Ultimate synchrotron radiation source with horizontal field wigglers

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Introduction: comparison *(IPAC-2012 M. Borland)*

Name	Date	E, GeV	Π, km	ε, pm	σ_δ, %	DA_x cm
MAX IV	2006	3	0.528	263	0.096	2.5
USRLS	2000	7	2.0	300		
XPS7	2005	7	1.1	78	0.176	
Tsumaki 2006	2006	6	2.0	35	0.089	0.5
USR7	2009	7	3.16	30	0.079	0.5
PEP-X ultimate	2011	4.5	2.2	24	0.13	<0.5(?)
IU ring	2011	5	2.66	9.1	0.038	0.2(?)
τUSR	2011	9	6.21	2.9	0.096	0.1
Spring-8 II	2012	6	1.4	67	0.096	0.4

$DA_x(cm) = R_x(cm)\sqrt{\frac{19(m)}{\beta_x(m)}}$ is normalized with respect to 19 m beta function.

Introduction: job description

Goals

- Emittance $\varepsilon_x \approx \varepsilon_y \approx 10$ pm (diffraction limit for 1 Å wave length).
- Compact as possible.
- -I map between non-interleaved sextupoles.
- Large dynamic aperture and energy acceptance.

Methods

- Natural emittance $\varepsilon_x \approx 100$ pm.
- Wigglers with horizontal field, $\varepsilon_x \approx \varepsilon_y \approx 10$ pm.
- Modified TME cell.
- Phase advance per cell is π, noninterleaved main sextupole pairs.
- Weak correcting sextupole pairs interleaved with main ones.

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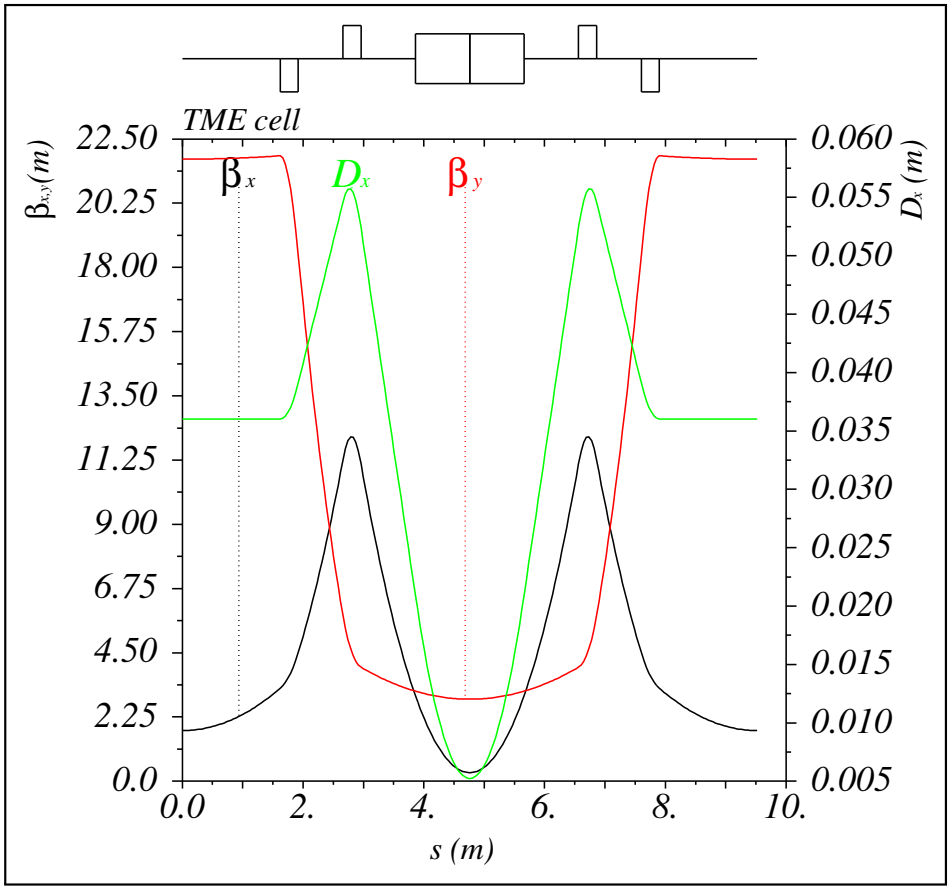
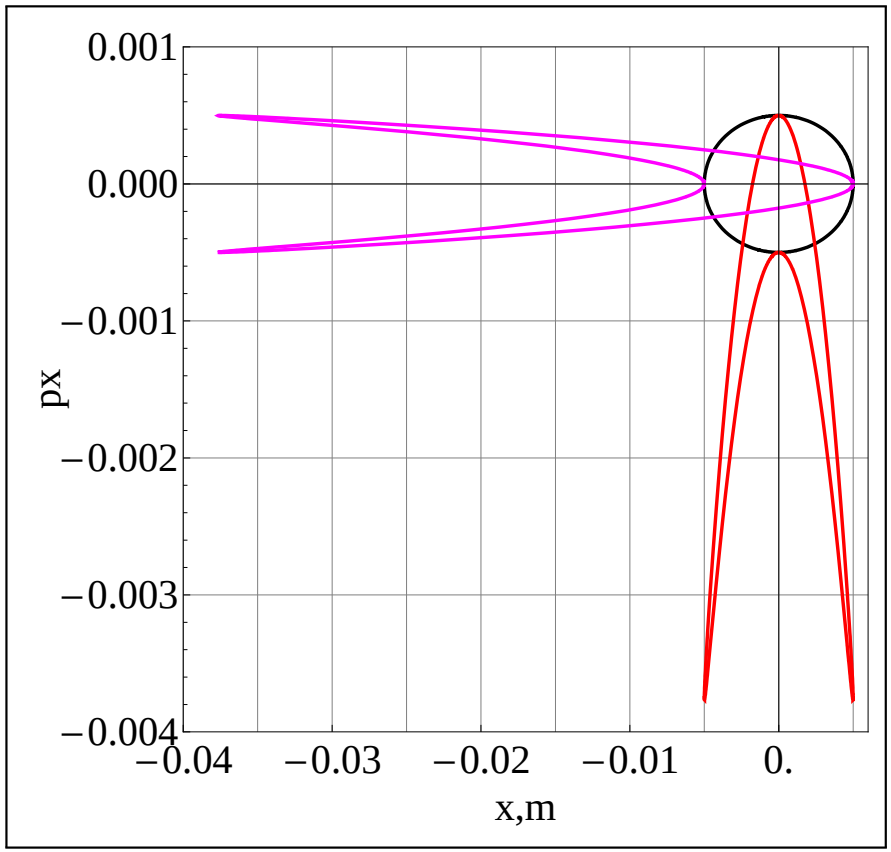
TME cell: $\mu_x = 3/2\pi$, $\mu_y = \pi/2$

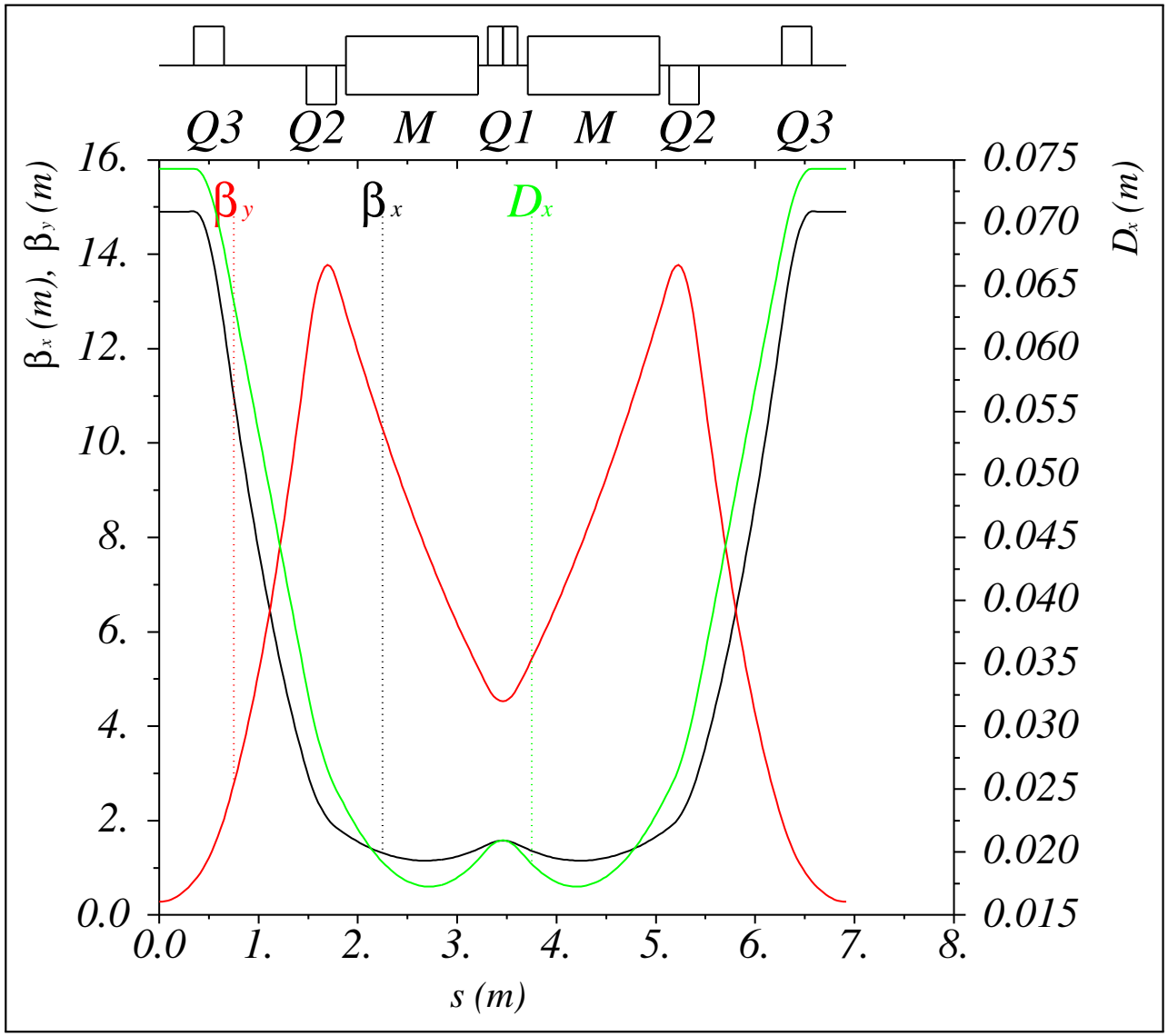




TME cell
Strong focusing
Strong sextupoles

Phase trajectories for -I pair:
black – just before the sextupole,
red – immediately after,
magenta – at $\pi/2$.

Modified TME cell: $\mu_x = \pi$, $\mu_y = \pi$



	L,m	K1, m^{-2}
Q3	0.3	1.92
Q2	0.3	-3.15
Q1	0.3	2.8

	L,m	B,T / θ°
M	1.33	0.18 / 1.35

$E = 3$ Gev

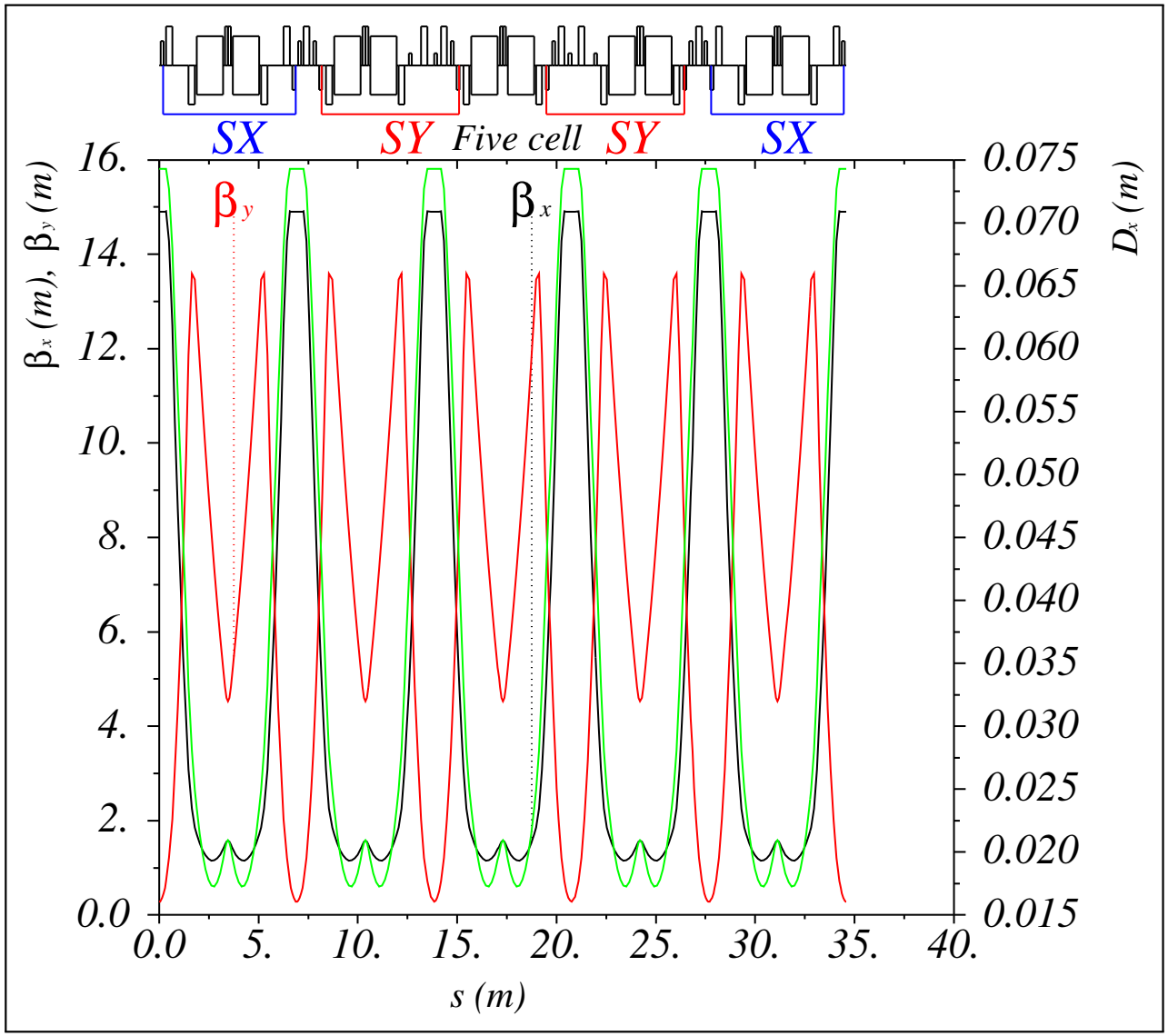
$B\rho = 10.007$ T/m

$\varepsilon_x = 66$ pm

$\varepsilon_{TME} = 27.8$ pm

$\xi_x = -1.1$, $\xi_y = -1.6$

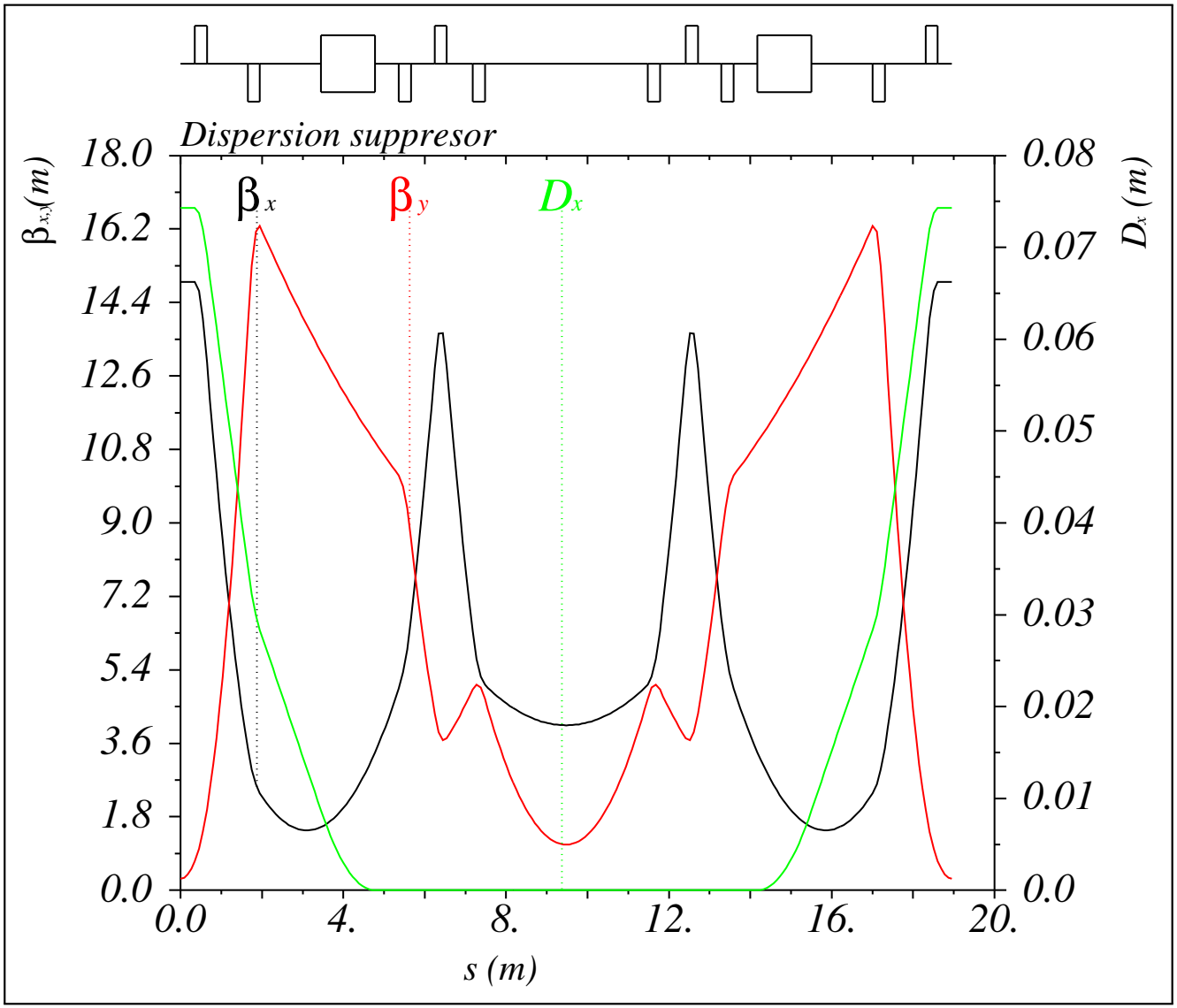
FiveCell: sextupole pairs



A.Bogomyagkov, S.Glukhov, E.Levichev, P.Piminov
Effect of the Sextupole Finite Length on Dynamic Aperture in the Collider Final Focus

http://arxiv.org/abs/0909.4872, 2009

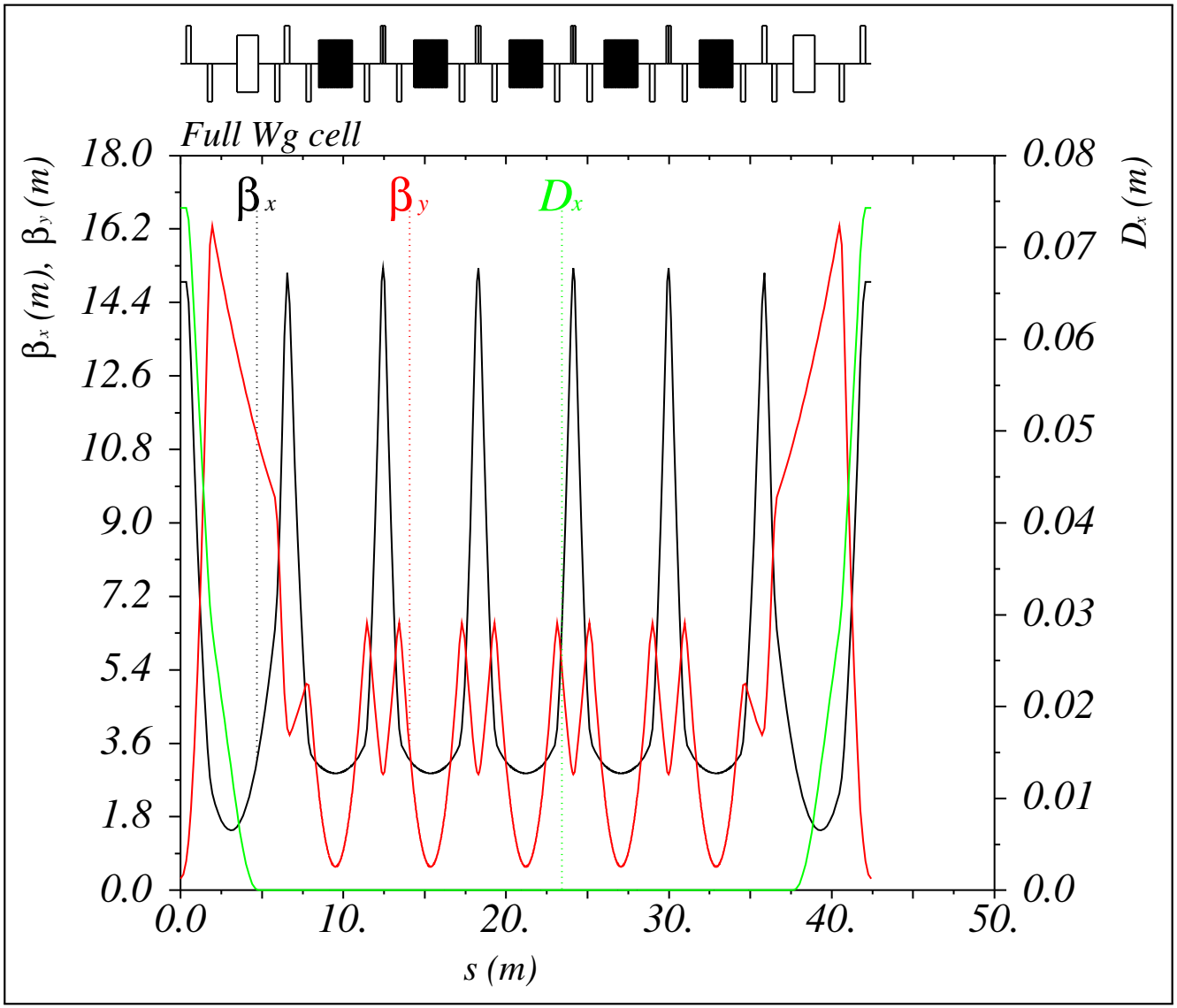
Straight section: empty for insertion device



	L,m	B,T/θ°
M	1.33	0.1/0.75

$L_{ID} = 4$ m

Straight section: damping wigglers with horizontal field



Wigglers with horizontal field:

$B = 2.3$ T

$\lambda = 4.8$ cm

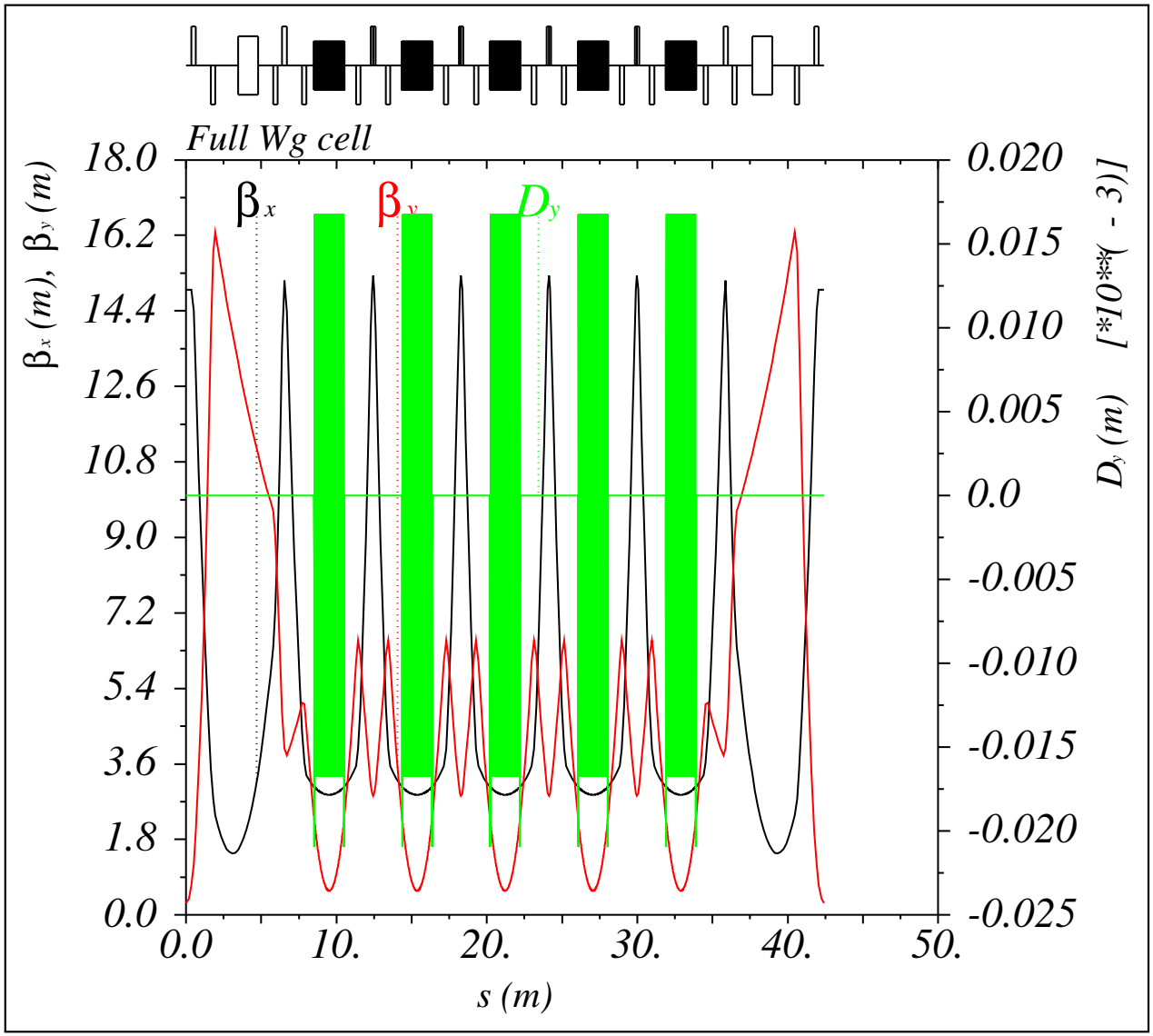
$N_\lambda = 42$

$L_{wiggler} = 2.04$ m

$N_{total} = 20$

$L_{total} = 40.8$ m

Straight section: damping wigglers with horizontal field



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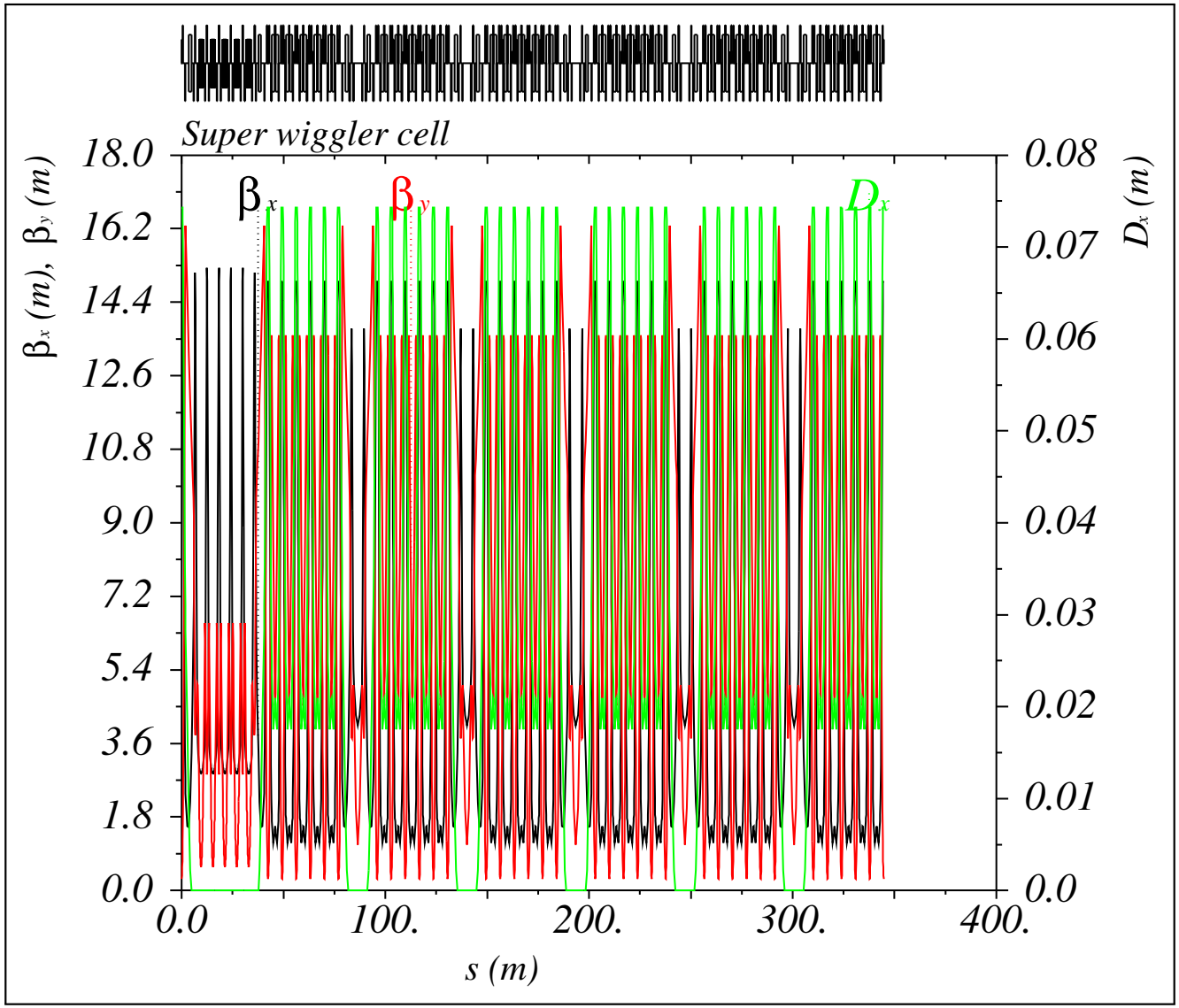
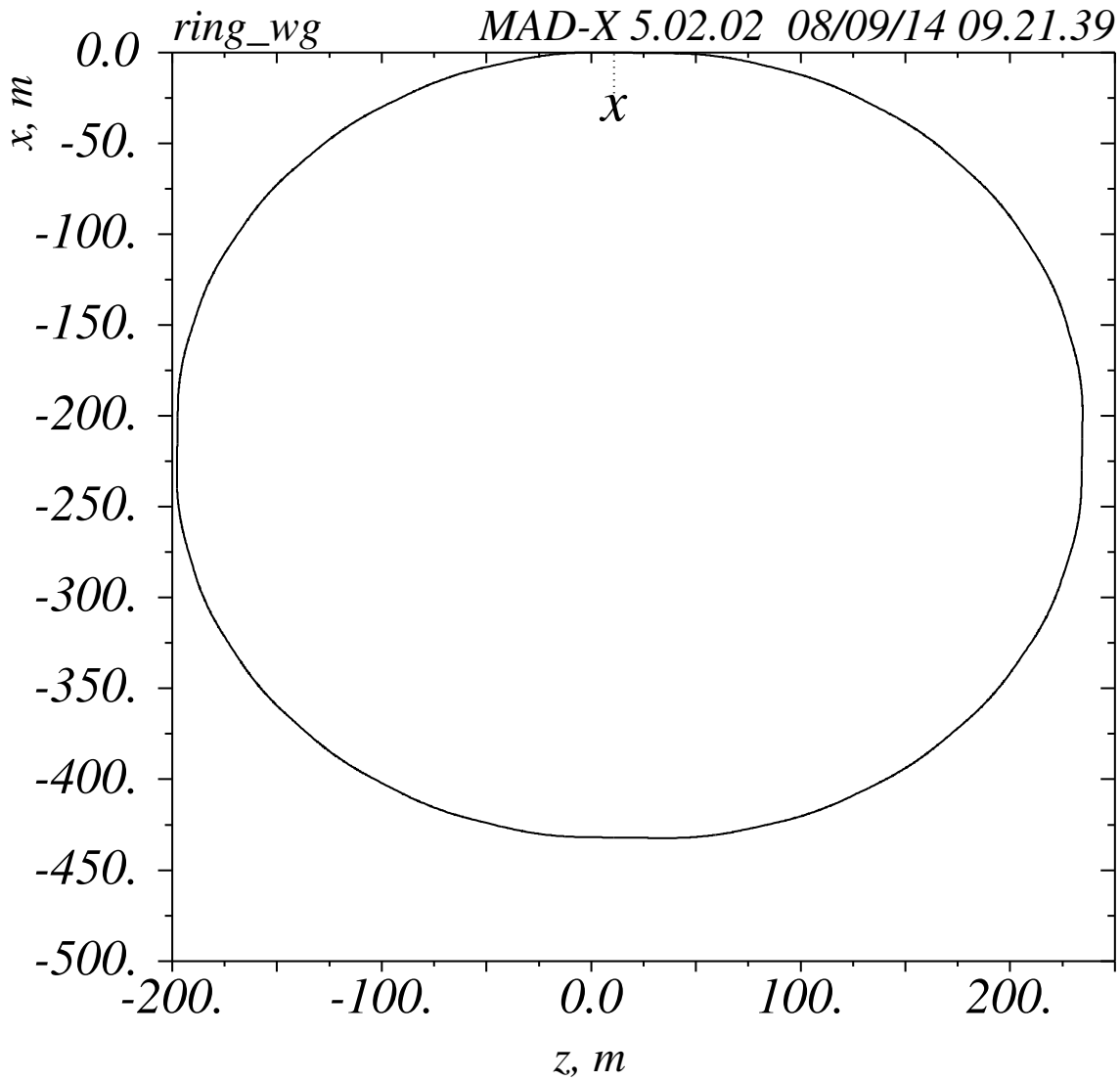
Super period: quarter of the ring



Ring layout


ring_wg
MAD-X 5.02.02 08/09/14 09.21.39
x
x, m
0.0
-50.
-100.
-150.
-200.
-250.
-300.
-350.
-400.
-450.
-500.
-200.
-100.
0.0
100.
200.
z, m

Parameters of the ring

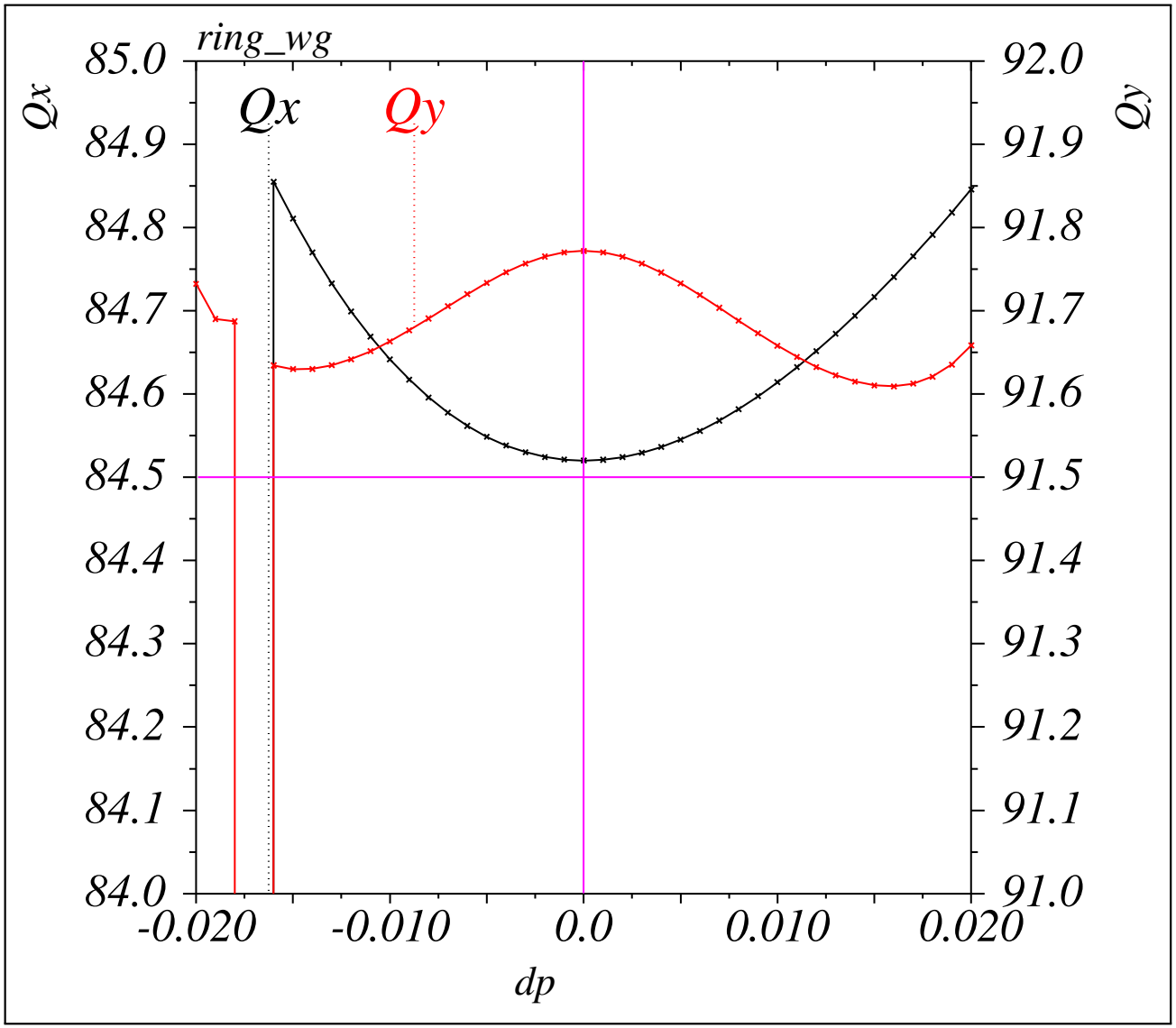
$$Ring = 4 \times 6 \times \left[5 \times FiveCell + Straight\right]$$

20 straight are sections empty

4 straight sections are occupied by damping wigglers

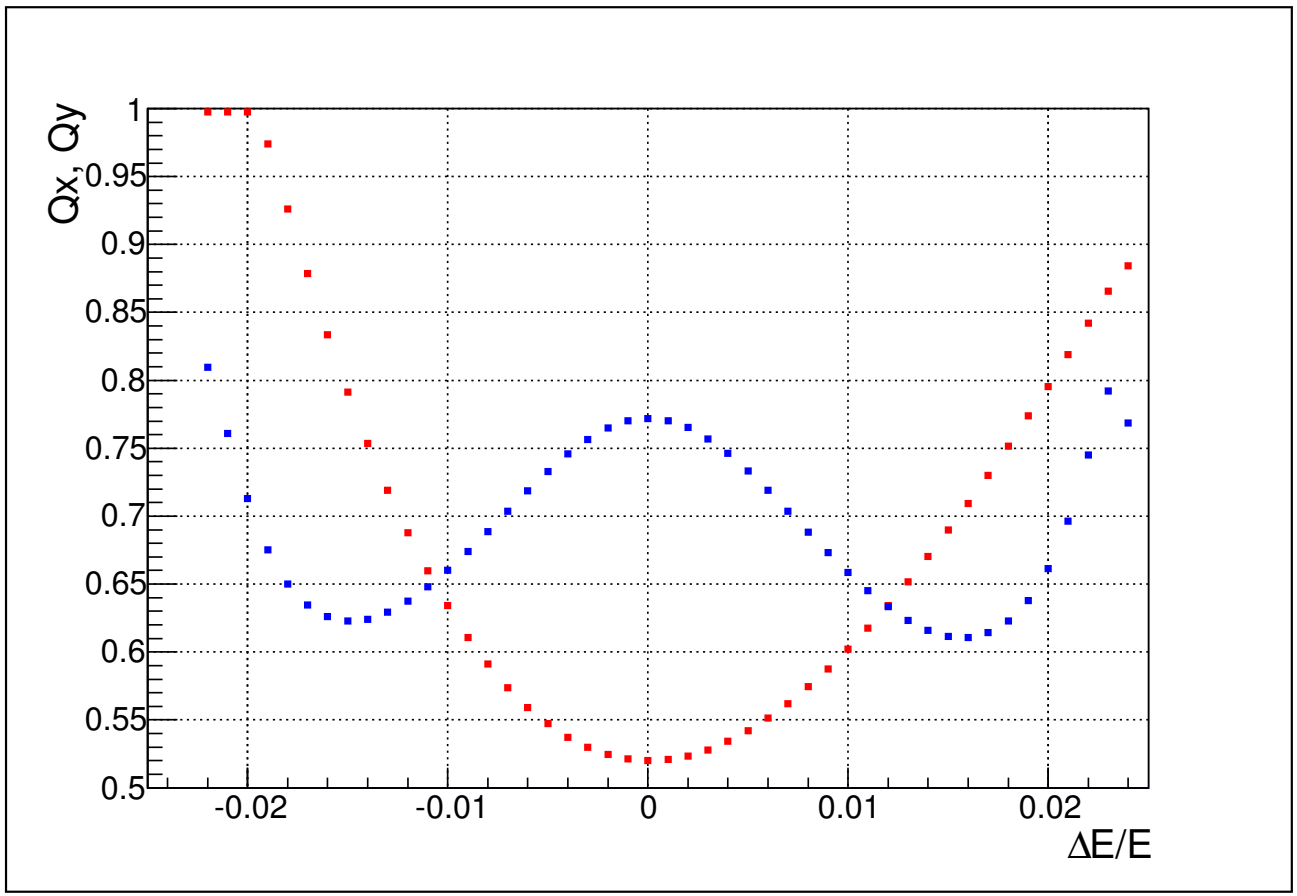
	Wigg OFF	Wigg ON
Energy, GeV	3	
Circumference, m	1379	
Chromaticity h/v	-184/-251	
Betatron tunes h/v	84.52/91.772	
Horizontal Emittance, pm rad	64	3
Vertical Emittance, pm rad	0.6	8.6
Energy spread	4×10^{-4}	1.2×10^{-3}
Momentum compaction	7.8×10^{-5}	7.8×10^{-5}
Damping times h/v/s, msec	210/210/105	10/10/5
Wiggler field, T	0	2.33

Tunes versus energy: MADX



$Q_x = 84.52$
$Q_y = 91.772$
Energy acceptance
$[-1.6\%, +2\%]$

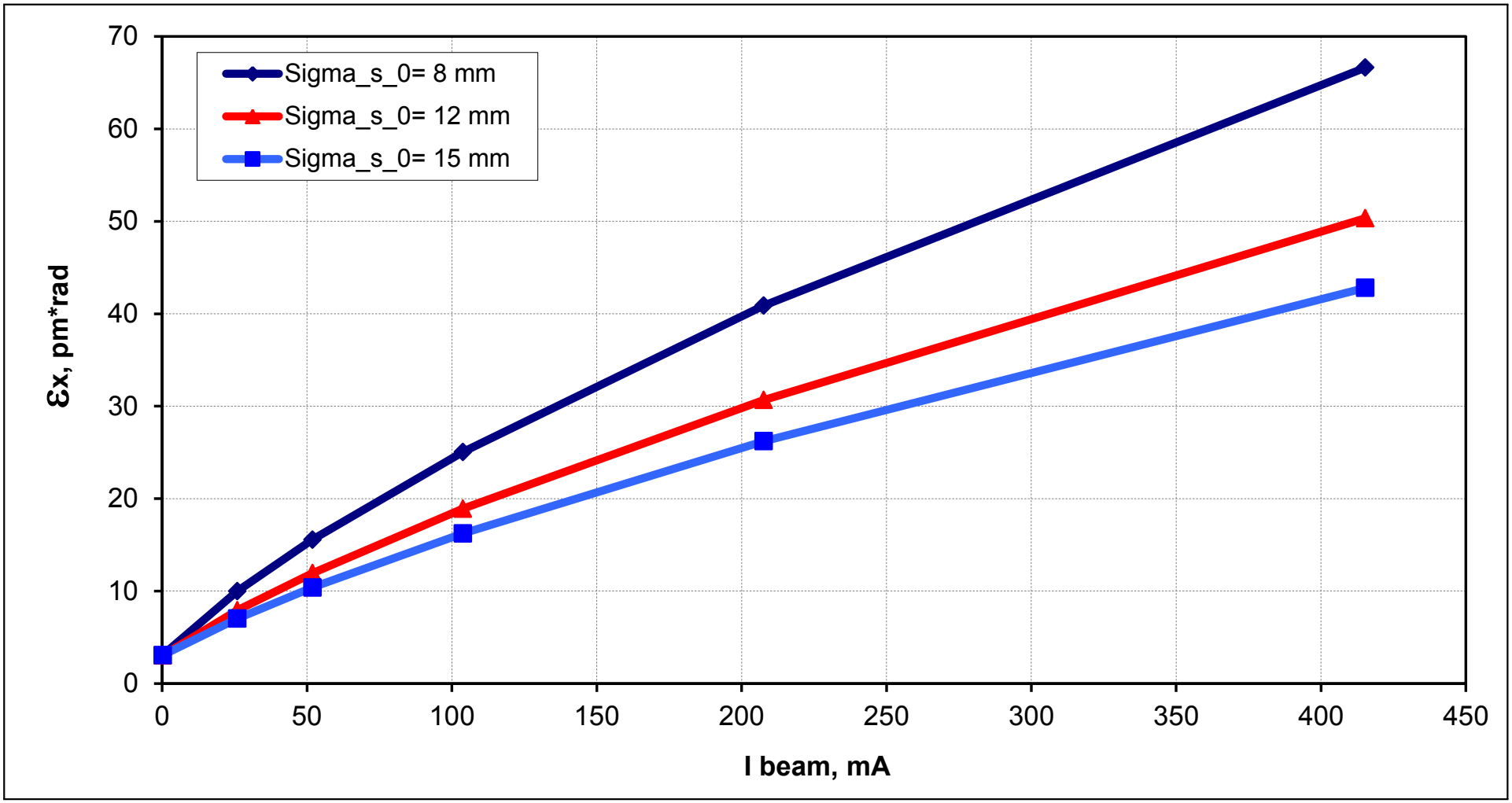
Tunes versus energy: ACCELERATICUM



Qx is red. Qy is blue.

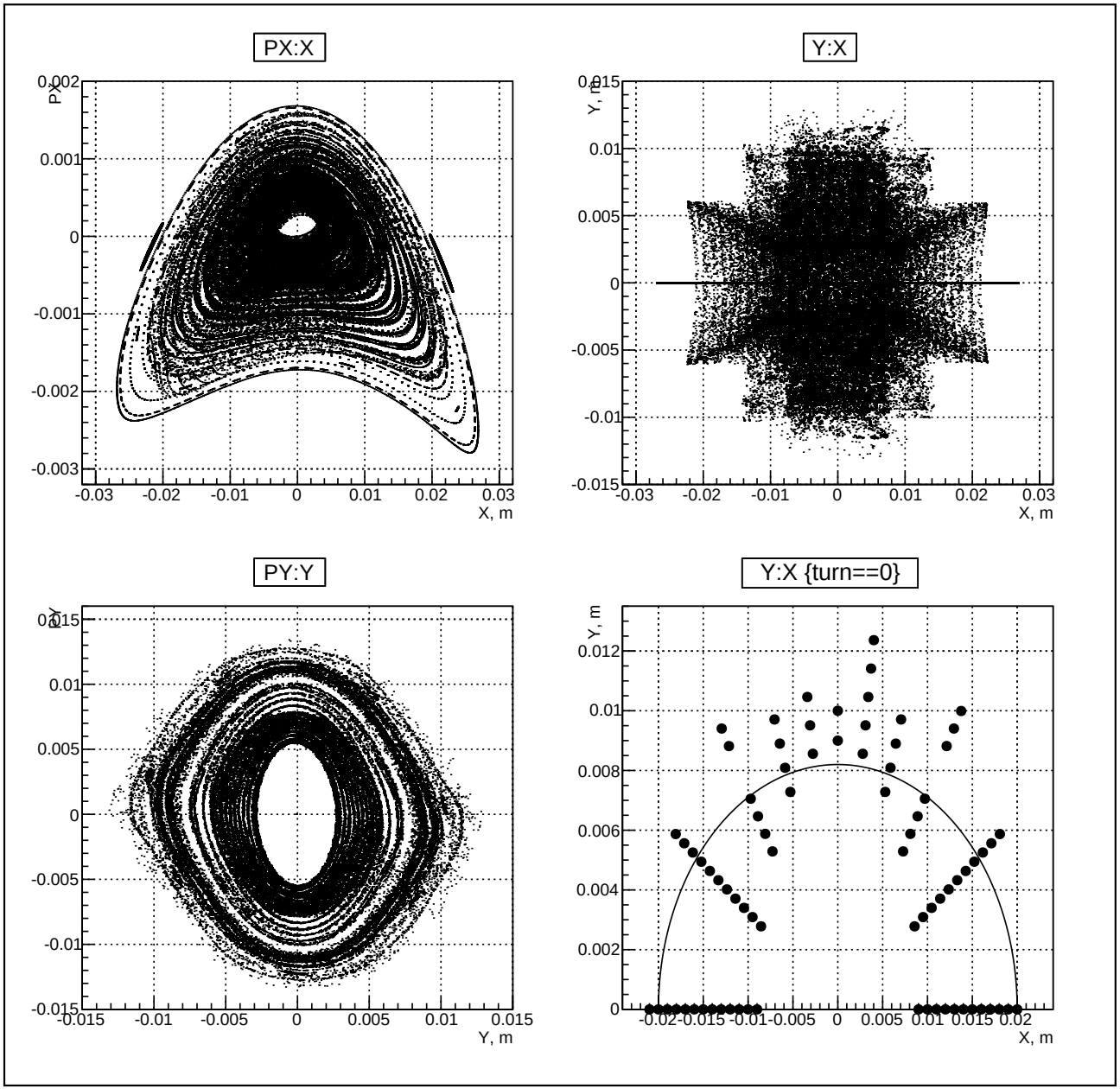
$Q_x = 84.52$
$Q_y = 91.772$
Energy acceptance
$[-2\%, +2\%]$

Emittance versus current (IBS)



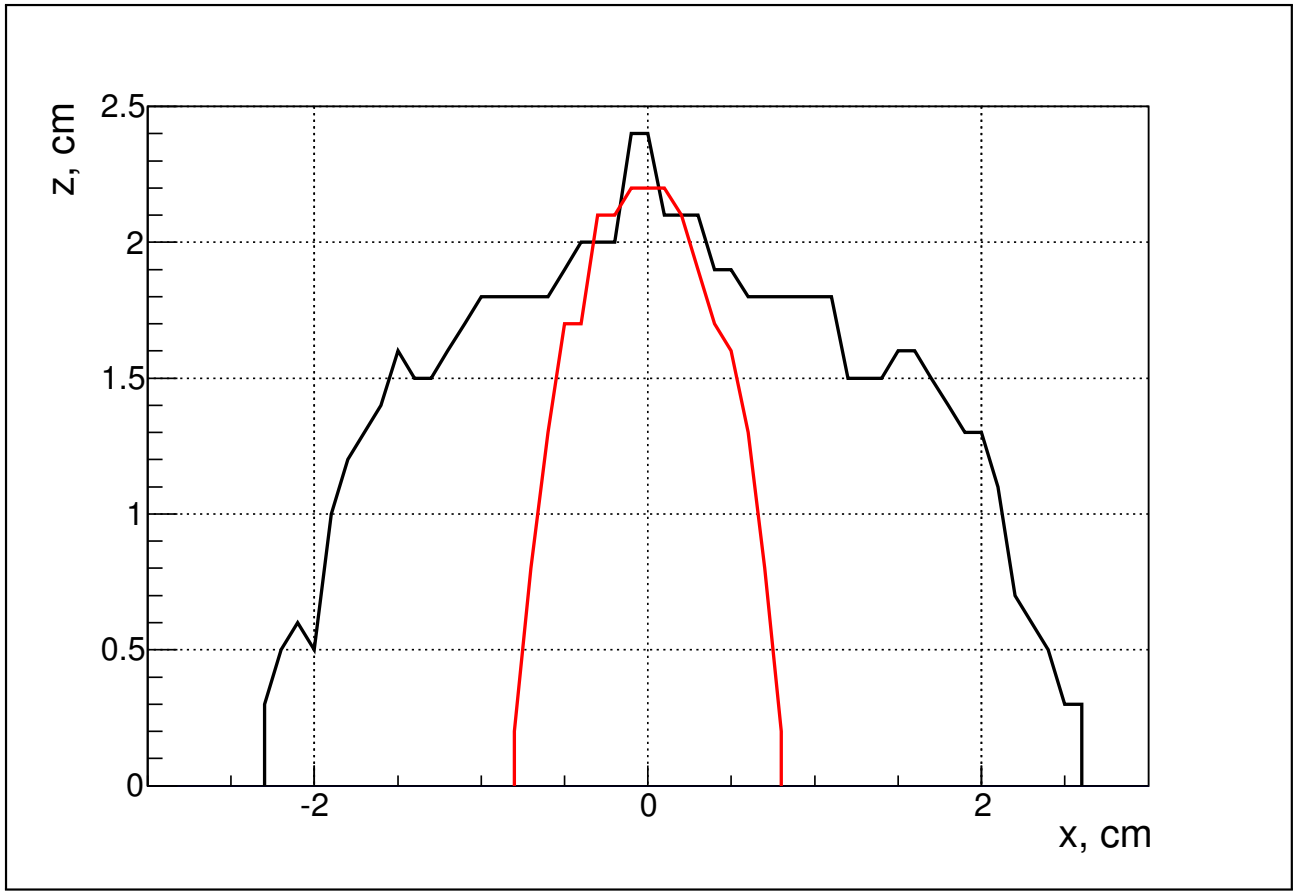
At 50 mA and $\sigma_s = 15$ mm $\varepsilon_x = 3$ pm becomes $\varepsilon_x = 10$ pm, $\varepsilon_y = 9$ pm. Touschek life time is 60000 sec.

Dynamic aperture: on momentum, PTC



$\beta_x = 14.9$ m
$\beta_y = 0.28$ m
$R_x = 0.02$ m
$R_y = 0.008$ m
$E = 3$ GeV
$ksy1 = -6707$ T/m^2
$ksx1 = 3293$ T/m^2
$ksy2 = -0.02 \cdot ksy1$
$ksx2 = -0.13 \cdot ksx1$
$Ls = 0.15$ m

Dynamic aperture: on momentum, ACCELERATICUM



Correcting sextupoles are OFF.

Correcting sextupoles are ON.

$\beta_x = 4$ m
$\beta_y = 1.1$ m
$R_x = 0.02$ m
$R_y = 0.008$ m
$E = 3$ GeV
$ksy1 = -6707$ T/m^2
$ksx1 = 3293$ T/m^2
$ksy2 = -0.02 \cdot ksy1$
$ksx2 = -0.13 \cdot ksx1$
$Ls = 0.15$ m

Conclusion

- Optics for diffraction limited angstrom-wavelength storage ring light source is presented.
- Circumference 1379 m.
- Noninterleaved sextupole pairs.
- Horizontal field wiggler $B = 2.3$ T, $\lambda = 4.8$ cm, $N_\lambda = 42$
  - Emittance $\varepsilon_x = 3$ pm, $\varepsilon_y = 8.6$ pm at 0 mA and $\sigma_s = 15$ mm.
  - Emittance $\varepsilon_x = 10$ pm, $\varepsilon_y = 9$ pm at 50 mA and $\sigma_s = 15$ mm.
- Energy acceptance $[-1.6\%; +2\%]$ or $[-2\%; +2\%]$.
- Dynamic aperture is $R_x = 2$ cm at $\beta_x = 14.9$ m, $R_y = 0.8$ cm at $\beta_y = 0.28$ m.
- Needs optimization with respect to IBS.