Work Report

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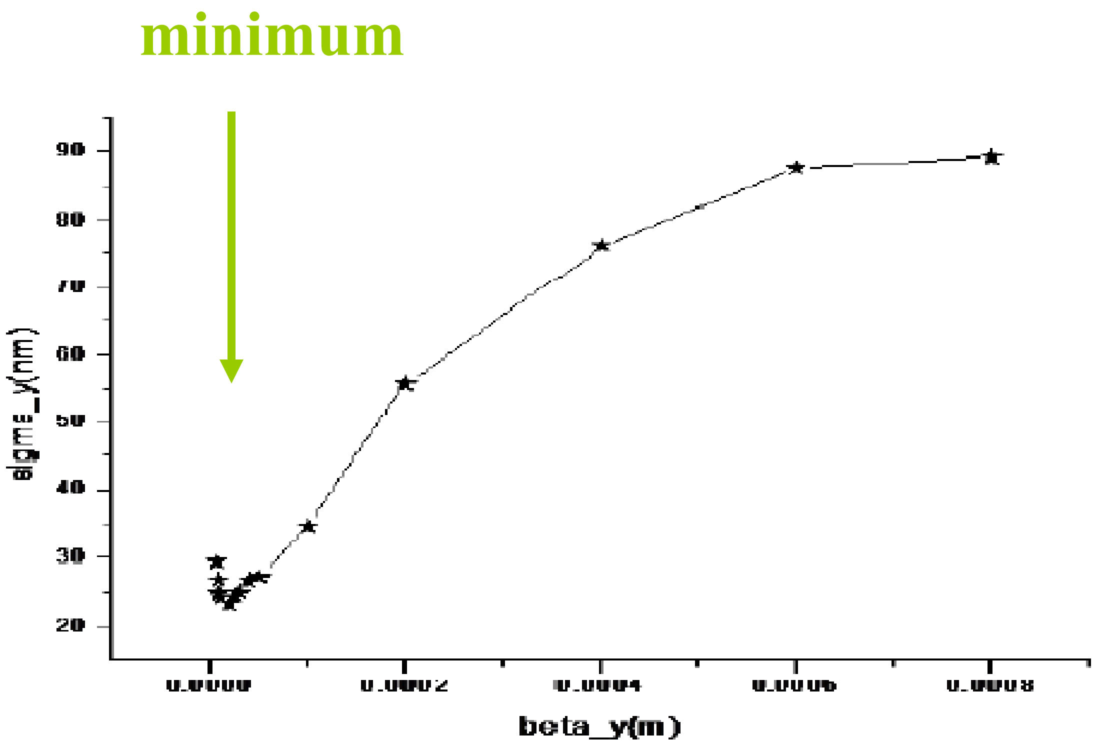
1. **Increasing β_y → gradual approach with looser tolerances**
2. **Reducing β_y → enhanced performance**

Variable beam size at the interaction point
(Gaussian fit to core)



→ Idem at displaced IP locations hosting other instruments

Variable βx,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:

$\beta x = 4 \times \beta x nominal$ $\beta y = 4 \times \beta y nominal$

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

$\beta x = 4 \times \beta x_{nominal} = 0.016m$, $\beta y = 4 \times \beta y_{nominal} = 0.0004m$

- 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 :

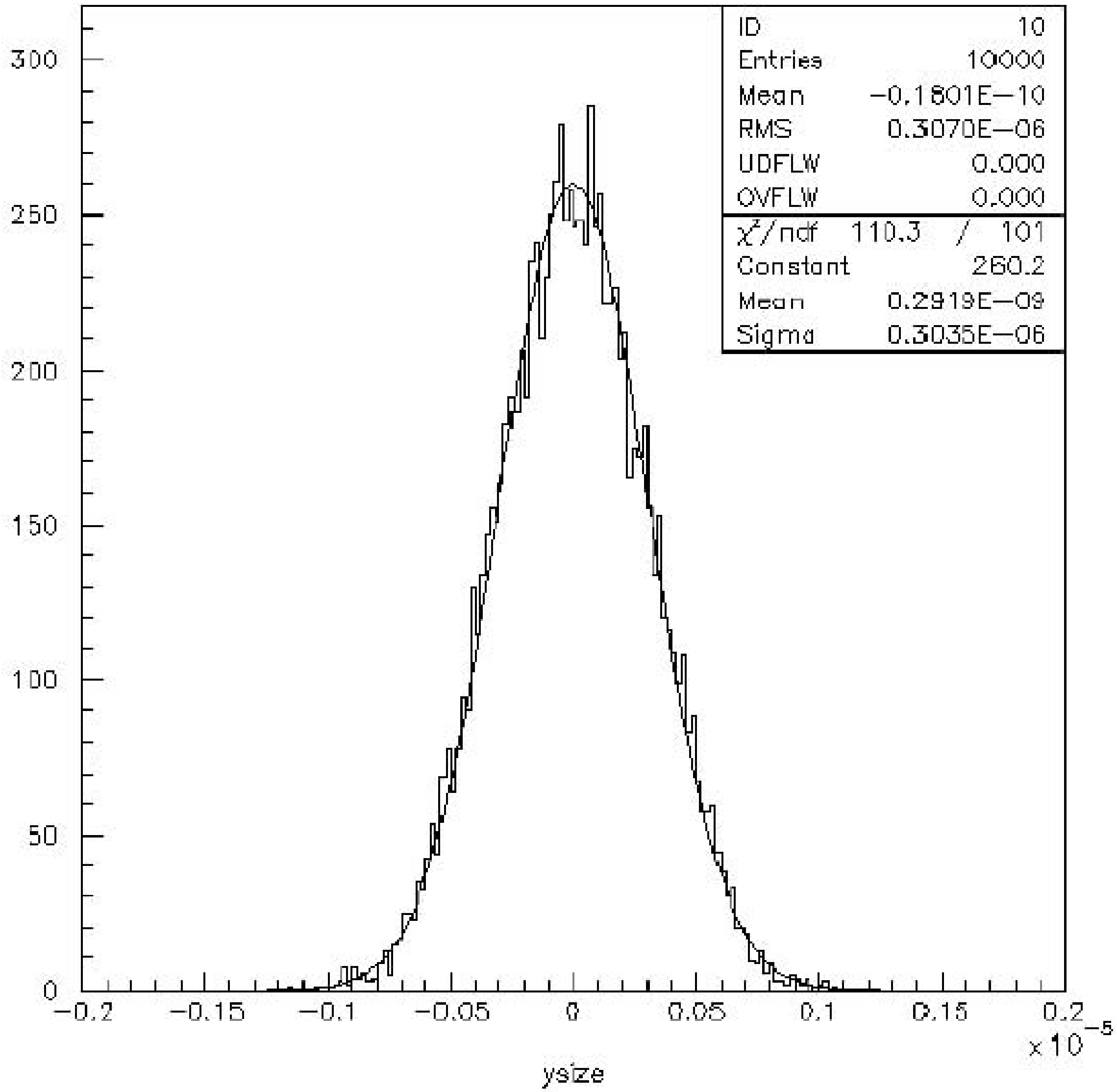
$\beta x = 0.004m$, $\beta y = 0.0001m$

4) fit all the five sextupoles to get:

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

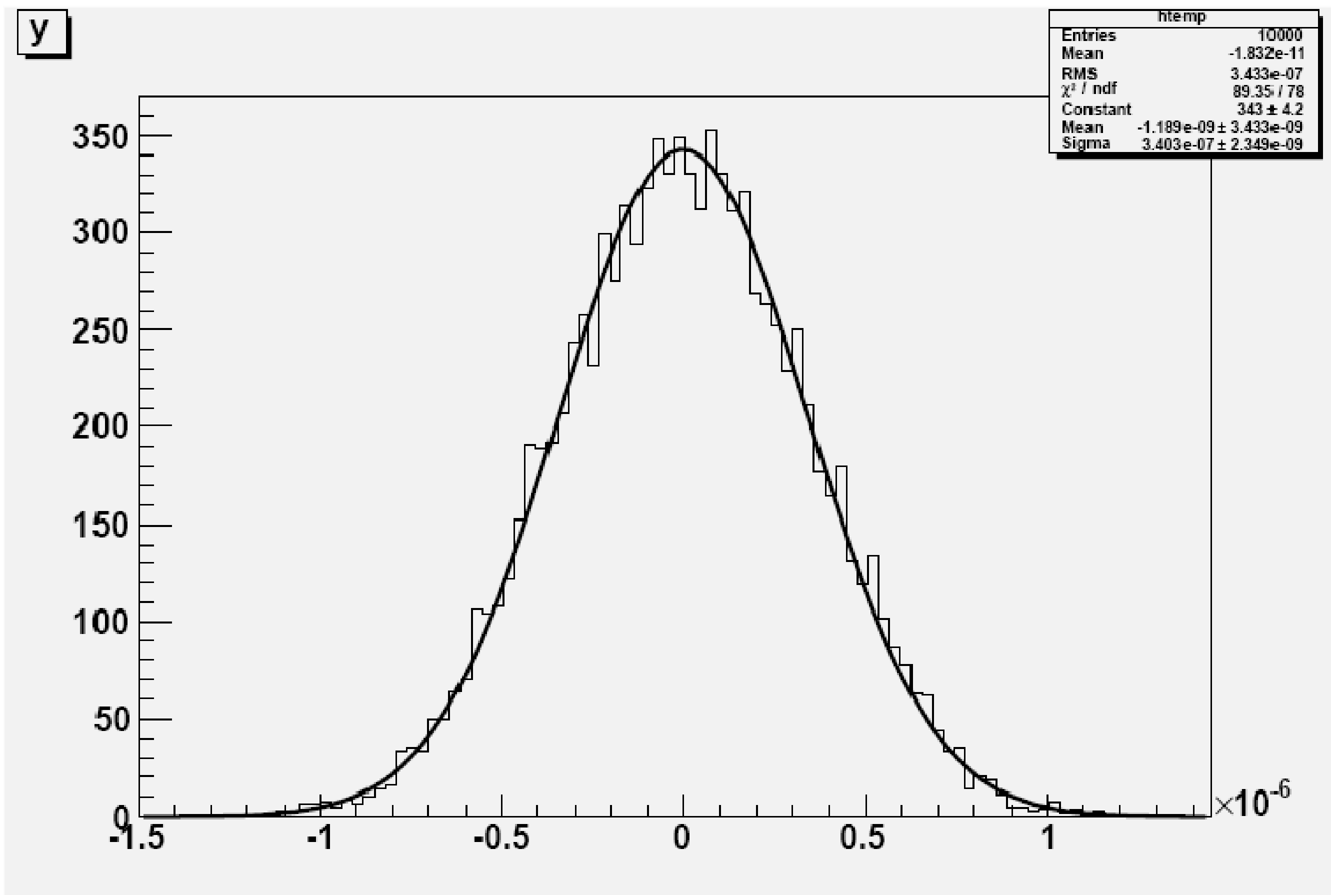
80×βynominal at IP-54cm can be obtained by rematching…

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



$100 \times \beta y$nominal 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:

$\beta x = 0.04m$, $\beta y = 0.08m$

$Dx = 0$, $\alpha x = \alpha y = 0$

at IP+39cm.

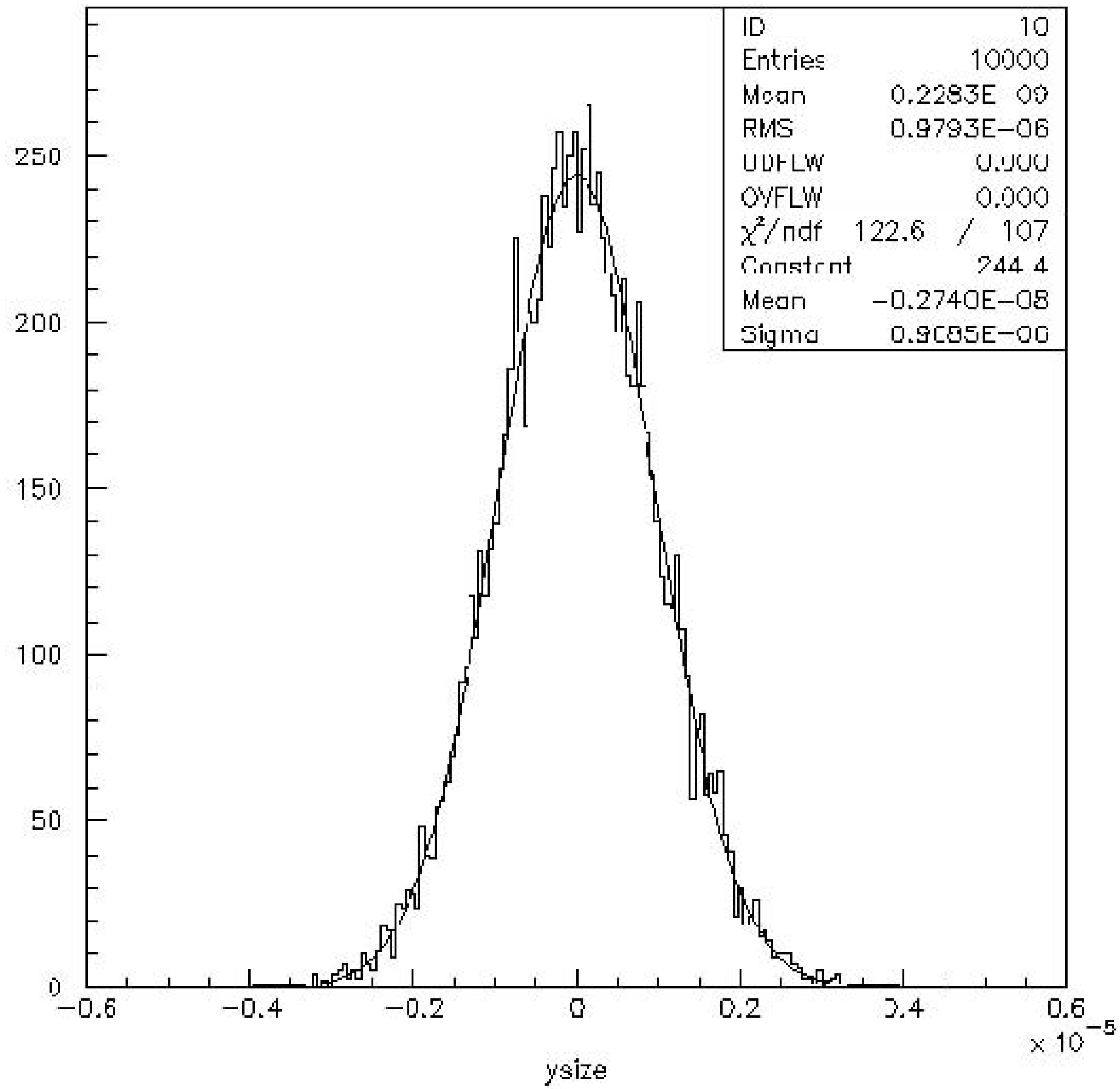
3) fit all the five sextupoles to get:

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

do tracking to get σy=968nm at IP+39cm.

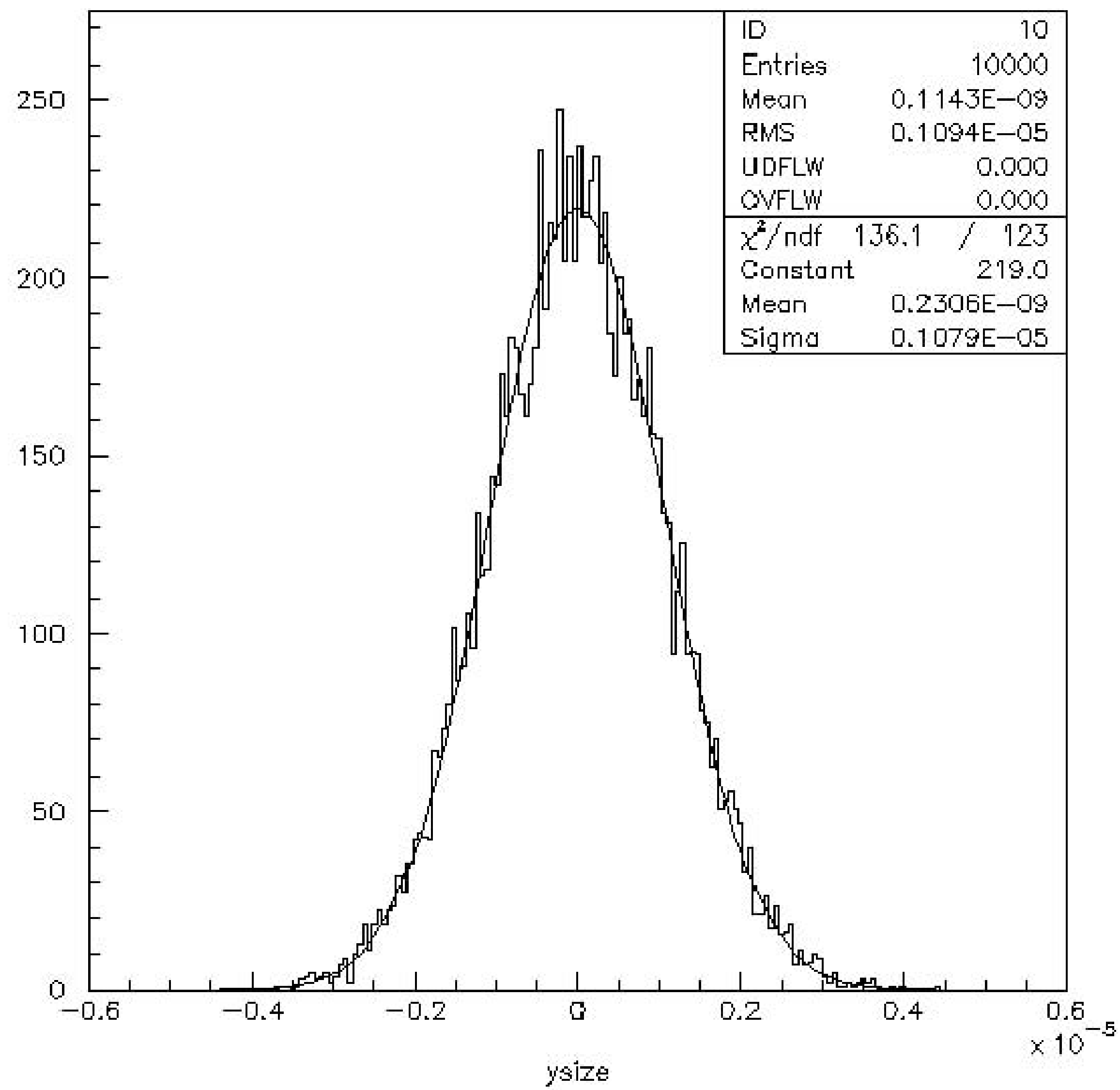
800 × βynominal at IP+39cm:

Linear optics βx =0.04m, βy=0.08m → σy = 971nm

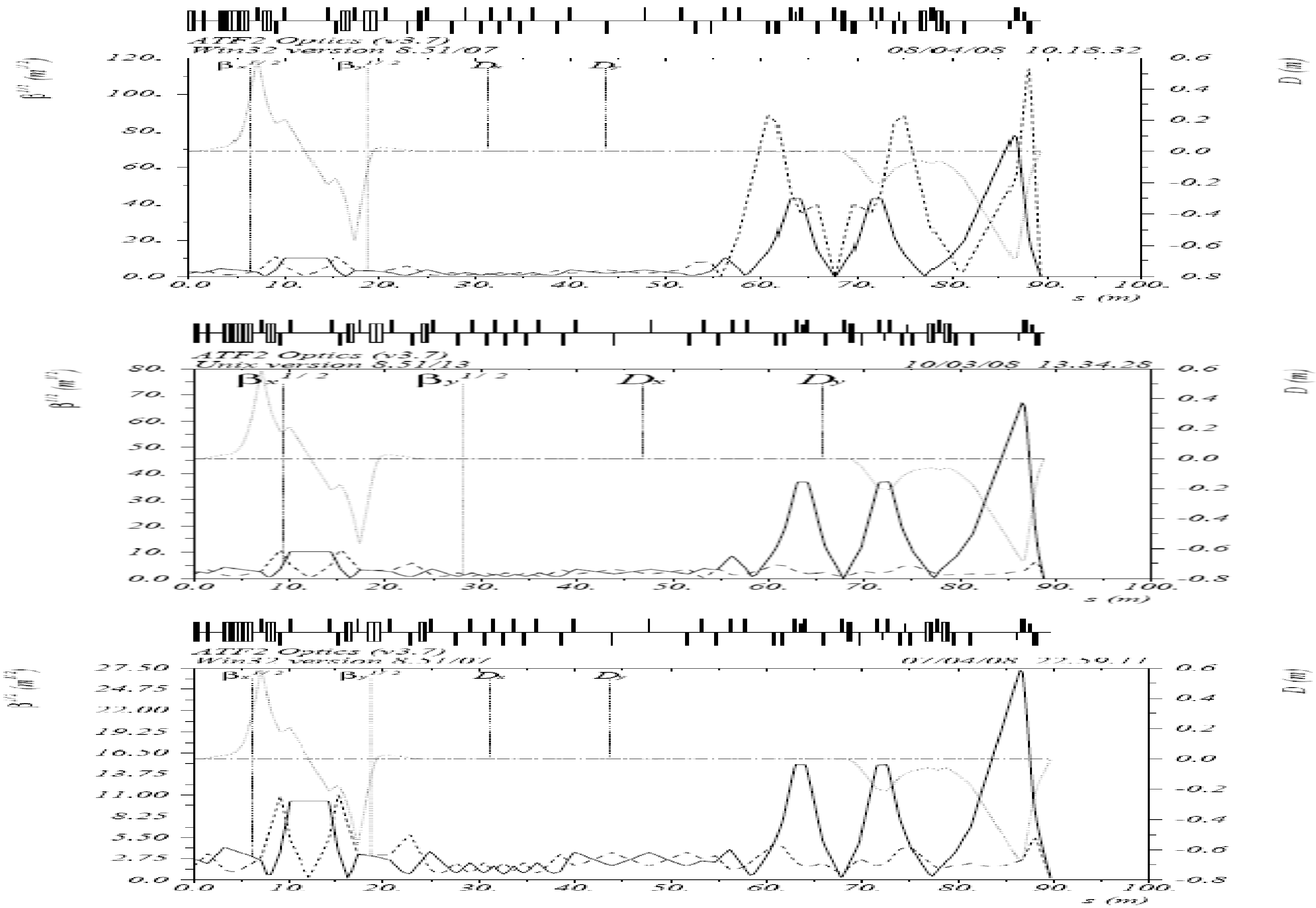


1000 × βynominal at IP+39cm:

Linear optics βx =0.04m, βy=0.1m → σy = 1086nm



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



Conclusion

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

Next step

1. Study tunability with imperfections as function of β_y; defined procedure and collaboration with Rogelio Tomas at CERN and with Yves Rénier → produced decks with:

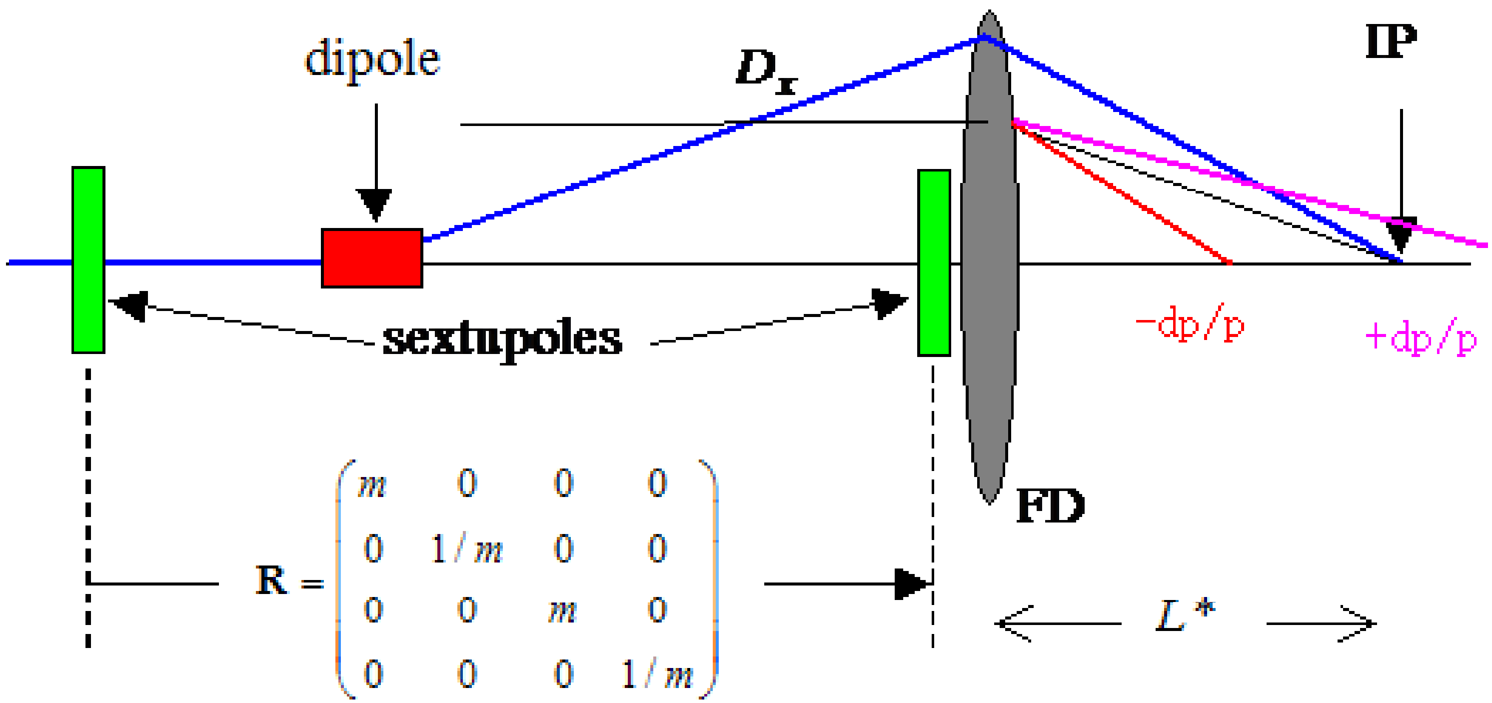
   - factor 2 in both β_x and β_y

   - factor 2 in β_x and factor 4 in β_y

   - Enlarged β_y by factor 10

   - also interested in understanding how tuning difficulty varies as function of betas,and maybe for a little later in the case the 'factor 4' reduction on β_y would need some further adjustment of the non-linearities, even using an extra sextupole or octupole, we should certainly consider that too.

   - Use MADX in the future ~~



local chromaticity correction with pairs of sextupole doublets

For a quadrupole:

$$dy' \approx -K_Q(1-\delta)y\,ds = (-K_Q y + K_Q\delta y)ds$$

$$dx' \approx \left(K_Q D_x\delta + K_Q x_\beta - K_Q D_x\delta^2 - K_Q\delta x_\beta\right)ds$$

For a sextupole:

$$dx' = \left[D_x\delta x_\beta + \frac{1}{2}D_x^2\delta^2 + \frac{1}{2}\left(x_\beta^2 - y_\beta^2\right)\right]K_S\,ds$$

$$dy' = -\left(D_x\delta y_\beta + x_\beta y_\beta\right)K_S\,ds$$

If $K_s D_x = K_Q$ is specified, the terms of these equations in $x\delta$ and $y\delta$ vanish, so cancelling the chromatic aberration.

For the vertical plane, the compensation is straightforward. but for the horizontal plane, it is a bit more complicated. Because a second order horizontal dispersion term appears, proportional to δ^2, of which just half compensated by this procedure.

In order to compensate fully this non-linear dispersion, one must impose that the entire chromaticity of the FFS be created once more upstream of FD, in a non-dispersive region. In this way, the sextupoles run twice stronger and compensate it as well.

Increased η' at IP:

Purpose of the work is to increase η' at IP in order to decrease the strength of the sextupoles on ATF2 final focus line , so the high order terms will also decrease.

$K_Q = Ks \downarrow Dx \uparrow$

Procedure:

- fit the angles of the bending magnets B5,B2,B1 in final focus line, to get 1.2 times of the eta prime at IP (then adjust the B1 angle to zero eta)

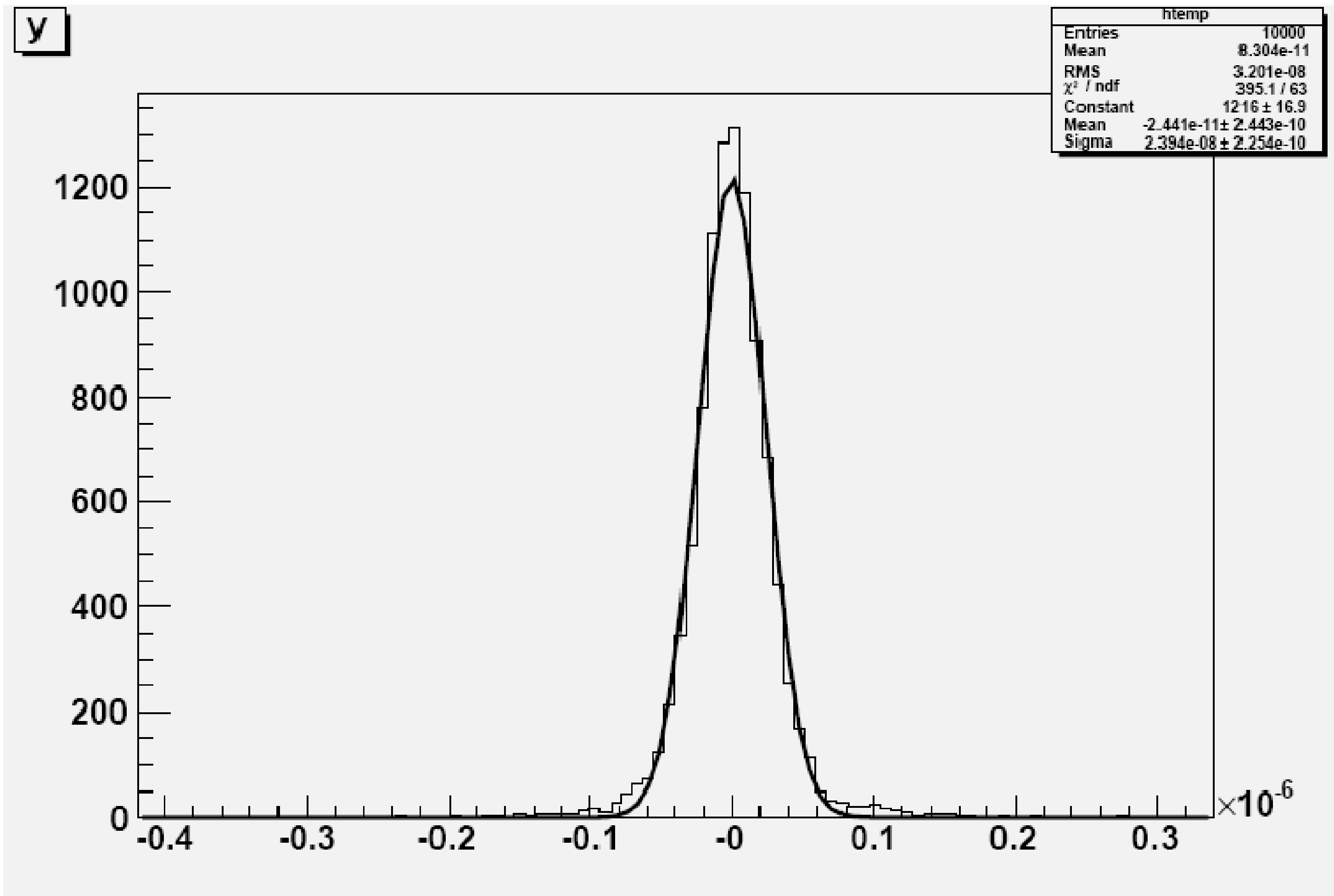
- refit the final doublet quads QD,QF to maintain the focus at IP ($\alpha_{x,y} = 0$)

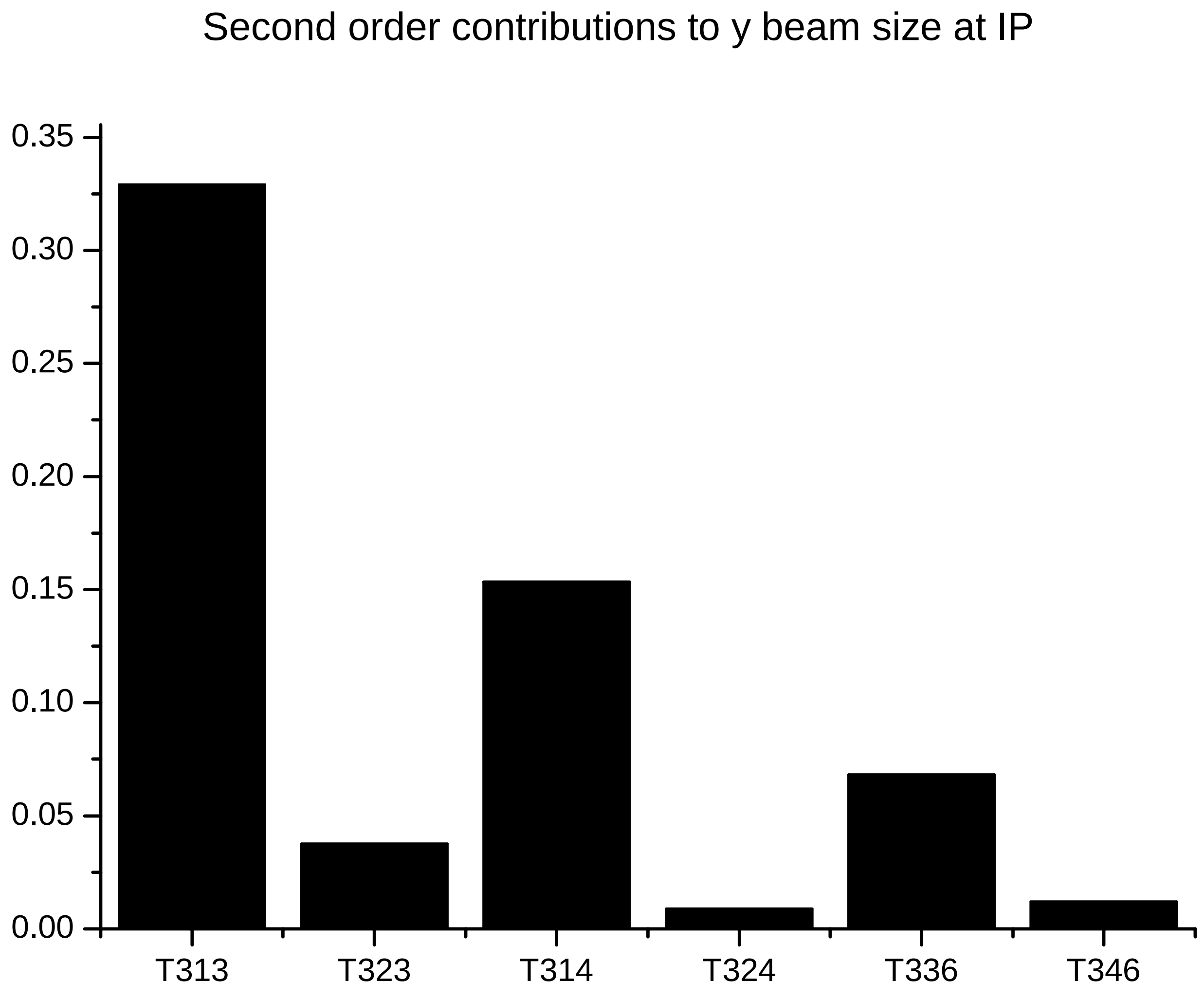
- use matching quads QM12-16 to obtain any wanted beta functions at IP

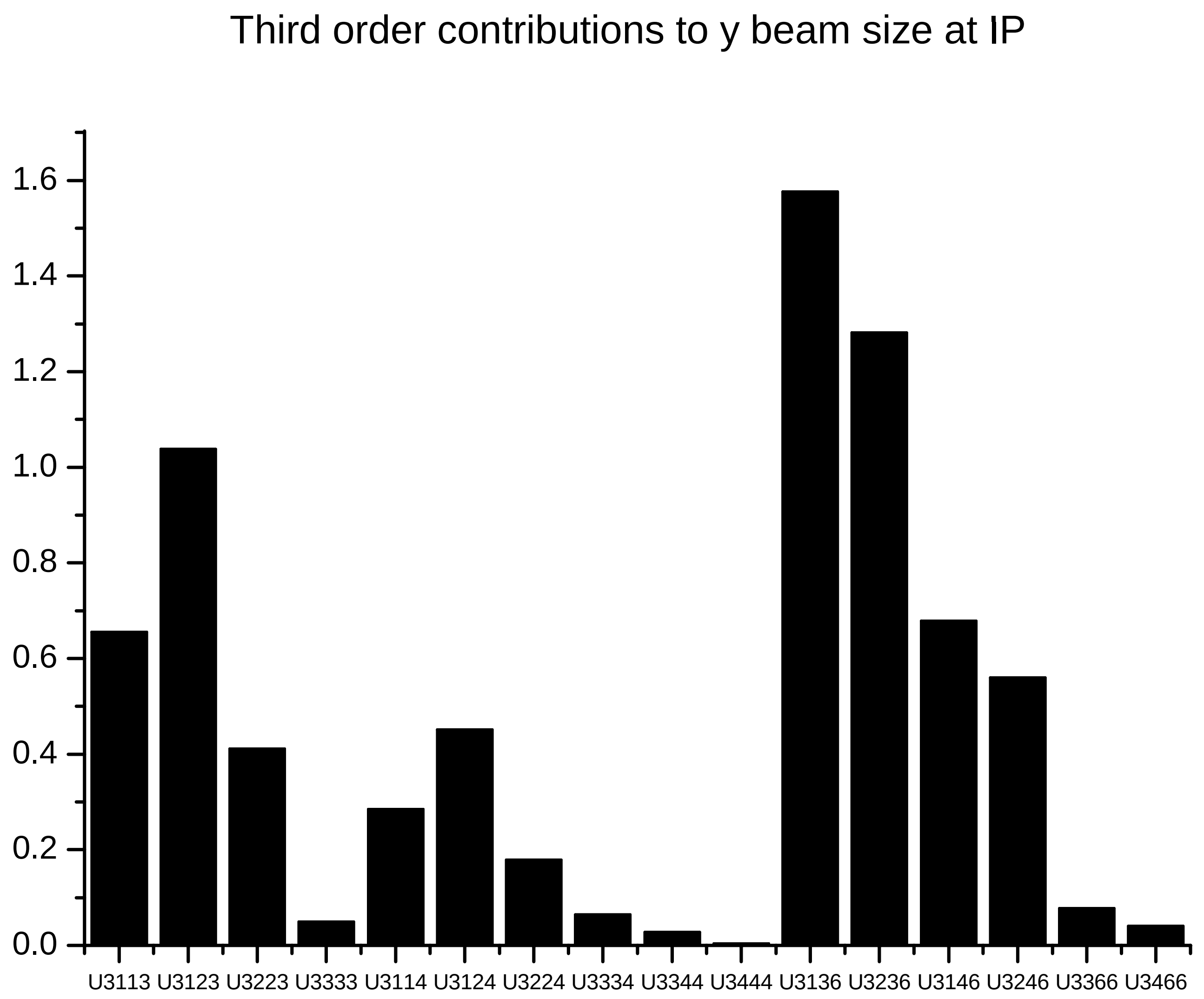
- use TRANSPORT to calculate second order and third order contributions to the y beam size at IP

NO increase in eta prime (nominal case):

β_y=3.0 x 10^{-5} m

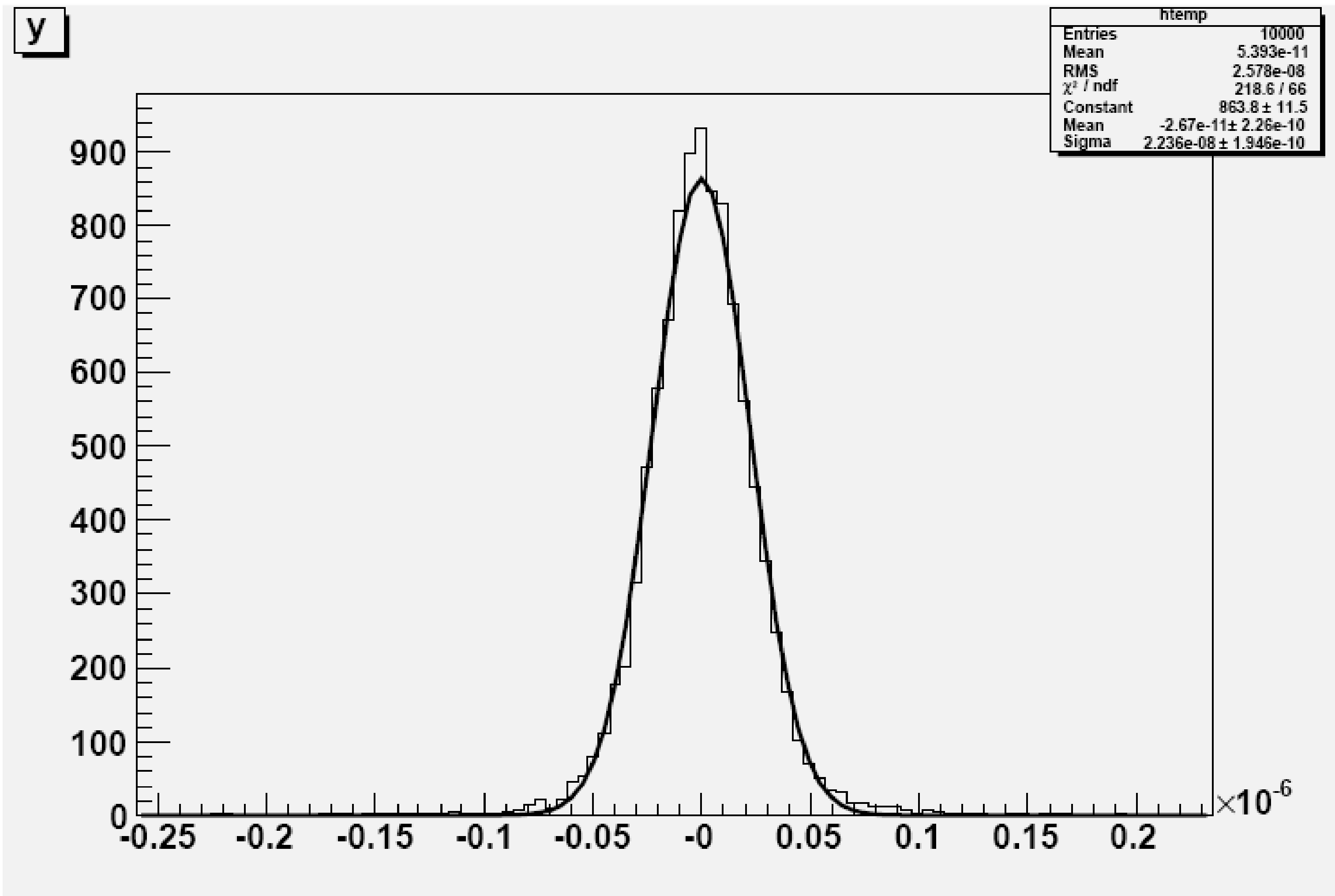


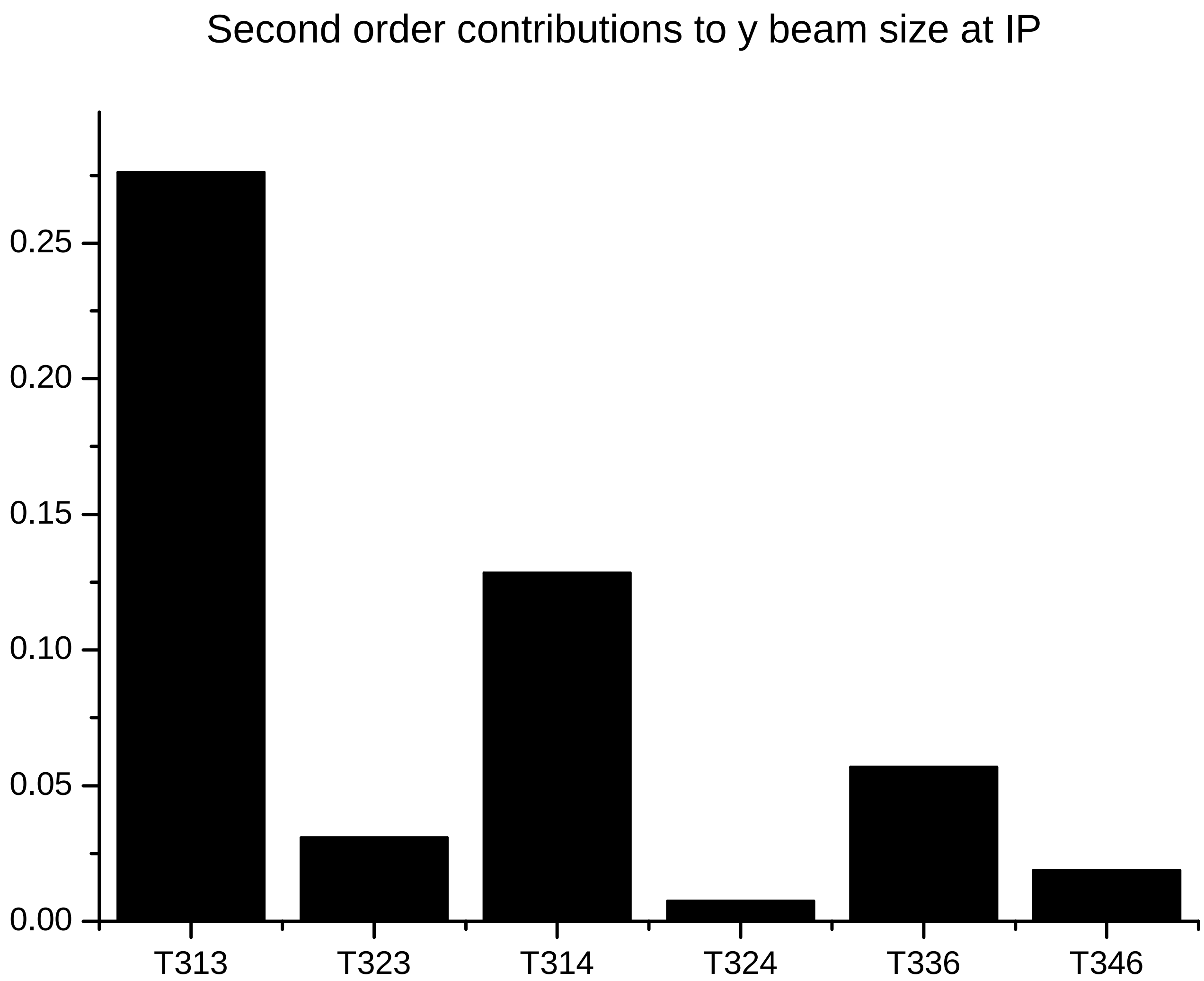

Second order contributions to y beam size at IP
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
T313
T323
T314
T324
T336
T346

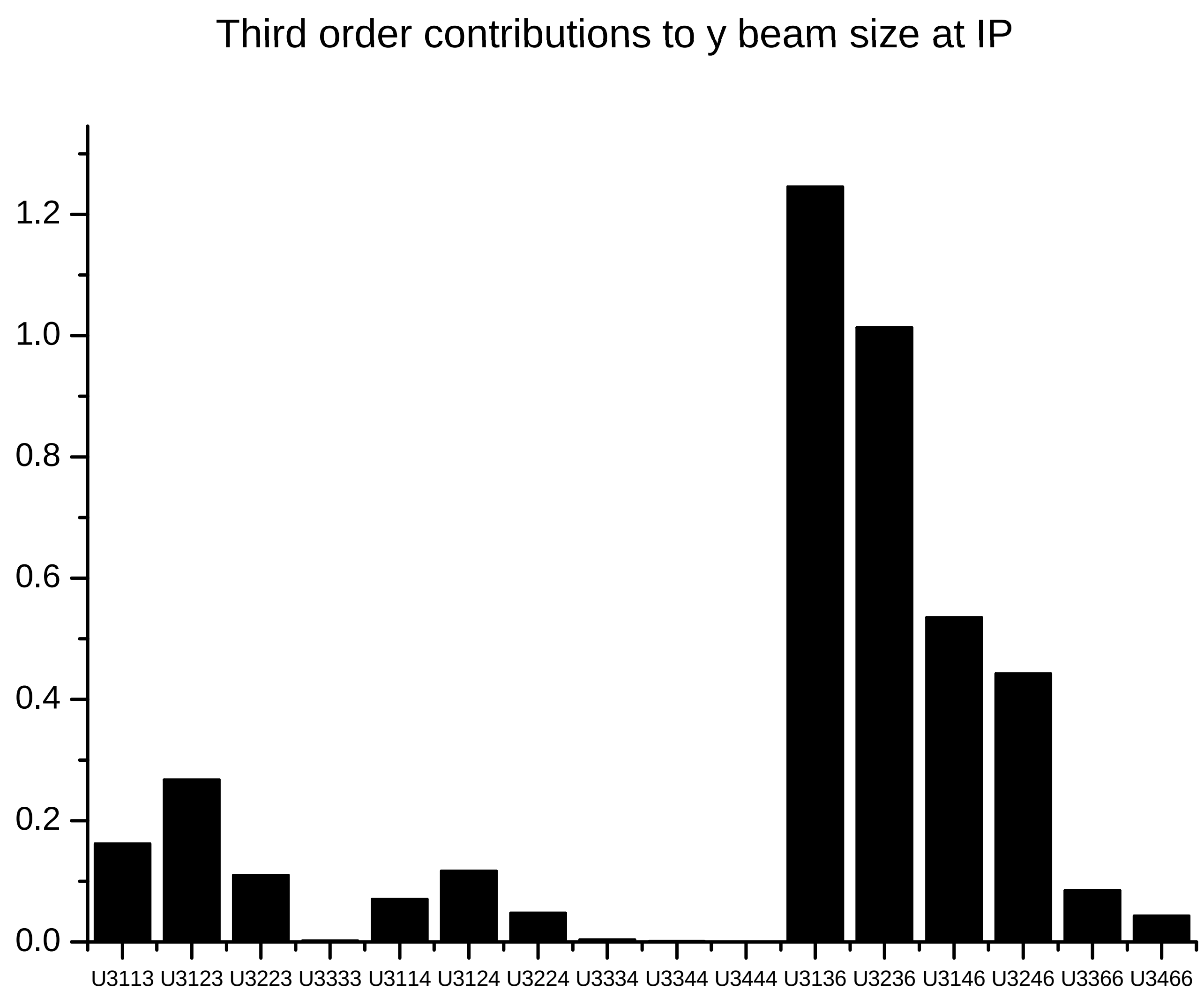

Third order contributions to y beam size at IP
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
U3113 U3123 U3223 U3333 U3114 U3124 U3224 U3334 U3344 U3444 U3136 U3236 U3146 U3246 U3366 U3466

Increased eta prime (by 20%):

$\beta y = 3.0 \times 10^{-5}$ m




Second order contributions to y beam size at IP
0.25
0.20
0.15
0.10
0.05
0.00
T313
T323
T314
T324
T336
T346



Third order contributions to y beam size at IP
0.0
0.2
0.4
0.6
0.8
1.0
1.2
U3113 U3123 U3223 U3333 U3114 U3124 U3224 U3334 U3344 U3444 U3136 U3236 U3146 U3246 U3366 U3466

Next steps

- increase eta prime by 50%
- MADX
- optimisation code from Rogelio Tomas