CLIC combiner ring lattice and stability

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Drive beam

Rf production

- **High charge**
- **Short bunches**
- **Short spacing**

CTF3 must demonstrate drive beam characteristics feasibility

CTF3 versus CLIC drive beam parameters

	CTF3	CLIC
Energy (GeV)	0.15	1.79
Bunch charge (nC)	2.3	9.6
Average final current (A)	35	144
Train final duration (nsec, m)	140 , 42	55.6 , 17
Bunch final separation (nsec)	0.067	0.067
N bunches/train	2100	834
Bunch length (ps, mm)	3.4 , 1	1.3 , 0.4
Peak current (A)	700	7400
Linac frequency (MHz)	2999	937
Pulse length (total train) (μs)	1.40	92
F Multiplication Factor	2 x 5	2 x 4 x 4

Main challenge for CTF3

From beam dynamics point of view

Low energy and high current bunches manipulation

With emittance preservation in 3D

Path length control

Alignment
Dipole modelling
Wiggler

CSR
↓
Increase energy spread
↓
increase of bunch length
↓
lost of isochronicity
↓
lost of peak power

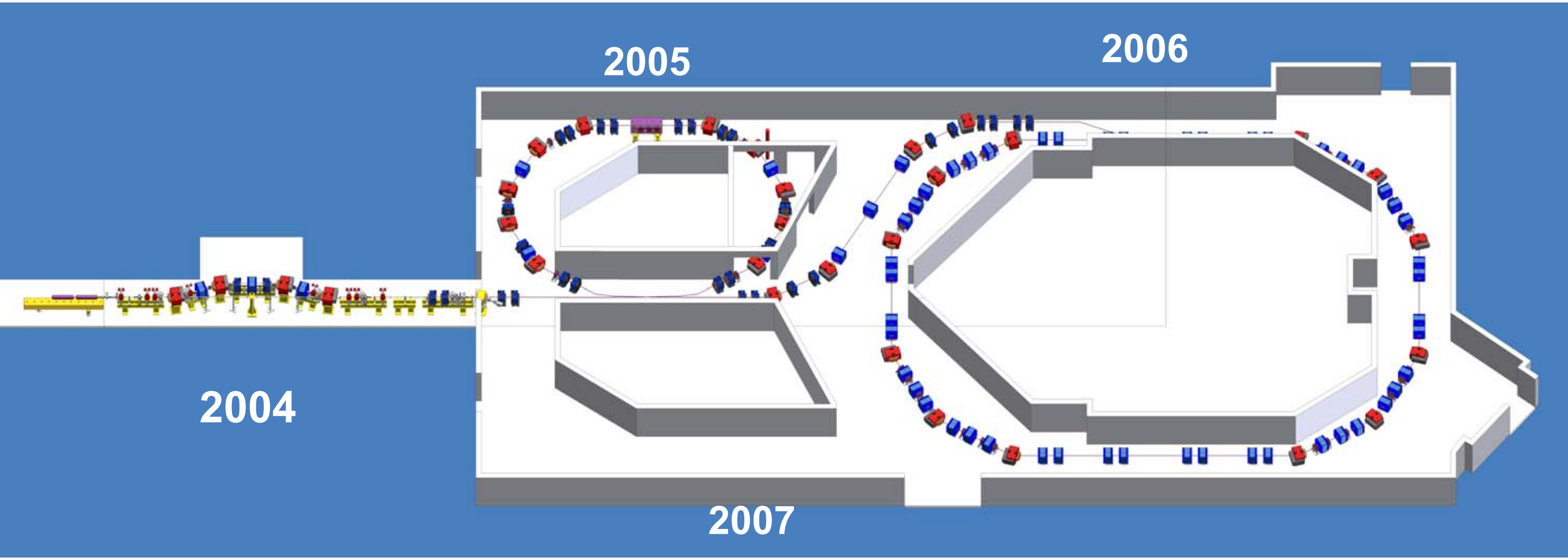
cures

stretcher before and compressor after the frequency multiplication

smooth linear optics

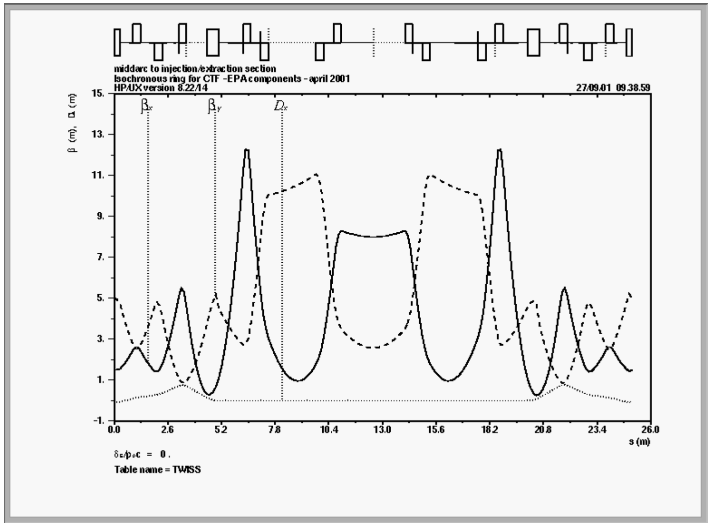
adequate sextupole compensation

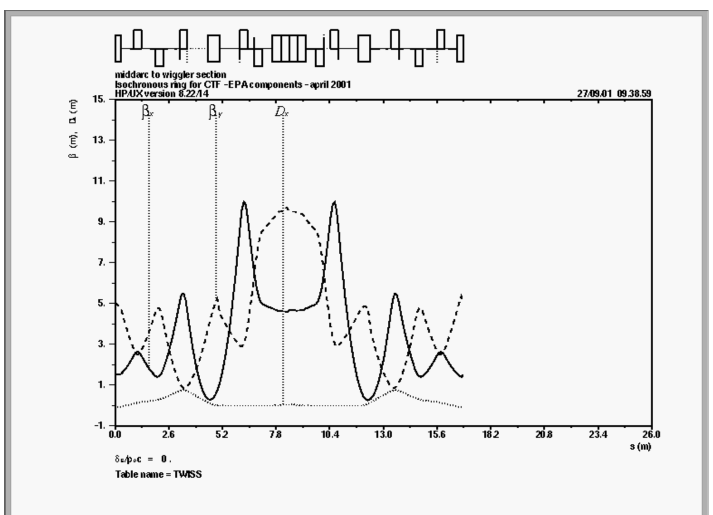
CTF3 frequency multiplication system layout



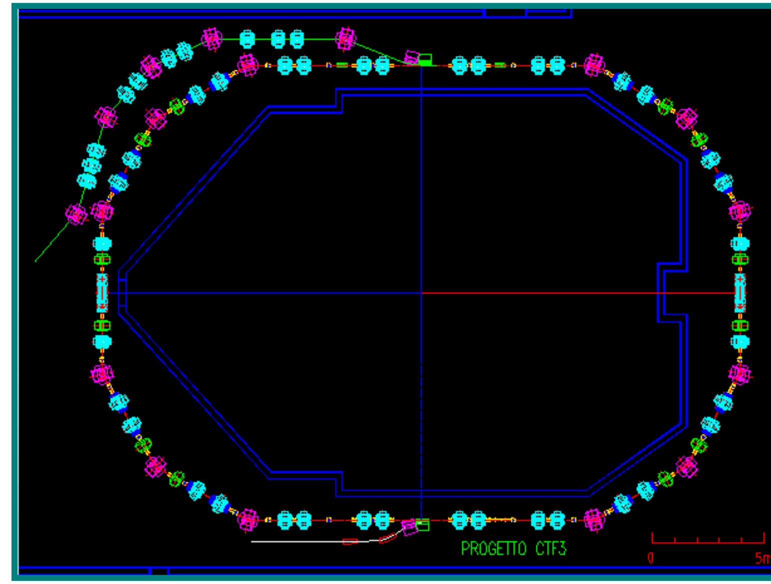
CTF3 - COMBINER RING

Injection/extraction sections





Wiggler sections

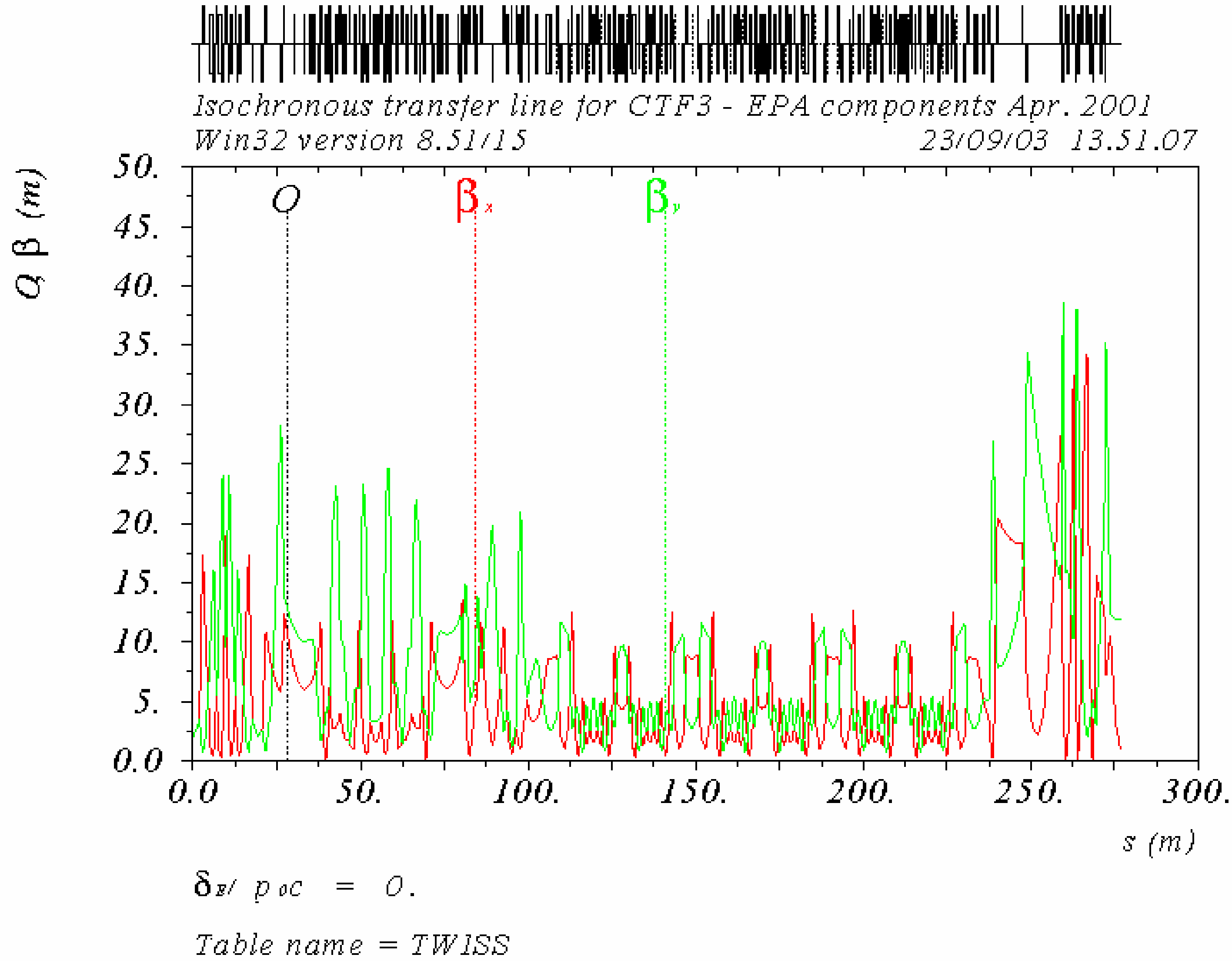


Isochronicity and achromaticity in each arc of the ring

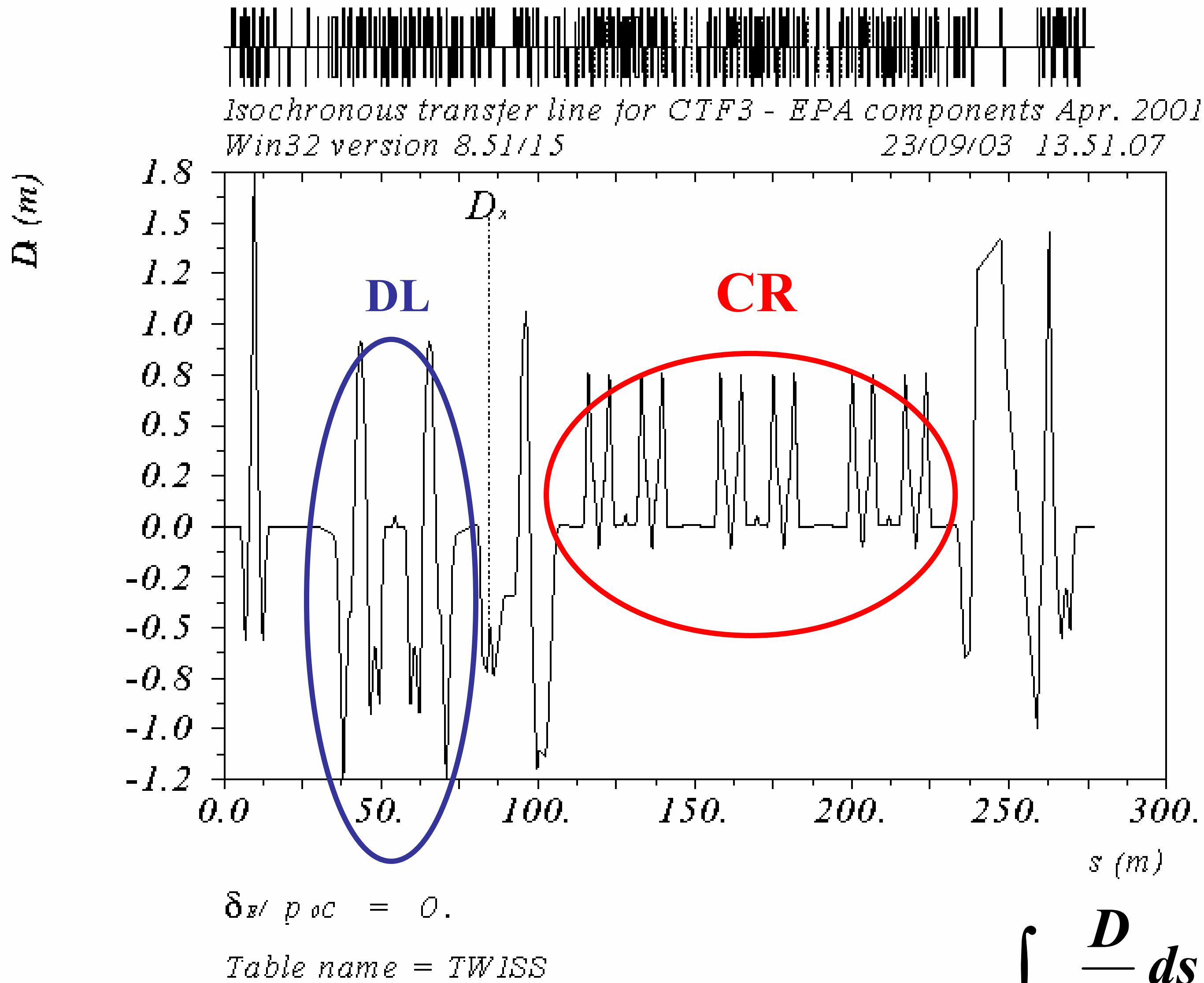
π phase advance between rf deflectors

Wigglers for path length tuning

From Linac to CR extraction



Dispersion



$$\int_{dipoles} \frac{D}{\rho} ds$$

2[nd] order isochronicity: $T_{5i6} = 0 \;\forall i$

$$ct = (ct)_{0+} R_{56}\frac{\Delta p}{p} + T_{516}\, x_0 \frac{\Delta p}{p} + T_{526}\, x_0' \frac{\Delta p}{p} + T_{536}\, y_0 \frac{\Delta p}{p} + $$
$$+ T_{546}\, y_0' \frac{\Delta p}{p} + T_{556}\, (ct)_0 \frac{\Delta p}{p} + T_{566} \left(\frac{\Delta p}{p}\right)^2$$

2[nd] order terms

relate transverse to longitudinal phase planes

Contribution of Transfer Lines high order terms can be as strong as rings'

FLEXIBILITY in the design is essential

Energy spread coming from the LINAC :

* **stretches the bunches**
(possibility of increasing R_{56} in stretcher up to ~30-40 cm in order to reduce the necessary $\Delta p/p$ for obtaining the 2mm long bunches)

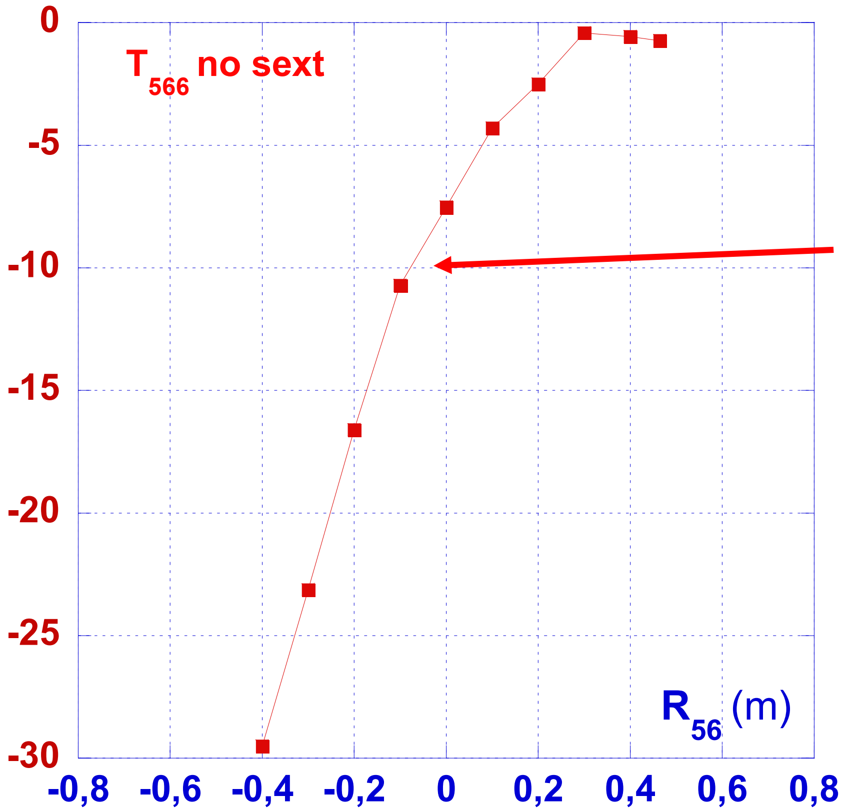
* **produce emittance filamentation**

For a given R_{56}:
Small T_{566} by small dispersion -> high betatron functions -> horizontal transverse plane more critical

Low betatron functions -> higher dispersion -> longitudinal plane more critical

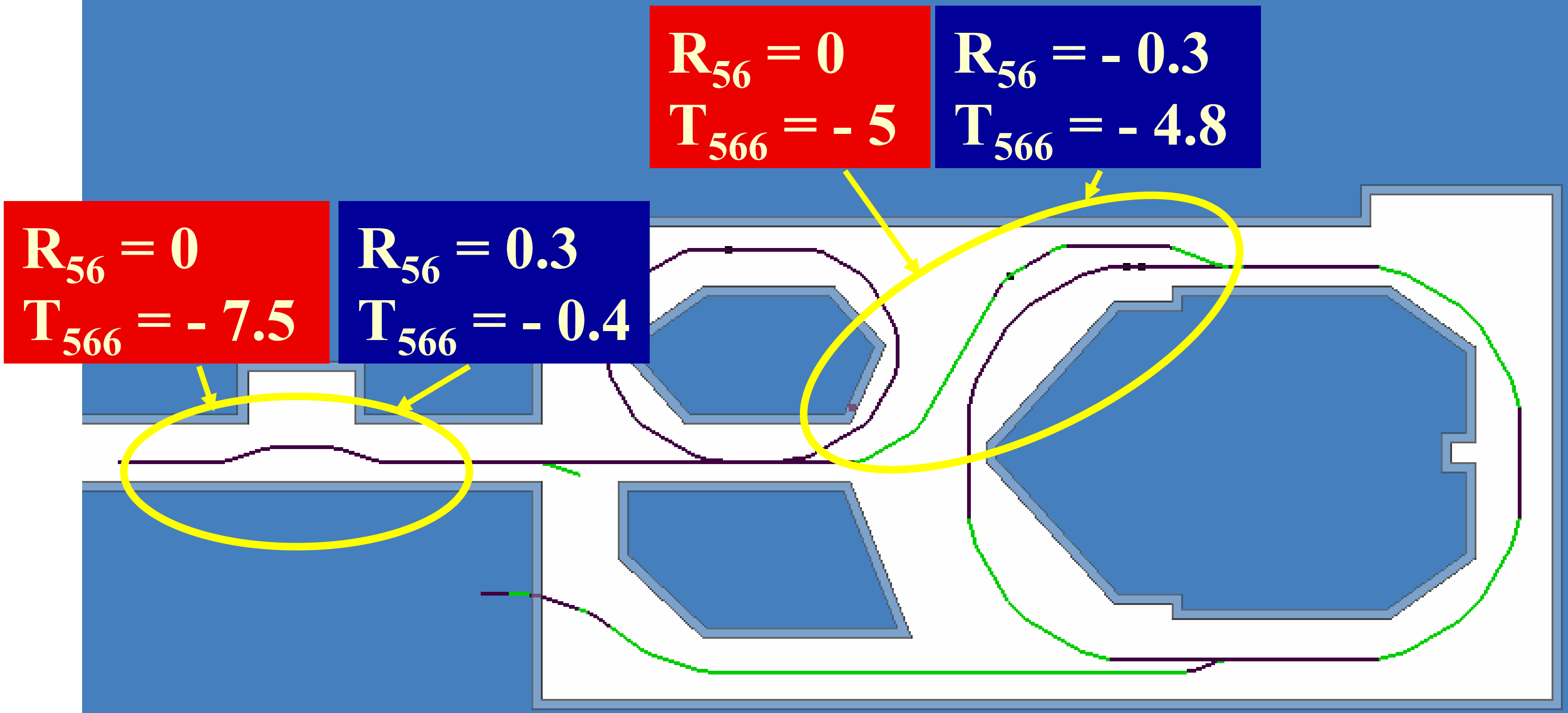
2^{nd} order term depends on the linear optics configuration

Example : Stretcher - compressor



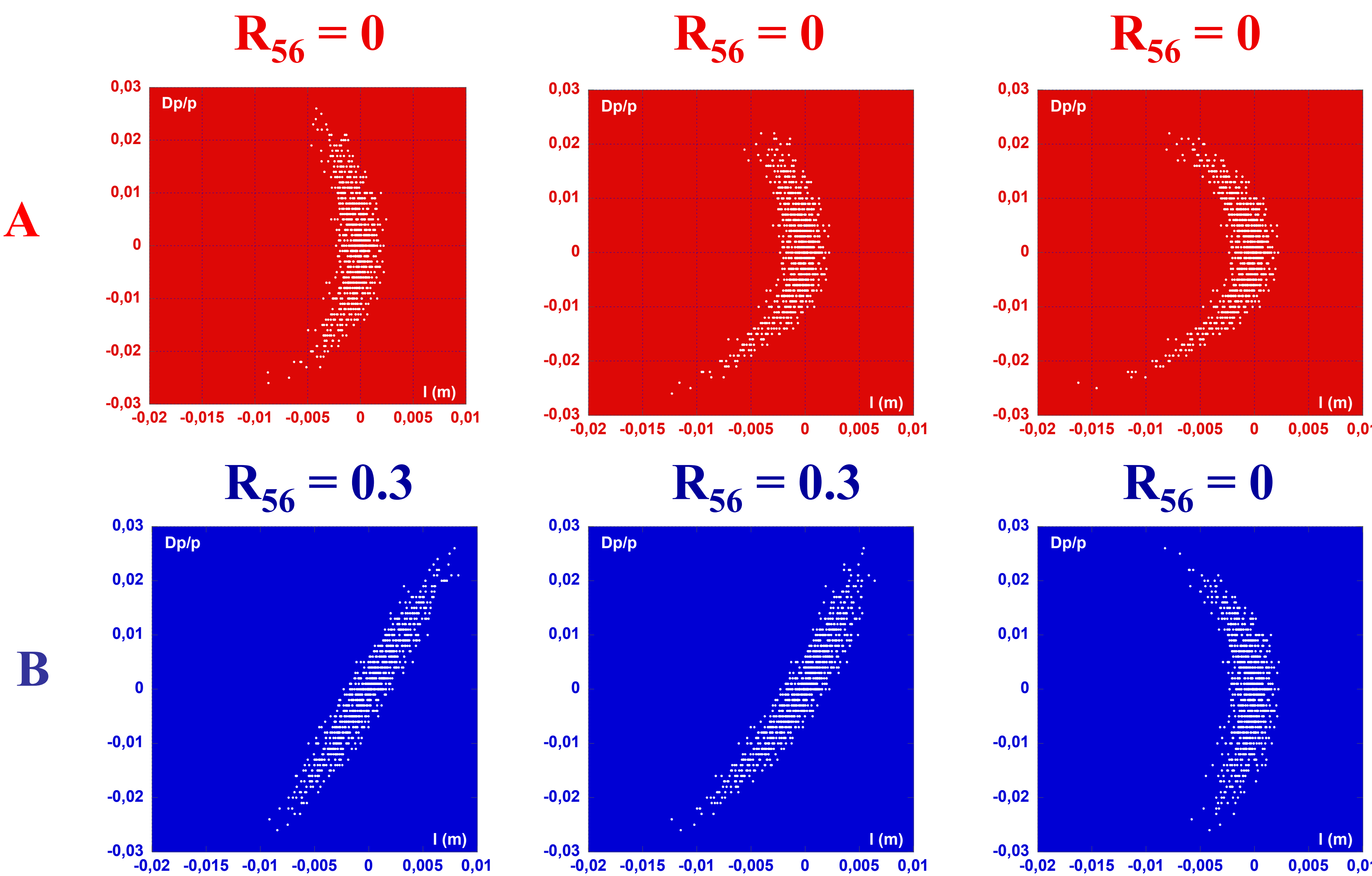
Dp/p = 1% => DL = 1 mm

Global optimisation



Stretcher + TL (DL -> CR)

R_{56} = 0.	R_{56} = 0.
T_{566} = - 12.5	T_{566} = - 5.2



After the stretcher **After the DL** **At CR input**

$\sigma_L = 1$ mm $\Delta p/p = 1\%$

CSR effect in CTF3

The energy losses give rise to relative phase errors between bunches through non-perfect ring isochronicity, which result in deterioration of the timing both among individual bunches and merging trains. The energy spread, in turn, leads to bunch lengthening and phase space distortion.

The energy spread due to CSR is $\Delta E = \pm 0.9$ MeV,

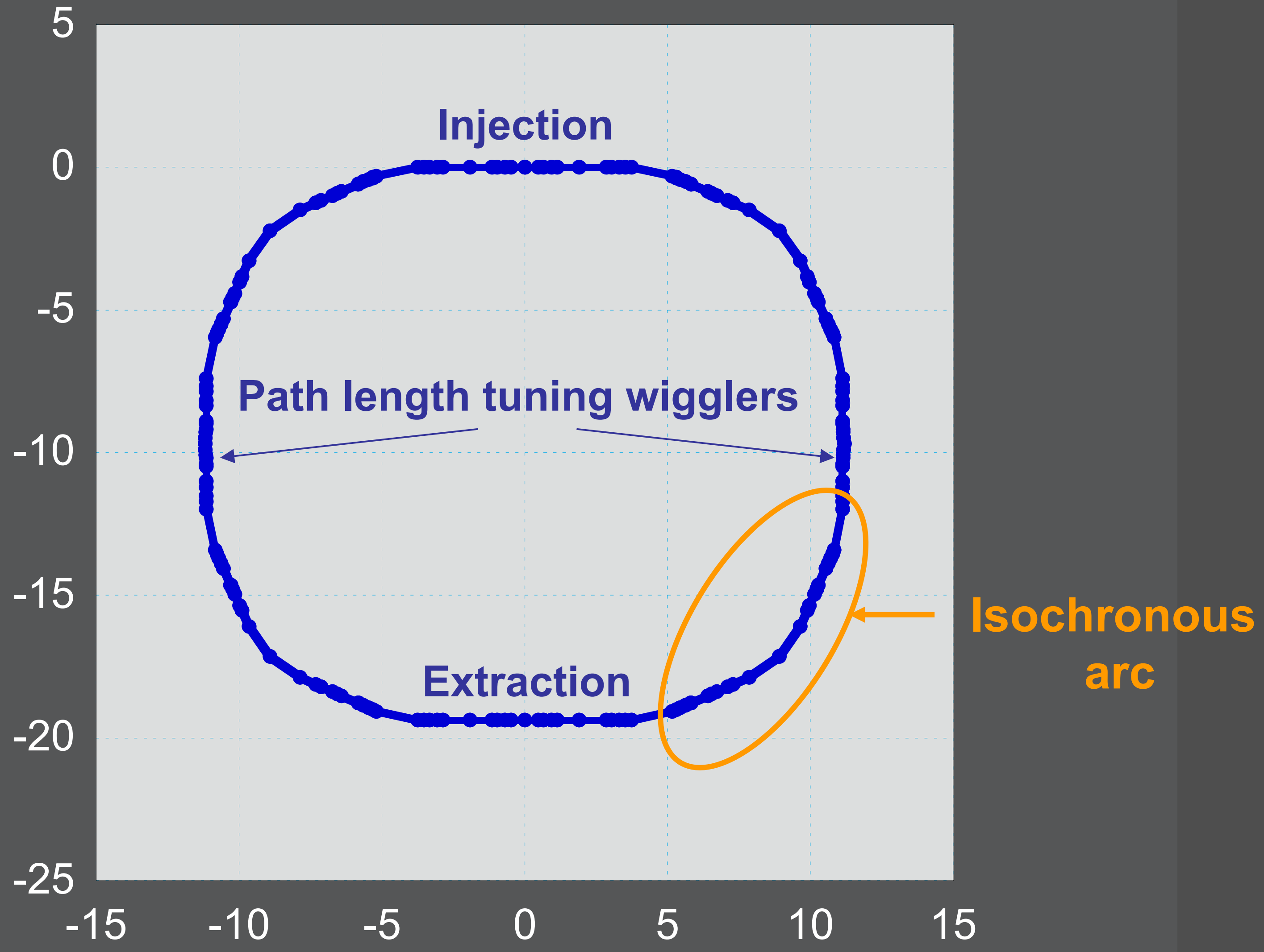
or $\Delta E/E \sim \pm 0.5\%$ for a 2 mm long bunch.

It is not reasonable to have bunches shorter than 2 mm in the CR since the energy spread grows rapidly with the bunch length (faster than $\sim \sigma^{-4/3}$). The energy spread for a 1 mm long bunch would exceed the acceptable value of $\Delta E/E = \pm 1\%$.

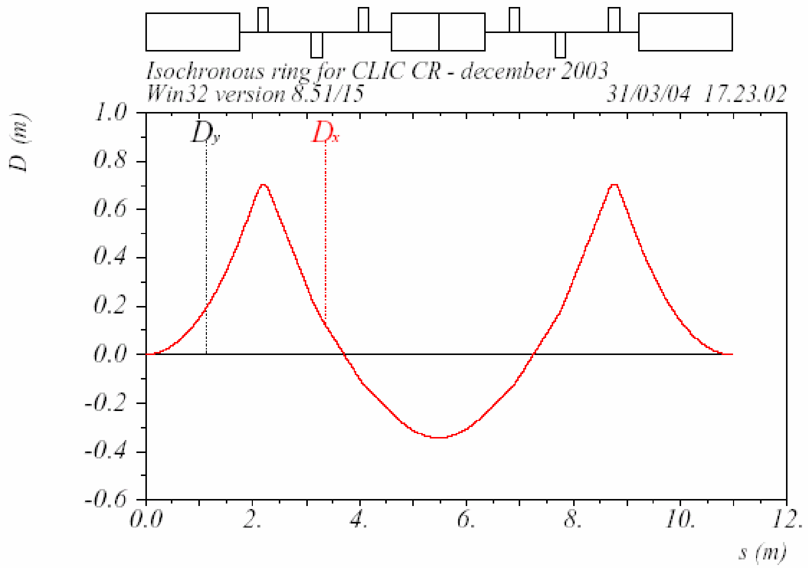
CLIC Drive Beam

- Higher energy (x 15)
- Higher current (x 4)
- No constraints (up to now) on layout and magnet characteristics
- Design based on CTF3 one

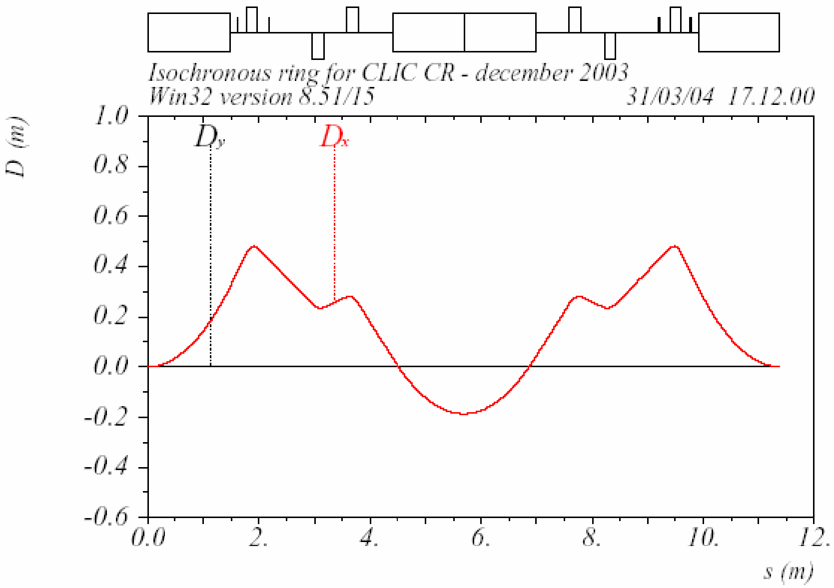
CLIC COMBINER RING



C = 70 m

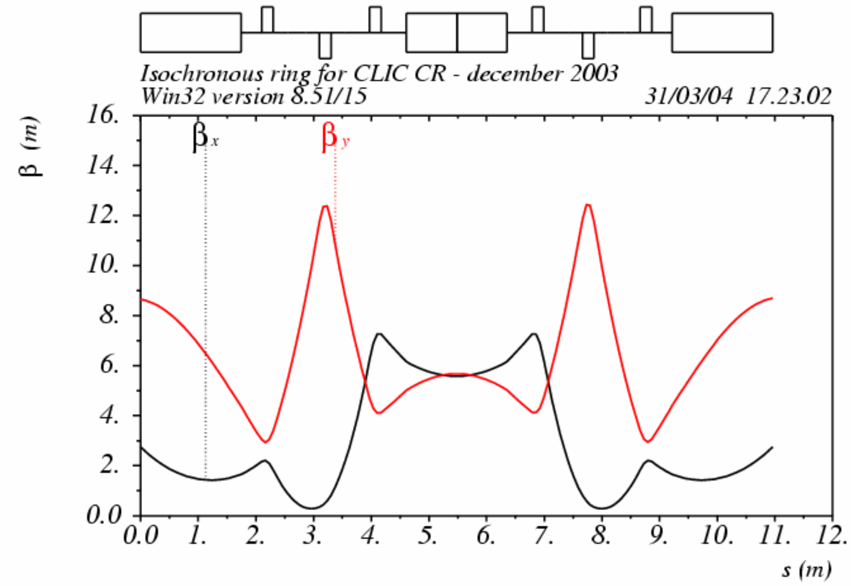


Following CTF3 design:
Three equal dipoles
(30°, 30°, 30°)
D_x max = 0.7 m
T_{566} = -9

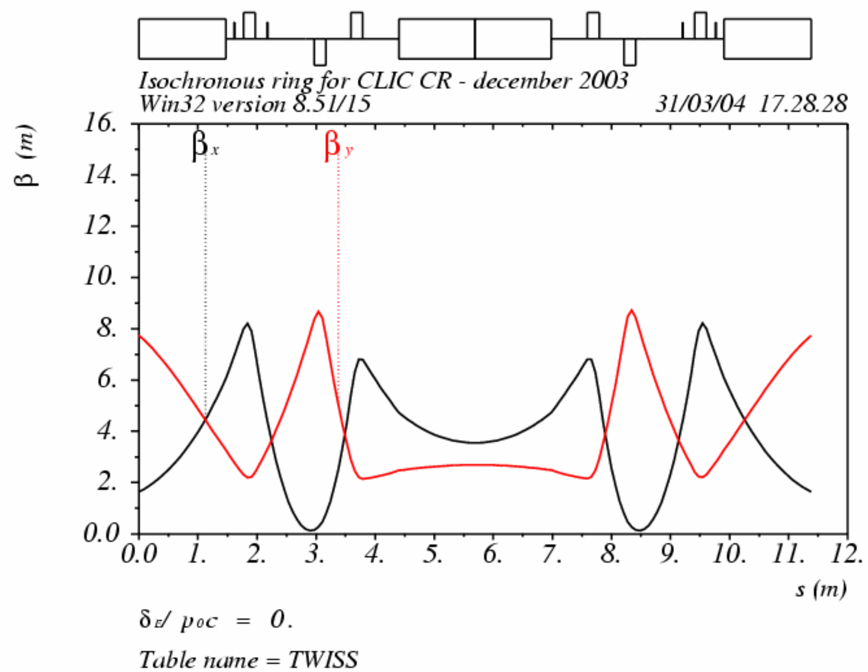


Longer central dipole
(24°, 42°, 24°)
D_x max = 0.5 m
T_{566} = -4

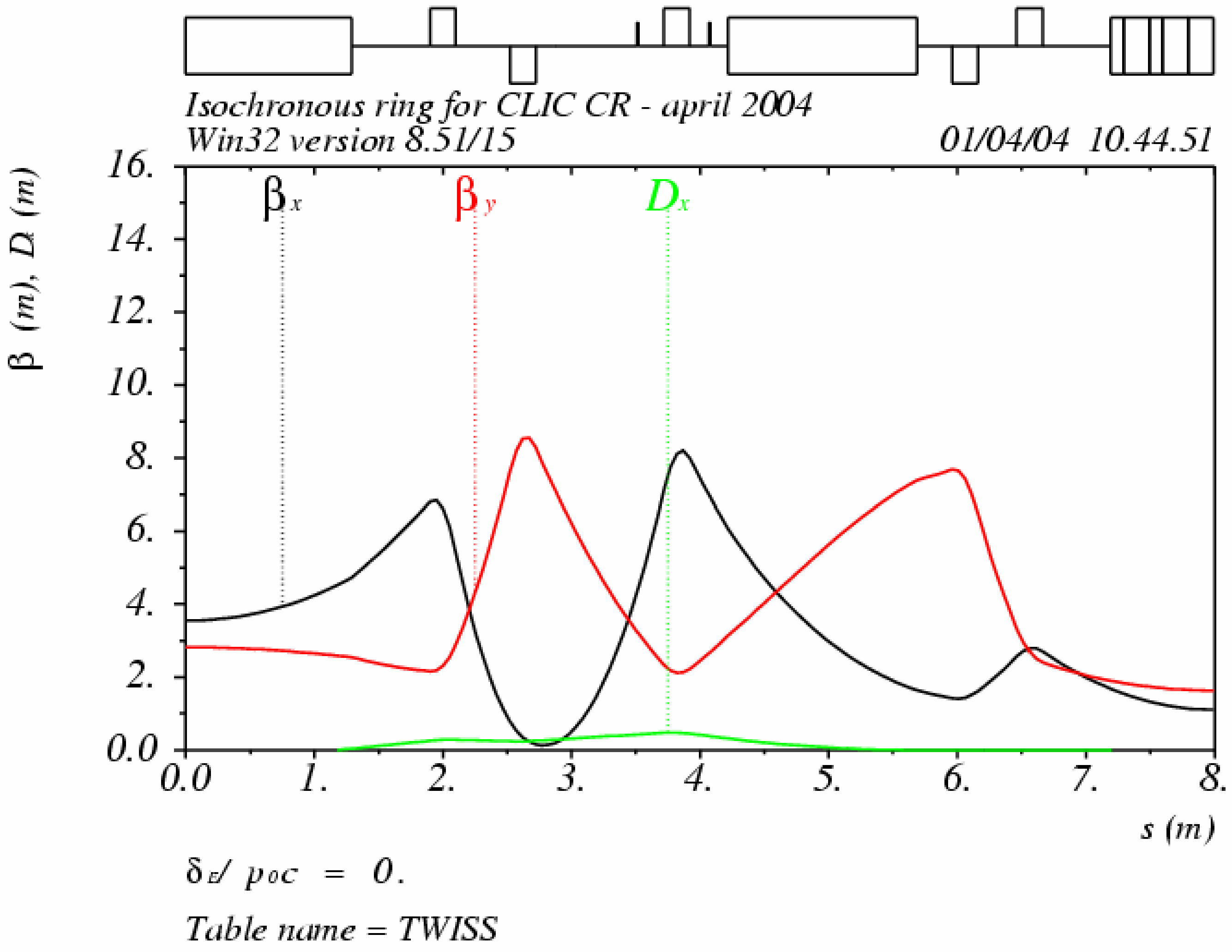
Arc betatron functions



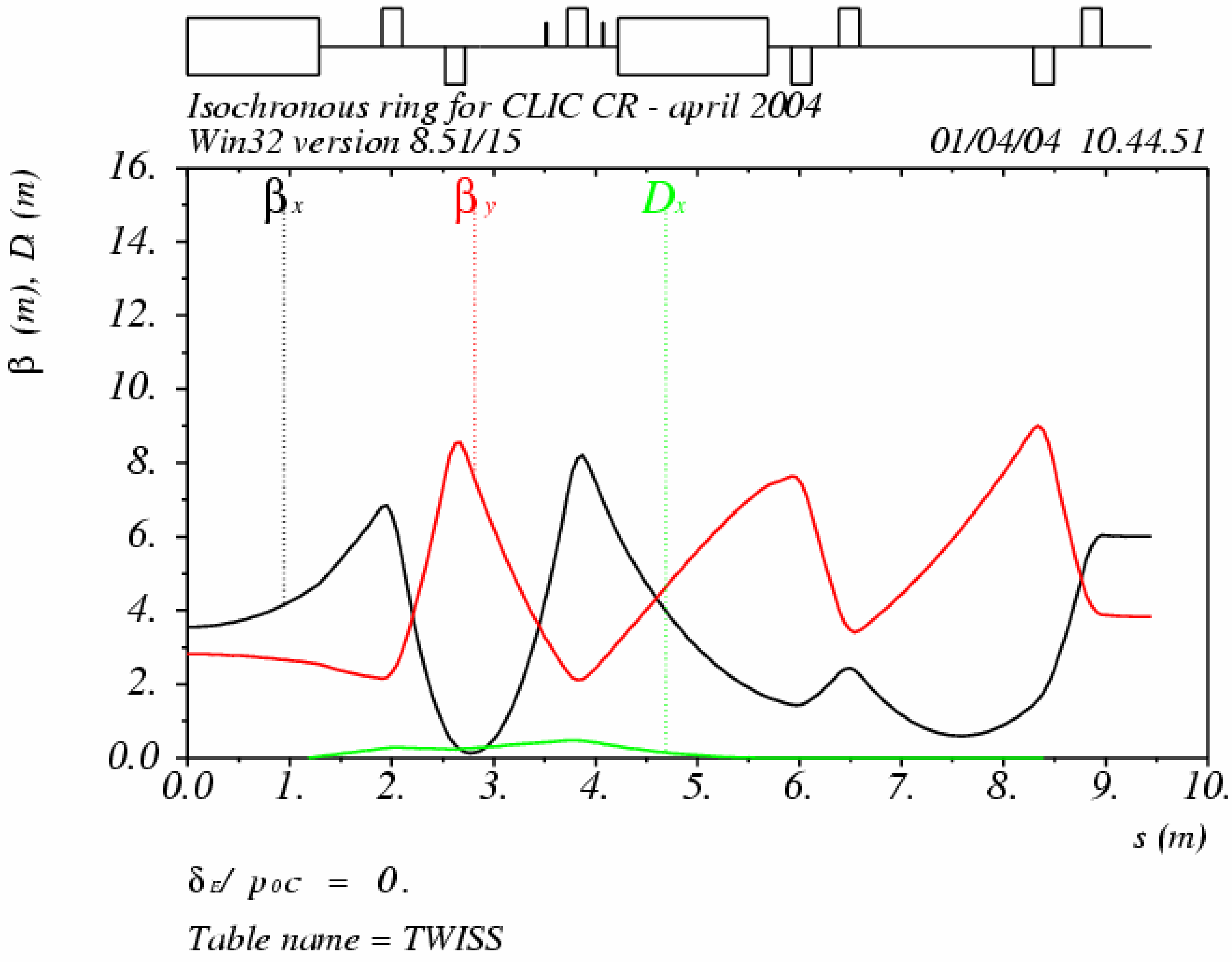
Three equal dipoles



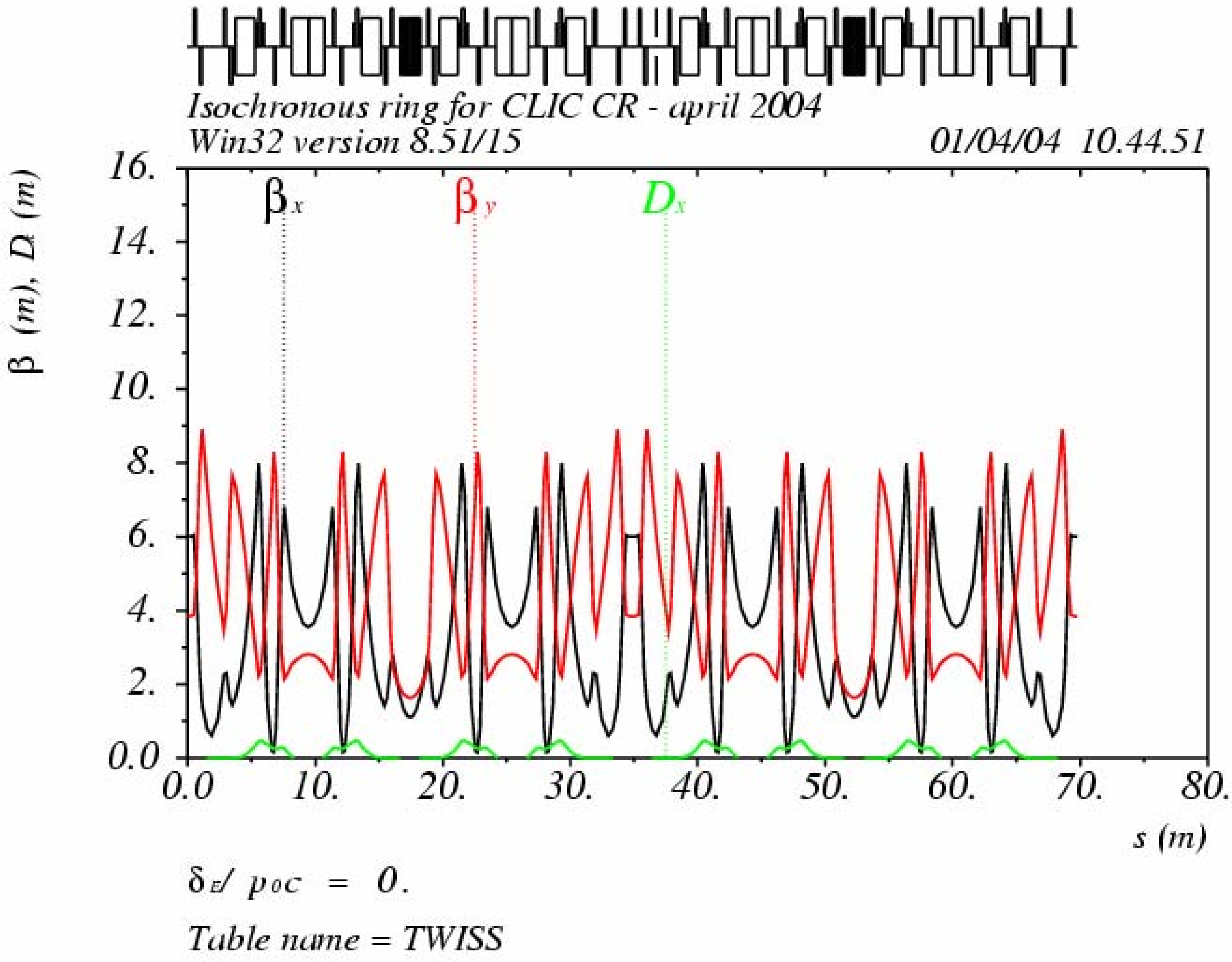
Longer central dipole



Arc to wiggler center



Arc to injection/extraction

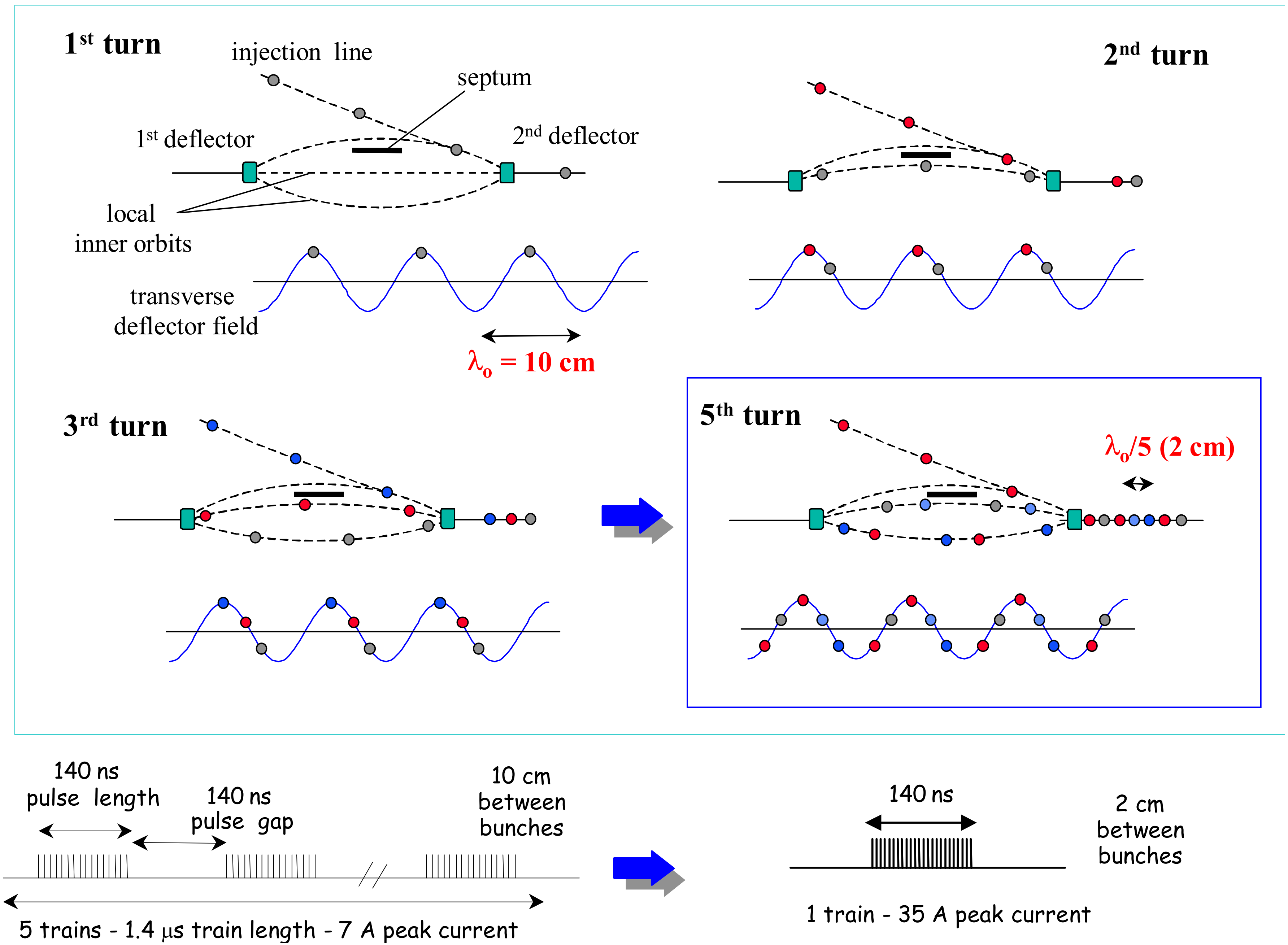

Isochronous ring for CLIC CR - april 2004
Win32 version 8.51/15
01/04/04 10.44.51
β (m), D (m)
βx
βy
Dx
16.
14.
12.
10.
8.
6.
4.
2.
0.0
0.0
10.
20.
30.
40.
50.
60.
70.
80.
s (m)
δE/ p0c = 0.
Table name = TWISS

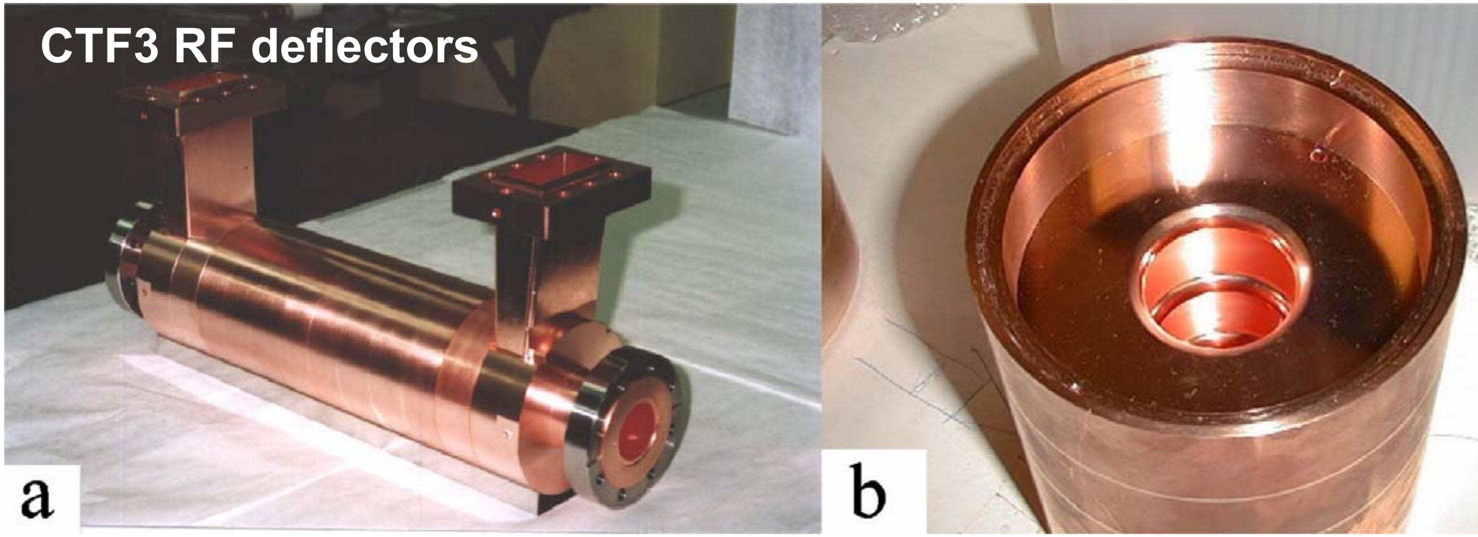
Total ring

Main ring parameters

C (m)	70.
E (GeV)	1.9
B (T)	1.8
β_x max (m)	8
β_y max (m)	9
D_x max (m)	0.47
R_{56} (m)	0.0
T_{566} (m) sext off	- 4.0
N quads	48
N sext	16 to 24

Effect of beam loading in RF DEFLECTORS on beam dynamics Applied to CTF3 case


1st turn
injection line
septum
1st deflector
2nd deflector
local
inner orbits
transverse
deflector field
λo = 10 cm
2nd turn
3rd turn
5th turn
λo/5 (2 cm)
140 ns
pulse length
140 ns
pulse gap
10 cm
between
bunches
5 trains - 1.4 μs train length - 7 A peak current
140 ns
2 cm
between
bunches
1 train - 35 A peak current



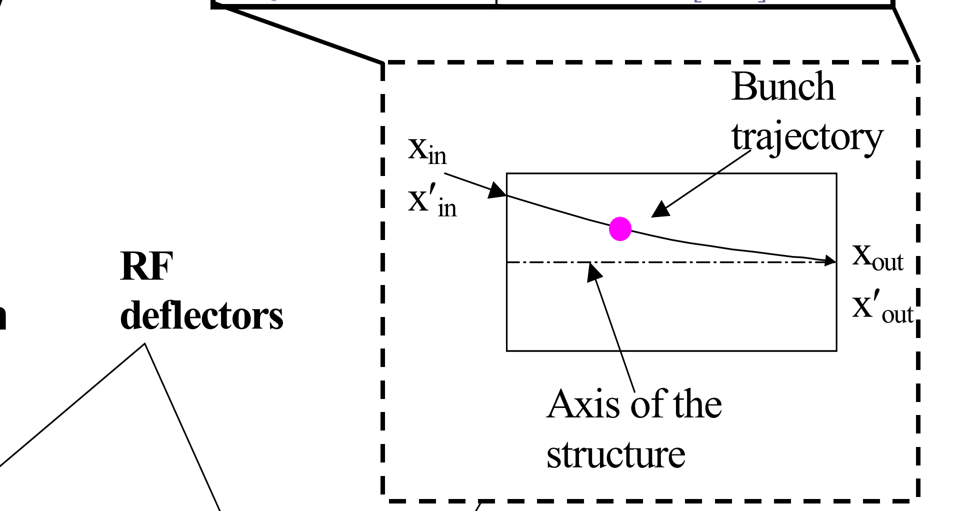
Frequency	**2.99855 [GHz]**
Cell length	**33.33 [mm]**
Cell radius	**56.01 [mm]**
Iris internal radius	**21.43 [mm]**
Iris thickness	**9.53 [mm]**
Number of active cells	**10**
Deflector length	**33 [cm]**
Filling time	**47 [ns]**
r_s/Q	**1425 MΩ/m**
Input power (P_{in})	**2 MW**
Deflection	**5 [mrad]**

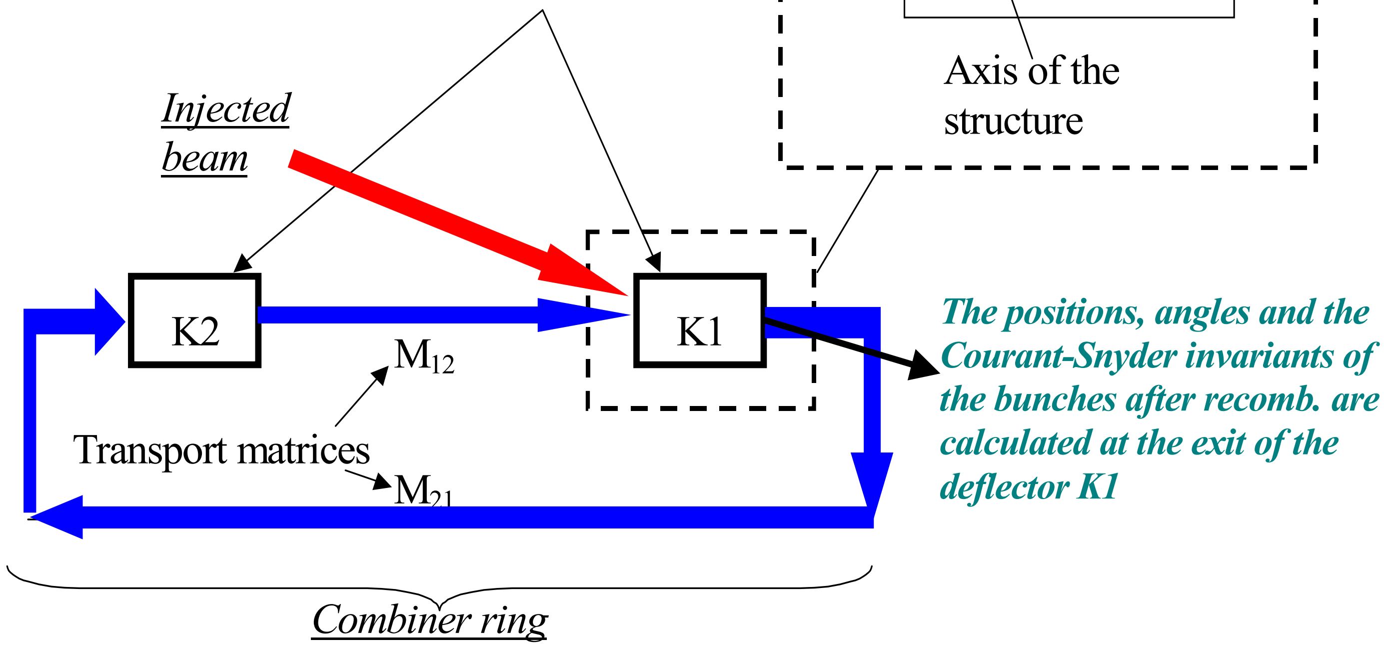
TRACKING CODE SCHEME

Each bunch, represented as a macroparticle, enters the 1st deflector with some horizontal initial conditions (xin,x'in), interacts with both the main RF deflecting field and the wake left by the bunches ahead, contributes to the wake and exits from the deflector with some new horizontal conditions (xout, x'out). It is then transported to the other deflector by the transport matrix M_{21}, interacts with the RF field and wakes of this second device and so on

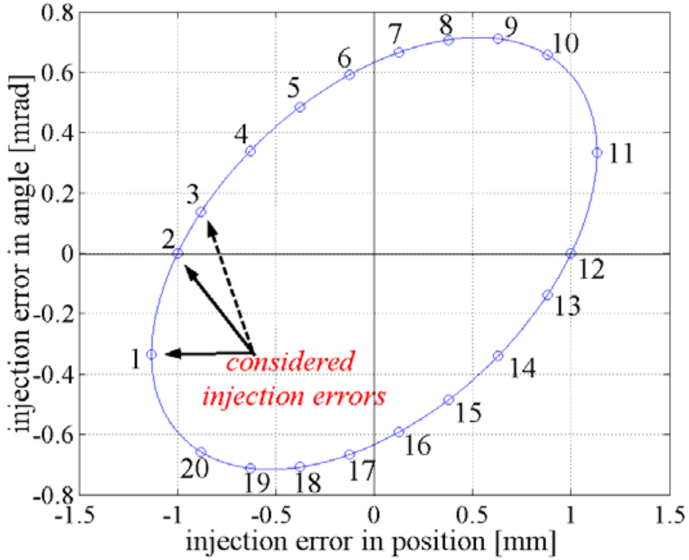
DEFLECTORS PARAMETERS

Deflector length (L)	0.33 [m]
Group velocity (v_g)	0.0244*c (c=velocity of light)
R/Q	1300 [Ω/m]



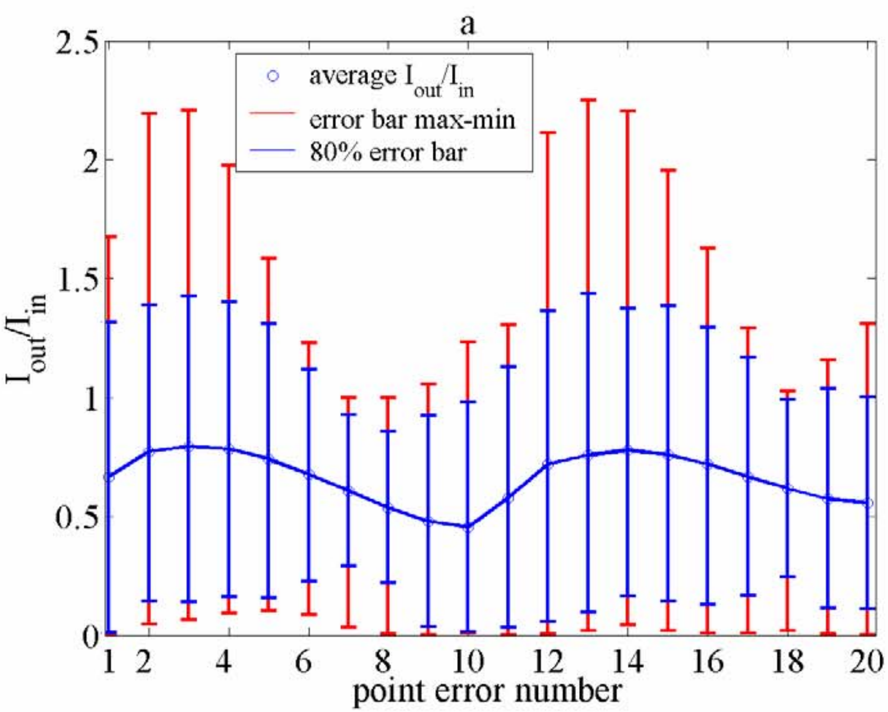


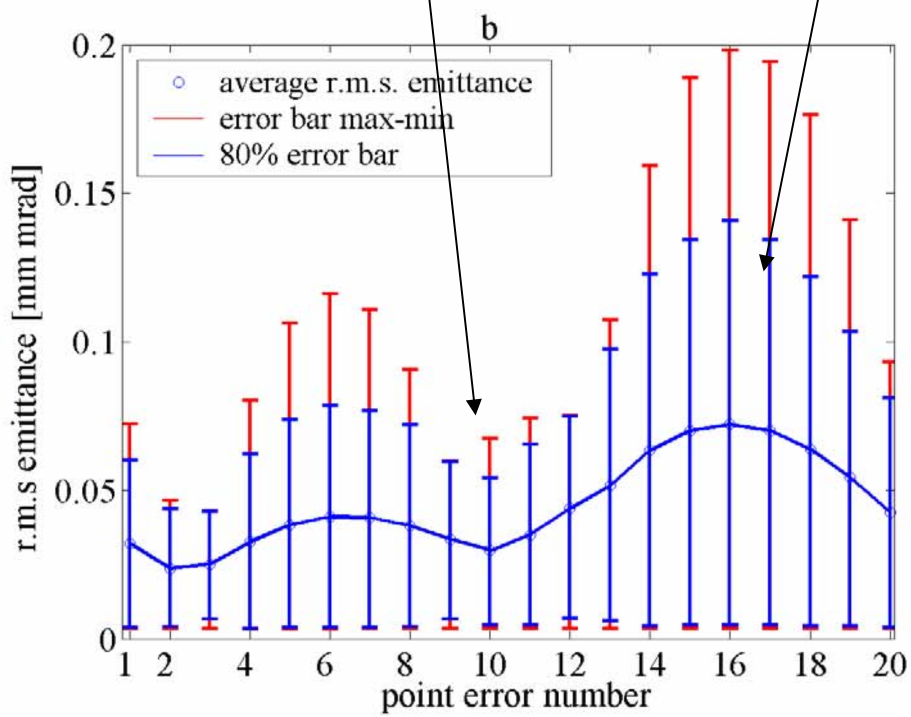
injection errors scan



Position errors

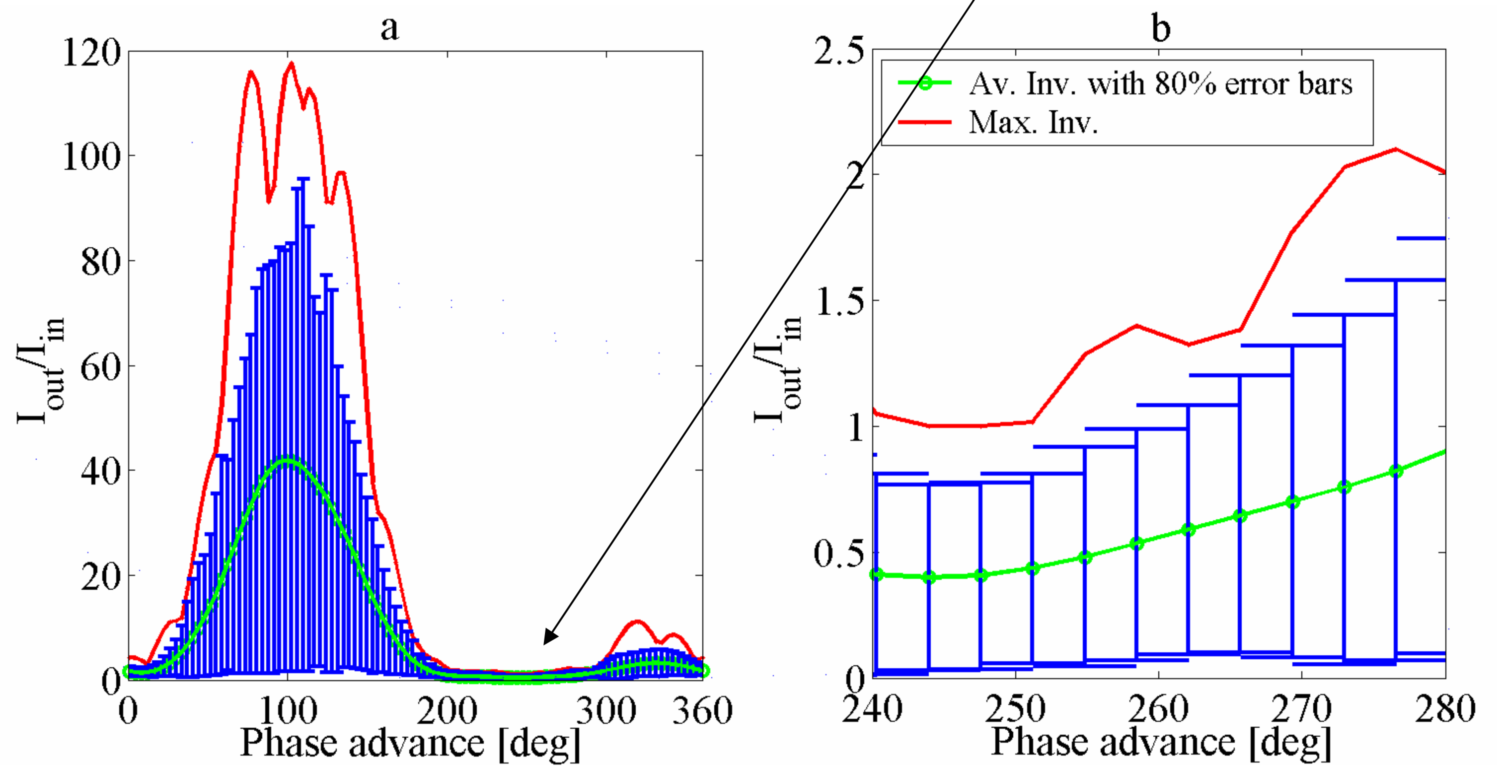
Angle errors





tune dependence
(fixed injection error)

Around nominal CTF3 working point



Beam loading at RF deflectors

- the beam emittance growth due to the wake field in the RF deflectors is negligible if the trains are injected perfectly on axis
- in case of injection errors the final emittance growth depends strongly on the betatron phase advance between the RF deflectors. It can be negligible with the appropiate choice for phase advance, with large tolerance
- simulations taking into account the finite bunch length shows that the scenario does not change for the central part of the bunches with respect to the case of zero bunch length. However, for some particular injection errors, the bunch tails can contribute to the increase of the total transverse bunch emittances.