New Design of the CLIC Drive Beam Recombination Complex for larger energy spread beams

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December 1st, 2015
CLIC Project Meeting #23, CERN

Outline

Motivation

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CLIC CDR Goal

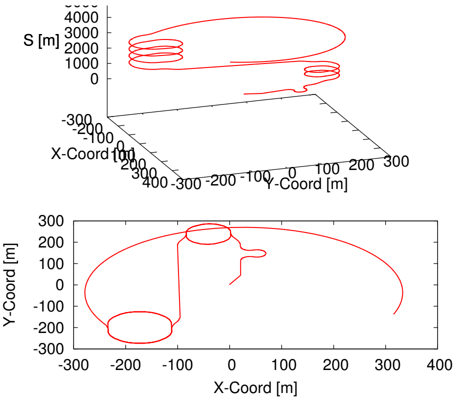
- Design the Drive Beam Recombination Complex (DBRC) capable of transporting a beam with an energy spread of $\pm 1\%$ (flat)
- Keeping $\Delta\epsilon \leq 50\%$ at the entrance of the decelerator

Strategy

- To replace arc cells of CR1 and CR2 based on TBA by the Chassman-Green cell [1]
  - offers lower emittance than TBA
  - requires weaker quadrupoles $\rightarrow$ smaller chromatic aberrations
  - R_{56} is easily tunable thanks to the short dipole

[1] Huang, N. Y. et al. in Proc. 2nd IPAC 2011 (SPAIN), http://accelconf.web.cern.ch/accelconf/IPAC2011/papers/wepc036.pdf

Sketch of DBRC



DL ⇒ **TL1** ⇒ **CR1** ⇒ **TL2** ⇒ **CR2** ⇒ **TTA**

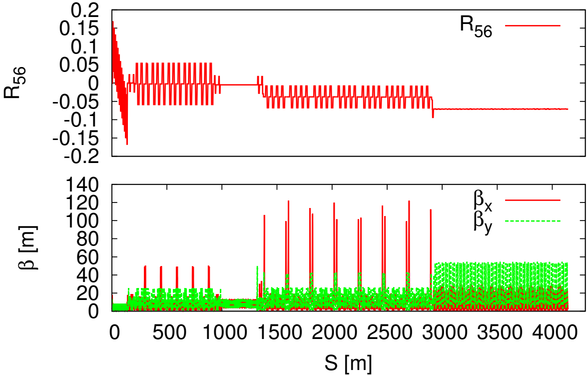
DBRC Parameters

Parameter	Units	DL	CR1	CR2	LTA
Energy	[GeV]	2.38	2.38	2.38	2.38
Norm. Emittance	[μm]	150	150	150	150
Energy spread (rms)	%	1	1	1	1
Length	[m]	146	293	439	1216
Combination factor		2	3	4	-
Average current	[A]	8.4	25	100	100
Bunch length	[mm]	1	1	1	1
RF deflector freq.	[GHz]	1.5	2	3	-

Previous Design

β and R_{56}

Arcs of combiner rings 1 and 2 are based on a TBA cell
Delay Line and transfer lines are based on the Chassman-Green cell

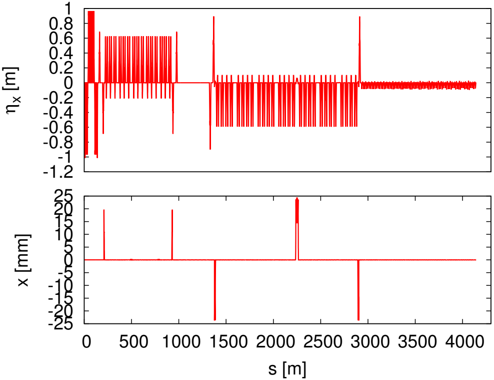


Orbit and Dispersion

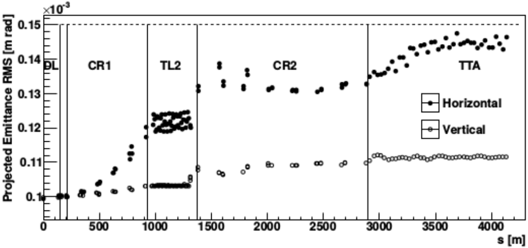
Isochronous tolerance $R_{56} = \pm 1$cm

Injection into CRs is based on bump offset of 2-3 cm (maximum kick from RF kickers)

η and η' after bump $\approx \pm 0.05$ m and ± 0.01, respectively



Emittance growth



Section	$\Delta\epsilon_x$ [%]	$\Delta\epsilon_y$ [%]
DL	1	1
TL1	1	1
CR1	16	3
TL2	30	8
CR2	31	10
LTA	43 [2]	12

[2] assuming an initial $\delta p/p$=0.35% (rms) and σ_z=2 mm.

Values published on CLIC-CDR v1

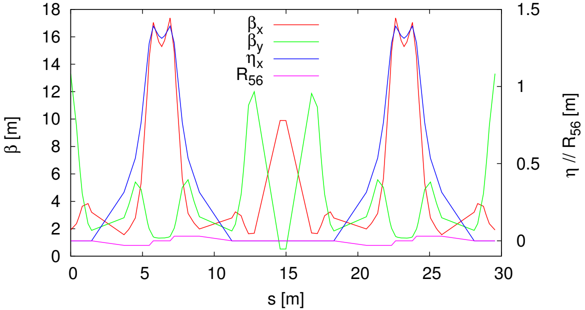
http://project-clic-cdr.web.cern.ch/project-CLIC-CDR/

New CR Designs

CR1

Arc Cell

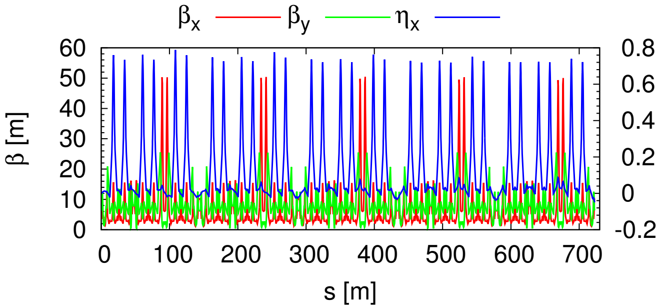
The TBA cell is replaced by a 2 modified DBA cells connected by 3 quadrupoles to match the Twiss parameters
Length and angle of dipoles is adjusted to set $B = 0.8$ T (1 T in CDR)



$$\Delta\epsilon_{x,y} \leq 5\% \text{ per arc cell @ } \Delta p/p{=}1\% \text{ (rms)}$$

$$R_{56} \approx 10^{-5} \qquad \eta_x \approx \mu\text{m}$$

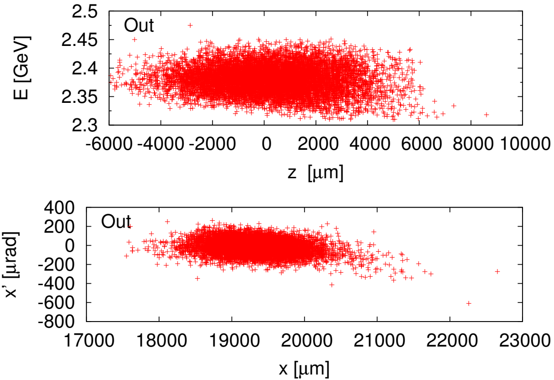
Twiss functions



	β_x [m]	α_x [rad]	β_y [m]	α_y [rad]	η_x [mm]	R_{56} [mm]
PLACET	10.01	0.10	6.37	0.17	-4.1	-0.7
CDR	9.92	0.10	6.40	0.17	-2.8	-2.4

Emittance Growth CR1

Initial Beam: $\Delta p/p = 1$ % $\sigma_z = 2$ mm $\gamma\epsilon_{x,y} = 100\ \mu$m



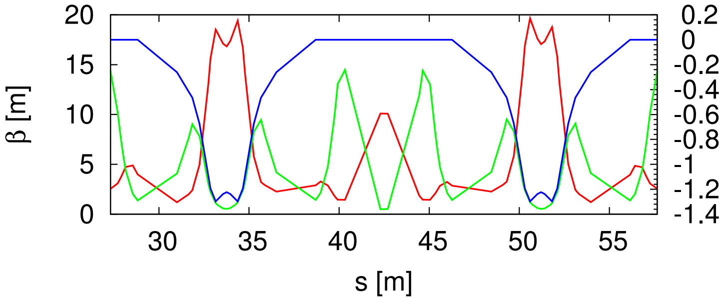
Final Emittances (2.5 turns): $\gamma\epsilon_x = 111\ \mu$m, $\gamma\epsilon_y = 107\ \mu$m

(PLACET simulation with 5 10^4 e^-)

CR2

Arc Cell

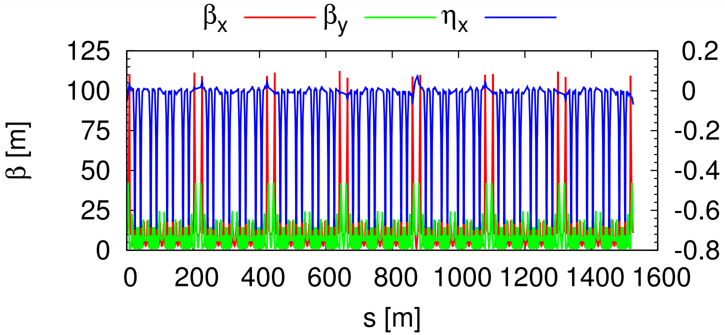
The TBA cell is replaced by a 2 DBA cells connected by 3 quadrupoles to match the Twiss parameters
Length and angle of dipoles is adjusted to set $B = 0.8$ T (0.8 T in CDR)



$\Delta\epsilon_{x,y} \leq 3\%$ per arc cell @ $\Delta p/p$=1% (rms)

$R_{56} \approx 10^{-5}$ $\eta_x \approx \mu$m

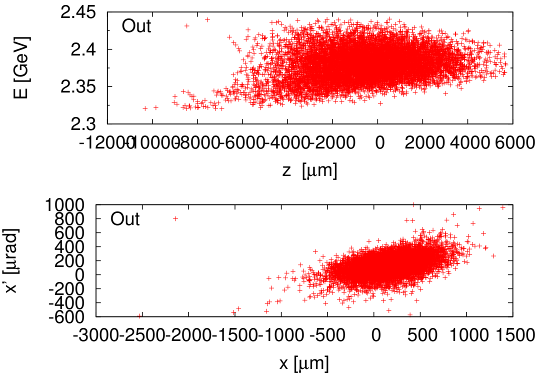
Twiss



	β_x [m]	α_x [rad]	β_y [m]	α_y [rad]	η_x [mm]	R_{56} [mm]
PLACET	10.8	0.39	11.81	2.76	-70	-5.2
CDR	9.9	0.48	11.60	2.71	-57	-3.9

Emittance Growth

Initial Beam: Δp/p=0.85 % $\sigma_z = 2$ mm $\gamma\epsilon_{x,y} = 100\ \mu$m

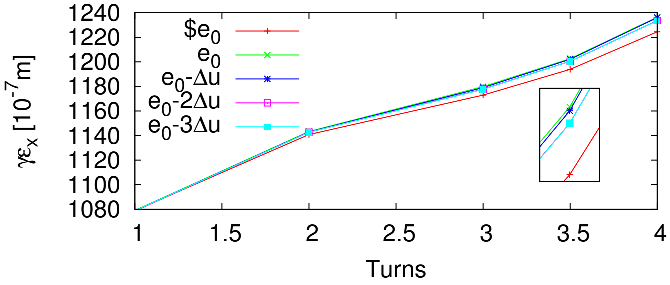


Final Emittances: $\gamma\epsilon_x = 133\ \mu$m $\gamma\epsilon_y = 110\ \mu$m

(assuming no kickers: $\gamma\epsilon_x = 123\ \mu$m $\gamma\epsilon_x = 106\ \mu$m @ Δp/p=1%)

SR On/Off Lattices

CR2 combines 4 bunches with different final energies[3]
However magnets can only be tailored to 1 bunch energy profile and just for 1 turn



Best transport is obtained when tailoring the magnets to the lowest energy bunch ($e_0 - 3\Delta u$)⇒ first arriving bunch during the 3$^{\rm rd}$ turn

[3]Energy loss per turn of Δu=0.32 MeV

S-2-E Simulations

Start-to-End Simulations

Optimization Protocol

- Gaussian beam ($5{\cdot}10^4 e^-$, $\sigma_z = 2mm$, $\Delta p/p = 0.85\%$)
- Quads and Sexts of TL1 and CR1 are optimized in conjunction for better dispersion matching into CR1
- Offset and angle (x-plane) are deliberately optimized at entrance of CR1 for better injection
- Same applies for TL2 and CR2, but using output beam from CR1
- Sexts of TL3 and TTA are optimized using output beam from CR2
- Emittance, dispersion and orbit are the optimization constraints
- SR is OFF during the optimization to speed up the process
- SR is activated once optimization is done for checking purposes

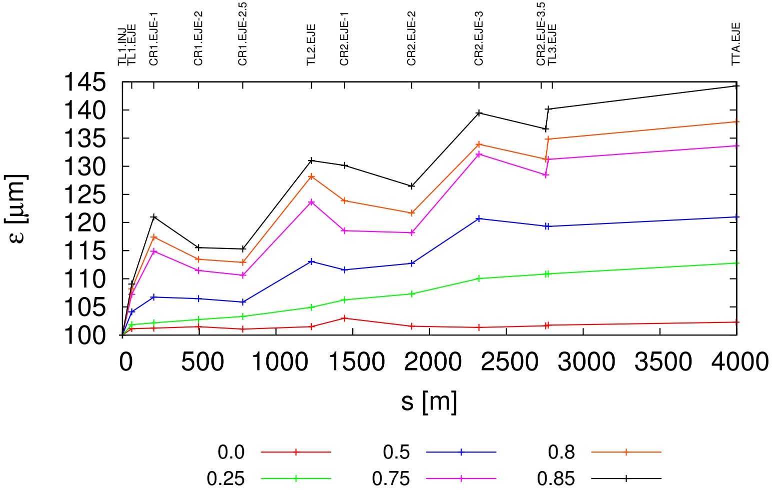
Twiss

Propagation of Twiss functions along DBRC
PLACET values obtained from beam distribution ($5 \cdot 10^4\ e^-$)
MADX values obtained by PTC code

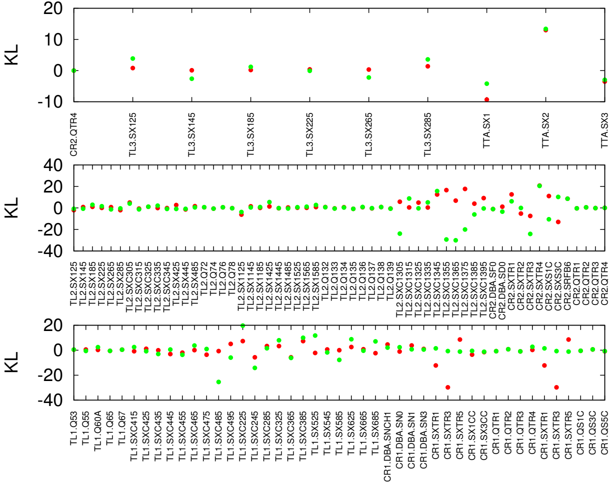
Exit of	β_x [m]	α_x []	β_y [m]	α_y []
TL1				
PLACET	9.2	-0.1	6.5	-0.3
MAD-X	10.2	-0.1	6.4	-0.2
CR1				
PLACET	8.8	0.2	6.1	0.2
MAD-X	9.9	0.1	6.4	0.2
TL2				
PLACET	11.2	-0.5	11.7	-2.7
MAD-X	11.1	-0.4	11.8	-2.8
CR2				
PLACET	8.7	0.2	12.1	2.8
MAD-X	9.9	0.5	11.6	2.7
TTA				
PLACET	2.3	0.0	7.9	0.0
MAD-X	2.1	-0.1	8.0	0.0

Start-to-End Simulations

- Beam with 0.85% energy spread (rms)



Strength Values



Summary

- Re-optimization of TL1, TL2, TL3 and TTA
- Obtained new designs of

  CR1 ($\Delta p/p = 1\%$) and CR2 ($\Delta p/p = 0.85\%$)
- Start-to-end (TL1$\Rightarrow$TTA) simulations showed $\Delta\epsilon_x$=44%(46% if SR ON) for a beam with $\Delta p/p$=0.85%

Outlook...

- Is there still some room for improvement? 1%?
- Sensitivity to injection errors
- Re-design the chicane for stretching the bunch from 1 to 2 mm assuming new $\Delta p/p$ (0.85%?)
- Integrate Delay Loop into the design
- Continue the S-2-E study with PLACET2 for multi-bunch tracking

Future Generation of Accelerator Physicists

PAU

Physicist
Accelerator
Ultimate

PAU

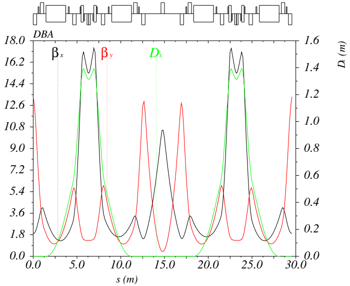
Computers!   **FFS!!**

Hamiltonian... 

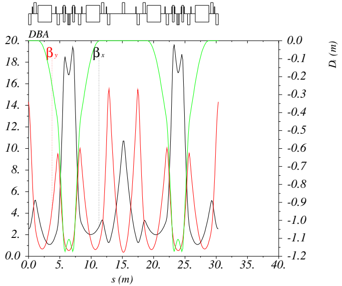
BACK UP

Arcs arrangement

CR1

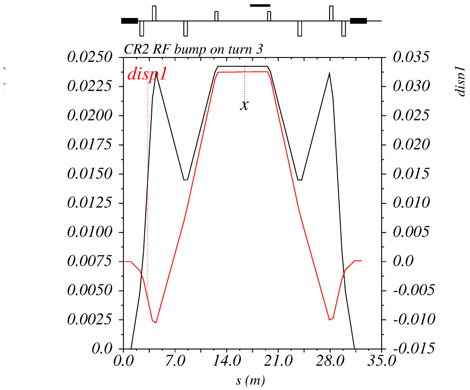


CR2



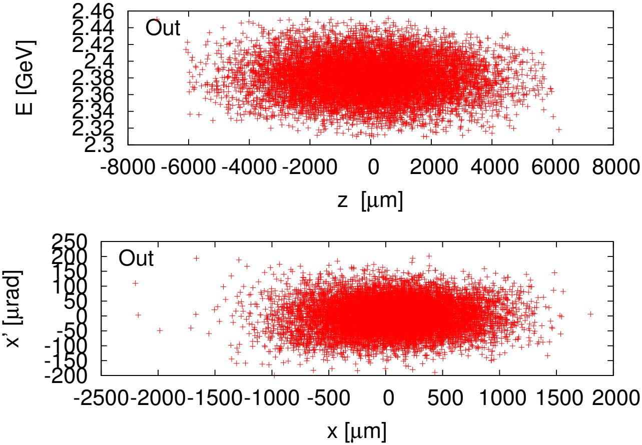
Orbit Bump Turn 3

Orbit and dispersion are closed by means of a pair of sextupole magnets



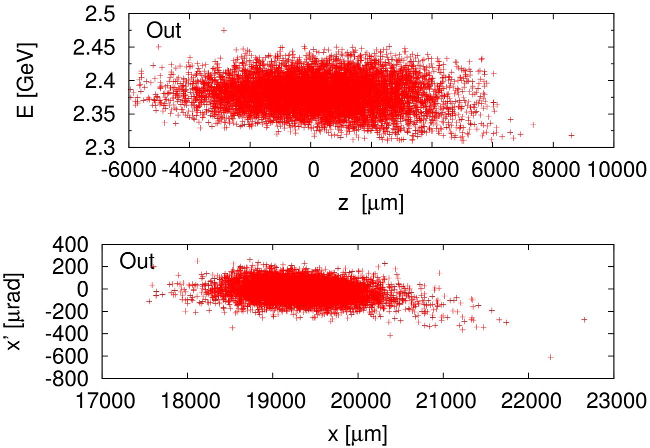
TL1

Beam distribution out of TL1



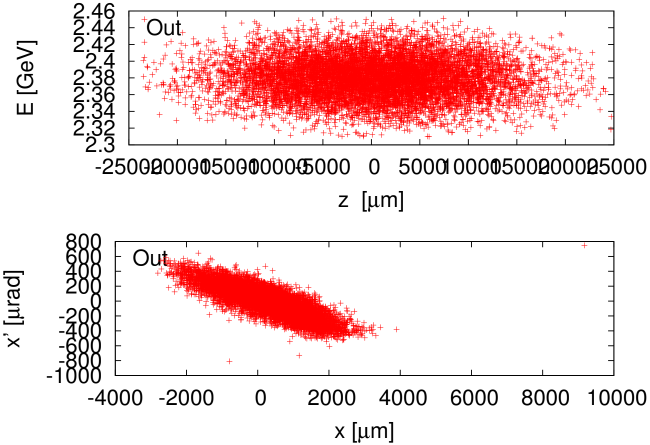
CR1

Beam distribution out of CR1



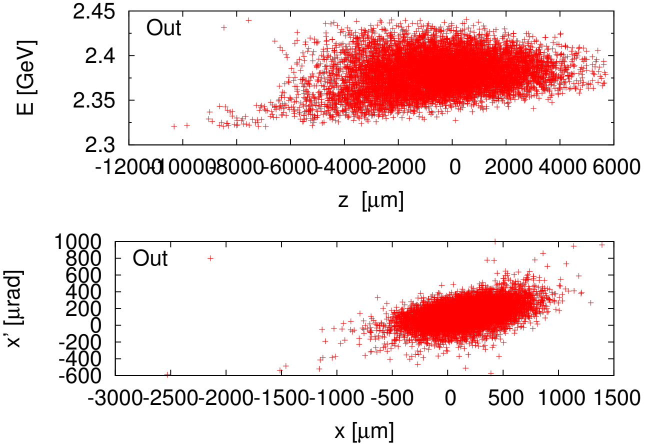
TL2

Beam distribution out of TL2



CR2

Beam distribution out of CR2



TTA

Beam distribution out of TTA