Design considerations for the CLIC pre-damping rings

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Abstract

The CLIC pre-damping rings (PDR) have to accommodate a large emittance beam, coming in particular from the positron target and reduce its size to low enough values for injection into the main damping rings (DR). The lattice design is based on theoretical minimum emittance (TME) arc cells and long straight sections filled with damping wigglers. Lattice design optimization considerations are presented with emphasis to the linear optics functions, tunability, chromatic properties and acceptance. A complete phase advance scan of the TME cells is undertaken for reducing the non-linear resonance driving terms and amplitude dependent tunespread and maximizing the ring's dynamic aperture (DA).

INTRODUCTION

The CLIC PDR are an essential part of the CLIC injector complex with most crucial the design of the positron ring. They have to digest a large injected beam, especially coming from the positron source[1], to low enough values for injection to the main damping rings (DR).

Table1. PDR injected and extracted parameters [2]

Parameters	Injected e-	Injected e+	Extracted
Energy [GeV]	2.86	2.86	2.86
Bunch population [10^9]	4.7	6.4	4.4
Bunch length [mm]	1	9	10
Energy spread [%]	0.07	1	0.5
Long. Emit. [keV.m]	2	257	143
Hor. Norm. emit. [μm]	100	7×10^3	63
Ver. Norm. emit. [μm]	100	7×10^3	1.5

Parameters guiding the design

- ❑ Large input beam size in both planes
- ❑ Large energy spread of the injected beam
- ❑ Small output emittances

Parameters which impact the design

- ➢ Large dynamic aperture (DA)
- ➢ Large momentum acceptance.

✓ Racetrack structure with 2 arc and 2 long straight sections.

✓ The arc sections filled with TME cells (the most compact low emittance cells).

✓ The low emittance and damping times are achieved by the strong focusing of the TME arcs and the inclusion of high field normal conducting damping wigglers in the long straight sections [5].

ANALYTICAL SOLUTION FOR THE TME CELLS

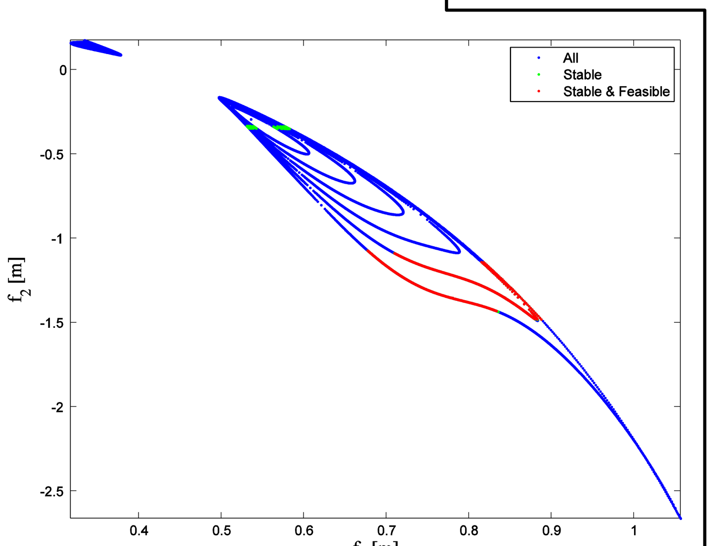
An analytical solution for the quadrupole strengths based on thin lens approximation was derived in order to understand the properties of the TME cells [3]

- ✓ Creates a multi-parametric space which fully describes the cell.
- ✓ Checks the stability of the solutions and the feasibility of the magnets (quadrupoles and sextupoles) providing each solution.

$$f_1 = \frac{l_2(4l_1L_d + L_d^2 + 8\eta_{x,cd}\rho)}{4l_1L_d + 4l_2L_d + L_d^2 - 8\eta_s\rho + 8\eta_{x,cd}\rho}$$

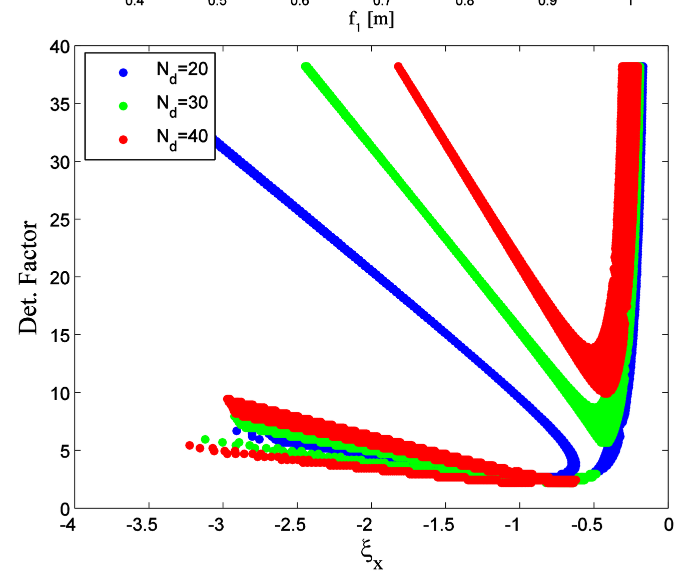
$$f_2 = \frac{8l_2\eta_s\rho}{-4l_1L_d - L_d^2 + 8\eta_s\rho - 8\eta_{x,cd}\rho}$$

η_s :the dispersion in the middle of the cell
l_1 l_2 l_3: drift lengths, L_d: dipole length, ρ: bending angle, $\eta_{x,cd}$: dispersion in the middle of the dipole



LINEAR LATTICE OPTIMIZATION

- The analytical solution was used for the linear lattice optimization.
- The parameter to be minimized is the chromaticity in order to minimize the required sextupole strengths
- Highly detuned lattice in order to achieve low chromaticity.



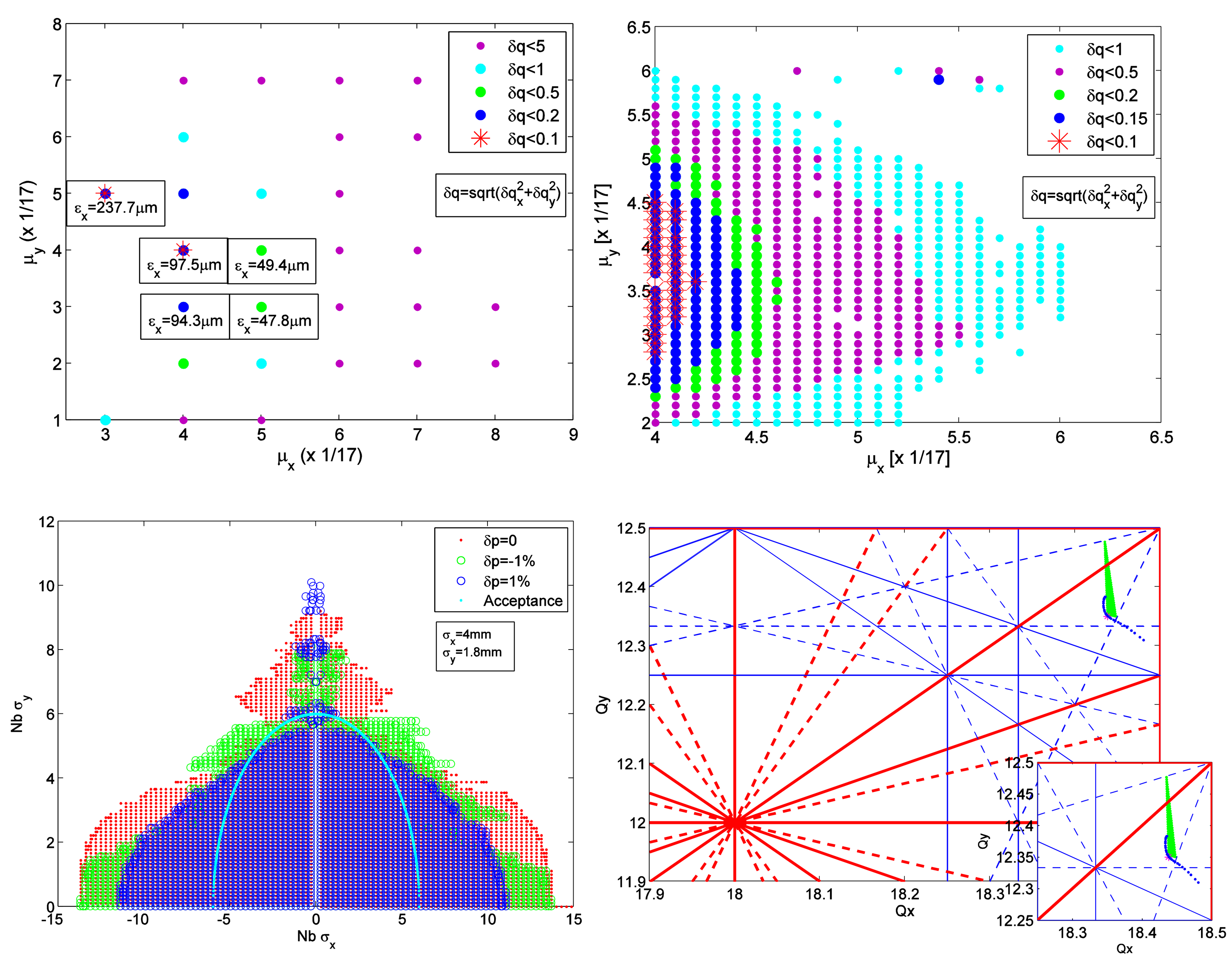
NON LINEAR OPTIMIZATION

➢ The choice of the phase advances of a cell, crucial for the minimization of the resonance driving terms.

- A part of a circular machine will not contribute to the excitation of any non-linear resonance, except of those defined by $n_x\mu_{xc}+n_x\mu_{xc}=2k_3\pi$, if $N_c\mu_{xc} = 2k_1\pi$ and $N_c\mu_{yc} = 2k_2\pi$ [4].

✓ For prime numbers of N_c, less resonances excited.

✓The optimal behavior is achieved for 17 TME / arc.

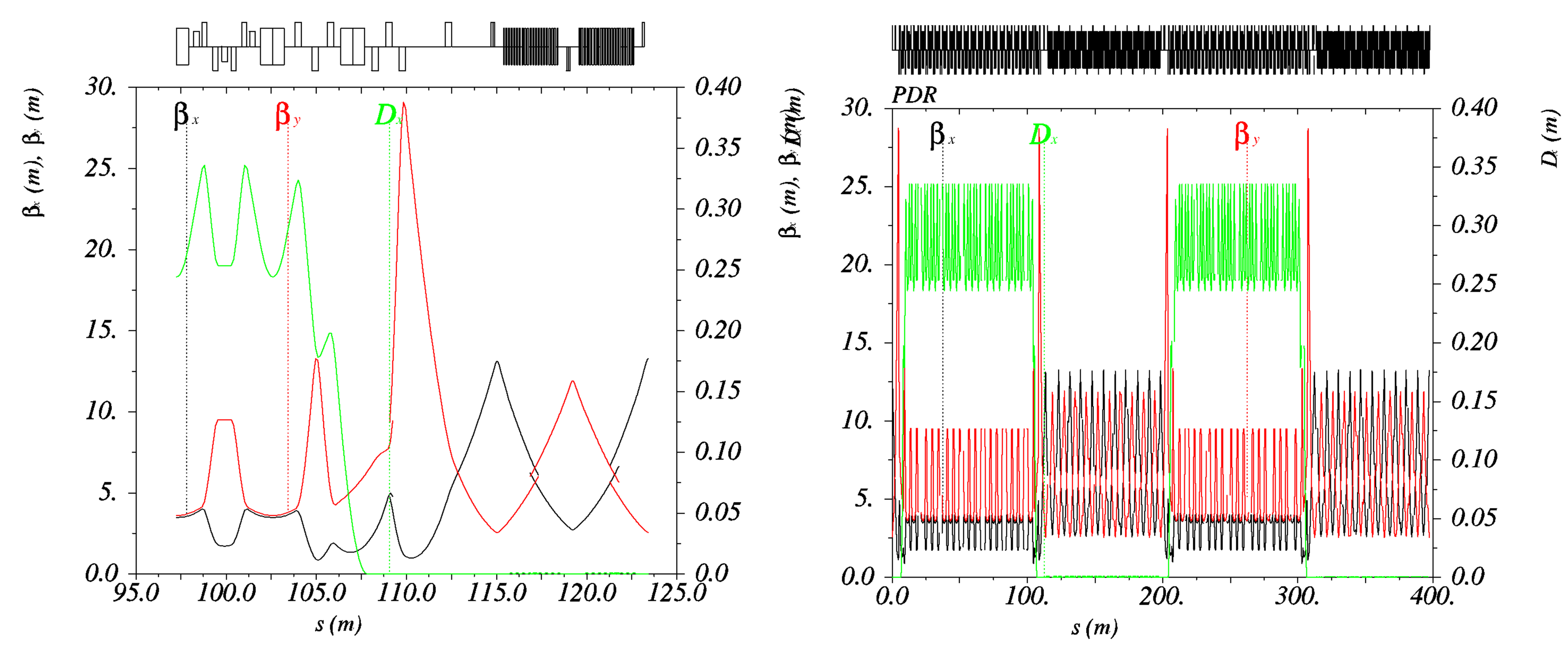


- ▪ Phase advance scan for integer multiples of 1/17 of μ_x and μ_y (up-left)
- ○ $\delta q=\sqrt{(\delta q_x^2+ \delta q_y^2)}$: first order tune shift with amplitude
- ▪ Finer Phase advance scan around the chosen values (up-right)
- ✓ Optimal pair of values:
  μ_x=0.2941=5/17
  μ_y=0.1765=3/17

❑ On and off momentum dynamic aperture for δp 0, 1% and -1% respectively (down-left).

❑ The working point in tune space (blue) for momentum deviations from -3% to 3% (down-right). With green is shown the tune shift with amplitude ate 6 $\sigma_{x,y}$. The on momentum working point is (18.44, 12.35)

LATTICE OPTICS



Left: Optics for the 3 types of cells (TME arc cell, dispersion suppressor-beta matching cell and FODO filled with wigglers long straight sections' cell)

Right: Optics of the PDR current design

Parameters for the current PDR design

Parameters, Symbol [Unit]	Value
Energy, E_n [GeV]	2.86
Circumference, C [m]	397.6
Bunches per train, N_b	312
Bunch population [10^9]	4.7
Bunch spacing, τ_b [ns]	0.5
Basic cell type	TME
Number of dipoles, N_d	38
Dipole Field, B_a [T]	1.2
Tunes (hor./ver./sync.),($Q_x/Q_y/Q_s$)	18.44/12.35/0.07
Nat. chromaticity (hor./vert.),(ξ_x/ξ_y)	-16.88/-23.52
Norm. Hor. Emit.,$\gamma\varepsilon_0$[mm mrad]	47.85
Damping times, ($\tau_x/\tau_y/\tau_\varepsilon$),[ms]	2.32/2.32/1.16
Mom. Compaction Factor, α_c [10^{-3}]	3.83
RF Voltage, V_{rf} [MV]	10
RF acceptance, ε_{rf} [%]	1.1
RF frequency, f_{rf} [GHz]	2
Harmonic Number, h	2652
Equil. energy spread (rms), σ_δ [%]	0.1
Equil. bunch length (rms), σ_s [mm]	3.3
Number of wigglers, N_{wig}	40
Wiggler peak field, B_w [T]	1.7
Wiggler length, L_{wig} [m]	3
Wiggler period, λ_w [cm]	30

CONCLUSION

An analytical solution for the TME cells can be useful for the linear lattice optimization. The present design achieves the base line configuration requirements for output parameters and a conformable DA. A working point analysis is in progress. A necessary final step of the non-linear optimization, is the inclusion of nonlinear errors in the main magnets and wigglers.

REFERENCES

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