# CLIC 380 GeV FFS optimization

LCWS 2021

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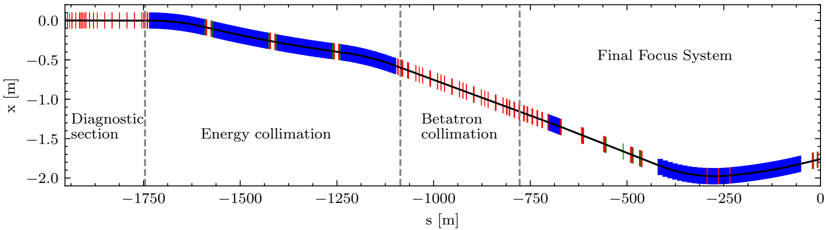
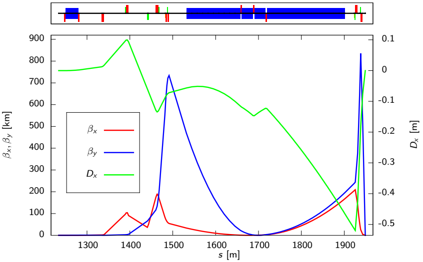
# Outline

# Beam Delivery System of CLIC@380 GeV:




**FFS optics**[1]:

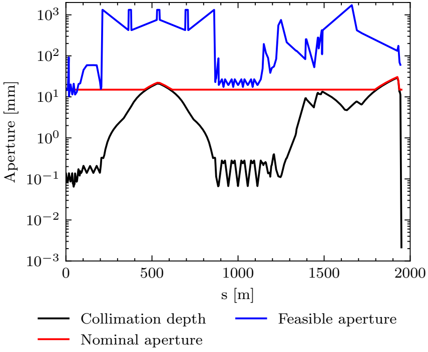



| | |
|---|---|
| FFS length [m] | 770 |
| $L^*$ [m] | 6 |
| $\epsilon_{n,x}/\epsilon_{n,y}$ [nm] | 950/30 |
| $\beta_x^*/\beta_y^*$ [mm]/[$\mu$m] | 8/70 |
| $\sigma_x^*/\sigma_y^*$ [nm] | 145/2.9 |
| $\sigma_z$ [$\mu$m] | 70 |
| $\delta_p$ [%] (Uniform distr.) | 1.0 |
| $\mathcal{L}$ [$10^{34}$cm$^{-2}$s$^{-1}$] | 1.66 |
| $\mathcal{L}_{1\%}$ [$10^{34}$cm$^{-2}$s$^{-1}$] | 0.96 |

[1] A. Pastushenko, "Optics calculations for CLIC". Master's thesis.

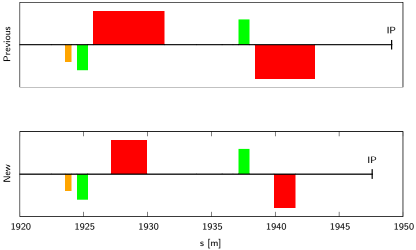
# Short FD

**Aperture distribution along the BDS:**




- The nominal apertures is based on the collimation depth of $15\sigma_x \times 55\sigma_y$[2].
- Feasible aperture is estimated with 1.5 T pole tip field for the reference.

**Short FD:**




1. Make FD shorter. Factor of 2 has been taken.
2. Restore the condition $L^* = 6$ m.

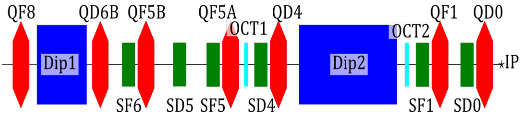
[2] J. Resta-Lopez et. al., "Status report of the baseline collimation system of CLIC", CLIC–Note 883

# CLIC 380 GeV optics with short FD

**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 2nd order dispersion simultaniously.
3. Match the beam size in Mapclass (5th order) with the sextupoles (there are 6 present in the CLIC lattice).
4. Further optimizations aimed to optimize the beam size/luminosity.

**Final Focus System scheme**



# FFS optics with the short FD

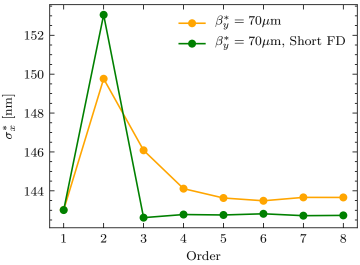
- Optimal upstream chromaticity is found by scanning the length between the FD and upstream elements.
- **Beam size** matched with the sextupoles at $5^{\text{th}}$ order:

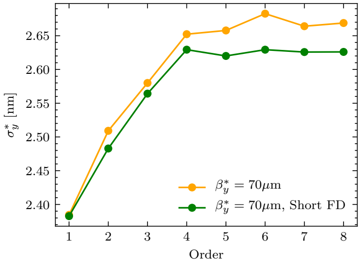
| | MAPCLASS | PLACET w/ SR |
|---|---|---|
| $\sigma_x^*$ [nm] | 142.74 | 144.72 |
| $\sigma_y^*$ [nm] | 2.63 | 2.71 |

***Target:** $\sigma_x^* = 143$ nm and $\sigma_y^* = 2.38$ nm.

- **Luminosity:**
  PLACET and Guniea-Pig:
  $\mathcal{L} = 1.66\times10^{34}\text{cm}^{-2}\text{s}^{-1}$
  $\mathcal{L}_{1\%} = 0.96\times10^{34}\text{cm}^{-2}\text{s}^{-1}$
- **Dispersion profile scan:**
  No change needed. The dipole angles are iterated in the range 0.37 - 1.31 % with a step $\sim$ 6%.

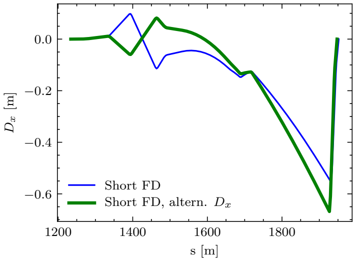
**Beam size at the IP:**



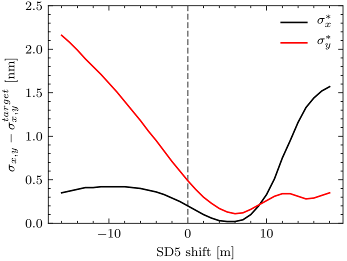



# FFS optics with short FD + different dispersion

- The feature of this optics is a new dispersion profile. In this case **QD6B** has the opposite polarity.
- Adjusting the upstream chromaticity.




- To reduce the 5$^{th}$ order beam size, **SD5** location is scanned.
- The 5$^{th}$ order beam size is reduced closely to the linear value by additional constraints in the matching.



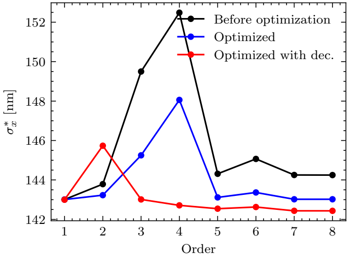

**Horizontal and vertical beam size vs shift of SD5 sextupole.**

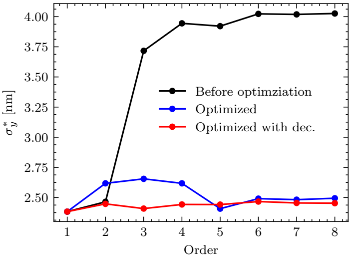
# FFS optics with short FD + alternative dispersion profile

- The "spike" in $\sigma_x^*$ at 3$^{rd}$ and 4$^{th}$ orders is removed with the pair of decapoles installed in the FD.
- Beam size

| | MAPCLASS | PLACET w/ SR |
|---|---|---|
| $\sigma_x^*$ [nm] | 142.97 | 145.62 |
| $\sigma_y^*$ [nm] | 2.52 | 2.87 |

- **Luminosity:** PLACET and Guniea-Pig:
  $\mathcal{L} = 1.73{\times}10^{34}\text{cm}^{-2}\text{s}^{-1}$
  $\mathcal{L}_{1\%} = 1.00{\times}10^{34}\text{cm}^{-2}\text{s}^{-1}$
- **Dispersion level scan:** The dipole angles are iterated in the range 0.37 - 1.31 % with a step $\sim$ 6%. The optimal choice is to reduce the dispersion by **12.5 %**.



# Optics comparison

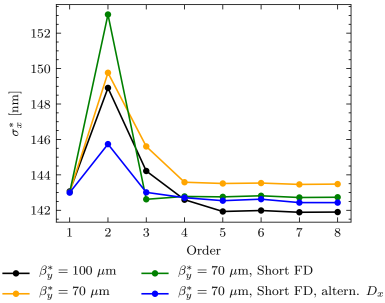
**Mapclass ($8^{th}$ order map):**

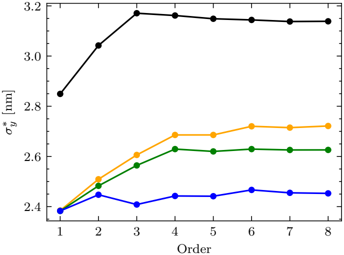
| Optics | $\sigma_x^*$ [nm] | $\sigma_y^*$ [nm] |
|---|---|---|
| $\beta_y^* = 100\mu$m | 141.90 | 3.14 |
| $\beta_y^* = 70\mu$m | 143.48 | 2.72 |
| $\beta_y^* = 70\mu$m, Short FD | 142.74 | 2.63 |
| $\beta_y^* = 70\mu$m, Short FD + $D_x$ mod. | 142.43 | 2.45 |

**PLACET (w/ SR):**

| Optics | $\sigma_x^*$ [nm] | $\sigma_y^*$ [nm] |
|---|---|---|
| $\beta_y^* = 100\mu$m | 144.22 | 3.14 |
| $\beta_y^* = 70\mu$m | 145.78 | 2.74 |
| $\beta_y^* = 70\mu$m, Short FD | 144.72 | 2.71 |
| $\beta_y^* = 70\mu$m, Short FD + $D_x$ mod. | 143.82 | 2.67 |

**Beam size:**



# Optics comparison

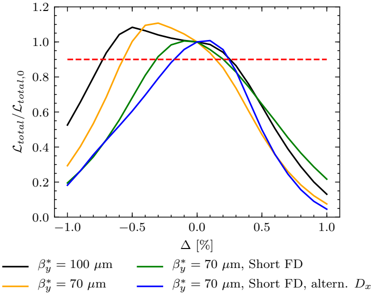
- **Luminosity:**($\times 10^{34}$cm$^{-2}$s$^{-1}$)

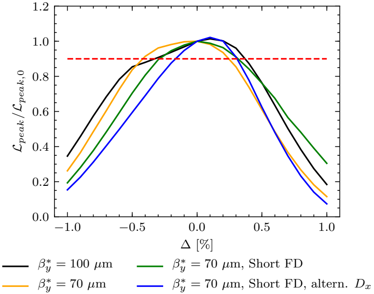
| Optics | $\mathcal{L}$ | $\mathcal{L}_{1\%}$ |
|---|---|---|
| $\beta_y^* = 100\mu$m | 1.63 | 0.93 |
| $\beta_y^* = 70\mu$m | 1.66 | 0.96 |
| $\beta_y^* = 70\mu$m, Short FD | **1.66** | **0.96** |
| $\beta_y^* = 70\mu$m, Short FD + $D_x$ mod. | **1.74** | **1.01** |

- **Momentum bandwidth:**

| Optics | $\sigma_{x,y}$ bandwidth [% |
|---|---|
| $\beta_y^* = 100\mu$m | 0.52 |
| $\beta_y^* = 70\mu$m | 0.35 |
| $\beta_y^* = 70\mu$m, Short FD | 0.42 |
| $\beta_y^* = 70\mu$m, Short FD + $D_x$ mod. | 0.3 |

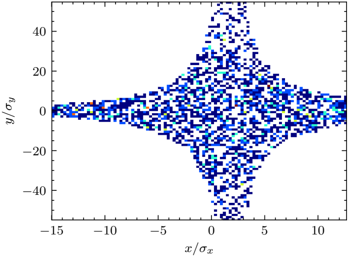
**Luminosity bandwidth:**



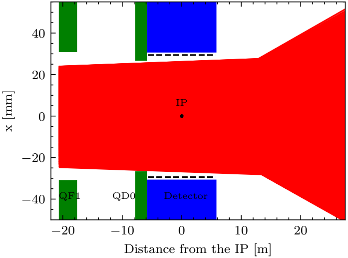



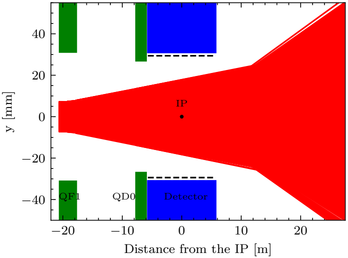
# Collimation depth

- 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:



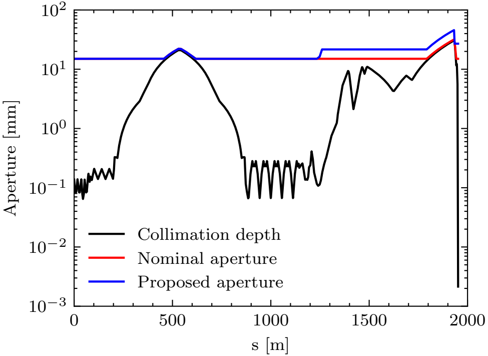

| | QF1 | QD0 |
|---|---|---|
| Gradient [T/m] | 16.3 | 73.7 |
| Aperture [mm] | 31.2 | 27.0 |
| Pole tip field [T] | 0.51 | 1.99 |



# Collimation depth

**Proposed BDS aperture:**
Including the new aperture of QD0 and a suggestion to increase by 44% aperture in the FFS(except the FD)[3]




[3] D. Arominski, A.Latina, D.Schulte, "Resistive wall effects in the CLIC Beam Delivery System", IPAC 10 proceedings.

# Summary

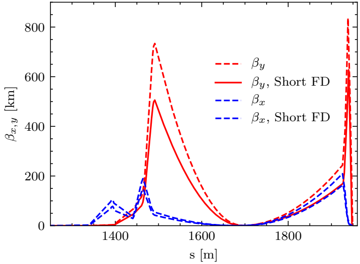
## Summary

- The FD was shortened (**QF1** and **QD0**) by the factor of 2.
- The optics with short FD was matched.
- A new optics with a different dispersion profile in the FFS was investigated. It offers a 5 % larger total and peak luminosities compared to the other optics with $\beta_y^* = 70\ \mu$m.
- The collimation depth of $15\sigma_x \times 55\sigma_y$ was verified.
- The aperture for CLIC 380 GeV is estimated.

**Thank you very much for your attention!**

# Beta comparison

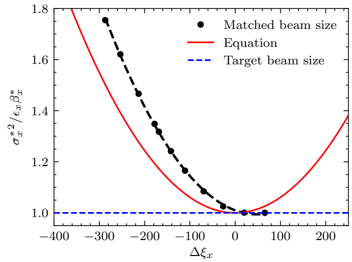
Beta functions $\beta_x$ and $\beta_y$ along the FFS for the design with short FD (solid line) and for the previous design of $\beta_y^* = 70\mu$m (dashed line).



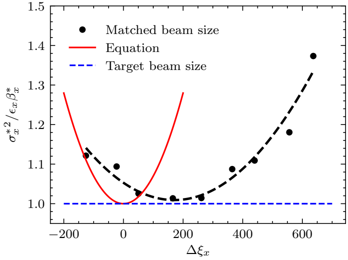
# Upstream chromaticity scan:

Horizontal beam size at the IP is a function of the chromaticity difference $\xi^*_{x,diff}$:

$$\sigma_x^2 \sim {\xi^*_{x,diff}}^2$$



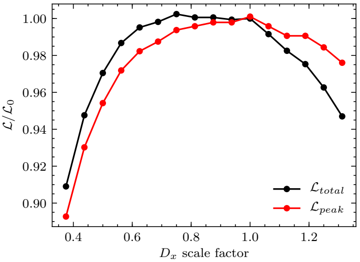

Short FD optics.



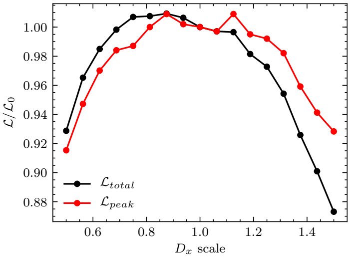

Short FD optics with alternative $D_x$ profile.

# Scans of the dispersion level

**Short FD.:**




**Short FD + alternative $D_x$**




No change is neeeded

Dispersion is reduced by 12.5 %

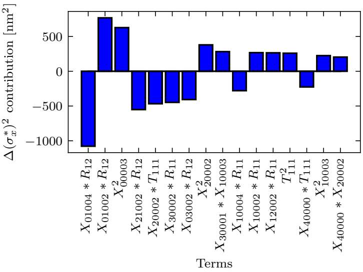
# Beam size contributions, alternative dispersion profile

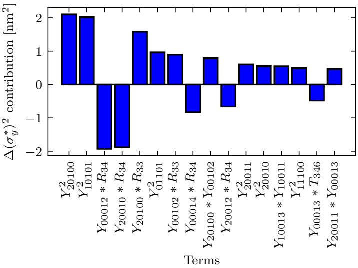
## Beam size contributions:

$$\sigma^{*\,2}_{x,y} = \sum_{\substack{jklmn \\ j'k'l'm'n'}} X(Y)_{jklmn} X(Y)_{j'k'l'm'n'}$$

$$\times \int {x_0}^{j+j'} {x'_0}^{k+k'} {y_0}^{l+l'} {y'_0}^{m+m'} {\delta_0}^{n+n'} \rho_0 dv_0 \ .$$

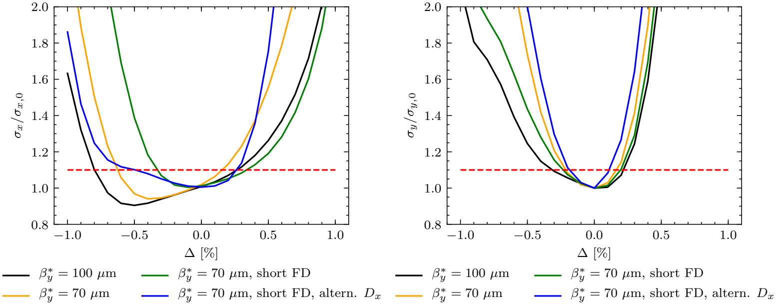
**Contributions to $\sigma_x^{*2}$ and $\sigma_x^{*2}$ before the optimization:**



# Energy bandwidth

The momentum bandwidth is defined as the width of the region where the beam size does not grow more than 10 %, compared to the on-momentum beam size.




The red dashed line correspond to 10 % beam size increase.