for Talk

Beam injection in 2021ab(Feb.-Jul.)

SuperKEKB Review Committee
1st Sep. 2021
N. Iida
for Emittance preservation task force
→ Beam Injection task force

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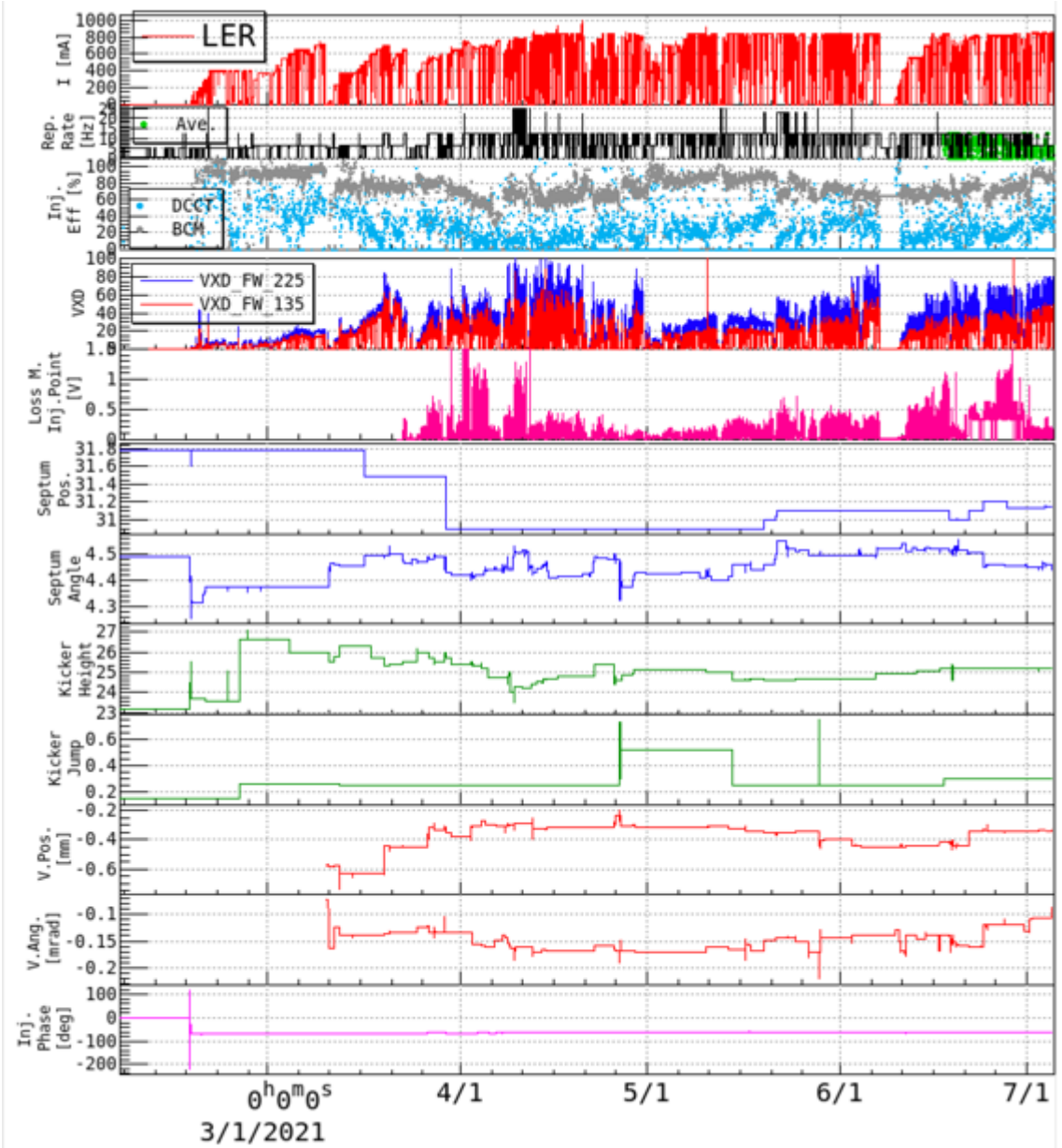
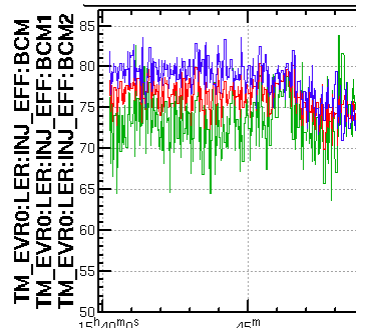
Contents

1. Injection status of LER

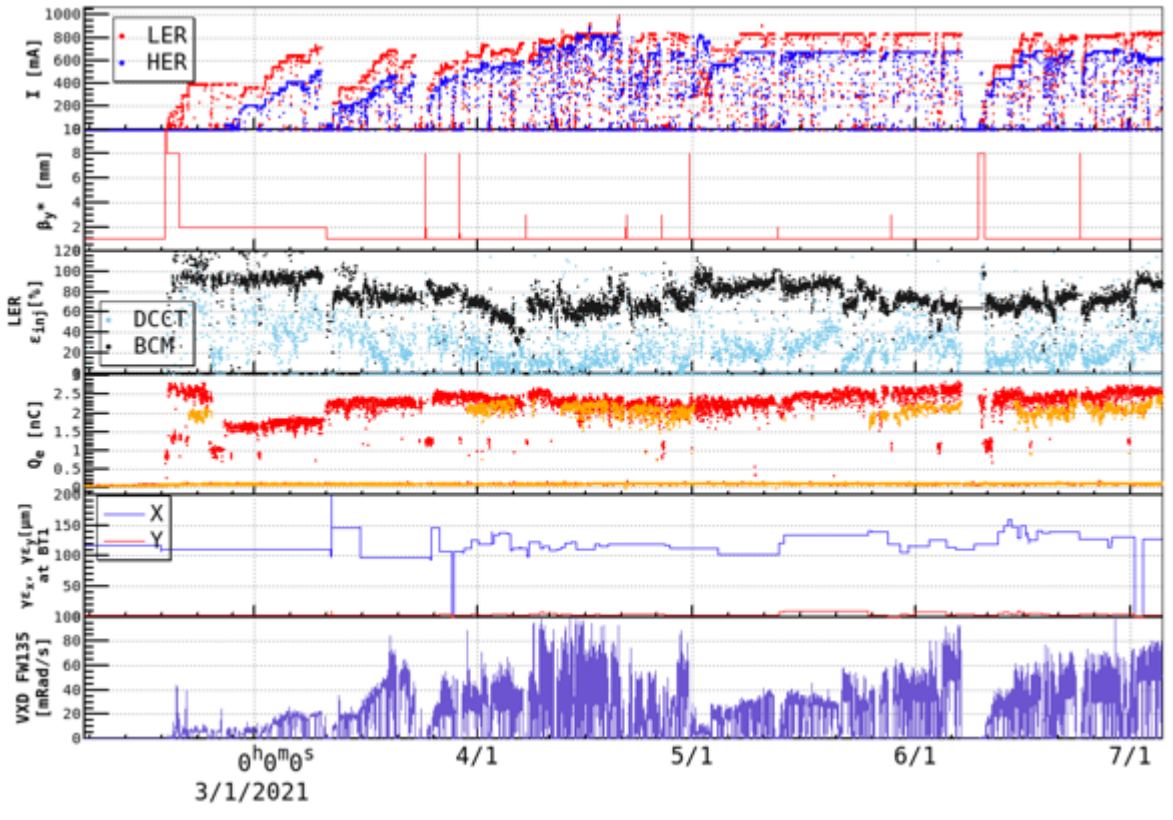


- The injection of 1st bunch (75~100%) is no problem, but for 2nd bunch it is about 10% worse.
- The beam background to Belle II is larger than HER
  - Nakayama-san's talk

Raw injection efficiency



1st bunch
Average
2nd bunch

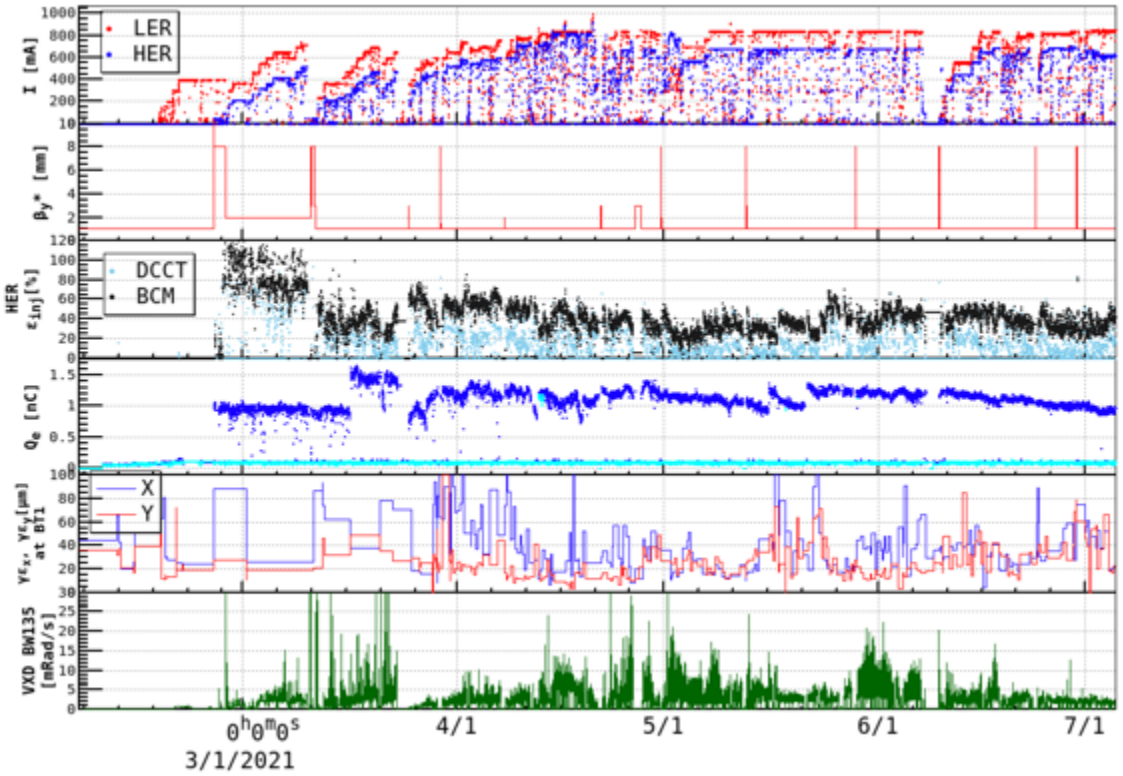


2. Injection status of HER

① Poor “raw” injection efficiency (30-70%)

- Background at VXD is low.
- A recently simulation:
  - The injected beam mainly losses at the vertical collimators.
  - The main losses are due to the emittance growth or/and optic mismatch rather than the injection oscillation.
  - The 70% injection efficiency can be explained.

- The magnetic field of the septum magnet
  - The field is getting lower as approaching the septum wall.



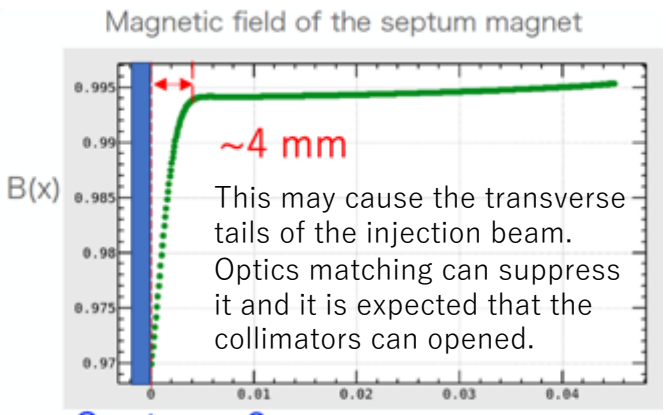
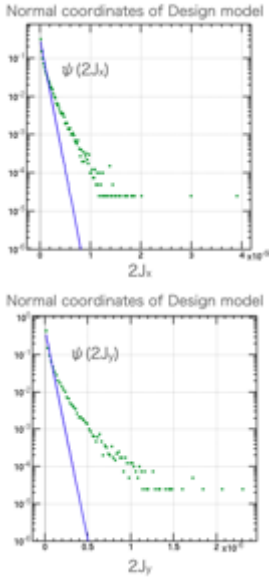
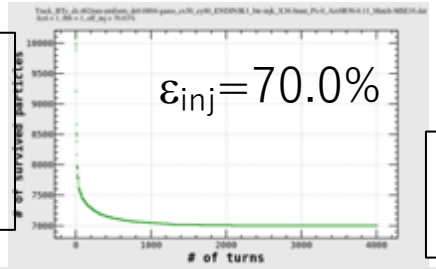


Fig. 4 Magnetic field as a function of distance from the septum plate (simulation by T. Mori)

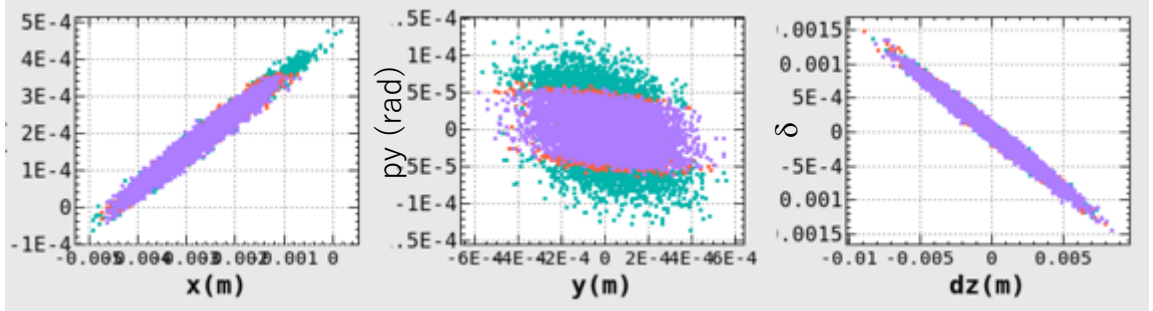
M. Kikuchi



10,000 particles.
collimator setting on Jul. 1.
synchrotron radiation & strong weak beam-beam are included.
No bunch-by-bunch FB.



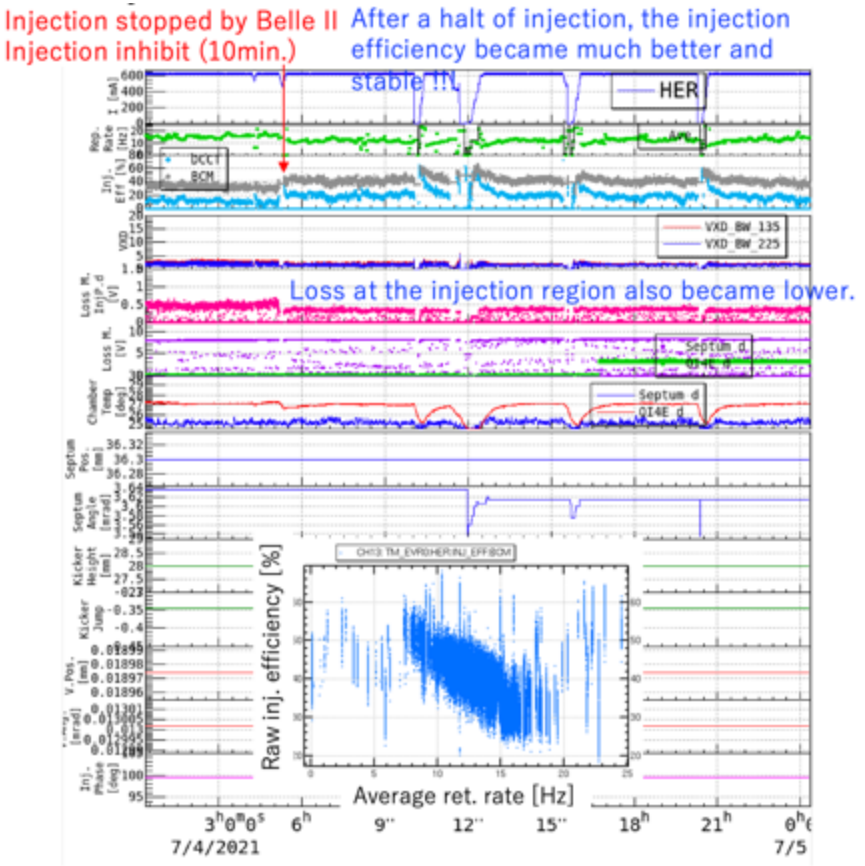
- Injected beam
- 20 turn
- 4000 turn



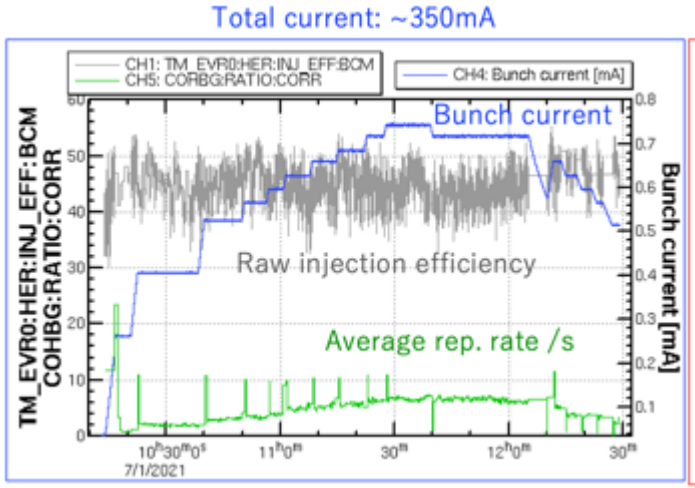
2. Injection status of HER (2)

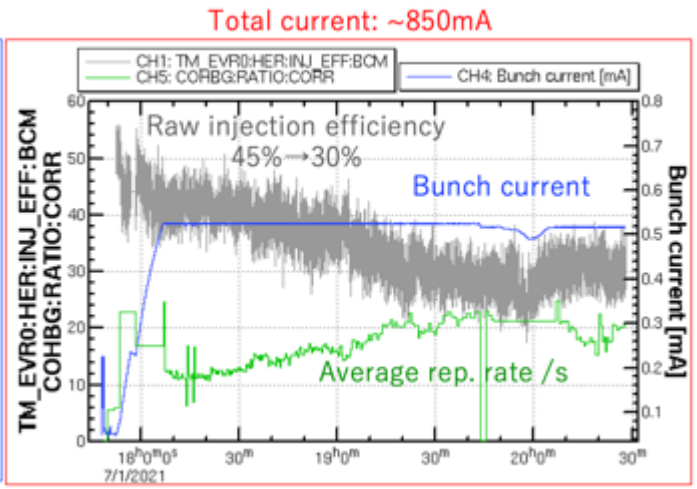
② Unstable injection

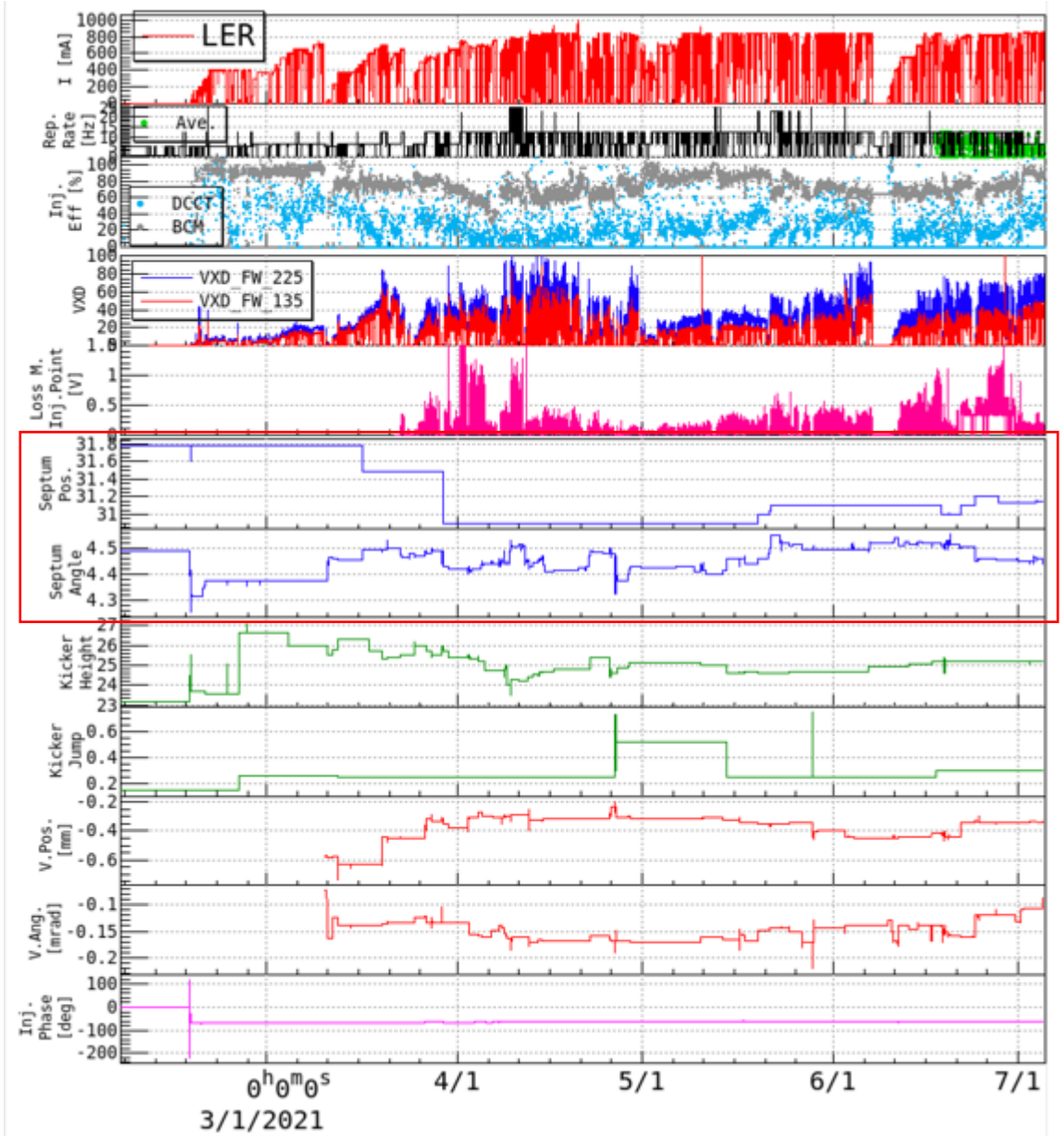
- The injection tuning, septum angle and position must be set larger.
- After abort (a halt of injection), the septum angle(~40μrad) must be lowered temporally.
- The Raw injection efficiency does not depend on the bunch current.
- The residual radioactivity downstream the injection quad has been one of the maximum level, 2.6mSv/h !
  - The injection channel starts here.
- The output of the septum may depend on the temperature of the capacitors in the power supply.

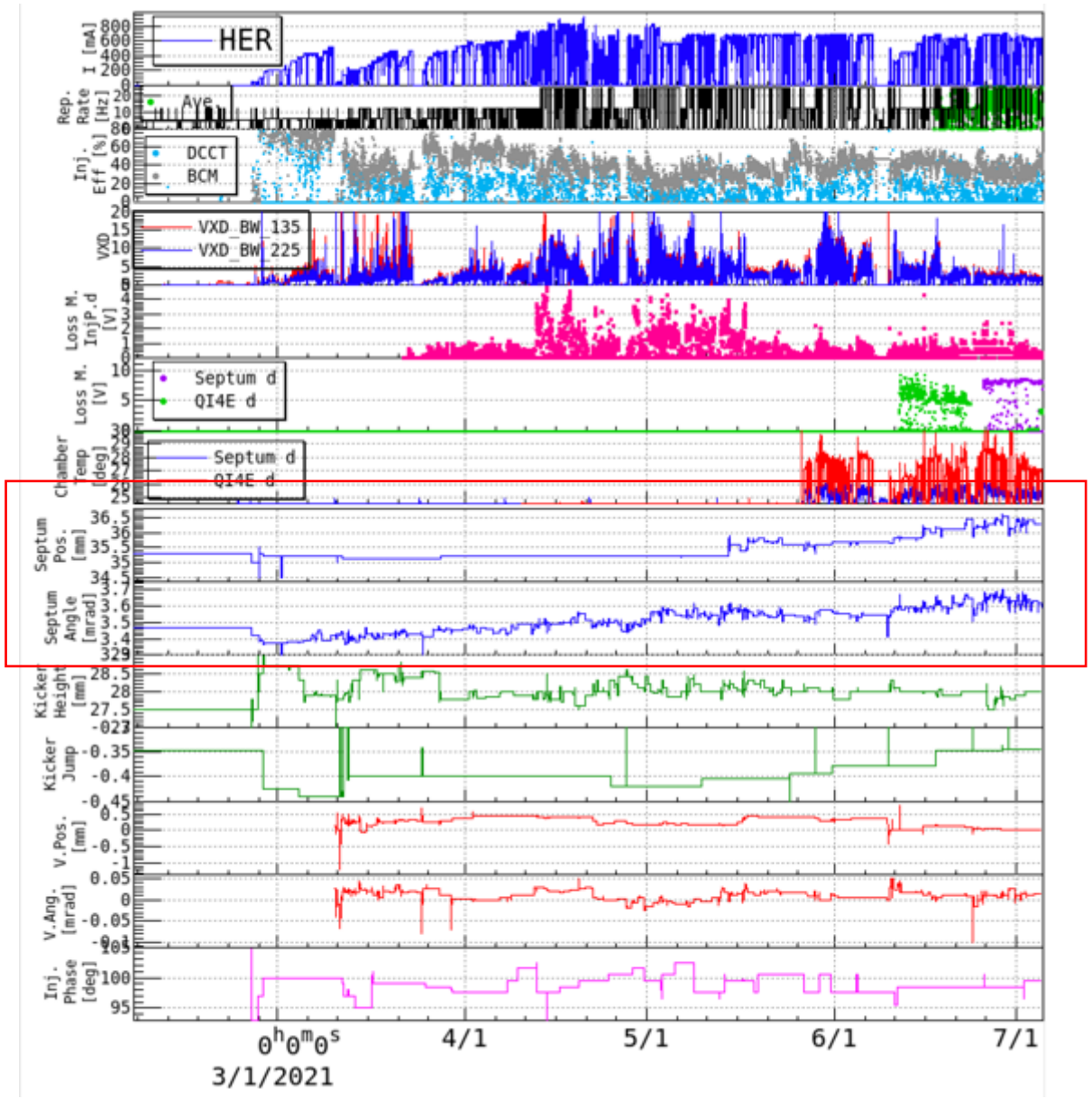


- Monitors are indispensable & urgent!
  - Monitoring and logging of the septum output current are extremely urgent.
  - Injection-BPM is now progressing.
  -



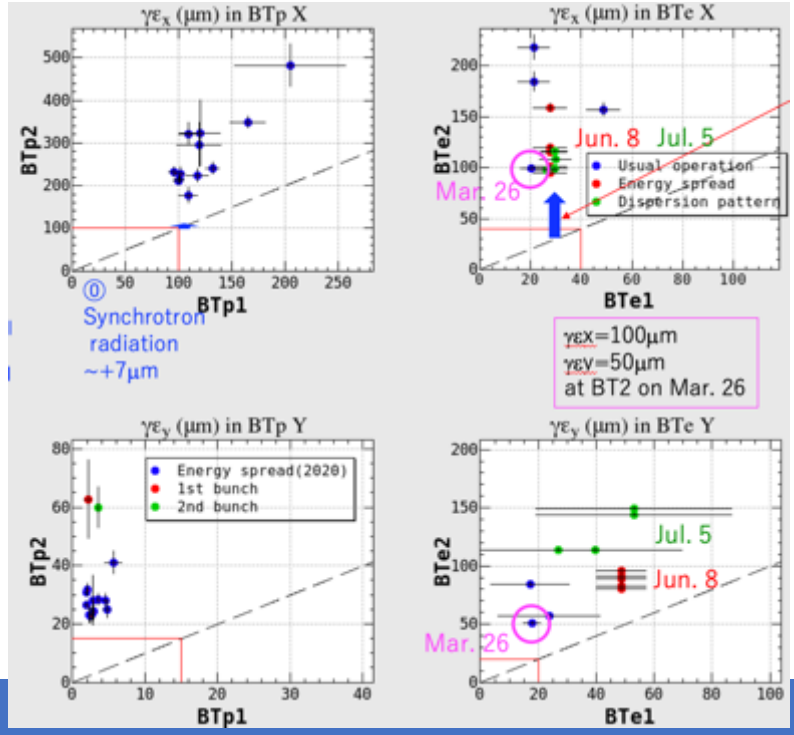



LER
I [mA]
Ave.
Rep. Rate [Hz]
DCCT
BCM
Inj. Eff [%]
VXD_FW_225
VXD_FW_135
VXD
Loss M. Inj.Point [V]
Septum Pos.
Septum Angle
Kicker Height
Kicker Jump
V.Pos. [mm]
V.Ang. [mrad]
Inj. Phase [deg]
0h0m0s
4/1
5/1
6/1
7/1
3/1/2021


HER
I [mA]
Ave.
Rep. Rate [Hz]
DCCT
BCM
Inj. Eff [%]
VXD_BW_135
VXD_BW_225
VXD
Loss M. InjP.d [V]
Septum d
QI4E d
Loss M. [V]
Chamber Temp [deg]
Septum Pos. [mm]
Septum Angle [mrad]
Kicker Height [mm]
Kicker Jump
V.Pos. [mm]
V.Ang. [mrad]
Inj. Phase [deg]
0h0m0s
4/1
5/1
6/1
7/1
3/1/2021

3. Emittance blowup in BT

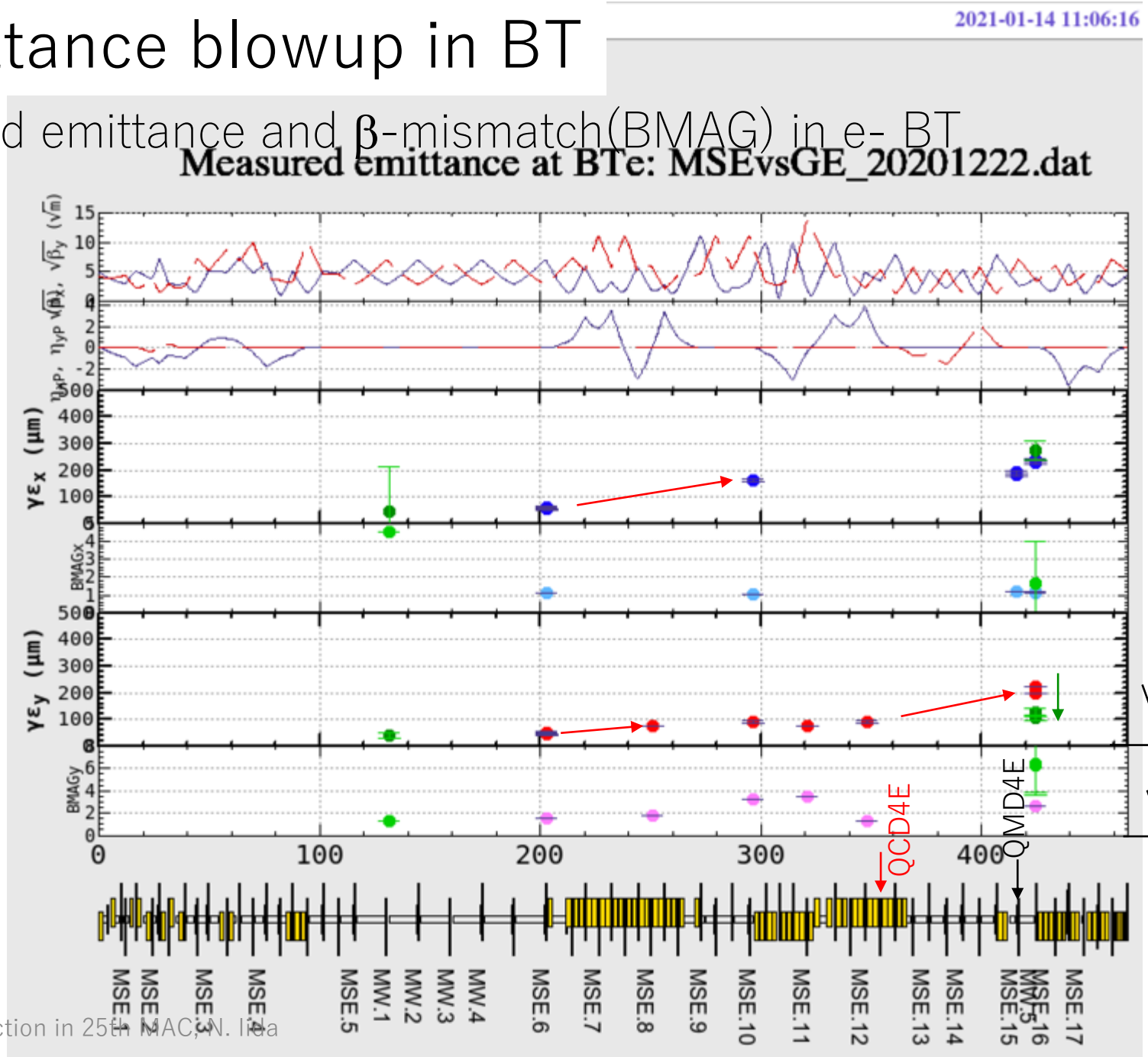
- e-
  - No obstacle has been found in the chamber of e- BT line.
  - An SRM in the HER newly joined the emittance measurements.



	e+	e-
Horizontal	• The reason why the horizontal emittance growth between BTp1 and BTp2 is not resolved. • The dispersion leak from ECS at SY3 will be corrected by installation of a quad at the center of chicane in the ECS in Aug. 2021.	• Synchrotron radiation causes the blowup of the horizontal emittance from 30 μm to 76 μm. • The emittance growth due to CSR effect is not confirmed yet.
Vertical	• The vertical emittance growth can be lower by installation of residual skew quads for the correction of skew quad components from the bends in Arc2-3.	• The vertical emittance growth should be resolved. • Unexpected vertical dispersion has been observed in Arc-1.

3. Emittance blowup in BT

Measured emittance and β-mismatch(BMAG) in e- BT



- ● : γε with WS
- ● : γεx measured with OTR
- ● : γεy measured with OTR
- ● : γε with SRM+gated camera

- The emittances were measured larger by errors of measuring systems of Q-scan.
- The HV sets were too high to measure the small beam size.
- Now the measured emitttances are not explored but still blowup.

M. Kikuchi, Y. Seimiya, N. Iida

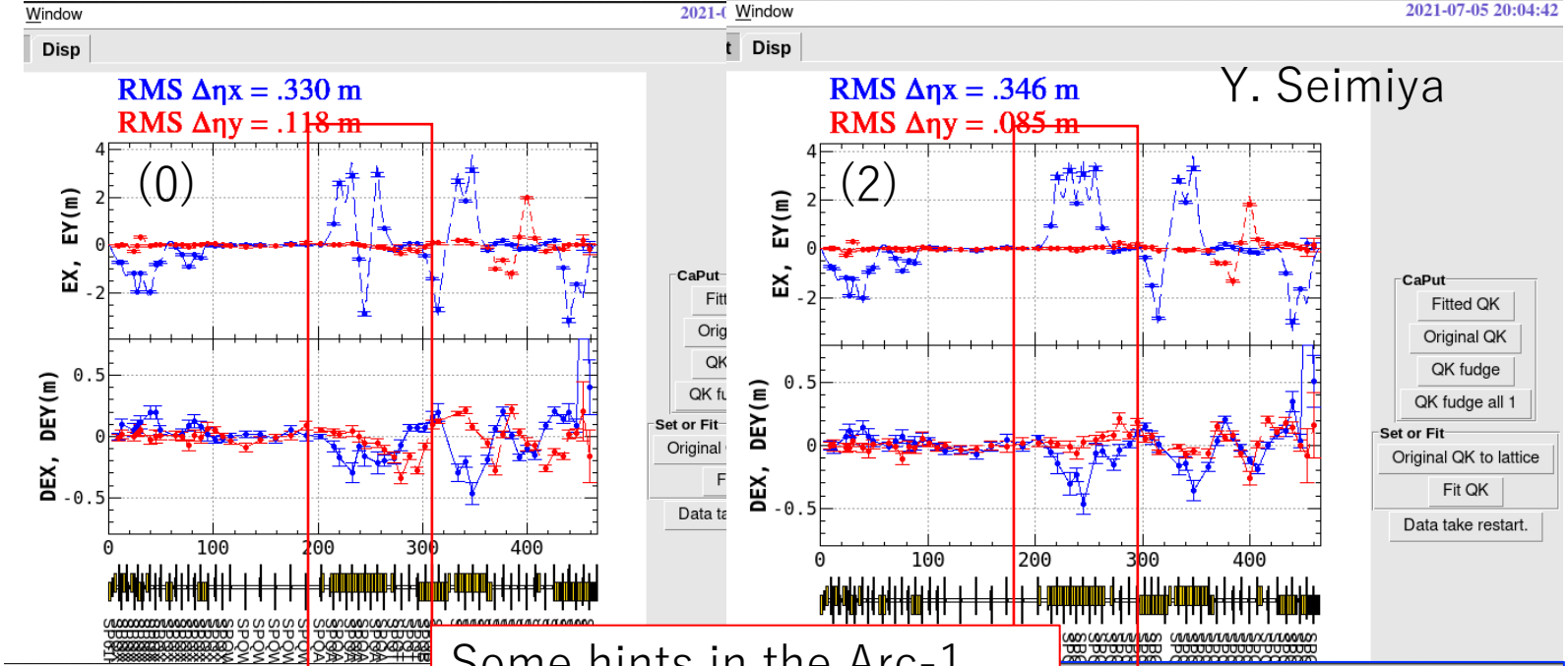
① Changing dispersion pattern and emittance measurements for CSR study

	BT2			Jul. 5
	γεx [μm]	BMAGx	γεy [μm]	BMAGy
(0)	116.4 ± 2.2	2.10	143.7 ± 1.7	1.65
(1)	108.3 ± 2.1	3.13	113.9 ± 2.4	2.77
(2)	99.6 ± 1.3	2.34	149.5 ± 1.9	1.56
(3)	97.7 ± 1.1	2.14	113.6 ± 1.4	2.27

- The horizontal emittance of (3) is smallest.
- From these results, the CSR effects are not clearly observed.

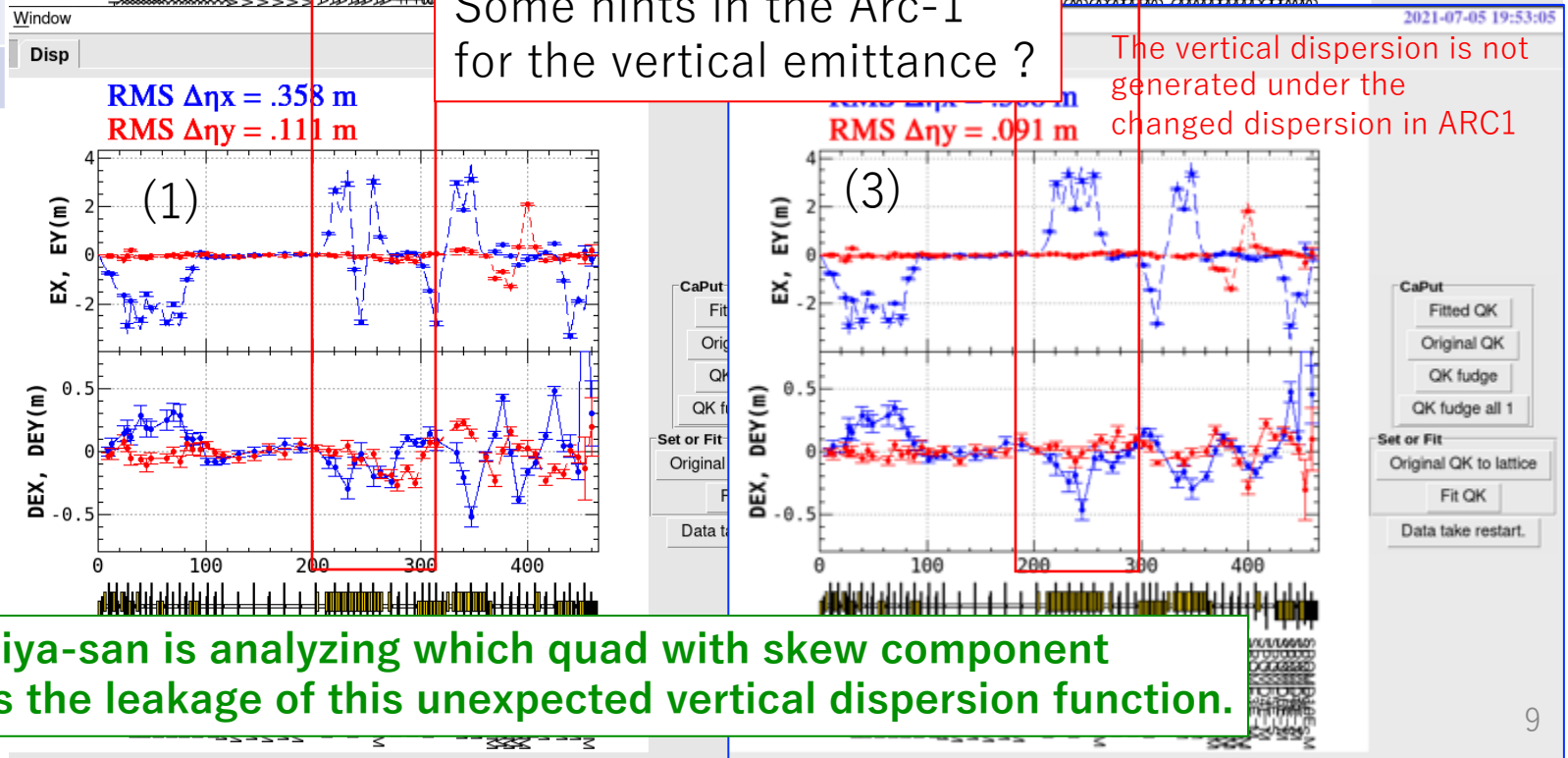
Study with 2nC beam should be done.

- The vertical emittances of (1) and (3), in which the dispersion of Arc0 changed, are small.



Y. Seimiya

Some hints in the Arc-1 for the vertical emittance ?



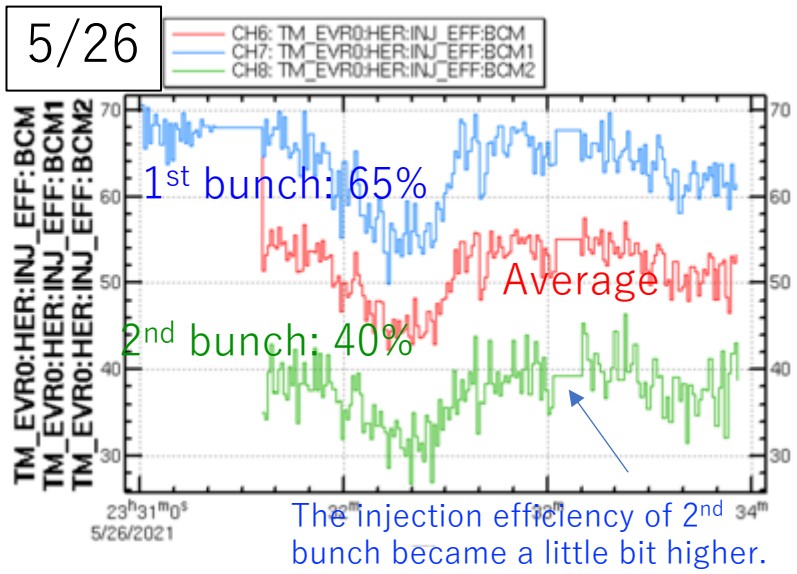
The vertical dispersion is not generated under the changed dispersion in ARC1

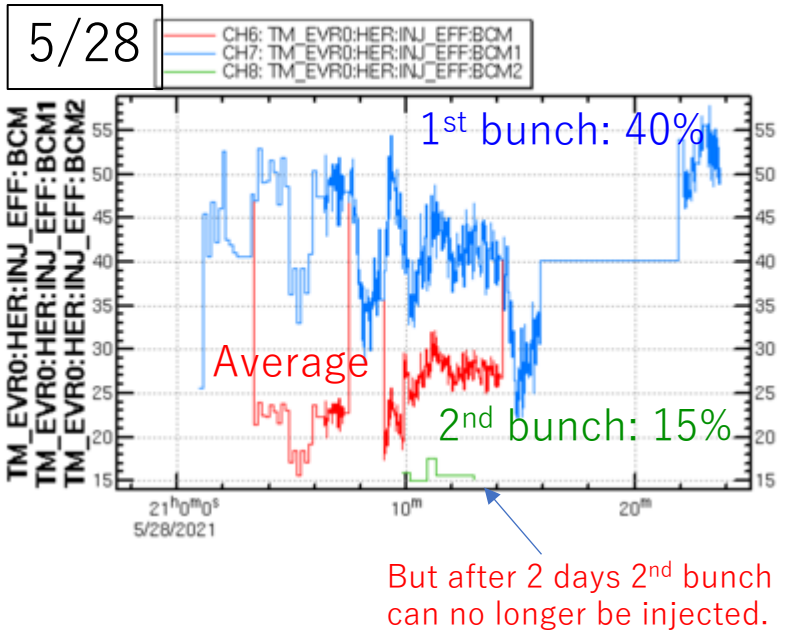
② Seimiya-san is analyzing which quad with skew component explains the leakage of this unexpected vertical dispersion function.

4. 2 bunch injection

- HER
  - **Injection efficiency of 2nd bunch is extremely low**
    - 2-bunch injection had been successfully done for 6 days in Jun. 2020 !
    - Parameters below have been checked.
      - Orbits from LINAC to BT line
      - Beam energy at BT line
      - Kicker timing of HER
      - Emittance growth only for 2nd bunch between Sector C and Sector 2
      - Timing mismatch in the RF phase in HER ?
- LER
  - 2-bunch injection is used for usual operation
    - 2-bunch injection was succeeded in Feb. 2021 by tuning an LLRF feedback loop in the DR.
    - Injection efficiency and background of 2nd bunch are worse than those of 1st bunch.

e- BT





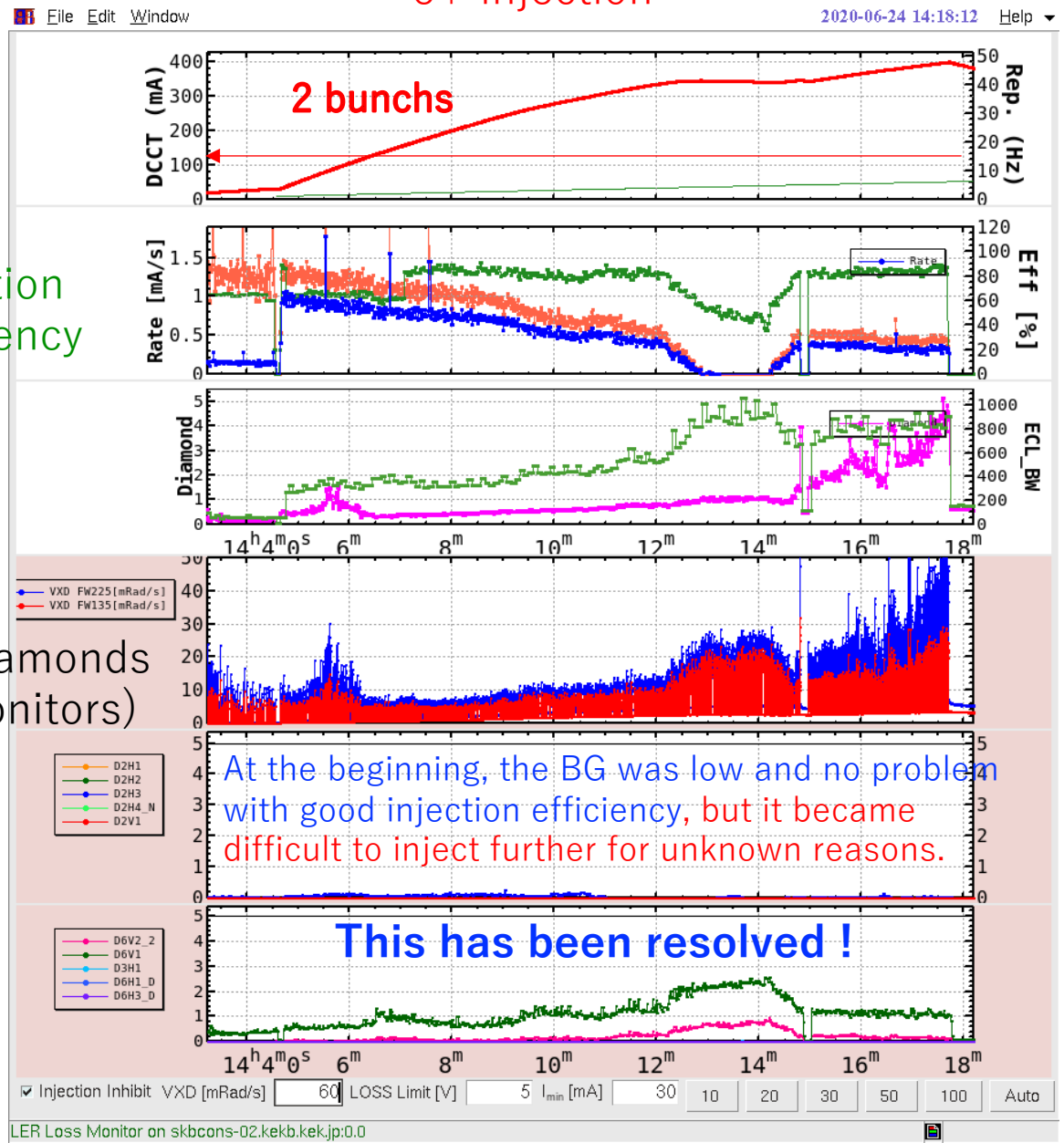
2 bunch injection and BG in 2020b

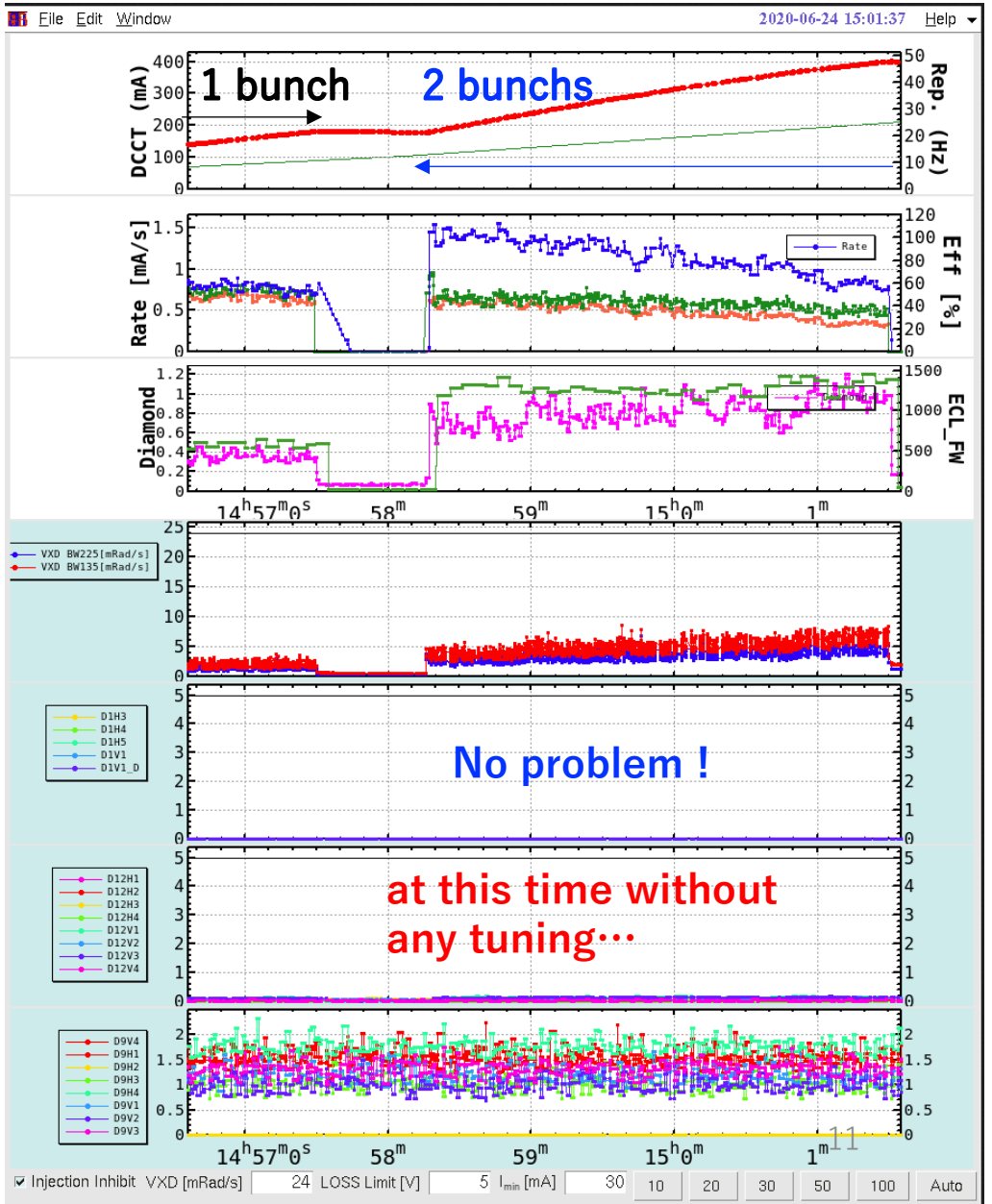
e+ injection

e- injection

Injection efficiency

VXD diamonds (BG monitors)



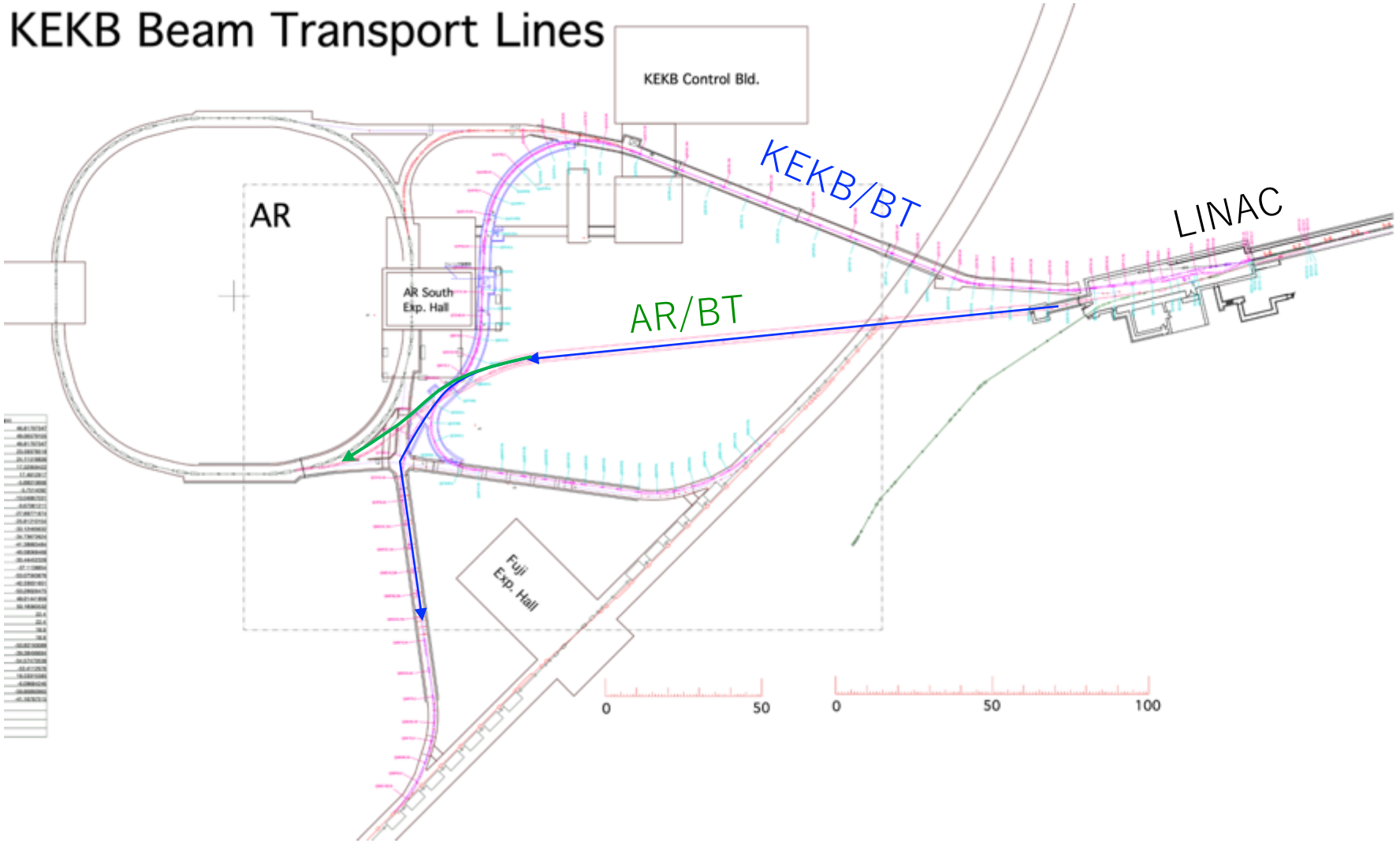


5. Another improvement for operation

- The “Fuji-mode” will be ready at 2021c operation.
  - BT dump mode operation can be done, even if people enter the half of the SuperKEKB tunnel, including Tsukuba area.
  - The beam study in BT can be performed short works during the usual operation as well as in the long shutdown.
  - Even in LINAC mode, there is an advantage that e- and e + can be studied at the same time. (Currently, only one beam can be studied.)

6. Long term plan

- **e- ECS in KEKB/BT line until 2026**
  - Preparing by Mitsuhiro Yoshida and H. Ego from 2022.
- **New e- BT line in the AR/BT straight tunnel ?**
  - For smaller horizontal emittance growth due to synchrotron radiation
  - There may be no mysterious emittance growth.
- **e- Damping ring in the Jarc ?**
  - **Polarized e- beam ?**



Summary (same as P. 5)

1. LER injection
   - The injection efficiency of 1st bunch is about 90%.
   - The injection efficiency and the BG of 2-bunch injection are much worse than 1-bunch.
   - LER 23 Hz operation is available.
2. Poor injection efficiency for HER
   - The septum angles of the injection tuning panel are different from the design values. -> will be fixed.
   - The injected beam mainly losses at the vertical collimators.
   - The losses are not from injection oscillation but emittance growth or/and optics mismatch.
   - The 70% injection efficiency has been reproduced in simulation.
3. Septum position and angle drifting at the HER injection ?
   - The magnetic field of septum is changing ?
   - Beam losses right after the septum exit causes one of the highest residual activation in the main ring.
   - If the beam loss is decreased placing the orbit apart from the septum wall.
   - Monitors and logging for pulsed magnets are necessary.
4. Emittance blowup is still problem
   - HER
     - Synchrotron radiation increases the horizontal emittance.
     - Study for CSR effects is in progress.
     - The source of vertical blowup is still in question.
   - LER
     - A quad will install in the center of the chicane in SY3 for the correction of dispersion leakage.
     - Residual skew quads in the ARC2-3 of e+ BT line
5. 2-bunch injection
   - Injection efficiency of 2nd bunch is extremely low for HER.
     - Emittance of 2nd bunch should be resolved.
     - 2 bunch injection of HER had been successful for 6 days in Jul. 2019.
6. Long-term plans are just begun to be considered.

Questions from Catia-san

- Slide 12: on the base of which considerations have you selected the collimator to open?
  Belle II people opened.
  Maybe, the collimators which are effective the injection from their experience.

  Slide 16: i t seems that QCS aperture does not plays a main role in reducing injection efficiency
  Yes, I think so, too. The injection beam with such emittances without mismatch are in the HER dynamic aperture.

  Slide 30-31: did you observe any seasonal trend in the septum displacement in HER?
  P. 26 shows more than one year. In 2020b, the septum angle and position were not changed higher, rather lower.

  Have you to optimize septum position and angle in the LER too?
  Yes, we did, but it was not so frequent as HER.

  Slide 33: do you observe any drift of the stored beam orbit in the injection section as a function of the stored beam current?
  No, I have not yet. I will check it.

  Slide 36: Monitoring pulsed power supply might be useful too.
  Yes, the monitor setting is urgent !

  SLIDE 65: vertical emittance reduction observed during the DR studies with 80 msec storing time suggests that a DR might improve the injection efficiency in HER, as you outline in your conclusions and future perspectives.
  Yes, the smaller vertical emittanceis better.
  The blowup in the vertical emittance in BT must be resolved as soon as possible.

  SLIDE 66-67: have you already tested 2 pulse operation with the new optics?
  No, we have not. The optics change has not succeeded yet. The next step is optics correction in the DR.