Non-linear optimization of the BDS using MADX-PTC

R. Tomás
in collaboration with J. Resta, D. Schulte &
F. Zimmermann

CLIC - 7th of February 2006

Motivation & contents

Compensate the residual high order aberrations of the FFS to increase luminosity

- Analytical computation of beam sizes at the IP
- The beam sigmas order by order
- Optimization of beam sizes
- What about the usable luminosity?
- Outlook

Computation of beam sizes at the IP

Given the transfer map between one location of the accelerator and the IP in the form:

$$x_{IP} = \sum X_{jklmn}\, x^j\, p_x^k\, y^l\, p_y^m\, \delta^n$$

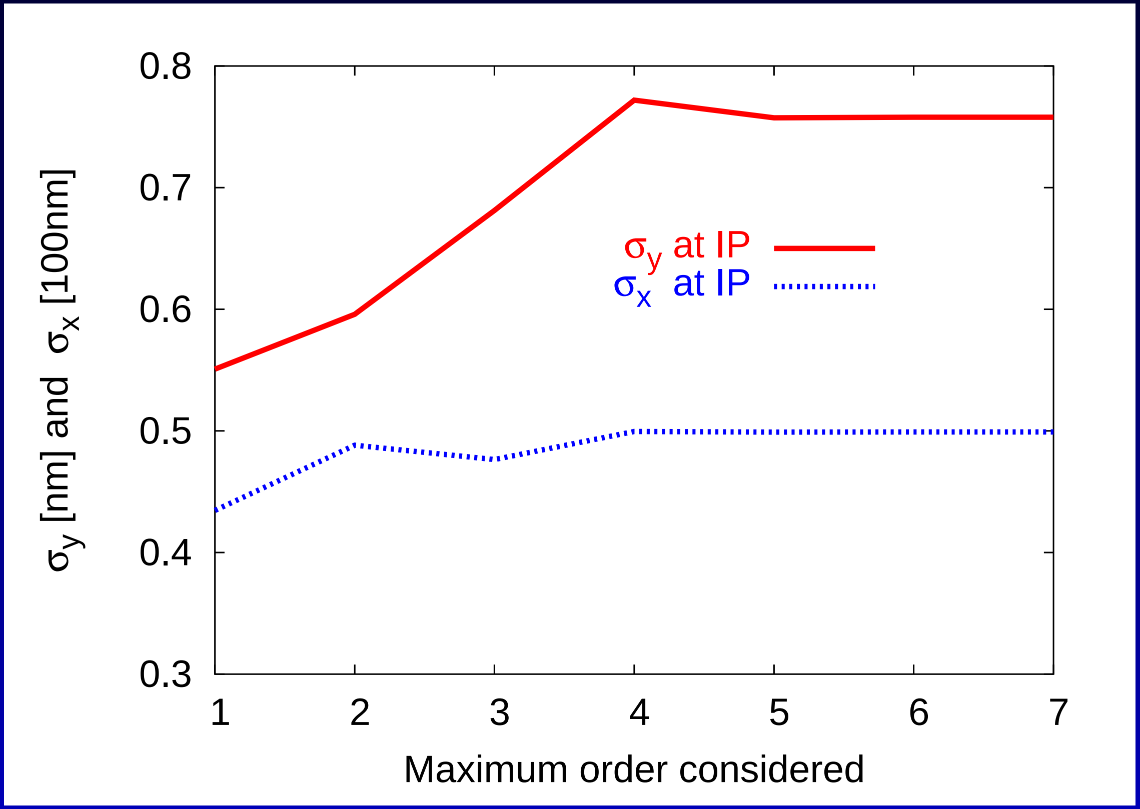
and given the particle density at the initial location, the rms beam size at the IP is given by:

$$\sigma_{IP}^2 = \sum X_{jklmn} X_{j'k'l'm'n'} \int x^{j+j'} p_x^{k+k'} y^{l+l'} p_y^{m+m'} \delta^{n+n'} \rho dv$$

The integral is performed depending on ρ and the X_{jklmn} are obtained to arbitrary order from MADX-PTC (thanks to E. Forest, F. Schmidt, et al).

The beam sigmas order by order

Nominal FFS design and beam parameters



Aberrations exist up to the fifth order!

Biggest contributors to vertical size

Contribution to σ_y^2	j	k	l	m	n	j'	k'	l'	m'	n'
6.109200e-19	0	0	1	0	0	0	0	1	0	0
-1.43715e-19	0	0	1	2	0	0	0	1	0	0
1.221256e-19	1	1	0	1	1	1	1	0	1	1
1.166679e-19	0	2	0	1	1	0	2	0	1	1
1.035384e-19	0	0	0	1	0	0	0	0	3	0
-1.02905e-19	0	2	0	1	1	0	0	0	1	1
9.762807e-20	0	0	1	0	0	0	0	1	0	2
-8.07838e-20	2	0	0	1	1	0	0	0	1	1
7.476994e-20	0	0	0	1	0	0	0	0	1	0
7.189904e-20	2	0	0	1	1	2	0	0	1	1
6.807446e-20	0	0	0	1	1	0	0	0	1	1
-6.58350e-20	0	0	0	1	2	0	0	0	1	0
...										

Third and Fourth order terms are the heaviest after linear

Optimization of the beam sizes

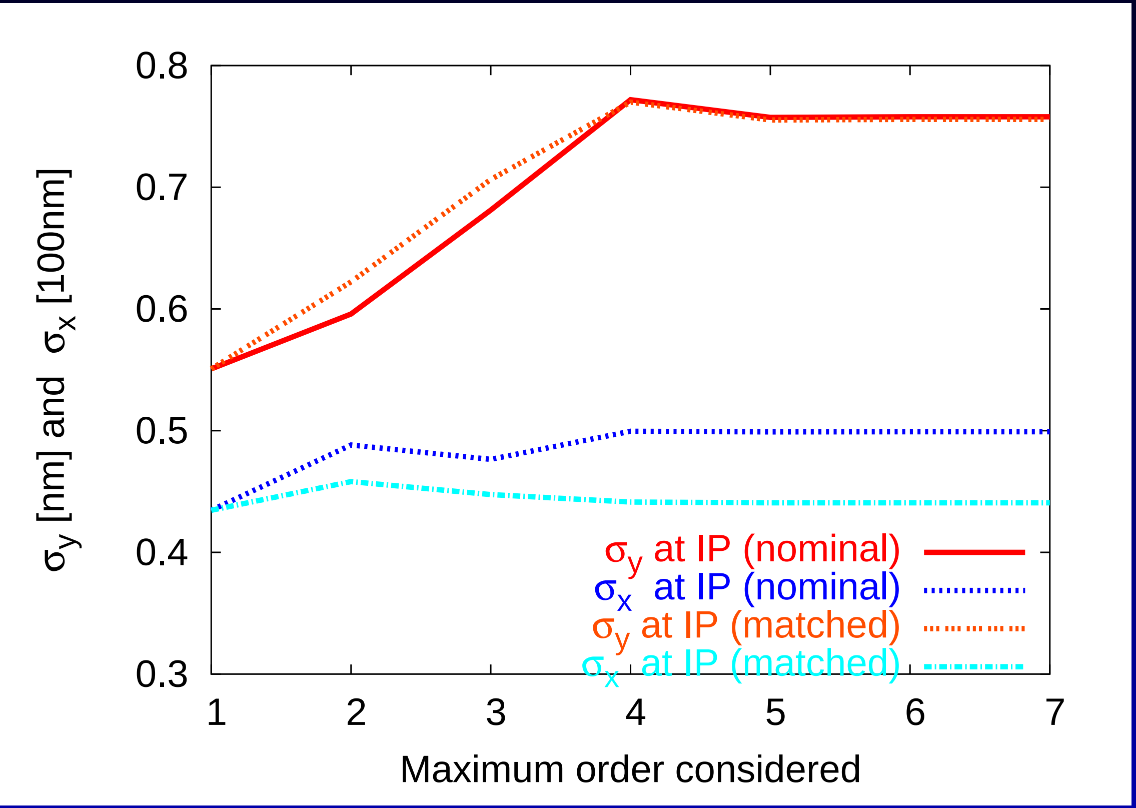
MAPCLASS is a Python code that:

- Generates/reads MADX input/output
- Computes σ_x and σ_y from map coefficients
- Uses either SVD or the Simplex algorithms to optimize the sigmas†

Four examples follow on the optimization of the FFS by varying strengths.
Luminosity is computed for the different cases with PLACET without SR.

† in general any quantity can be optimized

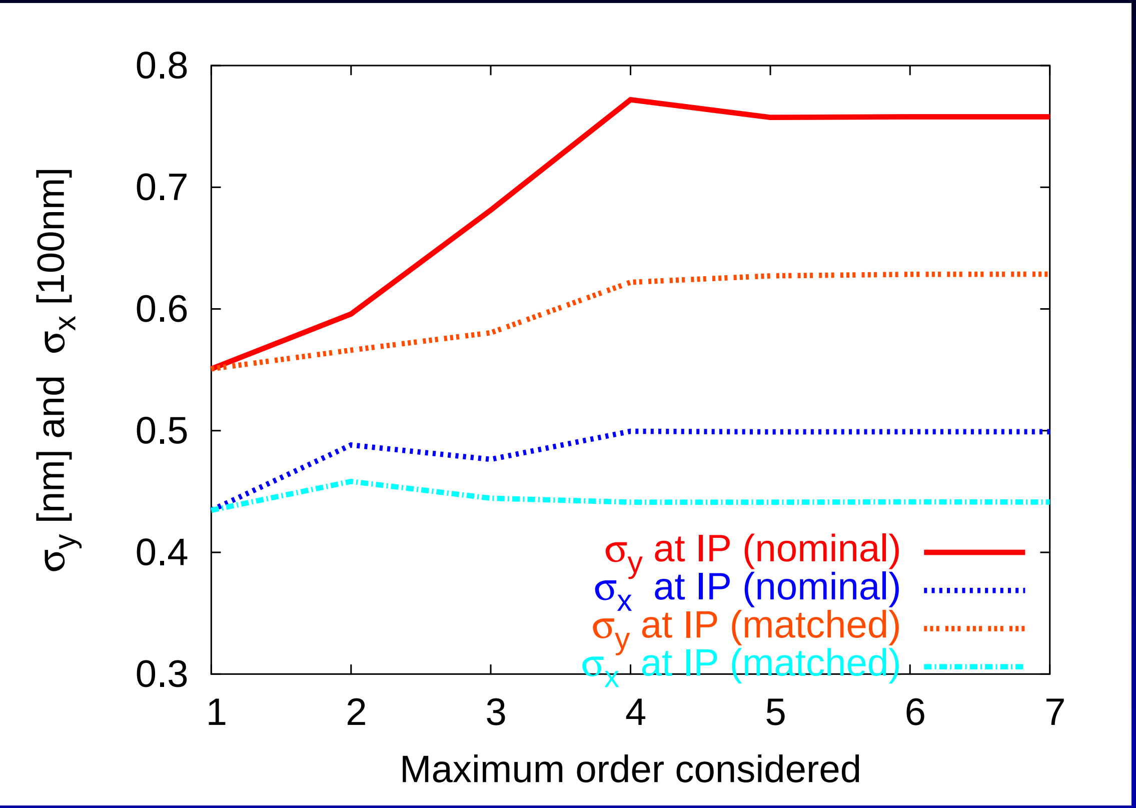
Using only the sextupoles



A small adjustment in the strengths of the 5 sextupoles gives a 12% reduction in σ_x leaving σ_y unchanged.

Luminosity increase of 4%

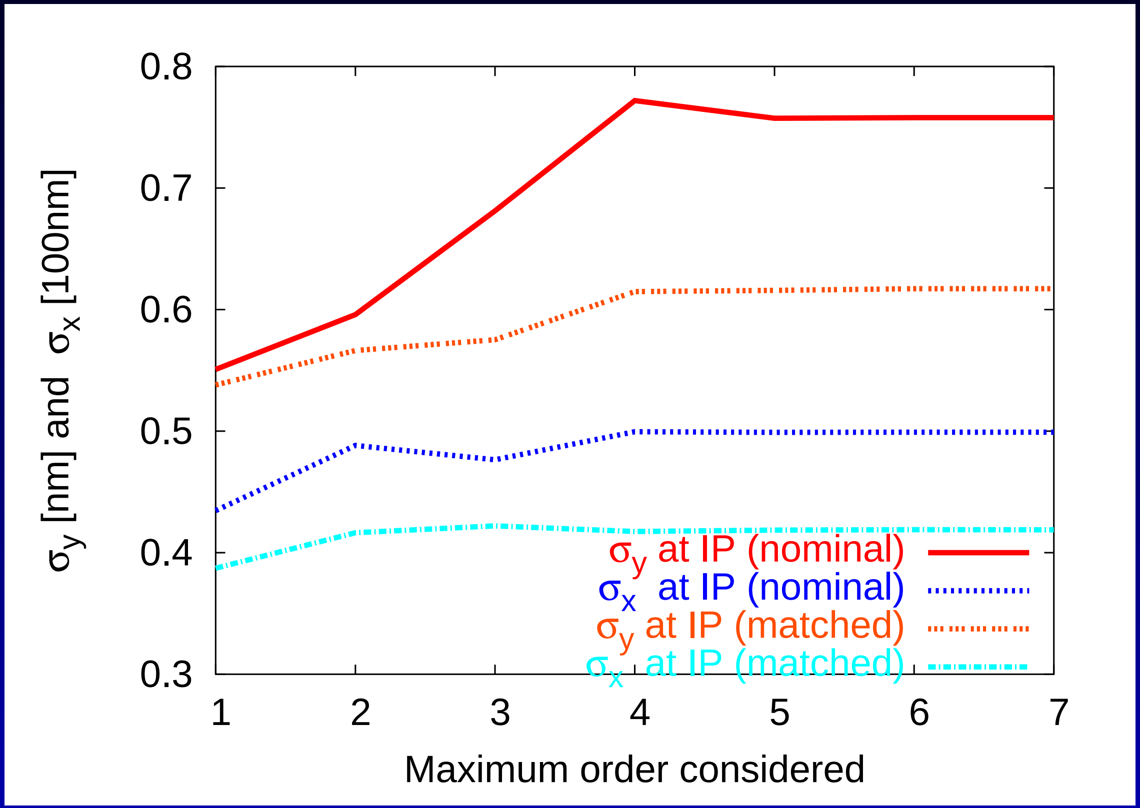
Plus 1 sextupole, 1 octupole & 2 decapoles



With a total of 9 parameters σ_x and σ_y are reduced by 12% and 17% respectively.

Luminosity increase of 5% $\Rightarrow$ Not corresponding

Plus using the strength of the quadrupoles

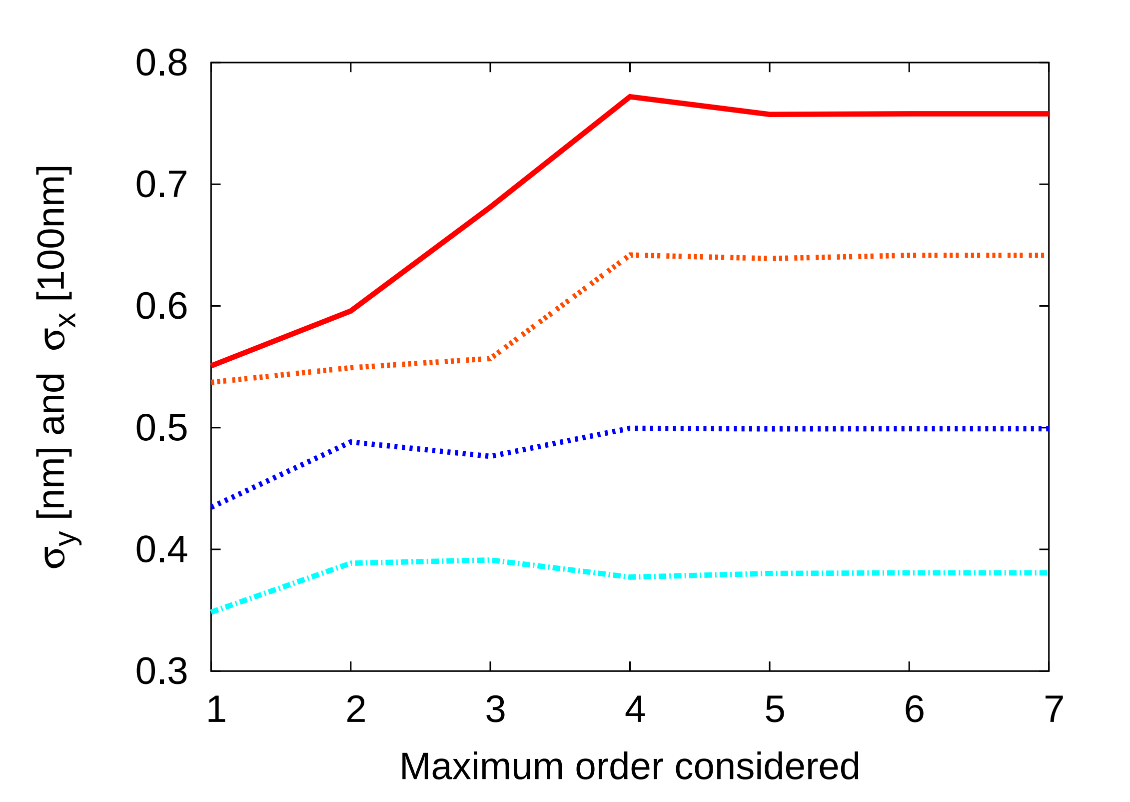


With a total of 21 parameters σ_x and σ_y are reduced by 16% and 18% respectively.

Luminosity increase of 17%

(β_x^*=6.3mm ≈-10%, β_y^*=86.8μm ≈-6%)

Pushing the envelope



With a total of 21 parameters σ_x and σ_y are reduced by 24% and 15% respectively.

Luminosity increase of 35%

(β_x^*=5.2mm ≈-26%, β_y^*=86.5μm ≈-5%)

What about the usable luminosity?

$L_{1\%}$ is the luminosity of the particles with an energy larger than $0.99 \times E_{peak}$, the *usable* luminosity.

$Case$	$-\frac{\Delta\sigma_x}{\sigma_x}$	$-\frac{\Delta\sigma_y}{\sigma_y}$	$\frac{\Delta L_{tot}}{L_{tot}}$	$\frac{\Delta L_{1\%}}{L_{1\%}}$	$\frac{L_{1\%}}{L_{tot}}$
Nominal	0	0	0	0	35
Only sexts	12	0	4	5	35
Sexts, oct & decs	12	17	5	13	38
Full I	16	18	17	14	34
Full II	24	15	35	15	30

(All numbers are percent)

$\Rightarrow$ Looks like $L_{1\%}$ is mostly affected by σ_y

Outlook

- Use more parameters and evaluate different optics
- Consider synchrotron radiation
- Optimize the full BDS at the same time (the non-linear collimation already optimized independently, see Javier's talk)
- Improve the model with $< xy >$, $< x^3 >$, $< y^4 >$,... ?