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ILC Damping Ring Alternative Lattice Design**

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

Presented by Dr. Qing Qin from IHEP, Beijing

1 Institute of High Energy Physics, CAS, Beijing

2 Key Laboratory of Heavy Ion Physics, Peking University, Beijing

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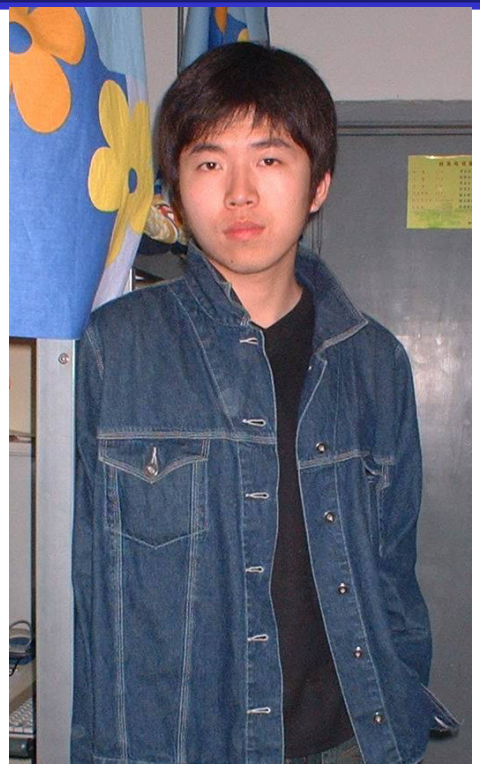
*ypsun@ihep.ac.cn

BRIEF INTRODUCTION OF THE PRIMARY AUTHOR



Mr. Sun Yi-Peng, born in 1982, is now a Ph. D student of Peking University and will have his doctor degree in 2007. Since 2005 he studied in the Institute of High Energy Physics under the guidance of Dr. Jie Gao.

His study mainly on:

- BEPCII lattice study.
- Bunch lengthening simulation and theoretical study.
- Single bunch transverse instability study on both BEPC and BEPCII synchrotron radiation ring.
- ILC damping ring FODO lattice design.

ILC DR – BASELINE SPECIFICATIONS

ILC Damping Rings Baseline Configuration Lattice Specifications

23 January 2006 – 650 MHz RF frequency

General Parameters

Circumference	6642.4784 m
Energy	5 GeV
RF frequency	**650 MHz**
Harmonic number	14402
Transverse damping time, e^+ DR (e^- DR)	<25 ms (<50 ms)
Normalized natural emittance	5 μm
Equilibrium bunch length	6 mm
Equilibrium energy spread	<0.13%
Momentum compaction	~ 4×10^{-4}
Damping wiggler peak field	1.67 T
Damping wiggler period	0.4 m
Energy acceptance	$\|\delta\|<0.5\%$
Dynamic aperture	$A_x+A_y<0.09$ m-rad (up to $\|\delta\|=0.5\%$)

ILC DR – BASELINE ARC

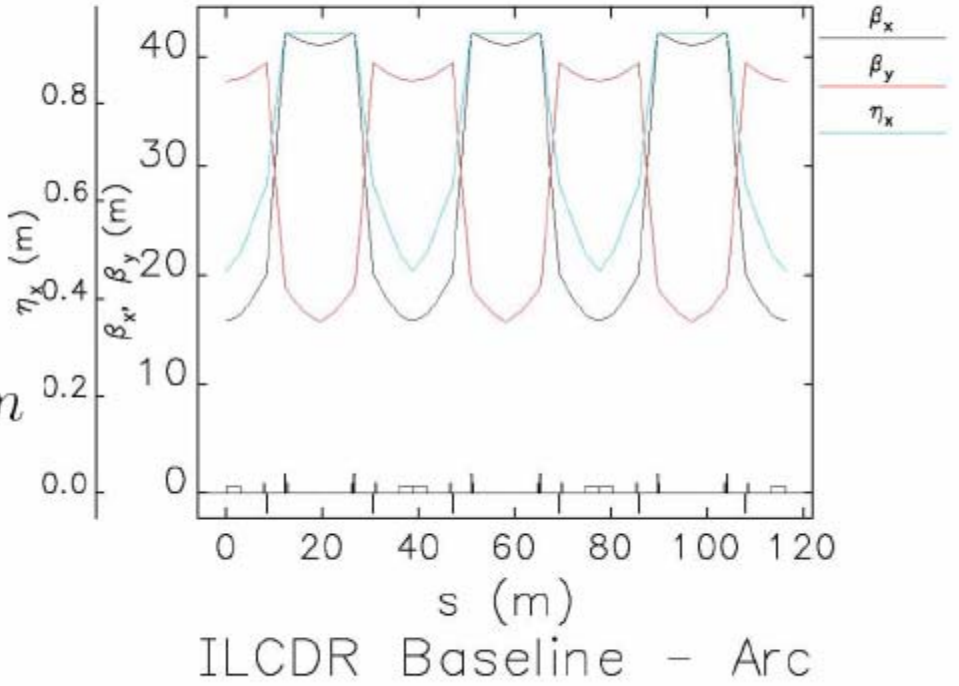
ILCDR Baseline – Arc Section

- Arc section is designed for required momentum compaction:

$$\alpha = \frac{I_1}{C} \qquad I_1 = \int_{dipoles} \frac{\eta}{\rho} ds$$

$$\bar{\eta} \approx 4 \times 10^{-4} \times 6500/2\pi \approx 0.4m$$

- 90^0 Arc cell, weak dependence on dipole length

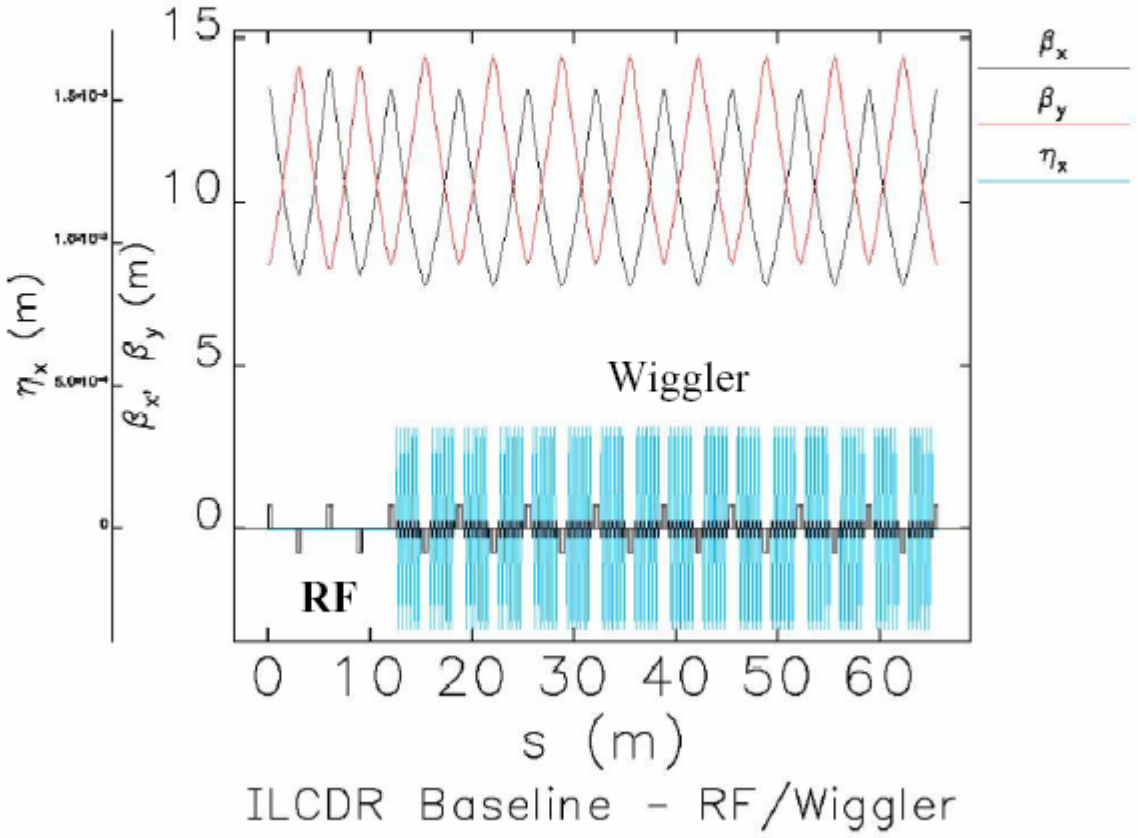


Courtesy from **Aimin Xiao/Louis Emery,** February 7, 2006: International Teleconference

ILC DR – BASELINE RF/WIGGLER

ILCDR Baseline – RF/Wiggler Section

- Determines emittance, damping time, and energy spread
- Modified "BRU" design



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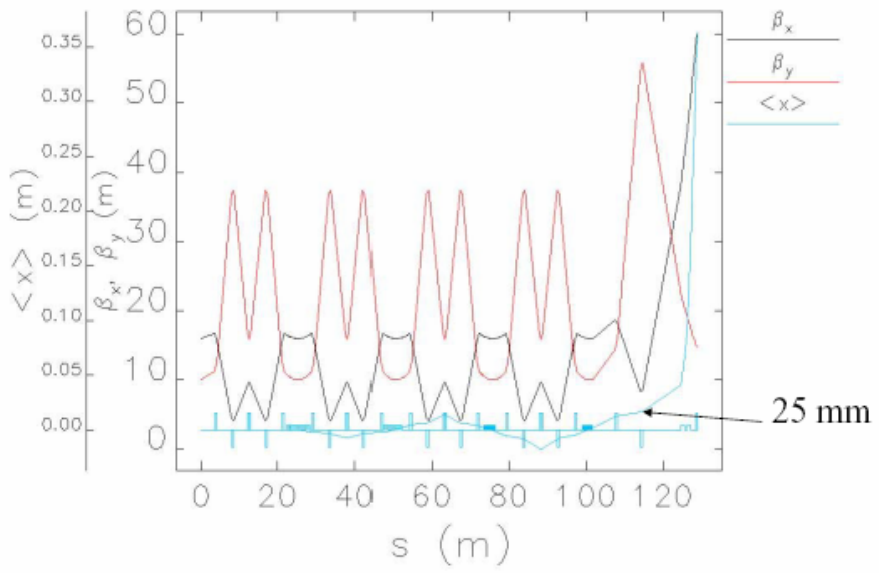
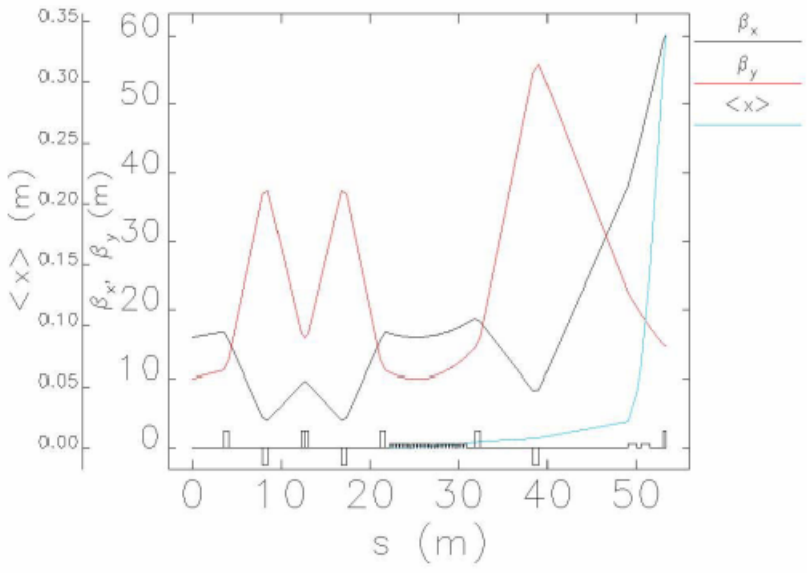
ILC DR – BASELINE INJECTION/EXTRACTION

Entire Injection Line Optics



Entire Extraction Line Optics



- Acceptance and aperture sets the maximum beta function at strip-line kicker:

$$2\sqrt{\beta_0 A_{x,max}} \leq d$$

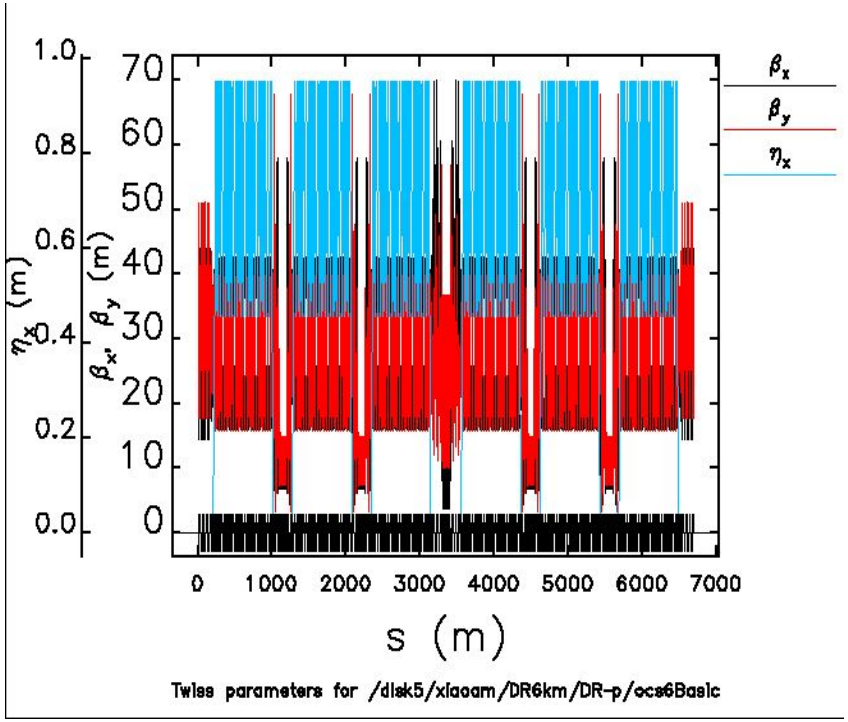
$$\beta_0 \leq 25m$$

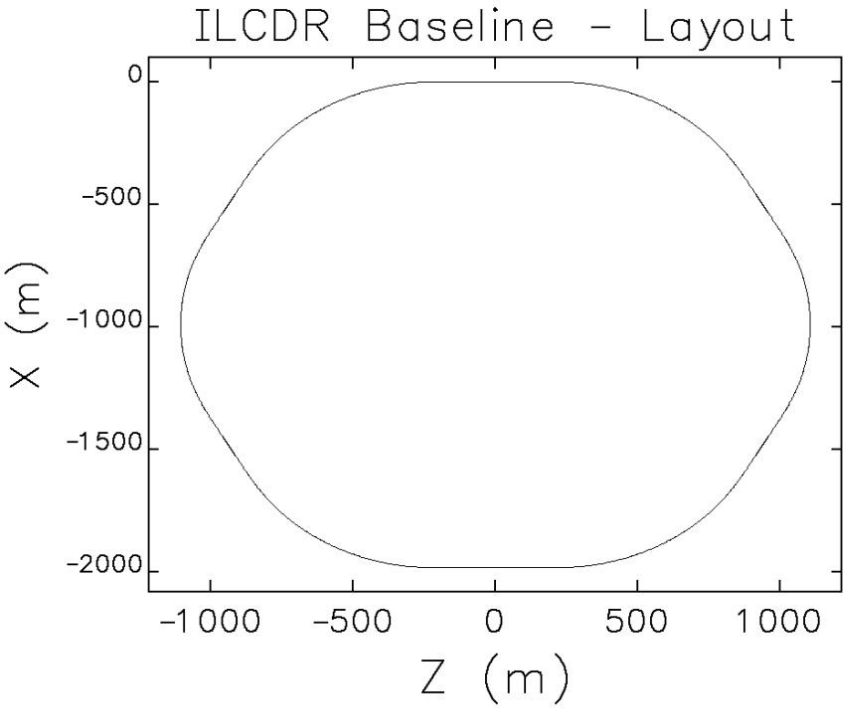
Including room for inject beam orbit excursion, say 2mm, -> β_0 < 16 m

- Similar as injection except the extract beam size is much smaller.
- Required kicker angle (total strip-line number) is about half of Injection.
- The tolerance on extraction beam orbit excursion can be large.

Courtesy from **Aimin Xiao/Louis Emery,** February 7, 2006: International Teleconference

ILC DR – BASELINE DESIGN





Left: TWISS parameters; Right: layout.

ILC DR baseline design use TME arc cells, there are totally **480** quadrupoles in the arc section. There are **4** wiggler sections (**8** before).

Courtesy from **Aimin Xiao/Louis Emery, on ILC GDE, July 20, 2006.**

DR FODO LATTICE DESIGN CONSIDERATIONS

I. To decrease the cost of the damping ring, use FODO arc cells to replace the original TME arc cells. The number of quadrupoles in the arc sections has been decreased a factor of two.

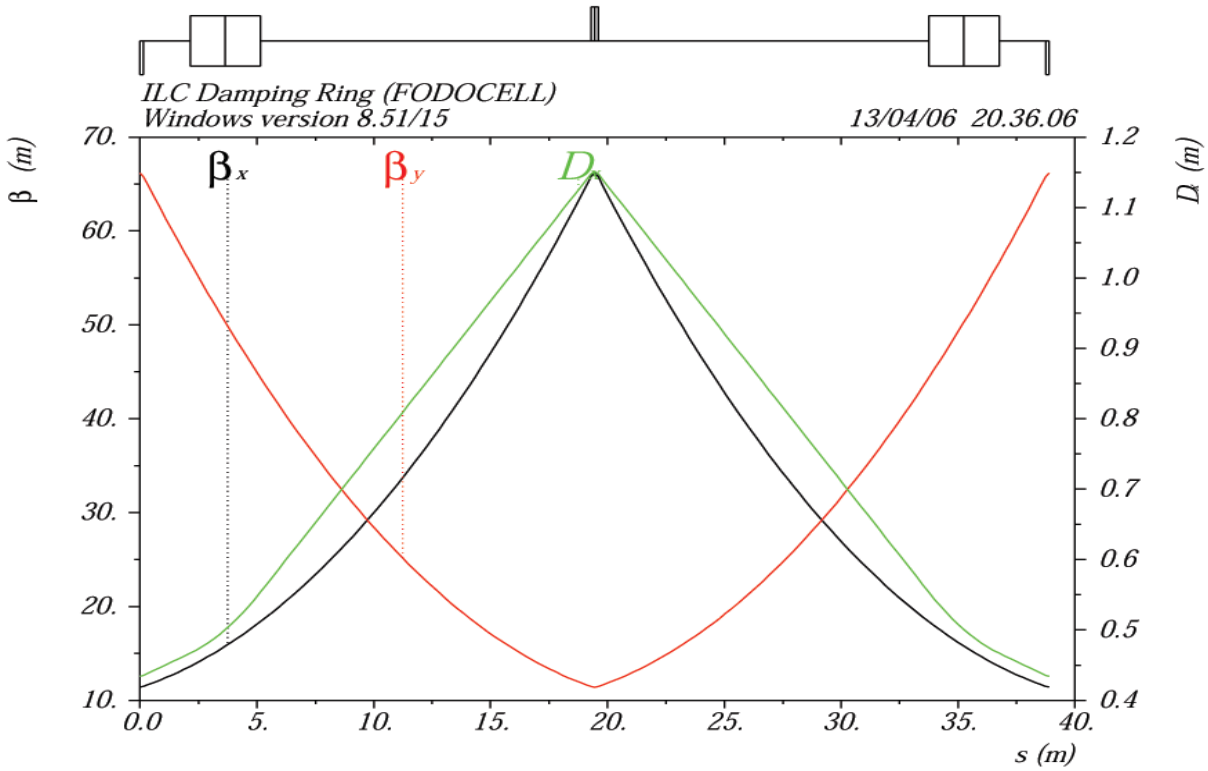
- Quadrupole number in TME DR lattice: **480**.
- Quadrupole number in FODO DR lattice: **240**.

II. To decrease the total construction expenses of the damping rings

- The civil engineering (the number of shafts).
- Cryogenic system.

The number of wiggler sections has been decreased from 8 to **2** in the ILC DR lattice.

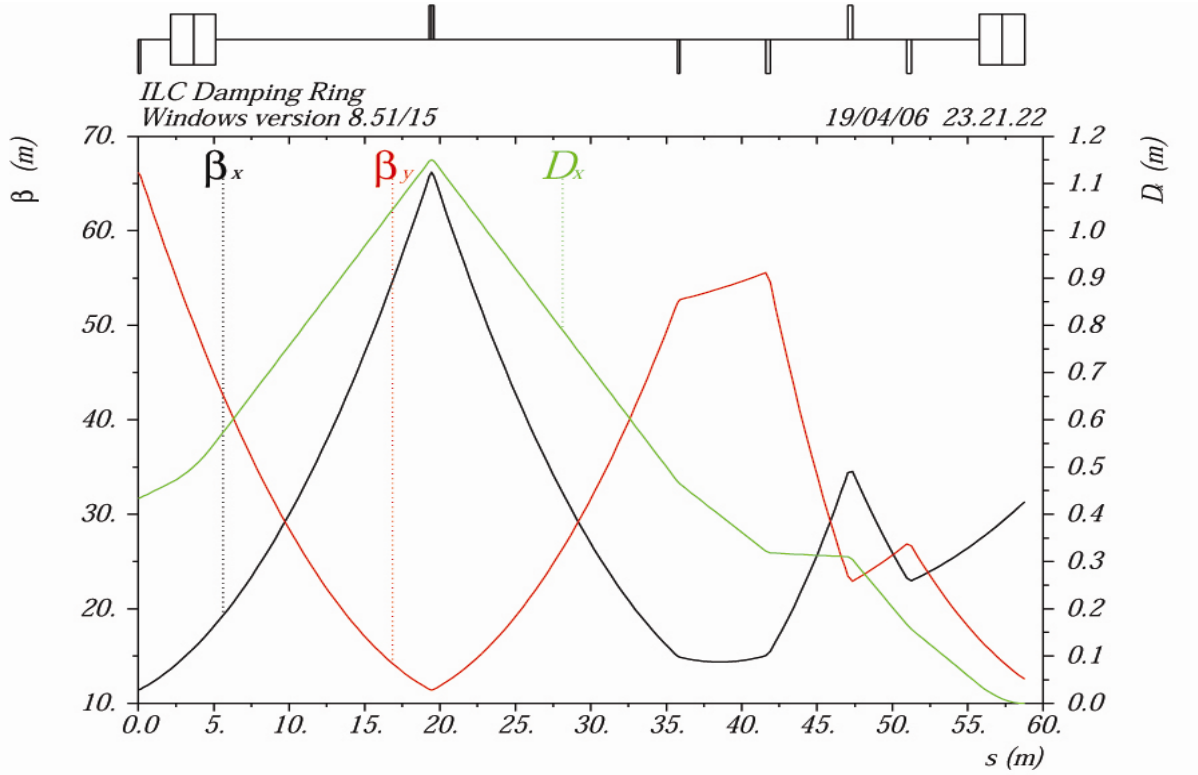
ARC CELL



The 90/90 degree modified FODO arc cell is chosen. The cell length is 38.9 m.

The length of the drifts that are between the quadrupoles is adjusted to be 13.7 m and 1.55 m with the maximum and the RMS horizontal dispersion function being 1.15 m and 0.77 m, respectively.

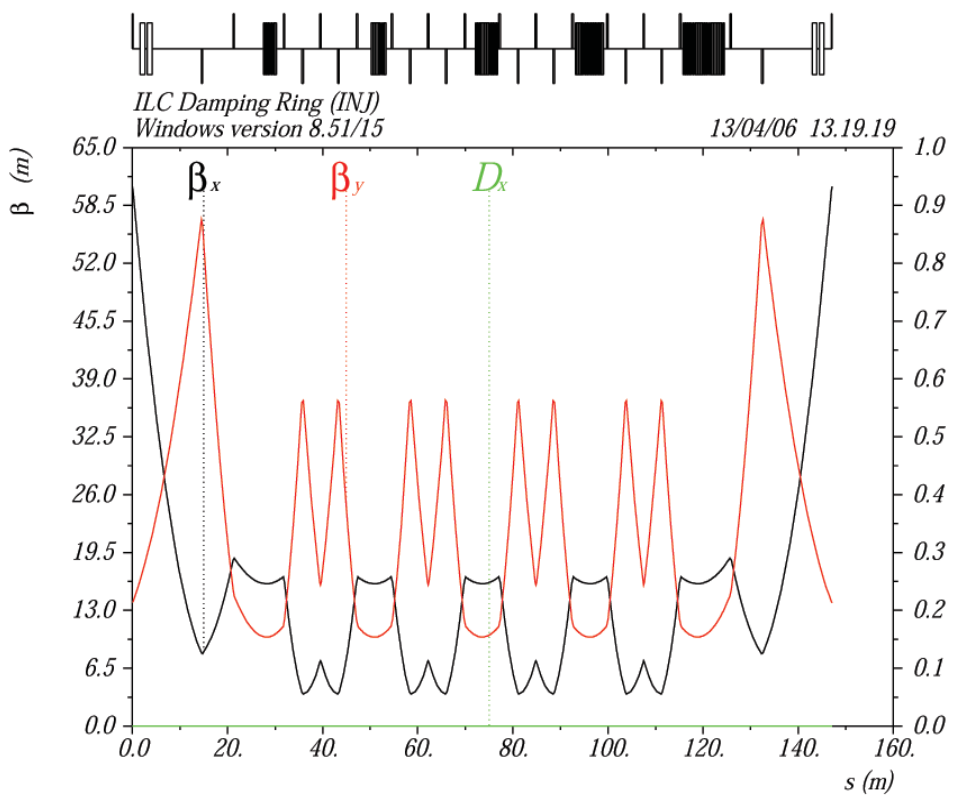
DISPERSION SUPPRESSOR



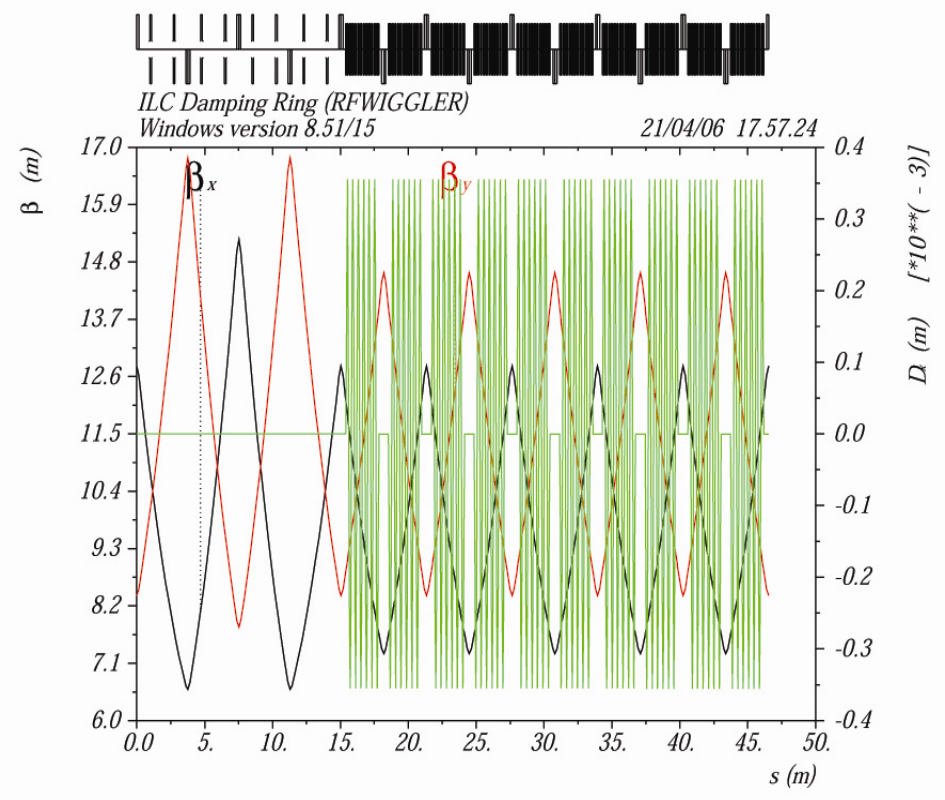
Insert three quadrupoles into the last arc cell to get a dispersion suppressor.

The aim is to have undisturbed TWISS parameters in the dispersion suppressor. Other dispersion suppressor solutions is under-study.

OTHER SECTIONS KEPT UNCHANGED

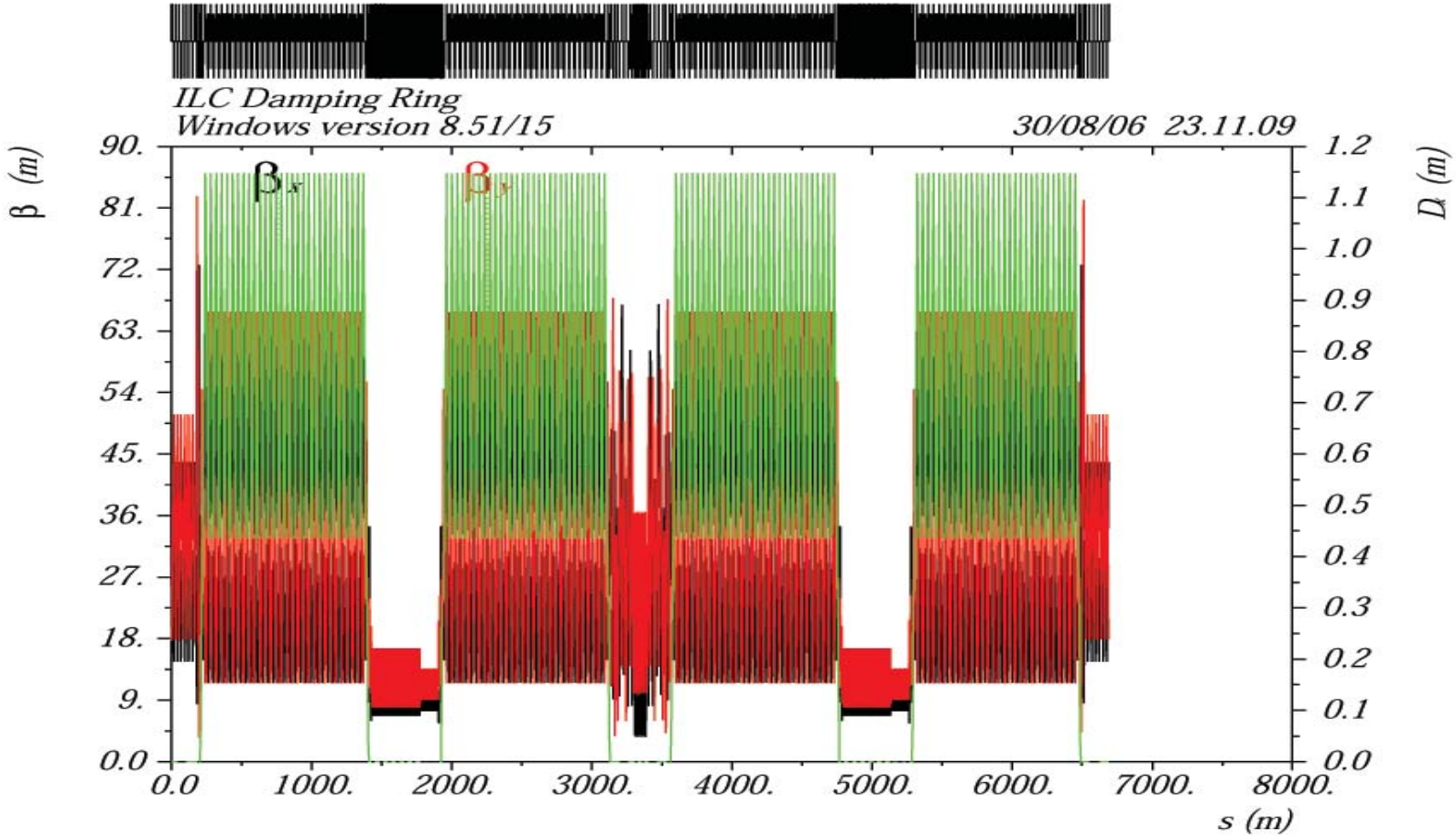


Injection (extraction) section.



Wiggler and RF cell.

TWISS PARAMETERS

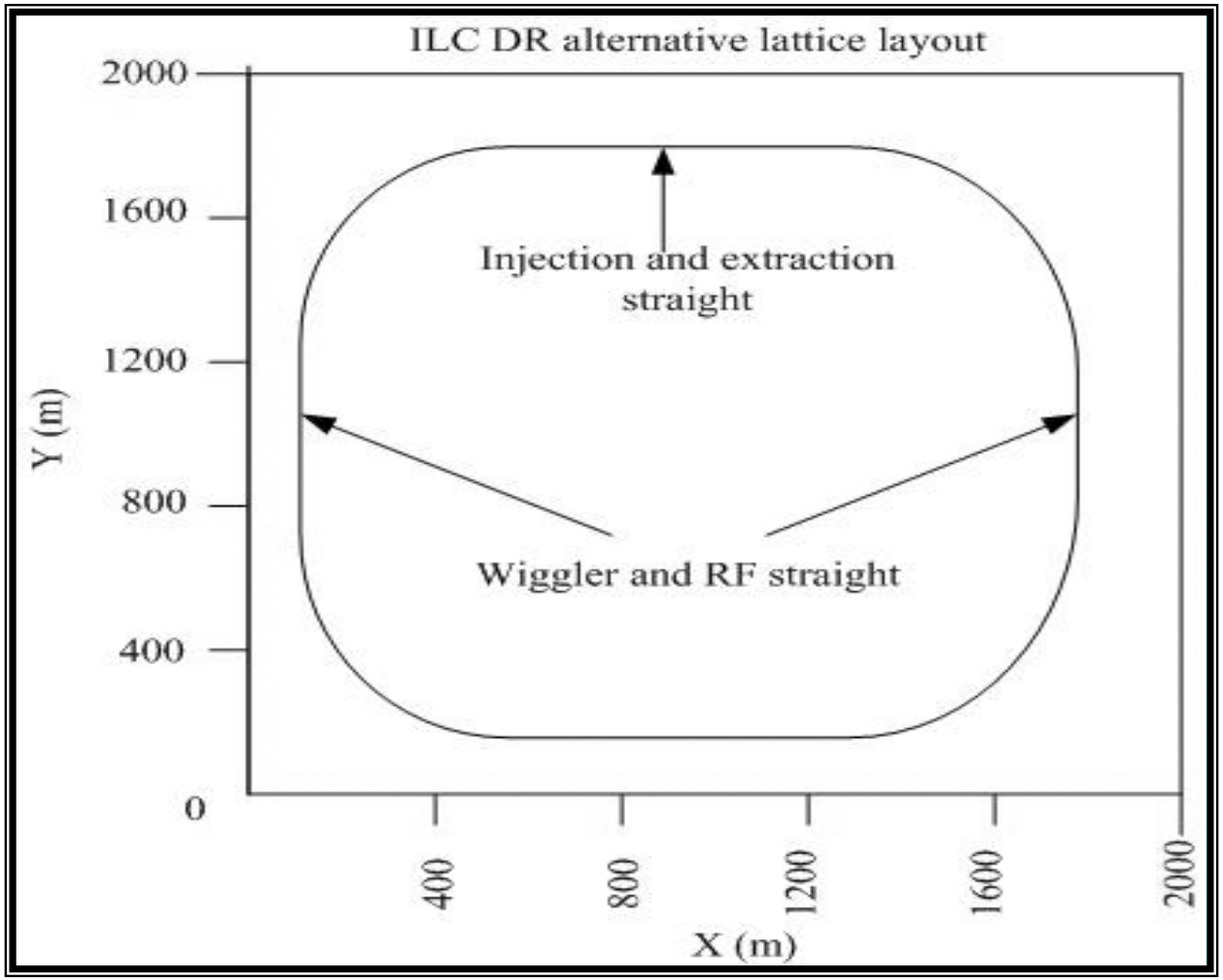


There are 120 arc cells in all, as in the previous lattice versions. About 21 FODO cells which is similar with the RF cell are inserted into the wiggler straights to maintain the circumference of 6695.057 m.

MAIN PARAMETERS OF THE DAMPING RING

Circumference [m]	**6695.057**
Harmonic number	14516
Energy [GeV]	5
Arc cell	**FODO**
Tune	48.35 / 45.32
Natural chromaticity	-59 / -61
Momentum compaction [10^{-4}]	**4**
Transverse damping time [ms]	25 / 25
Norm. Natural emittance [μm-rad]	4.2
RF voltage [MV]	**46.6**
Synchrotron tune	0.093
Synchrotron phase [^{o}]	169.2
RF frequency [MHz]	650
RF acceptance [%]	2.68
Natural bunch length [mm]	5.96
Natural energy spread [10^{-3}]	1.28

LAYOUT



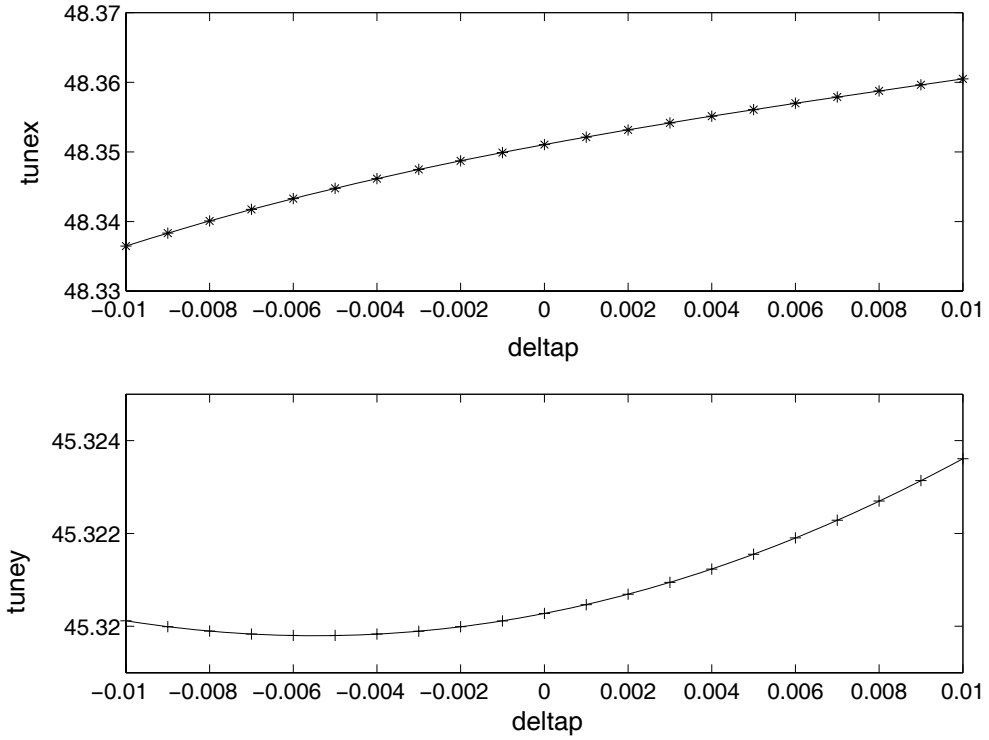
The number of wiggler and RF sections is decreased from 8 to **2**.

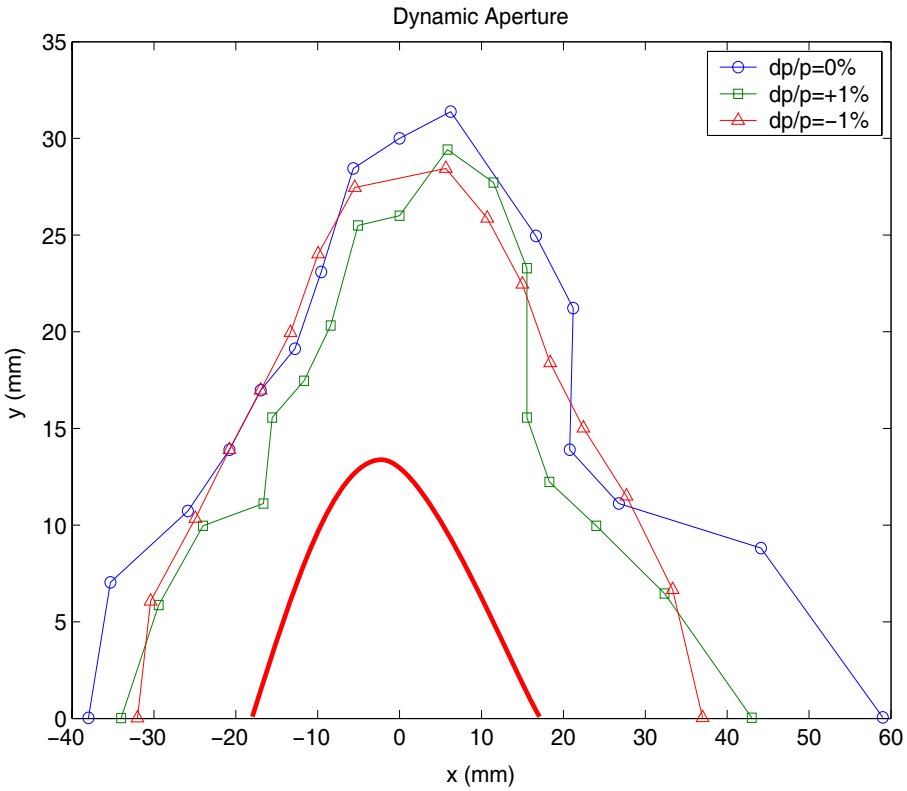
CHROMATICITY CORRECTION CONSIDERATIONS

1. The position of the two family sextupoles in the arc cell has been adjusted .
2. The phase advance in the straight section.
3. The phase advance between the last sextupole in one arc section and the first sextupole in the next arc section.
4. A proper total tune.

Following these matching criteria and the requirements for selecting a proper working point, the linear lattice matching, chromaticity correction and FMA (dynamic aperture) tracking process are repeated.

CHROMATICITY CORRECTION AND DYNAMIC APERTURE

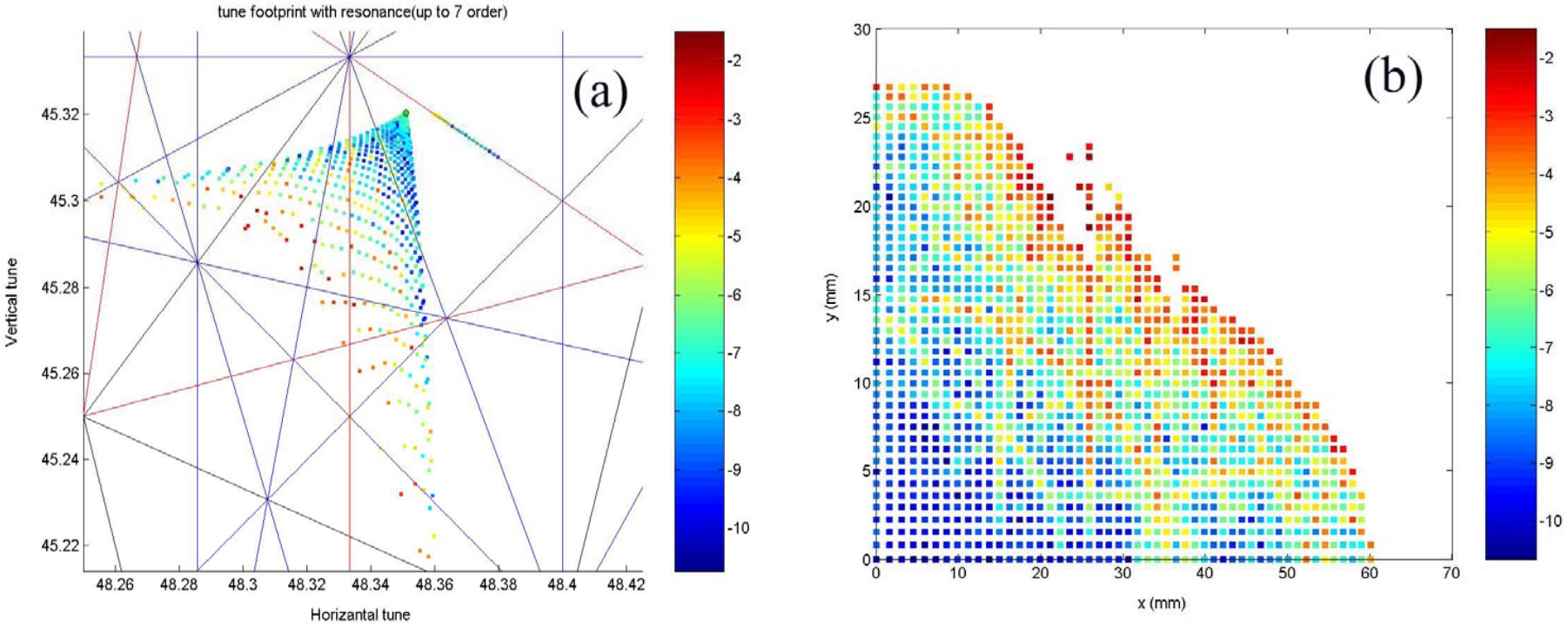




The chromaticity corrected to (0.42,0.31). The tune variation with momentum spread ±1% ; the dynamic aperture with momentum spread up to ±1% (with RF cavity, no errors).

With the same injection beam size as OCS. The red line is **3** times injected positron bunch size.

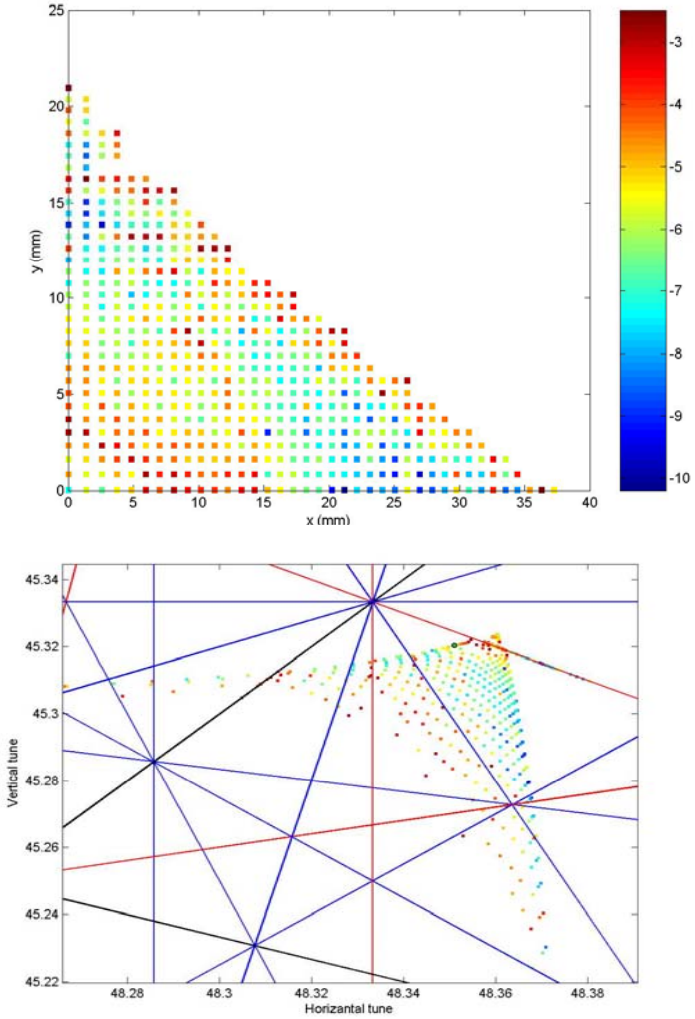
FREQUENCY MAP ANALYSIS (ON MOMENTUM)



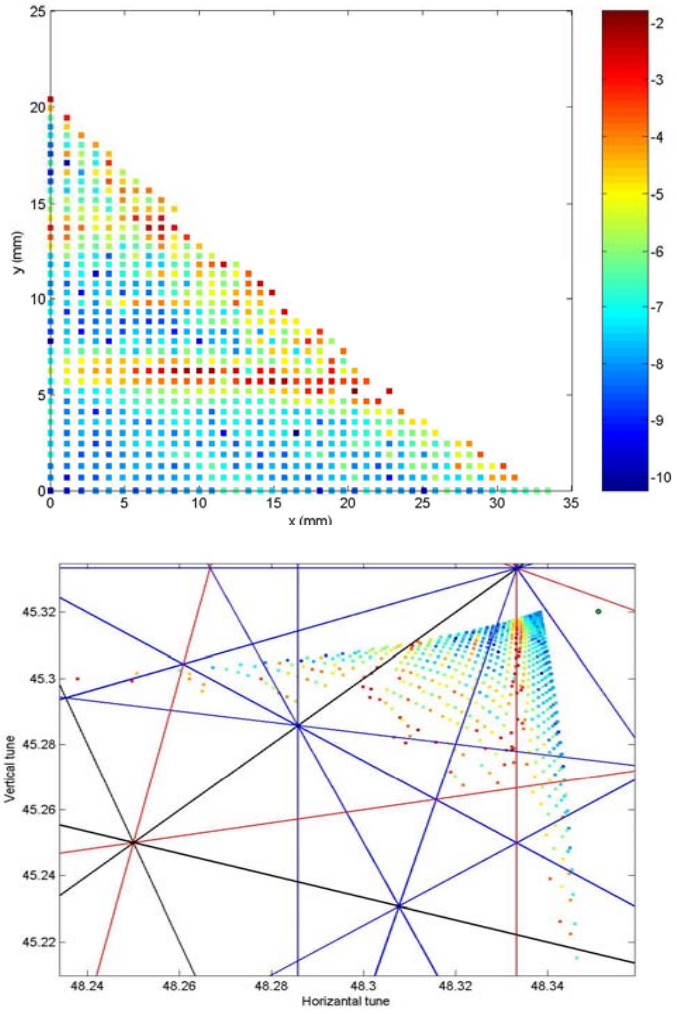
FMA analysis for on momentum particles: (a) footprint; (b) Dynamic aperture with FMA.

2500 particles distributed in the range of seven times the injected bunch size are tracked for 1024 turns.

FREQUENCY MAP ANALYSIS (OFF MOMENTUM)



$\Delta p/p = 0.01$



$\Delta p/p = -0.01$

CONCLUSIONS

- ILC DR alternative lattice design has been done with 90/90 degree FODO arc cells, with $\alpha_P = 4\times10^{-4}$.
  - The number of quadrupoles in the whole ring has been decreased by half compared with the original ILC damping ring BCD design.
  - The number of access shafts needed to supply power, cryogenics etc. for the wigglers and other systems, is decreased from 8 to 2.
  - The circumference, the equilibrium emittance, the bunch length, the acceptance, the dynamic aperture, and the damping time can fulfill the requirements for the ILC damping ring.

FUTURE STUDY

- ILC DR alternative lattice design with 60/60 degree FODO arc cells is on-going, for two momentum compaction cases:
  - 60/60 FODO arc cell: $\alpha_P = 4\times10^{-4}$.
  - 90/90 FODO arc cell: $\alpha_P = 2\times10^{-4}$.

With the aim of a large momentum compaction variation range of acceptable acceptance.

- Low emittance tuning with orbit and optics correction scheme.
- Realistic particle tracking.

Results to be presented on ILC GDE meeting, Beijing.

Thanks for your attention.