Tuning of the Traditonal FFS

Hector Garcia Morales[1,2], Rogelio Tomas Garcia[2], Andrea Latina[2]

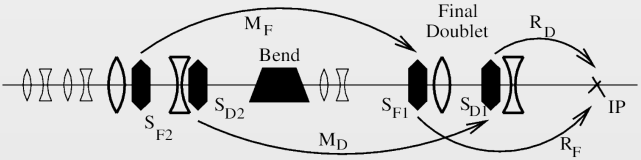
[1] Universitat Politècnica de Catalunya, Barcelona
[2] CERN, Geneve

CLIC Final Focus

- The generation of the nanometer IP spot size requires strong focusing.
- The main task of the Final Focus System (FFS) is to focus the beam to such small sizes.
- The chromatic aberrations of the beam transport in the FFS region need to be canceled with sextupoles and higher order multipoles.
- There exist two distinct approaches for the design of Final Focus Systems.
- The traditional design contains a section dedicated to the chromaticity correction,
- The newer local chromaticity approach the sextupoles are placed within the Final Doublet, allowing a shorter system.

Local Chromaticity Correction Scheme

Current CLIC FFS is based in the local chromaticity correction, initially regarded as a way to reduce the cost of the tunnel construction.



However, recent studies reveal that the current CLIC FFS poses severe challenges when considering realistic imperfections.

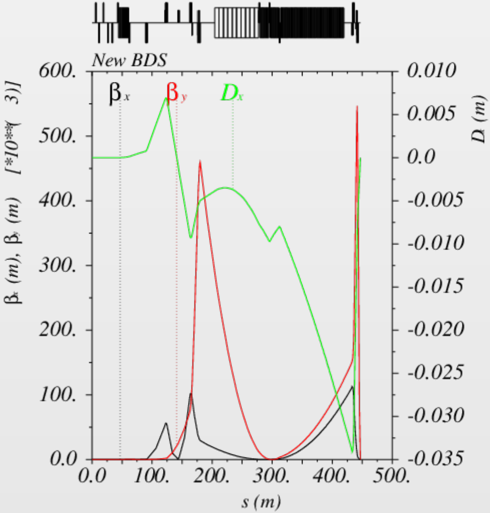
Current CLIC Final Focus System

$$L_{\rm FFS} = 450\text{m}$$

$$L^* = 3.5\text{m}$$

$$\beta_x^* = 6.9\text{mm}$$

$$\beta_y^* = 68\mu\text{m}$$



Traditional Chromaticity Correction Schemes

- The chromaticity is compensated in dedicated chromatic correction sections (CCX and CCY).
- Sextupoles in high dispersion and high betas regions.
- The geometric aberrations generated by the sextupoles are canceled using a $-I$ transformation between them.
- It is a relatively simple system for design and analysis.

Limitations *a priori* and previous studies

- The separate functionality of the lattice makes the system long.
- Relatively large β-functions and high dispersion functions which increase the length of the system and result in tighter tolerances.
- The non-local correction generates high-order aberrations which limit the momentum bandwidth.

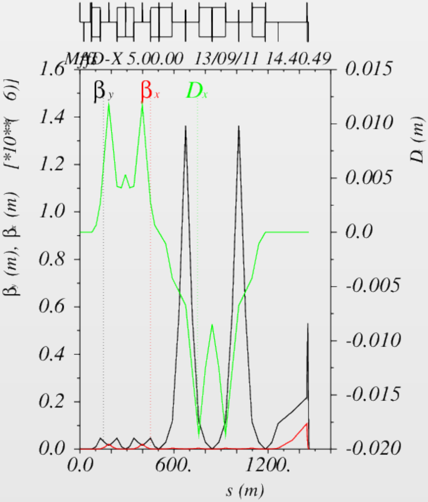
Short proposal scheme, $L_{\mathrm{FFS}} = 1.5\mathrm{km}$

$$L_{\mathrm{FFS}} = 1460.61\mathrm{m}$$

$$L^* = 3.5\mathrm{m}$$

$$\beta_x^* = 6.9\mathrm{mm}$$

$$\beta_y^* = 68\mu\mathrm{m}$$



Setup

- CLIC Traditional Final Focus System
- $\sqrt{s} = 3\text{TeV}$
- Integrated simulations: BBA+Tuning Knobs
- PLACET for tracking and Guinea-Pig for Luminosity calculations
- Initial random misalignment: $\sigma = 10\mu\text{m}$ RMS (x, y) for all elements
- BPM resolution: 10nm
- Corrector Block: BPM+Quadrupole+Corrector

Alignment procedure. (Andrea's script)

- Multipoles OFF:
  - 1:1 correction

$$\begin{pmatrix} b_x \\ b_y \end{pmatrix} = \begin{pmatrix} R_{xx} & 0 \\ 0 & R_{yy} \end{pmatrix} \begin{pmatrix} \theta_x \\ \theta_y \end{pmatrix}$$

  - DFS

$$\begin{pmatrix} b \\ \omega_1(\eta - \eta_0) \\ 0 \end{pmatrix} = \begin{pmatrix} R \\ \omega_1 D \\ \beta I \end{pmatrix} \begin{pmatrix} \theta_x \\ \theta_y \end{pmatrix}$$

- Multipole-Shunting
- Multipole Knobs
- Multipoles ON:
  - DFS

$$\begin{pmatrix} b \\ \omega_1(\eta - \eta_0) \\ 0 \end{pmatrix} = \begin{pmatrix} R \\ \omega_2 D \\ \beta I \end{pmatrix} \begin{pmatrix} \theta_x \\ \theta_y \end{pmatrix}$$

  - Multipole Shunting
  - Multipole Knobs

Tuning process

- Response Matrices
- Tune the free parameters $(\beta, \omega_1, \omega_2)$
- Optimize Gains
- BBA
- Knobs

Response Matrices

How to calculate response matrices:

- Orbit measurement via tracking.
- Optics: R_{12} elements.

Take into account:

- Nonlinearities.
- Synchrotron radiation.

Used here:

- Orbit measurement

Tuning of the weights

- 5 free parameters: (gain1, gain2, ω_1, ω_2, β)
- Tuning method
  - Fix gains.
  - Scan β.
  - Simplex on (ω_1, ω_2) average on 40 seeds.

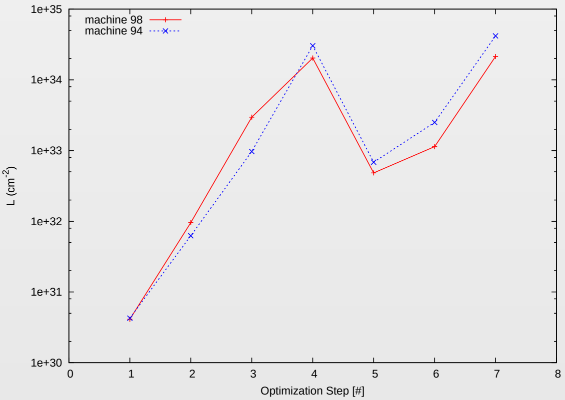
- We tried to optimize it but without success. We take the values obtained by Andrea for the Nominal CLIC FFS.
  - Gains: (0.7, 0.3)
  - $\beta = 10$
  - $\omega_1 = 635$
  - $\omega_2 = 11$

Tuning Knobs

- Tuning Knobs are calculated using SVD:
  - Beam covariances vs. 5 sextupole positions.
  - 10 Knobs are computed.
- Only 6 out of 10 Knobs ares used.
- Brent minimization algorithm.

Results

1: 1:1
2: DFS
3: Multipole Shunting
4: Knobs
5: DFS
6: Multipole Shunting
7: Knobs



Tuning results

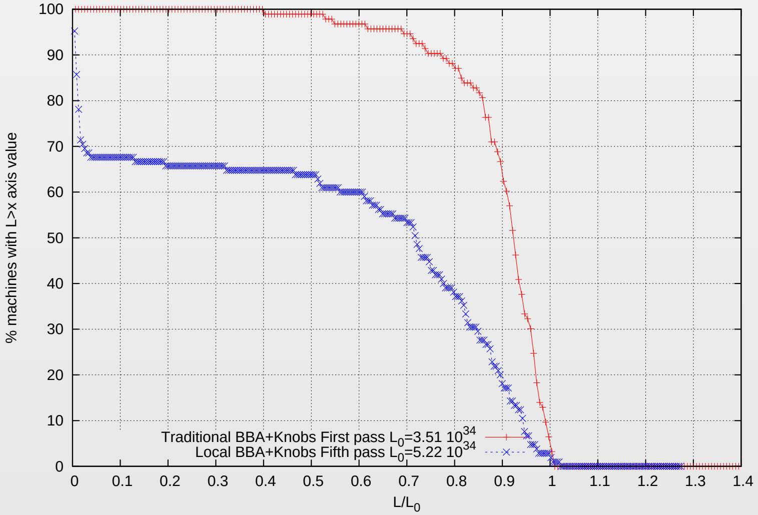


Figure: Tuning results for the Traditional correction scheme

Tuning results

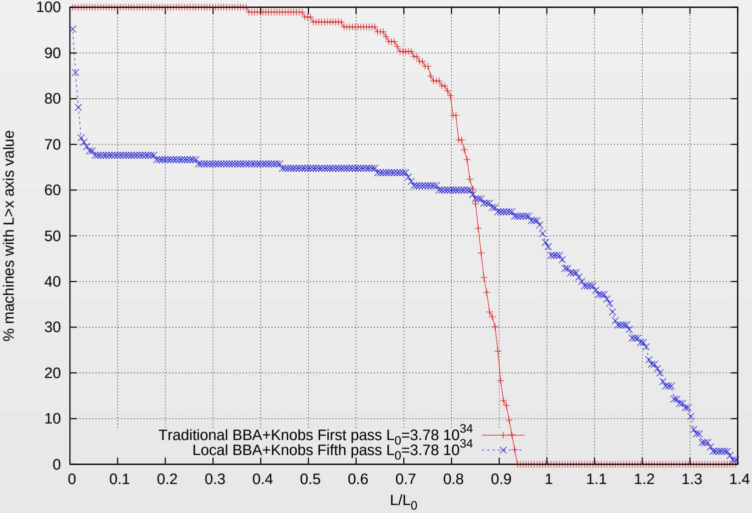


Figure: Tuning results for the Traditional correction scheme

Conclusions

Results

- We have tested the Tuning algorithm for another different lattice successfully.
- Although non-optimal free parameters, the convergence is good.
- After only a first pass, the alignment of the FFS seems to work fine.

Further studies

- Optimize free parameters.
- Introduce a new free parameter β_2.
- Second, third and more passes to see the final convergence of the algorithm.
- Tuning low energy options ($\sqrt{s} = 500\text{GeV}$)