Lattice Design of the SPring-8-II Storage Ring

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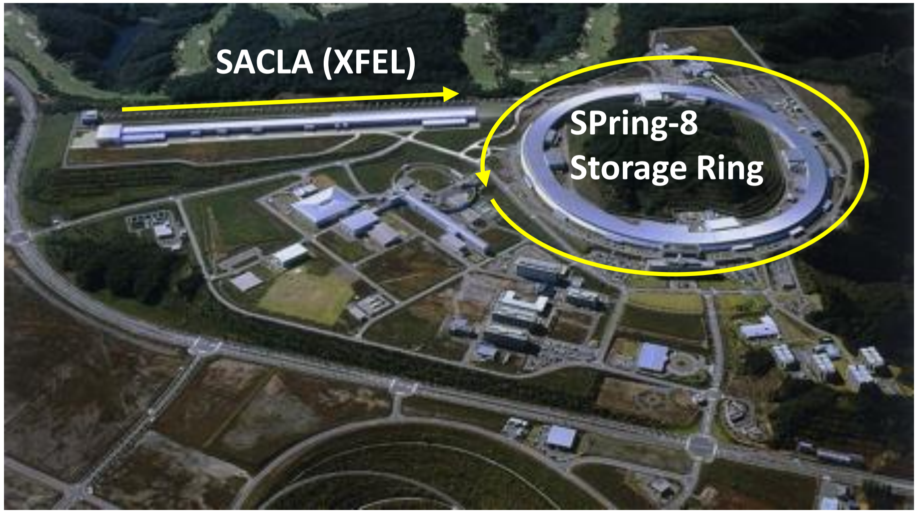
1. SPring-8-II Project
2. Design of Storage Ring Lattice
3. Some Topics
4. Summary



K.Soutome, T.Hiraiwa and H.Tanaka, IPAC2022

SPring-8-II Project

Conditions, considerations

> To replace existing storage ring to high coh. source
> ID positions fixed
> Approx. one year shutdown
> Better performance, less power consumption
> Still high stability and reliability

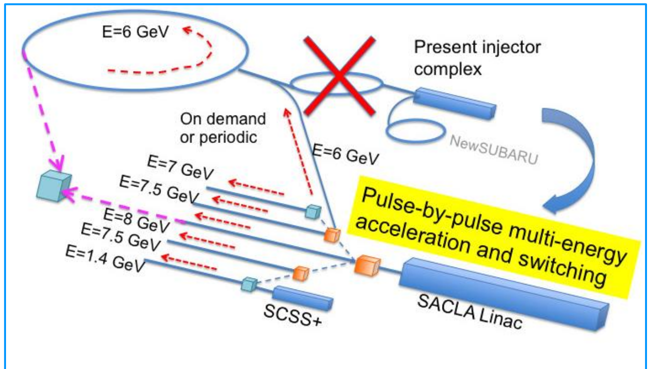


Figure 2: Schematic drawing of the SPring-8 accelerator complex after upgrading of SPring-8.

H.Tanaka, et al., IPAC2016

Our approach

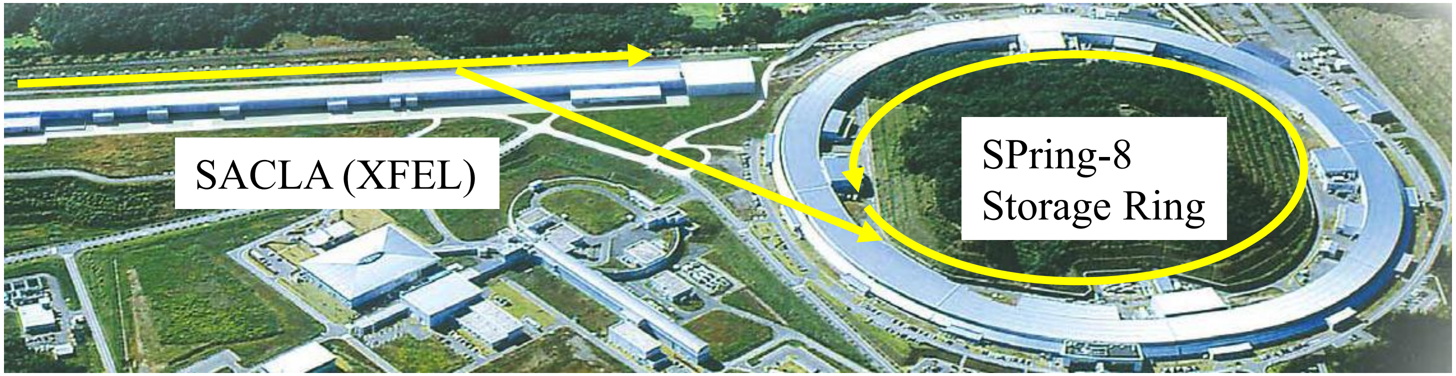
> Electron energy of 6 GeV (lowered from 8GeV)
> Five bend achromat lattice
> Use of damping wigglers in LSS
> Short period undulators for hard X-rays

**** Though the undulator becomes compact (4.5m -> 3.6m), the brilliance will be about 30~50 times.***

> High-quality beam injection from SACLA linac (On-demand pulse-by-pulse injection)

**** Injection from SACLA is already realized, and since 2020 SACLA is routinely used as an injector.***
(The 1GeV linac and the booster were shut down.)

> R&D of permanent magnet dipoles



SPring-8-II Project

SPring-8 (8GeV, 100mA, 2.4nmrad)

Design of New Storage Ring Lattice

R&D of Magnets, RF System, Vacuum Chamber, etc.

Injector Upgrading

SPring-8-II CDR published in 2014

http://rsc.riken.jp/eng/pdf/SPring-8-II.pdf

SPring-8-II

SPring-8-II Project

SPring-8 (8GeV, 100mA, 2.4nmrad)

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http://rsc.riken.jp/eng/pdf/SPring-8-II.pdf

R&D continued ... and

A new 3GeV SR facility project approved in 2019

SPring-8-II

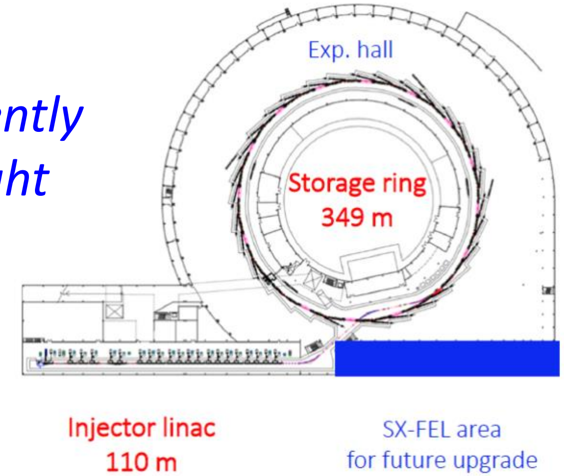
SPring-8-II Project

SPring-8 (8GeV, 100mA, 2.4nmrad)

Design of New Storage Ring Lattice
R&D of Magnets, RF System, Vacuum Chamber, etc.
Injector Upgrading

A new 3GeV SR Facility (NanoTerasu) is currently under construction in Sendai, and the first light will be observed in 2023.

Many hardware technologies developed for SPring-8-II are adopted.



N.Nishimori, IPAC2022

Feedback of experience

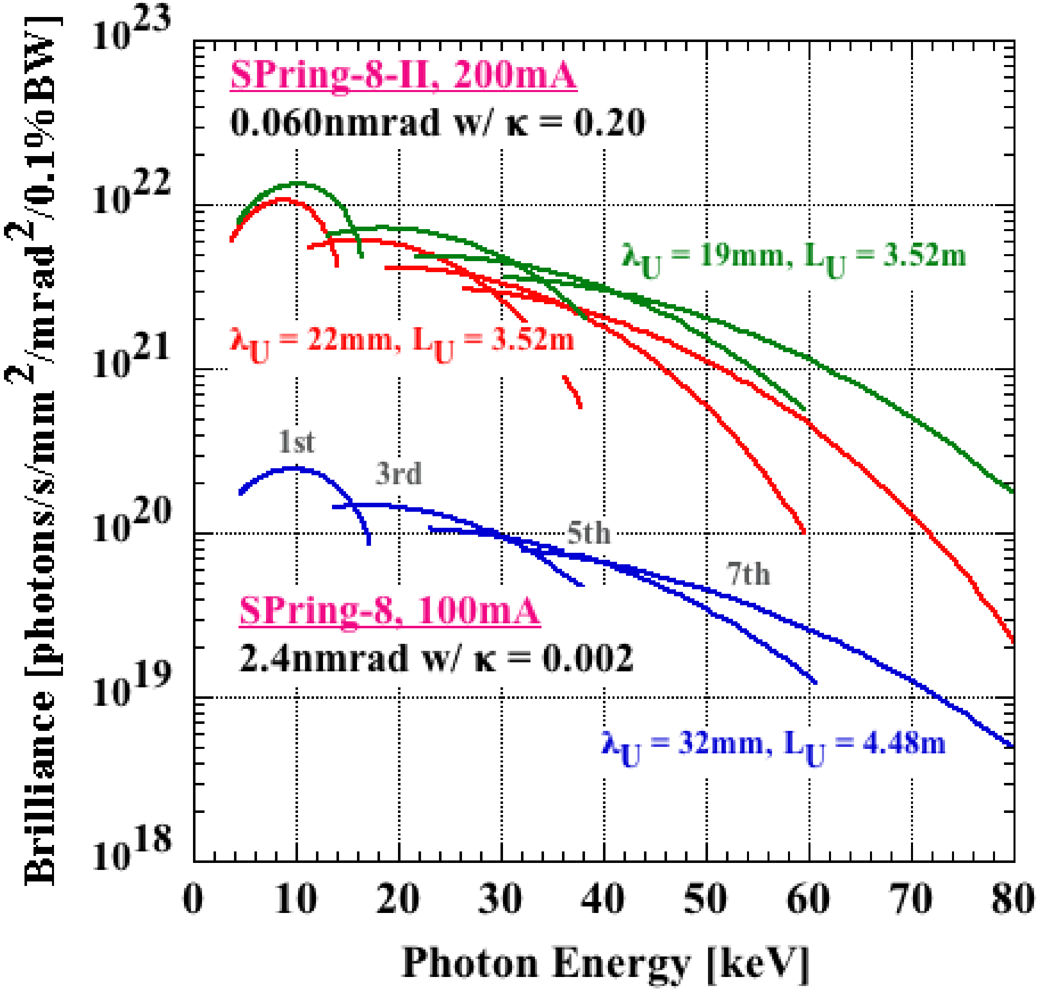
Now updating the SPring-8-II storage ring lattice design

Restart the SPring-8-II project in FY 2024

SPring-8-II (6GeV, 200mA, ~0.05nmrad w/ DWs)

SPring-8-II Project

Typical cases w/ DWs



Cal. by SPECTRA

Design of the Storage Ring Lattice

Points in Designing the SPring-8-II Lattice

For Emittance Reduction

- Reduce the beam energy from 8GeV to **6GeV** ($\varepsilon \propto E^2$) **w/ shortening the ID period**.
- Install **damping wigglers (DWs) in LSS** to realize ~50pmrad in user operation.
- Use **multi-bend achromat (MBA)** design w/ **longitudinal field gradient of dipoles**.
- Use **combined-function dipoles** to increase the horizontal damping partition number J_x .
- Optimize the dipole field distribution in a cell to reduce the **radiation loss by dipoles**.
  → *This enhances the effectiveness of radiation damping by DWs and IDs*.

For Nonlinear Optimization

- Optimize the **betatron phase between two arc sections** where sextupoles are localized.
  → *Dominant effects of nonlinear kicks almost cancel.*
- **Auxiliary weak sextupoles** are installed between the arcs.
  → *These sextupoles can further suppress the leakage effect of nonlinear kick cancellation.*
- **Matching of optical functions for on- and off-momentum electrons** at the boundary of LSS and the injection cell: $\beta(s) \equiv \boldsymbol{\beta_0(s)} + \boldsymbol{\beta_1(s)}\delta + \cdots$ $\quad \eta(s) \equiv \boldsymbol{\eta_1(s)} + \boldsymbol{\eta_2(s)}\delta + \cdots$ $\quad (\delta \equiv \Delta p/p)$
  → *This enlarges the mom. acceptance and allows us to redesign the LSS lattice locally according to users' requirements in the future.*

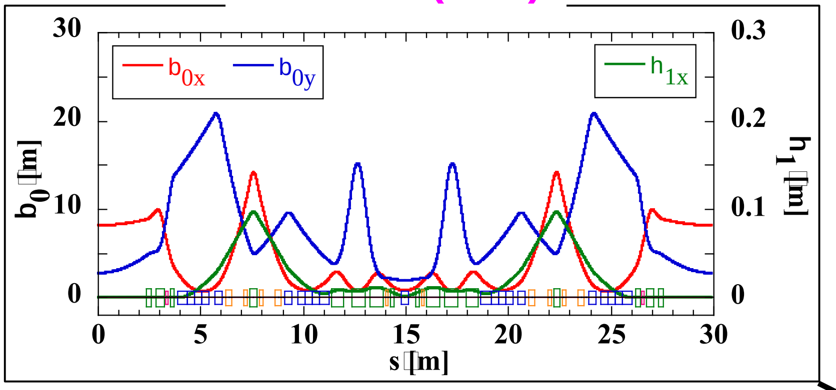
Constraints

- **Beta functions at the ID straight** must be reasonably small for getting high brilliance.
- **ID source point** must be unchanged.
- **A high-field (0.95T) dipole** in the center of the cell for beamline users
- **A transparent beam injection** without giving perturbation to the stored beam

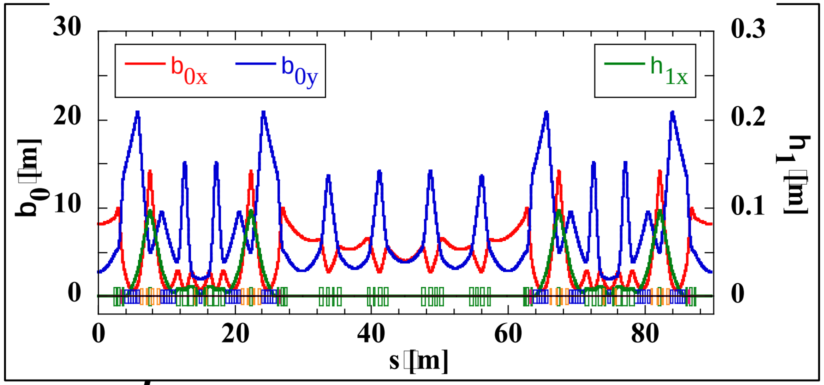
Ring Structure

as of Sep. 2022

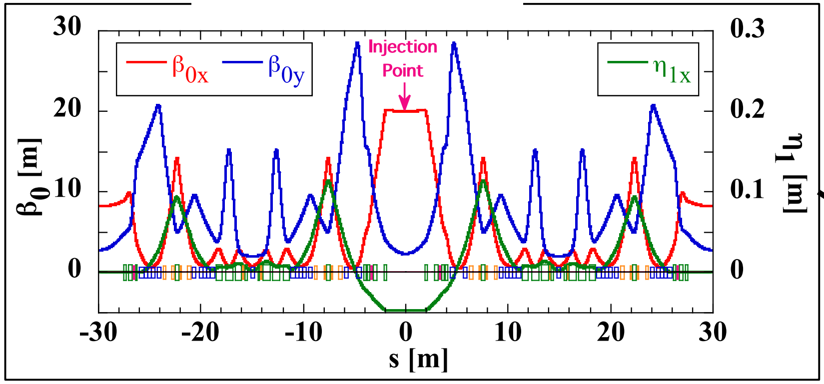
Unit Cell (5BA)

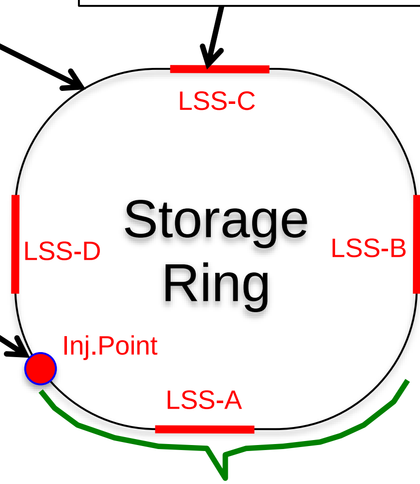


Long Straight and Matching Cells

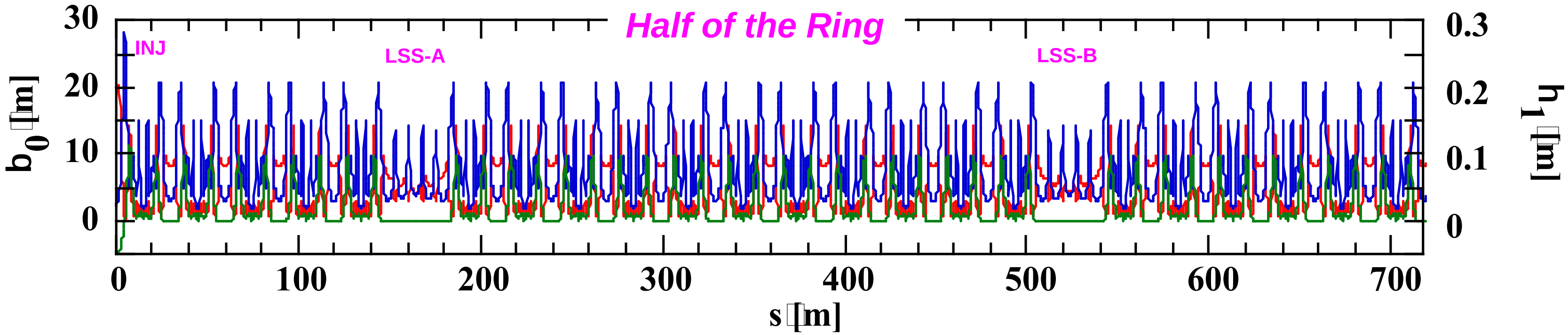


Injection Cells





42 Unit Cells
+ 2 Injection Cells
+ 4 Long Straight Cells



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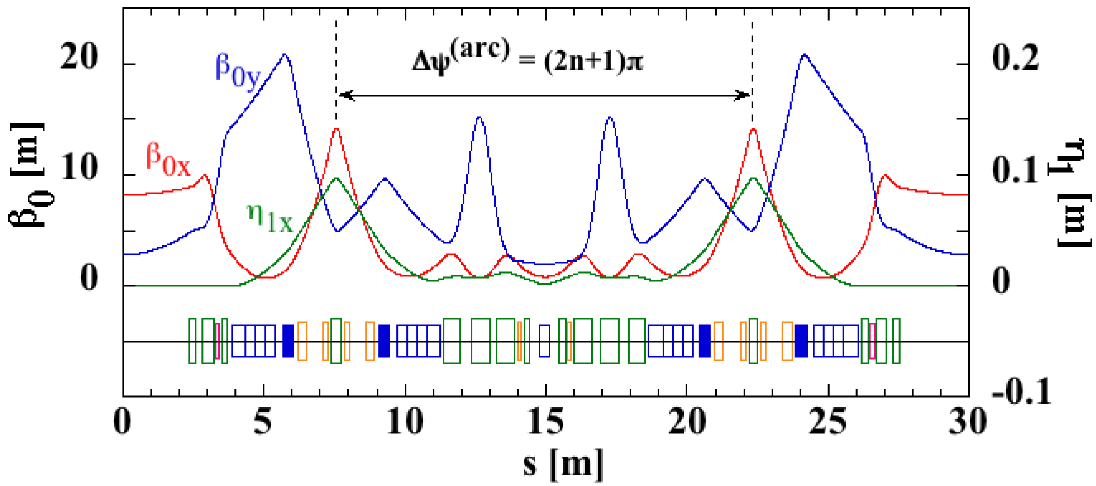
Machine Parameters

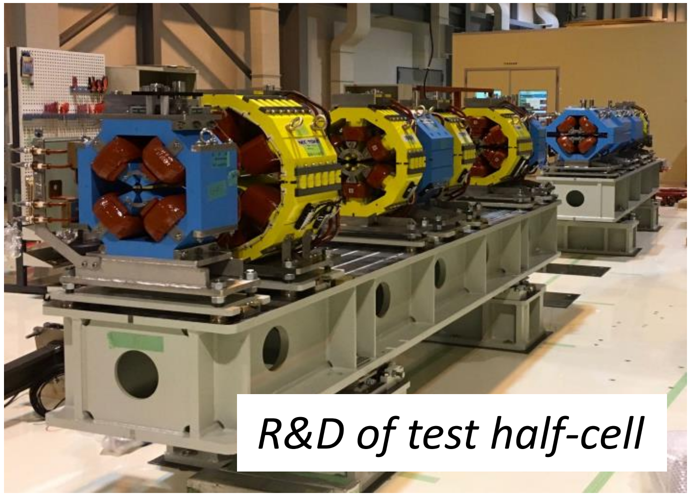
as of Sep. 2022

	SPring-8-II (Achromat Ver.)	SPring-8 (Present Ring)	
		Non-Achromat	Achromat
E [GeV]	6	6	
I [mA]	200	100	
C [m]	1435.43	1435.95	
Lattice	5BA (w/ Long. Var.)	DB	
ε [nmrad]	0.111 (bare) 0.05 w/ DWs	2.4	6.4
(β_x, β_y) [m] @ ID	(8.2, 2.8)	(31.2, 5.0)	(24.4, 5.8)
η_x [m] @ ID	0.0	0.146	0.0
(ν_x, ν_y)	(108.10, 42.58)	(41.14, 19.35)	(40.15, 18.35)
J_x, J_y, J_s	1.383, 1.0, 1.617	1.0, 1.0, 2.0	
$(\xi_x, \xi_y)_{natural}$	(-154, -149)	(-117, -47)	(-90, -41)
α	4.12e-5	1.60e-4	1.46e-4
$\sigma_{\Delta p/p}$ [%]	0.098	0.109	
κ [%]	10	0.2	
h	2436	2436	
f_{RF} [Hz]	508.76	508.58	
U_0 [MeV/turn]	2.62	9.12	

Design of Normal Cell



B Combined-B Q SX OCT



R&D of test half-cell

5BA lattiec of HMBA-type developed at the ESRF
(no combined-BM between the arcs)

Betatron phase between the arcs is slightly detuned to control the amplitude-dependent tune shift (ADTS): $\Delta\psi_x = 2.976\pi, \Delta\psi_y = 0.990\pi$

Octupoles are added as another tuning-knob to control the ADTS.

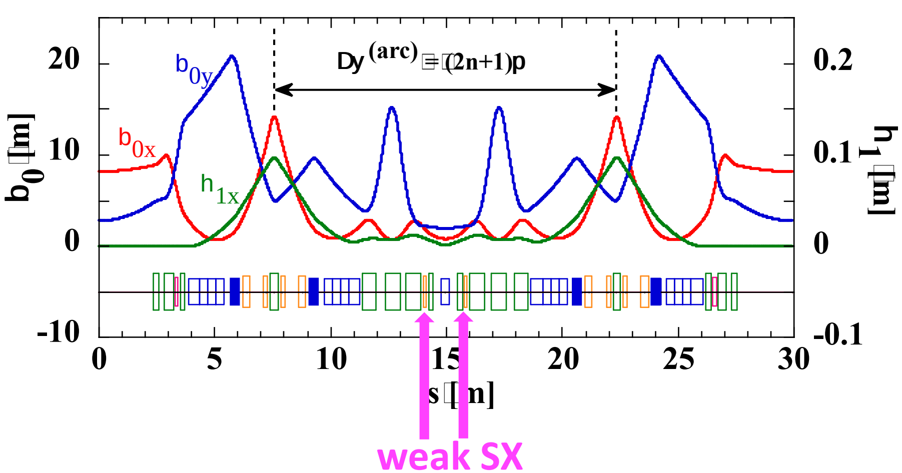
Max. Field of Magnets:
0.95 T (B), 55.7 T/m (Q), 2700 T/m^2 (SX)

Weak Sextupoles between the Arcs

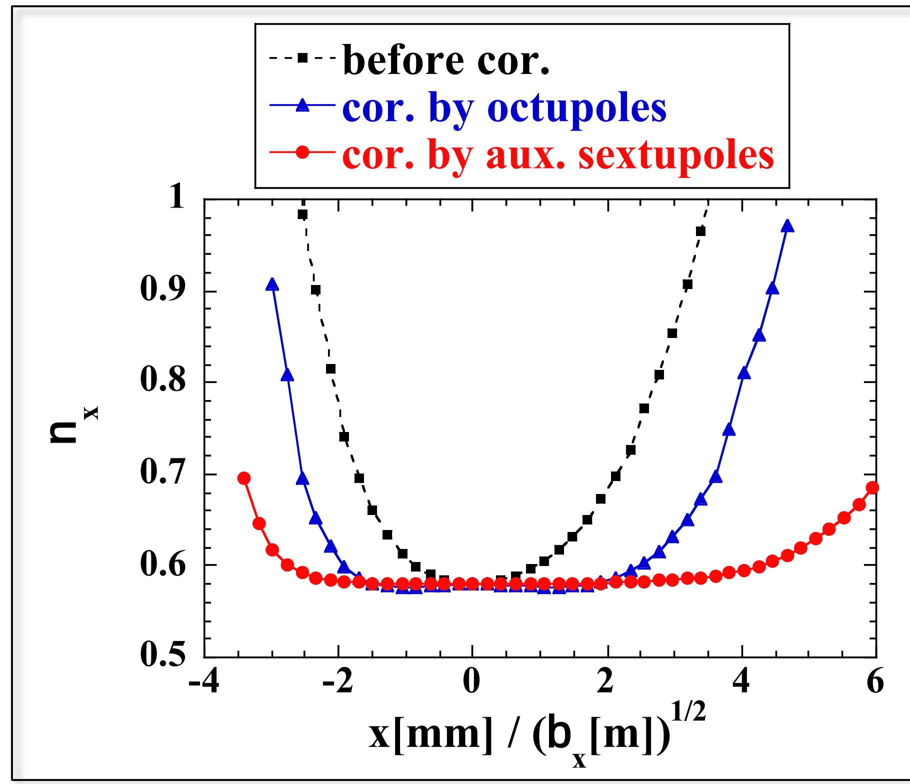
The cancellation of nonlinear kicks of sextupoles cannot be perfect.
But it can be improved by installing auxiliary weak sextupoles between the arcs to counteract the leaked kick.

Necessary strength is about one order of magnitude smaller than chromaticity correcting SXs.

The range of flatness is wider than the case using octupoles, which means that higher order terms are well controlled.



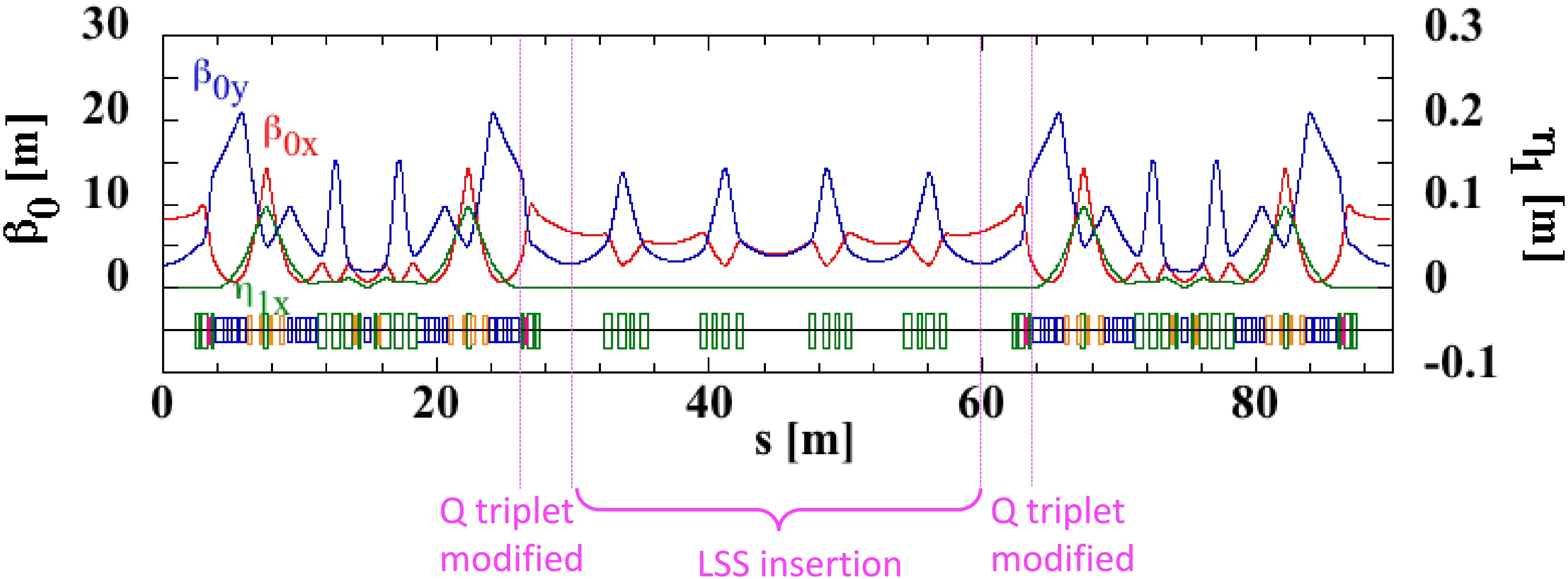
Example



K.Soutome, Y.Shimosaki, M.Takao and H.Tanaka, PAC2017

Design of Long Straight Section (LSS)

- Increase of the betatron phase advance of **2π** in hor. and ver. directions
- As **small natural chromaticity** as possible
- **No sextupoles**
- **Matching of on- and off-mom.** optical functions (beta and dispersion)



- The ring has four LSSs, and each **LSS optics can be changed independently** as long as the matching conditions are met.
- **The matching conditions are met even when the sextupoles strengths are changed.**

Energy-Dependence of Beta and Dispersion

By canonical perturbation calculations, we have

$$\beta(s) \equiv \beta_0(s) + \beta_1(s)\delta + \cdots \qquad \eta(s) \equiv \eta_1(s) + \eta_2(s)\delta \ldots$$

$$\boxed{\beta_1(s) = -\frac{\beta_0(s)}{2\sin 2\pi\nu_0}\oint ds'\beta_0(s')G_1(s')\cos(2\pi\nu_0 - 2|\phi_0(s) - \phi_0(s')|)}$$

$$\phi_0(s) \equiv \int_0^s \frac{ds'}{\beta_0(s')}$$

$$\boxed{\eta_2(s) = \frac{\sqrt{\beta_{0x}(s)}}{2\sin\pi\nu_{0x}}\oint ds' R_2(s')\sqrt{\beta_{0x}(s')}\cos(\pi\nu_{0x} - |\phi_{0x}(s) - \phi_{0x}(s')|)}$$

$$G_{x,1} = -g_0 + g_1\eta_1 - \frac{3}{2}K_x^2(1 - K_x\eta_1) + \frac{3}{2}g_0K_x\eta_1$$

$$G_{y,1} = g_0 - g_1\eta_1 + \frac{1}{2}K_x^2(1 - K_x\eta_1) - \frac{3}{2}g_0K_x\eta_1$$

$$R_2 = +g_0\eta_1 - \frac{1}{2}g_1\eta_1^2 - K_x\left(1 - \frac{1}{2}\eta_1'^2\right) + 2K_x^2\eta_1 - K_x^3\eta_1^2 - g_0K_x\eta_1^2$$

$g_0 \equiv \frac{B'}{[B\rho]}$: Quadrupole Field ($g_0 > 0$ for QF)

$g_1 \equiv \frac{B''}{[B\rho]}$: Sextupole Field ($g_1 > 0$ for SF)

$K_x \equiv \frac{1}{\rho}$: Curvature of Orbit

M.Takao, "Hamiltonian Formulation of Higher Order Dispersion and Chromaticity of Circular Accelerators",
J. Particle Accelerator Society of Japan, Vol.2 No.1 (2005) p.25. (in Japanese)
https://www.pasj.jp/kaishi/cgi-bin/kasokuki.cgi?articles%2F2%2Fp025.pdf

M.Takao, "Formulation of nonlinear chromaticity in circular accelerators by canonical perturbation method",
Phys. Rev. E72 (2005) 046502.

Optics Matching in LSS

The matching conditions for off-mom. optical functions (β_1 and η_2) are kept even when the sextupoles strengths are changed (see below).

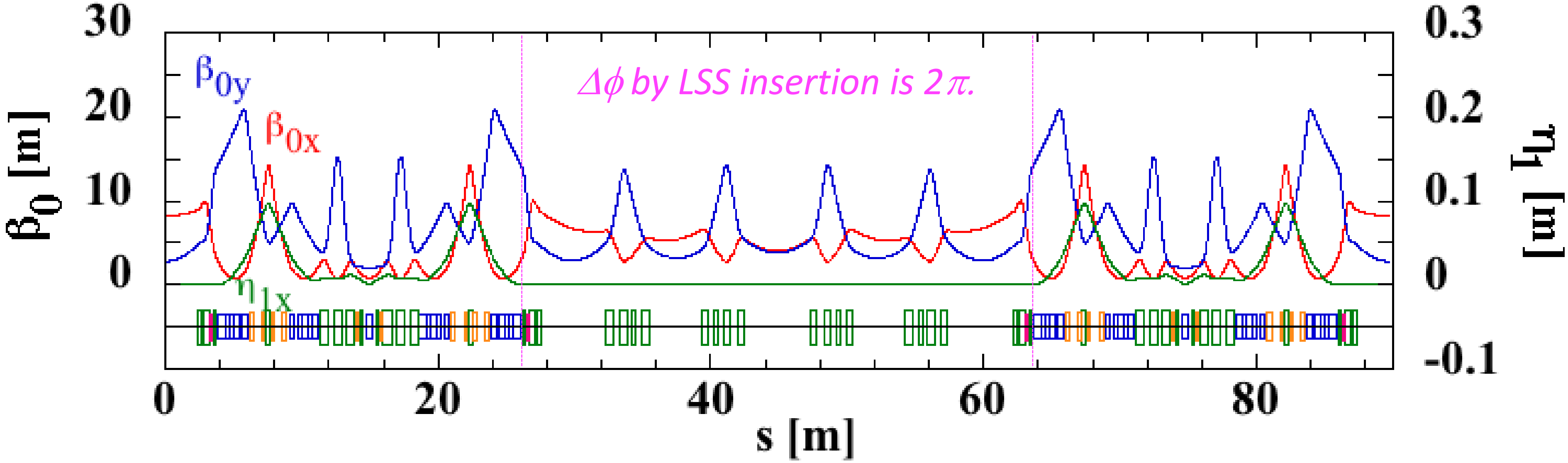
If we change the sextupole strength by Δg_1(s), the change of β_1 is

$$\Delta\beta_1(s) = -\frac{\beta_0(s)}{2\sin 2\pi\nu_0}\oint ds'\beta_0(s')\Delta g_1(s')\eta_1(s')\cos(2\pi\nu_0 - 2|\phi_0(s) - \phi_0(s')|)$$

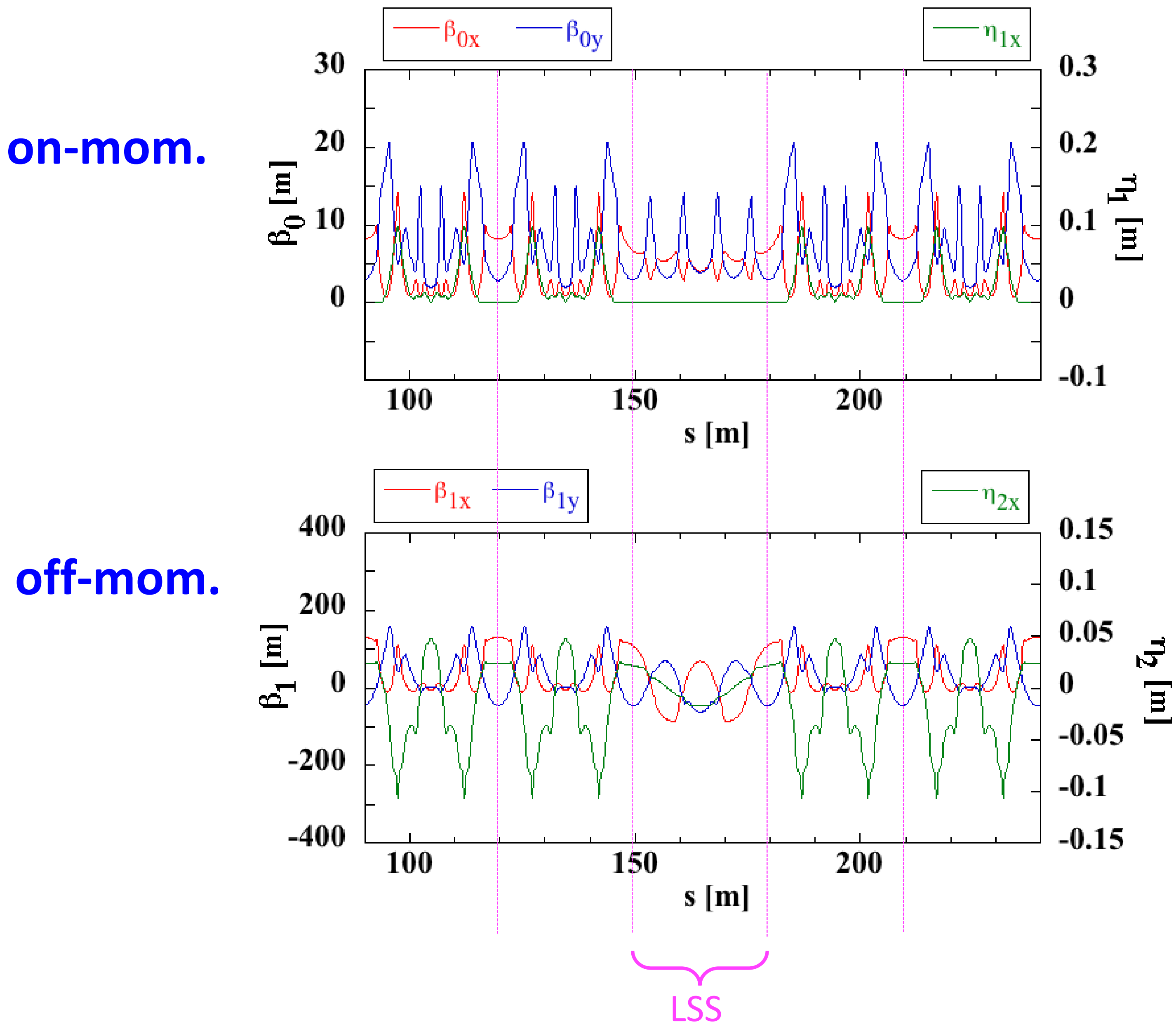
Since

- the RHS is evaluated only at sextupoles,
- the linear optics β_0 and η_1 at sextupoles are unchanged,
- the LSS insertion does not contain sextupoles, and
- the phase change by LSS insertion is 2π,

the periodicity of the LHS $\Delta\beta_1$ is kept. This automatically guarantees the matching condition at the boundary of each cell, and no β_1 –beating is generated.

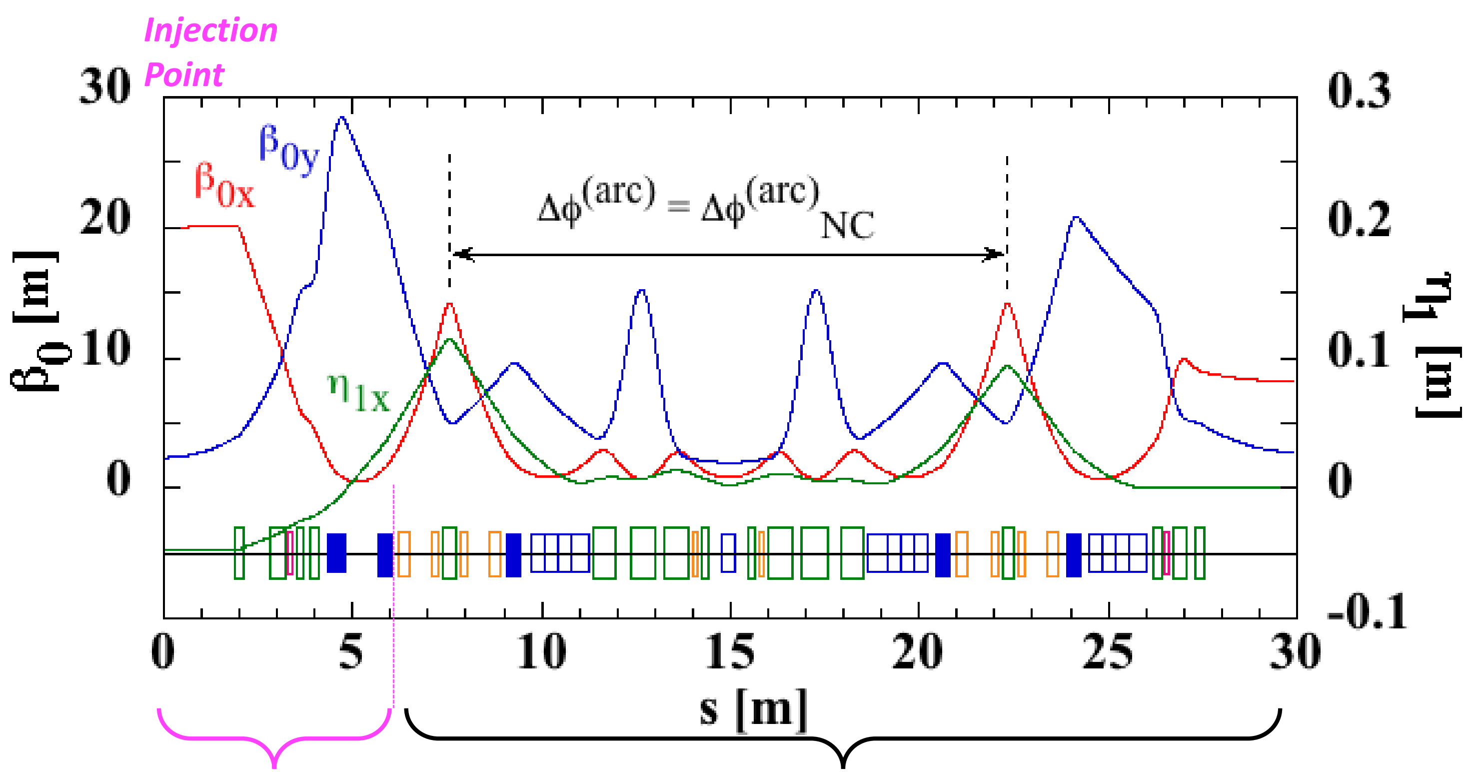


Optics Matching in LSS



Design of Injection Section

- High hor. beta of **20m**
- The **same betatron phase advance per cell** as the normal cell
- The **same betatron phase advance between the arcs** as the normal cell
- **Matching of on- and off-mom.** optical functions (beta and dispersion)
- Space for installing bump magnets for generating a **linear π-bump orbit**
- To suppress **emittance** degradation by local lattice modification

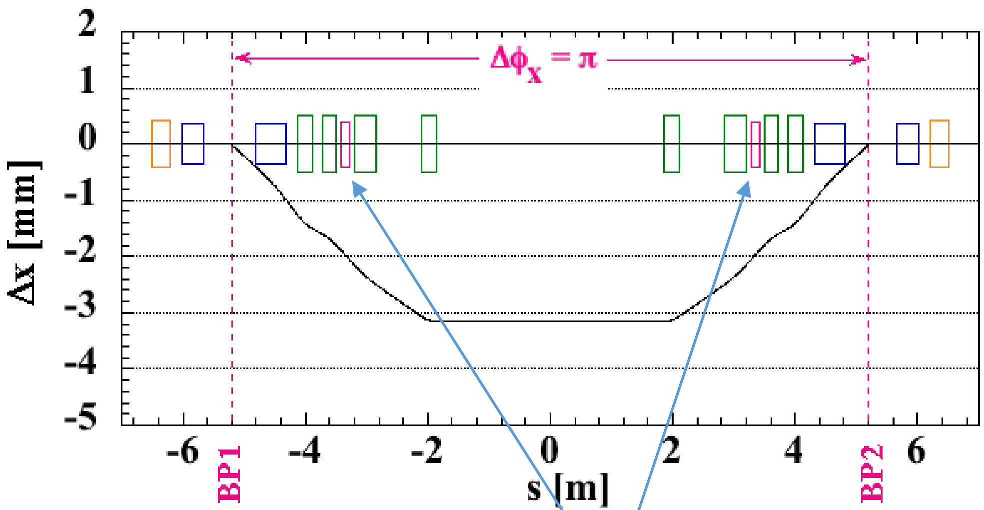


Lattice modified

Dipole field distribution was modified for η_2-matching.
Quadrupole and sextupole field components are unchanged.

Injection Scheme

■ Conventional **off-axis injection** scheme w/ a high-quality beam from **SACLA linac**
■ **Linear π-bump orbit** w/ two bump magnets connecting to a **common power supply**



Bump orbit for 1mrad kick

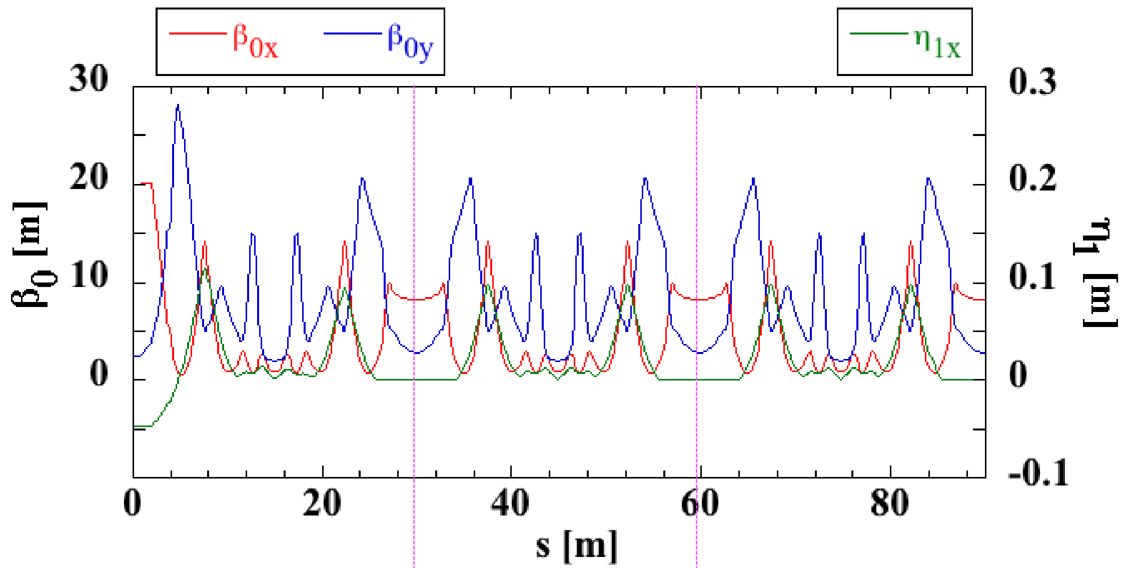
No sextupoles within the bump orbit
→ Transparent beam injection

After the optics tuning, these octupoles within a bump orbit will be switched off.
(The effect on the dynamic aperture is small.)

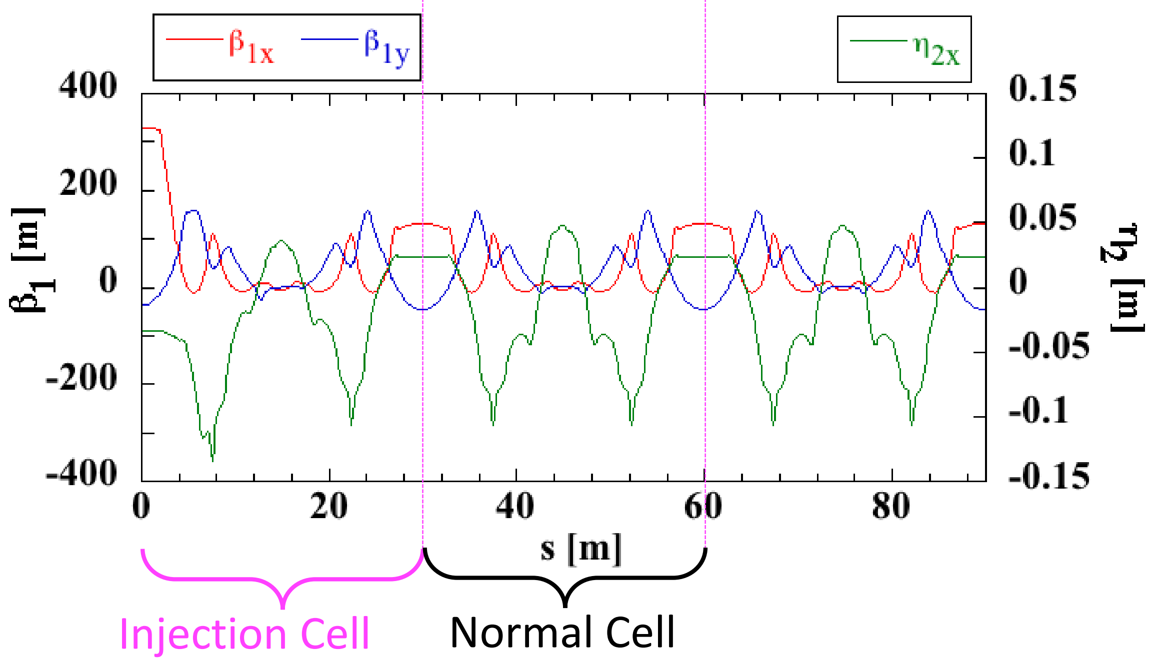
■ For fine tuning, some quadrupoles within a bump orbit will be used as knobs.
■ If needed, **auxiliary nonlinear kickers** will be installed to reduce the coherent amplitude of the injected beam (... under consideration).

Optics Matching in Injection Section

on-mom.



off-mom.



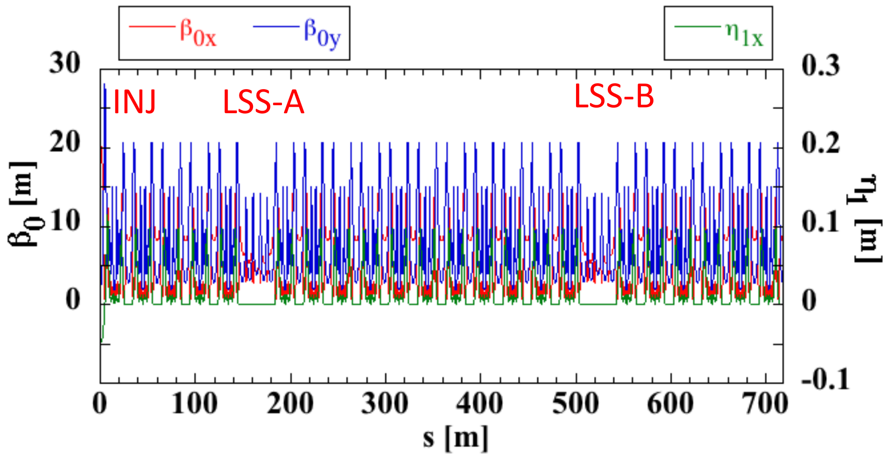
Effects of Off-Mom. Optics Matching on MA

$$\beta(s) \equiv \beta_0(s) + \beta_1(s)\delta + \cdots \qquad \eta(s) \equiv \eta_1(s) + \eta_2(s)\delta + \cdots \qquad (\delta \equiv \Delta p/p)$$

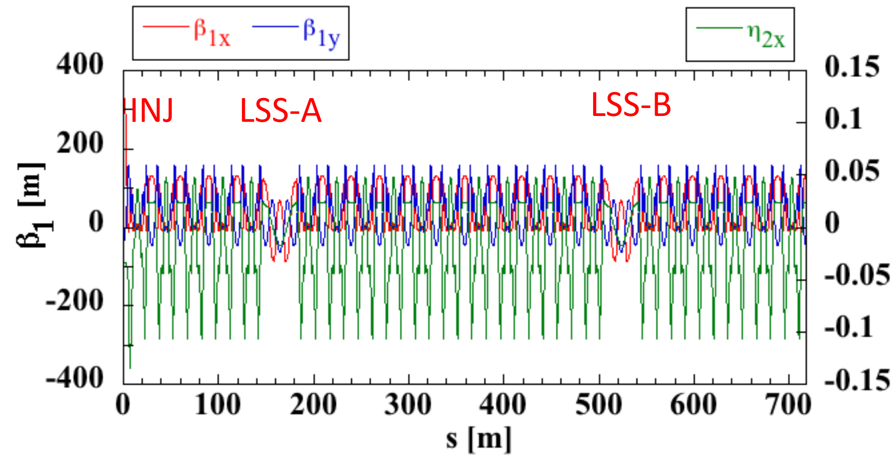
LSS insertion w/ β_1 matching (present design)

Half of the ring is shown.

Lowest Order

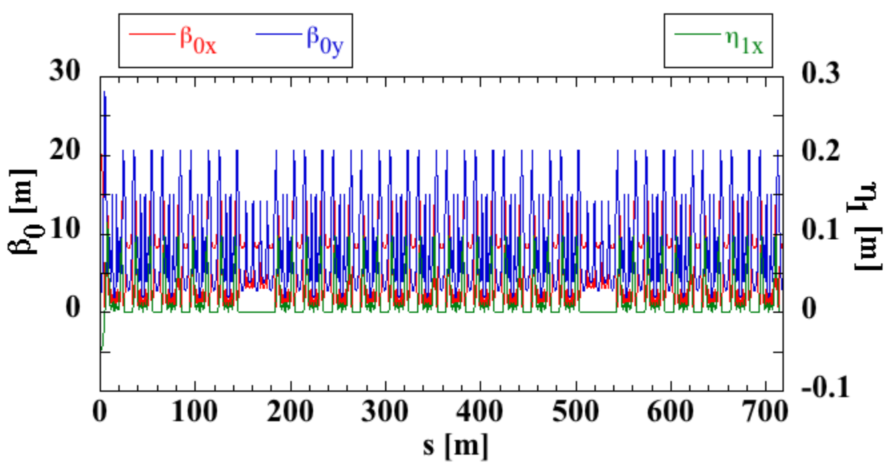


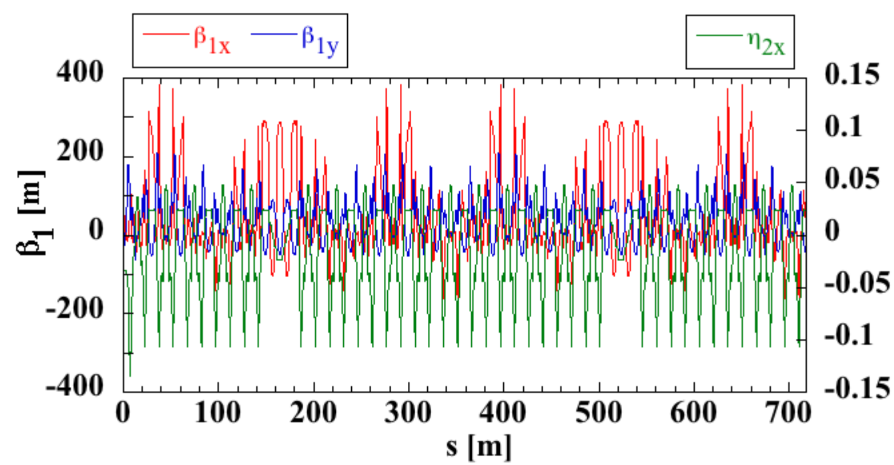
First Order



β_1 unmatched case (for comparison)

Large beta-beat for off-mom. electrons

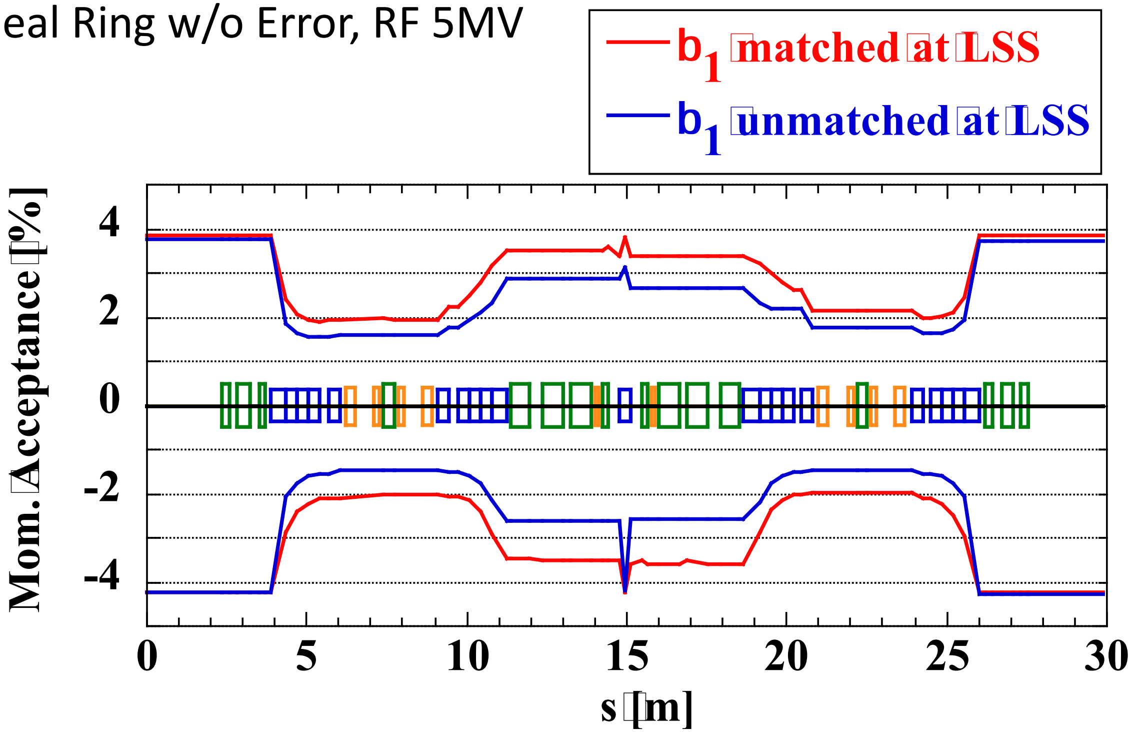


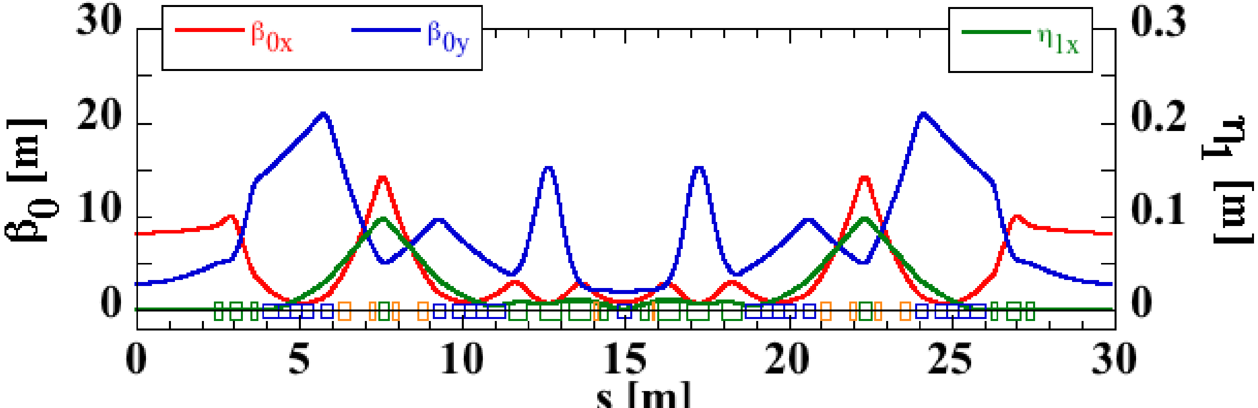


Effects of Off-Mom. Optics Matching on MA

Local Mom. Acceptance in Normal Cell

For Ideal Ring w/o Error, RF 5MV



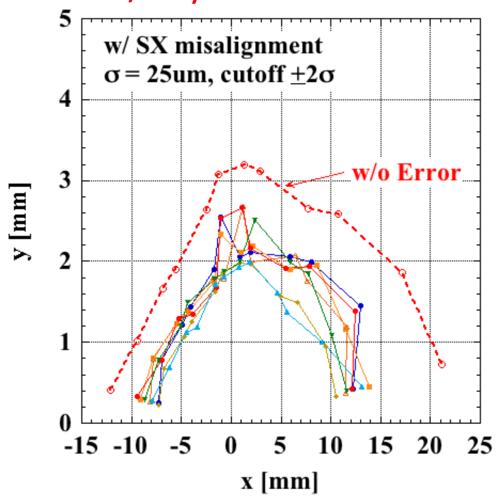


Dynamics of the Ring

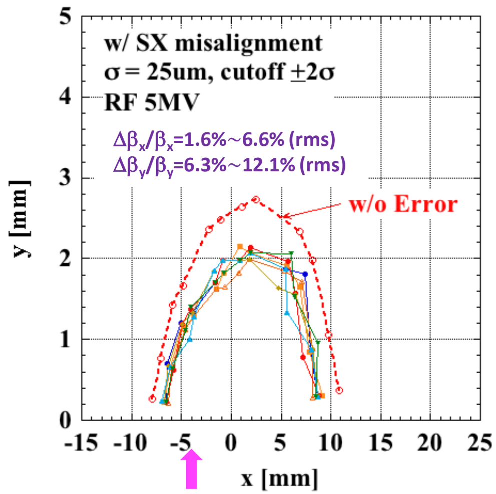
Dynamic Aperture @ IP

(β_x = 20.0m, β_y = 2.3m)

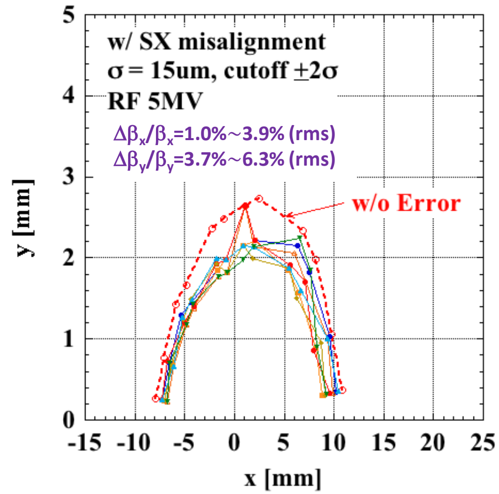
w/o Synchrotron Osc.



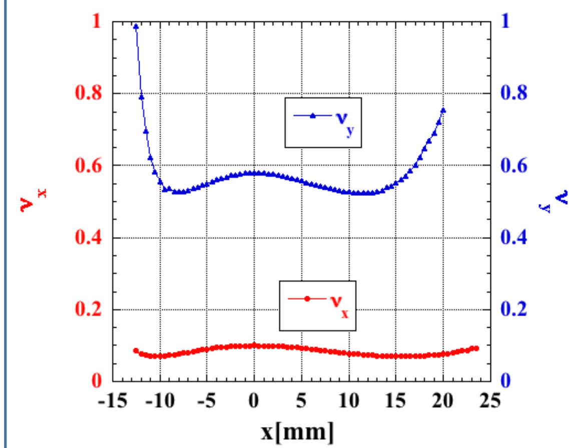
w/ Synchrotron Osc.

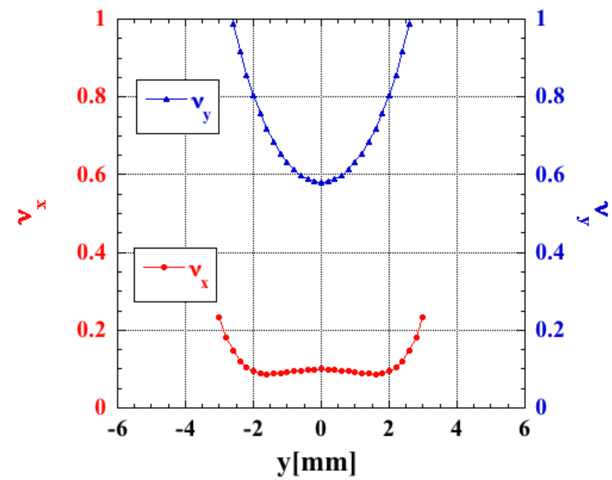


injected beam from SACLA

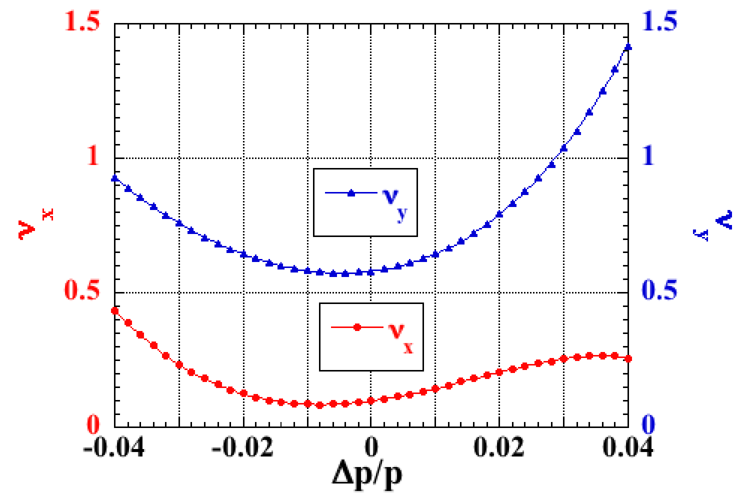


Amplitude-Dep. Tune Shift



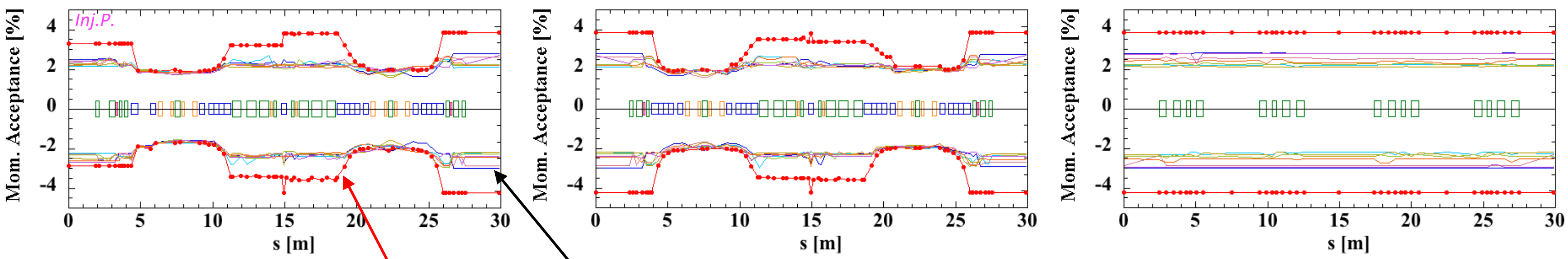


Chromaticity



Mom. Acceptance and Touschek Lifetime

MA (V_{RF} = 5MV)

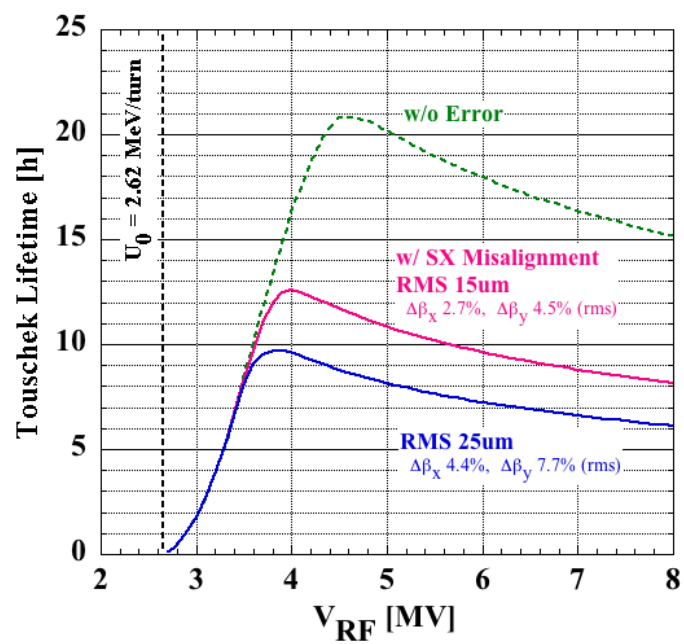


$\Delta\beta_x$ 1.6%~6.6% , $\Delta\beta_y$ 6.3%~12.1% (rms)

Touschek Lifetime

Beam Current: 100mA
Filling: Multi-bunch (1920/2436)
Coupling: 10%
Bunch lengthening factor: 1.5

We found that MA and Touschek lifetime can be improved by suppressing the 2nd order chromaticity and this will be further studied in the future.



Emittance Reduction by DWs in LSS

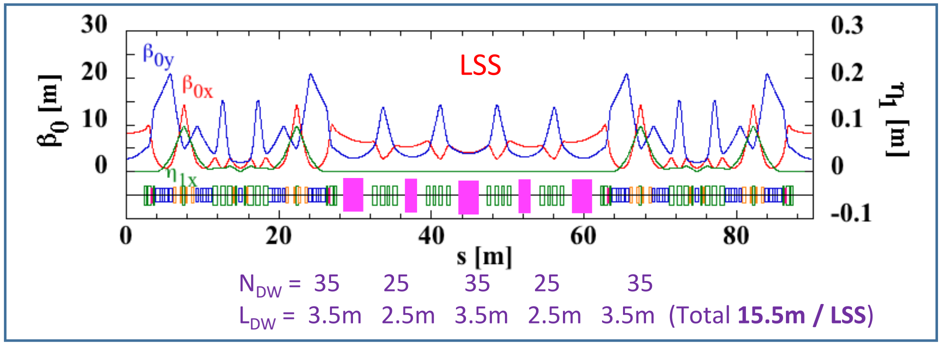
ID Parameters (assumed)

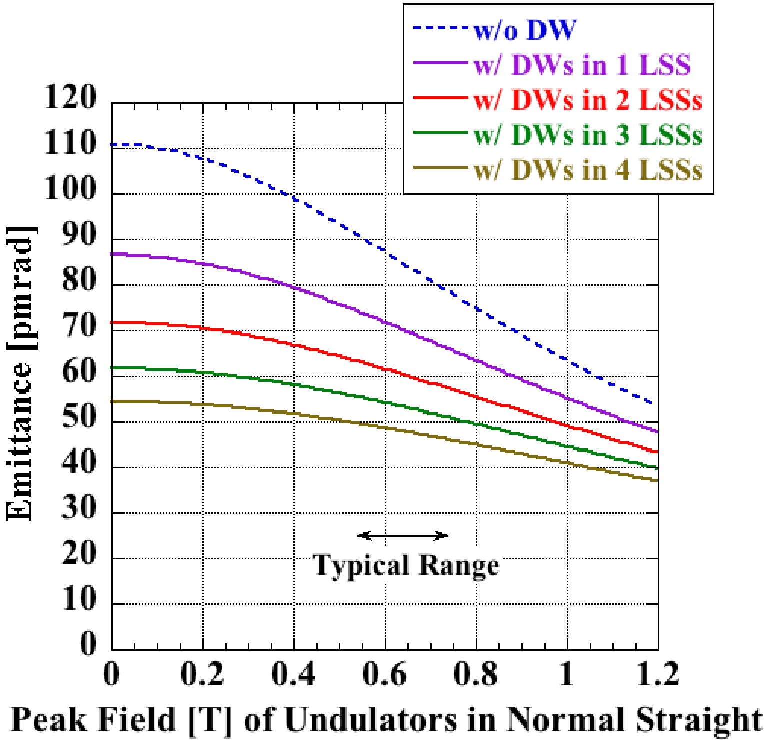
DW in LSS (cf. NSLS-II CDR, 2006):

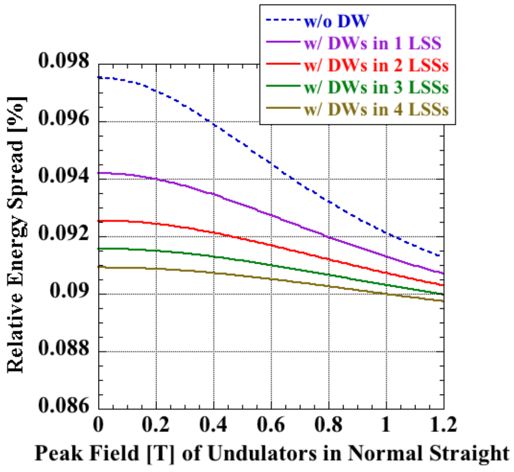
B_0 = 1.8T, λ_{DW} = 100mm

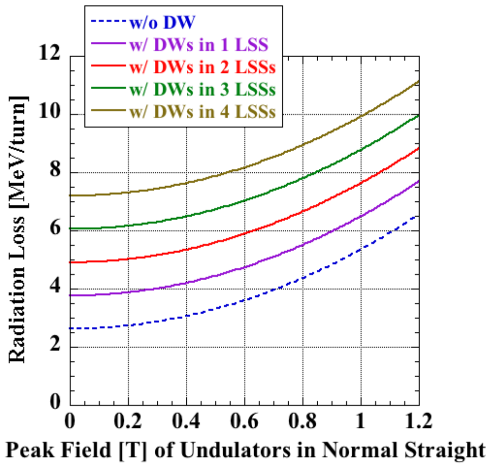
Undulator in Normal Straight:

λ_U = 22mm, N_U = 160, Total Number 34









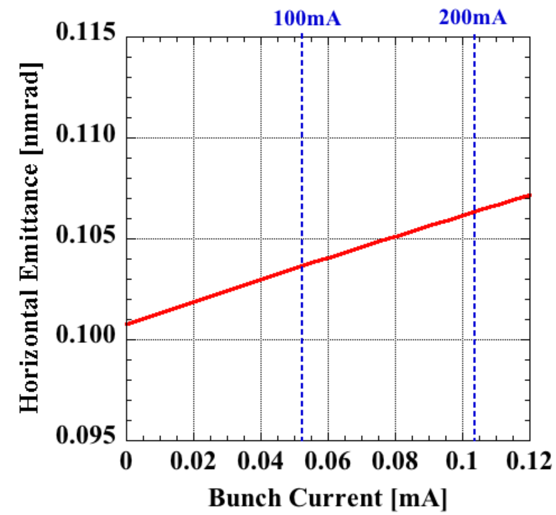
Heat load due to DWs needs to be considered separately.

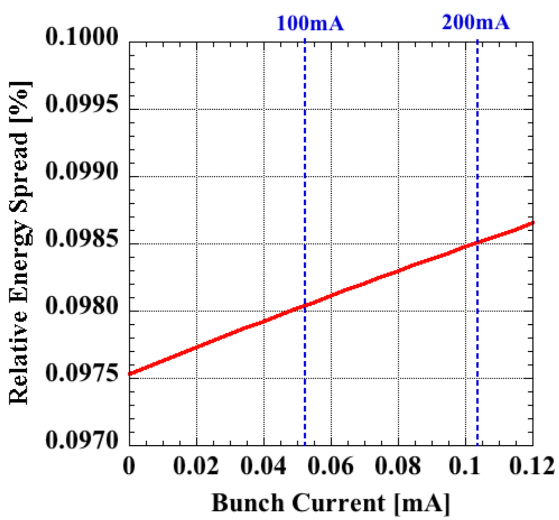
Intra-Beam Scattering

Filling: Multi-bunch (1920/2436)
RF voltage: 5MV
Bunch lengthening factor: 1.5

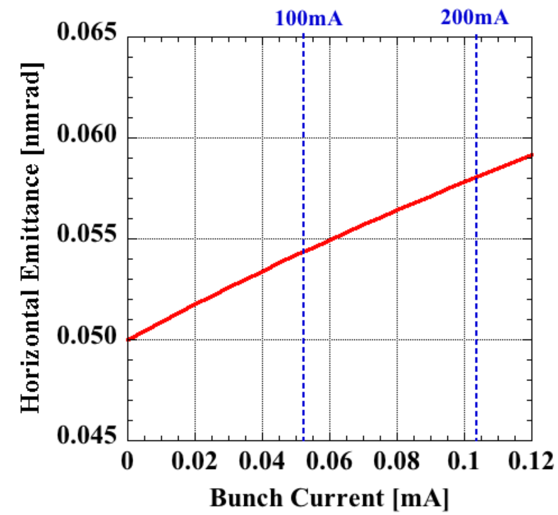
K.Bane, EPAC2002, p.1443;
PRST-AB 5 (2002) 084403

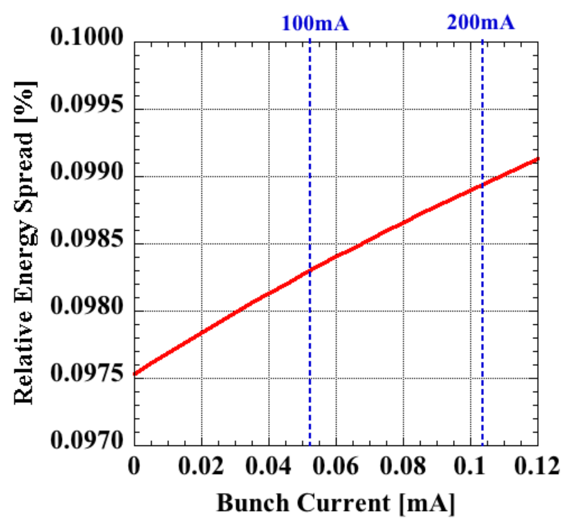
ε = 111pmrad, κ = 0.10





ε = 60pmrad, κ = 0.20





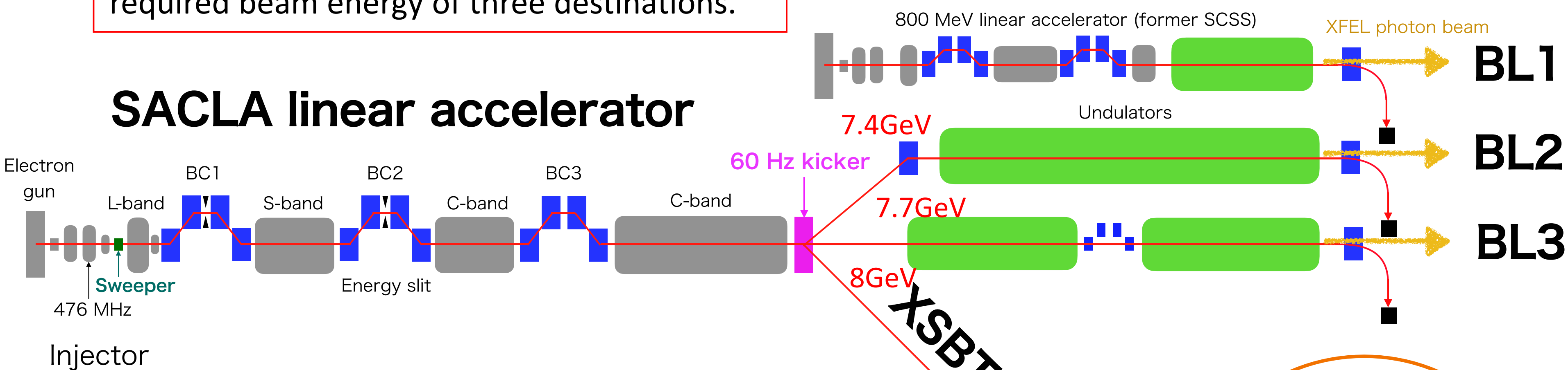
Some Topics

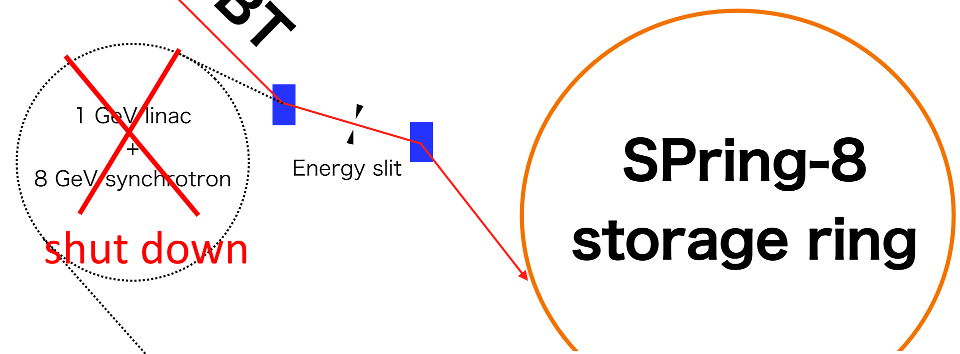
Topics: Beam Injection from SACLA Linac

T. Hara et al., PRAB 24, 110702 (2021); NAPAC 2022.

The number of RF cavities and their phases are changed bunch by bunch to satisfy the required beam energy of three destinations.

BL1: EUV and soft x-ray (20-150 eV)
BL2 and BL3: hard x-ray (4-15 keV)





SACLA electron beam

Energy **up to 8.5 GeV**

Bunch charge **~ 200 pC**

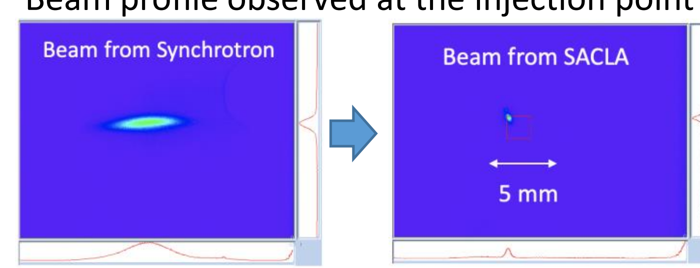
Repetition **60 Hz**

Emittance, Bunch Length, E.Spread

~ 0.15 nmrad, 20fs, 0.1% @ LINAC

~ 1 nmrad, 2ps, 0.1% @ injection point

Beam profile observed at the injection point

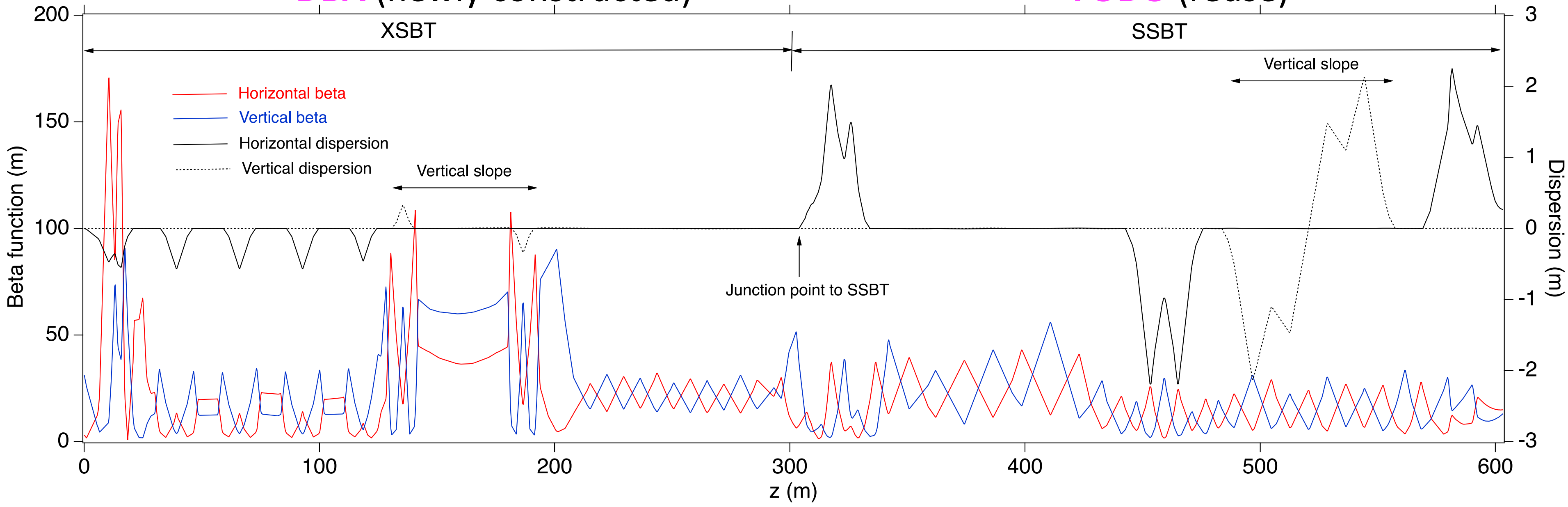


T. Hara, NAPAC 2022

Topics: Beam Injection from SACLA Linac

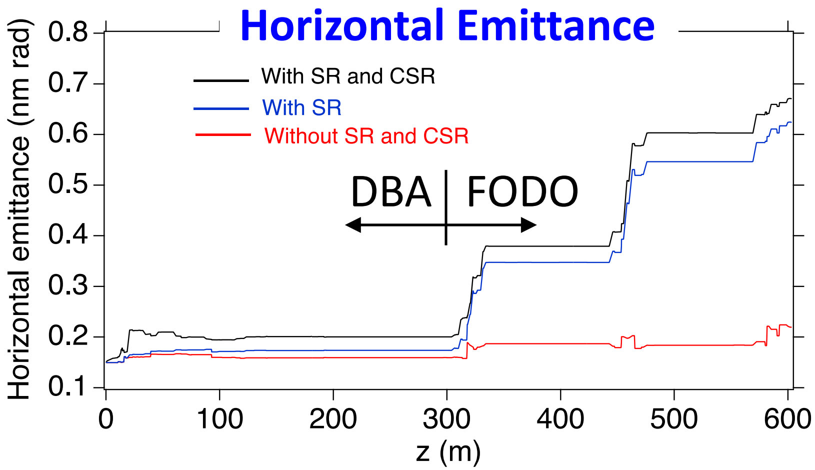
- XSBT (XFEL to Storage ring Beam Transport) is about 600 m long.
- First half of XSBT (300 m), connecting SACLA to an old synchrotron, was newly constructed with a DBA lattice.
- Last half of XSBT, connecting the old synchrotron to the SPring-8 storage ring, is the reuse of an old injection line with a FODO lattice.

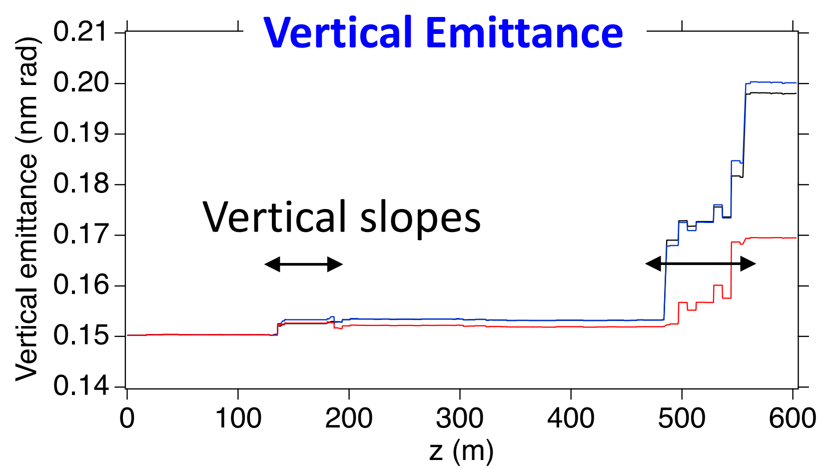
DBA (newly constructed) FODO (reuse)



T. Hara, NAPAC 2022

Topics: Beam Injection from SACLA Linac





Cal. by Elegant

Quantum excitation **Radiation damping**

$$\Delta\epsilon_{x,y} = \frac{55 r_e \hbar \gamma^5}{48\sqrt{3} m_e c} \int \frac{\mathcal{H}_{x,y}(z)}{\rho_{x,y}^3(z)} dz \quad >> \quad \Delta\epsilon_{x,y} \cong -\frac{2 r_e \gamma^3}{3} \int \frac{\epsilon_{x,y}(z)}{\rho_{x,y}^2(z)} dz$$

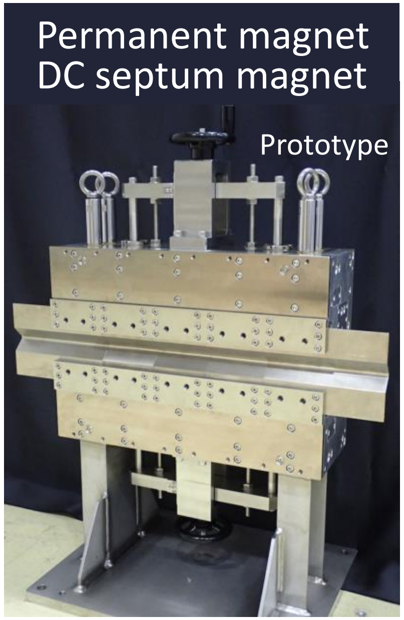
- Since the electron bunch is lengthened quickly at the first bend, emittance growth caused by CSR is limited.
- Main source of the emittance growth is quantum excitation due to synchrotron radiation.
- Due to very small emittance (0.15 nm-rad), radiation damping is negligible.
- Second-order dispersions also degrade the "emittance".

deduced from transverse phase space dist.

T. Hara, NAPAC 2022

Topics: Hardware developments for SPring-8-II

- Permanent magnet based bending magnets.
- Transparent injection (kickers*, power supplies, ceramic vacuum chambers).
- Compact in-vacuum undulator with magnetic-force cancellation.

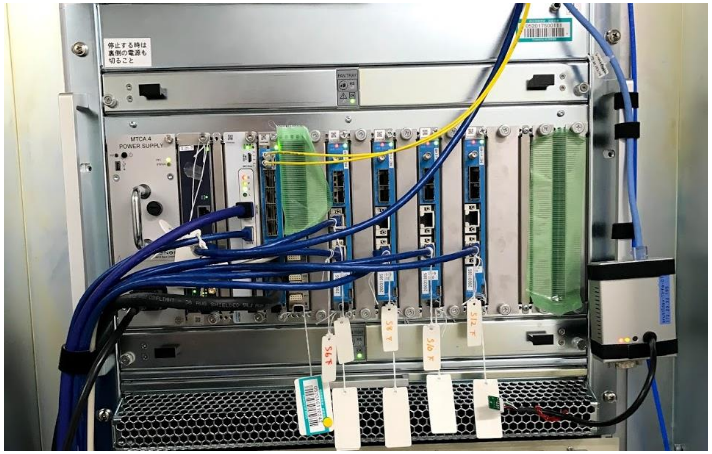


T. Taniuchi et al., PRAB 23, 012401 (2020).

Most developments for SPring-8-II have been applied for Japan 3 GeV ring (NanoTerasu) under construction.

- Electromagnets (quadrupoles, sextupoles, others).
- Stainless steel vacuum chambers with copper coating.
- MTCA.4 based beam position monitor (also running at present SPring-8).
- MTCA.4 based digital LLRF control system
- Electron beam dampers with beam shaker**.

Performance test will start soon on the real running machine.



* K. Fukami et al., Rev. Sci. Instrum. 93, 023301 (2022).

** T. Hiraiwa et al., PRAB 24, 114001 (2021).

Topics: What we learned from the experience of constructing a new 3GeV SR facility

(1) Review **vacuum system design** to compress fabrication period and shorten the time required for installation:

- Review **copper plating performance** required for stainless steel chamber surface.
- Reduce the number of **bellows** and **fiducial points** and optimize the structure of **photon absorbers** in order to simplify installation procedures of vacuum components.
- Simplify chamber connection mechanisms and procedures.
- No baking in the machine tunnel

(2) Promote **automation of magnet alignment procedures** for improving the efficiency of the work. For this purpose, it is needed to develop a program with good operability that works stably.

(3) Re-examine the **rigidity of magnet girders**: Rolling occurred on some girders, requiring an operation to bring them back in the tunnel.

(4) Evaluate the results of the **magnet and chamber alignment performed in the actual ring tunnel** and reflect this experience in SPring-8-II.

In SPring-8-II, unlike the greenfield 3GeV project, it is necessary to **dismantle a lot of current accelerator components and install new ones** within a short blackout period. Then, **strict project management** is required in fabrication, installation and adjustment in order to make the new light source available to users as quickly as possible.

Summary

■ Aiming at higher brilliance, higher coherence and less power consumption, we will be back to the SPring-8-II project in 2024 after constructing a new 3GeV SR facility and performing the beam commissioning.

■ Problems identified through the construction of the 3GeV facility will be solved, and the knowledge gained will be applied to the SPring-8-II project.

■ The baseline design of the new storage ring lattice is almost complete.

■ The replacement of the injector has already been completed, and the SCALA linac is fully used as a high-quality beam injector in user operation.

Acknowledgements

We thank Dr. Pantaleo Raimondi for showing us the tuning method of energy-dependent optics matching in LSS and for providing examples of such lattice data.

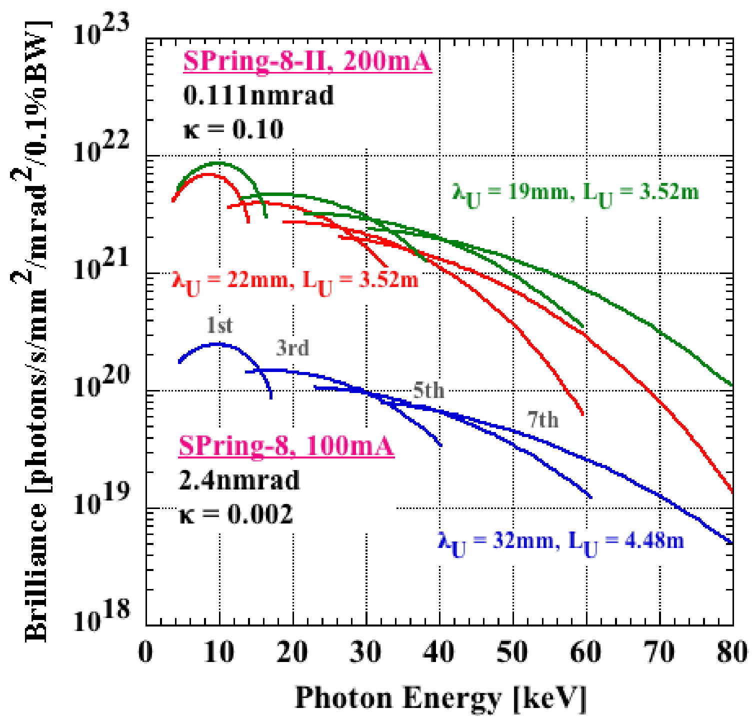
Thank you for your attention

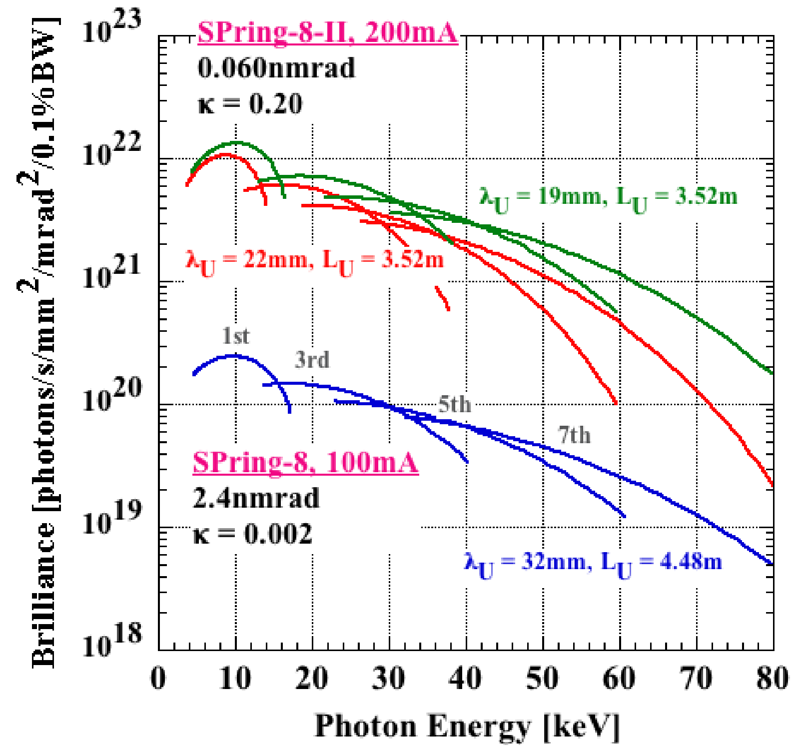
<u>backup slides</u>

SPring-8-II Project

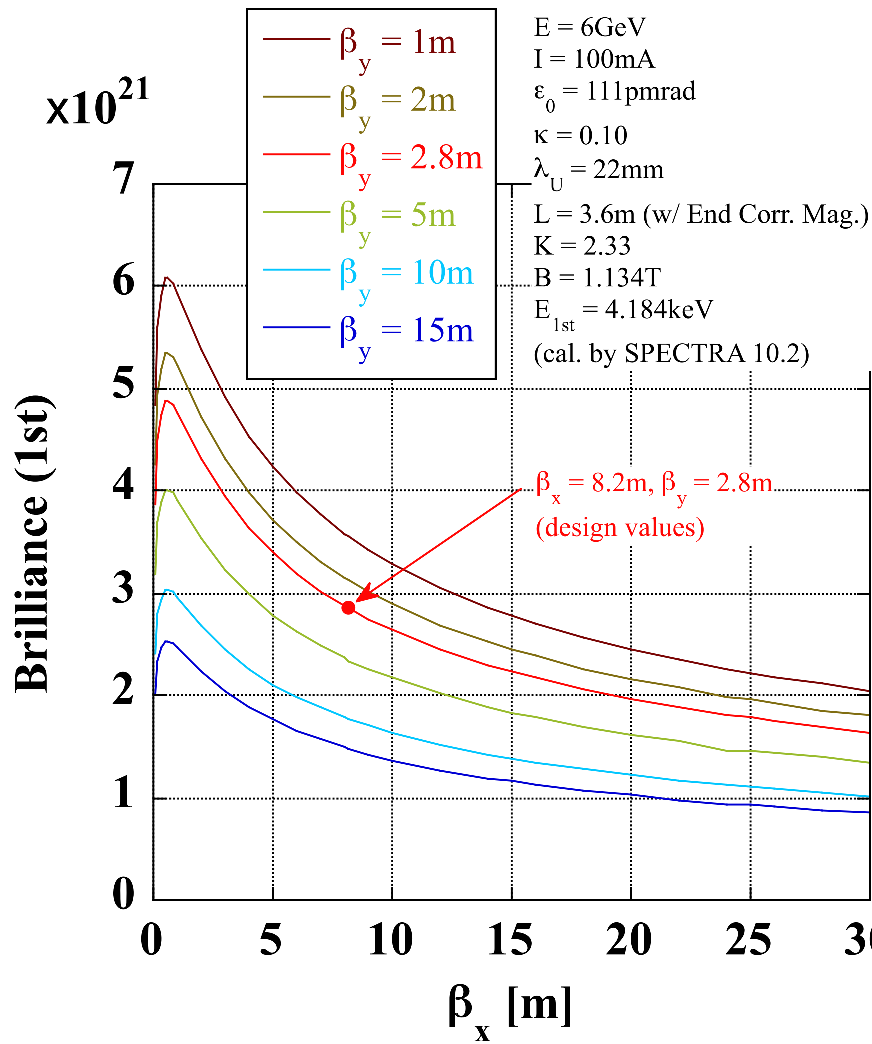
typical cases
(Cal. by SPECTRA)

wo Extra Damping → w/ Damping by DWs and Undulators





BETA-dependence of Brilliance

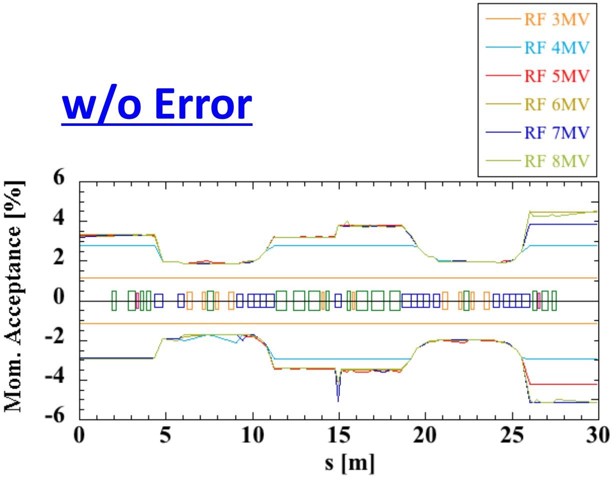


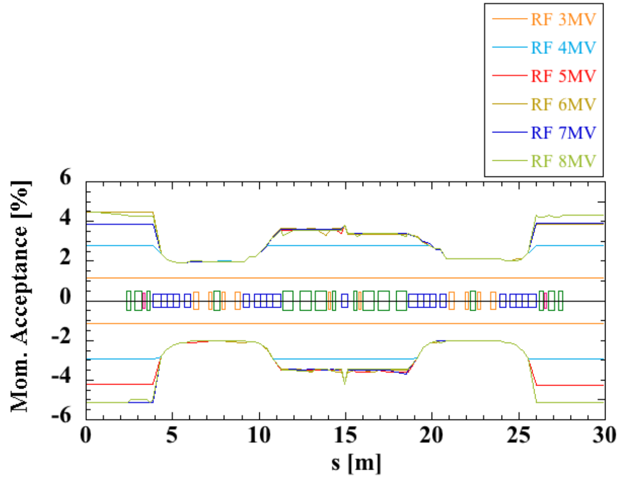
cal. by SPECTRA

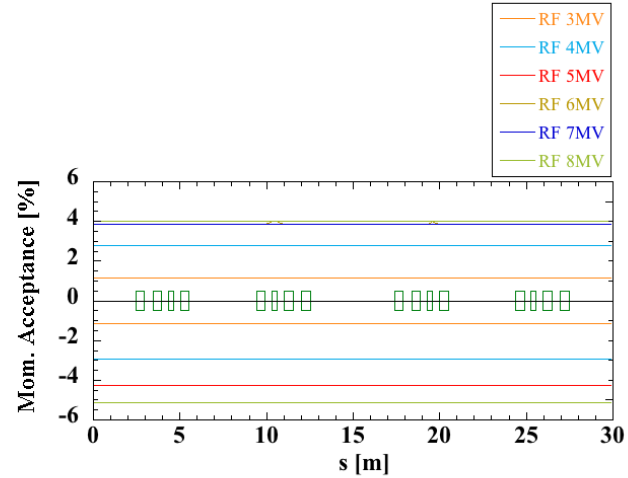
MA vs. RF Voltage

INJ(C01) NC(C02) LSS(C06)

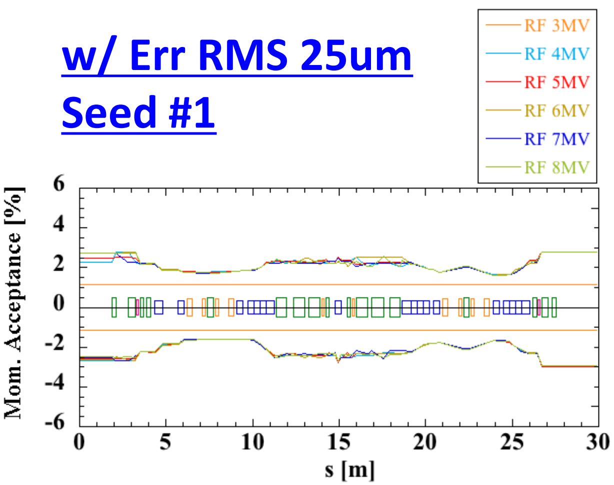
w/o Error

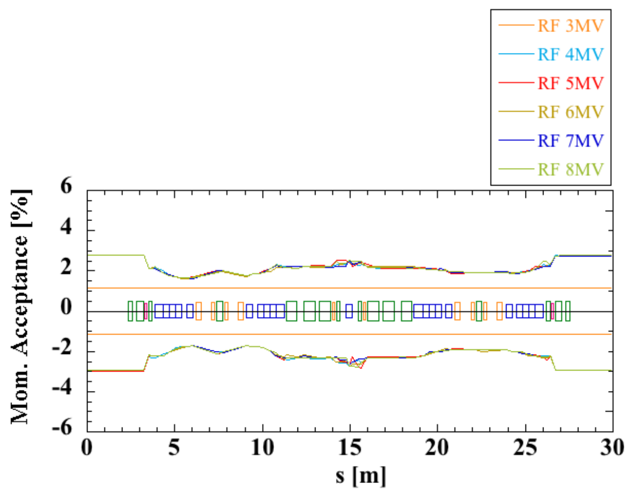


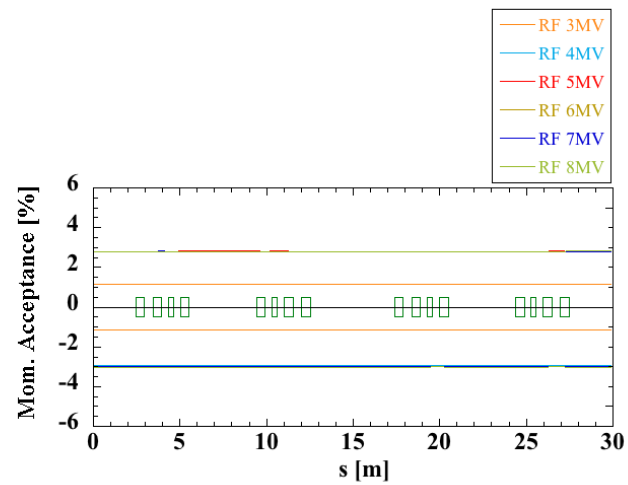




w/ Err RMS 25um
Seed #1







Non-Linear Kicker (NLK)

Emittance of coherent betatron oscillation:

$$\varepsilon = \gamma x^2 + 2\alpha x x' + \beta x'^2$$

Kick angle to minimize the emittance:

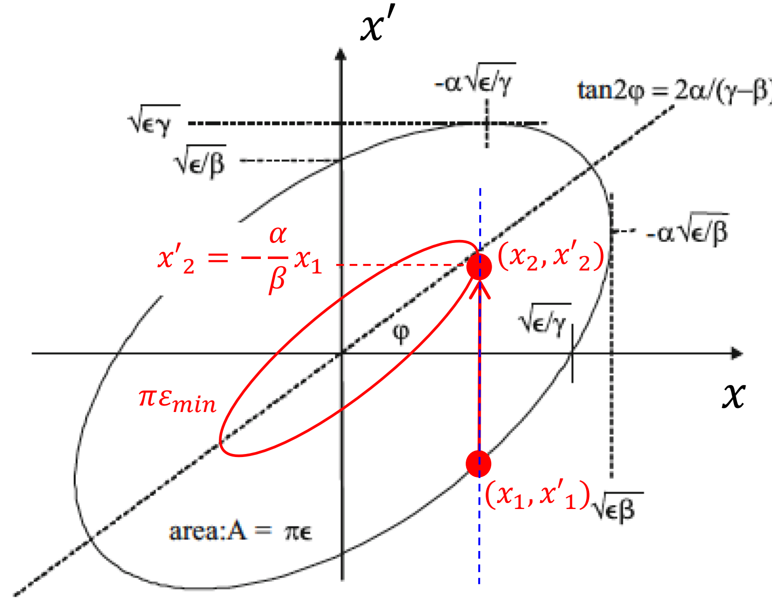
$$\frac{\partial \varepsilon}{\partial x'} = 2\alpha x + 2\beta x' = 0$$

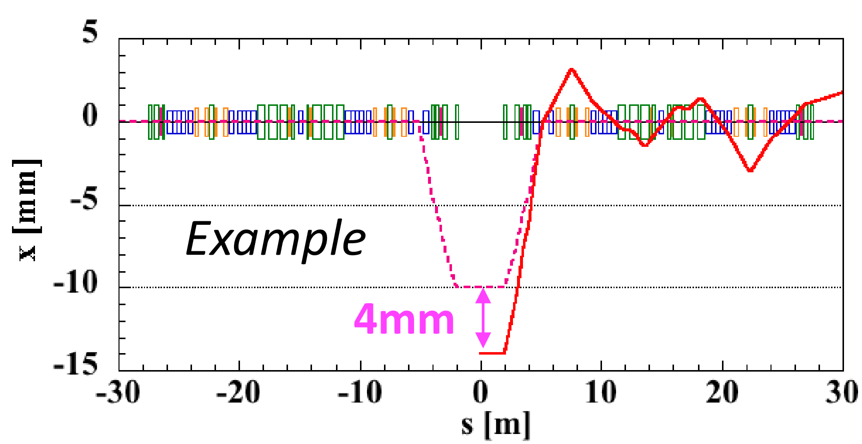
$$x' = -\frac{\alpha}{\beta} x$$

$$\Delta x' \equiv x'_2 - x'_1 = -\frac{\alpha}{\beta} x_1 - x'_1$$

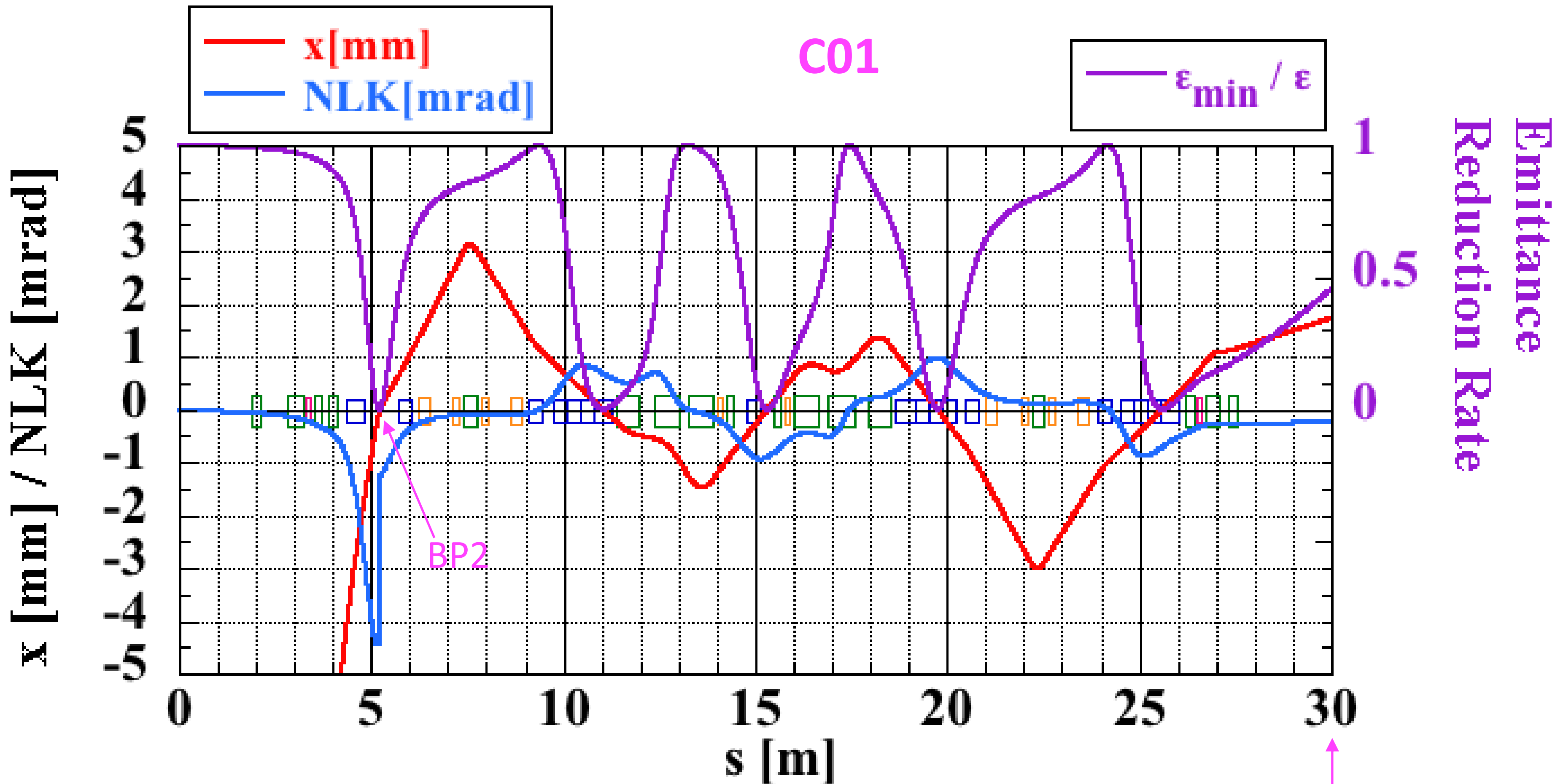
Minimum emittance:

$$\varepsilon_{min} = \frac{x_1^2}{\beta}$$





Suppression of Coh. Betatron Osc. by NLK

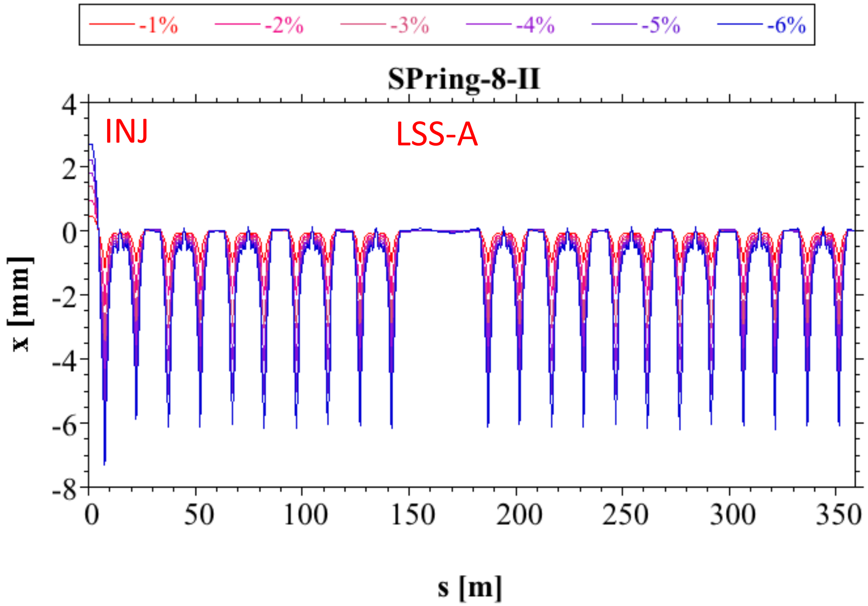


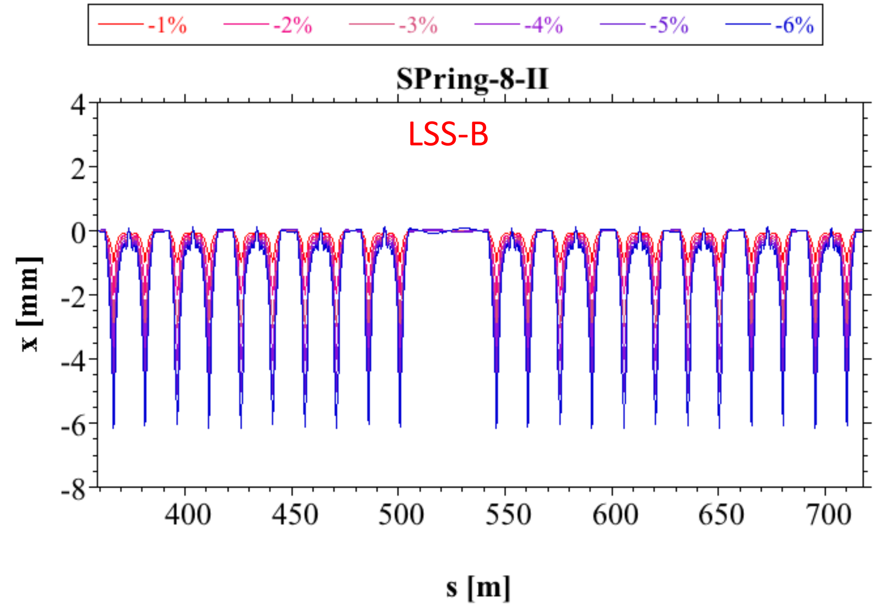
Example

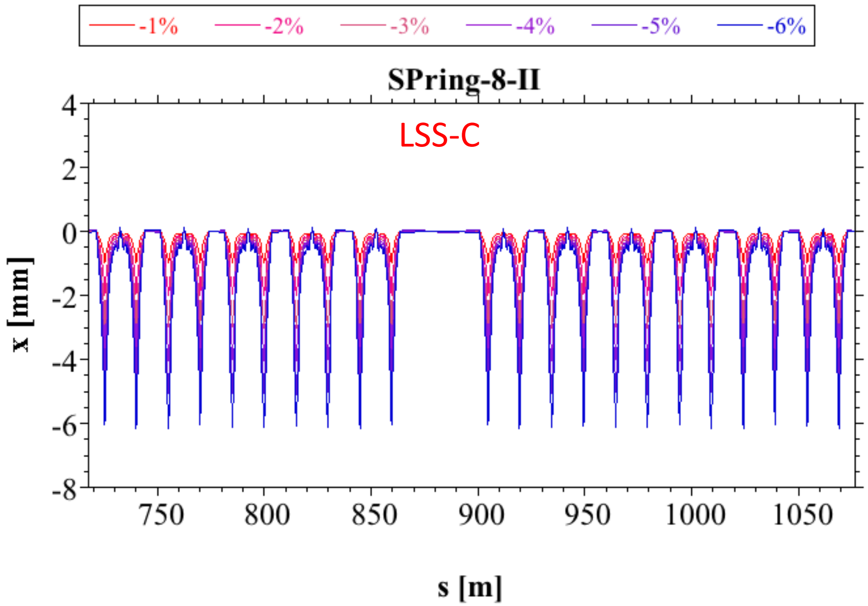
NLK = -0.232925mrad @ x = +1.7033490mm
Emit. Reduction Rate = 0.443

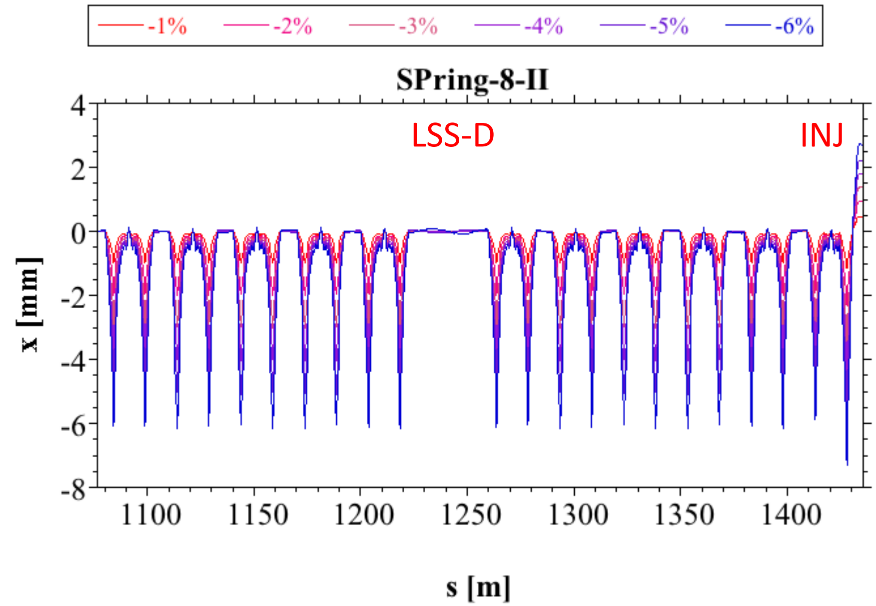
NLD by CETRA Tracking

Δp/p < 0



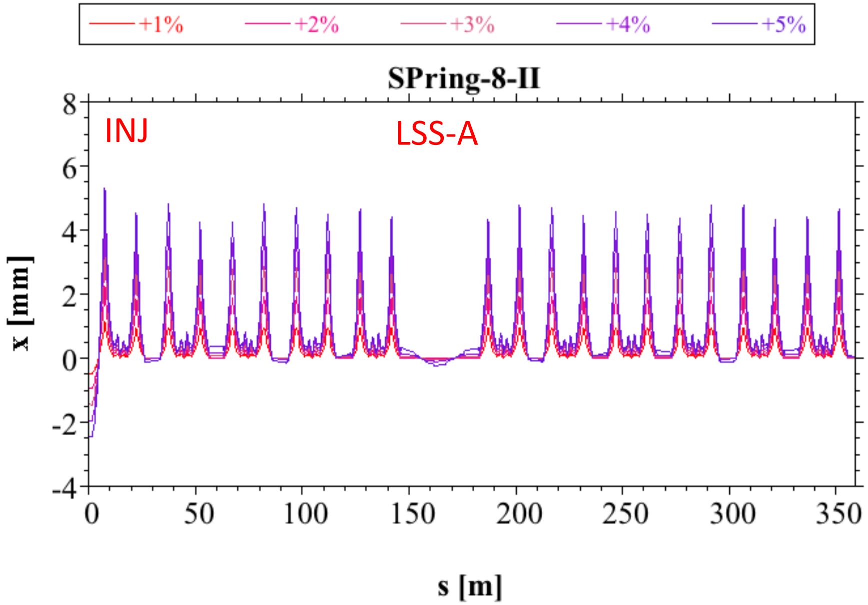


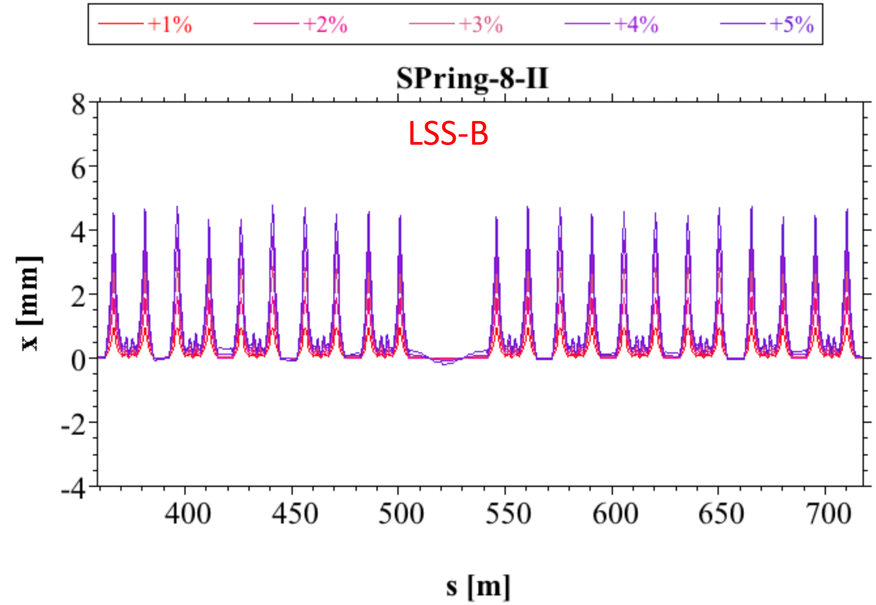


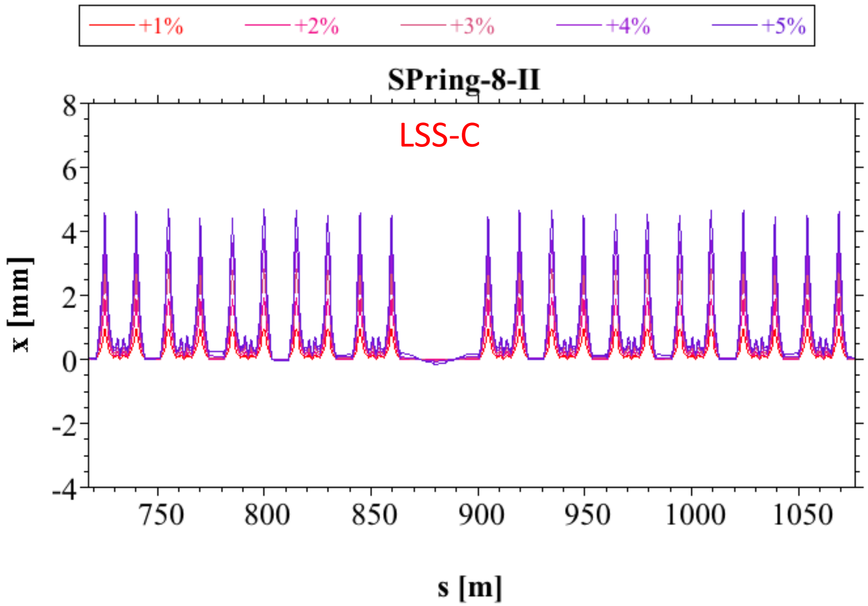


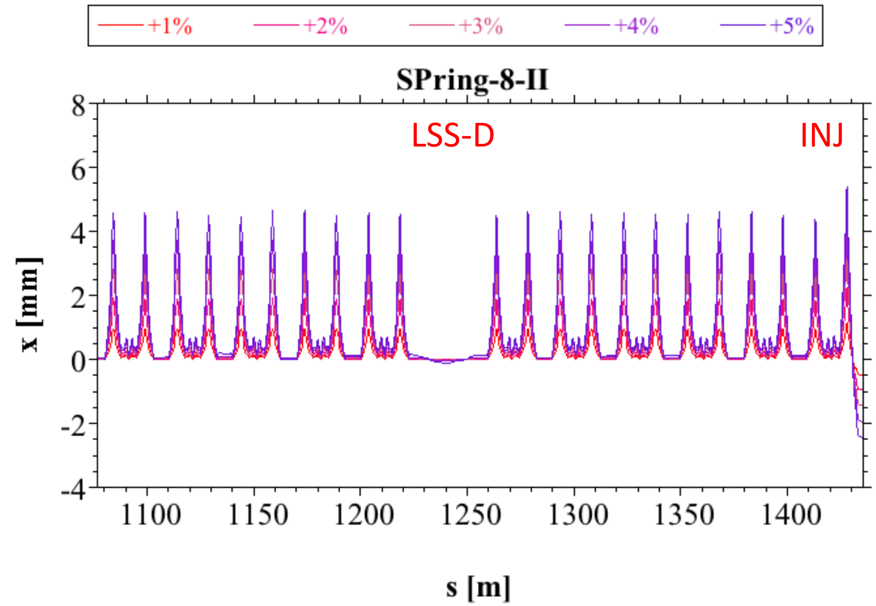
NLD by CETRA Tracking

$\Delta p/p > 0$





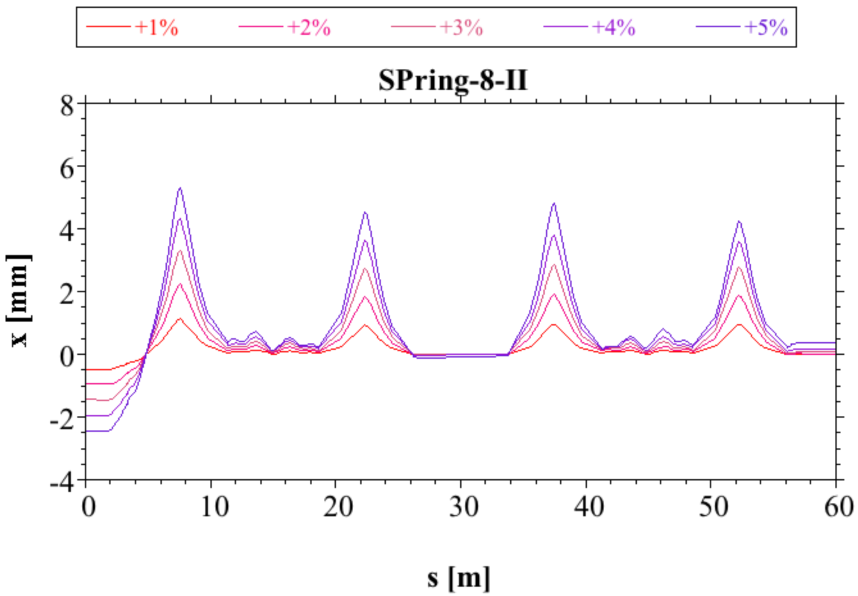




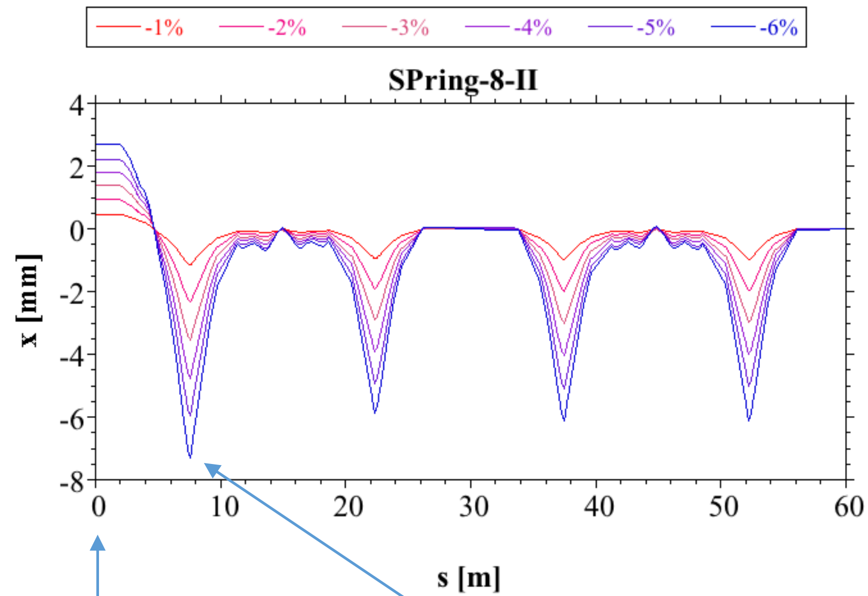
NLD by CETRA Tracking

around inj. point

$\Delta p/p > 0$

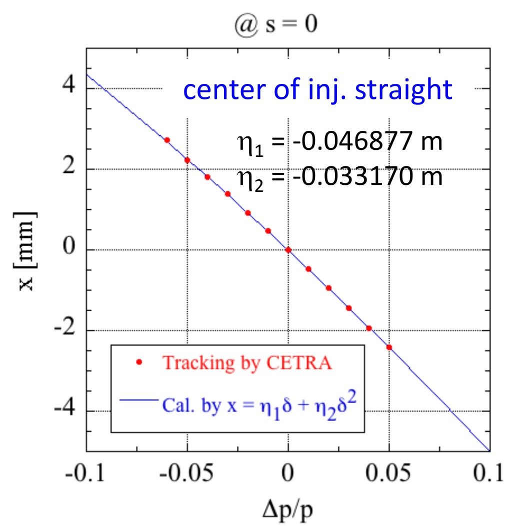


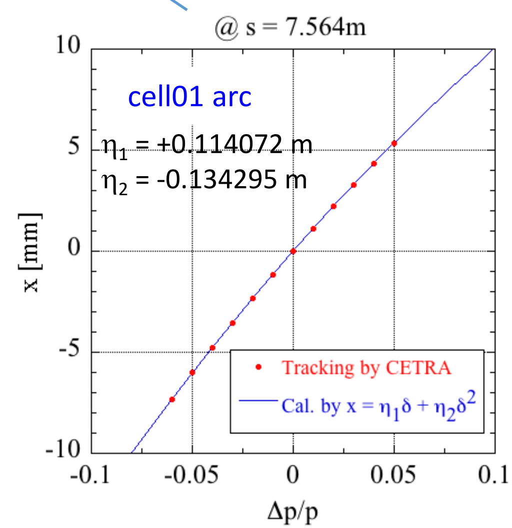
$\Delta p/p < 0$



Tracking data (markers) agrees well with perturbation calculation (solid lines):

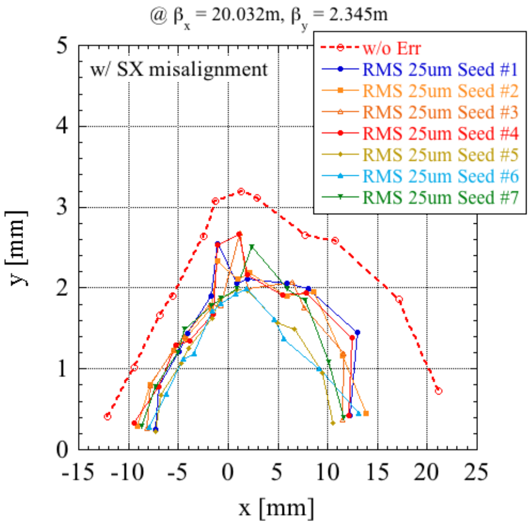
$$x = \eta_1\delta + \eta_2\delta^2$$

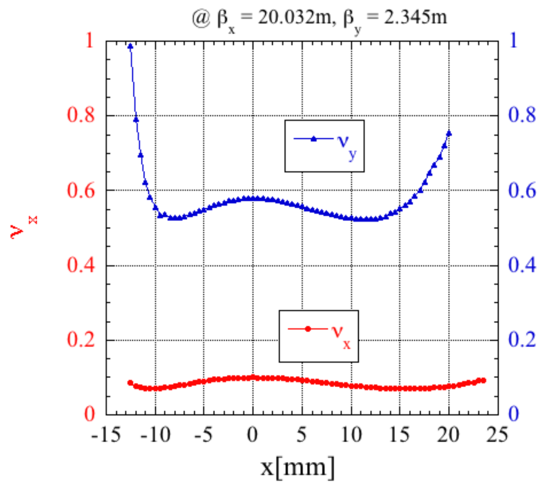


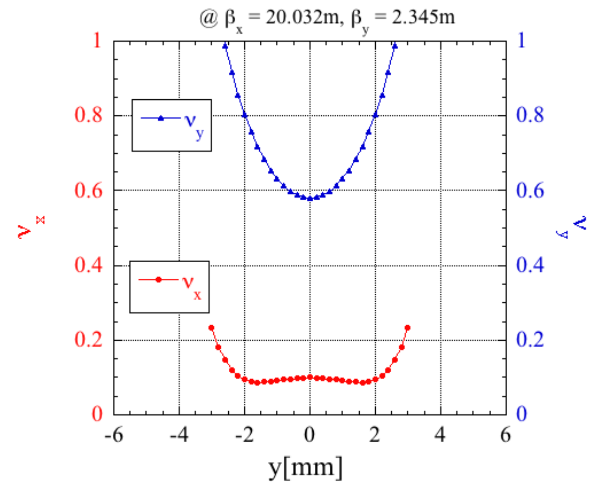


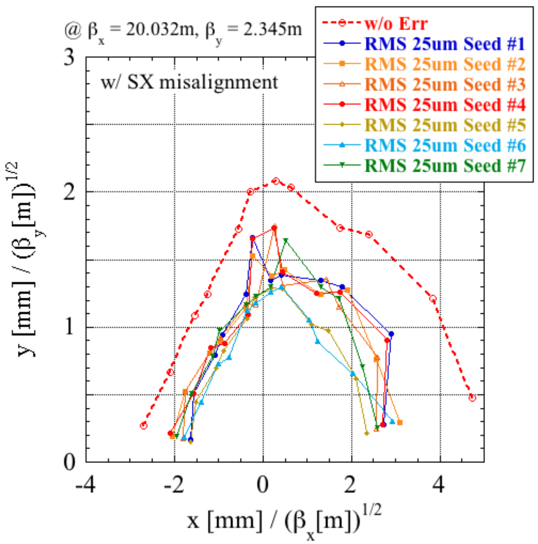
Dynamics

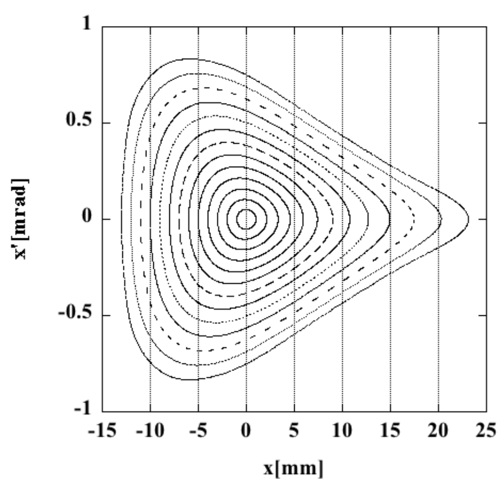
for RING (= 42*NC + 2*INJ + 4*LSS) , by CETRA





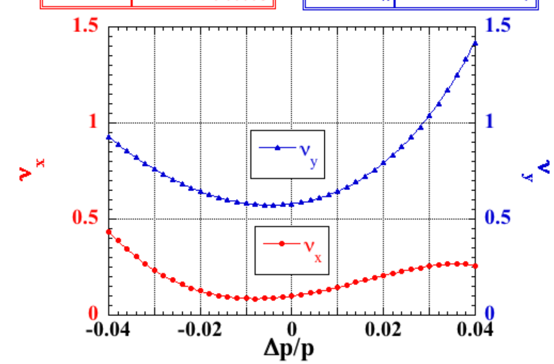






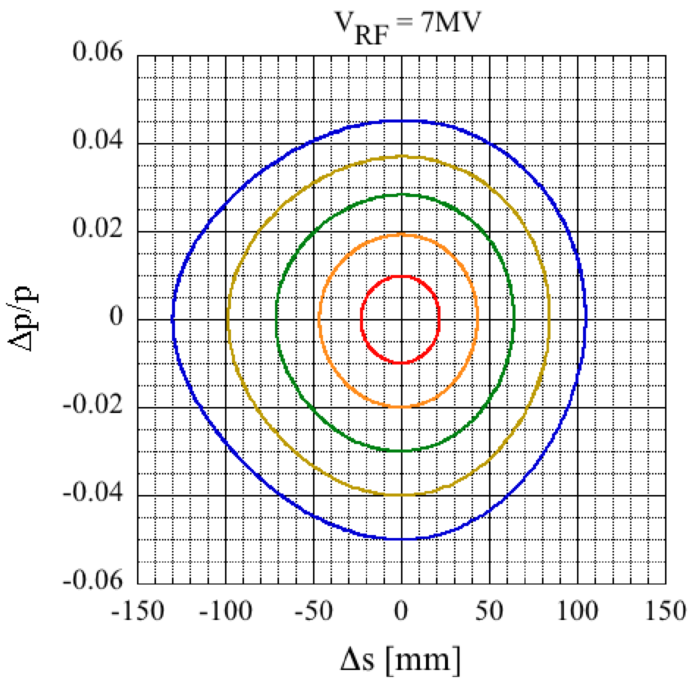
Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	0.099805
M1	3.2291
M2	168.52
M3	-2971.5
M4	-6479.9
M5	-2.6583e+5
M6	-1.2858e+6
R	0.99998

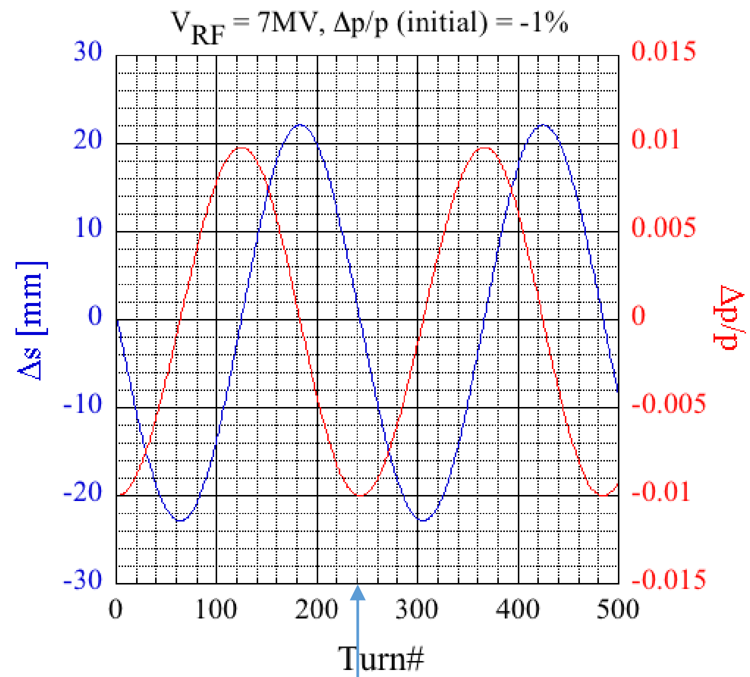
Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	0.58018
M1	3.0078
M2	343.21
M3	1654.4
M4	6216.5
M5	1.7091e+5
M6	7.0383e+6
R	1



Longitudinal Phase Space

RF 7MV, by CETRA





$\Delta s<0$: front side of bunch
A point in phase space rotates clockwise.

ν_s = 0.0041561
$1/\nu_s$ = 240.61 turn
@ V_{RF} = 7MV

CHROM2 Cor. by Octupoles

Octupole: $g(s) \equiv \dfrac{B'''(s)}{[B\rho]}$

Chromaticity

$$\xi_x^{(2)} = \frac{1}{8\pi}\int_0^C ds g\beta_x\eta_x^2$$

$$\boxed{\xi_y^{(2)} = \frac{-1}{8\pi}\int_0^C ds g\beta_y\eta_x^2}$$

$$\nu_x = \nu_{x0} + \xi_x^{(1)}\delta + \xi_x^{(2)}\delta^2 + \cdots$$

$$\nu_y = \nu_{y0} + \xi_y^{(1)}\delta + \xi_y^{(2)}\delta^2 + \cdots$$

Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	0.099805
M1	3.2291
M2	168.52
M3	-2971.5
M4	-6479.9
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Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	0.58018
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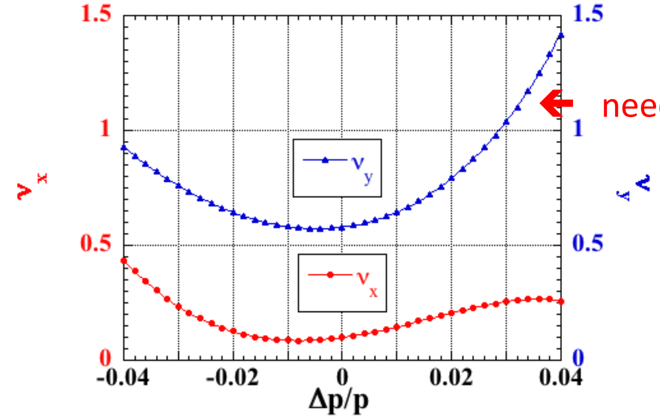


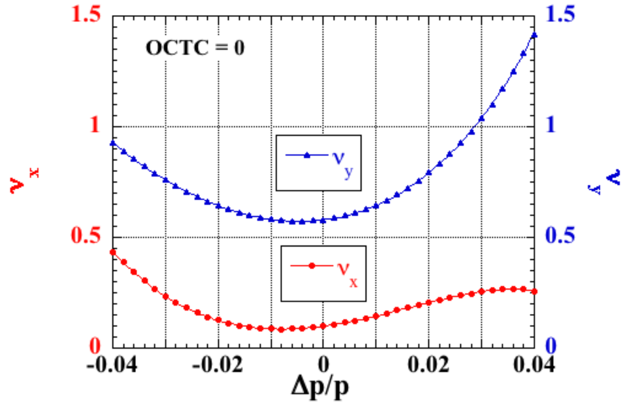
need to suppress $\xi_y^{(2)}$

ADTS

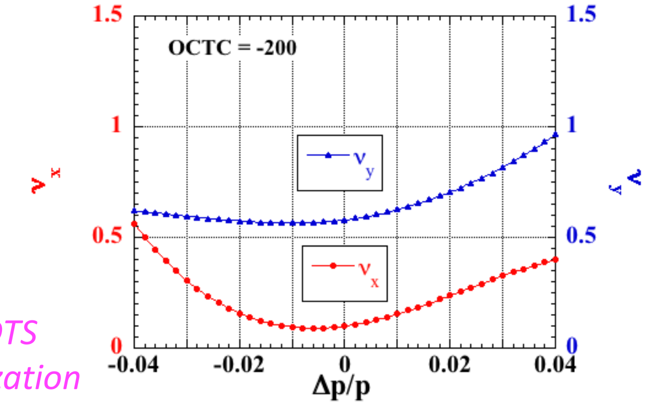
$$\nu_x = \nu_{x0} + J_x\frac{1}{16\pi}\int_0^C ds g\beta_x^2 - J_y\frac{1}{8\pi}\int_0^C ds g\beta_x\beta_y$$

$$\nu_y = \nu_{y0} - J_x\frac{1}{8\pi}\int_0^C ds g\beta_x\beta_y + J_y\frac{1}{16\pi}\int_0^C ds g\beta_y^2$$

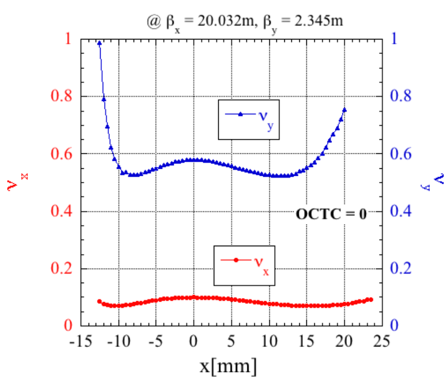
Effects of Octupoles in the Arc (Tentative)

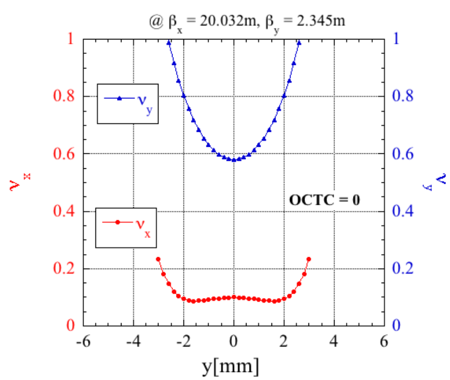


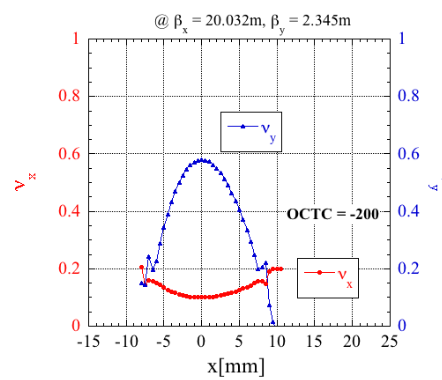
OCTC = -200

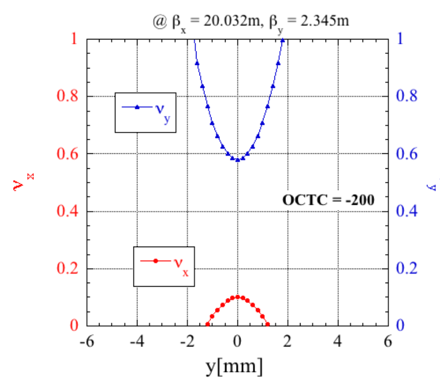


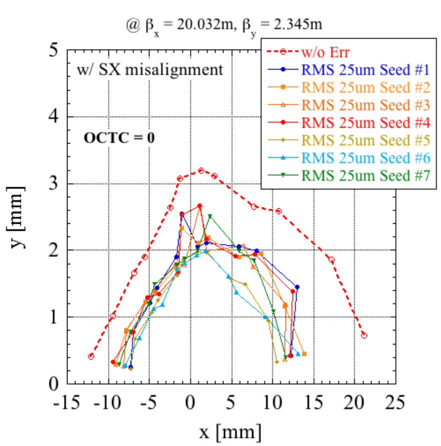
w/o ADTS optimization



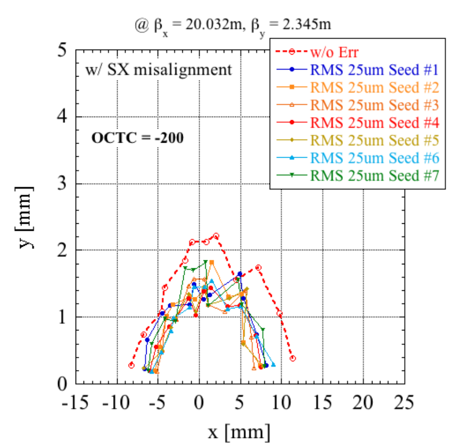




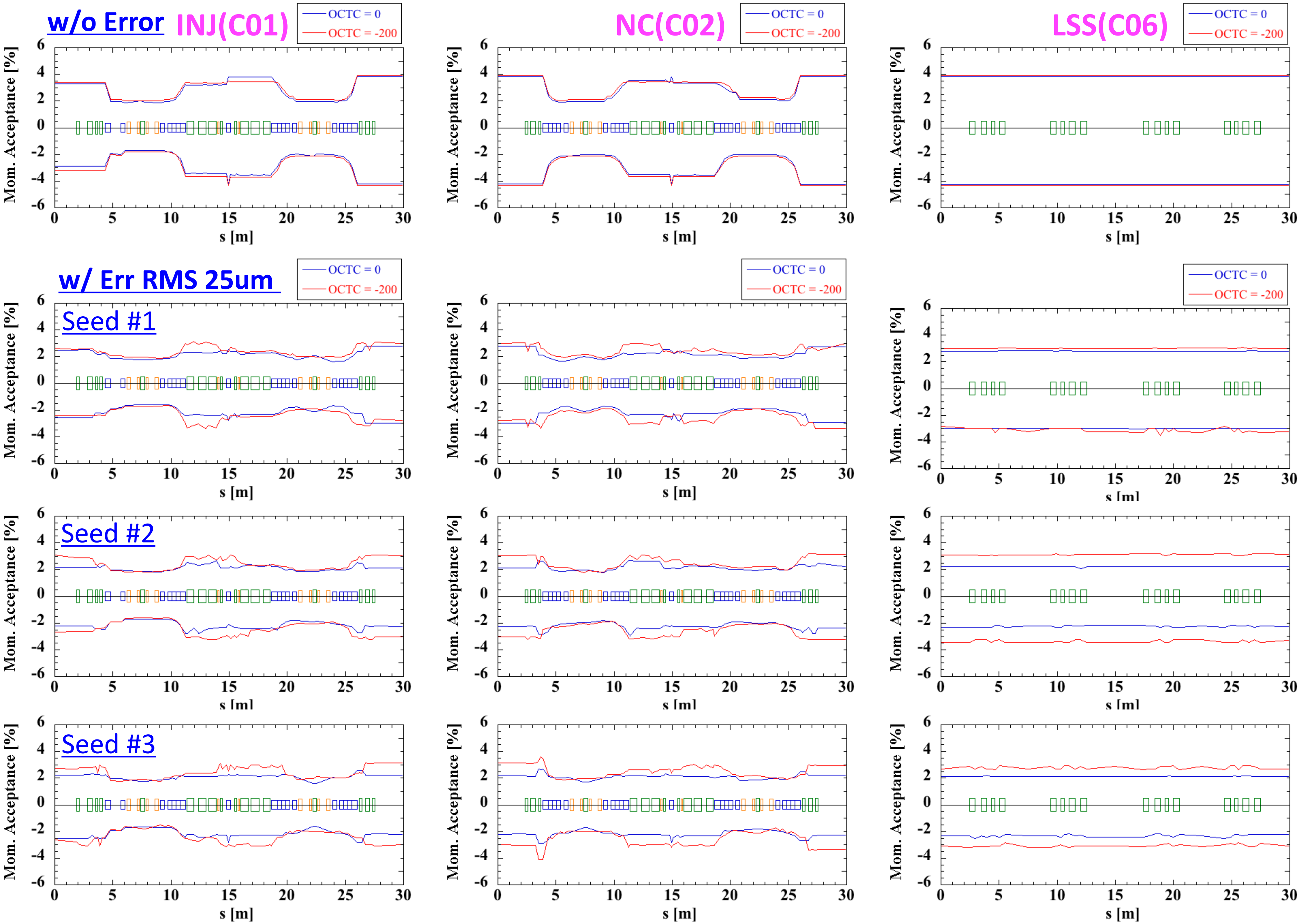




DA w/o Sy. Osc.



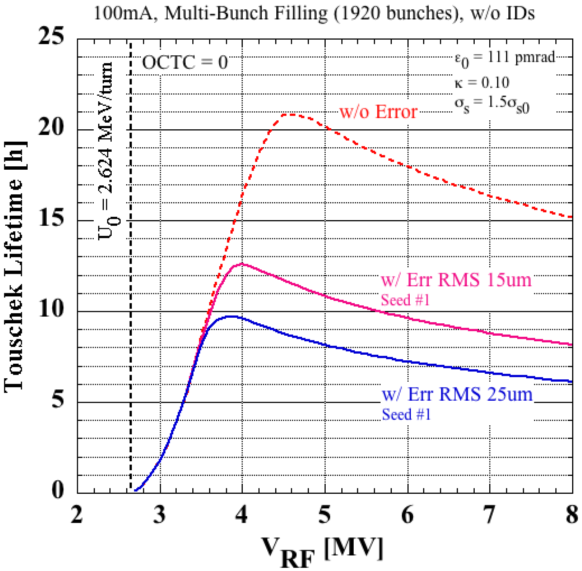
Effects on Local MA



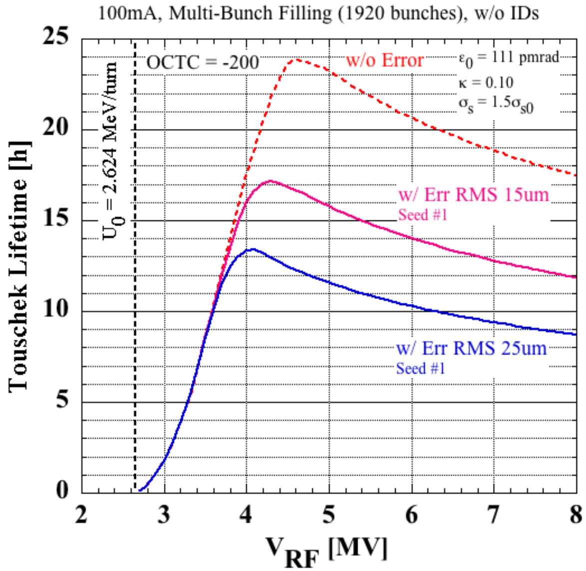
Effects on Touschek Lifetime

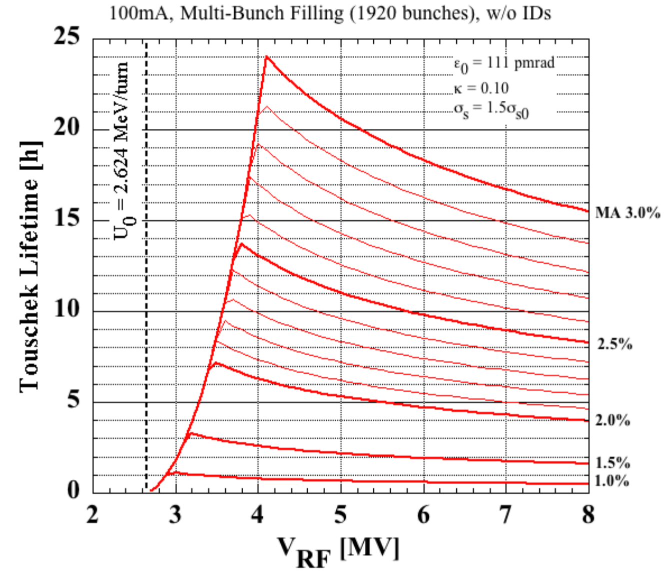
Coupling 10%, Bunch Lengthening Factor = 1.5, Filling = 1920 bunches, 100mA

OCTC = 0



OCTC = -200 (w/ CHROM2 cor.)

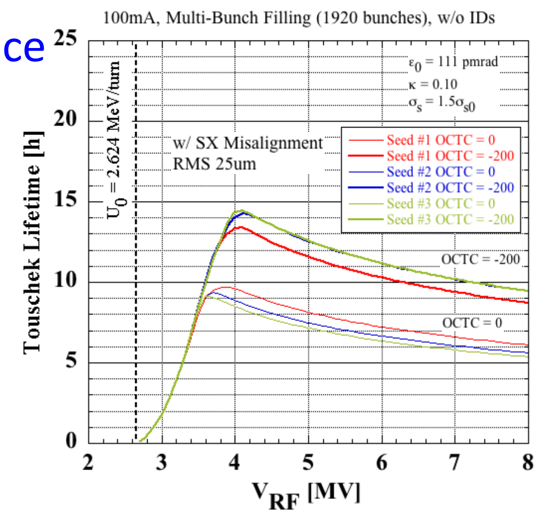




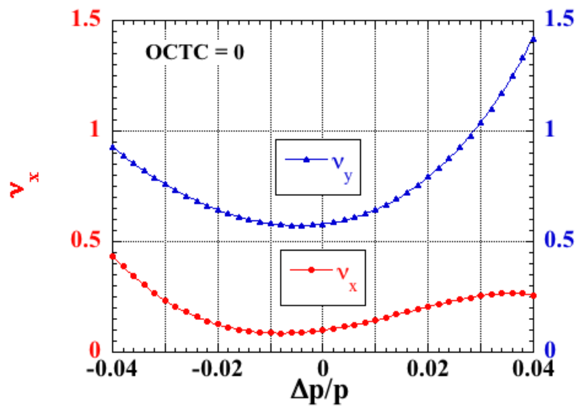
Error Seed Dependence

RMS 25um

$\Delta\tau$〜1h (@ 100mA)

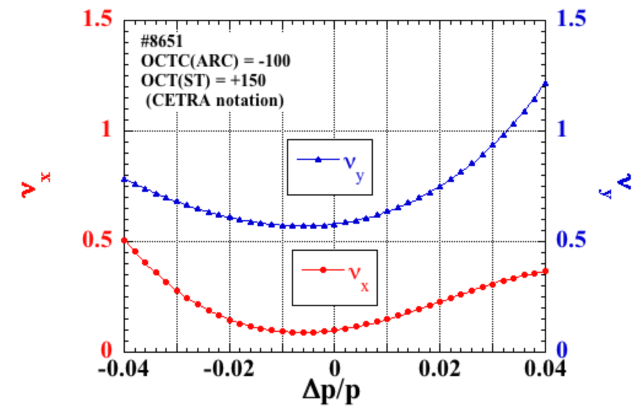


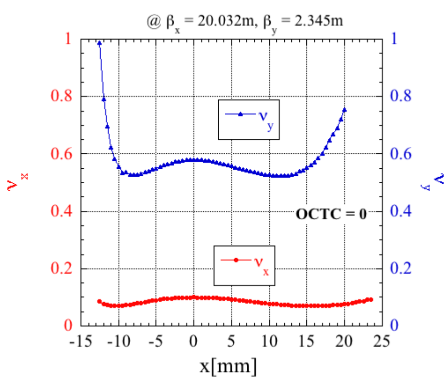
Effects of Octupoles in the Arc (Tentative)

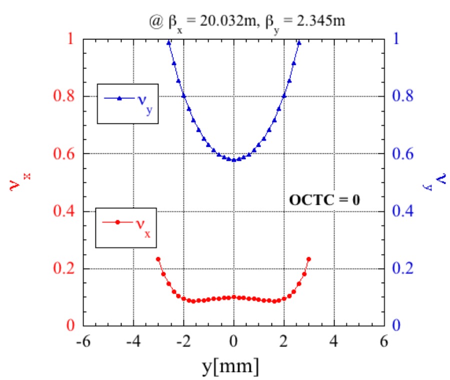


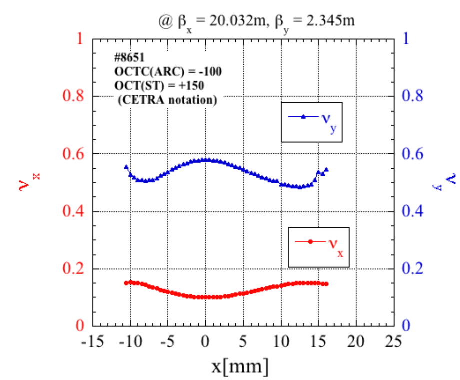
OCTC = -100

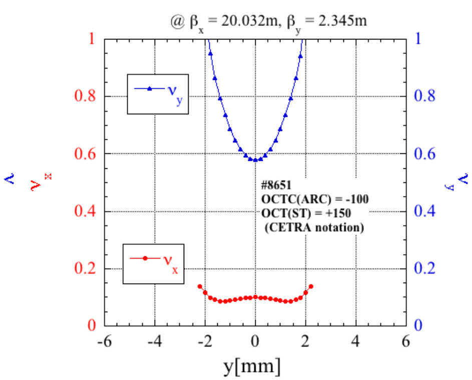
(weaker)

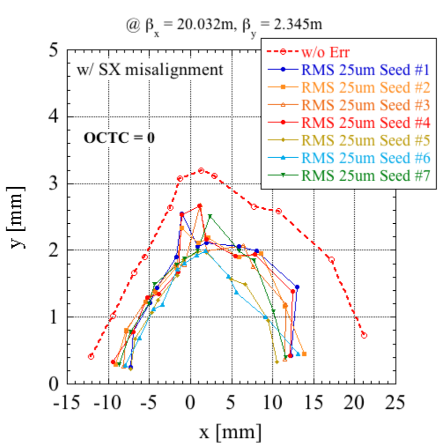












DA w/o Sy. Osc.