CLIC and ILC FFS Beam Dynamics

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LCWS12 INTERNATIONAL WORKSHOP ON FUTURE LINEAR COLLIDERS

Outline

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   - ILC Synchrotron radiation
   - IP Bandwidth
2. ILC Beam Dynamics
   - ILC Traveling Focus
   - β_y-scan (Hourglass effect)
   - New FFS lattice
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   - Traveling Focus in CLIC
   - β_x and β_y optimization
   - Traveling focus in CLIC500
4. Conclusions and Future prospects

CLIC and ILC Final Focus System

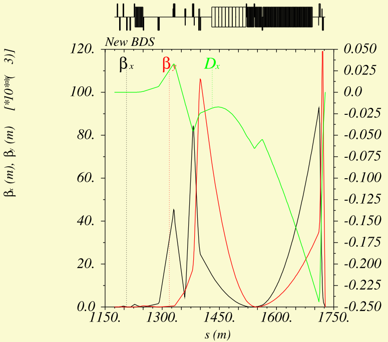
Both FFS follow the local chromaticity correction scheme proposed by P.Raimondi and A.Seryi.

Parameter [Units]	**CLIC500**	**ILC500**
FFS length/side [m]	553.1	735.4
Maximum energy/beam [TeV]	0.25	0.25
Distance from IP to first quad, l^* [m]	4.30	3.51/4.50
Crossing angle at IP [mrad]	18.6	14.0
Ccore beam size at IP, $\sigma^*, x/y$ [nm]	202/2.3	474/5.9
Beam divergence at IP, $\theta^*, x/y$ [μrad]	25/23	43/12
Beta-function at IP, $\beta^*, x/y$ [mm]	9.52/0.1	11/0.48
Bunch length, σ_z [μm]	72	300
Disruption parameters, $D, x/y$	0.1/12	0.3/24.6
Bunch population, N	$6.8 \cdot 10^9$	$2 \cdot 10^{10}$

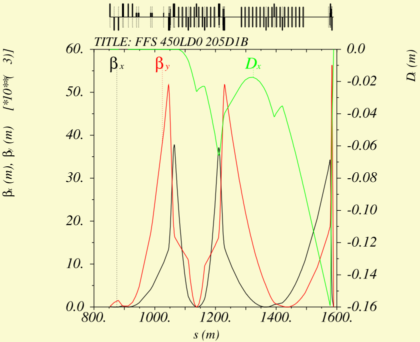
CLIC and ILC Final Focus System

Both FFS follow the local chromaticity correction scheme proposed by P.Raimondi and A.Seryi.

CLIC $\sqrt{s} = 500$ GeV



ILC $\sqrt{s} = 500$ GeV



CLIC and ILC comparison

- Optimization using 5 sextupoles: SF6, SF5, SD4, SF1, SD0.
- Momentum spread: $(\Delta p/p)_{\mathrm{CLIC}} = 0.01, (\Delta p/p)_{\mathrm{ILC}} = 0.00125$.
- MAPCLASS computation.
- CLIC $\beta-$functions are much smaller than ILC.
- CLIC aberrations are due to a 3 TeV geometry constraint.

$\sigma_x^{\mathrm{ILC}} = 490$ nm, $\sigma_x^{\mathrm{CLIC}} = 222$ nm

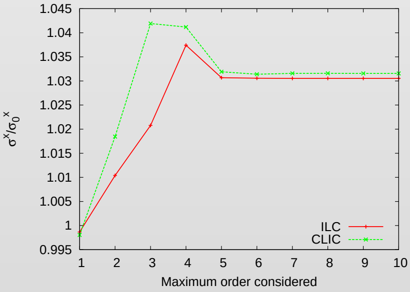


Figure: Nonlinear optimization for σ_x

$\sigma_y^{\mathrm{ILC}} = 6.6$ nm, $\sigma_y^{\mathrm{CLIC}} = 2.4$ nm

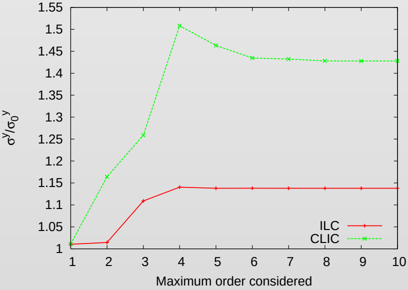


Figure: Nonlinear optimization for σ_y

ILC Synchrotron radiation

- We have replaced the full dipole configuration considering only one dipole out of five following real 500 GeV lattice.

Without SR

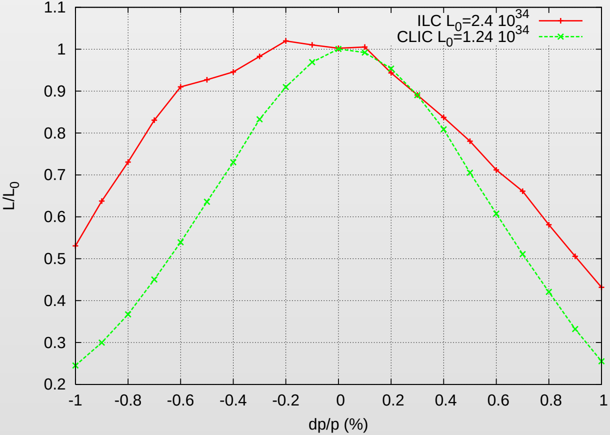
l^*	3.51	3.51'	4.50	4.50'
σ_x^*	479.5	479.5	488.3	488.3
σ_y^*	5.78	5.78	6.42	6.42
$\mathcal{L}_T$	2.25	2.23	2.45	2.45
$\mathcal{L}_{1\%}$	1.36	1.34	1.47	1.46

With SR

l^*	3.51	3.51'	4.50	4.50'
σ_x^*	480.2	480.6	488.5	488.5
σ_y^*	5.79	5.79	6.59	6.59
$\mathcal{L}_T$	2.25	2.22	2.46	2.47
$\mathcal{L}_{1\%}$	1.35	1.34	1.47	1.46

- Synchrotron radiation effects keep the beam size $< 0.5\%$. In agreement with expected results.
- Detailed information in O.Blanco talk about SR effects in ILC.

CLIC and ILC Luminosity bandwidth



- ILC scheme presents a higher luminosity (more charged beams) value and wider bandwidth.
- Nominal values for Peak Luminosities: $\mathcal{L}_{\text{CLIC}} = 1.4 \cdot 10^{34}\text{cm}^{-2}\text{s}^{-1}, \mathcal{L}_{\text{ILC}} = 2.0 \cdot 10^{34}\text{cm}^{-2}\text{s}^{-1}$

Traveling focus motivation

- So far we have considered head on collisions.
- If we consider the crossing angle scheme we have to consider crab cavities.
- Thanks to the crab cavities, we can introduce a controlled $E - z$ correlation in order to control the correct focusing of the head and the tail of the beam. Also called Traveling focus scheme.
- We analyze the case of ILC500 and CLIC500 via ideal distributions and its possible implementation in real lattices.

ILC Traveling focus: β_y-scan

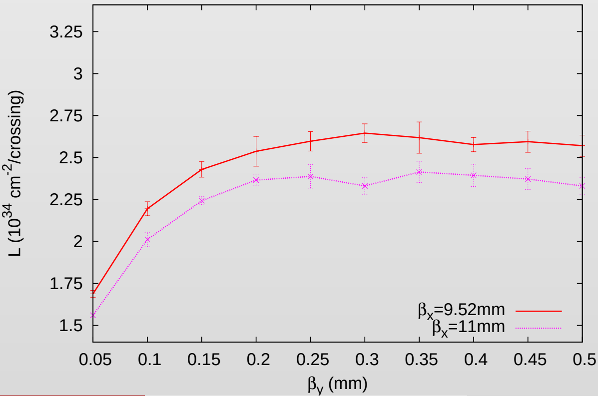
- First of all, we have to look for the optimal parameters to optimize the traveling focus effect-
- Look for the maximum in luminosity scanning two parameters β_y^* and $\frac{\partial w}{\partial z}$ (traveling waist) keeping β_x^*.

$$\mathcal{L} = \underbrace{\frac{N_1 N_2}{4\pi\sigma_x^*\sigma_y^*}}_{L_0} \underbrace{\frac{\cos\frac{\phi}{2}}{\sqrt{\pi}\sigma_s}\int \frac{e^{-s^2 A}}{1+\left(\frac{s}{\beta^*}\right)^2} ds}_{\text{Hourglass effect}}$$

ILC β_y-scan. Ideal distributions results

Generic head-on beam is mapped in the y-plane to introduce the traveling waist and waist shift parameters $\frac{\partial w}{\partial z}, z_{\text{waist}}$.

$$\mathcal{M} : y_0 \rightarrow y = y_0 + \frac{\partial w}{\partial z} z_0 y_0' + z_{\text{waist}} y_0'$$



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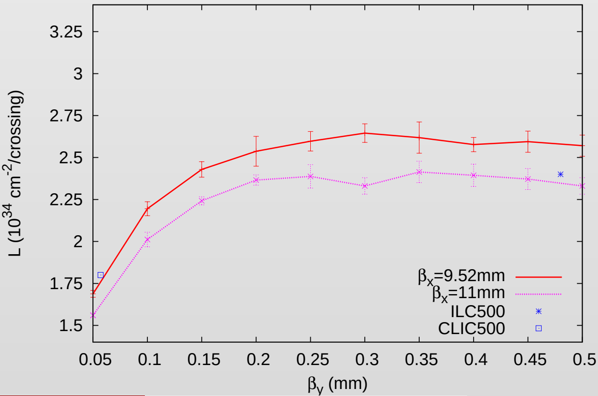

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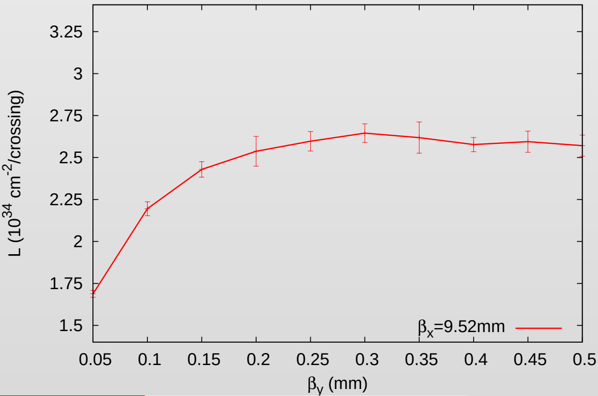

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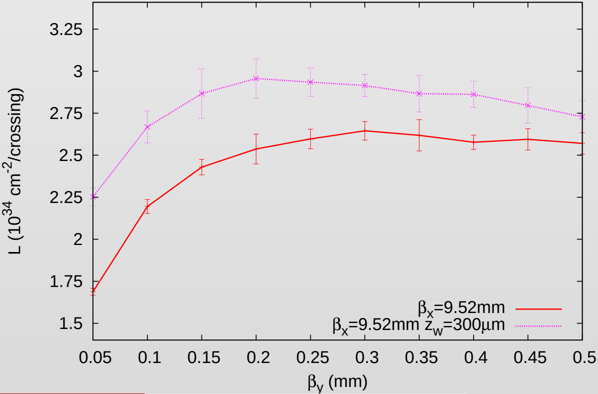

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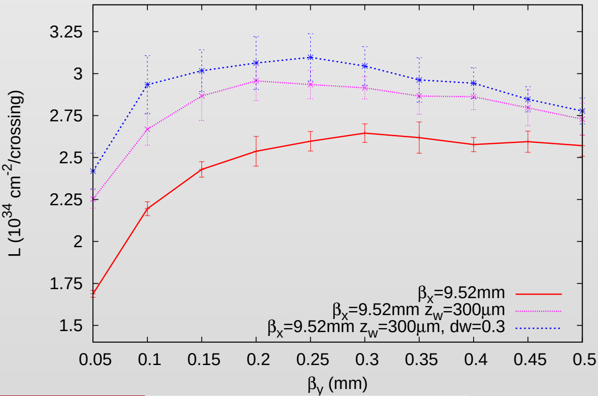


Traveling waist for ILC beam in CLIC500

First, we consider current CLIC500 lattice to cross-check the above results.

$$\frac{\partial w_y}{\partial z} = -\beta^* \sum_i^{\text{sext}} \sum_j^{\text{CC}} R_{12}^{\text{CC}_j - \text{sext}_i} \xi_c \beta_{x_i} K_{s_i} L_{s_i}$$

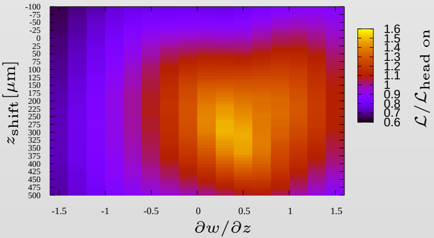
Head-on working point

$\frac{\partial w}{\partial z} = -0.11, \quad z_{\text{waist}} = -10.7\mu\text{m}$

Best working point

$$\frac{\partial w}{\partial z} = 0.4, \quad z_{\text{waist}} = 300\mu\text{m}$$

$\mathcal{L}_T = 2.48 \cdot 10^{34} \quad \mathcal{L}_{1\%} = 1.45 \cdot 10^{34}$



55% gain!

Moving to the working point

After ideal scan, we try to reproduce the same results with real distributions.

Waist shift z_{shift}

Vary QD0 strength slightly to move the waist:

$$z_{\text{shift}} = -\alpha^* \beta_y^*$$

$$\frac{\Delta K}{K} \sim \frac{z_{\text{shift}}}{\sqrt{\beta^{\text{QD0}} \beta^*}} \sim \mathcal{O}(10^{-5})$$

$$\Delta K / K \approx 3.0 \cdot 10^{-5}$$

$$z_{\text{shift}} = 216 \mu\text{m}$$

Traveling waist $\partial w / \partial z$

Choose Crab cavity location:

$$\frac{\partial w}{\partial z} \sim \frac{R_{12}^{\text{CC-sext}}}{R_{12}^{\text{CC-IP}}}$$

Best position: Between last Bend and SF1.

$$\partial w / \partial z = 0.329 \pm 0.004$$

Luminosity

$$\mathcal{L}_T = 2.43 \cdot 10^{34} (\sim +50\%)$$

$$\mathcal{L}_{1\%} = 1.43 \cdot 10^{34} (\sim +50\%)$$

New FFS lattice

- We want to move the working point to the optimal found in the β_y-scan.
- We move β_x and β_y to the maximum final luminosity point.
- Based on CLIC $\sqrt{s} = 500$ GeV lattice baseline.

Lattice optimization

$$\beta_x^* = 9.0\text{mm}$$

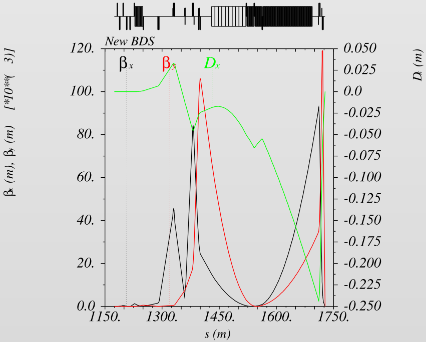
$$\beta_y^* = 0.25\text{mm}$$

$$\sigma_x^* = 436.72\text{nm}$$

$$\sigma_y^* = 4.74\text{nm}$$

$$\mathcal{L}_0 = 2.54 \cdot 10^{34}\text{cm}^{-2}$$

$$\mathcal{L}_{1\%} = 1.45 \cdot 10^{34}\text{cm}^{-2}$$



New FFS traveling waist results

- Important: Only one crab cavity needed for implementation.
- Cavity placed upstream QD2 and QF1.

Lattice parameters

Crossing angle: $\theta/2 = 0.010\text{mrad}$
Voltage needed: $V_{\text{CC}} = -0.38\text{MV}$
QD0 str. shift: $\Delta K/K = 5 \cdot 10^{-6}$

Distribution parameters

$z_w = 300\mu\text{m}$
$\partial w/\partial z = 0.35$

ILC luminosity

$$\mathcal{L}_T = 2.47 \cdot 10^{34}\text{cm}^{-2}$$

$$\mathcal{L}_{1\%} = 1.46 \cdot 10^{34}\text{cm}^{-2}$$

Luminosity Gain $> 20\%$ respect to ILC

$$\mathcal{L}_T = 3.07 \cdot 10^{34}\text{cm}^{-2}$$
$$\mathcal{L}_{1\%} = 1.74 \cdot 10^{34}\text{cm}^{-2}$$

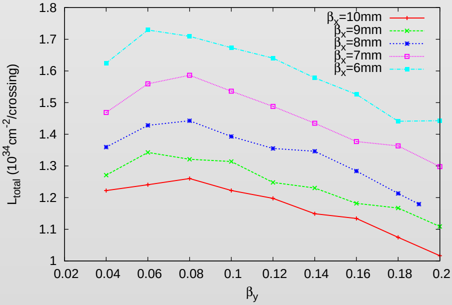
Implementing traveling waist in CLIC $\sqrt{s} = 500$ GeV

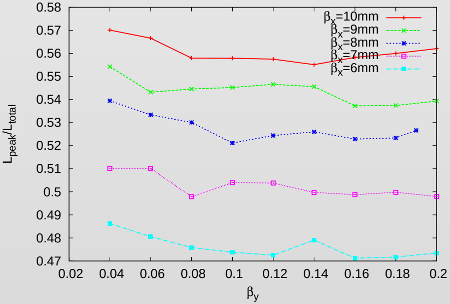
- Following the non negligible effect of the traveling focus on ILC we want to see how far we can go when we consider CLIC500.
- Short CLIC bunches compared to ILC bunches limits the expected luminosity gain.
- We follow the steps carried out in the ILC case.

β_x and β_y optimization

- We proceed in the same way as we did before.
- Find optimal β_x and β_y with ideal distributions.

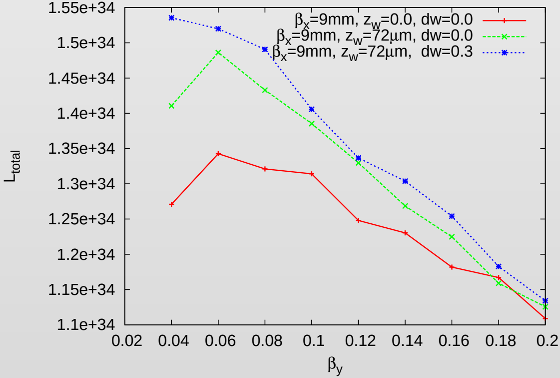
Beamstrahlung: $\langle \Upsilon \rangle \approx \frac{5}{6} \frac{N r_e^2 \gamma}{\alpha \sigma_z (\sigma_x + \sigma_y)}$





Traveling focus

- Beamstrahlung effects allow a $\beta_x < 9$mm.
- Current lattice is not able to cover that values and needs to be redesigned.
- A gain $> 10\%$ is expected.



Conclusions and Future prospects

- A CLIC500 and ILC500 lattices comparison is showed.
- A new FFS based on CLIC500 lattice is proposed as a way to estimate the traveling waist studies in ILC.
- More studies to implement this new lattice to ILC are needed.
- Ideal distributions show a 30% maximum luminosity gain for $\beta_y = 0.25$mm and $\partial w / \partial z = 0.3$.
- The luminosity gain in a real lattice is around 20% ($\mathcal{L} \sim 3.0 \cdot 10^{34}$cm^{-2}).
- The luminosity gain does not imply any new technical challenge.
- Similar studies for CLIC500 are already ongoing.