Study of alternative optical parameters for the ILC final focus

On-going work and plans

Philip Bambade

Laboratoire de l'Accélérateur Linéaire
Université Paris 11, Orsay, France

On behalf and based on collaboration with:

Vincent Tugayé (student, ENS-Lyon), Oscar Blanco (PhD), Jie Gao (IHEP), Dou Wang (IHEP), Yiwei Wang (PhD, IHEP)

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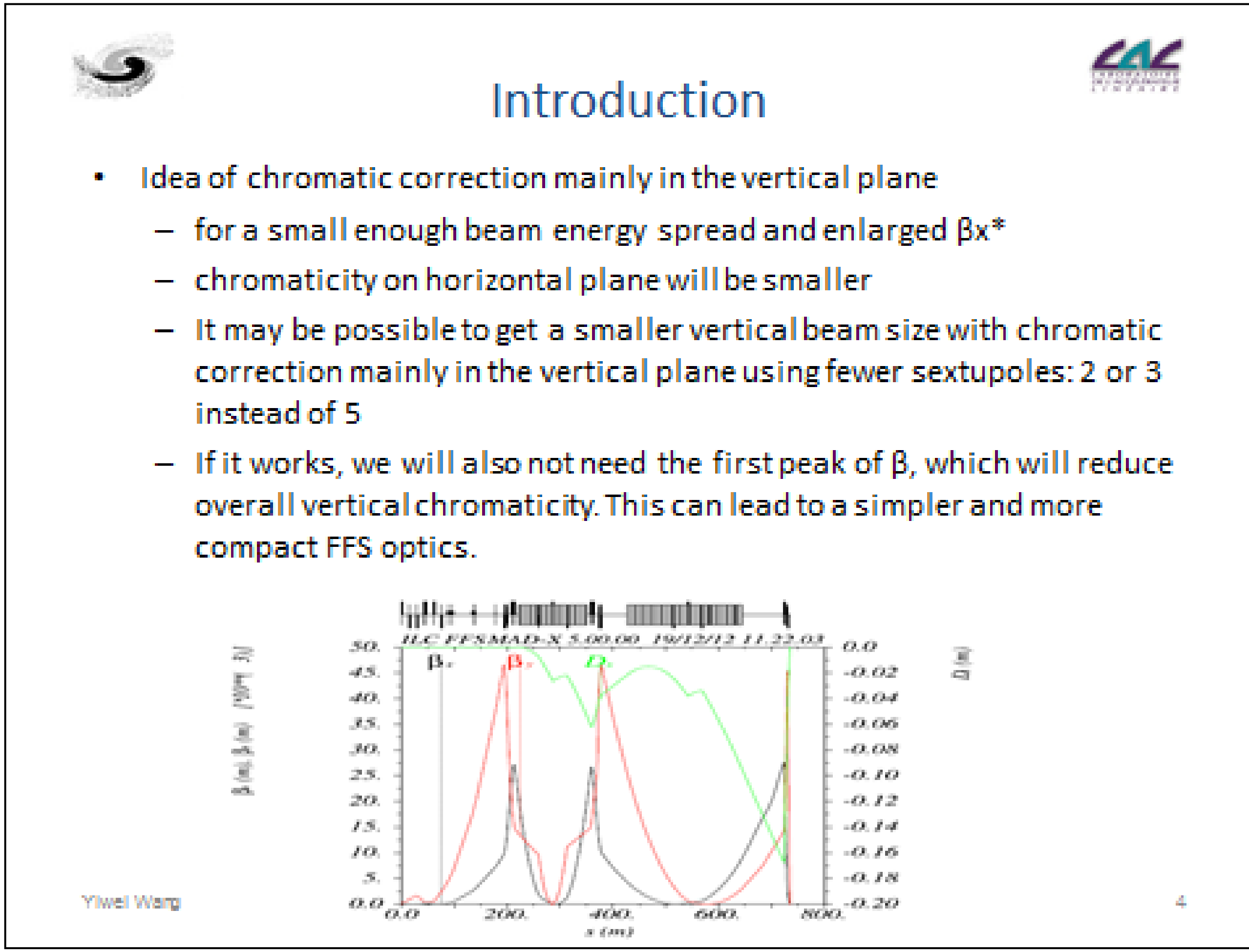
RE-OPTIMIZATION OF THE FINAL FOCUS SYSTEM OPTICS MAINLY WITH VERTICAL CHROMATIC CORRECTION



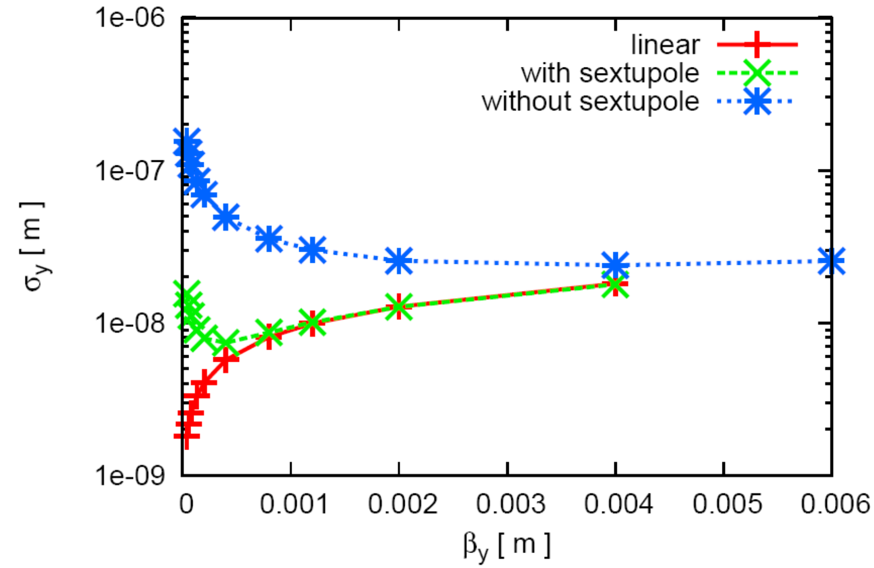
First presented by Yiwei WANG, CLIC workshop, January 2013

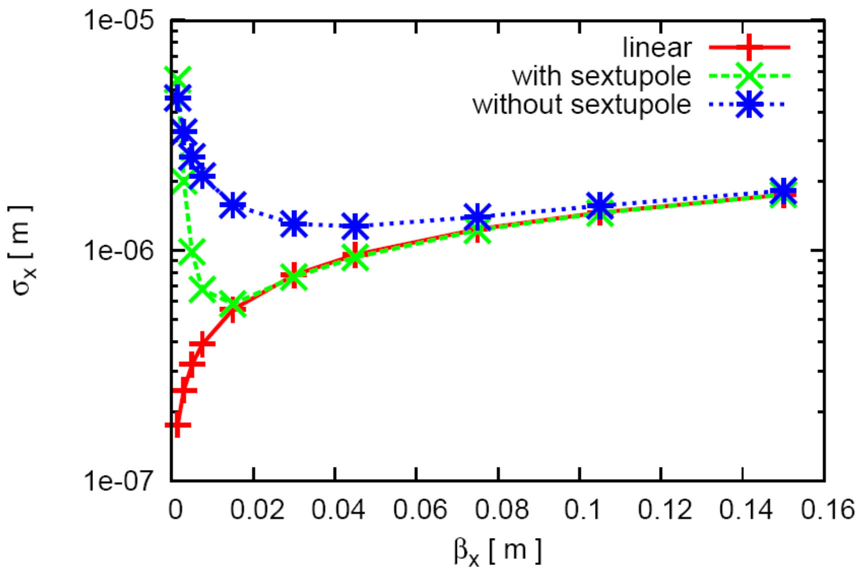
https://indico.cern.ch/contributionDisplay.py?contribId=191&confId=204269

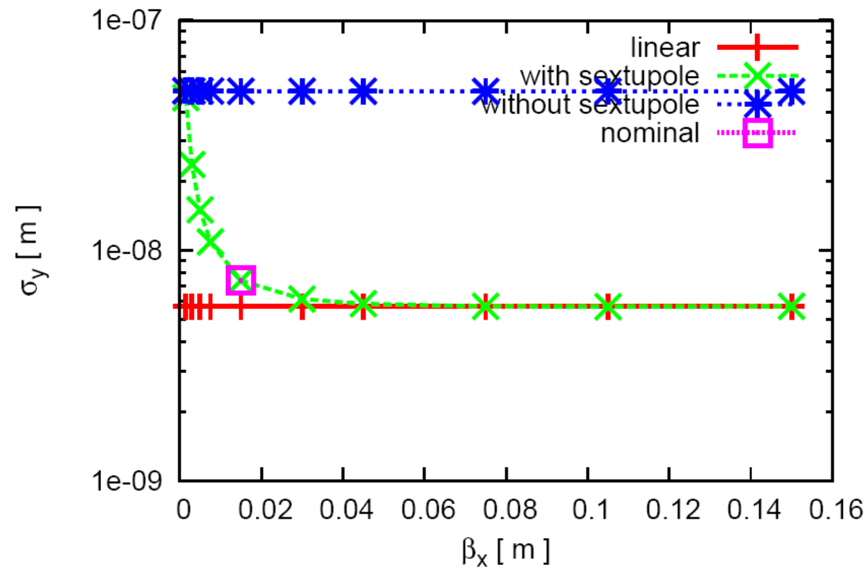
Further description, see TUPME024 @ IPAC13

Nominal ILC parameters used for initial study

Parameters	**Value**
Beam energy (GeV)	250
Normalized emittance (um)	10/0.04
Energy spread (%)	0.06
Beta functions at IP (mm)	15/0.4
Angular dispersion at IP	0.008
Beam sizes at IP (nm)	590/7.4
Beam divergence at IP (urad)	37/14

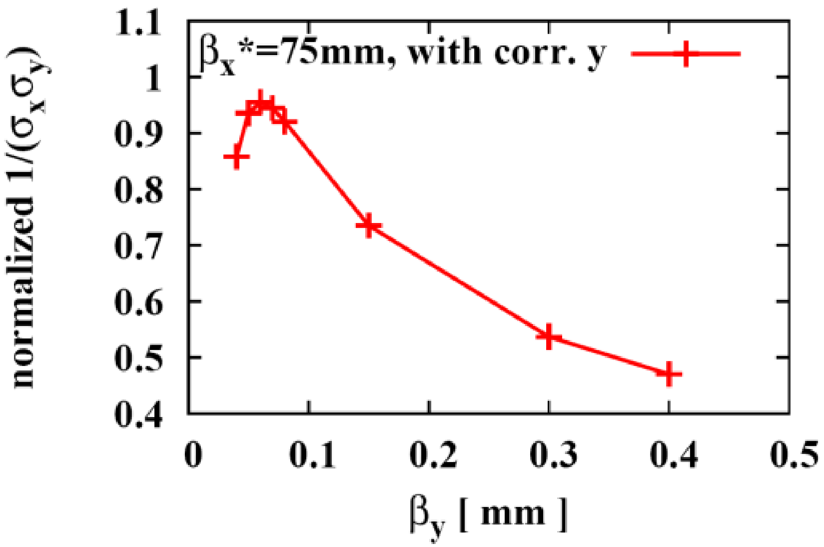






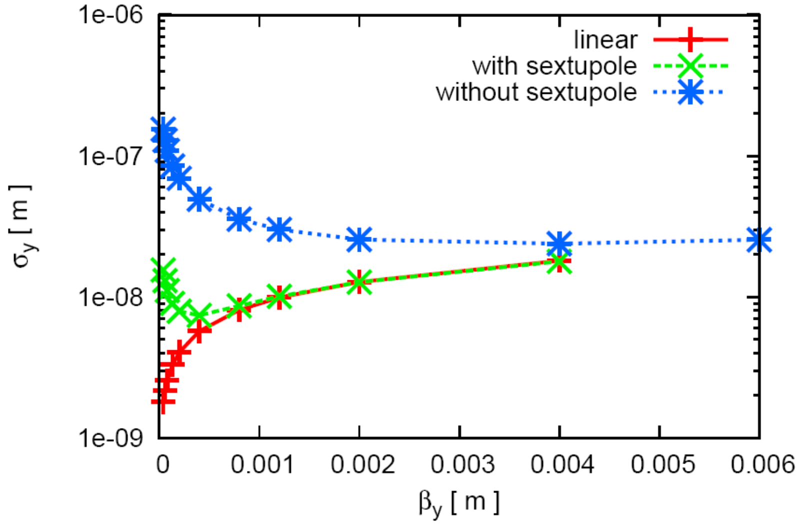
New parameters used for initial study

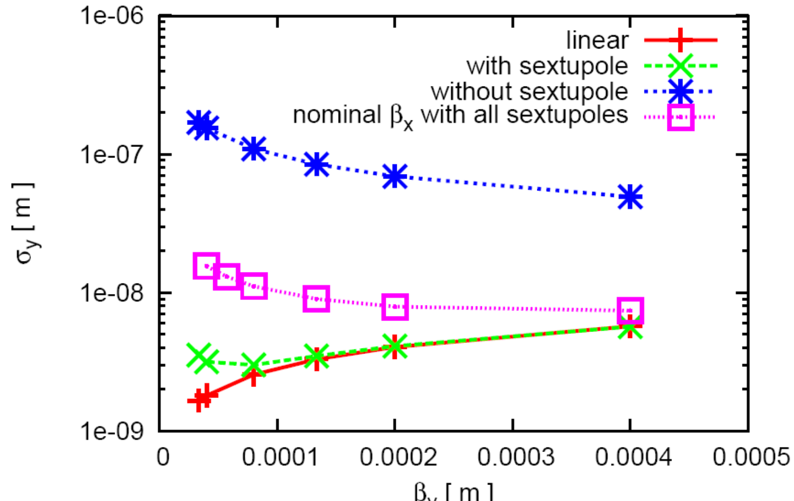
	Corr. x and y	Corr. y
sextupoles used	SD0, SF1, SD4, SF5, SF6	SD0, SD4
$\beta^*_{x,y}$ (mm)	15/0.4	75/0.06
$\sigma^*_{x,y}$ (μm/nm)	0.586/7.41	1.64/2.78



$$\delta_E \propto 1/(\sigma_x^2 \sigma_z)$$

σ_E/E_0=0.06%



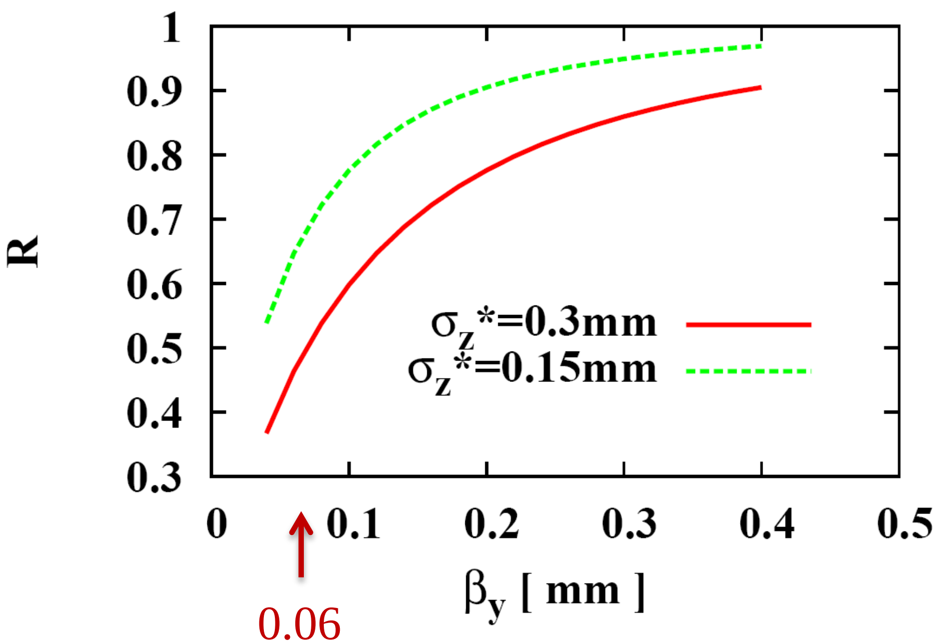


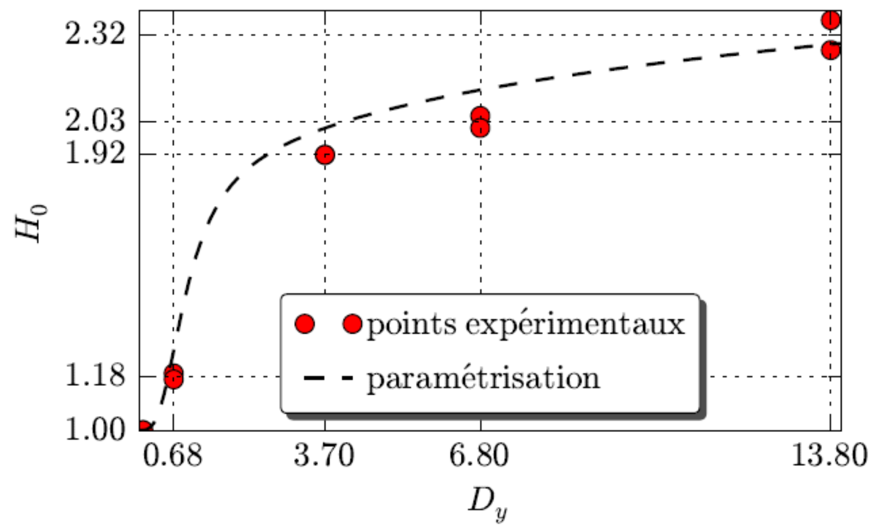
Problems

1. Hour glass degradation
2. Reduced pinch enhancement

$A_y = \sigma_z/\beta_y = 0.75 \rightarrow 2.5$

$D_y = \sigma_z/f_{eq} = 15.6 \rightarrow 7.5$





$$\eta(A_y) = \frac{1}{\sqrt{\pi} A_y} \exp\left(\frac{1}{2A_y^2}\right) \mathrm{K}_0\left(\frac{1}{2A_y^2}\right)$$

$$H_y \equiv 1 + D_y^{1/4} \frac{D_y^{\,3}}{1 + D_y^{\,3}} [\ln(1 + \sqrt{D_y}) + 2\ln(\frac{0.8}{A_y})]$$

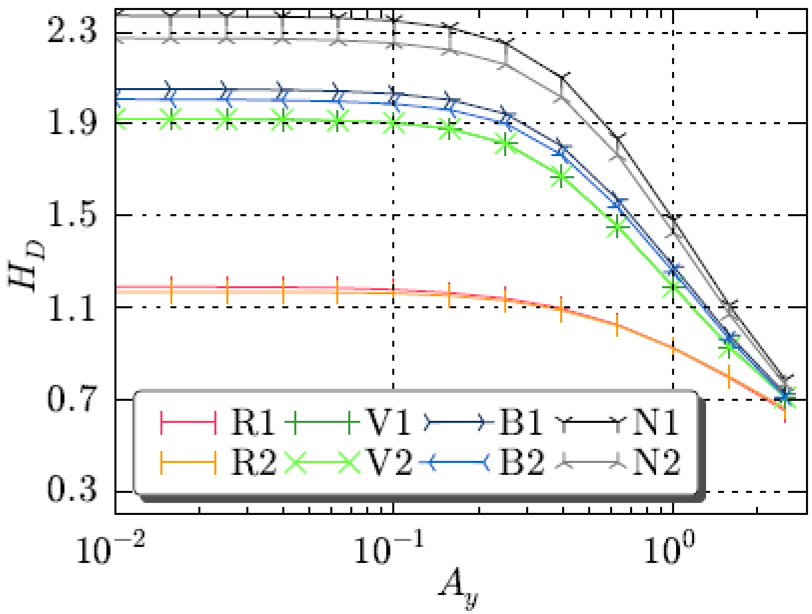
$$L = L_0 H_D \propto \frac{1}{\sigma_x^{\,*} \sigma_y^{\,*}} H_y^{\,1/3}$$ (for flat beam)

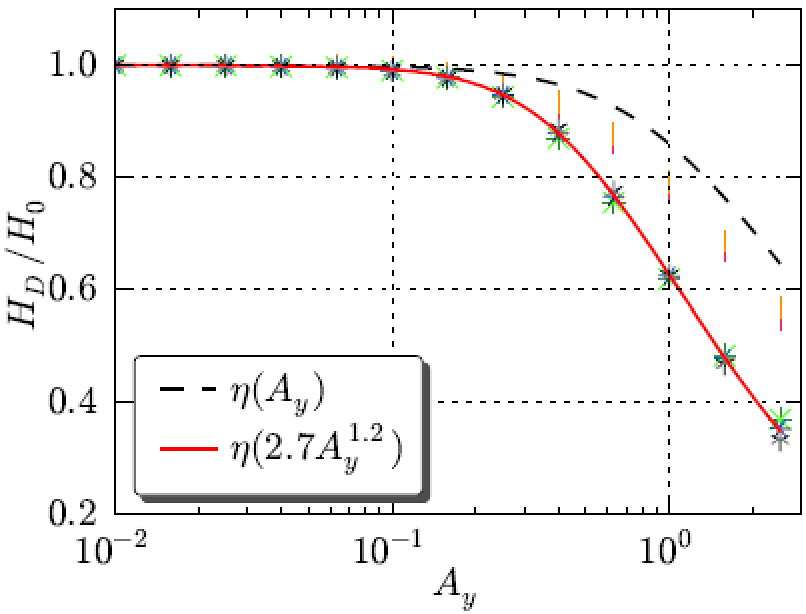
Yokoya-Chen parameterization **valid for Ay < 1**

Improved parameterization of pinch + hour glass effects

$$H_D \approx H_0.\eta(2.7A_y{}^{1.2})$$

H_0 from Yokoya-Chen parameterization for very small Ay (e.g. 0.1)

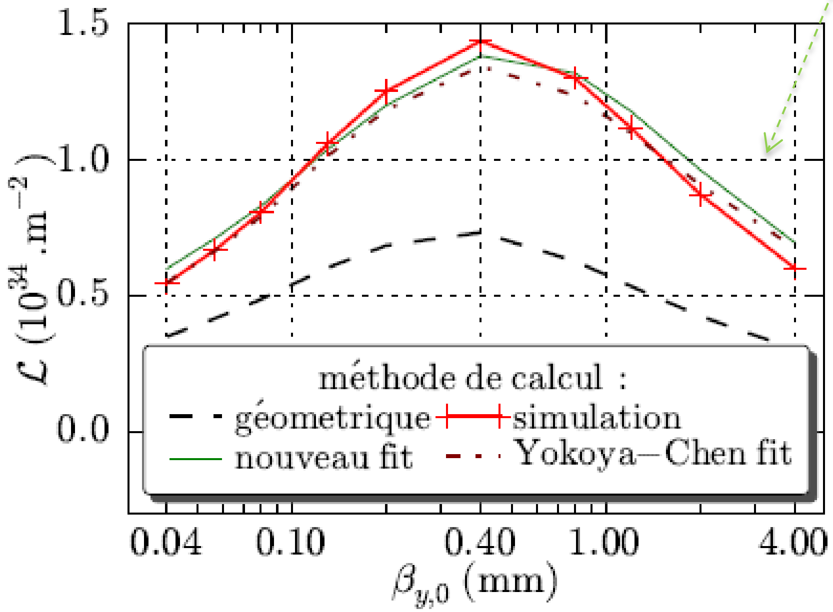




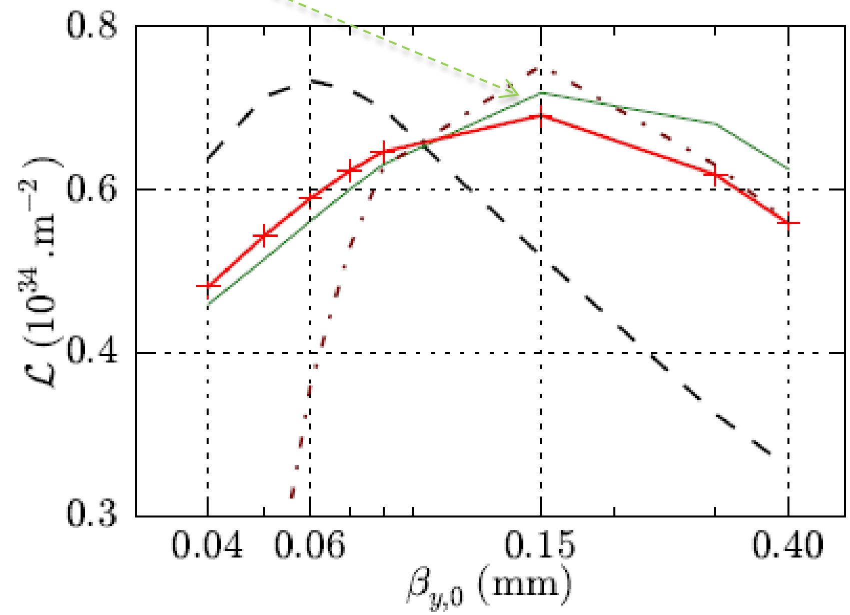
jeu		R1	R2	V1	V2	B1	B2	N1	N2
$\sigma_{x,y}$	nm	500/10		500/10		1000/5	500/10	490/10	495/5
σ_z	mm	0.3	0.15	0.3	0.15	0.15	0.3	0.3	
E	GeV	250	125	250	125	250		250	500
N	10^{10}	0.1		0.53		1	2	2	
D_y		0.68		3.7		0.68	0.69	13.8	

Comparing nominal and new parameters

$$H_D \approx H_0.\eta(2.7{A_y}^{1.2})$$



Nominal



New

→ factor 2 loss even with σ_z reduced to 0.15 mm…

(*effective β* used in parameterizations, H_0 = 2.3 for nominal & 2.0 for new*)

New alternative optical parameters

- For a flat beam like the one in ILC, the luminosity:

$$L = L_0 H_D \propto \frac{1}{\sigma_x{}^* \sigma_y{}^*} H_y{}^{1/3}$$

$$H_y \equiv 1 + D_y{}^{1/4} \frac{D_y{}^3}{1 + D_y{}^3} [\ln(1 + \sqrt{D_y}) + 2\ln(\frac{0.8}{A_y})]$$

$$D_y = \frac{2 N_e r_e \sigma_z}{\gamma \sigma_y{}^* (\sigma_x{}^* + \sigma_y{}^*)}$$

Yokoya-Chen parameterization

  - valid when $A_y = \frac{\sigma_z}{\beta_y{}^*} \leq 1$
- We try to get a more flat beam when keeping luminosity.
- Analysis to get target beam sizes
  - keep nominal luminosity L
  - reduce σ_z from 300 to 150 μm and keep $\beta_y{}^* \geq \sigma_z$ to mitigate hour glass effect
  - require $\sigma_y{}^* = \sqrt{(\varepsilon_y \cdot \beta_y{}^*)}$; usually possible if correct chromaticity mainly in vertical plane and beam sizes larger than minimum possible
  - get $\sigma_x{}^*$ with the formulas (to maintain luminosity)

New alternative optical parameters

- Just try some cases

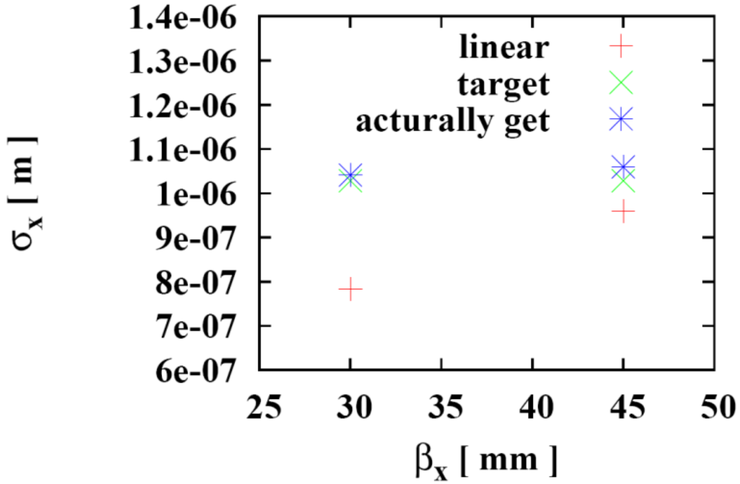
	Nominal	Alternative			
σz [um]	300	150			
$\beta x/\beta y$ [mm]	10/0.40	30/0.15	45/0.15	30/0.20	45/0.20
Ay	0.75	1.0	1.0	0.75	0.75
Dy	15.73	9.57	9.57	8.70	8.70
HD	1.68	1.40	1.40	1.53	1.53
$\sigma x/\sigma y$ [um/nm]	0.59/7.4	1.03/3.5	1.03/3.5	0.98/4.0	0.98/4.0

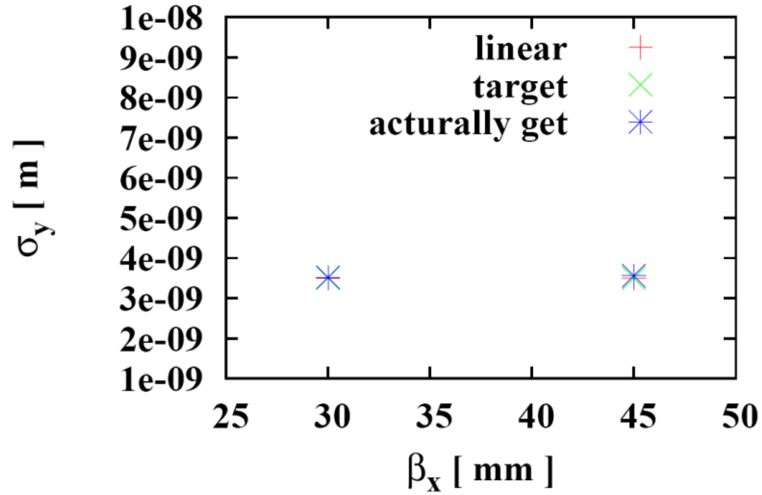
Approach to get actual beam size

- Approach to get actual beam size: refitting sextupoles for a partial horizontal chromaticity correction and full vertical chromaticity correction
- Benefits:
  - larger horizontal beam size lead to less beamstrahlung (good for the physics analysis, which need as narrow as possible a luminosity spectrum, and good to minimize the power losses in the post-IP extraction line)
  - hopefully weaker (and maybe fewer) sextupoles, which could make the experimental optics tuning easier and faster.

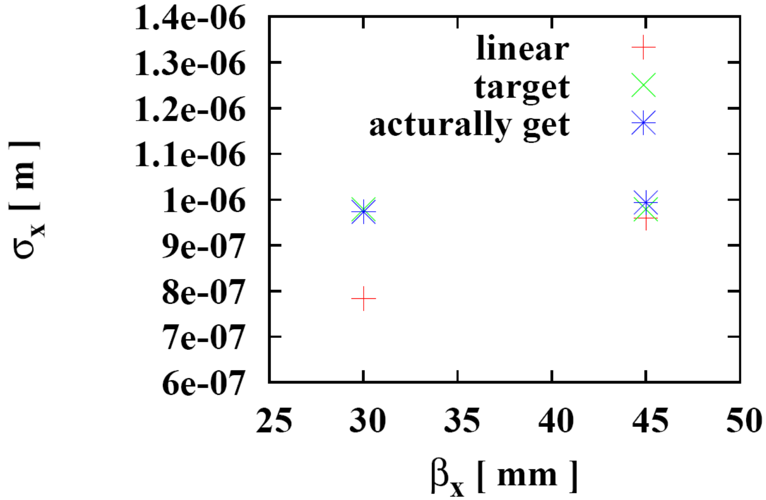
Beam sizes

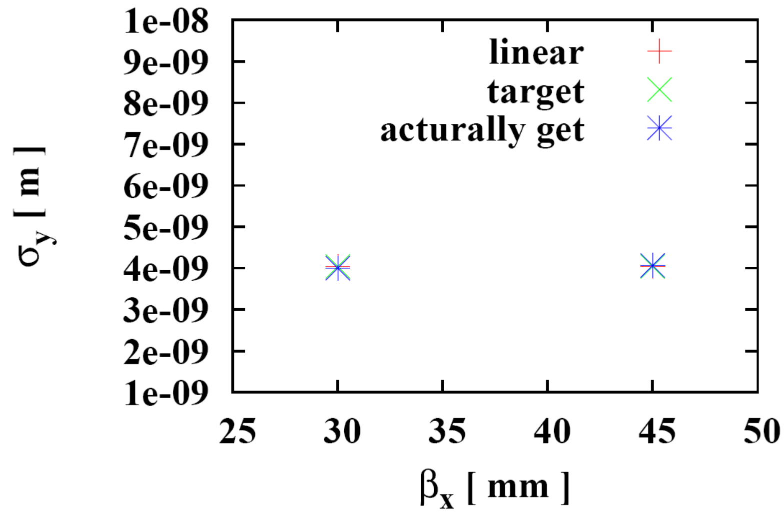
- βy* =0.15mm





- βy* =0.20mm





Strength of sextupoles

- Strength of sextuples reduced (unless SF5)
  - Luminosity almost kept (beam-beam effects and hour glass computed with Yokoya-Chen parameterization in its range validity; need to check explicitly with simulation and the newly improved parameterization)
  - require shorter bunch length
- What about reduced number of SF?

	Nominal	Alternative			
βx/βy [mm]	10/0.40	30/0.15	45/0.15	30/0.20	45/0.20
SF6 [T/m^2]	1.668071388	-0.9507968226	-1.037483768	-0.7057787623	-0.8239939231
SF5 [T/m^2]	-0.3405860307	-1.70228915	-1.86899529	-1.618001764	-1.935613445
SD4 [T/m^2]	3.101270368	2.800147791	2.857649495	2.851411093	2.98316516
SF1 [T/m^2]	-4.959589067	-1.195270433	-1.369704911	-1.732328281	-2.174174184
SD0 [T/m^2]	7.323742058	6.895163295	6.998757101	7.007166395	7.236357582

Conclusions and prospects

- Originally proposed scheme with only 2 sextupoles to correct only the vertical chromaticity would require unreasonably small bunch length to maintain the luminosity
- An intermediate scheme seems feasible, which retains some of advantages of flat beams while keeping high luminosity
  - weaker and / or fewer sextupoles for easier handling of the FFS
  - less beamstrahlung
- It can be considered as alternative parameter set of the existing design, not a new design
- There is room for optimization
- New parameterization of the pinch luminosity enhancement
- A full study should consider all energies and different energy spreads at ILC, as well as more complete beam-beam calculations
- For flatter beams, may still consider new / simplified FFS design ideas