Optimizing CLIC 380 GeV FFS with $L^* = 6$ m

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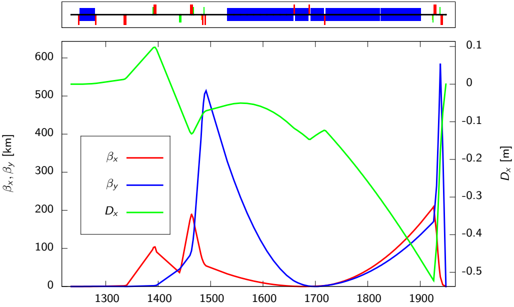
Outline

1. CLIC 380 GeV FFS, $\beta_y^* = 100\ \mu$m
   - Main parameters
   - Apertures and pole tip fields
2. CLIC 380 GeV FFS, $\beta_y^* = 70\ \mu$m
   - Optics matching
   - Luminosity
   - Energy bandwidth
3. Summary and conclusions

FFS nominal optics for $L^* = 6$ m.

The FFS optics with $L^* = 6$ is considered the best choice for CLIC ⇒ **QD0** is entirely outside the detector acceptance.



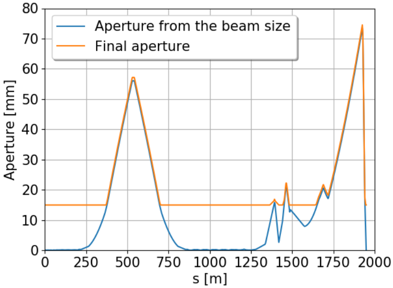
FFS length [m]	770
$\epsilon_{n,x}/\epsilon_{n,y}$ [nm]	950/30
β_x^*/β_y^* [mm]/[μm]	8/100
σ_x^*/σ_y^* [nm]	145/2.9
σ_z [μm]	70
δ_p [%]	0.35
$\mathcal{L}$ [10^{34}cm^{-2}s^{-1}]	1.5
$\mathcal{L}_{1\%}$ [10^{34}cm^{-2}s^{-1}]	0.9

BDS apertures and pole tip fields

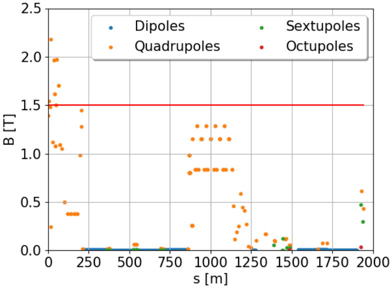
- Minimum required aperture is **15 mm**.
- Beam size calculated as:

$$\sigma_{x,y} = \sqrt{\epsilon_{x,y}\beta_{x,y} + (D_{x,y}\delta)^2}.$$

Aperture along the BDS.



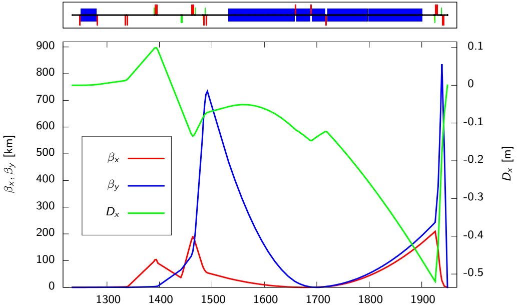
Magnets pole tip field



Some magnets should be **redesigned** to tolerate the magnetic field requirements.

FFS optics with $\beta_y^* = 70\ \mu$m

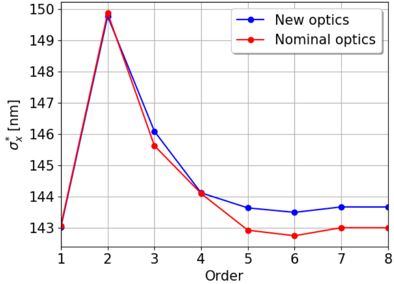
The IP vertical beta function β_y^* was reduced to **70 μm**.

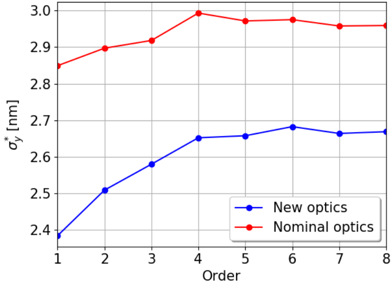


	β_x^* [mm]	β_y^* [μm]	D_x^* [m]	α_x^*	α_y^*
Nominal	8.0	100.0	0.0	-0.005	-0.021
Reduced β_y^*	8.0	70.0	0.0	0.0	0.0

Nonlinear matching

- The beam size at the IP was matched as much as possible to the linear value with MadX-PTC and MAPCLASS.
- The obtained optics is then tested with PLACET.

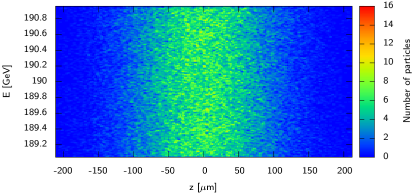




	σ_x^* [nm]	σ_y^* [nm]	Oide effect [nm]
MAPCLASS	143.66	2.67	0.21
Placet without SR	143.27	2.74	
Placet with SR	**145.76**	**2.75**	

Luminosity calculation

- The beam is tracked through the BDS with PLACET up to the IP.
- Beam distribution at the IP is used as an input for Guinea-Pig.



- Transverse Gaussian beam.
- 1% energy flat distribution in longitudinal plane.

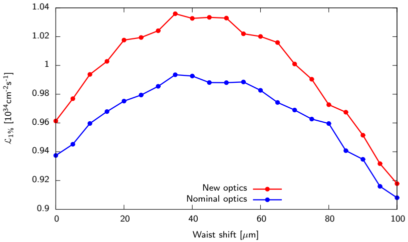
	$\mathcal{L}_{total}$ [10^{34}cm^{-2}s^{-1}]	$\mathcal{L}_{1\%}$ [10^{34}cm^{-2}s^{-1}]
Nominal optics	1.63	0.94
Reduced β_y^*	1.66	0.96

Beam-beam forces greatly affect the final luminosity - the highest luminosity is obtained **off waist**.

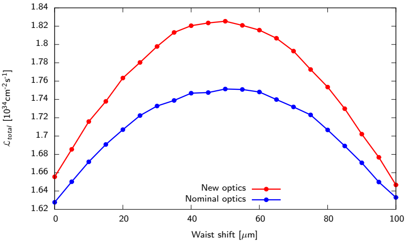
Luminosity - Waist location scan

- Due to the **pinch effect** the beams are focused upstream of the IP.
- The waist location is scanned for larger luminosity

Peak luminosity



Total luminosity

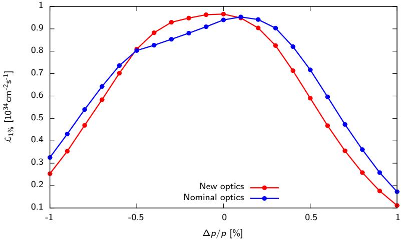


	$\mathcal{L}_{total}$ [10^{34}cm^{-2}s^{-1}]	$\mathcal{L}_{1\%}$ [10^{34}cm^{-2}s^{-1}]
Nominal optics at optimal waist	1.75	0.99
Reduced β_y^* at optimal waist	**1.83** (+4.5%)	**1.03** (+4%)

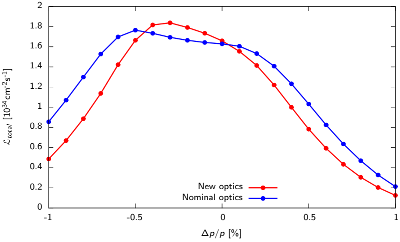
Energy bandwidth

- Energy bandwidth describes how the luminosity changes when the beam has an energy offset.
- The beam energy offset was iterated in the range $\frac{\Delta p}{p} \in [-1\%, 1\%]$.
- Obtained bandwidth is smaller for the new optics.

Peak luminosity



Total luminosity



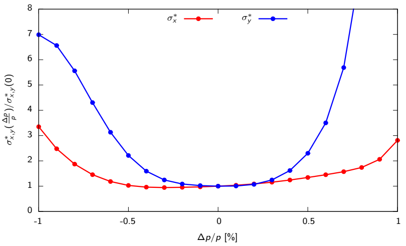
Energy bandwidth

- Geometrical luminosity depends on the beam size:

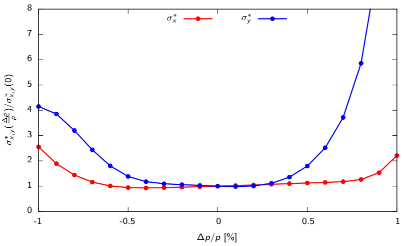
$$\mathcal{L}_0 = \frac{N^2 f N_b}{4\pi\sigma_x^*\sigma_y^*}.$$

- IP beam size dependence on the momentum offset is analyzed.

New optics



Nominal optics



Summary and conclusions

Summary

- Nominal optics of the FFS was examined for possible improvements.
- IP vertical beta function was decreased to 70 μm and matched to mitigate nonlinear beam size contributions.
- New optics design was examined for luminosity and energy bandwidth.

Conclusions

- Magnets in the FD should be redesigned.
- New optics should be optimized in terms of energy bandwidth.

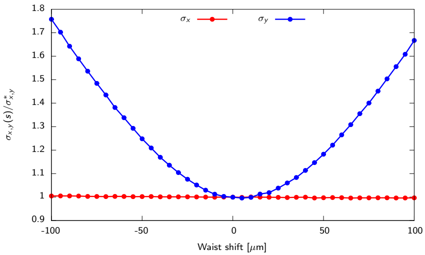
Thank you very much for your attention!

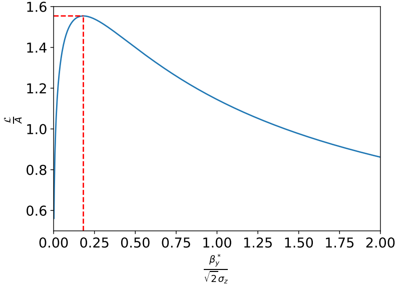
Back up slides

Hourglass effect

The **Hourglass effect** - the bunch particles interact with each other with different transverse beam size which changes significantly within the bunch.

Hourglass effect for the optics with $\beta_y^* = \sigma_z = 70\ \mu$m.





Luminosity reduction due to the Hourglass effect:

$$\mathcal{L} = \mathcal{L}_0 H_D = \mathcal{L}_0 \sqrt{\frac{2}{\pi}} a e^{a^2} K_0(a^2),$$

$a = \frac{\beta_y^*}{\sqrt{2}\sigma_z}$; K_0 is modified Bessel function.

Beta function dependence on momentum offset