

WEPH

Workshop for Electro- and Photoproduction
of Hypernuclei and Related Topics 2024

WEPH RE:2024, CAS, Rez, Czech Republic

Hypernuclear experiments at J-PARC by using S-2S

T. Gogami (Kyoto University)
for the S-2S Collaboration

Oct 15, 2024

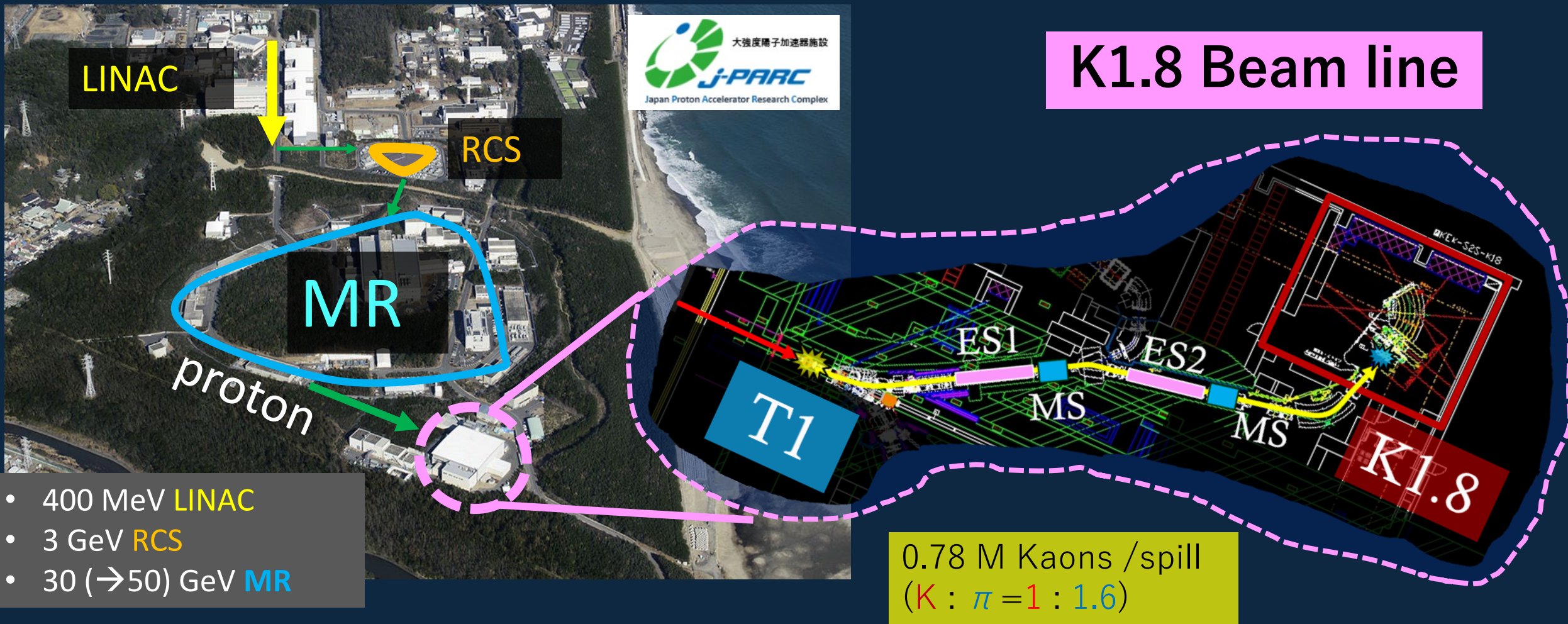


京都大学 理学研究科・理学部

GRADUATE
SCHOOL OF
FACULTY OF **SCIENCE**
KYOTO UNIVERSITY



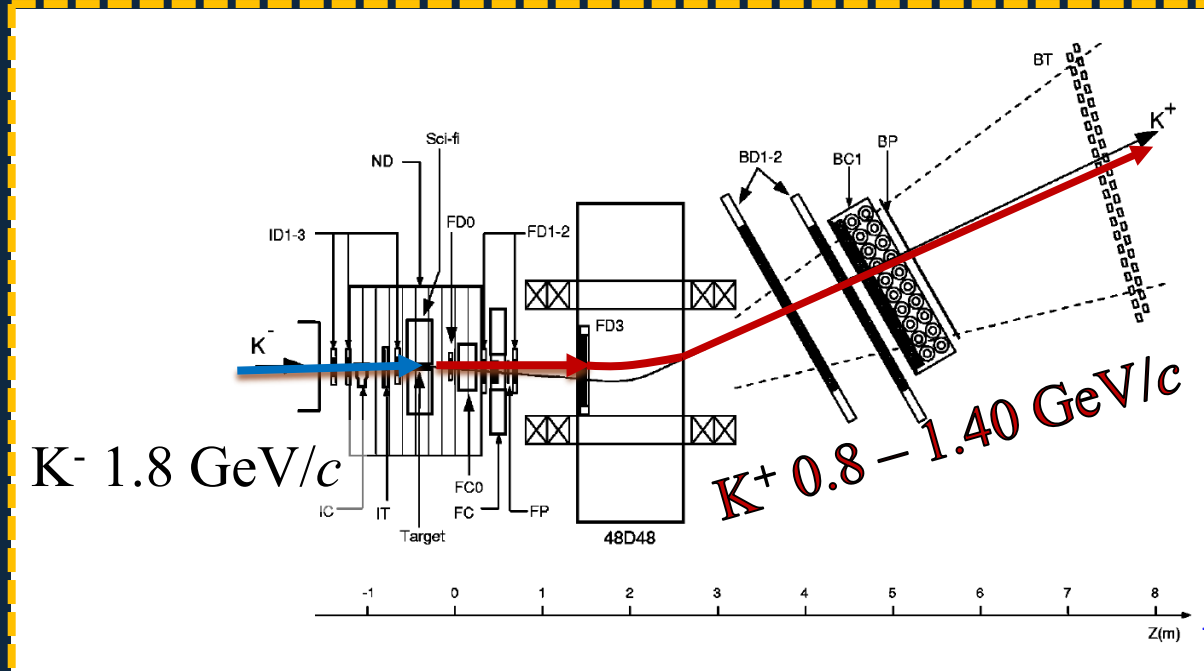
Japan Proton Accelerator Research Complex (J-PARC)



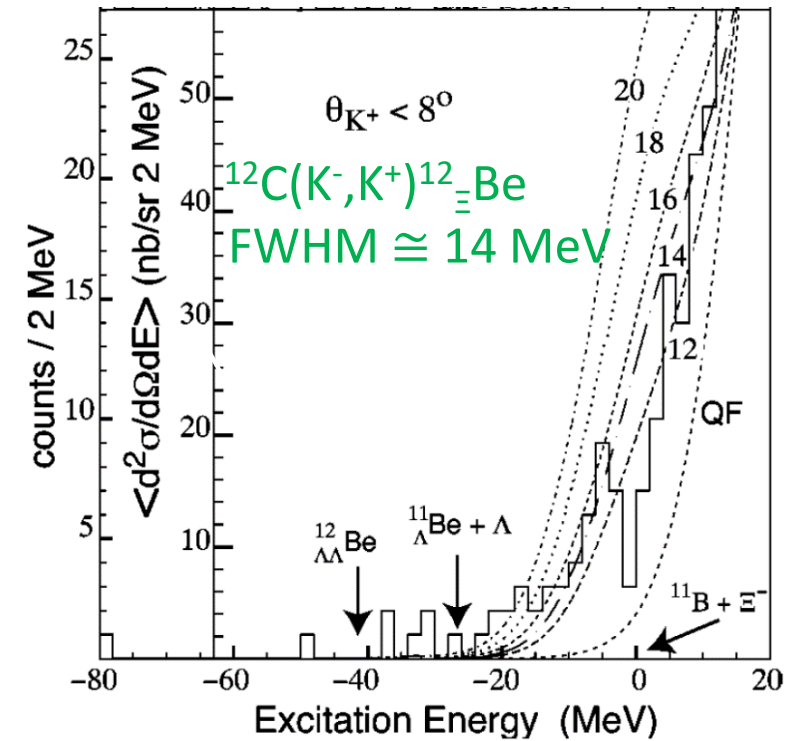
K1.8 Beam line

$^{12}\text{C}(K^-, K^+)^{12}_{\Lambda}\text{Be}$ spectroscopy

P. Khaustov et al., PRC 61 (2000) 054603



**BNL
E885**



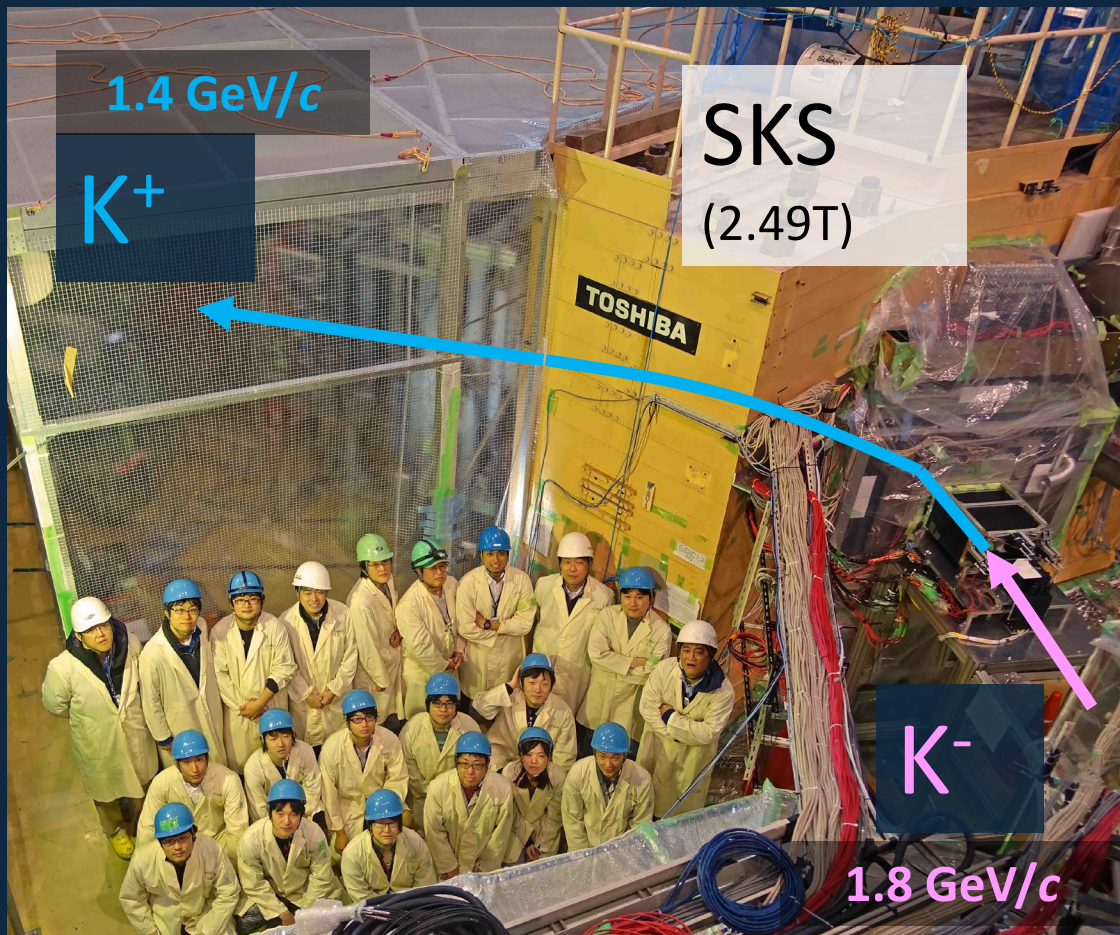
- 89 ± 14 nb/sr ($\theta < 8$ deg)
- 42 ± 5 nb/sr ($\theta < 14$ deg)

$\Rightarrow V_{0\Lambda} \leq 14$ MeV

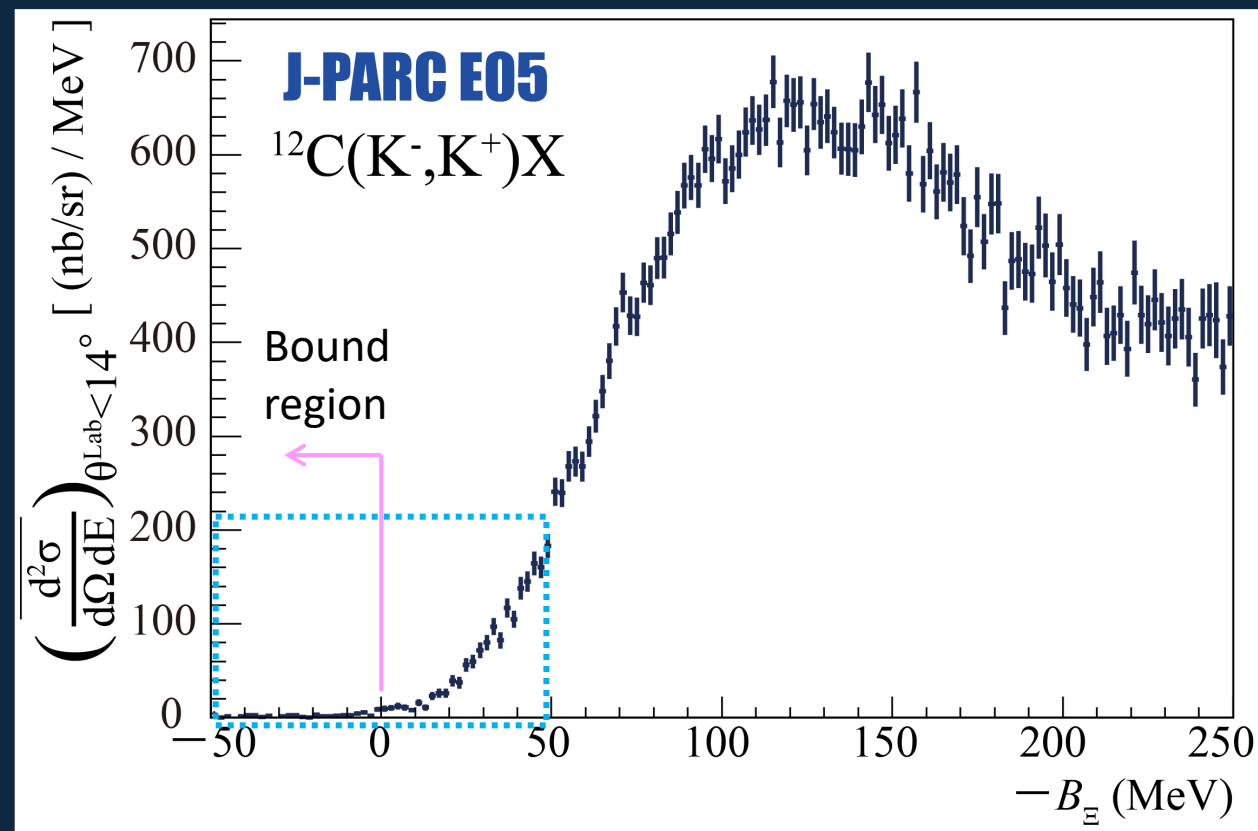
Experiment	KEK E224	BNL E885	J-PARC E05	J-PARC E70
Resolution in FWHM (MeV)	22	14	8	2

Best precision!

J-PARC E05 at K1.8 beam line



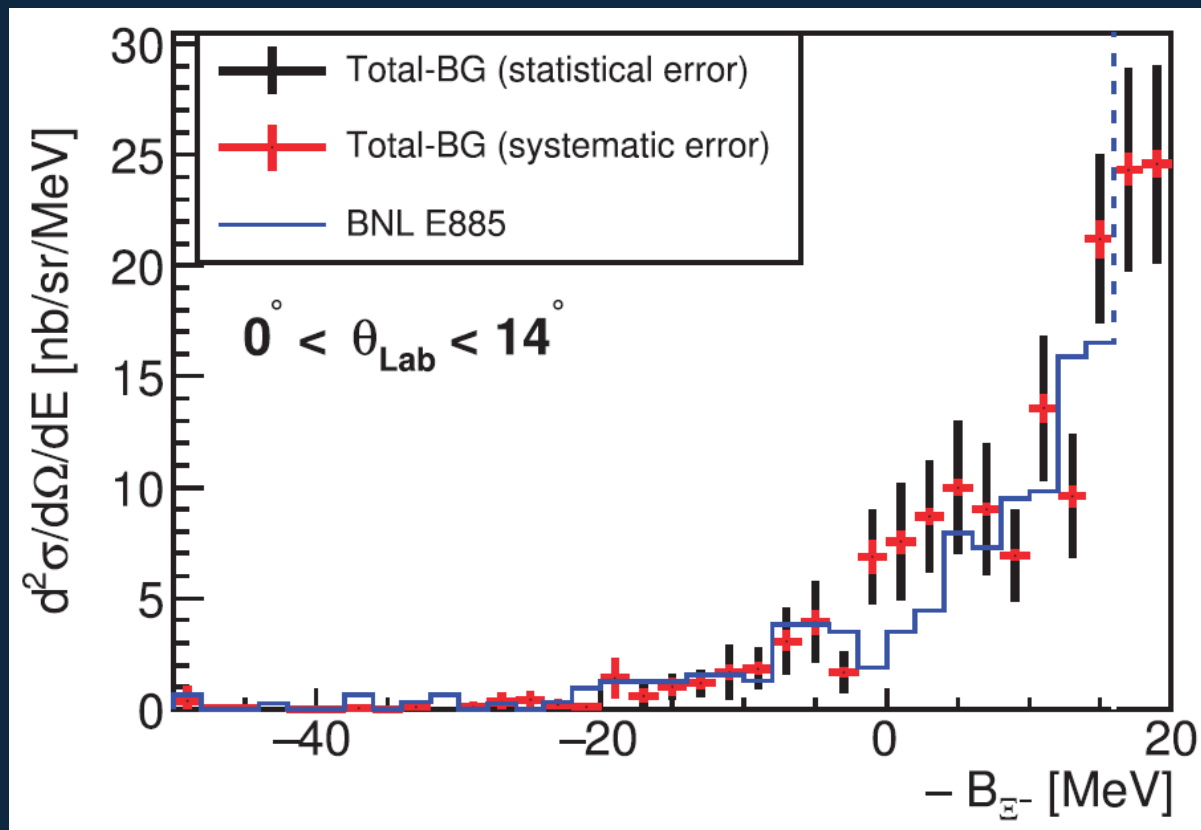
Analysis by Dr. Y. Ichikawa



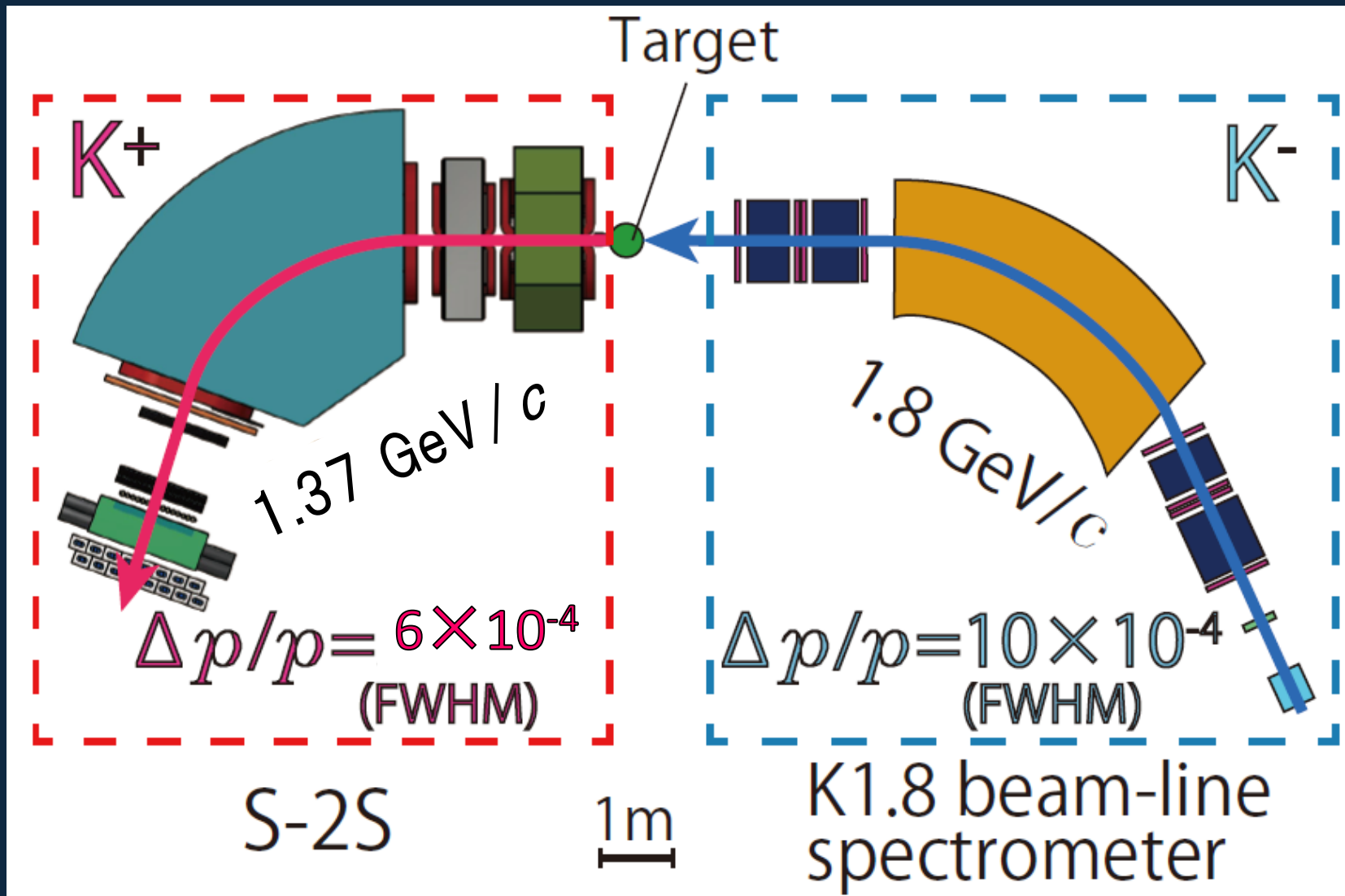
c.f.) Result for the $^{12}\text{C}(\text{K}^-, \text{p})$ reaction:
Y. Ichikawa et al., PTEP 2020, 123D01 (2020)

Result (J-PARC E05), 8 MeV (FWHM)

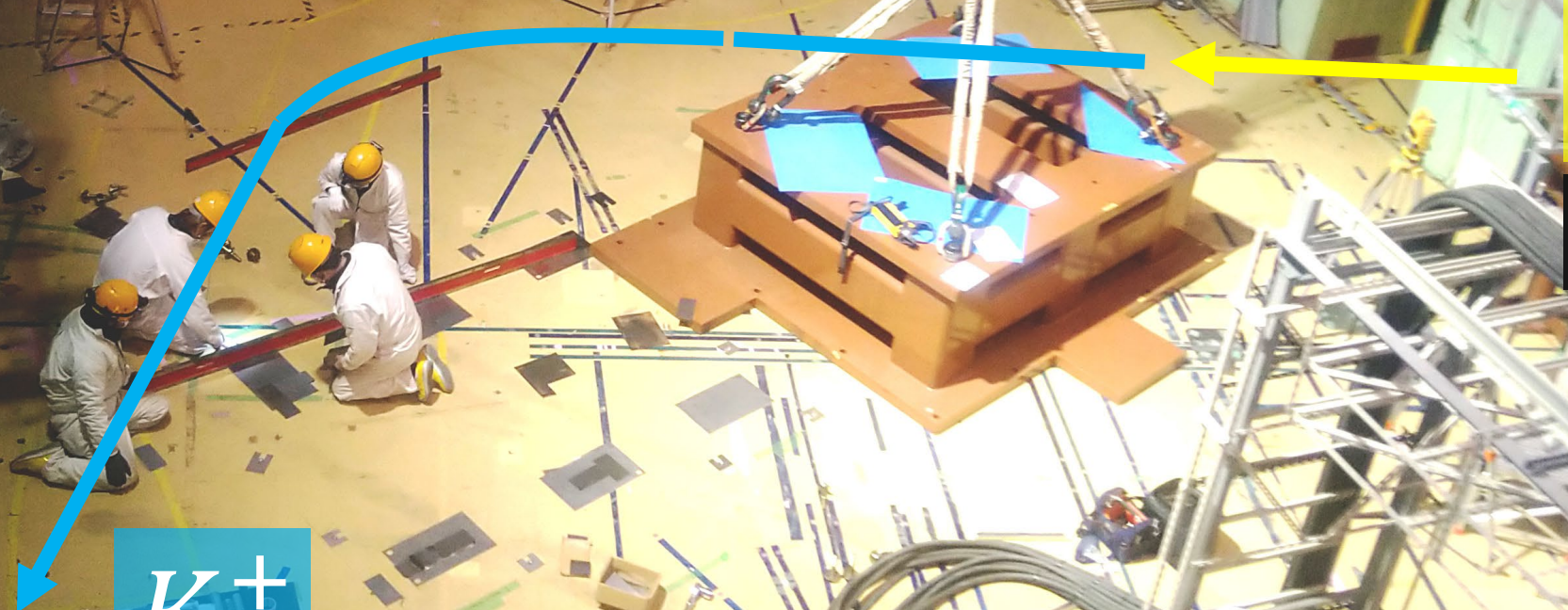
Y. Ichikawa et al., *PTEP* 2024, 9, 091D01 (2024), <https://doi.org/10.1093/ptep/ptae133>



E70 Experiment for higher resolution



Jan 20, 2022



K^+

1.37 GeV/c

K^-

1.8 GeV/c

Nov 2022

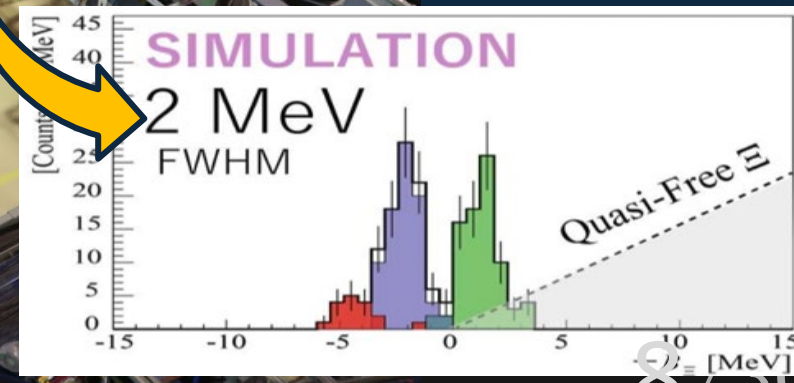
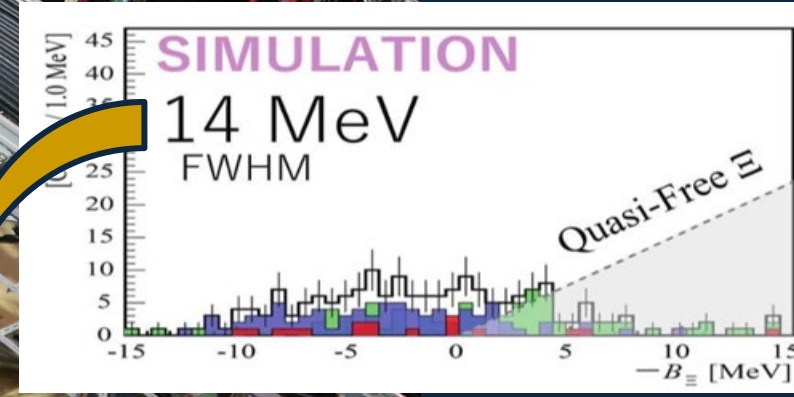
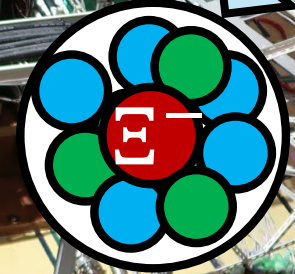
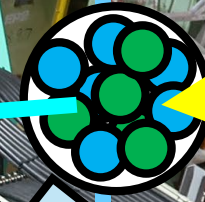
Q2 Q1

1.8 GeV/c

D

K^-

$s\bar{u}$



$s\bar{u}$

K^+

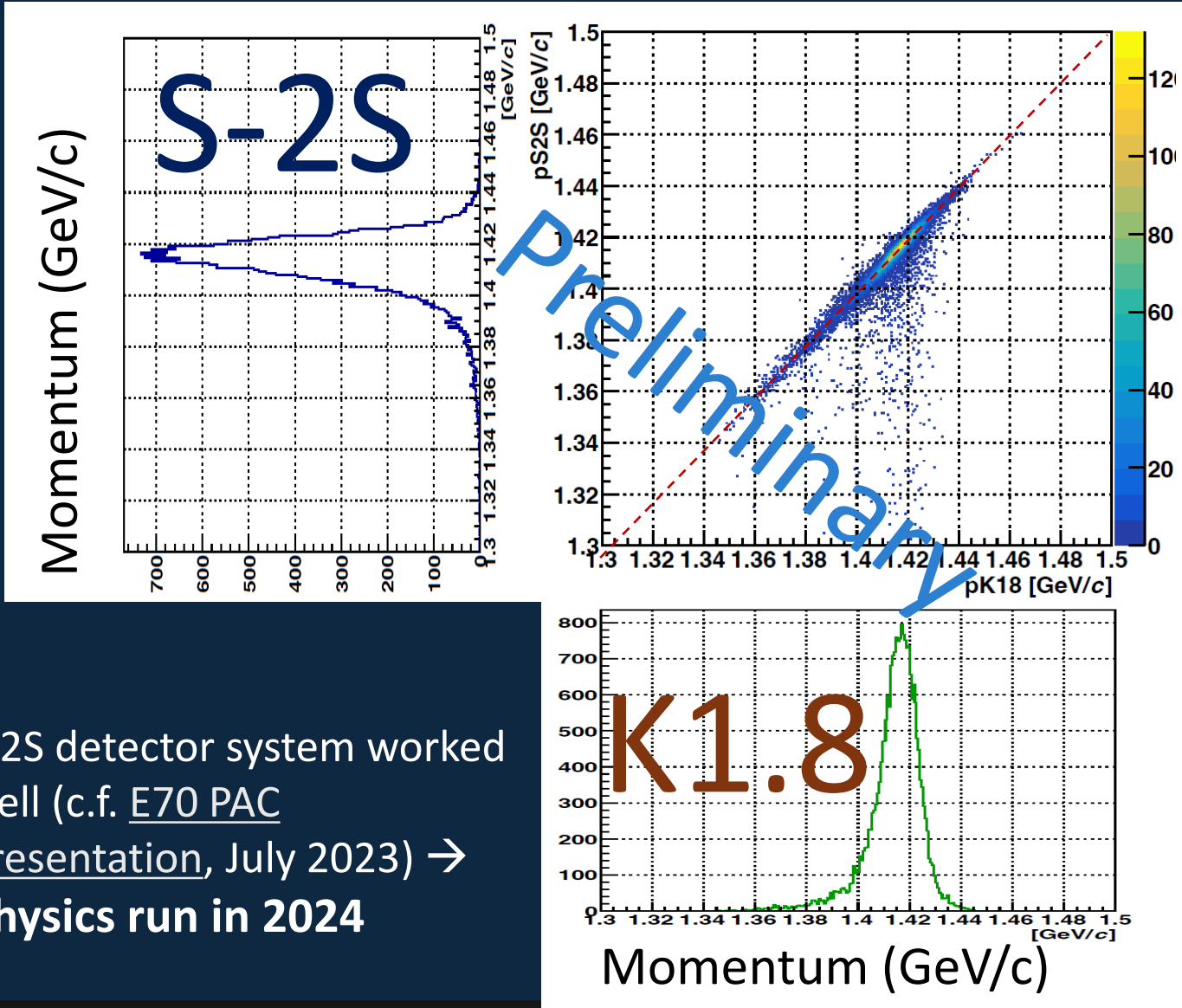
2 m

S-2S

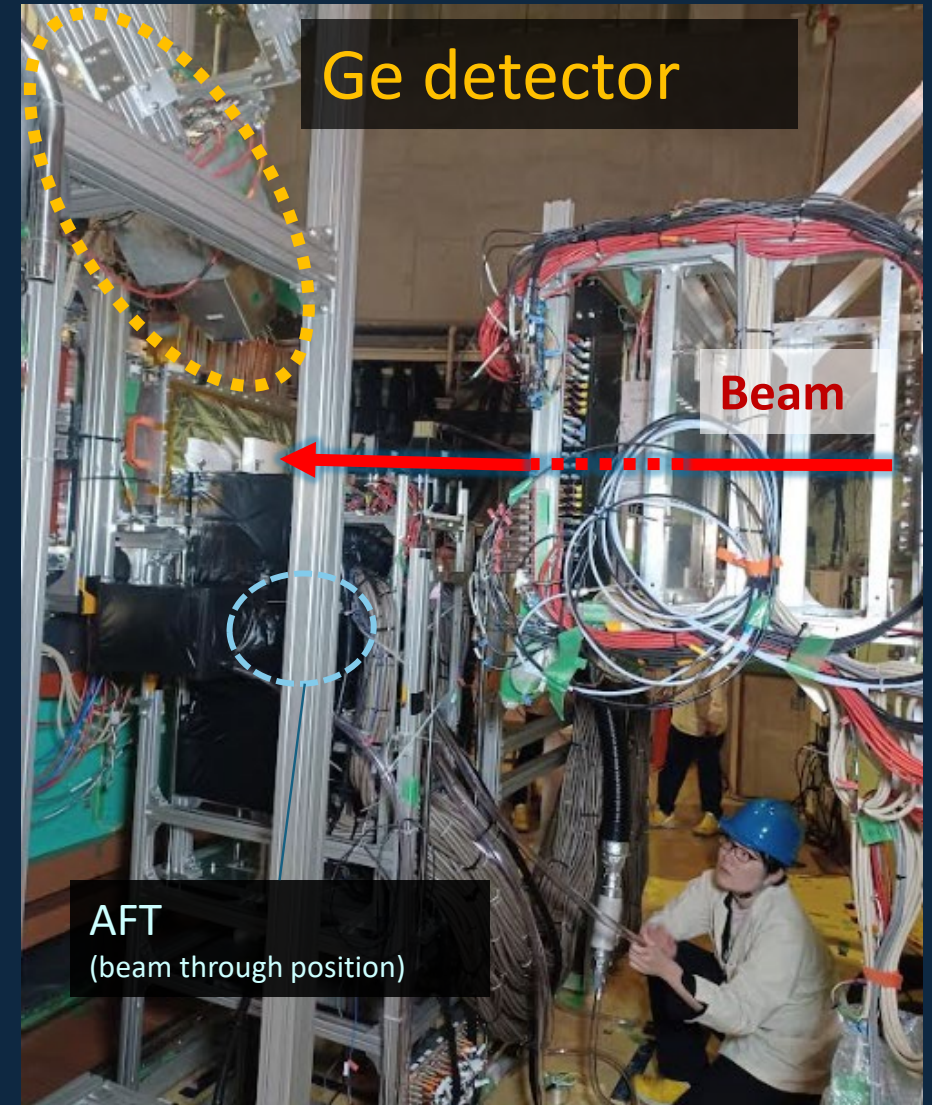
1.37 GeV/c

The first beam in June 2023

Beam through at $p = 1.4 \text{ GeV}/c$ (π^+)



S-2S detector system worked well (c.f. [E70 PAC presentation](#), July 2023) → **physics run in 2024**



Beam time request before summer 2024 (shown in the last PAC)

Beamtime (/ day)	1-2	3	4-5	6	7	7.5		7.5-10		1-2	3-7	8	9-			
Beam power				$\geq 80 \text{ kW}$					$\geq 80 \text{ kW}$				$\geq 80 \text{ kW}$			
Detectors	1						E73 @K1.8BR		Analysis			E96 Calibration				
BT		2									Start up					
AFT			3													
^{12}C														4		
CH ₂				5	6											
Physics run						7				7						7

$(6\text{d} - 17.97 \text{ h}) + (80\text{kW} \times 2.5\text{d})$
 $\approx 7.5 \text{ days request}$

$2\text{d} + 5\text{d} + (80\text{kW} \times 19.5\text{d})$
 $= 26.5 \text{ days (+ 1 day for E96)}$

Beam time request before summer 2024 (shown in the last PAC)

Beamtime (/ day)	1-2	3	4-5	6	7	7.5	E73 @K1.8BR		7.5-10	Analysis		1-2	3-7	8	9-	
Beam power				≥ 80 kW					≥ 80 kW							≥ 80 kW
Detectors	2															
BT		0.5														
AFT			1.5													
¹² C Λ													4			
CH ₂				5	6											
Physics run						7			7							7

(6d - 17.97 h) + (80kW × 2.5d)
≈ 7.5 days request

2d + 5d + (80kW × 19.5d)
 = **26.5 days (+ 1 day for E96)**

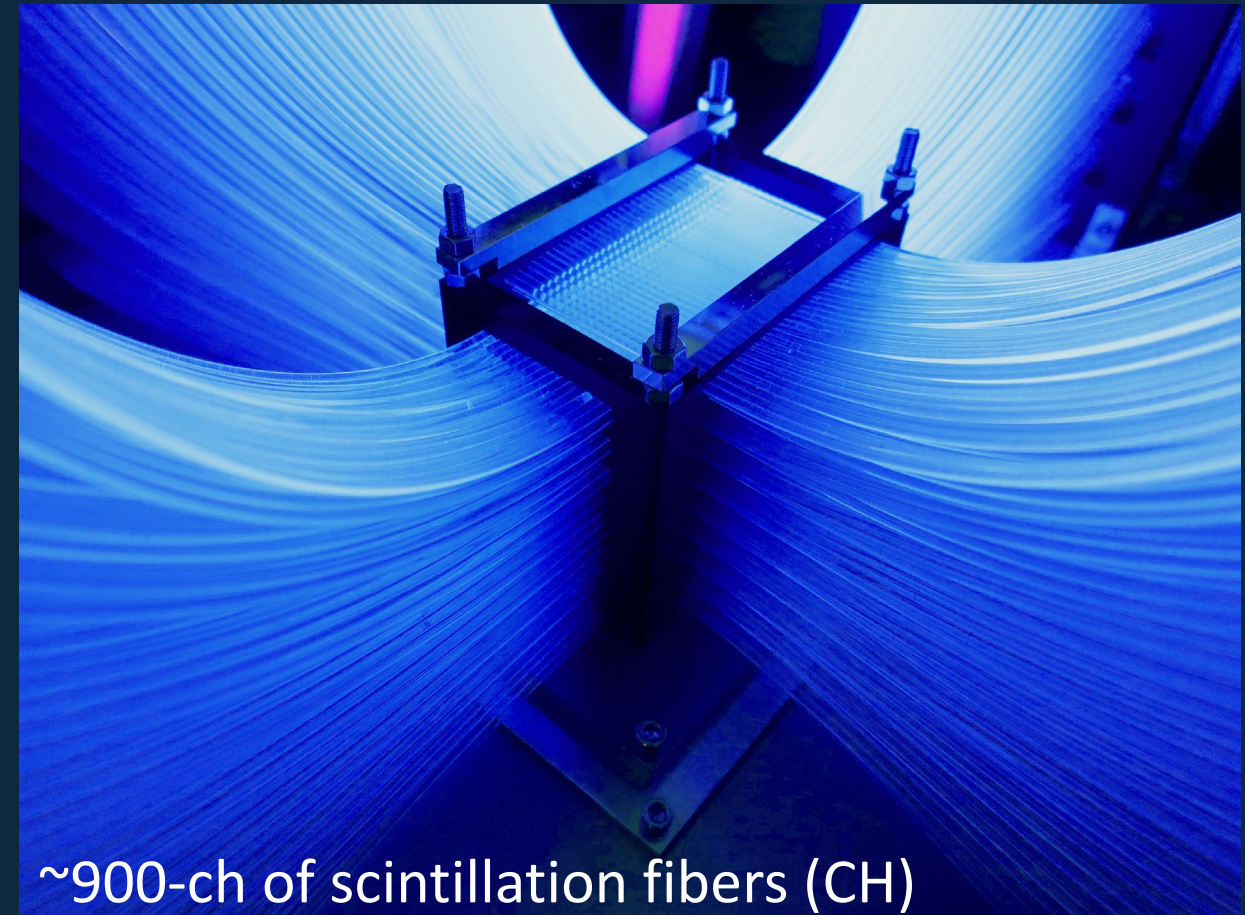
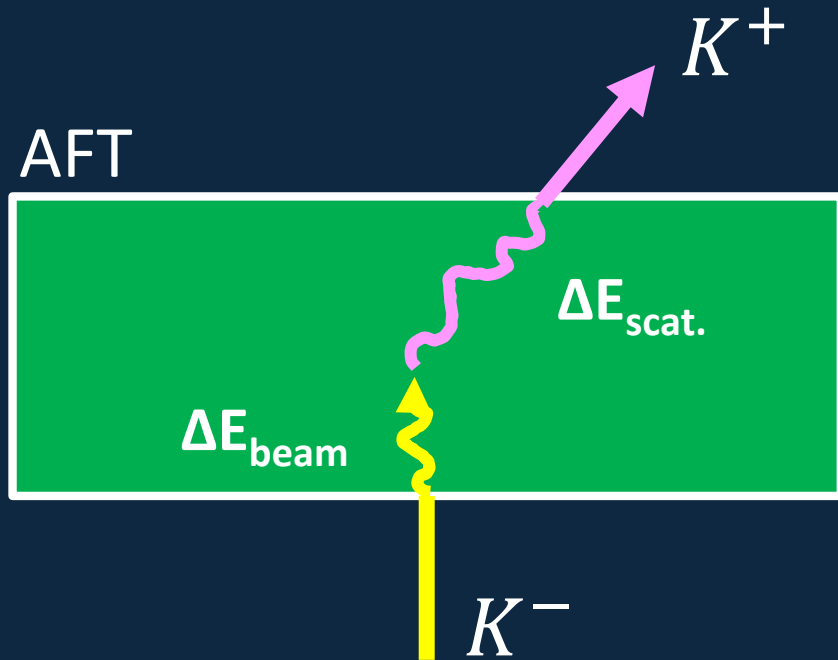


After the second commissioning beam time (May 2024)

T. Gogami (Kyoto Univ.), Hypernuclear experiments
at J-PARC by using S-2S, WEPH RE:2024, CAS, Rez, Czech Republic

Direct measurement of energy loss in target

T. K. Harada, *EPJ Web Conf.* 271 (2022) 03006



Thick target ...

→ But, high resolution!!

Direct measurement of energy loss in target

T. K. Harada, EPJ Web Conf. 271 (2022) 03006



T.K. Harada
(Kyoto Univ.)

R. Negishi
(Tokyo Inst. Tech)

T. Nanamura
(Kyoto Univ.)

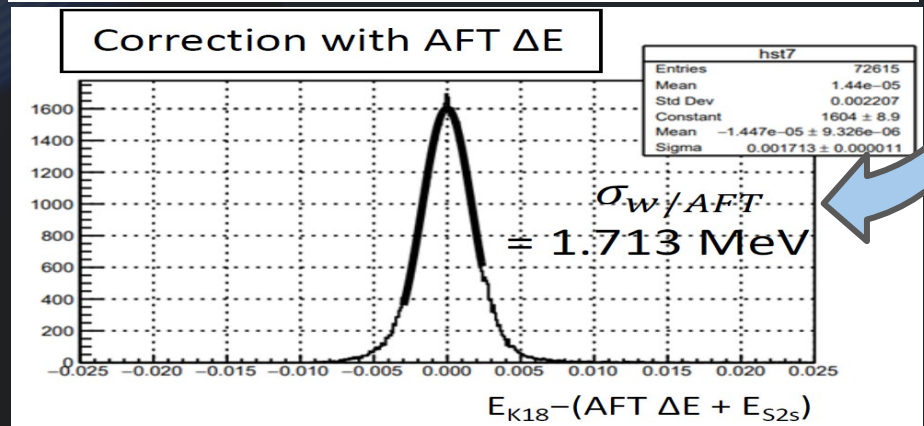
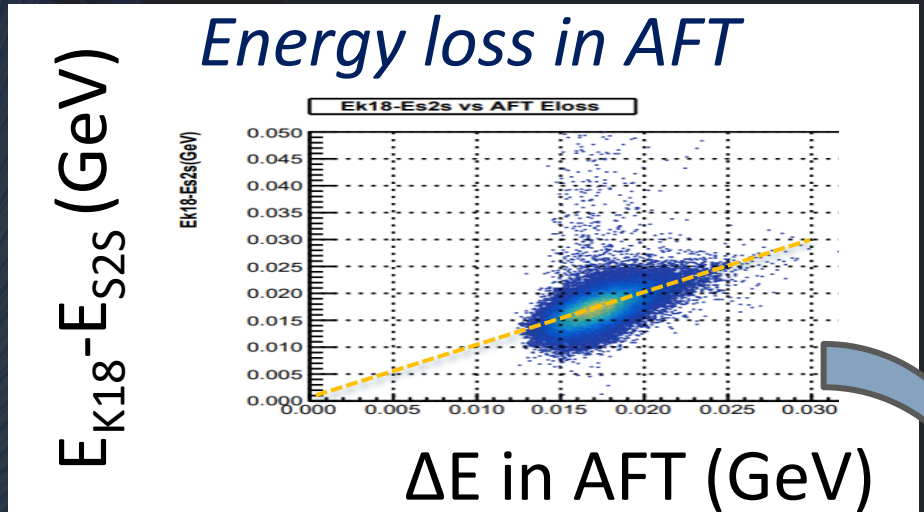
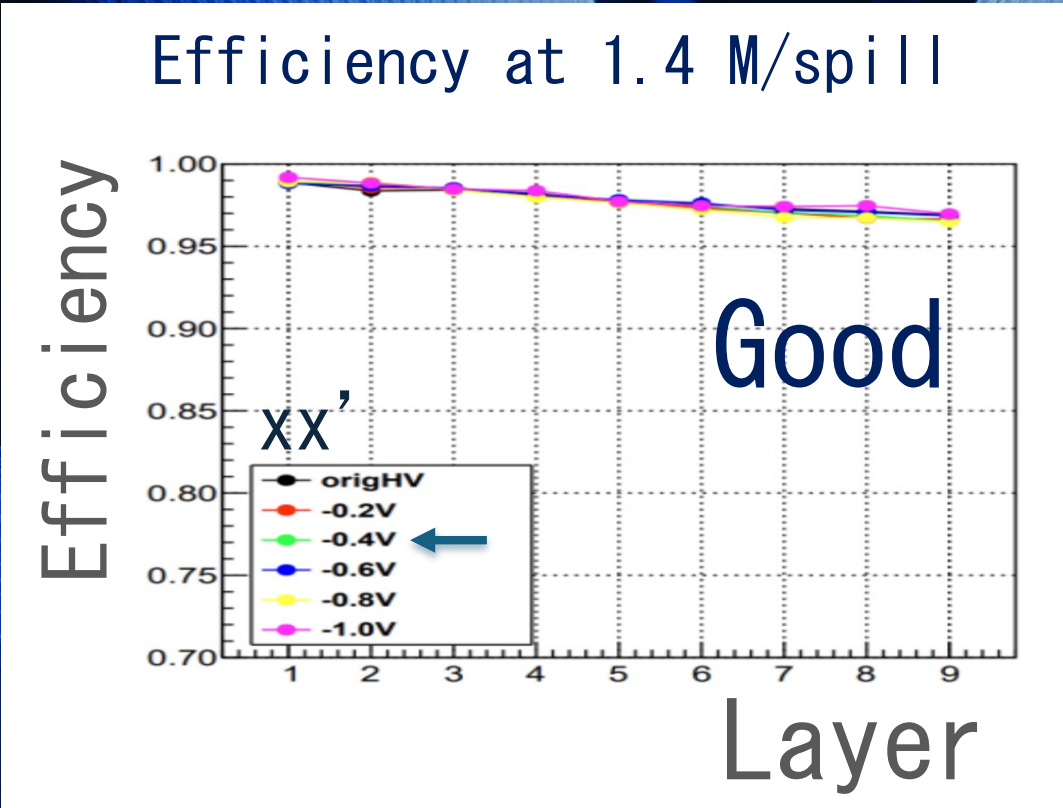
K. Ebata
(Kyoto Univ.)

T. Gogami
(Kyoto Univ.)

T. Kobori
(Tokyo Inst. Tech)

T. Gogami (Kyoto Univ.), Hypernuclear experiments (Feb 16, 2023)
at J-PARC by using S-2S, WEPH RE:2024, CAS, Rez, Czech Republic

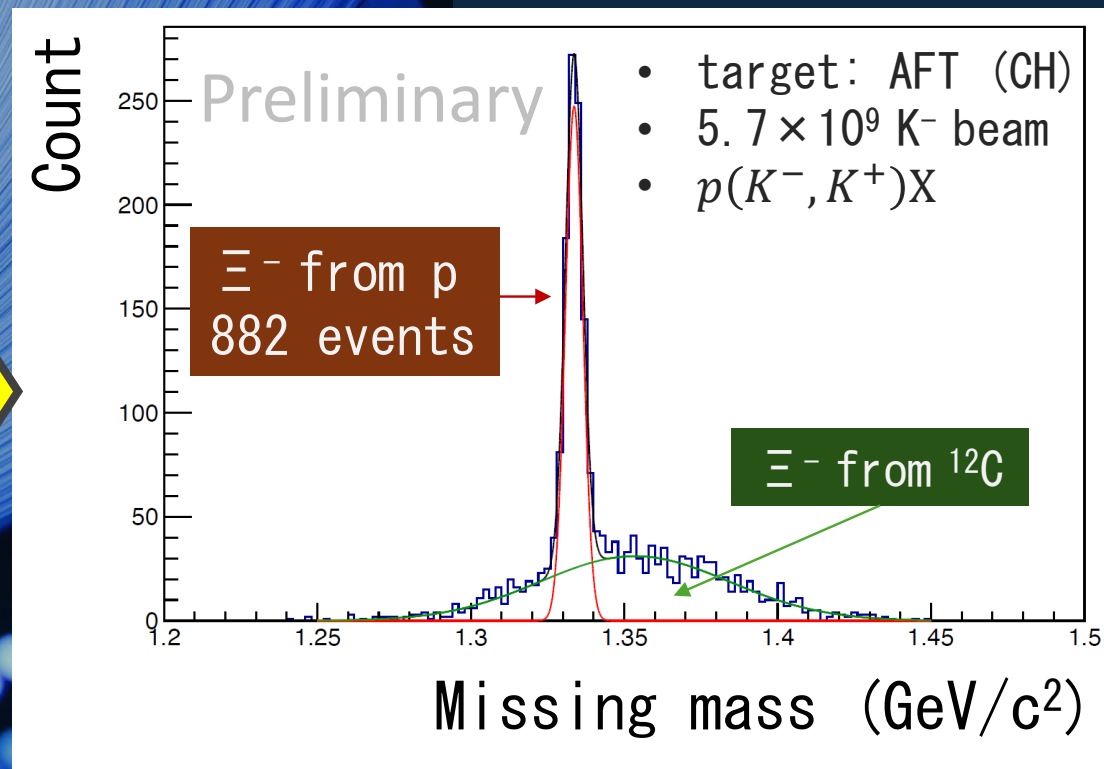
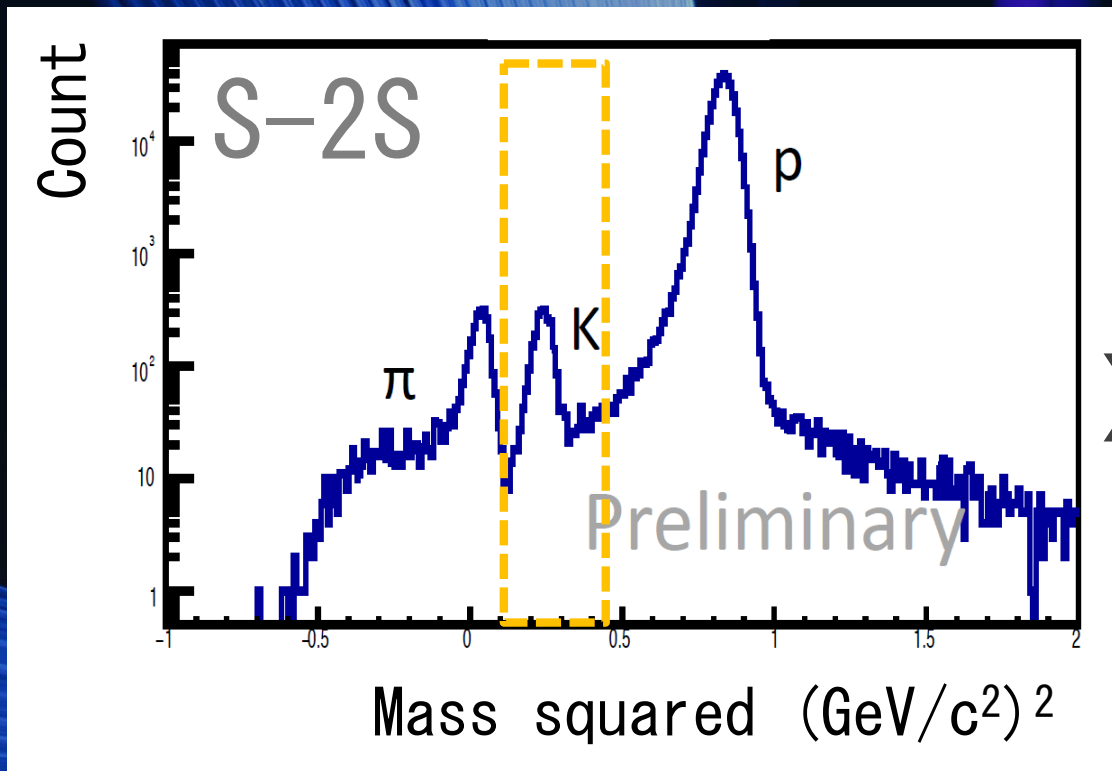
Active fiber target (AFT)



$\sigma_{AFT}/E = 5.9\%$ → The cause is being investigated
(c. f. 3.2% in 2023)

Contributions from S-2S and K1.8 beam line were subtracted (← by using data w/ and w/o AFT)

$p(K^-, K^+) \Xi^-$ reaction events from AFT



Particle identification

Ξ^- events from p targets in AFT were observed as expected in terms of statistics!!

Missing-mass resolution (status)

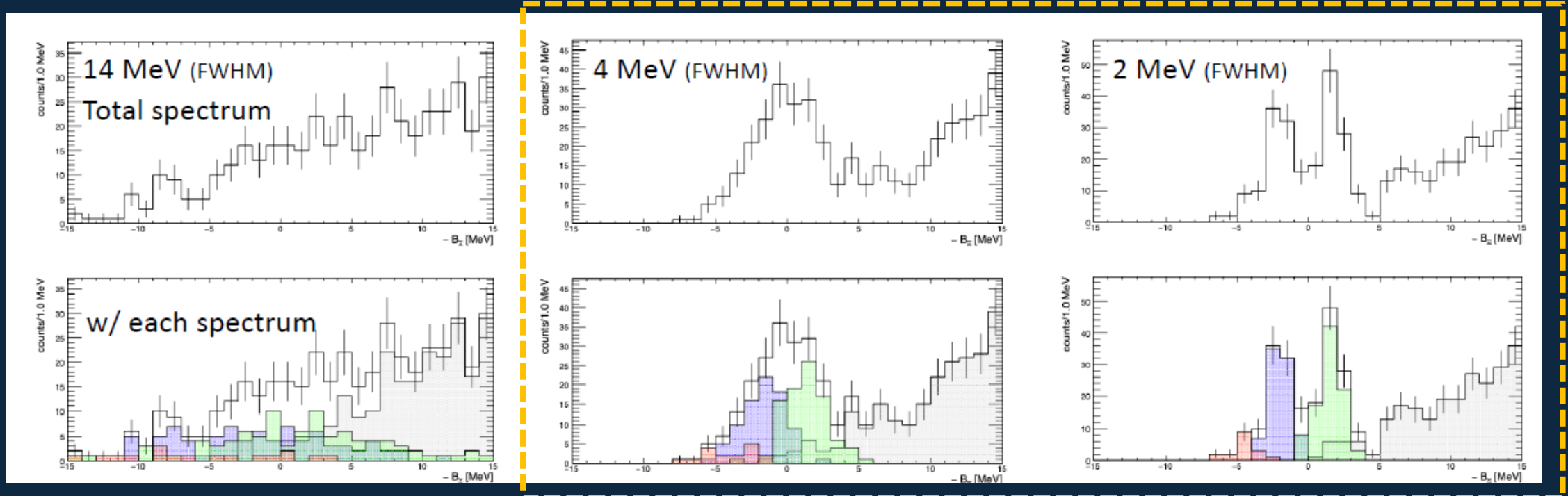
Case	Spectrometer		AFT		ΔM_{HYP} / (MeV/c ²)	Remark
	$\left(\frac{\Delta p}{p}\right)_{K18}$ (/10 ⁻⁴)	$\left(\frac{\Delta p}{p}\right)_{S2S}$ (/10 ⁻⁴)	ΔE_{beam} (/MeV)	$\Delta E_{\text{scat.}}$ (/MeV)		
A	10	5	0.9	0.9	2.0	Design
B	18	18	1.34	1.31	3.9	Present

→ Better than J-PARC E05 by a factor of 2

→ We will keep working on improving to the design value

Expected spectra

Theoretical prediction taken from T. Motoba, S. Sugimoto, Nucl. Phys A 835, 1-4, 223-230 (2010)
Hyperon-Nucleon interaction = ESC08c



The best resolution spectroscopy would be realized!!

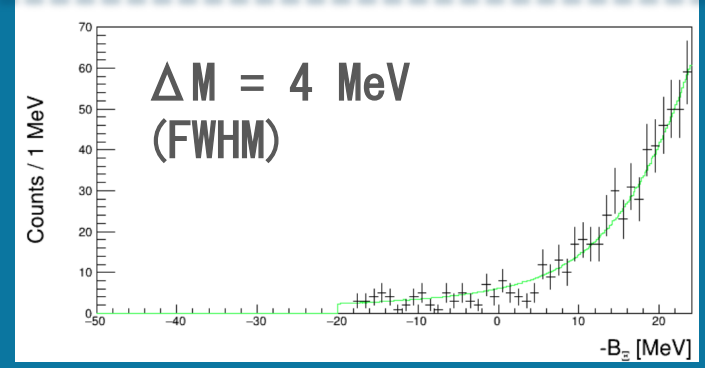
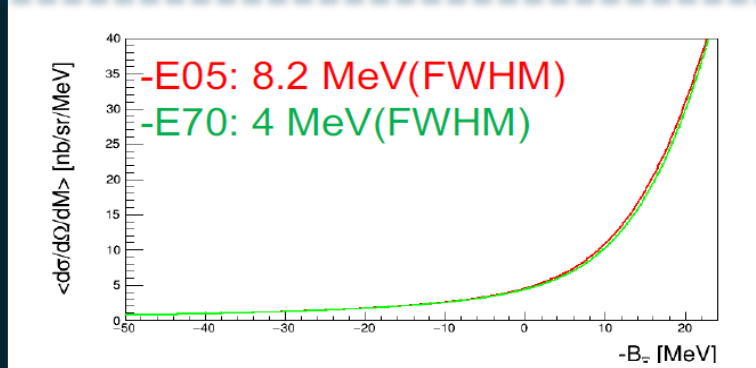
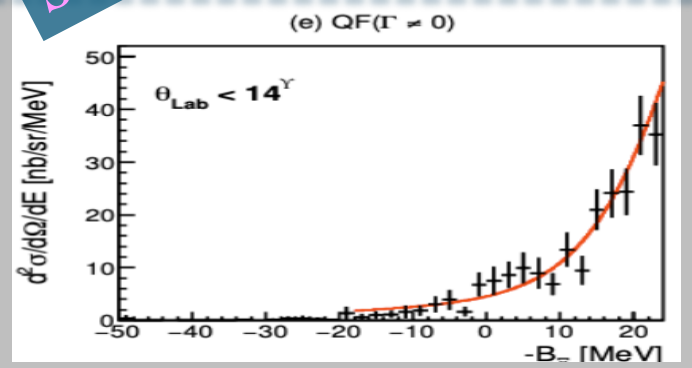
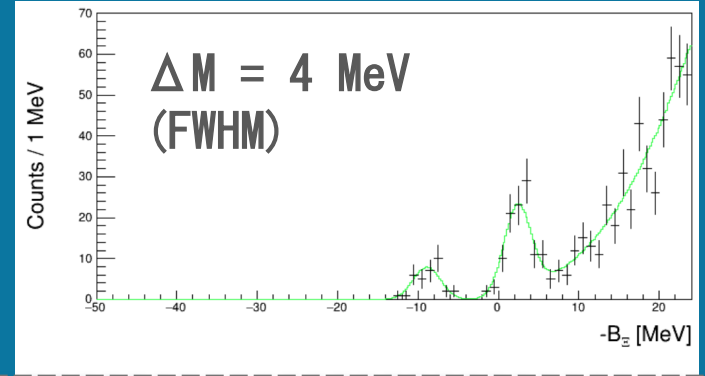
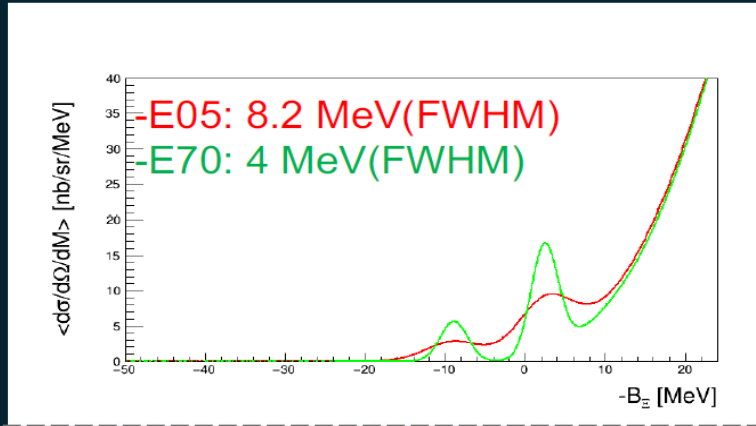
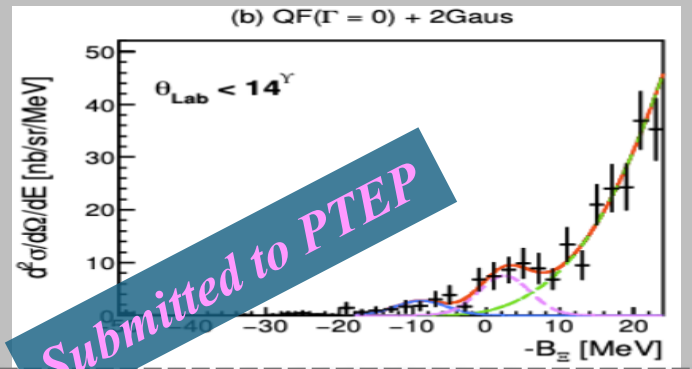
Expected spectra (based on E05 result)

J-PARC E05

J-PARC E70

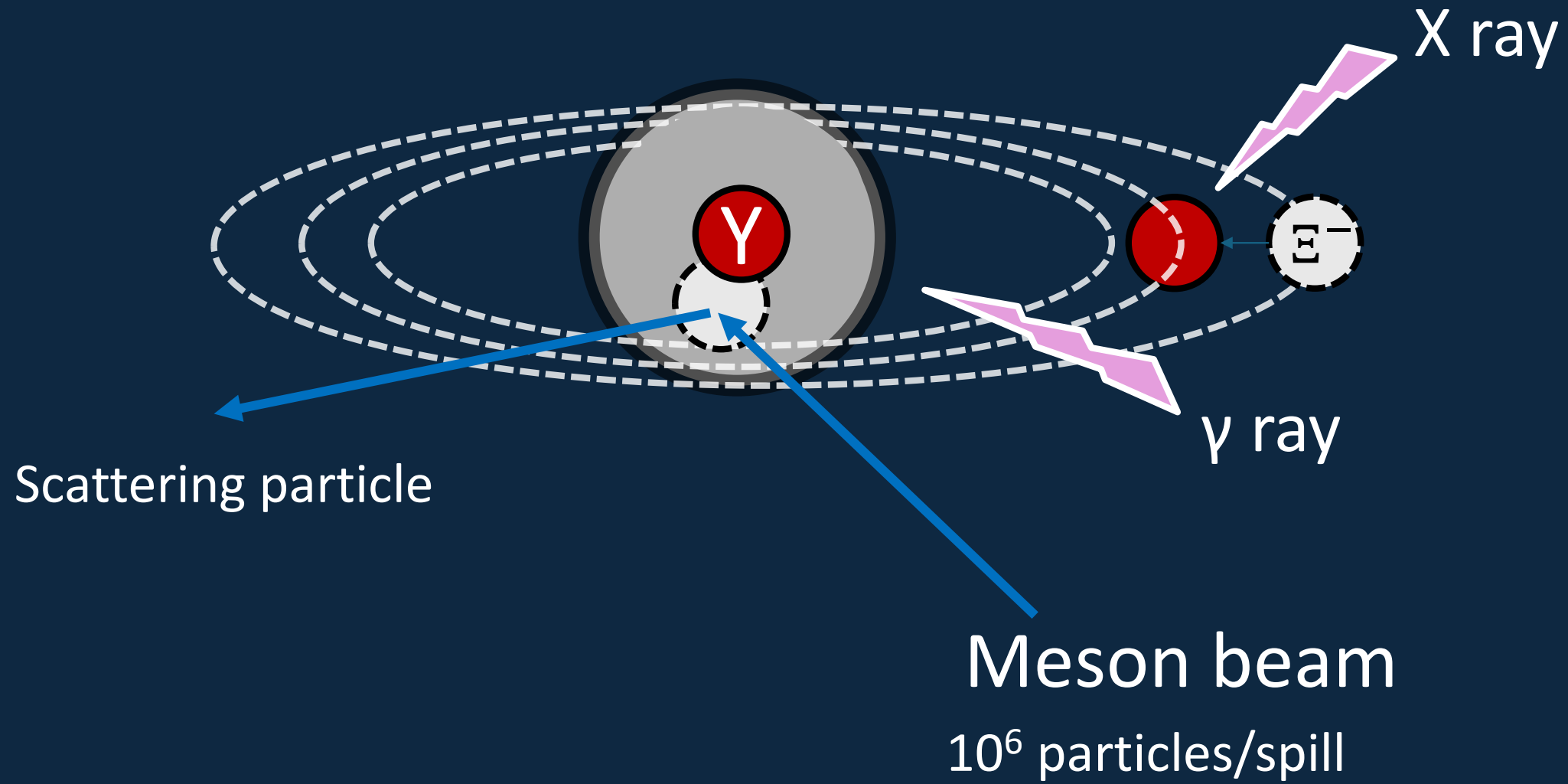
2 Gaus

No peak

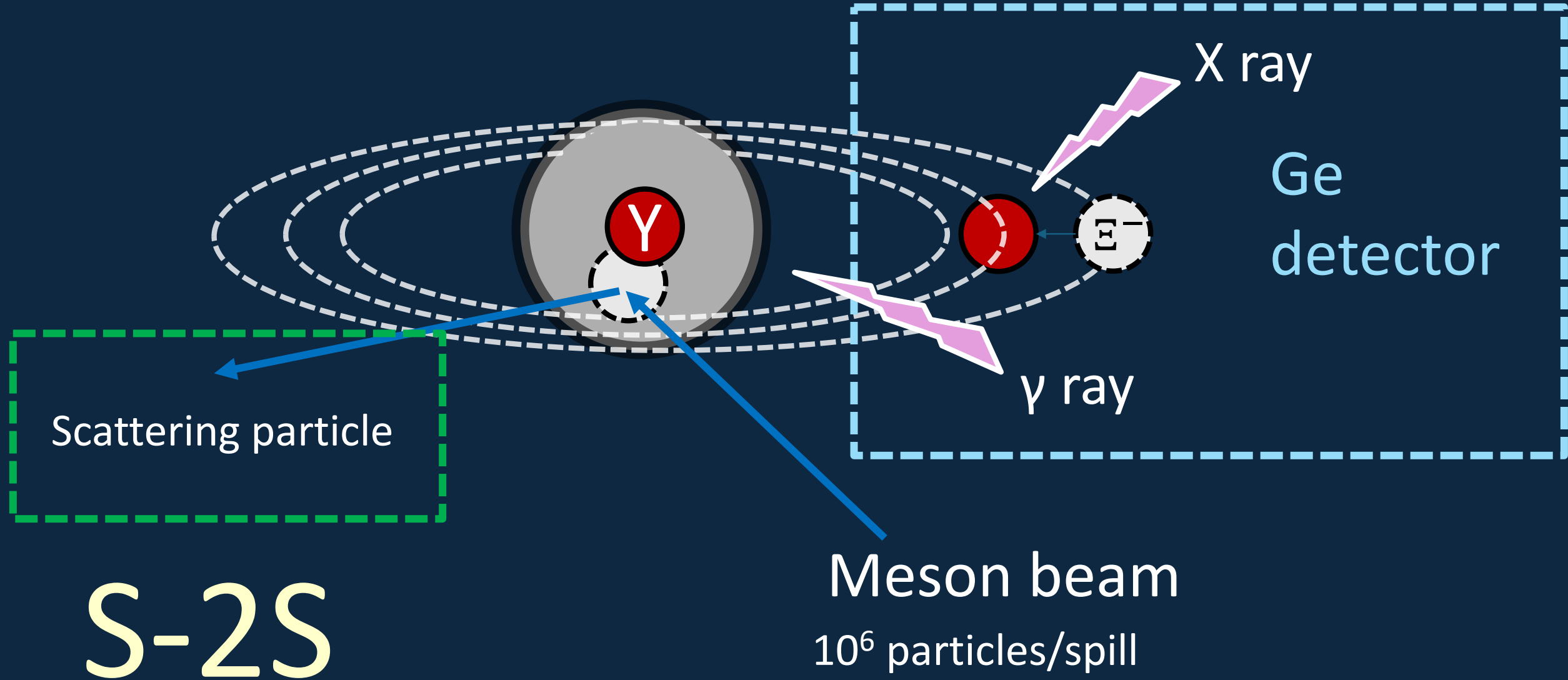


Currently achieved resolution, 4 MeV in FWHM, in E70
 → Two scenarios which E05 was not able to distinguish would be clarified!!

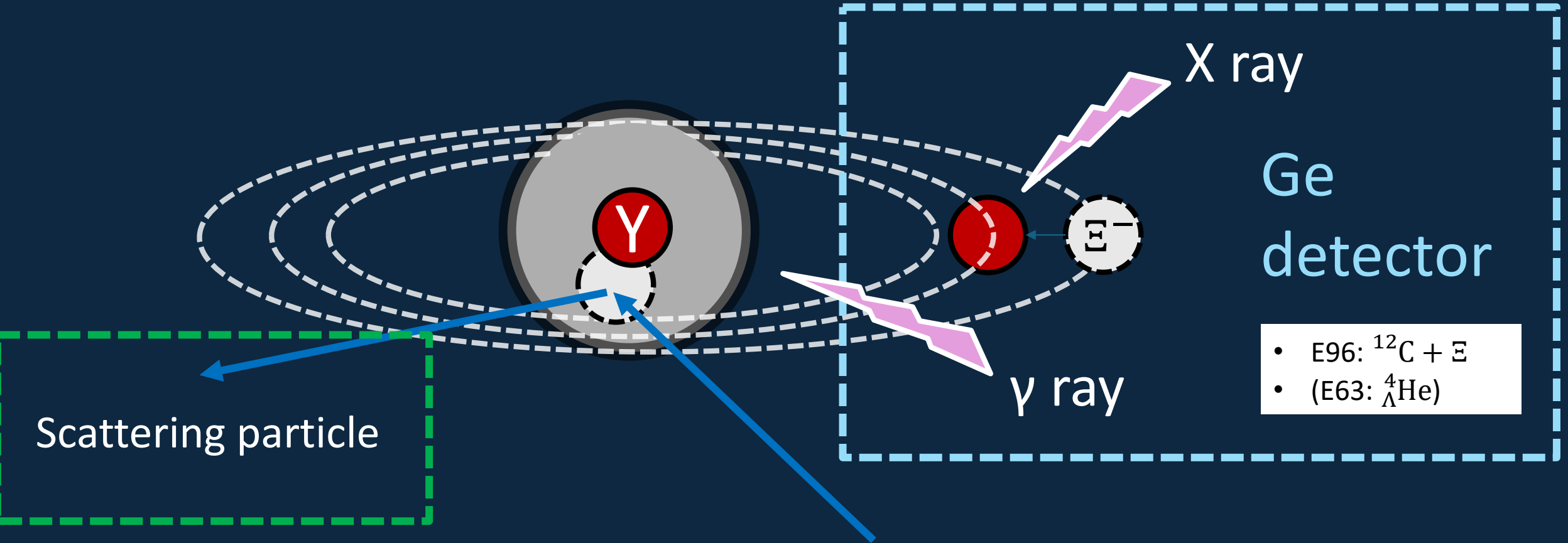
Strangeness nuclear physics by S-2S



Strangeness nuclear physics by S-2S



Strangeness nuclear physics by S-2S



- E96: $^{12}\text{C} + \text{E}$
- (E63: $^4_{\Lambda}\text{He}$)

S-2S

- E70: $^{12}_{\text{E}}\text{Be}$
- E75-1: $^7_{\text{E}}\text{H}$
- E94: $^7_{\Lambda}\text{Li}, ^{11}_{\Lambda}\text{B}, ^{12}_{\Lambda}\text{C}$

Meson beam
 10^6 particles/spill

Status of E96 Parallel data taking with E70 (carbon Ξ^- atomic x-ray measurement)

2023.6 commissioning

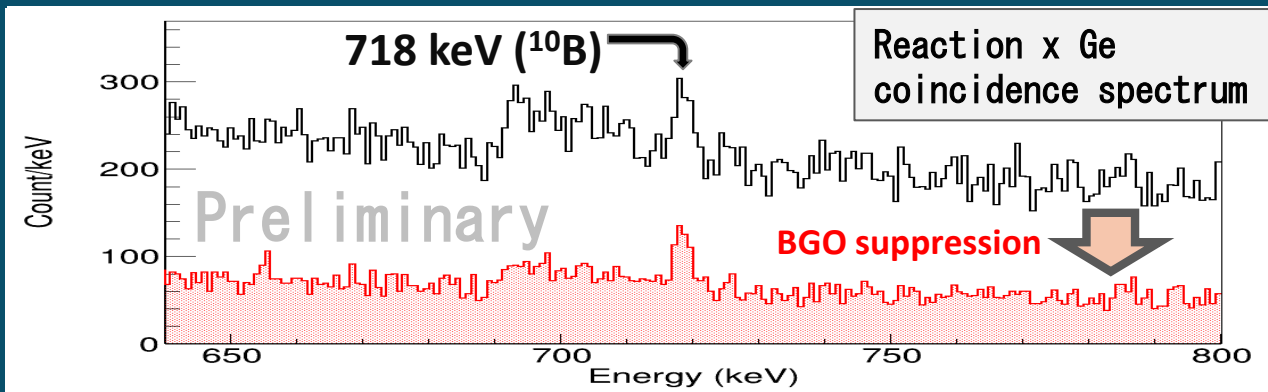
- One Ge+BGO detector unit for test
- Limited data for performance check (low beam intensity, no reaction data)



2024.4-6 commissioning

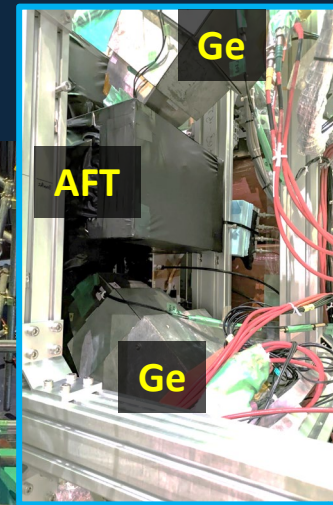
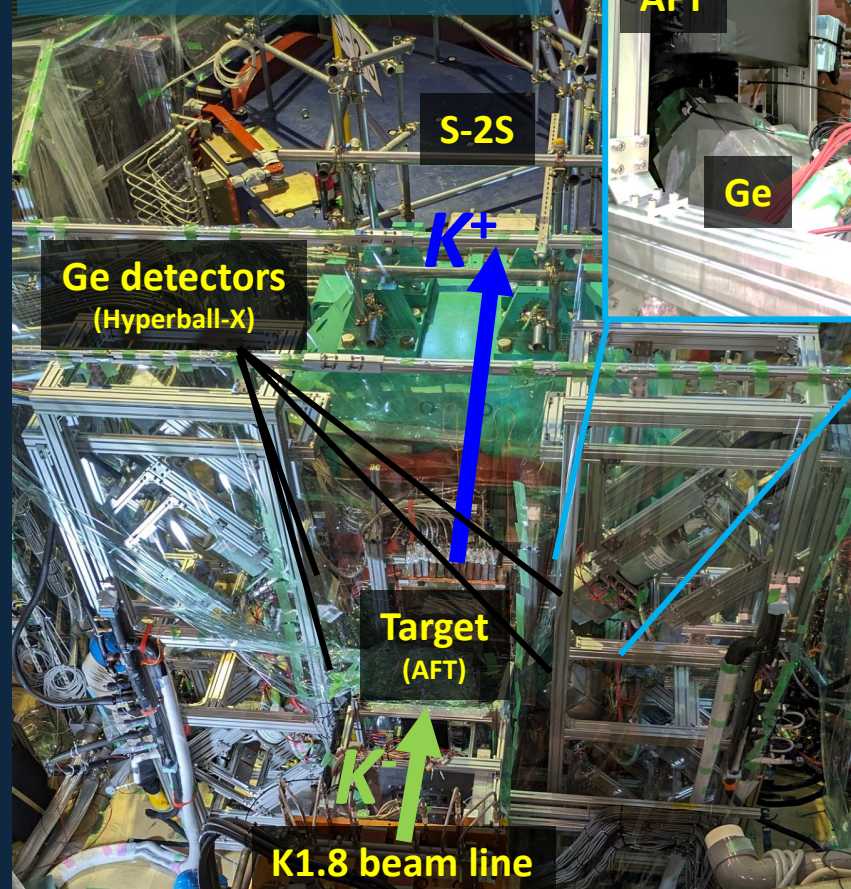
- Full (four) detectors!
- Enough data for evaluation of Hyperball-X (Actual beam condition, (K^-, K^+) reaction data)

No E96 dedicated beamtime



- Reaction \otimes γ coincidence measurement was established.
- Detector performance: OK

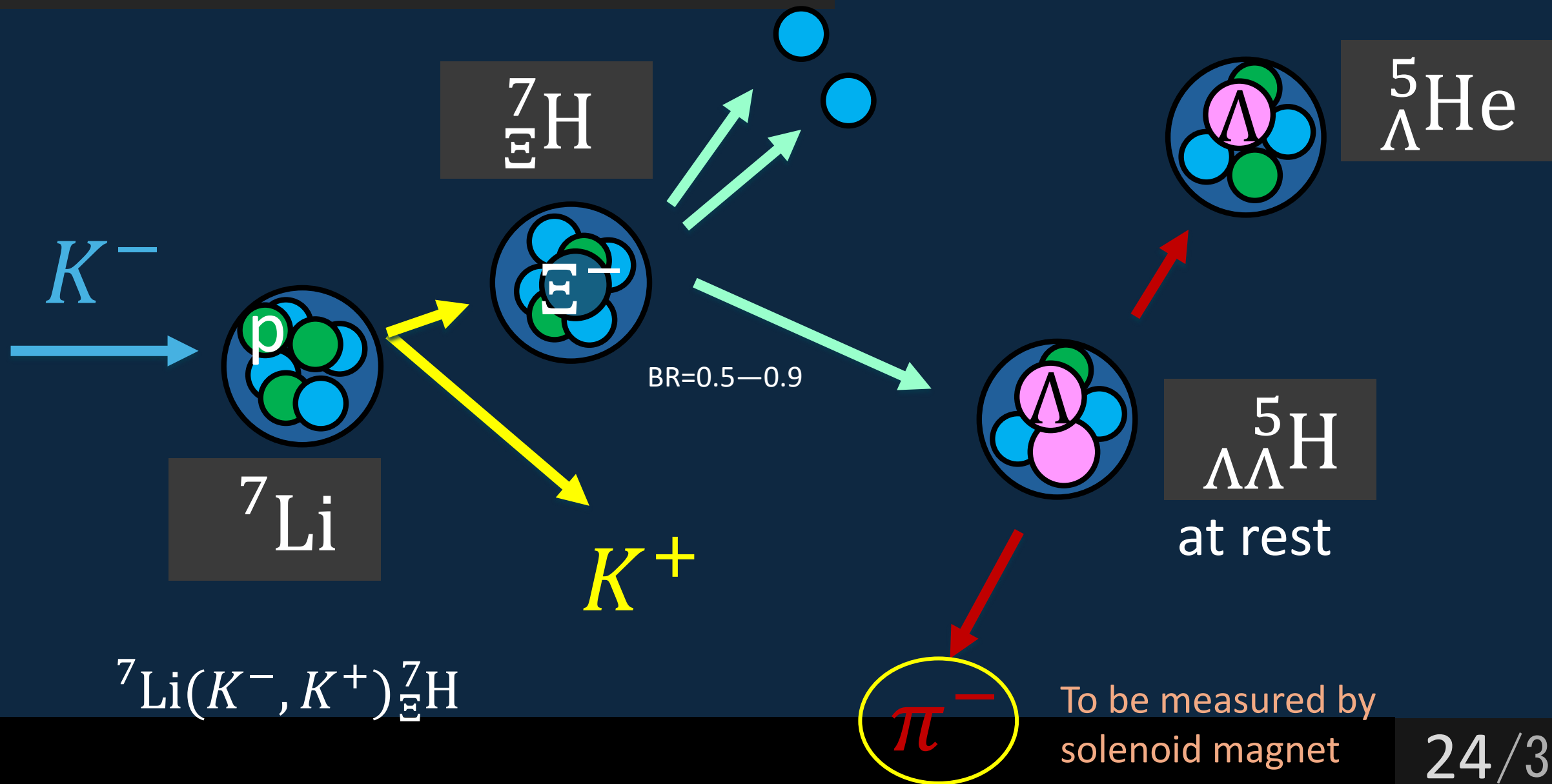
Photo in 2024.4-6 beamtime



Requested beam time: No change
1 day (E96 dedicated) beam time
in the E70 production period

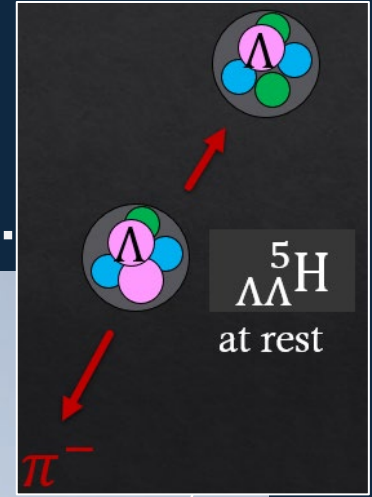
${}^5_{\Lambda\Lambda}\text{H}$ measurement (E75)

I. K. Fuse et al., PRC 54, R24–R27 (1996)
A. Ohnishi, et al., PTEP 2020, 063D01 (2020)

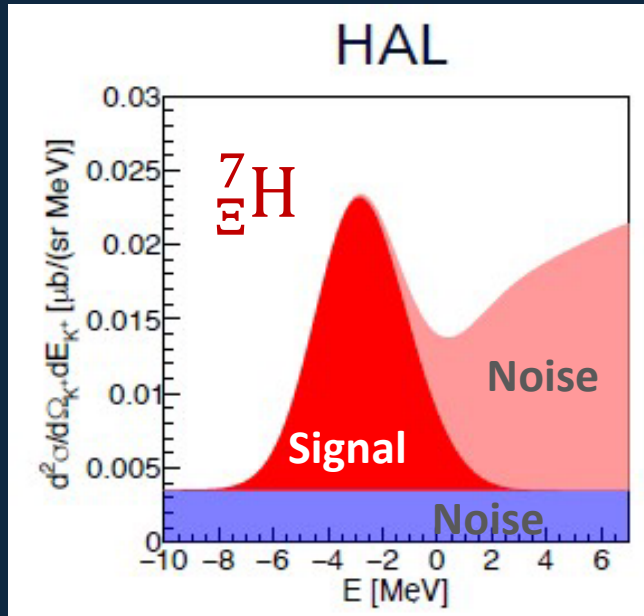


$\Lambda\Lambda^5\text{H}$ measurement (E75)

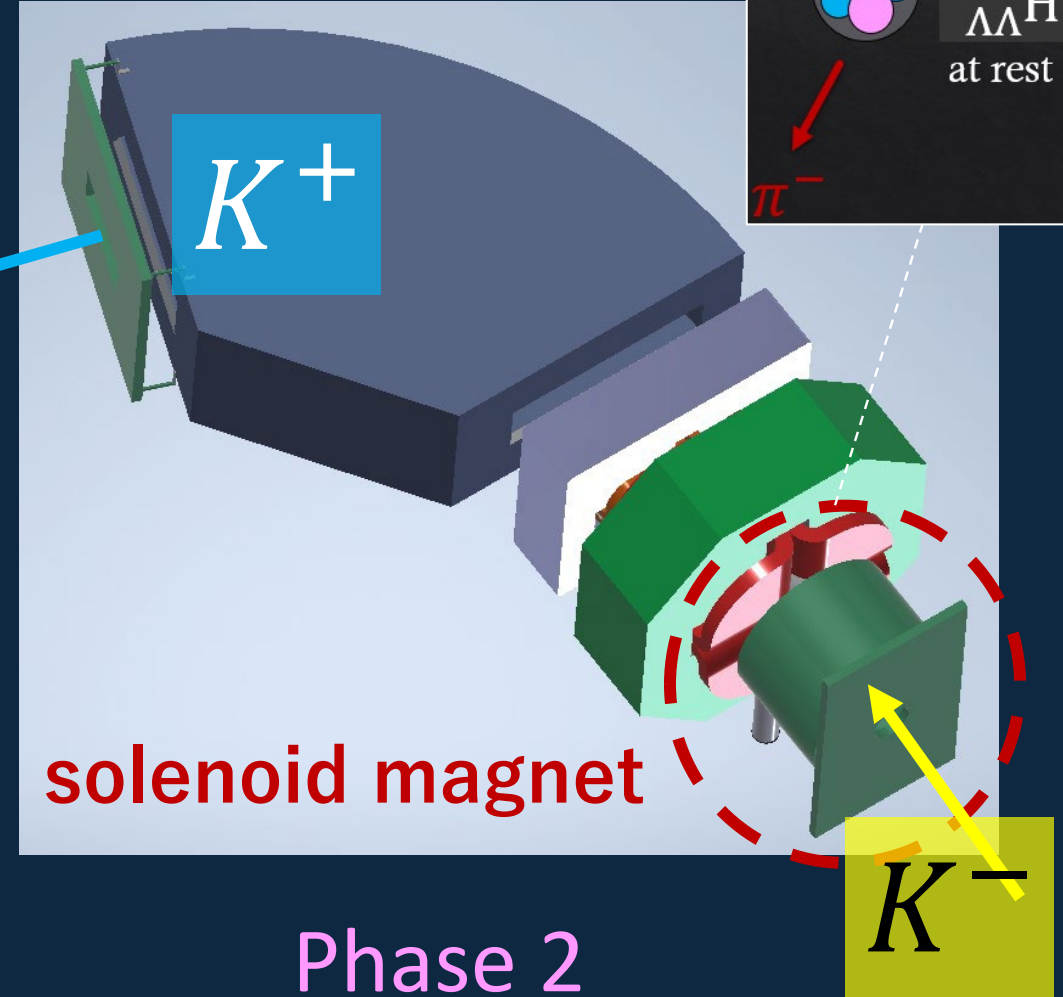
will be talked by Ebata on Oct 17, 2024



Reaction cross section of ${}^7\text{Li}(K^-, K^+){}^7_{\Lambda}\text{H}$ (w/o solenoid magnet)

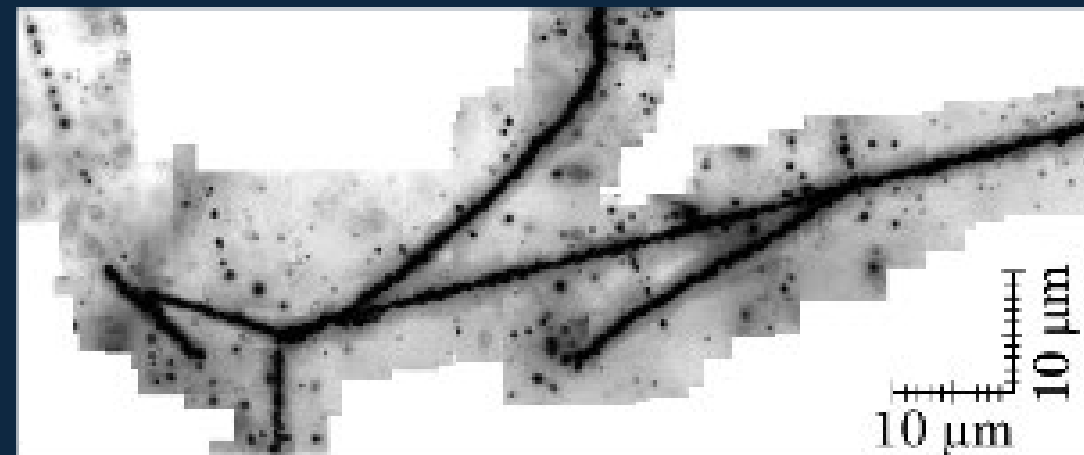
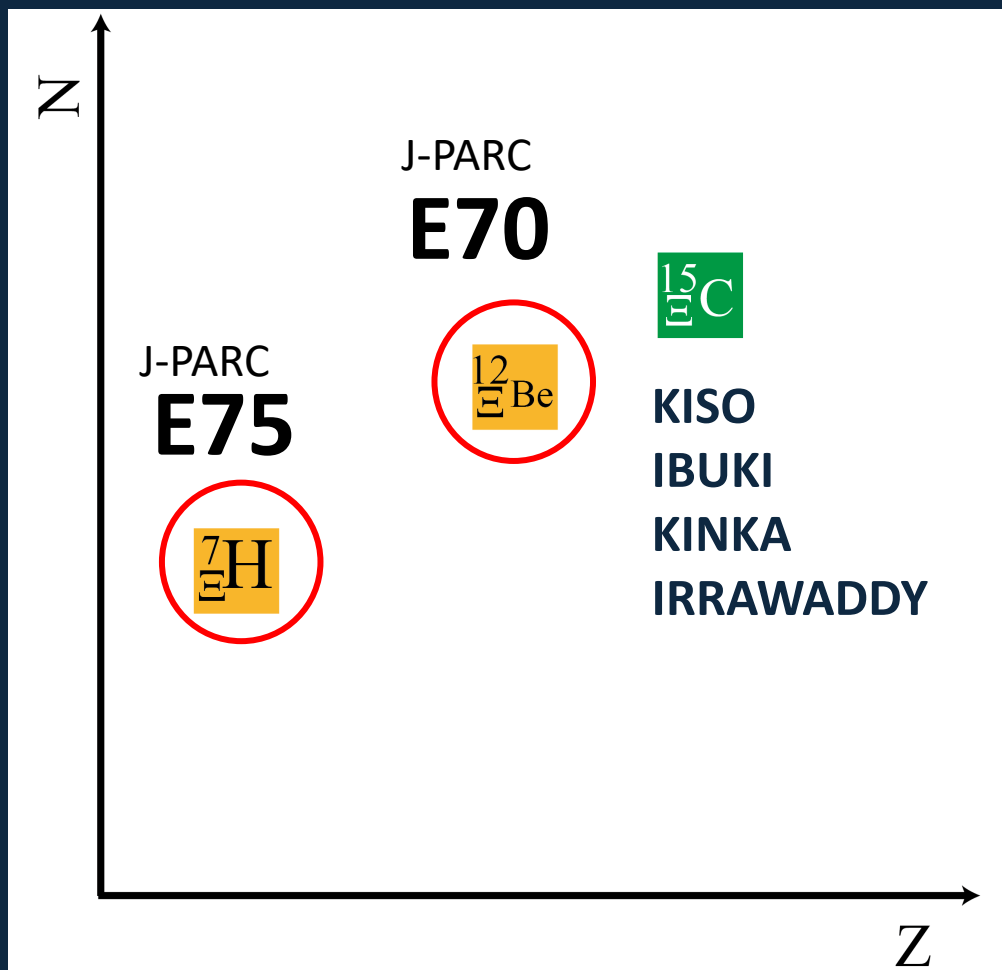


Phase 1



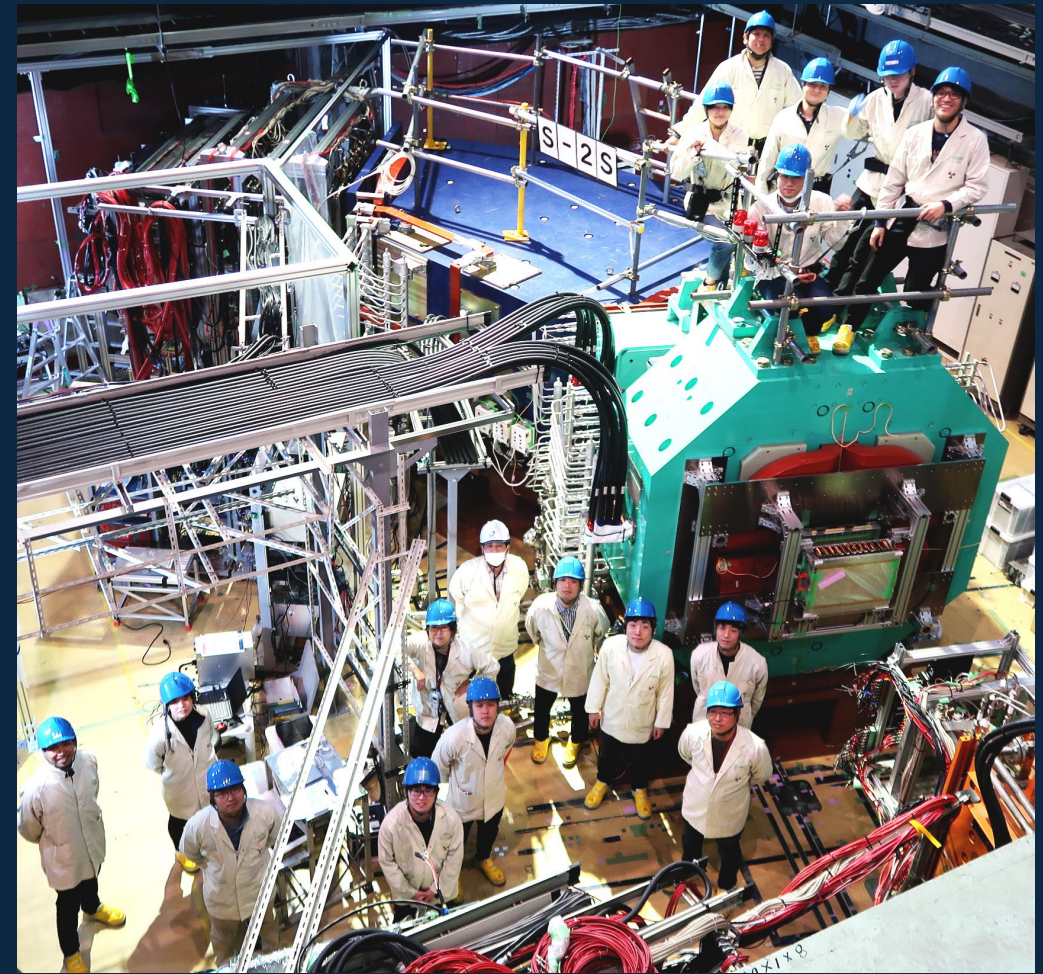
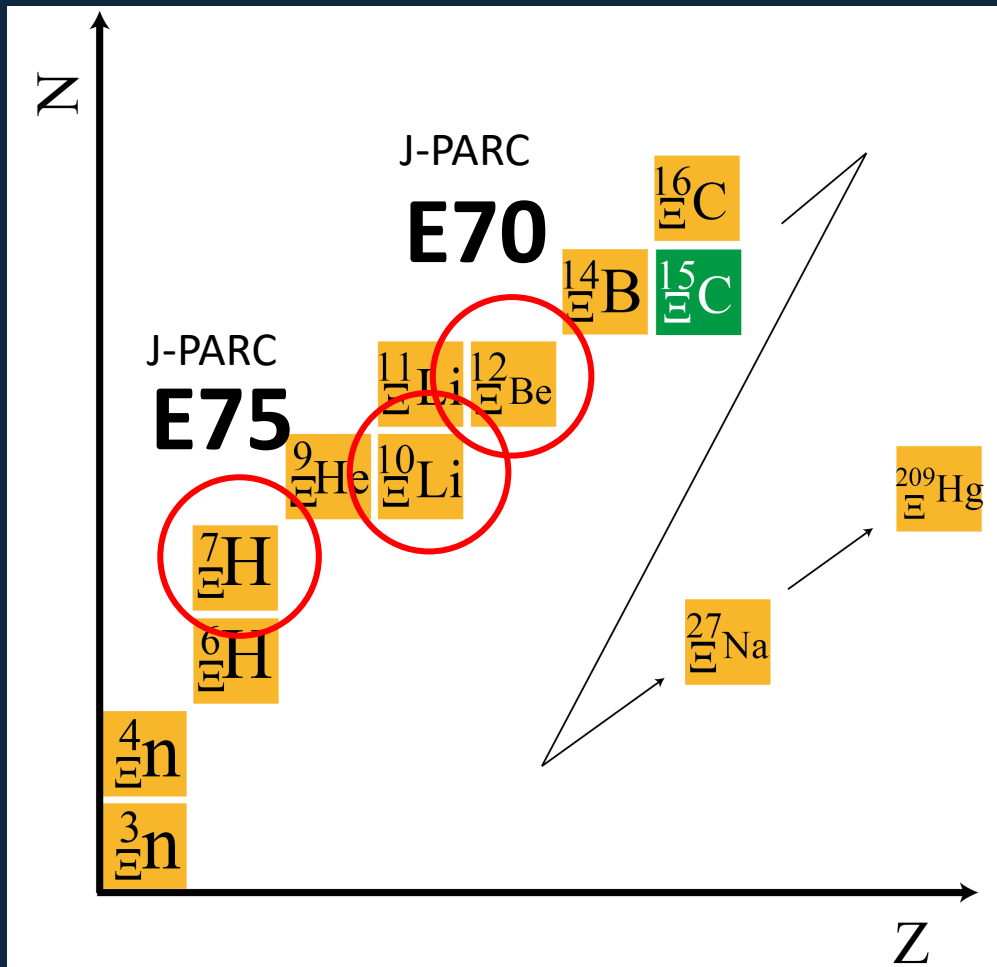
Phase 2

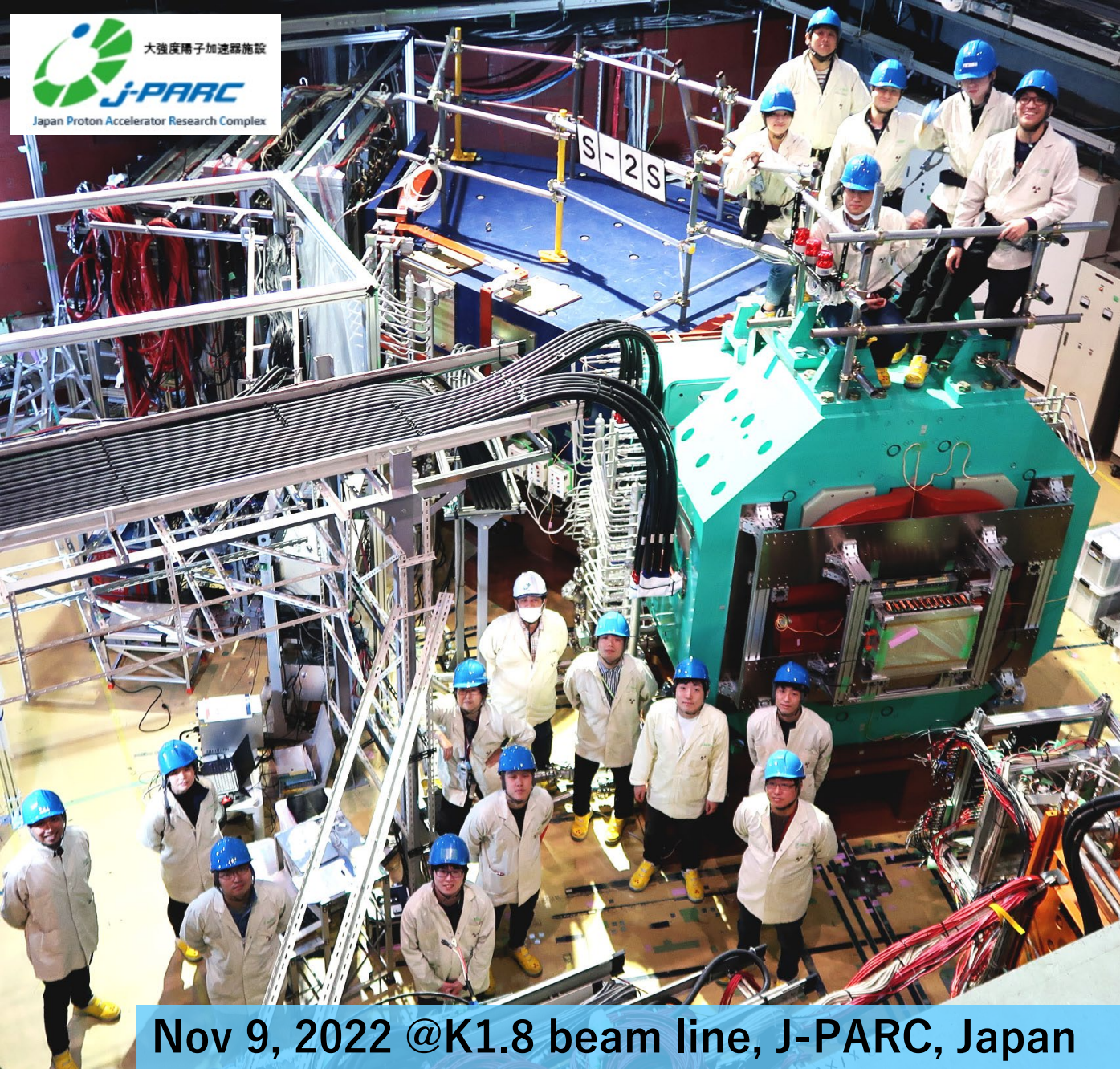
Nuclear chart (Strangeness = -2)



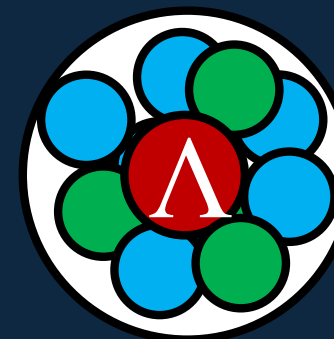
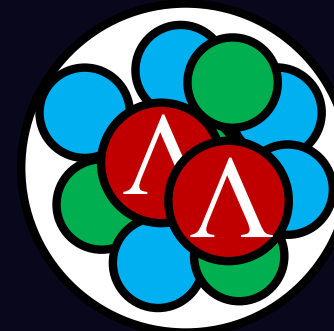
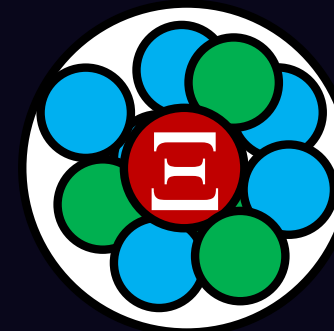
- K. Nakazawa et al., PTEP 2015, 033D02 (2015)
- M. Yoshimoto et al., PTEP 2021, 073D02 (2021)
- S. Hayakawa et al., PRL 126, 062501 (2021)

Nuclear chart (Strangeness = -2)





"S = -2" study
will start!



"S = -1"
as well

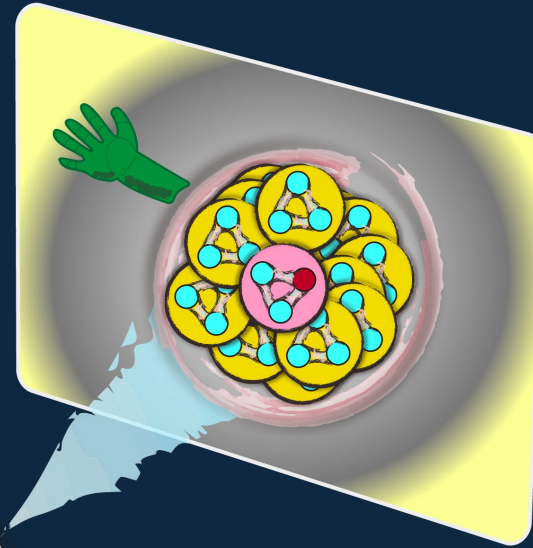
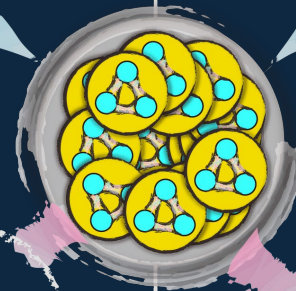
T. Gogami et al., [EPJ Web Conf. 271, 11002 \(2022\)](#).

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

T. Gogami (Kyoto Univ.), Hypernuclear experiments
at J-PARC by using S-2S, WEPH RE:2024, CAS, Rez, Czech Republic

Mirror Hypernuclear Study (Λ hypernuclei)

will be talked by Watanabe
on Oct 17, 2024



Summary

S-2S at K1.8 beamline, J-PARC

(→ Physics data taking in 2025)

- Missing mass of Ξ hypernuclei (E70, E75-1)
- X ray from Ξ atoms (E96)
- Λ hypernuclear study (E63, E94)
- Σ N cusp (E90)