Injection background(BG) and Beam abort caused by Injection beam

8.Jul.2019

SuperKEKB Review

N. Iida

Contents

I. Injection background

(0) Overview in Phase 3

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(2) Injection tuning

- Tuning for the background reduction of the MR

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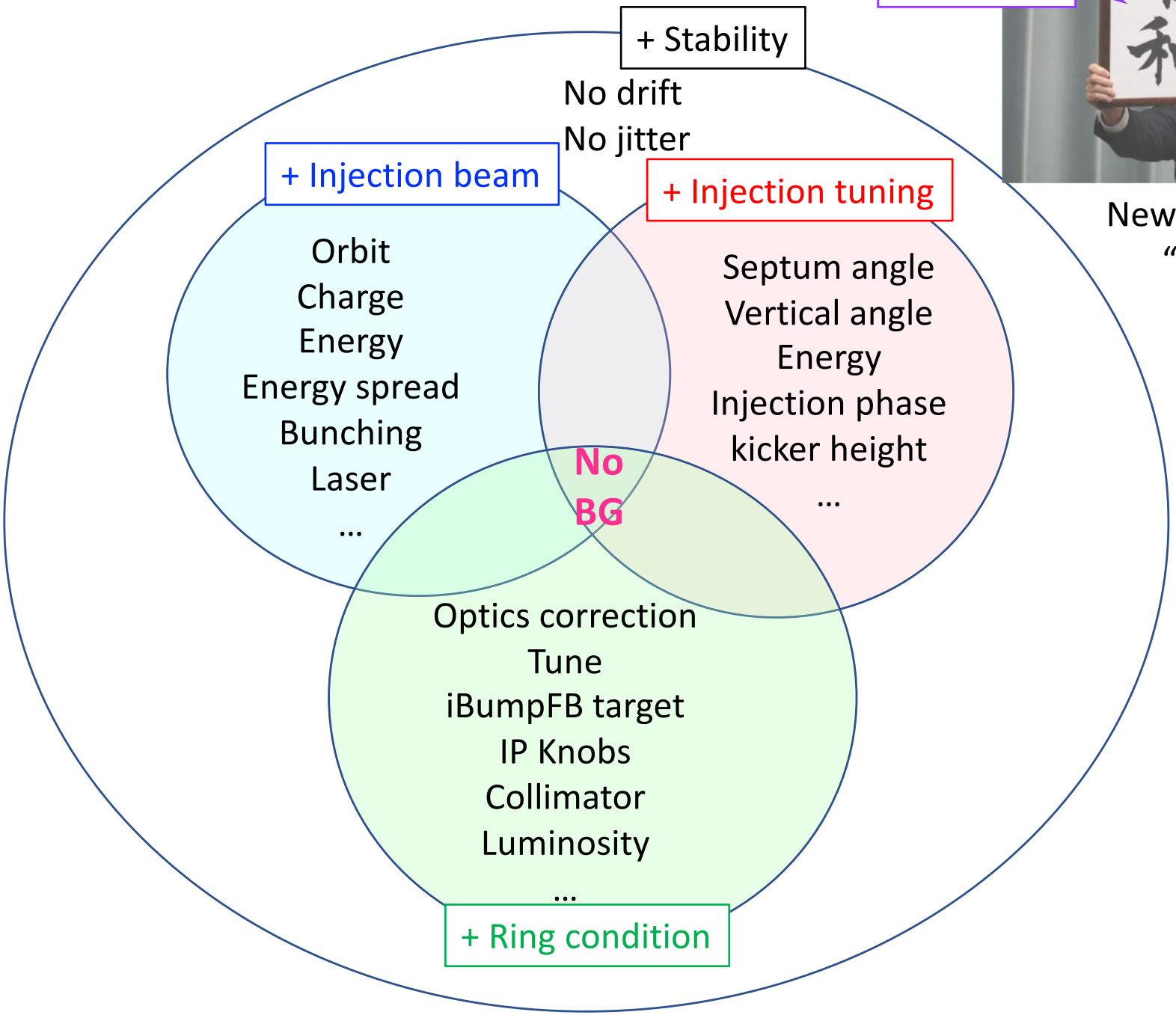
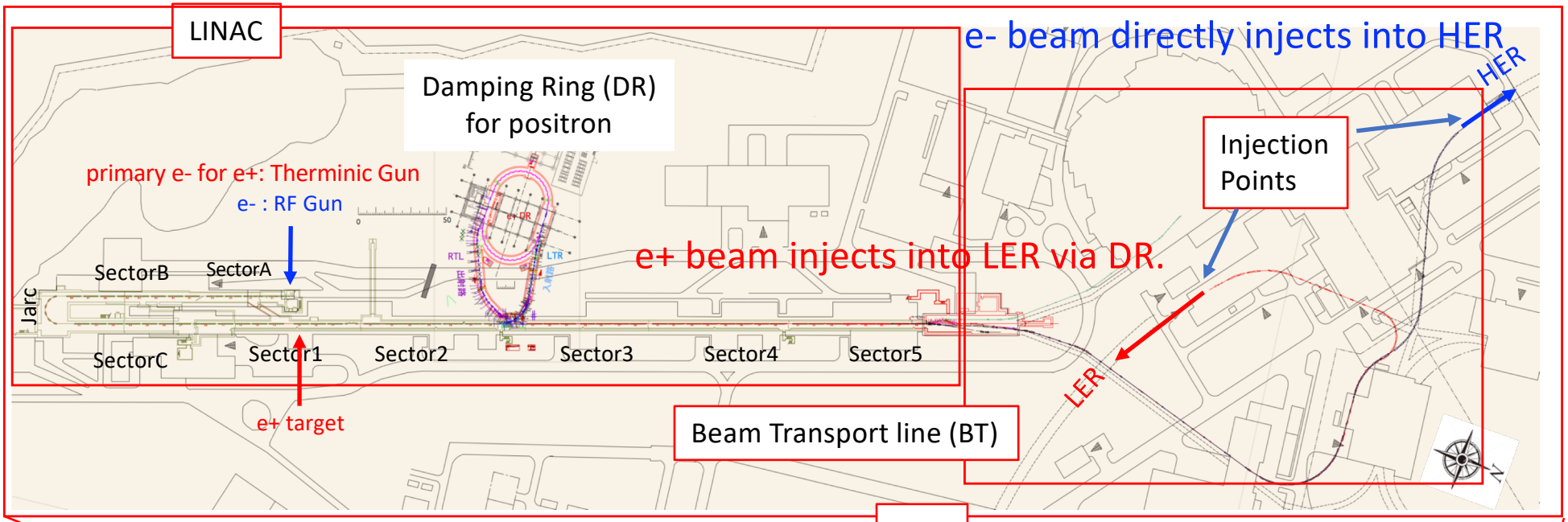
  - Big jump of the beam energy in LINAC

Injection BG tuning

New era name:
“Reiwa”

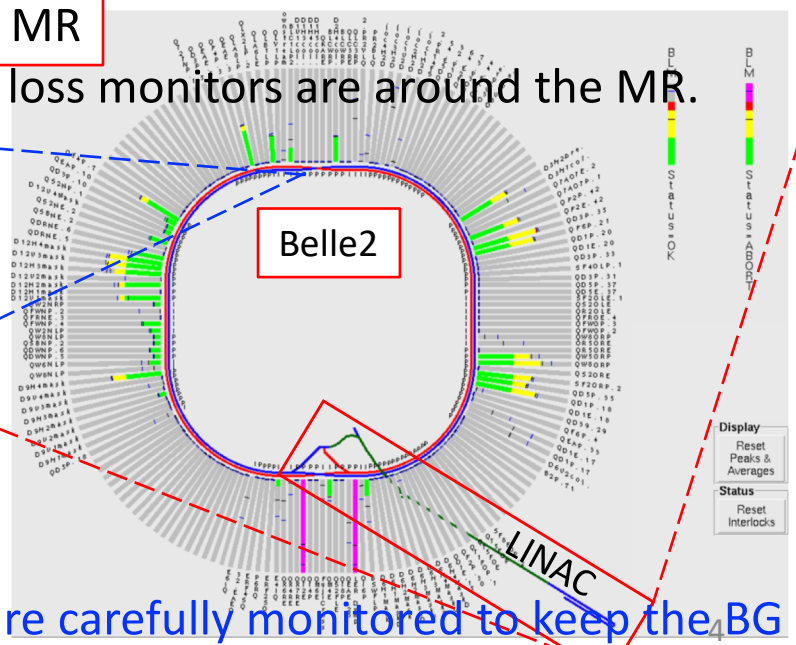


Layout of LINAC, BT, Injection to MR

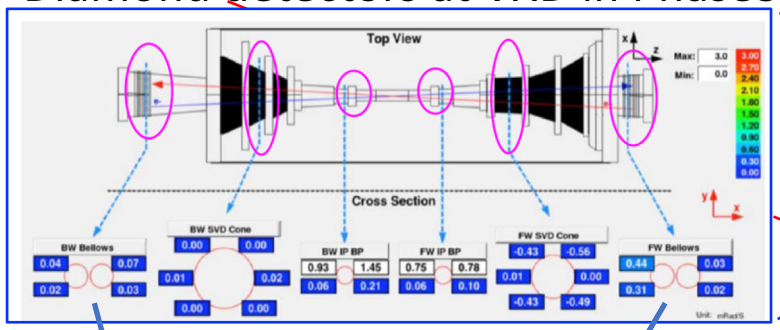


MR

Many loss monitors are around the MR.



Diamond detectors at VXD in Phase3



HER:
VXD(Diamond) BW135

LER:
VXD(Diamond) FW135

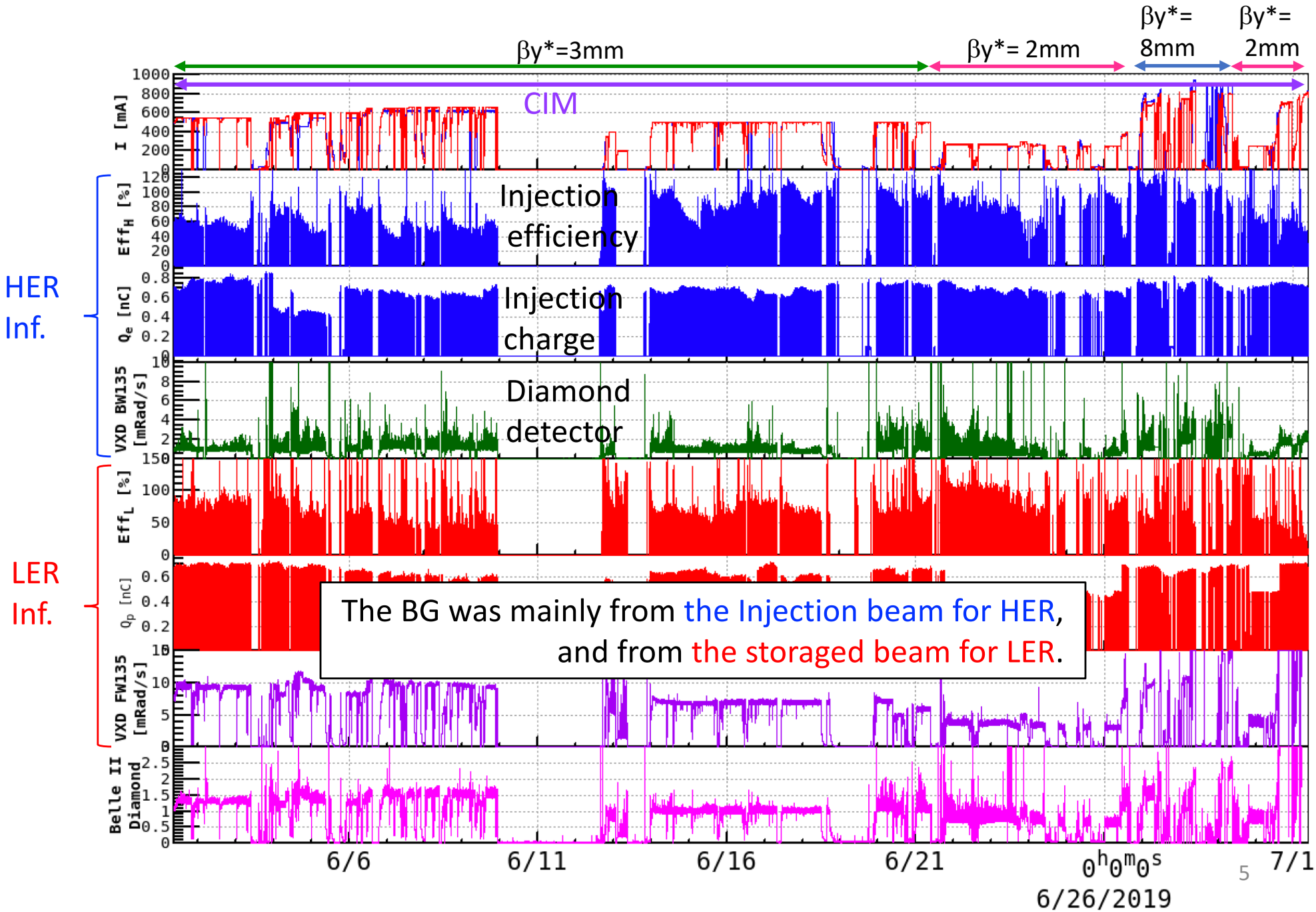
Most sensitive to the BG on Belle2.

The signals from the Diamonds and the loss monitors are carefully monitored to keep the BG low.

Some aborts are avoided by stopping injection when the signals are high.

JUNE

Injection status in the last 30days

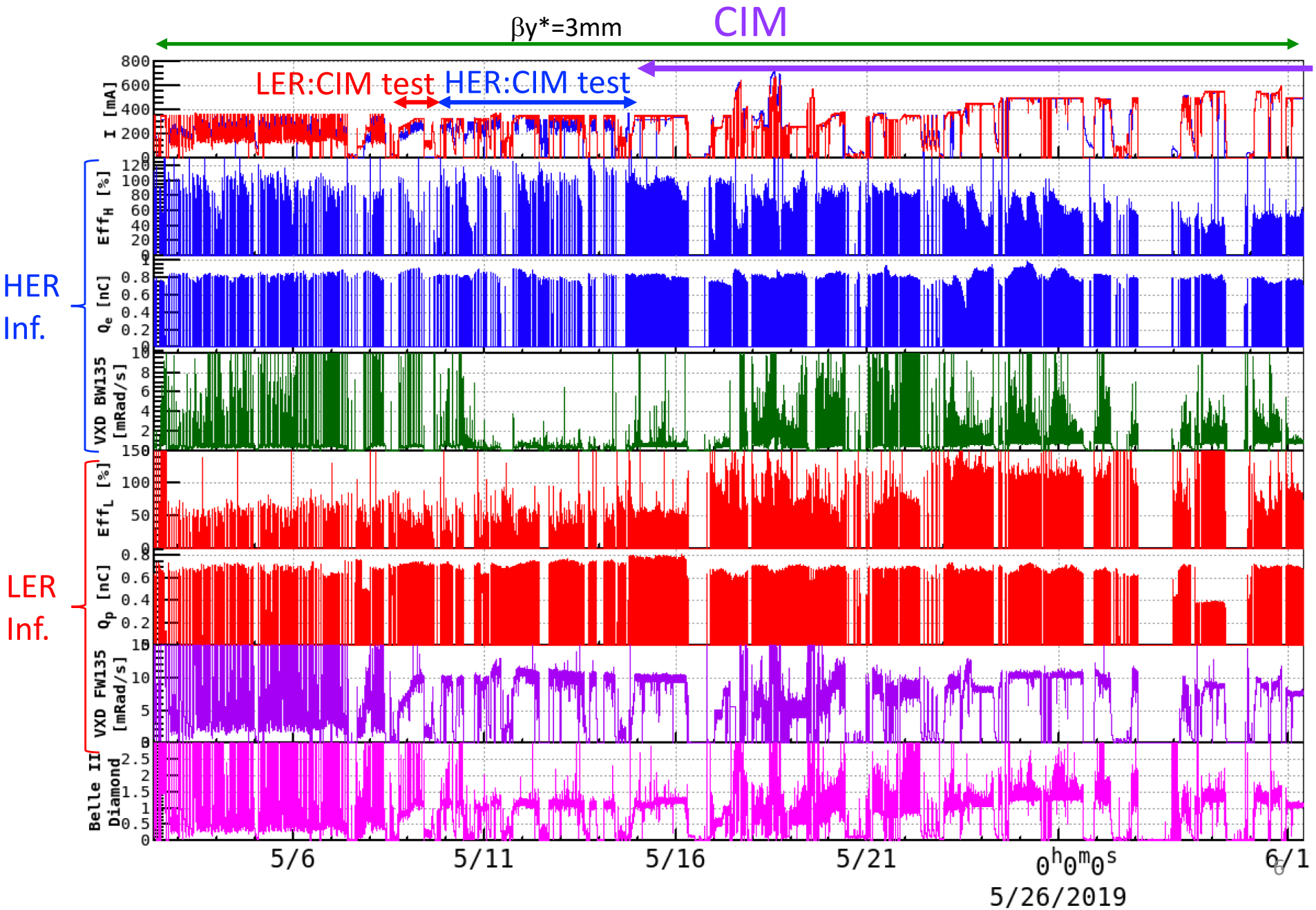


The BG was mainly from the Injection beam for HER, and from the storaged beam for LER.

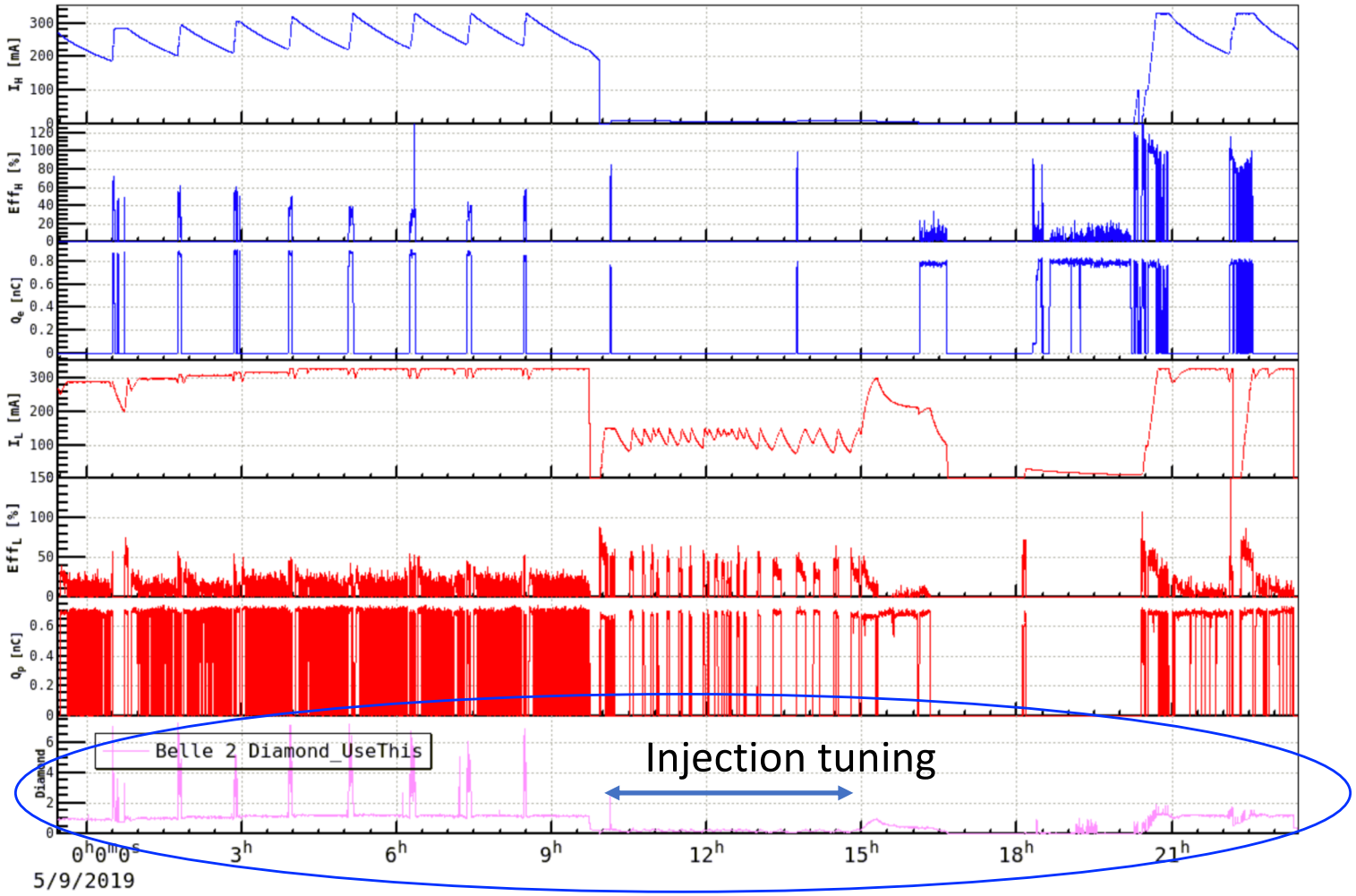
MAY

The injections were changed

To Continuous Injection Mode (CIM)



CIM test (9/MAY/2019)



Even for the continuous injection for both ring, the signals from Diamond,and CLAWS sensers were dramatically reduced !

How could we keep it ?

The tuning method for the injection was established.

- Search for parameters with small injection oscillations using Turn by turn BPM on “one-turn-injection” mode.
- The continuous injections were succesfully done.
- The stabilities are important after the good tuning.

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(1) Injection beam

TBI: To be introduced

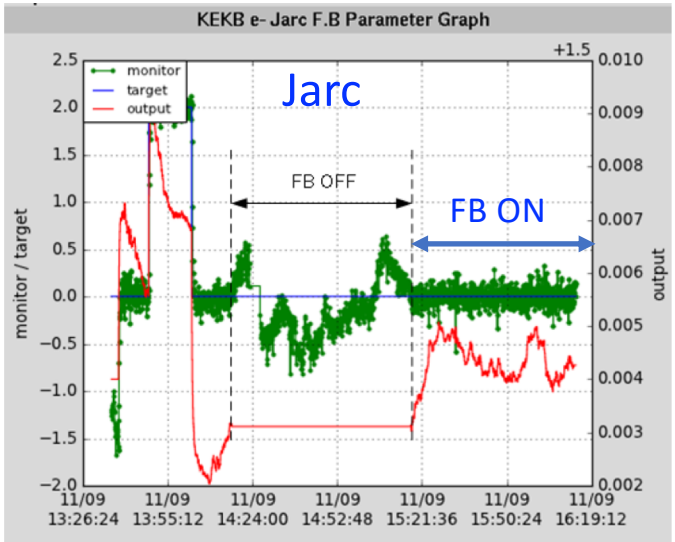
Improvements for stabilizing the injection beam

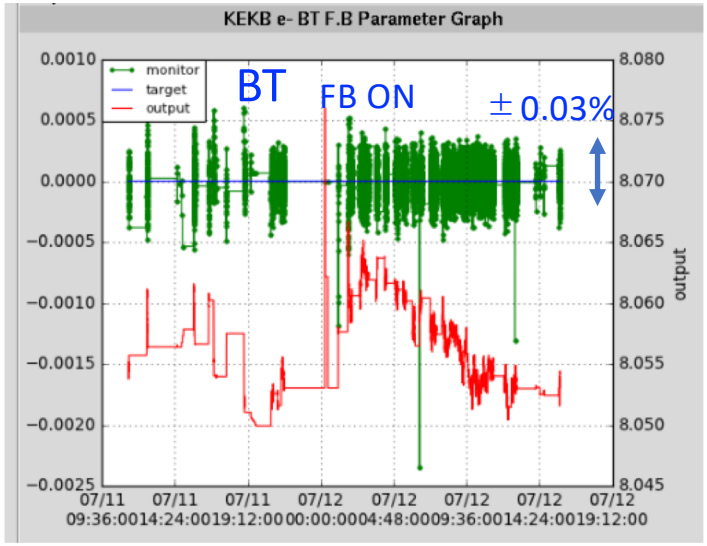
		Tool	Place	Achievement	Feedback	Talk
A	Energy	(A) Energy feedback	Jarc, DR, BT	○		
B	Energy spread	(B) Sub Hermonic Buncher 1 (SHB1) for LER beam	Thermionic Gun	○	—	
		SHB2		TBI	—	
		RF Phase monitor	LINAC	○	TBI	T. Miura
		RF Induced wave monitor	LINAC	△	—	
		OctoPos BPM monitor	Jarc	○	TBI	F. Miyahara
			BT	△	TBI	
C		(C) Temperature control	LINAC	△		
	Orbit	Orbit feedback	LINAC	○		Y. Seimiya
			End of BT	○		
D	Orbit jitter	(D) Pulsed magnet PS	Sector 3-5	△	—	Y. Seimiya
	Energy jitter	(D) Energy knob phase	Sector B, 2, 5	TBI	—	
		(D) RF phase	LINAC	△	—	T. Miura
	Injection phase	FB of Master oscillator	LINAC and MR	○		
E	Emittance	(E) e- RF gun	RF Gun	△(Stability)	TBI	R. Zhang
		e+ DR	DR	○	—	
		(E) Wire scanner	LINAC, BT	○	—	Y. Seimiya
			End of BT	△	—	T. Mori

(A) Energy Stabilizer (Energy FB)

T. Kudo,
M. Kikuchi

Phase2



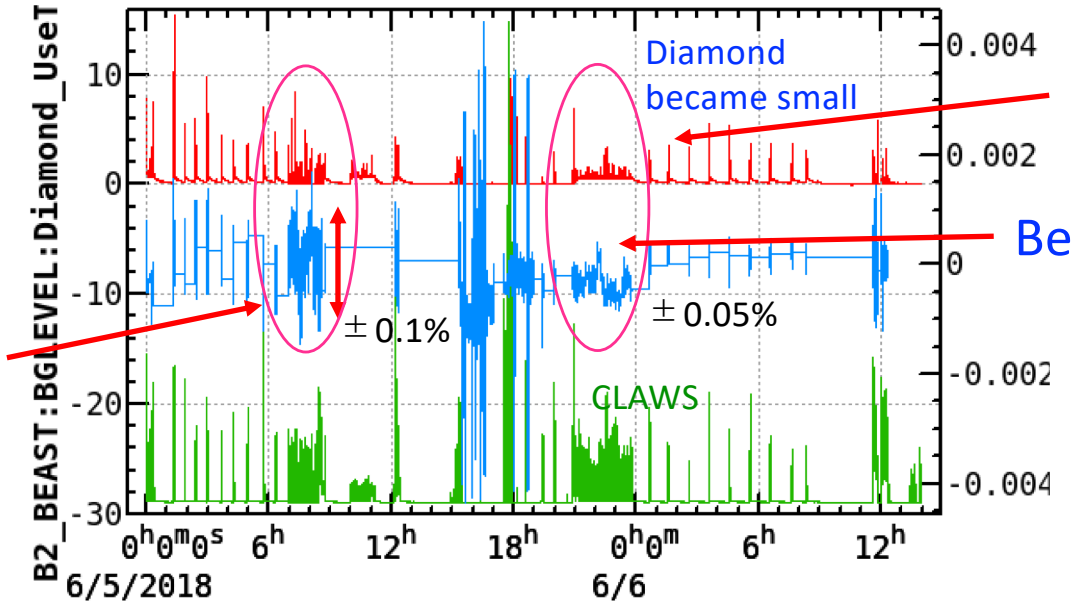


Target

Beam energy
(monitored)

Energy knob

The injection energies have been stabilized within ±0.03%(p-p) by the energy feedback.



Diamond Dose

Beam Energy

Energy FB did
not work well.

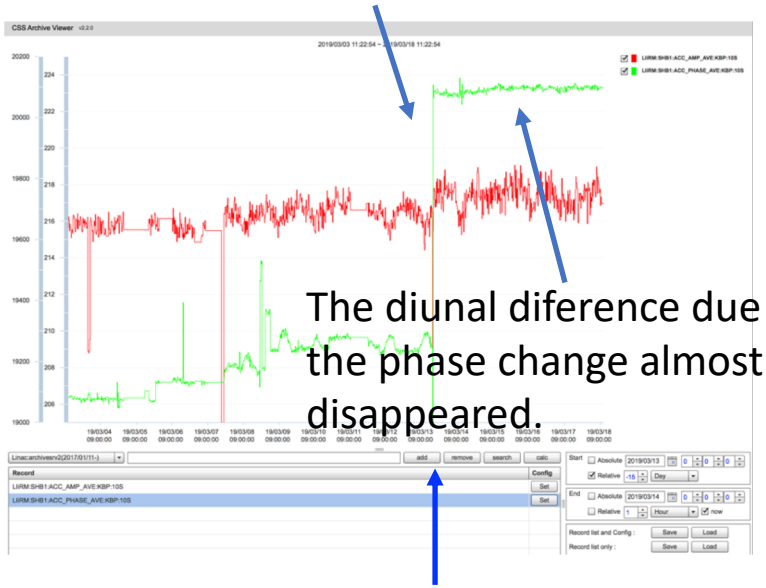
(B)Phase fluctuation of SHB1

The fluctuation of SHB depends on the charge from the thermionic gun.

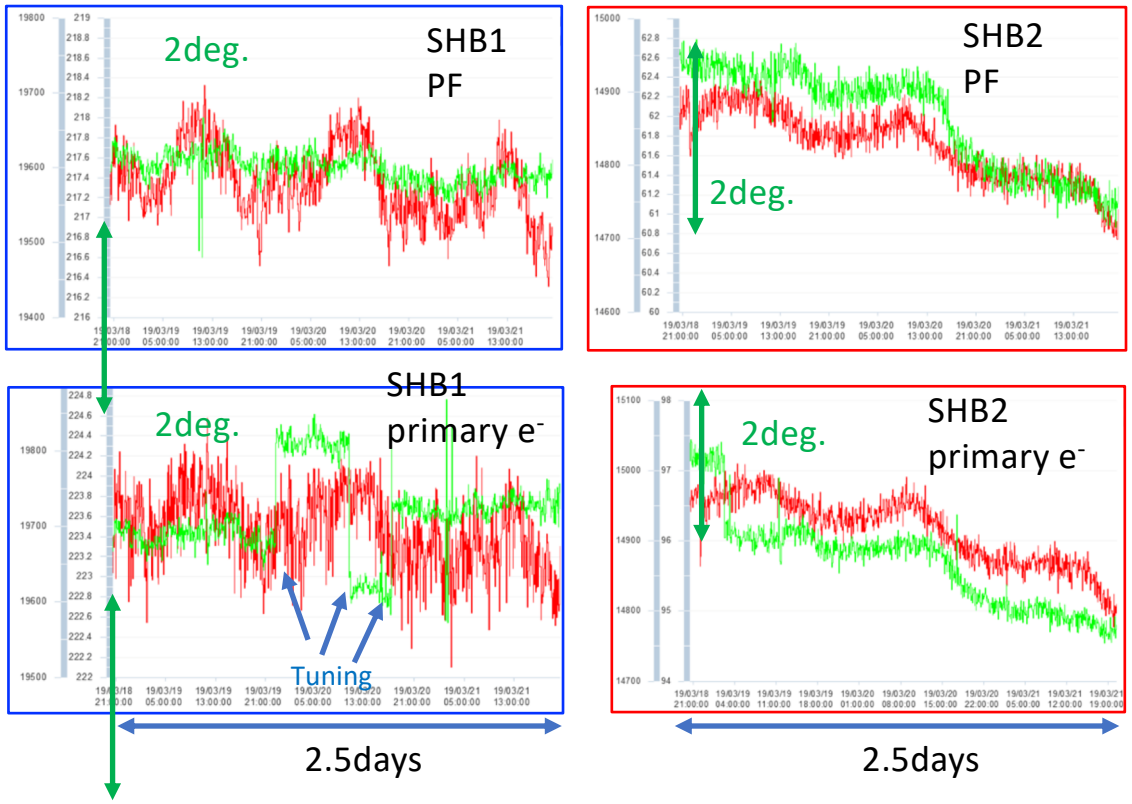
green：SHB1 Phase
red: SHB2 Amplitude

T. Miura

The long electric cable for 114MHz oscillation replaced to an optical fiber.



After worked, SHB1 becomes stable. SHB2 is still moving.



SHB1 SHB2

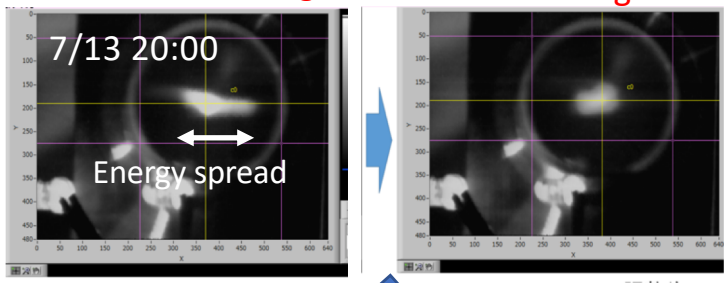
(C) Energy spread

Arc section in Beam Transport line (BT)

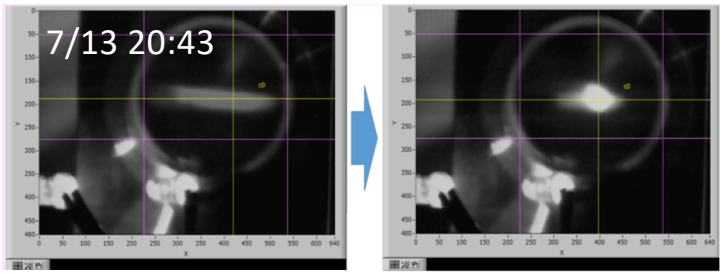
Phase2

Before tuning

After tuning



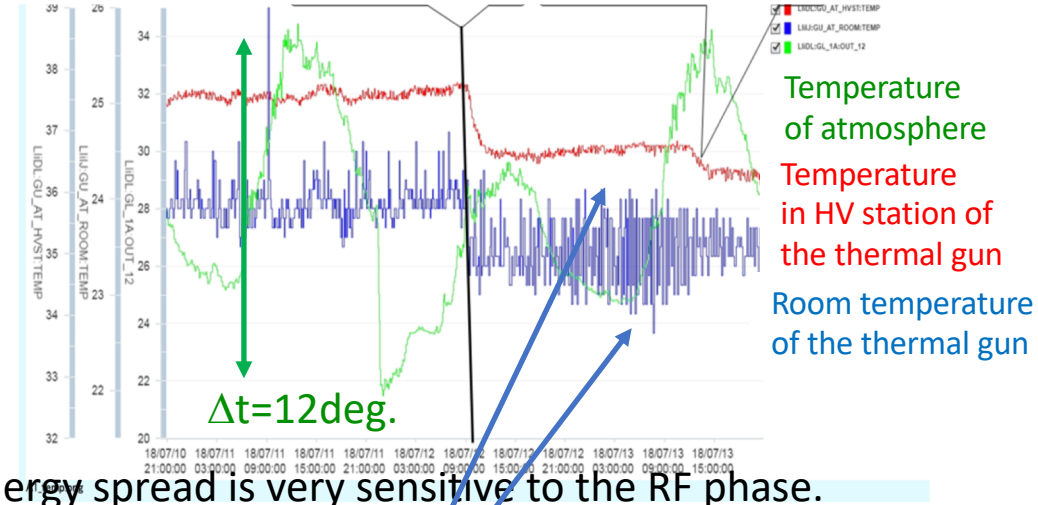
Just 40 min.
after tuning



The energy spread is monitored only by the destructive screen monitors.

→ Nondestructive monitors(OctoPos BPM) have been developed. (F. Miyahara)

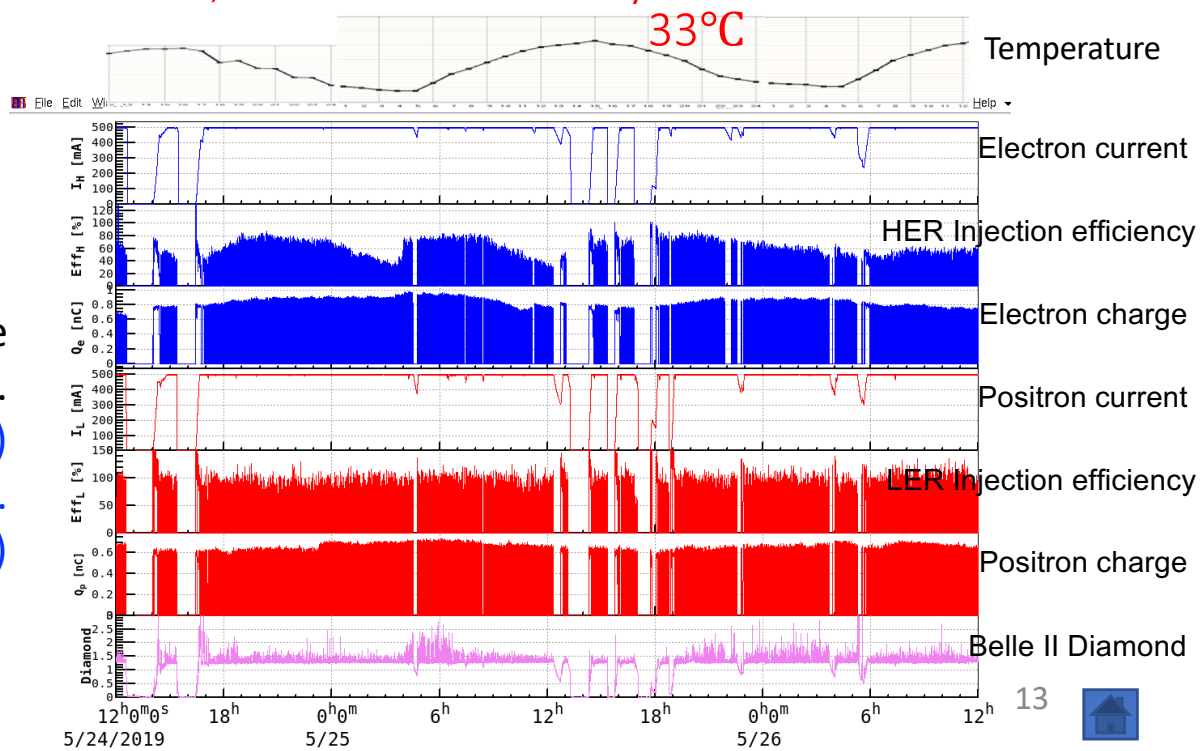
In Phase2, it was very hot especially in July.



Energy spread is very sensitive to the RF phase.
One source of the RF drifts is from the temperature change.
Some countermeasures have been done but not all yet.

→ RF phase/voltage monitors are ready. (T. Miura)

In Phase 3, It was also hot in a few days



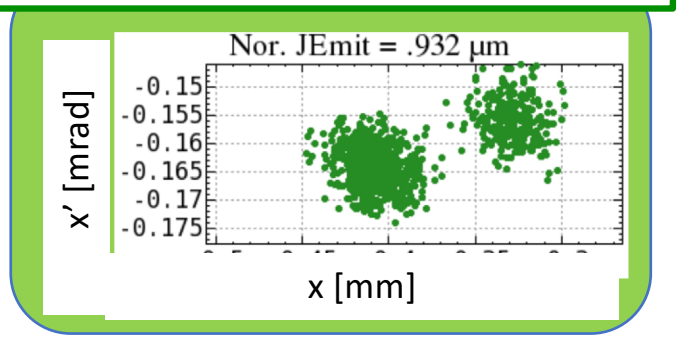
(D) Beam Jitter Sources

Causes of several beam fluctuations were revealed by BPMs and the new RF monitors.

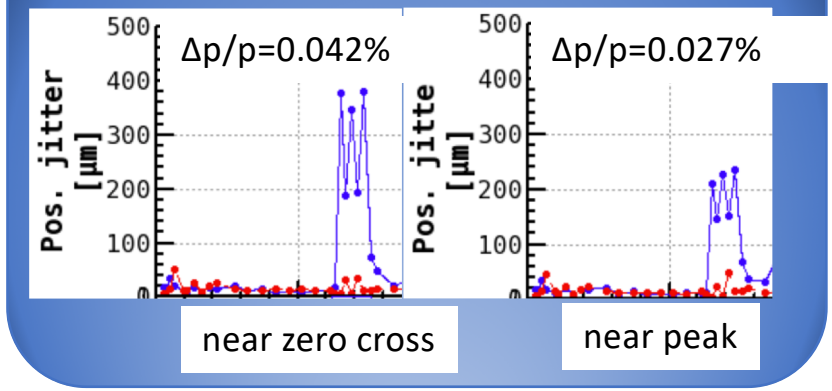
Y. Seimiya, F. Miyahara, T. Miura

Orbit

① Binarization from the Pulsed Magnets (at the straight section) will be repaired.



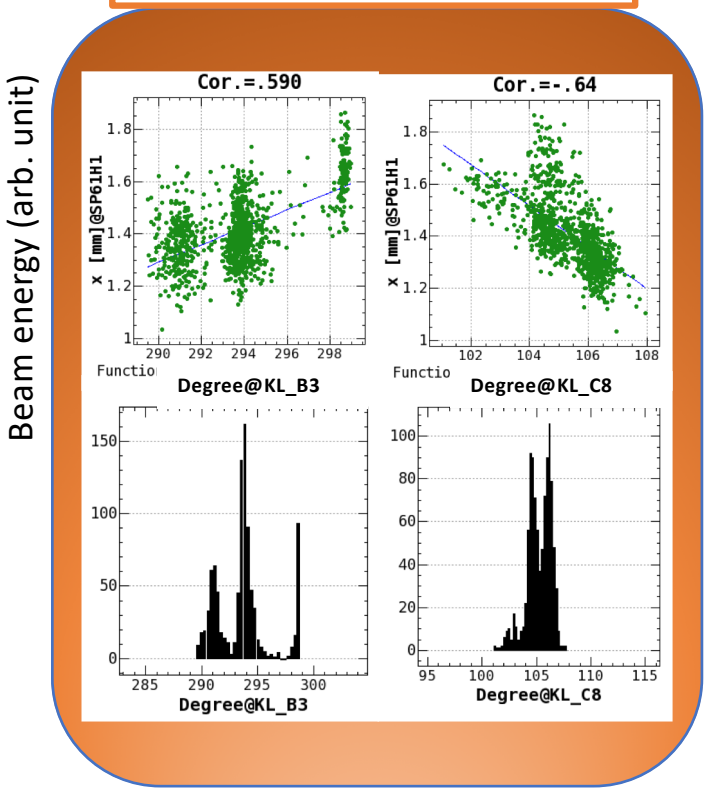
③ Large variation of Energy gain near zero cross of RF phase



It is planned that the energy knobs are used closer to the top of the RF wave.

Energy

② Binarization from the RF Phase (at the dispersive section)



RF phase monitor

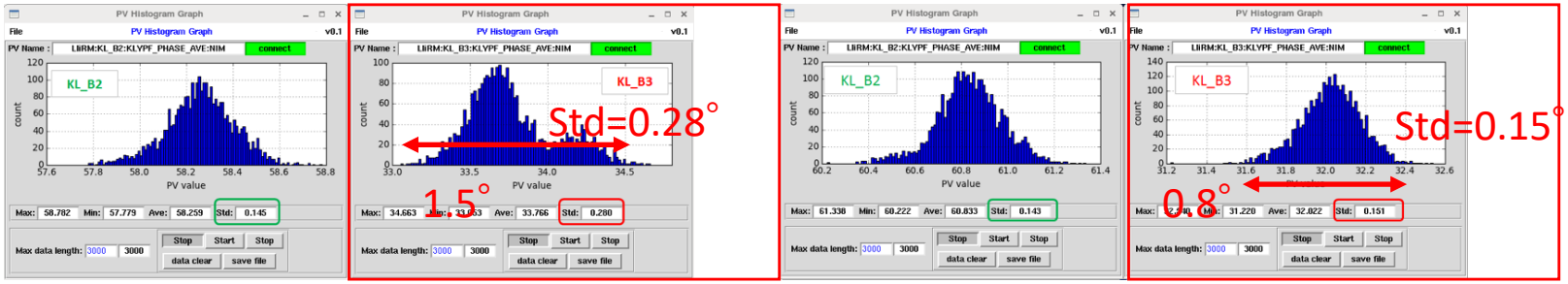
(D) Beam jitter (cause and remedy)

① Binarization from the Pulsed Magnets ← Orbit stabilization
- The power supplies will be repaired in this summer.

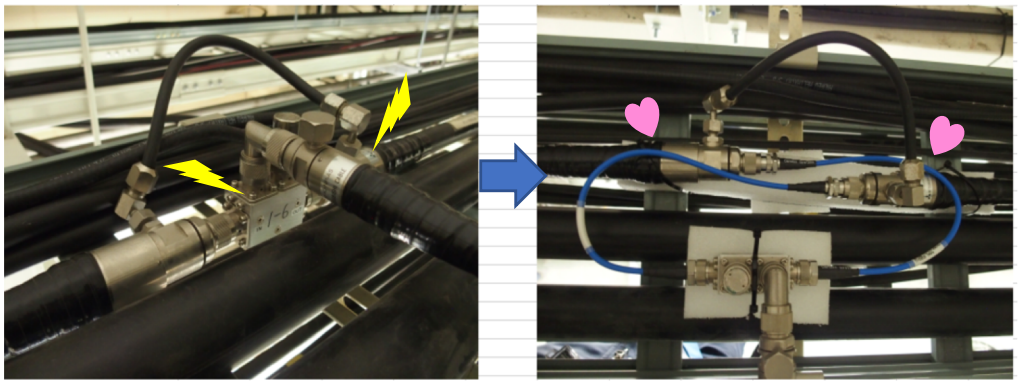
② Binarization from the RF Phase ← Beam energy stabilization
- Connector or Cable Problems

③ Large variation of RF phase near the zero cross
- Use the energy knob closer to the top of the RF wave

18:00 Before tightening the cable 20:00 After T. Miura, T. Matsumoto



Before

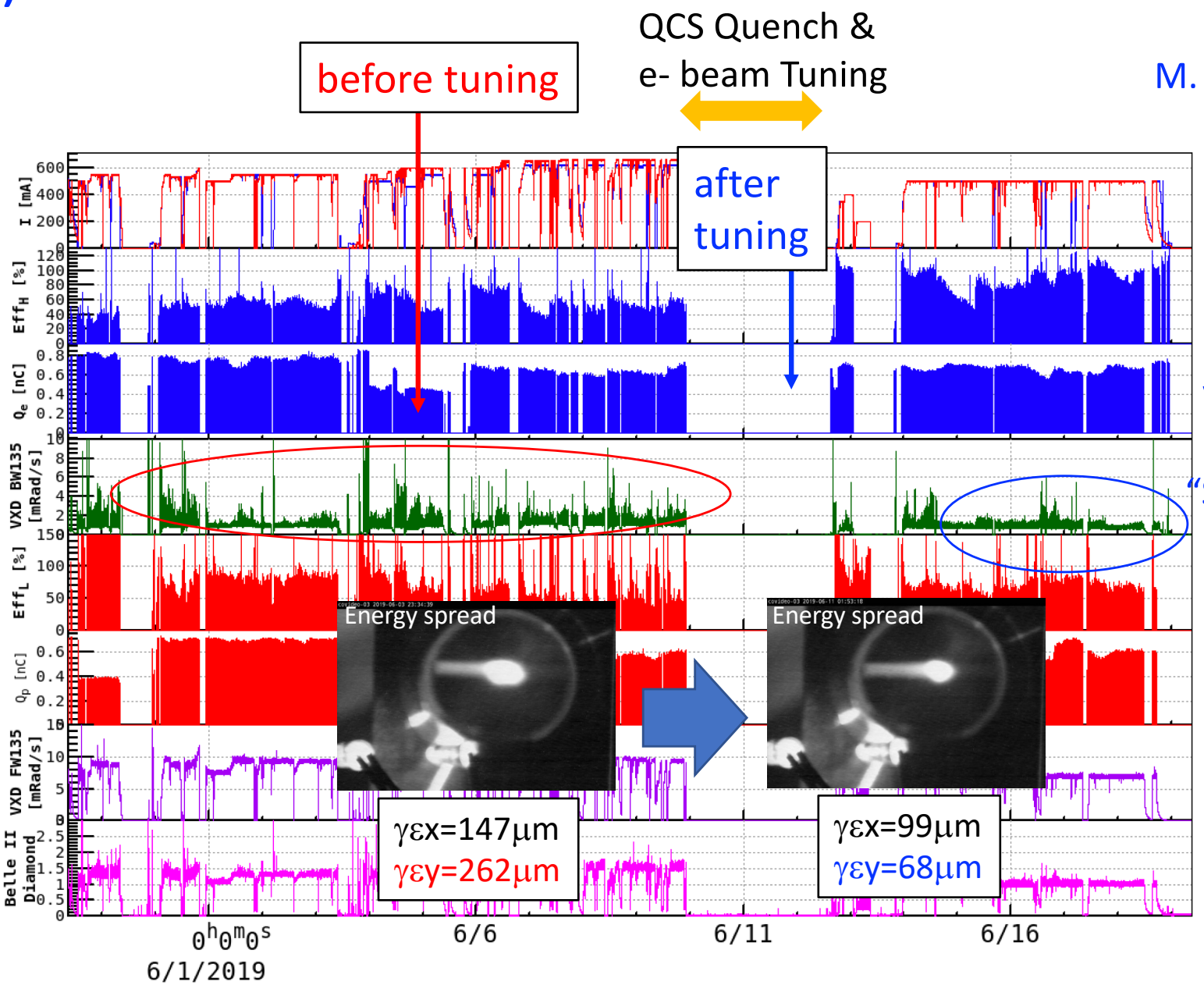


After

The cables are exchanged to soft ones.

(E) Emittance

M. Yoshida



VDX BW135 became "Super clean".

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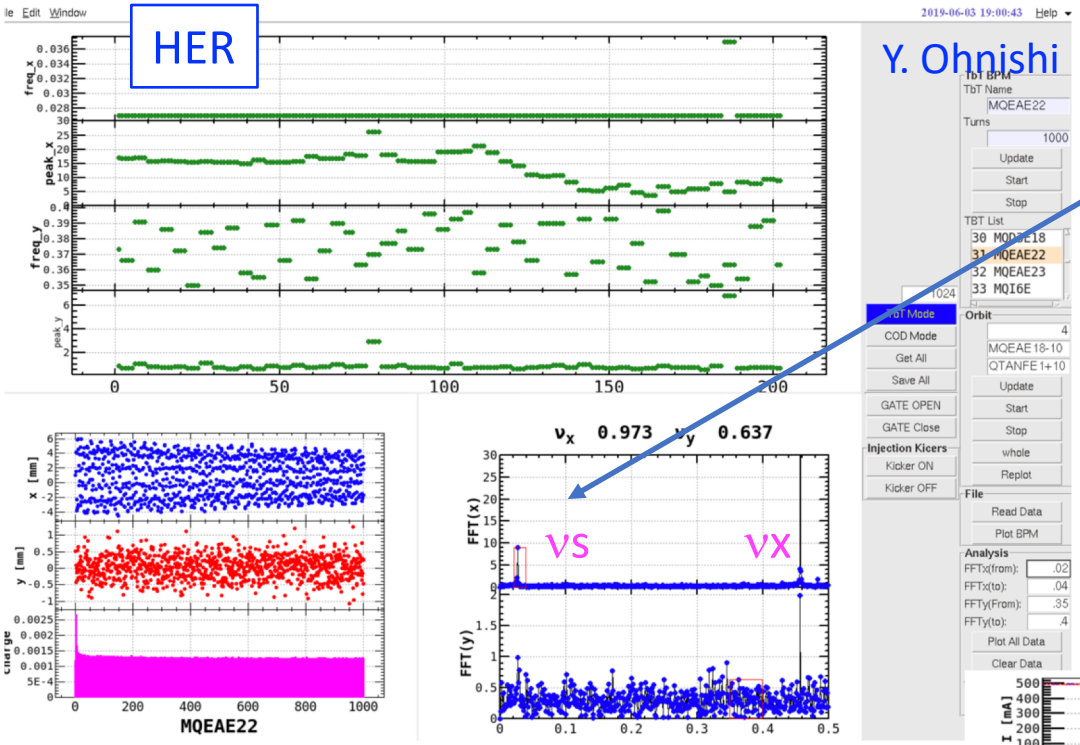
  - Big jump of the beam energy in LINAC

Since the efforts have been made to stabilize, fine tuning is always necessary.
Talk about the experience will be presented.

(2) Injection tuning

- Injection phase

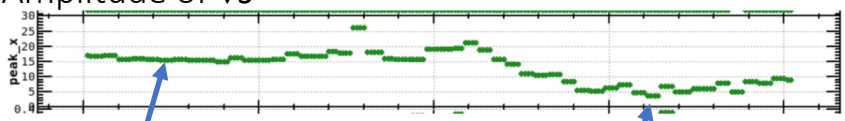


Before injection after no beam or optics changed, the injection tuning was done by using TBT BPM to reduce the amplitude of the tunes with one-turn injection mode (Injection kicker2 was Off).

New method !

For the synchrotron tune, the best injection phase with low background was 12deg.(in 571.2MHz) lower than the TBT adjusted phase.

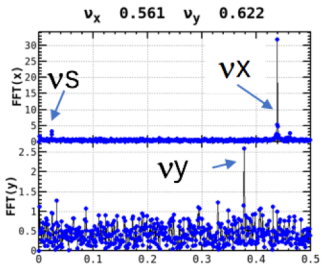
Amplitude of νs



ϕinj=226deg.

ϕinj=237deg.

The amplitude was much lower.



νx, νy were also tuned as well as νs.

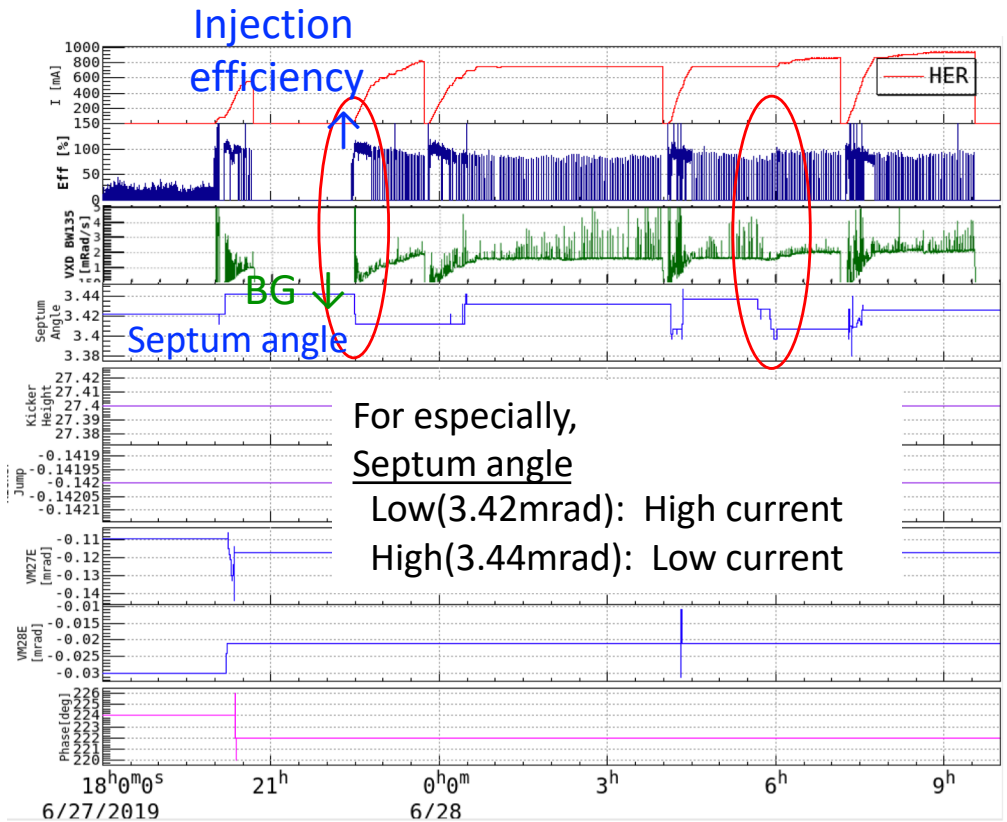
This suggests that the electron beam would have long tail in longitudinal phase space?

(2) Injection tuning (Cont'd)

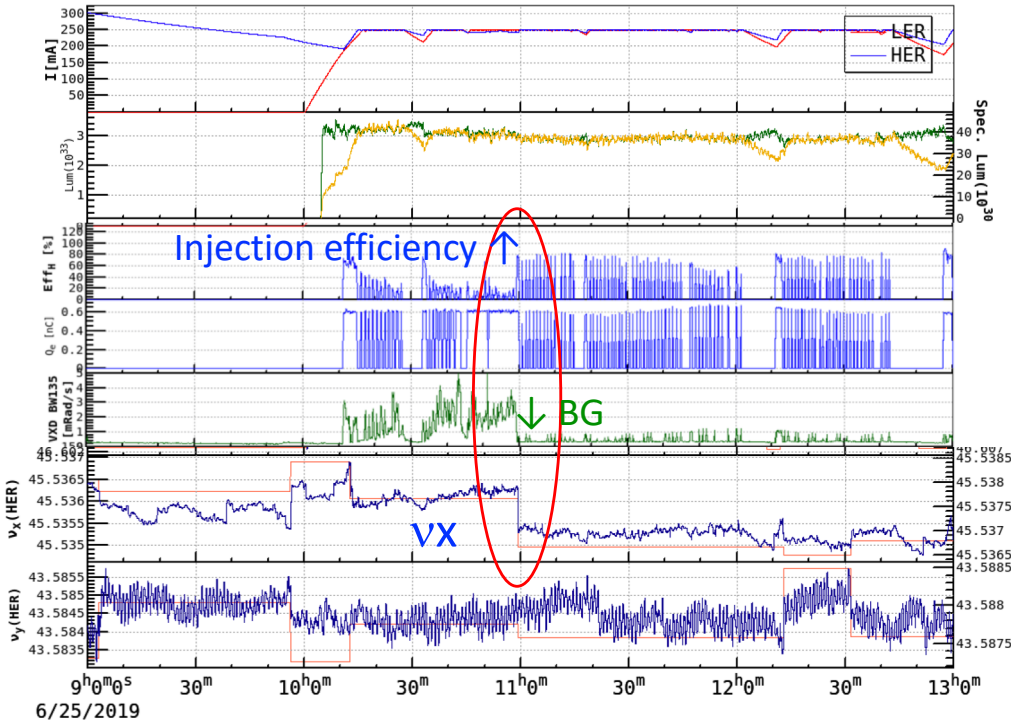
Even once the injection parameters are fixed, sometimes they should be re-tuned during the operations.

- Septum angle(Horizontal injection angle) (, Kicker tuning)
- Vertical injection angle
- Injection phase

The tuning was repeated cyclically.



- H. Tune



νx tuning is effective

HER injection became beautiful !

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  - Big jump of the orbit in LINAC
  - Big jump of the beam energy in LINAC
- There is no abort causing the QCS quench due to injection beam in Phase 3.

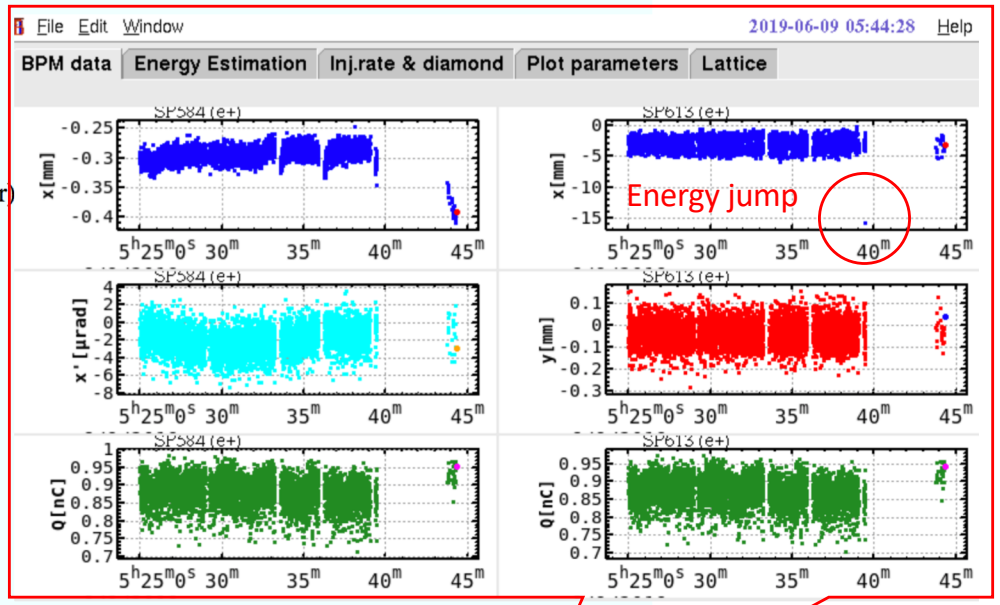
Abort caused by LINAC abnormal beam:
May/31 LER abort 0/9
Jun./01 LER abort 2/4
Jun./06 LER abort 0/3
The other causes are still unknown.

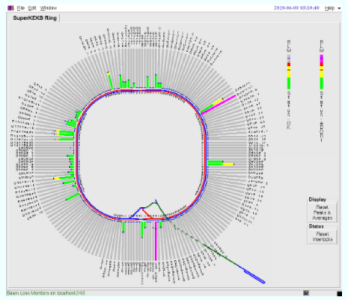
Operation log for SuperKEKB on one day

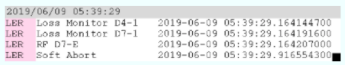
05:39:29 LER Beam Abort (659.9mA) LER 入射中

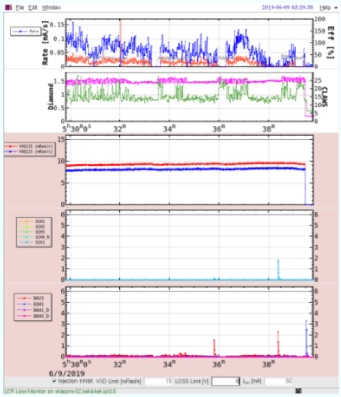
LER Abort Loss Monitor D4-1
LER Abort Loss Monitor D7-1
LER Abort RF D7-E
D05F REFLECT from 1-S
D05F REFLECT to CIR#3DL
Loss Monitor Abort BM_BLM:D07:ABORT1_2
LER Abort RF Software Abort
LER Abort Soft Abort
Loss Monitor Abort BM_BLM:D04:ABORT1_6 (D3H1 collimator)
D08E REFLECT from 2-S
D08B REFLECT from 2-S
D08B MT-DL INPOWER
D08A REFLECT from 2-S
D08E REFLECT from 1-S
D07A REFLECT from 1-S
D07B REFLECT from 1-S
D07C REFLECT from 2-S
D07E SQC ABORT TO RFOFF
D07E ARC COUPLER CAV#1-VAC

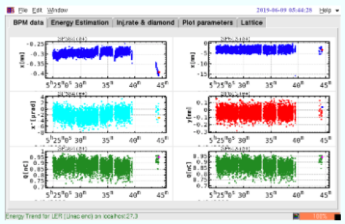
→ RF Recover、Loss Monitor Reset、Abort Reset











The new addional information from LINAC

Y. Seimiya, F. Miyahara

Due to

Fast beam position monitor(BPM) in LINAC

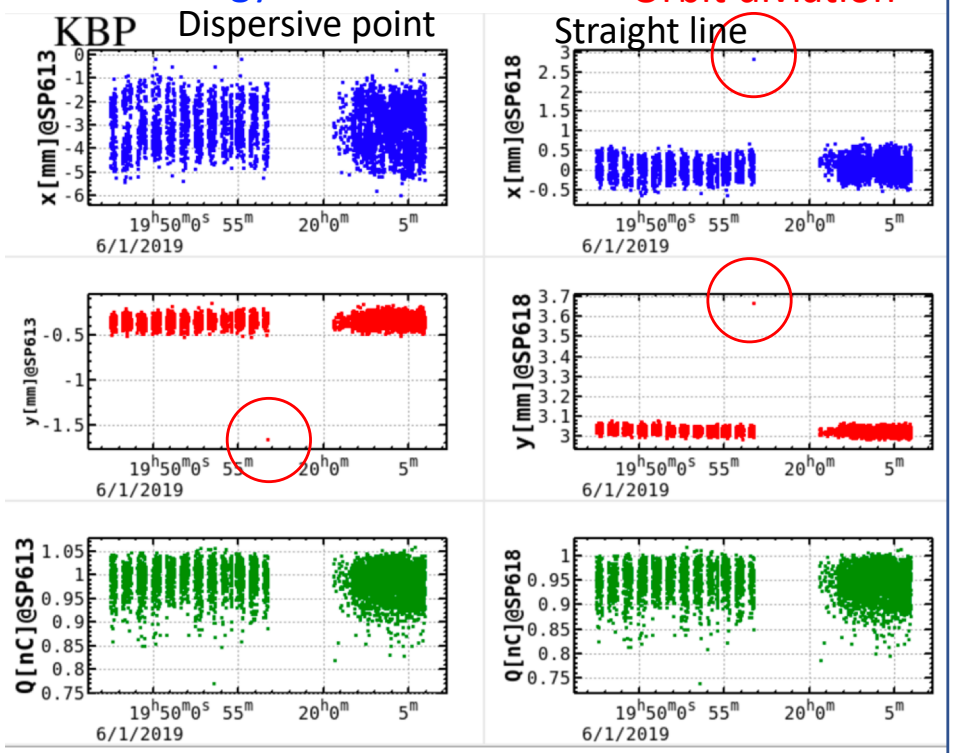
the injection beam just before abort can be monitored.

a. 1/Jun. 19:56

- LER D6V2 LM abort

No energy diviation

Orbit diviation

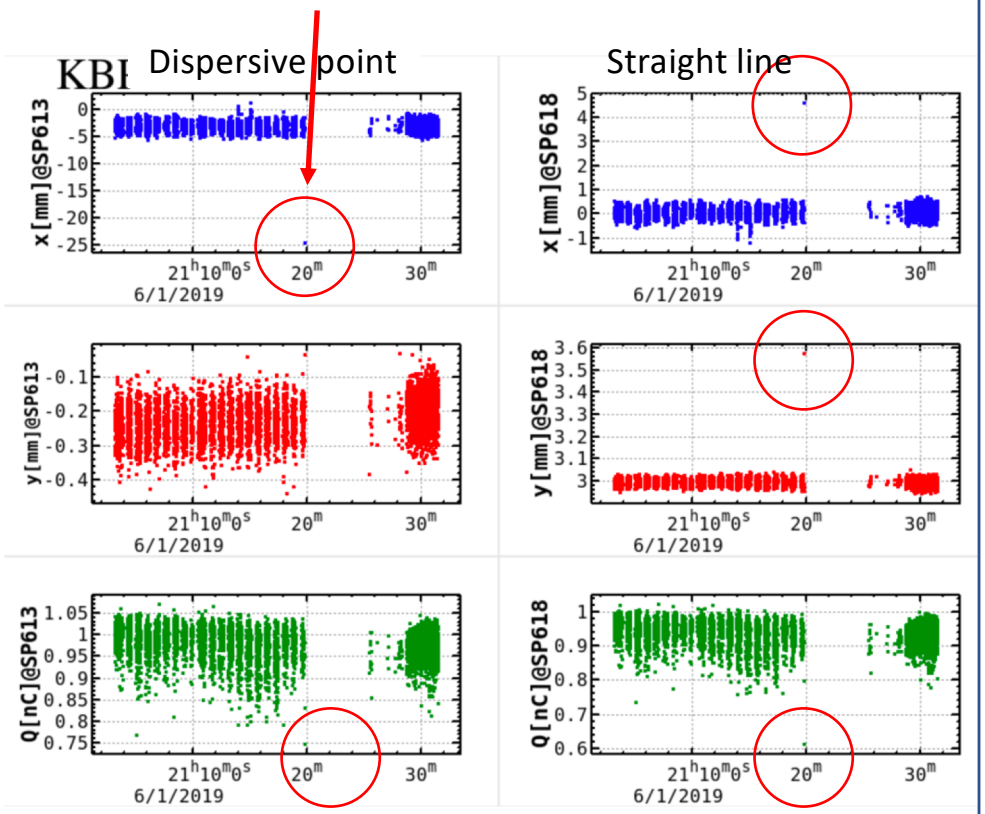


One station for the power supplies(PS) was set to 0 [A] due to a trigger missing of the PS.

b. 1/Jun. 21:19

- LER D6V2 LM abort

Beam energy was 50 MeV lower.



The klystron 51 was down at the time. The estimation was -46.5 MeV which is consistent with the beam position.

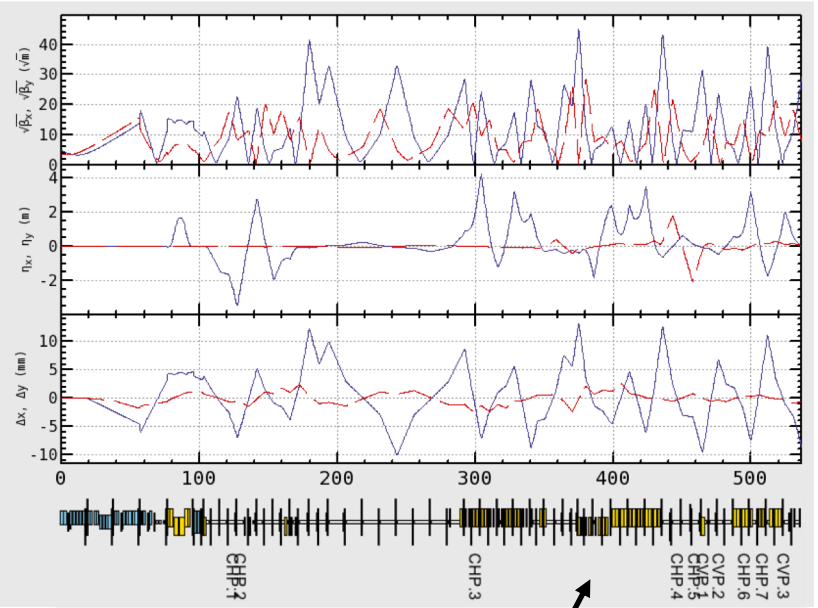
Simulations

In the both cases, the beams had been injected into the LER.

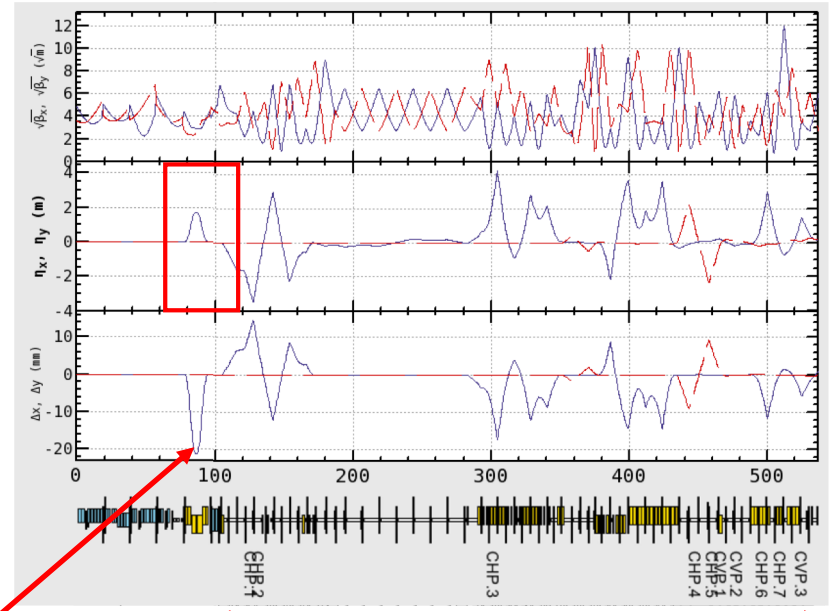
a. 1/Jun. 19:56

b. 1/Jun. 21:19

Y. Seimiya



BT line



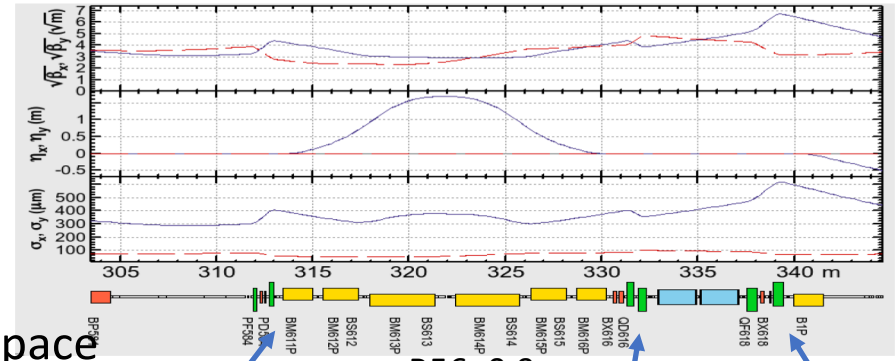
BT line

a. The collimators(CHP, CVP) in the BT could cut the beams with the abnormal orbits.

b. The lower energy beam can not be cut in the BT due to the Energy Compression System(ECS) at the end of the LINAC.
We have to install one more collimator, which is under planning.

- In HER, the collimator for protecting the lower energy beam will be also prepared in this summer.

Lower energy beam after the ECS in front of the BT



The longitudinal phase space

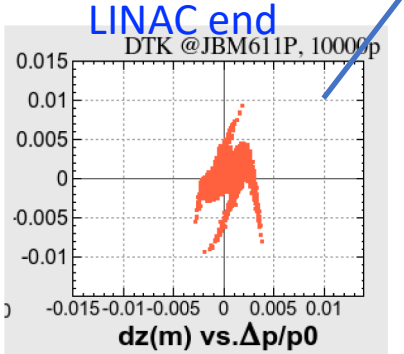
R56=0.9

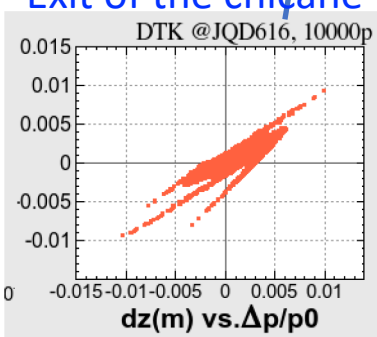
LINAC end

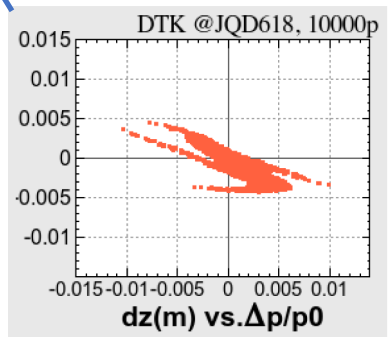
Exit of the chicane

Exit of ECS acc. structure

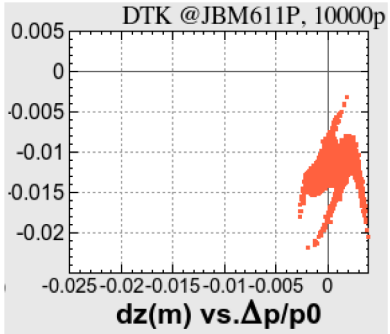
ΔE= 0

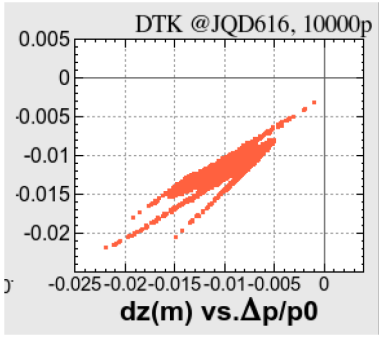


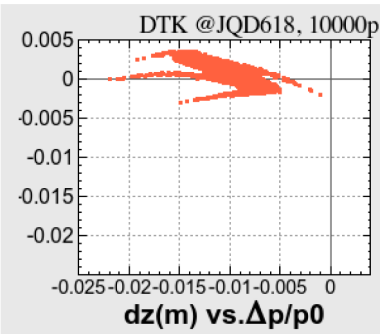




ΔE=-50MeV







Since the ECS restores the beam energy, the beam can inject while being shifted in the time direction, which could cause a LER abort.

Summary

I. Injection background

(0) Tuning method with TBT BPM on one-pass mode is established.

(1) Injection beam

- Improvement for stabilising the injection beam will be continued.

(2) Injection tuning

- HER
  - Some parameters such as the septum angle, the vertical steerings should be tuned to keep the low BG.
  - The tunes or collision tunings sometimes affects to the BG.
- LER injection is very stable. Thanks to the DR.

II. Beam aborts during the injection can be monitored

- ~10% of the aborts during injection were caused by the abnormal orbit or energy in LINAC.
  - The abnormal beam will be cut by the new collimators.
  - The other causes are still unknown.

Backup

(E) Emittance and Energy spread of the injection e- beam

3rd/Jun . (before tuning)

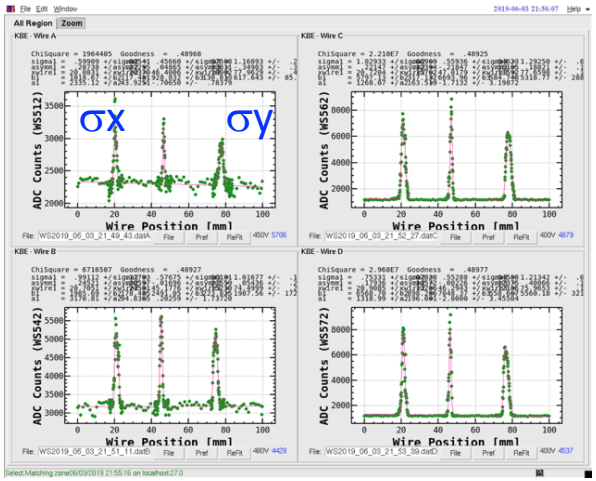
Energy spread

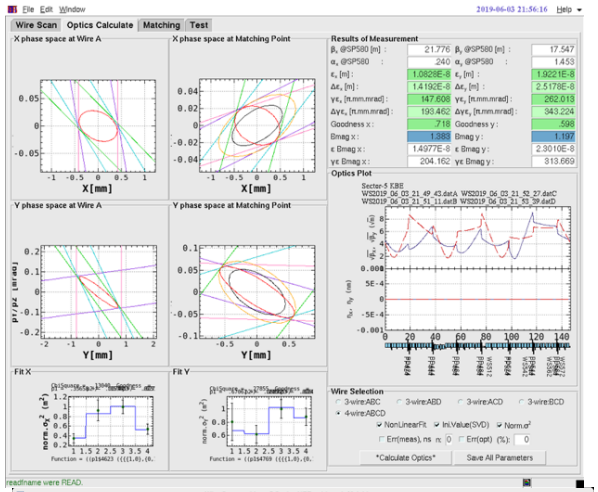
11th /Jun. (after tuning)

Energy spread

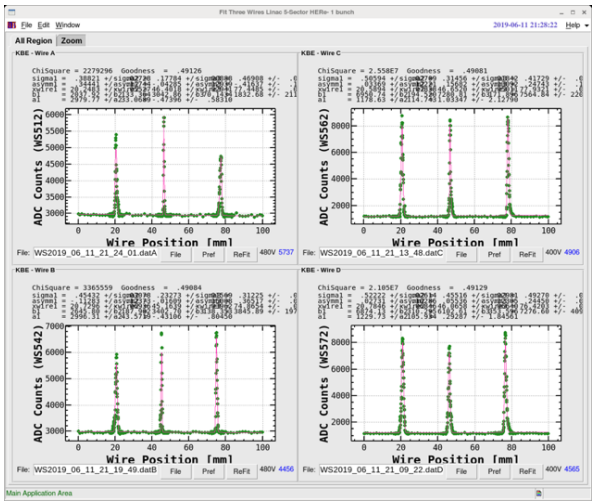
The energy spread became smaller.

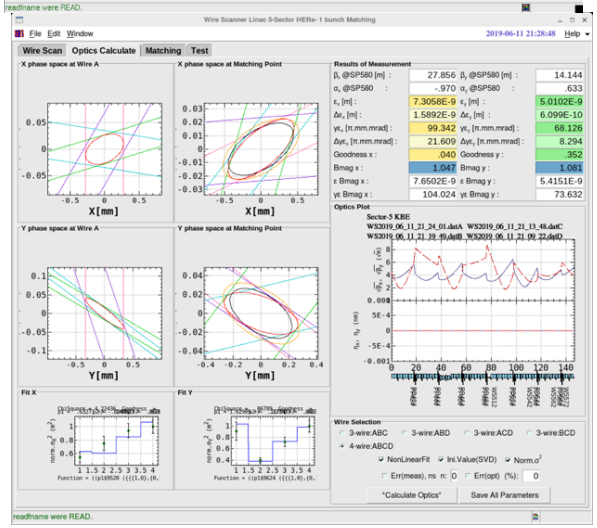
Emittances measured by the wire scanners at the BT





γεx=147μm
γεy=262μm





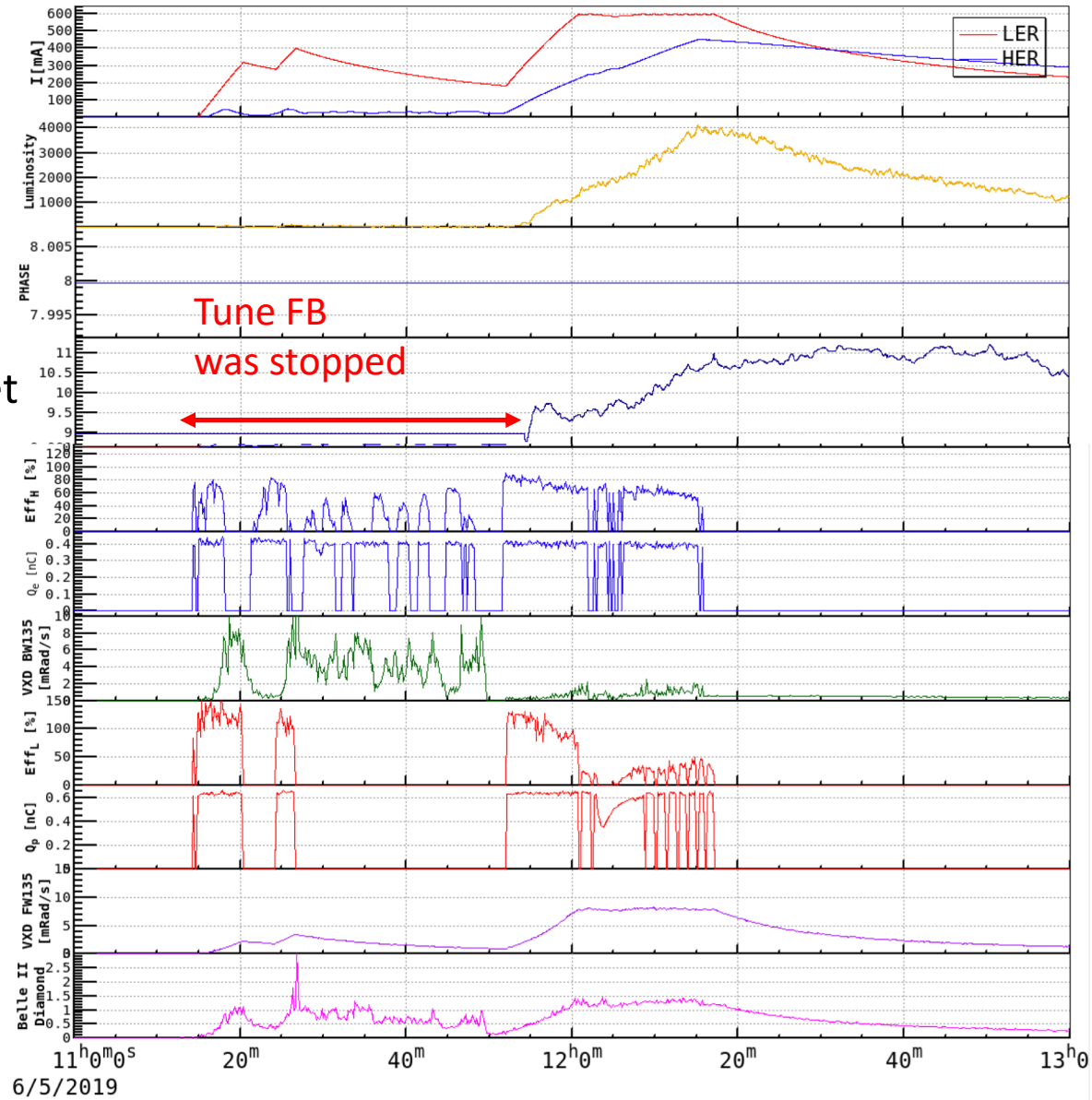
γεx=99μm
γεy=68μm

Especially the vertical emittance became smaller.

(2) Injection tuning (Cont'd)

- iBumpFB Target

V. Offset



Pulsed quads, Pulsed steering at the abort

One station for the power supplies was set to 0 [A] due to a trigger missing.

Y. Seimiya

Trigger failure of the power supplies of the pulsed magnets.