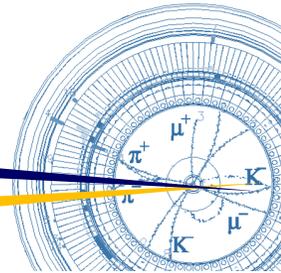


# SuperKEKB Status Report



20th annual BPAC Full Review meeting

10<sup>th</sup> February 2026

Kyo Shibata (KEK Accel. Lab.)

On behalf of the SuperKEKB

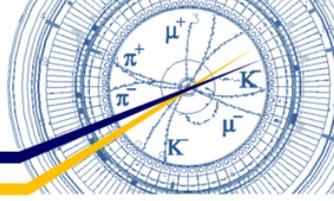


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- Overview of SuperKEKB in 2025
- Major work during the shutdown prior to the 2025c run
- 2025c run overview
- Countermeasures for issues in the 2025c run
- 2026ab run status
- Summary



# Overview of SuperKEKB in 2025



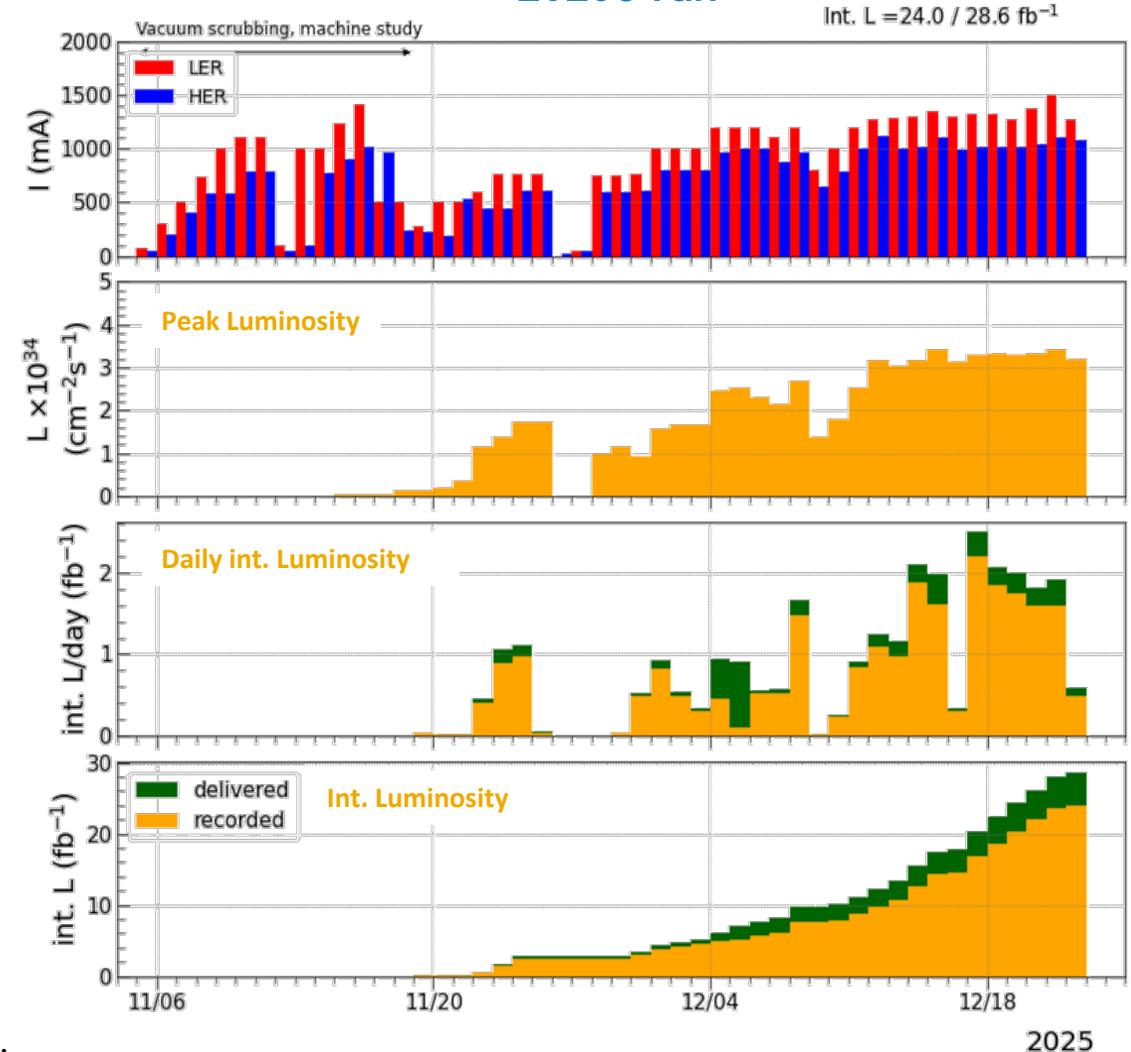
- Shutdown : 2024/Dec./27 – 2025/Nov./5, 313 days

- To improve operation efficiency, MR operation was changed from **2 periods per year to 1 period per year**.
  - To avoid operation during the hot season, 2025 run was scheduled to resume from November.
- During the shutdown, measures were implemented to;
  - Mitigate Sudden Beam Loss (SBL)
  - Reduce radiation levels near Non-linear collimator (NLC)
  - Improve injection efficiency

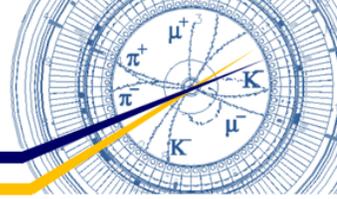
- 2025c run : 2025/Nov./5 – Dec./22, 47 days

- Peak luminosity :  **$3.4 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$** 
  - $\beta_y^*$ -squeezing : 1.0 mm
  - Maximum beam current : HER/LER = 1.35/1.49 A
- Int. luminosity : Delivered/Recorded =  **$28.7/24.0 \text{ fb}^{-1}$** .
  - Maximum daily int. luminosity : Delivered/Recorded = 2.5/2.2  $\text{fb}^{-1}$
  - Total int. luminosity : Delivered/Recorded = 681/599  $\text{fb}^{-1}$
- The run was terminated two days earlier than planned to investigate a QCS issue.
  - The subsequent winter shutdown and operation plans were also revised.

## 2025c run



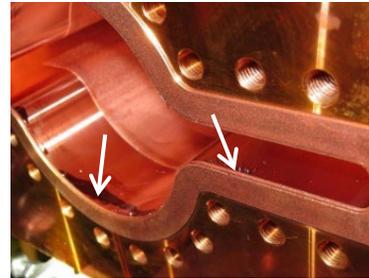
# Major work during shutdown (MR)



## 1. Beam pipe cleaning (HER/LER)

- Vacuum sealant (VACSEAL) removal as countermeasure against SBL
- At IR (HER/LER), LER wiggler sections (LER D04, D10, D11)

⇒ Improvement of accelerator stability



Beam pipe cleaning

## 2. Collimator works (HER/LER)

- Collimator relocation from D06V2 to D03V4 (LER)
- Damaged jaw replacement at D02V1, D05V1 (LER)
- New water-cooled D09V3 collimator (HER)

⇒ Protection of Belle II from SBL (D03V4)

Beam impedance reduction (D02V1, D05V1),  
Suppression of abnormal pressure increase (D09V3)

## 3. Beam pipe replacement and realignment at LER injection point (LER)

- Ceramic chamber replacement for suppression of beam oscillations caused by injection kickers (LER)
- Beam pipe realignment to mitigate aperture reduction at the injection point due to beam pipe deformation (LER)

⇒ Improvement of injection efficiency

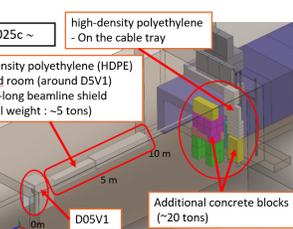
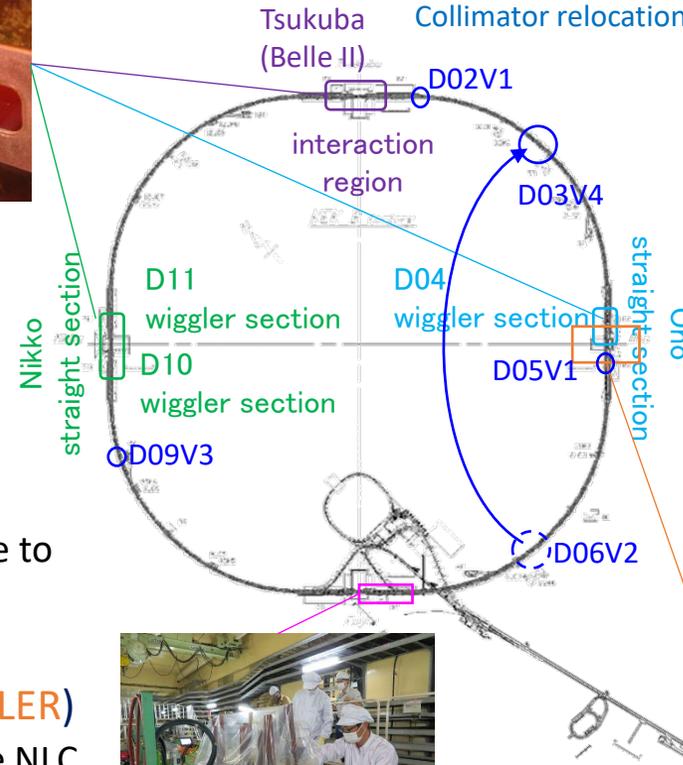
## 4. Radiation shield reinforcement and expansion of radiation control area (LER)

- Additional radiation shielding at the Oho straight section for full-scale use of the NLC
- Fence construction to expand radiation control area around Oho Experimental Hall

⇒ Background reduction, Beam impedance reduction



Collimator relocation (LER D06V2 → D03V4)



Radiation shield reinforcement



Beam pipe realignment at LER inj. point



NLC (D05V1)

# Major work during shutdown (Linac, DR, BT)

- Electron RF gun replacement (Linac)**
  - New RF-Gun less prone to discharge

⇒ Stable two-bunch injection
- Enabling new beam diagnostic line (Linac)**
  - Beam quality check in front of BTe simultaneously with HER injection

⇒ Improvement of injected beam quality and injection efficiency
- Fast kicker relocation and new kicker installation (Linac, DR)**
  - Relocation of the fast kicker from SY3 to Linac end to prevent radiation-induced failures
  - New horizontal kicker installed into DR extraction line

⇒ Improvement of injection efficiency
- Installation of ECS into electron BT line (BTe)**
  - Reduction of energy spread of high charged bunch

⇒ Improvement of injected beam quality and injection efficiency  
Increasing injected bunch charge
- Magnet pole replacement of positron BT line (BTp)**
  - Emittance growth mitigation by improving the magnetic field.

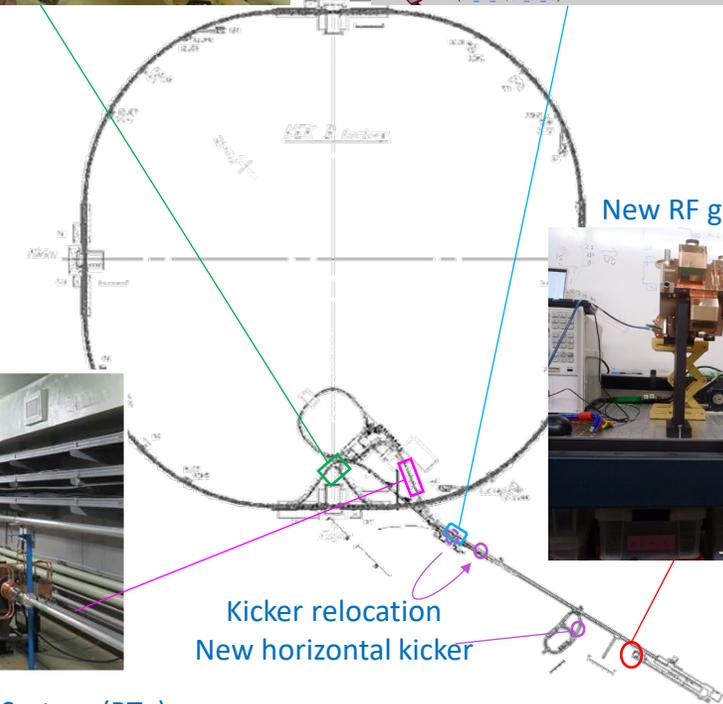
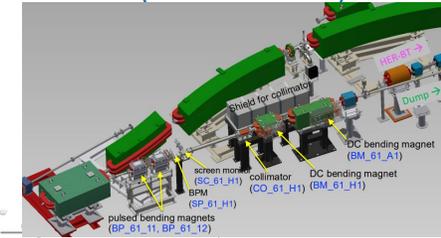
⇒ Improvement of injected beam quality and injection efficiency

\* Since Linac operation was maintained for the Photon Factory, the available working period for the Linac and BT was only a few months.

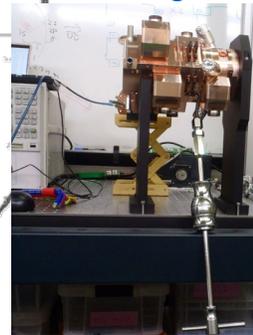
Magnet pole replacement (BTp)



New beam diagnostic line (electron beam)



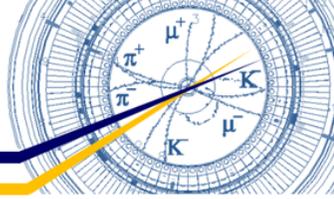
New RF gun



Kicker relocation  
New horizontal kicker

New Energy Compression System (BTp)

# 2025c run overview 1



## Operation policy for 2025c-2026ab run

- Highest priority is integrated luminosity (recorded) > **425 fb<sup>-1</sup>** (> 1 ab<sup>-1</sup> in total)

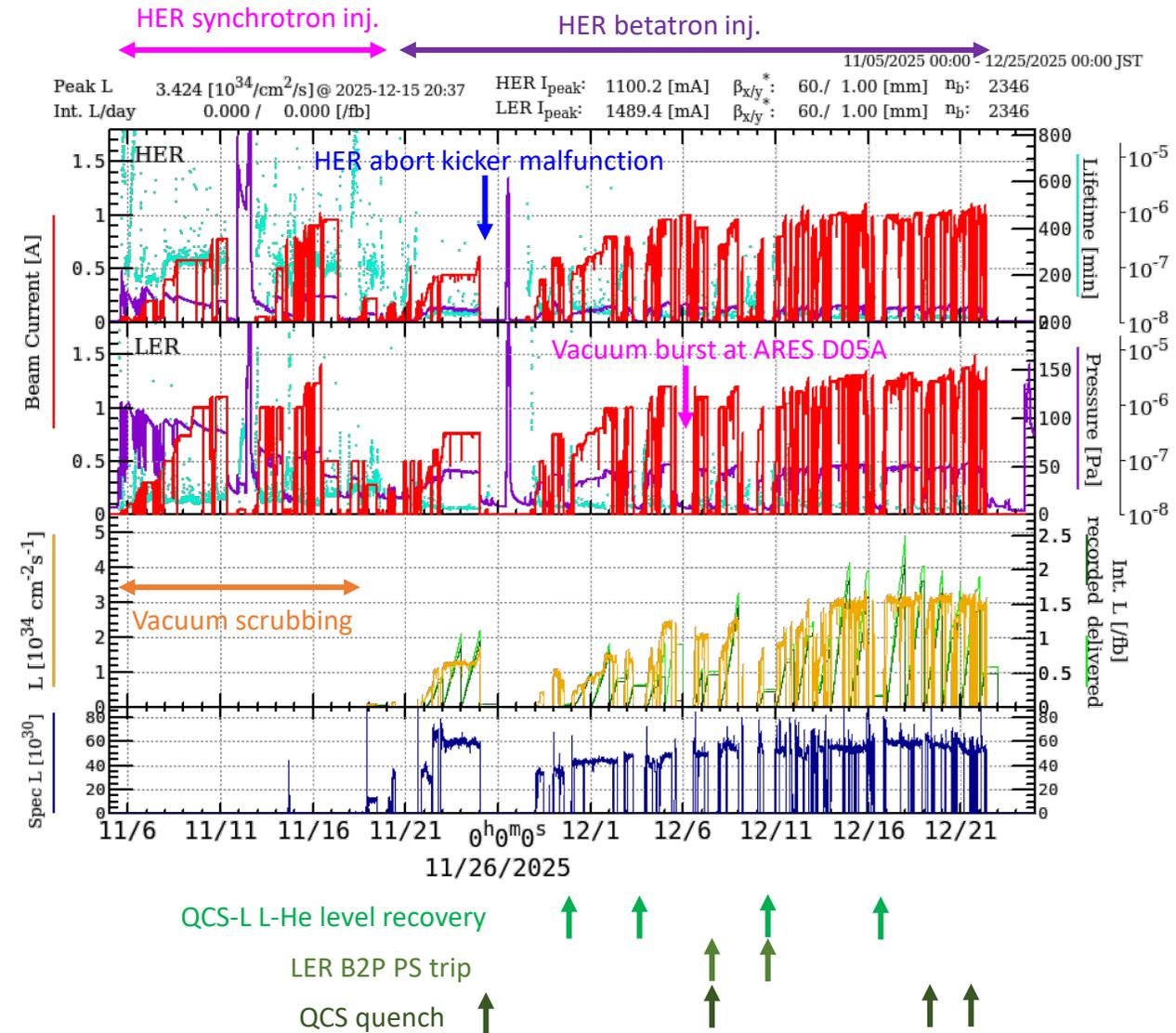
- 4 days per 3-week cycle are allocated to machine tuning, development, maintenance, etc.

## Operation schedule (Original plan)

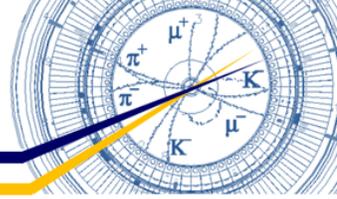
- 2025c run : Nov./19 – Dec./24
  - 2-week vacuum scrubbing is carried out at first.
- Winter shutdown : 2 weeks
  - To minimize the time required for physics run restart;
    - Cryogenic system operation is maintained.
    - No vacuum work is carried out.
- 2025ab run : Jan./9- Jun./1
  - No vacuum scrubbing is required.
  - Operation is suspended before the hot season.

## 2025c summary

- The effectiveness of VACSEAL removal in reducing SBL was confirmed.
- Synchrotron injection was demonstrated in the HER.
- As a result of major issues, the available operation time was reduced.
  - Operation plans need to be revised to address a QCS issue.



# 2025c run overview 2

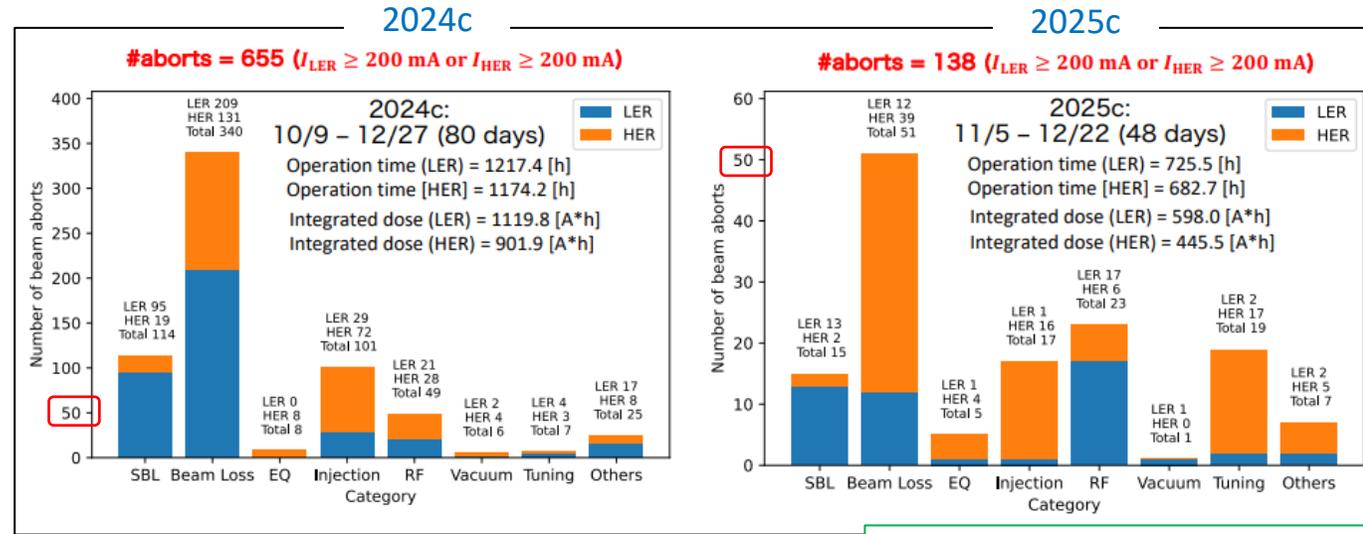


## Sudden Beam Loss

- Compared to the 2024c run, the frequency of SBL was significantly reduced.
  - The number of beam-loss aborts was also significantly reduced.
- SBL events accompanied by pressure bursts in the LER wiggler sections remained.
  - Pressure bursts were observed in the LER D04 and D11 sections.
    - Internal inspections and VACSEAL removal were performed prior to the 2025c run.
  - Bellows chambers located near the locations where pressure bursts were observed were replaced prior to the 2026a run.

## HER Synchrotron injection (SI)

- SI was introduced in the HER to enable further beam current increase in the future.
- It was demonstrated that SI could be used for physics runs down to  $\beta_y^* = 3$  mm.
  - With  $\beta_y^* = 1$  mm, a degradation of injection efficiency was observed during high-repetition injection.
  - Charge leakage into neighboring RF buckets was also observed.
- As a result, the physics run with  $\beta_y^* = 1$  mm was performed using conventional betatron injection.



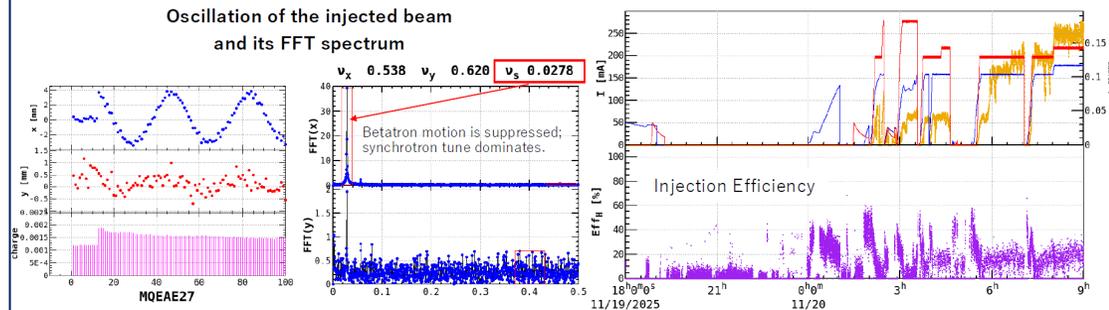
K. Uno, SKEKB Commissioning Meeting (2026.01.14)

## Synchrotron Injection in HER

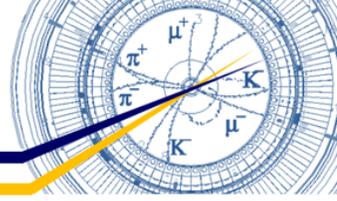
- Extensive machine tuning, including linac and collimator optimization.
- Successful beam injection for the  $\beta^* = 1$  mm optics after dedicated machine tuning.
- Attempted collision operation during the morning shift on Nov. 20.
- Unfortunately, the injection efficiency was low particularly at higher injection rates.
- We decided to return to betatron injection considering the low injection efficiency and uncontrollable beam backgrounds.

N. Iida *et al.*

H. Sugimoto, Belle2 Friday Meeting (Nov./21/2025)

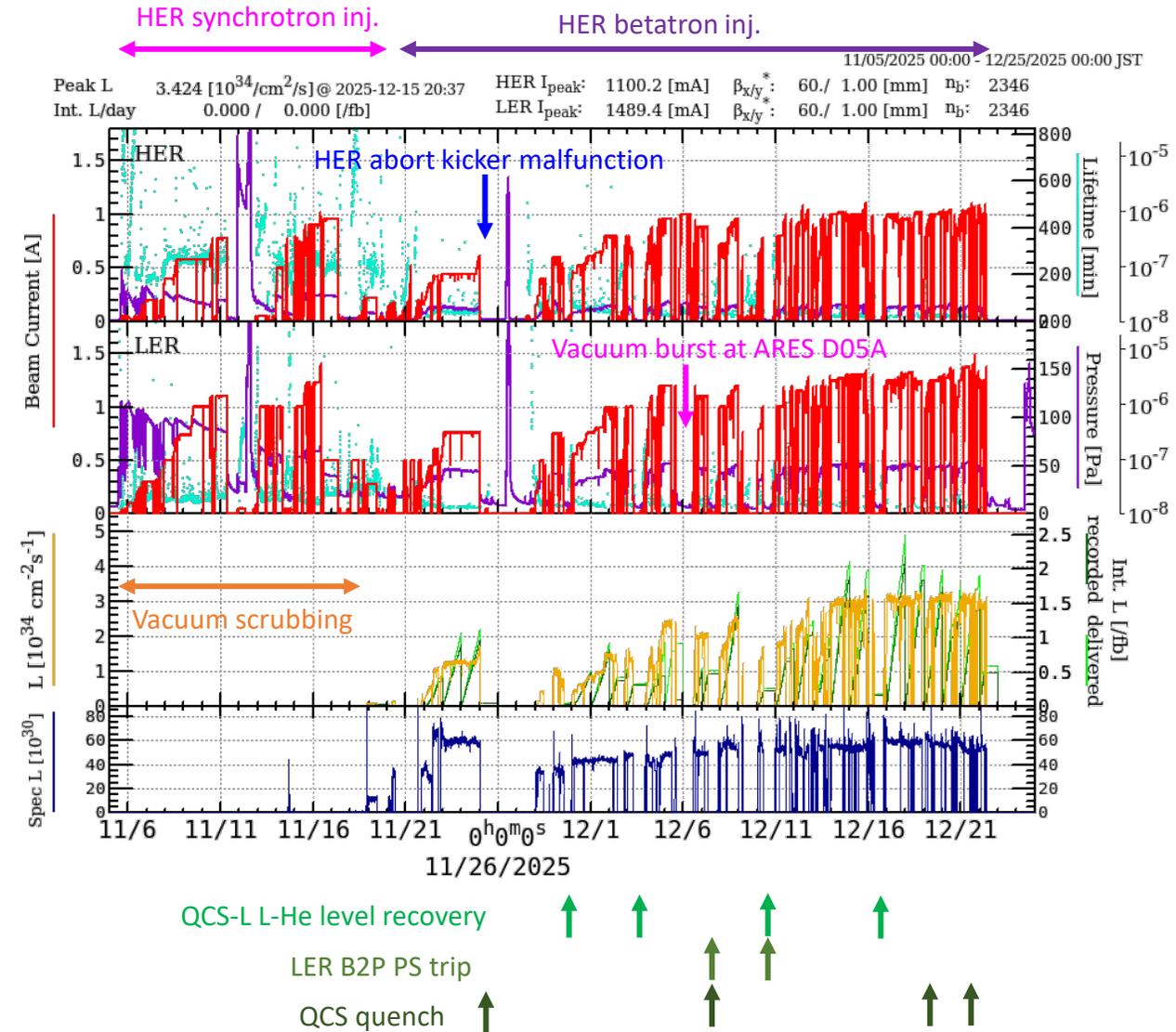


# 2025c run overview 3

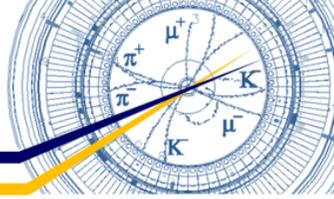


## Major issues in the 2025c run

- HER abort kicker malfunction (Nov. 25)
  - The weak-bend magnets were turned off by the safety system.
  - A large beam loss occurred in the IR, resulting in a significant radiation dose to Belle II, QCS quench, and damage to the D01V1 collimator jaws.
- QCS-L liquid helium level recovery (4 times)
  - A drop in the L-He level in QCS-L cryostat was observed after the QCS quench caused by the weak-bend abort.
  - To recover the L-He level, it was necessary to turn off QCS-L (Nov. 30, Dec. 3, Dec. 10, Dec. 16).
- Pressure burst at ARES cavity in the LER (Dec. 5-6)
  - A large pressure burst occurred in the LER D05A ARES cavity.
  - D05A and D05B cavities were detuned and excluded from operation.
  - The physics run was suspended for about one day for investigation, cavity conditioning, and tuning.
- LER global dipole (B2P) power supply trip (Dec. 7 & Dec. 10)
  - A power-down of the LER B2P power supply occurred due to a voltage fluctuation in the 6.6 kV high-voltage line at Fuji area, triggered by RF trip at Fuji at the time of a beam abort.
  - Optics correction was required to resume the physics run.
- QCS quenches (Nov. 25, Dec. 9, Dec. 18, Dec. 21)
  - Breakdown of causes ;
    - Weak-bend abort (Nov. 25) : 1 case
    - LER SBL (Dec. 9 & Dec. 21) : 2 cases
    - LER inj. kicker accidental firing (Dec. 18) : 1 case



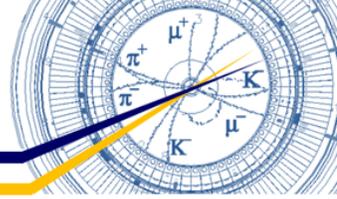
# Countermeasures 1



- All issues have been appropriately addressed to ensure continued operation.
  - The 2026 operation plan was revised to allow for investigation of QCS issue.
    - The cryogenic system was shutdown for QCS investigation, and MR startup was rescheduled from Jan. 7 to Jan. 26.
    - To secure sufficient operation time, the 2026b operation period will be postponed from June 1 to June 30.
- Actions taken so far and countermeasures under consideration
  - Weak-bend abort due to abort kicker malfunction
    - A new abort procedure was implemented.
      - In the event of an abort kicker power supply abnormality, the beam is kept, and the weak-bend magnets remain on, while Belle II HV is turned off promptly.
      - The abort kicker power supply is reset, and the kicker is manually fired if possible.
    - Extending the “no weak-bend abort” scheme is under consideration.
      - At this stage, the weak-bend magnets are still turned off, when an abort request is issued by other systems,
      - Personnel safety is fully ensured by independent safety systems, while potential risks to some components are carefully managed.
    - The installation of a new beam dump (a pair of steering magnets and a collimator) is also under consideration.
      - This modification could be done during a usual summer shutdown after preparation of all components.
  - QCS-L liquid helium level recovery
    - By adjusting the cooling scheme, we successfully eliminated the liquid helium level drop during the 2025c run.
      - MR operation can resume without IR work, including QCS-L extraction.
      - No helium level recovery will be required during the 2026ab run.
    - Investigations to identify the cause were carried out at the end of December.
      - No leak was found at the QCS-L cryostat.
      - The most likely cause of liquid helium level drop is a malfunction of valves in the liquid helium line.
    - The repair is under consideration after the 2026b run.

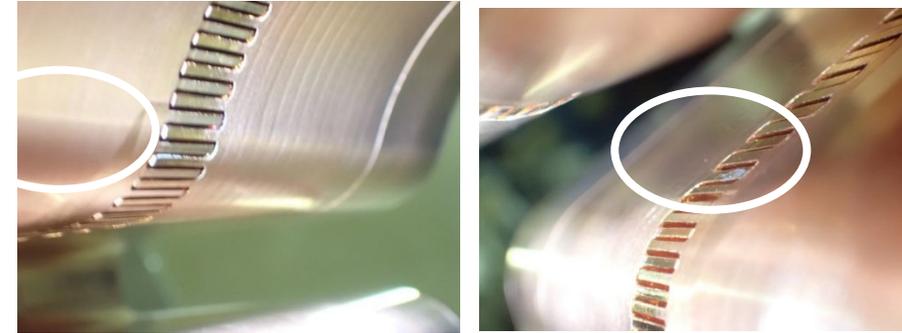


# Countermeasures 2



## • LER global dipole (B2P) power supply trip

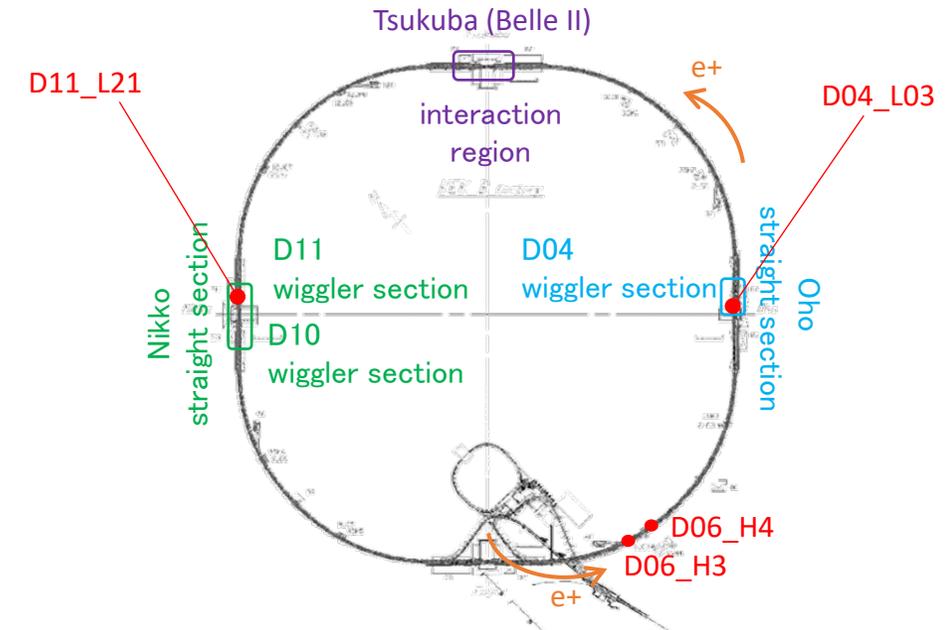
- The KEK Plant and Facilities Department investigated the issue, identified the cause, and addressed it during the 2025c run.
  - Cause;
    - Modification of the settings for the power factor correction capacitors in the 6.6 kV line at the AR substation (Fuji area) to save electricity.
    - The modification was carried out before the 2025c run.
  - The settings were restored to their original configuration during the 2025c run.
    - Closer coordination with the Plant and Facility Department is required.



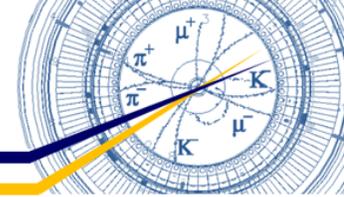
Inside the bellows near D10\_L21  
Some contamination was found, but it was not VACSEAL.

## • QCS quench

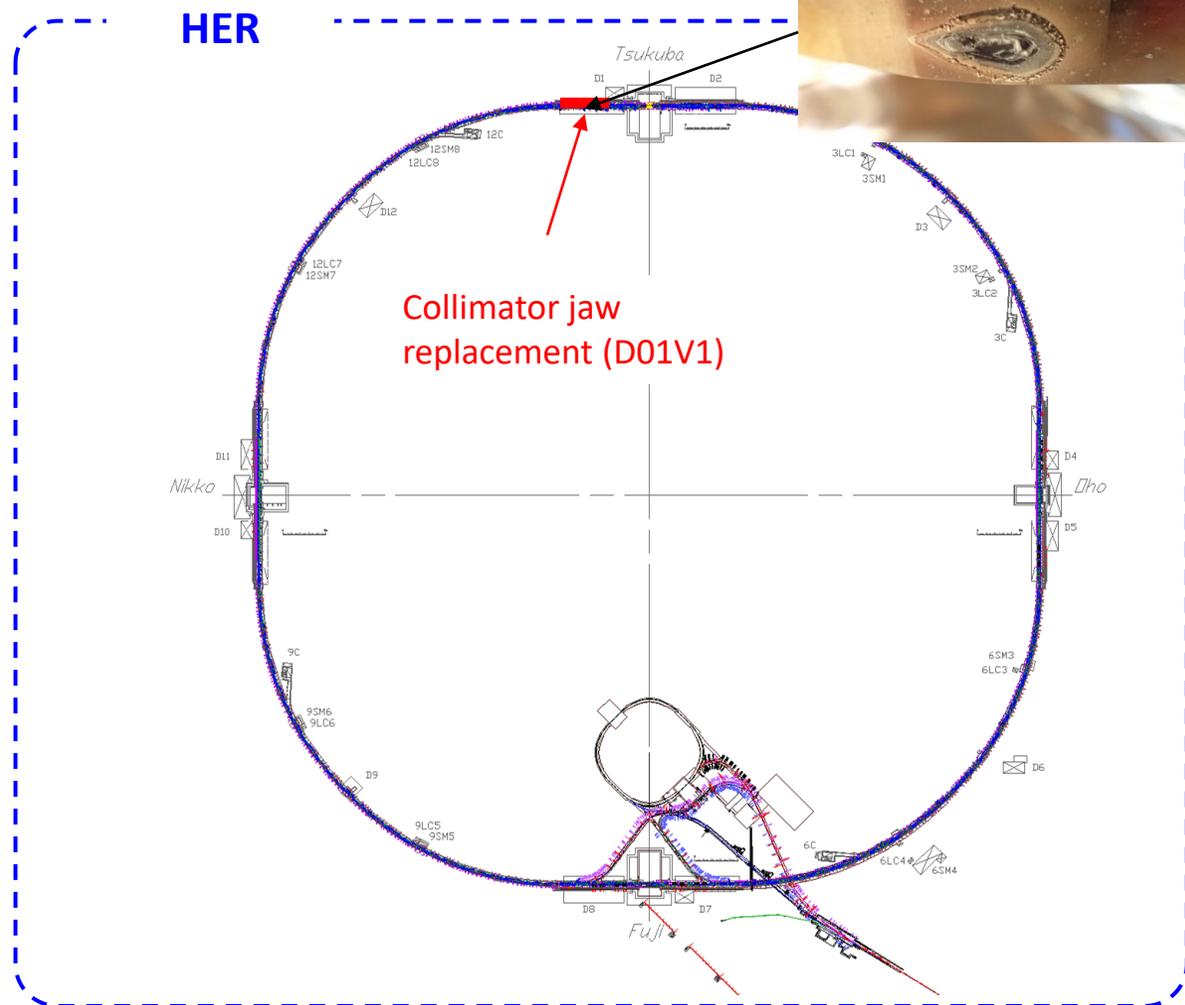
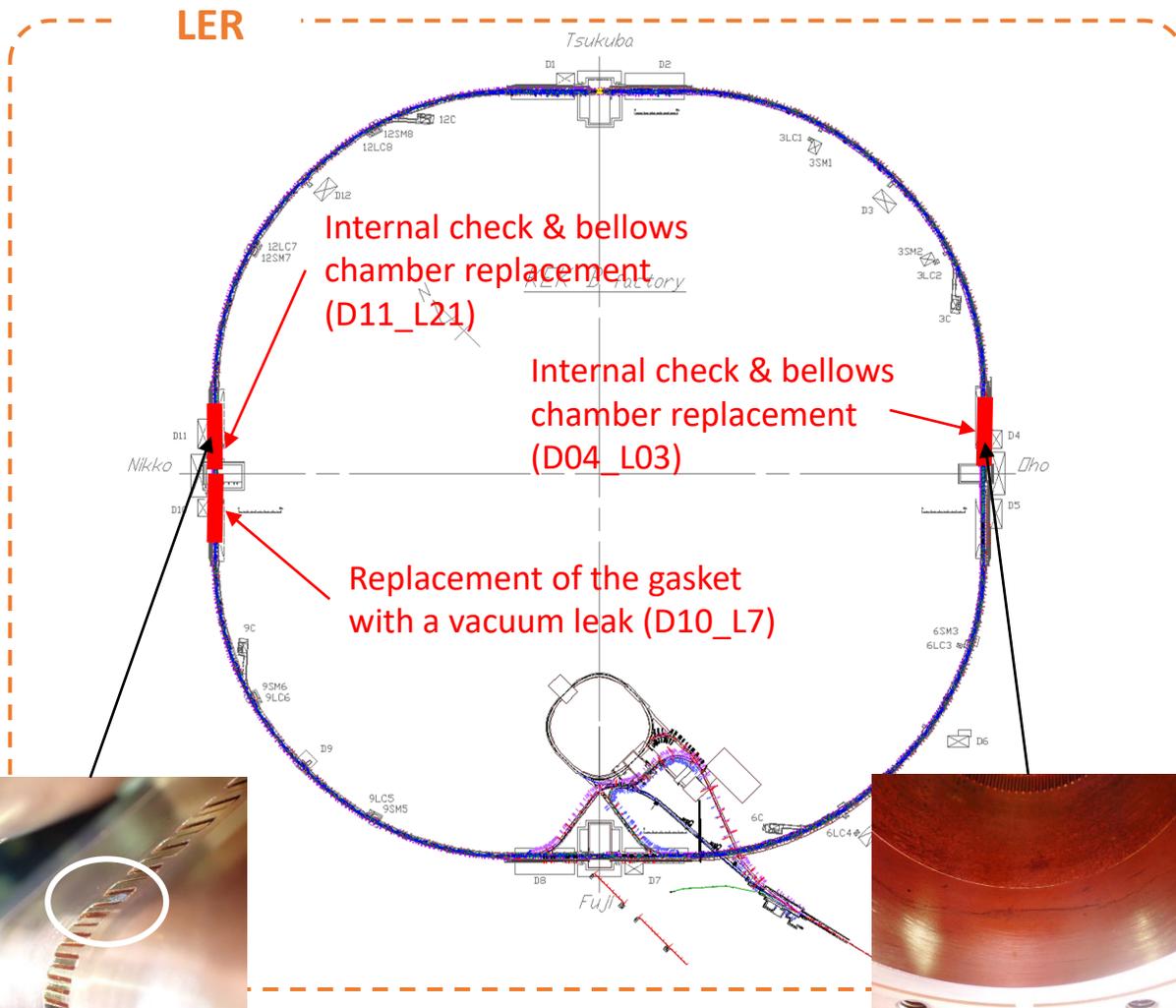
- Countermeasures against SBLs
  - Pressure bursts were observed at the D11 and D04 wiggler sections.
    - For both locations, internal inspections of the beam pipes and removal of VACSEAL had already been carried out before the 2025c run.
  - The bellows chambers were replaced with spares at both D11\_L21 and D04\_L03.
  - At D11\_L21, small contamination (not VACSEAL) was found in the bellows chamber.
  - At D04\_L03, no abnormality was observed.
- Countermeasures against the injection kicker accidental firing
  - The frequency of kicker accidental firing has been significantly reduced by optimizing the thyatron parameters before 2025c.



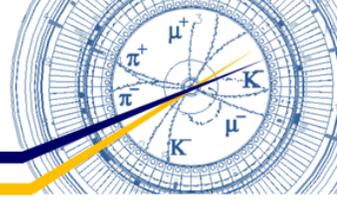
# Vacuum work during winter shutdown



— : vented section for vacuum work



# Revised operation plan



- Highest priority : Total integrated luminosity (recorded) > **1 ab<sup>-1</sup> (unchanged)**
  - Taking into account the recommendations from the operation review committee held in December and requests from Belle II, operation in June will be pursued as much as possible.
  - However, stable accelerator operation in June may be difficult due to high ambient temperatures.
  - The feasibility of June operation will be decided based on accelerator conditions in May.

## 2026a

January 6 days

Sun	Mon	Tue	Wed	Thu	Fri	Sat
27	28	29	30	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

February 28 days

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Maintenance day : 2/18

March 31 days

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	1	2	3	4

Maintenance day : 3/18

## 2026b

April 30 days

Sun	Mon	Tue	Wed	Thu	Fri	Sat
28	29	30	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	1	2

May 31 days

Sun	Mon	Tue	Wed	Thu	Fri	Sat
26	27	28	29	30	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31	1	2	3	4	5	6

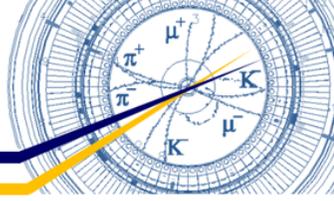
Maintenance day : To be determined

June 14 days ?, 30 days ?

Sun	Mon	Tue	Wed	Thu	Fri	Sat
31	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	1	2	3	4

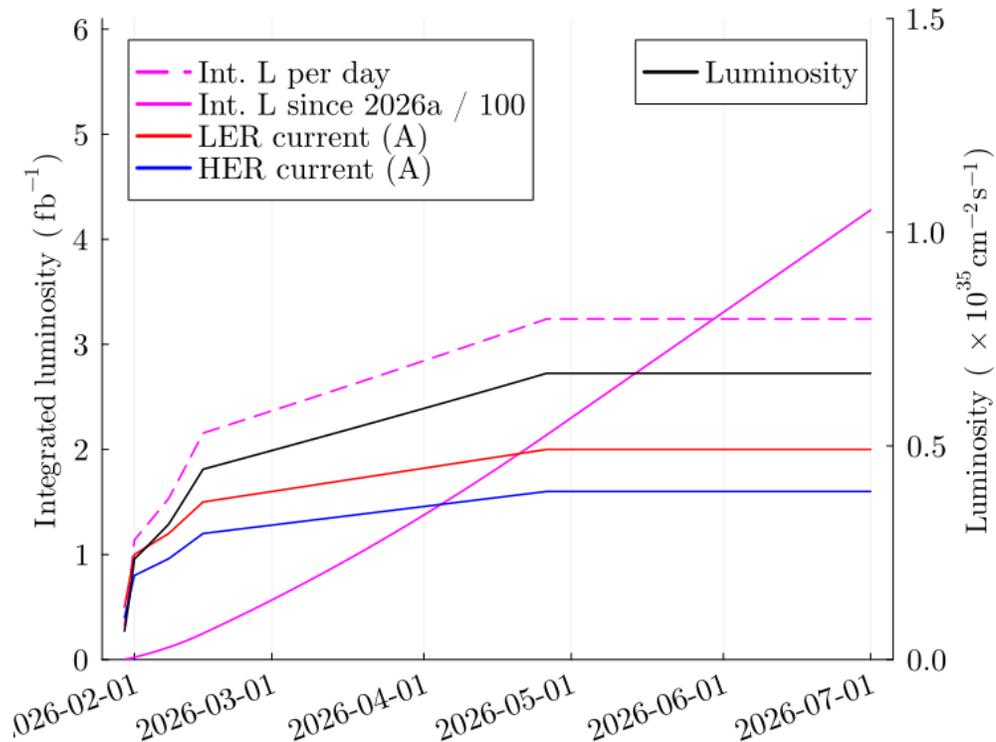


# 2026ab run plan



- Operation strategy

- Establish stable operation at  $5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- Increase the beam currents to reach  $6 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- Target an integrated luminosity of  $> 400 \text{ fb}^{-1}$
- If the accumulation of  $400 \text{ fb}^{-1}$  appears achievable, further squeeze  $\beta_y^*$  to aim for  $1 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$



- Target;

- Peak luminosity :  $6.6 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- Beam current : HER/LER = 1.6/2.0 A

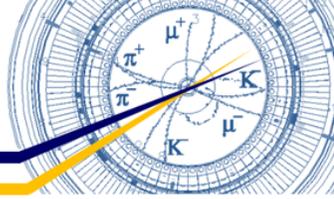
- Assumption;

- Physics run time : 70% of the total operation period
- Operation efficiency : 80%



- **Expected integrated luminosity (delivered) : 428 fb<sup>-1</sup>**

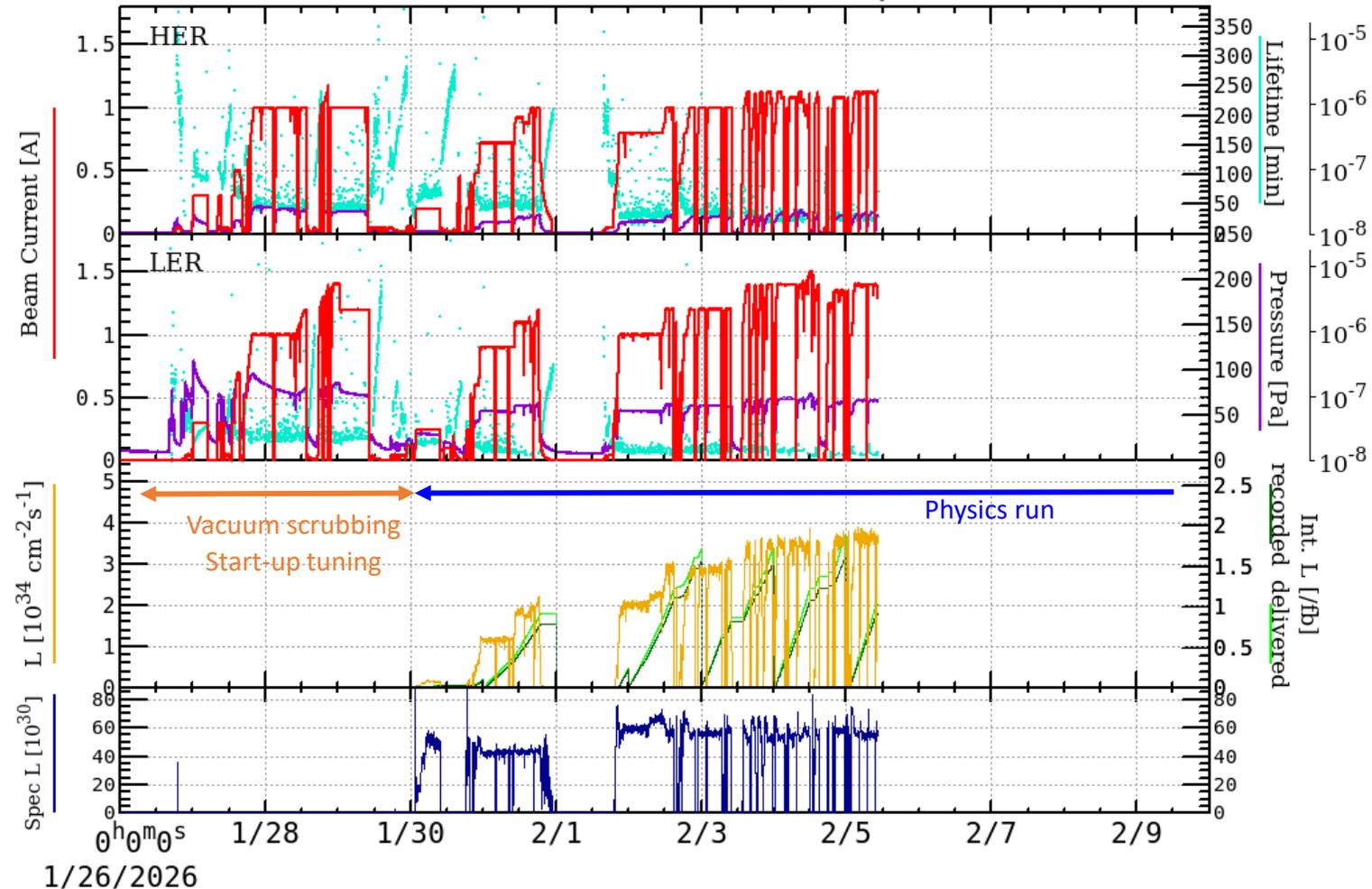
# 2026a run



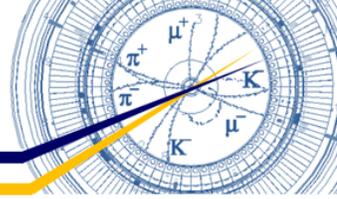
01/26/2026 00:00 - 02/10/2026 00:00 JST

Peak L 3.910 [ $10^{34}/\text{cm}^2/\text{s}$ ]@ 2026-02-04 11:49 HER  $I_{\text{peak}}$ : 1175.5 [mA]  $\beta_{x/y}^*$ : 60./ 1.00 [mm]  $n_p$ : 2346  
Int. L/day 0.915 / 1.039 [fb] LER  $I_{\text{peak}}$ : 1500.3 [mA]  $\beta_{x/y}^*$ : 60./ 1.00 [mm]  $n_p$ : 2346

- 2026a run resumed on Jan. 26.
  - Vacuum scrubbing and start-up tuning, including injection tuning, were conducted until Jan. 30.
  - The physics run started on Jan. 30.
- As of Feb. 4, the peak luminosity has reached  $3.9 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ .



# For higher beam currents



## • Before 2026a run

### • LER

- Increase in bunch charge (2 nC -> 3 nC)

### • HER

- SRM alignment in the BTe to allow injected-beam tuning simultaneously with beam injection
- Damaged D01V1-jaw replacement
- (2 bunch injection)

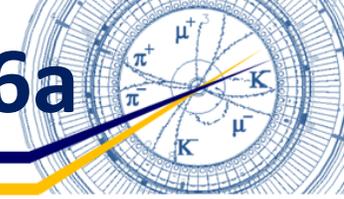
### • Both rings

- Sufficient time allocated for injection beam tuning before the physics run

## • During 2026ab run

- HER 2-bunch injection tuning
- Continuous injection tuning using machine learning
- Tune scan (search for an optimal working point)
- Adjustment of beta functions at the injection point and the interaction point.

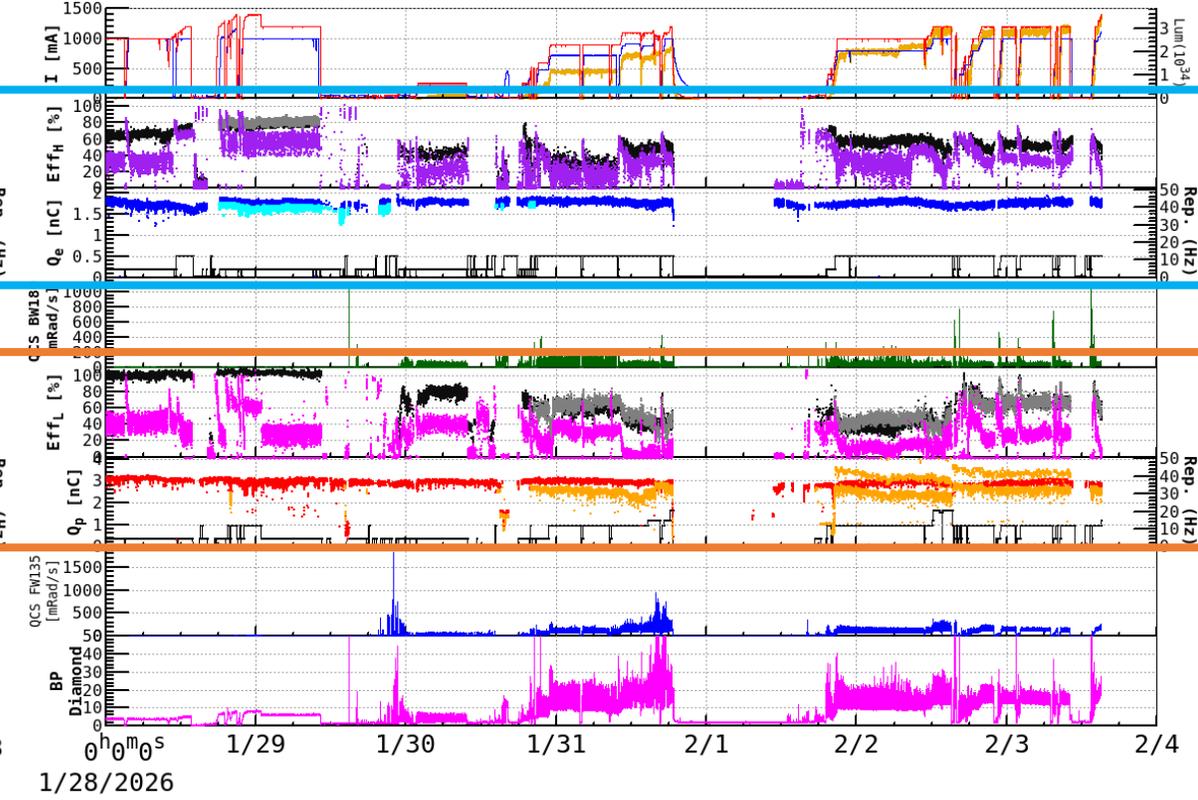
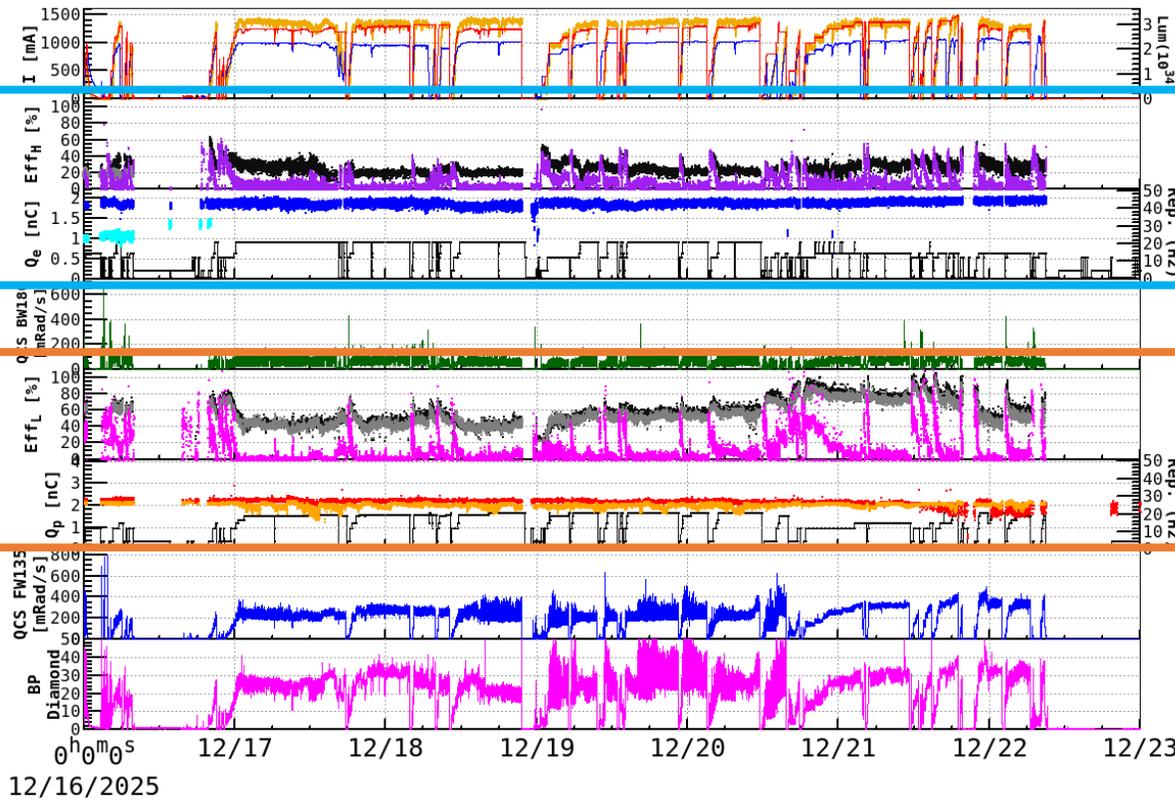
# Comparison of injection status in 2025c and 2026a



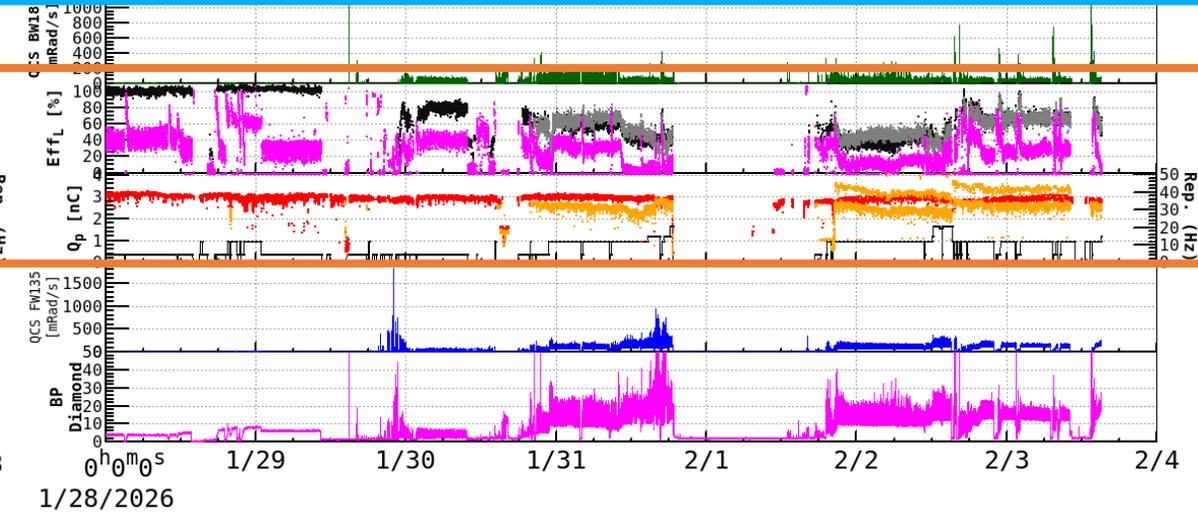
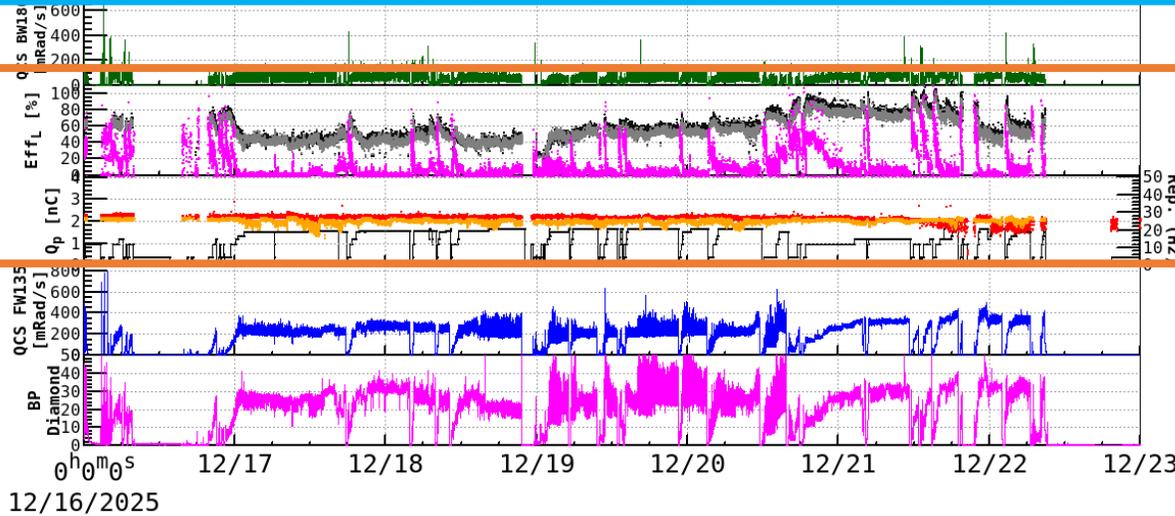
2025c

2026a

HER



LER

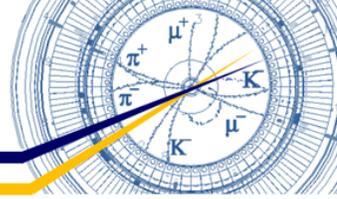


$\beta y^* = 1$  mm  
Physics run

Detuned optics  
Vacuum scrubbing

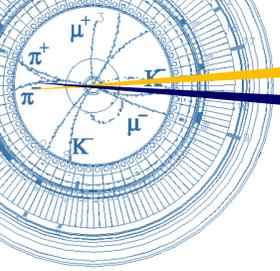
$\beta y^* = 1$  mm  
Physics run

# Summary

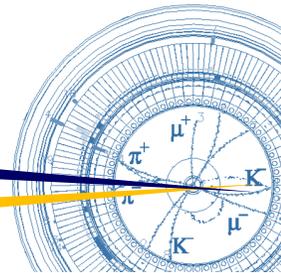


- The 2025c run demonstrated clear progress.
  - Peak luminosity :  $3.4 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ 
    - $\beta_y^*$ -squeezing : 1.0 mm
    - Maximum beam current : HER/LER = 1.35/1.49 A
  - Total int. luminosity : Delivered/Recorded = 681/599  $\text{fb}^{-1}$
  - A significant reduction of Sudden Beam Loss (SBL)
  - Successful tests of HER synchrotron injection.
- Several major issues were encountered during the run.
  - All have been appropriately addressed.
  - Investigation of the QCS issue required a revision of the 2026 operation schedule.
    - 2026ab run schedule : Jan. 7 – June 1 => Jan. 26 – June 30
- The 2026ab run started on Jan. 26, and no critical issues have been observed so far.
  - The highest priority remains achieving a total recorded integrated luminosity exceeding  $1 \text{ ab}^{-1}$ .
  - Operation plans have been optimized to balance performance, reliability, and safety.



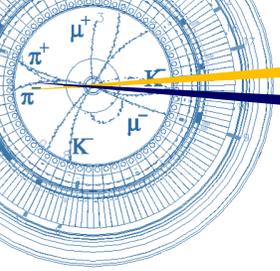


Fin.

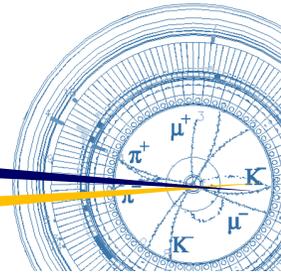


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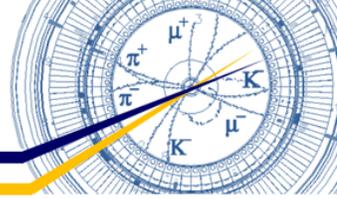




# Back up



# QCS investigation 1



T. Oki

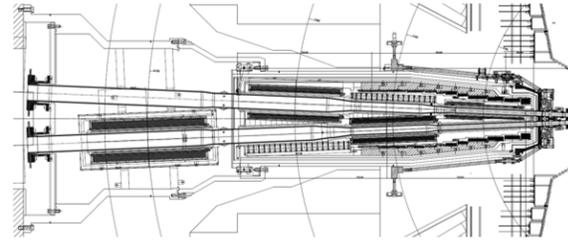
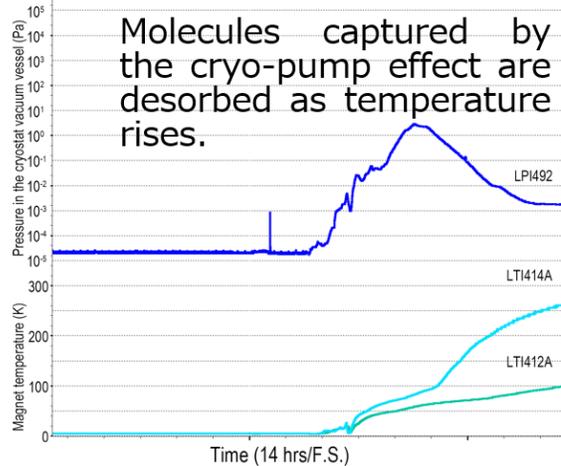
Measured just after 2025c

T. Oki

## Typical pressure characteristic of vacuum vessel during warm-up

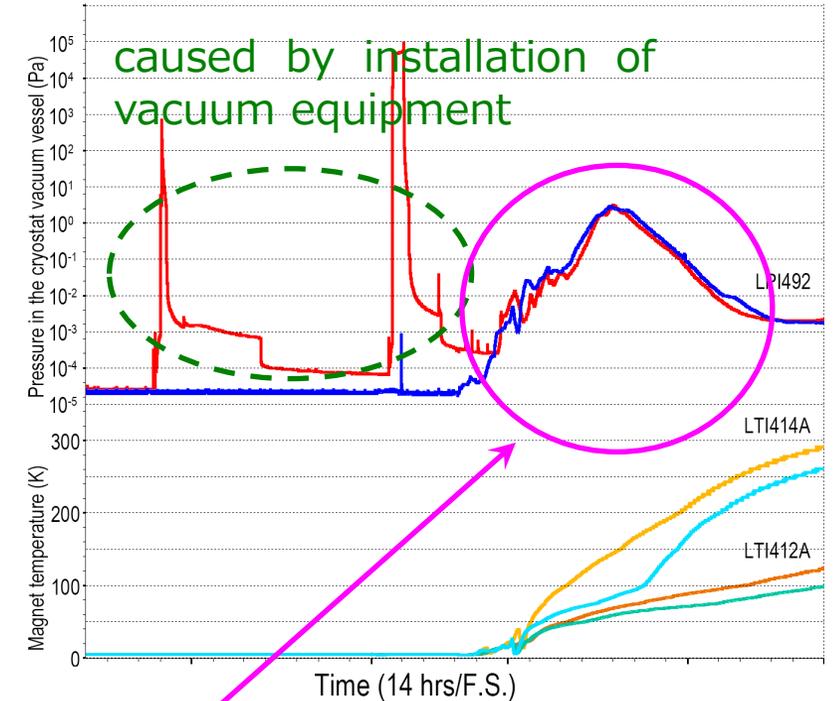
- Typically, as a reference case, the measured pressure result of the vacuum vessel when the magnet cryostat was warmed in Dec. 2024 is shown here.
- As the temperature rises, molecules captured on the surface of the helium vessel inside the vacuum vessel due to the cryo-pump effect desorb, causing the pressure to increase.

Measured in 2024 as reference



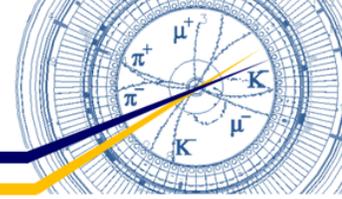
Pressure change in the cryostat vacuum vessel

Magnet temperature at different measurement points



No difference was observed between the measured results in 2025 and the reference data from 2024. Thus, no increase in matter captured by cryo-pump effect was detected.

# QCS investigation 2



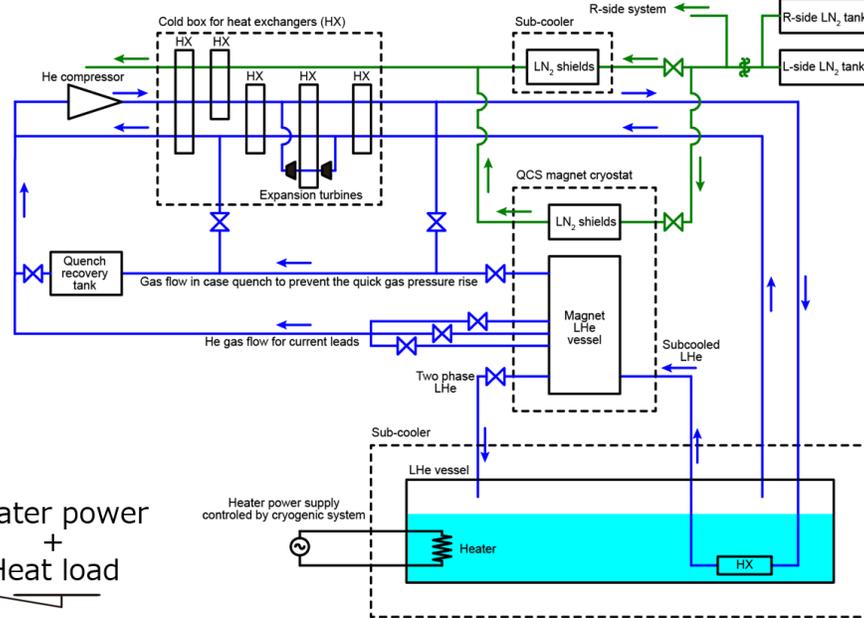
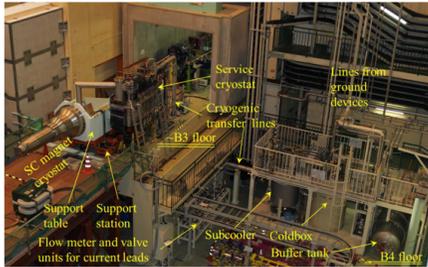
Cryogenic valve: CV413 and CV414

- For maintaining the valve, the concrete shield need to move back from IP.

T. Oki

## What is the liquid helium level control: our cryogenic system overview

- For a finite and constant liquefaction capacity, heater control system is used to balance variable heat loads.

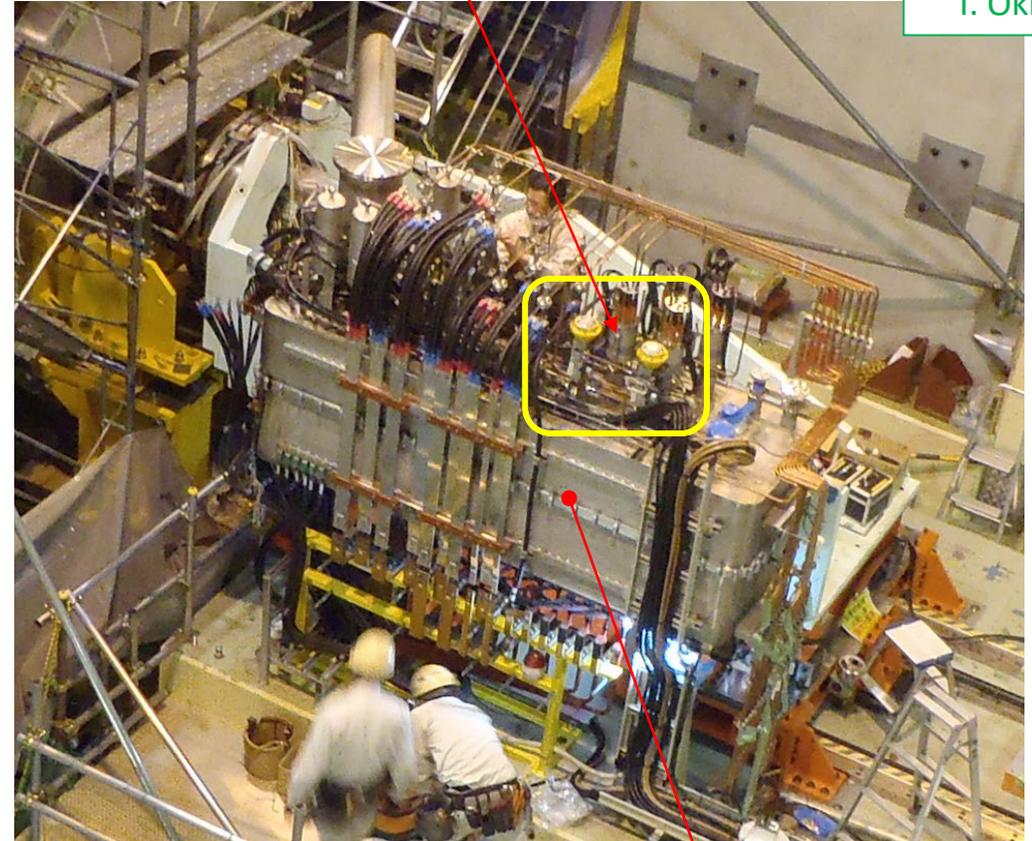


$$\text{Liquefaction capacity} = \text{Heater power} + \text{Heat load}$$

- Failure to keep the liquid level means either reduced liquefaction capacity or increased heat load.

For details, please refer to the backup slides.

T. Oki



Magnet cryostat service cryostat

# B2P power supply trip

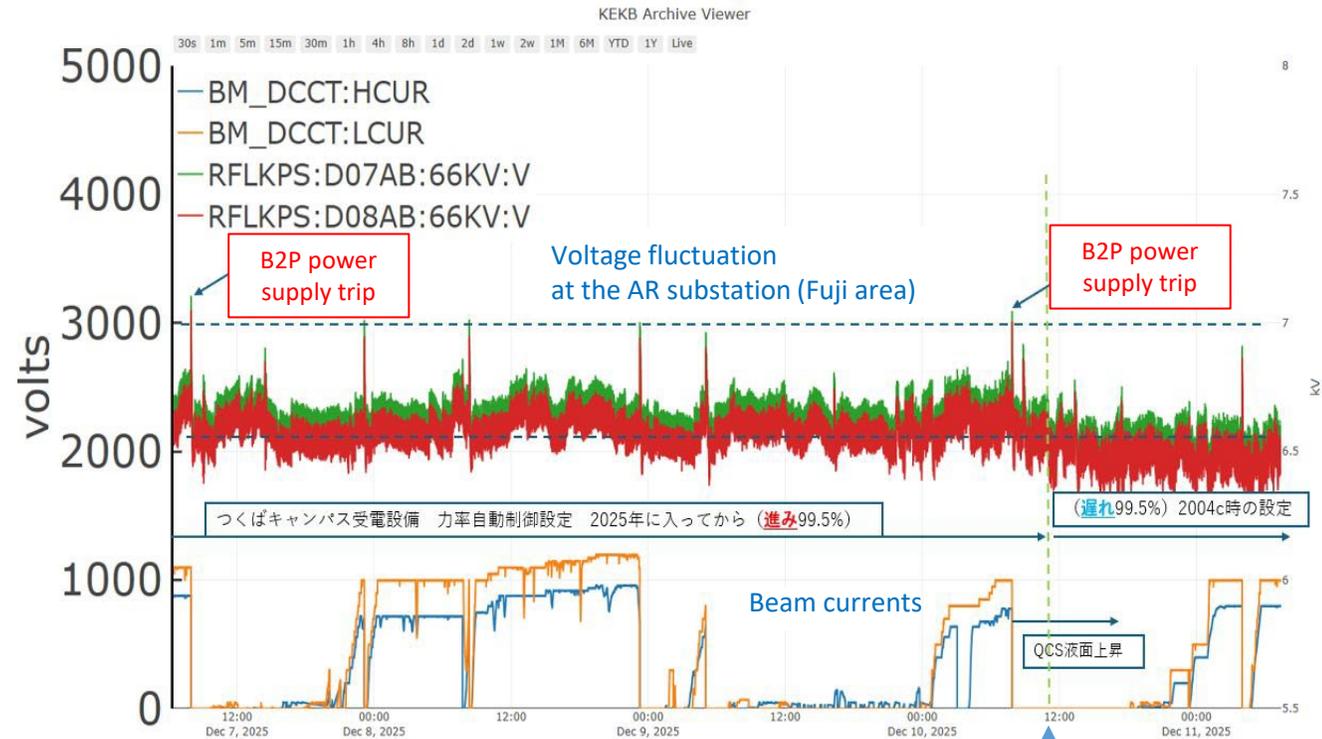
- LER global dipole (B2P) power supply trip

- Actions taken so far

- The KEK Plant and Facilities Department investigated the issue, identified the cause, and addressed it during the 2025c run.
- Cause
  - Modification of the settings for the power factor correction capacitors in the 6.6 kV line at the AR substation (Fuji area) to save electricity.
  - The modification was carried out before the 2025c run.
- Countermeasure
  - The settings were restored to their original configuration during the 2025c run.
  - Efforts were also made on the RF side to reduce power consumption in the Fuji area.

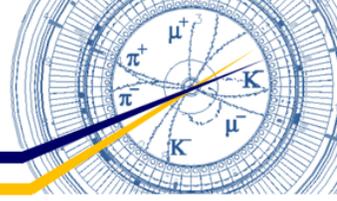
- Additional measures

- Closer coordination with the Plant and Facility Department is required.



AR substation setting restored to the 2024c configuration

# QCS quench



- QCS quench

- Countermeasures against SBLs

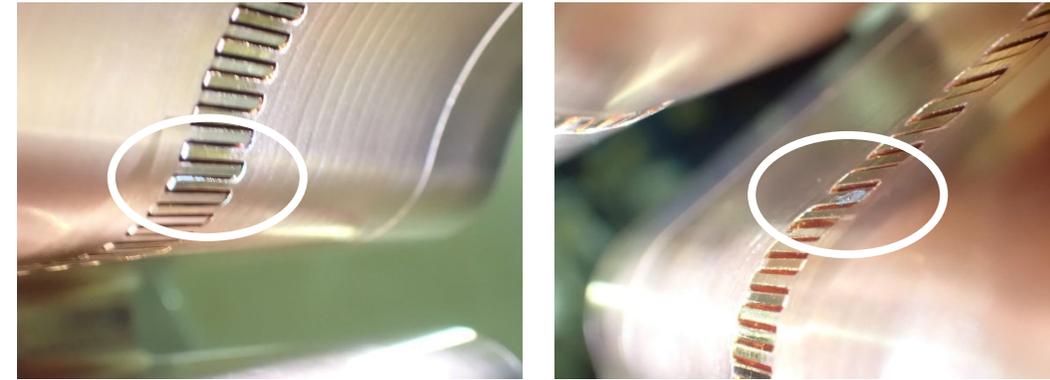
- Pressure bursts were observed at the D11 and D04 wiggler sections.
  - Pressure bursts at D11\_L21 (Dec. 9) and D04\_L03 (Dec. 21)
  - For both locations, internal inspections of the beam pipes and removal of VACSEAL had already been carried out before the 2025c run.

- During this shutdown

- The bellows chambers were replaced with spares at both D11\_L21 and D04\_L03.
- At D11\_L21, small contamination (not VACSEAL) was found in the bellows chamber.
- At D04\_L03, no abnormality was observed.

- Countermeasures against the injection kicker accidental firing

- The D06H collimators were intended to protect the QCS from the accidentally kicked beam.
  - They did not function as expected this time, although they had worked well previously.
  - The cause of the failure of the D06H collimators is under investigation.
- The frequency of kicker accidental firing has been significantly reduced by optimizing the thyatron parameters before 2025c.



Inside the bellows near D10\_L21  
Some contamination was found, but it was not VACSEAL.

