Non-Linear Collimation

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Diapositiva 1

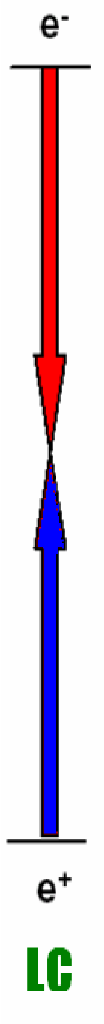
a1 report on non-linear collimation studies we carry out for :
-betatron and energy collimation for CLIC
-betatron collimation of LHC
-energy collimation of CLIC

afaus; 21/06/2005

Outline

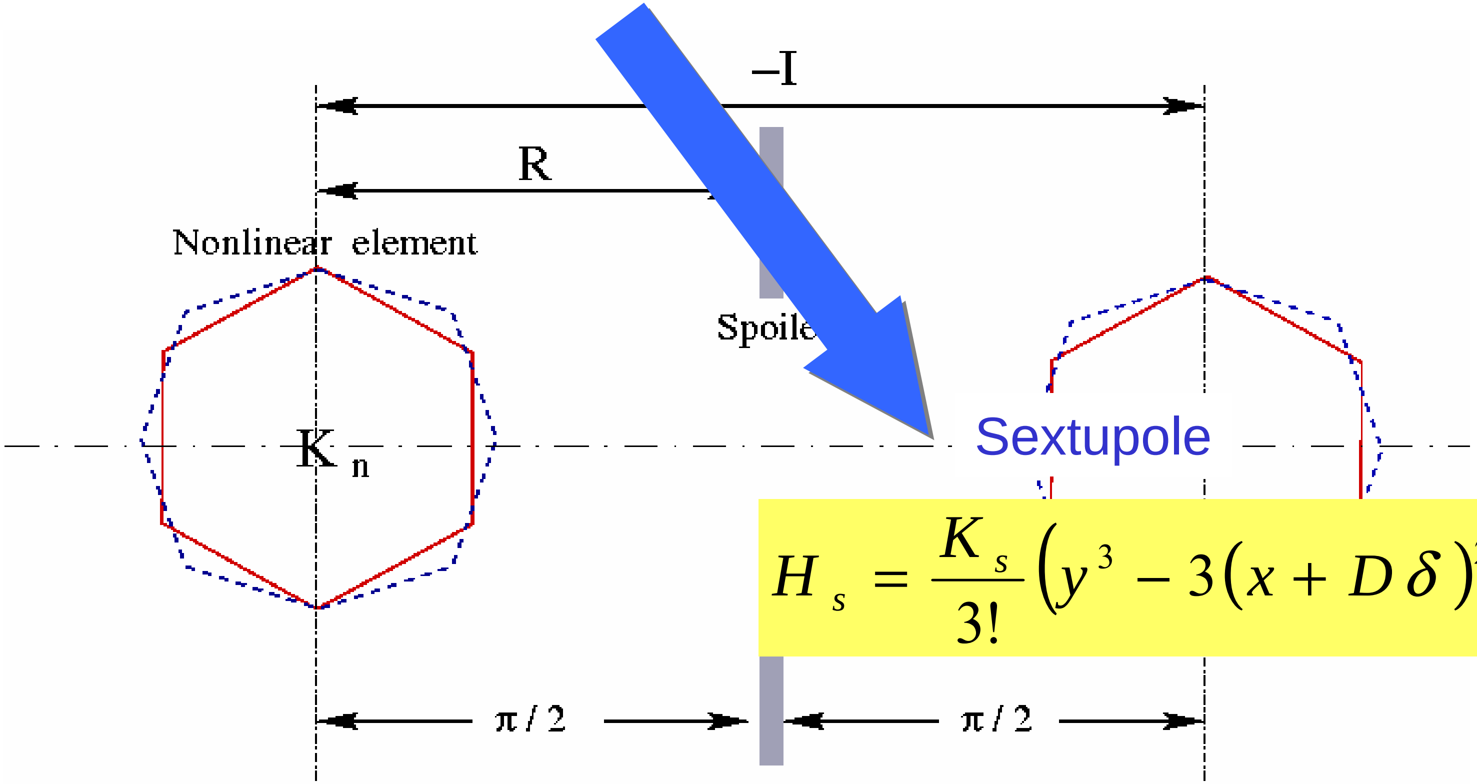
- Basic Principles
- Energy-Betatron collimation for CLIC
- Betatron collimation for LHC
- Energy collimation for CLIC

Basic Principles



Deflection at the nonlinear element

$$\Delta q_i' = -\partial H_n / \partial q_i$$



Sextupole

$$H_s = \frac{K_s}{3!}\left(y^3 - 3\left(x + D\delta\right)^2 y\right)$$

Energy-Betatron Collimation for CLIC

Optics design

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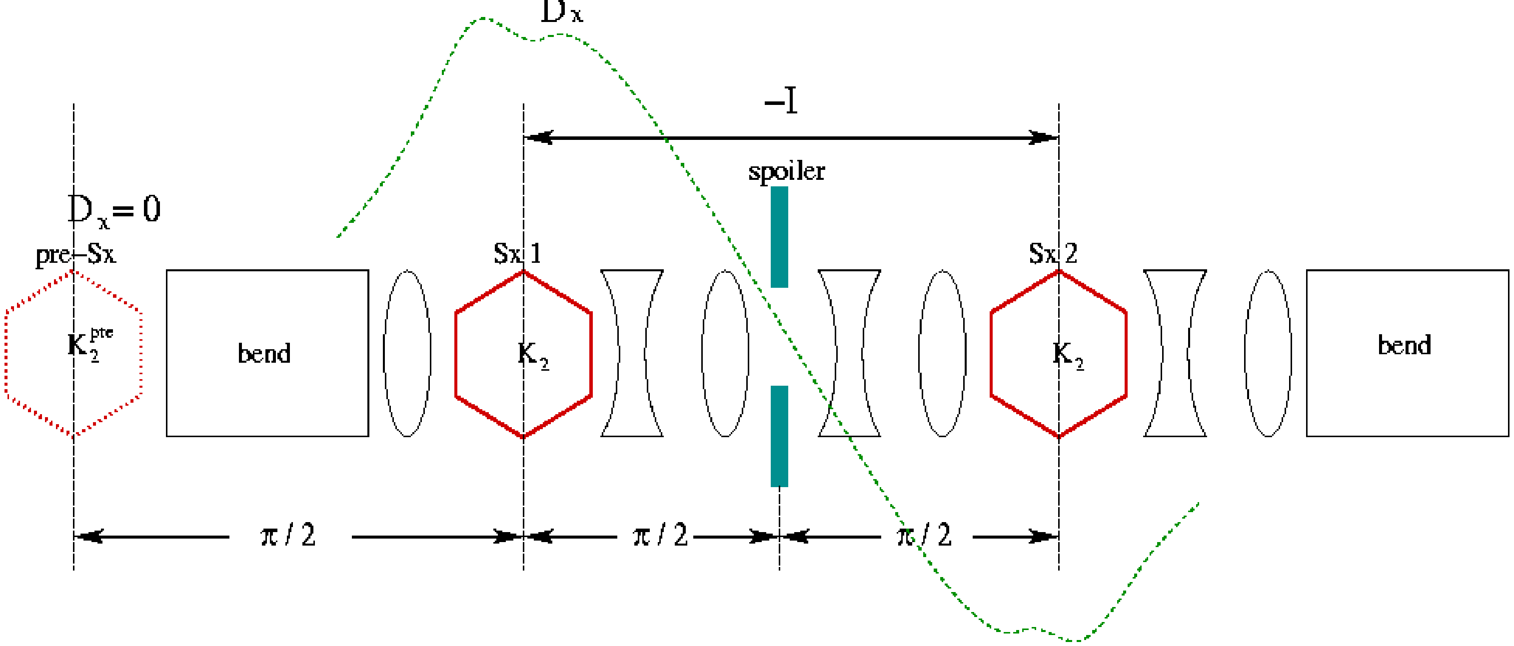

a2 1st application of such a system was made for CLIC.
The system employs a skew sextupole at a dispersive location, to increase the vertical beam size at the spoiler. A single vertical spoiler is place pi/2 in betatron phase advanceand collimates in all degress of freedom simultaneously. A second skew sextupole downstream of the spoiler at pi from the first sextupole, cancels all aberrations induced by the former.
The collimation for the ortogonal betatron phase, for which we assume less looser requirements, is accomplished by placing a hird much weaker skew sextupole pi/2 upstream of the first, in a region without dispersion.
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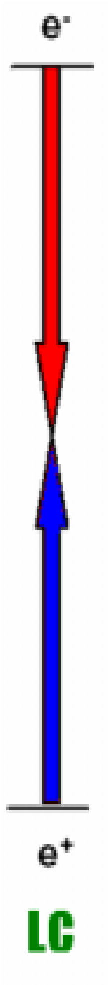
Energy-Betatron Collimation for



A weak skew sextupole

$\Delta\mu=\pi/2$

1st skew sextupole

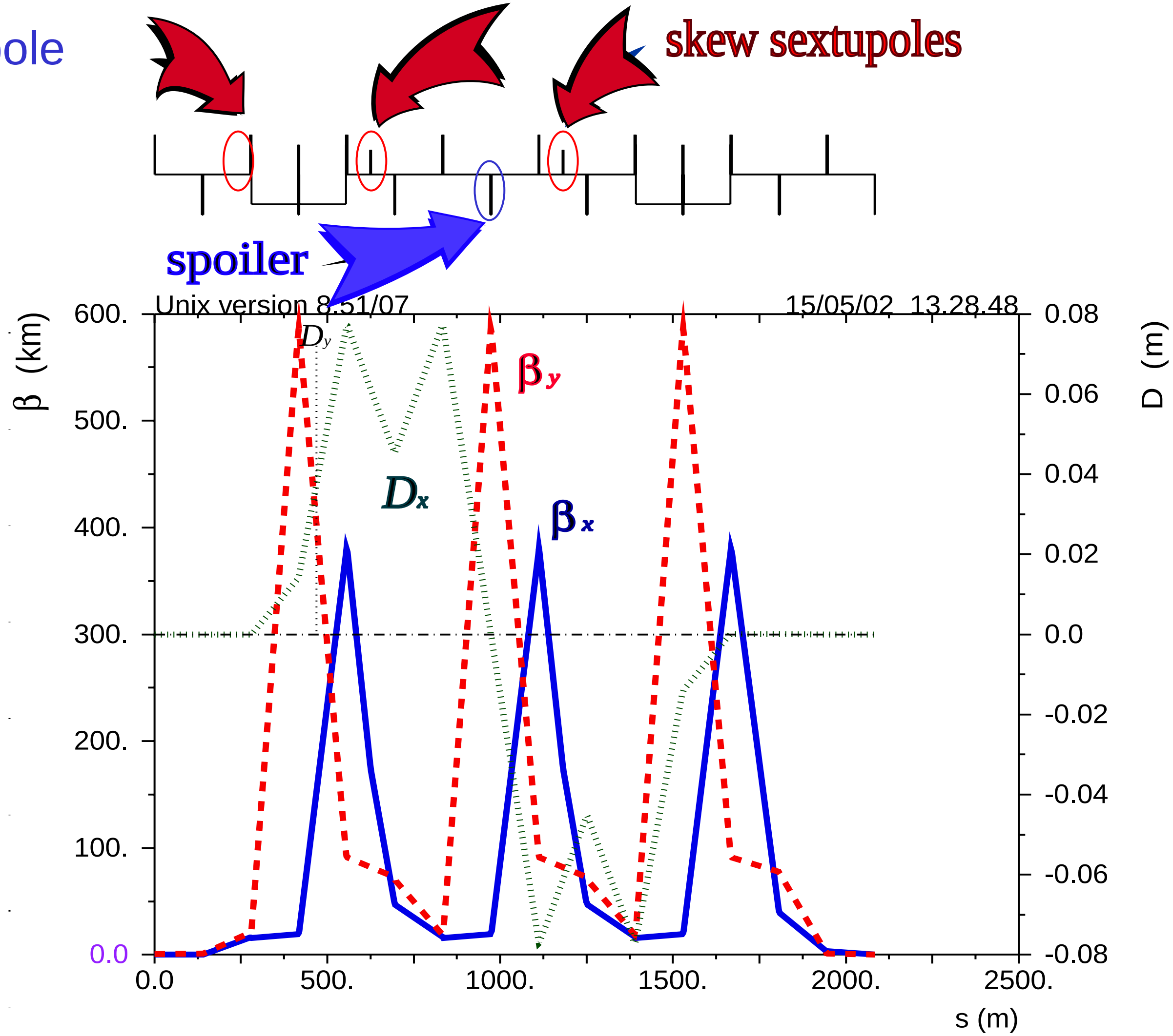
$\Delta\mu=\pi/2$

Single spoiler

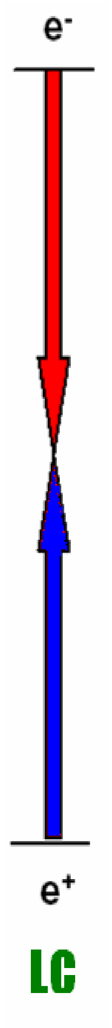
$\Delta\mu=\pi/2$

2nd skew sextupole

Does not include chromatic correction !



Energy-Betatron Collimation for CLIC

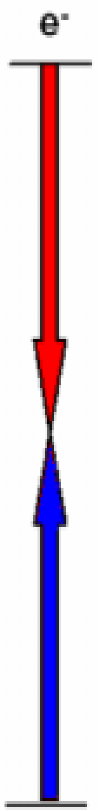


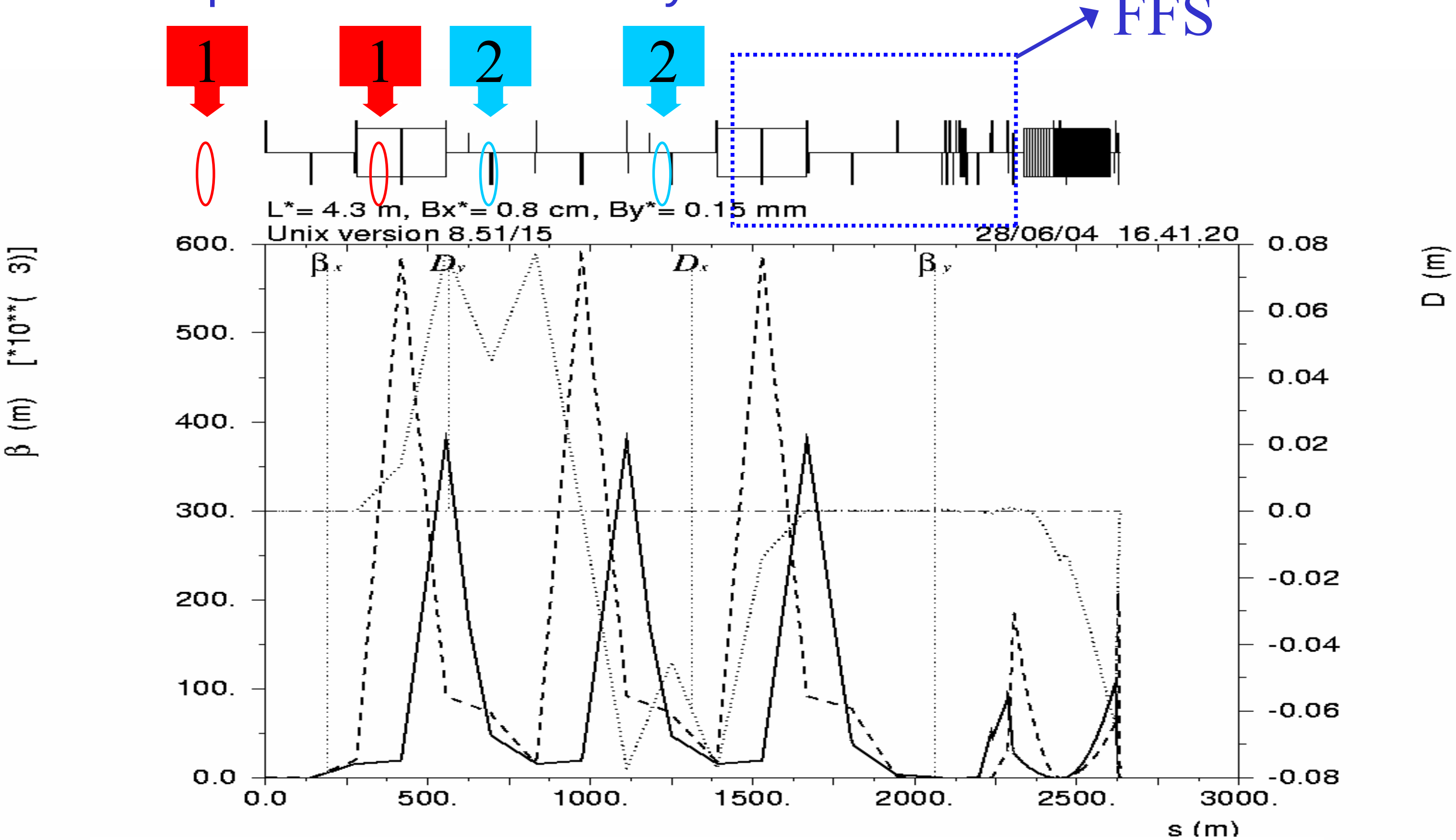
Beam, optics and collimation parameters

E	1.5	Tev
σ_ε	2.8×10^{-3}	
ε_x	0.23	pm
ε_y	6.8	fm
n_x	10	
n_y	80	
Δ	0.013	
L_t	2085	m
l_d	135	m
R_{12}^{sksp}	110.5	m
R_{34}^{sksp}	306.8	m
$\Delta\mu_{x,y}^{sksp}$	0.5	2π
β_x^0	81.7	m
β_y^0	473.0	m
I_5	1.0×10^{-19}	
K_s	104.3	m^{-2}
σ_x^{sp}	69.0	μm
σ_y^{sp}	209.0	μm
σ_r^{sp}	120	μm
a_y^{sp}	16.7	mm

Energy-Betatron Collimation for

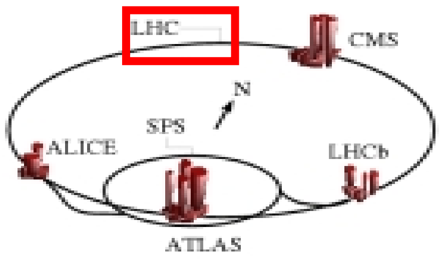
Normal sextupoles for chromaticity correction

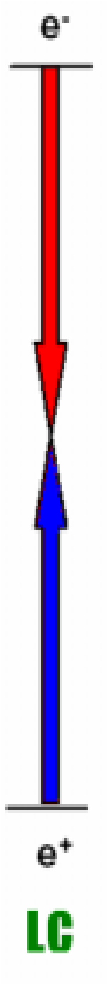




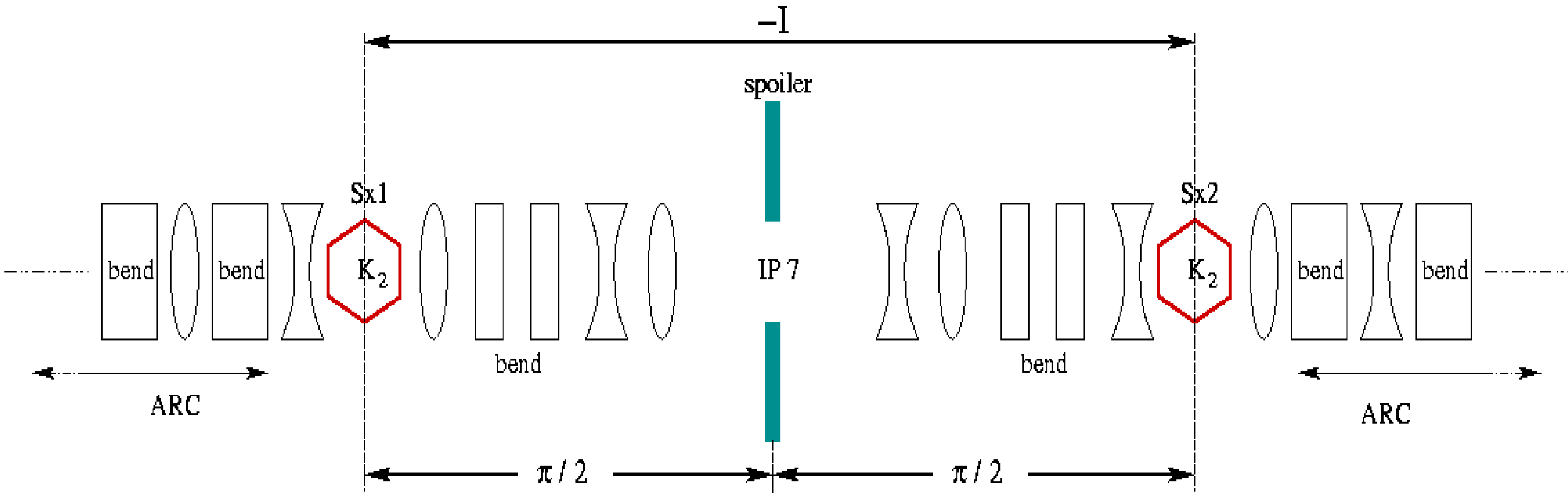
Tracking studies show: strong residual aberration

Betatron collimation for



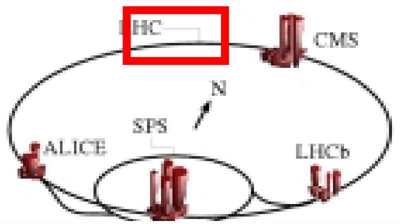


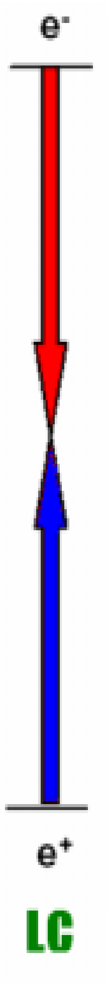
Optics design

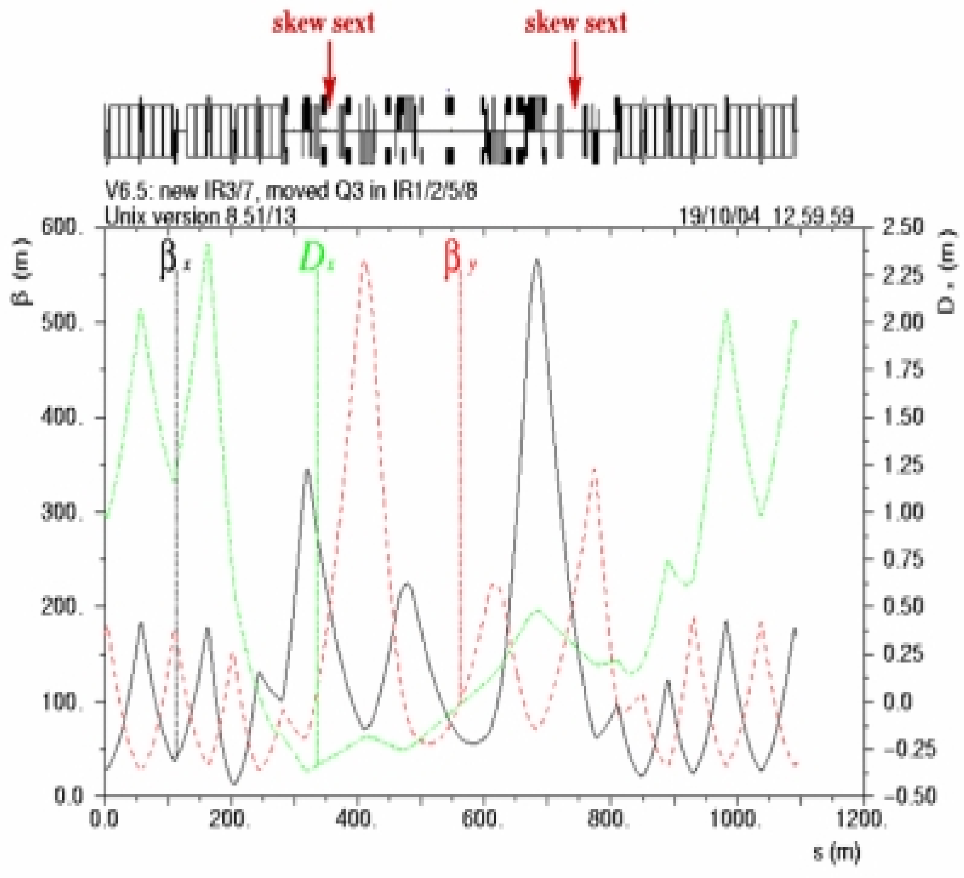


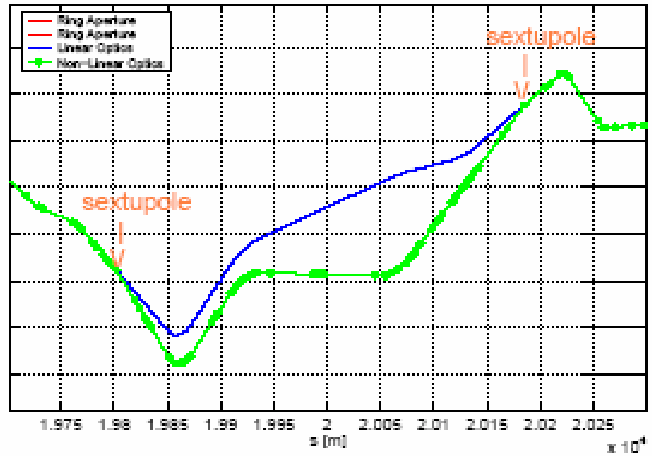
- The LHC momentum spread is 2 orders of magnitude smaller than in CLIC, cannot be exploited for widening the beam during collimation
- Emittance growth from SR is insignificant, not constrain in the design of the collimation system
- The geometric vertical emittance is about 3 orders of magnitude larger than in CLIC

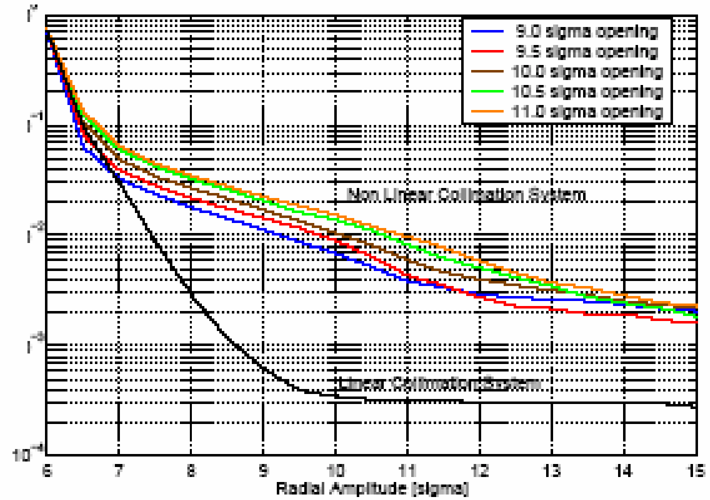
Betatron collimation for







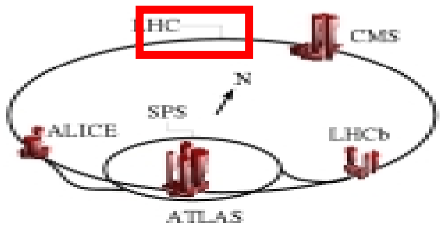


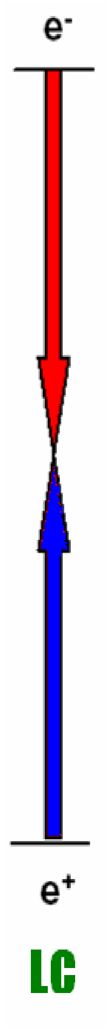


Multiparticle tracking shows encouraging results

LHC Collimation group

Betatron collimation for

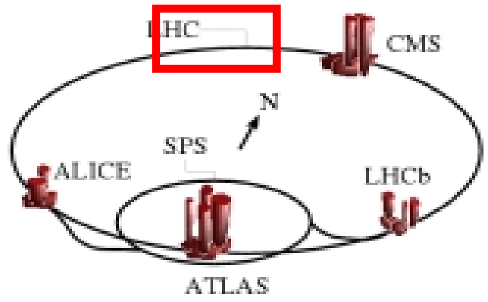




Beam, optics and collimation parameters

E	7.0	Tev
σ_ε	1.1×10^{-4}	
$\varepsilon_{x,y}$	503	pm
n_x	6	
n_y	6	
R_{12}^{sksp}	124.4	m
R_{34}^{sksp}	124.4	m
$\Delta\mu_{x,y}^{sksp}$	0.25	2π
K_s	7.0	m^{-2}
σ_x^{sp}	215.89	µm
σ_y^{sp}	263.96	µm
σ_r^{sp}	238.72	µm
a_y^{sp}	10.0	mm

Betatron collimation for



Further work:

- include spoiler between two skew sextupoles
- optimize the collimator's gap to reduce impedance budget

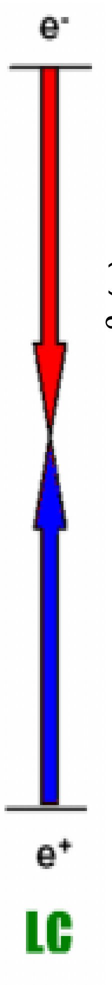
Energy Collimation for CLIC

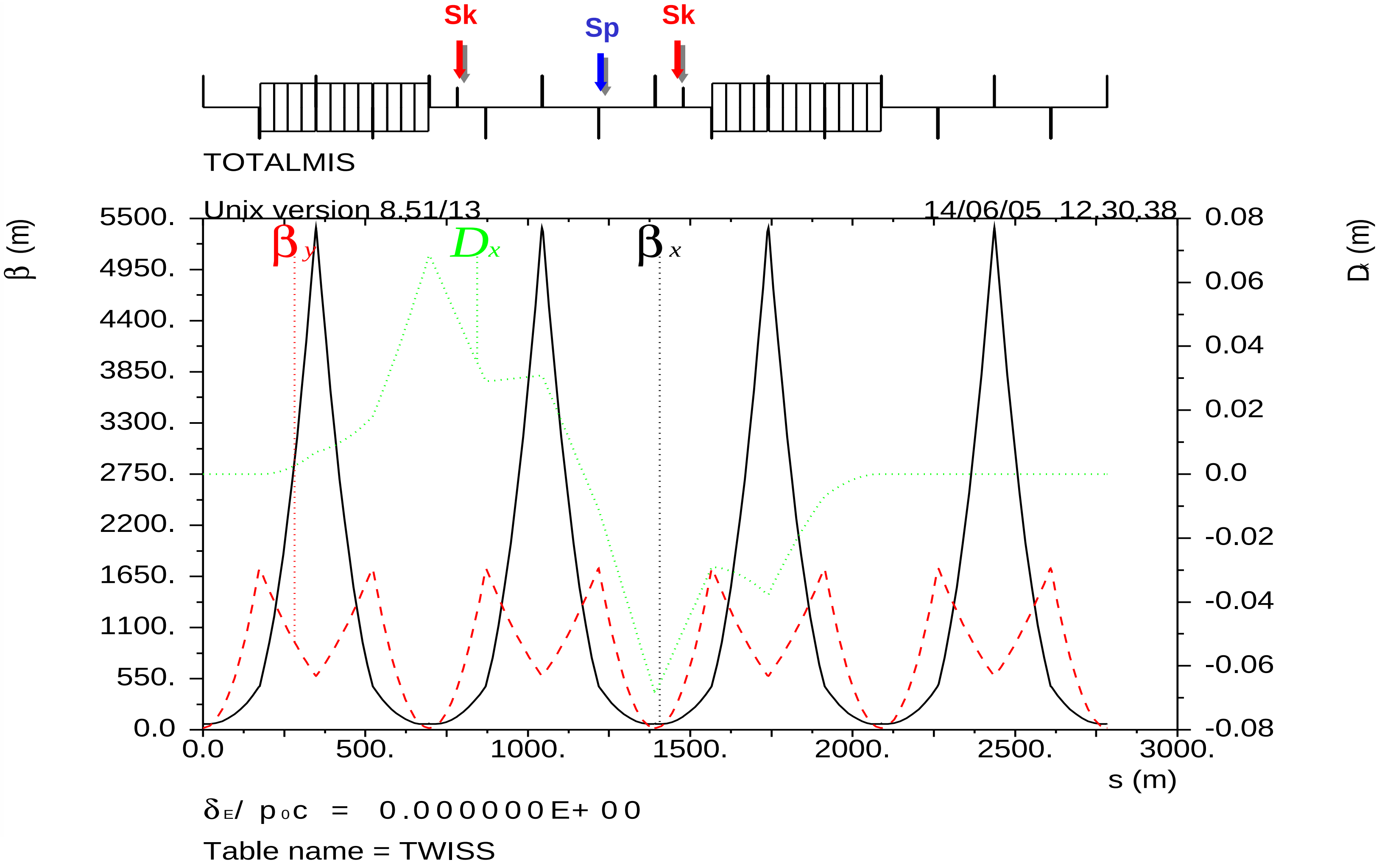
Main changes compared to previous CLIC design:

- collimation only in energy
  - linear energy collimation in x
  - skew sextupoles is only to increase vertical spot size at the spoiler
- increase the number of bends and the overall fraction of the system occupied by bends
- keep β-functions as regular as possible to avoid need of chromatic correction
- increase length and decrease bending angle until SR effect is reasonably small
- increase sextupole strength until the spot size is sufficiently large

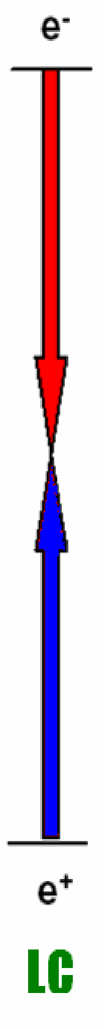
Energy Collimation for CLIC

First optics solution:





Energy Collimation for CLIC



Beam, optics and collimation parameters

E	1.5	Tev
σ_ε	2.8×10^{-3}	
ε_x	0.23	pm
ε_y	6.8	fm
Δ	0.013	
L_t	2784	m
l_d	170	m
R_{12}^{sksp}	86.6	m
R_{34}^{sksp}	87.4	m
$\Delta\mu_x^{sksp}$	0.322	2π
$\Delta\mu_y^{sksp}$	0.293	2π
β_x^0	65.0	m
β_y^0	18.0	m
θ_b	0.00008	rad
I_5	0.1×10^{-20}	
K_s	104.3	m^{-2}
σ_r^{sp}	29.6	µm
a_x^{sp}	889.0	µm
a_y^{sp}	73.4	µm

Energy Collimation for

There are however a few problems:

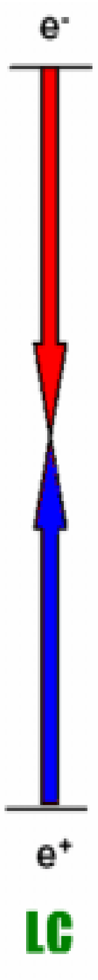
- mean spot size at the spoiler is 30 μm, less than target value of 100 μm
- collimation system is not that short (2.8 km)

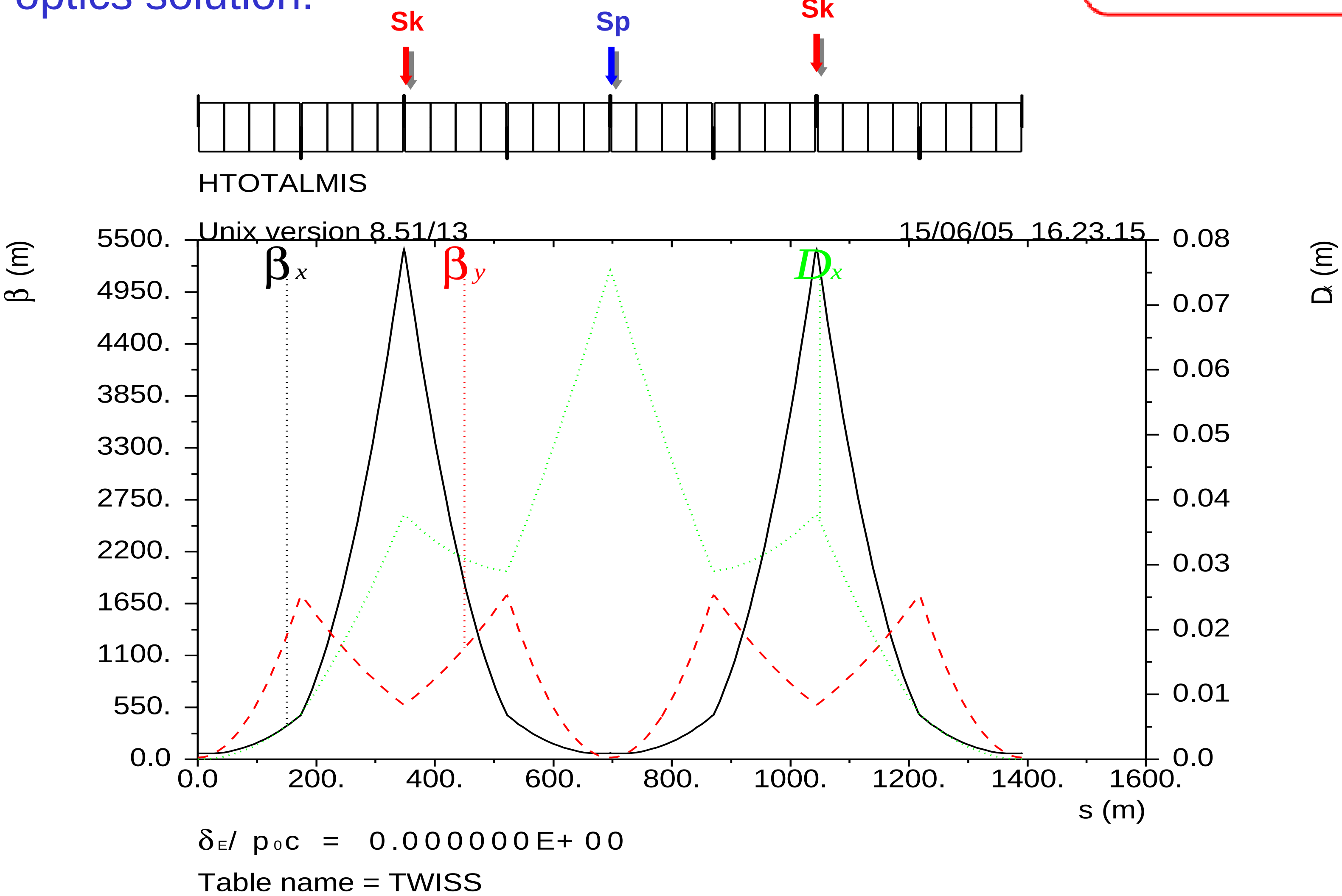
To make further progress…..

- fill as many of the cells with weak bends
- increase the dispersion at the spoiler

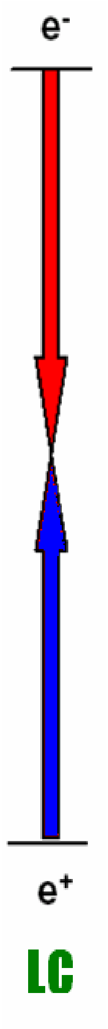
Energy Collimation for

1^{st} optics solution:





Energy Collimation for



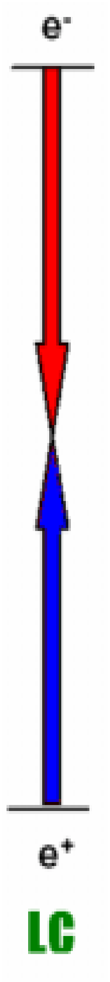
Beam, optics and collimation parameters

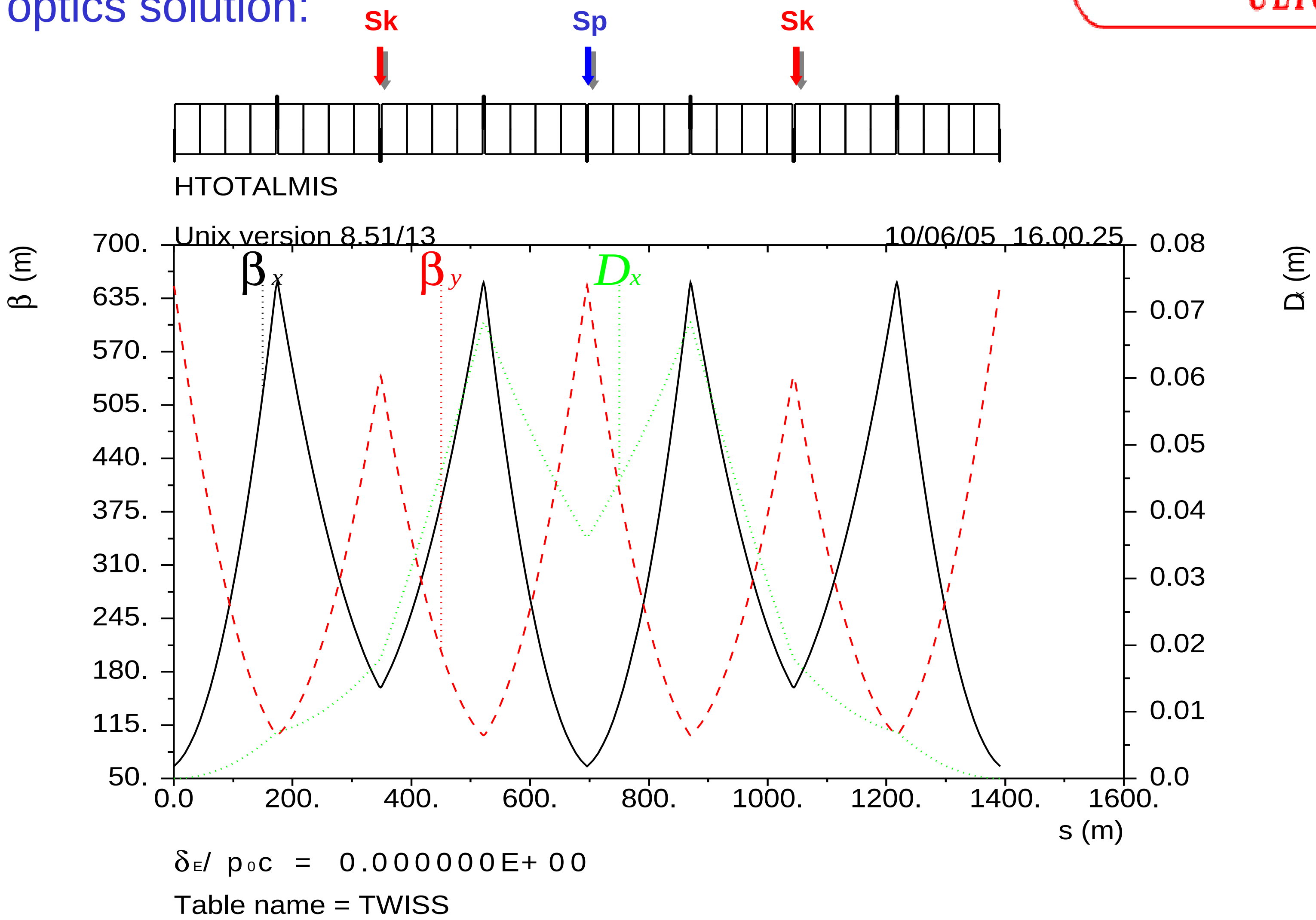
E	1.5	Tev
σ_ε	2.8 x 10^{-3}	
[illegible]	0.23	pm
[illegible]	6.8	fm
[illegible]	0.013	
[illegible]	1392	m
l_d	170	m
R_{12}^{sksp}	[illegible]592.5	m
R_{34}^{sksp}	[illegible]	m
$\Delta\mu_x^{sksp}$	[illegible]	2π
$\Delta\mu_y^{sksp}$	[illegible]	2π
β_x^0	65.[illegible]	m
β_y^0	18.0	[illegible]
θ_b	0.00008	[illegible]
I_5	0.5 x 10^{-20}	[illegible]
K_s	104.3	m[illegible]
σ_r^{sp}	25.9	μm
a_x^{sp}	979.1	μm
a_y^{sp}	51.1	μm

similar performances but half length.....

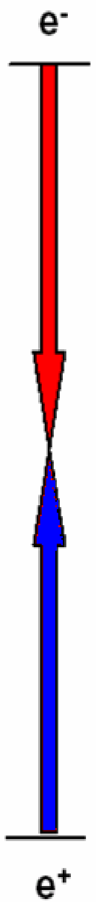
Energy Collimation for

2nd optics solution:





Energy Collimation for CLIC

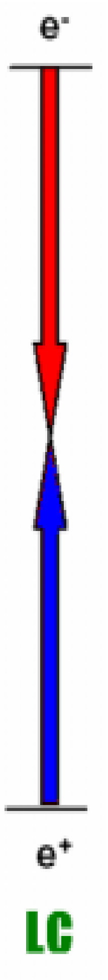


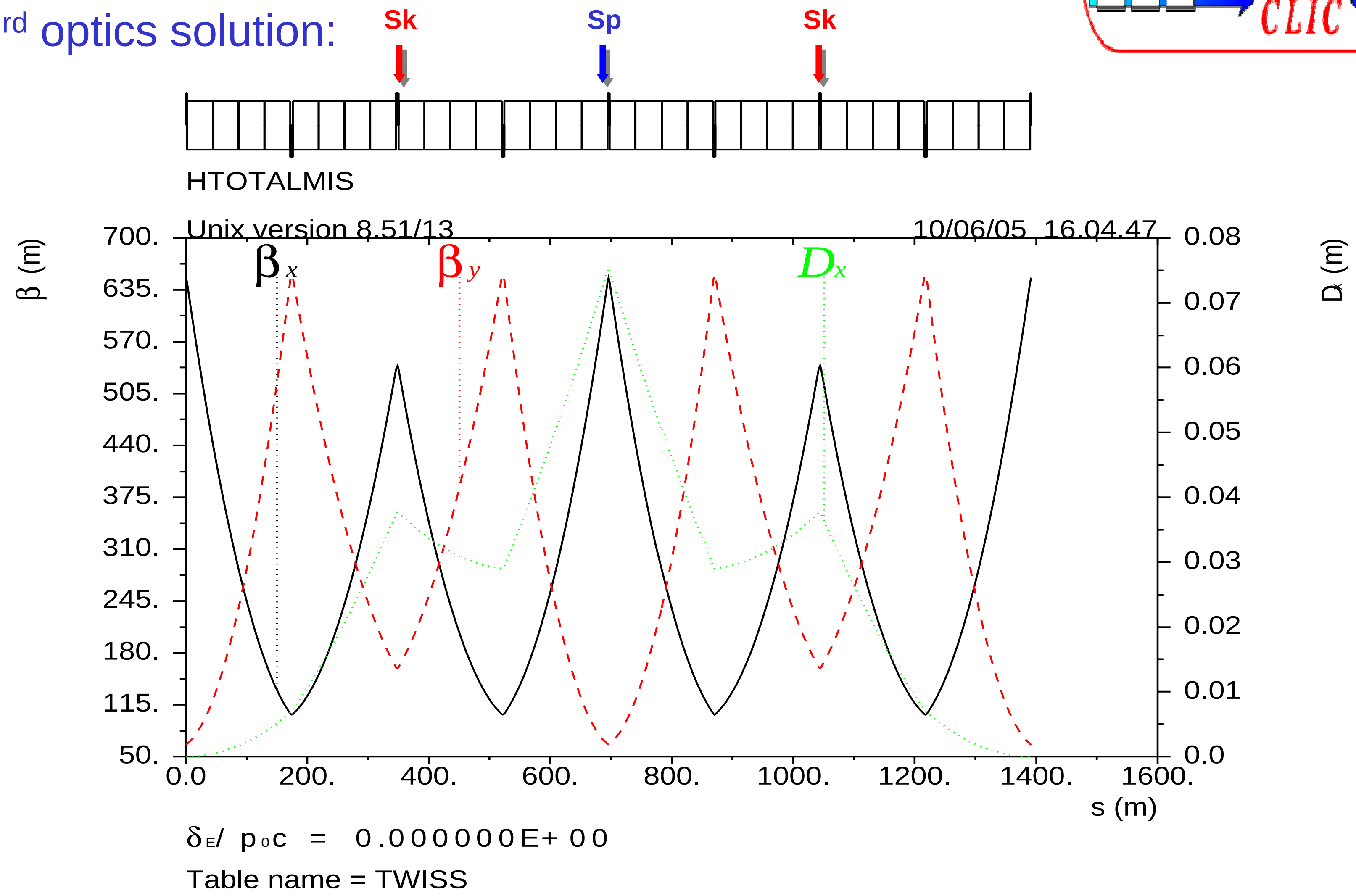
Beam, optics and collimation parameters

E	1.5	Tev
σ_ε	2.8×10^{-3}	
ε_x	0.23	pm
ε_y	6.8	fm
Δ	0.013	
L_t	1392	m
l_d	170	m
R_{12}^{sksp}	102.2	m
R_{34}^{sksp}	592.5	m
$\Delta\mu_x^{sksp}$	0.25	2π
$\Delta\mu_y^{sksp}$	0.25	2π
β_x^0	65.0	m
β_y^0	650.0	m
θ_b	0.00008	rad
I_5	0.1×10^{-20}	
K_s	104.3	m^{-2}
σ_r^{sp}	21.3	µm
a_x^{sp}	979.1	µm
a_y^{sp}	51.1	µm

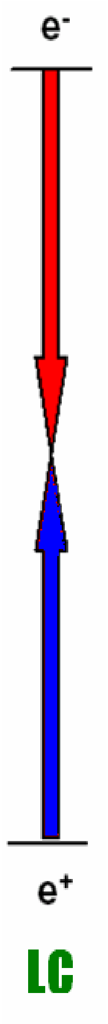
Energy Collimation for

3rd optics solution:





Energy Collimation for CLIC



Beam, optics and collimation parameters

E	1.5	Tev
σ_ε	2.8×10^{-3}	
ε_x	0.23	pm
ε_y	6.8	fm
Δ	0.013	
L_t	1392	m
l_d	170	m
R_{12}^{sksp}	592.5	m
R_{34}^{sksp}	102.2	m
$\Delta\mu_x^{sksp}$	0.25	2π
$\Delta\mu_y^{sksp}$	0.25	2π
β_x^0	650.0	m
β_y^0	65.0	m
θ_b	0.00008	rad
I_5	0.07×10^{-20}	
K_s	104.3	m^{-2}
σ_r^{sp}	26.1	µm
a_x^{sp}	979.1	µm
a_y^{sp}	51.1	µm

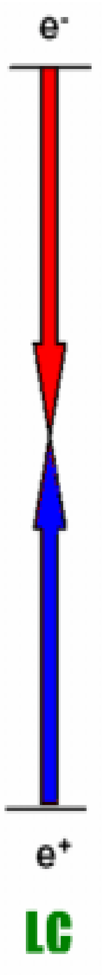
Energy Collimation for CLIC

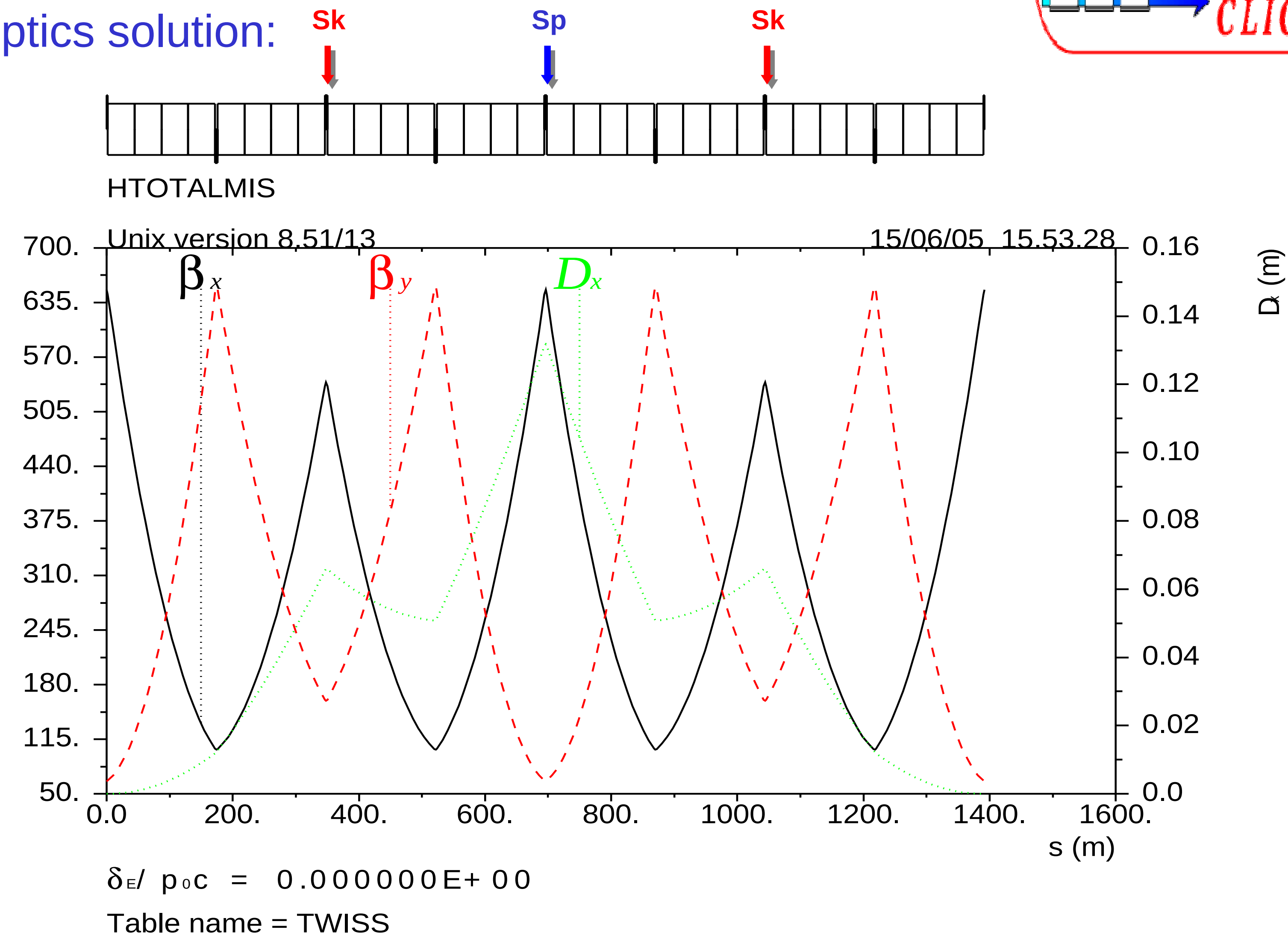
to increase the size at the spoiler we could:

- increase the bending angle ($I_5 < 1.0 \times 10^{-19}$)
- increase the cell length …

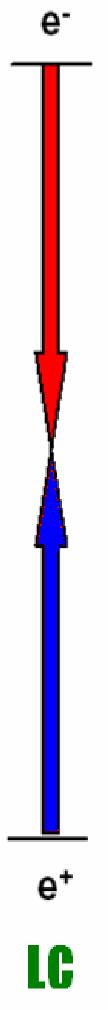
Energy Collimation for

3rd optics solution:





Energy Collimation for CLIC



Beam, optics and collimation parameters

E	1.5	Tev
σ_ε	2.8 x 10^{-3}	
ε_x	0.23	pm
ε_y	6.8	fm
Δ	0.013	
L_t	1792	m
l_d	220	m
R_{12}^{sksp}	763.2	m
R_{34}^{sksp}	131.5	m
$\Delta\mu_x^{sksp}$	0.25	2π
$\Delta\mu_y^{sksp}$	0.25	2π
β_x^0	650.0	m
β_y^0	65.0	m
θ_b	0.00014	rad
I_5	1.0 x 10^{-20}	
K_s	104.3	m^{-2}
σ_r^{sp}	99.4	µm
a_x^{sp}	2206.1	µm
a_y^{sp}	333.7	µm

Energy Collimation for

e⁻

e⁺

LC

Further work:

- add matching cell to be independent of initial/final conditions and gain in flexibility
- multiparticle tracking to study the impact of such a system in the BDS a3
- include betatron collimation by adding a weak pre-skew sextupole for orthogonal betatron phase as in former CLIC non linear optics

Diapositiva 25

a3 efficiency and bandwidth
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