SuperKEKB MR LS1 Status

（Progress after the previous B2GM）

Tetsuya Kobayashi (KEK)
(on behalf of SuperKEK Accelerator Group)

B2GM 2023.6.5

Contents

Challenges as a Luminosity Frontier Machine

shown in the previous B2GM by Shibata-san

Challenges recognized in recent commissioning

- To improve the machine further to achieve the goal, however, various challenges as follows should be solved:

1) Severe beam-beam effect (vertical beam size blow-up)
   - Vertical beam size (vertical emittance) blow-up has been observed at high bunch currents.
   - Relaxed by the crab-waist collision scheme, but it still remains.

2) Shorter beam lifetime than expected in the design phase.
   - The maximum bunch currents are limited by the balance between the lifetime and the injection power.
   - The dynamic aperture is very small due to the beam-beam effect and crab-waist sextupoles, while the physical aperture is limited by the beam collimators.

3) Lower bunch-current limit due to TMCI than expected.
   - The cause is higher impedance of beam collimators, where the apertures are smaller than the design values to suppress high background to Belle II.

4) Low machine stability
   - Abnormal beam aborts, sometimes leading to the damage of collimators.
   - Operation efficiency during 2021ab, for example, was almost 0.5, lower than expected one, 0.65. (Main causes: machine tunings, machine troubles, maintenance, etc.).

5) Aging of hardware and facilities, and so on.

2021/9/2

+ 6) Low injection efficiency especially in HER.

Y. Suetsugu (2021.09.02)
The 25th KEKB Accelerator Review Committee

Countermeasures against Challenges

shown in the previous B2GM by Shibata-san

Planned countermeasures

Y. Suetsugu (2021.09.02)
The 25th KEKB Accelerator Review Committee

- Major countermeasures discussed so far.
  - See Appendix C for some details.

Aim	Possible countermeasures	
・Increase injection power (efficiency)	Linac upgrade to designed specification	
	Large physical aperture at electron injection point (HER)	⇦ During LS1
	Linac upgrade beyond designed specification	
・Relax beam-beam effect ・Expand dynamic aperture	Utilizing rotatable sextuplole magnets (LER)	⇦ Done before LS1
	"Perfect matching"	⇦ Under consideration (It was found that it is not easy.)
	QCS modification (Option#1): Move QC1RP to the far side of IP	⇦ Under consideration
	Larger scale QCS modification (Option #8)	
・Suppress BG ・Expand physical aperture	QCS cryostat front panel modification and additional shield to IP bellows	⇦ During LS1
	Optimization of collimator location	⇦ Done before LS1
	Enlargemen of QCSR beam pipe (Option#3)	⇦ Under consideration
・Relax TMCI limit	"Non-linear collimator"	⇦ During LS1
・Improve stability	Robust collimators (collimator head replacements)	⇦ During LS1 (Partially)
	Upgrade of beam abort system and loss monitor system	⇦ During LS1 (Partially)
・Anti-aging measures	Preparation of standby machines and spares, repair of facilities, etc.	⇦ During LS1 (Partially)

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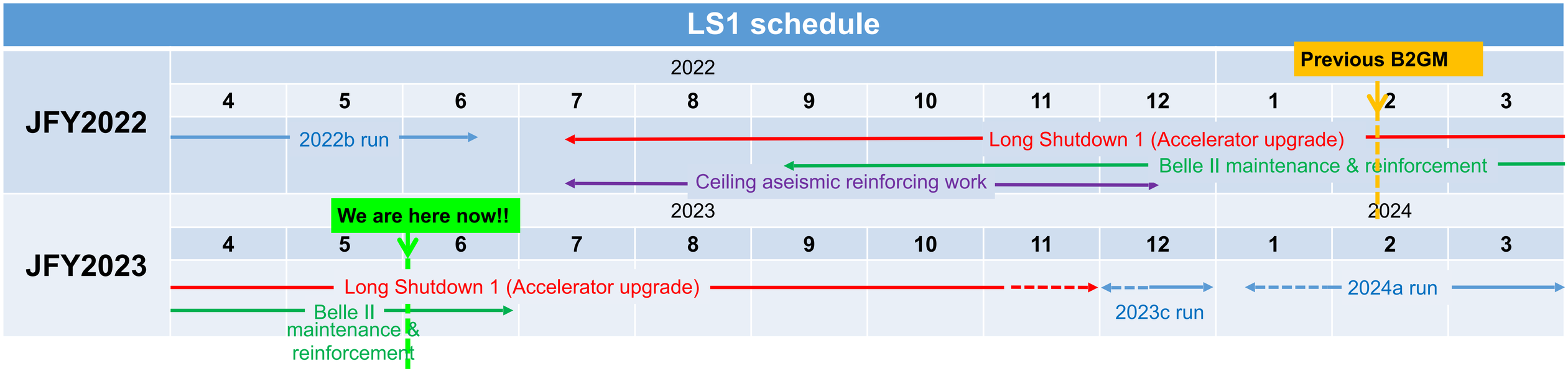
Schedule

- **LS1 : ~15 months from July 2022 to autumn 2023**
  - **2022b run stopped earlier than planned due to high electricity costs (22nd June), but LS1 major works began on 11th July as scheduled.**
  - **Beam operation will restart from December 2023.**
- **Major works during LS1 other than accelerator upgrade:**
  - **Belle II maintenance and reinforcement**
    - **Replacement of PXD and TOP MCP-PMTs, new IP beam pipes, and so on.**
    - **IR works are required, including QCS extraction & reinstallation, disassembly & reinstallation of magnets, beam pipes, radiation shields, etc.**
  - **Aseismic reinforcement of the ceiling at the laboratory buildings (Oho Lab. & Fuji Lab.)**
    - **It took about 5 months and it could be done only during long shutdown.**
    - **During this work, we could not use ceiling crane required for NLC construction at Oho Lab.!!**

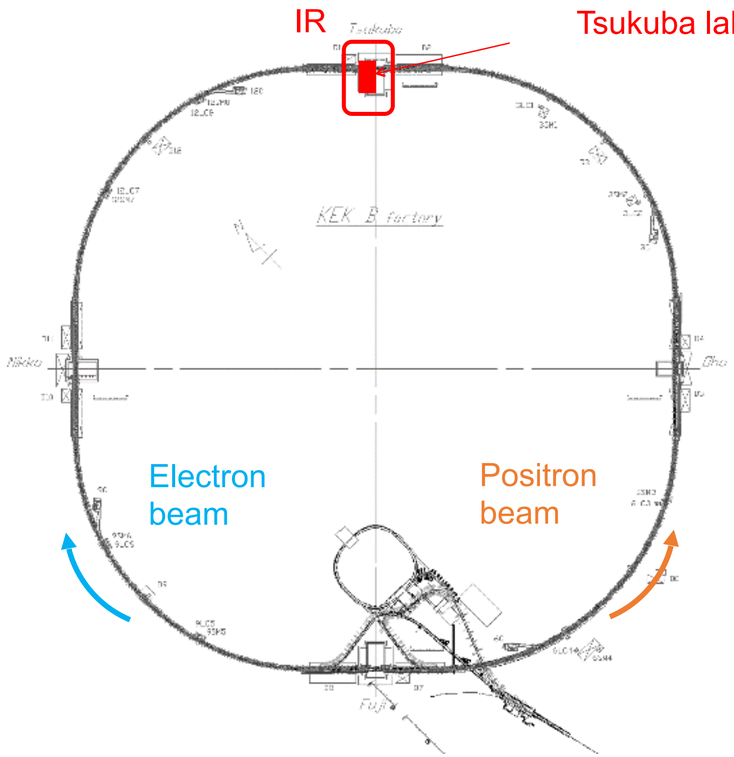
Ceiling aseismic reinforcing work

S. Nakamura



QCS @ Interaction Region (IR) (@Tsukuba Lab.)

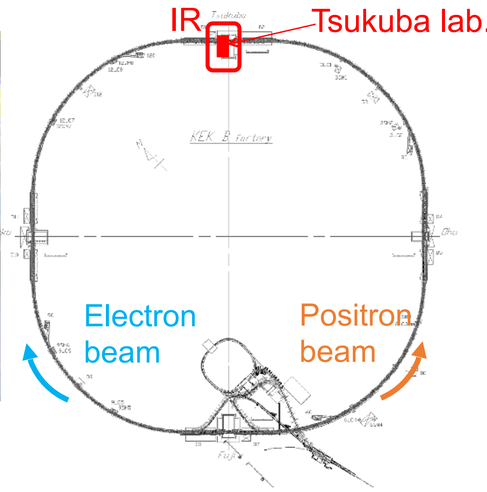
QCS = final focusing superconducting magnet system for the interaction point



Interaction Region (IR) @Tsukuba Lab.

- **Major work items in accelerator tunnel:**
  - **Disassembly and reinstallation of concrete radiation shields**
  - **Belle II maintenance & reinforcement work**
  - **Disassembly and reinstallation of magnets, beam pipes for QCS work**
  - **QCS extraction & reinstallation**
  - **QCSR cryostat leak test**
  - **QCSR cryostat vacuum leak repair**
  - **QCS cryostat modification**

Progressed works from previous B2GM



IR (Tsukuba straight section)

Previous B2GM

JFY2022

2022: 4 5 6 7 8 9 10 11 12 — 2023: 1 2 3

- 2022b run
- Concrete shield disassembly
- Belle II work
- Magnet & beam pipe disassembly
- QCS extraction
- QCSR cryostat leak test
- QCS cryostat modification
- Belle II maintenance & reinforcement

We are here now!!

JFY2023

2023: 4 5 6 7 8 9 10 11 12 — 2024: 1 2 3

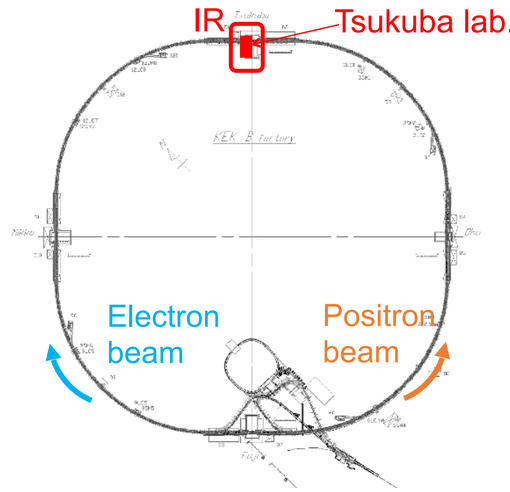
- QCS inspection
- Belle II maintenance & reinforcement
- Magnet & beam pipe reinstallation
- QCS reinstallation
- Belle II work
- Concrete shield reinstallation
- 2023c
- 2024a run

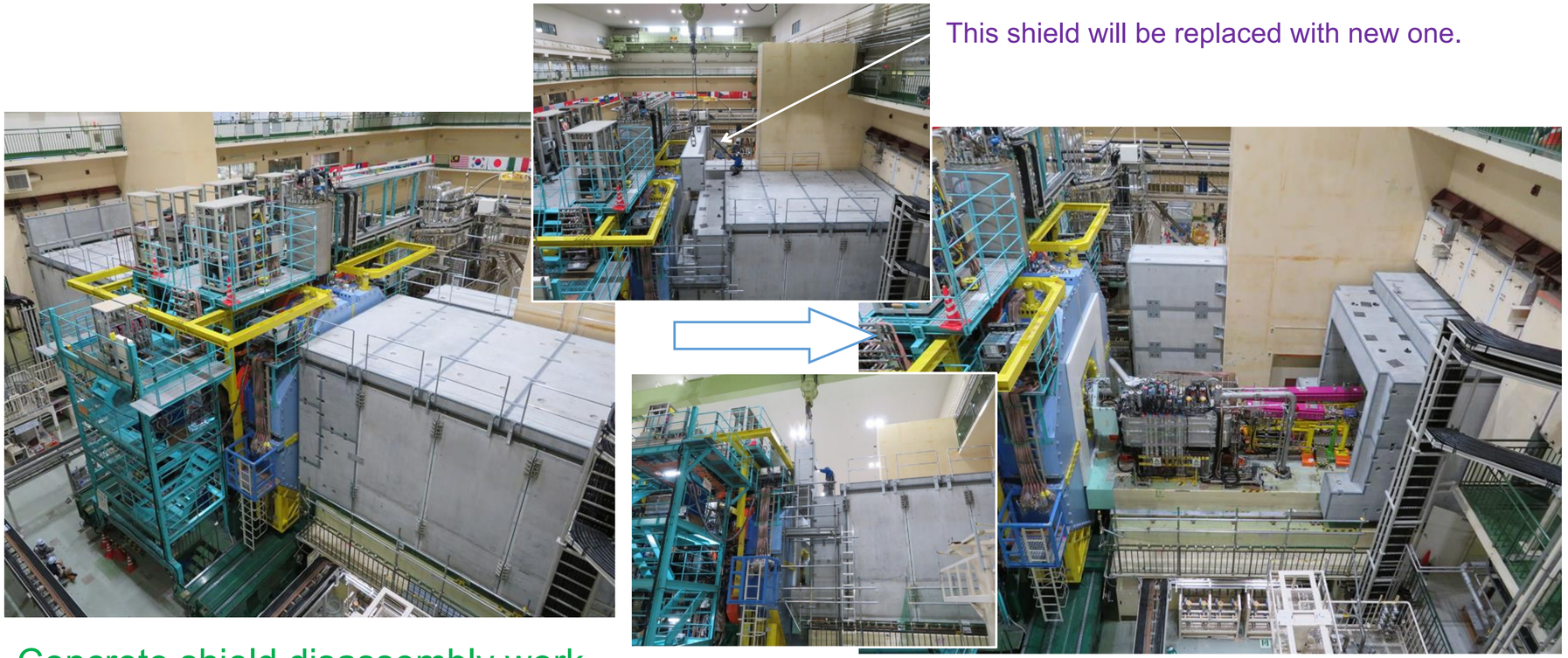
Disassembly of Concrete Radiation Shields

@ Tsukuba Ex. Hall

Done July 2022

- Concrete radiation shields disassembly
  Concrete radiation shields were temporarily removed for IR works.
  - **They will be reinstalled in November 2023.**
    - To suppress background noise of Belle II, 2 concrete shields will be replaced with new ones.
    - New shields will be delivered in March 2023.





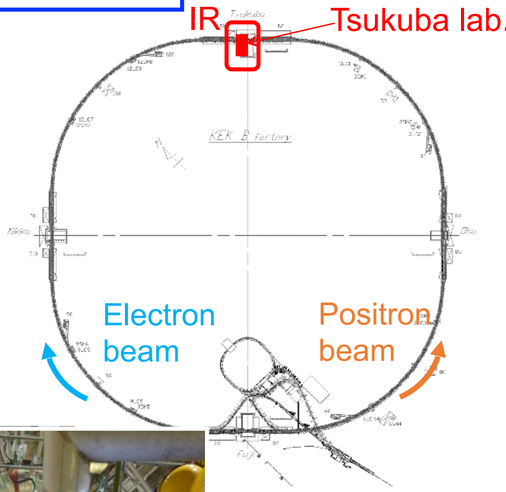
Concrete shield disassembly work

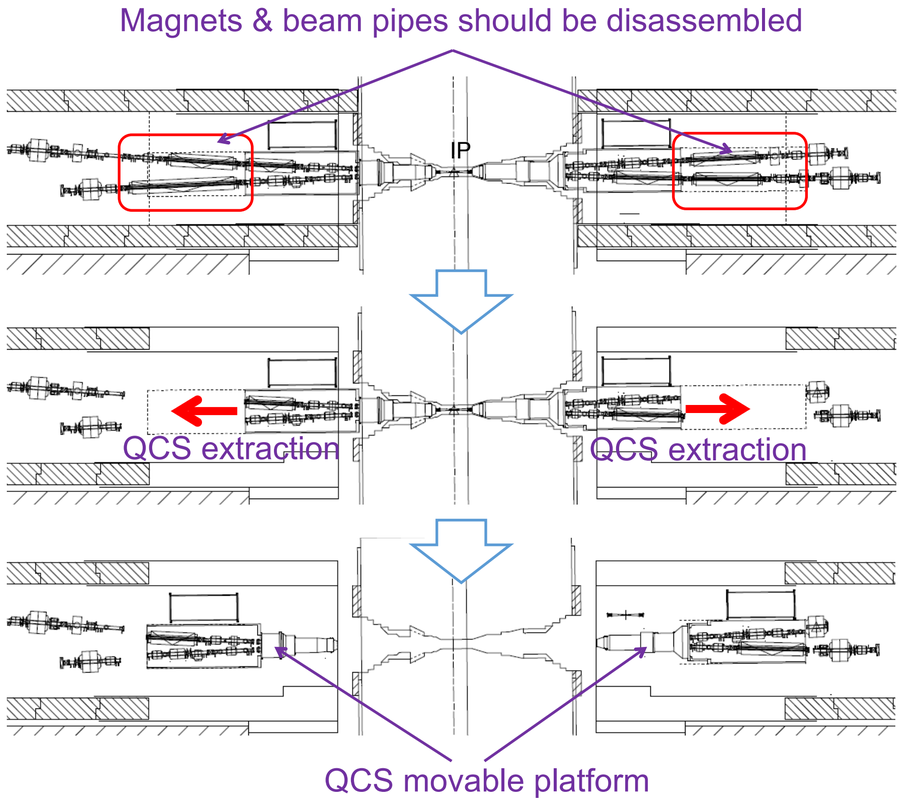
Disassembly of MG & Beam Pipes for QCS Extraction

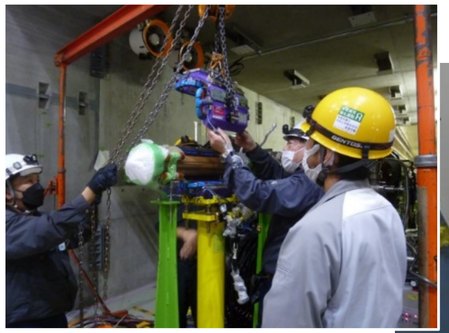
Done Sep. 2022

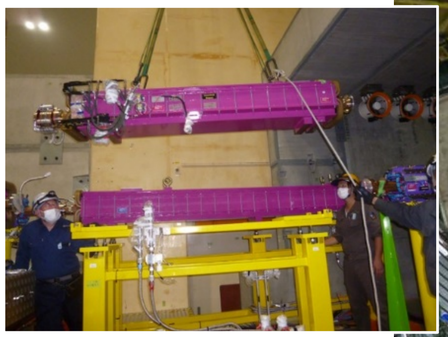
(Reported in the previous B2GM by Shibata-san)

- Disassembly of magnets & beam pipes for QCS extraction
  To make space for QCS extraction, magnets and beam pipes were removed.
  - For QCS cryostat work, some magnets and beam pipes on QCS movable platform were also removed.



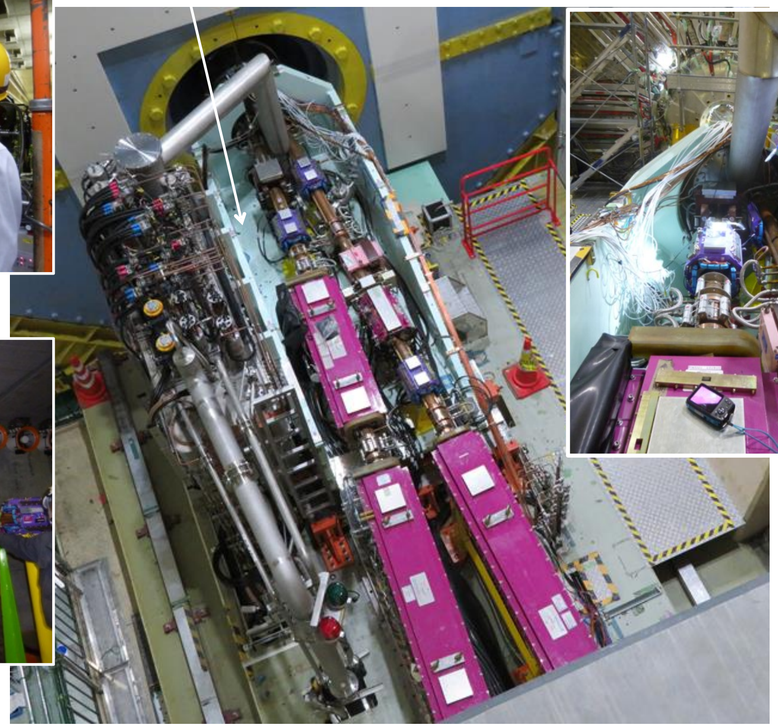


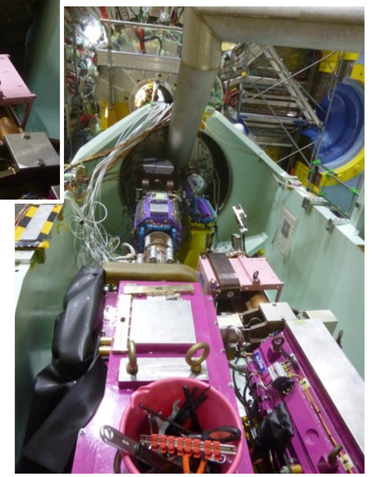




Disassembly work

QCS movable platform



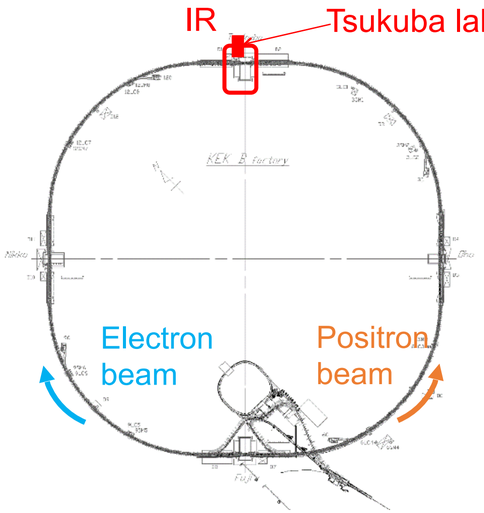


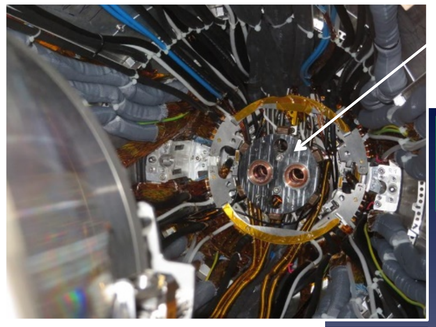
QCS Extraction

Done Sep. 2022

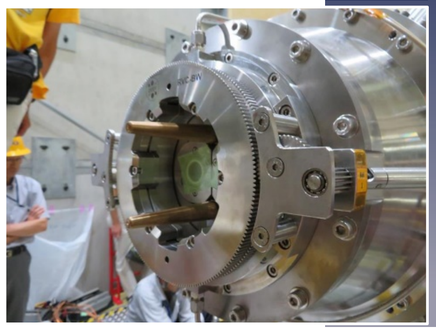
(Reported in the previous B2GM by Shibata-san)

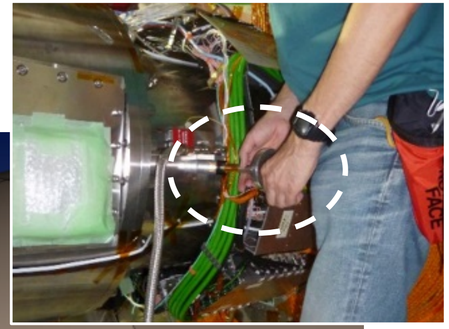
- **QCS extraction**
  - **RVC disassembly was performed by Belle II and SuperKEKB for the first time.**
    - RVC : Remote Vacuum Connection between IP bellows chambers and QCS beam pipes
    - DESY, who is RVC developer and has been in charge of RVC disassembly so far, also joined the work online. Thank you very much for the kind work manual and cooperation!!
    - Although camera for monitoring the RVC movement did not work, disassembly work went well.
  - QCS extractions of both sides were completed successfully in one day!!

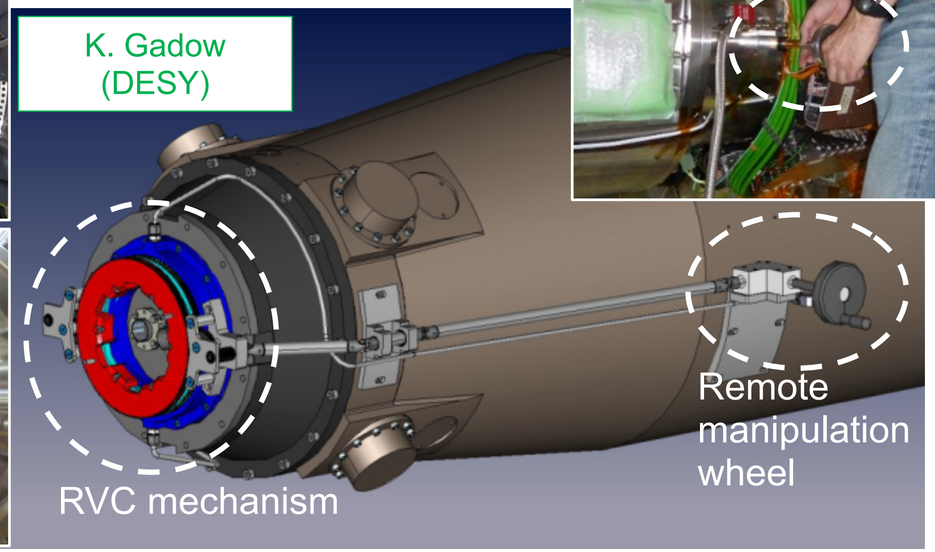


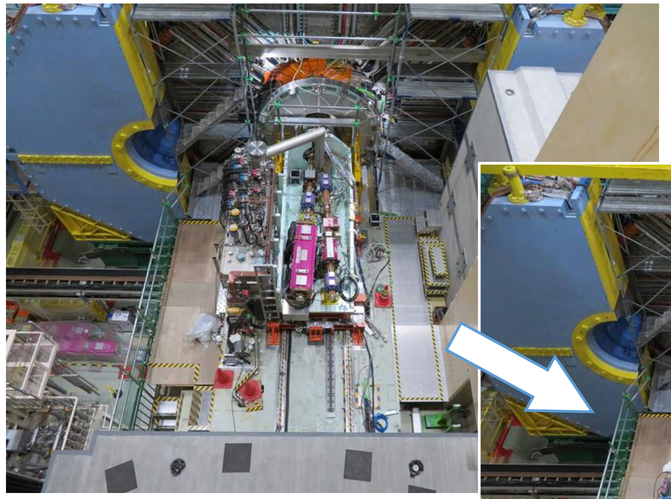


RVC lock flange of IP bellows chamber

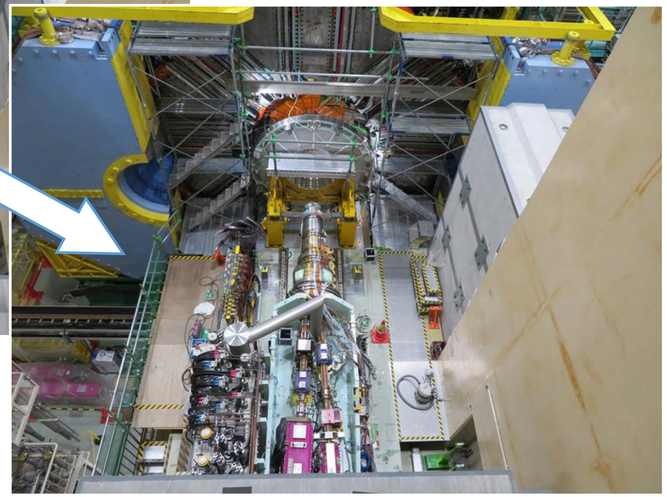








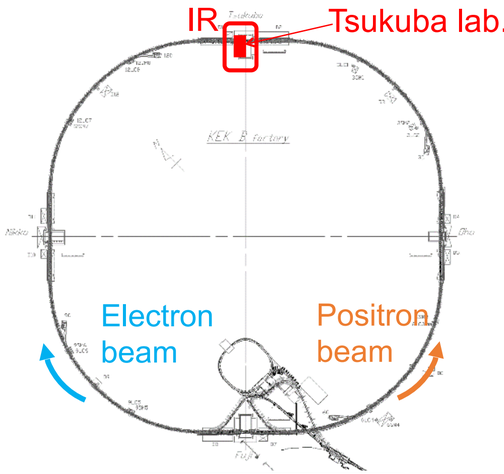
QCS extraction

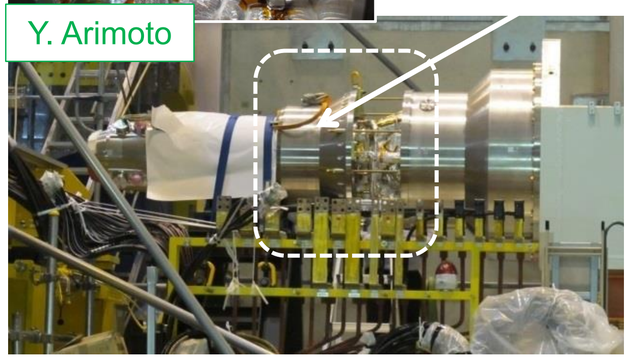


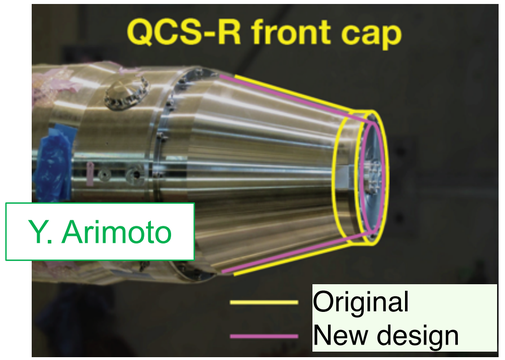
QCS Cryostat Modification

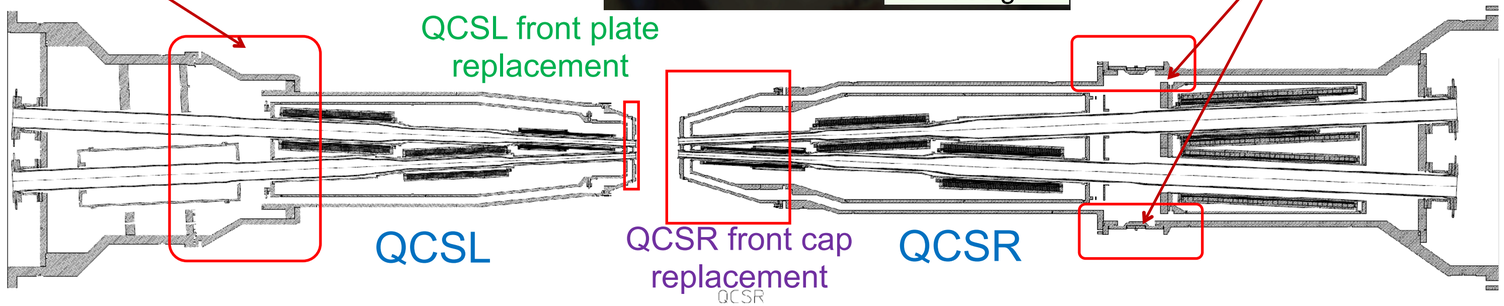
(progress after the previous B2GM)

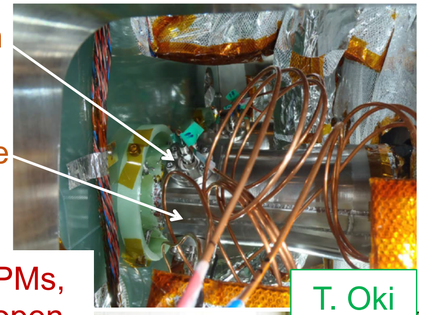
- **QCS cryostat modification**
  - **In order to reduce Belle II background noise, the material at the tip of QCS cryostat was changed from W to SUS.**
    - QCSR front cap replacement
    - QCSL front plate replacement
  - **In order to make more space for Belle II cables, the tip of QCSR cryostat was changed to thinner one.**
    - QCSR cryostat modification including front cap replacement







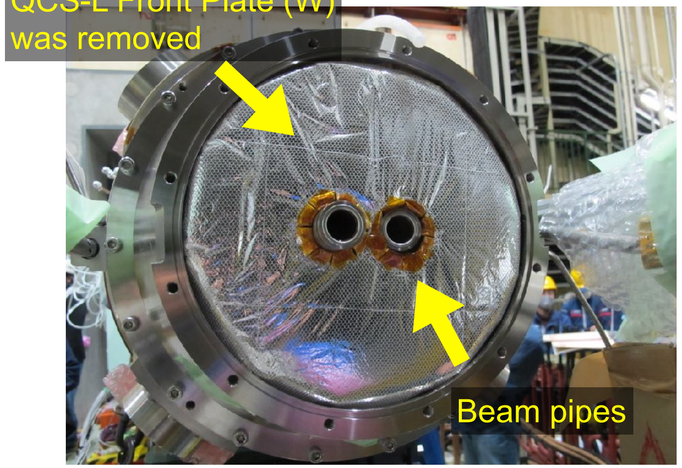


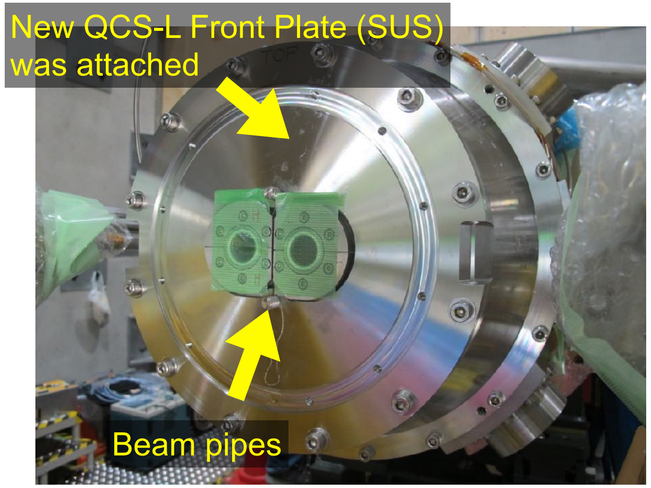


QCS Cryostat Modification (Feb. - Mar. 2023)

To reduce Belle II background noise,

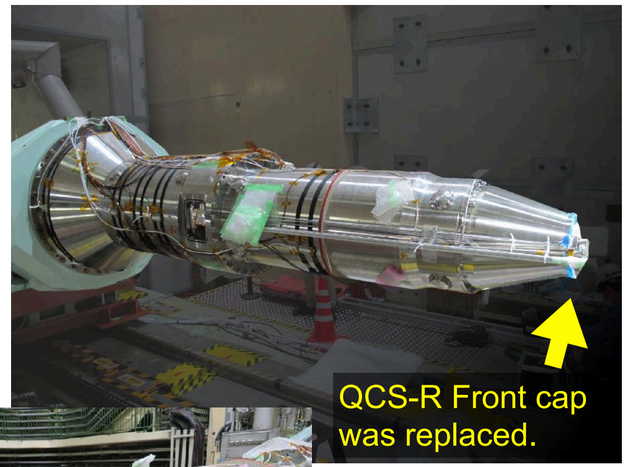
- **QCS-L**
  - **Changed the material of the front plate from tungsten to stainless steel**

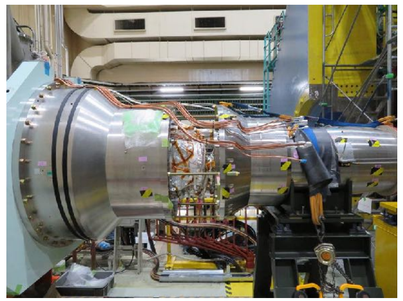




To make more space for Belle II cables,

- **QCS-R**
  - **Replace the front cap with thinner one**
  - **Made of stainless steel**





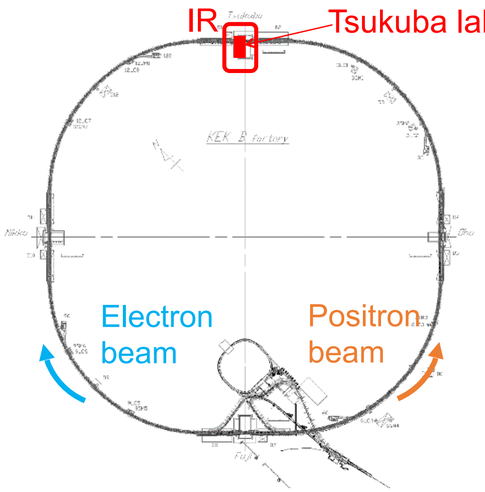
QCSR Sevice Cryostat Vacuum Leak

adiabatic vacuum **was found in 2022**

(As reported in the previous B2GM by Shibata-san)

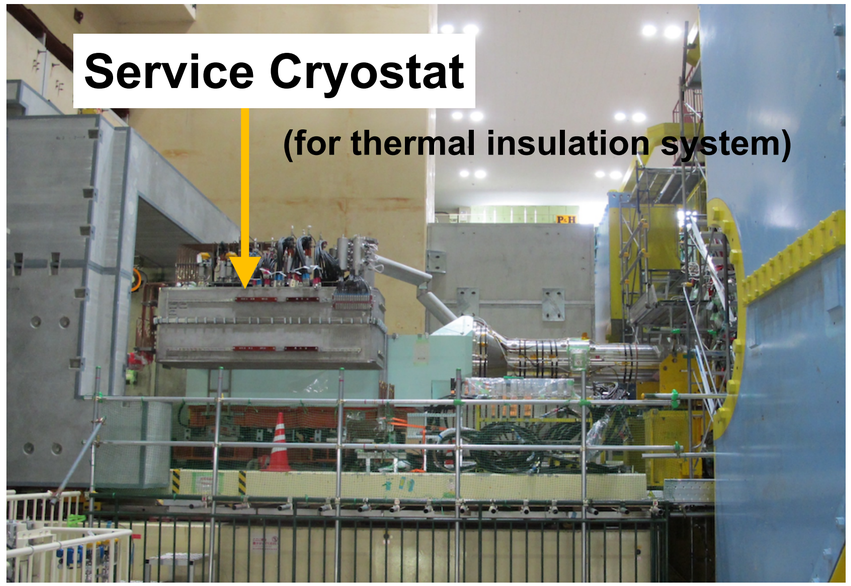
- QCSR service cryostat
  - Pressure in QCSR service cryostat has been higher than that in QCSL.
    - Residual gas analysis showed that vacuum leak has occurred in QCSR service cryostat.
    - However, vacuum leak test before LS1 did not detect any vacuum leak.

This vacuum is for thermal insulation to keep superconducting (not in beam line).



  - After QCS extraction, thorough vacuum leak test was performed.
    - At last, the location of the vacuum leak was identified!!. (Oct. 2022)

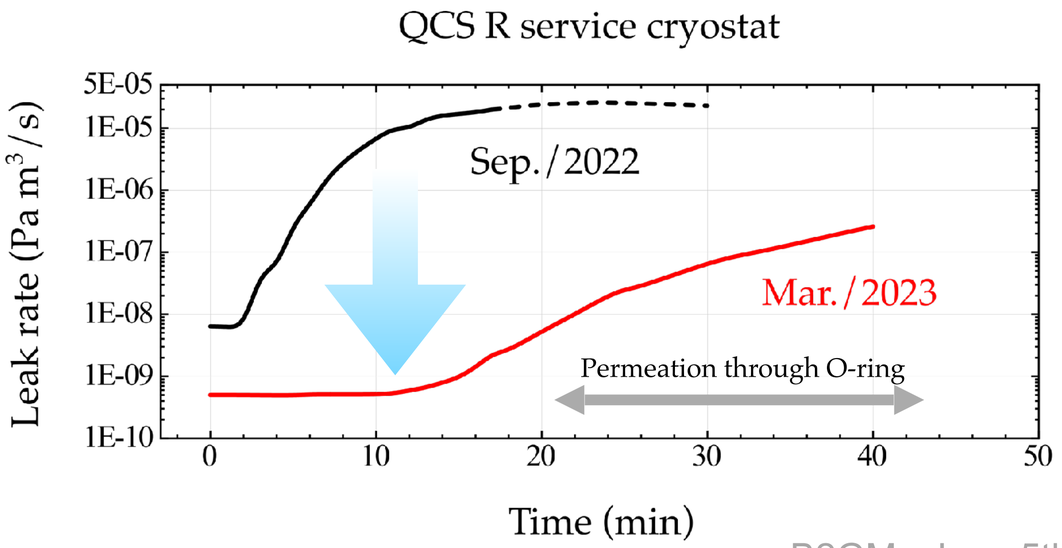
→ Repair work was progressed in this year.

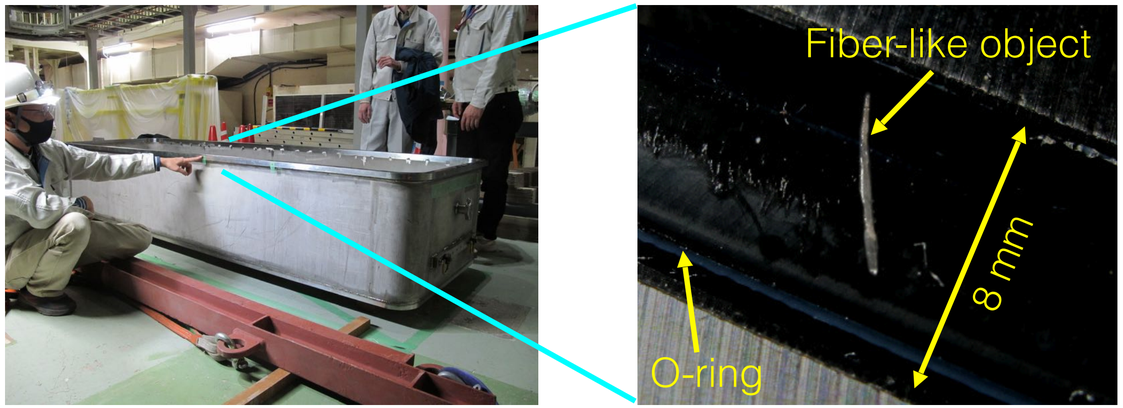


Vacuum leak test work of QCSR service cryostat

Vacuum Leak Repair Work (Mar. 2023)

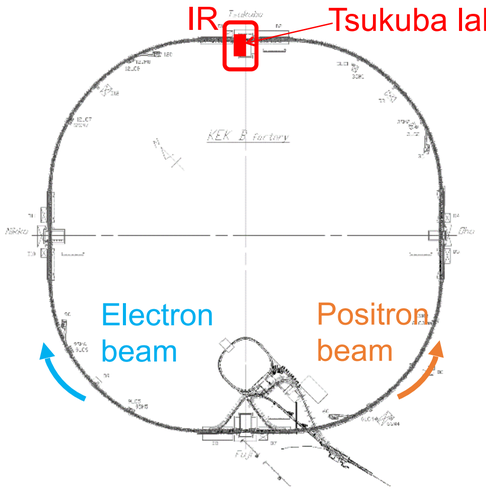
- **We opened the service cryostat at QCS-R and checked the O-ring surface**
- **The fiber-like object was found on the surface of the O-ring.**
- **We replaced the O-ring with the new one, cleaned the groove and the flange surface, and reassembled the cryostat.**
- **As the result of a helium leak test, It was confirmed that the leak has successfully stopped.**



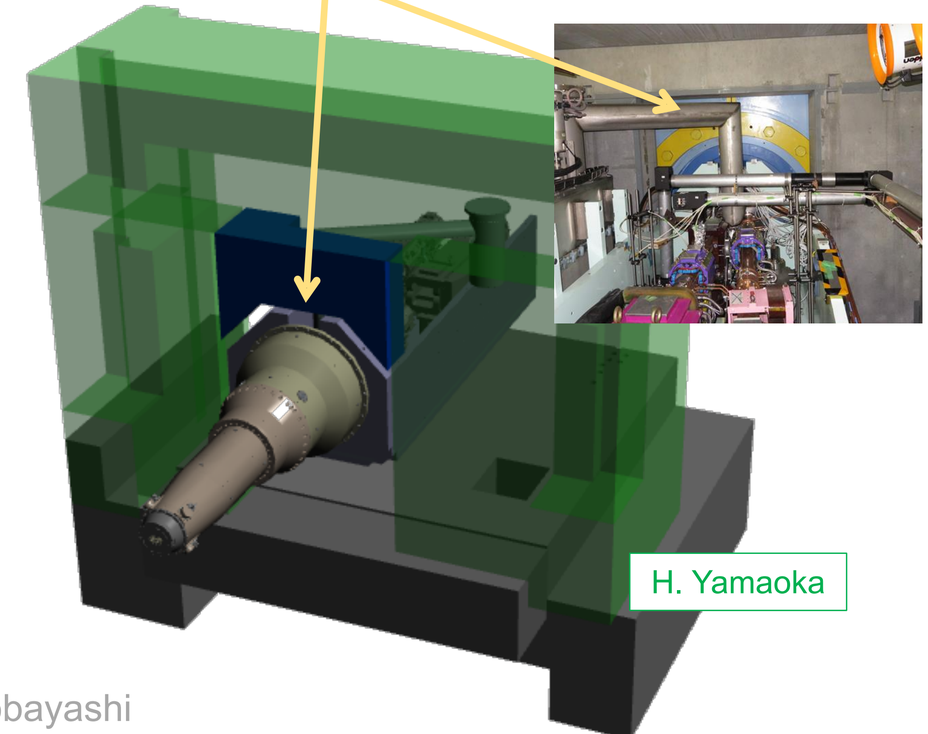


New Concrete Shields for IR

- **To suppress background noise of Belle II, two-concrete shields will be replaced with new ones.**
  - New concrete shields have been delivered in March 2023
  - **They will be reinstalled in mid September 2023.**



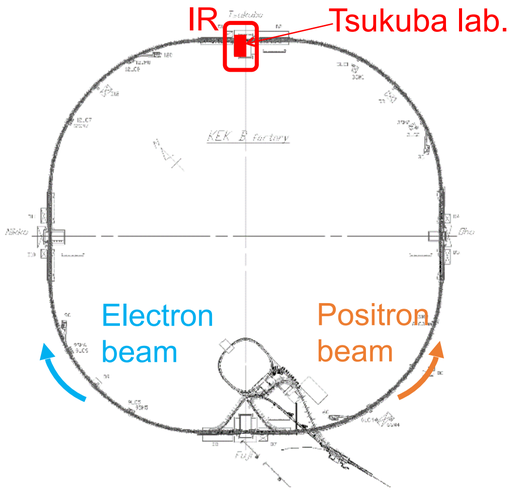
By using the new shields, this opened space will be filled with concrete.



H. Yamaoka

Remaining works for IR

- **Remaining works in accelerator tunnel:**
  - **Belle II maintenance & reinforcement (~ Sep 2023)**
  - **QCS periodical self-inspection (Jun 2023)**
  - **QCS reinstallation (Oct 2023)**
  - **Concrete shield reinstallation (Nov 2023)**
- **All works can be completed by the end of Nov 2023.**
  - **It is required to coordinate the schedule with Belle II work and NLC construction.**



IR (Tsukuba straight section)

JFY2022

2022: 4 5 6 7 8 9 10 11 12 | 2023: 1 2 3

Previous B2GM

- 2022b run
- Concrete shield disassembly
- Belle II work
- Magnet & beam pipe disassembly
- QCS extraction
- QCSR cryostat leak test
- QCS cryostat modification
- Belle II maintenance & reinforcement

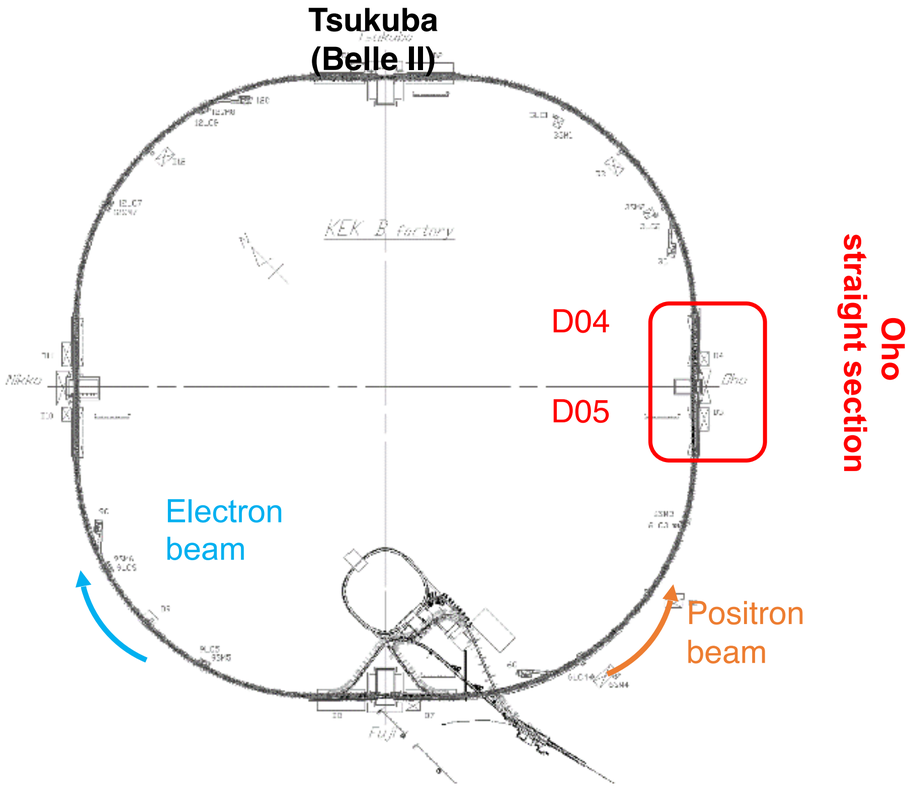
JFY2023

We are here now!!

2023: 4 5 6 7 8 9 10 11 12 | 2024: 1 2 3

- QCS inspection
- QCS reinstallation
- Concrete shield reinstallation
- Magnet & beam pipe reinstallation
- Belle II work
- 2023c
- 2024a run
- Belle II maintenance & reinforcement

Oho Straight Section

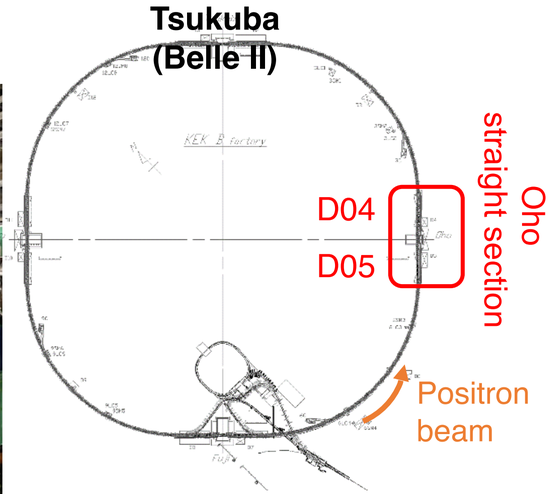


Oho Straight Section

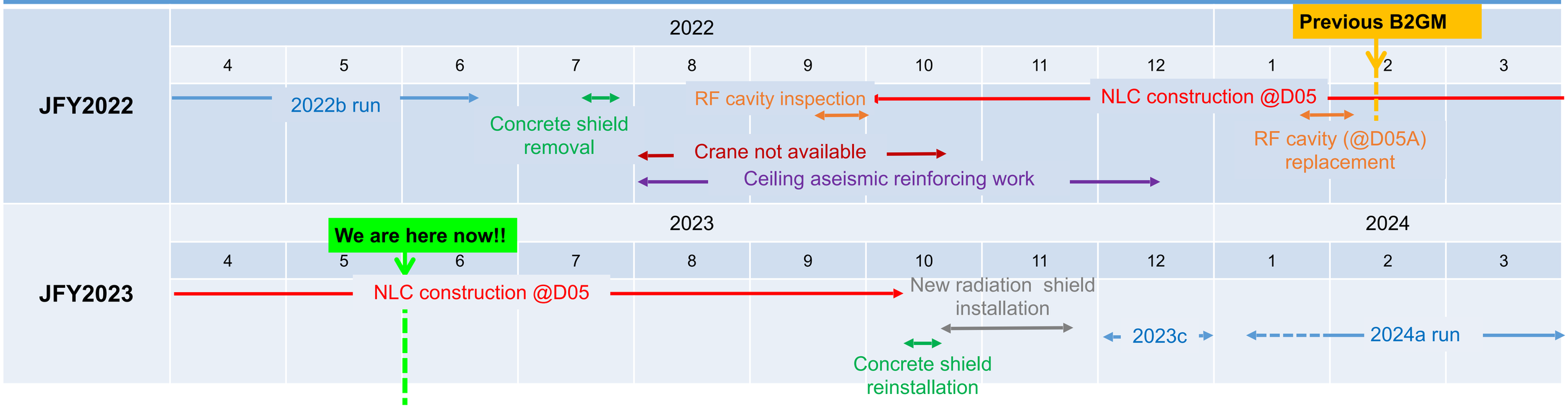
- **Major work items in accelerator tunnel:**
  - **Disassembly and reinstallation of concrete radiation shields**
  - **Non Linear Collimator (NLC) construction (LER)**
  - **RF cavity@D05A replacement (LER) … done!**
  - **Ceiling aseismic reinforcing work…done!**
  - **Installation of new radiation shields for NLC**

Concrete radiation shield

D05 straight section

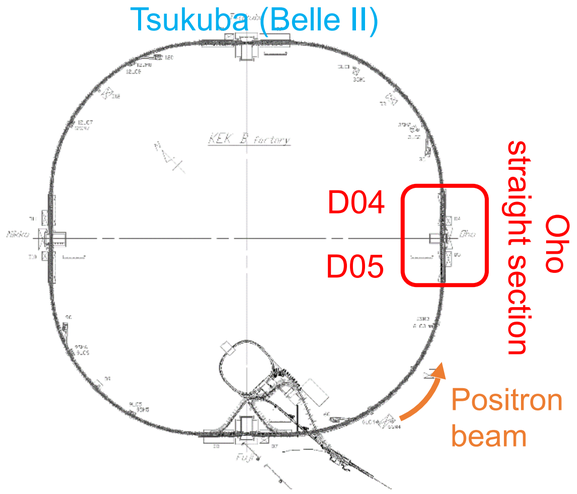


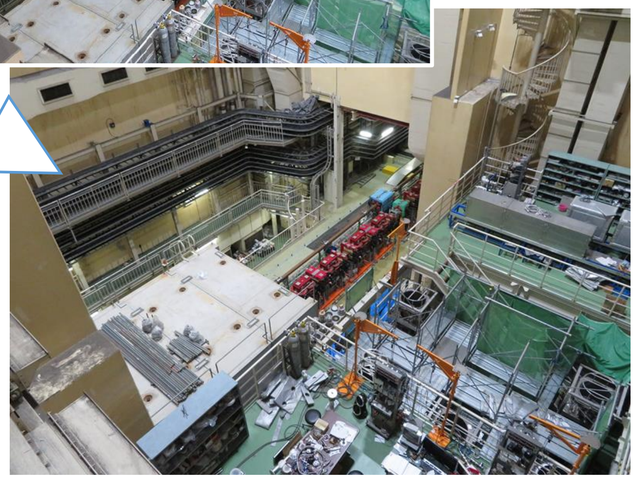
Oho straight section (D05)



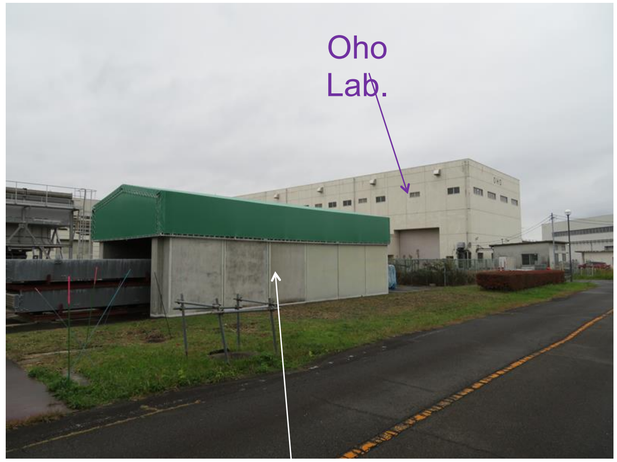
Concrete Shields Disassembly @Oho

- Concrete radiation shields disassembly (already done, July 2022)
  - **Concrete radiation shields were temporarily removed for NLC construction.**
    - The concrete shields are placed outside Oho laboratory building,now
  - **They will be reinstalled in October 2023.**





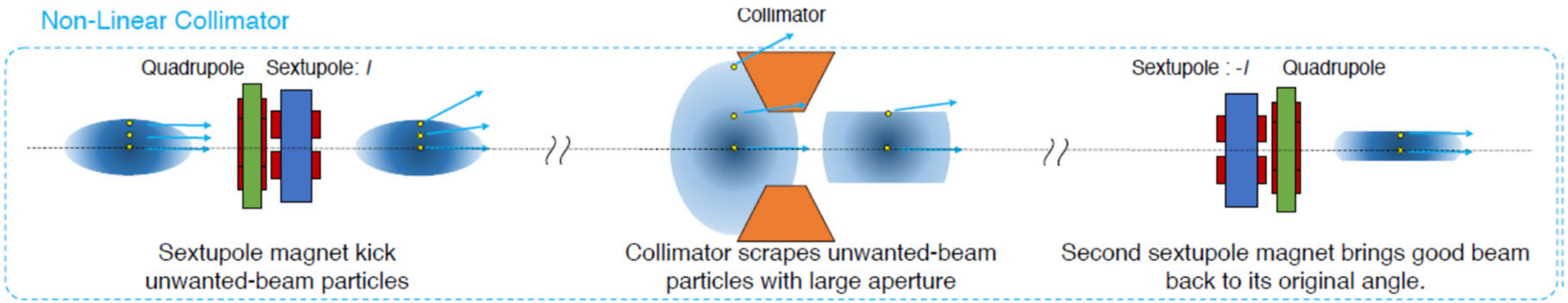
Concrete shield disassembly work



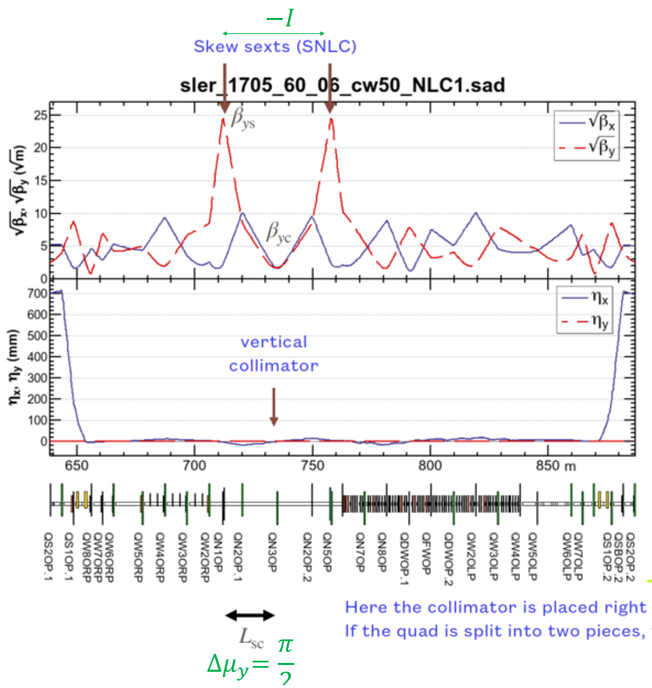
Disassembled concrete shield

Non Linear Collimator (NLC) Installation

In order to relax the transverse mode coupling instability (TMCI), NLC is applied to LER.



■ Enlarge beam size by nonlinear kick of the skew-sextupole



L_{sc}

$\Delta\mu_y = \frac{\pi}{2}$

[K. Oide]

Requirements for the NLC optics:

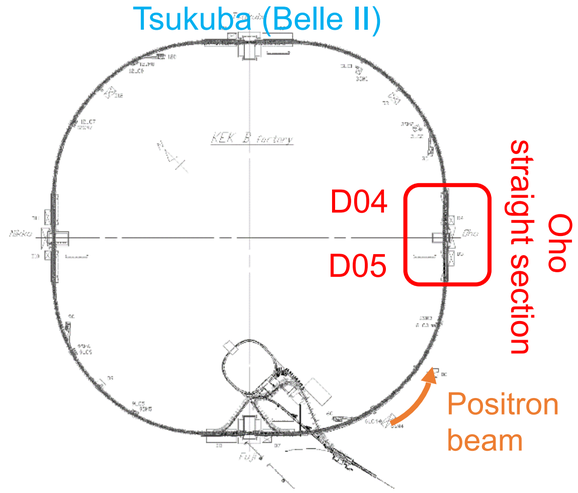
- Large $\beta_y = \beta_{ys}$ at the (skew) sextupole.
  - $\beta_y = \beta_{yc}$ at the collimator: $\frac{\beta_y}{\sqrt{\beta_{yc}\beta_{ys}}} \approx 1.7 \times L_{sc}$
- A (skew) sextupole pair connected by a $-I$ transformation.
- No dispersion at the sextupoles and the collimator.
- ≈ 0.25 vertical phase advance between the sexts and the IP.

Five sections of wigglers are removed!

Here the collimator is placed right before the center quad (QN3OP).
If the quad is split into two pieces, the collimator can be placed in the middle of them.

June 17, 2021 K. Oide

17



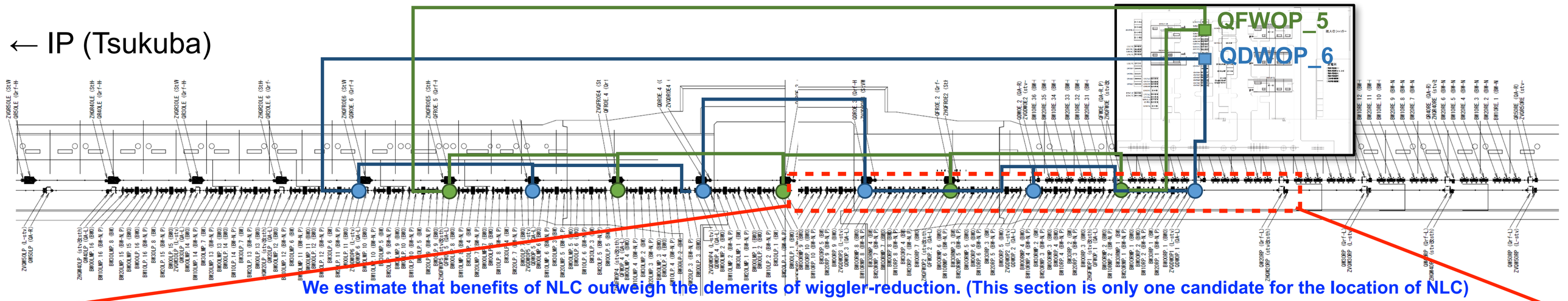
NLC is installed at Oho D05 section in LER, where the optics satisfies the requirements for NLC

Oho straight section is optimum for NLC-installation.

NLC Composition (Re-configuration of Beam Line)

is continuing…

@Oho Straight Section (downstream of D05 RF section)

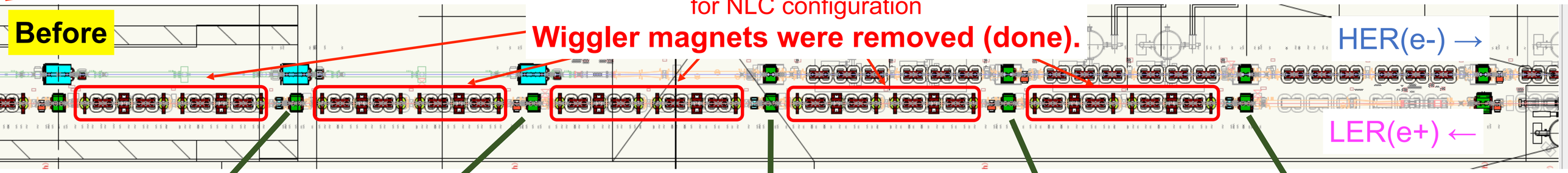


We estimate that benefits of NLC outweigh the demerits of wiggler-reduction. (This section is only one candidate for the location of NLC)

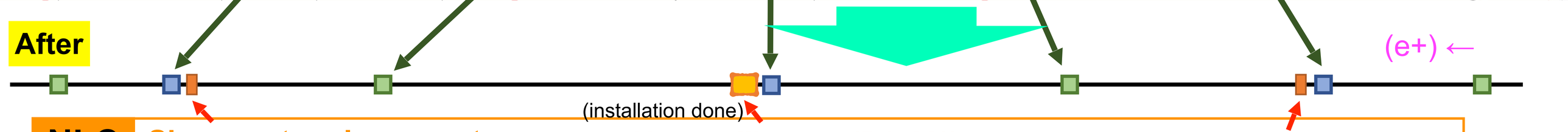
for NLC configuration

Before

Wiggler magnets were removed (done).



After



NLC Skew sextupole magnet — New collimator (D05V1) — Skew sextupole magnet

Quadrupole magnets were replaced.
& New collimator was installed.

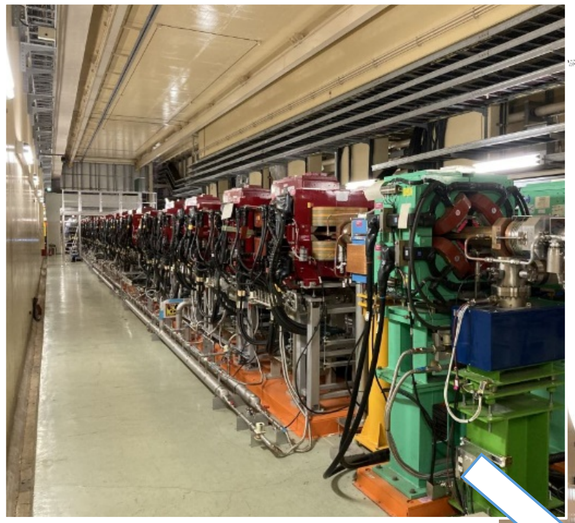
New skew sextupole magnets will be installed in September

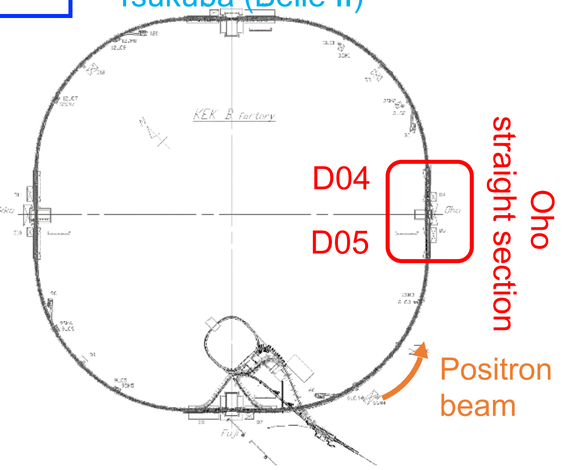
Removal of Wiggler and Beam-Pipe

Done in 2022

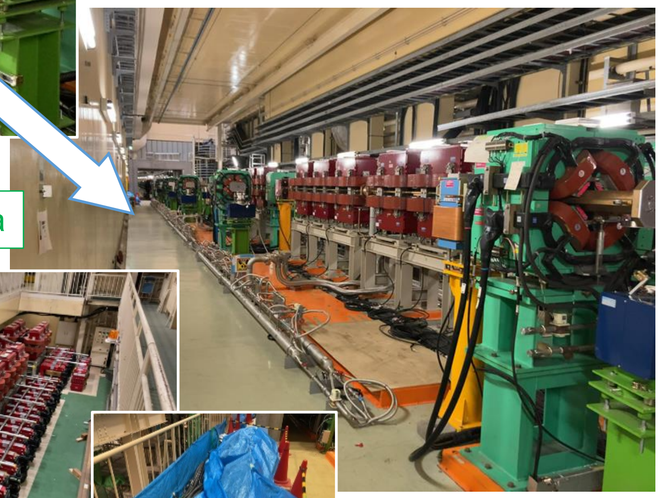
- **Wiggler magnets and beam pipe removal (already done)**
  - Removed wiggler magnet and cable : 50 magnets and their cables
    - Double pole magnet (3 ton) : 20
    - Single pole magnet (2 ton) : 10
    - Half pole magnet (1.5 ton) : 20
    - Cables : 3 ton
  - Removed beam pipe for wiggler magnet : 10 beam pipes
  - Disassembly procedure
    - Removal of wiggler magnet cables
    - Upper parts of wiggler magnets disassembly
    - Beam pipes removal
    - Upper parts of wiggler magnets reassembly
    - Wiggler magnets remova

10 times





S. Nakamura



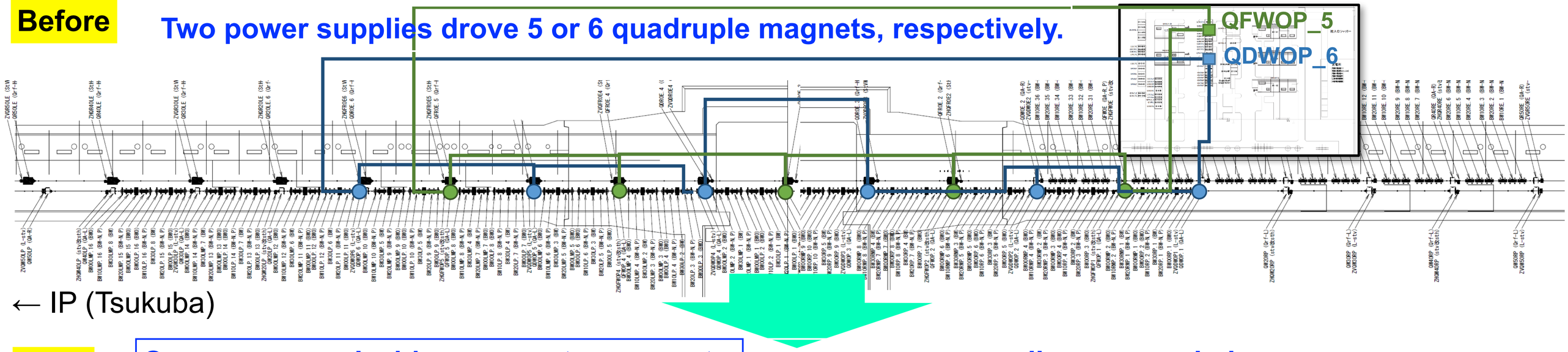
Wiggler beam pipe removal work

Magnet Re-Cabling for New Configuration

at D05 section

Before

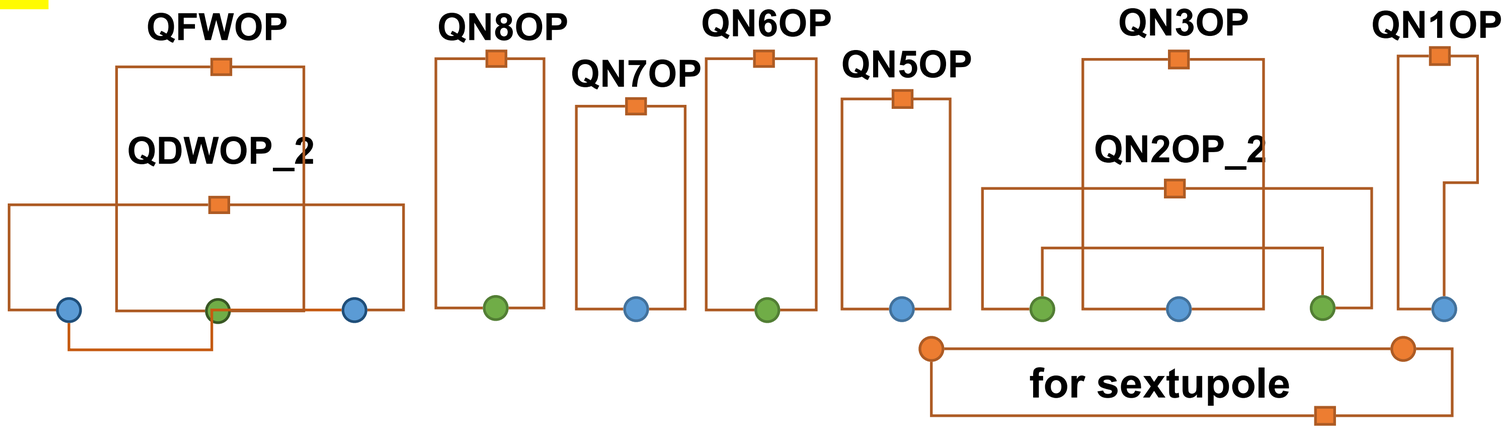
Two power supplies drove 5 or 6 quadruple magnets, respectively.



← IP (Tsukuba)

After

One power supply drives one or two magnets. → more power supplies are needed.



S. Nakamura

Additionally new power supplies will be installed in September, and test operation of them will start in October.

Re-wiring works between the power supplies and magnets has done.

Remaining1: New Radiation Shield Installation

New Pb radiation shield is required to be installed for NLC

← IP (Tsukuba)

Before

Wiggler magnets were removed.

HER(e-) →

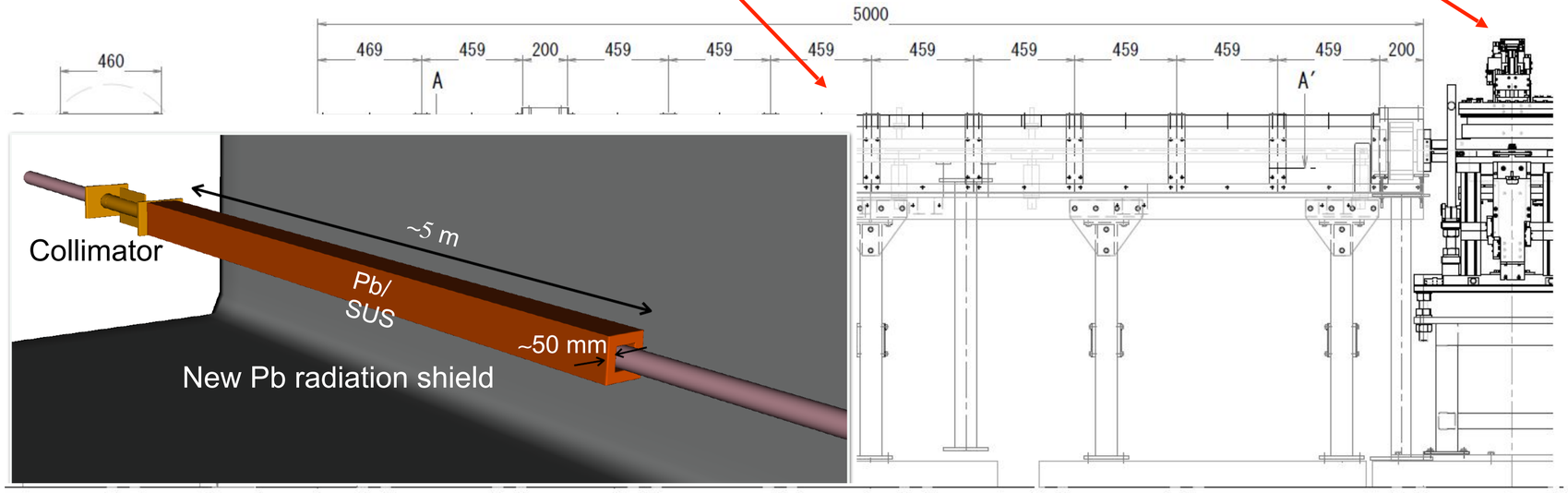
LER(e+) ←

After

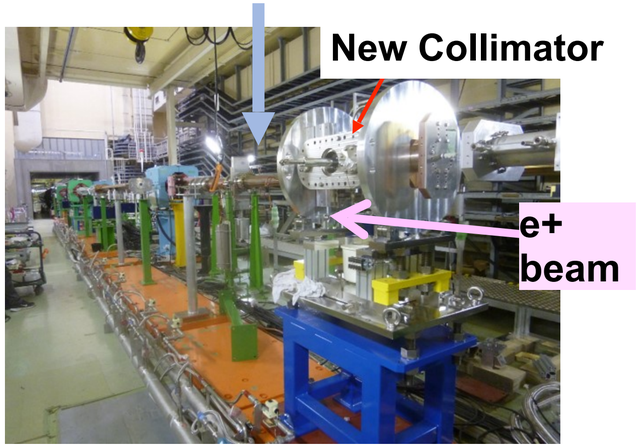
5 m

New Pb shields

New collimator (D05V1)

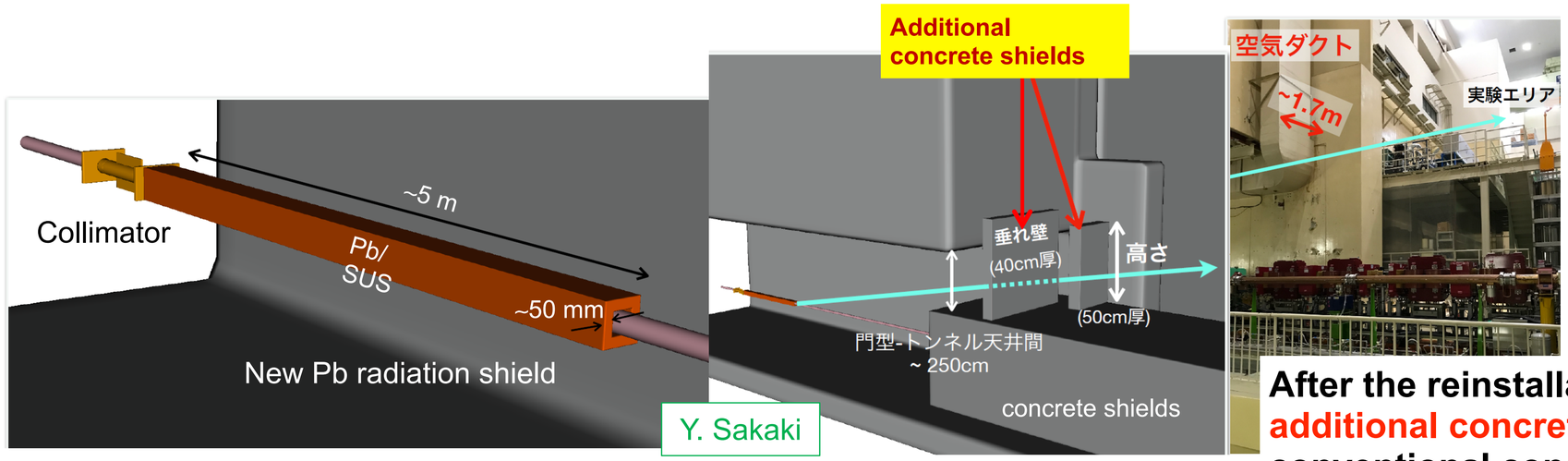


A 5-m Pb radiation shield will be installed at downstream side of the new collimator, in early to middle October.



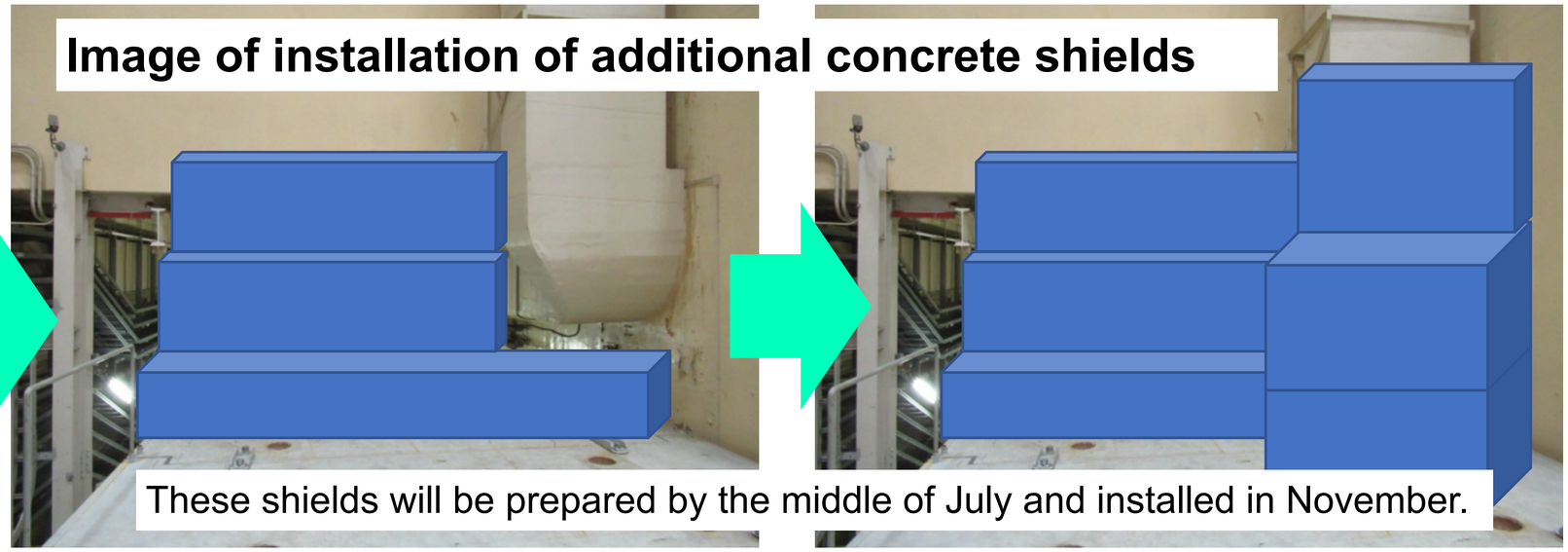
Remaining2: Concrete Shields Addition

The additional concrete shields will be install
to protect the OHO experimental hall from the radiation from the collimator.



After the reinstallation of the concrete shields, additional concrete shields will be placed on top of the conventional concrete shields.

Image of installation of additional concrete shields

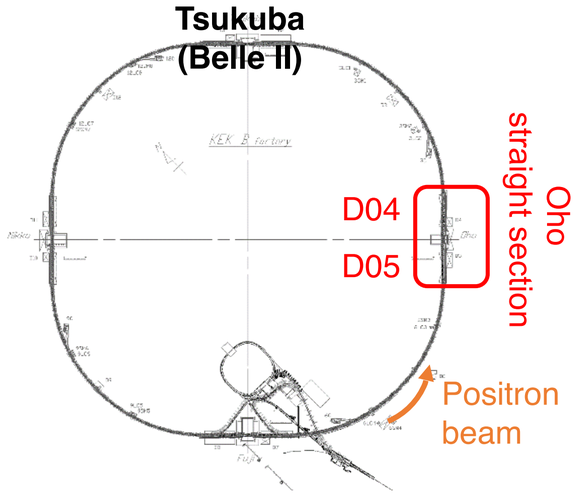


These shields will be prepared by the middle of July and installed in November.

Oho Straight Section

- **Remaining works in accelerator tunnel:**
  - **NLC construction (will be completed by Sept. 2023)**
  - **New radiation shield installation (Oct.~ Nov. 2023)**
  - **Concrete shield reinstallation (Oct. 2023)**

- **All works will be completed in December 2023.**
  - **Schedule is very tight.**



Oho straight section (D05)

JFY2022

2022: 4 5 6 7 8 9 10 11 12 — 2023: 1 2 3

Previous B2GM

- 2022b run
- Concrete shield removal
- RF cavity inspection
- Crane not available
- Ceiling aseismic reinforcing work
- NLC construction
- RF cavity replacement

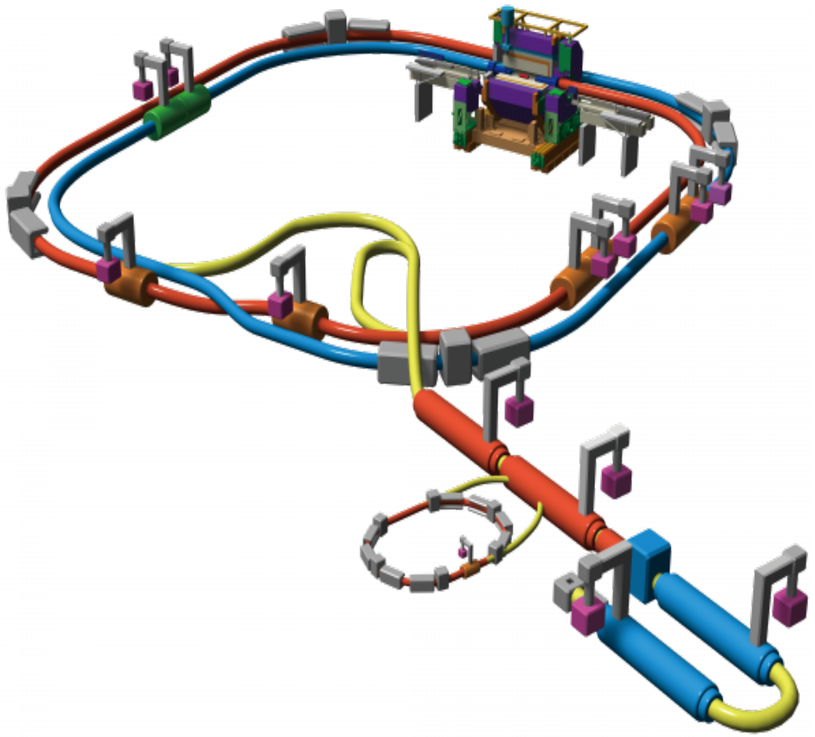
JFY2023

2023: 4 5 6 7 8 9 10 11 12 — 2024: 1 2 3

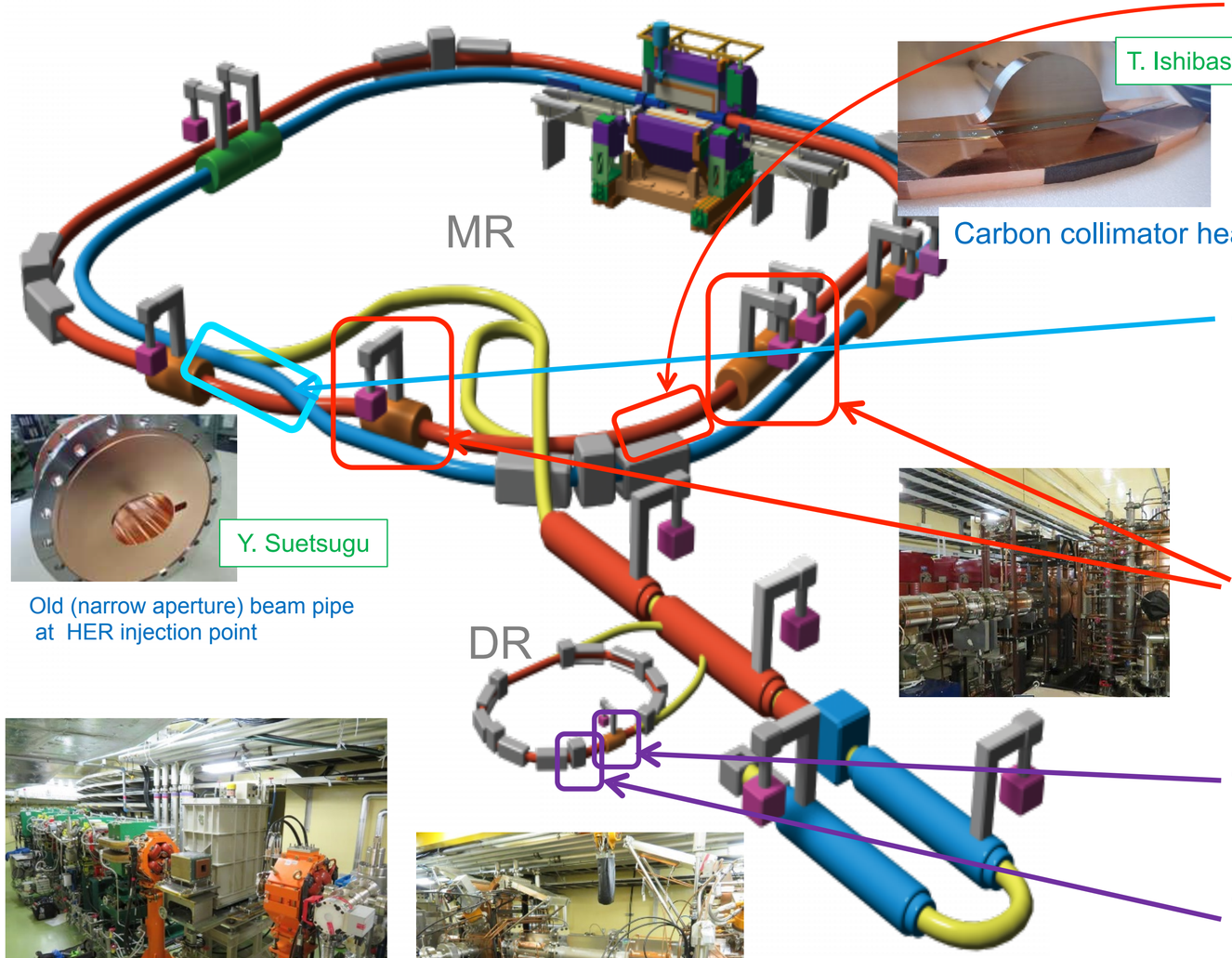
We are here now!!

- NLC construction
- Concrete shield reinstallation
- New radiation shield installation
- 2023c
- 2024a run

Other Works in MR



Other Major Works in MR during LS1



T. Ishibashi

Carbon collimator head

Y. Suetsugu

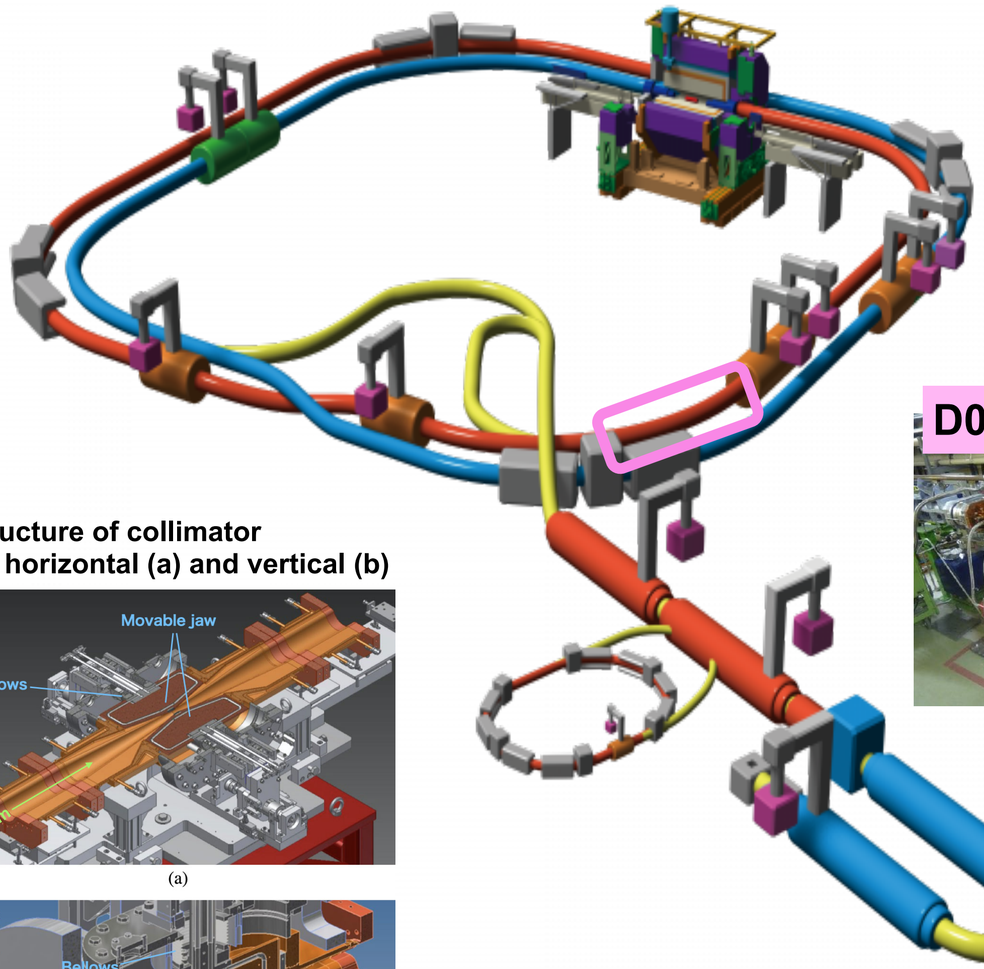
Old (narrow aperture) beam pipe at HER injection point

DR Ext. kicker

DR RF section

- **Robust collimator head (LER)**
  - As countermeasures against collimator destruction due to kicker-pulser misfiring
    - Replacement with carbon head of horizontal collimator D06H3
    - Relocation from D06H1 to D06H4
    - Carbon head production : ~ March 2023 (done)
    - Head replacement : Spring ~ Summer 2023
    - Collimator relocation : Spring ~ Summer 2023
- **New beam pipes at HER injection point for wide aperture**
  - For injection efficiency improvement
    - Beam pipe design at HER injection is changed for wider aperture & New BPM will be applied for precise measurement of injected beam
    - New beam pipe production : ~ March 2023 (done)
    - Beam pipe replacement : now ~ Summer 2023
    - Septum baking : ~ Summer 2023?
- RF cavity modification and replacement (LER) …..Done!
  - 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 (done)
- Vacuum seal replacement at RF section (DR)…..Done!
  - For pressure reduction
    - Elastomer gaskets were replaced with metal gaskets for dummy pipe connections.(done)
- DR Extraction kicker power supply modification and repair (DR)
  - For stable operation
    - Modification : December 2022 ~ August 2023
- And so on…

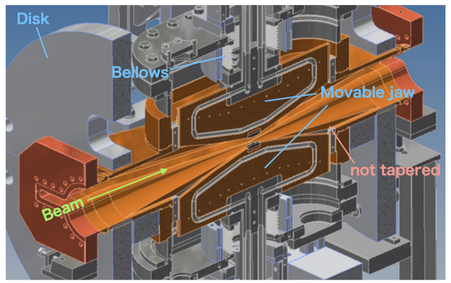
Change to Robust Collimator Head (LER)



- **As countermeasures against collimator destruction due to kicker-pulser misfiring,**
  - Replacement with carbon head of horizontal collimator D06H3.
  - Collimator relocation from D06H1 (upstream of D06H3) to D06H4 (downstream of D06H3) to collimate the beam passing through D06H3.

Structure of collimator for horizontal (a) and vertical (b)

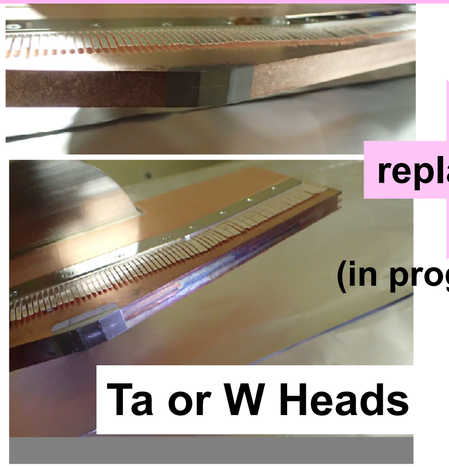
(a)



(b)

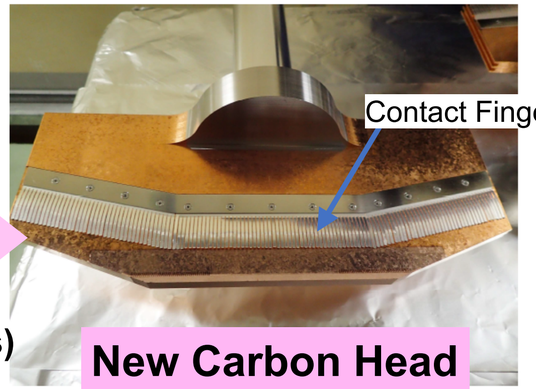
D06H3 collimator

Extracted Head from D06H3



replace

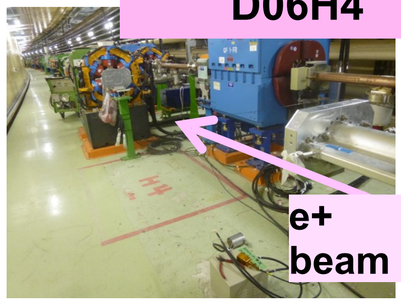
(in progress)



New Carbon Head

(wider head for robustness)

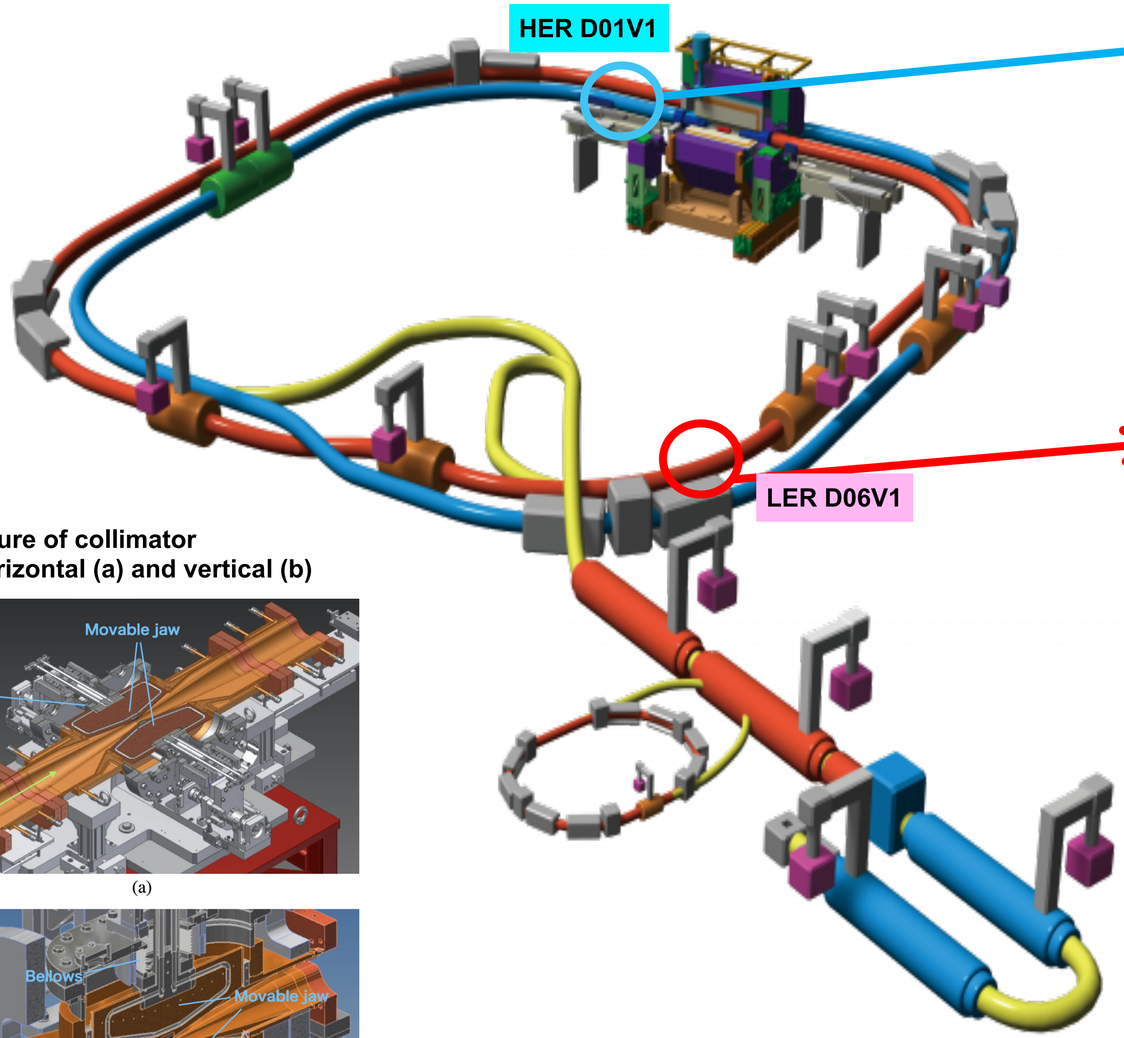
D06H4 **relocated from D06H1**



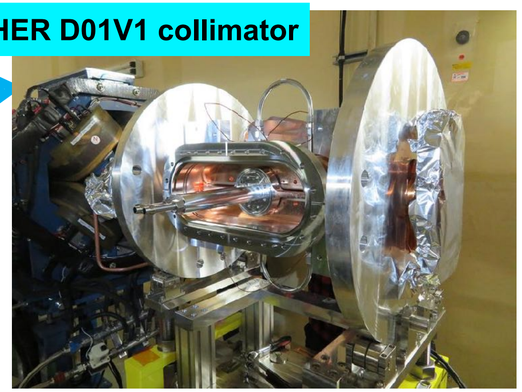
For details of the collimators, refer to "T. Ishibashi et al. Phys. Rev. Accel. Beams 23, 053501 (2020)"

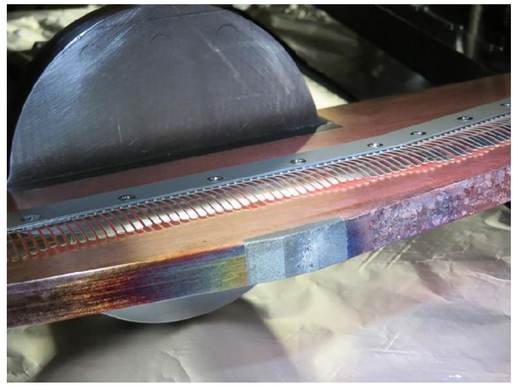
Damaged Collimator Head Replacement

in progress

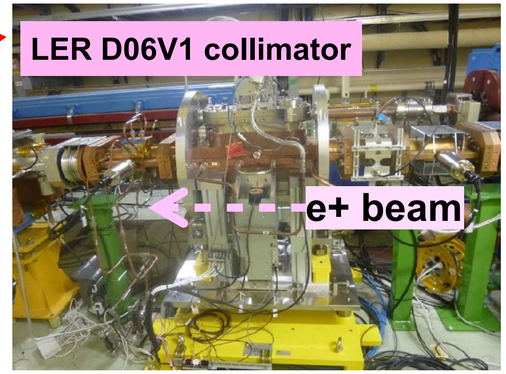


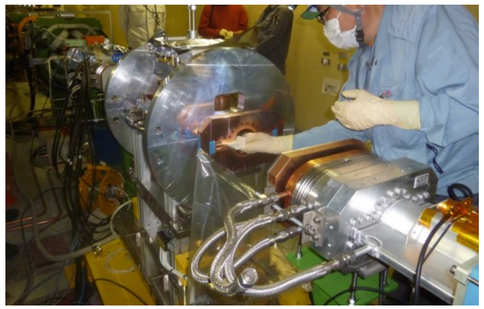
HER D01V1 collimator





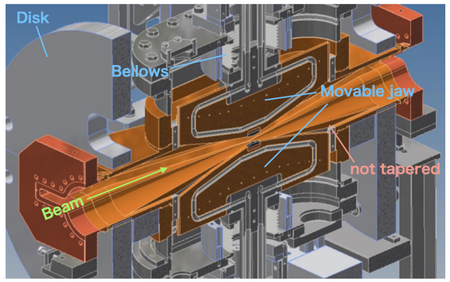
LER D06V1 collimator



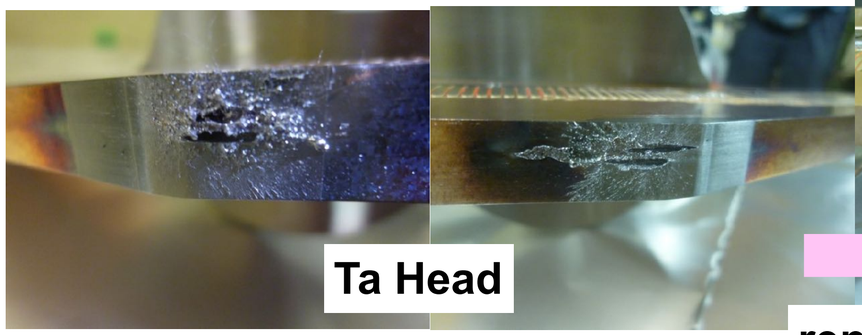


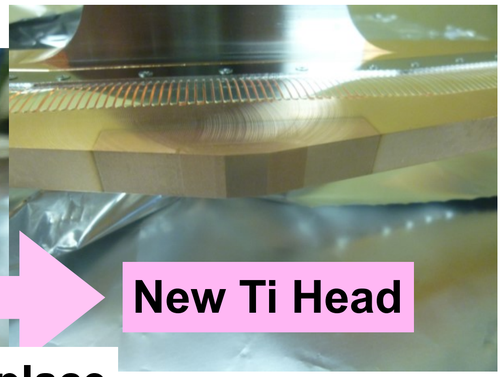
Structure of collimator
for horizontal (a) and vertical (b)

(a)



(b)





replace

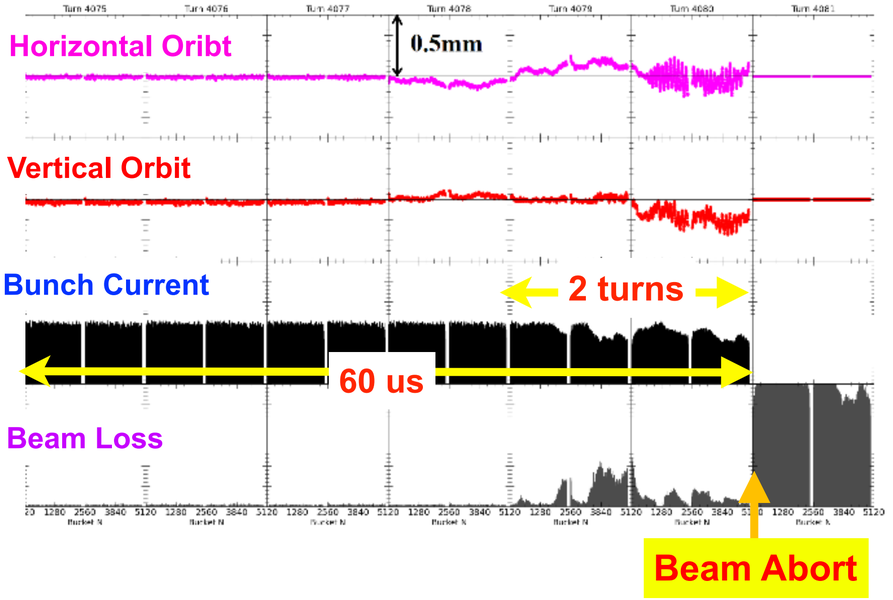
Sudden Beam Loss (SBL)

One of the major concerns for the operation

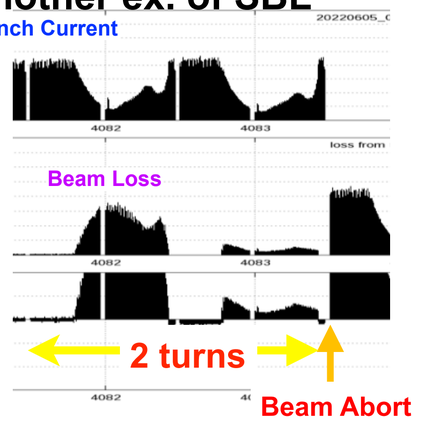
Sudden Beam Loss (SBL)

An obstacle for high luminosity of $10^{35}cm^{-2}s^{-1}$ is sudden beam loss (SBL).

- Frequently, (10~20% of all aborts)
  the beam suddenly disappears just before the abort.
  This is very rapid phenomenon within few turns.
  (1-turn = revolution period = 10us)
- <u>The cause of SBL is still unknown.</u>
- Harmful effects of SBL;
  - Damage to collimators and other accelerator components,
  - Quench of the final focusing superconducting magnets (QCS),
  - Large backgrounds to the Belle-II detector,
  - Inability to store high current due to beam abort.
    →A task force was established to investigate and resolve the causes of SBL.
- We continue to review the data before LS1 from various aspects.

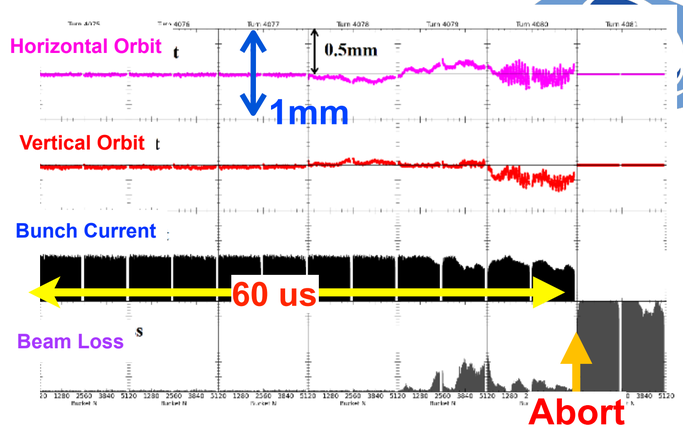


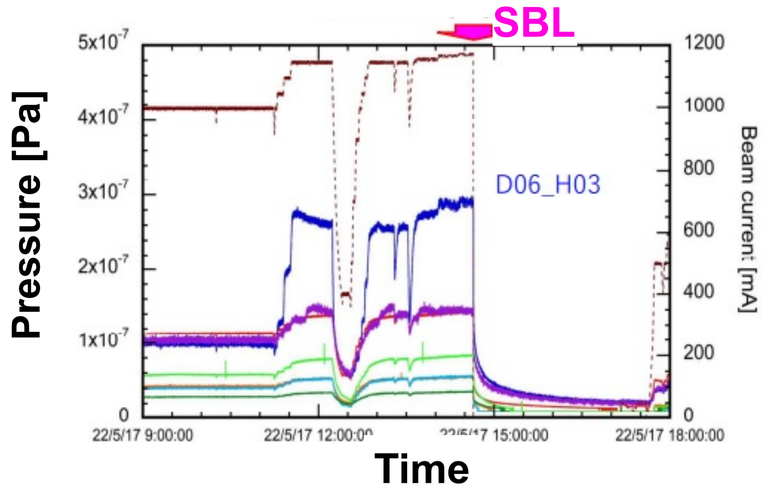
Another ex. of SBL

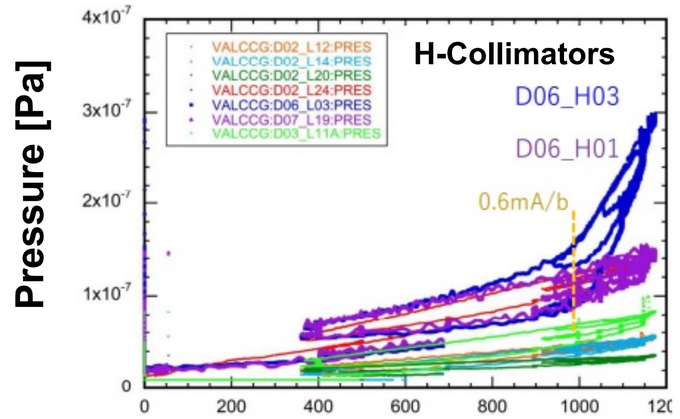


SBL : Observation (more details)

- The beam suddenly disappears just before the abort.
- Beam loss occurs in both HER and LER, but the damage to the hardware is particularly large when loss occurs in LER.
- We don't know if it will happen even with a single beam or low current beam because we haven't operated for a long time.
- The starting point of beam loss depends on the tuning of the collimator and is not limited to a specific location.
- Just before the beam loss begins, the orbit appears to move, but its value is small～O(0.1 mm).
  - The orbit is changing < O(1mm) after the beam loss.
  - No oscillations, which could be precursors to beam loss, are observed.
- Pressure bursts have been observed all over the place. (They rarely occur in the same place except at the collimator section.)
- Regarding the pressure of D06H3 and H1 collimators, there are rapid or nonlinear increase of pressure depending on the beam current.







Candidates for Reason of SBL

(Supposition of the reasons: none of these candidates are proved)

- **Damage of vacuum component (RF Finger) @KEKB & PEP-II**
  - Beam phase changes (beam energy losses) observed ms to several hundred μs before aborts.
    → The time scale differs from that of SBL.
  - Abnormal temperature rise at bellows chambers had been observed and the catastrophic damages in the RF-finger had been confirmed. → We could not find that damage.
- **Dust : Early stage @ SuperKEKB**
  - Vacuum chambers were cleaned or tapped to remove as much dust as possible.
- **Electron Cloud**
  - SBL should be measured only in LER.→ SBL is also measured in the HER beam.
  - Curious behavior of the pressure in D06H3 collimator may suggest the formation of a discharge or electron cloud.
  - Simulations show that the electron density distribution changes with time and a maximum electron density is on the order of 1E13/m3 to 1E14/m3 → How this relates to SBL?
- **Fireball (Measured @ RF cavity):**
  Microparticle heated by beam-induced field may cause plasma-growth or vacuum arc at metal surface.
  - The vacuum chamber is made of copper with low sublimation point and collimator head is made of tungsten or tantalum with high sublimation point.
    → The situation has the potential for a fireball to be formed.
  - This fireball hypothesis could explain SBL (~μs) due to the fast plasma evolution (~100 ns at the fastest)

Works during LS1 for SBL (in progress)

- Replacing damaged collimator head.
- Copper coating of collimator heads.
- Applying an external magnetic field of 40G or higher to collimator head.
- Enhancement of monitors (acoustic sensor, loss monitor, beam oscillation recorder...) .
- Simulations of plasma and beam interactions (Study for fireball hypothesis).

are in progress.

Investigation of SLB has to be continued…

Summary

- **Many upgrade & maintenance works are progressed during LS1.**
  - LS1 started in July 2022 and will end in November 2023.
  - Next beam operation is scheduled to restart in December 2023.

- **Progress of “IR works” & “NLC construction” were reported.**
  - And also, damaged collimator heads were replaced with new ones.
  - Most planed works will be completed by October 2023.
  - Beam operation will resumed from December 2023.

- **Sudden Beam Loss (SBL) is one of the concerned issues to be solved.**
  - Frequently, the beam suddenly disappears within few turns just before the abort.
  - The cause of SBL is still unknown. (Several candidates for the cause are considered.)
  - Continuation of investigation or study of SBL is needed to avoid it.

Thank you for your attention.

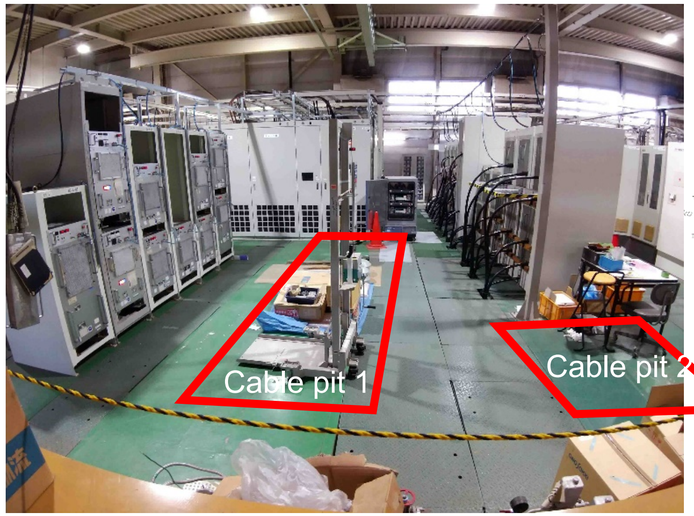
B2GM 2023.6.5

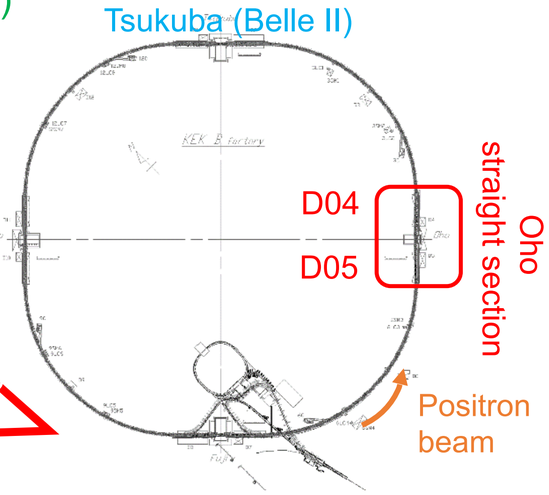
Backup Slides

Remaining Works for NLC

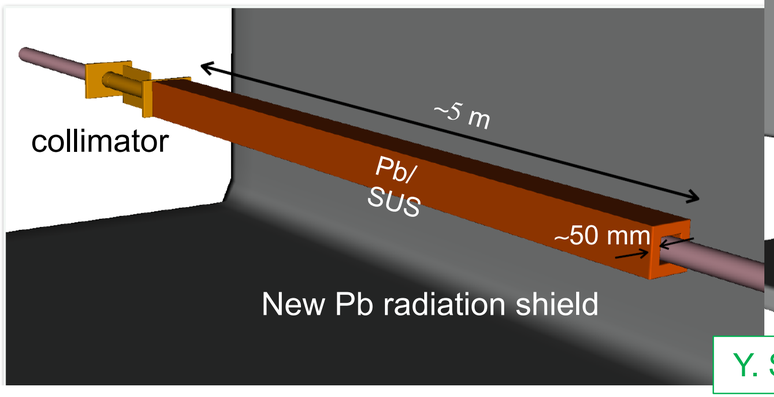
- **Required works for NLC construction**
  - Collimator relocation from D03V1
  - Q magnet relocation (done) and alignment
  - Skew sextuple magnets installation
  - Beam pipe installation
  - Installation of new power supplies
  - Magnet cabling works
- **Radiation shielding enhancement**
  - Production & installation of new Pb radiation shields
  - Production & installation of additional concrete shields
  - Reinstallation of concrete shields

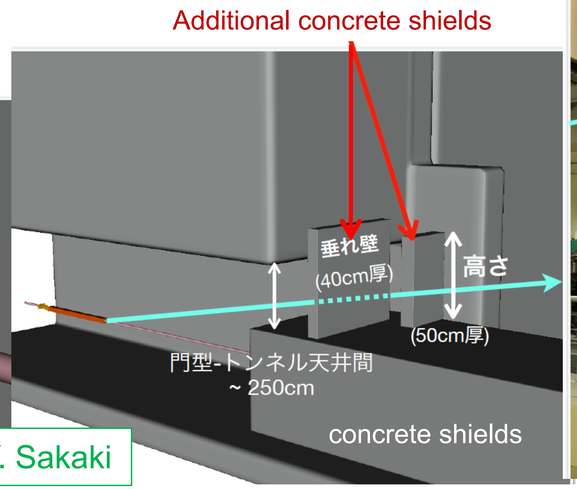
Magnet power supply room (ground level)



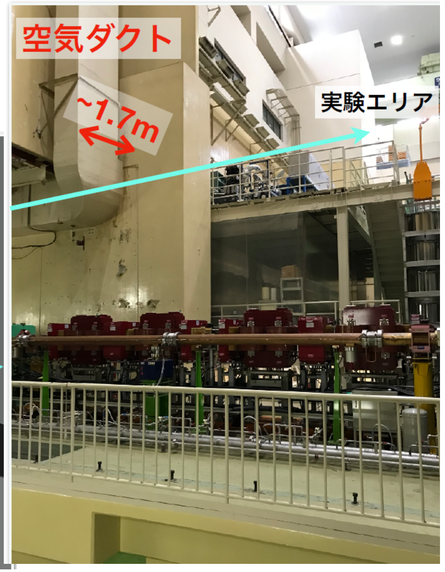


S. Nakamura





Y. Sakaki



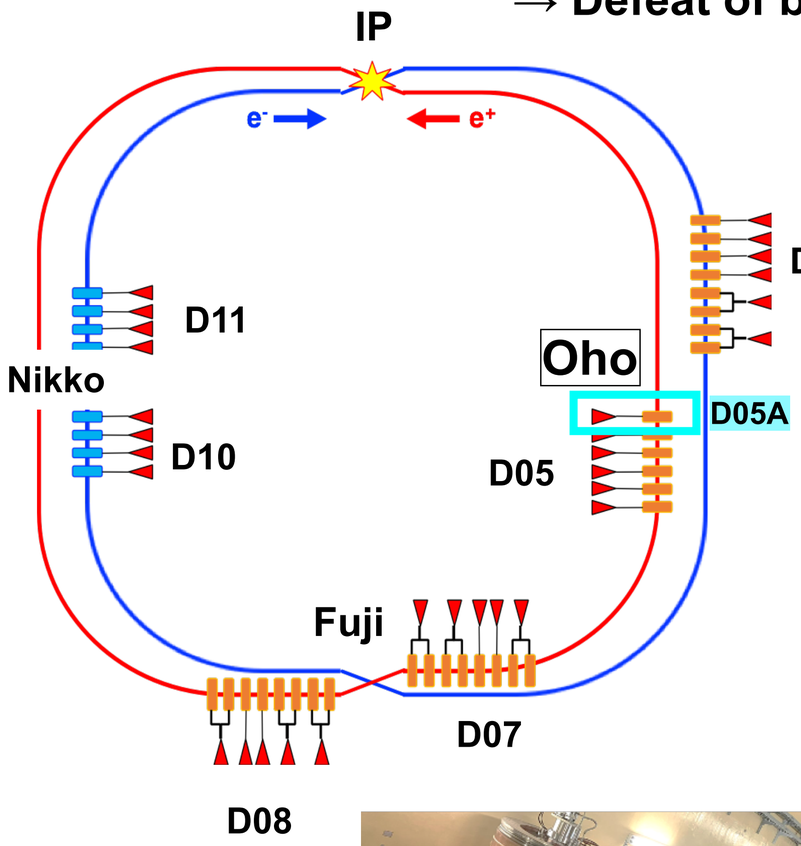
RF Cavity Replacement @ D05A

T. Abe

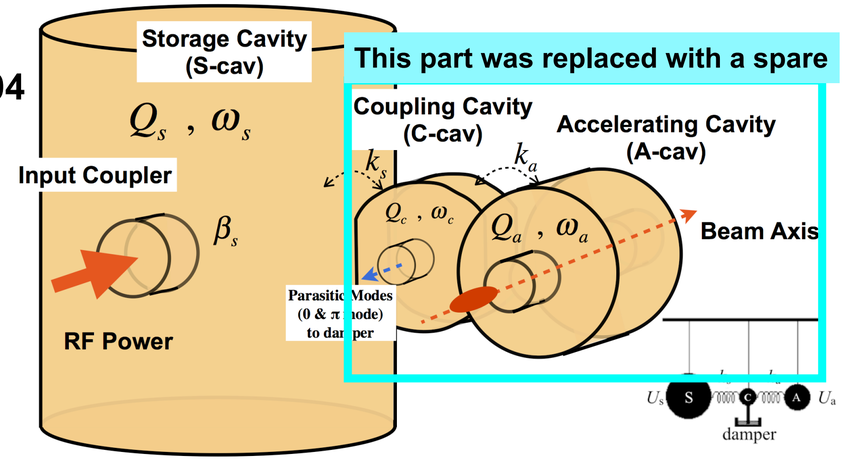
Breakdown often occurred at D05A cavity. (down rate was high at D05A)

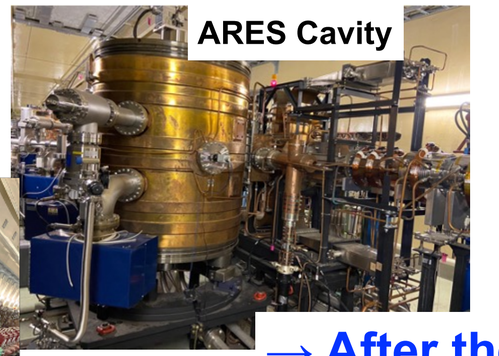
→ Defeat of brazing was found in the coupling cavity. → Replaced

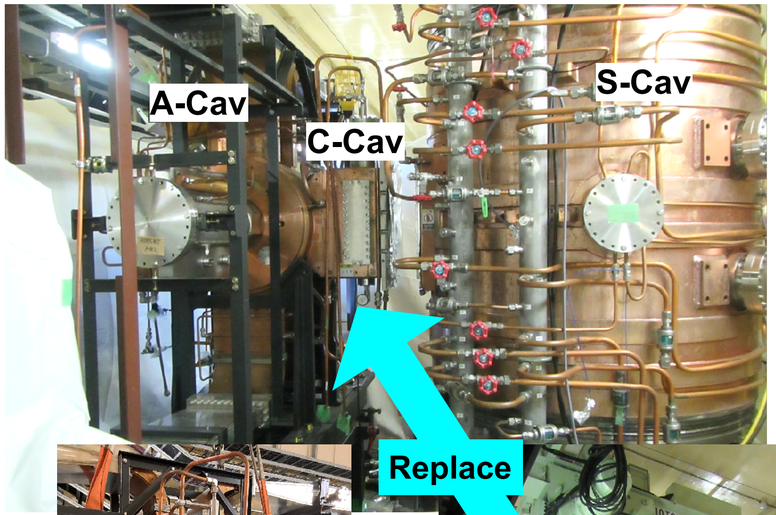
Done Feb. 2023



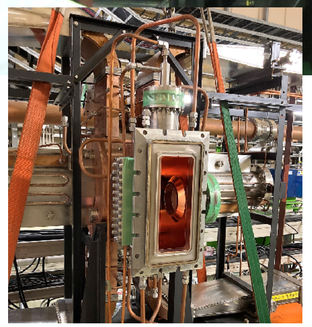
ARES Cavity (normal conducting)







Replace



S-C connection flange

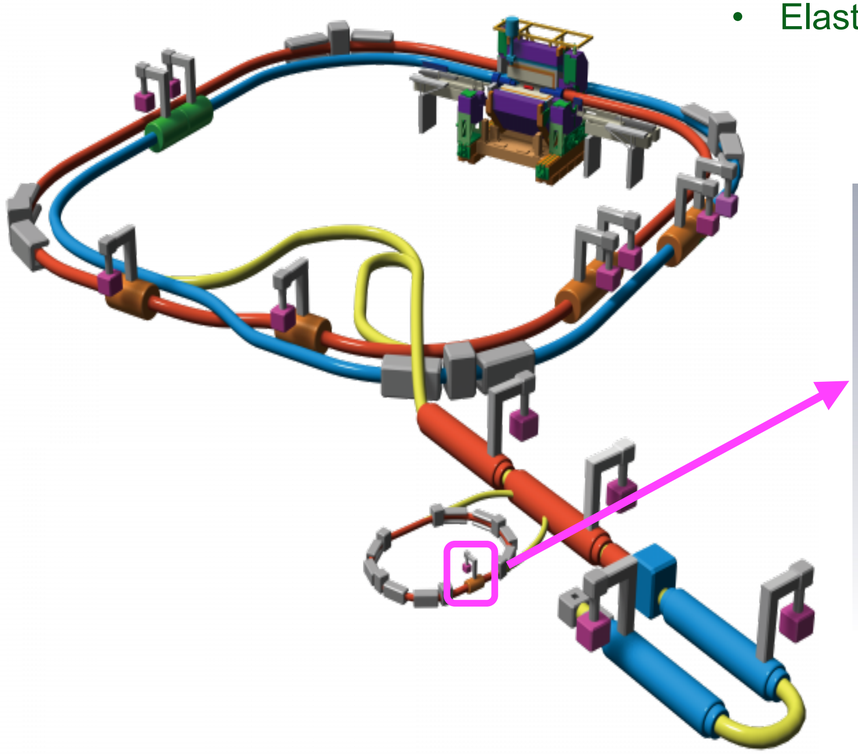
→ After the replacement,
RF conditioning was successfully done in April 2023 (No problem was found).

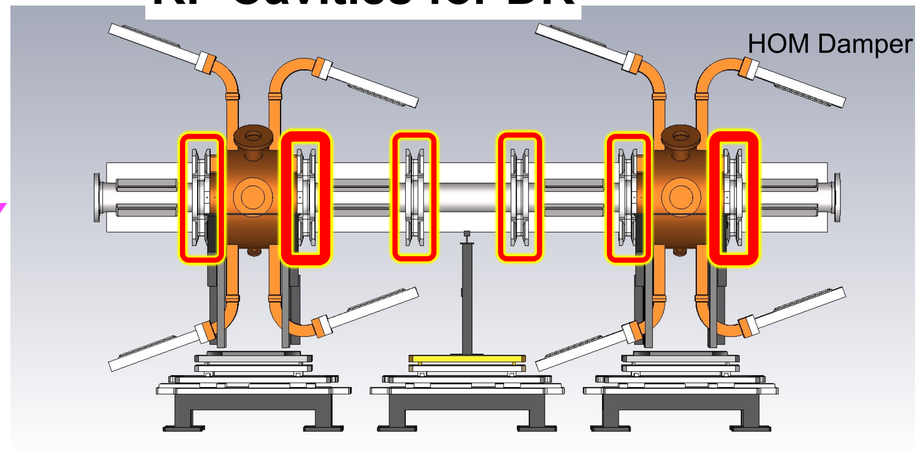
Vacuum Seal Replacement @ DR RF section

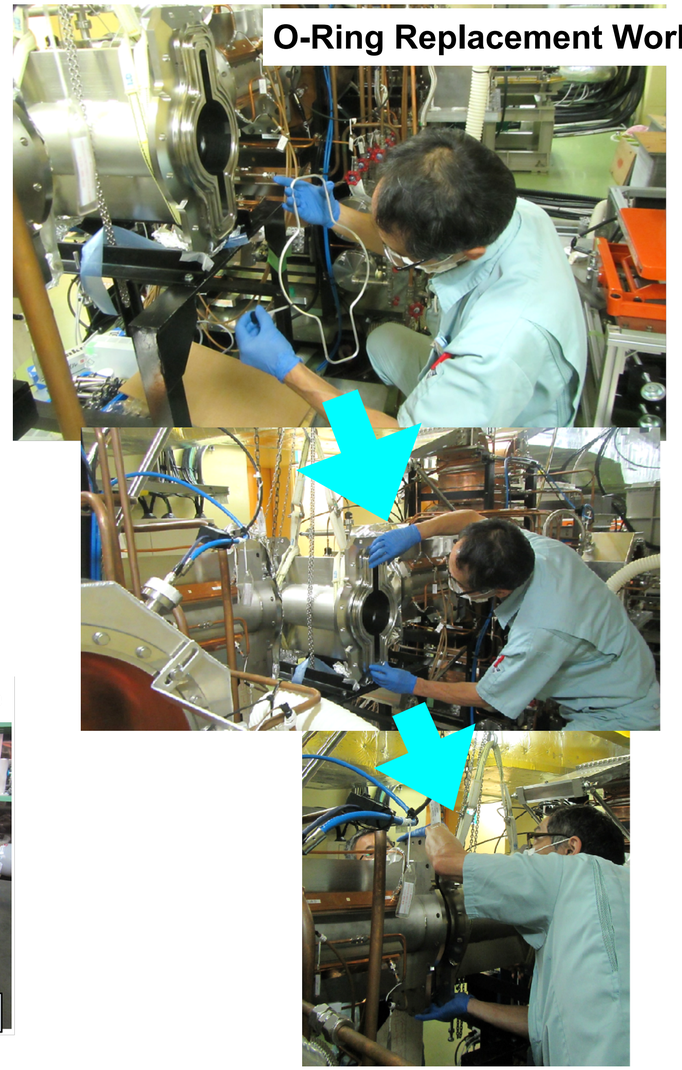
- Vacuum seal replacement at RF section (DR).....Done!
  - For pressure reduction
    - Elastomer gaskets were replaced with metal gaskets for dummy pipe connections.

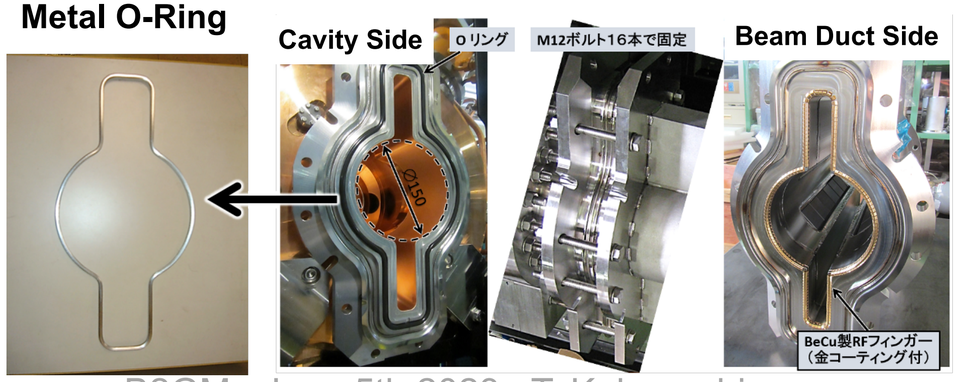
Done in 2022

T. Abe







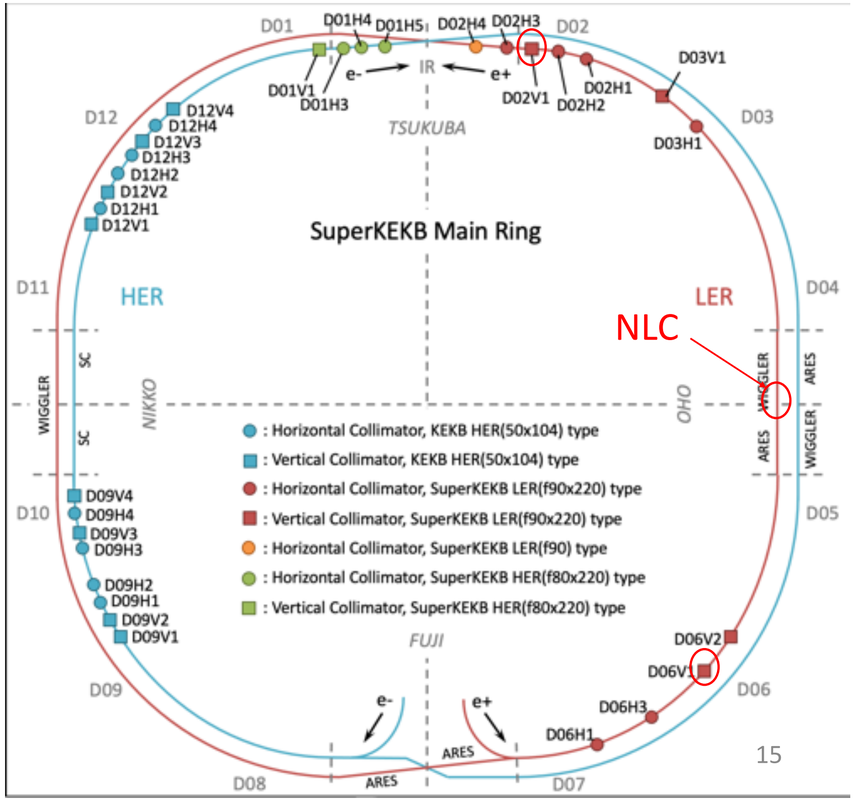


Plan – Non-linear collimator at LER OHO section

T. Ishibashi, IAS Program on HEP 2022

- Present collimator setting (2021ab)
  - D06V1: primary collimator: most tightly closed and suppresses the injection BG.
  - D02V1: second collimator: closest vertical collimator to IP and very important to suppress BG
  - D06V2, D03V1: backup: not so tightly closed. D03V1 can be used for a backup of D02V1.

- If we can replace D06V1 collimator with non-linear collimator (NLC) for example, the $\Sigma\beta_y k_y$ dramatically decreases.
  (βy: vertical beta function, ky: vertical kick factor)



Plan – Non-linear collimator at LER OHO section

T. Ishibashi, IAS Program on HEP 2022

- Collimator setting (half-aperture) during physics run in 2021b (βy*=1 mm)

	β_y [m]	2021-06-30 [mm]	2021-07-02 [mm]
D06V1 top	67.3	3.06	3.84
D06V1 bottom		-2.65	-2.65
D06V2 top	20.6	2.27	2.25
D06V2 bottom		-2.26	-2.24
D03V1 top	17.0	8.00	7.99
D03V1 bottom		-8.00	-7.99
D02V1 top	13.9	1.30	1.71
D02V1 bottom		-1.14	-1.35
NLC@OHO	2.9	5.7	5.7

- The β_y at the D06V1 is large, and the aperture is narrow.
- The β_y at the NLC is small, and the aperture is wide.

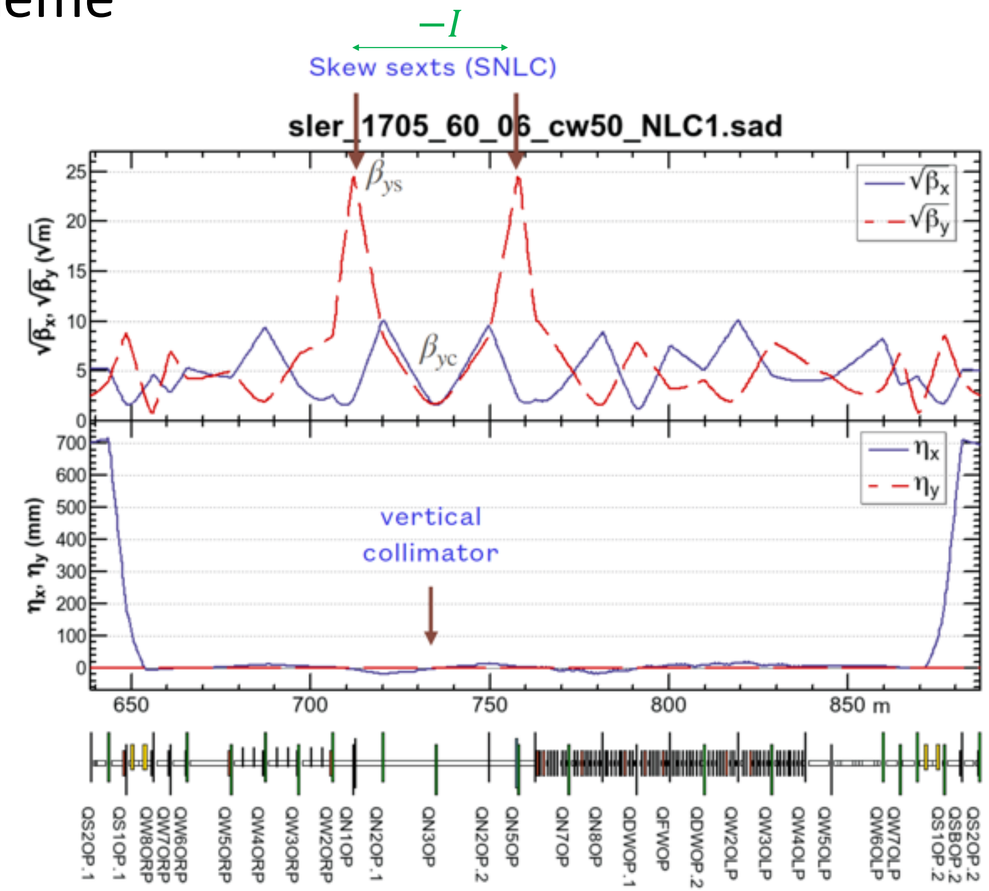
→ We could dramatically decrease the $\Sigma\beta_y k_y$ if we can replace D06V1 with NLC.

Plan – Non-linear collimator at LER OHO section

T. Ishibashi, IAS Program on HEP 2022

- Scheme

[K. Oide]



L_{sc}

$\Delta\mu_y = \frac{\pi}{2}$

Here the collimator is placed right before the center quad (QN3OP).
If the quad is split into two pieces, the collimator can be placed in the middle of them.

June 17, 2021 K. Oide

Requirements for the NLC optics:

- Large $\beta_y = \beta_{ys}$ at the (skew) sextupole.
  - $\beta_y = \beta_{yc}$ at the collimator: $\sqrt{\beta_{yc}\beta_{ys}} \approx 1.7 \times L_{sc}$
- A (skew) sextupole pair connected by a $-I$ transformation.
- No dispersion at the sextupoles and the collimator.
- ≈ 0.25 vertical phase advance between the sexts and the IP.

Five sections of wigglers are removed!

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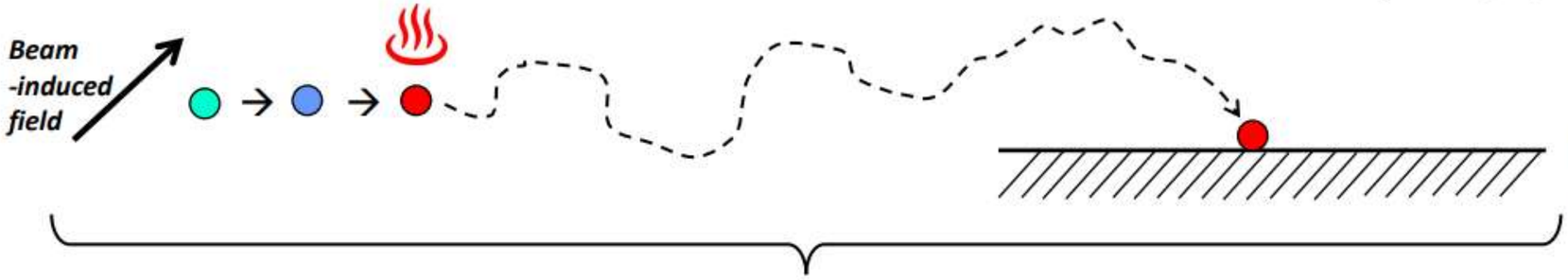
Fireball Hypothesis

T. Abe

Physical process of the "Fireball" hypothesis, leading to fast beam loss

① A microparticle with a high sublimation point is heated by the beam-induced field.
➔ **Fireball**

② The fireball touches some metal surface with a low sublimation point (e.g. copper).



Order of ~s or longer

③ Plasma is generated around the fireball.

Eating the RF-field energy

④ The plasma grows up into a macroscopic vacuum arc, possibly leading to significant interactions with the beam particles.

Order of ~100 ns at the fastest

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(T. Abe)