LS1 Status

The 26th KEKB Accelerator Review Committee

14th Dec. 2022

Kyo Shibata

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Challenges as a luminosity frontier machine

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.

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+ 6) Low injection efficiency especially in HER.

Countermeasures against challenges

Planned countermeasures

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

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

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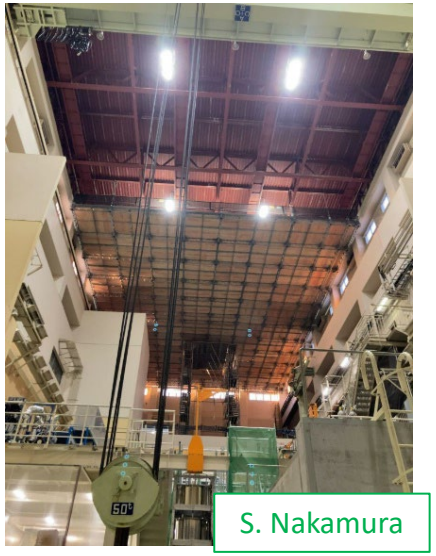
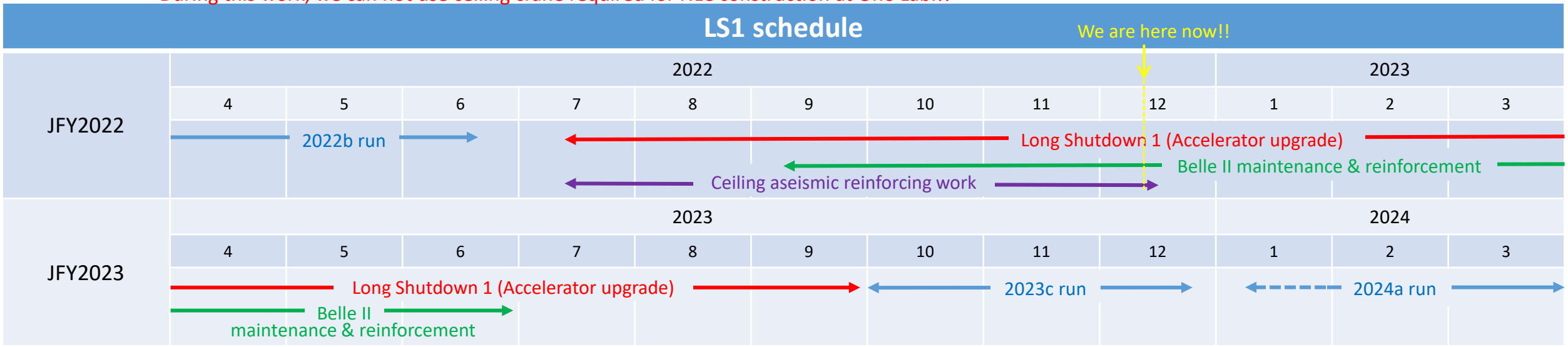
Schedule

- LS1 : 15 months from July 2022 to September 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 October 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 reinforcing work of the ceiling of the laboratory building (Oho Lab. & Fuji Lab.)
    - It takes about 5 months and it can be done only during long shutdown.
    - During this work, we can not use ceiling crane required for NLC construction at Oho Lab.!!

Ceiling aseismic reinforcing work

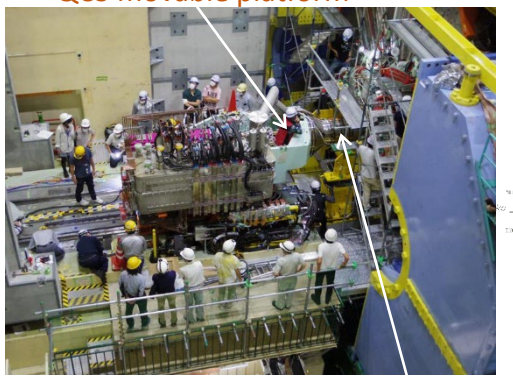


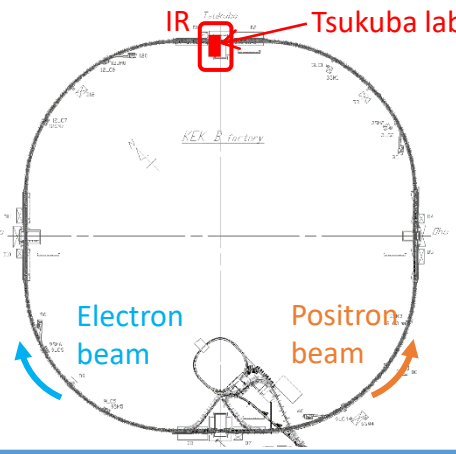
S. Nakamura



IR (Tsukuba straight section) #1

- 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





IR (Tsukuba straight section)

We are here now!!

JFY2022

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

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

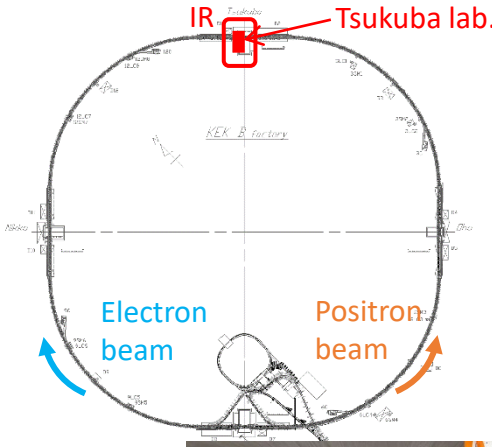
JFY2023

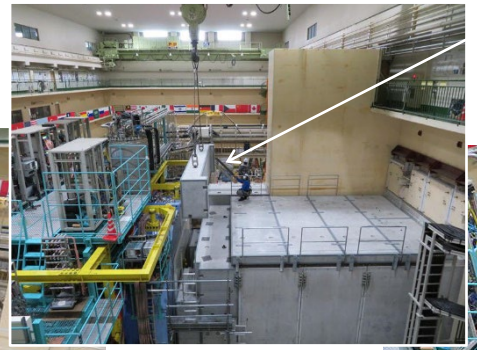
2023									2024		
4	5	6	7	8	9	10	11	12	1	2	3

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

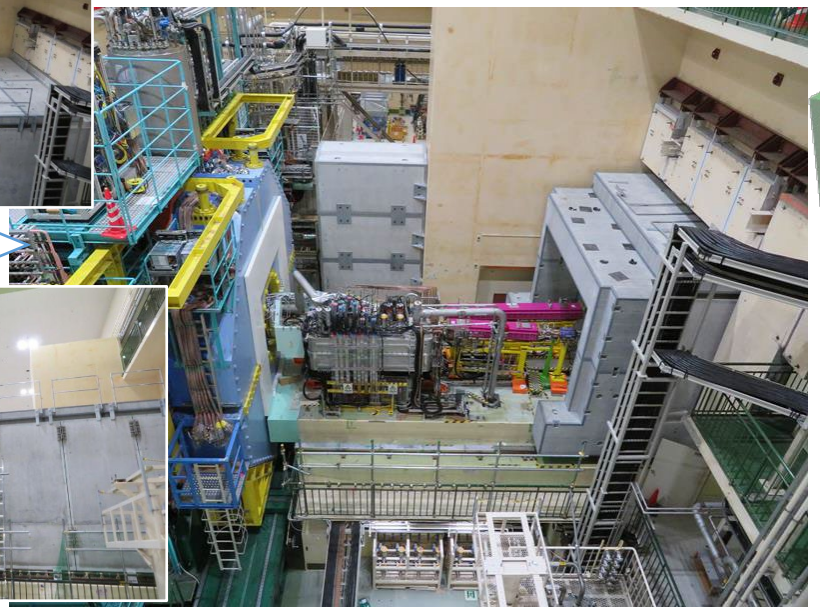
IR (Tsukuba straight section) #2

- Concrete radiation shields disassembly (already done)
  - Concrete radiation shields were temporarily removed for IR works.
  - They will be reinstalled in mid September 2023.
    - To suppress background noise of Belle II, 2 concrete shields will be replaced with new ones.
    - New shields will be delivered in February 2023.



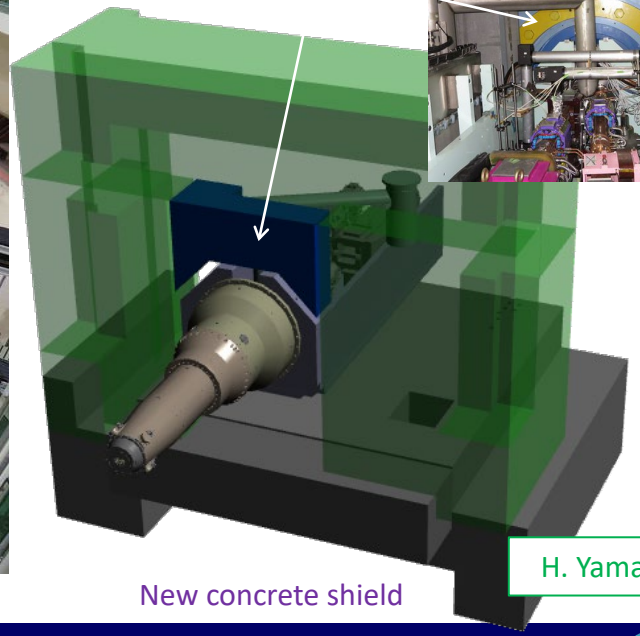


This shield will be replaced with new one.



Concrete shield disassembly work

This space will be filled with concrete.

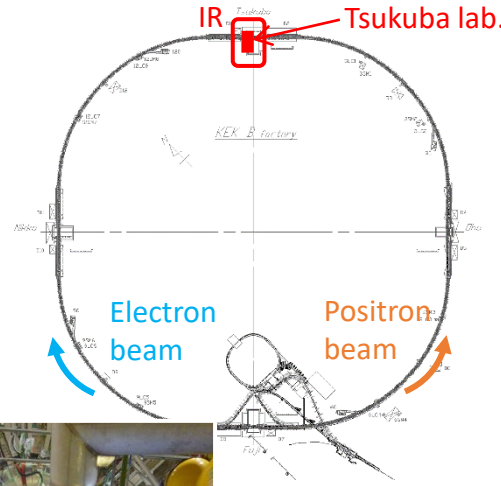


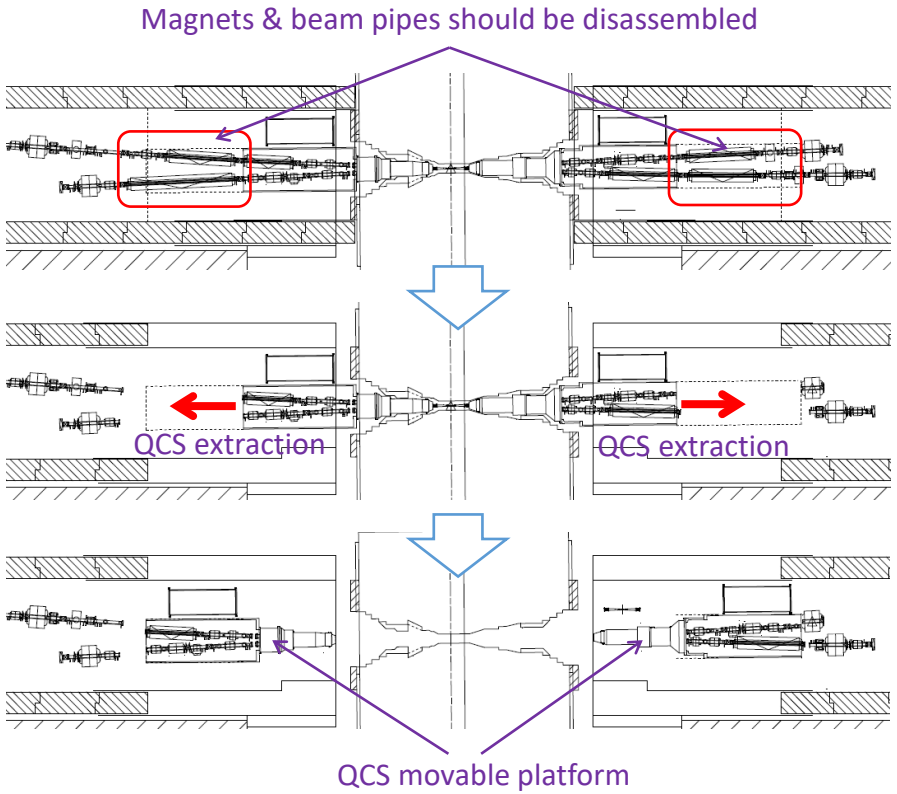
New concrete shield

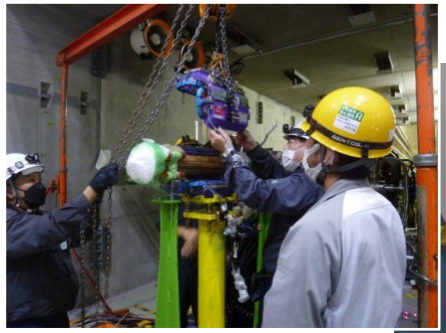
H. Yamaoka

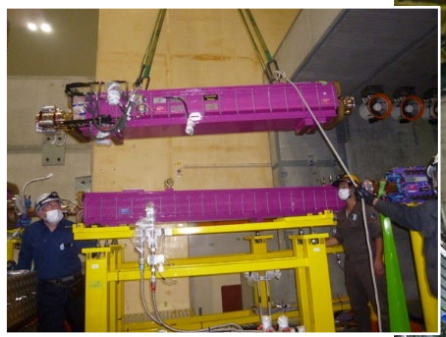
IR (Tsukuba straight section) #3

- Disassembly of magnets & beam pipes for QCS extraction (already done)
  - 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.



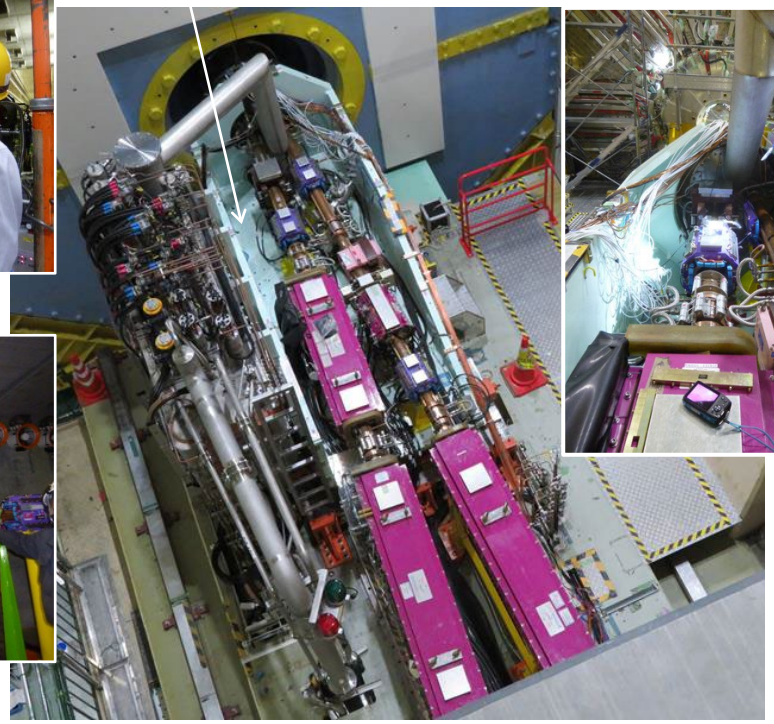


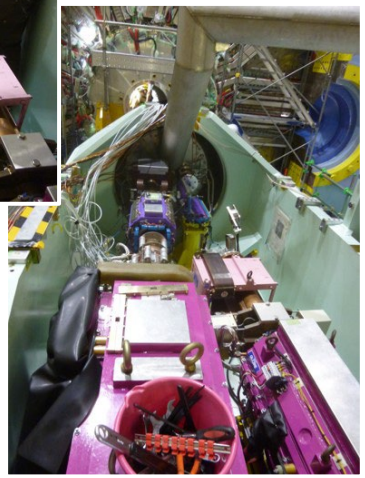




Disassembly work

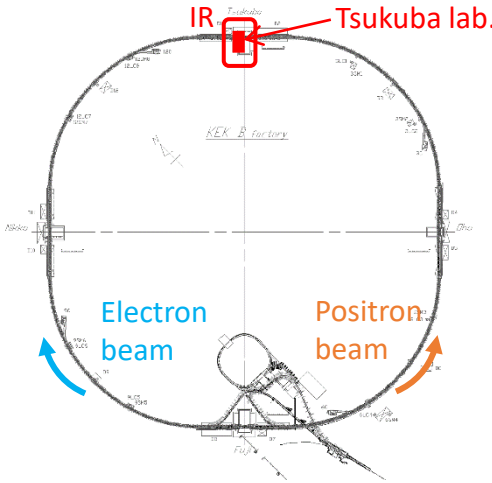
QCS movable platform

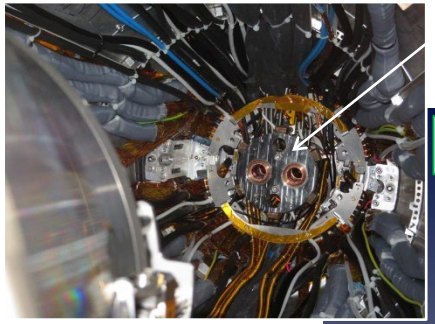




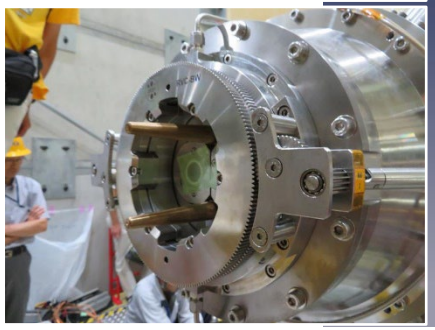
IR (Tsukuba straight section) #4

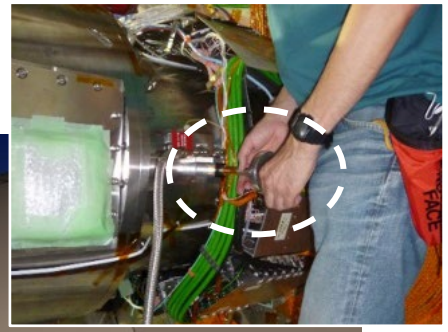
- QCS extraction (already done)
  - RVC disassembly was performed by Belle II and SuperKEKB for the first time.
    - RVC : Remote Vacuum Connection between IP bellows chambers and QCS beam pipes
    - DESY, who is RVC developer and has been in charge of RVC disassembly so far, also joined the work online. 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 extraction of both sides was completed successfully in one day!!

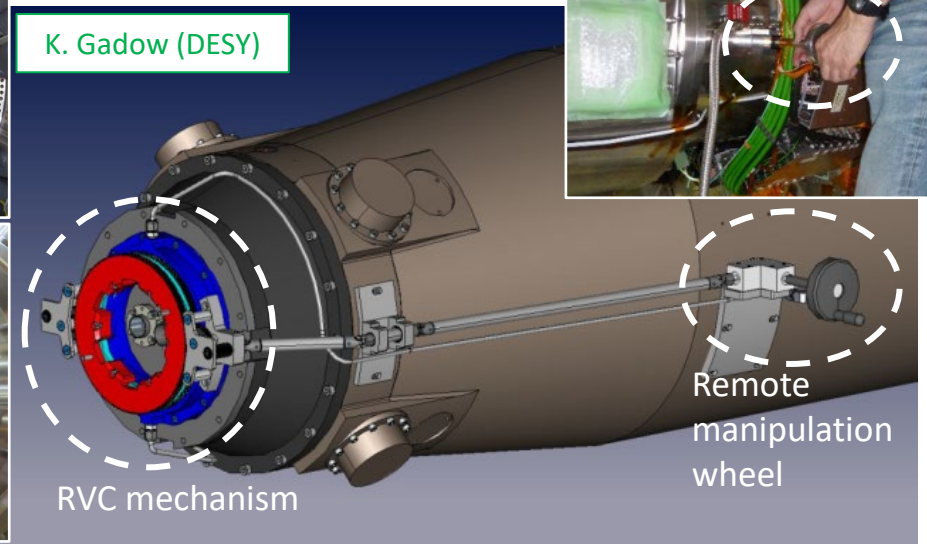


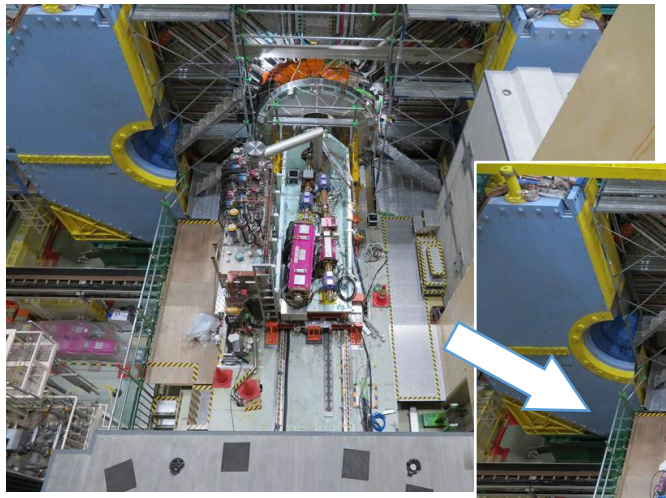


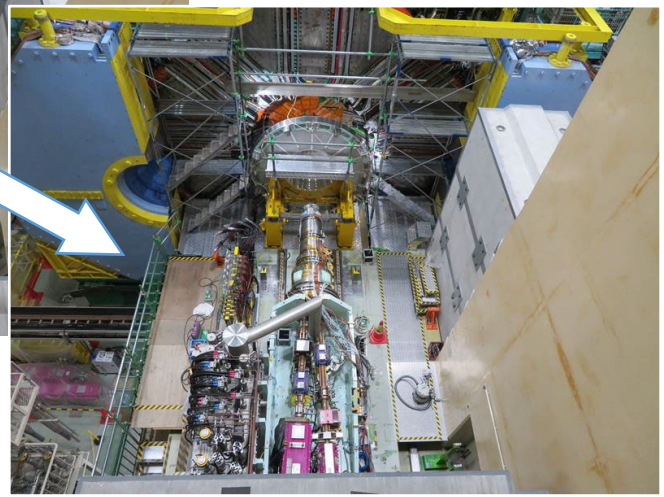
RVC lock flange of IP bellows chamber







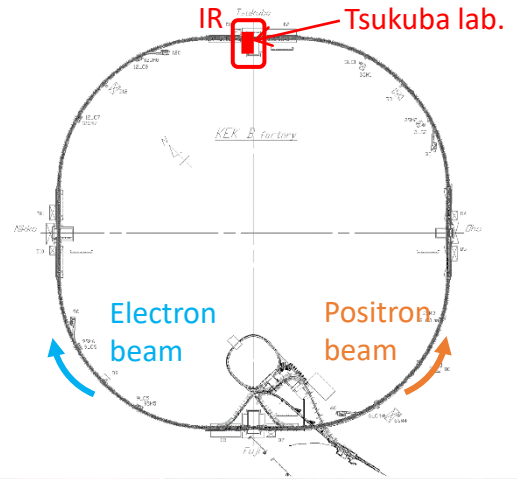


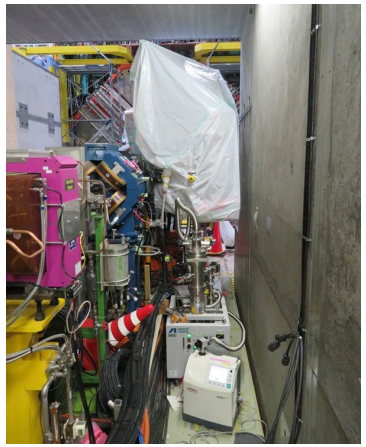


QCS extraction

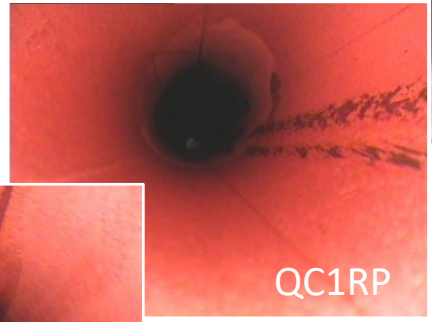
IR (Tsukuba straight section) #5

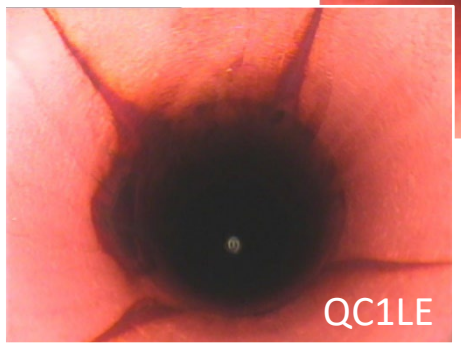
- QCSR cryostat leak test (already done)
  - Pressure in QCSR cryostat has been higher than that in QCSL cryostat.
    - Residual gas analysis showed that vacuum leak has occurred in QCSR cryostat.
    - However, vacuum leak test before LS1 did not detect any vacuum leak.
  - Thorough vacuum leak test was performed after QCS extraction.
    - At last, the location of the vacuum leak was identified!!
    - Vacuum leak will be stopped during LS1.
- Inside observation of beam pipes
  - Inside of IP bellows, QCS beam pipes were observed by fiberscope.
    - Fiberscope observations showed that RF fingers of IP bellows and QCS beam pipes are discolored but healthy.

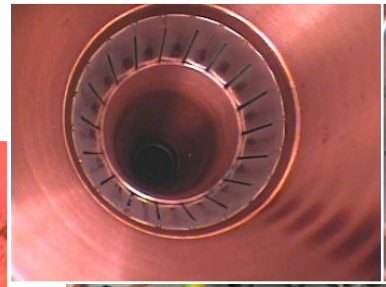


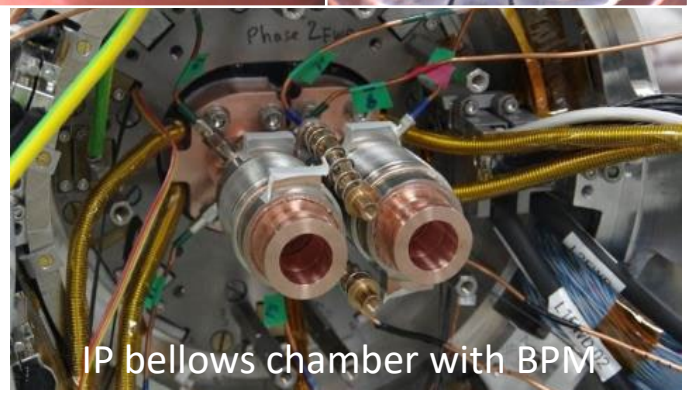


Vacuum leak test of QCSR cryostat



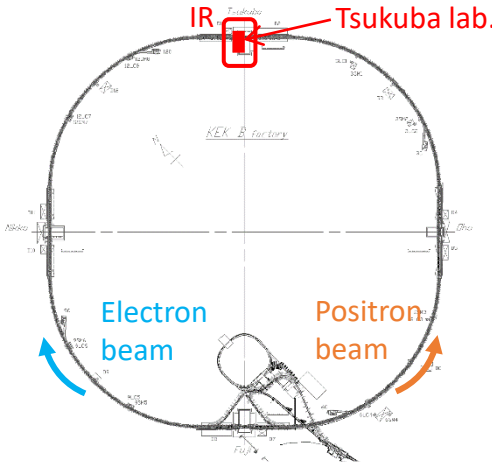






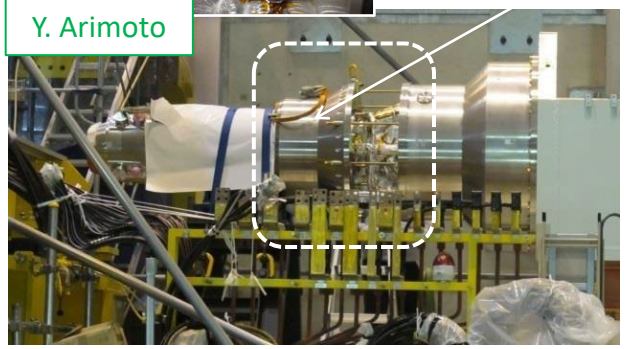
IR (Tsukuba straight section) #4

- Future works
  - QCS cryostat modification
    - To reduce Belle II background noise, the material at the tip of QCS cryostat will be changed from W to SUS.
      - QCSR front cap replacement
      - QCSL front plate replacement
    - To make more space for Belle II cables, the tip of QCSR cryostat will be thinner.
      - QCSR cryostat modification including front cap replacement
    - QCS cryostats will be disassembled for these works.
      - It is necessary to shift QCS beam pipes in longitudinal direction.

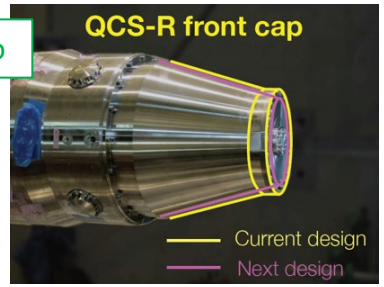


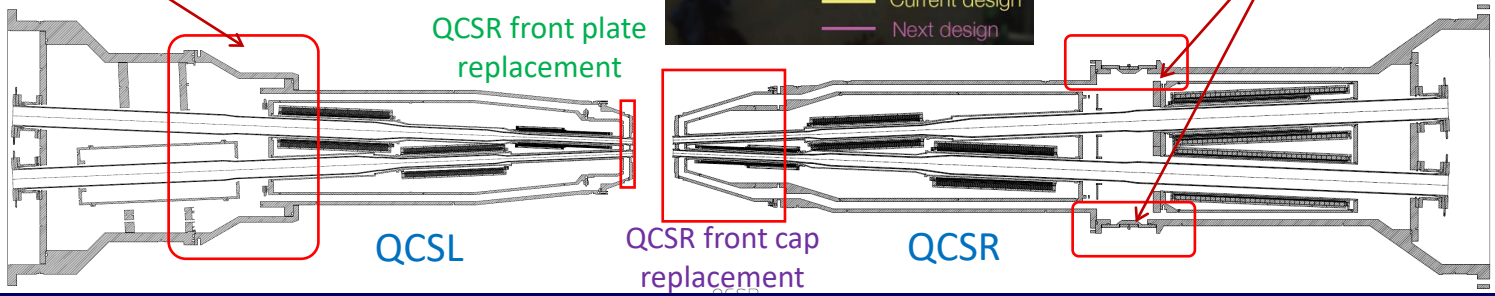
BPM feedthrough

Y. Arimoto



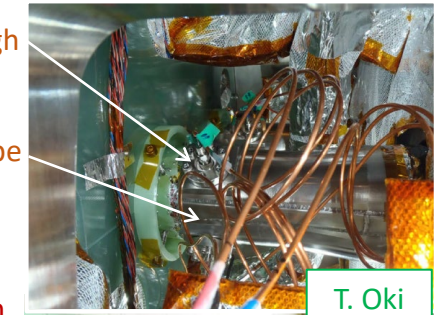
Y. Arimoto





BPM feedthrough

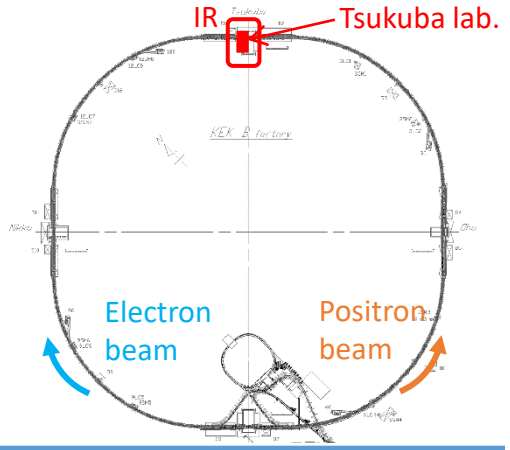
QCS beam pipe



T. Oki

IR (Tsukuba straight section) #5

- Remaining works in accelerator tunnel:
  - Belle II maintenance & reinforcement (~ June 2023)
  - QCS cryostat modification (March 2023)
  - QCS reinstallation (July ~ August 2023)
  - Concrete shield reinstallation (Sep. 2023)
- All works can be completed by the end of September 2023.
  - It is required to coordinate schedule with Belle II work and NLC construction.



IR (Tsukuba straight section)

We are here now!!

	2022									2023		
	4	5	6	7	8	9	10	11	12	1	2	3
JFY2022	2022b run			Concrete shield disassembly	Belle II work	QCS extraction	QCSR cryostat leak test	Belle II maintenance & reinforcement				QCS cryostat modification

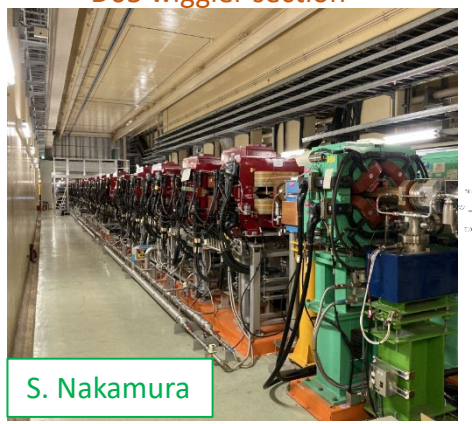
	2023									2024		
	4	5	6	7	8	9	10	11	12	1	2	3
JFY2023	Belle II maintenance & reinforcement			QCS reinstallation	Magnet & beam pipe disassembly	Belle II work	Concrete shield reinstallation	2023c run			2024a run	

Oho straight section #1

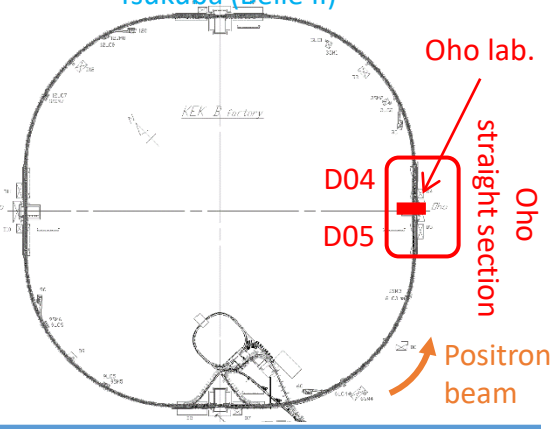
- Major work items in accelerator tunnel:
  - Disassembly and reinstallation of concrete radiation shields
  - NLC construction (LER)
  - RF cavity replacement (LER)
  - Ceiling aseismic reinforcing work
  - Installation of new radiation shields

Concrete radiation shield

D05 wiggler section



Tsukuba (Belle II)



Oho straight section (D05)

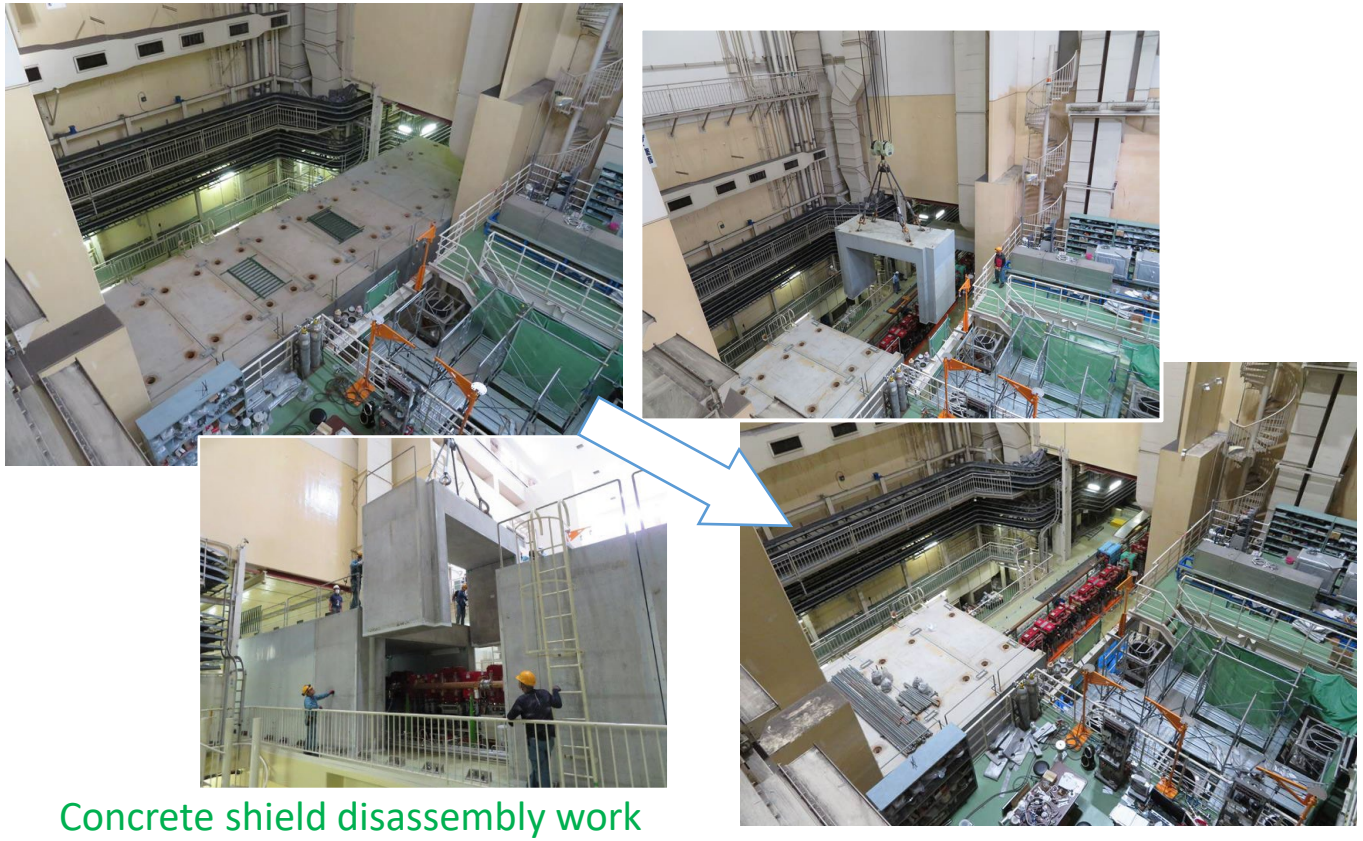
We are here now!!

	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							

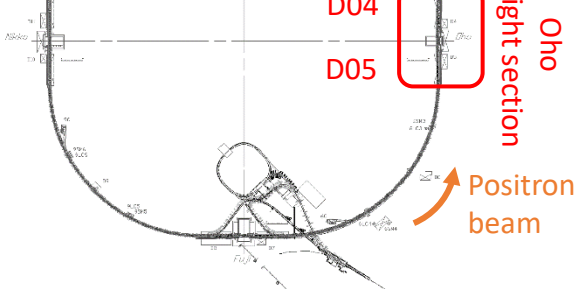
	2023									2024		
	4	5	6	7	8	9	10	11	12	1	2	3
JFY2023	NLC construction						2023c run				2024a run	
			New radiation shield installation									
					Concrete shield reinstallation							

Oho straight section #2

- Concrete radiation shields disassembly (already done)
  - Concrete radiation shields (6/12) were temporarily removed for NLC construction.
    - Concrete shields were placed outside Oho laboratory building.
  - They will be reinstalled in late August 2023.



Concrete shield disassembly work

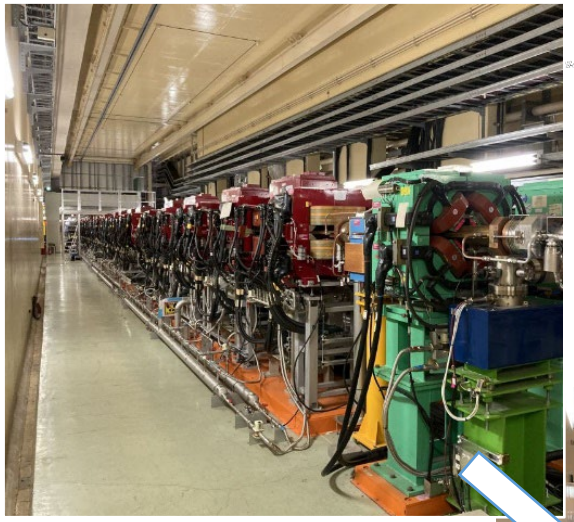


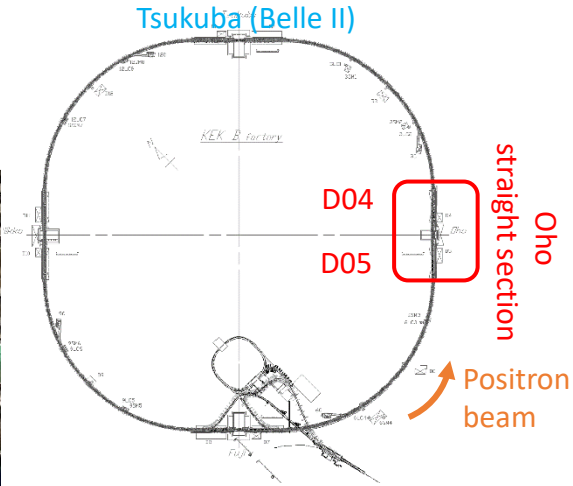
Disassembled concrete shield

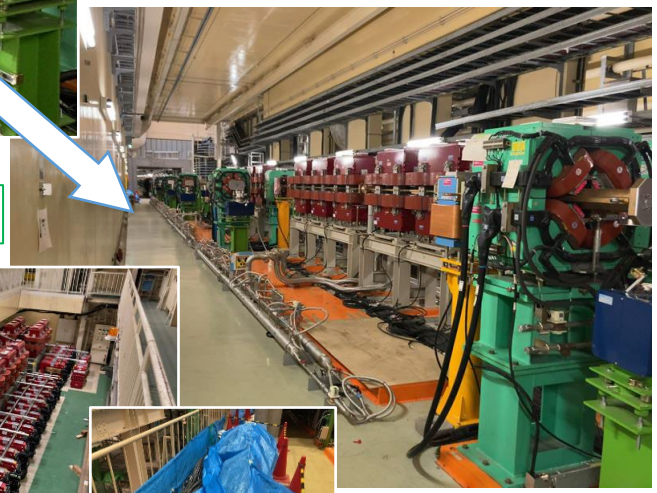
Oho straight section #3

- 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 removal

10 times







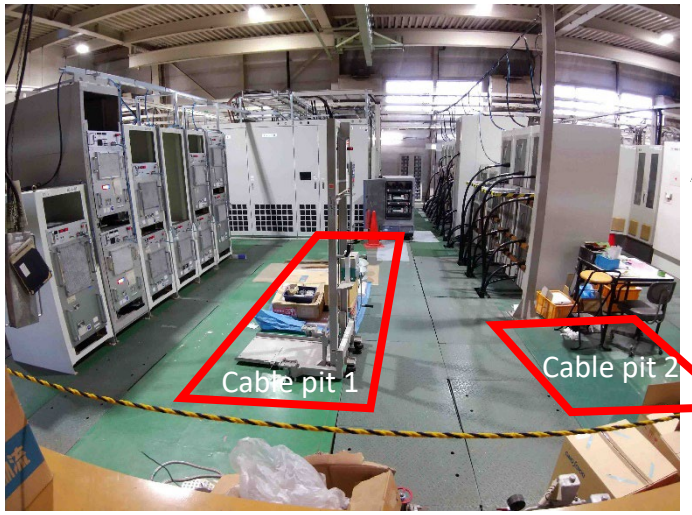
S. Nakamura

Wiggler beam pipe removal work

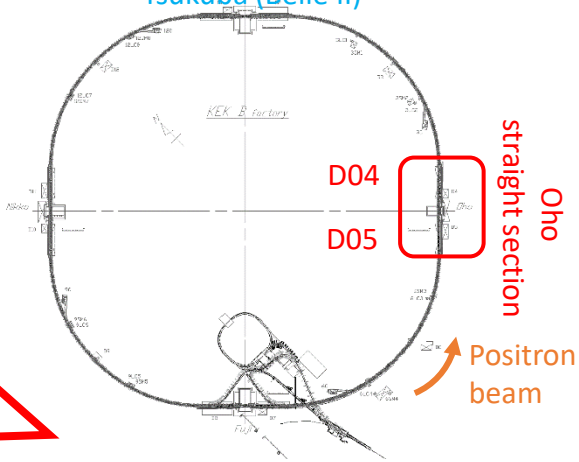
Oho straight section #4

- Future works for NLC construction
  - Collimator relocation from D03V1
  - Q magnet relocation
  - Skew sextuple magnets installation
  - Beam pipe installation
  - Installation of new power supplies
  - Magnet cabling works
- Future works for radiation shielding enhancement
  - Production & installation of new Pb radiation shields
  - Production & installation of additional concrete shields
  - Reinstallation of concrete shields

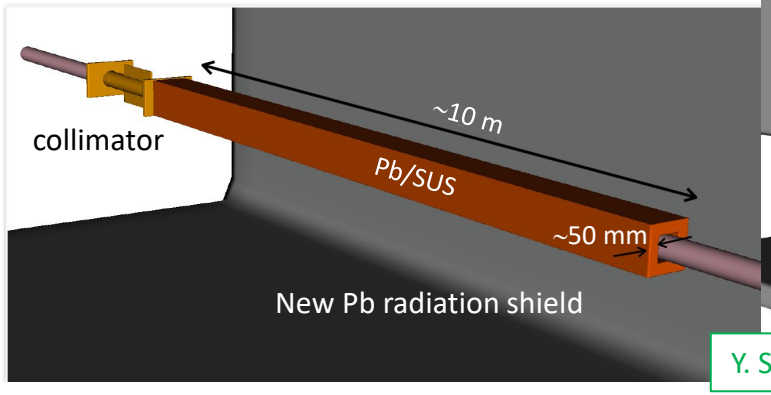
Magnet power supply room (ground level)



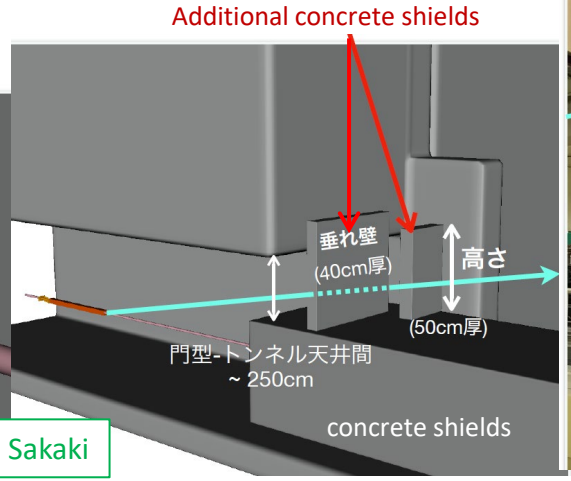
Tsukuba (Belle II)

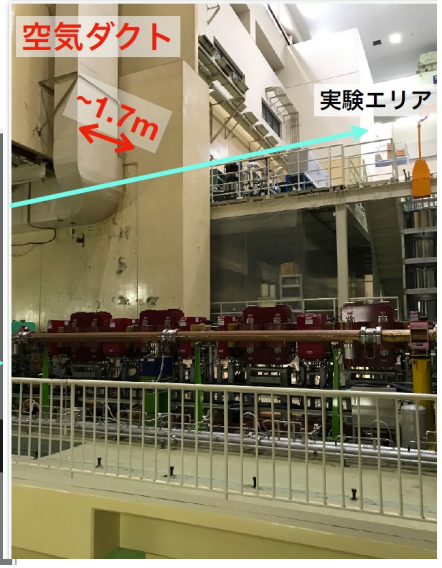


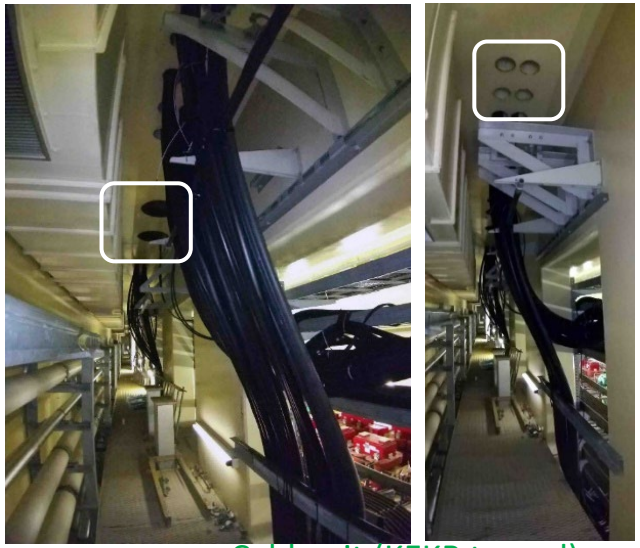
S. Nakamura



Y. Sakaki



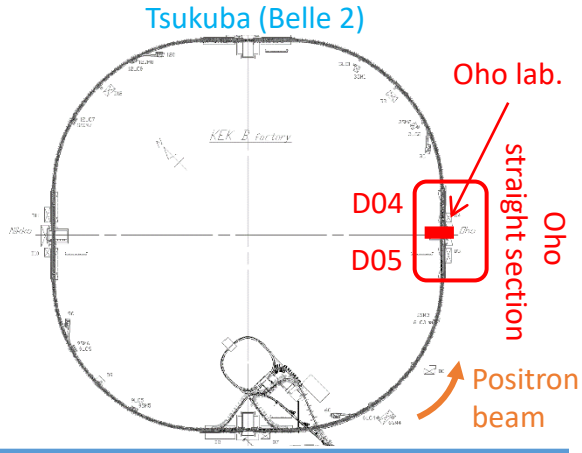




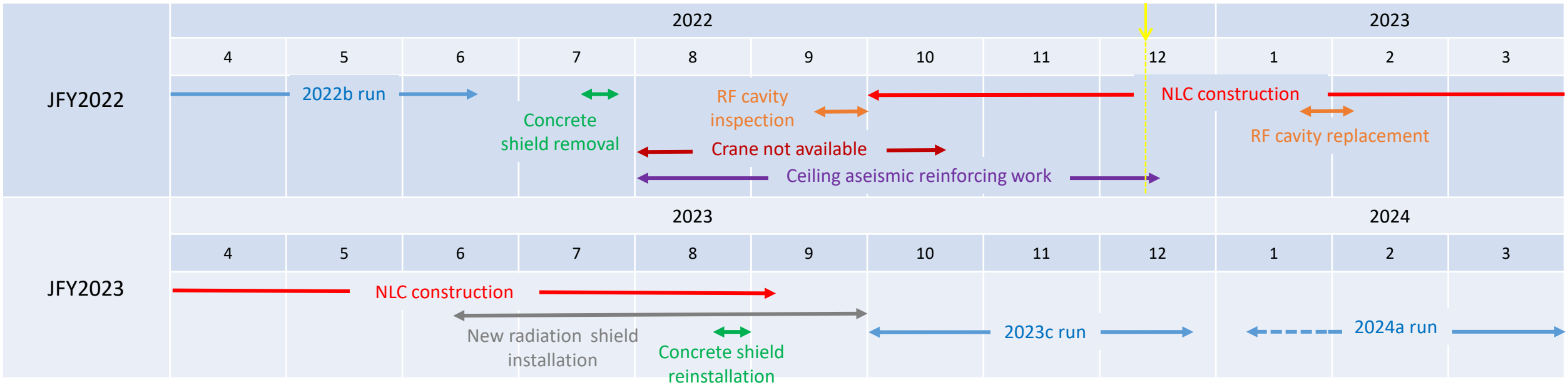
Cable pit (KEKB tunnel)

Oho straight section #5

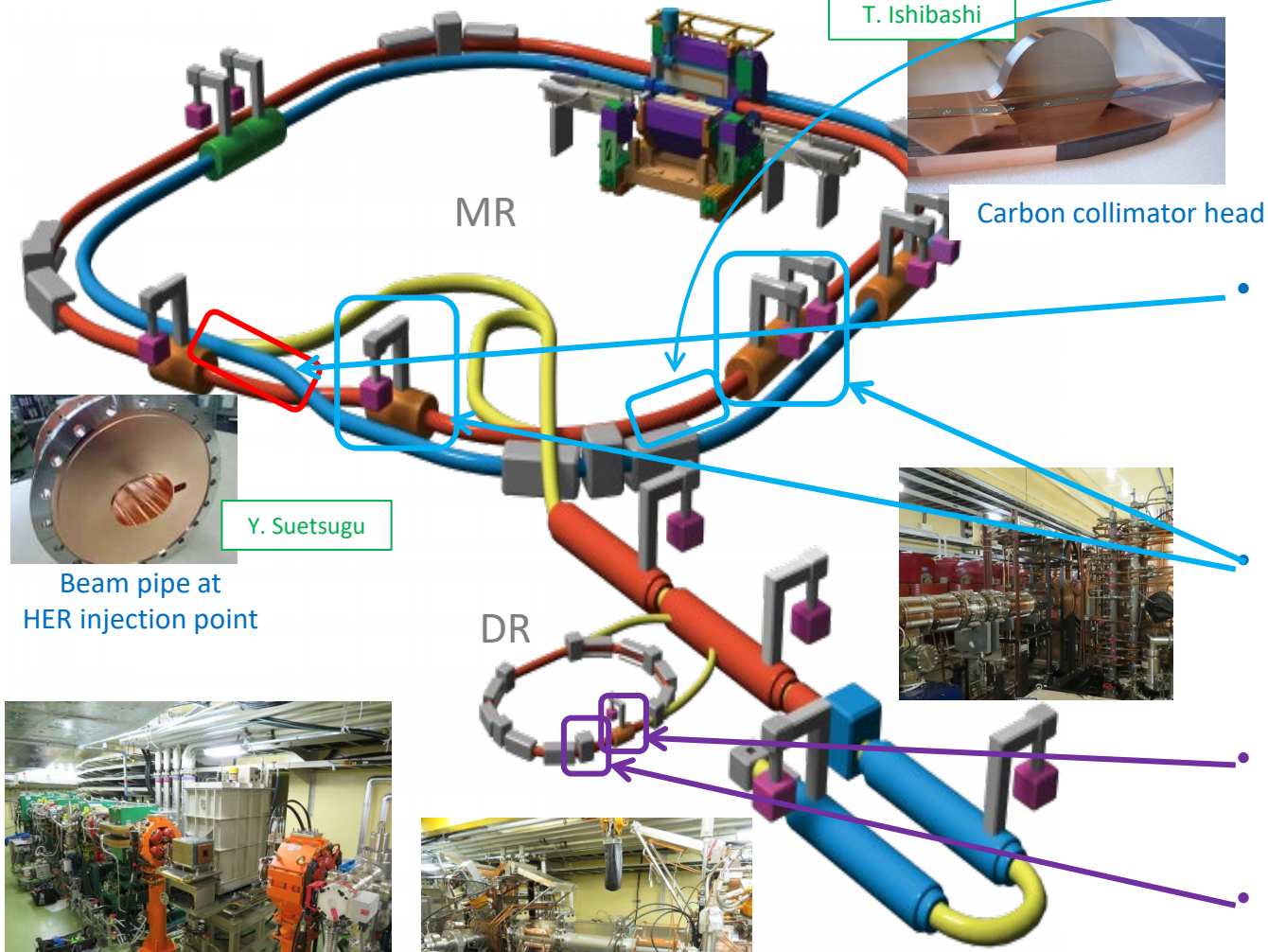
- Remaining works in accelerator tunnel:
  - NLC construction (~ Sept. 2023)
  - RF cavity replacement (Jan. ~ Feb. 2023)
  - New radiation shield installation (June ~ Sept. 2023)
  - Concrete shield reinstallation (August 2023)
- All works can be completed by the end of September 2023.
  - Schedule is very tight.



Oho straight section (D05)



Others 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…]

Summary

- Many upgrade works are done during Long Shutdown 1 (LS1).
  - LS1 started in July 2022 and will end in September 2023. (15 months)
  - “Belle II maintenance & reinforcement” and “Aseismic reinforcing works of the ceiling of the laboratory building” are also done during LS1.
- Status of “IR works” & “NLC construction” were reported in detail.
  - Both works are progressing as planned so far.
  - It is possible to complete all works by the end of September and resume beam operation from October 2023.
  - It takes much longer time for some materials and devices to be delivered, so more careful coordination of LS1 schedule until the end of LS1 is required.

Fin.

Thank you for your attention.