LTR, RTL Commissioning

	Measurement of the WS		Requirement from LER	
	Sector 3	Sector 5	Phase-2	Phase-3
$\gamma\varepsilon x$ (μm)	192±22.4	185±28.4	< 200	< 100
$\gamma\varepsilon y$ (μm)	2.01±0.363	1.72±0.704	< 40	< 15
Charge (nC)	w FC	1.4	0.5	4.0

14/Mar/2018

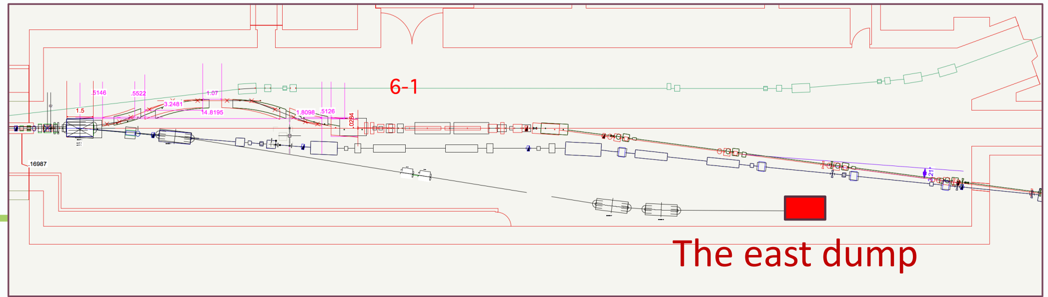
22nd SuperKEKB MAC

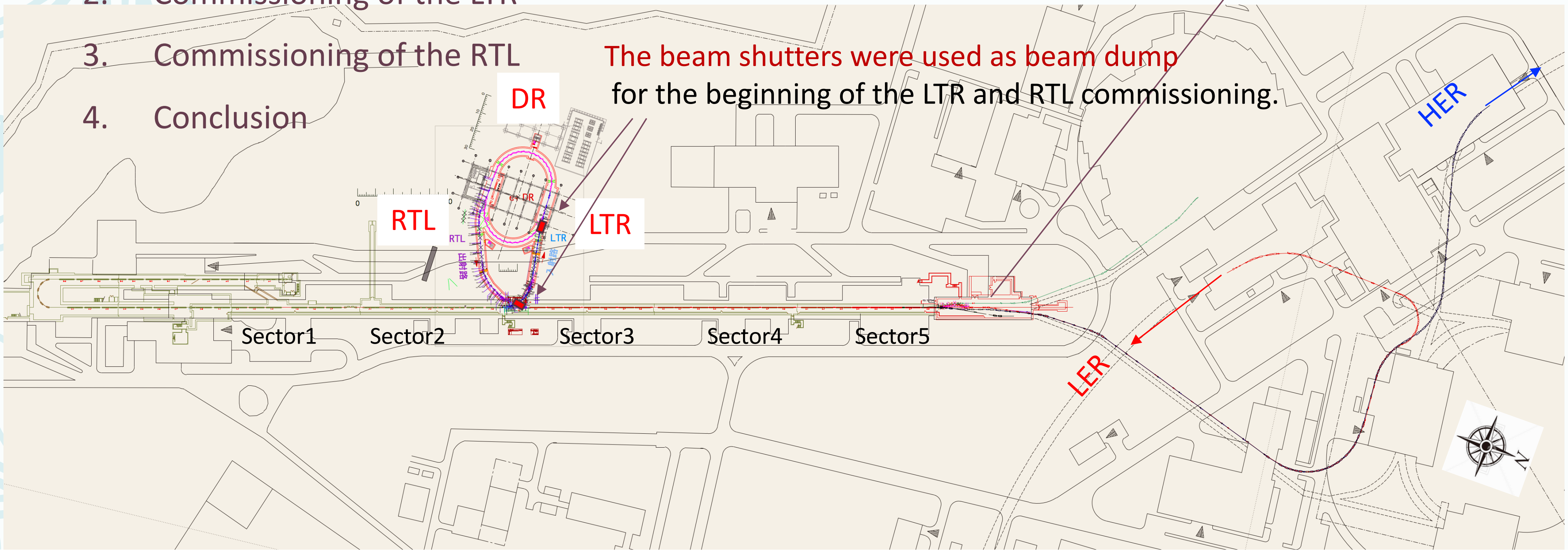
N. Iida for the KCG Group

Contents

1. The DR Complex
   - Positron Damping Ring(DR)
   - Linac To Ring(LTR) : The injection line of the DR
   - Ring To Linac(RTL) : The extraction line of the DR
2. Commissioning of the LTR
3. Commissioning of the RTL
4. Conclusion

After the DR and RTL commissioning, the beam was dumped to the east dump at the end of LINAC.



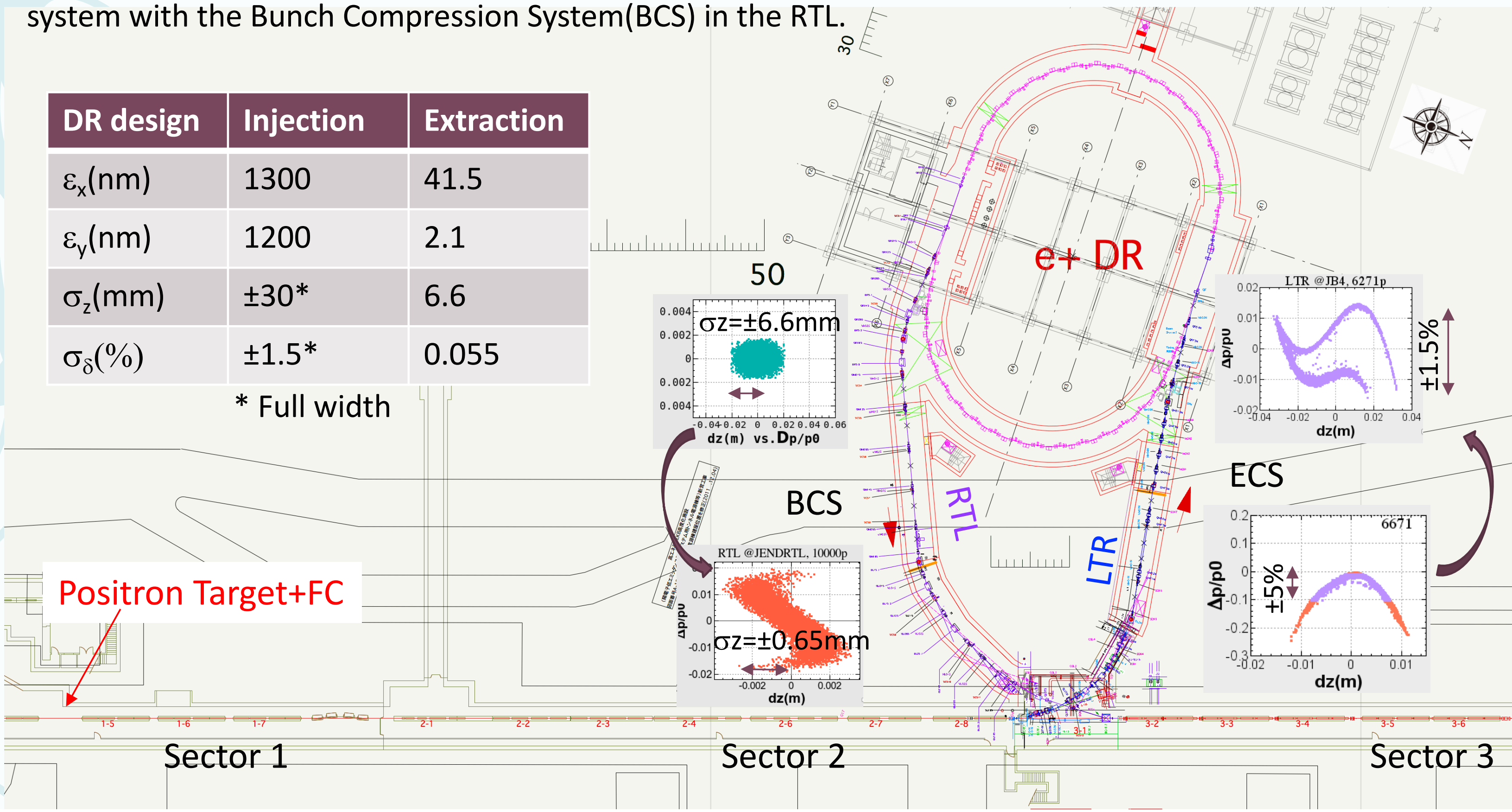


1. DR complex

The DR damps the emittance of the e+ beam to inject into the LER.
The positron beam from Flux Concentrator(FC) has a huge longitudinal distribution.
LTR: The energy spread(5%) should be reduced within the energy acceptance of the DR(1.5%) with the Energy Compression System(ECS) in the LTR.
RTL: The bunch length extracted from the DR(6.7mm) should be shortened(0.65mm) to fit the LINAC S-band system with the Bunch Compression System(BCS) in the RTL.

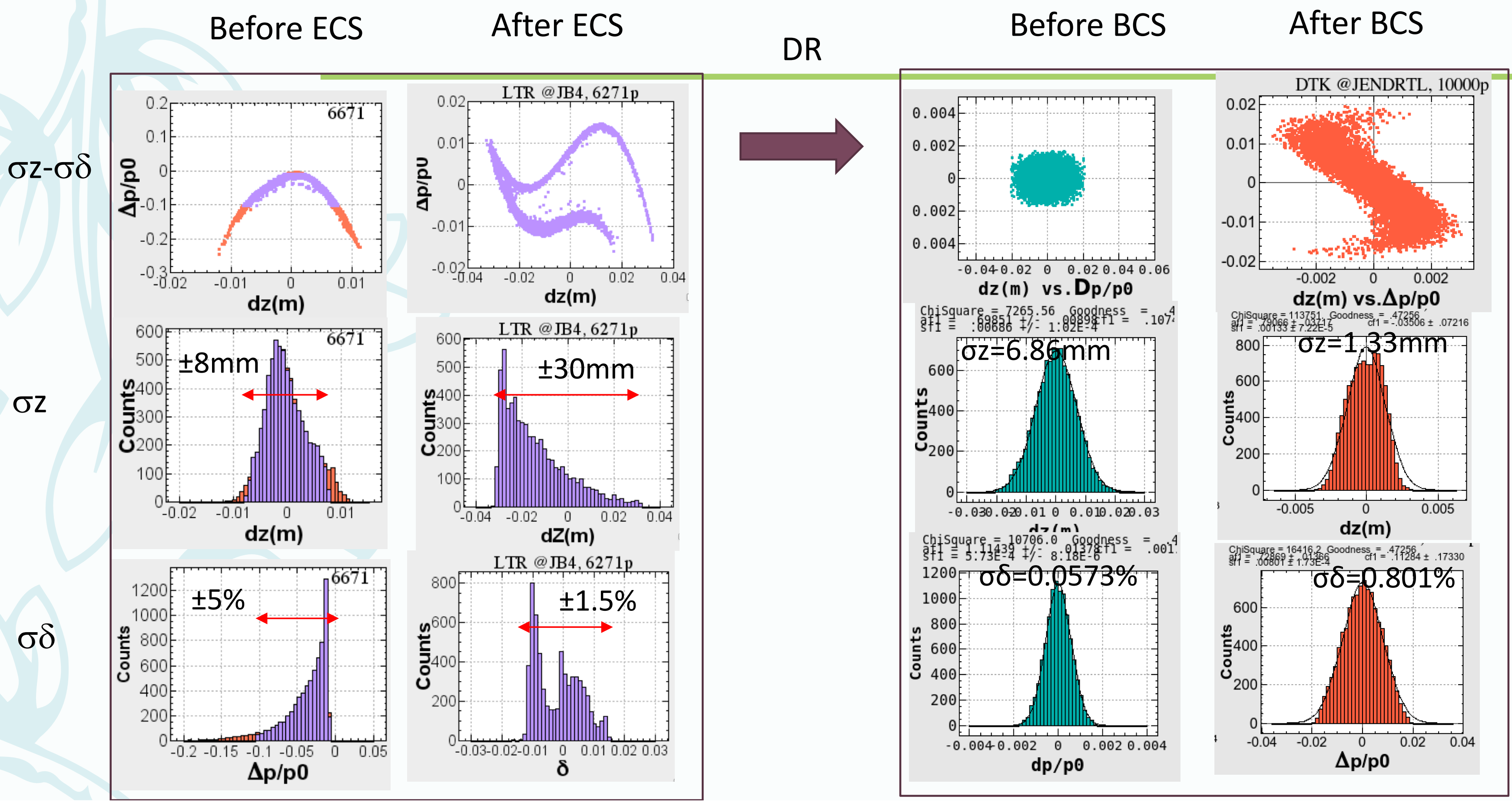
DR design	Injection	Extraction
ε_x(nm)	1300	41.5
ε_y(nm)	1200	2.1
σ_z(mm)	±30*	6.6
σ_δ(%)	±1.5*	0.055

* Full width



Distributions of the longitudinal phase space at the entrance and exit of the ECS and the BCS

The energy spread and the bunch length are big compared with the S-band of the ECS and the BCS

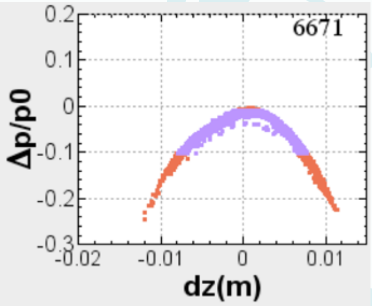


Parameters of the ECS and the BCS

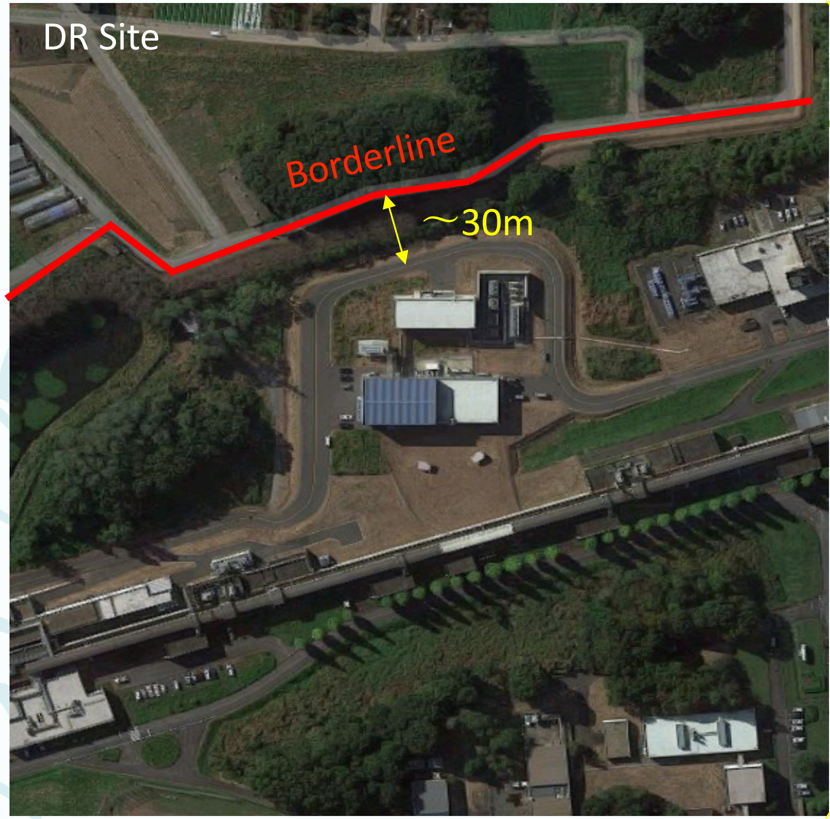
	ECS		BCS	
	Before ECS	After ECS	Before BCS	After BCS
Wisth of z	W=±8mm	±30mm	σz=6.6mm	σz=1.3mm
Width of δ	W=±5%	±1.5%	σδ=0.055%	σδ=0.80%
R56 [m]	- 0.61		- 1.05	
Vc [MV]	41		21.5	

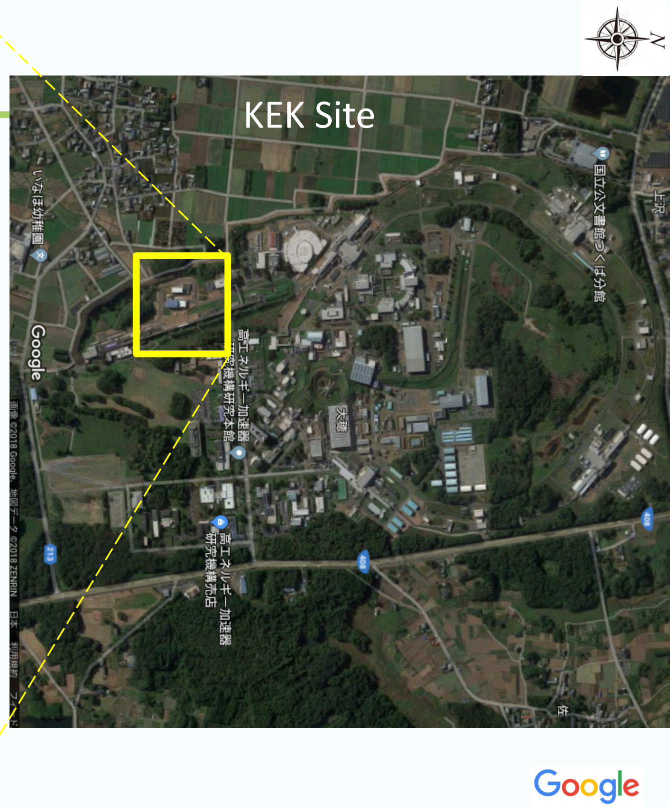
Site of the DR

Entrance of the LER



The energy tail can be cut up to 20% of the charge by the collimators at the LTR in LINAC region before loss in the DR.



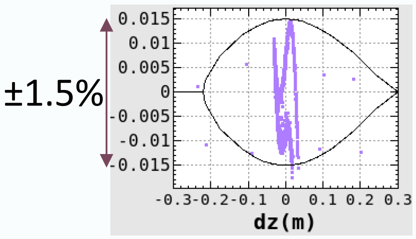


Because the borderline of KEK is close, the beam loss outside of LINAC should be low.

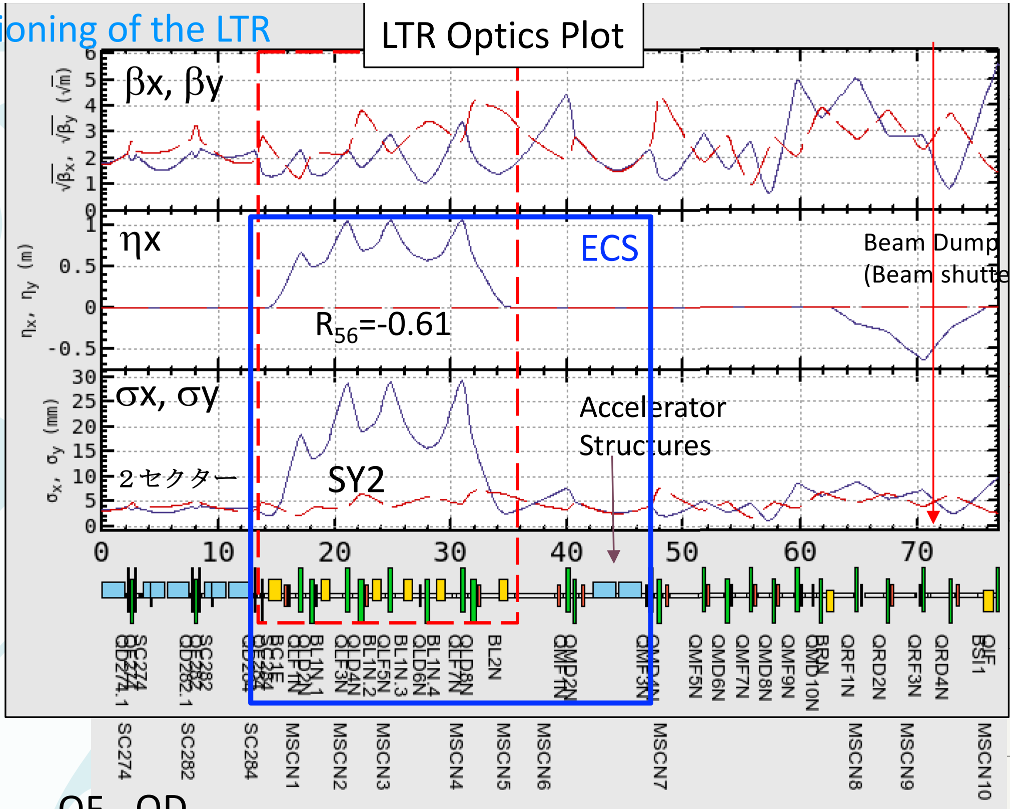
2. Commissioning of the LTR

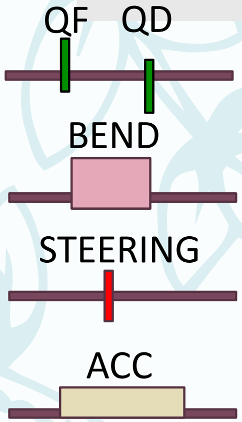
- The initial commissioning of the LTR started on Jan. 23rd.
  - The beam was reached to the end of the LTR on Jan. 24th .
- The charge from LINAC was 0.75nC/bunch without the FC.
- The beam loss outside of LINAC should be low because the borderline of KEK is close.
- The R_{56} of the 1st arc and an accelerating structure consist the Energy Compression System (ECS).
  - The energy spread (σ_δ) of the injection beam to the DR should be smaller than the energy acceptance, ±1.5%.
  - The ECS compresses σ_δ from ±5% to ±1.5%.
- The 4 collimators cut the low energy tail in the LTR.
- The magnets of the LTR and the RTL are set at the energy of the DR.

The entrance of the DR

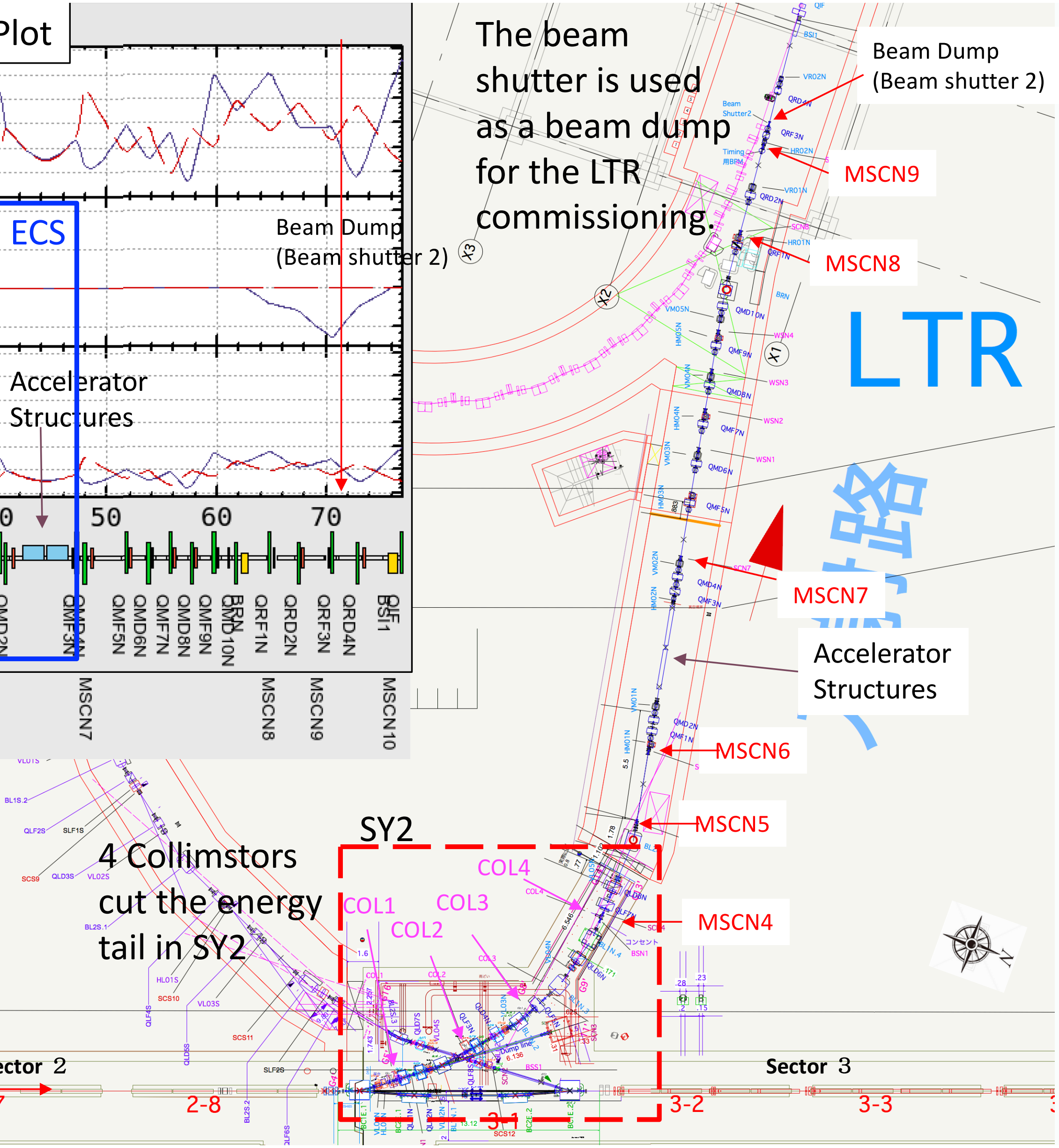


Commissioning of the LTR



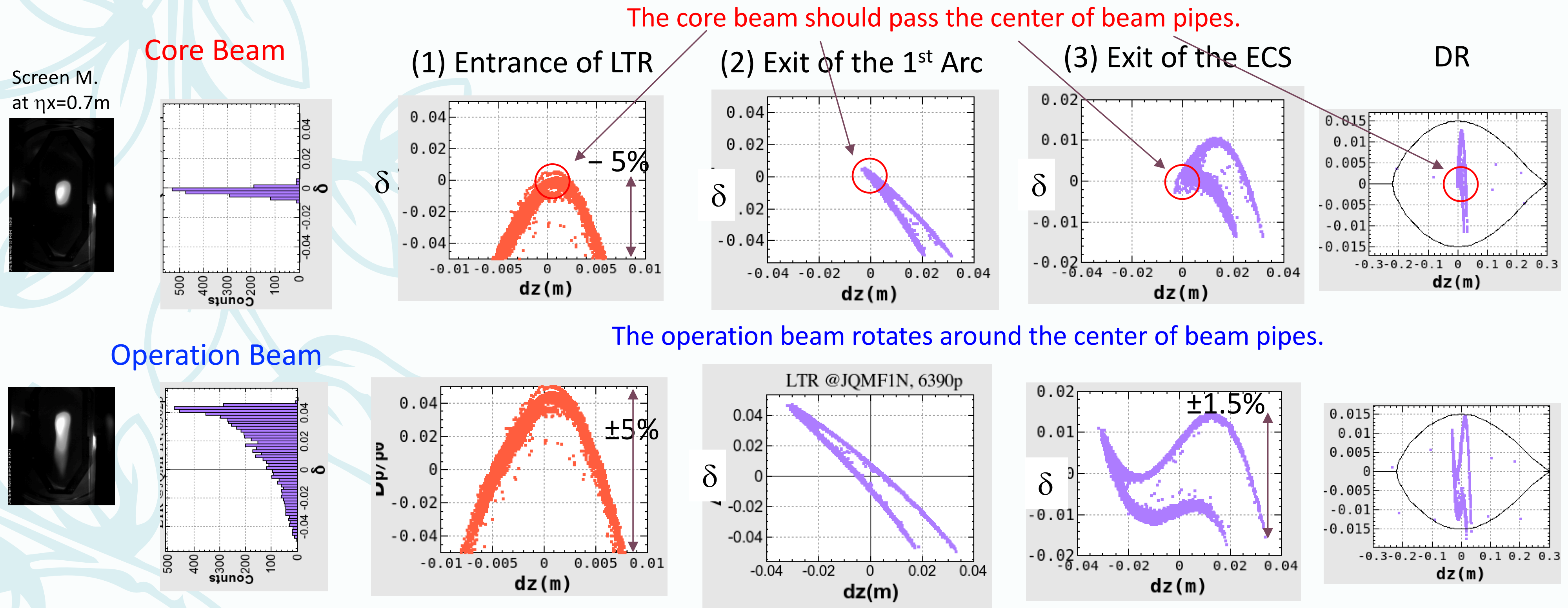


The beam shutter is used as a beam dump for the LTR commissioning.



Tuning of the LTR

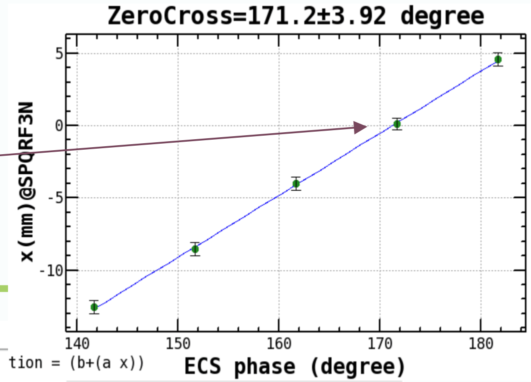
1. We made the "core beam" to adjust so that the centers of beam energy and dz pass through the center of beam pipes.
   - In this time, the core beam was made by lowering the energy of the beam and cutting deeply the tail of energy with the collimators.
2. The zero crossing of the ECS was scanned by using the core beam.
3. Finally, the energy of the beam was increased and the energy tail under -5% was cut with the collimators.



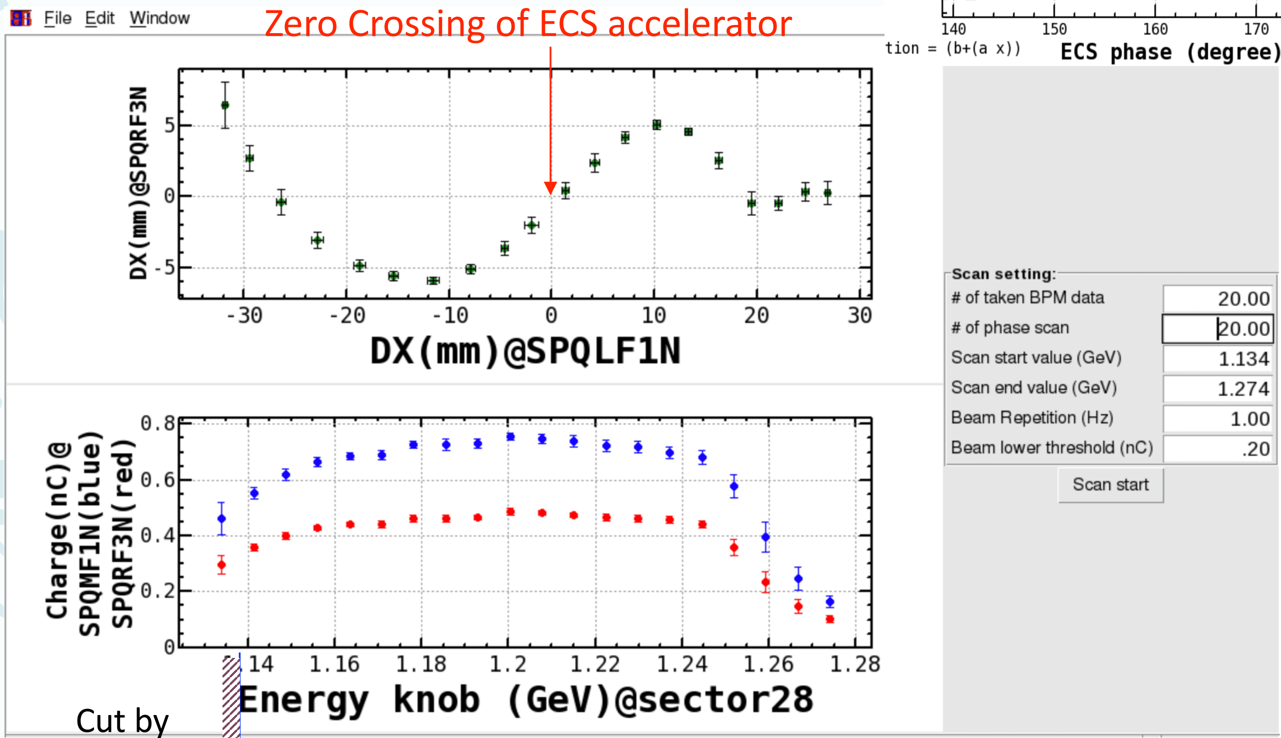
ECS Tuning

Y. Seimiya, N. Iida

We searched the zero-crossing phase of ECS



Zero Crossing of ECS accelerator

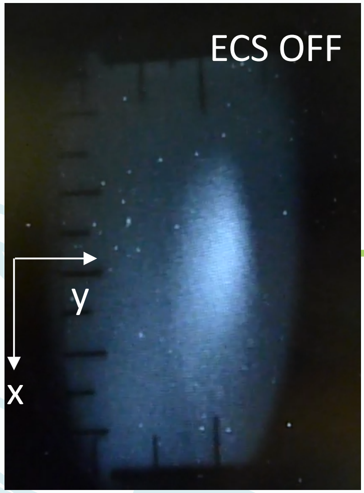


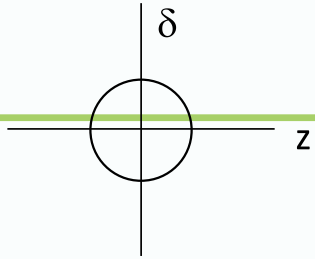
Cut by Collimators

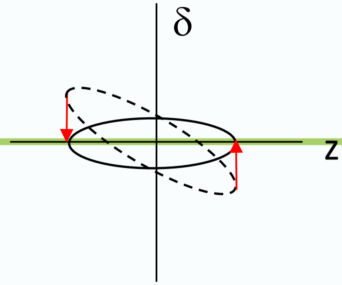
Energy Acceptance of LTR (±5%)

Shift report “2018_01_24_17_NakamuraS_EnomotoS.pptx”

Energy Spread is checked by the ECS ON/OFF on the screen monitor in the 2nd arc of the LTR

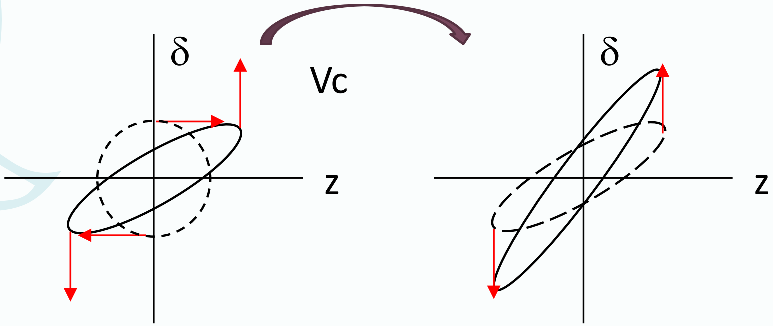






The beam size corresponding to energy spread is smaller properly.

Opposite Phase

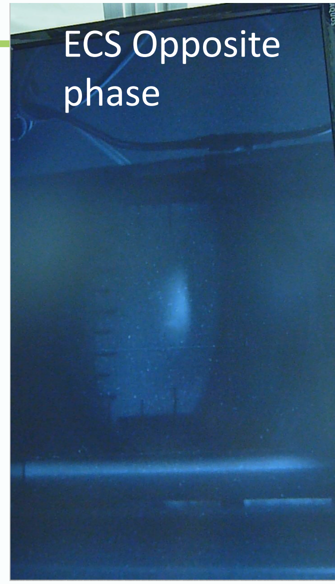


The energy spread is larger than that of ECS OFF.

By the way,

In the case of the core beam,

the energy spreads looks same in the three cases.



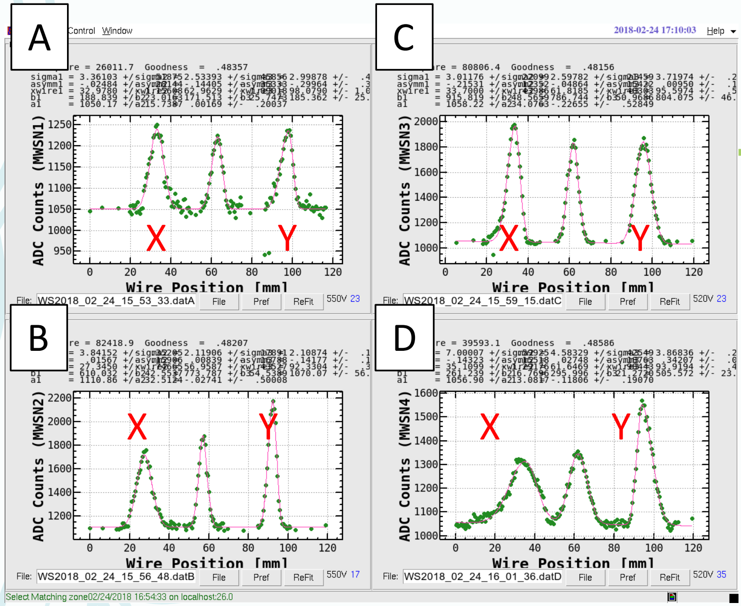
The core beam is independent on the ECS phase.

N. Iida, F Miyahara, Y. Yano, and Y. Ohnishi

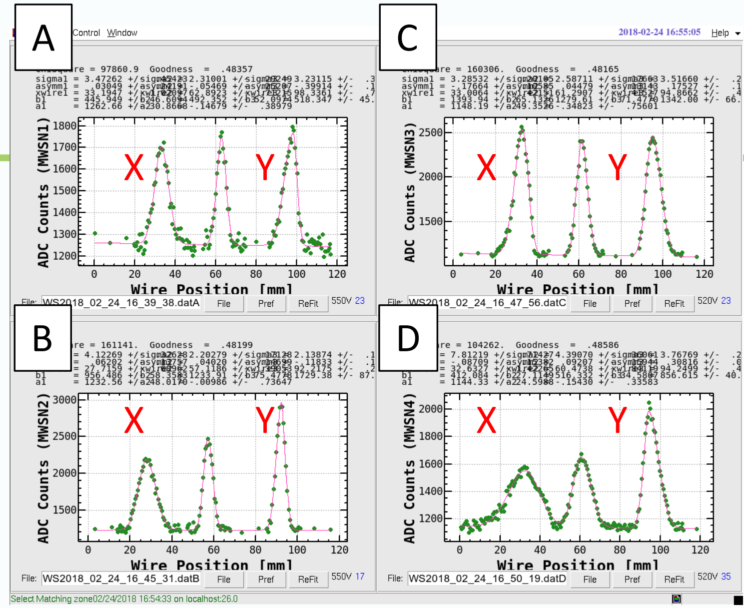
Measurements with the Wire Scanners in the LTR w/wo FC

The wire scanner system has four wire scanners(A, B, C, D) in one region.

FC
Stb



FC
Acc
5kV



	FC : Stand-by	FC : 5kV
γεx [μm]	245.5	288.5
γεy [μm]	241.8	255.8
BMAGx	1.58	1.00
BMAGy	1.53	1.01

No change was observed with FC Off and On.

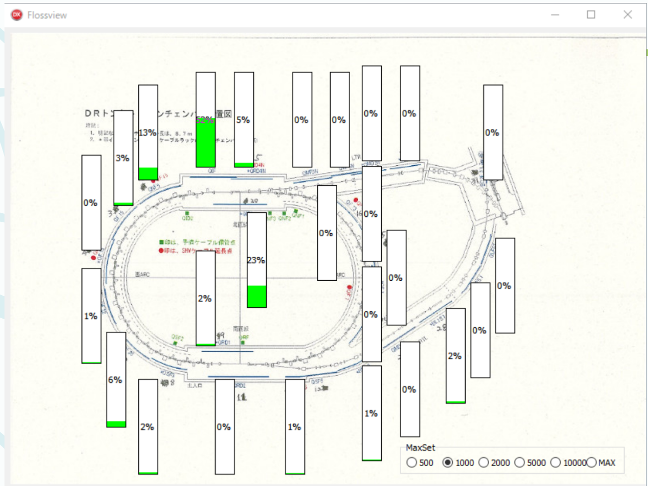
Loss Monitors

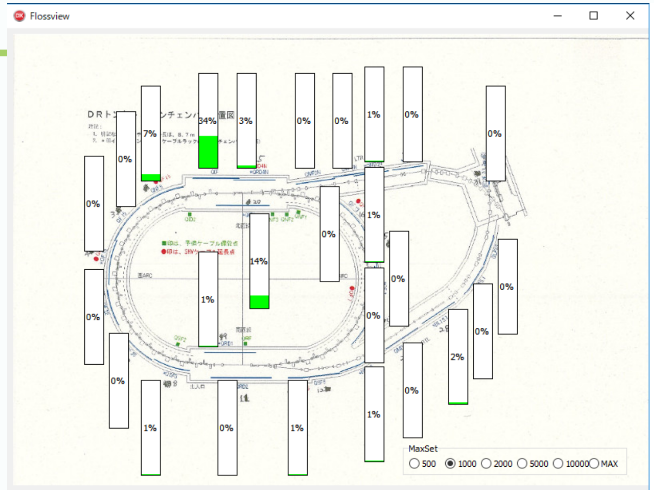
FC OFF

FC ON

H. Ikeda

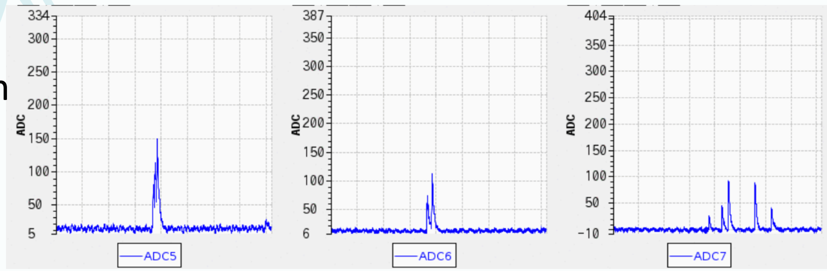
Loss Monitors

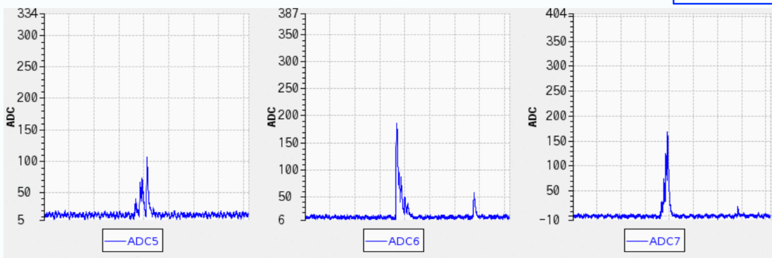




T. Kobayashi

Arc Sensers
of RF sustem





The signals of both of loss monitors and arc sensers of RF system are small enough.

Tuning items of the LTR

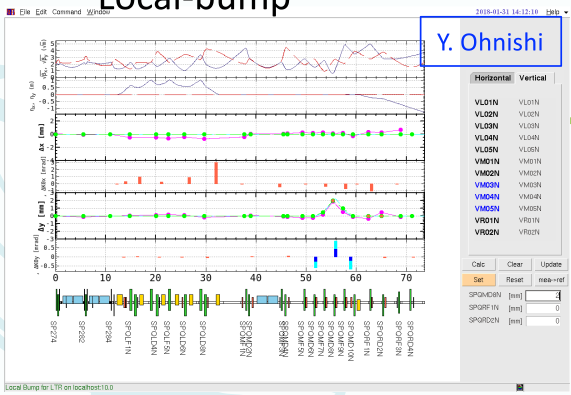
	LTR Study	Responsibles
1.	Dispersion Fine Tuning	Y. Seimiya, N. Iida
2.	3-BPM measurement	T. Ishibashi, H. Sugimoto
3.	Local Bump Study	Y. Ohnishi, R. Ueki
4.	Parameter Matching (Wire Scanner)	N. Iida, Y. Ohnishi, Y. Yano
5.	QuadBPM (Beam Based Alignment)	H. Sugimura, H. Sugimoto
6.	ECS Fine Tuning	Y. Seimiya, N. Iida
	Tuning of ECS Pulse Timing	LINAC Operator
7.	Single kick response measurement	M. Kikuchi

Many new rookies (more than 11) joined the commissioning of the LTR.

Many basic beam studies have been done.

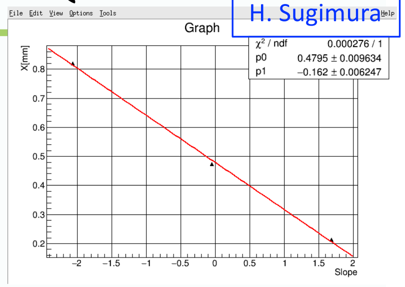
Local-bump

Y. Ohnishi



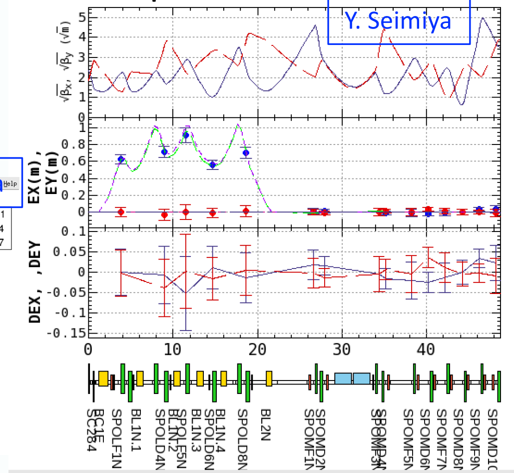
QuadBPM

H. Sugimura



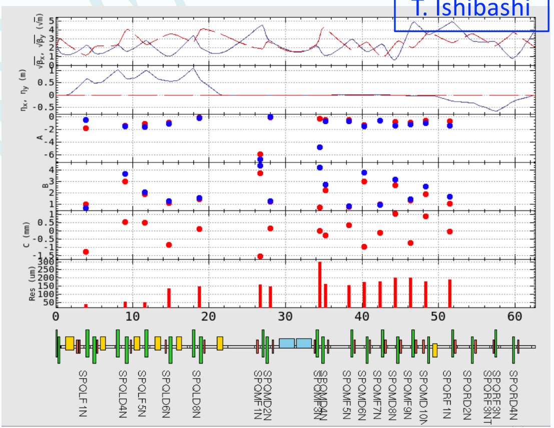
Dispersion correction

Y. Seimiya



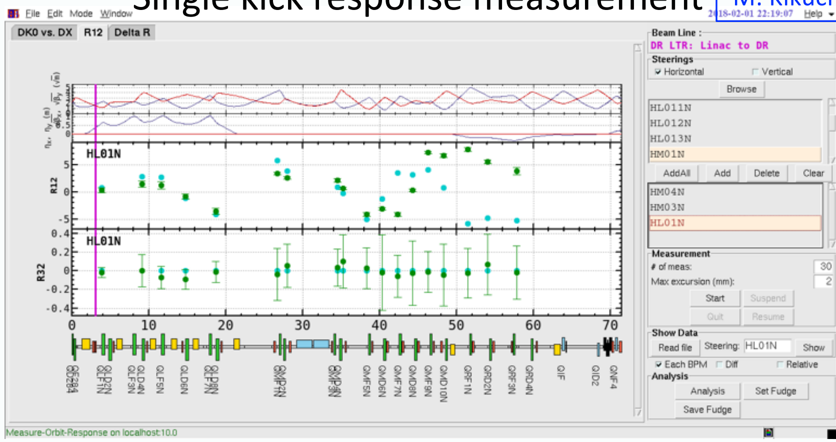
3-BPM

T. Ishibashi



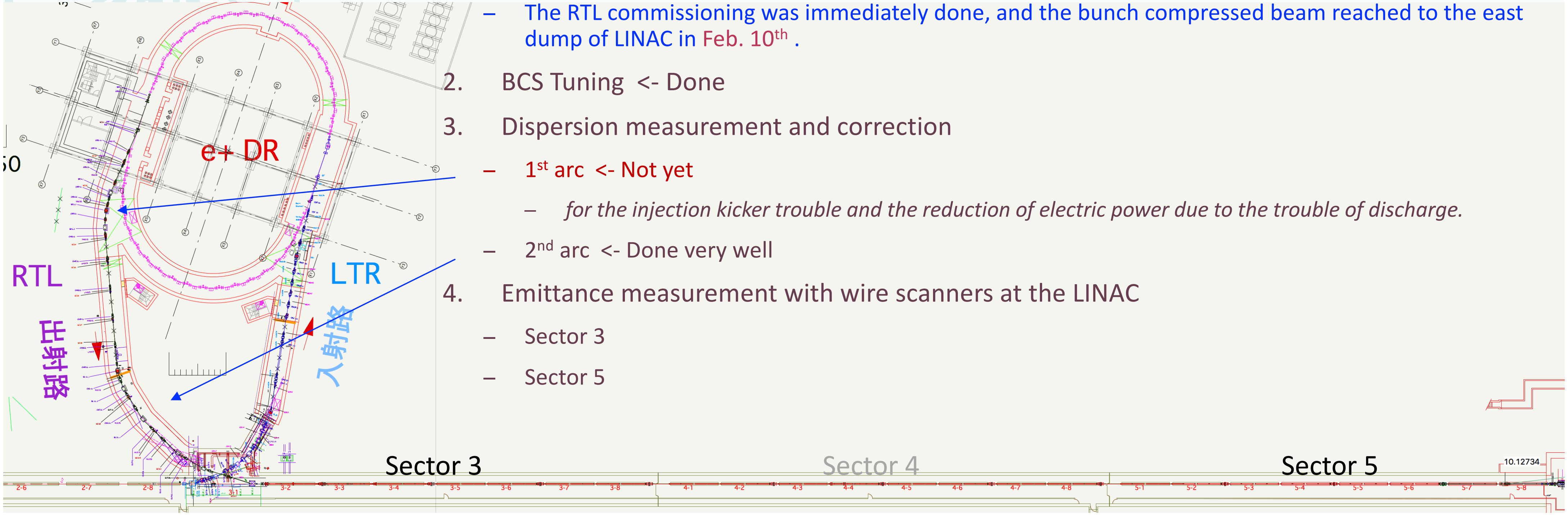
Single kick response measurement

M. Kikuchi

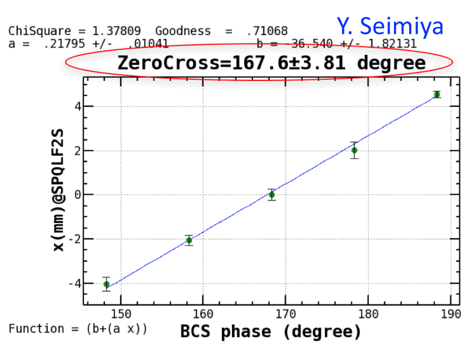


3. Commissioning of the RTL

1. The DR Commissioning started on Feb. 8th.
   - The RTL commissioning was immediately done, and the bunch compressed beam reached to the east dump of LINAC in Feb. 10th .
2. BCS Tuning <- Done
3. Dispersion measurement and correction
   - 1st arc <- Not yet
     - *for the injection kicker trouble and the reduction of electric power due to the trouble of discharge.*
   - 2nd arc <- Done very well
4. Emittance measurement with wire scanners at the LINAC
   - Sector 3
   - Sector 5



Commissioning of the RTL

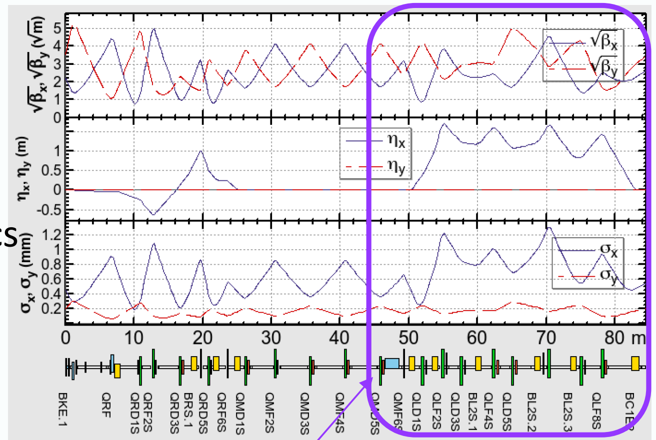


The BCS Tuning

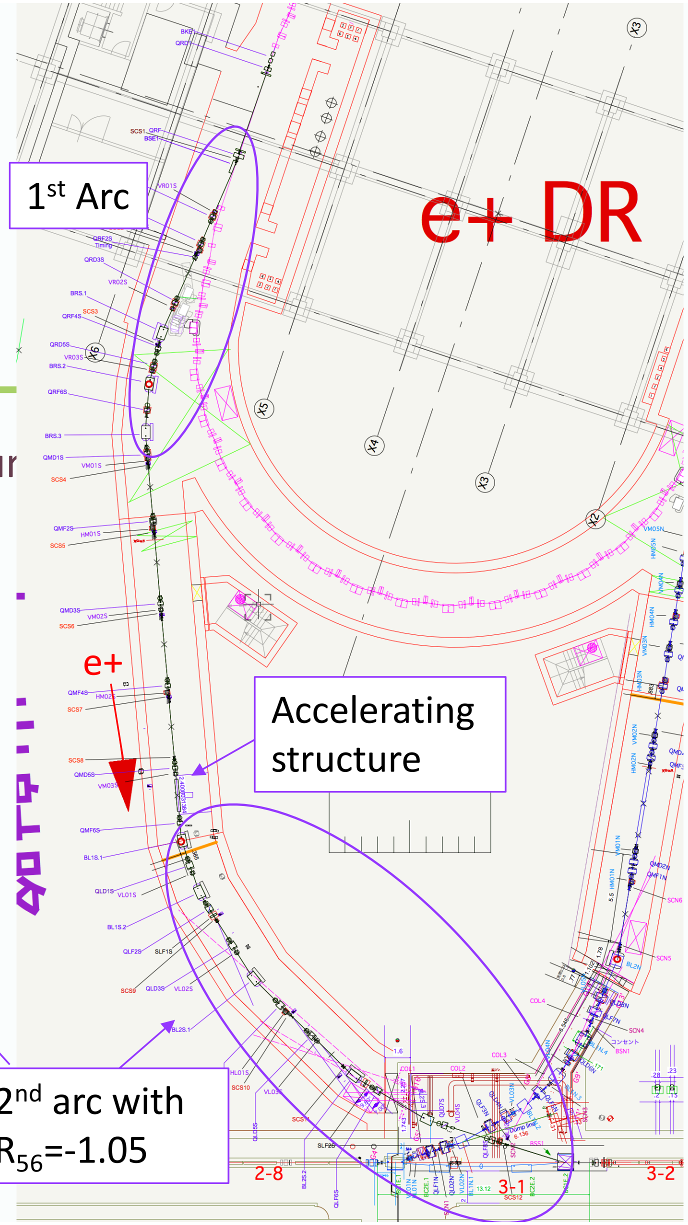
1. The orbits were corrected without the accelerating structur
2. The zero crossing phase of the BCS was found.
3. The accelerating phase of the sector 3-5 was searched.
4. The BCS phase was checked at the east dump.
   - 0 or π ?

BCS

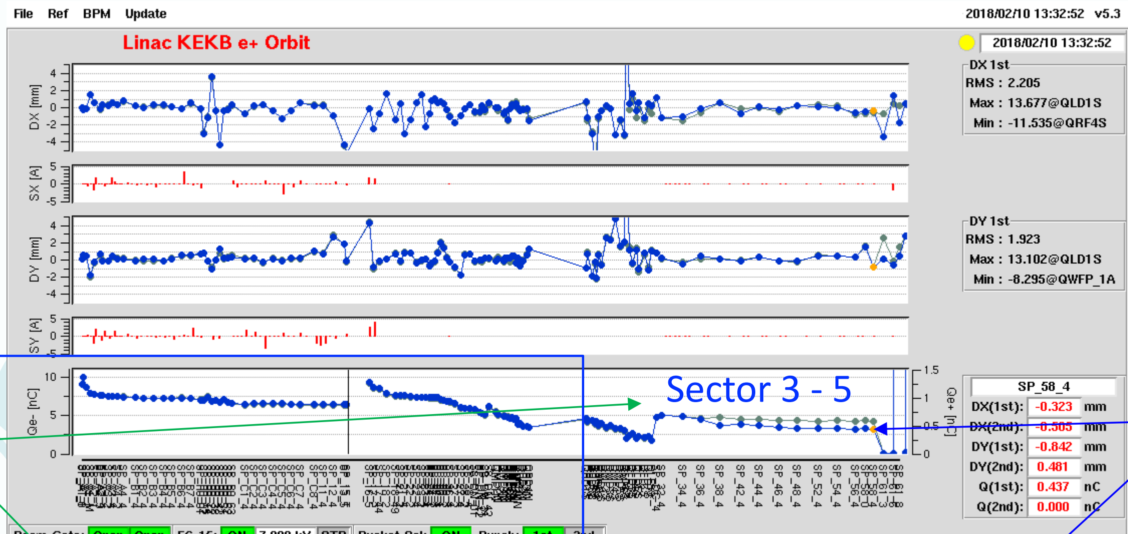
RTL Optics



Accelerating structure



Check the BCS Phase



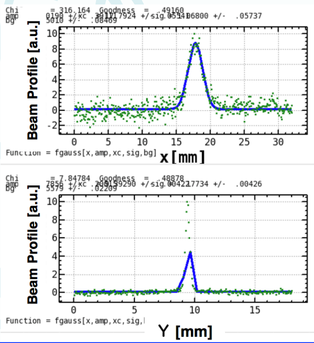
Sector 3 - 5

Green line: True phase of the BCS (347.7°)

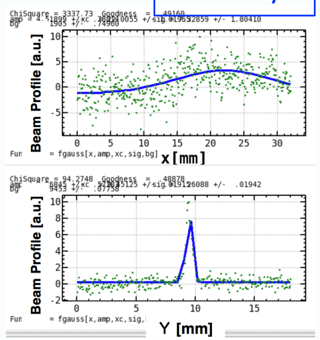
Blue line: The opposite phase of the BCS (167.6°)

The energy spread is small.

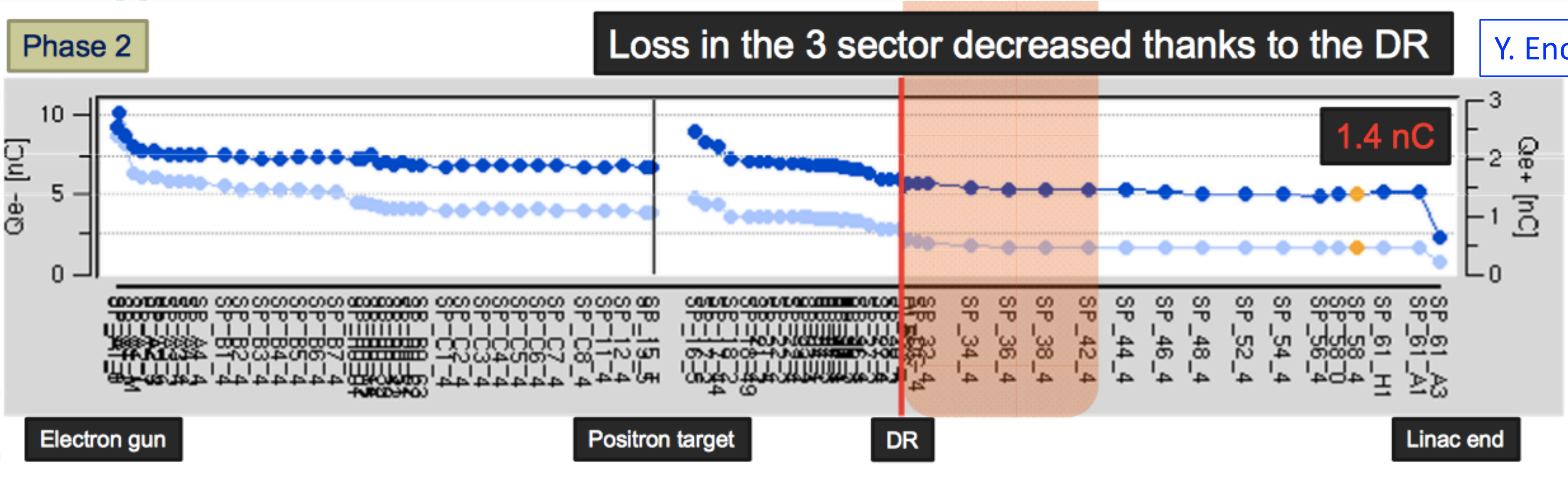
Screen monitor(YAG) in front of the east dump



Y. Seimiya



Return charge to the LINAC



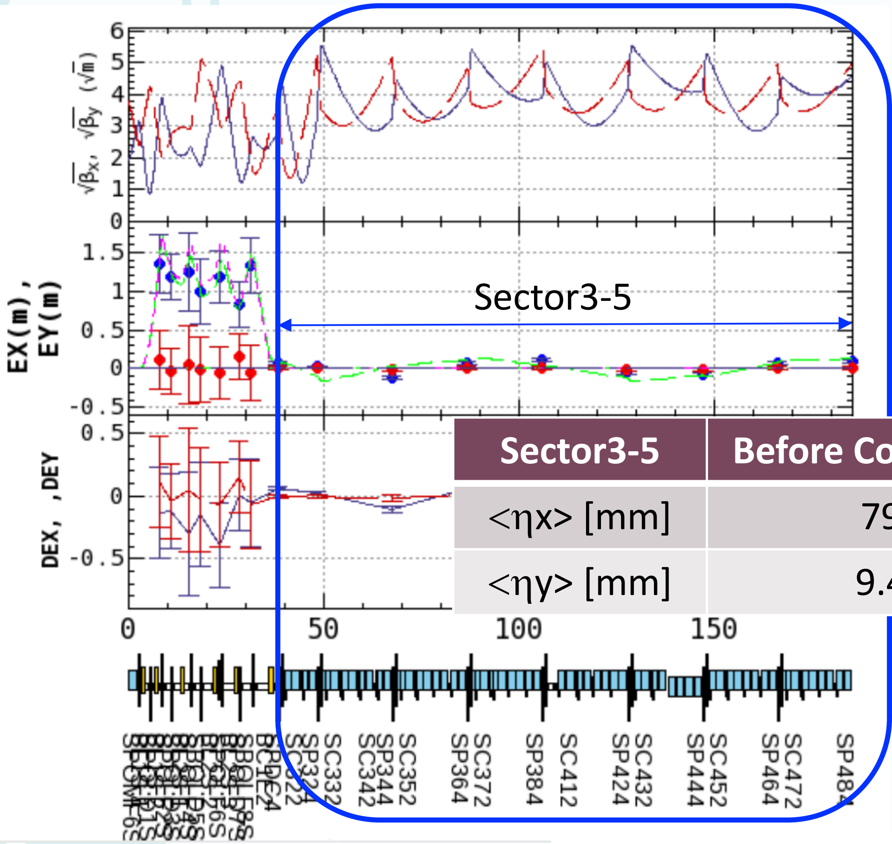
The charge returned from the RTL is almost same as that going to the LTR.
Even if the energy tail will be cut severly (20% in the maximum situation) ,
the charge is enough for the Phase-2.

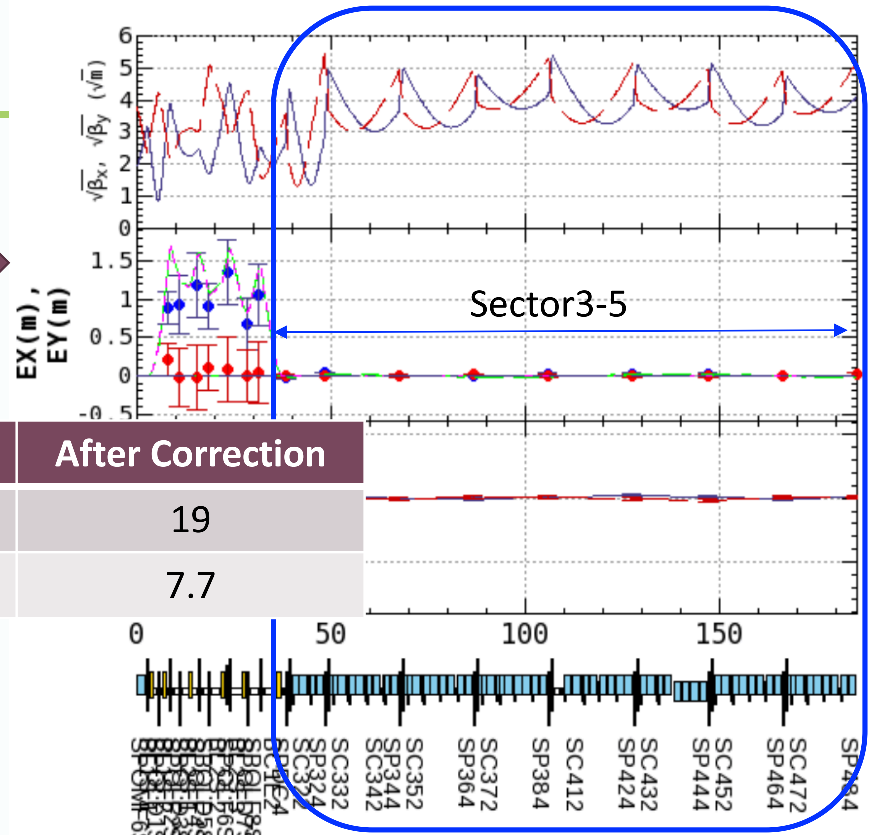
Dispersion correction of the 2^{nd} arc

RTL
2^{nd} Arc

The beam energy was changed by shifting the BCS phase.

Y. Seimiya





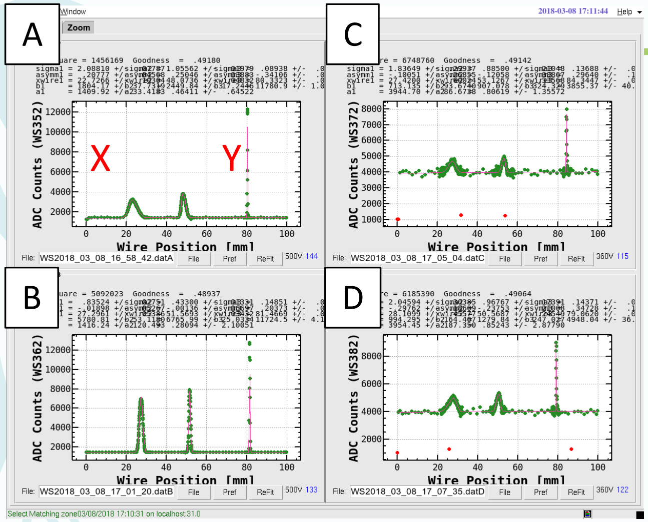
Sector3-5	Before Correction	After Correction
<ηx> [mm]	79	19
<ηy> [mm]	9.4	7.7

The leak of the horizontal dispersion decreased by a quarter.
The Fudge Factor of the quads in the 2^{nd} arc is 0.955.

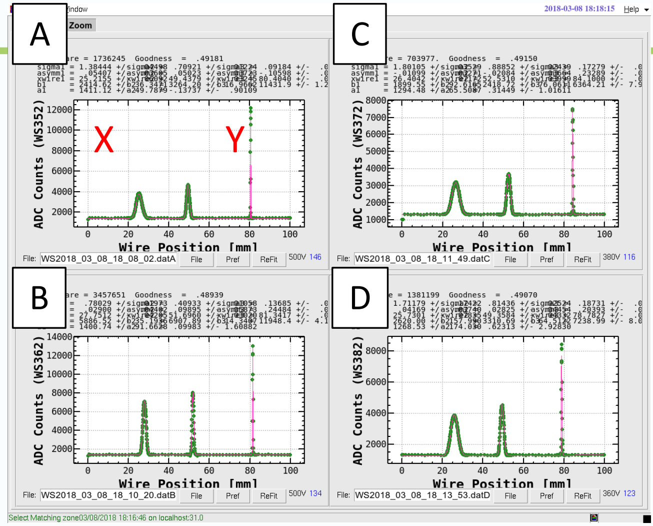
Emittance Measurement with the Wire Scanners in Sector 3

Emittance before and after the dispersion correction was measured by the WS in the sector 3

Before dispersion correction



After dispersion correction

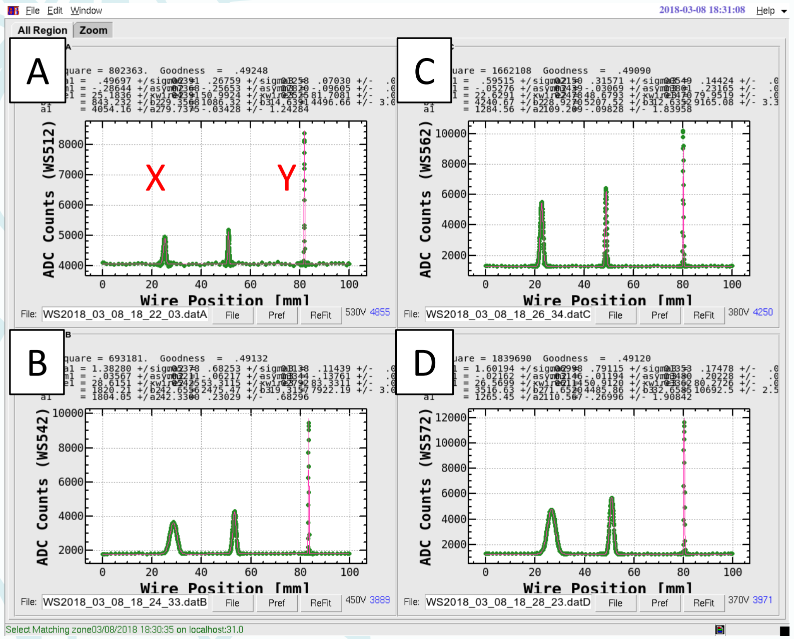


	Sector 3		DR(Optics Calculation)
	Before correction	After correction	
γεx (μm)	293±44.5	192±22.4	63.9
γεy (μm)	1.84±0.163	2.01±0.363	XY-coupling<=3.15±0.57%

The horizontal emittance is decreased 2/3.

The XY-coupling is estimated as less than 3.15%.

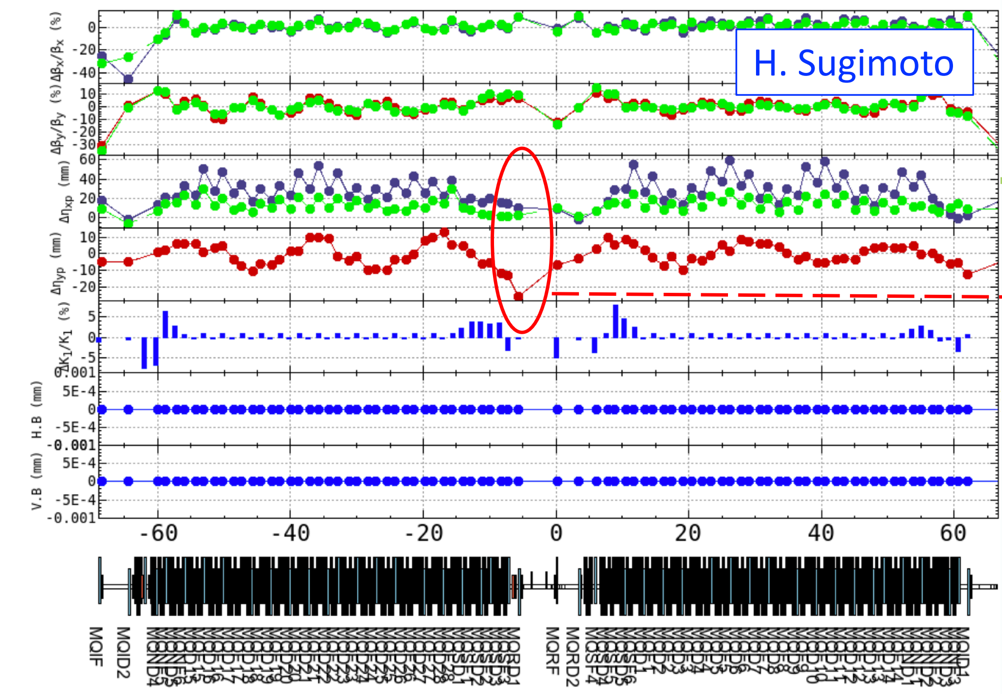
Emittance Measurement with the Wire Scanners in Sector 5

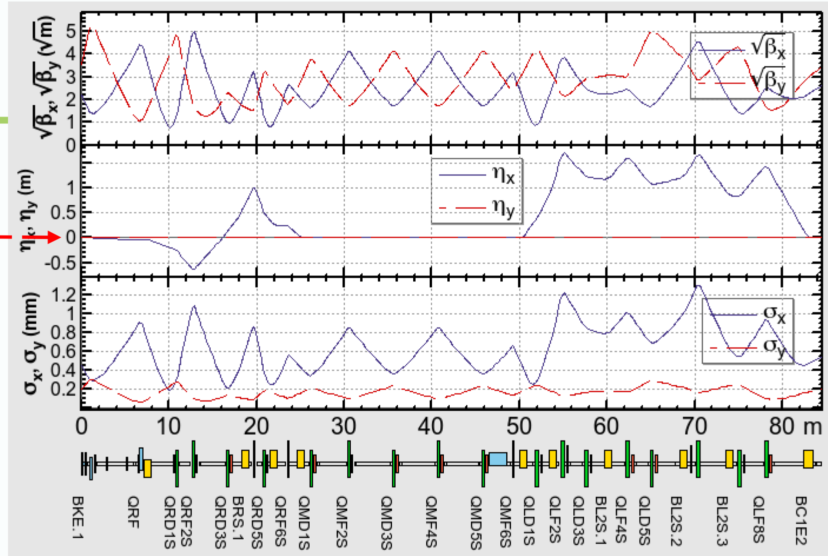


	Measurement of WS		Requirement from LER	
	Sector 3	Sector 5	Phase-2	Phase-3
γεx (μm)	192±22.4	185±28.4	< 200	< 100
γεy (μm)	2.01±0.363	1.72±0.704	< 40	< 15

- No emittance growth is observed with 0.75nC e+ beam between sector 3 and sector 5.
- The horizontal emittance satisfies the requrement of the Phase-2 but not Phase-3 yet.

Dispersion measurement of the DR





	$\mathcal{H}$ [m]	δ	Δε[m]	ε [m]	Δε/ε
X	6.08e-5	5.5e-4	1.84e-11	29.7e-9 (from DR Optics calculation)	6.2e-4
Y	4.49e-5		1.36e-11	9.3e-10 (from WS measurement)	1.5e-3

The increments of emittance from the dispersions at the extraction point affect negligibly small to the emittance growth.

The source of the remaining horizontal emittance grouth is the dispersion leak from the 1st arc.

List to do

1. The orbit feedbacks should be worked at,
   - the entrance of the LTR
   - the end of the LTR
   - the upstream of the 2nd arc of the RTL
2. Dispersion correction of the 1st arc in the RTL
   - By changing the beam energy of the DR
   - Emittance measurement with the wire scanner at the sector 3 and 5
3. Bunch length measurement with the streak camera at the sector 3
4. Energy spread measurement with the screen monitor(YAG) at the end of LINAC or with the wire scanner at the beam transport line of the LER.
   - Requarement : $3\sigma<0.5\%$
5. The beam based alignment should be done for the remained BPMs.
6. The bunch charge measurements with BPMs of LTR and RTL should be corrected.

Conclusion

- The first commissioning of the LTR, DR, and RTL were succesfully done.
- The LTR commissioning
  - The beam tuning is almost done
- The RTL commissioning
  - The emitttances satisfy the requirements of the Phase-2 but not Phase-3.
  - The dispersion of the 1^{st} arc should be corrected during the Phase-2.

Thank you for listening.

Backup

Machine Parameters of Positron Damping Ring

M. Kikuchi,
H. Sugimoto

Parameters		Unit
Energy	1.1	GeV
Circumference	135.498295	m
# of bunch	2	
# of bunch / train	2	
Max. stored current	70.8	mA
Energy loss per turn	0.0847	MV
Damping time (τ_x / τ_y / τ_z)	11.5 / 11.7 / 5.8	msec
Emittance (ε_x/ε_y/ ε_z)	41.5 / 2.1 / 3600	nm
ε_y / ε_x	5	%
ν_x / ν_y	8.240 / 7.265	
Energy spread (1σ)	0.055	%
Bunch length (1σ)	6.6	mm
Mom. Comp. factor	0.0141	
# of cells	32	
Total RF voltage	1.4	MV
RF frequency	509	MHz

8nC/bunch
spdr_0026.sad
01/26/2018

BCS Optimization

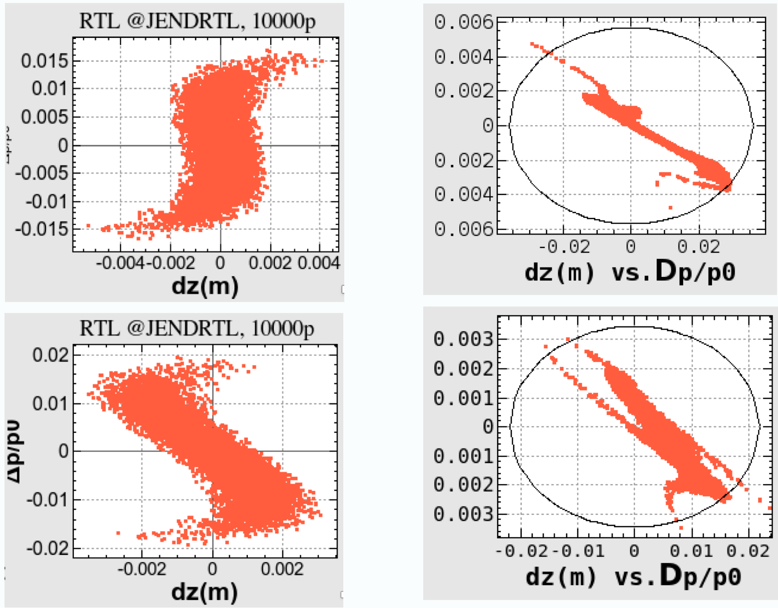
- Vc of BCS
  - Actually, we optimized more Vc of BCS to be small energy spread at the entrance of main ring, because we have one more ECS after LINAC and the beam transport line with large R56.

After BCS

Entrance of Main Ring

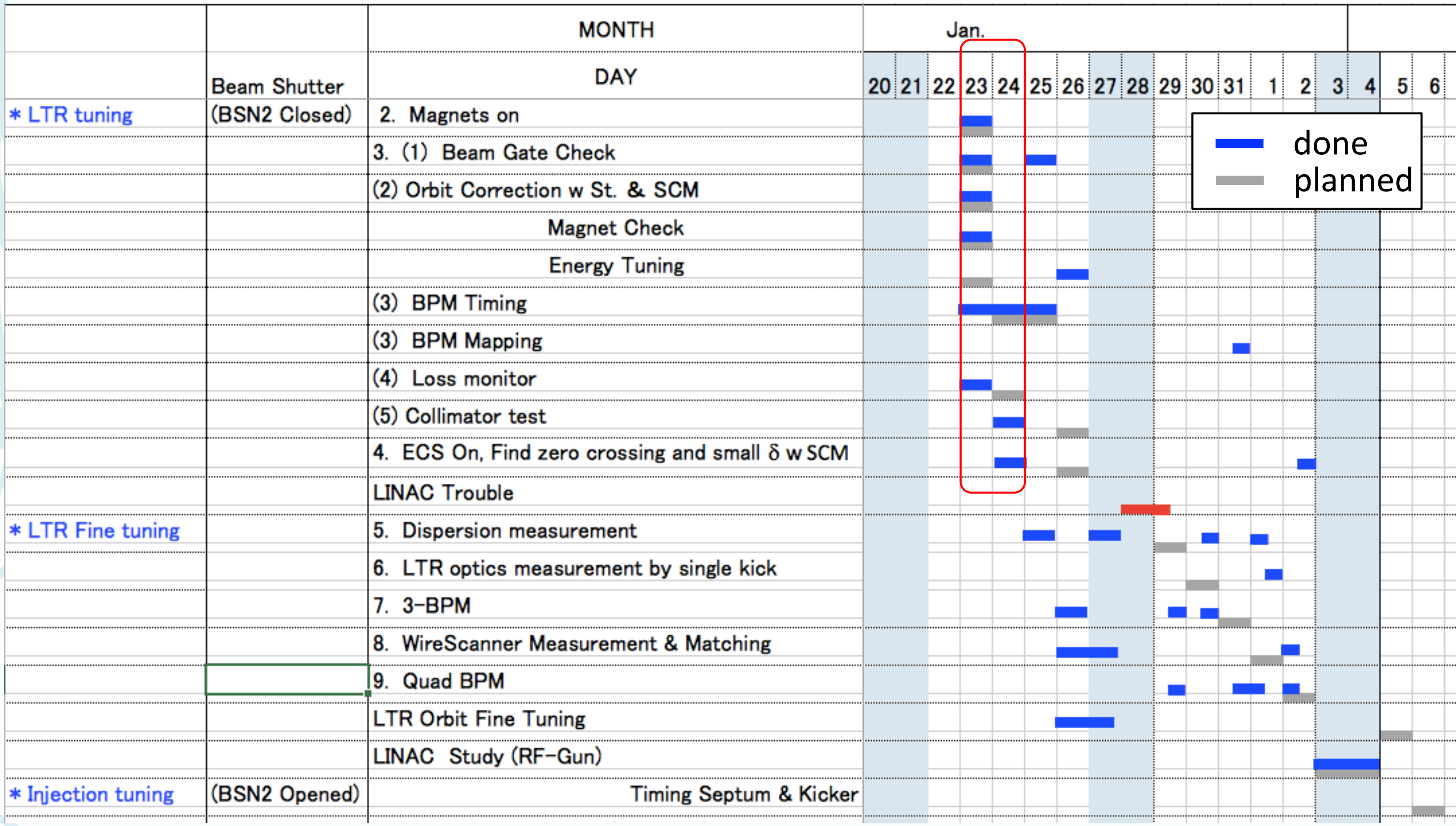
V=18.4MV

V=21.5MV



Schedule of LTR Commissioning

The beam passed to the end of LTR and is roughly tuned in two days !

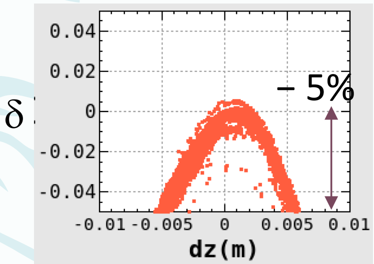


How tuning ?

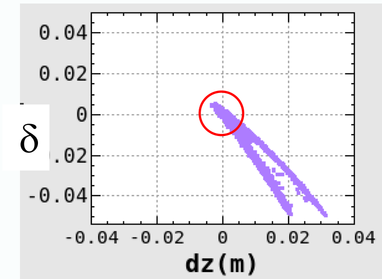
1. Making core beam
   - The beam is cut by the collimators at the 1st arc, and the energy is fixed.
   - The “choice beam” should pass the center of the orbit of the LTR.
   - The phase of the accelerating structure of the ECS should be fixed to the zero-crossing with the “core beam”.
   - The energy of the 2nd arc is fit to the “core beam”
2. The injection tunings are done with the “core beam”

Choice beam

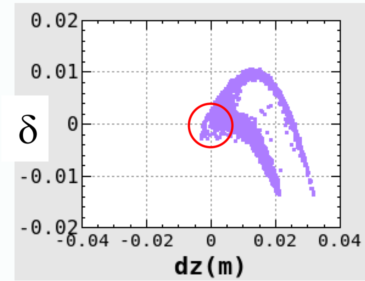
(1) Entrance of LTR



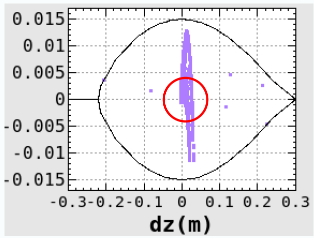
(2) Exit of the 1st arc



(3) Exit of the ECS



Entrance of the DR



The choice beam always pass the center of the design orbit.

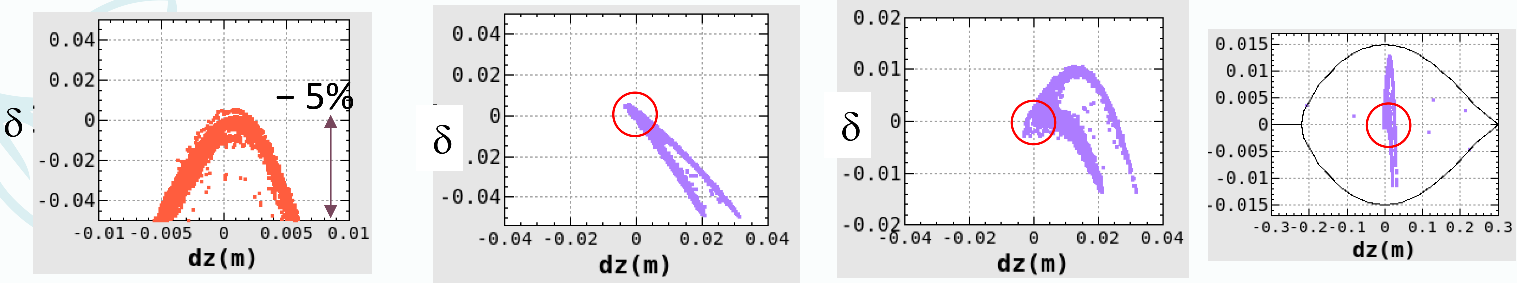
How tuning ?

3. Shift to the operation beam
   - Shift the beam energy up to 5%
   - The lower energy tail (- 5%) is cut by the collimators.
   - The phase of the ECS should NOT be moved.

The core beam always pass the center of the design orbit.

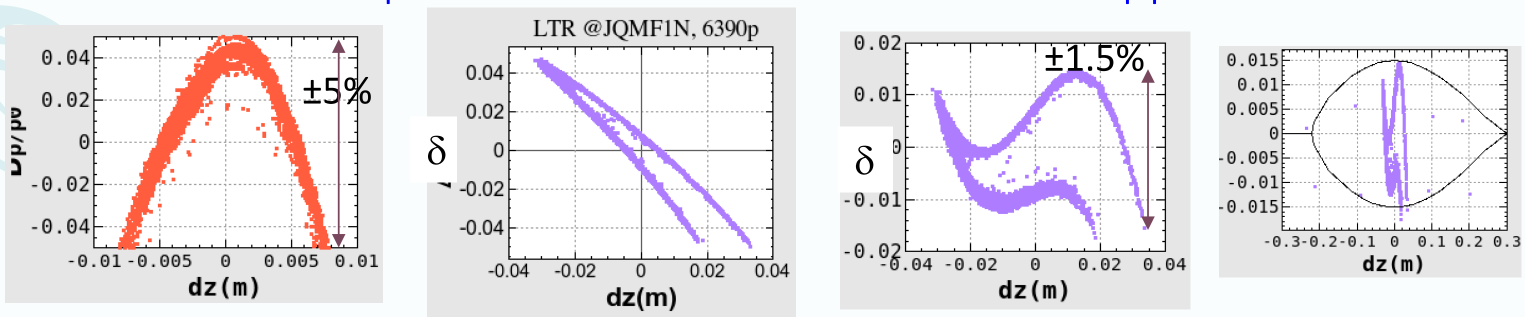
(1) Entrance of LTR | (2) Exit of the 1st arc | (3) Exit of the ECS | Entrance of the DR

Core beam



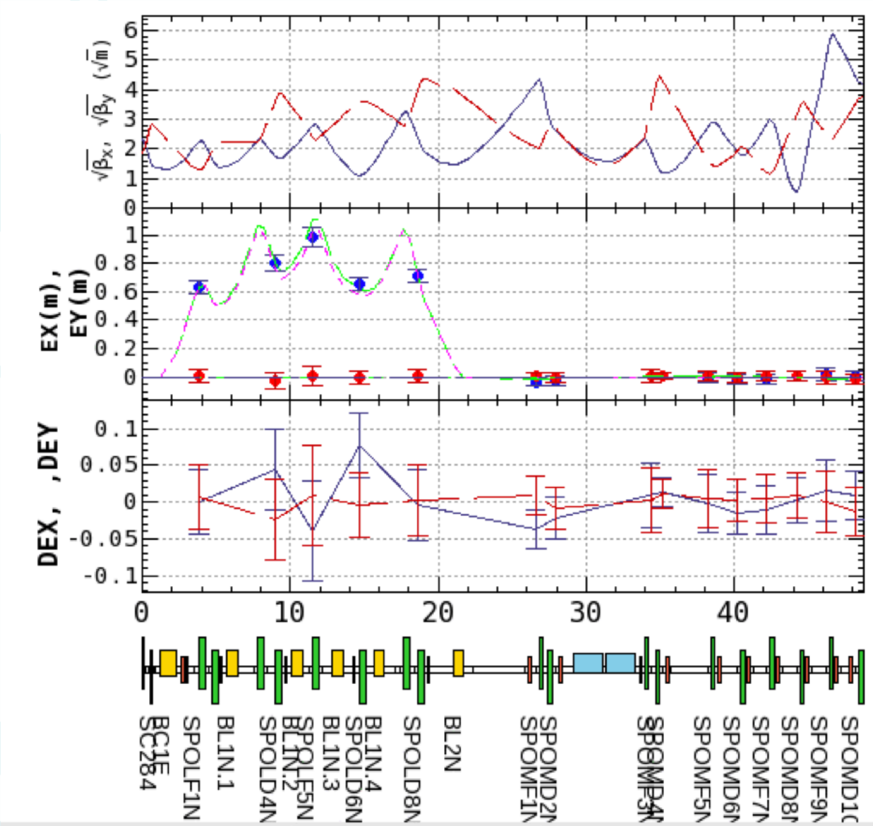
The operation beam rotates around the center of beam pipes.

Operation beam



Y. Seimiya

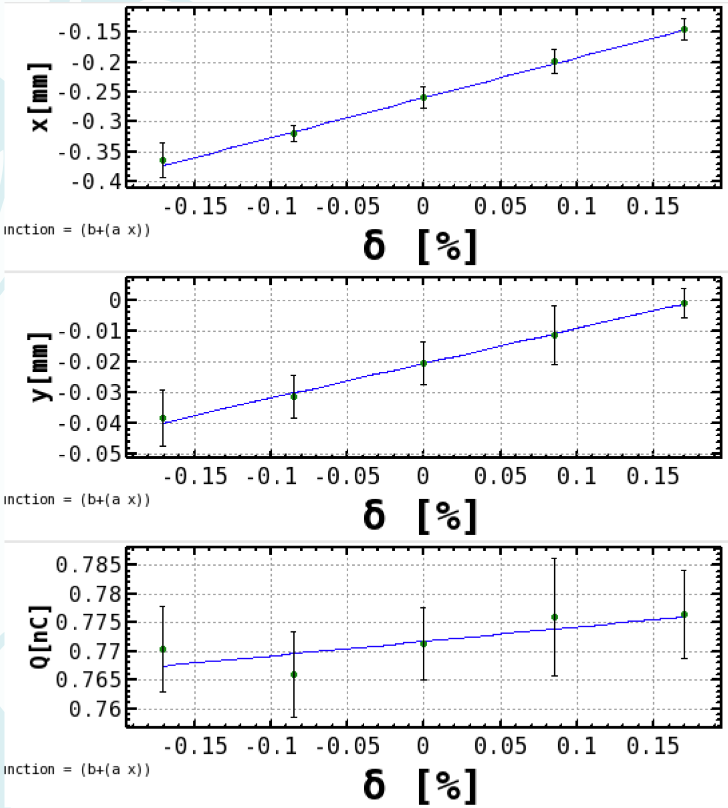
LTR Dispersion correction



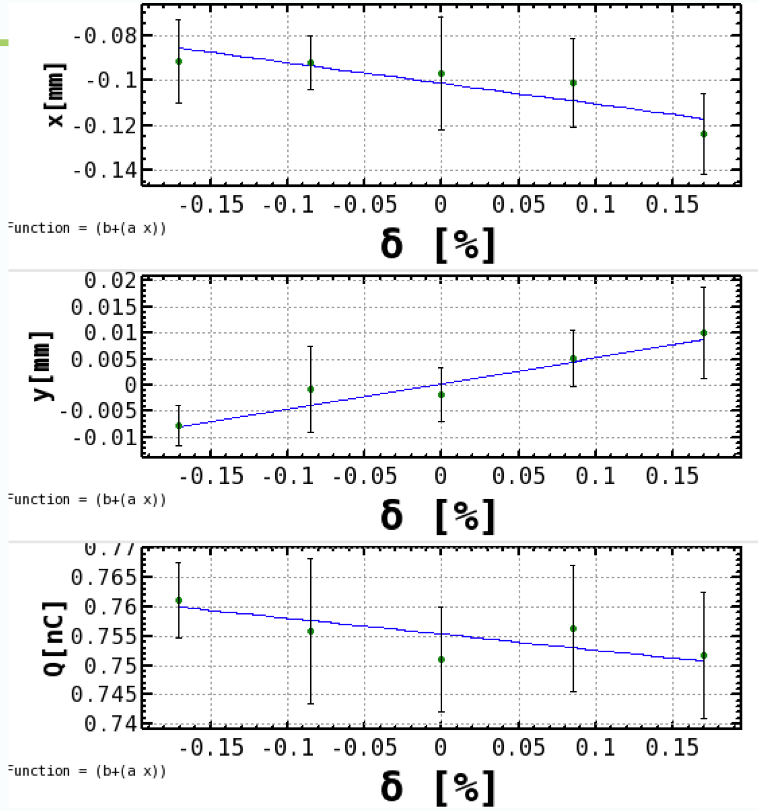
Y. Seimiya

Dispersion Correction（SP464）

Before

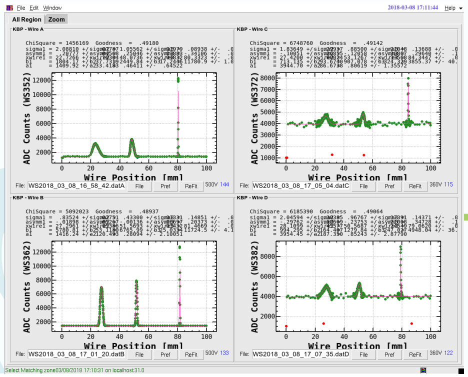


After

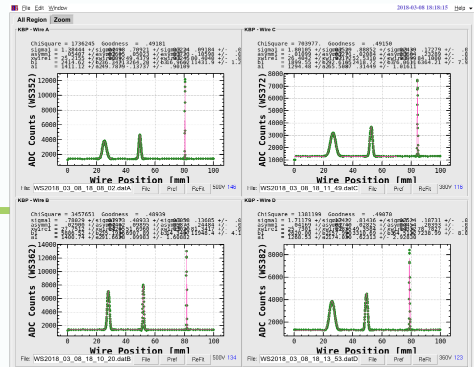


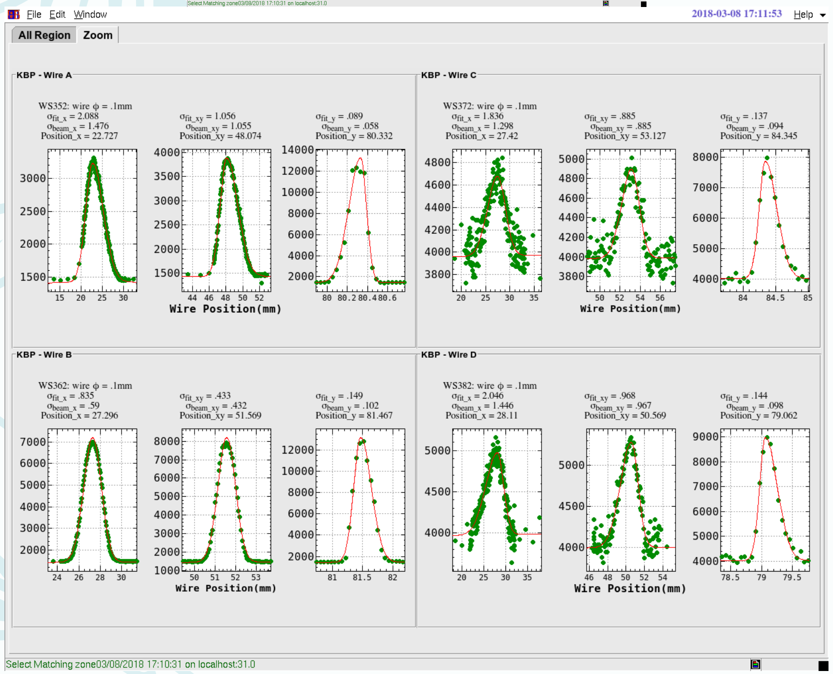
Wire Scanner測定（３セクター）補正前後

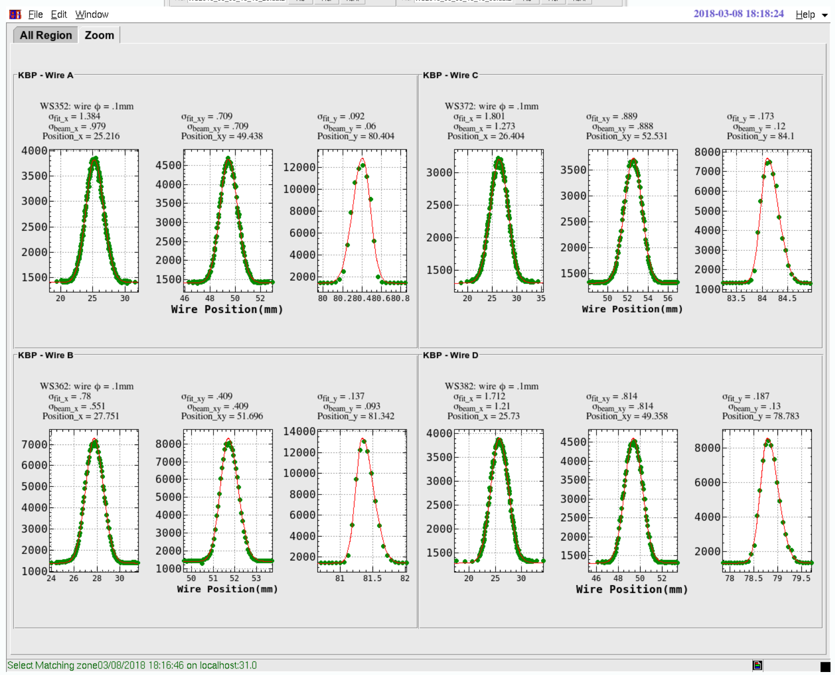
補正前



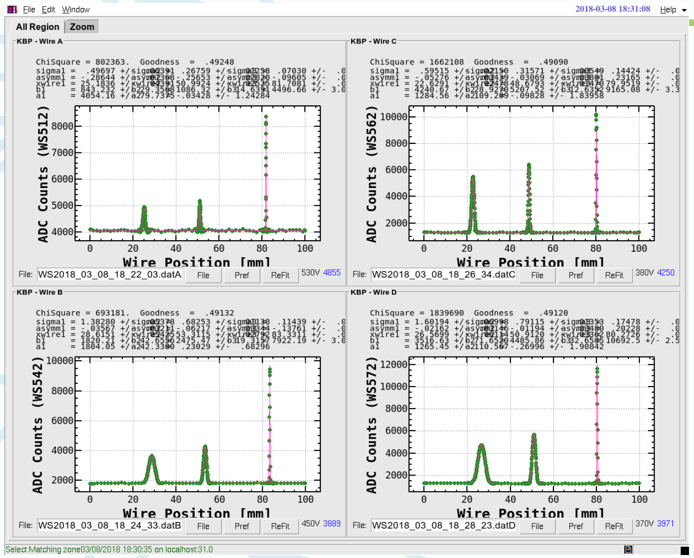
補正後

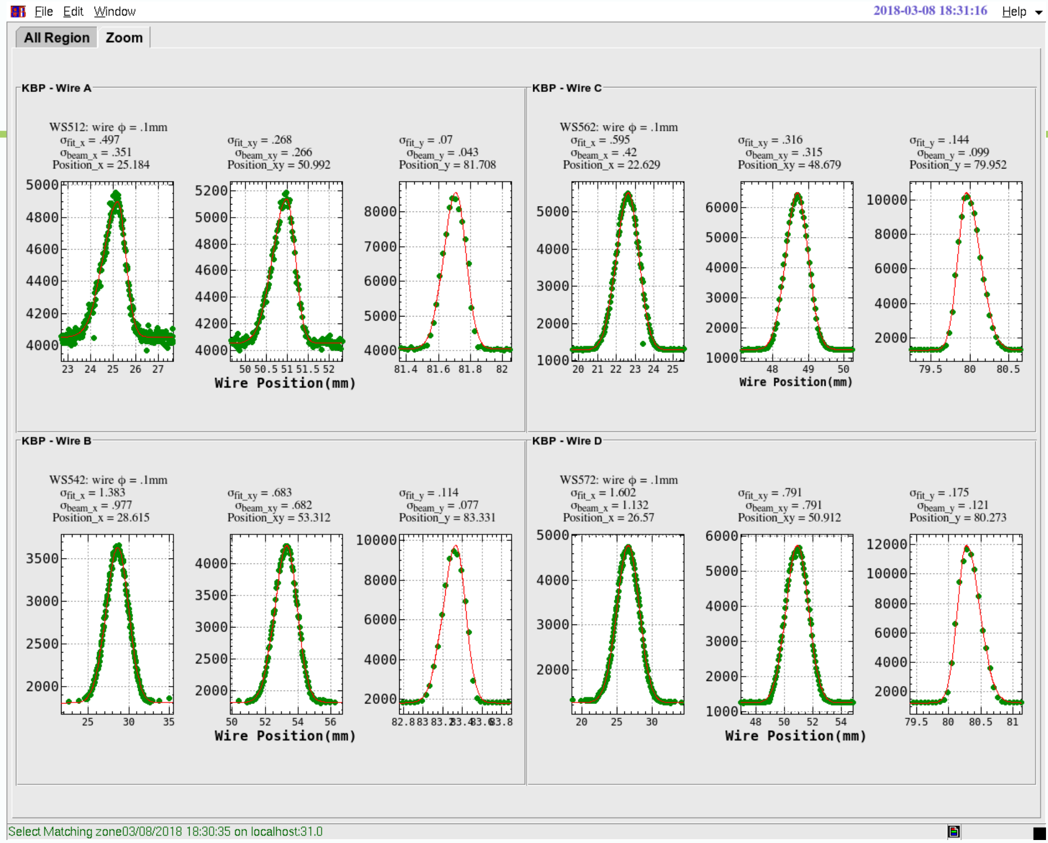




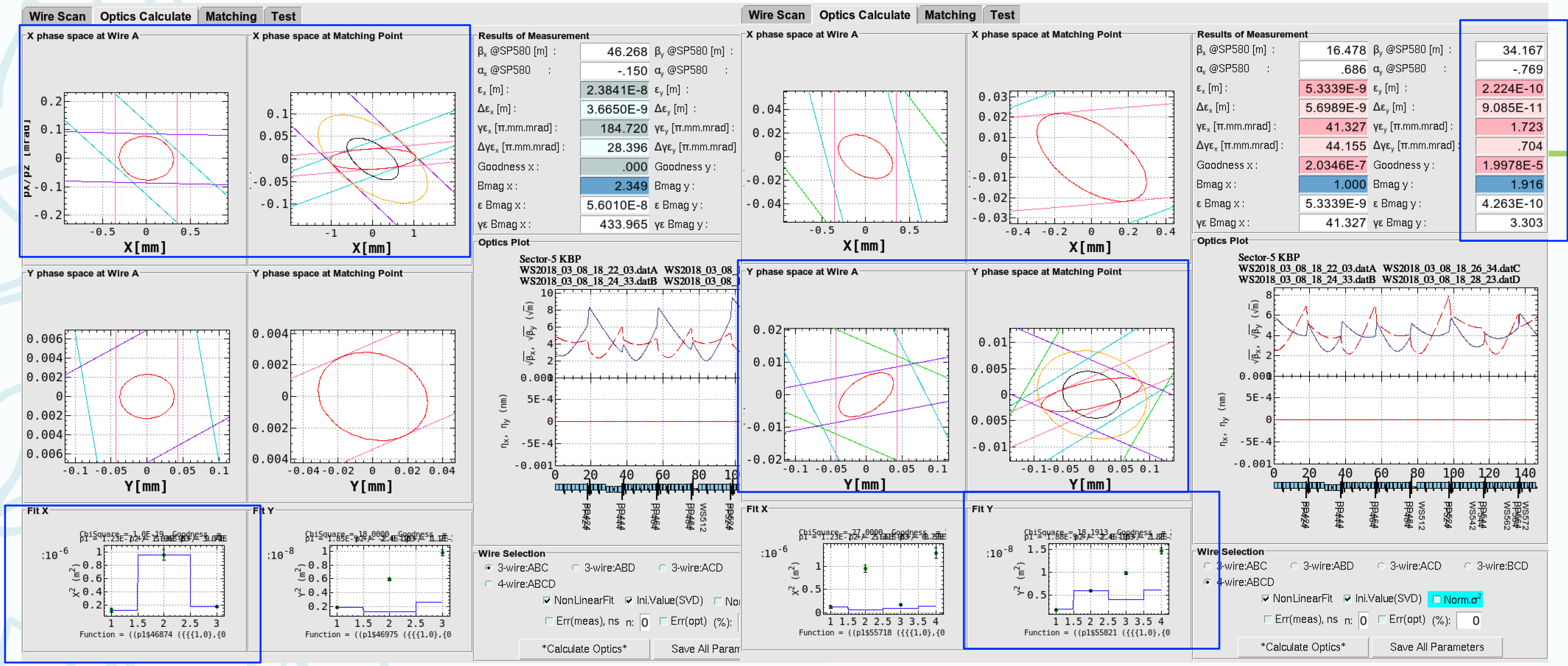


Wire Scanner測定（５セクター）補正後





Wire Scanner測定（５セクター）補正後

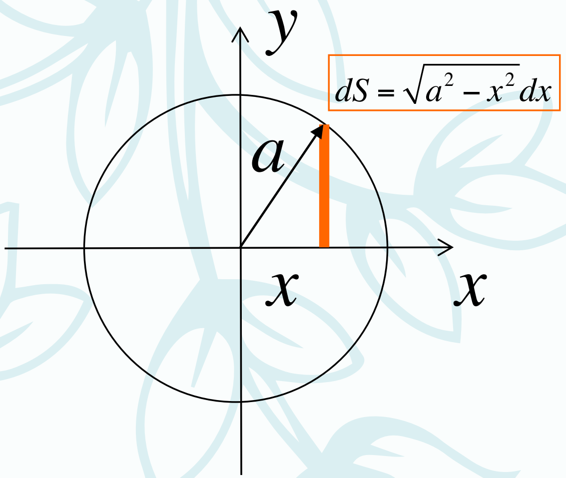


	３セクター	５セクター
γεx (μm)	192±22.4	185±28.4
γεy (μm)	2.01±0.363	1.72±0.704

３～５セクターで、
e+(0.75nC)のエミッタンス増大は観測されない。

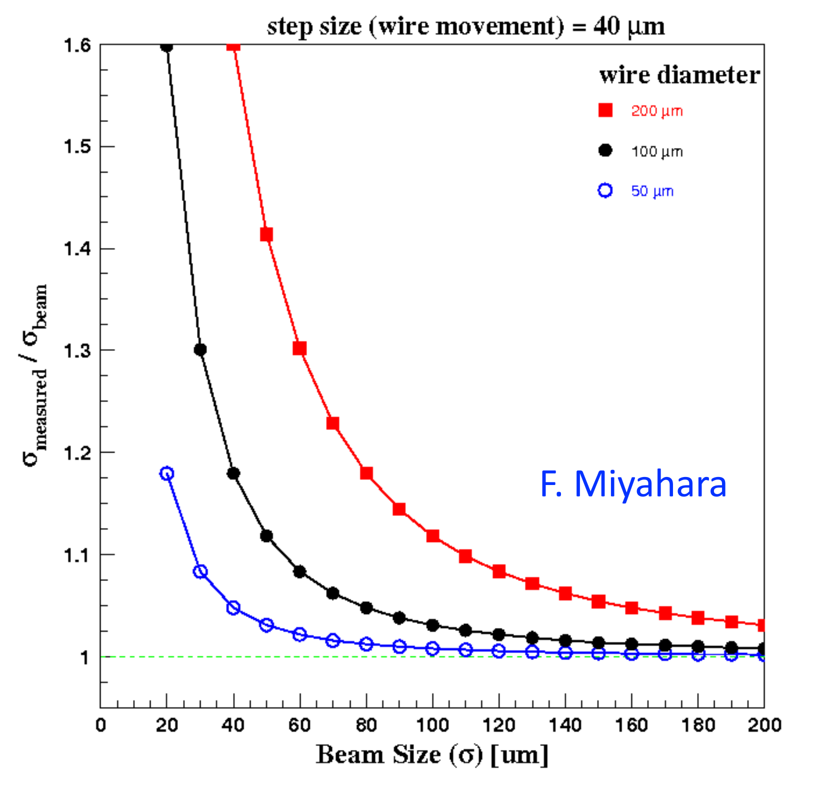
Expected value of the RMS of a wire

The expected value of the RMS of a wire with radius “a” can be written as follows;

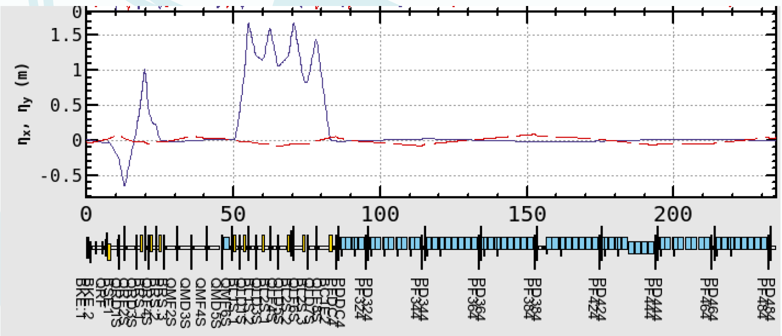


$$r_{rms} = \sqrt{\frac{\int_{-a}^{a} x^2 \sqrt{a^2 - x^2}\, dx}{\frac{\pi a^2}{2}}} = \frac{a}{2}$$

$$\sigma_{true} = \sqrt{\sigma_{meas}^2 - r_{rms}^2}$$

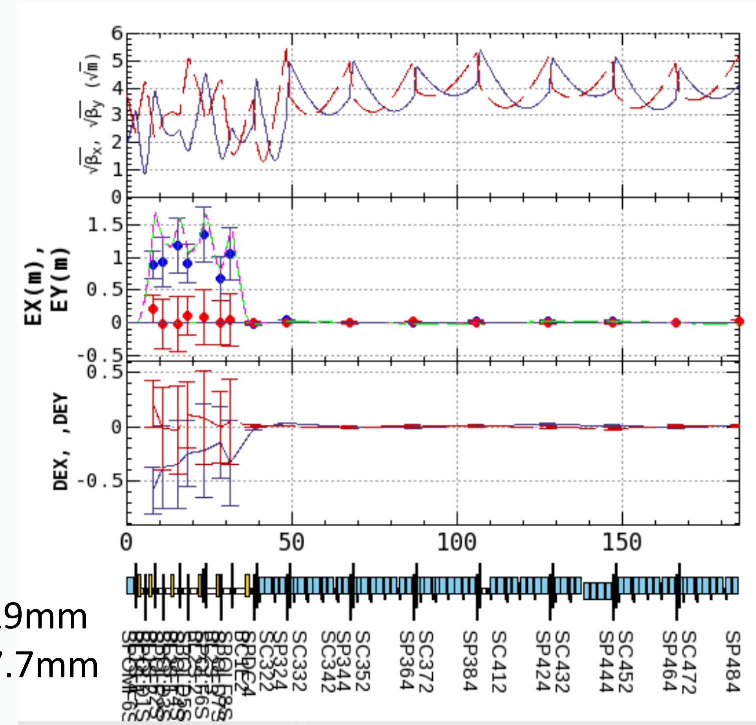


Dispersion leak does not appear downstream of the BCS



<ηx>=9.4mm
<ηy>=28.1mm

≠



<ηx>=19mm
<ηy>=7.7mm

Even if the dispersions leak to the RTL, after BCS, the energy conponents rotate to the bunch length.

Injection/Extraction kickers and septa