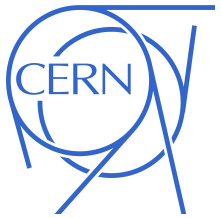


Crystal Focusing for FFS

Vera Cilento and Rogelio Tomás

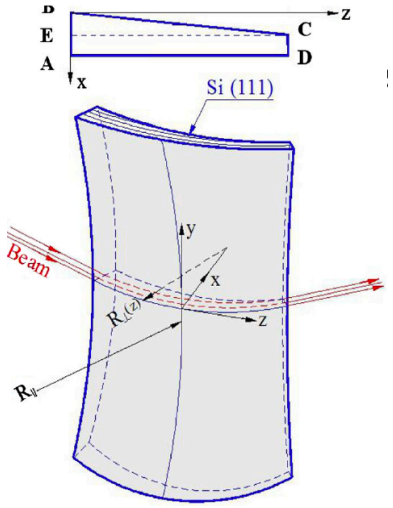
Outline

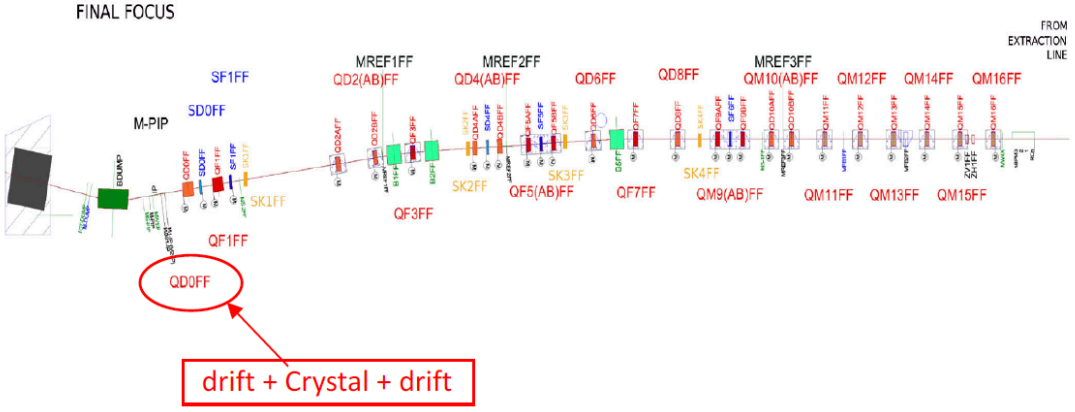
- Introduction
- Implementation of the Crystal in MAD-X
- Simulation studies
  - Impact on the beta function and on the horizontal dispersion
  - Impact on the natural chromaticity
  - Impact on the beam size
  - Impact on the luminosity for CLIC 1.5 TeV
- Conclusions

Introduction

- Two different cases have been studied in simulation:

  1. Lattice with QD0 from MAD-X of ATF2 → ultra-low β_y^* optics
  2. Development of a new lattice which includes the Si crystal → QD0 has been replaced by the crystal and 2 drifts





Introduction

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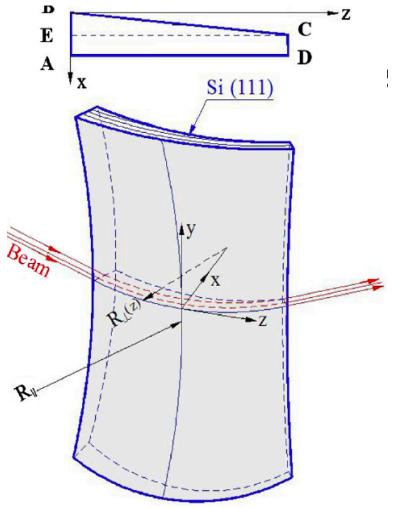
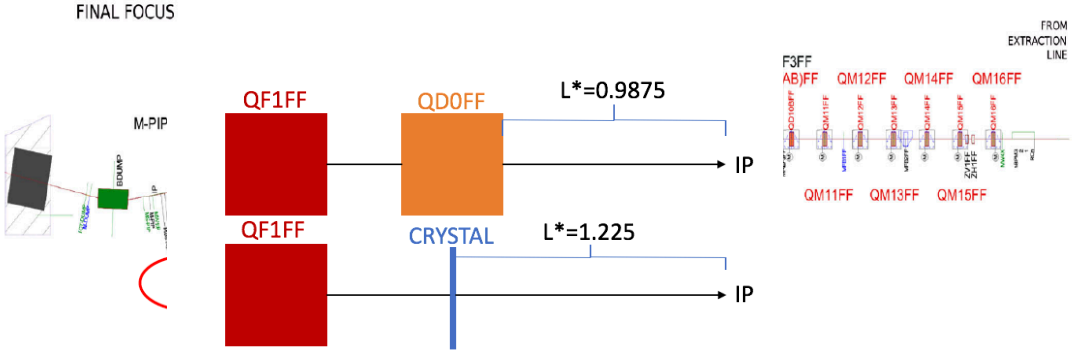
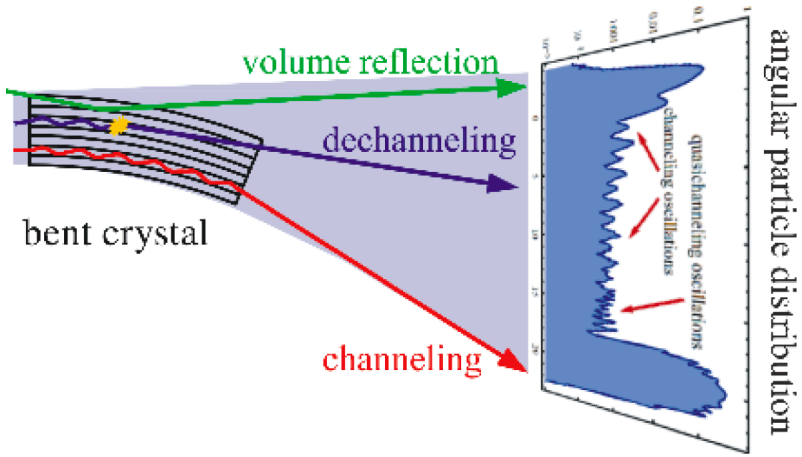


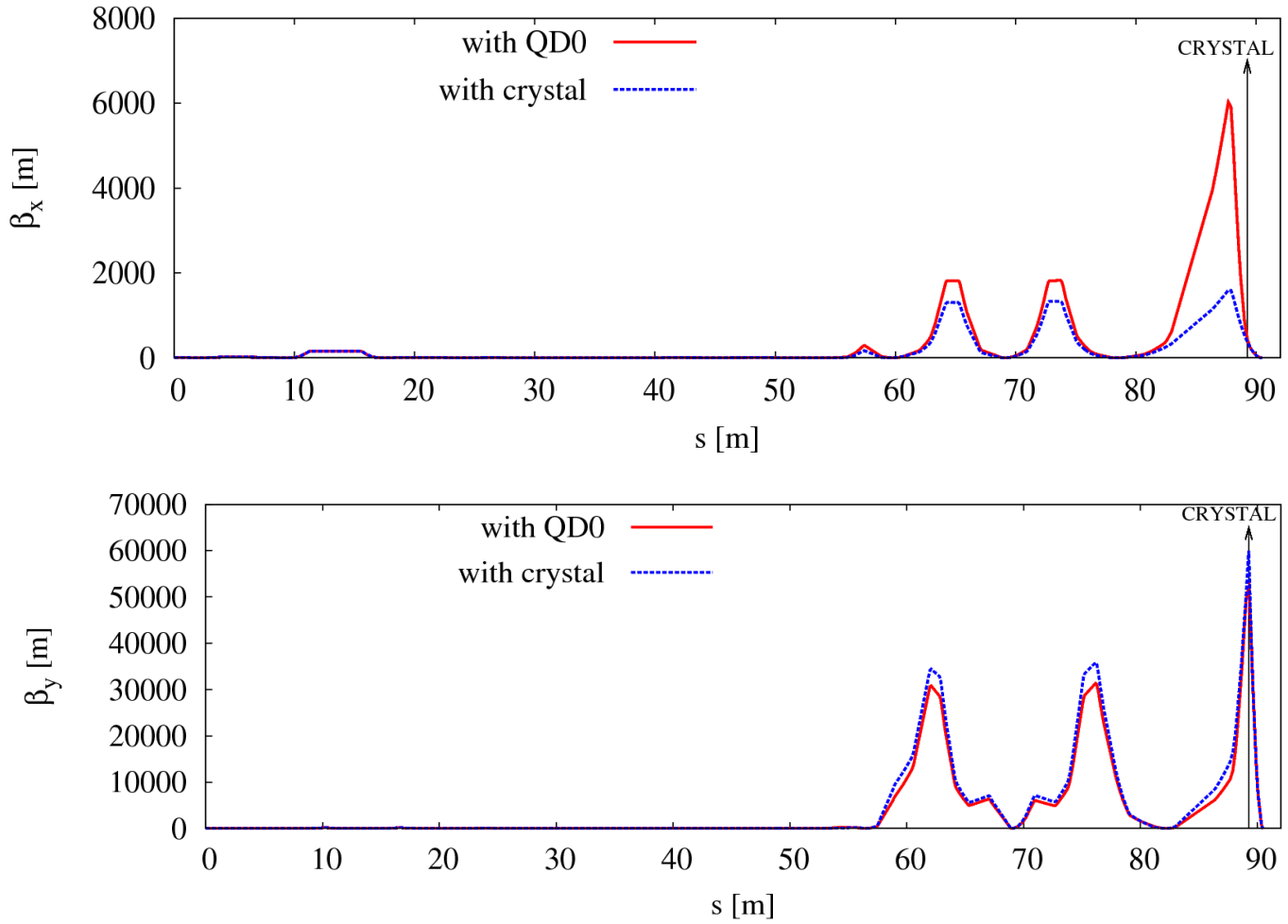


Implementation of the crystal in MAD-X

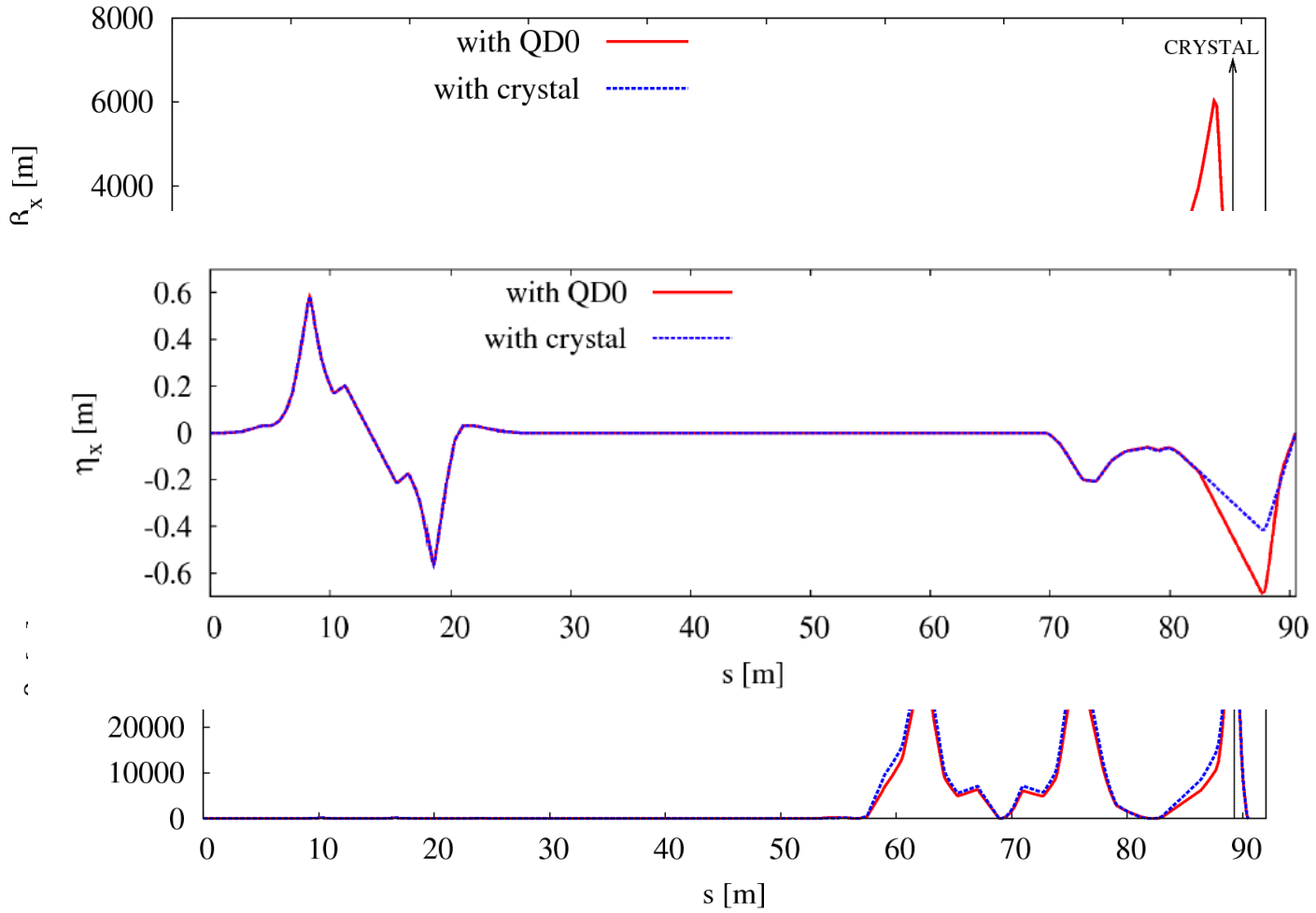
- Approximation of the crystal with a thin matrix element that only focuses in the vertical plane
- The crystal does not act in the horizontal plane
- Neglect of the bending of the beam by the crystal in the vertical direction
- Neglect of the volume reflection
- The chromatic aberration can be neglected due to the achromatic property of the crystal
- Neglect the fact that the particles inside a channel are not focused and the channel beam size grows with the divergence of the beam



Impact on the beta function and on the horizontal dispersion



Impact on the beta function and on the horizontal dispersion



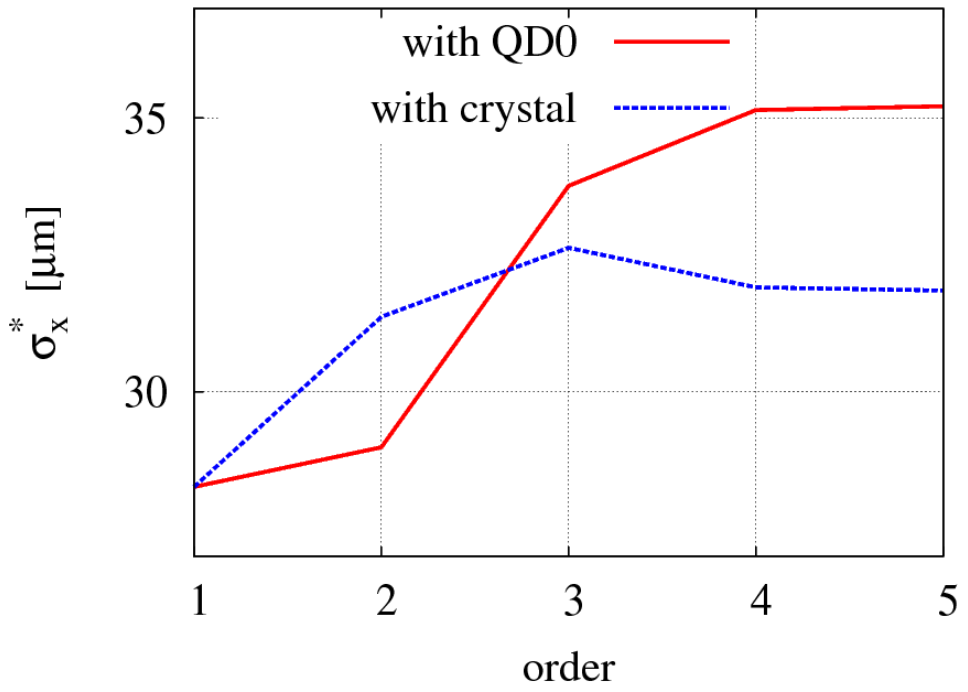
Impact on the natural chromaticity

- Sextupoles are switched off in order to get the natural chromaticity of quadrupoles that is expressed as:
  - $\xi_x^2 = X_{x,10001} X_{x,10001} \frac{\beta_{yo}}{\beta_y^*} + X_{x,01001} X_{x,01001} \frac{1}{\beta_{y0} \beta_y^*}$
  - $\xi_y^2 = X_{y,00101} X_{y,00101} \frac{\beta_{yo}}{\beta_y^*} + X_{y,00011} X_{y,00011} \frac{1}{\beta_{y0} \beta_y^*}$

- Visible impact on the chromaticity in both planes
  - Strong reduction of the chromaticity when including the Crystal → we replace a quadrupole with an achromatic element

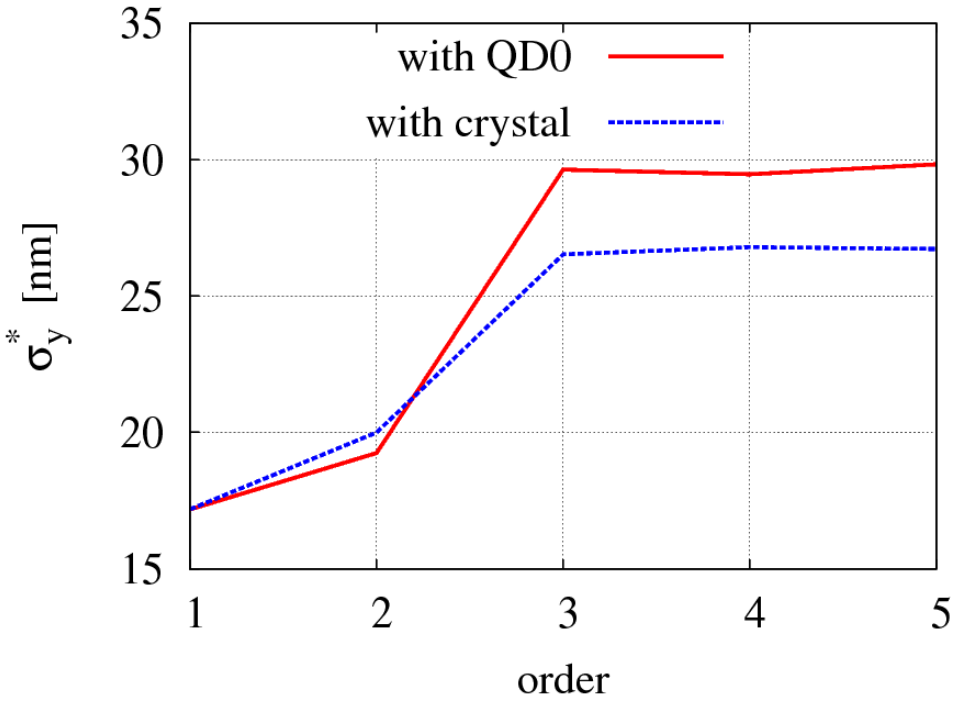
	QD0FF	Crystal
ξ_x	5868	2639
ξ_y	87888	56734

Impact on the beam size

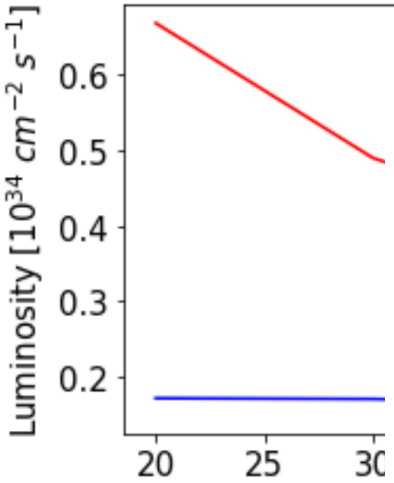


- With Crystal beam size reached:
  - σ_x^*= 3.18 μm
  - σ_y^*= 26.7 nm

- With QDO beam size reached:
  - σ_x^*= 3.52 μm
  - σ_y^*= 29.8 nm



Impact on the Luminosity for CLIC 1.5 TeV



Can electron beams be really focused by bent crystals?

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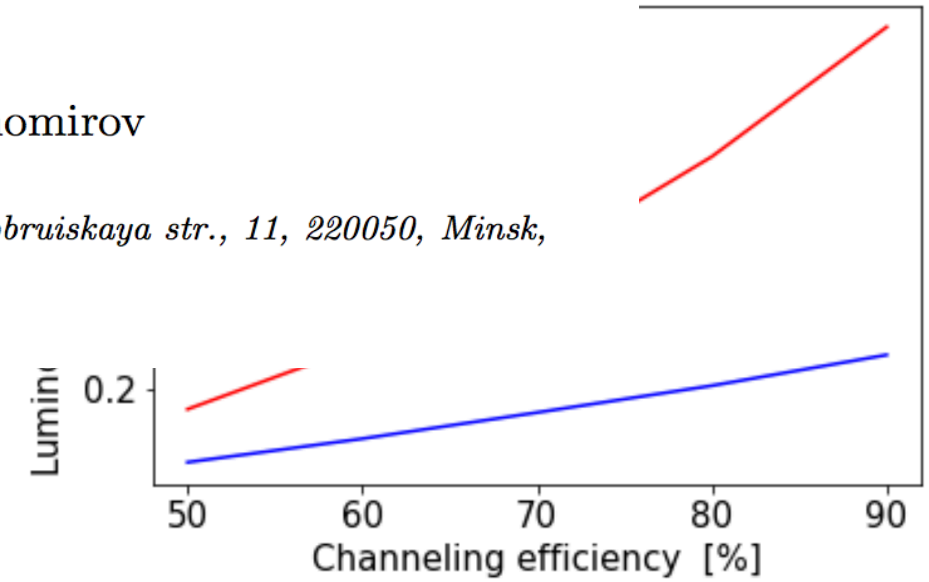
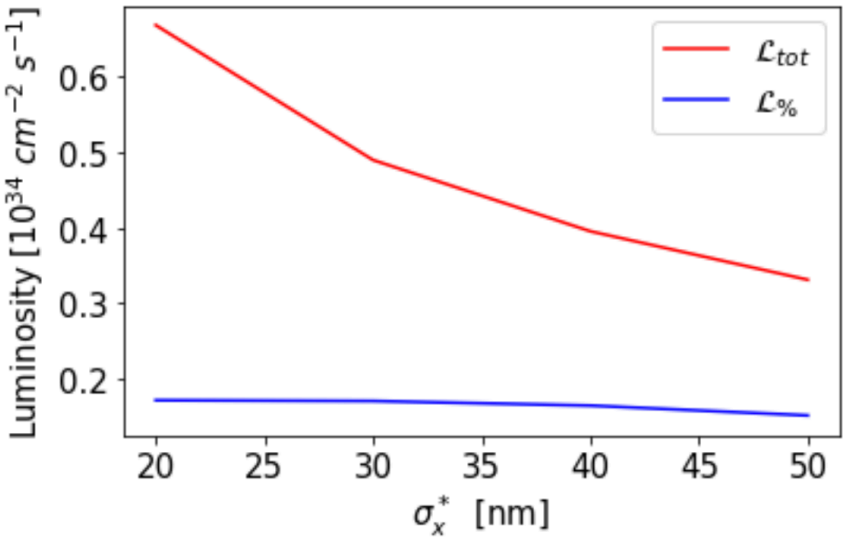
1 TeV e^-	1 TeV e^+
50	20-50
15	1
0-70	70-90

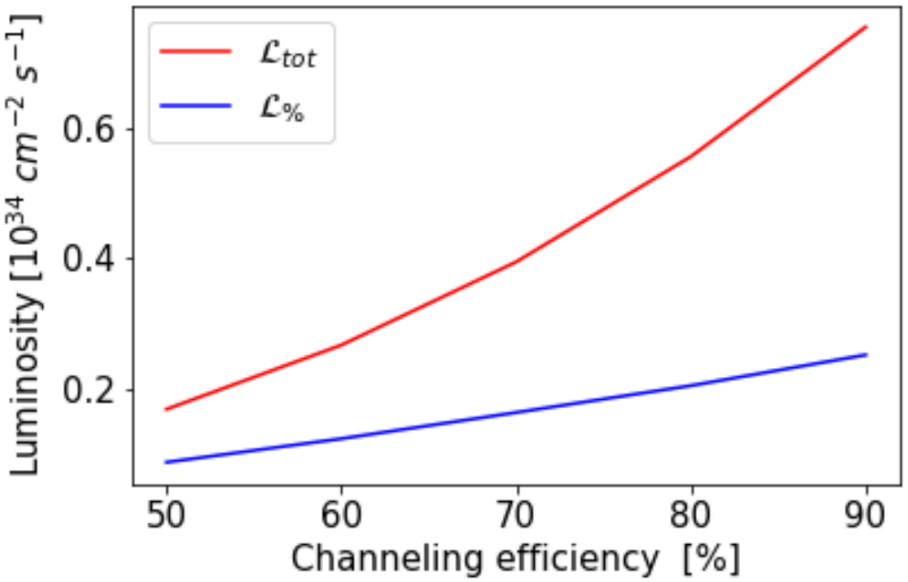


These results on the l
show a significant lower luminosity performance when using crystals to focus e- & e+ beams.
Lumonisity design values for CLIC 1.5 TeV:
$\mathcal{L}_{tot}$ = 3.7 and $\mathcal{L}_{\%}$ = 1.4 [10^{34} cm^{-2} s^{-1}]

Impact on the Luminosity for CLIC 1.5 TeV



	1 TeV e^-	1 TeV e^+
σ_x^* [nm]	50	20-50
σ_y^* [nm]	15	1
channeling efficiency [%]	50-70	70-90



These results on the luminosity reached for CLIC 1.5 TeV show a significant lower luminosity performance when using crystals to focus e- & e+ beams.
Lumonisity design values for CLIC 1.5 TeV:
$\mathcal{L}_{tot}$ = 3.7 and $\mathcal{L}_{\%}$ = 1.4 [10^{34} cm^{-2} s^{-1}]

Conclusions

- The optics simulations done initially showed a good potential for crystal focusing:
  - Good results in terms of beta function and natural chromaticity
  - Good decrease of the beam size at the IP both in horizontal and vertical planes
  - Aberrations that contribute the most for a σ_x^*, σ_y^* increase are the 2nd and 3rd order

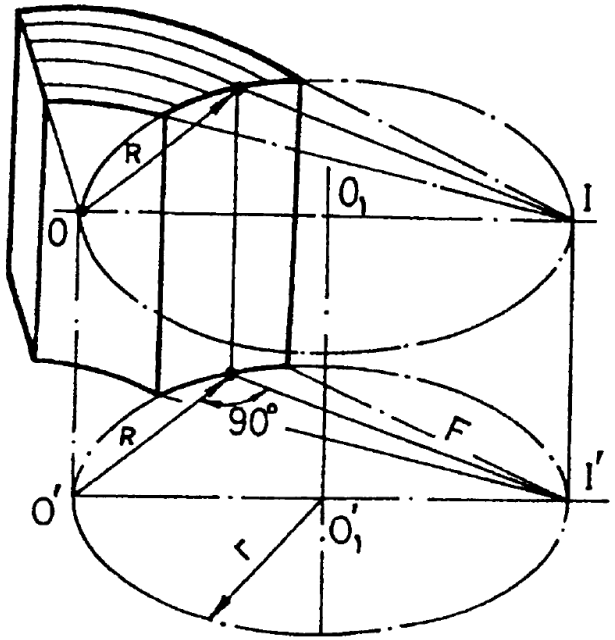
- The new results on CLIC 1.5 TeV showed a very significant decrease of luminosity for all the possible cases → significant limitations of using crystals for focusing e- beams

Thanks for the attention!

Back-up Slides

When the crystallographic planes are bent to form a cylinder of radius R it is essential to ensure that the line formed by the centers of curvature OO’ is located on the surface of a cylinder of radius r representing the shape of the exit face of the crystal.

- The focal length f is then $f = (4r^2 - R^2)^{1/2}$
- The critical angle is quite small → θ_c = 0.02−0.002 mrad for particles of energies from 100 GeV to 10 TeV for planar channelling in silicon
- This technology makes possible to achieve a focal length of the order of several centimeters
- The dimensions of the beam are ≈10μm for the GeV energies and ≈ 1μm for the TeV range.

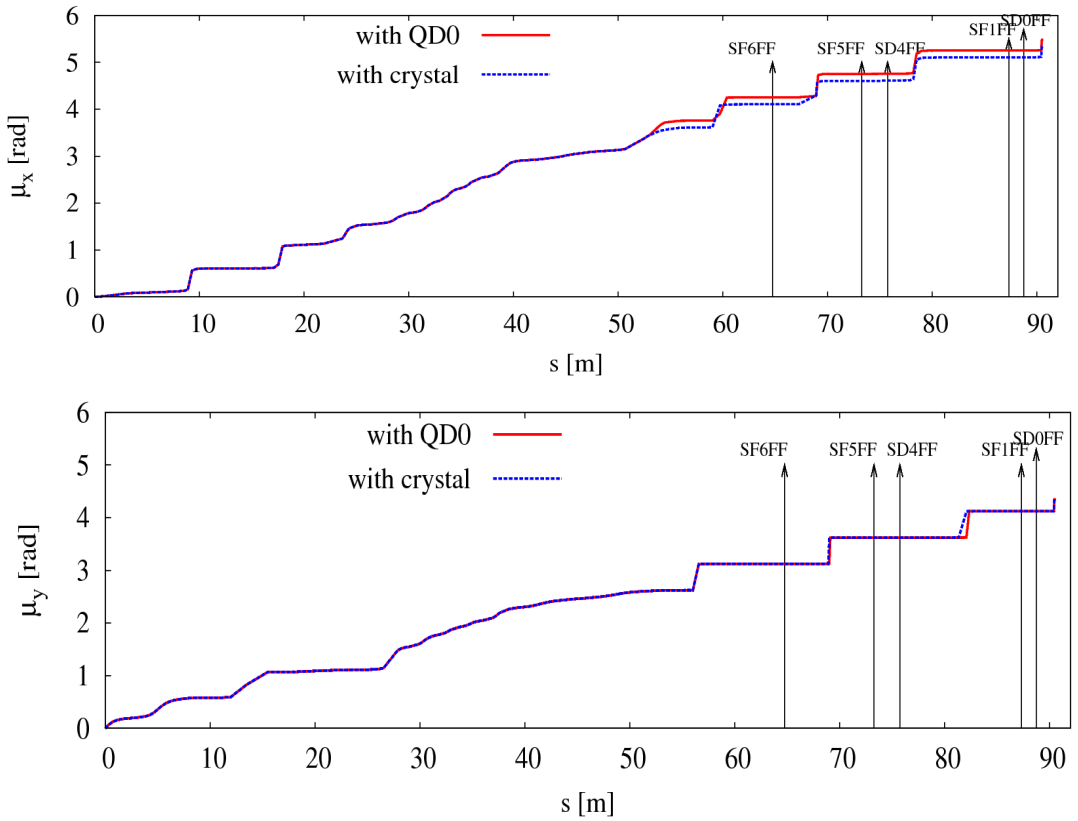


- Comparison between the sextupoles strengths for QD0 and Crystal:

k_s [m^{-2}]	QD0	CRYSTAL
SF6FF	9.08	8.77
SF5FF	-0.43	1.44
SD4FF	15.02	8.82
SF1FF	-2.62	-7.84
SD0FF	4.33	5.72
SK1FF	0.0029	-0.011
SK2FF	-0.12	-0.062
SK3FF	-0.059	-0.022
SK4FF	-0.092	-0.025

- An important feature of the FFS is that the phase advance between the sextupoles and the IP satisfies the condition:

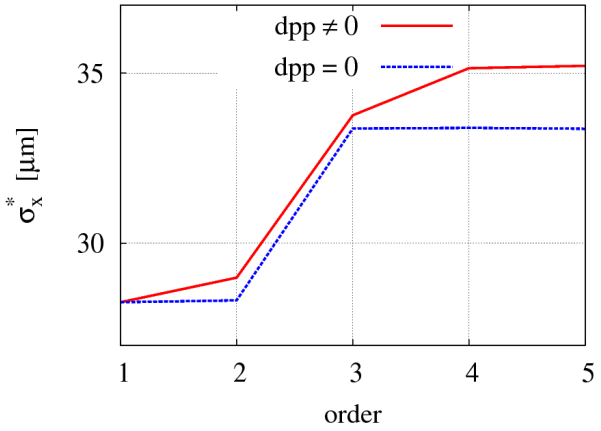
$$\Delta\mu_{x,y} = \frac{\pi}{2} + n\pi$$

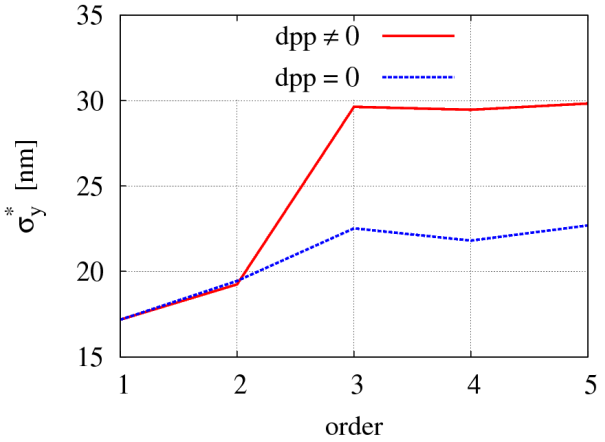


μ_x	QD0	CRYSTAL
SF1FF- SF5FF	0.50033	0.50083
SD0FF- SD4FF	0.49987	0.50024

μ_Y	QD0	CRYSTAL
SF1FF-SF5FF	0.50001	0.49994
SD0FF-SD4FF	0.50003	0.49999

- To compute the beam size at the IP considering only the geometric aberrations → dpp =0
  - For QD0:





  - For Crystal: