Update on HP-PS optics studies

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  - Ring layout
  - Main ring parameters
- Magnet parameters for the 50 and 75 GeV options
- Chromaticity correction
- Tunability studies
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  - Global tunability
- Dynamic Aperture studies
  - After closed orbit correction
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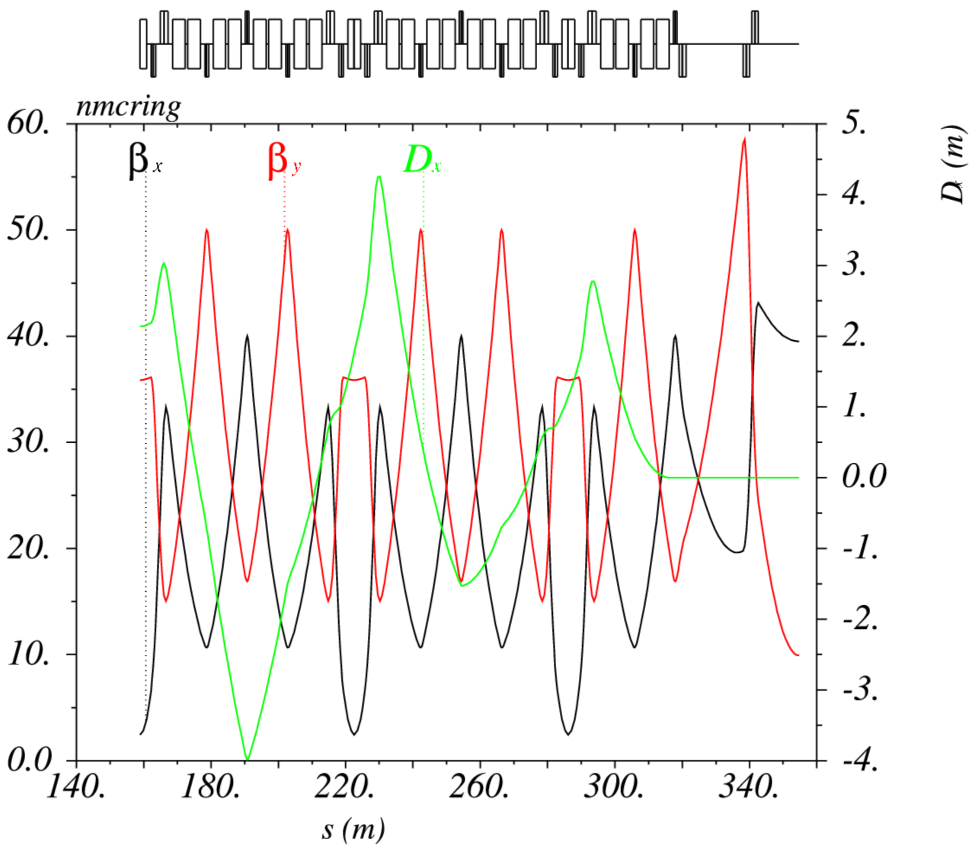
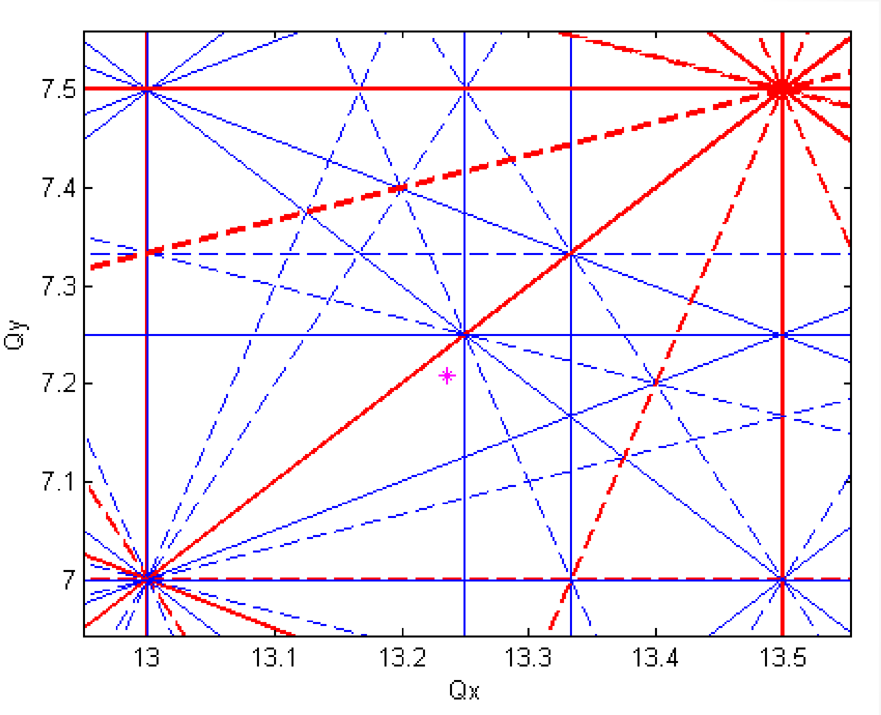
- Summary and Next steps

Optics and working point

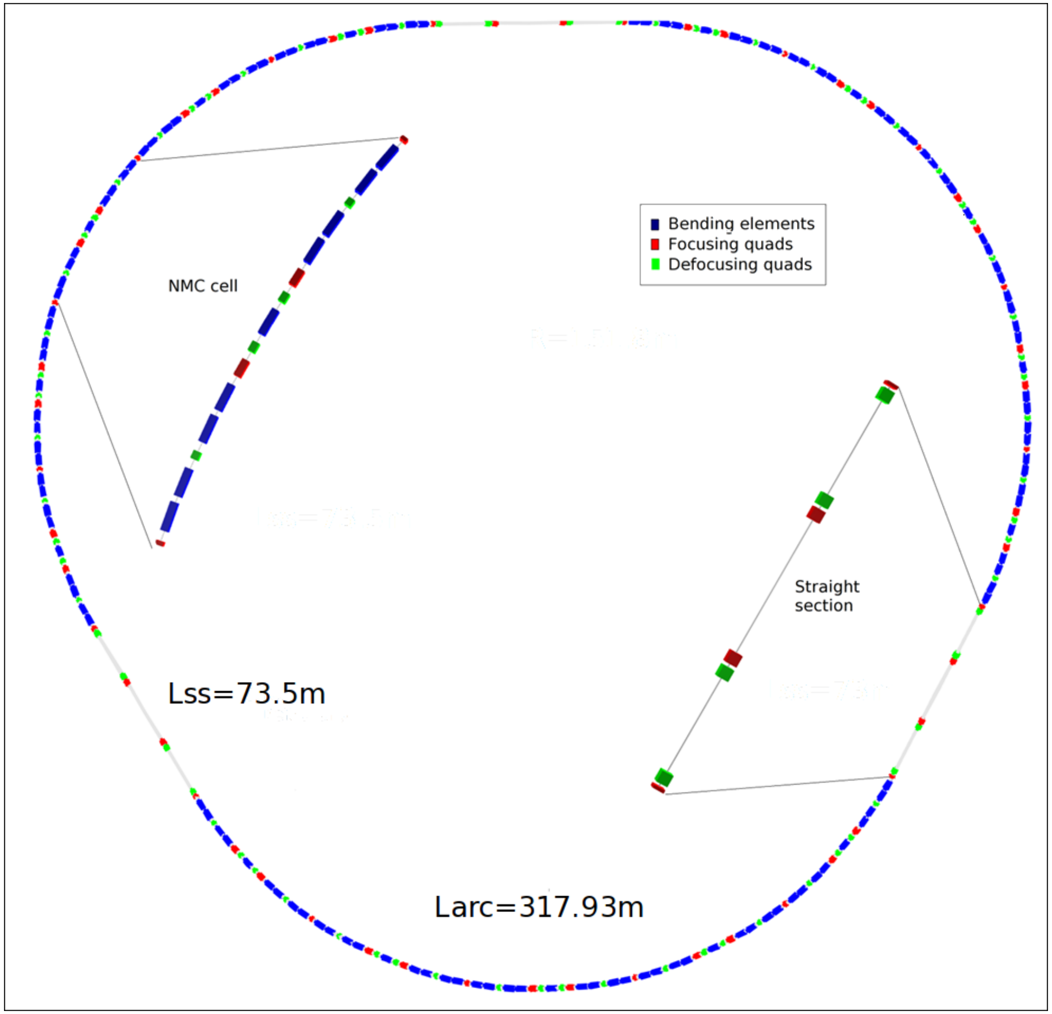




- Optics of one sextant of the ring

- Nominal working point $(Q_x, Q_y)=(13.24,7.21)$

Ring layout



- 3-fold symmetry
- NMC arc cells
- Doublet LSS
  - Space for injection/extraction, collimation and RF

Main parameters

Parameter	50 Gev	75 GeV
Circumference [m]	1174	
Symmetry	3-fold	
Beam Power [MW]	2	
Repetition Rate [Hz]	1	
RF frequency [MHz]	40	
Kinetic Energy @ inj./ext. [GeV]	4/50	4/75
Protons/pulse [10^{14}]	2.5	1.7
Dipole ramp rate [T/S]	4.2	5.9
Bending field @ ext. [T]	2.09	3.13
Max. quadrupole field [T]	1.36	1.82
Dipole gap height [mm]	111	92
Lattice type	Resonant NMC arc , doublet LSS	
Norm. emit. H/V [mm-mrad]	15/12.8	10.6/8.3

Magnet parameters for the 50 GeV option

Type	Length [m]	Strength [m^{-2}]	B_{pt} [T]	R_{xy} [mm]*
Type1 (LSS)	2	-0.0832	-0.89	63
Type2 (ARC)	1.4	-0.0657	-0.55	49
Type3 (ARC)	1.1	-0.0424	-0.42	58
Type1 (LSS)	2	-0.0136	-0.15	63
Type3 (ARC)	1.1	0.0494	0.49	58
Type1 (LSS)	2	0.07	0.75	63
Type4 (ARC)	2.4	0.1142	1.36	70

Dipole characteristics (135 dipoles):

B = 2.1 T with
Ramp rate: 3.82 T/s (500ms ramp up)
Max gap_x = 145.7 mm
Max gap_y = 110.9 mm

Number of type 1: 18
Number of type 2: 30
Number of type 3: 48
Number of type 4: 30

Total number: 126

*Beam pipe thickness considered: 8mm

Magnet parameters for the 75 GeV option

Type	Length [m]	Strength [m^{-2}]	B_{pt} [T]	R_{xy} [mm]*
type1	2	-0.0832	-1.1	52
type2	1.4	-0.0657	-0.73	44
type3	1.1	-0.0424	-0.54	50
type1	2	-0.0136	-0.18	52
type3	1.1	0.0494	0.63	50
type1	2	0.07	0.92	52
type4	2.4	0.1142	1.82	63

Dipole characteristics (135 dipoles):

B = 3.13 T with 5.9 T/s ramp rate

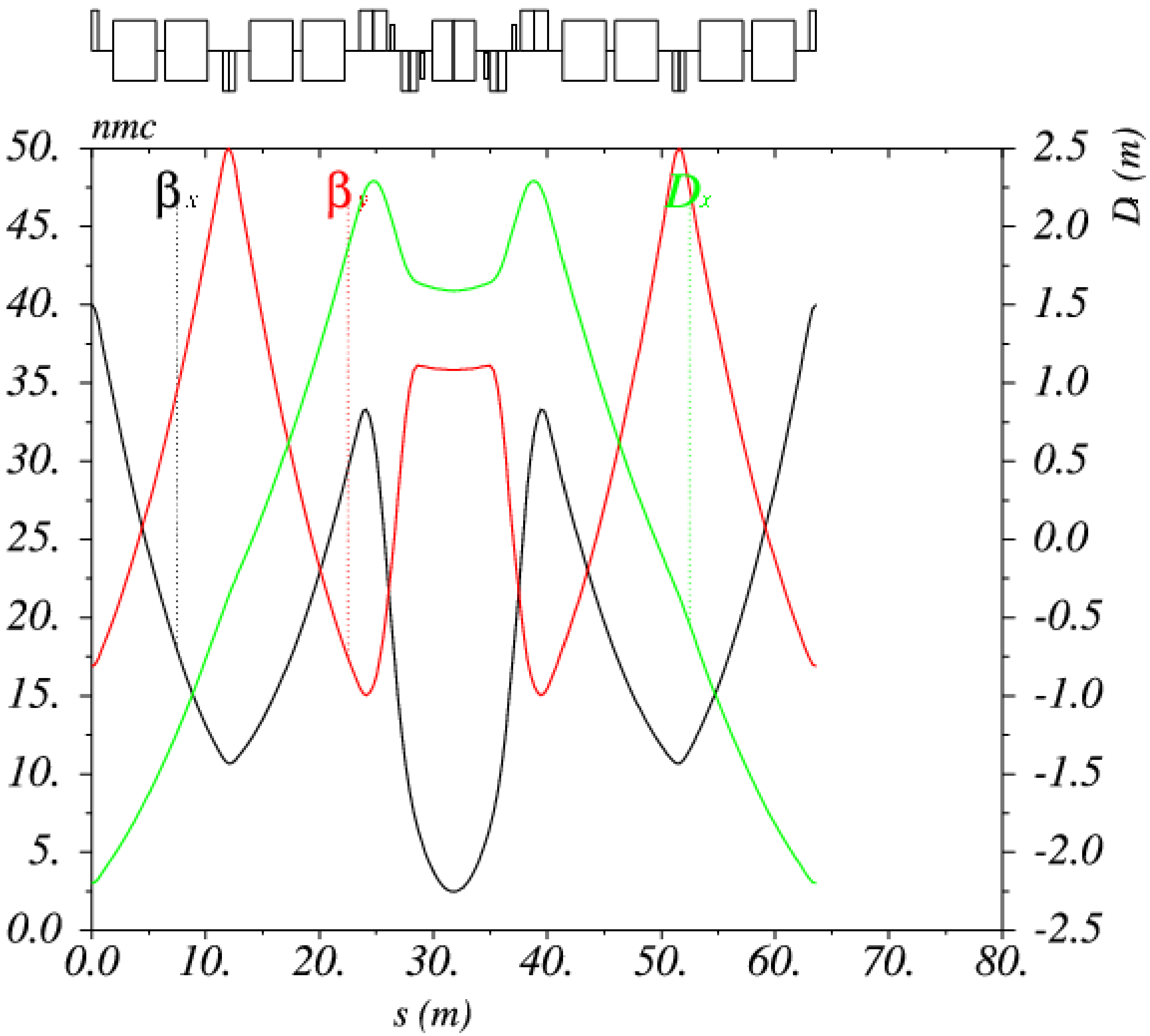
Max gap_x = 132.6 mm
Max gap_y = 92.3 mm

Number of type 1: 18
Number of type 2: 30
Number of type 3: 48
Number of type 4: 30

Total number: 126

*Beam pipe thickness considered: 8mm

Chromaticity correction



- Two sextupole families placed at high dispersion regions to reduce the sextupole strengths (Minimize the non-linear effects)
- a_{xx}=-19, a_{yy}=64, a_{xy}=209
  - First order tune shift with amplitude (at 10 sigma) : of the order of 10^{-4}
  - We don't expect that the DA will be limited by the sextupoles' non-linearities

Tunability studies

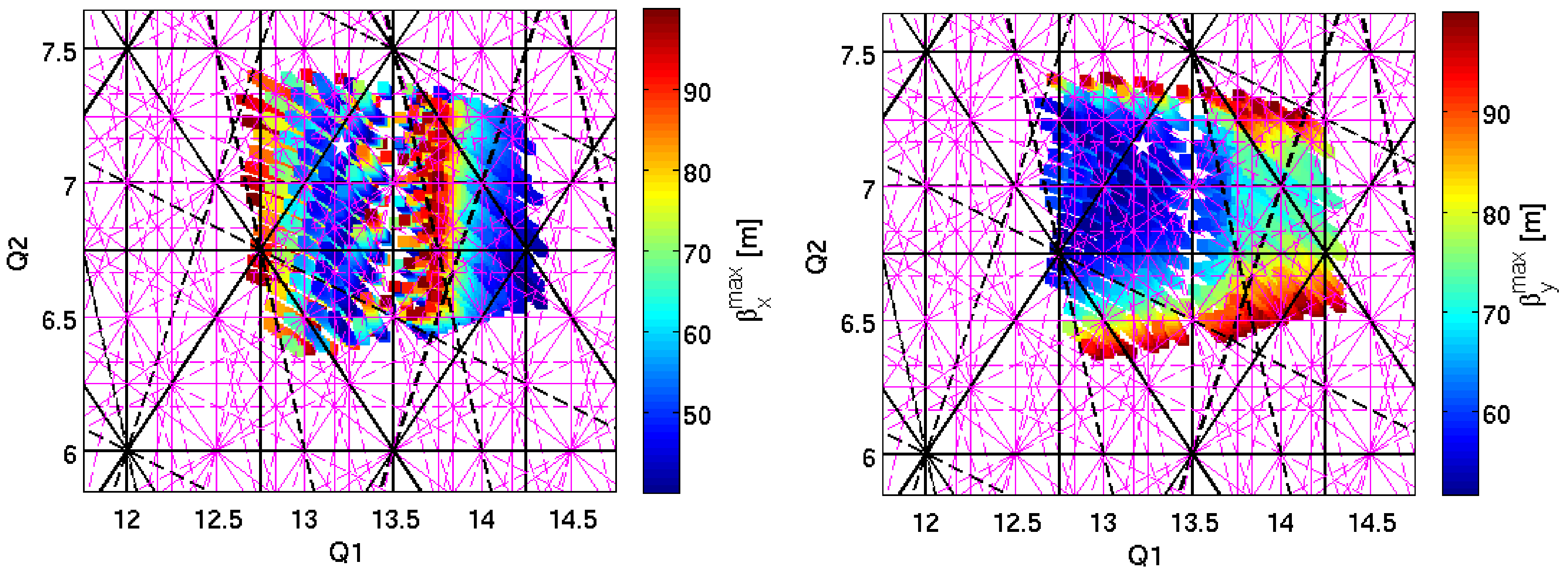
Long Straight Section (LSS) tunability

- For fixed arc quad strengths, the quad strengths of the LSS are varied and only stable solutions are kept
  - Around 30k cases are studied
- The tunes for each solution are shown in the tune diagrams color-coded with parameters of interest

Global tunability

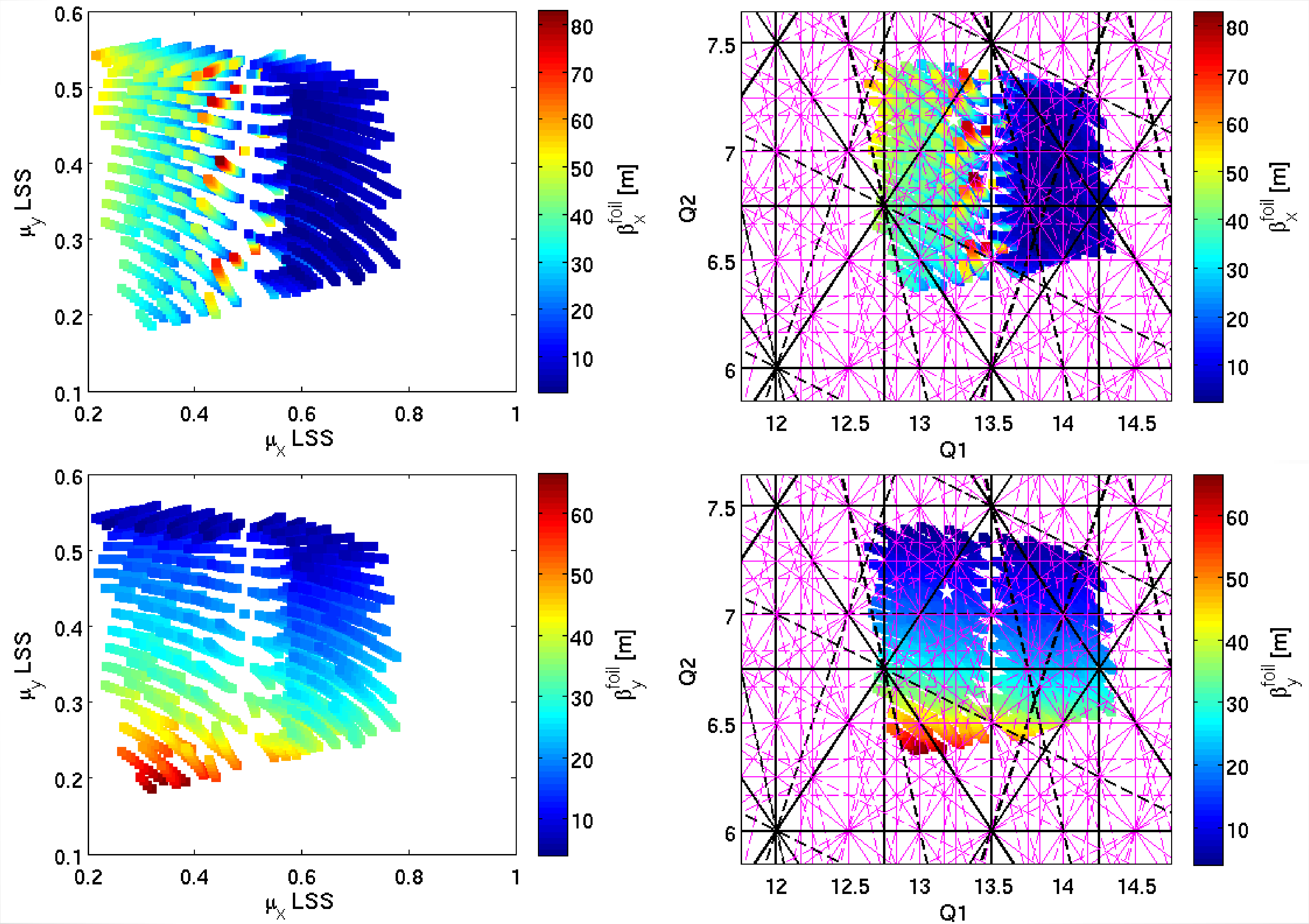
- The vertical phase advance (μ_y)of the arc is rematched
- For each μ_y the LSS quadrupole strengths are scanned
  - Around 30k cases are studied for each arc μ_y

Tunability of the LSS

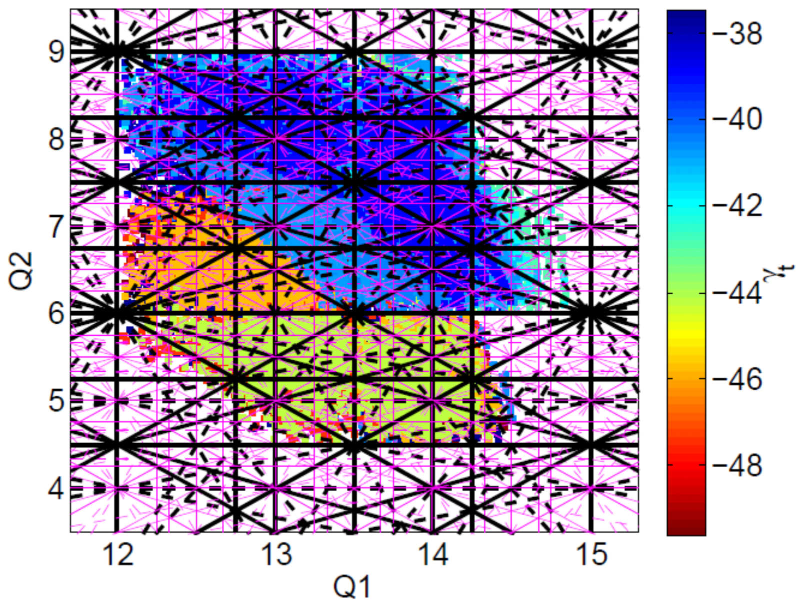


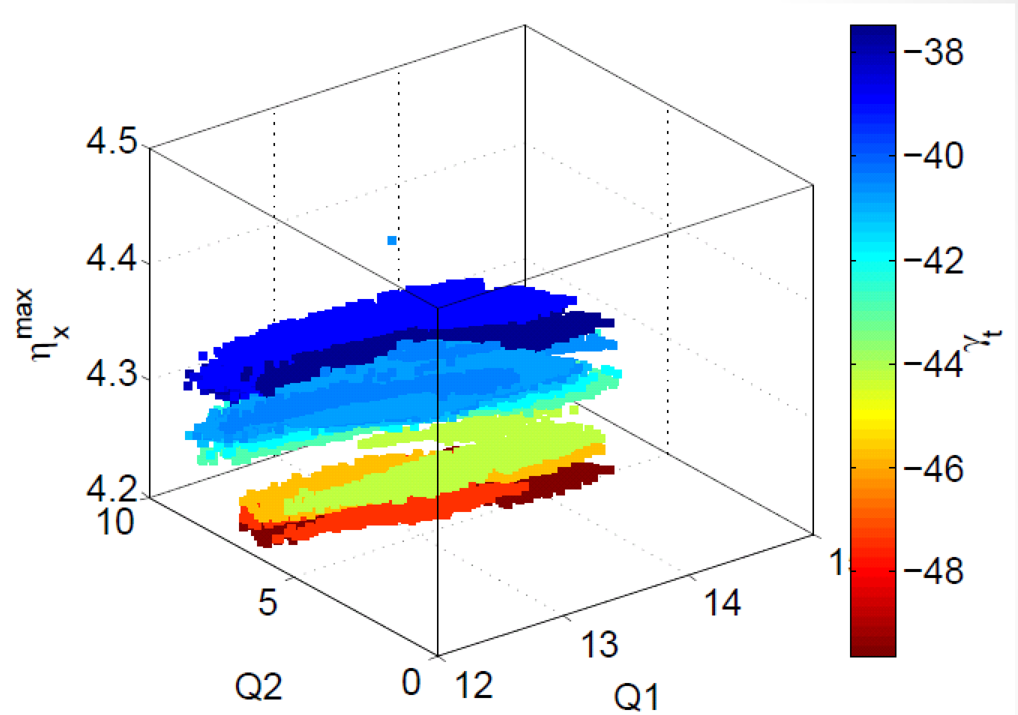
- Parameterization of the horizontal and vertical tunes of the ring with the maximum horizontal (top) and vertical (bottom) beta functions
- Resonances up to 4th order are shown
  - Systematic resonances are shown in black while non systematic in pink. The normal resonances are shown with solid lines while the skew ones with dashed lines.

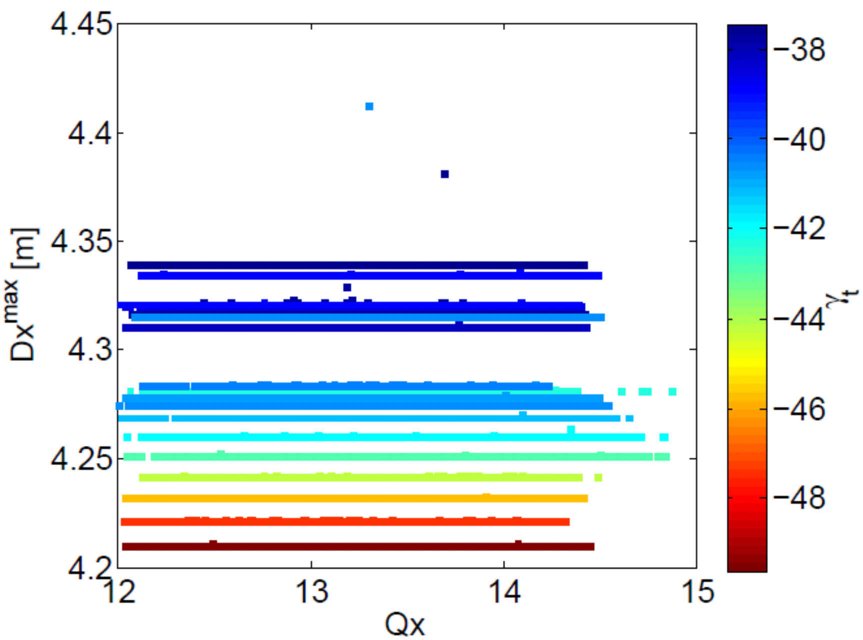
Tunability of the LSS - FOIL



Global tunability

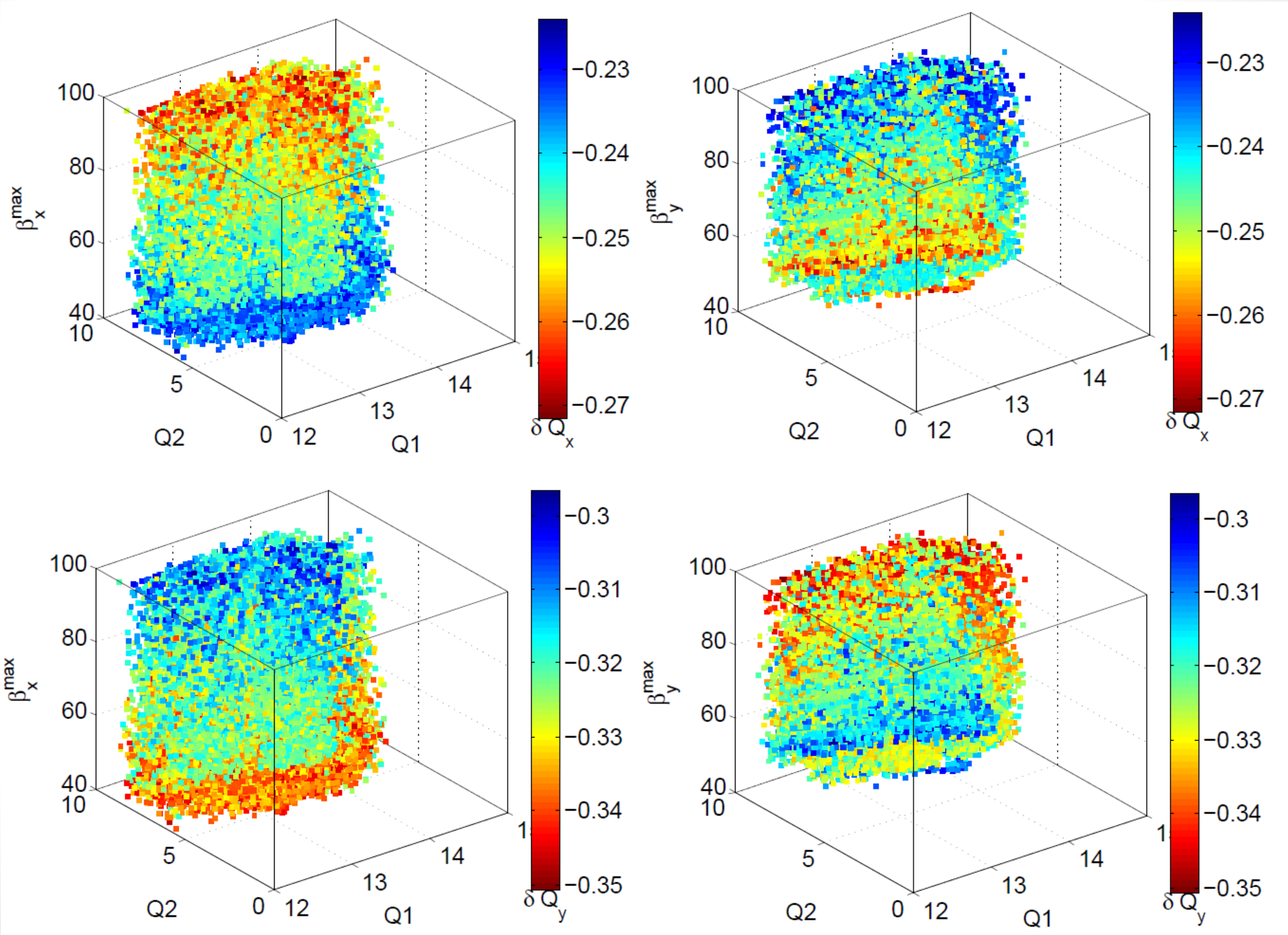




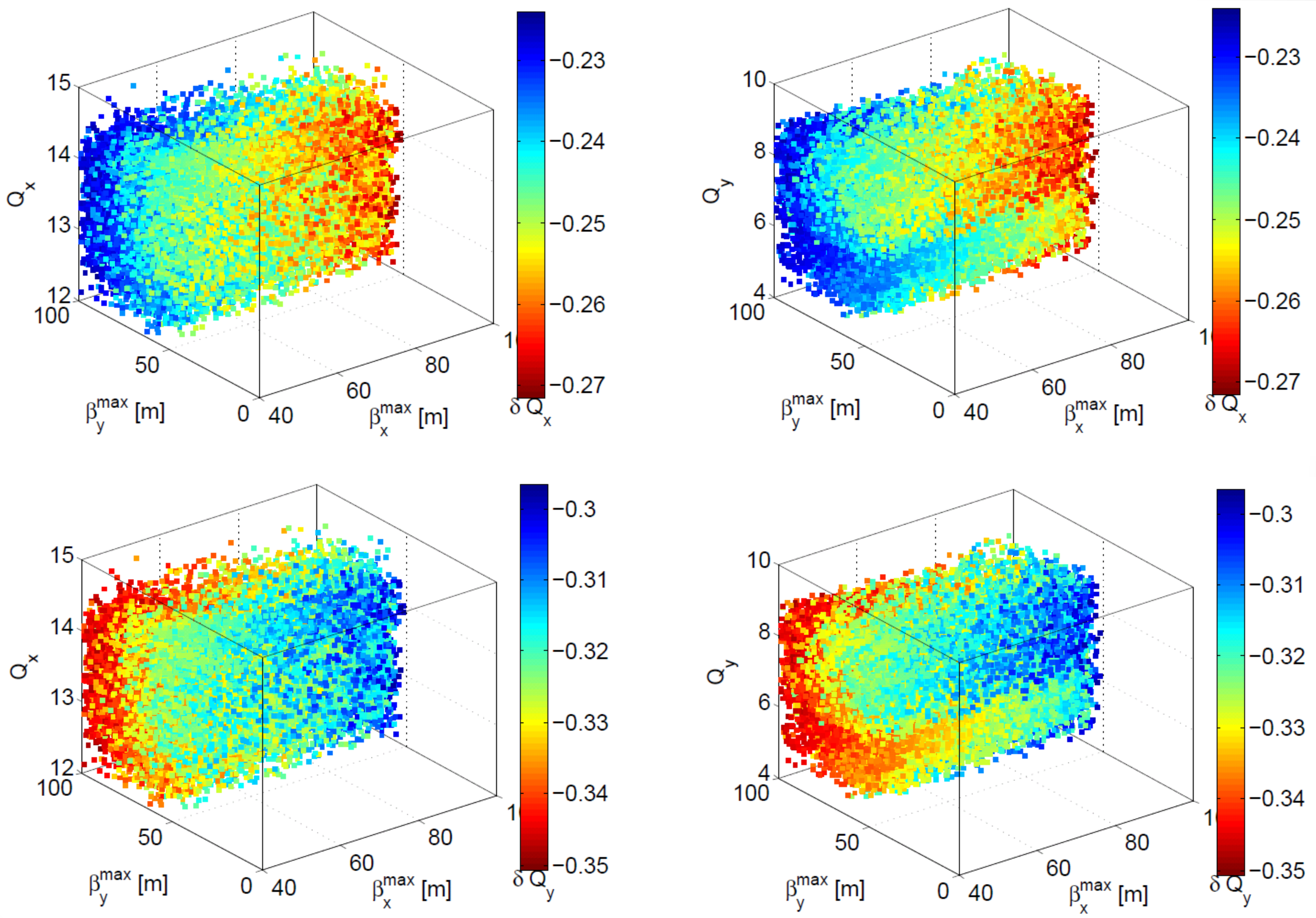


- Parameterization of the transition energy with the horizontal and vertical tunes (top, left), the horizontal tune and max dispersion (bottom) and the tunes and max dispersion (top, right)
- Strong dependence on the max dispersion (as expected)
  - Smaller γ_t for larger dispersion

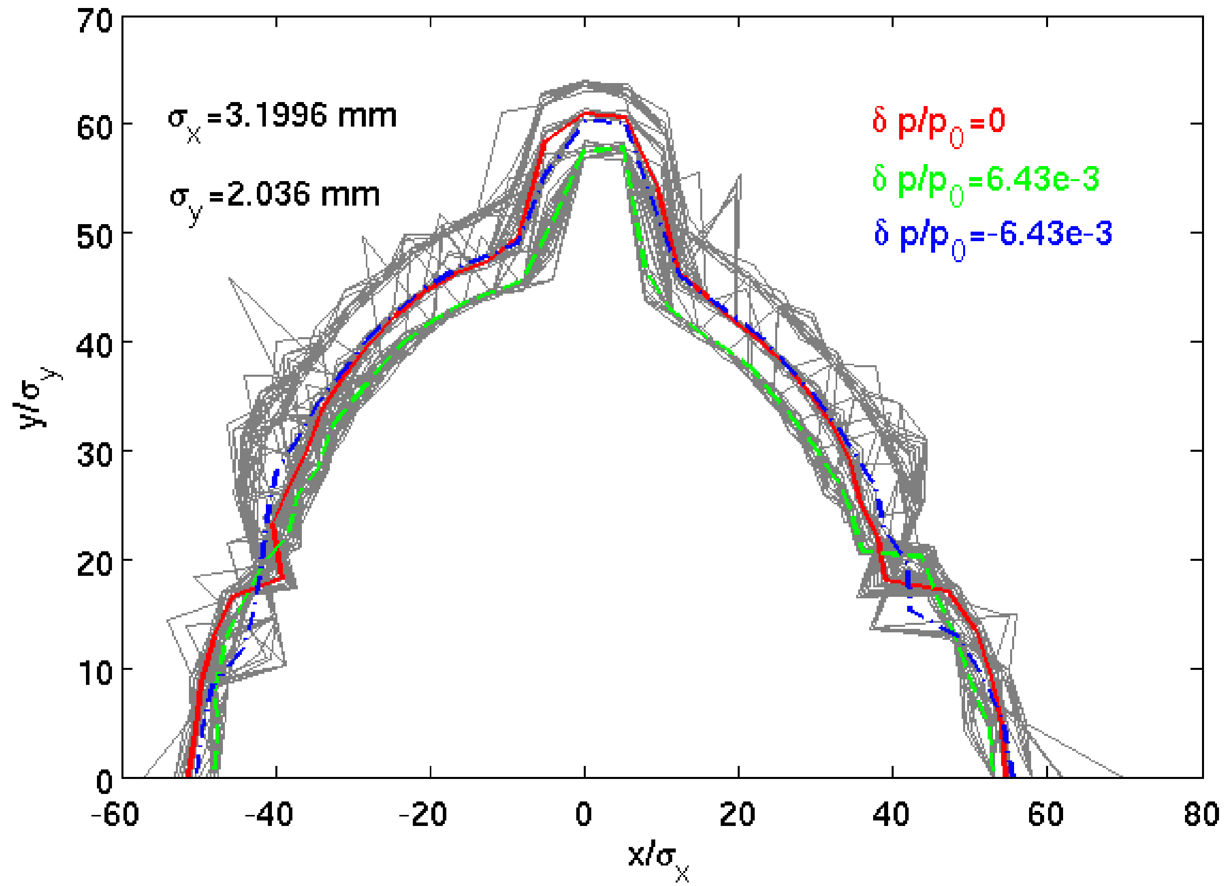
Global tunability



Global tunability

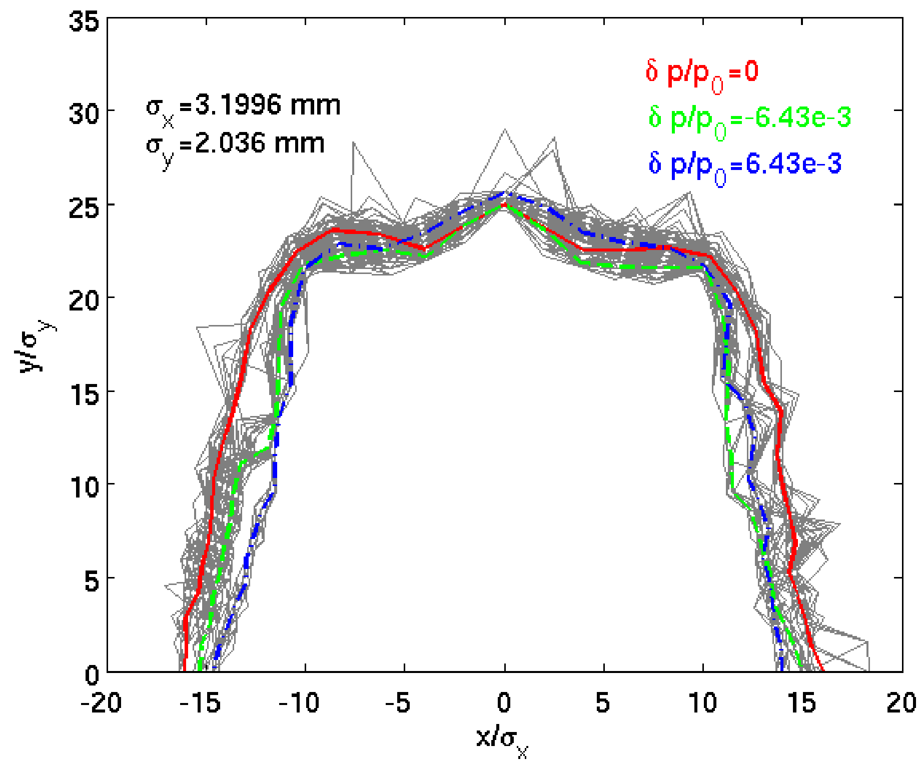


DA studies – Closed orbit correction



- On and off momentum DA calculations after orbit correction (100 seeds (gray))
- Very large DA → Not limited by orbit errors

DA studies - Multipole field errors



Order	Dipoles (R=3 cm)		Quadrupoles (R=5.95 cm)		Sextupoles (R=5.95 cm)	
	mean	random	mean	random	mean	random
n	b_n/b_1	b_n/b_1	b_n/b_2	b_n/b_2	b_n/b_3	b_n/b_3
1	10^4	5	0	0	0	0
2	0.15	0.1	10^4	5	0	0
3	1	0.5	-2	1	10^4	5
4	0.013	0.064	1	1	-0.5	1.5
5	-0.1	0.064	1	1.5	0.5	1.5
6	-0.003	0.003	3	1	-1	0.5
7	-0.026	0.005	0.5	1	1	0.5
8	0.001	0.001	0.5	0.5	0.5	0.5
9	-0.004	0.001	0.1	0.3	-4	0.3
10	-	-	0.5	0.3	0.1	0.5
11	-	-	0.1	0.3	0.1	0.5

Ref. PS2 CDR (H. Bartosik): Relative multipole components in units of 10^{-4} at the reference radius R.

- On and off momentum DA calculations for 100 seeds (gray)
  - After orbit correction, chromaticity correction and rematching of the tunes to the ones of the ideal lattice
- DA dominated by the multipole field errors however still very comfortable

Summary and Next steps

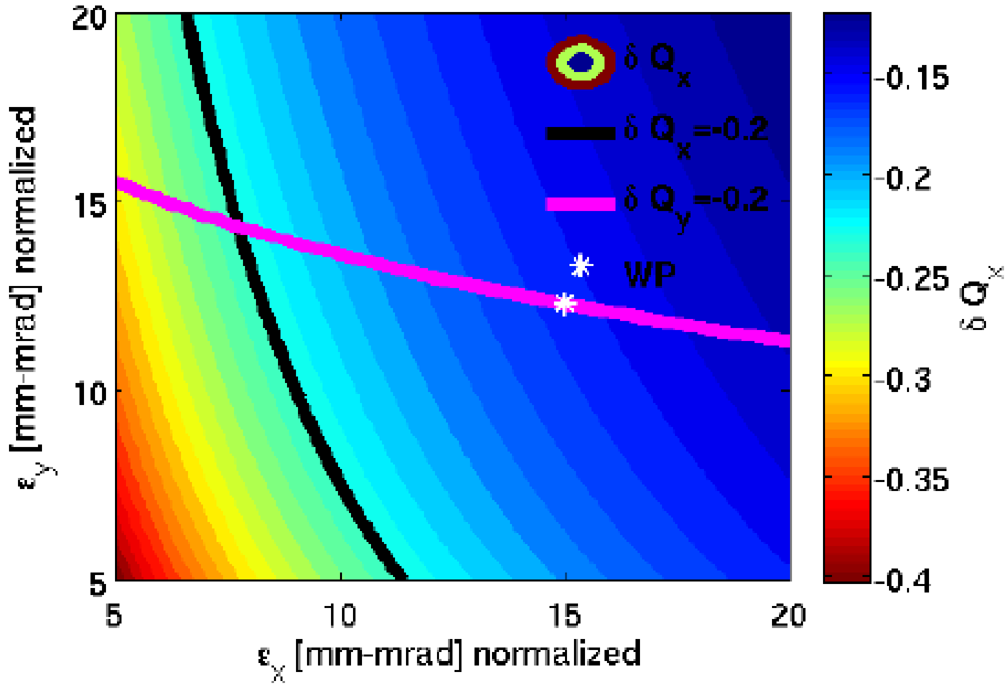
- Basic single particle dynamics studies are now finished
- Tunability studies showed that our working point is close to optimal
  - Your feedback is very welcome
- Dynamic aperture studies
  - Not limited by sextupole non-linearities
  - Not limited by orbit errors
  - Dominated by multipole field errors → Still the DA is comfortable
- Note that our twiki page is there and anyone can add his/her material: https://twiki.cern.ch/twiki/bin/view/Sandbox/LAGUNAHPPSWorkingGroup
- Next step: Space charge studies with realistic beam distribution and Collimation system

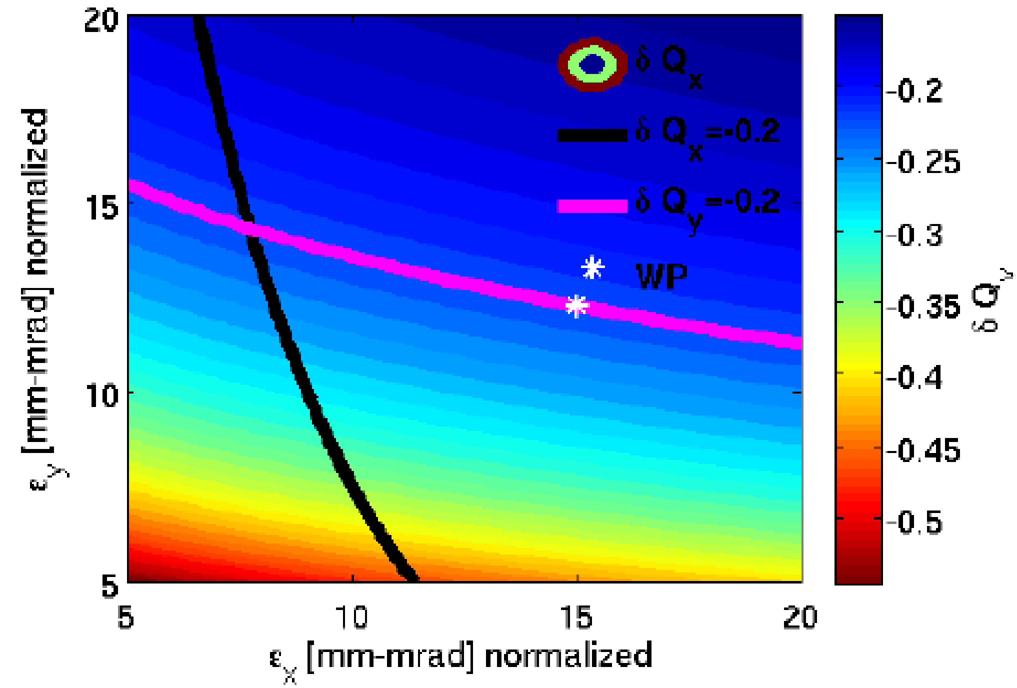
THANK YOU!

Special thanks to Hannes Bartosik for kindly providing his examples from the PS2 studies!

Backup slides

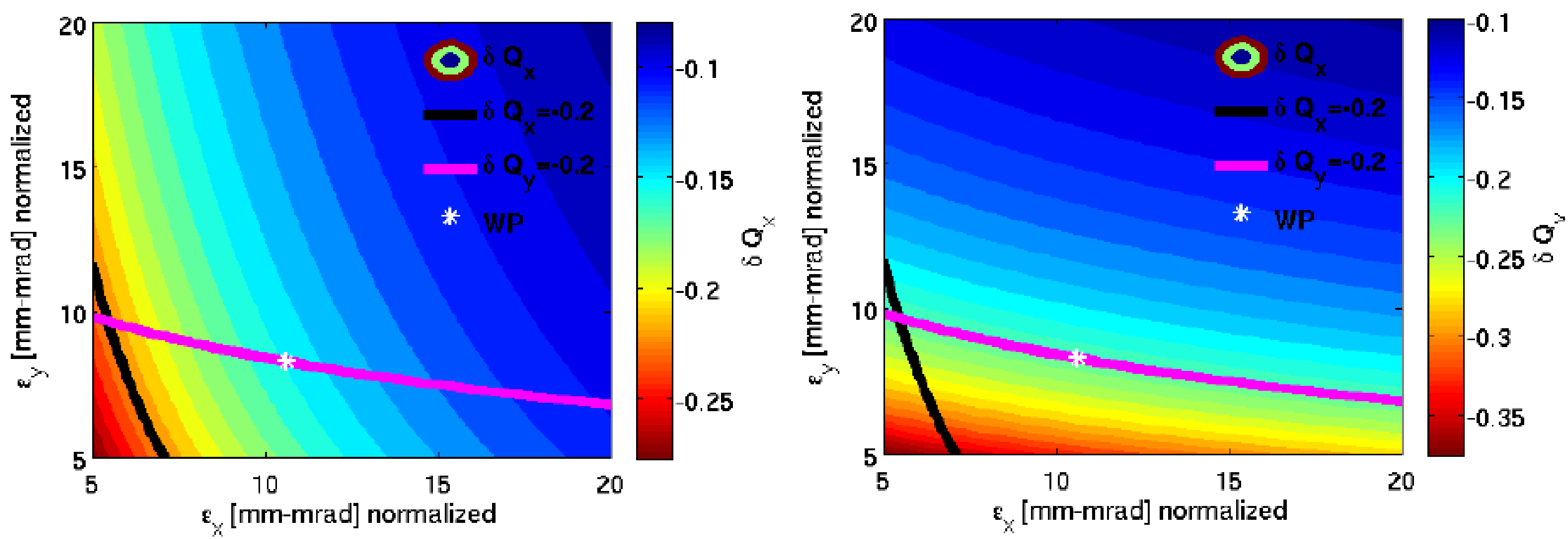
50 GeV option





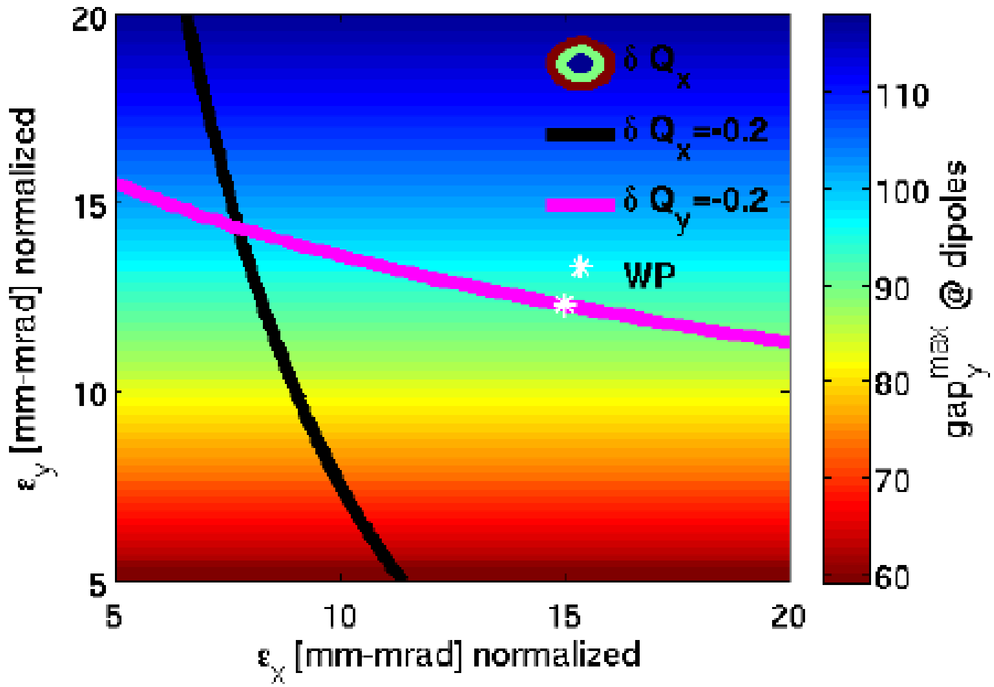
- N_p=2.5 10^{14} particles per pulse to get the 2MW
- To get the -0.2 Laslett space charge tune shift in both planes:
  - **ε_x = 15 mm-mrad & ε_y = 12.3 mm-mrad**

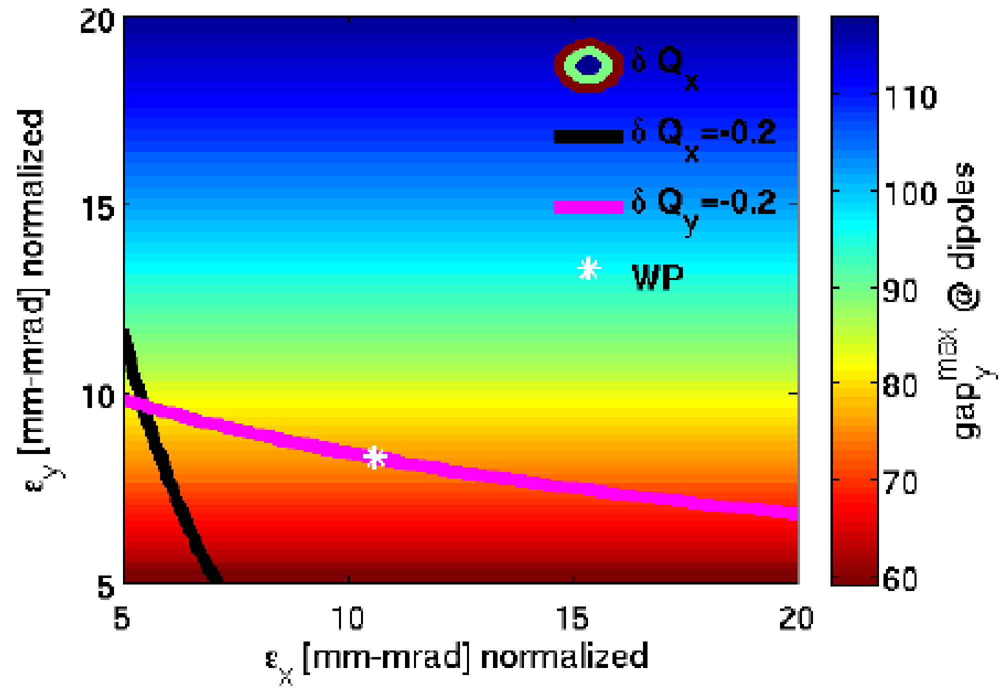
75 GeV option



- N_p=1.7 10^{14} particles per pulse to get the 2 MW
- To get the -0.2 Laslett space charge tune shift in both planes:
  - **ε_x = 10.7 mm-mrad & ε_y = 8.3 mm-mrad**

Dipole gap height





$$R^{\min}{}_{x,y} = n_{\sigma_{x,y}} \sqrt{\beta_{x,y}\varepsilon_{x,y}} + \eta_{x,y}\left(\frac{\delta p}{p_0}\right)_{\max}$$

- ❖Geometrical acceptace R^{min}: the minimum beam pipe radius to fit all the particles of the beam
- ❖ Calculations done at 4.5 σ

Ring acceptance @ 50 GeV and 75 GeV