Overview of FODO4 and FODO5 lattice for ILC DR

Yi-Peng Sun[1,2*], Jie Gao[1] , Zhi-Yu Guo[2]

Wei-Shi Wan[3]

1 Institute of High Energy Physics, CAS, China

2 State Key Laboratory of Nuclear Physics and Technology, Peking University, China

3 LBNL, USA

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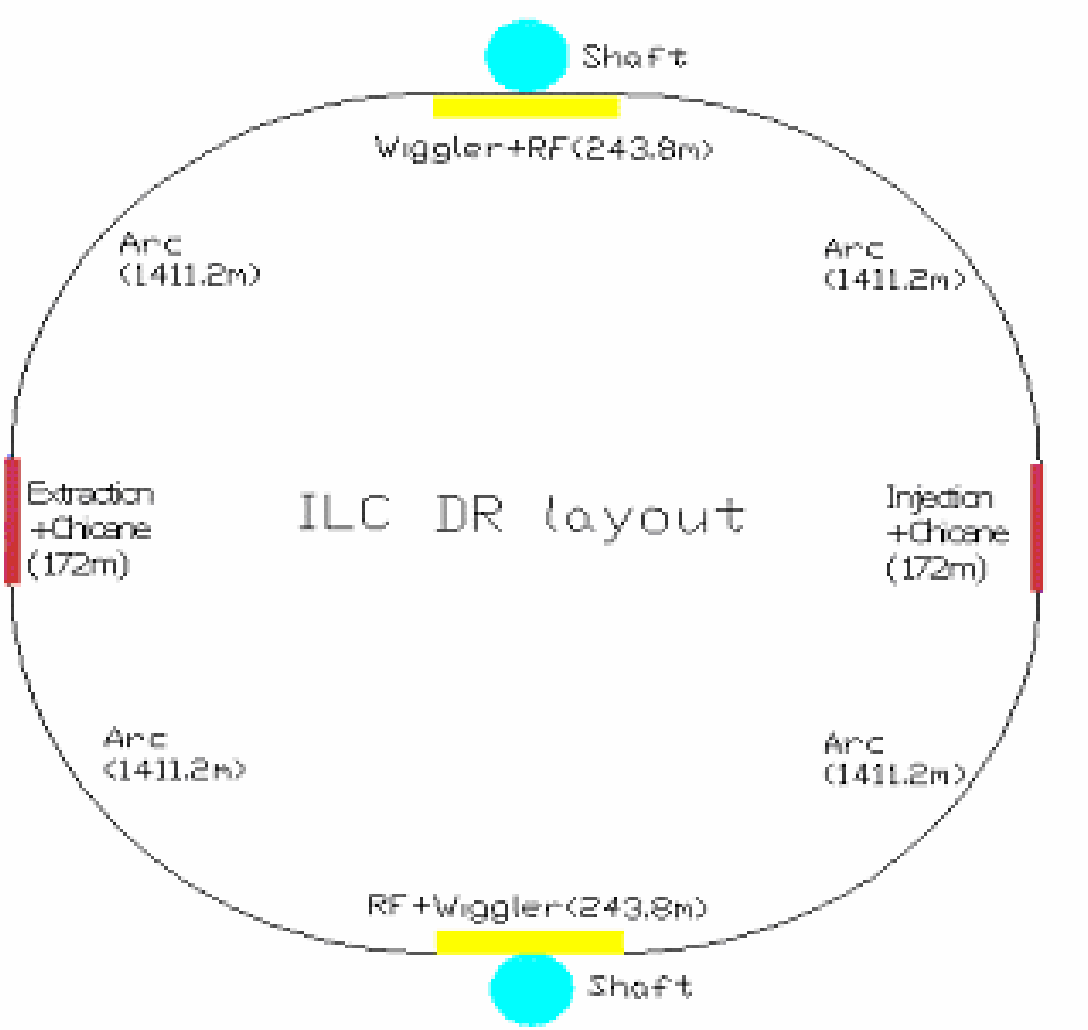
*Work now at CERN as research fellow.

SEVERAL FEATURES OF FODO4 LATTICE

1. Smaller number quadrupoles and sextupoles used (roughly two thirds of OCS8), and lower cost.
2. Freely tunable momentum compaction factor in the range between 2×10^{-4} and 6×10^{-4}.
3. Good dynamic aperture.
4. Simpler layout, with only two wiggler sections and cryogenics shaft, no long Transport Line for cryogenics needed.

FODO4 LAYOUT



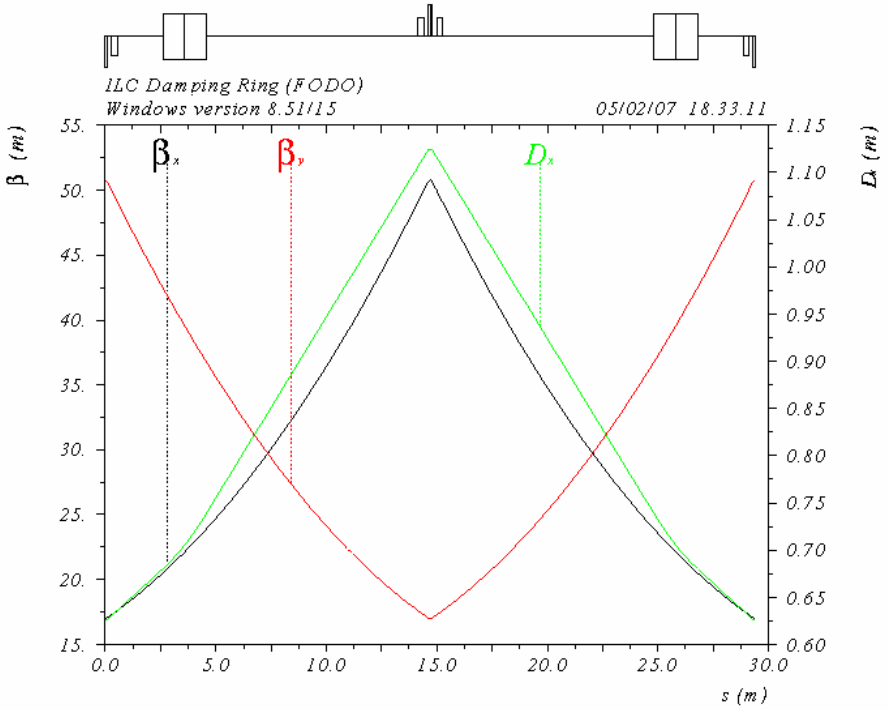
4 arc sections.

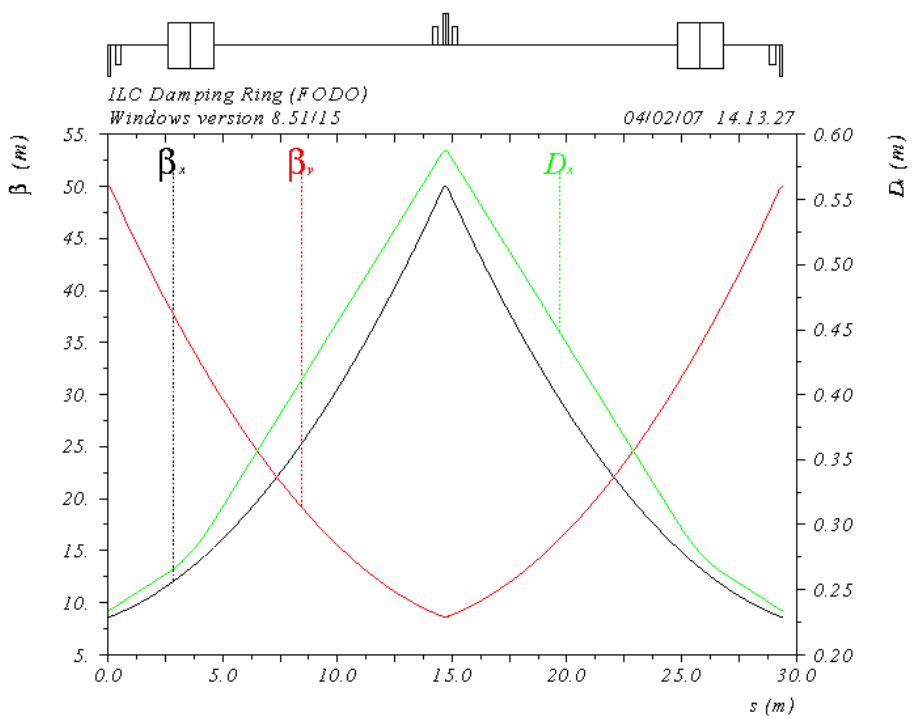
4 straight sections, one for injection, one for extraction, and the other two for RF/wiggler.

Two shafts in all and no TL.

Beam is counter-rotating.

ARC CELL DESIGN



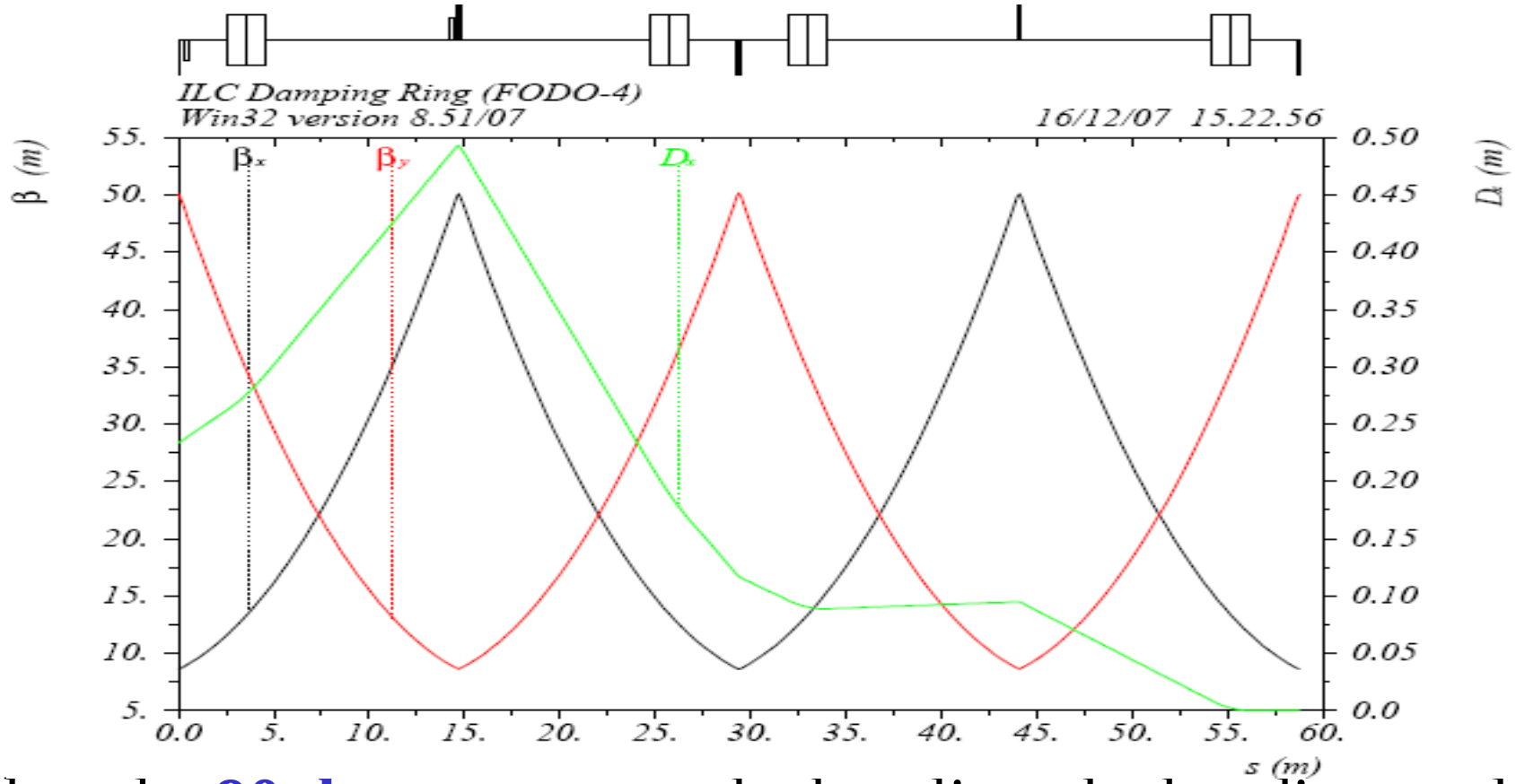


$$\beta^{\pm} = \frac{L_P(1 \pm \sin\frac{\mu}{2})}{\sin\mu} \qquad D^{\pm} = \frac{L_P\phi(1 \pm \frac{1}{2}\sin\frac{\mu}{2})}{4\sin^2\frac{\mu}{2}}$$

Left: 60/60 cell, corresponding to 6×10^{-4} alpha

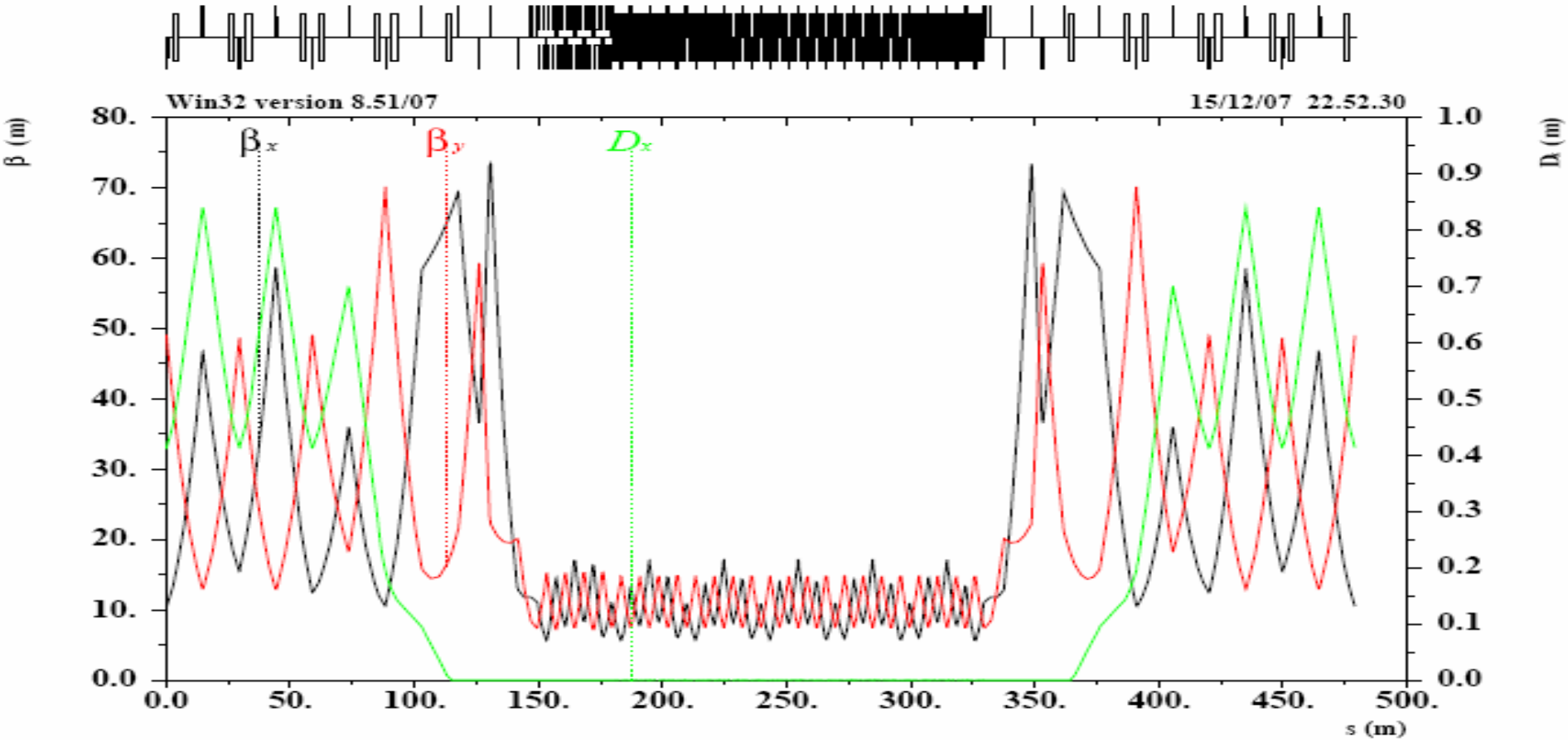
Left: 90/90 cell, corresponding to 2×10^{-4} alpha

DISPERSION SUPPRESSOR DESIGN (90 DEGREE CASE)



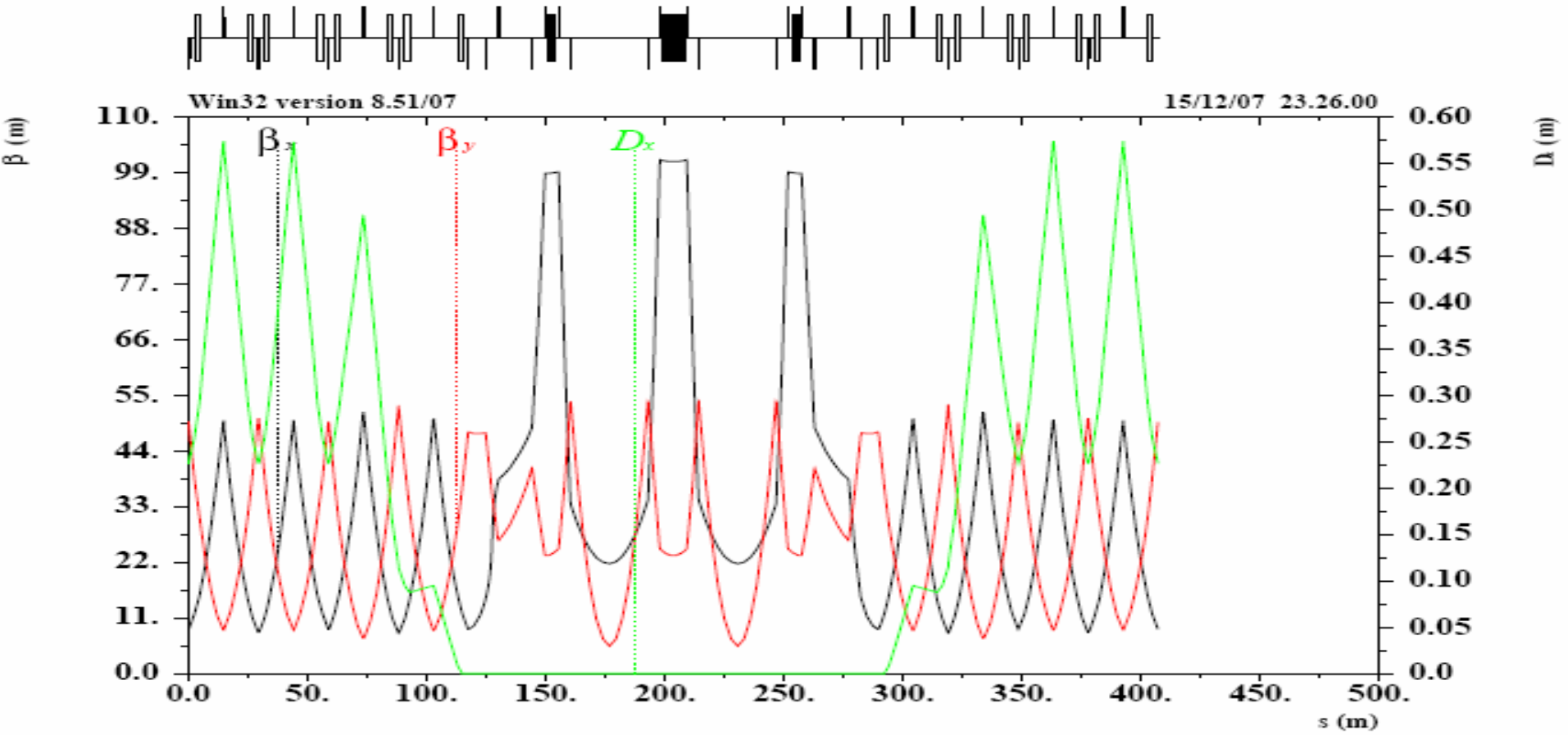
Select the **90 degree case** as the baseline, the bending angle in the dispersion suppressor is set to be half of the bending angle in the normal arc cell, so that zero dispersion at exit is got naturally for 90 degree case.

WIGGLER SECTION TOGETHER WITH DISPERSION SUPPRESSOR (72 DEGREE CASE)



Tune the quadrupole's strength in the dispersion suppressor for the **72 degree case**, to make sure dispersion is free at exit, and dipole strength not changed (Geometry is the same).

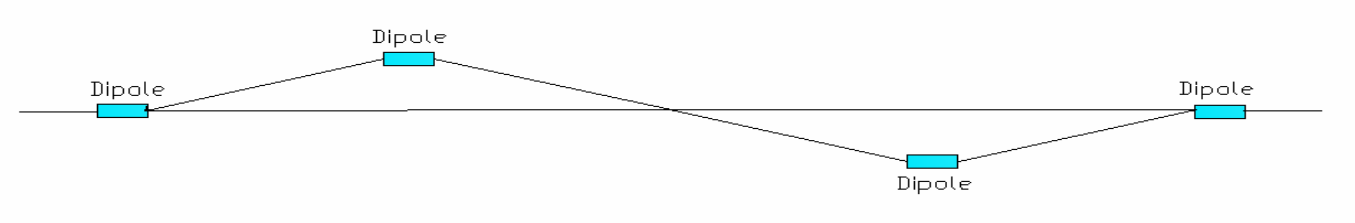
INJECTION/EXTRACTION DESIGN (90 DEGREE)



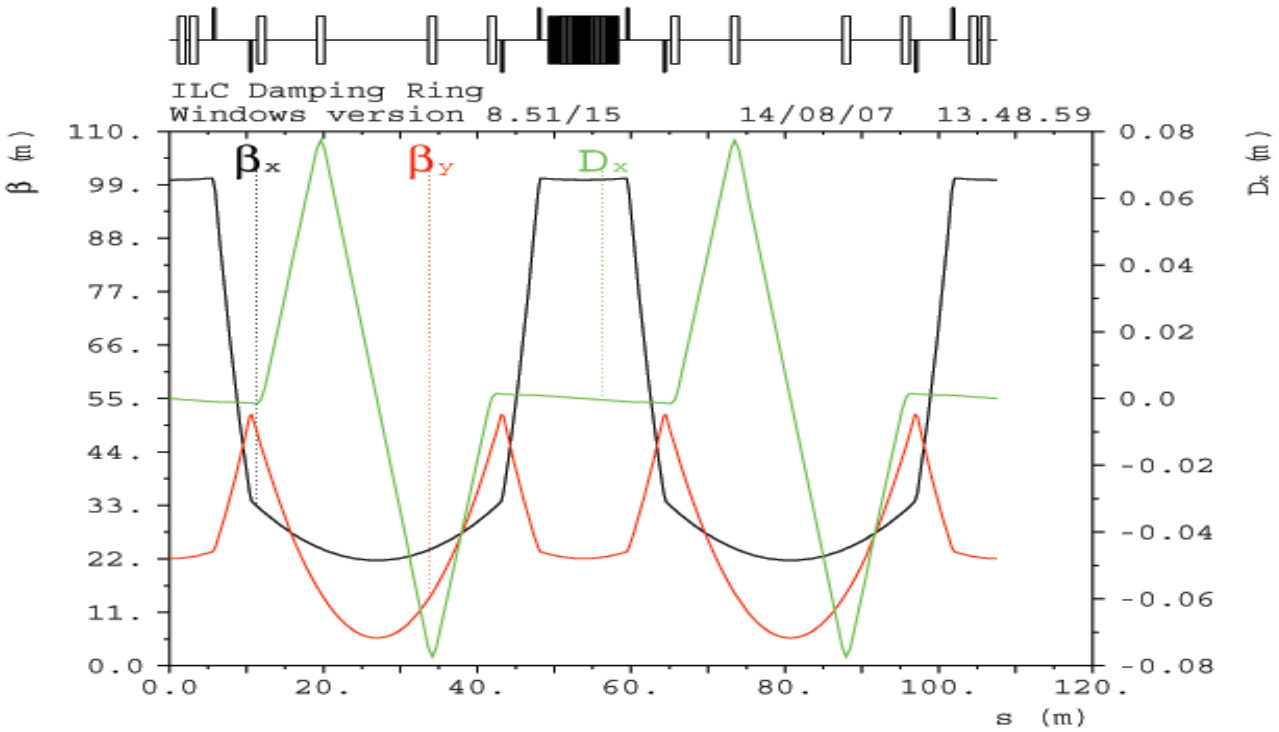
2 septums and 21 stripline kickers (lumped kickers)

Uses two periodic cells, with the total horizontal phase advance matched to be 180 degree

CHICANE (90 DEGREE CASE)



Adjustment of one Chicane: $\pm 2\theta^2\left(l_c + 0.5 l_B\right)$

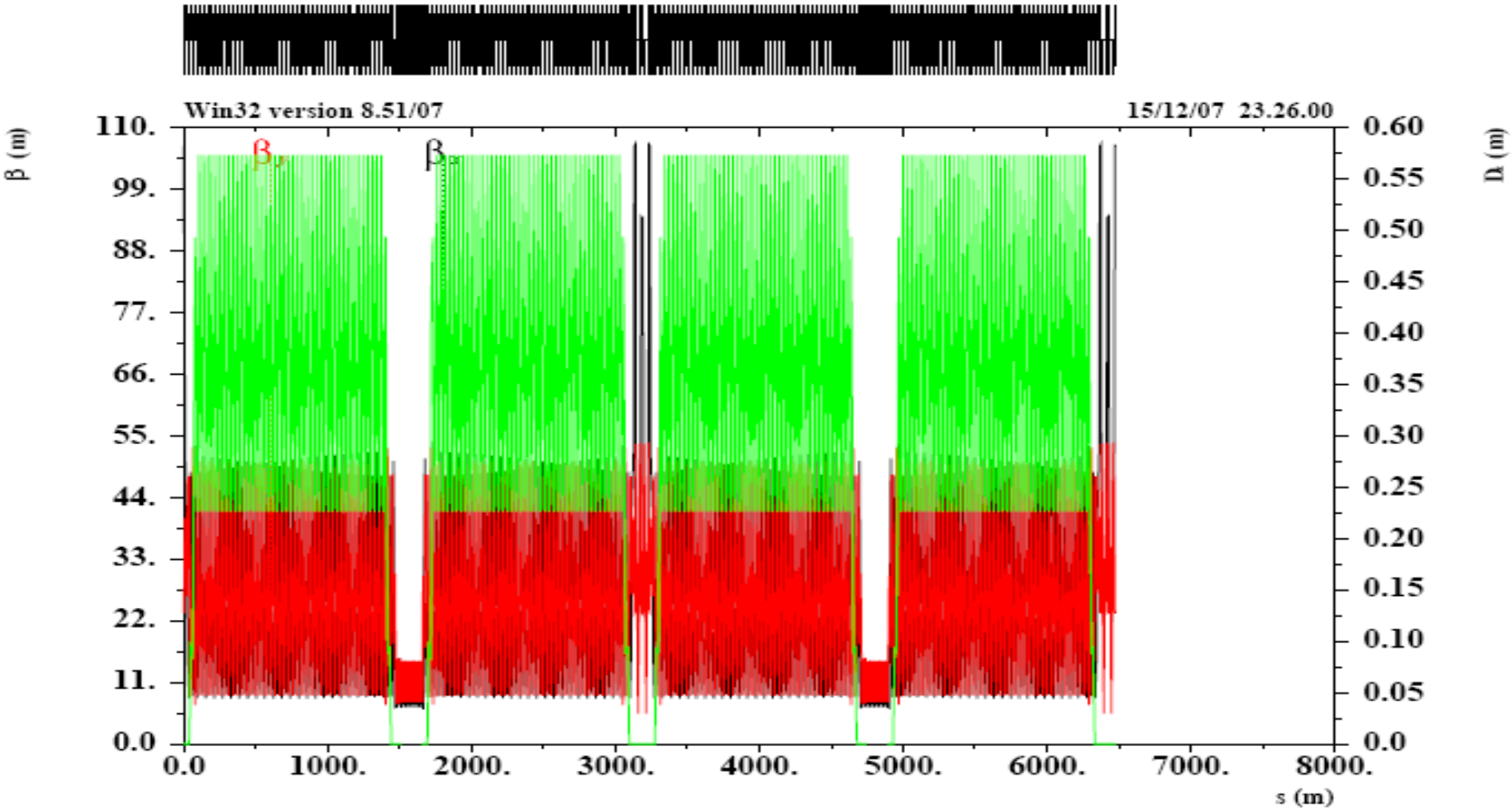


10^{-6} adjustable

4 Chicane

Emittance +9.2%

2×10^{-4} MOMENTUM COMPACTION

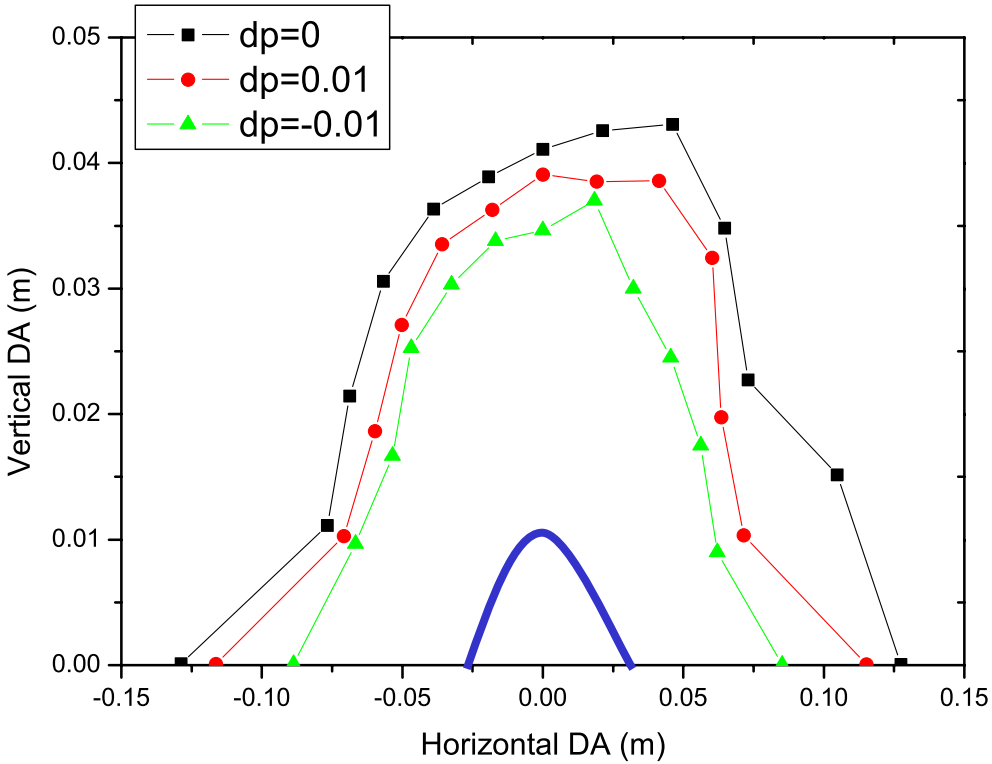


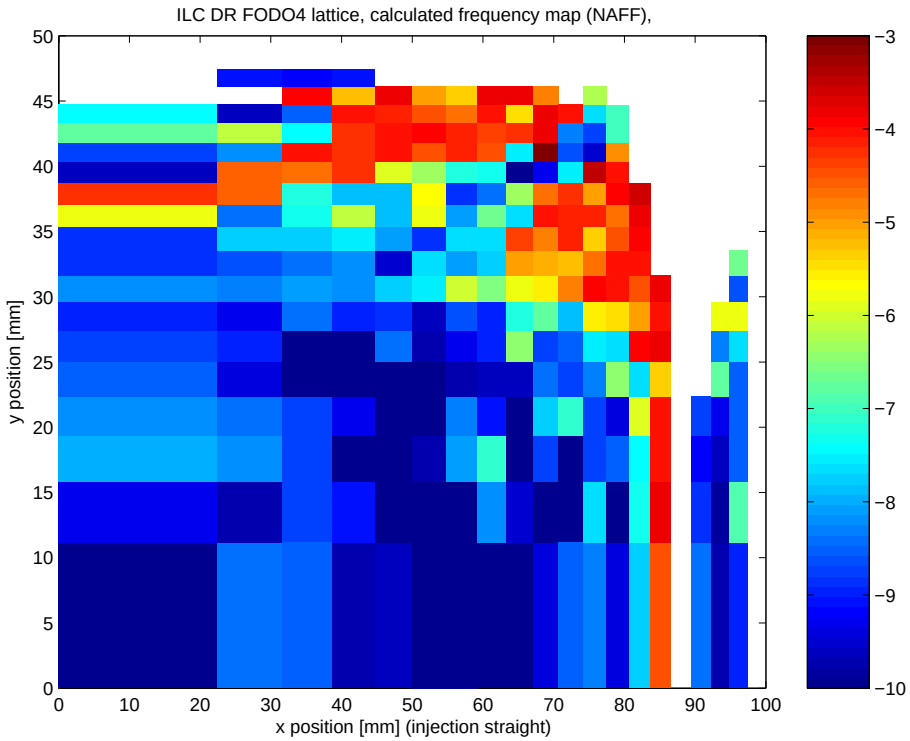
90/90 cell, 2×10^{-4} momentum compaction

PARAMETERS OF THREE CRITICAL MODES

Parameter	$\alpha_P=2\times10^{-4}$	$\alpha_P=4\times10^{-4}$	$\alpha_P=6\times10^{-4}$
Circumference [m]	6476.439	6476.439	6476.439
Harmonic number	14042	14042	14042
Energy [GeV]	5	5	5
Tune	58.29 / 57.25	46.28 / 47.24	40.29 / 41.25
Natural chromaticity	-74 / -73	-54 / -55	-48 / -49
Momentum compaction [10^{-4}]	2	4	6
Transverse damping time [ms]	25 / 25	25 / 25	25 / 25
Norm. Natural emittance [mm-mrad]	3.36	4.2	5.4
RF voltage [MV]	15	22	31
RF frequency [MHz]	650	650	650
RF acceptance [%]	1.21	1.48	1.65
Natural bunch length [mm]	9	9	9
Natural energy spread [10^{-3}]	1.28	1.28	1.28

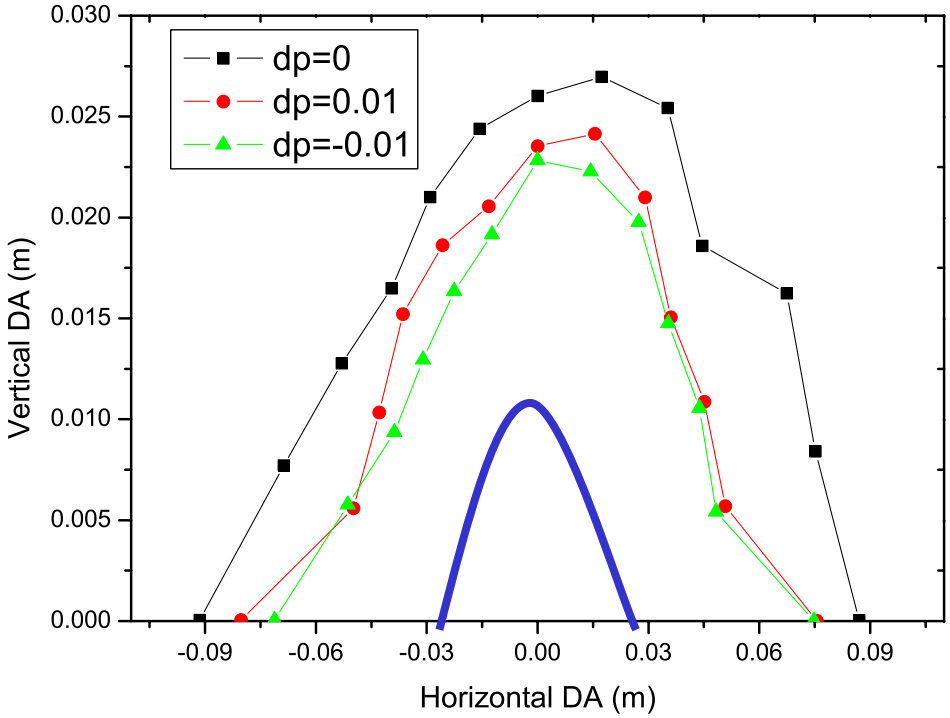
DYNAMIC APERTURE 6×10⁻⁴ ALPHA CASE

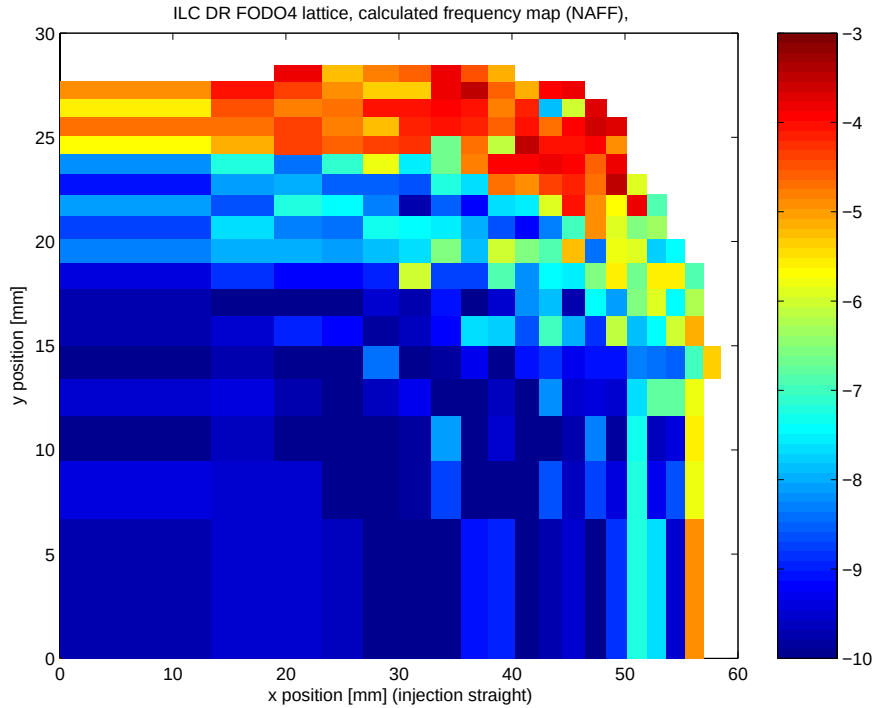




The blue line is **three times injected positron** bunch size.
Tracking for 1000 turns, no errors, using MAD.

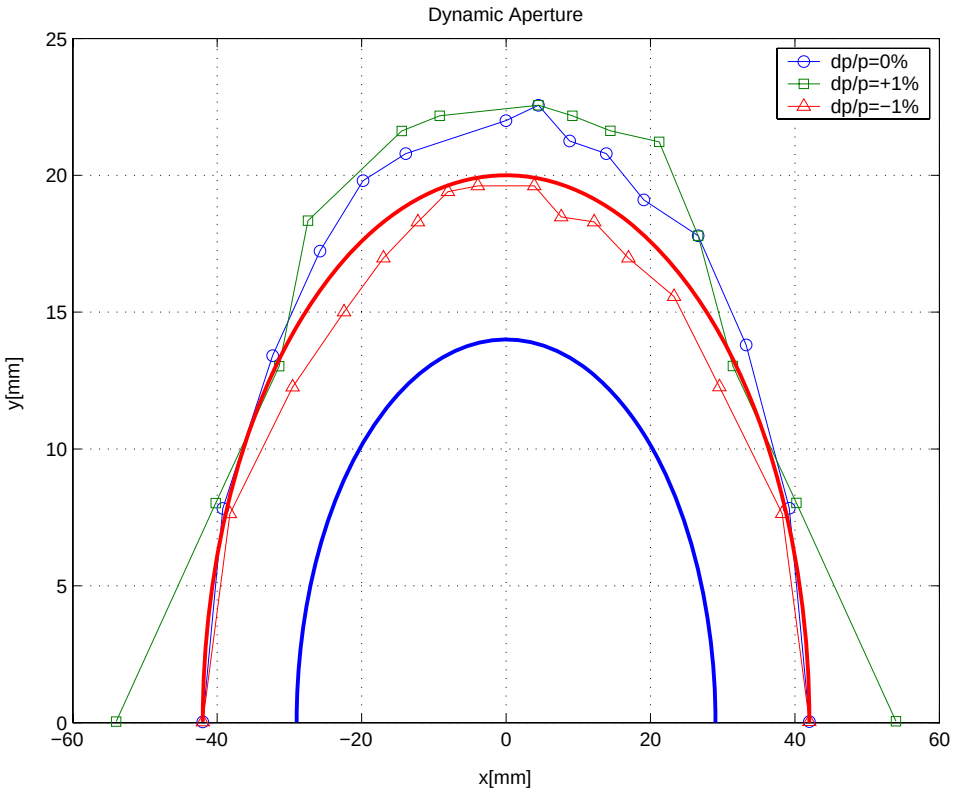
DYNAMIC APERTURE 4×10⁻⁴ ALPHA CASE

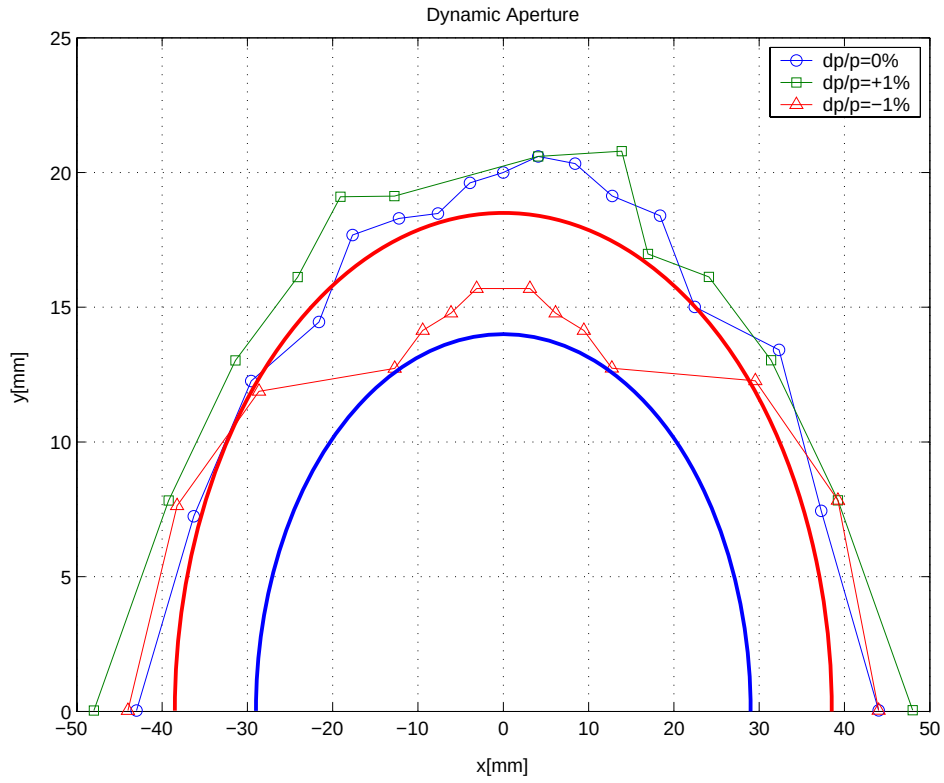




The blue line is **three times injected positron** bunch size.
Tracking for 1000 turns, no errors, using MAD.

DYNAMIC APERTURE 2×10⁻⁴ ALPHA CASE (AT RESULTS)

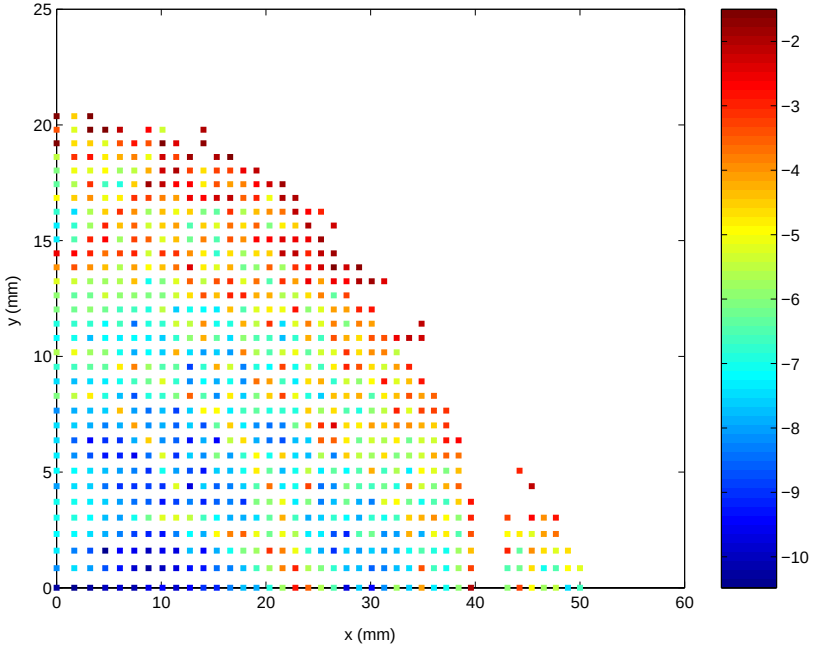


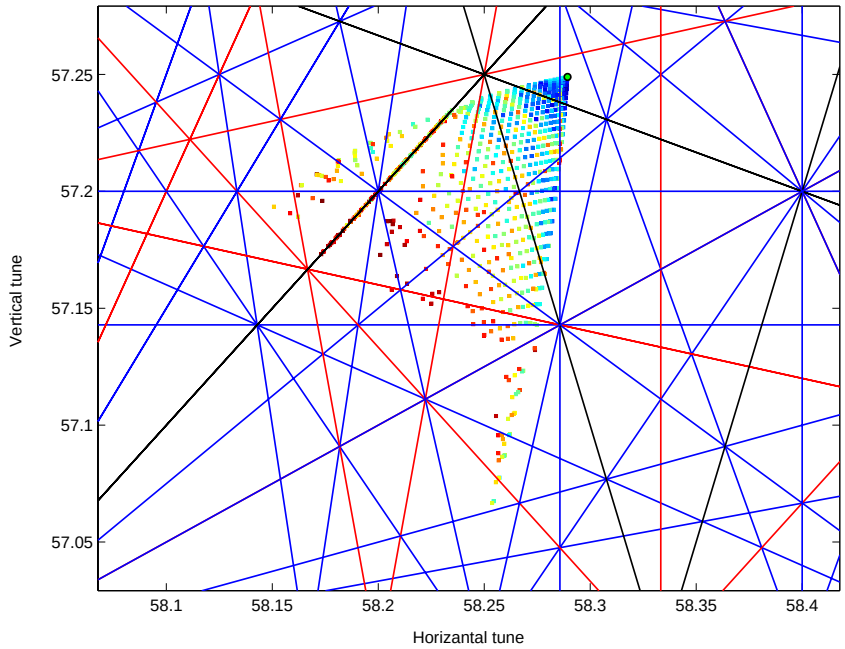


Left: no errors; Right: **with high order magnets errors**.

The blue line is **three times injected positron** bunch size.

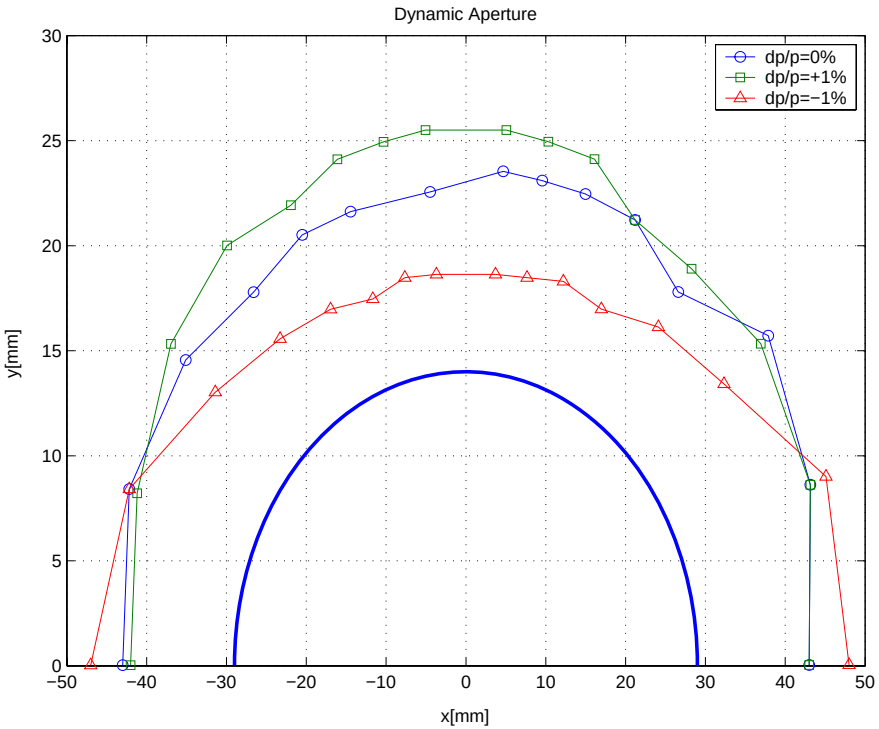
FMA OPTIMIZATION RESULTS

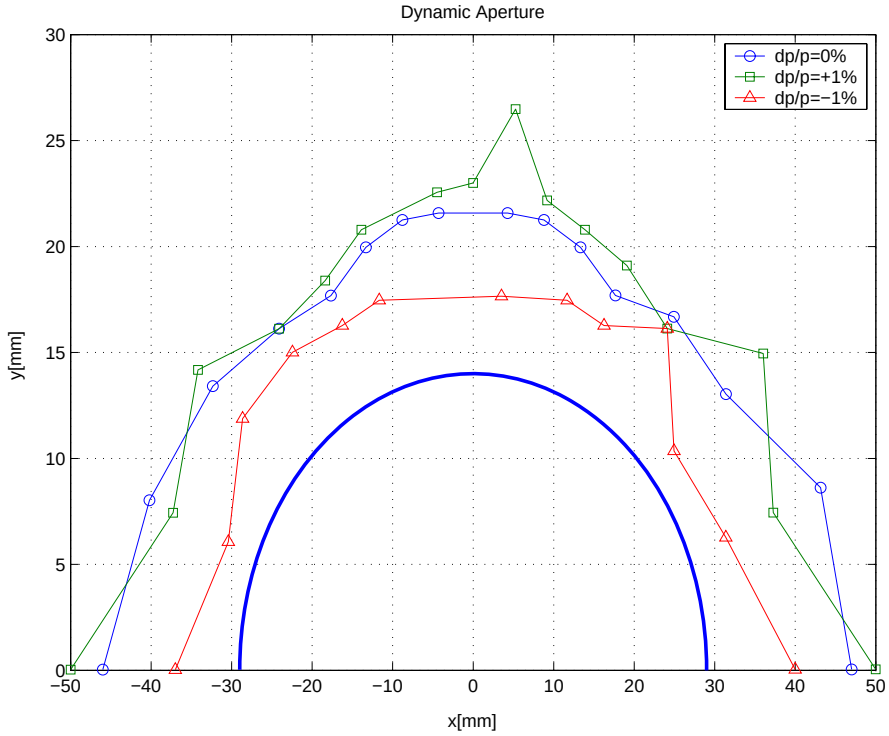




FMA is used to optimize the lattice and the DA. The optimized result for 2×10^{-4} momentum compaction mode

WITH HARMONIC SEXTUPOLES





2×10^{-4} momentum compaction mode, with **3** group harmonic sextupoles

Left: no errors; Right: **with high order magnets errors**

OTHERS

Element	Length [m]	Field or Gradient	Aperture[m]	Pole-tip field[T]
Dipole	2	0.2246 T	0.06	0.2246
Quadrupole	0.3	10 T/m	0.06	0.3
Sextupole	0.25	17.67 T/m2	0.06	0.00796

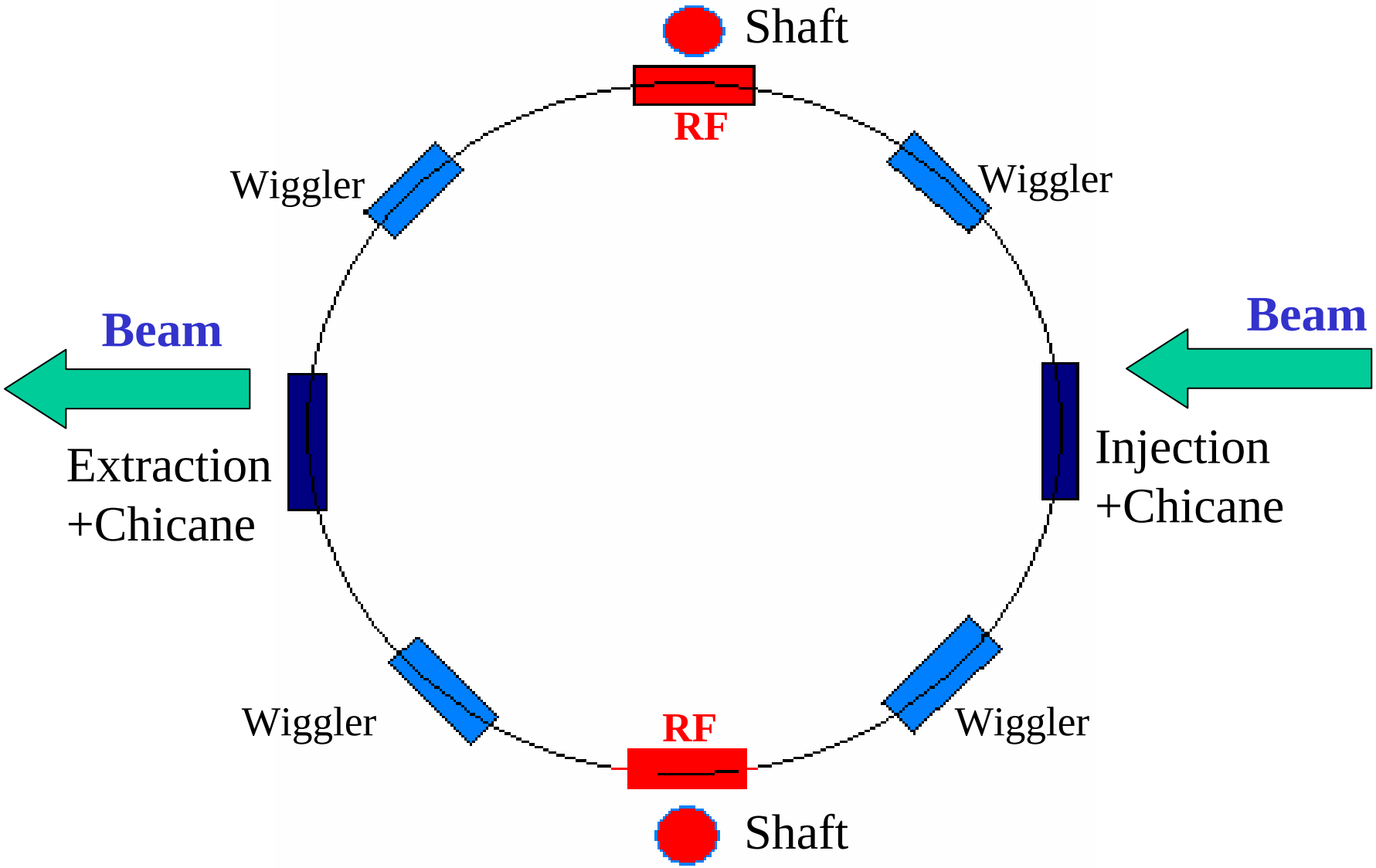
Touschek lifetime: $$\frac{1}{\tau} = \frac{r_e^2 c N_0}{8\pi\gamma^2 \delta_{\max}^3 \sigma_x \sigma_y \sigma_z} D(\varepsilon)$$

4×10^{-4} momentum compaction mode . Energy acceptance 1.48%, bunch population 2×10^{10}, Touschek lifetime is 160 minutes

FODO5 LATTICE

1. Freely tunable momentum compaction factor in the new range between 1.68×10^{-4} and 4×10^{-4}.
2. 8-folder symmetry layout which is the same with OCS8, with four separate wiggler straight sections and other two RF cavity straights. No radiation problem from wigglers anymore.
3. Use the new design of the wiggler and RF section, which is from OCS8 lattice. Arc cell slightly modified from FODO4. Same injection and extraction with FODO4.
4. Magnets number and other parameters similar with FODO4.

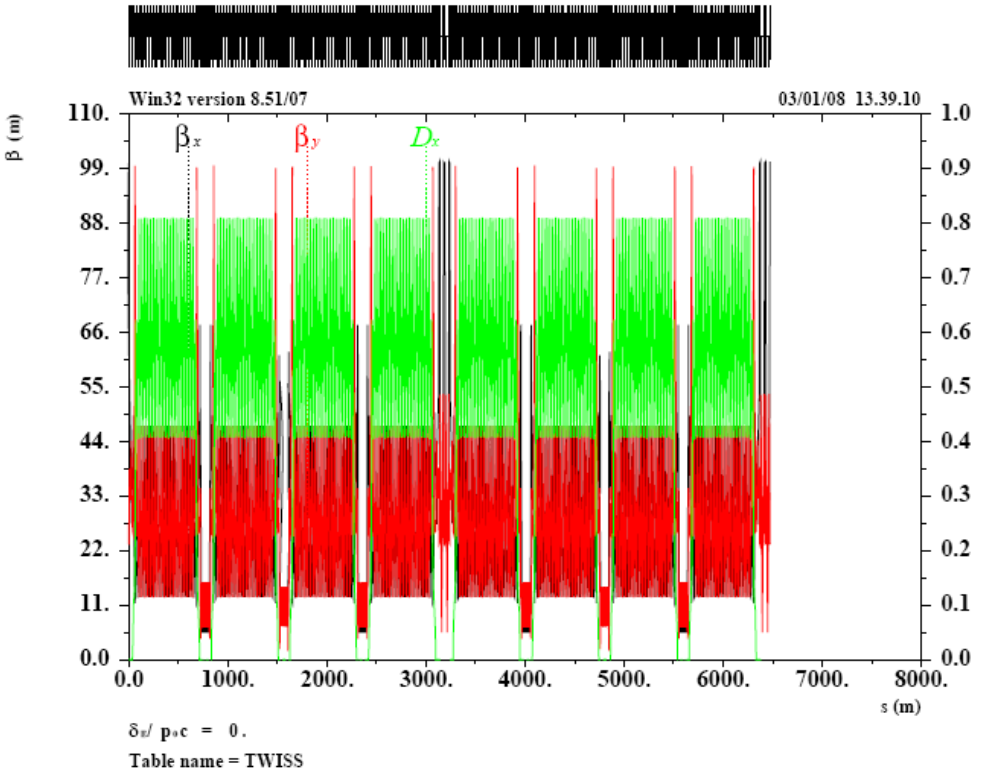
FODO5 SCHEMATIC LAYOUT

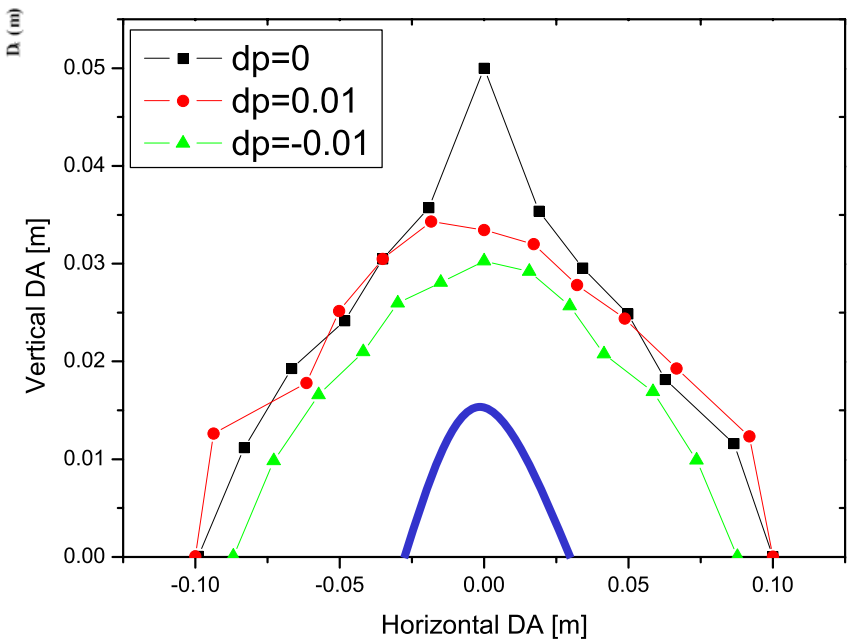


PARAMETERS OF THREE CRITICAL MODES

Parameter	$\alpha_P = 1.6 \times 10^{-4}$	$\alpha_P = 2.5 \times 10^{-4}$	$\alpha_P = 4 \times 10^{-4}$
Circumference [m]	6476.439	6476.439	6476.439
Harmonic number	14042	14042	14042
Energy [GeV]	5	5	5
Tune	72.28 / 69.23	61.3 / 62.24	50.3 / 51.25
Natural chromaticity	-107 / -100	-78 / -80	-63 / -63
Momentum compaction [10^{-4}]	1.68	2.54	4
Transverse damping time [ms]	25 / 25	25 / 25	25 / 25
Norm. Natural emittance [mm-mrad]	2.63	3.12	3.85
RF voltage [MV]	20	29	45
RF frequency [MHz]	650	650	650
RF acceptance [%]	2.17	2.45	2.7
Natural bunch length [mm]	9	9	9
Natural energy spread [10^{-3}]	1.28	1.28	1.28

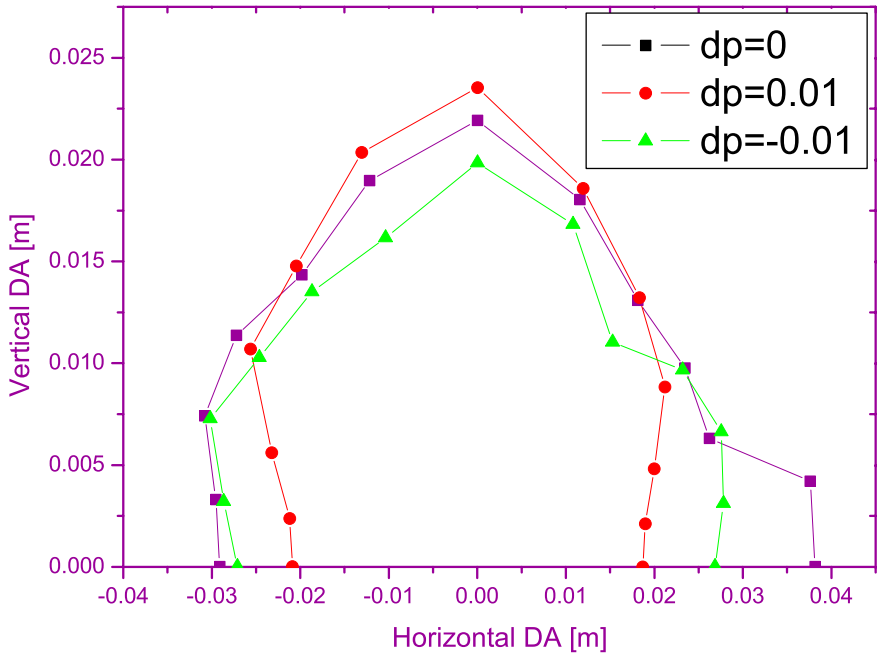
4×10^{-4} MOMENTUM COMPACTION CASE AND DA



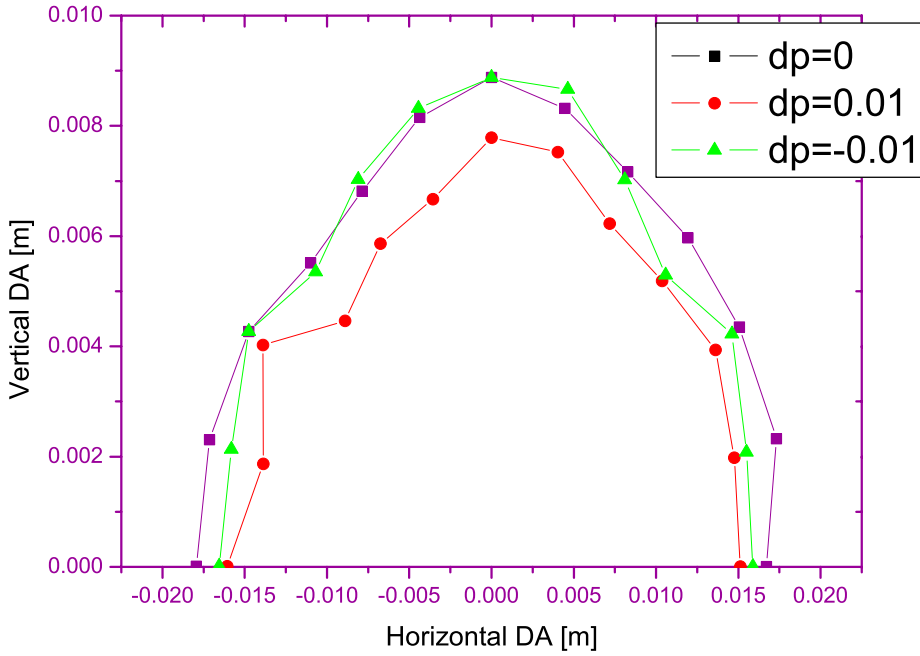


72/72 cell, **4×10^{-4}** momentum compaction

DYNAMIC APERTURE OF OTHER TWO CASE



90 degree case



108 degree case

These are preliminary results. Optimization work of dynamic aperture is on-going, and good dynamic aperture is believed to be gotten.

CONCLUSION OF FODO LATTICE

1. Freely tunable momentum compaction factor.
2. Dynamic aperture acceptable.
3. Layout could be adjusted easily.
4. Magnets number fewer. (quads and sextupoles)

ACKNOWLEDGEMENT

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