# Revised optics


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*LNF, INFN, Frascati*



**CTF3 Collaboration meeting, Sept-Oct 2003**

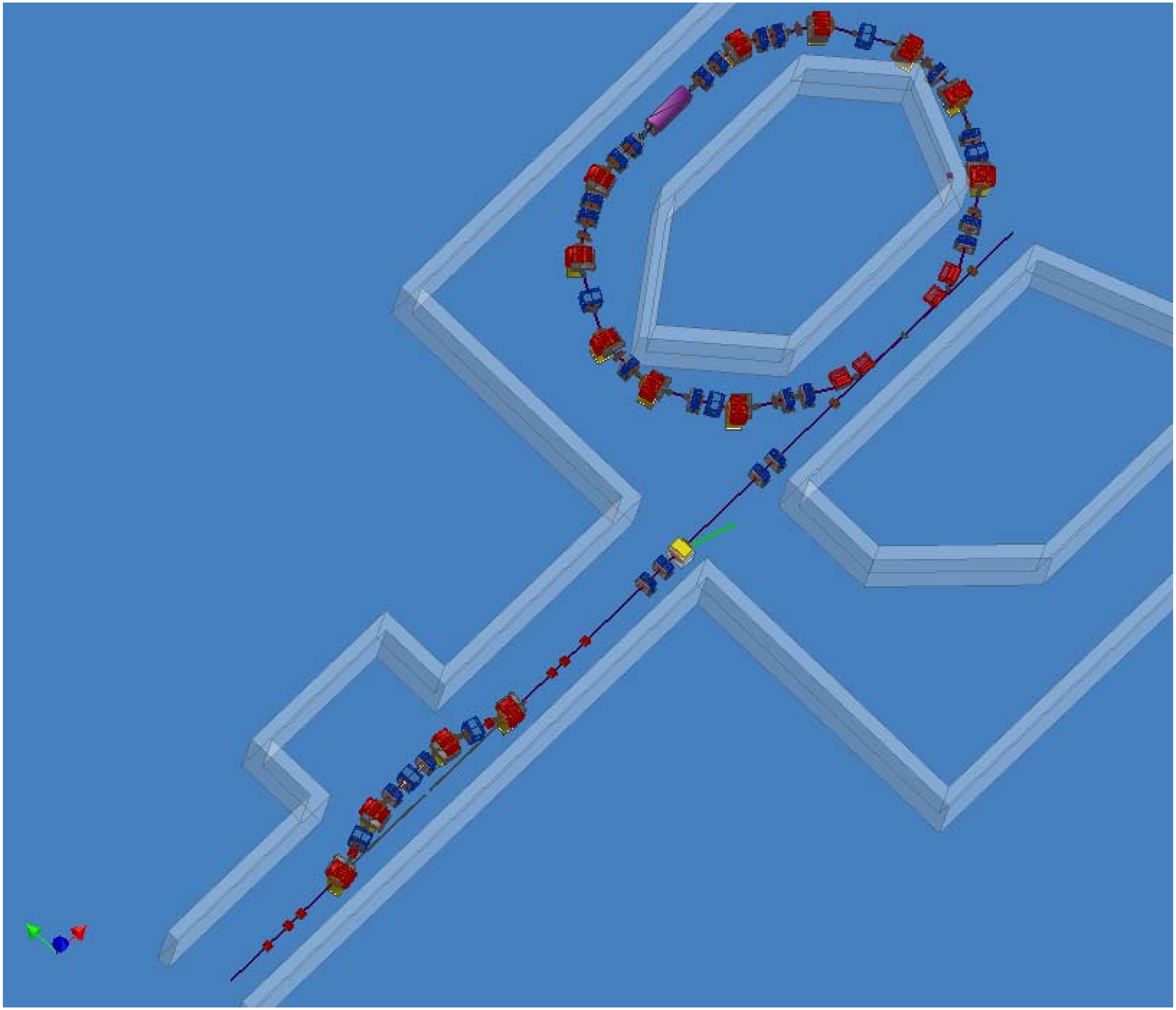
# Last review

## $7^{th}$ CLIC/CTF3 Meeting - June 2002

- CR before DL

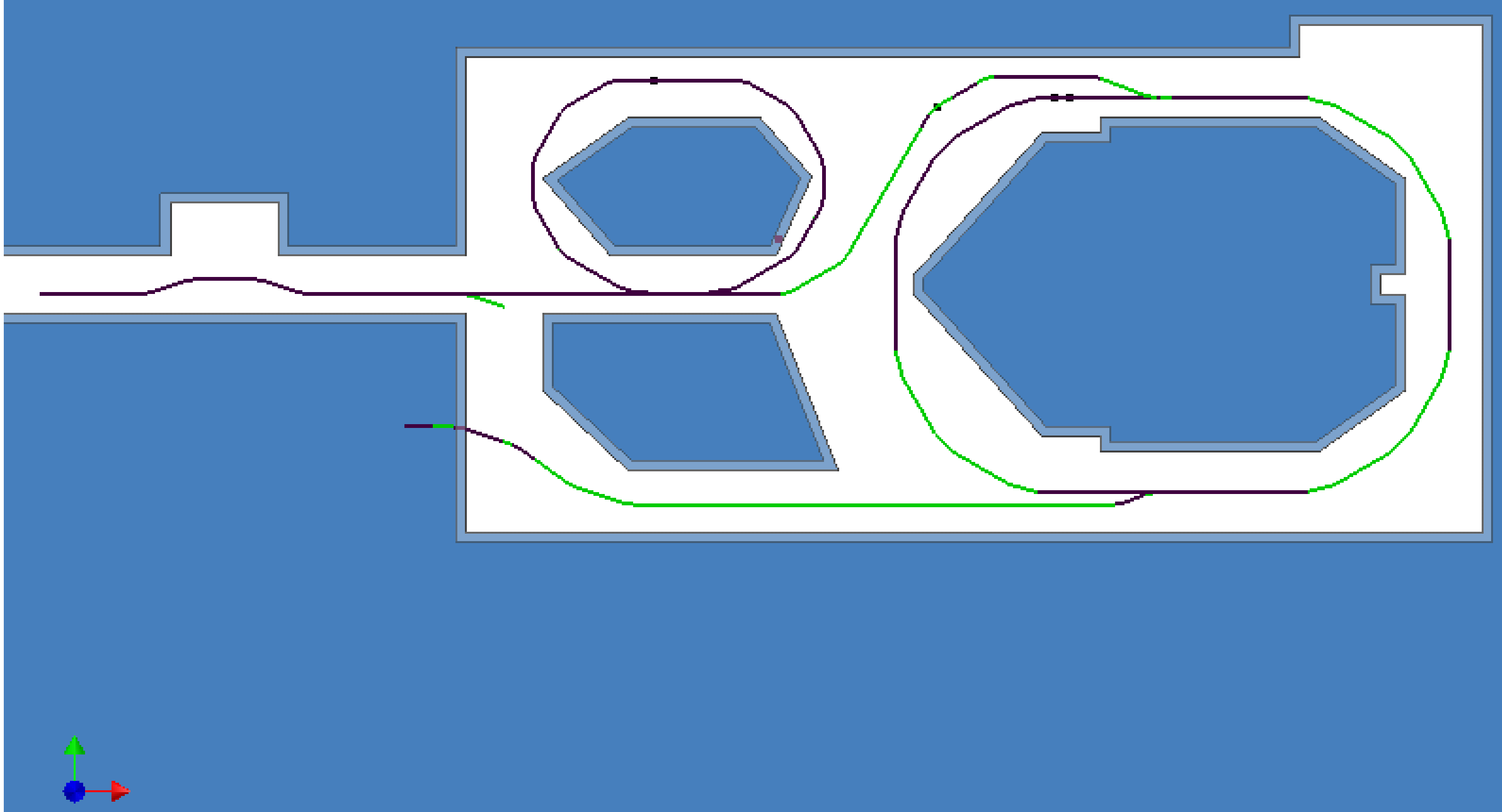
**Present schedule:**

- Stretcher/compressor
- DL
- TL to CR + CR
- Extraction

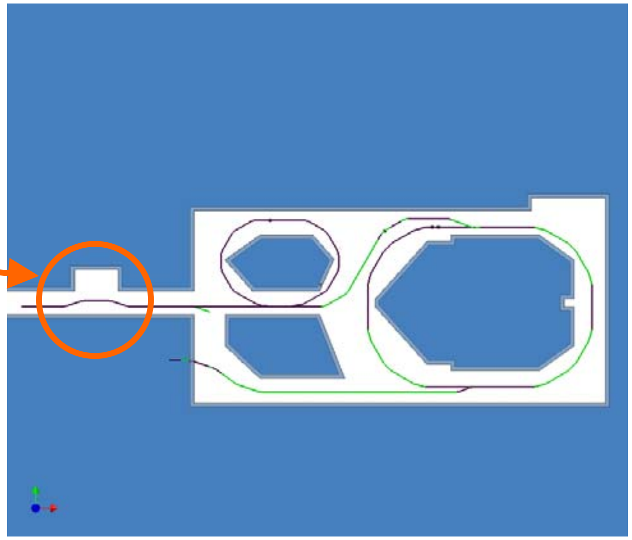


# Time and cost optimization with present hardware for the whole frequency multiplication system

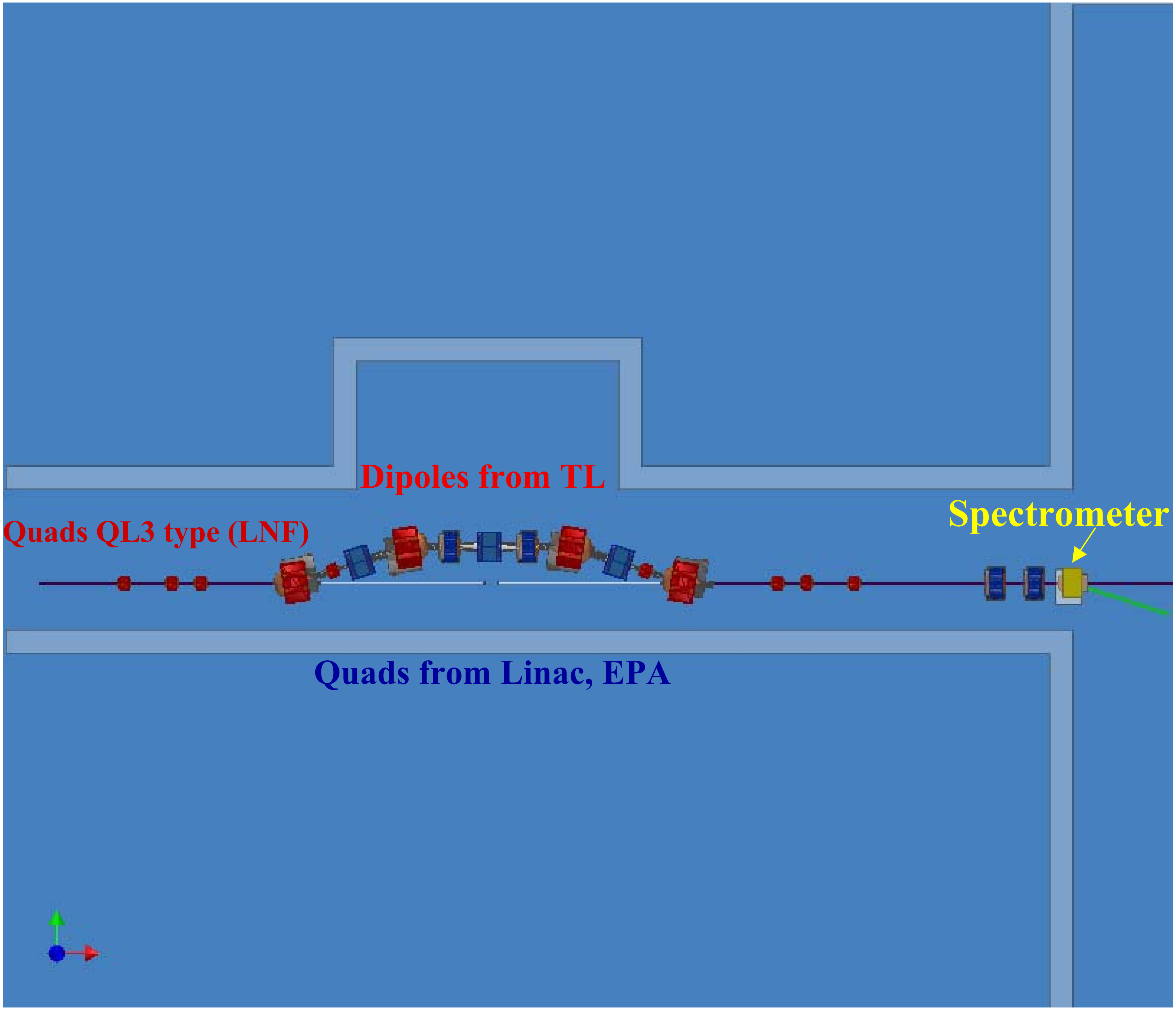
# Total layout



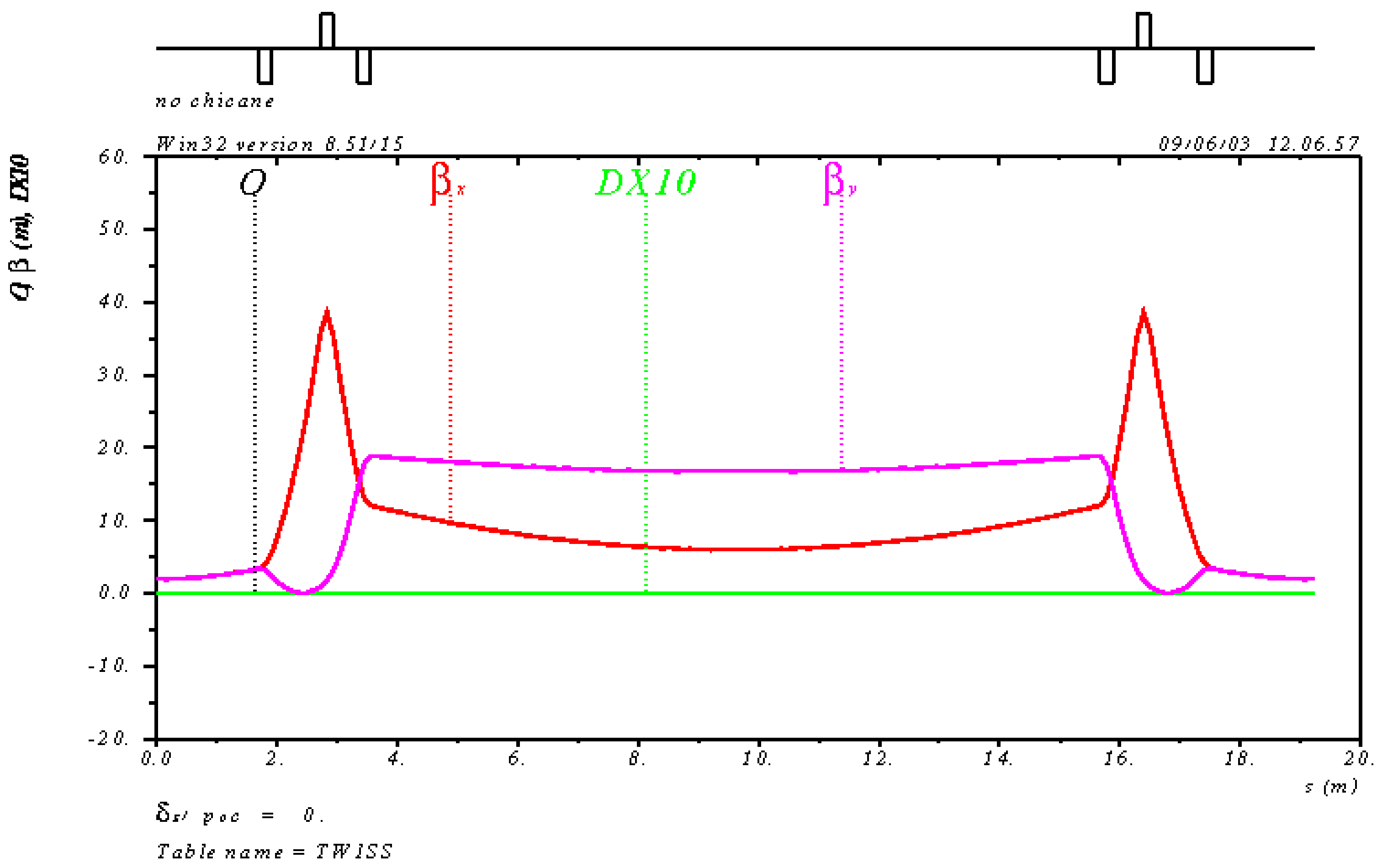
Stretcher



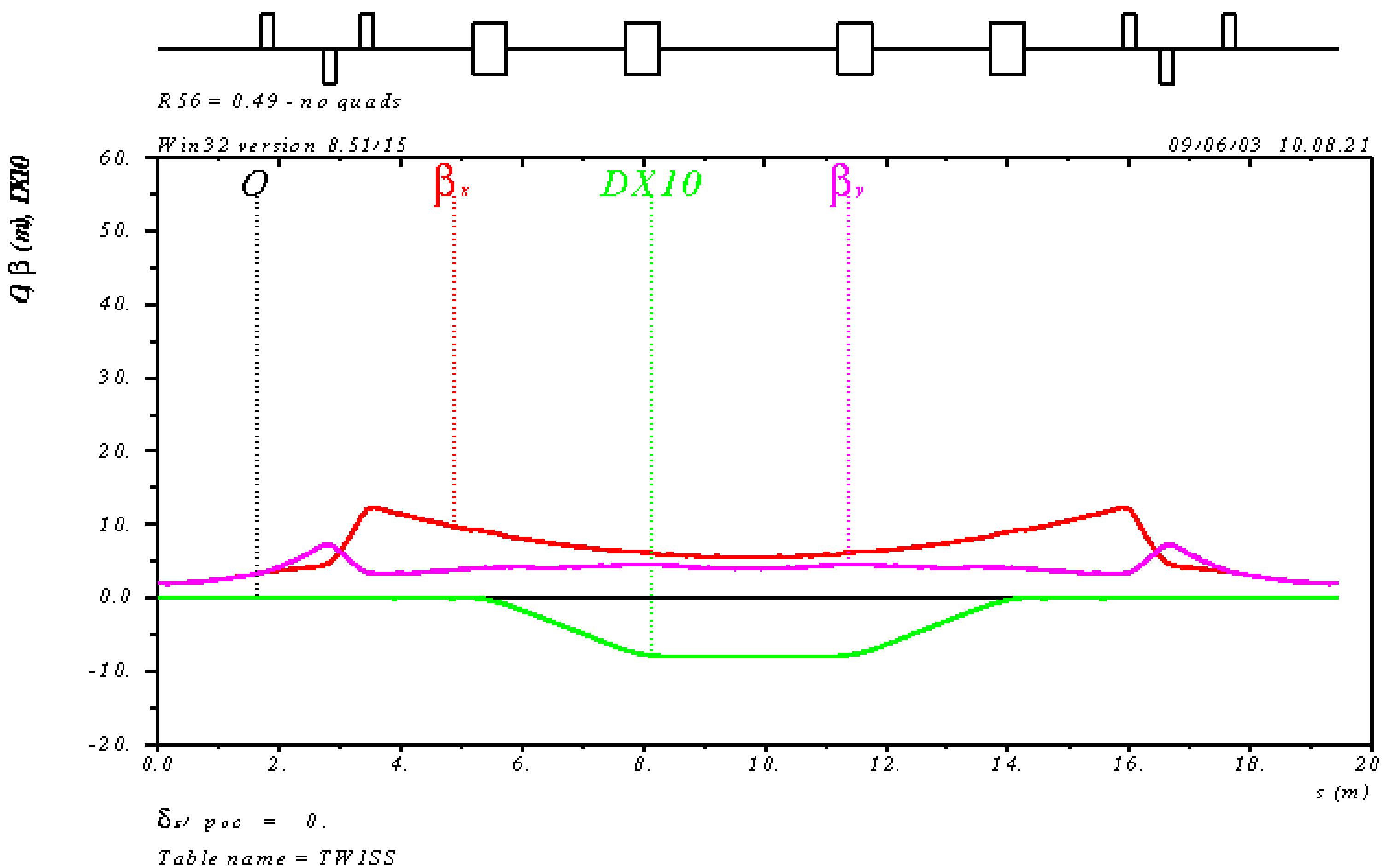
- Design based on 4 dipole, 7 quads chicane
- All existing magnets
- Increase of $R_{56}$ tunability range
- Complete design of hardware – vacuum chamber, vacuum pomps, diagnostics…
- End with spectrometer



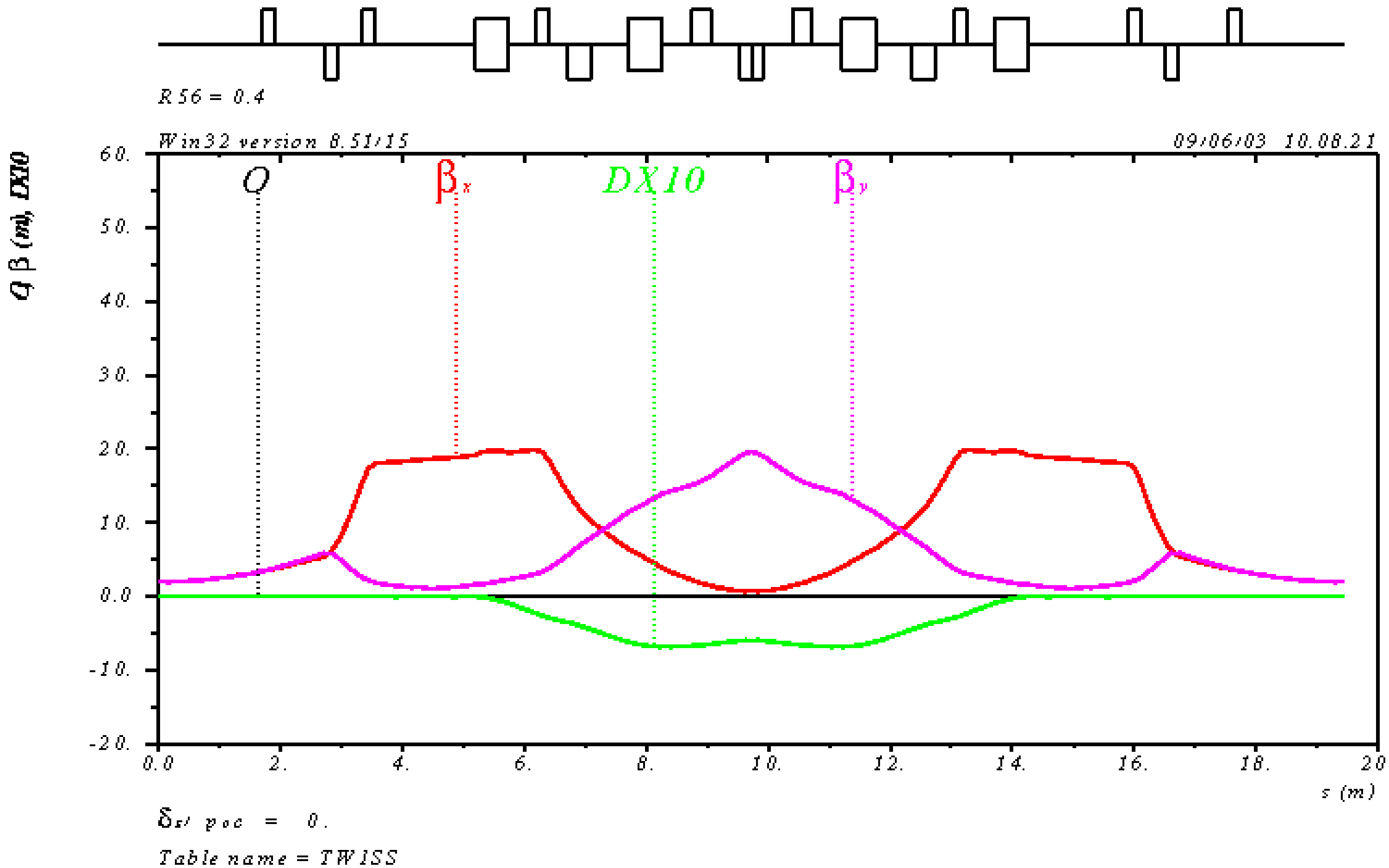
Dipoles from TL
Quads QL3 type (LNF)
Spectrometer
Quads from Linac, EPA



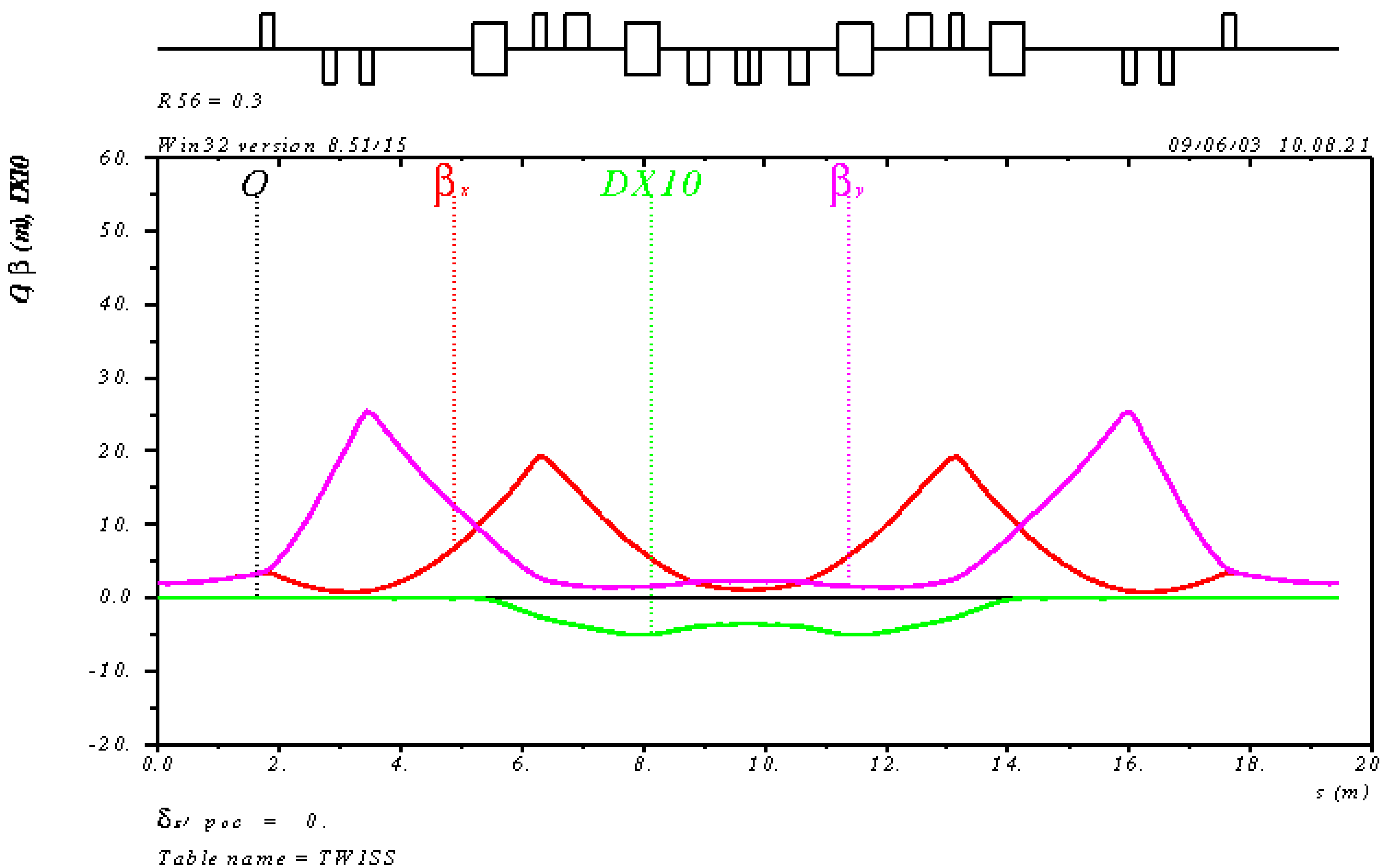

# Through the bypass – $R_{56} = 0$




$R_{56}$ = 0.47 m – quads off


R56 = 0.4
Win32 version 8.51/15
09/06/03 10.08.21
Q β (m), DX10
Q
βx
DX10
βy
60.
50.
40.
30.
20.
10.
0.0
-10.
-20.
0.0
2.
4.
6.
8.
10.
12.
14.
16.
18.
20.
s (m)
δE/ p0c = 0.
Table name = TWISS

**$R_{56}$ = 0.4 m**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09/06/03 10.08.21
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Q
βx
DX10
βy
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30.
20.
10.
0.0
-10.
-20.
0.0
2.
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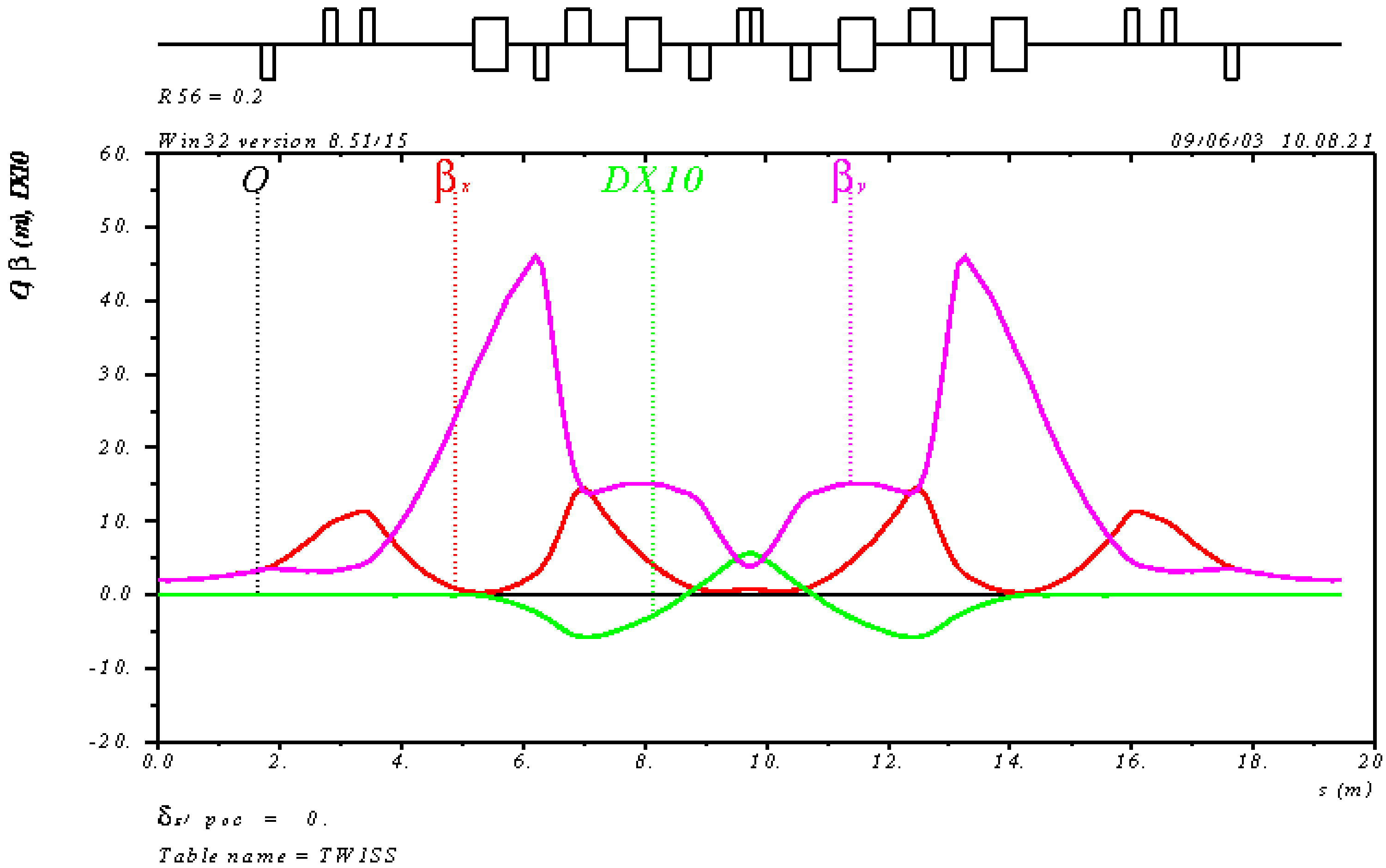
8.
10.
12.
14.
16.
18.
20.
s (m)
δs/ poc = 0.
Table name = TWISS

**$R_{56}$ = 0.3 m**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09/06/03 10.08.21
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Q
βx
DX10
βy
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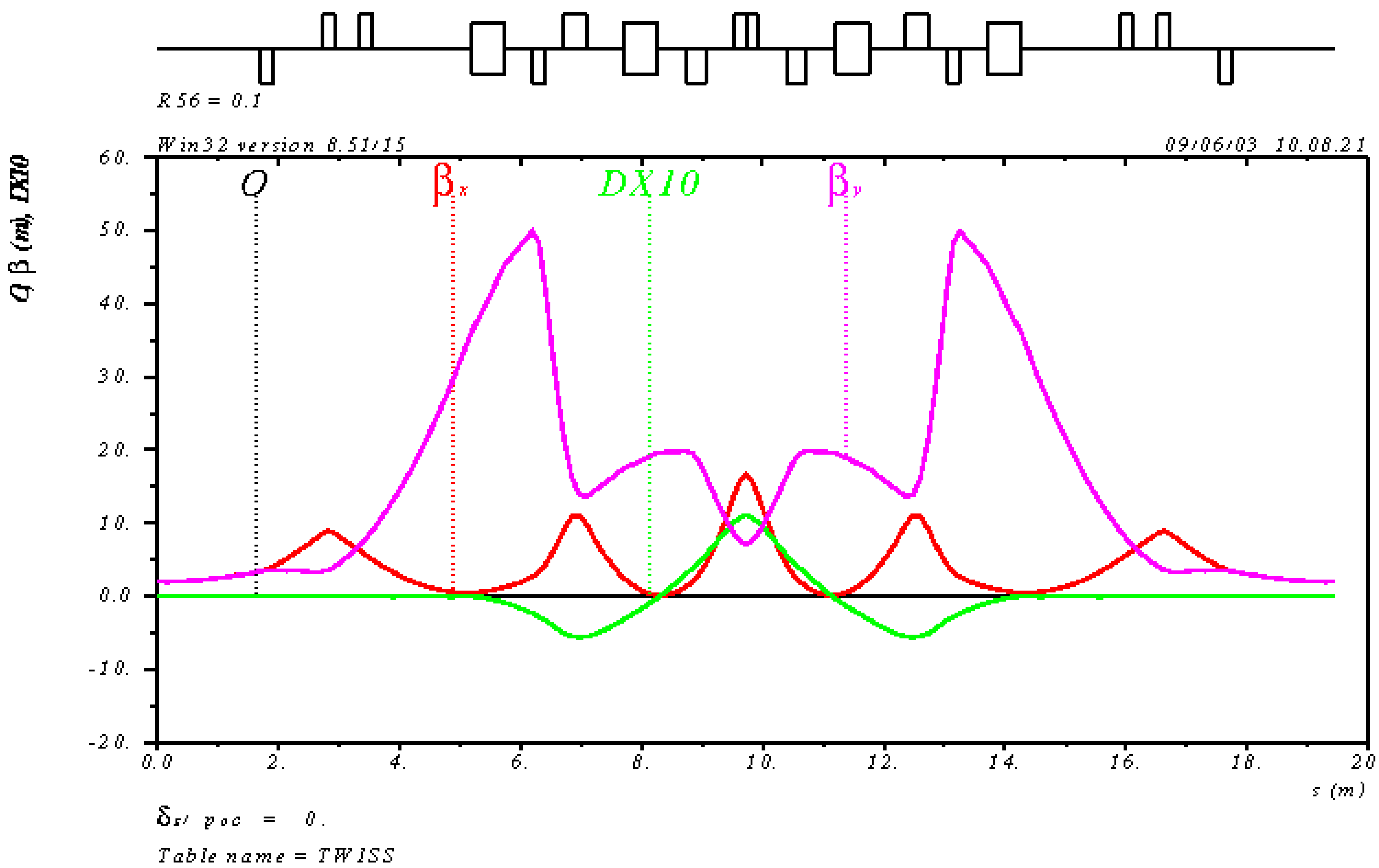
50.
40.
30.
20.
10.
0.0
-10.
-20.
0.0
2.
4.
6.
8.
10.
12.
14.
16.
18.
20.
s (m)
δE/ pc = 0.
Table name = TWISS

# $R_{56}$ = 0.2 m



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Win32 version 8.51/15
09/06/03 10.08.21
Q β (m), DX10
Q
βx
DX10
βy
60.
50.
40.
30.
20.
10.
0.0
-10.
-20.
0.0
2.
4.
6.
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10.
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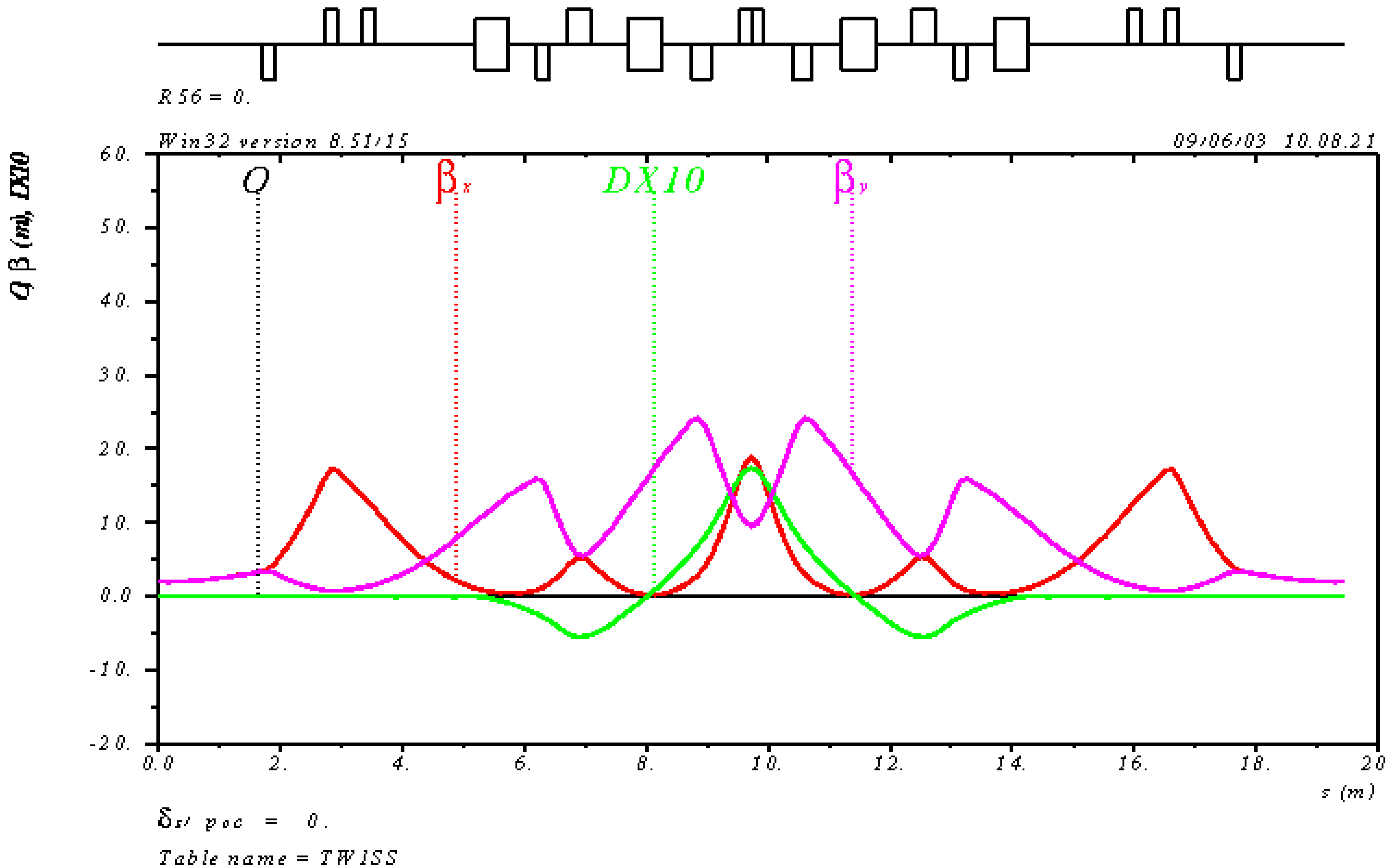
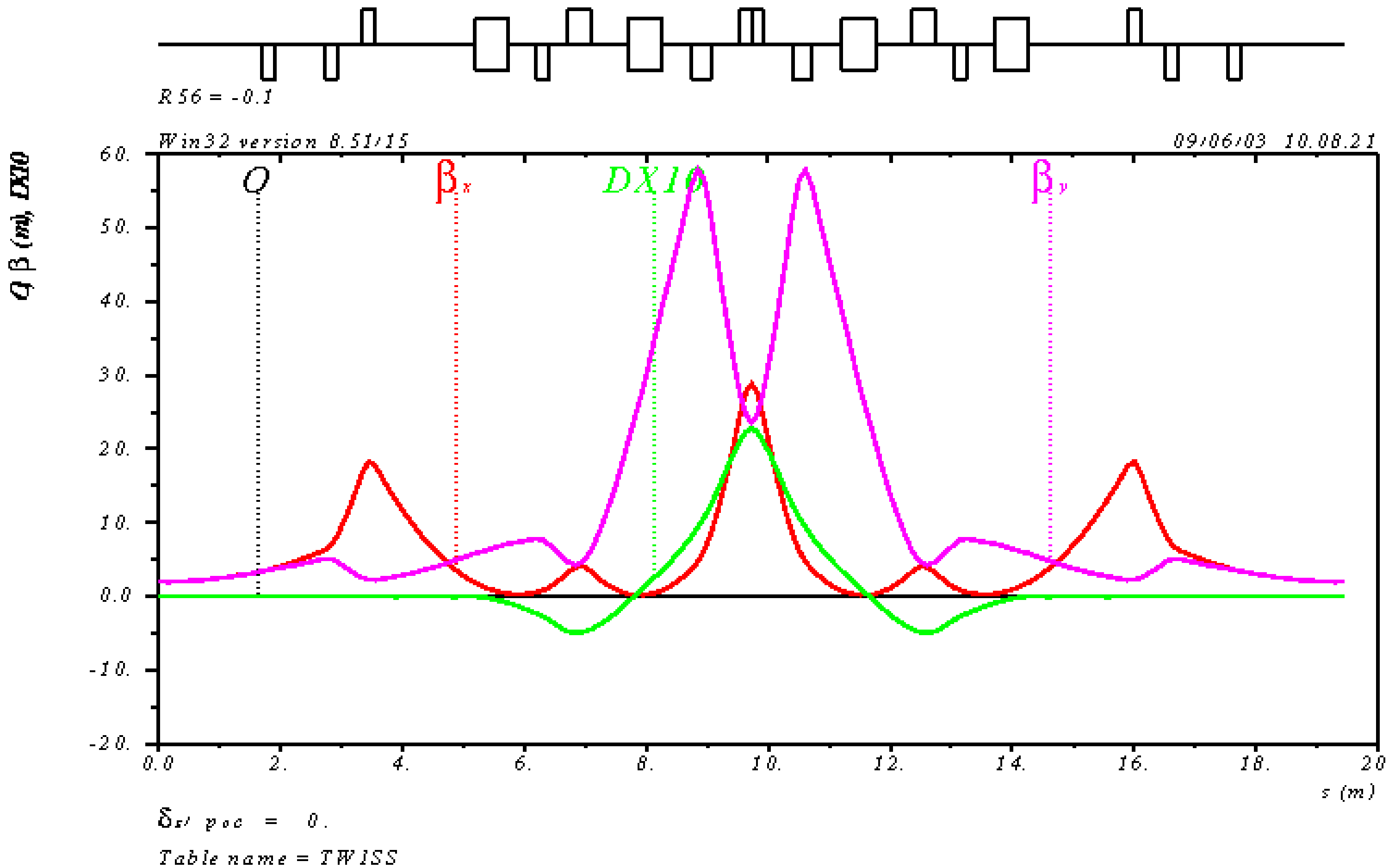
16.
18.
20.
s (m)
δE/ p0c = 0.
Table name = TWISS


**$R_{56}$ = 0.1 m**



R56 = 0.
Win32 version 8.51/15
09/06/03 10.08.21
Q β (m), DX10
Q
βx
DX10
βy
60.
50.
40.
30.
20.
10.
0.0
-10.
-20.
0.0
2.
4.
6.
8.
10.
12.
14.
16.
18.
20.
s (m)
δE/ p0c = 0.
Table name = TWISS


**$R_{56} = 0.0$ m**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Win32 version 8.51/15
09/06/03 10.08.21
Q β (m), DX10
Q
βx
DX10
βy
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50.
40.
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20.
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0.0
-10.
-20.
0.0
2.
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8.
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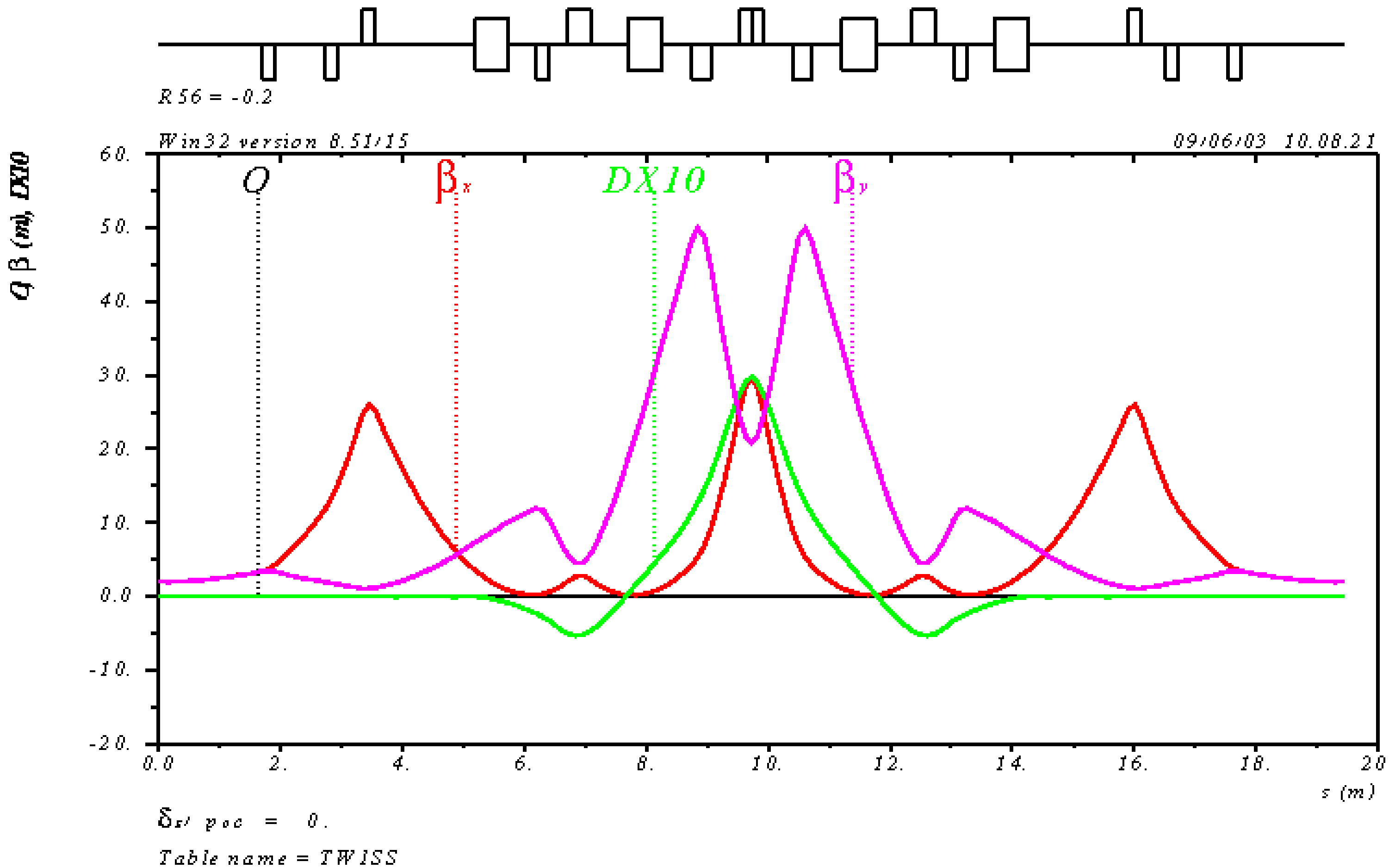
18.
20.
s (m)
δE/ pc = 0.
Table name = TWISS

# $R_{56}$ = - 0.1 m


R56 = -0.2
Win32 version 8.51/15
09/06/03 10.08.21
Q β (m), DX10
Q
βx
DX10
βy
60.
50.
40.
30.
20.
10.
0.0
-10.
-20.
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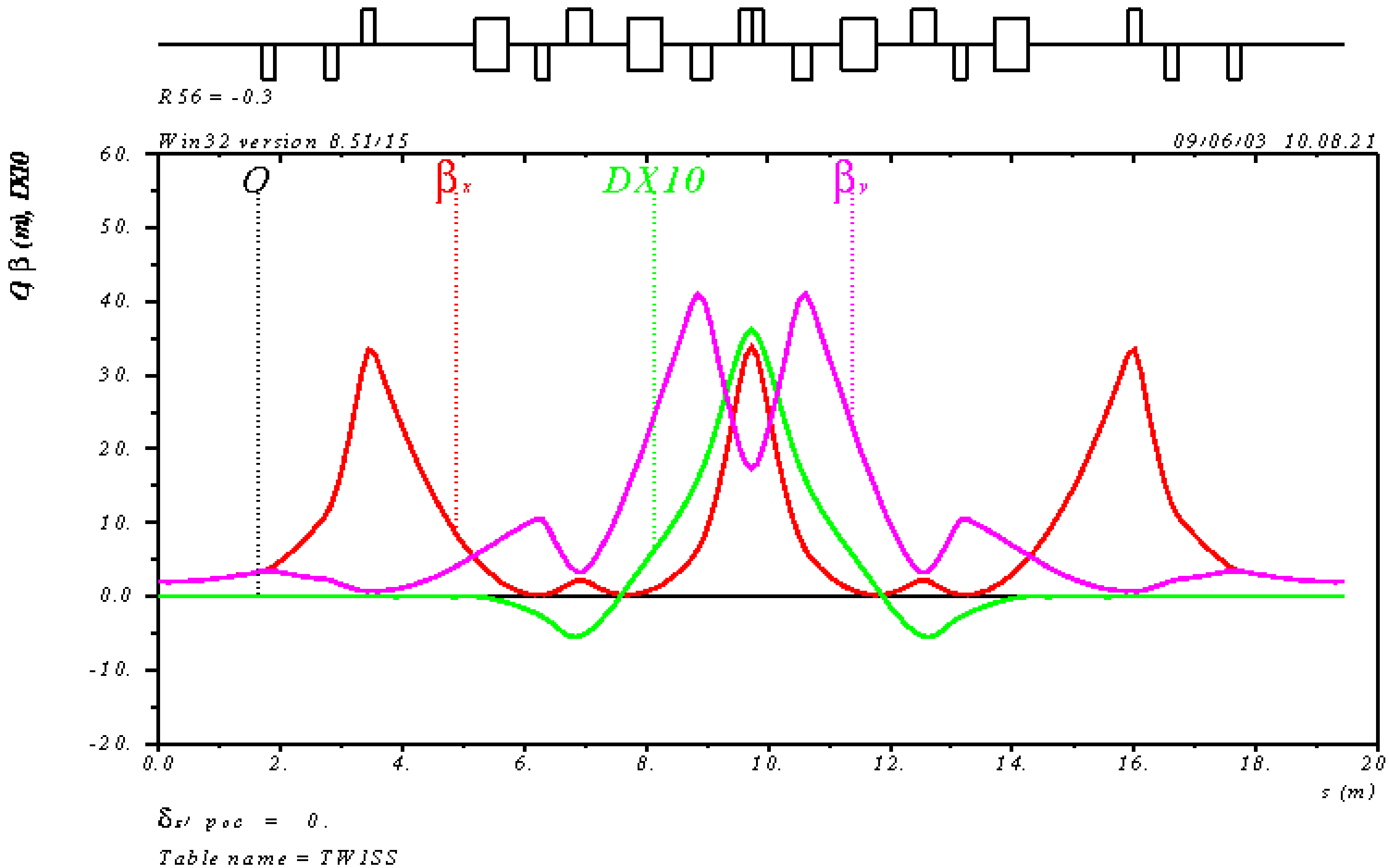
20.
s (m)
δE/ pc = 0.
Table name = TWISS

# $R_{56}$ = - 0.2 m


R56 = -0.3
Win32 version 8.51/15
09/06/03 10.08.21
Q β (m), DX10
Q
βx
DX10
βy
60.
50.
40.
30.
20.
10.
0.0
-10.
-20.
0.0
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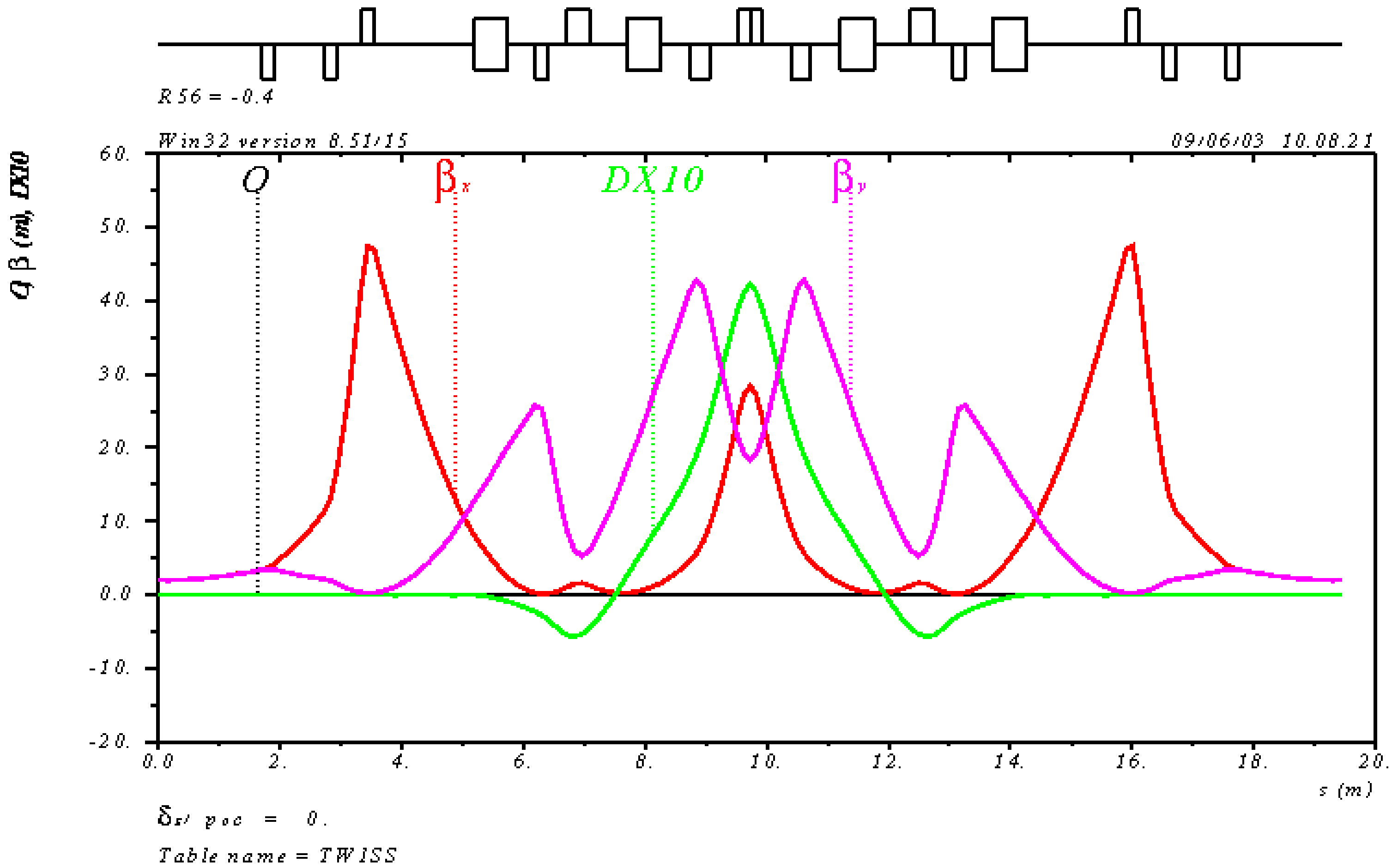
20.
s (m)
δE/ pc = 0.
Table name = TWISS

# $R_{56}$ = - 0.3 m


R56 = -0.4
Win32 version 8.51/15
09/06/03 10.08.21
Q
βx
DX10
βy
Q β (m), DX10
60.
50.
40.
30.
20.
10.
0.0
-10.
-20.
0.0
2.
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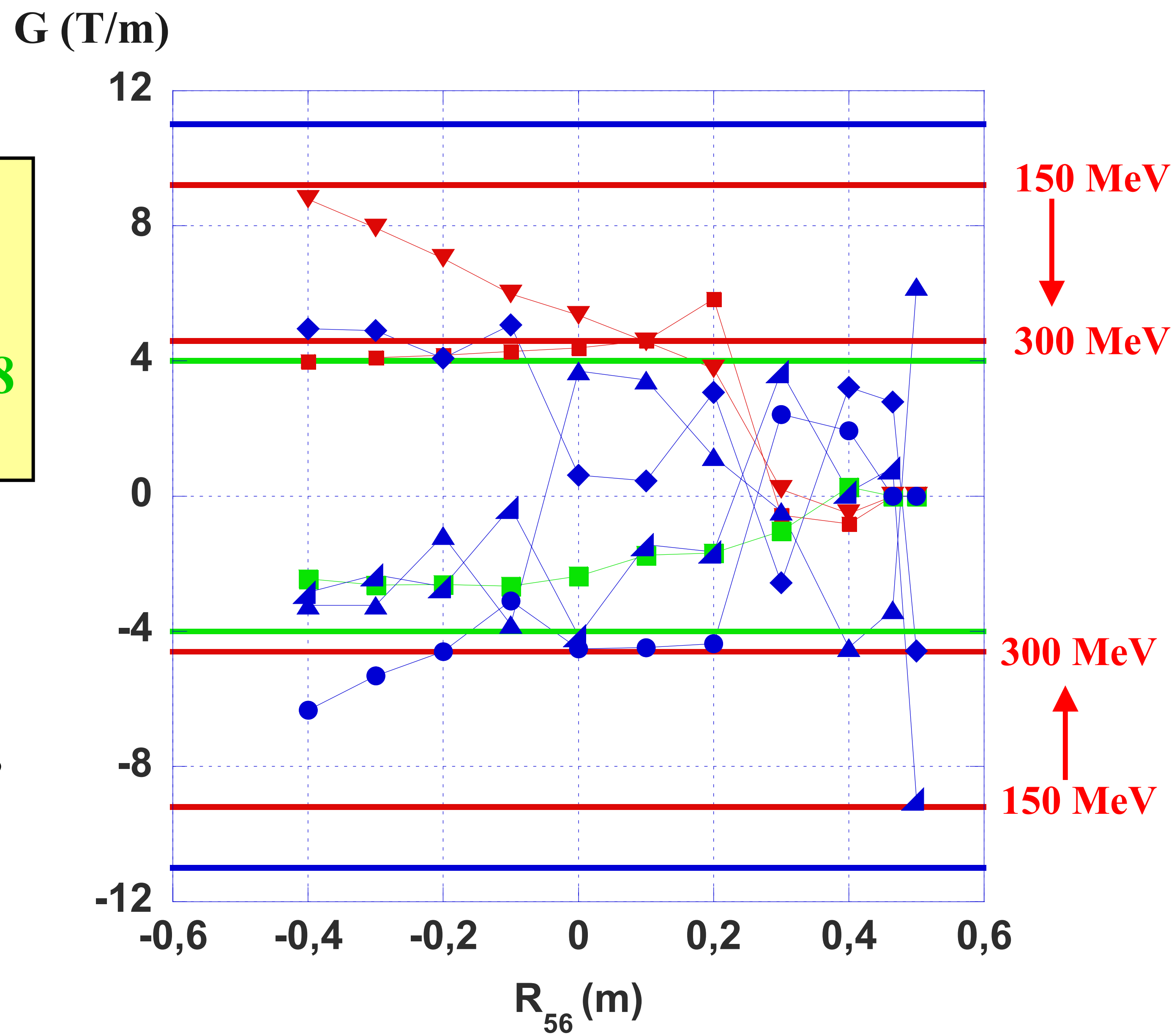
16.
18.
20.
s (m)
δE/ pc = 0.
Table name = TWISS

**$R_{56}$ = - 0.4 m**

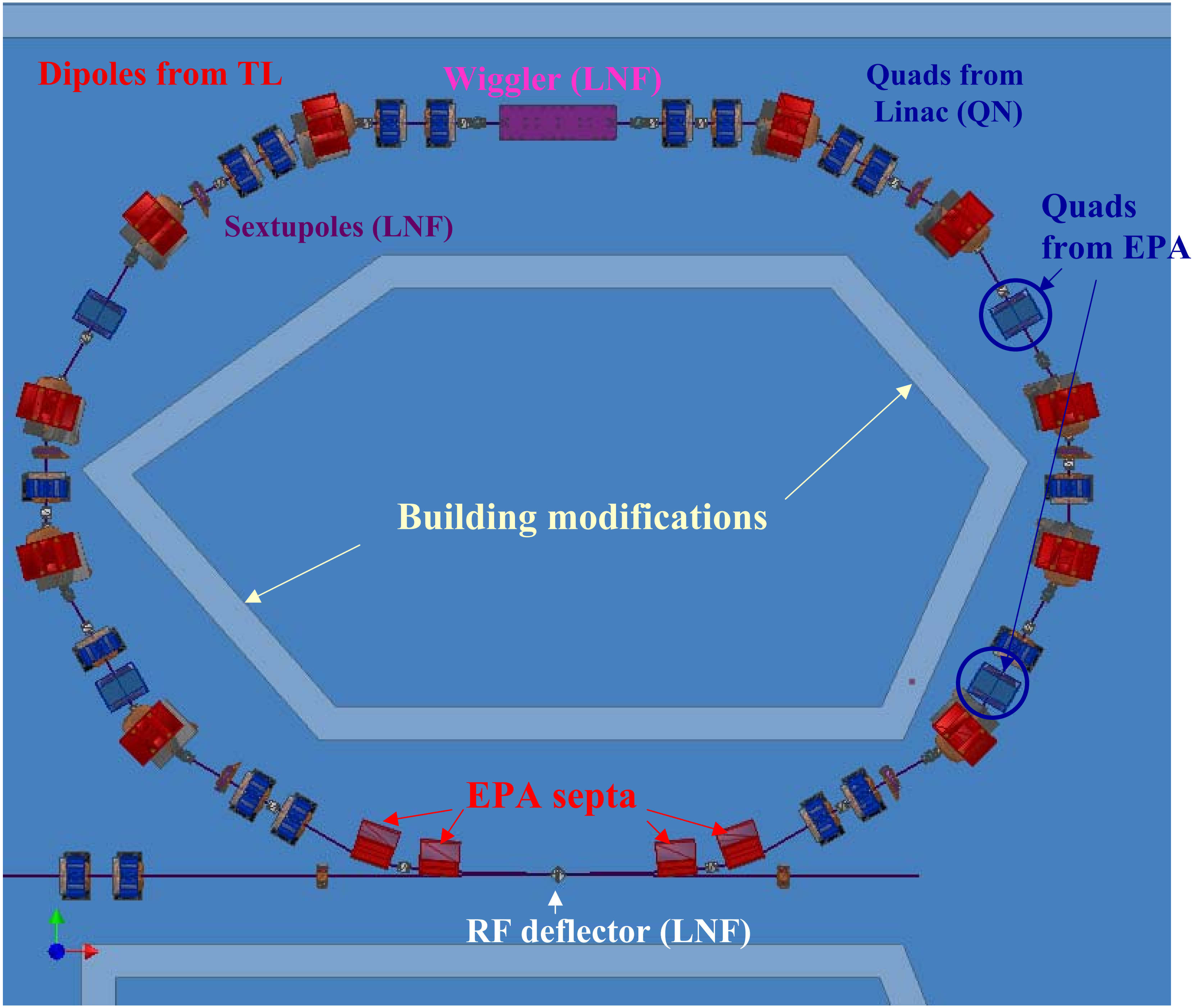
# Chicane quadrupoles

| Type | $L_{mag}$ |
|---|---|
| QL | 0.22 |
| QN | 0.328 |
| Qlarge | 0.38 |




Bipolar
power supplies

# Delay Loop



Dipoles from TL
Wiggler (LNF)
Quads from Linac (QN)
Sextupoles (LNF)
Quads from EPA
Building modifications
EPA septa
RF deflector (LNF)

**Design based on utilisation of available dipoles and quads**

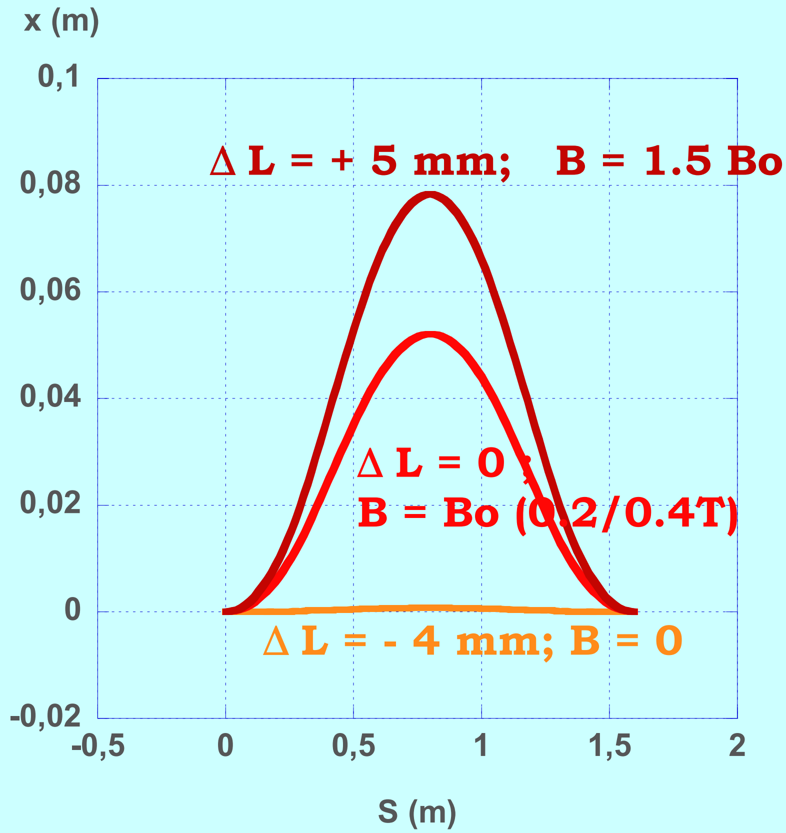
**2nd order dynamics =>**
**horizontal more critical than vertical plane**
**Relax conditions on vertical plane, fitting apertures for CSR**

**Horizontal phase advance between the two kicks of rf deflectors near multiple of $\pi$ (see Alesini talk)**

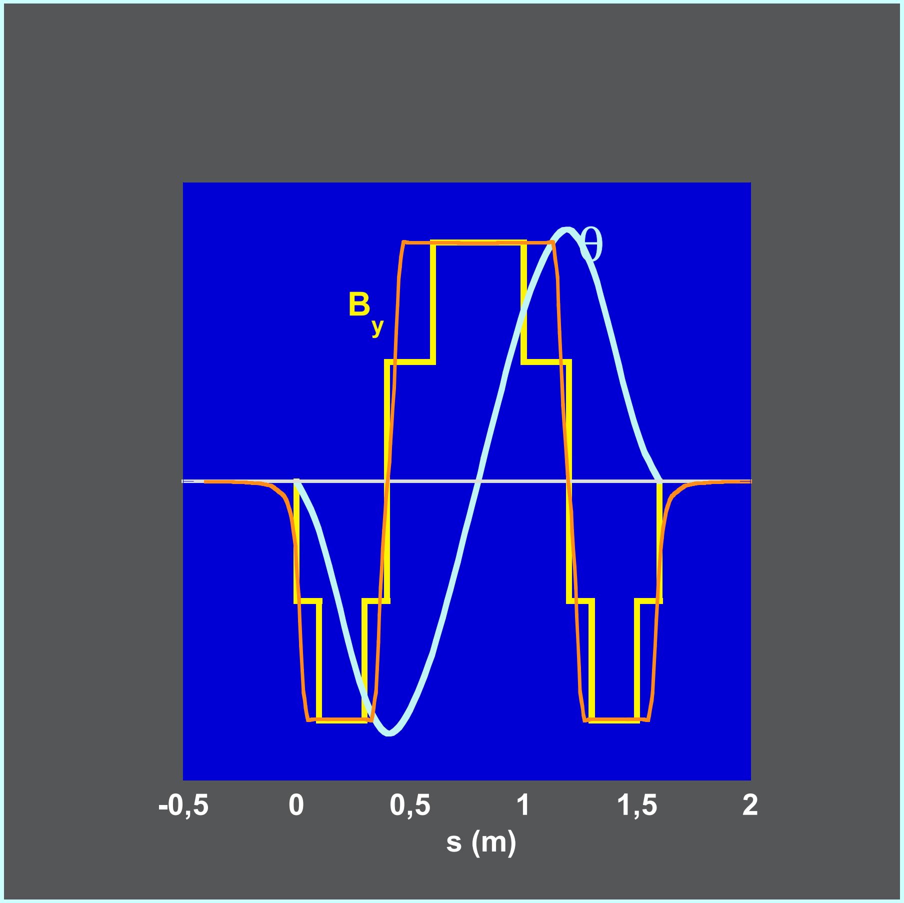
**Small $\beta_x$ @rf deflector to minimise transverse perturbation along the bunch train**

**Tunability of $R_{56}$**
**Decrease $T_{566}$ by linear optics (dispersion and chromaticity)**

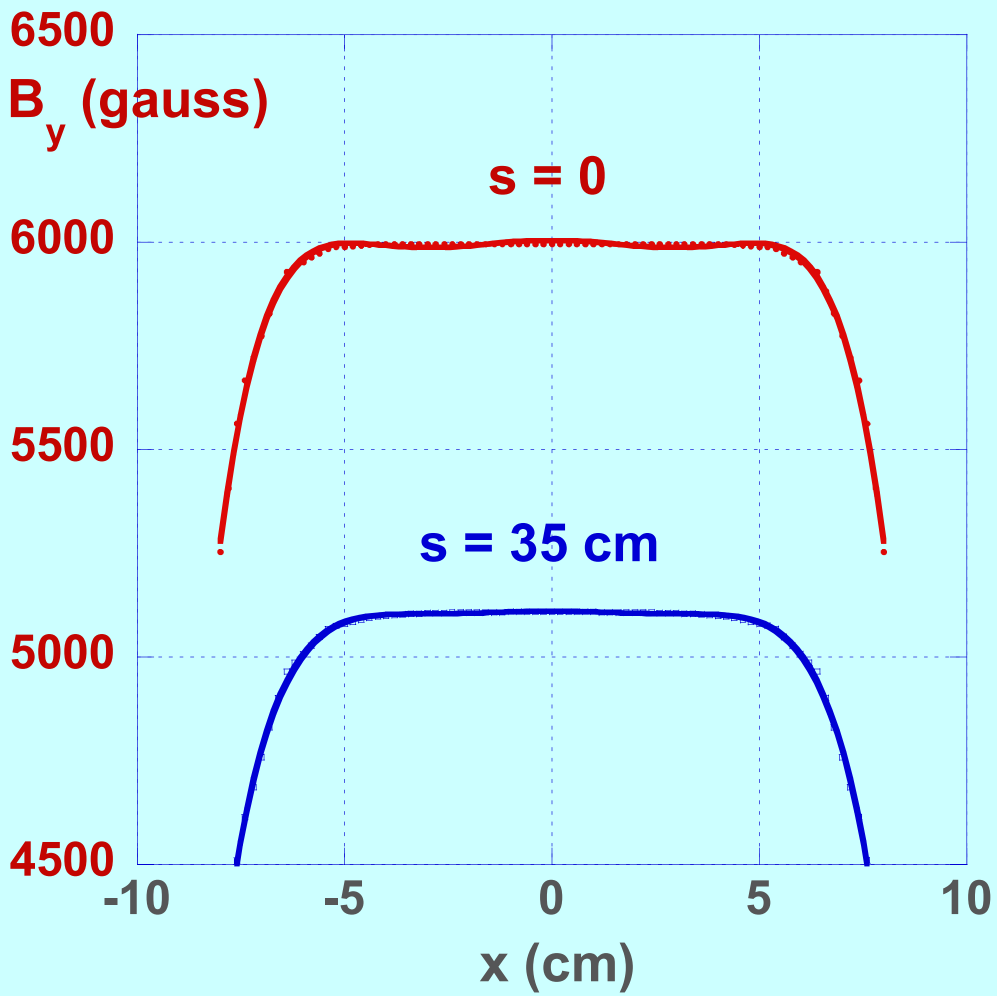
# Path length tuning wiggler +5 / -4 mm




## Optical linear model



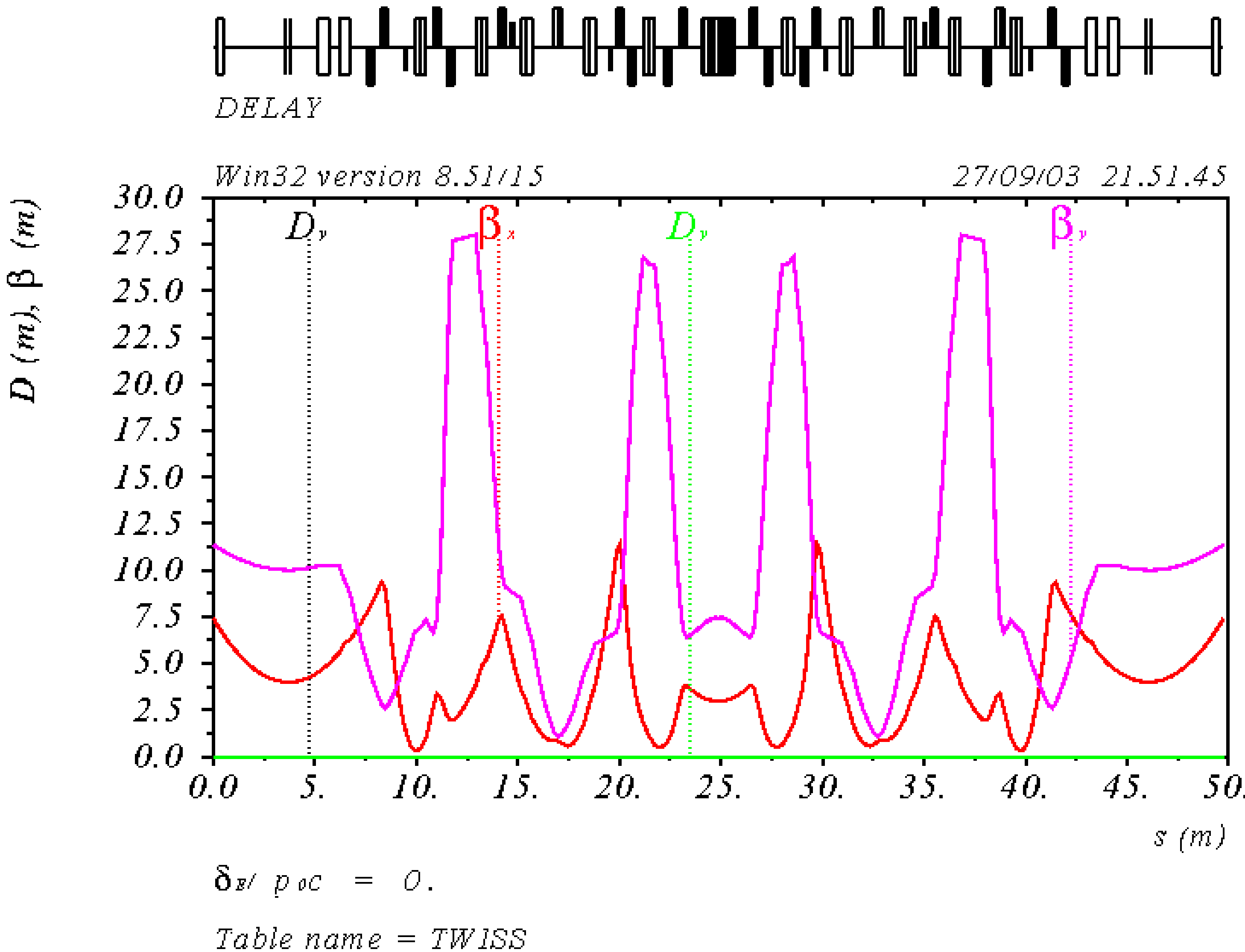
# 3D – analysis of Wiggler nonlinear terms

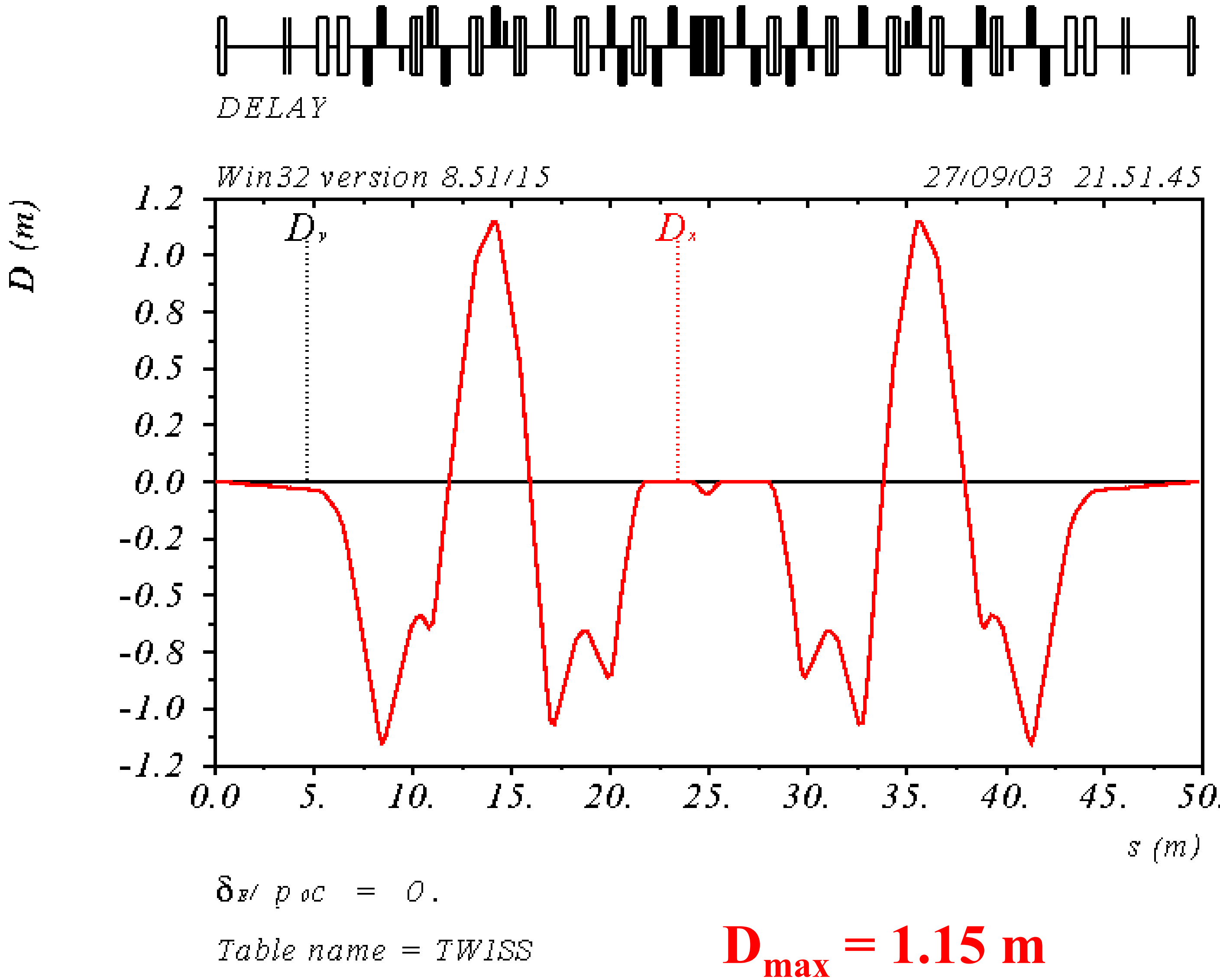



| Y = M0 + M1*x + ... M8*x^8 + M9*x^9 | |
|---|---|
| M0 | 6004,2 |
| M1 | -5,1067e-13 |
| M2 | -4,4595 |
| M3 | 4,287e-14 |
| M4 | 0,34373 |
| M5 | -6,0383e-16 |
| M6 | -0,0070471 |
| R | 0,99809 |

| Y = M0 + M1*x + ... M8*x^8 + M9*x^9 | |
|---|---|
| M0 | 5110,5 |
| M1 | 5,2781e-13 |
| M2 | -1,7687 |
| M3 | -4,3795e-14 |
| M4 | 0,16558 |
| M5 | 6,4689e-16 |
| M6 | -0,0054823 |
| R | 0,99953 |

# DL betatron functions



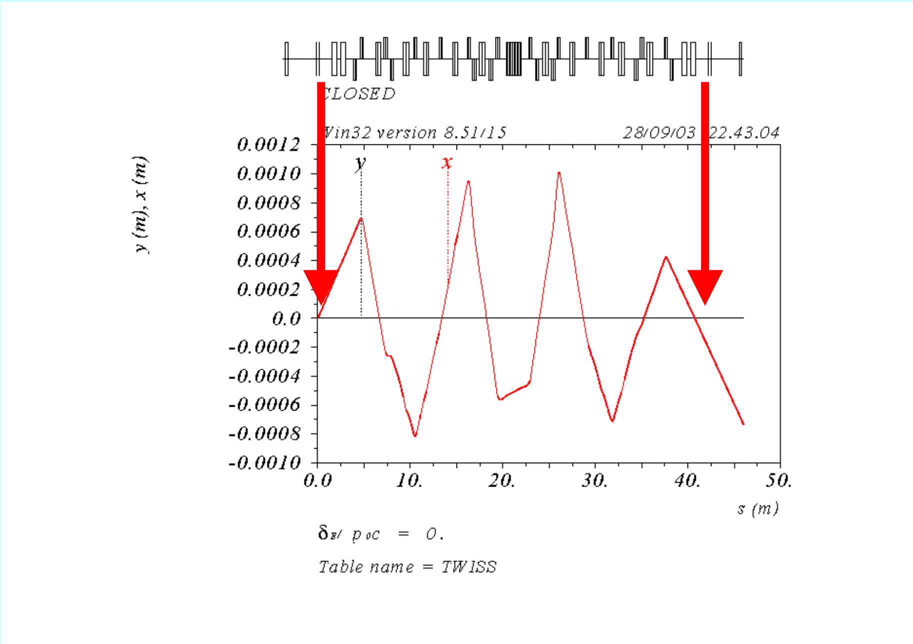



**$D_{max}$ = 1.15 m**

**$T_{566}$ = -14 (-18)**

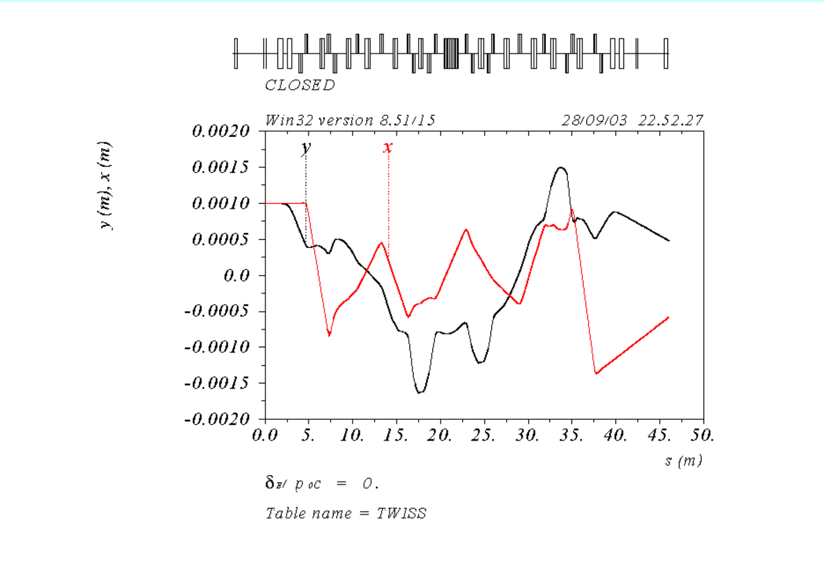
# Analysis of error trajectories

## 1% error in rf deflector kick




**Phase advance ≈ 3.5**

## 1mm injection error

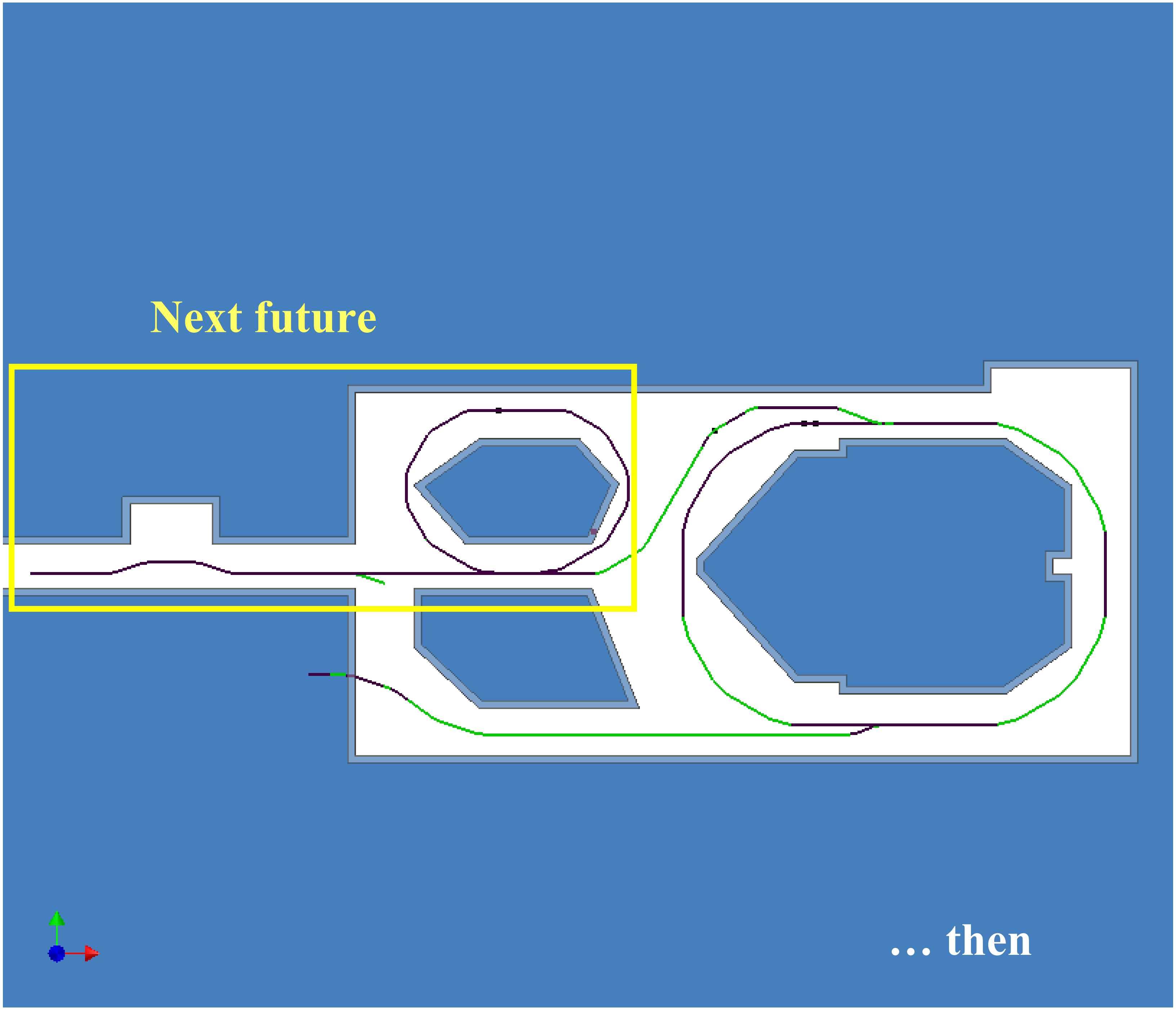


# Magnets

| | # | |
|---|---|---|
| Dipoles – flat poles | 10 | B = 0.53/1.07 T |
| Quadrupoles – from EPA | 2 x 2 | $GL_{max}$ = 0.8/1.6 T m |
| Quadrupoles – from LINAC | 2 x 8 | $GL_{max}$ = 0.6/1.2 T m |
| Sextupoles – LNF design | 2 x 3 | $GL_{max}$ = 5/10 $Tm^{-1}$ |
| Wiggler - New design | 1 | $B_{max}$ = 0.3/0.6 T |
| Correctors – LNF design | 8 | |
| Septa - from EPA | 4 | |
| | | |
| | | |
| | | |

# DELAY LOOP PARAMETERS

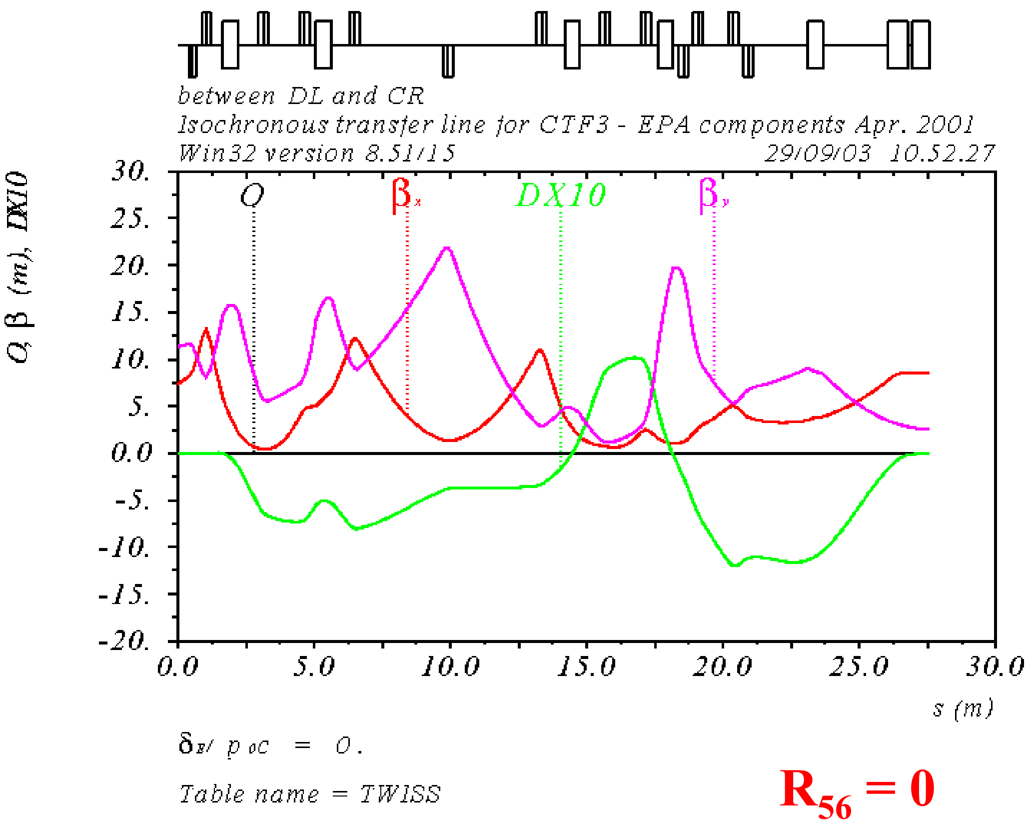
| | |
|---|---|
| Energy (MeV) | 150/300 |
| Bρ (T m) | 0.5/1.0 |
| Circumference (m) | 42.39 |
| Periodicity | 2 |
| Max. beta (m) (H/V) | 11.4/28.0 |
| Max. Dispersion (m) | 1.15 |
| Betatron Tune (H/V) | 3.56/1.12 |
| Natural Chromaticity (H/V) | -6.5/ -8.5 |
| Momentum compaction | $<10^{-4}$ |
| Horizontal emittance (μrad) | .34 /.17 |
| Vertical emittance (μrad) | .34 /.17 |
| Energy spread (%) | ±1 |
| Energy acceptance (%) | ±2.5 |


Next future
… then

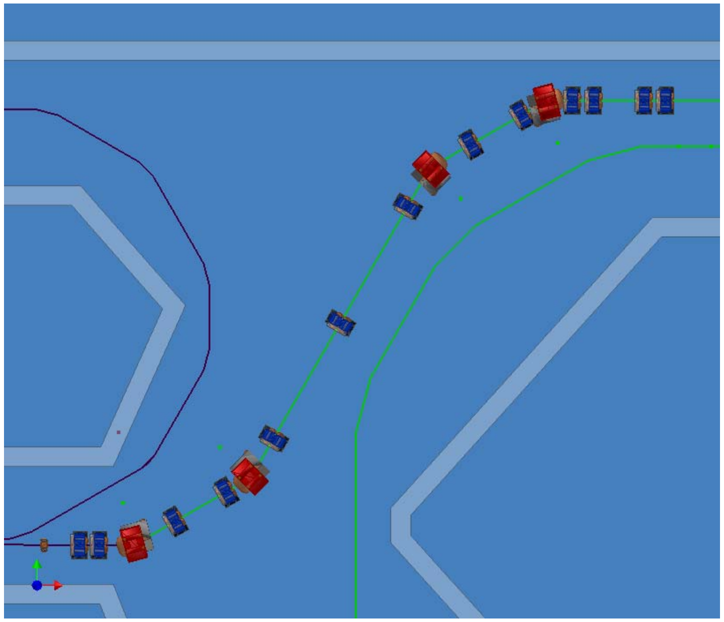
# TL from DL to CR

**New design with 4 + 1 dipoles**
**EPA type**

**Tunability of $R_{56}$ around isochronicity by more than ±30cm**




**$R_{56} = 0$**



# TL from DL to CR

**New design with 4 + 1 dipoles**
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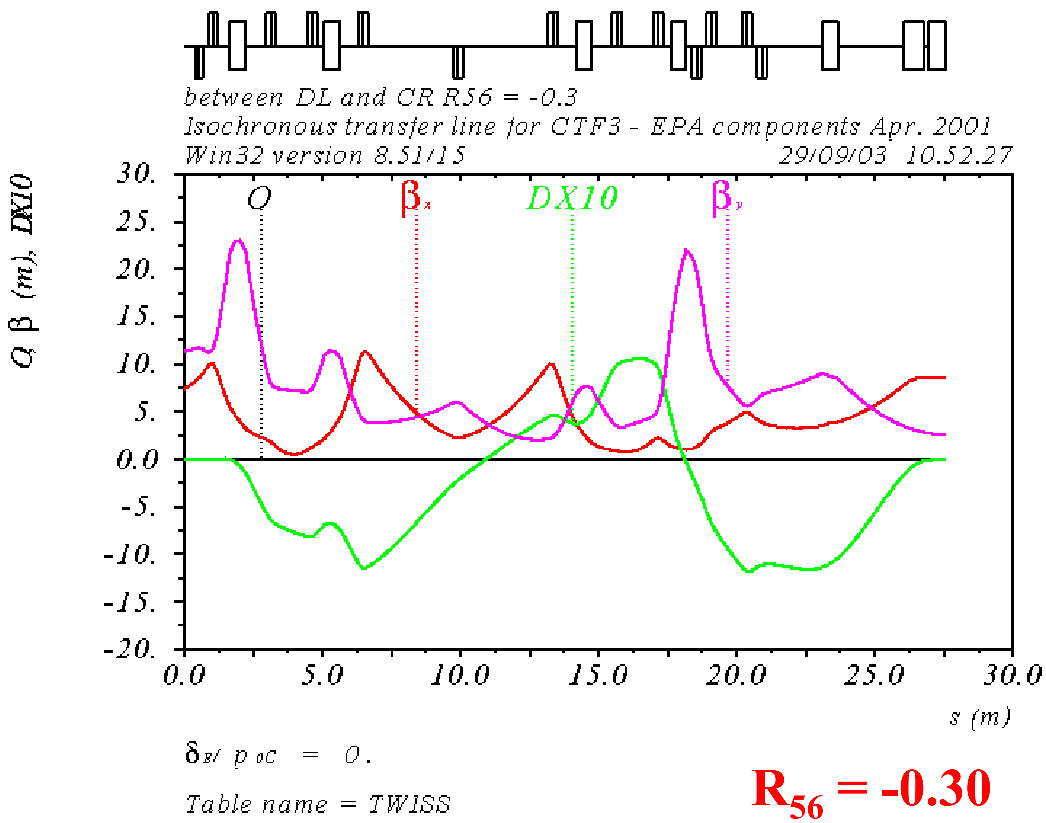
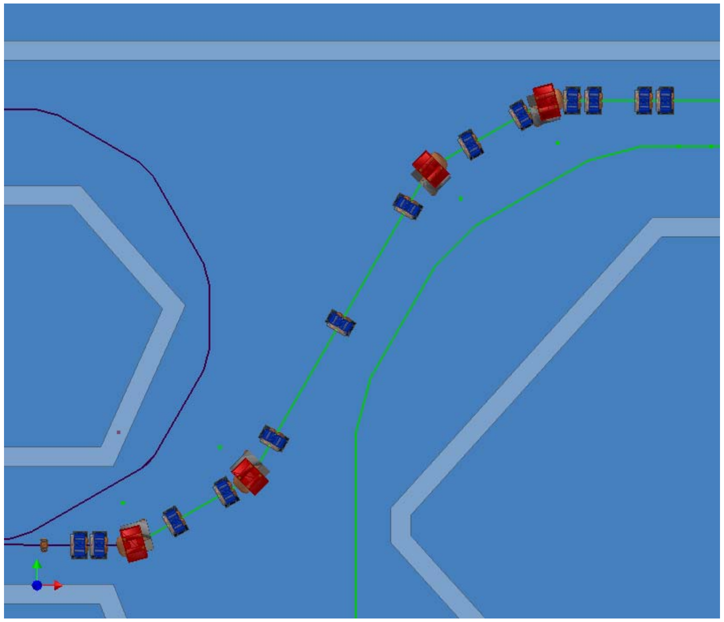


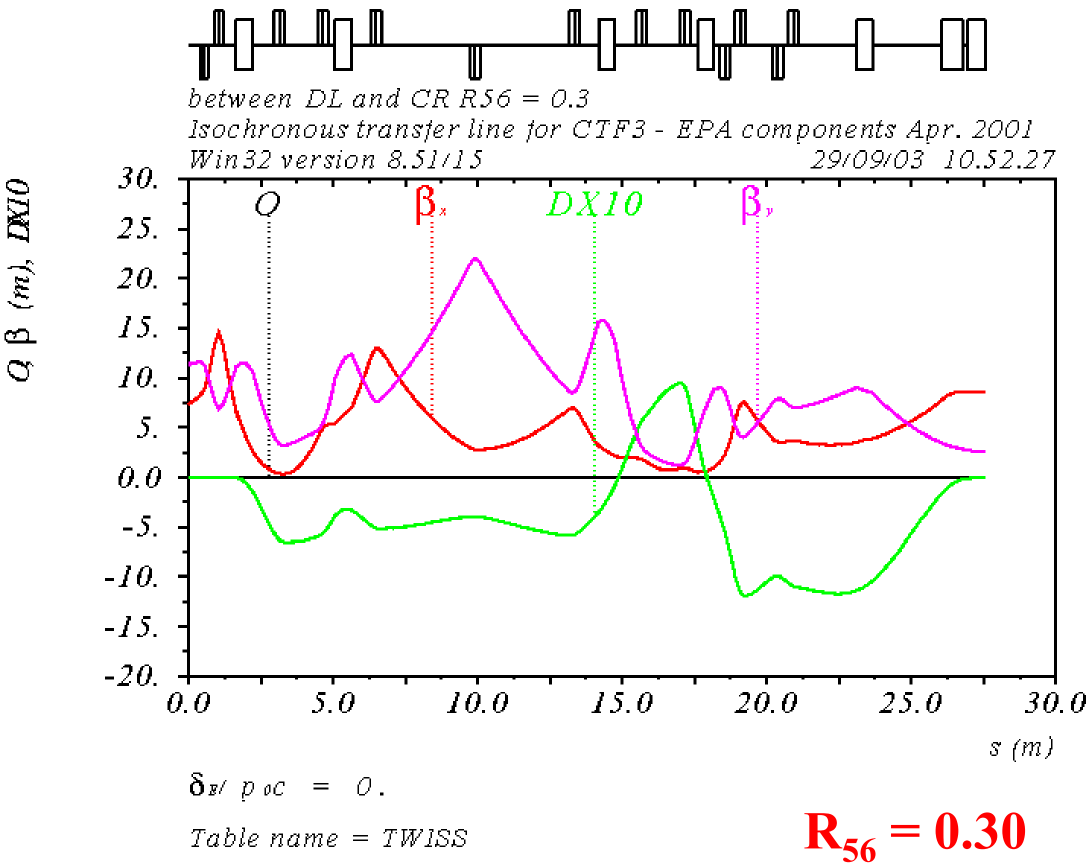

**$R_{56}$ = -0.30**



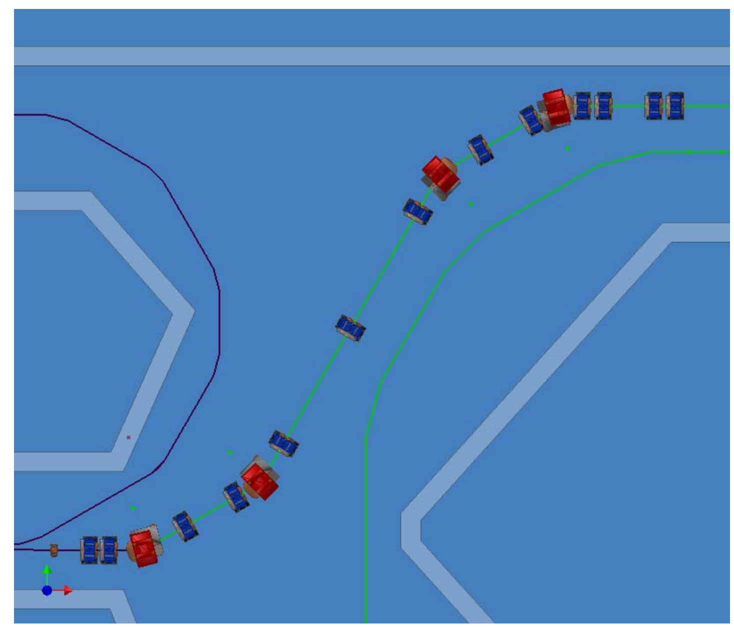
# TL from DL to CR

**New design with 4 + 1 dipoles**
**EPA type**

**Tunability of $R_{56}$ around isochronicity by more than ±30cm**

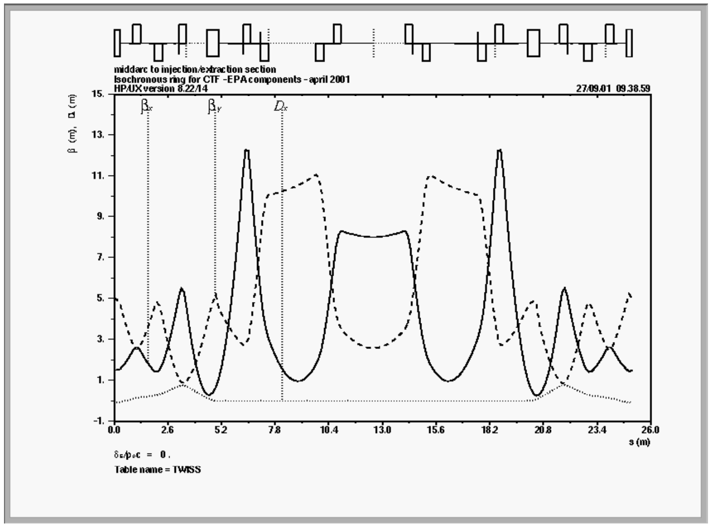


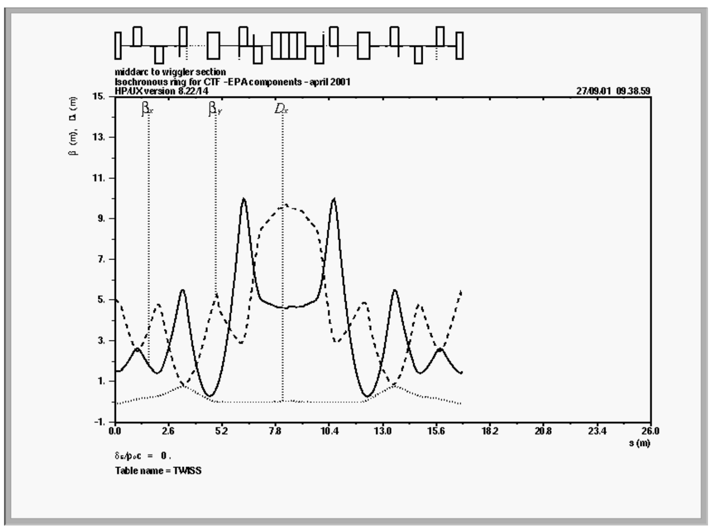

**$R_{56}$ = 0.30**



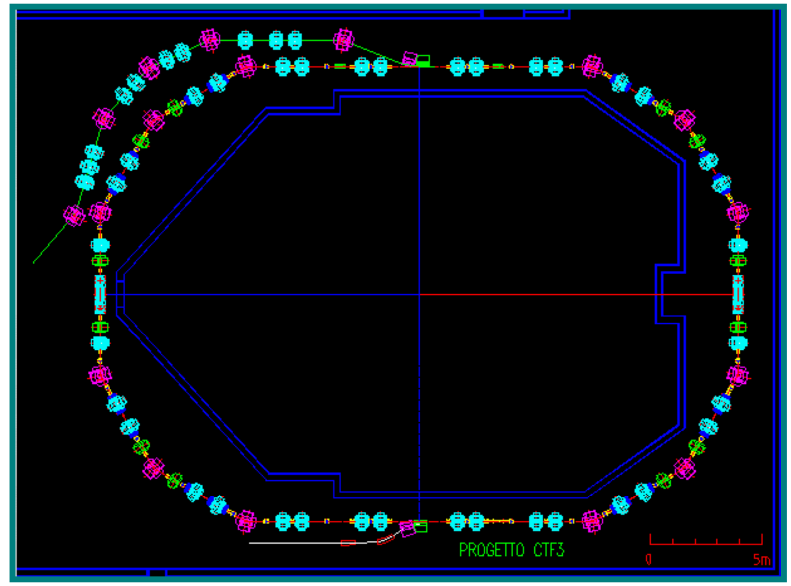
# Isochronicity in CR

**Injection/extraction sections**




**Wiggler sections**

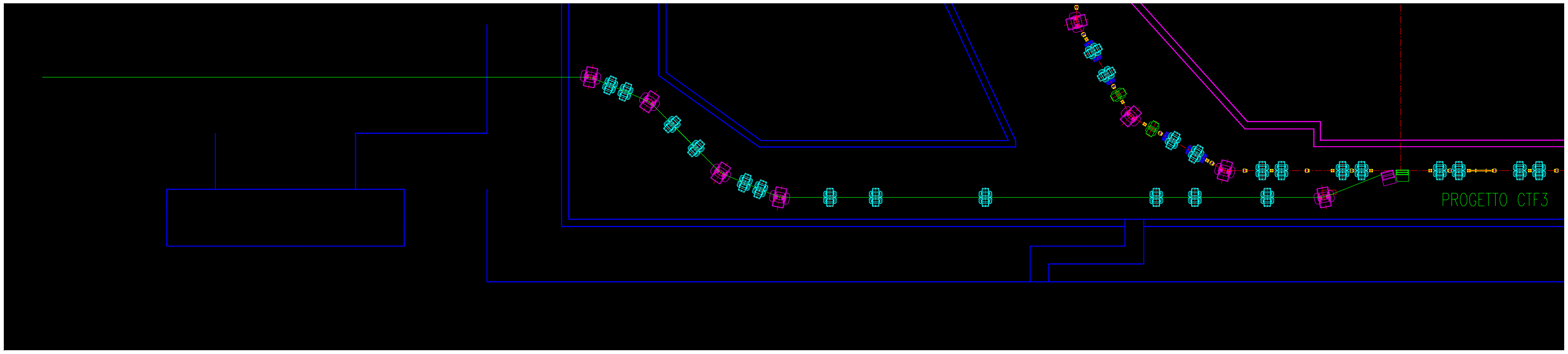



**Isochronicity and achromaticity in each arc of the ring**

**$\pi$ phase advance between rf deflectors**

**Optimum phase advance for minimum beam loading in rf deflectors**

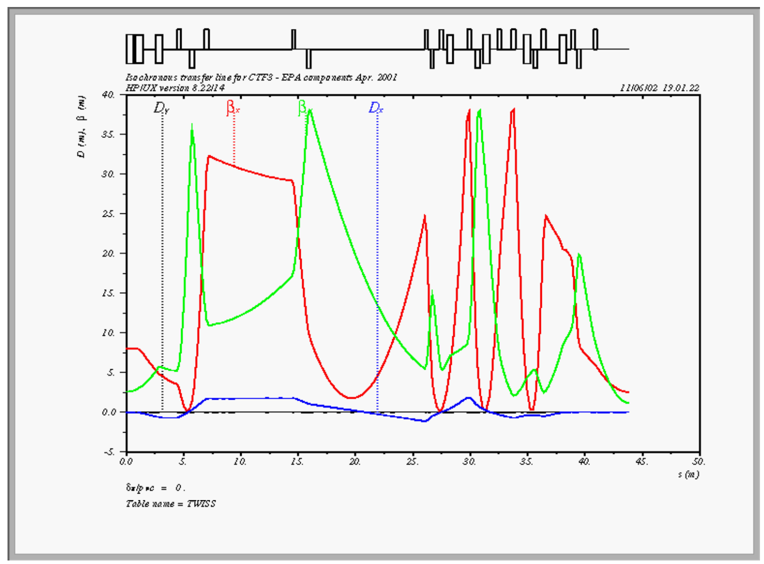
# Extraction Line



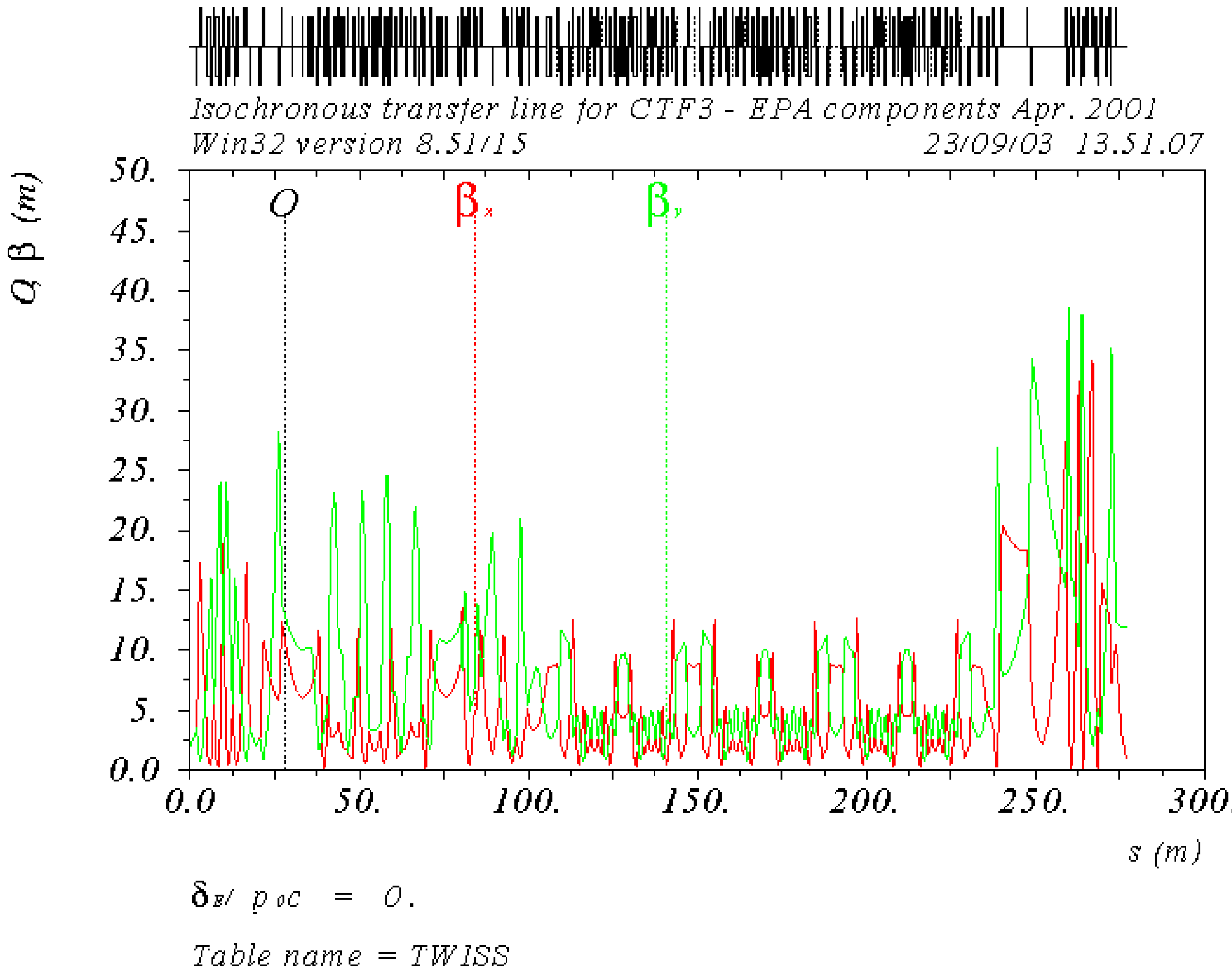

**4 dipoles - chicane**

**- isochronous**

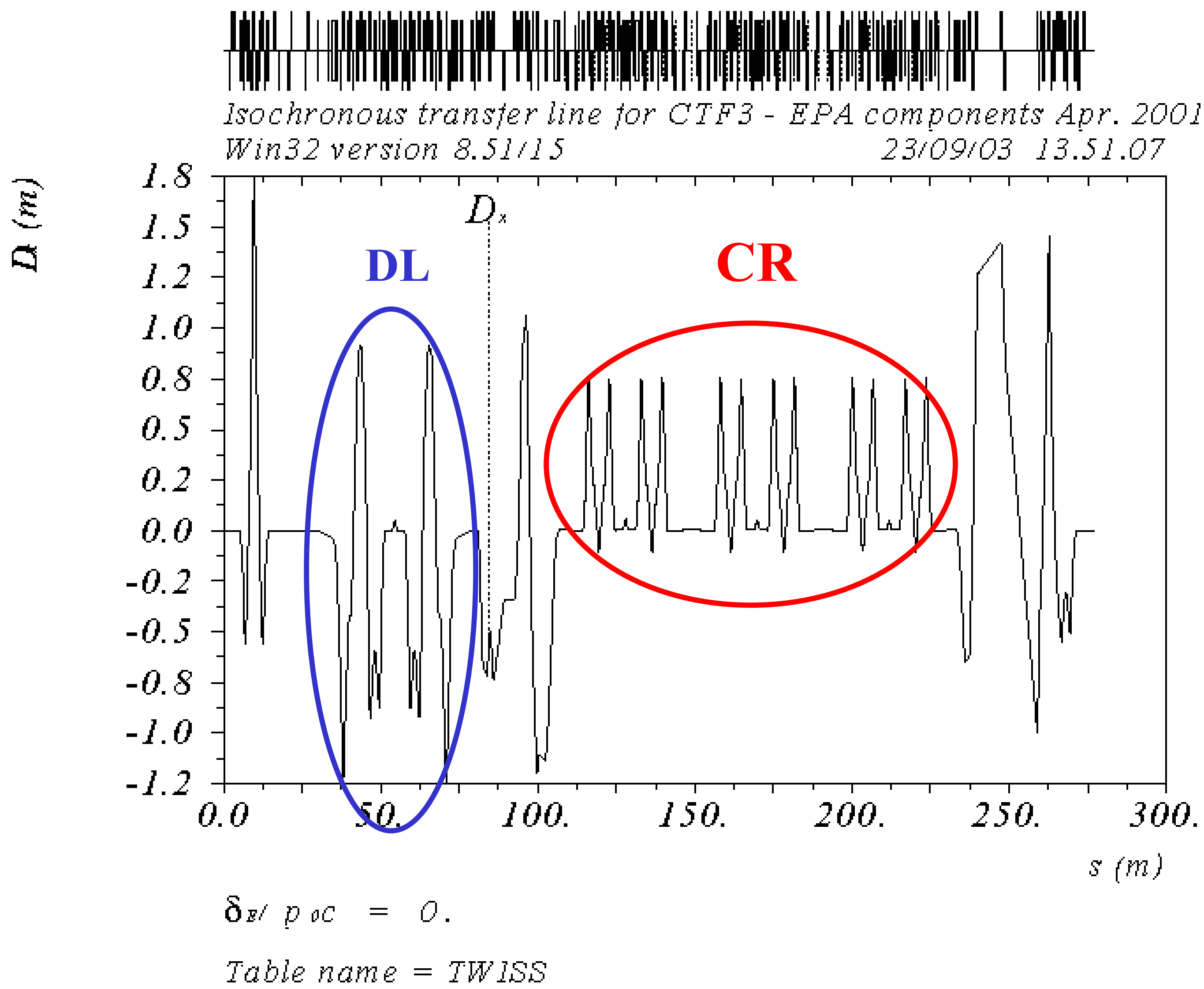
**- tunable $R_{56} \sim \pm 15$ cm**
**(compensates also for extraction dipoles contribution)**



# From Linac to extraction



# Dispersion



Isochronous transfer line for CTF3 - EPA components Apr. 2001
Win32 version 8.51/15
23/09/03 13.51.07
D (m)
$D_x$
DL
CR
1.8
1.5
1.2
1.0
0.8
0.5
0.2
0.0
-0.2
-0.5
-0.8
-1.0
-1.2
0.0
50.
100.
150.
200.
250.
300.
s (m)
$\delta_E/p_0c$ = 0.
Table name = TWISS

# Dipoles all along the FMS

| AVAILABLE | |
|---|---|
| Flat pole | Field index |
| 14 | 16 |

| | Flat pole | Field index |
|---|---|---|
| Stretcher | 4 | |
| DL | 10 | |
| TL to CR | 1 | 4 |
| CR | | 12 |
| TL from CR | 5 | |
| Total | 20 | 16 |

# Quadrupoles

| | Available |
|---|---|
| QN | … |
| Qlarge | … |
| QL3 | |
| others | |
| | |

| | QN | Qlarge | QL3 |
|---|---|---|---|
| **Linac-DL** | **6** | **3** | **3** |
| **DL** | **16** | **4** | |
| **DL - CR** | **13** | | |
| **CR** | **48** | | |
| **TL from CR** | **15** | | |
| **Total** | | | |

# Other Beam Dynamics considerations

**2nd order isochronicity:** $\boldsymbol{T_{5i6} = 0\ \forall i}$

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

**2nd order terms**

**relate transverse to longitudinal phase planes**

**Contribution of TL high order terms can be as strong as rings'**

**FLEXIBILITY in the design is essential**
**Sextupoles can be added in the last chicane…**

**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 Dp/p for obtaining the 2mm long bunches)**

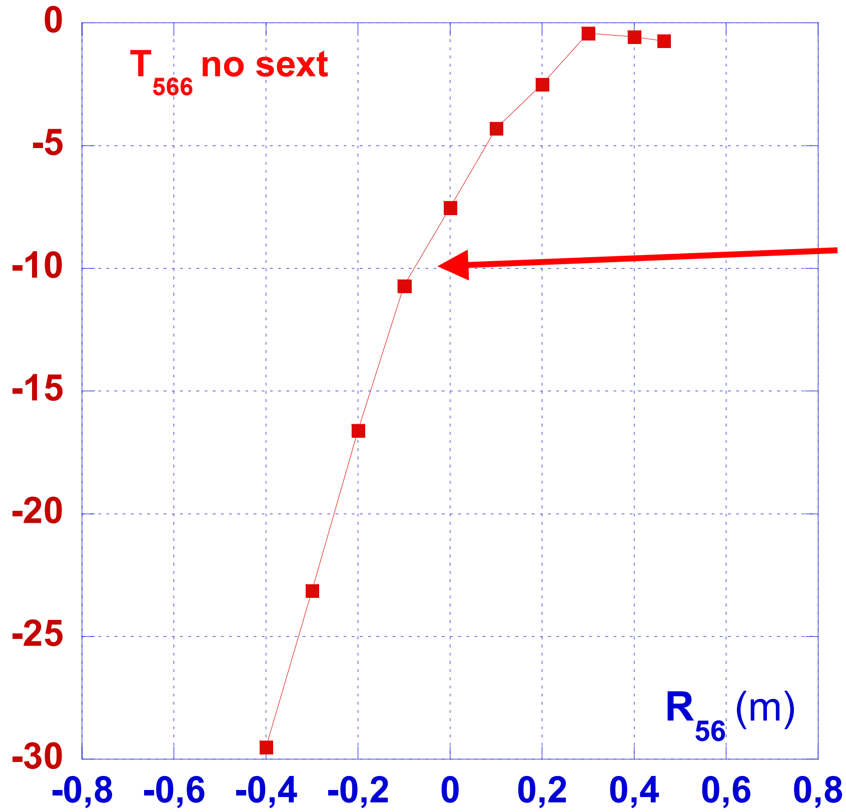
* **produce emittance filamentation**

**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**

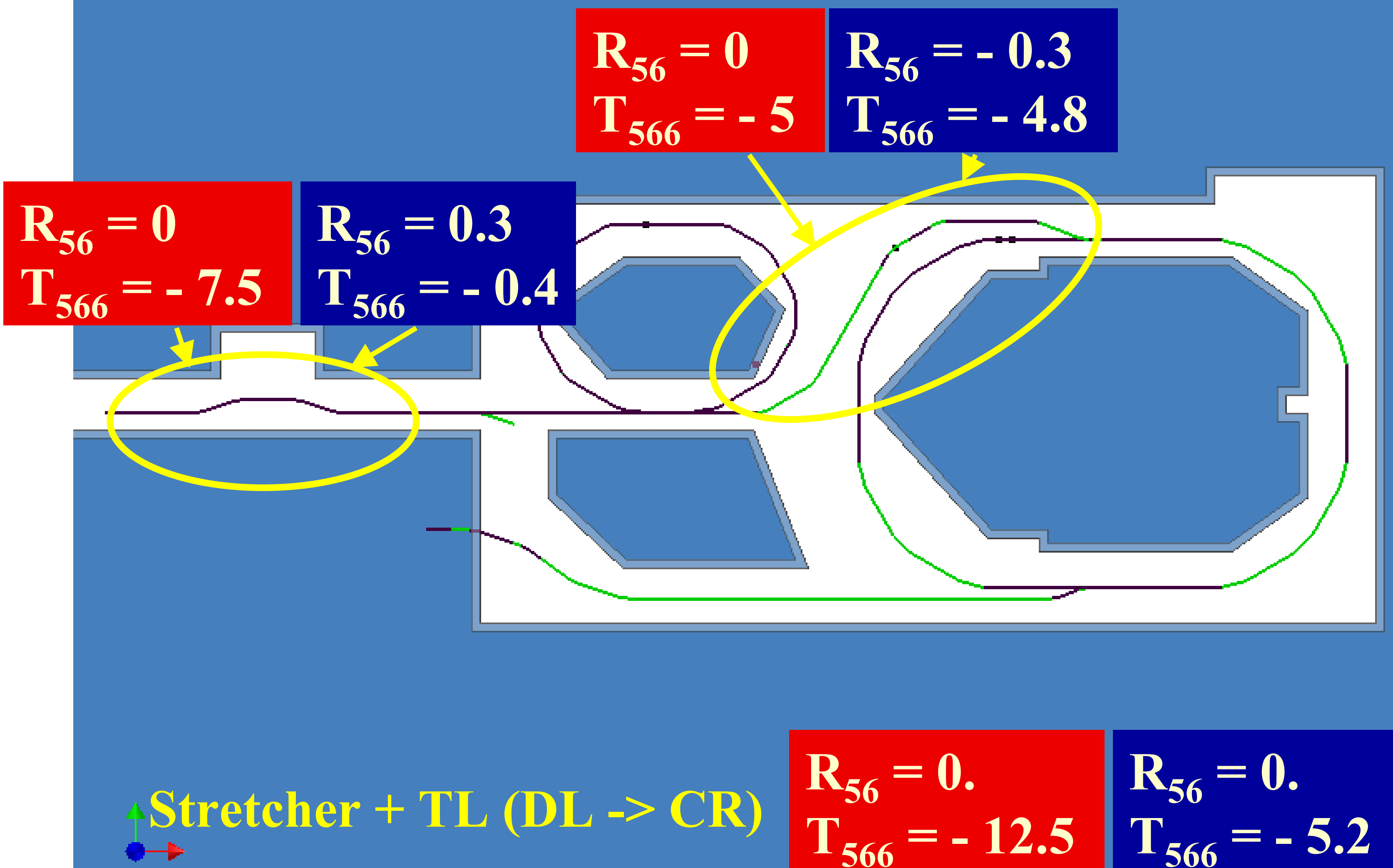
# 2nd order term depends on the linear optics configuration

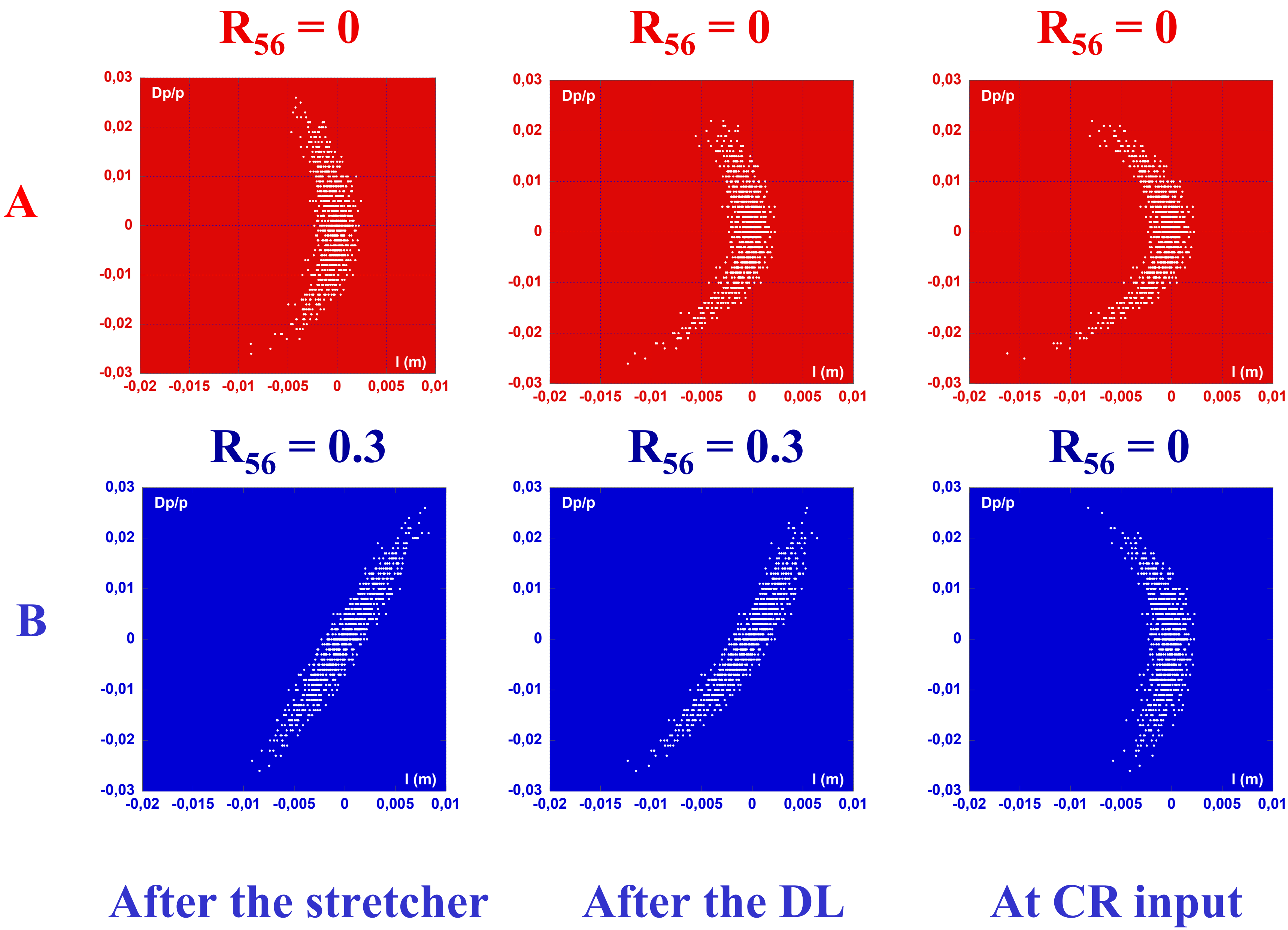
## Stretcher - compressor




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

# Global optimisation

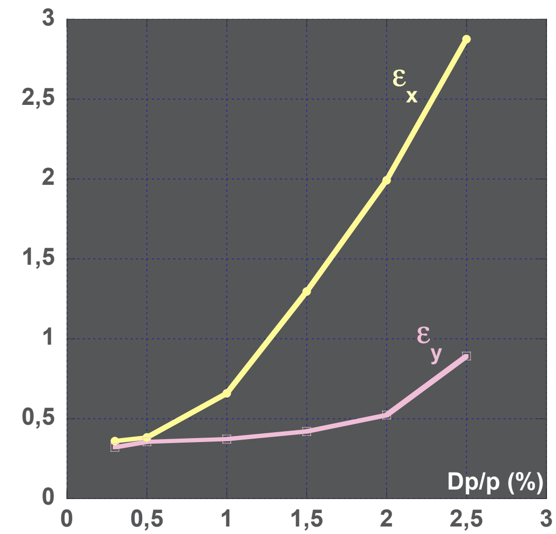




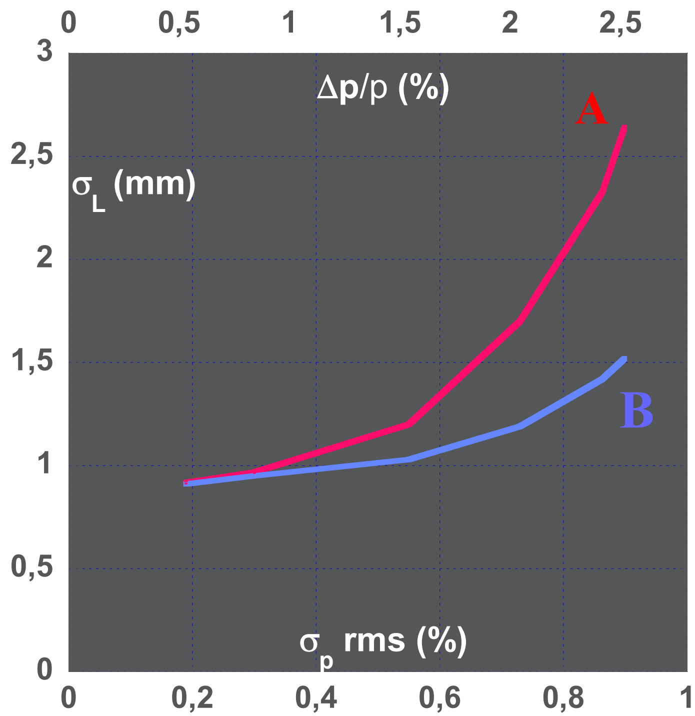
R56 = 0
R56 = 0
R56 = 0
A
R56 = 0.3
R56 = 0.3
R56 = 0
B
Dp/p
l (m)
0,03
0,02
0,01
0
-0,01
-0,02
-0,03
-0,02
-0,015
-0,01
-0,005
0
0,005
0,01
After the stretcher
After the DL
At CR input

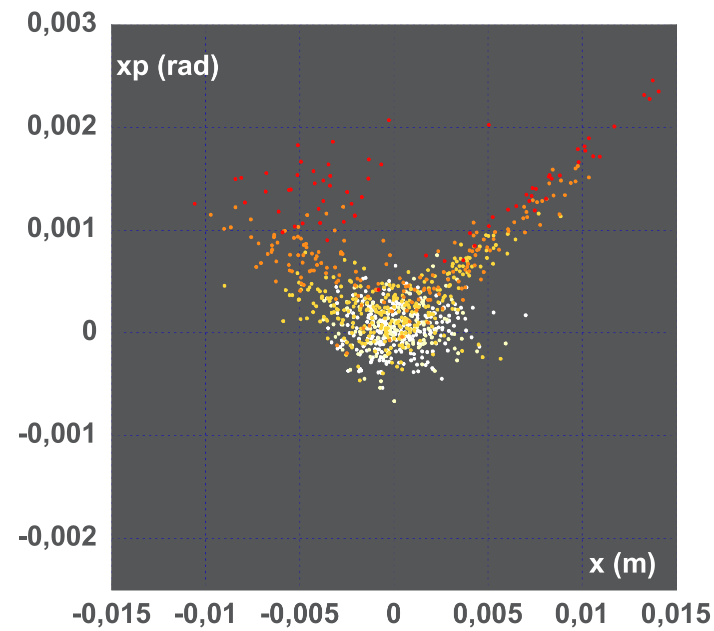
# Simulation from Linac exit to CR input – sexts in DL included

## Transverse plane




## Rms bunch length



# Conclusions - (from review of June 2002)

From beam dynamics point of view:

Main challenge

Low energy and high current bunches manipulation

Path length control

Alignment
Dipole modelling
Wiggler

CSR

large energy spread

increase of bunch length

lost of isochronicity

lost of peak power

cures

stretcher before and compressor after the f multiplication

smooth linear optics

adequate sextupole compensation