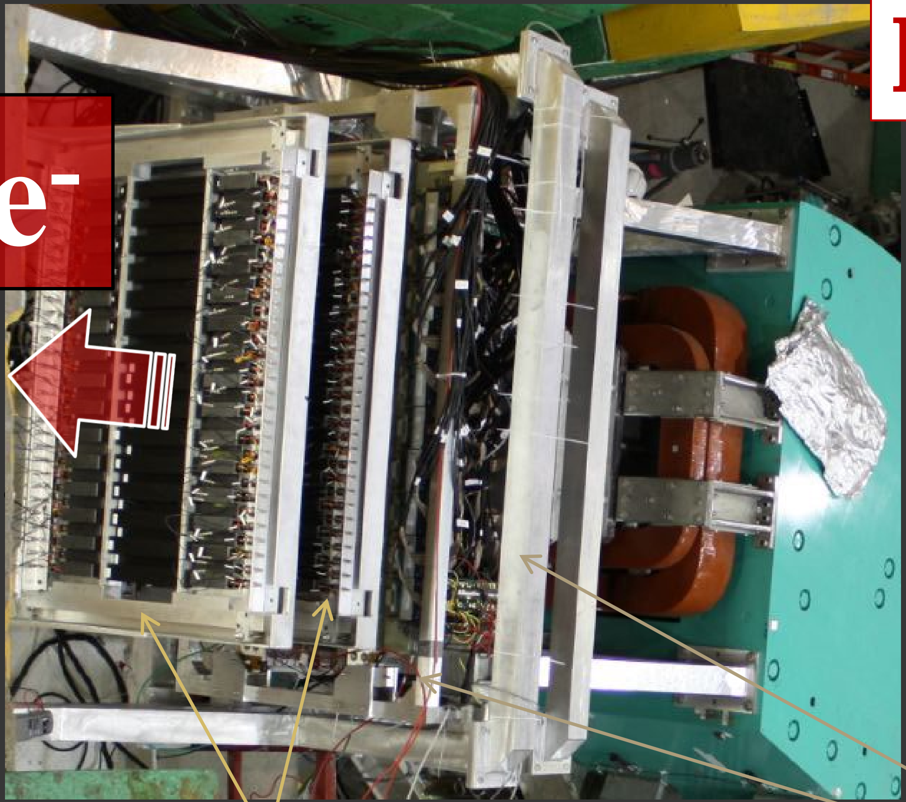
https://doi.org/10.1103/PhysRevC.105.L051001

Particle Detectors

TG et al., NIMA 900, 69—83 (2018)
TG et al., NIMA 729, 816—824 (2013)

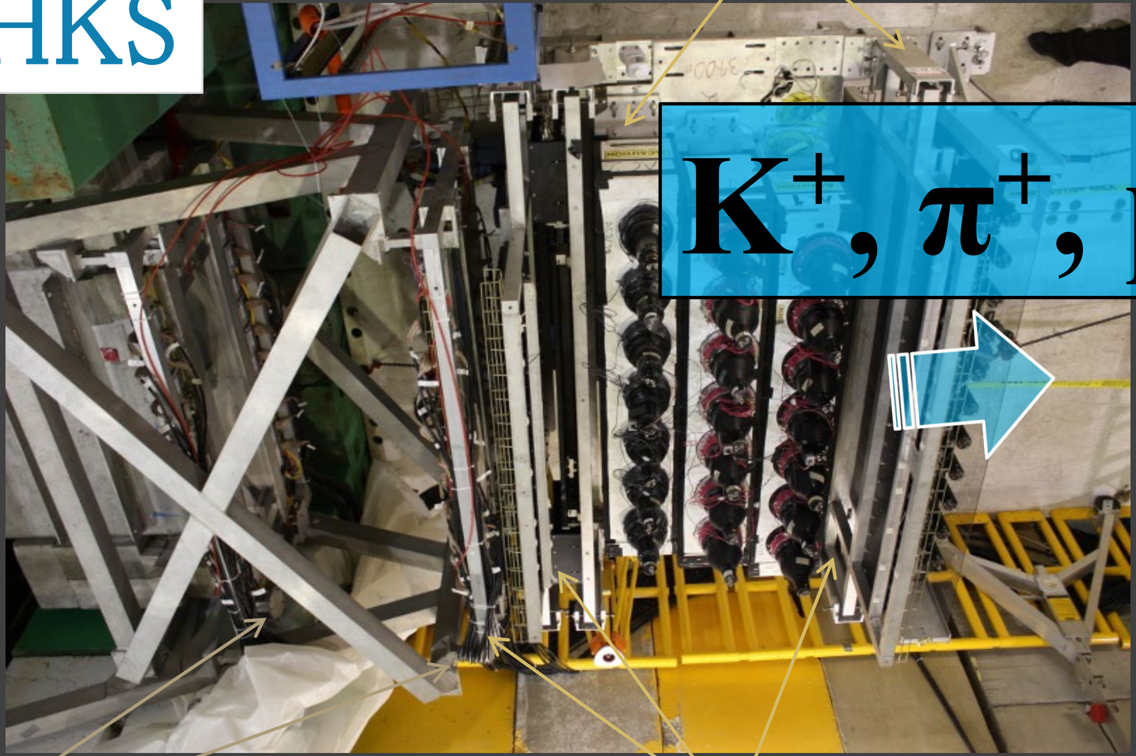
Cherenkov detectors
- **Aerogel (n=1.05)**
- **Water (n=1.33)**

HES



e^-

HKS



K^+, π^+, p

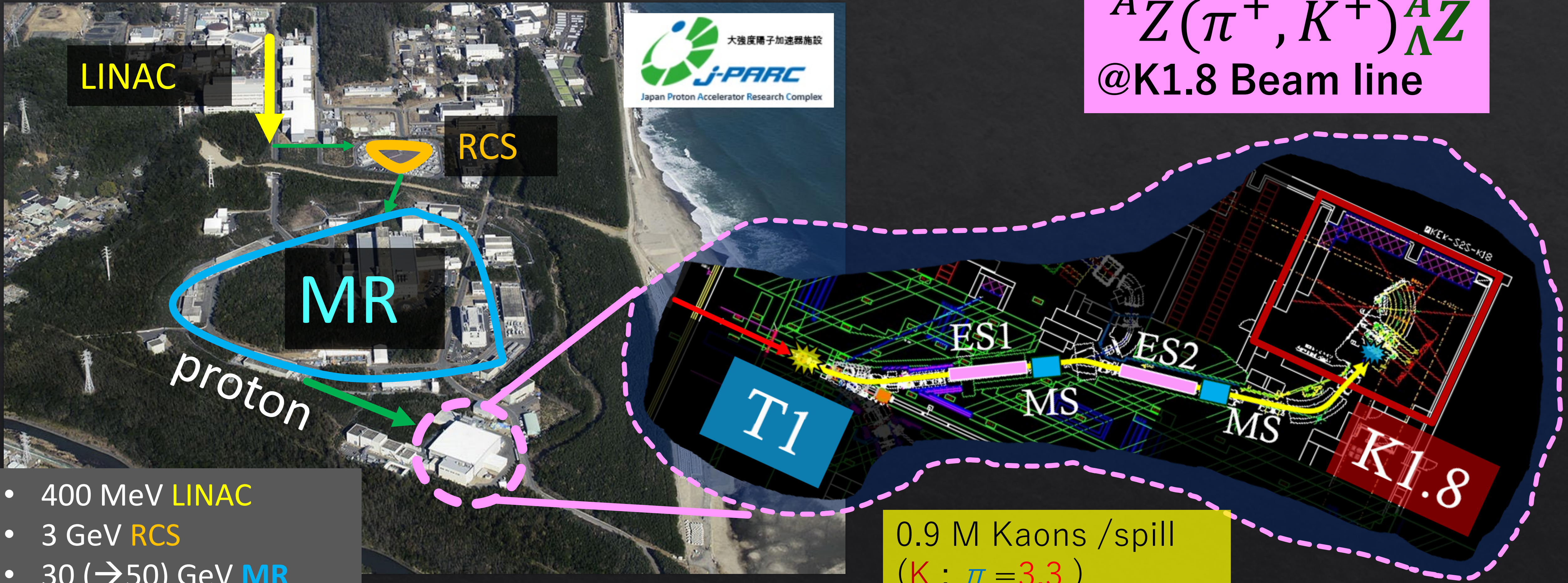
TOF walls (Plastic scintillators)

Drift chambers

TOF walls (Plastic scintillators)

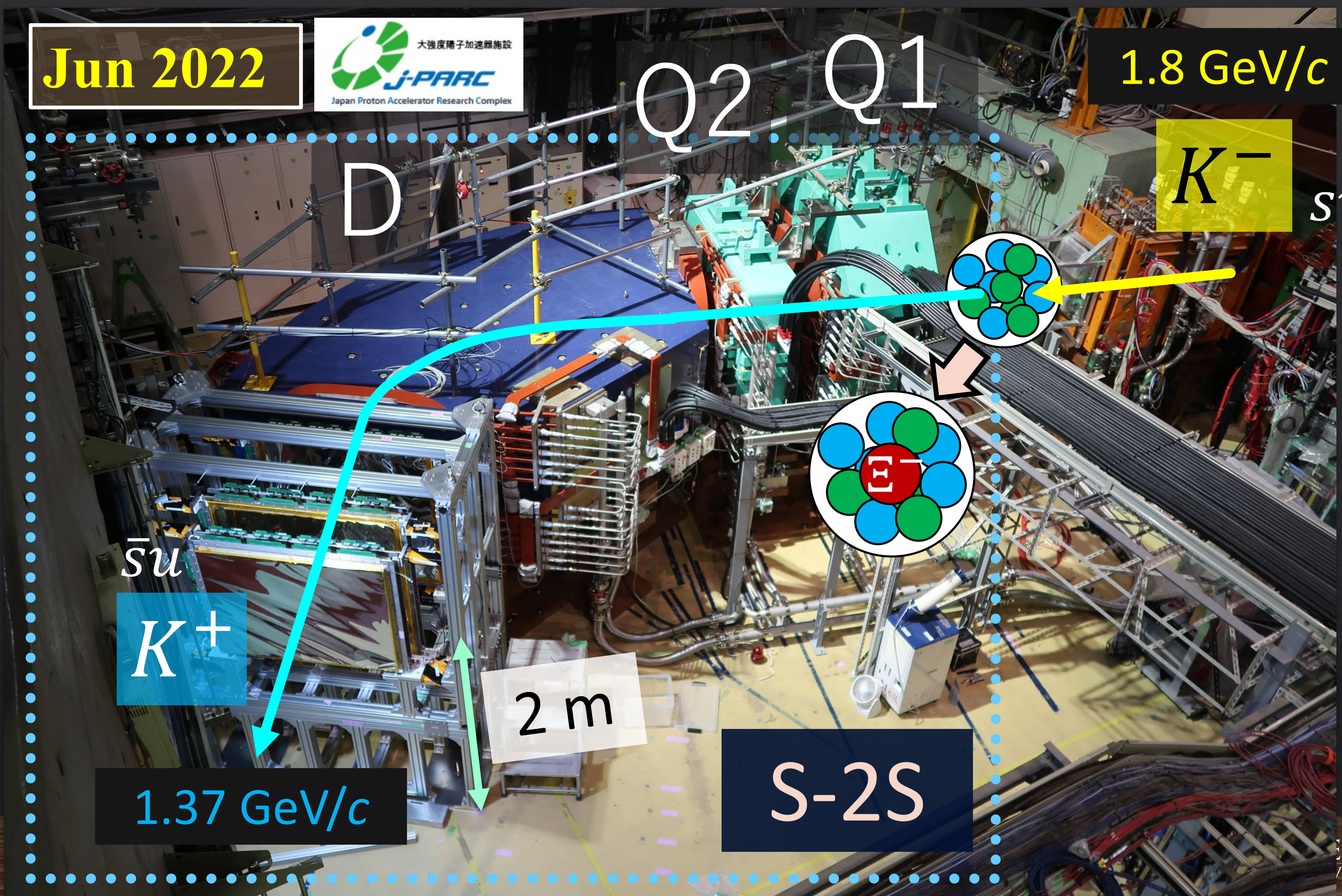
Japan Proton Accelerator Research Complex (J-PARC), Ibaraki, Japan

$^{A}Z(\pi^{+},K^{+})^{A}_{\Lambda}Z$
@K1.8 Beam line



- 400 MeV LINAC
- 3 GeV RCS
- 30 (→50) GeV MR

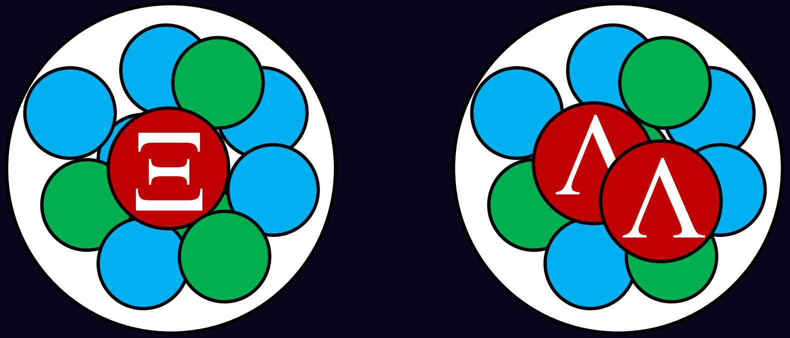
0.9 M Kaons /spill
(K : π =3.3)

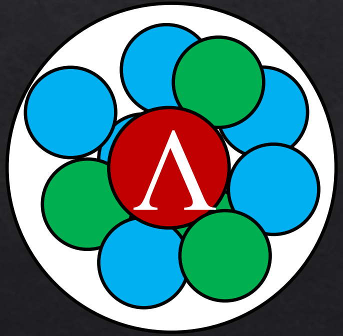


Jun 2022
大強度陽子加速器施設
J-PARC
Japan Proton Accelerator Research Complex
Q2
Q1
1.8 GeV/c
D
K^-
$s\bar{u}$
Ξ^-
$\bar{s}u$
K^+
2 m
1.37 GeV/c
S-2S

Nov 9, 2022 @K1.8 beam line, J-PARC, Japan

"S = −2" study will start!





"S = −1" as well

T. Gogami et al., EPJ Web Conf. 271, 11002 (2022).