Experimental procedure for IP beta-tuning / transport at 3 IP waists

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Variable $\beta_{x,y}$ at longitudinally displaced IP

Beam size at focal point is a function of choice of FD effective focal length (L*) and injected beam matching

→ L* adjusted by FD strength
→ injected beam adjusted by QM12,13,14,15,16

During commissioning, Honda monitor and wire scanner at displaced IP, respectively at -54cm and +39cm, with resolutions of 300-1000 nm.

Honda Monitor: 350nm – 1 micron

(-540mm from IP)

Carbon Wire: > 1 micron

(+390mm from IP)

Study on shifted IP+0.39m and IP-0.54m:

A. for IP-54cm, use the following procedure to get the focal point:

1) Use QM12~16 to obtain:

$\beta_x=4\times\beta_{xnominal}$ $\beta_y=4\times\beta_{ynominal}$

at the nominal IP.

2) Replace QM12~16 values obtained in 1) into files and fit QD, QF to obtain $\alpha_x=\alpha_y=0$

at the nominal IP.

at IP displaced by 54cm (not converged, because it's nonlinear)

3) do it step by step:

each time use QD, QF values obtained in last iteration.

Example: start from initial IP with

$\beta x = 4 \times \beta_{xnominal} = 0.016m$, $\beta y = 4 \times \beta_{ynominal} = 0.0004m$

- IP-0.1m :

$\beta x = 0.015m$, $\beta y = 0.0003m$

- IP-0.2m :

$\beta x = 0.014m$, $\beta y = 0.00027m$

- IP-0.3m :

$\beta x = 0.013m$, $\beta y = 0.0002m$

- IP-0.4m :

$\beta x = 0.012m$, $\beta y = 0.00013m$

- IP-0.54m :

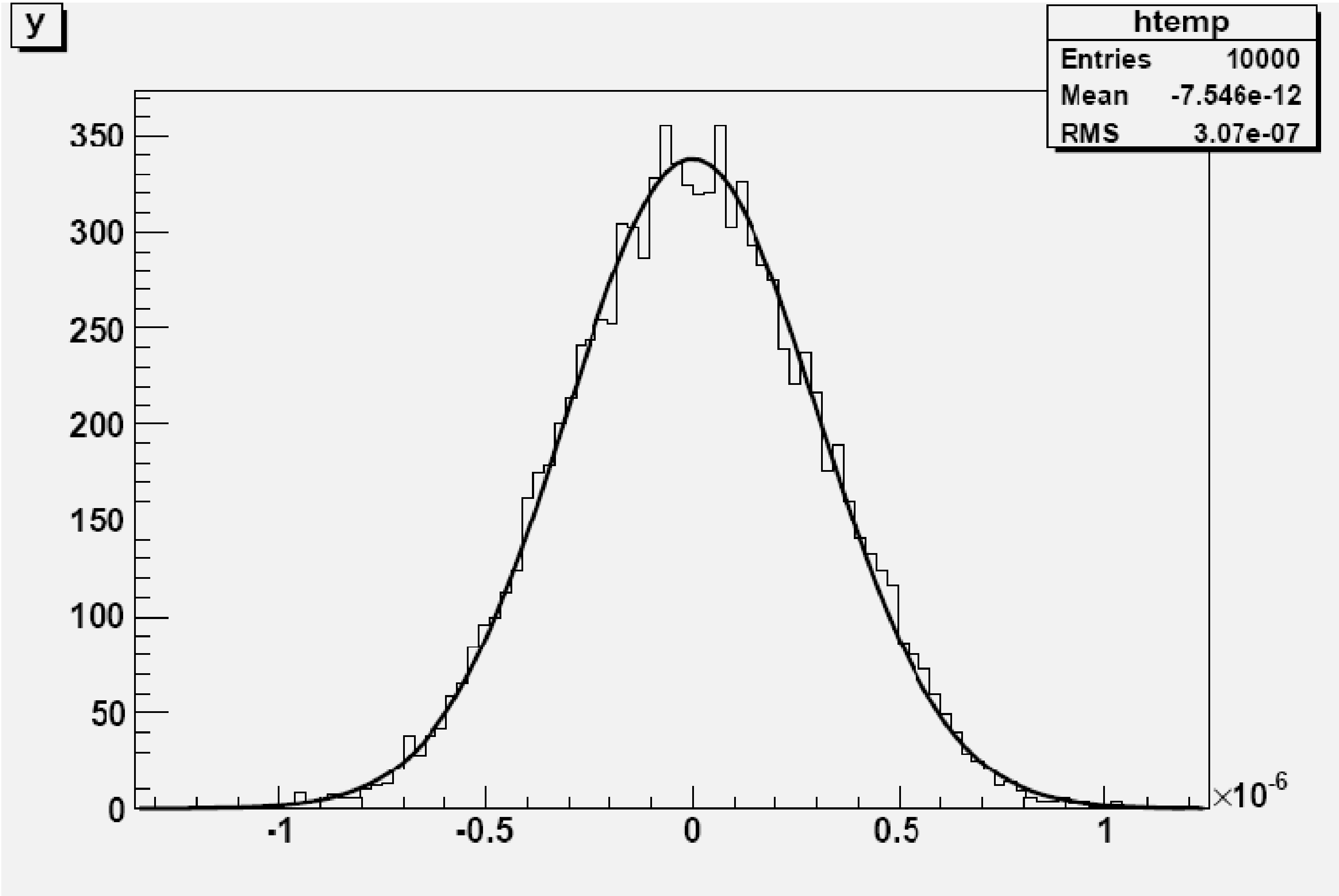
$\beta x = 0.004m$, $\beta y = 0.0001m$

4) fit all the five sextupoles to get:

T126=0, T122=0, T346=0, T342=0, T166=0

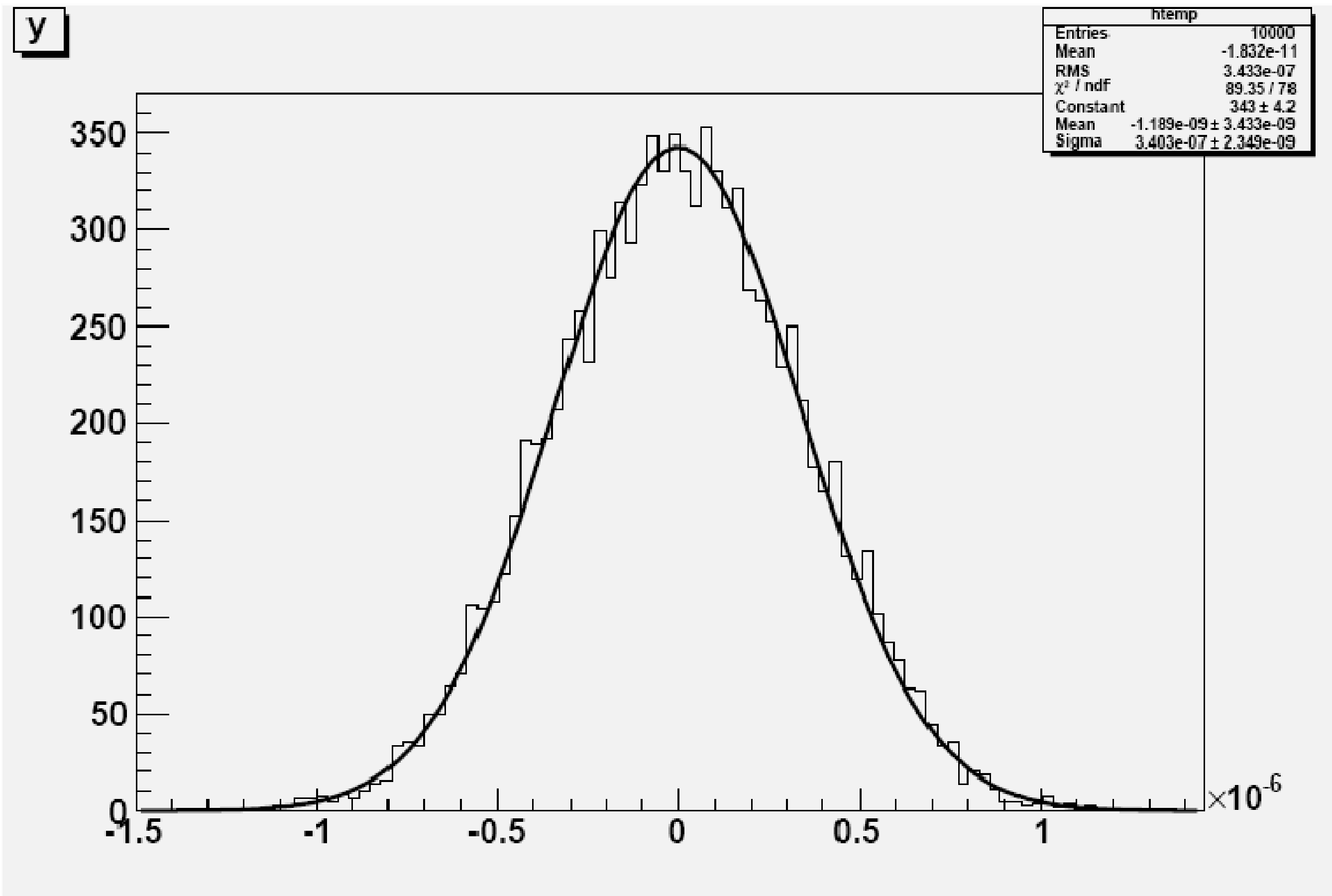
$80 \times \beta_{ynominal}$ at IP-54cm can be obtained by rematching…

Linear optics βx =0.004m, βy=0.008m → σy = 307nm



$100 \times \beta_{ynominal}$ at IP-54cm:

Linear optics βx =0.004m, βy=0.01m → σy = 340nm



B. for the IP+39cm, use the following procedure to get the focal point:

1) use the nominal values of QM12~16 and fit QD0, QF1 in final doublet to obtain $\alpha_x = \alpha_y = 0$.

KLQD0FF = -1.117399E+00

KLQF1FF = 7.030126E-01

2) fit QM12~16 to get:

$\beta_x = 0.04$m, $\beta_y = 0.08$m

$D_x = 0$, $\alpha_x = \alpha_y = 0$

at IP+39cm.

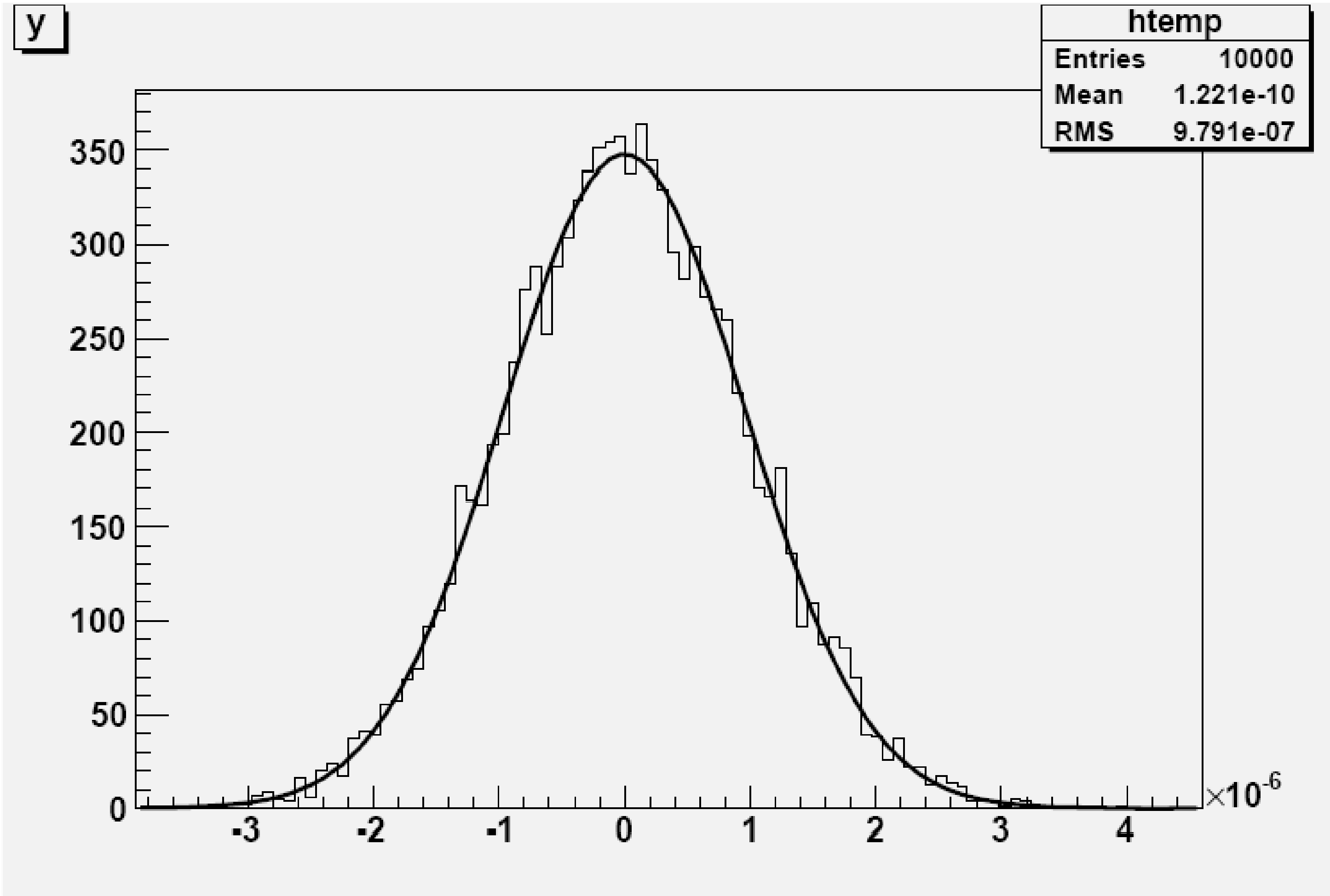
3) fit all the five sextupoles to get:

T126=0, T122=0, T346=0, T342=0, T166=0

do tracking to get $\sigma_y = 968$nm at IP+39cm.

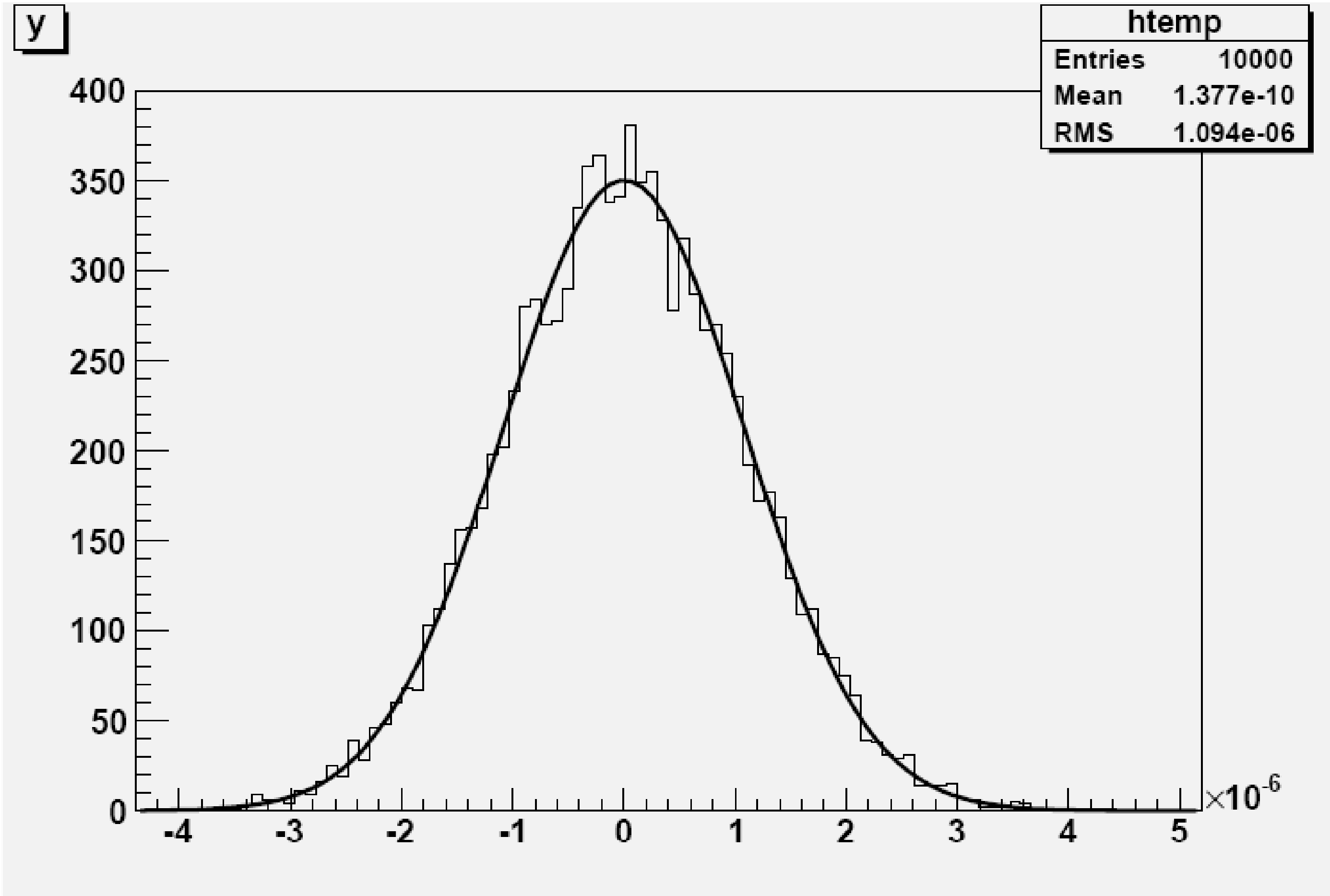
$800 \times \beta_{ynominal}$ at IP+39cm:

Linear optics $\beta x = 0.04m$, $\beta y = 0.08m$ → $\sigma y = 971nm$

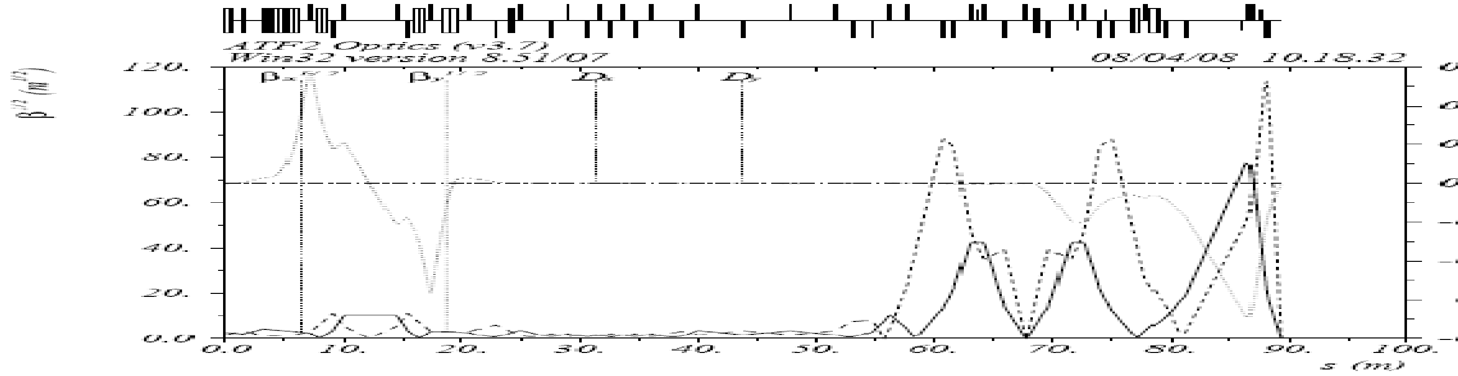


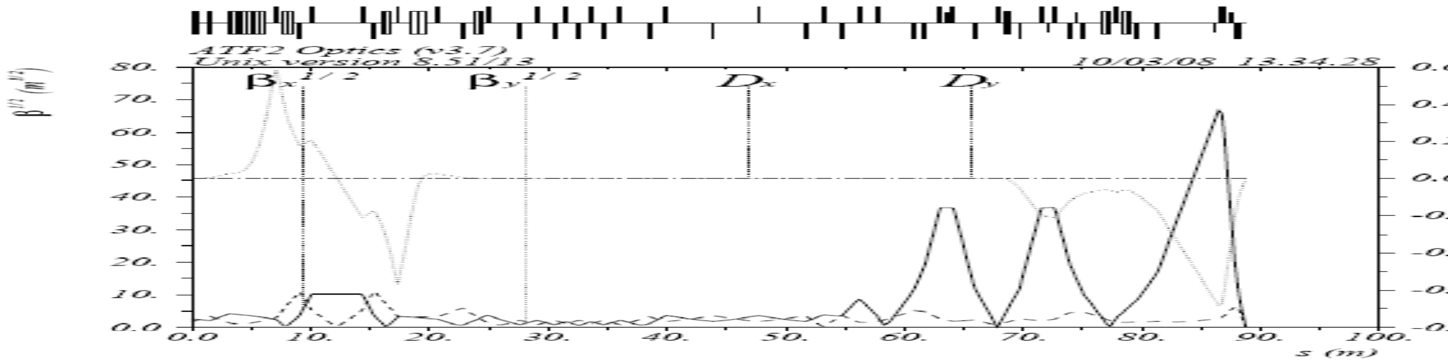
$1000 \times \beta_{ynominal}$ at IP+39cm:

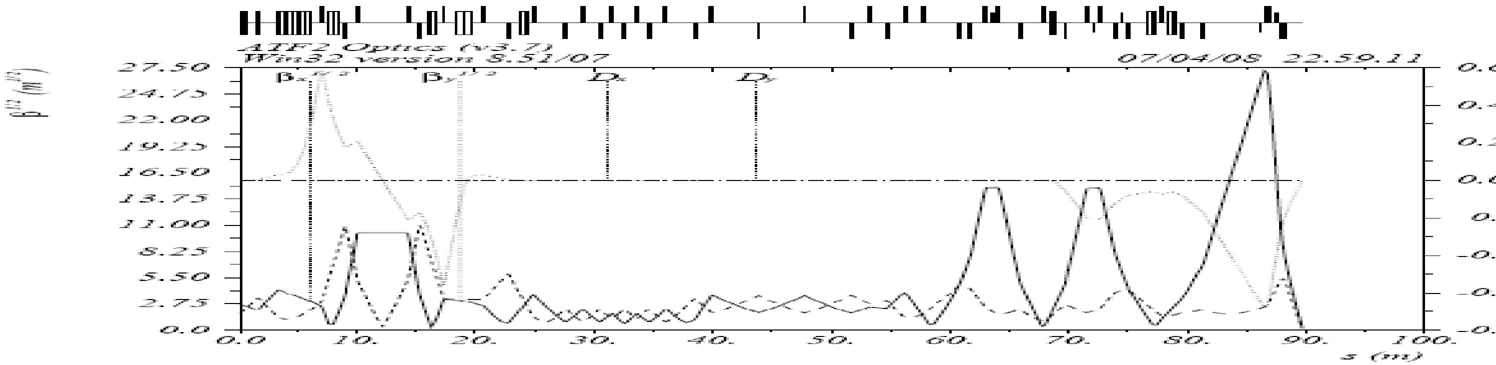
Linear optics $\beta x = 0.04m$, $\beta y = 0.1m$ → σy = 1086nm



Twiss of the three cases: nominal, 100 β_y at IP-54cm, 800 β_y at IP+39cm







Orthogonal waist scans:

$$\begin{pmatrix} \Delta f_x \\ \Delta f_y \end{pmatrix} = \begin{pmatrix} a\, b \\ c\, d \end{pmatrix} \begin{pmatrix} \delta_{QD} \\ \delta_{QF} \end{pmatrix}$$

$$M$$

$$\rightarrow \qquad \begin{pmatrix} \delta_{QD} \\ \delta_{QF} \end{pmatrix} = M^{-1} \begin{pmatrix} \Delta f_x \\ \Delta f_y \end{pmatrix}$$

Nominal IP:

$$M = \begin{pmatrix} 2.57 & -16.8 \\ -1.68 & 0.24 \end{pmatrix} \rightarrow M^{-1} = \begin{pmatrix} -0.0087 & -0.6085 \\ -0.0609 & -0.0931 \end{pmatrix}$$

IP+39cm:

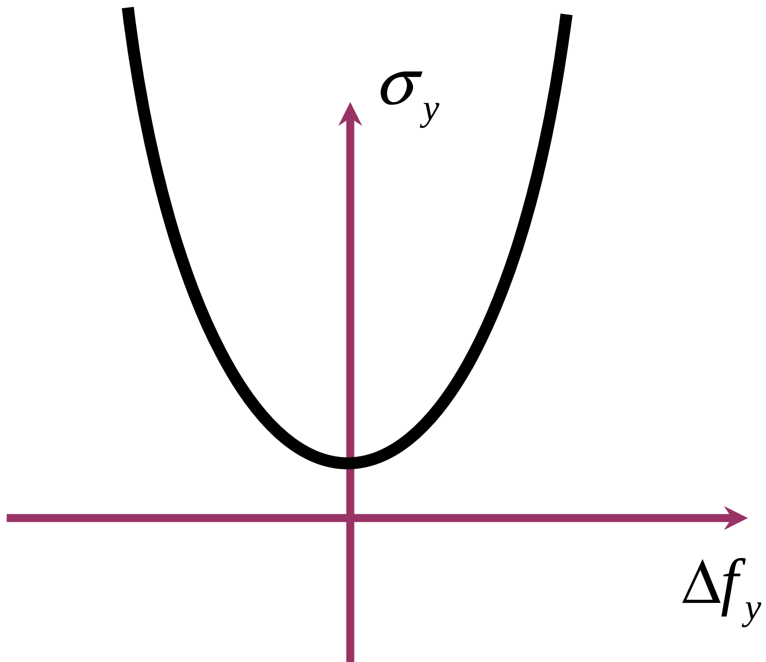
$$M^{-1} = \begin{pmatrix} -0.0087 & -0.418 \\ -0.0522 & -0.0741 \end{pmatrix}$$

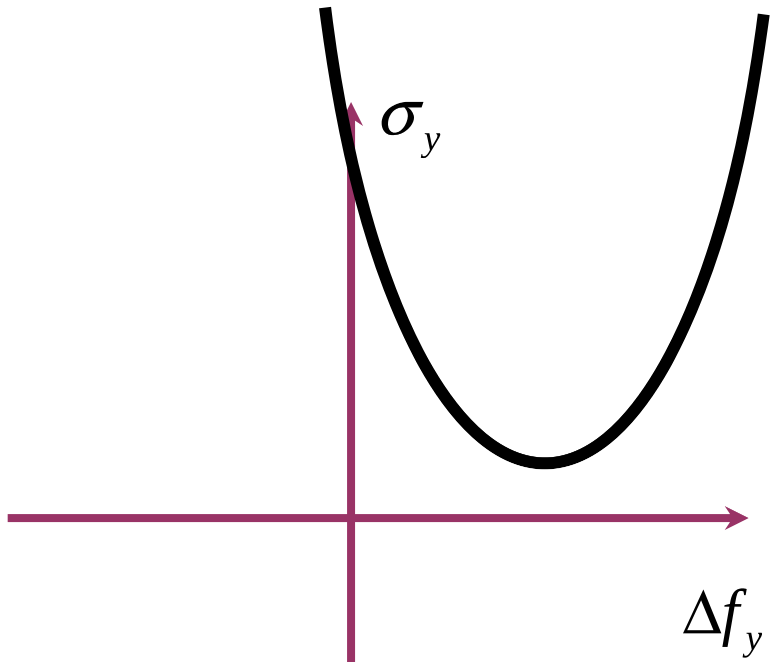
IP-54cm:

$$M^{-1} = \begin{pmatrix} -0.0076 & -1.3027 \\ -0.0746 & -0.1438 \end{pmatrix}$$

For different**β**, M remains the same.

The fractional quadrupole strength $\delta_{QD,QF}$ are in parts per thousand, and the longitudinal waist motions $\Delta f_{x,y}$ are in meters.





$$\sigma_{x,y}{}^2 = \varepsilon_{x,y}\beta_{x,y} + \frac{\varepsilon_{x,y}}{\beta_{x,y}}\Delta f_{x,y}{}^2$$

Without errors

With errors

The same for X !

$$\Delta f_x = 0 \quad \rightarrow \quad \begin{pmatrix} \delta_{QD} \\ \delta_{QF} \end{pmatrix}_y = M^{-1} \begin{pmatrix} 0 \\ \Delta f_y \end{pmatrix}$$

$$\Delta f_y = 0 \quad \rightarrow \quad \begin{pmatrix} \delta_{QD} \\ \delta_{QF} \end{pmatrix}_x = M^{-1} \begin{pmatrix} \Delta f_x \\ 0 \end{pmatrix}$$

Get waist in each plane !

conclusions & prospects

1. We can get any β_y at nominal IP in range [0.25,1000] * nominal value
2. At displaced IP-0.54m and IP+0.39m, β_y can be as large as is needed for the linear beam size to match the resolutions of the Honda monitor and wire-scanner, while preserving the basic features of the FFS optics
3. orthogonal waist scans can be expected to imply at different IP locations which can get waist in both planes