POSSIBILITIES FOR HYPERNUCLEAR PHYSICS IN HALL C

KYOTO UNIVERSITY

TOSHIYUKI GOGAMI

JULY 1, 2021

京都大学　理学研究科・理学部
GRADUATE SCHOOL OF
FACULTY OF SCIENCE
KYOTO UNIVERSITY

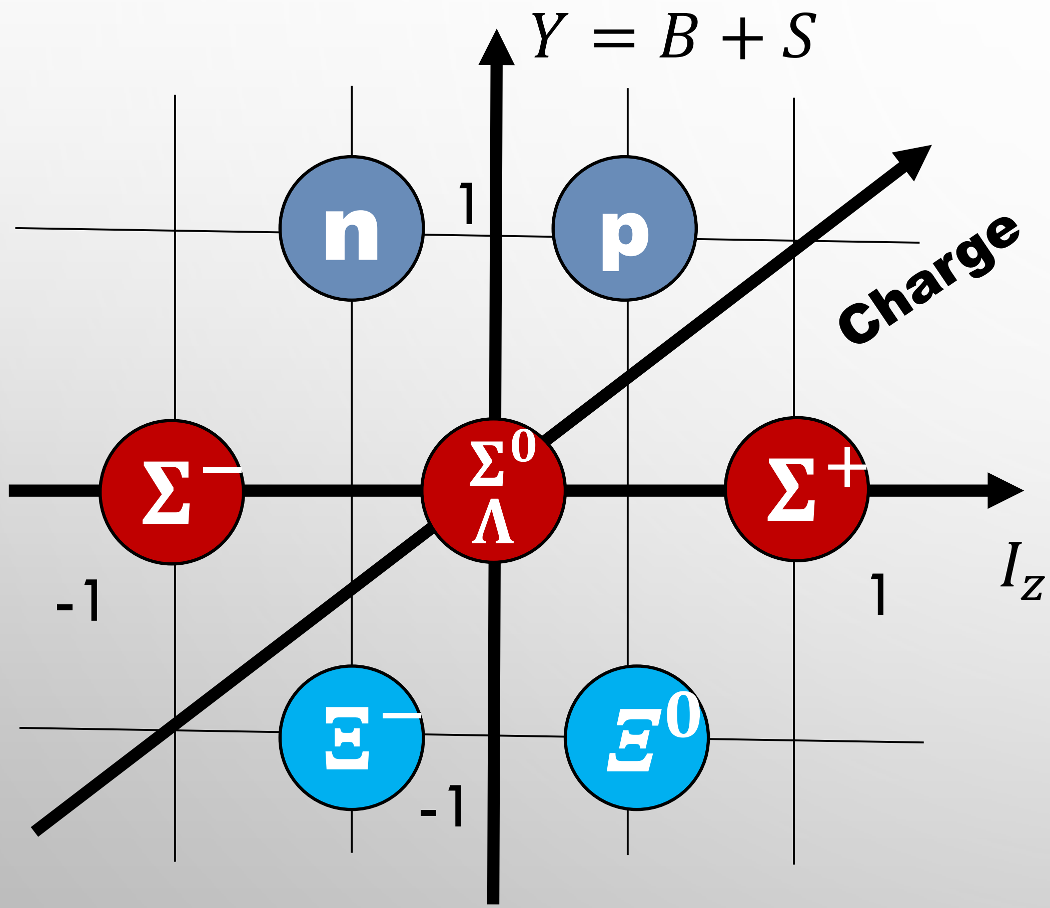
Thank you for preceding discussions and drawings !
→ Bert, Paul, Steve

CONTENTS

POSSIBILITY OF HYPERNUCLEAR EXPERIMENTS AT HALL C

- SPL + HES + HKS
- PCS + HES + HKS
- PCS + SHMS + HKS

STUDY ON BARYON INTERACTION (BB INT.)



Baryon Octet $J^\pi = \frac{1}{2}^+$

Nuclear Sector (NN)

- Rich data of scattering experiment
- Nuclear data > 3000

Strangeness Sector (ΛN, ΣN, ΞN etc.)

- Scarce data of scattering experiment
- Hypernuclear data ~ only 40 !!

Available facilities for HN experiments:

- ◆ $S = -1$: CERN, RHIC, GSI, J-PARC, MAMI, **JLab**
- ◆ $S = -2$: J-PARC

SOME OF PHYSICS MOTIVATION

- ΛN CHARGE SYMMETRY BREAKING
  - A = 3, 4: the aim depends on the results from Hall A (C12-19-002)
  - A = 9: The need of 500 keV resolution to determine the g.s. energy; TG et al, PRC 103, L041301 (2021)

- CLUSTER STRUCTURE, DEFORMATION
  - $^{27}\mathrm{Al}(e,e'K^{+})^{27}_{\Lambda}\mathrm{Mg}$: Identification of the triaxial deformation of ^{26}Mg (c.f. M. Isaka, et al., PRC 87, 021304R (2013))
  - Ne (A = 20—22) c.f. M. Isaka, PRC 83, 044323 (2011)
  - Si (A = 28—30) c.f. M.T. Win and K. Hagino, PRC 78, 054311 (2008)

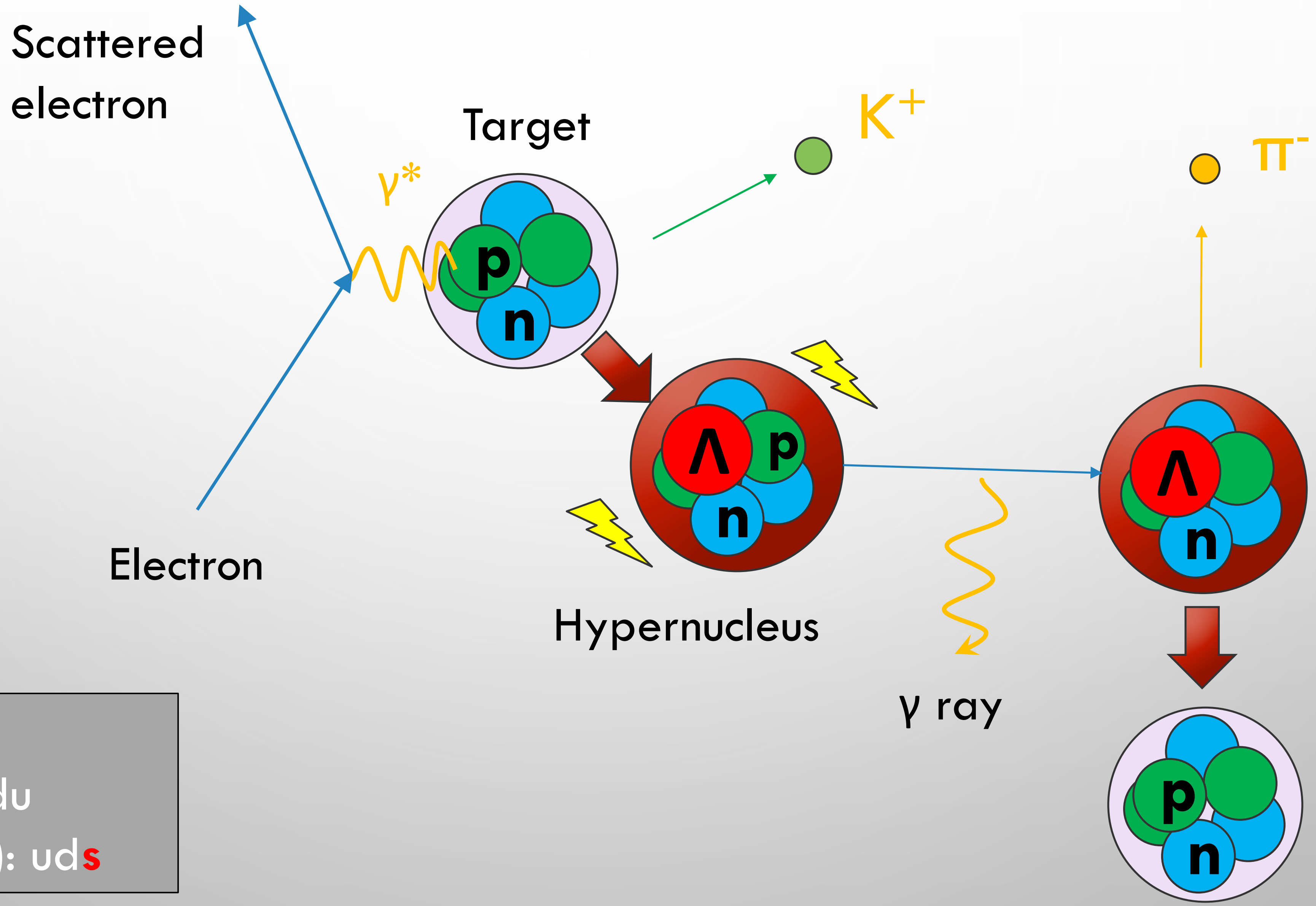
- ΛN INTERACTION PROPERTY IN DIFFERENT Δ ENVIRONMENT, MANY-BODY INTERACTION
  - Ca (A = 40—48) (40 and 48: E12-15-008)
  - Ni (A = 58—64)
  - Zr (A = 90—96)
  - Mo (A = 92—100)
  - Ru (A = 96—104)
  - Sn (A = 112—124)
  - Sm (A = 144—154)
  - Pb (A = 204—208) (208: E12-20-013)

No data with sub-MeV resolution

- CERN, BNL, KEK, J-PARC: > a few MeV (FWHM)
- Future plan at HIHR in J-PARC: sub-MeV
  ← In a stage of funding proposal submission
  (No beam line / apparatus exist yet)

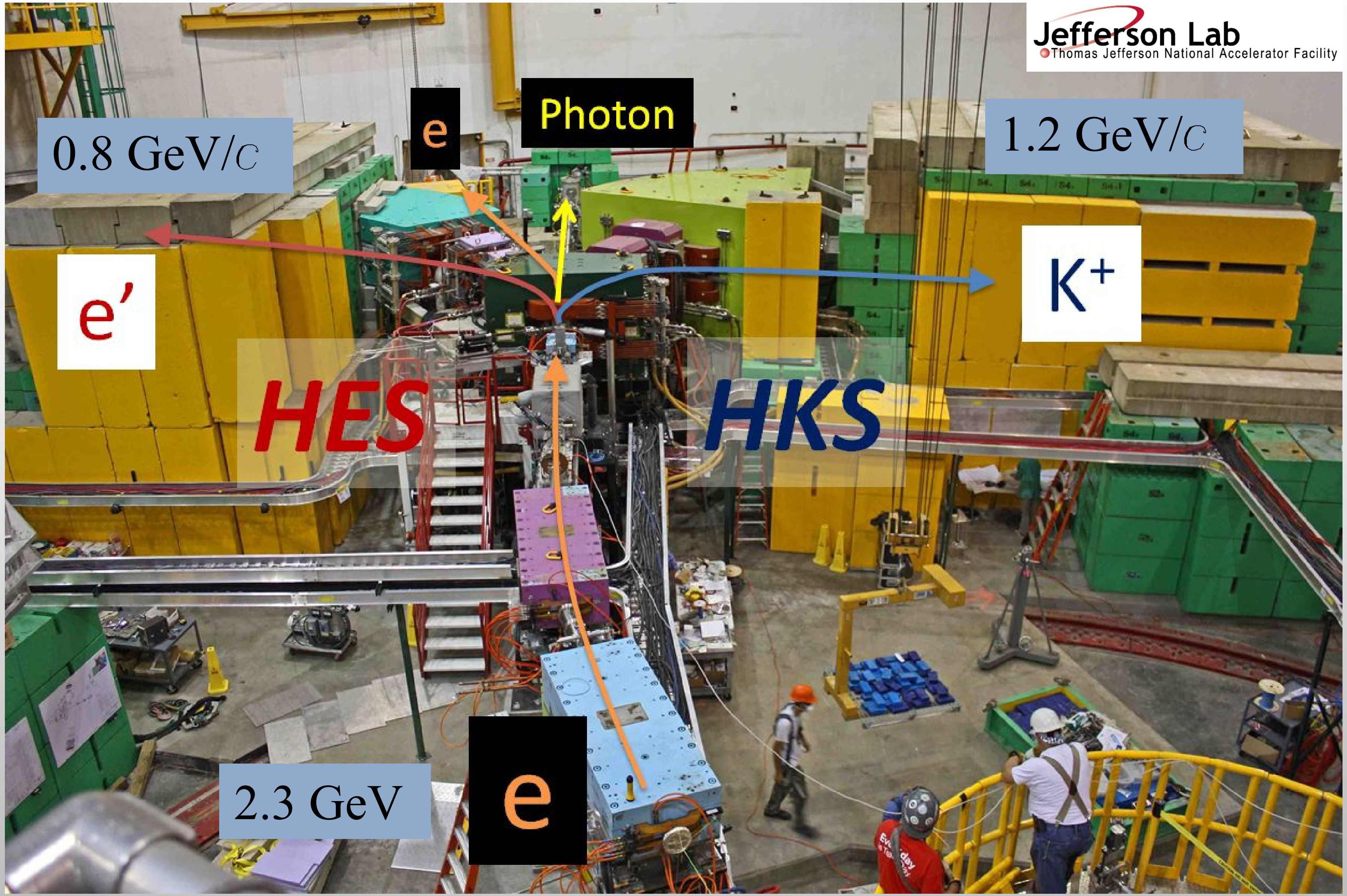
➔ JLab is a unique facility to realize it

ELECTRO PRODUCTION OF HYPERNUCLEI

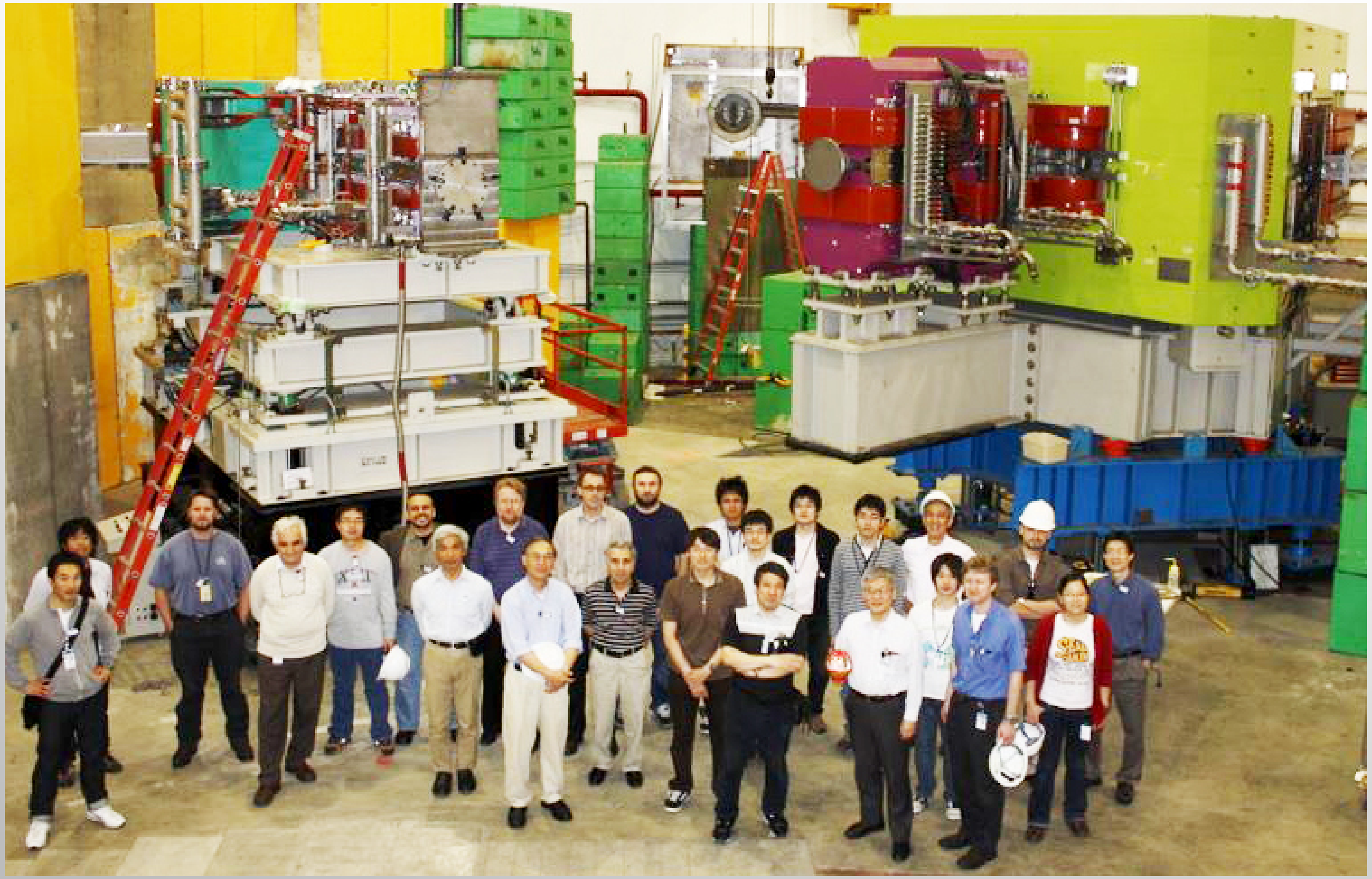


- Proton: uud
- Neutron: ddu
- Lambda (Λ): uds

Experimental setup for E05-115 (2009) at JLab Hall C



SPL+HES+HKS (E05-115) AT HALL C



TG et al., PRC 103, L041301 (2021).
TG et al., NIMA 900, 69—83 (2016)
TG et al., PRC 94, 021302(R) (2016).
TG et al., PRC 93, 034314 (2016).
Y. Fujii et al., NIMA 795, 351—363 (2015).
L. Tang et al., PRC 90, 034320 (2014).
TG et al., NIMA 729, 816—824 (2013).

ISSUE TO SOLVE IN HKS

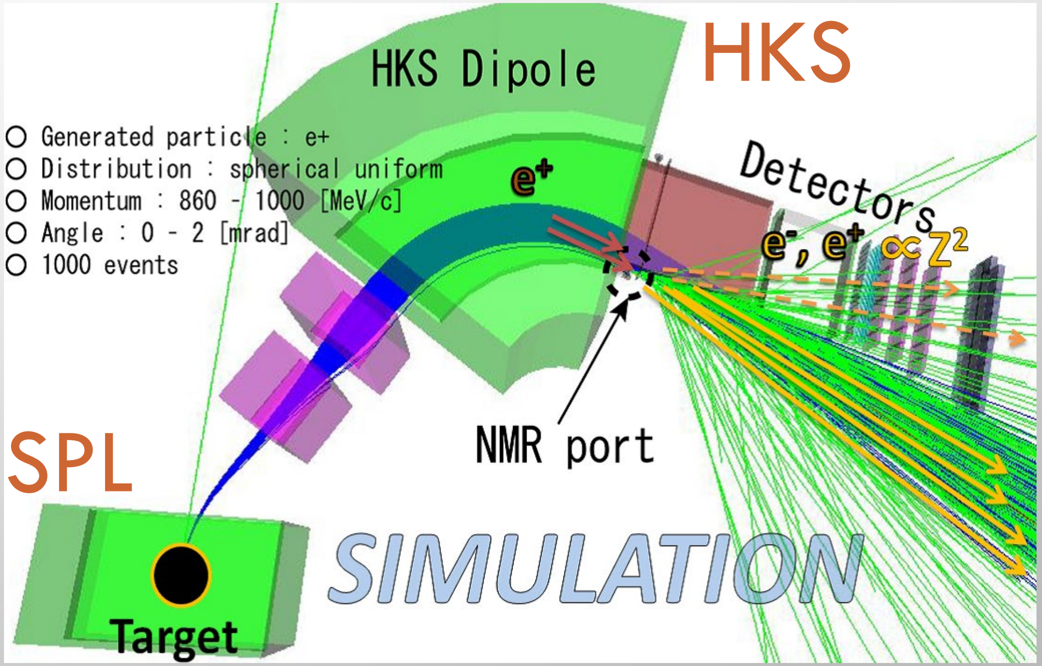
Ref.) TG et al., NIMA 900, 69—83 (2018)

e^+/e^- backgrounds generated at HKS-D exit

- High accidental coincidence rate
  - Beam intensity was limited particularly for a large Z target
  - S/N was bad in resulting spectra

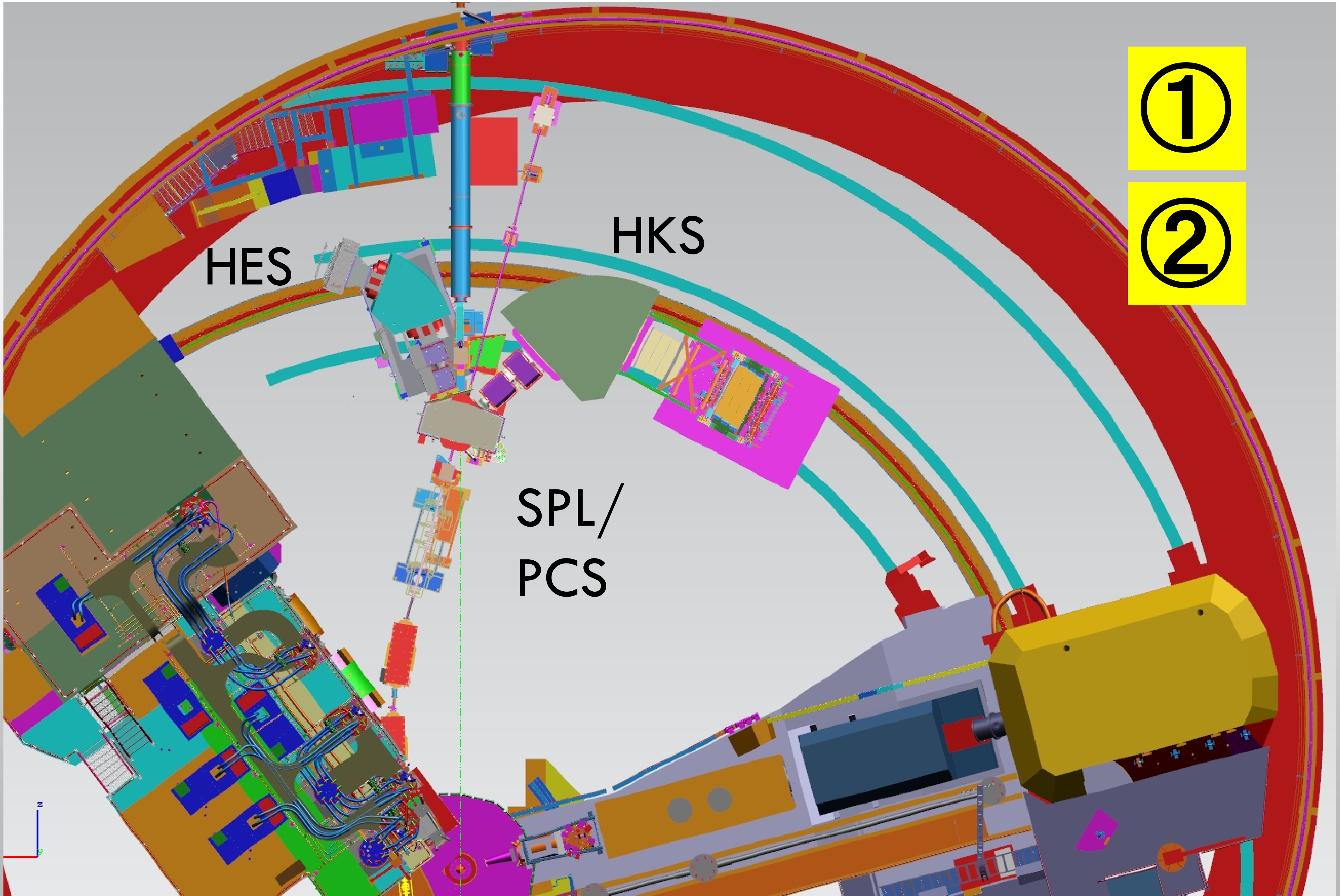
Possible solutions:

1. Introduction of a septum-type magnet
2. Changing to a lighter material for the lower momentum side of the HKS-D vacuum extension (or VE → He bag)
3. Changing to the vertical bending
   ← The need of massive modification (Base for HKS magnets, frames for detectors etc.)

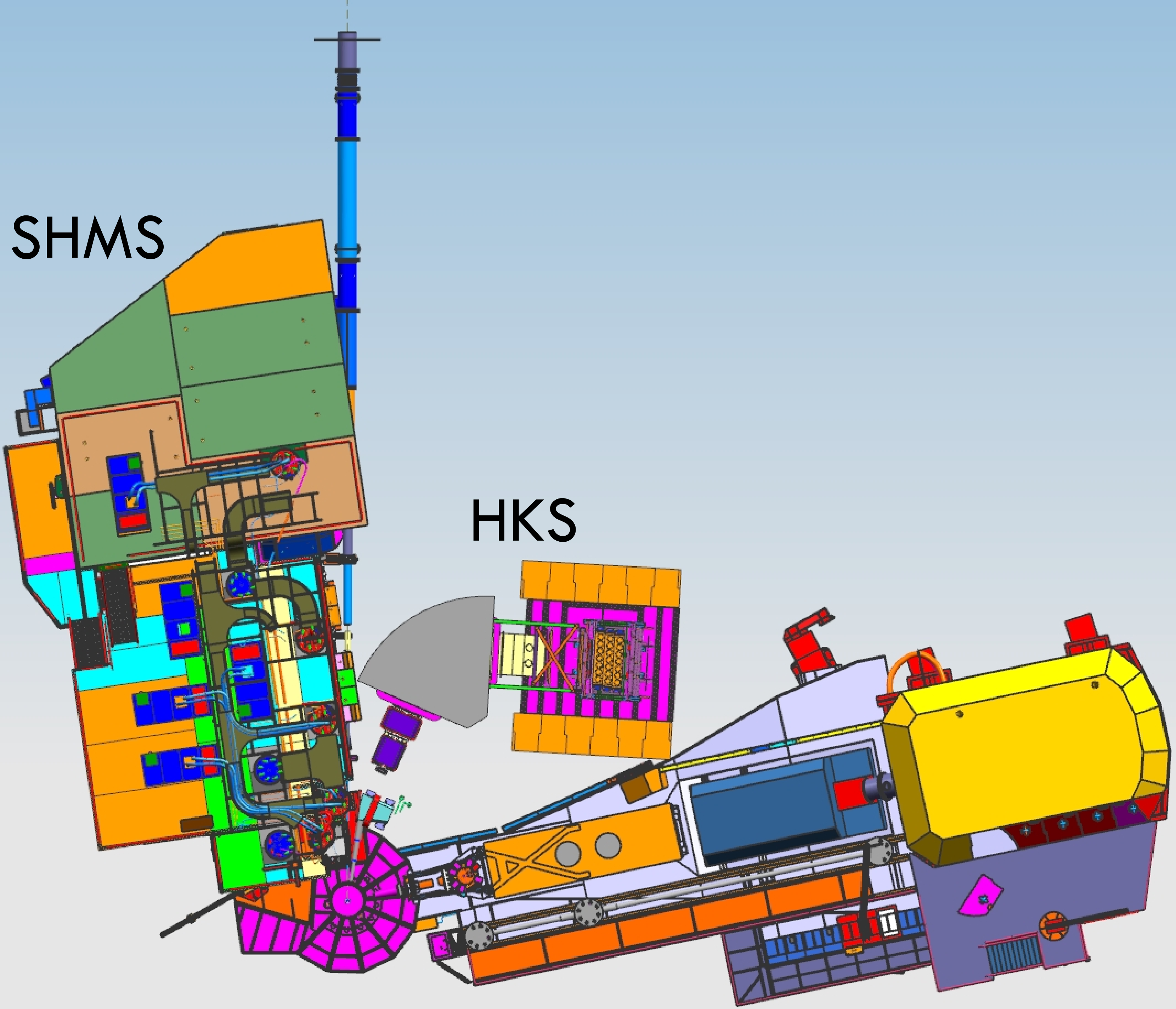


TO USE GAS TARGETS

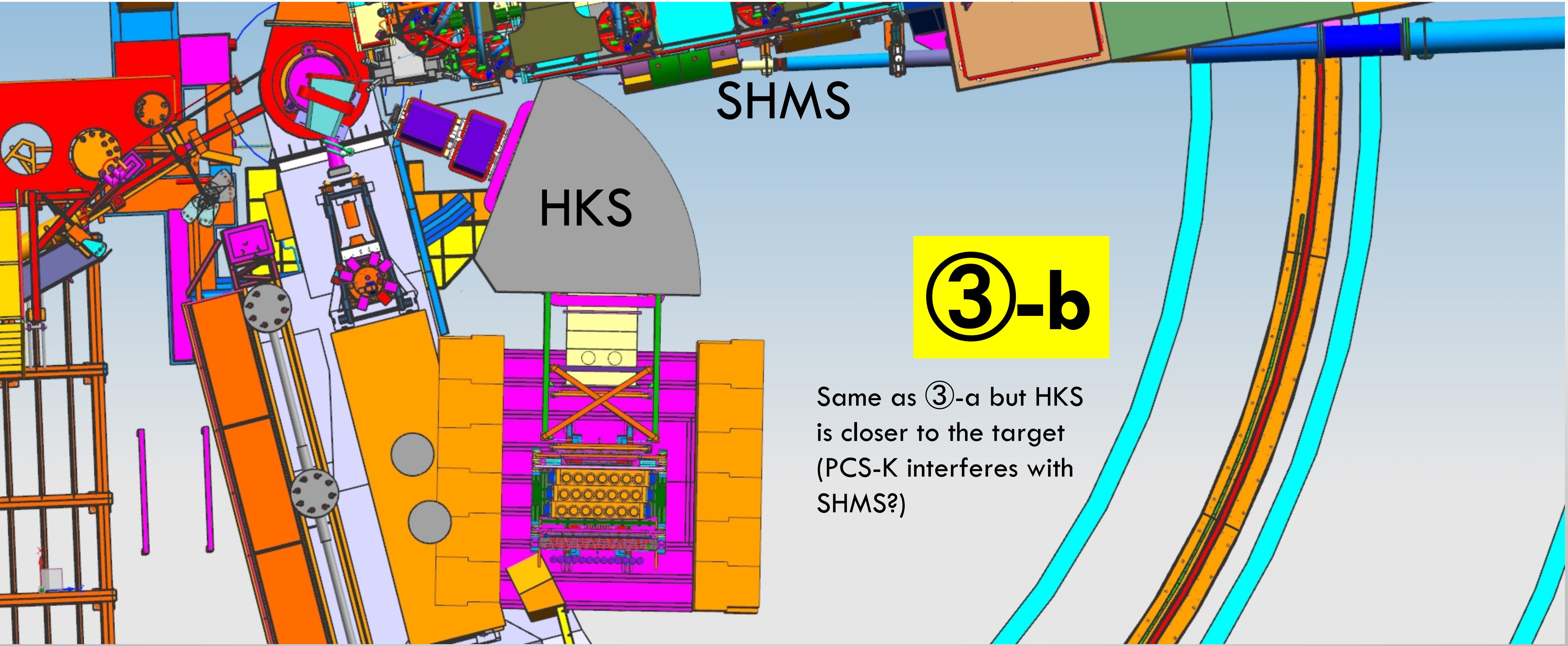
- Reaction-position information would need to be measured by a vertical bending magnet at least because a point production cannot be assumed for a long z target.
  - ✓ Previous configuration of HES-HKS is not suitable
  - ✓ SHMS for e’ ?



①
②
HES
HKS
SPL/
PCS



③-a

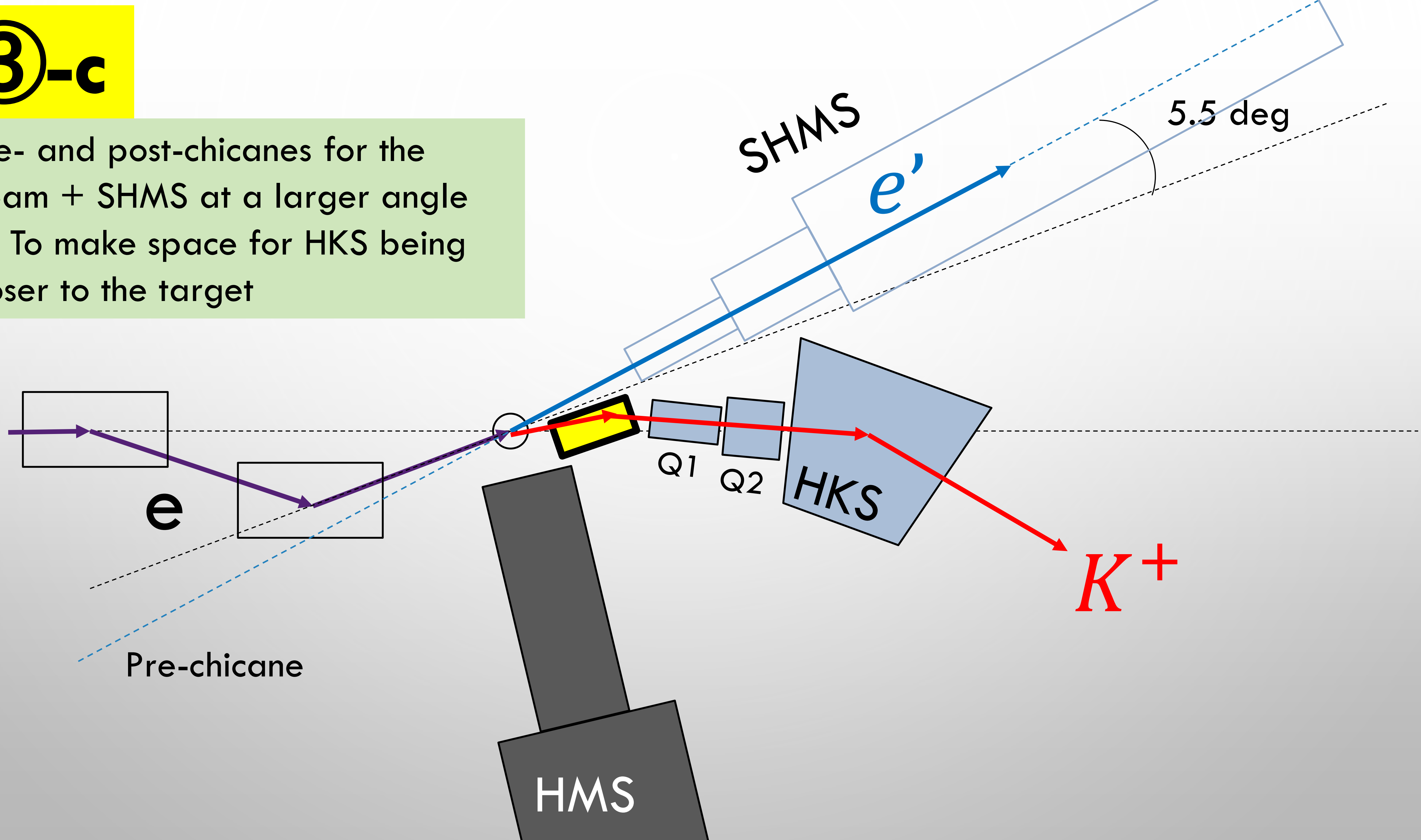


③-b

Same as ③-a but HKS is closer to the target (PCS-K interferes with SHMS?)

③-c

Pre- and post-chicanes for the beam + SHMS at a larger angle
→ To make space for HKS being closer to the target



ROUGH ESTIMATIONS

	Com. D0	e' (θ、Ω、dp)	K^+ ($\theta_{\gamma K}$ 、Ω、f_K)	Γ ($/10^{-5}$)	ΔE_Λ FWHM (/ MeV)	Yield per hour ^{12}C, 0.1 g/cm^2, 100 nb/sr, 30 μA	Fit to space ?	Gas target
①	SPL	HES (5° 、7 msr、17.5%)	HKS (7° 、8 msr、0.3)	5.7	0.4 + opt.	32.4	○	△
②	PCS	HES (6° 、5 msr、17.5%)	HKS (0° 、7 msr、0.27)	2.8		12.7	○	△
	PCS	SHMS (6° 、1.5 msr、40%)	HKS (0° 、7 msr、0.27)	1.9	0.9 + opt.	8.6	?	○
③-b ③-c	-	SHMS (6° 、2.0 msr、40%)	PCS+HKS (0° 、7 msr、0.27)	2.5		11.6	?	○
③-a	-	SHMS (6° 、2.0 msr、40%)	PCS+HKS (6° 、2 msr、0.25)	2.5	0.9 + opt.	3.1	○	○

e: 2.344 GeV, e': 0.844 GeV/c, K+: 1.2 GeV/c
Efficiency = 0.7

Yield per day @ 20μA

Configuration	ΔE_Λ (# of events needed for $\Delta B_\Lambda^{stat.} = 20$ keV)	$^{3}\mathrm{He} \rightarrow {}^{3}_{\Lambda}\mathrm{H}$ 5 nb/sr	$^{12}\mathrm{C} \rightarrow {}^{12}_{\Lambda}\mathrm{B}$ 100 nb/sr	$^{40}\mathrm{Ca} \rightarrow {}^{40}_{\Lambda}\mathrm{K}$ 10 nb/sr	$^{208}\mathrm{Pb} \rightarrow {}^{208}_{\Lambda}\mathrm{Tl}$ 10 nb/sr
SPL+(HES+HKS) ①	**0.5 (113)**	109 (1 day)	547	16 (7 days)	3.2 (35 days)
PCS+(HES+HKS) ②		40 (3 days)	203	6.1 (19 days)	1.2 (94 days)
SHMS+(PCS+HKS) ③**-b, c**	**1.0 (451)**	37 (12 days)	186	5.6 (81 days)	1.1 (410 days)
SHMS+(PCS+HKS) ③**-a**		9.9 (46 days)	45	1.5 (301 days)	0.29 (1555 days)

In case of $\Delta B_\Lambda^{stat.} = 50$ keV:
0.5 MeV FWHM → 18 counts
1.0 MeV FWHM → 72 counts

SUMMARY

The best precision / accuracy spectroscopy is possible at JLab

→ JLab is very unique to investigate the ΛN interaction and hidden features in hypernuclei

HES+HKS

- Could be the best option
- HKS needs to be modified (vacuum extension modification; VE → He bag)
- w/ PCS → S/N (could be) ↑、yield ↓
- For gas target, one of spectrometers may need to be modified to the vertical bending

SHMS+(PCS+HKS) with ③-b, c configuration

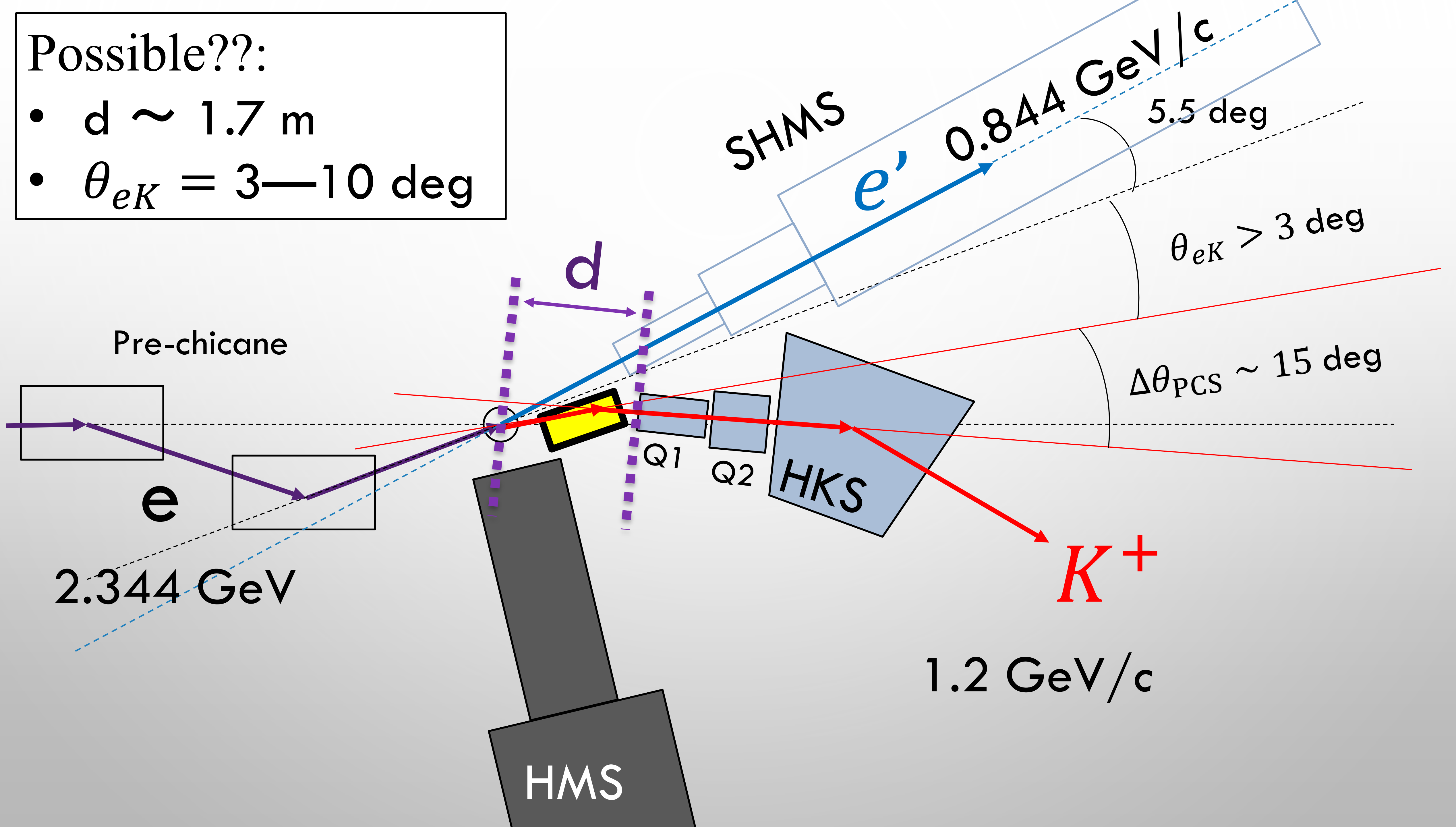
→We may take data which are similar quality to the Hall A experiment

➔ Here only yield and resolution are discussed.
➔ S/N needs to be studied as well.

BACKUP

Possible??:

- d ~ 1.7 m
- θ_{eK} = 3—10 deg



CF.)

- **APFB2020 (ONLINE+KANAZAWA(JAPAN), 1-5 MAR, 2021)**
  - T. GOGAMI, "LAMBDA HYPERTRITON BINDING ENERGY MEASUREMENT AT JEFFERSON LAB", MAR 2, 2021

(HTTPS://WIKI.JLAB.ORG/TEGWIKI/IMAGES/1/1E/APFB2020_GOGAMI_20210302_TOUPLOAD.PDF)