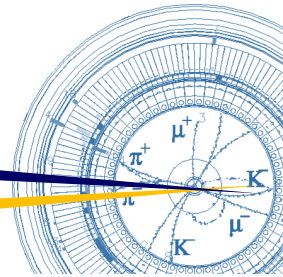


Vacuum



The 27th KEKB Accelerator Review Committee
26th March 2024

Kyo Shibata
On behalf of KEKB Vacuum Group

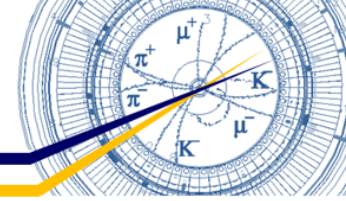


Contents

- Introduction
- Major Vacuum works during LS1
 - MR works
 - Collimator works & status
 - DR works
- MR vacuum status after LS1
- DR vacuum status after LS1
- Summary

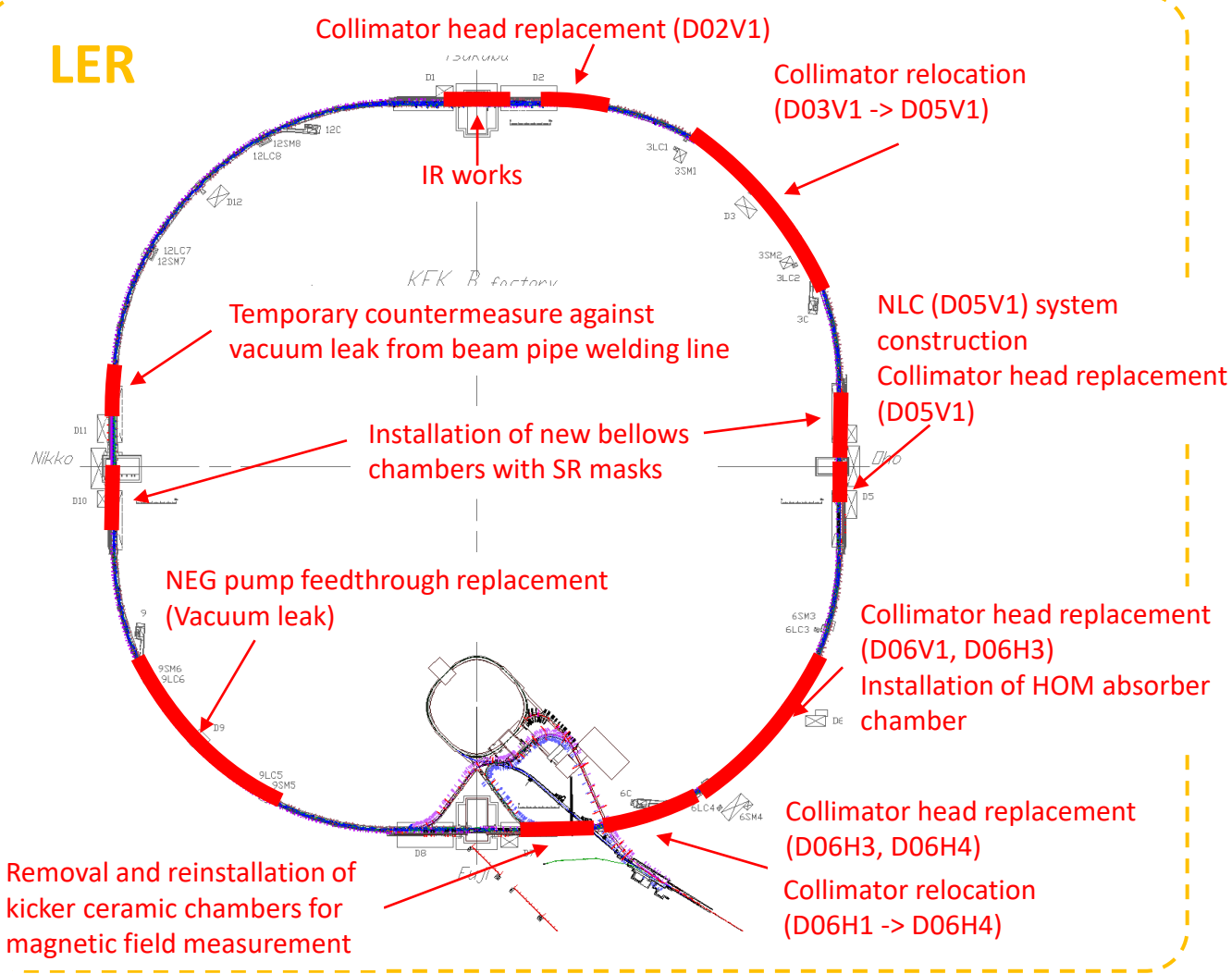


Vacuum works during LS1 at a glance (MR)

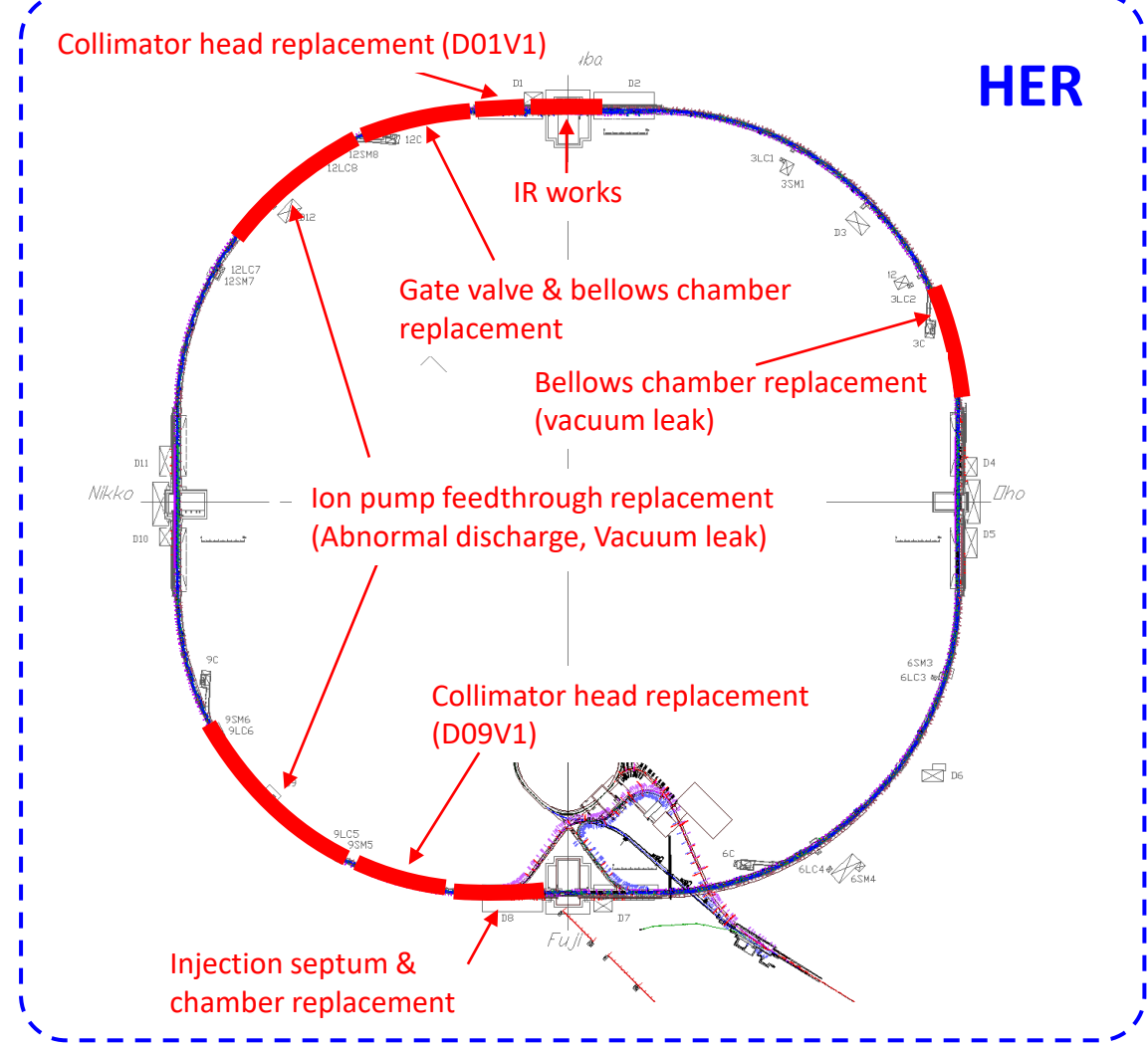


————— : Area open to dry nitrogen or atmosphere

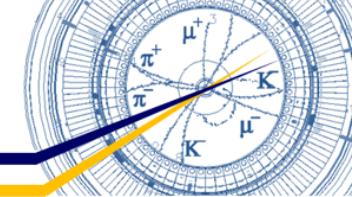
LER



HER

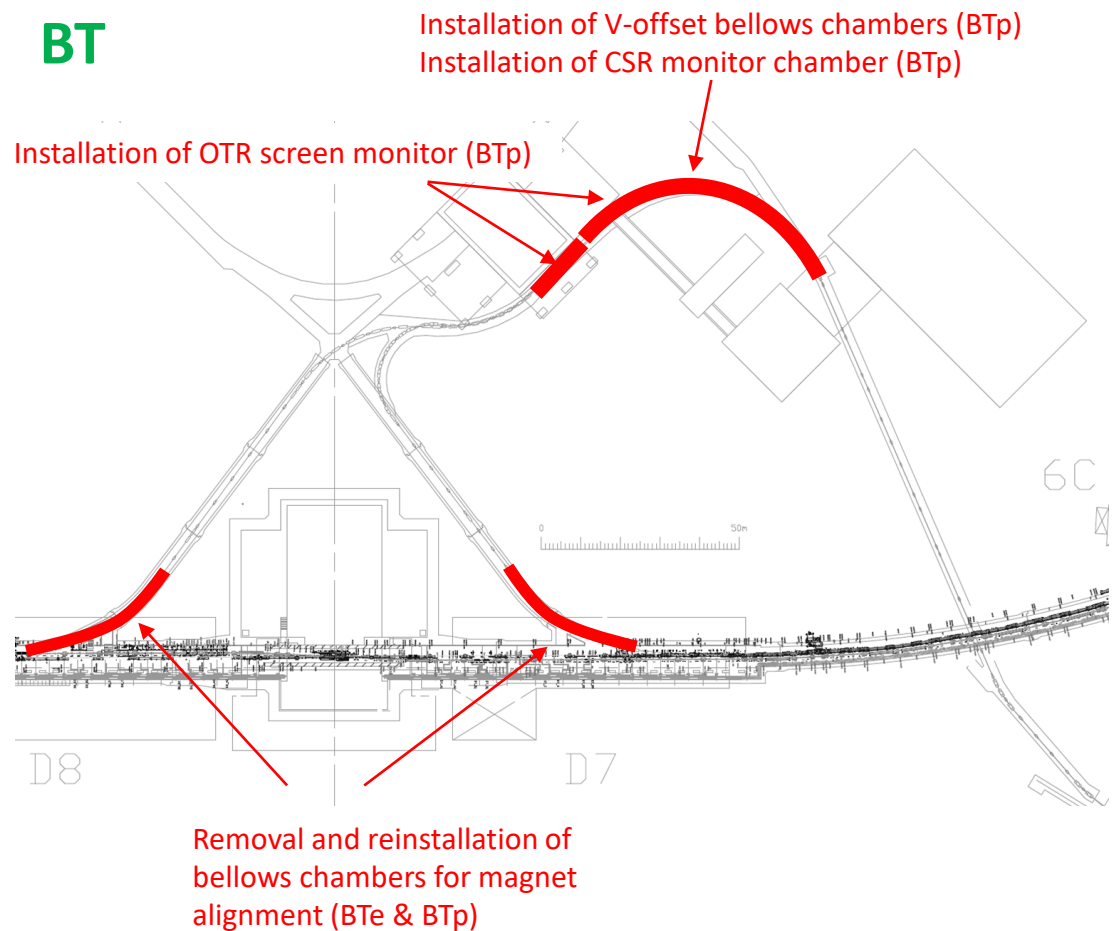


Vacuum works during LS1 at a glance (BT&DR)

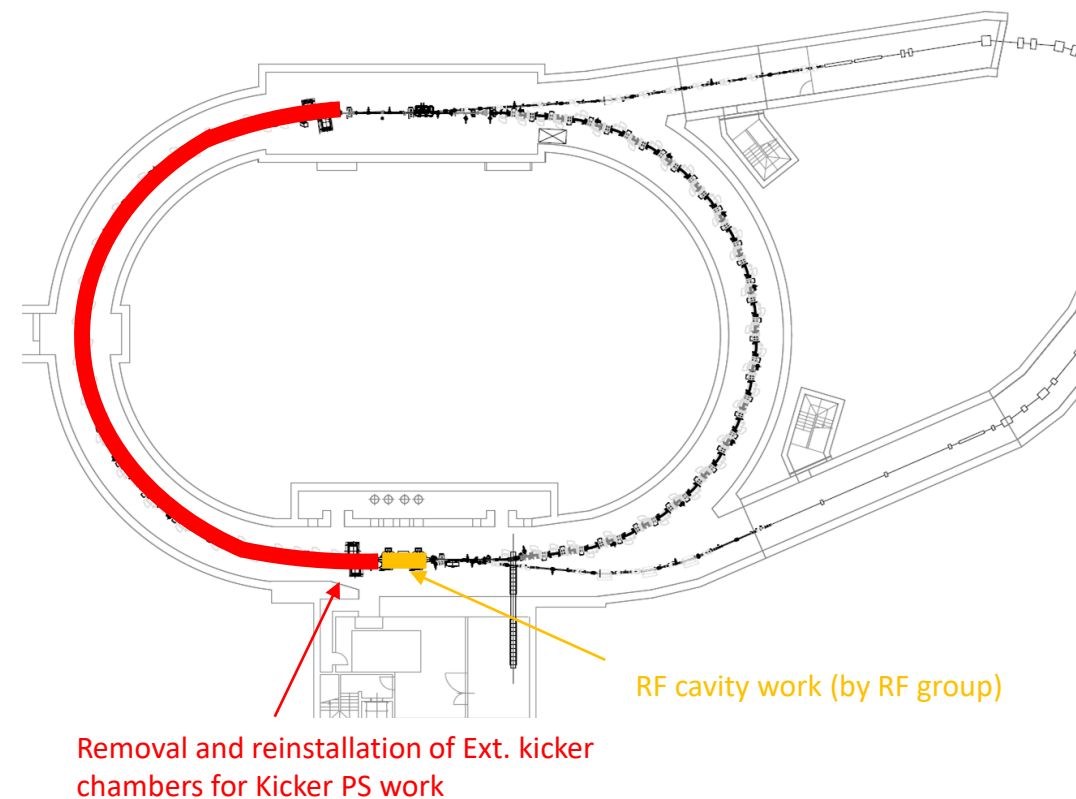


————— : Area open to dry nitrogen or atmosphere

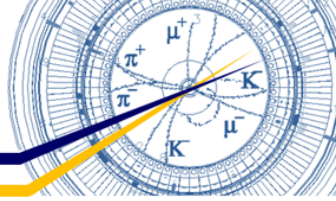
BT



DR



List of major works during LS1 (MR)



- IR work (LER&HER)
 - Replacement of IP bellows chambers
 - QCS cryostat modification
- NLC system construction (LER)
- Removal and reinstallation of kicker ceramic chambers for magnetic field measurement (LER)
- Replacement of beam pipes at HER Injection point (HER)
- Installation of new bellows chamber with SR mask at Wiggler sections (LER) Will be reported in this talk
(works mainly for vacuum system)
- Countermeasure against vacuum issues
 - NEG pump feedthrough replacement (countermeasure against vacuum leak, LER)
 - Ion pump feedthrough replacement (x4, countermeasure against abnormal discharge & vacuum leak, HER)
 - Bellows chamber replacement (countermeasure against vacuum leak, HER)
 - Temporary countermeasure against vacuum leak from beam pipe welding line (countermeasure against vacuum leak, LER)
 - Gate valve and bellows chamber replacement (countermeasure against pressure spike, HER)
- Collimator works (LER&HER)
 - Collimator relocation (LER:D03V1 -> D05V1(NLC), D06H1 -> D06H4)
 - Collimator head replacement (LER:D02V1, D05V1(NLC), D06V1, D06H3, D06H4, HER:D01V1, D09V1)
 - Installation HOM absorber chamber near D06V1 (LER)
 - Installation of permanent magnet on SuperKEKB-type horizontal collimators (countermeasure against SBL, LER&HER)
 - Upgrade of KEKB-type driving mechanism (HER:D09V1, D12V3) Not vacuum work

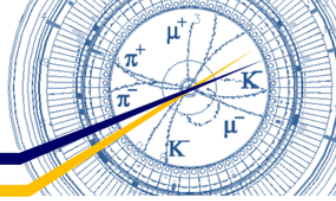
Vacuum work

Will be reported in this talk
(works mainly for vacuum system)

Not vacuum work



List of major works during LS1 (BT&DR)



- Removal and reinstallation of bellows chambers for magnet alignment (BTe & BTp)
- Installation of V-offset bellows chambers (BTp)
- Installation of CSR monitor chamber (BTp)
- Installation of OTR screen monitor (BTp)

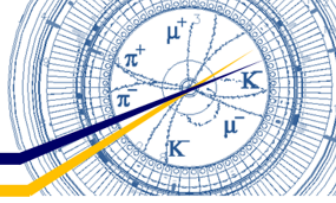
Requirements for vacuum system are less severe.

- Removal and reinstallation of Ext. kicker chambers for Kicker PS work (DR)

Will be reported in this talk
(First vacuum work after start of beam operation)

Vacuum work

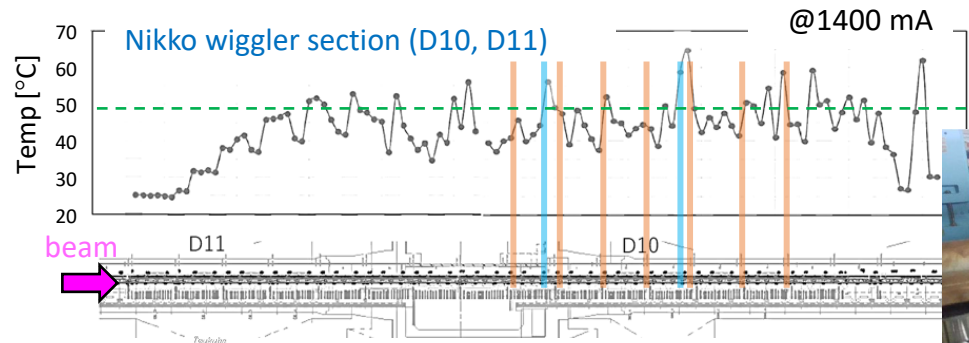
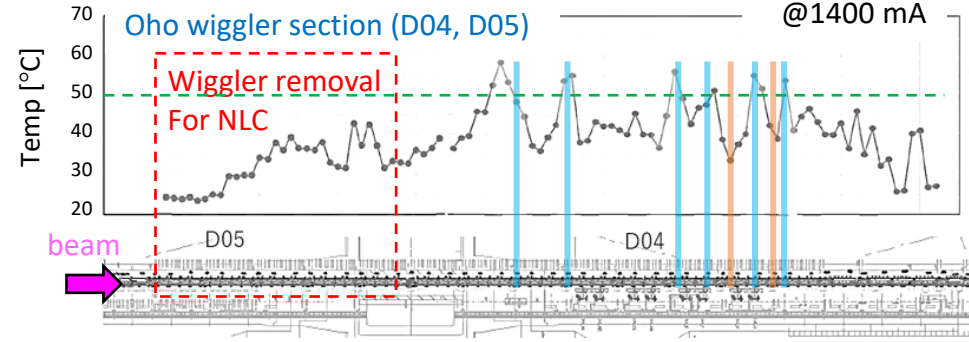
Major vacuum works during LS1 (MR) #1



Vacuum work at LER wiggler sections (LER)

Already reported in last KEKB Review

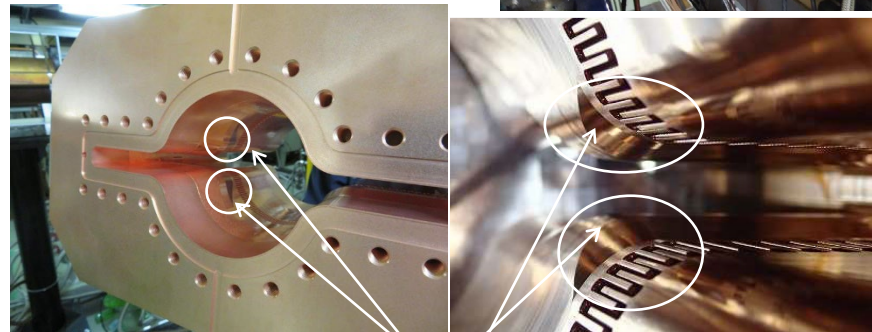
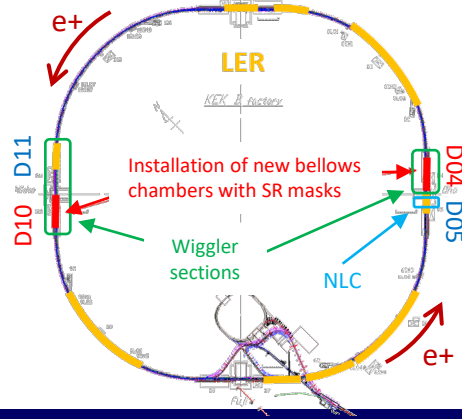
- Countermeasure against temperature rise of beam pipes downstream of Wiggler Sections
 - Beam current will be increased after LS1.
 - Magnetic field of wiggler magnets might be increased to compensate the reduction due to removed wiggler magnets for NLC system construction.
 - Strong SR should be absorbed by SR masks in the bellows chambers.
 - Locations of SR masks were optimized.
- Rearrangement of bellows chambers
 - Larger SR power locations: From bellows chamber w/o SR masks to w/ SR masks (9 chambers)
 - Smaller SR power locations: From bellows chamber w/ SR masks to w/o SR masks (8 chambers)
- Air and water cooling of the bellows chamber with SR masks were also enforced.



Bellows chamber replacement

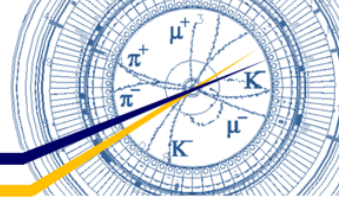
w/o → w/ SR masks

w/ → w/o SR masks

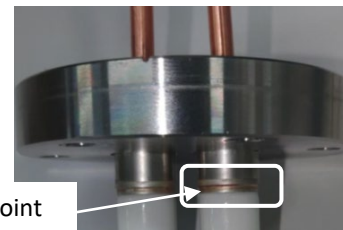
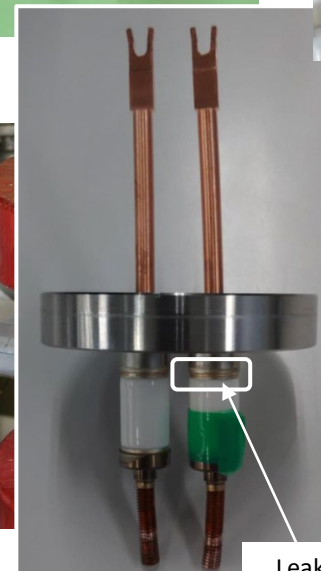
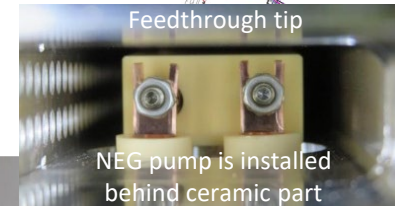
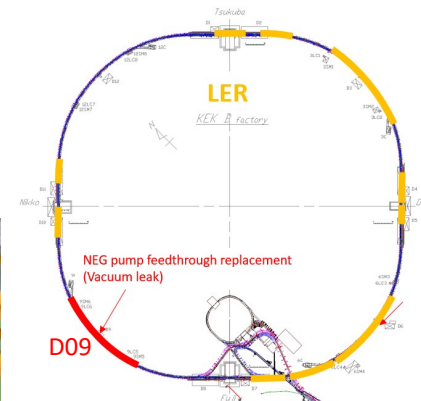
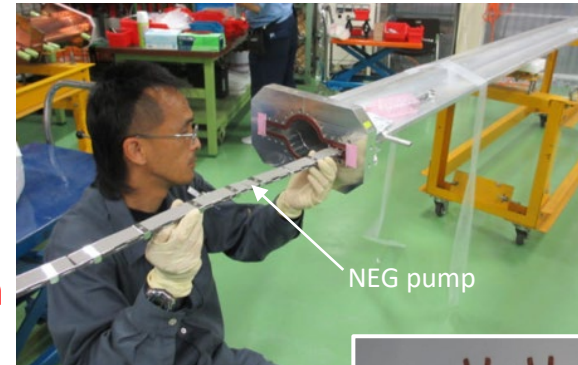
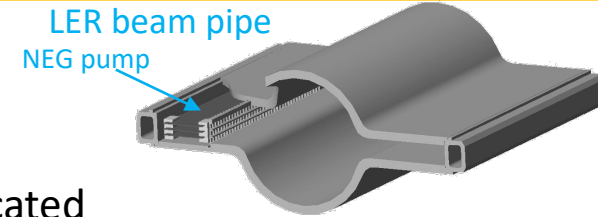


SR masks in bellow chamber

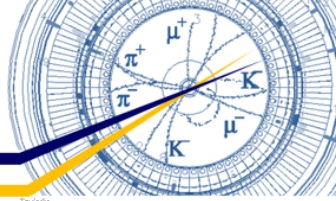
Major vacuum works during LS1 (MR) #2



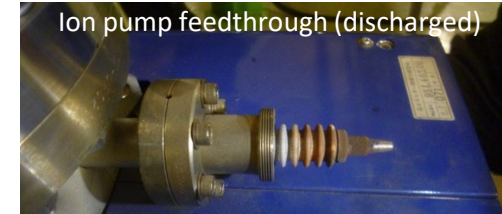
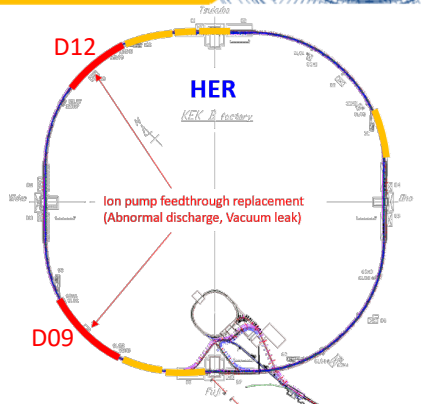
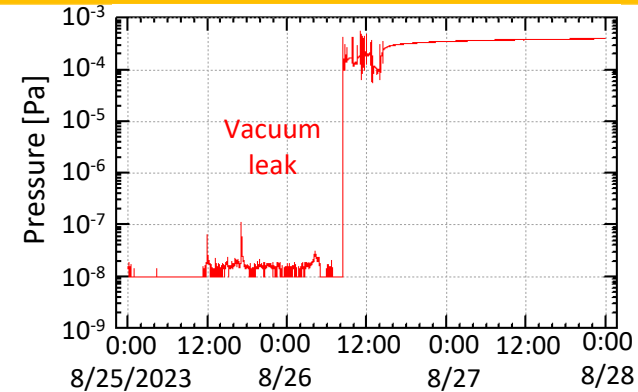
- NEG pump feedthrough replacement (LER)
 - Countermeasure against vacuum leak during LS1
 - It was found that a vacuum switch at D09 Arc Section in LER indicated abnormally high pressure. (2022/12/28)
 - Vacuum gauges and Ion pumps were turned off by I/L.
 - Unfortunately, data logging had been accidentally stopped, so pressure history was unknown.
 - D09 Arc Section was filled with air up to low vacuum at least.
 - Vacuum leak from NEG pump feedthrough was detected by vacuum leak test.
- Replacement and investigation of NEG pump feedthrough
 - Faulty feedthrough was replaced with new one.
 - It was found that vacuum leak was occurred at the brazed part between the ceramic and stainless steel.
 - Investigation with X-rays revealed a crack in the ceramic part.
 - Ceramic tube inside vacuum was also broken.
 - It is still unclear why the ceramic parts were damaged at this time.
 - No work near this feedthrough & no NEG activation at this time.
 - Remaining excessive force during installation?
 - No further countermeasure against this issue



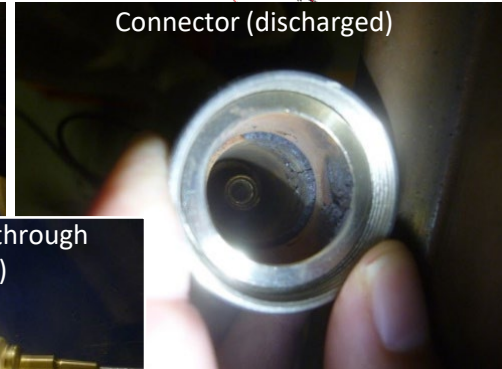
Major vacuum works during LS1 (MR) #3



- Ion pump feedthrough replacement (x4, HER)
 - Countermeasure against abnormal discharge and vacuum leak during LS1
 - Pressure at D12 Arc Section of HER suddenly increased to $\sim 10^{-4}$ Pa. (2023/8/25)
 - It was found that abnormal discharge occurred in HV connector of an ion pump.
 - There was abnormal sound from it and abnormal high temperature on it.
 - **Discharge in the connector resulted in vacuum leak.**
 - Replacement of HV feedthrough and investigation of other feedthroughs
 - Faulty feedthrough was replaced with new one. (Vacuum work)
 - Feedthroughs and connectors of other ion pumps were checked.
 - **It was found that abnormal discharge occurred in some connectors at D09 & D12 Arc Sections.**
 - **Three feedthroughs in D09 & D12 Arc Sections were replaced with new ones. (Vacuum work)**
 - **Others were reused after cleaning. (Not vacuum work)**
 - Similar issues occurred during LS1 although they did not result in vacuum leaks fortunately.
 - Similar issues has occurred several times over the past 20 years.
 - They may be due to an increase in humidity due to the air conditioner stopping.
 - Further countermeasures:
 - R&D of humidity-resistant HV feedthrough and connector was started.
 - Since the feedthrough is no longer in production and difficult to obtain, alternative feedthrough must be developed.



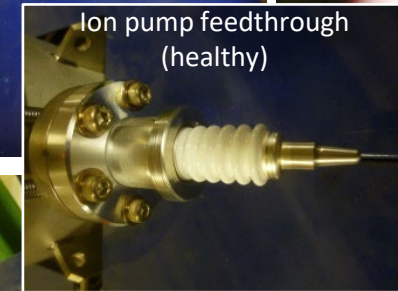
Ion pump feedthrough (discharged)



Connector (discharged)



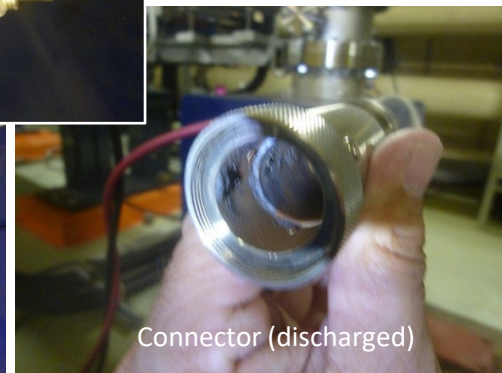
Ion pump



Ion pump feedthrough (healthy)

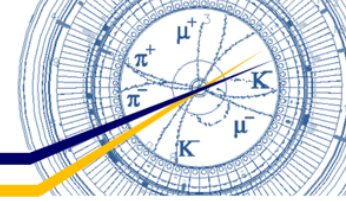


Ion pump feedthrough (discharged)

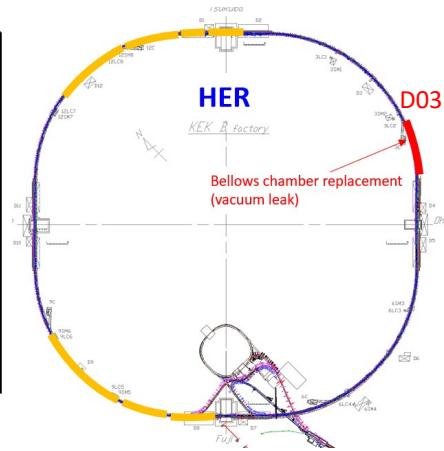
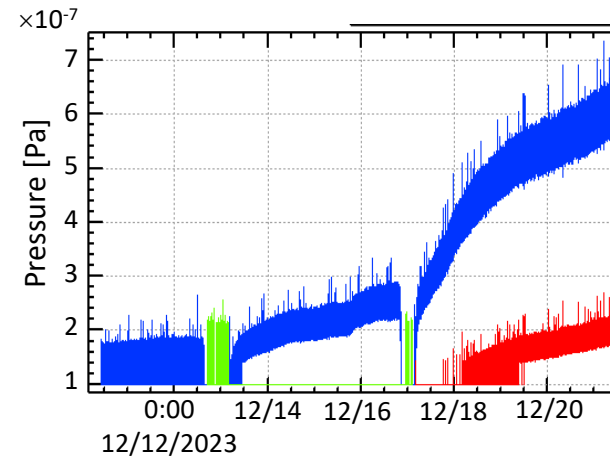


Connector (discharged)

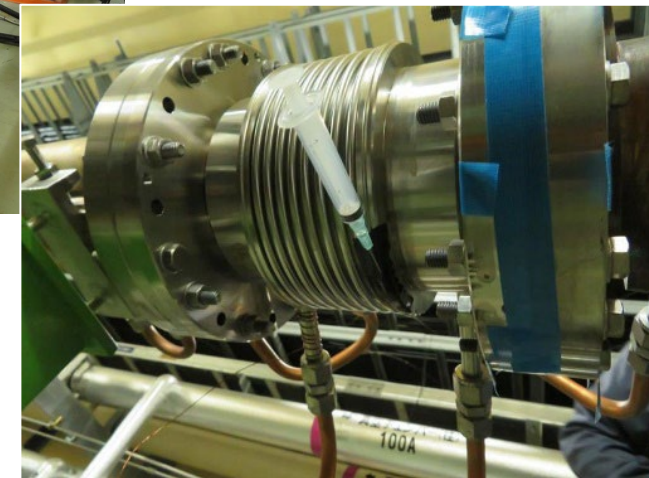
Major vacuum works during LS1 (MR) #4



- Bellows chamber replacement (HER)
 - Countermeasure against vacuum leak during LS1
 - Pressure at D03 Arc Section of HER gradually increased to $\sim 7 \times 10^{-7}$ Pa. (from 2023/12/13)
 - Leak test revealed that a vacuum leak occurred at the brazing line of a bellows chamber.
 - Faulty bellows chamber was replaced with new one.
 - It was installed into KEKB in 1997.
 - Still unclear why the vacuum leak occurred at this bellows chamber at this time
 - If vacuum leak occurs at other bellows chamber, it will be replaced with spare bellows chambers.
 - There are spare bellows chambers.

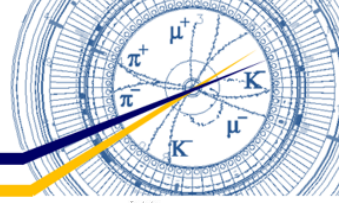


Leaked bellows chamber

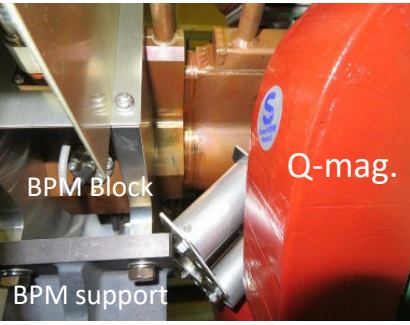
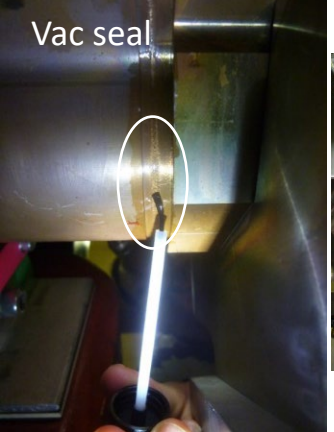
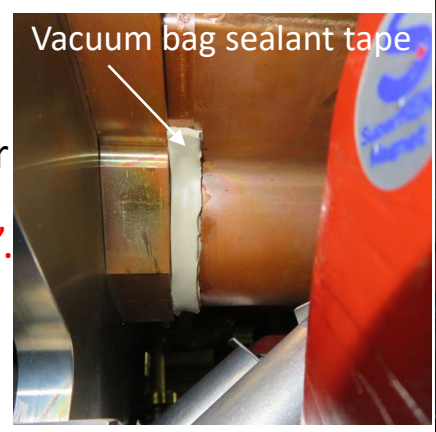
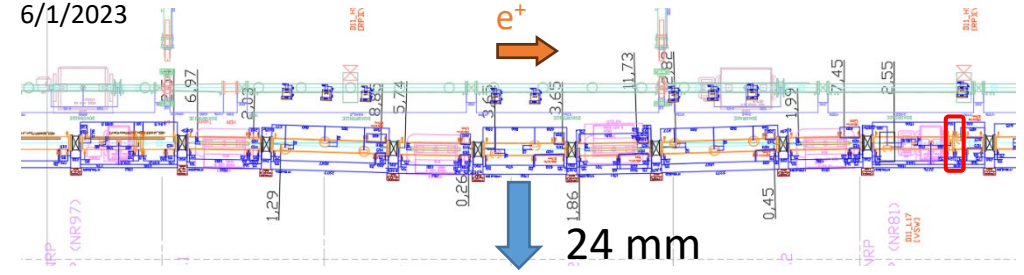
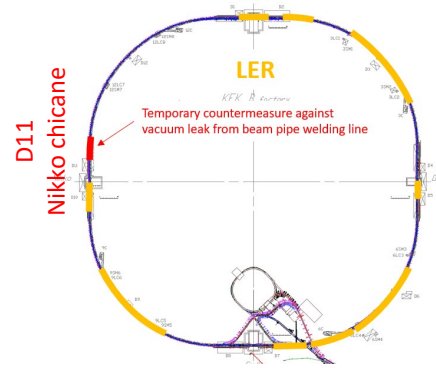
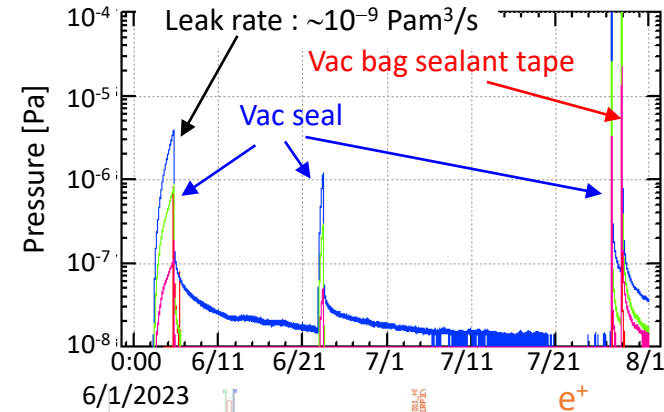


He gas was sprayed with a syringe to locate the leak point

Major vacuum works during LS1 (MR) #5

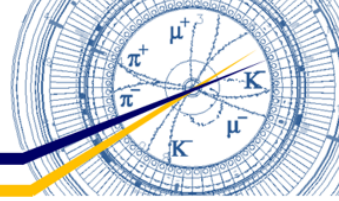


- Temporary countermeasure against vacuum leak from beam pipe welding line (LER)
 - Re-alignment of beam pipes in Nikko Chicane Section (not vacuum work)
 - To make orbit length the same as before removal of wiggler magnets in NLC section, beam pipes in Nikko chicane section were moved horizontally by up to 24 mm.
 - The BPM block of the Q-chamber, which had not been fixed for unknown reason, was fixed to the Q-magnet. (2023/4/28)
 - Vacuum leak occurred from the welding line of the BPM block. (2023/6/3)
 - Leak rate was $\sim 10^{-9}$ Pam³/s at this point.
 - This chamber was deformed during TiN coating process and repaired before installation into the SuperKEKB.
 - Stress due to repair work might be a cause of the vacuum leak.
 - Countermeasure against vacuum leak:
 - At first, the vacuum leak was stopped by “Vac seal”, however it could not be stopped by “Vac seal” in the end.
 - The vacuum leak was stopped by “Vacuum bag sealant tape”.
 - Further countermeasure
 - New beam pipe is currently being fabricated and is scheduled to be delivered on 27th March (tomorrow).



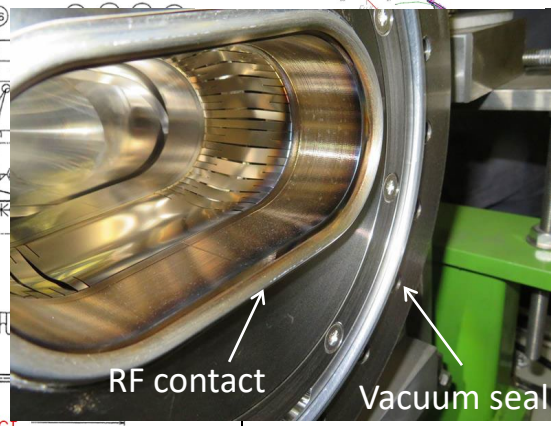
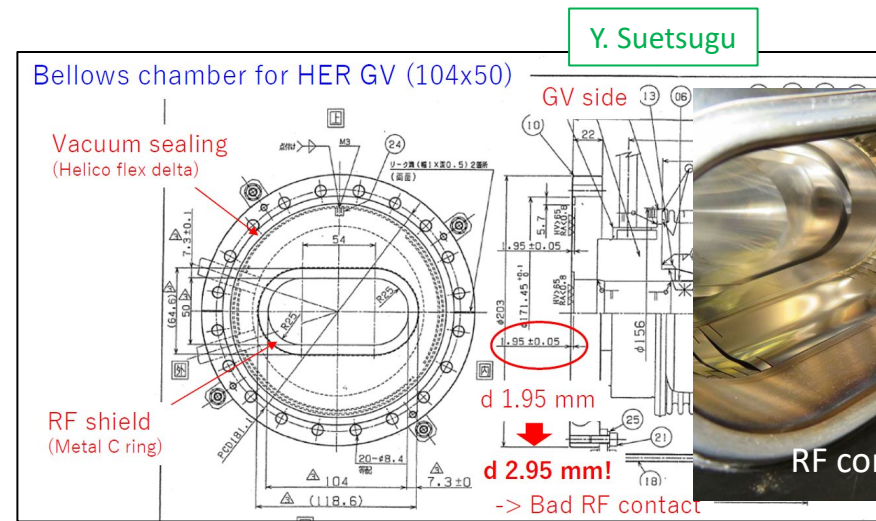
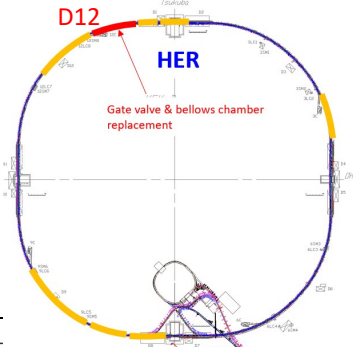
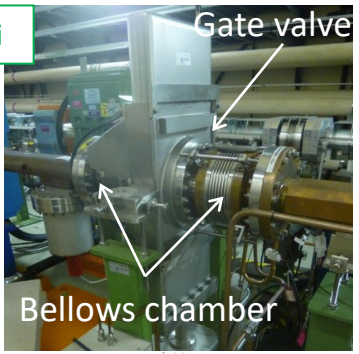
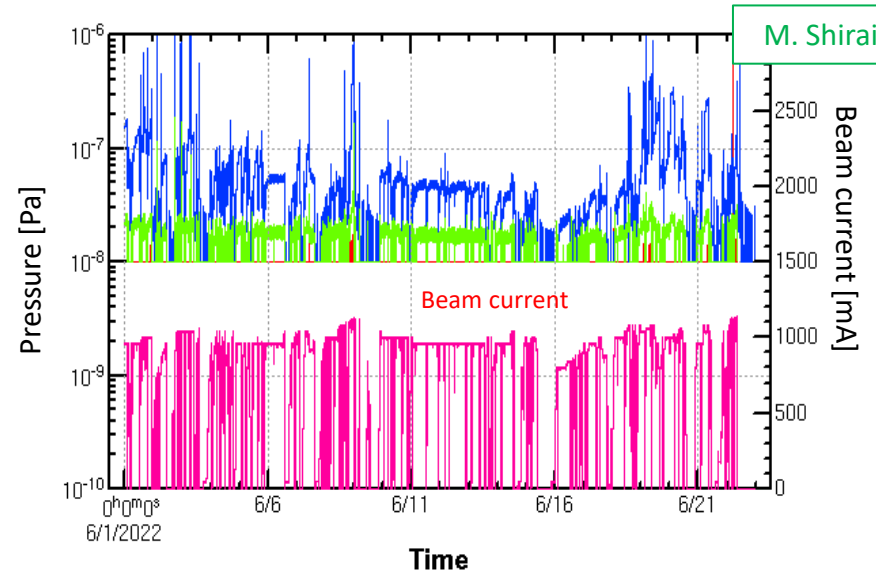
BPM block is fixed to Q-magnet by BPM support

Major vacuum works during LS1 (MR) #6

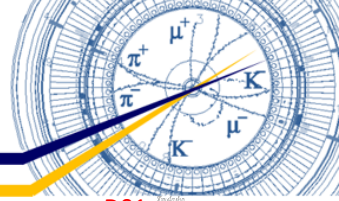


- Replacement of gate valve and bellows chamber (HER) Already reported in last KEKB Review

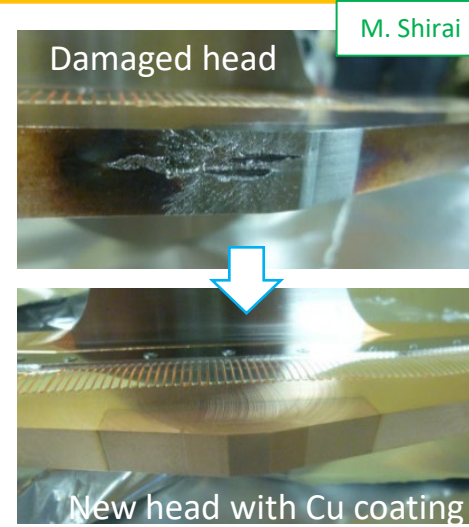
- Countermeasure against abnormal pressure spike
 - Abnormal pressure spikes near a gate valve were observed at HER D12 Arc Section (2022ab).
 - Abnormal temperature rise of the gate valve was also observed.
 - Internal visual check revealed that the groove for the RF contact of the bellows chamber connected to the gate valve was 1 mm deeper than designed. (Vacuum work)**
 - Possible cause is discharge at small gap due to poor contact between gate valve and bellows chamber.
- Gate valve and bellows chamber were replaced with new ones.
 - It was confirmed that the depth of the groove for the RF contact of installed bellows chamber was designed value.
 - It was also confirmed that the pressures and temperatures of other HER gate valves were normal.
 - The depth of the other bellows chamber grooves seems to be as designed.



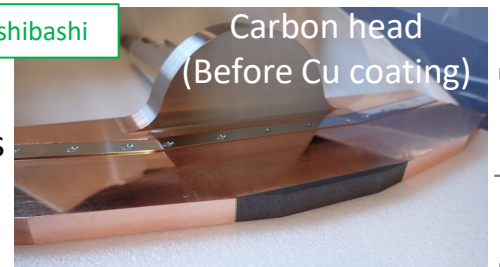
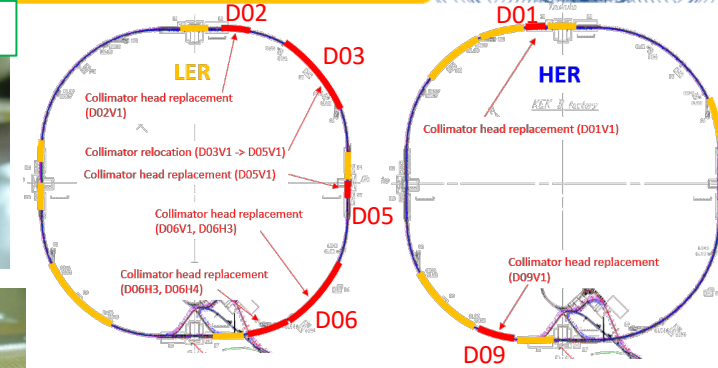
Collimator works during LS1 #1



- Collimator relocation and head replacement:
 - Replacement of damaged heads of vertical collimators
 - LER : D02V1, D06V1
 - HER : D01V1, D09V1
 - Relocation and head replacement for NLC
 - LER : D03V1 -> D05V1(NLC)
 - Head was replaced with shorter one (Ta, 5 mm) for scratch resistant
 - D06V1 (Ti, 10 mm) can be used as a spoiler for SBL
 - Countermeasure against injection kicker accidental firing (Horizontal collimators)
 - LER : D06H3
 - Head was replaced with Low-Z one (C, 16mm) for robustness
 - Spoiler against inj. kicker accidental firing.
 - LER : D06H1(upstream of D06H3) -> D06H4 (downstream of D06H3)
 - W head was replaced with Ta head (10mm) to suppress dust generation when damaged.
 - Absorber against inj. kicker accidental firing.
 - LER Inj. Kicker accidentally mis-fired several times in 2024a run, and Low-Z collimator seemed to work as expected.



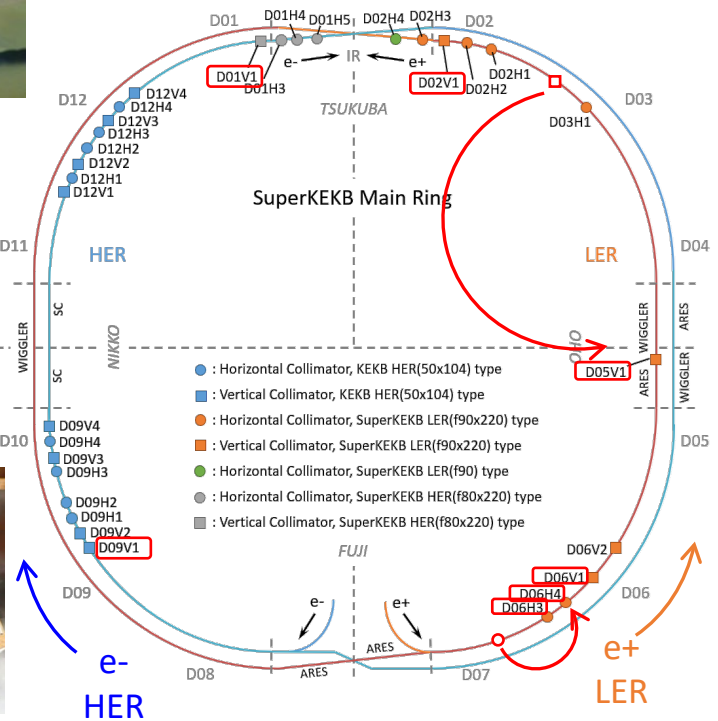
M. Shirai



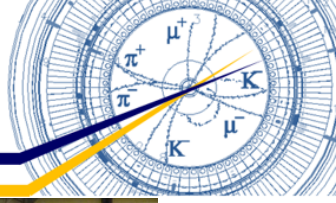
T. Ishibashi



S. Terui



Collimator works during LS1 #2



- Other collimator related works:

- Installation of HOM absorber chamber (LER)

- Beam pipe with HOM absorbers was installed near D06V1 collimator in LER.
 - For future high current beam operation.
 - HOM generated at collimator have not been serious issues so far.

- Installation of permanent magnet on SuperKEKB-type horizontal collimators (LER&HER)

- For suppression of electron cloud which may be the cause of SBL.
- All SuperKEKB-type horizontal collimators have permanent magnets on it.

- Precise alignment of collimators by Magnet Group.

- For SuperKEKB-type Vertical collimators whose heads were replaced during LS1
 - HER : D01V1
 - LER : D02V1, D05V1, D06V1

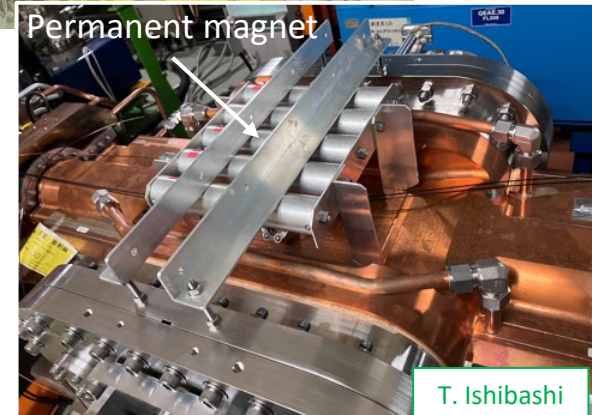
- Upgrade of KEKB-type driving mechanism

- For more precise and stable position control
 - HER : D09V1, D12V3

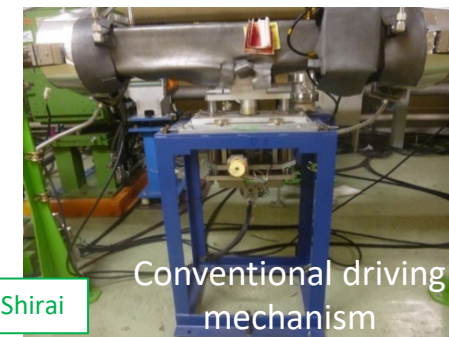
M. Shirai



Permanent magnet



T. Ishibashi



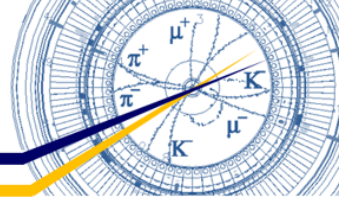
M. Shirai

Conventional driving mechanism

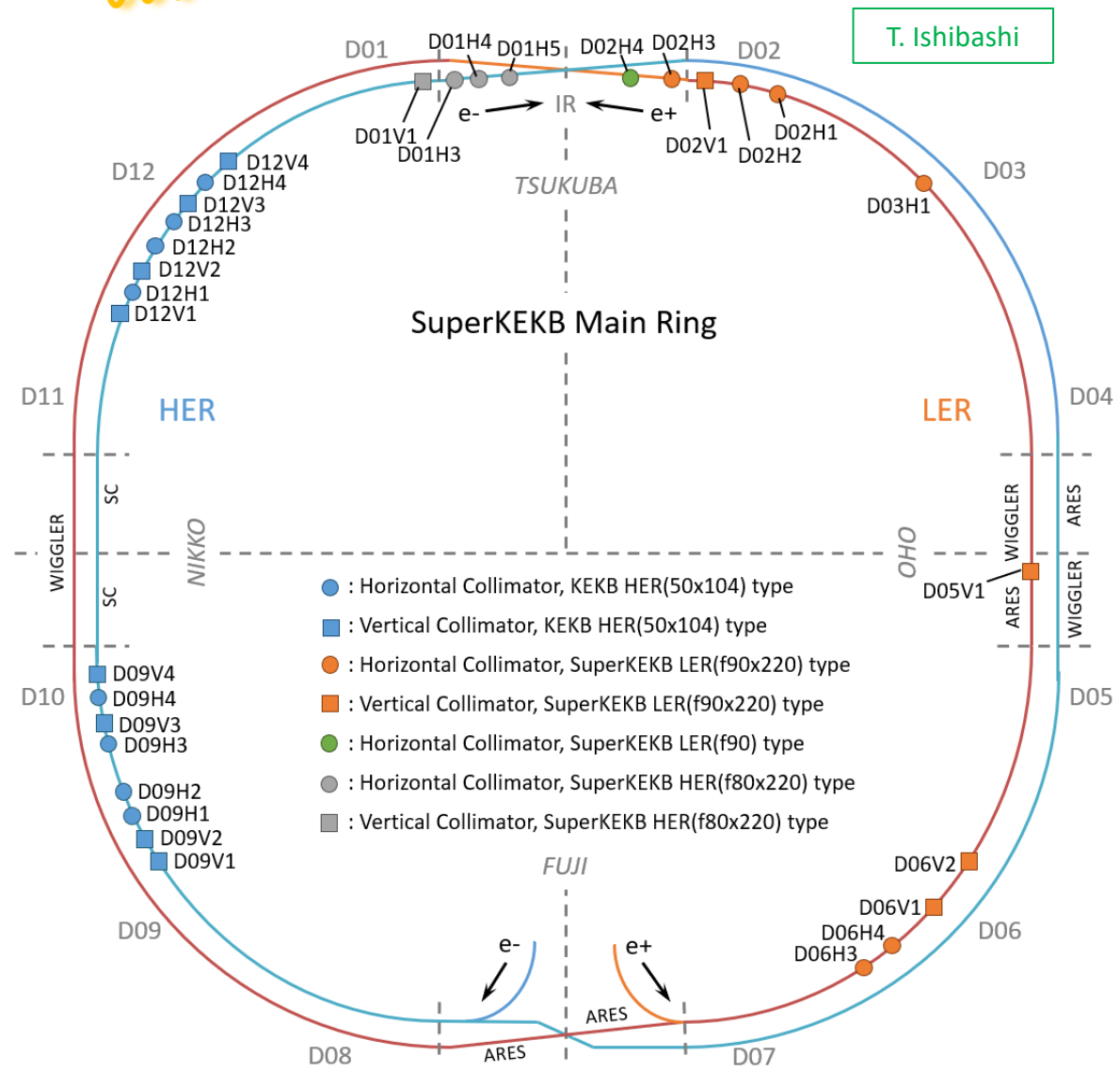


New driving mechanism

Status of LER collimator after LS1



T. Ishibashi



Vertical collimator

Name	Type	Tip Material	Cu coating	Tip condition
D02V1	SuperKEKB	Ta (160 mm)	○	○
D05V1	SuperKEKB	Ta (4 mm)	○	○
D06V1	SuperKEKB	Ti (10 mm)	○	○
D06V2	SuperKEKB	Hybrid (3 mm)	○	○

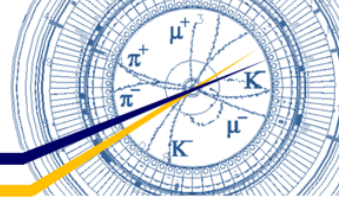
Horizontal collimator

Name	Type	Tip Material	Cu coating	Tip condition
D02H1-H4	SuperKEKB	W (10 mm)	×	○
D03H1	SuperKEKB	W (10 mm)	×	○
D06H3	SuperKEKB	C (160 mm)	○	○
D06H4	SuperKEKB	Ta (10 mm)	×	○

Remarks

- D06H3 and D06H4 work as spoiler and absorber against inj. kicker accidental firings.
- All collimator heads are healthy (Not damaged).
- All vertical collimator heads are coated with Cu.
- All horizontal collimator have permanent magnets.

Status of HER collimator after LS1



Vertical collimator

Name	Type	Tip Material	Cu coating	Tip condition
D01V1	SuperKEKB	Ta (10 mm)	○	○
D12V1, V2	KEKB	Ti (40 mm)	○	×
D12V3, V4	KEKB	Ti (40 mm)	○	○
D09V1-V4	KEKB	Ti (40 mm)	○	○

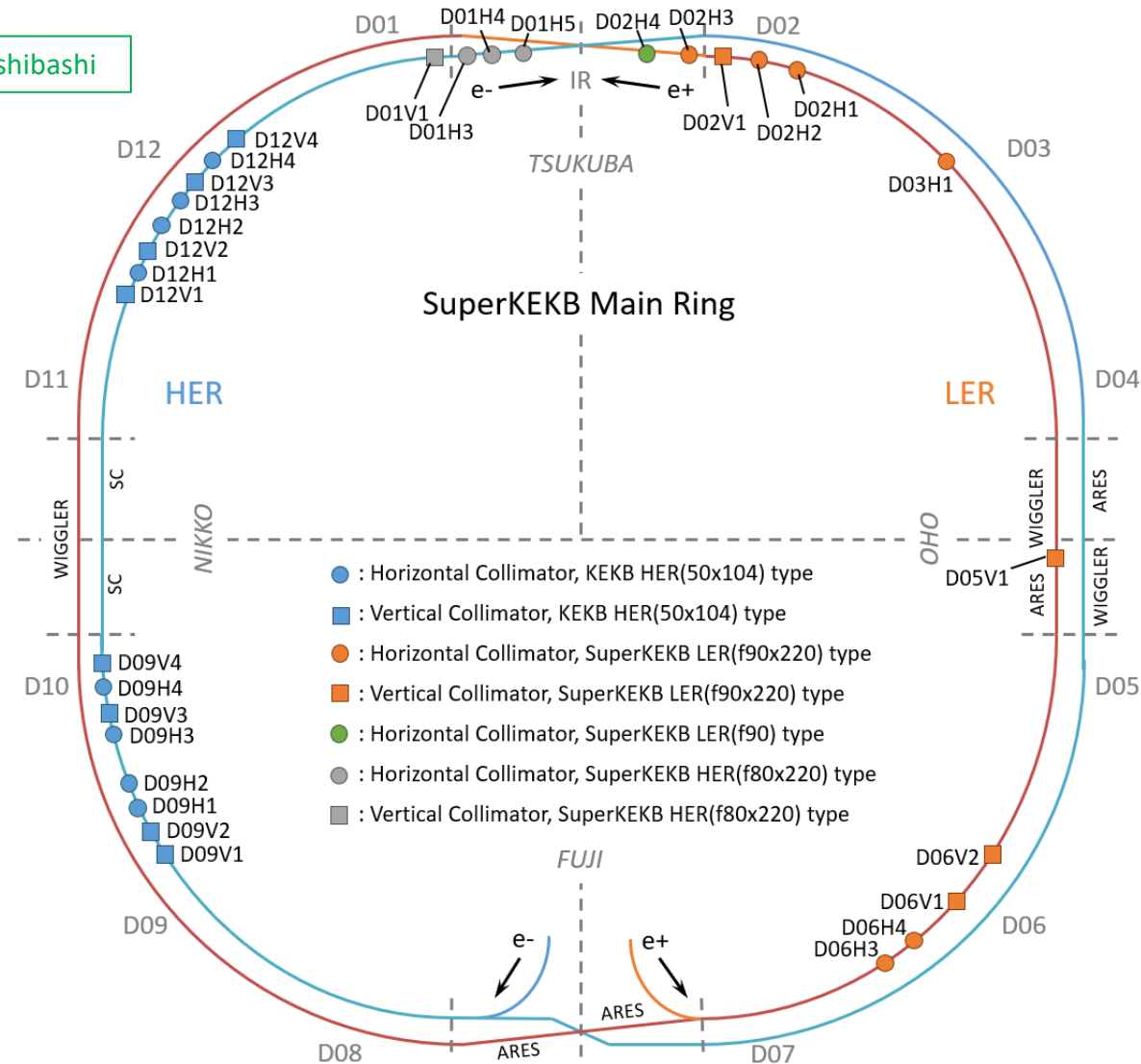
Horizontal collimator

Name	Type	Tip Material	Cu coating	Tip condition
D01H3-H5	SuperKEKB	W (10 mm)	×	○
D12H1, H3	KEKB	Ti (40 mm)	×	○
D12H2	KEKB	Ti (40 mm)	○	×
D12H4	KEKB	Ti (40 mm)	○	○
D09H1-H4	KEKB	Ti (40 mm)	○	×

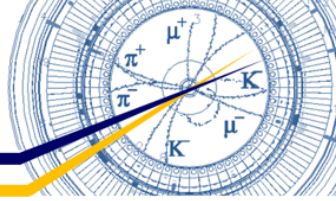
Remarks

- Drive mechanism of some KEKB-type collimators has been upgraded for precise and stable adjustment.
 - D09V1, D12V1, D12V3, D12V4

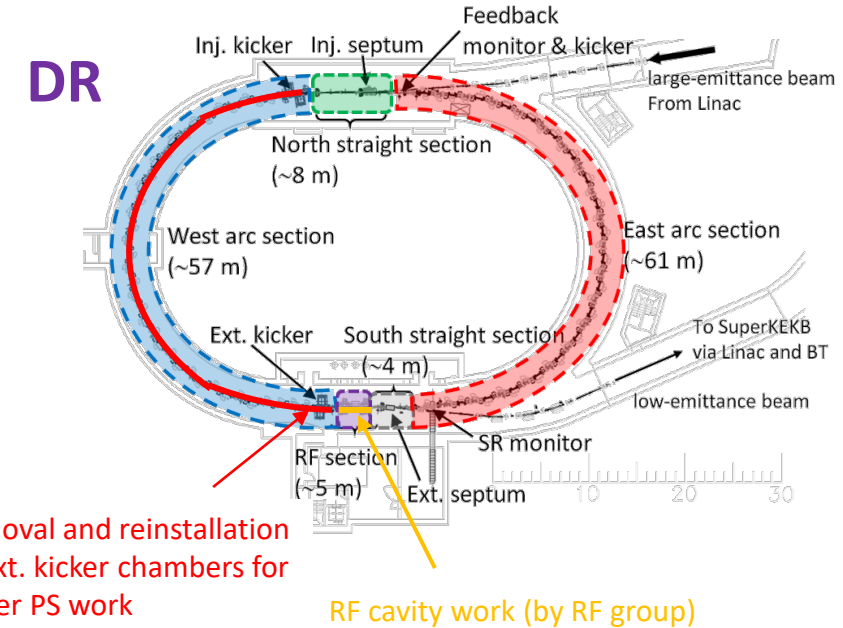
T. Ishibashi



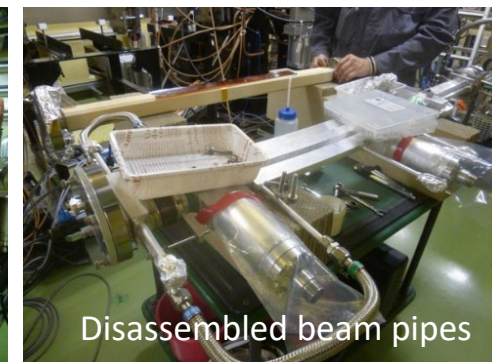
Major vacuum works during LS1 (DR)



- Two beam pipes were disassembled and reinstalled for Ext. Kicker PS work.
 - First vacuum work after DR construction
 - West Arc Section was filled with dry nitrogen.
 - Ceramic beam pipe for Ext. kicker and a beam pipe next to it were disassembled to remove Kicker PS.
 - These two beam pipes were filled with dry nitrogen and reinstalled into DR about 10 months later.
 - Remaining area of West Arc Section was also filled with dry nitrogen for about 10 months.
 - Other sections covered by Vacuum Group were kept in vacuum.
 - East Arc Section
 - North Straight Section
 - Sought Straight Section
 - RF Group also performed vacuum work at RF section during LS1
 - Vacuum system of RF section is covered by RF Group.
 - Pressure of RF section was improved by this work.
 - Pressures of West Arc Section and Sought Straight Section were also improved by this work.

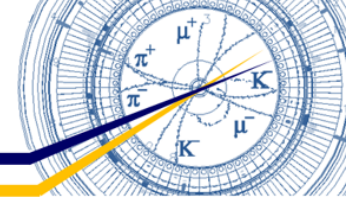


Ext. kicker and its PS

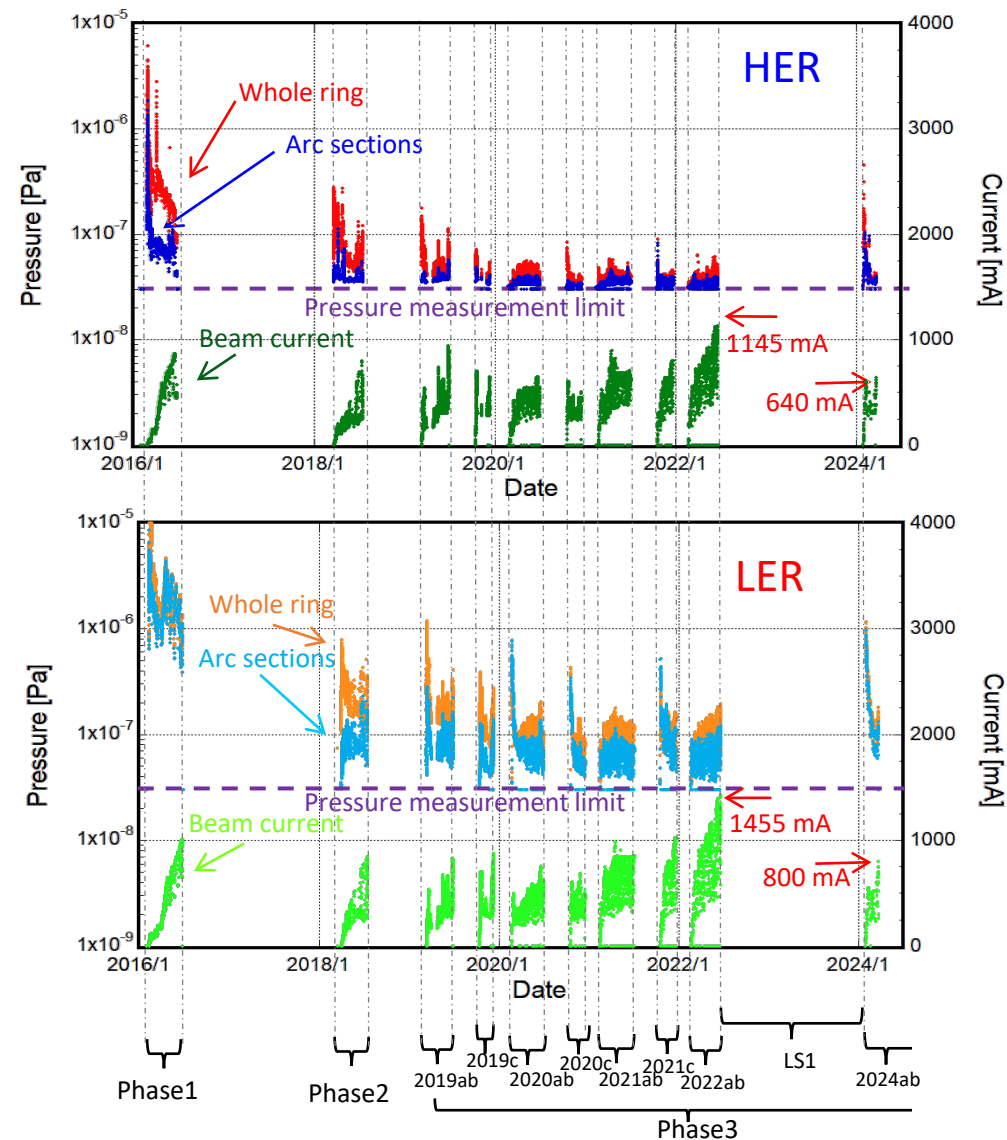
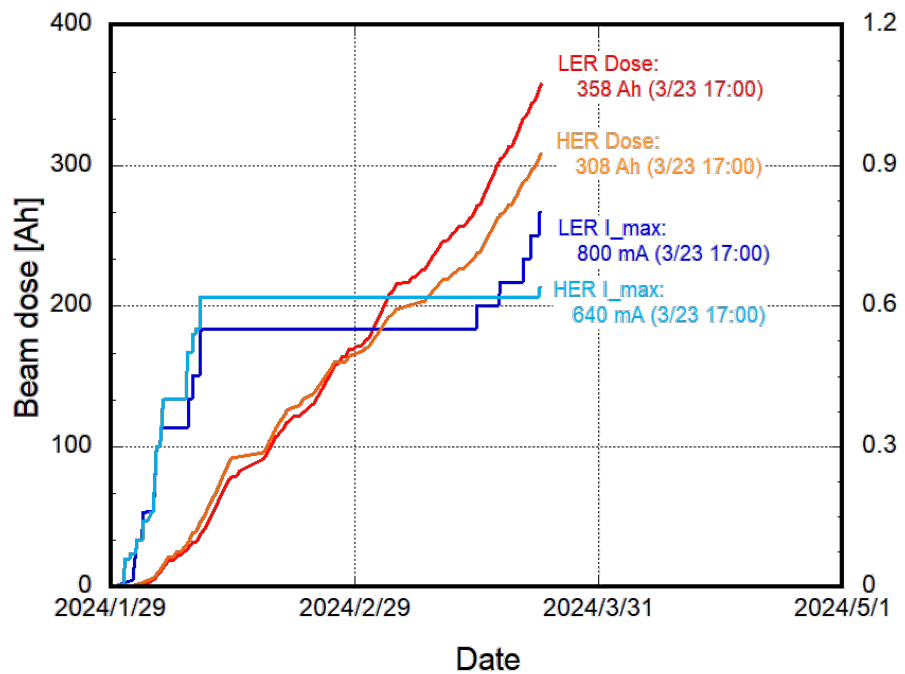


Disassembled beam pipes

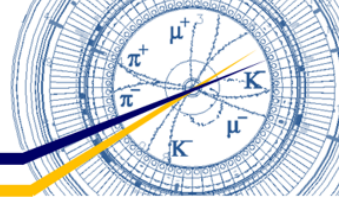
Beam dose & Maximum beam currents (MR)



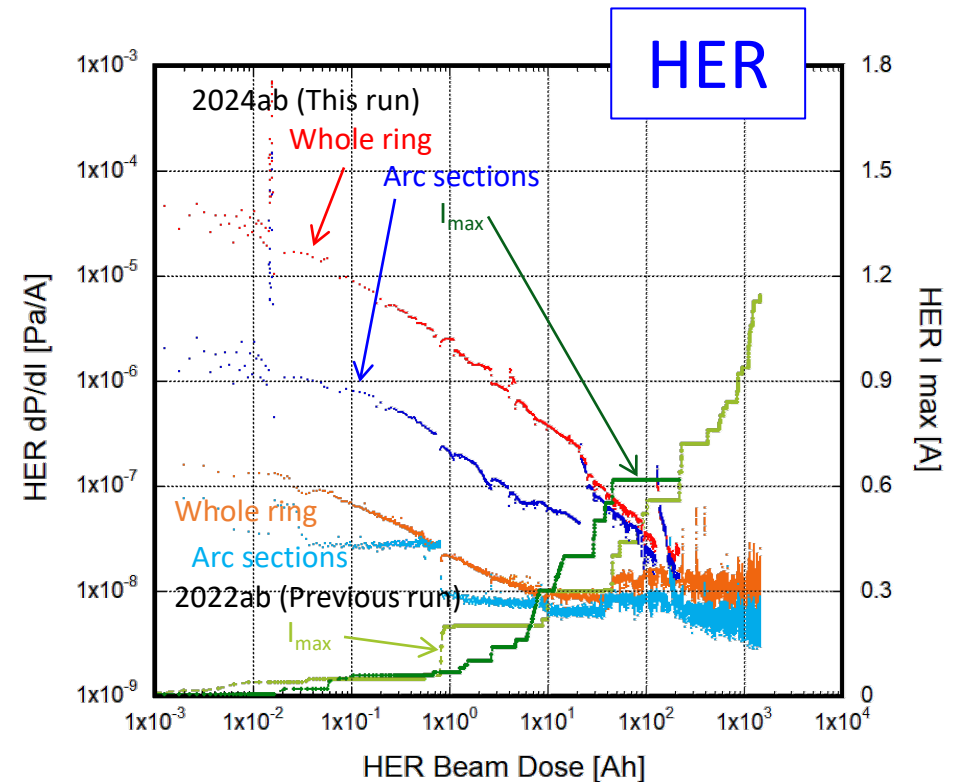
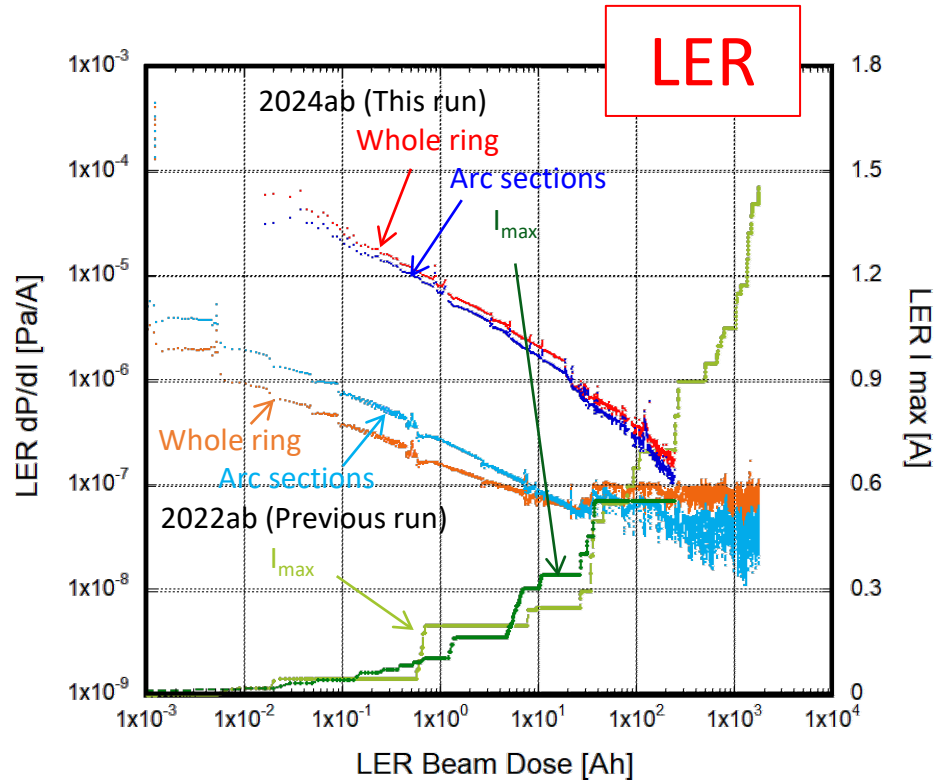
- Beam dose integrated in 2024a run (1/29 ~ 3/23)
 - HER : 308 Ah
 - LER : 358 Ah
 - No more dedicated vacuum scrubbing is required.
- Max. beam current in 2024a run (1/29 ~ 3/23)
 - HER : 640 mA
 - LER : 800 mA
- Max. beam current so far
 - HER : 1145 mA
 - LER : 1455 mA



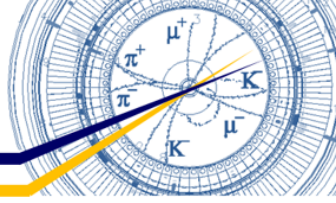
Vacuum scrubbing status (MR)



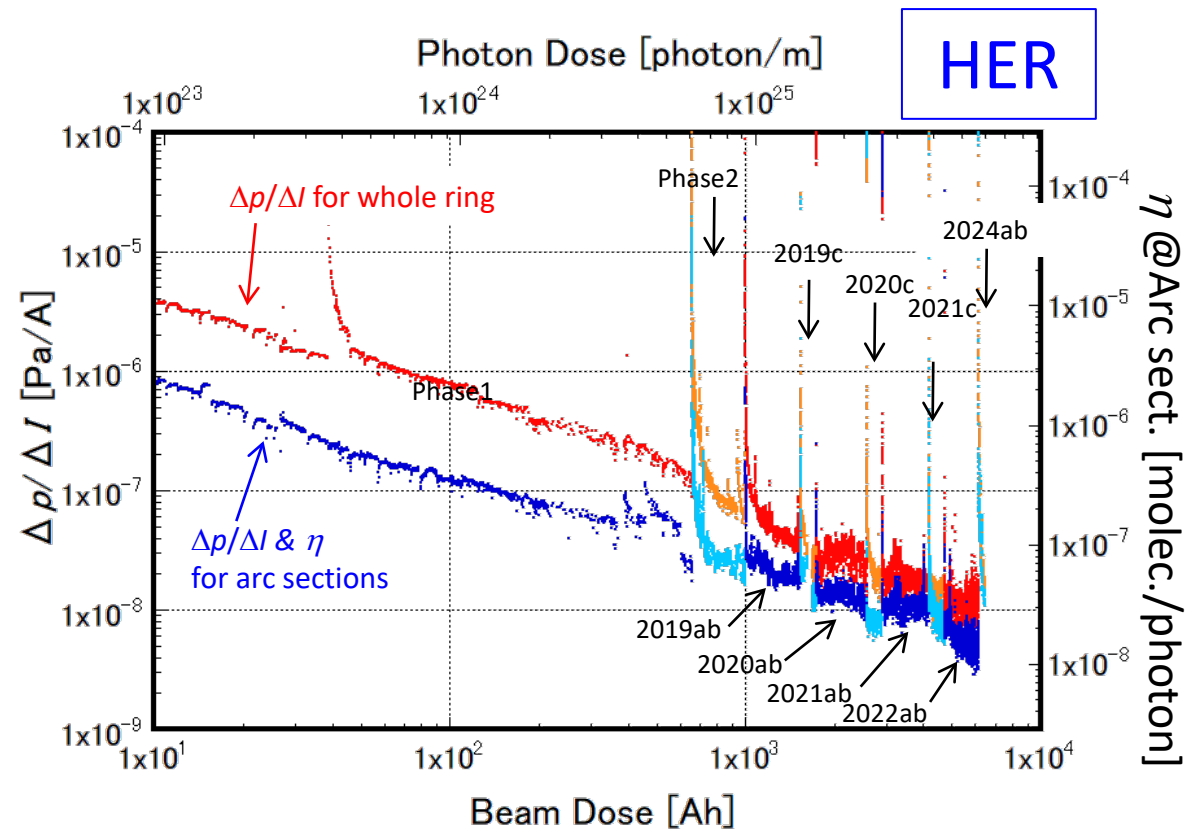
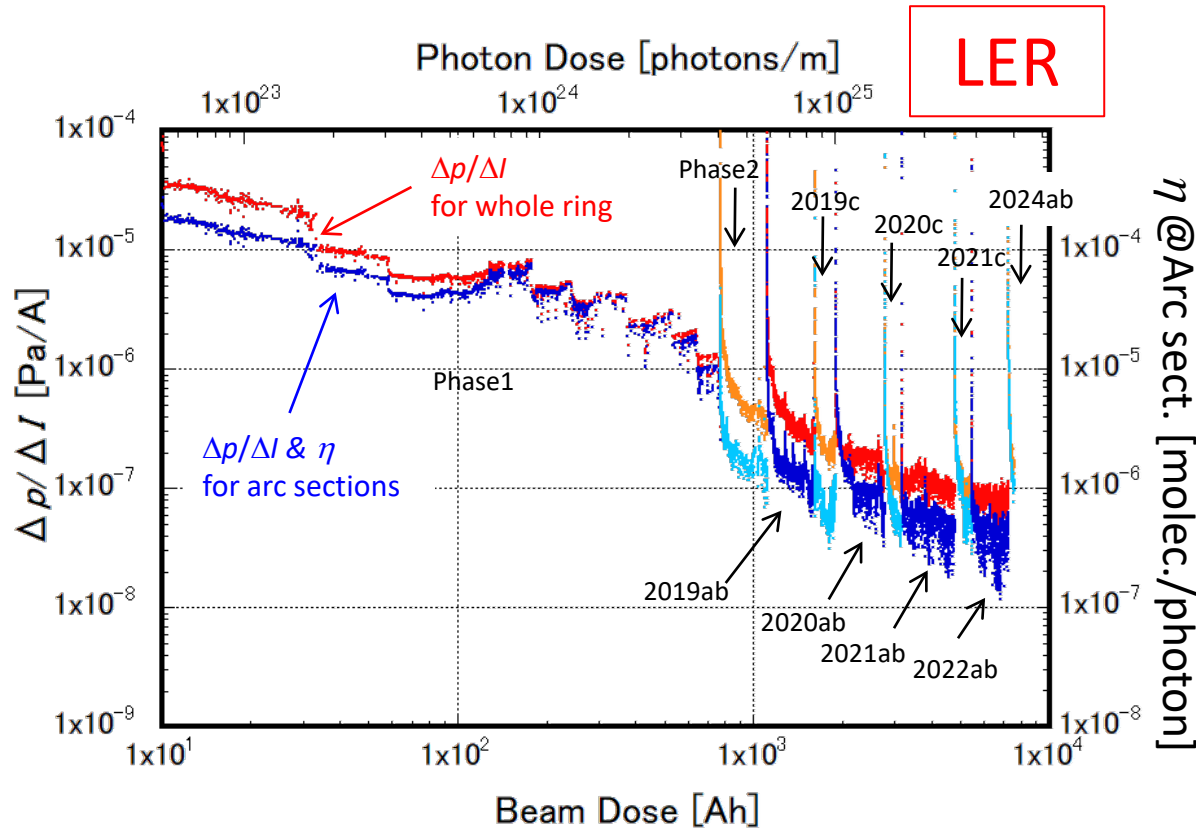
- Vacuum scrubbing is proceeding steadily in both rings.
 - $\Delta p/\Delta I$ is decreasing steadily as beam dose increases.
 - $\Delta p/\Delta I$ is higher in LER than HER.
 - Less memory effect in LER
 - More vacuum works in LER during LS1



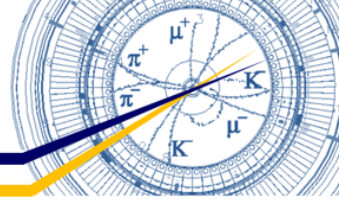
Vacuum scrubbing status (MR)



- Vacuum scrubbing status from Phase-I to Phase-III 2024ab run (~3/22)



Beam dose & Pressure (DR)

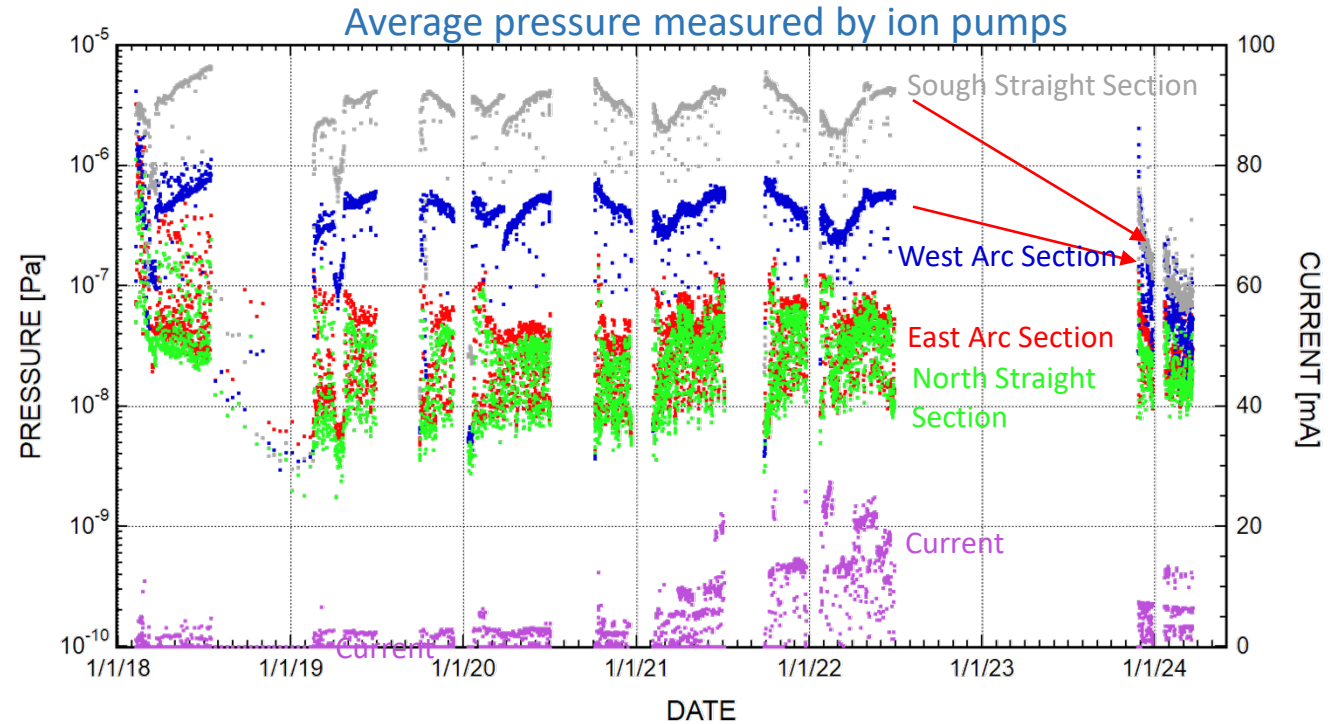
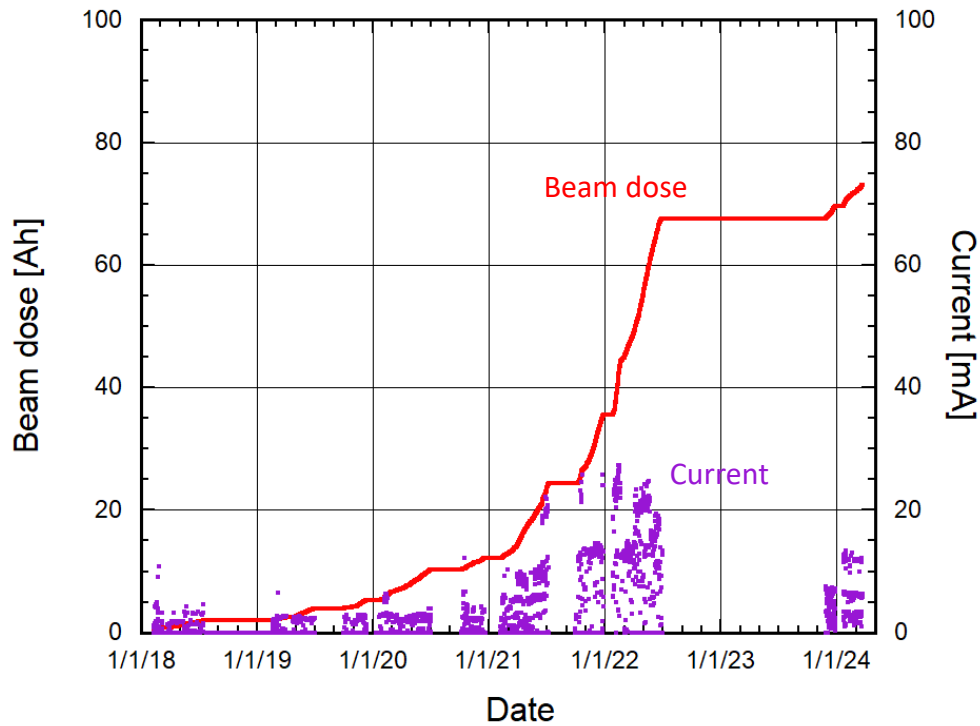
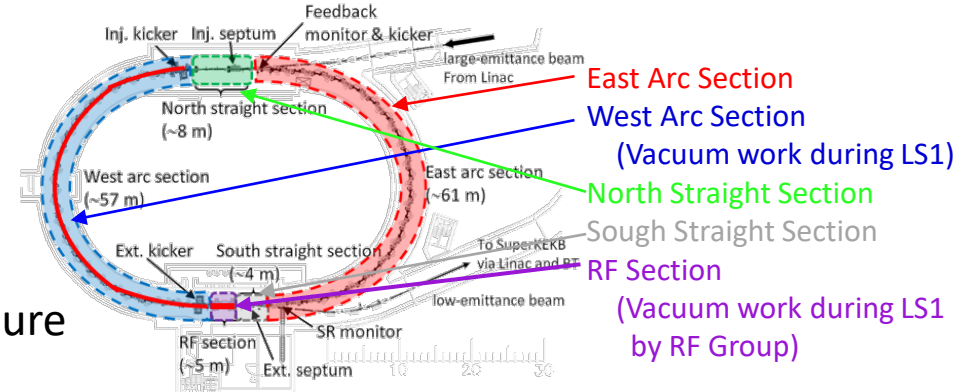


- Beam dose (until 3/22 0:00)

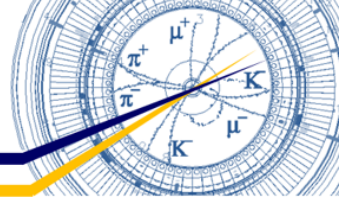
- 73.0 Ah (from start of beam operation)
- 5.4 Ah (after LS1)

- Pressure

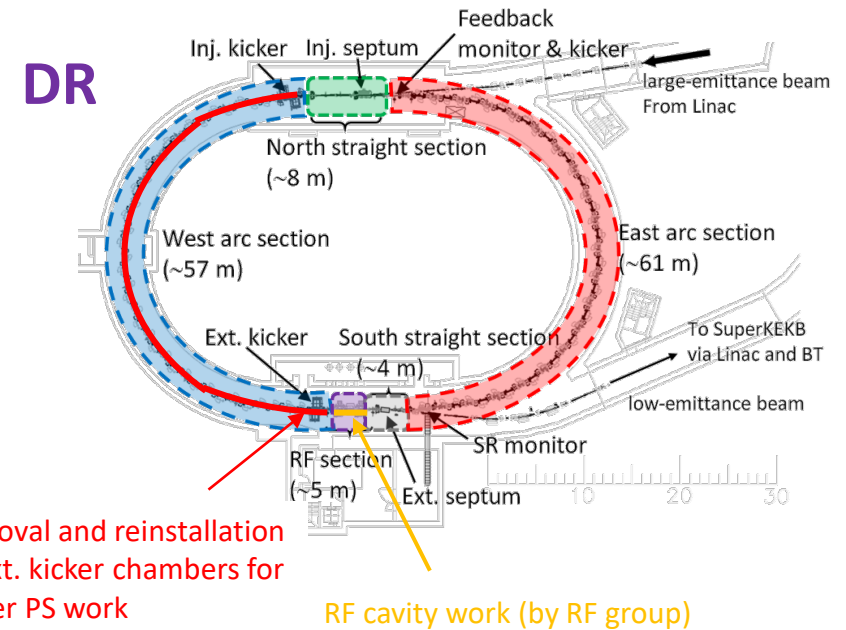
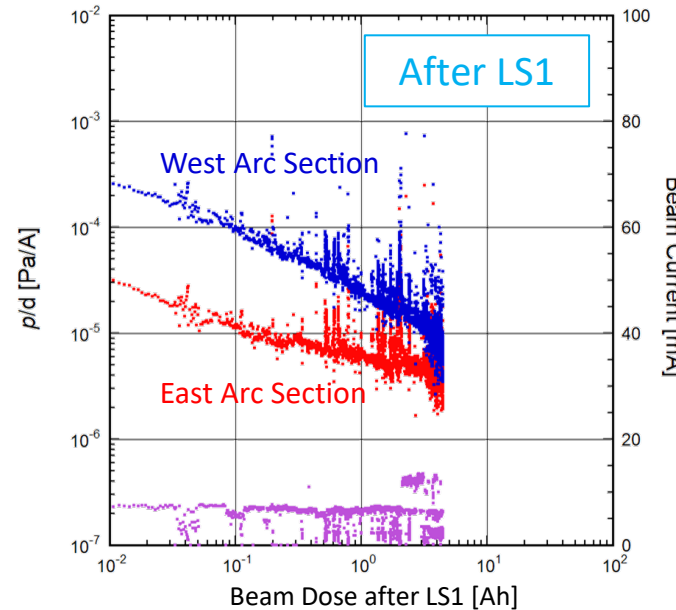
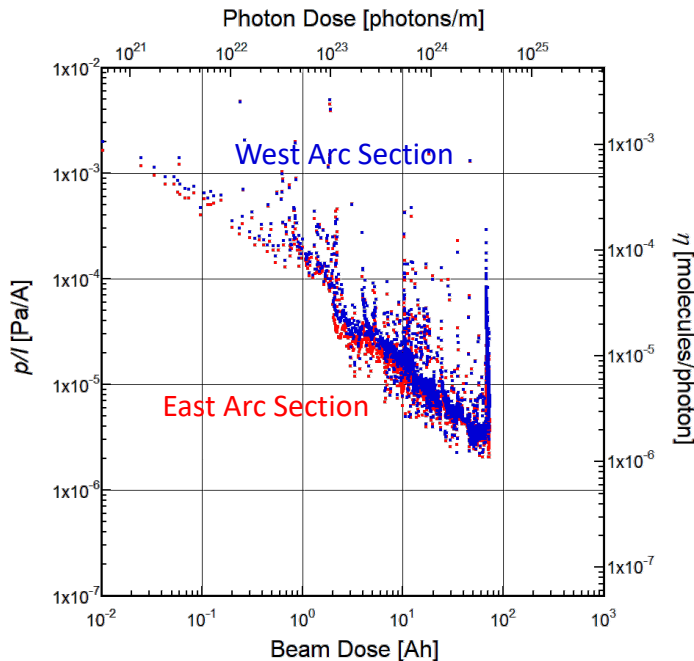
- RF Section work during LS1 has significantly reduced the average pressure in **West Arc Section** and South Straight Section.



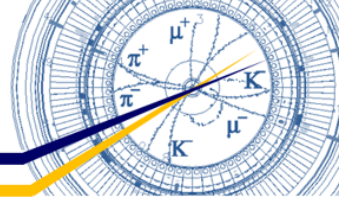
Vacuum scrubbing status (DR)



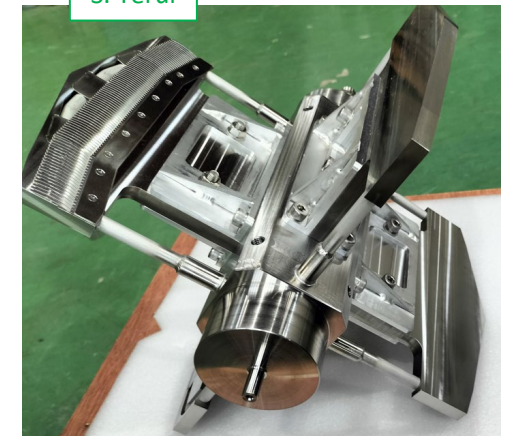
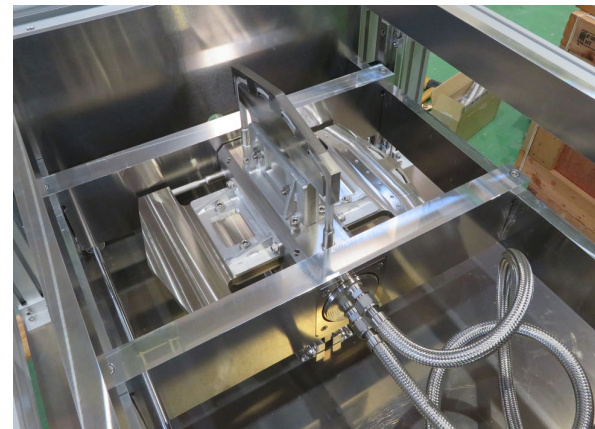
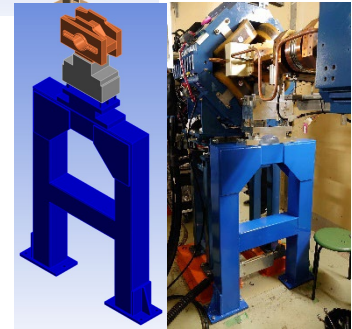
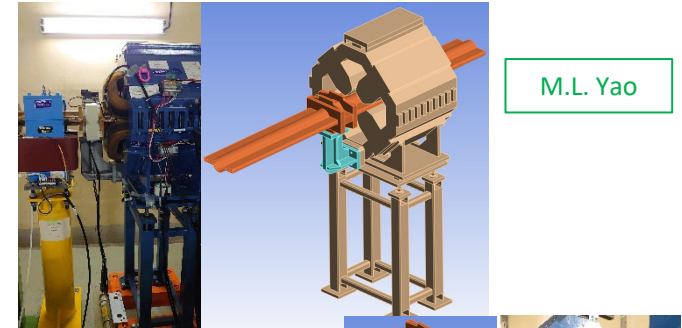
- Vacuum scrubbing of West Arc Section is proceeding steadily after LS1.
 - To eliminate the influence of pressure in RF section, average pressure measured by ion pumps excluding one near RF Section was shown as West Arc Section.
 - $\Delta p/\Delta I$ is decreasing steadily as beam dose increases.
- $\Delta p/\Delta I$ of West Arc Section is still higher than that of East Arc Section
 - Gap between West Arc Section and East Arc Section is narrowing.
 - Impact of long vacuum work in West Arc Section on the beam operation is not large.



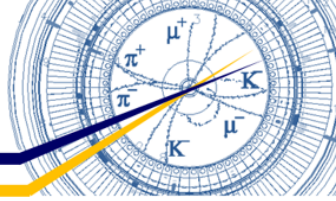
Other activities



- Investigation on beam pipe deformation due to SR heating in SLY section.
 - Measurement of deformation of beam pipes due and displacement of BPM and Q-magnet in SLY section
 - Simulation of deformation of beam pipes and displacement of BPM and Q-magnet in SLY section
 - Fabrication of new BPM supports to isolate BPM block from Q-mag.
 - They will be installed near future.
- Development of pressure anomaly detection method applying machine learning
 - Trial operation of pressure anomaly detection program from this month (March 2024).
- Collimator R&D
 - R&D of more robust head material such as MoGr
 - R&D of collimator with revolver heads
- And so on.

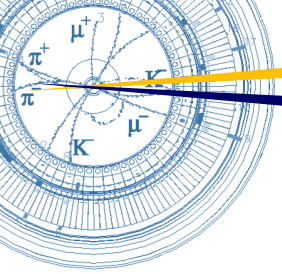


Summary

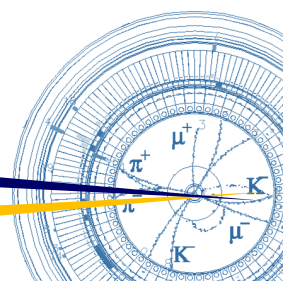


- A lot of vacuum works were done during LS1, and mainly vacuum works related to the vacuum system and collimator were reported.
 - Installation of new bellows chambers with SR mask at Wiggler Sections
 - NEG pump feedthrough replacement
 - Ion pump feedthrough replacement
 - Bellows chamber replacement
 - Temporary countermeasure against vacuum leak with vacuum sealant tape
 - Gate valve and bellows chamber replacement
 - Collimator relocation
 - Collimator head replacement
 - Installation HOM absorber chamber
 - Removal and reinstallation of Ext. kicker chambers (DR)
- All vacuum works planned during LS1 were successfully completed.
- Vacuum scrubbing is proceeding steadily.
 - No more dedicated vacuum scrubbing is required.
- Vacuum system is ready for higher beam current operation!!





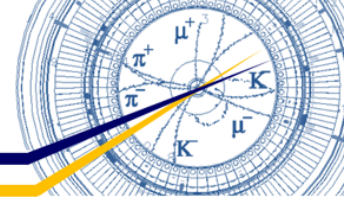
Fin.



Thank you for your attention.



Backup



- Vacuum Bag Sealant Tape

- <https://www.generalsealants.com/vacuum-bag-sealants/#1568264193156-000f6158-0e49>

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FILTER BY ROLL COLOR TEMPERATURE

All	Black	Blue	Bright Yellow	Brown	Dark Grey	Gray	Light Blue	Light Green	Mustard Yellow	Off-White	Orange	Purple	Red	Reddish Brown	Salmon	White
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