

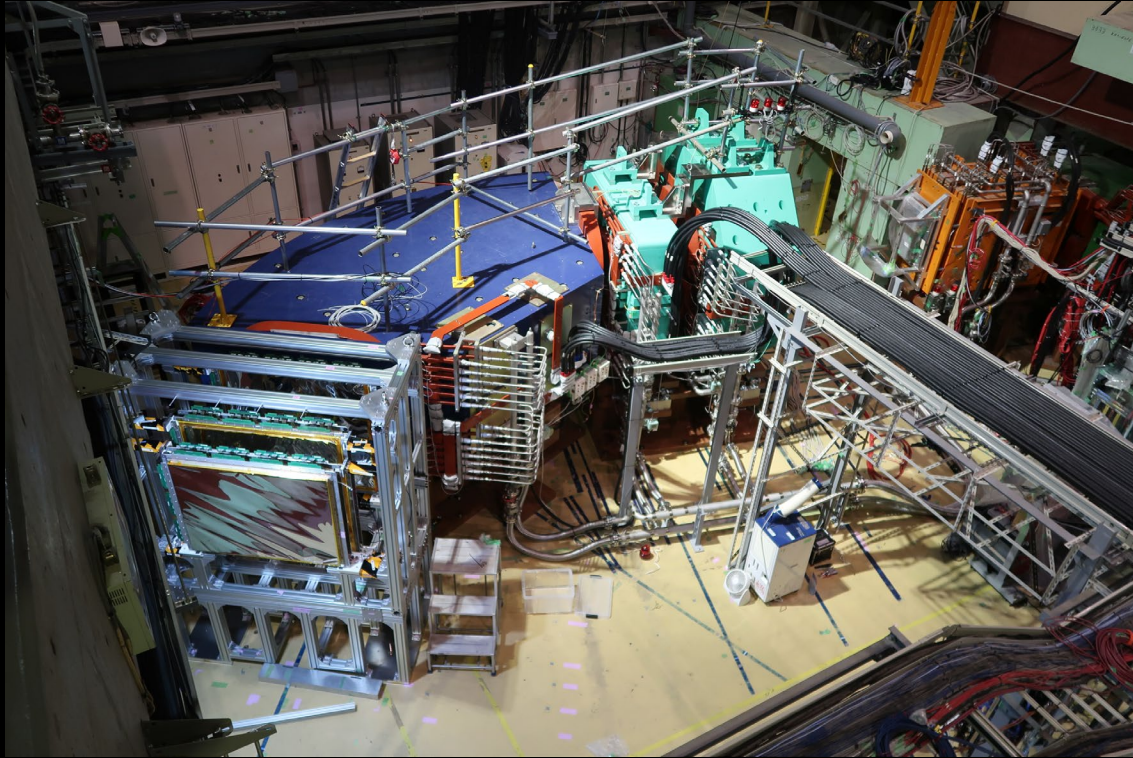
WEPH RE:2022 (online)

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

T. Gogami (Kyoto Univ.)

Oct 6, 2022

# $\Lambda$ , $\Xi$ HYPERNUCLEAR PRODUCTION



**S-2S** @ J-PARC, Japan

$\Lambda$ ,  $\Xi$  hypernuclei (2023~)



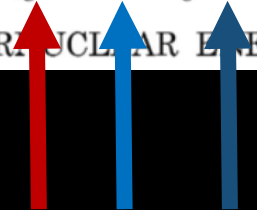
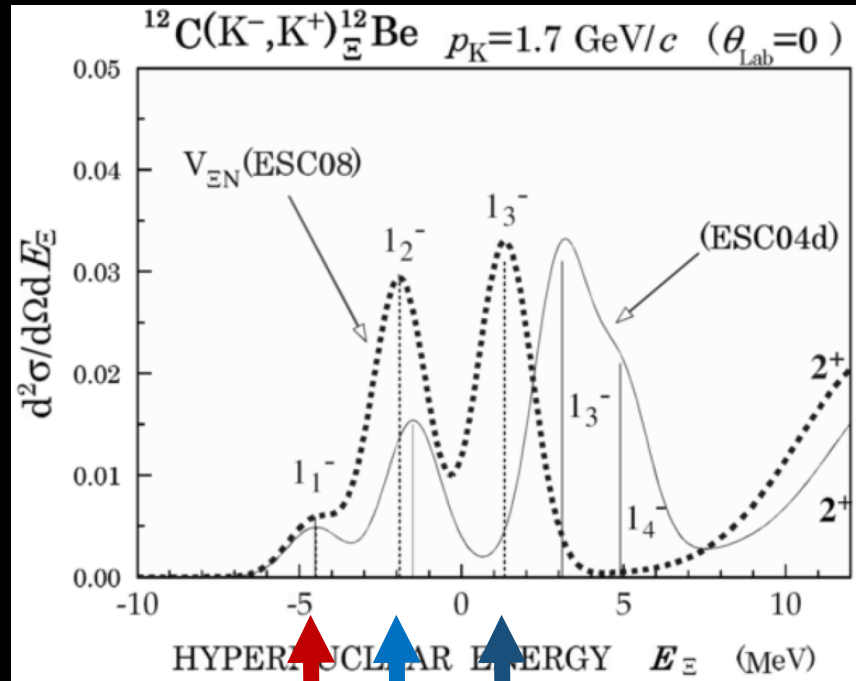
**HKS** @ JLab, US

$\Lambda$  hypernuclei (2025~)

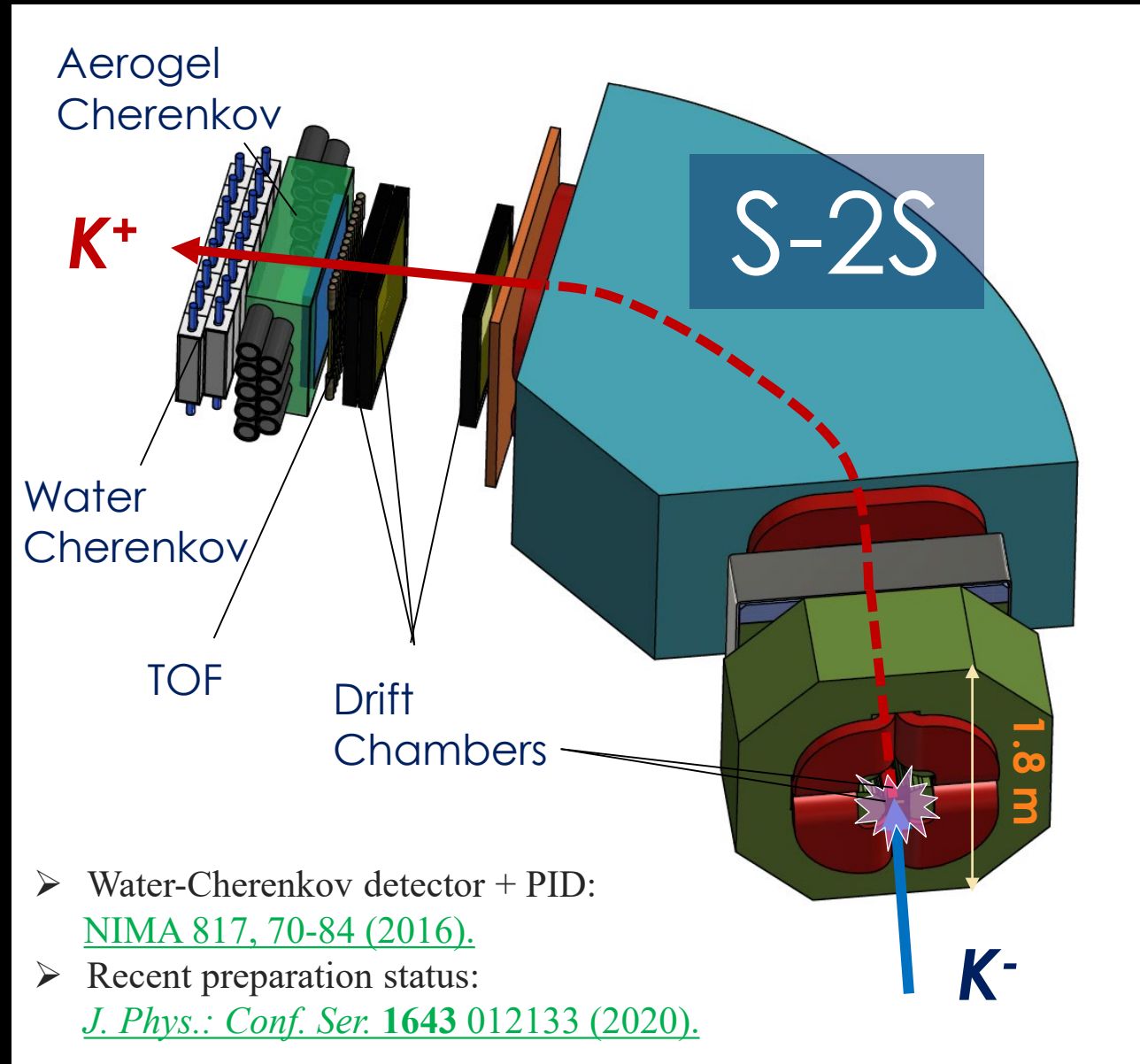
$$\Delta p/p = 6 \times 10^{-4} \text{ (FWHM)}$$

$$\rightarrow \Delta E \sim 2 \text{ MeV (FWHM)}$$

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



**Separable!!**



# $^{12}_{\text{E}}\text{Be} (^{11}\text{B} + \text{E}^-)$ : J-PARC E70

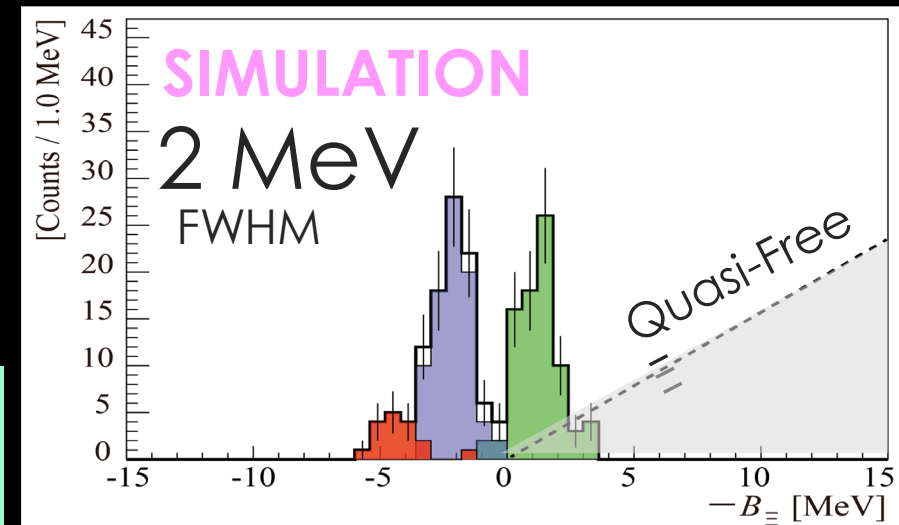
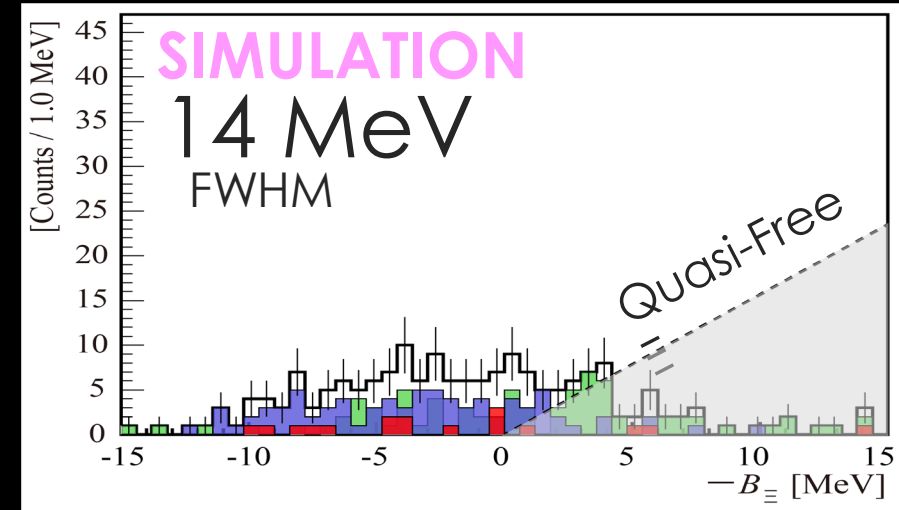
16/21

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

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

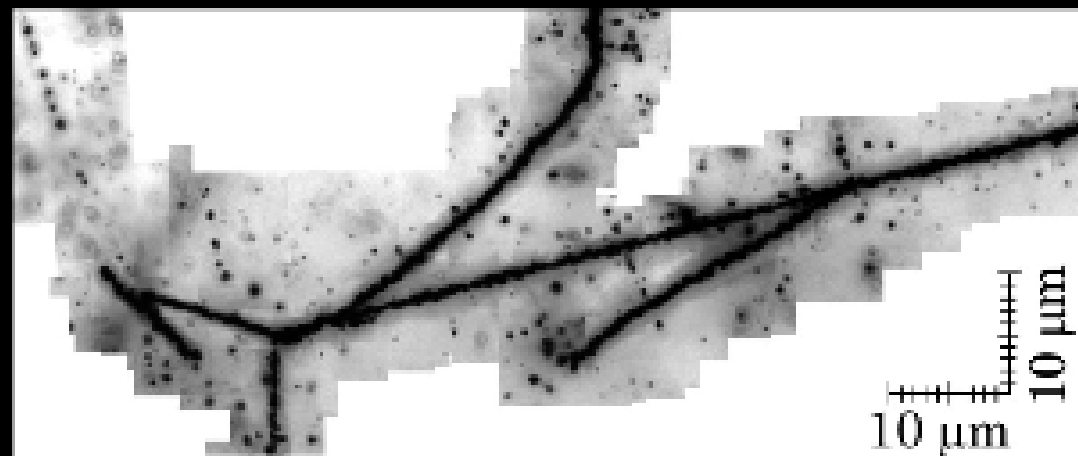
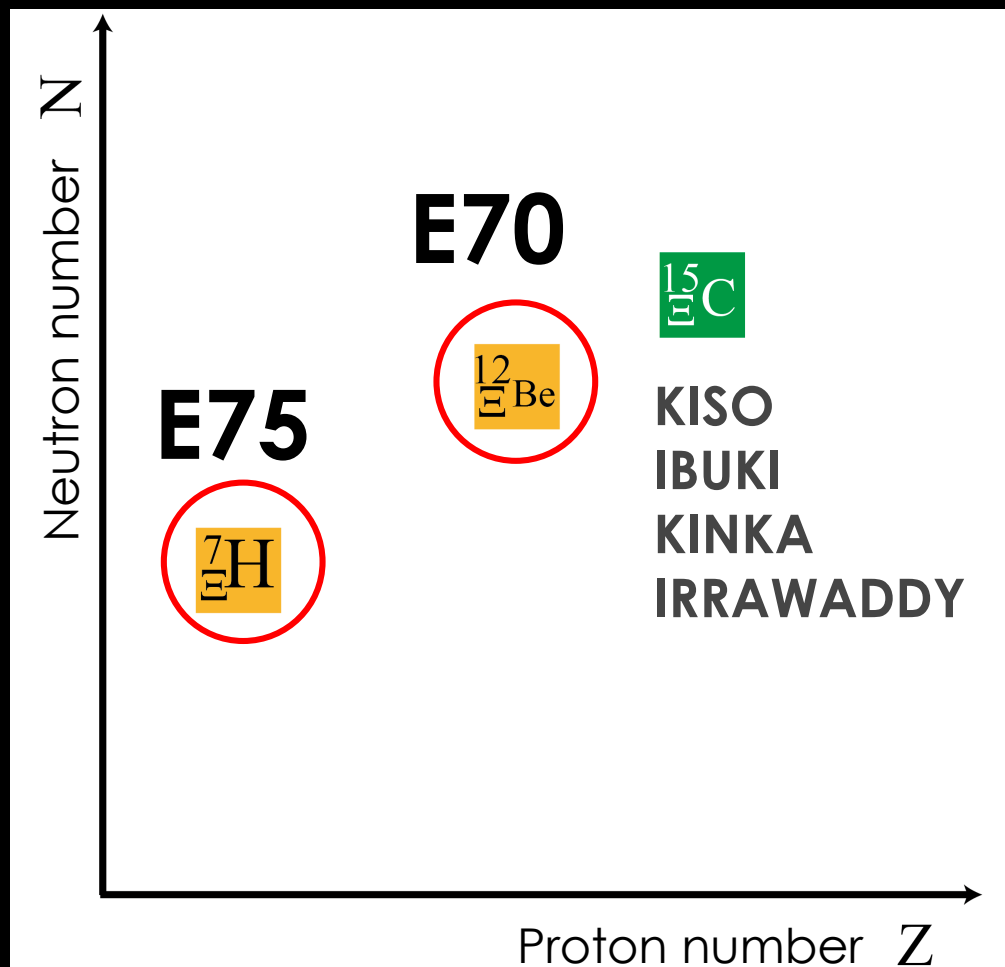
➔ **~100 counts**

**The experiment will start in 2023**



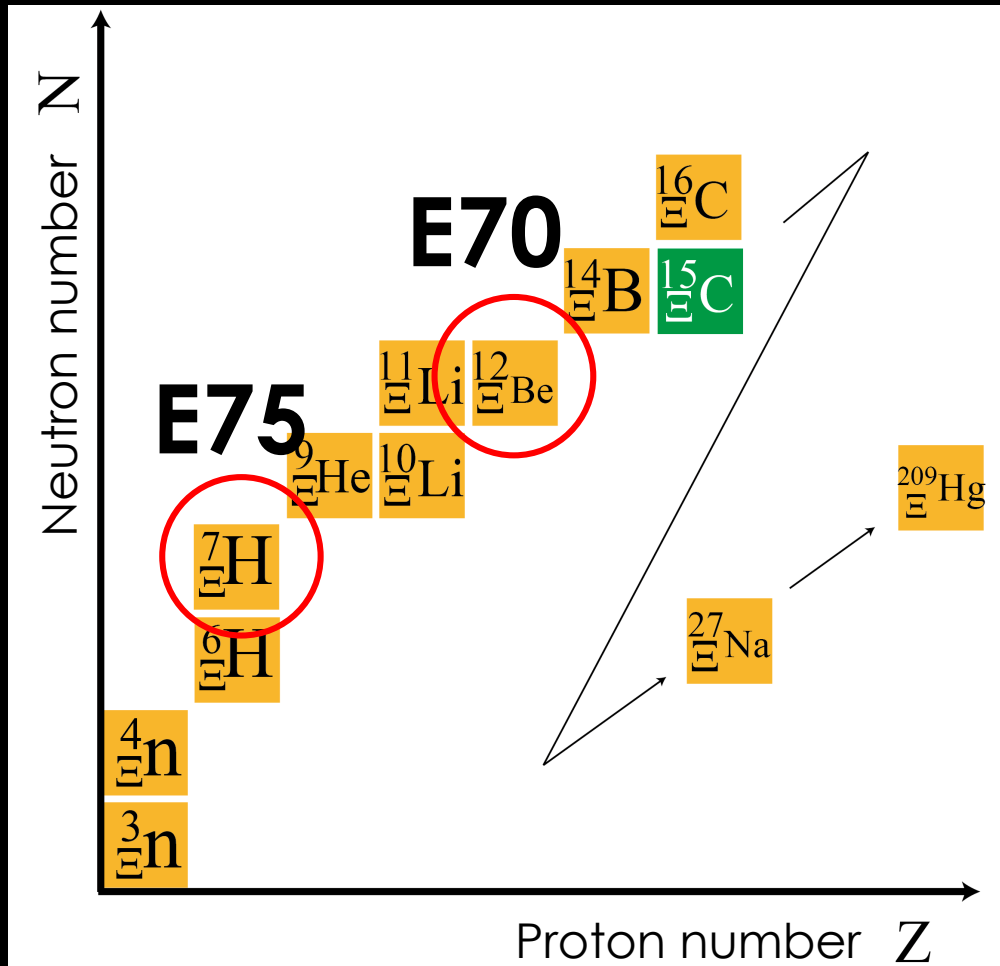
S-2S

# E 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  $\Xi / \Lambda$  hypernuclei

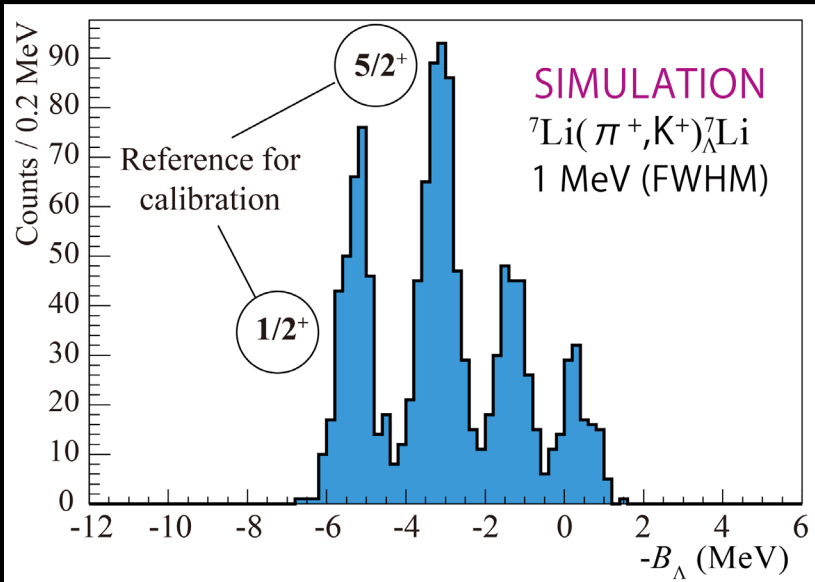
Theoretical supports are indispensable !

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

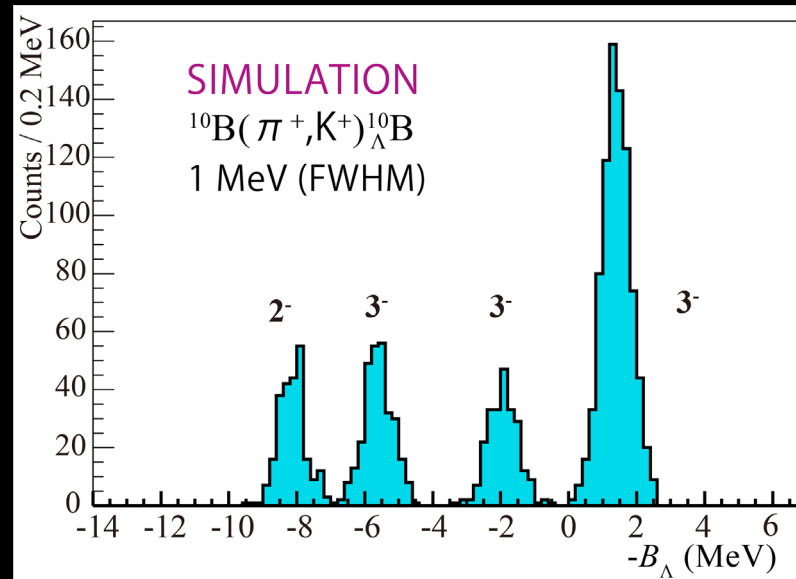
# New $\Lambda$ hypernuclear project with the $(\pi^+, K^+)$ reaction

16/20

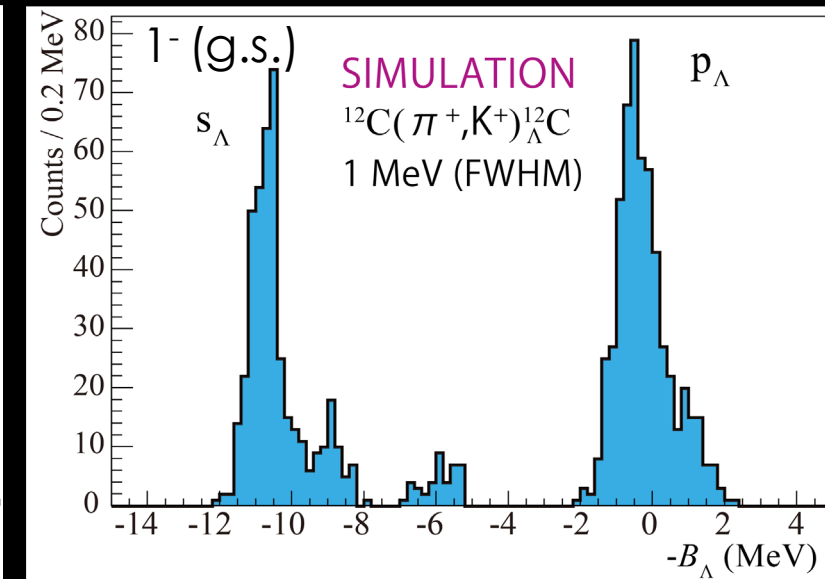
${}^7_{\Lambda}\text{Li}$



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



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



J-PARC E94

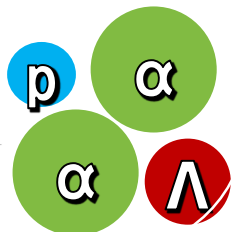
- Resolution = 1 MeV FWHM
- Accuracy = 100 keV

Download →

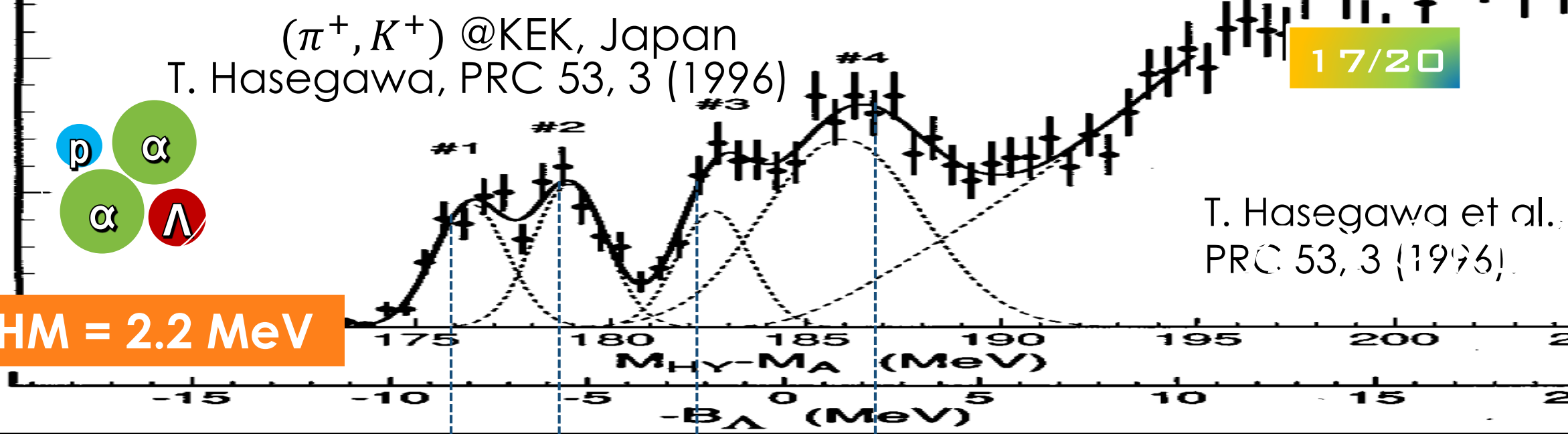
- ✓ [Proposal \(2022\)](#)
- ✓ [Presentation file in J-PARC PAC](#)

$(\pi^+, K^+)$  @KEK, Japan  
 T. Hasegawa, PRC 53, 3 (1996)

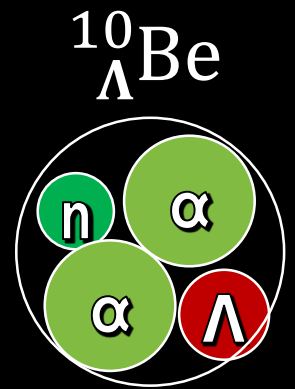
17/20



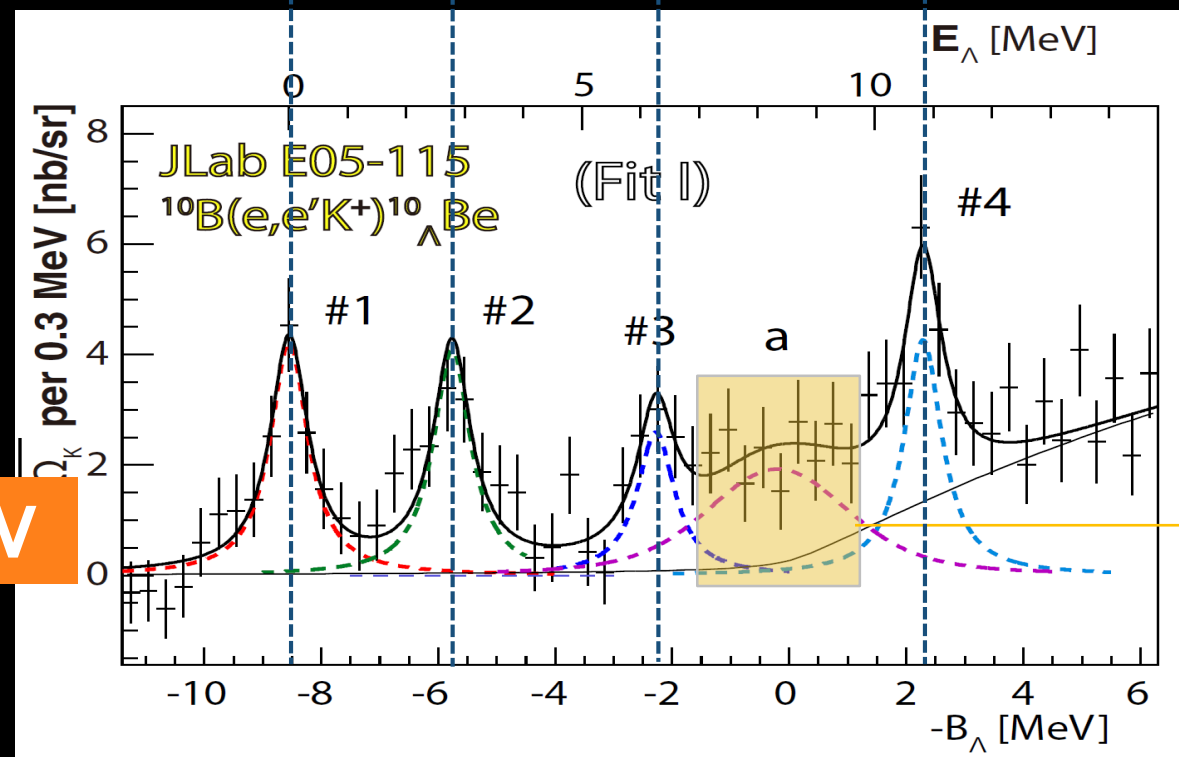
FWHM = 2.2 MeV



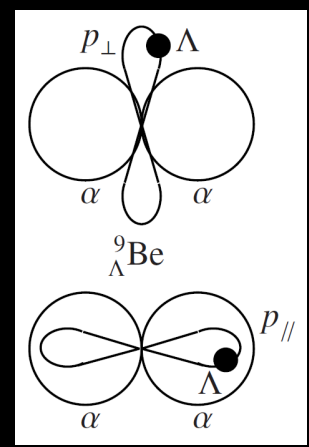
T. Hasegawa et al.,  
 PRC 53, 3 (1996).



FWHM = 0.8 MeV



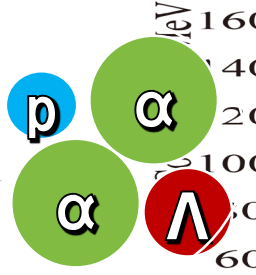
HKS Collaboration,  
 PRC 93, 034314 (2016).



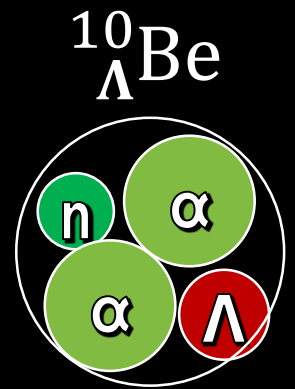
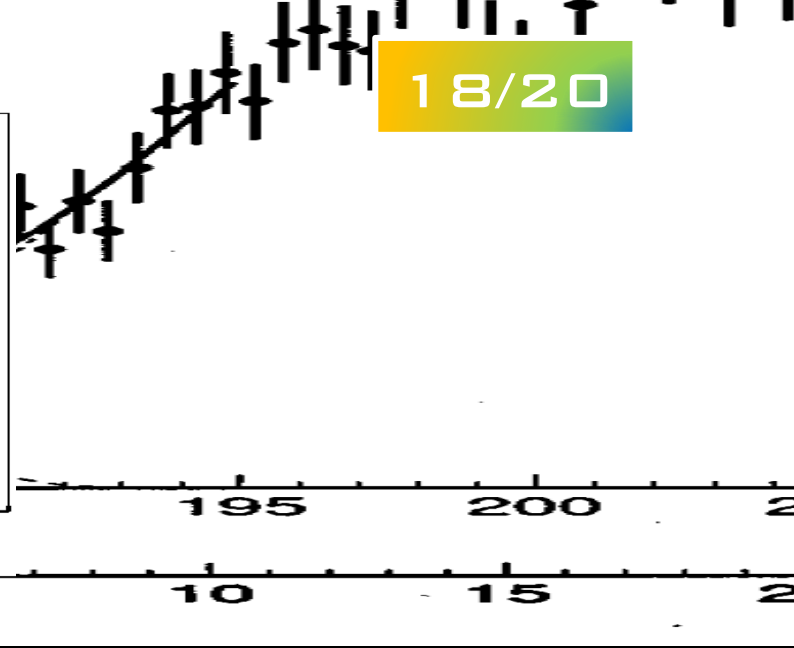
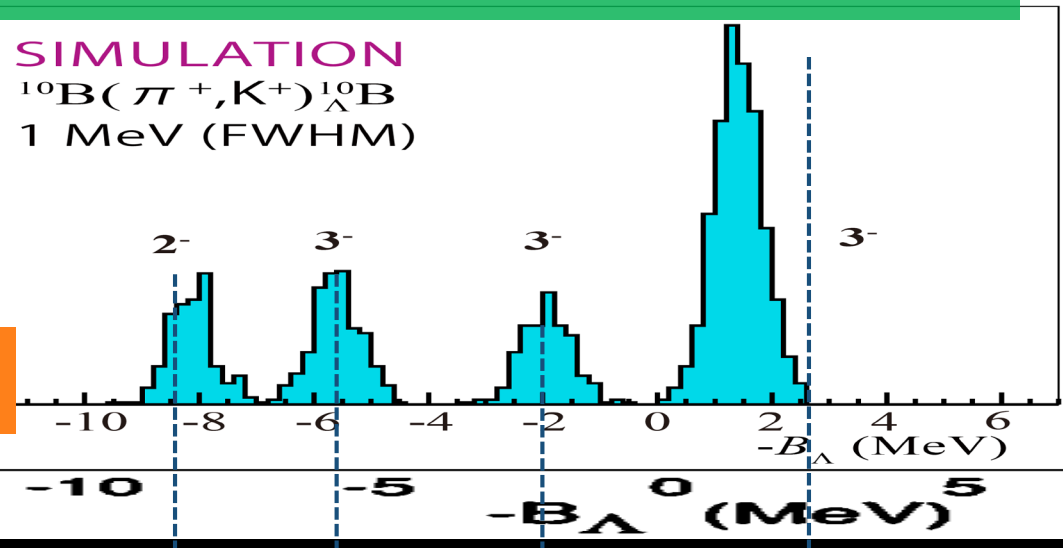
A. Umeya et al., *J. Phys.: Conf. Ser.* 1643 012110 (2020).



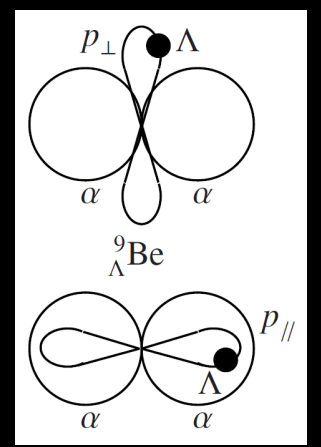
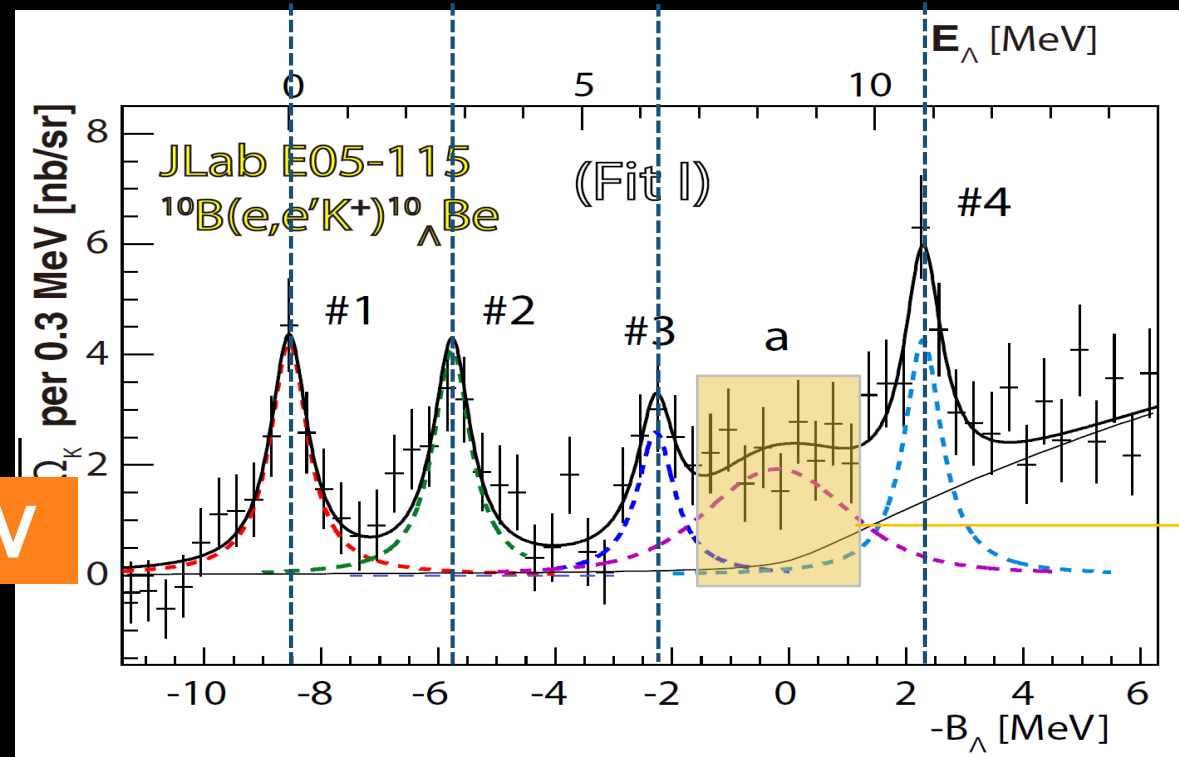
# $(\pi^+, K^+)$ J-PARC E94



FWHM = 1.0 MeV



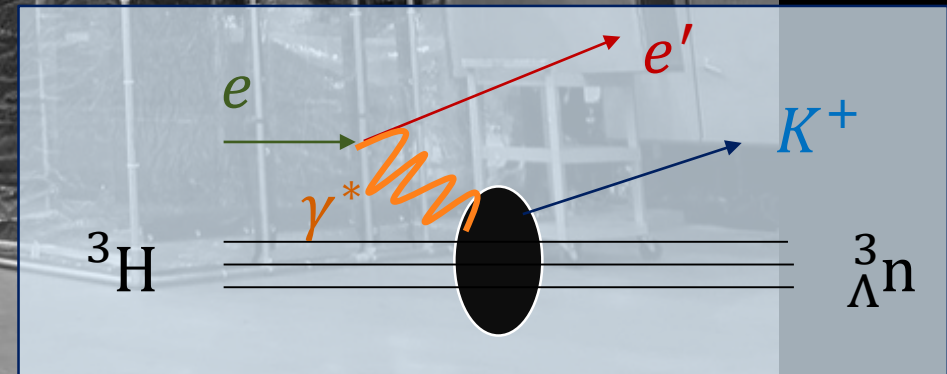
FWHM = 0.8 MeV



HKS Collaboration,  
 PRC 93, 034314 (2016).

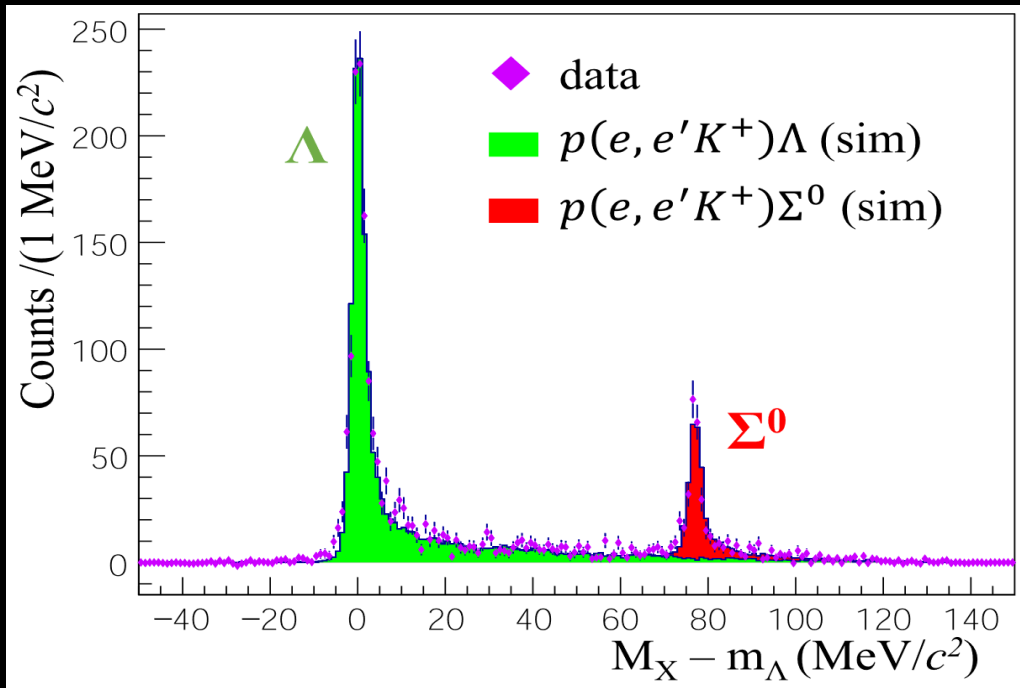
A. Umeya et al., *J. Phys.: Conf. Ser.* 1643 012110 (2020).

- 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).



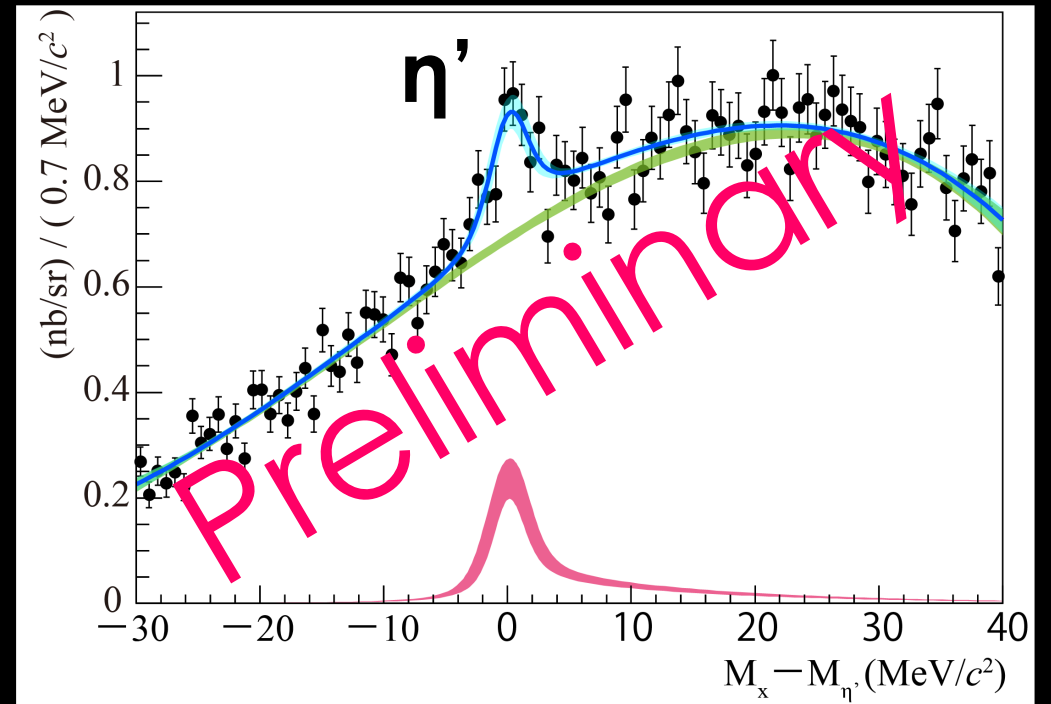
# Ongoing analyses for existing data from the $(e,e'K^+)$ experiment at JLab

PTEP 2022, 013D01 (2022)



Cross section for  $(\gamma^*, K^+)\Lambda, \Sigma^0$

➡ **K. Okuyama** (Tohoku Univ.)



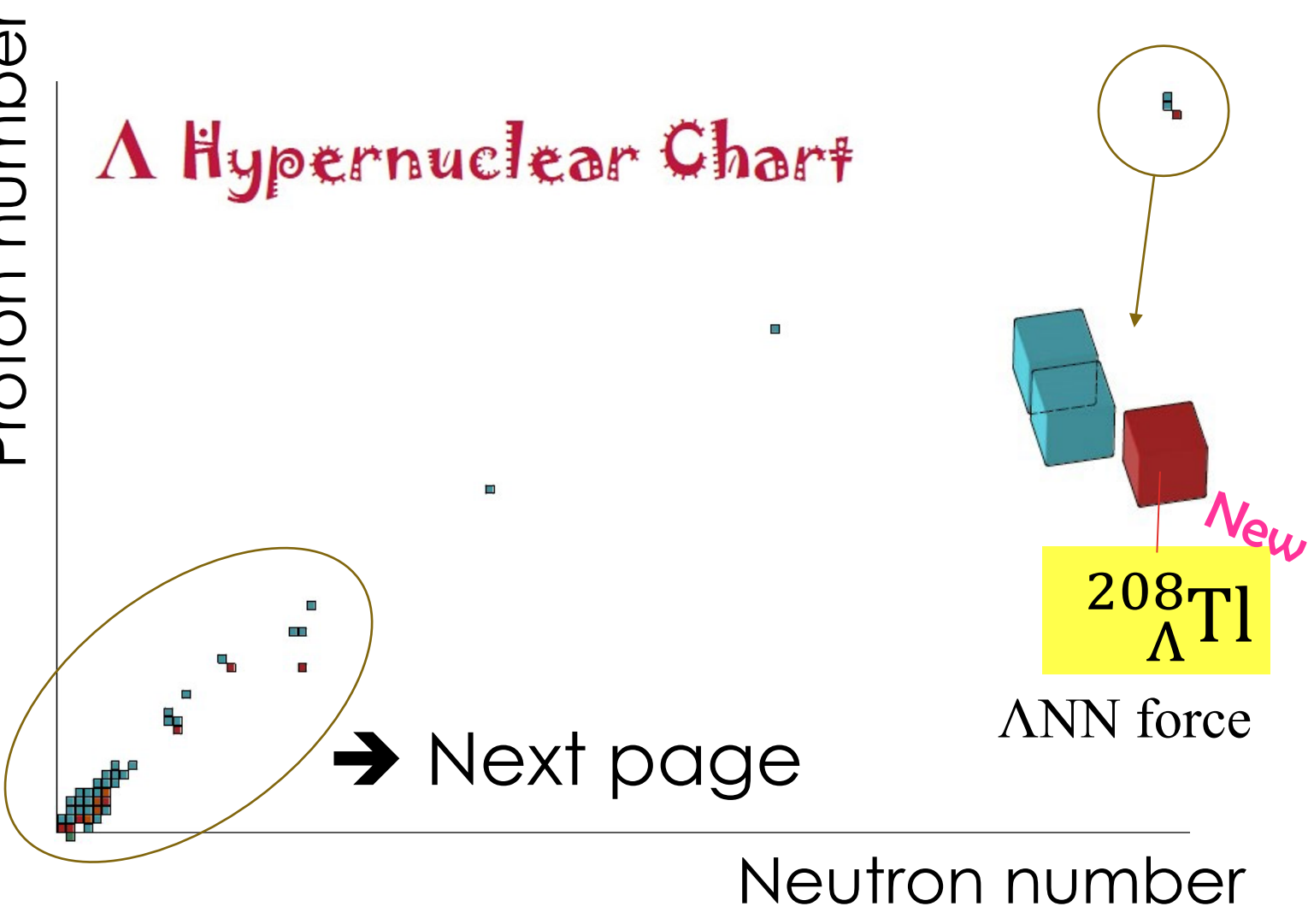
Cross section for  $(\gamma^*, p)\eta'$

➡ **T. Akiyama** (Tohoku Univ.)

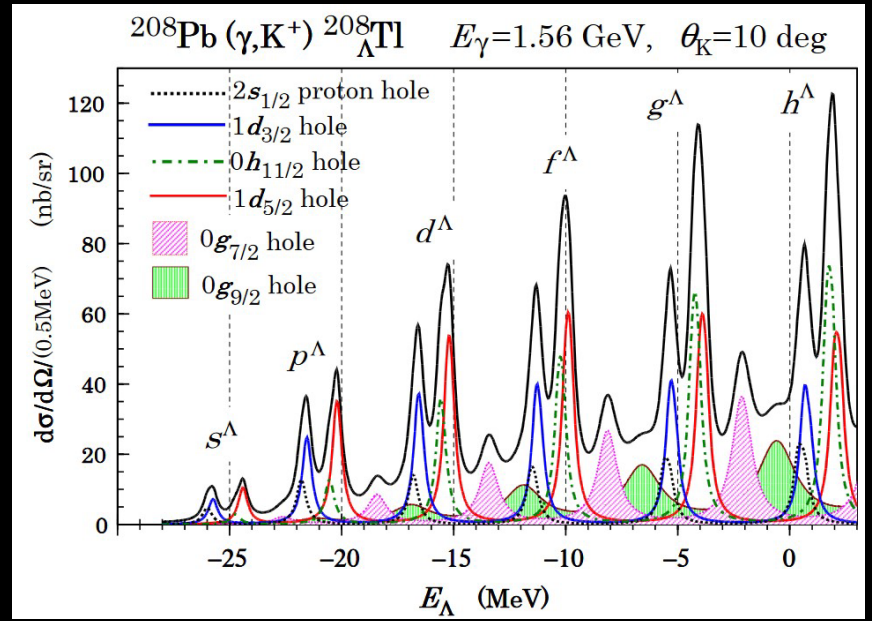
# Next experiments; light to heavy

Proton number

## $\Lambda$ Hypernuclear Chart



T. Motoba, [JPS Conf. Proc. 17, 011003 \(2017\)](#)

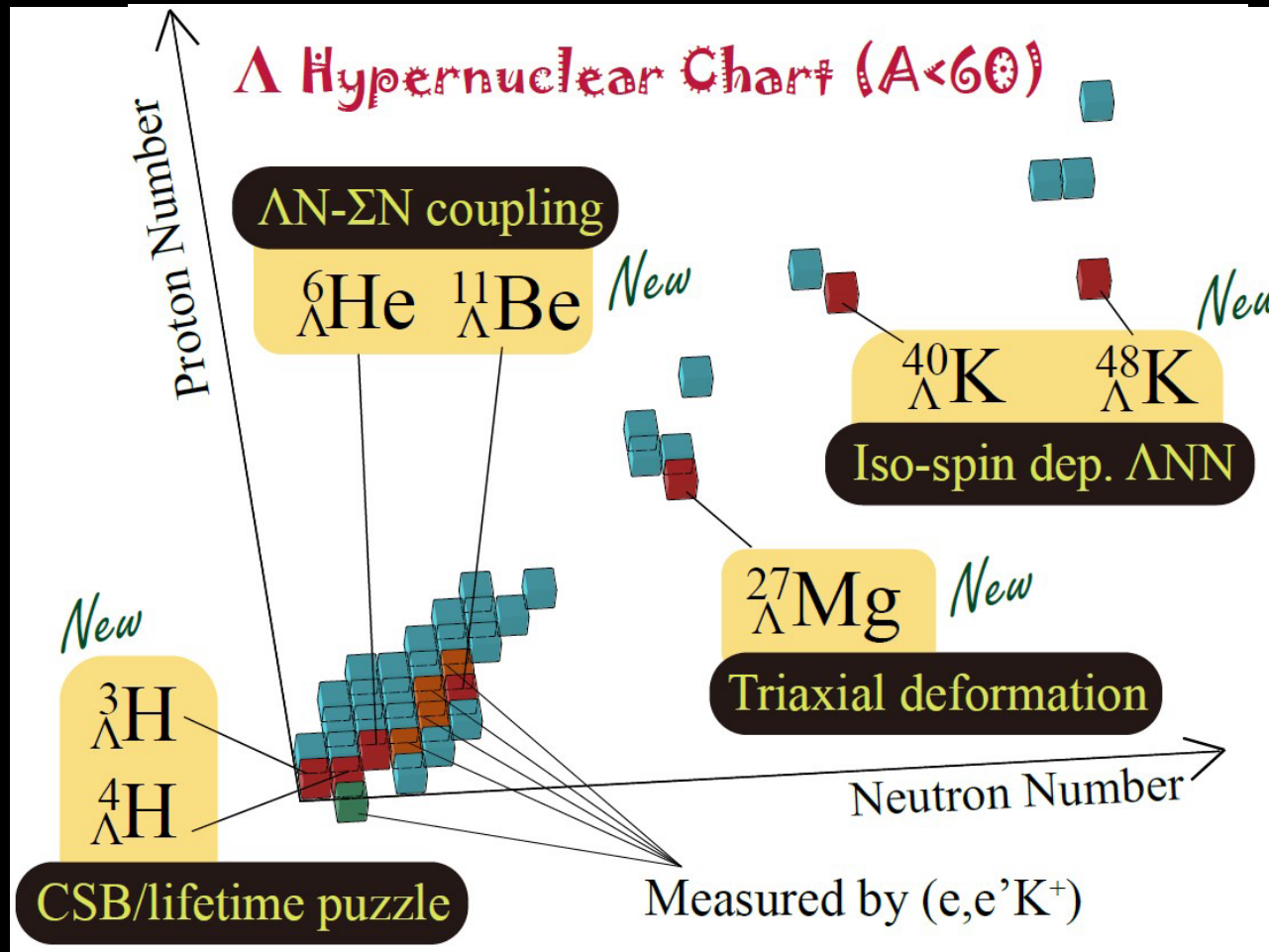


Approved experiments

➔ JLab E12-20-013

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

# Next experiments; light to heavy



## Approved experiments

→ **JLab E12-15-008**

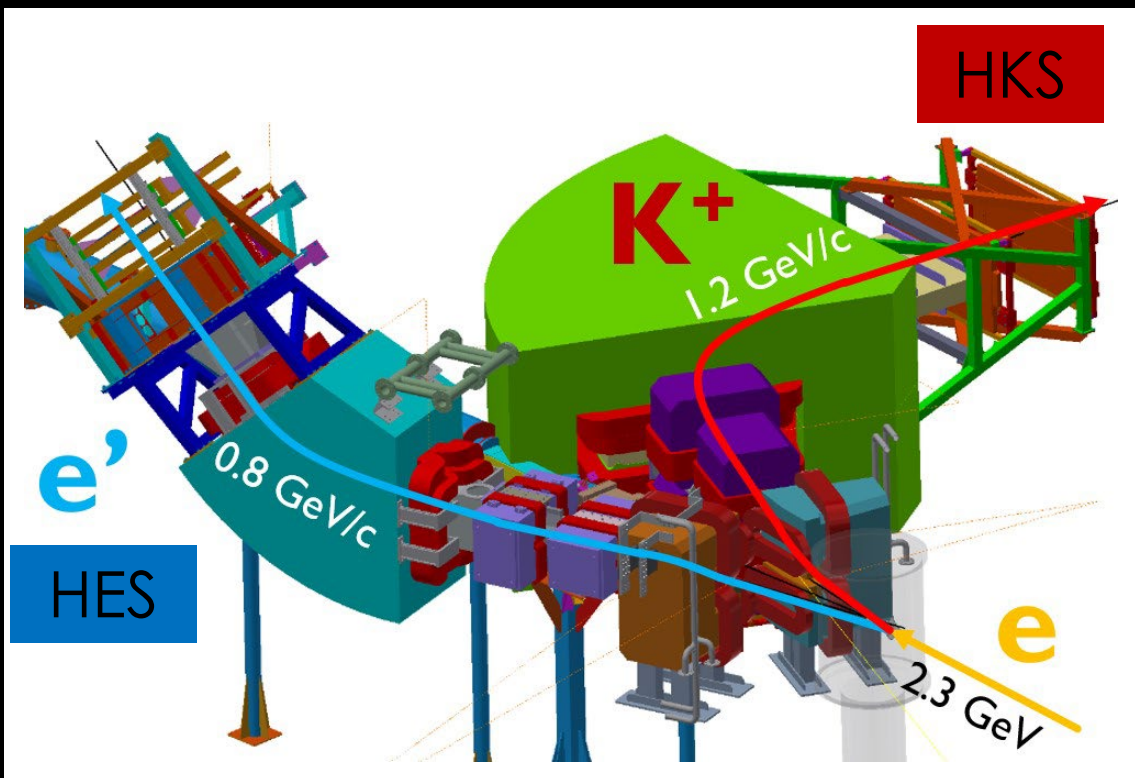
S.N. Nakamura et al,  
Proposal to JLab (2015)

→ **JLab E12-19-002**

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

## EXPERIMENTAL SETUP

Setup: PCS+HES+HKS



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

PCS



Already transported to JLab (2022)

# Engaging between theoretical and experimental work

Reaction	State etc.	Structure (calc.)	Cross section (calc.)	Experiment
${}^3\text{H}(e, e'K^+)nn\Lambda$	$nn\Lambda$ / FSI	○ / ?	✗ / ✗	○ / in progress
${}^3\text{He}(e, e'K^+){}^3_\Lambda\text{H}$	$1/2^+$ / $3/2^+$ , T=1	○ / ?	○ / ✗ (T. Mart et al., PRC 78, 01004 (2008))	Next (E12-19-002)
${}^4\text{He}(e, e'K^+){}^4_\Lambda\text{H}$	$1^+$	○ (Motoba, JPS Conf. Proc. 17, 011003 (2017))	○ (Motoba, JPS Conf. Proc. 17, 011003 (2017))	Next (E12-19-002)
${}^6\text{Li}(e, e'K^+){}^6_\Lambda\text{He}$		○ (E. Hiayama et al., PRC 53, 5, 2075 (1996))	✗	Next (E12-15-008)
${}^9\text{Be}(e, e'K^+){}^9_\Lambda\text{Li}$		○ (Motoba et al., PTPS 185 (2010))	○ (Motoba et al., PTPS 185 (2010))	○ (Halls A and C)
${}^{11}\text{B}(e, e'K^+){}^{11}_\Lambda\text{Be}$		○ (Umeya, Talk in JPS meeting 2022)	○ (Umeya, Talk in JPS meeting 2022)	Next (E12-15-008)
${}^{27}\text{Al}(e, e'K^+){}^{27}_\Lambda\text{Mg}$		○ (Isaka, talk in PPPY- $\Lambda$ 2021)	✗	Next (E12-19-002)
${}^{40}\text{Ca}(e, e'K^+){}^{40}_\Lambda\text{K}$		○ (Motoba et al., PTPS 185 (2010))	○ (Motoba et al., PTPS 185 (2010))	Next (E12-15-008)
${}^{48}\text{Ca}(e, e'K^+){}^{48}_\Lambda\text{K}$		○ (Umeya, talk in WEPH2021)	○ (Umeya, talk in WEPH2021)	Next (E12-15-008)
${}^{208}\text{Pb}(e, e'K^+){}^{208}_\Lambda\text{Tl}$		○ (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?

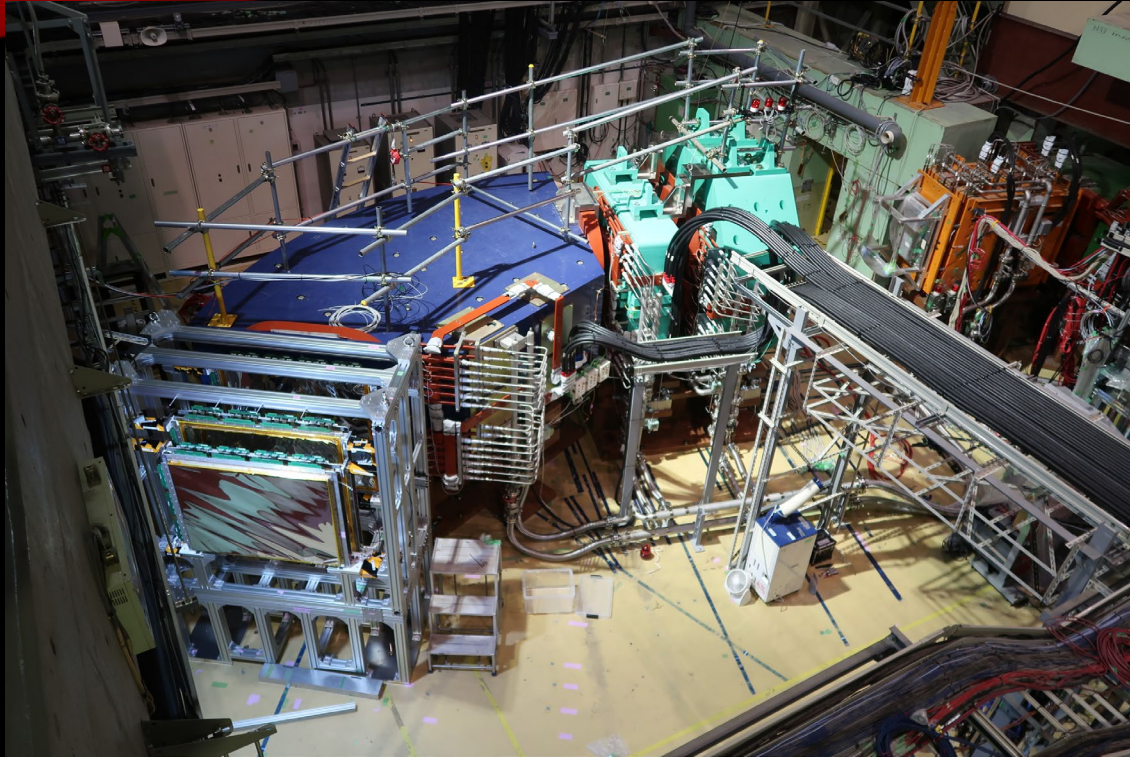
## Isobaric hypernuclei

- ${}^{48}\text{Ti}(e, e' K^+) {}_{\Lambda}^{48}\text{Sc}$ 
  - $(Z, N) = {}_{\Lambda}^{48}\text{Sc} (21, 26)$  vs.  ${}_{\Lambda}^{48}\text{K} (19, 28)$   
→ the same mass number, but the different  $\delta$
- ${}^{40}\text{Ar}(e, e' K^+) {}_{\Lambda}^{40}\text{Cl}$  vs.  ${}^{40}\text{Ca}(e, e' K^+) {}_{\Lambda}^{40}\text{K}$
- ${}^{46}\text{Ca}(e, e' K^+) {}_{\Lambda}^{46}\text{K}$  vs.  ${}^{46}\text{Ti}(e, e' K^+) {}_{\Lambda}^{46}\text{Sc}$
- ${}^{48}\text{Ca}(e, e' K^+) {}_{\Lambda}^{48}\text{K}$  vs.  ${}^{48}\text{Ti}(e, e' K^+) {}_{\Lambda}^{48}\text{Sc}$
- ${}^{50}\text{Ti}(e, e' K^+) {}_{\Lambda}^{50}\text{Sc}$  vs.  ${}^{50}\text{V}(e, e' K^+) {}_{\Lambda}^{50}\text{Ti}$  vs.  ${}^{50}\text{Cr}(e, e' K^+) {}_{\Lambda}^{50}\text{V}$
- ${}^{54}\text{Cr}(e, e' K^+) {}_{\Lambda}^{54}\text{V}$  vs.  ${}^{54}\text{Fe}(e, e' K^+) {}_{\Lambda}^{54}\text{Mn}$
- ... (many candidates)

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



# SUMMARY



**S-2S** @ J-PARC, Japan

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



**HKS** @ JLab, US

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

**Any suggestions for the next to next experiment?**