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Status of the chromaticity correction in the arcs

Bastian Haerer (CERN, Geneva; KIT, Karlsruhe) for the FCC-ee lattice design team

Acknowledgement: Thanks to Luis Medina for performing the DA study.

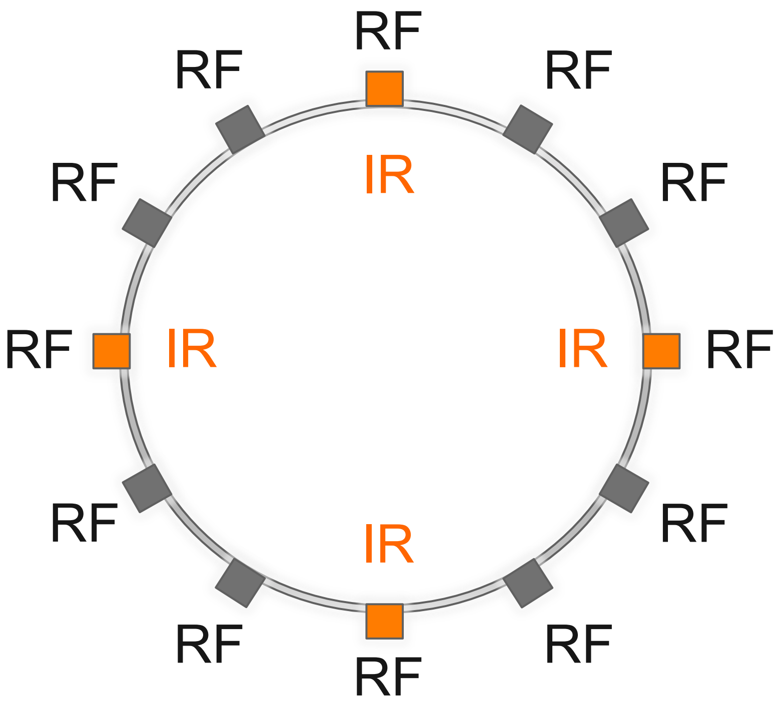
Outline

- First DA Results (Luis Medina)
- β^*_y = 1 mm: tuning the momentum acceptance
- β^*_y = 2 mm: momentum acceptance and chromaticities
- Summary and schedule until the Review

1) First DA study (Luis Medina)

Lattices for first DA test:

1) 12-fold layout, 4 IPs
2) 12-fold layout, 2 IPs
3) 12-fold layout, 4 IPs,
   0.249/0.166 phase advance
4) Baseline layout (2 IPs)



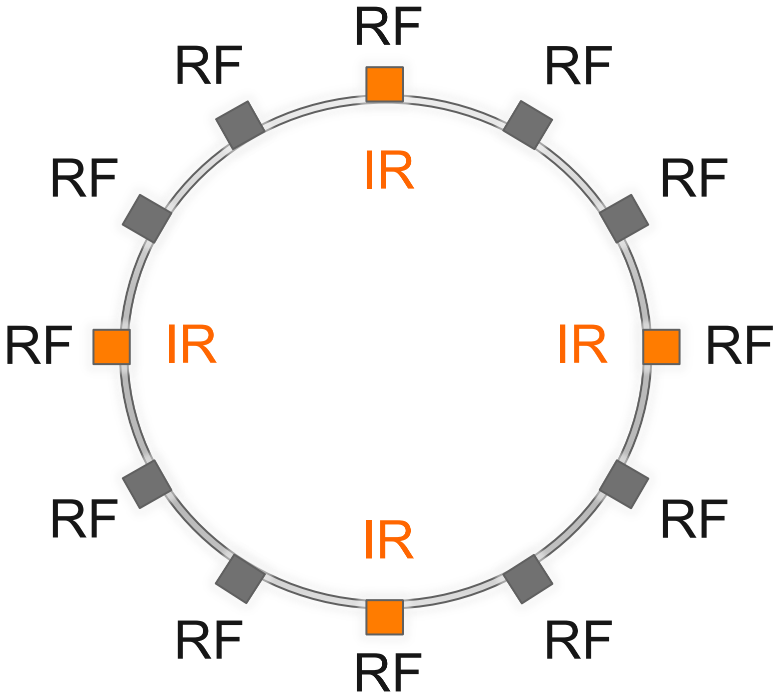
Chromaticity corrected with Montague formalism

1) First DA study (Luis Medina)

12-fold layout:

Circumference:	100 km
Arc length:	6.8 km
Straight section length:	1.5 km
Phase advance per cell:	90°/60°

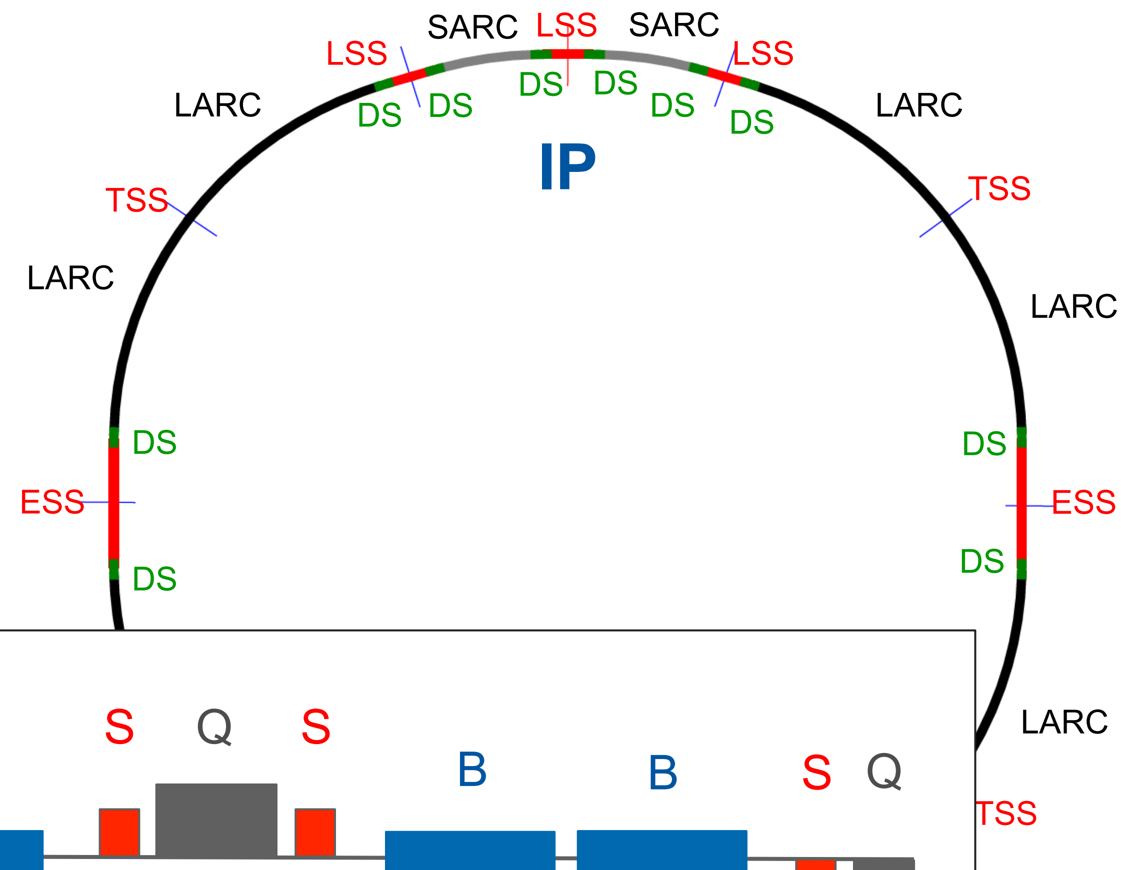
4 interaction regions (IR)
with mini-beta insertions

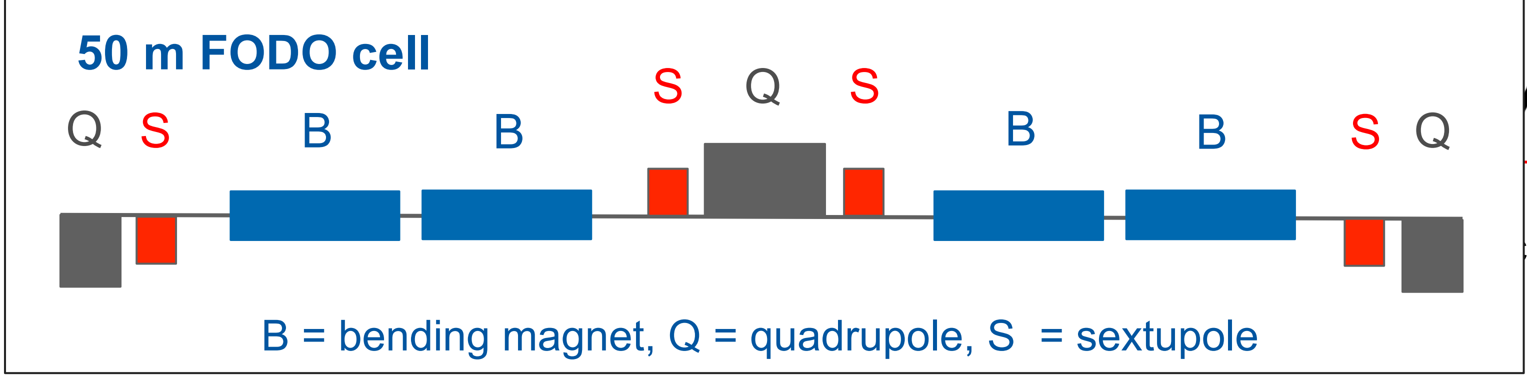


NO LOCAL CHROMATICITY CORRECTION

Baseline Layout (V17)

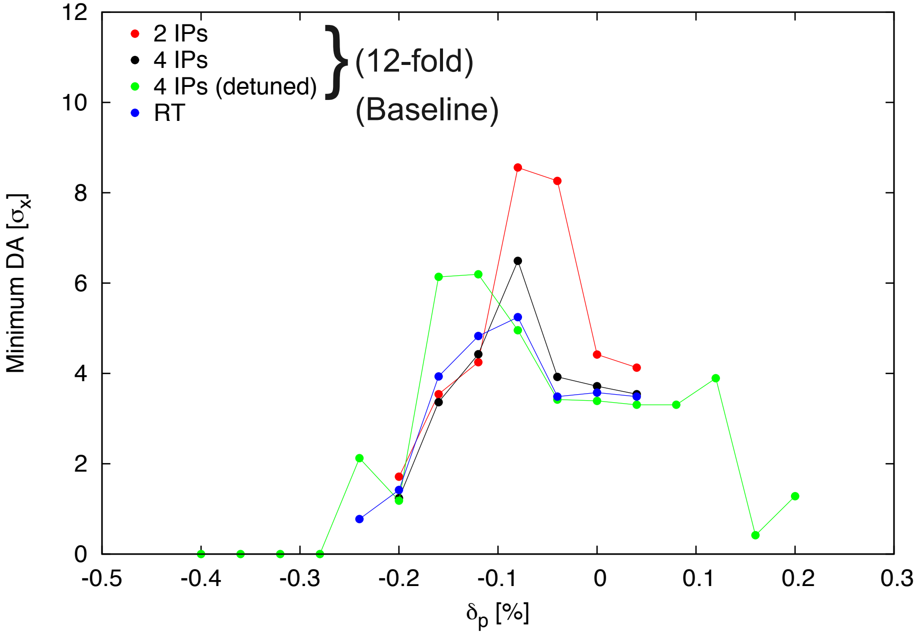
- 100 km circumference
- 2 IPs
- No local CCS



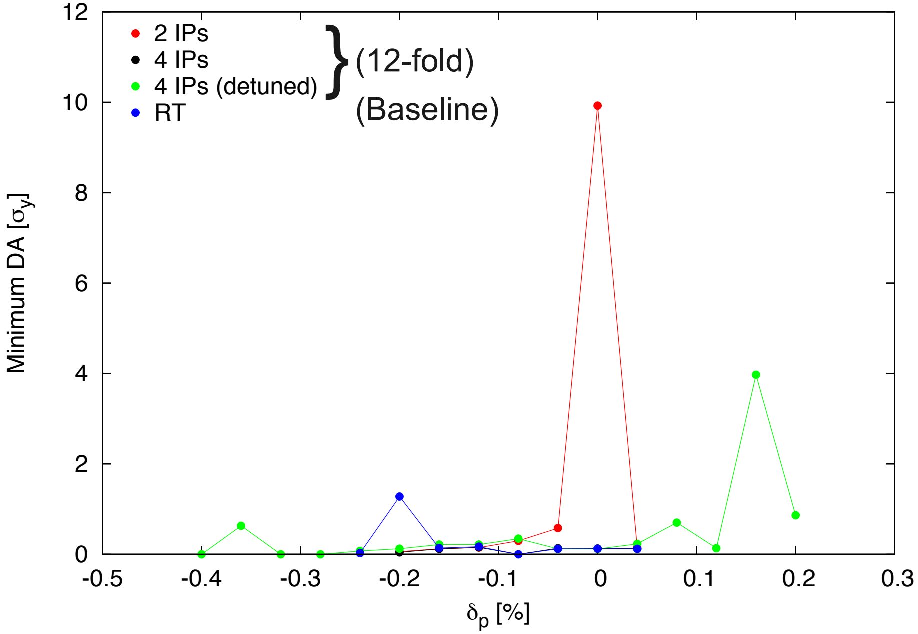


First DA results (Luis Medina)

Horizontal plane



Vertical plane

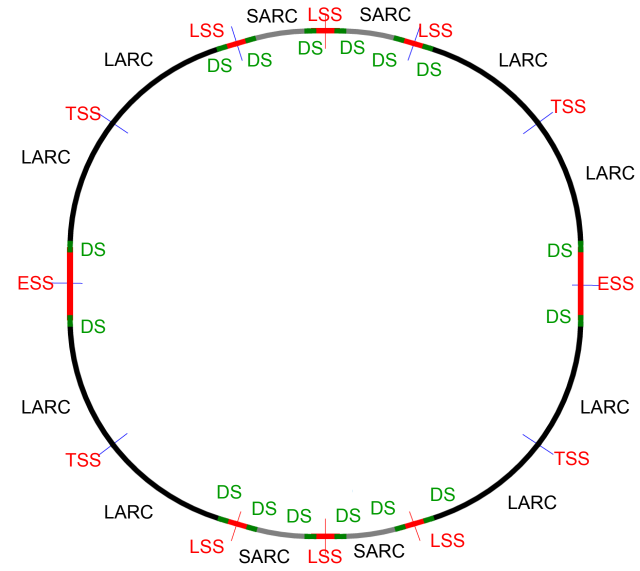


- Reduction No. of IP does not increase momentum acceptance but DA
- Detuning of the FODO cells increases momentum acceptance slightly

More DA studies of the Baseline Layout in progress …

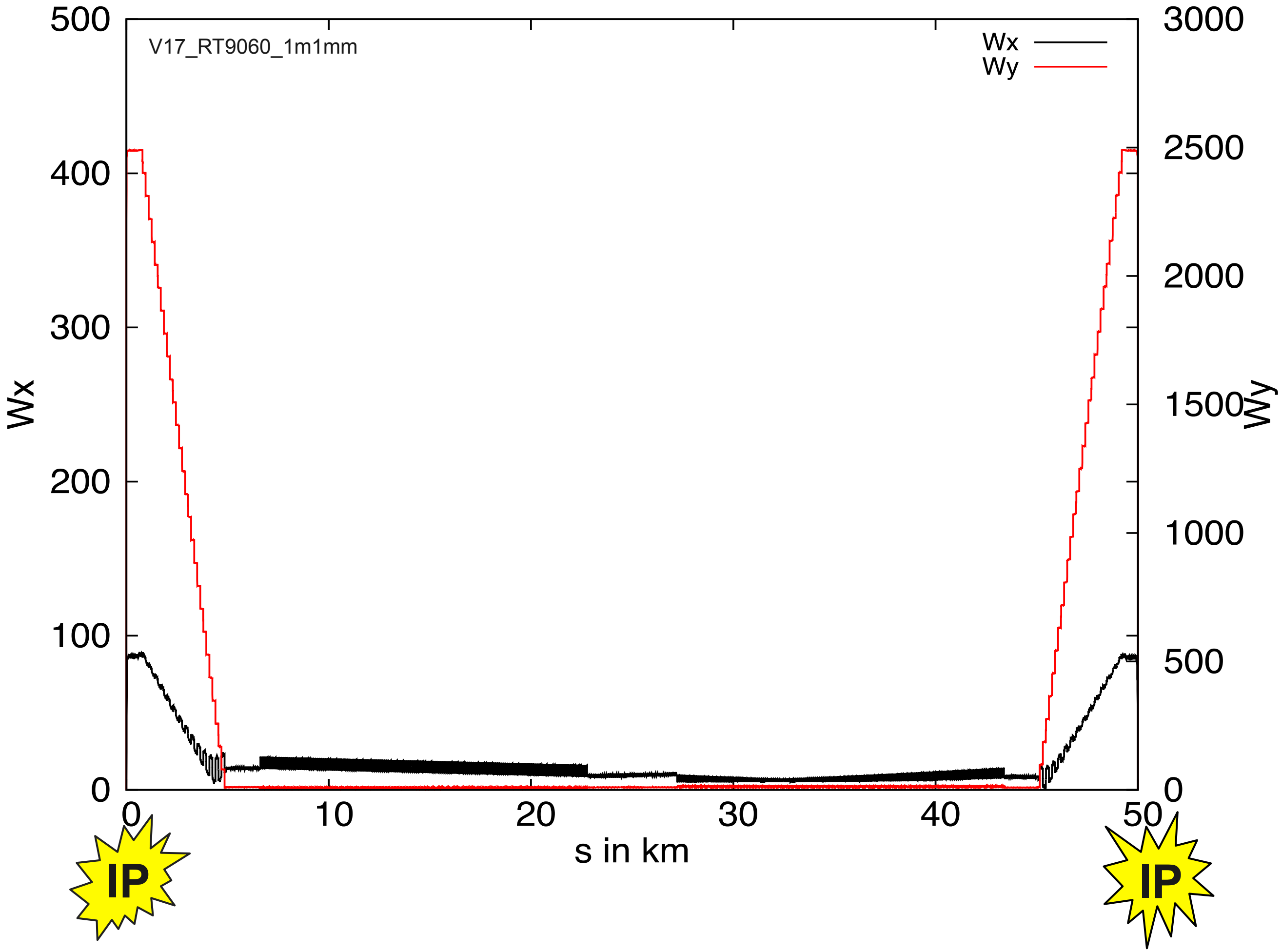
DA calculations and plots by Luis Medina

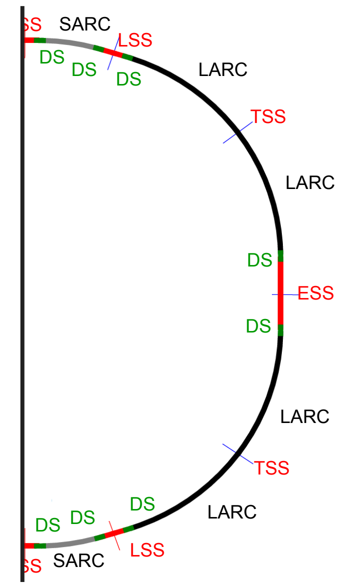
2) Momentum acceptance for $\beta^*_y = 1$ mm



- Baseline layout
- Phase advance per cell: 90°/60°
- 2 IRs with $\beta^*_x = 1$ m, $\beta^*_y = 1$ mm
- Chromaticity corrected with Montague formalism

W functions in the half-ring

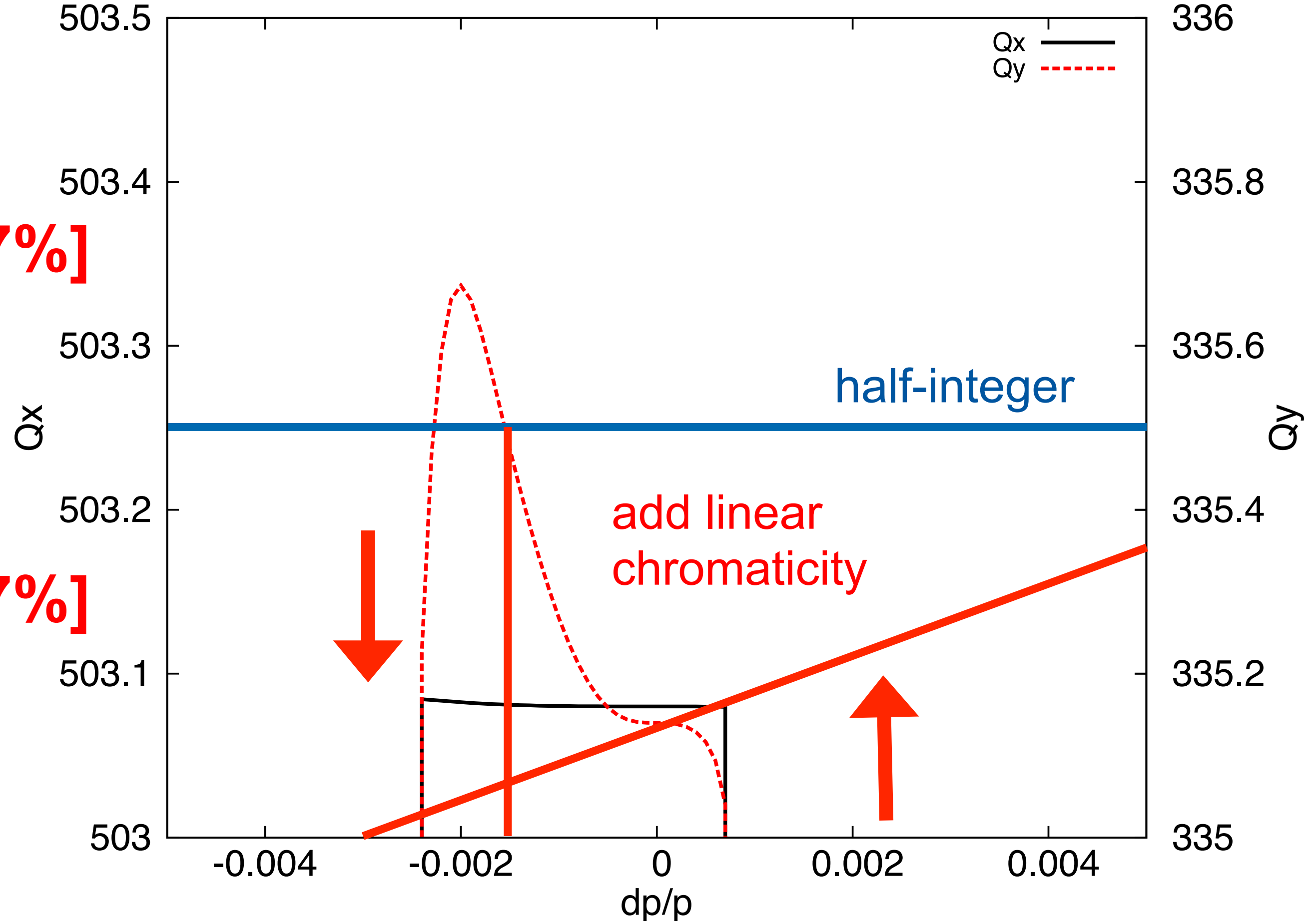




Initial momentum acceptance

[-0.24%, 0.07%]

[-0.15%, 0.07%]

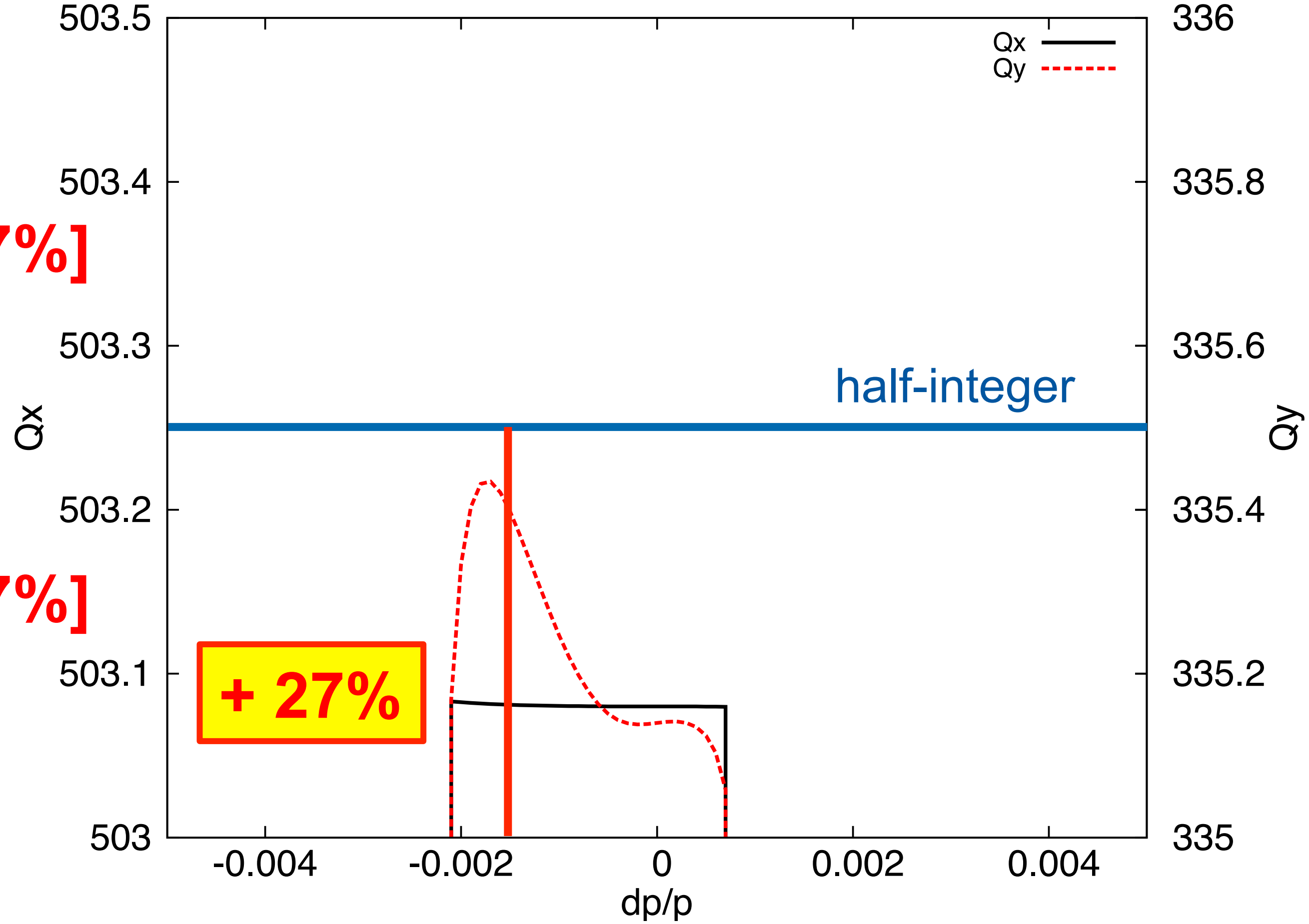


Tuned momentum acceptance

$Q'_y = 15$:

[-0.21%, 0.07%]

[-0.15%, 0.07%]



3) Momentum acceptance for $\beta^*_y = 2$ mm

- Baseline layout
- Phase advance per cell: 90°/60°
- Parameters for the Review
  → 2 IRs with $\beta^*_x = 1$ m, $\beta^*_y = 2$ mm

- Chromaticity corrected with Montague formalism

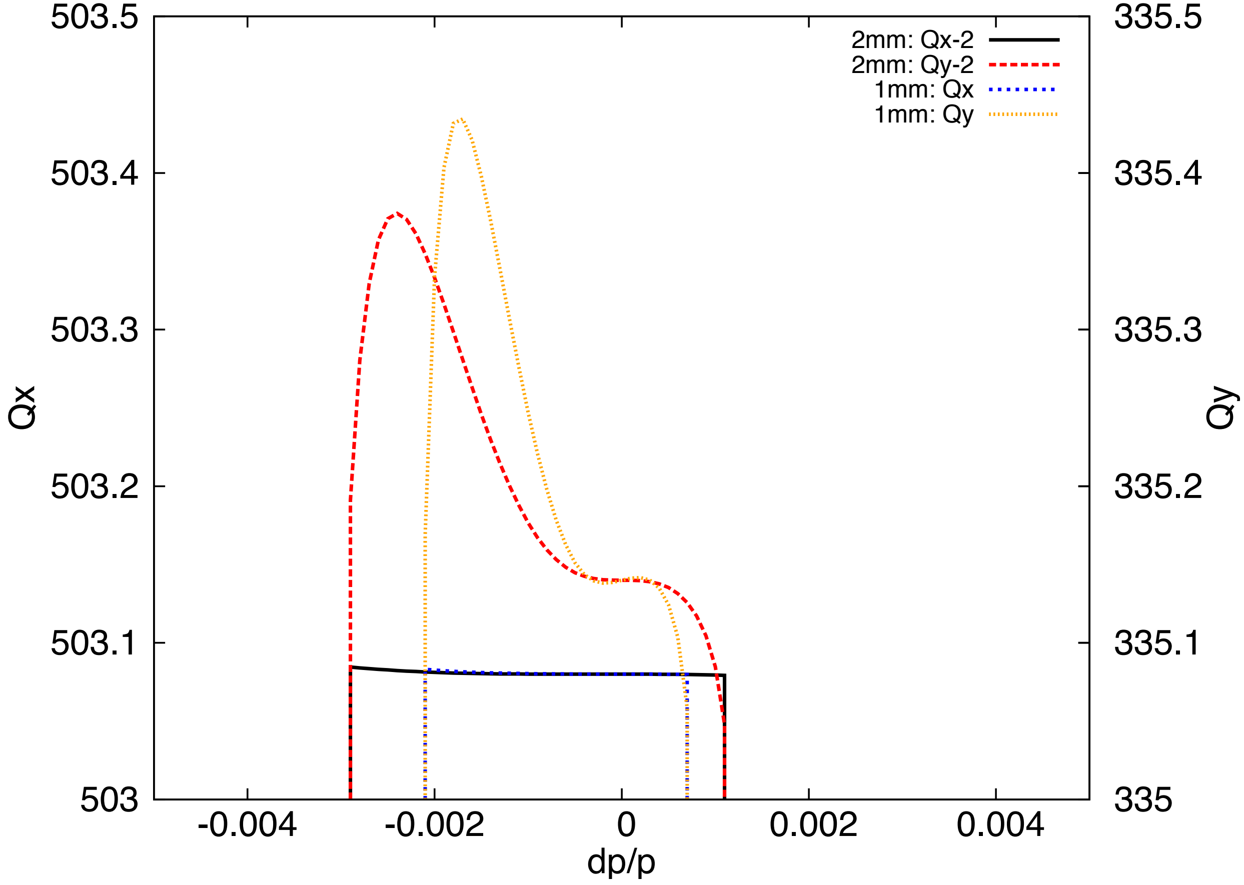
Natural chromaticity compared

	$\beta^*_y = 1$ mm	$\beta^*_y = 2$ mm	
Q_x	503.08	505.08	
Q_x'	-584.26	-587.67	
Q_x''	-3818.40	-3847.84	
$Q_x^{(3)}$	-1.43×10^8	-1.52×10^8	
$Q_x^{(4)}$	1.45×10^{13}	-1.41×10^{13}	
Q_y	335.14	337.14	
Q_y'	-2059.23	-860.42	(- 58 %)
Q_y''	-4.18×10^6	-1.04×10^6	(- 75 %)
$Q_y^{(3)}$	-1.19×10^{11}	-0.21×10^{11}	(- 82 %)
$Q_y^{(4)}$	-4.53×10^{15}	-0.53×10^{15}	(- 88 %)

Corrected chromaticity compared

	β^*_y = 1 mm	β^*_y = 2 mm
Q_x	503.08	505.08
Q_x'	-1.53×10^{-6}	-4.28×10^{-5}
Q_x''	4.30×10^{2}	-2.57×10^{2}
$Q_x^{(3)}$	-5.51×10^{6}	-5.97×10^{6}
$Q_x^{(4)}$	3.64×10^{12}	-1.36×10^{13}
Q_y	335.14	337.14
Q_y'	15.00	-4.66×10^{-5}
Q_y''	-2.34×10^{3}	1.34×10^{3}
$Q_y^{(3)}$	-9.20×10^{8}	-2.16×10^{8}
$Q_y^{(4)}$	2.28×10^{13}	1.02×10^{13}

Mom. acceptance compared



$\beta^*_y = 1$ mm:

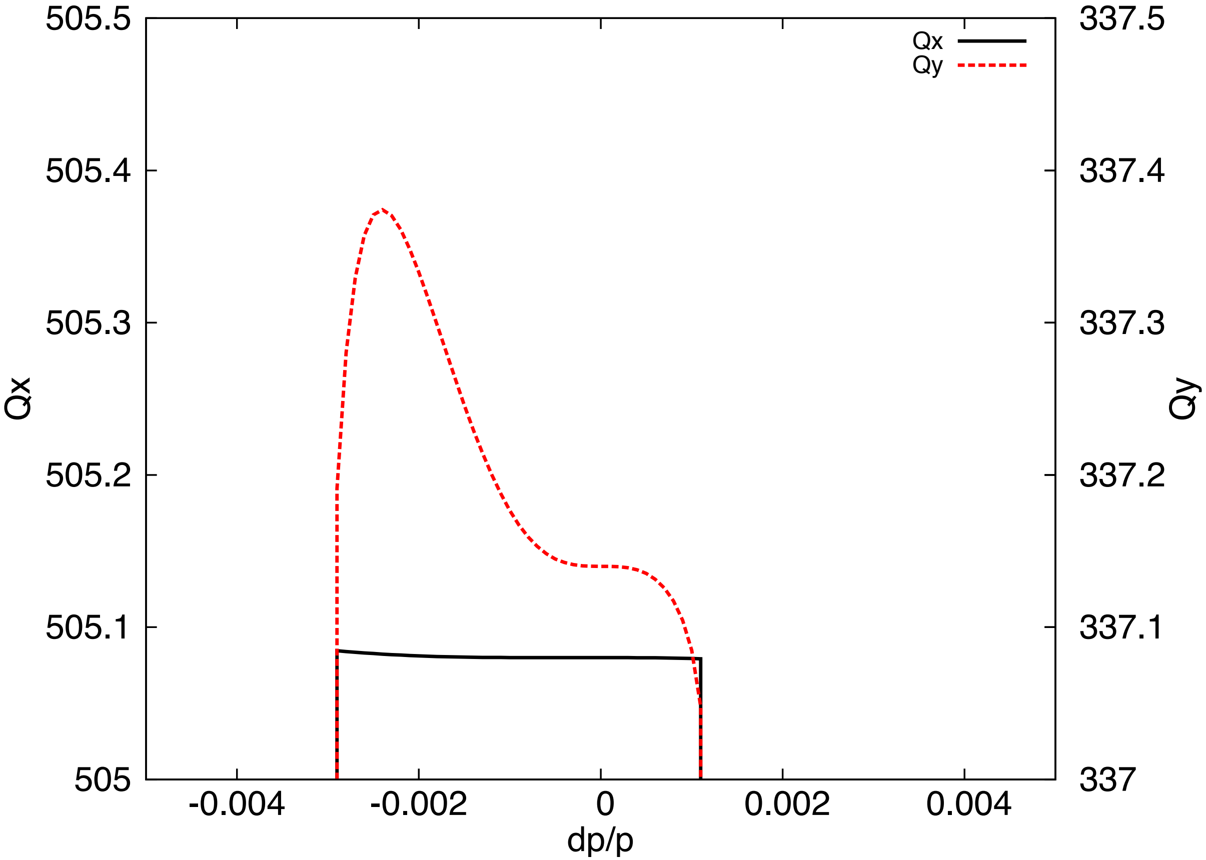
[-0.21%, 0.07%]

$\beta^*_y = 2$ mm:

[-0.29%, 0.11%]

+43 %

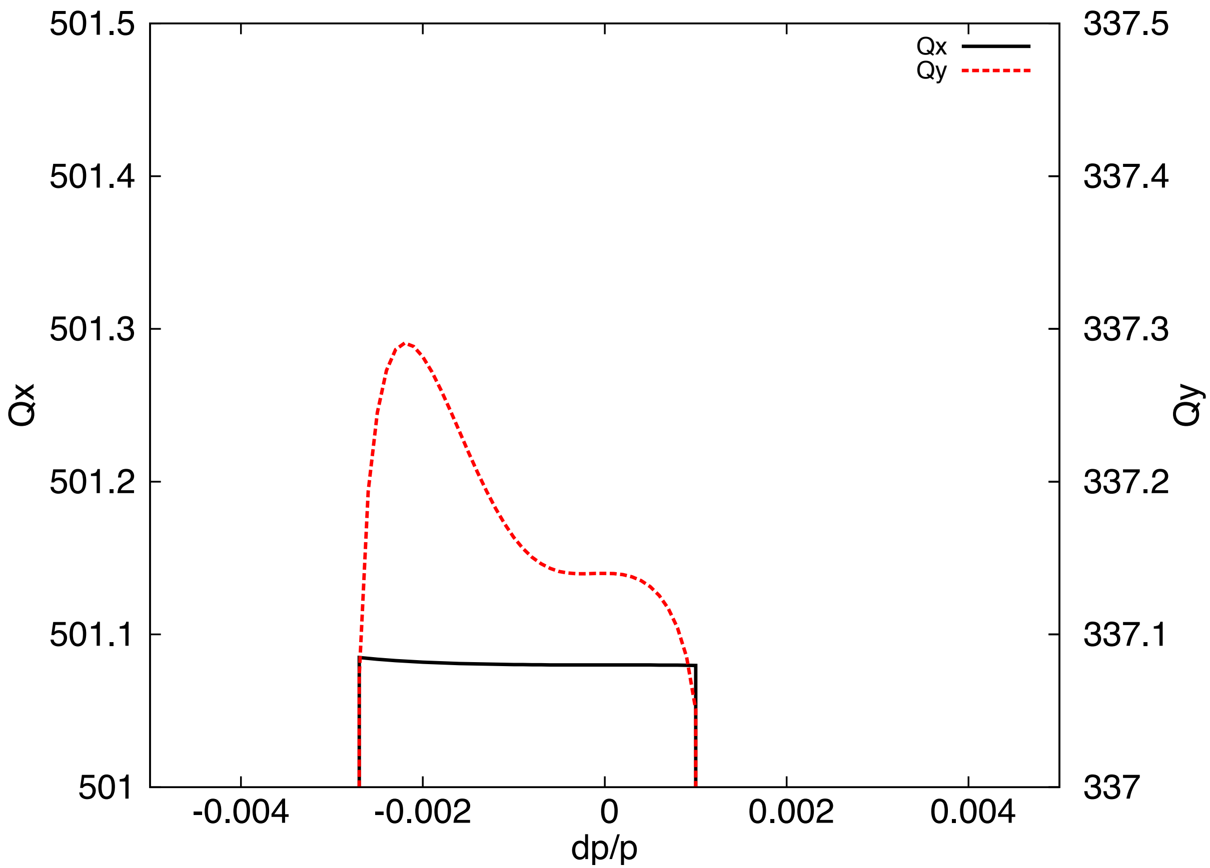
Baseline layout, β^*_y = 2 mm



[-0.29%, 0.11%]

	β^*_y = 2 mm
Q_x	505.08
Q_x'	-4.28×10^{-5}
Q_x''	-2.57×10^{2}
$Q_x^{(3)}$	-5.97×10^{6}
$Q_x^{(4)}$	-1.36×10^{13}
Q_y	337.14
Q_y'	-4.66×10^{-5}
Q_y''	1.34×10^{3}
$Q_y^{(3)}$	-2.16×10^{8}
$Q_y^{(4)}$	1.02×10^{13}

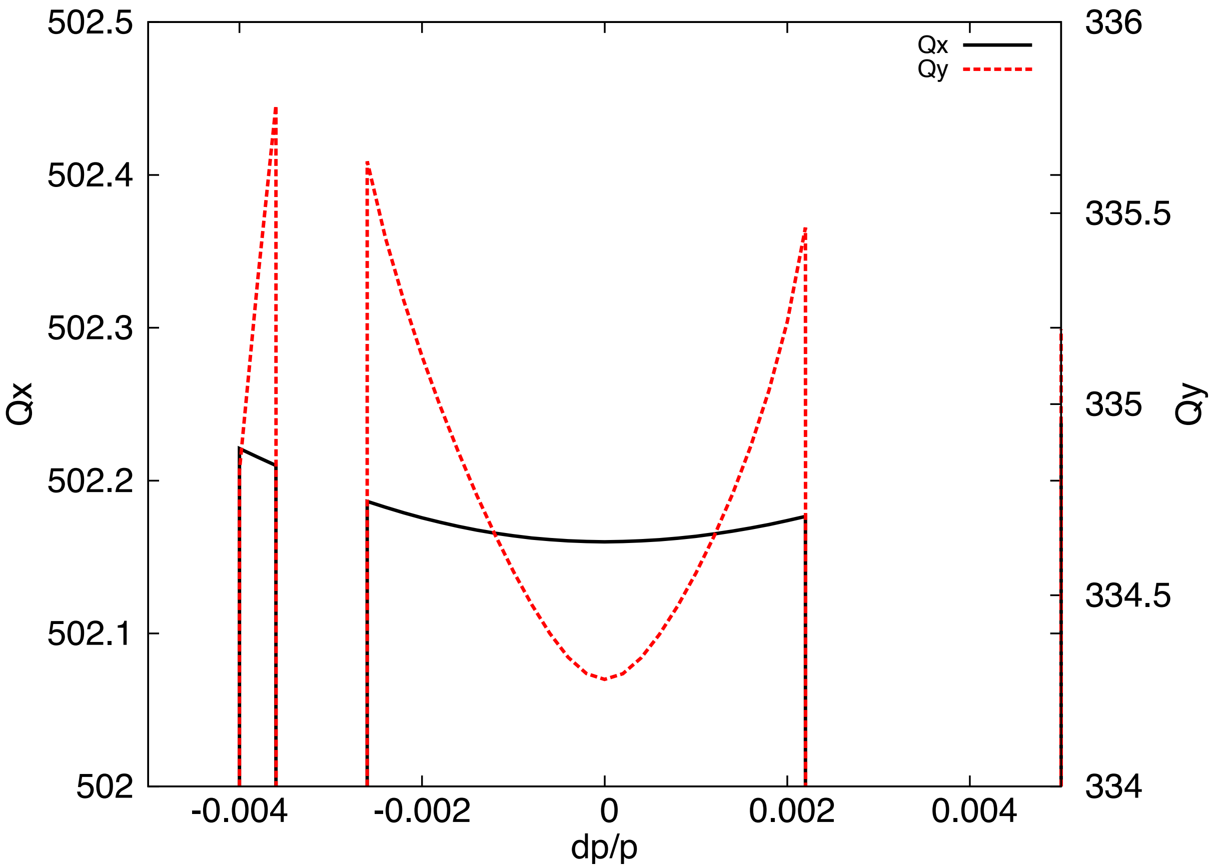
β^*_y = 2 mm, μ_{cell} = 0.249/0.167



[-0.27%, 0.10%]

	β^*_y = 2 mm
Q_x	501.08
Q_x'	-3.51×10^{-5}
Q_x''	2.27×10^{2}
$Q_x^{(3)}$	5.68×10^{6}
$Q_x^{(4)}$	3.37×10^{13}
Q_y	337.14
Q_y'	-1.76×10^{-6}
Q_y''	-2.81×10^{4}
$Q_y^{(3)}$	-2.22×10^{8}
$Q_y^{(4)}$	8.64×10^{12}

12-fold layout, 4 IPs, β^*_y = 1 mm, μ_{cell} = 0.249/0.167



[-0.24%, 0.22%]

	β^*_y = 1 mm
Q_x	502.16
Q_x'	2.27×10^{-7}
Q_x''	7.51×10^{3}
$Q_x^{(3)}$	-2.90×10^{6}
$Q_x^{(4)}$	1.82×10^{12}
Q_y	334.28
Q_y'	4.60×10^{-6}
Q_y''	7.76×10^{5}
$Q_y^{(3)}$	-5.23×10^{7}
$Q_y^{(4)}$	-2.36×10^{13}

Derivatives of the β function

The derivatives indicate places for an effective higher order chromaticity correction

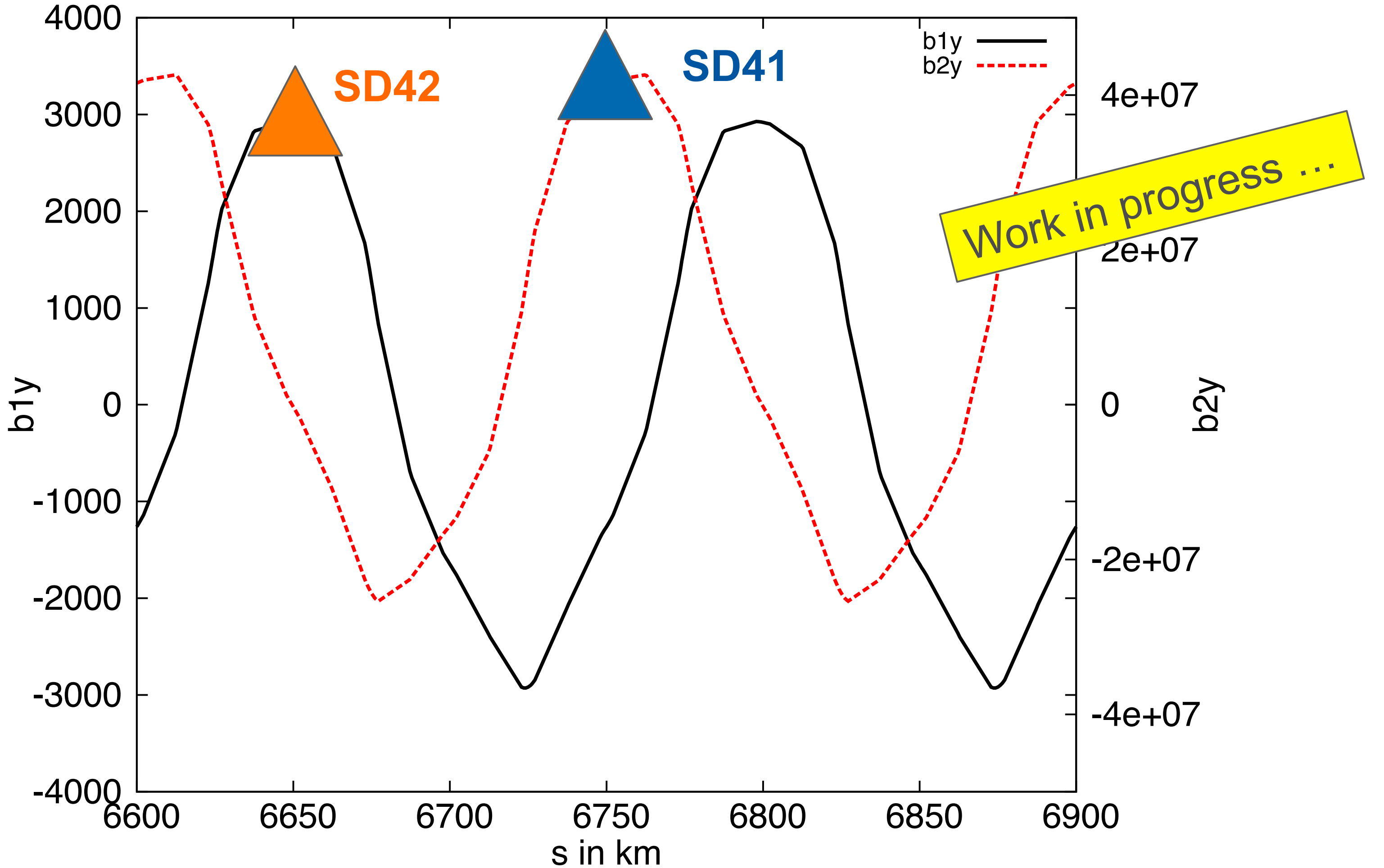
$$b_1 = \frac{\partial \beta}{\partial \delta} \qquad b_2 = \frac{1}{\beta}\frac{\partial^2 \beta}{\partial \delta^2}$$

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

$$\frac{\partial^3 \varphi_y}{\partial \delta^3} = 6\frac{\partial \varphi_y}{\partial \delta} - \int_0^{\Pi} \beta_y (K_1 - K_2\eta_0)(a_{y,1}^2 + b_{y,1}^2)\, ds + {} + 3\int_0^{\Pi} \beta_y (K_2\eta_1 - K_2\eta_2)\, ds + \frac{3}{2}\int_0^{\Pi} \beta_y b_{y,2}(K_1 - K_2\eta_0)\, ds\,.$$

(A. Bogomyagkov: “Crab waist interaction region for FCC-ee and the arc second attempt”, presentation in the FCC-ee meeting no. 13, 09 Febuary 2015)

Derivatives of the β function



Summary

- First DA studies performed:
  → DA very tight in vertical plane
  → Reducing No. of IPs did not increase momentum acceptance but DA
  → Detuning of the FODO cells increases momentum acceptance slightly

- Artificial positive linear chromaticity can help to avoid crossing resonances

Summary II

- Increasing β^*_y to 2 mm decreases some chromaticities about more than 80 %

- Using the same methods the momentum acceptance could be increased by 43 %

- Further investigation necessary to understand behavior for 0.249/0.167 phase advance

Schedule until the Review

1. Analysis of the derivatives of the β function (in progress)

2. DA studies of the Baseline Layout Lattice (in progress)

3. Lattice with split quadrupoles around one sextupole (Frank's proposal)

4. Lattice with individually powered interleaved sextupole pairs (complementary to Katsunobu's non-interleaved pairs)

Thank you for your attention!