SuperKEKB recent status and near- (until 2022b) and long-term operation plan

Y. Suetsugu

KEK Acc. Div.

- Details of long-term plan will be reported by Tobiyama-san.
- Beam injection issues will be covered by Iida-san.
- Collimator and TMCI issues will be covered by Ishibashi-san.

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- Long-term operation plan

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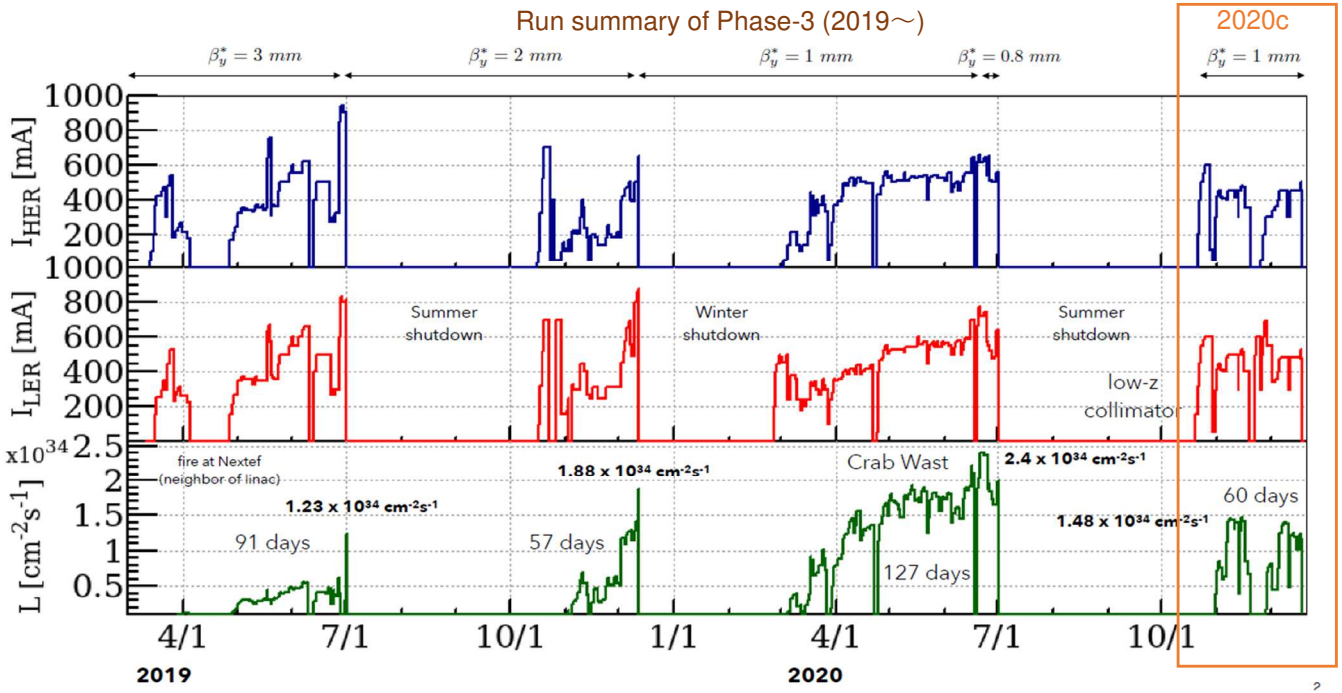
- Long-term operation plan

Brief review of MR in 2020c run

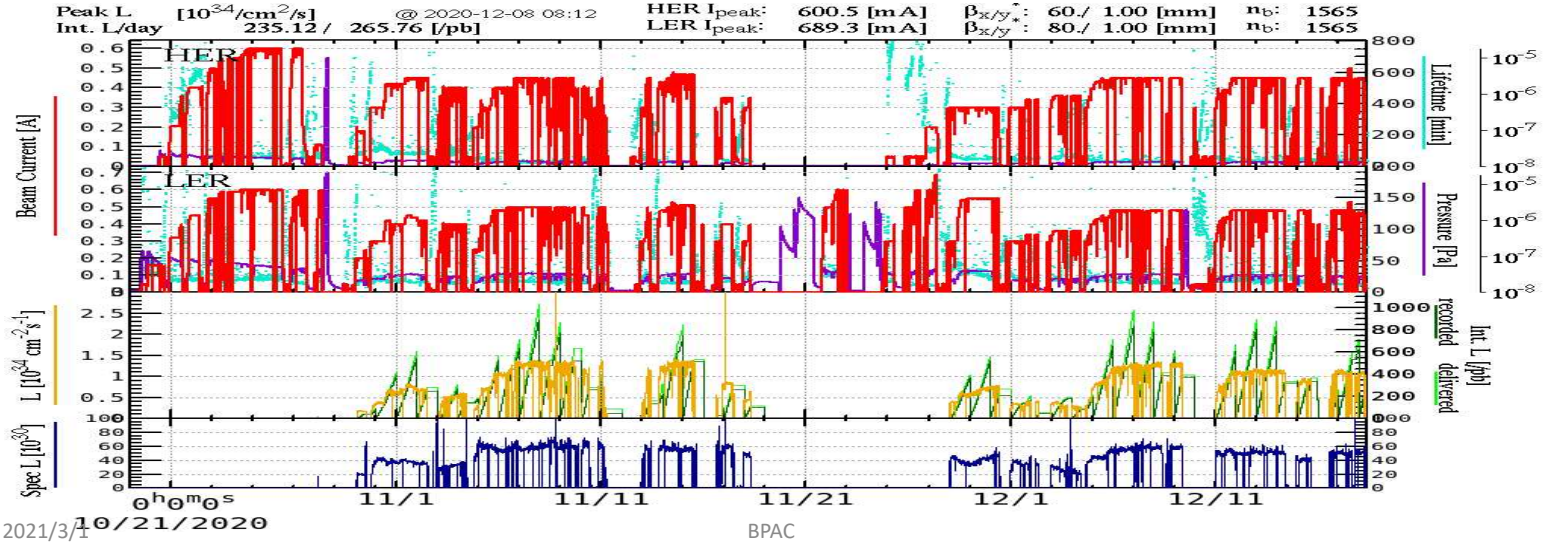
- SuperKEKB is continuing the physics run (Phase-3 operation) while struggling to improve the performance.
- 2020c run started on 19th Oct. and ended on 18th Dec., as scheduled.



Brief review of MR in 2020c run

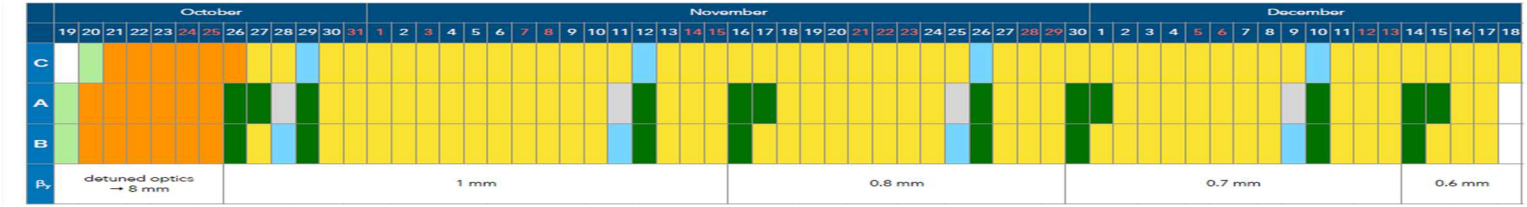
- In summary, the 2020c run was very challenging one.
  - The operation condition has been far from that in 2020b run.
    - Imax(LER) = 690 mA (27th Nov.), Imax(HER) = 600 mA (24th Nov) during vacuum scrubbing.
    - Max. peak luminosity was 1.48E34 $cm^{-2}s^{-1}$ (14th Nov.).
    - Min. β_y^* was 1.0 mm.
  - Various challenges and limitations were revealed.

2020c run summary (2020/10/19~2020/12/18)

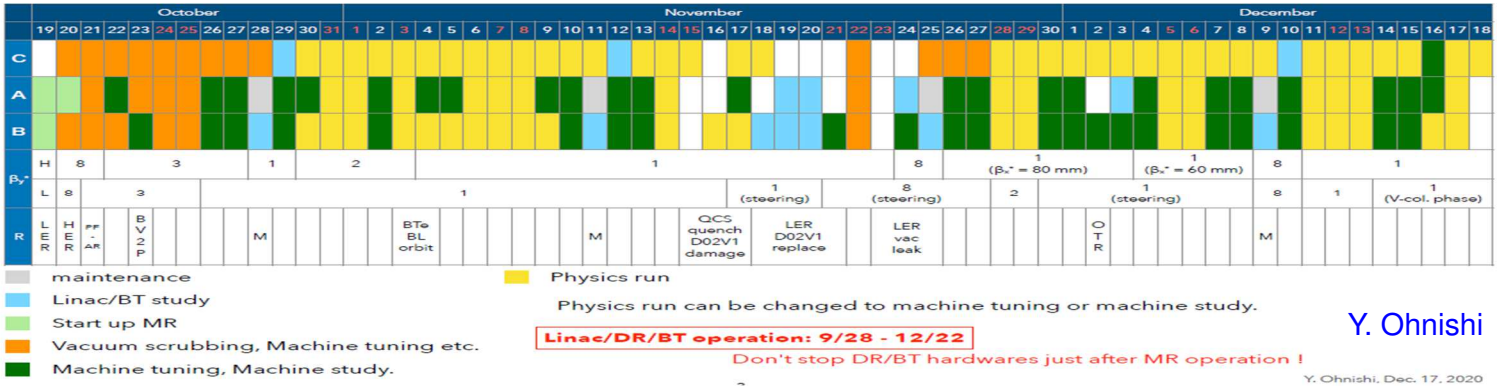


Brief review of MR in 2020c run

- Initial shift plan
  - 60 days (120 shifts) in total.



- Actual shifts
  - Most of day and swing shifts of weekdays were consumed to beam studies and tunings.



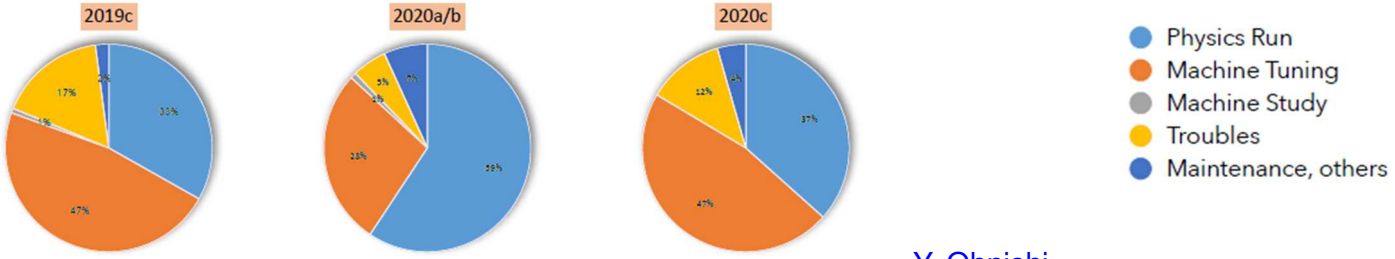
Y. Ohnishi

Brief review of MR in 2020c run

- Statistics
  - Lots of time were consumed to beam studies and tunings.
  - The operation statistics was accidentally similar to that of 2019c run, which was dedicated to the machine tuning.

→Need to increase machine availability for physics run as much as possible.

Please check the detailed run summary reports in “2020c Summary for Belle II” meeting. (https://kds.kek.jp/event/36742/)



Physics run: 33 %
Machine tuning: 47 %
2019c was dedicated to the machine tuning.

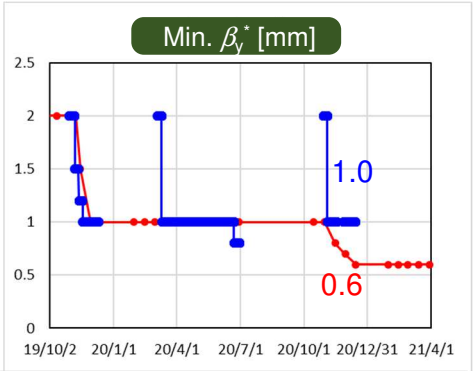
Physics run: 59 %
Machine tuning: 28 %

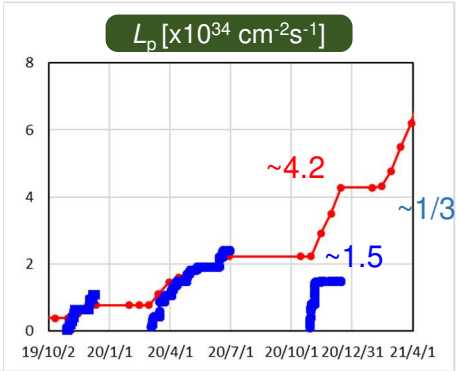
Physics run: 37 %
Machine tuning: 47 %

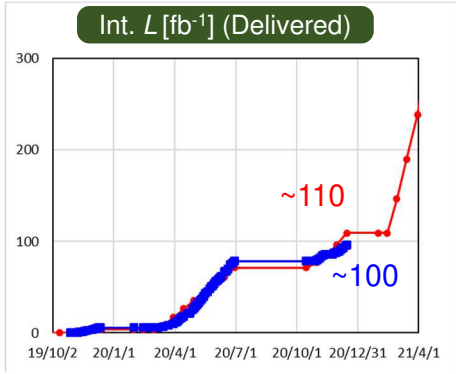
Y. Ohnishi

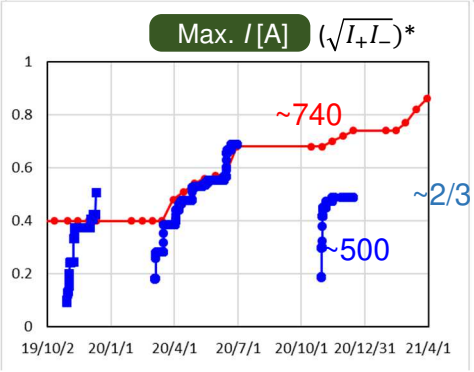
Brief review of MR in 2020c run

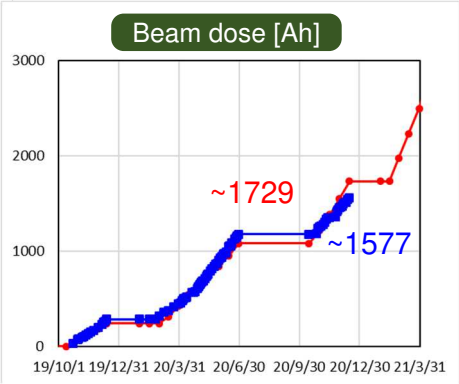
- Achieved luminosities and other major parameters











From 2019c run

- Original Plan
- Result until 2020c

	β_y^*	L_p	Int. L	I_{max}	Beam dose
Plan	0.6	~4.2E34	~110	~740	~1720
Result	1.0	~1.5E34	~100	~500	~1580

*Note: in the plan, the ratio of LER/HER beam currents are assumed to be 3.6/2.6, i.e., the ratio of the design currents.

Brief review of MR in 2020c run

- Main causes of the low luminosity
  - Lower beam currents than expected (~500 mA < ~740 mA)
    - Low injection efficiency
      - Unstable beams from BT and Linac
        - Time change (periodical change and drift) of beam orbits, energy spreads
        - Frequent break downs of RF-gun cavity
      - Low injection efficiency on HER (not “explosion” although still large)
        - Low physical aperture at injection points?
      - Short lifetime due to small physical and/or dynamic aperture in the ring
    - High background (especially background by injected beam)
      - Sometimes depended on optics.
    - Beam-size blow-up due to beam instability caused by collimator impedance in LER
    - Beam-size oscillation and/or blow-up due to beam-beam effect at high bunch currents
    - Hardware troubles -> limit max. beam currents.
      - Beam collimator, Cooling water system
  - Larger β_y^* than expected (1.0 mm at most > 0.6 mm)
    - Little time to try the low β_y^*. Even the condition of β_y^* = 1 mm has not been resumed.
- As a result, integrated luminosity was also lower than expected.

Brief review of MR in 2020c run

- Major challenges in 2020c run
  - Internal leak in a SC cavity of HER
  - Poor injection efficiency (through 2020c)
    - Many reasons, such as mis-setting of magnet parameters in BT, frequent break-down of RF-gun cavity, time change (oscillation and drift) of BT/Linac orbit and energy, narrow physical or dynamic aperture of the rings, beam instability, and so on.
  - Difficulty in squeezing HER β_y^* to 1 mm
  - High background by injected beams
  - Damage of D02V1 collimator jaw, and exchange work (~1 week break)
  - Big air leak from D02V1 collimator flange
  - Difficulty in resuming the LER/HER condition after the collimator trouble
    - High background by injected beam with new steering-magnet settings
  - TMCI in LER due to impedance of collimators
    - Strong excitation of TMCI with new phase-adjusted LER Optics
  - Vertical beam size oscillation and blow-up in HER due to beam-beam effect
  - Failure in cooling water pump
  - Etc.

See run summaries reports in “2020c Summary for Belle II” meeting. (https://kds.kek.jp/event/36742/)

- Some were solved, but some were not and to be studied further.

Preparation for 2021a run

- Main hardware work during 2021 winter shutdown for 2021a run
  - Replacement of D11D SC cavity to a reserve (HER)
    - The completion inspection and the issuance of completion certificate as a high-pressure gas device from the government agency, is expected in around mid of Feb.
  - Replacement of D06V1 collimator jaws (LER)
    - From 60 mm carbon to 5 mm tantalum
    - Reduction in the impedance is expected.
  - Replacement of D09V3 collimator jaws (HER)
    - KEKB type titanium jaw.
  - Replacement of D12V1 collimator drive mechanism (HER)
    - More precise positioning is expected.
  - *In situ* baking of D02V1 and D06V1 collimators (LER)
    - Reduction in the base pressure is expected.
  - Application of injection-veto modules to LM signals near collimators not to stop collimator and/or injection tunings
  - Installation of a collimator in the Linac electron line (BTe SY3)
  - Replacement of aged 66 kV high-voltage power supply lines [by Facility Department]
  - Other maintenance works
    - Repairs of aged power supplies for magnets, etc.

Preparation for 2021a run

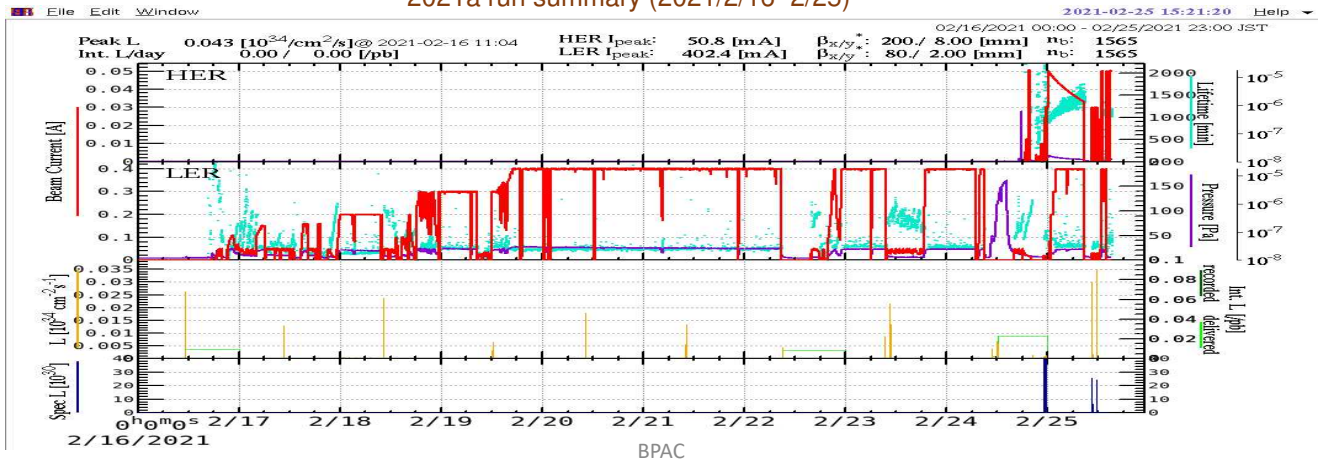
- Other improvements for 2021a run
  - Upgrade the backet-selection system to offer a degree of freedom in a choice of injection buckets.
    - Enables tow-pulse operation at DR
  - Prepare an interlock system in case of cooling water trouble for vacuum system.
    - Combined interlock with colling-water flow-meters and vacuum pressures.
  - Prepare an alarm system which indicates a possibility of collimator damage.
    - Combined alarm with pressure bursts and VXD signals.
  - Prepare a software to restore, check, and compare various setting parameters in BT (such as magnet settings) before starting run.
    - Discussion has started together with Belle II staff.

- Lessons not to follow the same rut
  - Do not forget beginner's mind even if it is a familiar work.
    - Use tooling as specified, for example.
  - Do not drastically change parameters at once, such as beam optics parameters.
    - Change them step by step while checking.

Present status

- 2021a run
  - The 2021a run has started on 16th Feb, 2021.
  - The first week was used for various studies, tunings and vacuum scrubbing of LER, and also for beam tunings of electron/positron beam transport lines.
    - A big progress was already made on the stable two-bunch injection in LER.
  - HER started from 24th Feb. after finishing cooling down and RF aging of super-conducting cavities (SCCs). (one troubled SCC was exchanged during the winter shutdown)
  - The collision tuning will start from 26th Feb., with β_y^*=2 mm.
  - The physics run with β_y^*= 1 mm will start from 1st Mar.

2021a run summary (2021/2/16~2/25)



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- Long-term operation plan

Schedule

- Operation schedule
  - 2021a run will end on 31st Mar.
    - Total operation period will be ~6.4 months in FY2020, thanks to the support from our director.
  - The process for the FY2021 budget request is ongoing. The followings are present plan.
    - 2021b run will start on 1st Apr. and end on 5th July. [Fixed]
    - 2021c run will start in the mid of Oct. and end around late Dec..
    - 2022a run will start in Feb. and end at the end of Mar..
      - Total operation period will be ~7 months in FY2021.
    - 2022b run will start on 1st Apr. and end in the middle of Jul..
      - Total operation period will be at most ~3.5 months in FY2022.
  - The PXD exchange work (LS1) will start from July, 2022. → See Ushiroda-san's talk.
  - Here we roughly divide the runs to two phases: "2021a, b, c" and "2022a, b"

	2020									2021			
FY2020	4	5	6	7	8	9	10	11	12	1	2	3	
Present plan (20th Oct.)		2020b ~3M	→					2020c ~2M	→			2021a ~1.4M	Total ~6.4M/y
	2021									2022			
FY2021	4	5	6	7	8	9	10	11	12	1	2	3	
Plan (not fixed)	4/1	2021b ~3.1M	→	7/5			10/19	2021c ~2.2M	12/23		2/9	2022a ~1.7M	Total ~7.0M/y
	2022									2023			
FY2022	4	5	6	7	8	9	10	11	12	1	2	3	
Plan (not fixed)		2022b ~3.5M	→	7/15	LS1 (PXD exchange)								Total ~3.5M/y

Goal

- Goal for 2021a, b, c runs
  - Put priority on the luminosity production.
  - Produce new physical results from enough data, over 400 fb^{-1} at least by the end of year.
    - For ref., the final integrated luminosity of BaBar is 424.2 fb^{-1} @Y(4s). (NIM A726 (2013) 203)

  → Realize stable operation at a high luminosity.
- Goal for 2022a, b runs
  - Shift focus onto the machine study and tuning anticipating luminosity boost after the LS1.
    - Gain a greater understanding of this difficult machine.
    - Get more information for making a decision of middle-upgrade of IR planned around 2026 (see Long-term plan)
  - Accumulate more luminosity before the LS1.

	2020									2021			
FY2020	4	5	6	7	8	9	10	11	12	1	2	3	
Present plan (20th Oct.)		2020b ~3M	→					2020c ~2M	←			2021a ~1.4M	Total ~6.4M/y
	2021									2022			
FY2021	4	5	6	7	8	9	10	11	12	1	2	3	
Plan (not fixed)	4/1	2021b ~3.1M	→	7/5			10/19	2021c ~2.2M	12/23		2/9	2022a ~1.7M	Total ~7.0M/y
	2022									2023			
FY2022	4	5	6	7	8	9	10	11	12	1	2	3	
Plan (not fixed)		2022b ~3.5M	→	7/15	LS1 (PXD exchange)								Total ~3.5M/y

Strategy

- Operation strategy for 2021a, b, c runs (1)
  - Operation strategy until 2020b run
    - Squeeze β_y^* and increase luminosity with moderate total beam currents within the limited background level, and then accumulate the data.
    - Suppress the increase in background resulting from β_y^* squeezing by adding or closing collimators.
    - Generally successful until 2020b
      - Achieved the world-record luminosity with moderate beam currents in 2020b at β_y^* = 1 mm.
  - 2020c run followed the strategy
    - Planned to squeeze β_y^* down to ~0.6 mm and improve luminosity further.
    - Add D03V1 collimator
    - However, lots of challenges were standing in the way before squeezing β_y^* down to less than 1 mm.
      - High background and low injection efficiency (unstable conditions of injection beam).
      - Strong beam instabilities (TMCI) due to high impedance of collimators
      - Strong beam-beam effects at high bunch currents, etc.
    - The situation would be worse if β_y^* is squeezed further in this condition.

Revise the strategy to achieve the goal of 2021a, b, c runs, through discussion with Belle II.

Strategy

- Operation strategy for 2021a, b, c runs (2)
  - Revised operation strategy for 2021a, b, c runs
    - Aim at stable operation
      - Remove the high-impedance carbon collimator to avoid beam instability. → Done.
      - Use the proven optics with β_y^* of 1 mm.
      - Increase the total beam current by increasing the number of bunches and run within a moderate bunch current.
      - Establish stable injection condition (essential).
    - Put priority on (Int.) luminosity rather than background.
      - Relax the background limit, for example, the TOP hit rate, which has been sometimes a major limit of increasing the total beam current.
      - Open collimators within the tolerable range, which could increase injection efficiency and decrease the impedance
    - Increase machine availability for physics run as much as possible.
      - For example, move on physics run as soon as possible after the maintenance even though the possible β_y^* is 2 mm in the day.
    - Continue the effort to understand various issues of the machine for the future as necessary.
    - Obtain experience at high current operation, too.

    → 2021a, b, c runs are very important in predicting the future

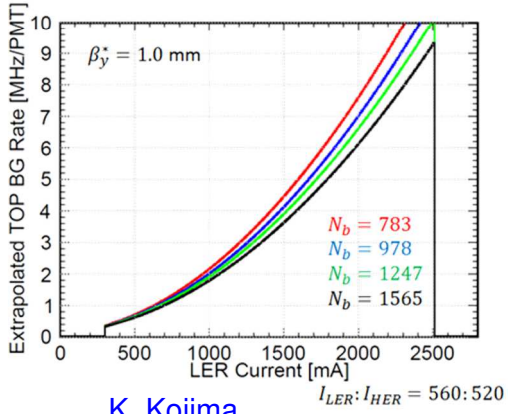
Strategy

- Operation strategy for 2022a, b runs
  - Although the strategy will depend on the results until 2021c run, main time will be offered to deeply understand the machine through beam studies, and to get more information for making a decision of middle-upgrade of IR planned around 2026.
  - More aggressive studies than 2021 runs will be tried, such as
    - β_y^* squeezing
    - High bunch current studies
  - Other machine studies will be continued, such as
    - Background
    - Physical and dynamic apertures
    - Injection efficiency and stability
    - Beam-beam effects (beam size blow-up, oscillation)
    - Beam instability (TMCI) and impedance
    - Chromatic coupling around IP
    - Beam loss and damage of collimators
    - Optics measurement and corrections, and so on
  - Physics run in parallel with machine studies to make good use of the spare time.
    - Actually, a certain period of physics run is required to check and evaluate the results of beam studies.

Run plan

- Basic run plan for 2021a, b, c runs
  1. Resume the ring condition at β_y^*= 1 mm, which was realized in 2020b run.
     - The starting point. Peak luminosity of ~2.4E34 $cm^{-2}s^{-1}$ at ~700 mA, 978 bunches.
       - It will take one month (by the end of March)?
     - Establish stable beam injection condition.
     - Use the proven optics, which had been used when the maximum luminosity was recorded in 2020b (reduction of background by D03V1 will not be expected.)
  2. Gradually increase beam currents at β_y^* = 1 mm with 1565 bunches.
     - TOP could relax the limit on the background from 1.2 to 3 MHz/PMT, which allows to increase total beam currents.
       - Considering the possibility of replacing PMT in 2026.
       - 3 MHz/PMT, for example, corresponds to LER = 1.3~1.4 A.
     - The number of bunches might be increased step by step, depending on the machine condition.
  3. Adiabatic beam tuning
     - Study on Rotatable sextupole magnets
  4. Option: Squeeze β_y^* down to 0.8 mm (and more)
     - If possible and if there is any indication to raise luminosity.
     - Note: We will not stop challenging lower β_y^* for the future.

Single beam backgrounds + constant injection backgrounds
(measured in the background study on May 9, 2020)



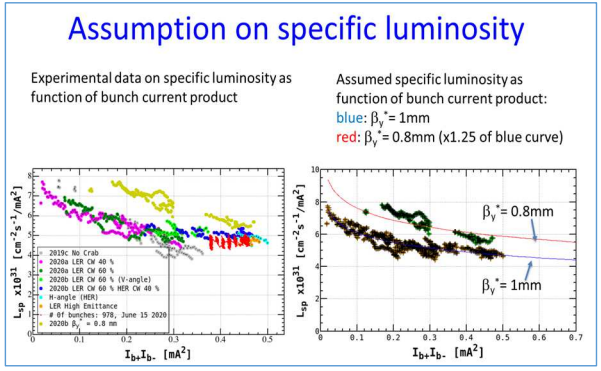
K. Kojima

Run plan

- Basic run plan for 2022a, b runs
  - The run plan will also strongly depend on the results until 2021c run.
    - The details will be finalized seeing the progress.
  - Basically, main part of shifts will be offered to the machine studies and tunings.
    - Similar to 2019c run.
  - Shifts at midnight, week ends, and holidays will be basically served as physics run.
    - Physics runs with higher beam currents and also lower β_y^* will be tried.

Luminosity profile

- The luminosity profile was re-evaluated based on the results of 2020c and following the operation strategy until 2022b run
- Assumptions for re-evaluating luminosity projection for 2021a, b, c runs
  - Beam current ← Key point
    - Considering the results of 2020c run, it seems reasonable to assume that the beam current will be ~1.1 A, although the TOP limit is relaxed.
  - Specific luminosity
    - Same level to 2020b run
      - Expected to be improved gradually by ~10%?
  - Others
    - The "efficiency factor" used for the calculation of Int. luminosity, is 0.65, based on the results so far and anticipating a stable operation.
    - Physics run for 28 days per month basically.
    - Move to 1565 bunches from 4/1.
    - The Int. luminosity includes that during the off-resonance run. (~1 week?)
    - Reduction in d*P*/d*I* ~ 60% at 6000 Ah.
    - No long-term break
      - No trouble in collimators and other hardware (~1 week break in the case) -> ~10 fb^{-1} loss
    - No intervene by COVID-19



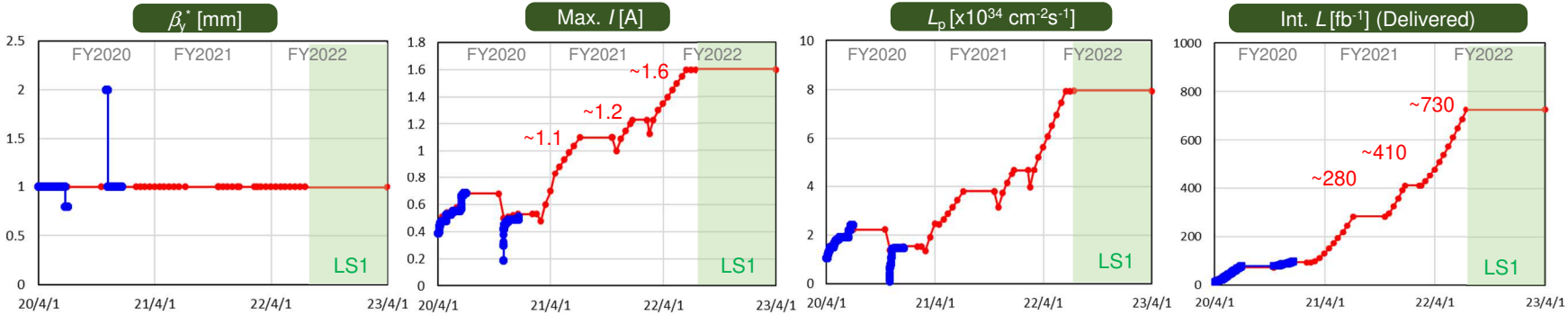
Y. Funakoshi

Luminosity profile

- Assumptions for evaluating luminosity projection for 2022a, b runs
  - Beam current
    - Beam current will be increased gradually up to 1.6 A.
  - β_y^*
    - Keep 1 mm
    - But will be squeezed further if we have chance.
  - Specific luminosity
    - Same level to 2020b run
  - Others
    - The “efficiency factor” is assumed to be 0.4, considering that the run is mainly served for the machine studies while assuming physics runs of 28 days per month basically.
    - Number of bunches will be kept to1565, but will be changed depending on the machine condition.
    - Reduction in d*P*/d*I* ~ 40% at 10000 Ah.
    - The Int. luminosity includes that during the off-resonance run.
    - No long-term break
      - No trouble in collimators and other hardware
    - No intervene by COVID-19
    - No physics run at 10.750GeV etc. (to be discussed)
      - It will take approximately 3 weeks at least considering the preparation, physics run, and restoration time.

Luminosity profile

- Luminosities
  - Run strategy 2021a, b, c runs: Put priority on (Int.) luminosity rather than background.
  - Run strategy for 2022a, b runs: Shift focus onto the machine study and tuning.



- Key point to realize the plan
  - How much can we store the beam currents?
    - Can we keep the injection condition stable?
    - Can we control beam instability and beam-beam effect at high bunch currents?

	β_y^*	L_p [E34]	Int. L [/fb]	I_{max}	
~2021b	1.0	~3.8	~280	~1.1	1.5~2 fb^{-1}/day
~2021c	1.0	~4.8	~410	~1.2	
~2022b	1.0	~8.0	~730	~1.6	

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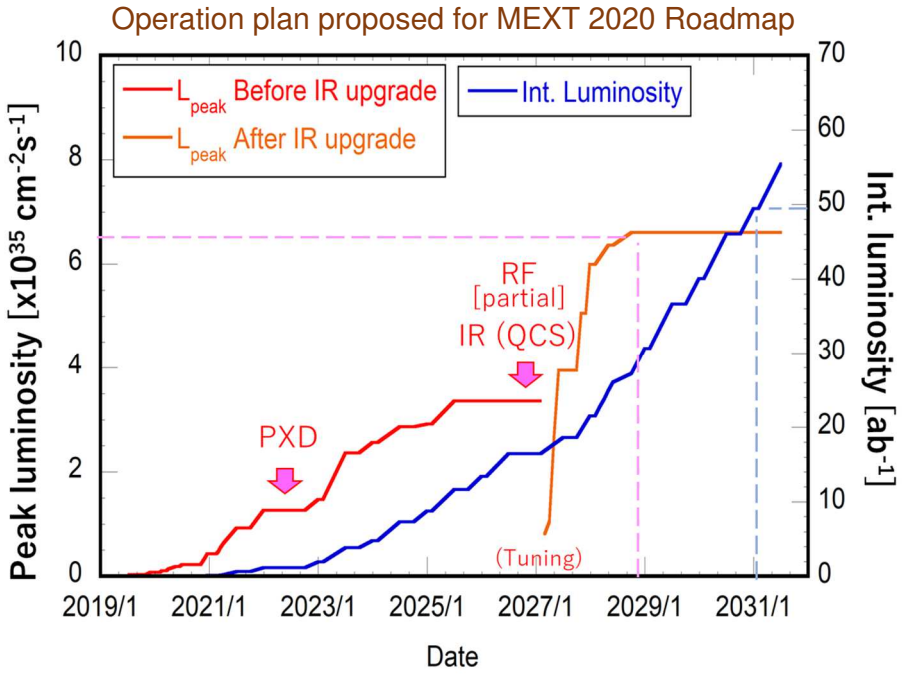
  - Current situation

MEXT Roadmap 2020

- For MEXT Roadmap 2020, we proposed to update the previous long-term operation plan (2019) considering the actual situation and the results obtained until 2019c.



- Peak luminosity ~6E35 $cm^{-2}s^{-1}$ in ~2028
- Integrated luminosity 50 ab^{-1} in ~2030 (40 ab^{-1} in ~2029)
- PXD exchange in 2021~2022
- Partial RF-power upgrade (2 stations) in 2026
- IR (QCS and its beam pipes etc.) upgrade in 2026
- β_y^*=0.3 mm in 2026 after IR upgrade, and ~0.5 mm before that
- Max. beam currents: LER 2.8 A, HER 2.0 A (1761 bunches) in 2027
- Basically, 8 moths' operation per year.

[Investment in equipment]

- QCS and its beam pipes etc.
- Partial RF-power upgrade (2 stations)
- Beam collimator upgrade
- Linac upgrade
- Belle II upgrade

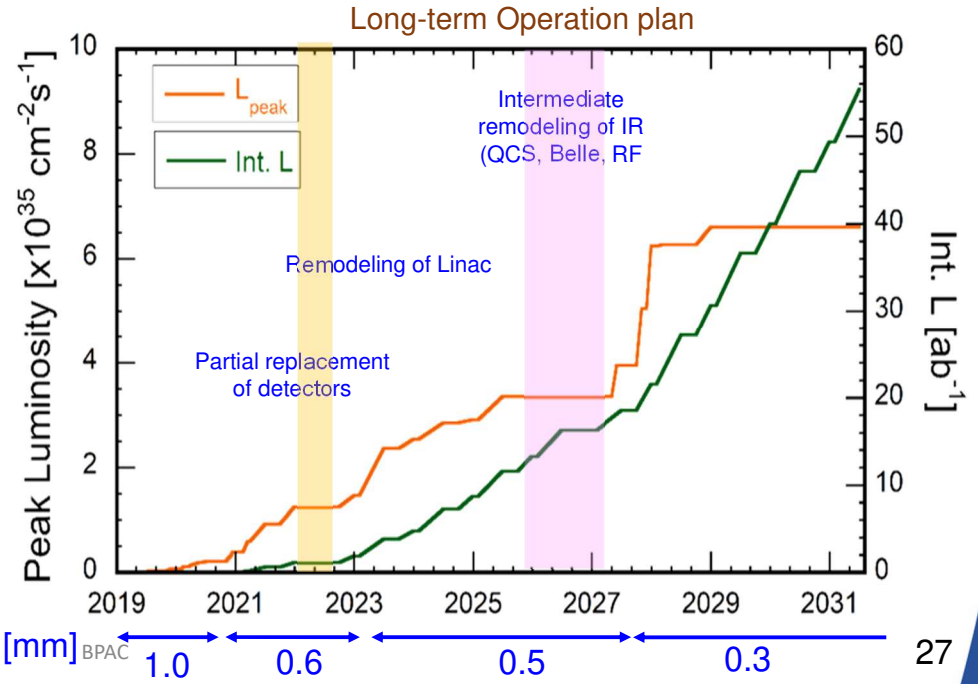
MEXT Roadmap 2020

- Key point : Intermediate upgrade of IR around 2026
  - Relocation of magnets: Make it possible to squeeze β_y^* to 0.3 mm, mitigate the beam-beam effect in the high bunch-current region
  - Enlargement of QCS beam pipes: Protect QCS, and reduce the background.

- Improvement of
  - Background
  - Beam lifetime
  - Collision efficiency

- Boost up of luminosity
  β_y^* : ~0.5 → ~0.3 mm
  L_{peak} : ~3E35 → ~6E35 $cm^{-2}s^{-1}$

- Until the upgrade, β_y^* will be gradually squeezed, and the beam currents will be increased gradually.



Current situation

- Current situation
  - The MEXT updated their roadmap 2020 in August, 2020.
  - The SuperKEKB/Belle II project was selected as one of 15 highest priority projects with an “AA” grade (the highest grade).

  - The plan was assessed by the external review committees (BPAC, 2020/6 and Accelerator Review Committee (ARC, 2020/7)).
  - Based on the recommendation from the review committees, “Long-term operation plan meeting” was launched in August, 2020.
    - Five times meeting have been held so far, and various subjects were discussed and investigated.
    - Some practical conclusion should be obtained in these two or three years, i.e., before the decision of whether the IR have to be upgraded or not around 2026.
    - Will be reported by Tobiyama-san

  - The actual long-term plan will be revised and finalized seeing the progress of the current luminosity improvement.

Summaries

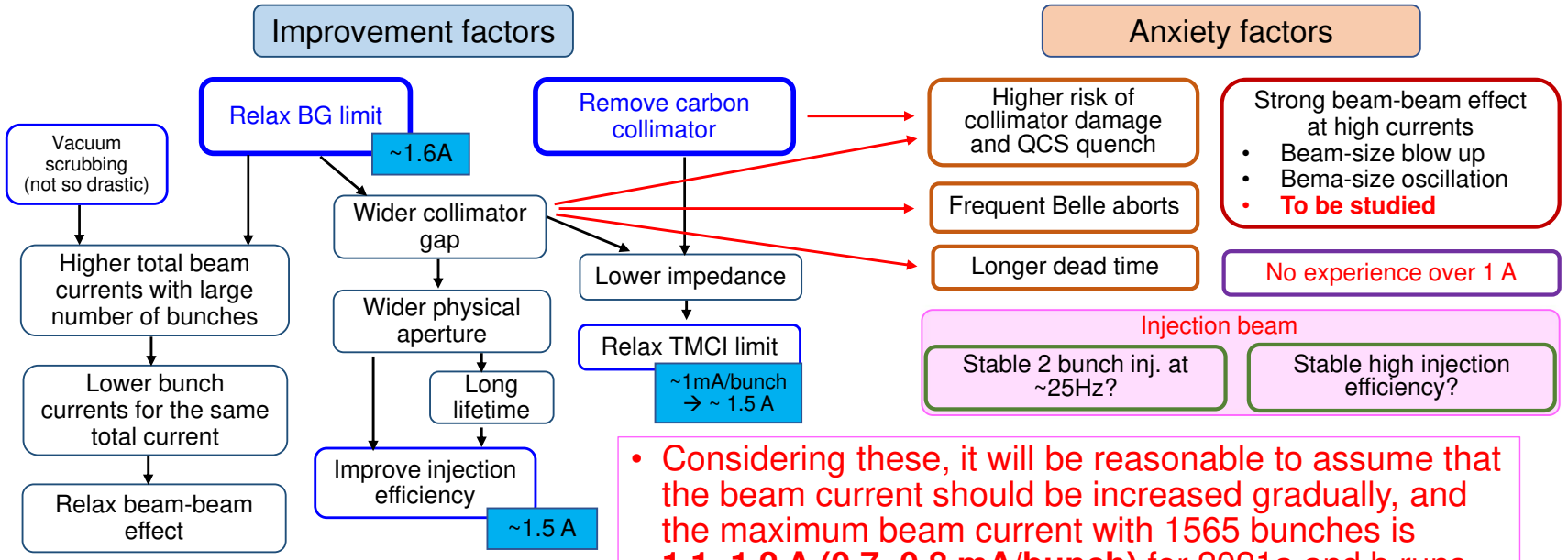
- SuperKEKB is continuing physics run (Phase-3)
  - 2020c run was very challenging one, and various challenges and limitations were revealed, although they were beneficial for the future operation.
- Near-term operation plan was revised and proposed based on the results in 2020c run.
  - The long shutdown (LS1) was postponed until summer, 2022.
  - Put priority on the luminosity rather than the background and aim at a stable operation for 2021a, b, c runs.
  - Shift focus onto the machine study and tuning for 2022a,b runs, anticipating luminosity boost after the LS1.
  - The goal int. luminosity is around 700 fb^{-1} by the end of 2022b, before the LS1.
- The present long-term operation plan follows that in the MEXT Roadmap 2020.
  - Various ideas and measures are under discussion in the “long-term operation plan meeting”, and also other regular meetings.
  - Some practical conclusion should be obtained in these two or three years, i.e., before the decision of whether the IR have to be upgraded or not around 2026.
  - The actual operation plan will be revised and finalized seeing the progress of the current luminosity improvement.

Thank you for your attention

Backup

Luminosity profile for 2021 runs

- The luminosity profile was re-evaluated based on the results of 2020c and following the strategy for 2021 runs.
- Assumptions for revaluating luminosity projection -1
  - Beam current ← Key point



- Considering these, it will be reasonable to assume that the beam current should be increased gradually, and the maximum beam current with 1565 bunches is **1.1~1.2 A (0.7~0.8 mA/bunch)** for 2021a and b runs.

Luminosity profile for 2021 runs

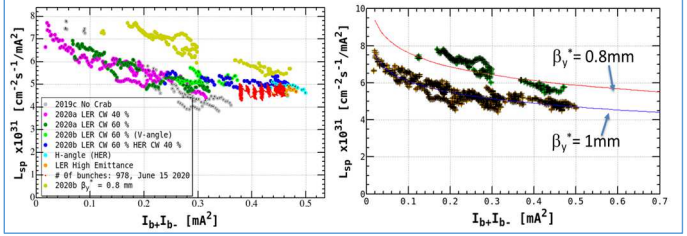
- Assumptions for revaluating luminosity projection -2
  - Specific luminosity
    - Same level to 2020b run
      - Expected to be improved gradually by ~10%?
  - Others
    - The luminosity used for the calculation of Int. Luminosity is 0.65 times of the peak luminosity, which has been assumed to be 0.7 so far.
      - Low reproducibility after run break
      - More tuning time will be required at high currents
        - Aging run before physics run, for example
      - But, no Linac study after maintenance day
        - Start physics run from night of the day
    - Physics run for 28 days per month basically. But,
      - First week after starting run has no physics run (4 days physics run between 2/16～2/28.)
      - Move to 1565 bunches from 4/1.
    - The Int. luminosity includes that during the off-resonance run.
      - ~1 week?
    - Reduction in d*P*/d*I* ~ 60% at 6000 Ah.
    - No long-term break
      - No trouble in collimators and other hardware (~1 week break in the case)
    - No intervene by COVID-19

Y. Funakoshi

Assumption on specific luminosity

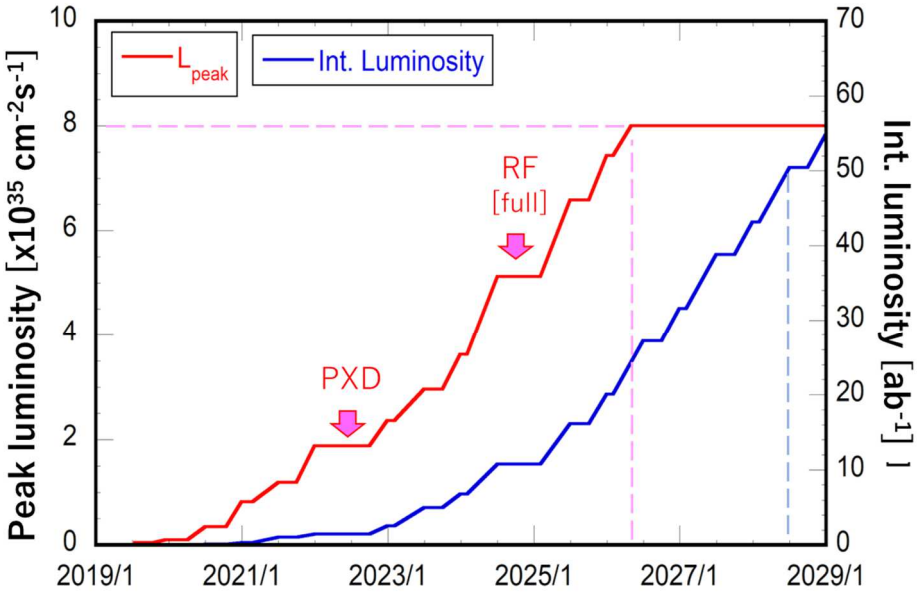
Experimental data on specific luminosity as function of bunch current product

Assumed specific luminosity as function of bunch current product:
blue: β_y^* = 1mm
red: β_y^* = 0.8mm (x1.25 of blue curve)



Long-term operation plan

Previous plan (Revised based on the results until Phase-2) (2019)



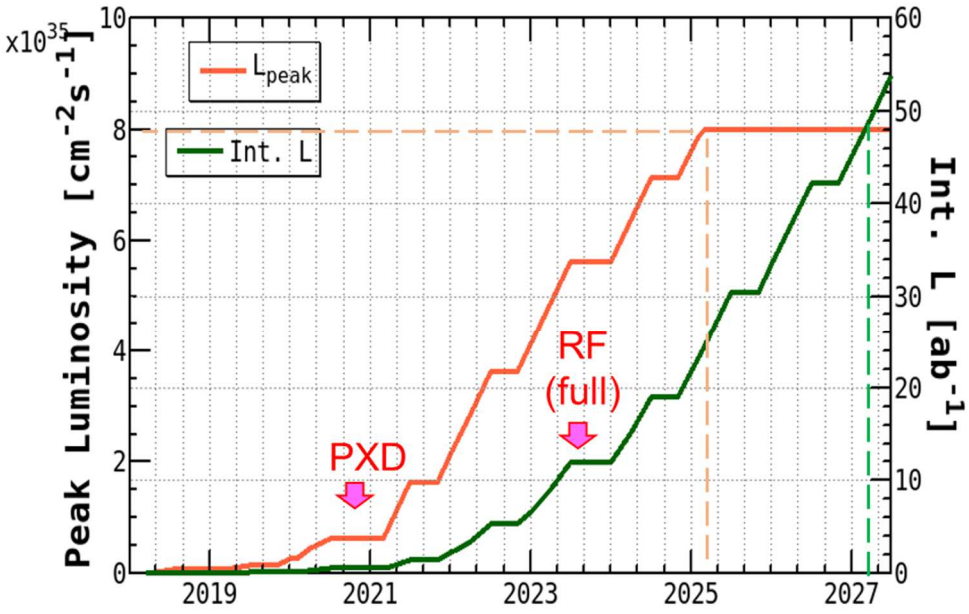
- Peak luminosity 8E35 $cm^{-2}s^{-1}$ in ~2026
- Integrated luminosity 50 ab^{-1} in ~2028
- b_y^* = 0.3 mm in 2021
- PXD exchange in 2021~2022
- RF full upgrade (4 stations) in 2024
- Max. beam currents: LER 3.6 A, HER 2.6 A (2500 bunches) in 2026
- Basically, 8 moths' operation per year.

[Investment in equipment]

- Full-scale RF-power upgrade (add 4 stations)
- Beam collimator upgrade
- Linac upgrade
- Belle II upgrade

Long-term operation plan

Original plan (~2018)



http://www-superkekb.kek.jp/img/ProjectedLuminosity_v20190128.png

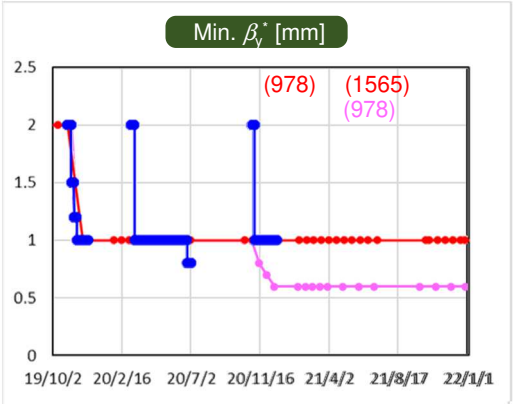
- Peak luminosity 8E35 $cm^{-2}s^{-1}$ in ~2025
- Integrated luminosity 50 ab^{-1} in ~2027
- PXD exchange in 2020~2021
- RF full upgrade (4 stations) in ~2023
- Max. beam currents: LER 3.6 A, HER 2.6 A (2500 bunches)
- Basically, 8 moths' operation per year.

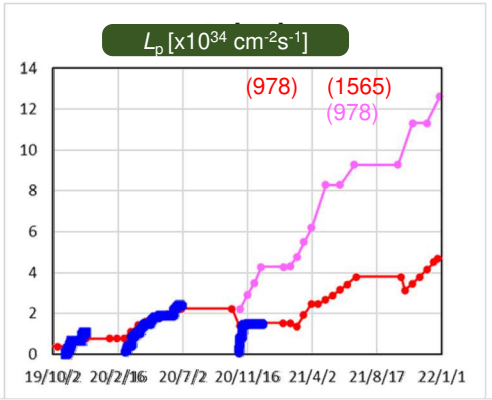
Investment in equipment

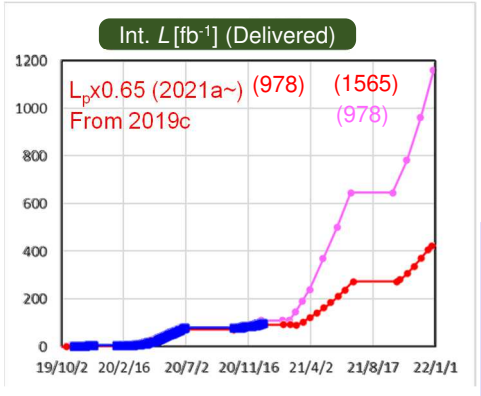
- Full-scale RF-power upgrade (4 stations)
- Beam collimator upgrade
- Linac upgrade
- Belle II upgrade

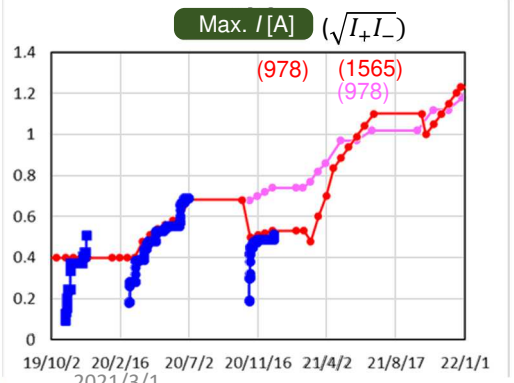
2021 and long-term operation plans

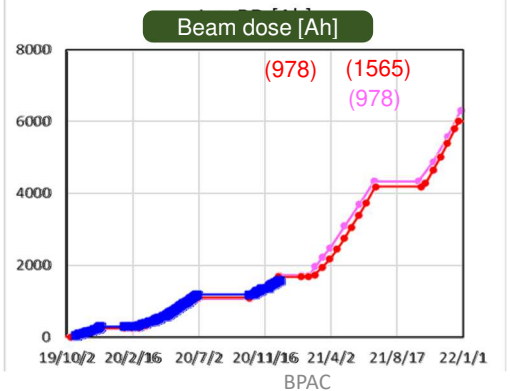
- Comparison of luminosity profiles in the revised 2021 plan and the long-term plan

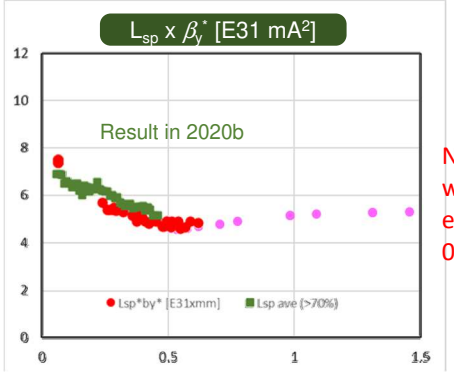












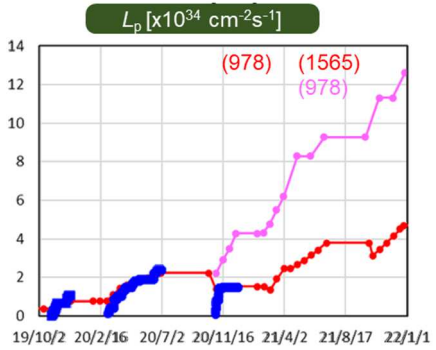
From 2019c run

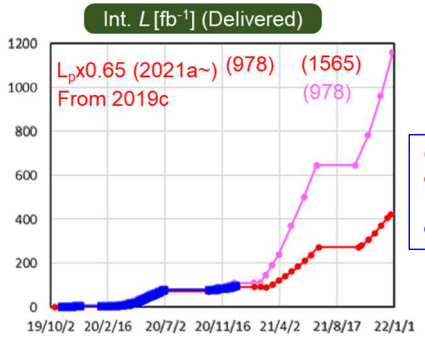
- Long-term Plan
- Revised 2021 Plan (base)
- Result until 2020c

Note: Constant L_p was assumed even for $i_{b+} * i_{b-} >$ 0.6 [mA^2]

2021 and long-term operation plans

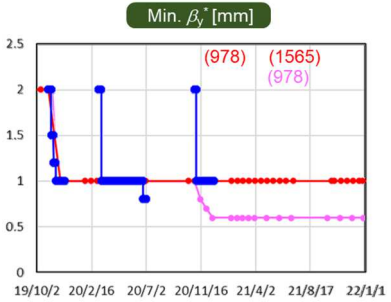
- The revised luminosity profile for near-term operation is far from that for the present long-term one.
  - The peak and Int. luminosities at the end of 2021 are almost a half or one third of original plan.

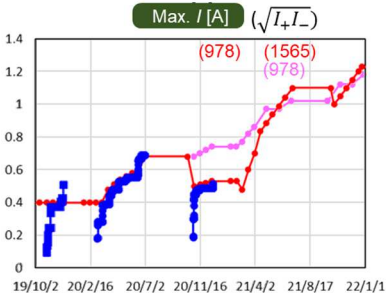


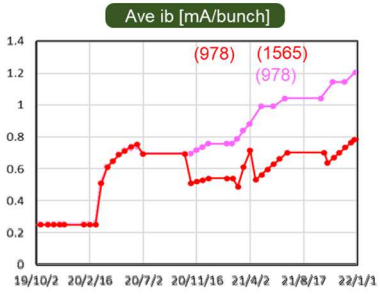


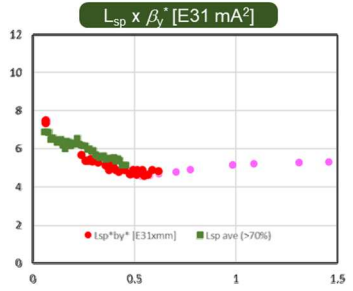
From 2019c run
- Long-term Plan
- Revised 2021 Plan (base)
- Result until 2020c

- Main Reasons:
  - Larger β_y^*
- Similar total beam current, but lower bunch current.
- The specific luminosities are almost the same.



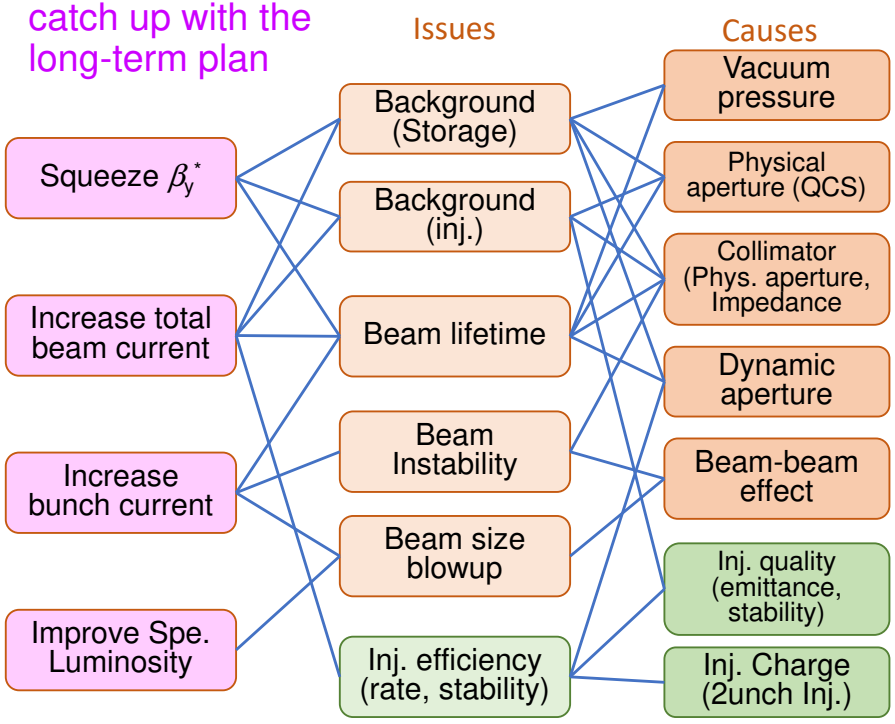






2021 and long-term operation plans

- What to do to catch up with the long-term plan
- What to be improved
- How to improve (some possible measures)



~2021 2022~ 2026~

Vacuum scrubbing (not so drastic)

Add shielding

QCS beam pipe remodeling

Relocation, Optics optimization
Remodeling (low impedance, robust)

Rotatable Sx, Perfect match

QCS remodeling?

Understanding of the mechanism (Chromatic coupling)?
Improvement in optics measurement and correction

Understanding the reasons of low efficiency (especially on HER)
FB system in BT and Linac (orbit, energy)

Establishment of stable 2 bunch injection
Stable operation of RF gun

Long-term operation plan

- BPAC Report (2020/6)
  - Based on the experience in operating SuperKEKB, the machine team has been developing ideas that could achieve the physics goal of the Belle II experiment with lower consumption of electricity . The committee understands that such an operation scenario over the next ten years was presented in the KEK submission to the MEXT Roadmap selection process, and finds this development timely and very attractive. Implementing such a plan requires an upgrade of the machine and detector. The BPAC strongly encourages a close collaboration between SuperKEKB and Belle II to further explore various ideas and conduct the necessary research and development work. Implementation of the necessary upgrade should then follow after positive evaluation of technical designs by the relevant committees. The BPAC is looking forward to hearing the progress in future meetings and strongly hopes for a positive outcome from the MEXT Roadmap selection.

Long-term operation plan

- KEKB Review Report (Long-term plan part) -1 (2020/7)
  - R7.2: Over the next year or so, perform beam measurements to determine if the proposed QCS upgrades with larger apertures are absolutely required to get to the design luminosity or, e.g., to half the design luminosity.
  - R7.6: Determine which technical studies (essential beam studies and QCS coil parameter studies) need to be carried out now, before a decision can be made, within about 2 years, on starting construction of new QCS quadrupoles.
  - R7.7: Determine the technical staffing and accelerator experts needed to construct the required hardware upgrades and examine if new technical staff will need to be trained or hired to design and execute these upgrades.
  - R7.9: Present a detailed SuperKEKB upgrade plan with underlying reasoning and data at the next ARC meeting.

Long-term operation plan

- KEKB Review Report (Long-term plan part) -2 (2020/7)
  - R7.8: Evaluate a backup plan to simply increase the luminosity with the existing hardware to about 2-3x10^{35} $cm^{-2}s^{-1}$ (with small upgrades but without major upgrades and the associated long installation downtimes and serious recommissioning) and then integrate luminosity for about 10-12 years at 7-8 months per year to obtain an integrated luminosity of 50 ab^{-1} by 2032-2034.
  - Detailed long-term upgrade plans should be finally decided once full performance with those upgrades is predicted within a quantitative performance model. This makes sure that the long-term quadrupole aperture is chosen wide enough, background sources and paths are understood, lower beam lifetime can be handled, impedance stays under control, and the collimator system is adequate.

Long-term operation plan meeting

- Four meetings have been held so far (~2021/2/4)
- The first meeting on 2020/8/21
  - The process so far [Y. Suetsugu]
  - Present status of QCS update project [N. Ohuchi]
  - Future plan of this meeting [H. Koiso, Chair]
- The second meeting on 2020/9/3
  - Summary of the first meeting [H. Koiso]
  - Examination status of the optics for QCS upgrade [A. Morita]
  - Crab waist, dynamic aperture and beam lifetime [K. Oide]
- The third meeting on 2020/9/26
  - Effect of IR Model V-20-20A (large physical aperture in QC1) on the beam optics [H. Sugimoto]
  - Examination of QC0P (Permanent magnet) [A. Morita]
  - Luminosity and lifetime (update) [K. Oide]
  - Effect of the enlarged physical aperture in QC1P on MDI mechanical design and background [H. Nakayama]
  - On flange at the top of QCS cryostat [N. Ohuchi]
  - Dependence of the injection efficiency on β_y^* [Y. Funakoshi]

Long-term operation plan meeting

- The fourth meeting on 2021/1/22
  - Progress report on QCS of upgrade project [N. Ohuchi]
  - LER dynamic aperture and luminosity (update) [K. Oide]
  - Status, issues and future plan of BT and Linac from the view point of beam commissioning [N. Iida]
  - Middle and long-term outlook on injection efficiency and luminosity [Y. Funakoshi]
- The fifth meeting on 2021/2/17 (planned)
  - Long-term strategy of BT [M. Tawada]
  - Long-term strategy of Linac [K. Furukawa]
  - Long-term strategy of beam collimators [T. Ishibashi and S. Terui]

- We have been also discussing about IR upgrade on other meetings, such as IR technical meeting (hosted by N. Ohuchi) and MDI meeting (hosted by H. Nakayama).