SuperKEKB Commissioning Status

– Phase-3 2019 Spring Run –

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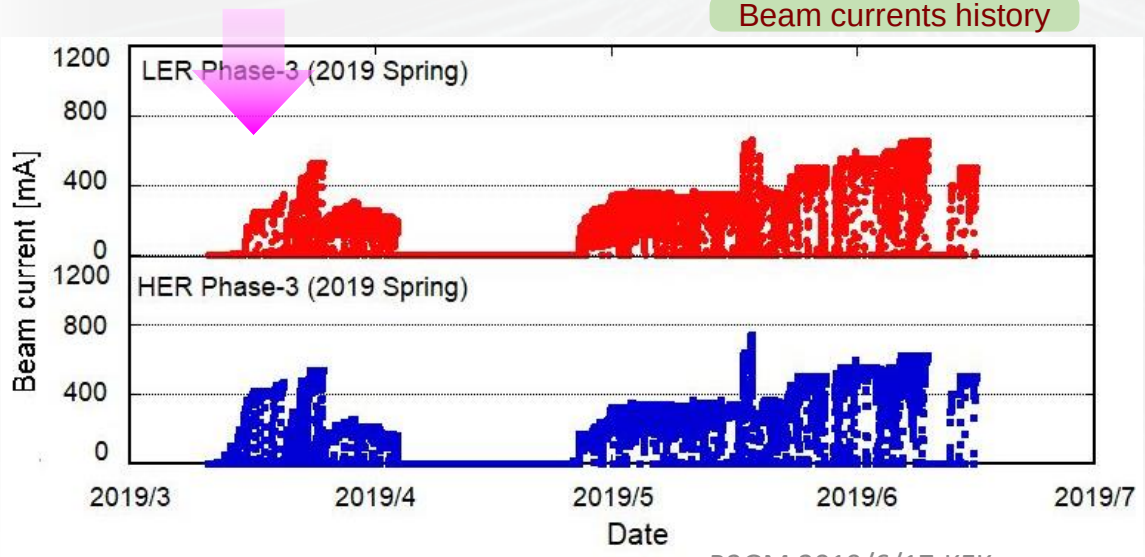
  - Brief review (~6/15)
  - Major results and challenges
  - Status of several key items
- Commissioning plan
  - 2019 Spring run (~7/1)
  - Summer shutdown and 2019 Autumn run (10/15-12/12)
  - Winter shutdown and 2020 Spring run (1/16?-6/30?)
- Summary

- Detailed commissioning status and plan → Morita's talk
- Injector linac status → Ego's talk

Phase-3 brief review

- Phase-3 commissioning started from 11th, March, as scheduled.
  - Started with a detuned optics (large β^*).
  - HER beam was stored on the same day.
  - LER beam was stored on 13th, although some difficulties in the injection tuning.
  - Vacuum scrubbing started from 14th with 1576 bunches.
- This quick start meant that the QCS positions were well restored after the retraction/insertion during the shutdown.

Beam currents history



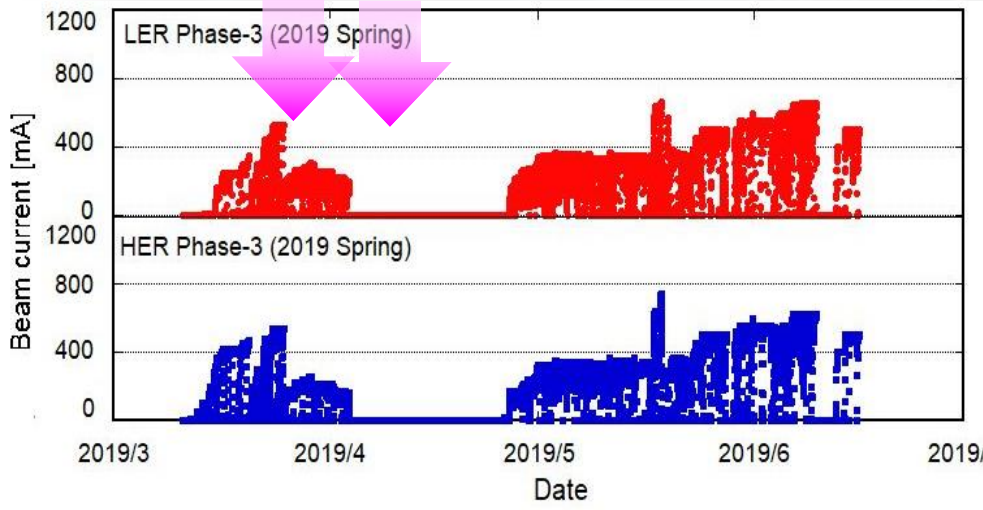
Retraction/insertion work of QCS

Phase-3 brief review

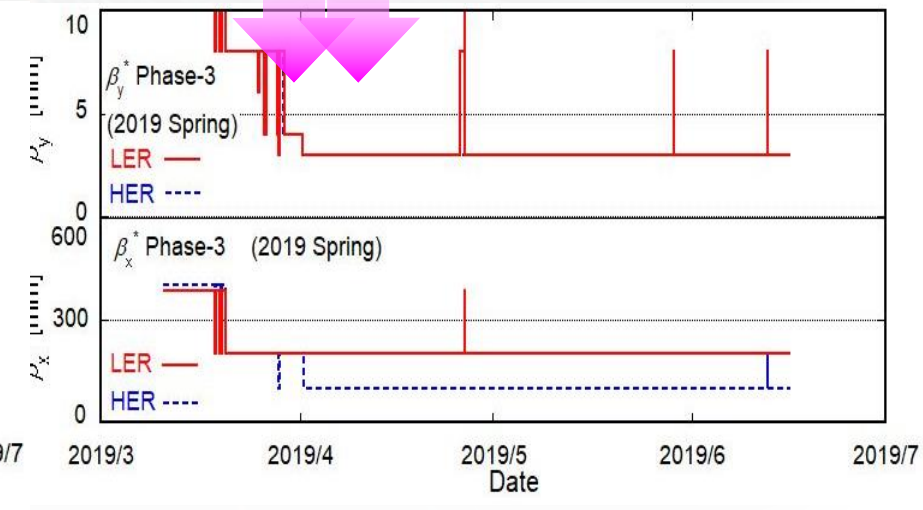
- The β_y^* was gradually squeezed from 18th, March, and moved to collision tuning from 20th with 789 bunches.
- The first collision event was observed on 25th, March.
- The optics with $\beta_y^* = 3$ mm was finally established on 1st, April, which was the same optics in Phase-2, and the physics run had actually started.

- Unfortunately, however, we had a fire incident in the linac building on 3rd, April. Details were reported by Tokushuku-san.

Beam currents history



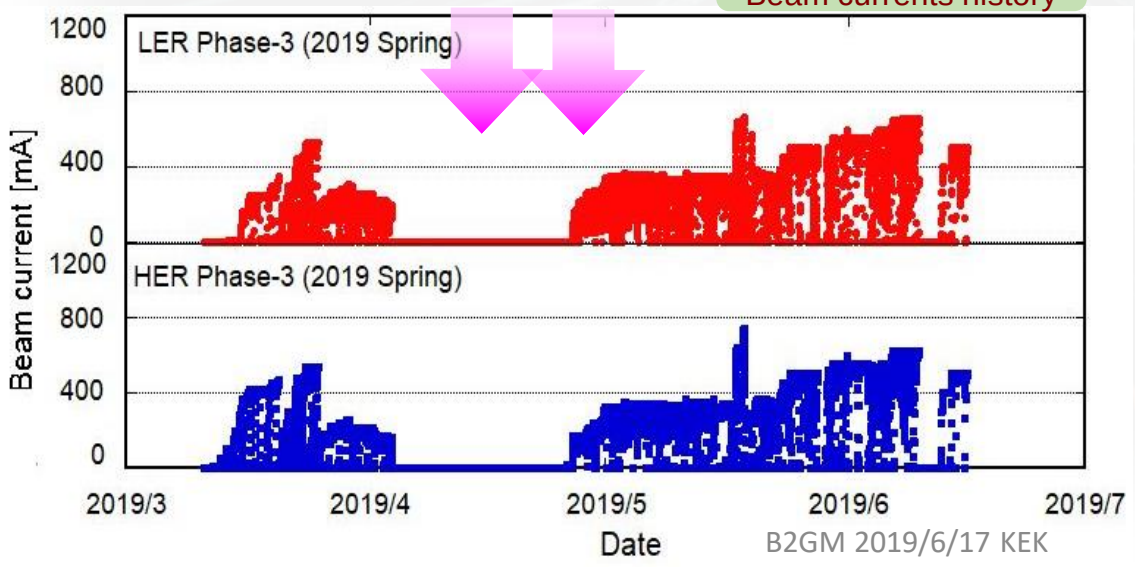
β^* history



Phase-3 brief review

- KEKB MR stopped during the recovery work at Linac, with no RF and Magnet power to save electric charge.
  - The Linac recovered very quickly thanks to great effort of staff and external contractors, and also heartful encouragement from Belle II groups and others.
- MR operation finally restarted from 25th, just before the Platinum week (i.e., ~10 days special national holidays for celebrating our new emperor).

Beam currents history



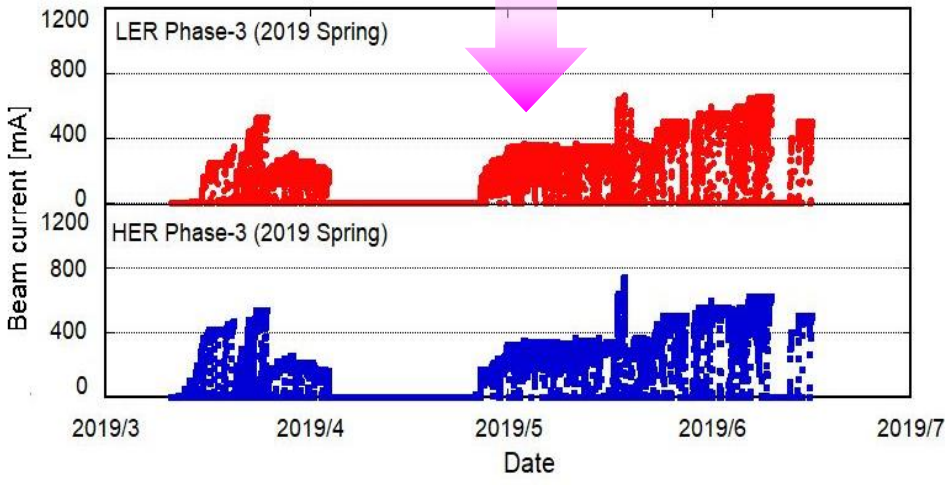
He is not the emperor

New era “REIWA”

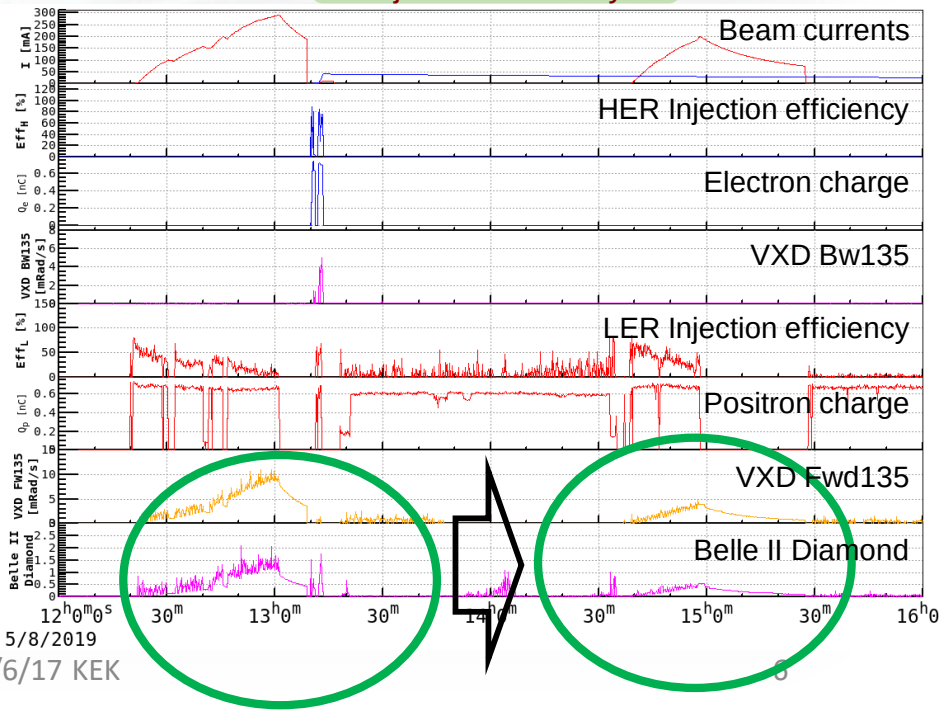
Phase-3 brief review

- Physics run continued during this Platinum week under non-aggressive tuning, but stably.
- Just after the holidays, the injection BG was drastically reduced by the elaborate tuning of collimators and new injection tuning method, which gave a light toward the continuous injection mode.

Beam currents history



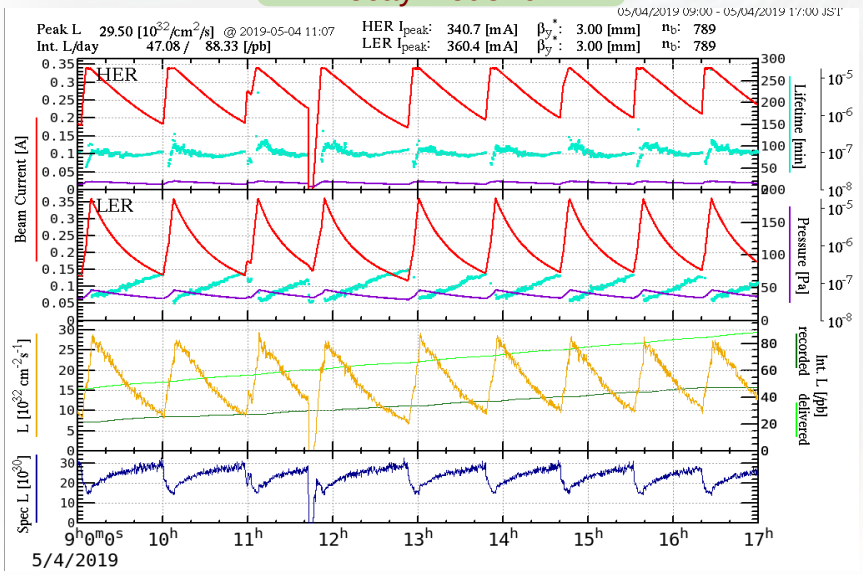
Injection summary



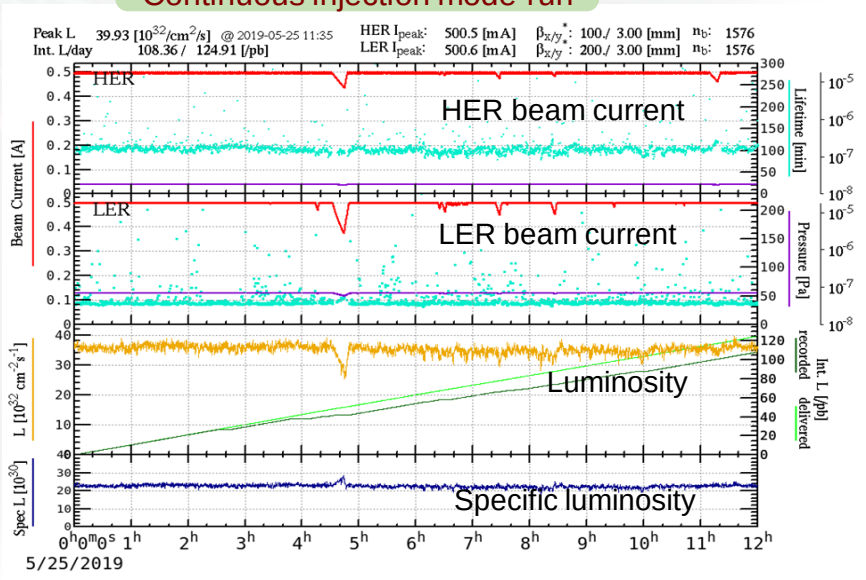
Phase-3 brief review

- Physics run continued during this Platinum week under non-aggressive tuning, but stably.
- Just after the holidays, the injection BG was drastically reduced by the elaborate tuning of collimators and new injection tuning method, which gave a light toward the continuous injection mode.
- LER continuous injection started from 7th, May.
- Finally, HER continuous injection started from 14th, May.

Decay mode run



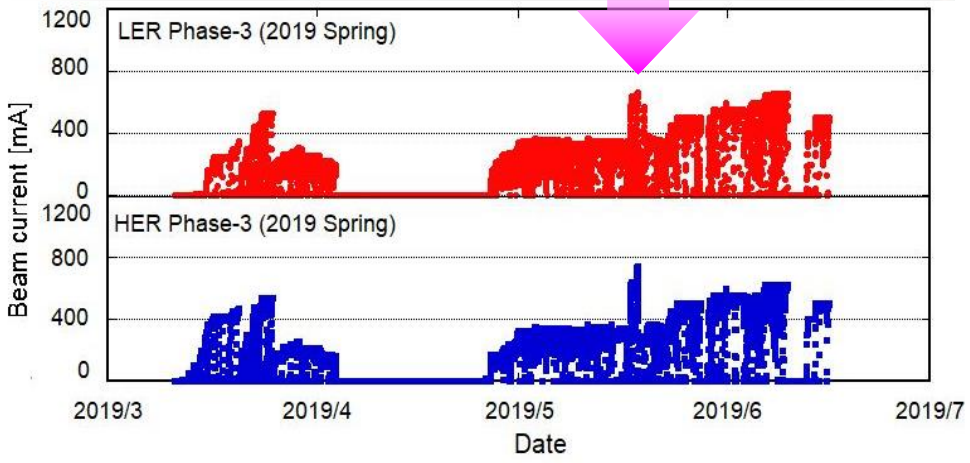
Continuous injection mode run



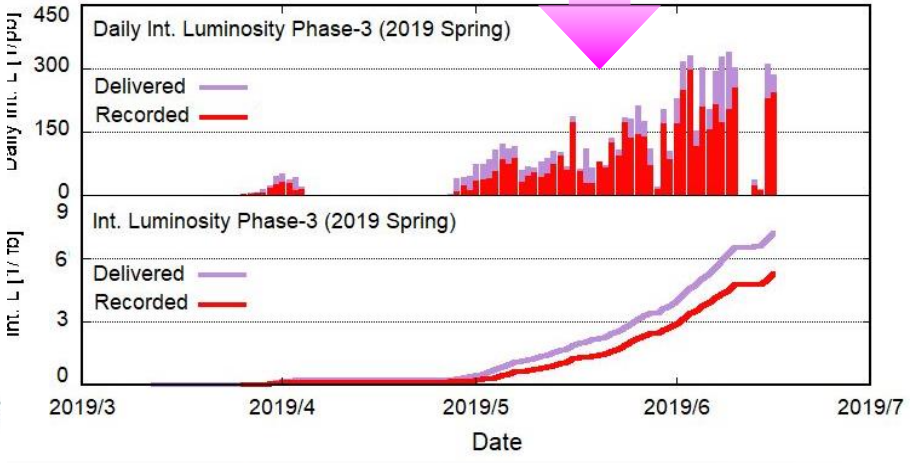
Phase-3 brief review

- From 17th,owl shifts were basically served for physics run, and collision knob tunings were continued incessantly.
- Day and swing shifts were used for various accelerator studies:
  - BT line and injection tuning studies
  - High current studies with 1576 bunches
  - Longitudinal feedback studies
  - Impedance measurements (collimators)
  - Beam-beam effect studies
  - X-ray beam size monitor calibration, etc.

Beam currents history



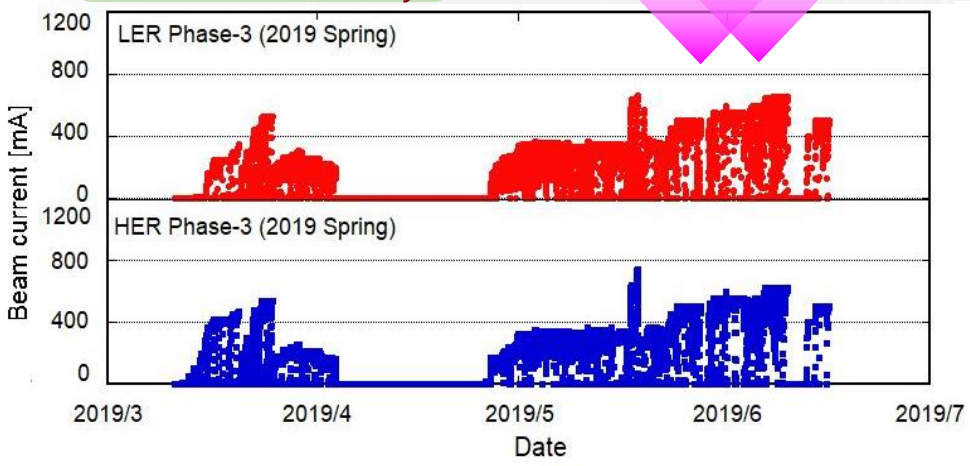
Luminosity history



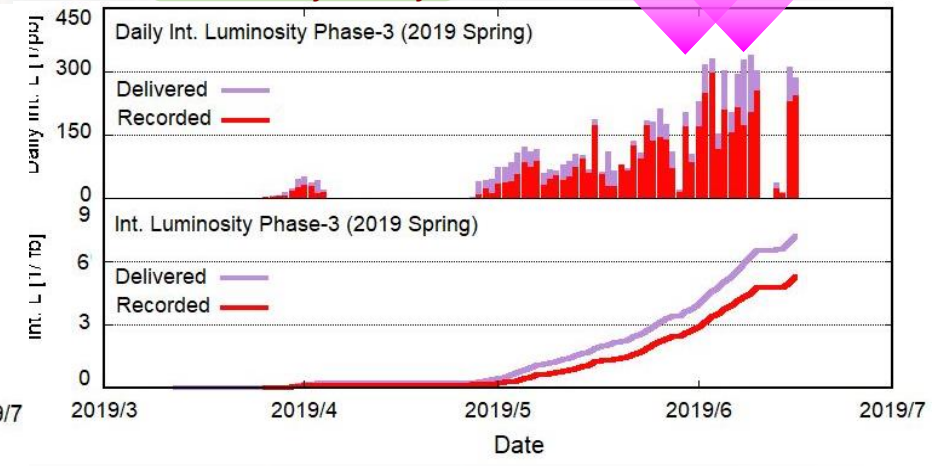
Phase-3 brief review

- The physics run with 1576 bunches (3.06 RF bucket spacing) started from 23rd, May.
- The beam current was increased gradually watching the BG status since then, and along with it, the integrated luminosity increased steadily.
- After the continuum run (ΔE = -60 MeV) from 28th, May to 3rd, June, the physics run on resonance restarted while increasing the beam currents up to 660 mA (LER) and 620 mA (HER).

Beam currents history



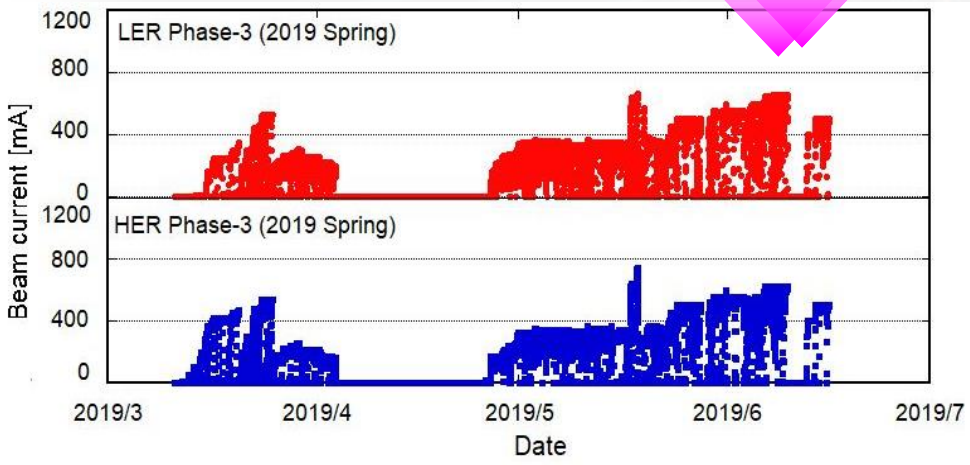
Luminosity history



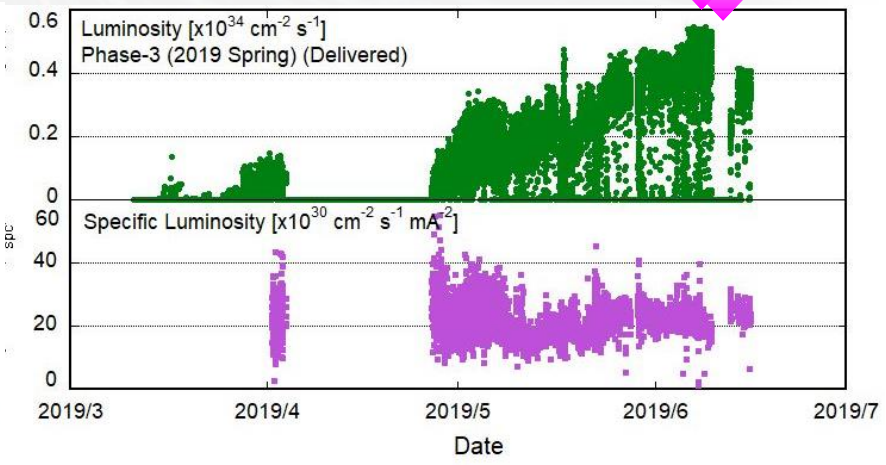
Phase-3 brief review

- The peak luminosity of 0.55×10^{34} $cm^{-2}s^{-1}$ was recorded on 8th, June.
- However, a heavy QCSR quench occurred on 9th, June, and it took approximately 3 days to recover it.

Beam currents history



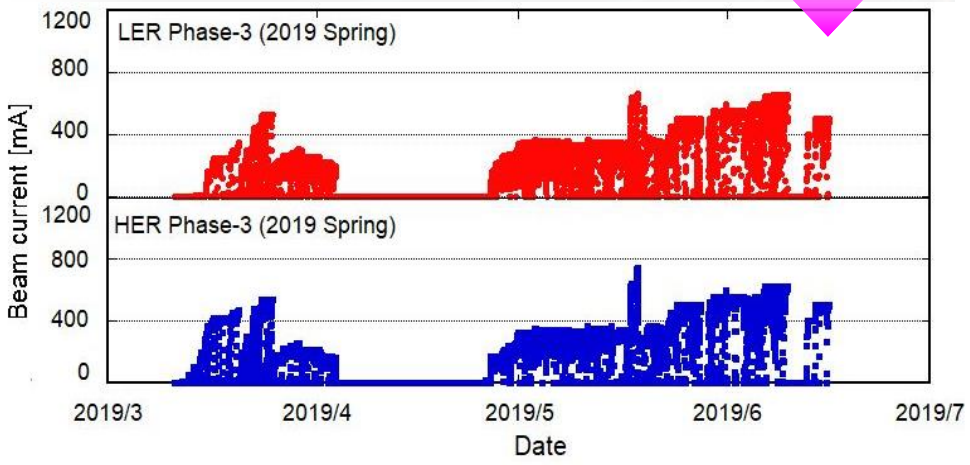
Luminosity history



Phase-3 brief review

- The peak luminosity of 0.55×10^{34} $cm^{-2}s^{-1}$ was recorded on 8th, June.
- However, a heavy QCSR quench occurred on 9th, June, and it took approximately 3 days to recover it.
- Since then, the beam current has been saved to 500 mA for safety, because the beam-dust collision at high beam currents was suspected as a cause of the quench.

Beam currents history



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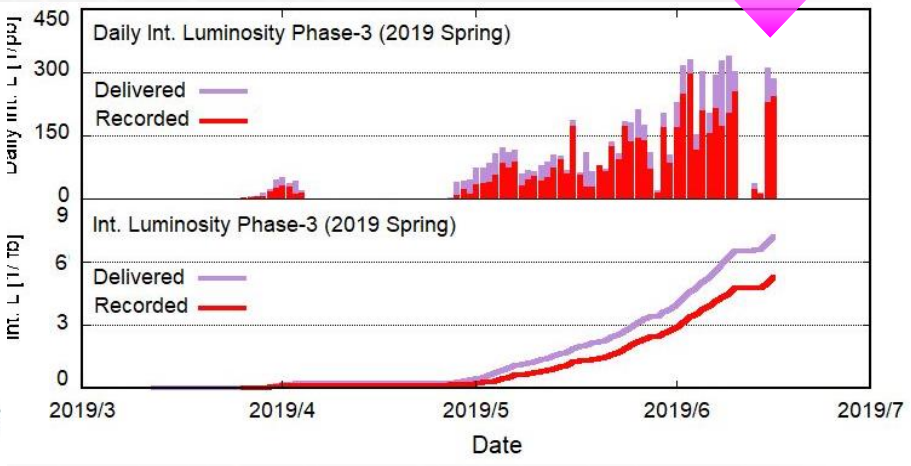
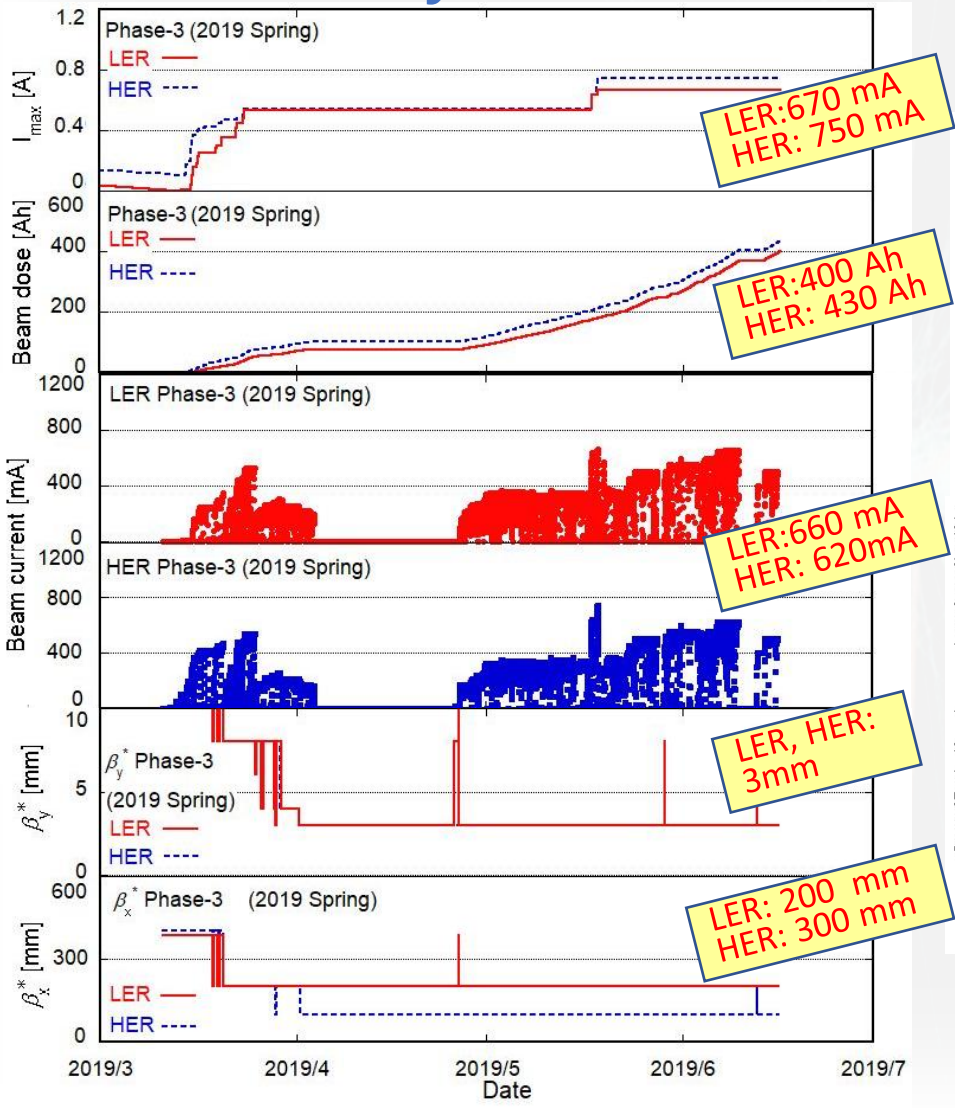


Major results and challenges

- Summary of results until 15th, June



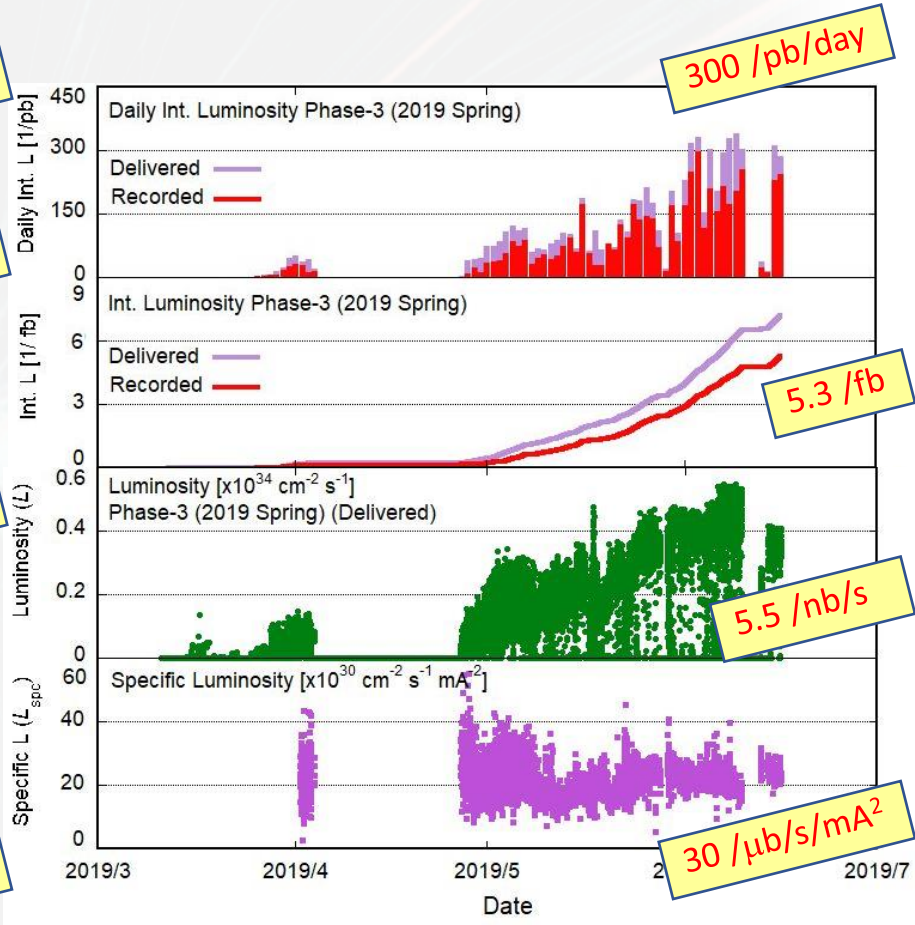
LER:670 mA
HER: 750 mA

LER:400 Ah
HER: 430 Ah

LER:660 mA
HER: 620mA

LER, HER: 3mm

LER: 200 mm
HER: 300 mm



300 /pb/day

5.3 /fb

5.5 /nb/s

30 /μb/s/mA^2

Major results and challenges

- Achieved machine parameters

Plan (Last B2GM)

	LER	HER
ε_x [nm]	2.0	4.6
$\varepsilon_y/\varepsilon_x$ [%]	8.0	8.0
β_x^* [mm]	100	100
β_y^* [mm]	3	3
σ_z [mm]	6	6
I [A] (Physics run)	1.2	1.0
Number of bunches	1576	
Bunch current [mA]	0.761	.635
σ_y^* [nm]	693	1051
ξ_y (beam-beam param.)	0.0262	0.0272
L [cm^{-2}s^{-1}]	1.06 x 10^{34}	

- β^*_y = 3mm collision is confirmed in Phase-2.
- Maximum stored beam currents are...
  0.858 / 0.788 A (LER/HER) in Phase-2
  1.010 / 0.879 A in Phase-1 w/o IP
- 1576 bunch operation is confirmed in Phase-2.
- Minimum colliding σ^*_y is 333 nm(ultra low bunch current).
- Maximum ξ_{y-} achieved in Phase-2 is 0.021.
- Maximum L_{peak} achieved in Phase-2 is 0.555 x 10^{34} cm^{-2}s^{-1}.

Beam-beam parameter: ξ_y

$$L = \frac{\gamma_\pm}{2er_e}\left(\frac{I_\pm \xi_{y\pm}}{\beta^*_{y\pm}}\right)$$

L: Luminosity I: Beam current
r_e: Classical electron radius

Major results and challenges

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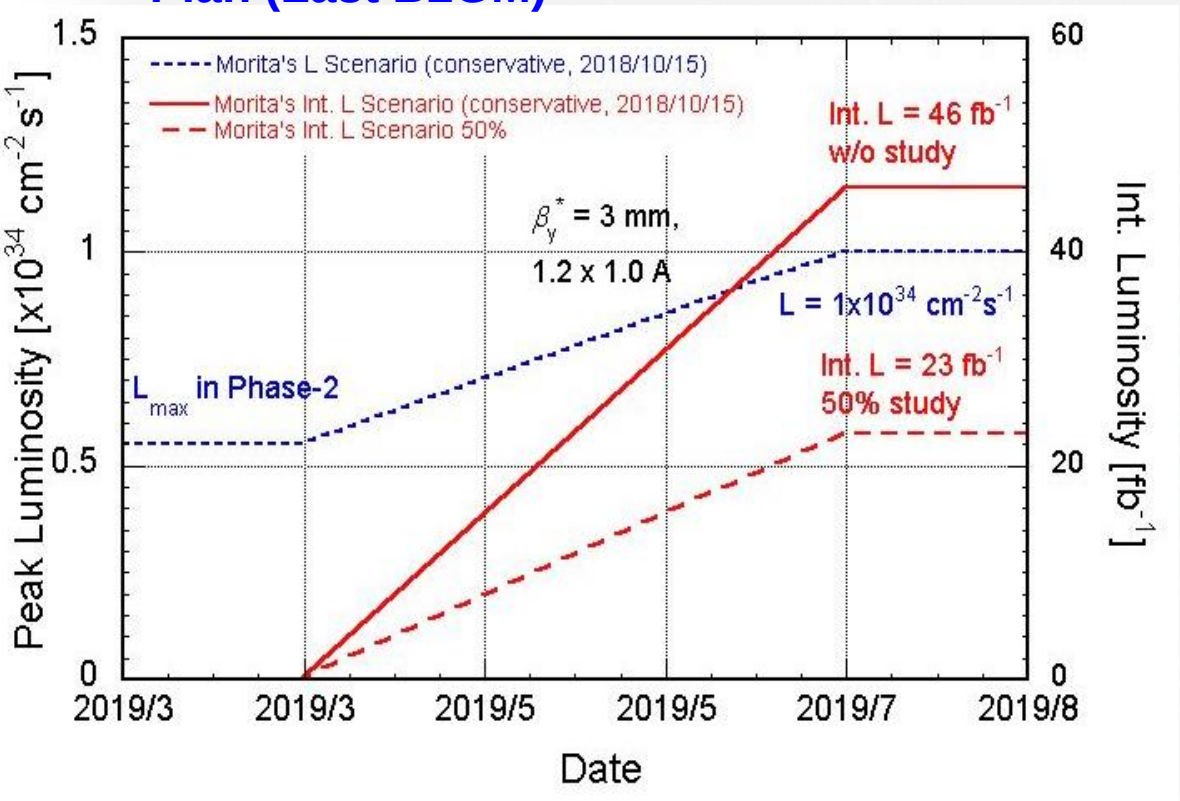
Results ~15th, June

		LER	HER
✔	ε_x [nm]	2.0	4.6
✔	$\varepsilon_y/\varepsilon_x$ [%]	< 8.0	< 8.0
✔	β_x^* [mm]	100	200
✔	β_y^* [mm]	3	3
✔	σ_z [mm]	~6	~6
--	I [A] (Physics run)	0.65	0.6
✔	Number of bunches	1576	
--	Bunch current [mA]	0.41	0.38
✔	σ_y^* [nm]	~500	~400
--	ξ_y (beam beam param.)	0.0266	0.0165
--	L [cm^{-2}s^{-1}]	0.5×10^{34}	

Major results and challenges

- Achieved luminosities

Plan (Last B2GM)



Conservative case
- $L_{peak\ limit}$ ~ 1.0 x 10^{34} $cm^{-2}s^{-1}$
- I ~ 1200 x 1000 mA
- L_{int} in 2019 Spring ~ 46 fb^{-1} w/o study

→ L_{int} ~ 23 fb^{-1} with 50% study

Worst (bad BG) case
- No improvements from Phase-2.
- Beam current is limited by BG.
- Sample from 2019.07.01 morning
- $L_{peak\ limit}$ ~ 0.2 x 10^{34} $cm^{-2}s^{-1}$
- I ~ 290 x 270 mA

→ L_{int} in 2019 Spring ~ 11.8 fb^{-1} w/o study

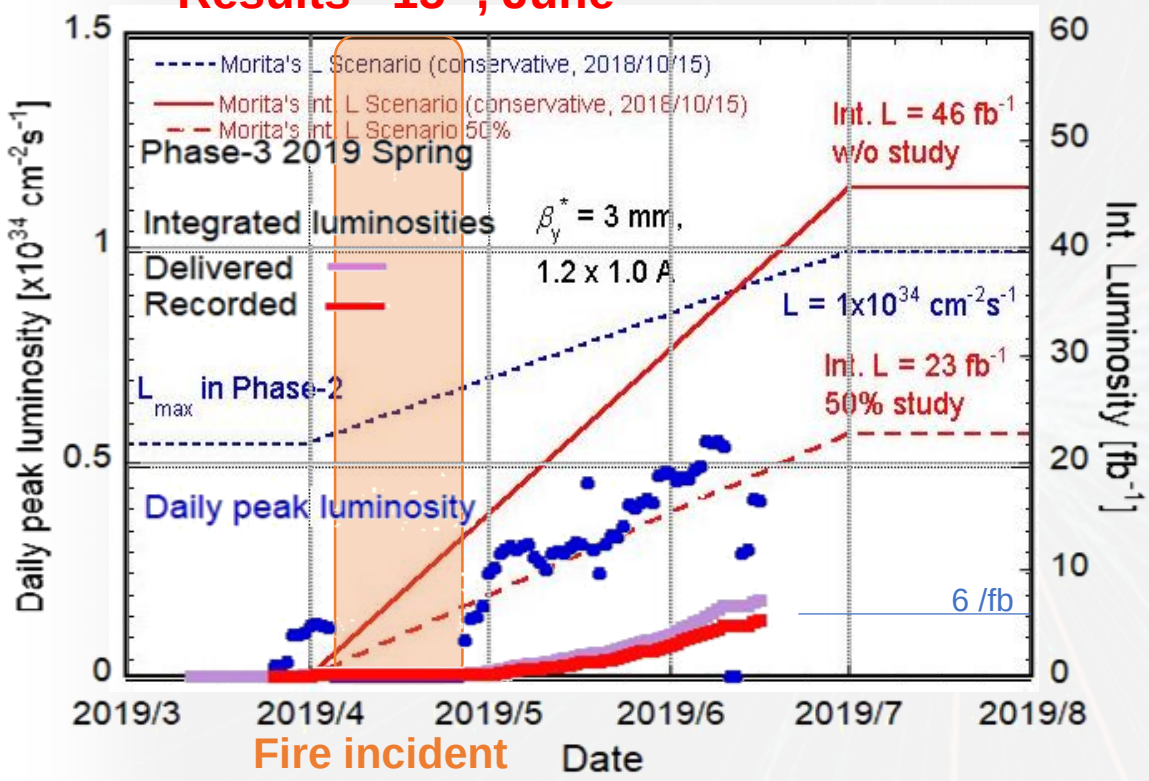
→ L_{int} ~ 5.9 fb^{-1} with 50% study

Assumptions
- L_{peak} increases linearly during beam operation.
- Efficiency L_{avg} / L_{peak} ~ 70%
- Belle works 24H during beam operation.(98days for 2019 spring run)
- Belle CAN take data with high beam current operation.(No BG limit)

Major results and challenges

- Achieved luminosities

Results ~15th, June



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Major results and challenges

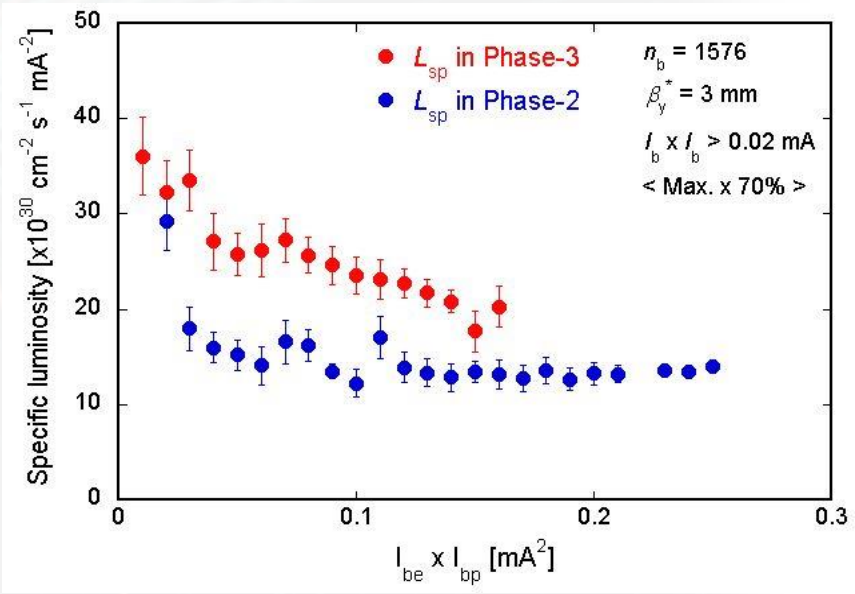
- Decrease in L_{sp} with bunch current product.

$$L_{sp} = \frac{L}{n_b I_{be} I_{bp}} \propto \frac{1}{\langle \sigma_y^* \rangle}$$

L_{sp}: Specific luminosity I_b: Bunch current
n_b: Number of bunches
$\langle \sigma_y^* \rangle$: Average vertical beam size at IP

- If $\langle \sigma_y^* \rangle$ is constant, L_{sp} should be constant against I_{be} x I_{bp}.
- Actually, however, L_{sp} decreases with an increase in I_{be} x I_{bp}.
- The decrease in L_{sp} is caused by the beam-size blowup due to the beam-beam effect.
- This could be one of serious problems for increasing luminosity in the future, if not solved.

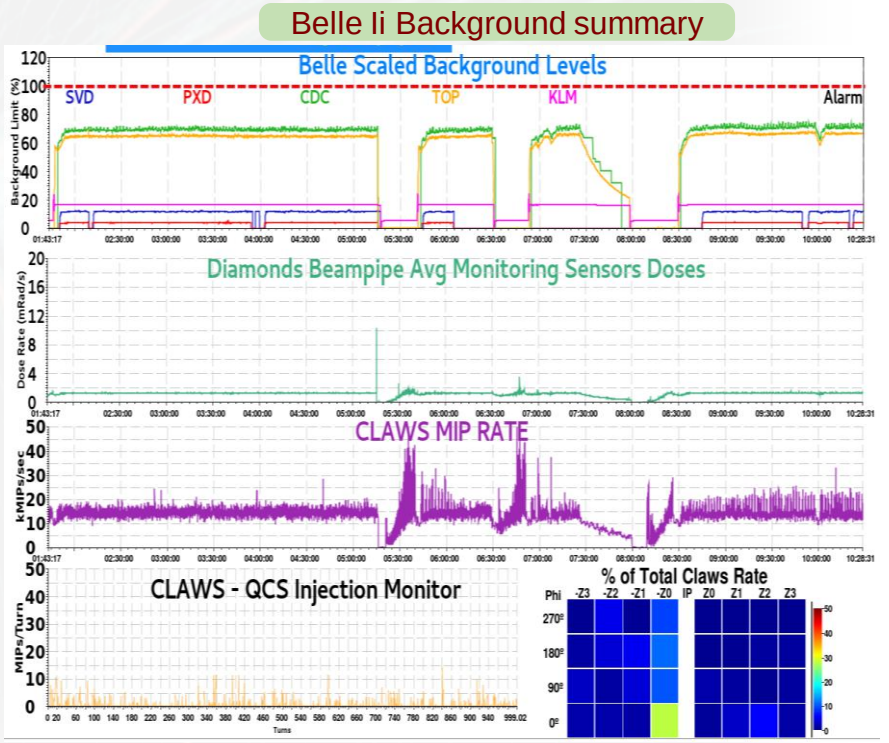
L_{sp} vs I_{be} x I_{bp}



→Next talk by Morita

Major results and challenges

- High background – LER stored beam
- Main BG source in LER storage mode was found to be the beam-gas Coulomb scattering from the dedicated BG studies by Belle II group (Nakayama-san, et al.).
- This raised the base of BG, and limited the beam currents during physics run.
  - A little room for BG form injection, and some BG bursts triggered CDC trips.

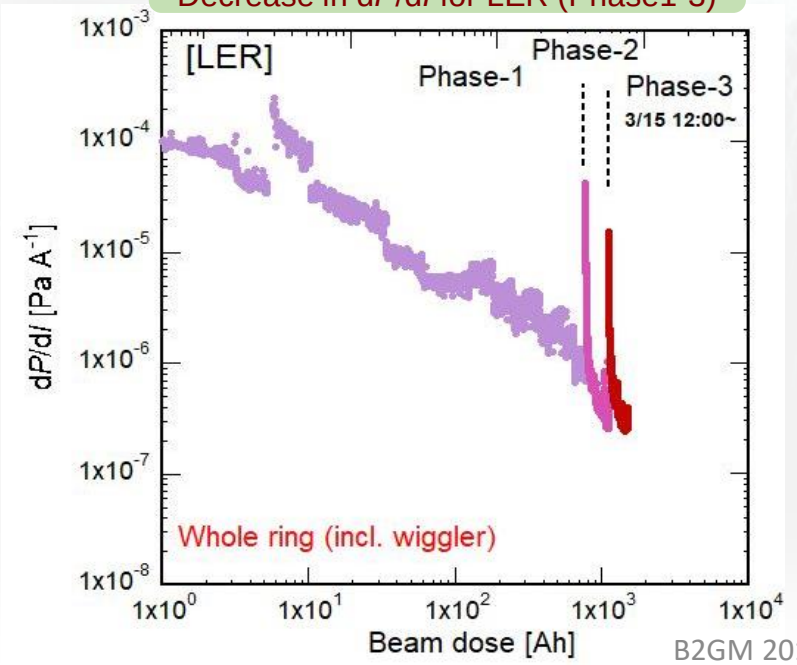


Major results and challenges

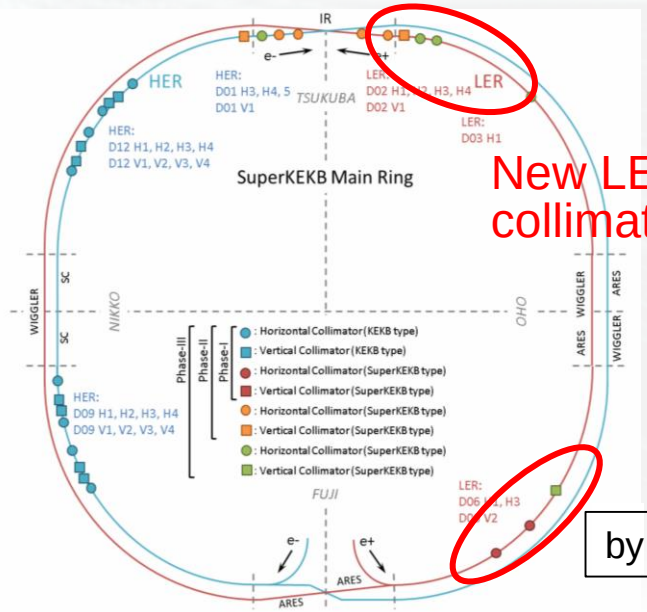
- Status of vacuum scrubbing

- Vacuum scrubbing of LER is steadily proceeding.
- At present, the average d*P*/d*I* is lower than that at the last in Phase-2.
- But, the pressure at the upstream side of IR is still high, where new collimators were installed just before Phase-3.
- Furthermore, the number of vertical collimators is still small.

Decrease in d*P*/d*I* for LER (Phase1-3)



Location of beam collimators



by Ishibashi

Major results and challenges

- High background – LER stored beam
- Main BG source in LER storage mode was found to be the beam-gas Coulomb scattering from the dedicated BG studies by Belle II group (Nakayama-san, et al.)

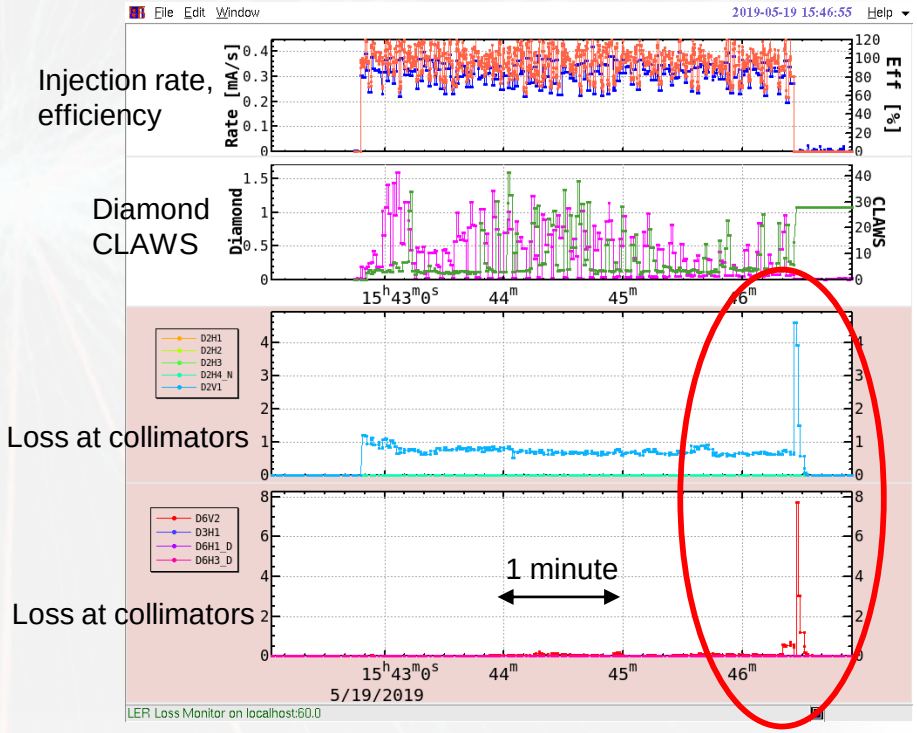
[Countermeasures]

- CDC trip threshold was raised by Belle II group.
- A vertical collimator is under manufacturing, and will be installed during this winter shutdown.
  - More collimators in the future? ← Impedance issue
- Optimization of betatron phases at collimator locations is also planed.
- Expect further vacuum scrubbing. (Please be patient…)
  - If the source point is localized, enforcement of vacuum pumps there might be considered, although some remodeling of beam pipes will be required.

Major results and challenges

- High background – LER Injection beam
- Bursts of beam loss at collimators followed by beam aborts have been frequently observed during LER injection.
- Properties are:
  - During injection
  - ~10 s or longer bursts
  - No correlation to collision or not, and to beam current
  - Loss monitor at collimators and VXD beam dose are correlated.
  - Big horizontal kick?
  - Kicker system and septum system seem to be stable.

Beam loss during injection (LER)



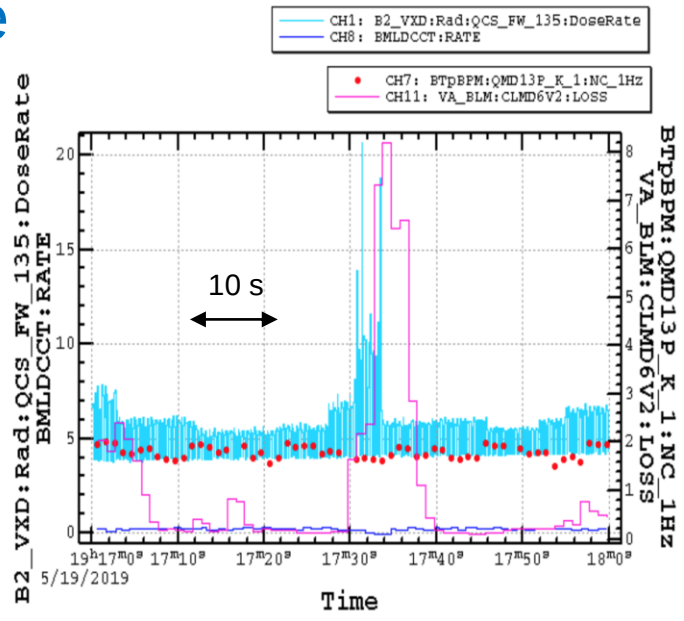
Major results and challenges

- High background – LER Injection beam
- Bursts of beam loss at collimators followed by beam aborts have been frequently observed during LER injection.

[Countermeasures (tentative)]

- A program is running that inhibits the beam injection when the VXD Diamond level or beam losses at collimator exceeds a specified level.
  ⇒ Frequency of this type aborts decreased.
- However the cause of this burst has not been fully understood yet. The investigation is ongoing.

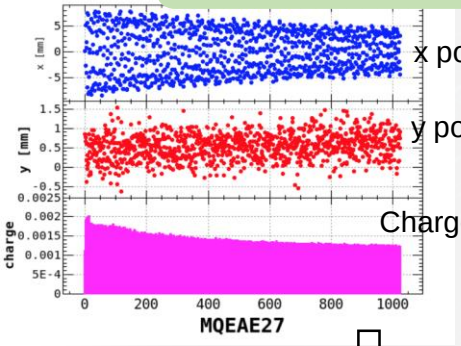
Timing of VXD Diamond (Fw135) signal and loss monitor signal at collimator (D06V2)



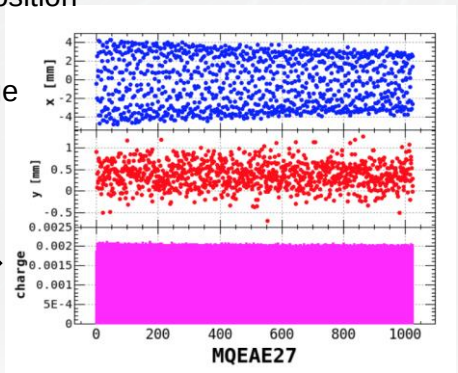
Major results and challenges

- High background – HER, LER Injection beam
- A strategy to drastically reduce the BG during HER and LER injections was developed just after the Platinum week.
  - A systematic tuning of injection parameters (septum angle, kicker height/jump, injection phase, etc.) to reduce betatron and synchrotron oscillations of the injected bunch.
  - This actually makes the continuous injection available.

Position of injected bunch and it's charge.
(5/9 HER Injection tuning by Iida and Ohnishi)



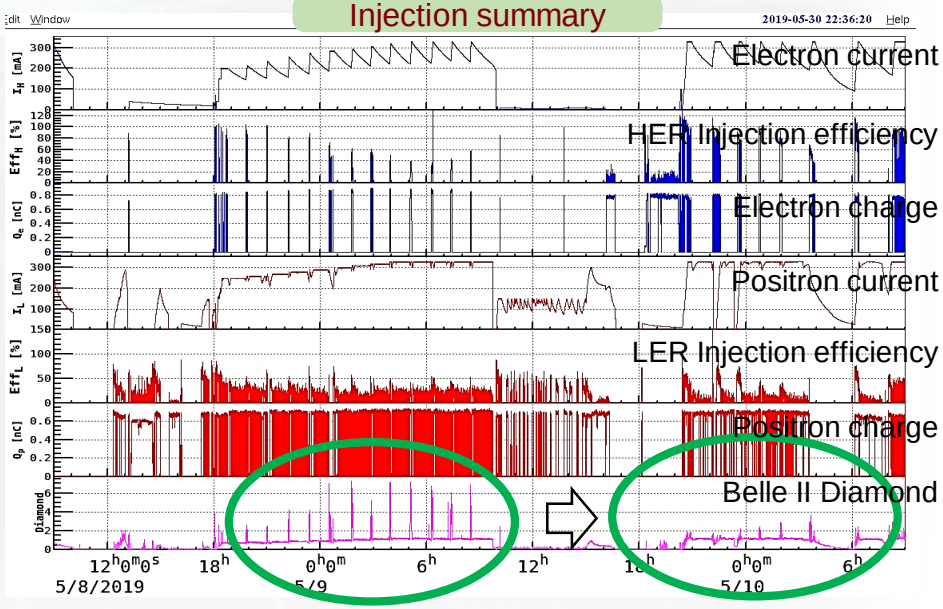
Turn number



Turn number

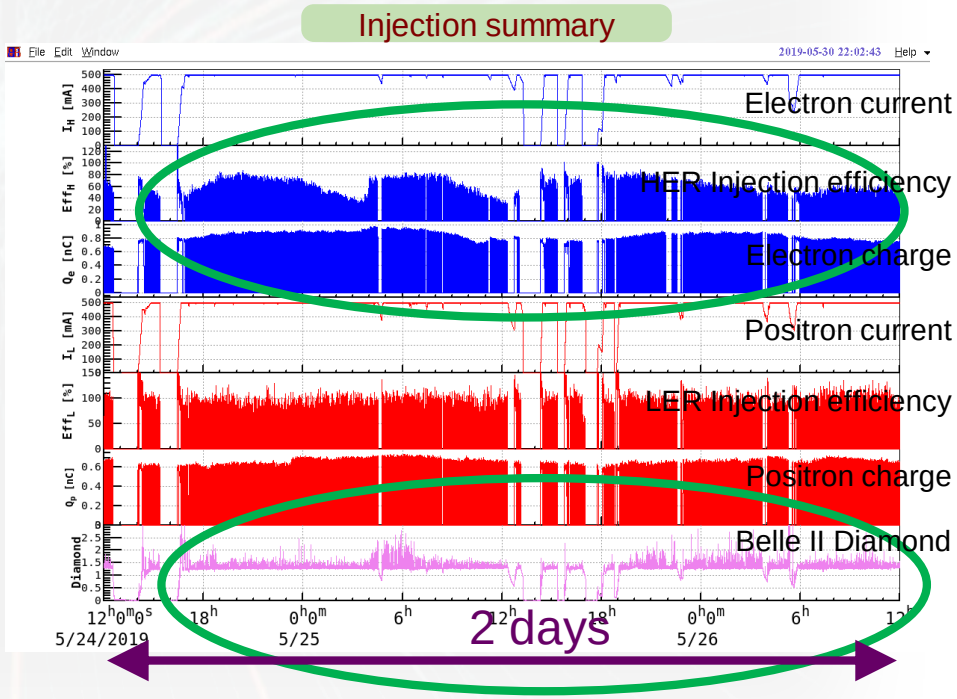
by Ohnishi, Iida

Injection summary



Major results and challenges

- High background – HER, LER Injection beam
- However, it is difficult to keep the good injection condition.
- BG as well as the injection efficiency degrades gradually, even in a shift (8 hours).
- Sometimes, a slight tuning of injection parameters recovers the situation.
- Or orbit correction of linac can restore the injection efficiency (especially for HER).
- Weather (temperature) dependence is also indicated.
- We have to find the source of this change and cure it.

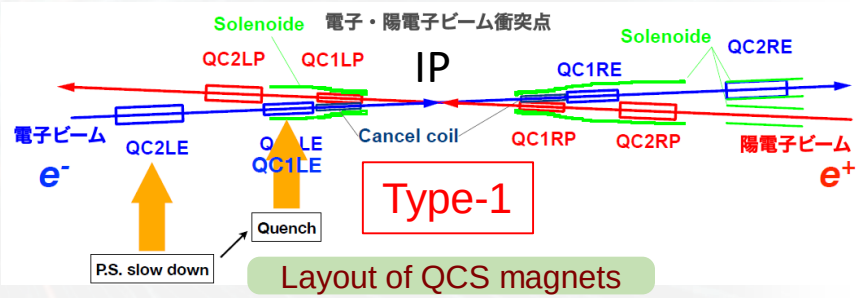


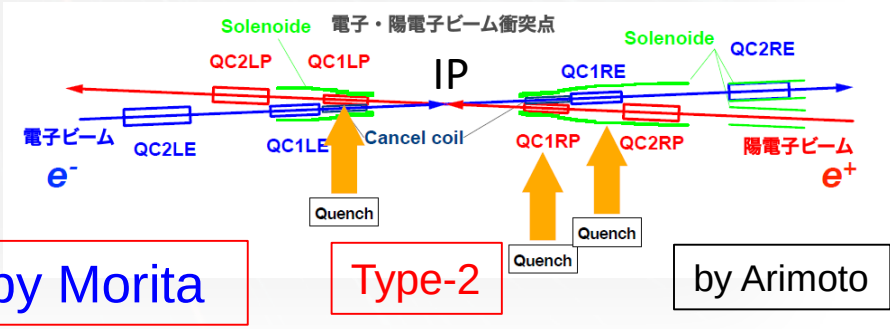
Major results and challenges

- QCS quenches
- Frequency of QCS quenches decreased compared to that in Phase-2.
  - Quick beam abort by Diamond sensor at IP.
  - Narrower apertures at beam collimators than those in QCS.
- However, six quenches (two types) happened up to now.

  [Type-1]: caused by the malfunction of QC2LE power supply.

  [Type-2]: suspected to be caused by the steered beam which lost energy by a collision with dusts (LER).
- Heavy damages to PXD and collimator heads





→Next talk by Morita

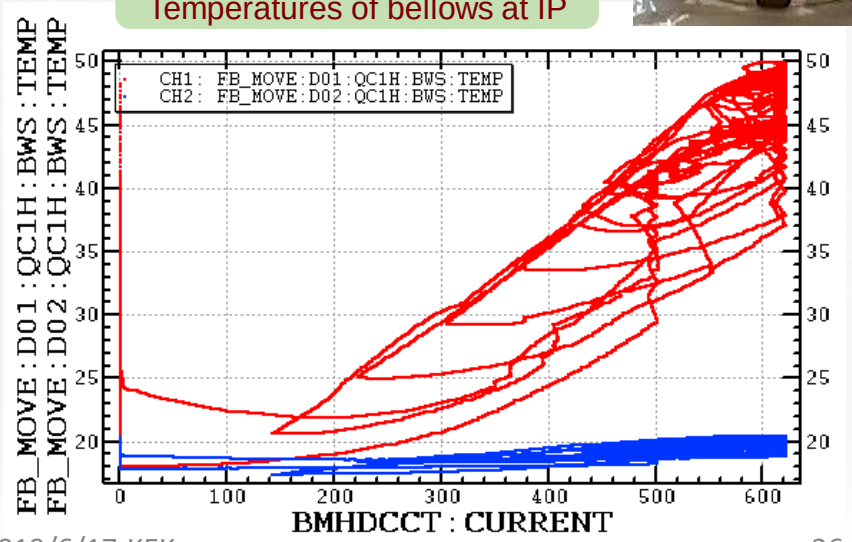
by Arimoto

Major results and challenges

- Heating of bellows at IP
- The HER bellows at backward side of IP is heated up, and is a concern at high currents: ~50˚ at ~ 600 mA (n_b=1576).
- The behavior against beam current changes with bunch numbers. →not SR, but HOM (RF).
- It will be replaced to a spare used in Phase-2 this summer.
  - Inside of bellows will be checked using a fiber scope before retracting QCSL, to check any troubles during last connection work.
  - Production defect?

Bellows at IP

Temperatures of bellows at IP

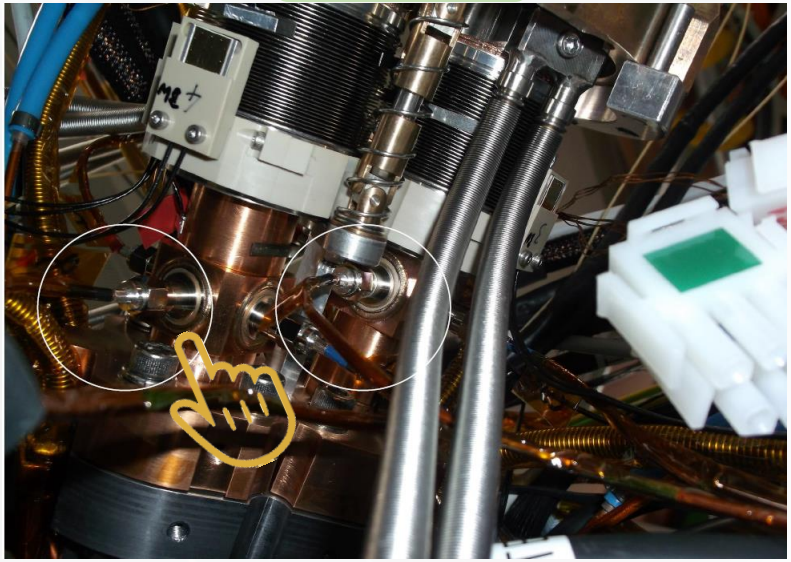


Major results and challenges

- QC1L BPM connectors
- Troubles were found in two coaxial cables for BPMs at QC1L. (Reported in last BPAC)
- TDR measurements suggest accidental damage at the SMA connectors.
- Useable with three BPMs, but the accuracy will be insufficient for the next autumn and winter commissioning.
- These BPM cables will be also replaced to new one during this summer shutdown.
  - The fastening toque will be well controlled.

by Tobiyama

BPM at QC1L



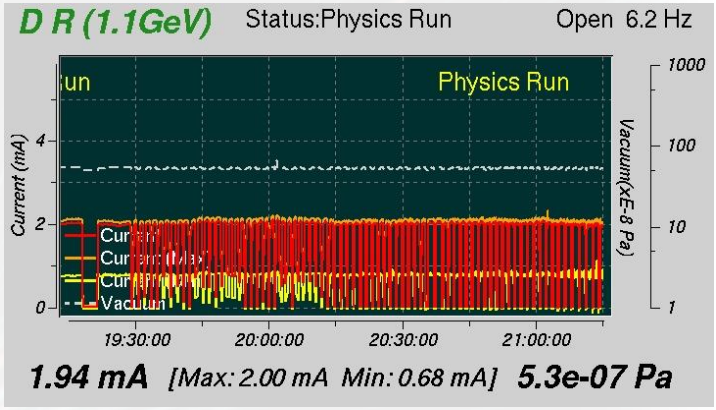
Status of several key items

- Status of damping ring (DR)
- DR has been working well.
- Damping of bunch:
- While the beam at first blows up just after the injection to the ring, the longitudinal and horizontal beam sizes well damp after 20 ms by the radiation damping.

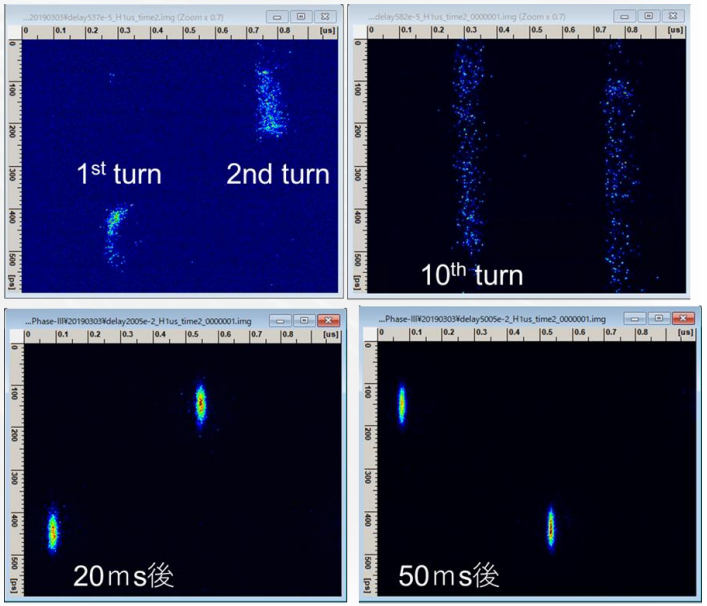
by Ikeda

- Trouble:
- The power supply for extraction septum failed once in March. However, the symptom was not reproduced.
  - Some spare parts had been ordered.

Operation status of DR



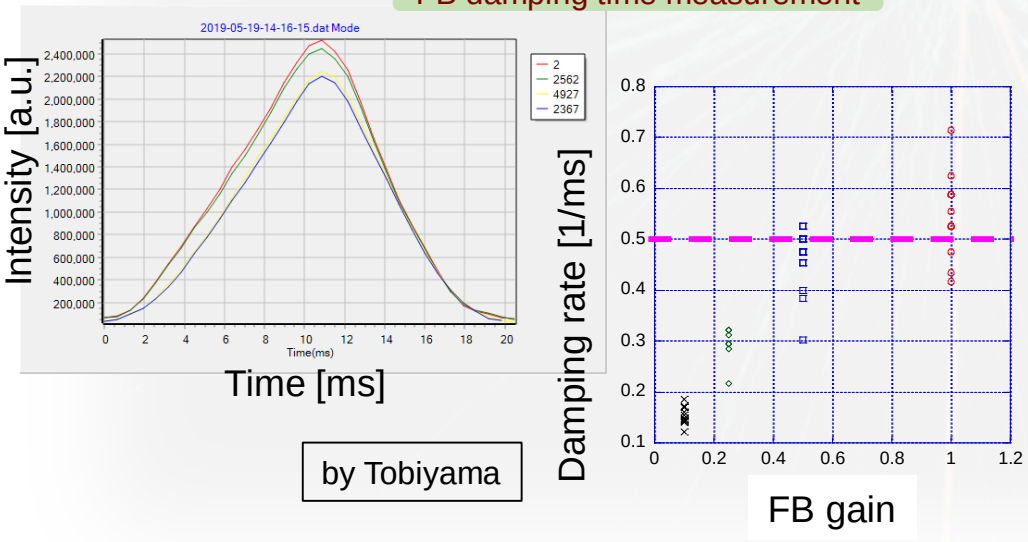
Longitudinal beam size (vertical) and horizontal beam size (horizontal) after injection [Streak camera]



Status of several key items

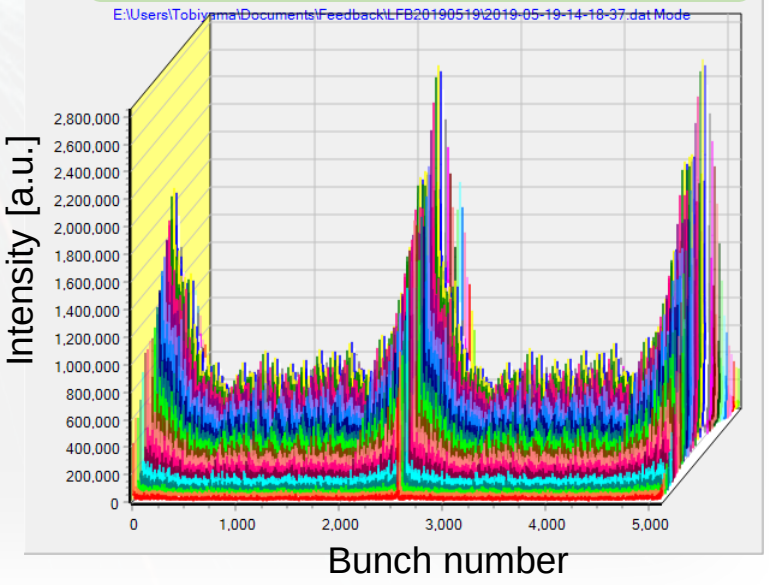
- Status of longitudinal bunch feedback systems
- Transient-domain (Excite-damp) experiments show the feedback damping time less than 2 ms is realized.
- No spontaneous longitudinal coupled-bunch instability (CBI) was observed even with 2 RF-bucket spacings fill pattern at a beam current of 500 mA.
  - Note: A longitudinal CBI was observed around 200 mA at Phase-2 with 2 RF-bucket spacings.

FB damping time measurement



by Tobiyama

Beam spectrum for 2 RF bucket spacings.
No oscillation was observed.

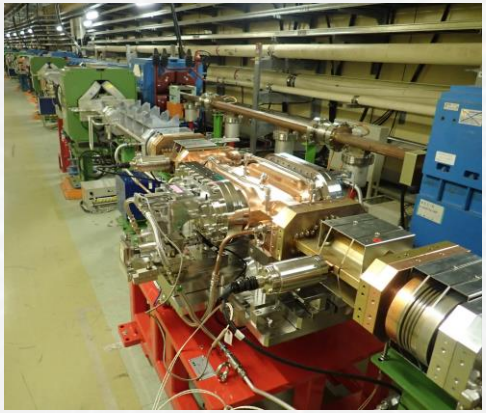


Status of several key items

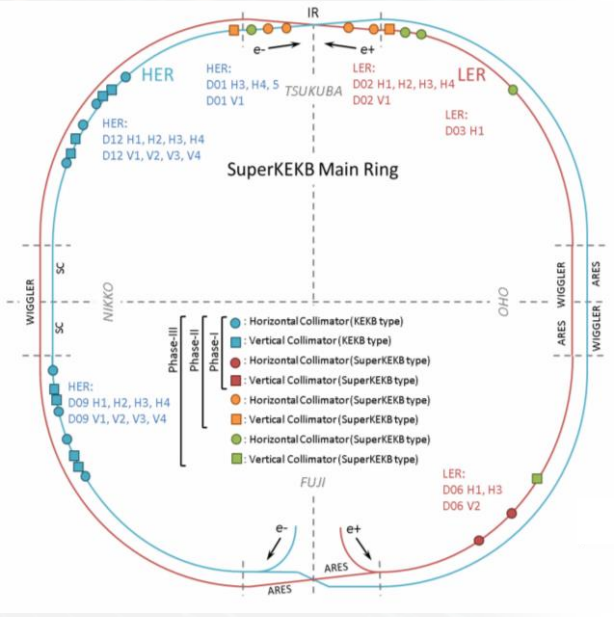
- Status of collimators
- Now we have 9 beam collimators in LER including 2 vertical types, although the number is still smaller than HER.
- Working well.

Vertical type collimator

Horizontal type collimator



Layout of collimators in Phase-3

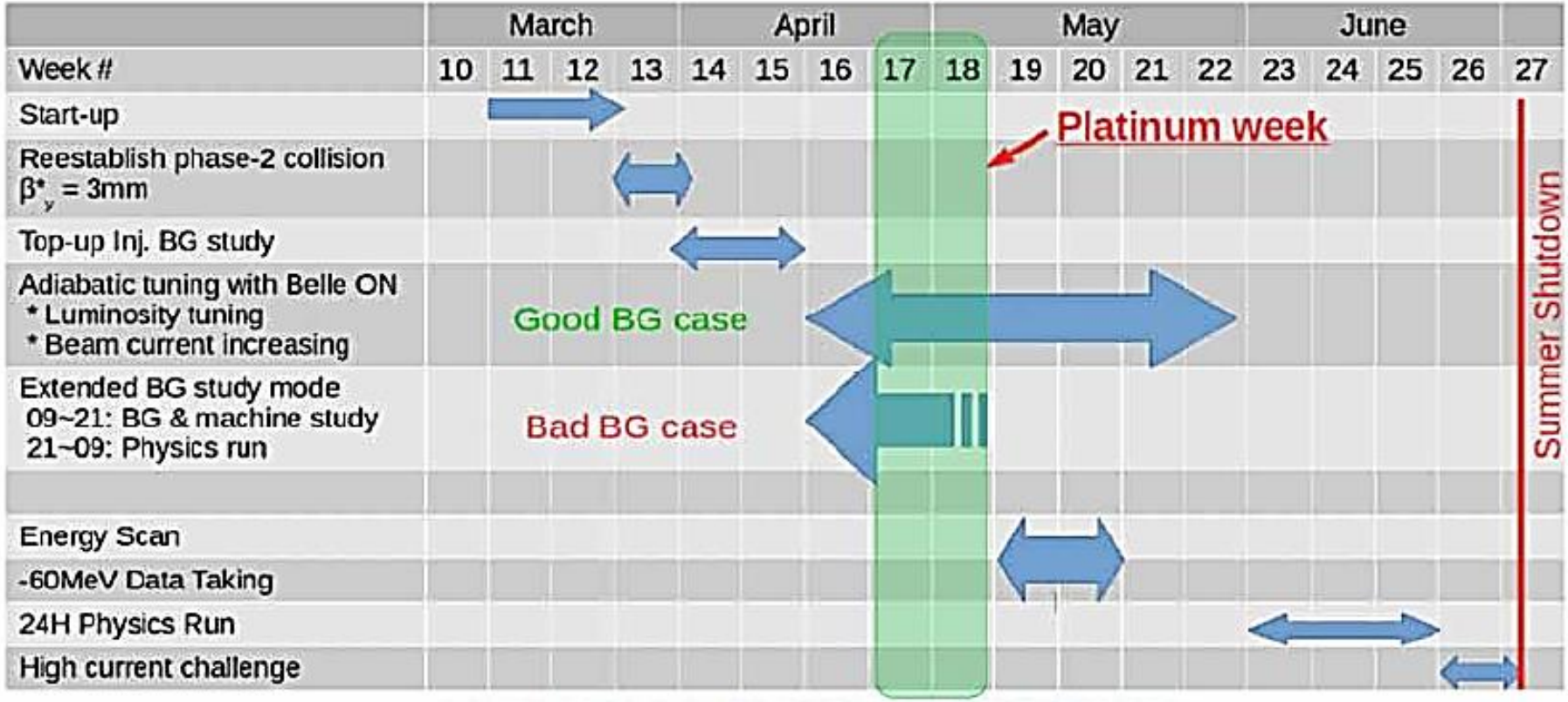


- Damage on the head:
  →Drastic countermeasures against the damages by beams should be considered in long term.
- A vertical-type collimator, which is effective to reduce BG due to beam-gas Coulomb scattering, is now under manufacturing, and will be installed in next winter.

Commissioning plan

- 2019 Spring run (~7/1)

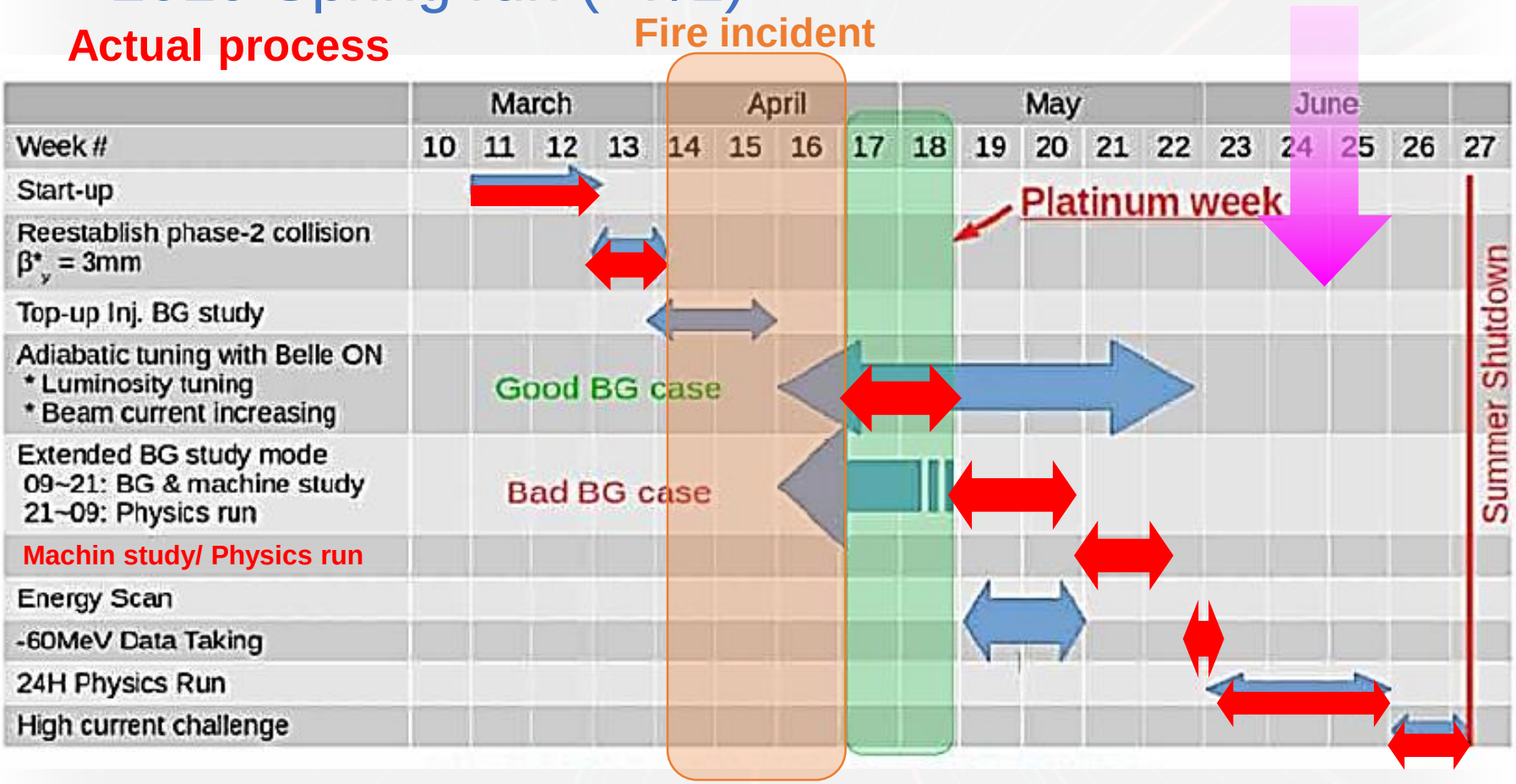
Plan (Last B2GM)



Commissioning plan

- 2019 Spring run (~7/1)

Actual process



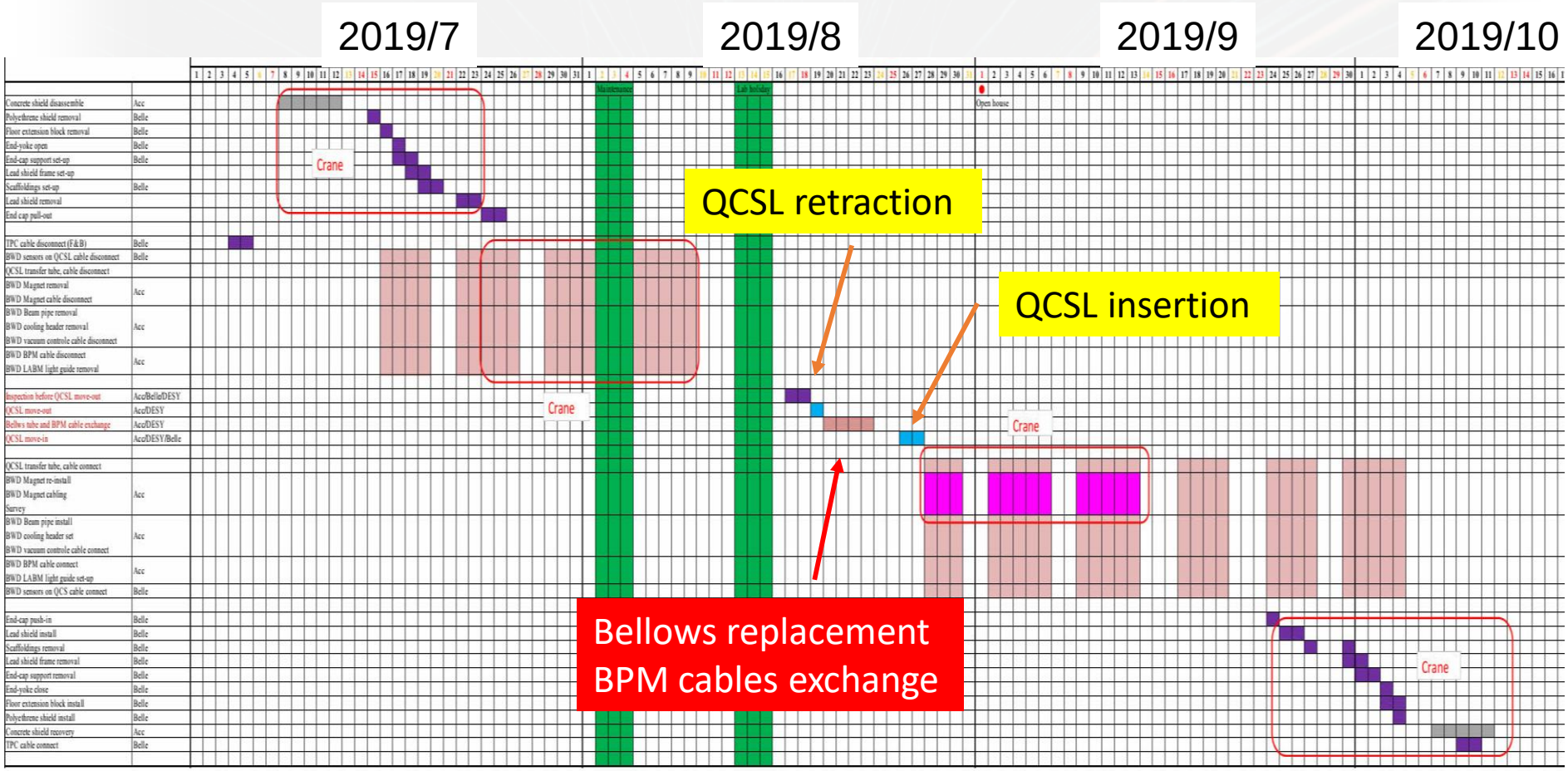
- ~3 weeks loss due to the fire incident, and some tuning, BG studies and machine studies were forced to be omitted.

Commissioning plan

- Summer shutdown
- This 2019 Spring run will end at 9:00 on 1st, July.
- Major works during the summer shutdown
  - Replacement of the bellows at IP. A spare, which had been used during Phase-2 commissioning, will be installed.
    - Four new ones are to be fabricated by the end of this year.
  - Replacement of QC1L BPM cables at IP, which have contact failures at the connectors.
  - These works require the retraction/insertion of QCS-L.
  - Any measures against QCS quenches if available.

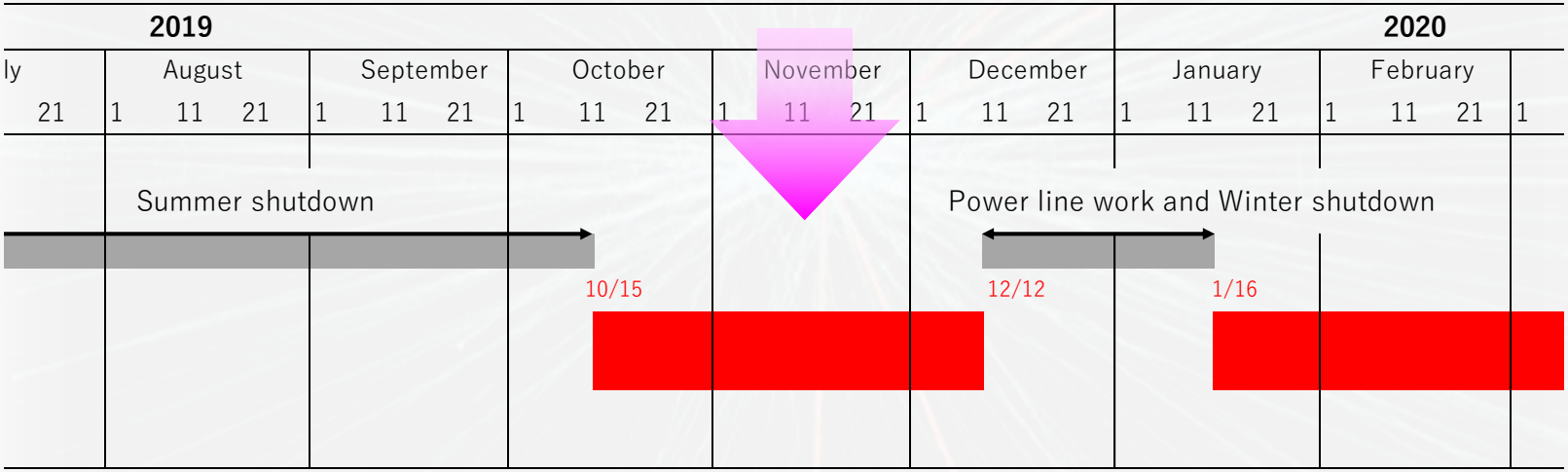
Commissioning plan

- Summer shutdown
  - Detailed IR schedule by Kanazawa



Commissioning plan

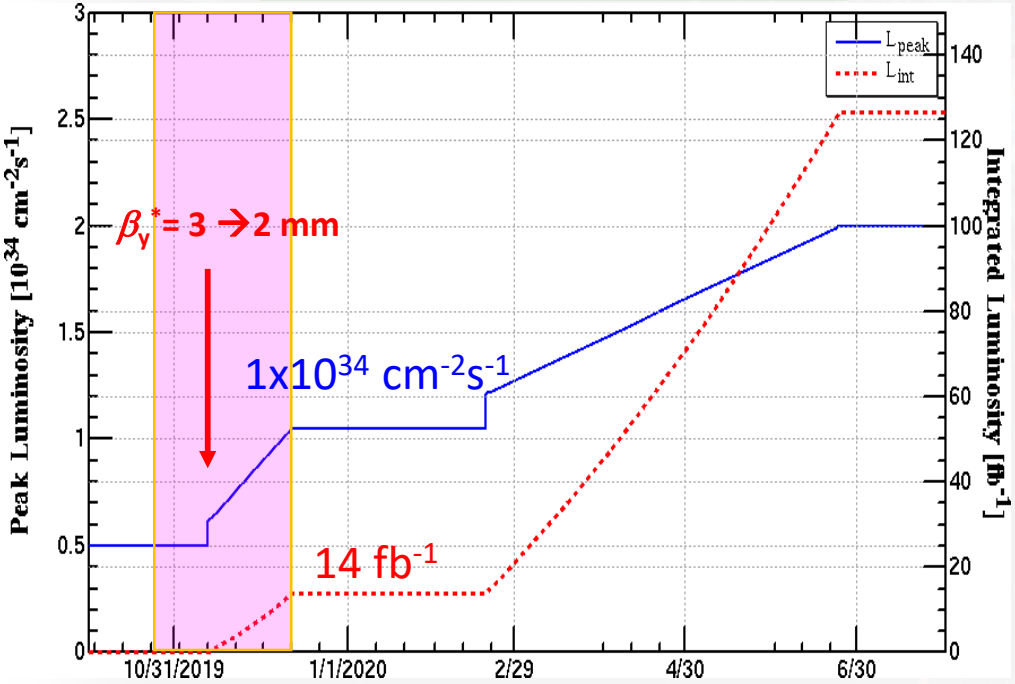
- Autumn run
- 2019 Autumn run will start on 15th, October and will end on 12th, December.
  - Continue the physics run and machine tunings.



Commissioning plan

- Autumn run
- 2019 Autumn run will start on 15th, October and will end on 12th, December.
  - Continue the physics run and machine tunings.

Conservative luminosity projection (2019/10-2020/6) [Morita]



→Next talk by Morita

Potential:

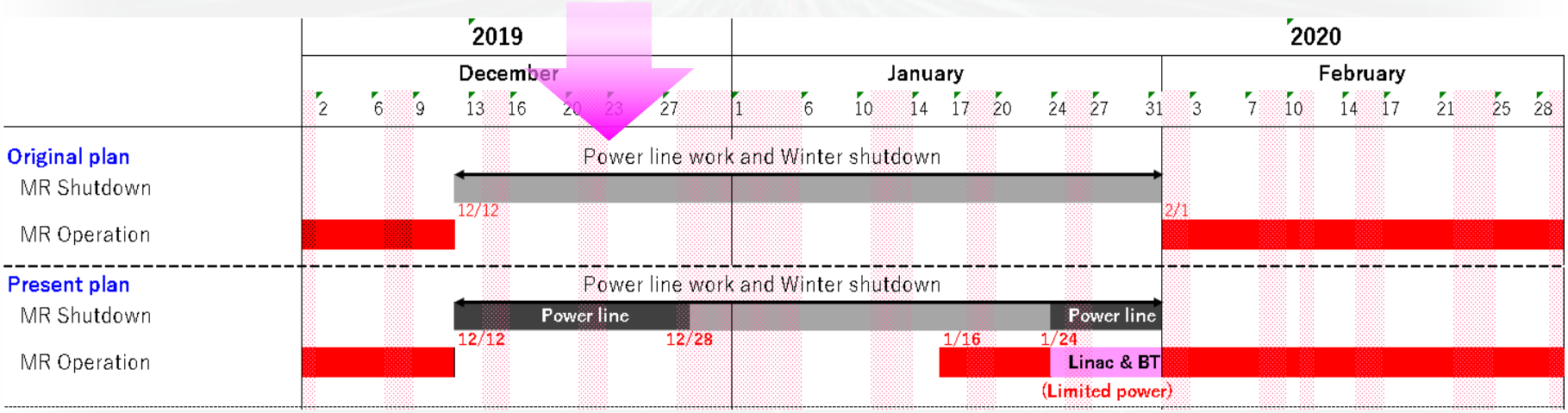
- Increase in beam-beam parameter
- Fill pattern optimization

Assumptions

- **Operation modes**
  - Start up: 2020/10/15 - 2019/11/11
    - Vacuum scrubbing: 3 weeks
    - Collision tuning (β_y^* = 2.0 mm): 1 week
  - Luminosity run: 2020/11/11 - 2020/12/12
- **Total occupancy rate ~65%**
  - Available operation time : 90%
  - Occupancy rate of machine: 85%
  - Occupancy rate of Belle II DAQ: 85%
- **Luminosity**
  - Increase in luminosity: Sqrt[3/2] -> (3/2)
  - Beam-beam parameter limit: no increase
  - Beam current: 1.4 times until 2019 end
  - No machine study time

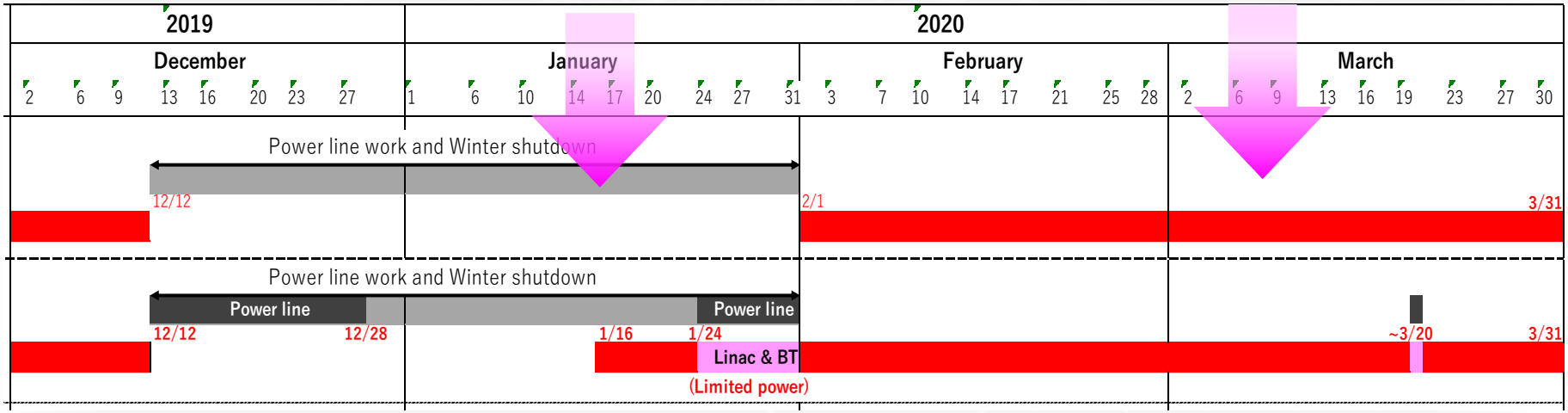
Commissioning plan

- Winter shutdown
- 2019 Autumn run will end on 12th, December.
- Major works during the winter shutdown:
  - 150 kV power line work by TEPCO
    - The electric power in KEK was restricted to less than 50 MW.
    - The MR have to be stopped. Linac, DR, and BT can be operated.
  - Condenser replacement
  - A vertical-type collimator will be installed into LER.



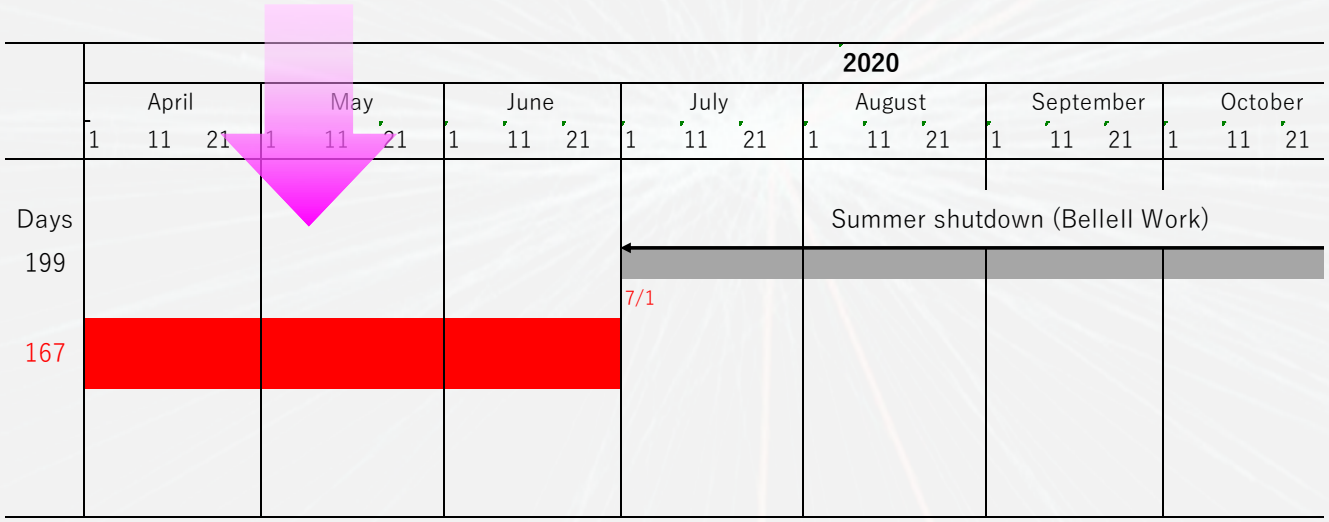
Commissioning plan

- 2020 Spring run
- 2020 Spring run of MR will start from 16th, January, although it is still in discussion.
  - Two weeks earlier than the original plan (2/1 start).
  - Compensation of loss time due to fire incident (~22 days).
  - Operation in January will be for mainly BT tuning and MR vacuum scrubbing.
- Run in March will continue as long as the budget allows.



Commissioning plan

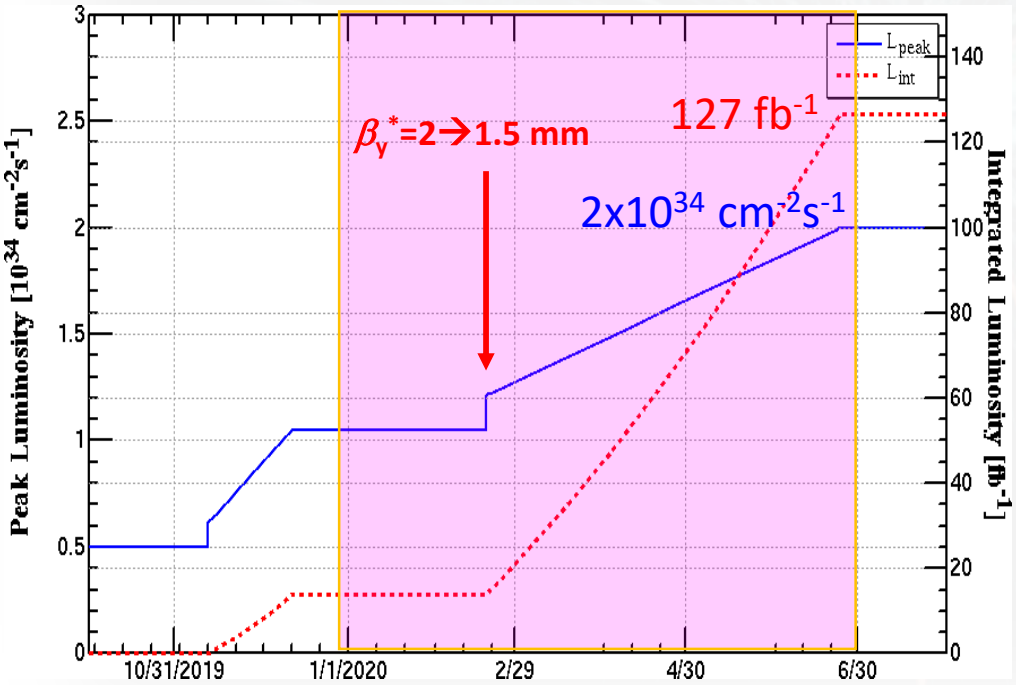
- 2020 Spring run
- 2020 Spring run of MR will be continued until the end of June. (not decided)
  - Continue the physics run and machine tunings.



Commissioning plan

- 2020 Spring run
- 2020 Spring run of MR will be continued until the end of June. (not decided)
  - Continue the physics run and machine tunings.

Conservative luminosity projection (2019/10-2020/6) [Morita]



→Next talk by Morita

Potentials:

- Increase in beam-beam parameter
- Reduction of BG by additional collimator → Higher beam current

Assumptions

- **Operation modes**
  - **Start up: 2020/01/16 - 2020/02/21**
    - Vacuum scrubbing: 2 weeks
    - Squeezing study (β_y^* = 1.5 mm): 1 week
    - Collision tuning: 1week
  - **Luminosity run: 2020/02/21 - 2020/07/01**
- **Total occupancy rate ~65%**
  - Available operation time : 90%
  - Occupancy rate of machine: 85%
  - Occupancy rate of Belle II DAQ: 85%
- **Luminosity**
  - Increase in luminosity: Sqrt[2/1.5] -> (2/1.5)
  - Beam-beam parameter limit: no increase
  - Beam current: twice until 2020 summer
  - No machine study time

Plan after April, 2020

- 2020 summer and after
- The operation schedule in FY2020 is still under discussion.
  - 8 month's run will be proposed in FY2020.

Summary-1

- Phase-3 commissioning is now ongoing.
  - Started from 11th, March 2019, as scheduled.
  - In spite of approximately three weeks' delay due to the fire incident in April, the data are being steadily accumulated by Belle II.
  - The continuous injections for both rings are available in regular operation.
- Key challenges to increase luminosity
  - High background level
    - BG from stored beam and from the injection beam.
    - Good after tuning, but the situation changes gradually.
  - Low specific luminosity at high bunch current product
    - Mechanism of the beam-beam effect should be understood.
  - Stable operation
    - Measures against QCS quenches
    - Improvement in beam abort system

Summary-2

- Commissioning plan
  - Plan until March, 2020, is almost fixed, and aim ~ 7 months' operation.
    - 2019 Spring run: ~7/1
    - 2019 Summer shutdown: 7/1 ~ 10/14
      - Replacement of bellows at IP, repair of QCS BPM.
    - 2019 Autumn run: 10/15 ~ 12/12
      - Squeeze β_y (~2 mm), increase currents with tunings
    - 2019 Winter shutdown: 12/12 ~2020/1/15
      - Power line work in Tsukuba campus
      - Installation of a vertical-type collimator into LER
    - 2020 Spring run: 2020/1/16 (not fixed) ~ (6/30)
      - Squeeze β_y (~1.5 mm), increase currents with tuning
  - The schedule of 2020～2021 are under discussion.

Thank you for your attention.

Backup

US-Japan collaboration in HEP

SLAC/Stanford:

IP feedback, Beam background, Collimators, HOM suppression, BxB feedback, LLRF, X-ray monitor, etc.

U. Hawaii

X-ray monitor

Wayne St. Univ.

LABM

Multi-National Partnership Project (MNPP-01)

LAL: Fast luminosity monitor

CERN, IHEP : Commissioning

Major results and challenges

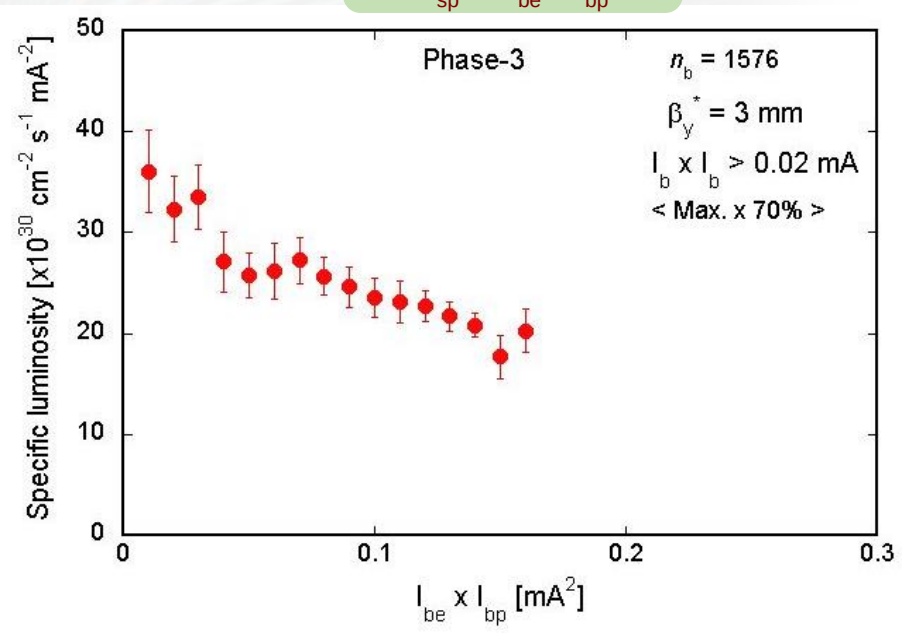
- Decrease in L_{sp} with bunch current product.

$$L_{sp} = \frac{L}{n_b I_{be} I_{bp}} \propto \frac{1}{\langle \sigma_y^* \rangle}$$

L_{sp}: Specific luminosity I_b: Bunch current
n_b: Number of bunches
$\langle \sigma_y^* \rangle$: Average vertical beam size at IP

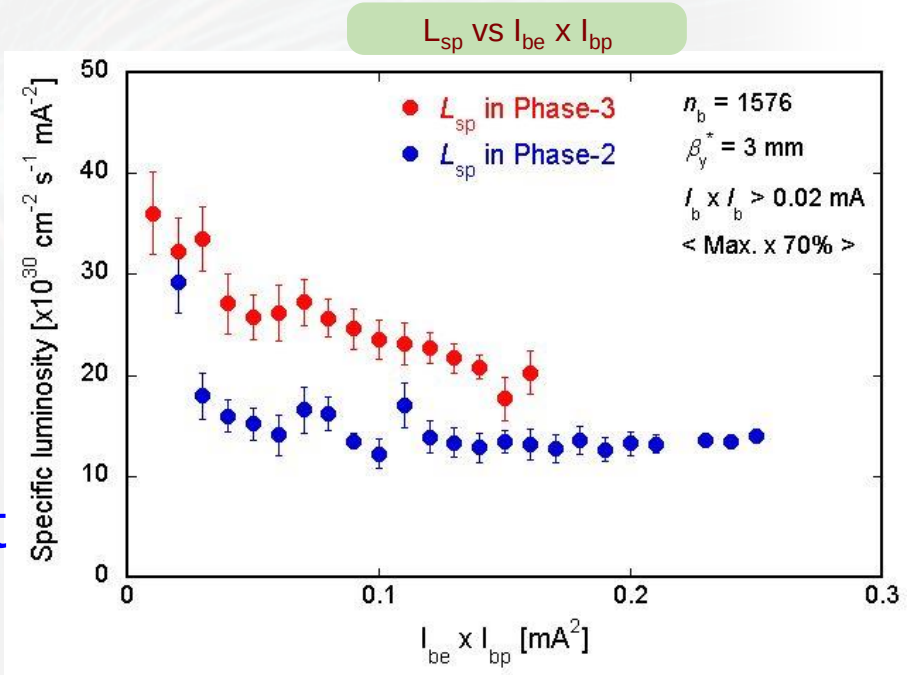
- If $\langle \sigma_y^* \rangle$ is constant, L_{sp} should be constant against I_{be} x I_{bp}.
- Actually, however, L_{sp} decreases with an increase in I_{be} x I_{bp}.
- The decrease in L_{sp} is caused by the beam-size blowup due to the beam-beam effect.

L_{sp} vs I_{be} x I_{bp}



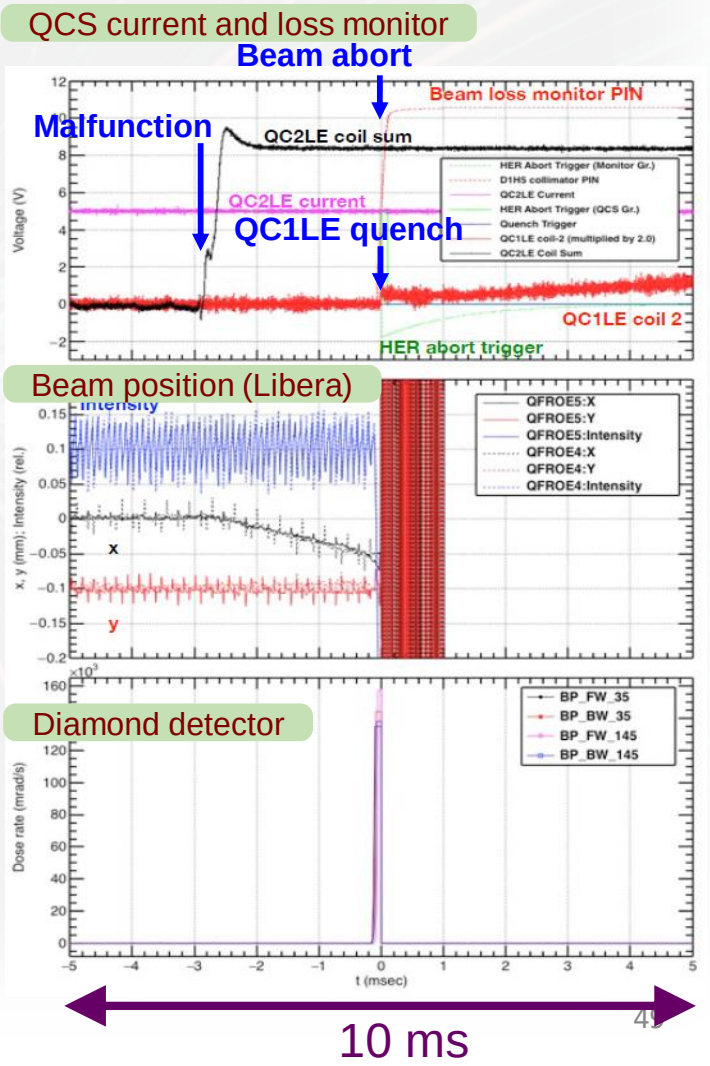
Major results and challenges

- Decrease in L_{sp} with bunch current product.
- The degree of degradation of L_{sp} against bunch current product improved in Phase-3 compared to that in Phase-2.
  - Elaborate collision tuning
  - Beam-beam effect study, and development of tuning knobs.
- As a cause, the non-linear chromatic coupling in optics at IP is suspected.
- But, the mechanism has not been well understood yet.
- This could be one of serious problems for increasing luminosity in the future, if not solved.
- Allow us more time to understand the machine.



Major results and challenges

- QCS quench - [Type-1]
- Four quenches were caused by the malfunction of QC2LE power supply.
  - The current of QC2LE slowly changed for ~3 ms due to the malfunction of PS until the beam was aborted by the loss monitor signal, and the steered beam hit QC1LE resulting in a quench.
  - Just before the beam abort (~100 μs), the high dose of radiation entered to PXD, and gave it heavy damage.

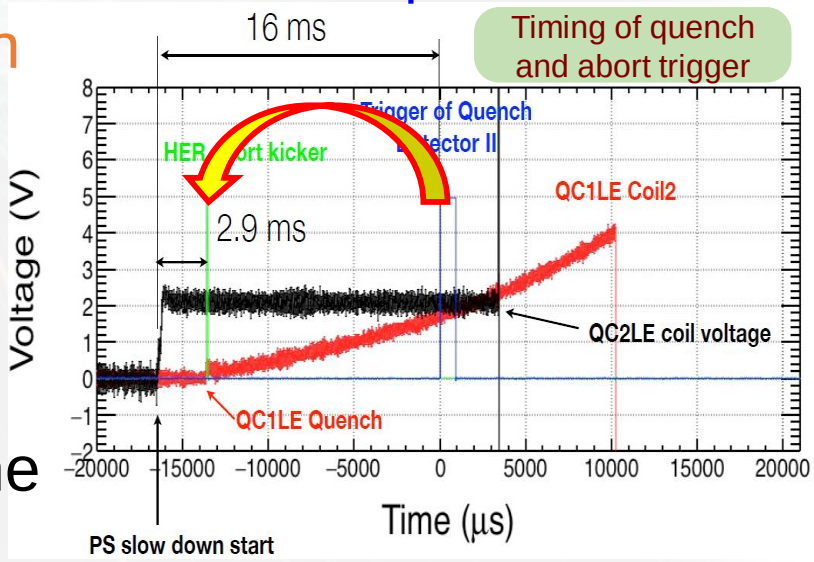


Major results and challenges

- QCS quench - [Type-1]
- Four quenches were caused by the malfunction of QC2LE power supply.

[Countermeasures]

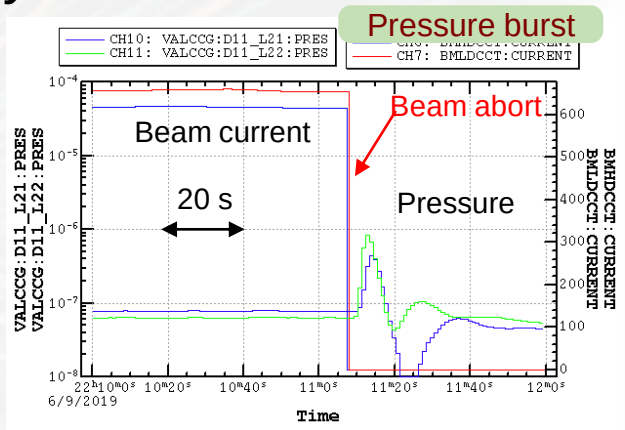
- SVD: The dynamic range was widen to detect higher dose without saturation, and trigger the beam abort earlier.
  - This change (5th) saved the SVD at the third quench!
- QCS: The delay time of quench detector was shorten from 16 ms to less than 3 ms on 13th, June as a quick measure.
- Modification of PS to directly issue an abort trigger is also in consideration, but it will be done after summer.

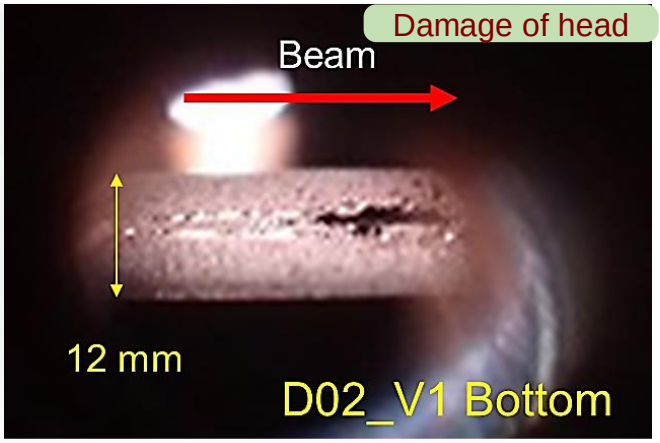


- The cause of PS malfunction is still under investigation.

Major results and challenges

- QCS quench - [Type-2]
- Other two quenches were suspected to be induced by beam-dust collision in LER.
  - A pressure burst was simultaneously observed at an arc or a wiggler section in each case.
  - Horizontal shift of the beam orbit due to the energy loss was observed just before the abort, although small.
- The second quench (6/9) was very sever.
  - High radiation dose damaged PXD.
  - Collimator heads of D02_V1 (vertical type collimator) were heavily damaged.
  - Liquid He of QCSR was completely evaporated.

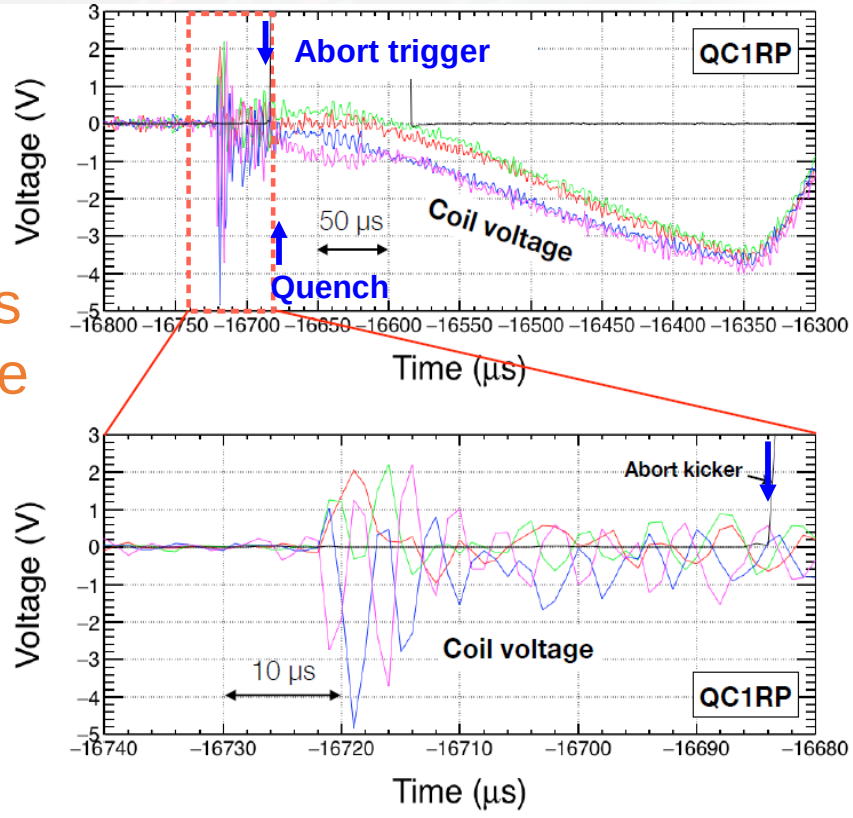




Major results and challenges

- QCS quench - [Type-2]
- Other two quenches were suspected to be induced by beam-dust collision in LER.
- The event was very fast.
  - The first beam abort trigger was issued from VXD Diamond sensor.
  - The beam was aborted after 30~40 μs (3~4 turns), which is almost the fastest timing in the present abort system.
  - But, ~150 mA out of 660 mA was lost until the beam abort, i.e., during this 3~4 turns.

Timing of quench and abort trigger

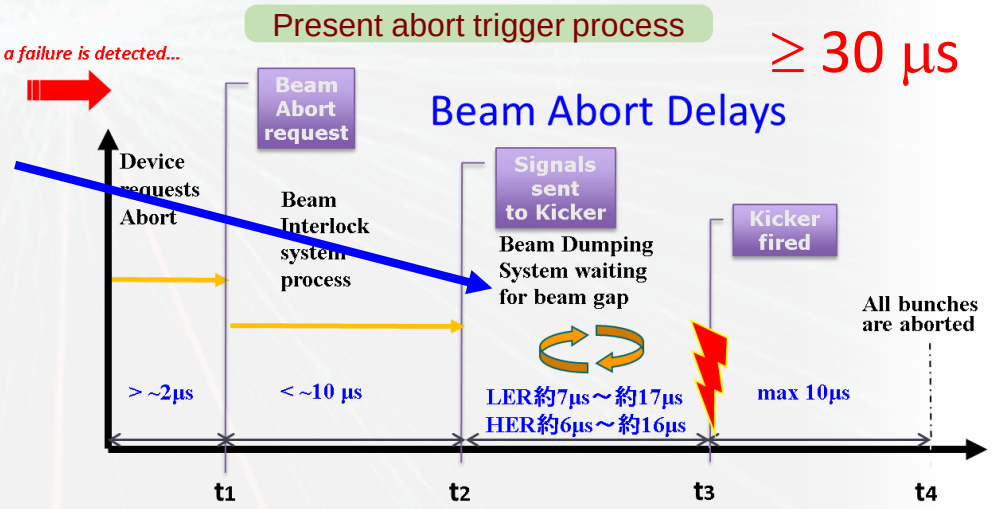


Major results and challenges

- QCS quench - [Type-2]
- Other two quenches were suspected to be induced by beam-dust collision in LER.

[Countermeasures]

- We are considering to shorten the time lag between the abort trigger and the kicker firing, but it is not so easy.
  - For example,
  - Increase the number of abort gaps (~5 μs)

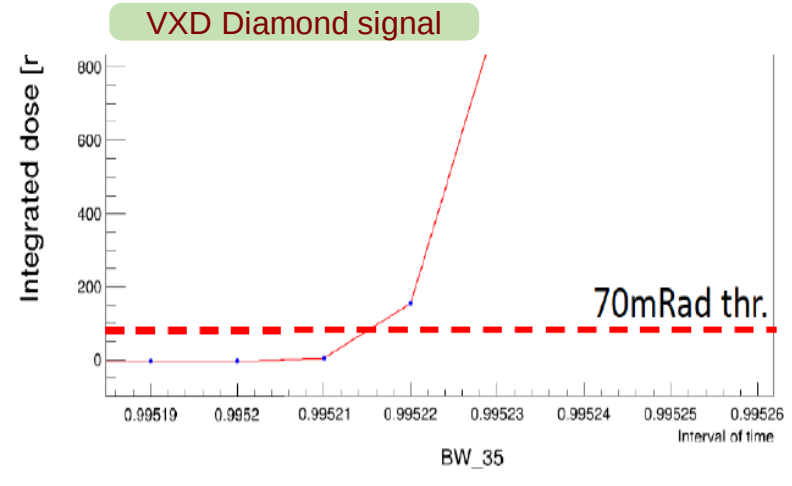


Major results and challenges

- QCS quench - [Type-2]
- Other two quenches were suspected to be induced by beam-dust collision in LER.

[Countermeasures]

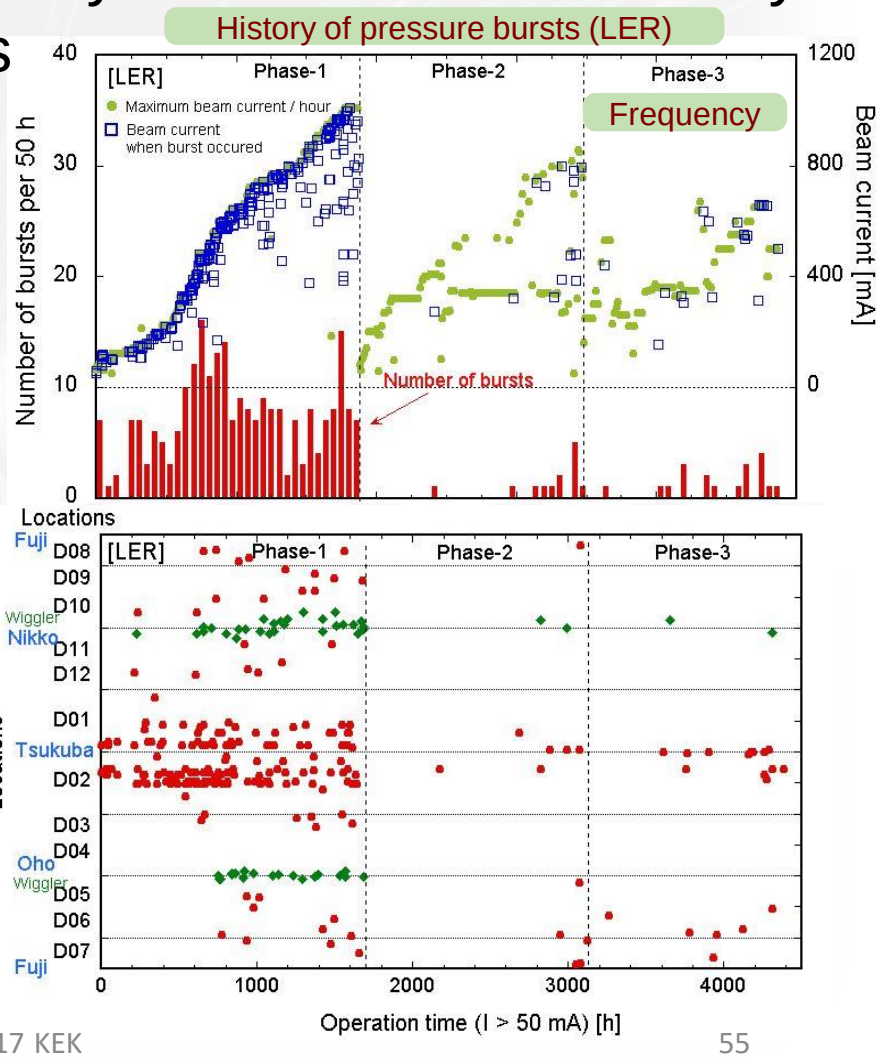
- We are considering to shorten the time lag between the abort trigger and the kicker firing, but it is not so easy.
- On Belle side, the fast abort threshold of VXD Diamond was lowered to 10 mrad/s from 70 mrad/s to issue the trigger earlier (6/12).



- If the cause is actually the beam-dust collision ….
  - It is impossible to remove all dusts from beam pipes.
  - But it will be possible to reduce the probability.

Major results and challenges

- Status of pressure bursts in LER
- Pressure bursts accompanied by beam aborts caused by possibly beam-dust collisions have been observed since Phase-1, but the frequency decreased drastically in Phase-2 and Phase-3 (up to now).
  - Aging effect? (lower beam currents in Phase-2 and 3)
  - Fast beam abort system? (VXD Diamond, narrow collimators)
  - Knocking of beam pipes before Phase-2? (at Tsukuba)



Major results and challenges

- QCS quench - [Type-2]
- Other two quenches were suspected to be induced by beam-dust collision in LER.

[Countermeasures (if beam-dust collision is a cause)]

- BEFORE starting the physics run, increase the beam current and confirm the stable operation. → "Aging run" After that, start the physics run with a somewhat lower beam current.
  - A dedicated time will be required to increase the beam current before the physics run.
- Knock beam pipes in the ring during a long shut down, and drop dust in advance.
  - Already done at Tsukuba straight section before Phase-2.
- Any radical measures should be discussed ASAP to solve this Type-2 quench for stable operation.

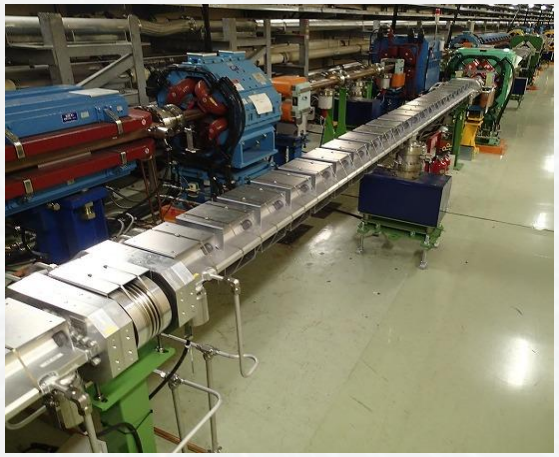
Major results and challenges

- Others
- Failures in key components
  - For example, DR Septum PS (March), QCS PS (May, June), QCS cryostat vacuum system (June)
  - Preparation of spear parts for the special component is a pressing need for the stable operation, as long as the budget allows, and some are on going.(some spare circuit for septum PS, MR HER septum magnet, vacuum pumps, etc.)
- Troubles caused by high atmospheric temperatures (even in May)
  - Fluctuation of magnet cooling water sometimes exceeded the interlock level, and it trigger the beam abort.
  - The temperature of RF water load goes up near to the interlock level, and it raised an alarm.
  - These sometimes interrupt the operation, especially in day time. → Difficulty in operating in summer.

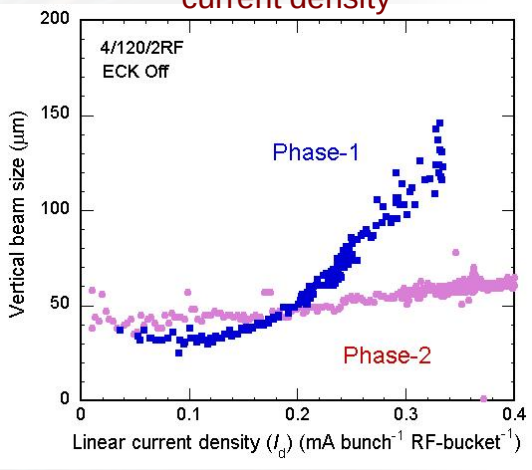
Status of several key items

- Status of electron cloud effect (ECE) in LER
- The ECE greatly deteriorates the luminosity.
  - Beam-size blow up caused by single bunch instability.
- The ECE observed in Phase-1 was suppressed in Phase-2 using permanent magnets around beam pipes.

Permanent magnets around beam pipes



Beam sizes vs linear current density



- No indication of ECE has been observed also in Phase-3 so far, although still small linear current density.
- The ECE will be studied again in this run (end of June?).
- Effect of the permanent magnets on the beam optics is still an concern, and has been studied.

A juggling in 2021

- We have to reinforce the ceiling of Tsukuba Ex. Hall in 2021, to follow the revised Building Standard Law.
  - Revised after the big Tohoku earthquake in 2011.
- The work area is divided into three areas. At present, the work at the ring side is planed in 2021 summer shutdown, because a high radiation level is expected there with beam.
- The crane work is prohibited for ~2 months, and it should have a big impact on the summer schedule.