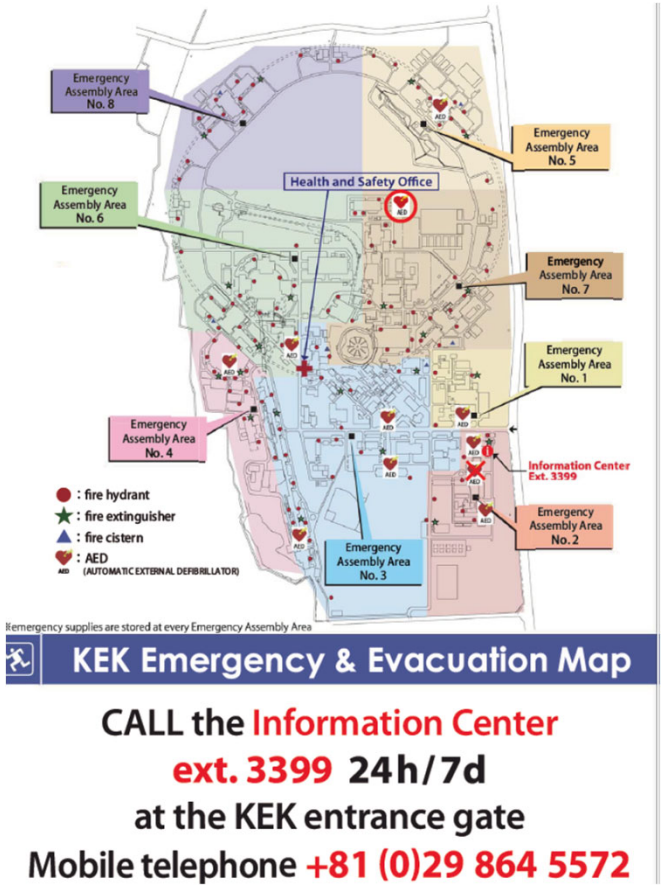
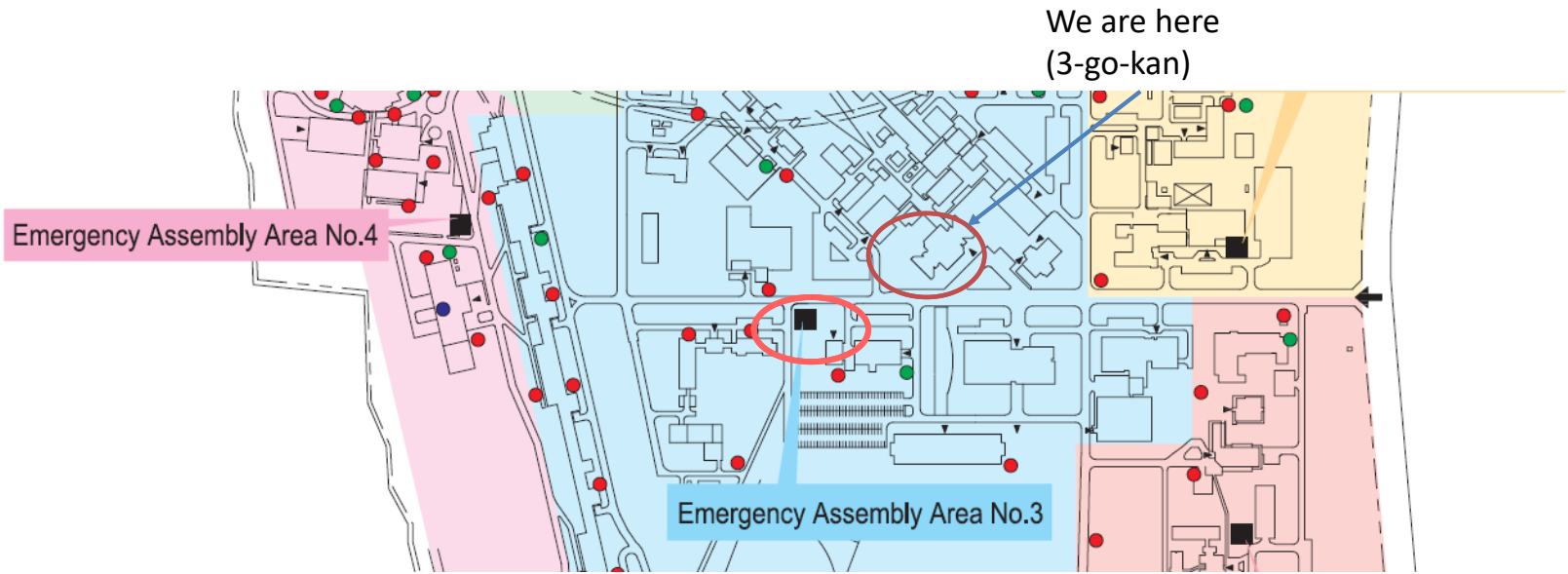
# *Welcome and short summary of upgrade work (LS1)*

Mika Masuzawa, Hiroyasu Ego, Makoto Tobiyama

KEK Accelerator Laboratory

# Emergency Assembly Area

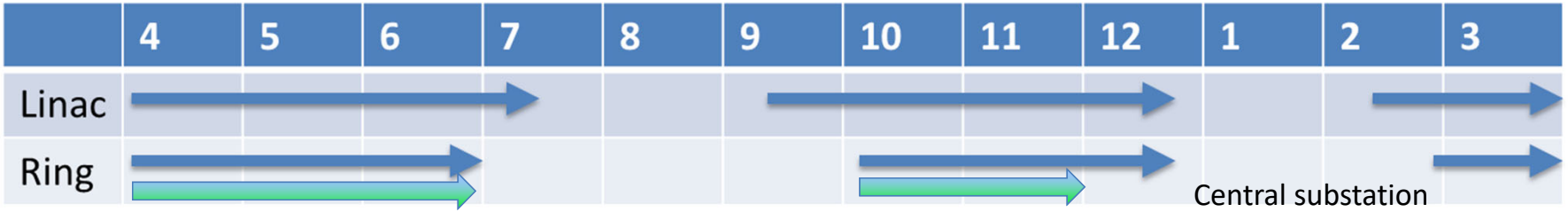



We are here
(3-go-kan)
Emergency Assembly Area No.4
Emergency Assembly Area No.3

# The 27th KEKB Accelerator Review

- 25/Mar/2024 – 27/Mar/2024
- https://superkekb.kek.jp/event/135/
- https://us02web.zoom.us/j/82433765439?pwd=Y0R3V2dpYTI2a2t5cnlvRXFTY2Ztdz09
  - Meeting ID 824 3376 5439
  - Passcode 3300
- A. Hutton*, R. Rimmer, C. Milardi, F. Zimmermann, E. Perevedentsev*, J. Fox, J. Seeman, P. Craievich, M. Sullivan, P. Chiggiato, Q. Qin, R. Assmann, R. Tomas, T. Taylor, K. Oide*
  - * Remote

# JFY2024 SuperKEKB operation plan



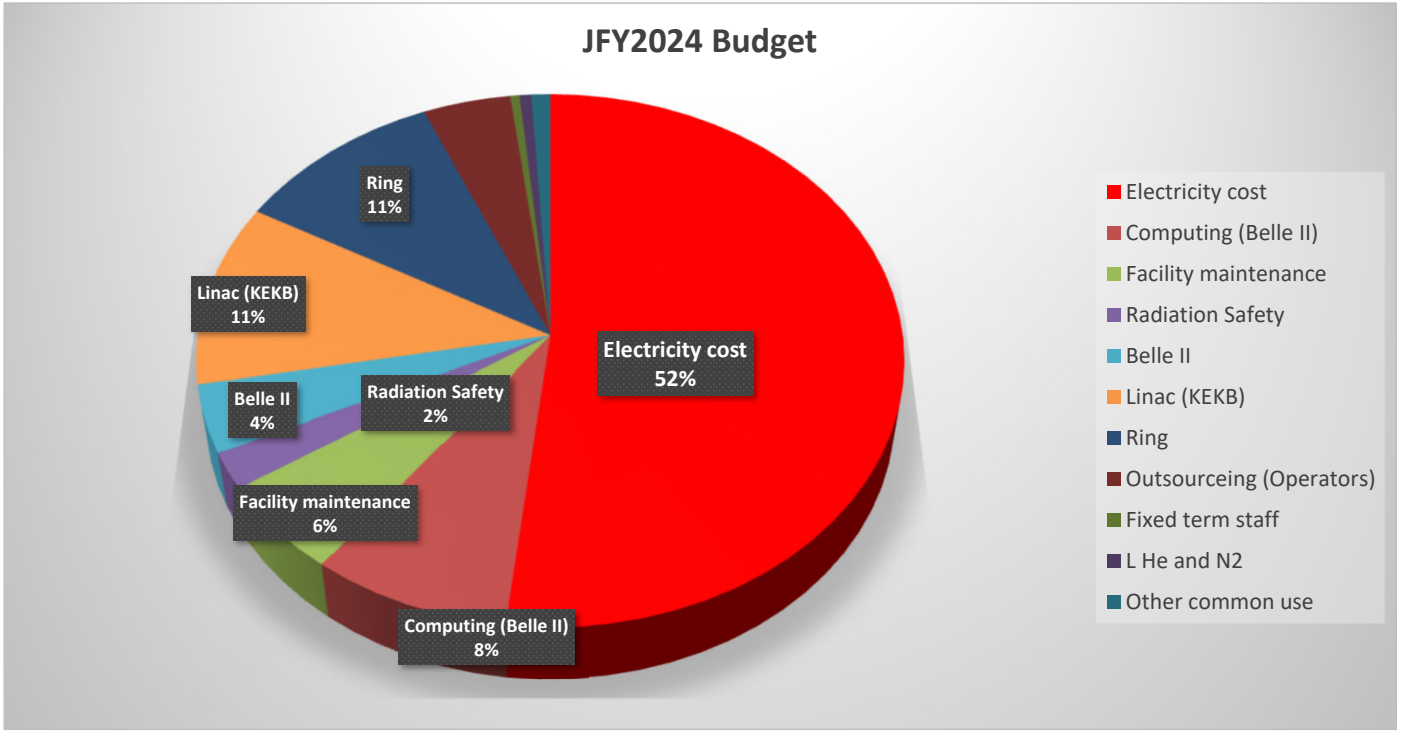

Central substation (150MW) switching works.

- With the inital budget allocated by MEXT, it seems likely that the rings will only be able to operation for three months until July (due to huge electricity costs).
- With additional operating budget by KEK, we will be able to operate the rings after summer, maybe 1.5 month.
- If there is a supplemental budget from MEXT, it will be possible to operate in March (and probably in December).

# Budget for SuperKEKB Project

## Same level as JFY2023

- Budget for JFY2023 was extremely tight, in reality.



# Supplemental budget form KEK for anti-aging measures

## JFY2023

- Repair of cooling water system, especially inverter system of the pumps.
- Plan have been scaled back and delayed (significantly) due to bidding failures (several times) due to soaring prices and major delays in parts delivery.
- First repairment is scheduled for summer 2024.

## JFY2024

- The cost of measure to prevent aging of power supplies and magnets will be taken.

# Human resources (JFY2024)

## ACCL 3rd (Head: Kyo Shibata)

- Safety, Vacuum, RF system, ARES cavity, SC cavity, Cryogenics
- Prof: 3, Assoc Prof: 6, Assist. Prof. 3 , Technical Staff: 9, Senior Staff: 9 PD: 2

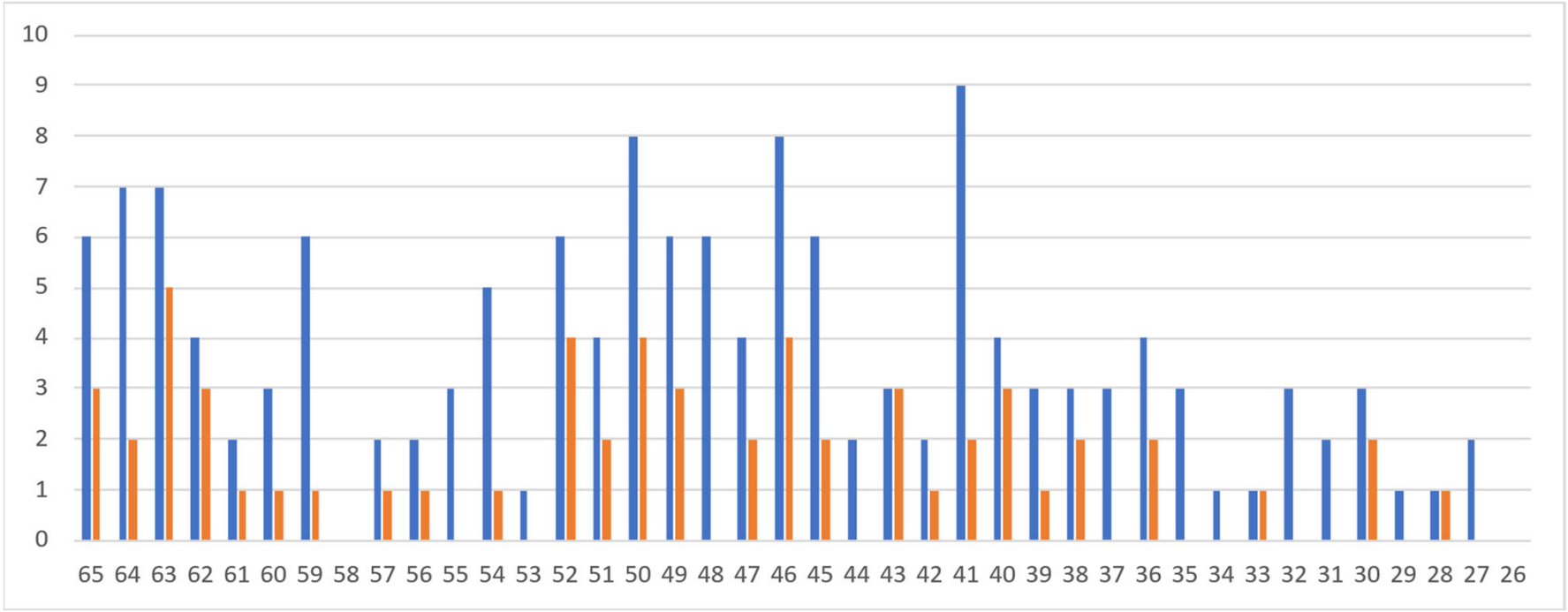
## ACCL 4th (Head: Makoto Tobiyama)

- Control, Beam Transport, Beam Instruments, Magnet, SC Magnet,  Commissioning
- Prof. 3, Assoc Prof. 7 Assist Prof : 5, Technical staff: 9, Senior Staff: 8

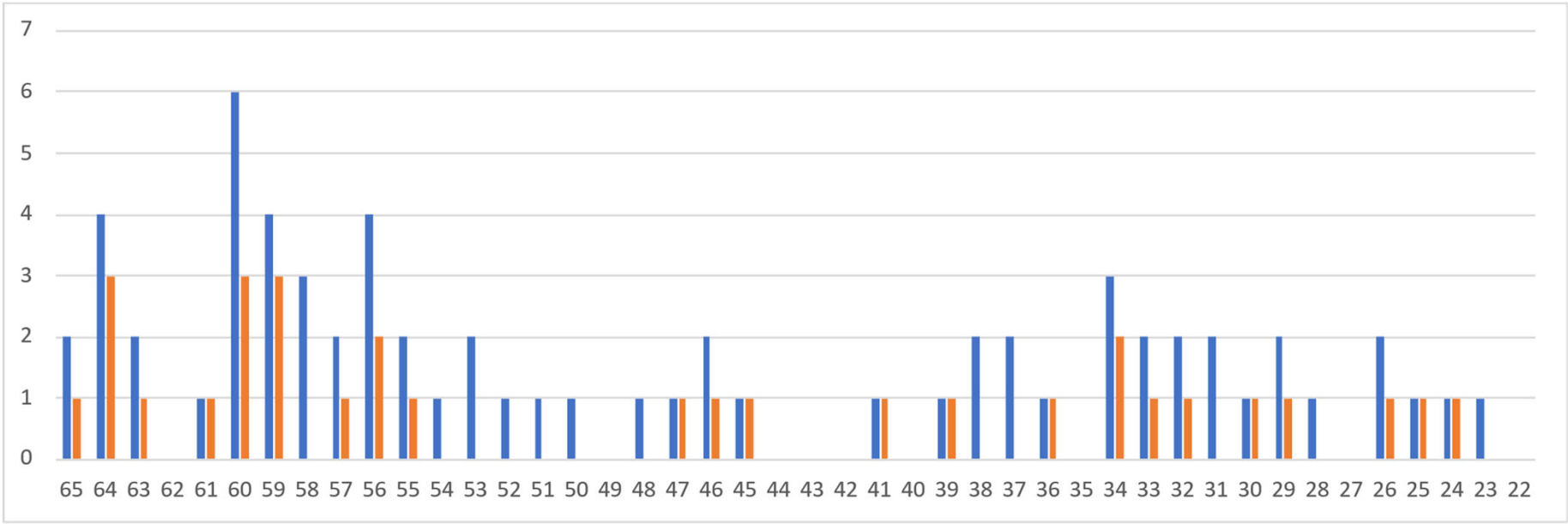
## ACCL 5th (Head: Hiroyasu Ego)

- Prof. 6, Assoc Prof. 6, Assist Prof. 5, PD 1, Technical Staff: 7, Senior Staff: 11

# Academic Staff



# Technical Staff



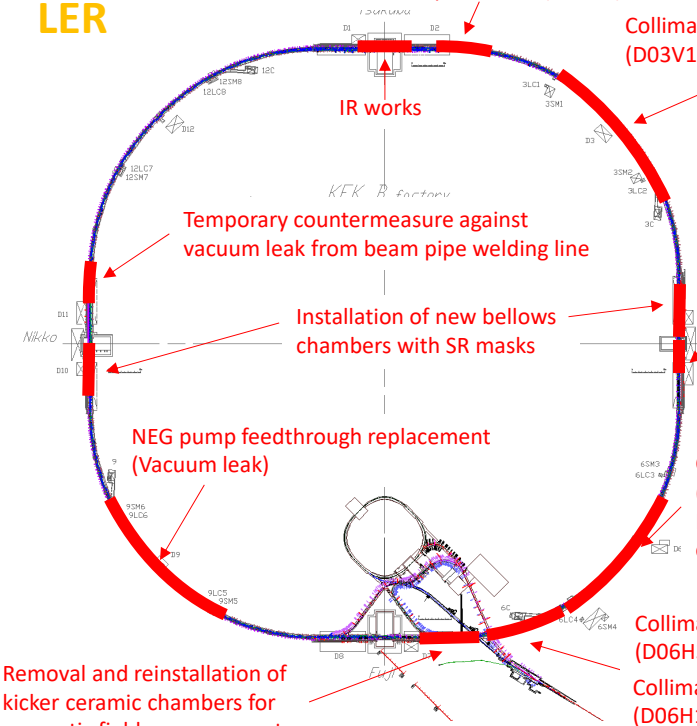
# International Collaboration

- MNPP-01 (R&D for high energy colliders)
  - SLAC, IHEP, CERN, IJCLab, INFN
- US-Japan collaboration
  - R&D for SuperKEKB and the next generation high luminosity colliders(SLAC, ANL, BNL, FNAL..)
  - Development and Study of Superconducting Magnet Upgrades for SuperKEKB(BNL, FNAL)
  - etc..
- Many young collaborators have been joined the commissioning of the rings after LS1
  - Supported by EAJADE program in EU.
  - >15 young scientists have been contributing.

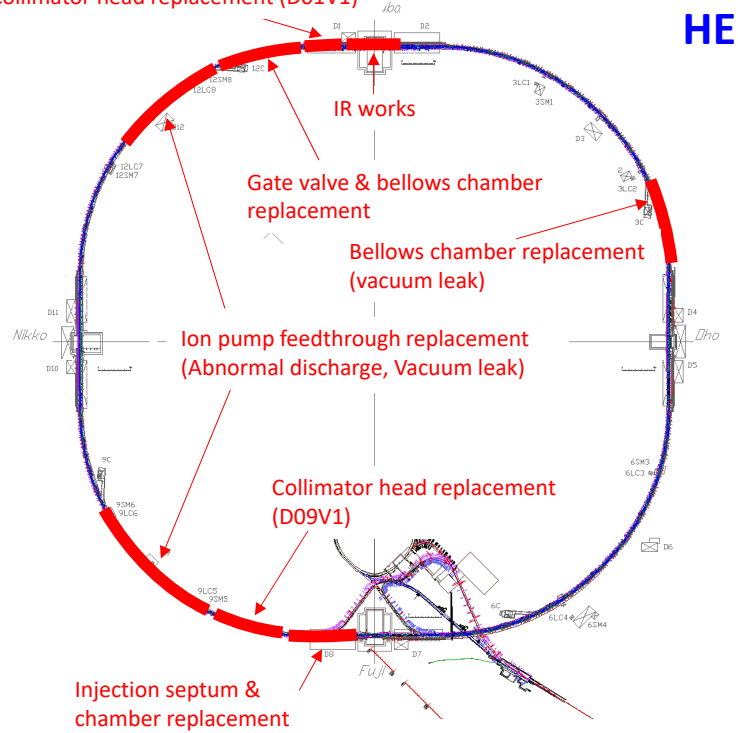
# Vacuum works during LS1 at a glance (MR)

: Area open to dry nitrogen or atmosphere

## LER




## HER



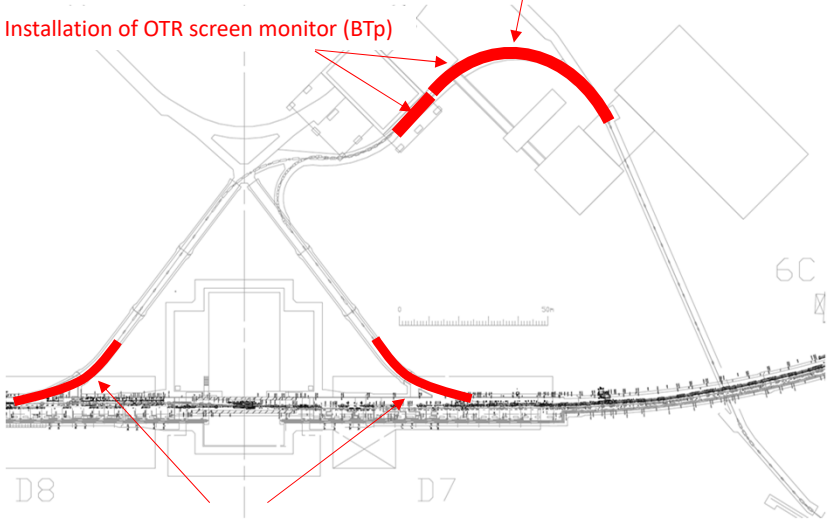
# Vacuum works during LS1 at a glance (BT&DR)

: Area open to dry nitrogen or atmosphere

## BT

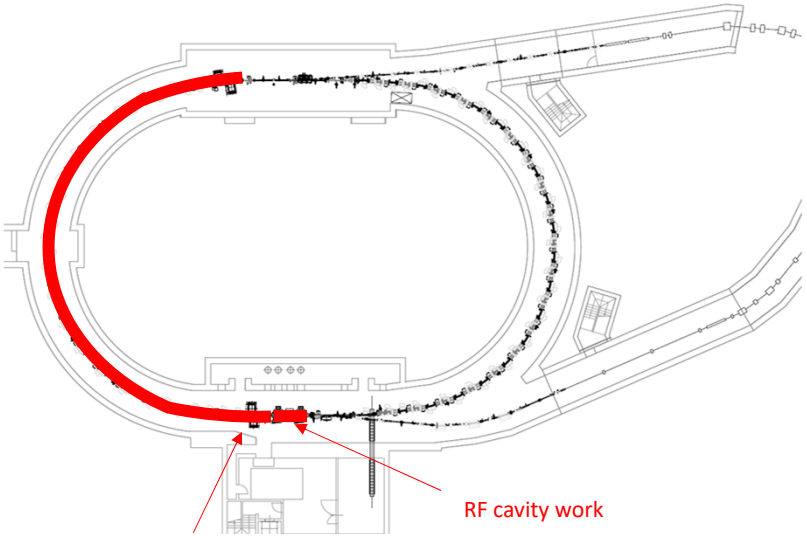
Installation of V-offset bellows chambers (BTp)
Installation of CSR monitor chamber (BTp)

Installation of OTR screen monitor (BTp)




Removal and reinstallation of bellows chambers for magnet alignment (BTe & BTp)

## DR



RF cavity work

Removal and reinstallation of Ext. kicker chambers for Kicker PS work

# *Major upgrade items of LS1*

- Replacement of damaged collimator heads on both rings.
- QCSR cryostat vacuum leak
- Aperture enlargement of injection channel and modification of injection final septum of HER.
- IR radiation shield modifications.
- Non-linear collimator at OHO straight section of LER.
- Installment of beam loss monitors/ acoustic sensors/ bunch oscillation monitors to monitor sudden beam loss event.
- DR kicker power supply maintenance.

- Detailed story will be presented by the individual talks.

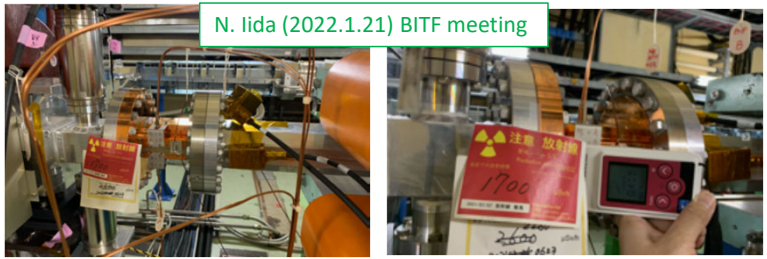
T. Oki

# QCSR 真空漏れ 改修 (1/5)

# Aperture enlargement of HER injection channel

- Problem of HER injection
  - Wall can be an obstacle to injection.
    - A wall should be placed between beam channels for stored beam and injected beam.
    - Injected beam orbit is too close to the wall.
    - High levels of radiation detected at the injection BPM chamber indicates that the injected beam hits the wall.
    - It is hard to modify the injection beam orbit.

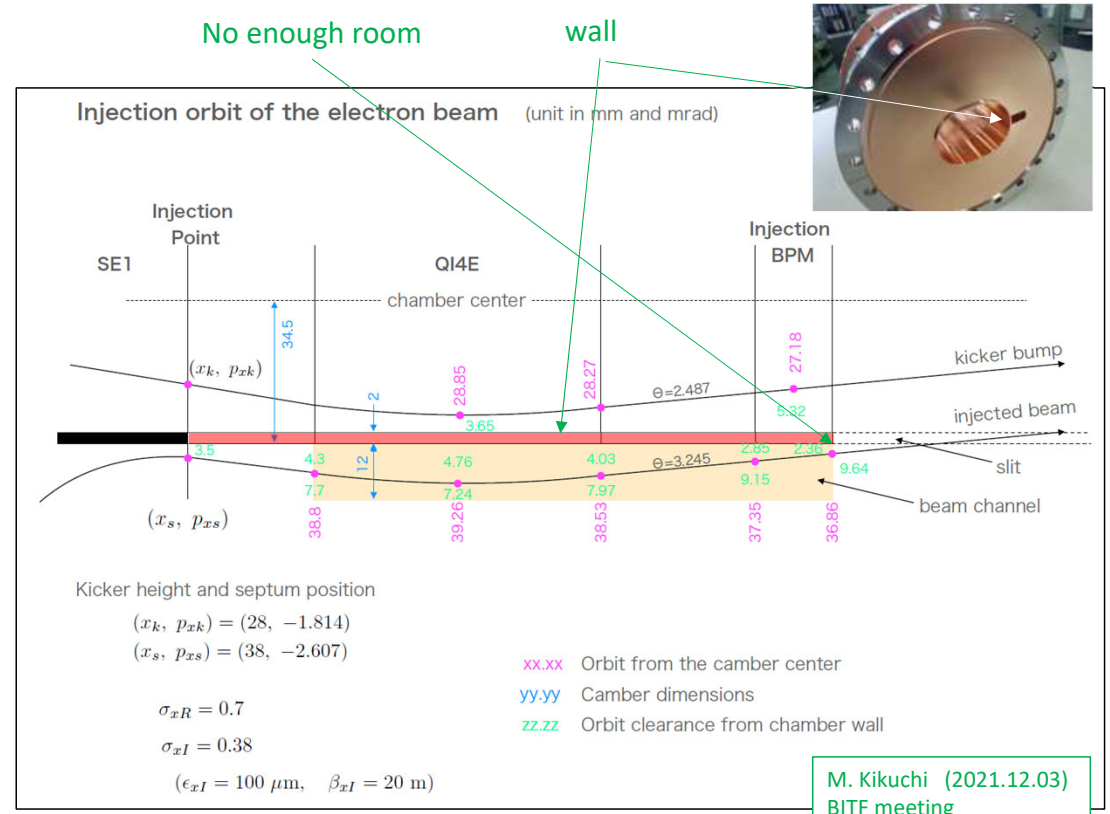
    ⇒ it is necessary to enlarge the horizontal aperture of the injection channel.



N. Iida (2022.1.21) BITF meeting

  - What is planned during LS1
    - Replacement of three beam chambers with new ones.
    - Update of injection BPM

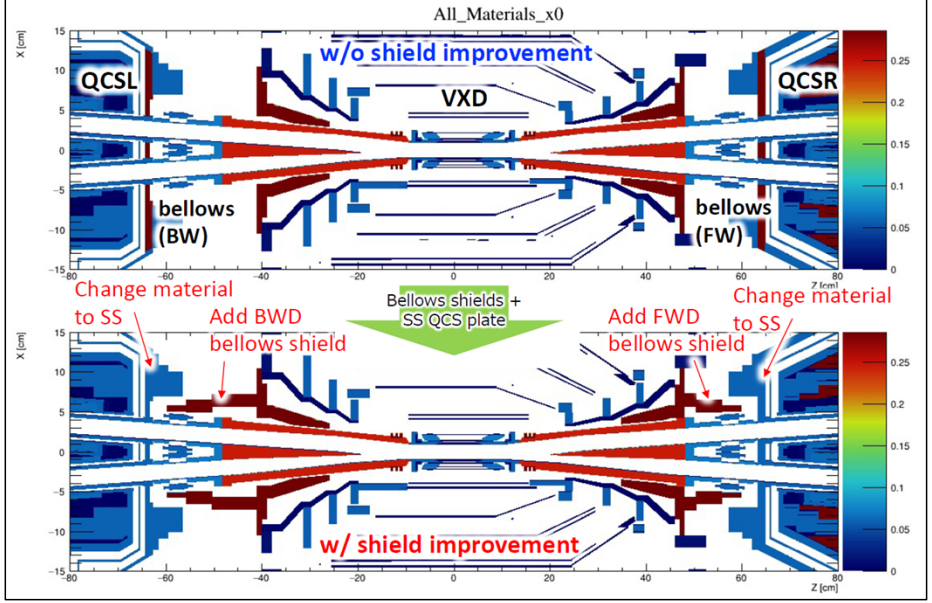
    ⇒ More precise injection tuning




M. Kikuchi (2021.12.03) BITF meeting

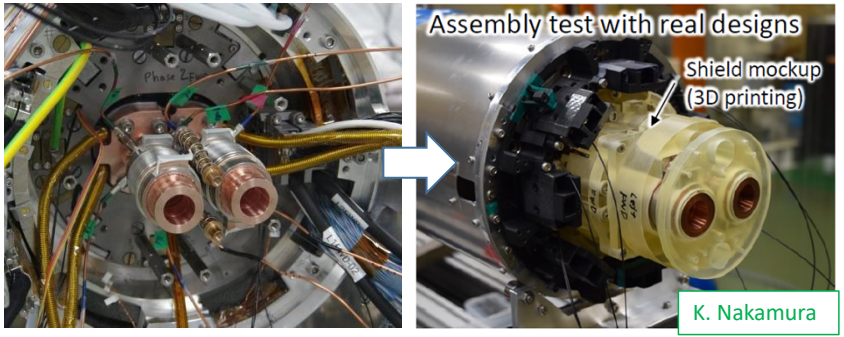
# IR radiation shield modification

## Implementation on Geant4 Geometory

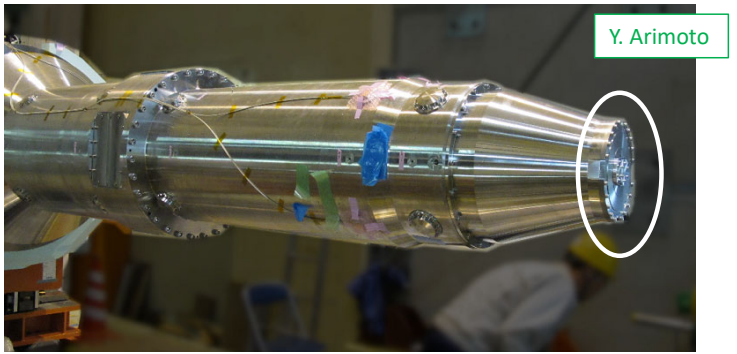



- **Additional shields reduce the beam BG of CDC and TOP well.**
  - –CDC: 13%~30% for single beam BG, 30~50% for luminosity BG
  - –TOP: about 20% for both single beam BG and luminosity BG
- **No bad signature on the beam BG of PXD and SVD.**

K. Nakamura (2022.02.04)
10th SuperKEKB long-term operation plan meeting



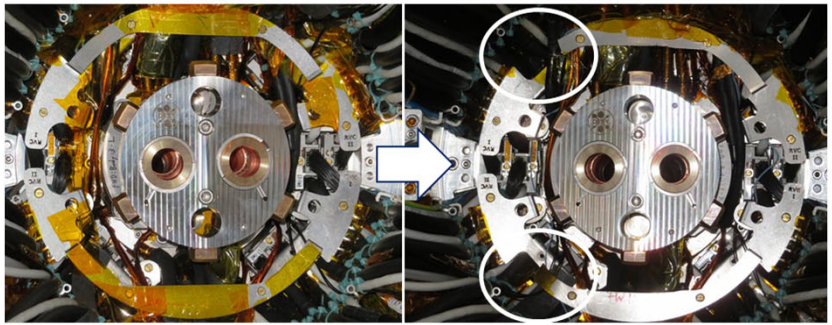

New heavy metal shield on IP bellows

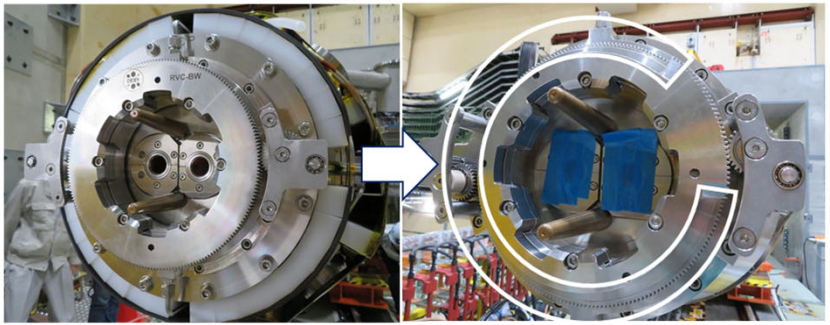



Material change from W to SUS (QCS cryostat front plate)
(Tip of QCS cryostat will be modified to make more space)

# QCS-R re-install

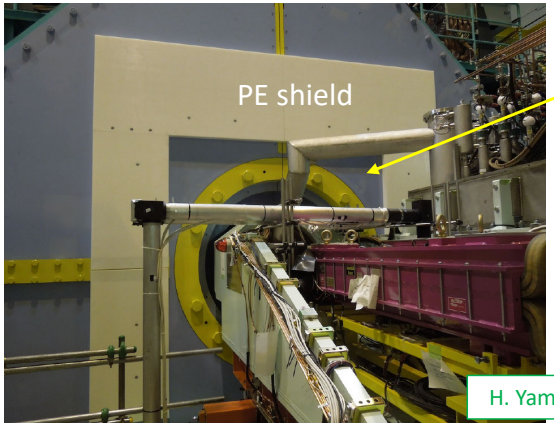
- Re-tried on 23/Oct/2023 with
  - Modified RVC gear
  - Modified VXD cable support
  - The QCS supports was carefully advanced by Tanaka-san.
- RVC worked very smoothly- no vacuum leak found.



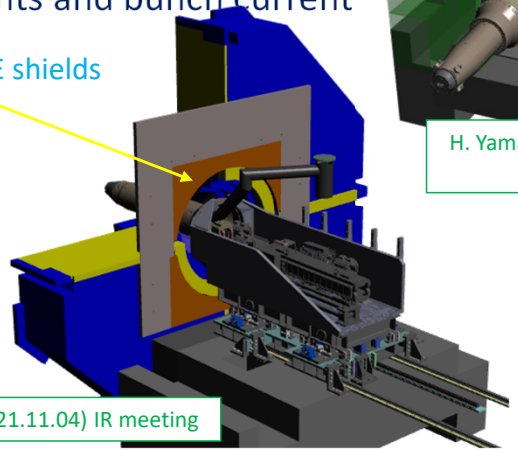


# IR radiation shield modification

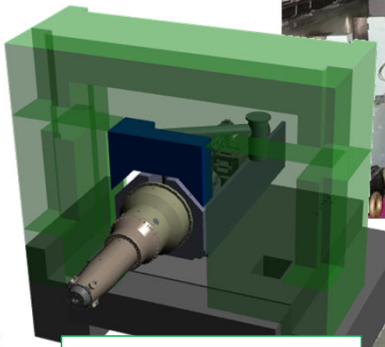
- Additional concrete shield (IR) & polyethylene shield (Belle2)
  - For shielding fast neutrons
    - New concrete shields and polyethylene (PE) shield will be added to a space that currently has no shield.
    - Additional PE shields around QCS are also planed.
- Expected effects of shield modification
  - Physics run with wider collimator setting
  - Physics run with larger total currents and bunch current



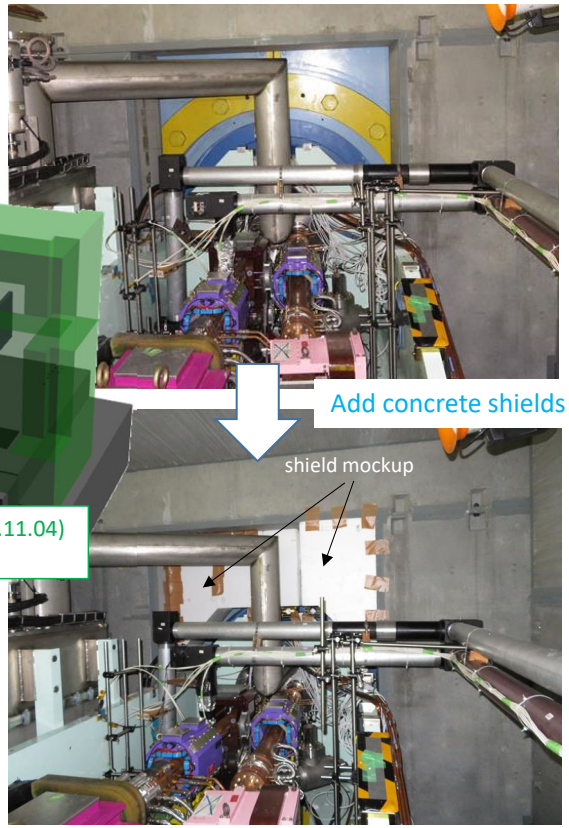

Add PE shields



H. Yamaoka (2021.11.04) IR meeting

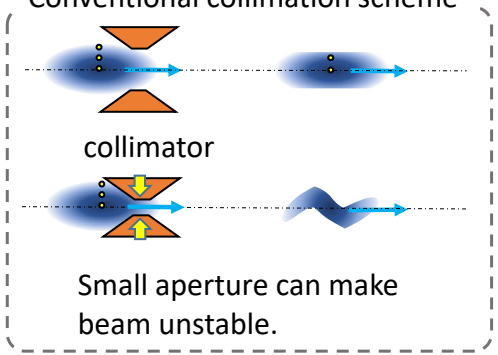


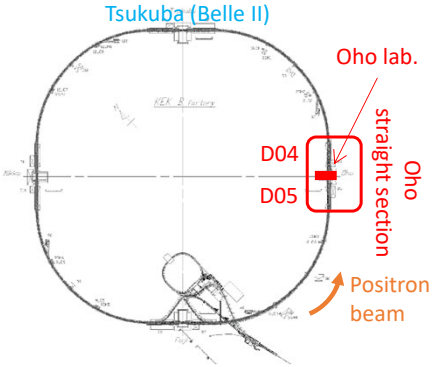
H. Yamaoka (2021.11.04) IR meeting

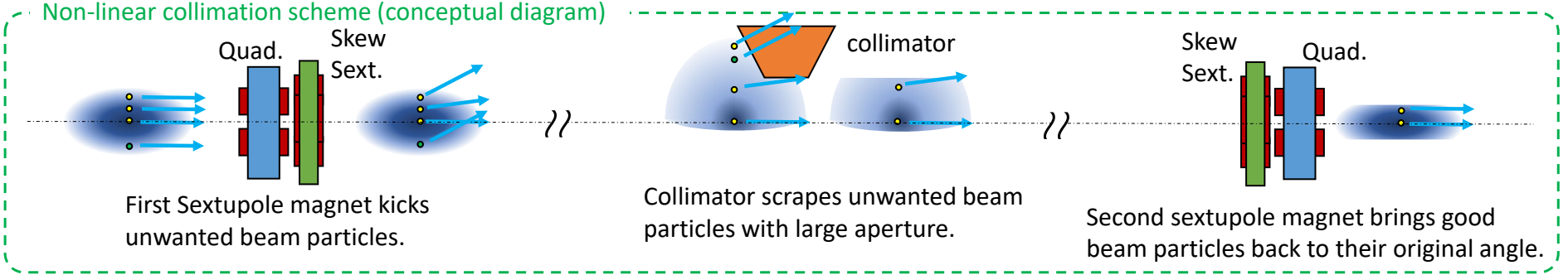


# NLC construction

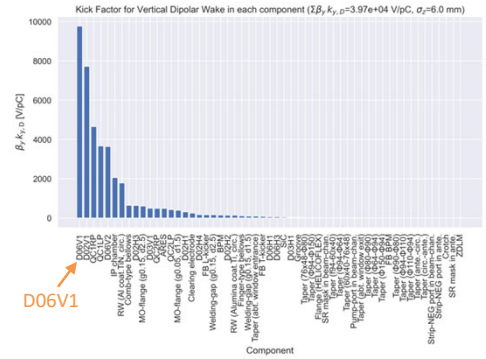
- Non-linear collimator (NLC) is being installed in LER Oho straight section.
  - Impedance of NLC is much lower than that of conventional collimator due to its large aperture.
  - NLC can relax TMCI bunch current limit.
  - Oho straight section is the location where the optics satisfies the requirements for NLC.
  - A part of wiggler magnets need to be removed.
  - New skew sextupole magnets and beam pipes in them need to be fabricated.
  - New power supplies, cabling works and new radiation shields are also required.



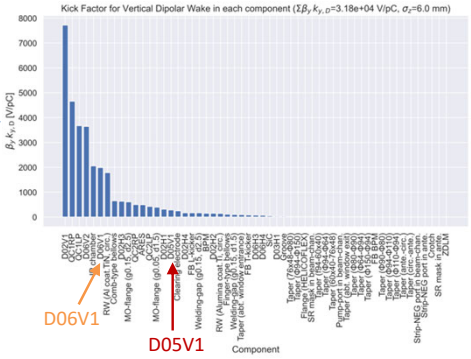



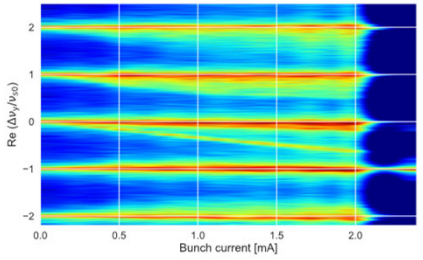
2021c physics run




LS1後

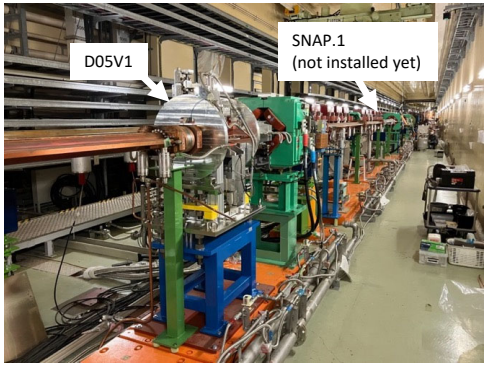



$\beta_y^*$=1 mm
$\beta_x^*$=80 mm



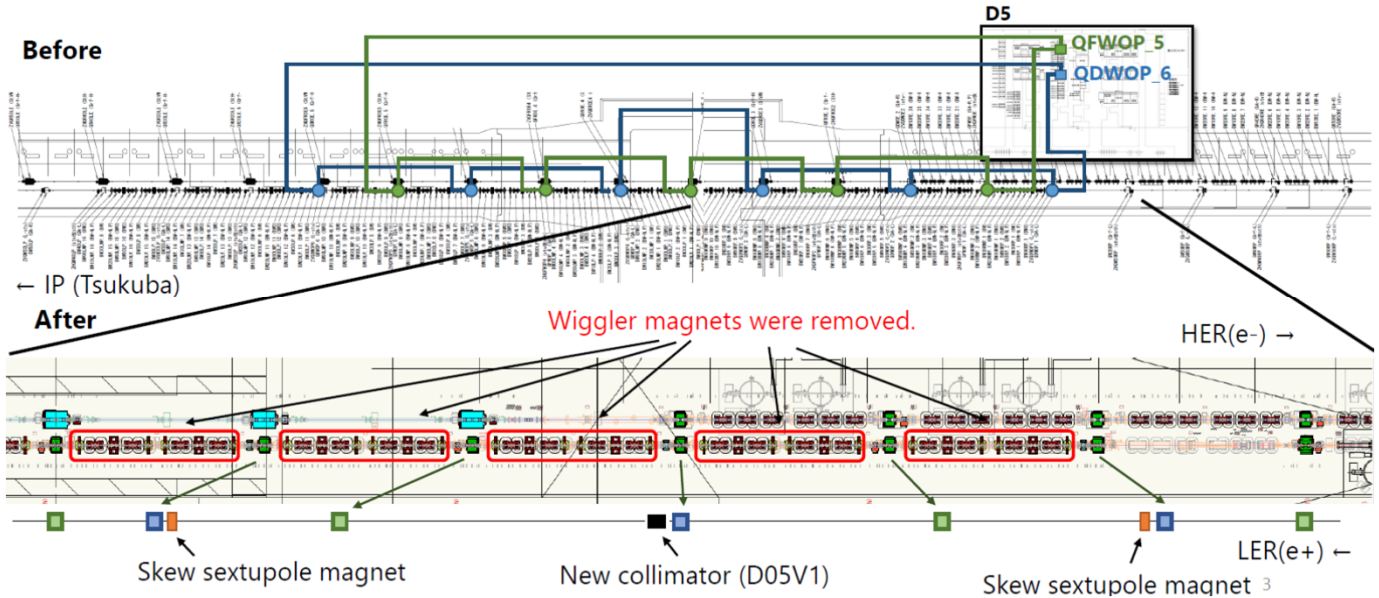

- $\Sigma\beta_y k_y$ will reduce from 3.97e4 downto 3.18e4 V/pC
- Threshold of TMCI is estimated to increase more than 2.mA/bunch

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

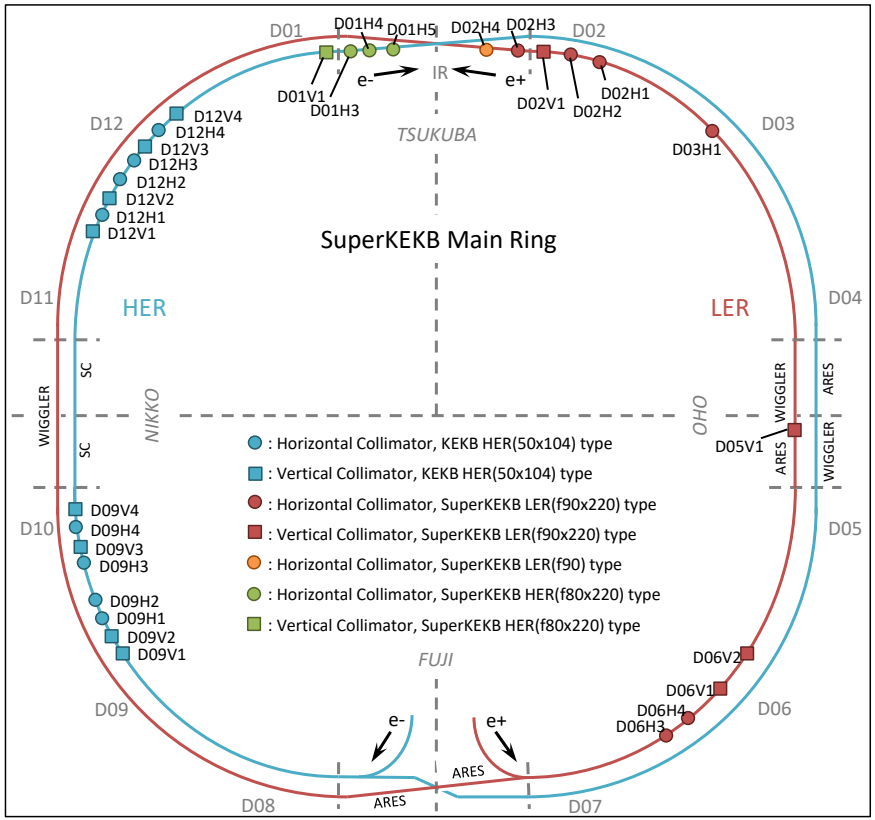


# Nonlinear Collimator

# Nonlinear Collimator



# Other Collimators



# Status of LER collimator

| Name | Type | Tip Material<br>(): 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 | |

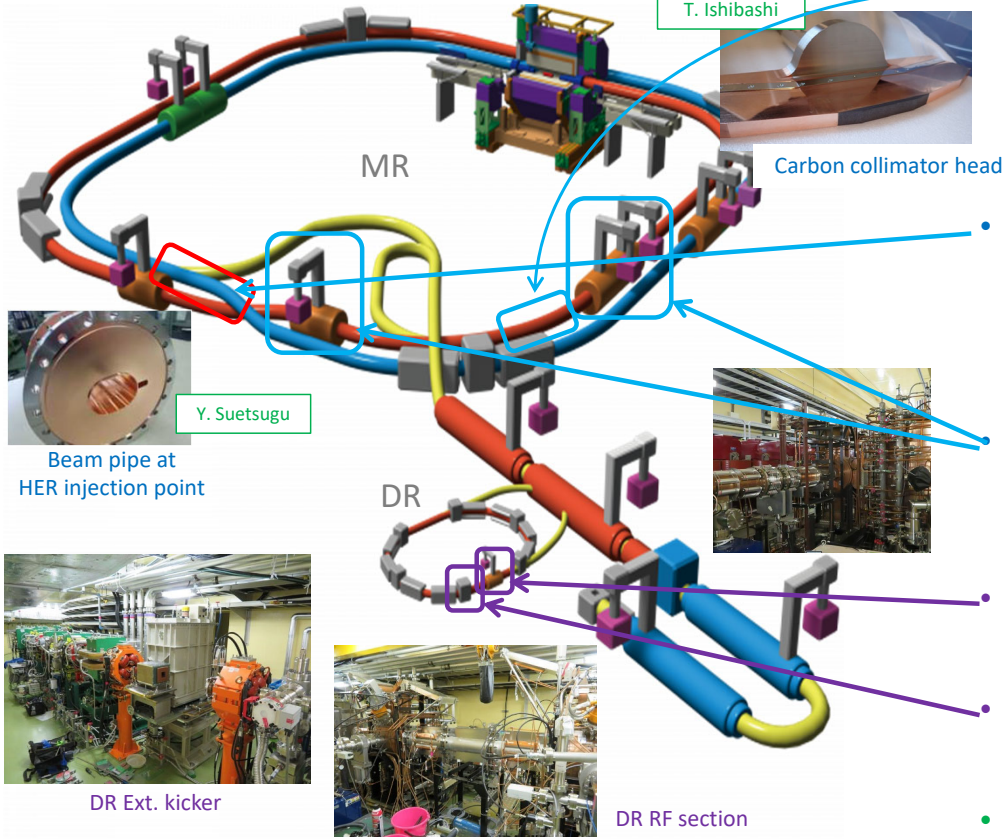
# Status of HER collimator

| Name | Type | Tip Material<br>(): 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<br>(): longitudinal length in mm | Collimator to be installed<br>(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 | |

# Other major works (excluding Linac)




T. Ishibashi



Carbon collimator head



Y. Suetsugu

Beam pipe at
HER injection point





DR Ext. kicker



DR RF section

- [Robust collimator head (LER)]
  - As countermeasure against kicker-pulser misfiring and resulting destruction of collimator
    - Replacement with carbon head of horizontal collimator D06H3 and relocation from D06H1 to D06H4
    - Carbon head production : ~ March 2023
    - Head replacement : Spring ~ Summer 2023
    - Collimator relocation : Spring ~ Summer 2023
- [New beam pipes with wider aperture at HER injection point]
  - For injection efficiency improvement
    - New beam pipes with wider aperture & New BPM for precise measurement of injected beam
    - Beam pipe production : ~ March 2023
    - Beam pipe replacement : Spring ~ Summer 2023
    - Septum baking : ~ Summer 2023?
- [RF cavity modification and replacement (LER)]
  - For stable operation with larger beam current
    - Modification : Input coupler replacement, cooling power enhancement, coaxial line modification, etc. (done)
    - Cavity replacement (D05A) : January ~ February 2023
- [Vacuum seal replacement at RF section (DR)]
  - For pressure reduction
    - Replacement from elastomer gasket to metal gasket for dummy pipes (done)
- [DR Extraction kicker power supply modification and repair (DR)]
  - For stable operation
    - Modification : December 2022 ~ August 2023
- [And so on…]

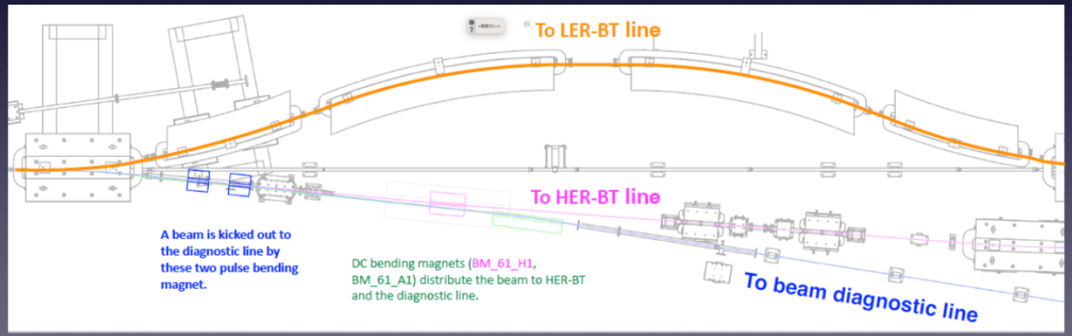
# Injector Linac

- Replaced 16 old accelerating structures with new ones (with larger energy gain).
  - Starting fabrication of 12 additional accelerating structures
- New fast kickers (kick first and second bunch independently), larger aperture pulsed-Qs have been installed.
  - Sucessful beam tuning using machine-learning method (Bayesian optimization)
- Study of BT beam blowup
  - Rejected the CSR-induced beam blowup in positron line
  - Still hunting the cause of blowups.
- Next step
  - Beam diagnostic line at SY3
  - BTe-ECS(2024-2025)
  - Beam optimization
  - etc..

# Beam diagnostic line at SY3

## Construction of a line for beam diagnostics amid steady-state injection

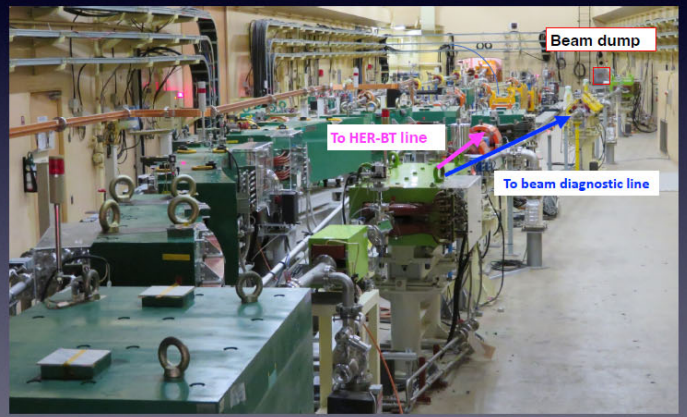
- Modification of the beam-dump line on the east side of SY3 to extract a beam at regular intervals for continuous diagnostics and data accumulation without affecting HER beam injection
- Scheduled in Summer 2024 (equipment manufacturing and procurement are in progress)
- Essential system to improve beam-control accuracy and achieve highly stable beam




T. Kamitani, T. Okayasu

# Beam diagnostic line at SY3

**Installation of high-precision beam diagnostic instruments**




**Beam position monitor**

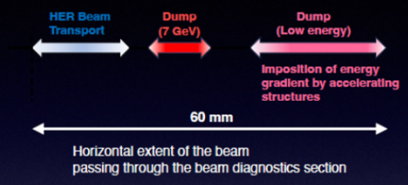
- Beam orbit measurement
- Optimization and maintenance of beam energy

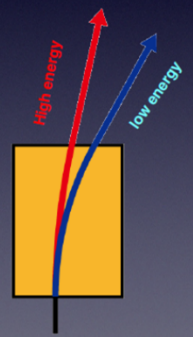
**Beam profile monitor**

- Beam energy distribution
- Optimization and maintenance of longitudinal beam structure

F. Miyahara

# Beam diagnostic line at SY3




The difference in energy appears as a difference in trajectory

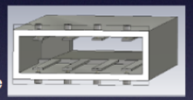
The difference in energy appears as a difference in trajectory in the beam diagnostic line

**Monitors with high resolution and wide range**

## Beam Position Monitor (BPM)

**High-precision position measurement**

- Maintain trajectory
- Energy maintenance correcting energy change



Schematic BPM

**Components**

- Wide-range 8-electrode BPM
- High precision DAQ

- Position resolution : 7~30 μm
- Energy resolution : < 0.01%

## Beam Profile monitor (YAG screen type)

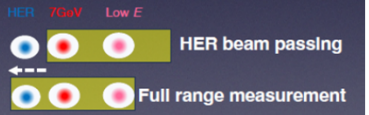
**High-resolution profile measurement**

- Energy distribution
- Longitudinal beam profile

**Components**

- 2-stage screen
- High resolution optics

Beam profiles on YAG screen



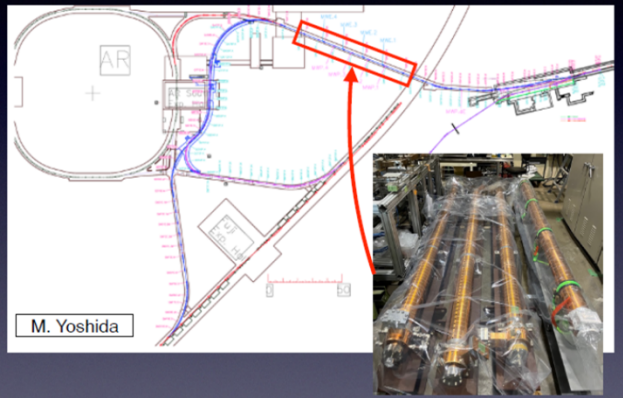

- Resolution : 25 μm
- Energy resolution $\sigma_E$ : 0.01% (↔ required $\sigma_E$ : 0.07%)

F. Miyahara

# BTe-ECS (2024-2025)

## Reduction in longitudinal beam emittance of HER by new ECS system

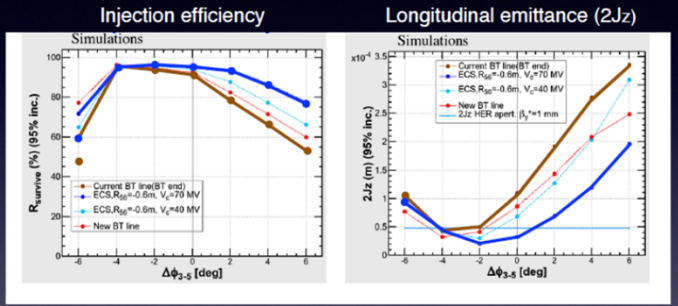
### Schematic layout




S-band 3m accelerating structure

- Equipment fabrication and procurement in progress
- Installation of RF source completed and application procedures for utilization of the RF system in progress
- High power test and radiation measurement of S-band 3m accelerating structure (transferred from SPring-8) from January 2024

### Beam simulation




N. Iida, T. Yoshimoto

**Simulation results**

- Effective reduction in longitudinal emittance lower than HER acceptance at operating condition of $R_{56}$ = - 0.6 m and Vc = 70 MV
- Estimated injection efficiency over 95%

# Summary

- Thank you so much for your participation in this 27th KEKB Accelerator Review.
- We plan to operate SuperKEKB rings at least 4.5 month.
  - 2024a 29/Jan to 31/Mar, 2024b 1/Apr to 1/Jul. 2024c 9/Oct to end of Nov.??
  - Hoping to receive supplemental operation budget to enable longer operation, especially on Mar/2025.
- Accelerator works of Long shutdown 1 was completed almost on schedule and resumed the beam operation.
- Please refer to the following presentations for the achievements of this LS1.

# Backup slides