ILC Damping Ring Design TDR and Lower Emittance

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Contents

Revisit Damping Ring Design in TDR

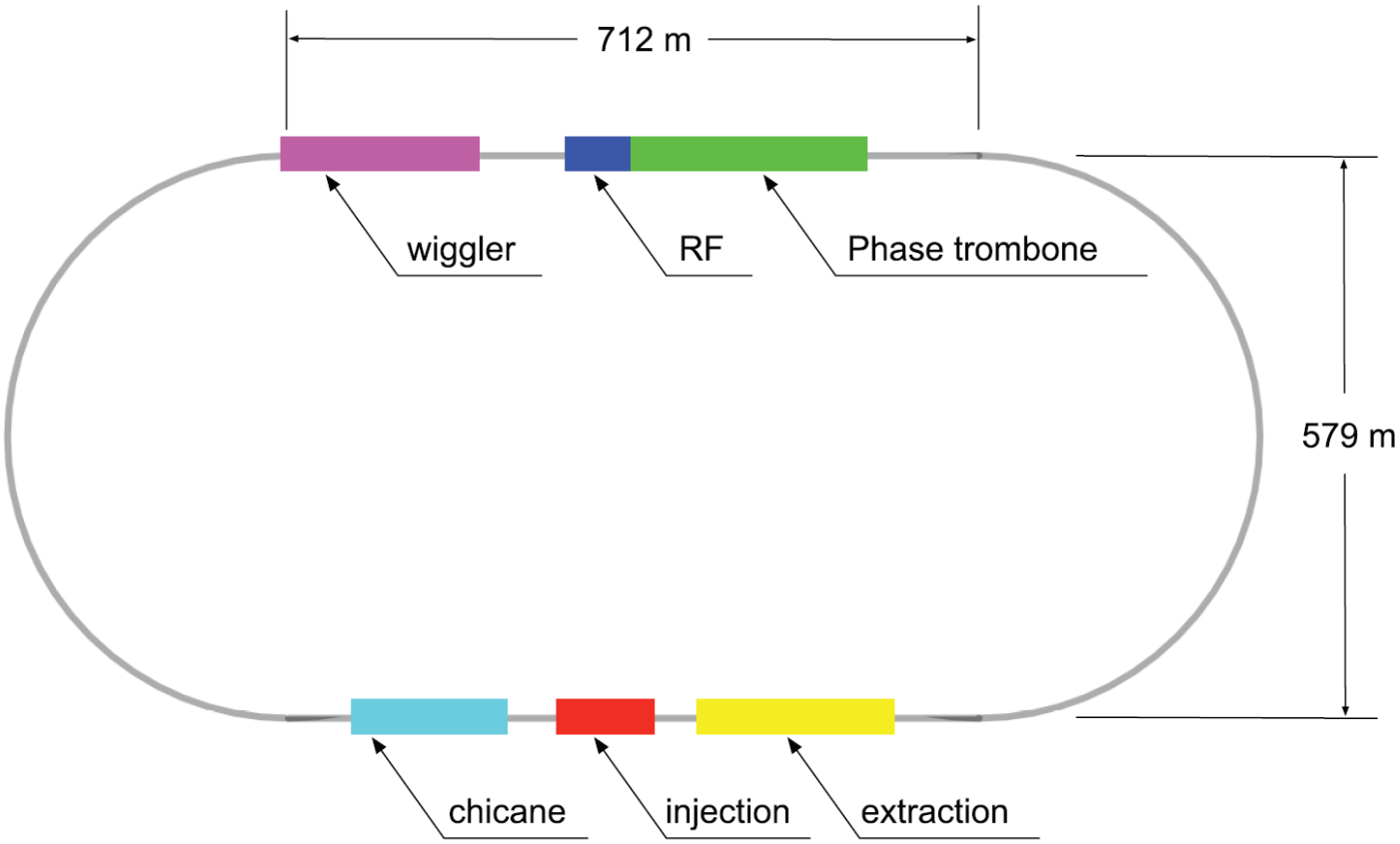
- Lattice data given by M. Woodley (SLAC) (2016)
- Translated to “SAD” format
- Checked optics parameters (tunes, betas, dispersion)
- Checked horizontal emittance
- Tried to check dynamic aperture

Modification for Lower Horizontal Emittance

- 6.3 um to 4.0 um, (at IP 10 um(TDR) to 5 um (new))

Layout (TDR)

Figure 6.1
Damping-ring layout: the circumference is 3238.7 m; the length of each straight is 710.2 m.

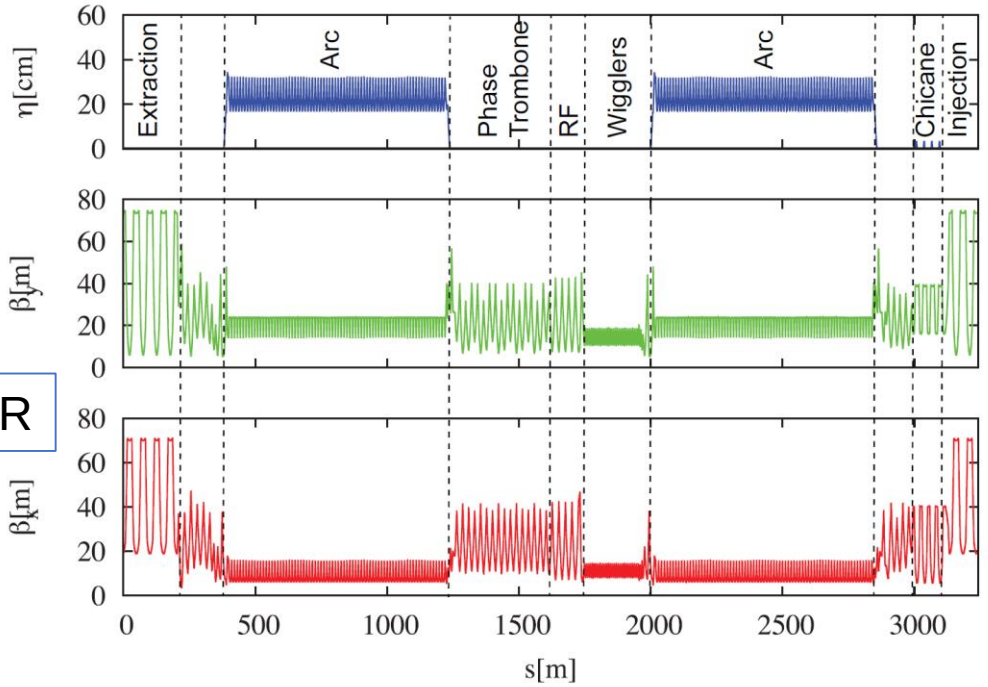


Wiggler dominant

82% of Energy loss in wigglers, 18% in Arcs

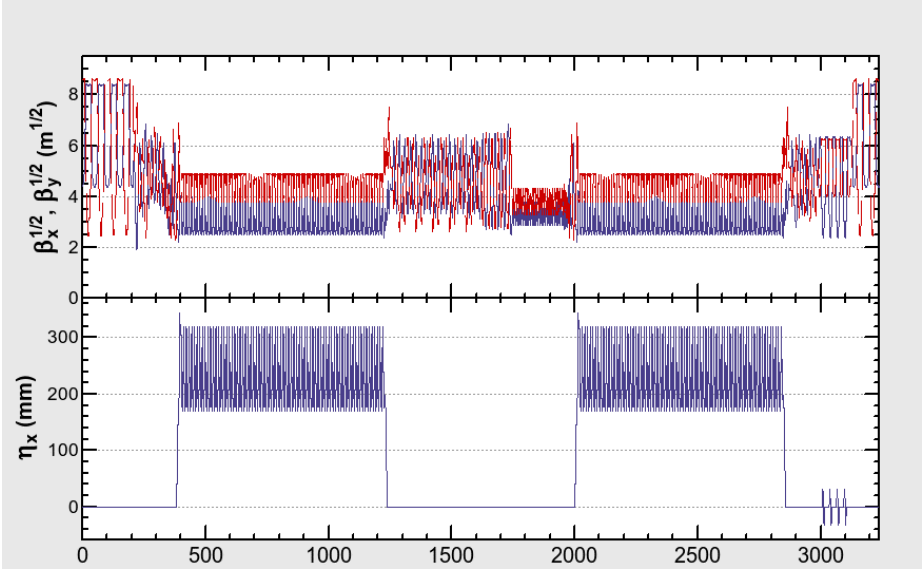
Lattice Functions

ice functions with the major functional sections (injection, extraction arcs, RF, wigglers, circumference chicane, and phase trombone) labelled.



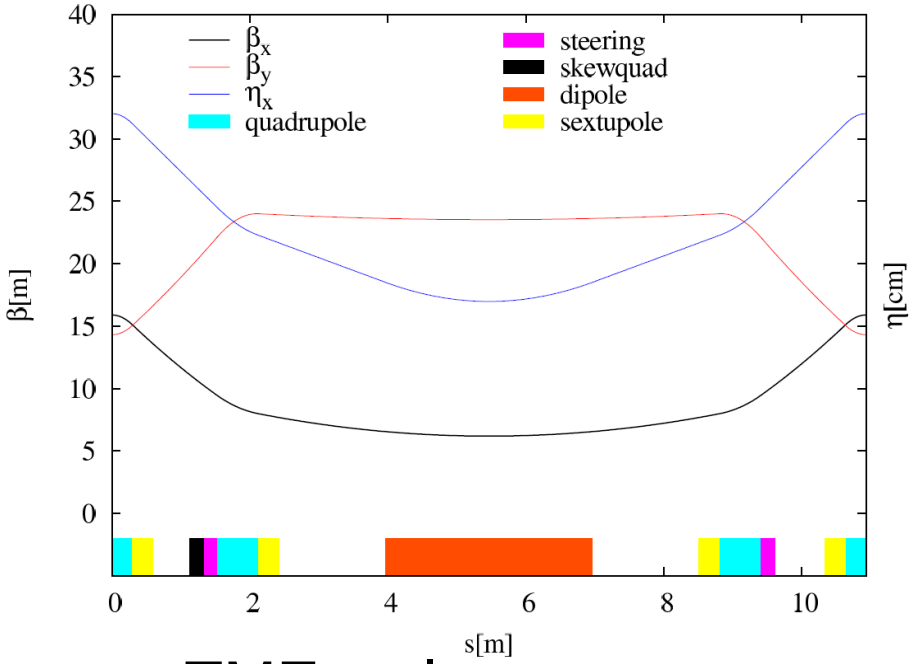
Copied from TDR

Calculate by SAD

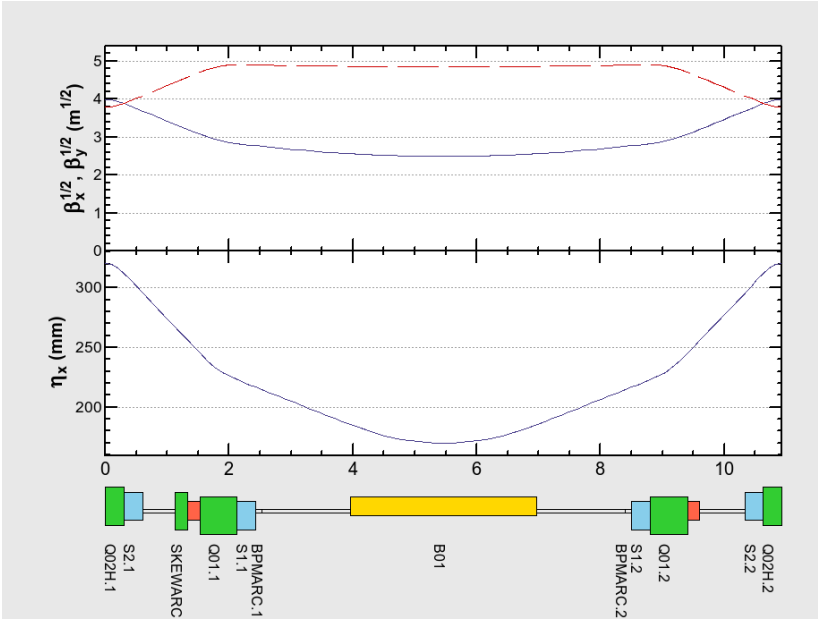


Arc Cell

TDR



SAD



TME-style

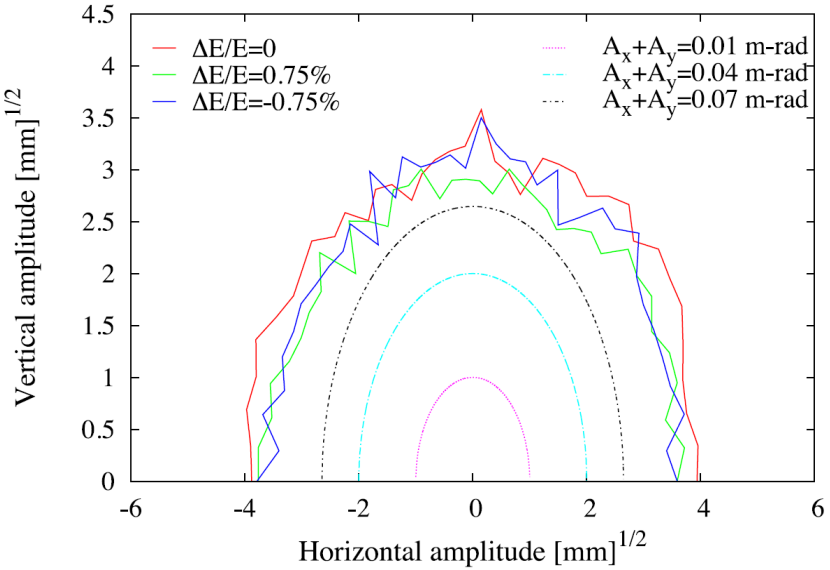
10.931 m/cell, 75 cells/arc (150 cells/ring)

MAD to SAD translation looks OK: Comparison of some parameters

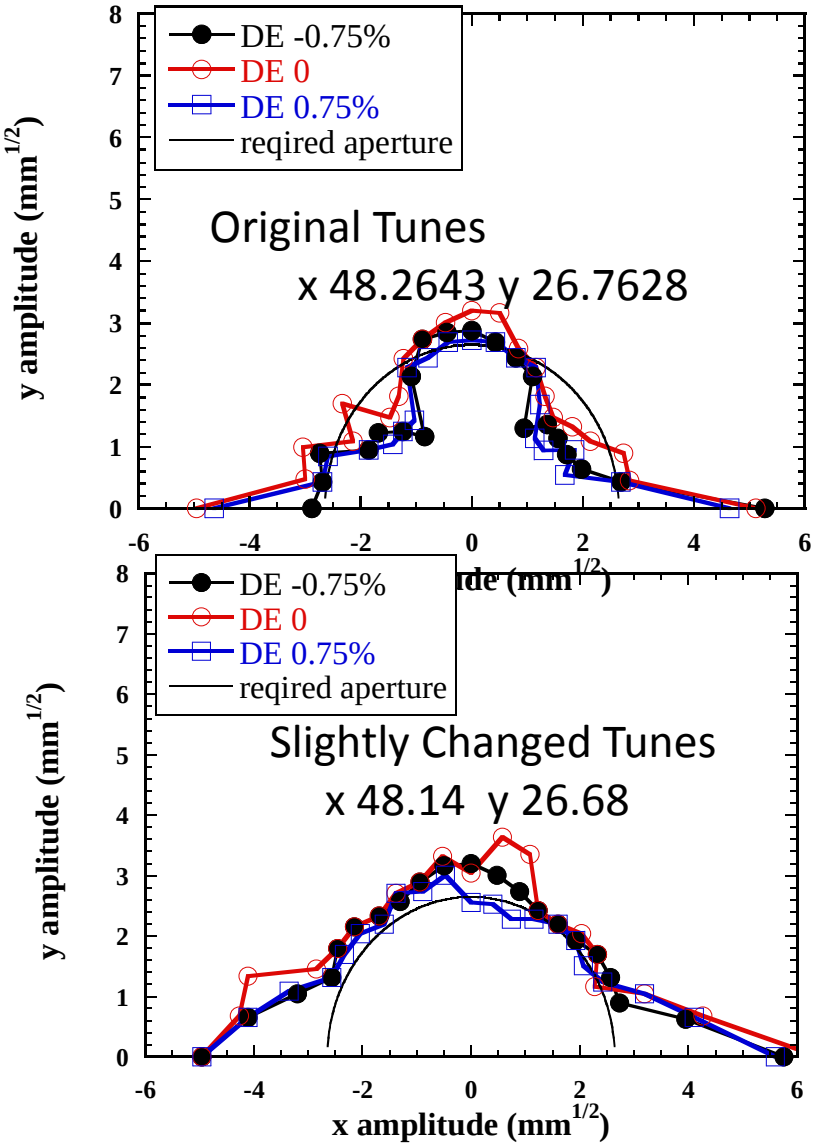
	SAD	MAD (by M.W.)
Circumference (km)	3.2386807	3.238680589
Damping time x/y/z (ms)	23.88/23.87/11.94	23.95/23.95/12.0
Bunch length (mm) wo/w IBS	6.23/ 6.25	6.02
Energy spread (%) wo/w IBS	0.11/0.11	0.11
Horizontal normalized Emittance (um) wo/w IBS	5.7/6.3	5.7
Tune x/y	48.264315 /26.762788	48.264313 /26.762786

Dynamic Aperture

TDR (“with errors”)



SAD (no error)



Dynamic aperture in TDR cannot be reproduced.. ??
Depend on tunes, etc.
Could not find details of the calculations of TDR.

Lower Horizontal Emittance

Why lower emittance?

- Parameter at collision optimization at ECM 250GeV
  - Reduction of horizontal beam size
  - Need lower emittance, $\gamma\varepsilon_x$=5μm (TDR 10μm)

Emittance in DR ~ 4 μm considering emittance growth (in turnaround)

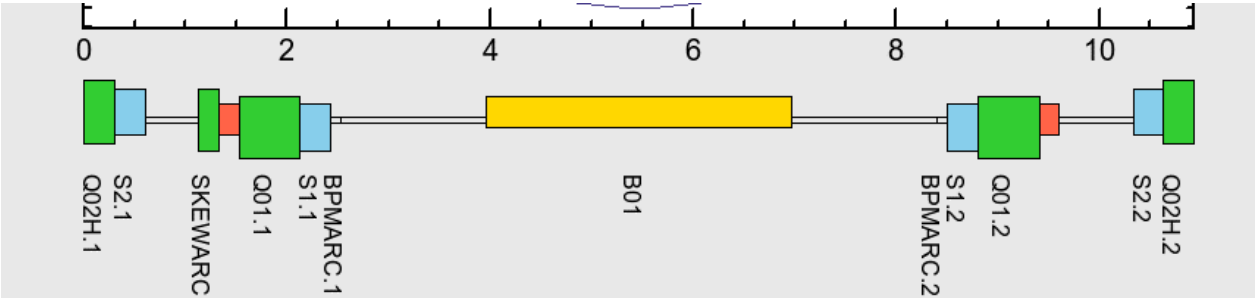
How?

- Stronger focusing will reduce dynamic aperture.
- Reduce bending field by increasing magnet length.

Reduction of bending field

In Wiggler Dominant Ring, emittance ~ $1/\rho^2$ in arc

Space for longer bending magnet (3 m → 5 m)

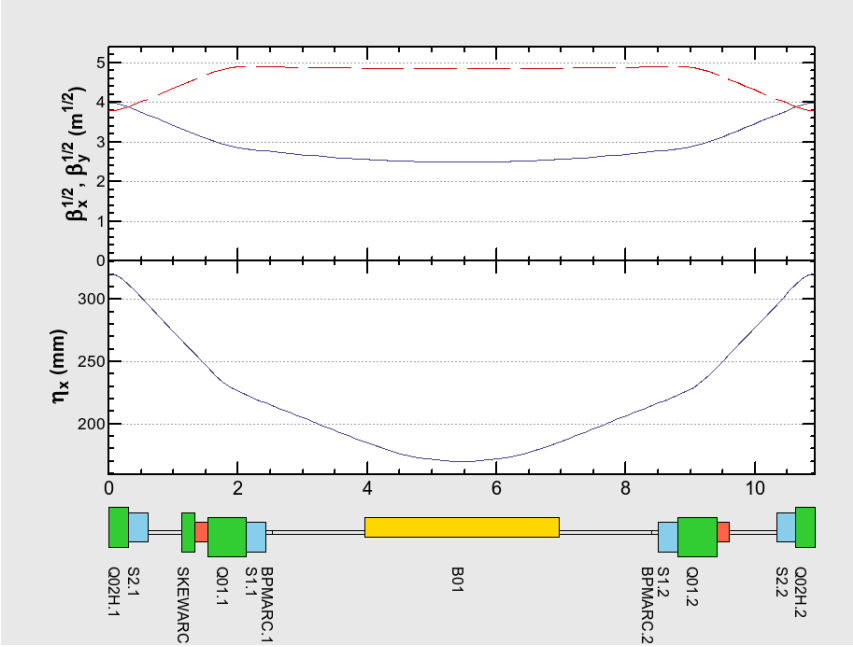


Tried longer bend lattice

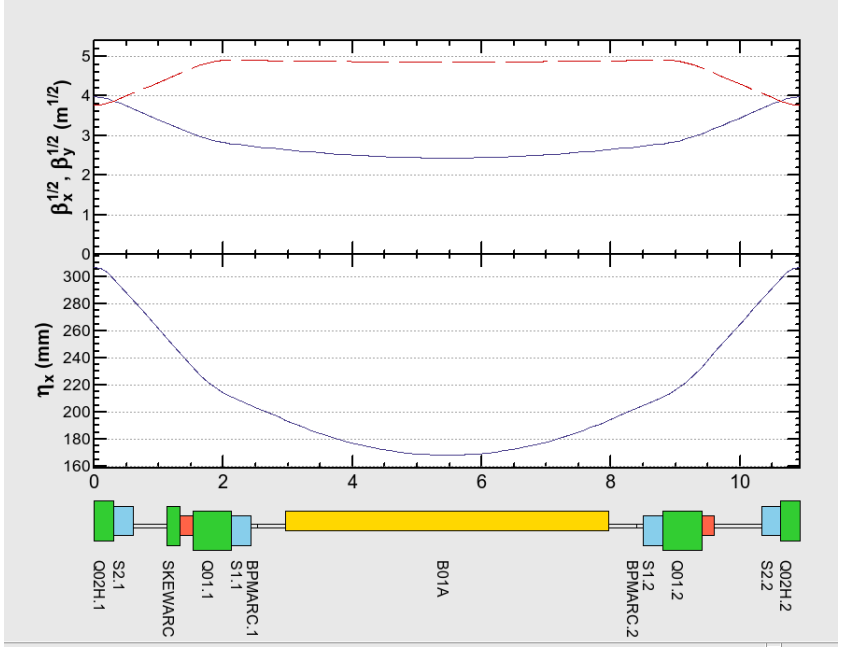
- No change in straight sections, except for minor changes for optics matching
- Set phase advance/cell for emittance = 4 μm with IBS

Arc Cell

Original

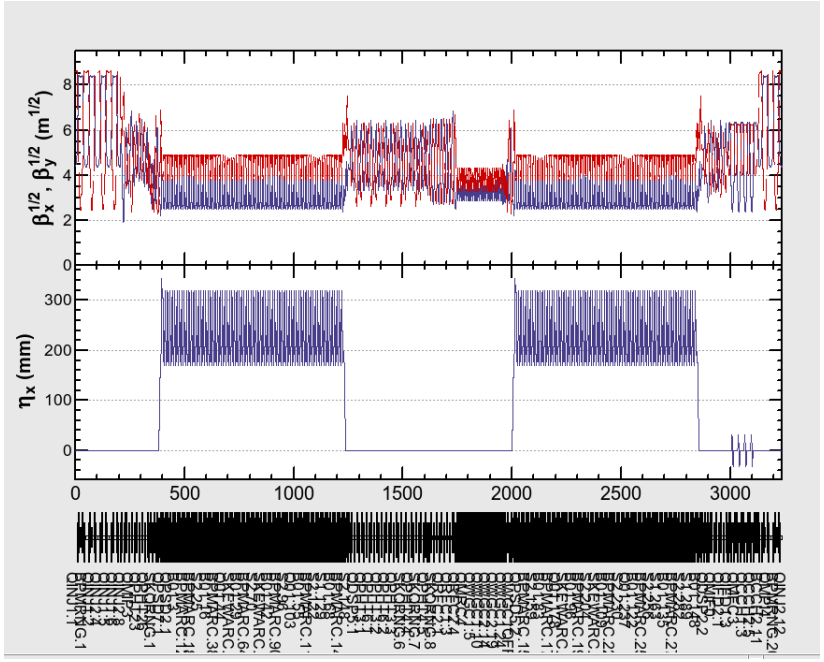


New (long bend)

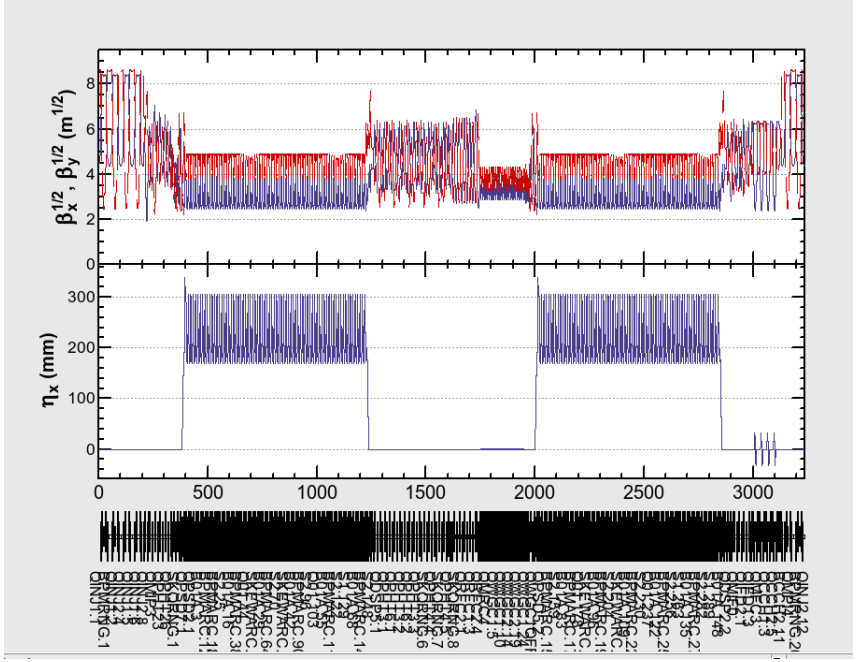


Whole Ring

Original



New long bend



Some Parameters

	Original	New (long bend)
Horizontal normalized Emittance (um) wo, w IBS	5.74, 6.27	3.14, 3.97
Tune x/y	48.26/26.76	49.33/26.86
phase adv./cell /2pi x/y	0.21891 /0.08098	0.2250 /0.0808
Damping time x/y/z (ms)	23.9/23.9/11.9	25.5/25.5/12.8

- Damping times slightly increased. This may be acceptable, or wigglers can be strengthen a little.
- Some surveys of phase advances/cell and total tunes were performed, for good dynamic aperture.

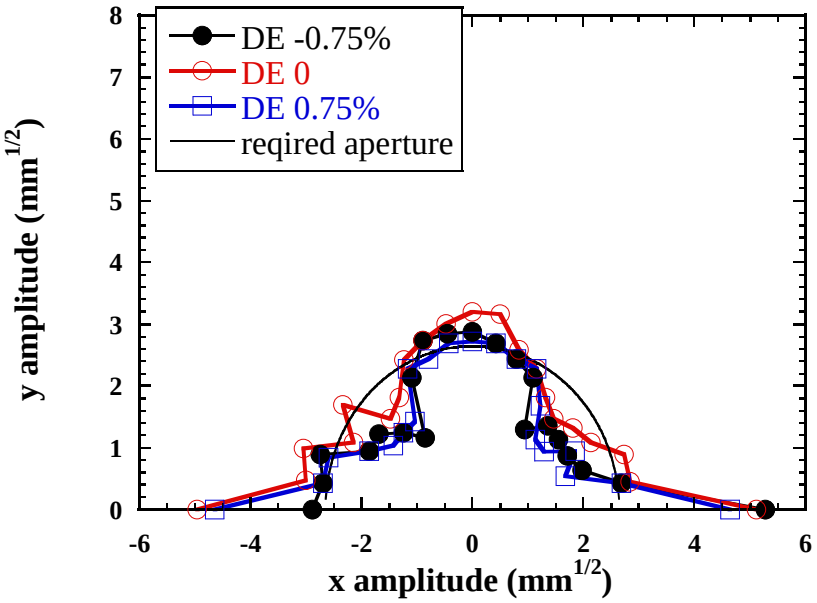
Dynamic Aperture calculation

Tool prepared in SAD

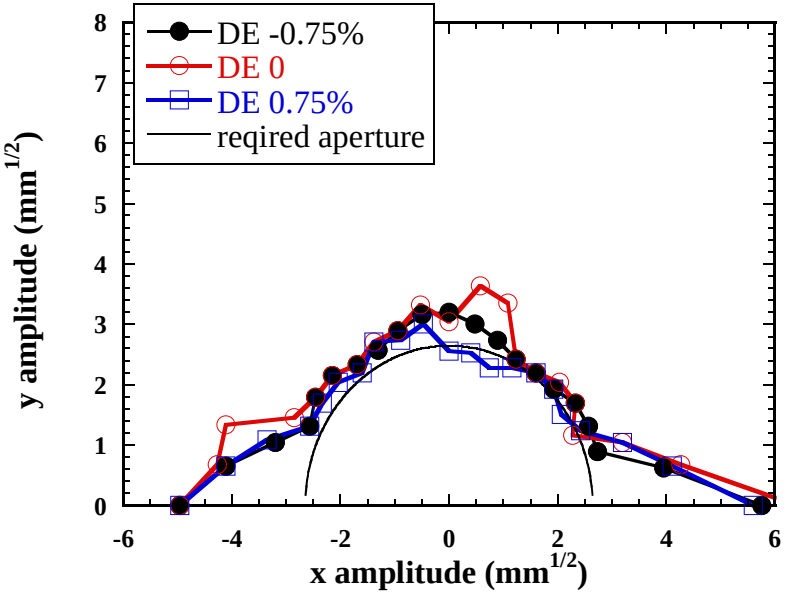
- Set initial orbit and energy deviation and perform tracking
- Survived in 1000 turns tracking → “accepted”
- No errors included.
- No special treatment (non-linear fringe field etc.) of wiggler’s magnetic field.

Aperture with original arc cell (3 m bend)

Original
Tune x 48.2643 y 26.7628

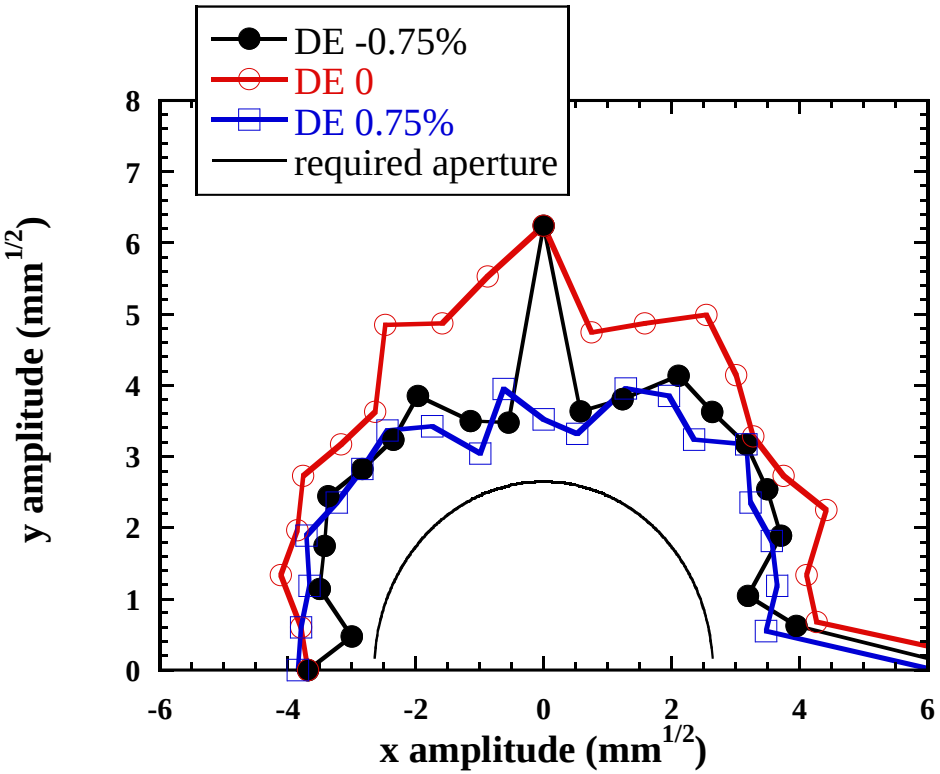


Original cell, change tunes
Tune x 48.14 y 26.68



Dynamic aperture: long bend

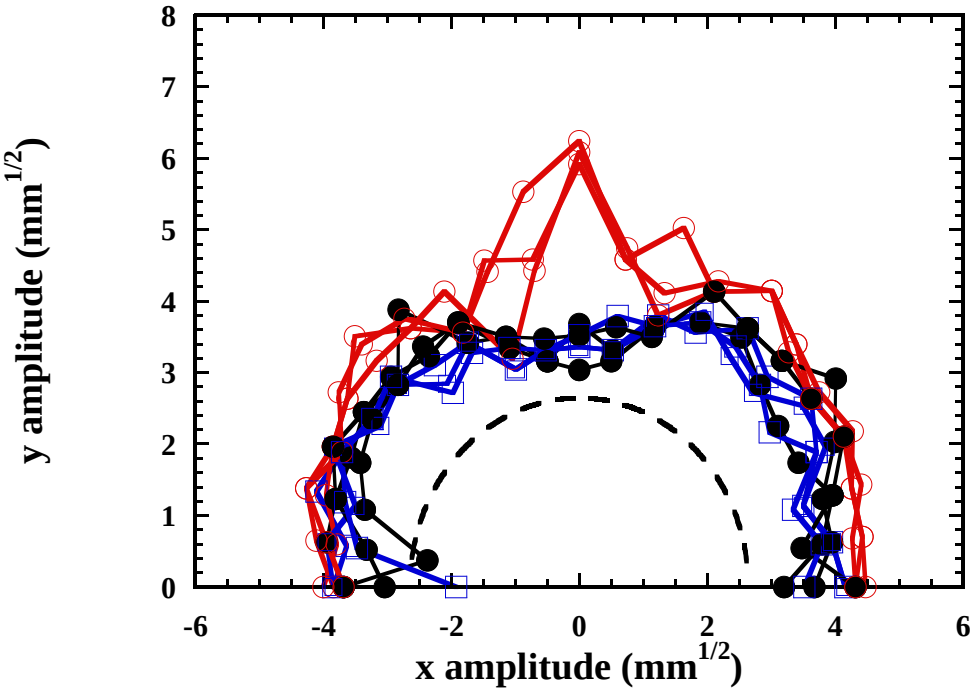
New arc cell: long (5 m) bend
tune/cell: x.225 y.0808
Tune: x49.33 y26.86



Dynamic aperture: long bend Misalignment + correction

New arc cell: long (5 m) bend
tune/cell: x.225 y.0808
Tune: x49.33 y26.86

Quadrupole & sextupole offset: 50 um
Quadrupole roll: 100 urad
BPM offset: 100 um
BPM roll: 10 mrad
COD & Dispersion correction



Another possible problem: Electron Cloud

- Electron cloud density will not depend on beam emittance.
- Electron density threshold for instability will reduced for smaller horizontal emittance. (using formula from Ohmi, see next slide)

Threshold ~ (horizontal beam size)$^{1/2}$

~ (horizontal emittance)$^{1/4}$ ~ 0.9

TDR: 6.4.4.3 EC Instability

The above estimates of cloud density place an ~~upper limit on the~~ ring-averaged density of about $4 \times 10^{10} \mathrm{m}^{-3}$, about a factor of three below the expected single bunch instability threshold ~~[110]~~.

→ Probably OK

E-cloud instability
Formula from Ohmi

E-cloud density threshold:

$$\rho_{e,th} = \frac{2\gamma\nu_s\omega_e\sigma_z/c}{\sqrt{3}KQr_e\beta_y L}$$

$$\omega_e = \left(\frac{2\lambda_b r_e c^2}{\sigma_y(\sigma_x+\sigma_y)}\right)^{1/2} \sim 5\times10^{12}\ \mathrm{s}^{-1}$$

$$\lambda_b = N/\sqrt{2\pi}\sigma_z$$

L : Circumference

$$K = \omega_e\sigma_z/c \sim 5$$

$$Q = \min(\omega_e\sigma_z/c, 10) \sim 5$$

$$\rightarrow \rho_{e,th} \propto Q^{-1} \propto \omega_e^{-1} \propto \sigma_x^{1/2}\sigma_y^{1/2}$$

Summary, Discussion

ILC DR TDR has TME-style, wiggler dominant Damping Ring

Reduction of horizontal emittance required (6.3 um → 4.0 um)

- Easy way to reduce emittance, keeping dynamic aperture, is using longer bending magnets in arcs.
  - 3 m → 5 m (weaker bending field)
  - Dynamic aperture calculated. Seems OK, but without field errors.

Problem can be dynamic aperture

- Dynamic aperture calculations of original lattice in past paper(s) could not be checked.
- Major design changes have not been studied.