The FCC-ee booster synchrotron

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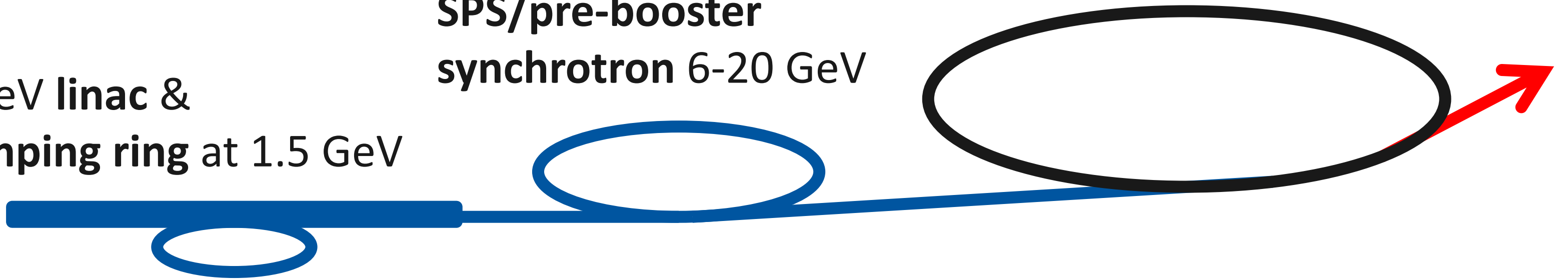
Topical Workshop on Injection and Injection Systems
28-30 August 2017, BESSY II Berlin

Booster parameters

100 km top-up booster
20 GeV – 175 GeV

SPS/pre-booster synchrotron 6-20 GeV

6 GeV **linac** &
damping ring at 1.5 GeV

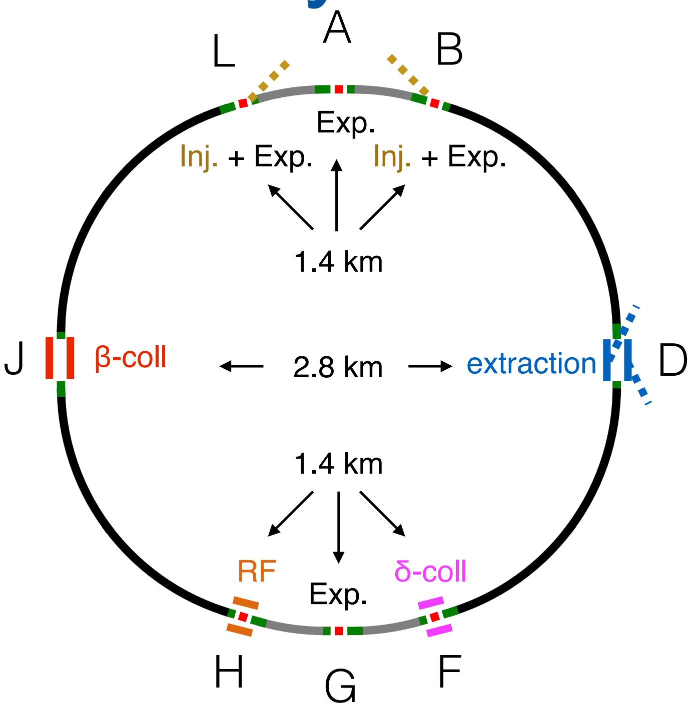


Accelerator	FCCee-Z		FCCee-W		FCCee-H		FCCee-tt	
Energy [GeV]	45.6		80		120		175	
Type of filling	Full	Top-up	Full	Top-up	Full	Top-up	Full	Top-up
BR # of bunches	7100	35500	5260		60	780	62	
BR cycle time [s]	26.75	97.75	68.6		7.1	20.3	7.12	
#of BR cycles	20	2	4	1	13	1	10	1
Total number of bunches	71000		5260		780		62	
Filling time (both species) [sec]	1070	391	548.8	84.6	184.6	40.6	142.4	14.2
Injected bunch population [10^{10}]	4.3	0.21	6.0	0.12	8.0	0.16	22.1	0.44

Preliminary!

Y. Papaphilippou

FCC Layout

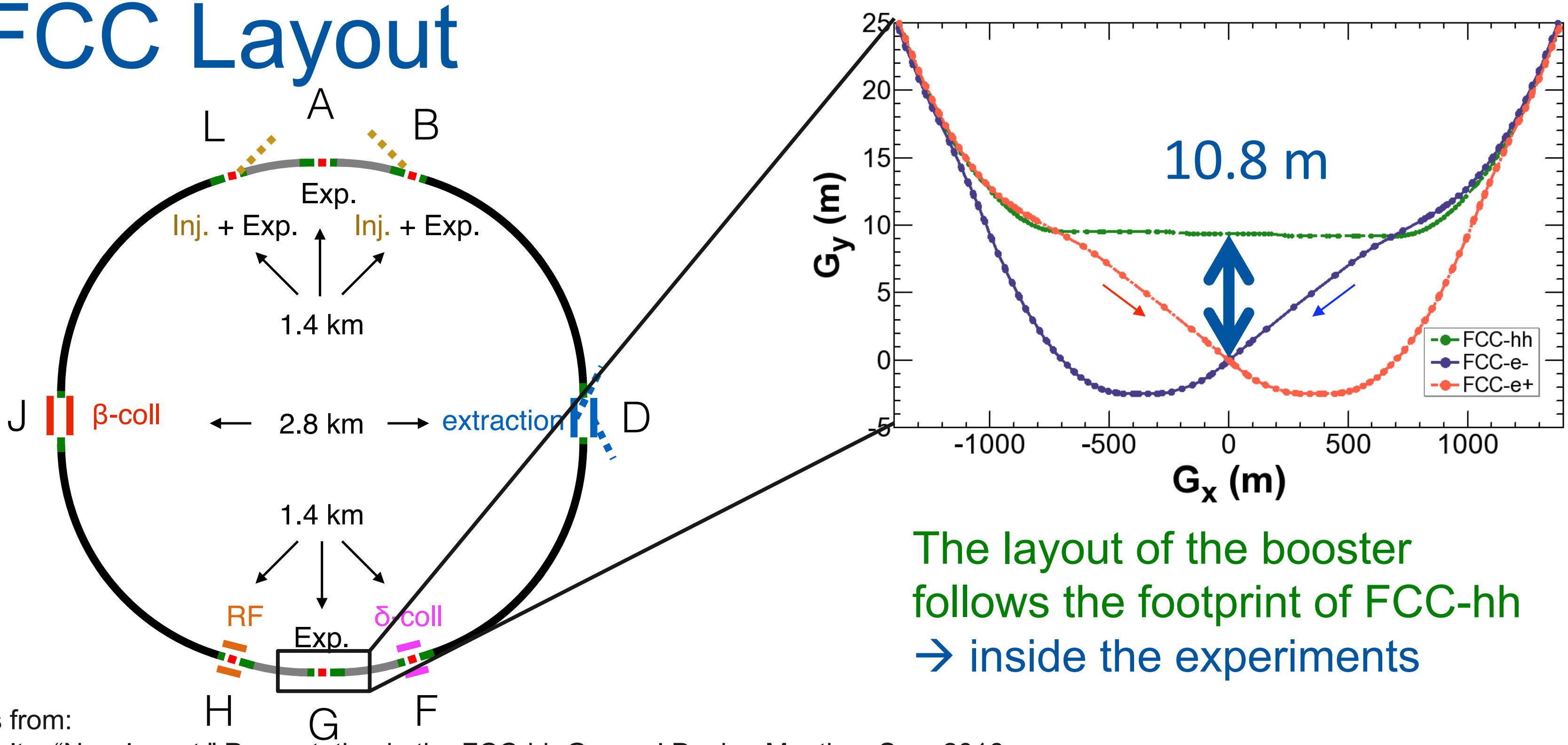


Circumference: C = 97.75 km
Bending radius: ρ = 10.5 km

2 experimental straight sections (A & G)
2 RF sections in points D and J

We would like to avoid "tapering"
→ To be confirmed by 6D tracking studies

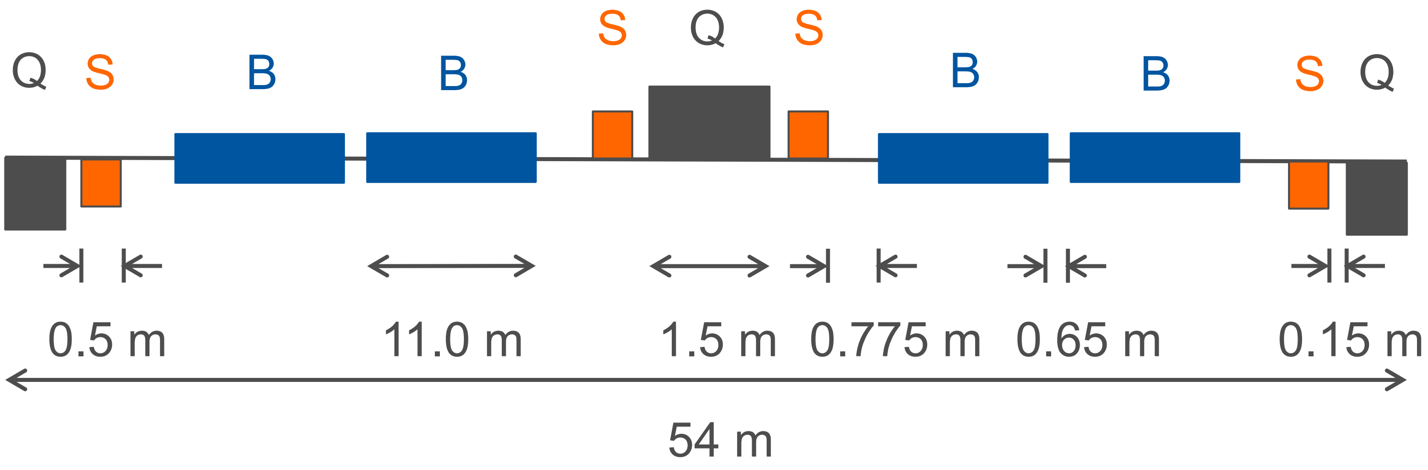
FCC Layout



The layout of the booster follows the footprint of FCC-hh
→ inside the experiments

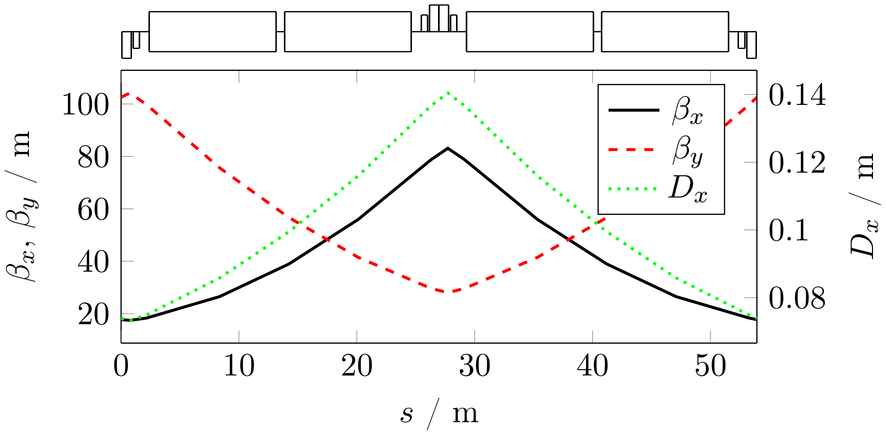
Images from:
D. Schulte, “New layout,” Presentation in the FCC-hh General Design Meeting, Sep. 2016.
K. Oide *et al.*, "Design of beam optics for the future circular collider *e+e−* collider rings," Phys. Rev. Accel. Beams, vol. 19, p. 111005, Nov 2016.

FODO cell of the FCC-ee booster



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

Optics for 80-175 GeV*

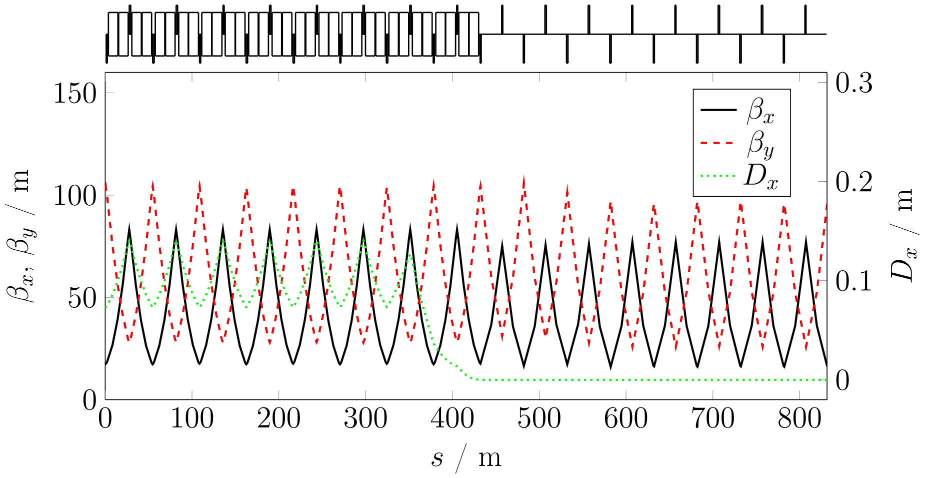


FODO cell:

L = 54 m

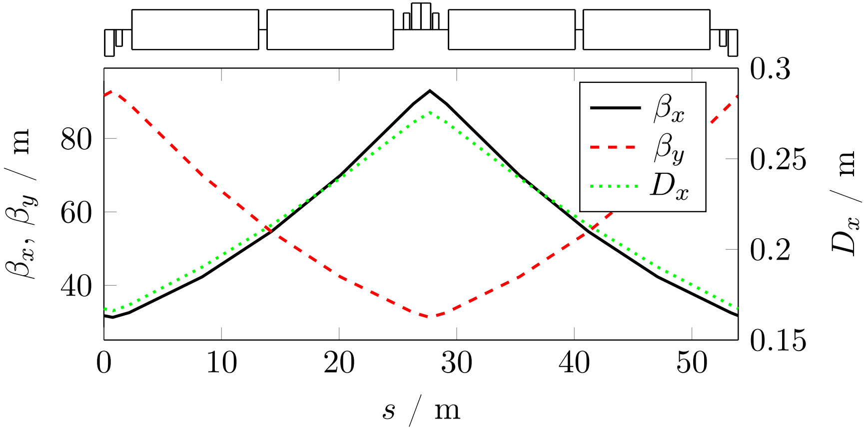
φ = 90°/60°

2-cell half-bend dispersion suppressor

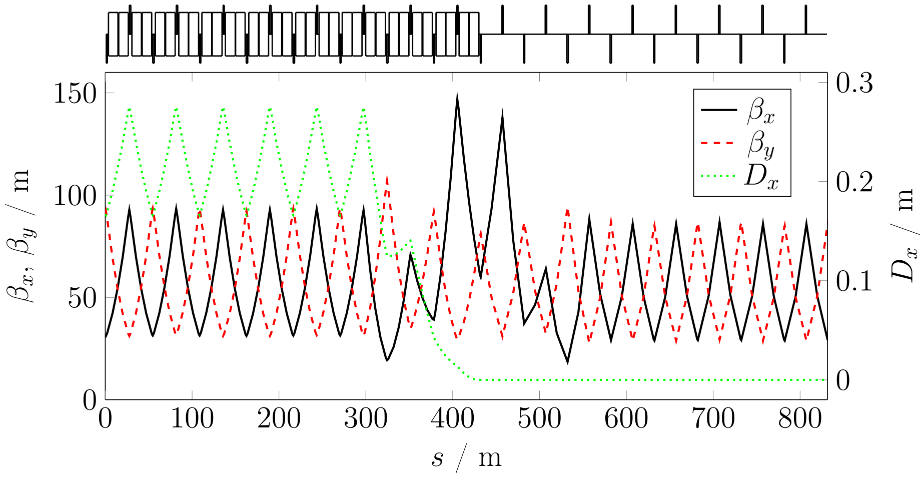


* maximum beam energy in collider

Optics for 45 GeV*



Dispersion suppressor
supported by quadrupoles



FODO cell:

L = 54 m

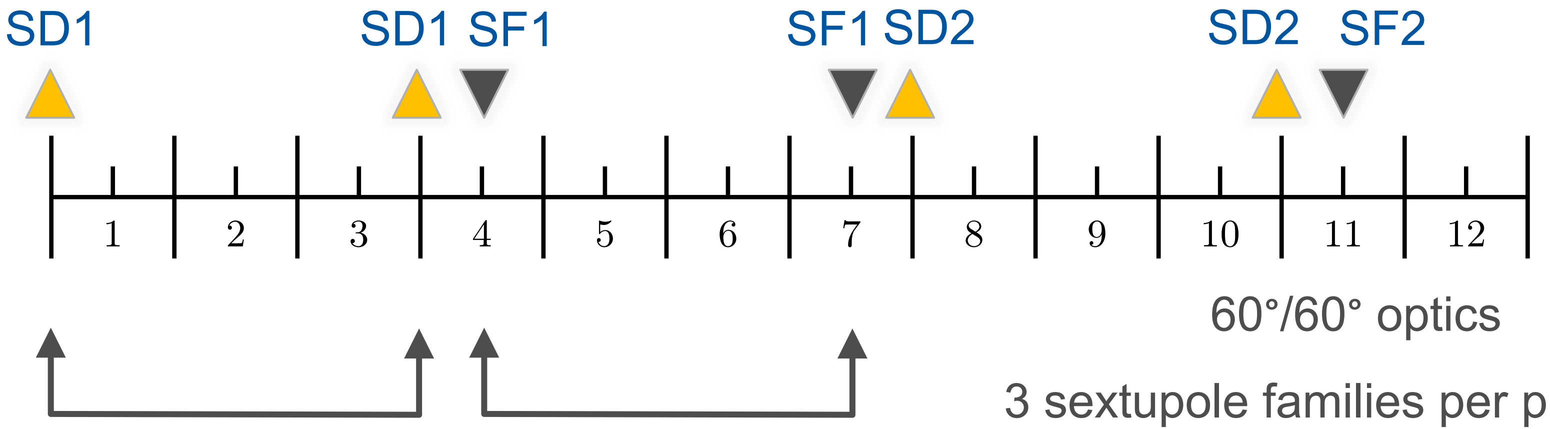
φ = 60°/60°

* maximum beam energy in collider

Parameters

	60°/60°	90°/60°
Q_x	306.225	457.225
Q_y	304.290	304.290
ξ_x	-338.778	-507.658
ξ_y	-336.455	-420.928
α_c /10^{-6}	13.7	6.5
ε_x (20 GeV)/nm rad	0.045	0.015
ε_x (45 GeV)/nm rad	0.235	0.075
ε_x (175 GeV)/nm rad	3.540	1.124

Non-interleaved sextupole scheme



60°/60° optics

3 sextupole families per plane

$\mu_x = \mu_y = 180°$ (→ -I transformation)

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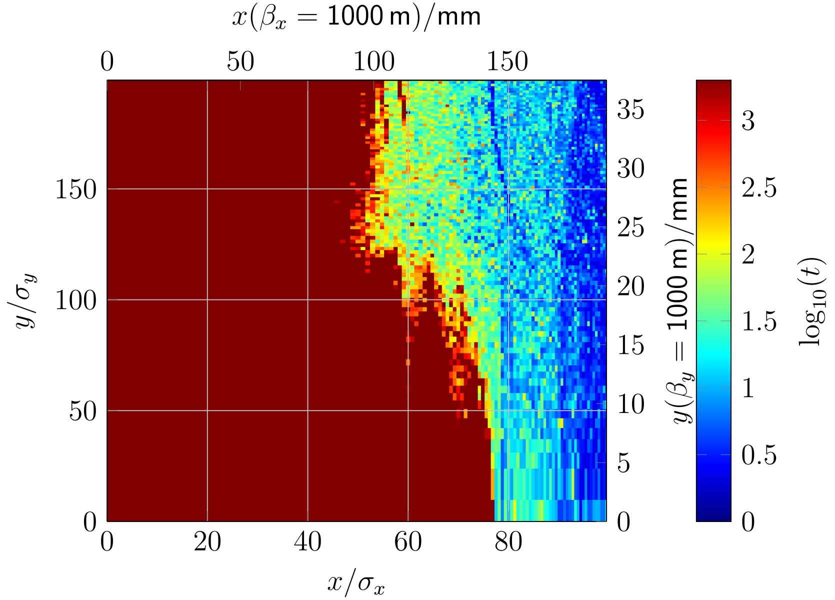
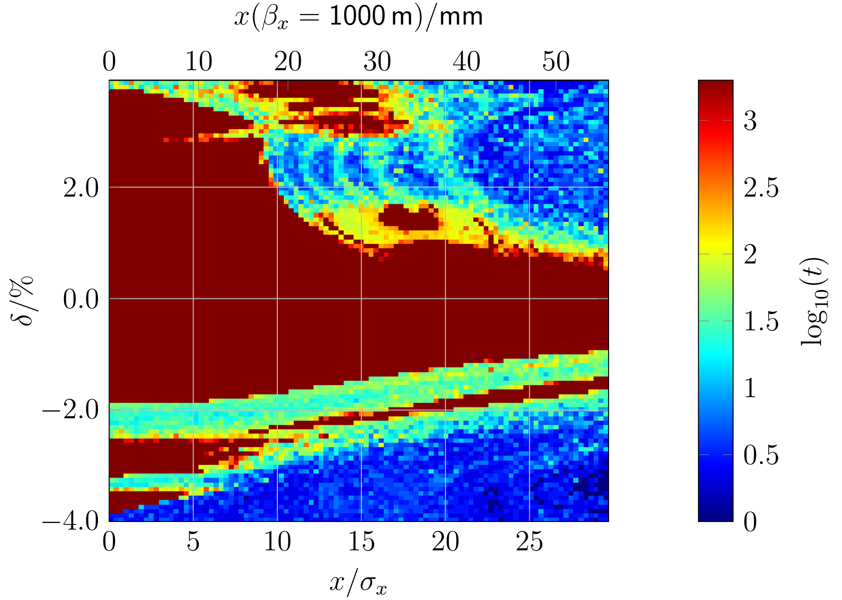
Dynamic aperture (at 175 GeV)

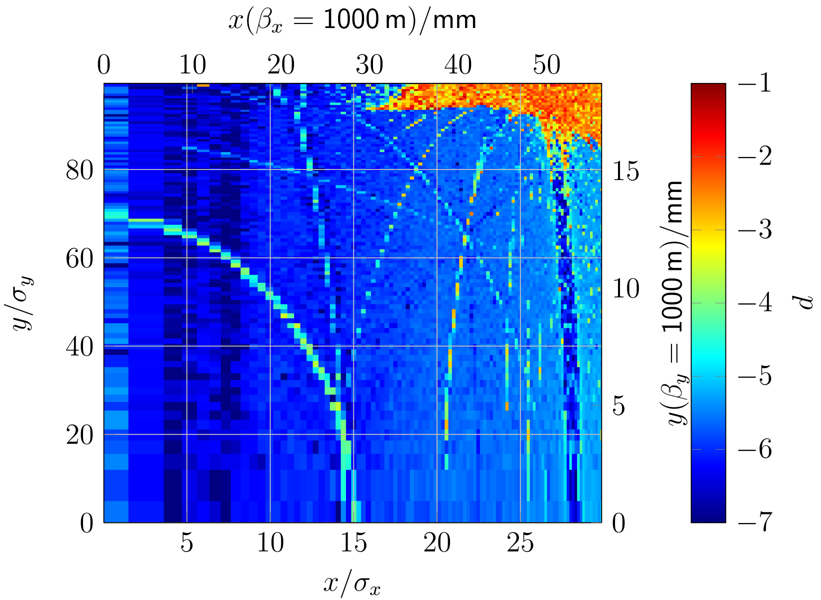




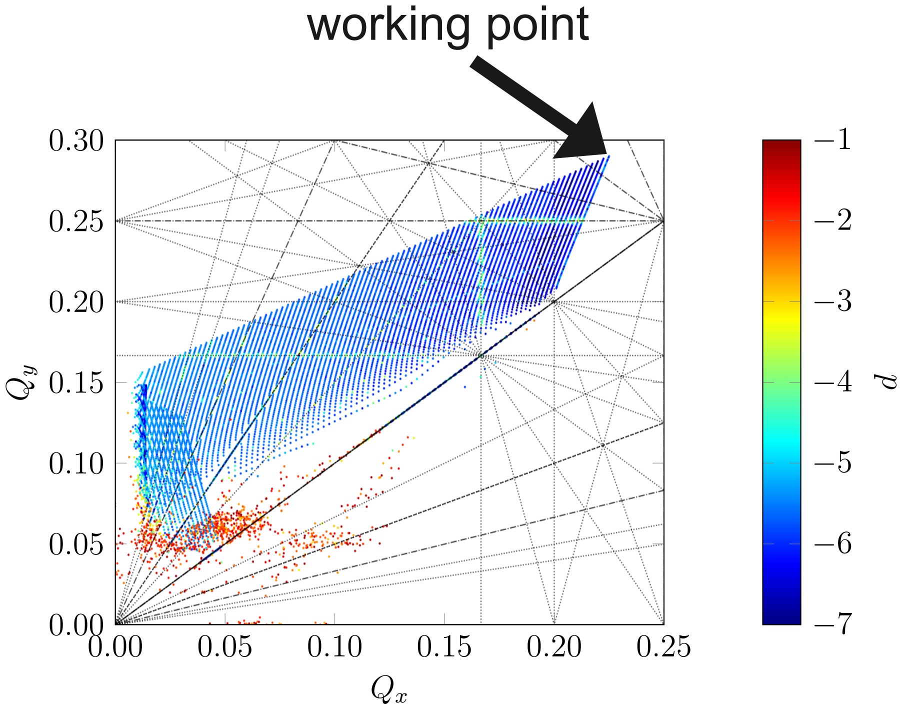
Only linear chromaticity is compensated

±2% acceptance no problem

60°/60° optics

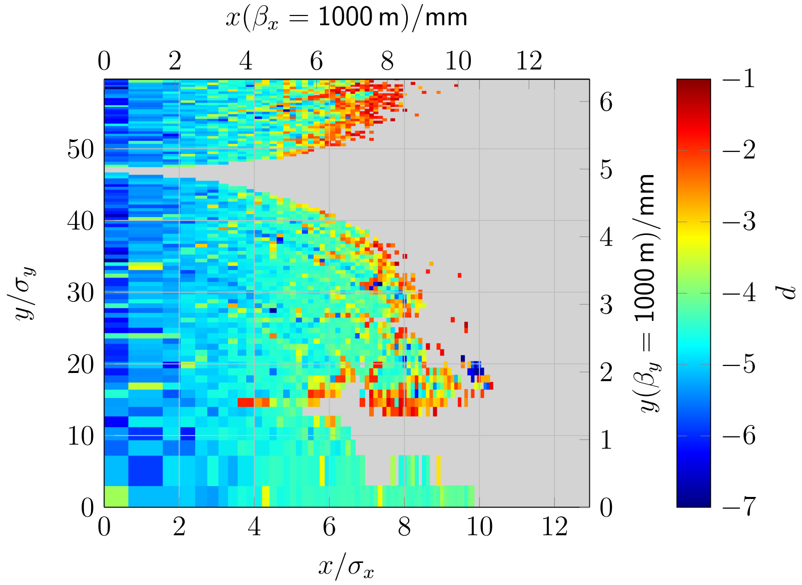


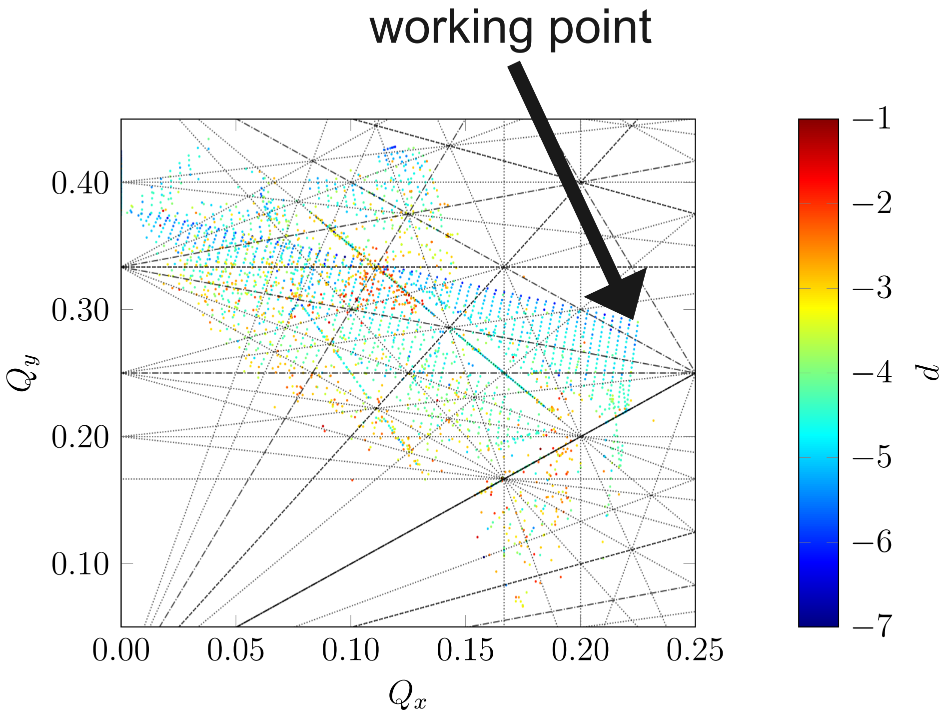
$$d = \log_{10}\left[\sqrt{\left(\nu_x^{(2)} - \nu_x^{(1)}\right)^2 + \left(\nu_y^{(2)} - \nu_y^{(1)}\right)^2}\right]$$



tune footprint

90°/60° optics





interleaved sextupole scheme

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Detuning with amplitude

- Detuning in first order given by

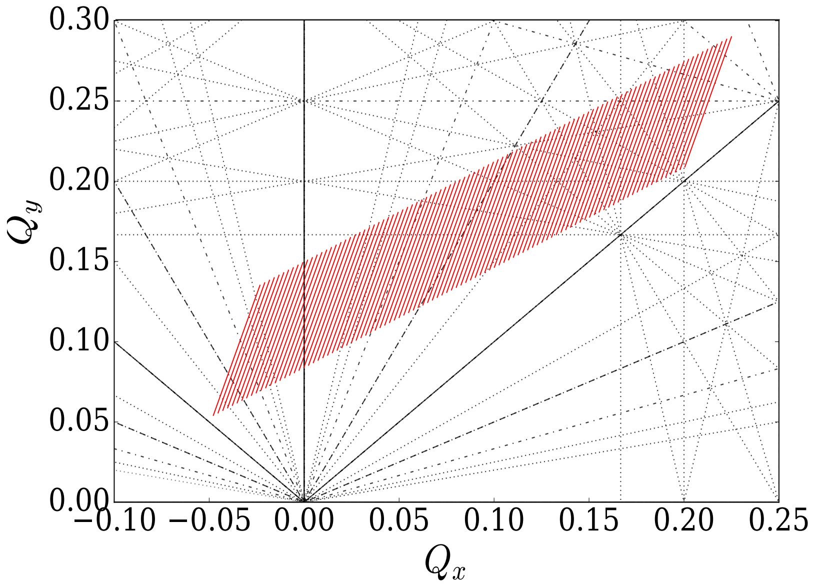
$$Q_x = Q_{x,0} + \alpha_{xx} J_x + \alpha_{xy} J_y$$

$$Q_x = Q_{x,0} + \alpha_{yx} J_x + \alpha_{yy} J_y$$

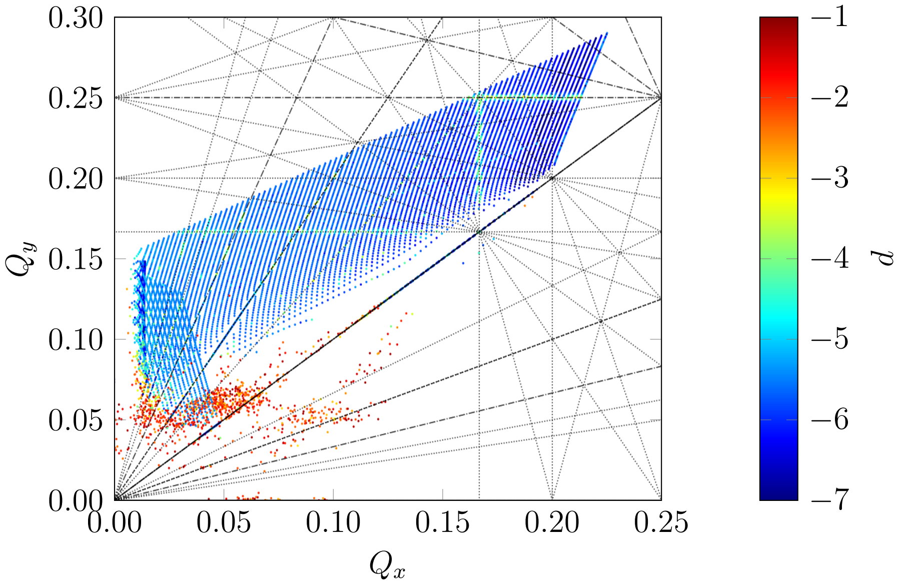
- $\boldsymbol{\alpha}_{ij}$ are the detuning coefficients, J the action

- Detuning coefficients (also higher orders) can be quickly calculated with PTC_normal

Tune footprints of 60°/60° optics



Analytic calculation based on first order PTC_normal results



Tracking results

Summary and Outlook

- Sufficient dynamic aperture of more than 70 σ achieved with the 60°/60° optics
- We are confident to find a suitable sextupole scheme for 90°/60° optics using the PTC normal form analysis

  → Multi-family sextupole scheme allows to modify higher orders of chromaticity and detuning with amplitude

- Future step: estimate the strength of instabilities and the emittance evolution during filling and ramp-up

Thank you for your attention!

Acknowledgements:

Thanks to B. Holzer, Y. Papaphilippou, K. Oide and T. Tydecks for their input!