Status of Accelerator Upgrades during LS1

BPAC

Kyo Shibata (KEK Accelerator Laboratory)

2023.06.26

Contents

- Upgrade items during LS1
- MR upgrade
- Injector Linac upgrade
- Others
- Summary

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Upgrade Items

- To overcome challenges of accelerators, upgrade works are undergoing now.

Challenges as Lumi. Frontier machine

1. Short beam lifetime
2. Beam instabilities
3. Low machine stability
4. Low Injection efficiency

Luminosity after LS1 : ~2.4×10^{35} $cm^{-2}s^{-1}$

- ✓ Increasing total beam currents
- ✓ Increasing bunch current
- ✓ Squeezing β_y^*

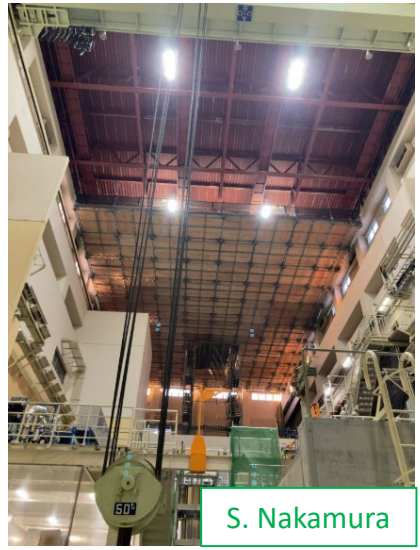
Major upgrade items

- Radiation shield enhancement at IR
- Non-linear collimator with low impedance in LER
- Robust collimator head in LER
- Modification of HER injection point
- Pulsed quad. magnet at Linac
- New accelerating structure at Linac
- Fast kicker for 2nd bunch orbit correction at Linac
- Magnet alignment at BT
- Etc.

Schedule

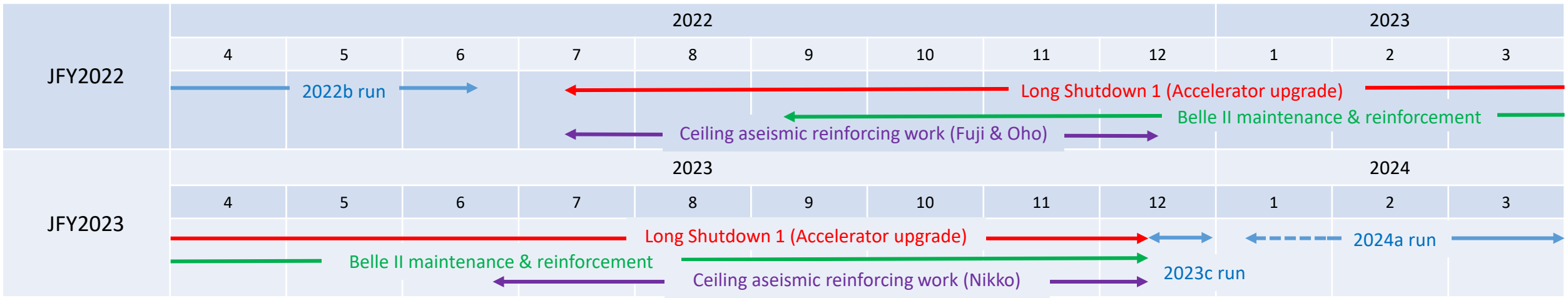
- LS1 : from July 2022 to December 2023
  - 2022b run stopped earlier than planned due to high electricity costs (22nd June), but LS1 major works began on 11th July as scheduled.
  - Beam operation will restart from December 2023.
- Major works during LS1 other than accelerator upgrade:
  - Belle II 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 ceilings in the laboratory buildings (Oho Lab., Fuji Lab. and Nikko 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

LS1 schedule



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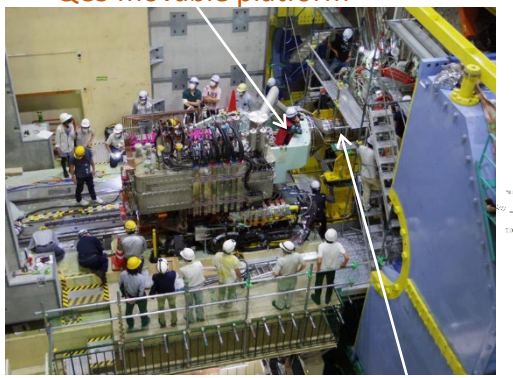
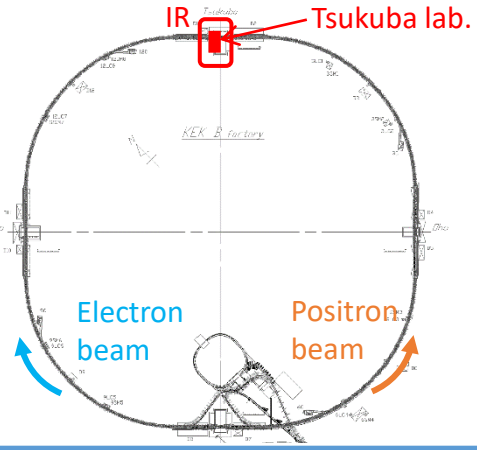
IR (Tsukuba straight section)

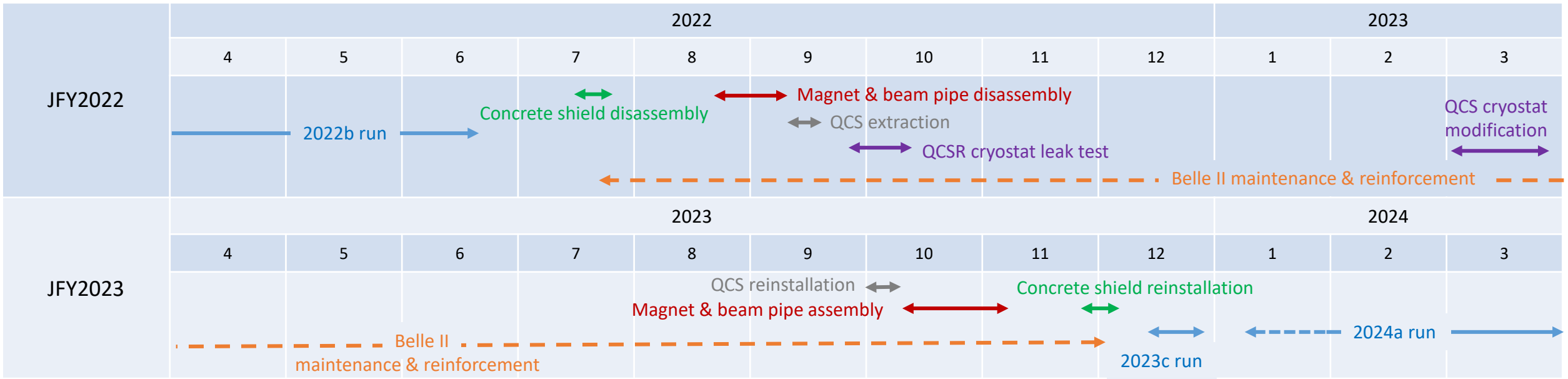
- Major work items in accelerator tunnel:
  - Disassembly and reinstallation of concrete radiation shields
  - Belle II maintenance & reinforcement work
  - Disassembly and reinstallation of magnets, beam pipes for QCS work
  - QCS extraction & reinstallation
  - QCSR cryostat leak test
  - QCS cryostat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

← Reported in this talk



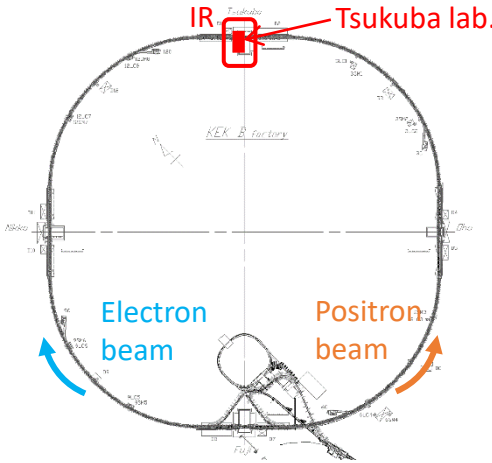


IR (Tsukuba straight section)



QCS cryostat modification #1

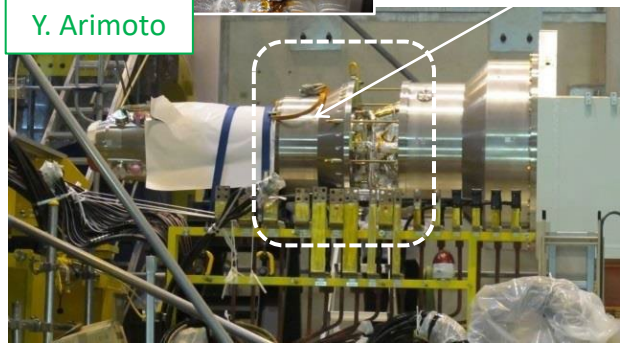
- To reduce Belle II background noise;
  - Material at the tip of QCS cryostat was changed from W to SUS
- To make more space for Belle II cables;
  - QCSR cryostat tip shape was modified to be thinner
- For these upgrades
  - FWD side : QCSR cryostat front cap replacement, Modification of inner structure of QCSR cryostat to fit thinner front cap
  - BWD side : QCSL cryostat front plate replacement



BPM feedthrough

QCS beam pipe

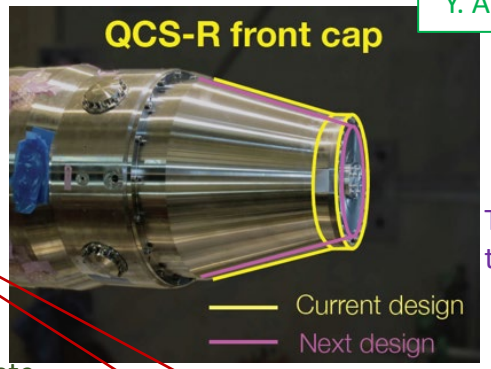
Y. Arimoto

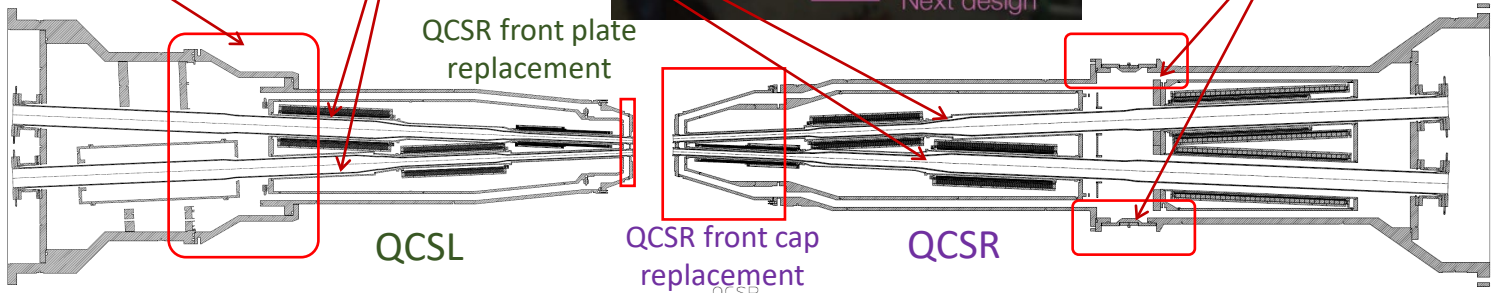


To access QCS pipes & BPMs, this part should be disassembled.

QCS beam pipes must be moved for these works!!

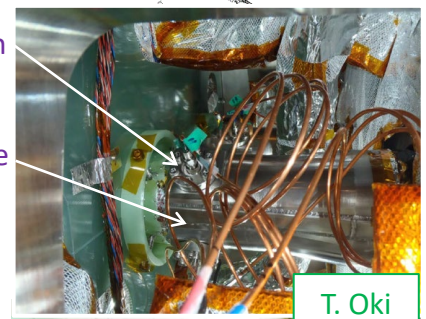
Y. Arimoto





To access QCS pipes & BPMs, these windows should be open.

BPM feedthrough



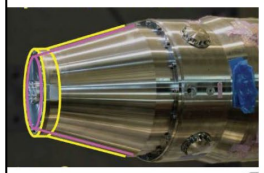
QCS beam pipe

T. Oki

QCS cryostat modification #2

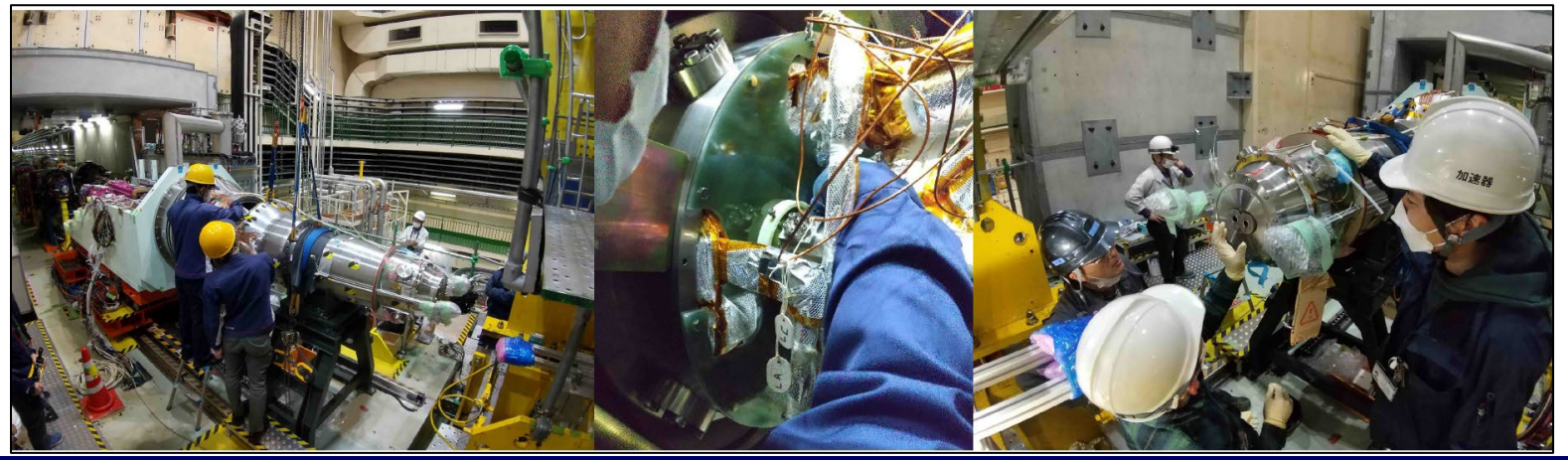
- QCS cryostat modification works were successfully completed.

QCSR(2/5)



QCSR(5/5)

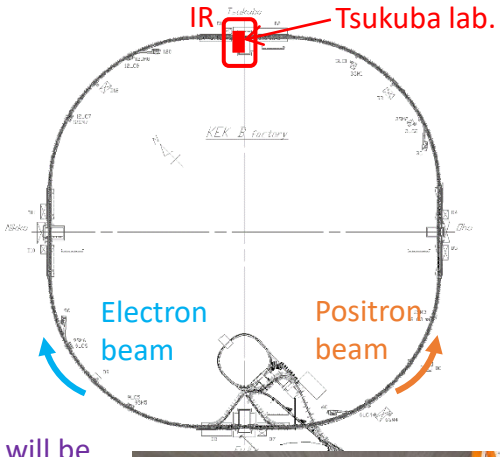
QCSL

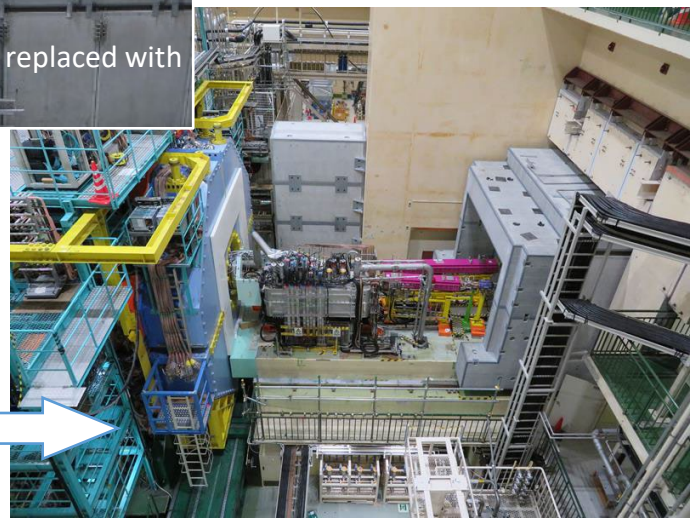


T. Oki

New concrete shields

- New concrete shields have been delivered to Tsukuba experimental hall.
  - Concrete radiation shields were temporarily removed for IR works.
  - They will be reinstalled in ~~mid September~~ November 2023.
  - To suppress background noise of Belle II, 2 concrete shields will be replaced with new ones.

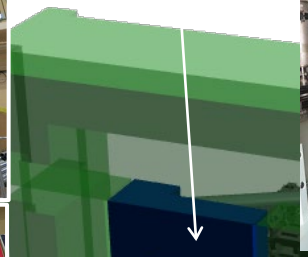




Concrete shield disassembly work

This photo was replaced.

This space will be filled with concrete.

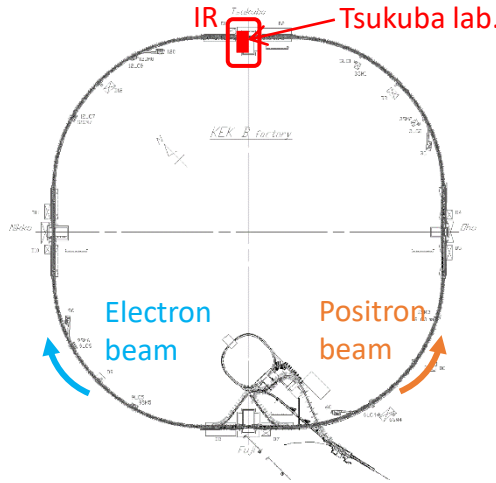


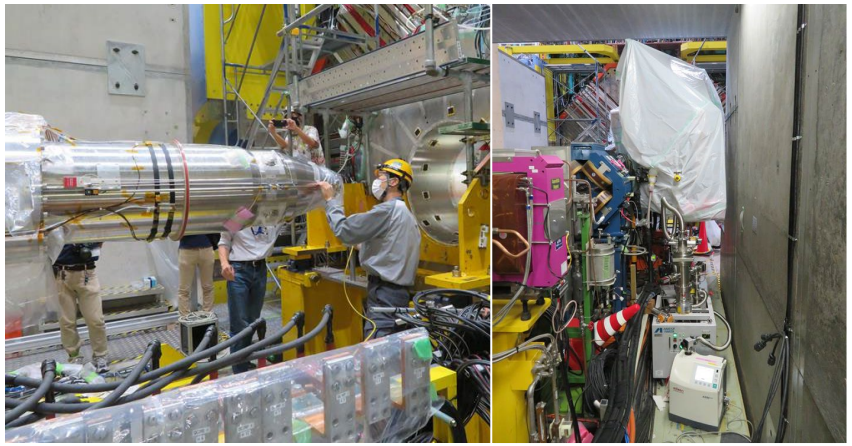
New concrete shields

H. Yamaoka

Vacuum leak repair at QCSR cryostat

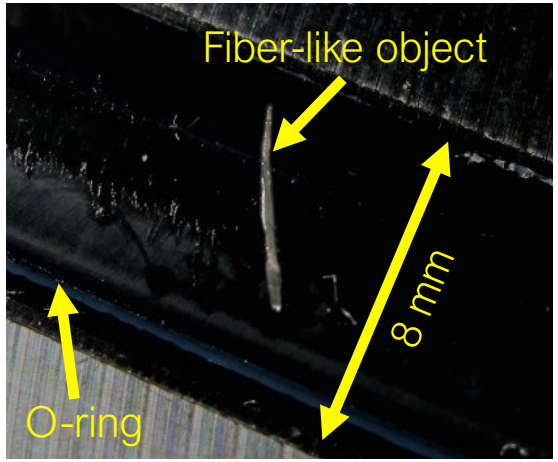
- Pressure in QCSR cryostat has been higher than that in QCSL cryostat.
  - Vacuum leak test before LS1 did not detect any vacuum leaks.
  - Location of the vacuum leak was identified by the vacuum leak test after QCS extraction!!
- Repair works were made at the same time as the cryostat modification works.
  - Service cryostat at QCSR was opened to check the vacuum sealing (O-ring), and a fiber-like object was found on the O-ring surface.
  - O-ring was replaced with new one.
  - Vacuum sealing surfaces were cleaned.





Vacuum leak test of QCSR cryostat

Y. Arimoto

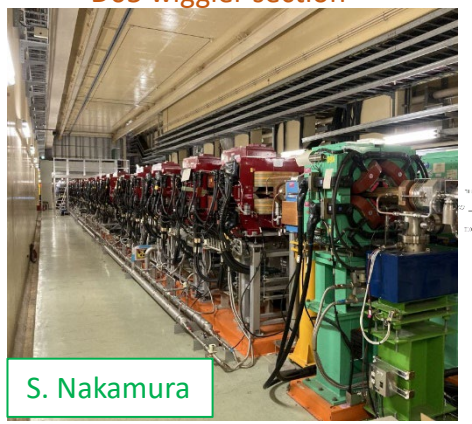


Oho straight section

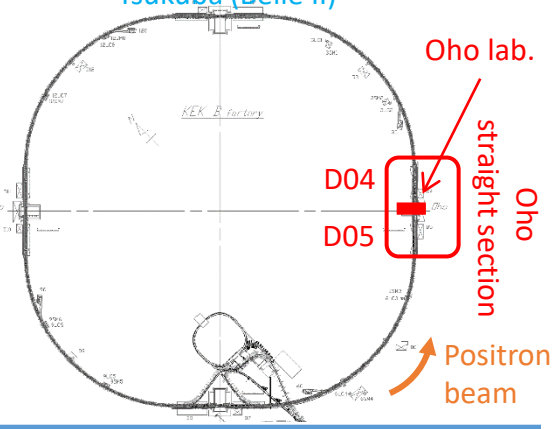
- Major work items in accelerator tunnel:
  - Disassembly and reinstallation of concrete radiation shields
  - NLC construction (LER) ← Reported in this talk
  - RF cavity replacement (LER)
  - Ceiling aseismic reinforcing work
  - Installation of new radiation shields for NLC

Concrete radiation shield

D05 wiggler section



Tsukuba (Belle II)



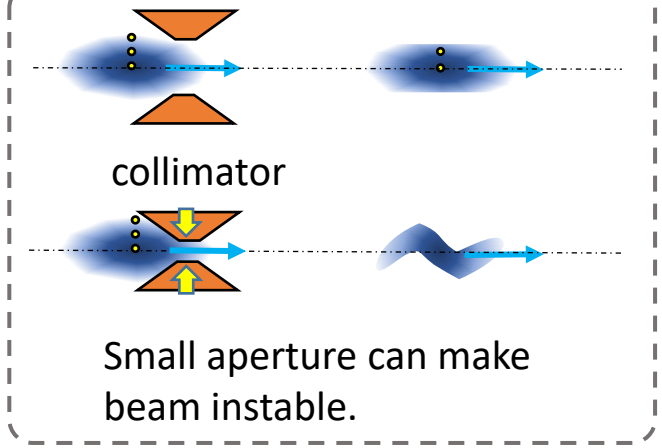
Oho straight section (D05)

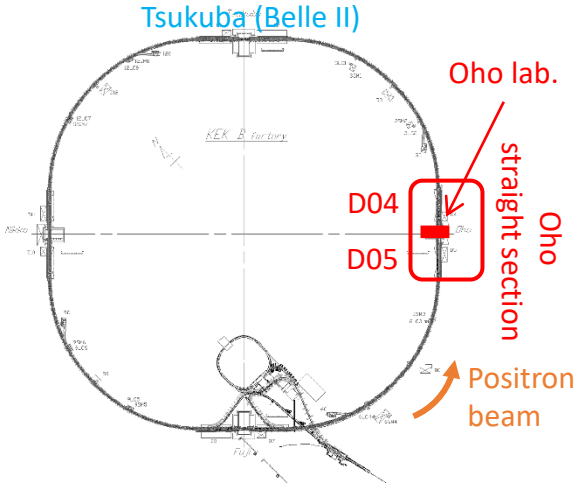
	2022									2023		
	4	5	6	7	8	9	10	11	12	1	2	3
JFY2022		2022b run		Concrete shield removal	RF cavity inspection		NLC construction			RF cavity replacement		
					Crane not available							
					Ceiling aseismic reinforcing work							

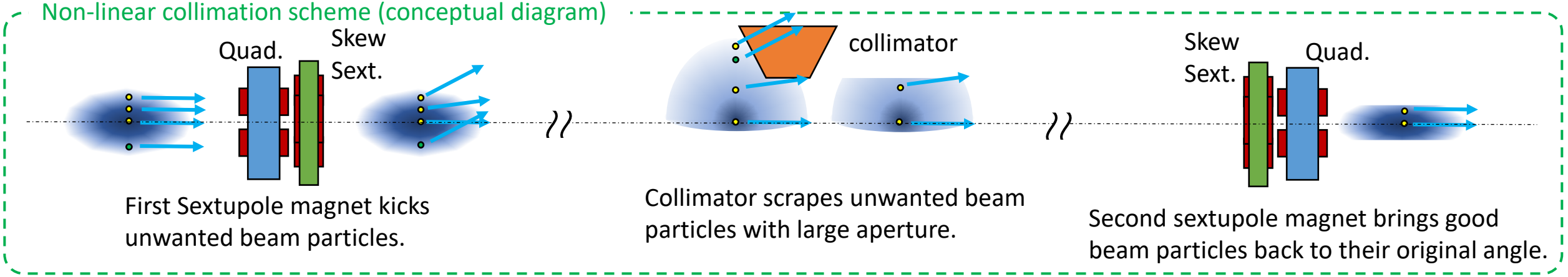
	2023									2024		
	4	5	6	7	8	9	10	11	12	1	2	3
JFY2023	NLC construction											
						New radiation shield installation		Concrete shield reinstallation	2023c run		2024a run	

NLC construction #1

- 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.



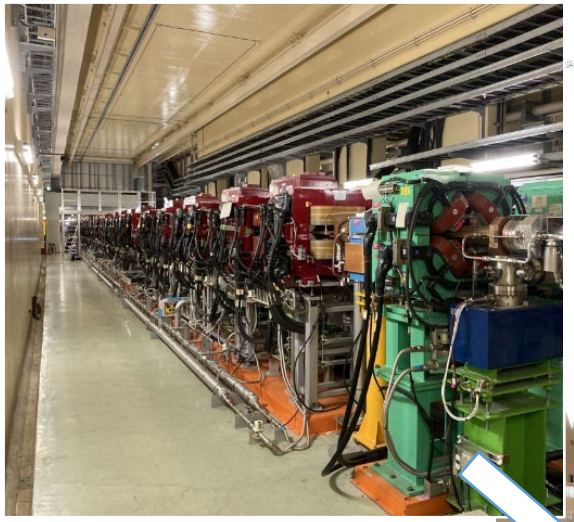


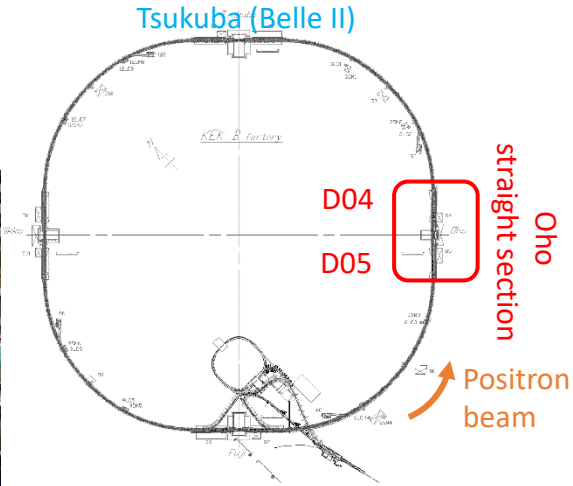


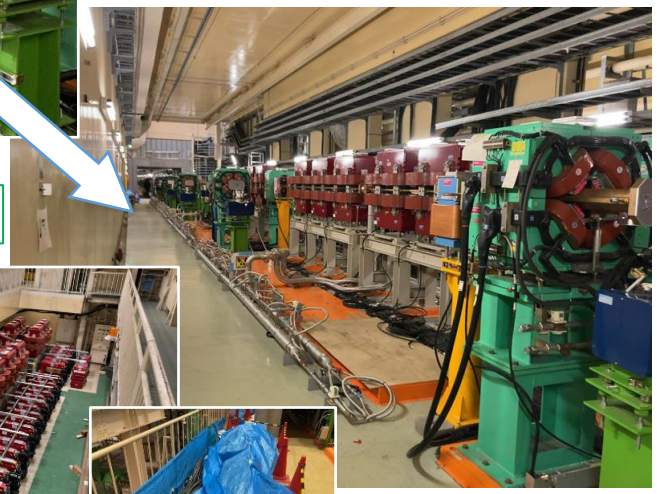
NLC construction #2

- Wiggler magnets and beam pipes were removed.
  - 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 removal

10 times







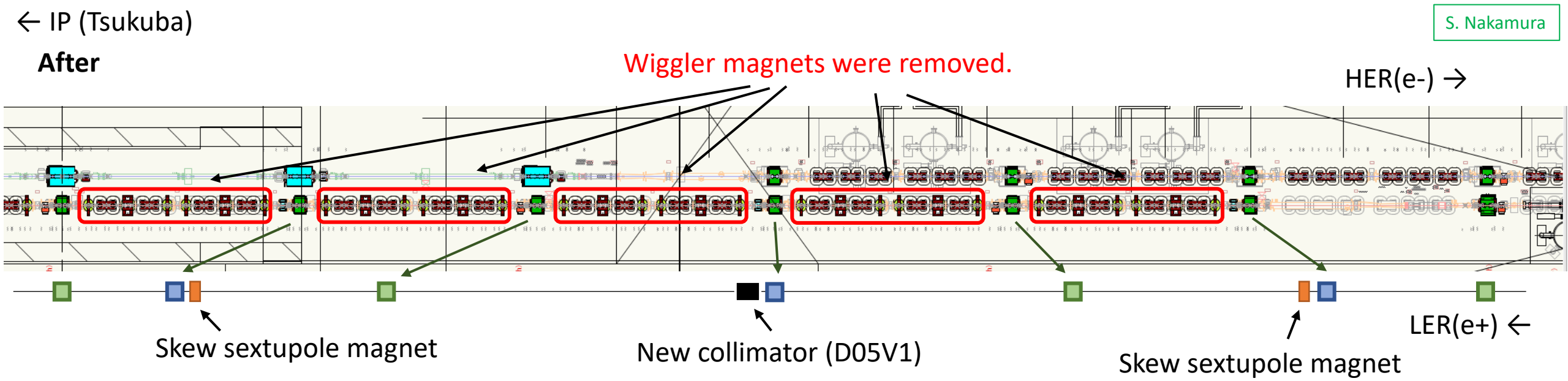
S. Nakamura

Wiggler beam pipe removal work

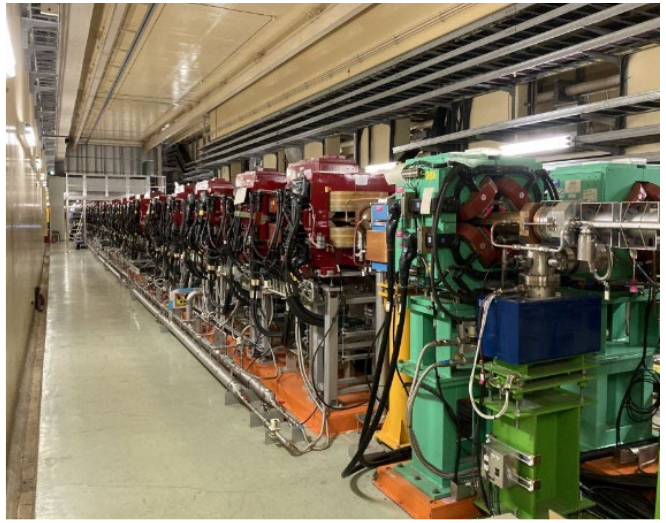
NLC construction #3

- Relocation of the quadrupole magnets and re-wiring between the power supply and the magnets have been completed.
  - New skew sextupole magnets and one power supply will be installed in September.
- Collimator and almost all beam pipes have been installed.
  - Collimator D05V1 was relocated from D03V1.
  - Beam pipes for the skew sextupole magnets will be installed after skew sextupole magnet installation.

S. Nakamura



NLC construction #4



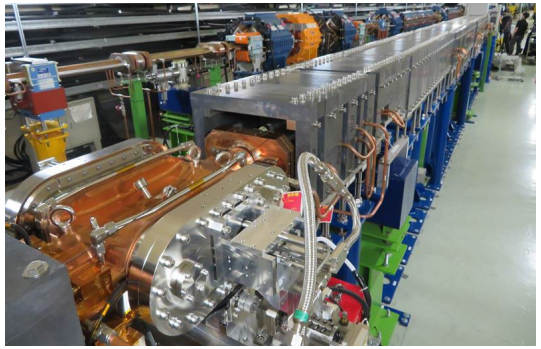
Skew sextupole magnet and beam pipe will be installed here.

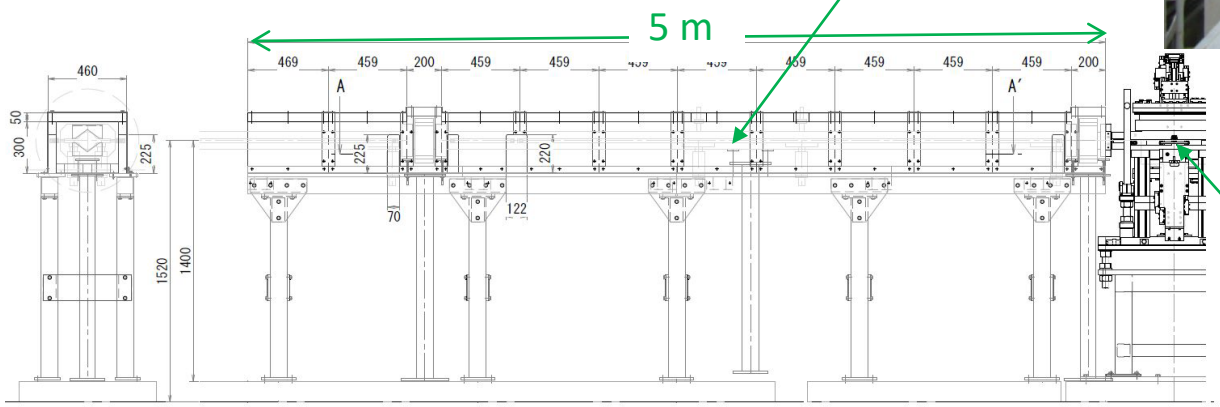
Skew sextupole magnet and beam pipe will be installed here.

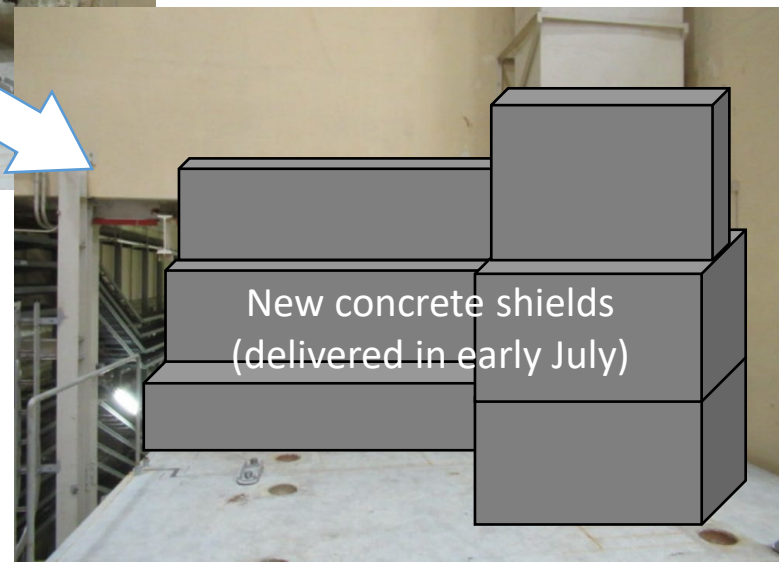
NLC construction #5

- New radiation shields are required to protect Oho experimental hall.
  - New Pb radiation shields will be installed 5m-downstream region of D05V1. (Octorber)
  - New concrete shields will be installed to fill the space between the SuperKEKB tunnel and the existing concrete shields. (November)

Pb shield at Tsukuba straight section

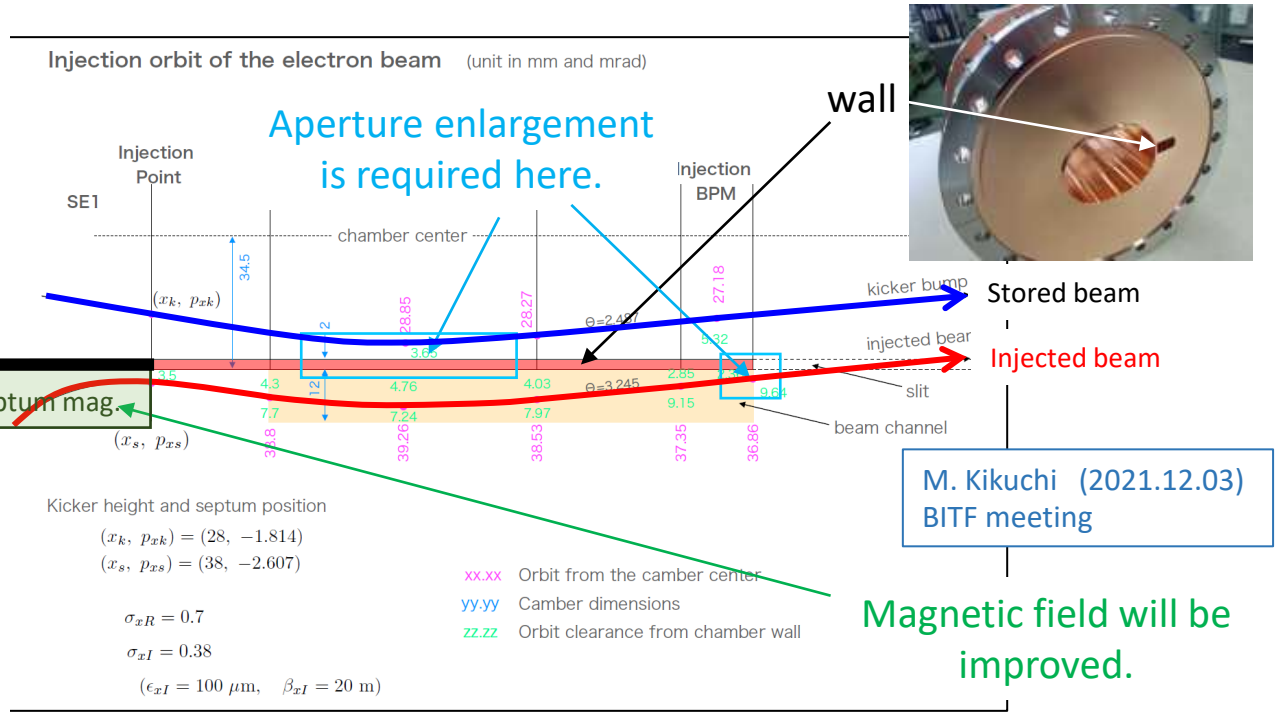






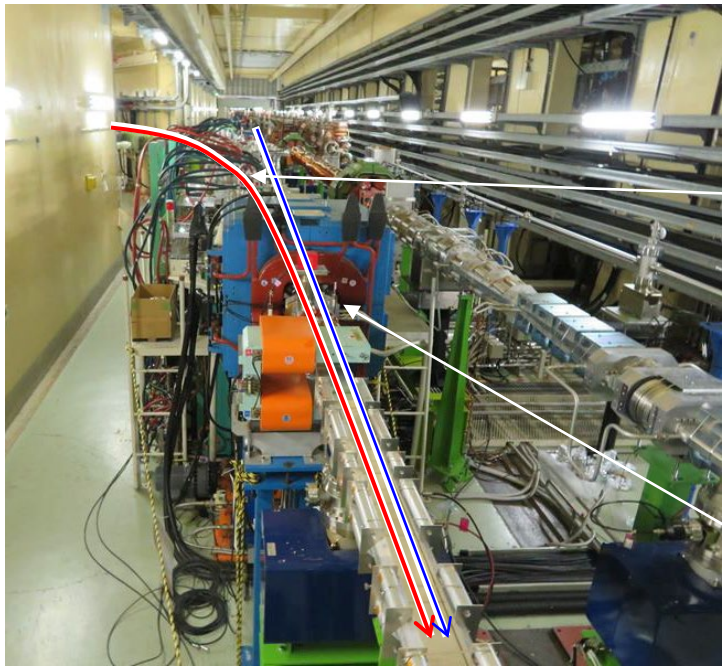
HER injection point

- Required upgrade to improve HER injection efficiency (what we have learned from beam operation until 2022b);
  - Enlargement of the horizontal aperture of beam pipe
  - ⇨ Replacement of beam pipes at injection point with new one with larger aperture (last week)
  - Reduction of amplitude of horizontal oscillation of injected beam
  - ⇨ Replacement of injection septum magnet with new one with improved magnetic field (Oct.)



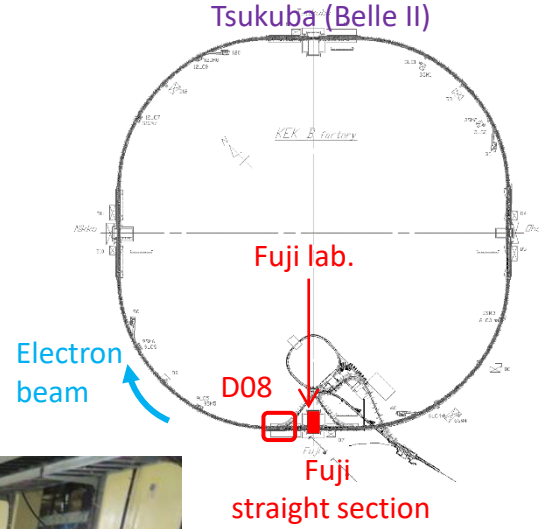
M. Kikuchi (2021.12.03)
BITF meeting

Magnetic field will be improved.



Septum mag. will be replaced.

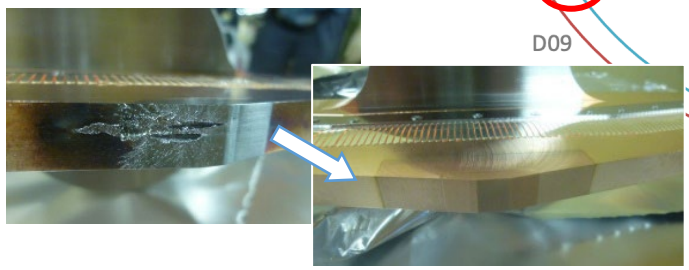
Beam pipes were replaced.

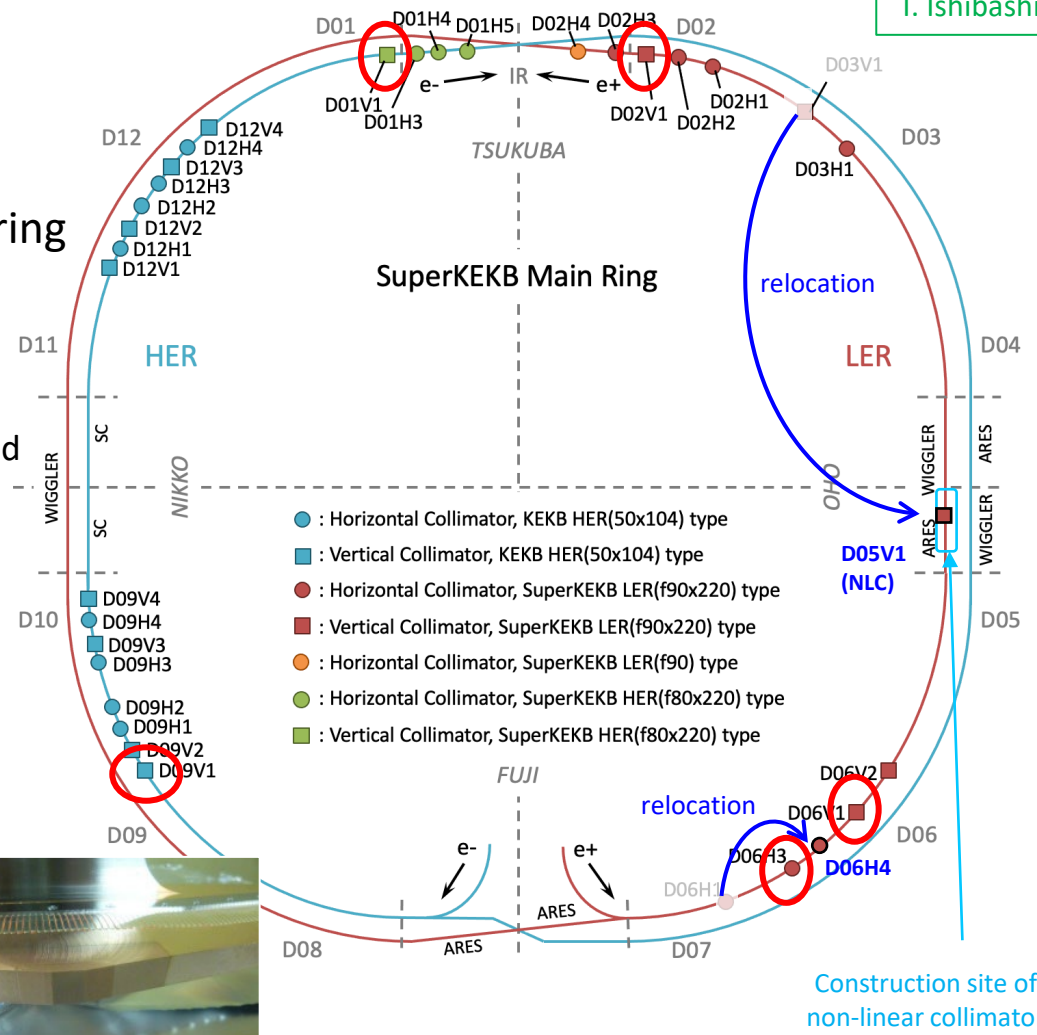


Collimator head replacement

T. Ishibashi

- LER
  - D02V1, D06V1 : SuperKEKB type, Damaged by Sudden Beam Loss
    - D02V1 : Ta -> Ta with Cu coating
    - D06V1 : Ta -> Ti with Cu coating
  - D06H3 : SuperKEKB type, Damaged by injection kicker-pulser misfiring
    - Ta(in), W(out) -> C with Cu coating (Low-Z robust head)
    - D06H1 (upstream of D06H3) was relocated to D06H4 (downstream of D06H3) to collimate the beam passing through D06H3.
    - To prevent misfiring, long-term conditioning of injection kicker will be performed before beam operation.
- HER
  - D01V1 : SuperKEKB type, Damaged by Sudden Beam Loss
    - W -> Ta with Cu coating
  - D09V1 : KEKB type, Damaged during KEKB operation
    - Ti -> Ti, Cu coating (not yet)
    - Replacement work will be done in September.
- All newly installed heads have a Cu coating.
  - Low impedance
  - Countermeasure against Sudden Beam Loss (based on Fireball hypothesis)





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Injector Linac upgrade #1

For injection efficiency improvement;

- New pulsed Quads for the simultaneous dedicated matching of HER/LER injection beam
- New pulsed Quads for low beta optics of HER injection beam
- Fast kicker for 2nd bunch orbit correction

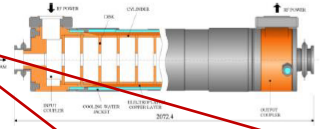
For stable operation;

- New accelerating structure
- Replacement of air conditioners in the tunnel

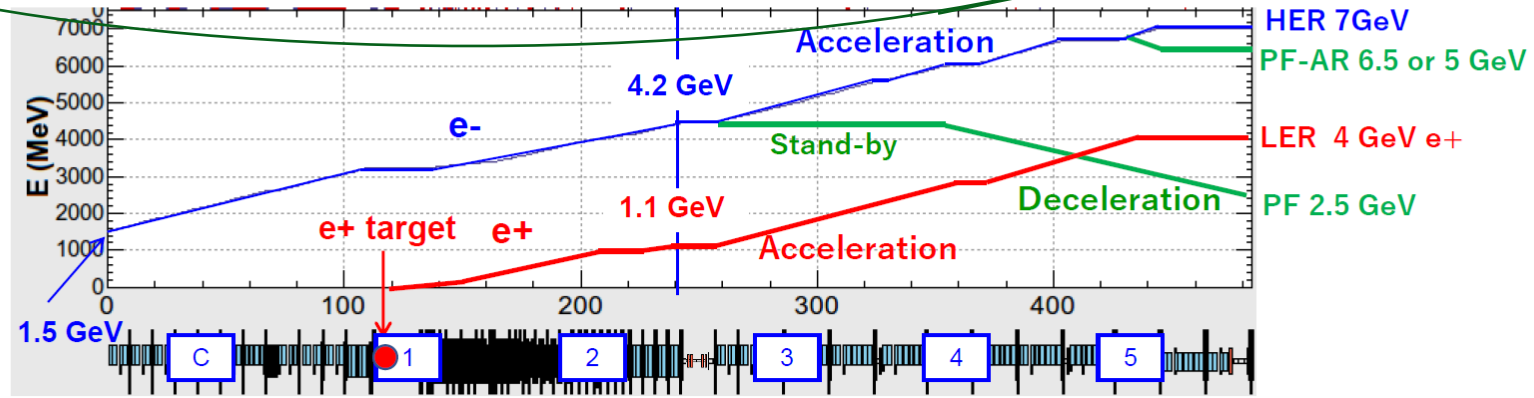
Injector Linac Layout

Outline

60 klystron units
240 accelerating structures (S-band 2-m-long)



- Two electron sources:
  RF gun: HER injection
  Thermionic DC gun: LER, PF, PF-AR
- Sector 3-5:
  All magnets are pulsed magnets.
  Continuous orbit feedback
- DC magnet settings are same for different beam mode



Beam energy variation for each beam mode along the beam line after J-ARC

Masanori Satoh (KEK)

M. Satoh

Injector Linac upgrade #2

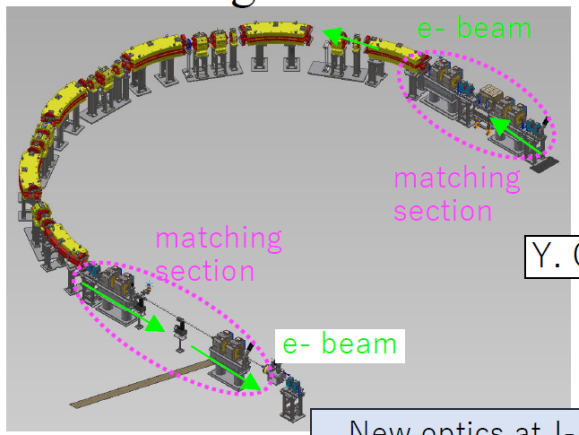
- Pulsed Quads (x8) for the simultaneous dedicated matching of HER/LER injection beam will be installed at J-ARC.

M. Satoh

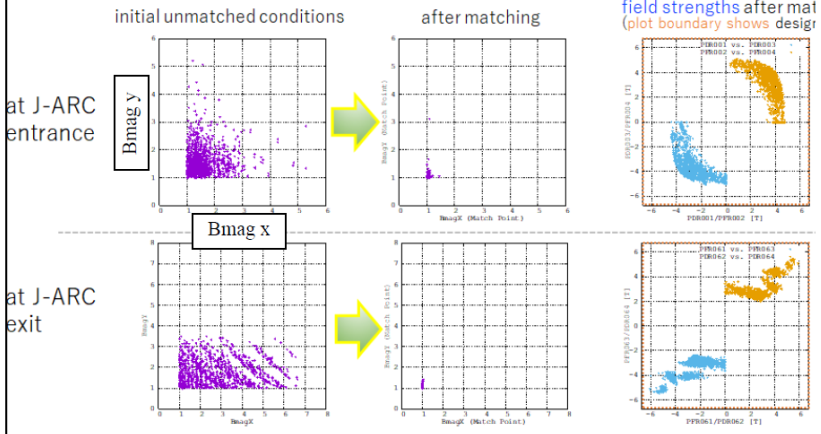
Pulsed Quads at J-ARC for optics matching

Upgrade during LS1

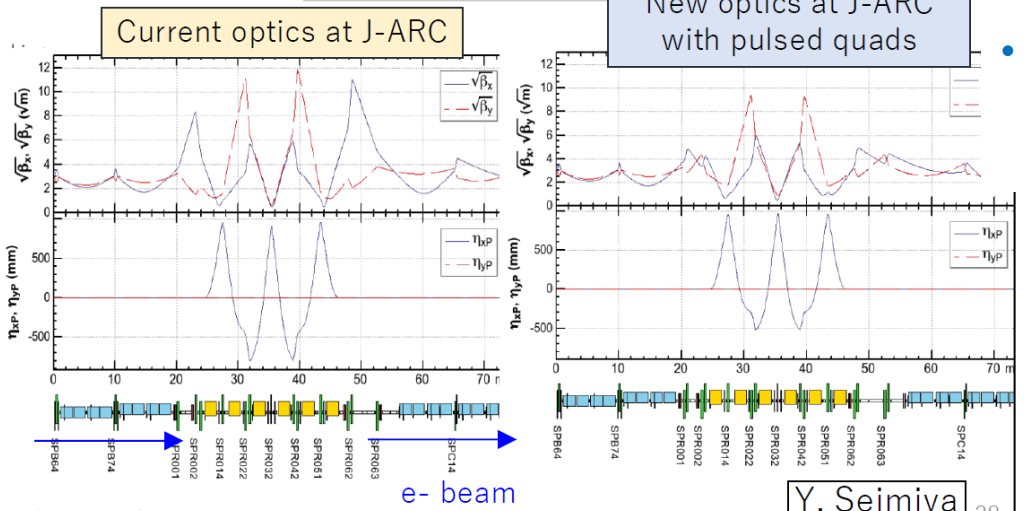
- At the entrance and exit of 180 deg. J-ARC region, a good optics matching is very important to mitigate beam loss and emittance growth.
- Simultaneous matching for both of HER/LER injection beam requires the pulsed quads.
- From the simulation result, 4 pulsed quads at both of entrance and exit of J-ARC are sufficient.



Y. Okayasu



Matching simulation



Y. Seimiya

- Without pulsed Quads, only the HER injection beam could be tuned well.
- With these pulsed Quads, both HER and LER injection beam can be tuned well.

Improvement of LER injection beam

Injector Linac upgrade #3

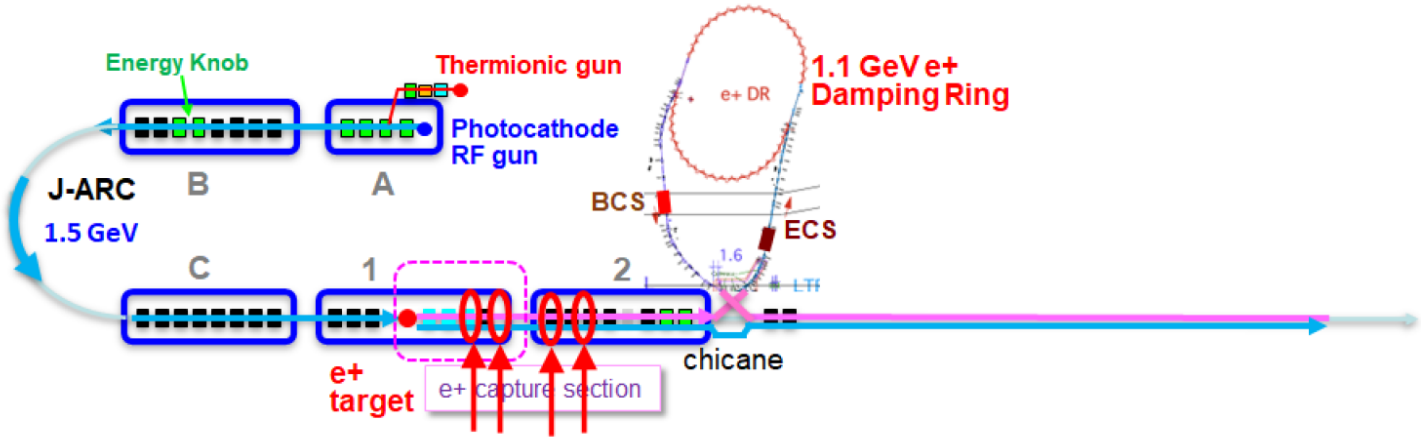
- Pulsed Quads (x4) for low beta optics of HER injection beam will be installed at Sector1&2.

M. Satoh

Upgrade during LS1

Pulsed Quads at J-ARC for e- low beta optics

- Current optics at Sector1, 2
  - Large emittance e+ beam is accelerated from 0.1 GeV to 1.1 GeV for DR injection.
  - Quad settings is optimized for e+ beam.
  - For e- beam (3 ～ 4 GeV), focusing force is weak in comparison with optimum parameter. It could cause the emittance growth.



Four DC quads will be replaced by pulsed one.

- After only these four pulsed quads are optimized for the e- beam, the β-function can be decreased.
- Simulation result shows that it can help to decrease the emittance less than half.

↓ + Fast kicker for e- 2nd bunch tuning

Improvement of HER injection beam

Injector Linac upgrade #4

- 5-year upgrade plan to fabricate and install new accelerator structures is in progress now.

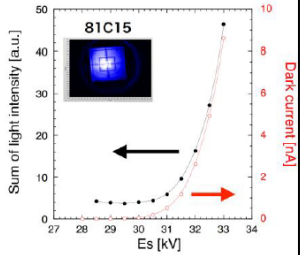
M. Satoh

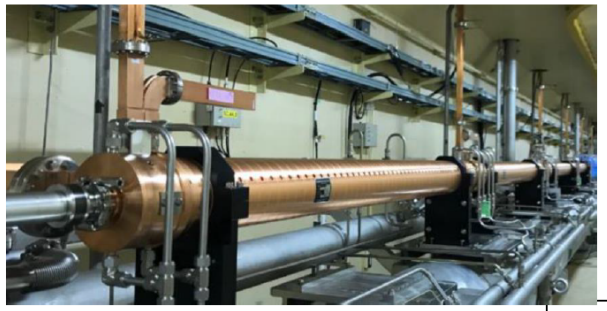
New accelerating structure

- Mitigation of accelerating structure failures
  - Originally designed for 8 MeV/m (PF injector), but used at 20 MeV/m (KEKB upgrade)
  - Degradation that lead to high field emission rate and discharges
  - Water leaks, field emission , discharge in waveguide, and so on (29 of 60 units have some problems)
  - Not only future Y(6S) but even Y(4S) could be suffered
- 5-year upgrade plan to fabricate and install new accelerator structures (FY2018 – FY2022)
  - 4 units (16 acc. structures) will be replaced by new one. (Unit44 was replaced in this summer)
  - New acc. structure: acc. gain ↑7%, surface field ↓20% (reduce breakdown)
  - New pulse compressor (SCPC) was also developed and installed in Unit44.

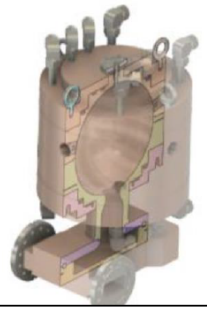
Upgrade during LS1

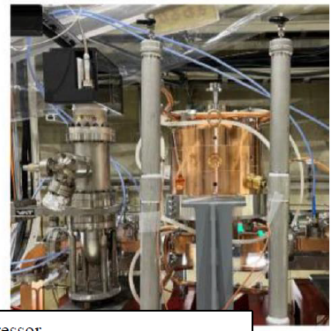
Damaged iris



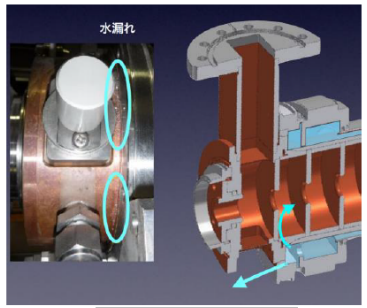


New S-band 2-m-long TW acc. structure





New pulse compressor
Spherical-Cavity Pulse Compressor (SCPC)



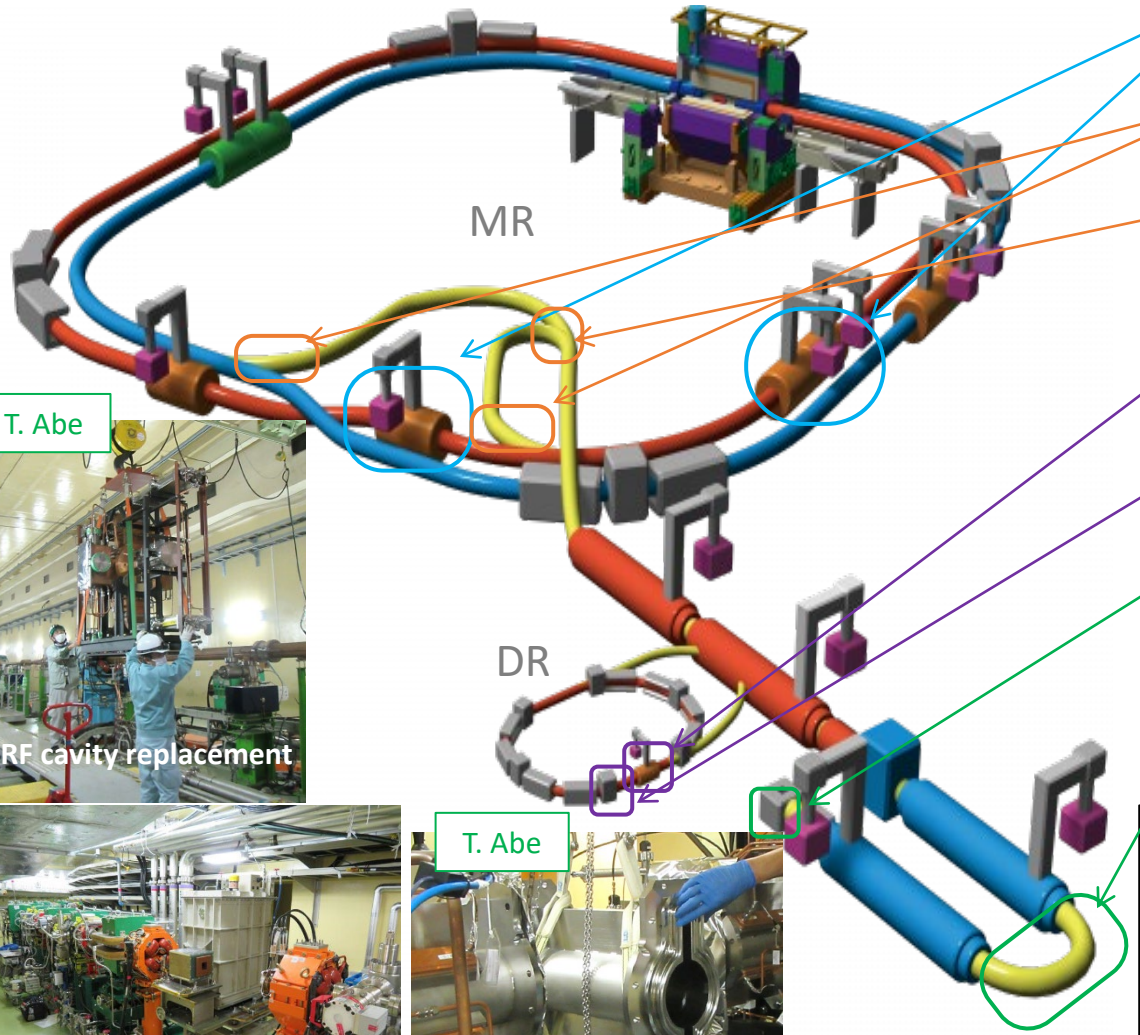
Colling water leakage

H. Ego 31

Contents

- Upgrade items during LS1
- MR upgrade
- Injector Linac upgrade
- Others
- Summary

Others



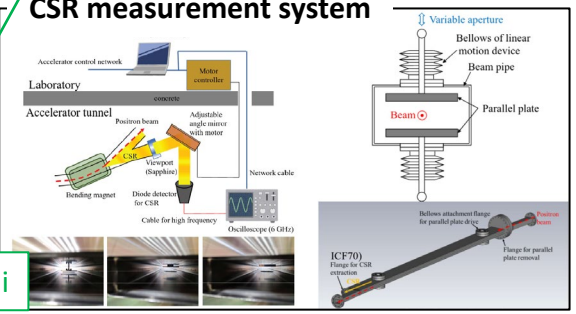
- RF cavity modification and replacement (LER)
  - For stable operation with larger beam current
- BT magnet re-alignment (BT)
  - For injection efficiency improvement
- CSR measurement system (BT)
  - For injection efficiency improvement
- Vacuum seal replacement at RF section (DR)
  - For stable operation (pressure reduction)
- DR Extraction kicker power supply modification and repair (DR)
  - For stable operation & injection efficiency improvement
- Improvement of RF-gun laser window degradation (Linac)
  - For injection power improvement
- Precise beam tuning with beam monitors at J-ARC (Linac)
  - For injection power improvement & injection efficiency improvement
- And so on…

T. Abe

T. Abe

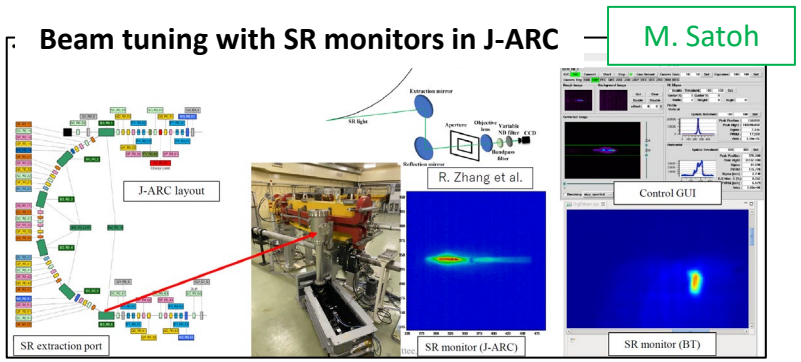
S. Terui

CSR measurement system



Beam tuning with SR monitors in J-ARC

M. Satoh



Contents

- Upgrade items during LS1
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Summary

- Many works are in progress during LS1
  - LS1 started in July 2022 and will end in early December 2023.
  - Belle II works are also underway.
  - Beam operation is scheduled to resume in December 2023.

- Major upgrade items :
  - Radiation shield enhancement at IR
  - Non-linear collimator with low impedance in LER
  - Robust collimator head in LER
  - Modification of HER injection point
  - Pulsed quad. magnets at Linac
  - New accelerating structure at Linac
  - BT magnet re-alignment
  - Etc.

- Major maintenance items :
  - Damaged collimator head replacement
  - Repair of vacuum leak in QCSR cryostat
  - RF cavity modification and replacement
  - Repair and modification of DR ext. kicker power supply
  - Etc.

- All planed works are being performed almost as scheduled so far.
  - Accelerator upgrades will be completed in early December 2023.
  - Schedule is very tight, and strict process control is required.

Fin.

Thank you for your attention.

Backup