SuperKEKB Status and Run 2025 - 2026

G. Mitsuka, Y. Ohnishi, K. Shibata, T. Ishibashi, K. Uno, S. Uno,
F. Miyahara, T. Okada, H. Sugimoto, R Ueki (KEK)

Machine Parameters of SuperKEKB

Step-by-Step Improvement

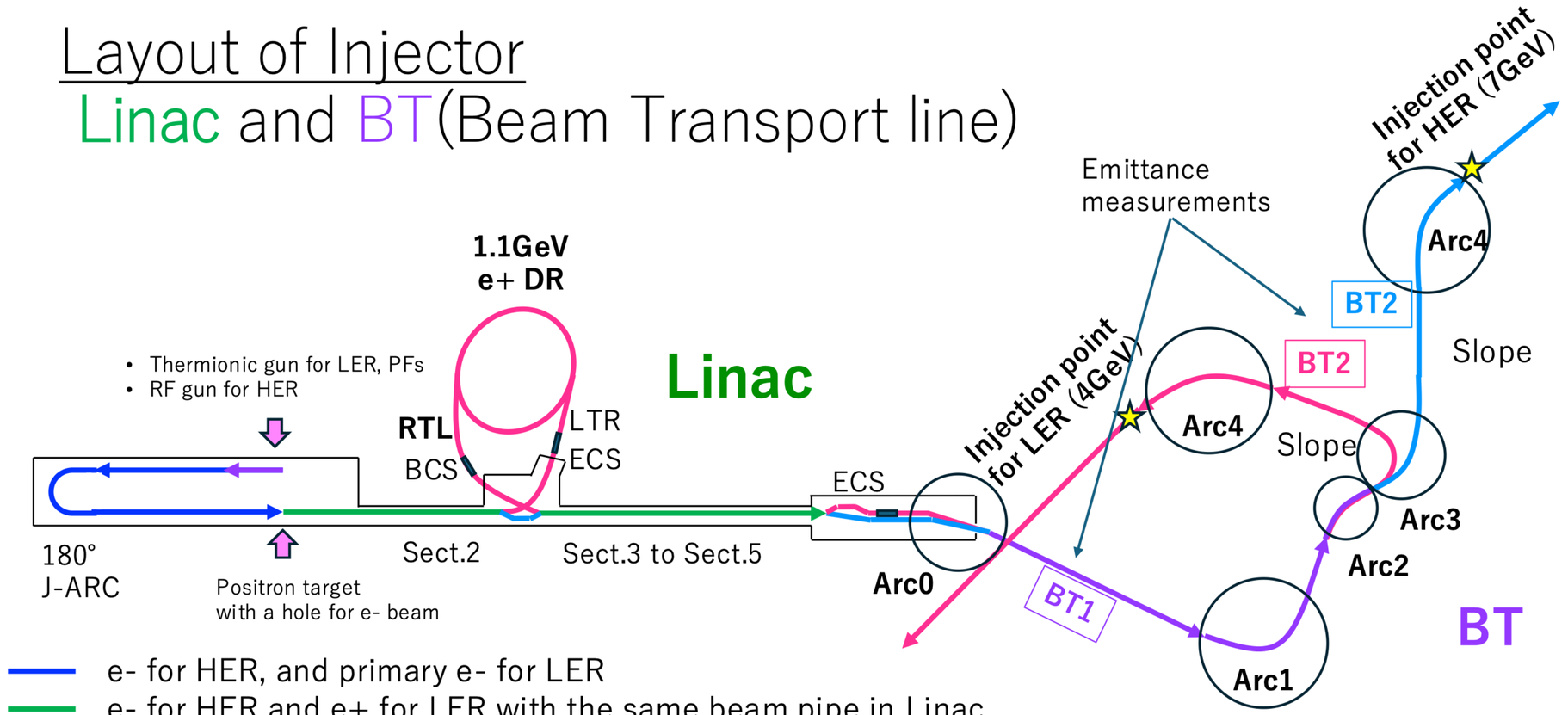
	December 27, 2024		Next Target		Target before LS2		Unit
Ring	LER	HER	LER	HER	LER	HER	
Emittance	4.0	4.6	4.0	4.6	4.0	4.6	nm
Beam Current	1632	1259	2080	1480	3026	2000	mA
Number of bunches	2346		2346		2346		
Bunch current	0.696	0.537	0.89	0.63	1.29	0.85	mA
Horizontal size σ_x^*	15.5	16.6	15.5	16.6	15.5	16.6	μm
Vertical cap sigma Σ_y^*	375		217		159		mm
Vertical size σ_y^*	265		154		112		nm
Betatron tunes ν_x / ν_y	44.525 / 46.589	45.531 / 43.599	44.525 / 46.589	45.532 / 43.573	44.525 / 46.589	45.532 / 43.573	
β_x^* / β_y^*	60 / 1.0	60 / 1.0	60 / 0.8	60 / 0.8	60 / 0.6	60 / 0.6	mm
σ_z	4.6 (6.0*)	5.1 (6.1*)	4.6 (6.5*)	5.1 (6.4*)	4.6 (7.5*)	5.1 (6.9*)	mm
Piwinski angle	12.3	12.7	12.3	12.7	12.3	12.7	
Crab waist ratio	80	60	80	80	80	80	%
Beam-Beam ξ_y	0.036	0.027	0.0444	0.0356	0.0549	0.0475	
Specific luminosity	5.8×10^{31}		7.62×10^{31}		9.30×10^{31}		$cm^{-2}s^{-1}/mA^2$
Luminosity	**5.1×10^{34}**		**1×10^{35}**		**2.4×10^{35}**		$cm^{-2}s^{-1}$

Luminosity is expected from the achieved values obtained at the beam-beam study.

Major Issues

- Sudden Beam Loss in SuperKEKB
  - Beam-Dust Interactions; Amorphous Graphite: VACSEAL Was Exposed to Intense SR.
- Beam-Beam Issues
  - X-Z Instability Can Be Mitigated by Squeezing β_x^*.
  - Cause of Beam-Beam Blowup Still Under Investigation.
  - Combined Effects of Beam-Beam, Lattice Nonlinear, Wakefield ← International Working Group
- Short Lifetime in Nano-Beam Scheme with Crab-Waist Scheme for β_y^* Squeezing
  - Small Dynamic Aperture and Beam-Beam Effects → Sextupole Optimization, Synchrotron Injection(Synchro-Betatron).
- Large Emittance of Stored Beam: Large ε_y in HER, X-Y Couplings/η_y due to Orbit Drift (Long-Term)
- Impedance Reduction
  - Nonlinear Collimator Helps Reduce the Impedance While Mitigating Backgrounds.
- Emittance Blowup at Beam Transport Line

Layout of Injector
Linac and BT(Beam Transport line)



e- for HER, and primary e- for LER
e- for HER and e+ for LER with the same beam pipe in Linac
e+ for LER
e- for HER
e- and e+ pipes with two-story structure

There are 5 arcs in the BT, which can be the source of emittance blowups for both e- and e+ lines.

N. Iida et al.

Major Works during Summer Shutdown

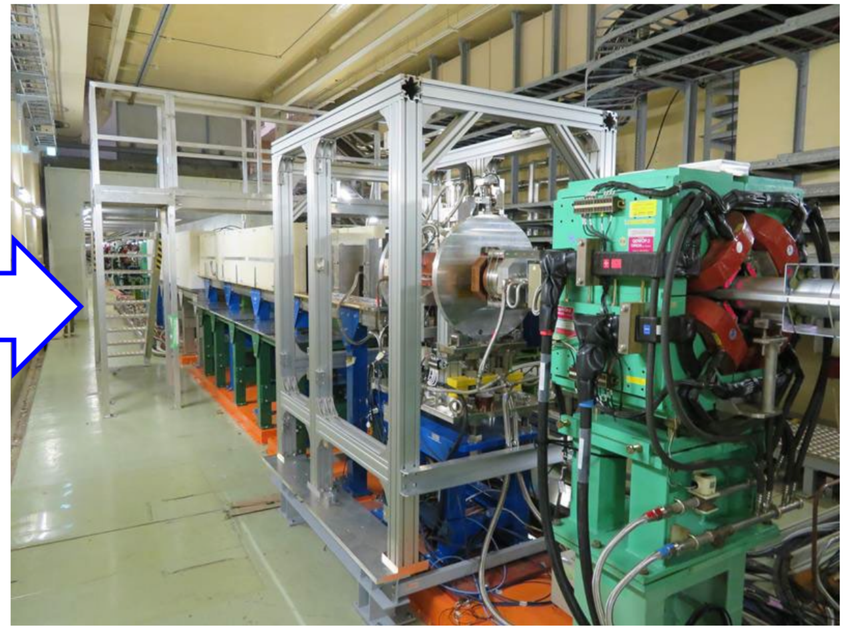
- Two Long Shutdowns Inefficient. → One Long Summer Shutdown + Short Winter Break (Less Impact on Resumption). Total Operation Period Unchanged.
- SBL → Beam-Dust Interaction; Amorphous Graphite formed from VACSEAL exposed to SR
  - Beam Pipe Cleaning in Summer Shutdown (IR and Wiggler Sections)
- Collimators
  - Relocation from D06V2 to D03V4 in LER
  - Damaged Jaw Replacement (D02V1 and D05V1) in LER
  - Radiation Shield Reinforcement at Nonlinear Collimator
- Beam Pipe Realignment at LER Injection Point. (Deviation from design: 3.6 mm → 2.5 mm) Improvement of Injection Efficiency and Stability

Major Works during Summer Shutdown (Cont'd)

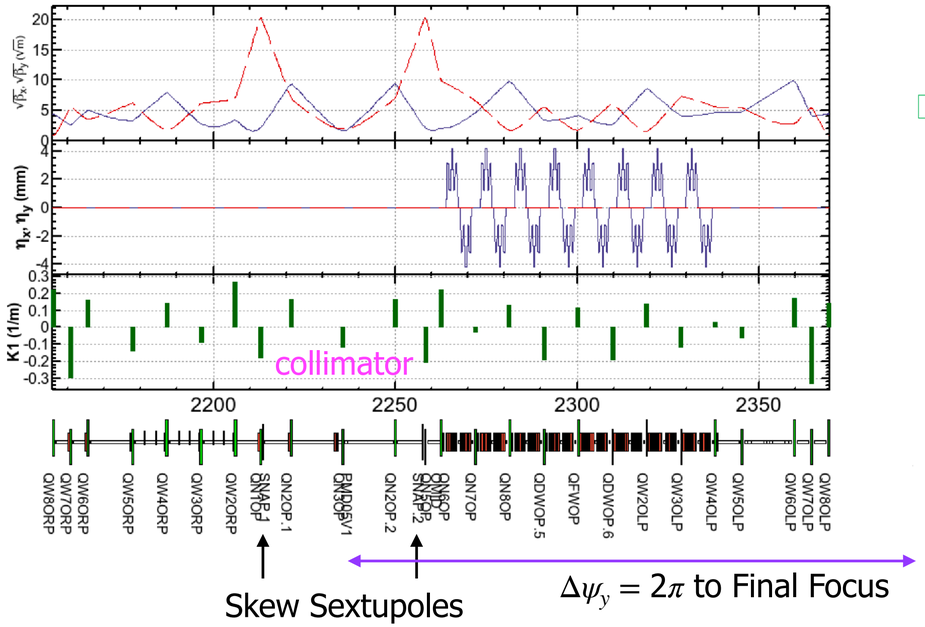
- Electron RF Gun Replacement
  - To Make Stable Operation and Two-Bunch Injection
- Installation of ECS in the Electron Beam Transport Line
  - To Reduce Energy Spread for High Intensity Bunch Charge
- Magnet Pole Replacement in the Positron Beam Transport Line
  - To Mitigate Emittance Blowup due to Nonlinear Magnetic Field
- and more ...

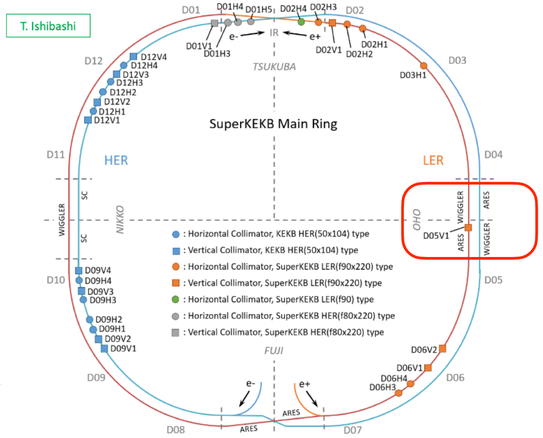
LER Reinforcement of Radiation Shield for Nonlinear Collimator

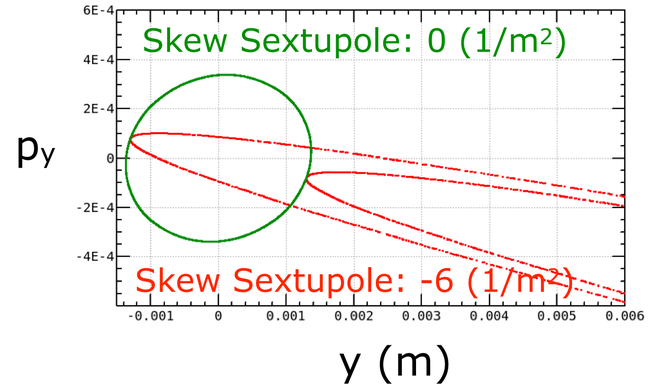
K. Shibata, K. Watanabe (KEK)



Frame for installing the shielding around D05V1 (NLC) has been completed.

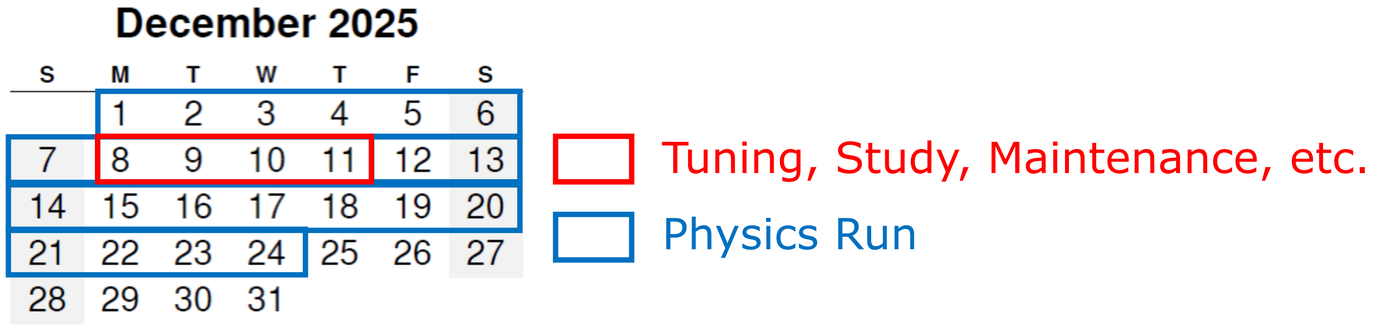






Operational Plan for 2025c-2026b

- **Highest Priority in 2025c-2026b: Integrated Luminosity > 425 fb^{-1}.**
- 2025c–2026b Run: 5 Nov. 2025 – 1 Jun. 2026
  - Vacuum Scrubbing: 5 Nov. 2025 – 17 Nov. 2025 = 13 Days
  - Collision Run in 2025c: 19 Nov. 2025 – 24 Dec. 2025 = 36 Days
  - (Winter Shutdown: 24 Dec. 2025 – 7 Jan. 2026 = 15 days)
  - Collision Run in 2026a/b: 9 Jan. 2026 – 1 Jun. 2026 = 144 Days
  - **Collision Run total: 36 Days + 144 Days = 180 Days**
- Physics Runs account for 80% of Full Collision Operation, about 150 Days.
  - 4 Days every 3 Weeks Are Allocated to Machine Tuning, Study, Maintenance, etc.



Plan A: Baseline

Target

Peak Luminosity: $1\times10^{35}\,\mathrm{cm^{-2}s^{-1}}$

Integrated Luminosity > 425 $\mathrm{fb^{-1}}$

Key Parameters

Specific Luminosity: **5.0×10^{31}** $\mathrm{cm^{-2}s^{-1}/mA^2}$ at 0.86 $\mathrm{mA^2}$

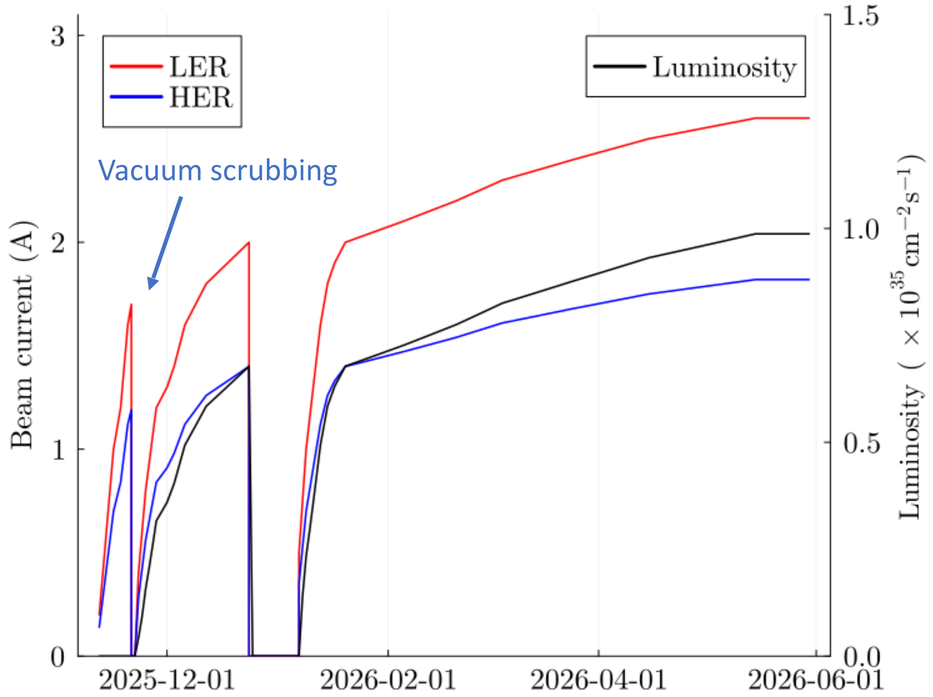
Reliability > 60% (about 67% at 1.7 A and 1.3 A in 2024c)

Requirements

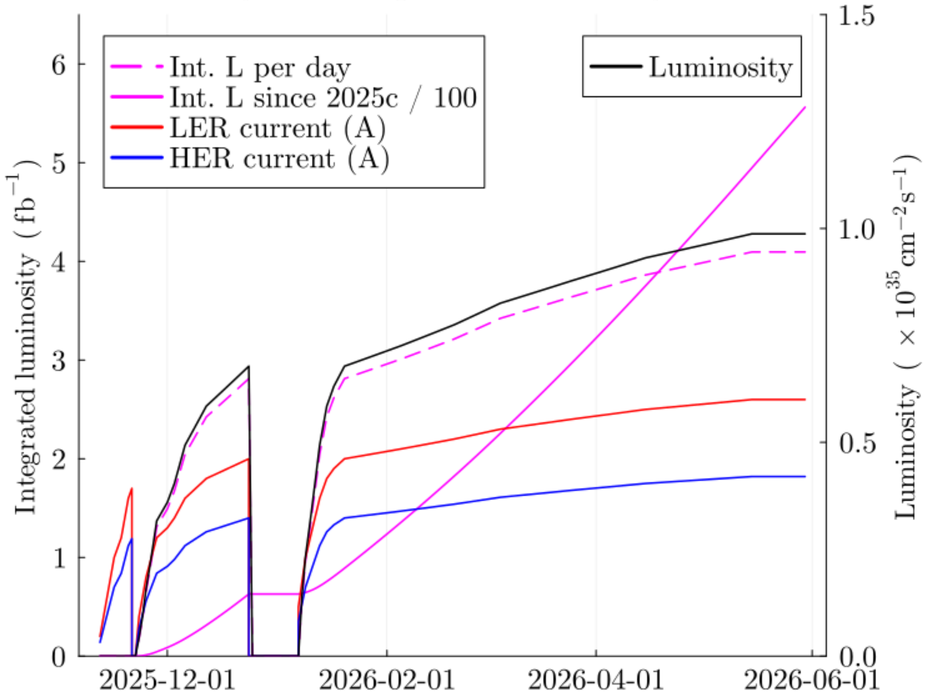
2-bunch Injection in HER and LER, β_y^* Squeezing to 0.8 mm (β_x^* Squeezing to avoid X-Z Instability)

Mitigation of Beam-Beam Effects (Blowup and Injection)

Beam current and peak luminosity



Luminosity and integrated luminosity



Plan B: Alternative

Target

Peak Luminosity: $6\times10^{34}\,\mathrm{cm^{-2}s^{-1}}$

Integrated Luminosity > $425\ \mathrm{fb^{-1}}$

Key Parameters

Specific Luminosity: **$5.9\times10^{31}\,\mathrm{cm^{-2}s^{-1}/mA^2}$** at 0.44 $\mathrm{mA^2}$

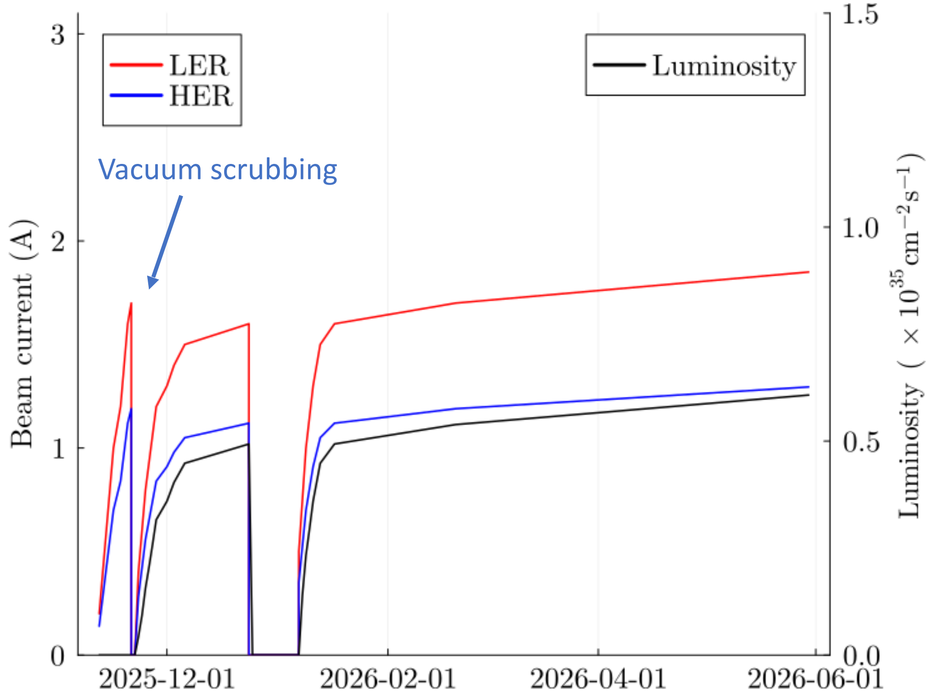
Reliability > 85% (Highest record: ~88% in 2022c)

Requirements

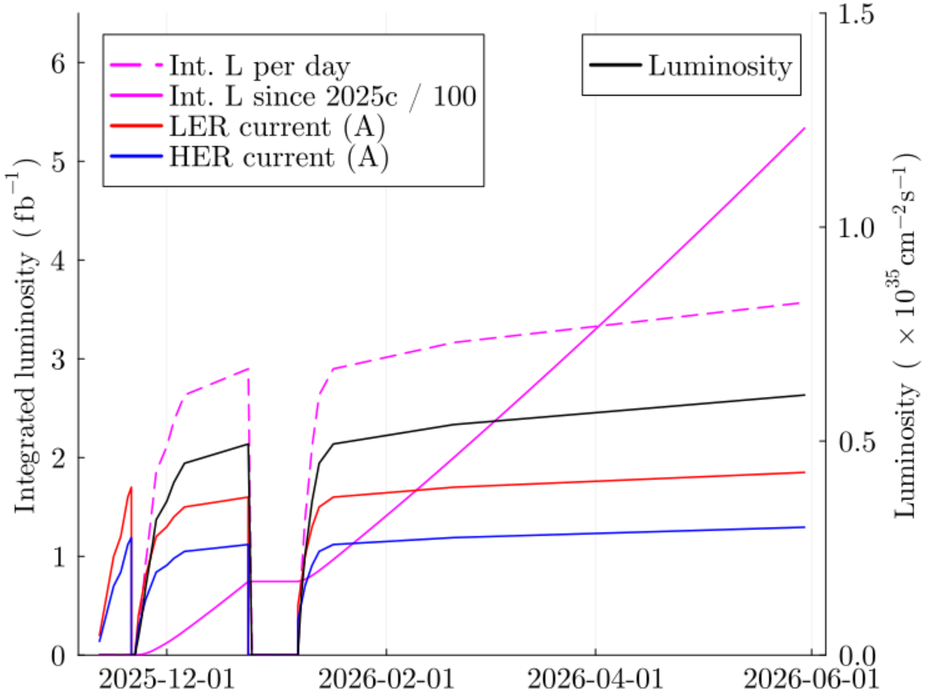
Stable Operation (Reduced SBL, QCS Quench, and Machine/Detector Trouble)

2-Bunch Injection in LER, Mitigation of Beam-Beam Effects

Beam current and peak luminosity

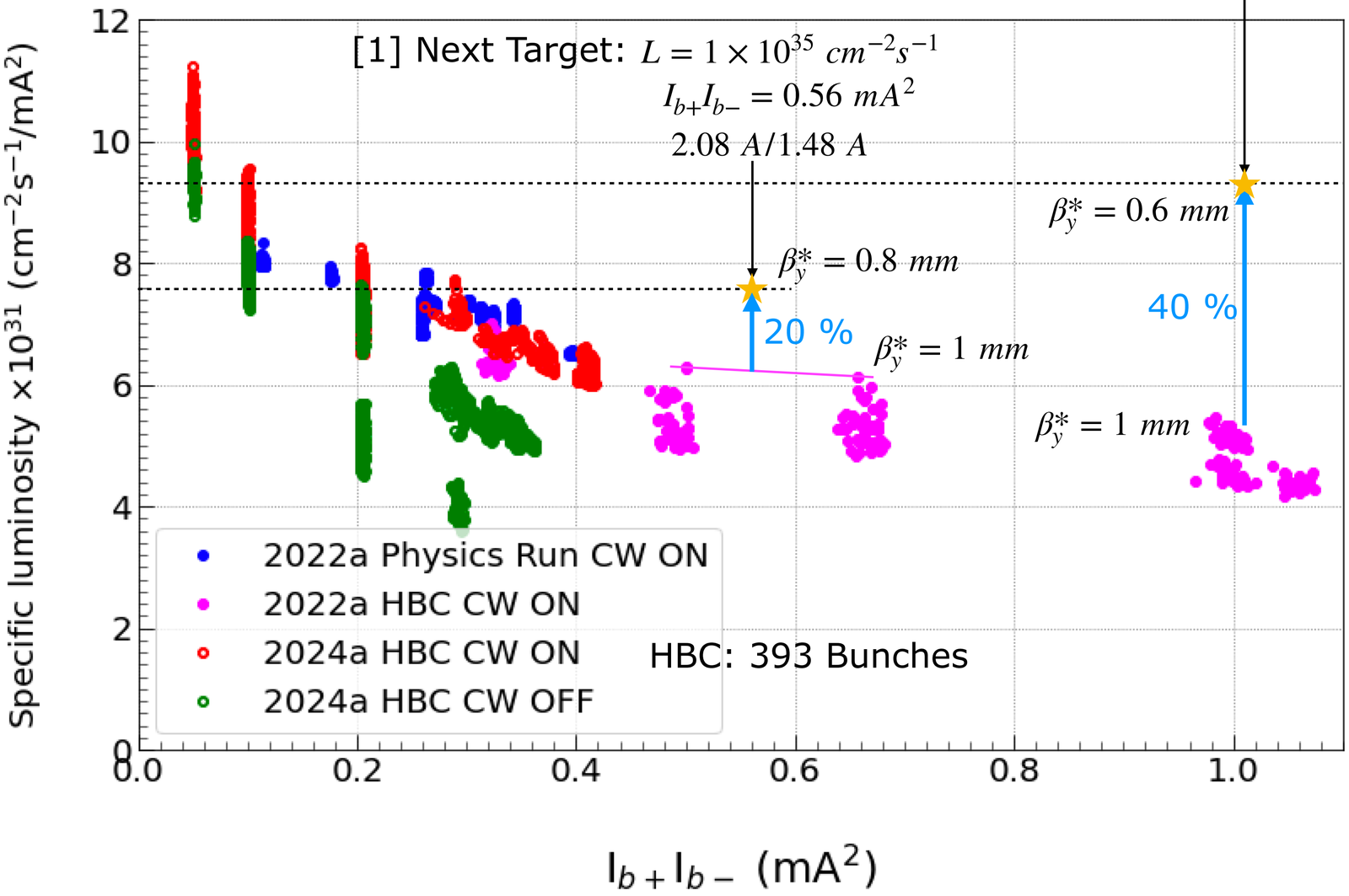


Luminosity and integrated luminosity



Luminosity Prediction Based on Beam-Beam Experiment

$$L_{sp} = \frac{L}{I_{b+} I_{b-} n_b} \propto \frac{1}{\sigma_y^*}$$



Assumption:
$L_{sp} \propto \frac{1}{\beta_y^*}$

Constant Ratio of β_y^* to ε_y

References

- eeFACT2025 (https://indico.jacow.org/event/75/)
- Mini-Workshop on SuperKEKB and Implication for the FCC-ee (https://indico.cern.ch/event/1542123/)
- NAPAC2025 (https://events.slac.stanford.edu/napac25)
- International Beam-Beam Working Group Meeting (https://kds.kek.jp/category/1840/)
- International Beam Injection Meeting (https://kds.kek.jp/category/2282/)
  - Joint Student Meeting for Injection Beam Study (https://kds.kek.jp/event/56992/)

Study Plan in 2025c Operation

- Vacuum Scrubbing: 5 Nov. 2025 – 17 Nov. 2025
  - Hardware Tuning
    - Sanity Check
    - Calibration (Timing, BPM Gain Mapping, BBA, Collimator Position)
  - Optics Tuning: ε_y in HER (Global Orbit and IR Optics and Orbit)
  - 1st Trial of Turn-by-Turn Measurements in Multi-Bunch Operation
  - 1-Bucket Spacing Pattern vs. SCC HOM Power, etc.
- Collision Run in 2025c: 19 Nov. 2025 – 24 Dec. 2025
  - Correction to Cancel Coil Defect using QC1RE Skew Sextupole or Flip of Pol. of Power Supply in HER
  - BG Reduction, Checking Pressure Rise (HOM) near the Nonlinear Collimator
  - Betatron Tune Measurement along Bunch Train
  - LLRF CBI Damper Optimization
  - Beam-Beam Study
- Beam Tuning
  - Physical and Dynamic Aperture (Sextupole Optimization, TBT Measurements, Impedance, ...)
  - σ_y vs. Bunch Current (BxB FB Parameter Optimization)

Key Members

- Commissioning/Operation:　G. Mitsuka, Y. Ohnishi
- Optics:　H. Sugimoto, Y. Ohnishi
- Beam-Beam Working Group:　Y. Funakoshi, Y. Yamamoto
- Vacuum: T. Ishibashi, K. Shibata
- Magnet/IP Feedback: R. Ueki
- RF System: T. Kobayashi
- Beam Monitor: G. Mitsuka, M. Tobiyama
- Linac/BT/Injection:　H. Kaji, N. Iida, T. Mori

KEK Visit from EU

- If you have a plan to visit KEK, please download and fill out the application form below. Short document is enough.
- https://www-linac.kek.jp/skekb/status/web/ForVisitors.html (Application Form) ← This is for our record.
- Email: skb-icb@ml.post.kek.jp
- Before planning a visit to KEK, we recommend to make discussions with us via ZOOM meeting or e-mail. Especially, if you are Ph.D. student, we also require the help and commitment of your supervisor at your home institute.

Name	Institute	Date	Remarks
Nikita Z van Gils	CERN/UMCG	Oct. 15 - Nov. 15, 2025	Simulations, Linac/BT, Injection, Xsuite
Giulia Nigrelli	CERN/Roma University	Nov. 7 - Nov. 28, 2025	Injection Background
Andrea Aquirre	DESY	Oct. 16 - Dec. 16, 2025	Emittance at Linac/BT, Injection Efficiency, Simulation Work
Meng Li	IJCLab/IHEP	Oct. 7 - Dec. 29, 2025	Injection Simulations, Beam Loss Study
Mael Le Garrec	CNRS IN2P3/LAPP	Dec. 1 - Dec. 12, 2025	RDT, Chromaticity, Amplitude Detuning
Christian Goffing	CERN/KIT	?	BBA, Calibration of BPMs, Beam Orbit and Optics
John Patric Salvesen	CERN/University of Oxford	Oct. 25 - Nov. 25, 2025	Collision Tuning, Xsuite for MR/BT, iBump FB