Topics for Discussion

(1) manipulation of non-linearity of the ring
to enlarge the dynamic aperture

(2) realization of efficient injection scheme
to reduce the oscillation amplitued

Other Topics

Comments, New Idea

(1) manipulation of non-linearity

(1.1) sextupole optimization (resonance suppression)
for on- and off-momentum particles

(1.2) octupole magnets (amplitude-dependent tune shift)

(1.3) modified (Gaussian) sextupole magnets

(1.4) cancellation of sextupole kicks
"-I transformation" / "interleaved" / "noninterleaved"
"sextupole symmetrization (SLS)"

.....

(1.3) modified (Gaussian) sextupole magnets

M.Cornacchia and K.Halbach, NIM A290 (1990) 19

$$B_x = Se^{K(x^2-y^2)}\left[\left(x^2-y^2\right)\sin\left(2Kxy\right)+2xy\cos\left(2Kxy\right)\right]$$

$$B_y = Se^{K(x^2-y^2)}\left[\left(x^2-y^2\right)\cos\left(2Kxy\right)-2xy\sin\left(2Kxy\right)\right]$$

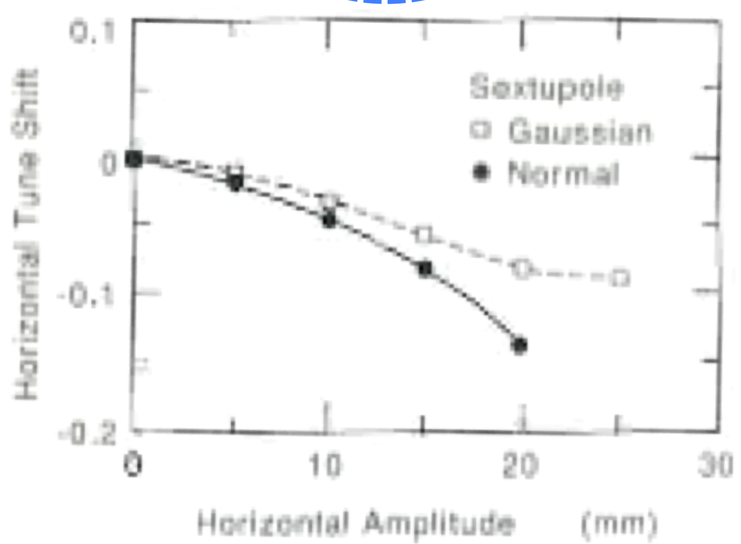


Fig. 4. Horizontal tune shift versus maximum betatron amplitude for normal and Gaussian sextupoles.

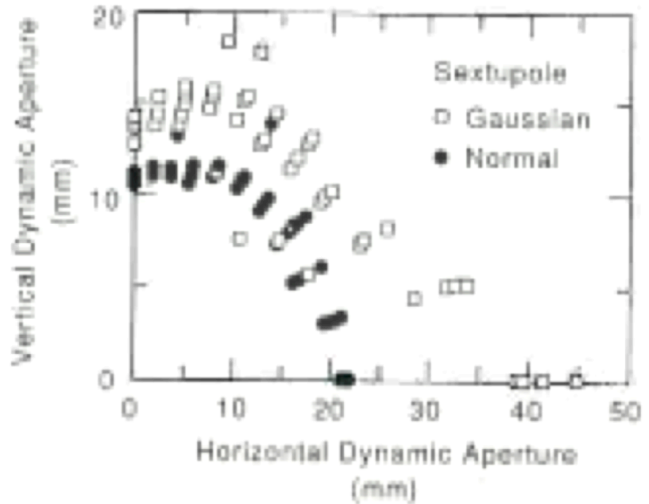


Fig. 6. Dynamic aperture of five different machines having magnetic field gradient errors randomly distributed in the quadrupoles. The rms value of the distribution of the relative gradient errors is 0.001.

(1.3) modified (Gaussian) sextupole magnets

J.C.Lee and W.Wiedemann, EPAC98

K < 0 for SF (since x > y usually)
K > 0 for SD (since x < y usually)
one parameter search

=> **ring w/o error for $\delta = 0$: Effective**
ring w/o error for δ != 0 : Not Effective
ring w/ error : Not Effective

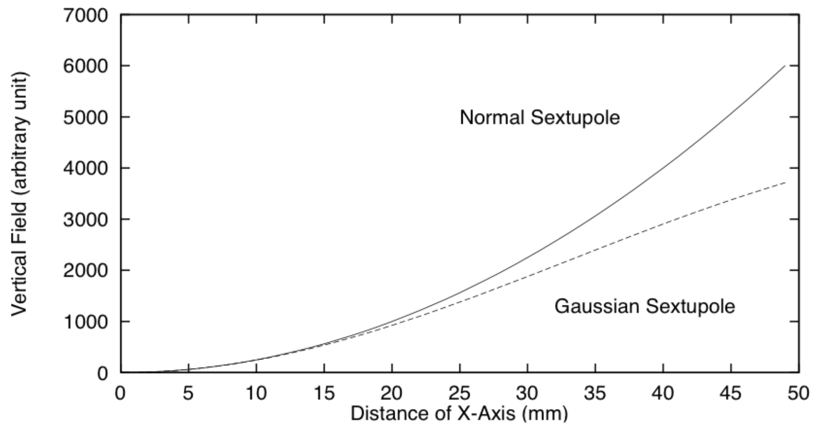


Figure 2: Vertical magnetic field along the horizontal axis for the normal and Gaussian sextupoles with $K = 200\ m^{-2}$.

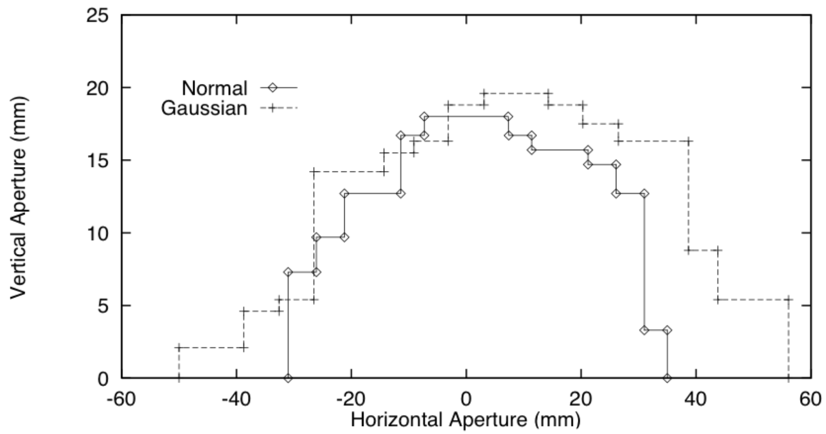


Figure 5: Comparison of on-momentum dynamic aperture of bare lattice for the normal and the chosen Gaussian sextupoles.

(1.3) modified (Gaussian) sextupole magnets

What we tried (Y.Shimosaki)

$$B_x = Se^{K\left(x^2-y^2\right)}\left[\left(x^2-y^2\right)\sin\left(2Kxy\right)+2xy\cos\left(2Kxy\right)\right]$$

$$\approx S\left[1+K\left(x^2-y^2\right)\right]\left[\left(x^2-y^2\right)2Kxy+2xy\right]$$

$$\approx 2Sxy+4SK\left(x^2-y^2\right)xy$$

$$B_y = Se^{K\left(x^2-y^2\right)}\left[\left(x^2-y^2\right)\cos\left(2Kxy\right)-2xy\sin\left(2Kxy\right)\right]$$

$$\approx S\left[1+K\left(x^2-y^2\right)\right]\left[x^2-y^2-4Kx^2y^2\right]$$

$$\approx S\left(x^2-y^2\right)+SK\left(x^4-6x^2y^2+y^4\right)$$

sextupole + decapole

(1.3) modified (Gaussian) sextupole magnets

$$H = H_0 + U$$

$$U = \frac{S}{B\rho}\left\{\left(\frac{1}{3}x^3 - xy^2\right) + K\left(\frac{1}{5}x^5 - 2x^3y^2 + xy^4\right)\right\}$$

=> $$U = \frac{S}{B\rho}\left\{\underline{\underline{\left(\frac{1}{3} + \frac{K}{5}x^2\right)}}x^3 + \underline{\underline{\left(-1 - 2Kx^2 + Ky^2\right)}}xy^2\right\}$$

y=0 y!=0

=> $$\underline{\underline{\frac{1}{3} + \frac{K}{5}\left\langle 2\beta_x I_x \frac{1+\cos 2\psi_x}{2}\right\rangle}}$$

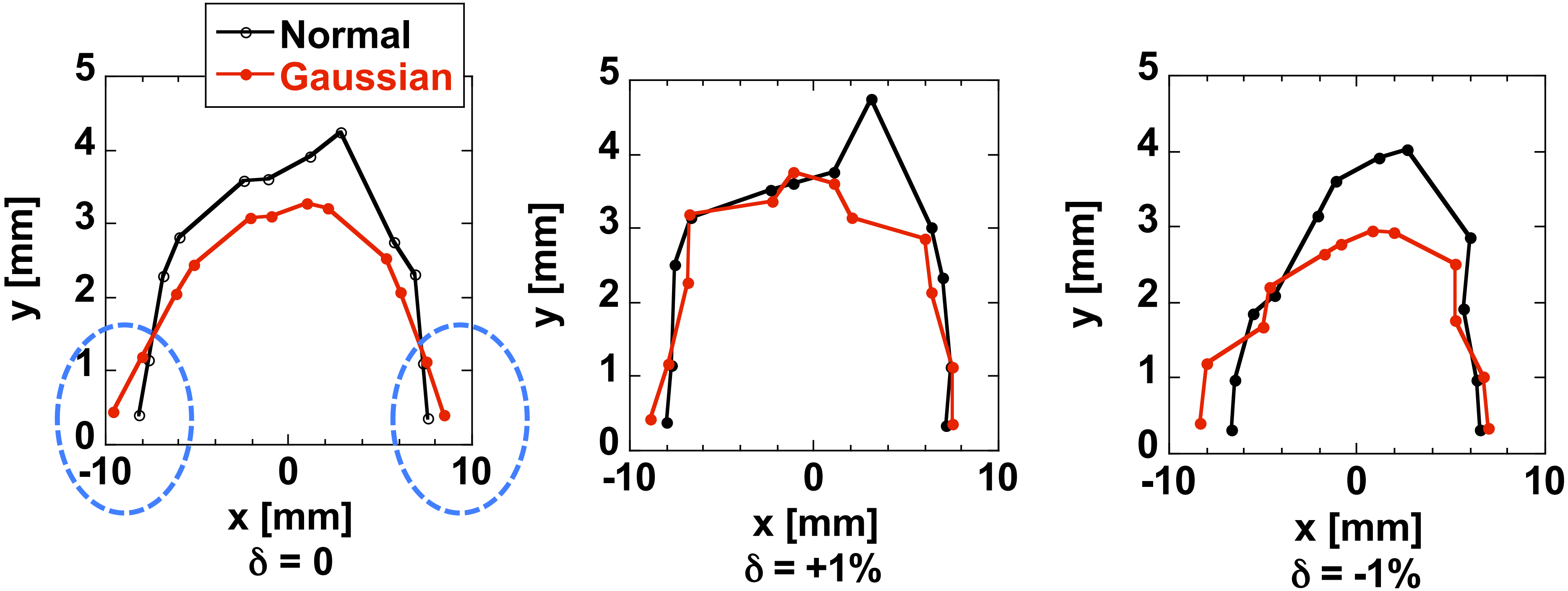
$$\approx \frac{1}{3} + \frac{K}{5}\frac{\beta_x I_x}{2\pi} = 0 \quad \rightarrow \quad K \propto \frac{1}{\beta_x}$$

(1.3) modified (Gaussian) sextupole magnets

We then set

$$K\left(I_0\right)=\frac{I_0}{\beta_x}$$

for all Gaussian SXs and searched an optimum value of I_0 (one parameter).



(1.3) modified (Gaussian) sextupole magnets

Next: We set

$$K\left(I_0\right)=\frac{I_0}{\beta_x}$$

but treat I_0 for each SX as independent.

Optimization procedure?

... resonance suppression?

... *Genetic Algorithms* (C.Steier) applicable?

Other idea?

(1.3) modified (Gaussian) sextupole magnets

(1.2) octupole magnets

MAX IV *S.C.Leemann et al., PRST-AB 12(2009)120701*

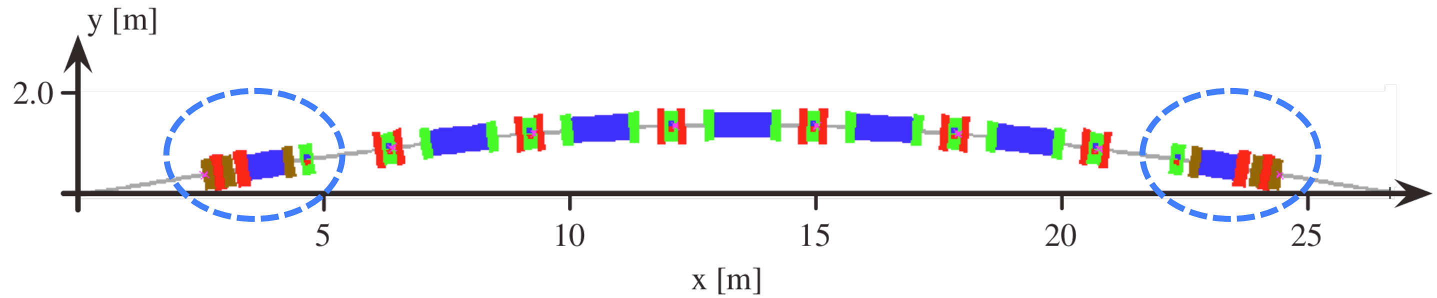
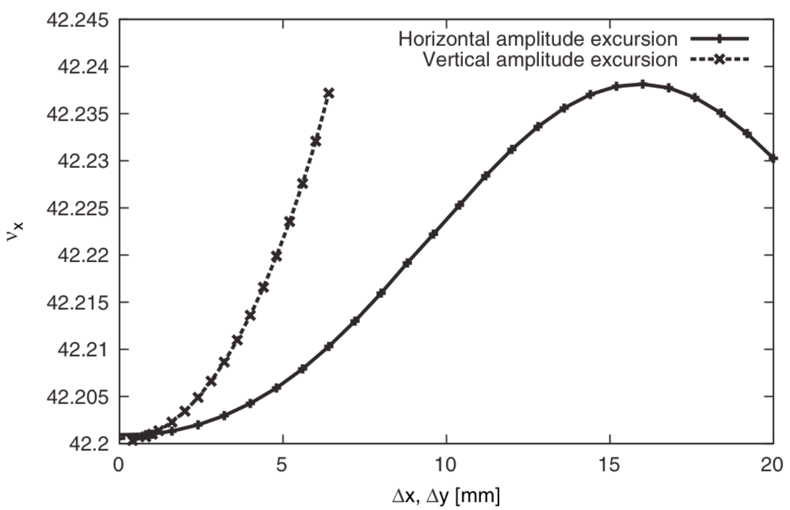


FIG. 1. (Color) Schematic of one of the 20 achromats in the 3 GeV storage ring. Magnets indicated are gradient dipoles (blue), focusing quadrupoles (red), sextupoles (green), and octupoles (brown).



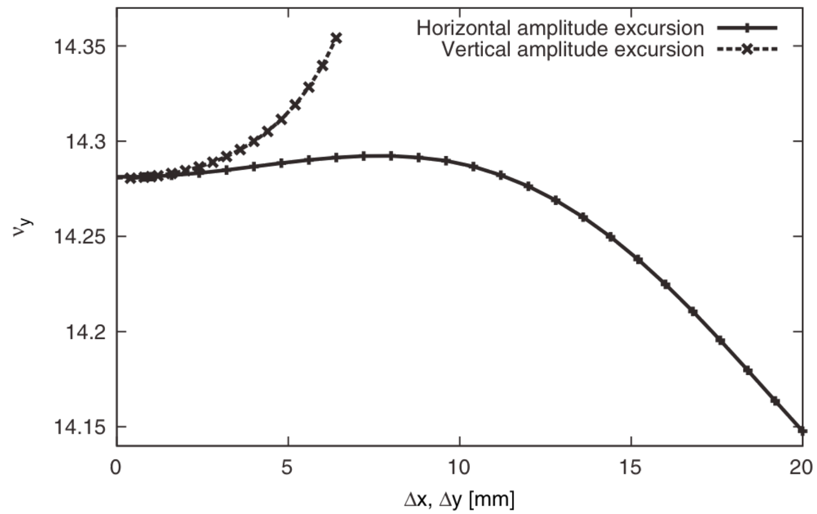


FIG. 3. Amplitude-dependent tune shifts for the 3 GeV storage-ring bare lattice. Sextupoles and octupoles have been included in this calculation.

3 Families for Amplitude-Dependent Tune Control

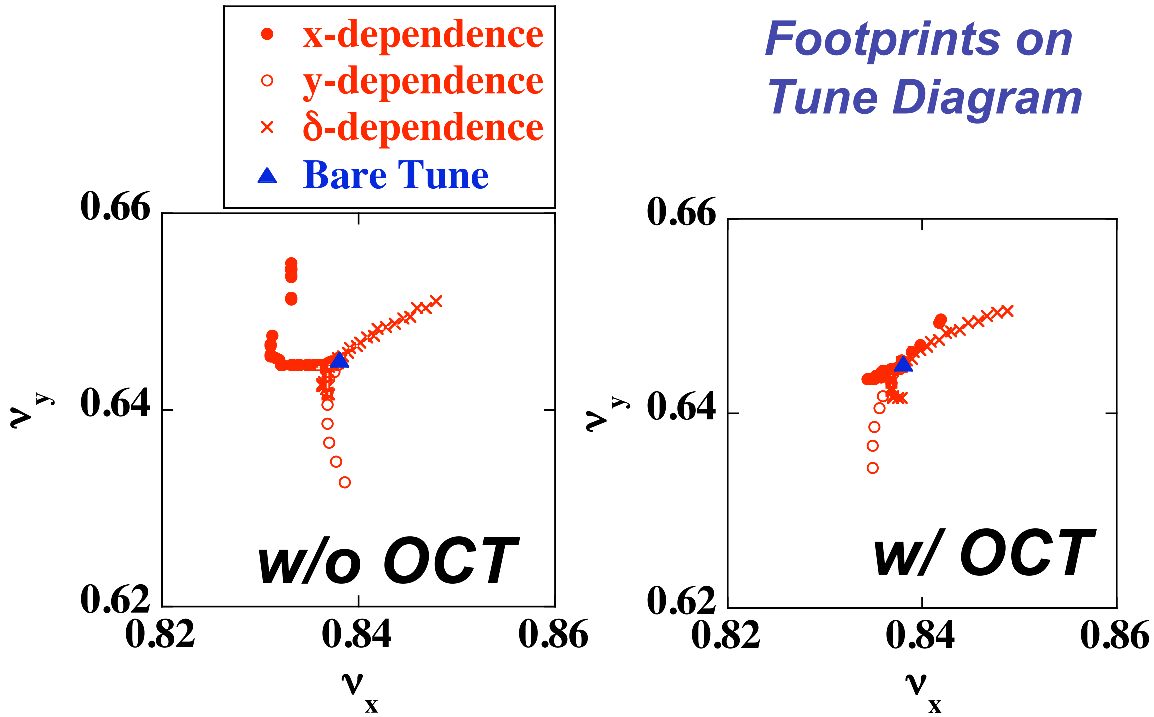
(1.2) octupole magnets

SPring-8 case

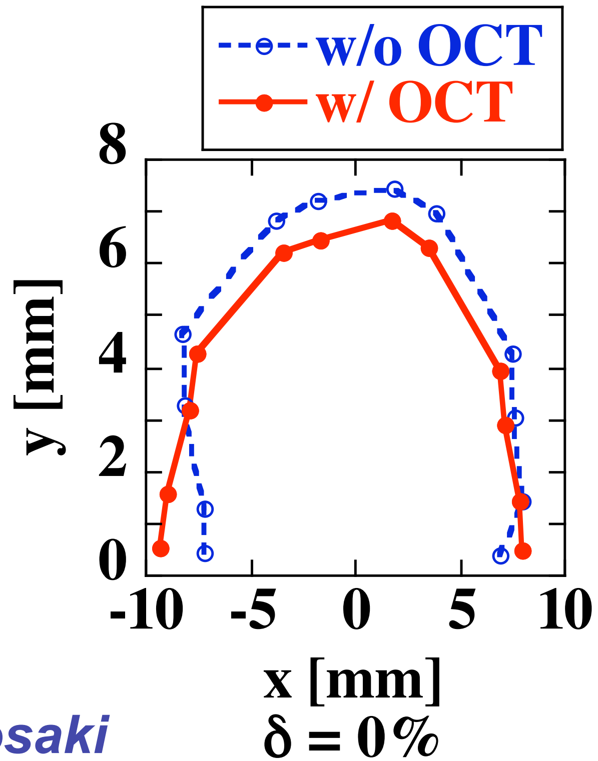
for a unit cell of QB lattice (preliminary cal.)

Amplitude-dependent tune shifts and resonances by octupoles are controlled (with 8 families).

Footprints on Tune Diagram



Dynamic Apt.



Y.Shimosaki

(1.2) octupole magnets

Perturbed tune:

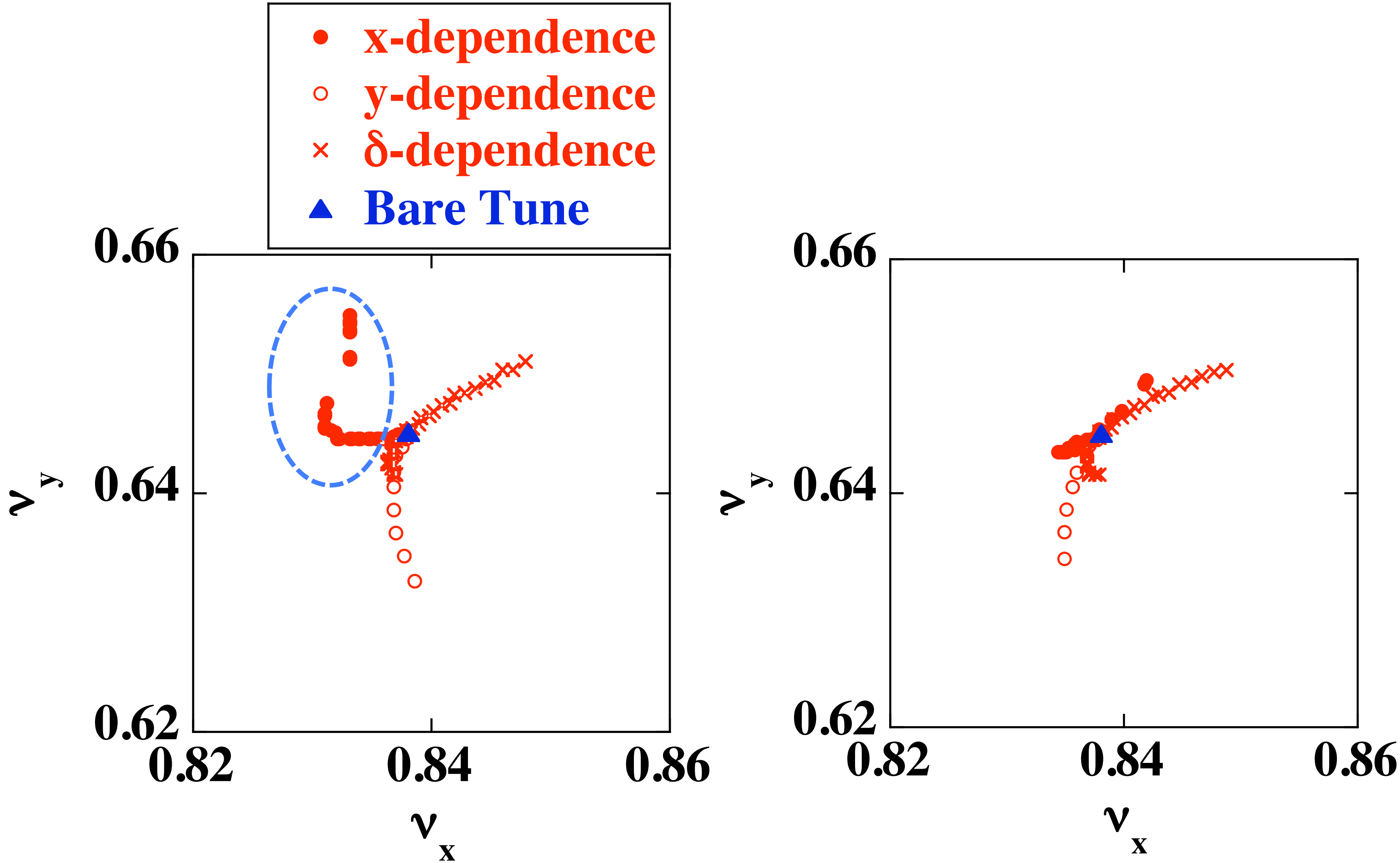
$$\nu_x(I_x, I_y) = \nu_{x0} + c_{xx}I_x + c_{xy}I_y + \Delta\nu_{\mathrm{resonance}}(I_x, I_y)$$
$$\nu_y(I_x, I_y) = \nu_{y0} + c_{xy}I_x + c_{yy}I_y + \Delta\nu_{\mathrm{resonance}}(I_x, I_y)$$

Resonance Correction ($\Delta\nu_{\mathrm{resonance}} = 0$)
and
Tune-Shift Control (c_{xx}, c_{yy}, c_{xy})

8 Families of OCT at the same position of SX in a cell

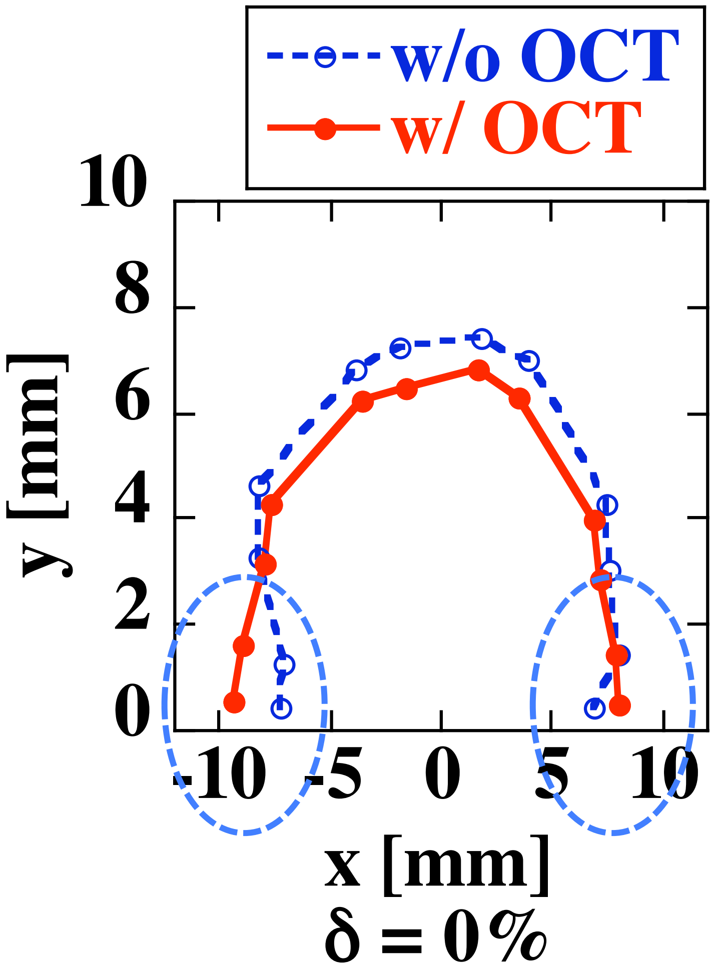
(1.2) octupole magnets

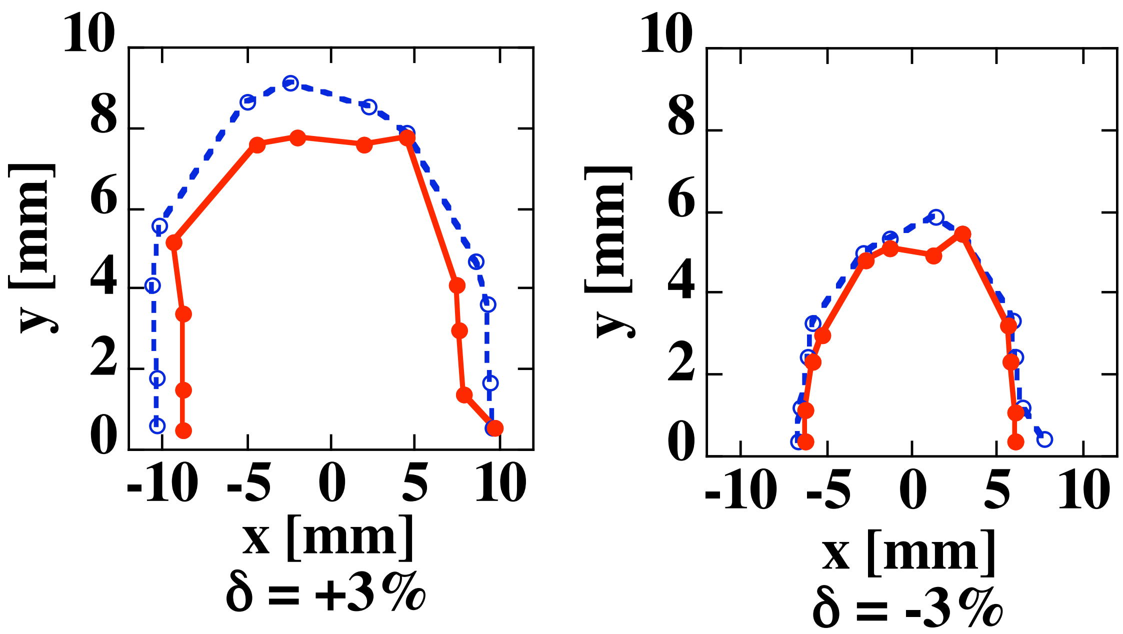
We tried to control x-dependene at y = 0 , δ = 0
and harmful resonances.



(1.2) octupole magnets

DA for y=0, δ=0 enlarged but not enough number of OCT for correcting off-mom. DA





(1.2) octupole magnets

... *Genetic Algorithms* (C.Steier) applicable?

(1.4) cancellation of sextupole kicks

Use of "-*I*" Transformation between two SXs

Is it possible to apply “noninterleaved sextupoles” scheme to very small emittance rings ?

**We will need to put a set of sextupoles by considering betatron phase and amplitude in both H and V directions.
Can we design such a ring?**

SLS: "sextupole symmetrization", NLBD-WS (2009)

(2) injection scheme

(2.1) pulsed bump magnets (std. scheme of off-axis inj.)

(2.2) pulsed multipole magnets

(2.3) synchrotron injection

(2.4) On-Axis Swap-Out Scheme with Accumulator
(APS Plan)

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(2.2) pulsed multipole magnets

Injection with a Pulsed Q (SX) at KEK

K.Harada et al., PRST-AB 10(2007)123501; EPAC06; PAC05

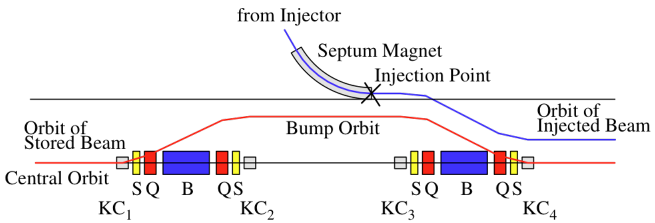


FIG. 1. (Color) Schematic drawing of a conventional injection scheme. After the injected beam is bent into the orbit by the septum magnet, the injected beam is perturbed by two kicker magnets KC_3 and KC_4; it then oscillates with a large amplitude in the ring. For the stored beam, the pulsed bump orbit is produced by four kicker magnets KC_1, KC_2, KC_3, and KC_4. B, Q, and S denote the bending, quadrupole, and sextupole magnets, respectively. The cross represents the injection point.

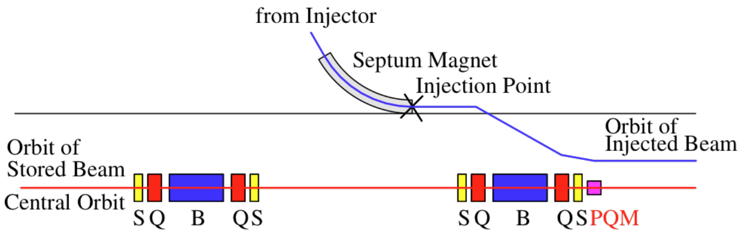


FIG. 2. (Color) Same as Fig. 1, but the injection scheme is using the PQM instead of the four kicker magnets. The injected beam is perturbed by the PQM; it then oscillates with a large amplitude in the ring. The stored beam passes through the central position of the PQM and its orbit is preserved on a central orbit.

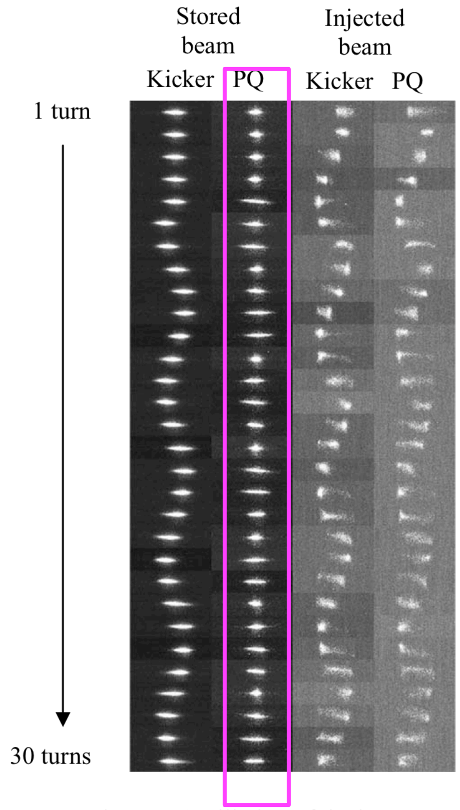


Figure 6 Oscillation of the beam.

repetition rate until the stored current reached at 10mA as shown in Fig. 4. As the stored current increased, the injection rate decreased. When the stored current reached about 30mA, the injection rate dropped to zero. Figure 5 shows the oscillation of the stored beam detected by the beam oscillation detector (BOD). Even after the COD correction, the small oscillation was remained. The

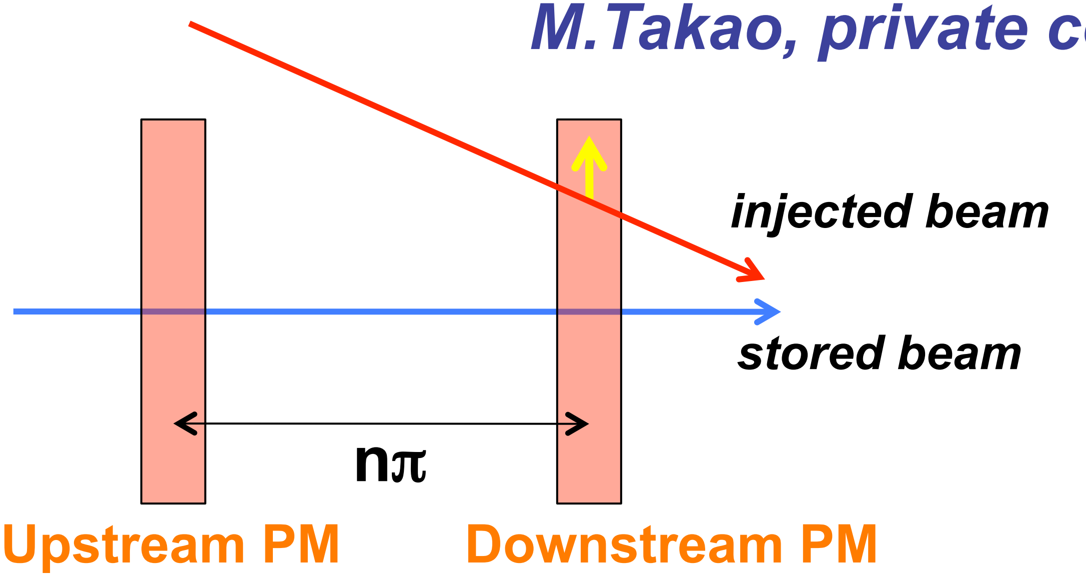
Successful in beam injection but ...

Quadrupole oscillation mode was induced in a stored beam.

(2.2) pulsed multipole magnets

Additional upstream pulsed magnet separated by nπ in betatron phase will suppress the quadrupole oscillation mode of a stored beam.

M.Takao, private com.



It will be possible to combine the above scheme with a standard pulsed bump magnets.

➔ e.g. possibility of a scheme like

bump magnets and a series of pulsed SXs

(2.3) synchrotron injection

Injection with Energy Offset at Dispersive Section

P.Collier, PAC95; Y.Onishi, private com.

Injection amplitude is shared in transverse and longitudinal phase spaces.

Large dispersion is needed.
➔ dispersion control at injection section (*lattice, chicane, ...*)

100mm dispersion and 1% energy offset
➔ 1mm reduction of osc. amplitude