ILC 3.2 km DR design with FODO Arcs (DMC1)

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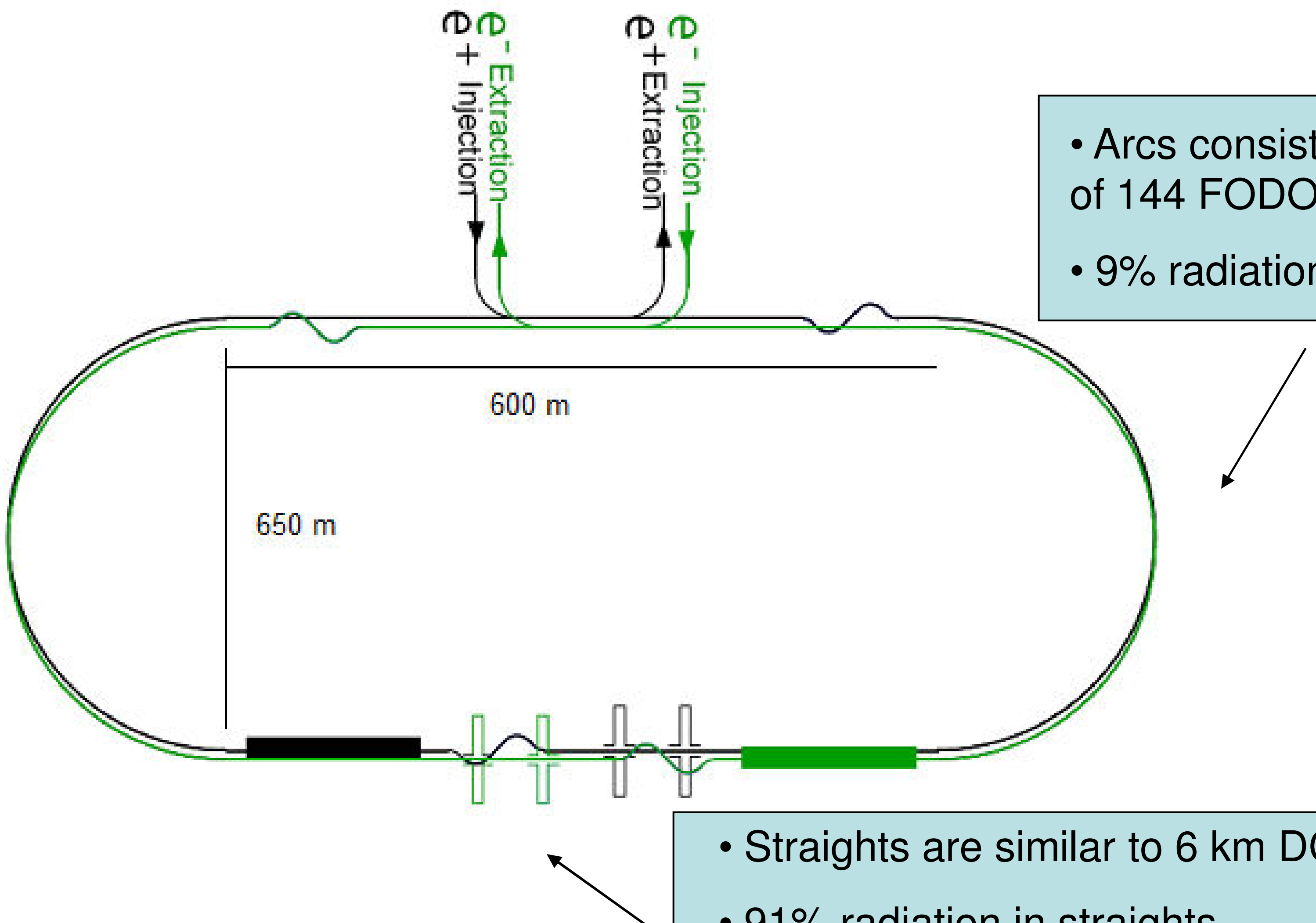
Overall considerations

- Keep the racetrack structure
- Keep the damping time a little smaller than 25 ms
  - decided by the repetition frequency (storage time=200ms)
- Keep the nomalised natural emittance ~ 4 um
- The momentum compaction factor is tunable (10^{-4})
- The injection and extraction beam lines for both e+ and e- rings can be in the same tunel
- Locating the rf and wigglers near each other to minimise cryogenic transfer lines. But rf must be upstream to avoid the synchrotron radiation.

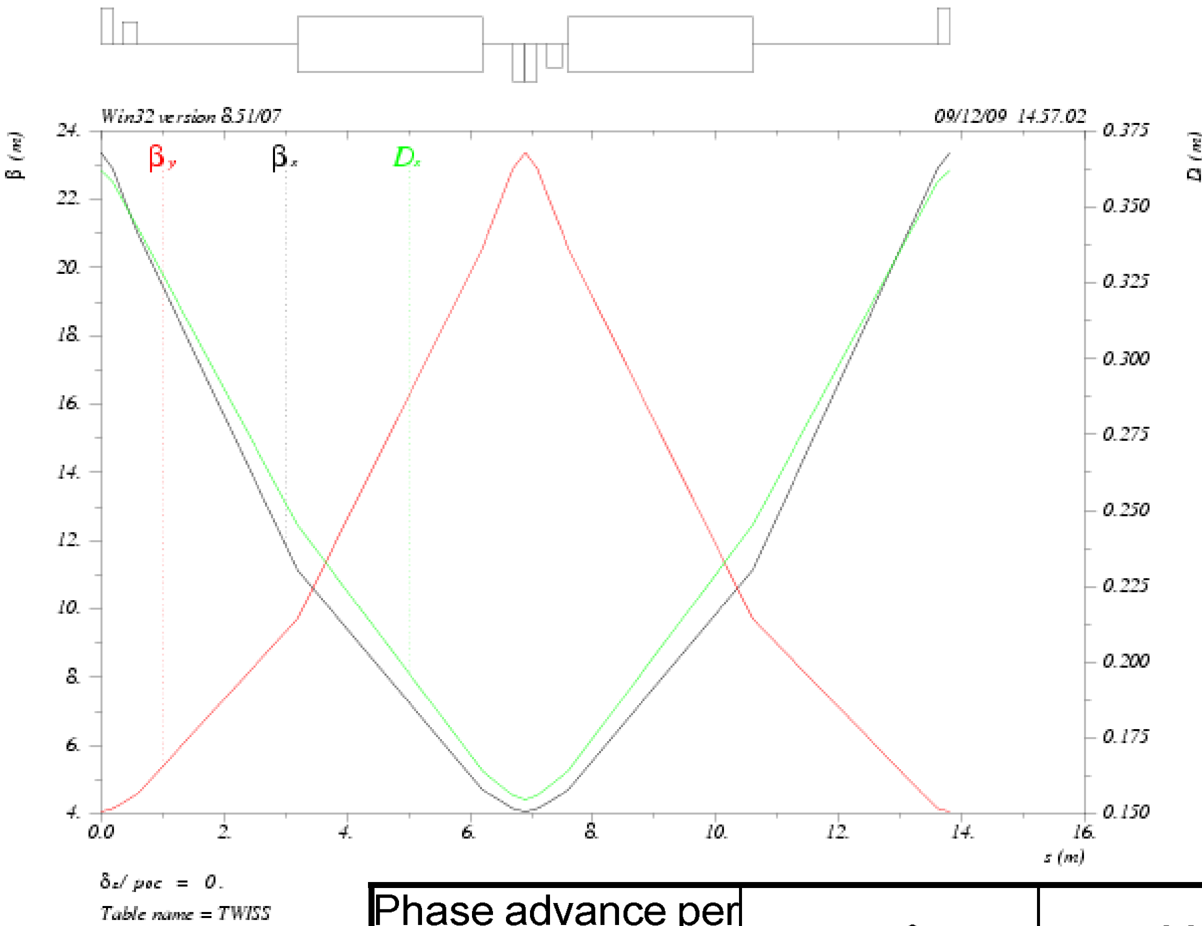
Layout



- Arcs consist of a total of 144 FODO cells
- 9% radiation in arcs

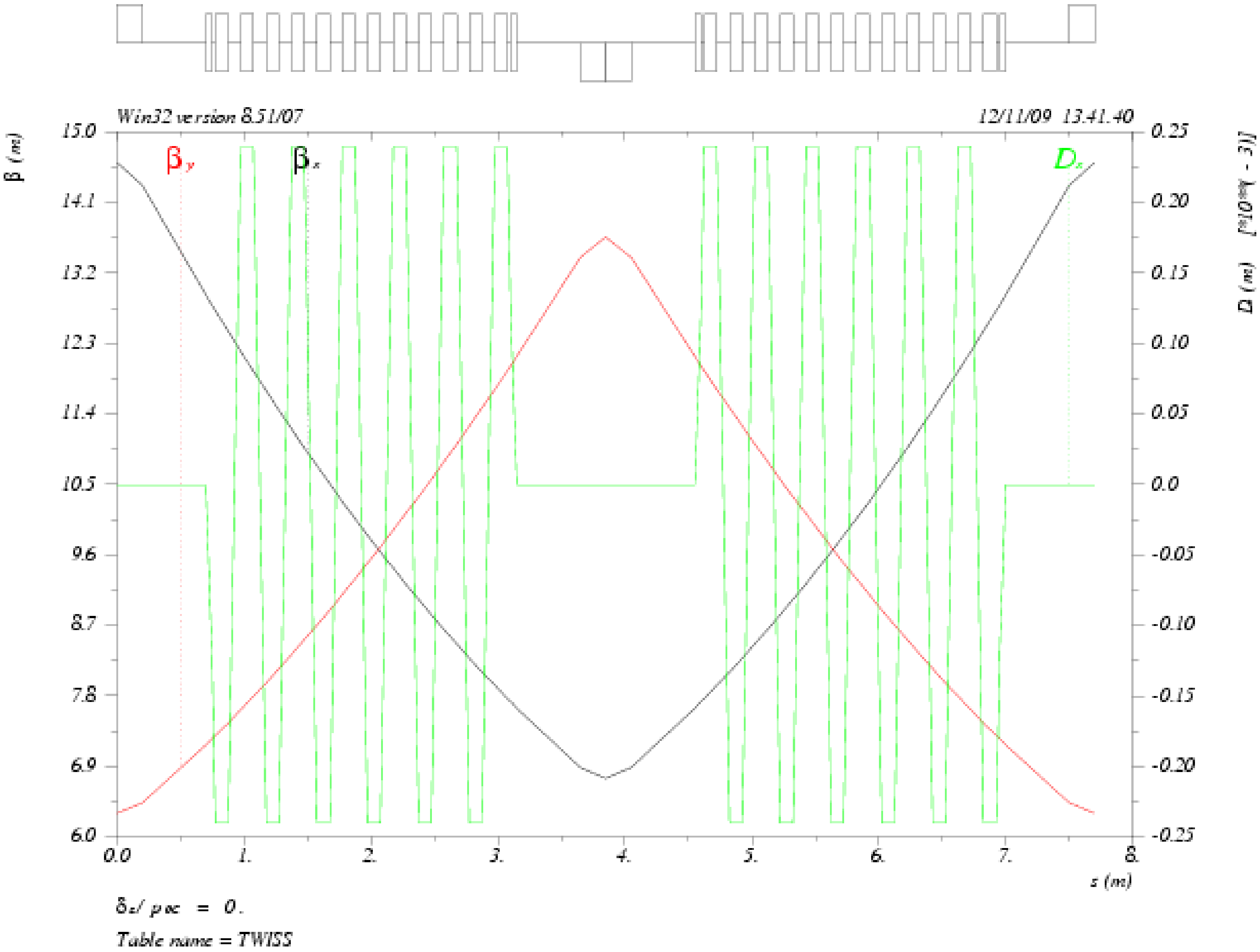
- Straights are similar to 6 km DCO4
- 91% radiation in straights

Arc cell (90°)

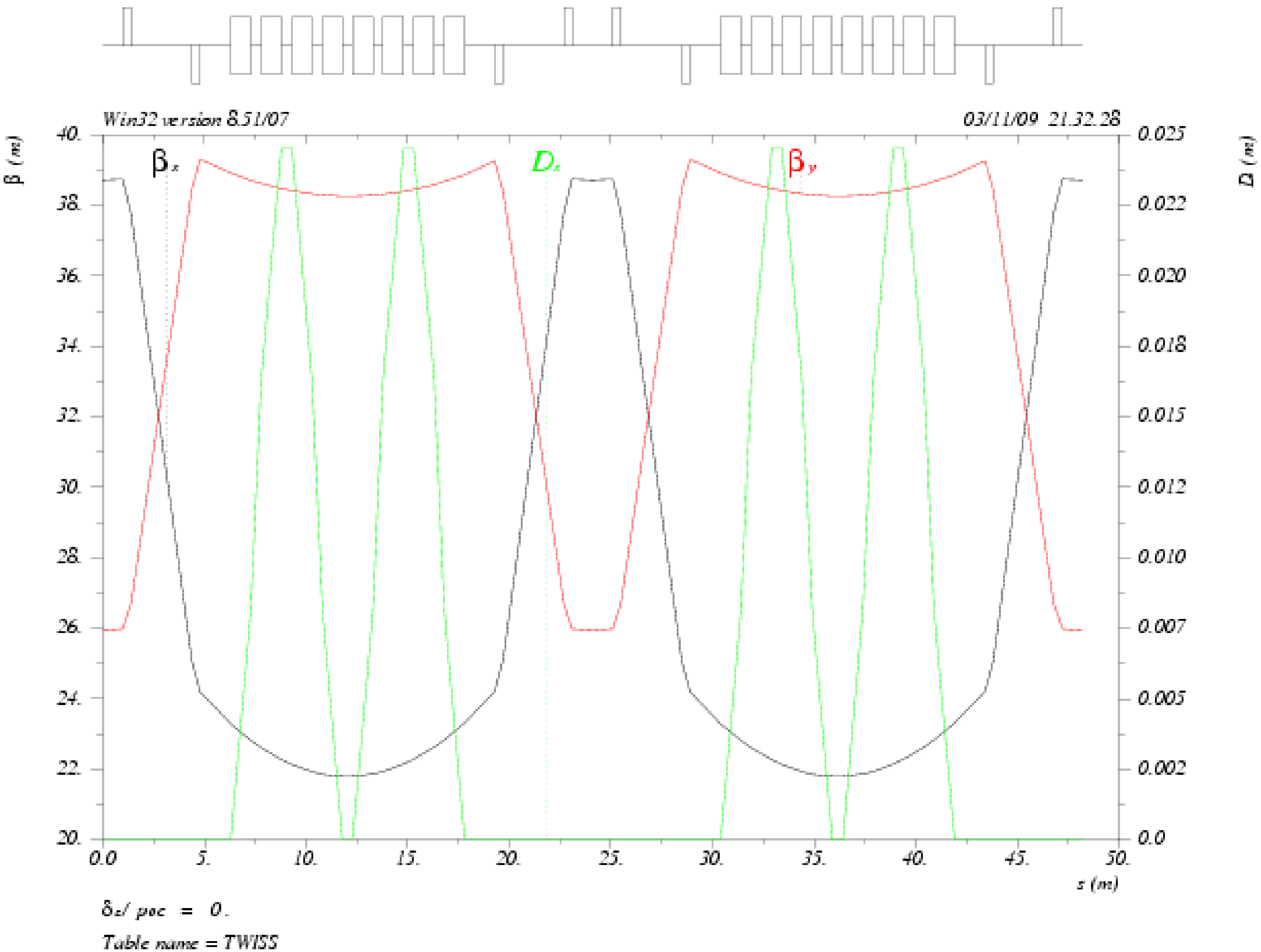


Phase advance per arc cell	75°	90°	110°
Mumentum compaction	5.49×10^{-4}	3.84×10^{-4}	2.60×10^{-4}

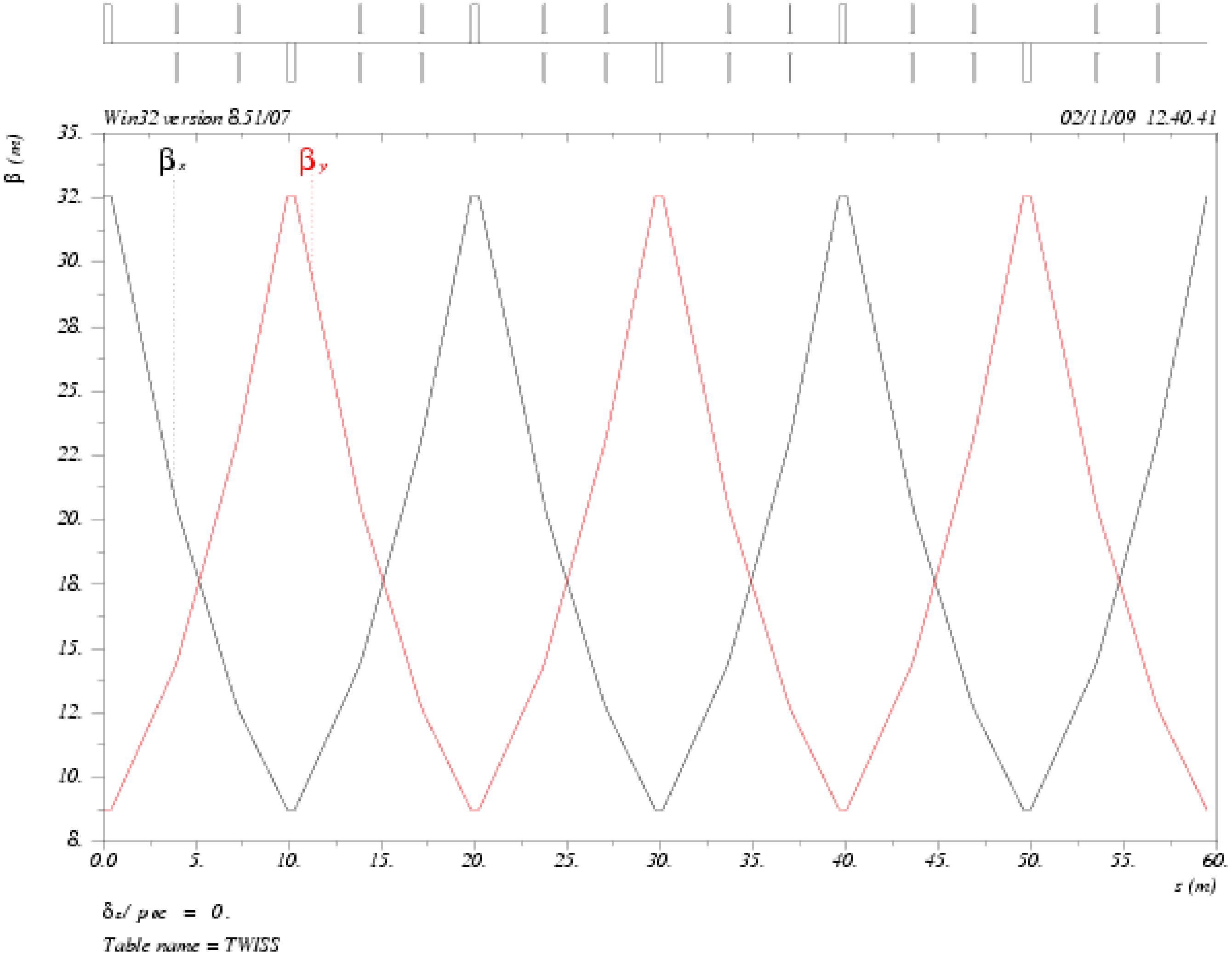
Wiggler cell



Chicane cell



RF section



Win32 version 8.51/07
02/11/09 12.40.41
β (m)
βx
βy
35.
32.
30.
28.
25.
22.
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12.
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8.
0.0
5.
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15.
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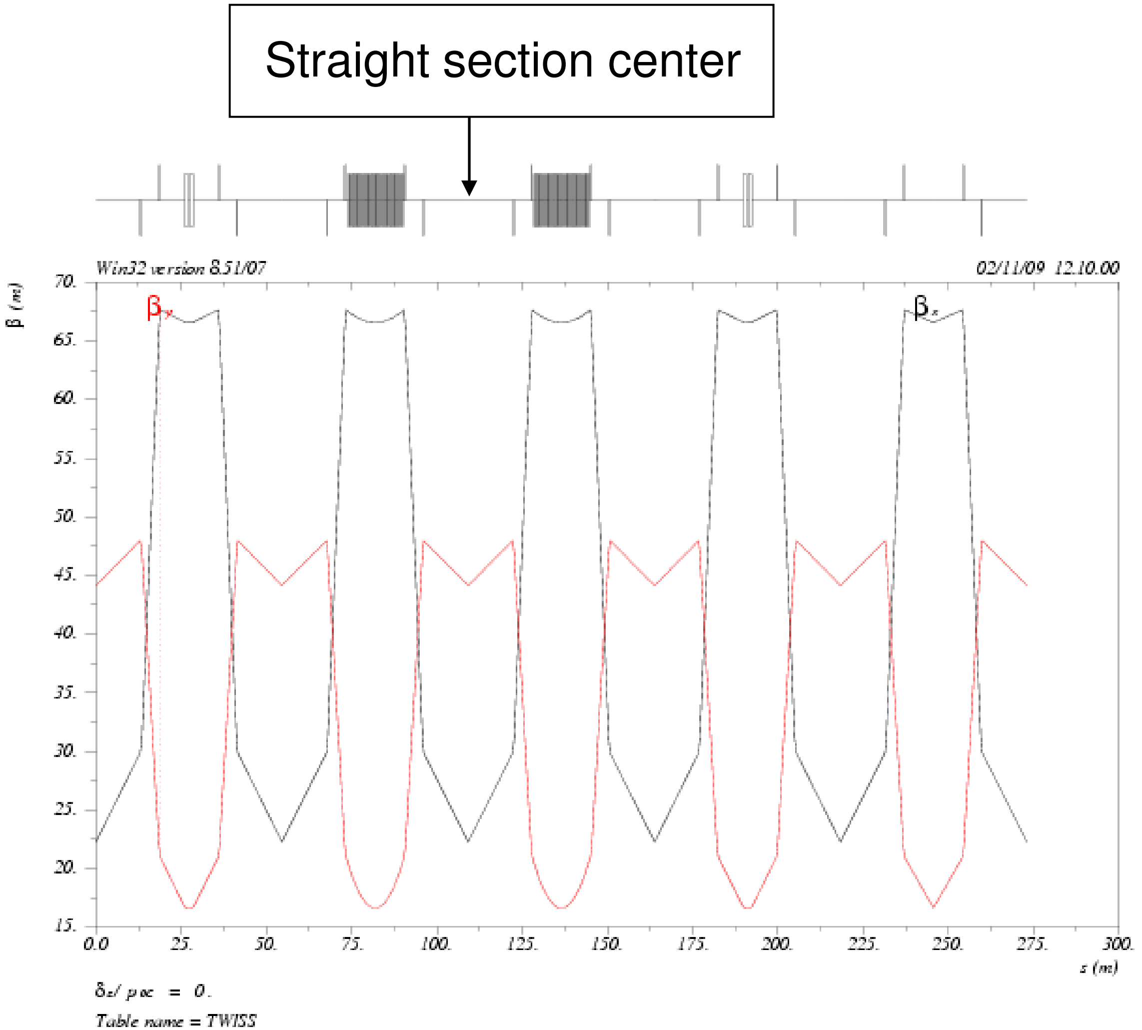
40.
45.
50.
55.
60.
s (m)
δE/ p0c = 0.
Table name = TWISS

Inj/Extr section



Ring

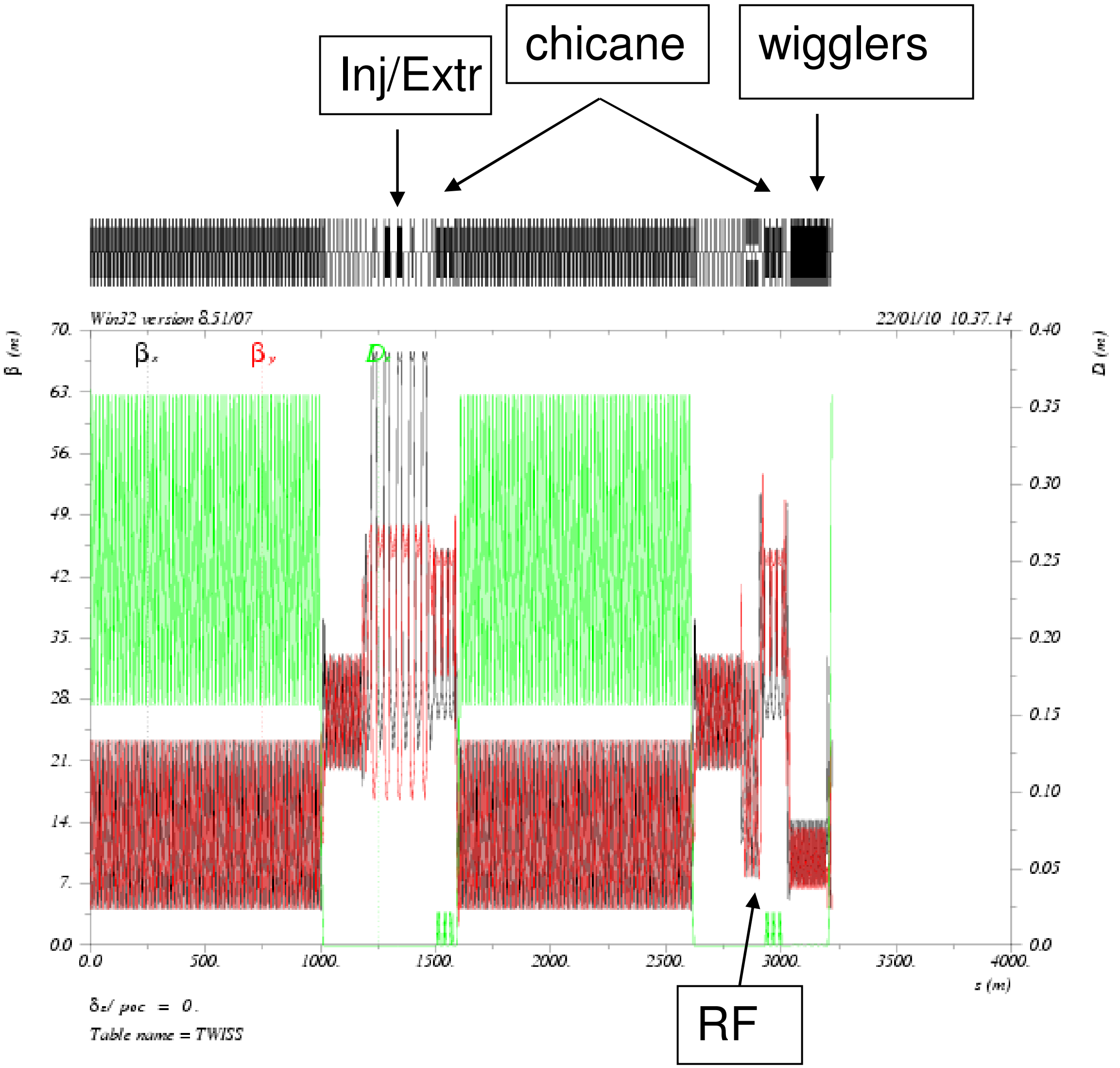

Inj/Extr
chicane
wigglers
Win32 version 8.51/07
22/01/10 10.37.14
β (m)
D (m)
βx
βy
Dx
s (m)
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Table name = TWISS
RF

Major parameters for DMC1

Beam energy	5.0 GeV		
Circumference	3220 m		
RF frequency	650 MHz		
Harmonic number	6981		
Transverse damping time	23.0 ms		
Natural bunch length	6 mm		
Natural energy spread	1.27×10^{-3}		
Phase advance per FODO cell	75°	90°	110°
Momentum compaction factor	5.49×10^{-4}	3.84×10^{-4}	2.60×10^{-4}
Nomalised natural emittance	4.47um	3.62 um	3.11um
RF voltage	29.16MV	20.64 MV	14.40MV
RF acceptance	2.72%	2.57%	2.35%
Synchrotron tune	0.059	0.041	0.028
Working point x/y	40.0/40.1	46.4/46.1	53.9/54.3
Natural chromaticity x/y	-48.0/-46.5	-57.7/-57.8	-78.2/-77.7
Maximum quadrupole gradient	11.0 T/m	12.9 T/m	14.1 T/m
Maximum sextupole gradient	73.8 T/m^2	121.2 T/m^2	205.6 T/m^2

Major parameters for DCO4 and SB2009

	DCO4			SB2009
Beam energy	5.0 GeV			5.0 GeV
Circumference	6476.4 m			3238.22
RF frequency	650 MHz			650 MHz
Harmonic number	14042			7021
Transverse damping time	21.1 ms			20.6
Natural bunch length	6 mm			6 mm
Natural energy spread	1.27×10^{-3}			1.2×10^{-3}
Phase advance per FODO cell	72°	90°	100°	41°(x phase advance)
Momentum compaction factor	2.9×10^{-4}	1.6×10^{-4}	1.3×10^{-4}	1.8×10^{-4}
Nomalised natural emittance	6.4um	4.4um	3.9um	3.4um
RF voltage	32.6MV	20.4MV	17.1 MV	11MV
RF acceptance	2.38%	1.96%	1.72%	
Synchrotron tune	0.063	0.036	0.028	
Working point x/y	61.1/60.4	71.1/71.4	76.1/75.4	
Natural chromaticity x/y	-71.0/-72.6	-89.2/-91.0	-99.8/-100.7	-102/-66

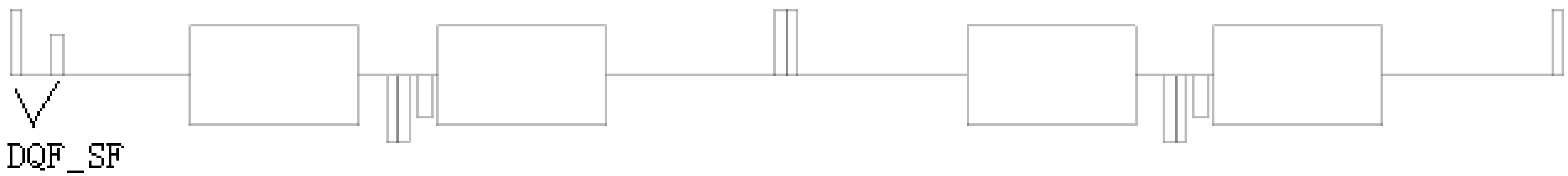
Magnet parameters

	DMC1	SB2009	DCO4
Arc dipole length	3.00 m	2.7 m	2.0 m
Arc dipole field	0.12 T	0.26/0.36 T	0.27 T
Number of arc dipoles	296	128	200
Chicane dipole length	1.50 m	1.0 m	1.0 m
Chicane dipole field	0.12 T	0.27 T	0.27 T
Number of chicane dipoles	48	48	48
Quadrupole length	0.40 m	0.6/0.3 m	0.3 m
Total number of quadrupoles	480	590	692
Maximum quadrupole gradient	11.0 ~ 14.1T/m	7.5 T/m	12.0 T/m
Total number of sextupoles	216	192	392
Maximum sextupole gradient	73.8 ~ 205.6 T/m^2	145 T/m^2	215 T/m^2

Wigglers

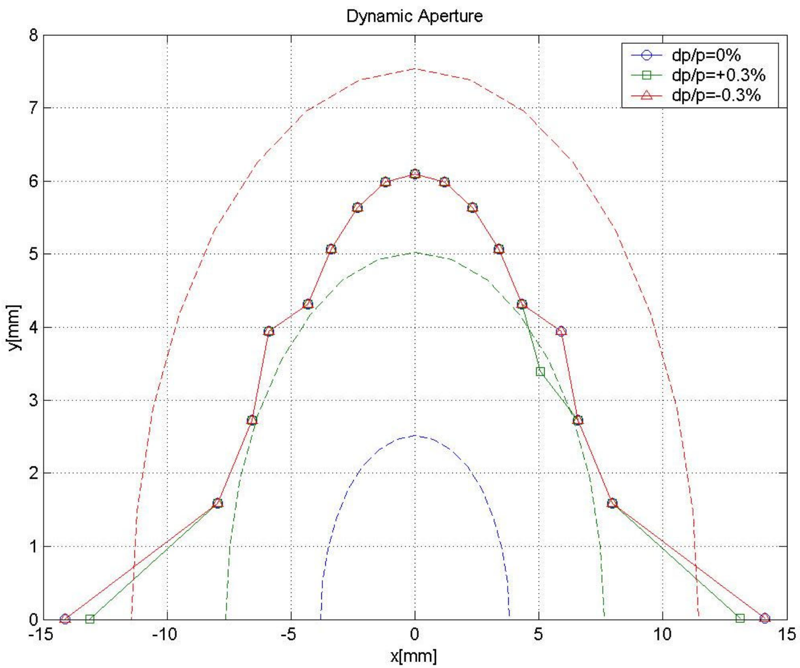
	DMC1	SB2009	DCO4
Wiggler peak field	1.6 T	1.6 T	1.6 T
Wiggler period length	0.4 m	0.4 m	0.4 m
Number of wigglers	40	32	88
Wiggler unit length	2.45 m	2.45 m	2.45 m
Wiggler total length	98 m	78.4 m	215.6 m

Primary work on dynamic aperture

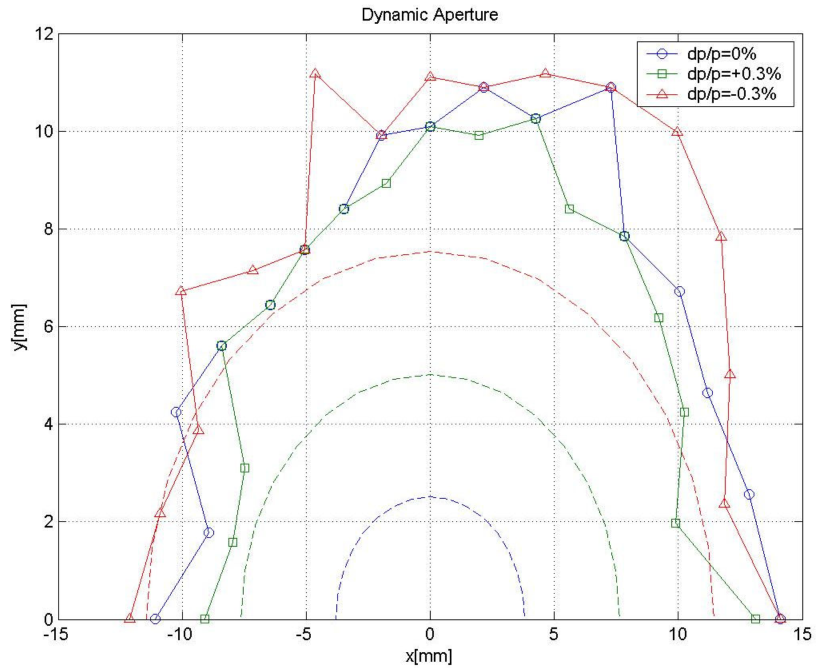


- We use one defocusing sextupole per arc cell and one focusing sextupole every two arc cell.
- We change the distance between the focusing quadrupole and the focusing sextupole (DQF_SF) to scan the dynamic aperture up to 0.3% energy deviation.
- No errors are included in these trackings.
- Further dynamic aperture optimization is in progress (optimising arc cell and straights phase advance…).

Dynamic aperture for 75°lattice



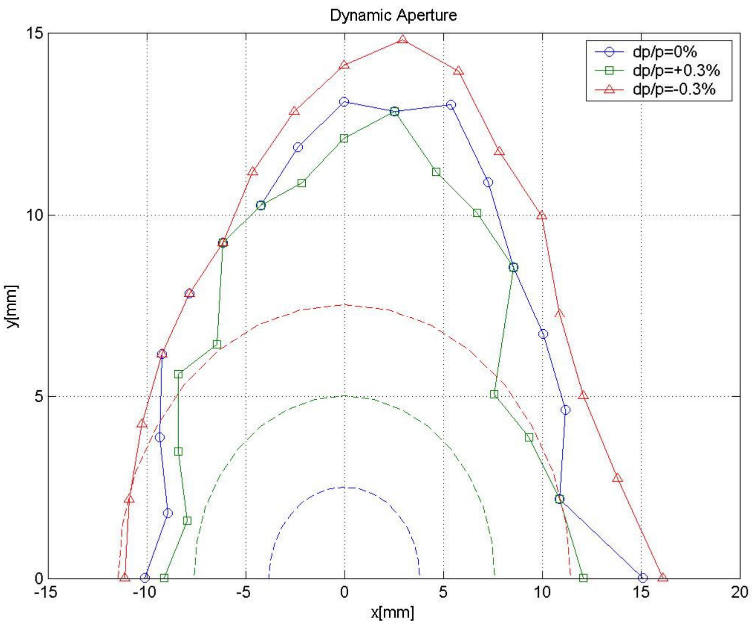
DQF_SF=0.15 m (turns=300)



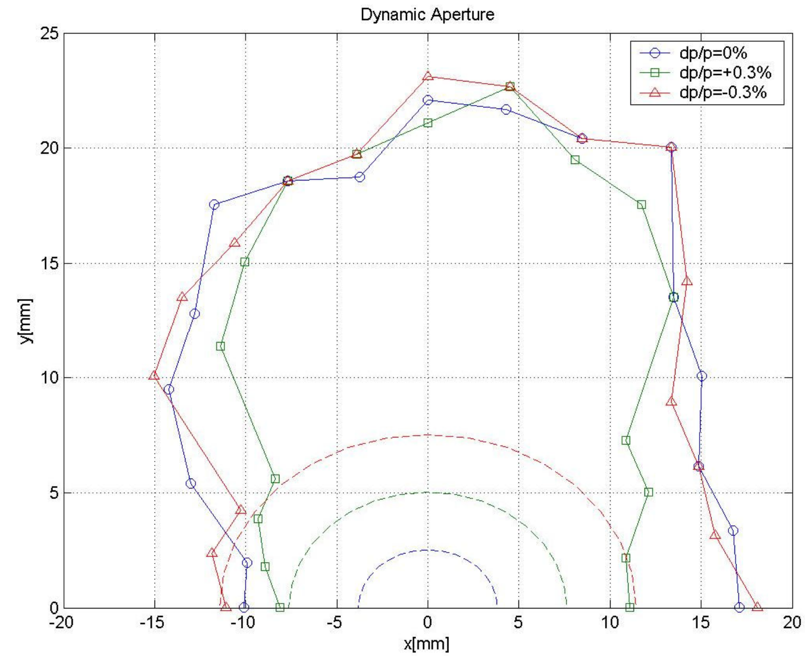
DQF_SF=0. 5 m (turns=300)

Three dashed ellipses are one injected beam size, double injected beam size and triple injected beam size respectively.

Dynamic aperture for 75°lattice

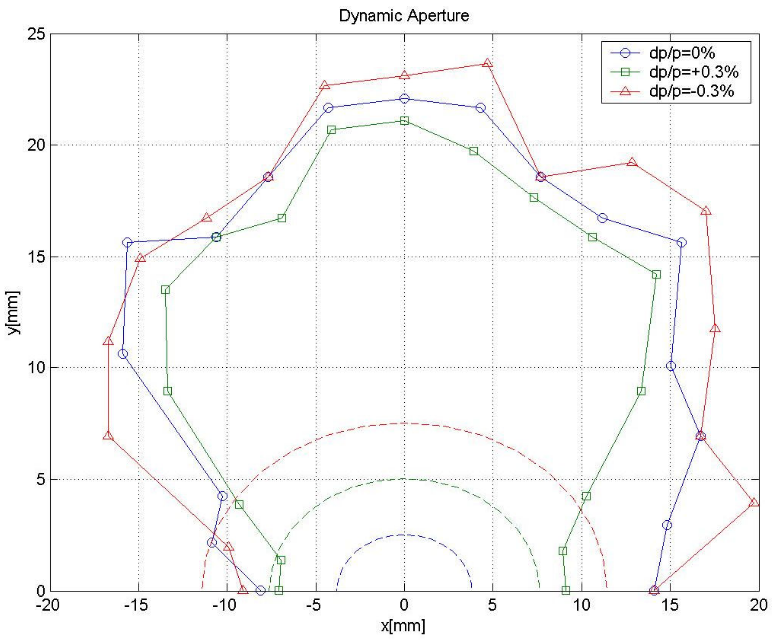


DQF_SF=1 m (turns=300)

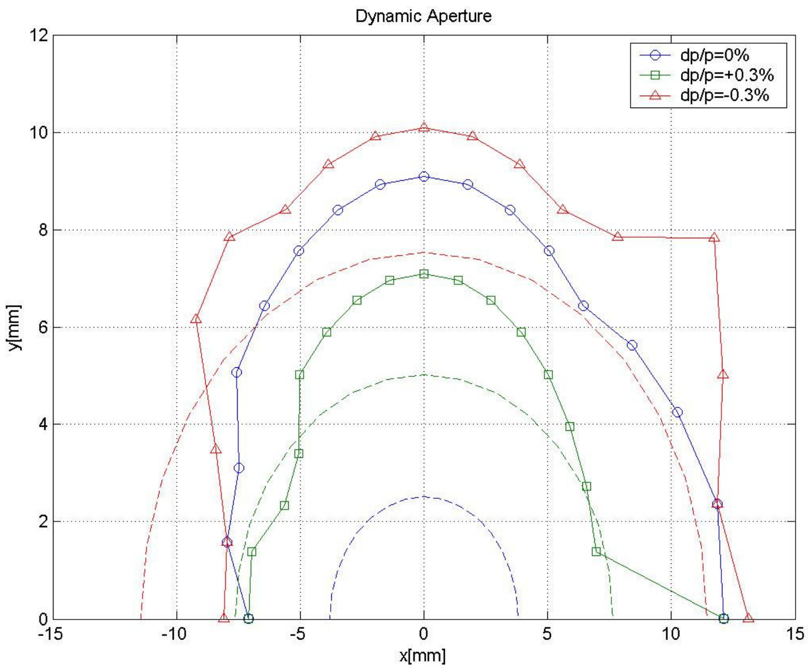


DQF_SF=1.5 m (turns=300)

Dynamic aperture for 75°lattice

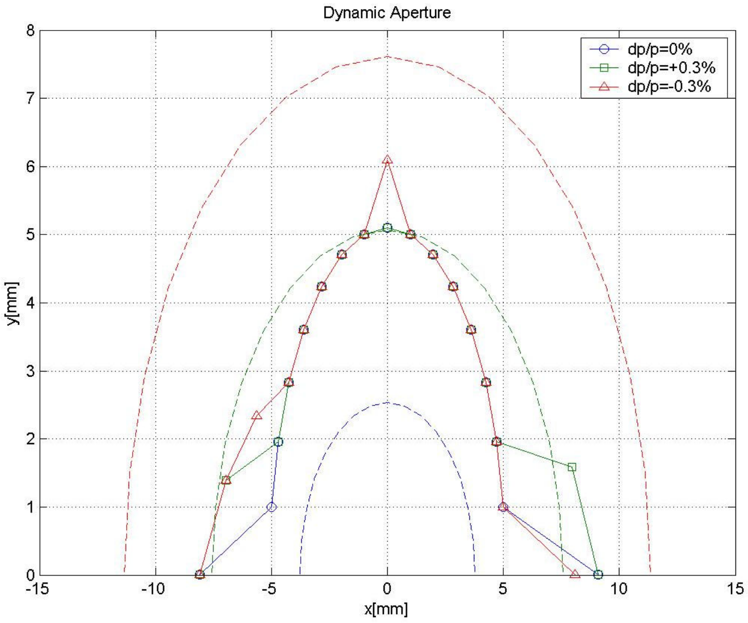


DQF_SF=2 m
(turns=300)

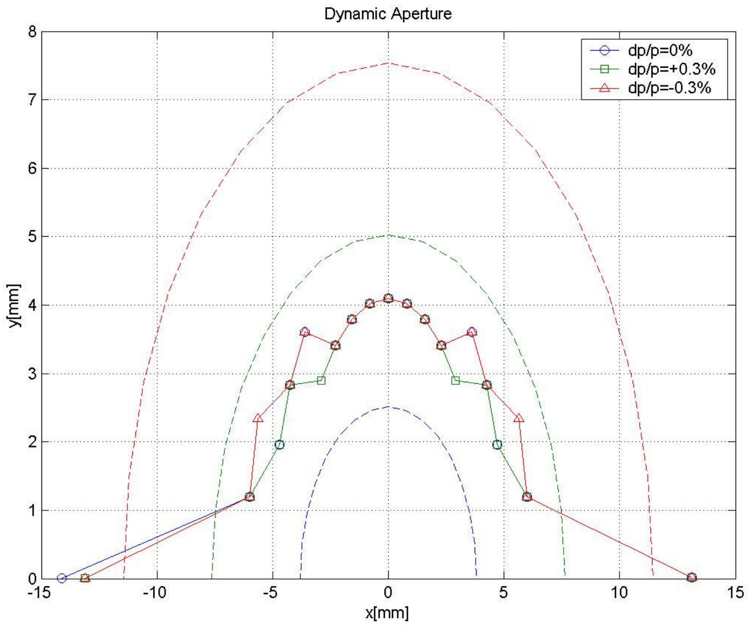


DQF_SF=2.5 m (turns=300)

Dynamic aperture for 90°lattice

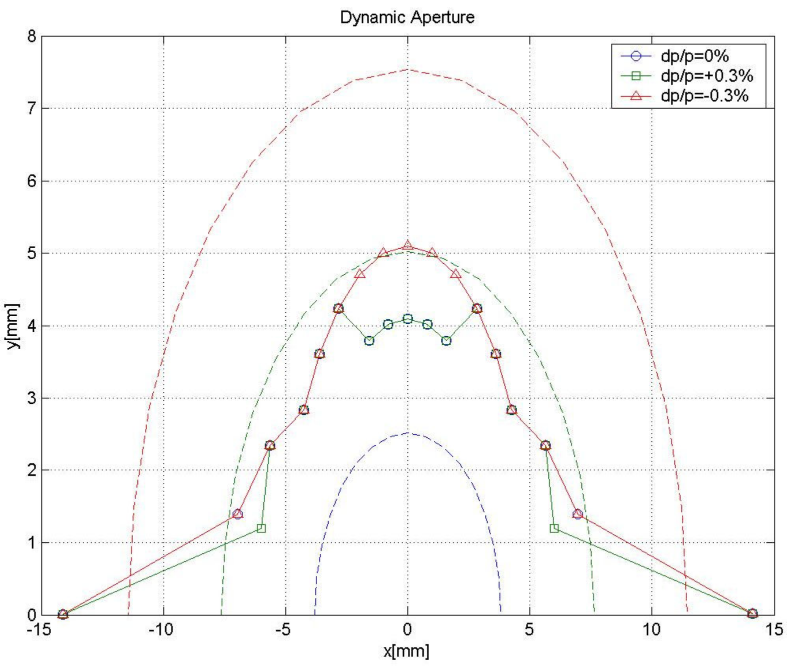


DQF_SF=0.15 m (turns=300)

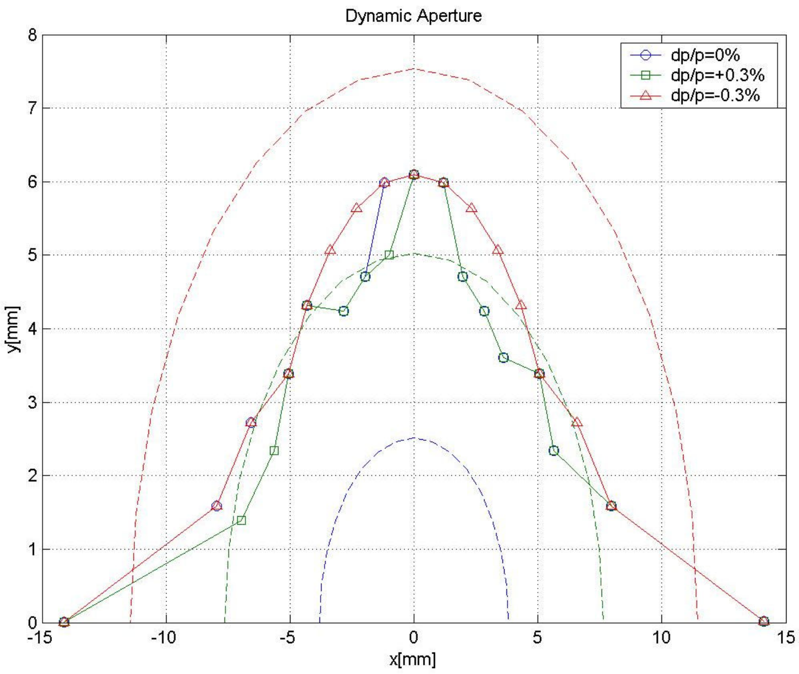


DQF_SF=0. 5 m (turns=300)

Dynamic aperture for 90°lattice

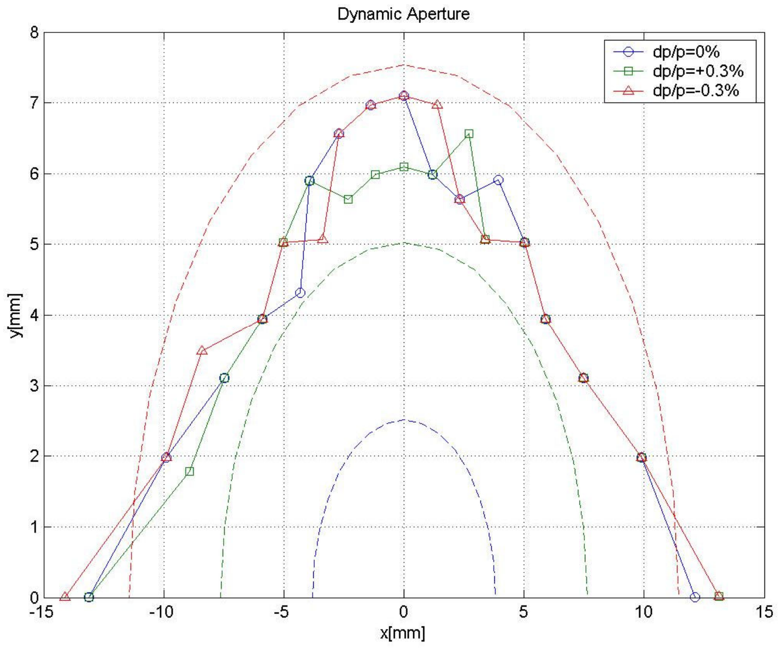


DQF_SF=1 m (turns=300)

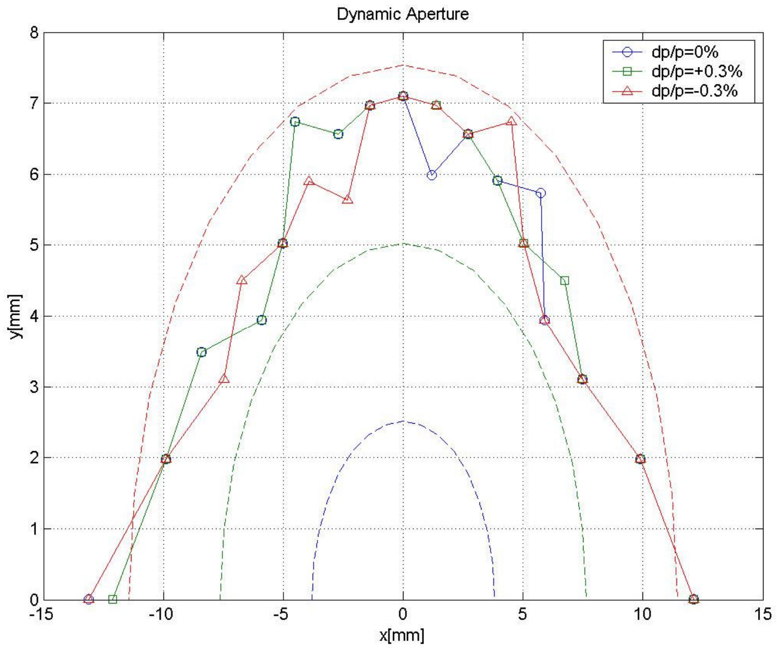


DQF_SF=1.5 m (turns=300)

Dynamic aperture for 90°lattice

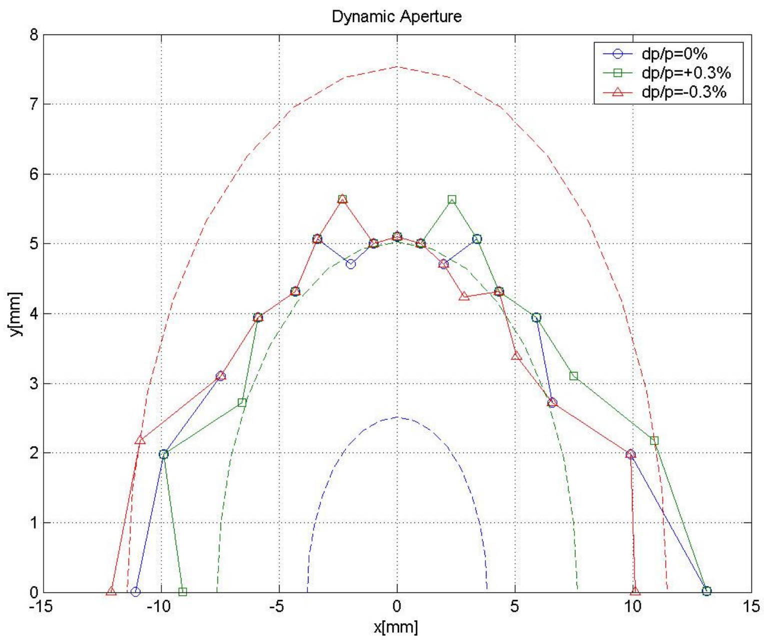


DQF_SF=2 m (turns=300)

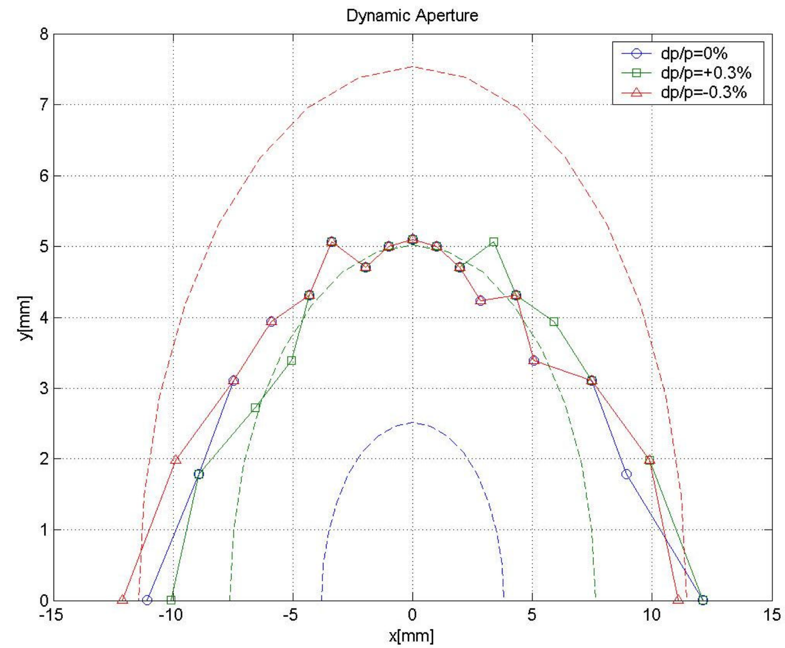


DQF_SF=2.5 m (turns=300)

Dynamic aperture for 100°lattice

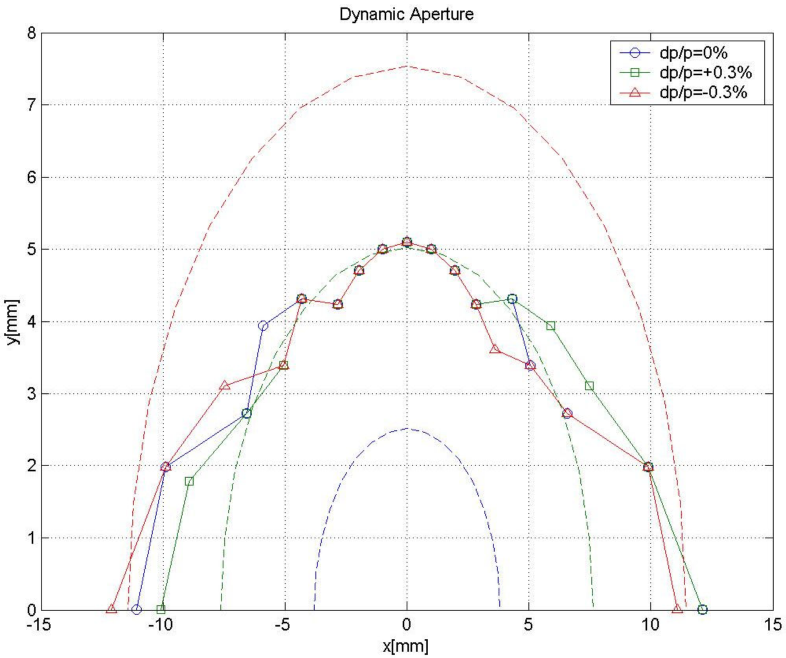


DQF_SF=0.15 m (turns=300)

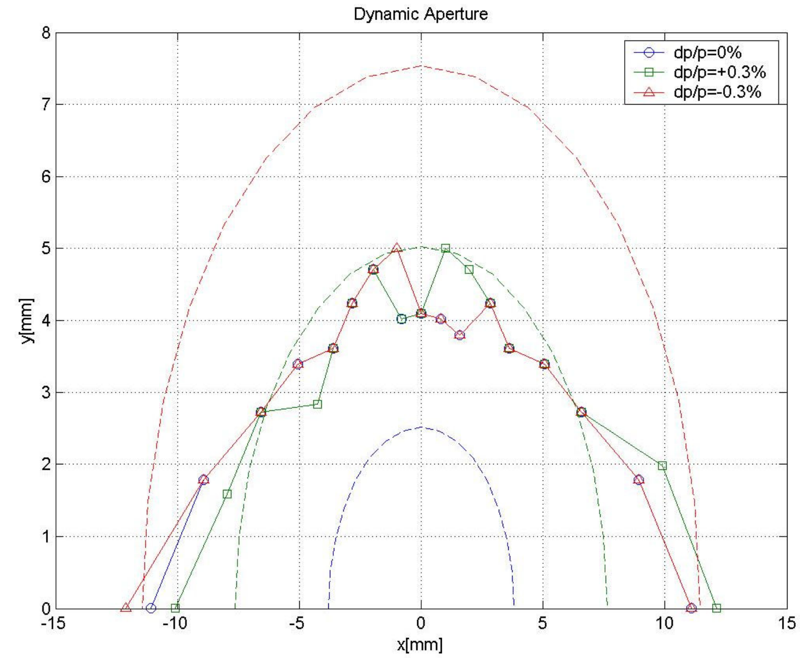


DQF_SF=0. 5 m (turns=300)

Dynamic aperture for 100°lattice

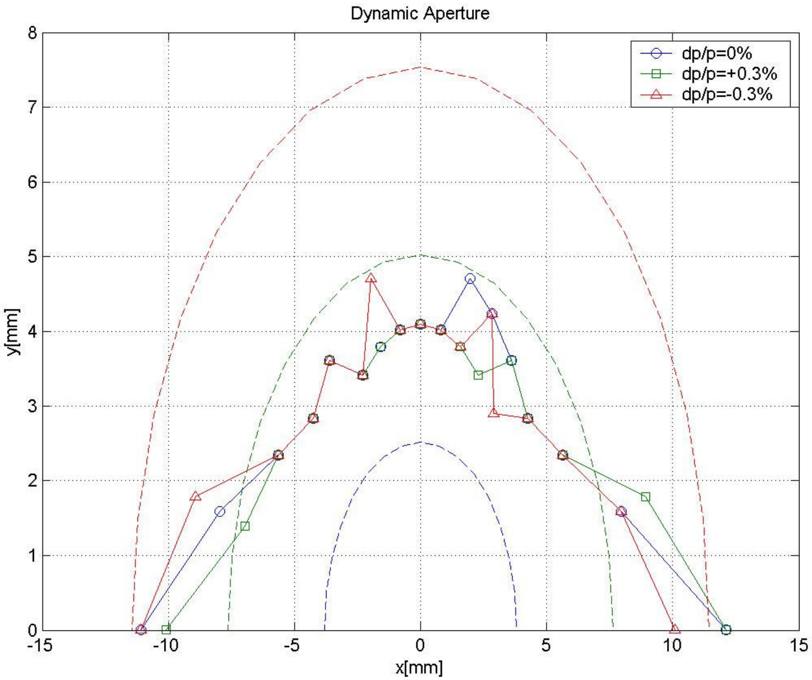


DQF_SF=1 m (turns=300)

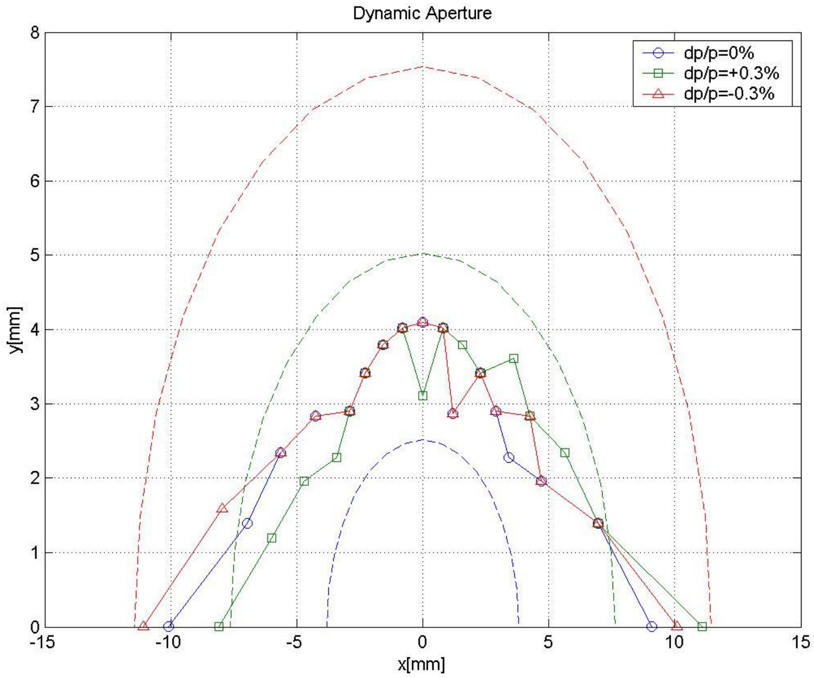


DQF_SF=1.5 m (turns=300)

Dynamic aperture for 100°lattice



DQF_SF=2 m (turns=300)



DQF_SF=2.5 m (turns=300)

summary

- Our design satisfies all the principal requirements for the smaller ring.
- The momentum compaction factor is tunable in a large range (2.6×10^{-4} ~ 5.5×10^{-4}).
  - There is just a little possibility to reduce the momentum compaction further. But it is easy to enlarge it by about two times.
  - Allows 6 mm rms bunch length with the total rf voltage from 14.4 MV to 29.16 MV
- Total magnet number is 23% (292) less than DC04, but a bit (82) more than SB2009.
  - Dipole number ~ 96 more than DCO4, 168 more than SB2009
  - Quadrupole number ~ 212 less than DCO4, 110 less than SB2009
  - Sextupole number ~ 176 less than DCO4, 24 more than SB2009
- Dynamic aperture looks reasonable (larger than double injected beam size).
  - good for higher momentum compaction factor
  - becomes difficult at lower momentum compaction factor because of small dispersion
- More work on DA optimization need to be done.
  - optimize phase advance of arc section
  - optimize phase advance of straight section
  - add additional sextupoles dispersion free sections

  …

Thank you!