



Preparation for 2026 Accelerator Upgrade

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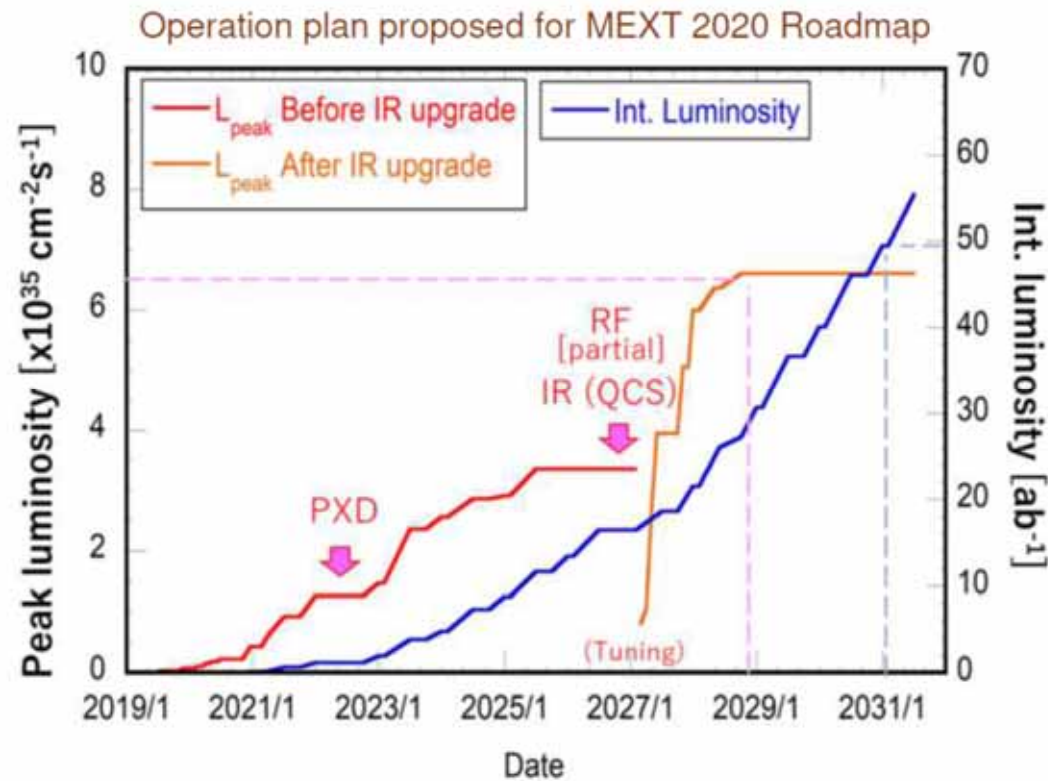
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@BPAC Review



Long-term operation plan



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



- Peak luminosity 6E35 in 2028
- Integrated luminosity 50 ab⁻¹ in 2030
- Partial RF-power upgrade (2 stations) in 2026
- IR upgrade in 2026
- by* = 0.3mm in 2026 after IR upgrade and 0.5mm before that
- Max. beam currents: LER 2.8A, HER 2.0A (1761 bunches) in 2027
- Basically, 8 months operation per year.





Long-term operation plan



■ Present status

- MEXT updated their roadmap 2020 in Aug, 2020.
- The SuperKEKB/Belle II project was selected as one of 15 highest priority projects with an “aa” grade (the highest).
- The actual plan will be finalized by seeing the progress of the luminosity improvement.
- The plan was accessed by the external review committee (BPAC[2020/6] and Accelerator Review Committee (2020/7)).
- Based on the recommendation from the review committees, “Long-term operation plan meeting” was launched in August, 2020 (Accelerator team and Belle II group) most of the members are Japanese, though.





- In the meeting, following issues will be discussed and examined in these 2 or 3 years.

- Is IR upgrade really required?

- Examination of crab-waist scheme
- Verification of the effect of rotatable sextupole magnets
- Investigation of beam-beam effect
- Understanding of background issue
- β_y^* squeezing and luminosity
- Understanding of beam lifetime
- Collimators and their impedance issues
- Injection efficiency
- Examination of the base plan (with present QCS)

- Is IR upgrade really possible?

- Making practical model of QCS magnet field configuration
- Making practical beam optics
 - The range of remodeling
- Examination of technical issues
 - Manufacturability, Materials of SC cables, Magnet alignment method
- Examination of human resources
- Conflict with Belle II detector
 - IP chamber, Connection method
- Manufacturing schedule
- Commissioning after the upgrade



- Short-term commissioning plan
- Establish the performance model

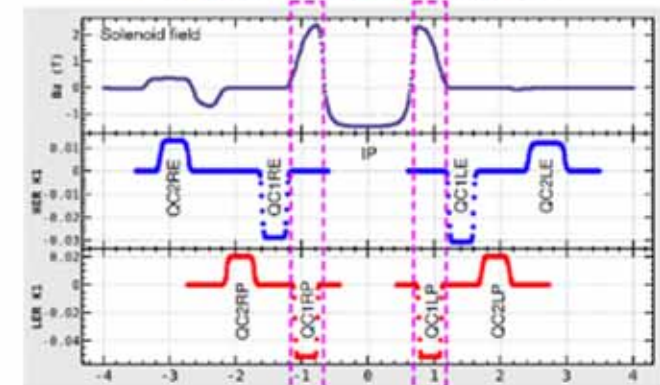
- Five meetings have been held so far (17/Feb/2021)
- In IR meeting, MDI meeting and other (hardware and optics) meeting, the upgrade related topics have been discussed.



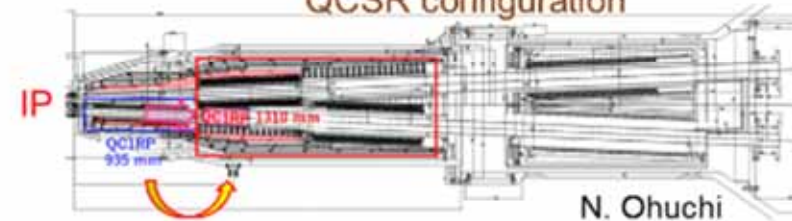
- Narrow dynamic aperture/lower luminosity at high-bunch current regions due to strong beam-beam effect

- A promising method to mitigate the effect was said to be the modification of QCS to avoid interference between the quadrupole magnetic field and the Belle II solenoid field for the LER.
- Two ideas to relocate QC1P to places farther from IP were examined at first.
- However, up to now, it was found that little improvement was expected even without beam-beam effect.
- On the other hand, it was also found in a simulation that the effect will be cured using the rotatable-sextupole magnets installed in the local correction region at Tsukuba.
- We will try it this during 2021 run.

Magnetic fields around IR



QCSR configuration



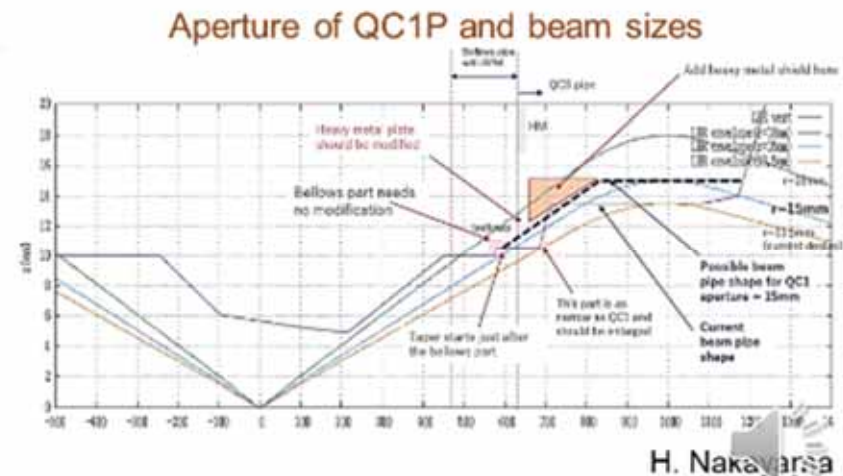
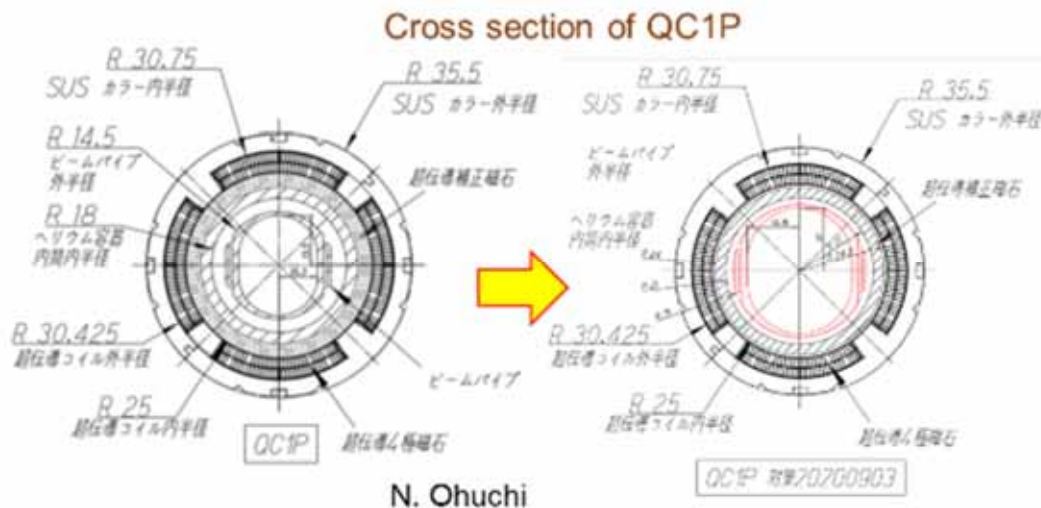
Rotatable Sextupole magnet



M. Masuzawa



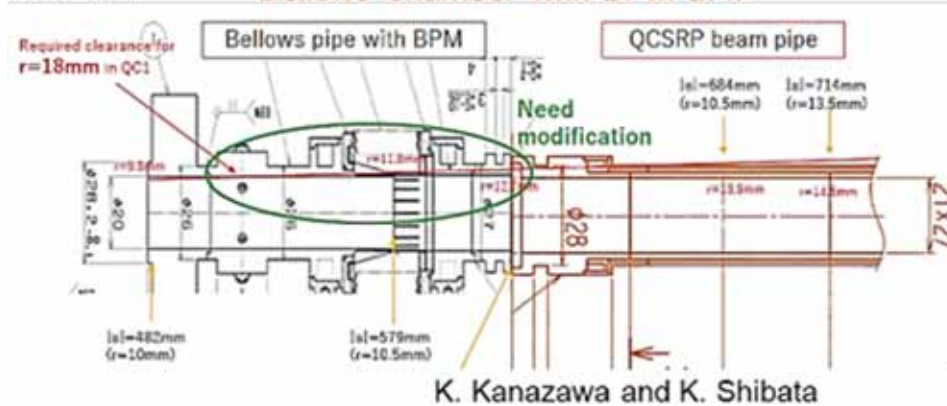
- Narrow physical aperture in the QC1RP -1
- Enlargement of the (vertical) aperture of beam pipes in QC1RP has been discussed.
 - The enlargement is expected to increase the physical aperture and then increase beam lifetime, reduce background, resulting increase the TMCI threshold.
 - Although little improvement in the lifetime determined by the dynamic aperture.
 - The aperture can be enlarged by relocating the correction magnets to outside of the main quadrupole magnets.
- It will be possible to increase the inner diameter from 13.5 mm to 18 mm geometrically.
- The range required for the modification was examined, and it was reported that the modification near to the BPM and bellows near to IP is also required.



- **Narrow physical aperture in the QC1RP -2**
 - The R&D for the beam pipes, BPM and bellows has started.
 - Required R&D
 - **Beam pipes for QC1RP**
 - Remodeling of connection flange at IP side (RVC) → R&D and testing together with DESY group.
 - Change in the vacuum sealing mechanism between the QCSR cryostat and the beam pipe. (O-ring seal)
 - Manufacturing method of beam pipes and TiN coating method.
 - **Bellows chamber with BPM**
 - Change in the cross-section of bellows from circular one to an ellipse or a race-track one
 - Change in the flange at QCS side.

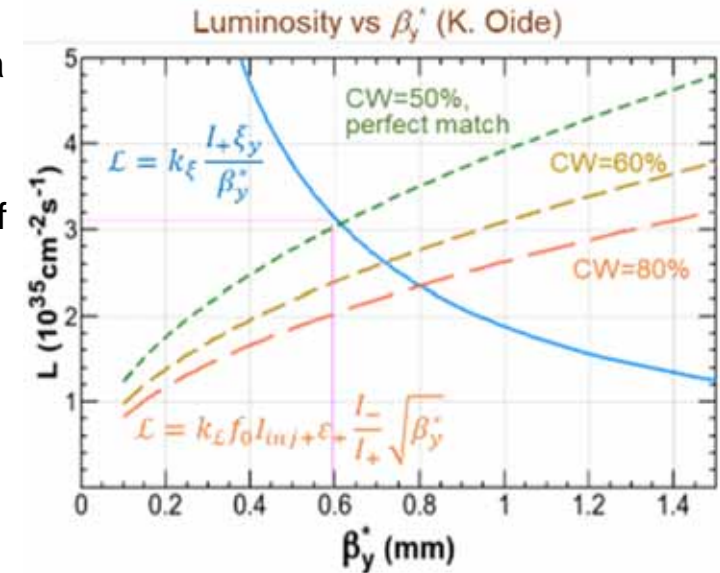


Bellows chamber with BPM at IP

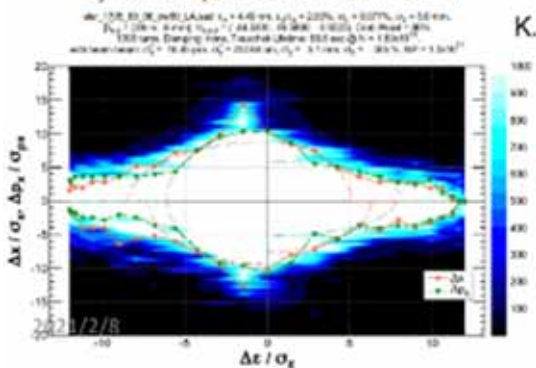


Examination of the base plan (with present QCS)

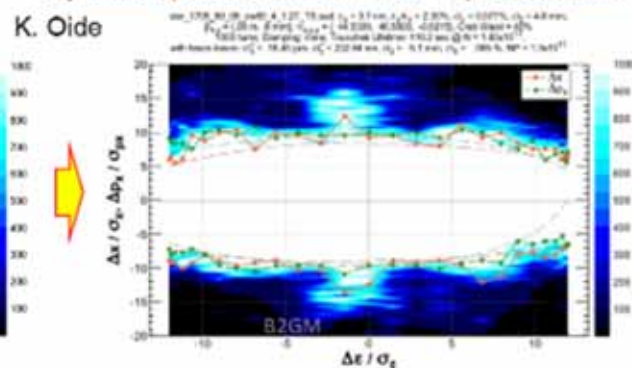
- The performance with the present QCS is being examined by a simulation including beam-beam effect.
- Recently it was reported that the Touschek beam lifetime will be increased by 60% and a luminosity of around $3E35 \text{ cm}^{-2}\text{s}^{-1}$ could be achieved by introducing a “perfect match” and 40% of the crab-waist in LER
 - Perfect injection condition, TMCI suppressed situation..
- $\sim 3E35 \text{ cm}^{-2}\text{s}^{-1}$: Extreme goal luminosity before the 2026 upgrade.
- How to practically realize the “perfect match” using normal-conducting quadrupole magnets, for example, is being investigated.
- Preparation of hardware need >1 years so will not be able to install during LS1 but will be able to install before LS2.



Dynamic aperture with CW=80%



Dynamic aperture with CW=40% + “perfect match”



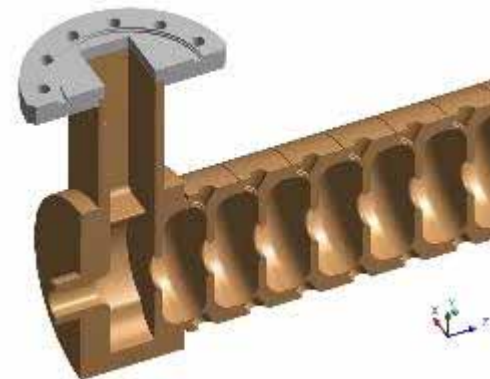
“Perfect match”:

- Phase shifts between SLYTRP2/SLYTLP1 and IP are just 0.5 (x) and 0.75 (y).
- The values of β_x and β_y at the center of four SLY (SLYTLP1&2, SLYTLP1&2) are set to be the same, respectively.

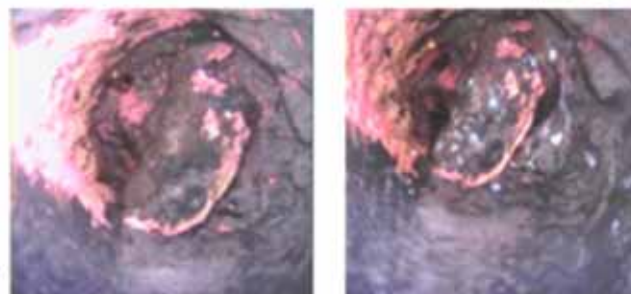


■ Linac long-term upgrade plan

- Replacement of aged accelerating structures (on going)
 - 7% of the structures will be replaced until 2023.
- Movable supports and beam collimator
 - Emittance preservation
- ECS for electron beam
 - Comments on the necessities, other method (chirp at the end of linac)
- More pulse magnets
 - Fast kickers to make each bunch in a pulse independent
- PCB measures (capacitors in the modulators, until JFY2026 by law)
- RF gun
- Positron yield (Optimization of capture section)



- Beam transport lines, positron damping ring.
- Many aged components
 - Power supply (>24 years), increasing failure rate, no support from the company
 - Need to renew before spending the spare cards, etc.
 - Copper oxide precipitate in the hollow conductors of magnets.
 - Old BPM electronics using oscilloscopes
 - Improvement of stability
 - Better Thyatron
 - Fast correction kicker for injection
 - SR monitor lines in BT



- We plan to investigate the aged components and update them systematically.

- Urgent components will be taken care using nominal operation budget. (30MJYP per year?),
 - Utilize LS1 as much as possible.
 - Measures for items that require long-term shutdown.
- For RF components (LLRF etc) which need much larger investment, we expect direct support from MEXT, following the roadmap 2020.





Other (important) topics



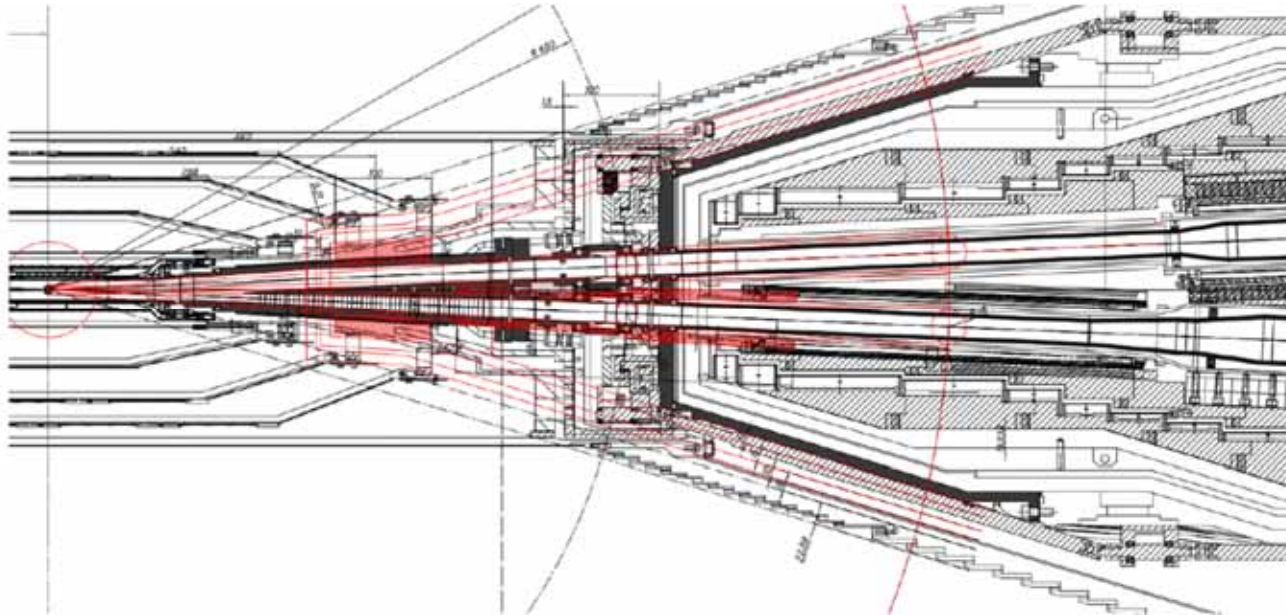
- RF upgrade plan
- Beam instrumentation system ?
- Improvement of energy efficiency



Large-scale IR renovation



- Forgetting the current (physical) limitation on the space around IR, how much improvement of the luminosity will be expected?
- Examine the case of moving QC1Ps to L=600mm position



- Need complete different SVD/Pixel support, vacuum connection mechanism, etc.





Large-scale IR renovation



- LER QCS Toy model study (not using realistic magnetic field distribution) has shown roughly x2 improvement of lifetime on simulation.
- Will double performance gains be worth the long construction period and large investment?



Upgrade plan



- We would like to start Linac upgrade soon.
 - Before 2026 upgrade
 - Hoping enough budget support from MEXT for JFY2022 and after.
- Optics upgrade around IR including “Perfect matching”
 - Would like to start preparation of the magnets, power supplies with high priority after fixing the modification items.
- Beam transport lines
 - Preparation of spare components (power supplies, magnets) with high priority
- QCS and IR upgrade
 - First decision to ask ARC will be made before July/2021.
 - Simulation, R&D of hardware components will be needed.
- International collaboration
 - Depends on the COVID-19 situation. Hoping to restart direct (in-person) and long-term contributions.
 - Planning international workshop on SuperKEKB collider (Remote, Aug/2021?)
 - Try to ask “remote” contributions under COVID situation.



Summary



- “Long-term operation plan meeting” was launched based on the recommendation from the review committees to discuss the detailed and practical issues in the plan.
 - To date, there have been 5 (+) meetings..
 - QCS, IR aperture, better optics correction scheme, Injector, Beam transport and damping ring, beam collimators, etc.
 - Linac upgrade is already on going (but without enough budget support).
- The first plan will be shown for the KEKB accelerator review on this year.

