Explain the strategy for beam lifetime and injection rate at 1e35 referring Injector-CurrentInjectionTF-KEKB-Review2026.pdf | what limits the LER lifetime ?

Strategy Toward a Luminosity of 10^{35}

Develop a strategy to achieve a luminosity of 10^{35} $cm^{-2}s^{-1}$ from three perspectives: **Injection, Lifetime, and Specific Luminosity**.

1. Injection

Increase in Injection Beam Charge and Reduction of Emittance

Electron Beam:

- The initial emittance remains at a similar level up to 4 nC.
- If the injection beam charge can be increased to 4 nC, the injection rate could exceed the HER beam loss rate.
- As a first step, we will establish stable operation at 3 nC.
- To achieve this, emittance growth in the Linac and BT must be suppressed.
- As the beam charge increases, wakefield effects become more significant, requiring more precise orbit control than before.
- Since the energy spread is close to the required limit, we will increase the RF input power to the ECS to achieve further energy compression.
- This will require improved beam position measurement accuracy in the BT and an upgrade of the fast kicker system for second-bunch control.

Positron Beam:

- A significant increase in the emission current from the cathode is not expected.
- We have confirmed that the beam charge can be increased by a factor of 1.4 by widening the grid pulser pulse and extending the pulse width at the electron gun exit.
- However, this causes satellite bunches to form.
- One possible solution is to optimize velocity bunching downstream of the electron gun. However, since the RF input power to the subharmonic buncher is already approximately 95% of its rated value, significant improvement may be difficult under the current conditions.

The following issues associated with increasing the beam charge will be investigated through beam tests in December 2026:

- Can the higher-bunch-charge beam be injected into the DR with the same efficiency as before?
- Are beam losses in the LTR (Linac-to-DR Beam Transport Line) and DR within acceptable limits?
- Will emittance growth from the DR to the LER increase?

Common Challenges for Electron and Positron Beams:

- Suppress emittance blowup in the BT.
- Utilize BT collimators to reduce injection backgrounds.

Starting in December 2026, beam transport and injection tests with increased bunch charge will be conducted for both electron and positron beams. These tests will focus on identifying problems and improving beam quality and injection efficiency.

Injection

Long-Term Improvement Plans

- New electron beamline (utilizing the existing AR injection beamline)
- Implementation of synchrotron injection into the LER

2. Lifetime

LER:

- Coulomb scattering losses become dominant at high beam currents.
- At 1600 mA, Coulomb scattering is estimated to account for more than 60% of the total beam loss.
- The Coulomb scattering loss estimated from the measured average vacuum pressure is inconsistent with the measured 2Jx, suggesting that residual gas in the interaction region (IR) may be a major cause of the reduced beam lifetime.
- Residual gas in the IR also has a significant impact on beam backgrounds.

HER:

- The dominant cause of the beam lifetime reduction has not yet been clearly identified.
- Further investigations will be conducted to identify the main cause.

Countermeasures

Reaching 1×10^{35} $cm^{-2}s^{-1}$ requires a longer lifetime.
Lowering the IR pressure is very likely to extend the lifetime.
The IR pressure will not improve quickly, so raising the current means steadily working on many small items: improving the vacuum in the RF sections (not yet considered), opening the collimator half-gaps, improving injection with

3. Specific Luminosity

Achieving *by = 0.8 mm** is a necessary condition.
We will investigate the causes of the following known issues and implement countermeasures.

Known Issues

- Injection efficiency decreases when by* is reduced to 0.8 mm.
- The specific luminosity at βy* = 0.9 mm in the 2025ab run was lower than that at βy* = 1.0 mm in the 2022 run (Current/Injection Appendix, p. 51).
- Specific luminosity decreases at high bunch currents.

Countermeasures

1. Improve Injection Beam Quality

- Increase the injection beam charge and reduce the emittance.

2. Optimize Ring Optics and Collimation

- Optimize sextupole settings.
- Optimize ring collimator settings.
- Reduce injection backgrounds using BT collimators, allowing the ring collimator settings to be relaxed.

3. Evaluate the Effects of Ground Subsidence and Magnet Misalignment

- Evaluate and validate the effects of ground subsidence and magnet misalignment using simulations and experimental data.

4. Improve the LER Injection Point Chamber

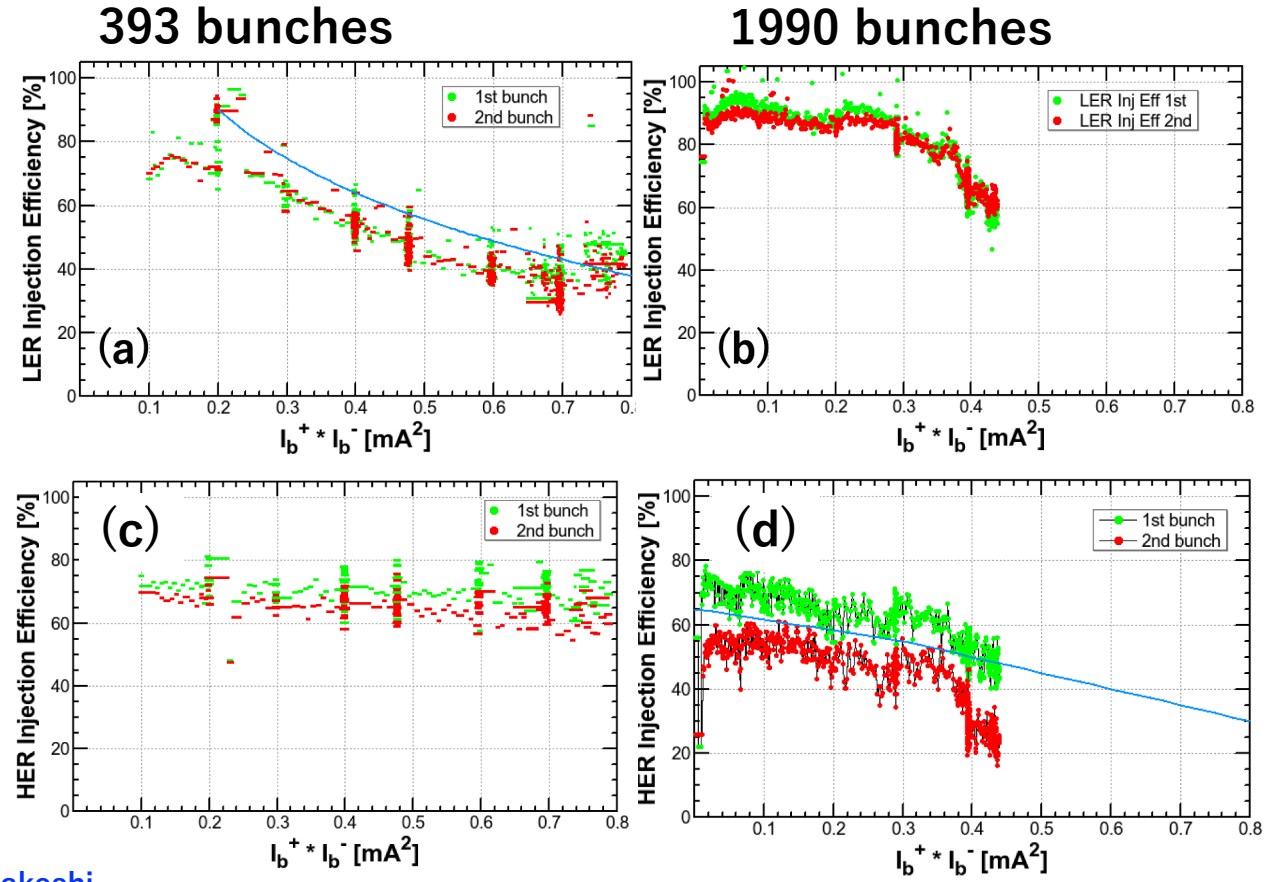
- Install the upgraded LER injection point chamber, scheduled for December 2026.

Appendix

Collision

LER

HER

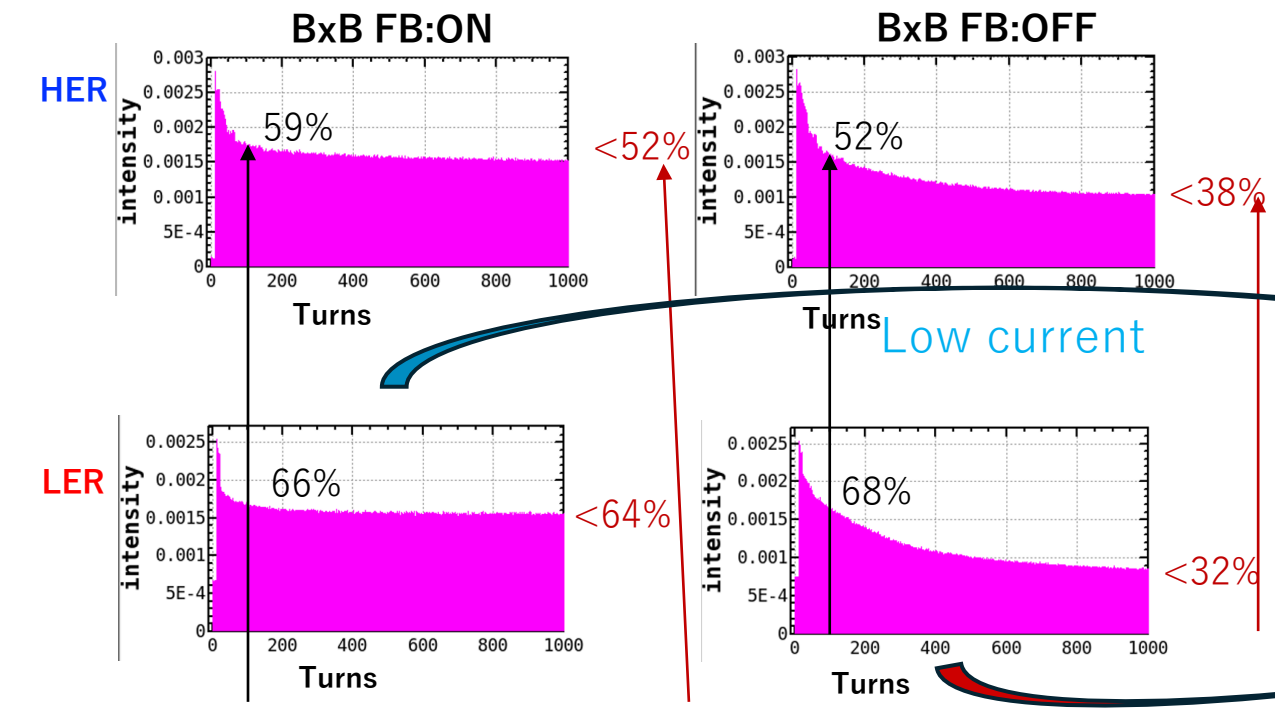


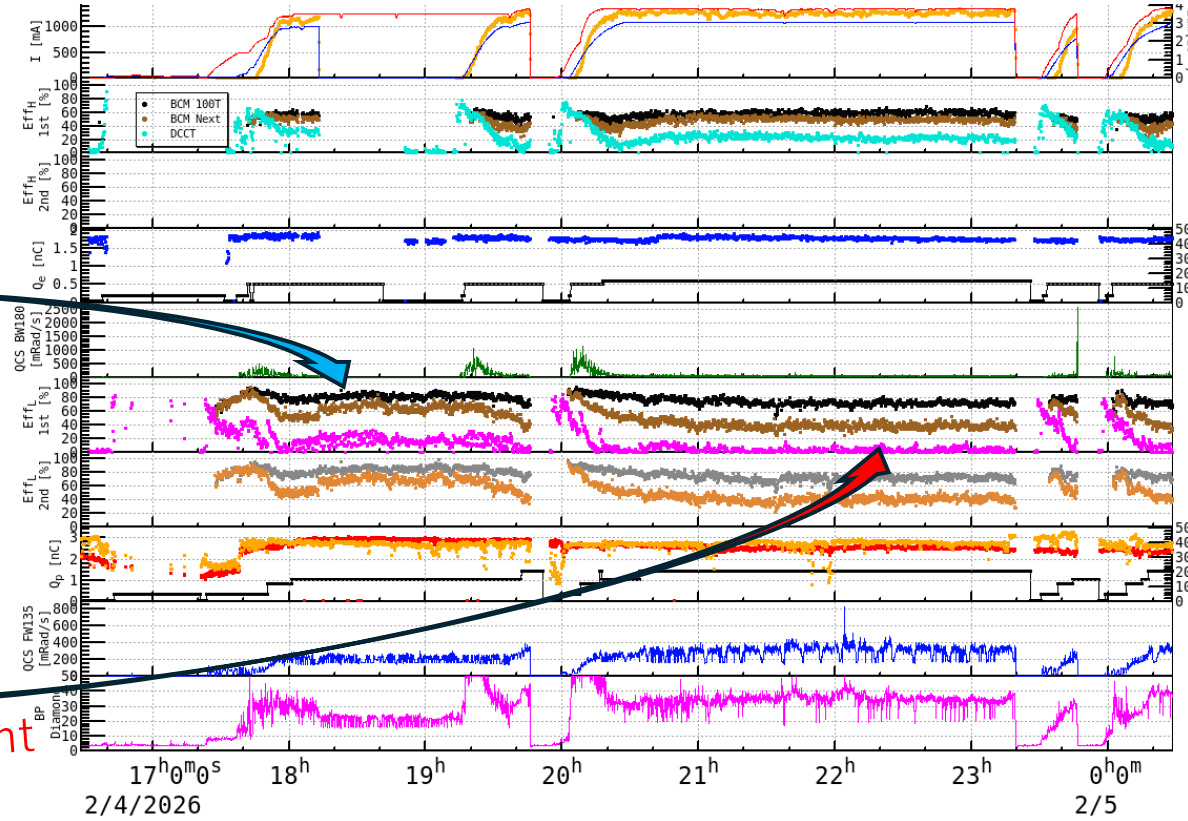
Y. Funakoshi

- The reason why injection efficiency decreases at high bunch currents, mainly in LER(a), is because the BxB FB (Bunhc by bunch Feedback) (next page) becomes less effective with respect to the injection beam.
  - P. 5-2.
- The reason why injection efficiency decreases in (b) and (d) at the high total current is unknown and needs to be investigated.
- For (d), one possible explanation is the tracking ability of feedback to tune changes due to the resistive wall.

N. Iida *et al.*, "RECENT INJECTION STATUS AT SuperKEKB", PASJ2026, Sendai, Japan, Aug. 2026, THP006

Injection efficiencies

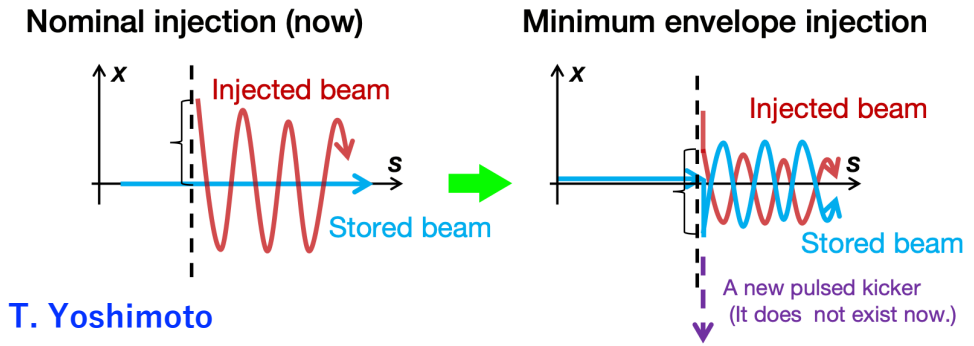




A) The injection efficiency in the first approximately 100T is easily affected by the effects of the injection beam (injection adjustment, injection beam emittance, etc.).
B) From 1000T onwards, it is mainly affected by the effects of the ring (tuning, beam-beam).

Injection beam

1. Emittance blowup investigation
   - Mis-alignment of the BT and non-linear magnetic fields of the dipoles and quads should be included in the tracking simulation(by Mori-san)
   - In a beam study, we will correlate the RF phase of the ECS accelerating tube, the acceleration phase of Linac, and the measured emittance. (Scheduled for December 2026)
2. Injection oscillation reduction
   - The chamber at the LER injection point will be modified.
   - Future plan: smaller injection oscillation plan has not yet been explored in detail.
     - https://www-kekb.kek.jp/MAC/2025/Report/Yoshimoto.pdf



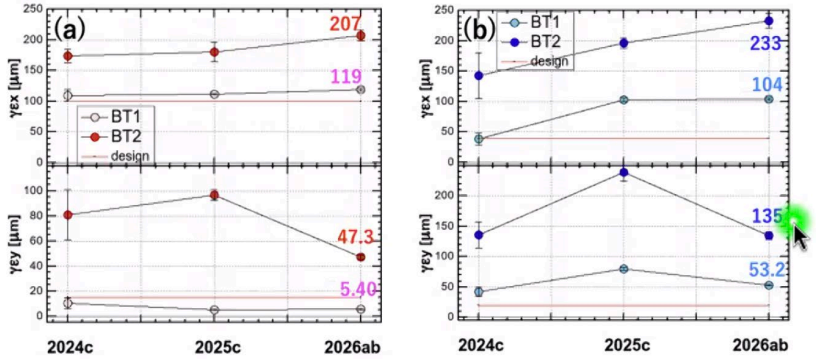


Figure 4: Average emittances for the 2024c, 2025c, and 2026ab operations: (a) e^+ and (b) e^-. Upper and lower plots show the horizontal and vertical emittances at BT1 and BT2, respectively. Red lines indicate the ring design values. The bunch charge was 3 nC for e^+ and 2 nC for e^-.

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

	CSI	Injected beam		Ring acc.
HER	$2J_x$ [μm]	1.01	<	1.4
	$2J_y$ [μm]	0.059 ($6\varepsilon_y$)	≫	0.038
LER	$2J_x$ [μm]	1.48	≫	1.15
	$2J_y$ [μm]	0.036 ($6\varepsilon_y$)	<	0.044

- For e-, the vertical emittanceis critical.
- For e+, both of the horizontal injection oscillation and the horizontal emittance are critical.

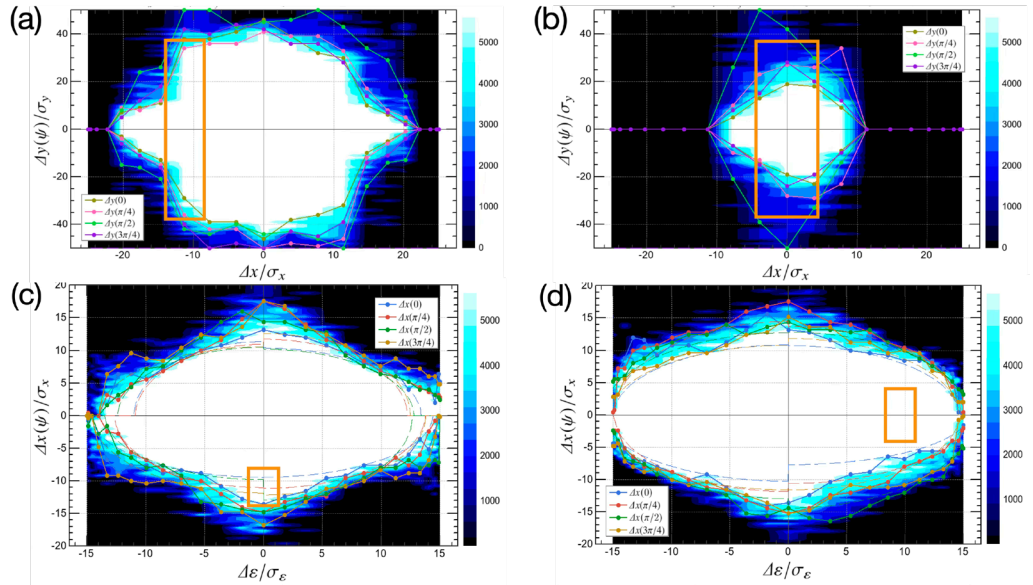
Dynamic Aperture optimization with sextupoles by Simulations

□ : Injected beam

BI SI

x-y

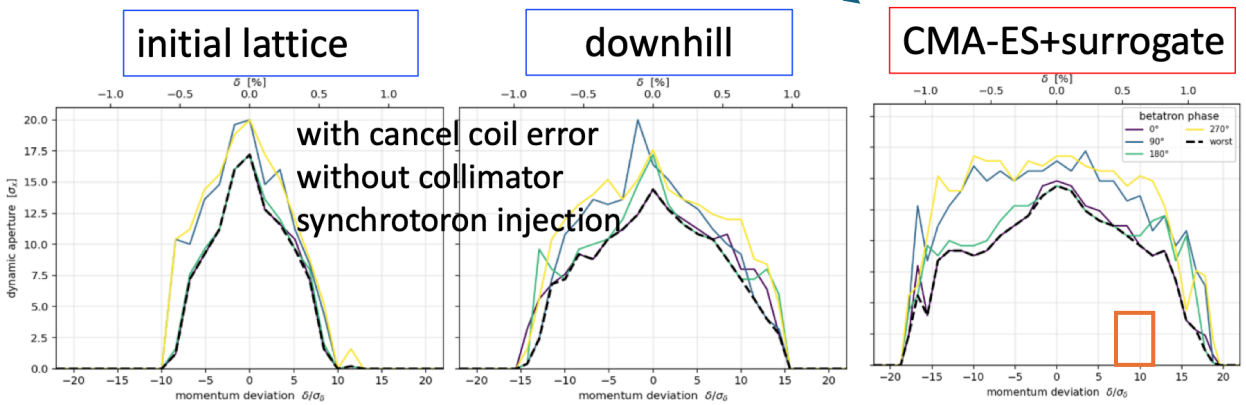
z-xy



K. Oide

- (a), (b): The transverse dynamic aperture. **The orange square indicates ~ ±2.5 σ of the injected beam**. As for SI(b), the tracking starts with an initial momentum offset Δp/p0 = 0.6 %, and perform a synchrotron motion.
- (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.**
  - In both BI and SI cases, the injection efficiency is not 100%, due to the large vertical emittance of the injected particles.

The DA could be the wider another optimization such as CMA-ES by T. Koga.
(Taskforce report: AI/ML)



- **The wider DA optimization is expected to have the following two effects:**
  - **Increased ring beam lifetime**
  - **Reduced injection particle loss (particularly beneficial in SI in sextupole optimization)**

Tune dependence of the injection efficiency

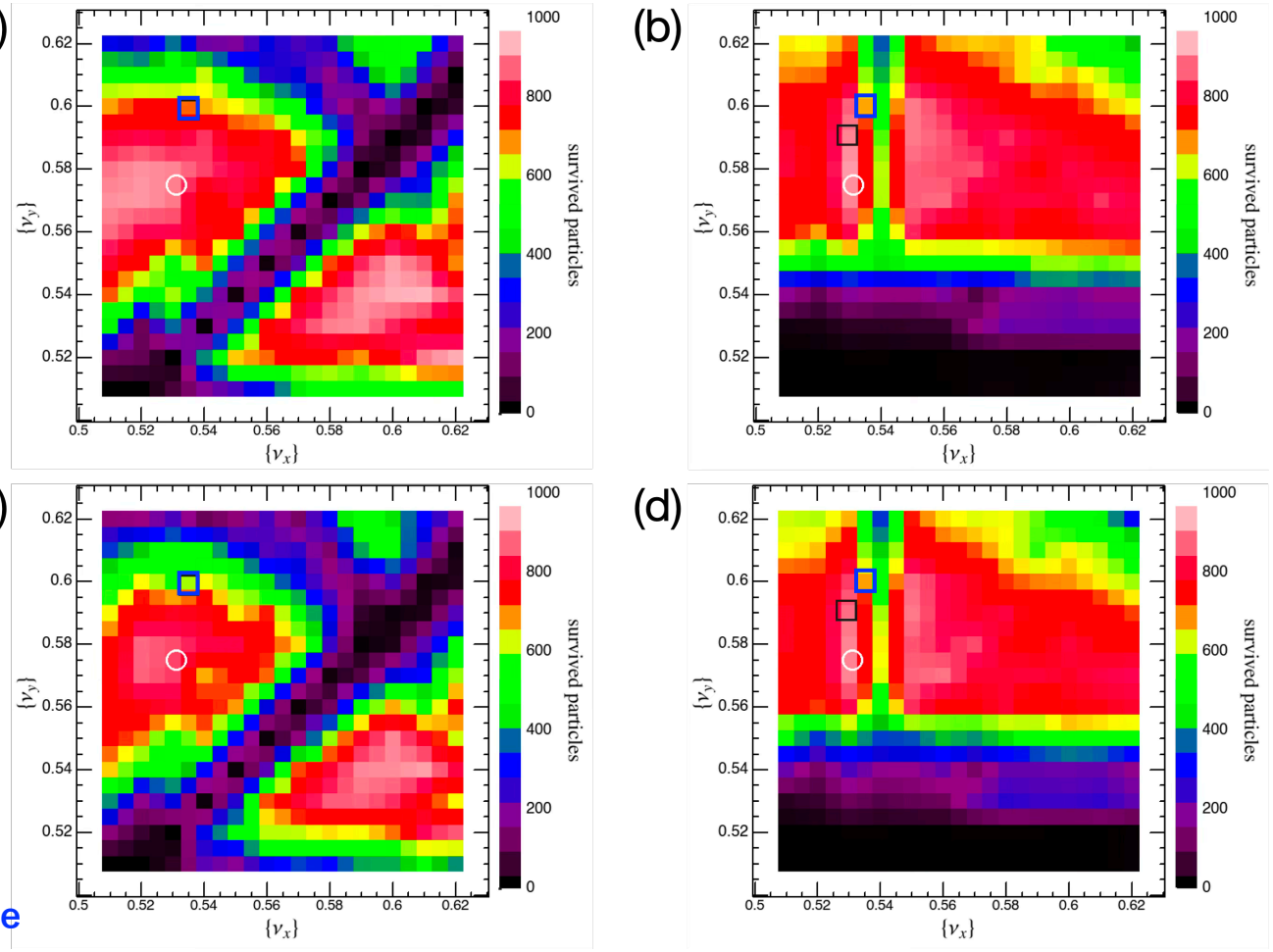
BI

○ : DA optimized point
□ : Operating point in 2026

SI

w/o
beam-beam,
collimators,
knobs,
tune

w
beam-beam,
collimators,
knobs,
tune(ope.)



- **The tune points for sextupole optimization are currently different from the luminosity maximum.**
- **But optimizing at high luminosity points may yield good tuning for both injection and luminosity.**

K. Oide

Future

- New BT line for e- beam
  - Next page
- The synchrotron injection for LER
  - Unlike HER, LER requires significant hardware modifications.
  - Moving the ARES in the injection point region is essential, requiring major modifications.

Future: New BT line utilizing existing the AR/BT tunnel

N. Iida

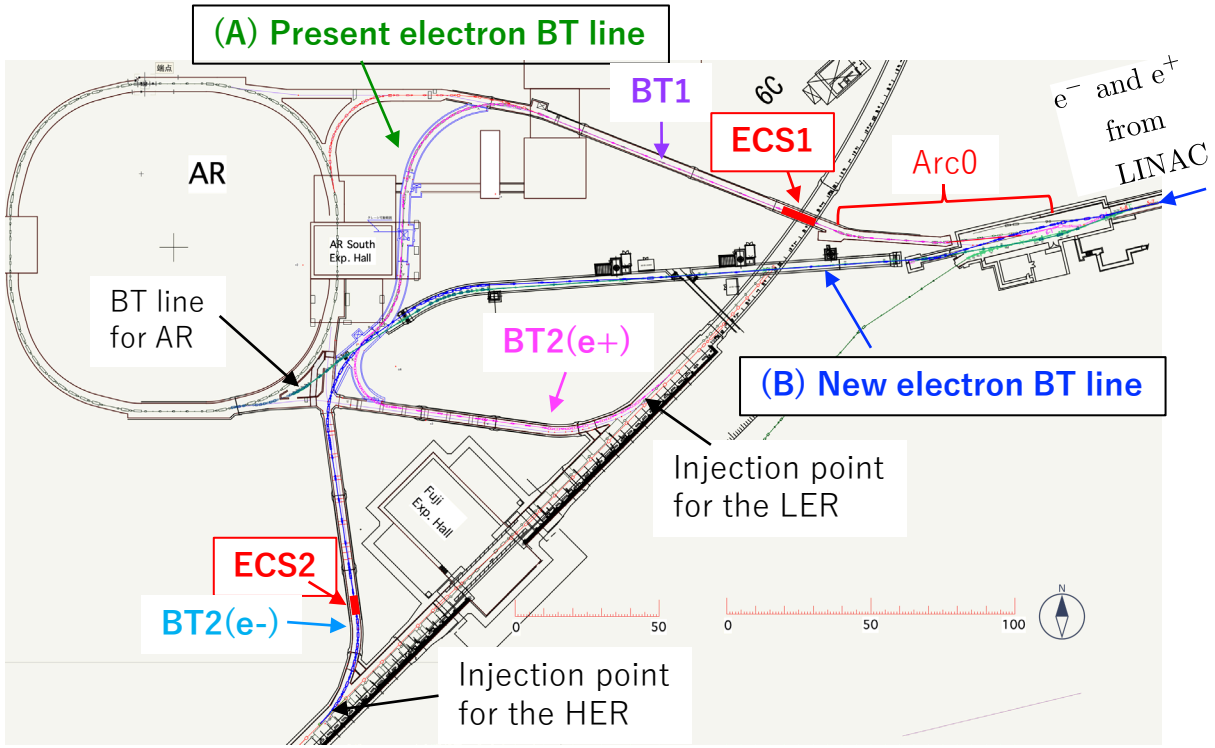
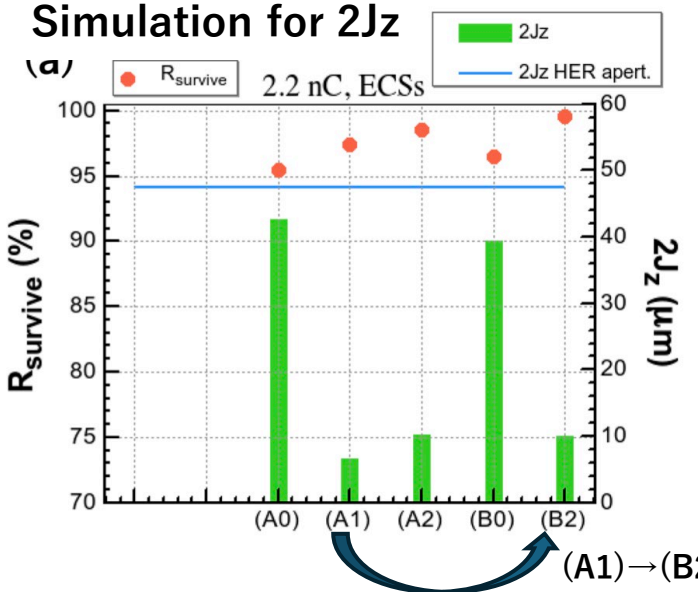


Table 1

	(A)	(B)
total angle [rad]	5.92	3.55
radius of curvature [m]min.	16.4	17.6
radius of curvature [m] av.	23.9	25.3
Magnetic field [T] av.	1.00	0.95
# of dipoles	68	45
# of quads	62	52
# of steering	45	34
# of Acc. tube	4	2

Simulation for 2Jz



Simulation for γεx and γεy

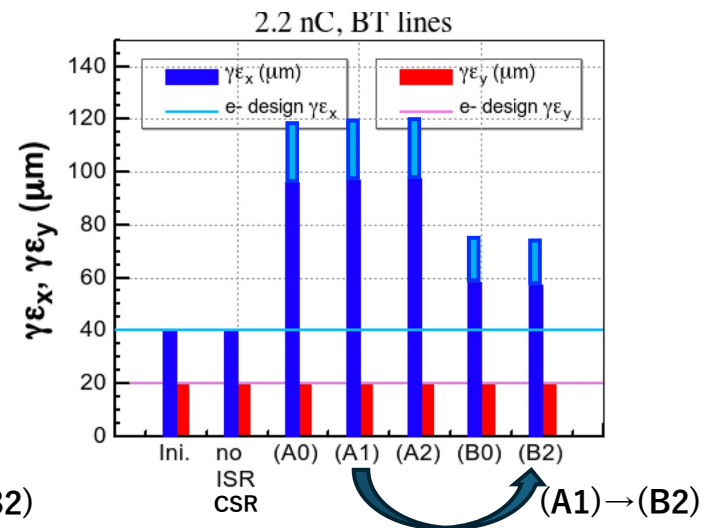


Table 2: The ECS Parameters in the BT Lines

	BT line	ECS	R_{56} [m]	V_c^{Total} [MV]
(A0)	Present	—	-0.11(Arc0)	—
(A1)	Present	"ECS1"	-1.0(Arc0)	72
(A2)	Present	"ECS2"	-4.3	34
(B0)	New	—	—	—
(B2)	New	"ECS2"	-1.6	70