

# Non-linear Optimization of the CLIC Damping Ring

Y. Renier, Y. Papaphilipou

CERN

LCWS11

# Headlines

Lattice

Frequency Map Production

Magnet imperfections and correction

Frequency Map of CLIC DR with Corrected Errors

Conclusion and Prospects

Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects

# Headlines

Lattice

Frequency Map Production

Magnet imperfections and correction

Frequency Map of CLIC DR with Corrected Errors

Conclusion and Prospects

Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects

# Layout

Non-linear  
CLIC DR

Y. Renier

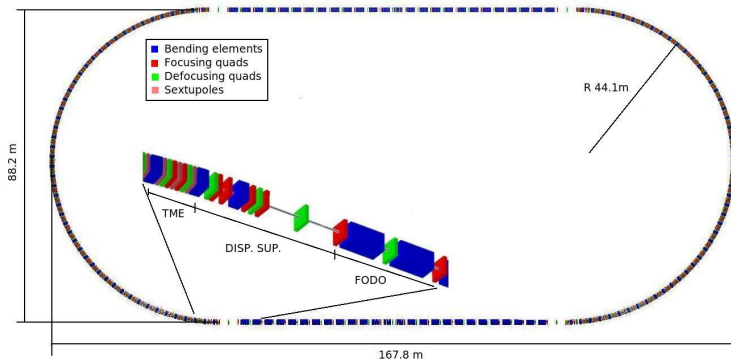
## Lattice

Frequency Map  
Production

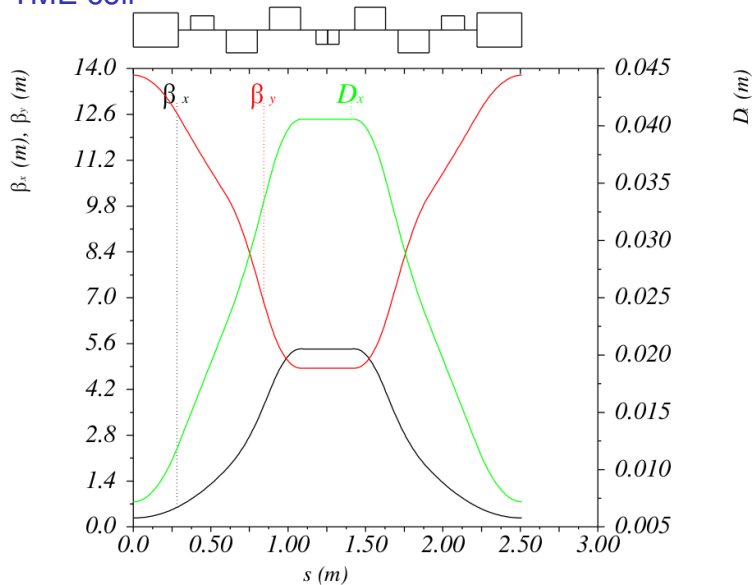
Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects



## TME cell



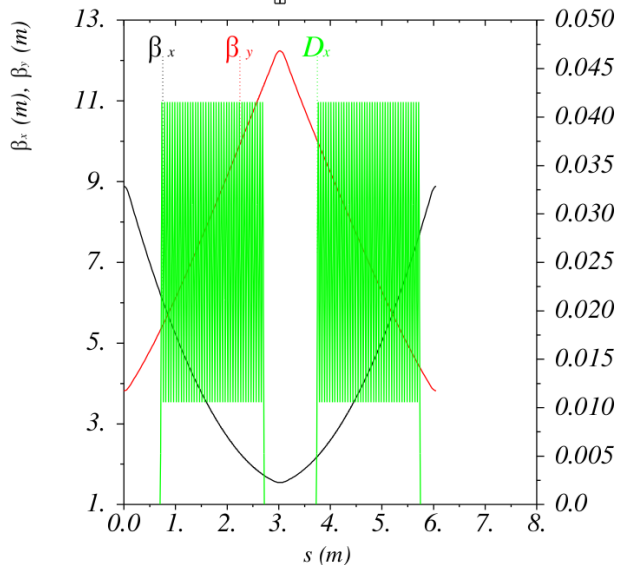
### Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

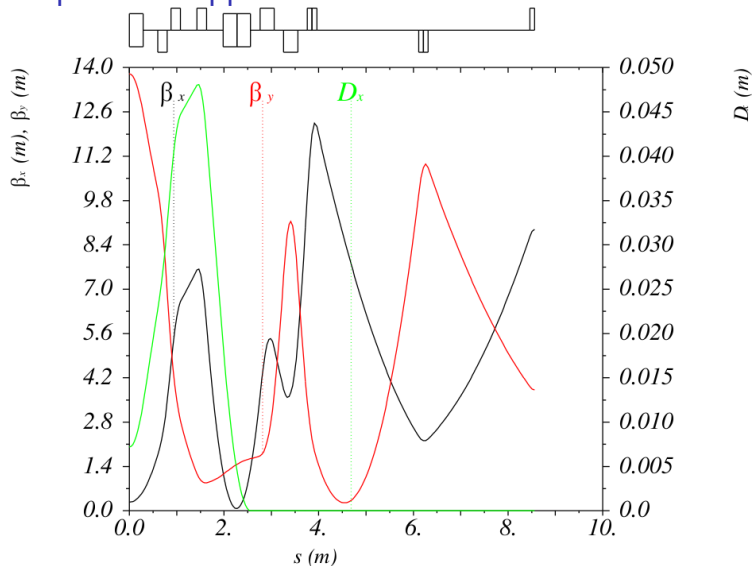
Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects



$D_x$  (m) [ $*10^{*3}$ ]

## Dispersion Suppressor



### Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects

# Headlines

Lattice

Frequency Map Production

Magnet imperfections and correction

Frequency Map of CLIC DR with Corrected Errors

Conclusion and Prospects

Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects



# Frequency Map Production

## Initial Conditions

- ▶ Beam offsets for uniform tune shift (square of the position)
- ▶ Analysis done for  $-5, 0,$  and  $5 \times 10^{-3}$  momentum offsets.

## Each point

- ▶ Tracking a particle with MADX-PTC for 1056 turns.
- ▶ If it survived, tune is obtained by Laskar's NAFF algorithm.
- ▶  $\nu_{x1}$  and  $\nu_{y1}$  tunes computed for first half turns.
- ▶  $\nu_{x2}$  and  $\nu_{y2}$  tunes computed for remaining turns.
- ▶ Diffusion coefficient  $D$  is computed as :  
$$D = \log (|\nu_{x1} - \nu_{x2}| + |\nu_{y1} - \nu_{y2}|) .$$

# Perfect Lattice

- ▶ Working point :  $\nu_x = 48.35$ ,  $\nu_y = 10.40$
- ▶ Arc sextupoles tuned for 0 chromaticity.
- ▶ Wigglers: bends with alternating polarity.
- ▶ No errors.

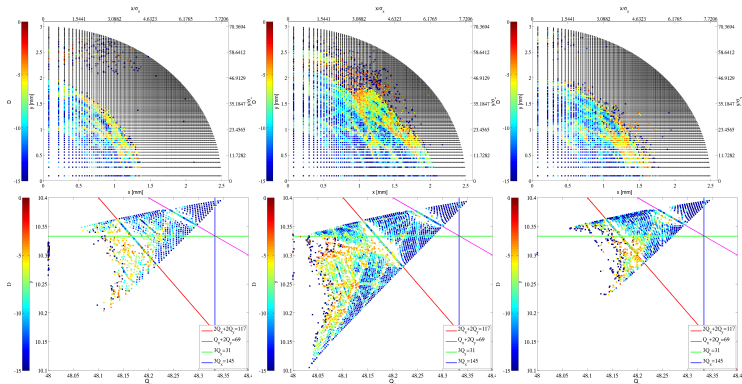
Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects



$$dp = -5 \times 10^{-3}$$

$$dp = 0$$

$$dp = 5 \times 10^{-3}$$



## Dynamic Aperture

- ▶ On-momentum dynamic aperture :  $6\sigma_x$  and  $60\sigma_y$ .
- ▶ Off-momentum : 25% reduction in aperture.

## Other

- ▶ Same resonances for off-momentum.
- ▶ Earlier loss than for on-momentum.

Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects

# Headlines

Lattice

Frequency Map Production

**Magnet imperfections and correction**

Frequency Map of CLIC DR with Corrected Errors

Conclusion and Prospects

Lattice

Frequency Map  
Production

**Magnet  
imperfections and  
correction**

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects

# Magnet imperfections

Error type	Elements	RMS
Misalignment (Hor. & Vert.)	Quadrupoles	$5 \mu\text{m}$
Normalized multipole	Quadrupoles	
Quadrupolar		$10^{-4}$
Skew quadrupolar		$10^{-5}$
Sextupolar		$10^{-4}$
Skew sextupolar		$10^{-5}$
Integral field error	Wigglers	
1st vertical		$10^{-5} \text{ Tm}$
1st horizontal		$10^{-6} \text{ Tm}$
2nd vertical		$10^{-4} \text{ Tm}^2$
2nd horizontal		$3 \cdot 10^{-6} \text{ Tm}^2$

Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects

To restore the properties of the DR, several corrections are performed in the following order:

- ▶ orbit correction,
- ▶ tune matching (straight section quads),
- ▶ horizontal dispersion matching (disp. match correctors and quads),
- ▶ Twiss matching (disp match quads),
- ▶ chromaticities cancellation (arc sextupoles).

Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects

# Correction Results

Step	$\beta_x$ [m]	$\nu_x$	$Q'_x$
Nominal	7.90	48.351	0.007
With errors	7.79	48.345	-0.002
Orbit corr.	7.90	48.352	-0.055
Tune match.	7.90	48.351	-0.054
$D_x$ match.	7.90	48.354	0.029
Twiss match.	7.90	48.353	-0.004
Chromaticity	7.89	48.353	-0.000

Step	$\beta_y$ [m]	$\epsilon_{yn}$ [nm]	$\nu_y$	$Q'_y$
Nominal	5.75	0.00	10.396	-0.117
With errors	5.98	135	10.394	-0.063
Orbit corr.	5.68	0.40	10.389	-0.048
Tune match.	5.68	0.37	10.396	-0.039
$D_x$ match.	5.69	0.40	10.394	-0.056
Twiss match.	5.75	0.39	10.395	-0.047
Chromaticity	5.75	0.39	10.395	-0.000

Lattice

Frequency Map  
ProductionMagnet  
imperfections and  
correctionFrequency Map of  
CLIC DR with  
Corrected ErrorsConclusion and  
Prospects



# Headlines

Lattice

Frequency Map Production

Magnet imperfections and correction

Frequency Map of CLIC DR with Corrected Errors

Conclusion and Prospects

Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects

# Results

Non-linear  
CLIC DR

Y. Renier

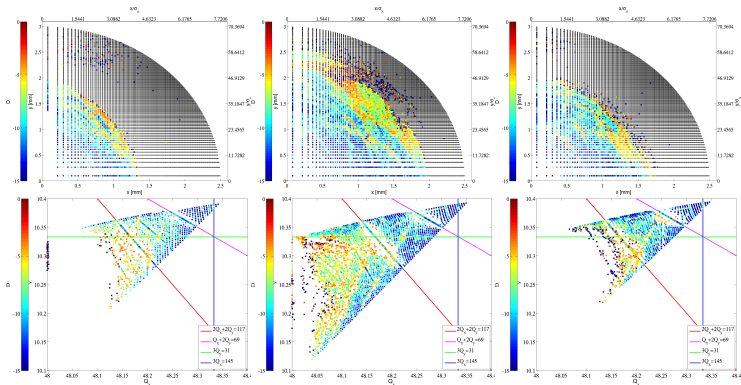
Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects

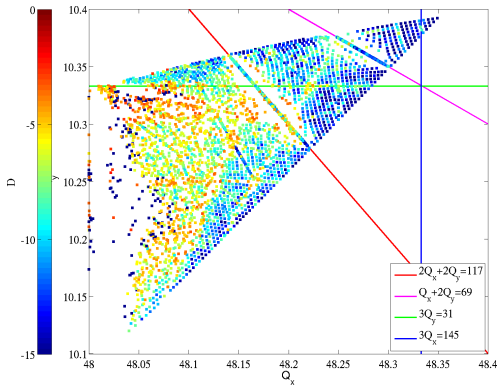


$$dp = -5 \times 10^{-3}$$

$$dp = 0$$

$$dp = 5 \times 10^{-3}$$

# Results



- ▶ FM very similar to the perfect lattice.
- ▶ Slight increase of the diffusion (broken symmetry  $\Rightarrow$  more excited resonance).
- ▶ Same dynamic aperture than for the perfect lattice.

# Headlines

Lattice

Frequency Map Production

Magnet imperfections and correction

Frequency Map of CLIC DR with Corrected Errors

Conclusion and Prospects

Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects

## Conclusion

- ▶ Non-linear dynamics studies on CLIC DR on-going.
- ▶ Small horizontal dynamic aperture ( $6\sigma_x$ ) due to large horizontal tune shift.
- ▶ The introduced errors were successfully corrected (same DA as perfect lattice).

## Prospects

- ▶ Control the large tune shift (with additional sextupoles or octupoles).
- ▶ Add more errors to be more realistic.
- ▶ Include space charge effects in simulation.

Lattice

Frequency Map  
Production

Magnet  
imperfections and  
correction

Frequency Map of  
CLIC DR with  
Corrected Errors

Conclusion and  
Prospects