ILC DR Lower Horizontal Emittance, preliminary study

20170629

Kiyoshi Kubo (KEK)

Motivation

- Modification of parameter set for higher luminosity is planned.

- For High Luminosity, low Horizontal Emittance is required

- At IP, 10 μm (TDR) → 5 μm or lower

  (normalized horizontal emittance)

Horizontal emittance design in TDR

- At IP: 10 μm
- At Linac end: 9.4 μm
- At Linac entrance: 8.4 μm
- Growth in RTML: 0.9 μm (synchrotron radiation)
- In DR: 6.3 μm

Growth by 0.9 in RTML, but source of other 2.8 μm growth is not clear.

(90 nm (1.1%) in the Arc, 380 nm (4.8%) in the Turn-around, and 430 nm (5.4%) in the Bunch Compressor in its nominal configuration)

For 5 μm at IP, ~4 μm in DR is probably OK (?)

Possible Problems of small horizontal emittance

- Electron Cloud in e+ Ring
- Dynamic Aperture
- ???

Electron Cloud with lower emittance

- Electron cloud density will not depend on beam emittance.
- Electron density threshold for instability will be reduced for smaller horizontal emittance.

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

~ (horizontal emittance)$^{1/2}$

Dependence is weak

TDR: 6.4.4.3 EC Instability

The above estimates of cloud density place an upper limit on the ring-averaged density of about $4\times10^{10}\mathrm{m}^{-3}$, about a factor of three below the expected single bunch instability threshold [110].

→ Probably OK

Formula from Ohmi for e- cloud

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

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

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

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

(Private communication with K.Ohmi)

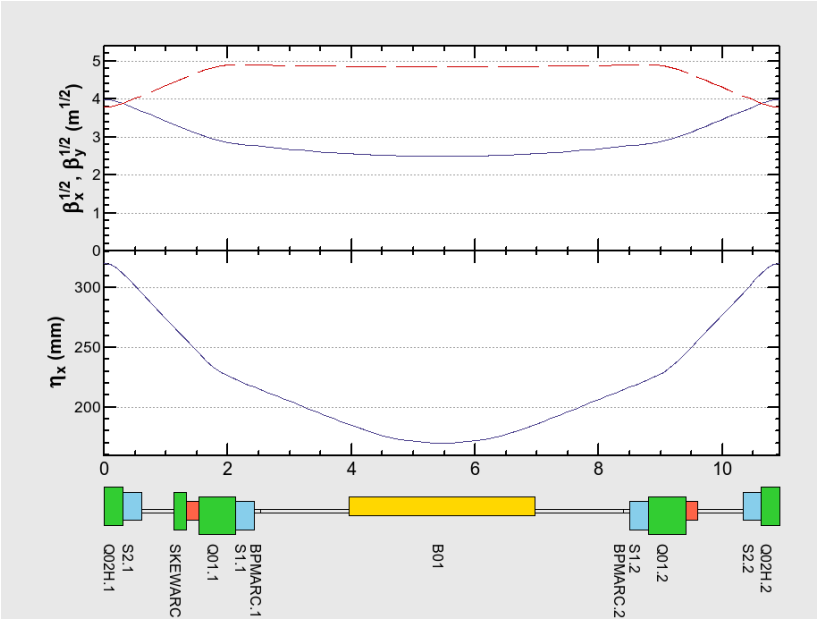
Modification of DR optics was tried

- Based on TDR DR Lattice data
  - Given by M. Woodley, ILC DR lattice (2016)
  - Translated to “SAD” format
- Modified arc cell optics to reduce horizontal emittance.
- Looked dynamic aperture

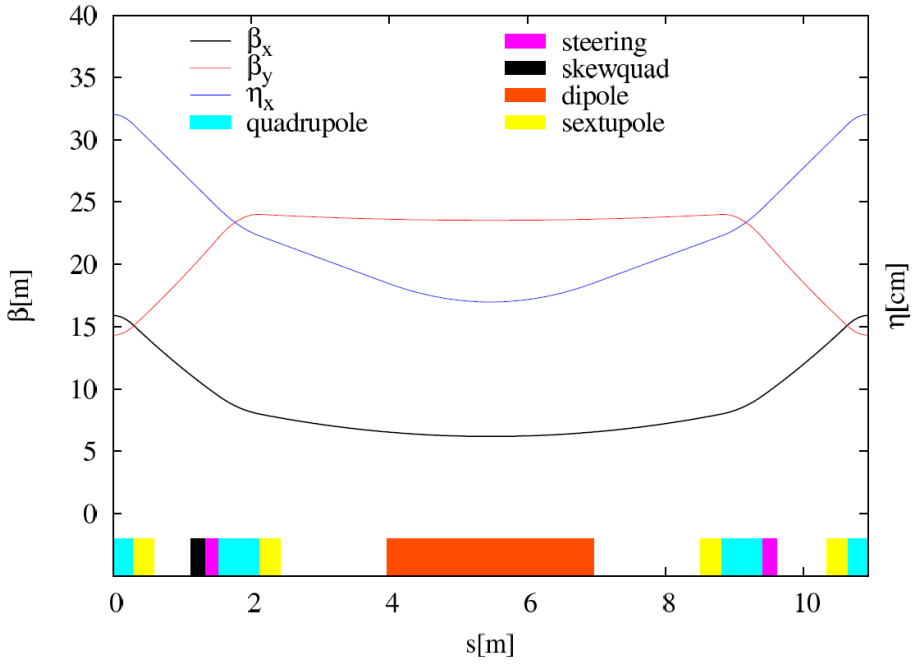
ILC-DR SAD deck was made from Lattice file 2016 by M.Woodley

Optics of Arc Cell

SAD

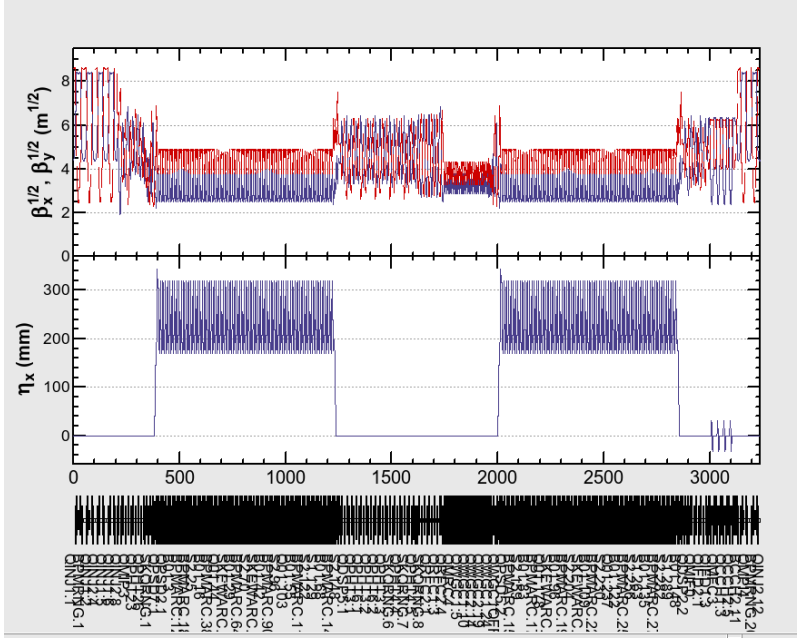


TDR

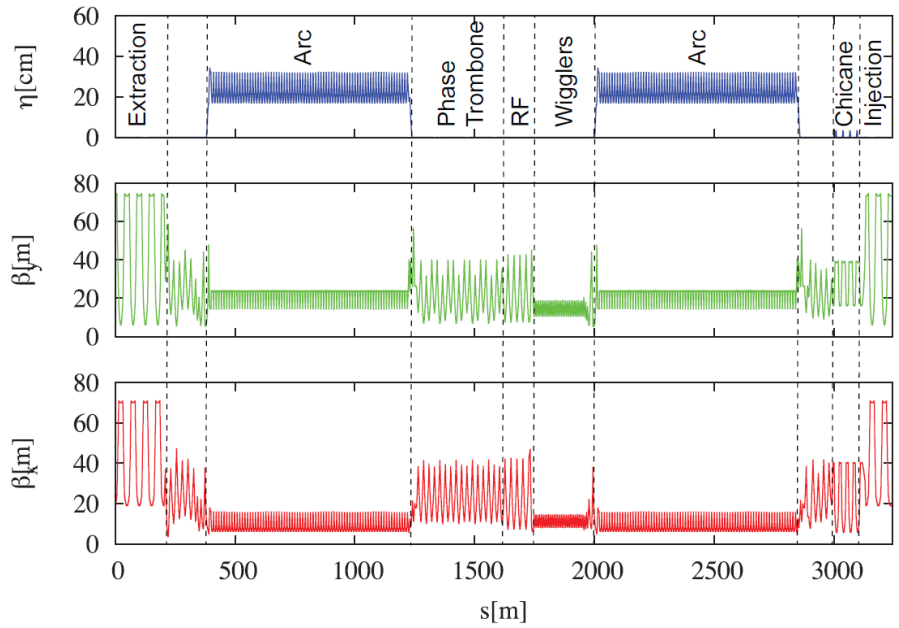


Optics of Whole Ring

SAD



TDR



Comparison of some parameters

	SAD (deck translated from Woodley's data)	TDR (MAD by M.W.)
Circumference (km)	3.2386807	3.238 (3.238680589)
Damping time x/y/z (ms)	23.88/23.87/11.94	23.95/23.95/12.0
Horizontal normalized Emittance (um)	5.74, 6.27 (IBS)	5.7
Tune x/y	48.264315 /26.762788	(48.264313 /26.762786)

Translation seems OK.
Horizontal emittance is 6.27 um with intra-beam scattering.

2 ways of Reduction of Horizontal Emittance

Reduce dispersion and/or beta_x in bending magnets

- Stronger focusing
  - Reduction of dynamic aperture expected

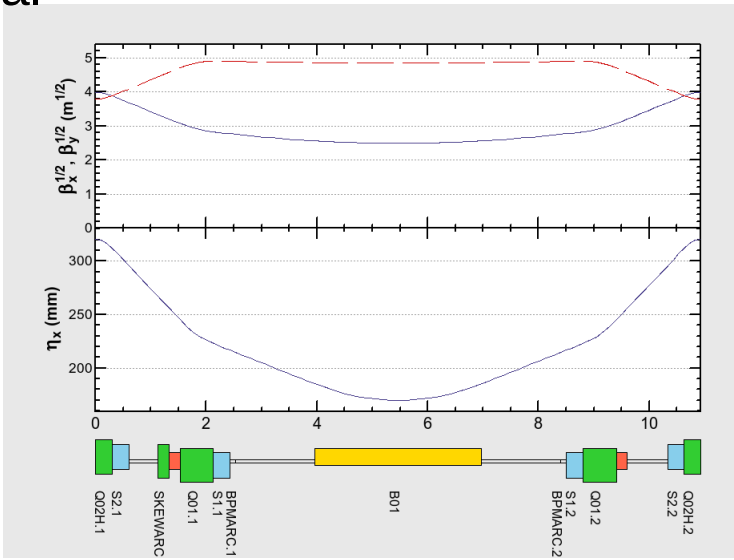
Reduction of bending field

- In Wiggler dominant ring, emittance ~ 1/rho^2 in arc
- Bending magnet can be longer (3 m → e.g. 5 m)
- Tried 5 m long bend optics

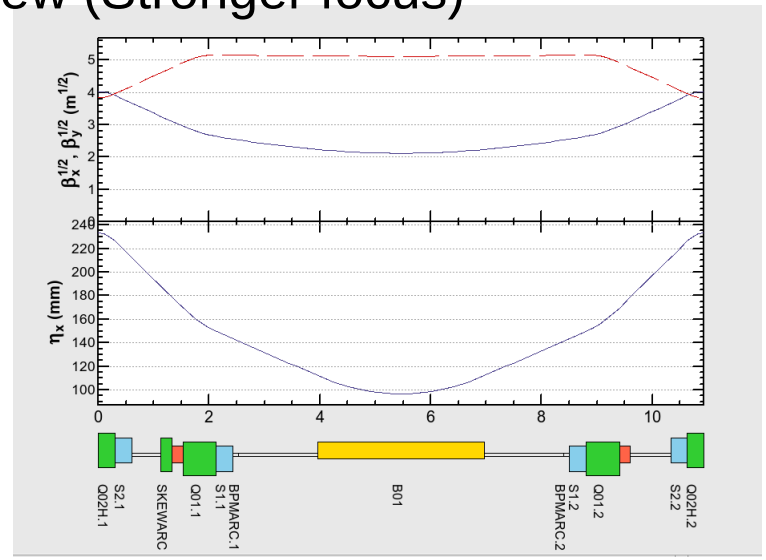
- No change in straight sections, except for minor changes for optics matching
- Set phase advance/cell for emittance = 4 um with IBS

Optics of Arc Cell

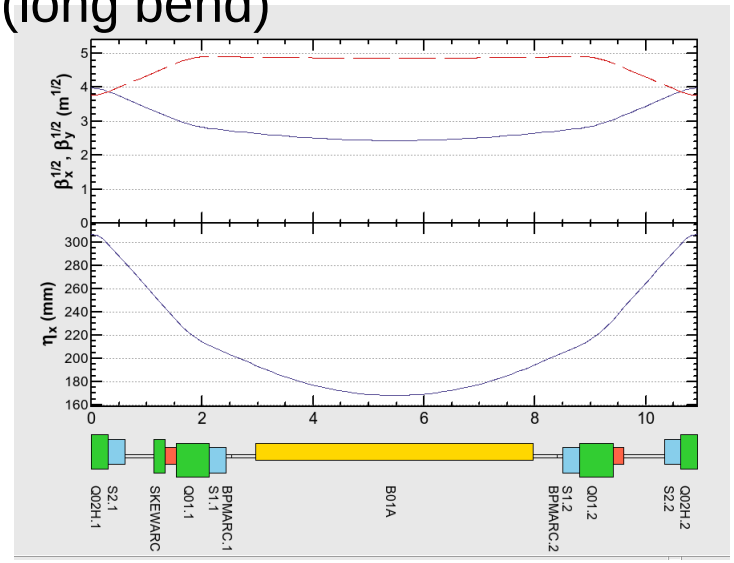
Original



New (Stronger focus)

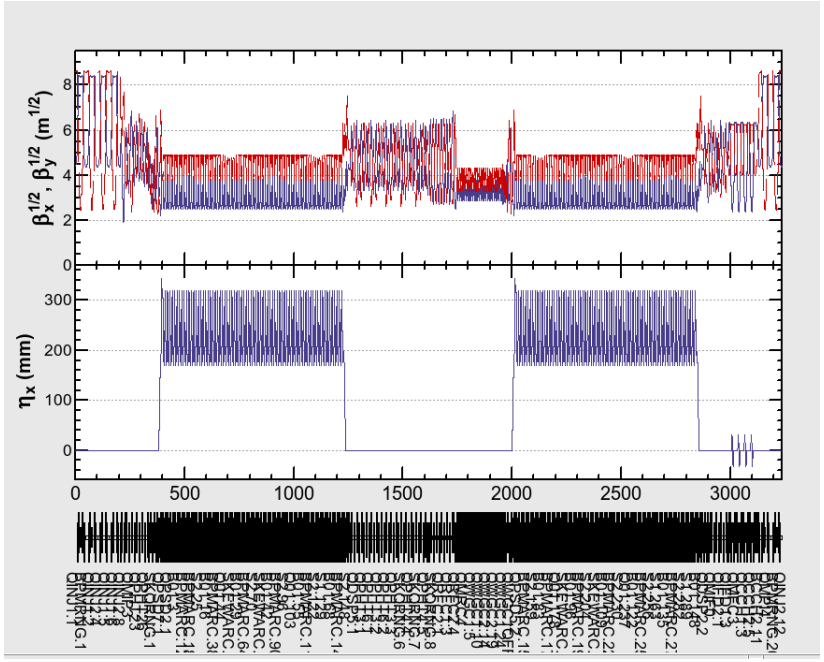


New (long bend)

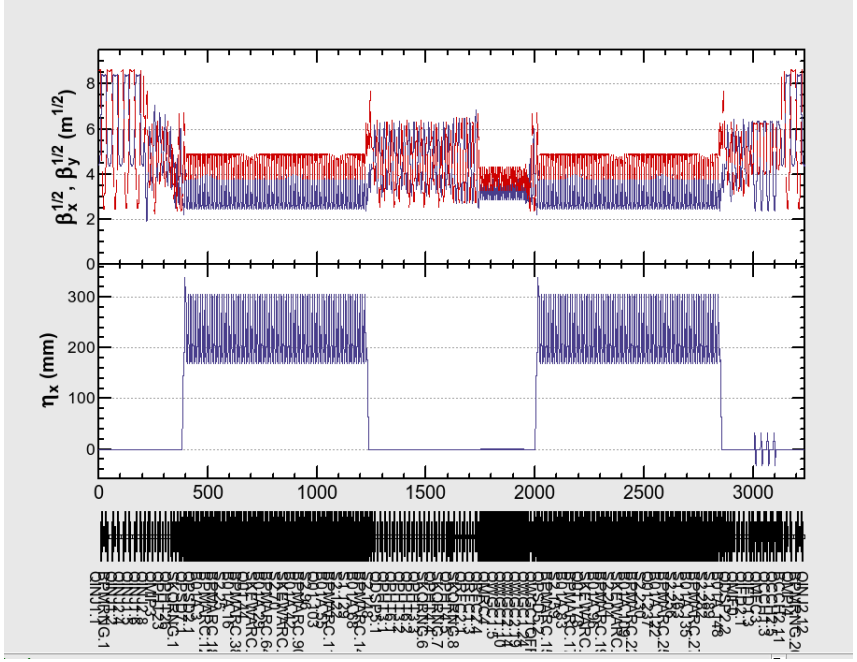


Optics of Whole Ring

Original



New (long bend)



	Original	New (stronger focus)	New (long bend)
Horizontal normalized Emittance (um)	5.74, 6.27 (IBS)	3.22, 4.00(IBS)	3.14, 3.97 (IBS)
Tune x/y	48.26/26.76	57.79/26.46	49.33/26.86
phase adv./cell /2pi x/y	0.21891 /0.08098	0.2788 /0.08	0.2250 /0.0808
Damping time x/y/z (ms)	23.9/23.9/11.9	23.9/23.9/11.9	25.5/25.5/12.8

For new designs, emiitance is adjusted as ~4 um.

Some surveys of phase advances/cell and total tunes were performed, for good dynamic aperture. (Surveys were not complete.)

Dynamic aperture and emittance

- Stronger focus makes emittance smaller, but need stronger sextupoles and reduce dynamic aperture.
- Dynamic aperture in TDR is already tight compare with assumed injection positron beam quality.

(positron beam quality was determined by DR aperture?)

TDR: “In practice, the dynamic aperture shrinks as the focusing strength is increased”

Proceedings of IPAC2011, MOOCA03 “UPDATES TO THE INTERNATIONAL LINEAR COLLIDER DAMPING RINGS BASELINE DESIGN” Susanna Guiducci,et.al.: “There is some flexibility to vary emittance and momentum compaction by adjusting the arc cell focusing, but typically this comes at the expense of dynamic aperture.”

Dynamic Aperture calculation

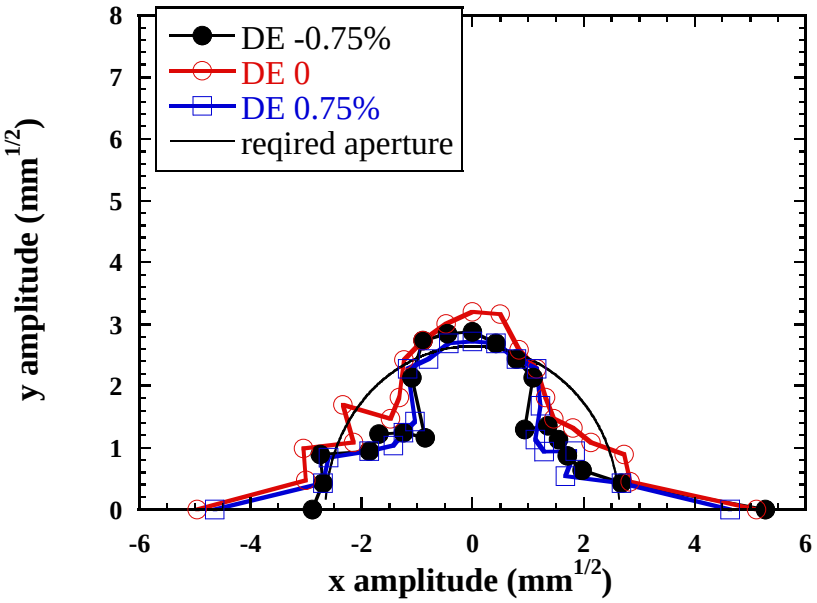
Tool prepared in SAD

- Set initial orbit and energy deviation and perform tracking
- Survived in 1000 turns tracking → “accepted”
- No special treatment of wiggler’s magnetic field.

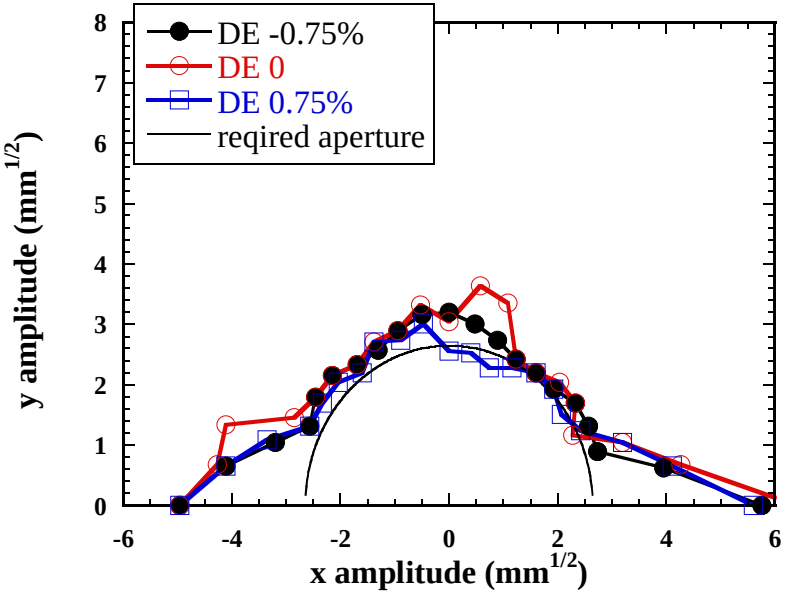
Aperture with original arc cell

(Tune surveyed roughly)

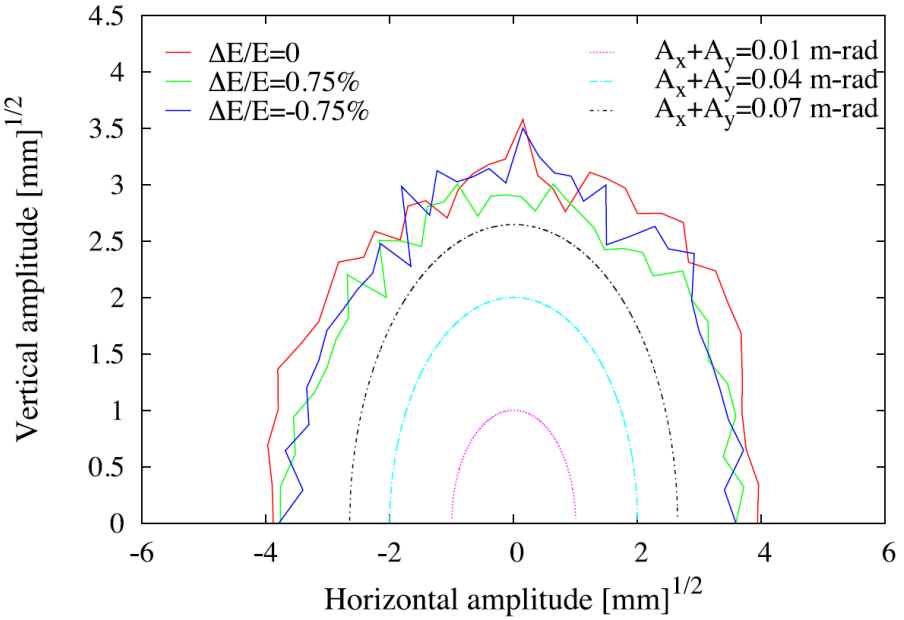
Original
Tune x 48.2643 y 26.7628



Original cell, change tunes
Tune x 48.14 y 26.68



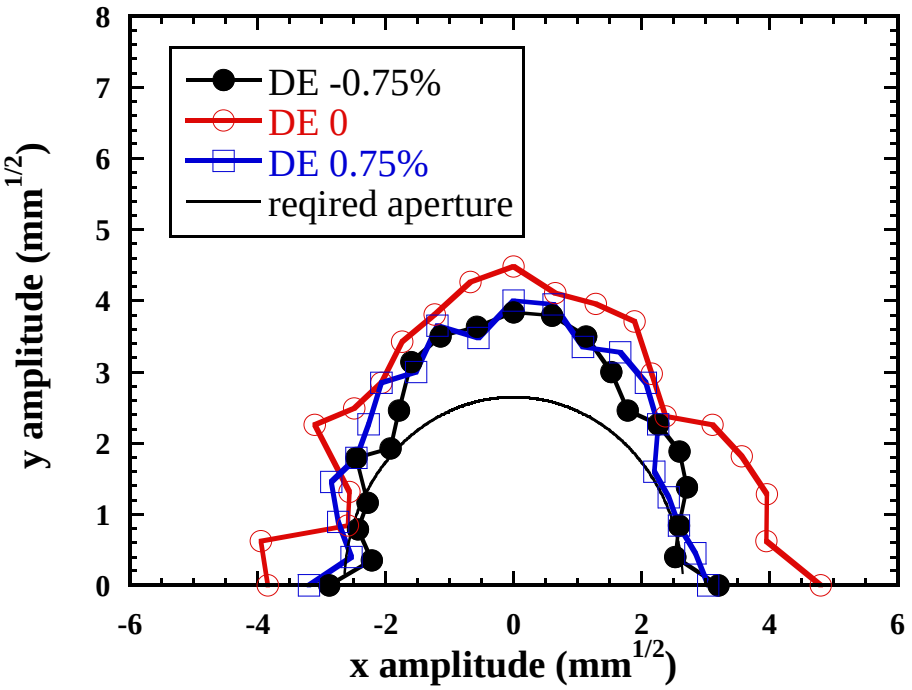
Dynamic Aperture in TDR



Dynamic aperture in TDR cannot be reproduced.. ??

Dynamic aperture: stronger focus

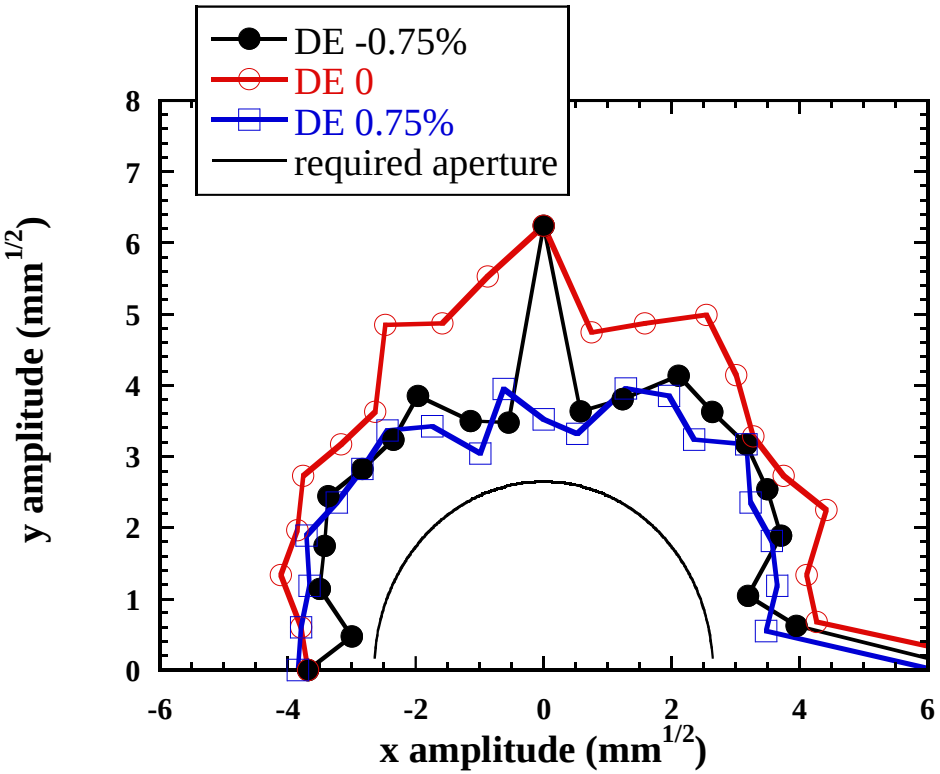
New arc cell: stronger focus
tune/cell: x.2788 y.0800
Tune: x 57.79 y 26.46



Horizontal aperture significantly reduced.

Dynamic aperture: long bend

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

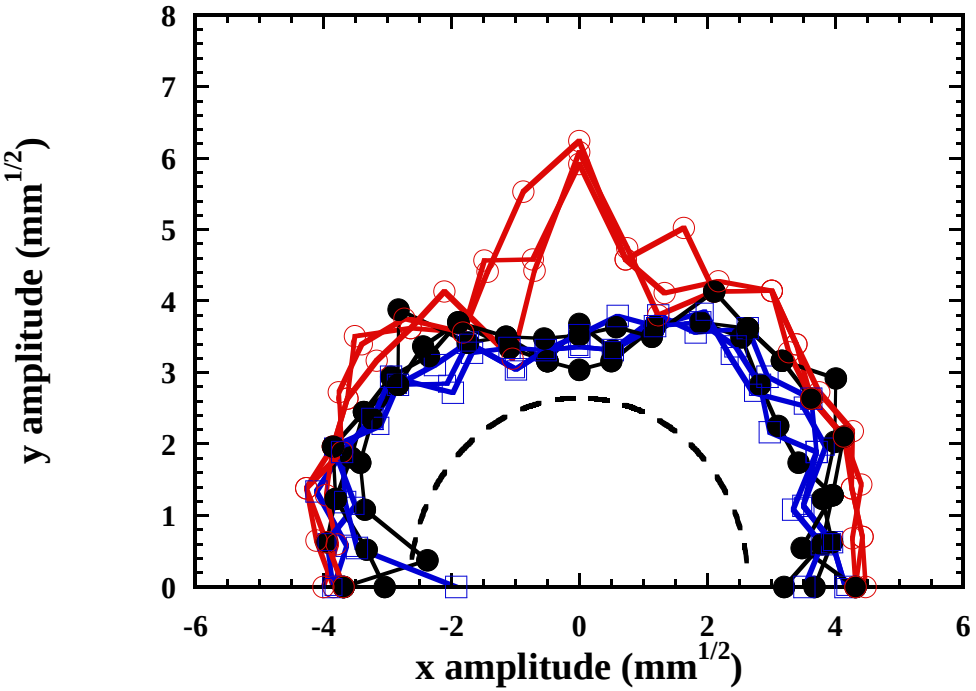


Aperture is larger than requirement

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



These errors are not important for dynamic aperture.

Summary & Discussion

- Electron cloud will not be an issue. (very rough estimation)
- Easy way to reduce emittance, keeping dynamic aperture, is using longer bending magnets in arcs.
  - E.g., 3 m → 5 m (any problems with long bend?)
  - Horizontal emittance 4 um seems possible
- Dynamic aperture of original lattice in past paper(s) could not be reproduced.
- Stronger focusing (for lower emittance) reduces dynamic aperture.
- Low emittance with larger dynamic aperture may be possible with major changes of design. (not studied here)
  - More wigglers
  - Stronger focus of more sophisticated optics deign (like Hybrid Multi Bend Acrhomat in new generation light sources ?)