Experimental setup

Tohoku University

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2021/12/07

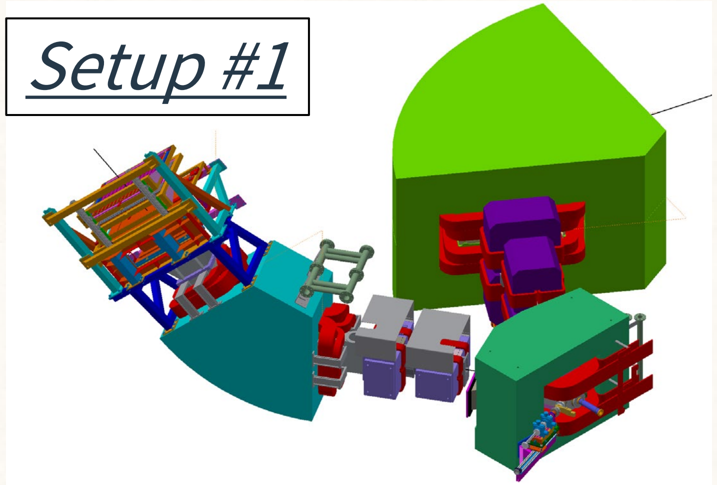
Contents

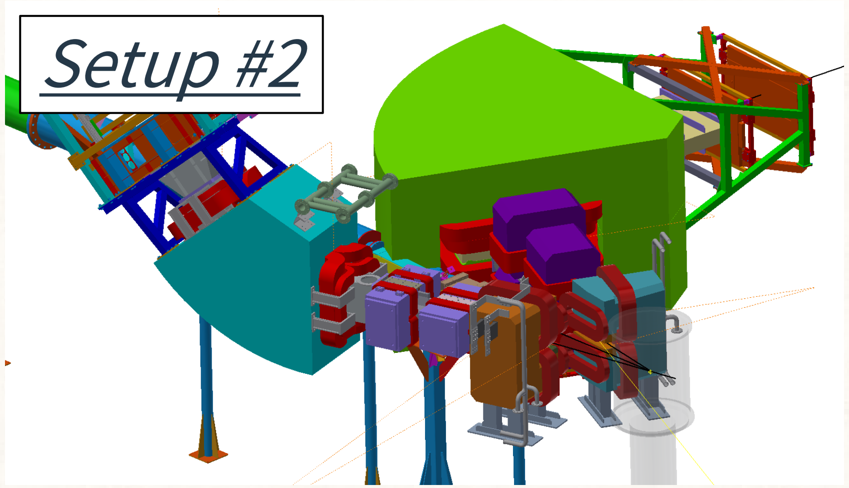
Setup Plans

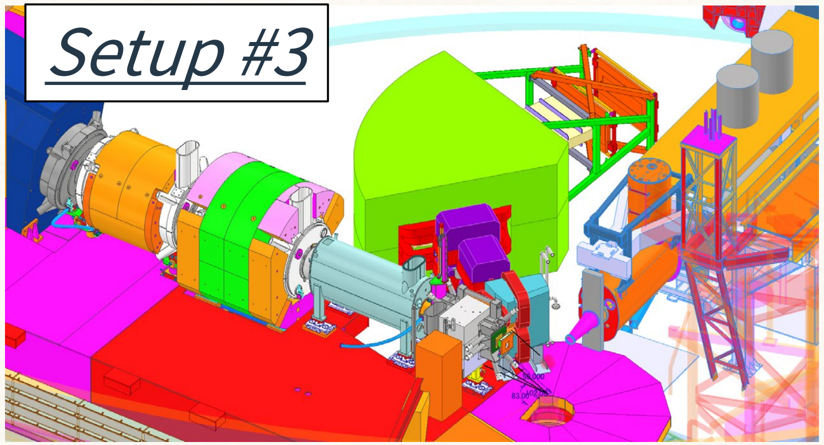
The (e,e’K⁺) experiment requires two magnetic spectrometers.

Additional magnets getting the forward acceptance are necessary for higher hypernuclear yield.

	e’		K^+		Yield	B.G.	Res. (MeV)	Z_t (cm)	Cost
	Fw. Magnet	Spec. Magnet	Fw. Magnet	Spec. Magnet					
#0	SPL	HES	SPL	HKS	H	H	0.5	×	L
#1	SPL	HES (V mode)	SPL	HKS	M	H	~ 0.5	2	H
#2	PCS(e’)	HES (V mode)	PCS(K)	HKS	M	L	~ 0.5	2	H
#3		SHMS	PCS(K)	HKS	L	L	1	< 1	L







The (e,e'K+) reaction

$$\frac{d\sigma}{d^5E_{e'}d\Omega_e d\Omega_K^*} = \Gamma_v \frac{d^2\sigma_v}{d\Omega_K^*}$$

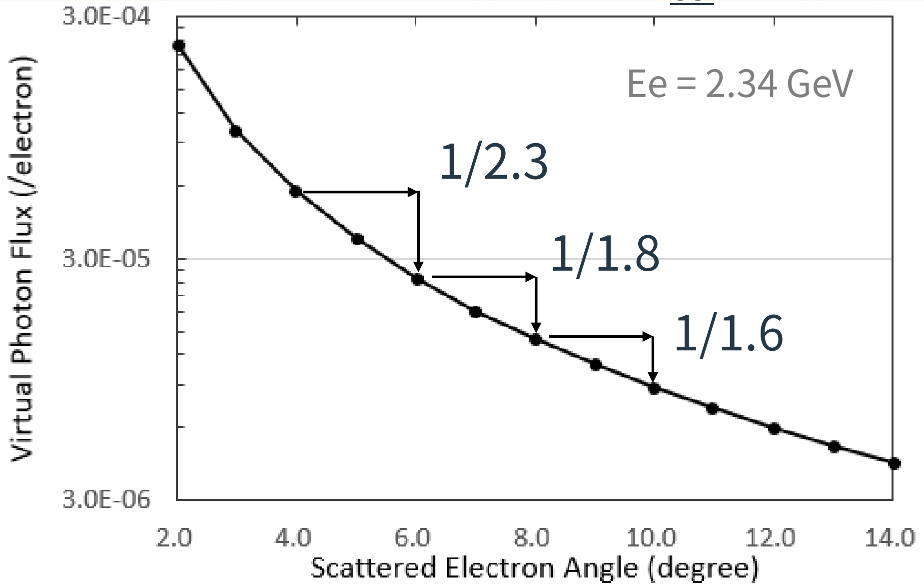
$$\left(\Gamma_v = \frac{\alpha}{2\pi^2} \frac{E_{e'}}{E_e} \frac{k_\gamma}{Q^2} \frac{1}{1-\epsilon} \right)$$

Hypernuclear yield is proportional to the virtual photon flux (Γ). → maximized at $\theta_{ee'} = 0°$

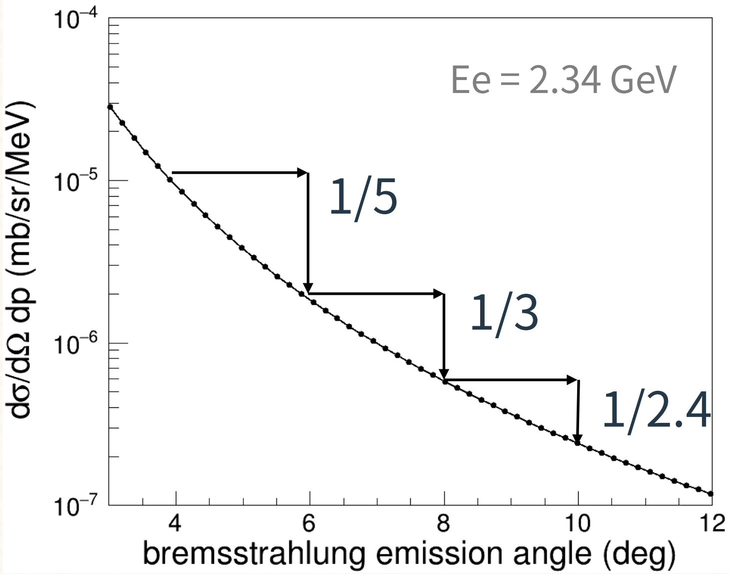
⇕

Dominant background in e' side is bremsstrahlung. → max. at $\theta_{ee'} = 0°$

Γ dependence on $\theta_{ee'}$



Bremsstrahlung C.S dependence on $\theta_{ee'}$

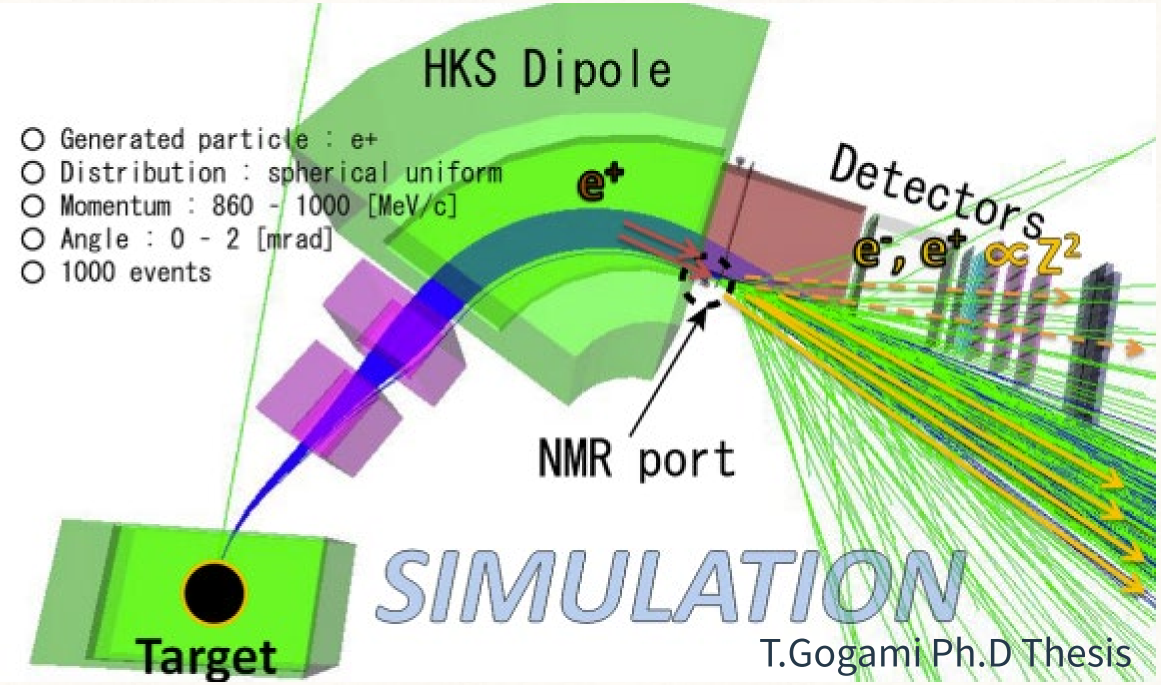


Setting $\theta_{ee'}$ with reasonably (several degrees) forward angles is important.

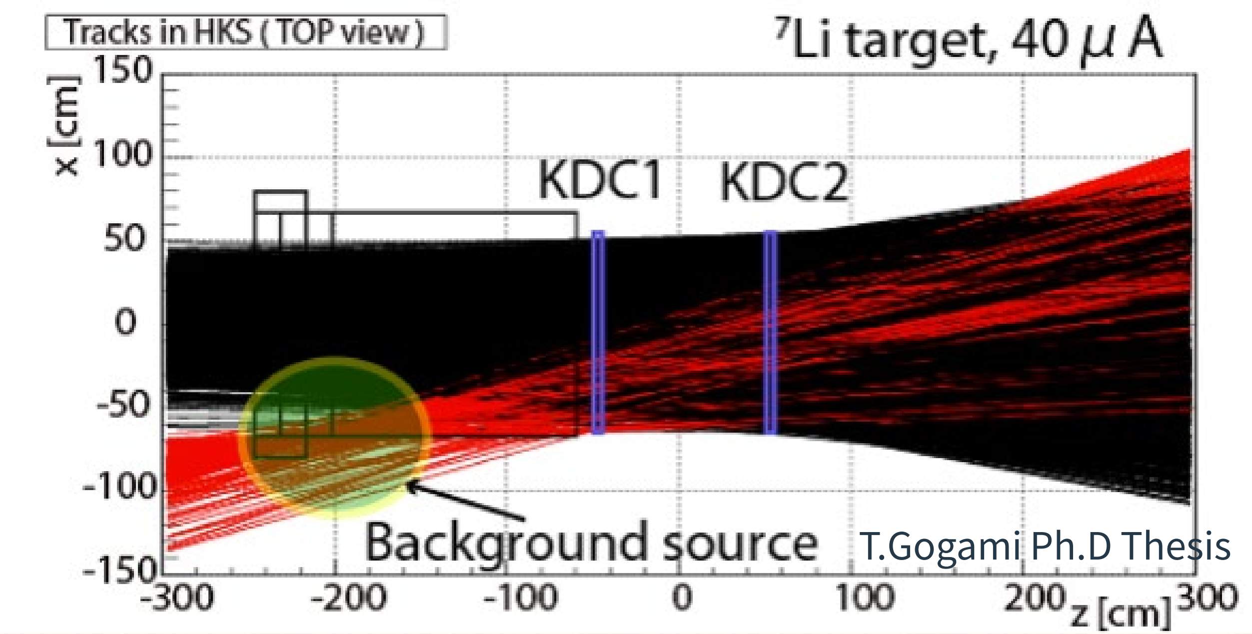
What we learn in the past experiment

HES set $\theta_{ee'}$ ~ 4° with a tilted method in E05-115. → background suppression of 1/200.
Low energy and forward e^+ was a large background source in HKS.
~60% of HKS track was come from the background source in med-heavy target.

Background simulation of HKS

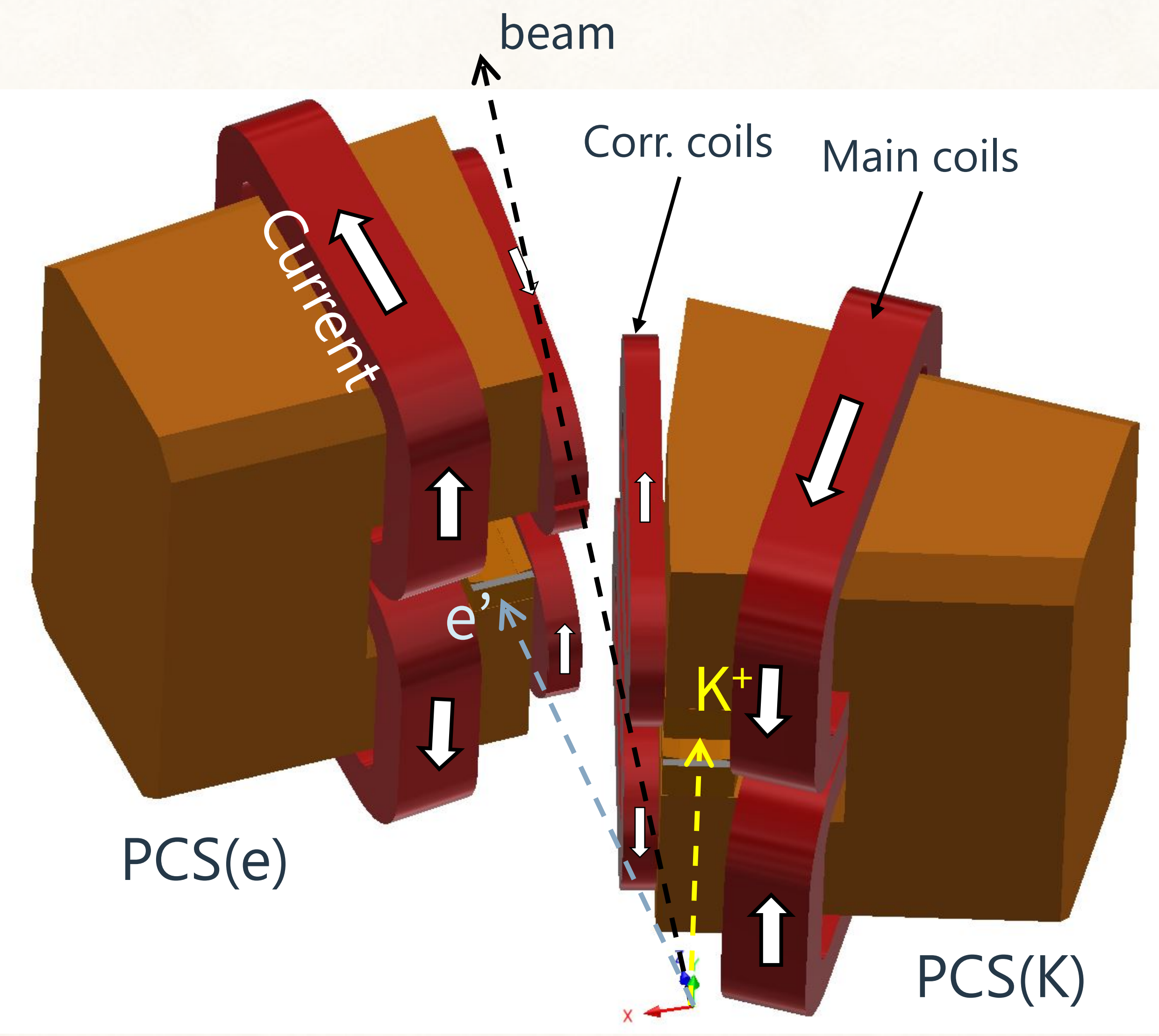


Tracking in HKS (Data of E05-115)



SPL magnet provides high hypernuclear yield, but it's not optimum....

Particle Charge Separator (PCS)

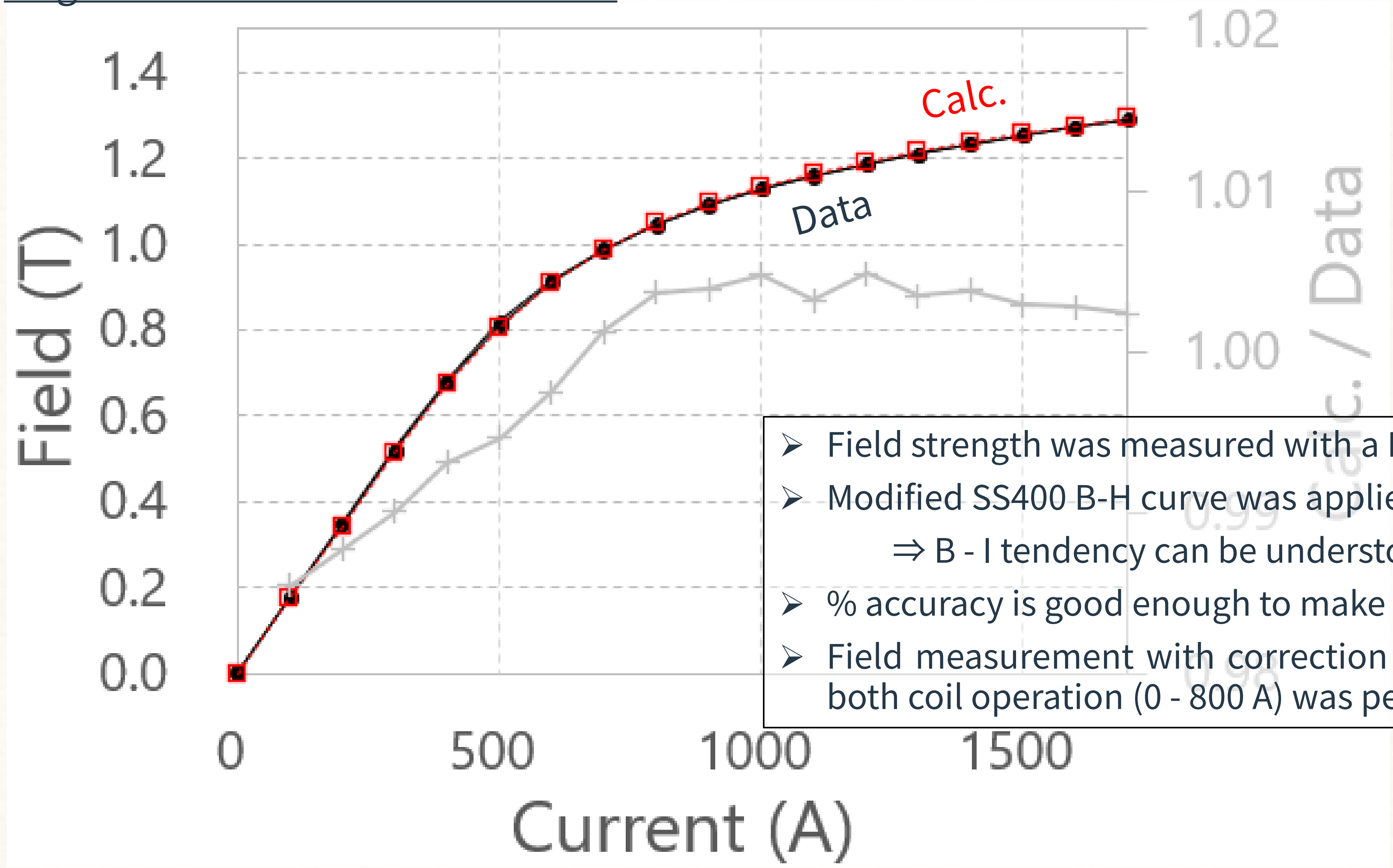


		PCS(K)	PCS(e)
Weight		7.8 t	8.0 t
Max. Field		1.3 T	
Main Coil	Geometry	16×16 / Φ10	
	Turns	96 / coil	
	Current	1700 A	
	Voltage	106 V / each mag.	
	Δt	20°C	
Corr. Coil	Geometry	14×9 / 10×5	
	Turns	88 / coil	
	Current	1000 A	
	Voltage	97 V / each mag.	
	Δt	11°C	

Photos

B - I Curve

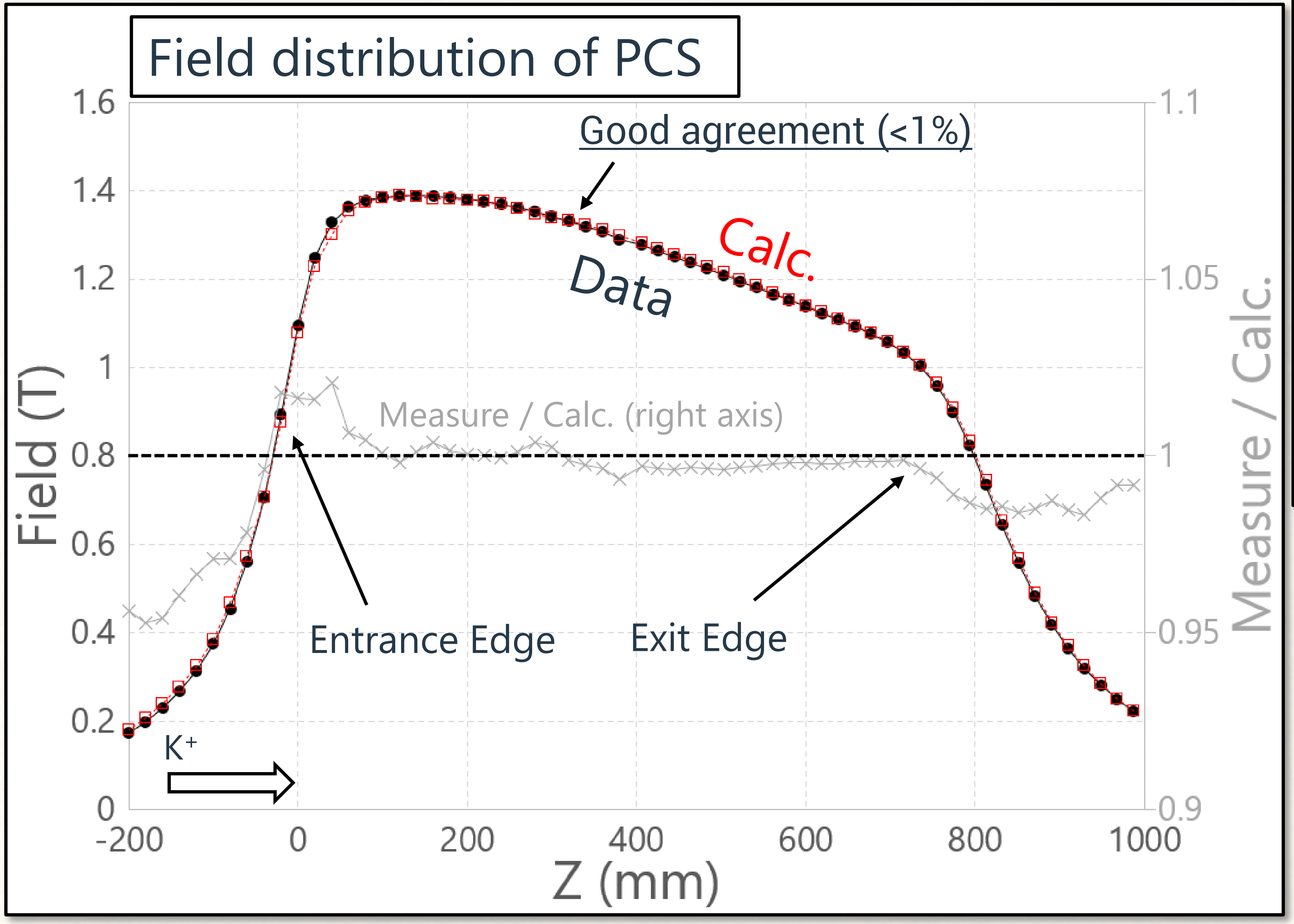
Magnetic Field v.s Main coil current

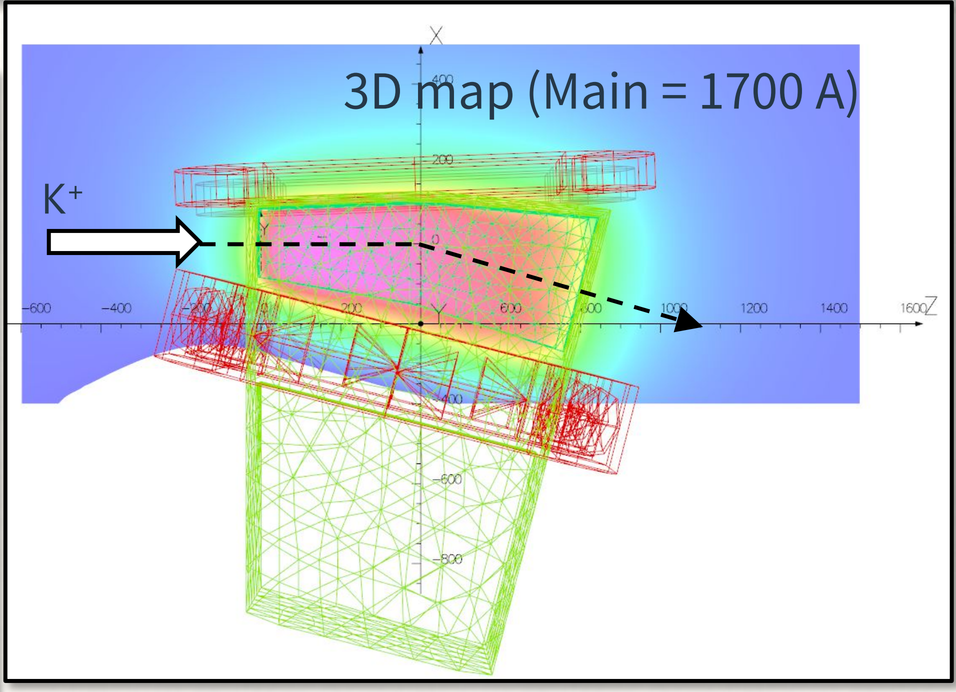


- Field strength was measured with a Hall prove.
- Modified SS400 B-H curve was applied in TOSCA.

  ⇒ B - I tendency can be understood in the simulation well.
- % accuracy is good enough to make initial transfer matrix.
- Field measurement with correction coil operation (0 - 1000 A) and both coil operation (0 - 800 A) was performed also.

Field strength along the track

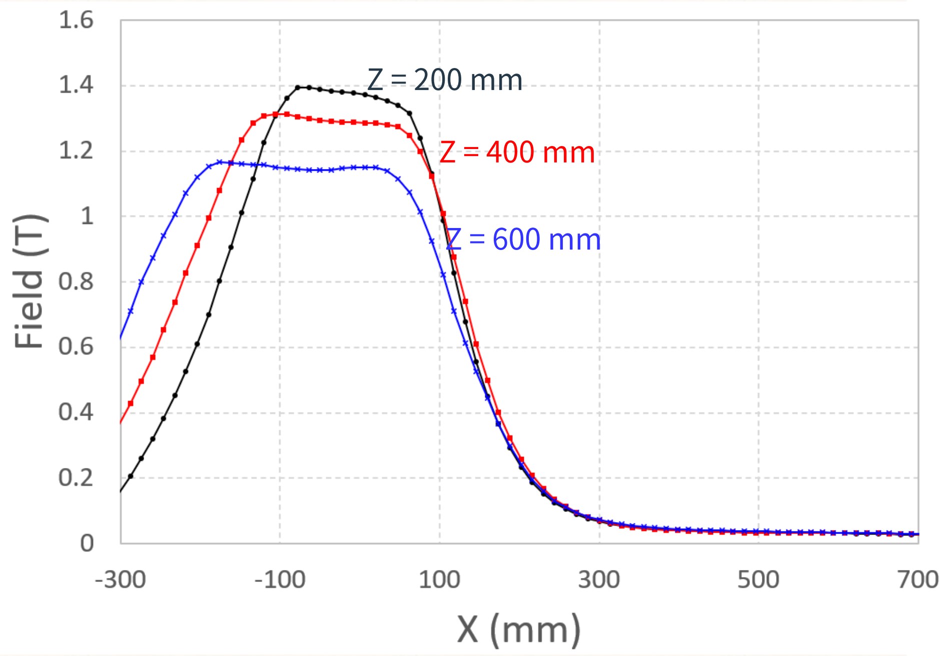


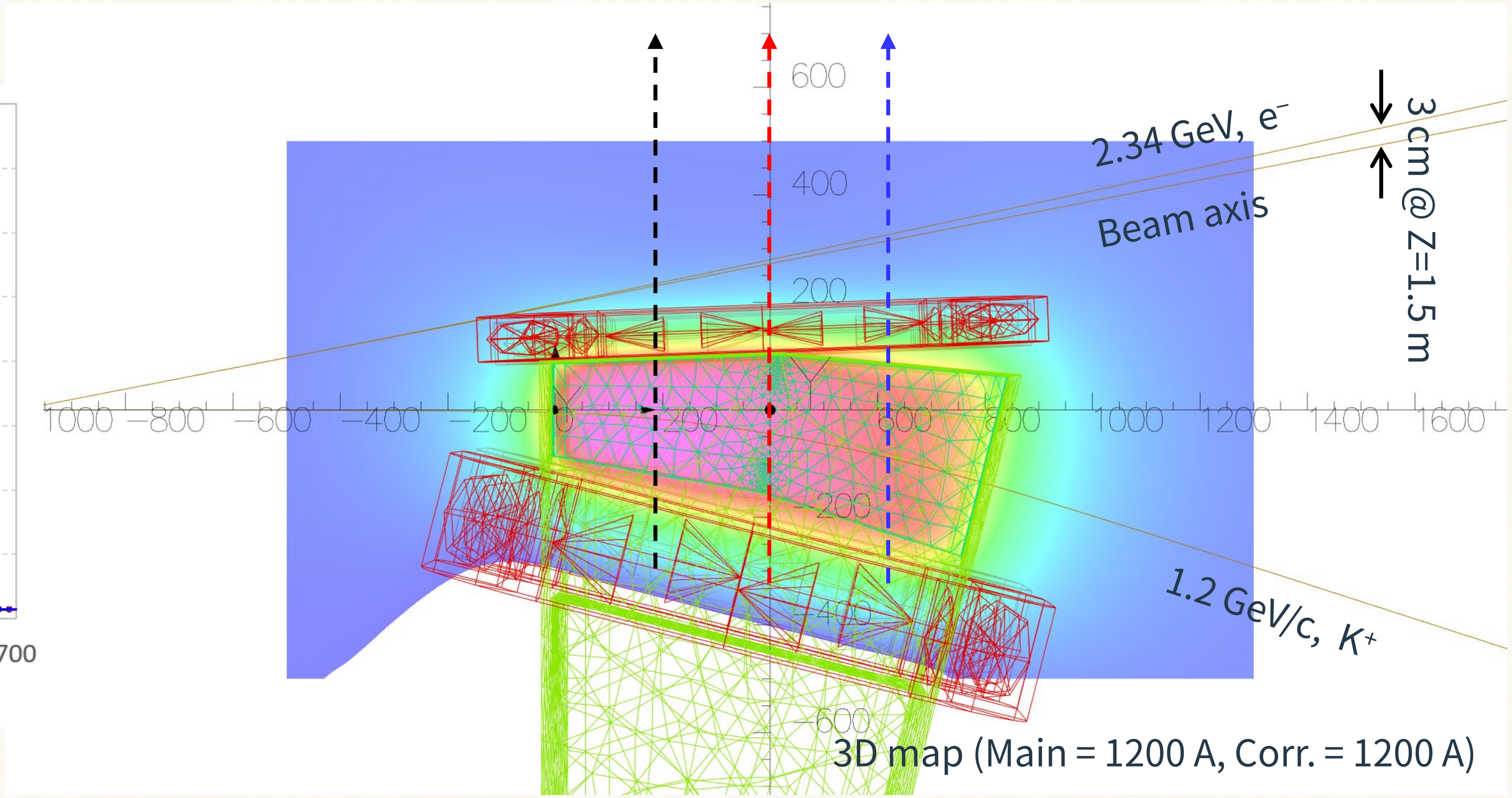


Field along the particle track is good agreement with TOSCA results.

Field Leakage

Field dist. along X-axis (TOSCA Calc.)

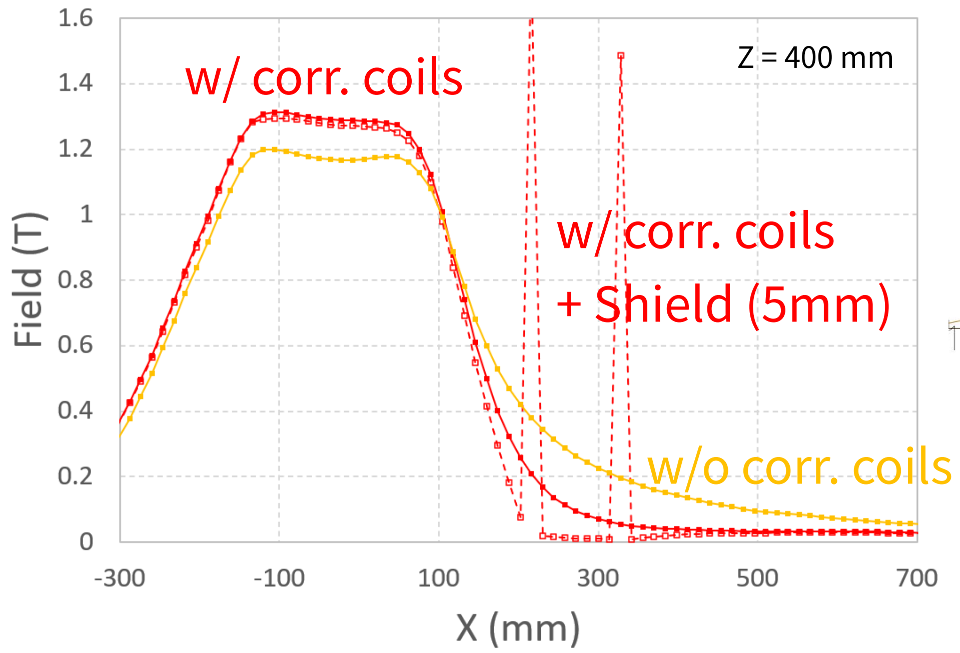


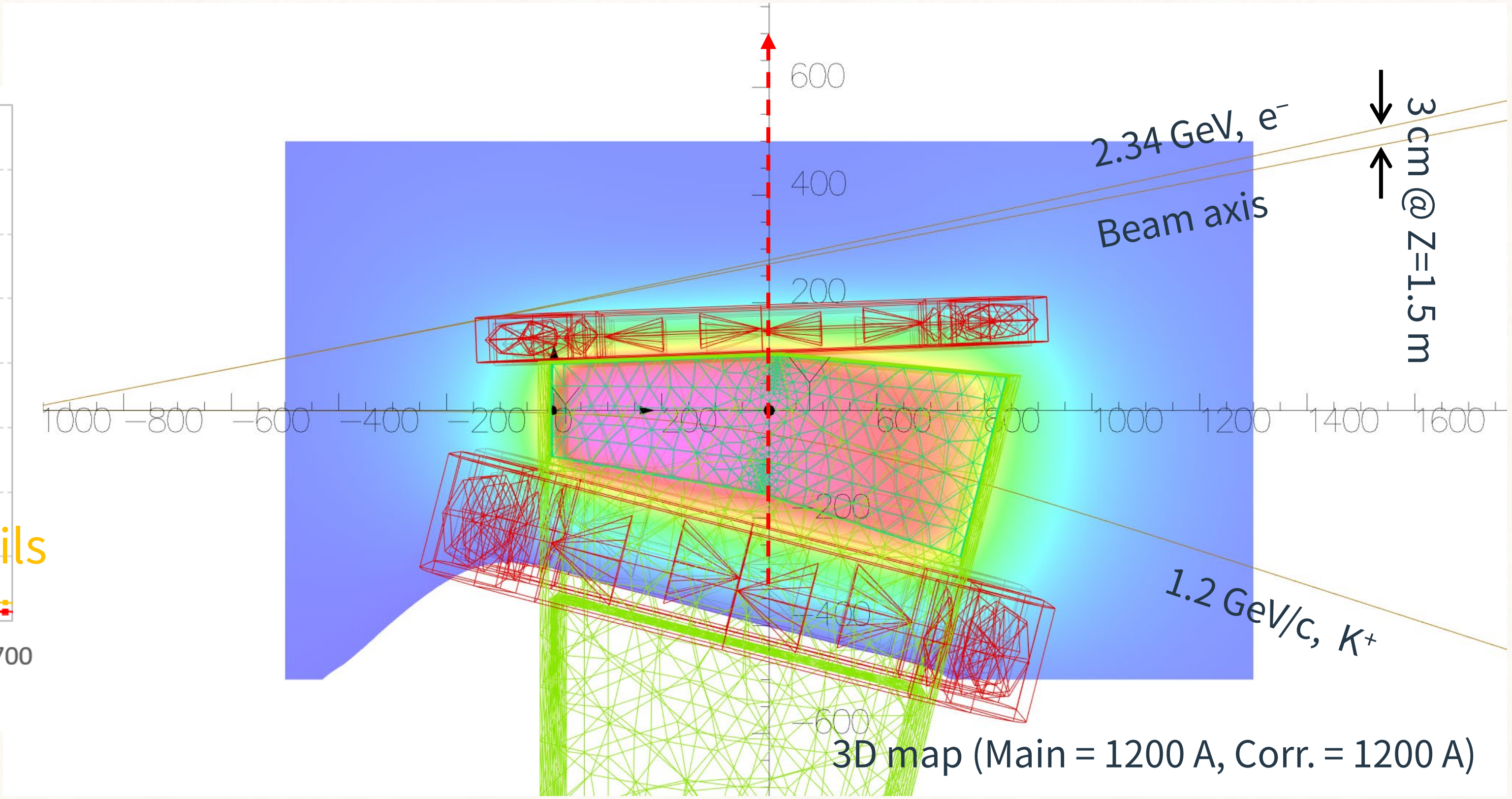


- Field leakage is suppressed with correction coils.
- Magnetic shielding of the beam pipe and correction magnet is necessary.
- Integral B·dl along the beamline will be 0.2 (T·m) w/o shield and 0.034 (T·m) w/ shield

Field Leakage

Field dist. along X-axis (TOSCA Calc.)





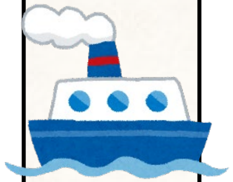
- ➢ Field leakage is suppressed with correction coils.
- ➢ Magnetic shielding of the beam pipe and correction magnet is necessary.
- ➢ Integral B·dl along the beamline will be 0.2 (T·m) w/o shield and 0.034 (T·m) w/ shield

Shipping Schedule

Tohoku Univ. → TOKIN → by NITTSU

Utsunomiya
- Packing
- Setting data logger

Yokohama
- Waiting for ship
- Exportation procedure



Norfolk
- Custom procedure
- Unloading

by A.N. Dellinger

JLab
- Unloading from truck
- Storage & Unpacking
- Collecting logger data

Late Dec.

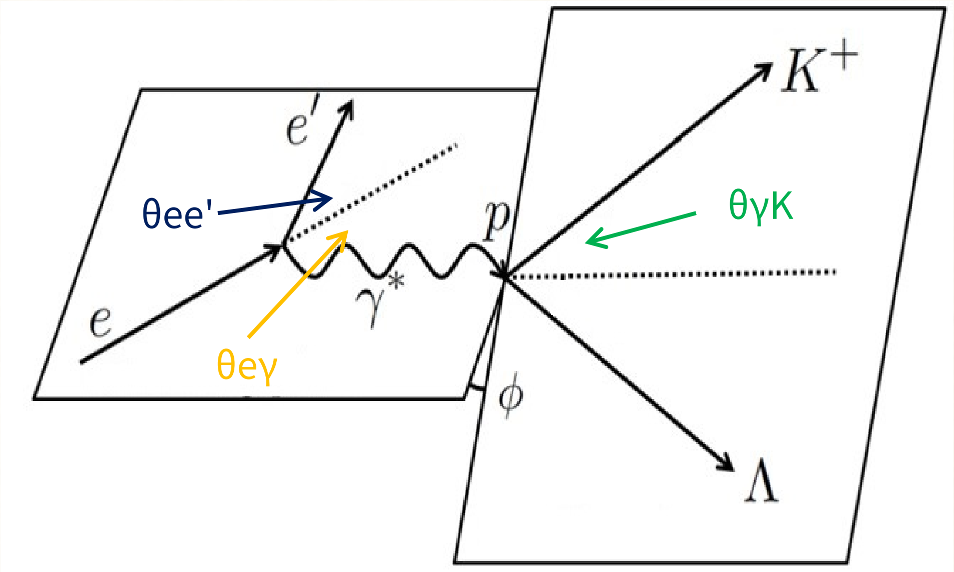
Early Feb.

- Shipping is contracted with TOKIN (PCS manufacture company).
- TOKIN organized shipments with NITTSU.
- PCS will be imported and arrive at JLab on Feb. 2022 with tax exemption.

Kinematical difference between Hall-A and -C

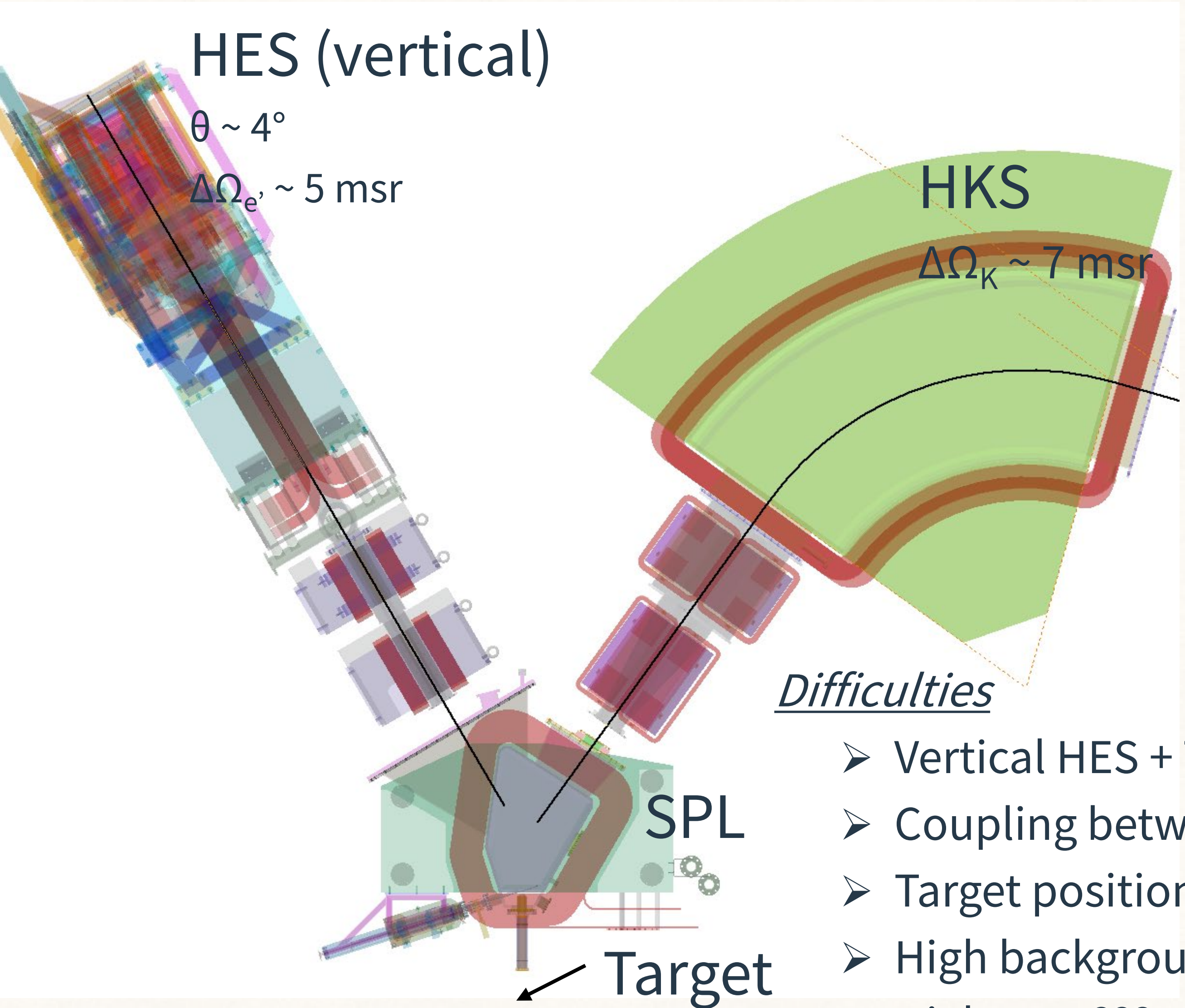
Kinematics of Hall-A and -C

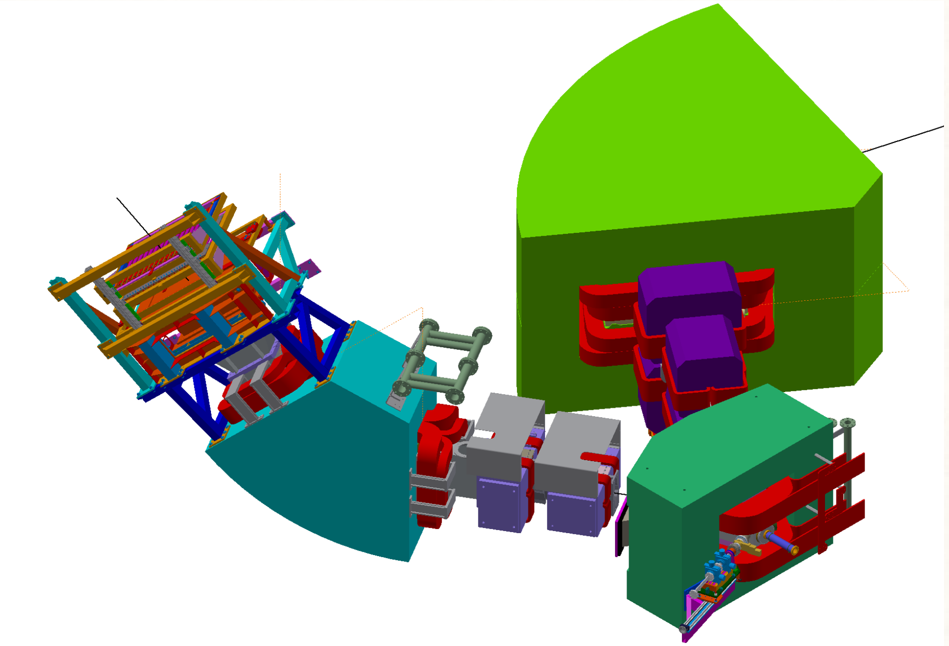
		Hall-A	Hall-C
Beam	E_e	4.23 GeV	2.34 GeV
e'	$\theta(ee')$, p_e	6.5°, 2.73 GeV/c	6-10°, 0.84 GeV/c
γ^*	$\theta(e\gamma)$, E_γ	11.5°, 1.5 GeV	~4°, 1.5 GeV
K^+	$\theta(\gamma K)$, p_K	0°, 1.2 GeV/c	~5°, 1.2 GeV/c



- 1-pass beam would be used.
- e' momentum would be 2.7 → 0.8 GeV/c.
  - Background (bremsstrahlung) increases.
  - Transverse momentum of VP decreases.
  - More forward angles must cover. (looking $\theta_{\gamma K} = 0°$)
  - Setting with $\theta_{\gamma K} \neq 0°$ must be considered.

Setup #1 (SPL + HES + HKS)





Difficulties

- Vertical HES + Tilt method
- Coupling between SPL and HES
- Target position
- High background
- High cost ???

$\mathbb{G} = 2.3 \times 1 \times 1.2 \sim 2.8$

Rate(e') = 1.5 MHz (10 μA, 100 mg ^{12}C)

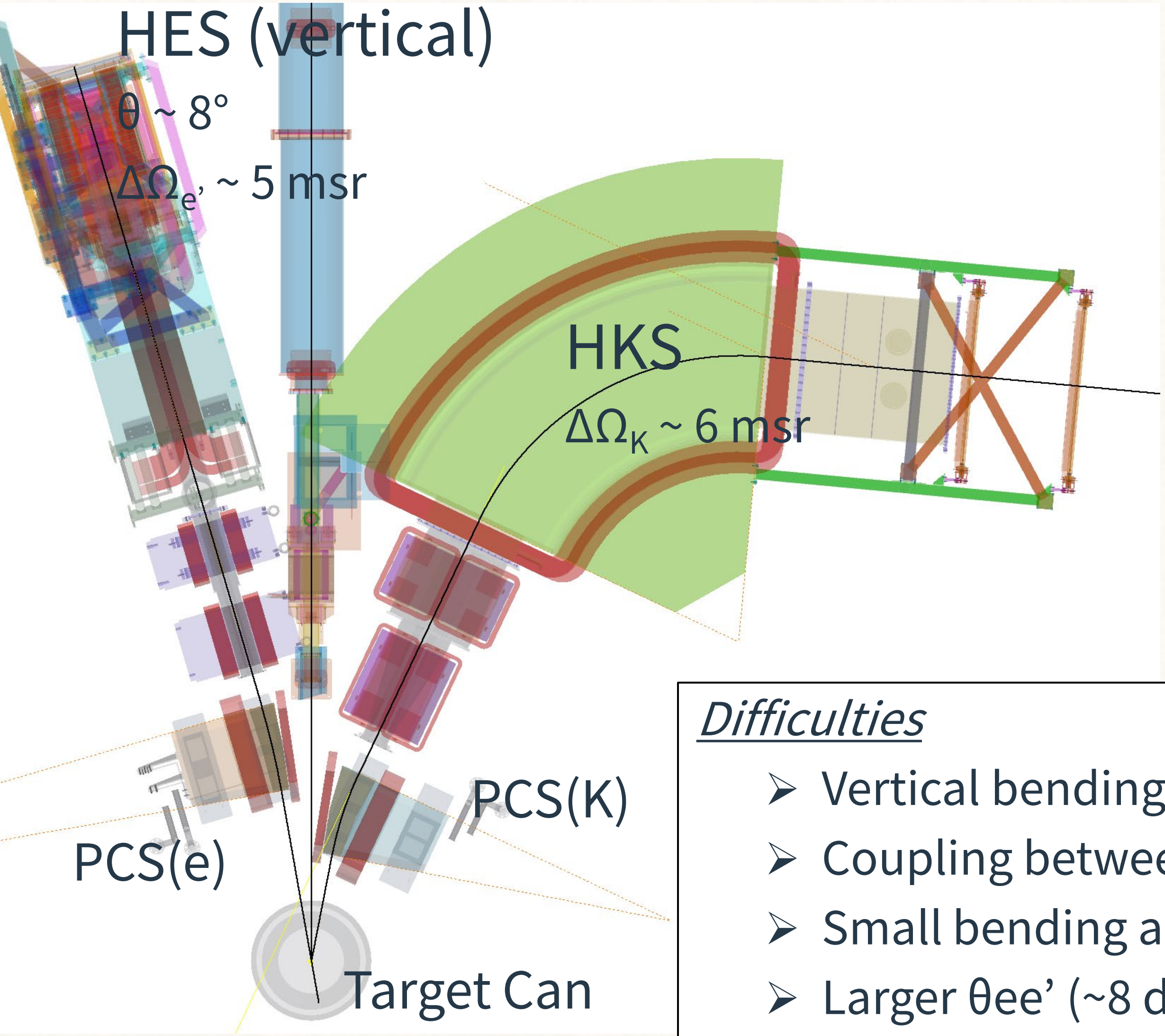
= 20 MHz (10 μA, 100 mg ^{40}Ca)

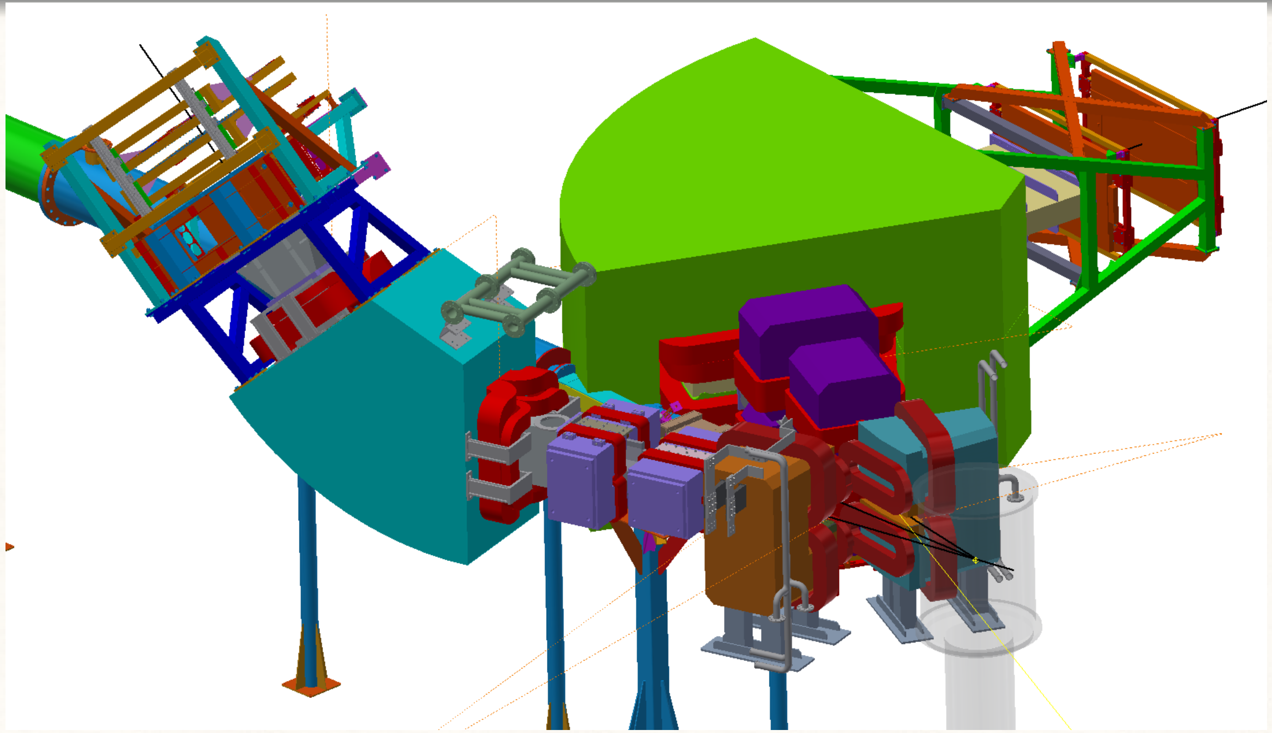
= 10 MHz (2 μA, 100 mg ^{208}Pb)

ΔM = 0.5 MeV (FWHM)

※ Gain Factor $= \Gamma \times \Delta\Omega_{e'} \times \Delta\Omega_K$ / Hall-A option

Setup #2 (PCS + HES + HKS)





Difficulties

- Vertical bending HES
- Coupling between PCS(e) and HES
- Small bending angle of PCS(e)
- Larger θee' (~8 degrees)
- High cost ???

$\mathbb{G} = 0.6 \times 0.9 \times 1 \sim 0.5$

Rate(e') = 0.1 MHz (10 μA, 100 mg ^{12}C)

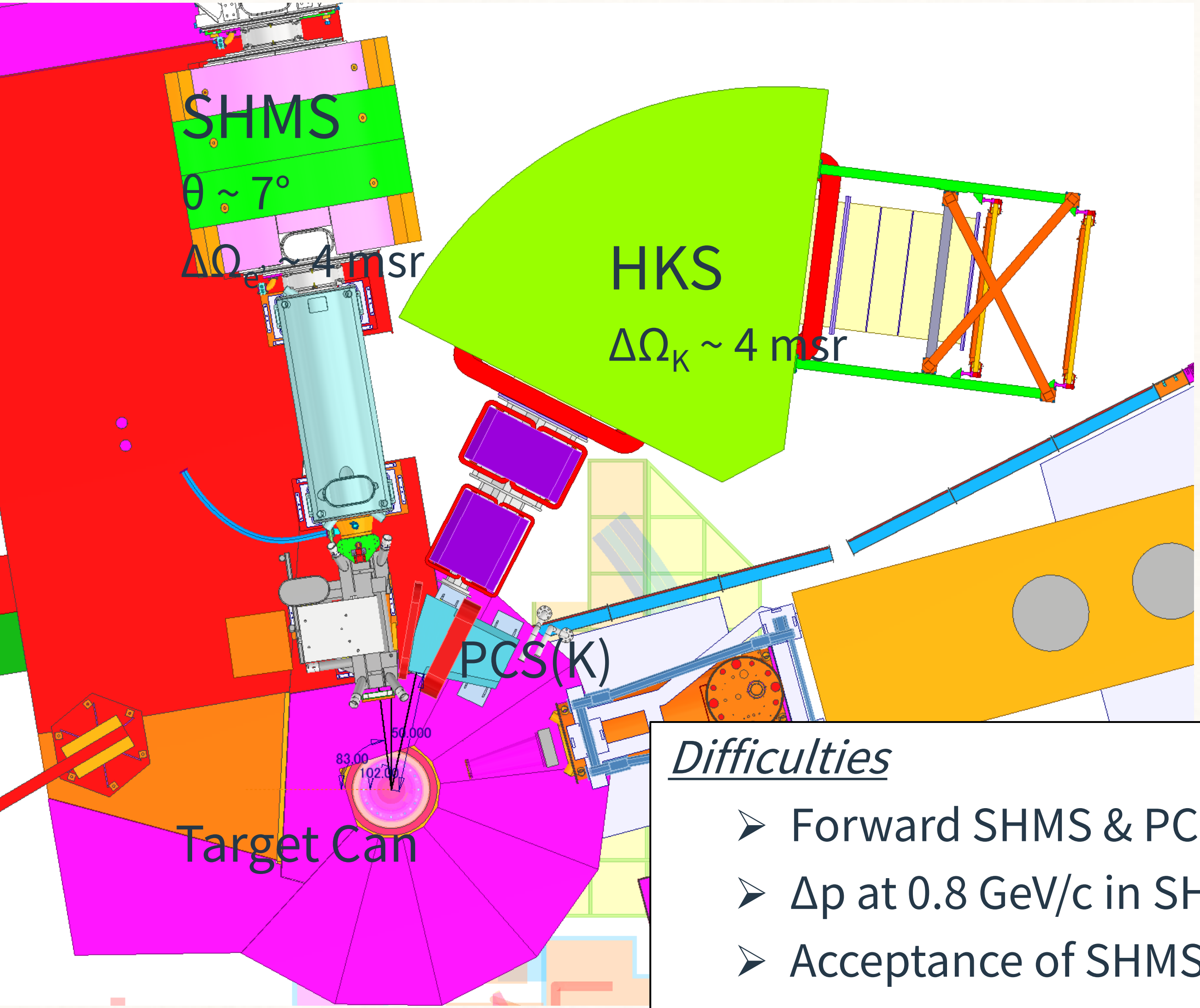
= 1 MHz (10 μA, 100 mg ^{40}Ca)

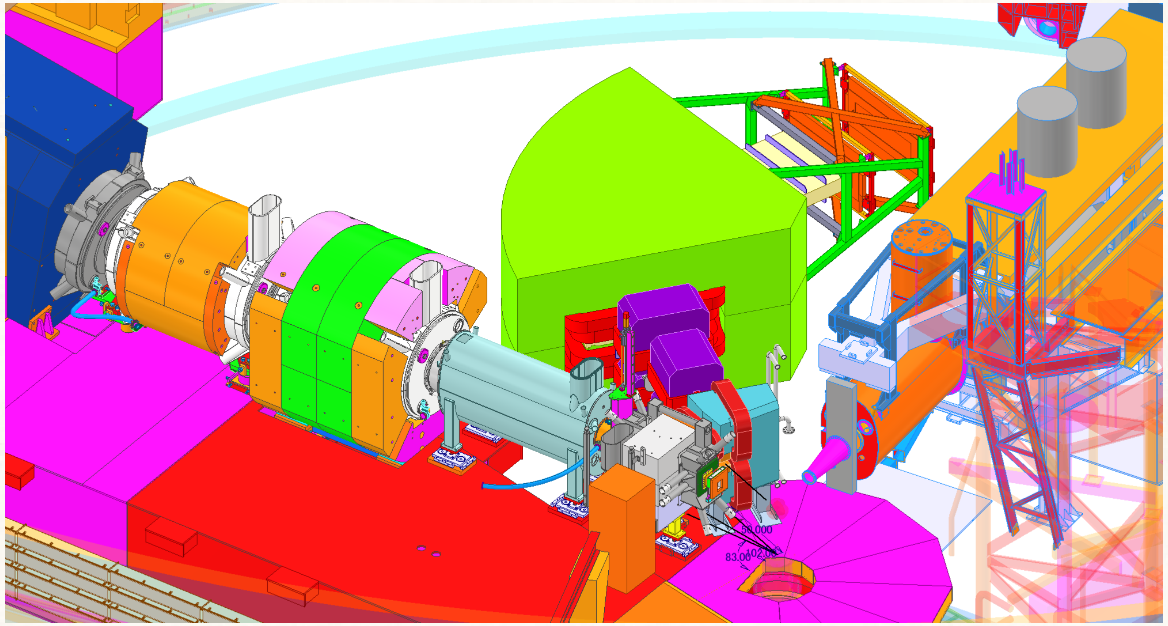
= 20 MHz (10 μA, 100 mg ^{208}Pb)

ΔM = 0.5 MeV (FWHM)

※ Gain Factor = $\Gamma \times \Delta\Omega_{e'} \times \Delta\Omega_K$ / Hall-A option

Setup #3 (PCS + SHMS + HKS)





Difficulties

- Forward SHMS & PCS(K)
- Δp at 0.8 GeV/c in SHMS
- Acceptance of SHMS
- Interference w. HKS detector hut

$\mathbb{G} = 0.8 \times 0.8 \times 0.7 \sim 0.4$

Rate(e') = 0.2 MHz (10 μA, 100 mg ^{12}C)

= 2 MHz (10 μA, 100 mg ^{40}Ca)

= 30 MHz (10 μA, 100 mg ^{208}Pb)

ΔM = 1 MeV (FWHM)

※ Gain Factor $= \Gamma \times \Delta\Omega_{e'} \times \Delta\Omega_K$ / Hall-A option

Summary

The (e,e'K$^+$) experiments

- Spectrometer setup of reasonably forward angle is essential for the hypernuclear experiments.
- Background due to SPL in the previous Hall-C experiment.
- Magnets without acceptance ~0° is important → PCS.

PCS

- Magnetic field is understood with the TOSCA simulation well.
- Shielding is necessary to suppress the field leakage around the beam line.
- PCS will arrive on Feb. 2022.

Setting

- SPL or PCS for the forward magnets.
- HES or SHMS for e' spectrometer.

	Gain Factor	e' rate @^{40}Ca (MHz)
SPL+HES+HKS	2.8	20
PCS+HES+HKS	0.5	1
PCS+SHMS+HKS	0.4	2