CLIC 380 GeV FFS optimization

LCWS 2021

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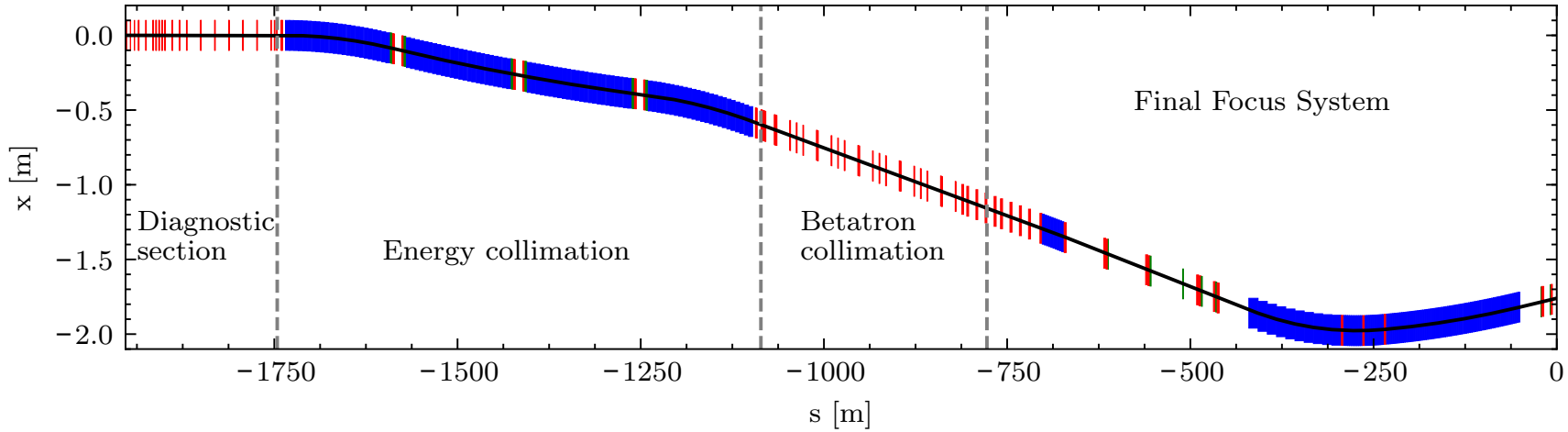
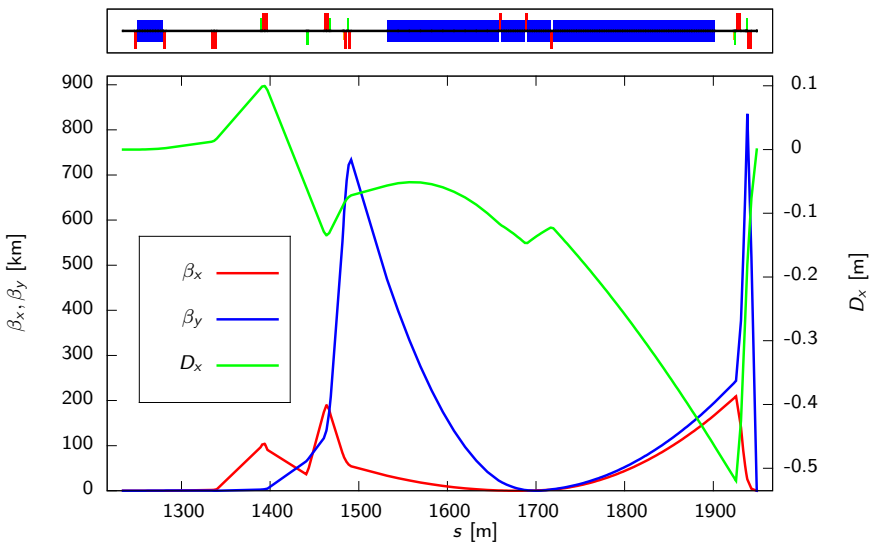
Outline

Beam Delivery System of CLIC@380 GeV:



FFS optics[1]:

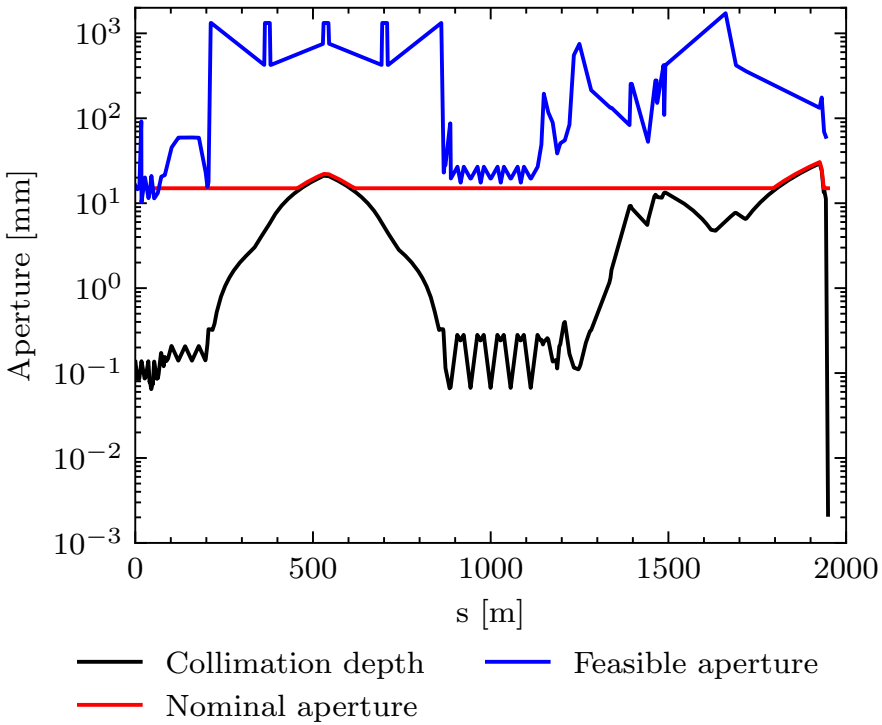


FFS length [m]	770
L^* [m]	6
$\epsilon_{n,x}/\epsilon_{n,y}$ [nm]	950/30
β_x^*/β_y^* [mm]/[μm]	8/70
σ_x^*/σ_y^* [nm]	145/2.9
σ_z [μm]	70
δ_p [%] (Uniform distr.)	1.0
L [10^{34}cm^{-2}s^{-1}]	1.66
$L_{1\%}$ [10^{34}cm^{-2}s^{-1}]	0.96

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

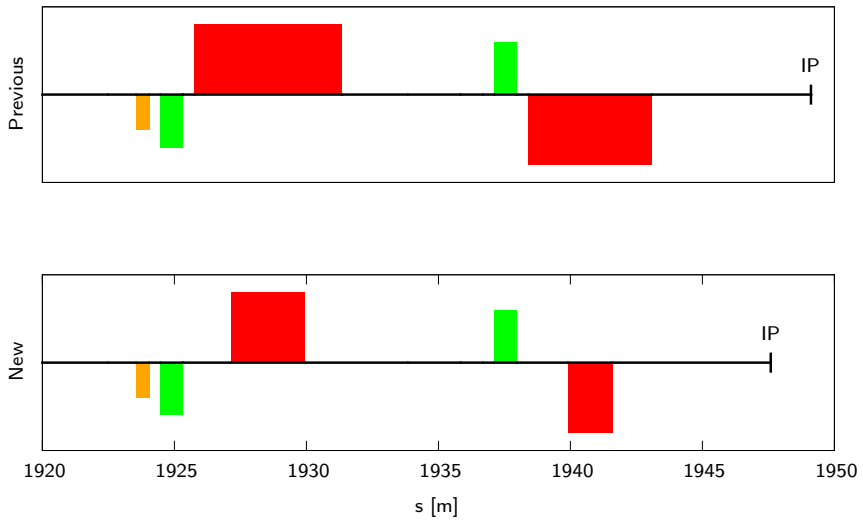
Short FD

Aperture distribution along the BDS:



- The nominal apertures is based on the collimation depth of $15\sigma_x \quad 55\sigma_y$[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.

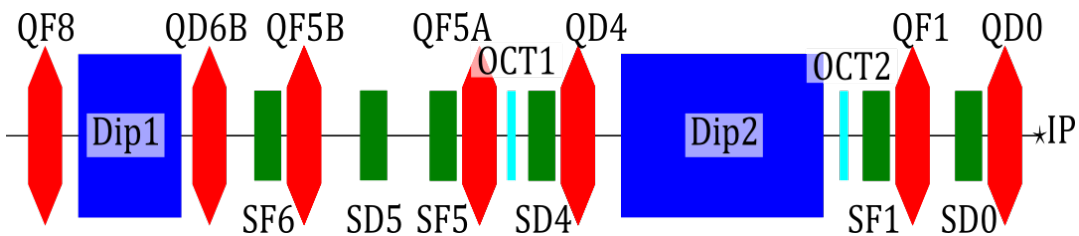
[2] J. Resta-Lopez et. al., "Status report of the baseline collimation system of CLIC", CLIC–Note 883

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 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. Further optimizations aimed to optimize the beam size/luminosity.

Final Focus System scheme



FFS optics with the short FD

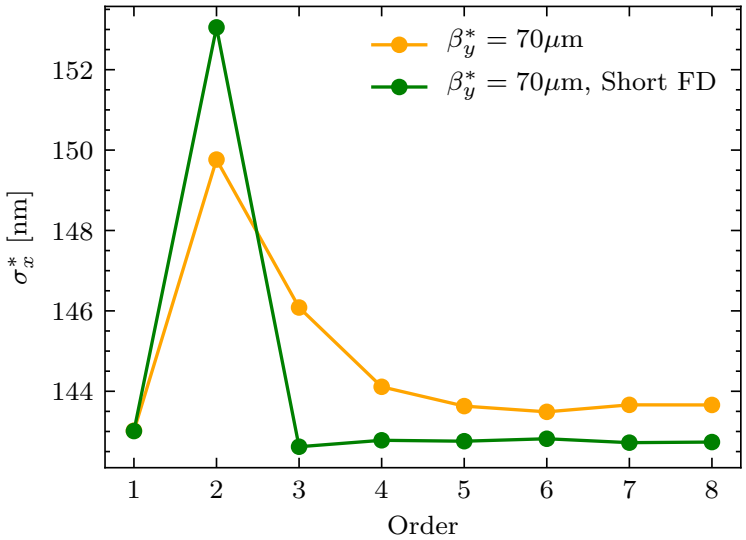
- Optimal upstream chromaticity is found by scanning the length between the FD and upstream elements.
- **Beam size** matched with the sextupoles at 5^{th} order:

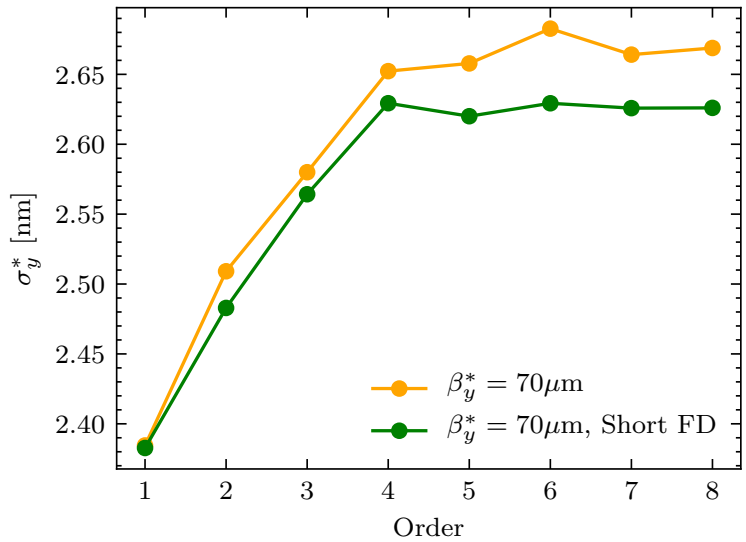
	MAPCLASS	PLACET w/ SR
σ_x^* [nm]	142.74	144.72
σ_y^* [nm]	2.63	2.71

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

- **Luminosity:**
  PLACET and Guniea-Pig:
  $L = 1.66 \quad 10^{34}cm^{-2}s^{-1}$
  $L_{1\%} = 0.96 \quad 10^{34}cm^{-2}s^{-1}$
- **Dispersion profile scan:**
  No change needed. The dipole angles are iterated in the range 0.37 - 1.31 % with a step 6%.

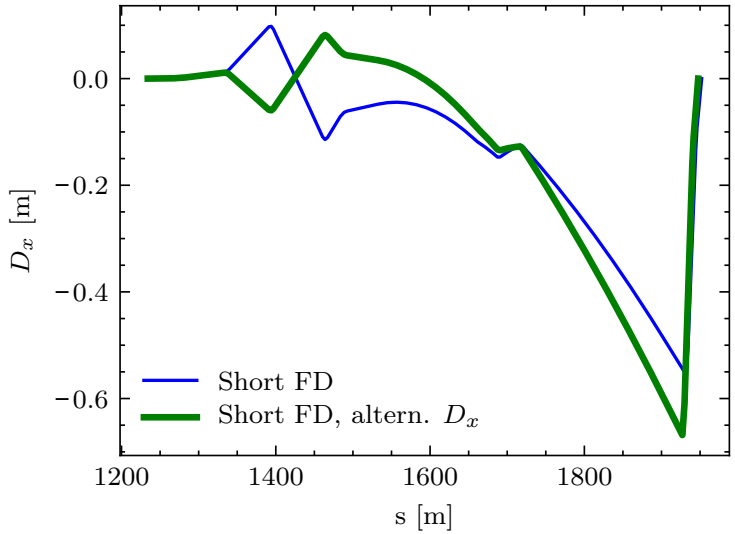
Beam size at the IP:



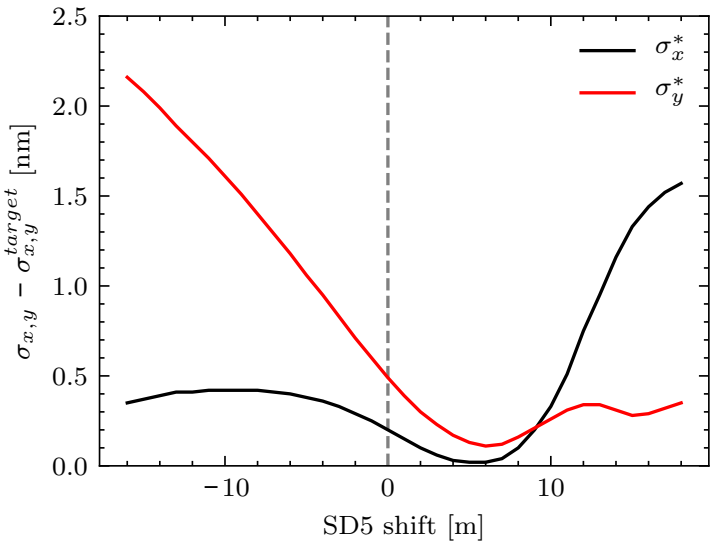


FFS optics with short FD + different dispersion

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



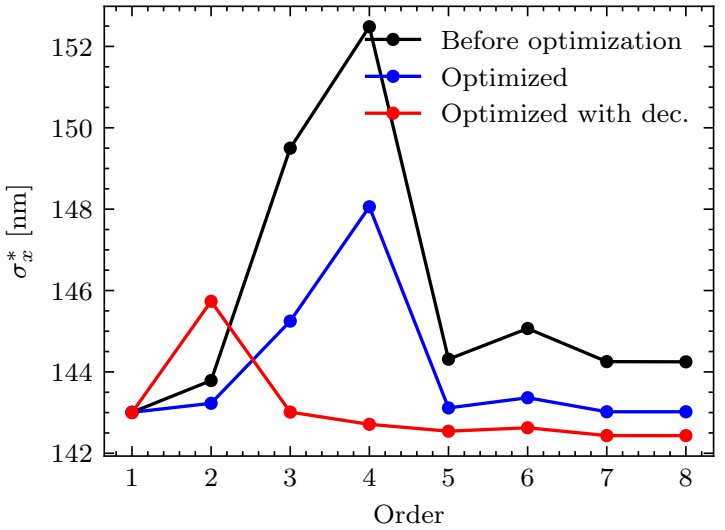
Horizontal and vertical beam size vs shift of SD5 sextupole.

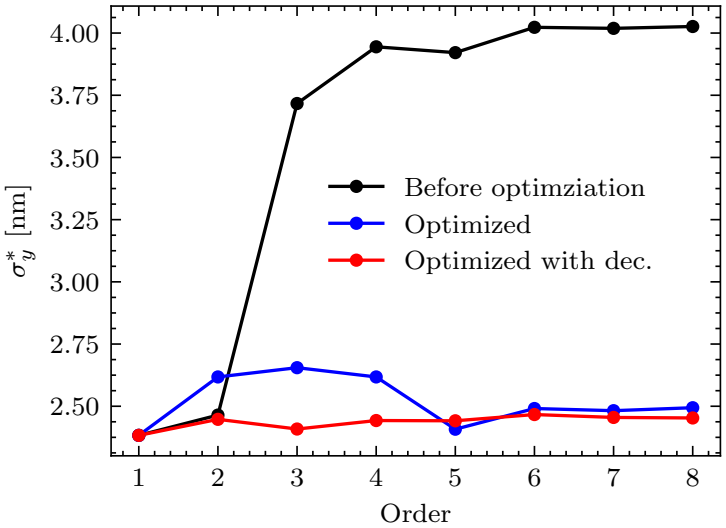
FFS optics with short FD + alternative dispersion profile

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

	MAPCLASS	PLACET w/ SR
σ_x^* [nm]	142.97	145.62
σ_y^* [nm]	2.52	2.87

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





Optics comparison

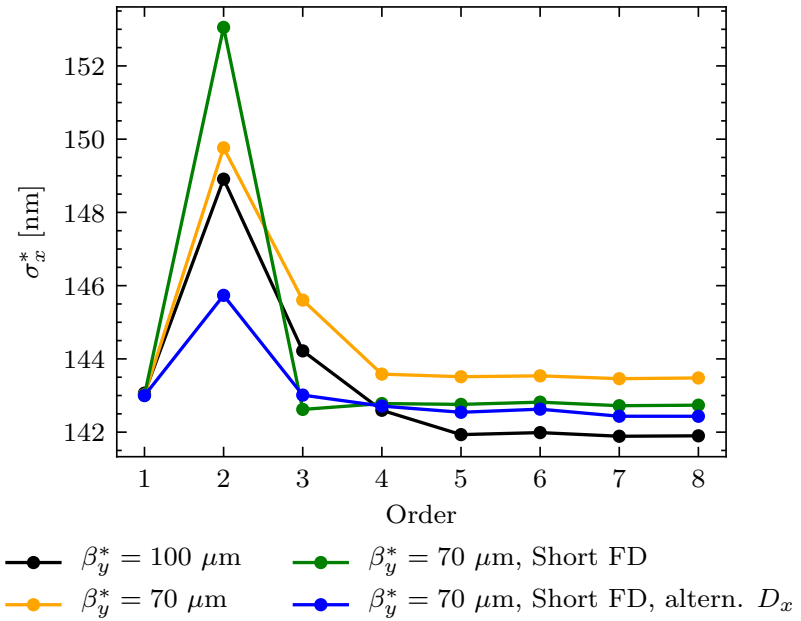
Mapclass (8^{th} order map):

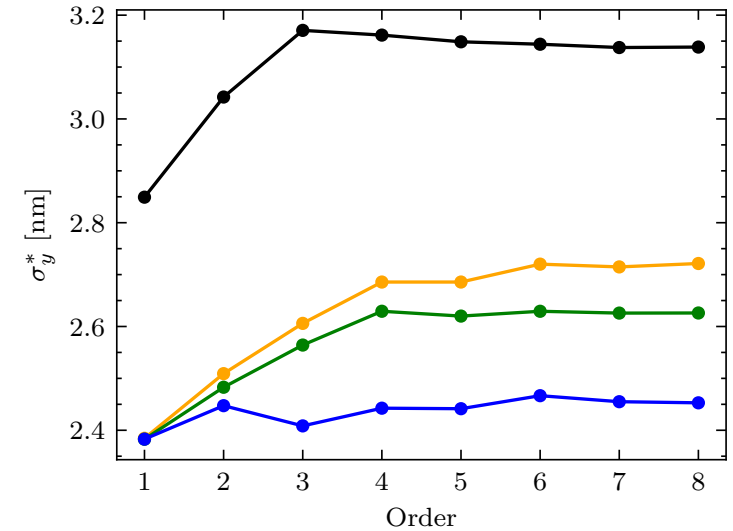
Optics	σ_x^* [nm]	σ_y^* [nm]
$\beta_y^* = 100\mu$m	141.90	3.14
$\beta_y^* = 70\mu$m	143.48	2.72
$\beta_y^* = 70\mu$m, Short FD	142.74	2.63
$\beta_y^* = 70\mu$m, Short FD + D_x mod.	142.43	2.45

PLACET (w/ SR):

Optics	σ_x^* [nm]	σ_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

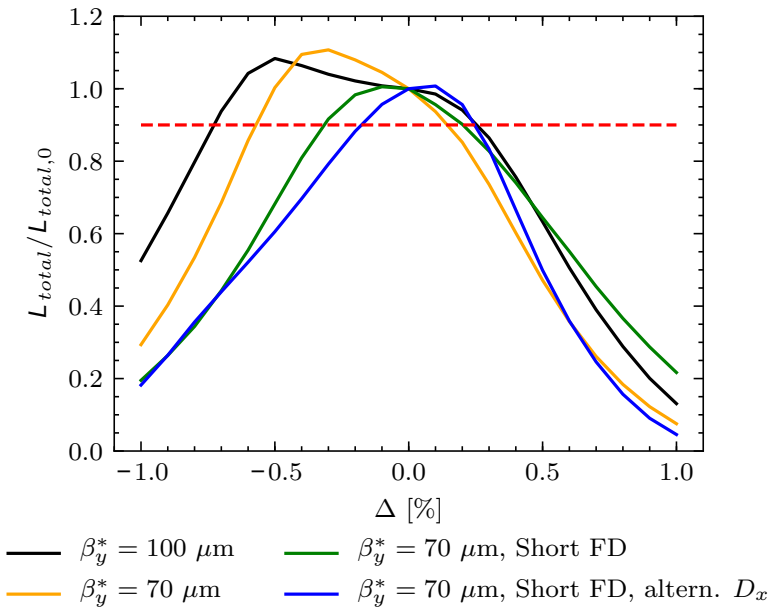
- **Luminosity:**($10^{34}\text{cm}^{-2}\text{s}^{-1}$)

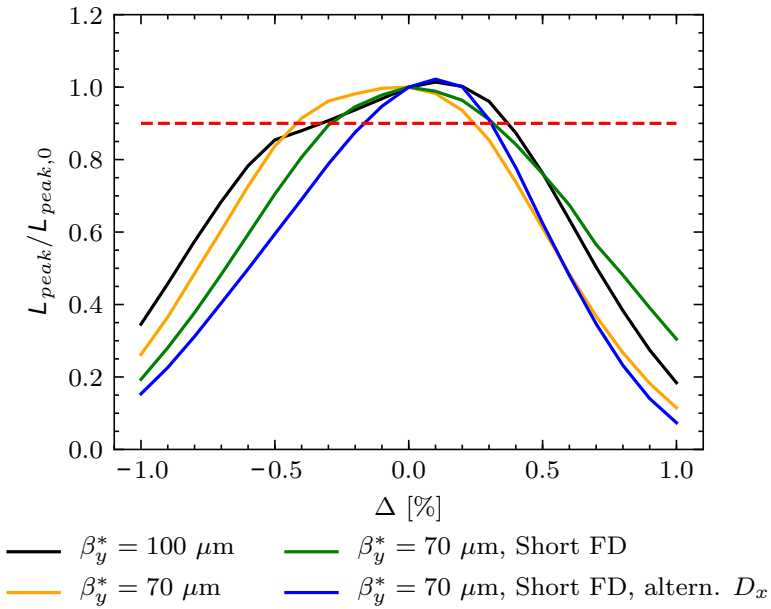
Optics	L	$L_{1\%}$
$\beta_y^* = 100\mu$m	1.63	0.93
$\beta_y^* = 70\mu$m	1.66	0.96
$\beta_y^* = 70\mu$m, Short FD	**1.66**	**0.96**
$\beta_y^* = 70\mu$m, Short FD + D_x mod.	**1.74**	**1.01**

- **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

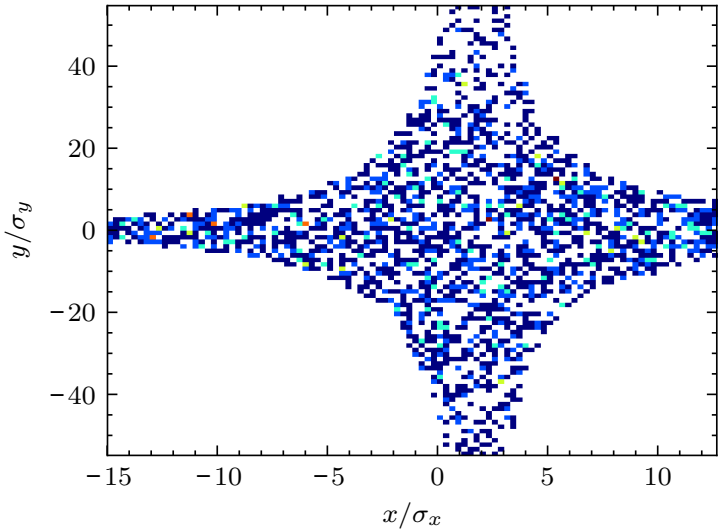
Luminosity bandwidth:



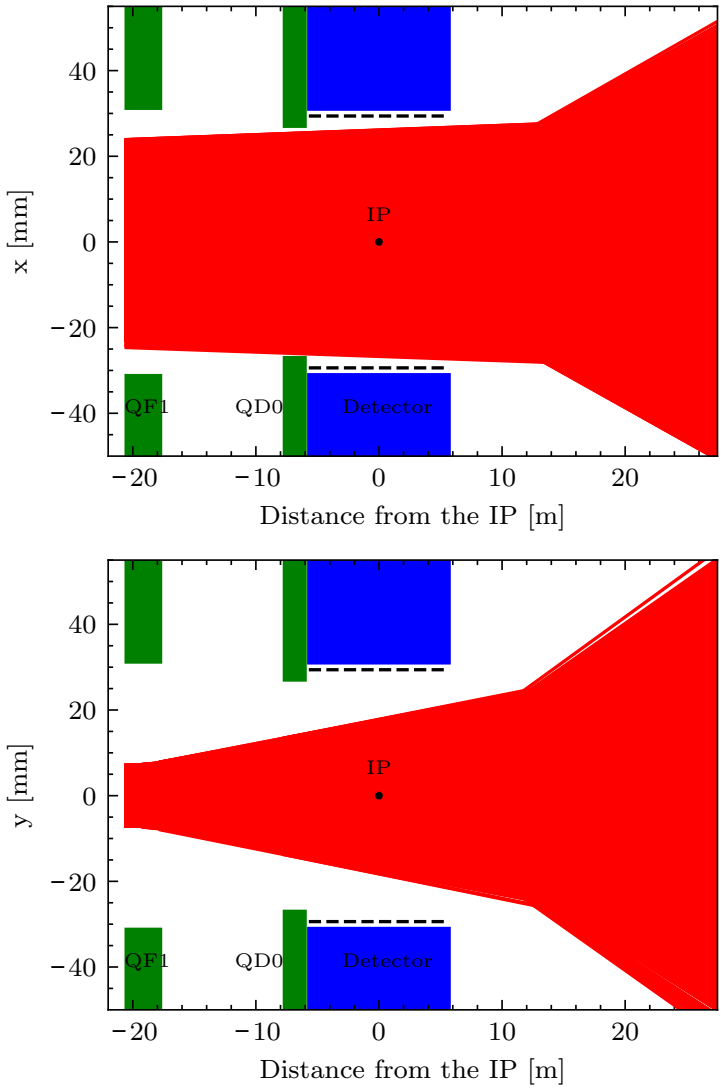


Collimation depth

- 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:

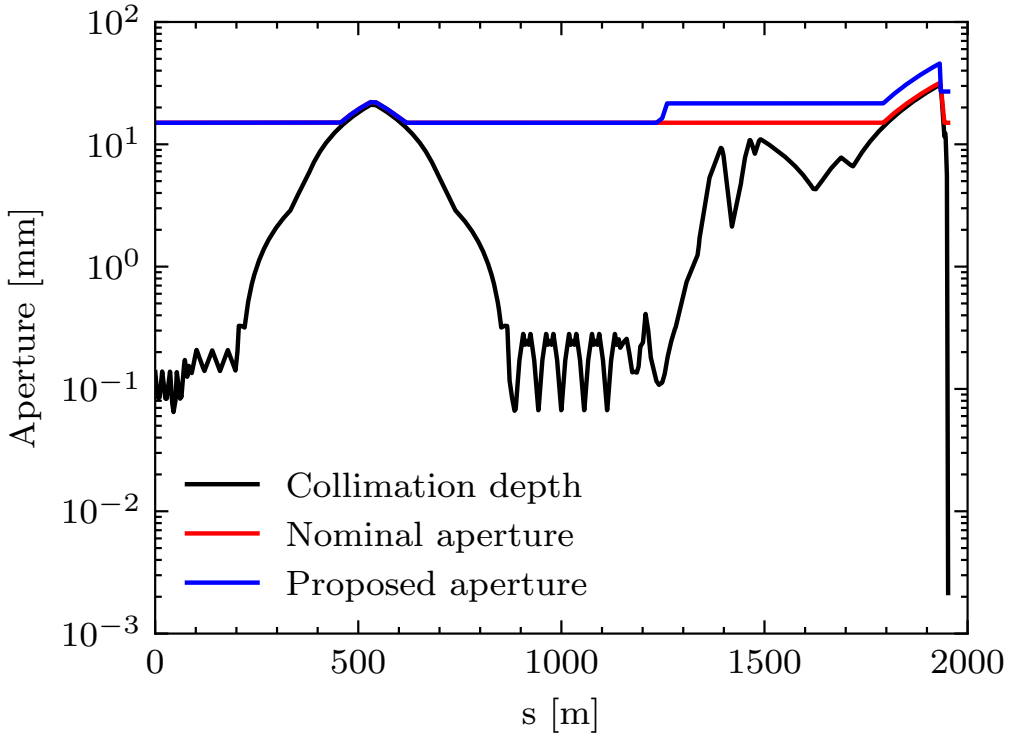


	QF1	QD0
Gradient [T/m]	16.3	73.7
Aperture [mm]	31.2	27.0
Pole tip field [T]	0.51	1.99



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

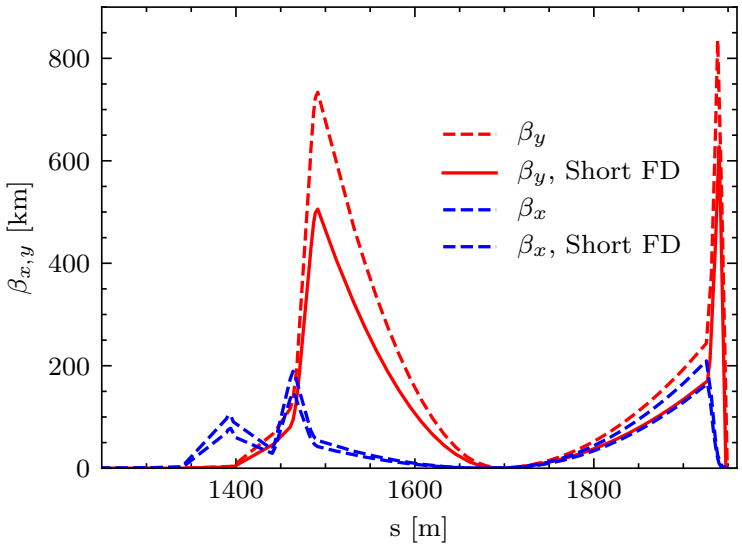
Summary

- 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 $\beta_y^* = 70$ μm.
- The collimation depth of $15\sigma_x$ $55\sigma_y$ was verified.
- The aperture for CLIC 380 GeV is estimated.

Thank you very much for your attention!

Beta comparison

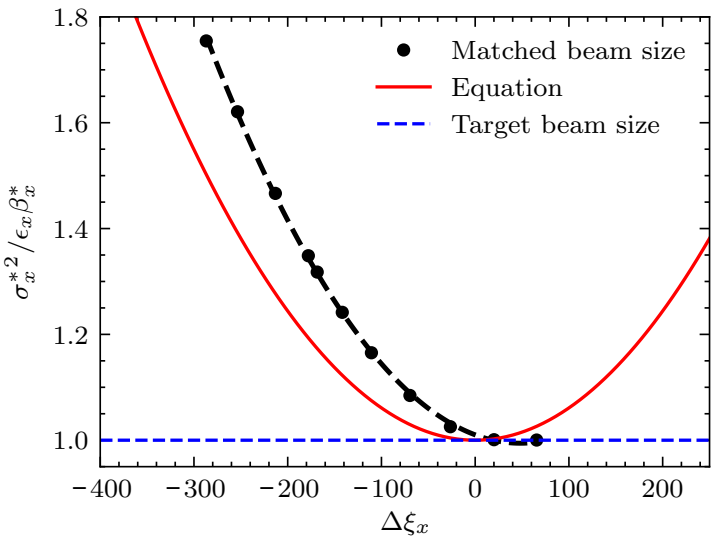
Beta functions β_x and β_y along the FFS for the design with short FD (solid line) and for the previous design of $\beta_y^* = 70\mu$m (dashed line).



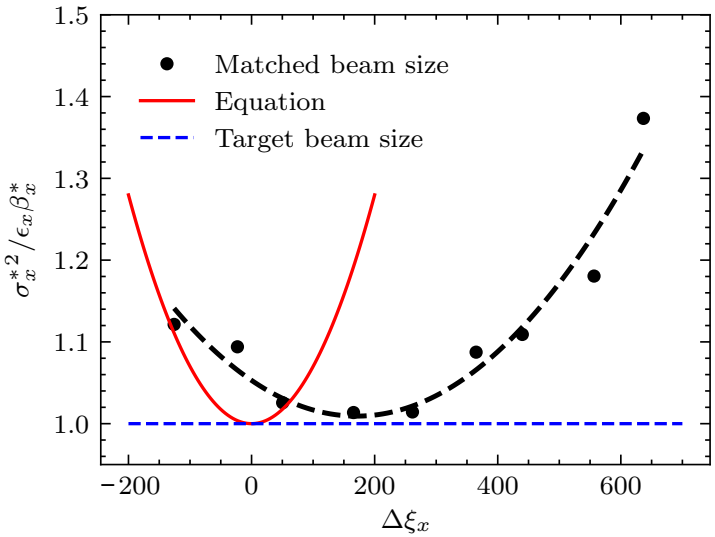
Upstream chromaticity scan:

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

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



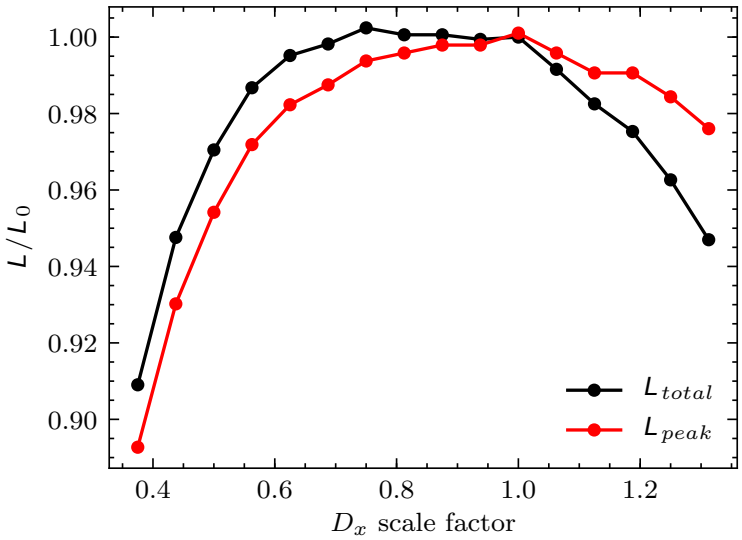
Short FD optics.



Short FD optics with alternative D_x profile.

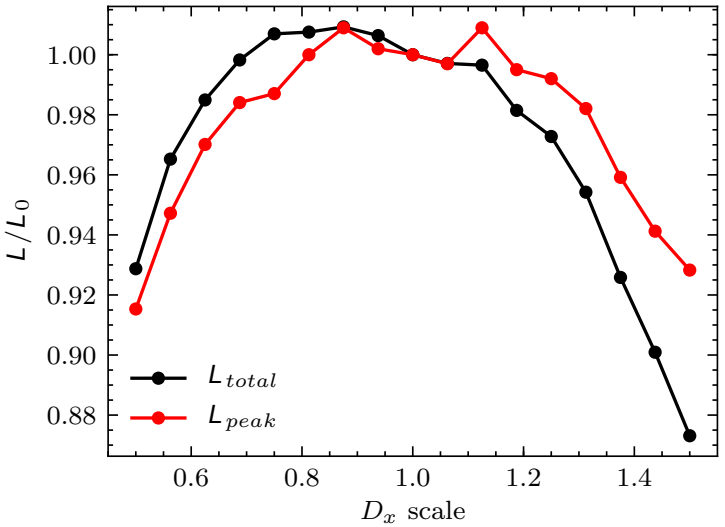
Scans of the dispersion level

Short FD.:



No change is neeeded

Short FD + alternative D_x



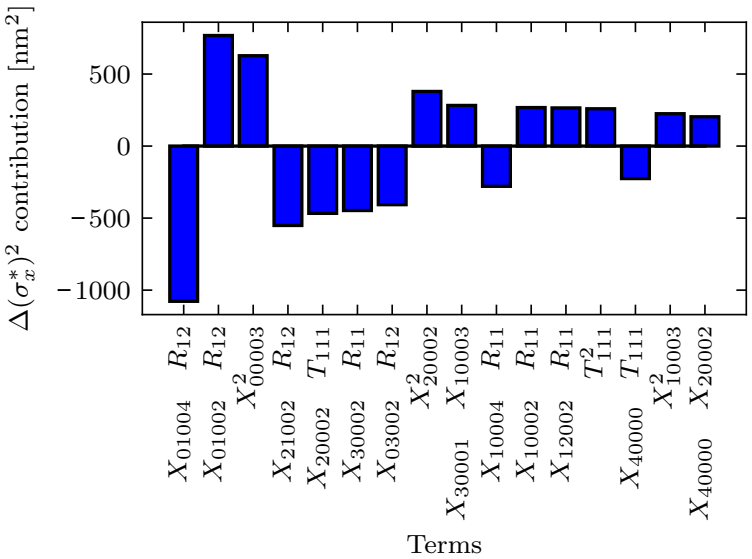
Dispersion is reduced by 12.5 %

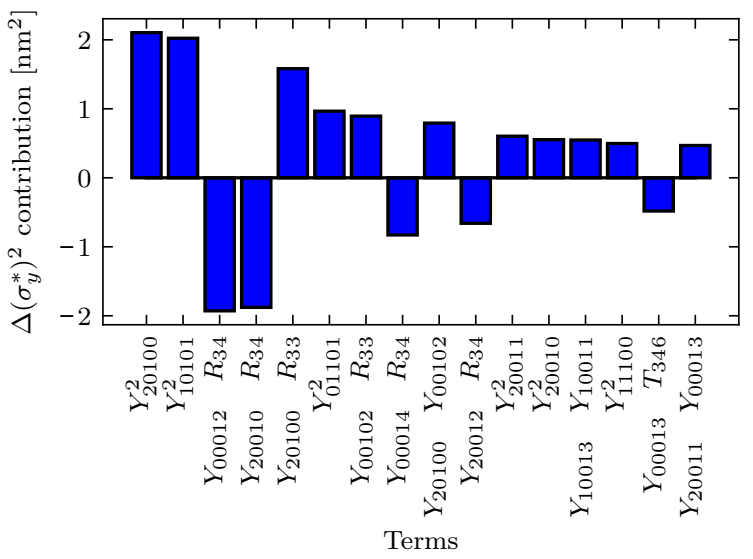
Beam size contributions, alternative dispersion profile

Beam size contributions:

$$\sigma_{x,y}^{*\,2} = \sum_{\substack{jklmn \\ j'k'l'm'n'}} X(Y)_{jklmn} X(Y)_{j'k'l'm'n'} \int x_0^{j+j'} x_0'^{k+k'} y_0^{l+l'} y_0'^{m+m'} \delta_0^{n+n'} \rho_0 \, dv_0 \ .$$

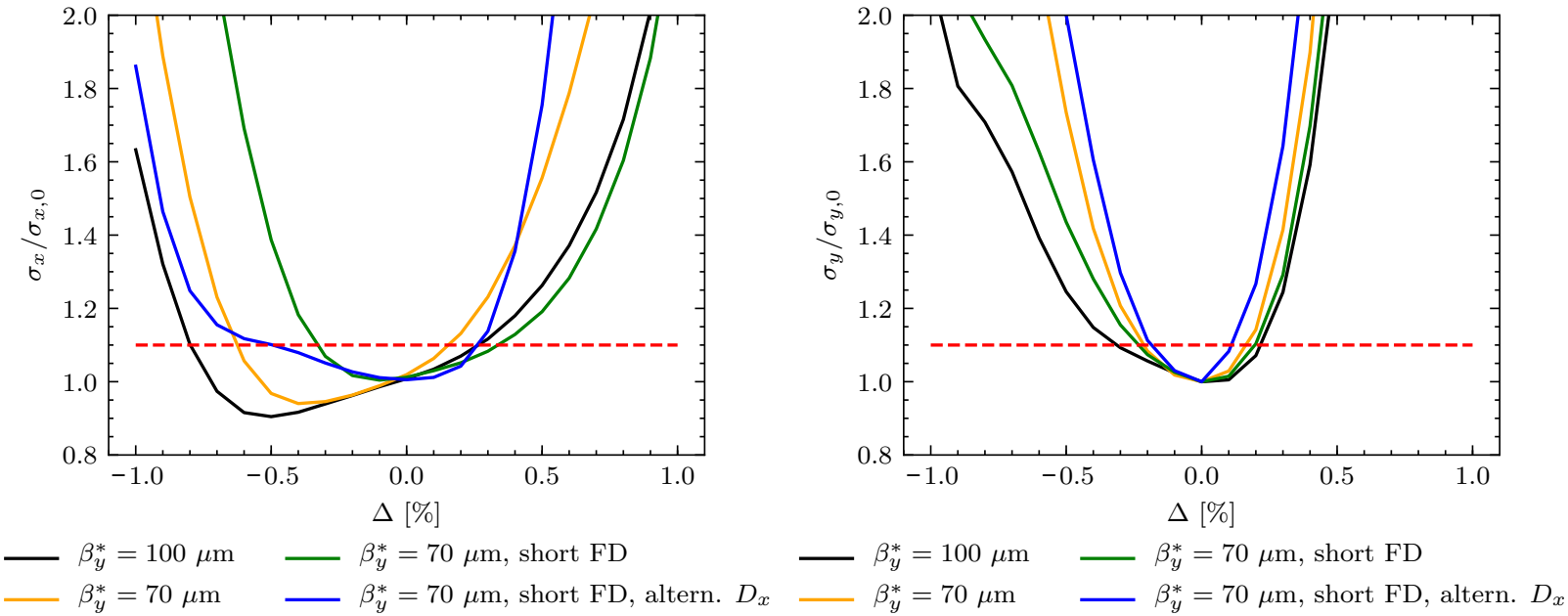
Contributions to $\sigma_x^{*\,2}$ and $\sigma_x^{*\,2}$ before the optimization:





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.