SuperKEKB Ring status

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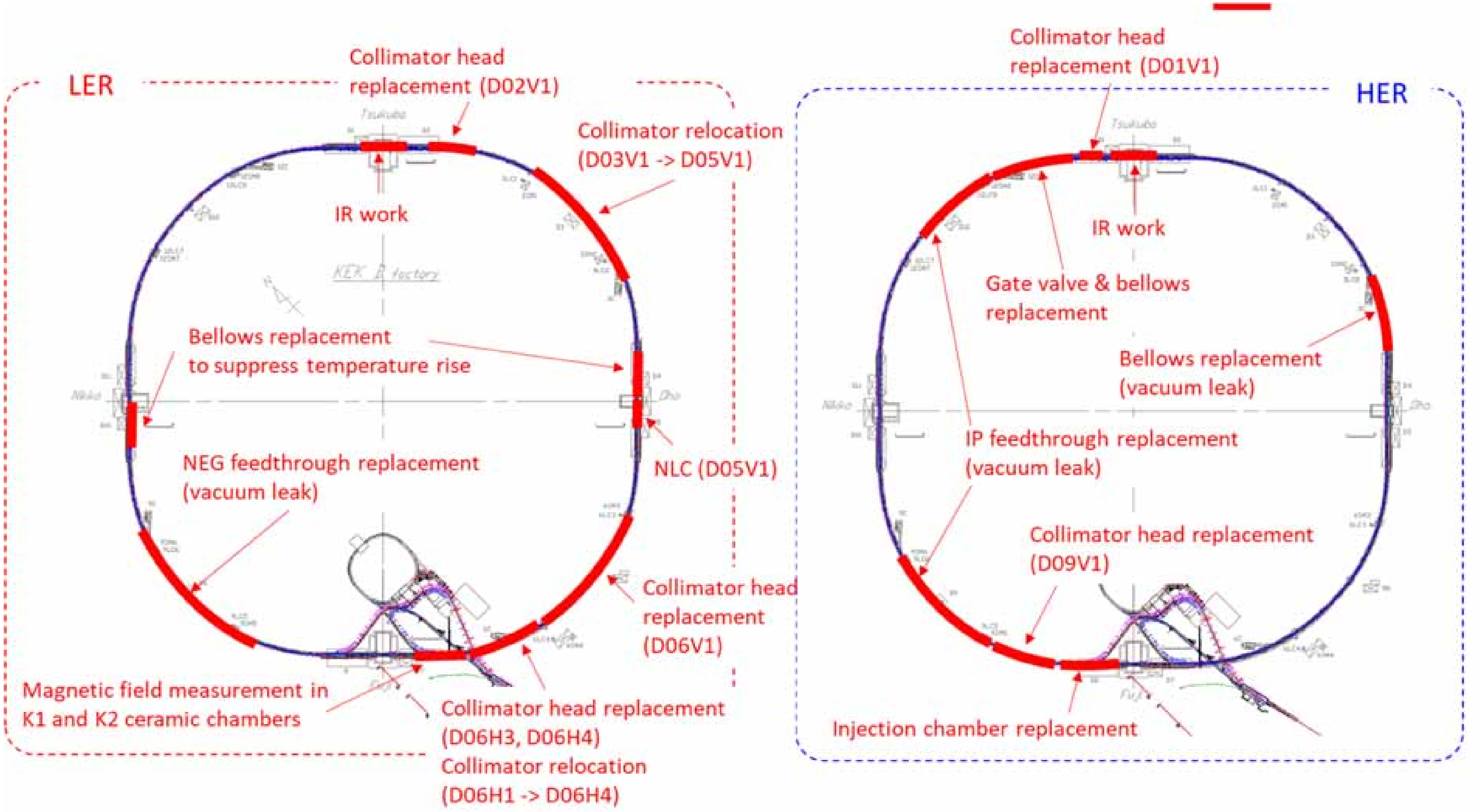
KEK Accelerator Laboratory

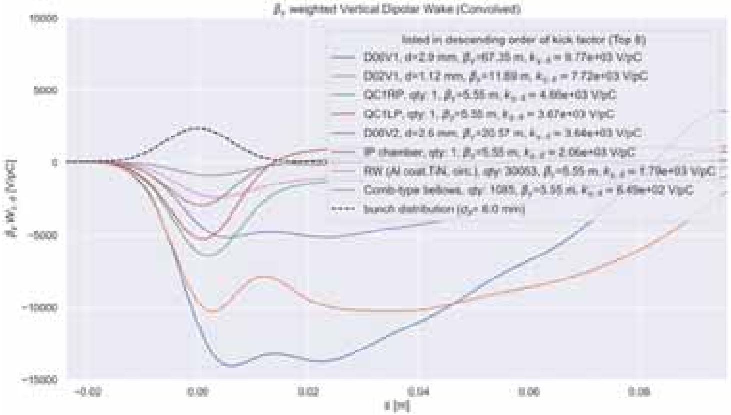
BPAC Reivew 5/Feb/2024

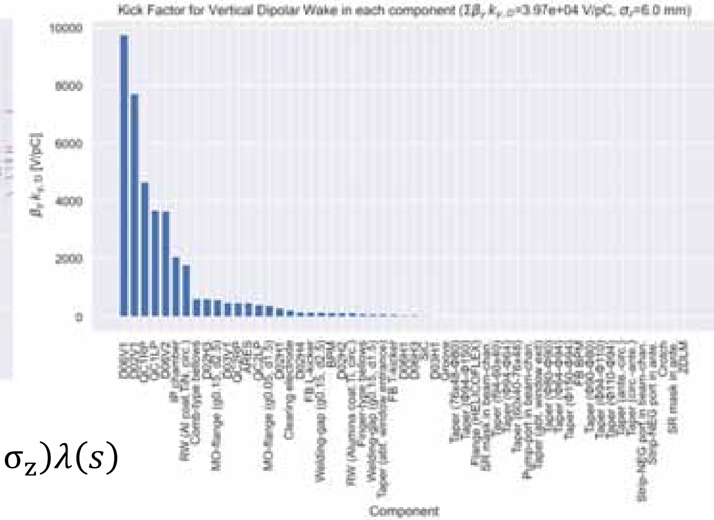
Major Vacuum Works during LS1



LER vertical impedance (β_y^*=1 mm, Before LS1)

σ_z=6.0 mm





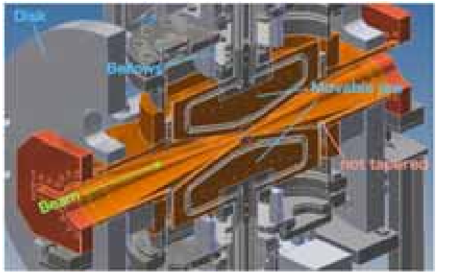
Vertical dipolar kick factor: $k_{\mathrm{y,d}} = \int ds W_{\mathrm{y,d}}(s,\sigma_z)\lambda(s)$

Vertical tune shift: $\Delta\nu_{\mathrm{y}} = \frac{I_{\mathrm{b}}T_0}{4\pi(E/e)}\sum_i \beta_{\mathrm{y},i}k_{\mathrm{y,d},i}$

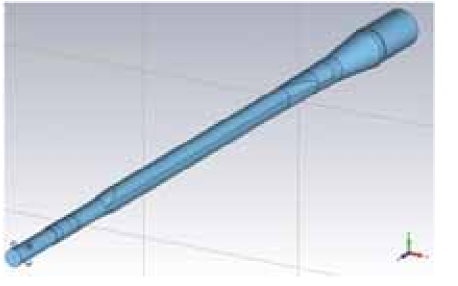
TMCI threshold: $I_{th} = \frac{4\pi\nu_s(E/e)}{T_0\sum_i \beta_{y,i}k_{y,i}}$

- **Transverse Mode Coupling Instability (TMCI)**
- **Major impedance sources: Vertical collimator, QCS beam pipe, IP chamber**

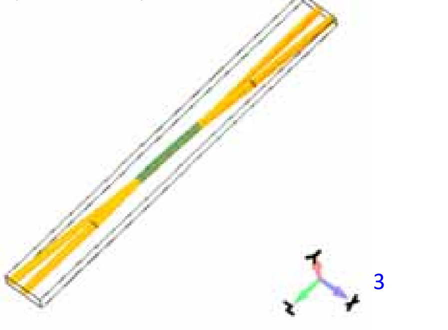
Vertical collimator



Tapered beam-pipe with BPM in final focusing magnet (QC1)



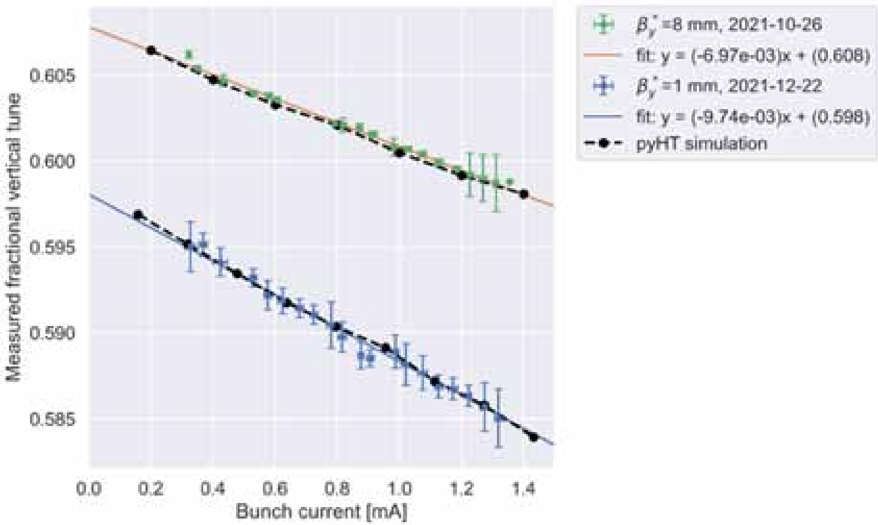
Beam-pipe around interaction point (IP chamber)

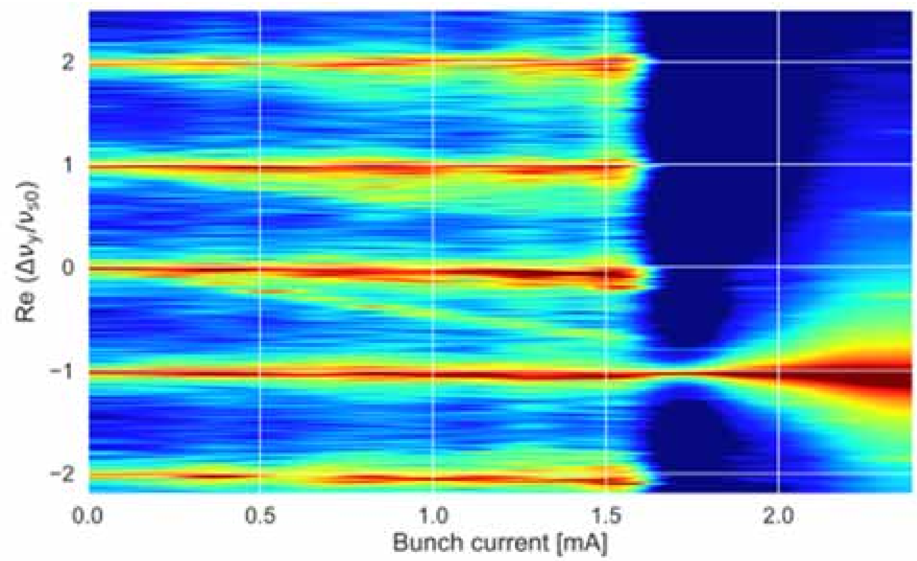


LER – Veritcal (β_y^*=1 mm, Before LS1)

- **Bunch current dependent vertical tune shift: agreed the simulation results using impedance models (GdfidL, CST)**
- **Simulated threshold of TMCI ~1.75 mA/bunch**
- **Design bunch current：1.44 mA/bunch**

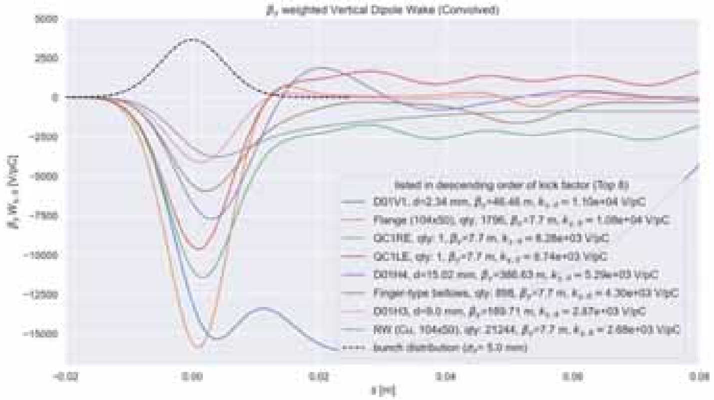
vertical tune shift

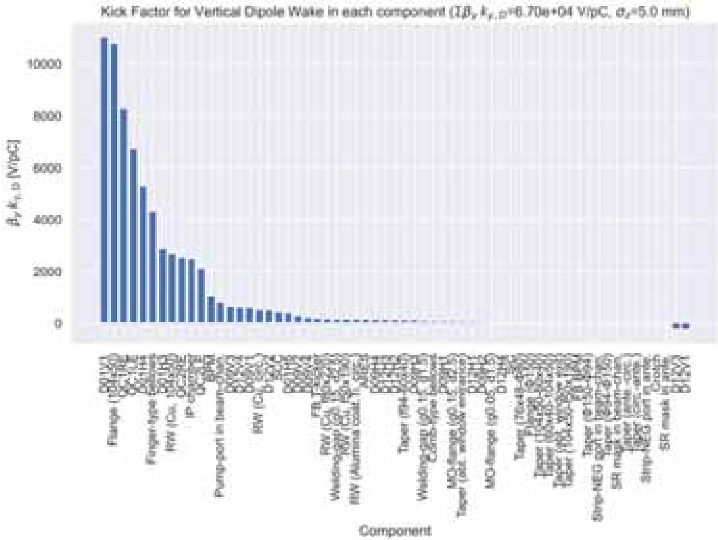




HER – Vertical (β_y^*=1 mm)

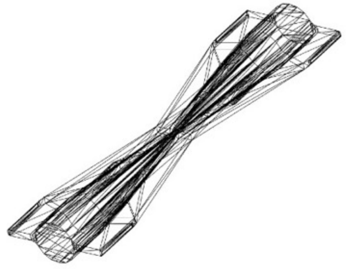
σ_z=5.0 mm



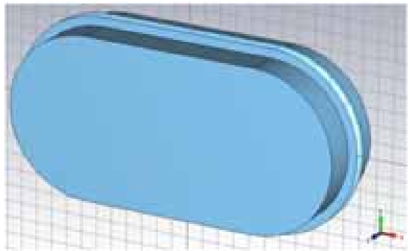


- **Major impedance sources: Vertical collimator, Vacuum flanges (helicoflex), Bellows, QCS beam pipe**

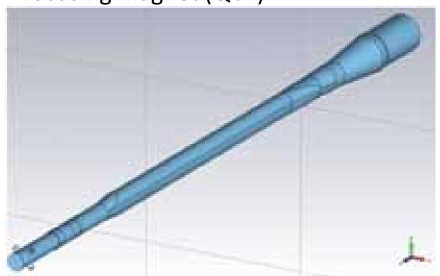
Vertical collimator



Flange (104x50)



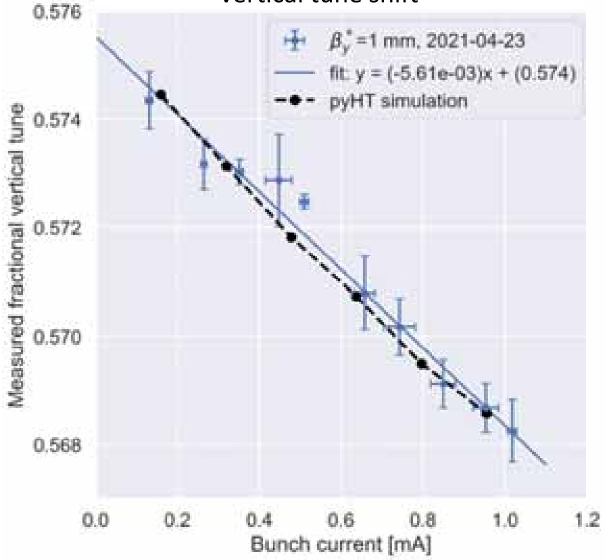
Tapered beam-pipe with BPM in final focusing magnet (QC1)

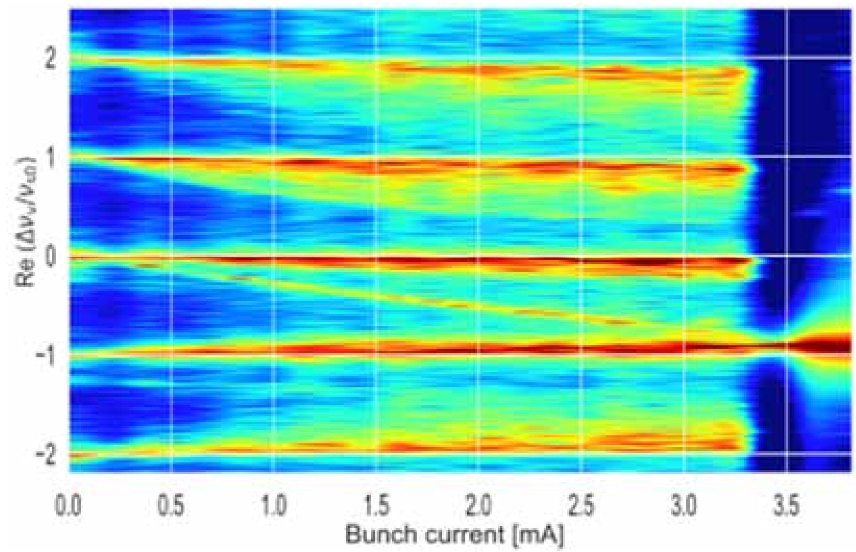


HER – Vertical (β_y^*=1 mm)

- **Bunch current dependent tune shift: agreed the simulation results**
- **TMCIの閾値：~3.5 mA/bunch**
- **設計バンチ電流：1.04 mA/bunch**

vertical tune shift





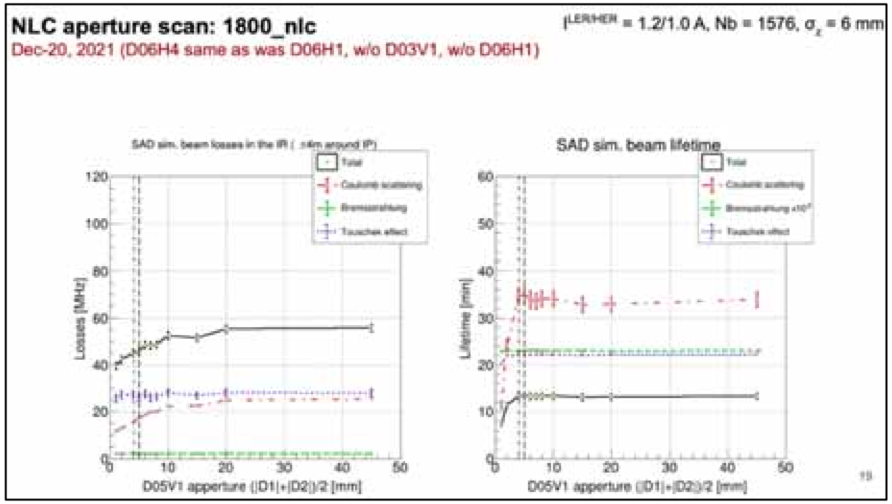
LER – Nonlinear collimator

[A. Natochii]

[example] collimator setting and $\beta_y k_y$ for βy^*=1 mm optics.

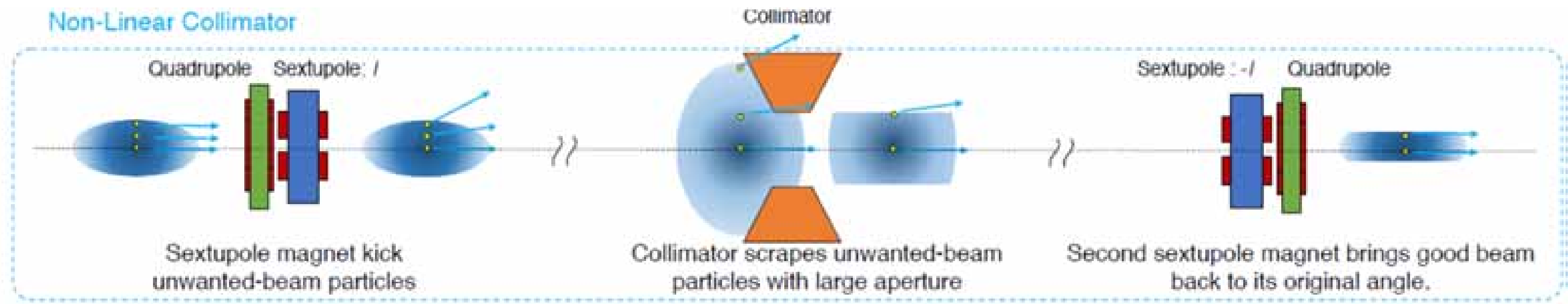
Collimator	β_y [m]	Half-aperture [mm] a)	$\beta_y k_y$ [$\times 10^{15}$, V/C]
D06V1	67.35	2.9	9.77
D06V2	20.57	2.6	3.64
D03V1	16.96	8.0	0.50
D02V1	11.89	1.1	7.72
D05V1	4.05 b)	5	0.28

a) Averaged value of top and bottom half-aperture at 2021-12-22
b) Optics file: sler_1800_80_1.sad

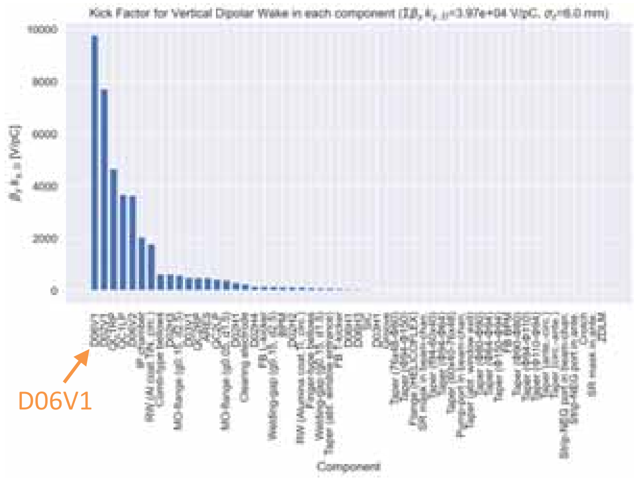


Bunch current threshold of TMCI

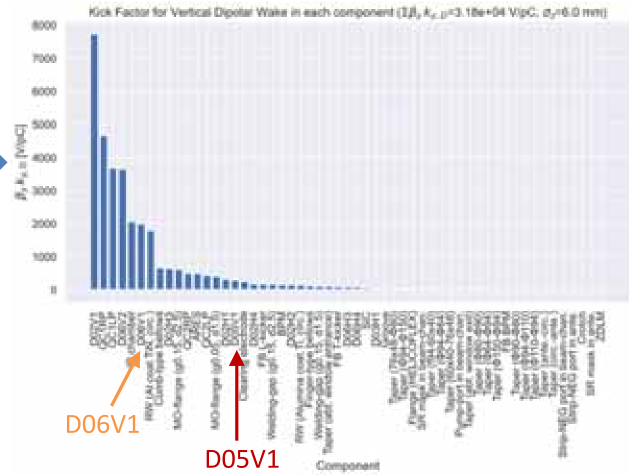
$$I_{th} = \frac{4\pi\nu_s(E/e)}{T_0\sum_i \beta_{y,i}k_{y,i}}$$



2021c physics run



LS1後



β_y^*=1 mm
β_x^*=80 mm

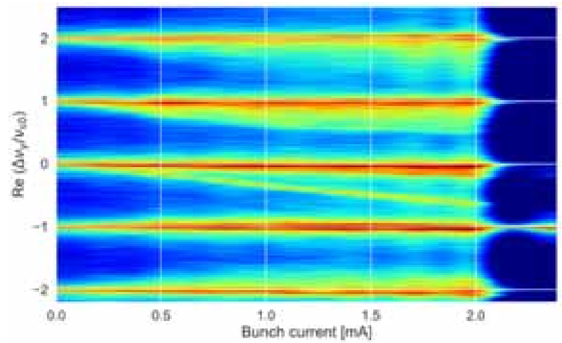
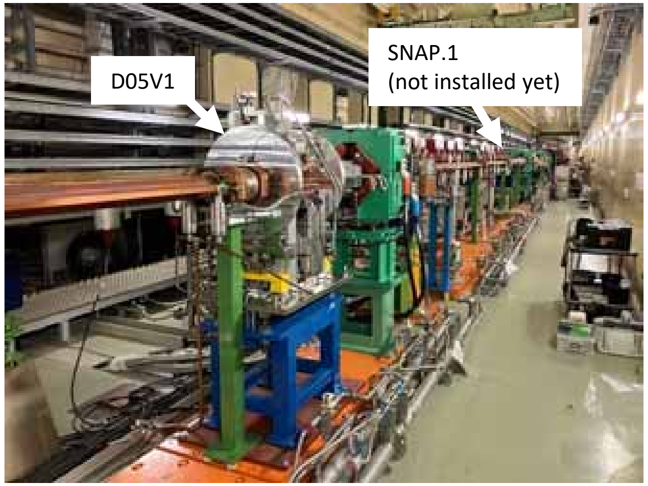
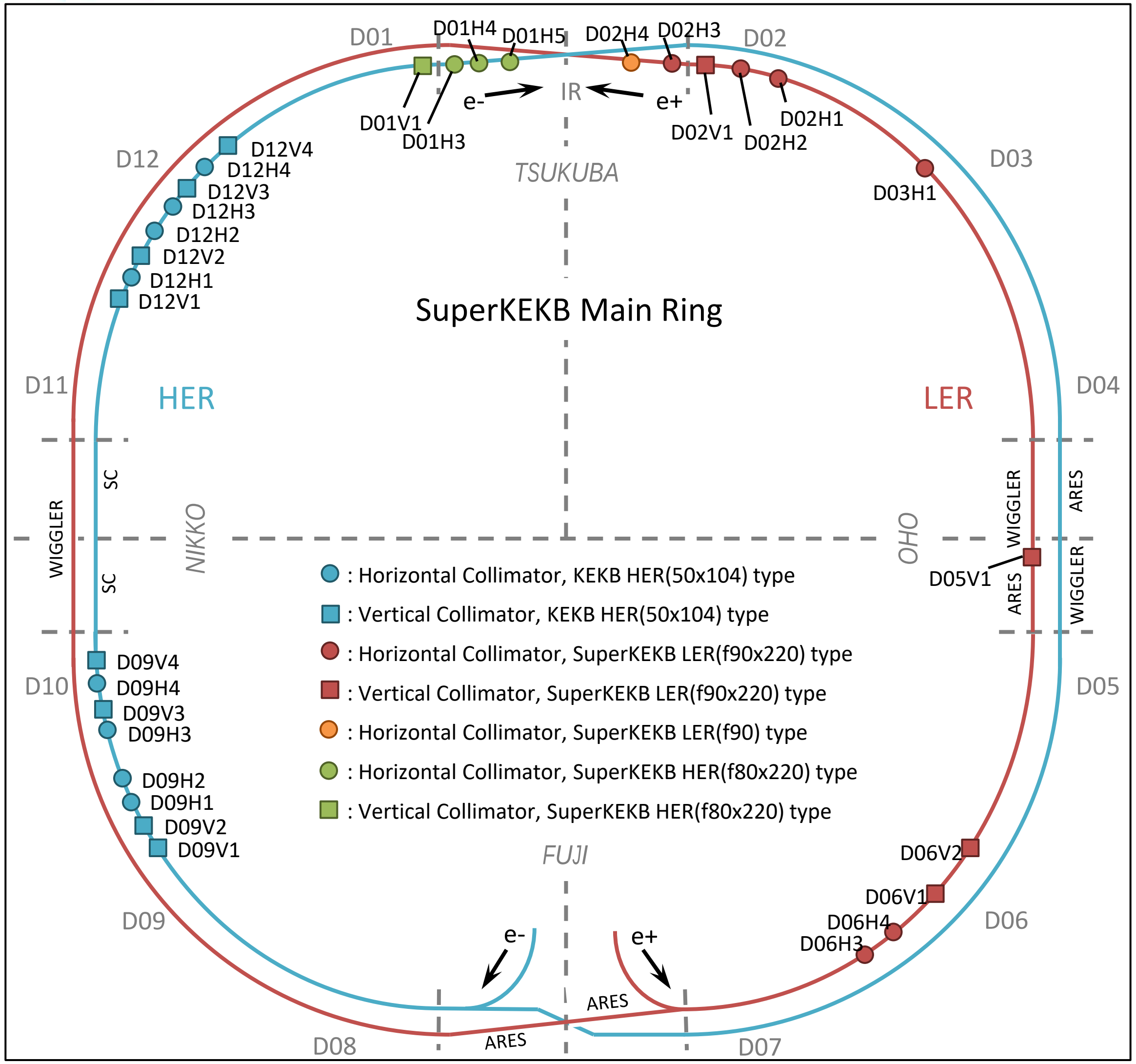


Photo of the non-linear collimator section (2023-05-26)



- $\Sigma\beta_y k_y$ will reduce from 3.97e4 downto 3.18e4 V/pC
- Threshold of TMCI is estimated to increase more than 2.mA/bunch

Collimators



Status of LER collimator

Name	Type	Tip Material (): longitudinal length in mm	Tip Condition	Remarks
D06H3	SuperKEKB	Cu coated C (160)	healthy	spoiler against inj. kickers' accidental firings
D06H4	SuperKEKB	Ta (10)	healthy	absorber against inj. kickers' accidental firings
D03H1	SuperKEKB	W (10)	healthy	
D02H1	SuperKEKB	W (10)	healthy	
D02H2	SuperKEKB	W (10)	healthy	
D02H3	SuperKEKB	W (10)	healthy	
D02H4	SuperKEKB	W (10)	healthy	
D06V1	SuperKEKB	Cu coated Ti (10)	healthy	
D06V2	SuperKEKB	hybrid (3)	healthy	
D05V1	SuperKEKB	Cu coated Ta (4)	healthy	
D02V1	SuperKEKB	Cu coated Ta (10)	healthy	

Status of HER collimator

Name	Type	Tip Material (): longitudinal length in mm	Tip Condition	Drive Mechanism	Remarks
D09H1	KEKB	Cu coated Ti (40)	damaged		
D09H2	KEKB	Cu coated Ti (40)	damaged		
D09H3	KEKB	Cu coated Ti (40)	damaged		
D09H4	KEKB	Cu coated Ti (40)	damaged		
D12H1	KEKB	Ti (40)	healthy		
D12H2	KEKB	Cu coated Ti (40)	damaged		
D12H3	KEKB	Ti (40)	healthy		
D12H4	KEKB	Cu coated Ti (40)	healthy		
D01H3	SuperKEKB	W (10)	healthy	-	
D01H4	SuperKEKB	W (10)	healthy	-	
D01H5	SuperKEKB	W (10)	healthy	-	
D09V1	KEKB	Cu coated Ti (40)	healthy	upgraded	
D09V2	KEKB	Cu coated Ti (40)	healthy		
D09V3	KEKB	Cu coated Ti (40)	healthy		
D09V4	KEKB	Cu coated Ti (40)	healthy		
D12V1	KEKB	Cu coated Ti (40)	damaged	upgraded	
D12V2	KEKB	Cu coated Ti (40)	damaged		
D12V3	KEKB	Cu coated Ti (40)	healthy	upgraded	
D12V4	KEKB	Cu coated Ti (40)	healthy	upgraded	
D01V1	SuperKEKB	Cu coated Ta (10)	healthy	-	

Spare jaws

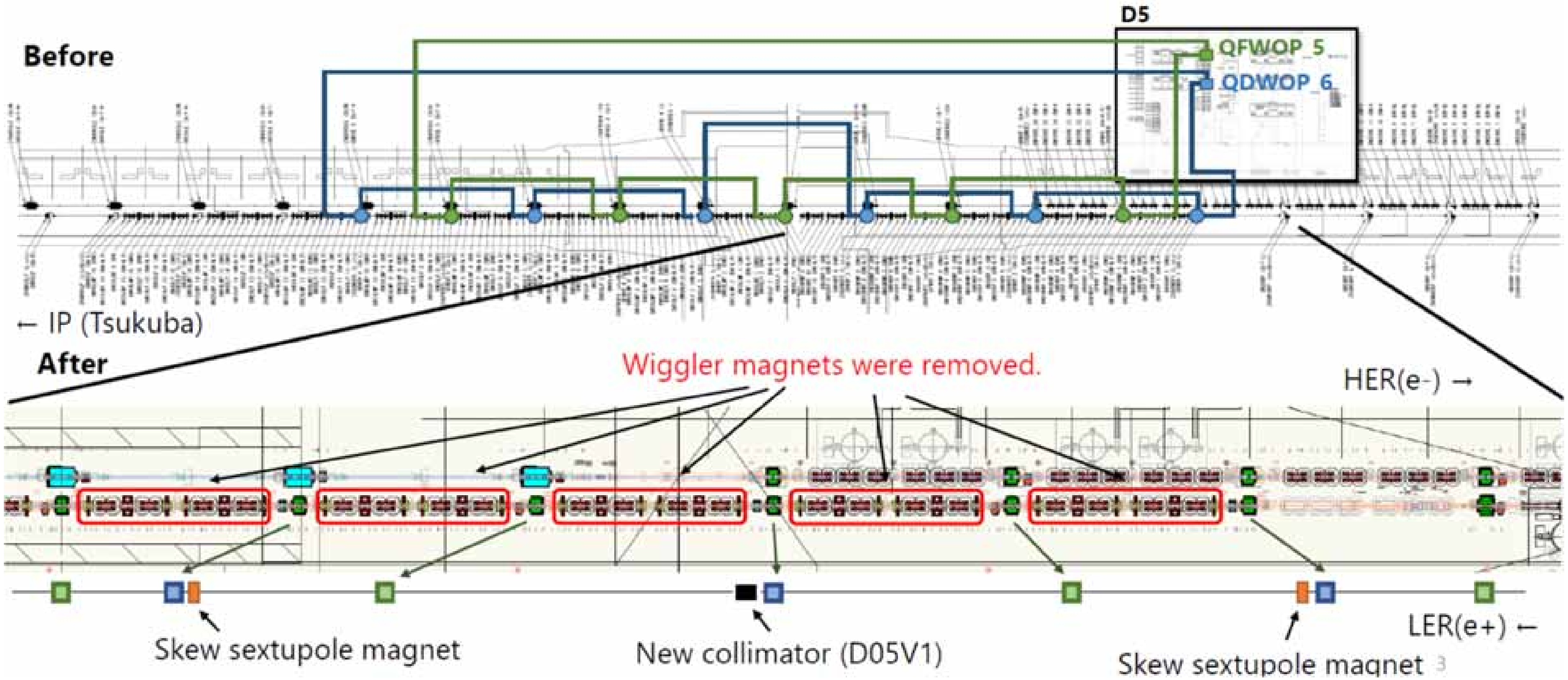
Tip Material (): longitudinal length in mm	Collimator to be installed (assumed)	Remarks
HER vertical: Cu coated Ta (10)	D01V1	Plan to deliver in this fiscal year.
HER vertical: Cu coated Ta (10)	D01V1	Plan to deliver in this fiscal year.
HER vertical: Cu coated Ti (40)	D09V1-V4, D12V1-V4	
HER vertical: Cu coated Ti (40)	D09V1-V4, D12V1-V4	
LER vertical: Cu coated Ta (10)	D02V1	
LER vertical: Cu coated Ta (10)	D02V1	
LER vertical: hybrid (3)	D05V1, D06V1-V2	
LER vertical: hybrid (3)	D05V1, D06V1-V2	
LER vertical: Cu coated Ta (10)	D02V1, D05V1, D06V1-V2	Plan to deliver in this fiscal year.
LER vertical: Cu coated Ta (10)	D02V1, D05V1, D06V1-V2	Plan to deliver in this fiscal year.
LER horizontal: Ta (10)	D06H4	

Sudden beam loss

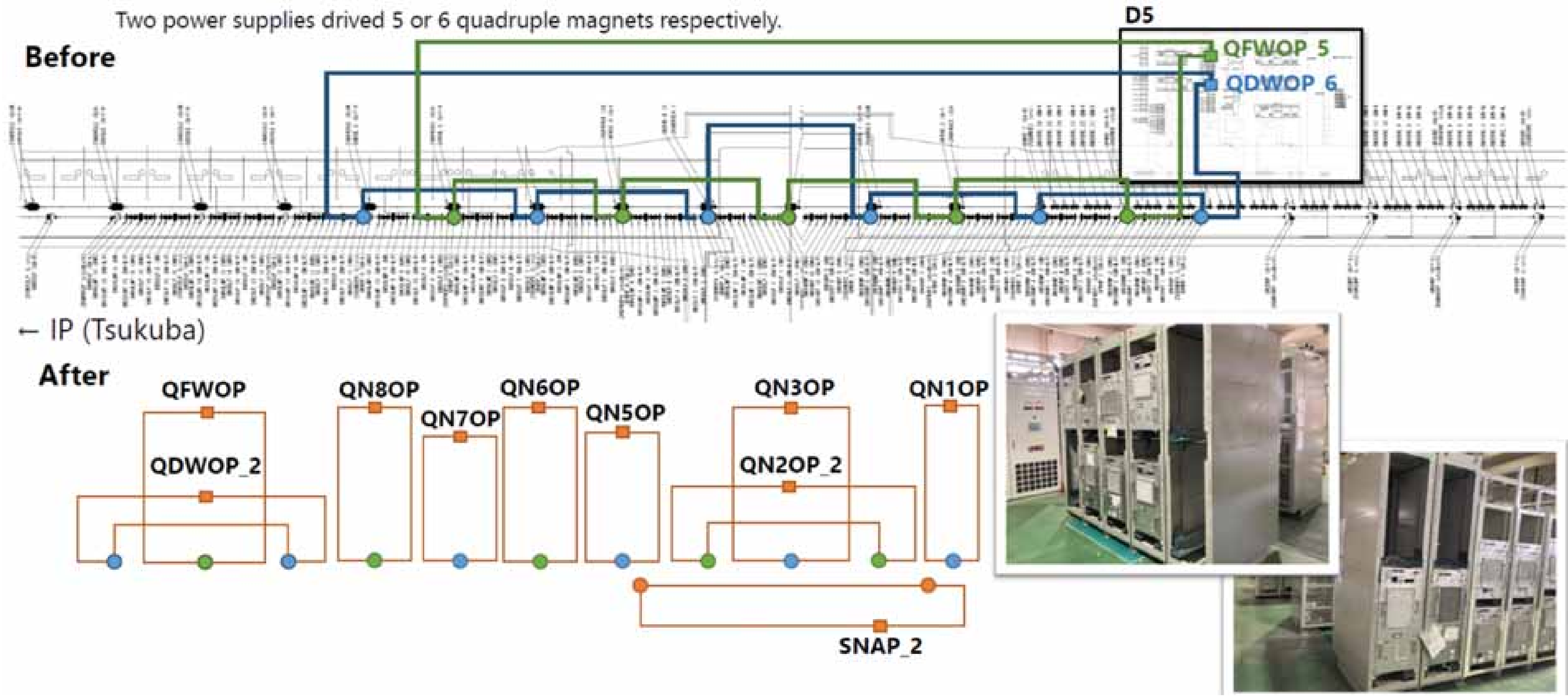
- Replaces the damaged collimator heads
- Cu coated heads in vertical plane
- (Large vertical gap to D6V1 due to NLC)
- Bunch by bunch beam position monitor using
  - Existing BOR
  - iGp12 Block RAM: phase space monitoring
  - Simple BOR using oscilloscope (D7 and D5)
- More loss monitors around collimators
- Acoustic monitors at collimators and QCS beam pipe

Non-Linear Collimator

Non Linear Collimator

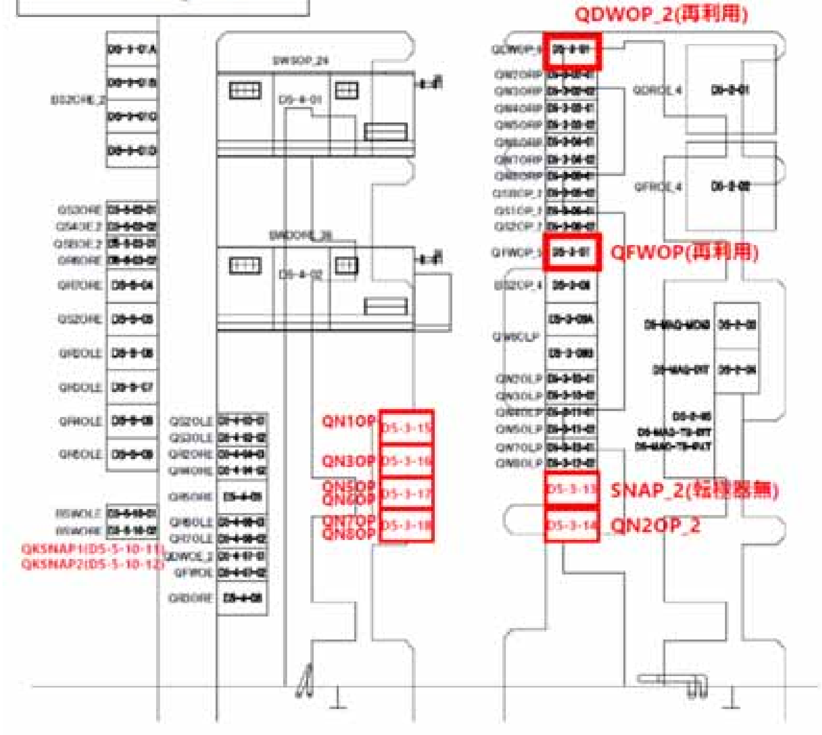


Power supplies

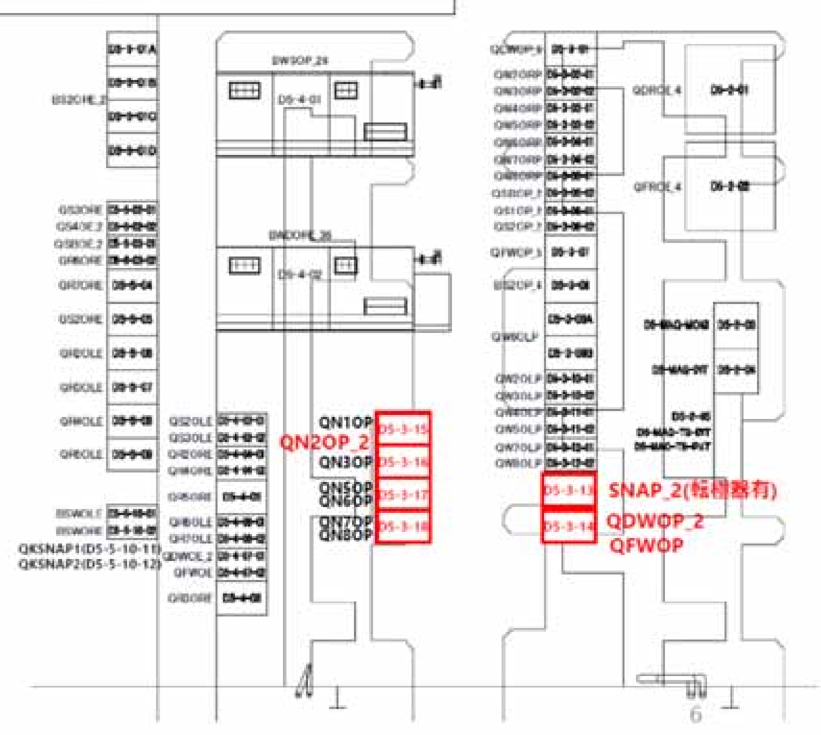


Temporally using old power supplies

2024年1月



2024年10月（予定）



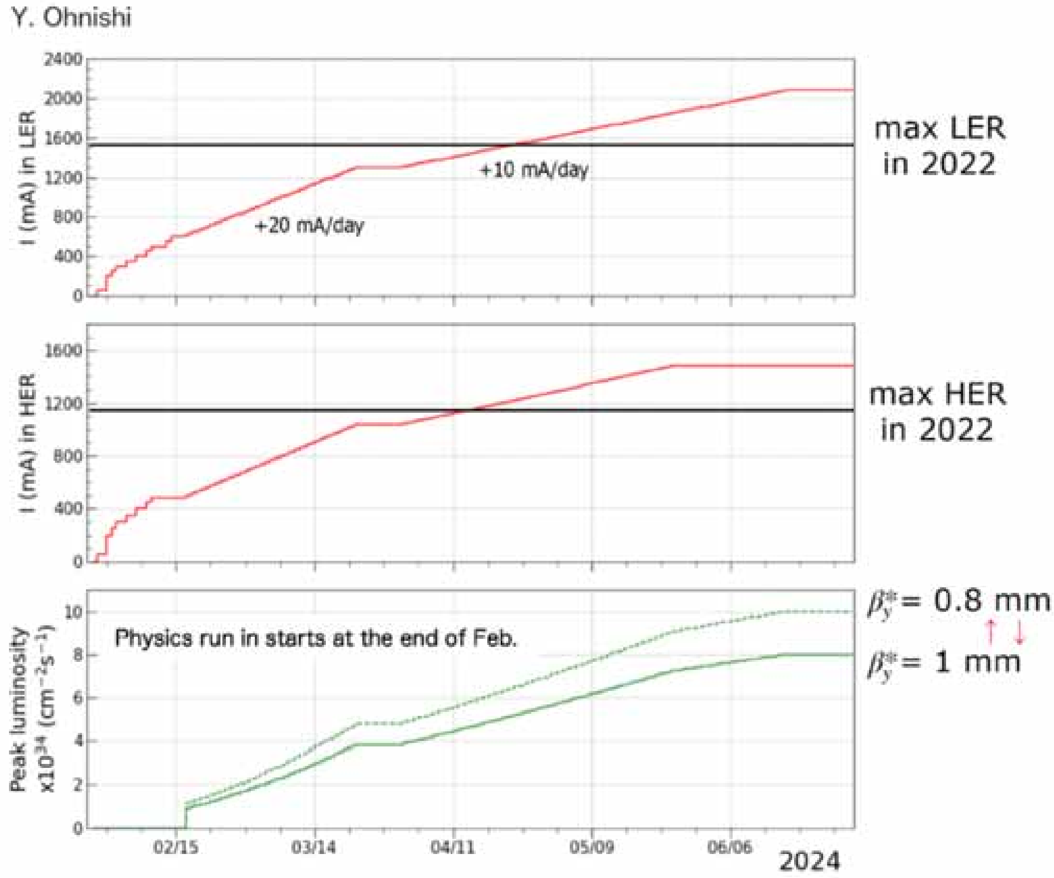
2024	January					February	
	27 (Sat)	28 (Sun)	29 (Mon)	30 (Tue)	31 (Wed)	1 (Thu)	2 (Fri)
				HER vacuum scrubbing 100 mA	HER vacuum scrubbing 200 mA LER vacuum scrubbing 100 mA	HER vacuum scrubbing 250 mA LER vacuum scrubbing 200 mA	HER vacuum scrubbing 250 mA LER vacuum scrubbing 250 mA
			HER β_y^* = 81.0 mm Find COD HER BCM	LER β_y^* = 48.6 mm (without D05V1) Find COD HER BCM	LER/HER TBT BPM study	LER β_y^* = 48.6 mm (with D05V1) LER optics correction D05V1 study	DA measurement
			HER BxB FB tuning	LER BxB FB tuning	HER injection tuning HER kicker jump HER septum tuning	D05V1 study LER impedance meas.	DA measurement
			HER BxB FB tuning	LER BxB FB tuning	LER injection tuning LER kicker jump LER septum tuning	LER/HER QuadBPM	acoustic sensor (SBL)
			HER BPM gain mapping HER optics correction HER injection tuning	LER BPM gain mapping LER optics correction LER injection tuning	LER/HER QuadBPM	LER/HER QuadBPM	acoustic sensor (SBL)

2024	February						
	3 (Sat)	4 (Sun)	5 (Mon)	6 (Tue)	7 (Wed)	8 (Thu)	9 (Fri)
	HER vacuum scrubbing 300 mA LER vacuum scrubbing 300 mA	HER vacuum scrubbing 300 mA LER vacuum scrubbing 300 mA	HER vacuum scrubbing 350 mA LER vacuum scrubbing 350 mA	HER vacuum scrubbing 350 mA LER vacuum scrubbing 350 mA	HER vacuum scrubbing 400 mA LER vacuum scrubbing 400 mA	HER vacuum scrubbing 400 mA LER vacuum scrubbing 400 mA	HER vacuum scrubbing 450 mA LER vacuum scrubbing 450 mA
			LER NEG activation	LER β_y^* = 48.6 → 8 mm LER β_y^* = 8 → 3 mm LER β_y^* = 3 → 2 mm LER β_y^* = 2 → 1 mm	HER β_y^* = 81 → 8 mm HER β_y^* = 8 → 3 mm HER β_y^* = 3 → 2 mm HER β_y^* = 2 → 1 mm	collision tuning find collision backet	LER D05V1 study
			LER NEG activation	LER optics correction	HER optics correction	collision tuning	LER D05V1 study
			HER optics correction LER optics correction	LER BxB FB tuning	HER BxB FB tuning	LER TBT BPM study	collimator tuning
				LER injection tuning LER collimator tuning LER impedance meas.	HER injection tuning HER collimator tuning HER impedance meas.	HER TBT BPM study	collimator tuning

2024	February						
	10 (Sat)	11 (Sun)	12 (Mon)	13 (Tue)	14 (Wed)	15 (Thu)	16 (Fri)
	HER vacuum scrubbing 500 mA LER vacuum scrubbing 500 mA	HER vacuum scrubbing 500 mA LER vacuum scrubbing 500 mA	HER vacuum scrubbing 500 mA LER vacuum scrubbing 500 mA	HER vacuum scrubbing 550 mA LER vacuum scrubbing 550 mA	HER vacuum scrubbing 600 mA LER vacuum scrubbing 600 mA	HER vacuum scrubbing 600 mA LER vacuum scrubbing 600 mA	HER vacuum scrubbing 600 mA LER vacuum scrubbing 600 mA
				HER sextupole study	LER sextupole study	LER rotating sextupole	
				HER sextupole study	LER sextupole study	LER rotating sextupole	
				HER TBT BPM study	LER TBT BPM study		
				HER TBT BPM study	LER TBT BPM study		

2024	February						
	17 (Sat)	18 (Sun)	19 (Mon)	20 (Tue)	21 (Wed)	22 (Thu)	23 (Fri)
	HER vacuum scrubbing 600 mA LER vacuum scrubbing 600 mA	HER vacuum scrubbing 600 mA LER vacuum scrubbing 600 mA	HER vacuum scrubbing 600 mA LER vacuum scrubbing 600 mA	HER vacuum scrubbing 496 mA LER vacuum scrubbing 620 mA			
			tuning for physics run		maintenance (regular)		
			tuning for physics run				

Current, Luminosity



Recover the 2022 peak luminosity with $\beta_y^* = 1mm$

↑ ↓

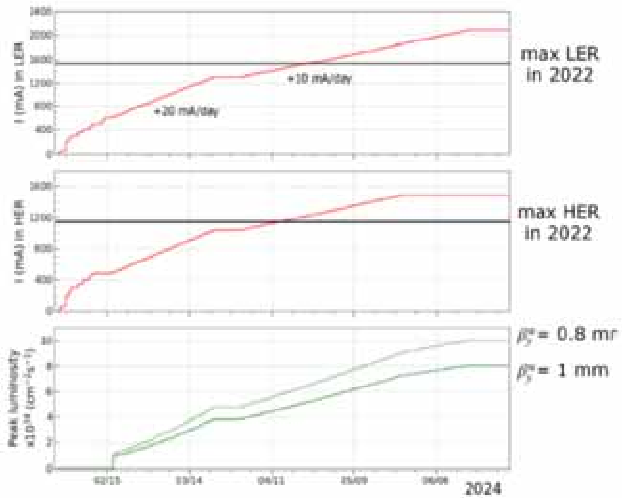
$\beta_y^* = 0.8\,mm$ study

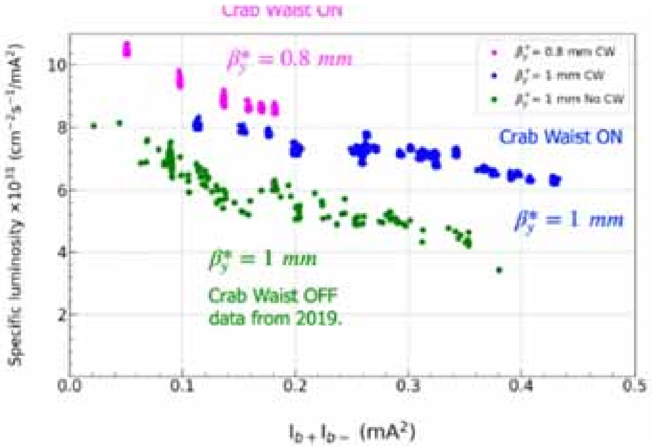
↑ ↓

Aim at Luminosity run with $\beta_y^* = 0.8\,mm$

It is not possible to say at this stage when β_y^* will be changed.

(Needless to say that) luminosity will be lower while tuning the machine with new parameters, such as β_y^*.





- Increasing the total beam currents (bunch currents)
  ↔ (obstruction) Sudden Beam Loss

- Squeezing β_y^*
  ↔Dynamic aperture, lifetime, background control, injection
  ► sextupole settings, collimator settings

- Optimizing the Crab waist ratio for both LER and HER.

Crab waist (CW)

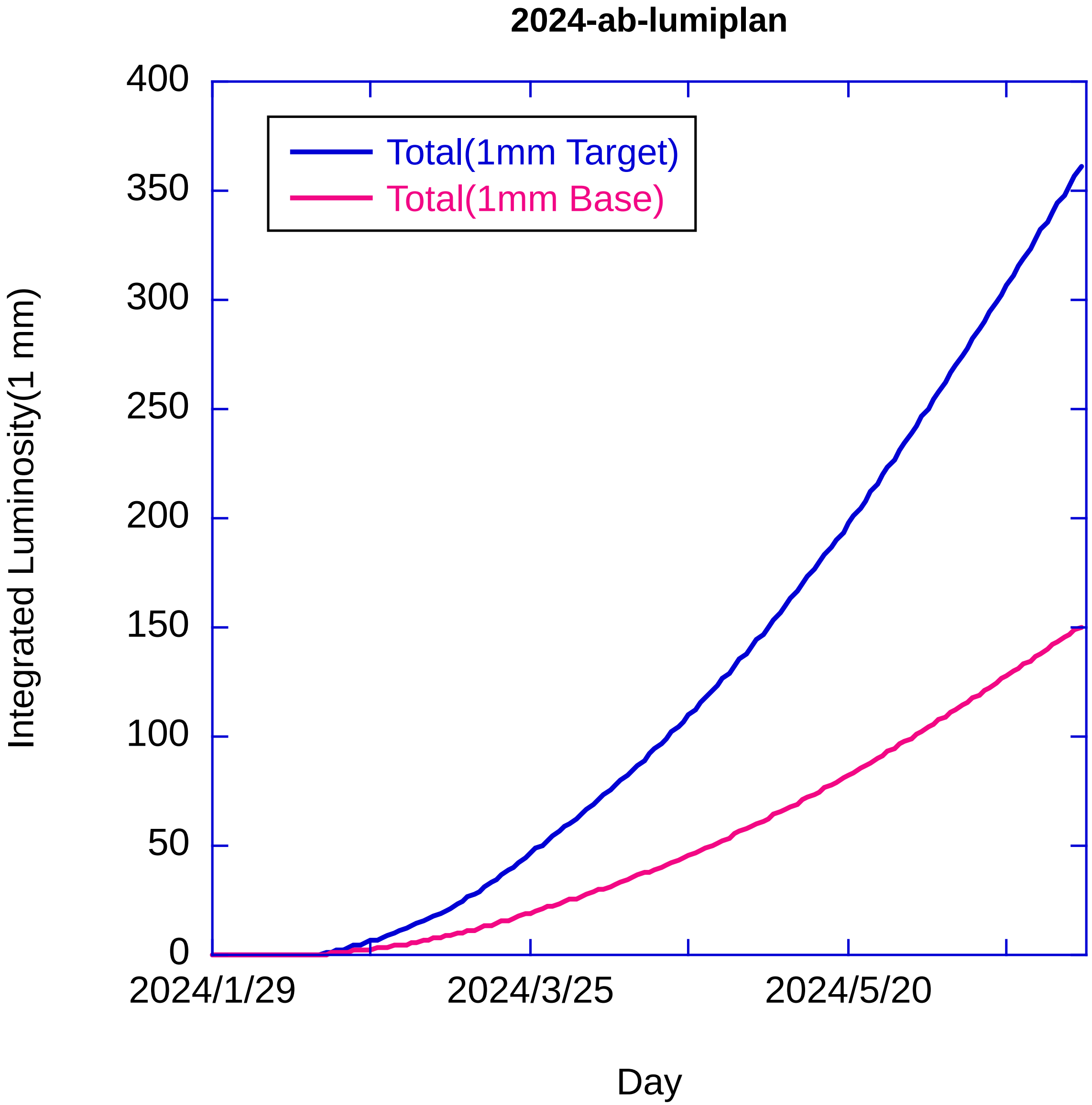
- Reduces resonance lines and beam-tail due to beam-beam interactions.

- CW seemed to have improved luminosity.
  - We will confirm the luminosity gain.

- The CW ratio (LER 80%, HER 40% in 2022) will be optimized
  - lifetime vs luminosity gain

Machine study time
↑ ↓
Physics run

Base and Target Plan



Base plan:
1mm 40% eff : 150fb-1

Target plan:
1mm 60% eff : 360 fb-1

Ring status

29/Jan

- Start injection to HER, struggled to find the BT-end orbit and final septum settings.
- Confirmed 6-7 turns of revolution without RF, starting RF on operation.

30/Jan

- 0:01 confirmed storing beam after many trial (tune, injection phase, injection kicker settings)
- HER FB timing adjustments, HER optics tuning.
- Start LER injection tuning

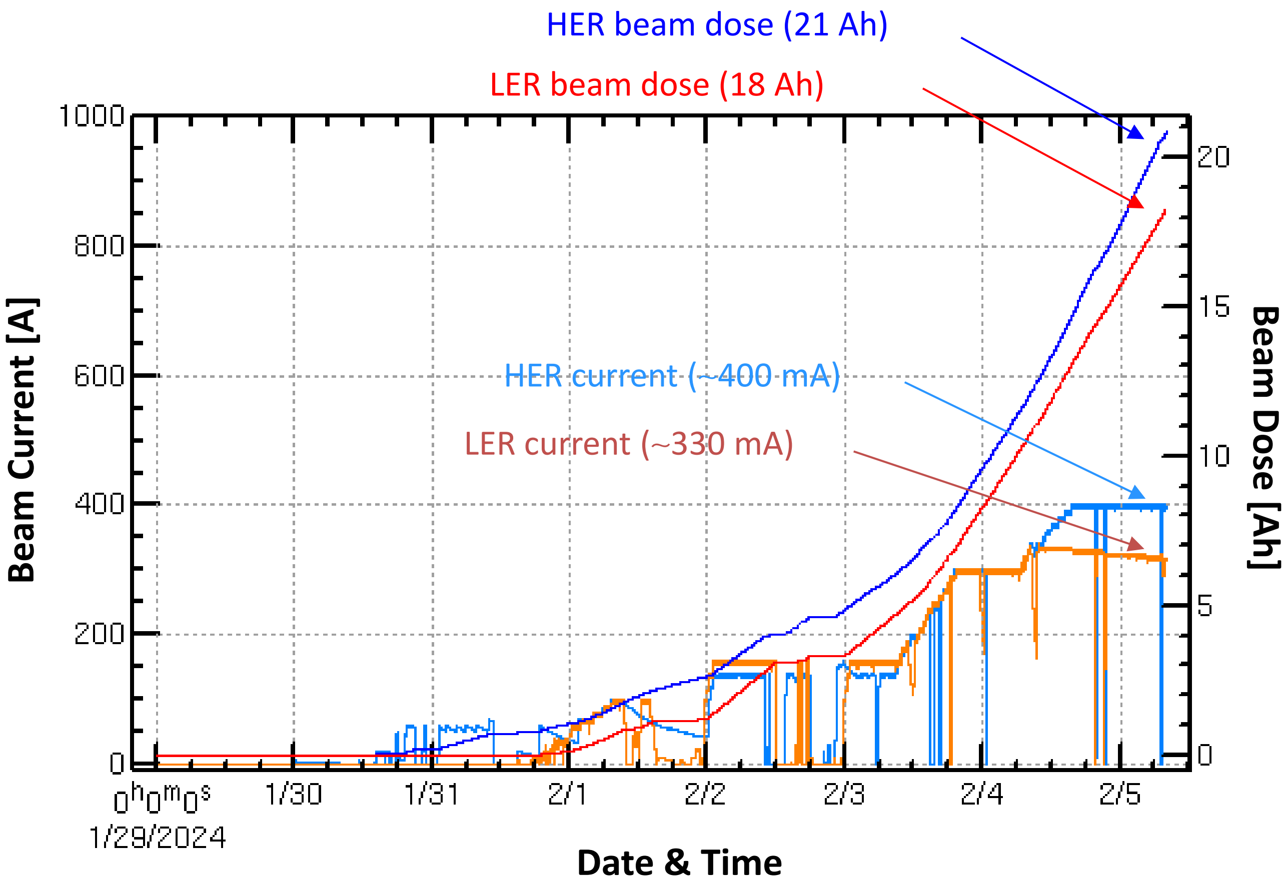
31/Jan

- LER beam storage
- LER FB timing adjustments, LER optics tuning.

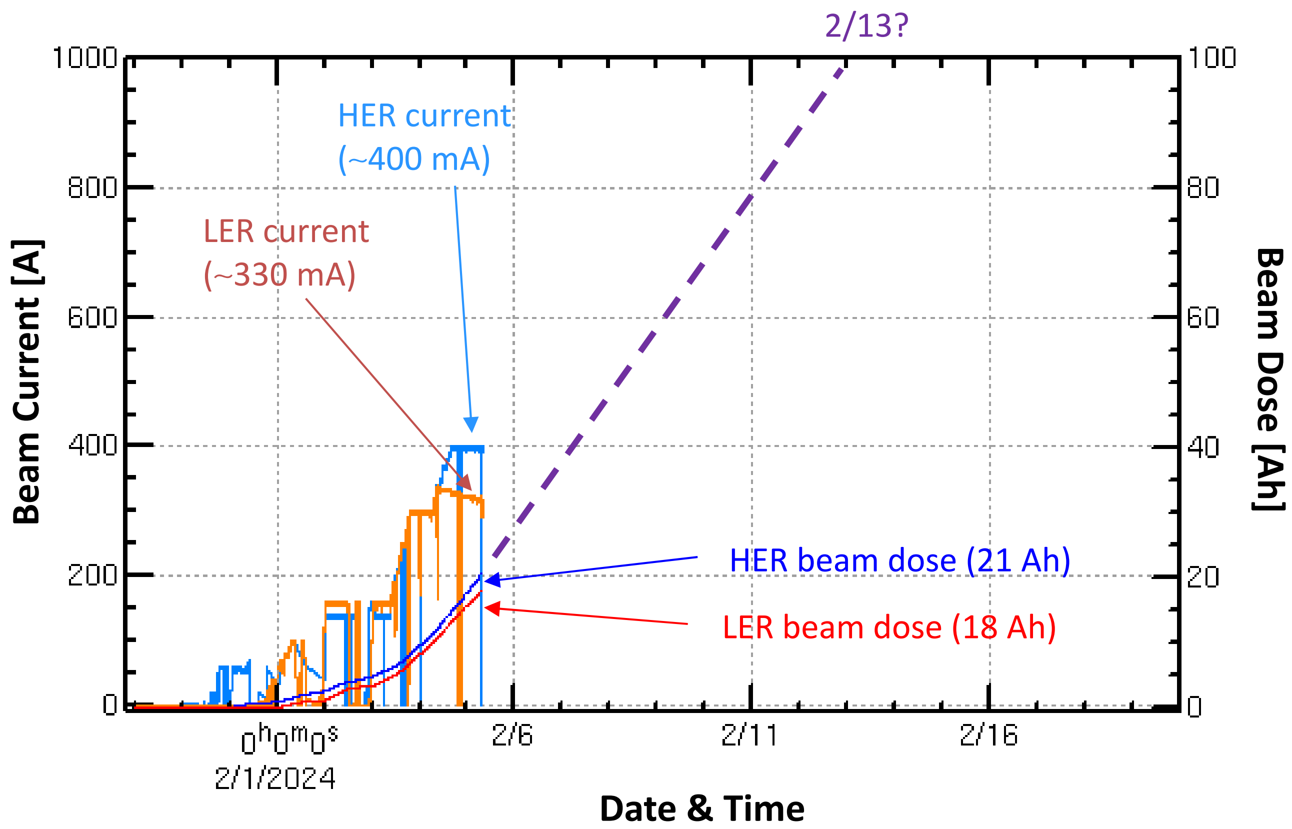
5/Feb

- NEG activation (day shift)

Beam Dose (1/29 ~ 2/5 8:00)

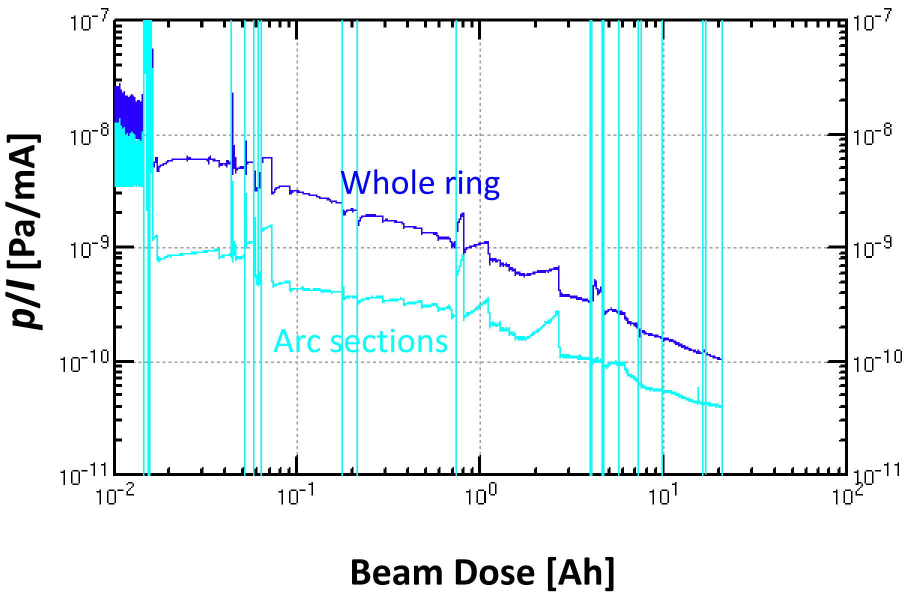


Beam Dose (1/29 ~ 2/5 8:00)

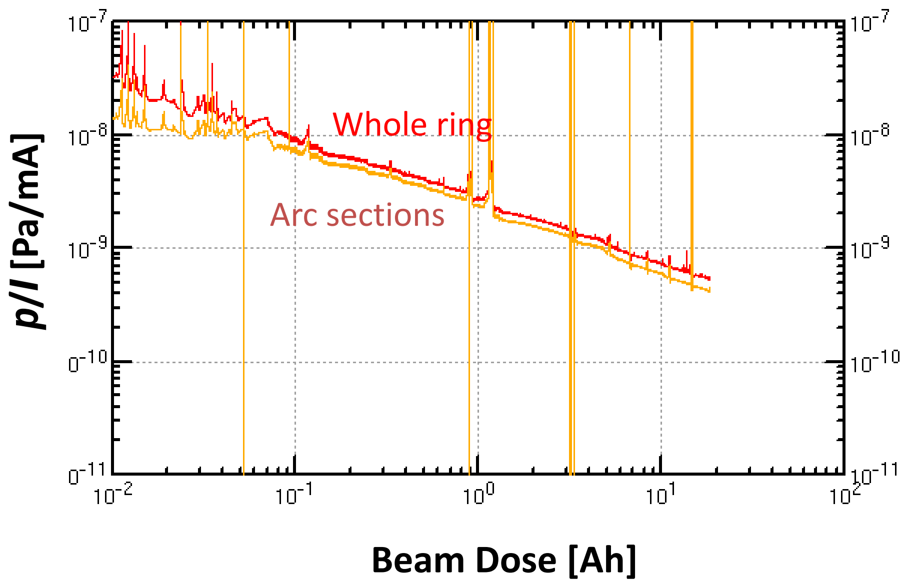


Vacuum Scrubbing (1/29 ~ 2/5 8:00)

HER

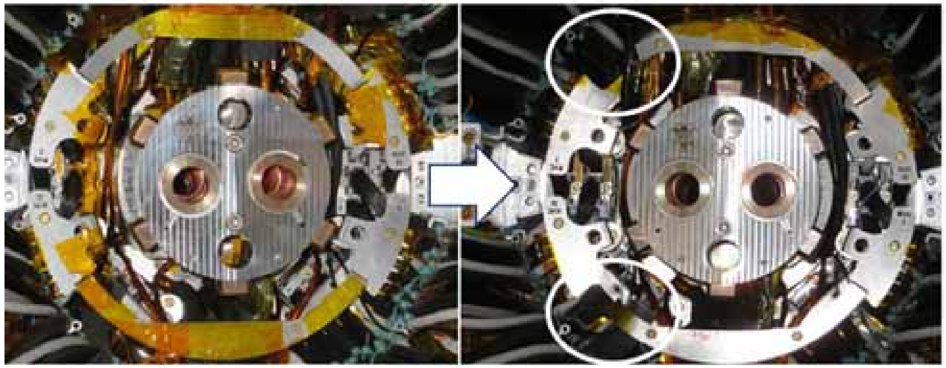


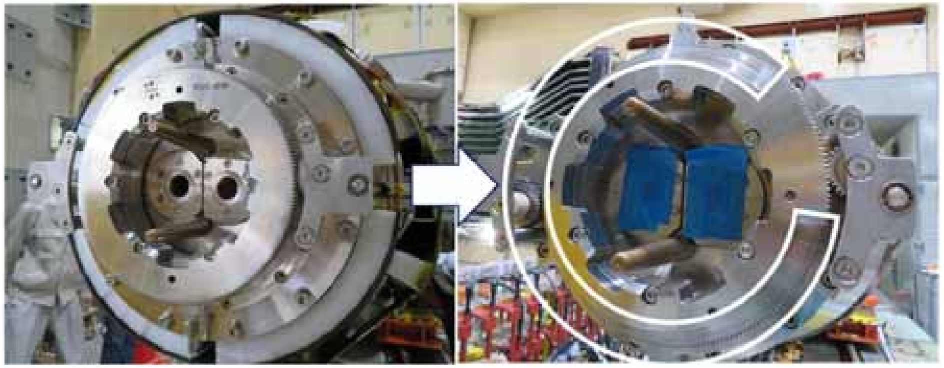
LER



QCS-R re-install

- Re-tried on 23/Oct/2023 with
  - Modified RVC gear
  - Modified VXD cable support
  - The QCS supports was carefully advanced by Tanaka-san.
- RVC worked very smoothly– no vacuum leak found.





Recovery of IR concrete shields

- IR concreate shield recovery works (2024/1/9-1/12)
  - 門型シールド前進
  - 足場設置
  - 取り外したシールドを設置、固定(1)
  - Installment of new shields
  - 取り外したシールドを設置、固定(2)
  - 門型シールドを最終位置まで前進
  - 門型シールド固定
  - 足場撤去

IR shield works

- IR concreate shield recovery works (2024/1/9-1/12)
  - 門型シールド前進
  - 足場設置
  - 取り外したシールドを設置、固定（1）
  - Installment of new sheilds
  - 取り外したシールドを設置、固定（2）
  - 門型シールドを最終位置まで前進
  - 門型シールド固定
  - 足場撤去

IR shield works

- IR concreate shields recovery works (2024/1/9-1/12)
  - 門型シールド前進
  - 足場設置
  - 取り外したシールドを設置、固定 (1)
  - 新シールドを設置
  - **取り外したシールドを設置、固定 (2)**
  - **門型シールドを最終位置まで前進**
  - **門型シールド固定**
  - **足場撤去**





Oho Radiation shield

- Re-use of concreate shield used at IR
  - NLC下流側の大穂実験棟の門型シールド上に設置 (2023年11月)
  - もう1台は廃棄
- New radiation controlled-area: Oho experimental hall, D5, Pump/PS building after 1/15

廃棄されたIR旧コンクリートシールド

この空間を埋める必要あり

Oho radiation shield

- Re-use of the concreate shields used at IR
  - NLC下流側の大穂実験棟の門型シールド上に設置 (2023年11月)
  - もう1台は廃棄