Idea for new proposal

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Idea

- ${}^{6}_{\Lambda}\mathrm{He}$
- ${}^{9}_{\Lambda}\mathrm{Li}$
- ${}^{11}_{\Lambda}\mathrm{Be}$

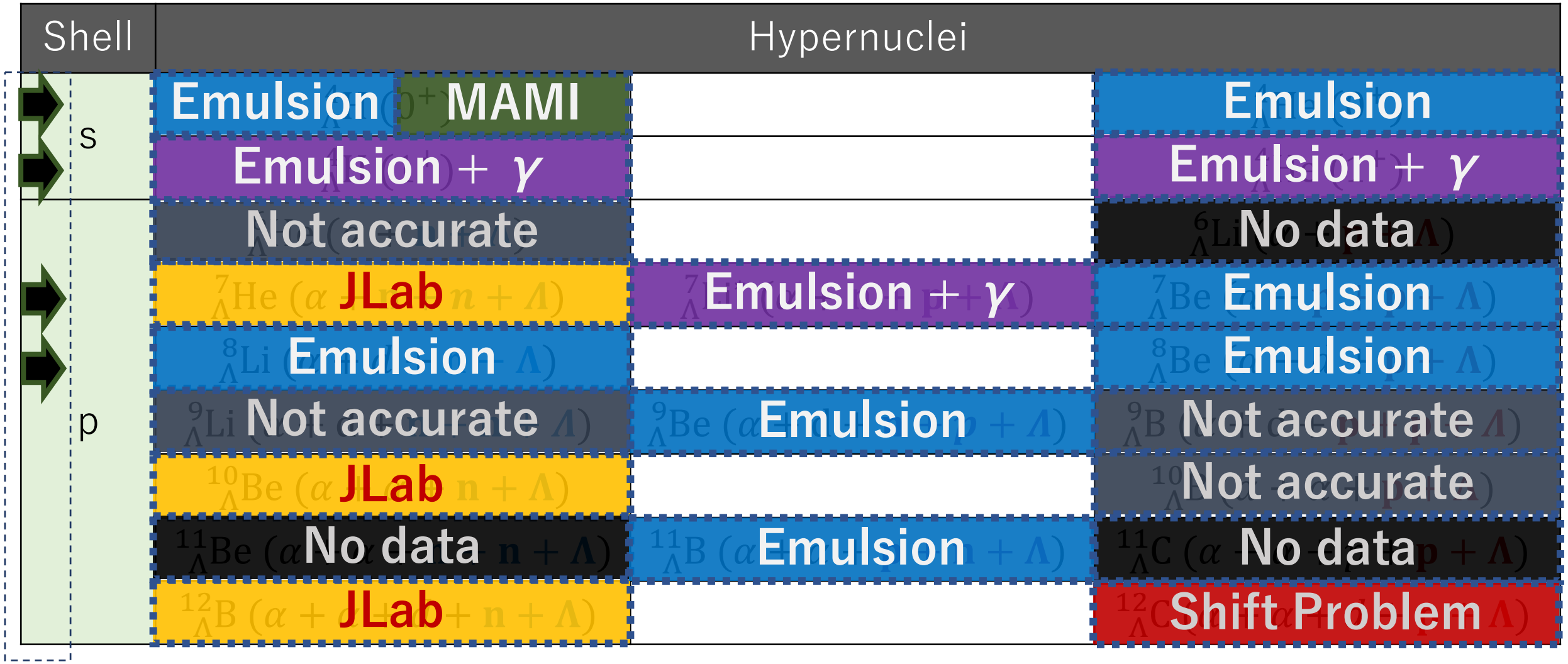
$10 + 10 + 5 =$ **25 PAC days**

➡ To complete CSB data set in p-shell

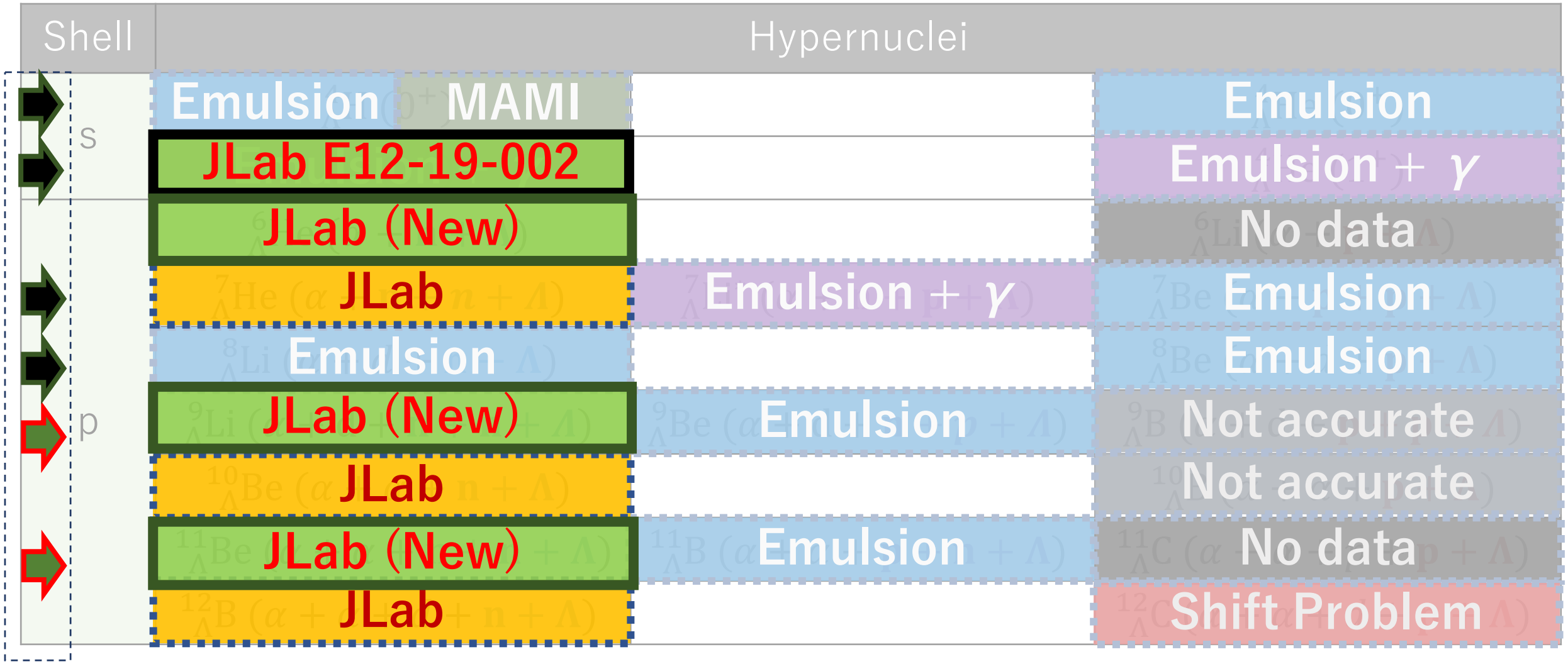
Data to investigate ΛN CSB

Shell	Hypernuclei		
s	${}^{4}_{\Lambda}\mathrm{H}\ (0^{+})$		${}^{4}_{\Lambda}\mathrm{He}\ (0^{+})$
	${}^{4}_{\Lambda}\mathrm{H}\ (1^{+})$		${}^{4}_{\Lambda}\mathrm{He}\ (1^{+})$
p	${}^{6}_{\Lambda}\mathrm{He}\ (\alpha + \mathbf{n} + \boldsymbol{\Lambda})$		${}^{6}_{\Lambda}\mathrm{Li}\ (\alpha + \mathbf{p} + \boldsymbol{\Lambda})$
	${}^{7}_{\Lambda}\mathrm{He}\ (\alpha + \mathbf{n} + \boldsymbol{n} + \boldsymbol{\Lambda})$	${}^{7}_{\Lambda}\mathrm{Li}^{*}\ (\alpha + \mathbf{n} + \mathbf{p} + \boldsymbol{\Lambda})$	${}^{7}_{\Lambda}\mathrm{Be}\ (\alpha + \mathbf{p} + \mathbf{p} + \boldsymbol{\Lambda})$
	${}^{8}_{\Lambda}\mathrm{Li}\ (\alpha + d + \mathbf{n} + \boldsymbol{\Lambda})$		${}^{8}_{\Lambda}\mathrm{Be}\ (\alpha + d + \mathbf{p} + \boldsymbol{\Lambda})$
	${}^{9}_{\Lambda}\mathrm{Li}\ (\alpha + \mathrm{d} + \mathbf{n} + \mathbf{n} + \boldsymbol{\Lambda})$	${}^{9}_{\Lambda}\mathrm{Be}\ (\alpha + \mathrm{d} + \mathbf{n} + \boldsymbol{p} + \boldsymbol{\Lambda})$	${}^{9}_{\Lambda}\mathrm{B}\ (\alpha + \mathrm{d} + \mathbf{p} + \mathbf{p} + \boldsymbol{\Lambda})$
	${}^{10}_{\Lambda}\mathrm{Be}\ (\alpha + \alpha + \mathbf{n} + \boldsymbol{\Lambda})$		${}^{10}_{\Lambda}\mathrm{B}\ (\alpha + \alpha + \mathbf{p} + \boldsymbol{\Lambda})$
	${}^{11}_{\Lambda}\mathrm{Be}\ (\alpha + \alpha + \mathbf{n} + \mathbf{n} + \boldsymbol{\Lambda})$	${}^{11}_{\Lambda}\mathrm{B}\ (\alpha + \alpha + \mathbf{p} + \mathbf{n} + \boldsymbol{\Lambda})$	${}^{11}_{\Lambda}\mathrm{C}\ (\alpha + \alpha + p + \mathbf{p} + \boldsymbol{\Lambda})$
	${}^{12}_{\Lambda}\mathrm{B}\ (\alpha + \alpha + d + \mathbf{n} + \boldsymbol{\Lambda})$		${}^{12}_{\Lambda}\mathrm{C}\ (\alpha + \alpha + d + \mathbf{p} + \boldsymbol{\Lambda})$

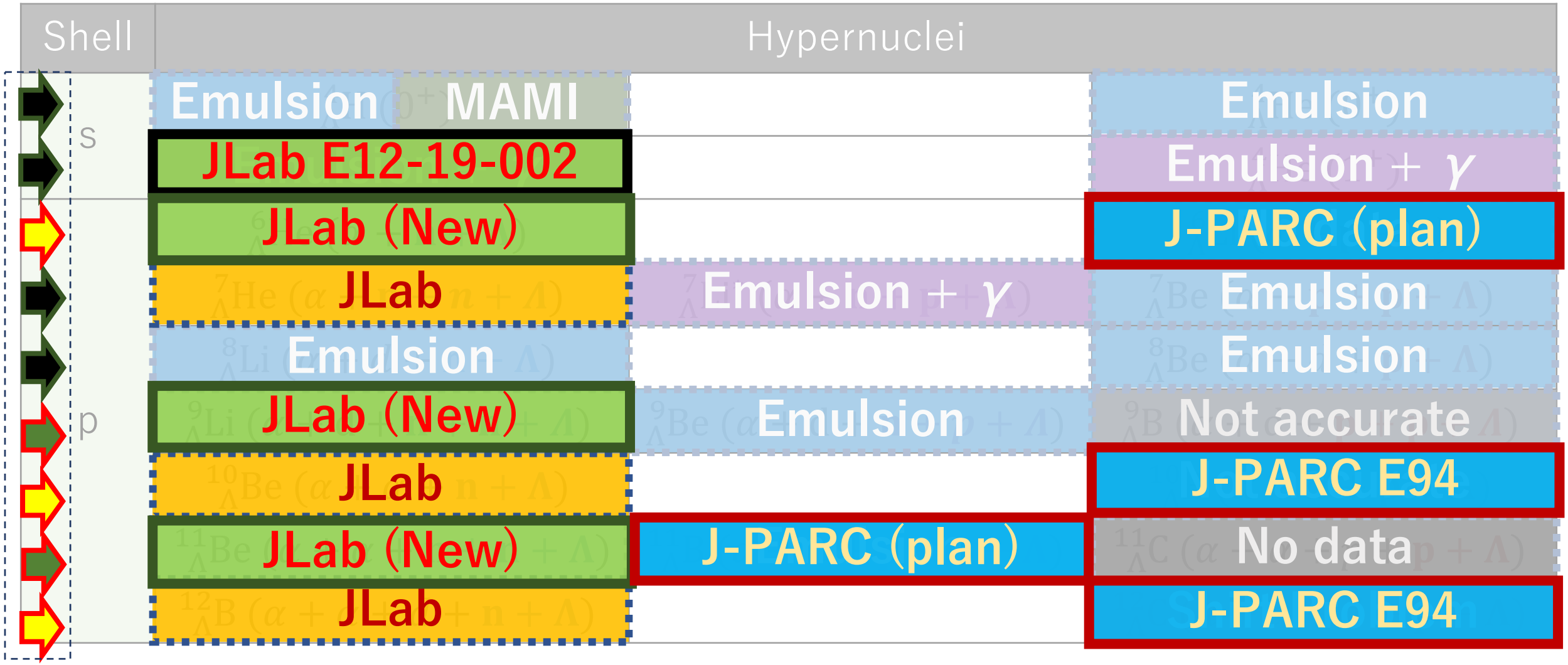
Data to investigate Λ N CSB



Data to investigate ΛN CSB



Data to investigate Λ N CSB



Yield estimation

Table 3.3: Estimated yields for the solid targets.

Hypernucleus	${}^{6}_{\Lambda}$He	${}^{11}_{\Lambda}$Be	${}^{12}_{\Lambda}$B	${}^{40}_{\Lambda}$K	${}^{48}_{\Lambda}$K	${}^{208}_{\Lambda}$Tl
Target thickness [/(mg/cm^2)]	100	100	100	77.5	77.5	100
Cross section (g.s.) [/(nb/sr)]	10	10	100	50	50	86
Beam intensity (/μA)			50			25
Beam time (/hours)	28	28	36	230	280	480
Yield (g.s.)	21	11	120	130	130	42

https://researchmap.jp/gogami/published_papers/41459812/attachment_file.pdf

- Systematic error = 55 keV
- Energy resolution = 600 keV FWHM
- No accidental background

Hypernucleus	Assumed CS [/(nb/sr)]	T thickness [/mg/cm^2]	Beam current (/ μ A)	Beam time [/days (/hours)]	Yield	Total error
${}^{6}_{\Lambda}$He	10	100	20	10 (240)	72	$<$ **65 keV**
${}^{9}_{\Lambda}$Li	10	100	30	10 (240)	72	
${}^{11}_{\Lambda}$Be	30	100	30	5 (120)	84	

Reference for ${}^{11}_{\Lambda}$Be production → https://wiki.jlab.org/tegwiki/index.php/HIEI2022_20220316

TABLE IV. Contributions to CSB in the $A = 7$ and 8 isospin multiplets, based on the YN potentials NLO13(500) and NLO19(500) (including 3N forces and SRG-induced YNN interactions). The results are for the original potentials (without CSB force) and for the scenario CSB1, see text. Results by Gal [37] and by Hiyama *et al.* [13] are included for the ease of comparison. All energies are in keV. The estimated uncertainties for $A = 7$ and 8 systems are 30 and 50 keV, respectively.

				ΔV_{YN}			
		ΔT	ΔV_{NN}	$^1S_0$	$^3S_1$	Total	ΔB_Λ
$^7_\Lambda$Be - $^7_\Lambda$Li*	NLO13	7	−24	−1	0	0	−17
	NLO13-CSB	8	−24	−49	26	−24	−40
	NLO19	6	−40	−1	0	0	−34
	NLO19-CSB	6	−41	−43	42	9	−35
	Hiyama [13]		−70			200	150
	Gal [37]	3	−70			50	−17
	Experiment [6]						-100 ± 90
$^7_\Lambda$Li* - $^7_\Lambda$He	NLO13	8	−13	0	0	0	−5
	NLO13-CSB	7	−14	−49	26	−24	−31
	NLO19	5	−22	−43	42	0	−17
	NLO19-CSB	5	−21	−38	37	−1	−16
	Hiyama [13]		−80			200	130
	Gal [38]	2	−80			50	−28
	Experiment [6]						-20 ± 230[a] -50 ± 190
$^8_\Lambda$Be - $^8_\Lambda$Li	NLO13	12	8	−2	0	−4	16
	NLO13-CSB	12	7	100	56	159	178
	NLO19	7	−11	−1	0	−2	−6
	NLO19-CSB	6	−11	62	79	147	143
	Hiyama [13]		40				160
	Gal [37]	11	−81			119	49
	Experiment [4]						40 ± 60

[a]The difference between $B_\Lambda(^7_\Lambda\text{Li}^*)$ and $B_\Lambda(^7_\Lambda\text{He})$ is -20 ± 230 keV for the FINUDA and JLab results, but -50 ± 190 keV when the revised SKS and JLab results are used [6].

NCSM

Cluster + Phenom. CSB

Shell model + eff. Λ Σ coup.

Hoai Le et al., Phys. Rev. C 107, 024002 (2023) https://doi.org/10.1103/PhysRevC.107.024002

Summary

- ${}^{6}_{\Lambda}\mathrm{He}$
- ${}^{9}_{\Lambda}\mathrm{Li}$
- ${}^{11}_{\Lambda}\mathrm{Be}$

$10 + 10 + 5 =$ **25 PAC days**

To complete CSB data set in p-shell

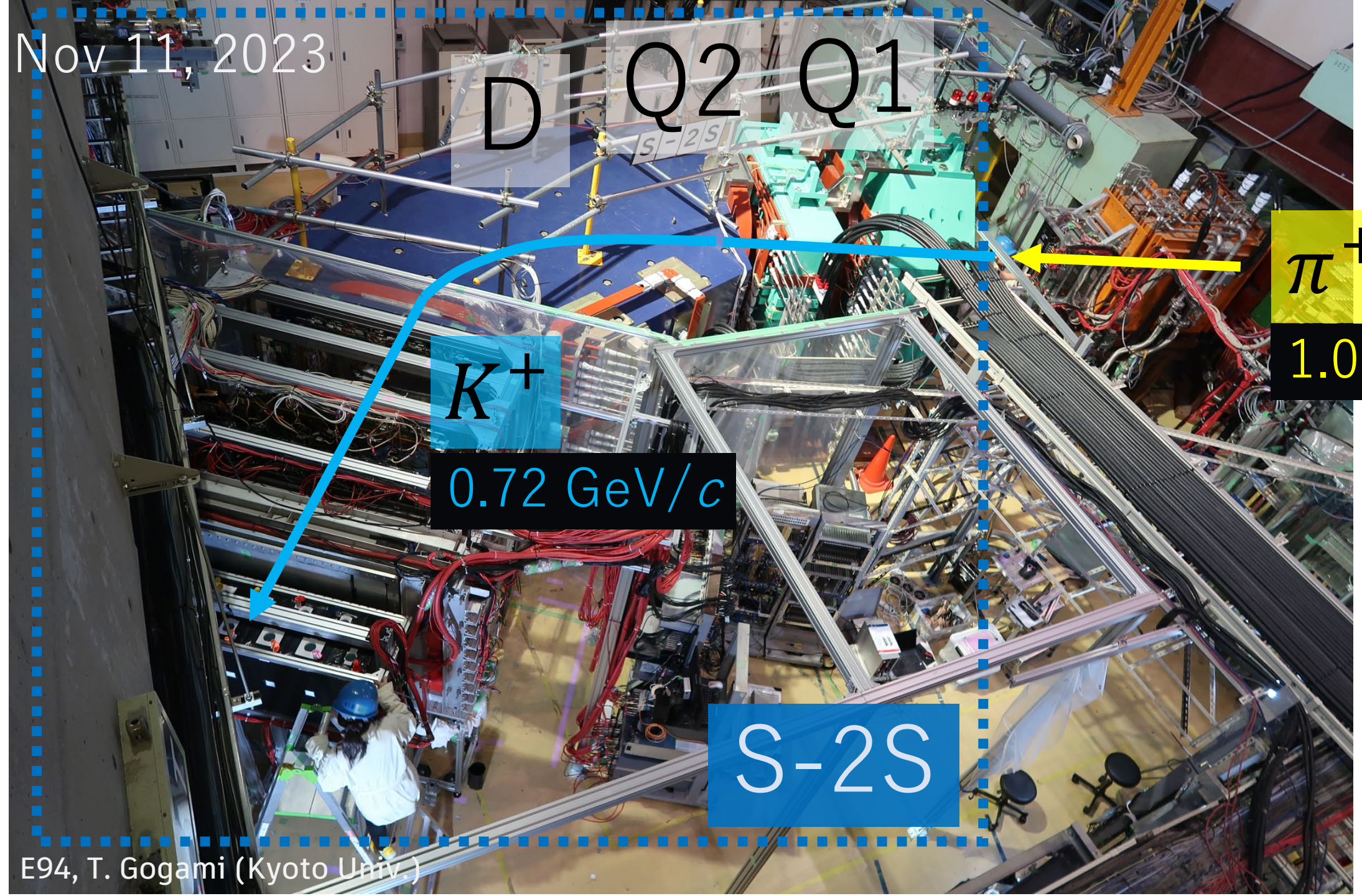
Backup

J-PARC E94

New generation Λ hypernuclear spectroscopy with the (π^+,K^+) reaction by S-2S

Proposal:
https://j-parc.jp/researcher/Hadron/en/pac_2208/pdf/P94_2022-18.pdf

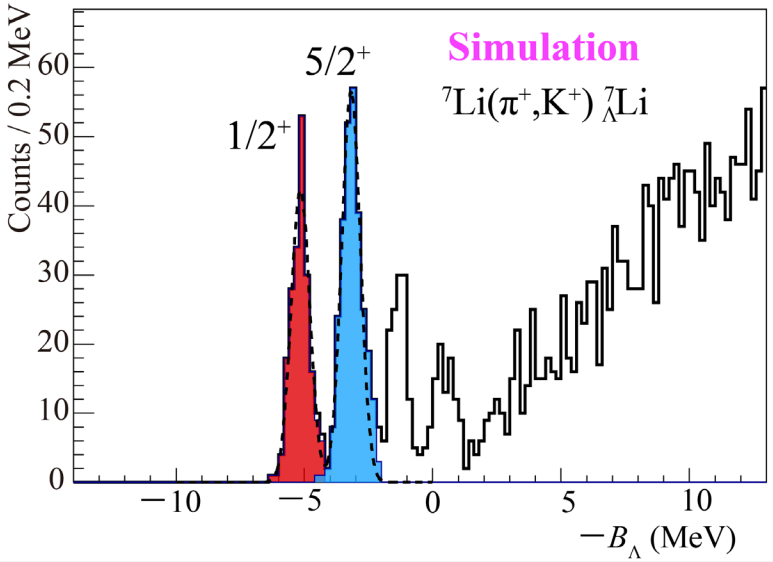
Recent presentation (in 35th J-PARC PAC):
https://researchmap.jp/gogami/presentations/41252398/attachment_file.pdf


Nov 11, 2023
D
Q2
Q1
S-2S
K^+
0.72 GeV/c
π^+
1.05 GeV/c
S-2S
E94, T. Gogami (Kyoto Univ.)

Expected spectra in J-PARC E94

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

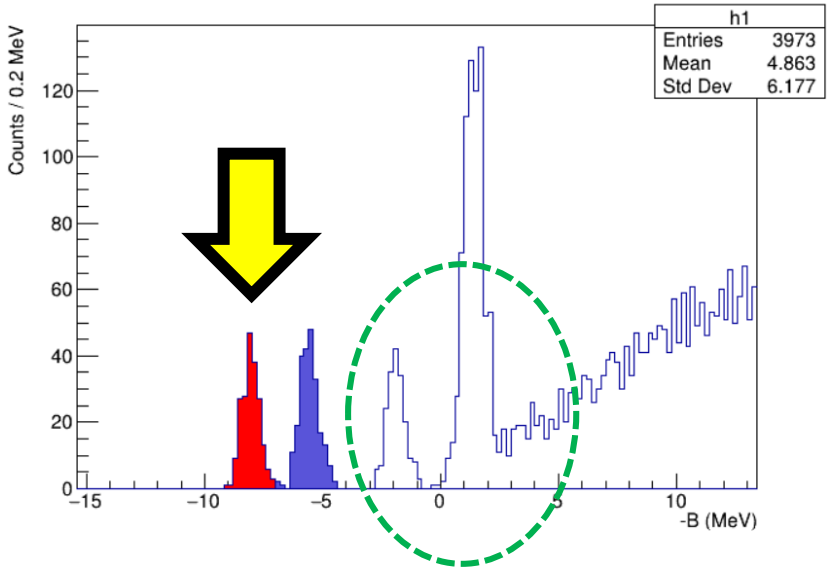
80 hours



Used for calibration

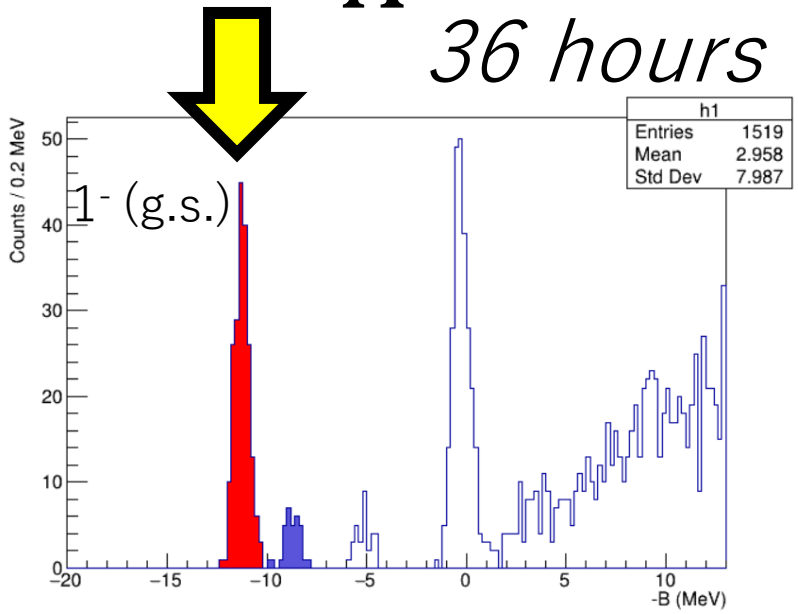
$^{10}_{\Lambda}\mathrm{B}$

112 hours



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

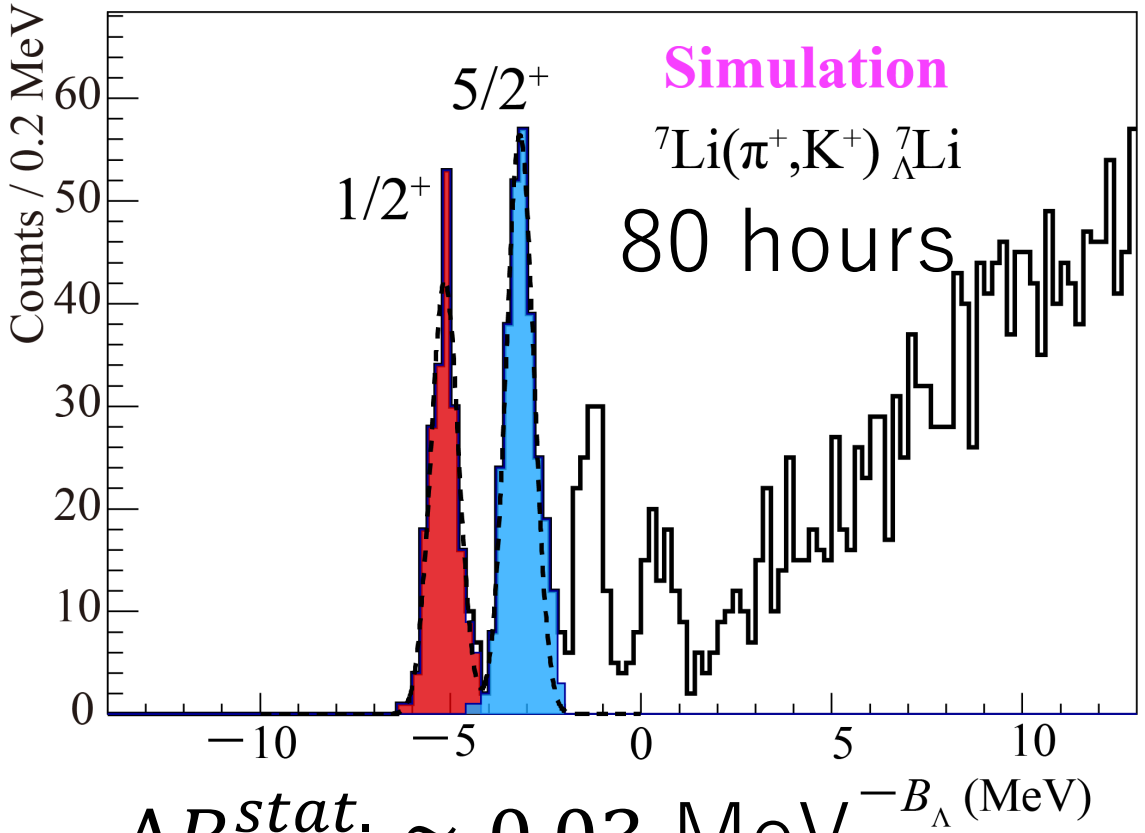
36 hours



Statistical error for the first peak:

$|\Delta B_{\Lambda}^{stat.}| < 0.04$ MeV

Calibration with well known energies
→ high accuracy



$\Delta B_{\Lambda}^{stat.} \simeq 0.03$ MeV

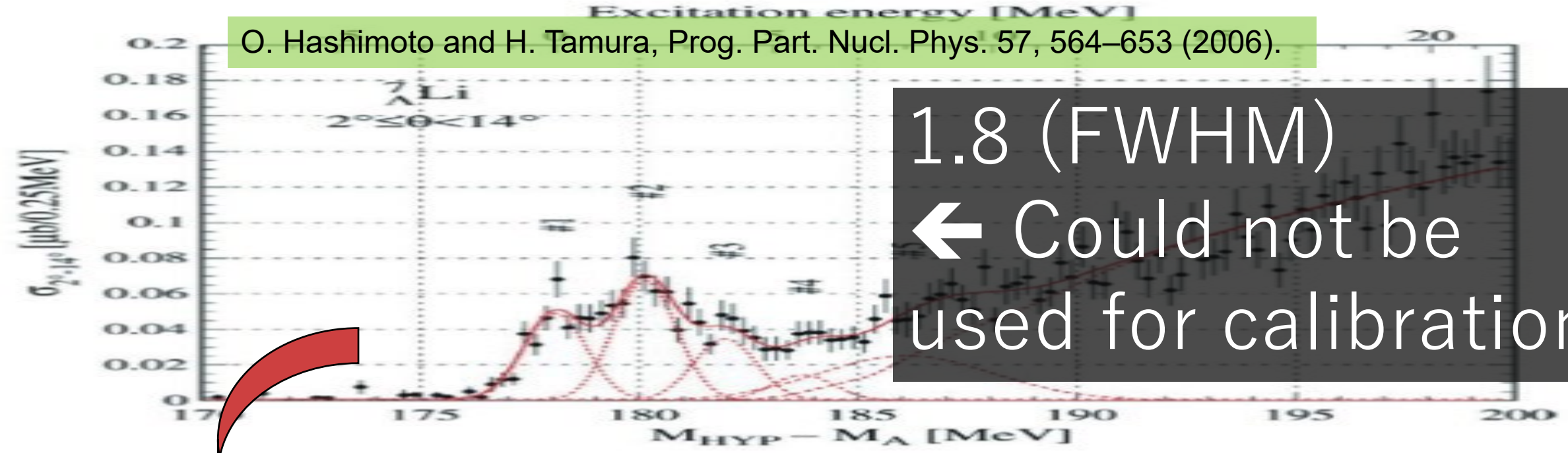
→ Comparable to the errors on known energies

Known energies
(systematic err = 0.04—0.05 MeV)

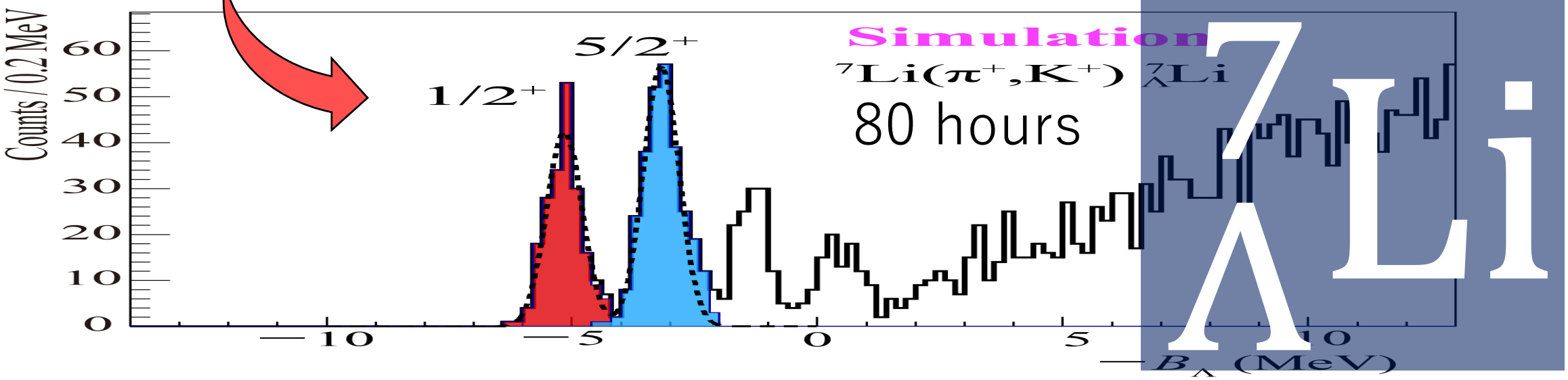
J^{π}	B_{Λ} (/MeV)
1/2^{+}	$\mathbf{5.58 \pm 0.03^{stat.}}$
5/2^{+}	$\mathbf{3.53 \pm 0.03^{stat.}}$

Emulsion:
D.H. Davis, NPA 754 3c—13c (2015).
γ-ray:
K. Tanida et al., PRL86, 10 (2001).
M. Ukai et al., PRC73, 012501(R) (2006).

O. Hashimoto and H. Tamura, Prog. Part. Nucl. Phys. 57, 564–653 (2006).



1.8 (FWHM)
← Could not be used for calibration



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

E94, T. Gogami (Kyoto Univ.)

Table 3
Binding energies of light hypernuclei measured in emulsion. In addition to the quoted statistical errors, there are systematic errors (~ 0.04 MeV) which have been minimised by measuring M_Λ in the same emulsion stack

Hypernuclide	B_Λ/MeV	Hypernuclide	B_Λ/MeV
${}^{3}_{\Lambda}$H	0.13 ± 0.05	${}^{9}_{\Lambda}$Li	8.50 ± 0.12
${}^{4}_{\Lambda}$H	2.04 ± 0.04	${}^{9}_{\Lambda}$Be	6.71 ± 0.04
${}^{4}_{\Lambda}$He	2.39 ± 0.03	${}^{9}_{\Lambda}$B	8.29 ± 0.18
${}^{5}_{\Lambda}$He	3.12 ± 0.02	${}^{10}_{\Lambda}$Be	9.11 ± 0.22
${}^{6}_{\Lambda}$He	4.18 ± 0.10	${}^{10}_{\Lambda}$B	8.89 ± 0.12
${}^{7}_{\Lambda}$He	not averaged	${}^{11}_{\Lambda}$B	10.24 ± 0.05
${}^{7}_{\Lambda}$Li	5.58 ± 0.03	${}^{12}_{\Lambda}$B	11.37 ± 0.06
${}^{7}_{\Lambda}$Be	5.16 ± 0.08	${}^{12}_{\Lambda}$C	10.76 ± 0.19
${}^{8}_{\Lambda}$He	7.16 ± 0.70	${}^{13}_{\Lambda}$C	11.69 ± 0.12
${}^{8}_{\Lambda}$Li	6.80 ± 0.03	${}^{14}_{\Lambda}$C	12.17 ± 0.33
${}^{8}_{\Lambda}$Be	6.84 ± 0.05	${}^{15}_{\Lambda}$N	13.59 ± 0.15

https://www.sciencedirect.com/science/article/pii/S0375947405000047