Beam transport lines for SuperKEKB

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15th KEKB Review

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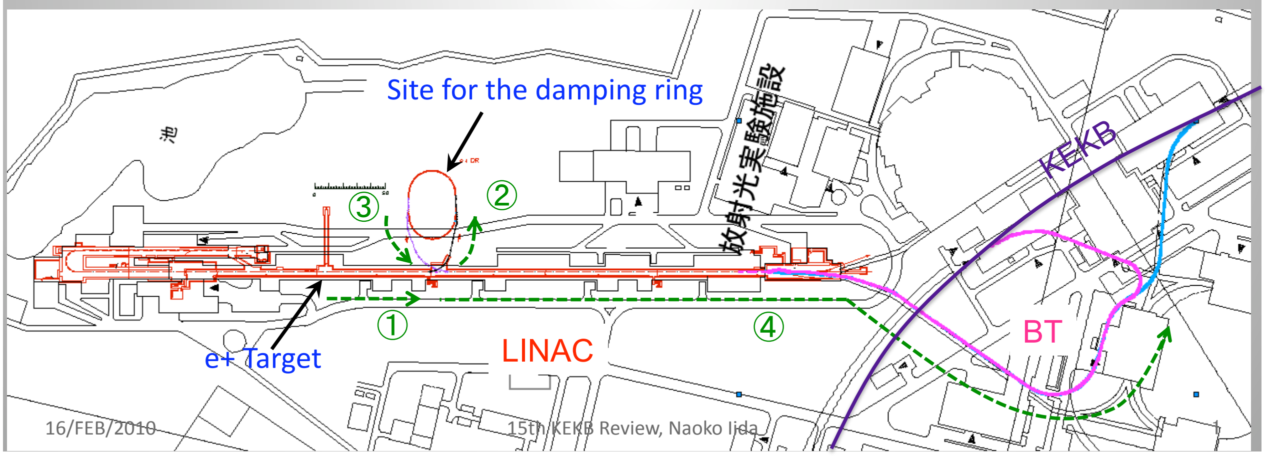
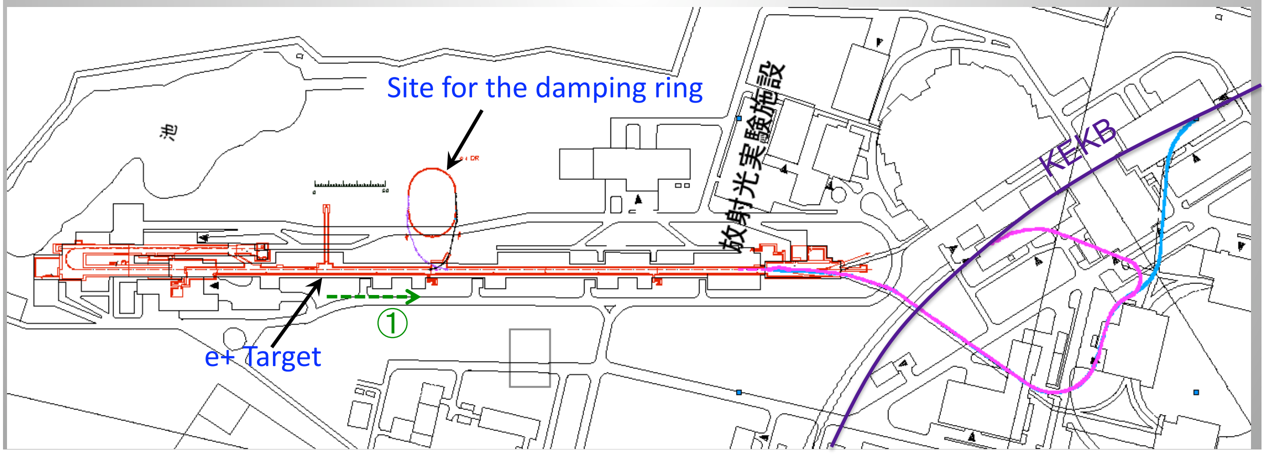


① e+ Target → the end of sector 2

Tracking simulation



Initial parameters of e+ capture section

T.Kamitani

	Present KEKB present capt. section	SuperKEKB L-band capt. section
accelerating structures	1m x 2 + 2m x 2	2m x 2 + 2m x 4
RF frequency	2856 MHz (λ=10.5cm)	1298 MHz (λ=23.1cm)
aperture of the structures	20 mm in diameter	30 mm in diameter
accel. field gradient	14.0 ~ 13.2 MV/m	10.0 MV/m
accel. phase	-30 deg	-30 deg
solenoid field (strong)	2.0 T x 45 mm QWT	6.0 T x 220 mm AMD
solenoid field (weak)	0.4 T x 7.9 m	0.4 T x 13.1 m
energy after capt. sec.	~ 80 MeV	~ 120 MeV

Increase e+ capture efficiency by enlarging these acceptances !

- longitudinal acceptance by longer wave length of L-band RF
- transverse acceptance by larger aperture of L-band structure
- energy acceptance by adiabatic matching device

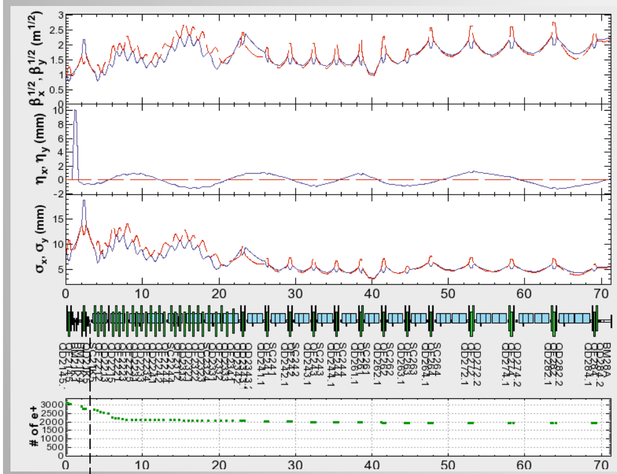
Q_{e+} = 1 nC ⇨ 4 nC

prelim. simulation result by N. Iida suggests Q_{e+} ~ 8 nC @ DR

Optics

Present KEKB

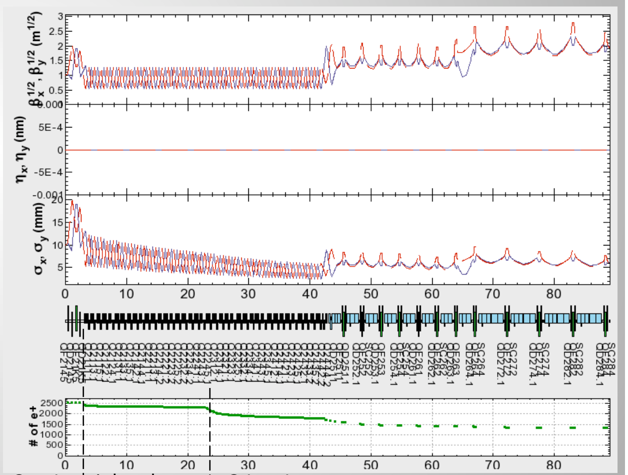
S-band
εx= εy=75e-6m
Momentum=85.7GeV



Quad : 30mmφ | S-band 20mmφ

SuperKEKB

L-band
εx= εy=100e-6m
Momentum=120GeV



Quad : 60mmφ | L-band 40mmφ | S-band 20mmφ

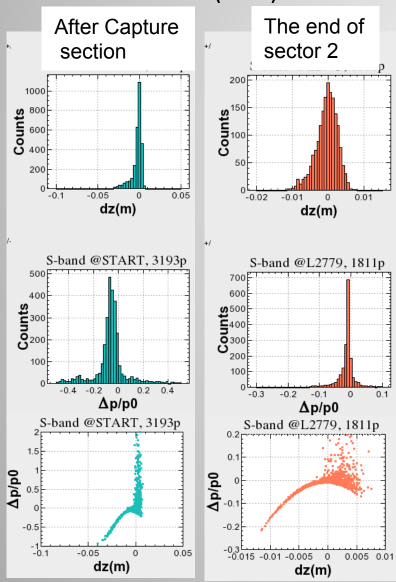
This section is crowded with quads.

Results of Tracking at the end of 2 sector

Present KEKB

S-band
Number of particles :
10000(Primary e-)
→ 3193(after capture section)
→ 1811(end of 2 sector)
(18%)

After Capture section | The end of sector 2



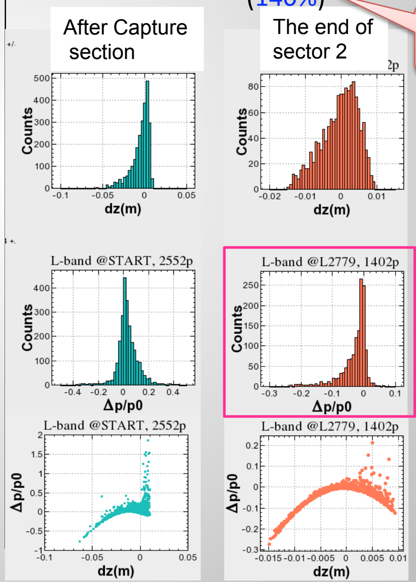
1GeV
εx=0.824μm
εy=0.672μm

γεx=1610μm
γεy=1320μm

SuperKEKB

L-band
Number of particles : 8nC
1000(Primary e-)
→ 2552(after capture section)
→ 1402(end of 2 sector)
(140%) 11.2nC → 10nC

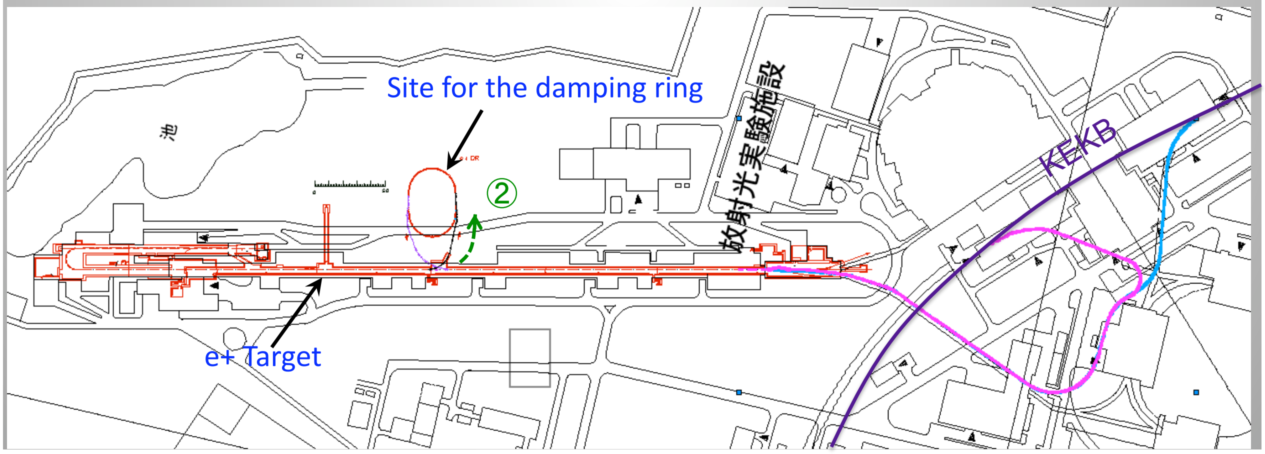
After Capture section | The end of sector 2



1GeV
εx=2.17μm
εy=2.12μm

γεx=4250μm
γεy=4150μm

② LINAC → Damping ring (LTR)



LINAC to Damping ring

- Beam from LINAC is so huge.

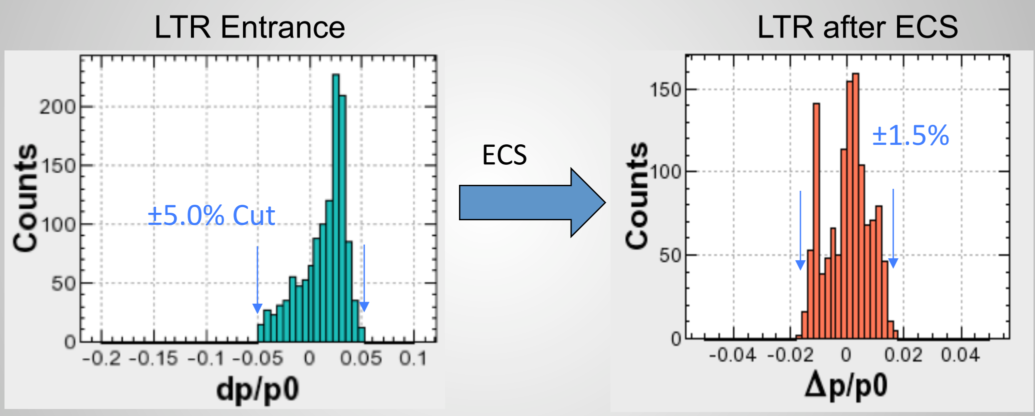
	KEKB	SuperKEKB
Charge (nC/bunch)	1	10(Max)
Emittance@1GeV ε_x (μm)	1.0	2.1
ε_y (μm)	1.0	2.1
Energy spread (hard edge) (%)	0.15	±5.0 → ±1.5
Bunch length (hard edge) (mm)	1.3	14 → ±27

Momentum aperture of the damping ring

Energy Compression System (ECS) is needed.

ECS

Tracking simulation

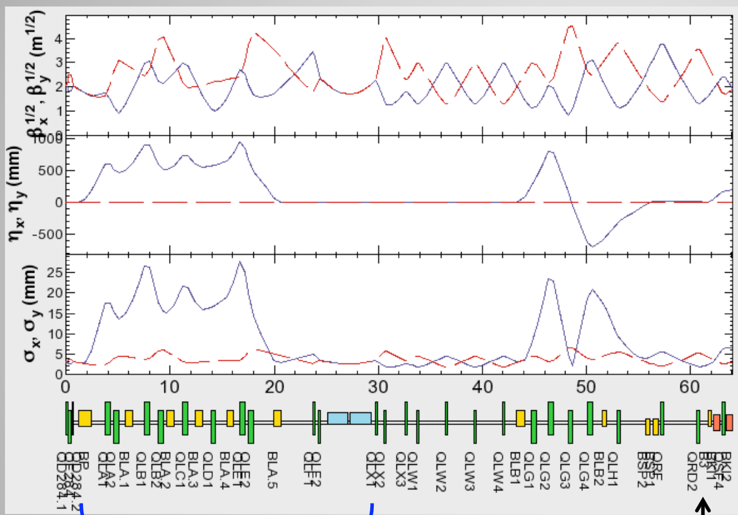


- Particles in the range of σ_δ<±5.0% at the entrance of LTR are compressed to σ_δ<±1.5% after ECS.
- Almost all particles are injected to the damping ring.
- 5% energy-cut brings 12.7% beam loss.

Charge from LINAC to Damping ring

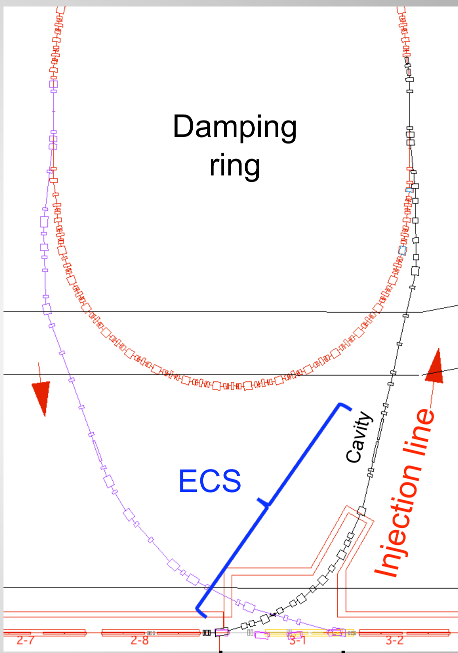
- We assume e^+ charge will be 10nC at the end of 2 sector.
- 5% energy-cut brings 12.7% loss.
  But we assume 20% loss with a safety margin.
  This corresponds to 8nC/bunch.
- We will start beam operation with 4nC/bunch because of a radiation safety regulation.

Injection line (LTR)



ECS

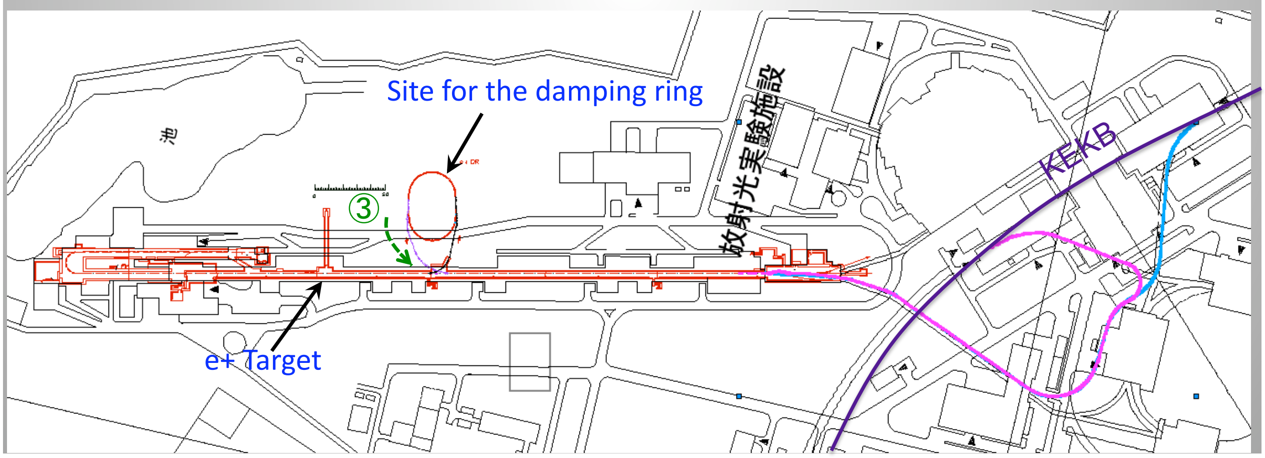
R_{56}=-0.52 Vc=38MV



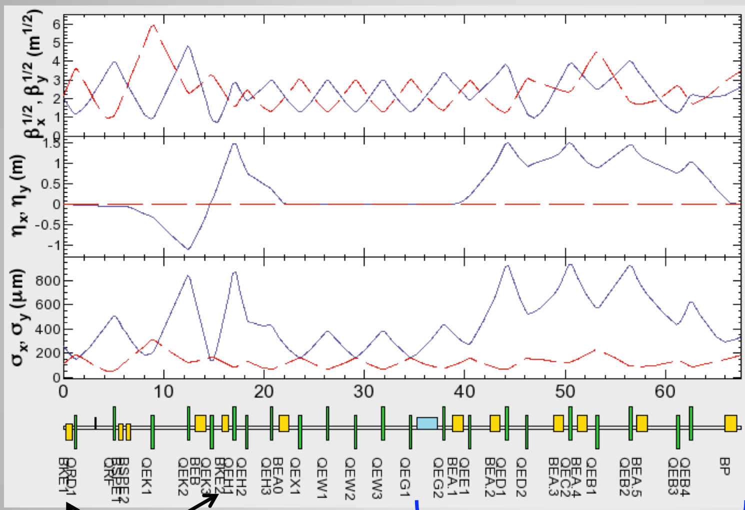
ε_x=2.17μm
ε_y=2.15μm

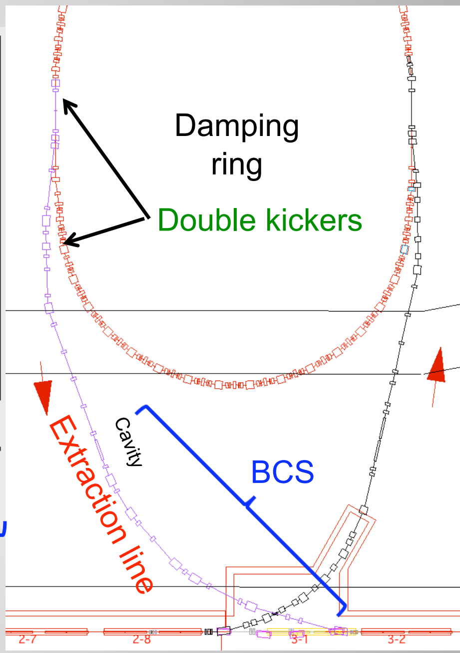
e- bypass line

③ Damping ring → LINAC (RTL)



Extraction line (RTL)





Double kickers

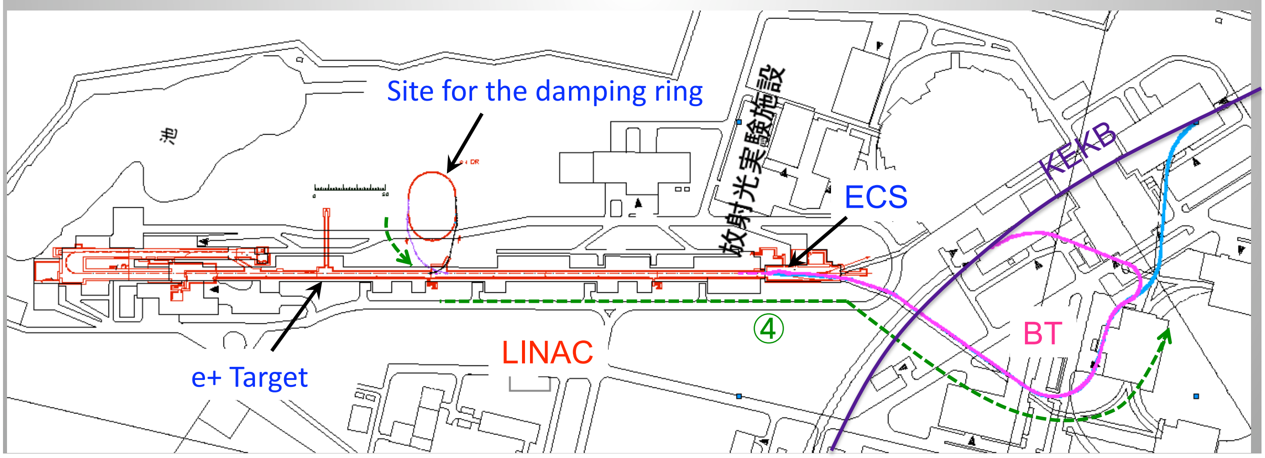
BCS

Vc=19MV R_{56}=-0.9

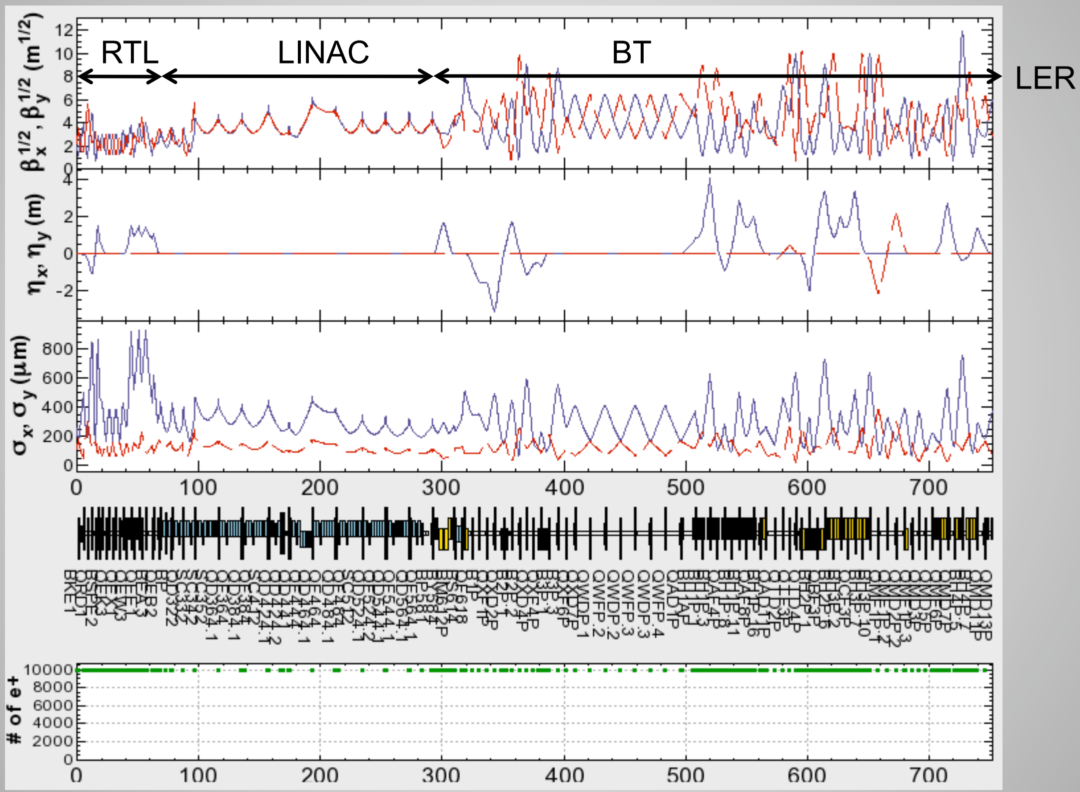
εx=16.3nm
εy=2.7nm

σ_z : 5.03mm → 0.501mm
σ_δ : 5.29e-4 → 5.72e-3

④ Damping ring → LER

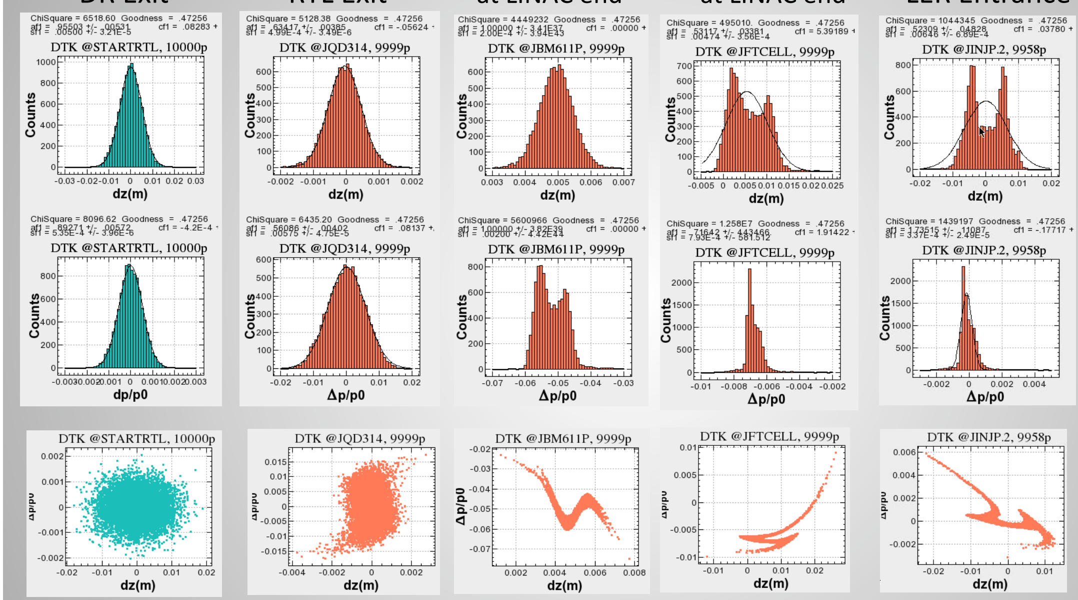


Damping ring → LER



Damping ring Exit～LER Entrance

DR Exit	RTL Exit	ECS Entrance at LINAC end	ECS Exit at LINAC end	LER Entrance

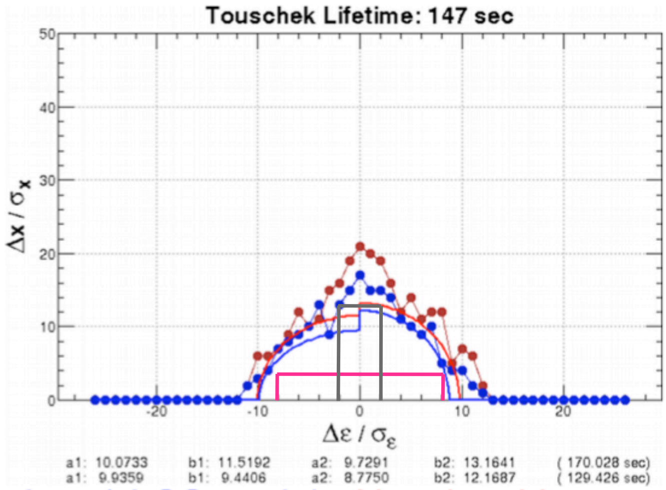


σ_z = ±12mm (hard edge)

σ_δ = ±0.15% (hard edge)

DR Exit	RTL Exit	ECS Entrance at LINAC end	ECS Exit at LINAC end	LER Entrance
εx=16.3nm	εx=16.5nm	εx=4.17nm	εx=4.17nm	εx=4.30nm
εy= 2.7nm	εy= 2.7nm	εy=0.673nm	εy=0.677nm	εy=0.712nm

LER Dynamic Aperture(1-LCC)

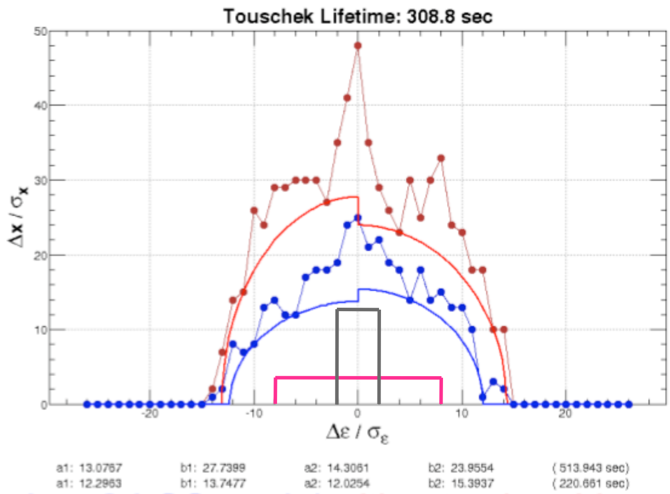


- Calculated on 1-LCC model with solenoid
- Horizontal Emittance is 3.8nm

Synchrotron Injection ($\delta_0 = 0.5\,\%,\ \sigma_\delta = 0.08\ \%$)

Betatron Injection (β_R =90 m, w_s =5 mm)

LER Dynamic Aperture(2-LCC)



- Calculated on 2-LCC model without solenoid

Synchrotron Injection ($\delta_0 = 0.5\,\%,\ \sigma_\delta = 0.08\ \%$)

Betatron Injection (β_R =90 m, w_s =5 mm)

e+ injection beam seems to be in the LER dynamic aperture.

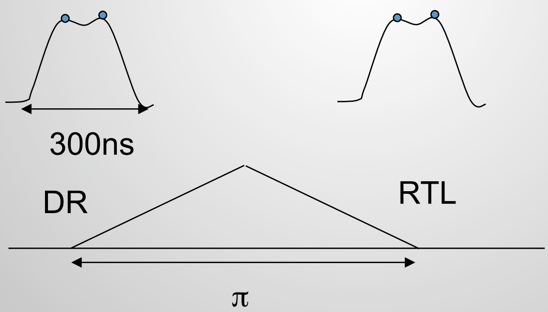
Future plan

- We have to re-design configuration of the quadrupole magnets in the L-band region.
- Tolerance of alignment for LINAC devices should be estimated by tracking simulation with transverse wake.
- e^- beam-transport and injection should be studied.
  - Compatible optics with LER and PF beam in LINAC.
  - Timing jitters of LINAC beam should be considered for the injection to KEKB ring.

Backup slides

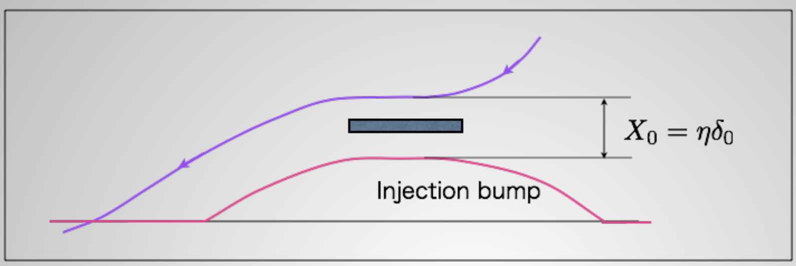
Double kicker system

- Double kicker system will be installed in RTL.
  - σx'= √ (εx/βx)=√(13.7e-9/10)=0.037 mrad.
    In case of θ=5.4mrad,
    σx'/ θ=0.69%~Δθkick



M. Kikuchi

Synchrotron phase space injection



- Shift the energy of the injection beam : δ_0
- Adjust the injection amplitude to the closed orbit of the injection energy.

$$(X_0, X_0') = (\eta, \eta')\delta_0$$

- Oscillating in the synchrotron phase space.

$$\begin{aligned} X_0 &= 2.5\sigma_i + 3\sigma_R + w_s \\ &= 0.71 + 0.77 + 5 = 6.48 \text{ mm (LER)} \end{aligned}$$

$$\eta = 1.28 \text{ m (LER)}, 1.2 \text{ m (HER)} \longrightarrow \delta_0 = 0.5 \%$$