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Karlsruhe Institute of Technology

Performance Comparison of Interleaved Sextupole Schemes + New Racetrack Lattice

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

1) Chromaticity Correction

Systematic investigation of chromaticity correction schemes for FCC-ee:

1. Interleaved sextupole scheme using Montague Formalism → LEP-like IRs
2. Comparison 4 IPs and 2 IPs (90°/60°)
3. Phase advance 0.249/0.166
4. (Direct matching of chromaticities)

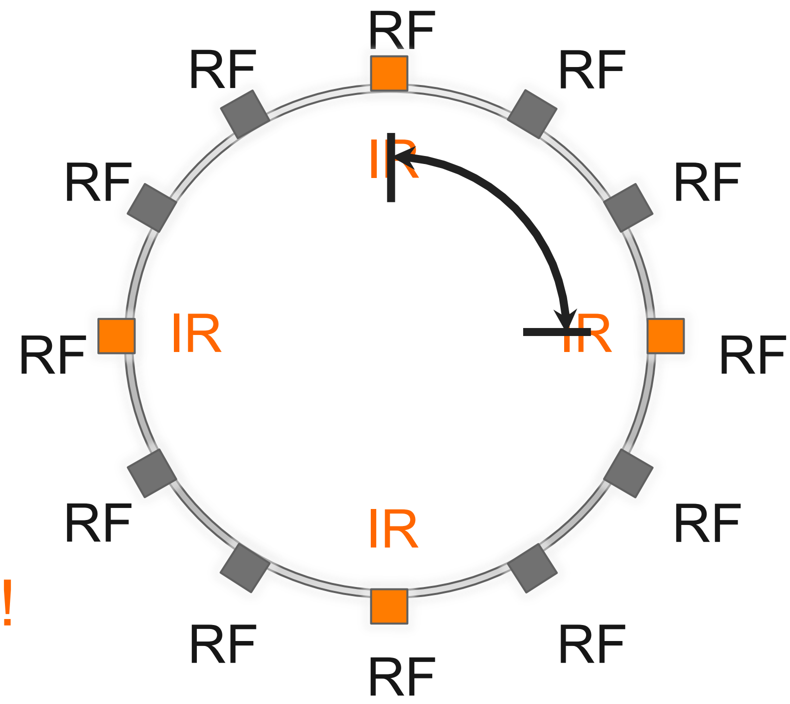
12-fold lattice

Circumference: 100 km

Arc length: 6.8 km

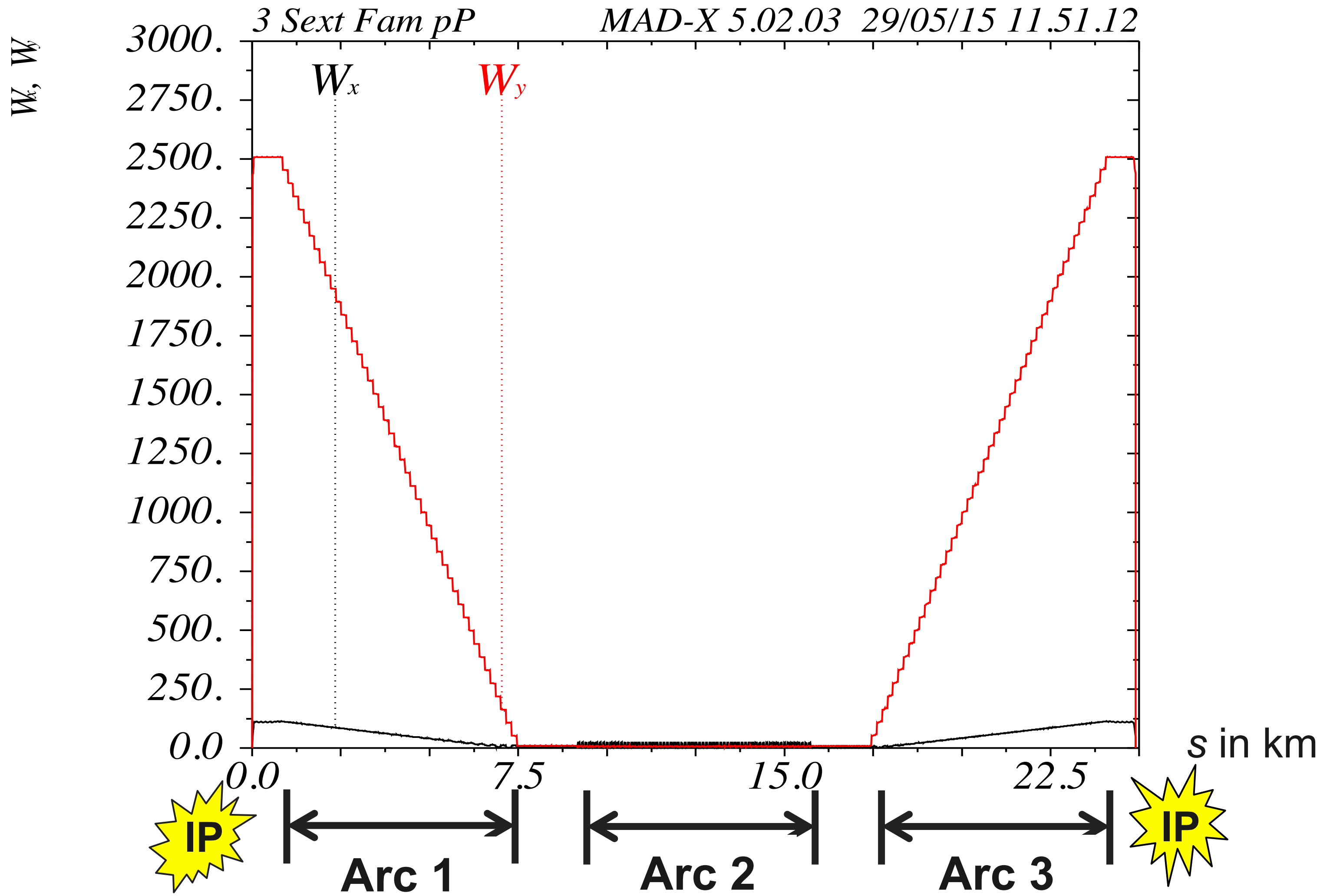
Straight section length: 1.5 km

4 LEP-like mini-beta insertions (IR)!



B = bending magnet, Q = quadrupole, S = sextupole

Both W functions in the 1st quarter



Corrected Chromaticity

Symmetric FODO			
	Natural Chromaticities	Corrected Chromaticities	ΔQ (δ=0.05 %)
Q_x	506.16	509.08	
Q_x'	-629.88	-4.20	-2.10e-03
Q_x''	-1.6e+04	6.6e+03	8.19e-04
Q_x'''	-2.7e+08	-1.5e+07	-3.13e-04
Q_x''''	-4.1e+12	-2.9e+10	-6.73e-05
Q_y	334.28	334.28	
Q_y'	-2059.23	6.7e-02	3.36e-05
Q_y''	-8.6e+06	-9.8e+03	-1.22e-03
Q_y'''	-2.0e+11	-2.5e+09	-5.11e-02
Q_y''''	-6.7e+15	-1.5e+12	-3.92e-03

New procedure

Before:

- Matching W functions first in one plane then in another

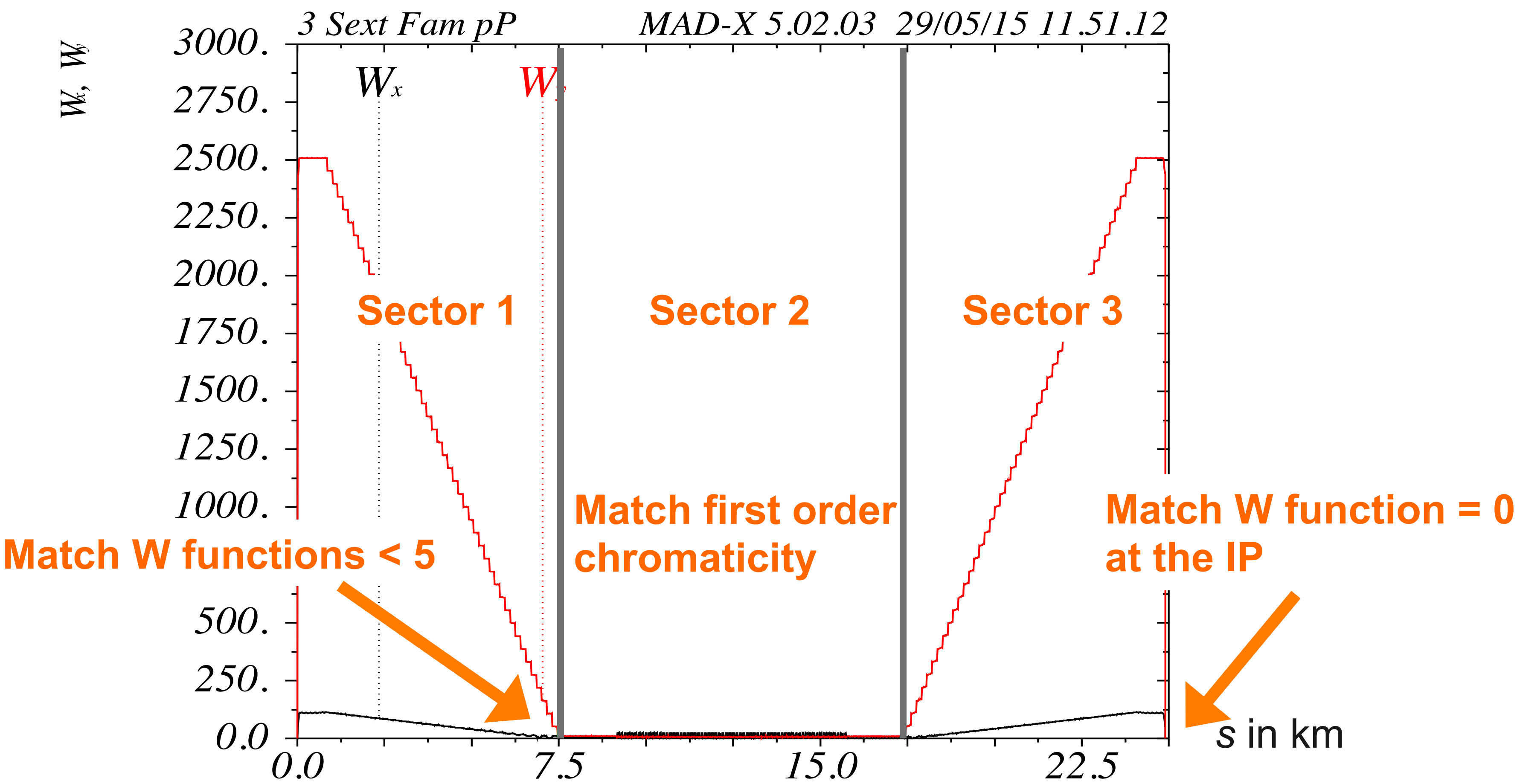
Now:

- Matching W functions of both planes at the same time in sector wise

→ 1st arc, 2nd arc, 3rd arc, all arcs, all arcs (periodic)

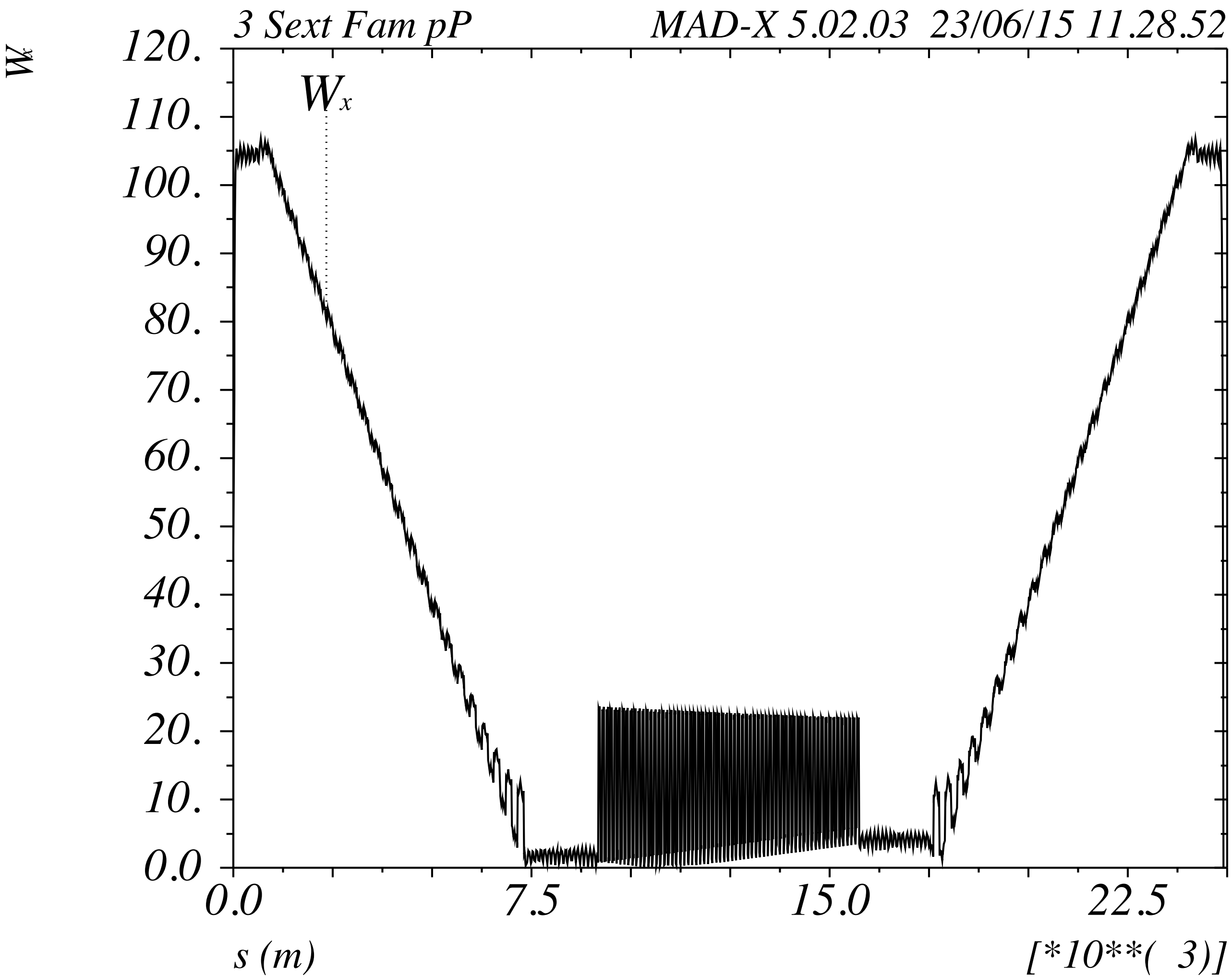
- Optimised phase advance between FD and Arc

Sectors



3 Sext Fam pP
MAD-X 5.02.03 29/05/15 11.51.12
W_x, W_y
3000.
2750.
2500.
2250.
2000.
1750.
1500.
1250.
1000.
500.
250.
0.0
W_x
W_y
Sector 1
Sector 2
Sector 3
Match first order chromaticity
Match W function = 0 at the IP
Match W functions < 5
0.0
7.5
15.0
22.5
s in km

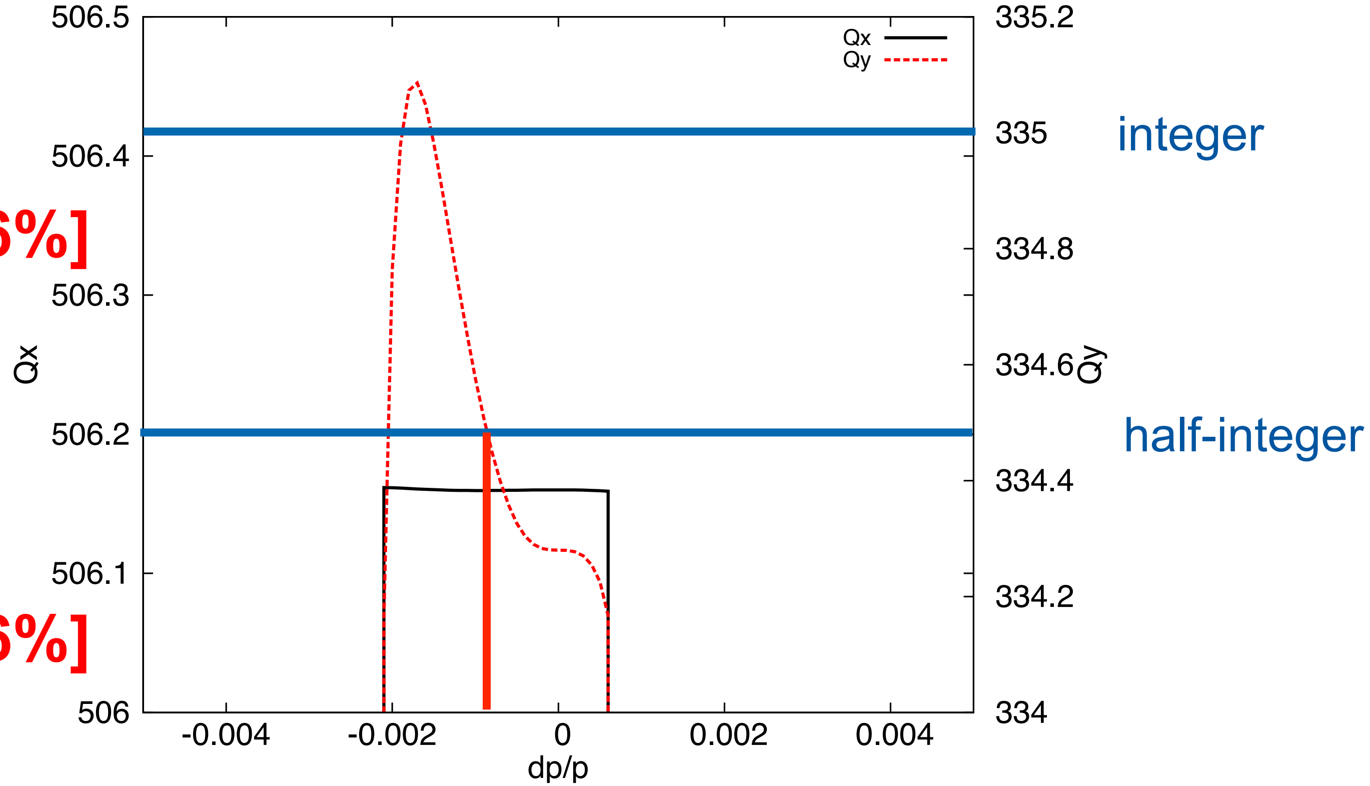
4 IPs: Horizontal W function



4 IPs

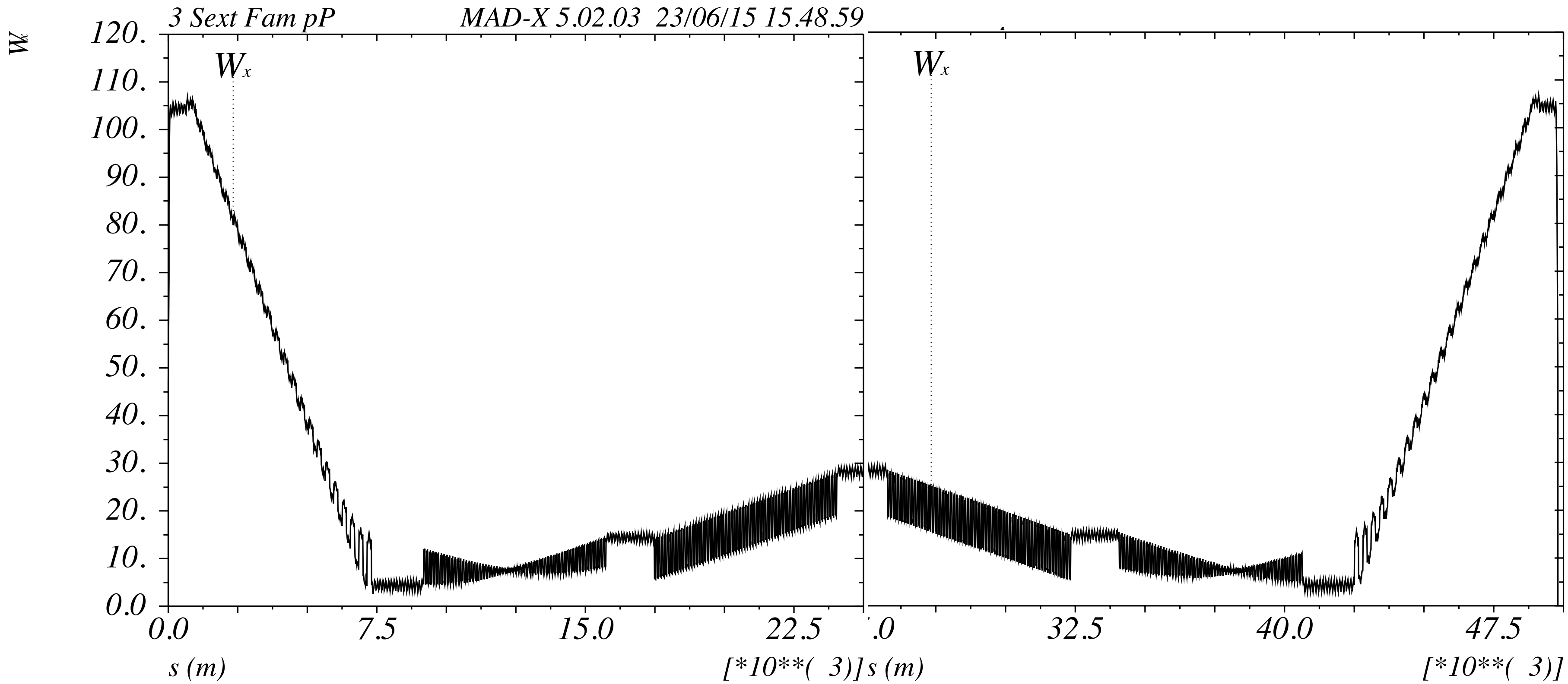
[-0.22%, 0.06%]

[-0.08%, 0.06%]



$$
\begin{aligned}
dq1\_0 &= 506.16 ; & dq2\_0 &= 334.28 ; \\
dq1\_1 &= \text{-3.467448551e-06} ; & dq2\_1 &= \text{-1.222133506e-05} ; \\
dq1\_2 &= -2704.155122 ; & dq2\_2 &= 9069.253792 ; \\
dq1\_3 &= -8242295.735 ; & dq2\_3 &= -2173067060 ; \\
dq1\_4 &= 4.547473509e{+}12 ; & dq2\_4 &= 4.865796654e{+}13 ;
\end{aligned}
$$

2 IPs: Horizontal W function



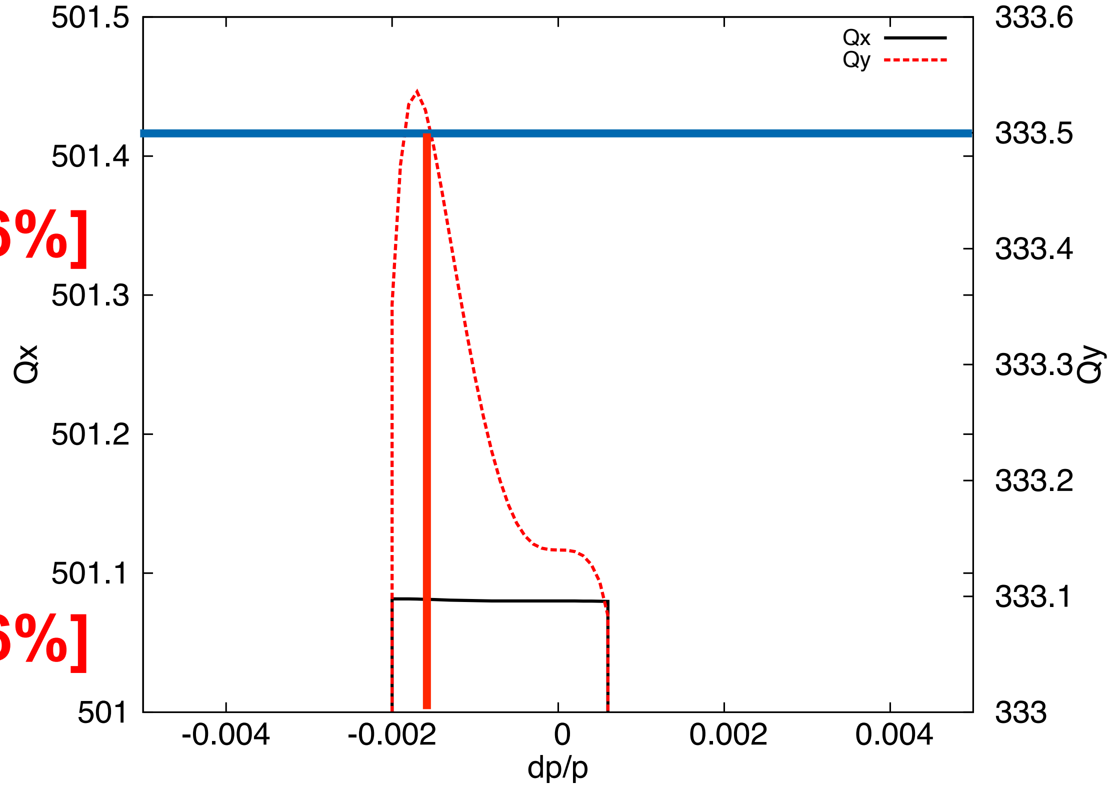
Sextupole strengths: **Arc2 = Arc5**
Arc3 = Arc4

2 IPs

[-0.20%, 0.06%]

↓

[-0.15%, 0.06%]

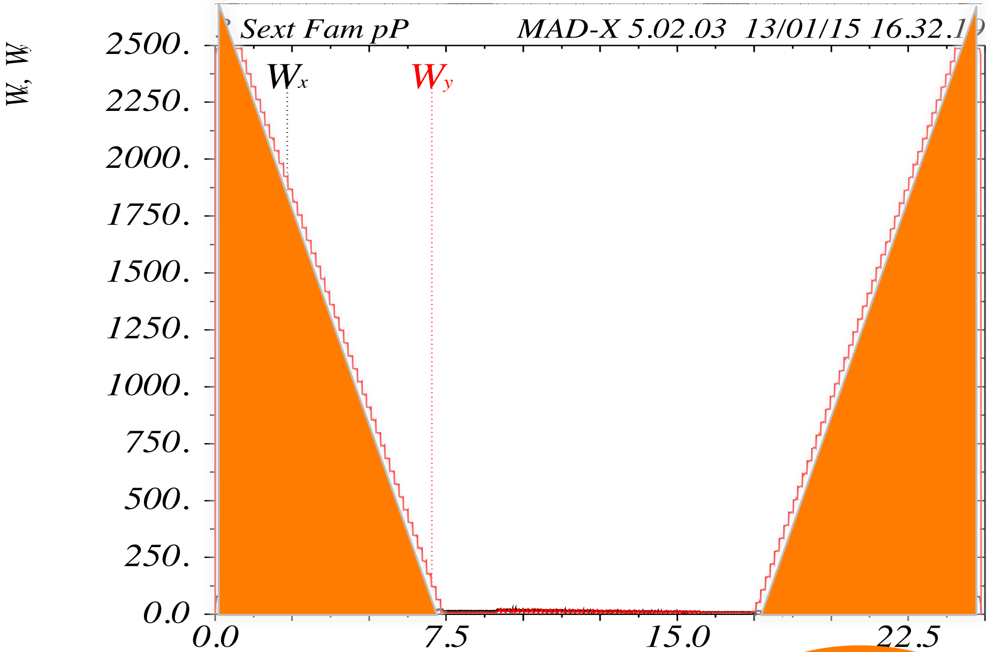


half-integer

dq1_0 =	501.0799999 ;	dq2_0 =	333.1399999 ;
dq1_1 =	-3.490185918e-05 ;	dq2_1 =	-0.0001485318535 ;
dq1_2 =	-448.380888 ;	dq2_2 =	4915.136742 ;
dq1_3 =	-5059064.279 ;	dq2_3 =	-1089460966 ;
dq1_4 =	-1.364242053e+13 ;	dq2_4 =	-1.909938874e+13 ;

3rd order chromaticity

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



$$\frac{d^3\phi}{d\delta^3} = 6\frac{d\phi}{d\delta} + \int_0^\mu \beta^2 (K_1 - K_2\eta_0)(a_1^2 + b_1^2)\,d\phi$$
$$- 3\int_0^\mu \beta^2 \left(K_2\eta_1 + K_3\frac{\eta_0^2}{2} - K_2\eta_2 + K_3\eta_0\eta_1 \right) d\phi$$
$$- \frac{3}{2}\int_0^\mu \beta^2 b_2 (K_1 - K_2\eta_0)\,d\phi$$

~W^2

Put Sextupole where b_2 is large

Octupoles

Anton Bogomyagkov

Comparison chromaticities

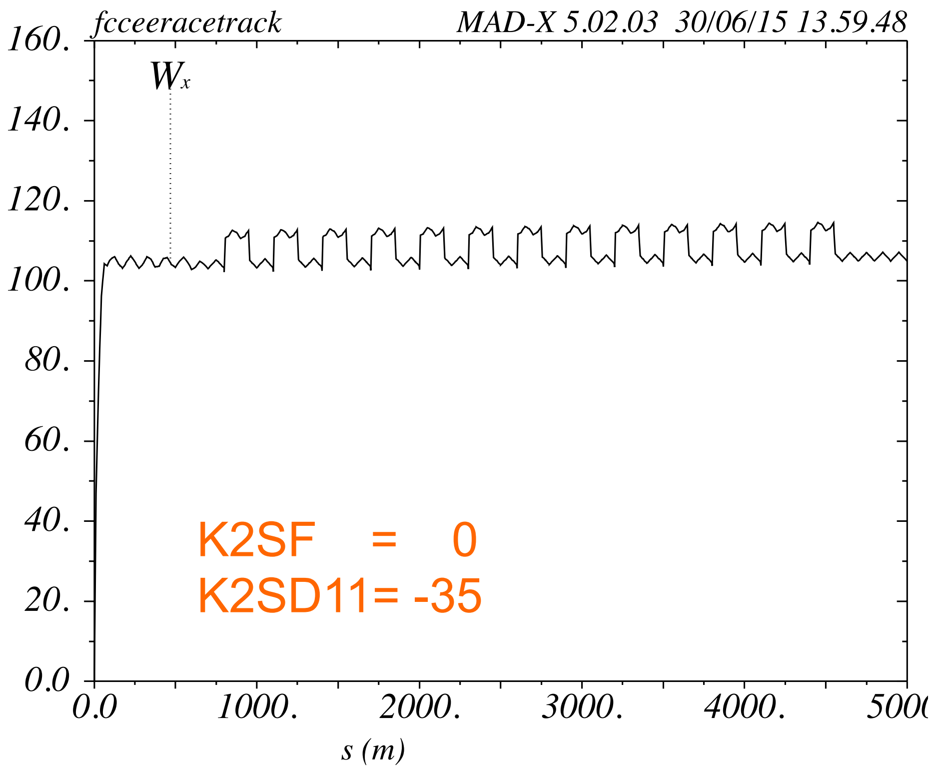
- 4 IPs (90°/60°):

dq1_0 =	506.16 ;	dq2_0 =	334.28 ;
dq1_1 =	-3.467448551e-06 ;	dq2_1 =	-1.222133506e-05 ;
dq1_2 =	-2704.155122 ;	dq2_2 =	9069.253792 ;
dq1_3 =	-8242295.735 ;	dq2_3 =	-2173067060 ;
dq1_4 =	4.547473509e+12 ;	dq2_4 =	4.865796654e+13 ;

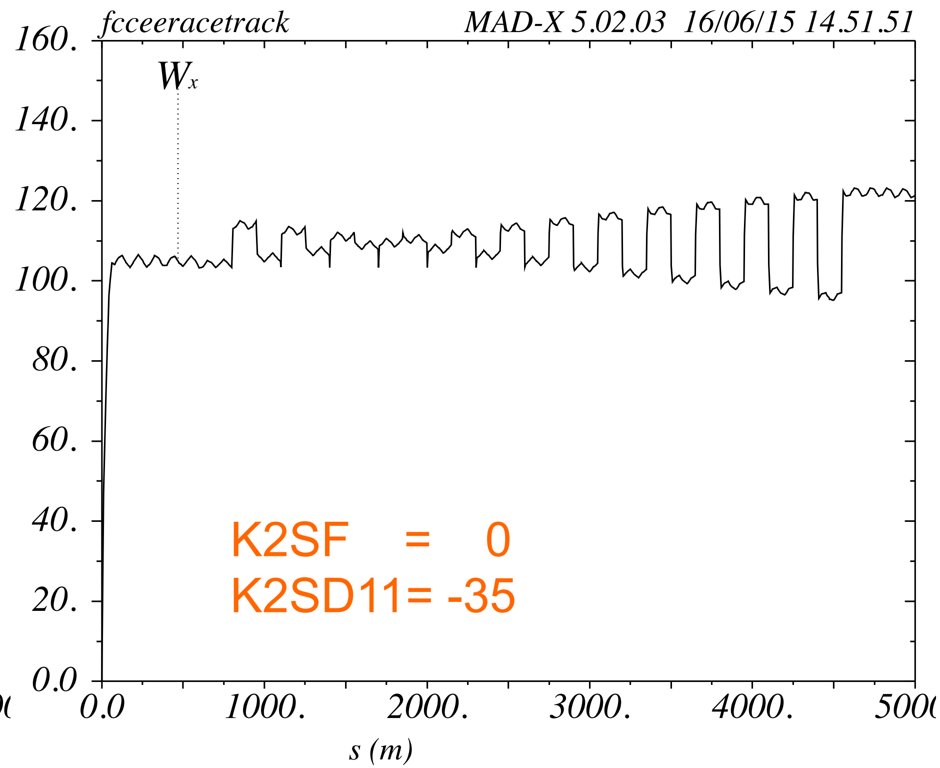
- 2IPs (90°/60°):

dq1_0 =	501.0799999 ;	dq2_0 =	333.1399999 ;
dq1_1 =	-3.490185918e-05 ;	dq2_1 =	-0.0001485318535 ;
dq1_2 =	-448.380888 ;	dq2_2 =	4915.136742 ;
dq1_3 =	-5059064.279 ;	dq2_3 =	-1089460966 ;
dq1_4 =	-1.364242053e+13 ;	dq2_4 =	-1.909938874e+13 ;

Detuning the Arc Cells

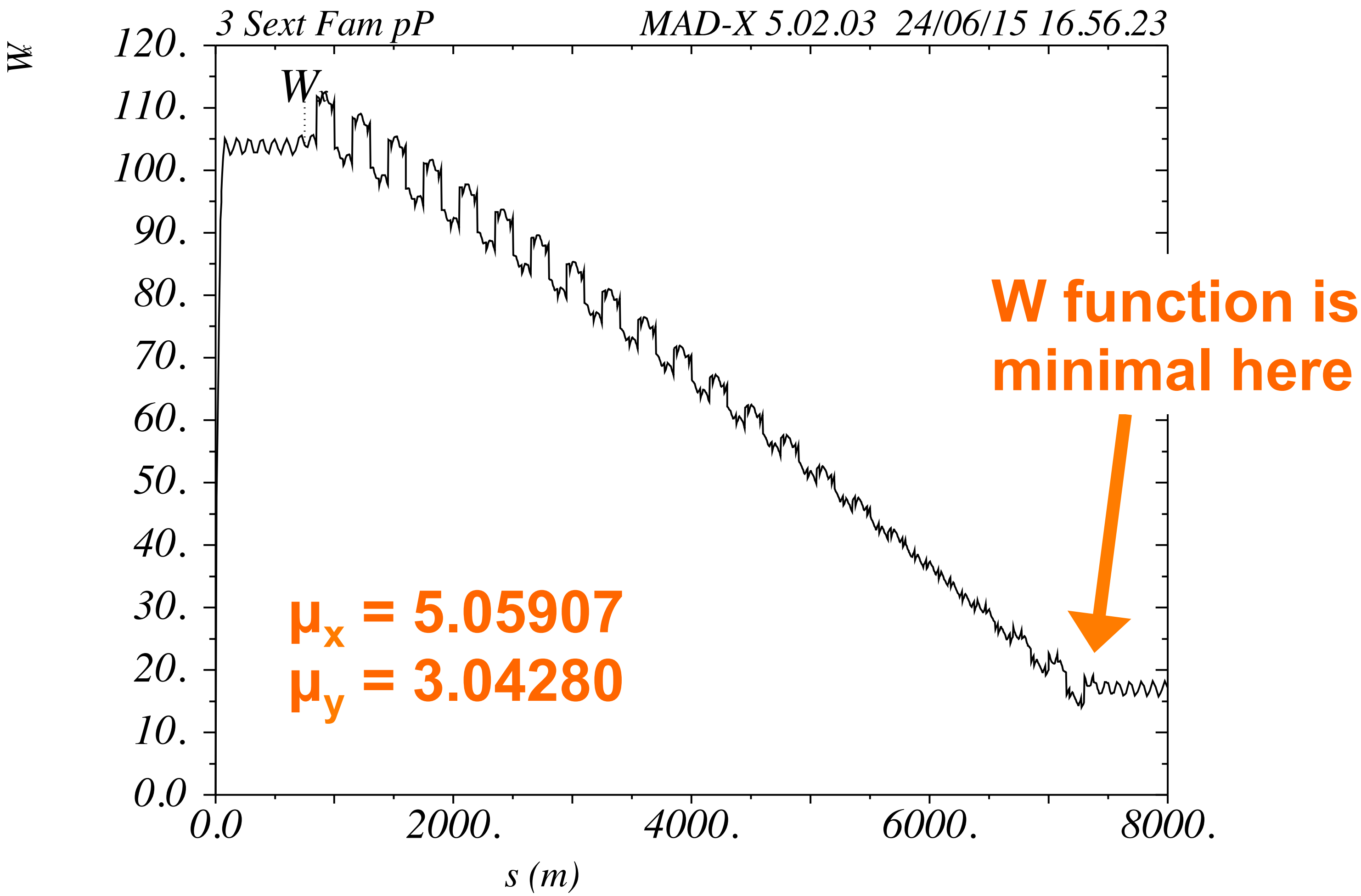


(90°/60°)



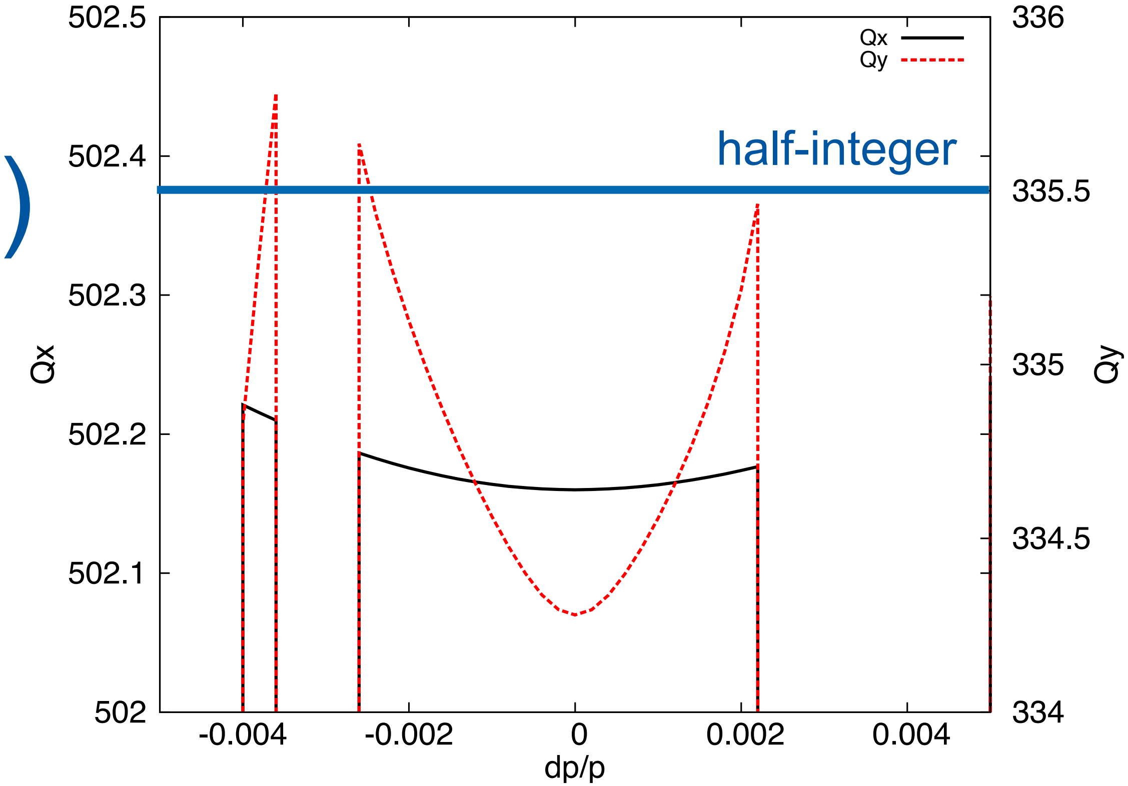
(0.249/0.166)

Matching of the phase advance between Final Doublet and Arc



4 IPs
(0.249, 0.166)

[-0.24%, 0.22%]



$$dq1\_0 = 502.1600001 \; ; \quad dq2\_0 = 334.2799998 \; ;$$
$$dq1\_1 = 2.273736754\text{e-}07 \; ; \quad dq2\_1 = 4.604316928\text{e-}06 \; ;$$
$$dq1\_2 = 7512.539923 \; ; \quad dq2\_2 = 776216.6661 \; ;$$
$$dq1\_3 = -2899014.362 \; ; \quad dq2\_3 = -52295945.35 \; ;$$
$$dq1\_4 = 1.818989404\text{e+}12 \; ; \quad dq2\_4 = -2.364686225\text{e+}13 \; ;$$

Next steps

- Repeat Matching of W functions for Racetrack Layout (get a set of comparable cases to analyse)
  → Start DA studies with Luis

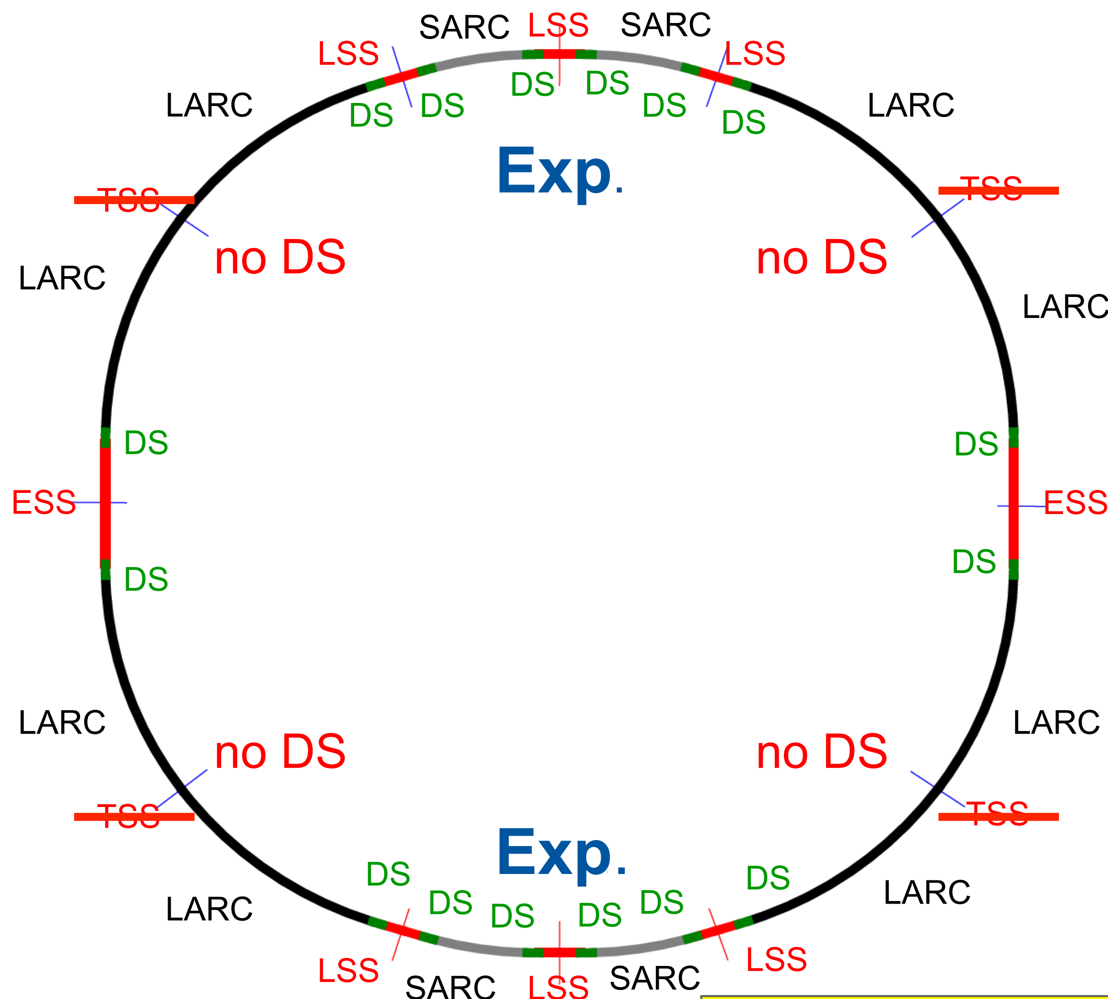
- Need to get 3rd order chroma under control
  → Analyse higher order derivatives of β functions
  → Change weights in matching routine
  (→ Introduce octupoles)

- Try direct matching of chromaticities
- Try 60°/60° optics
- Try non-interleaved schemes

2) New Baseline Layout (V17)

100 km circumference
→ Longer arcs (before ≈95 km)

No Technical Straight Sections (TSS)



P. Lebrun & J. Osborne

Lattice Modules

	Number	Length Lebrun & Osborne*	Length FCC-ee V17
LSS	6	1400 m	1400 m
ESS	2	4200 m	4200 m
DS	16	400 m	100 m
SARC	4	3200 m	4200 m
LARC	8	8000 m	8100 m

DS-SARC-DS: 400 m longer than proposed by Lebrun & Osborne
→ Required for nice arrangement of sextupole families
→ CEA: no problem for FCC-hh lattice

*P. Lebrun et al.: FCC layout: naming, numbering, lengths, preliminary siting, FCC Infrastructure & Operation, Meeting, 22 October 2014

Thank you for your attention!