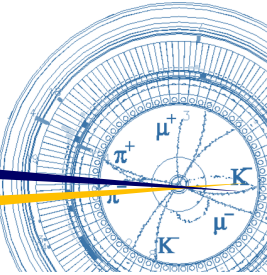


SuperKEKB Near-term Plan



The 28th KEKB Accelerator Review Committee
15th January 2025

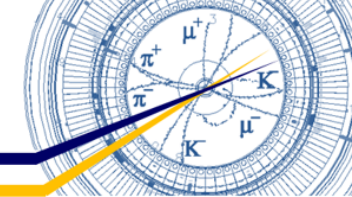
Kyo Shibata



Contents

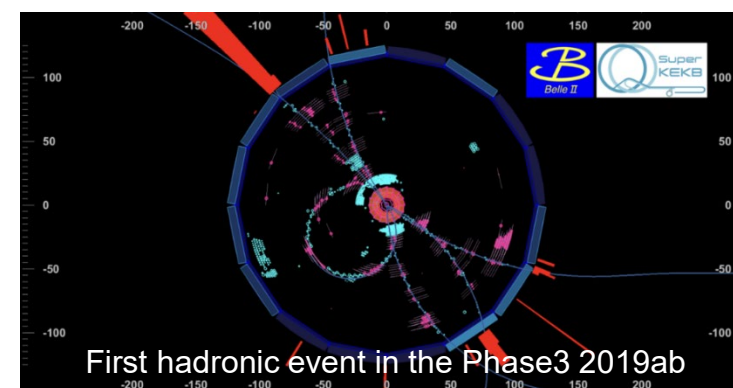
- Introduction
- Long-term plan update
- Near-term plan
 - 2025 run plan
 - Work items during shutdown
 - Strategy toward milestones
- Summary

SuperKEKB project history

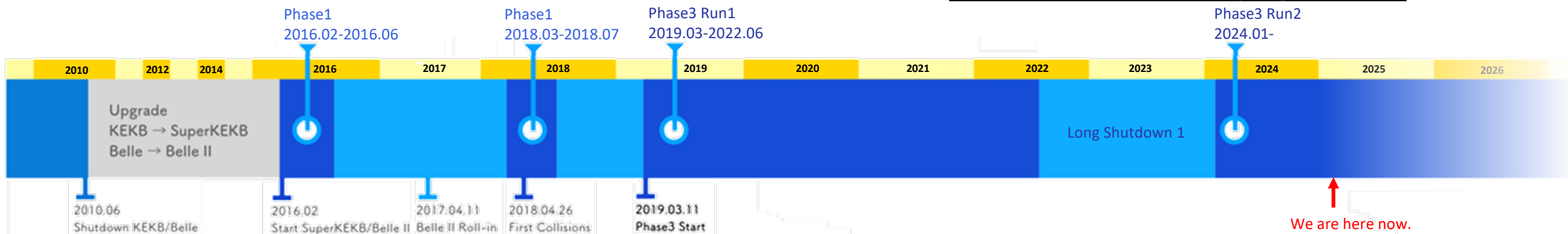


- Phase1 operation (2016.Feb. ~ June);
 - Vacuum scrubbing, low emittance beam tuning, and background study for Belle II detector installation
 - w/o final focusing system (QCS) and Belle II detector
- Phase2 operation (2018.Mar. ~ July);
 - Pilot run of SuperKEKB and Belle II w/o pixel vertex detector (PXD)
 - Demonstration of nano-beam collision scheme
 - Study on background larger than at KEKB due to much lower beta functions at IP.

- Phase3 operation (2019.March~);
 - Physics run with fully instrumented detector.
 - Phase3 Run1 : 2019.10~2022.7
 - Long shutdown 1 : 2022.7~2024.01
 - Phase3 Run2 : 2024.01~



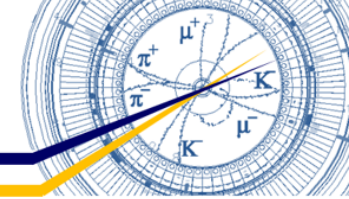
First hadronic event in the Phase3 2019ab



We are here now.



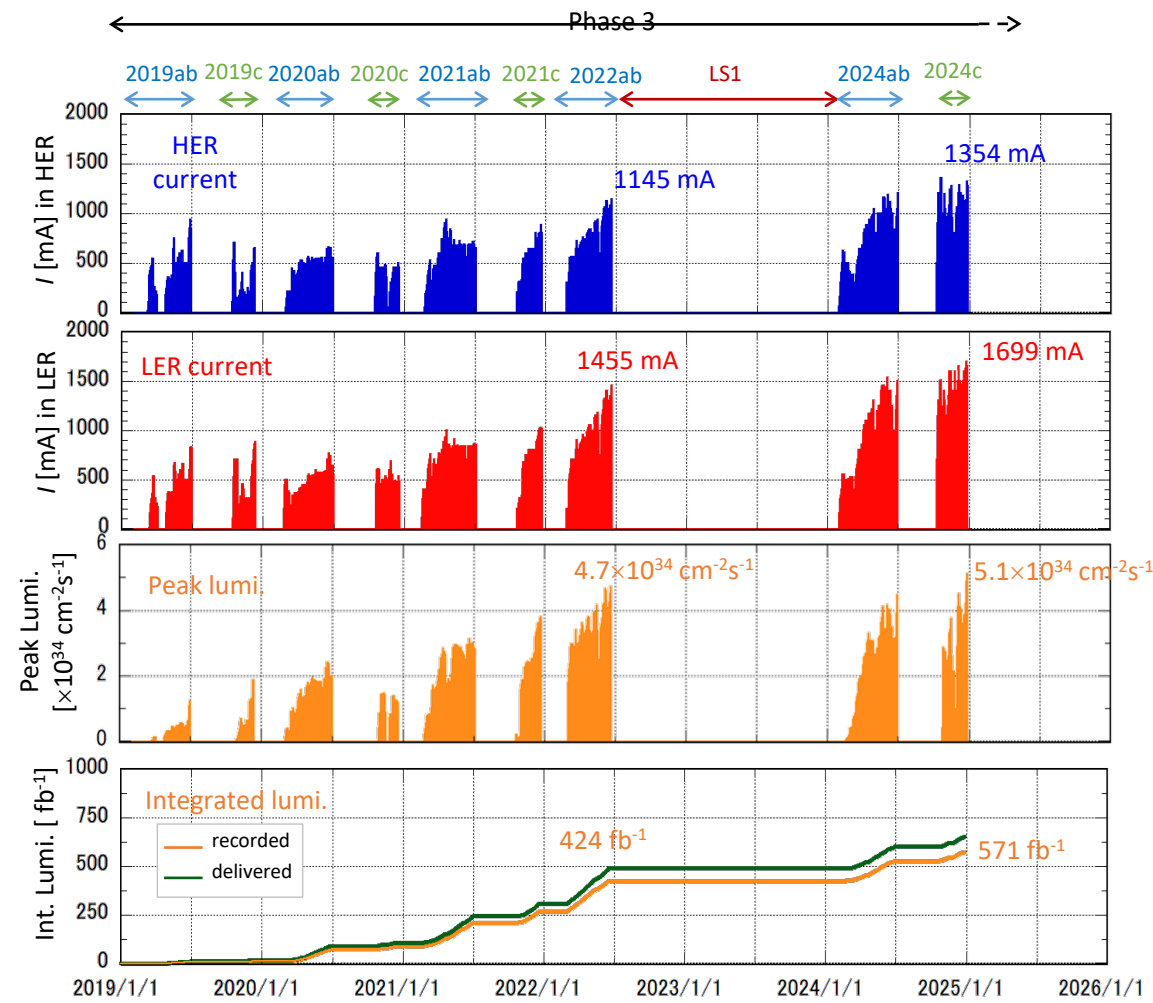
Phase 3 commissioning history



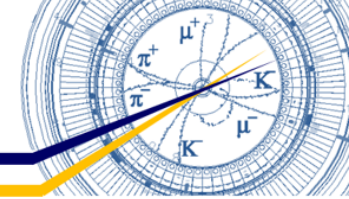
- Phase3 operation (2019.March~);
 - Physics run with fully instrumented detector
 - Naming rule of Phase3 operation

March is end of Japanese fiscal year.

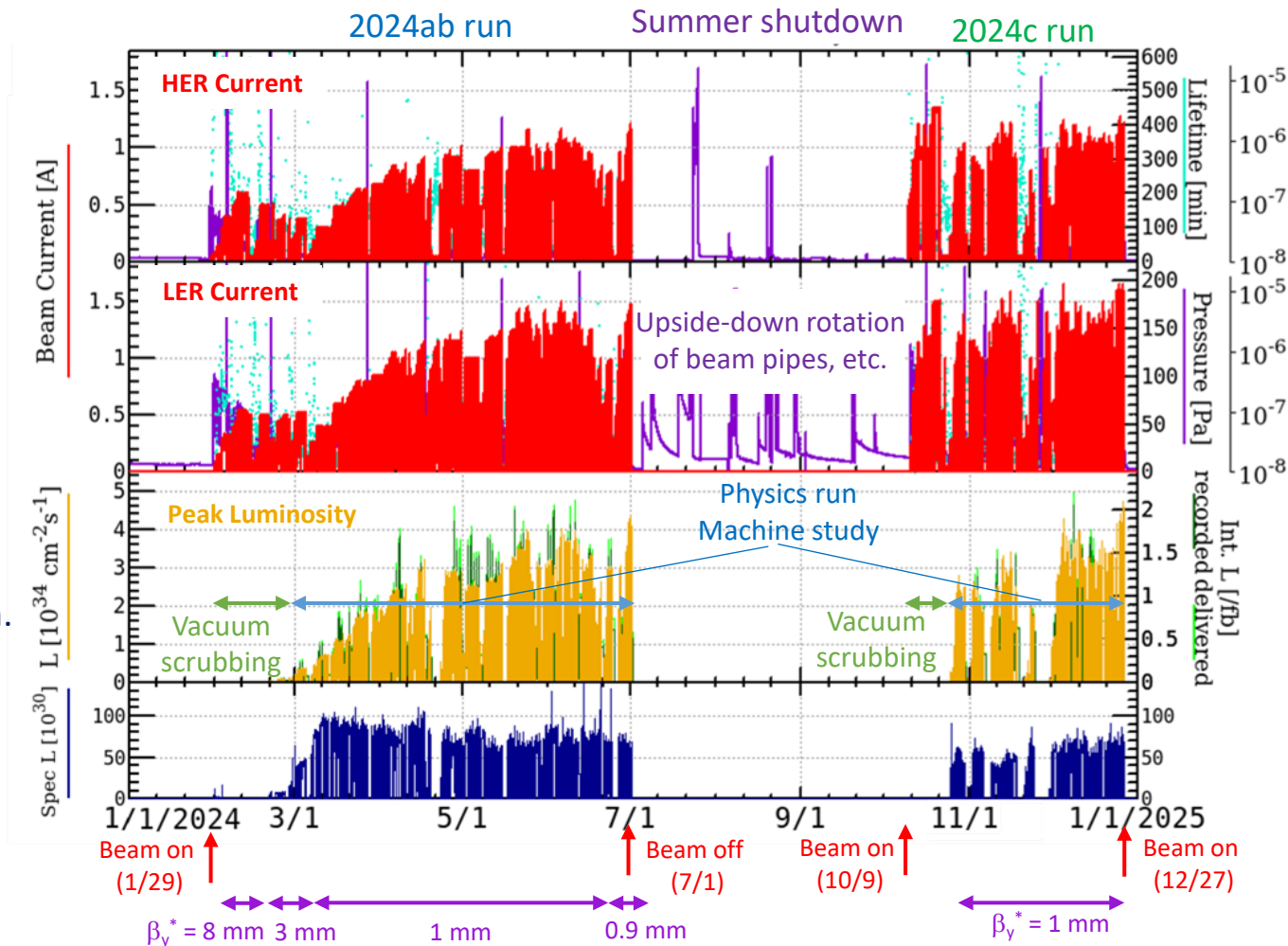
<ul style="list-style-type: none"> "YYYYxx run" <ul style="list-style-type: none"> Calendar year 	<ul style="list-style-type: none"> a : End of winter shutdown - March b : April – Start of summer shutdown ab : End of winter shutdown – Start of summer shutdown c : End of Summer shutdown – Start of winter shutdown
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- 2019/March-2022/Jun : Run1
 - 2019c, 2020ab, 2020c, 2021ab, 2021c, 2022ab
 - Luminosity (peak/integrated) : $4.7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}/424 \text{ fb}^{-1}$
 - β_y^* squeezing : $\sim 0.8 \text{ mm}$ (1 mm for most of the time)
 - Maximum beam current : HER/LER = 1145/1455
 - Facing various challenges for luminosity improvement
 - Severe beam-beam effect, Shorter beam lifetime, Lower bunch current limit, Low machine stability, Low injection efficiency, Sudden beam loss, Aging of hardware and facilities.
- 2022-2024 : Long shutdown 1 (LS1)
 - Accelerator upgrades
 - Belle II reinforcement and maintenance
- 2024/Jan.- : Run2
 - 2024ab, 2024c, ...
 - Luminosity (peak/integrated) : $5.1 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}/571 \text{ fb}^{-1}$ (total)
 - β_y^* squeezing : $\sim 0.9 \text{ mm}$ (1 mm for most of the time)
 - Maximum beam current : HER/LER = 1354/1699
- 2032? : Long shutdown 2 (LS2)



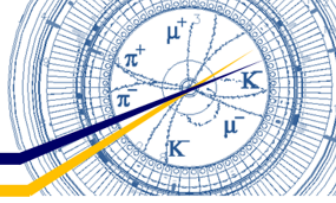
2024ab & 2024c run overview



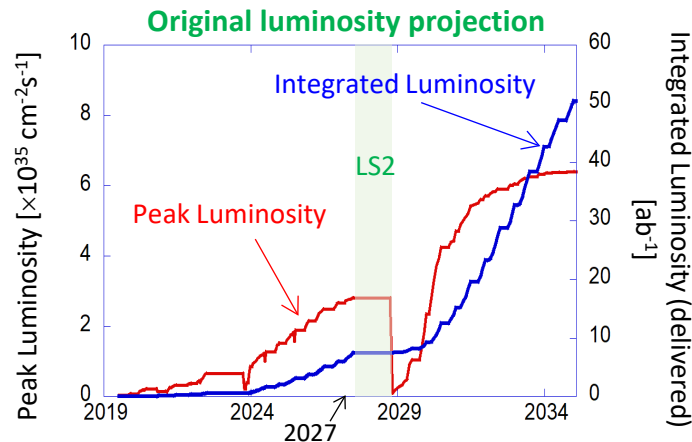
- 2024ab run : 2024/Jan./29 – July/1, 155 days
 - Start-up after a long shutdown
 - First demonstration of the effectiveness of the NLC system
 - Peak luminosity : $4.47 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
 - Maximum beam current : HER/LER = 1210/1539 mA
 - β_y^* -squeezing (Vertical β -function at IP) : $\sim 0.9 \text{ mm}$
 - Mostly operated with $\beta_y^* = 1.0 \text{ mm}$
 - Struggled with Sudden Beam Loss, poor injection efficiency, low machine stability
- Summer shutdown
 - Upside-down rotation of beam chambers with electron clearing electrodes at Oho wiggler section
- 2024c run : 2024/Oct./9 – Dec. /27, 79 days
 - Target luminosity : $1 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$
 - More time was spent on machine studies than on physics run.
 - Verification of SBL measures during summer shutdown
 - Machine studies to increase beam currents
 - Machine studies to investigate HER vertical beam blowup
 - Peak luminosity : $5.1 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ (Belle II HV off)
 - We updated our record!!
 - Maximum beam current : HER/LER = 1354/1699 mA
 - β_y^* -squeezing (Vertical β -function at IP) : 1.0 mm
 - Still struggled with SBL
 - But, it was found out that the VACseal is a most likely cause of SBL.



Long-term plan

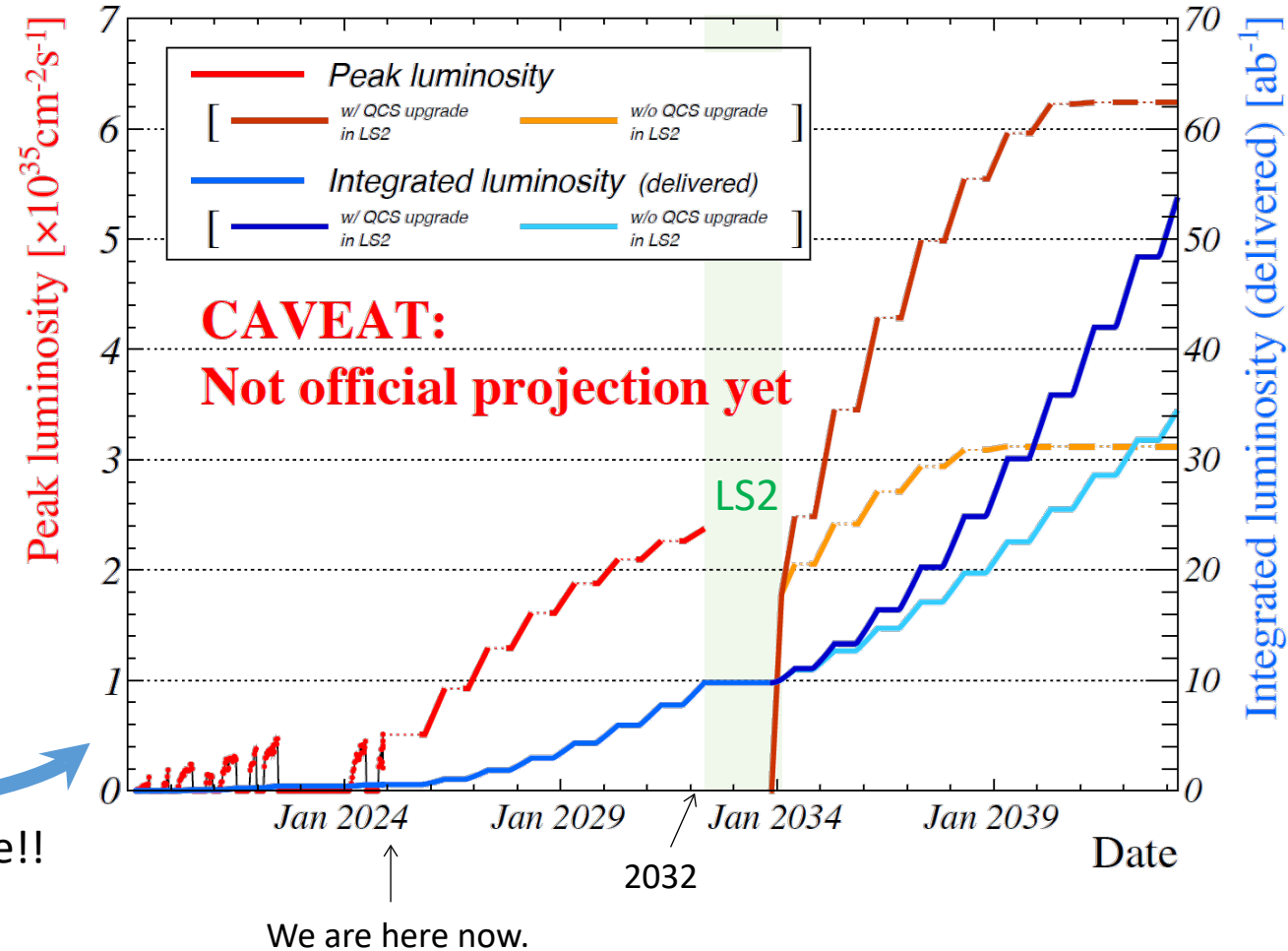


- New long-term plan is currently being created.
 - The proposed luminosity projection is under review.
 - New plan is expected to be finalized in near future.
- Major changes from original plan:
 - Long Shutdown 2 (LS2) is moved from 2027 to around 2032.
 - After LS2, luminosity projection shows two lines.
 - luminosity improvement of $\times 1.3$ is expected due to the beam current increase mainly by the RF reinforcement (beam current increasement).
 - IR upgrade is assumed to be able to increase the luminosity much more.
 - Technical feasibility of the IR upgrade and the exact luminosity gain remain uncertain.
 - Operation needs to be continued by 2042 to deliver 50 ab^{-1} with IR upgrade.

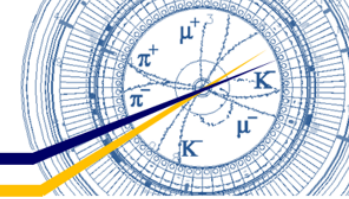


Update!!

New luminosity projection (under consideration)

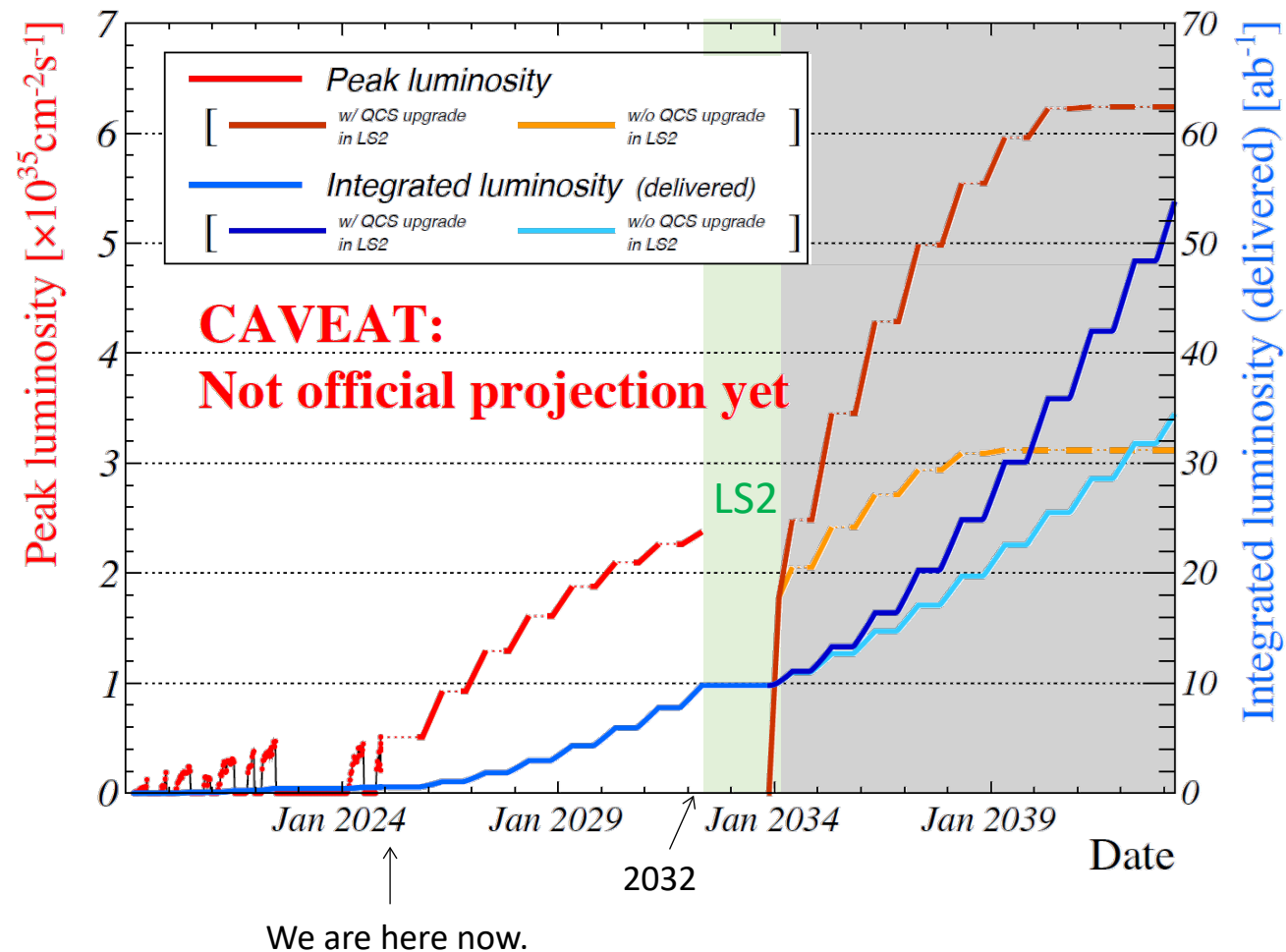


Important milestones before LS2

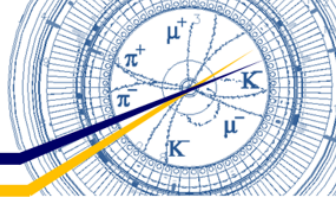


- Integrated luminosity target;
 - 0.58 ab^{-1} in JFY2024 (current value)
 - 1 ab^{-1} in JFY2025
 - 2 ab^{-1} in JFY2026
 - 5 ab^{-1} by around 2028-2029
 - LHC Run3 results will appear around 2028-2029
- Peak luminosity target;
 - $0.51 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ by the end of JFY2024 (current value)
 - $1.0 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$
 - $2.4 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ before LS2

New luminosity projection (under consideration)



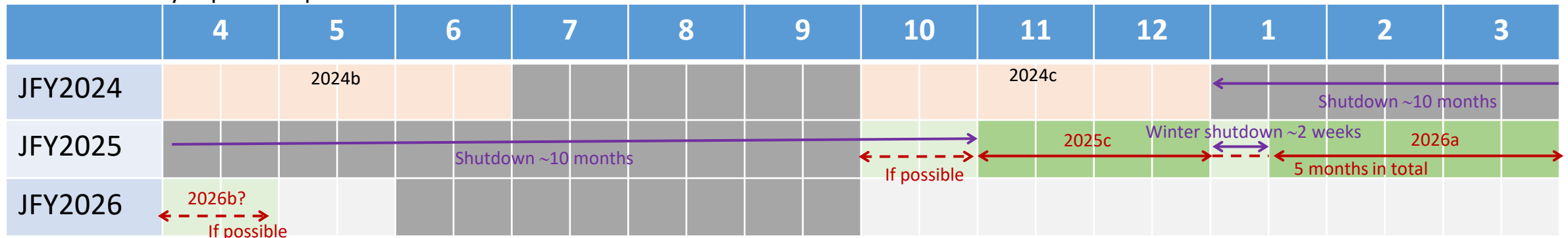
2025 run plan



- By the end of JFY2024
 - Operation is impossible by the end of February due to updating of power receiving equipment.
- From the perspective of operation efficiency
 - The run period should be as long as possible to make the operation efficient.
 - It should be at least 3 months.
 - Operation should be avoided in June as it is too hot and will reduce efficiency.
- From the perspective of budget
 - KEK requested budget for 7 months operation to [MEXT](#). [MEXT](#) : Ministry of Education, Culture, Sports, Science and Technology
 - MEXT is very supportive for SuperKEKB/Belle II and is asking [MOF](#) for increase of the budget. [MOF](#) : Ministry of Finance
 - However, we cannot expect a significant budget increase under Japanese budget system.
 - Assuming a realistic slight budget increase, the expected operation time in JFY2025 would be 3.5 months.
 - Supplementary budget for 1.5 months operation for JFY2024 can be carried over to JFY2025.
 - Realistically expected operation time in JFY2025 would be 5 months.



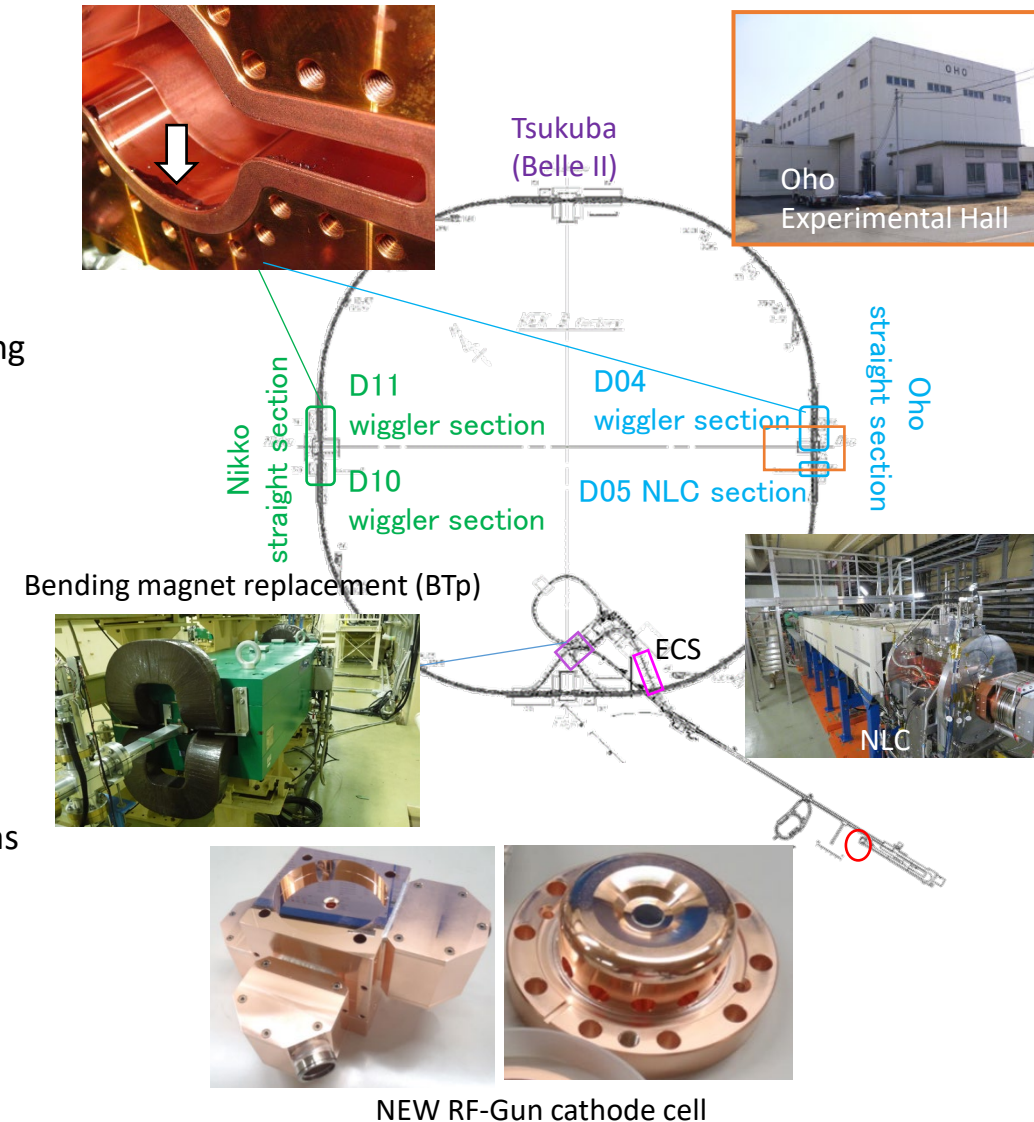
- Our decision;
 - 2025ab run will be skipped.
 - 2025c run and 2026a run will be conducted.
 - 2025c run will start in November.
 - Winter shutdown will be shortened as much as possible. (~2 weeks)
 - 2026a run will be continued by the end of JFY2026.
 - With more supplementary budget, 2025c or 2026b will be extended.
- We are in 10-month shutdown now.
 - It is required to prioritize works to increase both peak luminosity and integrated luminosity in the next run.
 - Human resources and budget are limited.



Works during this shutdown 1

- Major work items (decided)

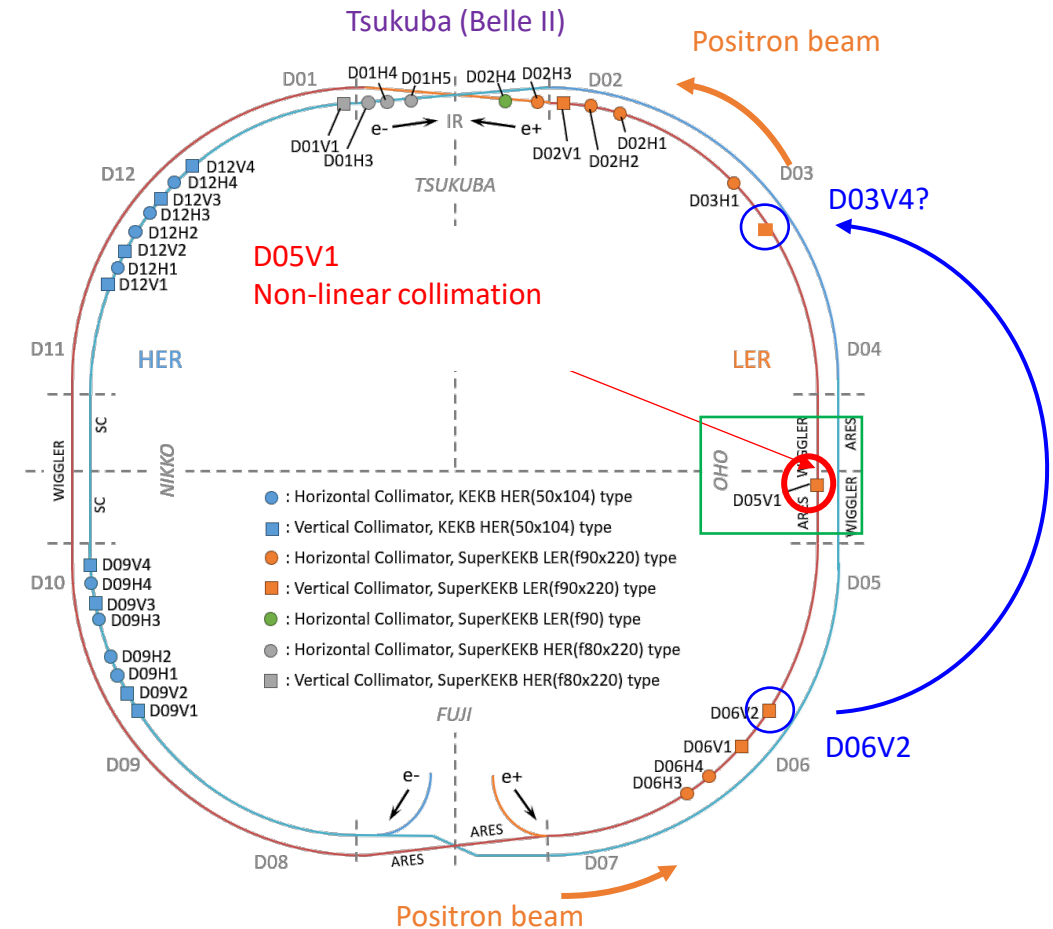
- Radiation shielding reinforcement and expanding radiation control area near Oho exp. Hall.
 - Required for achieving higher LER beam current using NLC at OHO.
- Linac RF gun replacement
 - New RF-gun cathode will be delivered by the end of March and be installed during next summer.
- ECS installation at BTe
 - Accelerating structure will be installed at BTe by the end of March and new ECS will be available from 2025c run.
- Bending magnet replacement at BTp
 - A few old bending magnets will be replaced during next summer.
- Inner cleaning of beam chambers at LER wiggler sections
 - Countermeasure against LER SBL
 - Upside-down rotation of beam pipes with electrodes at Nikko wiggler section was canceled.
- Various works carried out by the Plant and Facilities Department
 - Roof renovation work in Tsukuba Hall
 - Replacement of 6 kV HV power cables



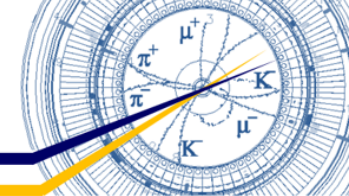
NEW RF-Gun cathode cell

Works during this shutdown 2

- Other work items (under consideration)
 - LER D06V2 collimator relocation to D03 Arc section
 - To protect Belle II and D02V1 collimator from uncontrollable beams
 - The best location is currently being determined.
 - Countermeasure against HER SBL
 - we need to do something, but we don't have any concrete plans yet.
 - And so on.
 - We appreciate your suggestions and recommendations!!
- Creating a commissioning plan of 2025c&2026a run
 - The specific plan is yet to be created.
 - Luminosity target;
 - Peak luminosity : $1 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
 - Integrated luminosity : 1 ab^{-1}



Strategy toward $1.0 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$



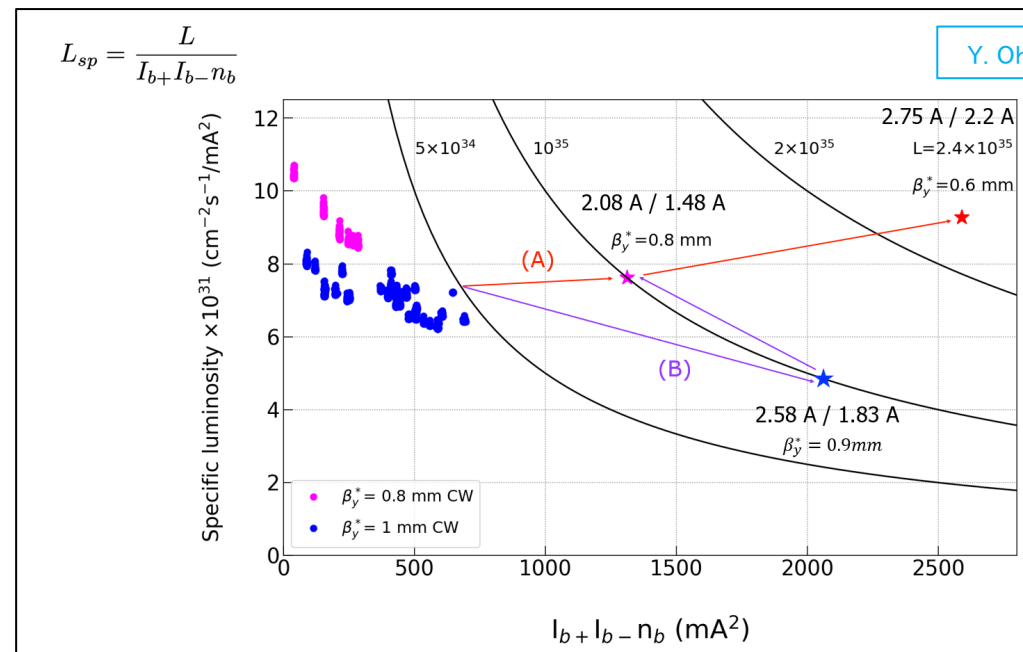
• Strategy toward $1.0 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$: Route (B)

- Increase beam current with $\beta_y^* = 0.9 \text{ mm}$
- Target current : 2.58 A / 1.83 A
 - Improve injection under influence of Beam-Beam interactions
 - Reduce injection errors with modified injection scheme
- Required specific luminosity : $L_{sp} = 5 \times 10^{31} \text{ cm}^{-1}\text{s}^{-1} \text{ mA}^{-2}$

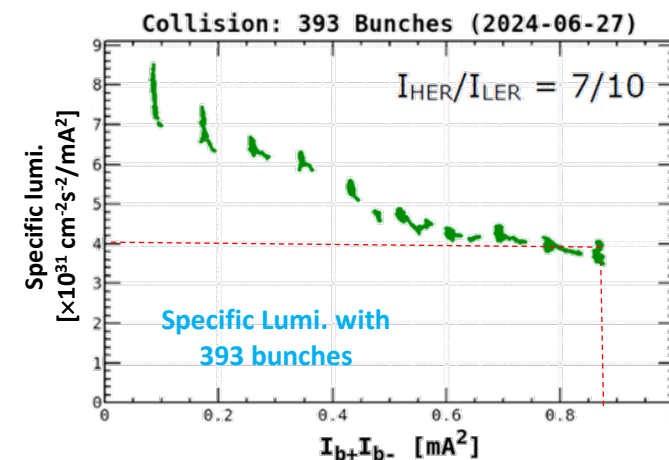
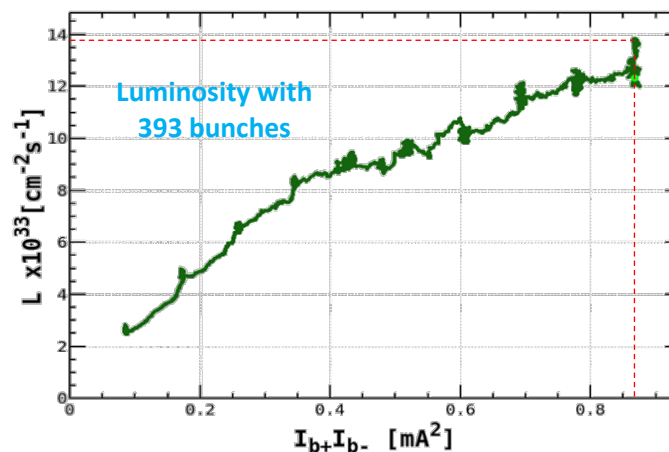
• 2024ab results and outlook

- With 393 bunches (Result of high bunch current study)
 - $L(393 \text{ bunches}) = 1.38 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
 - $L_{sp}(393 \text{ bunches}) = \sim 4 \times 10^{31} \text{ cm}^{-1}\text{s}^{-1} \text{ mA}^{-2}$
 - Degradation due to beam blowup at high bunch current
- With 2346 bunches (outlook)
 - $L(393 \text{ bunches}) = 1.38 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$

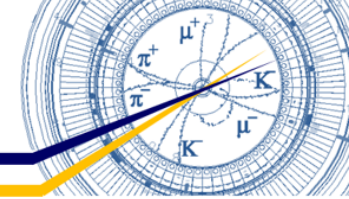
$\downarrow \times 2346/393$ (increase bunches)
 $8.27 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
 $\downarrow \times 5/4$ (L_{sp} improvement)
 $1.0 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$



Y. Ohnishi

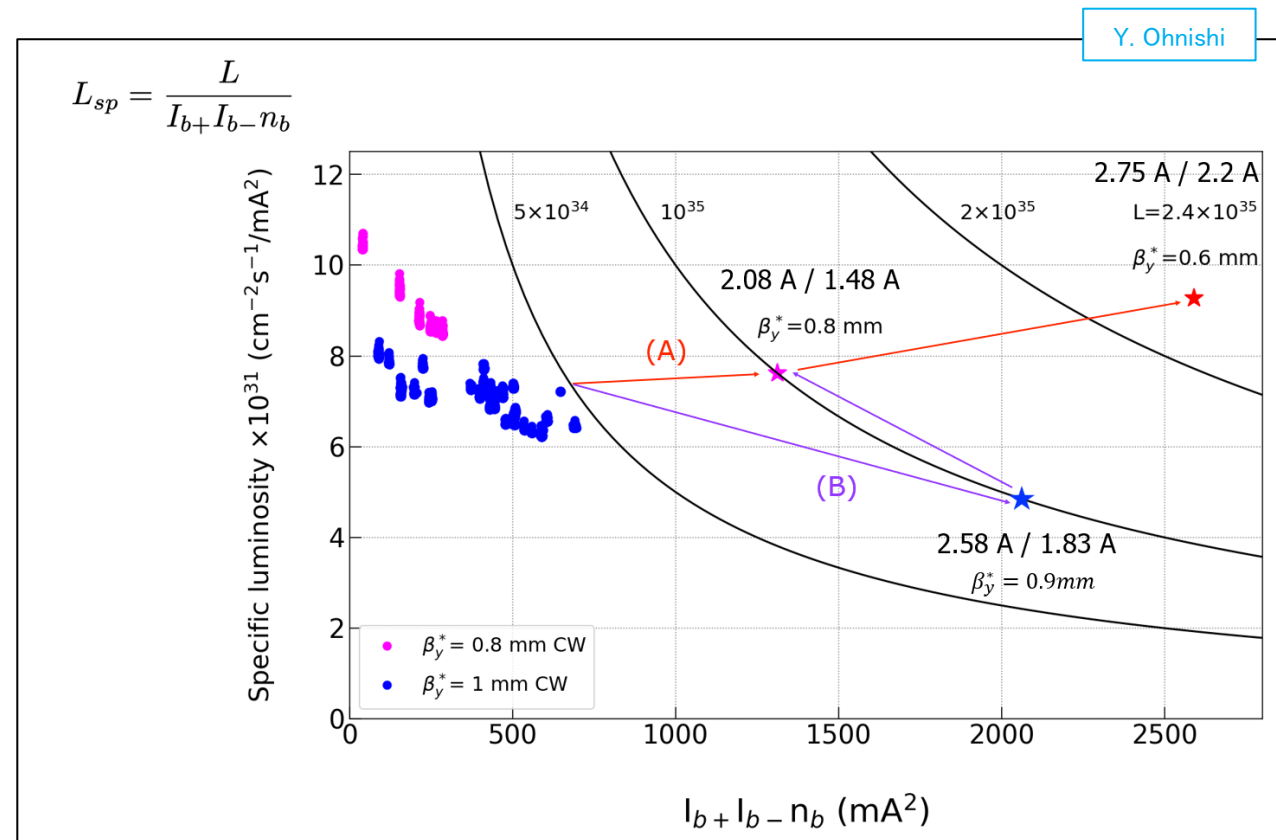


Strategy toward $2.4 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$

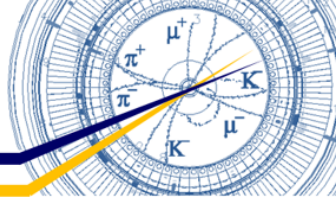


• Strategy toward $2.4 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$: **Route (A)**

- β_y^* squeezing down to 0.6 mm :
 - Down to 0.6 mm from 0.9 mm (3 steps)
 - Dynamic aperture improvement :
 - Sextupole optimization
 - Off-momentum optics tuning
 - Comparison between simulations and measurement
- Increase beam current : 2.75 A/ 2.2 A
- Increase specific luminosity (Beam-beam parameter)
 - Up to $L_{sp} \sim 9 \times 10^{31} \text{ cm}^{-1}\text{s}^{-1} \text{ mA}^{-2}$
 - **Improve prediction accuracy of Beam-Beam simulation**

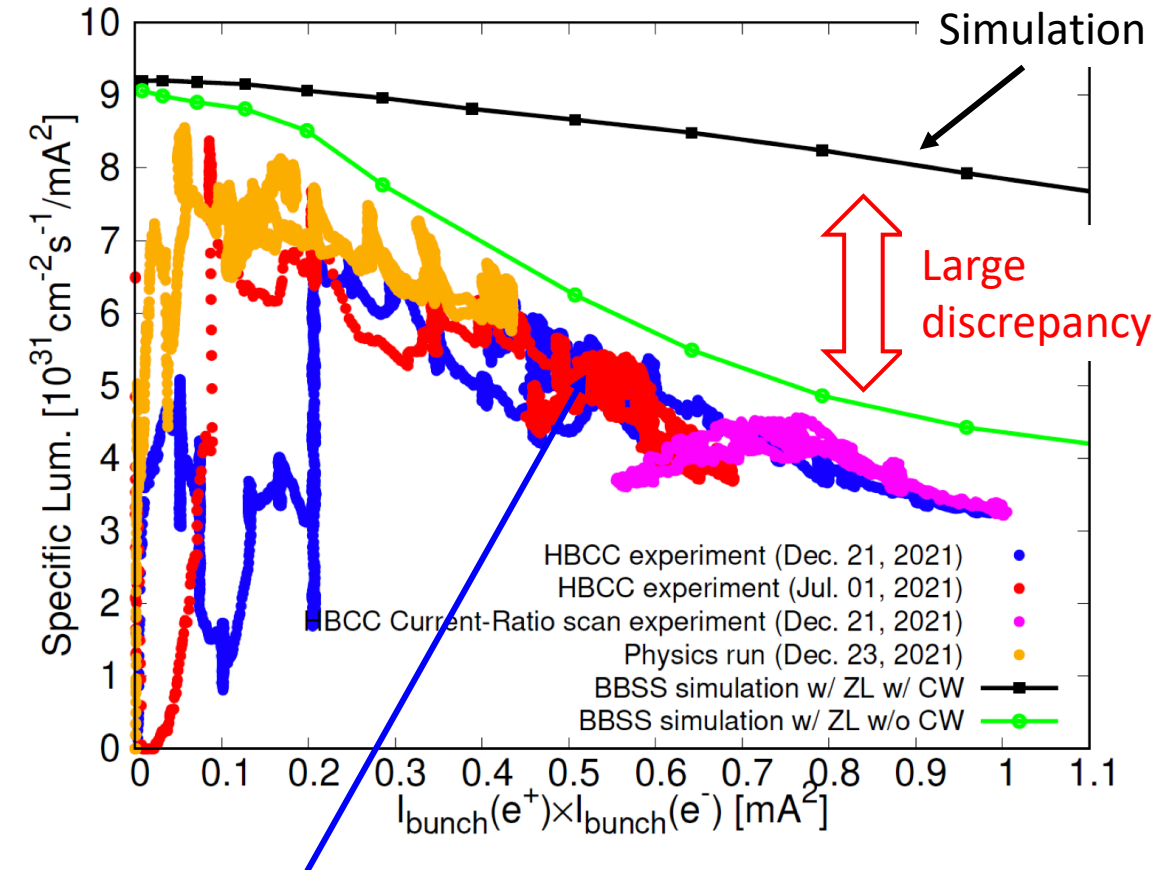


Strategy toward $2.4 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$



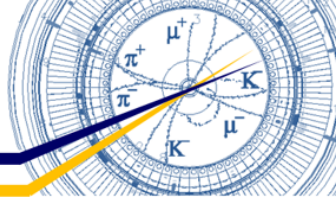
- Beam-Beam simulation shows much higher specific luminosity
 - It is still unclear why experimental results are much smaller than the simulation.
 - Can simulation miss some important factors?
 - There should be hints to increase luminosity of SuperKEKB.
 - If we identify the cause of the reduction in the luminosity, measures can be taken to improve luminosity.
- Important issue not just for SuperKEKB, but for future colliders with nano-beam collision scheme.
- Currently working on establishing a framework for international collaboration with CERN, IHEP, etc. especially on Beam-Beam simulations.
 - Several researchers will join SuperKEKB beam-beam team for 1-2 years to solve the mystery of SuperKEKB.

Strong-Strong Beam-Beam simulation (D. Zhou)



Experimental results

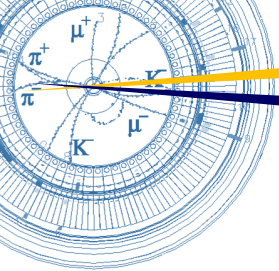
Summary



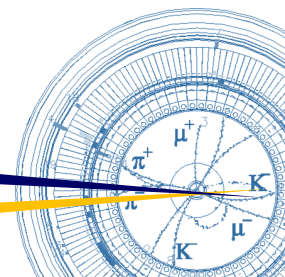
- Long-term plan
 - New long-term plan is currently being created.
 - Operation needs to be continued by 2042 to deliver 50 ab^{-1} with IR upgrade.
 - Major changes from original plan are
 - LS 2 is moved from 2027 to around 2032
 - After LS2, luminosity projection shows two lines (w/ and w/o IR upgrade)
 - Technical feasibility of the IR upgrade and exact luminosity gain remain uncertain.
- 2025 run plan
 - 2025ab run will be skipped.
 - 2025c run and 2026a run will be conducted.
 - Winter shutdown will be shortened as much as possible.
 - With more supplementary budget, 2025c or 2026b will be extended.
 - We are just beginning a 10-month shutdown.
- During the 10-month shutdown
 - Work items is currently under consideration.
 - It is required to prioritize works to increase both peak and integrated luminosity in the next run.
 - Specific commissioning plan is yet to be created.
 - Luminosity target : $1 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ (peak) / 1 ab^{-1} (total integrated)

We really appreciate your recommendations and suggestions!!



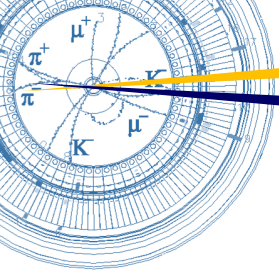


Fin.



Thank you for your attention.





Back up

