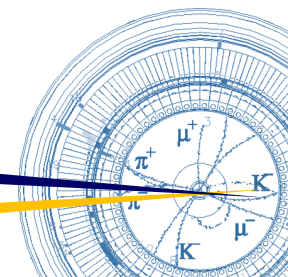


SuperKEKB operation status and overview



The 29th KEKB Accelerator Review Committee
26th October 2026

Kyo Shibata



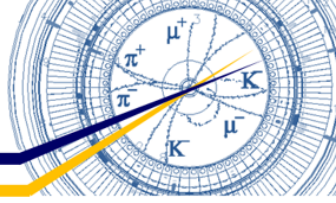
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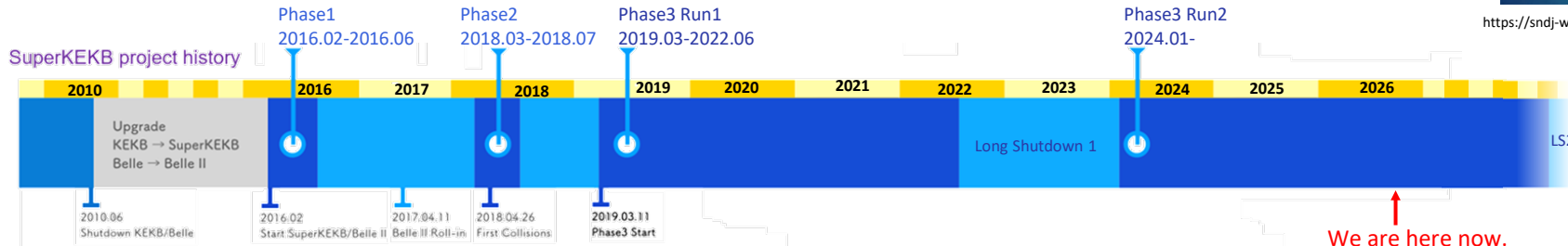
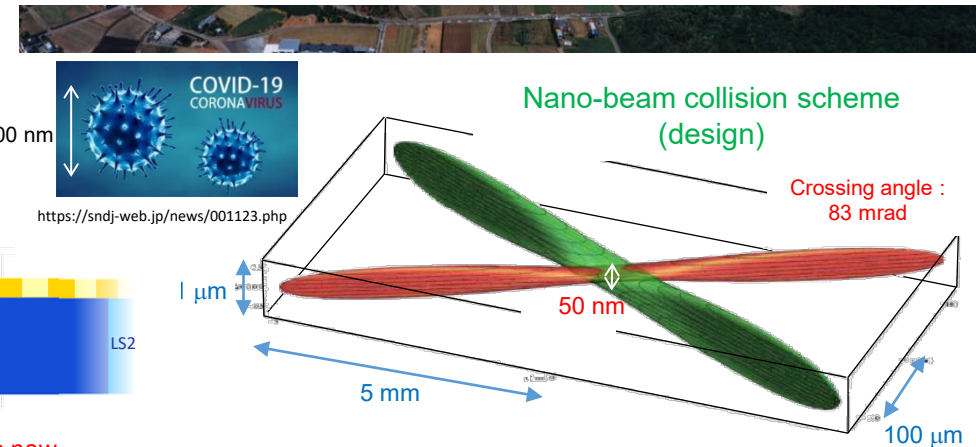
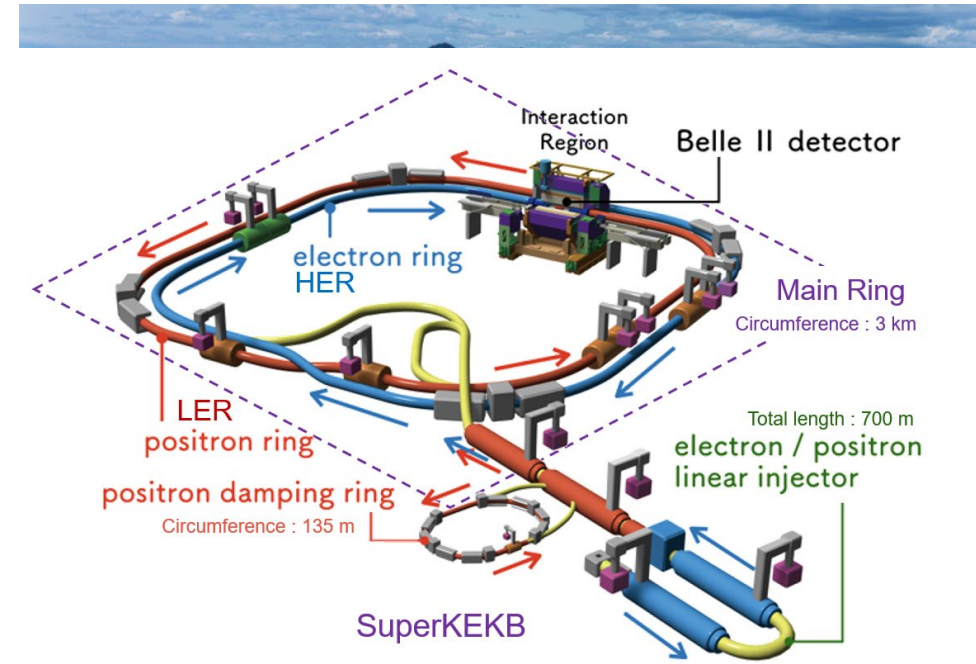
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SuperKEKB

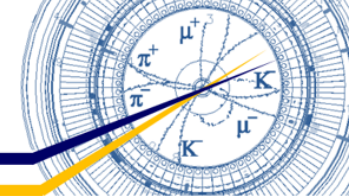


• SuperKEKB;

- Asymmetric-energy electron-positron collider operating at KEK Tsukuba site
 - An upgrade of KEKB B-factory (KEKB)
 - High-luminosity machine in search of new physics in the B-meson regime.
- Accelerator complex consisting of;
 - Injector (Linac), Positron Damping Ring (DR), Beam Transport Lines (BT), Main Ring (MR) with Belle II Detector
 - MR : High Energy Ring (7.0 GeV e⁻, HER), Low Energy Ring (4.0 GeV e⁺, LER)
- The world's first practical implementation of the “nano-beam scheme”
 - The only operating collider employing the nano-beam collision scheme envisioned for future Higgs factories.
- Operation started in 2016.
 - Physics run with fully instrumented detector (Phase 3 operation) started from 2019.
 - Currently we are conducting Phase-3 Run-2 operation.
 - Long Shutdown 2 is planned in 2032 for the upgrade.

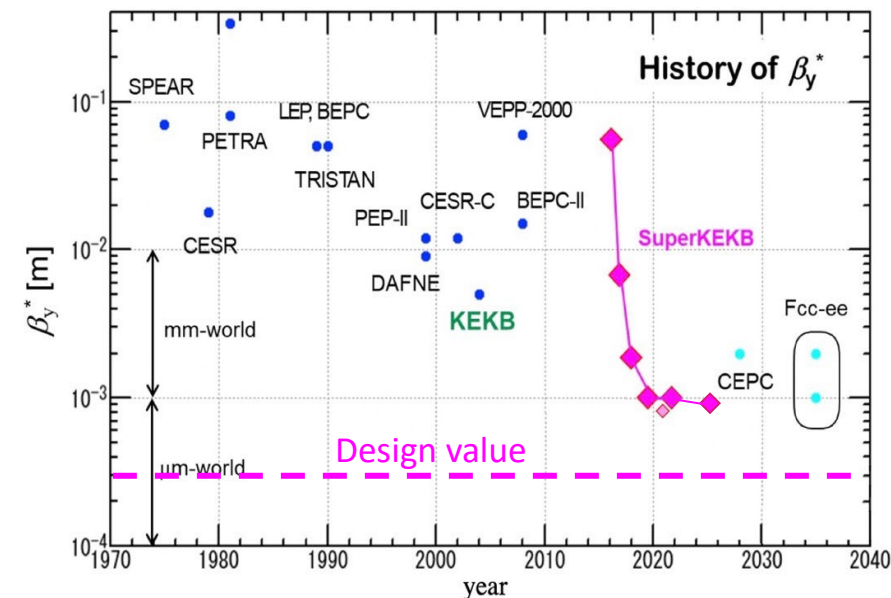


Machine parameters



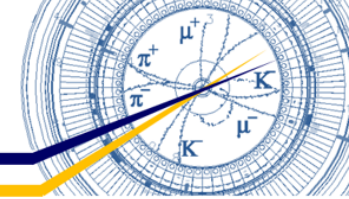
	KEKB (LER/HER)		SuperKEKB (LER/HER) 2026/6/30	
Beam Energy [GeV]	3.5/8.0		4.0/7.0	
Beam current [A]	1.64/1.19		1.60/1.20	
# of bunches	1584		1990	
β_x^*/β_y^* [mm]	1200/5.9	1200/5.9	55/0.9	55/0.9
σ_x^*/σ_y^* [μm]	147/0.94	170/0.94	18/0.23	18/0.24
Half crossing angle θ [mrad]	11		41.5	
Piwinski angle [rad]	0 with crab crossing		~ 12	
Luminosity [$\times 10^{34}$ $\text{cm}^{-2}\text{s}^{-1}$]	2.1		5.32 (w/o Belle II operation)	

$5.28 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
 (with Belle II operation)

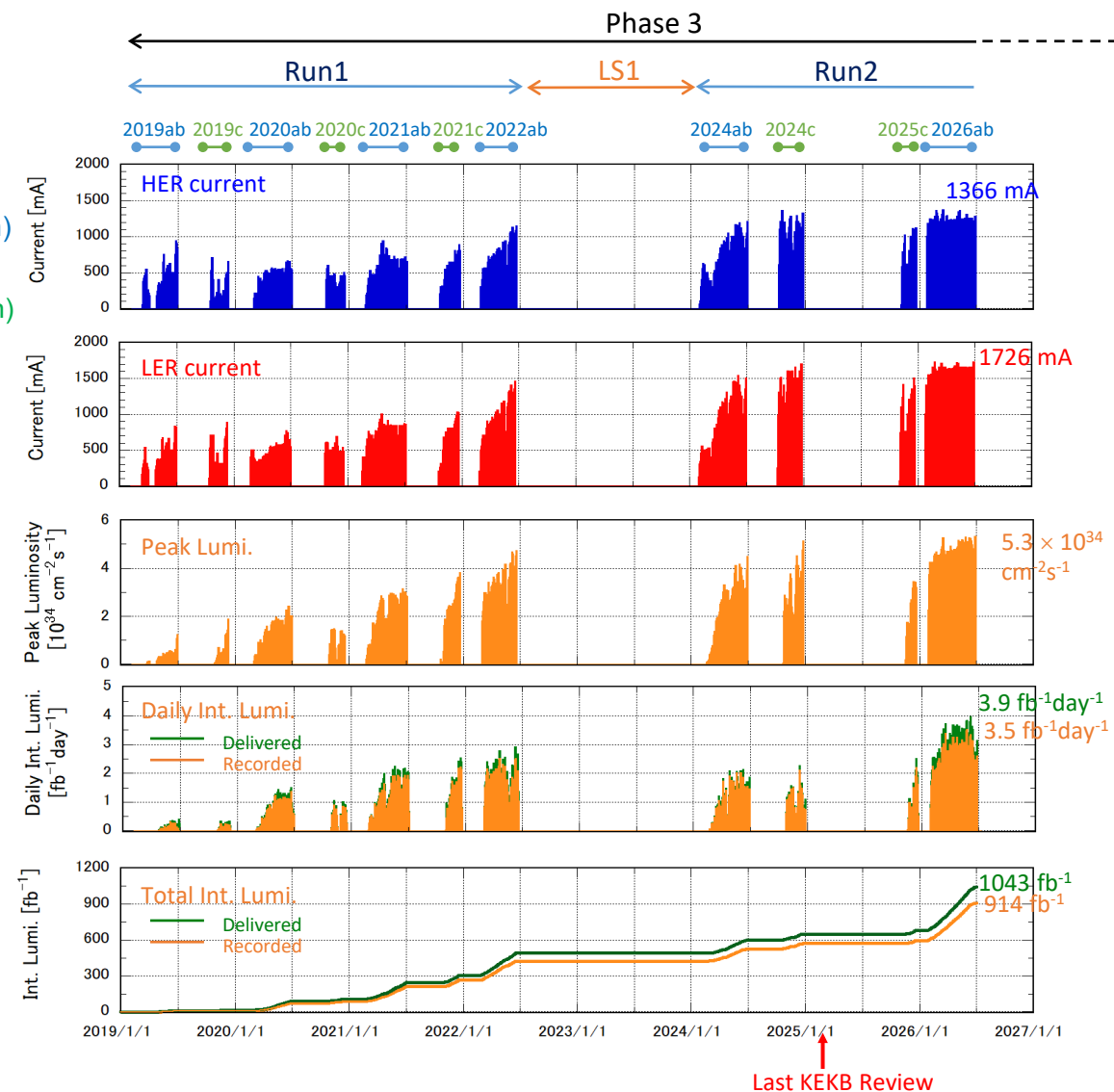


Control room at the moment of the Lumi. record update!!

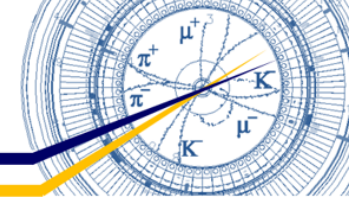
Phase 3 commissioning history



- Phase3 operation (2019.March~);
 - Naming rule of Phase3 operation
 - "YYYYxx run"
 - Calendar year
 - ab: End of winter shutdown – Start of summer shutdown (Spring run)
 - a : End of winter shutdown – March (End of Japanese fiscal year)
 - b : April – Start of summer shutdown
 - c: End of Summer shutdown – Start of winter shutdown (Autumn run)
- Scheduling policy
 - Concentrating the operation period to improve operational efficiency
 - Shortening the winter shutdown (Minimize vacuum work)
 - Starting the summer shutdown earlier (Avoid operation in June due to high temp.)
- After last KEKB Review in Feb. 2025:
 - Shutdown btw 2024c – 2025c (10-month shutdown)
 - 2025ab run skipped due to high-voltage electrical substation upgrades.
 - 2025c run
 - Winter shutdown
 - 2026ab run
 - Summer shutdown
 - 2026c run skipped due to preparation for 2027ab run.
- 2027ab will start in Jan. 2027.



Challenges for higher luminosity

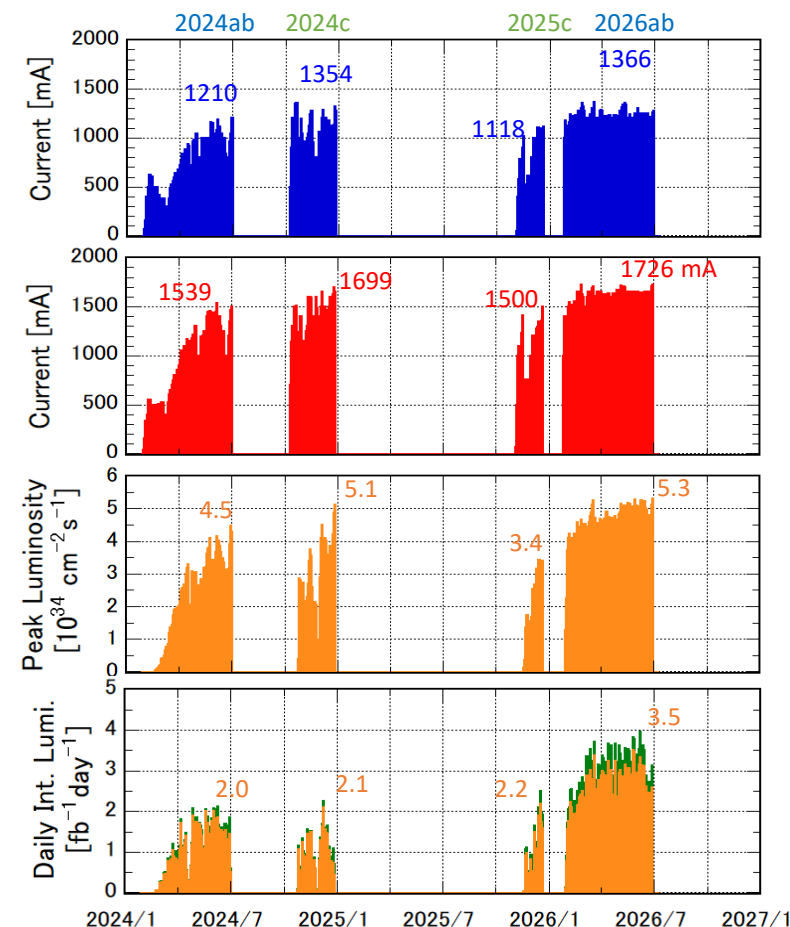


- Challenges in achieving higher peak luminosity

- Low stored beam currents
 - Low injection efficiency
 - Short beam lifetime
 - Hardware limitations (e.g., vacuum leaks due to high beam current)
 - Limitations due to radiation dose
- Low specific luminosity
 - Decrease in specific luminosity with increasing beam currents
 - Unexplained emittance blow-up

- Challenges in achieving higher integrated luminosity

- Sudden beam loss (SBL)
 - Limits beam current increases, thereby limiting peak luminosity.
- Operational interruptions due to equipment failures
- Operational interruptions due to aging equipment and infrastructure
- Reduced operation time due to rising electricity costs

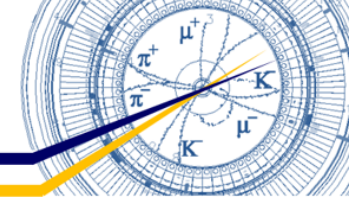


Machine performance has been gradually improved by addressing these issues.
We have repeatedly achieved new peak luminosity records.

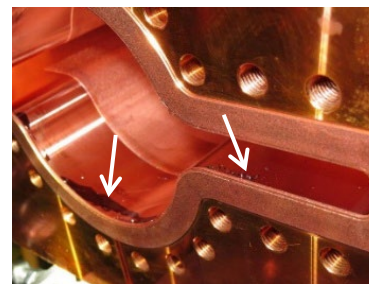
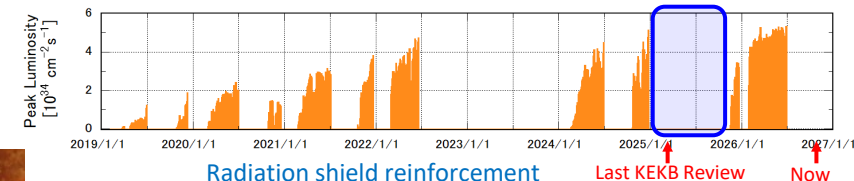
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Shutdown between 2024c and 2025c



- Countermeasures against SBL (highest priority)
 - Extensive VACSEAL removal during the long shutdown
 - The effectiveness of VACSEAL removal in reducing SBL frequency was confirmed during the 2024c run.
 - Internal cleaning of beam pipes in the IR and LER wiggler sections
- Countermeasures to increase beam currents
 - Beam pipe realignment at the injection point
 - Reinforcement of radiation shielding in the NLC section
 - RF electron gun replacement
 - Installation of an energy compression system (ECS) in BTe
 - Magnet pole replacement in BTp
 - Relocation and installation of fast kickers in Linac and BT
 - Development of a new electron beam diagnostic line at Linac end



Beam pipe cleaning



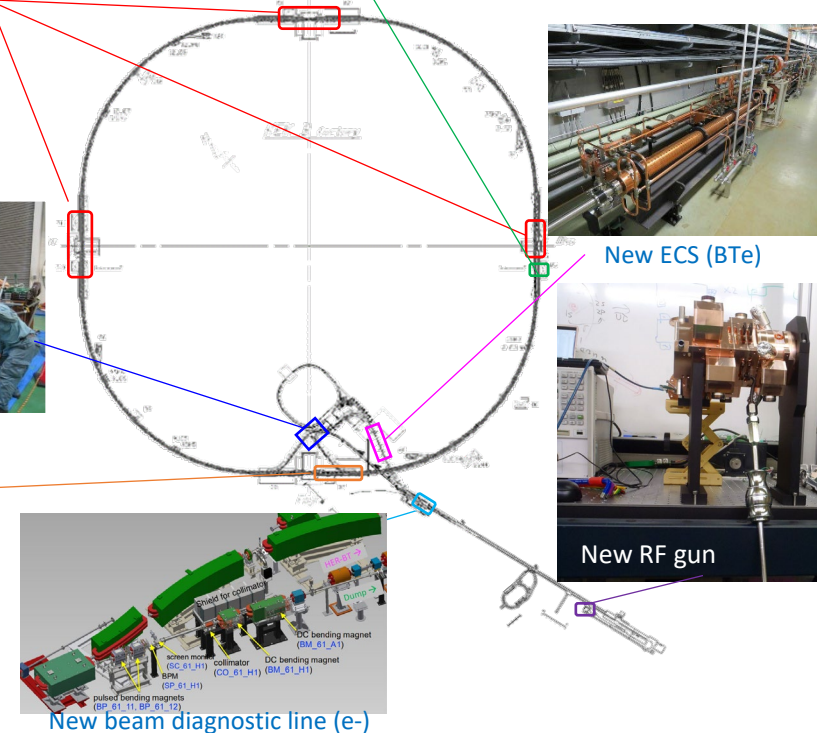
Radiation shield reinforcement



Magnet pole replacement (BTp)



Beam pipe realignment at LER inj. point

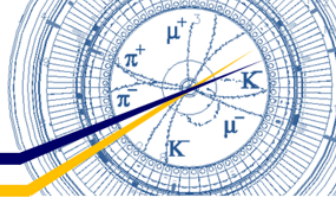


New ECS (BTe)

New RF gun

New beam diagnostic line (e-)

2025c run overview

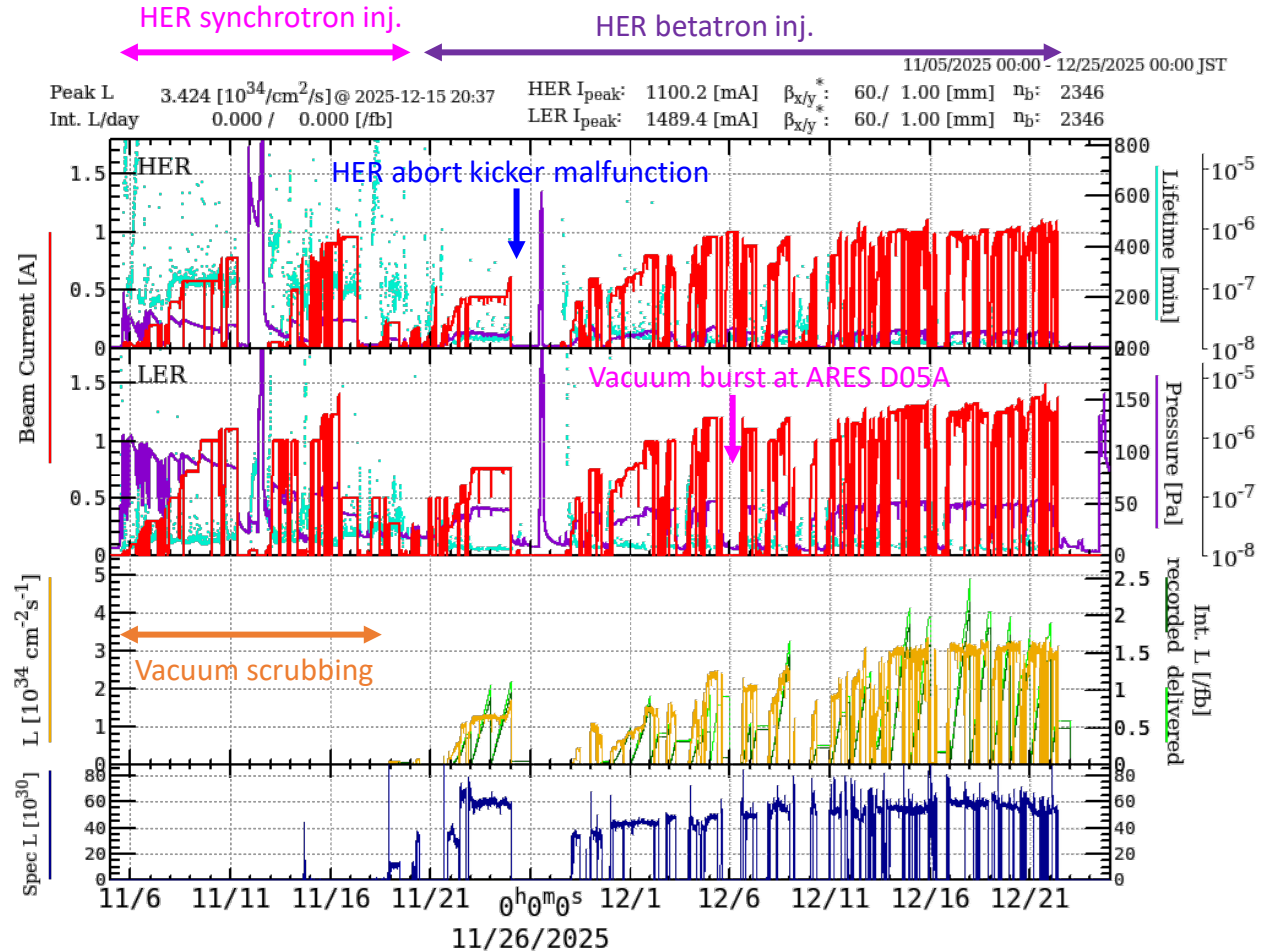
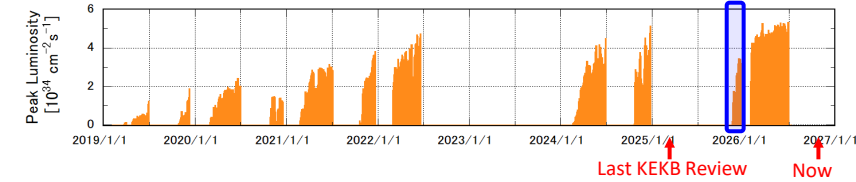


• Operation policy for 2025c-2026ab run

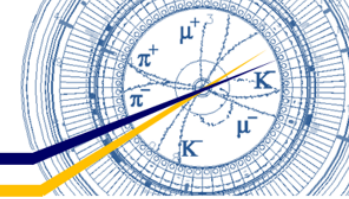
- The highest priority was integrated luminosity (recorded) $> 425 \text{ fb}^{-1}$ ($> 1 \text{ ab}^{-1}$ in total)
 - 4 days per 3-week cycle are allocated to machine tuning, development, maintenance, etc.
 - The winter shutdown was initially planned to last approximately two weeks.

• 2025c summary

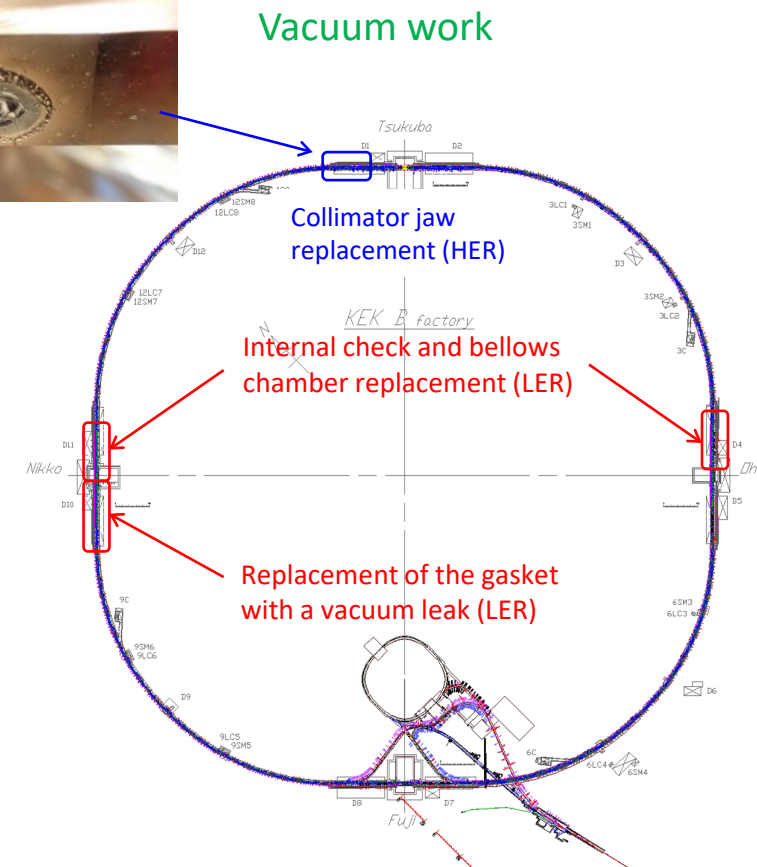
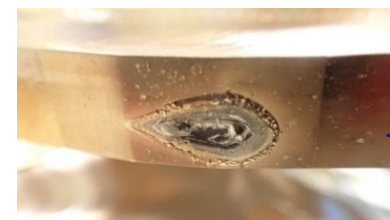
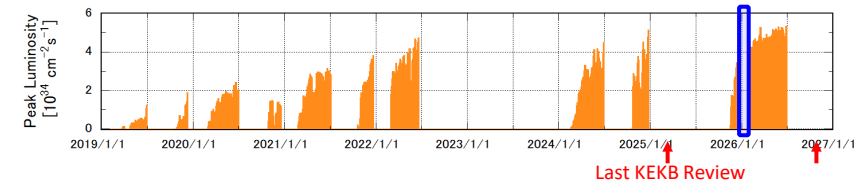
- The effectiveness of VACSEAL removal in reducing SBL was confirmed.
- Synchrotron injection was demonstrated in the HER.
- Frequent equipment problems prevented us from establishing stable operation.
 - As a result of major issues, the available operation time was reduced.
 - HER abort kicker malfunction
 - Degradation of the QCS cryogenic system performance
 - Abnormal pressure increase in the LER ARES cavity
- The winter shutdown was extended from two weeks to four weeks to address these issues.



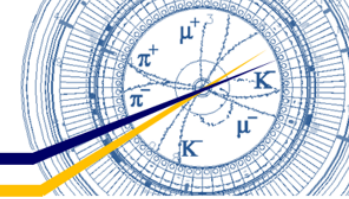
Winter shutdown btw. 2025c – 2026ab



- Countermeasures against problems identified during 2025c run
 - Verification of the integrity of the QCS cryogenic system and the cryostat insulation vacuum vessel
 - Replacement of damaged collimator jaws (HER)
 - Collimator jaws were significantly damaged by Abort Kicker PS malfunction issue.
 - Internal check of bellows chambers (LER)
 - Vacuum spikes were observed with SBLs.
 - Optical alignment of the SR monitor in the BTe
- The MR startup was postponed to late January
 - The cryogenic system was shut down for inspection during the winter shutdown.
- The 2026ab operation schedule was revised.
 - The run period was extended from the originally planned end of May to the end of June.
 - From 2027 onward, the spring run is planned to end in May to avoid operation during hot weather.
- Extensive injection beam tuning was carried out before the MR startup
 - Machine-learning-based tools for injection beam tuning were developed and put into full-scale operation.



2026ab run overview



2026ab summary

- Highest priority is integrated luminosity (recorded) $> 400 \text{ fb}^{-1}$ ($> 1 \text{ ab}^{-1}$ in total)

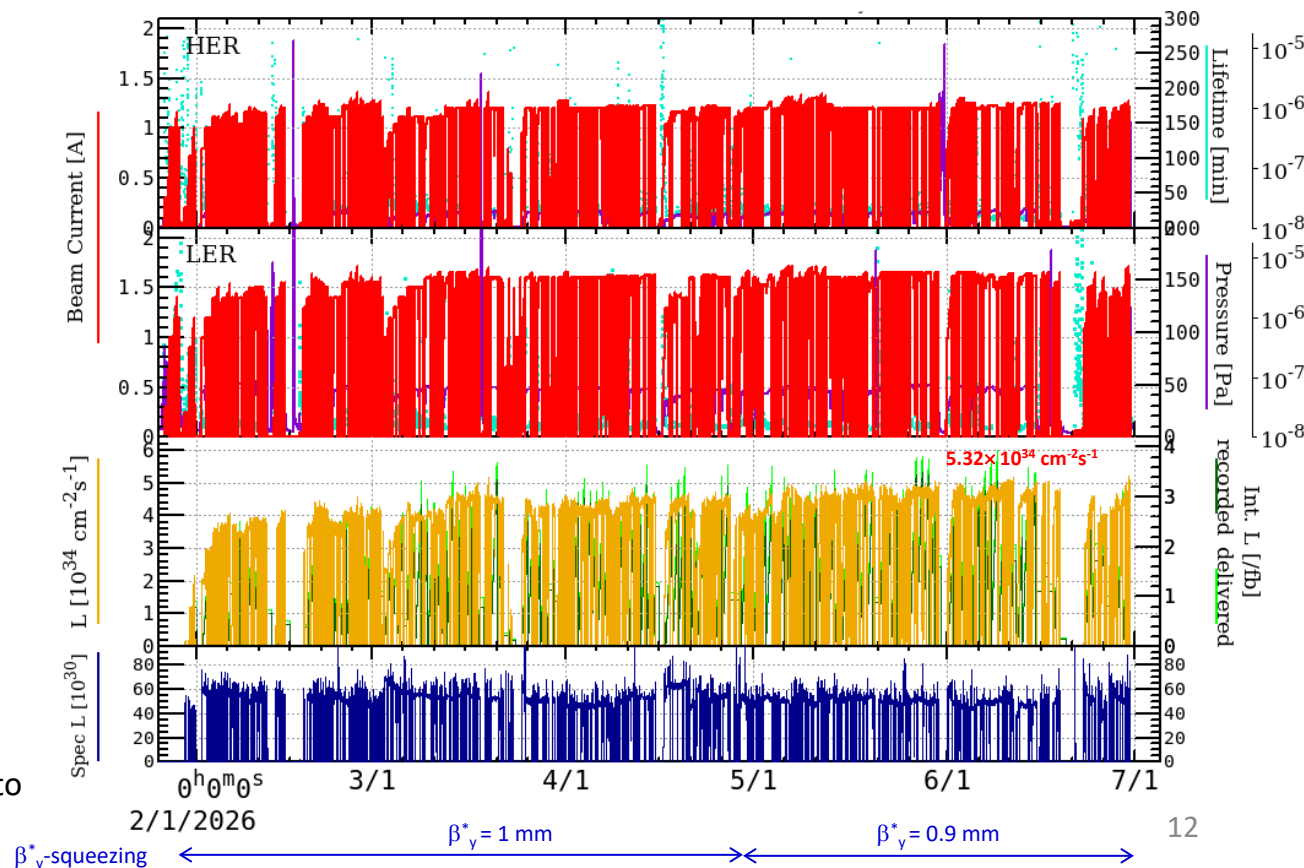
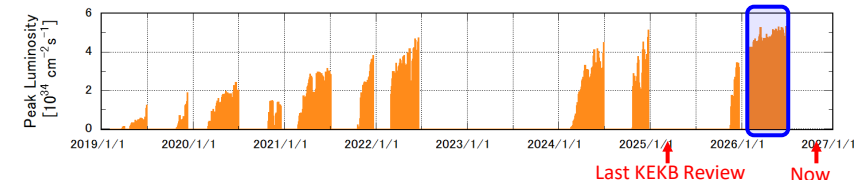
- Machine study time was allocated after it became clear that 0.9 ab^{-1} was achievable.
- However, sufficient study time could not be secured due to a campus-wide power outage.
- Further squeezing was postponed to 2027ab run.

New records were achieved for various luminosities.

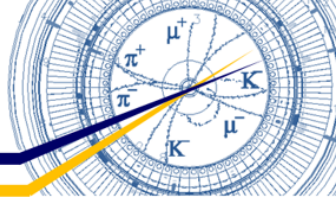
- Peak lumi :
 - $5.32 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ (Belle II HV OFF)
 - $5.28 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ (Belle II HV ON)
- Daily integrated lumi.:
 - 3.50 (recorded) / 3.95 (delivered) $\text{fb}^{-1}/\text{day}$
- Integrated lumi. per 7 days:
 - 21.8 (recorded) / 24.2 (delivered) $\text{fb}^{-1}/7\text{day}$
- Accumulated luminosity:
 - 2026ab: 314 (recorded) / 361 (delivered) fb^{-1}
 - Total: 915 (recorded) / 1043 (delivered) fb^{-1}**

Stable operation was established at a peak luminosity of $\sim 5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$

- Peak luminosity record was updated by reducing β_y^* from 1.0 mm to 0.9 mm .
- New maximum beam current records were also achieved.



2026ab run overview

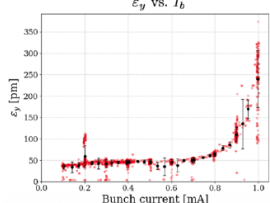


- Specific luminosity gain obtained by β_y^* -squeezing was confirmed.
 - Specific luminosity increased by 10% by β_y^* -squeezing from 1.0 mm to 0.9 mm.
- The rate of integrated luminosity accumulation increased significantly.
 - Higher peak luminosity and more stable operation were achieved during the 2026ab run.
 - 1.4 times the accumulation rate achieved in the 2022ab run.

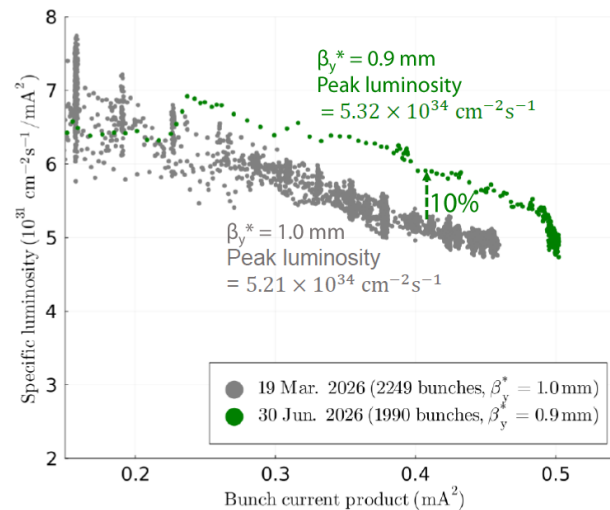
Increasing peak luminosity with lower β_y^*

G. Mitsuka

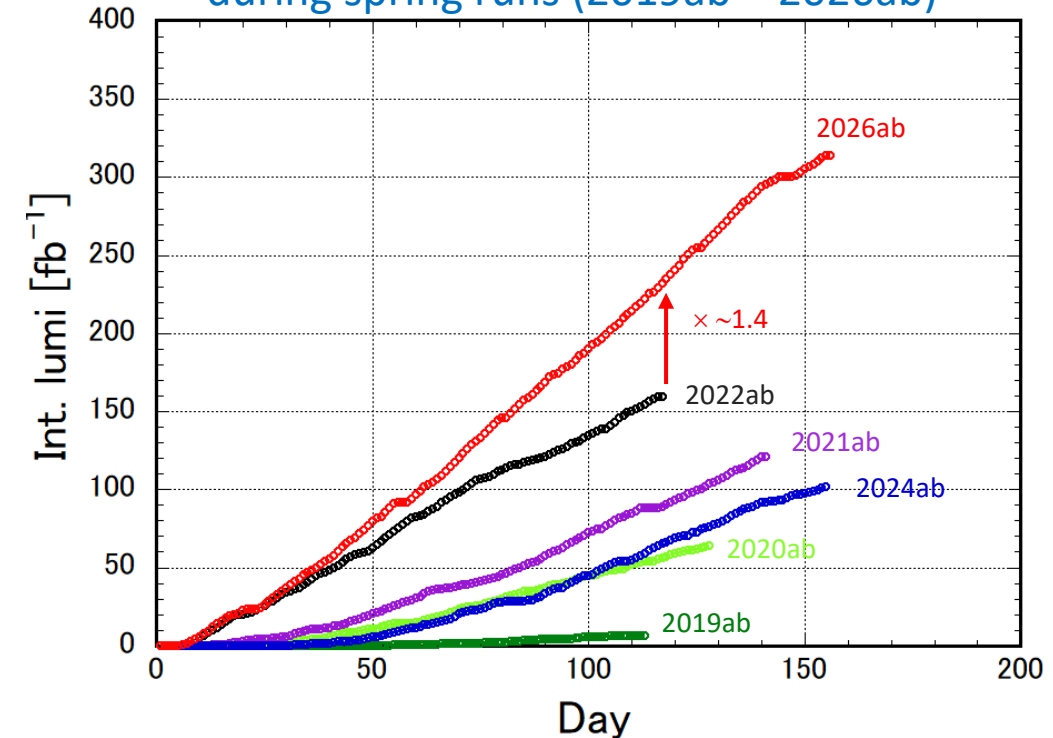
- SuperKEKB has been successfully operated with $\beta_y^* = 0.9$ mm since 30 Apr. 2026 (1.0 mm until then).
 - For increasing luminosity and accumulating integrated luminosity
 - Without raising the beam current, which would be accompanied by an increase in the abort rate.
 - A trial aimed at a future peak luminosity of 10^{35} .
 - Could maintain dynamic aperture enough for the beam current >1.7 A (LER) and >1.3 A (HER).
- **Specific luminosity with $\beta_y^* = 0.9$ mm is ~10% higher than $\beta_y^* = 1.0$ mm, which is in agreement with $1/\beta_y^*$.**



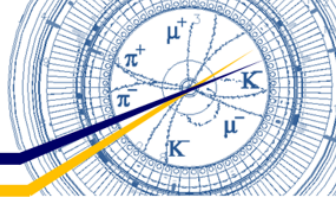
The specific luminosity drop-off around 0.5 mA² possibly result from increased impedance and beam size due to damaged collimator(s).



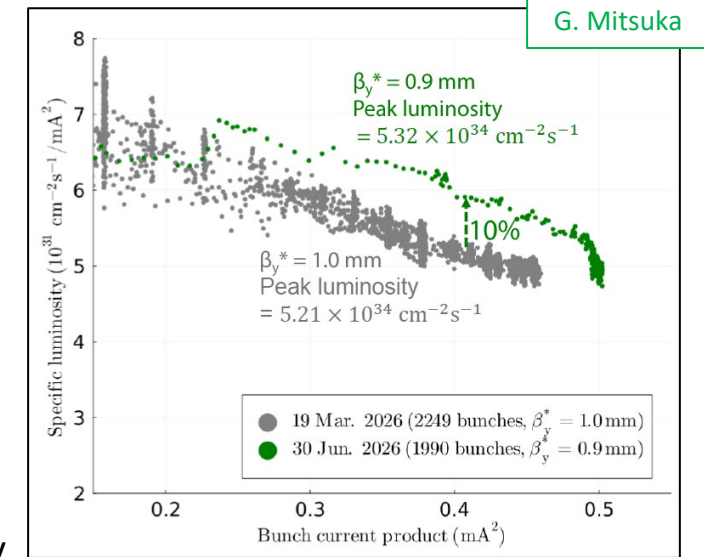
Comparison of integrated luminosity during spring runs (2019ab – 2026ab)



2026ab run overview



- Challenges in achieving higher luminosity remained.
 - Degradation of specific luminosity with increasing beam current
 - Decrease in injection efficiency with increasing beam current
 - Short beam lifetime and large beam-beam effect
 - SBLs
 - Beam currents were not aggressively increased because of frequent SBL events accompanied by QCS quenches.
 - SBLs in the HER became more prominent, though the frequency of SBL in the LER decreased.
 - Other concerns about increasing beam currents
 - Vacuum pressure deterioration in ARES cavity, Beam pipe heating in the wiggler sections, etc.
 - Addressing these issues was identified as essential for increasing beam currents and luminosity in the 2027ab run
 - Hardware failures due to aging caused prolonged interruptions to operation
 - Failures of the injection kicker power supply, QCS cryogenic gas line solenoid valve, air conditioner at the control room, etc.
 - Reduced cooling water flow in the BT magnets also caused operation interruption



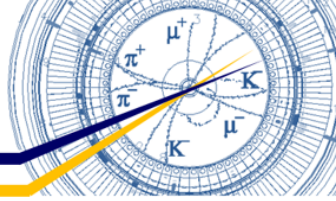
- These challenges are considered major obstacles to achieving the performance targets for the 2026ab run.

	Plan	Achieved	
Peak luminosity	6.3×10^{34}	5.3×10^{34}	$\text{cm}^{-2}\text{s}^{-1}$
Beam current (LER/HER)	2.00/1.60	1.72/1.37	A
Total integrated luminosity	1	0.92	ab^{-1}

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Summer shutdown btw. 2026ab – 2027ab



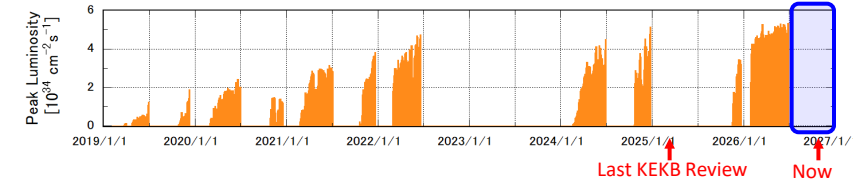
- Major activities

- Linac

- RF electron gun replacement
 - Eliminate concerns about performance degradation due to manufacturing defects.
 - Repair of fast kicker power supplies
 - Repair the fast kicker power supplies that failed during the 2026ab run
 - Replacement of 12 aging accelerating structures with new ones

- BT

- Improvement of cooling water quality for magnets
 - Prevent operation interruptions caused by cooling water interlocks.
 - Installation of additional magnet temperature sensors
 - Enable monitoring of temperature increases caused by reduced cooling water flow.
 - Upgrade of the beam position monitor signal readout system
 - Eliminate signal overlap between the first and second bunches, enabling more precise beam control.



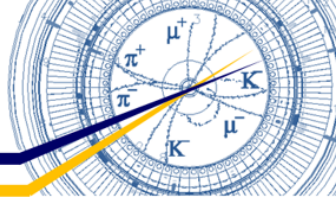
Expected benefits

Improved injection efficiency,
Higher beam currents,
Increased peak luminosity

Reduced downtime,
increased integrated luminosity

Improved injection efficiency,
Higher beam currents,
Increased peak luminosity

Summer shutdown btw. 2026ab – 2027ab



• Major activities

• Injection point

- Upgrade of the LER injection kicker power supplies
 - Prevent beam aborts and QCS quenches caused by accidental kicker firing.
- Replacement of the LER injection beam pipe
 - Restore the injection beam aperture reduced by beam pipe deformation

• MR

- Investigation and countermeasures against vacuum pressure deterioration in LER RF cavities
 - Two cavities were taken out of operation due to vacuum pressure deterioration during the 2025c-2026ab runs.
 - The causes of the vacuum pressure deterioration were identified.
- Installation of water-cooled bellows chambers in the LER wiggler sections
 - Reduce temperature rises caused by SR downstream of the wigglers and prevent vacuum leaks.
- Installation of additional beam loss monitors to enable faster beam aborts.
- Investigation of the causes of SBLs
 - Internal inspection of beam pipes by X-ray camera.
- Replacement of damaged collimator jaws and water-cooled collimators

Expected benefits

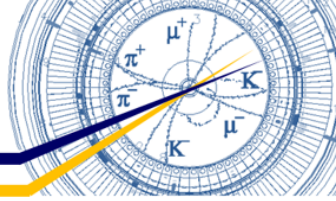
Reduced downtime,
increased integrated luminosity

Improved injection efficiency,
Higher beam currents,
Increased peak luminosity

Higher beam currents,
Increased peak luminosity

More stable operation,
Reduced beam background,
Higher beam currents,
Faster beam aborts,
increased peak and integrated luminosity

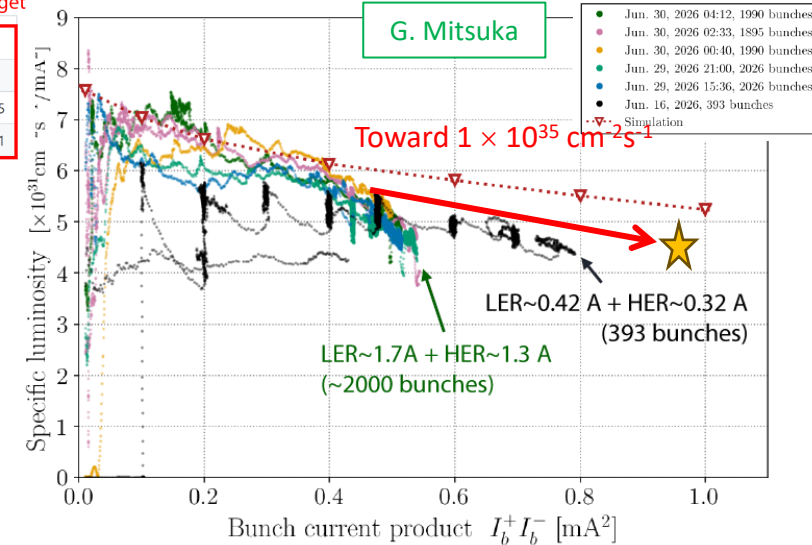
Toward $1 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$



• Target operating point:

- Specific luminosity : $4.4 \times 10^{31} \text{ cm}^{-2}\text{s}^{-1}\text{mA}^{-2}$
 - β_y^* : 0.8 ~ 0.9 mm
- LER current : 1726 -> 2600 mA
- HER current : 1366 -> 2000 mA
- Strategy will be presented by Mitsuka-san at the SuperKEKB Project Advisory Committee review on the afternoon of October 28.

	2024/12 reached					Next target
Peak luminosity	5e34	6e34	7e34	8e34	9e34	10e34
Specific luminosity	5.5	5.3	5.1	4.8	4.5	4.4
HER beam (A) / bunch (mA) current	1.31/0.56	1.46/0.62	1.62/0.69	1.77/0.75	1.93/0.82	2.00/0.85
LER beam (A) / bunch (mA) current	1.64/0.70	1.83/0.78	2.02/0.86	2.21/0.94	2.41/1.03	2.60/1.11



• Key Challenges

- Achieving higher beam currents
 - Improve injection efficiency at high currents
 - Increase lifetime and dynamic aperture
 - Mitigate beam-beam related injection losses
 - Mitigate hardware limitations
- Mitigating specific luminosity degradation
 - Understand and mitigate emittance blow-up
- Improving operational stability
 - Reduce SBL and QCS quenches
 - Minimize beam losses and Belle II backgrounds
- Prevent equipment failures and operational interruptions
 - Address aging equipment and infrastructure

Countermeasures and action plans are being developed by hardware groups and task forces

Hardware groups:

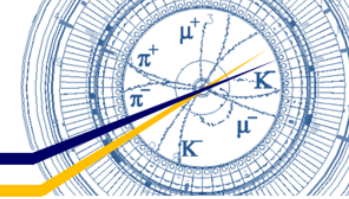
Magnet, Vacuum, RF, Control/Monitor, Gun, Cryogenics, Facility

Commissioning task forces:

Current/Injection, Beam-beam, ML/AI beam tuning, SBL

Countermeasures and action plans will be presented by the respective groups and task forces.

2027 run schedule



- The 2027 spring run (2027ab run) will start in January 2027.
 - Extensive injection beam tuning will be carried out before the 2027ab run.
 - Linac operation started on September 14.
 - BT/DR operation is scheduled to start on November 30.
 - Linac, BT, and DR operation for injection beam study and tuning will continue in parallel with MR start-up activities.
 - MR operation will start on Jan. 25.
 - Operation will stop on May 31.
 - 126 days of MR operation.
 - A detailed plan for the 2027ab run will be presented by Mitsuka-san at the SuperKEKB Project Advisory Committee review on the afternoon of October 28.
- The 2027 autumn run may start in November.
 - 7-month run (April, May, Nov., Dec., Jan, Feb, March.) in JFY2027.
 - Subject to budget availability and electricity costs.
 - The JFY2027 budget is expected to be finalized in December.

2026c
December

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

2027a
January

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

2027b
End of May

Sun	Mon	Tue	Wed	Thu	Fri	Sat
23 ← MR →	24	25	26	27	28	29
30 ← MR →	31	1	2	3	4	5

Linac/BT/DR
Study&Tuning

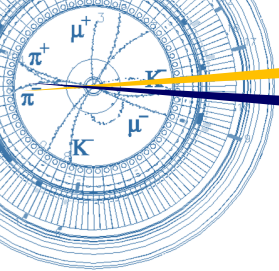
MR operation
126 days

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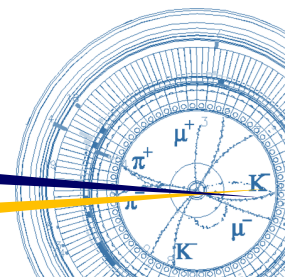
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 - 2025c and 2026ab runs
- Preparations for the 2027ab run
 - Toward $1 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
 - 2027ab run schedule
- Summary

Summary

- Significant progress was made during the 2026ab run.
 - New luminosity records were achieved, with a peak luminosity of $5.32 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$.
 - More stable operation improved the integrated luminosity accumulation rate.
- Several challenges remain for further luminosity improvement.
 - Higher beam currents and improved specific luminosity are essential.
 - SBLs, QCS quenches, injection limitations, and equipment failures remain major concerns.
- Preparations are underway for the 2027ab run.
 - Countermeasures are being implemented to improve beam performance and operational stability.
 - Further studies are needed to understand the present performance limitations.
- We would particularly appreciate the ARC's technical review and recommendations on our understanding of the present performance limitations, and our plans to overcome them.

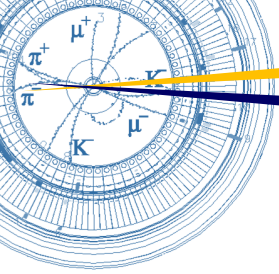


Fin.

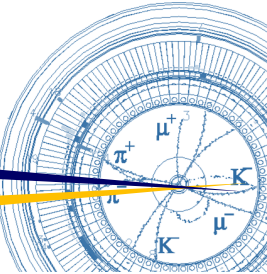


Thank you for your attention.

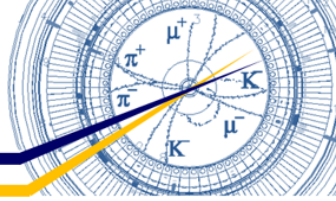




Back up



International collaboration



CERN–KEK Collaboration Overview / Joint Activities

Joint activity / Topic	KEK	CERN
Optics Modelling for FCC-ee and SuperKEKB incl. solenoid, crossing angle, overlapping elements, and fringe fields – automatic converter	Y. Ohnishi, K. Oide	J. Salvesen, G. Broggi, G. Iadarola, H. Burkhardt
Linear and nonlinear optics correction for FCC-ee and SuperKEKB	Y. Ohnishi	R. Tomas, M. Le Garrec, J. Keintzel
Modelling and mitigating emittance blow up in SuperKEKB BT line	T. Mori, N. Iida	J. Salvesen, N. Z. van Gils
Beam-Beam effects	H. Sugimoto	X. Buffat
IP feedback for FCC-ee and SuperKEKB	R. Ueki, M. Masuzawa	J. Salvesen
IP aberration tuning, including Bayesian optimization	H. Nakayama	J. Sai Jagabathuni, V. Gawas
Belle II background modelling	H. Nakayama	G. Broggi, J. Salvesen, G. Nigrelli, M. Boscolo
Modeling sudden beam loss events	M. Tobiyama, K. Ohmi	G. Iadarola, C. Wiesner
Quasi-Strong-Strong modeling of bootstrapping injection in FCC-ee	T. Mori, K. Oide	K. Oide, F. Zimmermann
Frequency scanning interferometry	R. Ueki, S. Nakamura	M. Sosin
Survey and alignment; Geodetic metrology	S. Nakamura, M. Masuzawa	F. Klumb
Structured laser beam for linac alignment and ground stability	R. Zhang	D. Mergelkuhl, M. Dusek
Structured laser beam for beam abort	H. Kaji	D. Mergelkuhl, M. Dusek

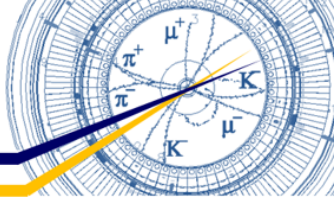
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A beam-beam TF is currently active with participation from CERN, China, and KEK

Joint R&D on the QCS upgrade is being conducted with FNAL and BNL.

Joint R&D on the dithering system with SLAC.





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