Energy spread in ATF2 final focus simplified line

Beta functions and emittance

Beta functions : describes the amplitude of the transverse beam motion

ε : emittance of the beam

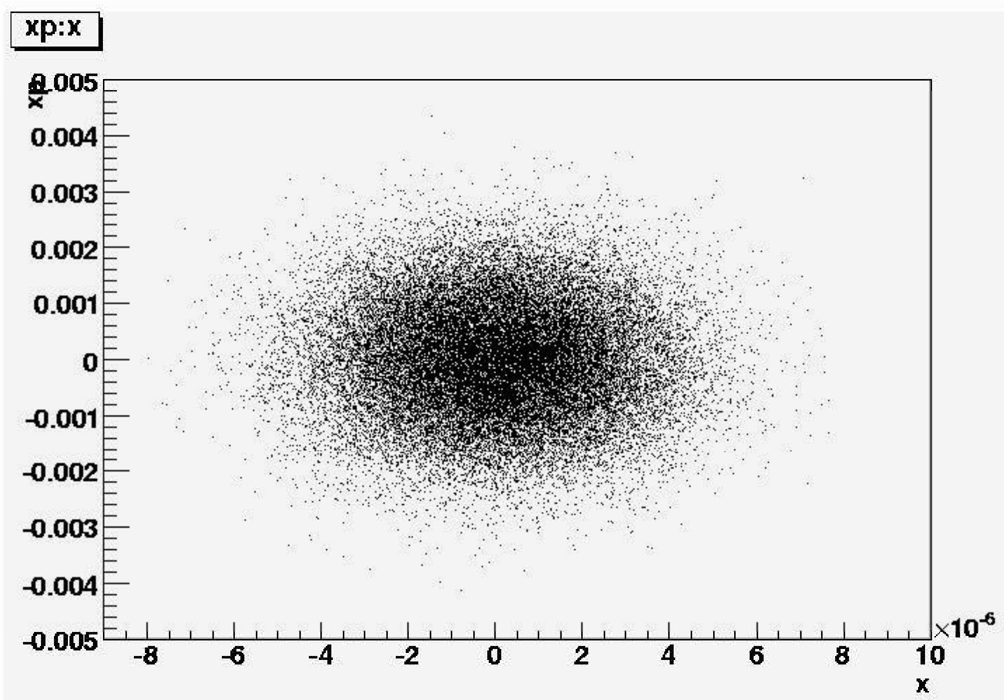
x : transverse size of the beam

x' : angle of each particle trajectory within the beam

$$x = \sqrt{\varepsilon_x \beta_x}$$

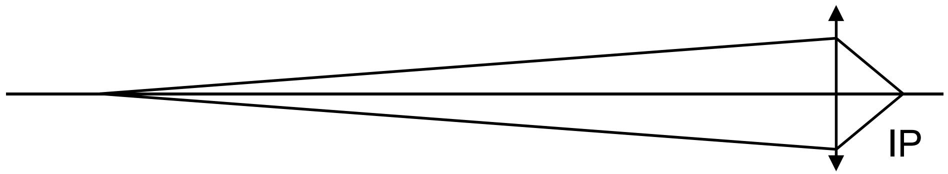
$$x' = \sqrt{\frac{\varepsilon_x}{\beta_x}}$$

In ATF2 line,
ε_x=2.e-9
β_x=0.004
ε_y=1.17e-11
β_y=0.0001

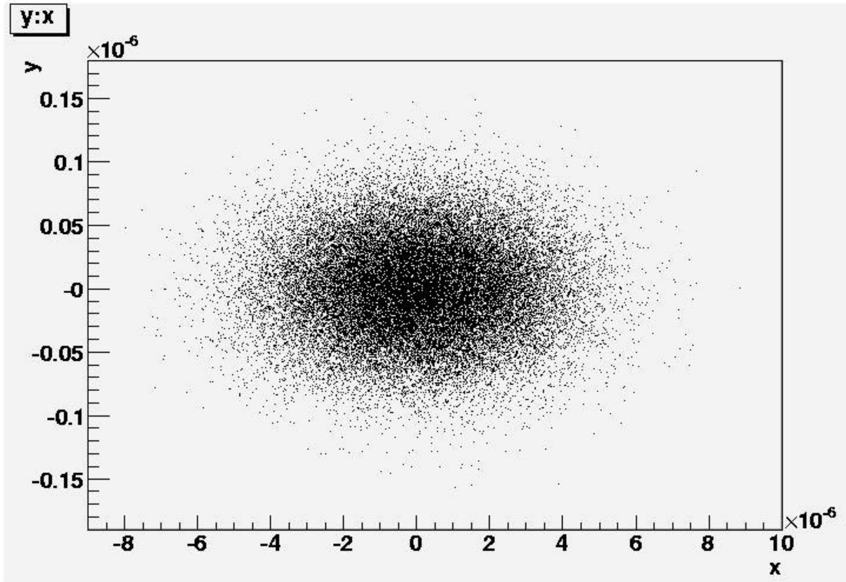


Simplified line with just two quadrupoles

Simplified line with one focusing and one defocusing quadrupole.

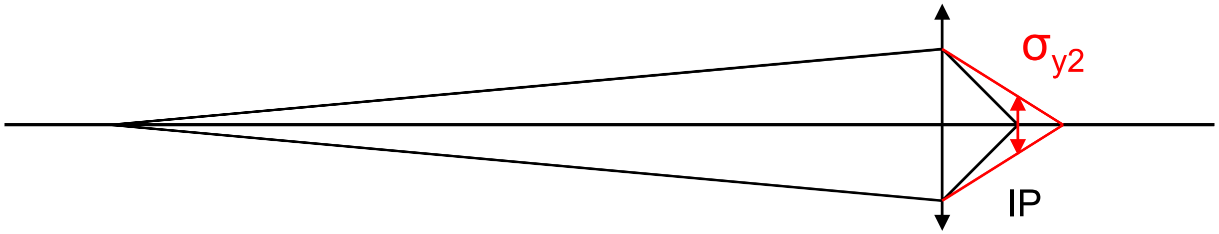


Quadrupole is like a magnetic lens, but can only focus in one transverse plan.



Beam at the interaction point

Beam size with quadrupoles and energy spread



Beam size :

E_{spread}=0, σy=34nm and x=2.9µm

$E_{spread}=10^{-3}$, σy=465nm due to chromaticity

To get the minimal beam size with the energy spread, the first and second order contributions must balance :

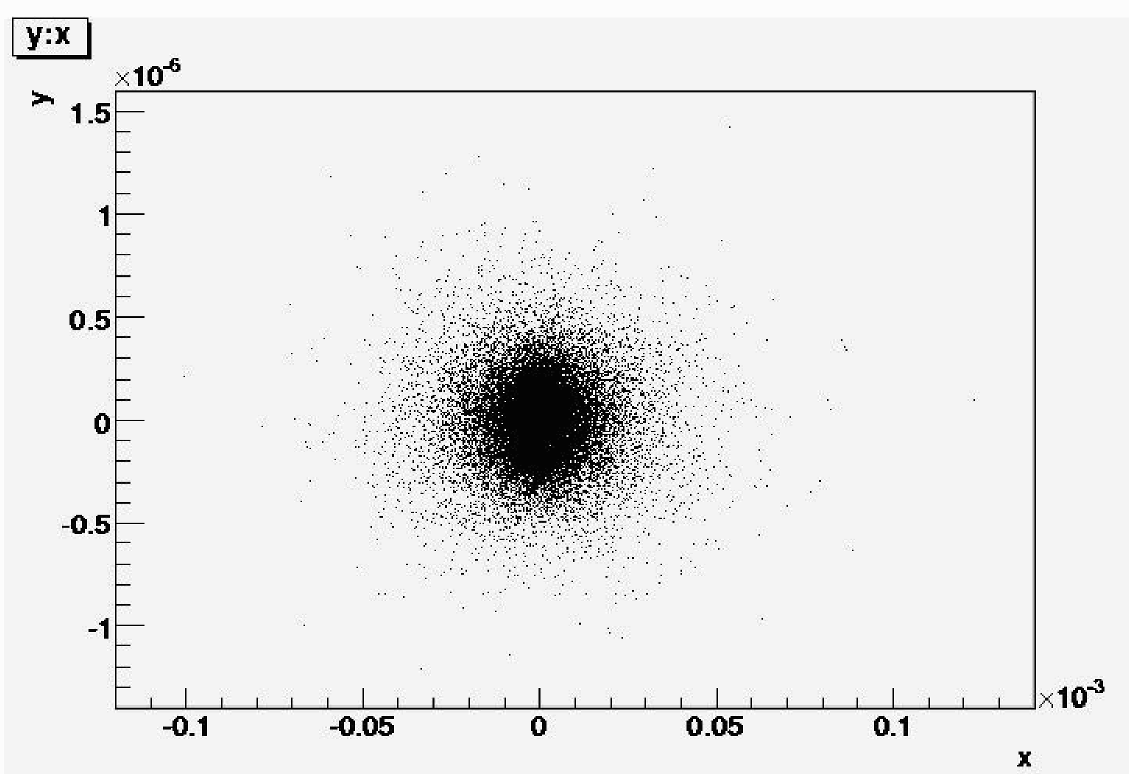
$$\sigma_y^2 = \sigma_{y1}^2 + \sigma_{y2}^2$$

Minimum beam size with quadrupoles and energy spread

$$\sigma_{y1} = \sqrt{\varepsilon\beta} = l\frac{\delta p}{p}\sqrt{\frac{\varepsilon}{\beta}} = \sigma_{y2}$$

so $$\beta = l\frac{\delta p}{p} = 10^{-3}$$

and σ_y =170nm.



σ_y =183nm

Simplified line with sextupoles

Dependance of quadrupole strength with en energy spread :

$$K = K_Q (1 - \delta)$$

$$\delta = \frac{p - p_0}{p_0}$$ where d is the relative momentum deviation

Horizontal displacement

$$x \rightarrow x + D_x \delta$$

Chromaticity compensation

Compensation by the sextupoles of quadrupole chromaticity

$$dx'_Q = K_Q l_Q (1-\delta)(x + D_x\delta)$$
$$= K_Q l_Q (x + D_x\delta - x\delta - D_x\delta^2)$$

$$dy'_Q = K_Q l_Q (1-\delta) y$$
$$= K_Q l_Q (y - \delta y)$$

$$dx'_S = \frac{1}{2} K_S l_S (x + D_x\delta)^2$$
$$= \frac{1}{2} K_S l_S (x^2 + 2D_x x\delta + D_x^2\delta^2)$$

$$dy'_S = K_S l_S (x + D_x\delta) y$$
$$= K_S l_S (xy + yD_x\delta)$$

Second order aberrations contributions

This is an approximation of the aberrations. In fact, the beam size can be written as :

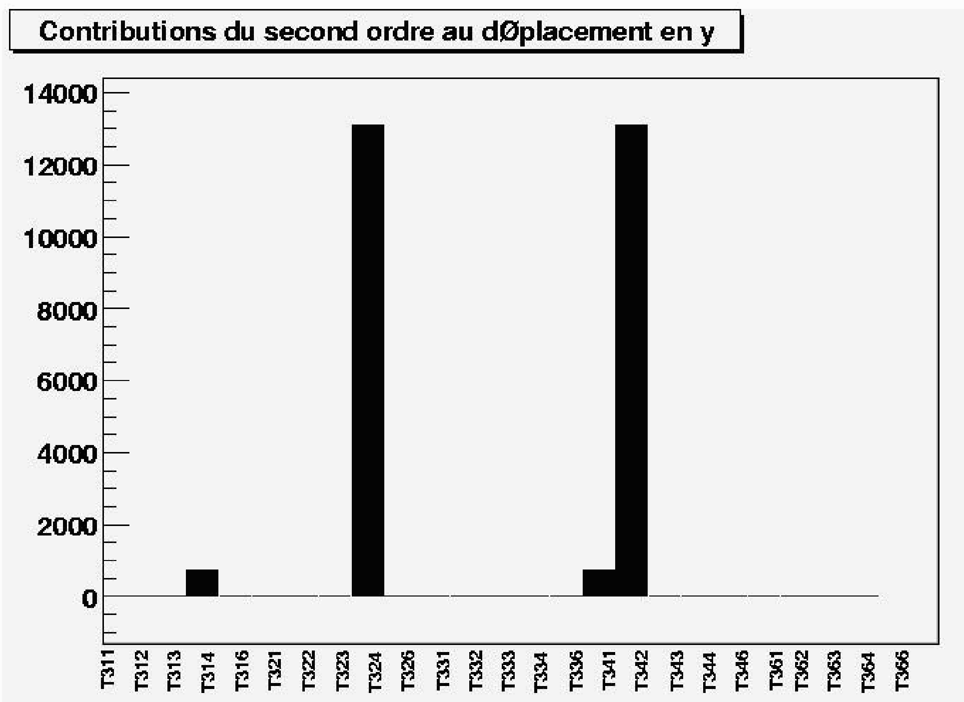
$$\Delta x_i^{(2)} = T_{ijk} \Delta x_j^{(1)} \Delta x_k^{(1)}$$

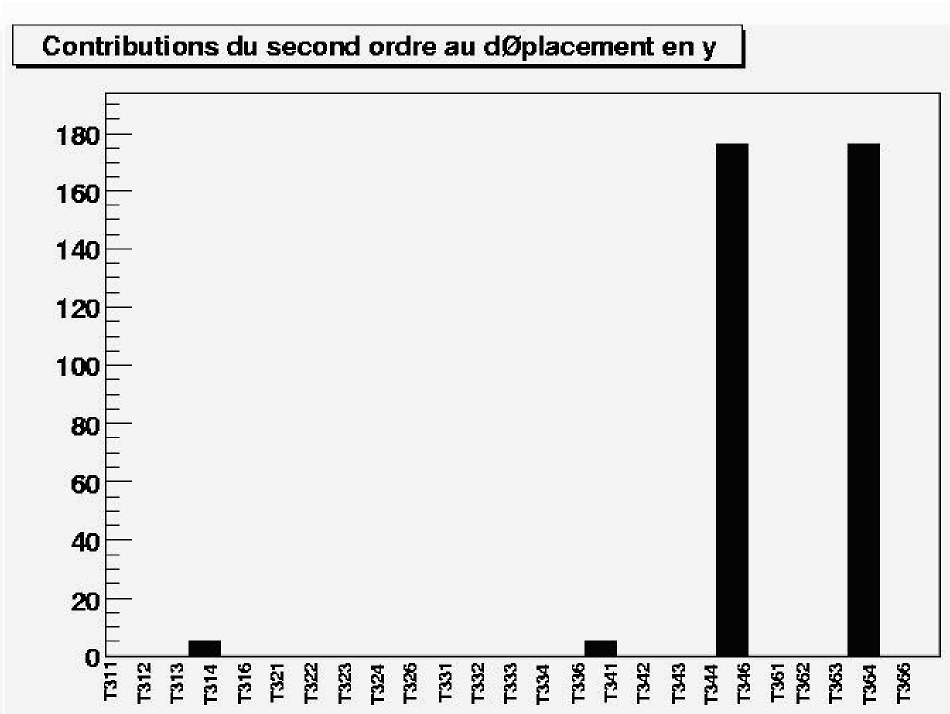
Horizontal contribution : T_{126} and T_{166}

Veritical contribution : T_{346} and T_{342}

The sextupoles can be fitted with MAD8, in order to cancel some of the aberrations. In the simplified line, there are not enough sextupoles to cancel T_{324} and T_{346}, which give the main vertical contributions.

Contributions of second order aberrations

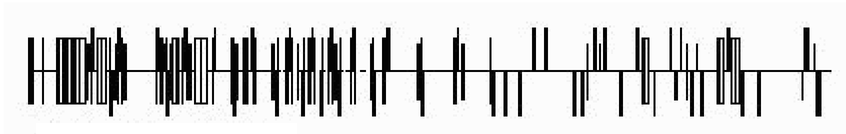




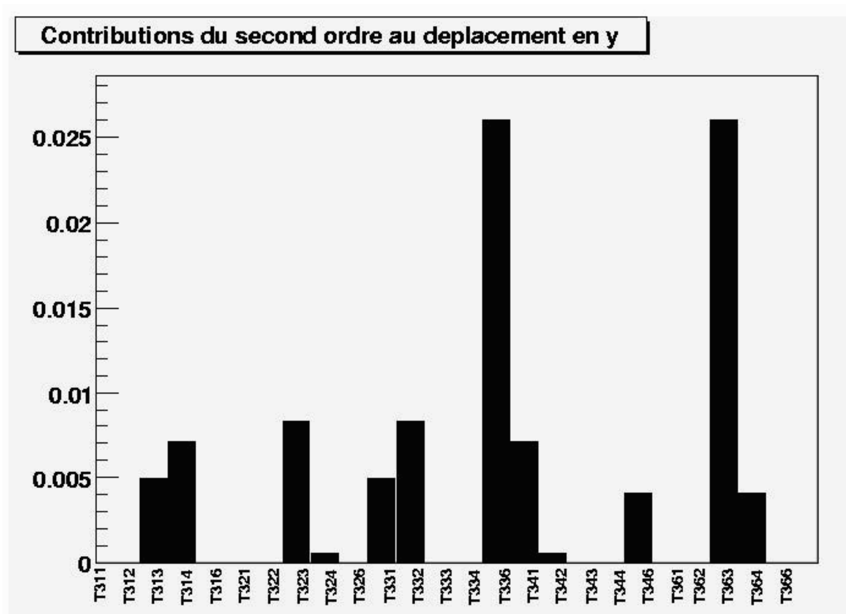
T_{346}=0, y=31.2μm

T_{342}=0, y=793μm

ATF2 line

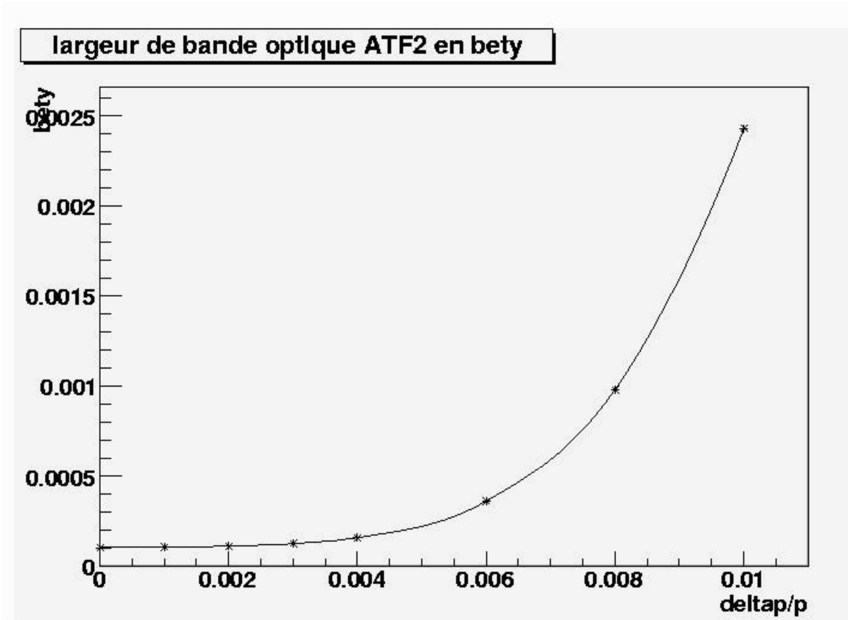


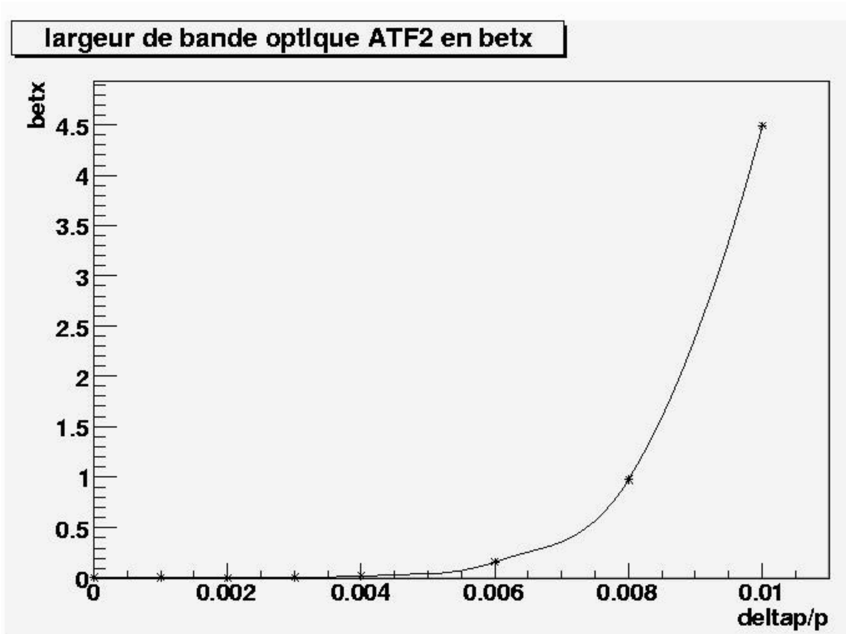
Many quadrupoles and
sextupoles to correct chromaticity



ATF2 line

Stability of betax and betay until energy spread =0.004





Perspectives

- Get different parameters (IP beta functions) for ATF2 line
- Determine third order contribution with energy spread
- Oide effect, and energy independance