Long L* design for the FFS of CLIC

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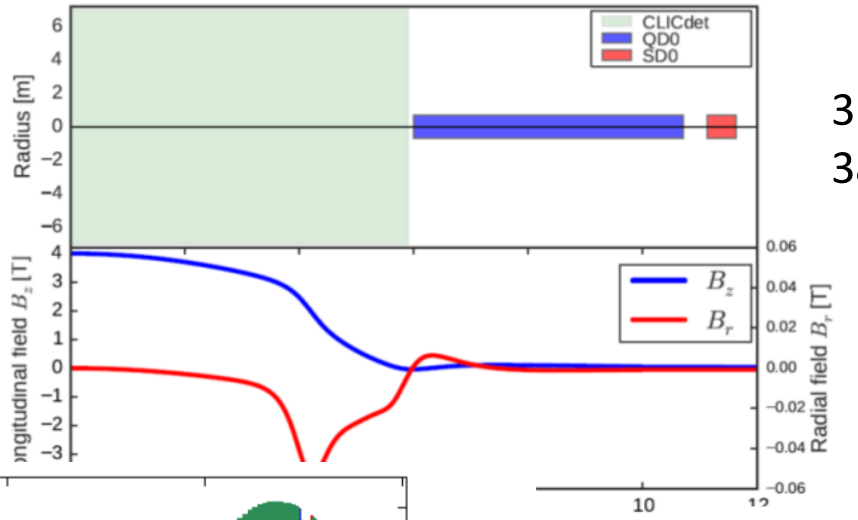
In Longer L* optics, QD0 is foreseen to be located outside of the detector.

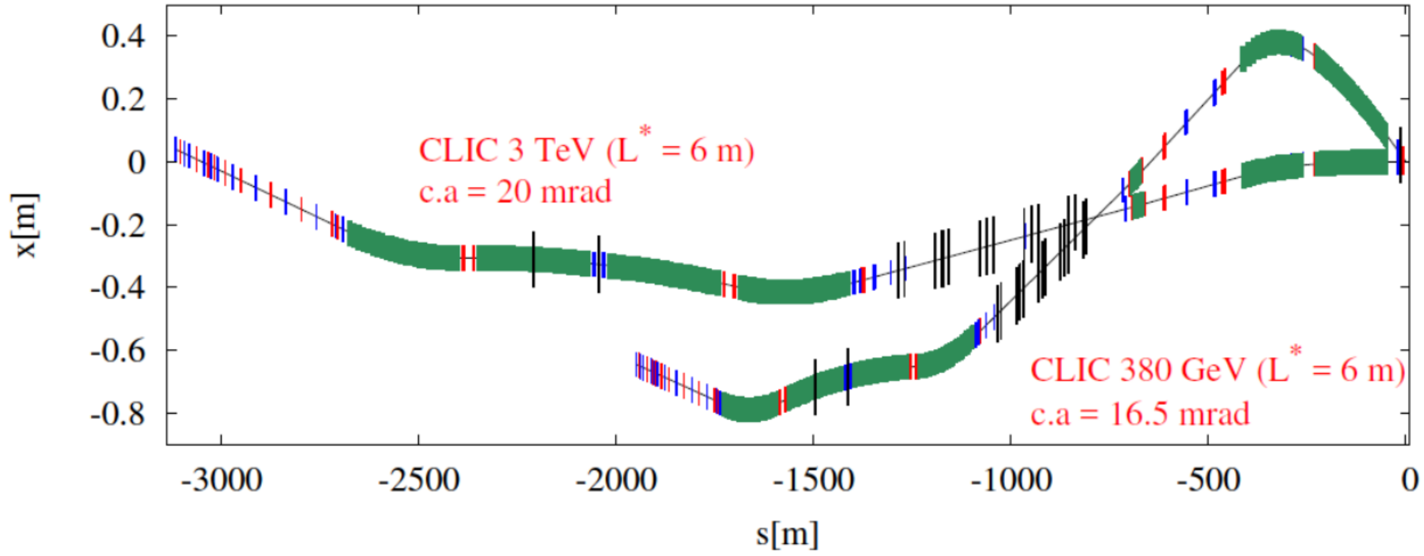
Why it is needed:

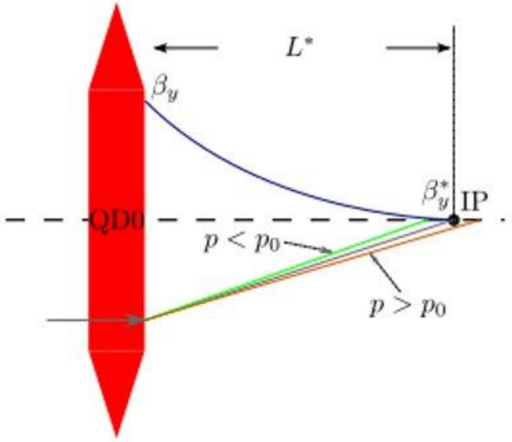
- To alleviate engineering and stabilization issues of the MDI.
- Easier access to the detector and QD0 region.
- Minimized solenoid field impact.

CLICdet for optics with $L^* = 6$ m[1]:



3 TeV: 3.5 m -> 6 m
380 GeV: 4.3 m -> 6 m





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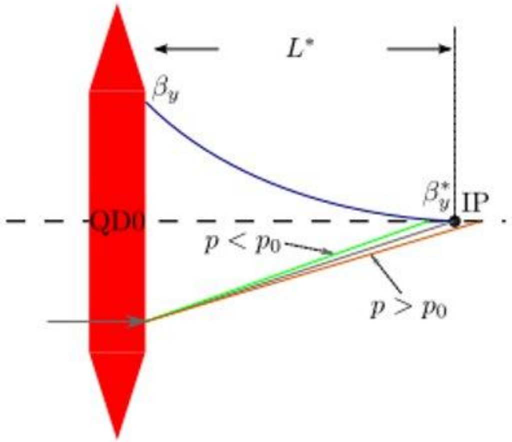
$$\sigma^{*}_{x,y}{}^{2} = \epsilon_{x,y}\beta^{*}_{x,y}(1 + \xi^{2}_{x,y}\delta^{2}_{p})$$

- Larger vertical chromaticity: $\xi_y \approx \frac{L^*}{\beta^*_y}$.
- Higher $\beta_{x,y}$ at the FD:

$$\beta_y(s) = \beta^*_y + \frac{s^2}{\beta^*_y}$$

- Higher-order aberrations and potentialy a need of high-order elements (octupoles, decapoles..).
- Potential collimation issues.



FFS@380 GeV optics was scalled from $L^* = 4.3$ m to $L^* = 6$ m:

L*	$\mathcal{L}_{total}$	$\mathcal{L}_{peak}$
4.3 m	1.70	0.96
$(6\,\text{m})^2$	1.63	0.93

The case of 3 TeV:

Design	$\mathcal{L}_{\text{total}}$ $[10^{34}\text{cm}^{-2}\text{s}^{-1}]$	$\mathcal{L}_{1\%}$
$\text{L}^* = 3.5$ m	7.6	2.4
$\text{L}^* = 6$ m	6.4	2.3

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Main drawbacks:

- **Higher β-functions at the FD:**
  Larger FD aperture, growth of the high-order aberrations, the optics becomes more sensitive to the magnet imperfections
- **Stronger sextupoles:**
  Required to compensate chromaticity growth, potential high-order aberrations
- **Potentially, high-order elements (octupoles, decapoles) may be required**
- **Potential tuning difficulties**
  It correlates with increased chromaticity, and higher sensitivity to magnet inperfections (especially in the FD)
- **Potential collimation issues**
  Performance of the collimation and post collision line have to be checked

Long L* design for the FFS of CLIC

Work dedicated to the beam dynamics studies with Long L*

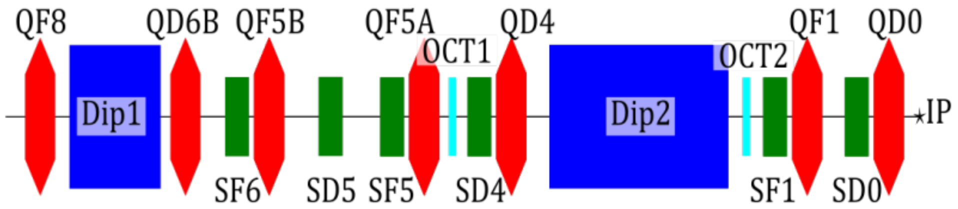
- **F. Plassard et. al. "Quadrupole-free detector optics design for the Compact Linear Collider final focus system at 3 TeV"**
  -FFS length optimization, sextupole strength matching, dispersion level scan, verification of the collimation properties.
- **A. Pastushenko et. al. "The optics design with longer L* for the Final Focus System of CLIC 380 GeV".**
  -FD is shortened to reduce the chromaticity, sextupole strength matching, new dispersion profile, dispersion level scan, verification of the collimation properties.
- **V. Cilento et. al. "Dual beam delivery system serving two interaction regions for the Compact Linear Collider".**
  -Design of the BDS with 2 interaction regions, investigation of the solenoid field impact.
- **J. Ögren et. al. "Tuning the Compact Linear Collider 380 GeV final-focus system using realistic beam-beam signals"**
  Tuning performance of the design with Longer L*
- **R. Bodenstein et. al. "INVESTIGATION OF CLIC 380 GeV POST-COLLISION LINE"**

Long L* design for the FFS of CLIC

The strategy to optimize the FFS lattice:

1. Match the Twiss at the IP.
2. Adjust the horizontal chromaticity to be able to correct the chromaticity and 2^{nd} order dispersion simultaniously.
3. Match the beam size in Mapclass (5^{th} order) with the sextupoles (there are 6 present in the CLIC lattice).
4. Additional optimizations + high-order elements (octupoles, decapoles..) are introduced if needed.
5. Adjustment of the dispersion level by scanning the different bending angles.

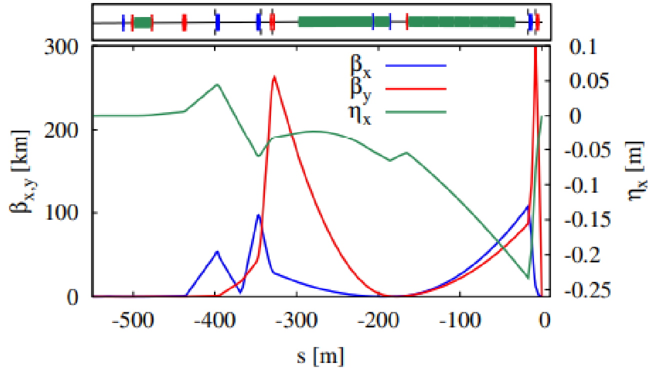
Final Focus System scheme

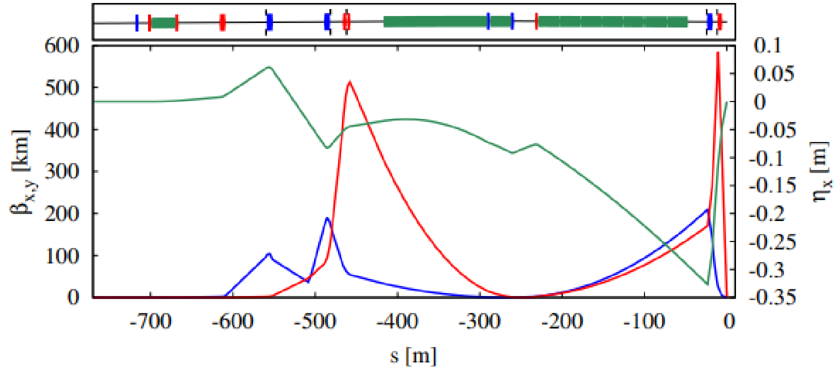


Long L* design for the FFS of CLIC

CLIC 380 GeV

FFS length [m]	770
L^* [m]	6
$\epsilon_{n,x}/\epsilon_{n,y}$ [nm]	950/30
β_x^*/β_y^* [mm]/[μm]	8/70
σ_x^*/σ_y^* [nm]	145/2.9
σ_z [μm]	70
δ_p [%] (Uniform distr.)	1.0
$\mathcal{L}$ [10^{34}cm^{-2}s^{-1}]	1.66
$\mathcal{L}_{1\%}$ [10^{34}cm^{-2}s^{-1}]	0.96





Comparison of the luminosities for the designs with L* = 6 m for CLIC 380 GeV

	MAPCLASS		PLACET + Guinea-Pig				
Optics	σ_x^* [nm]	σ_y^* [nm]	σ_x^* [nm]	σ_y^* [nm]	$\sigma_{x,y}$ bandwidth [%]	$\mathcal{L}_{total}$	$\mathcal{L}_{peak}$
$\beta_y^* = 100$ μm	141.90	3.14	144.22	3.14	0.52	1.63	0.93
$\beta_y^* = 70$ μm	143.48	2.72	145.78	2.74	0.35	1.66	0.96
$\beta_y^* = 70$ μm, Short FD	142.74	2.63	144.72	2.71	0.42	1.66	0.96
$\beta_y^* = 70$ μm, Short FD + altern. D_x	142.43	2.45	143.82	2.67	0.3	1.74	1.01

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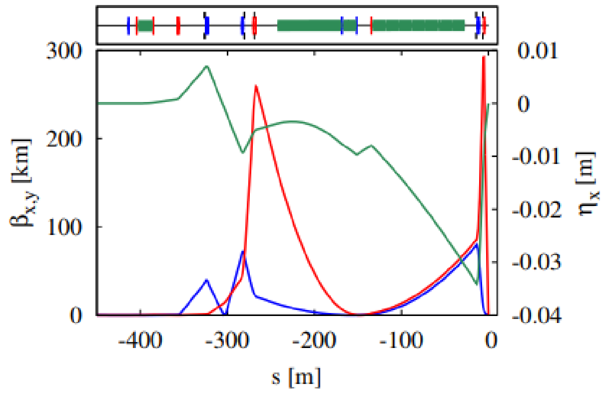
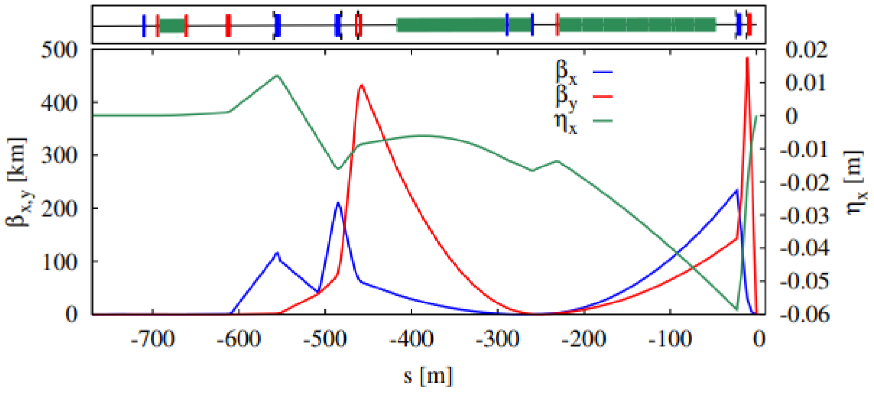
Table 3.1: CLIC 3 TeV design parameters

L* [m]	3.5	6
FFS length [m]	450	770
Norm. emittance (IP) $\gamma\varepsilon_x/\gamma\varepsilon_y$ [nm]	660 / 20	660 / 20
Beta function (IP) β_x^*/β_y^* [mm]	7 / 0.068	7 / 0.12
IP beam size σ_x^*/σ_y^* [nm]	40 / 0.7	40 / 0.9
Bunch length σ_z [μm]	44	44
rms energy spread δ_p [%]	0.3	0.3
Bunch population N_e [$\times 10^9$]	3.72	3.72
Number of bunches n_b	312	312
Repetition rate f_{rep} [Hz]	50	50
Luminosity $\mathcal{L}_{total}$ [10^{34}cm^{-2}s^{-1}]	5.9	5.9
Peak luminosity $\mathcal{L}_{1\%}$ [10^{34}cm^{-2}s^{-1}]	2	2





Design	ξ_y^*	$\frac{\sigma_x^*}{\sigma_x^{*noSR}}$	$\frac{\sigma_y^*}{\sigma_y^{*noSR}}$	$\mathcal{L}_{total}$ [10^{34}cm^{-2}s^{-1}]	$\mathcal{L}_{1\%}$ [10^{34}cm^{-2}s^{-1}]	$\frac{\mathcal{L}_{1\%}}{\mathcal{L}_{1\%}^{noSR}}$	$\sigma_{y,Oide}$ [nm]
L* = 3.5 m	82027	1.18	1.86	7.04	2.3	0.81	0.92
L* = 6 m	79913	1.21	1.35	6.5	2.14	0.88	0.45

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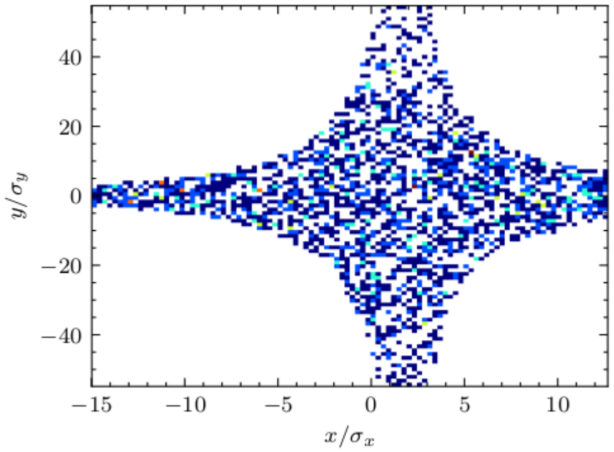
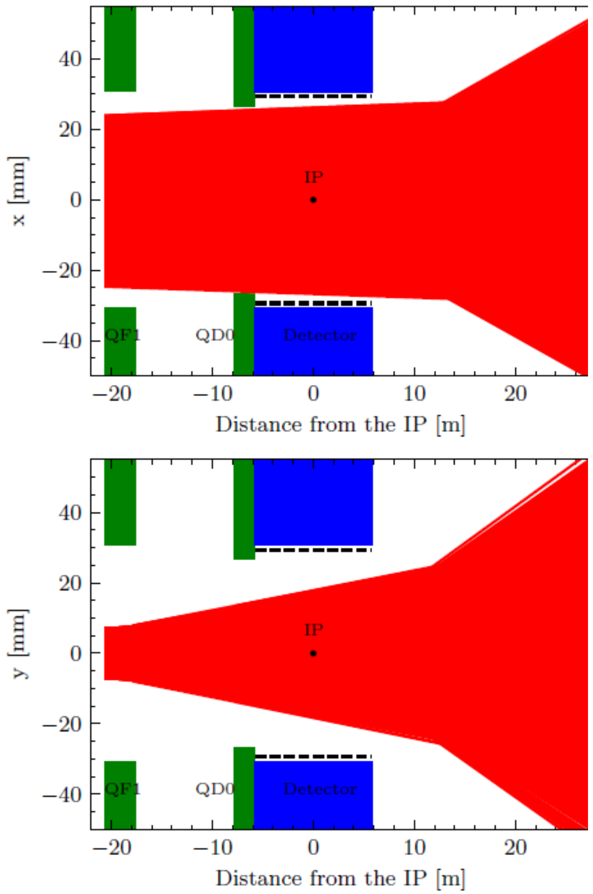
Collimation with $15\sigma_x$ X $55\sigma_y$ collimation depth:

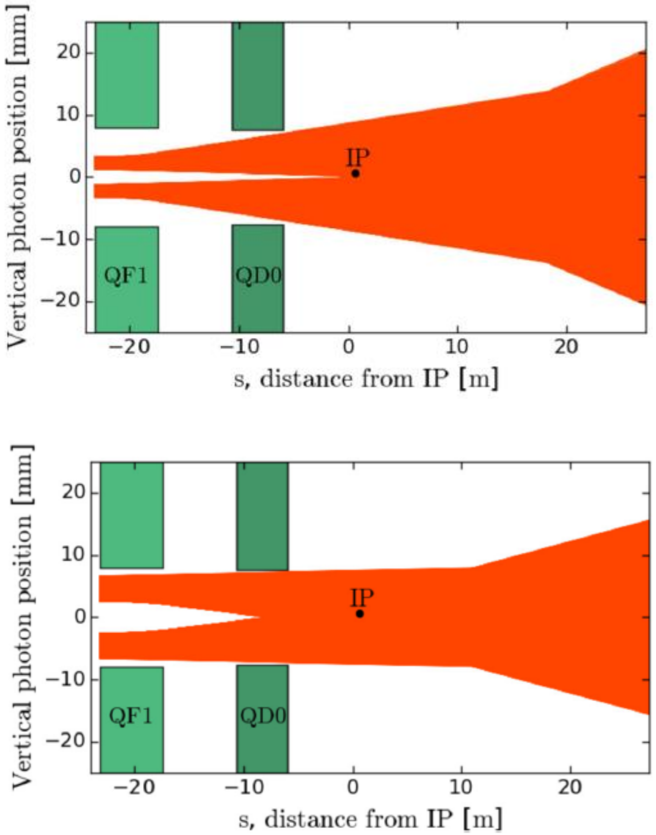
The collimation depth has to satisfy the condition that neither beam halo nor emitted photons hit the FD or the detector. The beam halo used in the simulations:



Case of 380 GeV:



Case of 3 TeV:



Thank you for your attention!