Lattice Design of a Very Low-emittance Storage Ring for SPring-8 II

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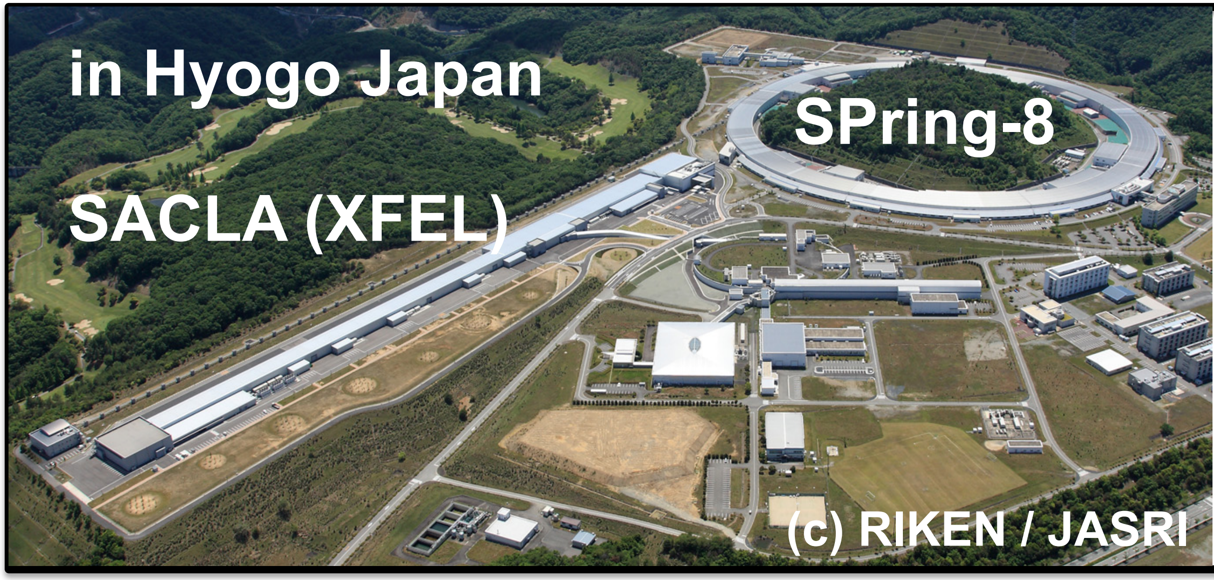
JASRI / SPring-8



3rd Generation Synchrotron Radiation Facility (1450 m)

Agenda

1. Introduction of SPring-8 II

1.1 SPring-8 v.s. SPring-8 II
1.2 Lattice Structure
1.3 Injection Scheme

2. Strategy of Lattice Design for Dynamic Aperture Correction

2.1 Strategy for Lattice Design
2.2 Example of Dynamic Aperture Enlargement

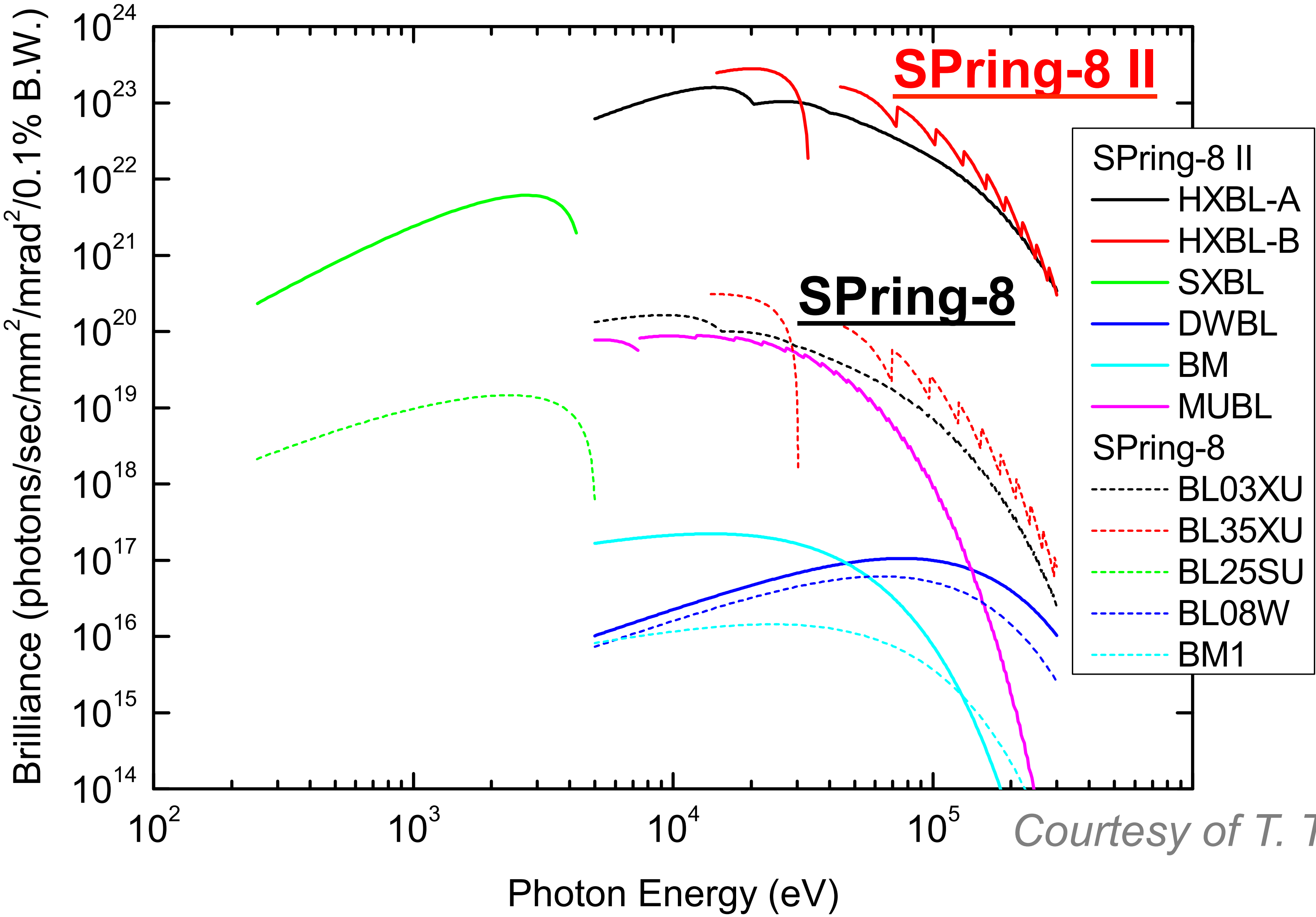
3. Latest Results of Lattice Design

3.1 Dynamic Aperture and Momentum Aperture without / with Sx-Alignment Error

4. Summary

SPring-8 v.s. SPring-8 II

Ultimate Goal of SPring-8 II: To provide 10^3 times higher brilliance than that of SPring-8 (0.5 ~ 100 keV).

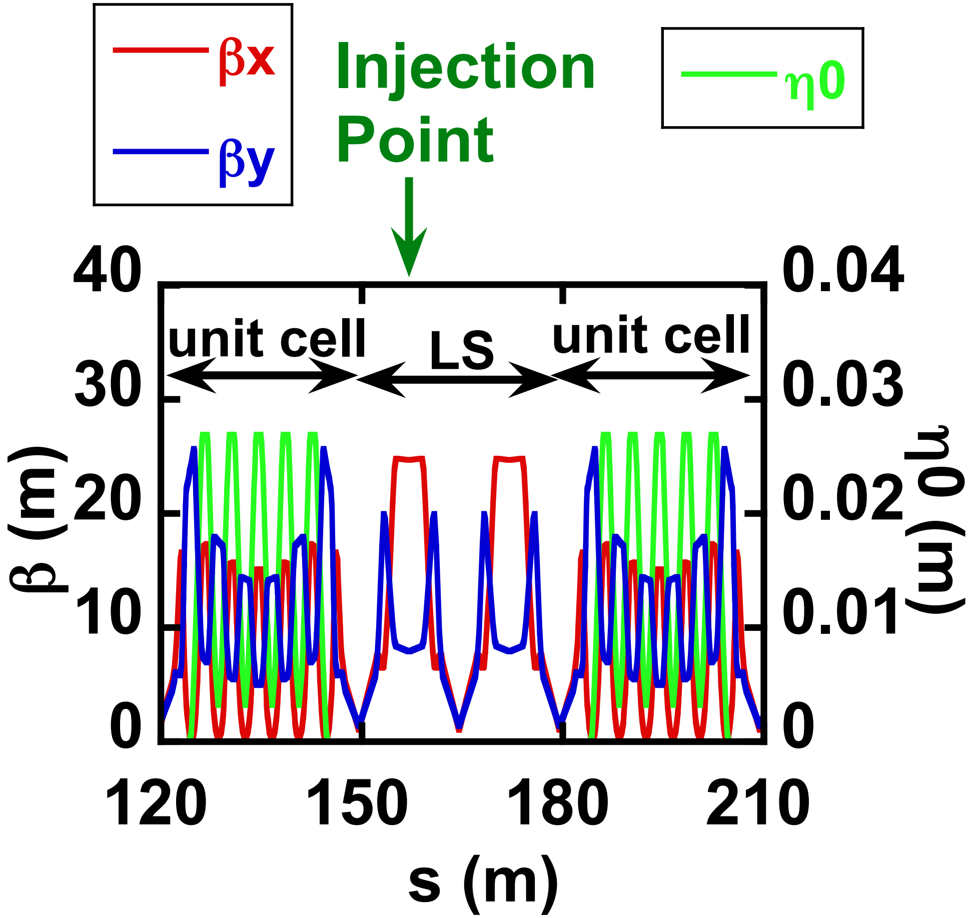


Courtesy of T. Tanaka

SPring-8 v.s. SPring-8 II

	SPring-8	SPring-8 II (Latest design)
Electron energy	8 GeV	6 GeV
Stored current	100 mA	300 mA
Lattice	Double Bend (2B)	6 Bend Achromat (6BA)
Natural emittance	3400 pm.rad	67.5 pm.rad (w/o D.W.) 10 ~ 20 pm.rad (w/ D.W.)
Tune (x, y)	(40.14, 18.35)	(141.865, 36.65)
Natural chrom.	(-88, -42)	(-475, -191)
Power loss	9 MeV (Bend) 2 MeV (ID)	4 MeV (Bend) 2 + 4 MeV (ID + D.W.)
Max. B	0.68 T	0.70 T
Max. Q: $B'L / B\rho$	0.40 m^{-1}	1.65 m^{-1}
Max. Sx: $B''L / B\rho$	6.44 m^{-2}	114 m^{-2}

Lattice Structure of SPring-8 II



6BA lattice function

"Ring" = 4 x {11 x "unit cell" + "Long Straight (LS)"}

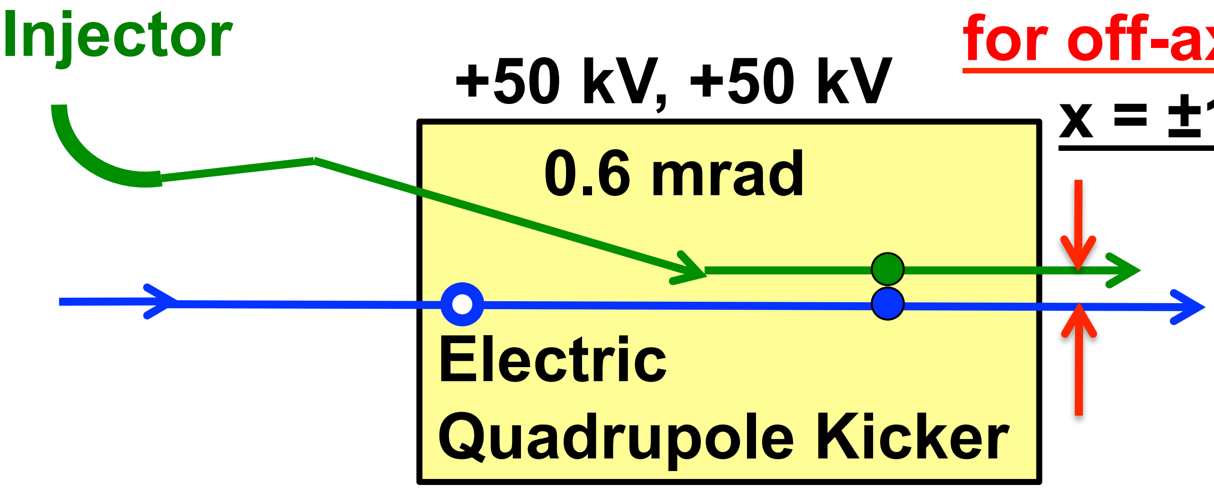
High-beta (β_x ~ 25 m) @ Injection Point

Low-beta ($\beta_x \sim \beta_y \sim$ 1 m) @ ID

Injection Scheme of SPring-8 II

For stable user operation, off-axis injection is required
not only for top-up operation,
but also for nominal accumulation.

Injection Scheme:



Required dynamic aperture (DA) for off-axis injection:

x = ±1 mm @ Injection point

$(\beta_x, \beta_y, \eta_0) \sim (25, 8, 0)$ (m)

$\alpha_x = \alpha_y = \eta'_0 = 0$

Poster (TUPC095): Nakamura, "Bucket-by-bucket On/Off-axis Injection with Variable Field Fast Kicker".

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   - 2.1 Strategy for Lattice Design
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4. Summary

Our Strategy of Lattice Design

Design of Linear Optics

"as lower natural-chromaticity as Sx becomes lower"

↓

Tune Selection

1 avoidance of strong resonances

2 phase adjustment for (non-)interleaved sextupole

↓

Design of Nonlinear Optics

harmonic method with (non-)interleaved Sx

for correcting

1 nonlinear resonances independent on $\Delta p/p$,

2 nonlinear resonances by Q and Sx for off-momentum,

3 higher order resonances for on-momentum.

Iteration (tune survey, etc)

Design of Nonlinear Optics (What & How)

Isolated Resonance Hamiltonian

(Qx, Qy): Tune

What | **How**

Resonant potential induced by Sx without Δp/p

$$\langle H \rangle \propto \langle U(Q_x \sim \mathrm{int.}) \rangle_{Sx} + \langle U(3Q_x \sim \mathrm{int.}) \rangle_{Sx} + \langle U(Q_x \pm 2Q_y \sim \mathrm{int.}) \rangle_{Sx}$$

Set to ~ 0

(Off-momentum) Resonant potential by Q

$$+ \frac{\Delta p}{p} \left\{ \langle U(2Q_x \sim \mathrm{int.}) \rangle_Q + \langle U(2Q_y \sim \mathrm{int.}) \rangle_Q \right\}$$

Cancel

(Off-momentum) by Sx

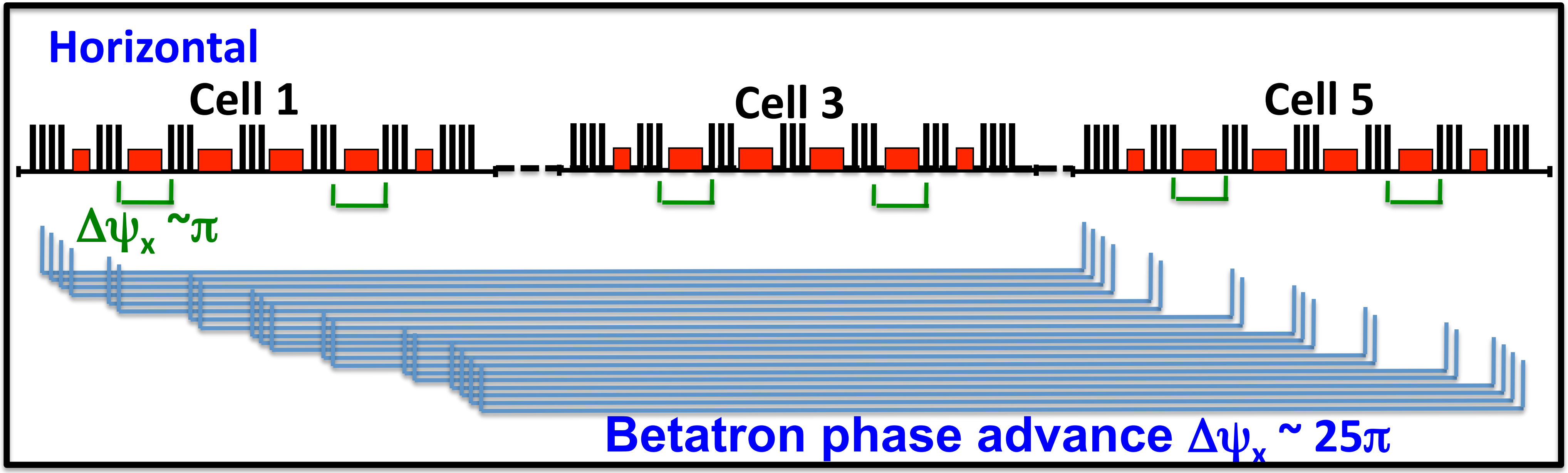
$$+ \frac{\Delta p}{p} \left\{ \langle U(2Q_x \sim \mathrm{int.}) \rangle_{Sx} + \langle U(2Q_y \sim \mathrm{int.}) \rangle_{Sx} \right\}$$

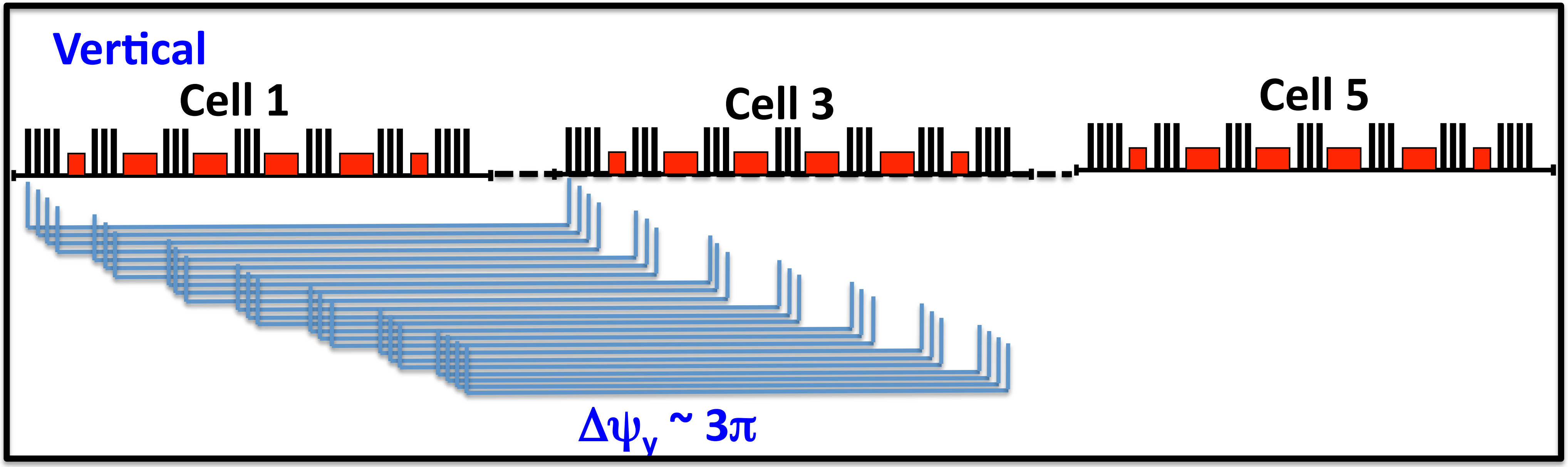
Suppress

+ "(on-momentum) Higher order resonant potentials by Sx"

(Non-)interleaved Sextupole

- / transformation

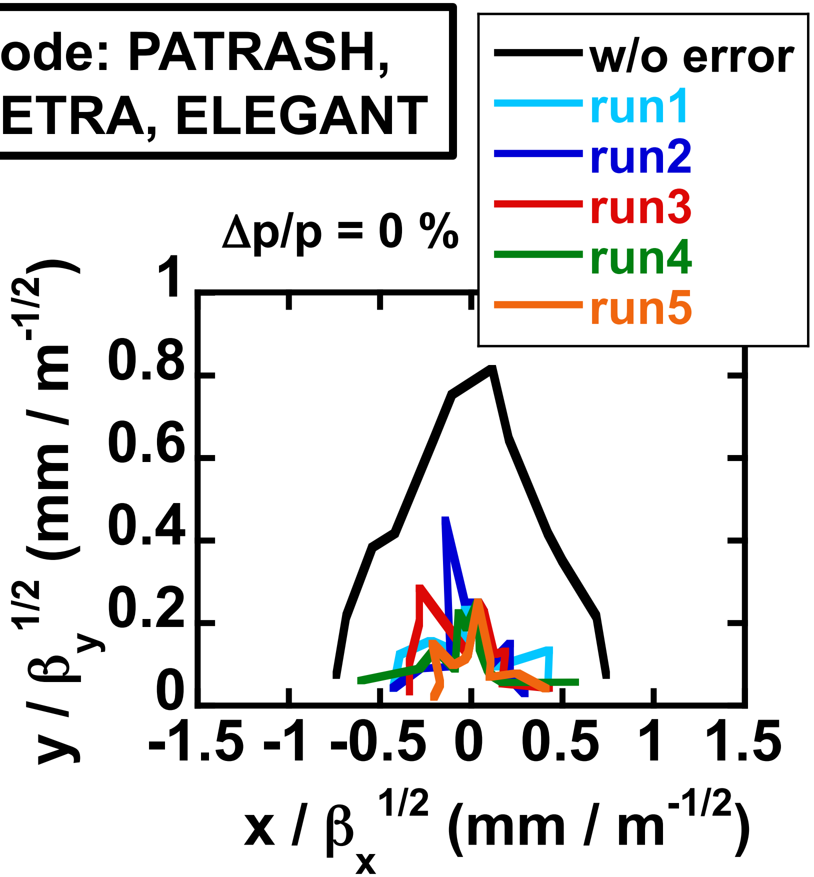




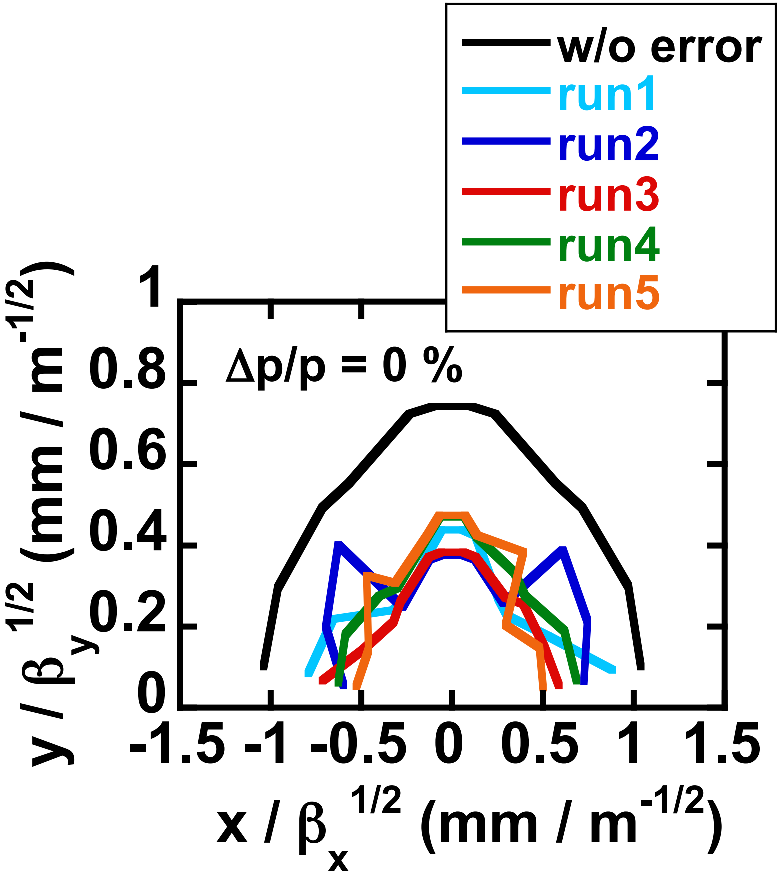
Example of DA Enlargement

Comparison DA between Conventional & Our design w/ Sx-Align. Error (Gaussian, 2σ cut, σ = 5μm, no correction)

Code: PATRASH, CETRA, ELEGANT



(Conventional) Dynamic aperture.
Nat.Chrom.: (-595, -193)
Max. Sx: 136 m^{-2}



(Our design) Dynamic aperture
Nat.Chrom.: (-475, -191)
Max. Sx: 114 m^{-2}

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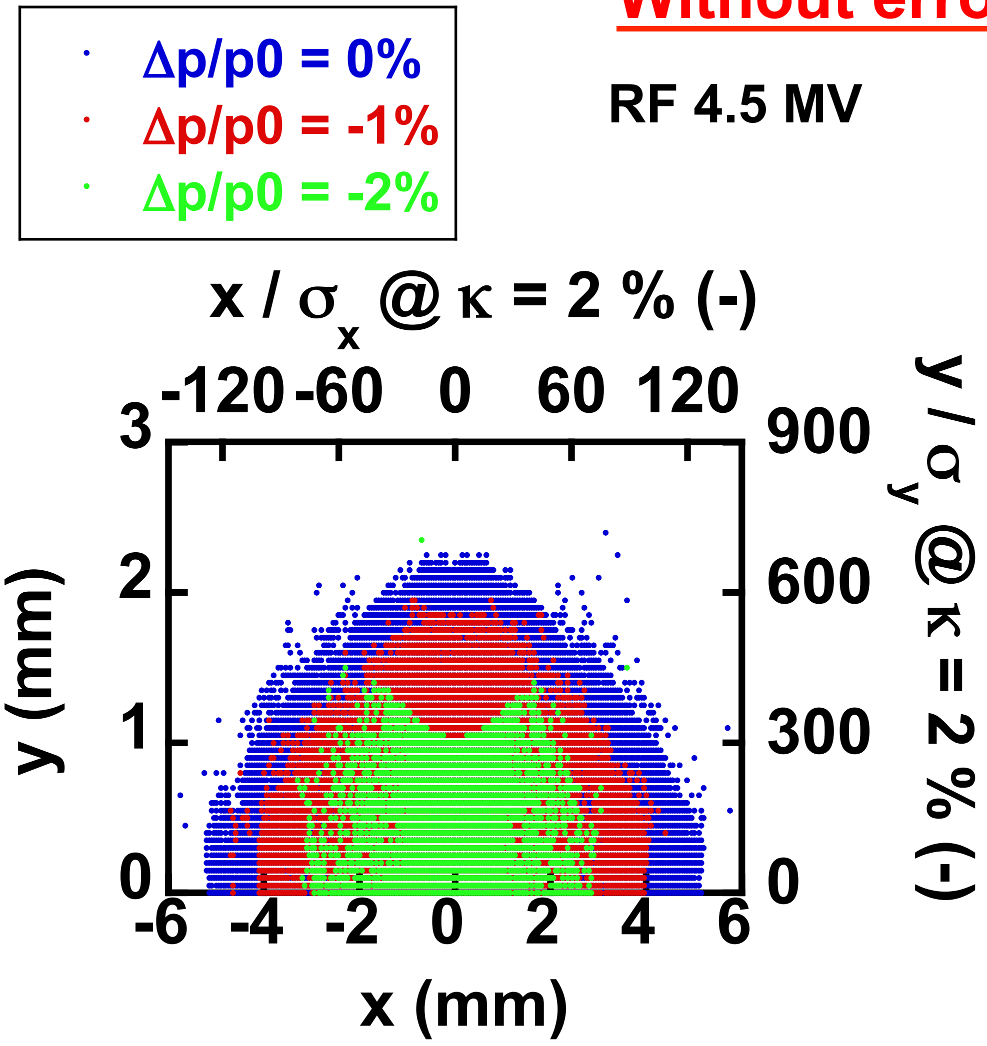
4. Summary

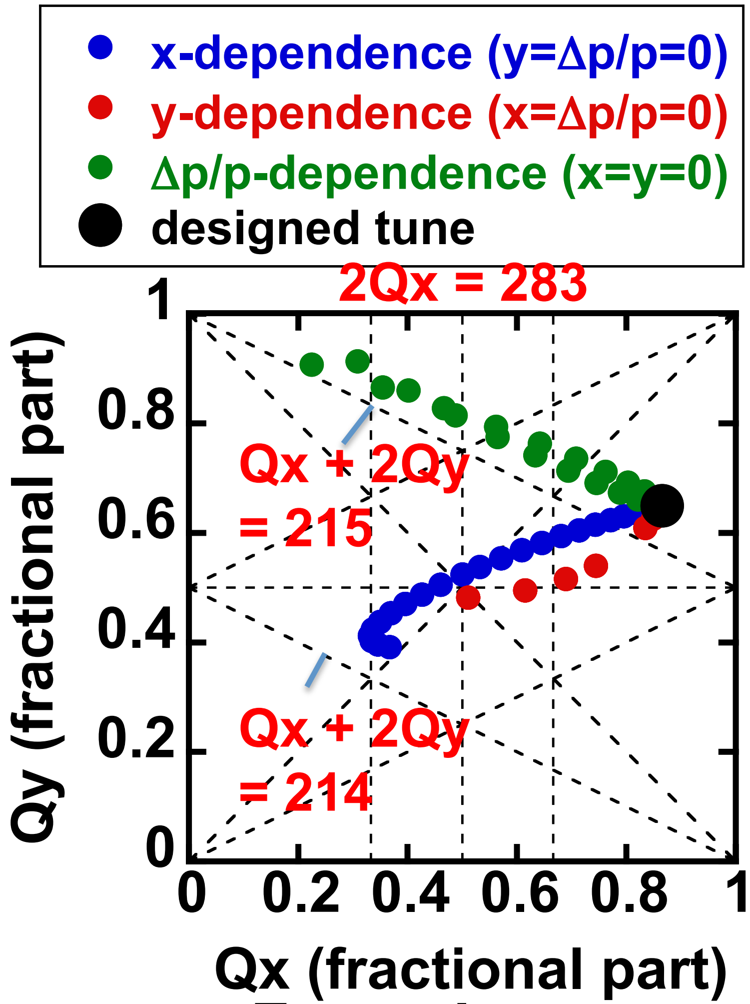
Dynamic Aperture

Without error in lattice

RF 4.5 MV



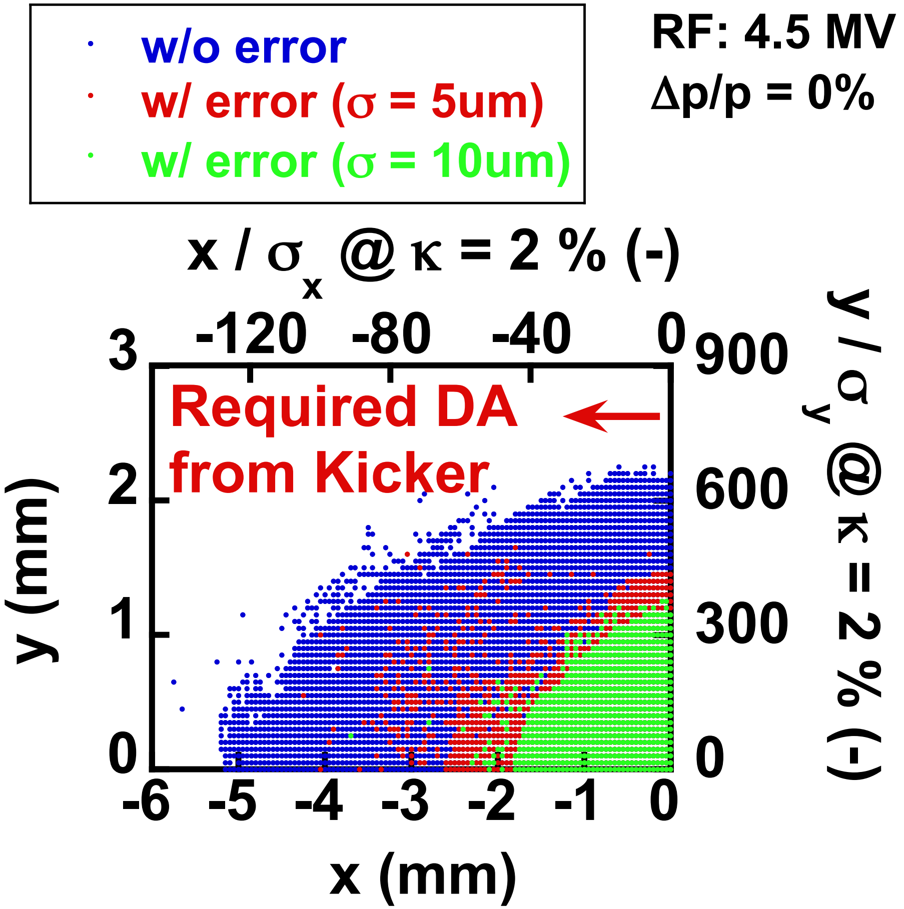
Dynamic Aperture at injection point



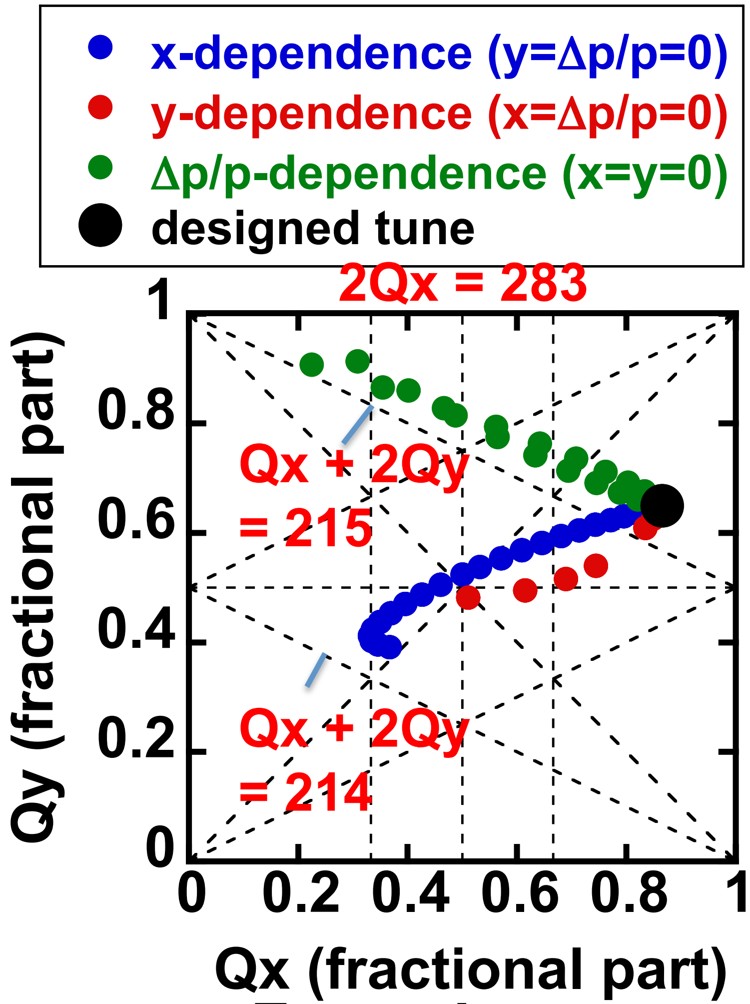
Footprints on tune diagram

Dynamic Aperture

w/ Sx-Align. Error (Gaussian, 2σ cut, no correction)



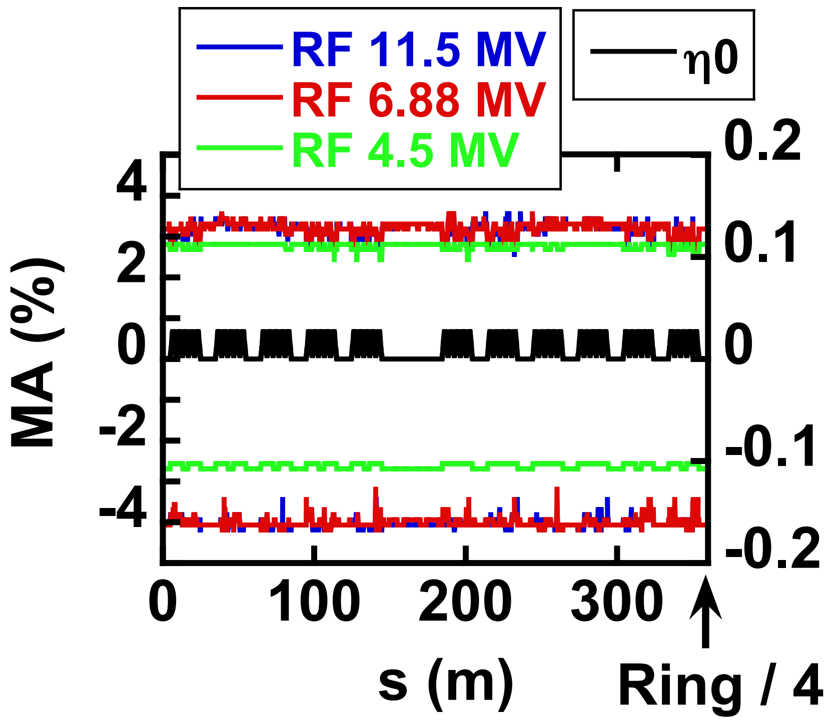
Dynamic Aperture at injection point



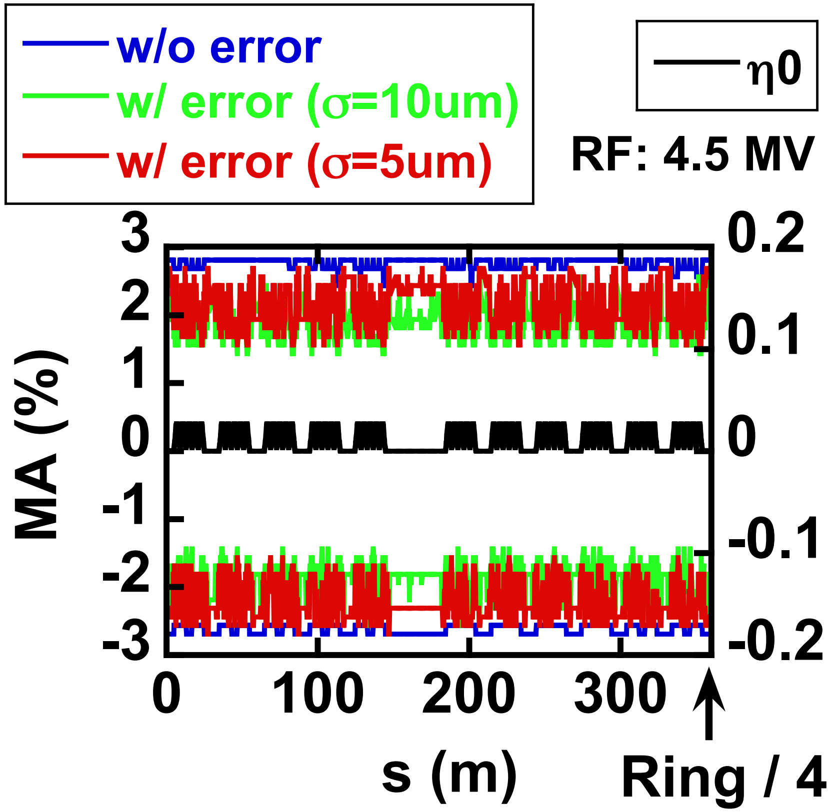
Footprints on tune diagram

Momentum Aperture

w/o & w/ Sx-Align. Error (Gaussian, 2σ cut, no correction)



Momentum Aperture dependent on RF voltage



Momentum Aperture dependent on error

Summary

DA: Dynamic Aperture
MA: Momentum Aperture

1. Design study of SPring-8 II is in progress.

2. Following strategy is adopted for DA correction:
   - Linear optics as low natural chromaticity.
   - Harmonic method with (non-)interleaved Sx for correcting
     nonlinear resonances without $\Delta p/p$,
     nonlinear resonances for off-momentum,
     and higher order resonances for on-momentum.

3. Large DA and MA for very-low ε ring (67.5 pm.rad @ 6GeV):
   x ~ ± 5 mm (~ 120 σ_x) and MA ~± 2.7 % for ideal ring,
   ~ ± 2.5 mm (~ 60 σ_x) ~ ± 2.1 % with alignment error.
   (σ = 5 μm for Sx)
   ~ ± 1.8 mm (~ 48 σ_x) ~ ± 1.8 % with σ = 10 μm (Sx)

4. We will study additional aperture enlargement, ID' s effects, correction scheme against errors, etc, in detail.

Feasibility Study of SPring-8 II

Lattice (TUOAB01) : *My Talk.*

Overview of project (THPC031) : Watanabe et al., "Current Status of SPring-8 Upgrade Plan".

Injection (TUPC095) : Nakamura, "Bucket-by-bucket On/Off-axis Injection with Variable Field Fast Kicker".

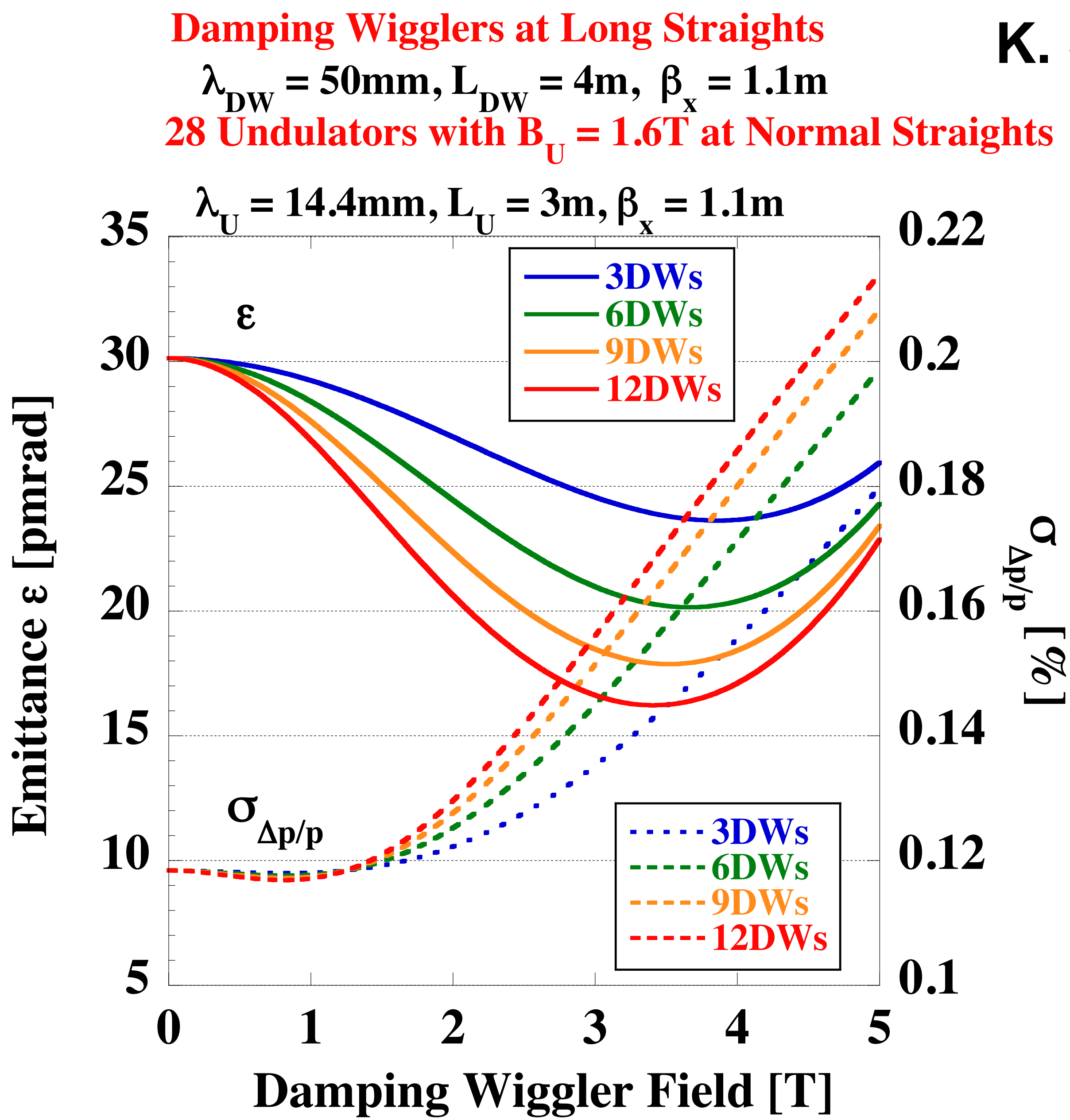
Short bunch (THPC028) : Masaki et al., "A Proposal of Short X-ray Pulse Generation from Compressed Bunches by mm-wave iFEL in the SPring-8 Upgrade Plan".

(c.f.)
Magnet / Vacuum (THPC143) : Fukami et al., "Beam-based Alignment for Injection Bump Magnets of the Storage Ring using Remote Tilt-control System".

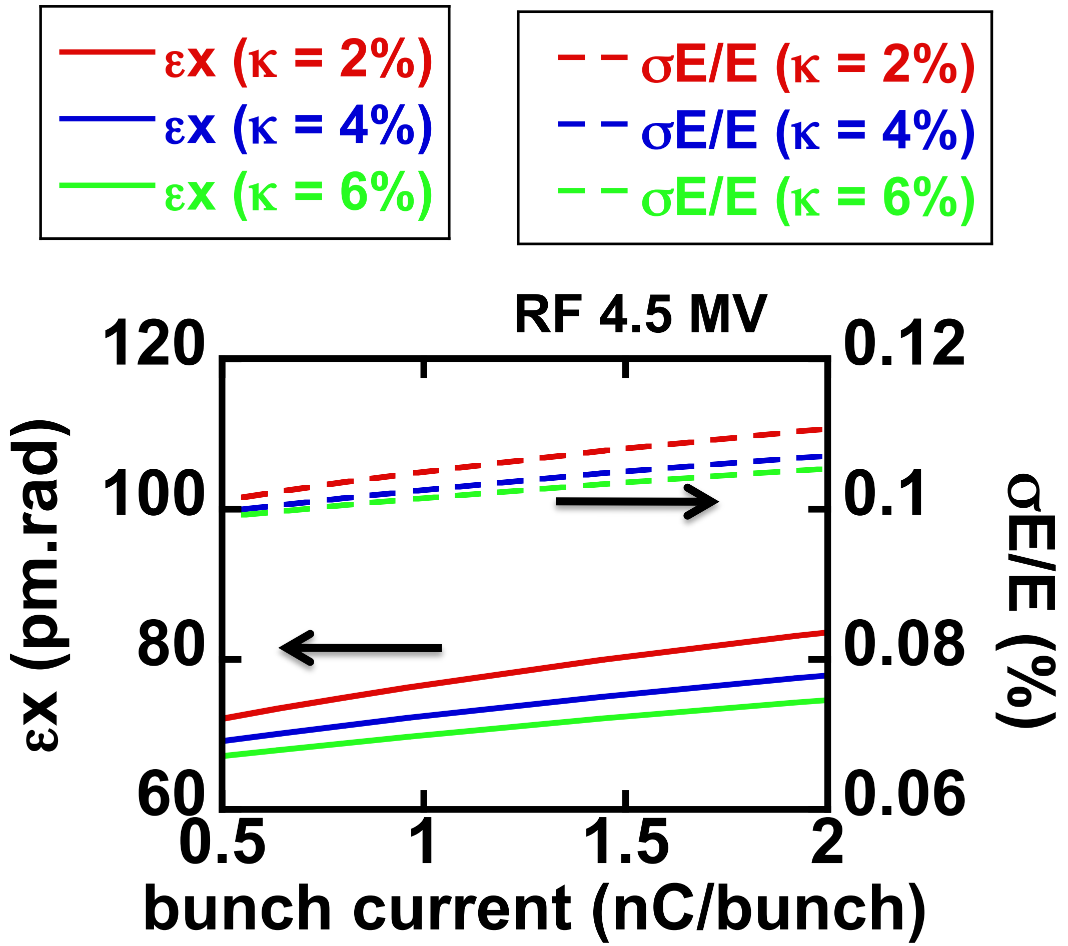
For Question

Damping Wiggler

K. Soutome

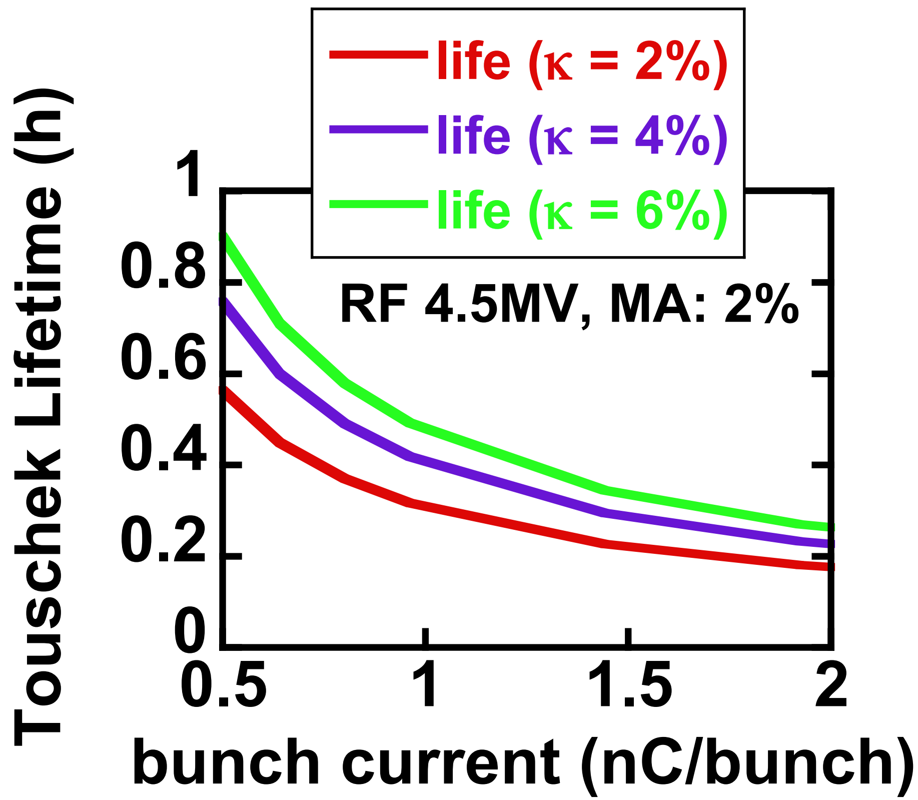


IBS and Lifetime



Effects of Intra-Beam Scattering (IBS)

Bunch lengthening by Harmonic Cavity is planed



Touschek Lifetime (Requirement from injection: 0.5 h)

Tolerance from DA (when <u>no correction</u>)

	Tolerance from DA
Q field error	10^{-4}
Sx field error	10^{-4}
Q alignment error (σ)*	1 μm (?)
Sx alignment error (σ)	10 μm

* Q-align.-error-induced-COD is not acceptable for Sx.

⇩

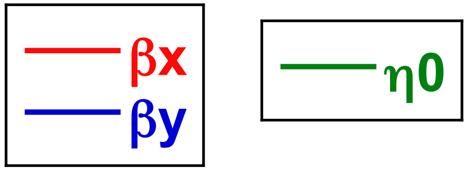
COD correction within tolerance of Sx alignment error (σ = 10 μm) has been studied with

- Remote controlled x-y stage for magnets,
- COD correction by beam-based-alignment,
- Automatic COD correction, etc.

Number of Magnet family

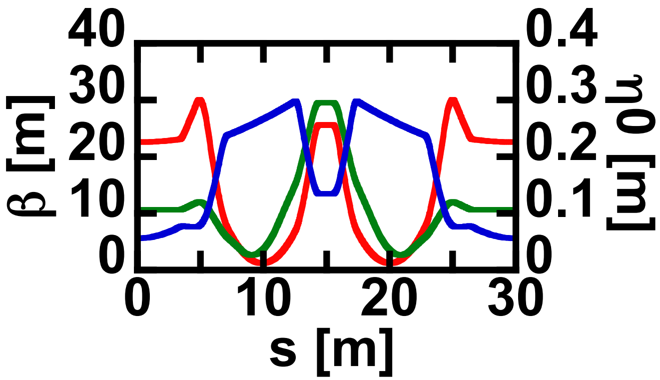
	SPring-8	SPring8 II
B	1	2
Q	14	13
Sx	9	12

Examination of Multi-bend Lattice for SPring-8 II

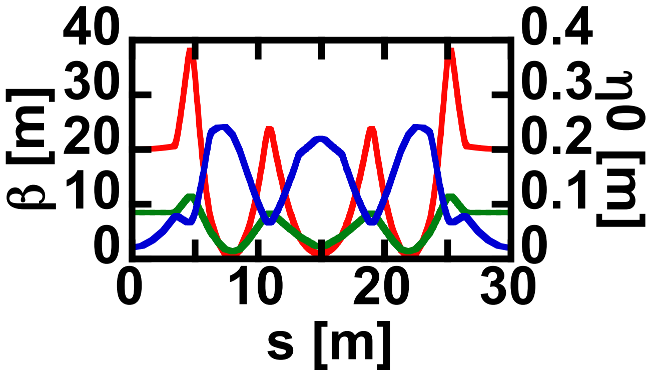


(Natural emittance on 6 GeV)

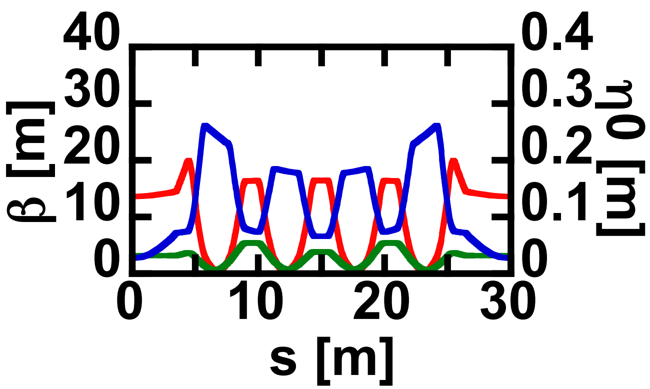
2B (2000 pm.rad)



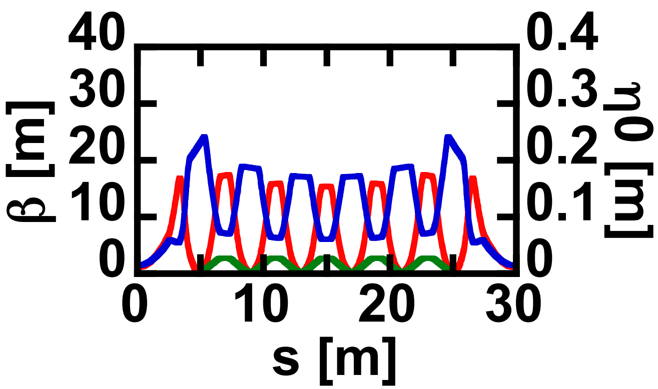
3B (400 pm.rad)



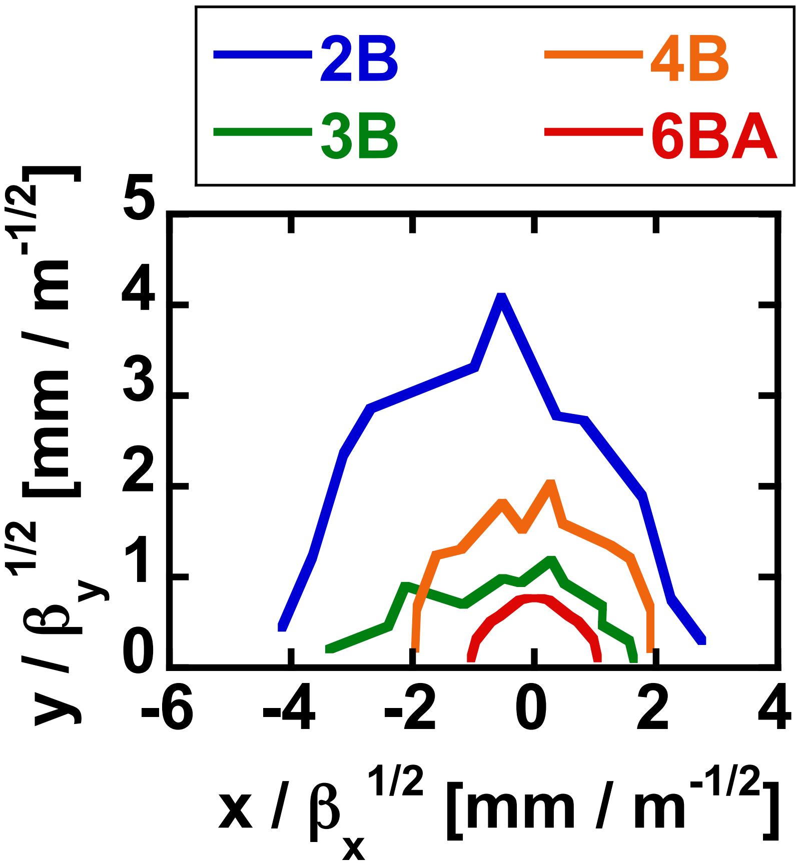
4B (170 pm.rad)



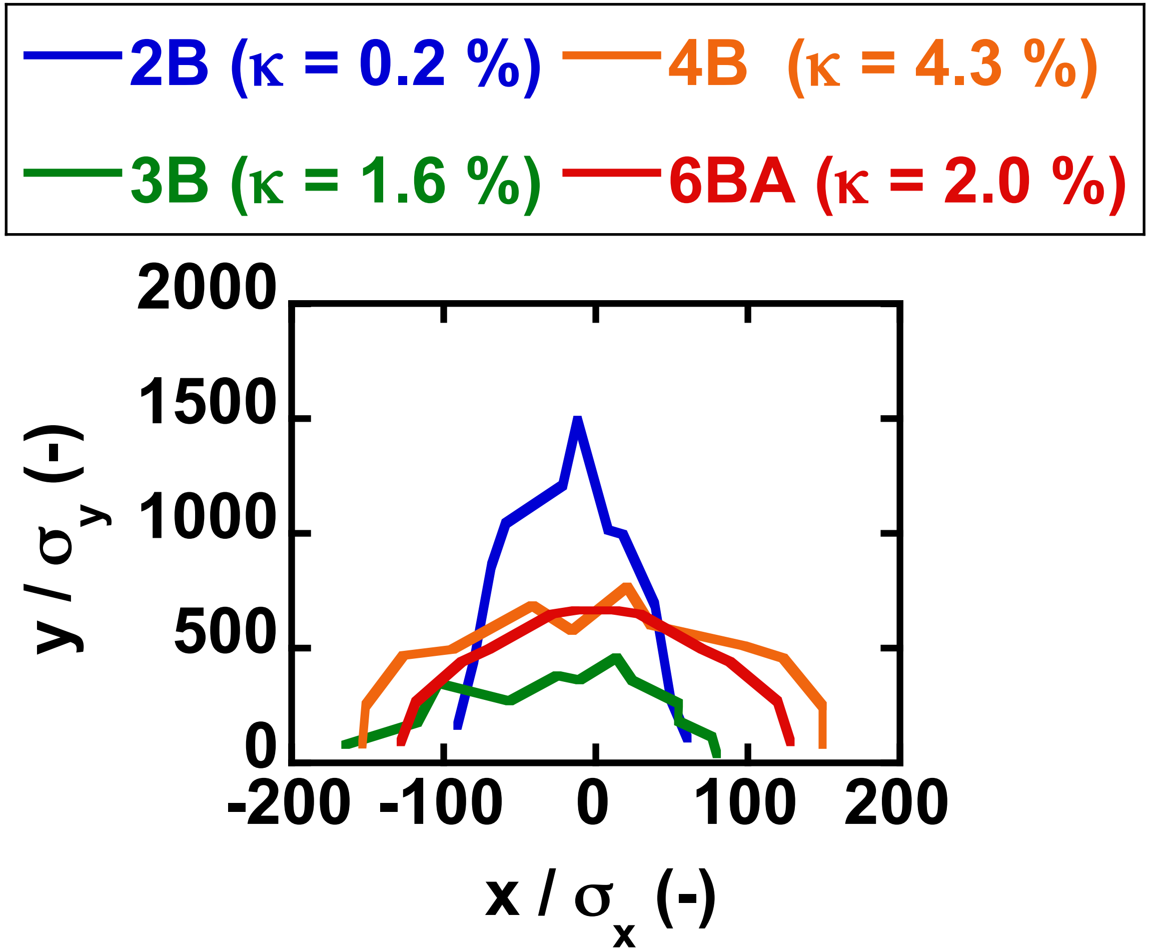
6BA (70 pm.rad)



Examination of Multi-bend Lattice for SPring-8 II



DA normalized by root-beta
(Δp / p = 0%, no error)



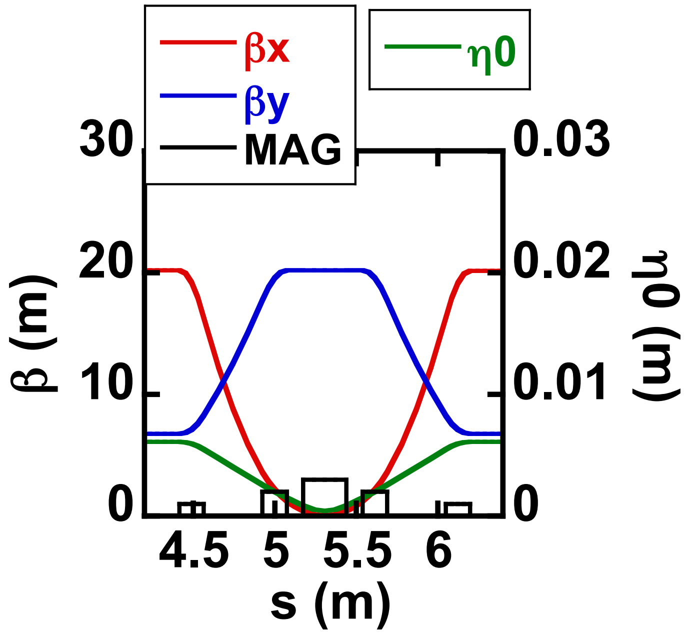
DA normalized by beam size
(Δp / p = 0%, no error)

Design of Low Natural-Chromaticity Lattice

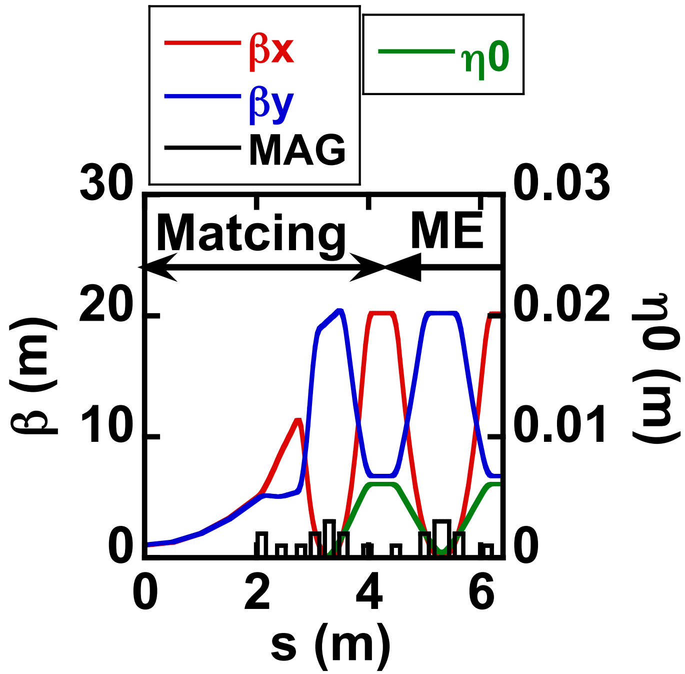
"Unit cell of 6BA"= 4 x "Minimum Emittance (ME) part"
+ 2 x "Matching part (achromat, β)"

D.Einfeld and M.Plesko, NIMA 335, 402(1993).

Position and strength of B and Q are numerically determined as low natural-chromaticity at each part.



ME part



ME + Matcing