CERN-BINP Workshop

Comparative study of the tuning performances of the nominal and long L^* CLIC Final Focus system

FFS design for CLIC 380 GeV

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Thanks to: *Andrea Latina*[1], *Eduardo Marin*[1], *Jochem Snuverink*[3], *Ryan Bodentsein*[3], *Marcin Patecki*[1] *and the MDI working group*[1]

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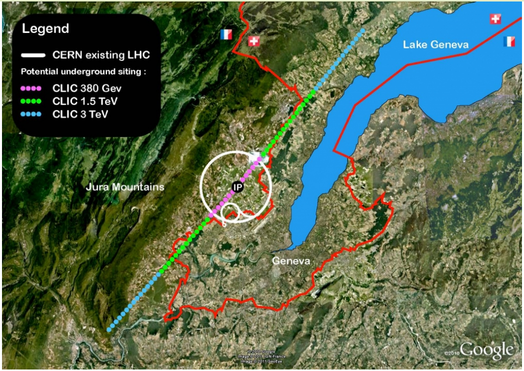
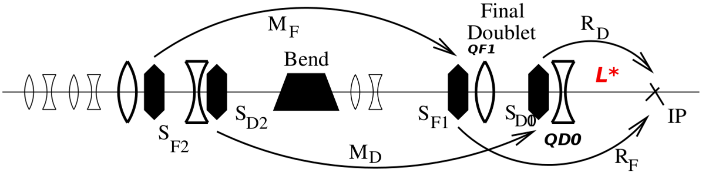
OUTLINES

CLIC Final Focus System (FFS)

- The first stage of CLIC will collide $e^- e^+$ beams at $\sqrt{s}$ = **380 GeV** and will be upgraded up to $\sqrt{s}$ = **3 TeV**
- FFS $\Rightarrow$ correct the chromaticity generated by the FD and deliver small beam size at the IP
- Scheme based on **local chromaticity correction**
- **Two L^* options** are studied here for the **first and last stage** of the CLIC FFS : Nominal and Long L^*

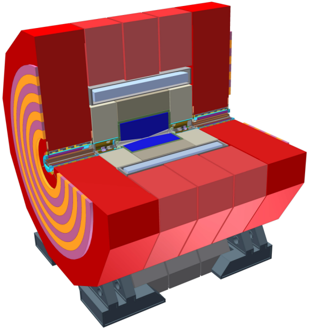


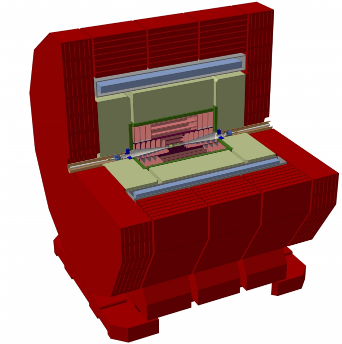
- The chromaticity generated by the FD scales as $\xi_y \propto L^*/\beta_y^*$

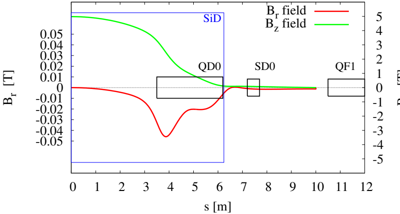


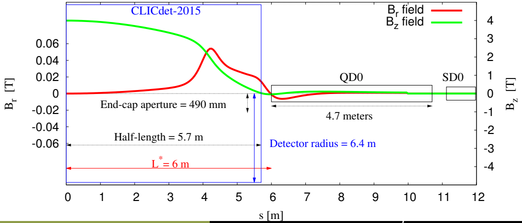
Motivations for longer L^*

No interplays between the solenoid field and QD0 field, reduces QD0 vibration, eases stabilization and acess to QD0, increases forward acceptance



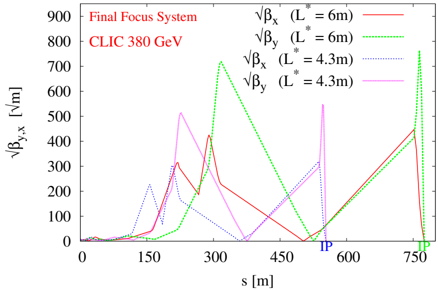


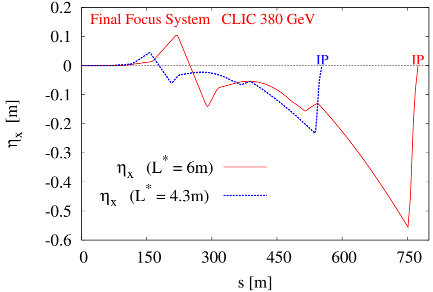




Parameters & Performances

CLIC energy	380 GeV	380 GeV
L^* (m)	**4.3**	**6**
FFS length (m)	**553**	**770**
$\gamma\epsilon_x/\gamma\epsilon_y$ (nm)	950 / 20	950 / 20
β^*_x/β^*_y (mm)	8.2 / 0.1	8.2 / 0.1
σ^*_x ($\sigma^*_{x,design}$) (nm)	**150** (145)	**160** (145)
σ^*_y ($\sigma^*_{y,design}$) (nm)	**2.7** (2.3)	**3.5** (2.3)
L_{tot} ($L_{\text{tot, design}}$) ($10^{34}\text{cm}^{-2}\text{s}^{-1}$)	**1.9** (1.5)	**1.65** (1.5)
$L_{1\%}$ ($L_{1\%\text{, design}}$) ($10^{34}\text{cm}^{-2}\text{s}^{-1}$)	**1.1** (0.9)	**1** (0.9)
Chrom. ξ_y (L^*/β^*_y)	43000	60000

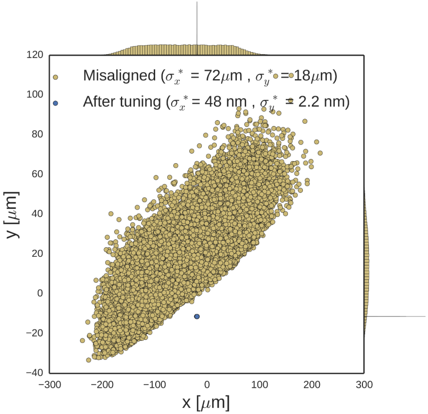




- The length of the FFS have been scaled according to the increase of L^*
- Longer L^* inevitably reduce the luminosity
- Performances computed after dispersion optimization in the FFS

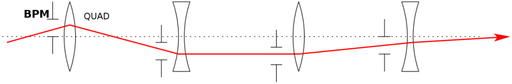
Tuning the FFS

- The **tuning aims to recover the luminosity loss due to static misalignment** of the optics
- CLIC FFS is very sensitive to alignment errors and the luminosity drops by several orders of magnitude when a transverse misalignment of σ_{RMS} = 10 μm is assumed
- Tunability determine the feasibility of the FFS lattice
- Tuning effectiveness will be decisive for the final layout of the CLIC FFS



Tuning algorithm applied

1. **Transverse misalignment** of the quadrupoles, sextupoles and BPMs (σ_{RMS} = 10 μm)
2. **One-to-One correction** : steer the beam **through the center of all BPMs** using transverse kickers (dispersion still present)

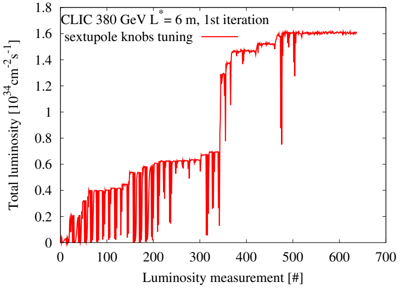


3. **Dispersion Free Steering** (DFS) : presence of **dispersion is measured** and the kickers are used to correct it. One has to solve the following system :

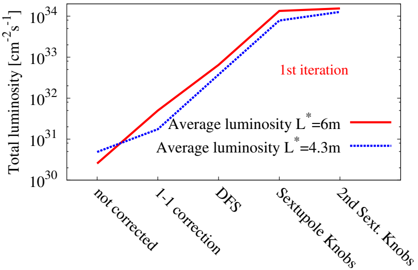
$$\begin{pmatrix} b - b_0 \\ \omega(\eta - \eta_0) \\ 0 \end{pmatrix} = \begin{pmatrix} R \\ \omega D \\ \beta I \end{pmatrix} \begin{pmatrix} \theta_1 \\ \dots \\ \theta_n \end{pmatrix} \quad (1)$$

Where R,D and I are the response and identity matrices and β, ω are weighting factors

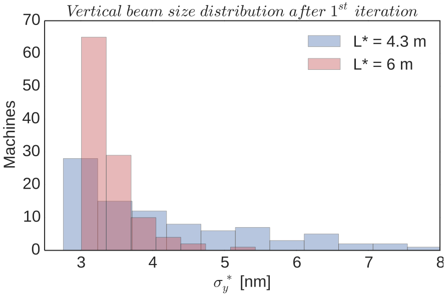
4. **Sextupole knobs tuning** : pre-computed combinations of sextupole transverse displacements meant to **control a chosen set of linear beam aberrations** ($\beta^*_{x,y}$, $\alpha^*_{x,y}$, $\eta^*_{x,y}$, $\eta_y^{'*}$, $< x, y >$, $< x^{'}, y >$, $< x^{'}, y^{'} >$)
   Each knob is scanned by looking at the **optimum Luminosity**
   Knobs are not fully orthogonal $\Rightarrow$ **Iterations needed**
5. **2^{nd} Sextupole knobs tuning**

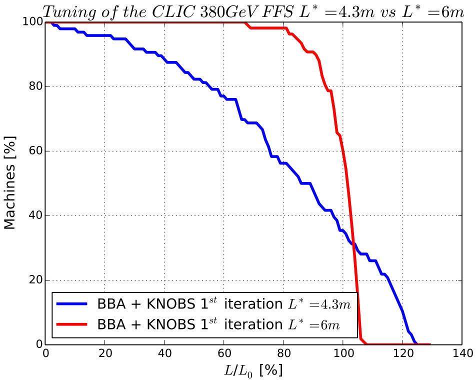


Tuning of the CLIC 380 GeV FFS : L^*= 4.3 m vs L^*=6 m



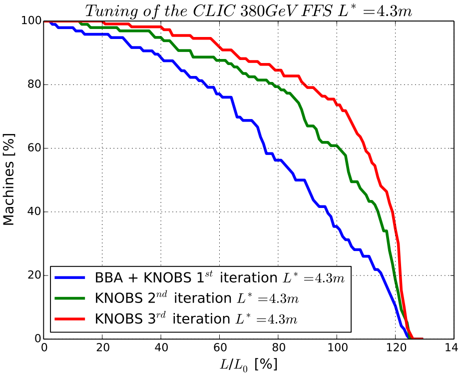
- After 1 iteration the **long L^* lattice shows better tuning efficiency** than the nominal one
- The difference of **sextupole strengths** explains the gap of efficiency between the two lattices (see next slides)

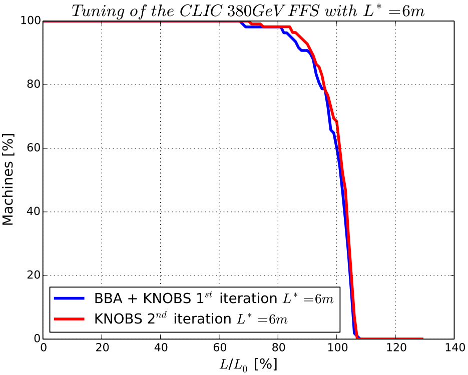




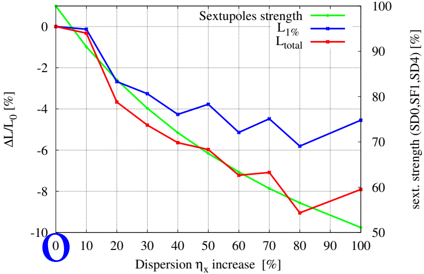
Tuning of the CLIC 380 GeV FFS : L^*= 4.3 m vs L^*=6 m

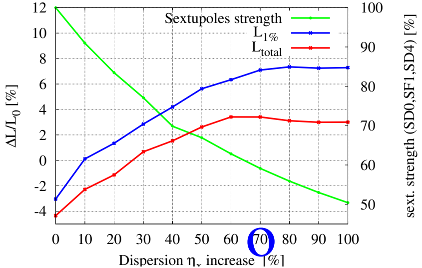
- L^*= 4.3 m : after **3 iterations 80% of the machines achieve 90% of** L_0 **and 75% of the machines achieve 100% of** L_0
- L^*= 6 m : No large improvement after the **2nd iteration**
  94% of the machines achieve 90% of L_0
  and 70% of the machines achieve 100% of L_0



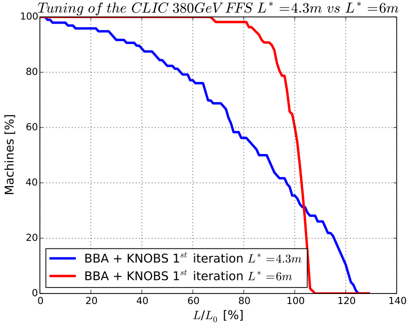


Tuning of the CLIC 380 GeV FFS : L^*= 4.3 m vs L^*=6 m

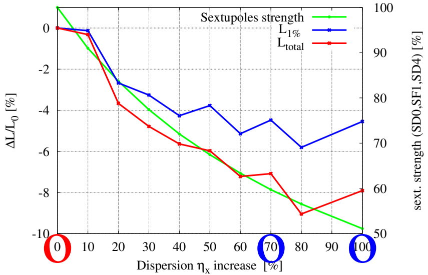


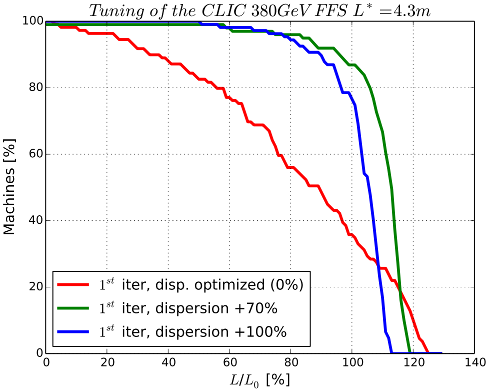


- For L^* = 6 m (upper rigth plot), dispersion level has been increased by 70% leading to **reduce the average sextupole strength of the FFS by 40%**
- For L^* = 4.3 m, no increase of dispersion in the FFS ⇒ Sextupole **strength unchanged**



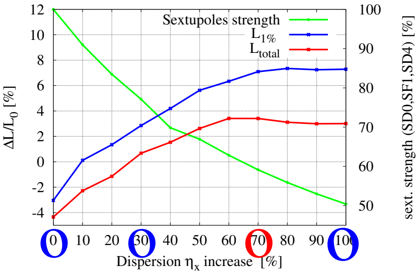
Tuning of the CLIC 380 GeV FFS : L^*= 4.3 m (Dispersion impact)

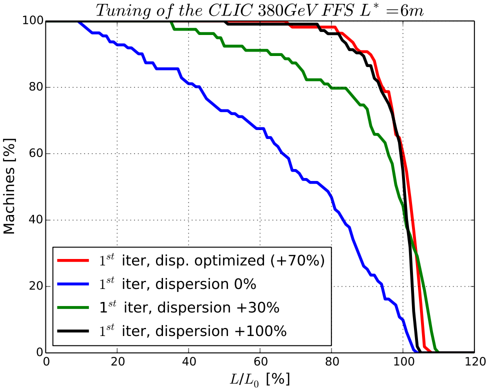




- For L^* = 4.3 m, increasing dispersion in the FFS **reduces the maximum luminosity** achievable but **increases the tuning efficiency**
- More detailed studies of the tunability will decide the final layout of the FFS

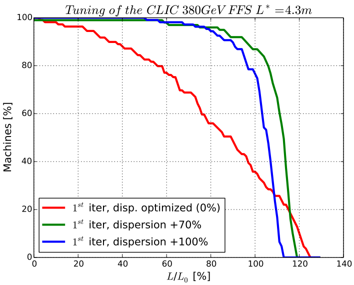
Tuning of the CLIC 380 GeV FFS : L^*= 6 m (Dispersion impact)

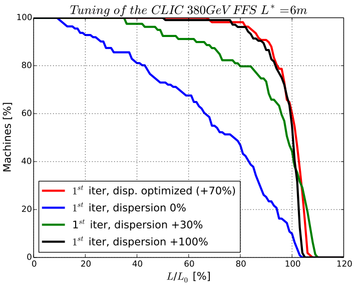


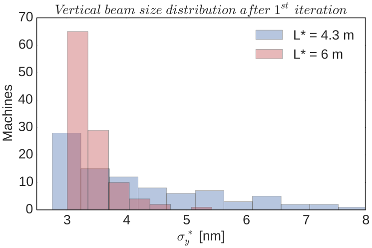


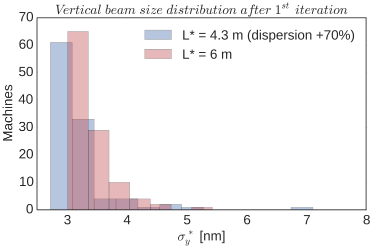
- For L^* = 6 m, reducing dispersion in the FFS **reduce the maximum luminosity** achievable and **reduce the tuning efficiency**
- Tuning efficiency has a limit when increasing dispersion in the FFS (black line)

CLIC 380 GeV FFS : L^*= 6 m & L^*= 4.3 m (Dispersion impact)









FFS SEXTUPOLE STRENGTHS HAVE A LARGE IMPACT ON THE TUNING EFFICIENCY

Summary

Tuning of the CLIC 380 GeV FFS

- **Strong impact of the sextupole strengths** in the FFS on the tuning efficiency
- Tuning performance of the lattice with L^*= 4.3 m has been improved by **increasing dispersion** in the FFS
- Both designs (nominal and long L^*) shows now **good tuning performance**
- More imperfections will be added in further tuning simulation : roll, tilt and strength errors