DRIVE BEAM
FROM LINAC TO DECELERATOR

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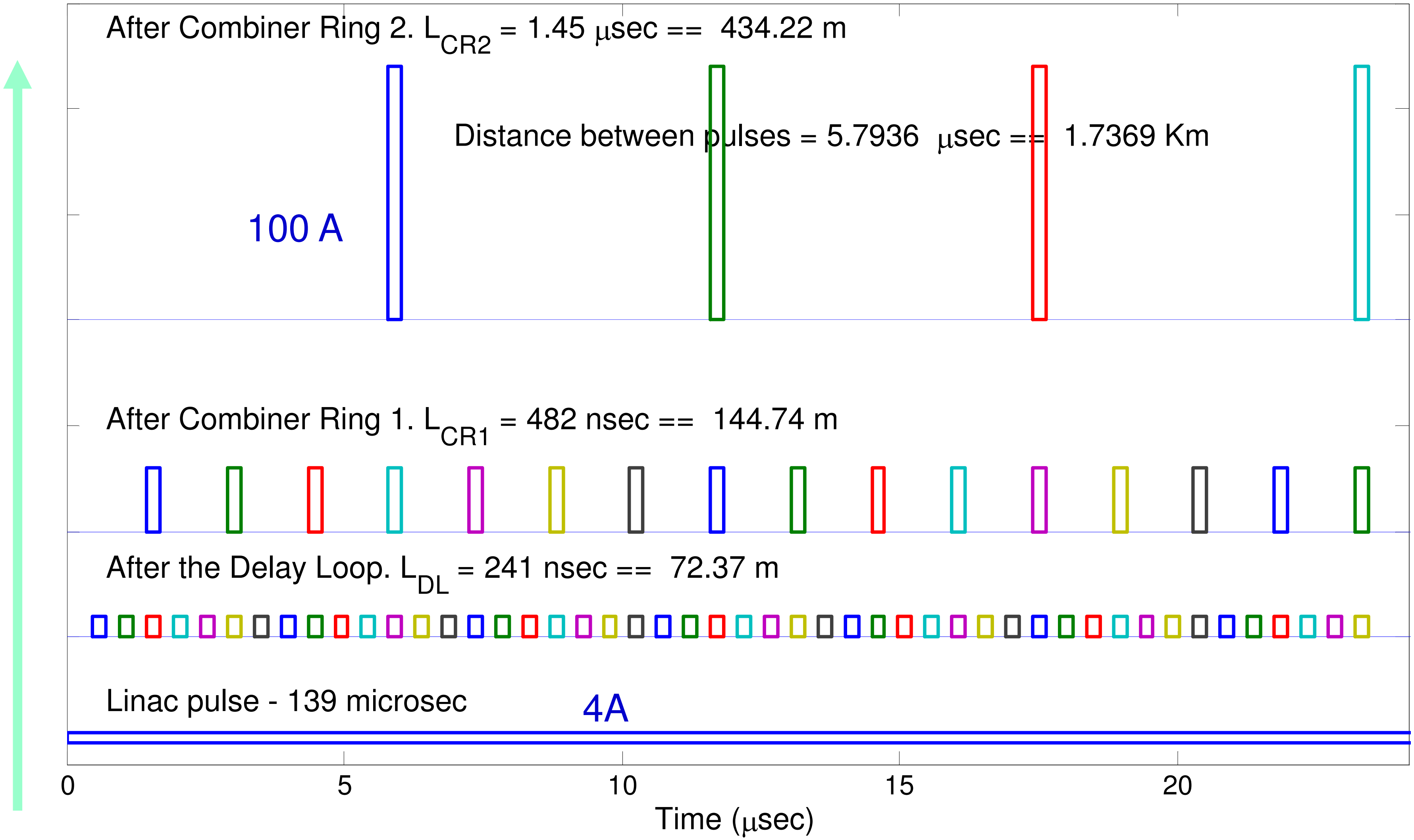
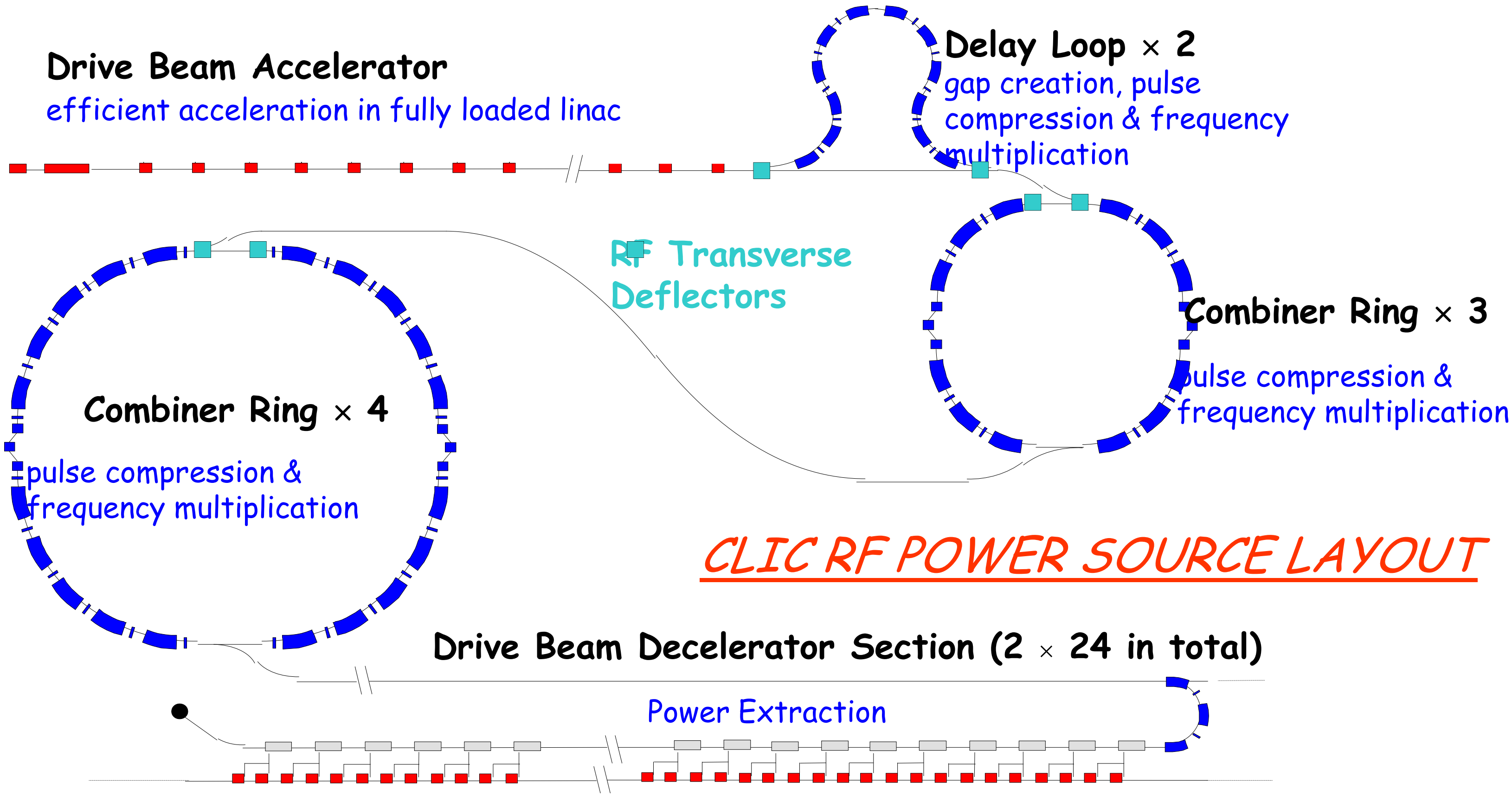
Beam temporal structure along the frequency multiplication system



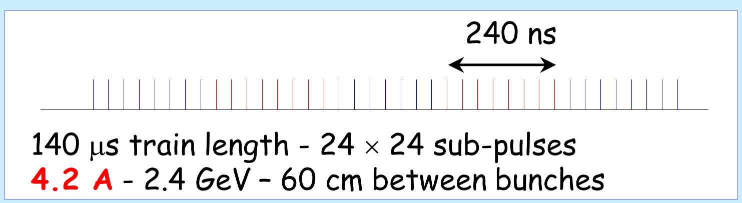
E=2.37 GeV,
Energy spread < 1%,
Bunch charge = 8.4 nC

Emittance ~ 100 μm rad
Bunch length 2mm
Final bunch separation = 2.5 cm

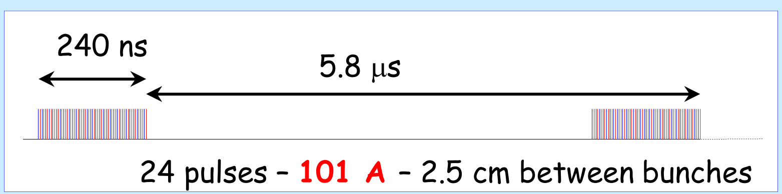
CLIC Drive Beam generation



Drive beam time structure - initial



Drive beam time structure - final



Main issues for drive beam recombination and transportation from Linac to decelerator:

Drive beam at decelerator input: From yesterday Erik's talk

Parameters	Symbol	TBL value	CLIC value	Unit
Number of FODO cells	N_{cell}	8	500	-
Bunch separation	z_{bb}	25	25	mm
Bunch rms length	σ_z	1	1	mm
Pulse length	t_{pulse}	140	240	ns
Transient length	$t_{transient}$	3	1	ns
Initial average current	I_0	30	100	A
Power production	P	159	135	MW
Initial energy	E_0	150	2400	MeV
Final min. energy	E_{min}	59	240	MeV
Final max. energy spread	S	61	90	-
Initial norm. emit.	$\epsilon_{n\,x,y}$	150	150	μm rad

Emittance preservation
Beam loading in rf deflectors (David Alesini – next talk)
ISR energy loss
CSR induced energy spread and energy loss
Longitudinal and transverse acceptance
Isochronicity of successive stages
Achromaticity of Injection bumps in the rings
Final bunch compression
…

Main parameters of the rings

Parameter		DL	TA	CR1	CR2
L	m	73.05	146 + 73	146.09	438.28
Combination factor		2	2	3	4
RF deflector frequency	GHz	1.5	1.5	2.	3.
N of dipoles		12	12	12	16
ρ	m	4.7	4.7	4.7	12
B	T	1.7	1.7	1.7	0.7
N of quadrupoles / families		18 / 9	44/17	48 / 9	64 + fodo quads
$l_q * dB/dx$ max	T	10	11	6	6

For decreasing ISR energy losses

Energy loss per turn (Incoherent Synchrotron Radiation)

$$U_0(keV) = 88.46\,\frac{E(GeV)^4}{\rho(m)} =$$

$$= 0.6\,MeV \qquad \rho = 4.7m$$

$$= 0.235\,MeV \qquad \rho = 12m$$

@CR2

Number of turns

0 -1.1

0.5 - 1.5 - 2.5

0.5 -1.5 - 2.5 - 3.5

From 1 turn to 7.1 turns: energy loss from 0.42 to 3 MeV

↓

Spread between the minimum and maximum lost: ΔE/E ~ 0.1 %

SPIDER-2 PROGRAM (L. Falbo)

The program SPIDER (Simulation Program for Impedances Distributed along Electron Rings) was created to simulate the longitudinal single bunch dynamics in a ring where the bunch length is not constant along the ring. To study such a phenomenon the code studies the longitudinal phase space evolution along an arbitrary section of a ring. As a consequence it can be easily used to study bunch dynamics in a transfer line.

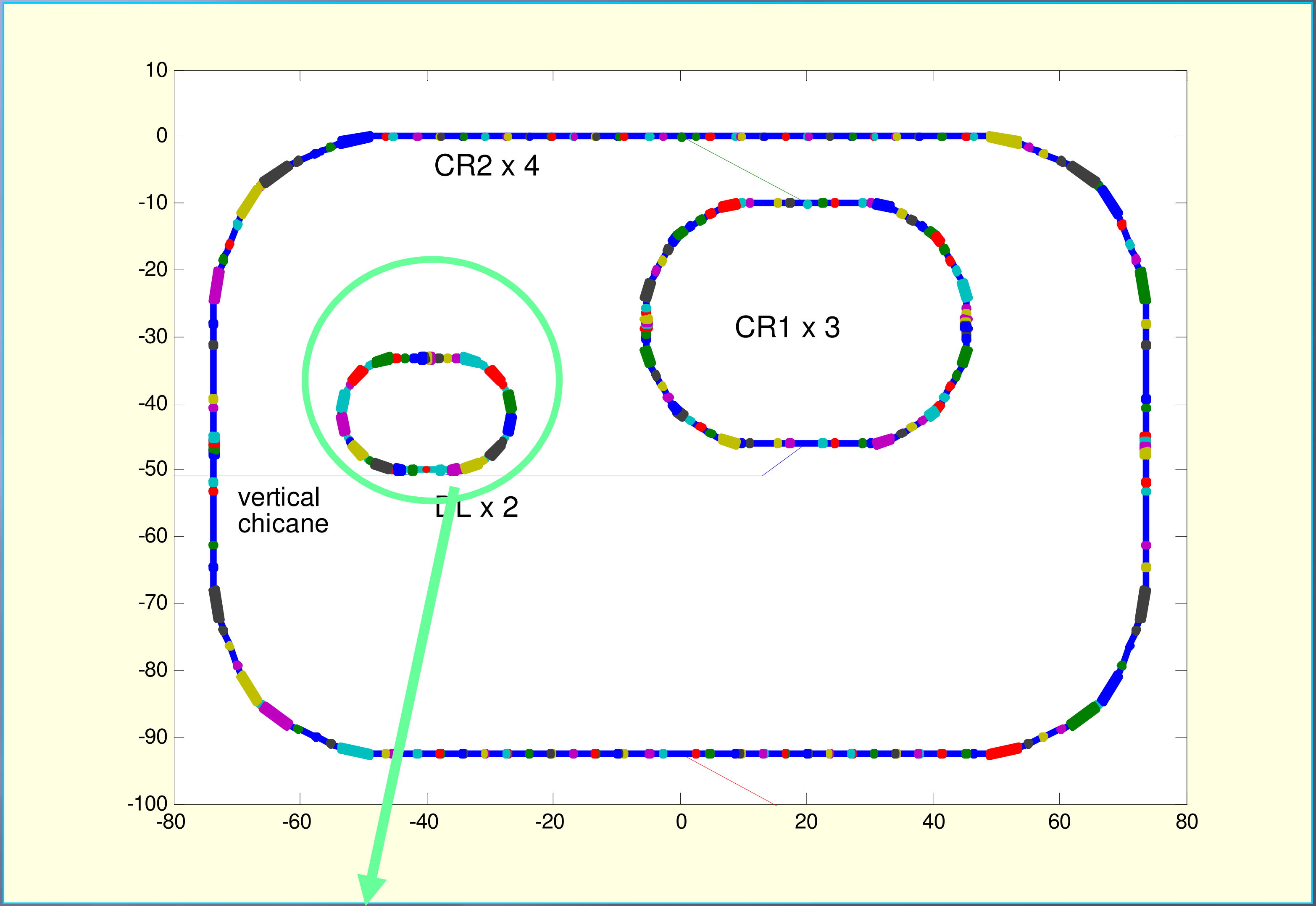
The effects that can be studied are:

a) Interaction with the vacuum chamber (Pipe wakefield)
b) Incoherent synchrotron radiation
c) Several aspects of Coherent synchrotron radiation (CSR) : in a “Long” dipole, in a dipole in which the entrance and/or the exit effects are important, in a dipole with the pipe shielding effect, in a wiggler.
d) Space charge effects

The code reproduced DAFNE dynamics and was used to study lattices characterised by bunch length modulation.

The code has been recently upgraded (SPIDER2) to study also effects in hadron rings.

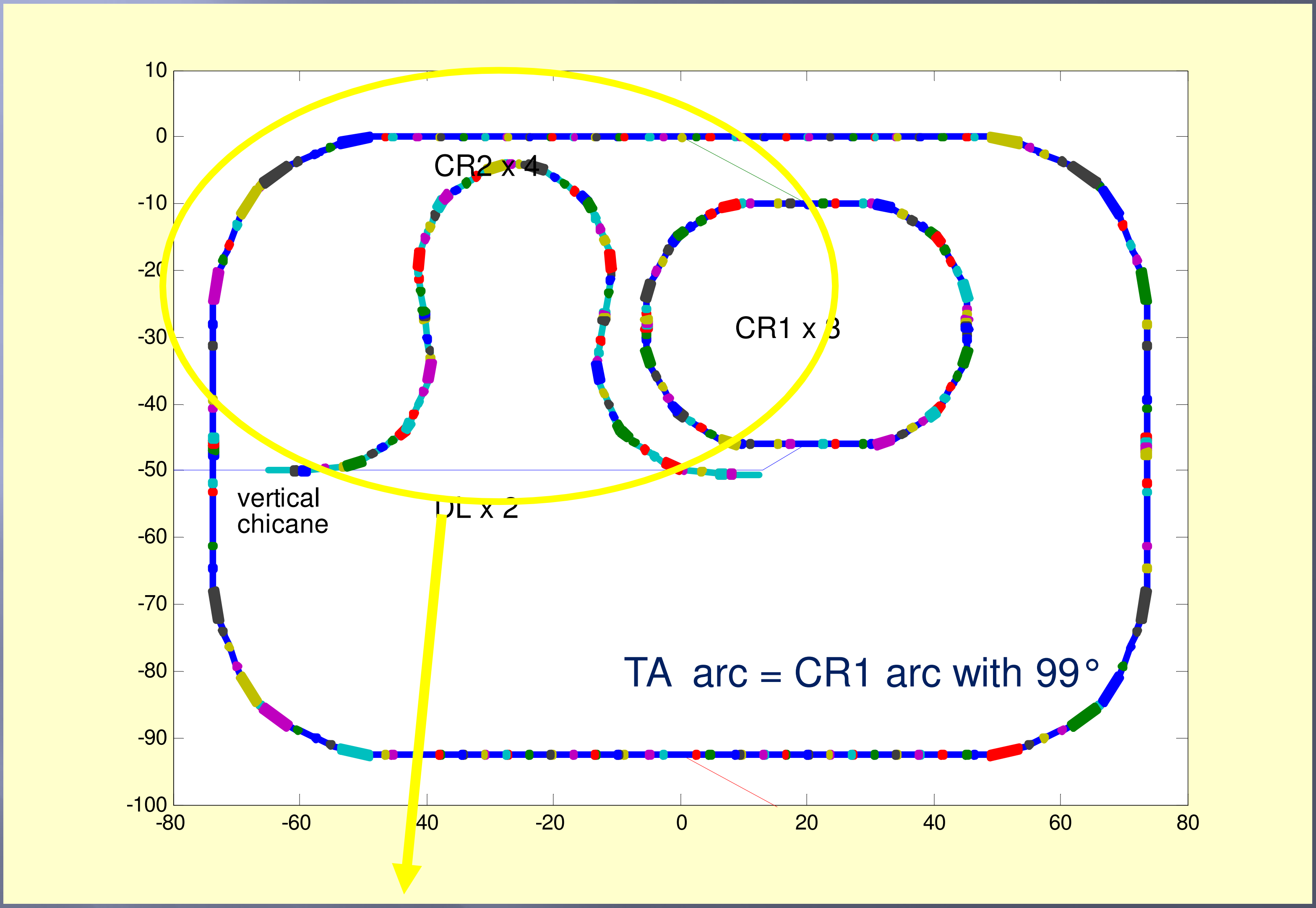
FMS layout



Delay Loop as in CTF3

October 08

FMS layout



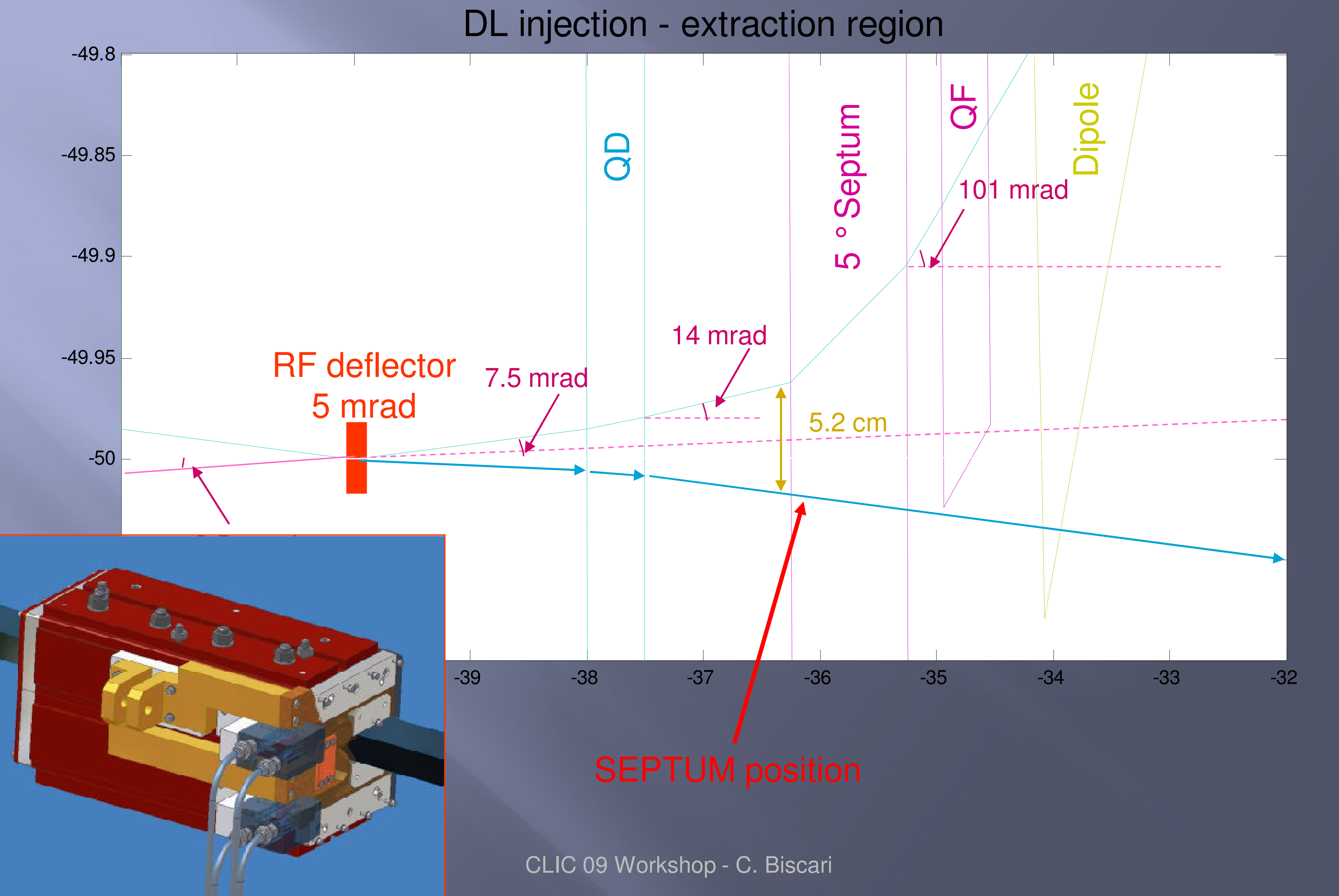
Turn Around Loop

June 09

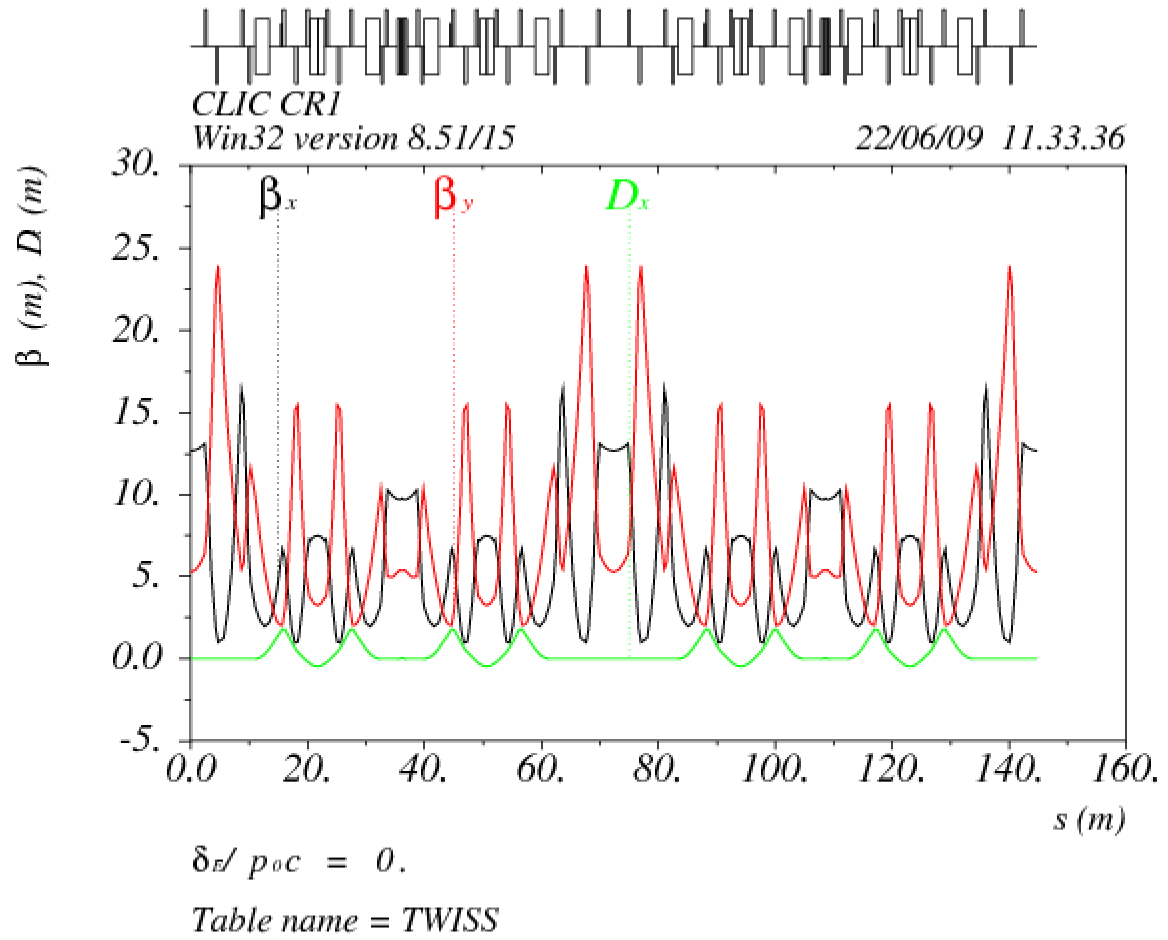
DL against TA

DELAY LOOP	TURN AROUND
L = 73 m	L = 73 * 2 + 73 m
Total bending angle = 2p	Total bending angle > 10%
Low number of elements	High number of elements
1 rf deflector	2 rf deflectors
High element density	Low element density
Higher T566 (-55m, sext off)	Lower T566 (-35, sext off)
	Better tunability

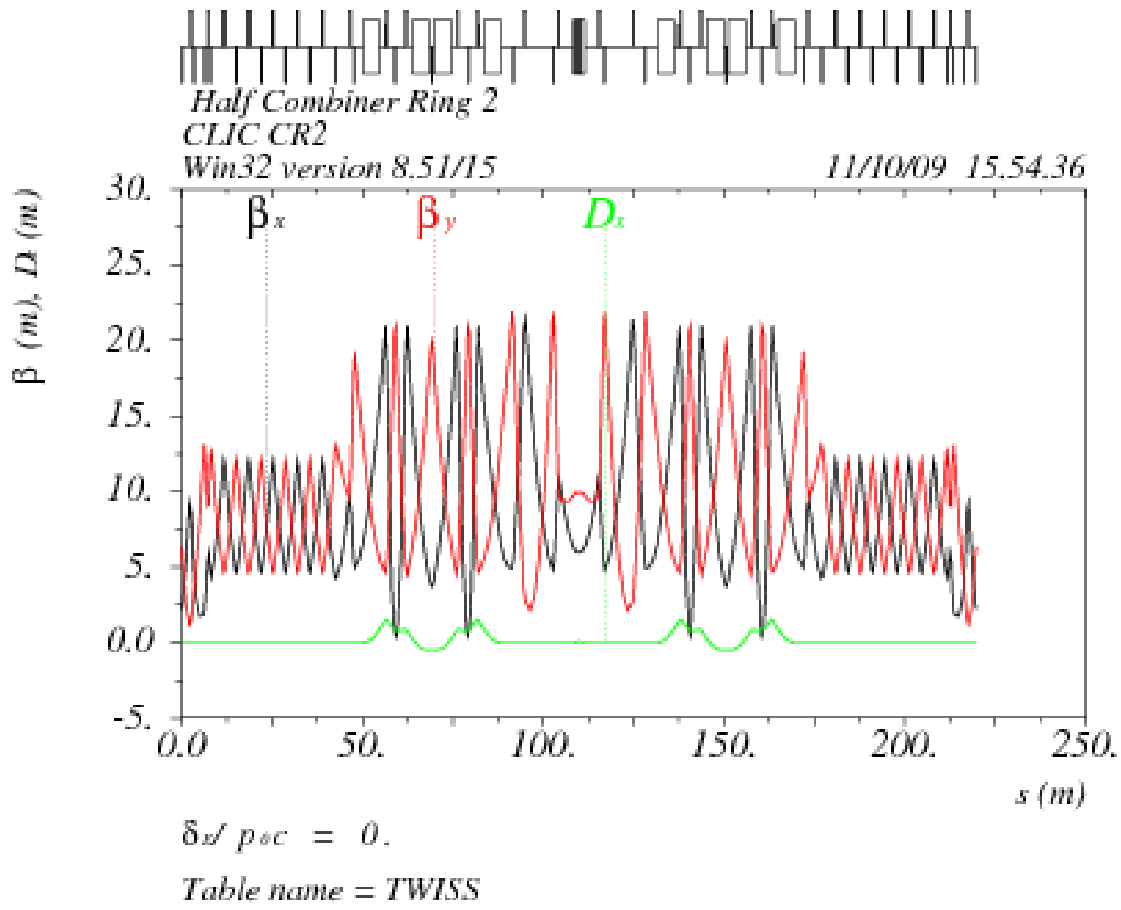
ADDING a Dquad between the rf deflector and the septum
The odd and even bunches are separated and vertically focused on the septum position



1° combiner ring



2° combiner ring



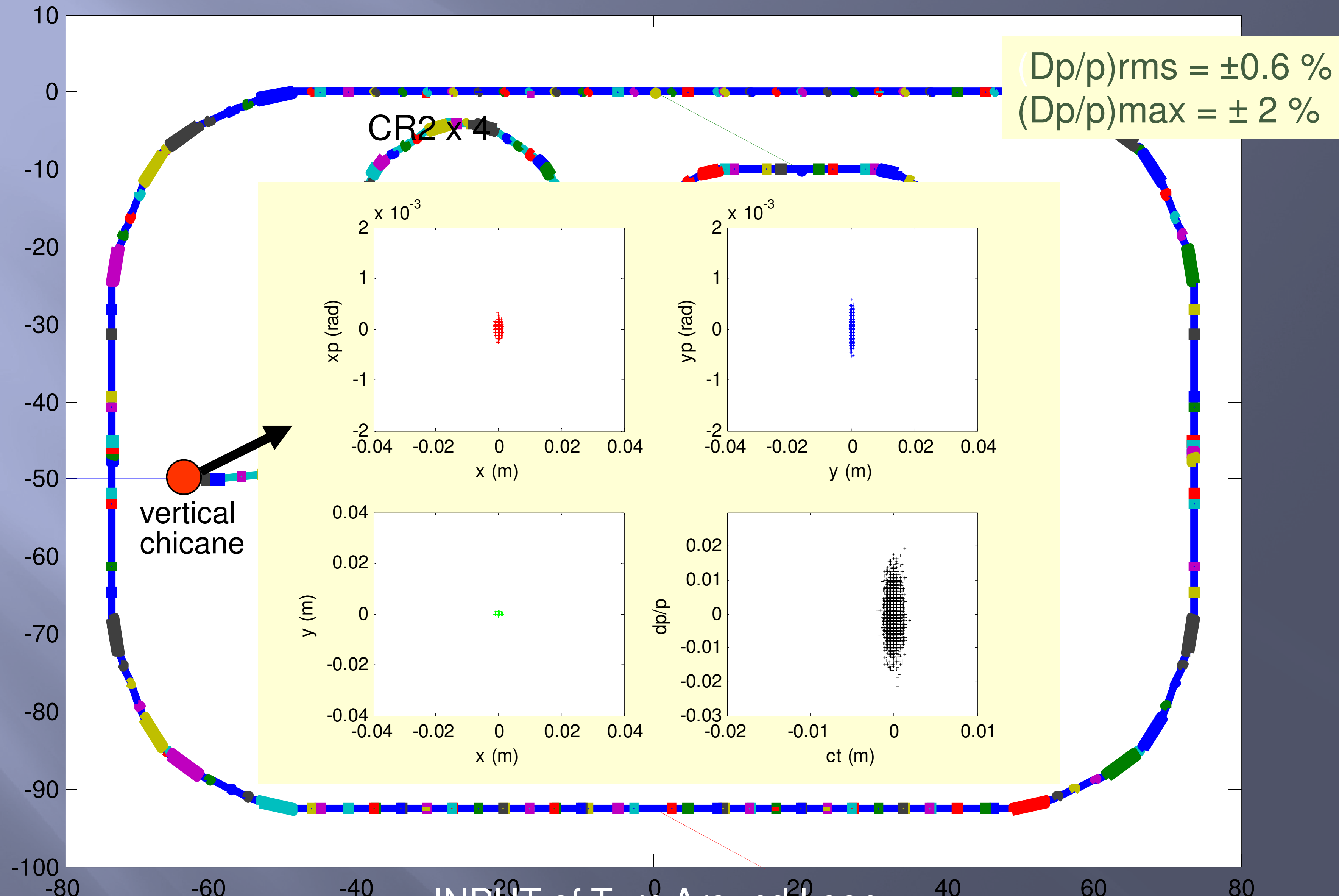
Tracking 6d particle distribution along fms with two different energy spread values – mad8

Optimisation of 2 order chromaticity terms

- Beam energy spread is the parameter mostly influencing the three phase spaces.
- Correcting the 2° term isochronicity by sextupoles can be harmful for the transverse planes.
- Up to ± 1% of energy spread 3 emittances are easily preserved.
- Particles with higher energy deviations can be lost transversely when sextupoles are not carefully optimised

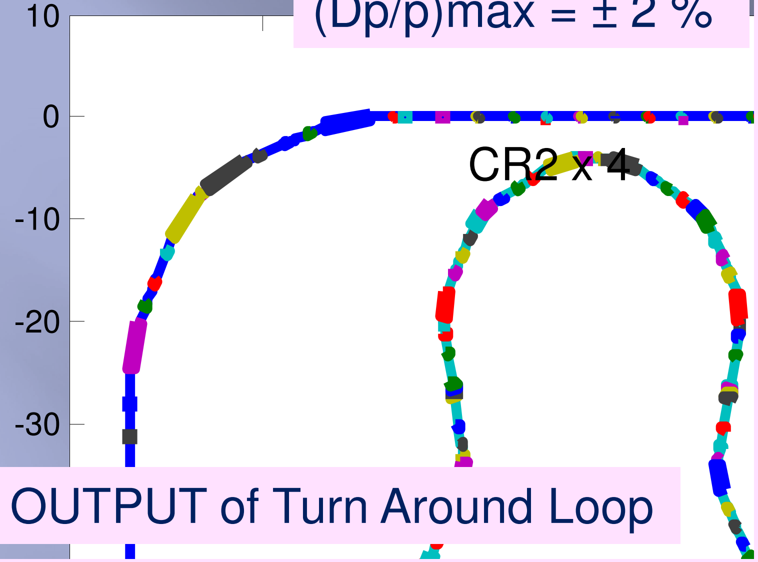
Dp/p = 1% -> 3.5 mm

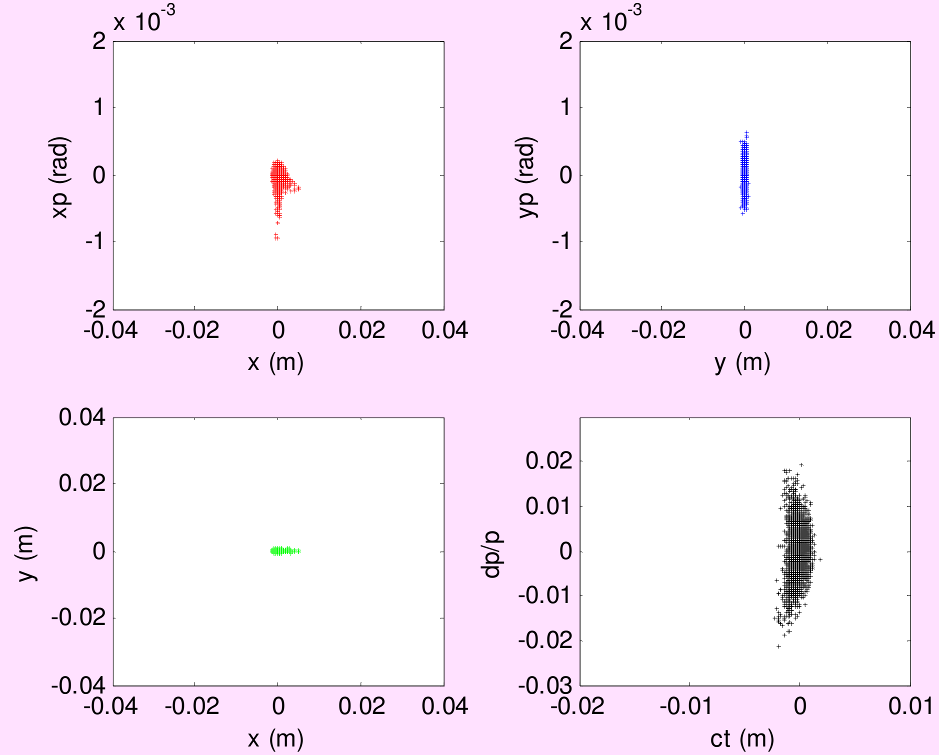
	TA	CR1	CR2
T566 sext off	-34.6	-19.2	-13.4
T566 sext on	-4.4	-0.6	0.2
T166 sext off	-42.	-4.5	22.6
T166 sext on	5.8	-0.5	-48.



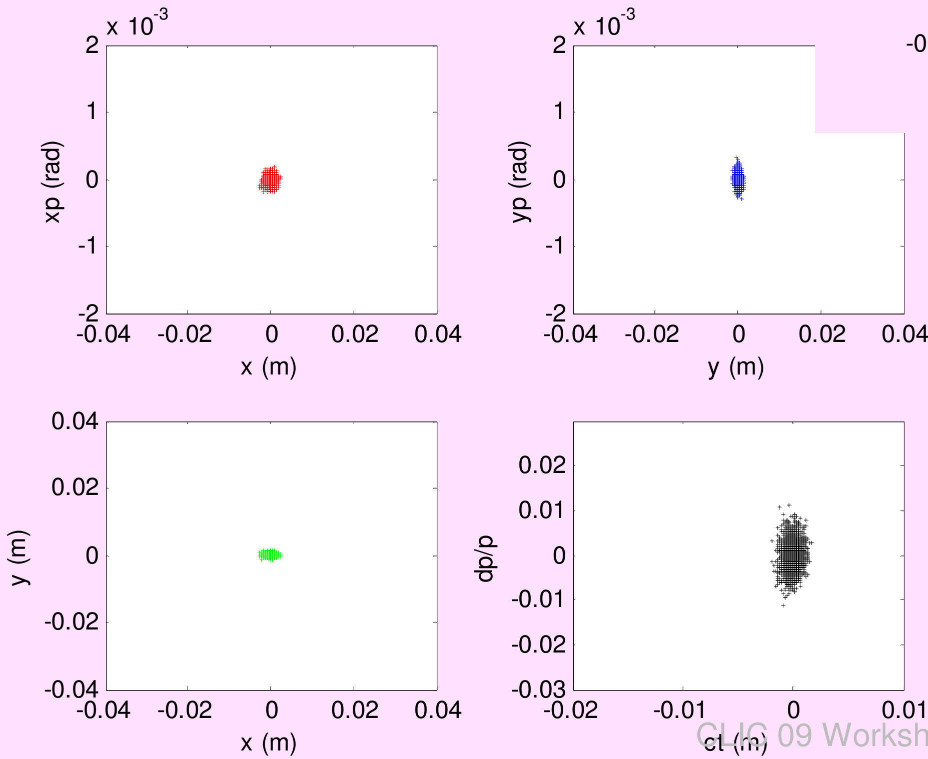
INPUT of Turn Around Loop

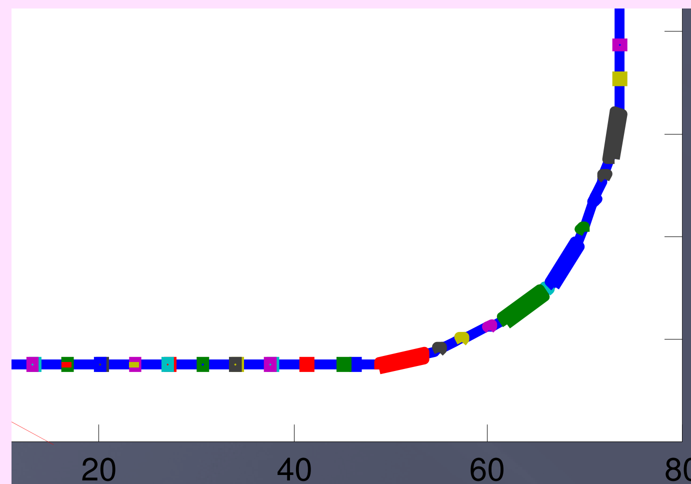
(Dp/p)rms = ±0.6 %
(Dp/p)max = ± 2 %



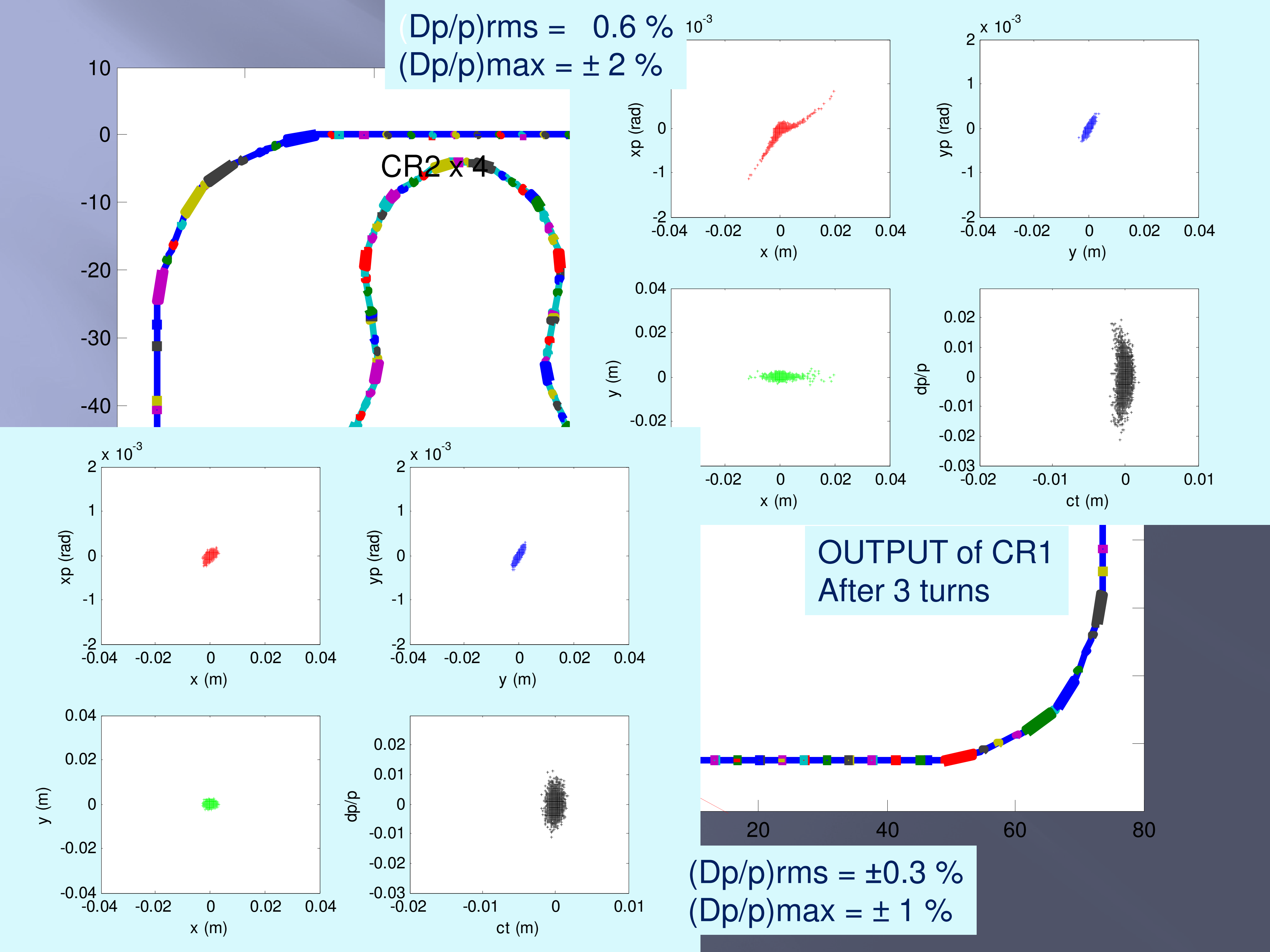


OUTPUT of Turn Around Loop

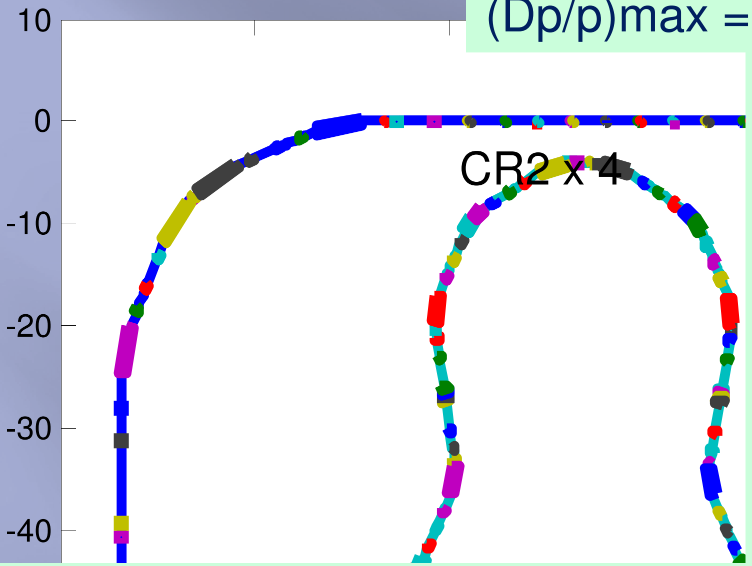


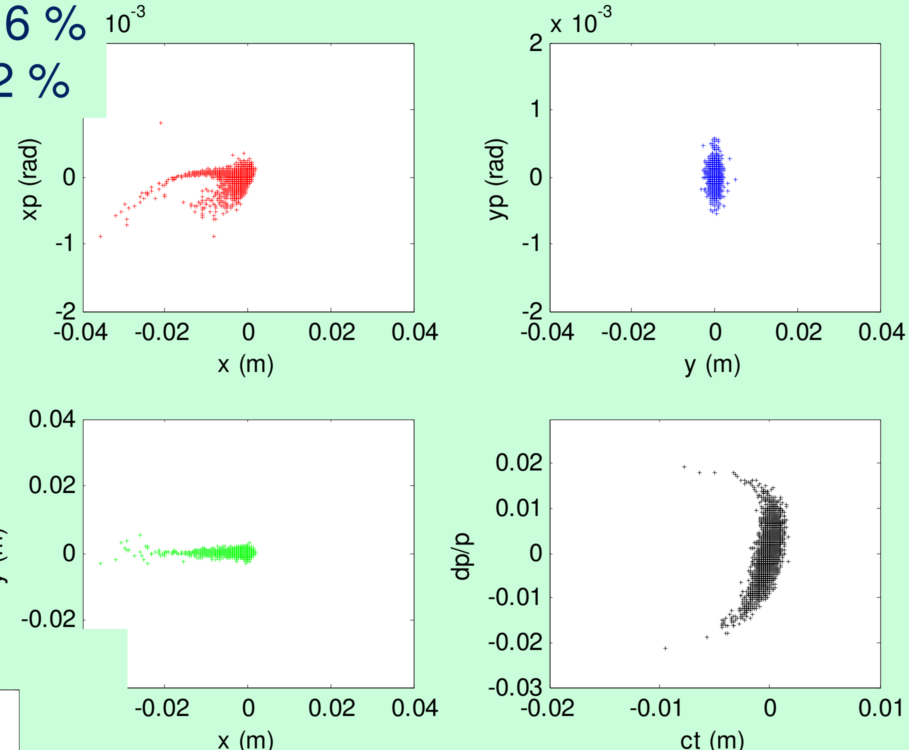


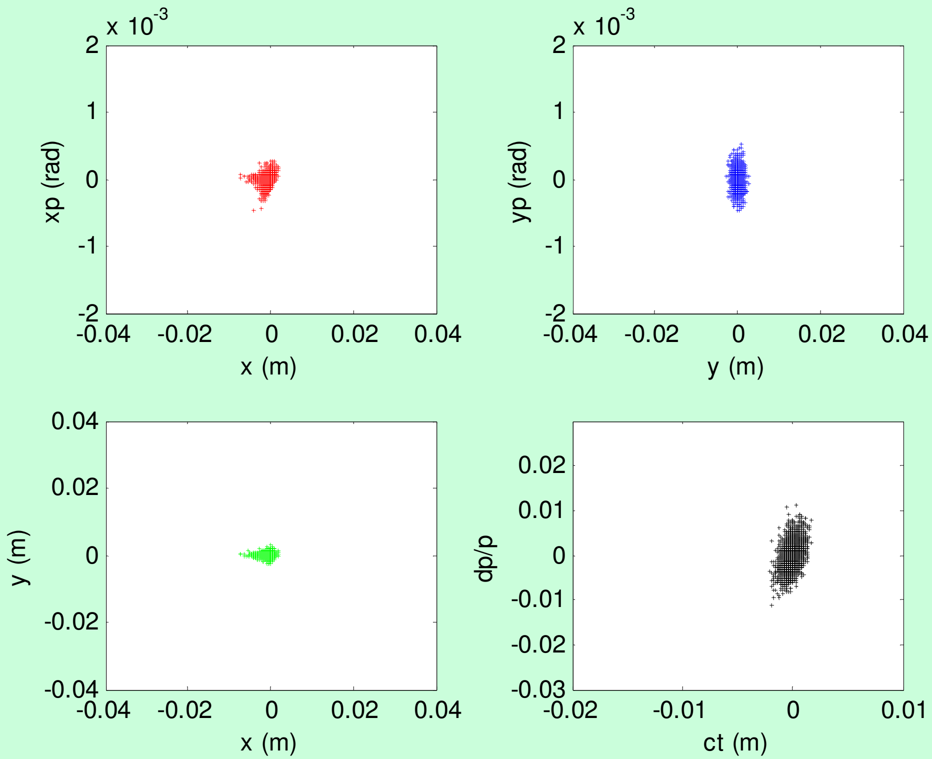
(Dp/p)rms = ±0.3 %
(Dp/p)max = ± 1 %


(Dp/p)rms = 0.6 %
(Dp/p)max = ± 2 %
CR2 x 4
OUTPUT of CR1
After 3 turns
(Dp/p)rms = ±0.3 %
(Dp/p)max = ± 1 %
xp (rad)
x (m)
yp (rad)
y (m)
y (m)
x (m)
dp/p
ct (m)
x 10^-3

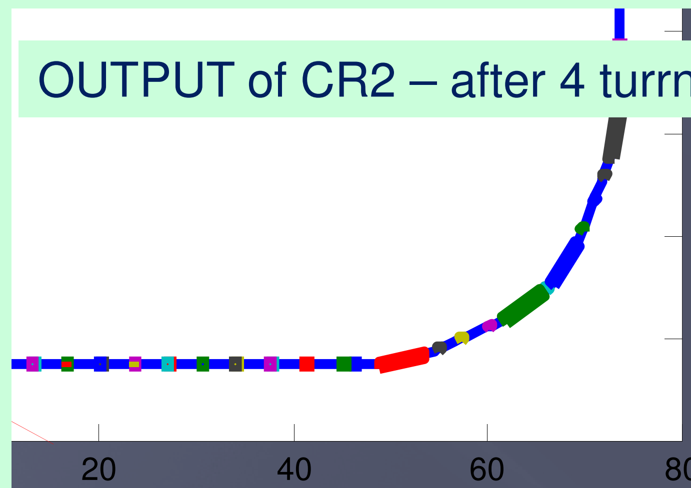
(Dp/p)rms = 0.6 %
(Dp/p)max = ± 2 %







OUTPUT of CR2 – after 4 turrns



(Dp/p)rms = ±0.3 %
(Dp/p)max = ± 1 %

TRACKING IN CR1
With MADX

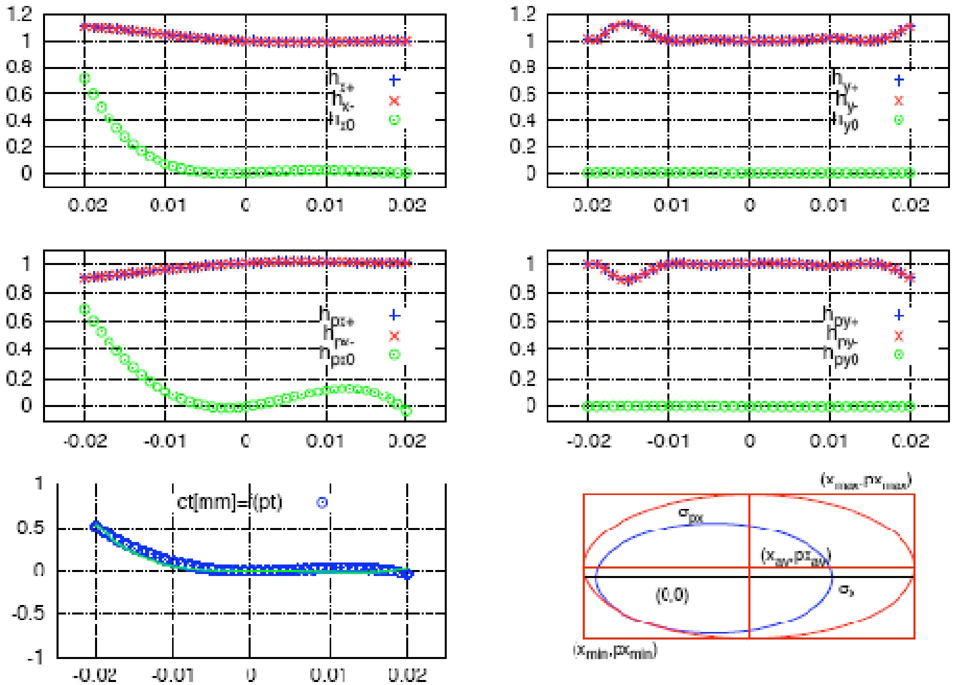


Figure 2: The results of thee turns tracking through CR1. Four upper pictures : the functions $h(\delta_p)$ defined in the text for the four canonical transverse phase-space variables x, px, y, py. Down right: the extrema of the 1σ deformed phase-space (red) at δ_p observed in the tracking data which are used to construct the h functions, compared to the nominal (blue) phase-space ellipse (σ_x, σ_{px}). Down-left : the residual ct error with δ_p . The red-curve is an eye-fit mixing of polynom with 3^{rd} and 4^{th} terms.

$$h_{x+}(\delta_p) = [x_{\max}(\delta_p) - x_{av}(\delta_p)] / \sigma_{\beta,x}$$

$$h_{x-}(\delta_p) = [x_{av}(\delta_p) - x_{\min v}(\delta_p)] / \sigma_{\beta,x}$$

$$h_{x0}(\delta_p) = x_{av}(\delta_p) / \sigma_{\beta,x}$$

MAD X

Correction for CR1 : one sextupole family

T566 = 0

Q'x = -9.8 sext off, and -2.1 sext on

Q'y = -10.4 sext off, and -13.6 sext on

$\Delta\beta/\beta < 0.22$ for 2% of δp.

Tracking particles of amplitudes $A_{x,y}$ = 1,2,3 $\sigma_{x;y}$ evenly spaced in phase and covering the momentum range $\pm$ 2% over three turns:

- no significative deformation of the vertical phase-space
- the horizontal phase-space is preserved up to $\delta p = \pm 1.2$ %

- Qualitatively and quantitatively same results of Mad8, but with different sextupole strengths

MadX – Mad8

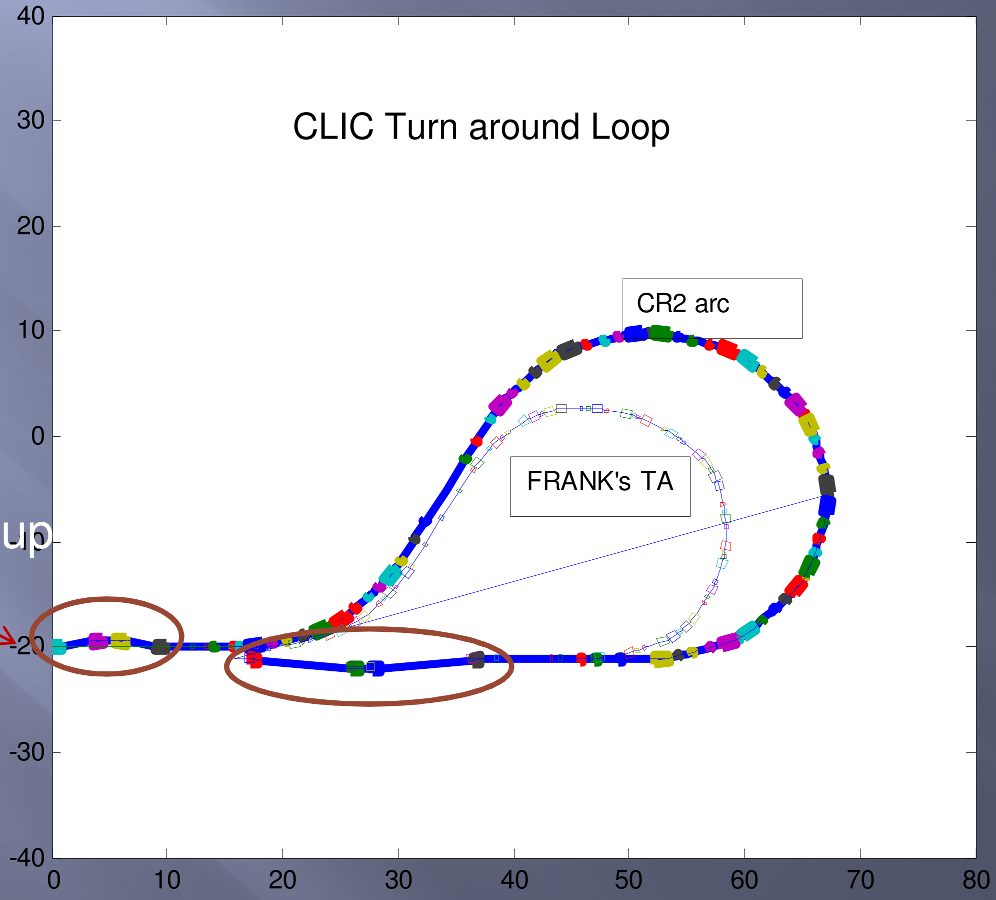
- Different values for chromaticity evaluation
- 2 order longitudinal correction slightly different

Use ctf3 combiner ring as benchmark:

Apply sextupole corrections for bunch length and chromaticity optimisation
Measurements of bunch length and of beam emittances in TL2

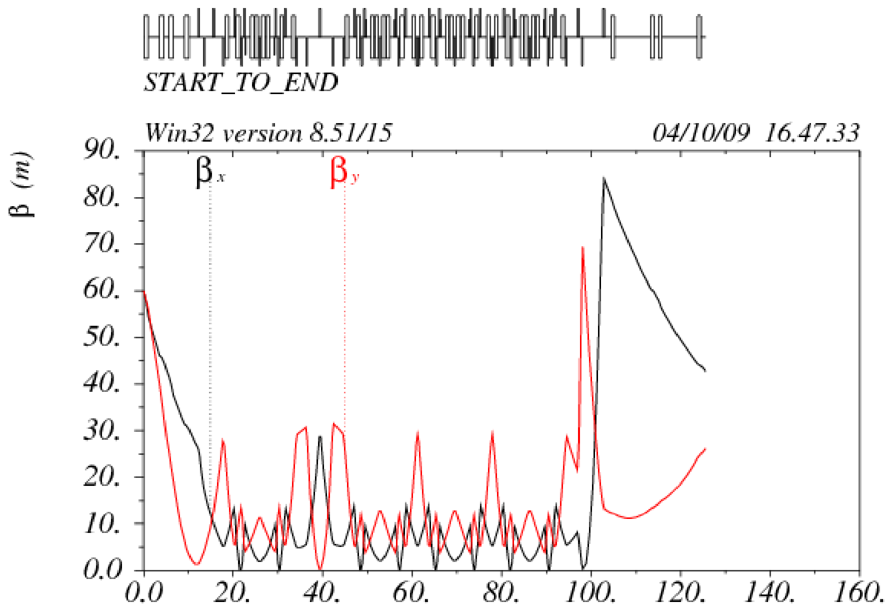
Turn Around to the decelerator

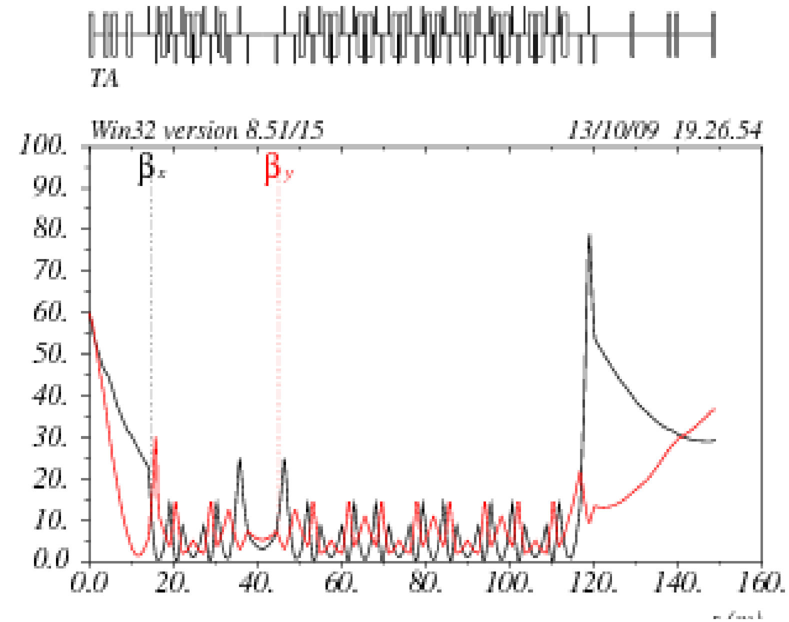
Energy chirp
Energy spread up

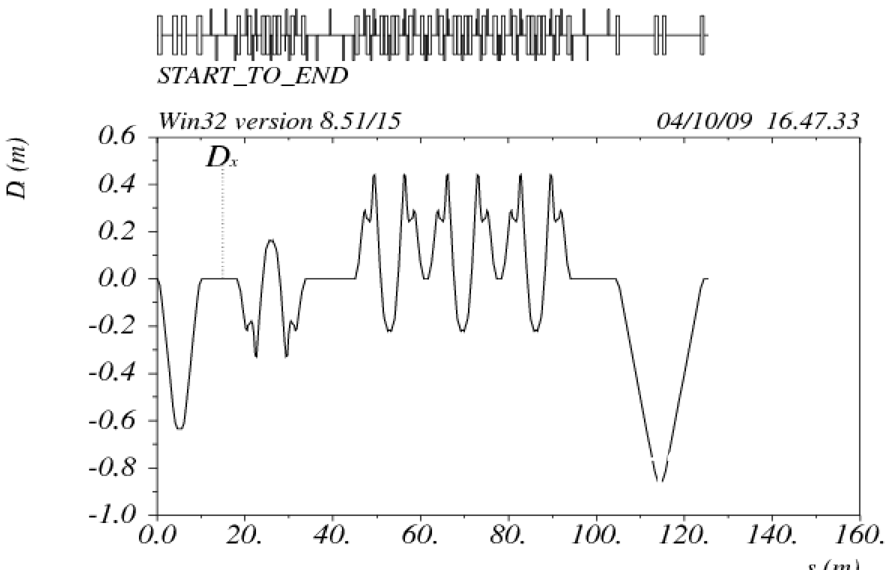


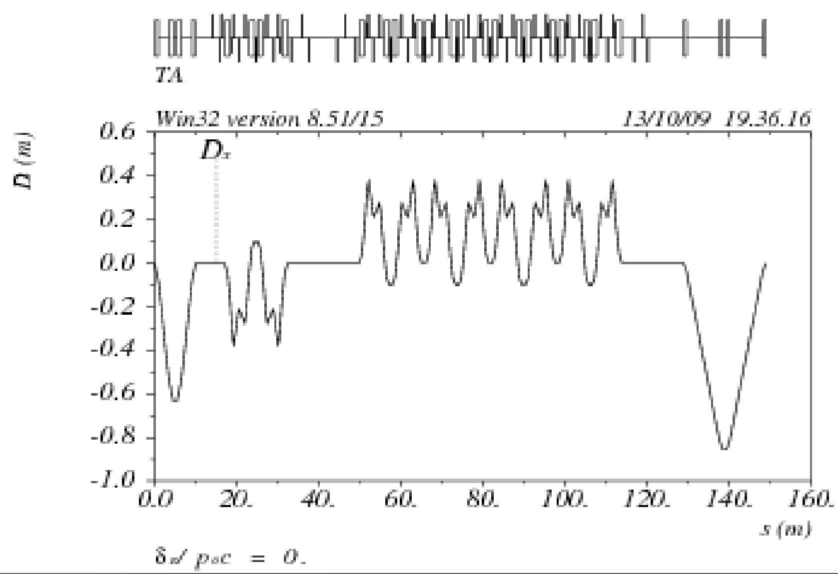
‘Short’ TA

‘Long’ TA

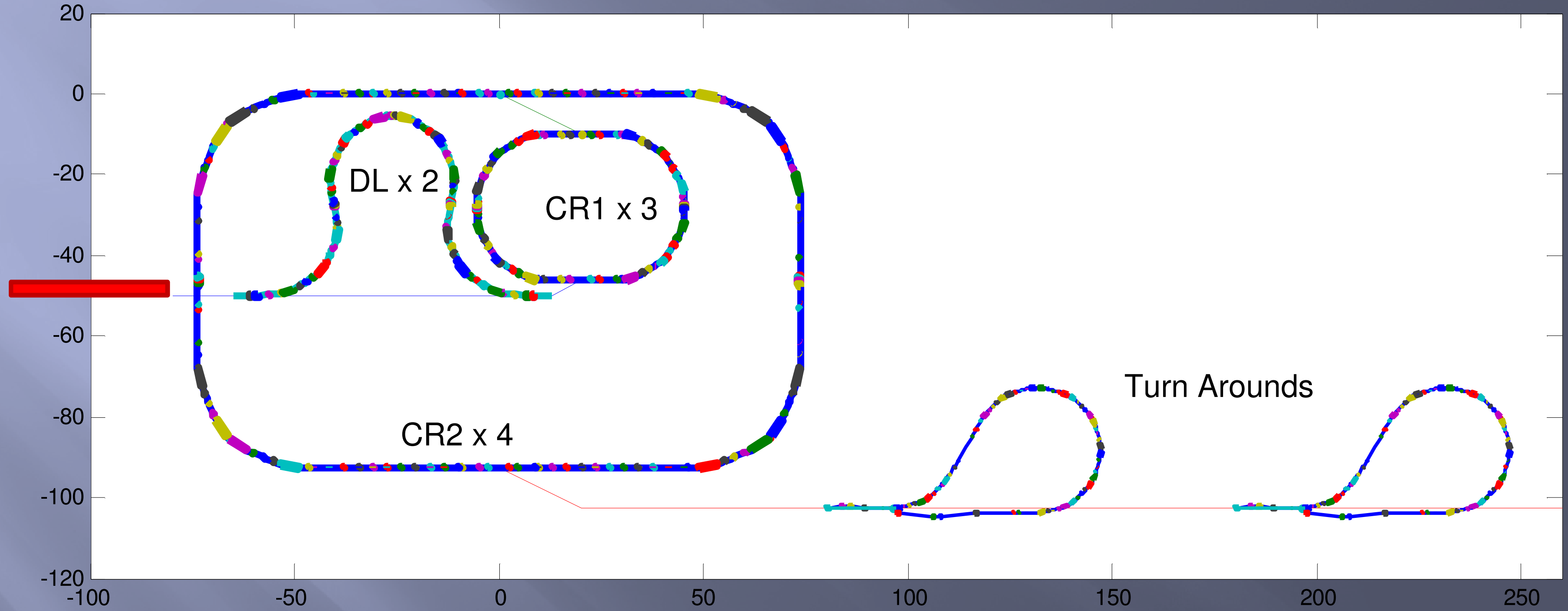








Whole system from Linac to Linac

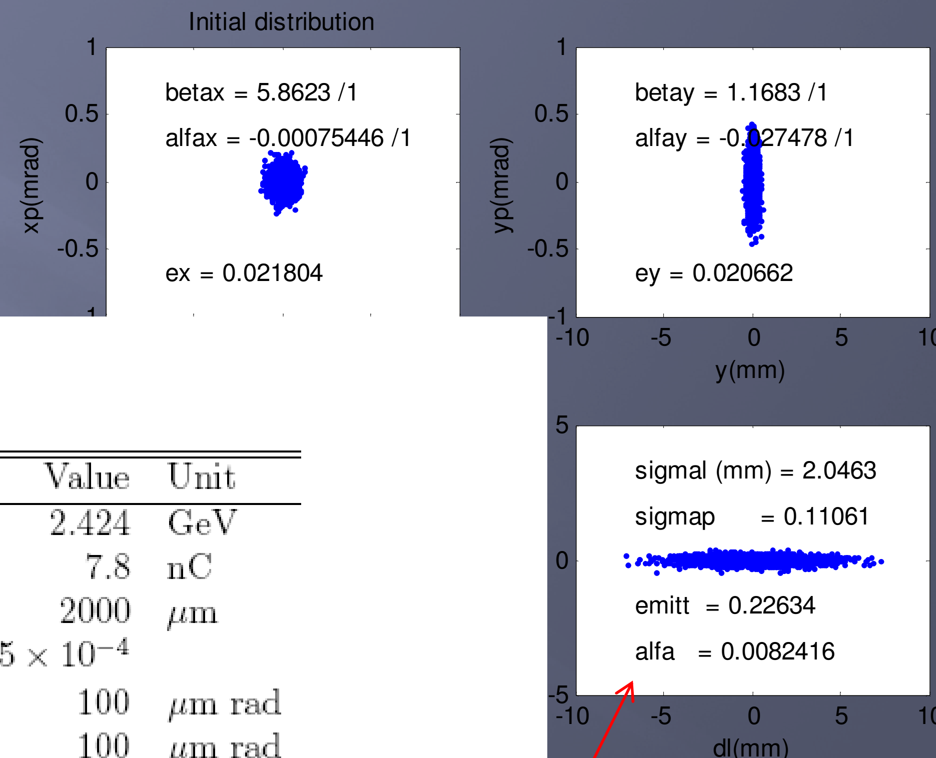


Conceptual Design of Bunch Compressors and Turn Around Loops for a Multi-TeV Linear Collider, Final Report on PSI's Activities within the EUROTeV Collaboration

F. Stulle*, A. Adelmann, M. Pedrozzi
Paul Scherrer Institut, Villigen, Switzerland

August 20, 2008

EUROTeV-Report-2008-025



Property	Symbol	Value	Unit
Electron energy	E_0	2.424	GeV
Bunch charge	Q_0	7.8	nC
Bunch length	$\sigma_{s,i}$	2000	μm
Uncorrelated energy spread	$\frac{\sigma_{E,unc}}{E_0}$	2.5×10^{-4}	
Normalized emittance	$\varepsilon_{n,x}$	100	μm rad
	$\varepsilon_{n,y}$	100	μm rad

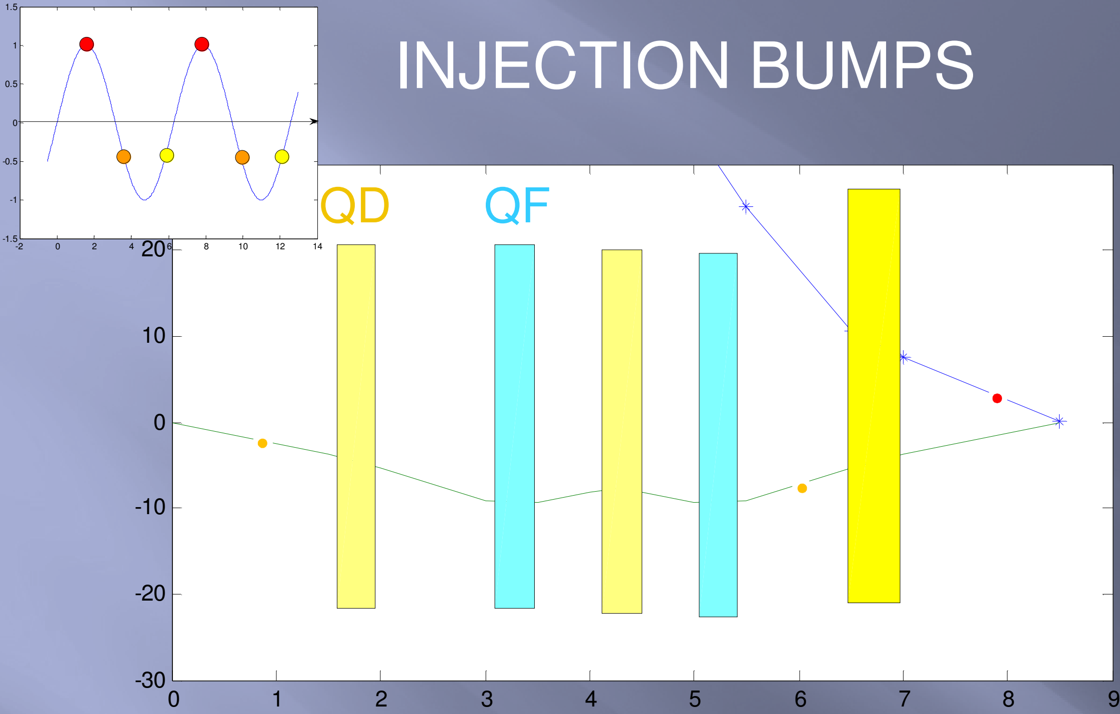
Table 6: Parameters of the electron bunch behind the combiner rings.

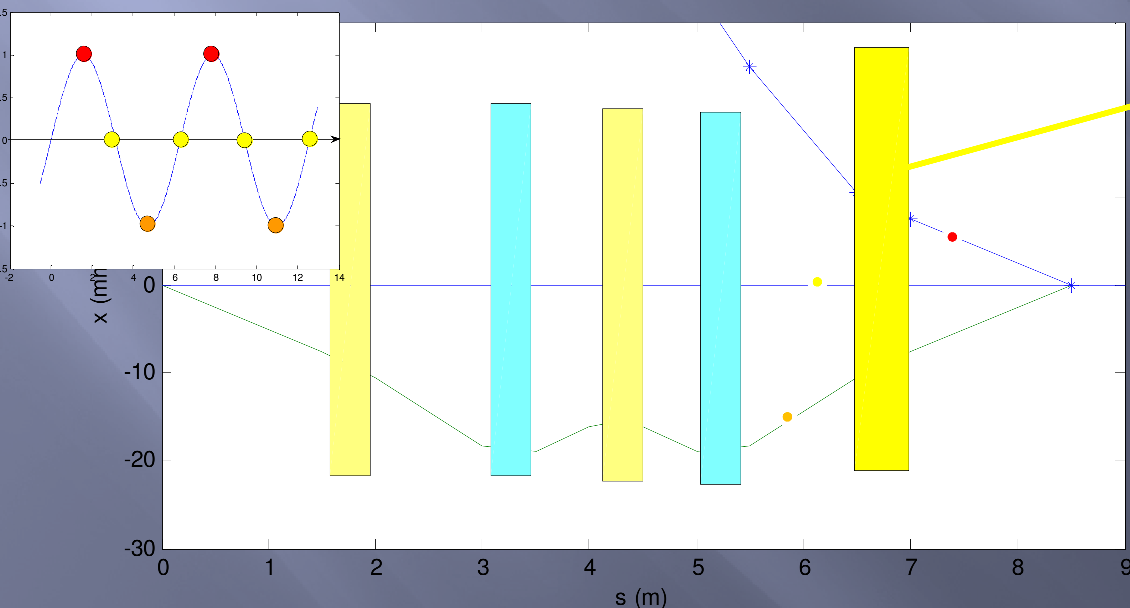
Property	Symbol	Value	Unit
Electron energy	E_0	2.424	GeV
Bunch charge	Q_0	7.8	nC
Bunch length	$\sigma_{s,i}$	1000	μm
Total energy spread	$\frac{\sigma_{E,tot}}{E_0}$	$< 5 \times 10^{-3}$	
Normalized emittance	$\varepsilon_{n,x}$	< 110	μm rad
	$\varepsilon_{n,y}$	< 110	μm rad
Phase jitter	σ_ϕ	< 0.2	deg

Table 7: Required parameters of the electron bunch at the entrance of the decelerator.

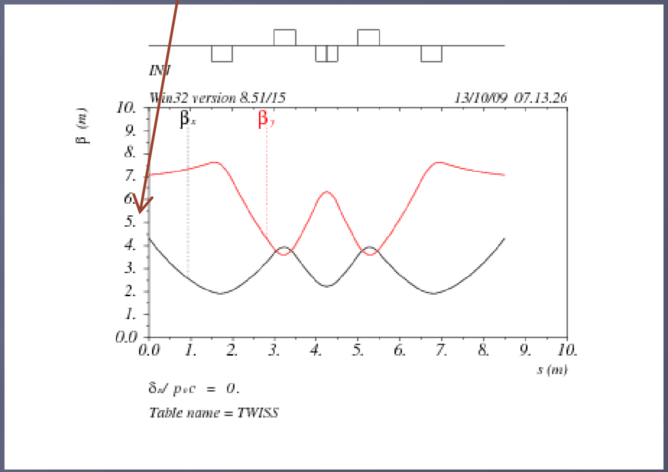
Uncorrelated energy spread 0.1% accounting for ISR effects

INJECTION BUMPS





Low h β at rf deflectors (see David's talk)



SEPTUM Quadrupole

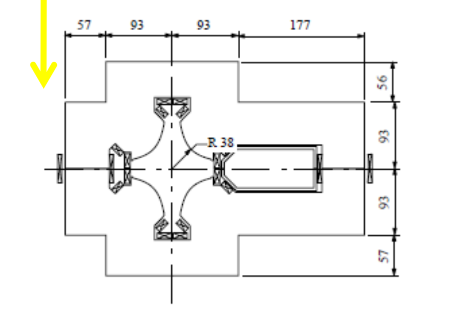


Figure 1: Cross section of septum quadrupole magnet (QC1LE)

SPECIAL QUADRUPOLE MAGNETS FOR KEKB INTERACTION REGION

M. Tawada, H. Nakayama, K. Satoh, KEK, Tsukuba, Japan

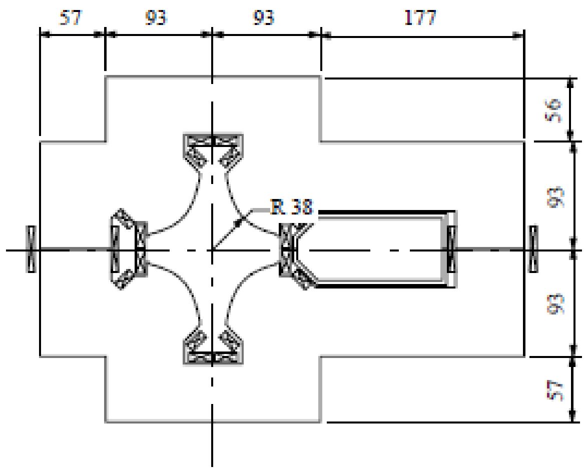


Figure 1: Cross section of septum quadrupole magnet (QC1LE)

item	unit	QC1LE
Field gradient	T/m	15.60
Bore radius	mm	38
Pole length	mm	600
Current density	A/mm^2	85
Coil turn	/pole	3
Max. currents	A	3000
Power	kW	125
Flow rates	l/min	40.0
Water lines		12

CONCEPT FOR A NEW MAGNETIC SEPTUM QUADRUPOLE

M. Marx, B.Parker, and H. Wümpelmann, DESY, Hamburg, Germany

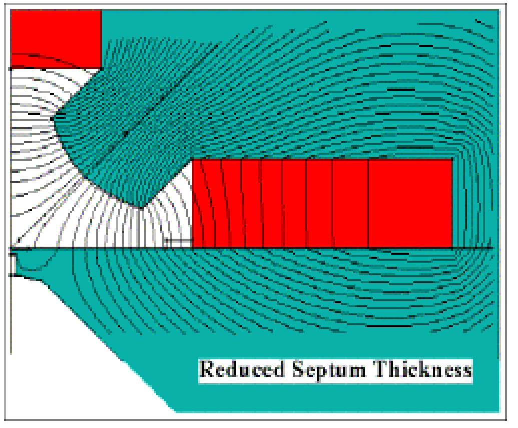
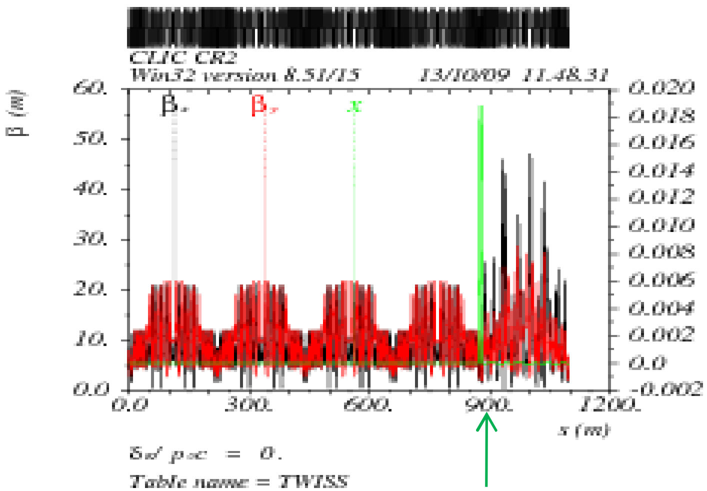
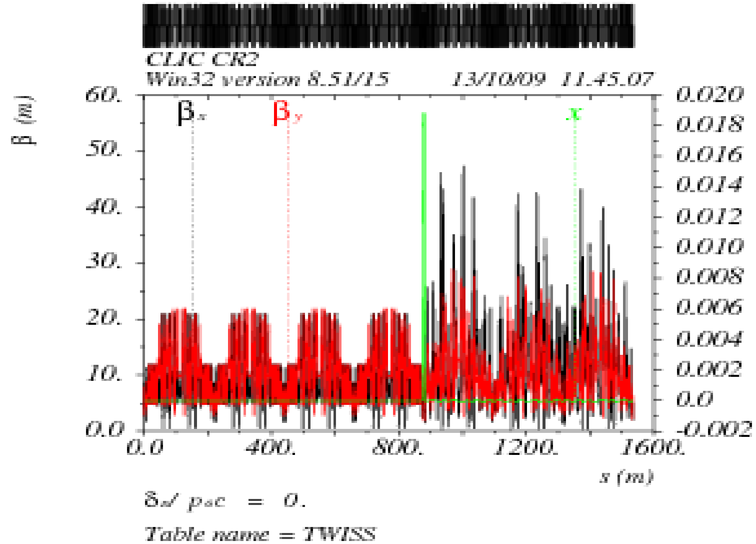


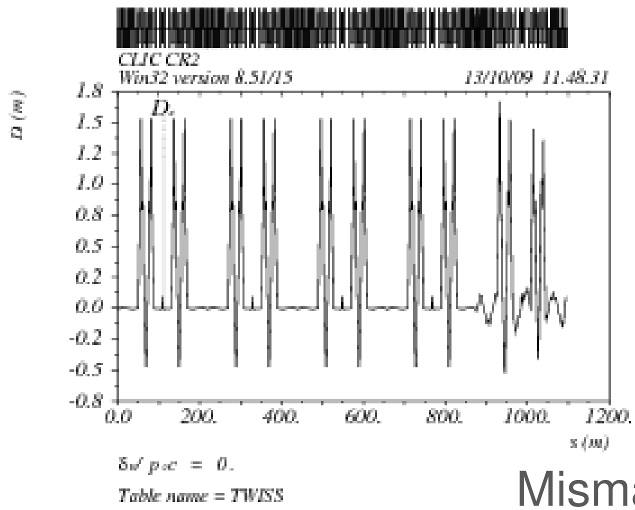
Figure 2: MSQ same as Fig. 1 but with additional 2×8 mm cut leaving 2 mm thick septum.

CR2 optical functions

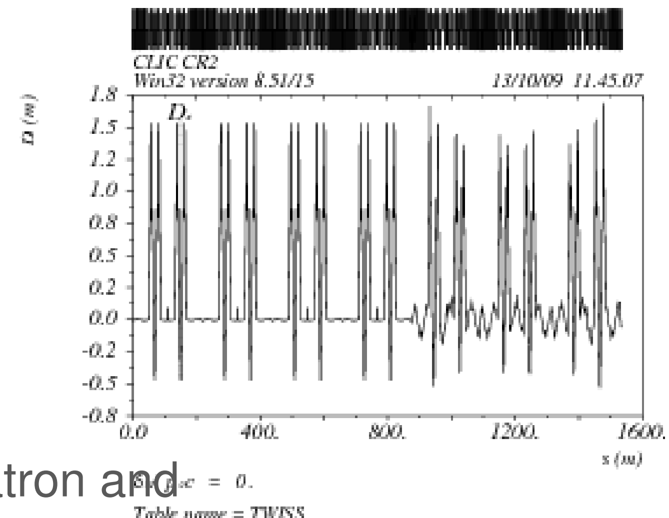


Injection bump





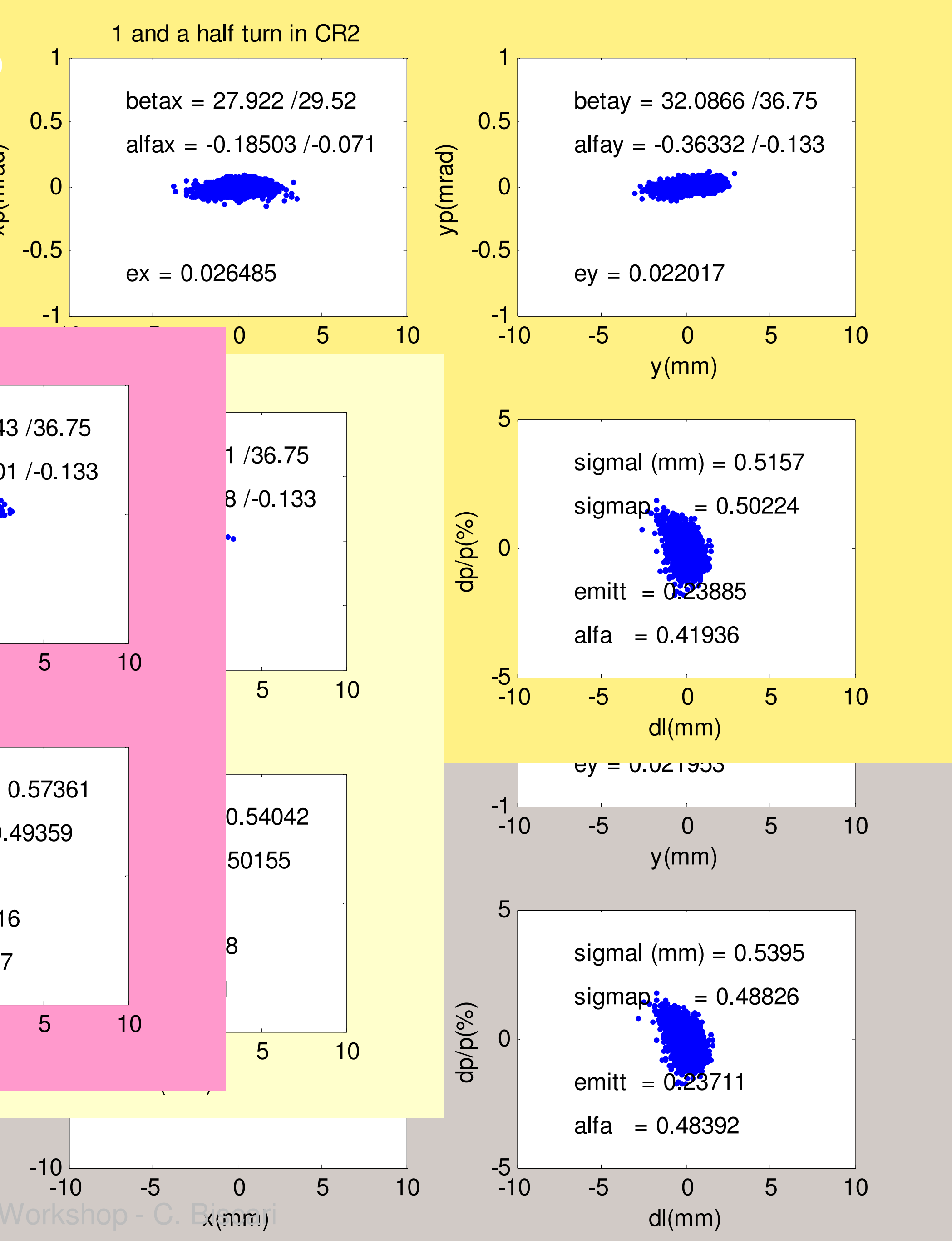
2.5 turns

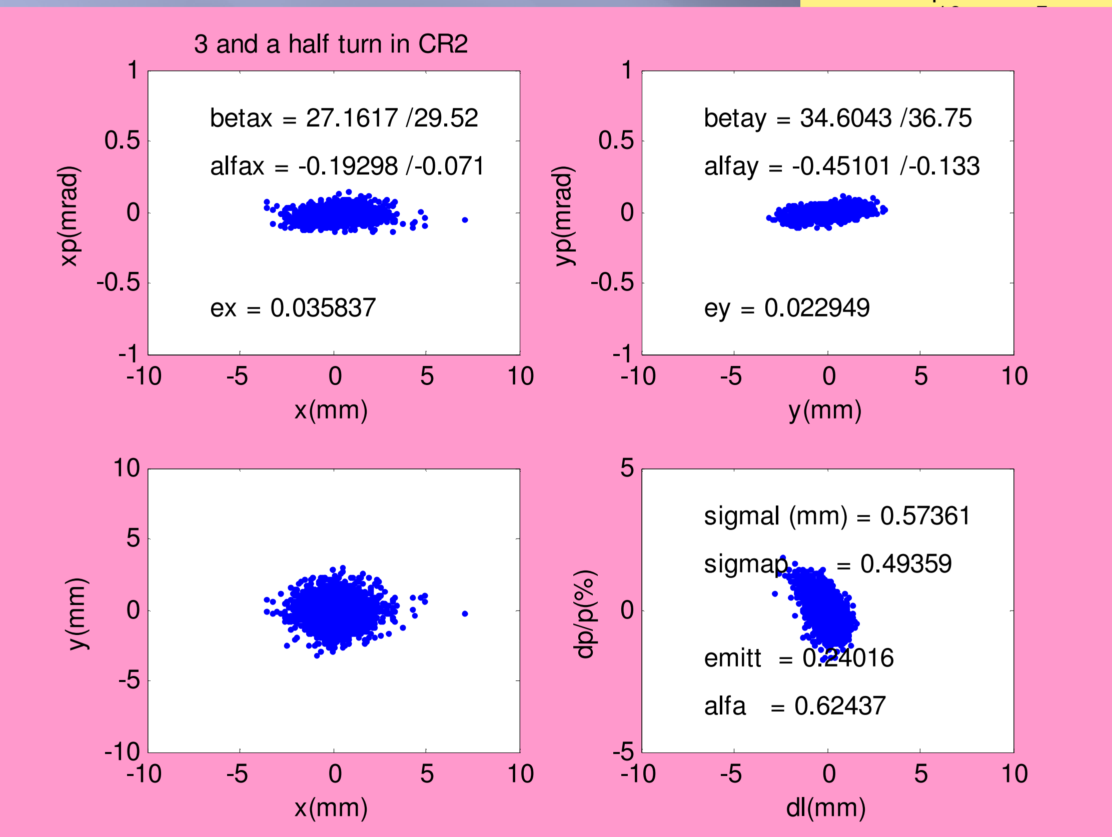


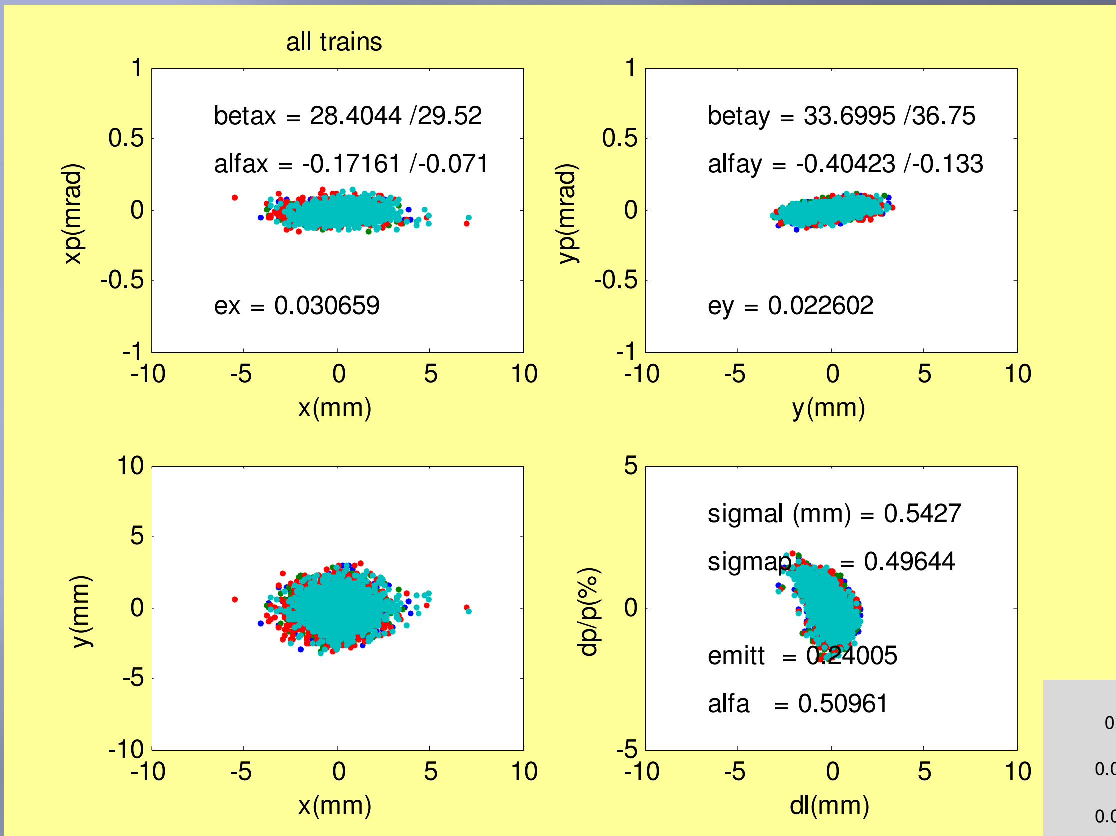
3.5 turns

Mismatch of betatron and dispersion functions after the bump passage

Tracking through Delay Loop (TA) +
through CR1 (3 turns neglecting bump effects) +
Through CR2 (four different trains) +
energy chirp +
Through Turn Around

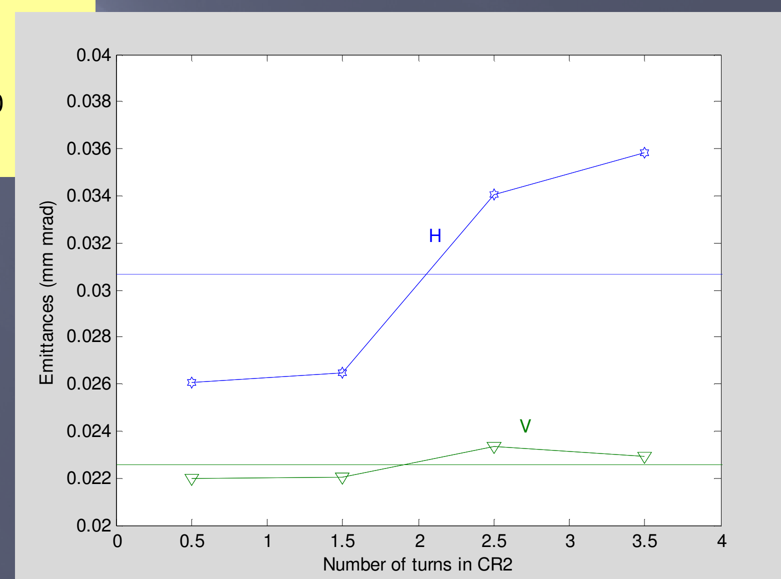






Superposition of the 4 distributions of different trains

Emittance of different trains



Increase of normalized horizontal emittance from 100 to 150 μrad (average).

CR1 bump not taken into account – to be added

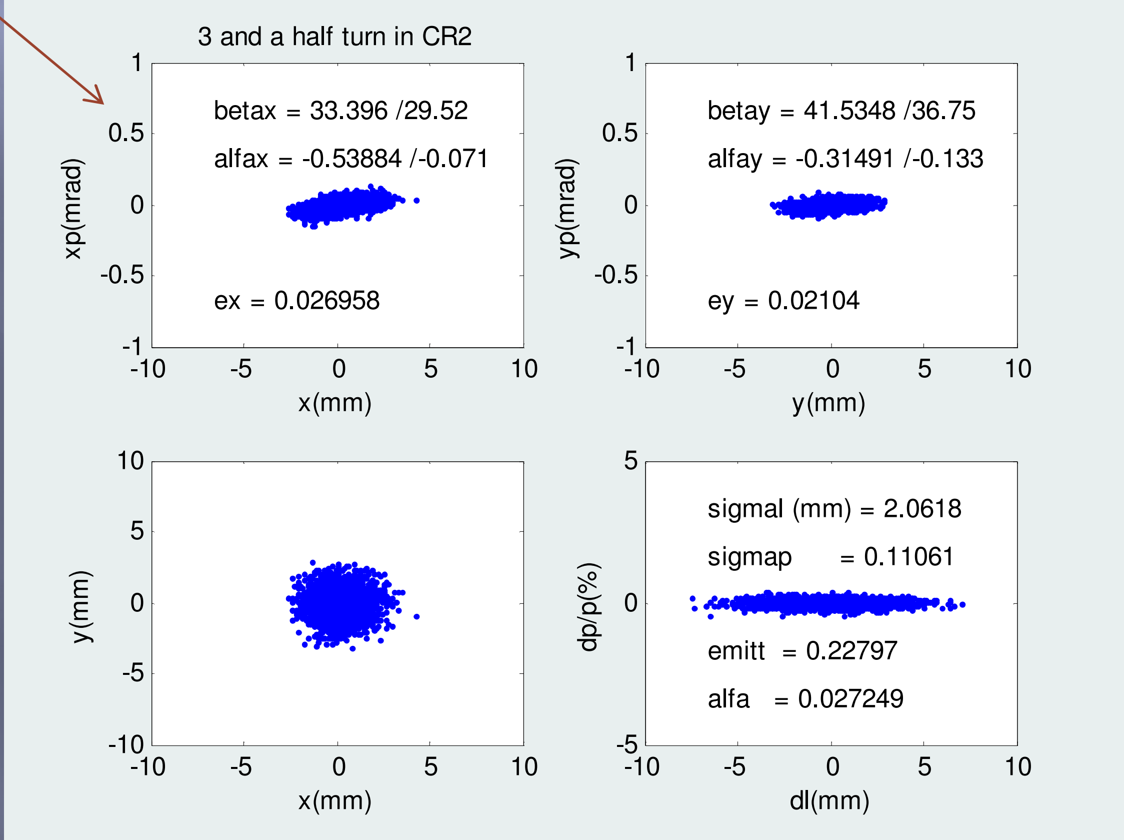
Where does the emittance increase come from?

End of Turn Around – 3.5 turns in CR2 – no energy chirp:
Horizontal emittance increase negligible (0.027 instead of 0.035 mm mrad)

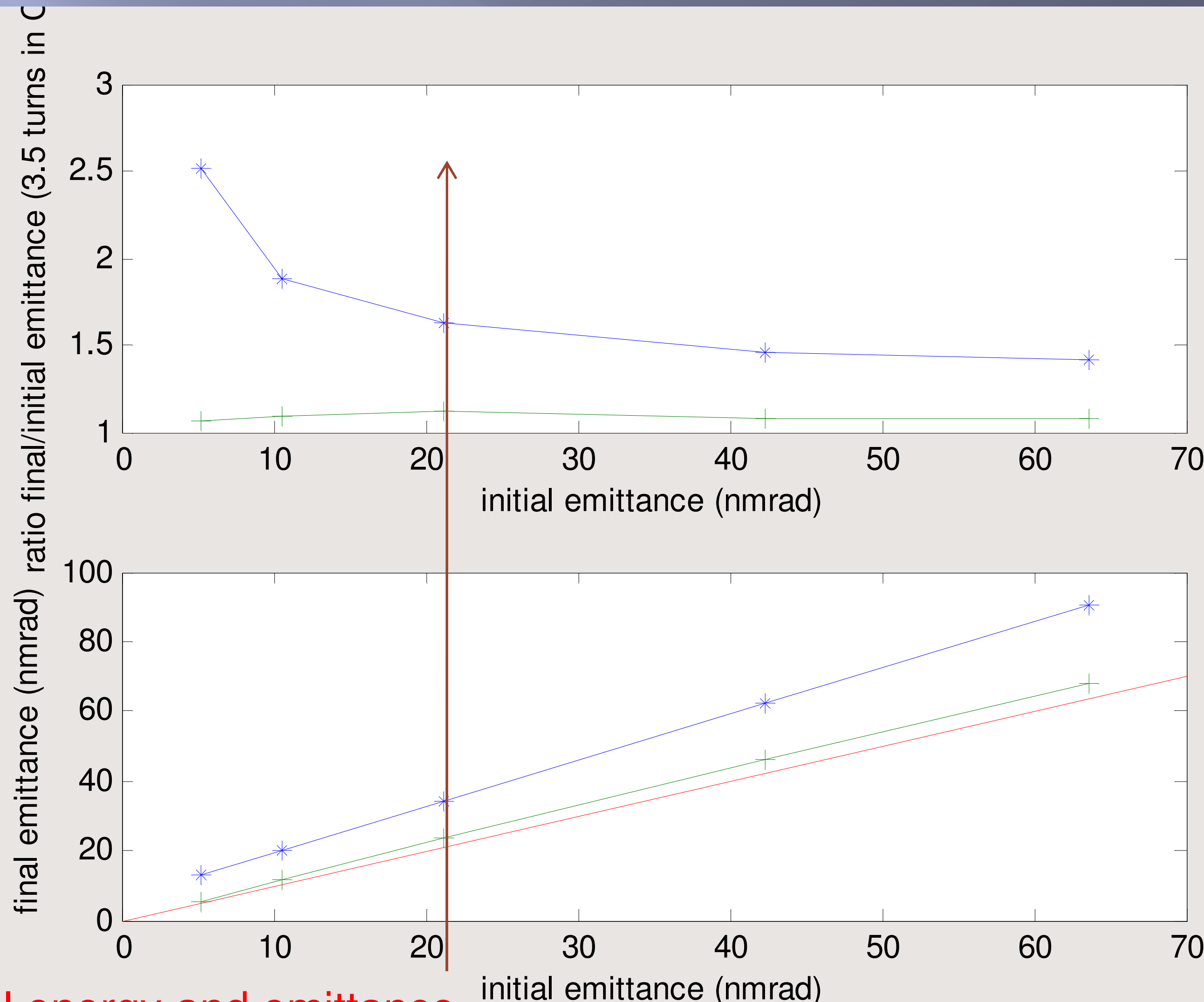
The maximum ‘emittance’ increase comes from the bump residual dispersion when the beam energy spread is increased before the last turn around.

Possible cures: use a lower energy chirp and larger R56 (now 0.36 m total - 2 chicanes)

Find a solution for an achromatic injection bump



Lower energy in drive beam: higher emittance



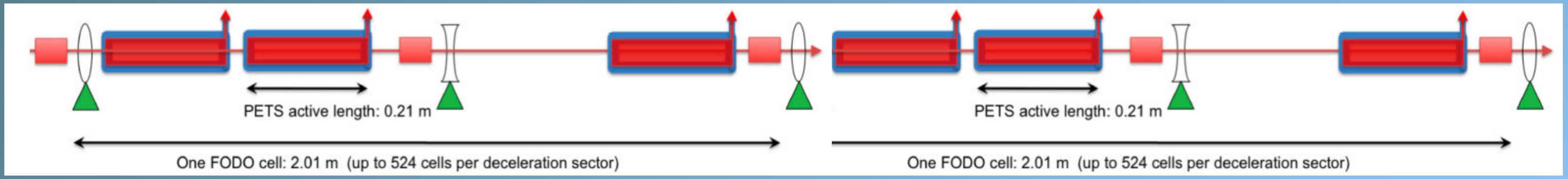
Nominal energy and emittance

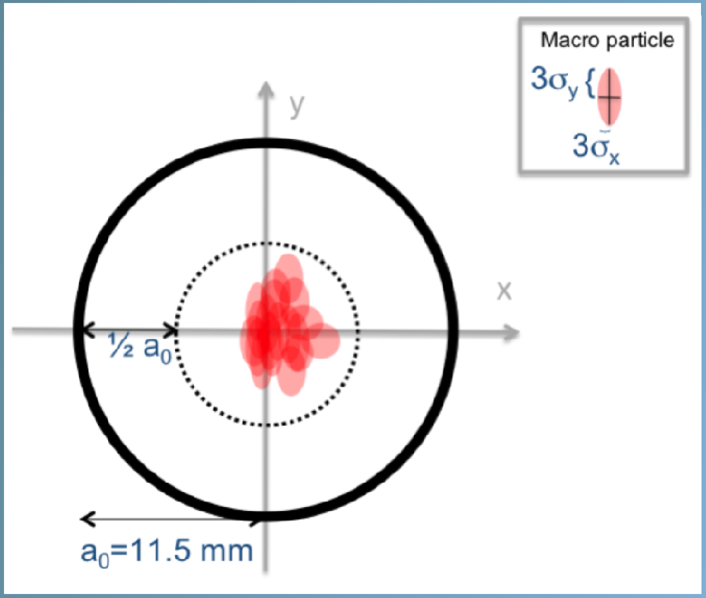
ERIK's talk

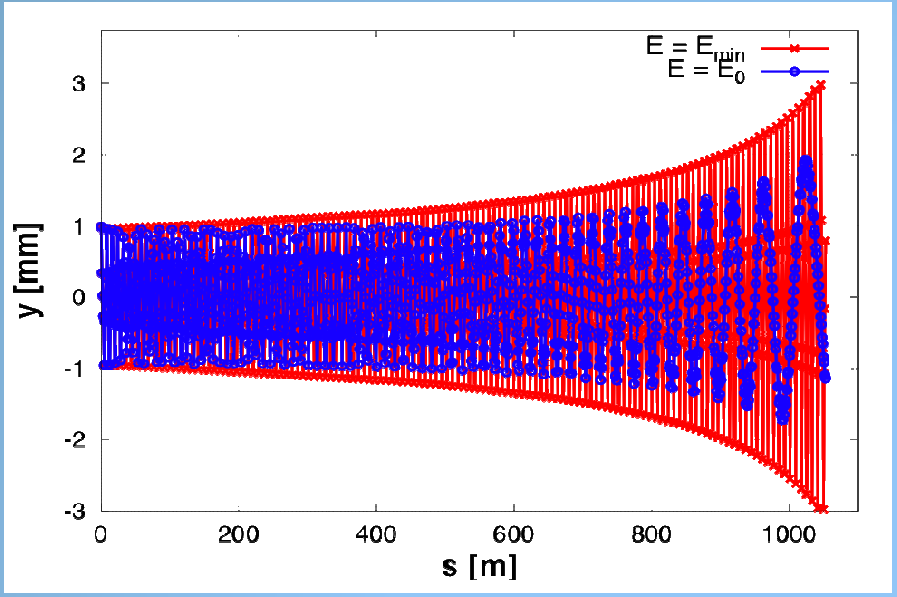
Decelerator beam transport

Uniform power production implies that the beam must be transported to the end with very small losses (< 1 % level). We require robust transport of the entire beam through the ~1 km decelerator sectors.

PLACET simulations are the main tool for the decelerator studies.







Simulation criterion:
3σ of *all* beam slices < ½ aperture (5.8 mm)

Beam transport along lattice, for ideal injection into a perfect machine : minimum envelope ~ 3 mm

Conclusions

- FMS and TA Layout and first order optics defined
- 2 order chromaticity compensation in CR1 and CR2 satisfactory for nominal beam energy spread
- Rf deflector main parameters defined taking into account beam loading simulations
- Optimisation of injection bump in progress
- Start to end simulations in progress
- CSR computation tools
- Start to end from Linac + FMS + TA + Decelerator needed
- Misalignment and field error tolerances, correction schemes, diagnostics to be defined.