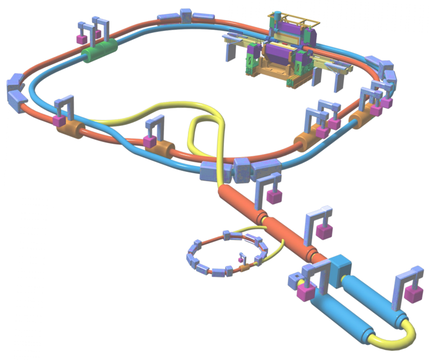
MOPM045

A Numerical Study on Injection Efficiency Improvement at SuperKEKB Electron Ring



T. Yoshimoto†, N. Iida, T. Mori, M. Kikuchi, Y. Onishi, Y. Funakoshi,
High Energy Accelerator Research Organization (KEK), 3050801 Tsukuba, Japan

† yoshimo@post.kek.jp

SuperKEKB is an asymmetric lepton collider with 7-GeV electron and 4-GeV positron beams. In Run 2024, the vertical beta function β_y^* at the collision point was set to approximately 1 mm. The measured results confirmed that reducing β_y^* led to narrower dynamic apertures in the horizontal and vertical directions and decreased the beam injection efficiency into the ring. This study describes a potential mitigation scheme of aperture sharing injection to improve the electron injection efficiency and achieve higher beam luminosity.

Dynamic Apertures

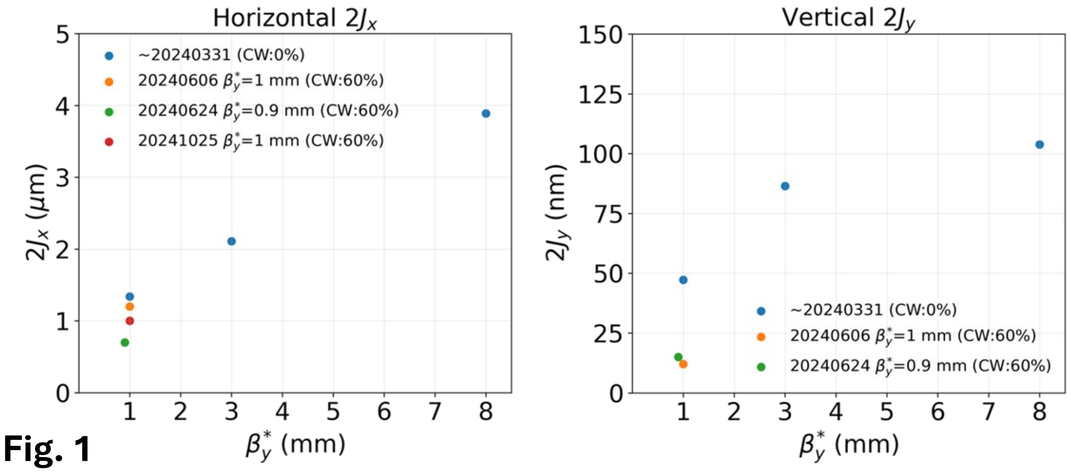


Fig. 1

The shrinkage of both the horizontal and vertical dynamic apertures, as illustrated in Fig. 1, is one of the unfavorable effects of the low-beta optics scheme. The data were measured using Turn-by-Turn Beam Position Monitors (TbT-BPM) and dipole kickers in the operational collimator setting. The transverse dynamic apertures shrank rapidly as β_y^* decreased. Lower β_y^* optics require a larger $\beta_{x/y}^*$ at the superconducting quadrupole magnets near the IP because the lower β_x^* is correspondingly reduced. Hence, the HER injection efficiency drops were observed as β_y^* decreased, although this varied with the HER collimator setting.

Injection Overview

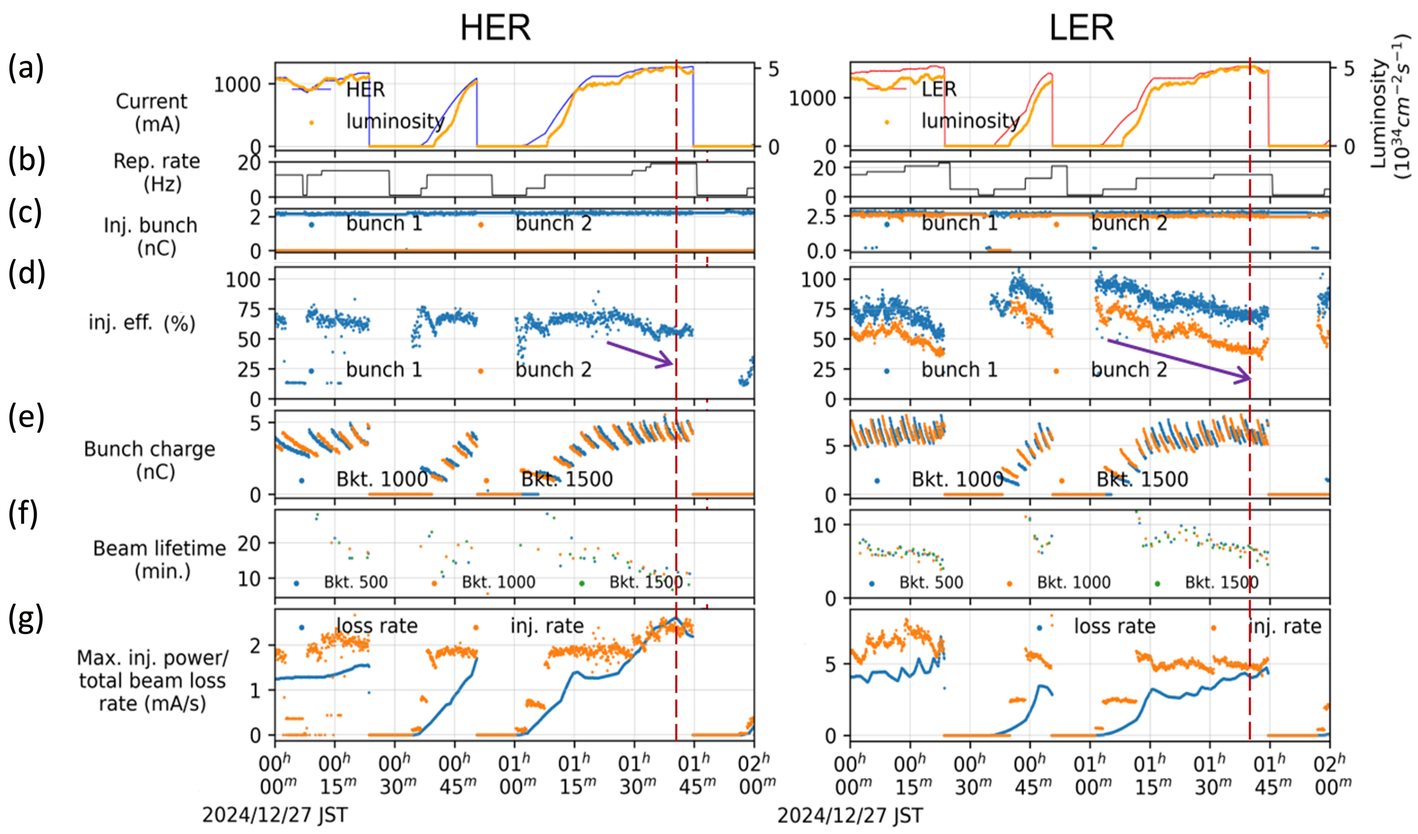
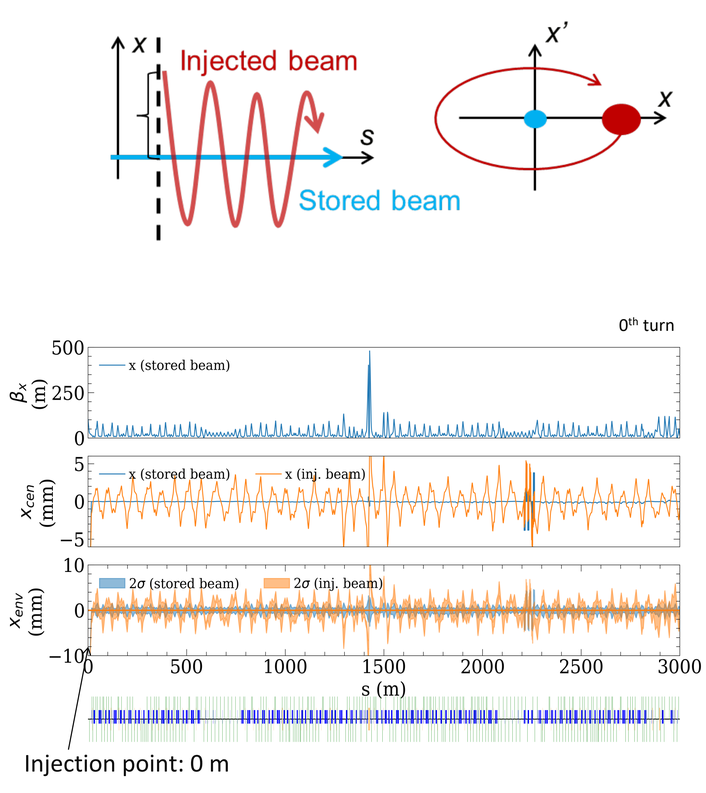


Fig. 2

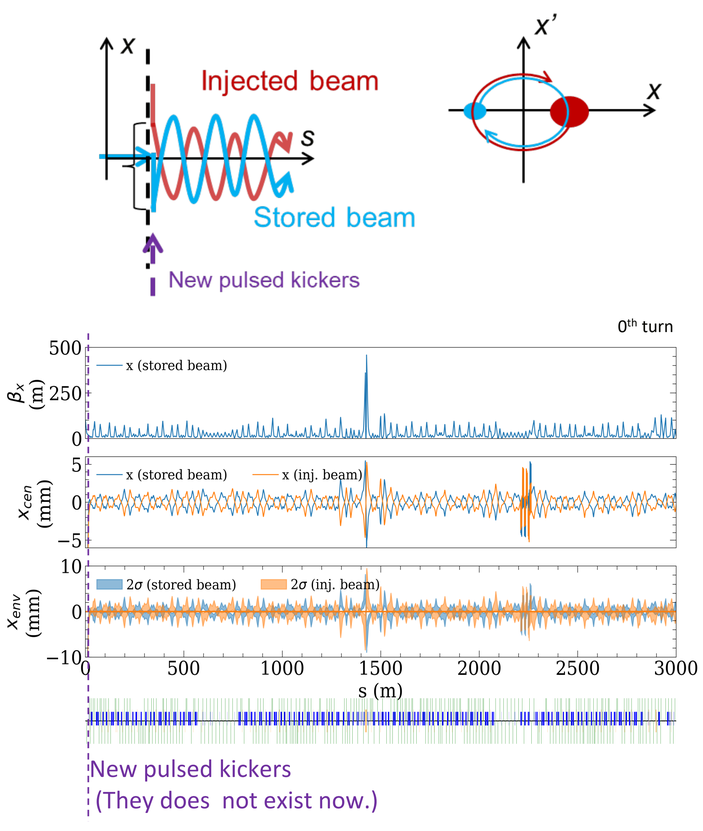
- The injection efficiencies are affected by beam collisions at the IP owing to the beam-beam kick.
- The HER injection efficiency decreased as the HER storage current exceeded approximately 1 A, whereas the LER injection efficiency decreased as the LER storage current increased [Fig. 2(d)].
- beam lifetimes [Fig. 2(f)] decreased as the stored bunch currents [Fig. 2(e)] increased, in addition to an increase in ring vacuum pressures (not shown in the figure), owing to the Touschek effect and residual gas scattering.
- Consequently, the injection power and beam loss rates were balanced at peak luminosity [Fig. 2(g)] in both rings.
- The HER and LER injection performances for high-luminosity operations require further improvement.
- For HER, stable double-bunch injection is useful.

Comparison of Injection Schemes

Betatron Injection



Aperture Sharing (AS) Injection



Aperture Sharing Injection:
The stored and injected beams exhibits nearly the same oscillation amplitude after the injection.

Required developments

- **Two new fast pulsed kickers** (~100 ns)
  - They are placed after the main injection kickers.
  - They nullify the intermediate trajectory between the horizontal orbits of the injected and stored beams.
- **A sophisticated bunch-by-bunch (B-by-B) orbit feedback (FB) system**.
  - It must be configured to turn off for the injected buckets and turn on for all others until the next injection.

Simulation results (SAD)

- The horizontal emittances of the injected and stored beams were 10.9 nm and 4.45 nm.
- Collimators : completely open

Table 1: Comparison of the horizontal actions $2J_x$ (μm)

Injection scheme	Stored beam	Injected beam	Stored and injected beams
Betatron	0.022	0.47	0.47
AS	0.14	0.20	0.20

Summary

These simulation results demonstrated the advantages of AS injection over betatron injection for the SuperKEKB. A technical feasibility study on the fast kickers, sophisticated TbT feedback system, beam instabilities, and emittance degradation of the non-injected adjacent bunches is planned to be conducted in the future.