Crab waist interaction region for FCC-ee (TLEP)

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Parameters for crab waist

	Z	W	H	tt
Energy [GeV]	45	80	120	175
Perimeter [km]	100			
Crossing angle [mrad]	30			
Particles per bunch [10^{11}]	1	4	4.7	4
Number of bunches	29791	739	127	33
Energy spread [10^{-3}]	1.1	2.1	2.4	2.6
Emittance hor. [nm]	0.14	0.44	1	2.1
Emittance ver. [pm]	1	2	2	4.3
β_x^*/β_y^* [m]	0.5 / 0.001			
Luminosity / IP [$10^{34}\ cm^{-2}s^{-1}$]	212	36	9	1.3
Energy loss / turn [GeV]	0.03	0.3	1.7	7.7

Chromaticity estimations

Montague functions

$$b_y = \frac{1}{\beta_y}\frac{\partial \beta_y}{\partial \delta}\,, \qquad \frac{\partial b_y}{\partial s} = -\frac{2a_y}{\beta_y}\,,$$
$$a_y = \frac{\partial \alpha_y}{\partial \delta} - \frac{\alpha_y}{\beta_y}\frac{\partial \beta_y}{\partial \delta}\,, \quad \frac{\partial a_y}{\partial s} = (K_1 - K_2\eta_0)\beta_y + \frac{2b_y}{\beta_y}\,.$$

Chromaticity

$$\frac{\partial \varphi_y}{\partial \delta} = \frac{1}{2}\int_0^{\Pi} \beta_y (K_1 - K_2\eta_0) ds\,,$$
$$\frac{\partial^2 \varphi_y}{\partial \delta^2} = -2\frac{\partial \varphi_y}{\partial \delta} - \int_0^{\Pi} \beta_y K_2 \eta_1 ds + +\frac{1}{2}\int_0^{\Pi} \beta_y b_y (K_1 - K_2\eta_0) ds\,.$$

Chromaticity estimations

First quadrupole Q0

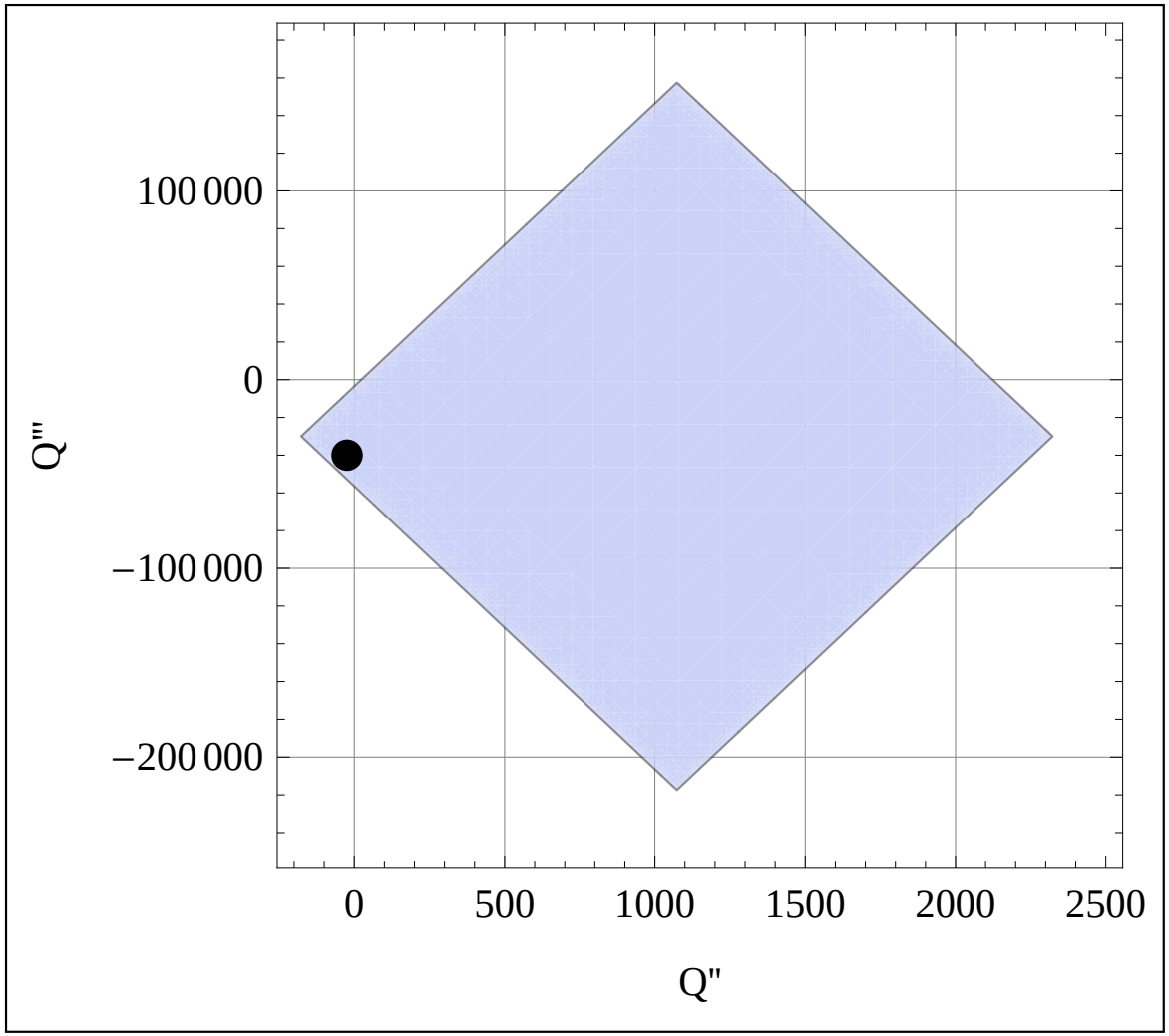
$K_1 L = -\frac{2}{L^*}$, where L^* is distance from IP, changes sign of α_y.

$$
\begin{aligned}
a_y(Q0) &= K_1 L \beta(Q0) \approx -2\frac{L^*}{\beta_y^*} \approx -7.6 \times 10^3 \,, \\
b_y(\varphi_y) &= -a_y(Q0) \sin\left(2\left(\varphi_y - \varphi_y(Q0)\right)\right) \to -7.6 \times 10^3 \,.
\end{aligned}
$$

$$
\begin{aligned}
\frac{\partial \varphi_y}{\partial \delta}(Q0) &\approx -3.8 \times 10^3 \,, \\
\partial^2 \varphi / \partial \delta^2 &\approx 1.2 \times 10^5
\end{aligned}
$$

Chromaticity estimations

$$0 \leq Q(\delta) - Q_0 \leq 0.5$$

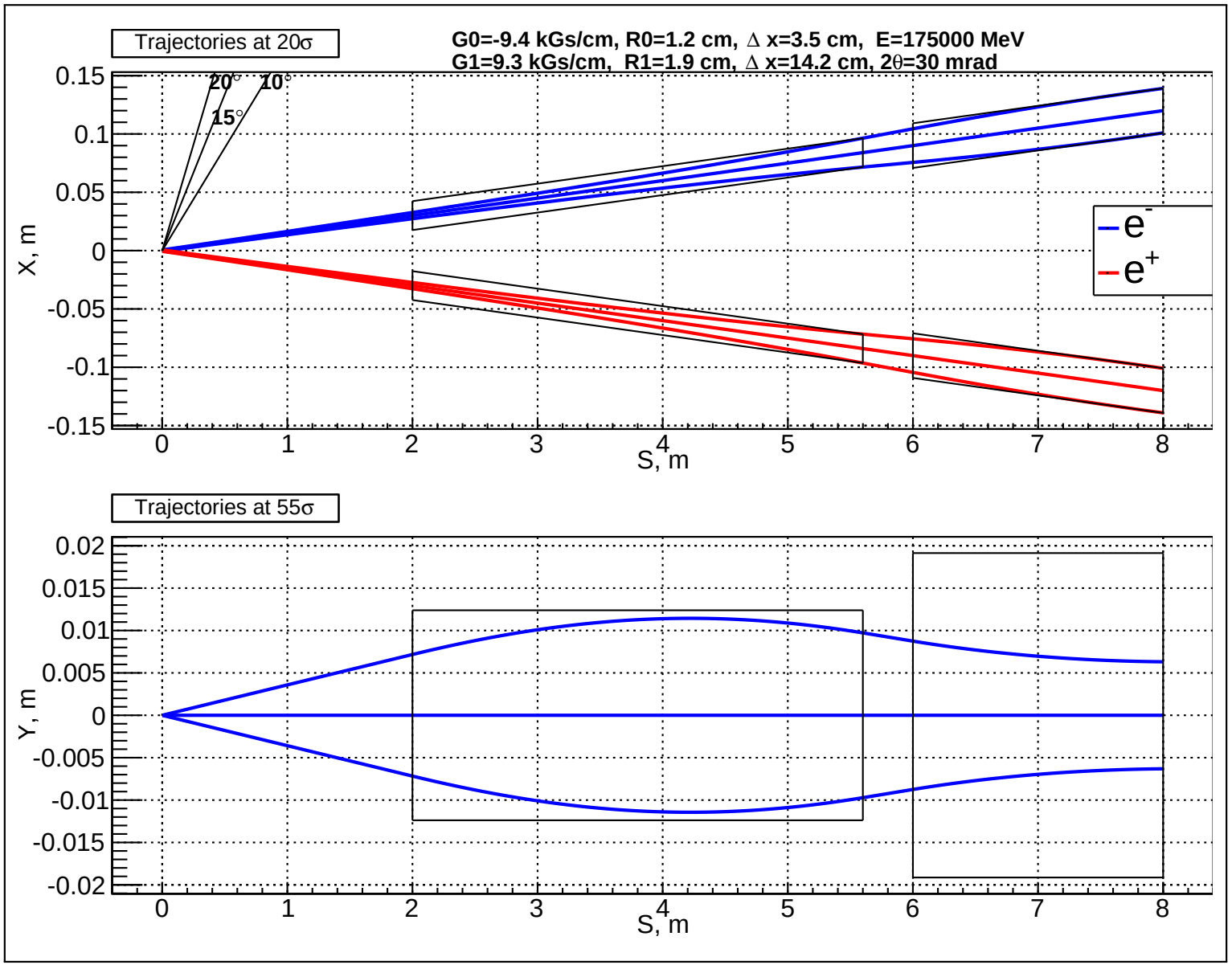


$$Q(\delta) = Q_0 + Q_0'\delta + Q_0''\frac{\delta^2}{2} + Q_0'''\frac{\delta^3}{6} + Q_0''''\frac{\delta^4}{24}$$

$$Q_0' = 2,\ Q_0'''' = 5.3 \cdot 10^6$$

$$\delta \in [-0.02; 0.02]$$

Final Focus layout

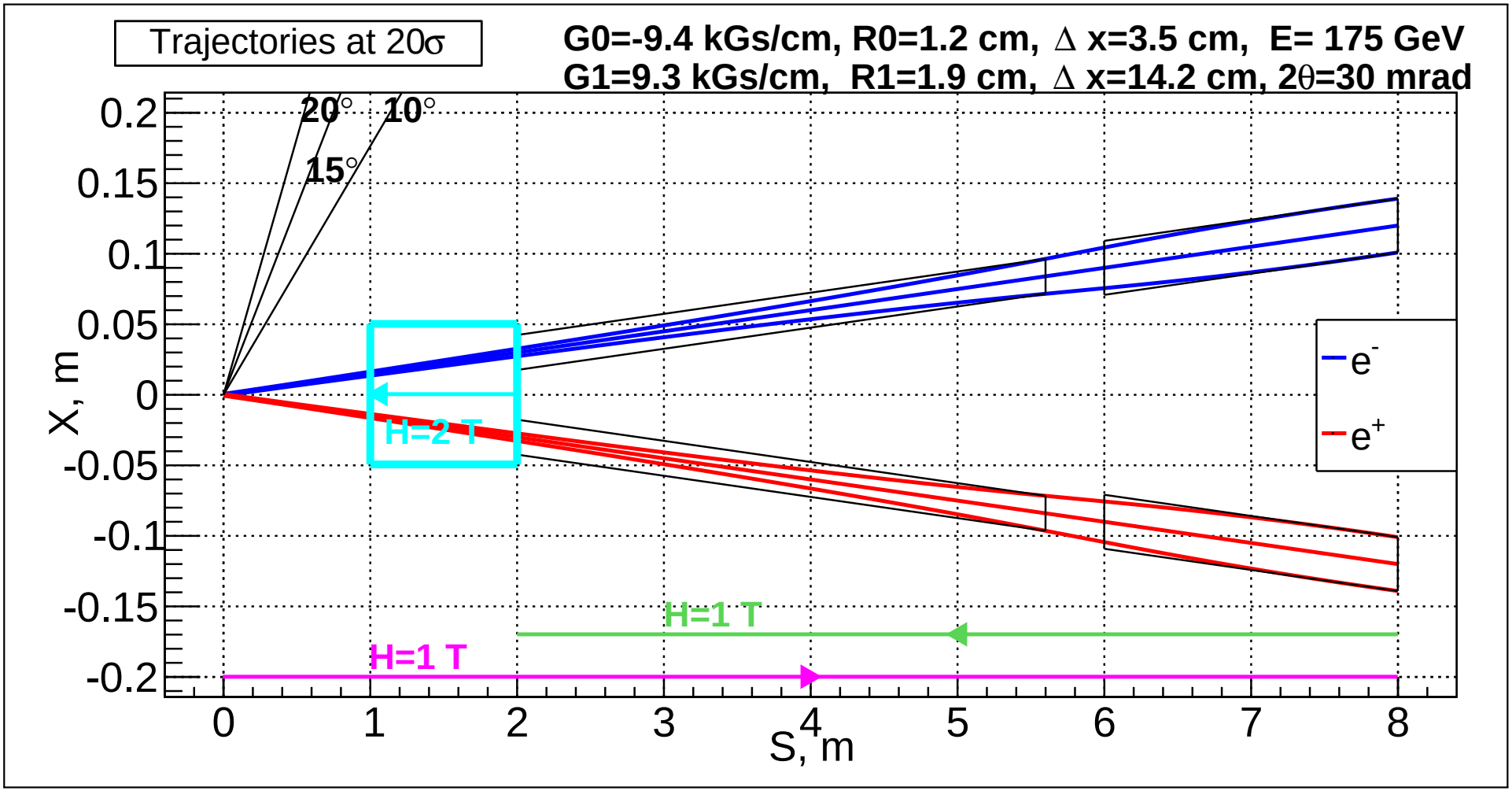


Rectangles represent bare apertures.

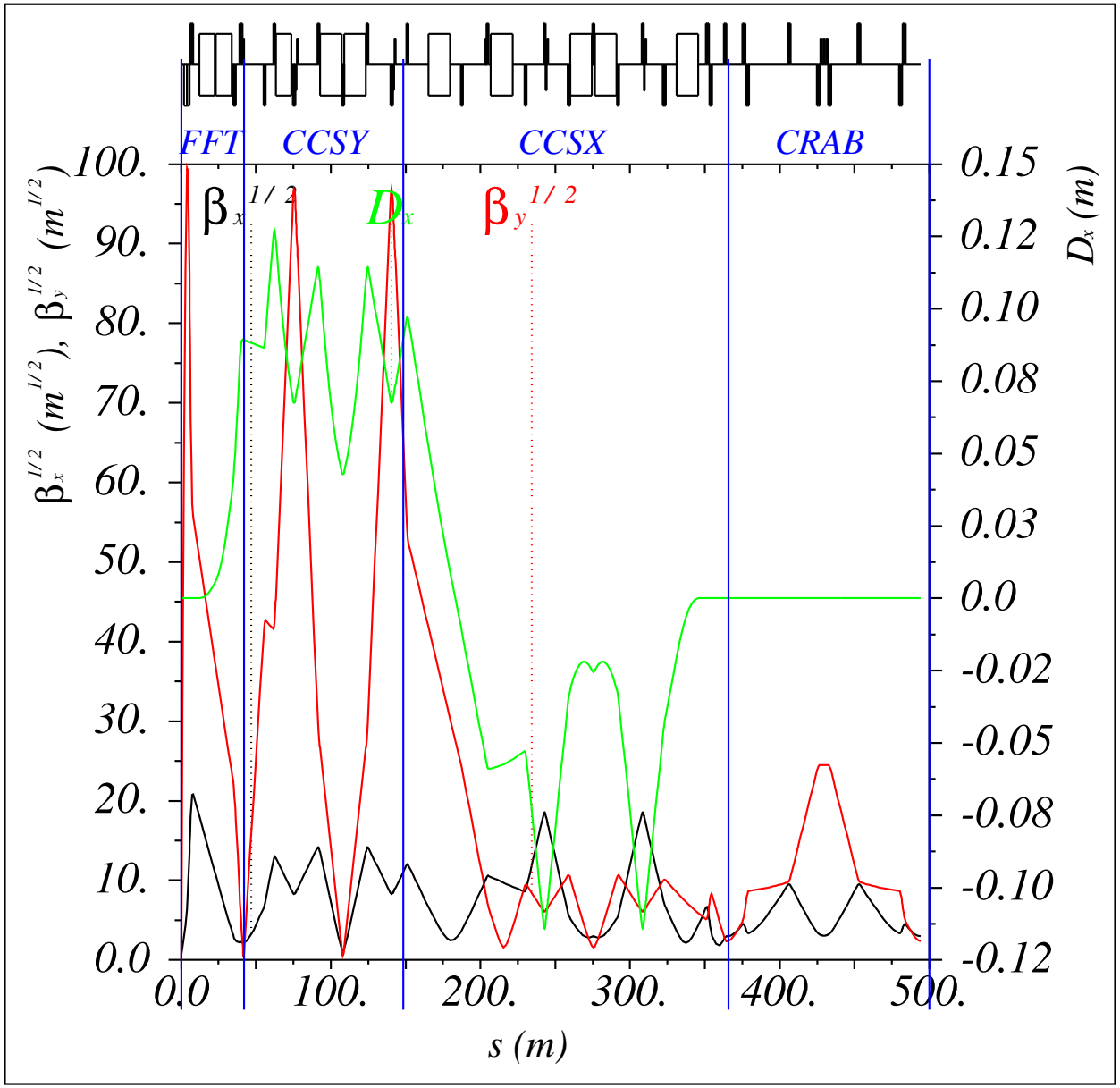
	L [m]
Q0	3.6
Q1	2

	R [m]
Q0	0.012
Q1	0.019

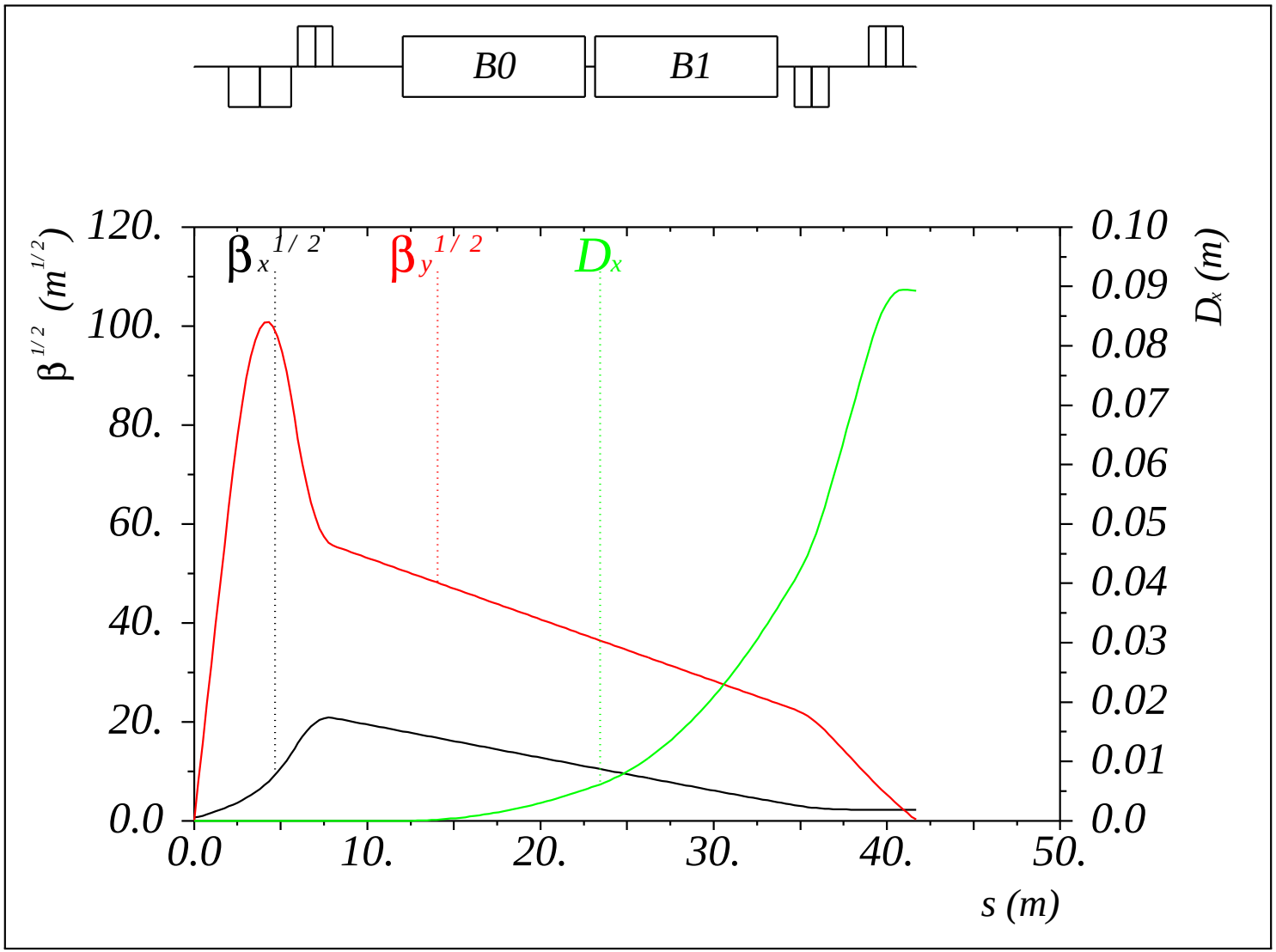
Final Focus layout: sketch of solenoids



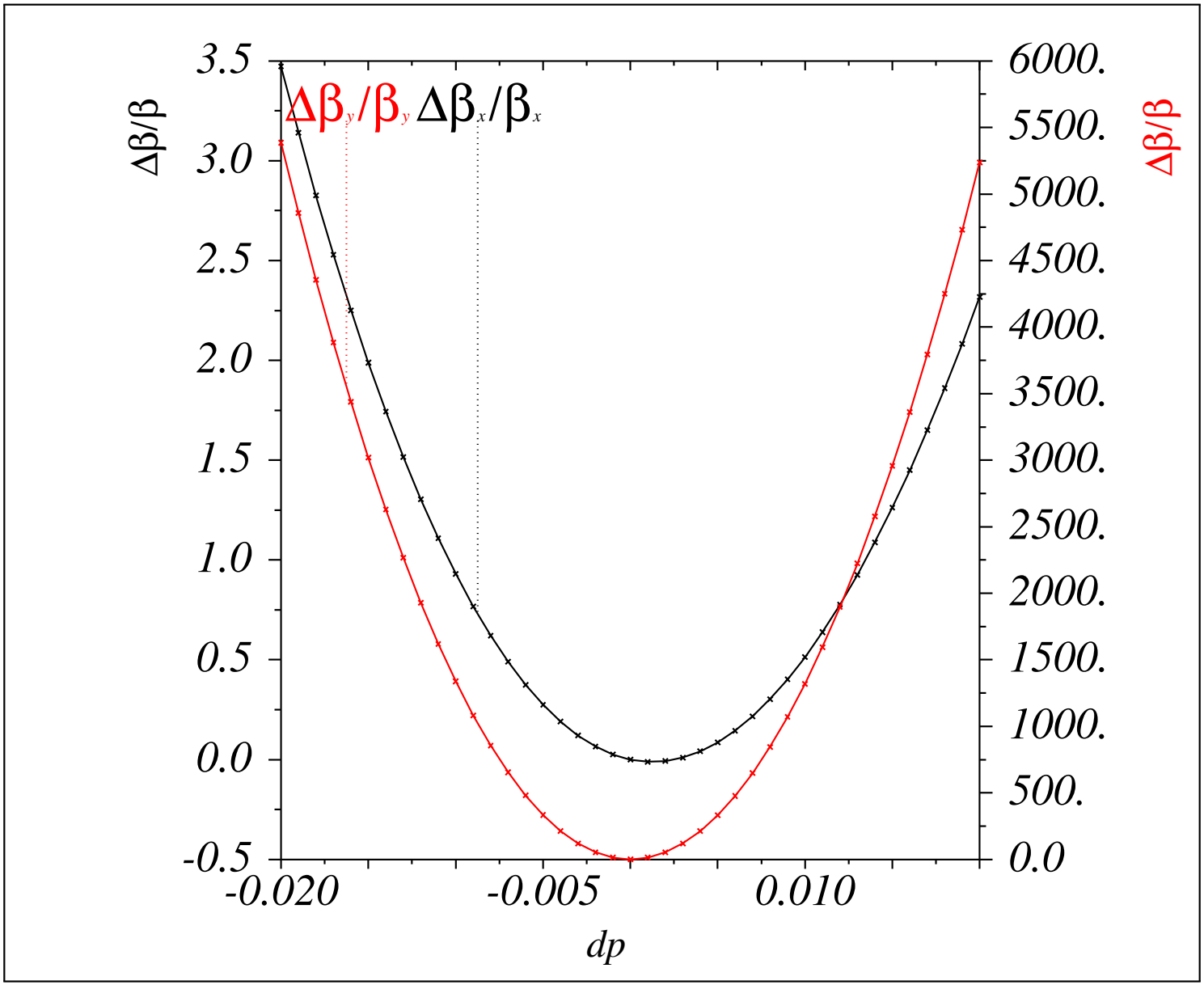
Interaction Region optical functions



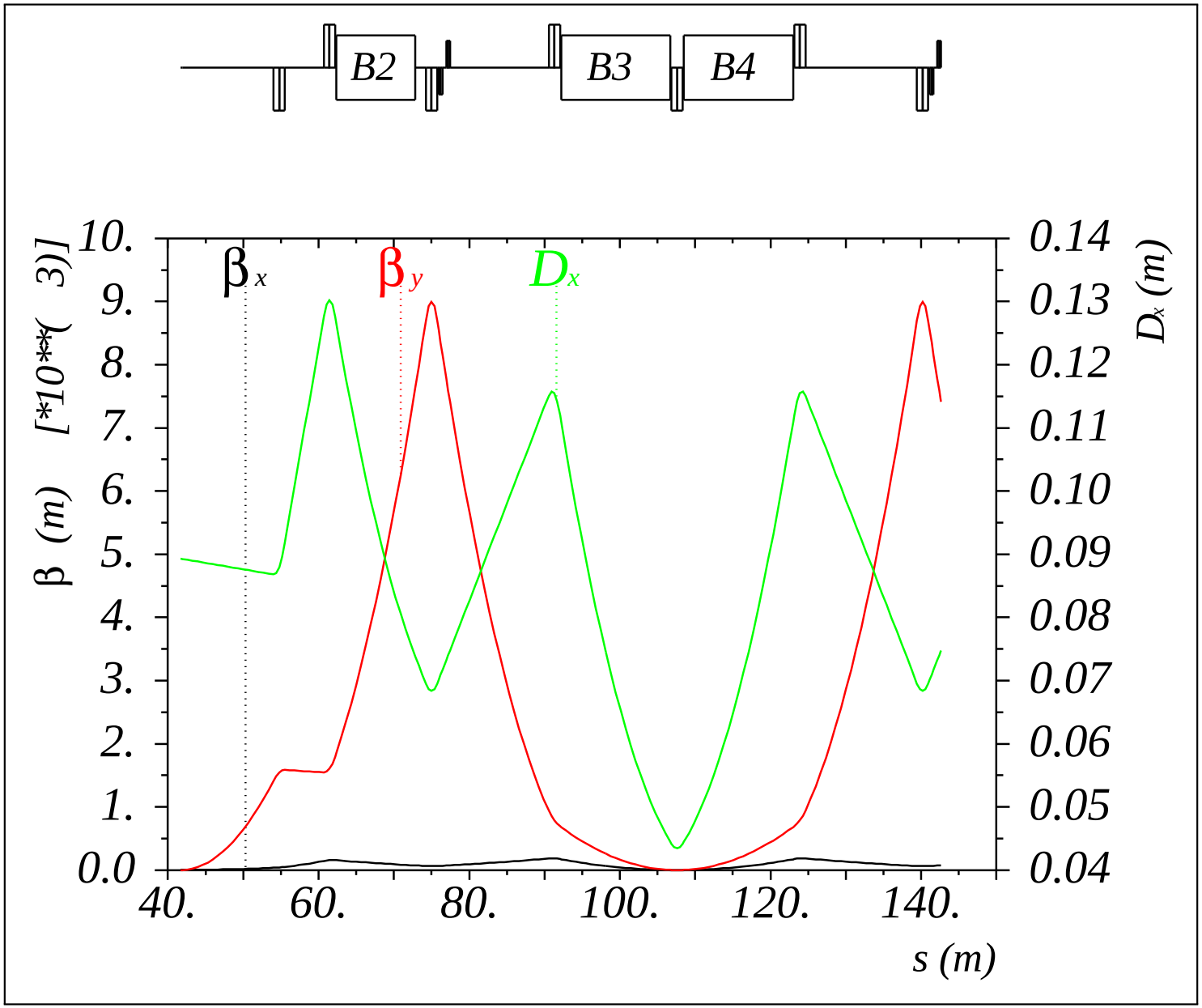
Final Focus Telescope



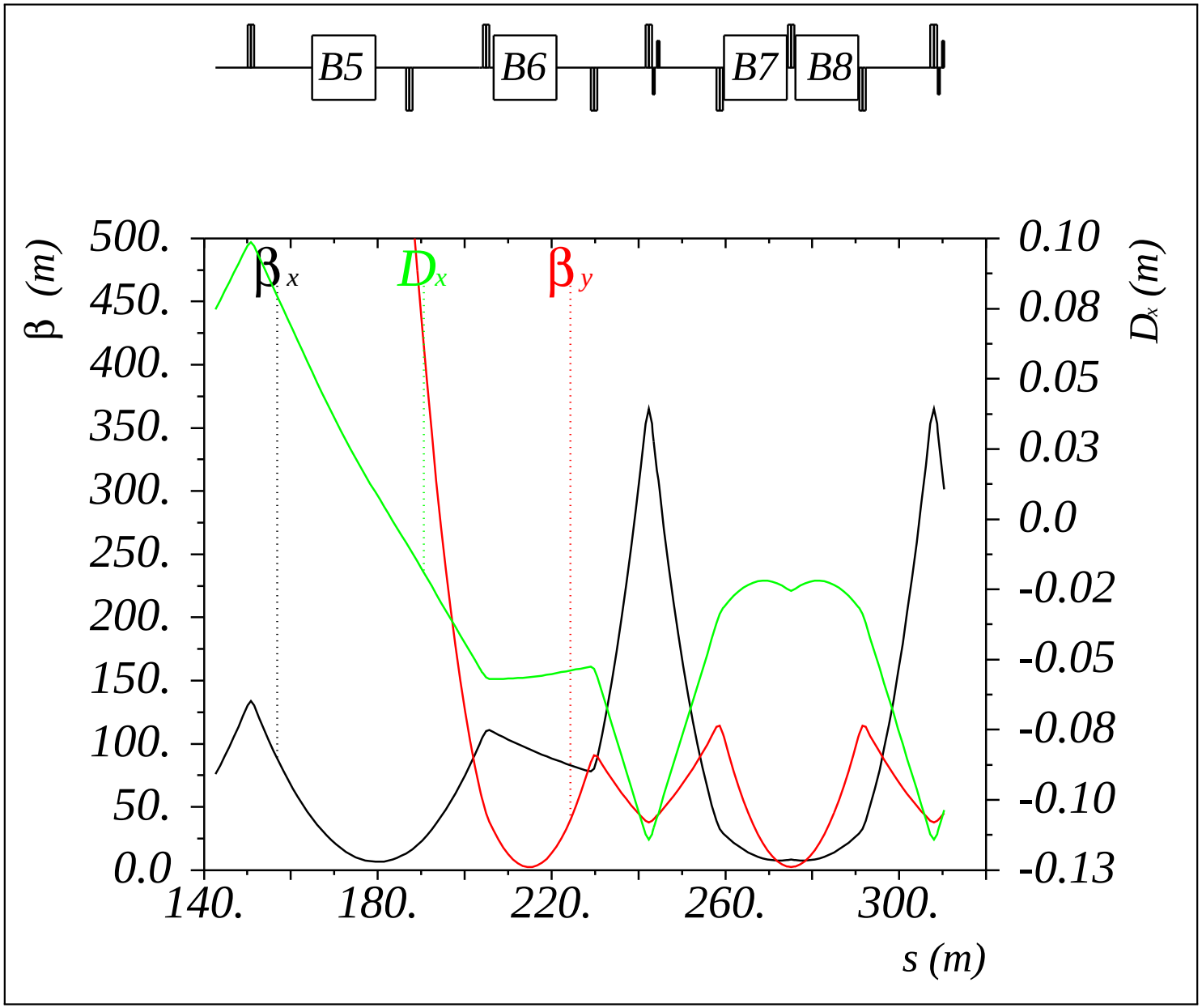
Final Focus Telescope: beta chromaticity



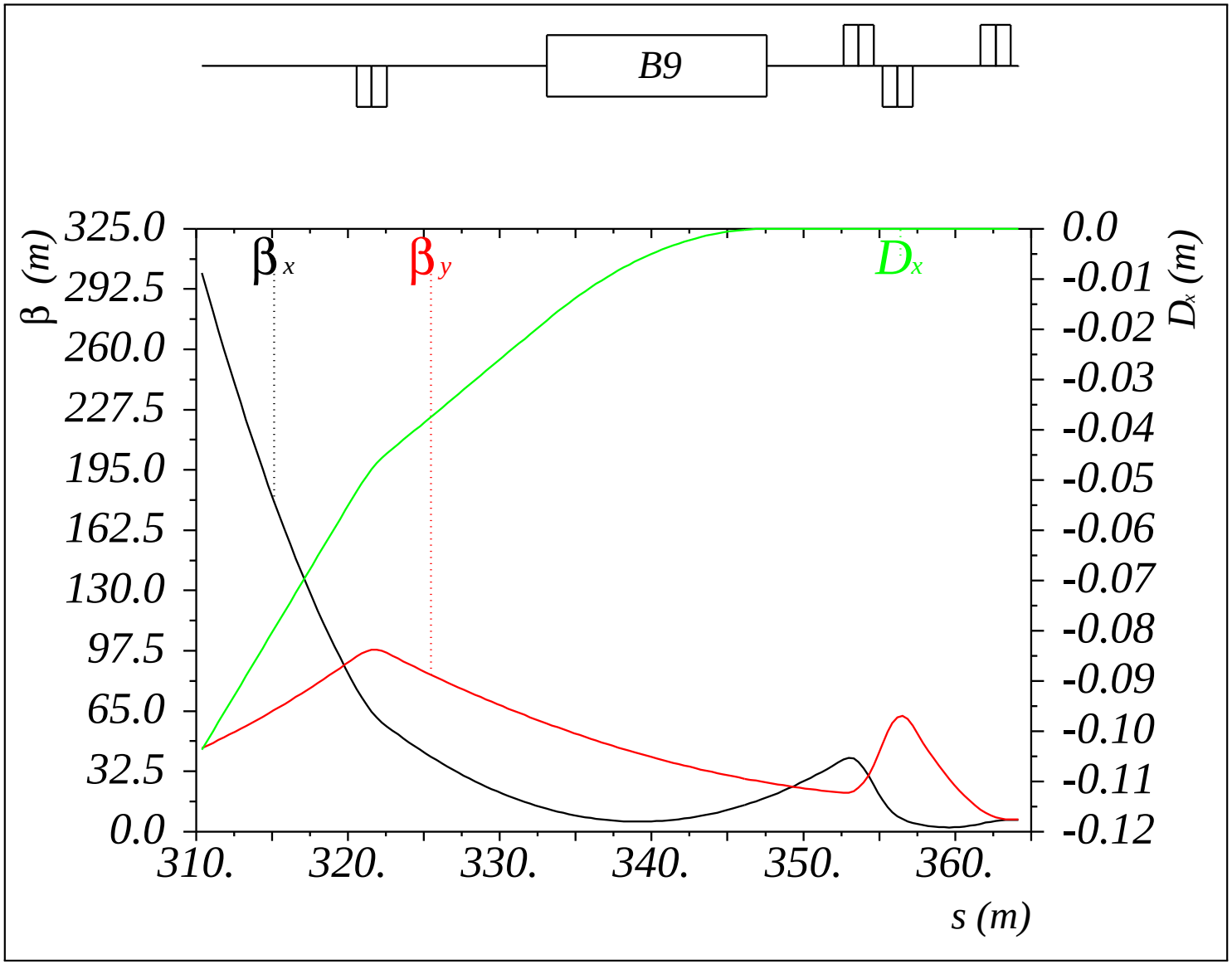
Y Chromaticity Correction Section



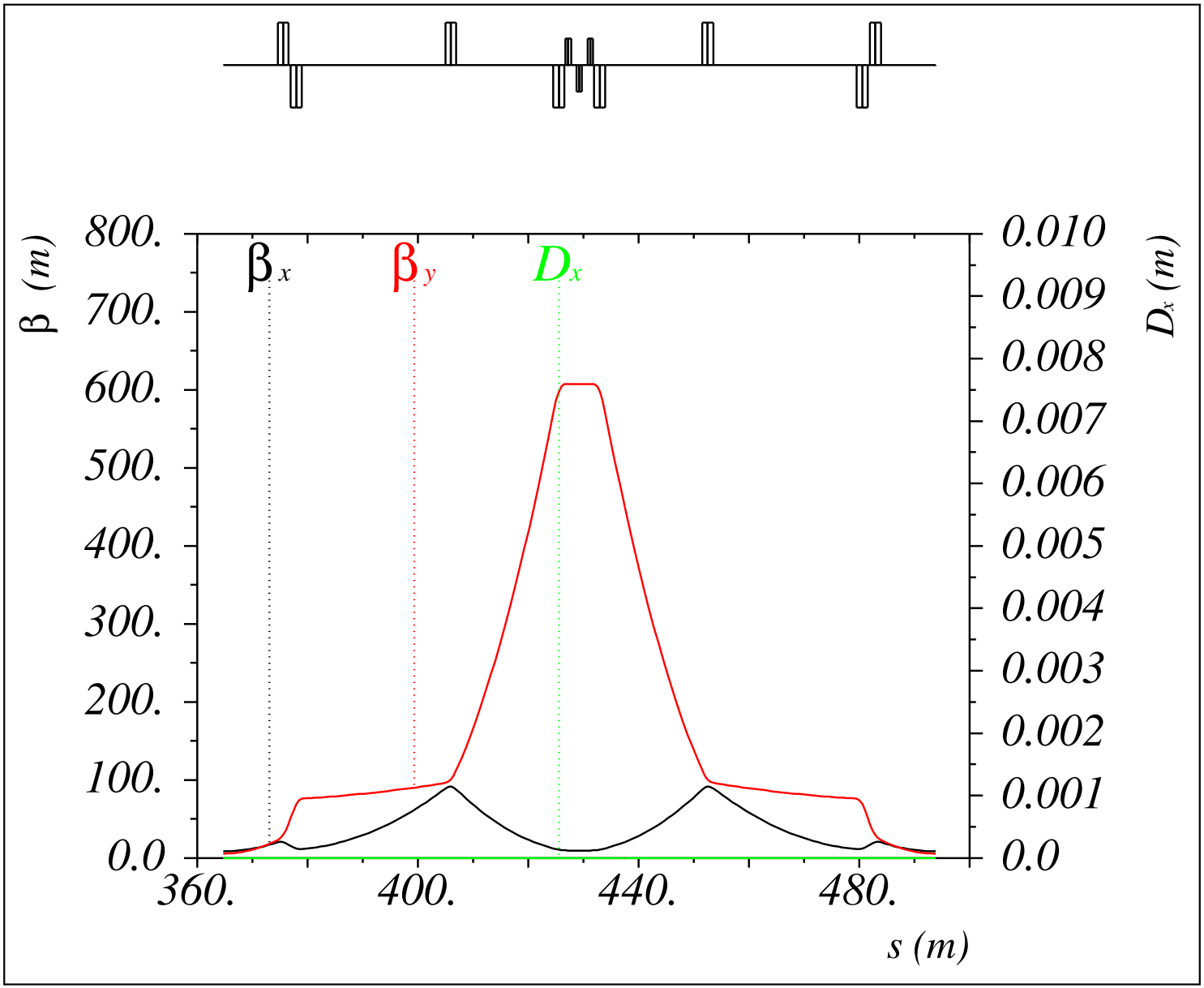
X Chromaticity Correction Section



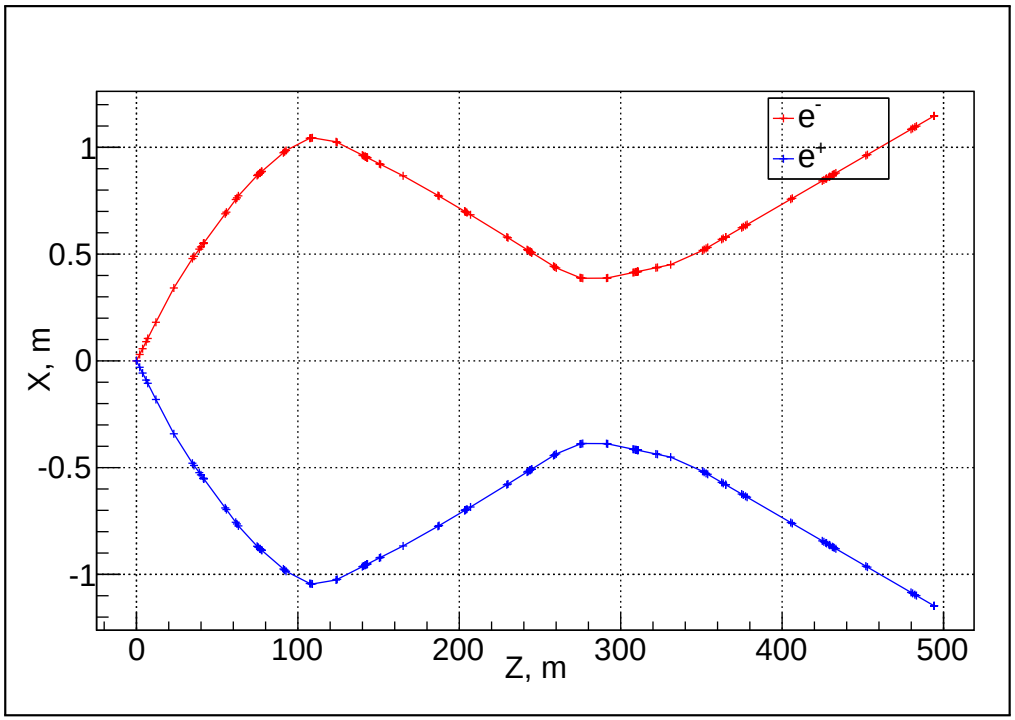
Chromaticity Correction Telescope



CRAB section



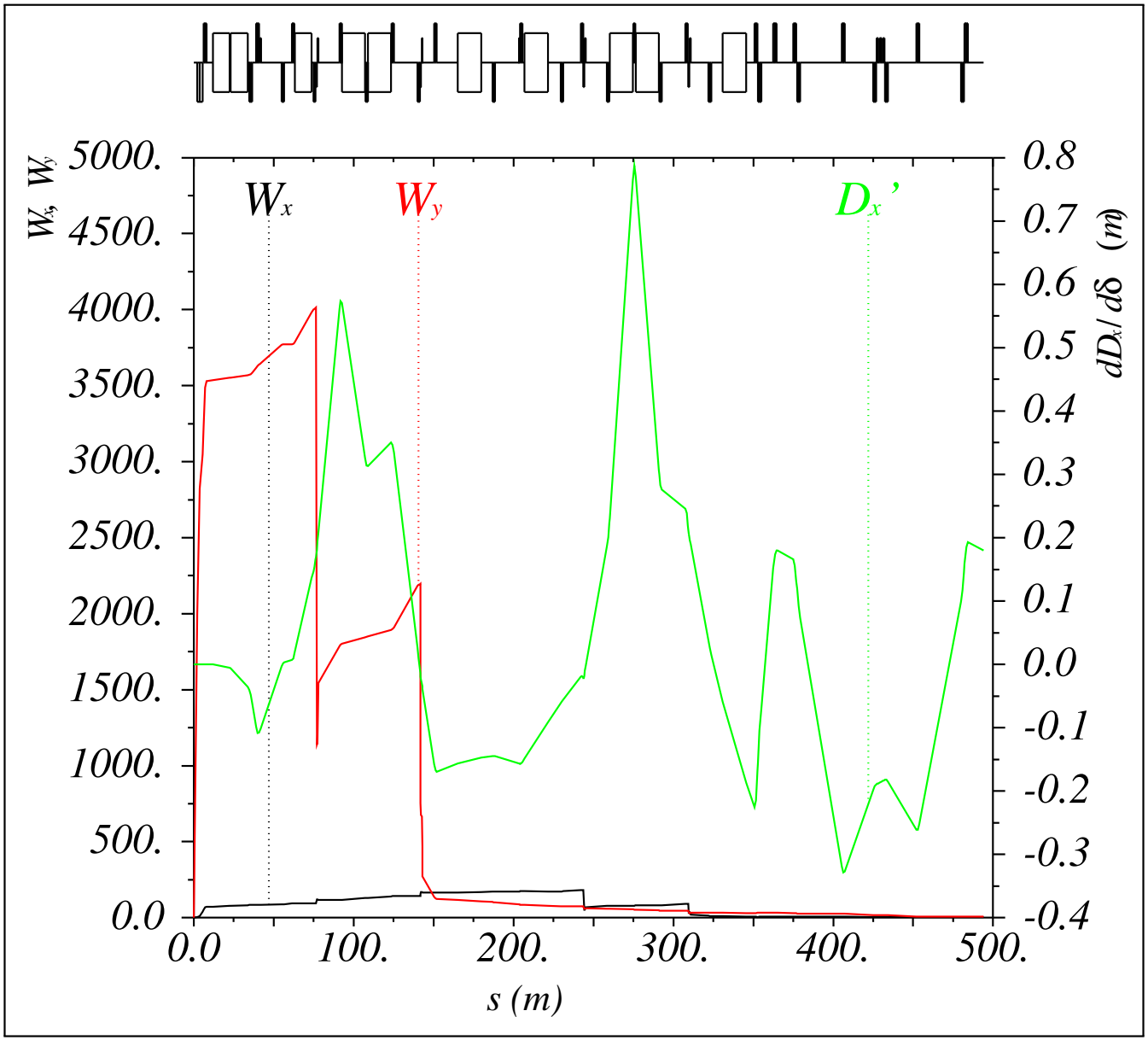
Interaction Region layout



Divergence of the beam lines is 8.8 mrad.
Energy loss is 0.11 GeV at $E = 175$ GeV.

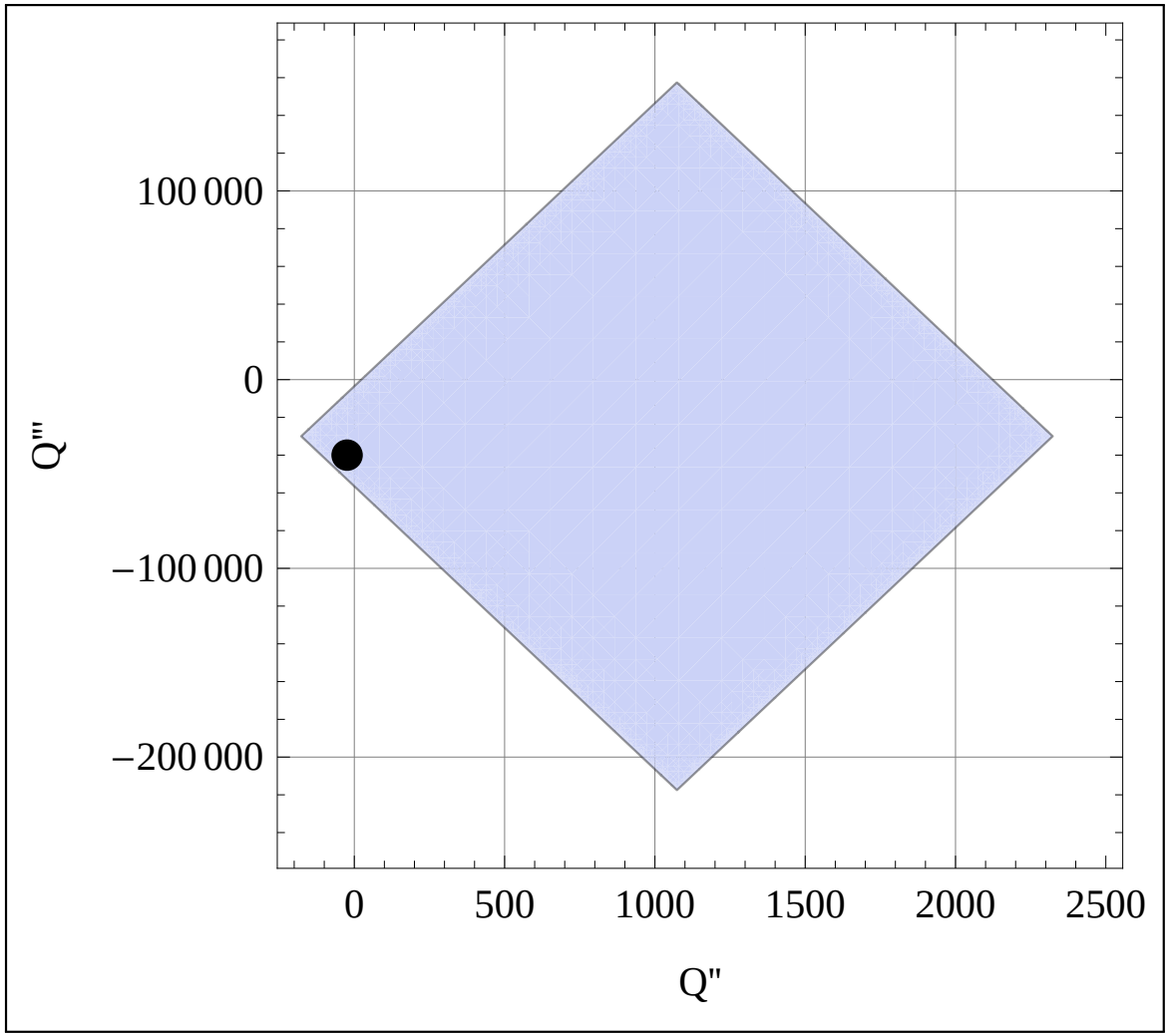
	L [m]	B [T]	ϕ [mrad]
SEB0	10.5	0.06	1
SEB1	10.5	0.21	3.7
SEB2	10.5	0.21	3.8
SEB3	14.5	0.21	5.2
SEB4	14.5	0.21	5.2
SEB5	14.5	0.03	0.6
SEB6	14.5	0.01	0.2
SEB7	14.5	-0.13	-3.2
SEB8	14.5	-0.13	-3.2
SEB9	14.5	-0.11	-2.8
Total			11

Chromaticity: Montague functions



Chromaticity estimations

$$0 \leq Q(\delta) - Q_0 \leq 0.5$$



$$Q(\delta) = Q_0 + Q_0'\delta + Q_0''\frac{\delta^2}{2} + Q_0'''\frac{\delta^3}{6} + Q_0''''\frac{\delta^4}{24}$$

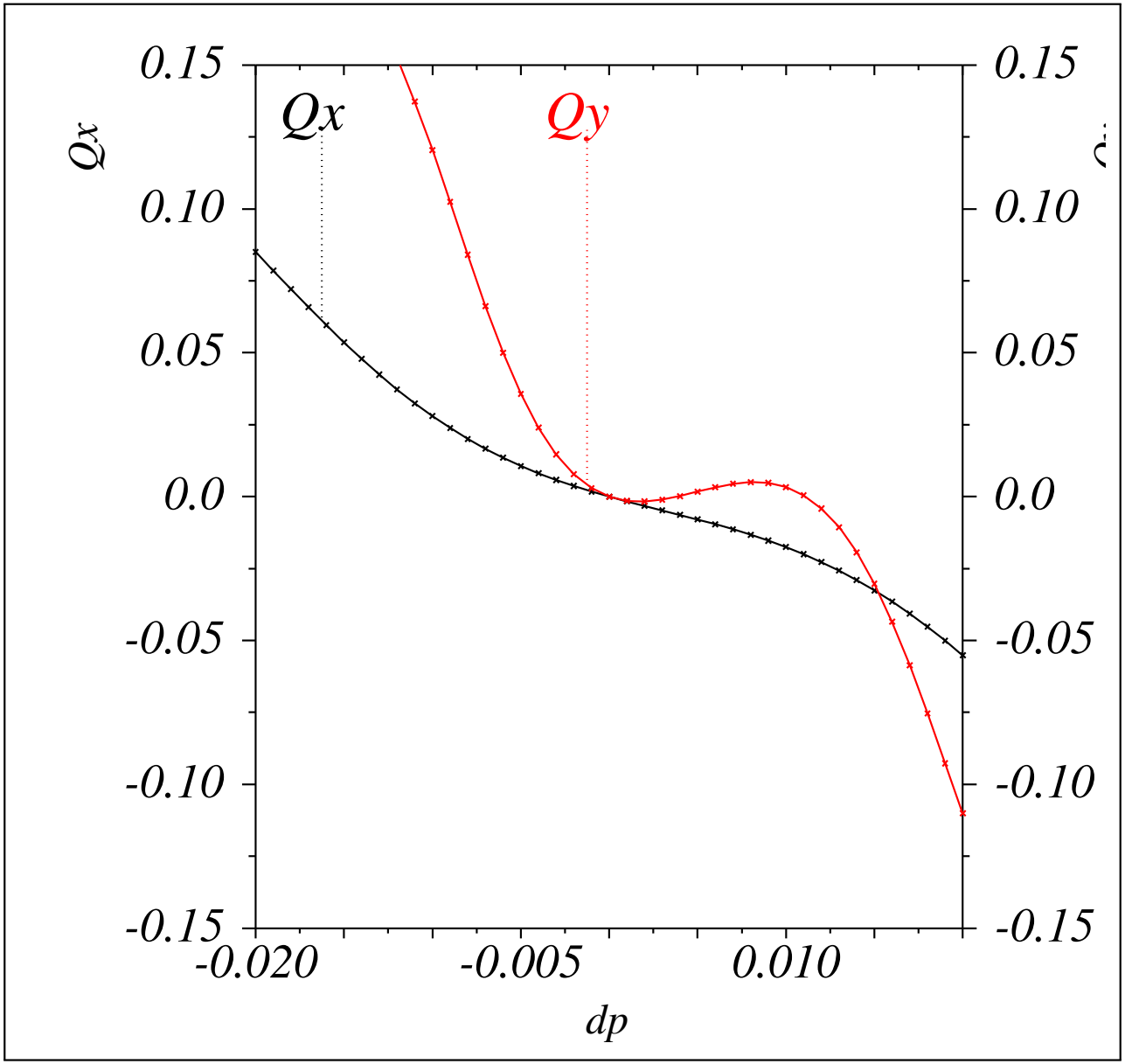
$$Q_0' = 2,\ Q_0'''' = 5.3 \cdot 10^6$$

$$\delta \in [-0.02; 0.02]$$

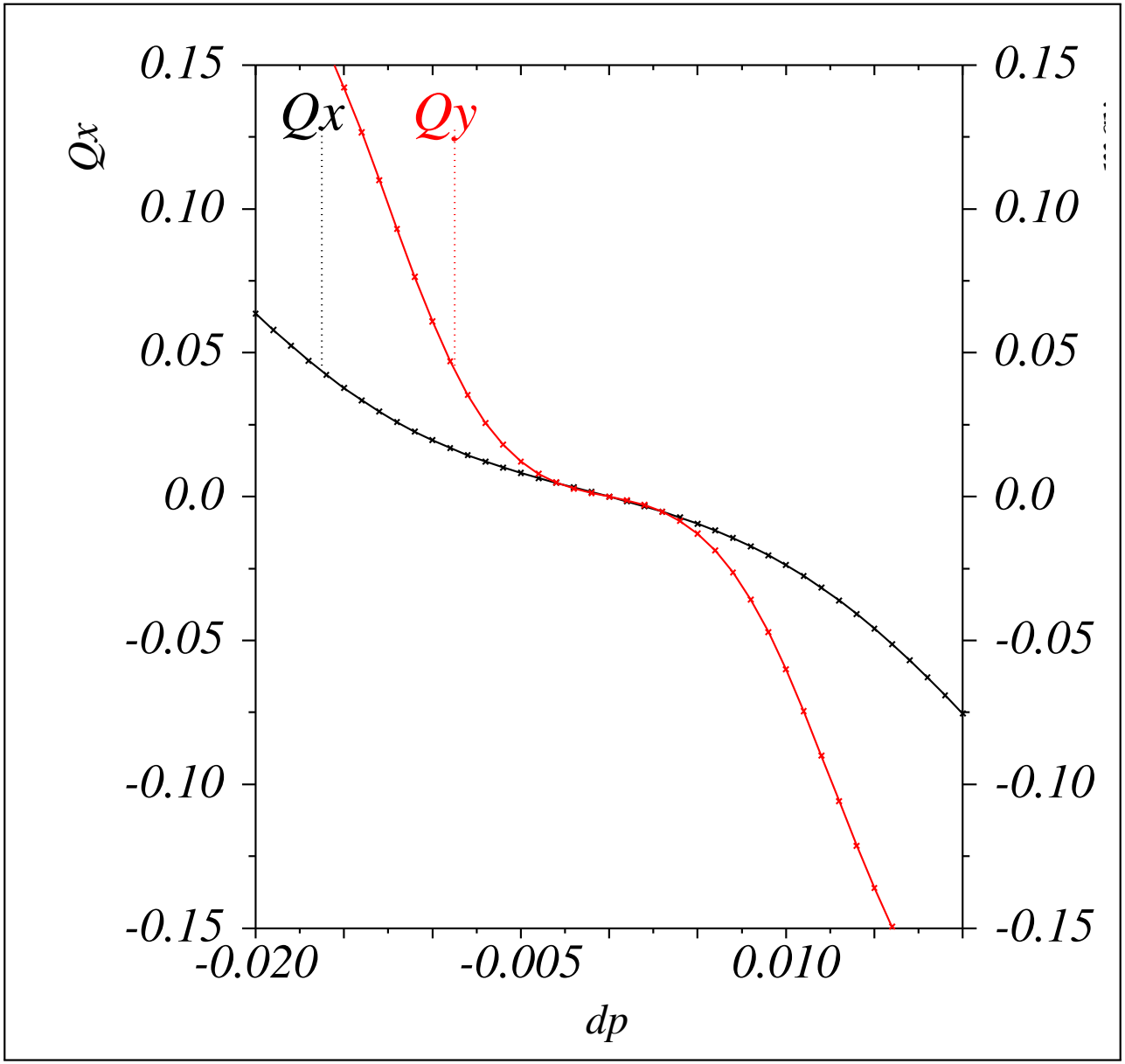
Chromaticity: IR phase advance

	Sextupoles in phase	Sextupoles shifted	Sextupoles additional
Q_x	4		
Q'_x	-1.71	-1.62	-1.27
Q''_x	110	-48	-144
Q'''_x	$-3.6 \cdot 10^4$	$-3.4 \cdot 10^4$	$-2.9 \cdot 10^4$
Q''''_x	$-5.3 \cdot 10^5$	$7.4 \cdot 10^5$	$8.9 \cdot 10^5$
Q_y	3		
Q'_y	-2.15	-1.22	-1.51
Q''_y	$1.5 \cdot 10^3$	-38	-24
Q'''_y	$-3.1 \cdot 10^5$	$-3.1 \cdot 10^5$	$-4 \cdot 10^4$
Q''''_y	$-1 \cdot 10^6$	$5.8 \cdot 10^6$	$5.3 \cdot 10^6$

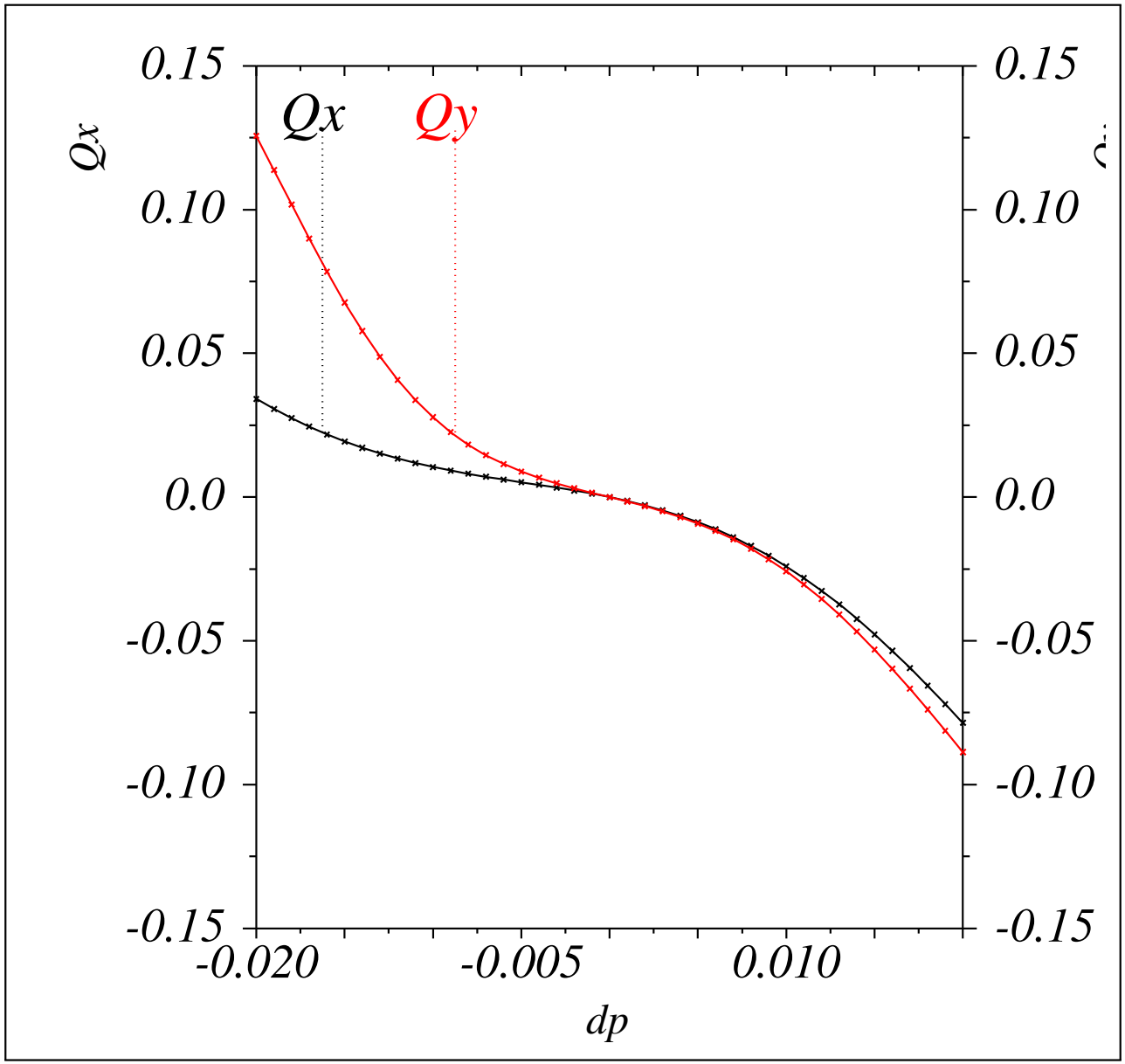
Sextupoles in phase and no additional sextupoles



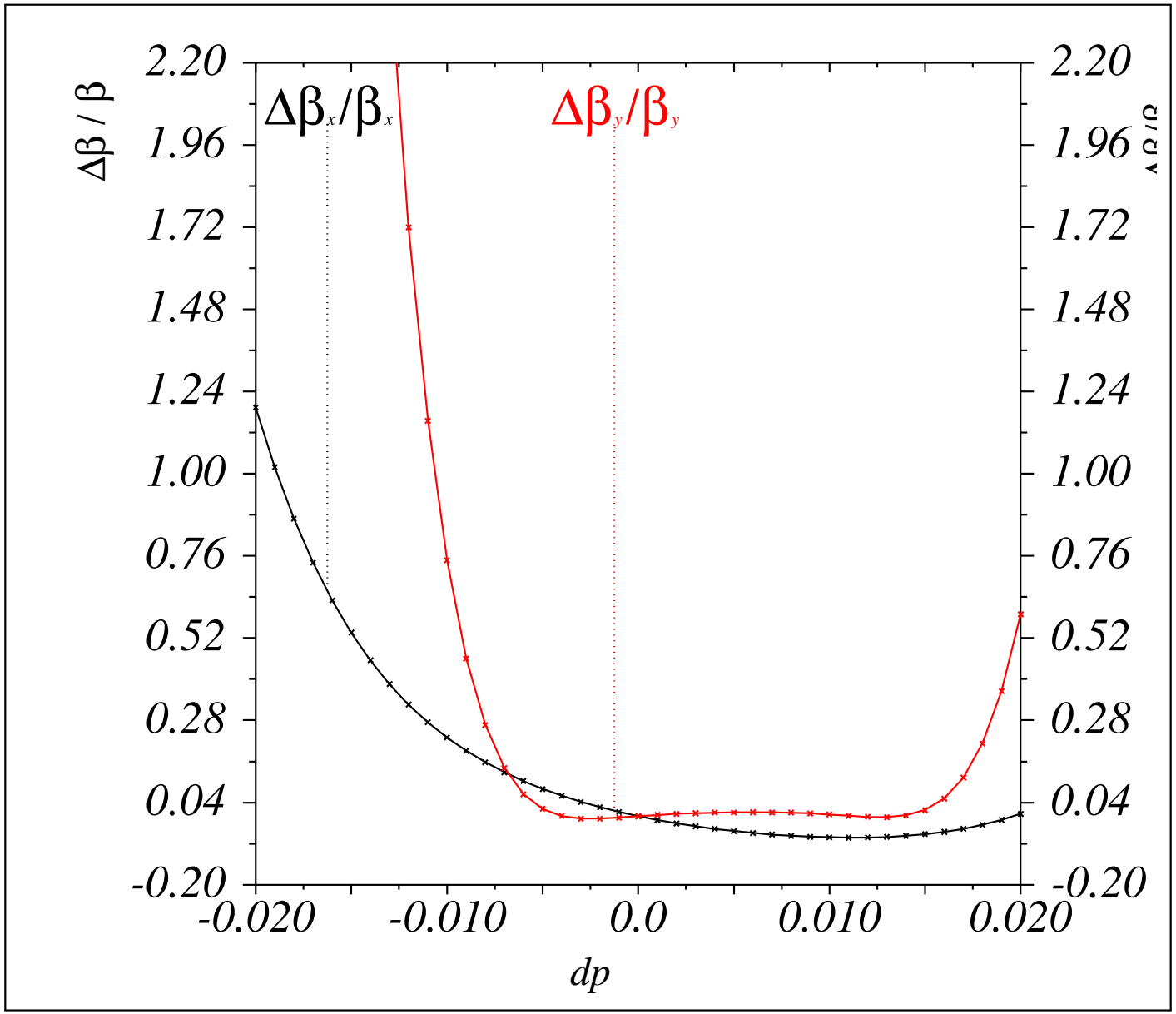
Sextupoles shifted and no additional sextupoles



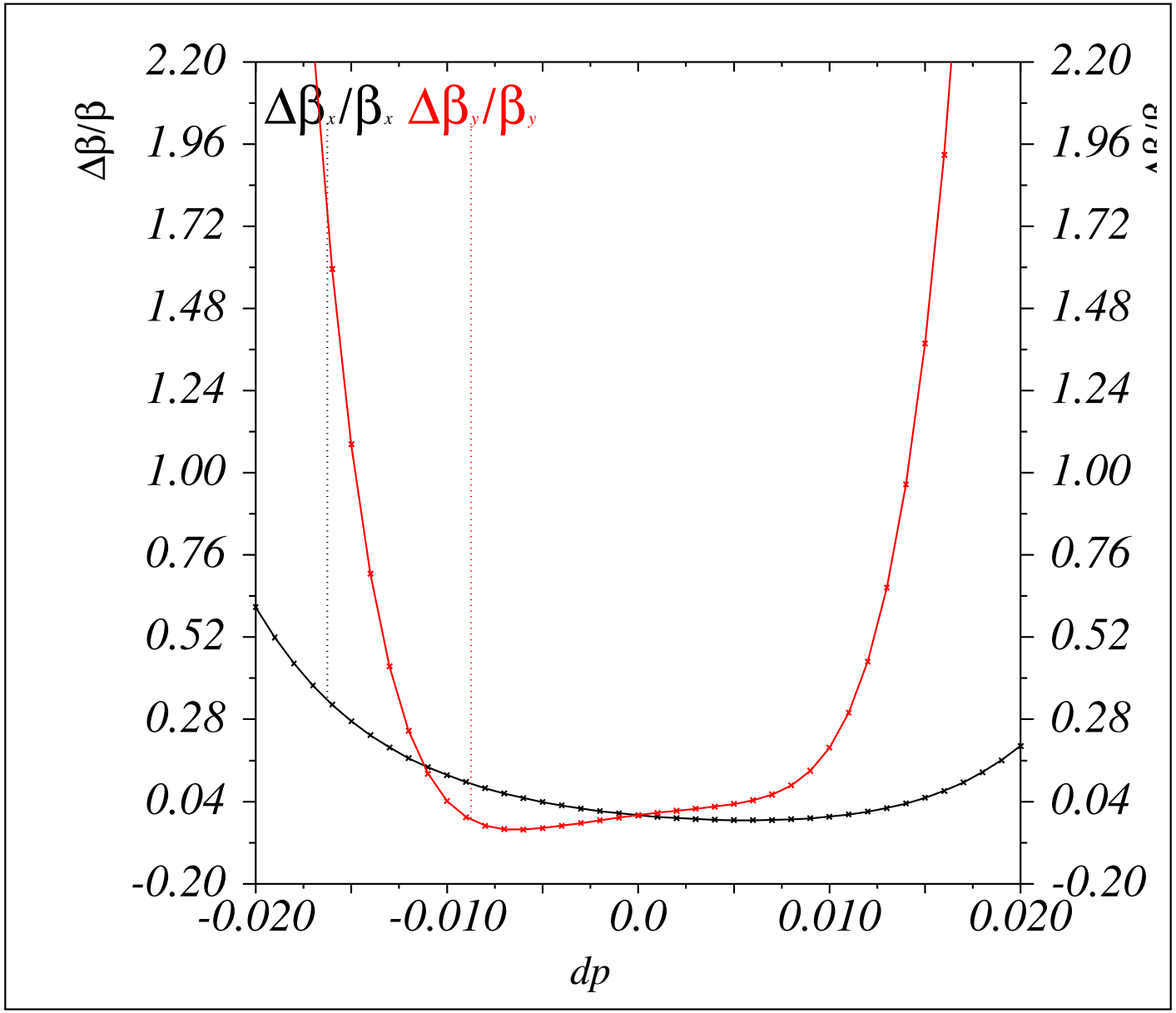
Sextupoles shifted and two additional sextupoles



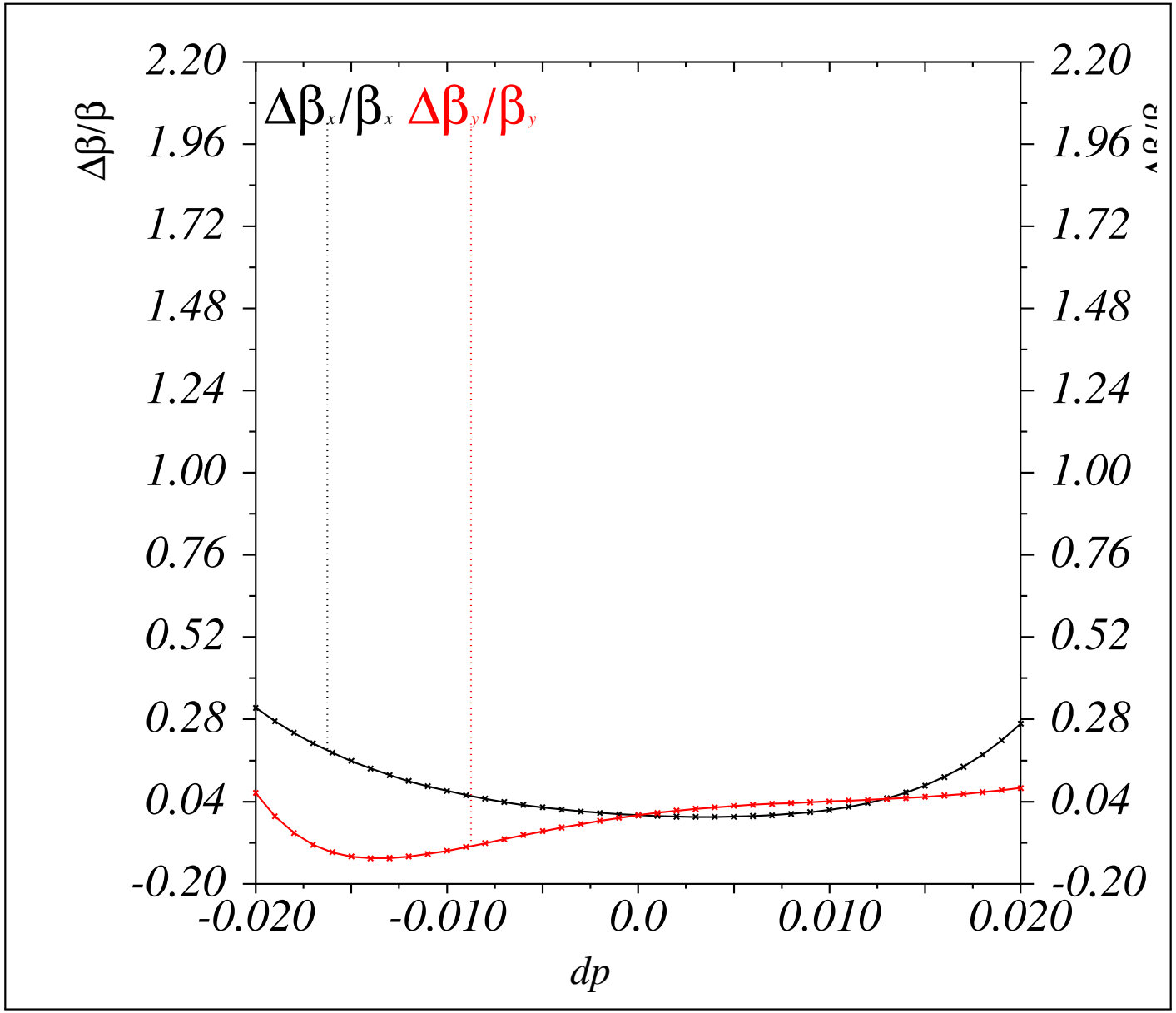
Sextupoles in phase and no additional sextupoles



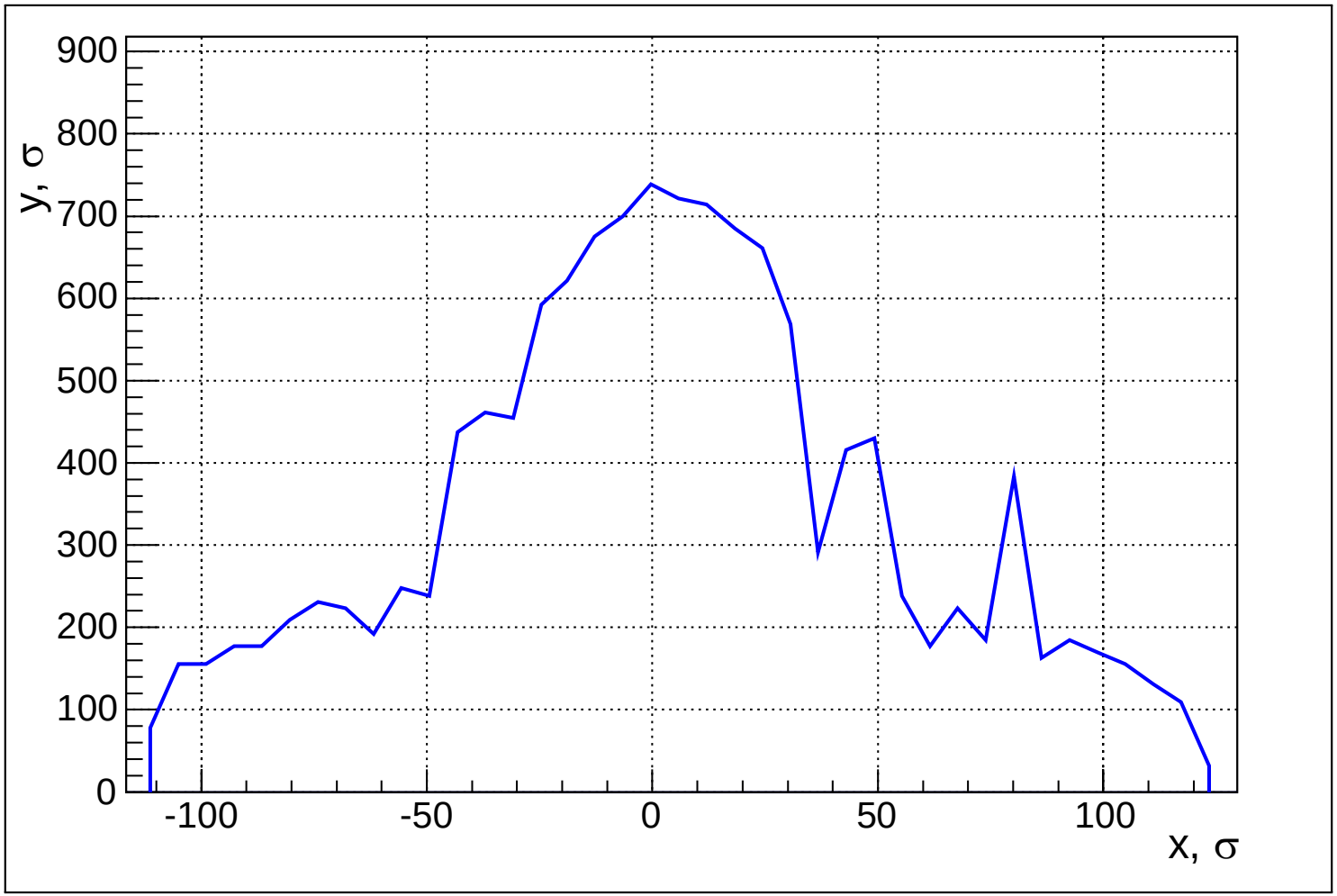
Sextupoles shifted and no additional sextupoles



Sextupoles shifted and two additional sextupoles



Dynamic aperture



Saturday, October 11, 2014

09:00 (6) Choice of L* II: IR optics and dynamic aperture 30'

Speaker: Dr. Eugene Levichev (BINP)

Summary

Conclusion

1. A version of interaction region with crab waist is ready.
2. Synchrotron radiation is low.
3. Beam lines are symmetrical, making tunnel straight.

Questions

1. Is it possible to build required final focus quadrupoles?
2. How longitudinal detector field will be compensated?
3. Is there a need to increase L^*?
4. Do position and fields of the dipoles allow for synchrotron radiation shielding and detector background minimization?