

# POSSIBILITIES FOR HYPERNUCLEAR PHYSICS IN HALL C

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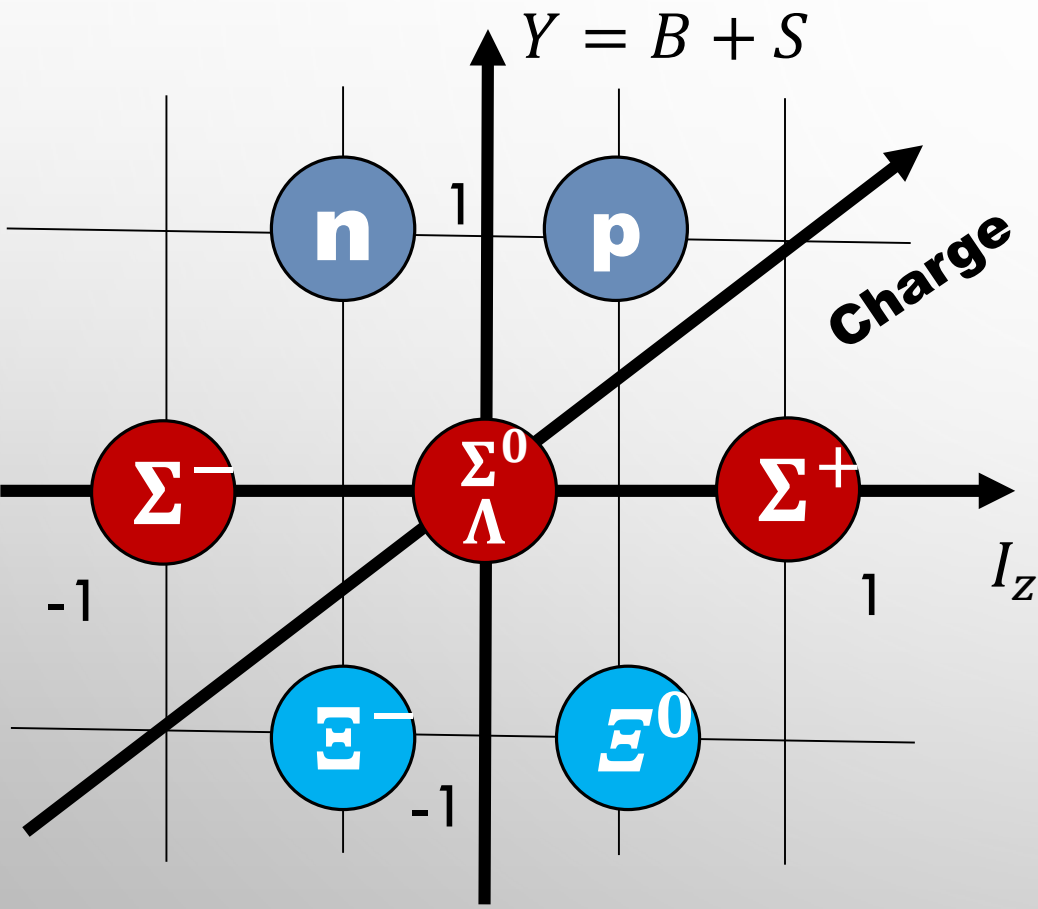
Thank you for preceding  
discussions and drawings !  
→ Bert, Paul, Steve

# CONTENTS

Possibility of hypernuclear experiments at Hall C

- SPL + HES + HKS : used for E05-115
- PCS + HES + HKS : PCS is a magnet for Hall A HN exp.
- 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 ( $\Lambda N, \Sigma N, \Xi N$  etc.)**

- Scarce data of scattering experiment
- Hypernuclear data  $\sim$  only 40 !!

- Available facilities for HN experiments:
- ◆  $S = -1$ : CERN, RHIC, GSI, J-PARC, MAMI, **JLab**
  - ◆  $S = -2$ : J-PARC

# SOME OF PHYSICS MOTIVATION

## • AN 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

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

## • AN INTERACTION PROPERTY IN DIFFERENT $\Delta$ ENVIRONMENT, MANY-BODY INTERACTION

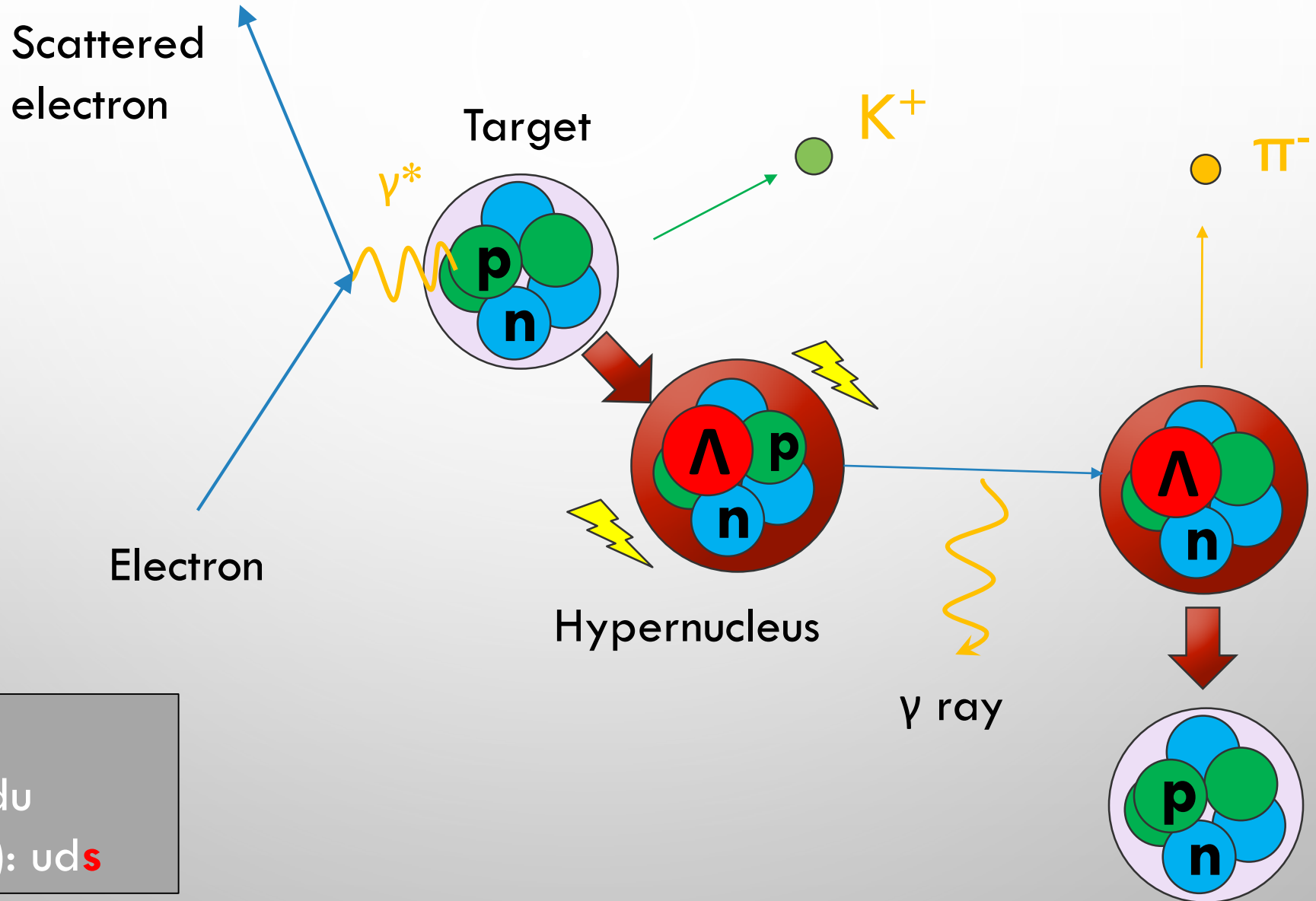
- Ca ( $A = 40\text{—}48$ ) (40 and 48: E12-15-008)
- Ni ( $A = 58\text{—}64$ )
- Zr ( $A = 90\text{—}96$ )
- Mo ( $A = 92\text{—}100$ )
- Ru ( $A = 96\text{—}104$ )
- Sn ( $A = 112\text{—}124$ )
- Sm ( $A = 144\text{—}154$ )
- Pb ( $A = 204\text{—}208$ ) (208: E12-20-013)

### **No data with sub-MeV resolution**

- CERN, BNL, KEK, J-PARC:  $>$  a few MeV (FWHM)
- Future plan at HHR 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**

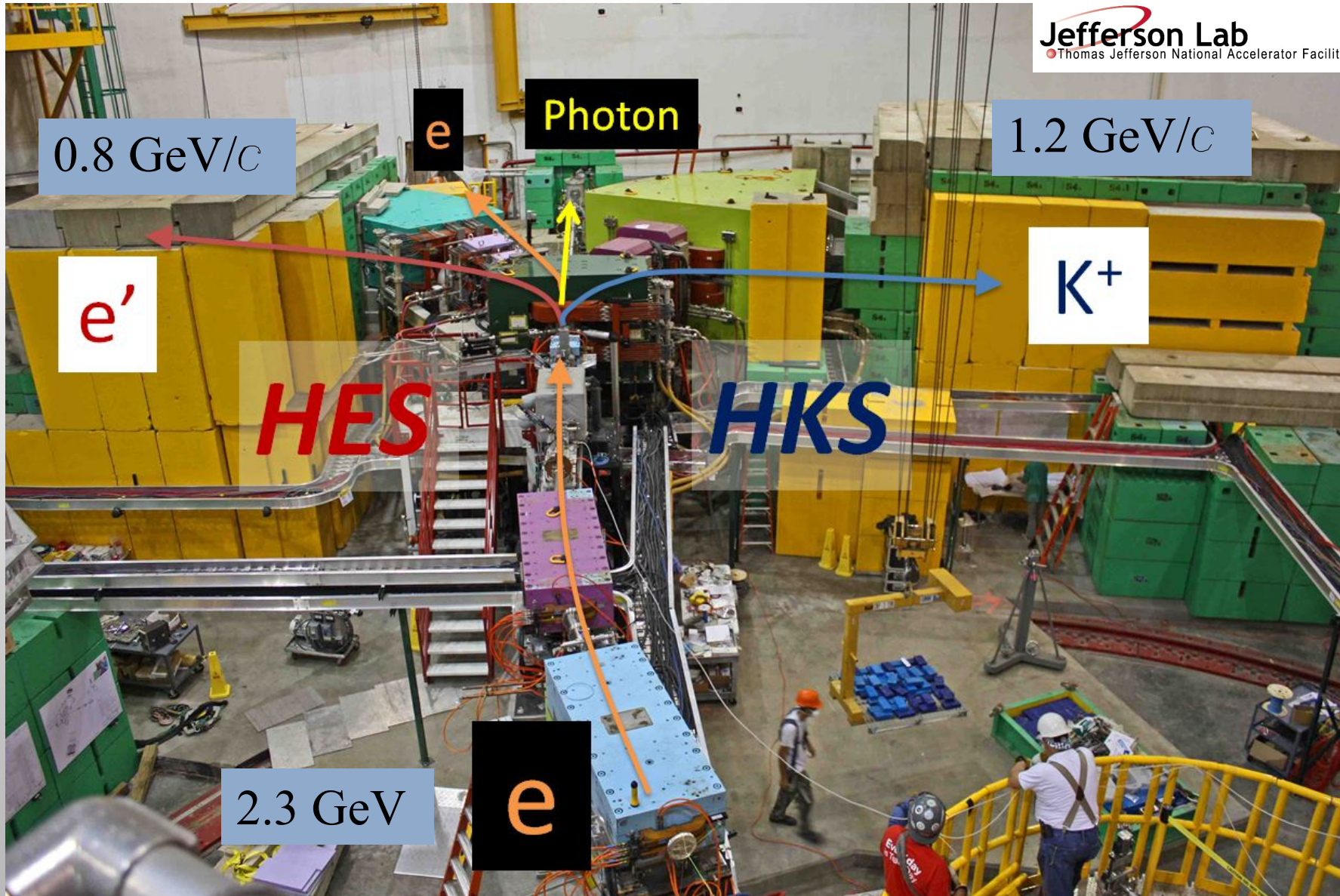
# ELECTRO PRODUCTION OF HYPERNUCLEI



- Proton: uud
- Neutron: ddu
- Lambda ( $\Lambda$ ): ud**s**

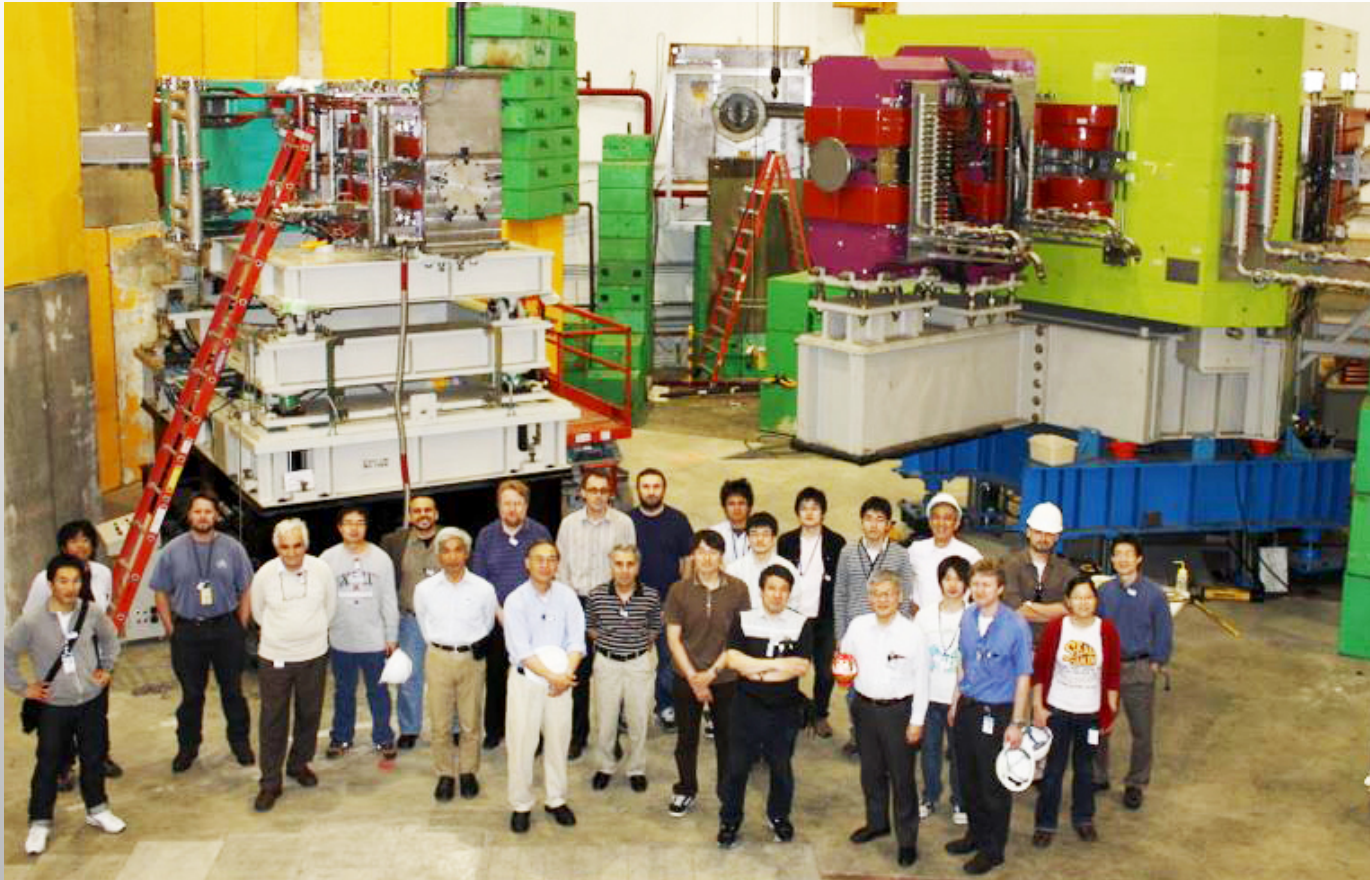
# Experimental setup for E05-115 (2009) at JLab Hall C

Jefferson Lab  
Thomas Jefferson National Accelerator Facility



PCS+HES+HKS  
~\$ 5 M

# 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

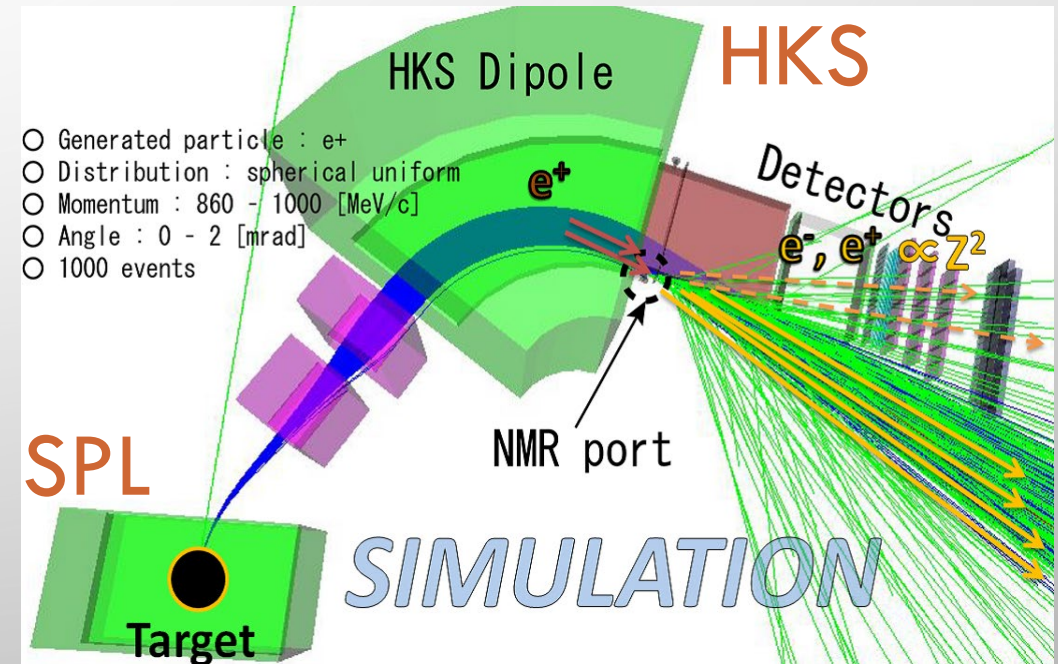
Ref.) TG et al., NIMA 900, 69—83 (2018)

$e^+/e^-$  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:

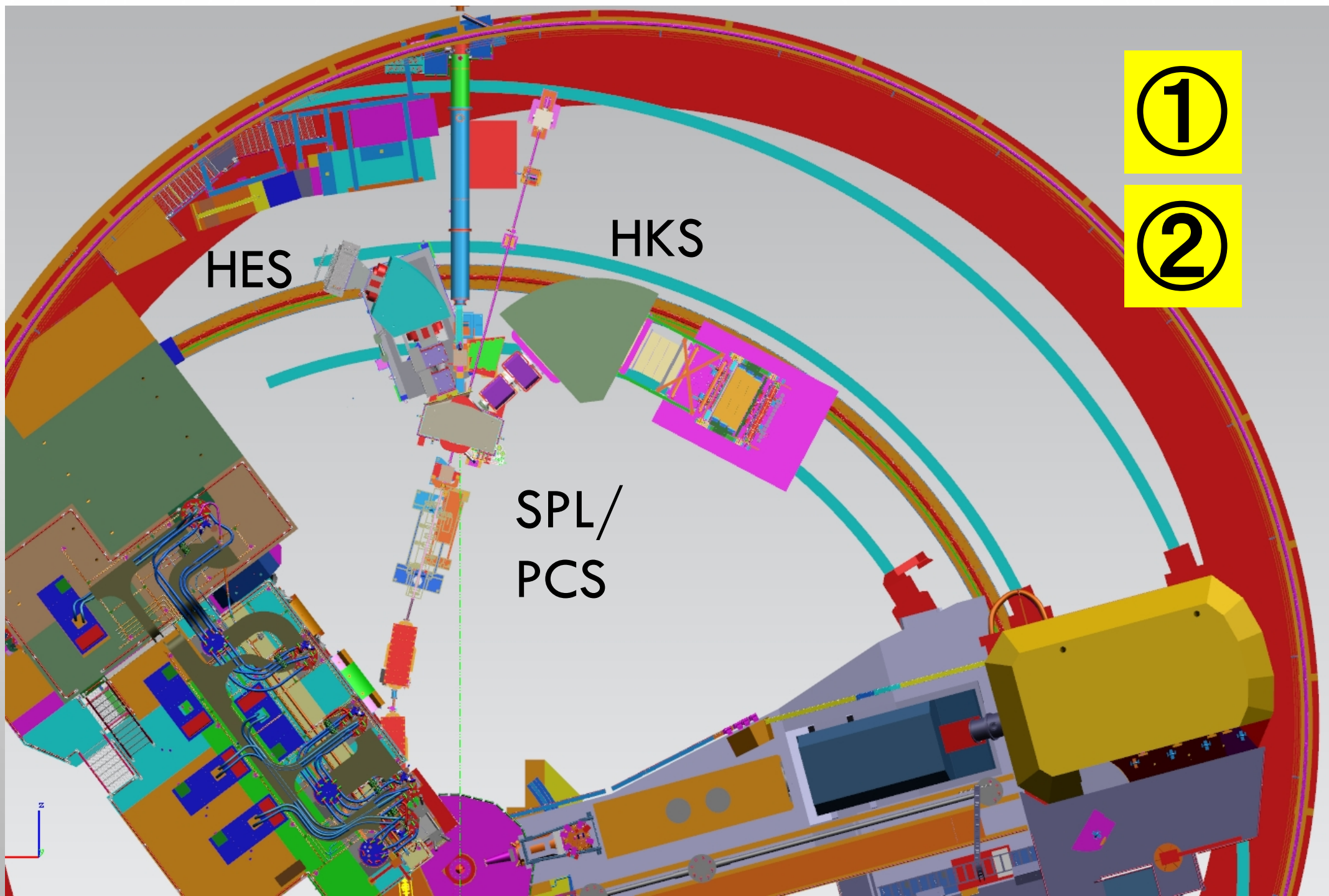
1. Introduction of a septum-type magnet
2. Changing to a lighter material for the lower momentum side of the HKS-D vacuum extension (or VE  $\rightarrow$  He bag)
3. Changing to the vertical bending  
← The need of massive modification (Base for HKS magnets, frames for detectors etc.)





# 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  $e'$  ?



HES

HKS

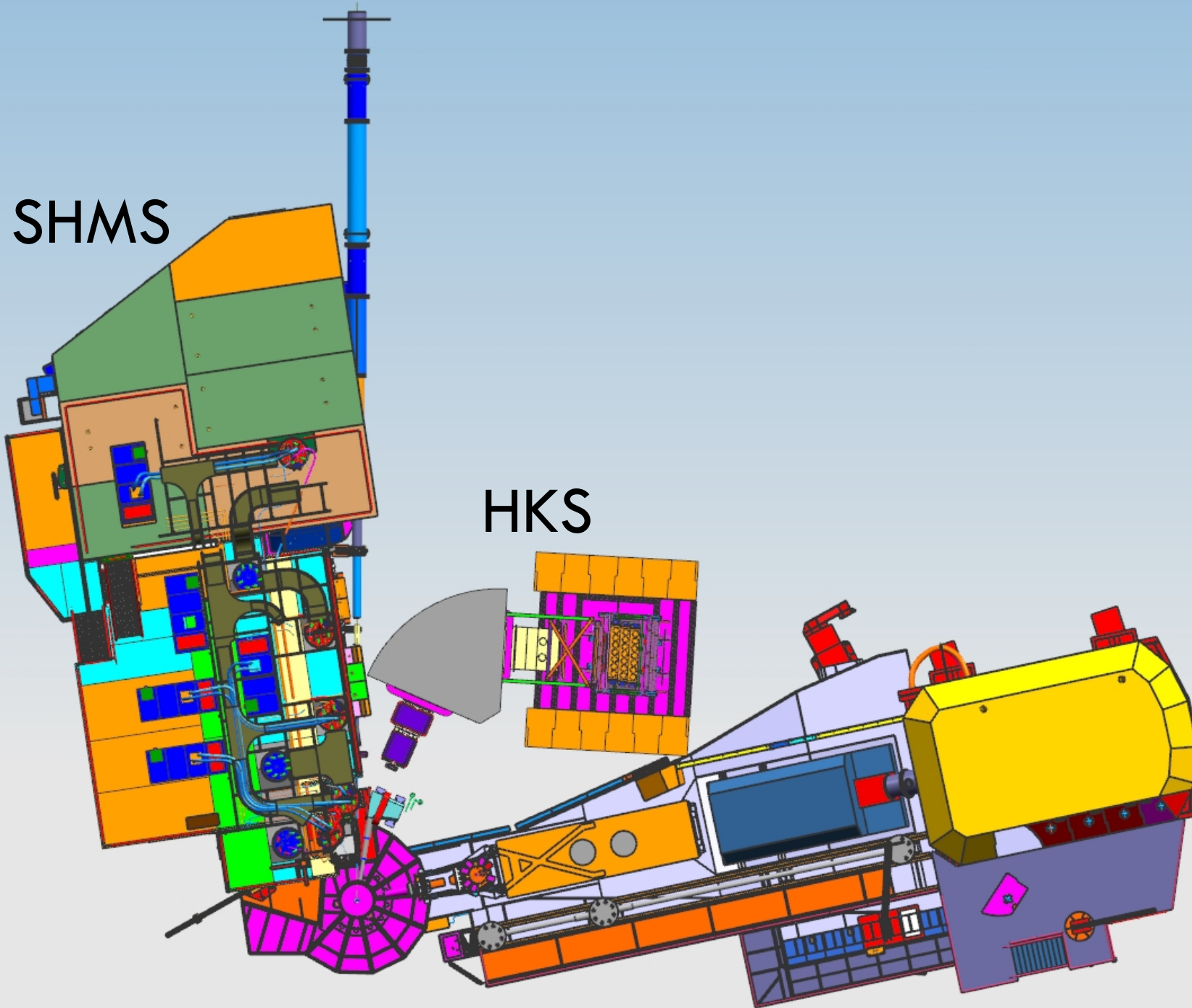
SPL/  
PCS

①

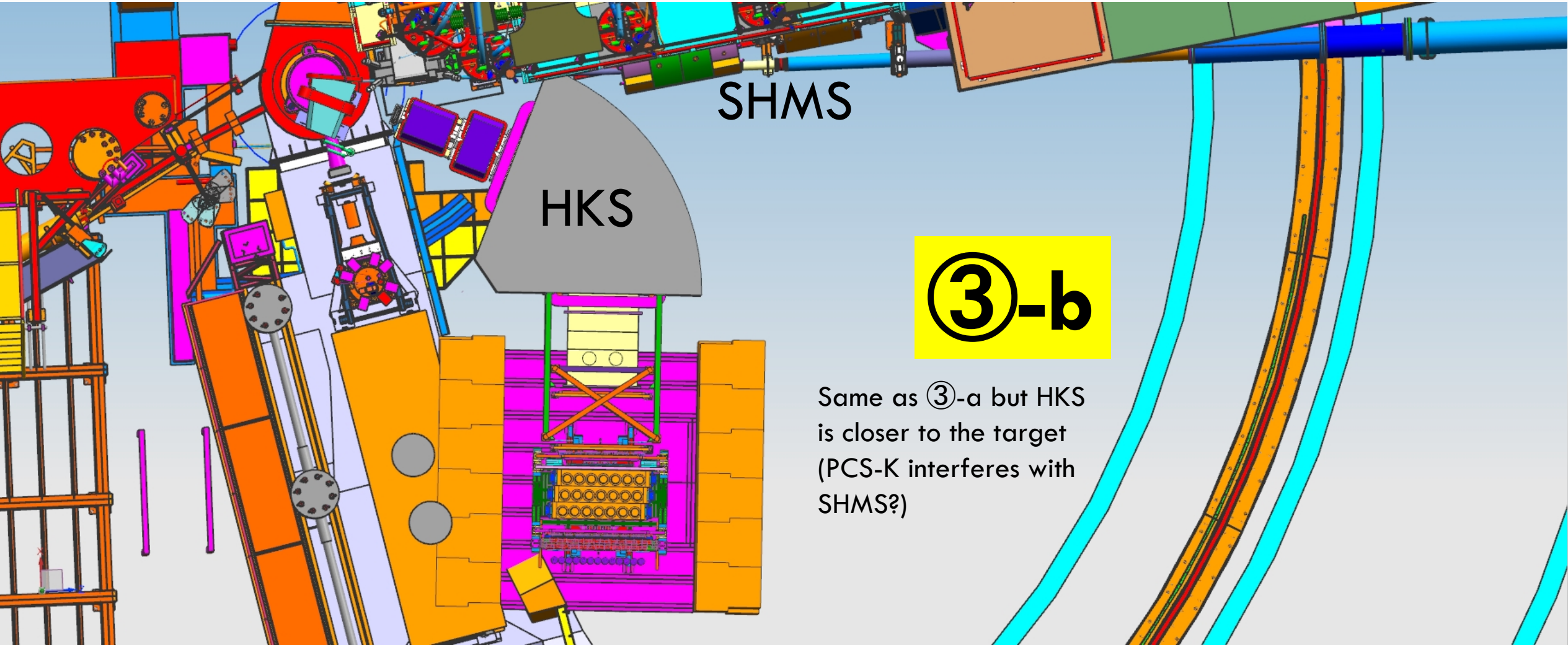
②

SHMS

HKS



③-a



SHMS

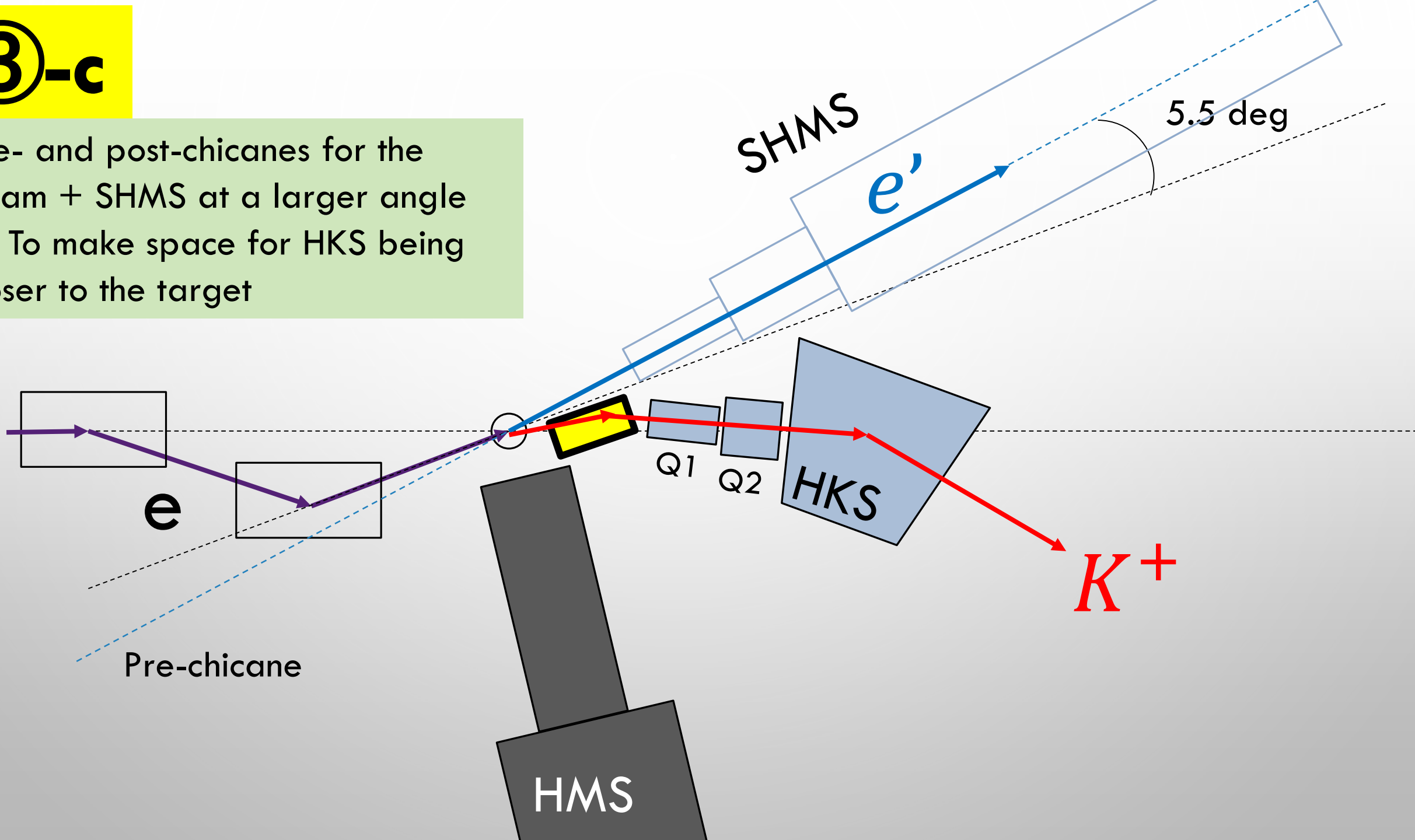
HKS

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' ( $\theta$ , $\Omega$ , dp)	K <sup>+</sup> ( $\theta_{\gamma K}$ , $\Omega$ , $f_K$ )	$\Gamma$ (/10 <sup>-5</sup> )	$\Delta E_{\Lambda}$ FWHM (/ MeV)	Yield per hour <sup>12</sup> C, 0.1 g/cm <sup>2</sup> , 100 nb/sr, 30 $\mu$ A	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 @ 20 $\mu$ A

Configuration	$\Delta E_{\Lambda}$ (# of events needed for $\Delta B_{\Lambda}^{\text{stat.}} = 20 \text{ keV}$ )	${}^3\text{He} \rightarrow {}^3_{\Lambda}\text{H}$ 5 nb/sr	${}^{12}\text{C} \rightarrow {}^{12}_{\Lambda}\text{B}$ 100 nb/sr	${}^{40}\text{Ca} \rightarrow {}^{40}_{\Lambda}\text{K}$ 10 nb/sr	${}^{208}\text{Pb} \rightarrow {}^{208}_{\Lambda}\text{Tl}$ 10 nb/sr
SPL+(HES+HKS) ①	<b>0.5</b> <b>(113)</b>	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	<b>1.0</b> <b>(451)</b>	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  $\Delta B_{\Lambda}^{\text{stat.}} = 50 \text{ keV}$ :  
 0.5 MeV FWHM  $\rightarrow$  18 counts  
 1.0 MeV FWHM  $\rightarrow$  72 counts

# SUMMARY

The best precision / accuracy spectroscopy is possible at JLab

→ JLab is **very unique** to investigate the  $\Lambda$ N 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.

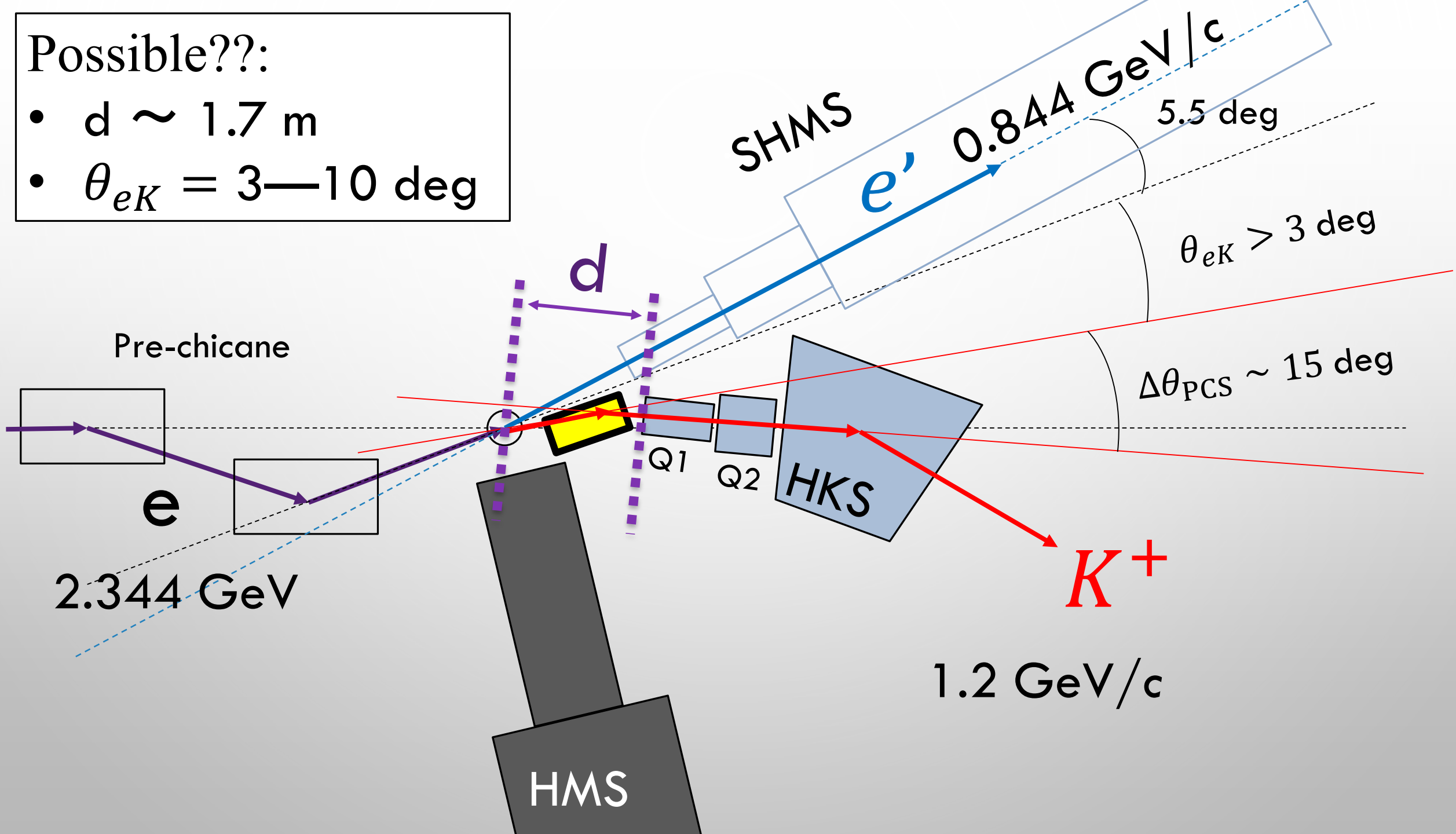


**BACKUP**



Possible??:

- $d \sim 1.7$  m
- $\theta_{eK} = 3\text{---}10$  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](https://wiki.jlab.org/tegwiki/images/1/1E/APFB2020_GOGAMI_20210302_TOUPLoad.pdf))