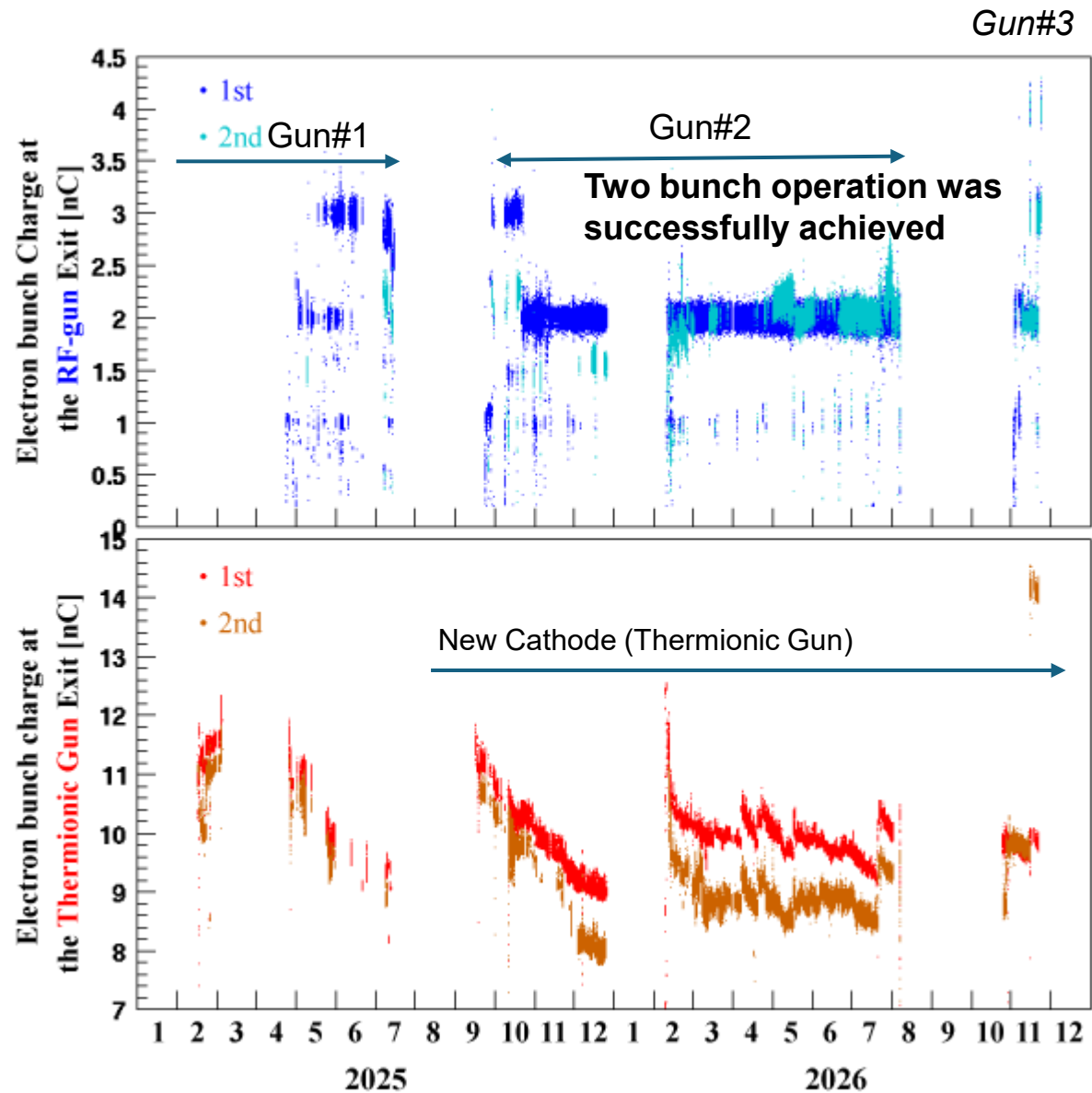


Injector

F. Miyahara for KEK e-/e⁺ Injector Linac

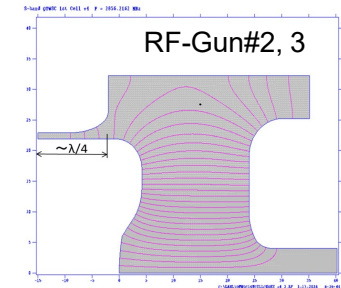
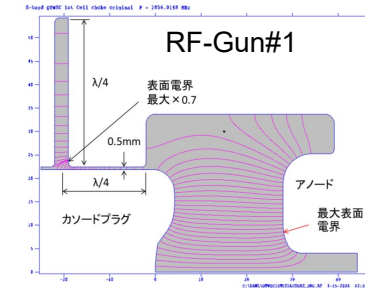
Status Report from 2025a to Present and Overview of Upgrades

Gun Status



Electron Beam

Gun#1: Frequent electrical discharges → Improved structure of the 1st cell



M. Yoshida

Gun#2: Brazed the cavity cells in the wrong order
→ Inner diameter corrected afterward
Operated with a shorter pulse width than designed

Gun#3: Operated at the designed pulse width. The 2nd bunch is also stable

Positron Beam

- The charge from the thermionic electron gun gradually decreases (The cause remains unknown)
- Cathode was replaced in summer 2025, but the new cathode shows the same trend
- Even with an increased heater current, the charge only reaches about 11 nC (a characteristic of this cathode)



- **Increase the charge by extending the pulse width** (2nd bunch only).
- There is an issue with satellite bunch generation, but tuning and testing are currently underway.

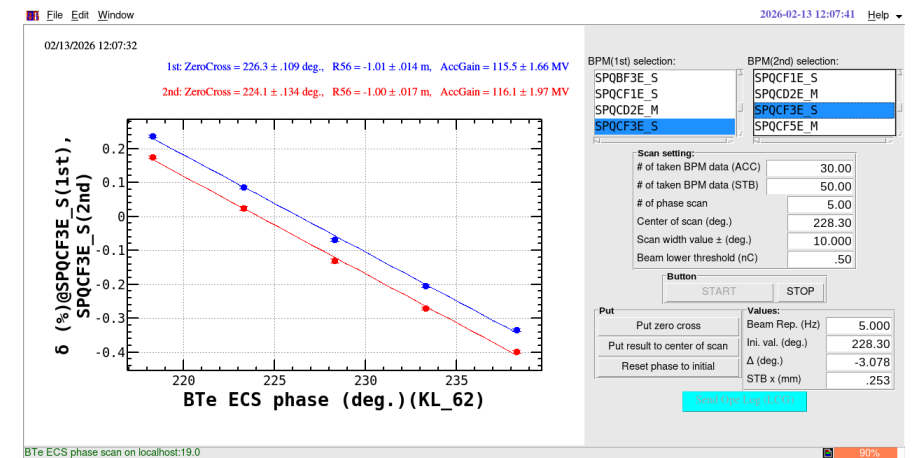
Detail will be presented in Electron gun/Positron source(Zhou-san's talk).

Stable operation was achieved during the 2026ab run.

Energy Compression System (ECS)



Four 3-m S-band accelerating structure



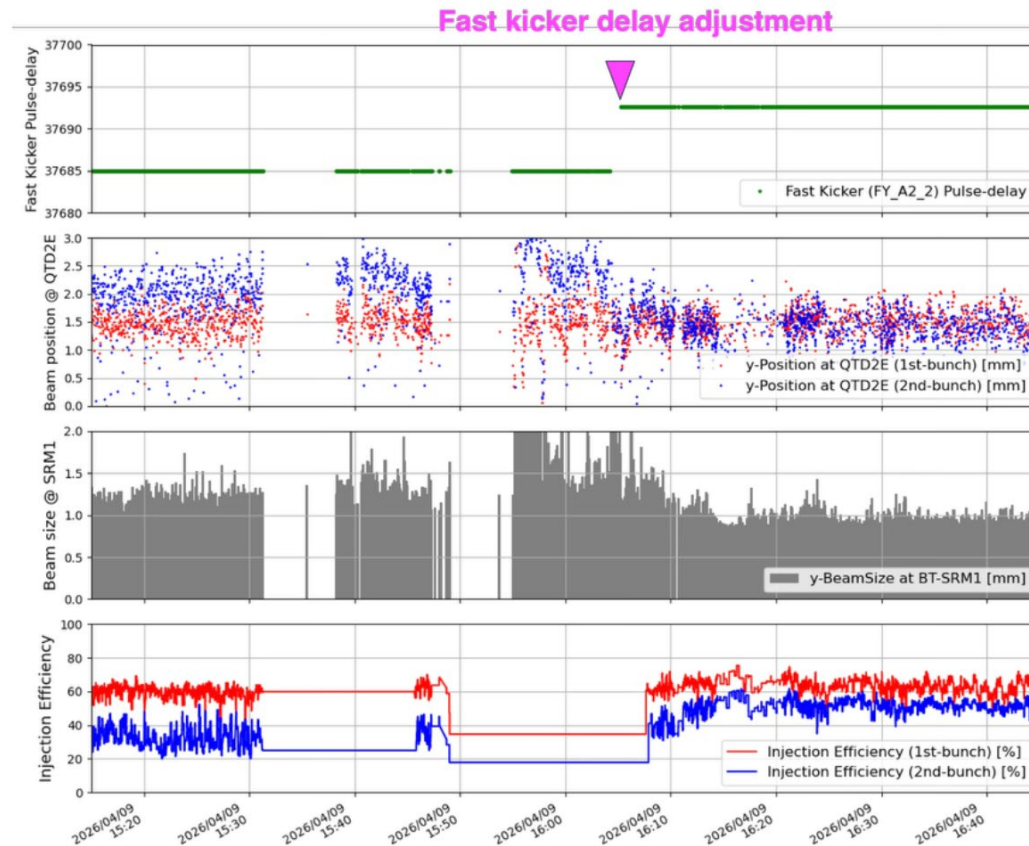
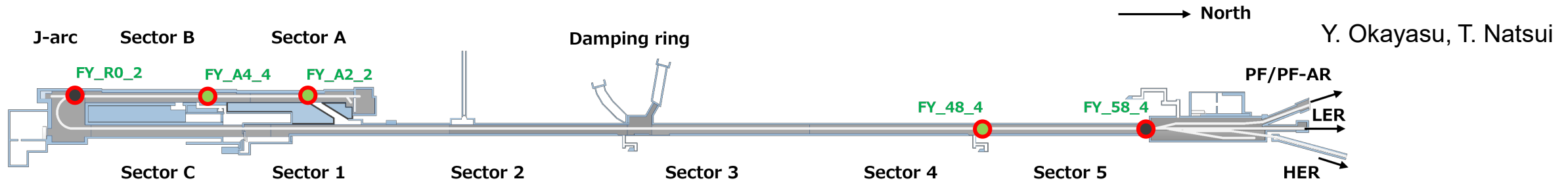
Panel for zero-crossing phase search and accelerating gradient measurement

Current Energy Spread and Required Specifications

	1 st only	1 st +2 nd	1 st +2 nd (energy adjusted)	Requirement
e-	0.033%	0.076%	0.074%	0.07%

- Installation was completed during the 2025 summer shutdown.
- Due to **electrical discharges** in the waveguide (caused by a flange issue), operation has been carried out at reduced RF power.
- **The energy spread in the HER BT has been successfully suppressed.**
- RF contactors were installed during the 2026 summer shutdown.
- RF conditioning and testing are scheduled to begin at the end of October 2026 → High RF power

Fast Kicker: Operational use began in the 2026ab run

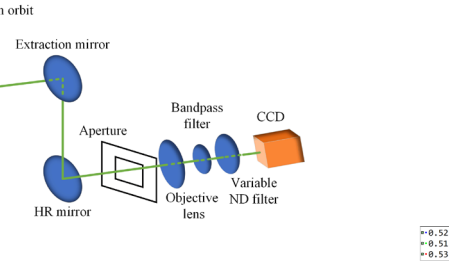


Orbit correction using the Fast Kicker and Its Effect

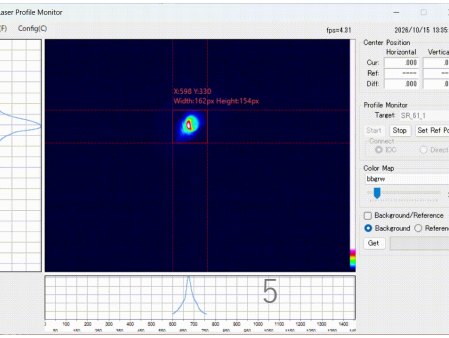
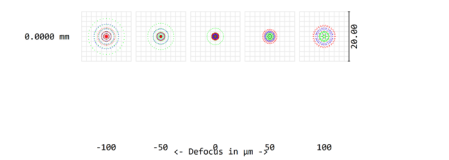
Fast Kicker led to stable injection of the second bunch

- A failure occurred in April 2026
→ Repairs and countermeasures have been completed
- Radiation shielding is currently being designed for the area where the failure occurred due to high radiation levels.

Imaging system layout

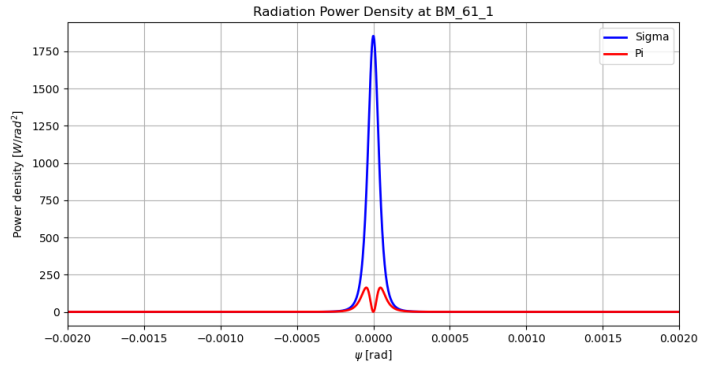
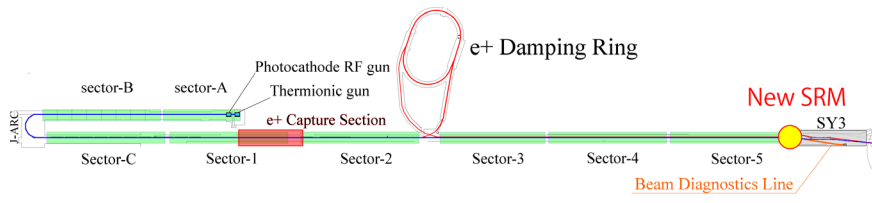


Beam patterns near focus point

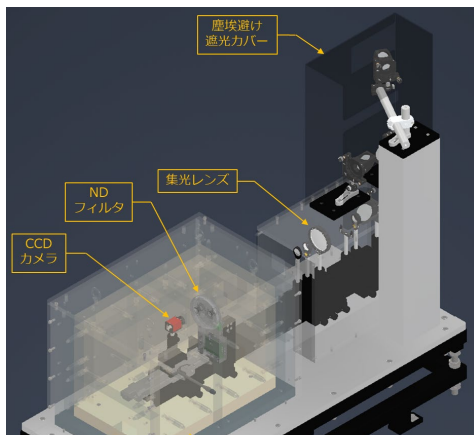
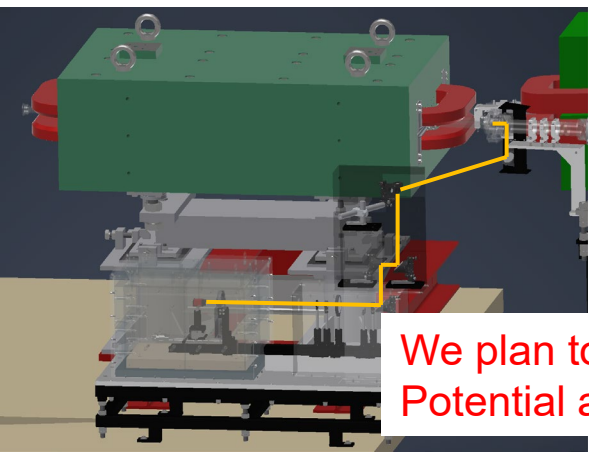


New SR Monitor (SRM_61_1) at SY3 entrance

- **Synchrotron radiation intensity calculation and optics design**
 - The SRM was designed for installation at bending magnet BM_61_1 in the linac's 3rd switchyard (SY3), beginning in August 2025
 - Synchrotron radiation power on the first HR mirror: $\sim 0.3171\text{ W}$; no water cooling required (7.0 GeV KBE electron beam)
 - Radiation power density is also much lower than in the DR and Main Ring cases
 - Single lens imaging configuration
 - $l = 3500\text{ mm}$, $f = 500\text{ mm}$, $\beta = 0.167$ (Limited by the available space)
 - Commercial Achromatic lens: $F\# = 10$ (Based on the simulation results)
 - Remote control of the ND filter wheel and horizontal and longitudinal stages for optimal imaging
 - Solid radiation shield is designed for protection of CCD and motorized stages



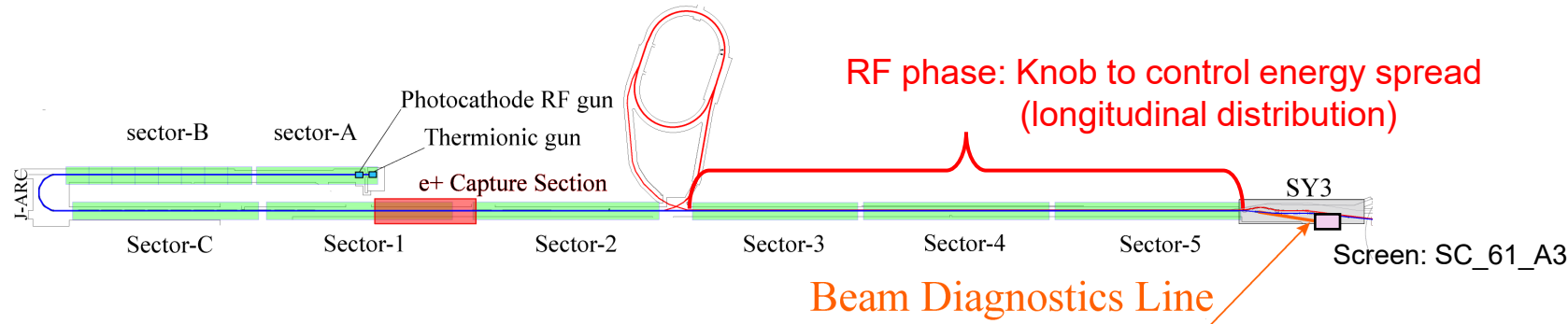
• **Installeld in summer this year**
• **Synchrotron radiation from a 7 GeV e- beam was successfully observed**



We plan to incorporate this SR monitor in to the emittance tuning system. Potential applications to the positron beam are also expected.

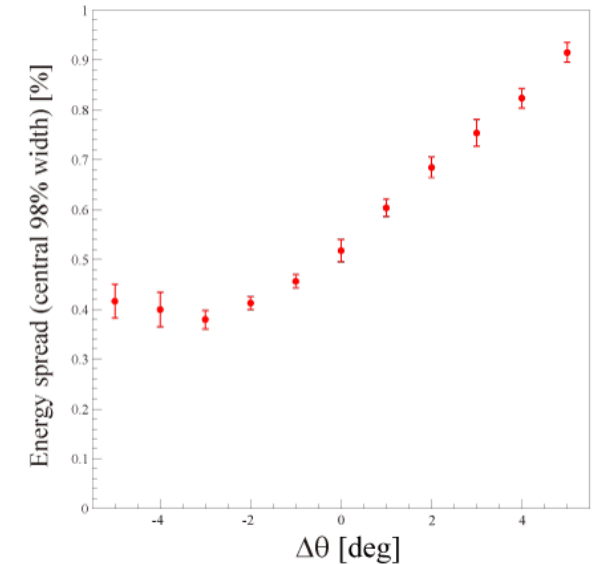
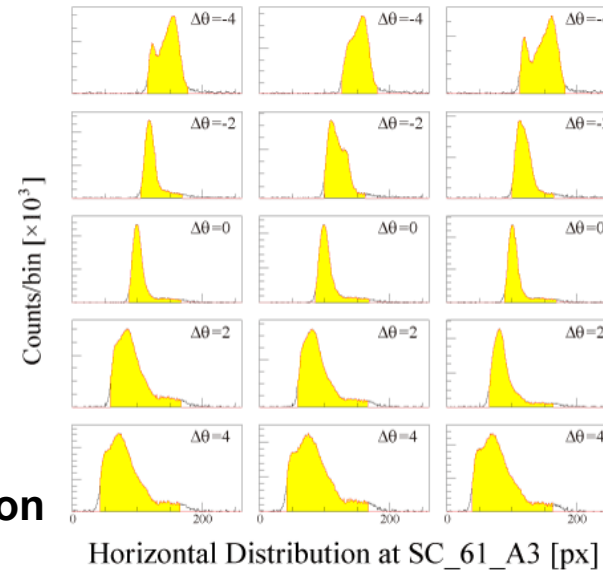
SY3 Beam Diagnostic Line

Energy distribution measurements can be performed by intermittently (1Hz or less) diverting a duplicated KBE (e- for HER) beam mode to the SY3 diagnostic line during normal HER injection operation.



- The beam energy distribution can be measured using the screen monitor at the end of the diagnostic beamline.
- The energy distribution can be controlled by adjusting the RF phases in Sectors 3–5.
- During operation, beam diagnostics can be performed using a test beam mode copied from the KBE mode (Rep. rate ≤ 1 Hz)

Issue: Radiation-induced camera failures and degradation
→ Improved radiation shielding is required



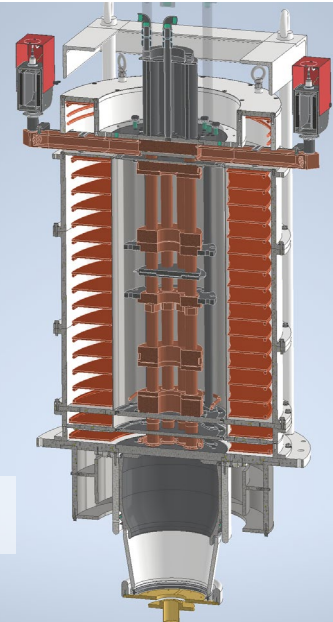
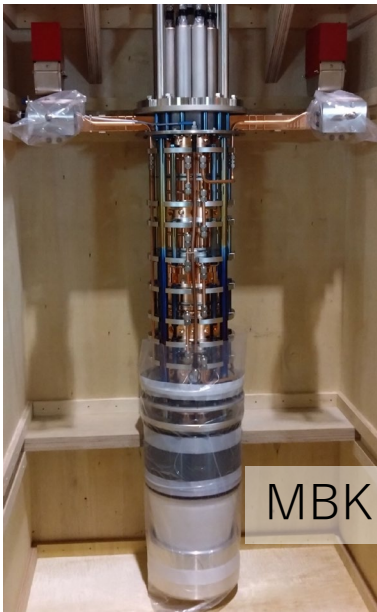
Energy distributions at different upstream RF (sector 3-5) phases, and energy spread as a function of upstream RF phase.

New development: Multi-beam Klystron

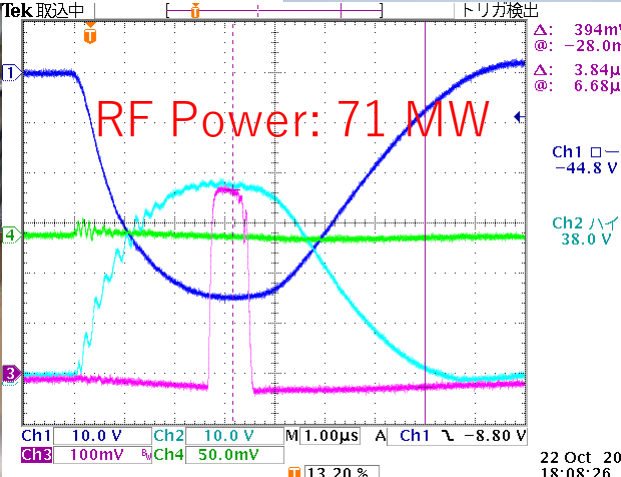
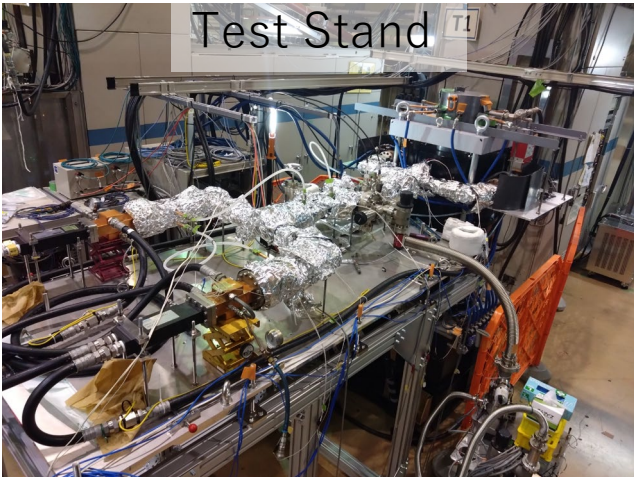
We are developing klystrons to achieve **high efficiency** and **high output power**. Although the beam power is at the same level as that of conventional models, the output will be 80 MW due to improved efficiency.

S. Wang

	E3730A	MBK (KMS80)
Power : MW	50	80
Efficiency : %	45	70
# of Beam	1	8
Perveance(10^{-6}).	2.1	2.2 (0.27×8)
Cathode V : kV	312	304
Cathode I : A	362	376
Gain Min: dB	51	51
Pulse width (RF): us	4.0	
Rep rate :pps	50	



T. Natsui



We have already begun RF conditioning and have confirmed an output of **71 MW**.

A **higher accelerating voltage** can be achieved with lower RF power

Summary

Electron Gun

- The RF gun upgrade during the 2026 summer shutdown enabled operation with the input pulse width at its design value.
- An improvement in beam quality is expected, particularly for the second bunch compared with the 2026ab run.

HER BT ECS

- Although the design RF power could not be applied due to discharges in the waveguide, the energy spread was successfully reduced to nearly the required level.
- The installation of an RF contactor in summer 2026 is expected to allow higher RF power.
- RF conditioning and beam studies will begin in the 2026c run.

Fast Kicker

- The fast kicker contributed to stable injection of the second bunch.
- Countermeasures against electrical discharges have been implemented.
- Radiation shielding is being designed for areas with high radiation dose rates.

SR Monitor at SY3

- Non-destructive monitoring of electron and positron beams at the end of the LINAC has become possible.
- The monitor is also expected to be useful for positron beam tuning.

SY3 Beam Diagnostic Line

- The diagnostic line allows a portion of the electron beam to be sampled and directed to the diagnostic line for direct measurement of the energy spread.
- It was confirmed that the energy spread can be controlled by adjusting the RF phases in sectors 3–5.
- The camera frequently stops functioning due to beam losses at the dispersive section near the screen monitor and radiation from the beam dump.
- Radiation shielding needs to be designed and implemented.

New development: Multi-Beam Klystron (MBK)

- A high-efficiency klystron has been successfully developed as part of the injector upgrade program.
- The MBK achieves an efficiency of 70%, compared with 45% for conventional klystrons.
- High-power testing is progressing smoothly.
- More stable operation and higher accelerating gradients are expected.

Current / Injection

F. Miyahara for Current/Injection Task force

Challenges of the Current/Injection Task Force

We aim to improve injection beam quality and injection efficiency, and increase beam current to achieve higher luminosity.

Collaborative efforts among optics and hardware experts are important to improve performance and resolve outstanding issues.

Members of the Optics, Hardware, and Belle II teams are working together to address these challenges.

Current Status

Injection Status



Beam Current

Maximum beam current

LER: 1650 mA, HER: 1300 mA

Injection Beam Emittance

During the 2026ab run, injection efficiency improved and could be maintained at a high level, particularly in the HER.

- Daily Injection Turning
- Emittance Auto Tuning
- Automatic Orbit Feedback

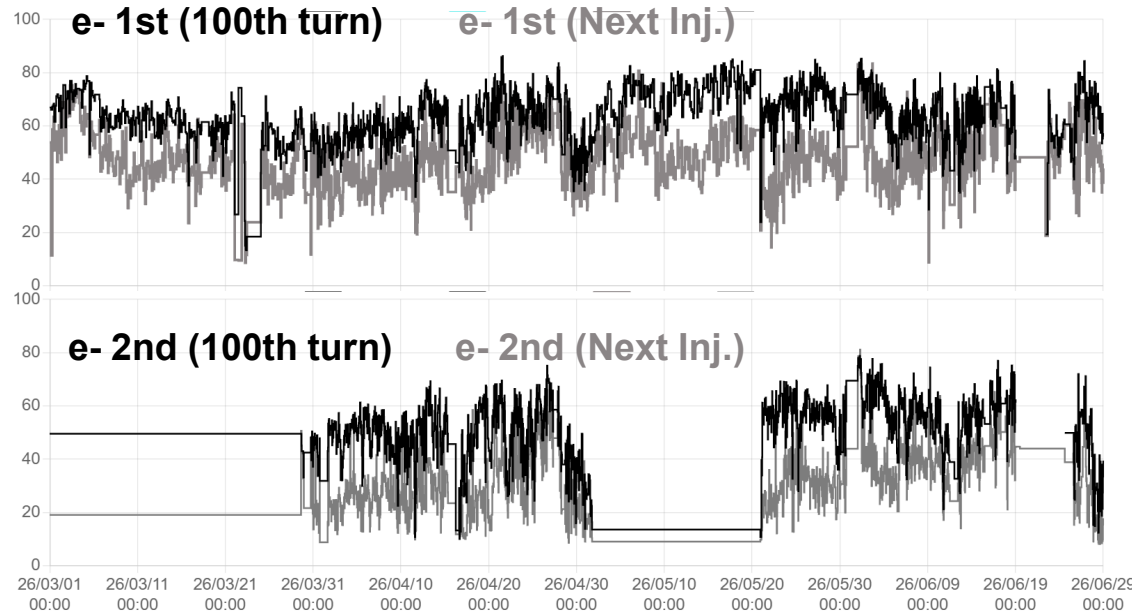
Bunch Current

- The positron beam charge gradually decreased due to a reduction in electron emission from the cathode of the thermionic gun.
- The electron beam charge remained stable at 2 nC/bunch.
- Successfully achieved stable injection of the second bunch

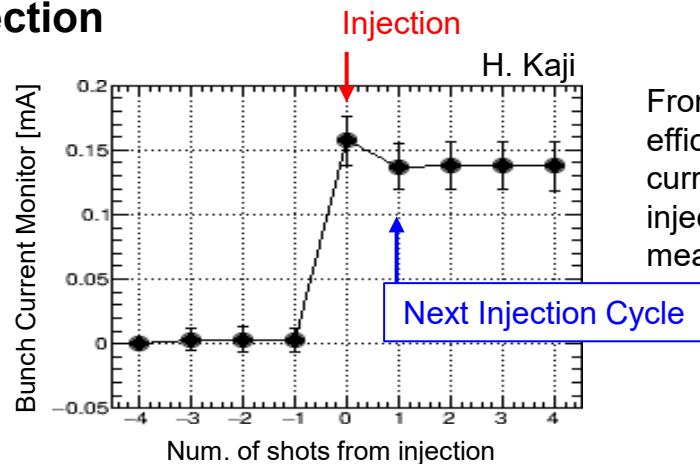
Power outage: Many devices lost their calibration

Injection Status: Injection Efficiency

HER

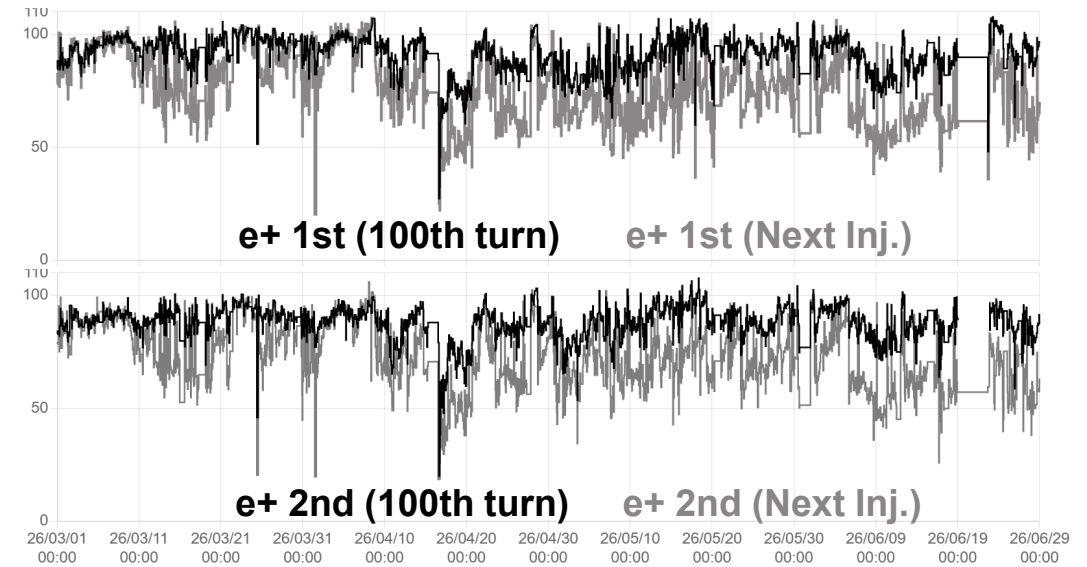


Injection efficiency at the next injection



From the 2026ab run, the injection efficiency calculated from the bunch current at the timing of the next injection cycle has also been measured and archived.

LER



- Injection efficiency 100 turns after injection

Depends on { • Injection beam quality (ϵ , σ_E)
• Injection tuning (Septum, Kicker)

- Injection efficiency at the next injection timing

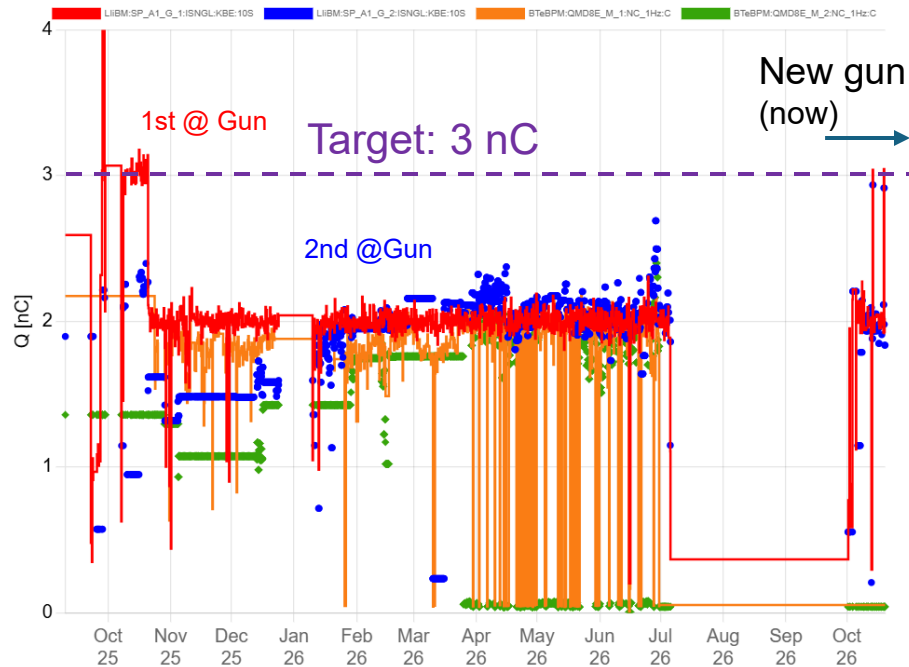
Depends on MR condition (tune, Collimator, ...)

The net injection efficiency is the injection efficiency at the next injection timing.

Improving injection efficiency measured at next injection is also important.

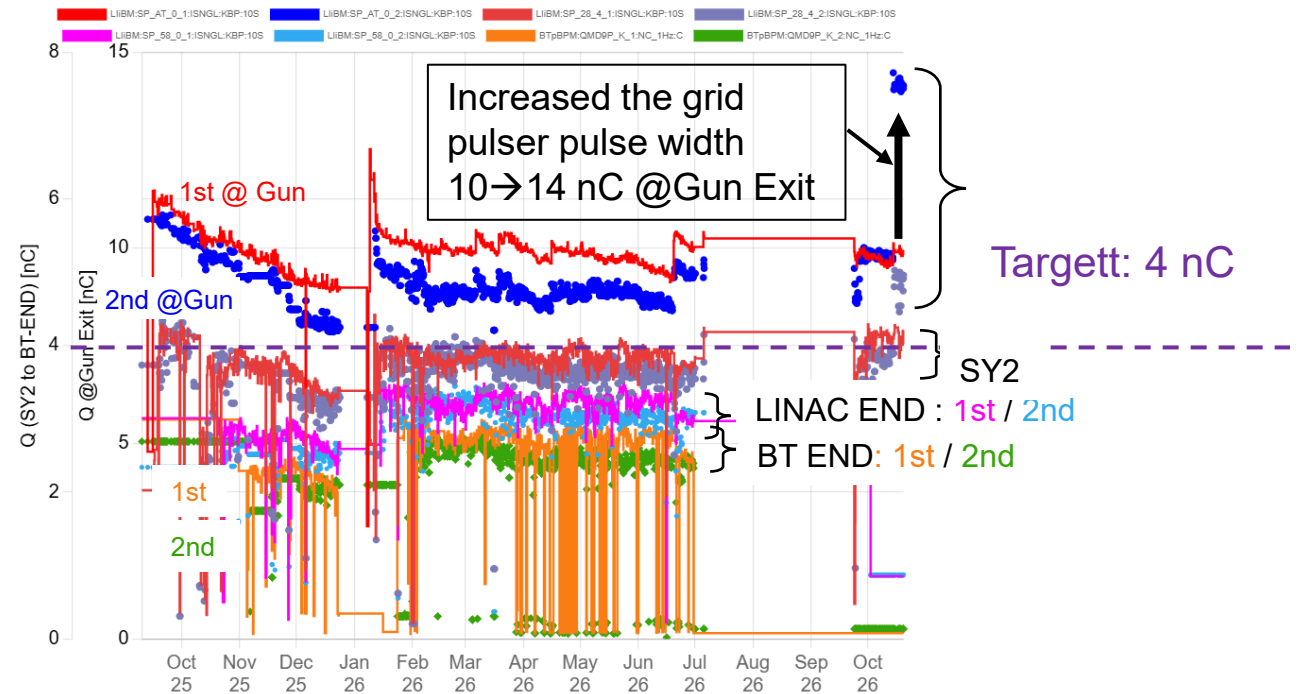
Required Parameters and Current Status: Bunch Charge at BT END

Electron Beam



- Previously operated at 2 nC.
- Confirmed 4 nC beam extraction from the electron gun.
- Currently optimizing and verifying the generation and transport of low-emittance beams at high bunch charge.

Positron Beam



- Cathode emission current has been gradually decreasing.
- In 2026ab, positron capture was optimized to maximize transmission efficiency to the DR → The bunch charge at BT remained constant of 2.5 nC
- Extended the grid pulser pulse width to increase the bunch charge
Gun Exit: 10→14 nC SY2 (BT to DR Entrance): 3.9 → 4.9 nC
→ Currently conducting beam tests up to SY2.
Beam tests up to DR-BT are scheduled for December.

Detail: Electron gun/Positron source talk (Zhou-san).

Required Parameters and Current Status: Energy Spread

Current Energy Spread and Required Specifications

Y. Seimiya

	1 st only	1 st +2 nd	1 st +2 nd (energy adjusted)	Requirement
e-	0.033%	0.076%	0.074%	0.07%
e+	0.058%	0.069%	0.067%	0.16%

Electron Beam

- The electron beam energy spread is close to the required value.
- Phase drifts in the downstream LINAC can occasionally cause the energy spread to exceed the required limit.

The input RF power was limited by discharges at the waveguide flange, but a countermeasure was implemented in the summer of 2026 by installing an RF contactor.

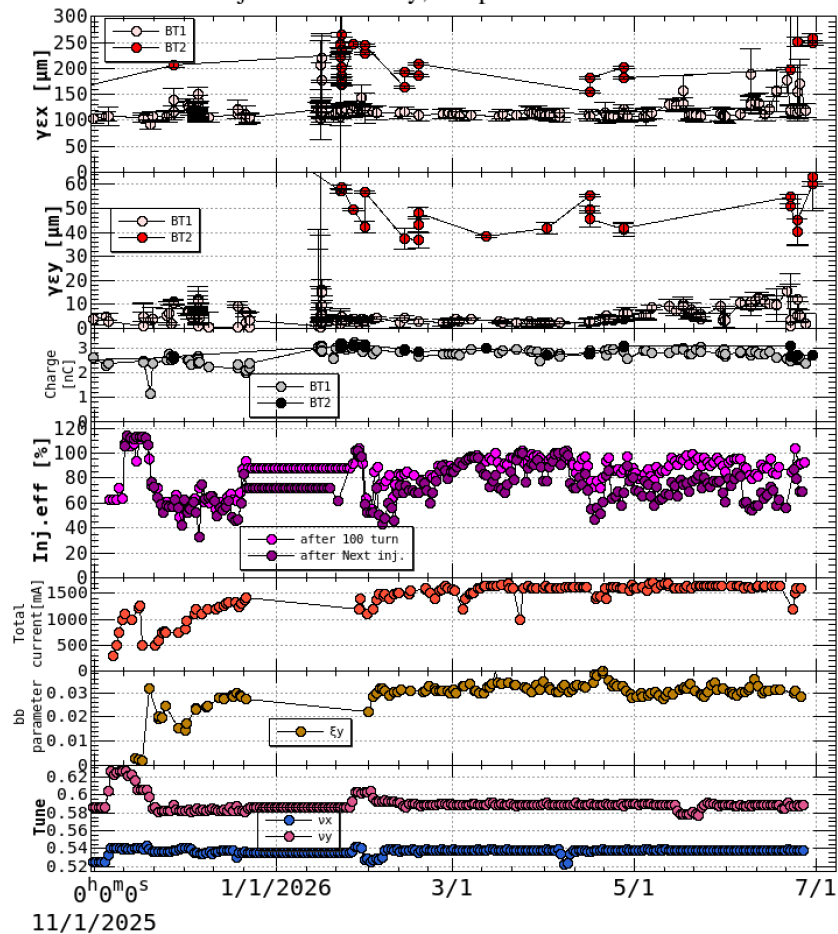
Increase the ECS accelerating gradient to further reduce the energy spread.

Positron Beam

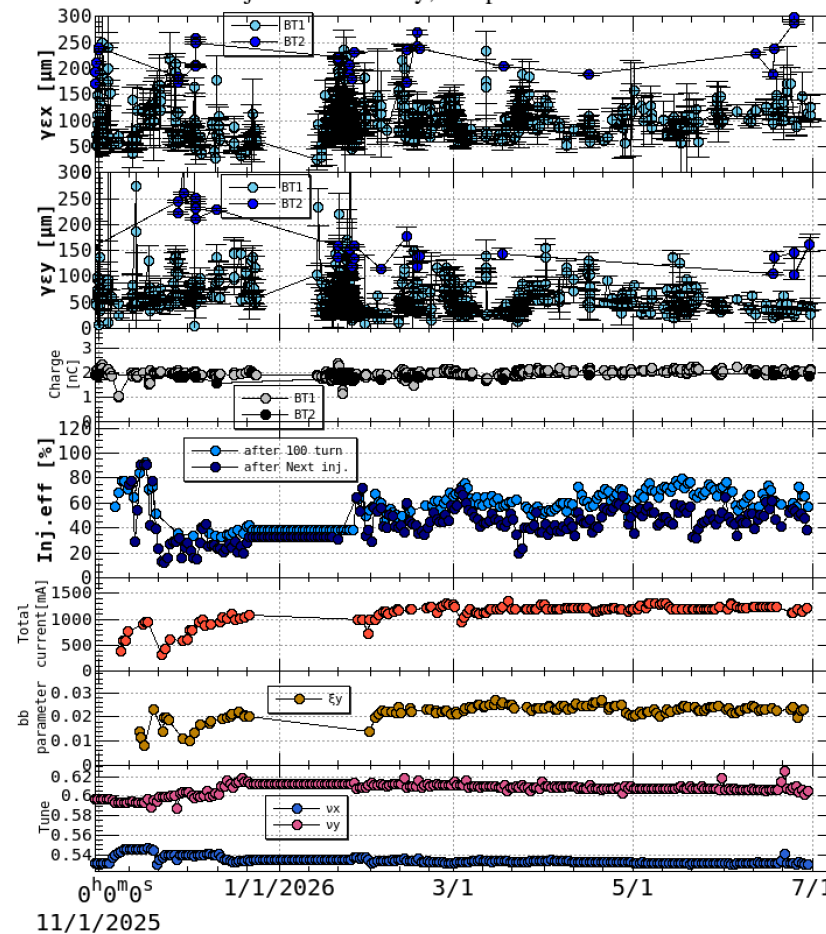
- The energy spread of the positron beam is sufficiently small

Required Parameters : Emittance of the Injection Beam

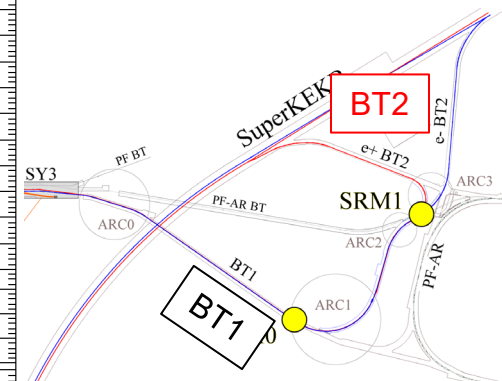
e+ Measured emittance in BT, Bunch charge, Injection efficiency, and parameters in LER



e- Measured emittance in BT, Bunch charge, Injection efficiency, and parameters in HER



N. Iida



e+ 2026ab	BT1	BT2	Req.
$\gamma\epsilon_x$ [μm]	119 ± 2	207 ± 9	100
$\gamma\epsilon_y$ [μm]	5.4 ± 0.4	47 ± 2	15

e- 2026ab	BT1	BT2	Req.
$\gamma\epsilon_x$ [μm]	104 ± 2	233 ± 11	40
$\gamma\epsilon_y$ [μm]	52.8 ± 1.6	135 ± 7	20

Significant emittance blowup from BT1 to BT2 is a major issue for both e- and e+ beams

Emittance Blow-up in BT

One of the highest-priority issues

→ Mori-san's talk

Betatron Oscillation Amplitude and Ring Acceptance

LER

HER

N. Iida

2024c

βy^*	Action	Injected beam	Ring Acc.
1.0	$2J_x [\mu\text{m}]$	1.29 ~	1.4
	$2J_y [\mu\text{m}]$	0.062(6 σ) >>	0.025

2024c

βy^*	Action	Injected beam	Ring Acc.
1.0	$2J_x [\mu\text{m}]$	0.95 ~	0.90
	$2J_y [\mu\text{m}]$	0.060(6 σ) >>	0.04

2026ab

βy^*	Action	Injected beam	Ring Acc.
0.9	$2J_x [\mu\text{m}]$	1.48 >>	1.15
	$2J_y [\mu\text{m}]$	0.036(6 σ) <	0.044
1.0	$2J_x [\mu\text{m}]$		1.65
	$2J_y [\mu\text{m}]$		0.04

2026ab

βy^*	Action	Injected beam	Ring Acc.
0.9	$2J_x [\mu\text{m}]$	1.01 <	1.4
	$2J_y [\mu\text{m}]$	0.059 >>	0.038
1.0	$2J_x [\mu\text{m}]$		1.7
	$2J_y [\mu\text{m}]$		0.037

Table 2: The Courant-Snyder invariants of the injected beam and the measured acceptance of the ring

	CSI	Injected beam		Ring acc.
HER	$2J_x [\mu\text{m}]$	1.01	<	1.4
	$2J_y [\mu\text{m}]$	0.059 (6 ϵ_y)	>>	0.038
LER	$2J_x [\mu\text{m}]$	1.48	>>	1.15
	$2J_y [\mu\text{m}]$	0.036 (6 ϵ_y)	<	0.044

HER: Vertical Emittance is Critical
LER: Horizontal Emittance is Critical

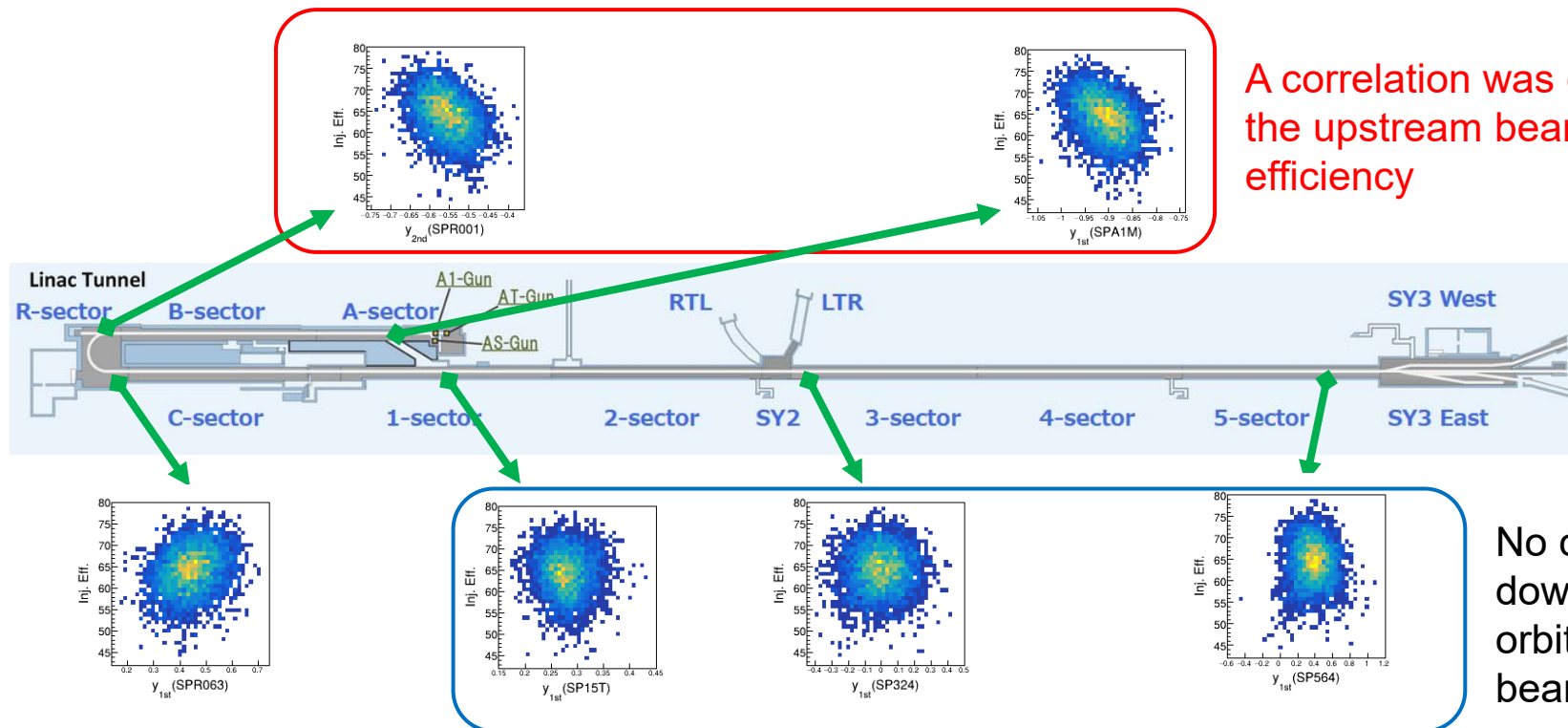
Emittance Automatic Tuning

Laser-RF relative phase and Injection Efficiency

Objectives: Identify the factors causing variations in beam emittance and injection efficiency

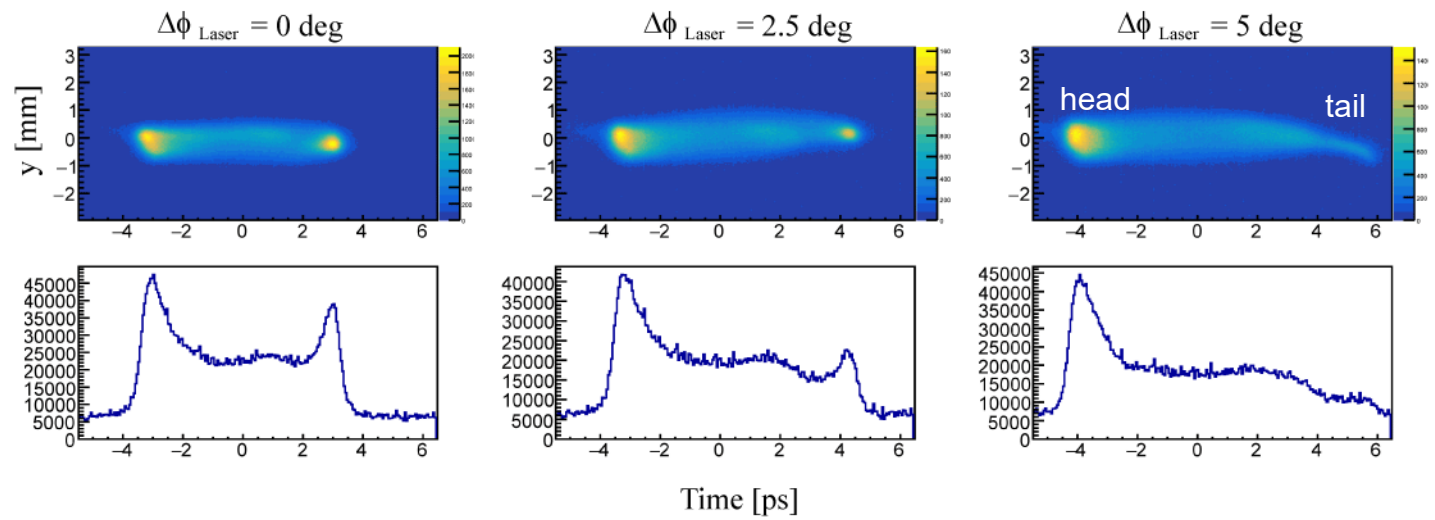
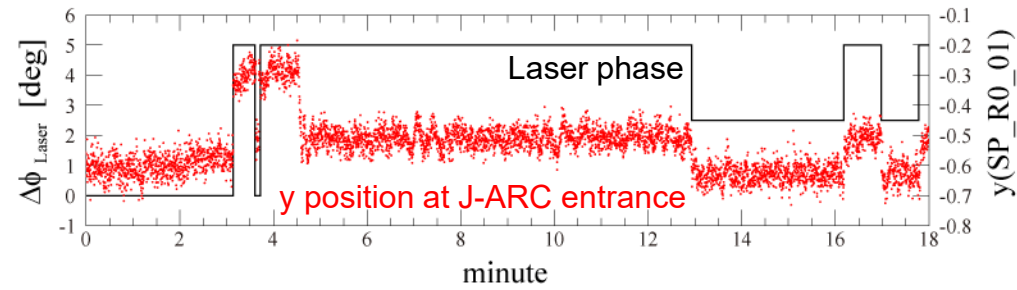
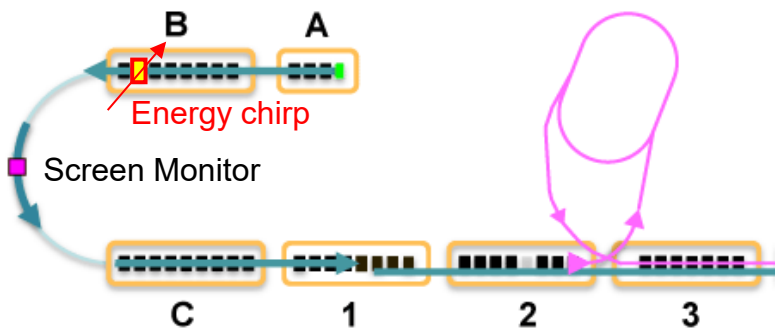
1. SRM beam size variations and injection efficiency degradation are often associated with vertical orbit deviations just downstream of the electron gun
2. Upstream orbit changes induce kicks on the bunch tail
3. Relative phase between Laser and RF affects the beam orbit

1) Beam orbit and Injection Efficiency



2,3) Effect of Laser-RF relative phase on the beam orbit and Wakefield-induced kicks

- Varied the laser phase to observe beam orbit changes
- Applied an energy chirp in Sector-B to measure the longitudinal (time) distributions

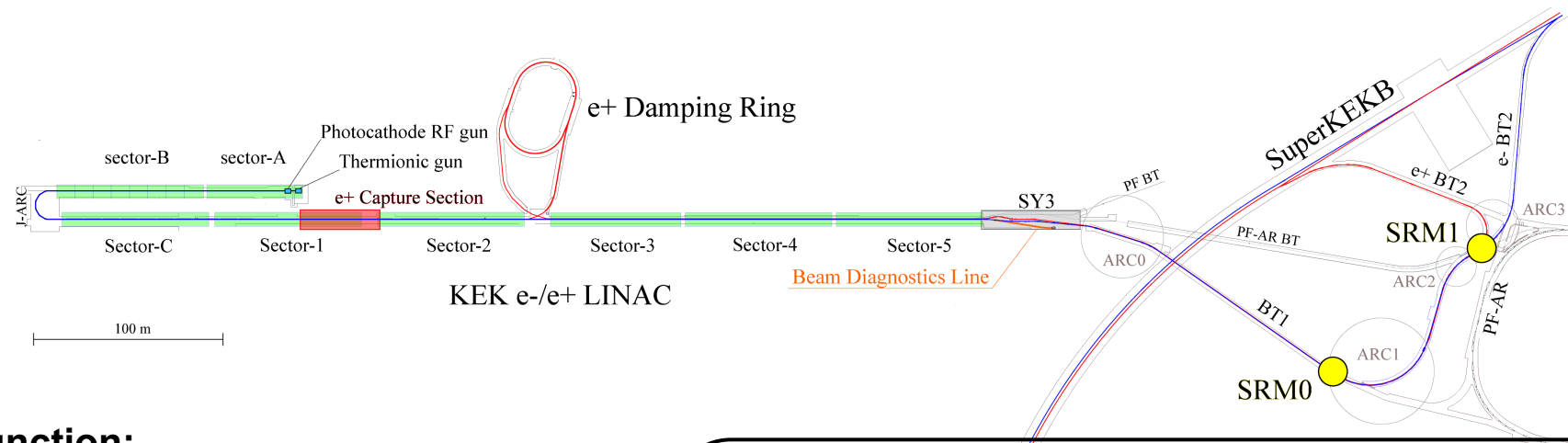


Beam position changes with laser phase (top) and beam profile measured at the center of J-ARC with an applied energy chirp (bottom). The horizontal axis is converted to an approximate time scale. Wakefield-induced kicks on the bunch tail when the beam orbit deviates from the optimal operating orbit ($\Delta\phi_{\text{Laser}} = 2.5, 5 \text{ deg}$).

The laser–RF relative phase affects beam emittance.
It also affects energy spread by shifting the beam phase relative to the accelerating RF.

➡ **Adjusting the relative phase between the laser and RF is required to maintain low emittance**

Emittance Auto Tuning (EAT)



Y. Seimiya

Objective function:

$$\frac{\sum_i \sigma_{x,i}^2 / \beta_{x,i} + w \sum_i \sigma_{y,i}^2 / \beta_{y,i}}{Q_{\text{Linac end}}^2 / Q_{\text{RF gun}}^2}$$

$\sigma_{x,i} / \sigma_{y,i}$: Horizontal / Vertical Beam size at SRM i ($i = 0, 1$)

$\beta_{x,i} / \beta_{y,i}$: Horizontal / Vertical β function at SRM i

$Q_{\text{RF gun}} / Q_{\text{Linac end}}$: Bunch charge at Gun exit / Linac end

w : Weighting factor ($w=2$) to emphasize vertical emittance

- Optimize the beam orbit to minimize the beam sizes measured at two SRMs
- In two-bunch operation, this also minimizes the overlap of the two bunches, leading to an overall improvement in injection efficiency

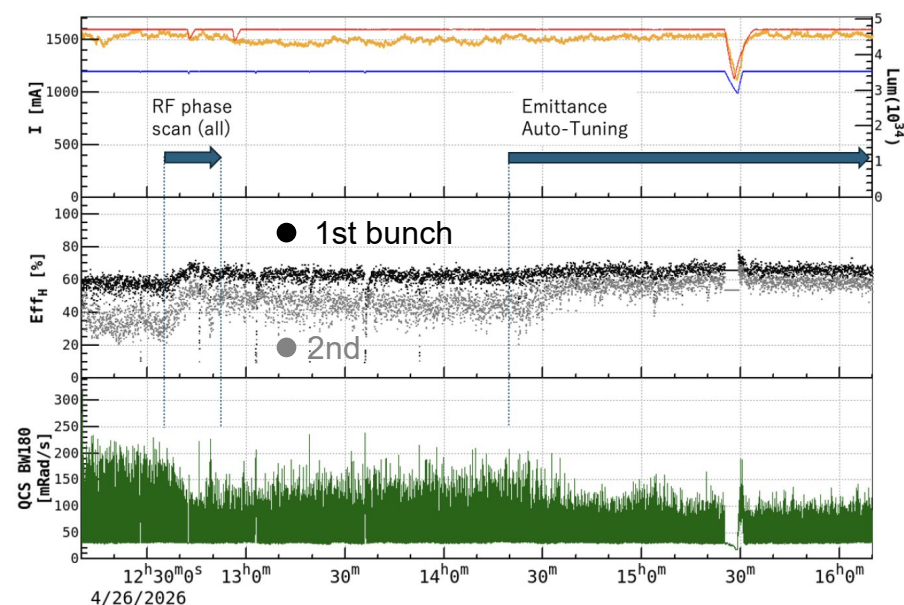
Upgrade of EAT

Objective: Add the adjustment of the relative phase between the laser and RF to the EAT

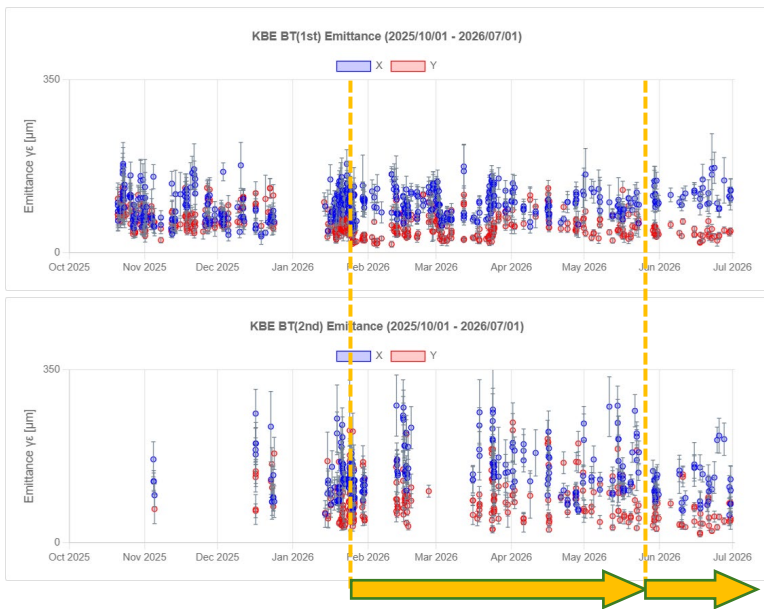
Injection efficiency improvement through Emittance Auto Tuning

Y. Seimiya

Include the overall LINAC RF phase in Emittance Auto-Tuning (EAT)



Improved injection efficiency and reduced Belle II background with RF Phase Adjustment and Emittance Auto Tuning.



Comparison of emittance before and after the introduction of EAT

KBE		Feb./13/2026		Jun./24/2026	
BT1 (WS)		1 st	2 nd	1 st	2 nd
$\gamma\epsilon_x$ [μm]		81 ± 9	144 ± 16	100 ± 16	208 ± 26
$\gamma\epsilon_y$ [μm]		41 ± 5	79 ± 8	24 ± 11	31 ± 6
BT2 (MSE.16)		1 st	1 st + 2 nd	1 st	1 st + 2 nd
$\gamma\epsilon_x$ [μm]		173 ± 3	237 ± 3	289 ± 3	104 ± 9
$\gamma\epsilon_y$ [μm]		134 ± 84	176 ± 18	145 ± 11	104 ± 9

- Vertical emittance at BT1 has been significantly reduced.
- Emittance blowup between BT1 and BT2 remains a major challenge.

- EAT and RF phase optimization significantly improved HER injection efficiency and reduced the Belle II background.
- A reduction in beam emittance in the BTeV was confirmed.

- Future Improvements
- Optimization of energy spread with SY3 beam diagnostic line
 - Implement automatic tuning of the 2nd bunch using the Fast Kicker
 - Using the new SR Monitor at SY3

Automatic Orbit Feedback

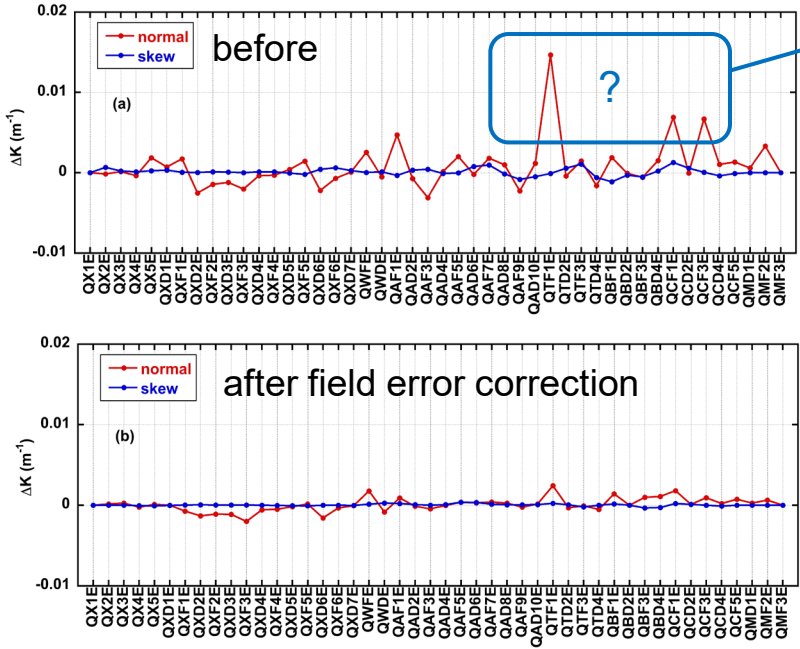
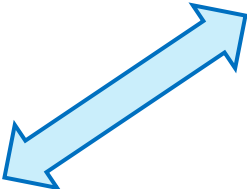
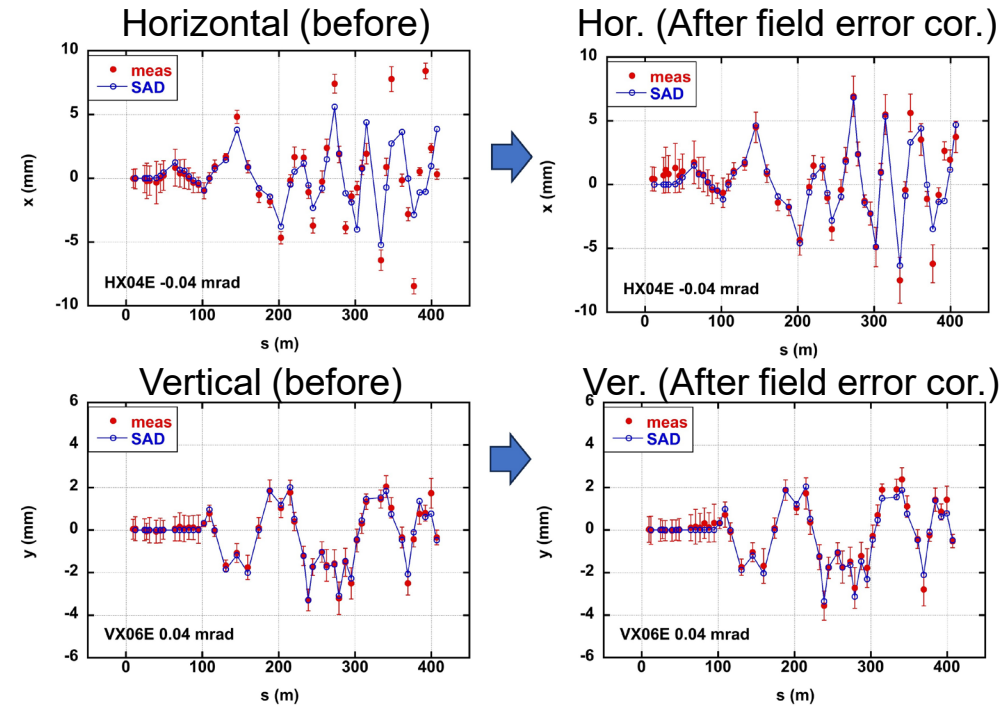
Reconstruction of the BT simulation Model and Implementation of Automatic Orbit Feedback

Y. Shimosaki

Objectives: Compare model predictions with measurements and Stabilize the injection beam orbit

Response Function Measurement and Model Reconstruction

- 1. Measure the orbit response function (displacement per unit kick angle) and dispersion function
- 2. Evaluate the normal and skew quadrupole field errors required to reproduce the measured response in SAD simulations.



Large error
Cause unknown

Magnetic field errors of individual Quadrupoles(Top: Before correction; Bottom: After Correction)

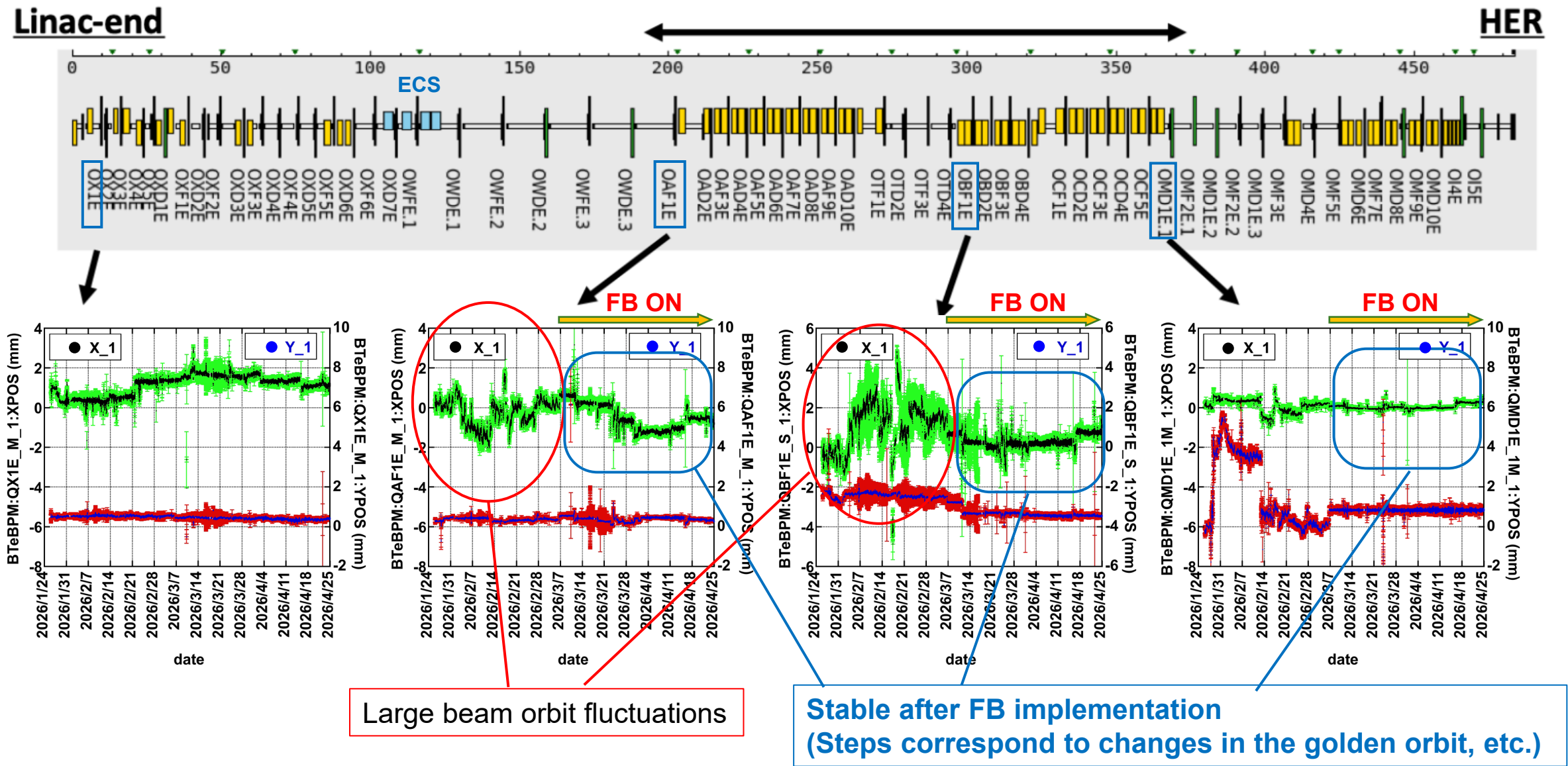
Automatic Correction

Calculate the steering kick angles required to correct the orbit deviations from the golden orbit.

Comparison of measured and simulated injection beam orbit

Automatic Orbit Feedback in BTeV

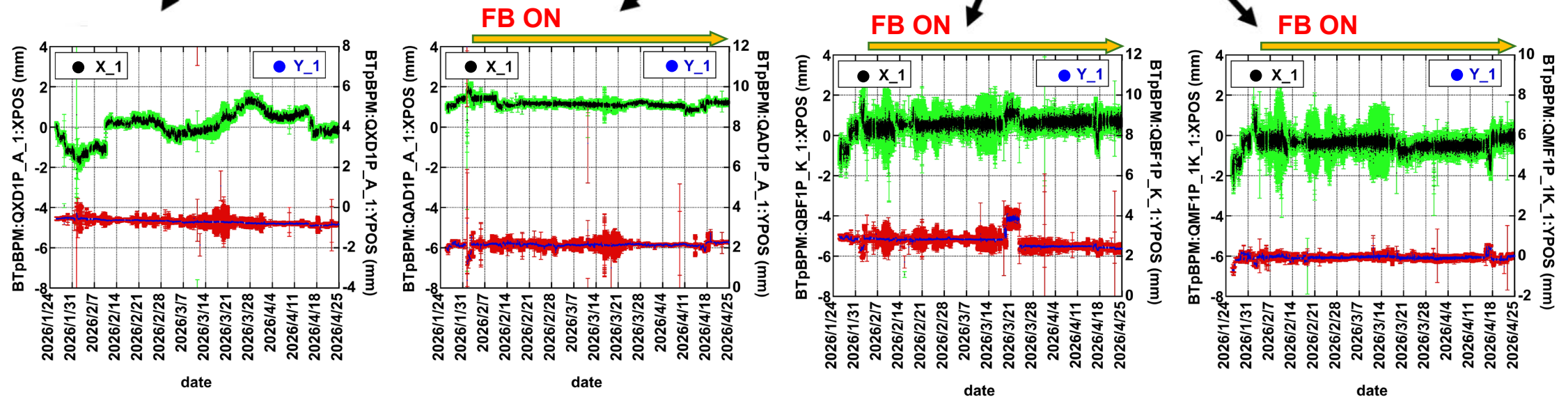
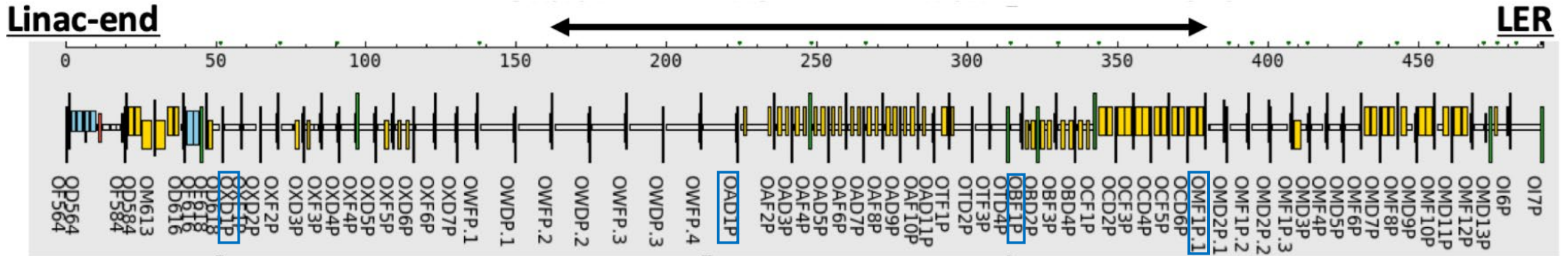
Y. Shimosaki



Long-term beam orbit drift was eliminated, and orbit jitter was significantly reduced

Automatic Orbit Feedback in BTP

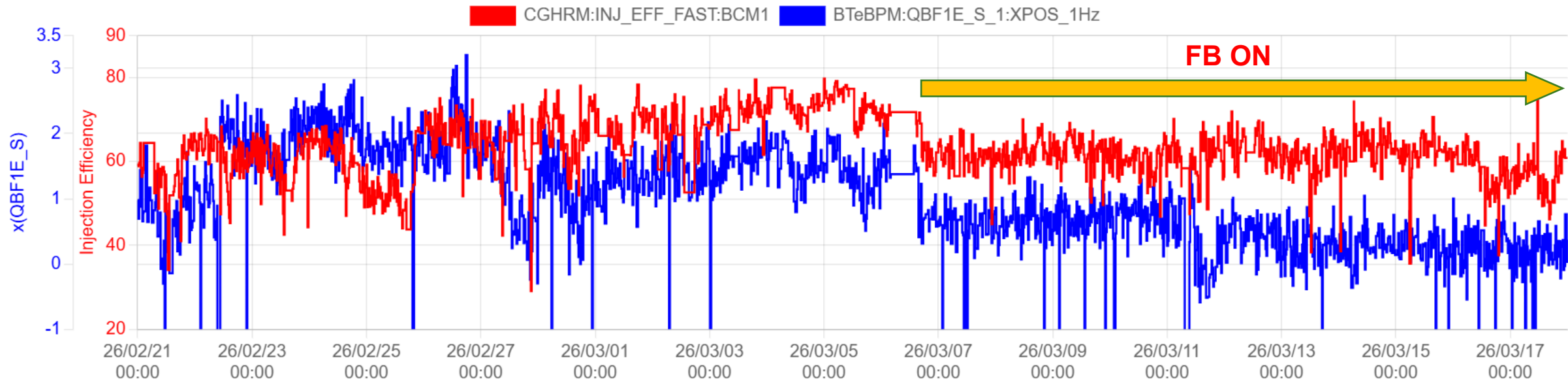
Y. Shimosaki



Positron beam orbit is also stabilized

In the LER, since correcting for field errors still resulted in large discrepancies between simulations and experiments, orbit correction is performed using the measured response matrix.

Automatic Orbit Feedback and Injection Stability



Long-term beam orbit drift was eliminated, resulting in stable injection efficiency

Implementation of
Automatic Orbit FB



- Injection stability was greatly improved
- Enabled practical use of collimators (Studies are planned for the next operation period)

Future Improvements

- Improve FB accuracy and stability by increasing the number of BPMs (BPM signal overlap issue is resolved) and optimizing BPM and steering magnet selection
- Investigate the causes of large magnetic field errors

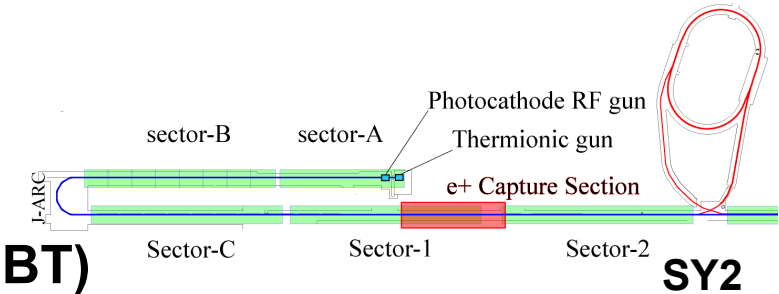
Increase in Positron bunch charge

Increase in Positron bunch charge

- At the thermionic gun exit

→ Detail will be presented tomorrow by Zhou-san.

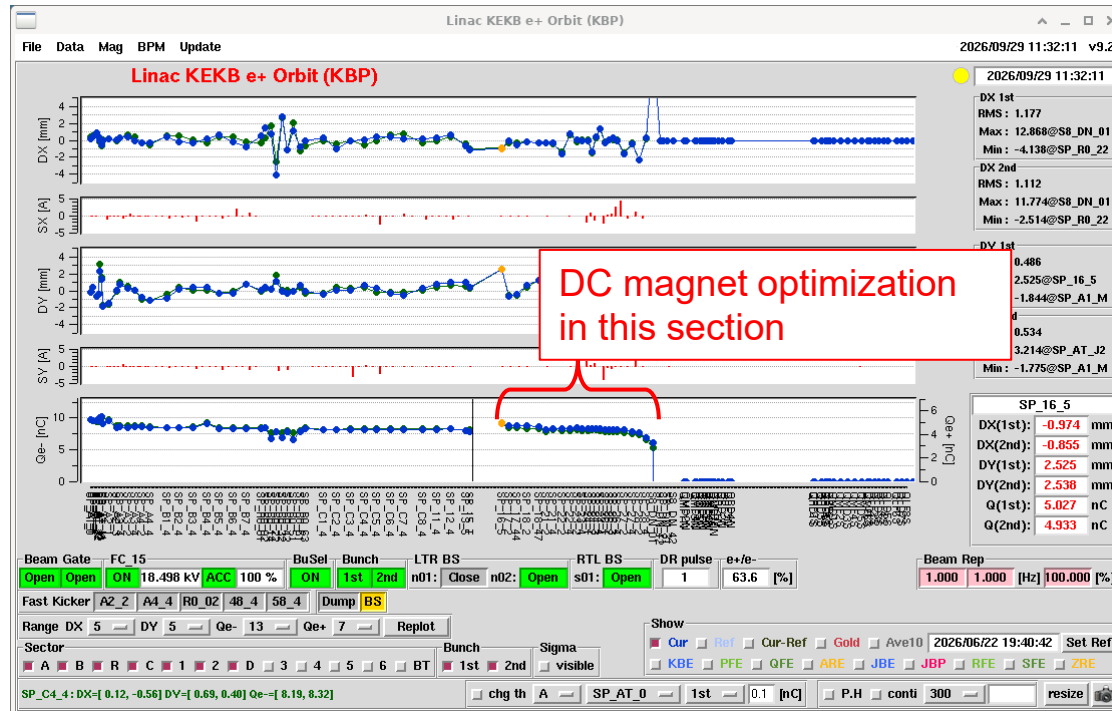
- e⁺ Capture Section → SY2 (entrance of Linac To Damping Ring BT)



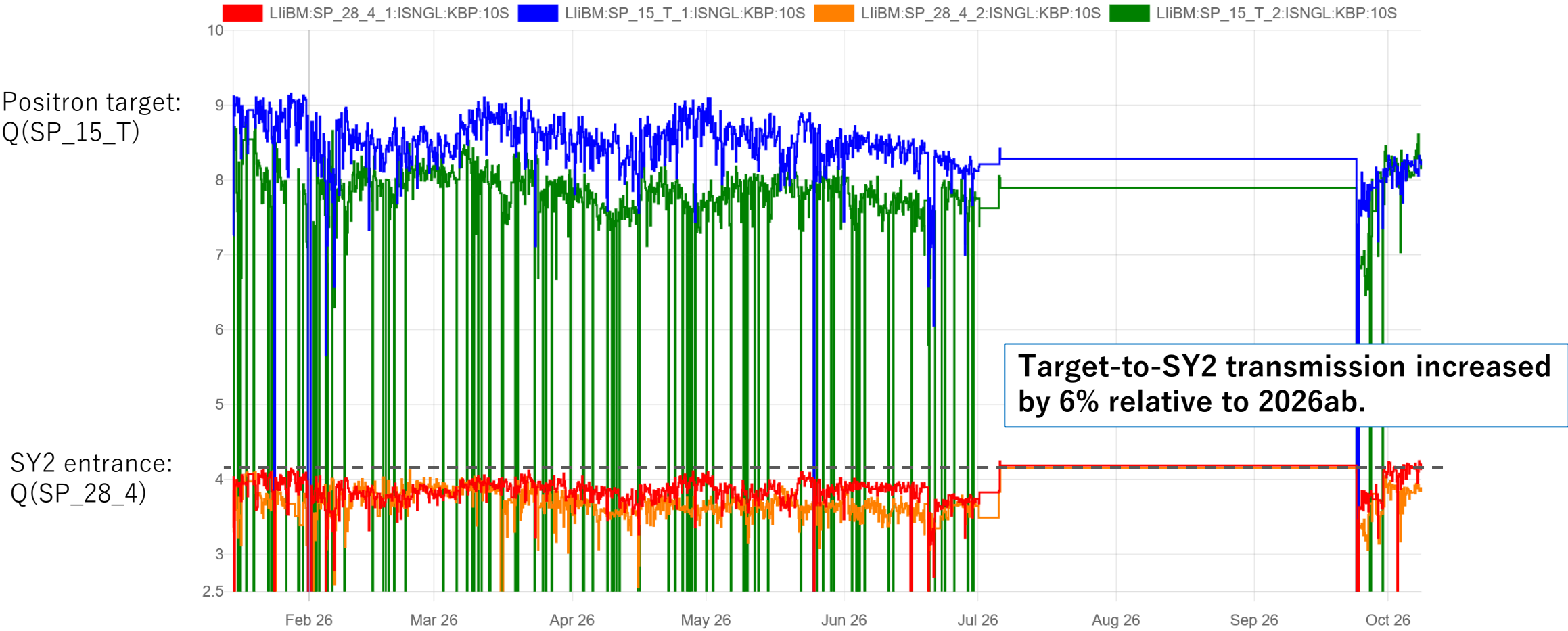
There are more than 100 DC quadrupole magnets, and their settings cannot be changed during PF operation. Due to the time-consuming tuning process, optimization to increase the transmission efficiency had been performed only once before this October.

→ In this October this year, we performed optimization again.

T. Natsui



Optimization of Positron Production and the Downstream Section of the Capture Section



	Q _{target} [nC]	Transmission: 15T→28_4
2026/1	9	45%
2026/10	8.3	51%

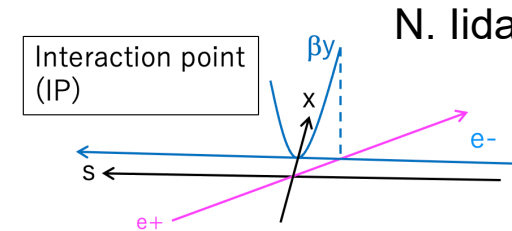
Optimization including the BT from SY2 to the DR is planned for December

Optimize the capture phase in the Capture Section and the magnets downstream of SY2.

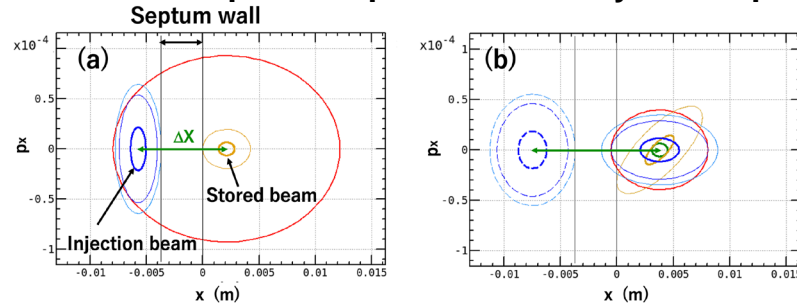
HER Synchrotron Injection

Why synchrotron injection

N. Iida

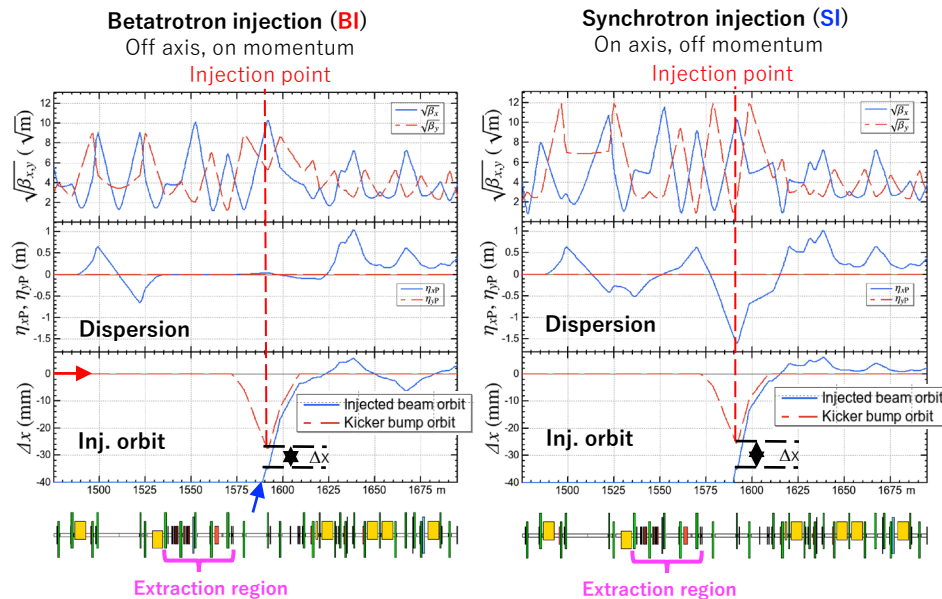


- The horizontal phase space at the injection point



In SI, the horizontal betatron injection oscillation is replaced by longitudinal synchrotron oscillation by utilizing the horizontal dispersion and an energy offset of the injected beam

- Optics and orbits in the injection region



- $\eta_x = \Delta X / \delta$: horizontal dispersion = orbits of the beam with offset energy (δ)
- In SI, the **energy of injection beam** is made **0.6% higher** = The injection beam's orbit makes the dispersion orbit.
- In the non-dispersive region.
 - **$\Delta X = 0$ at the interaction region.**
 - However, although it oscillates in the longitudinal direction, its impact on collisions is small.

Comparisons of the betatron injection (BI) and synchrotron injection (SI)

	BI	SI
Beam-beam kick at IP	Large H. oscillation	No H. oscillation
Beam-beam with nano-beam	H. osci. causes shift of $s \rightarrow$ large β_y	(Coll. at $s \sim 10\sigma_z$)
Dynamic aperture (DA)	Large H. osci. decreases V. DA	No H. osci.
SR to the IP beam pipe	Larger due to H. osci.	No H. osci.
Damping time	58 ms (Horizontal)	29 ms (Longitudinal)
Sensitivity to b-b, sext. misalignment, and tune	More sensitive	Less sensitive

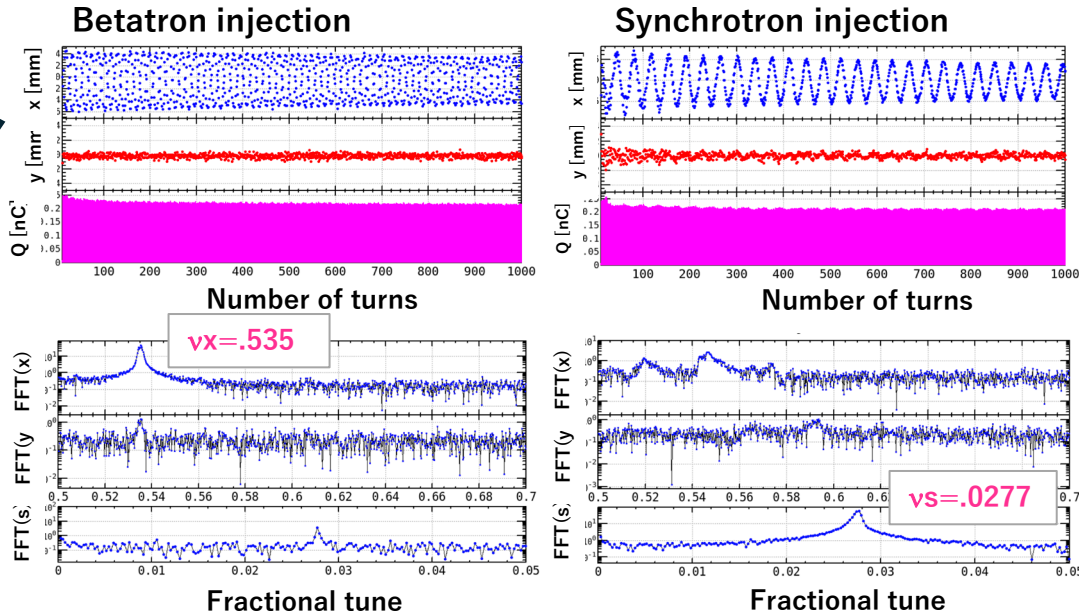
Injection Comissioning

N. Iida

- Comparison of ten-minutes operation with the $\beta y^*=1$ mm optics

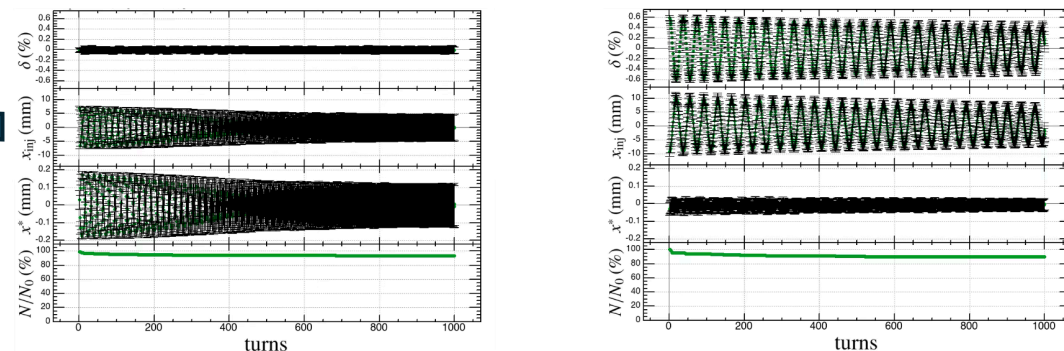
The SI was tested from Nov.6 to 20 in 2025.

- Measured beam oscillations using TbT-BPMs with the detuned optics



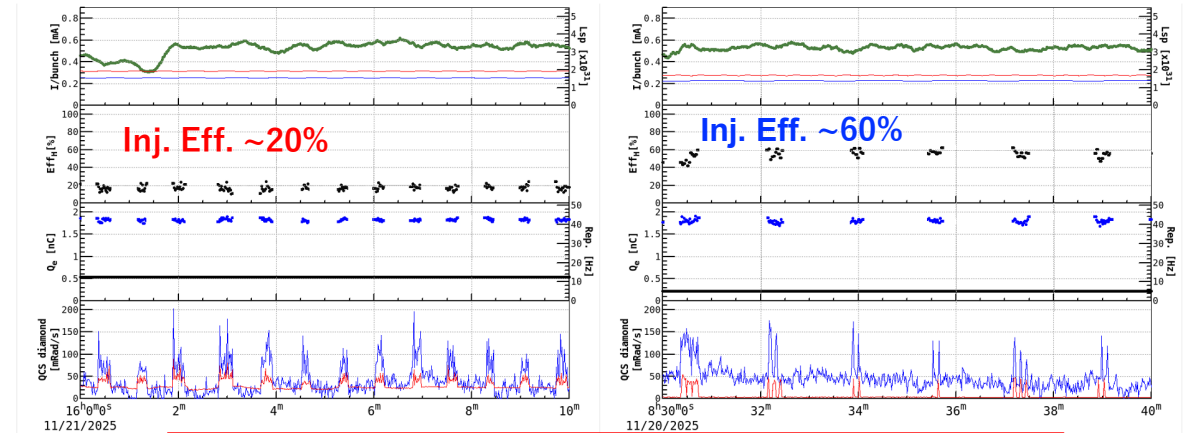
A peak appears in the frequency spectra at the horizontal tune in BI, while the synchrotron tune in SI. These results indicate **a perfect realization of the synchrotron injection** as the simulation results.

- Simulations ($\beta y^*=1$ mm, w/o collimators, knobs, b-b, and different tune)



BI(21-Nov-2025)

SI(20-Nov-2025)



The injection efficiency of SI reached 60% after 7.5hr-tuning, on the other hand, that of BI stayed only 20% after 4 days.

Injection tuning is easier because it is less sensitive to the tune and sextupole misalignments, etc.

The test was terminated after a short period because:

- Beam injection onto adjacent RF buckets occurred, and the cause could not be identified. (This had also occurred during BI, but only rarely)
- Changin the rep. rate from 5 to 12.5 Hz increased the background
- The physics run was scheduled immediately afterward.

- In 2026ab, the injection efficiency reached 60% even with BI, thanks to Emittance Auto-Tuning and injection optimization.
- We aim to evaluate the effect of Synchrotron Injection under the same injected beam conditions.

Parameters Required for Luminosity of 1×10^{35} and Future Plans

Parameters Required for Luminosity of 1×10^{35}

Parameters Required to Achieve a Luminosity of 1×10^{35} , and Expected Loss and Injection Rates, Based on Measured Injection Efficiency, Beam Lifetime, and Specific Luminosity in 2026ab

Y. Funakoshi

	Spec. Lum. Case A Based on the Maximum Spe. Lum. Archived in 2026ab		Spec. Lum. Case B $\beta y^*=0.8$ and 112.5% of Case A	
	LER	HER	LER	HER
Luminosity [$10^{35}\text{cm}^{-2}\text{s}^{-1}$]	1		1	
Nb	2746		2346	
Total beam current [mA]	3033	2426	2365	1892
Bunch current [mA]	1.104	0.8835	1.008	0.8066
Bunch current product [mA^2]	0.9758		0.8133	
Specific luminosity [$10^{31}\text{cm}^{-2}\text{s}^{-1}\text{mA}^{-2}$]	3.732		5.241	
βy^* [mm]	0.9		0.8	
Lifetime [min.]	4.29	11.3	5.11	12.4
Loss rate [mAs^{-1}]	11.8	3.58	7.71	2.55
Injection rate [mAs^{-1}] #	4.19	3.16	5.12	4.37

Assumption: e+/e- **Bunch charge = 3 nC**, Beam Rep. Rate: LER 23 Hz, HER 25 Hz

One Model Scenario: Model-Dependent Due to the Unexplored Beam Current Regime

In the LER, the beam loss rate significantly exceeds the injection rate.
The situation is also challenging for the HER.

Hardware Upgrade

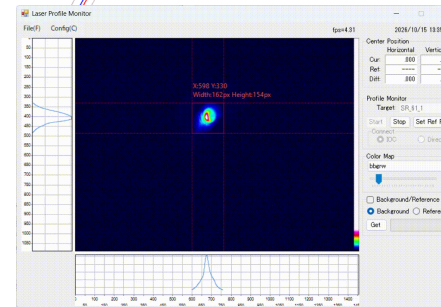
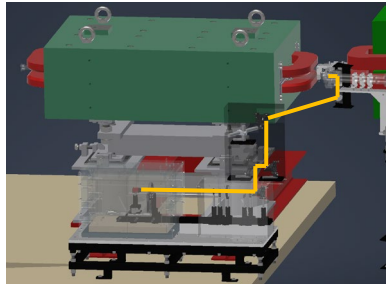
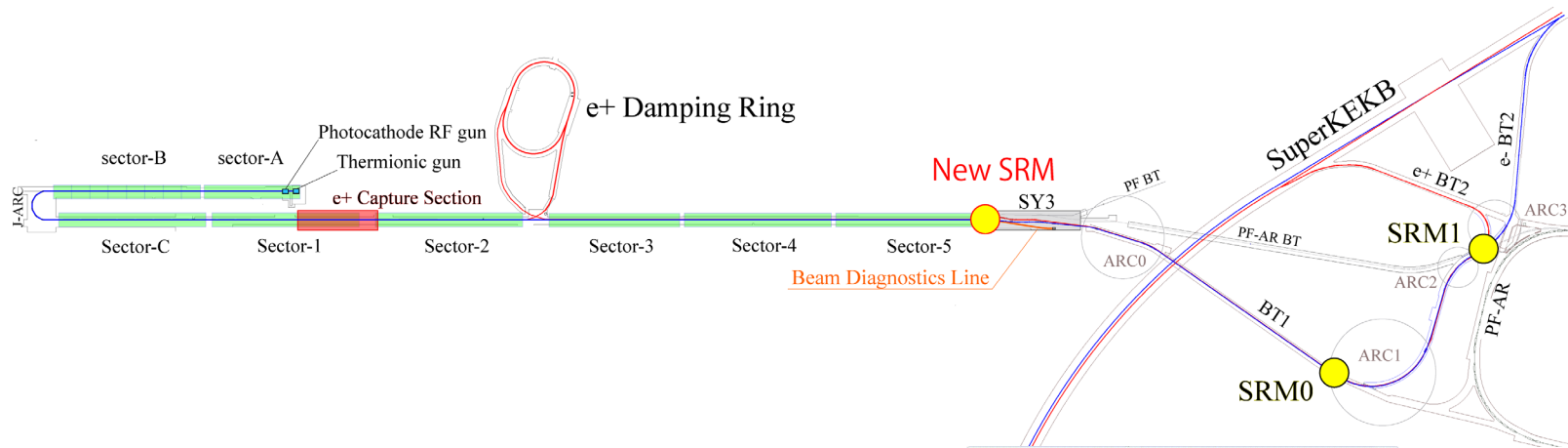
Requests to the Hardware Group

Requests for Hardware Improvements to Enhance Injection Efficiency, Reduce Injection Background, and Investigate Issues Such as Emittance Growth

- **Installation of New Synchrotron Monitor at SY3 and the LER BT**

A new SRM has been installed at SY3.

Tests to integrate the new SRM into automated emittance tuning are planned to begin in December.



R. Zhang, Y. Okayasu

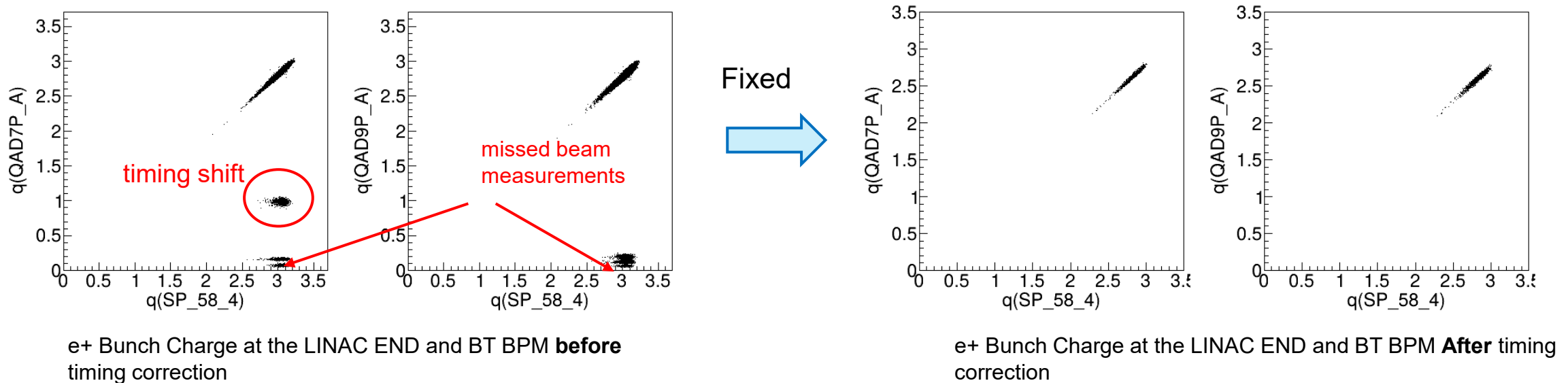
No SRM has been installed in the LER BT yet.

- **Radiation Protection for the SY3 Beam Diagnostic line Camera**

- Frequent camera shutdowns due to radiation from the beam dump prevent stable measurements.
- Radiation shielding upgrades were postponed from the summer shutdown to the next shutdown due to higher-priority work, including SRM installation.

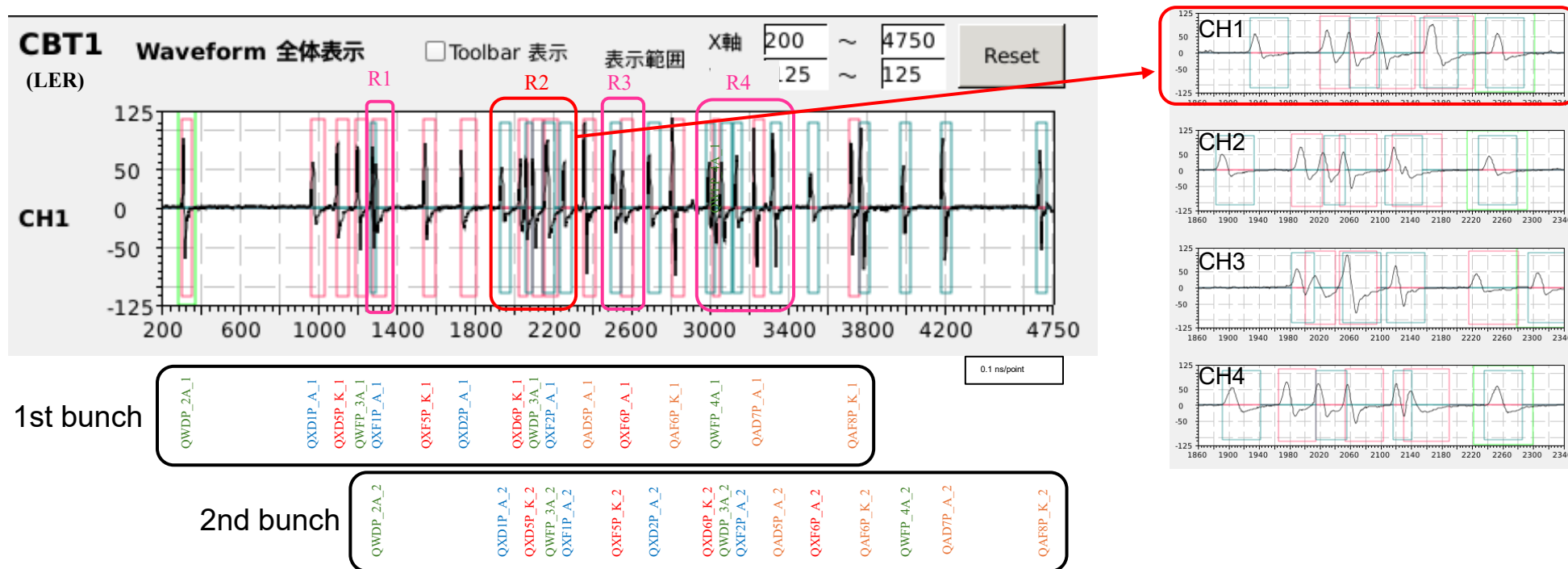
- **Addressing BT BPM Issues and Improving Performance**

Issue1: Abnormal oscilloscope trigger timing in the BT BPM system caused missed beam measurements and timing shifts.



An issue that complicates beam operation and root cause investigation.

- Fewer BPMs provide valid measurements during double-bunch operation.
- Limited BPM availability for orbit feedback.
- Few BPMs can measure both bunches, requiring orbit comparisons using different BPMs for the 1st and 2nd bunches.
- BPM resolution-induced position spread exceeds orbit jitter, making it difficult to identify the underlying problems.



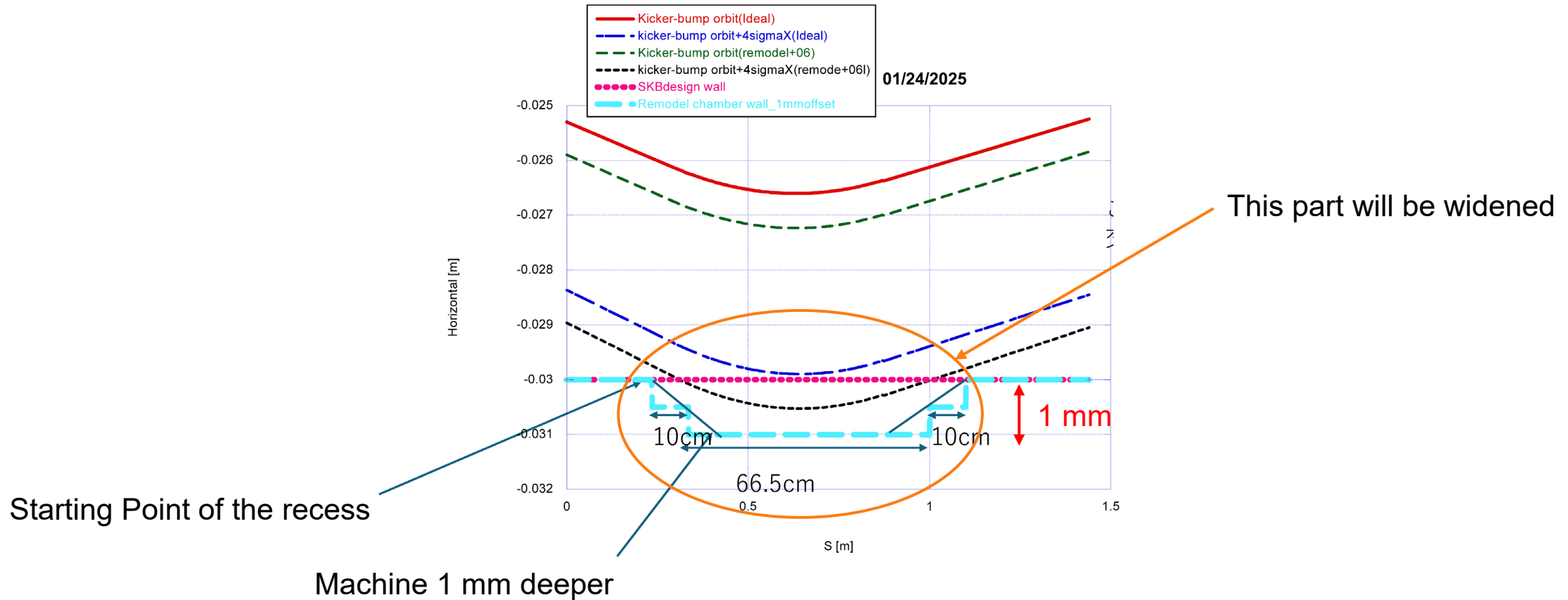
Overlap of the BPM raw signals.

➔Detail will be presented in this afternoon's Control/Monitor session (Ikeda-san's talk).

• LER Injection Point Chamber Upgrade

Enlarge the aperture on the stored beam side of the Q-magnet chamber at the injection point

→ Increase the kicker height to reduce the separation between the injected and stored beam, thereby reducing the amplitude of injection oscillations



An injection-point chamber with an enlarged aperture will be installed in December

Challenges for Luminosity Improvement

◆ Specific Luminosity

- Worse than in 2022 → Investigate the cause (Ground subsidence? Magnet misalignment?)
- Investigate the cause of **the decrease in Specific Luminosity at high beam currents**
- In 2024ab, The beam injection efficiency dropped at $\beta_y=0.8$ → Search for better operating condition?

◆ Beam Lifetime

- Beam-gas Coulomb → Improvement of Vacuum Pressure
- Touschek → Optimization of Dynamic Aperture (Sextupole Optimization)
- Crab waist ratio Optimization

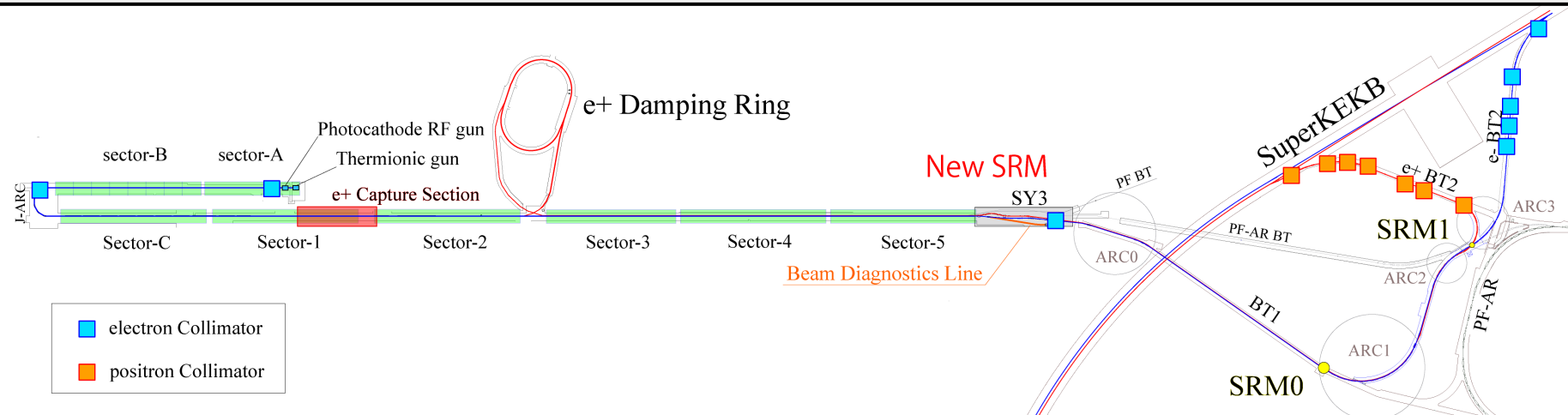
◆ Injection Efficiency / Rate

- Injection beam emittance → Reduction of Initial Emittance (RF-gun?)
Investigation of the Cause of Emittance Blow-up in BT and its Mitigation
- Injection efficiency degradation along the train → Investigation of the Cause (Beam loading?, Tune?)
- Increase in Charge → Attempt to transport a Low-Emittance Beam during the 2026c and 2027a Runs
- Improved Automatic Orbit Feedback Precision Following the BT BPM Upgrade
← In Later Slides and the Control/Monitor Talk (Ikeda-san)
- Improved Emittance Auto Tuning (EAT) with SY3 beam diagnostics line, following the BT BPM Upgrade

◆ Injection Background

High Injection Background → $\left\{ \begin{array}{l} \bullet \text{ Reduce DAQ Efficiency Due to Injection Veto} \\ \bullet \text{ MR Beam Current Limited by Increased Injection and Storage Background} \end{array} \right.$

Objective: Remove beam halo and energy tails using collimators at SY3 and in the BT before injection to Reduce Injection Beam-Loss Background



Why Haven't we used the Collimators? Large orbit drifts previously prevented collimator use.

However, successful orbit feedback now makes collimator operation feasible

Challenges:

- Confirm compliance with internal beam loss and radiation limits.
- Review the limits with the Radiation Science Center if necessary.
- Measure the radiation dose at the injection kicker power supply downstream of the collimators and evaluate the risk of radiation damage.

Planned Measurements

- Radiation levels at critical locations (Radiation Science Center).
- Collimator position vs. beam charge (beam profile scan).
- Long-term beam loss stability.
- Gamma-ray and neutron dose at the kicker power supply.
- Collimator position vs. injection background.

Summary

HER/LER Beam Current

During the 2026ab run, the beam currents reached 1650 mA for the LER and 1300 mA for the HER. Further increases in beam current are planned starting from the 2027a run (see Mitsuka-san's talk).

Challenges:

- Beam lifetime currently limits the achievable beam current.
- To reach a luminosity of $\sim 10^{35}$, it is necessary not only to increase the injection power but also to reduce the beam loss rate.
- Beam loss between successive injections (the difference between the injection efficiency at the 100th turn and that of the next injection) needs to be reduced.
- For SBL, see Uno-san's talk.

Injection Beam Charge

During the 2026ab run, injection beam charges of 2 nC for the HER and 2.6 nC for the LER were achieved. Higher bunch charges are expected through the RF gun upgrade and an increase in the pulse width of the thermionic electron gun.

Beam studies with higher bunch charges will begin in the 2026c run.

Injection Background Mitigation

- We plan to reduce injection background by cutting the energy and emittance tails using collimators in SY3 and the HER/LER BT lines.
- It is necessary to evaluate the constraints imposed by radiation dose limits at KEK and the risk of radiation damage to the kicker power supplies downstream of the collimators.
- Beam studies will begin in the 2026c run.

Injection Beam Emittance, Energy Spread, and Beam Stability

Electron

- Emittance Auto Tuning (EAT) and Automatic Orbit Feedback have enabled stable injection of low-emittance beams.
- Stable injection of the second bunch into the HER has been achieved.
- The gun upgrade is expected to improve the second-bunch quality to a level comparable to that of the first bunch.
- We will further improve EAT and Automatic Orbit Feedback using the SRM at SY3, the upgraded BT BPMs, and the SY3 diagnostic line, aiming to reduce the emittance at the BT end.
- The ECS can now compress the energy spread to the required level. However, the accelerating gradient is lower than the design value, leaving little margin relative to the requirement.
- Higher RF power is expected to become available after addressing the waveguide discharge issue. Beam studies will begin in the 2026c run.

Positron

- Automatic Orbit Feedback has enabled stable beam orbit control from the DR to injection.

Common Challenges

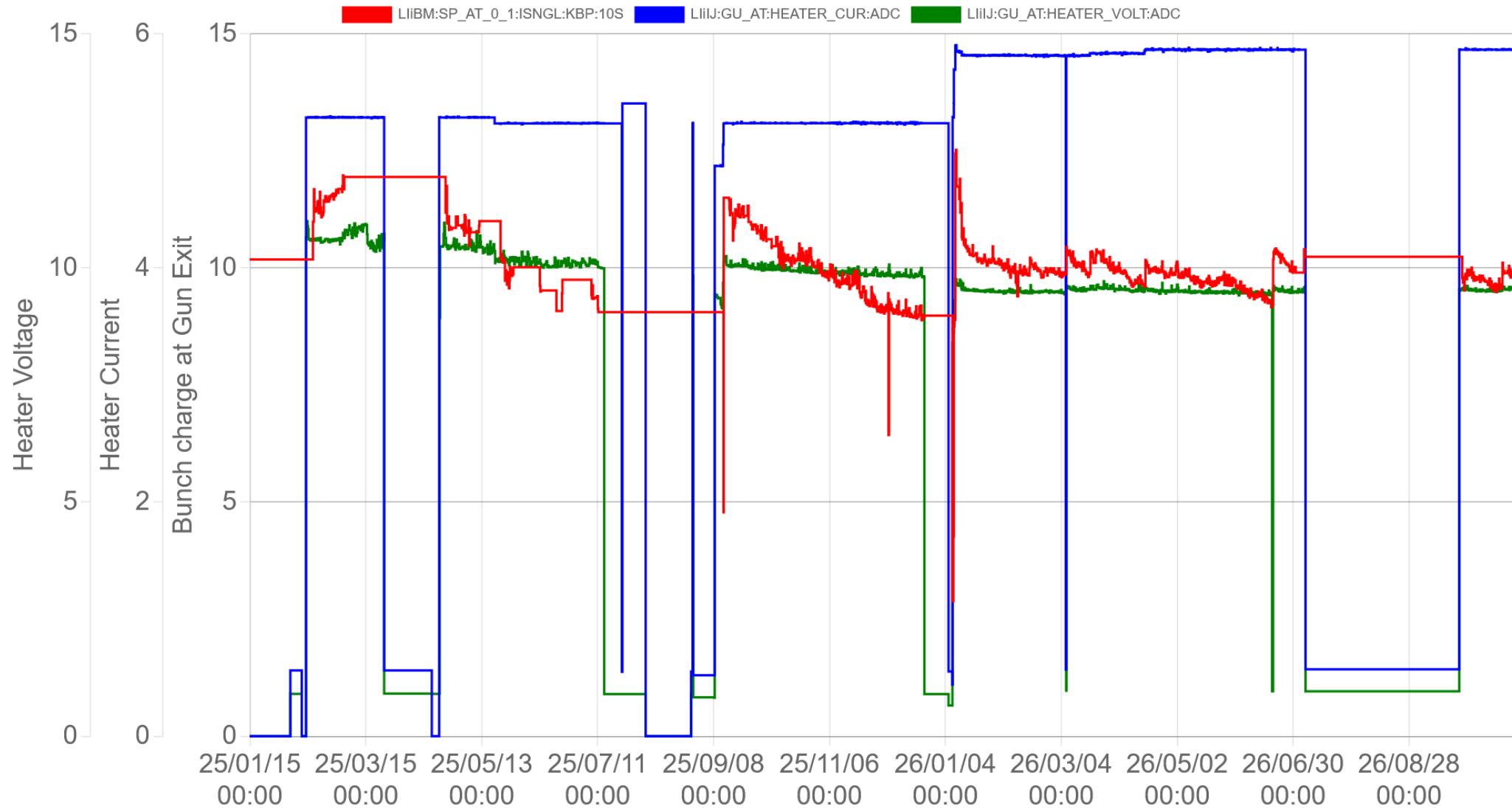
- Emittance blow-up in the BT remains a major bottleneck. Identifying its cause and implementing countermeasures are urgent priorities.
- The upgraded BT BPMs are expected to facilitate further investigation of this issue.

Synchrotron Injection

- Synchrotron injection successfully suppressed injection oscillations, making injection tuning easier.
- Due to limited beam study time, a detailed comparison with betatron injection could not be completed.
- We plan to make the necessary preparations and perform a more detailed comparison in a future beam study.

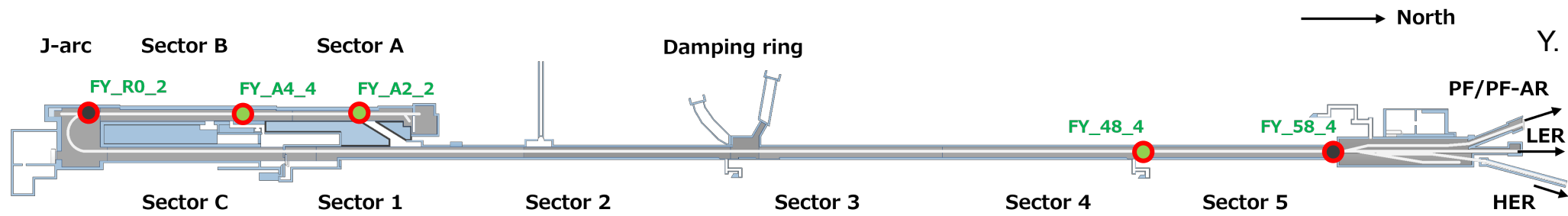
Appendix

Thermionic Gun Heater Current and Bunch Charge



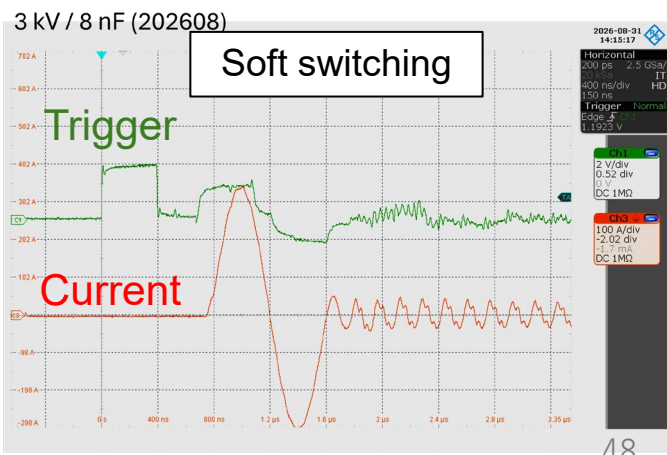
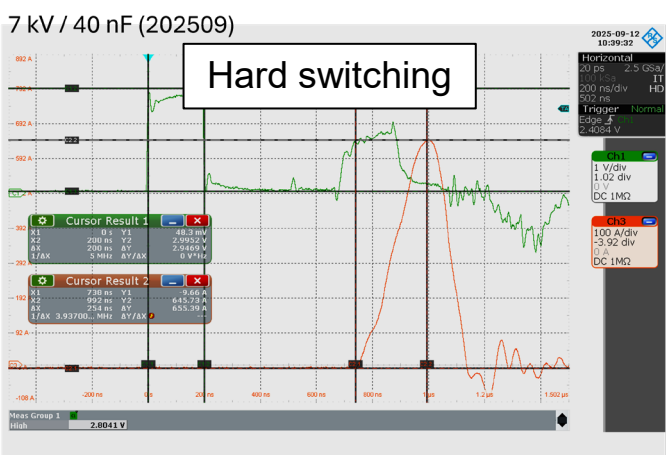
Fast Kicker: Operational use began in the 2026ab run

Y. Okayasu, T. Natsui



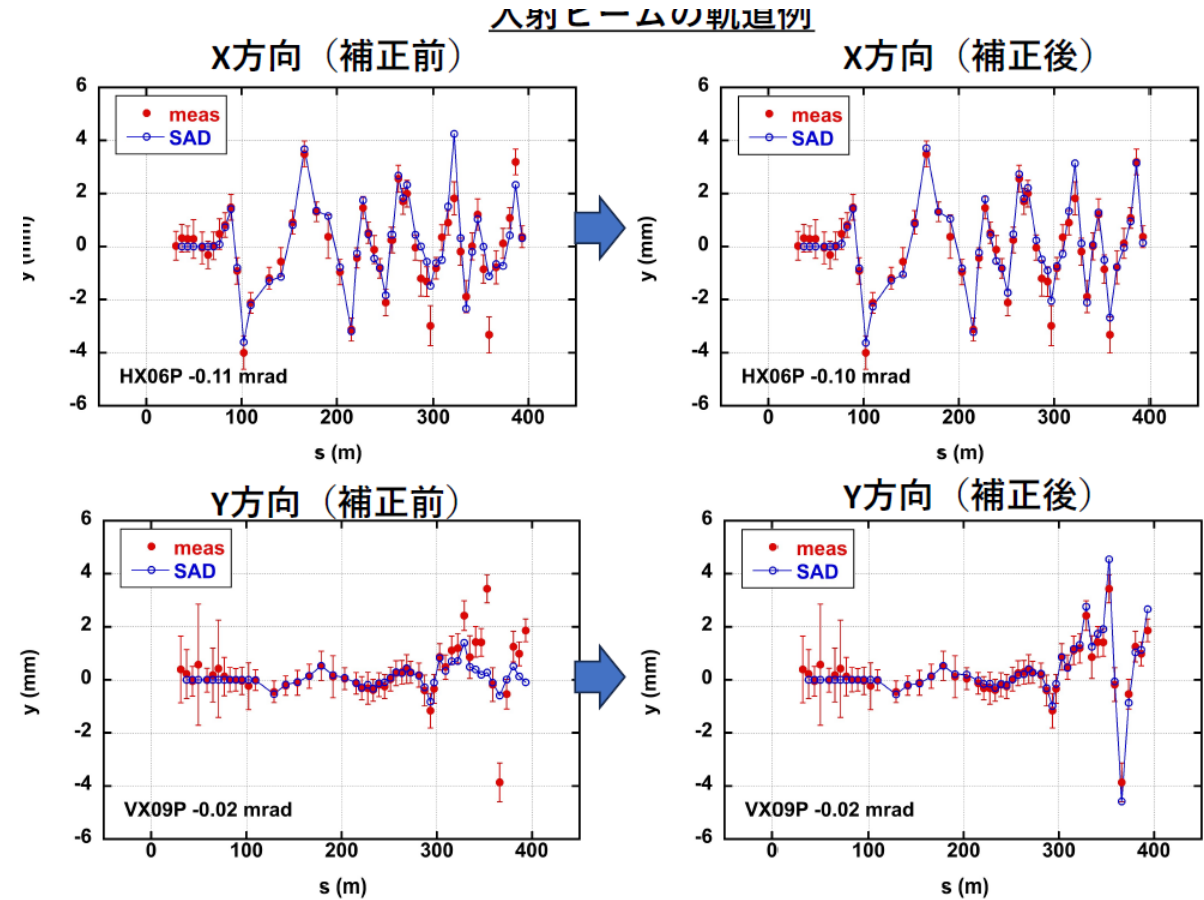
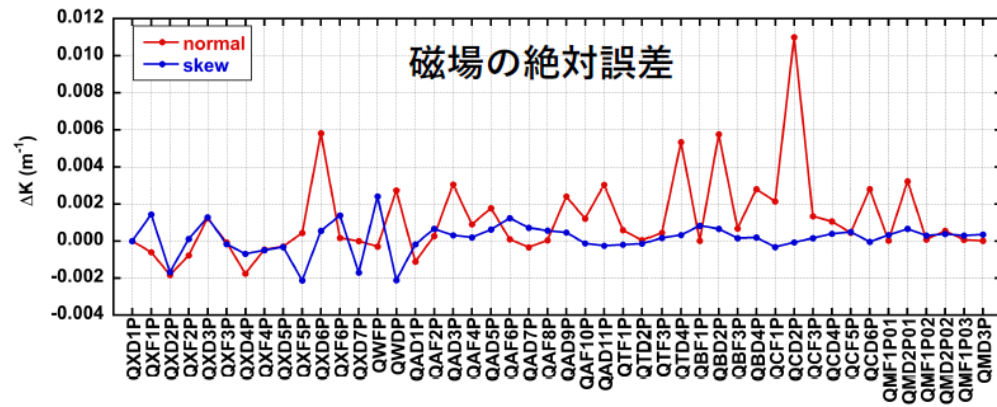
Name	date	Status	Notes
FY_A2_2	2024/8	Operation	Polarity Reversed, Capacitor: 40 μ F $\rightarrow$ 8 μ F
FY_A4_4	2024/8	Operation	Capacitor: 40 μ F $\rightarrow$ 8 μ F
FY_R0_2	2022/8	Shut down	Enhanced shielding is required
FY_48_4	2026/4	Ope. $\rightarrow$ failure	Improving the High-Voltage Withstand Capability of Litz Wire. Capacitor: 40 μ F $\rightarrow$ 8 μ F
FY_58_4	2025/8	Operation	Enhanced shielding is required

- To avoid the risk of damaging the high-speed switching module (¥1.6 million) due to hard switching (high induced voltage), the capacitance was reduced to achieve soft switching. However, soft switching increased the overshoot amplitude, so the introduction of a diode is being considered. In the current configuration, the 1st and 2nd bunches can be kicked in opposite directions, with sufficiently good waveform reproducibility.
- On June 22, 2026, an electrical discharge occurred in the Litz wire of FY_48_4, and the cable was replaced. However, another discharge occurred on July 1, leading to the suspension of operation. The voltage withstand capability of the Litz wire was improved
- Shielding for FY_R0_2 and FY_58_4 is currently being designed using PHITS.



Fast Kicker led to stable injection of the second bunch.

BTP simulation Model and Automatic Orbit Feedback



In the LER, since correcting for field errors still resulted in large discrepancies between simulations and experiments, orbit correction is performed using the measured response matrix.

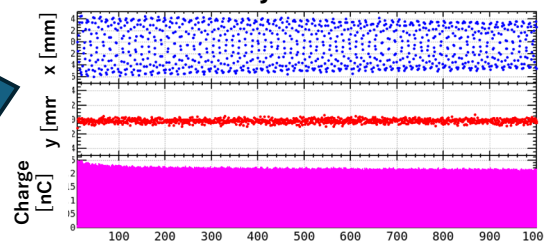
Injection Commissioning

N. Iida

The SI was tested from Nov.6 to 20 in 2025.

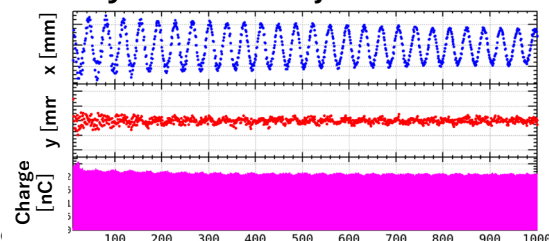
- Measured beam oscillations using TbT-BPMs with the detuned optics

Betatron injection



Number of turns

Synchrotron injection

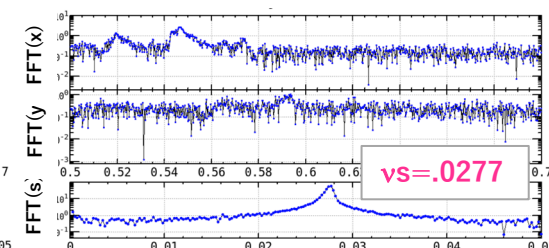


Number of turns

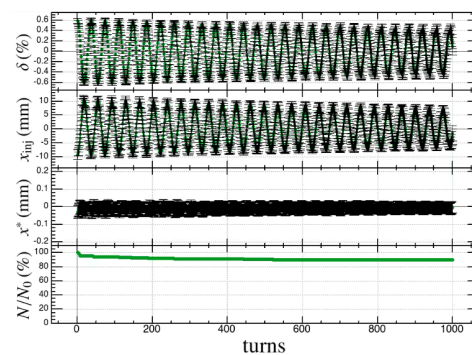
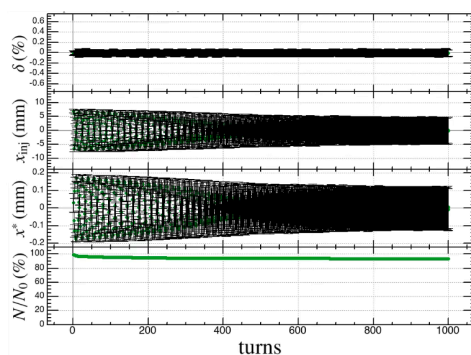
Fractional tune

A peak appears in the frequency spectra at the horizontal tune in BI, while the synchrotron tune in SI. These results indicate **a perfect realization of the synchrotron injection** as the simulation results.

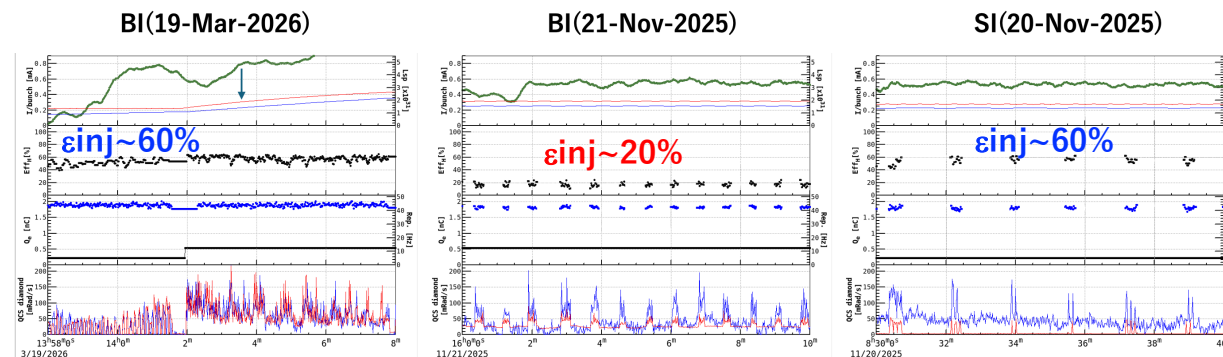
Fractional tune


 $v_s = .0277$

- Simulations ($\beta y^* = 1 \text{ mm}$, w/o collimators, knobs, b-b, and different tune)

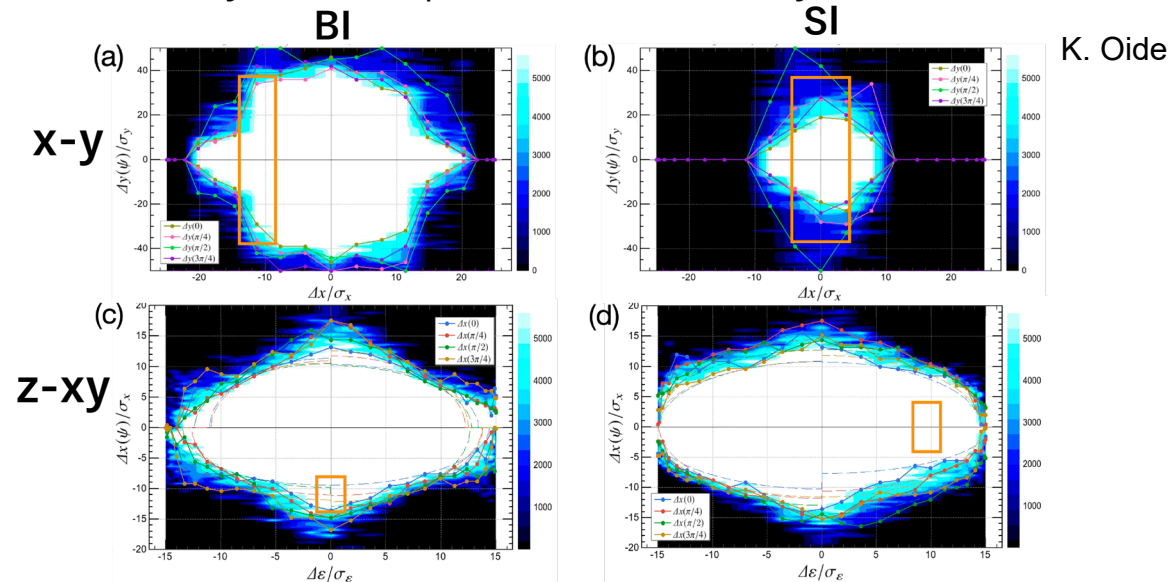


- Comparison of ten-minutes operation with the $\beta y^* = 1 \text{ mm}$ optics



The injection efficiency of SI reached 60% after 7.5hr-tuning, on the other hand, that of BI stayed only 20% after 4 days. However, after retuning of injection in Feb. 2026, 60% was achieved by BI.

Dynamic apertures (DA) by simulations



- (a), (b): The transverse dynamic aperture. **The orange square indicates $\sim \pm 2.5 \sigma$ of the injected beam.** As for SI(b), the tracking starts with an initial momentum offset $\Delta p/p_0 = 0.6 \%$, the perform a synchrotron motion. The amplitude ratio J_y/J_x are set at 1 %.
- (c), (d): The dynamic momentum acceptance are plotted in (c) BI and (d) SI, respectively, where the horizontal axes are the initial momentum offset. **The orange squares show the horizontal size and momentum spread of the injected beams.**
- Possibility of larger off-momentum DA, see Koga-san's talk tomorrow.

Frequency components

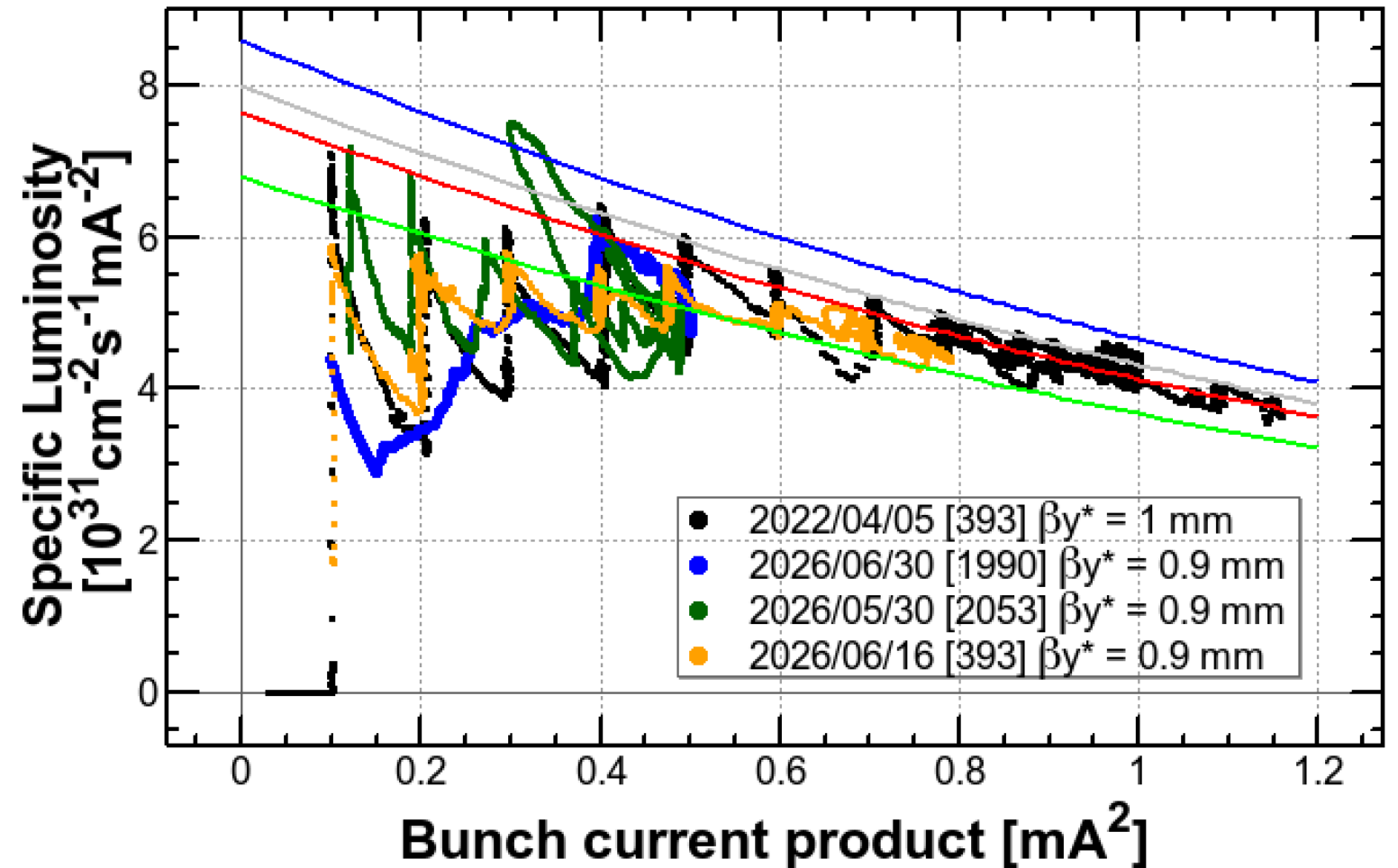
Specific Luminosity

Used to evaluate the required parameters

Y. Funakoshi

Assumption

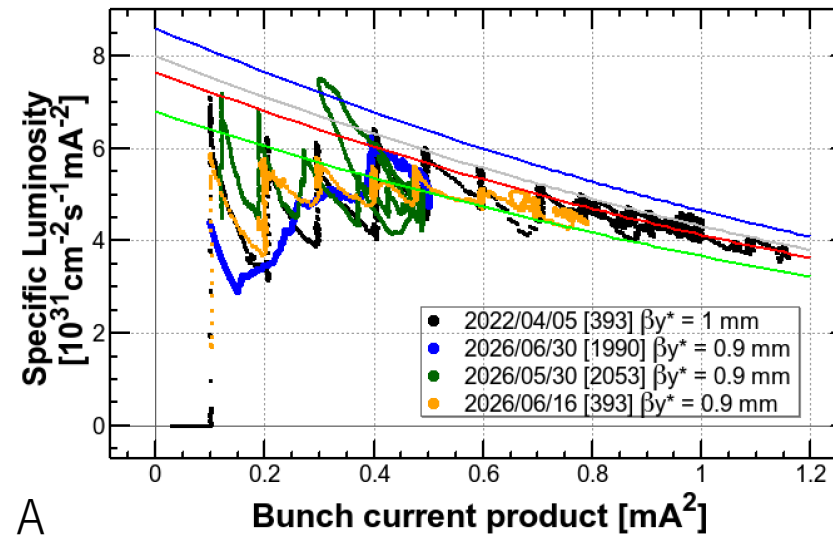
- Specific luminosity@ $\beta y^*=0.9$ mm
HBC study (2026/6/16)
Red line (Case A):
a line tangent to the HBC study data
- Specific luminosity@ $\beta y^*=0.9$ mm
HBC study (2026/6/16) * (1-0.125)
Green line
(12.5% degrade at high beam currents)
- Specific luminosity@ $\beta y^*=0.8$ mm
(Red line * (1 + 0.125))
Blue line (Case B)
- Specific luminosity
Grey line (fit to 2022 data ($\beta y^*=1$ mm))



Luminosity as function of LER Current

Used to evaluate the required parameters

Y. Funakoshi

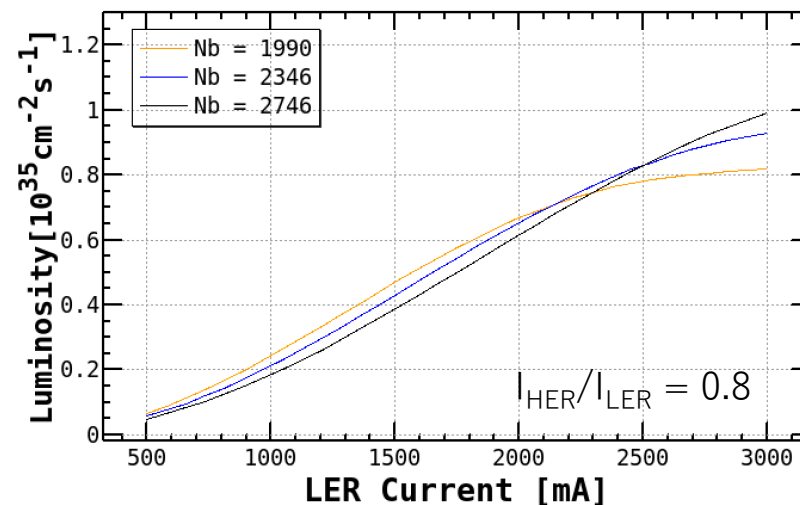


Case A

Case B

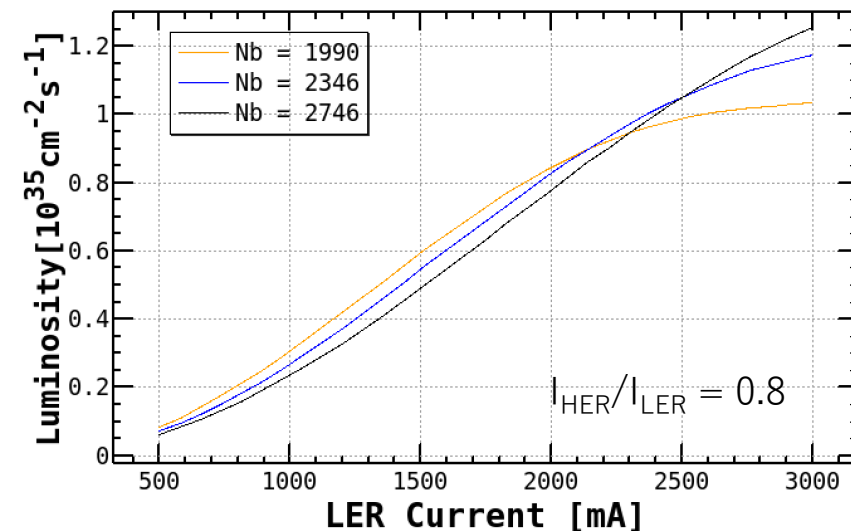
Based on the Maximum Archived
in 2026ab

Specific luminosity: red



$\beta y^* = 0.8$ and 112.5% of Case A

Specific luminosity: blue

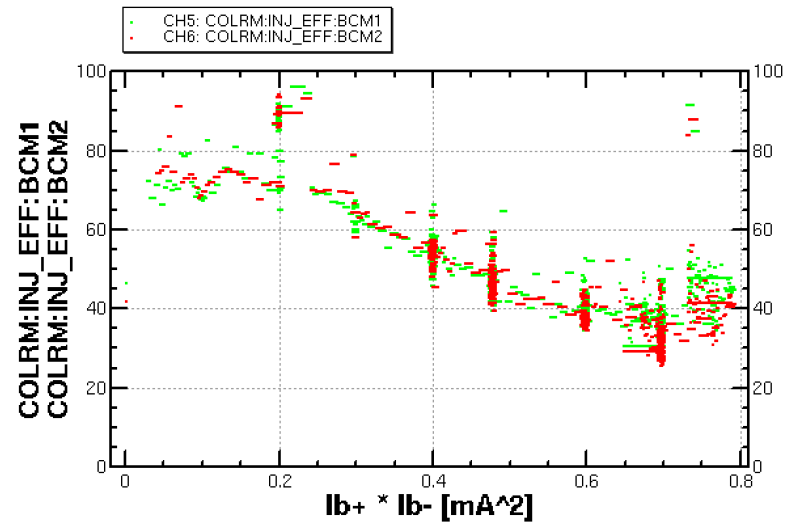


Injection Efficiency model

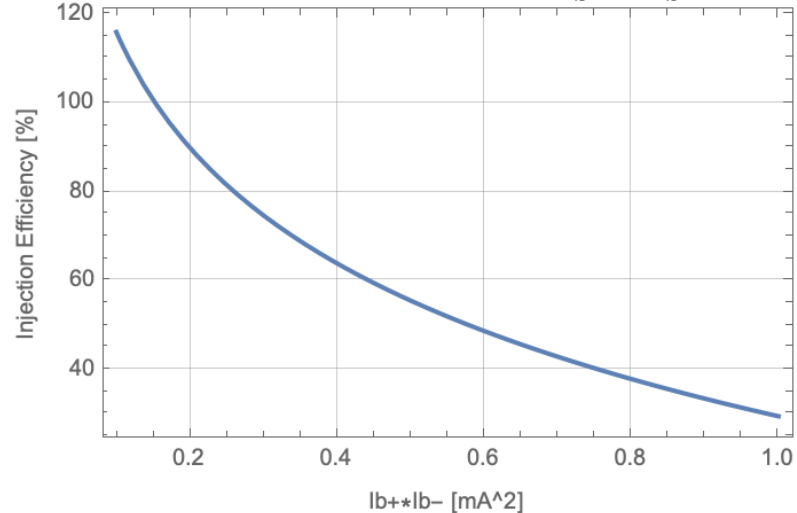
Used to evaluate the required parameters

LER

High beam current collision Study (2026/6/16)

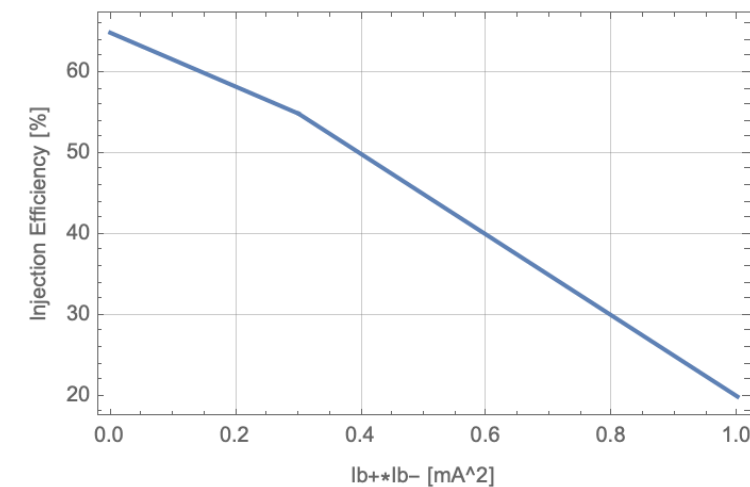
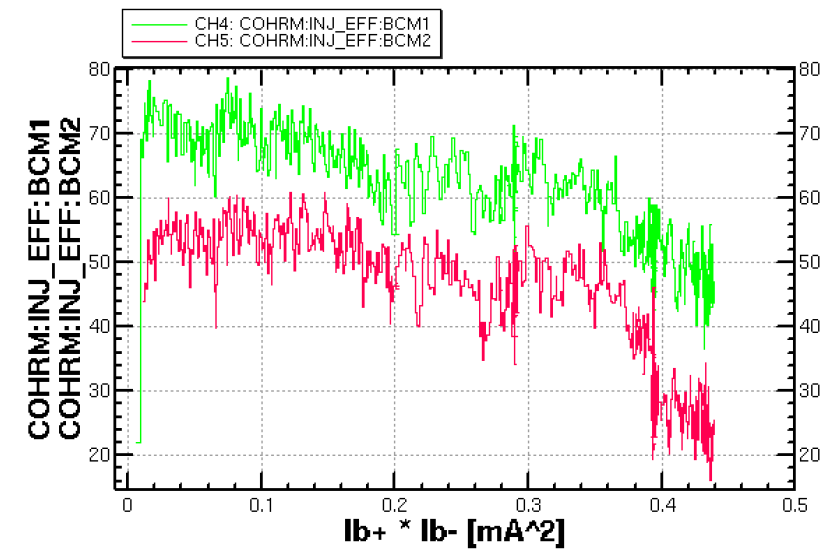


$$InjEff_{LER} = -37.52 * \text{Log}[I_b^+ * I_b^-] + 29.62$$



HER

Y. Funakoshi



Beam Lifetime model (LER)

Used to evaluate the required parameters

Y. Funakoshi

LER: Touschek and vacuum lifetime is considered.

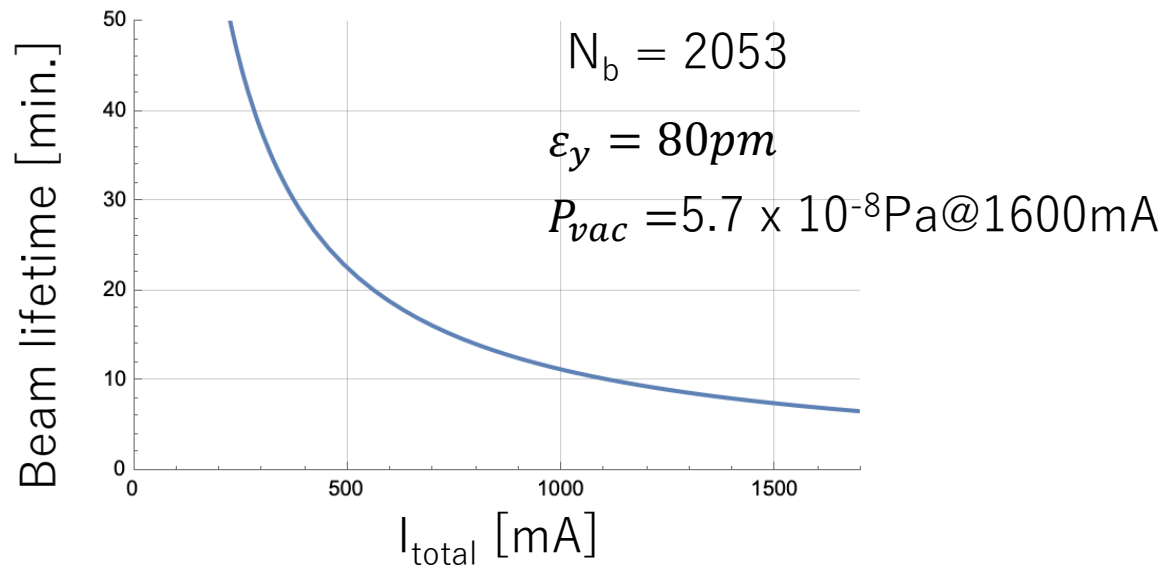
$$\tau_{LER}^{-1} = K_L^T \frac{I_{total}}{N_b} \frac{1}{\sqrt{\varepsilon_x} \cdot \sqrt{\varepsilon_y} \cdot \sigma_z} + K_L^V P_{vac}$$

$$= C_L^T \frac{I_{total}}{N_b} + C_L^V I_{total}$$

$I_{total} = 1600 \text{ mA}$, $N_b = 2249$, $\varepsilon_y = 80 \text{ pm}$, $P_{vac} = 5.7 \times 10^{-8} \text{ Pa}$
 $\rightarrow \tau_{HER} = \sim 7.4 \text{ min.}$ (Touschek: 14.8 min., Vac: 14.8 min.)

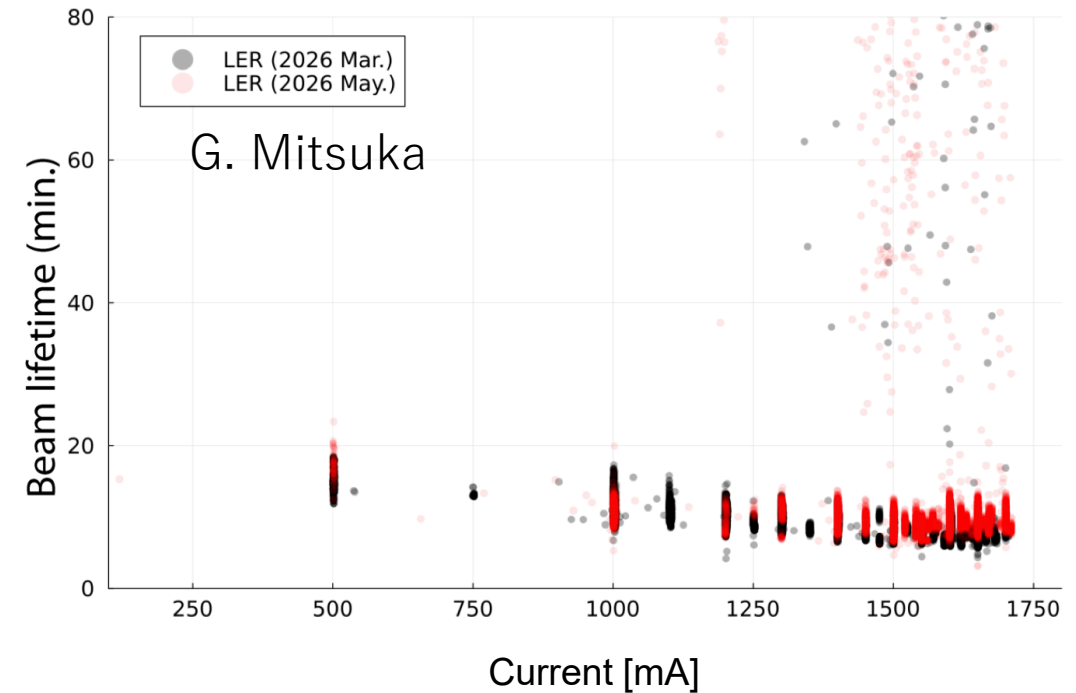


$$C_L^T = 0.0950 [\text{mA}^{-1} \cdot \text{min}^{-1}], C_L^V = 4.223 \text{e-}5 [\text{mA}^{-1} \cdot \text{min}^{-1}]$$



Data during beam collisions

ビーム衝突時 ($I_{LER} * 0.7 < I_{HER} < I_{LER} * 0.85$)



Beam Lifetime model (HER)

Used to evaluate the required parameters

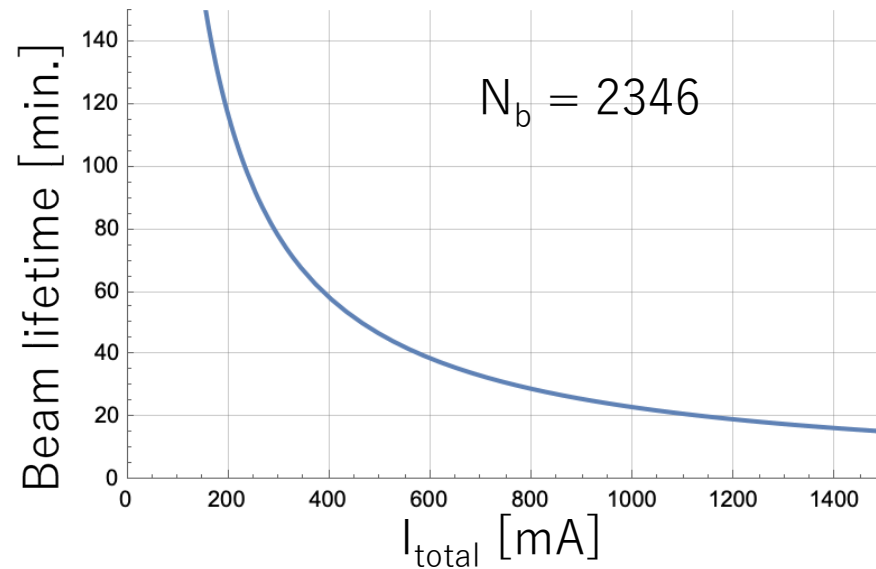
Y. Funakoshi

HER: Touschek lifetime is considered.

$$\tau_{HER}^{-1} = K_H \frac{I_{total}}{N_b} \frac{1}{\sqrt{\varepsilon_x} \cdot \sqrt{\varepsilon_y} \cdot \sigma_z} = C_H \frac{I_{total}}{N_b}$$

$I_{total} = 1300 \text{ mA}$, $N_b = 2346 \rightarrow \tau_{HER} = \sim 18 \text{ min.}$

$C_H = 0.1003 \text{ [mA}^{-1} \cdot \text{min}^{-1}\text{]}, \tau_{HER} \text{ [min]}$



Data during beam collisions

ビーム衝突時 ($I_{LER} * 0.7 < I_{HER} < I_{LER} * 0.85$)

