Status of PCS & MC simulation study

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2022/07/22

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PCS & Experimental Setup

- Requirements for the experiments
- Status of PCS magnets
- Possible setups

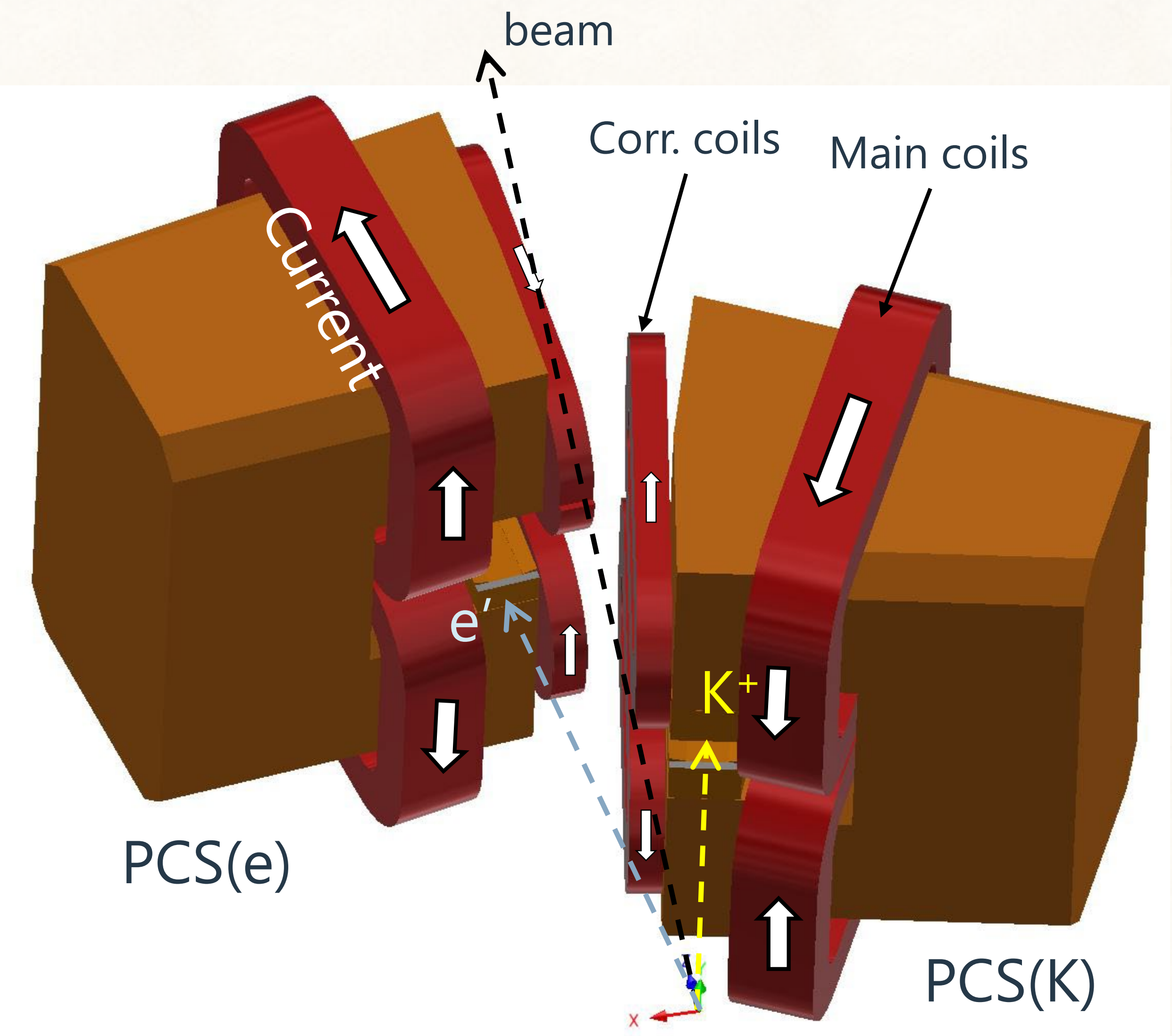
Monte Carlo Simulation Study

- Expected resolution, acceptance
- Rate, Yield estimation

Requirements

- e′ spectrometer with p ~ 0.8 GeV/c & $\Delta p/p$ ~ several×10^{-4} (FWHM)
- K^+ spectrometer with p ~ 1.2 GeV/c & $\Delta p/p$ ~ a few×10^{-4} (FWHM)
- e^- beam & brems γ to the beam dump.
- Septum magnets to cover the forward angle
- Z vertex reconstruction (σ < a few cm)

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℃	
Corr. Coil	Geometry	14×9 / 10×5	
	Turns	88 / coil	
	Current	1000 A	
	Voltage	97 V / each mag.	
	Δt	11℃	

Sieve slit will be prepared just before the PCS entrance.

Base design is necessary.

2000A / 200V PW (SBS power) is necessary.

PCS is now in ESB

PCS transported from JAN to USA.

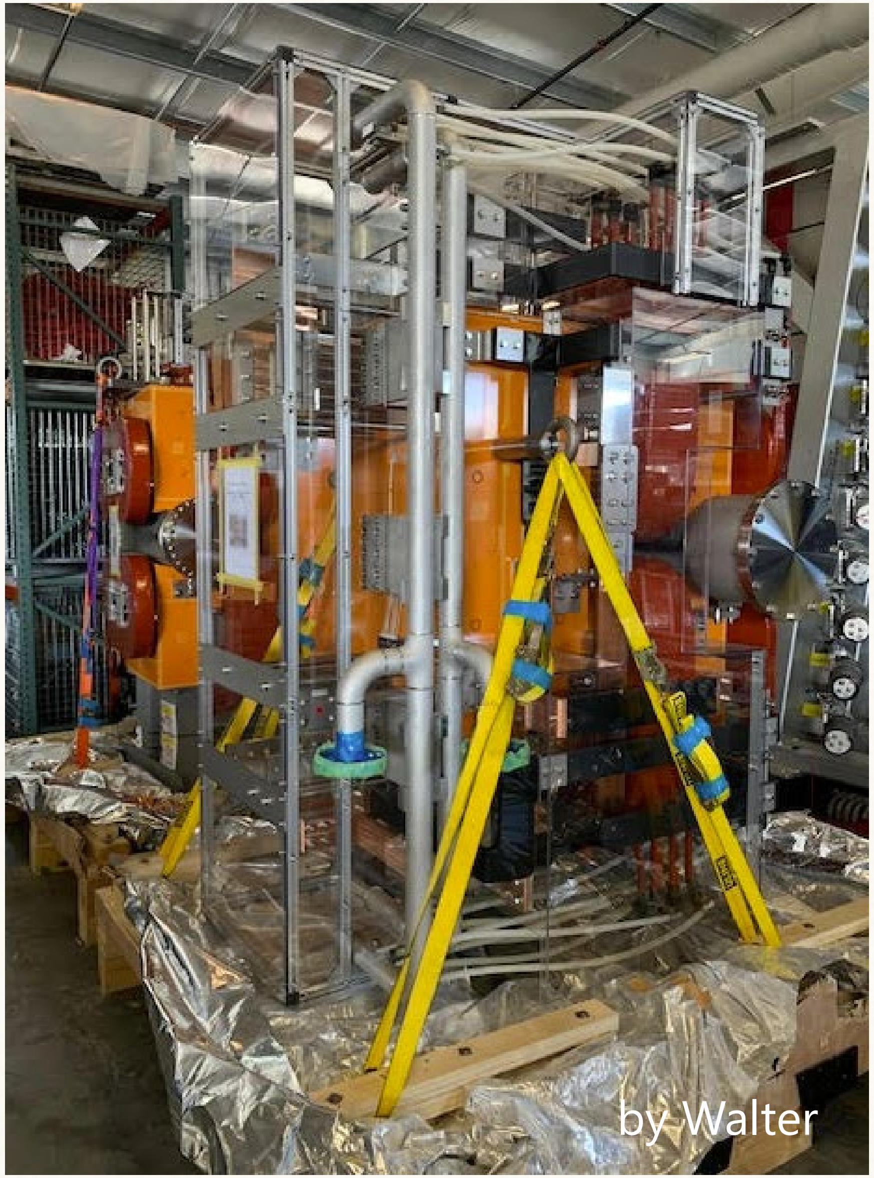
Japan

- Construction
- Sendai → Pt. Yokohama
- Departure on 29 Dec. 2021

USA

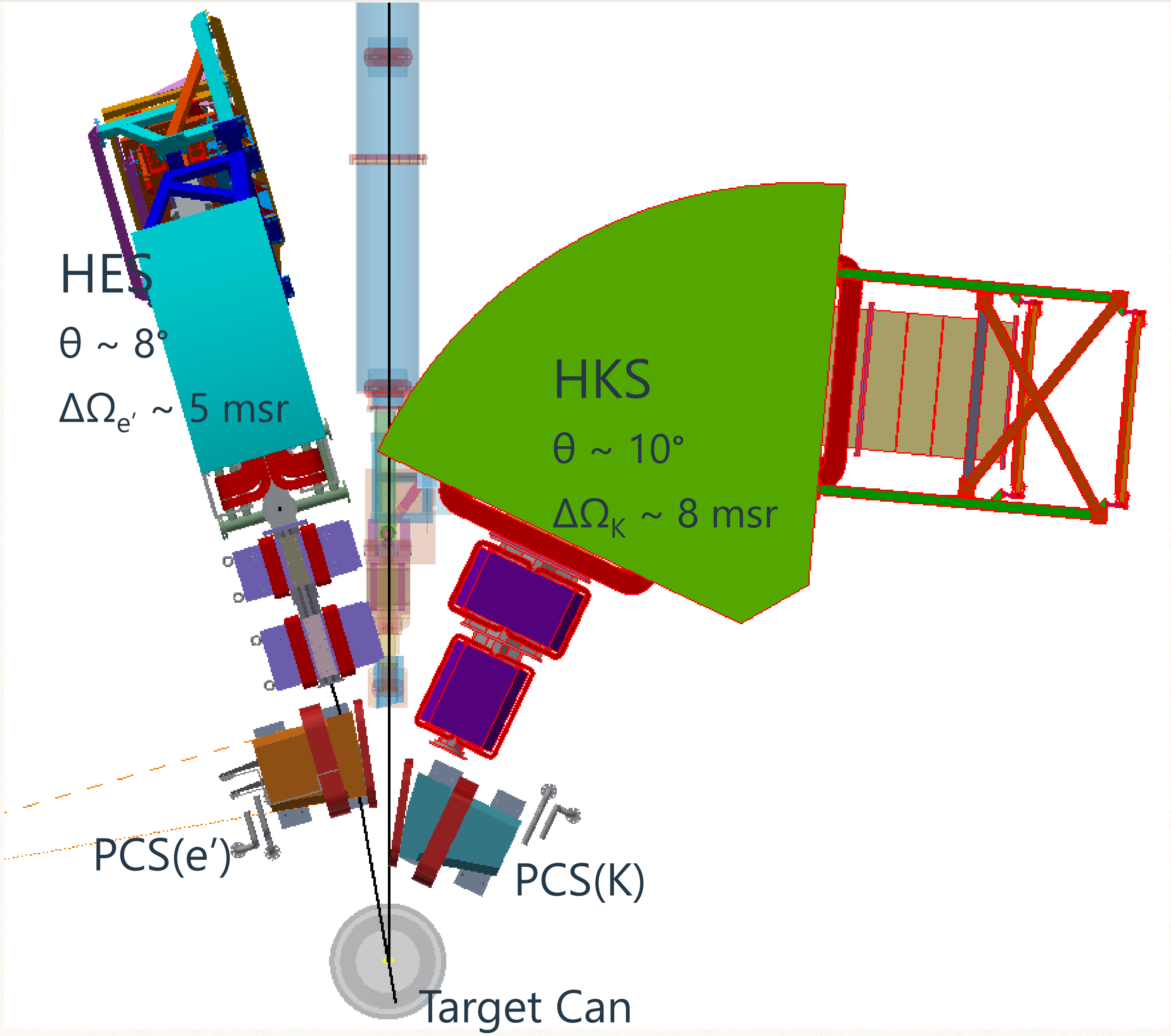
- Pt. Norfolk → JLab (11 Feb.)
- Storing in ESB
- Un-packing

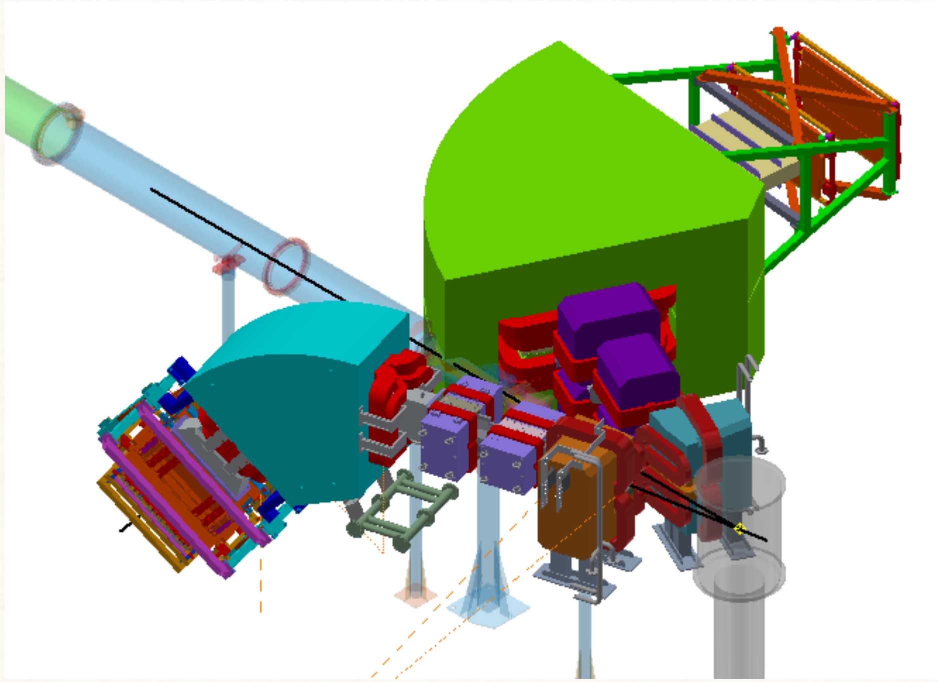
by Walter



by Walter

Experimental Setup A (Vertical HES, the first candidate)

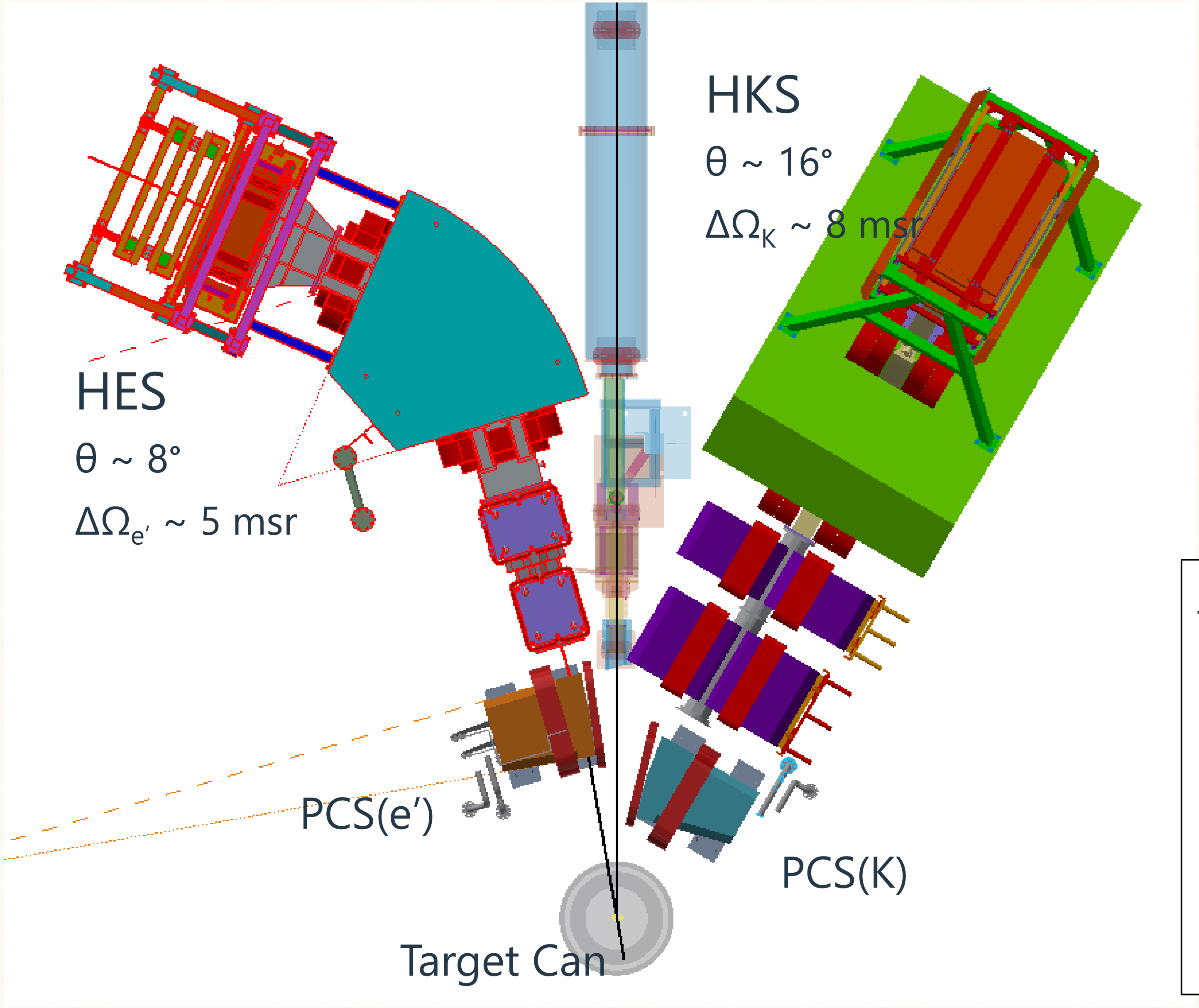


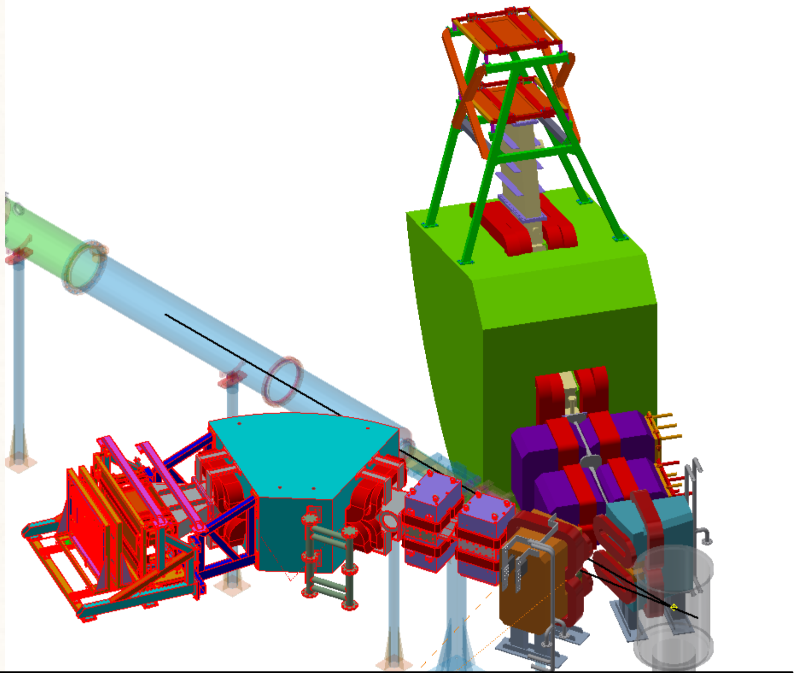


Characteristics

- Forward HES + HKS with PCS
- Good (~ 0.6 MeV) mass resolution
- Miss-matching bet. PCS(e′) and HES
- New support frame is needed for HES
- Mid. cost

Experimental Setup B (Vertical HKS)

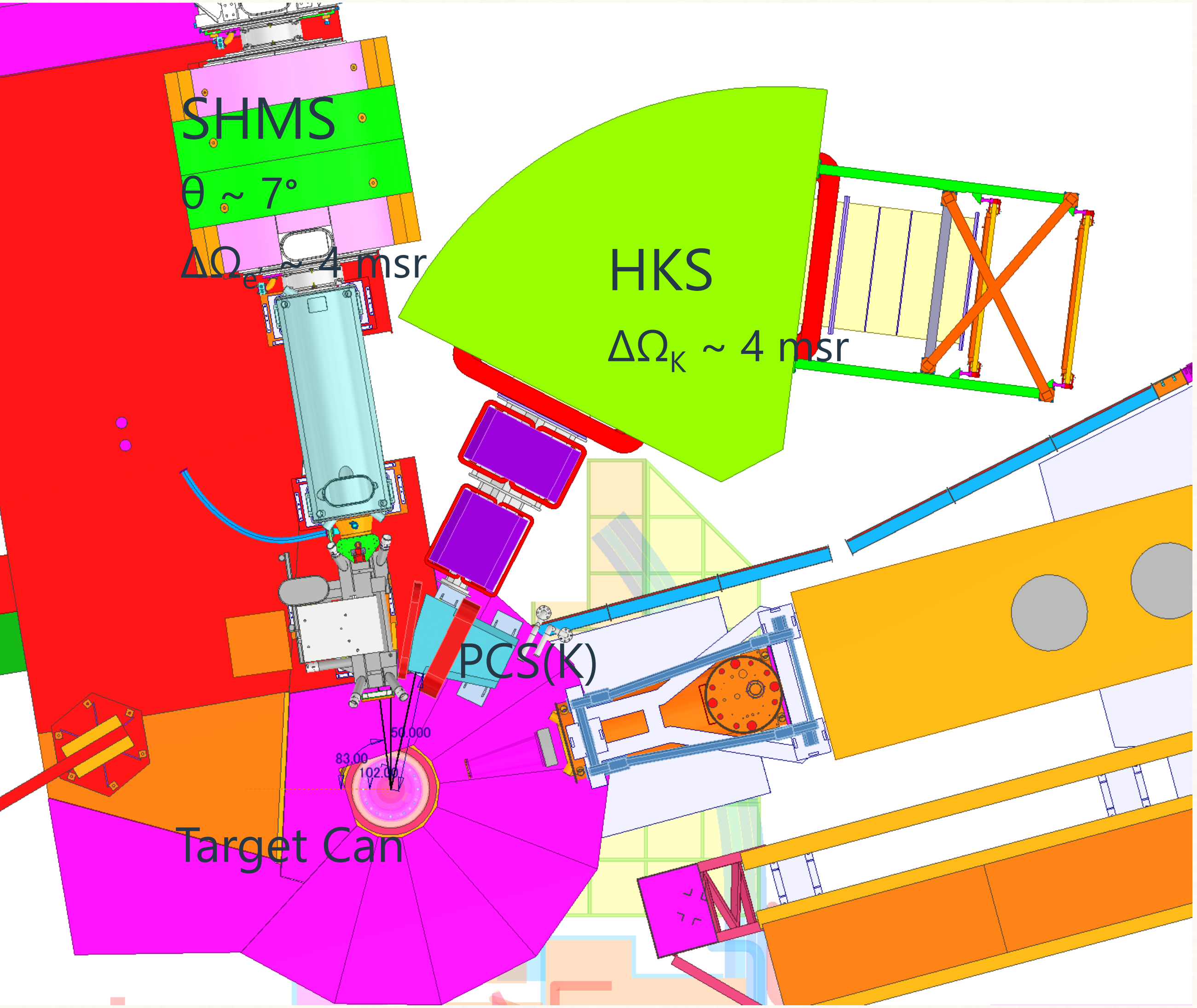


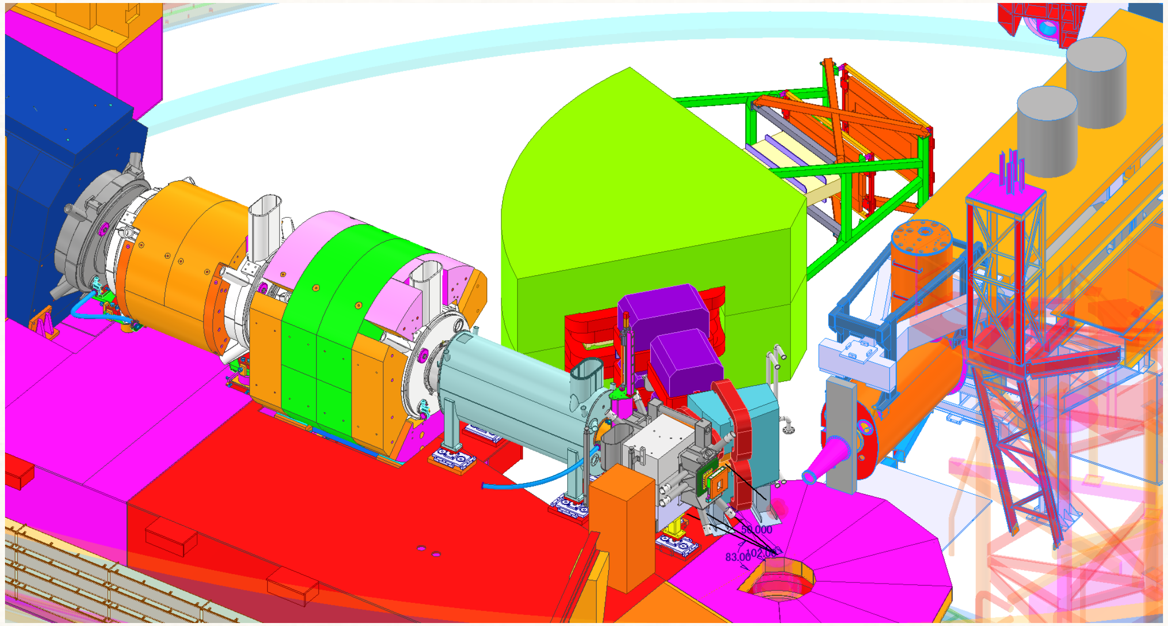


Characteristics

- Forward HES + HKS with PCSs
- Good (~ 0.6 MeV) Mass resolution
- Miss-Matching bet. PCS(e′) and HES
- Interference with HKS Q1 Mag.
- New support frame for HKS is needed
- High cost

Experimental Setup C [PCS + SHMS + HKS (holi. or vert.)]





Characteristics

- Forward SHMS & PCS(K) + HKS
- Low mom. setting (0.8 GeV/c) of SHMS
- Vacuum extension (Target - SHMS)
- ~ 1 MeV Mass resolution
- Low cost

Simulation results (Resolution)

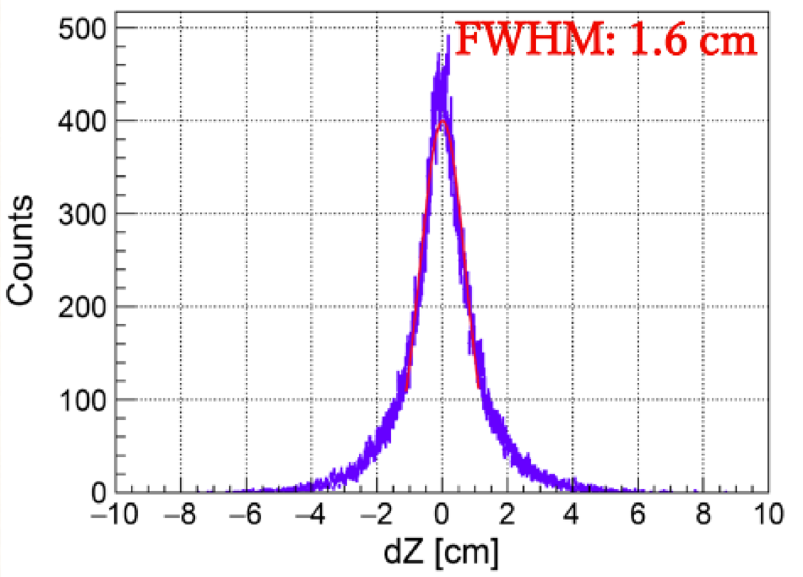
Optical Monte-Carlo simulation on Geant4.

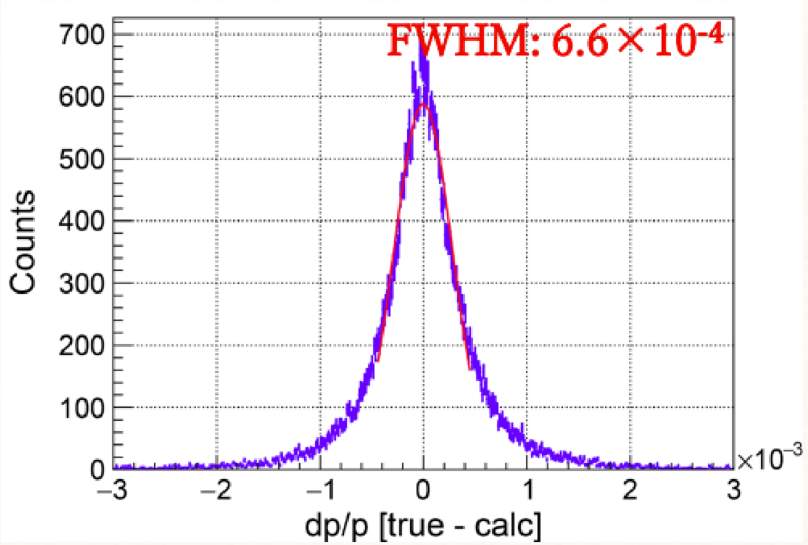
	HES(V) + HKS	HES + HKS(V)	SHMS + HKS
$\Delta p/p$ (e') [FWHM]	5.9 (6.6)×10^{-4}	4.3	10
$\Delta p/p$ (K^+) [FWHM]	2.7×10^{-4}	4.0 (6.3)	2.7
σ_z [cm]	0.7	0.8	
ΔM [MeV/c^2]	0.54 (0.58)	0.55 (0.78)	0.79

Note1: Results for the gaseous targets in parenthesis.

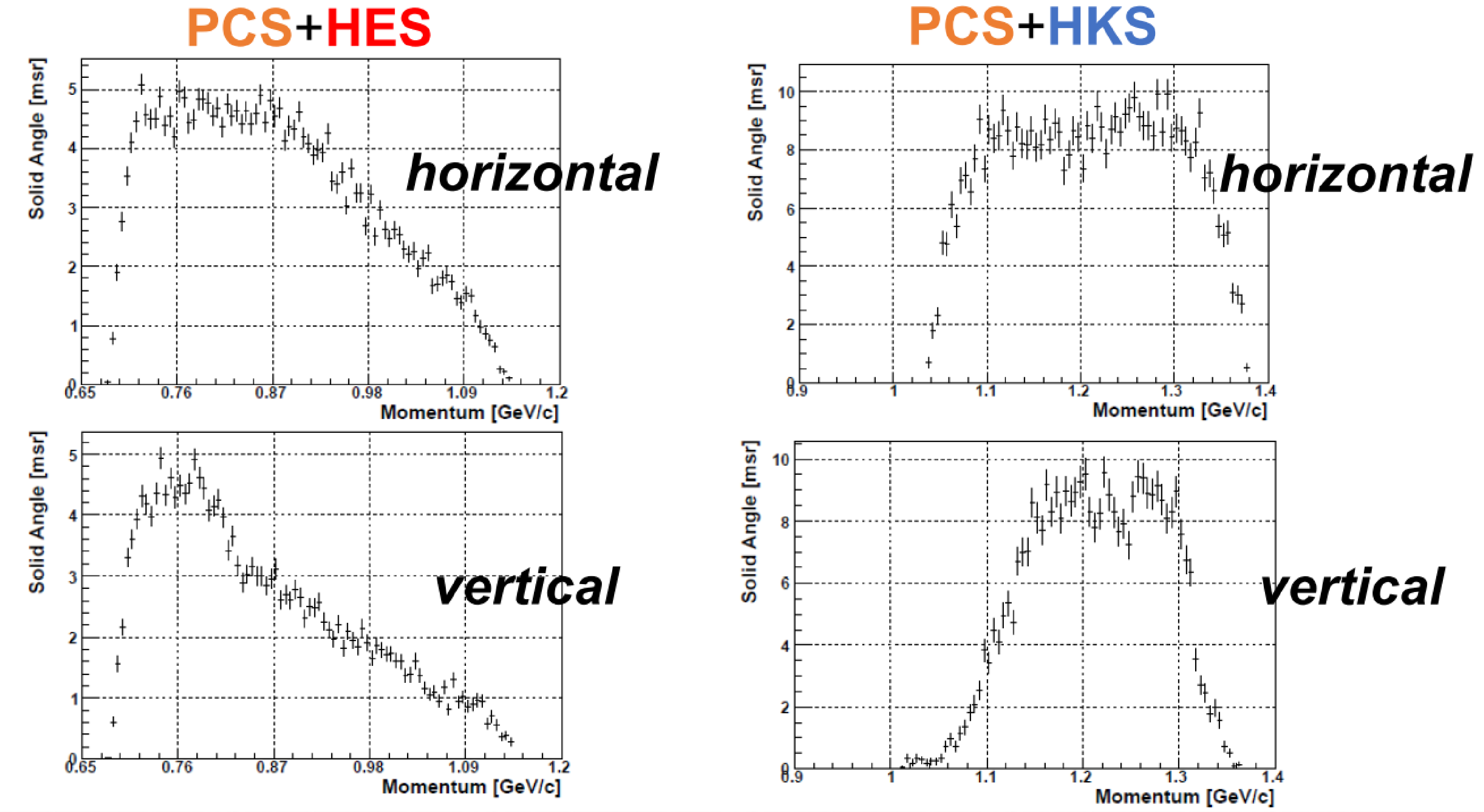
Note2: Detector resolution ON, Energy struggling OFF

- Z vertex could be reconstructed by vertical bending HES or HKS.
- Optics of the vertical HES and HKS is not optimal. Best performance cannot be expected.
- These spectrometers could have enough resolution for the hypernuclear spectroscopy.





Simulation Results (Acceptance)



by K. Okuyama (shown in the last collaboration meeting)

Yield & S/N

Target	e′ Arm Rate	Hadron Arm Rate	Hyper Yield	S/N ratio
^{12}C	130 kHz	20 kHz	56 cnts / day	7
^{40}Ca	400 kHz	15 kHz	9 cnts / day	0.4
^{208}Pb	1,000 kHz	10 kHz	3 cnts / day	0.05

Note1: Current = 20 μA, Thickness = 100 mg/cm^2

Note2: Rate and Yield would be proportional to the current and the thickness.

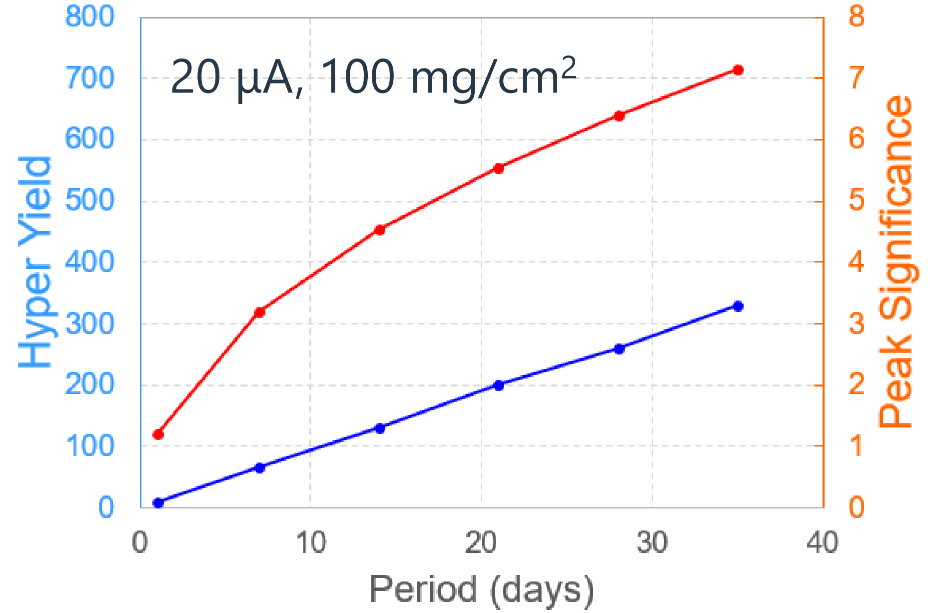
Note3: S/N would be in inverse proportional to the current and the thickness.

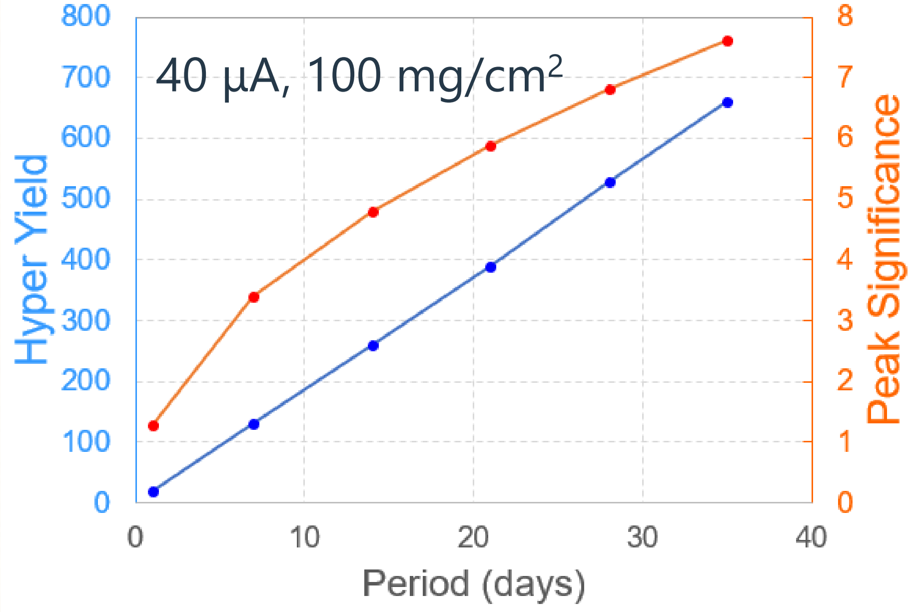
Note4: S/N was 2 for ^{12}C, 0.25 for ^{7}Li, 0.08 for ^{52}Cr targets in E05-115

- Detector rates of e′ & hadron arm would be more relax (1/4 ~ 1/5) than those in E05-115 because of the larger e′ angles and the less e^+ contamination in the hadron arm.
- Detectors would survive even for 20 μA & Lead target, though the S/N ratio would be low.

Yield and Peak Significance

$^{40}{}_{\Lambda}K$ (Ca target)





- 200 cnts of ${}_{\Lambda}K$ could be detected in 3 weeks at 20 μA (1.5 weeks at 40 μA).
- Peak significances ($S/\sqrt{(S+N)}$) are not so different between the 20- and 40-uA beam currents.
- > 3~4 weeks beam time for both $^{40\,\&\,48}Ca$ targets (doubled the original beam time) is necessary getting >5σ significance.

Summary

PCS

- Magnets were successfully transported to JLab ESB on Feb. 2022.
- Waiting for installation
- Preparation of PCS base, Sieve collimator and Power Supply (SBS power?) are necessary.

Setup Plans

- PCS + HES(vertical) + HKS may be the first candidate.
- vertical HKS is better compared to vertical HES in terms of physics output
- Technical and Mechanical supports are very important to consider the possibility of vertical bending HES (or/and HKS).
- Lower beam current (20 uA)

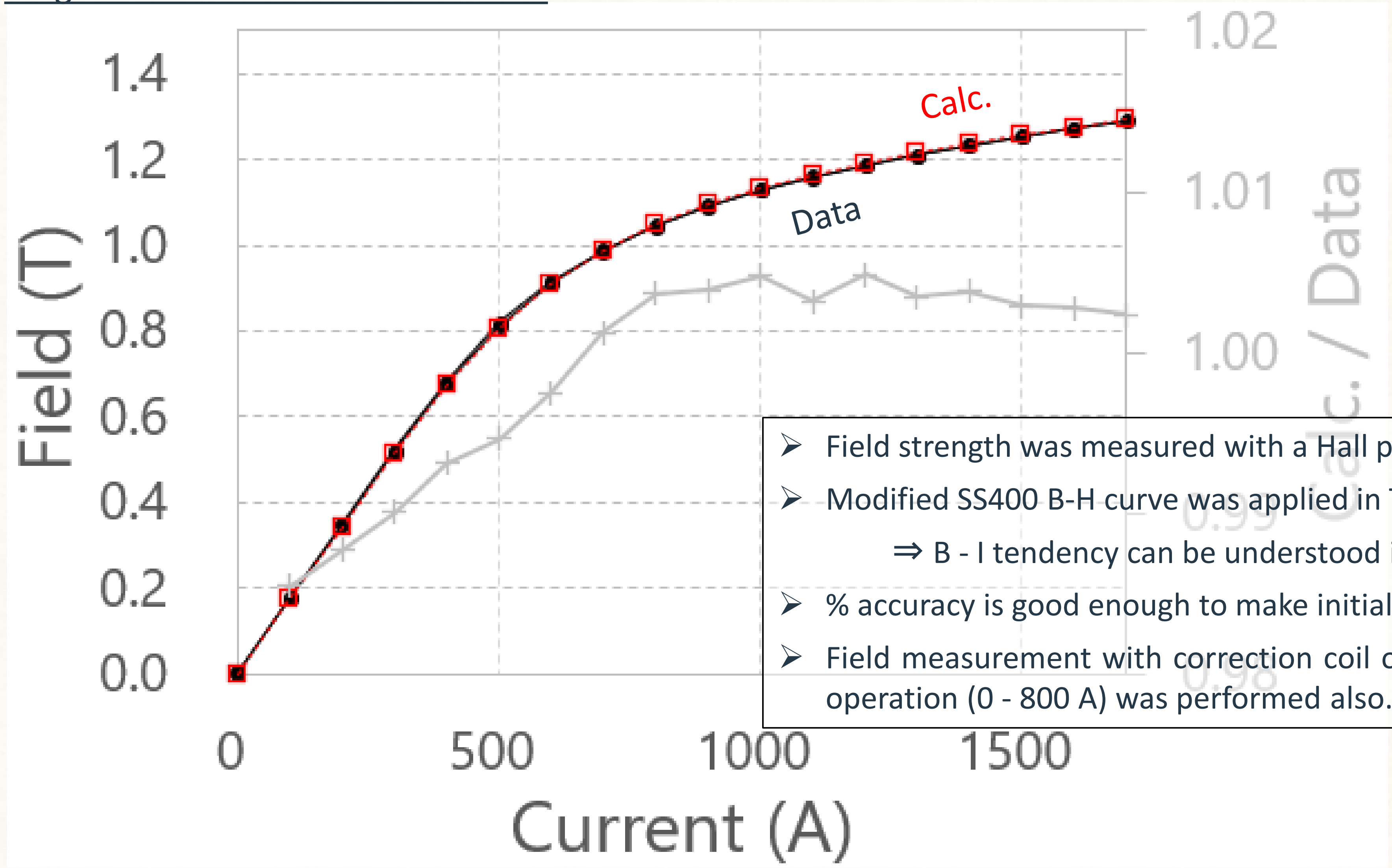
  → Doubled beam time would be necessary to achieve the enough peak significance.

Backup

Photos

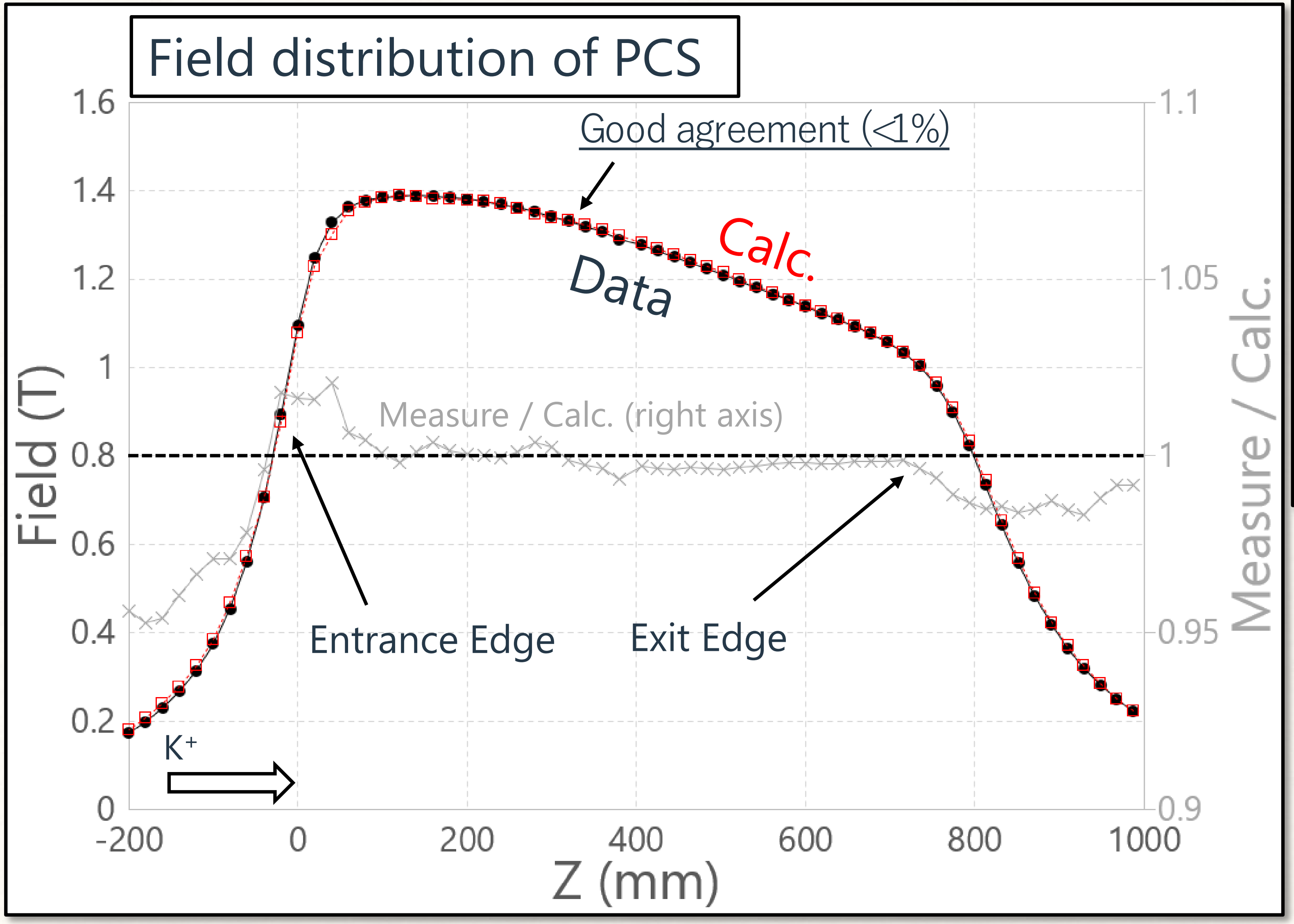
B - I Curve

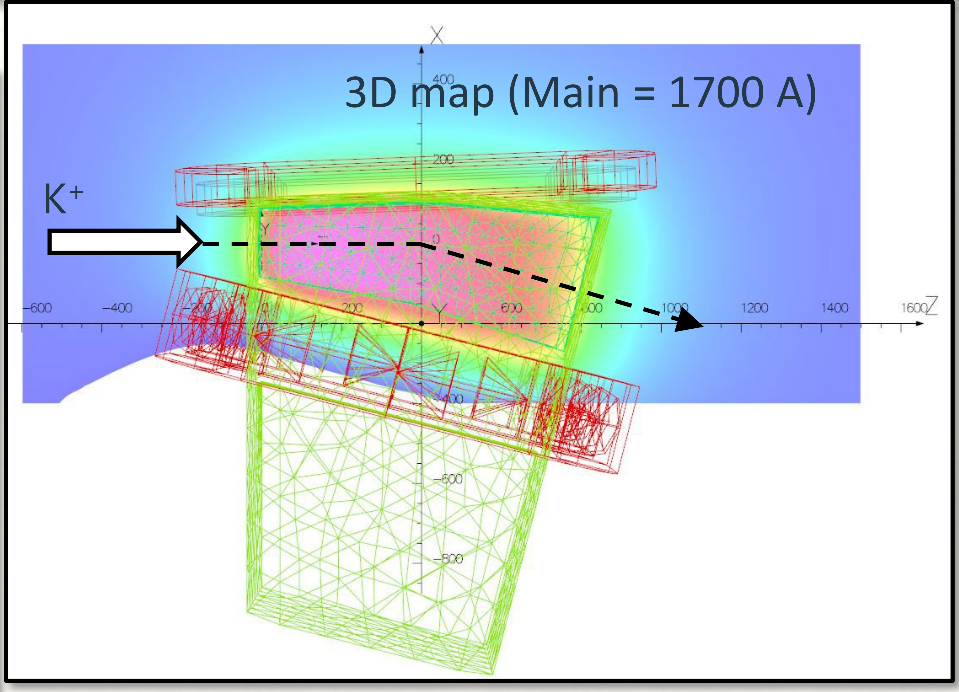
Magnetic Field v.s Main coil current



- 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

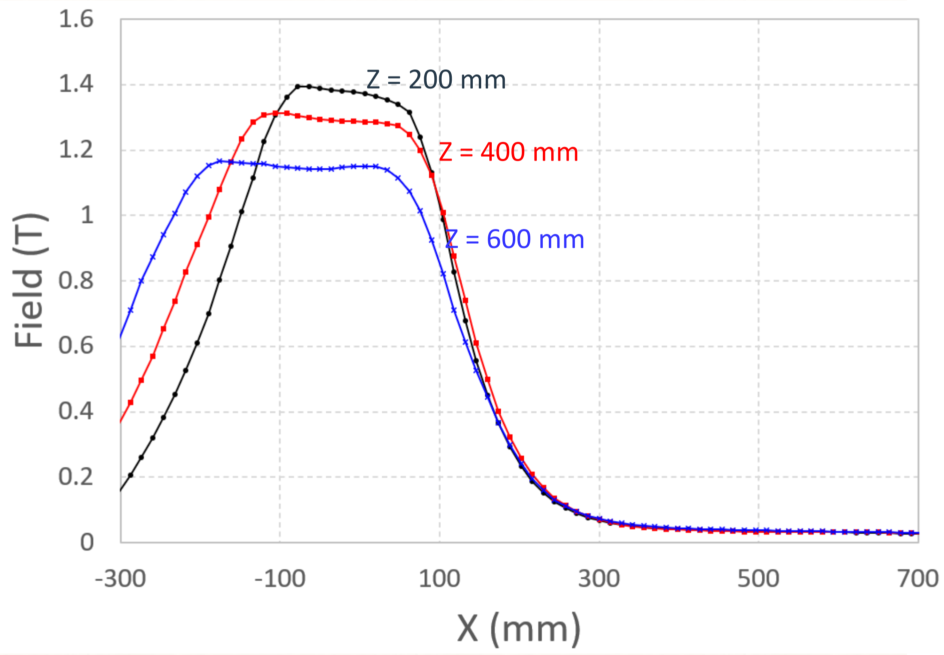


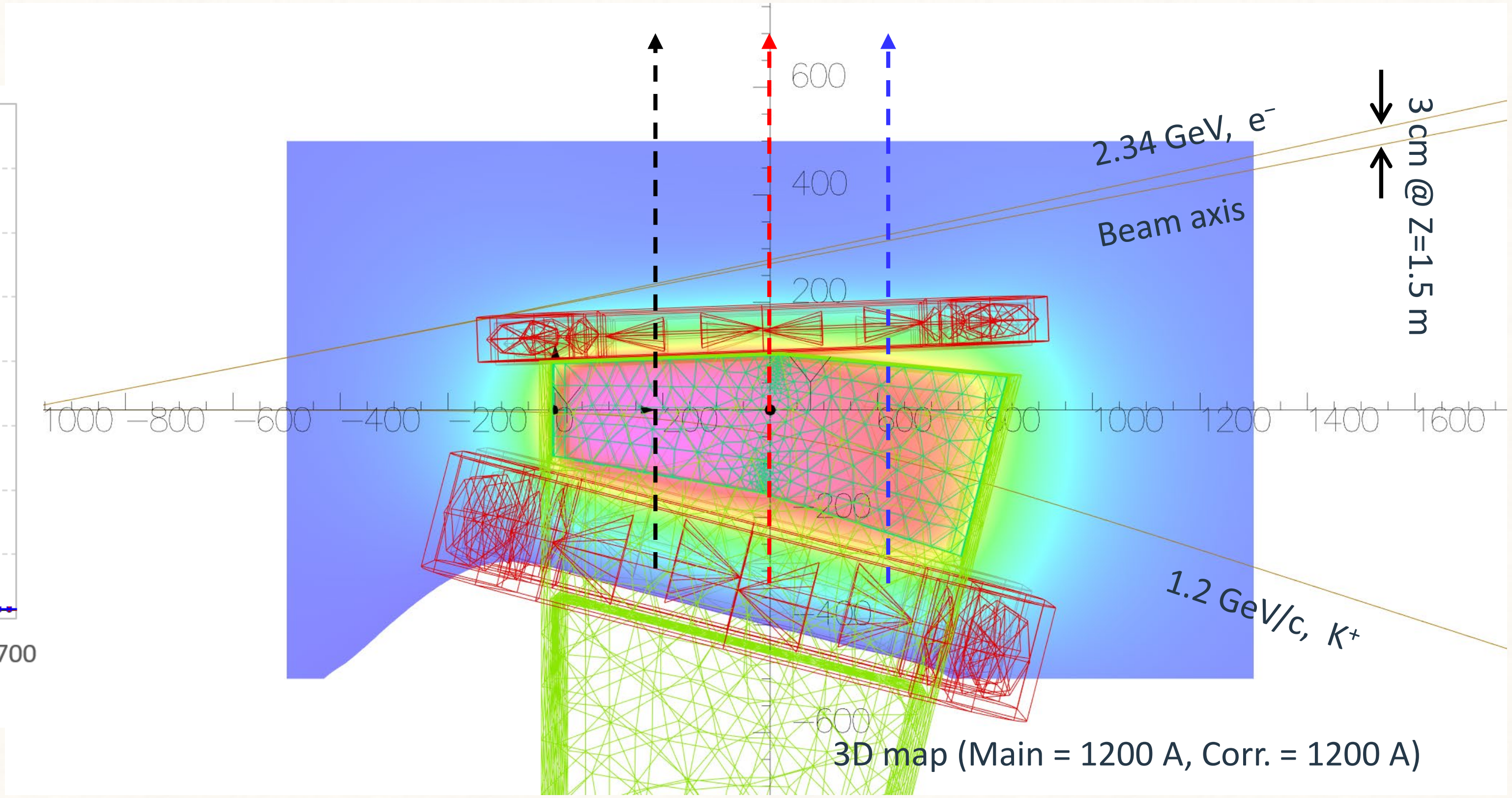


Field along the particle track is good agreement with TOSCA results.

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

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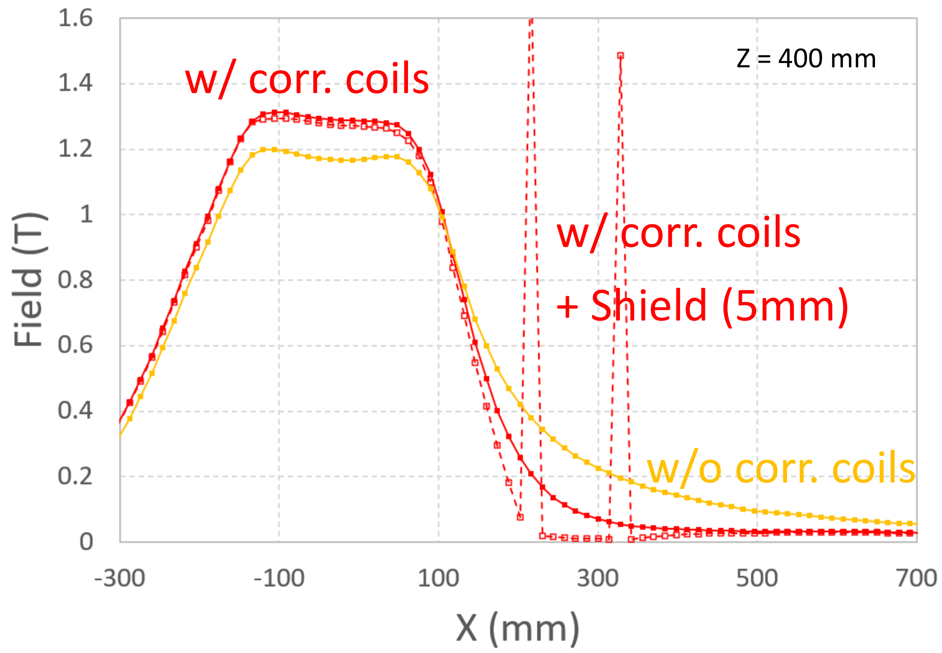

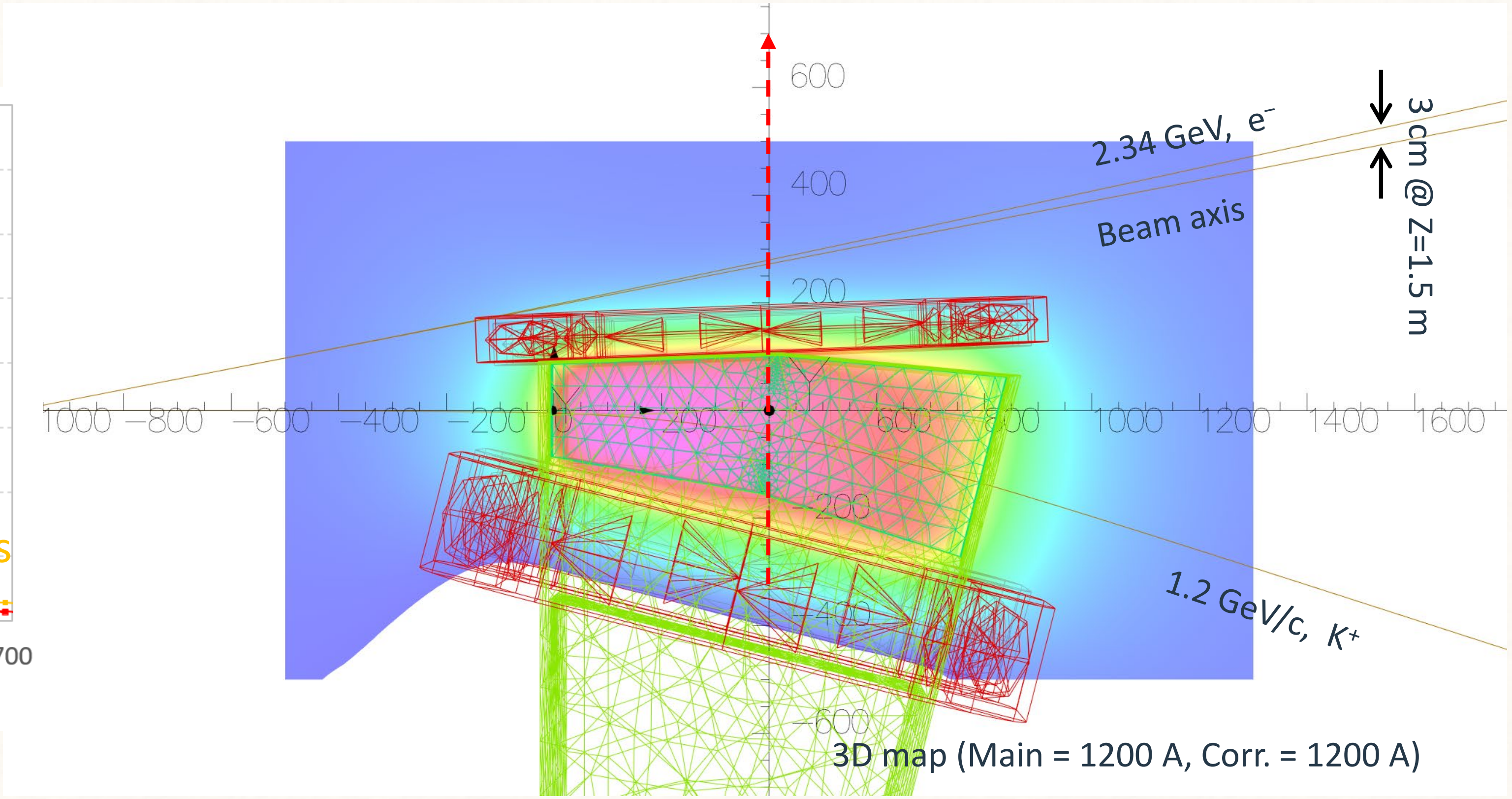

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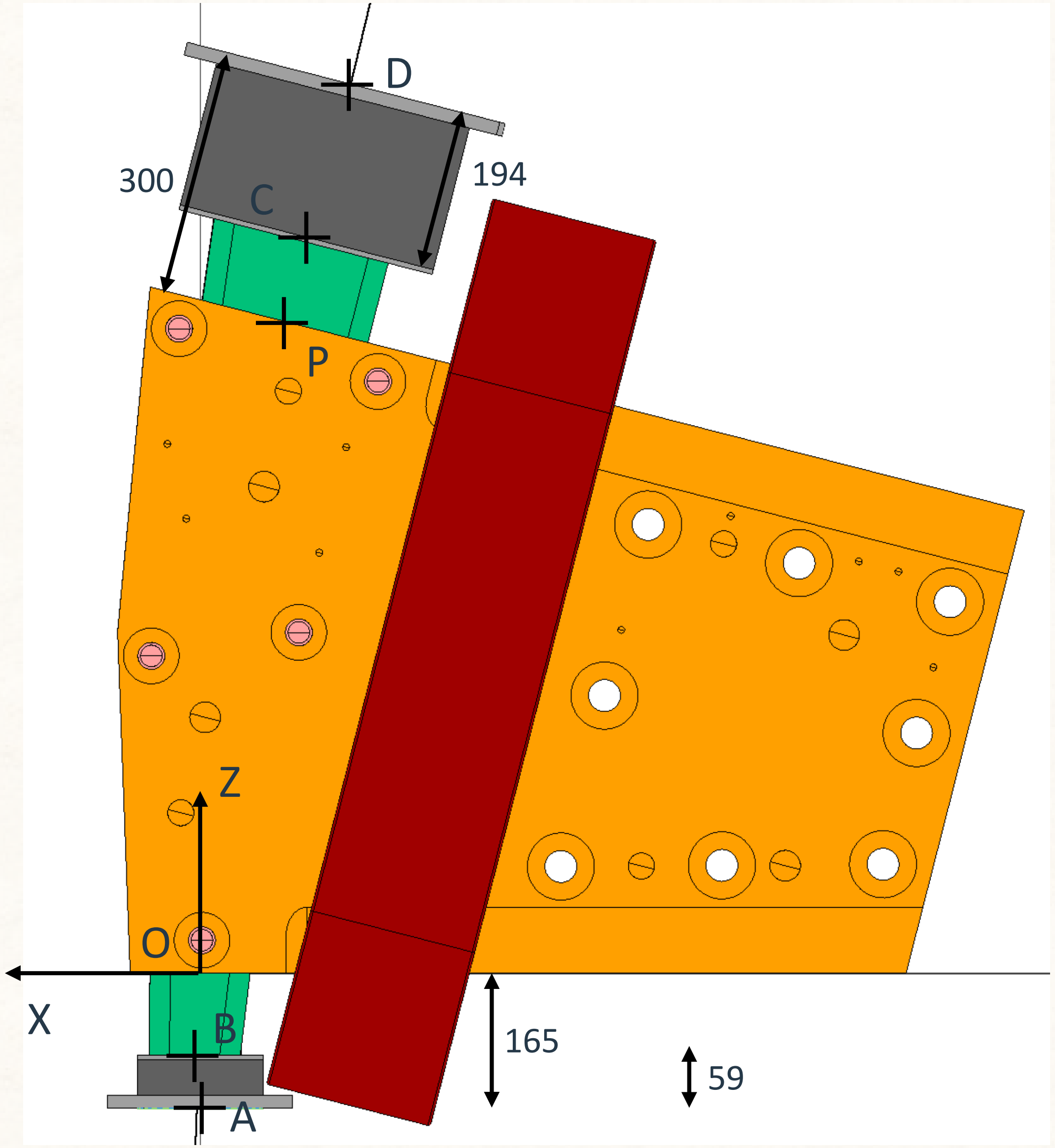
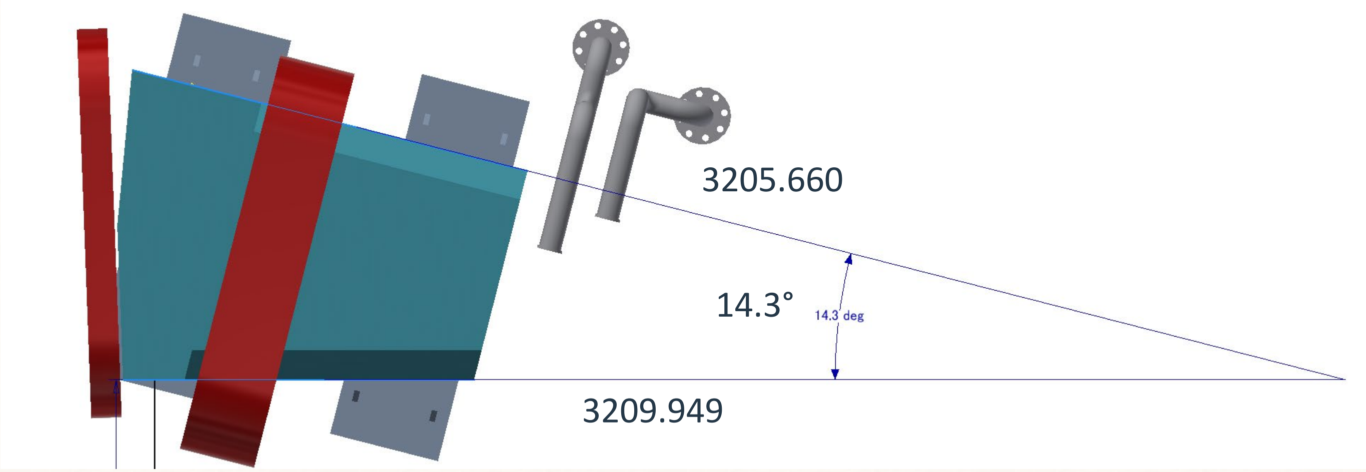
PCS (K)





O：PCS SM1(K)原点、Pole中点

X = 0, Y = 0, Z = 0

P：PCS SM1(K)出口、Pole中点

X = -103.4, Y = 0, Z = 793.8

A：入口フランジ中心

X = 0, Y = 0, Z = −165, Φ_1 = 153, Φ_2 = 225

B：真空箱入口中央

X = 7.1 (±90.5555), Y = 0 (±31.38), Z = −106

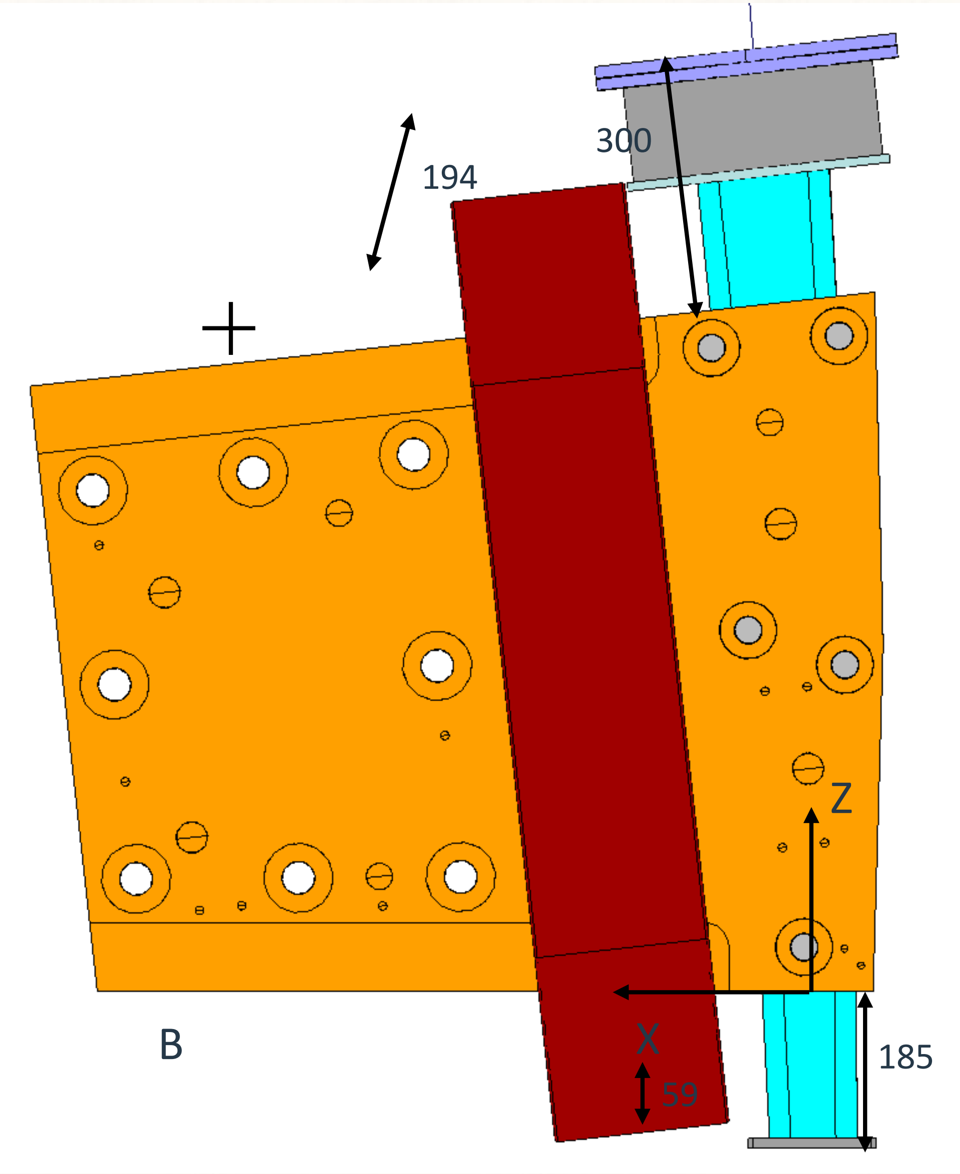
C：真空箱出口中央

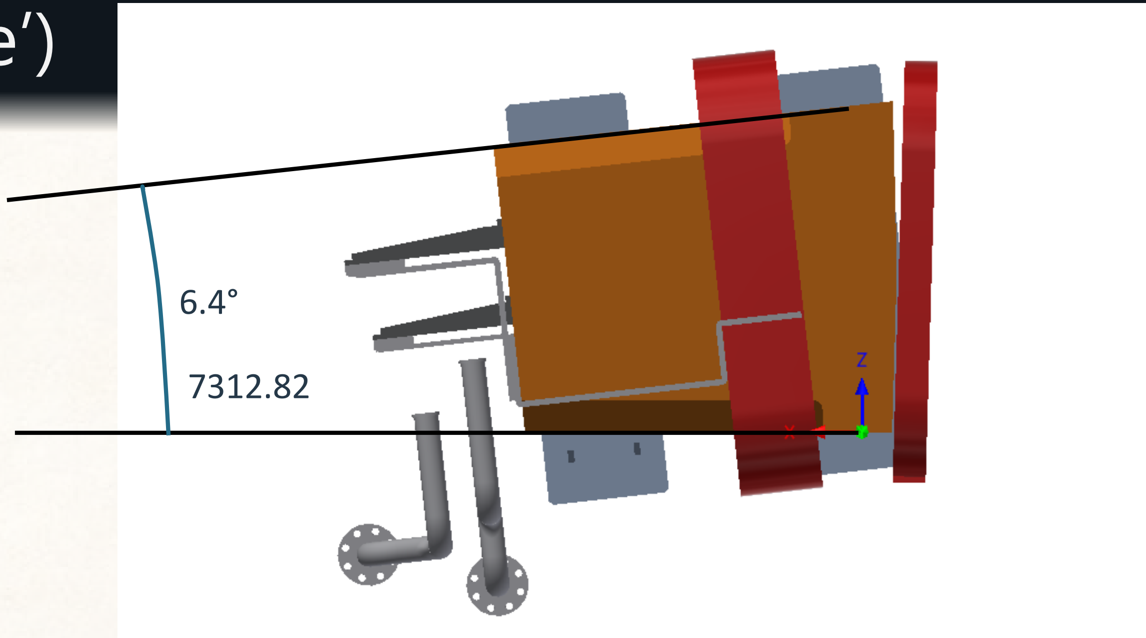
X = −123.8 (±99.5), Y =0 (±84) , Z = 897.7

D：出口フランジ中心

X = −178.3, Y = 0, Z = 1084.2, Φ_1 = 318.5, Φ_2 = 40000

PCS (e′)





O：PCS SM1(K)原点、Pole中点

X = 0, Y = 0, Z = 0

P：PCS SM1(K)出口、Pole中点

X = 44.88, Y = 0, Z =

A：入口フランジ中心

X = 0, Y = 0, Z = , Φ_1 = , Φ_2 =

B：真空箱入口中央

X = , Y = , Z =

C：真空箱出口中央

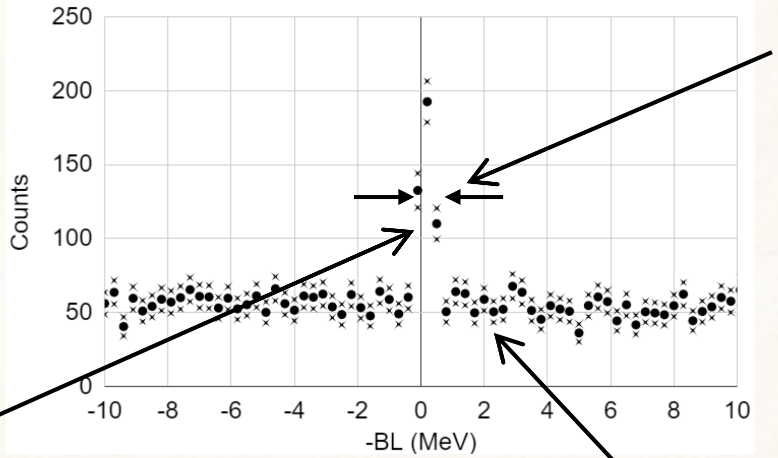
X = , Y = , Z =

D：出口フランジ中心

X = , Y = 0, Z =, Φ_1 =, Φ_2 =

Estimator

Google SpreadSheet



Resolution

Peak width is estimated by a Monte-Carlo code which assumed angular and momentum resolution of each spectrometer.

Ref. "Spectrometer" sheet

No. of peak counts

Accidental background height

$N_{HYP} = N_e \times Int(\Gamma(E,\theta)) \times N_t \times d\sigma/d\Omega \times f(Q^2) \times \Delta\Omega_K \times \varepsilon \times t$

$Int(\Gamma(E,\theta)) = \Gamma(E,\theta) \times \Delta\Omega_{e'} \times [\Gamma(E05exp)/\Gamma(E05calc)]$

$= 0.14$

$\varepsilon = \varepsilon_{etrig} \times \varepsilon_{etrack} \times \varepsilon_{decay} \times \varepsilon_{Ktrig} \times \varepsilon_{Ktrack} \times \varepsilon_{KAC} \times \varepsilon_{KWC} \times \varepsilon_{KMass} \times \varepsilon_{DAQ}$

$f(Q^2) = (Q^2 + 2.67)^{-2} / 2.67^{-2}$ C.J.Bebek et al., PRD15(1997)3082.

$S/N = F_{SN} \times \Delta Mass$

$P.S. = 0.68 \times N_{HYP} / \surd(0.68 \times N_{HYP} + N_{HYP}/(S/N))$

$H_{acc} = N_{HYP} / F_{SN} \times F_{norm} \times F_{bin}$

F_{norm}: Normalization factor (1/8) to reproduce $^{10}{}_{\Lambda}Be$ spectrum.

F_{bin}: Binning scale factor, it's proportional to the bin size.

$F_{SN} = \mathbb{R}_{HYP} / (\mathbb{R}_{e'} \times \mathbb{R}_K) \times 10^{11}$

$\mathbb{R}_{HYP} = N_{HYP} / t$

$\mathbb{R}_{e'} = Ne \times Nt \times d\sigma/d\Omega dp \times \Delta\Omega \times \Delta p$

$\mathbb{R}_K = ((\mathbb{R}_{pi} + \mathbb{R}_e) \times \varepsilon_{pi} + \mathbb{R}_K \times \varepsilon_K + \mathbb{R}_p \times \varepsilon_p) \times \varepsilon_{DAQ}$

$\varepsilon_x = \varepsilon_{trig} \times \varepsilon_{chere} \times \varepsilon_{ana}$