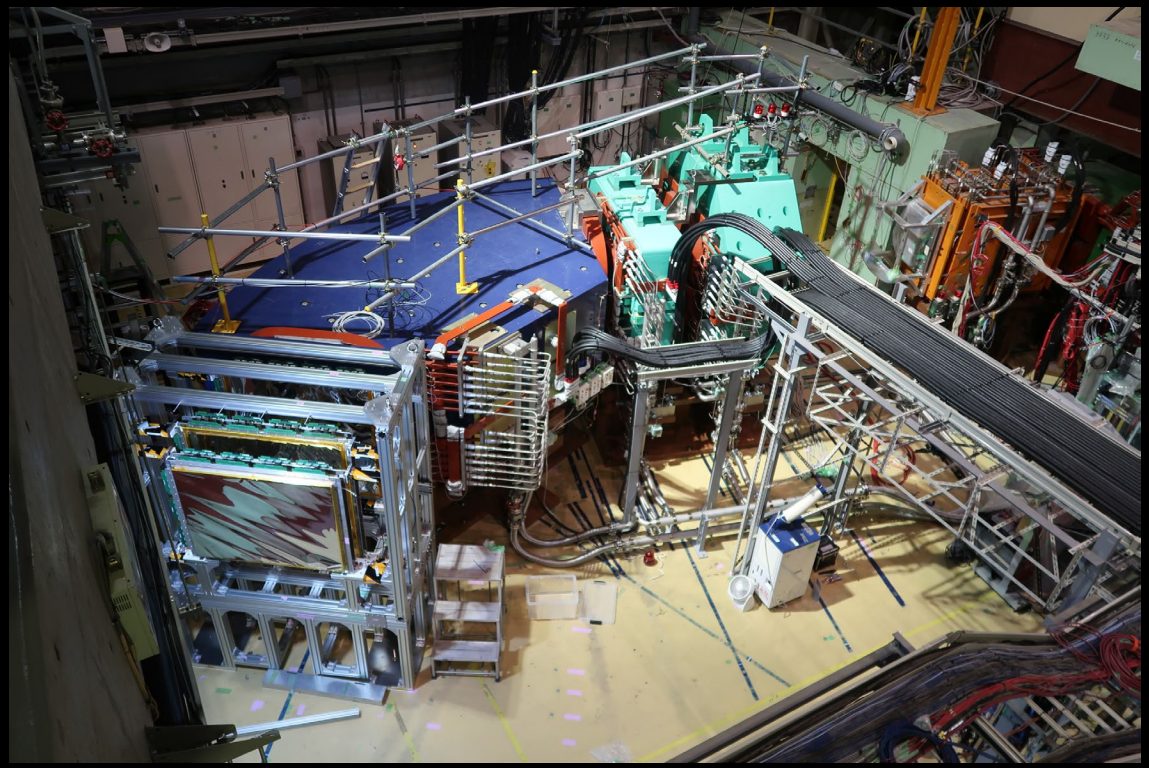
WEPH RE:2022 (online)

Study on strangeness-baryon interaction at JLab and J-PARC

T. Gogami (Kyoto Univ.)

Oct 6, 2022

Λ, Ξ HYPERNUCLEAR PRODUCTION



S-2S @ J-PARC, Japan

Λ, Ξ hypernuclei (2023~)

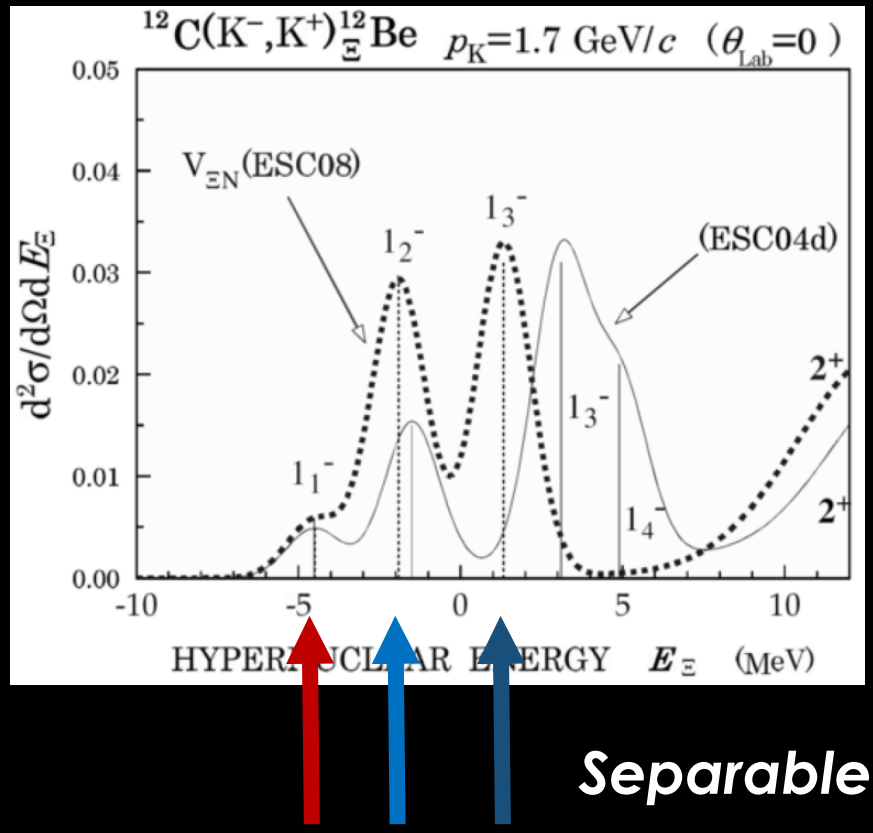
HKS @ JLab, US

Λ hypernuclei (2025~)

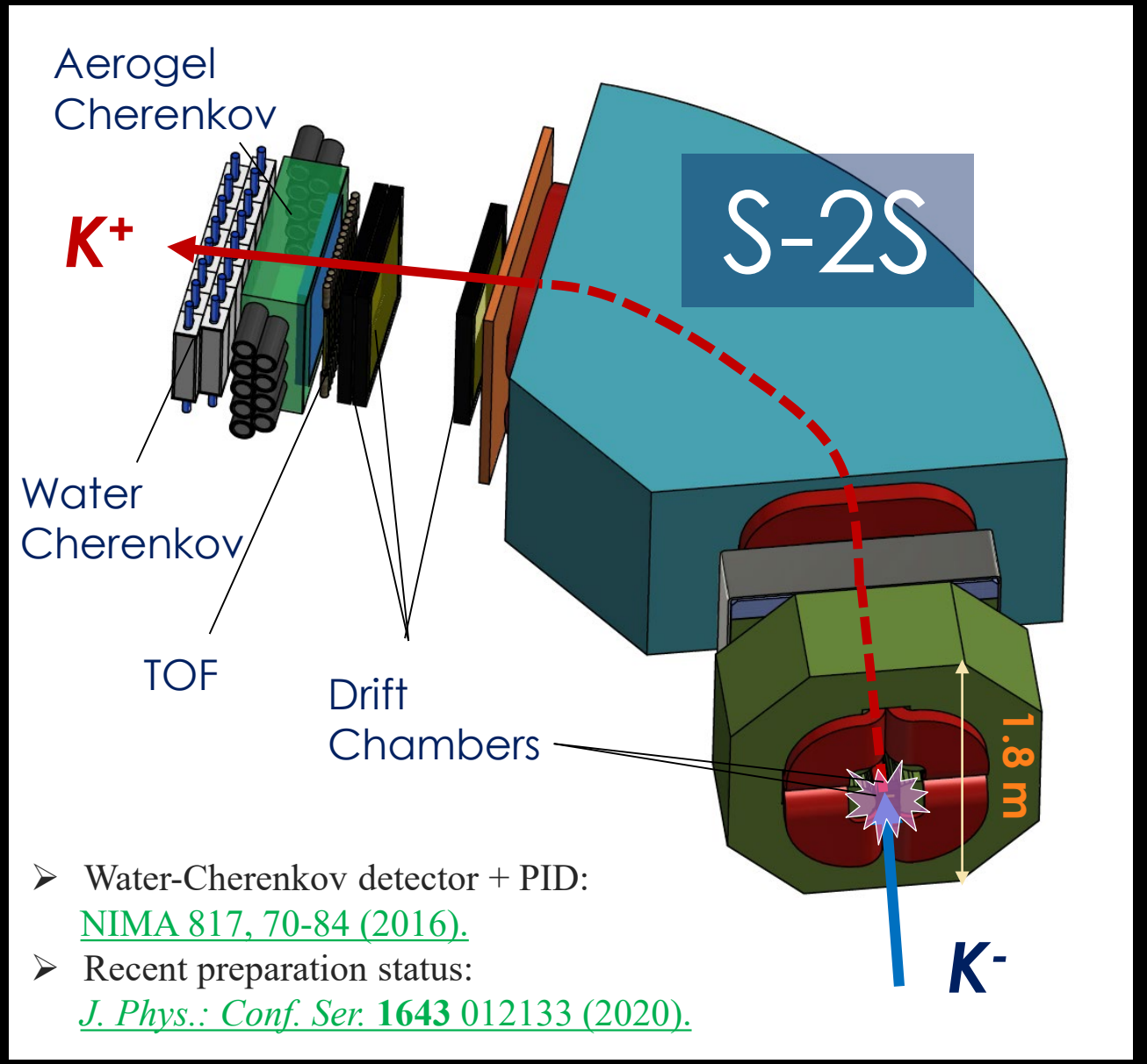
J-PARC E70

$\Delta p/p = 6 \times 10^{-4}$ (FWHM)
➔ $\Delta E \sim 2$ MeV (FWHM)

T. Motoba and S. Sugimoto, *NPA* **835** (2010) 223-230



Separable!!



- Water-Cherenkov detector + PID:
  NIMA 817, 70-84 (2016).
- Recent preparation status:
  J. Phys.: Conf. Ser. **1643** 012133 (2020).

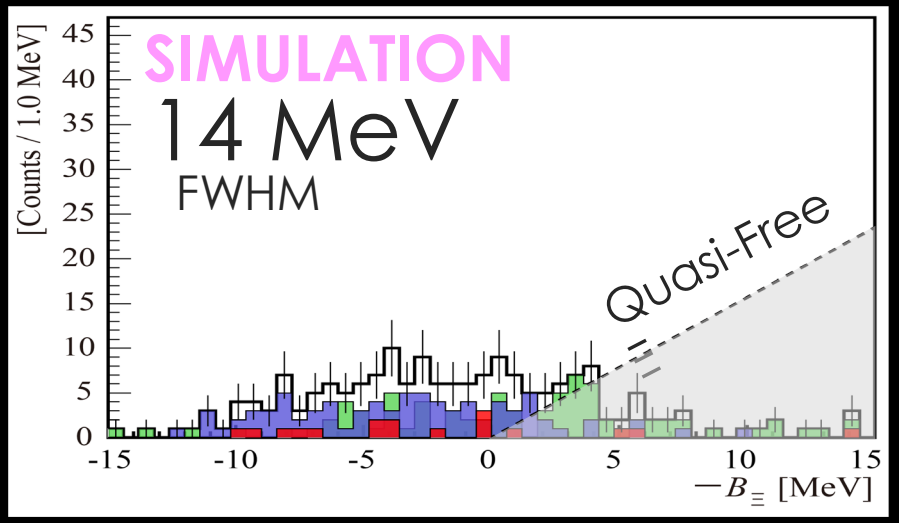
${}^{12}_{\Xi}\mathrm{Be}$ (${}^{11}\mathrm{B} + \Xi^-$): J-PARC E70

$^{12}\mathrm{C}(K^-, K^+)\,^{12}_{\Xi}\mathrm{Be}$ @ $p_\pi = 1.8$ GeV/c

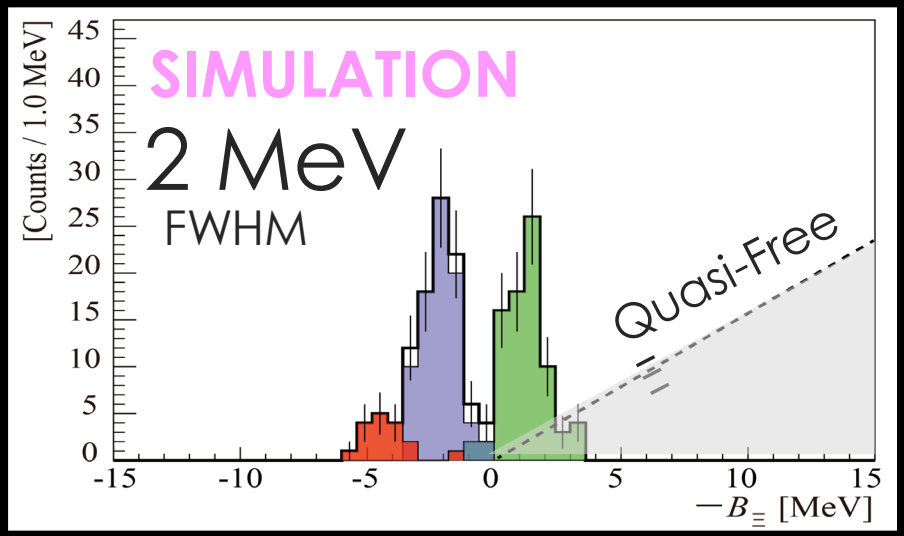
- Total efficiency = 0.5
- K survival ratio = 0.46 (8 m optical length)
- 60 msr
- 60 nb/sr (0—10 deg)
- 9 g/cm^2 (AFT made of CH)
- 0.8 M kaon per spill (spill cycle of 4.2 sec)
- 20 days

➡ **~100 counts**

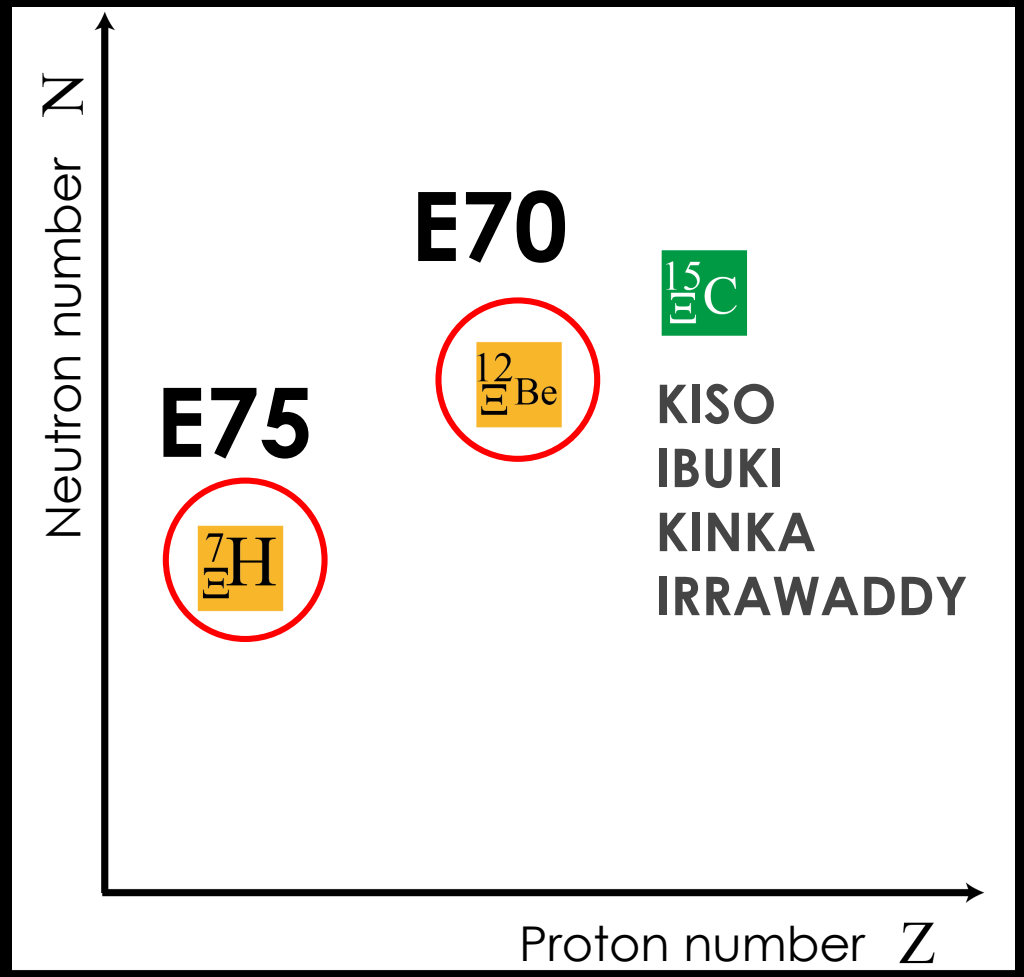
The experiment will start in 2023

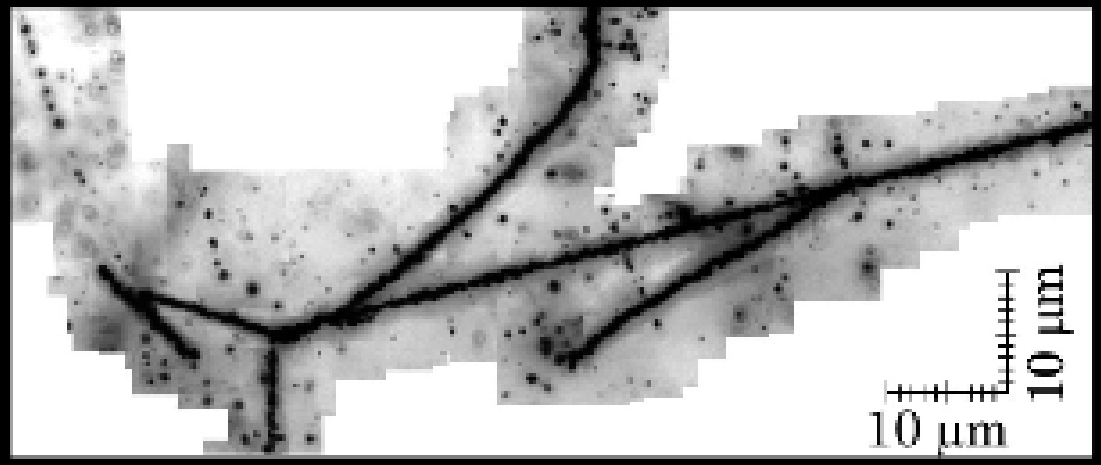


S-2S



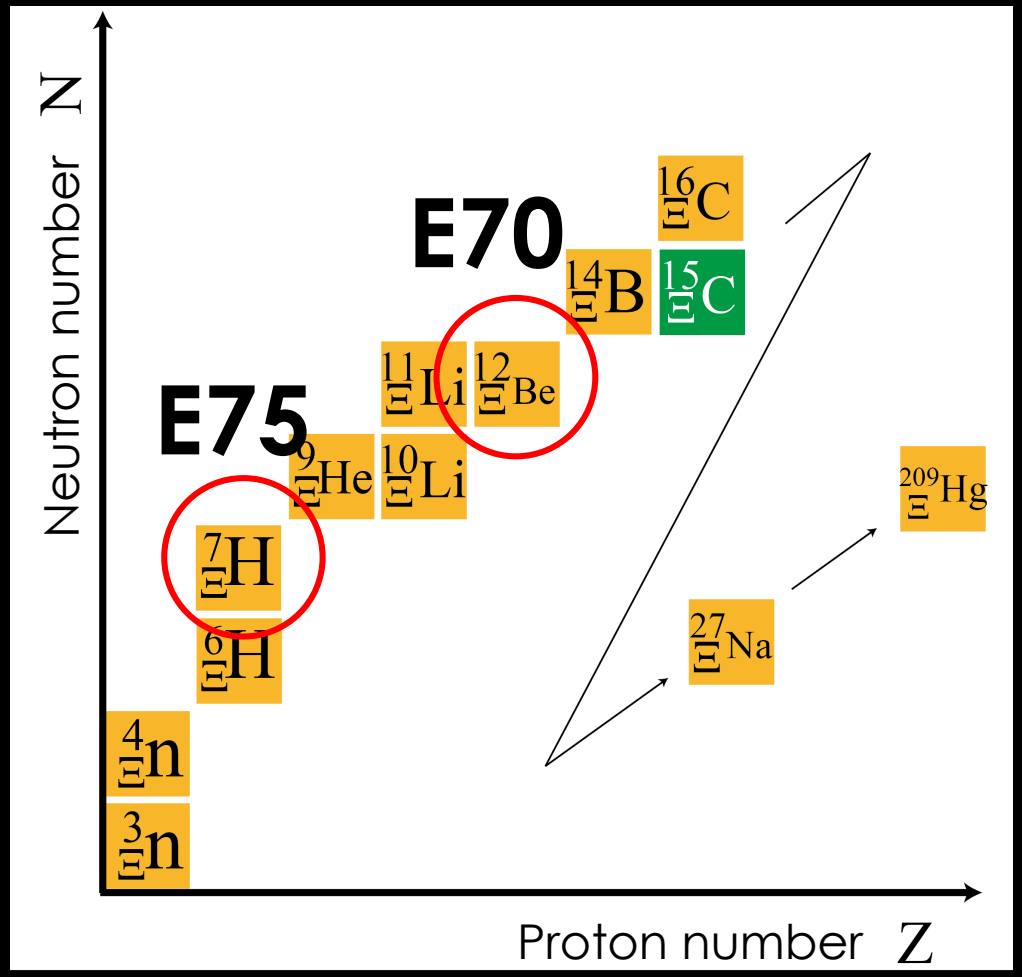
Ξ HYPERNUCLEAR STUDY AT J-PARC





- K. Nakazawa et al., PTEP 2015, 033D02 (2015)
- M. Yoshimoto et al., PTEP 2021, 073D02 (2021)
- S. Hayakawa et al., PRL 126, 062501 (2021)

Ξ HYPERNUCLEAR STUDY AT J-PARC



S-2S will open new era

- Missing mass spectroscopy
- X / gamma ray spectroscopy
- decay pion spectroscopy

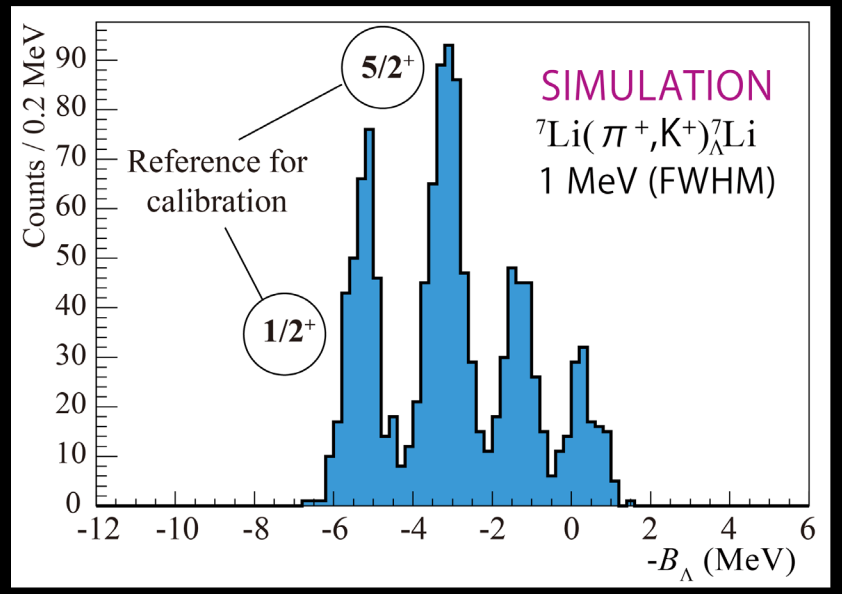
for variety of Ξ / ΛΛ hypernuclei

Theoretical supports are indispensable !

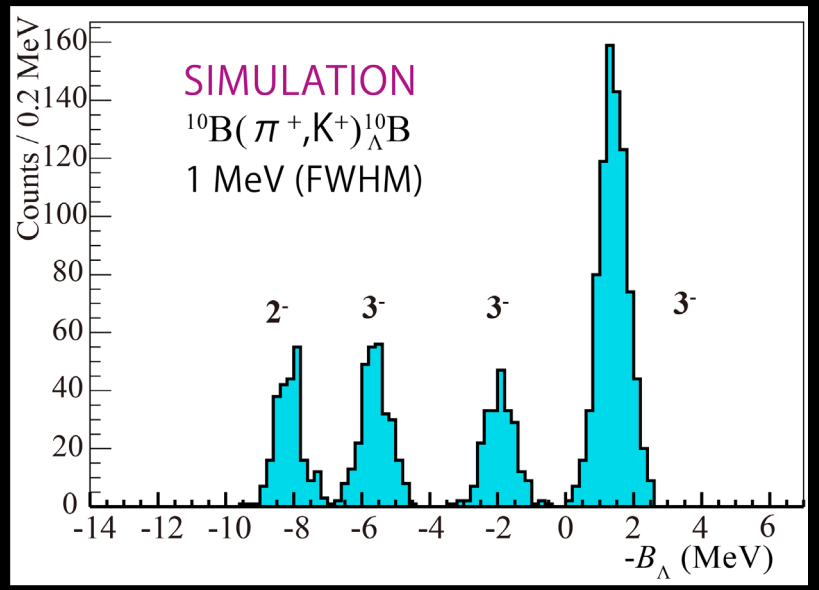
- ✓ Structure
- ✓ **Production**
- ✓ Decay

New Λ hypernuclear project with the (π^+,K^+) reaction

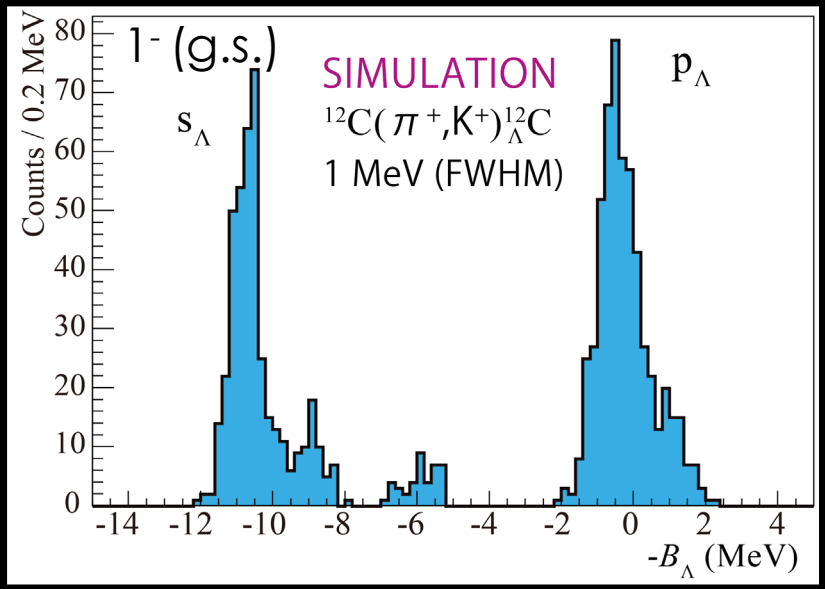
$^{7}_{\Lambda}$Li



$^{10}_{\Lambda}$B



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



J-PARC E94

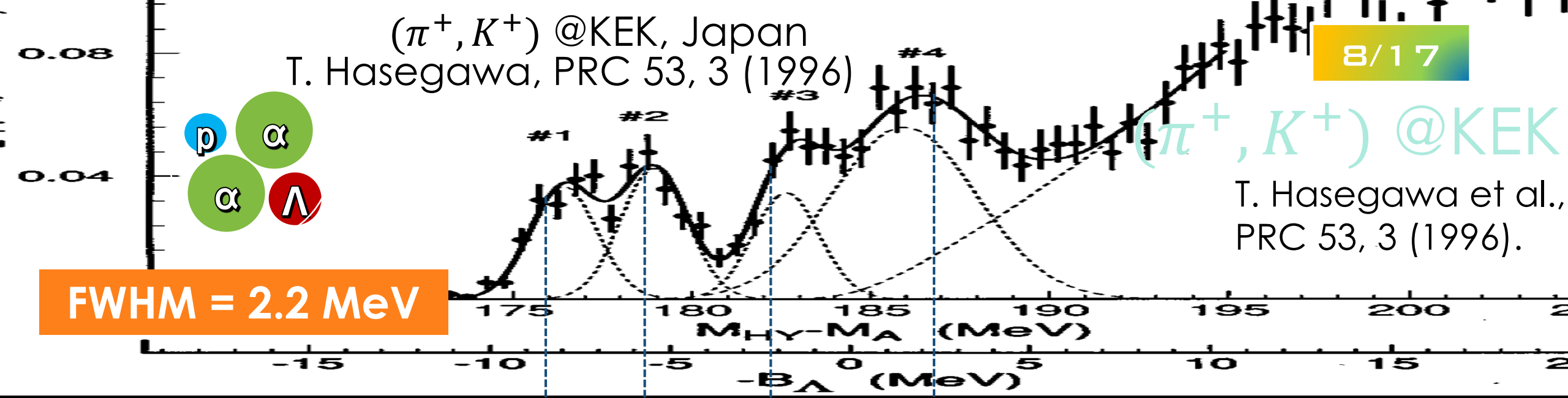
- Resolution = 1 MeV FWHM
- Accuracy = 100 keV

Download ➔

- ✓ Proposal (2022)
- ✓ Presentation file in J-PARC PAC

(π^+, K^+) @KEK, Japan

T. Hasegawa, PRC 53, 3 (1996)

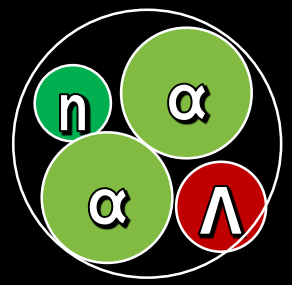


FWHM = 2.2 MeV

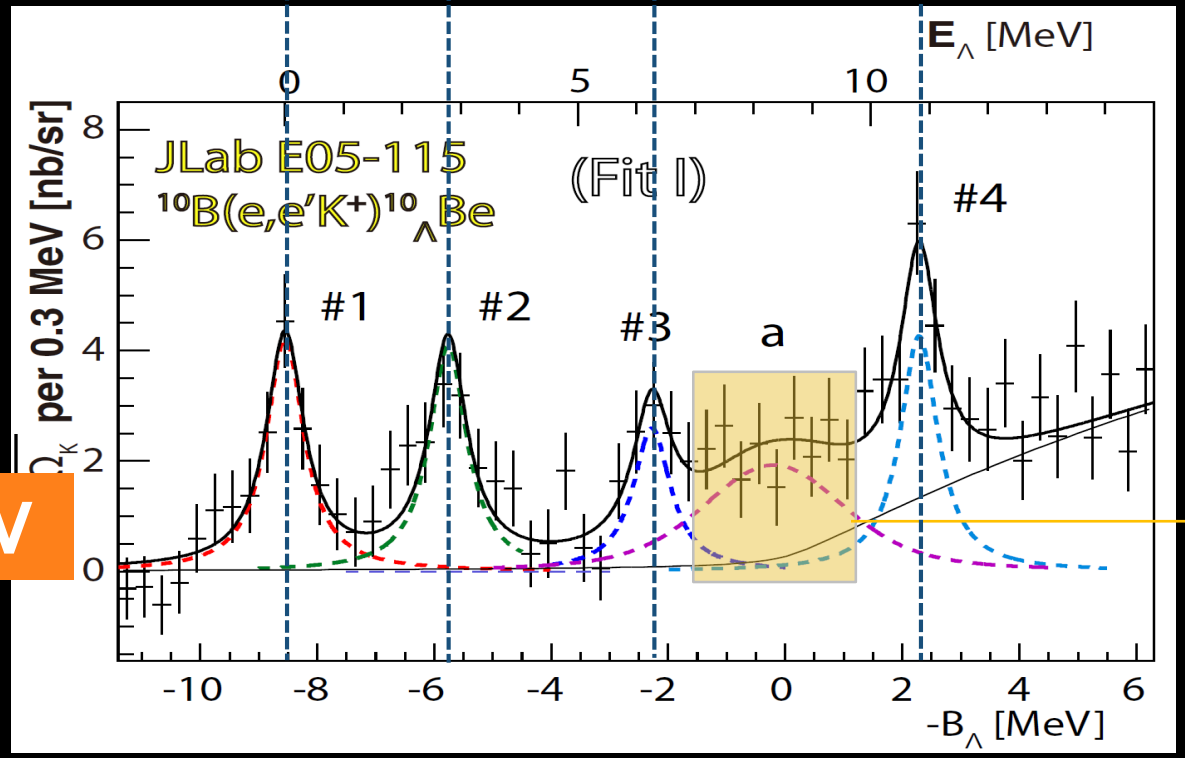
(π^+, K^+) @KEK

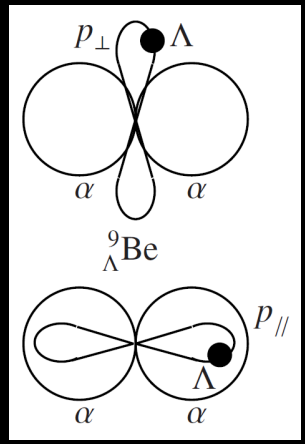
T. Hasegawa et al., PRC 53, 3 (1996).

$^{10}_{\Lambda}$Be



FWHM = 0.8 MeV



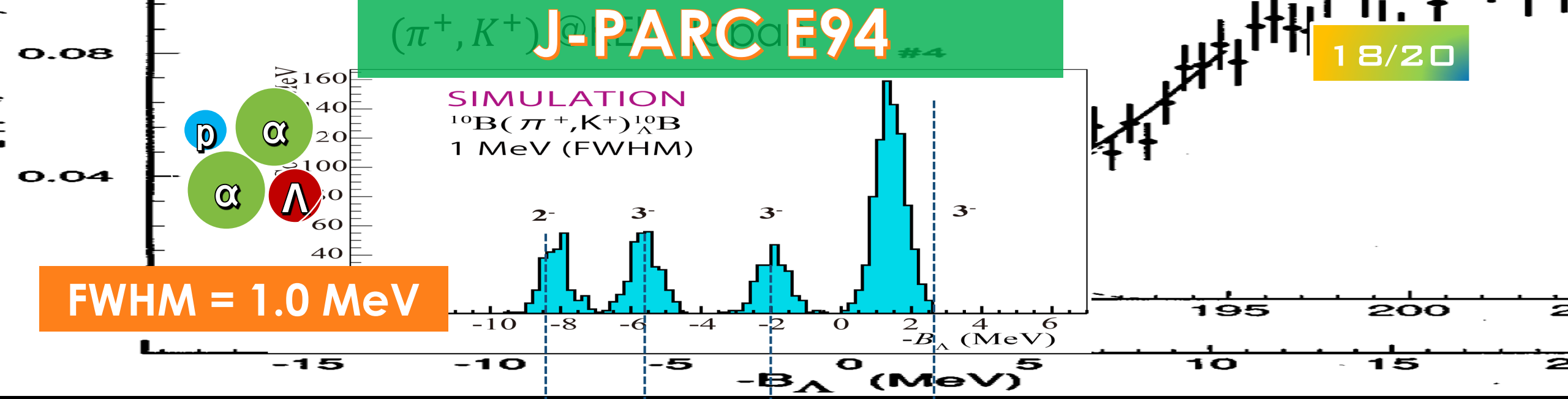


HKS Collaboration, PRC 93, 034314 (2016).

A. Umeya *et al.*, *J. Phys.: Conf. Ser.* **1643** 012110 (2020).

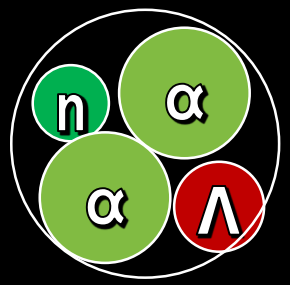
J-PARC E94

(π^+, K^+) @ E

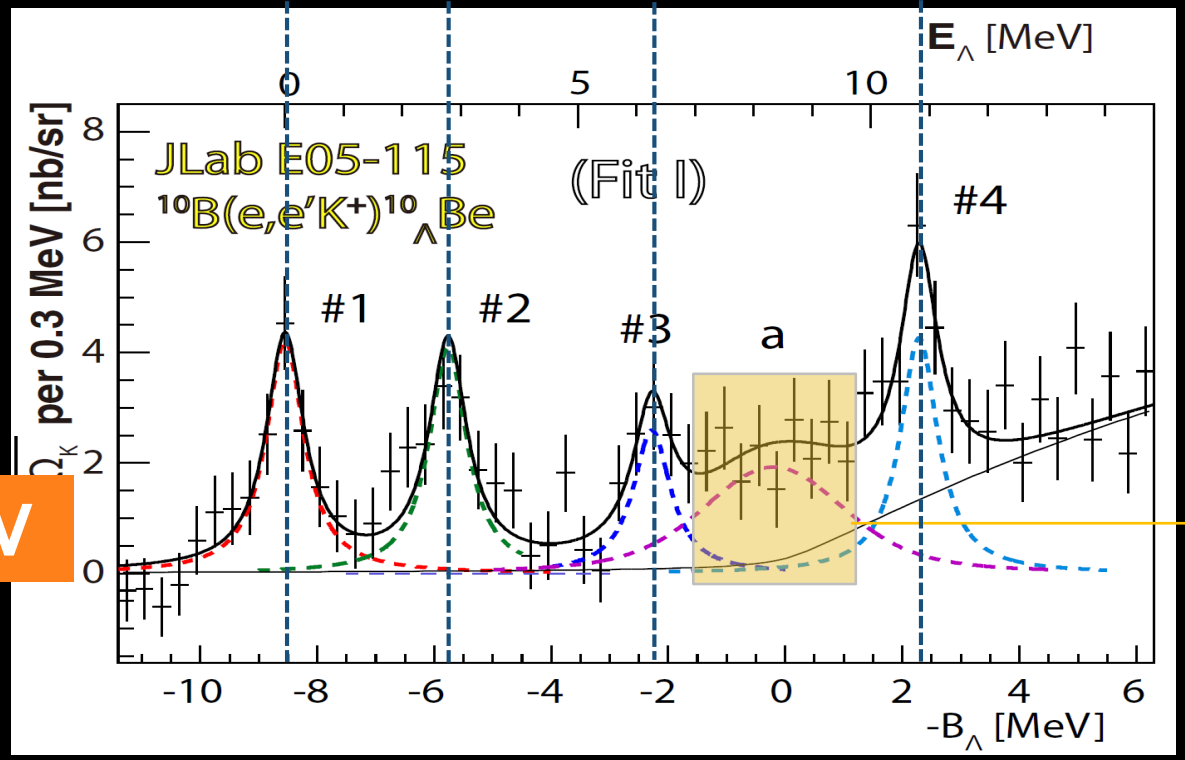


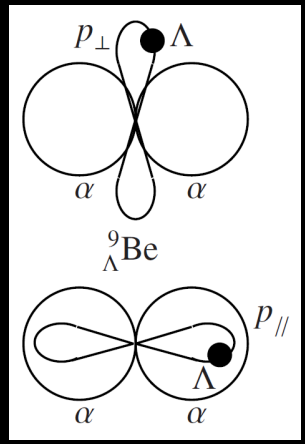
FWHM = 1.0 MeV

$^{10}_{\Lambda}Be$



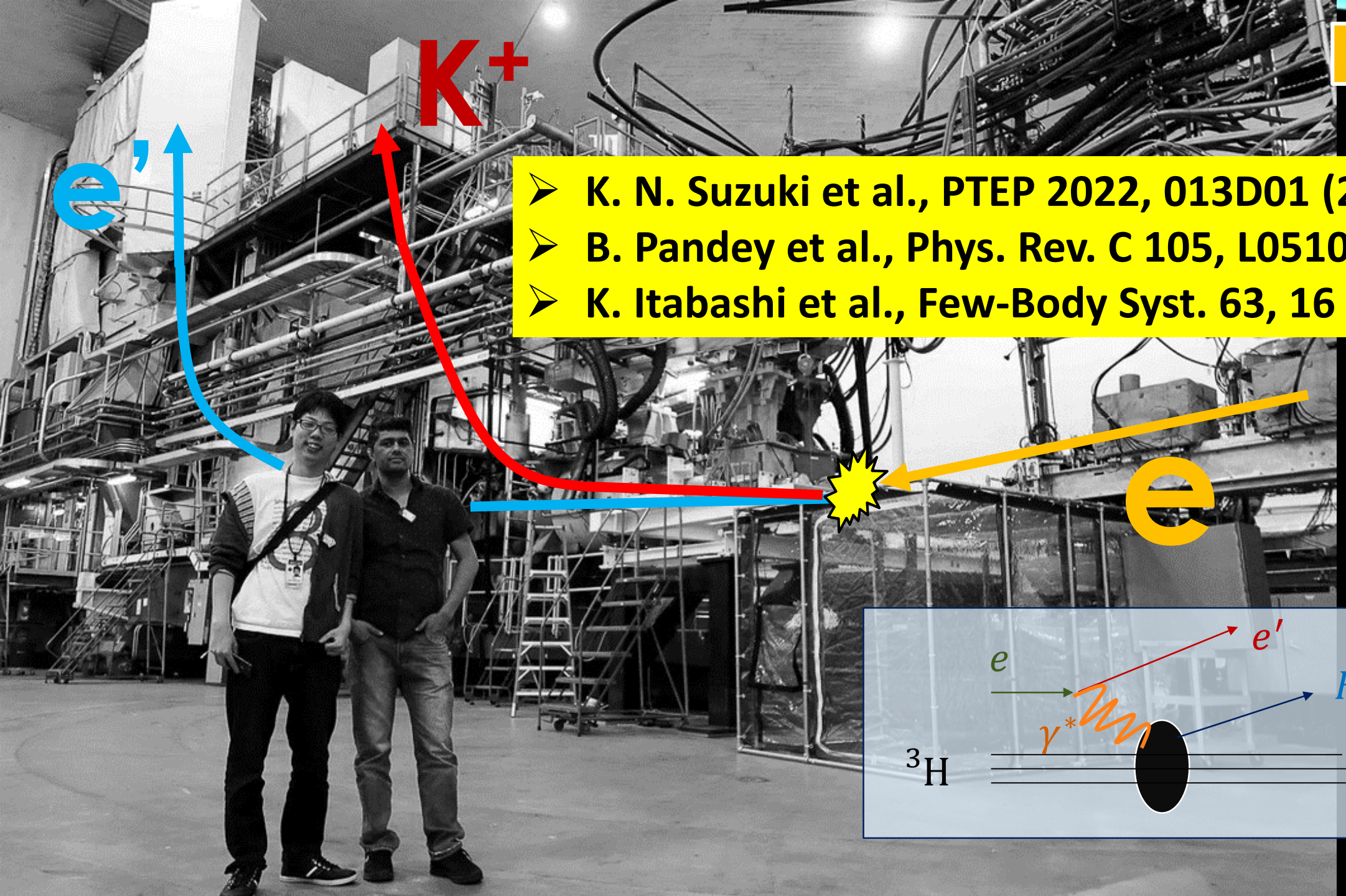
FWHM = 0.8 MeV





HKS Collaboration, PRC 93, 034314 (2016).

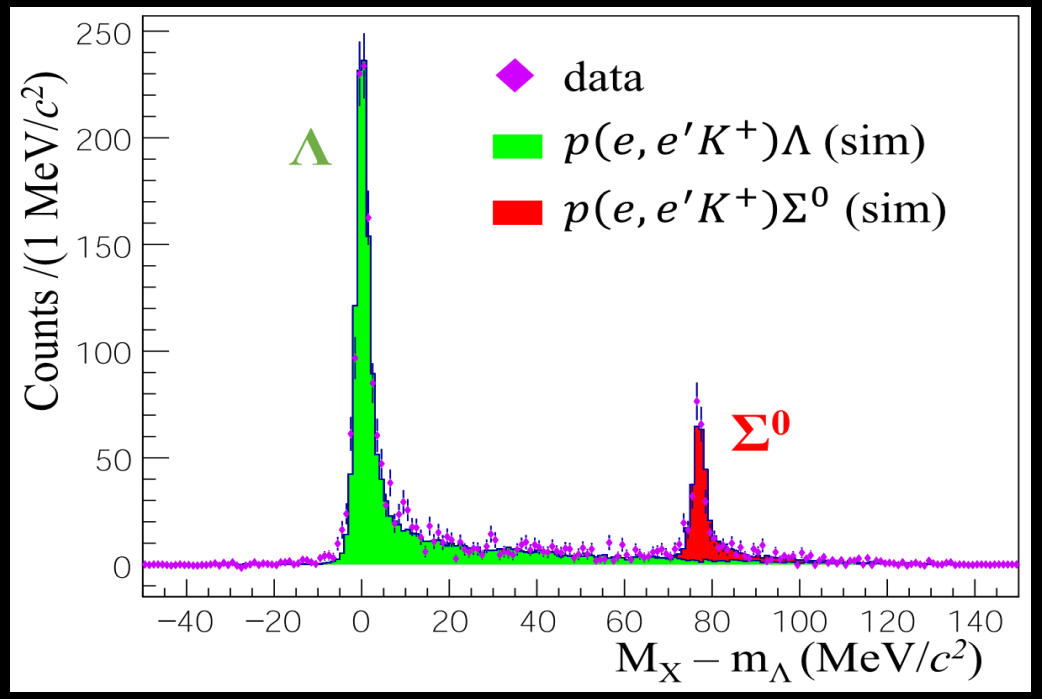
A. Umeya *et al., J. Phys.: Conf. Ser.* **1643** 012110 (2020).



- K. N. Suzuki et al., PTEP 2022, 013D01 (2022).
- B. Pandey et al., Phys. Rev. C 105, L051001 (2022).
- K. Itabashi et al., Few-Body Syst. 63, 16 (2022).

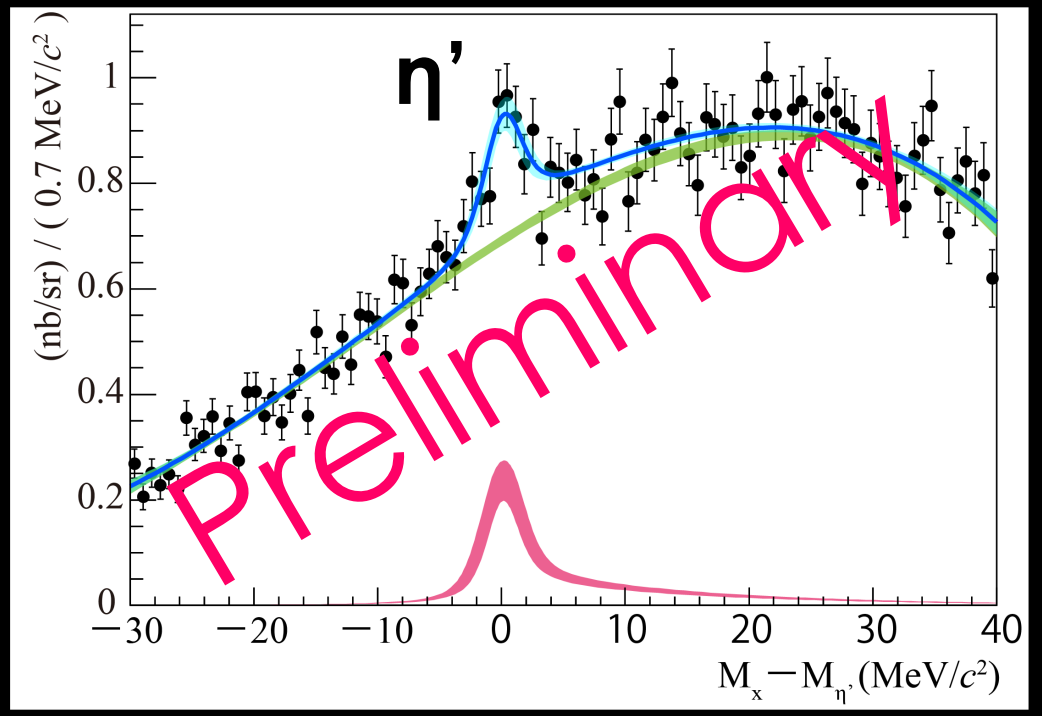
Ongoing analyses for existing data from the (e,e'K$^+$) experiment at JLab

PTEP 2022, 013D01 (2022)



Cross section for (γ*,K$^+$)Λ,Σ^0

➡ **K. Okuyama** (Tohoku Univ.)



Cross section for (γ*,p)η'

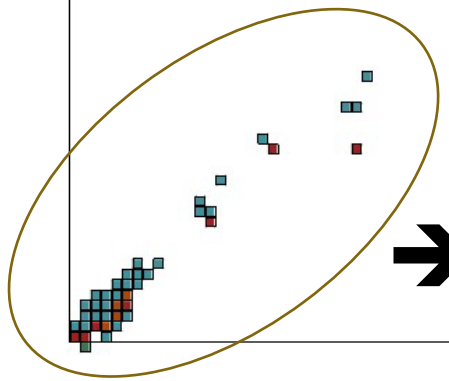
➡ **T. Akiyama** (Tohoku Univ.)

Next experiments; light to heavy

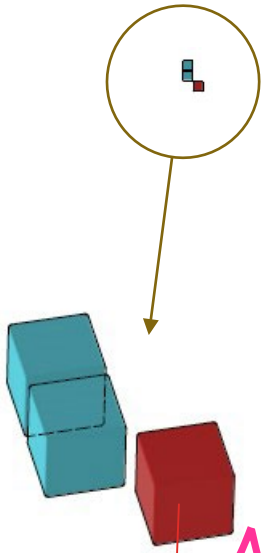
Proton number

Neutron number

Λ Hypernuclear Chart



➔ Next page

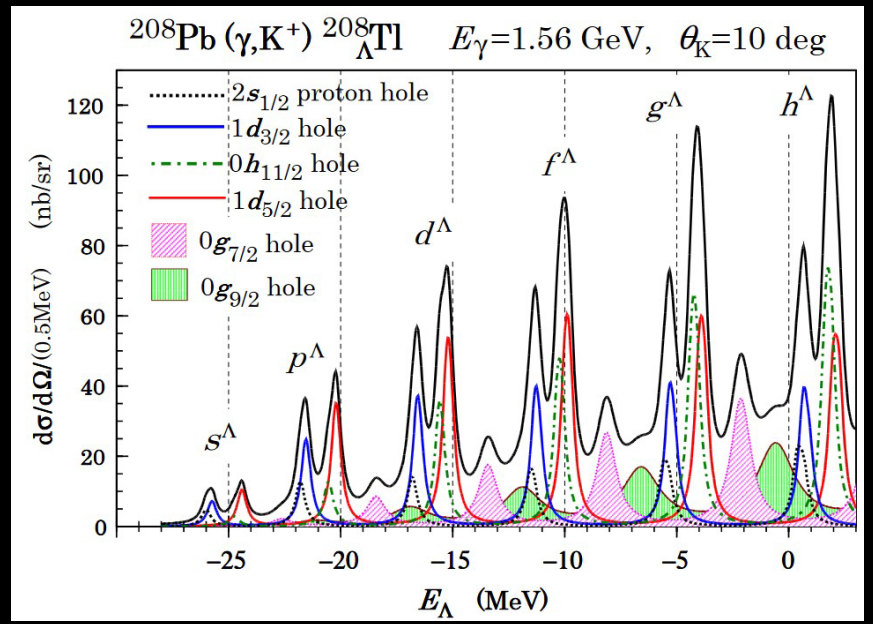


New

$^{208}_{\Lambda}$Tl

ΛNN force

T. Motoba, JPS Conf. Proc. 17, 011003 (2017)

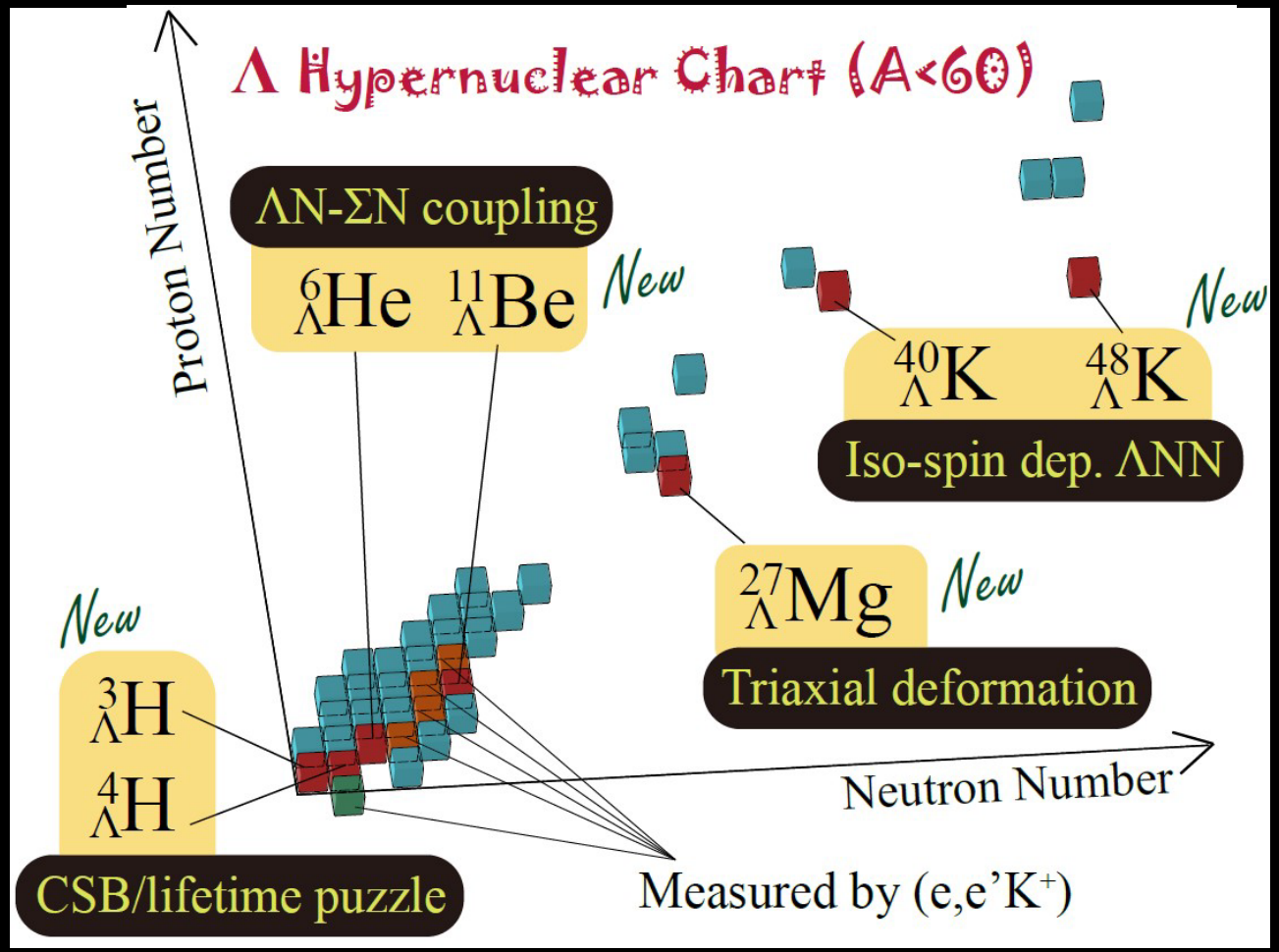


Approved experiments

➔ JLab E12-20-013

F. Garibaldi et al,
Proposal to JLab (2020)

Next experiments; light to heavy



Approved experiments

➔ **JLab E12-15-008**

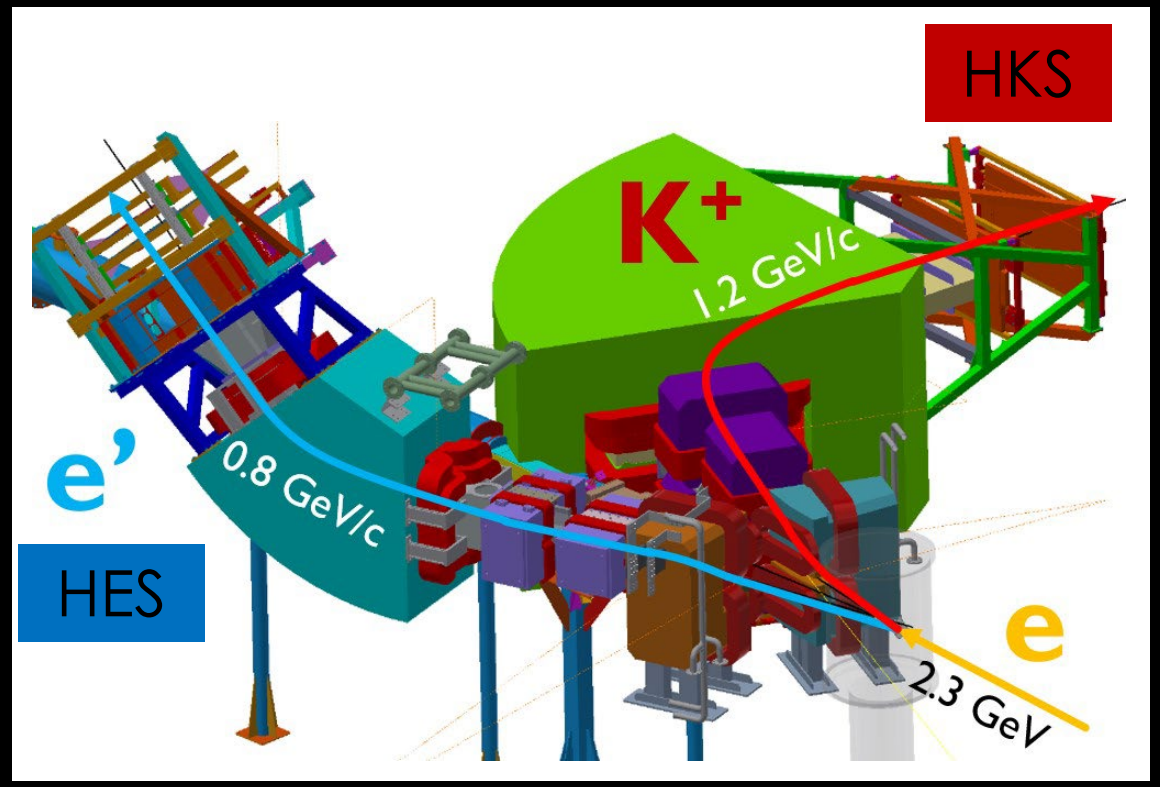
S.N. Nakamura et al,
Proposal to JLab (2015)

➔ **JLab E12-19-002**

T. Gogami et al,
Proposal to JLab (2019)

EXPERIMENTAL SETUP

Setup: PCS+HES+HKS



PCS

- **HES + HKS**: existing
- **PCS**: new

Already transported to JLab (2022)

Engaging between theoretical and experimental work

Reaction	State etc.	Structure (calc.)	Cross section (calc.)	Experiment
$^{3}\mathrm{H}(e,e'K^{+})nn\Lambda$	nnΛ / FSI	○ / ?	× / ×	○ / in progress
$^{3}\mathrm{He}(e,e'K^{+})^{3}_{\Lambda}\mathrm{H}$	$1/2^{+}$/ $3/2^{+}$, T=1	○ / ?	○ / × (T. Mart et al., PRC 78, 01004 (2008))	Next (E12-19-002)
$^{4}\mathrm{He}(e,e'K^{+})^{4}_{\Lambda}\mathrm{H}$	1^{+}	○ (Motoba, JPS Conf. Proc. 17, 011003 (2017))	○ (Motoba, JPS Conf. Proc. 17, 011003 (2017))	Next (E12-19-002)
$^{6}\mathrm{Li}(e,e'K^{+})^{6}_{\Lambda}\mathrm{He}$		○ (E. Hiayama et al., PRC 53, 5, 2075 (1996))	×	Next (E12-15-008)
$^{9}\mathrm{Be}(e,e'K^{+})^{9}_{\Lambda}\mathrm{Li}$		○ (Motoba et al., PTPS 185 (2010))	○ (Motoba et al., PTPS 185 (2010))	○ (Halls A and C)
$^{11}\mathrm{B}(e,e'K^{+})^{11}_{\Lambda}\mathrm{Be}$		○ (Umeya, Talk in JPS meeting 2022)	○ (Umeya, Talk in JPS meeting 2022)	Next (E12-15-008)
$^{27}\mathrm{Al}(e,e'K^{+})^{27}_{\Lambda}\mathrm{Mg}$		○ (Isaka, talk in PPPY-Λ2021)	×	Next (E12-19-002)
$^{40}\mathrm{Ca}(e,e'K^{+})^{40}_{\Lambda}\mathrm{K}$		○ (Motoba et al., PTPS 185 (2010))	○ (Motoba et al., PTPS 185 (2010))	Next (E12-15-008)
$^{48}\mathrm{Ca}(e,e'K^{+})^{48}_{\Lambda}\mathrm{K}$		○ (Umeya, talk in WEPH2021)	○ (Umeya, talk in WEPH2021)	Next (E12-15-008)
$^{208}\mathrm{Pb}(e,e'K^{+})^{208}_{\Lambda}\mathrm{Tl}$		○ (Motoba, JPS Conf. Proc. 17, 011003 (2017))	○ (Motoba, JPS Conf. Proc. 17, 011003 (2017))	Next (E12-20-013)

➡ Calculations by different frameworks are necessary for data analysis & discussion

WHAT'S NEXT TO THE NEXT?

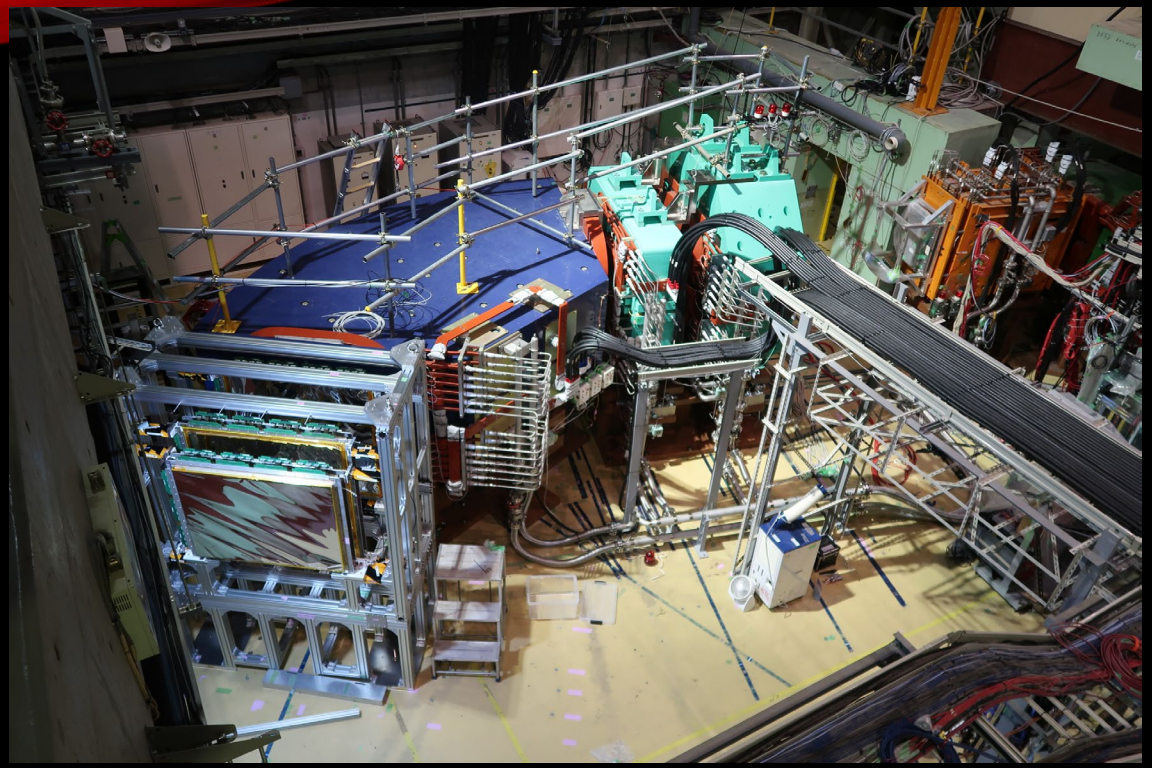
Isobaric hypernuclei

- ${}^{48}\mathrm{Ti}(e,e'K^+){}^{48}_{\Lambda}\mathrm{Sc}$
  - (Z, N) = ${}^{48}_{\Lambda}\mathrm{Sc}$ (21, 26) vs. ${}^{48}_{\Lambda}\mathrm{K}$ (19, 28)

  → the same mass number, but the different δ
- ${}^{40}\mathrm{Ar}(e,e'K^+){}^{40}_{\Lambda}\mathrm{Cl}$ vs. ${}^{40}\mathrm{Ca}(e,e'K^+){}^{40}_{\Lambda}\mathrm{K}$
- ${}^{46}\mathrm{Ca}(e,e'K^+){}^{46}_{\Lambda}\mathrm{K}$ vs. ${}^{46}\mathrm{Ti}(e,e'K^+){}^{46}_{\Lambda}\mathrm{Sc}$
- ${}^{48}\mathrm{Ca}(e,e'K^+){}^{48}_{\Lambda}\mathrm{K}$ vs. ${}^{48}\mathrm{Ti}(e,e'K^+){}^{48}_{\Lambda}\mathrm{Sc}$
- ${}^{50}\mathrm{Ti}(e,e'K^+){}^{50}_{\Lambda}\mathrm{Sc}$ vs. ${}^{50}\mathrm{V}(e,e'K^+){}^{50}_{\Lambda}\mathrm{Ti}$ vs. ${}^{50}\mathrm{Cr}(e,e'K^+){}^{50}_{\Lambda}\mathrm{V}$
- ${}^{54}\mathrm{Cr}(e,e'K^+){}^{54}_{\Lambda}\mathrm{V}$ vs. ${}^{54}\mathrm{Fe}(e,e'K^+){}^{54}_{\Lambda}\mathrm{Mn}$
- … (many candidates)

$p(e,e'K^+K^+)\Xi^-$

SUMMARY



S-2S @ J-PARC, Japan

$^{12}_{\Xi}$Be, $^{7}_{\Lambda}$Li, $^{10}_{\Lambda}$B, $^{12}_{\Lambda}$C (2023~)

HKS @ JLab, US

$^{3,4}_{\Lambda}$H, $^{6}_{\Lambda}$Li, $^{11}_{\Lambda}$Be, $^{40,48}_{\Lambda}$K, $^{27}_{\Lambda}$Mg, $^{208}_{\Lambda}$Tl (2025~)

Any suggestions for the next to next experiment?