Measurements and analysis of beam parameters at post-IP wire-scanner

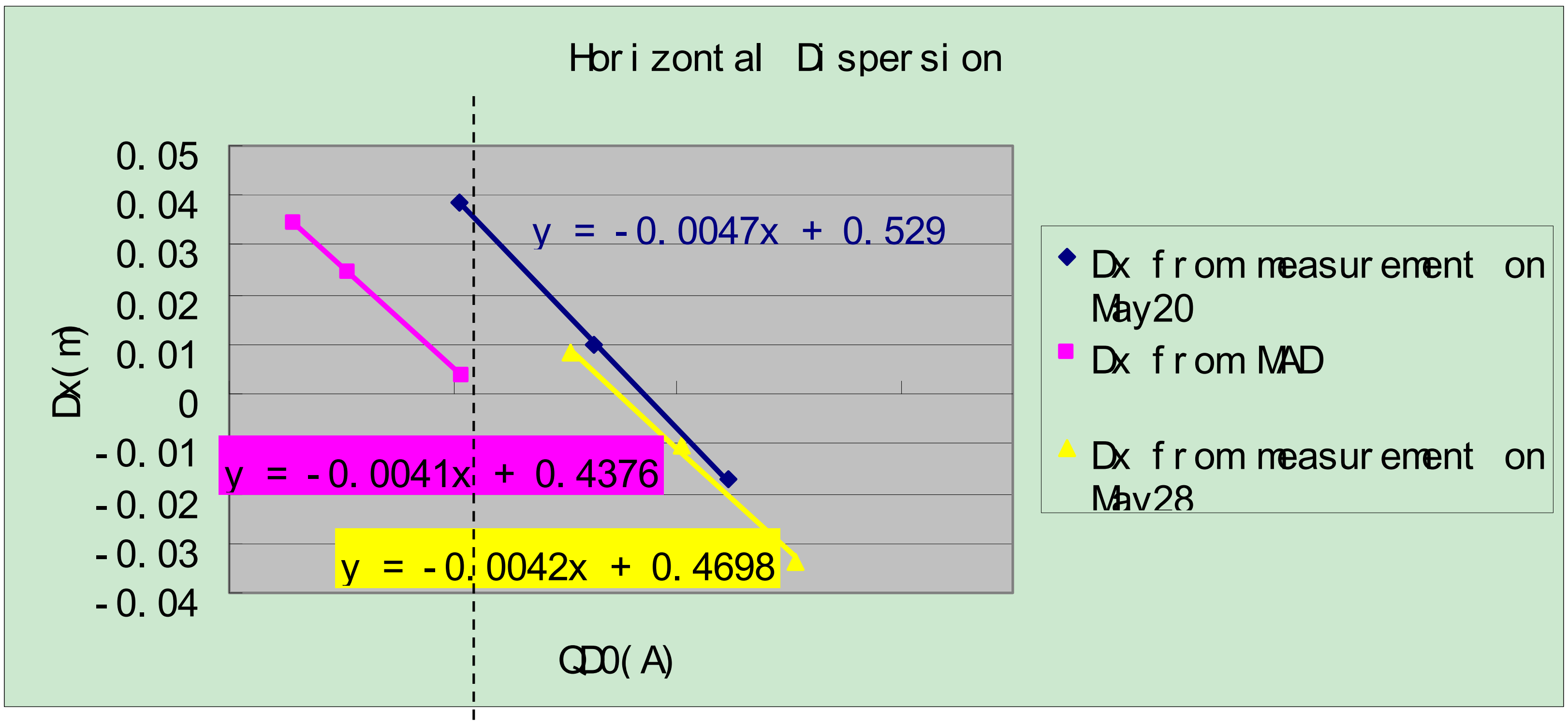
Sha Bai, Philip Bambade, Feng Zhou

2009-06-09

Motivation

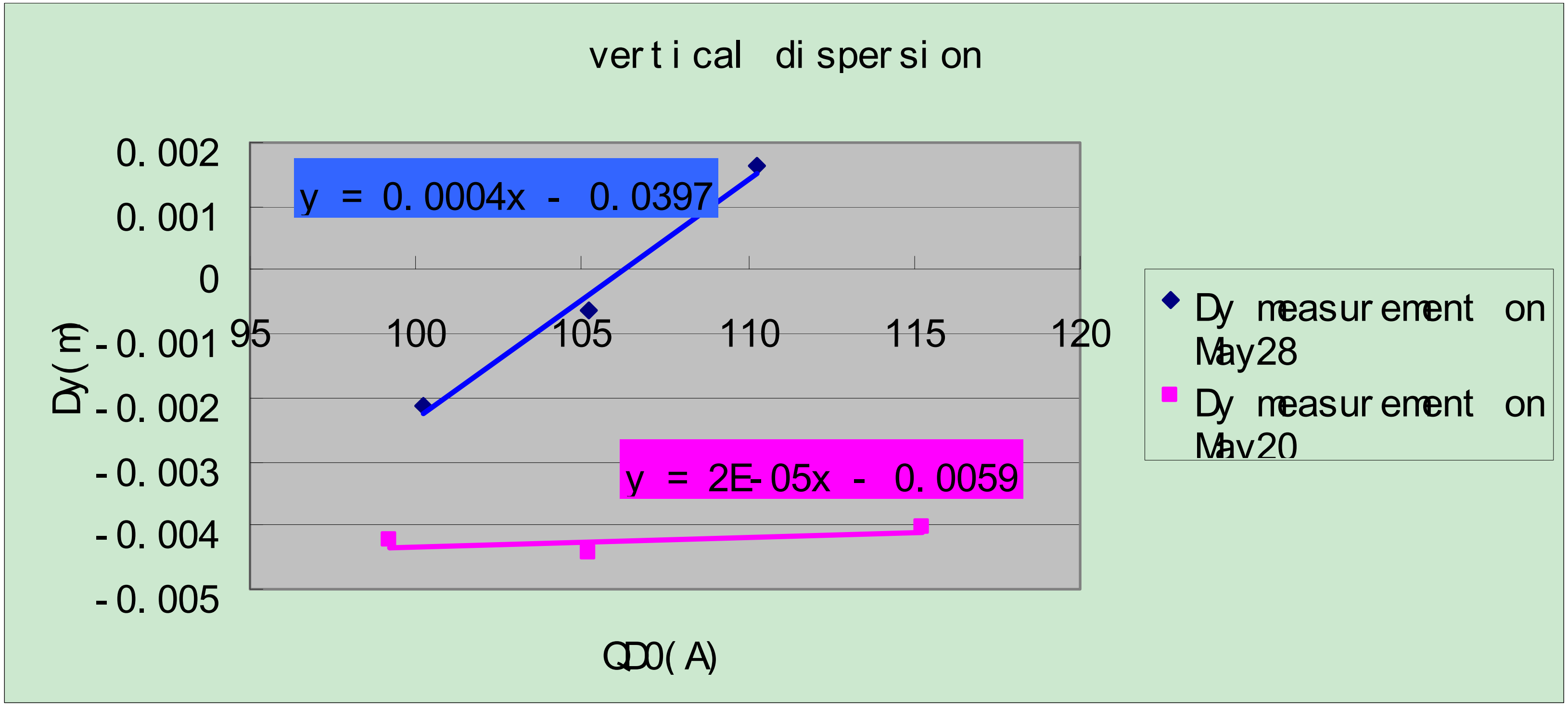
- During the commissioning, we measured the beam size at PIP wire scanner to get initial experience results and to be a prepare for Shintake monitor.
- Waist scan measurements using final doublet to get beam size at PIP wire scanner.
- Measurements which got from the last shifts at PIP wire scanner compared with the ones which propagated from the EXT.

Comparison of horizontal dispersion between measurement and MAD



Design waist

Comparison of vertical dispersion between measurement and MAD



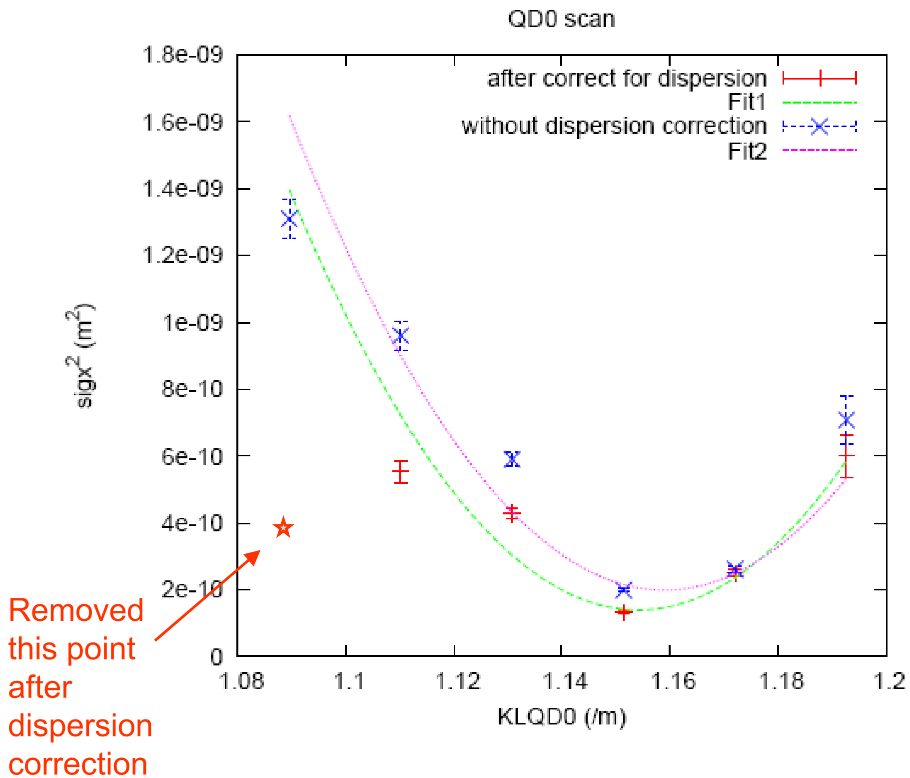
Q-scan X, Y with QD0FF on shift May20

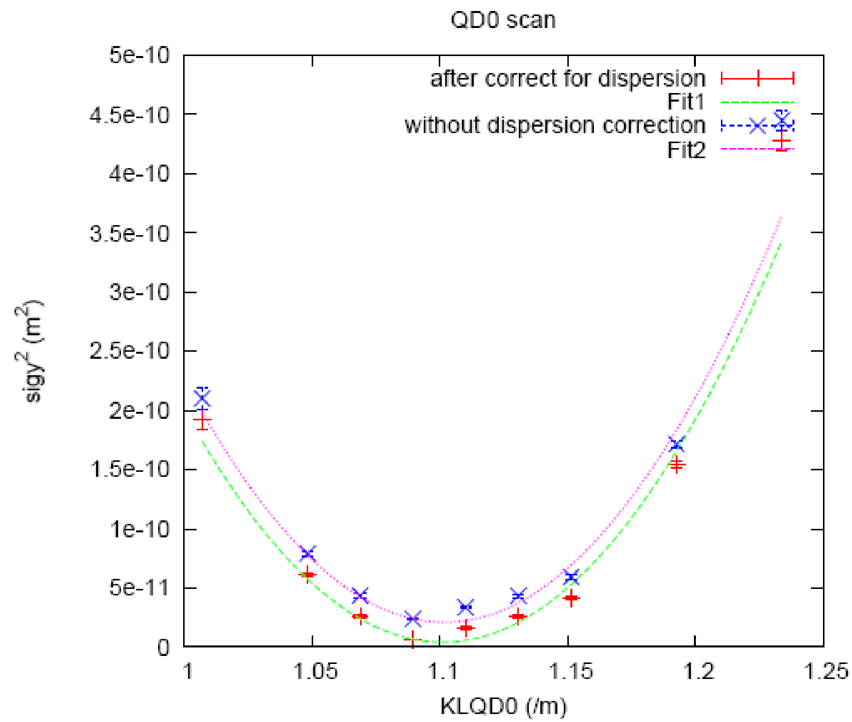
QD0FF, A	Sigma X, um	Sigma Y, um
97.24		14.5 ±0.3
101.24		8.9 ± 0.1
103.24		6.6 ± 0.2
105.24	36.2 ± 0.8	4.9 ± 0.0
107.24	31.0 ± 0.7	5.8 ± 0.1
109.24	24.3 ± 0.4	6.6 ± 0.1
111.24	14.1 ± 0.2	7.7 ± 0.1
113.24	16.2 ± 0.3	
115.24	26.6 ± 1.3	13.1 ± 0.1
119.24		21.1 ± 0.2

Q-scan X, Y with QD0FF on shift May28

QD0FF, A	Sigma X, um	Sigma Y, um
95.24		10.4 ±0.1
100.24		7.2 ± 0.1
102.74		5.4 ± 0.1
105.24	44.5 ± 0.8	3.8 ± 0.1
107.74	33.7 ± 0.6	4.3 ± 0.1
110.24	25.4 ± 0.6	5.1 ± 0.1
112.74	18.9 ± 0.4	6.8 ± 0.1
115.24	16.8 ± 0.4	7.5 ± 0.1
117.74	23.7 ± 0.4	
120.24	33.7 ± 0.9	12.2 ± 0.1
122.74	47.5 ± 2.0	
125.24	54.0 ± 1.5	

Q-scan X, Y with QD0FF on shift May20

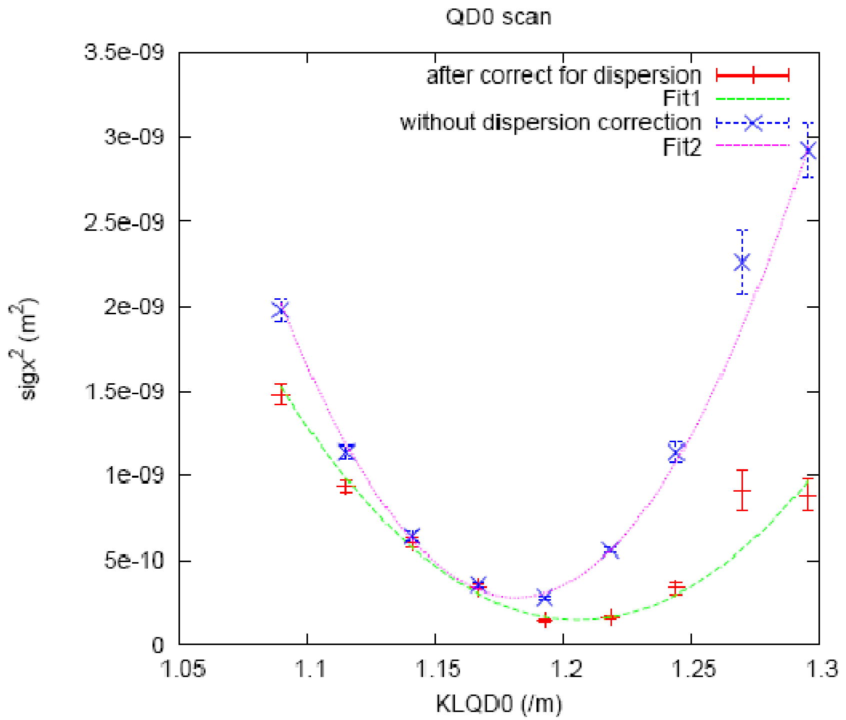


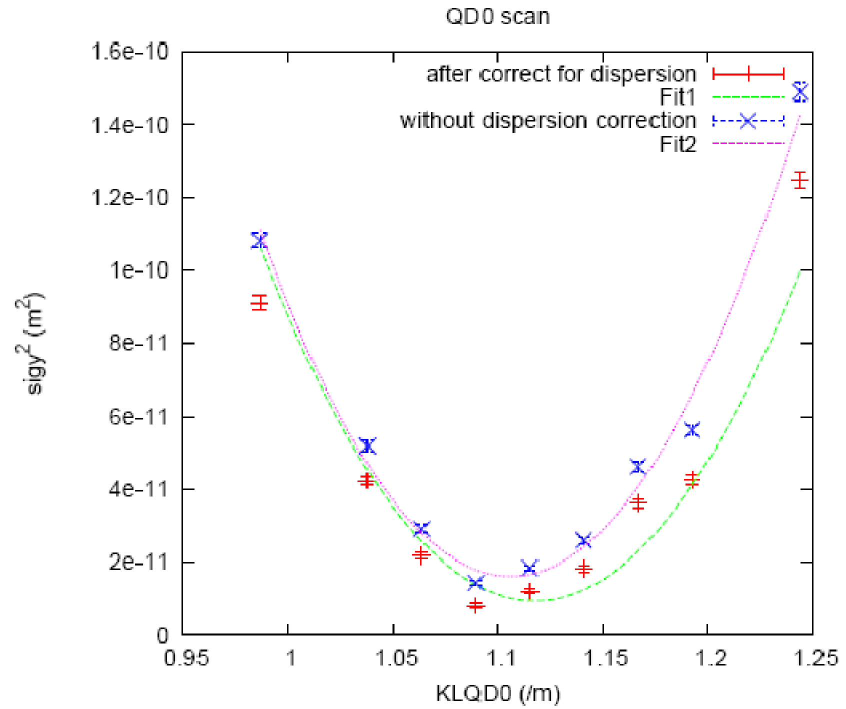


Fit with y=A*(x-B)^2+C
A = (3.0 ± 0.9) e-7
B = 1.154 ± 0.004
C = (1.4 ± 0.3) e-10
COV_{AC}= -0.393

Fit with y=A*(x-B)^2+C
A = (1.9 ± 0.2) e-8
B = 1.101 ± 0.003
C = (4.1 ± 1.7) e-12
COV_{AC}= -0.624

Q-scan X, Y with QD0FF on shift May28

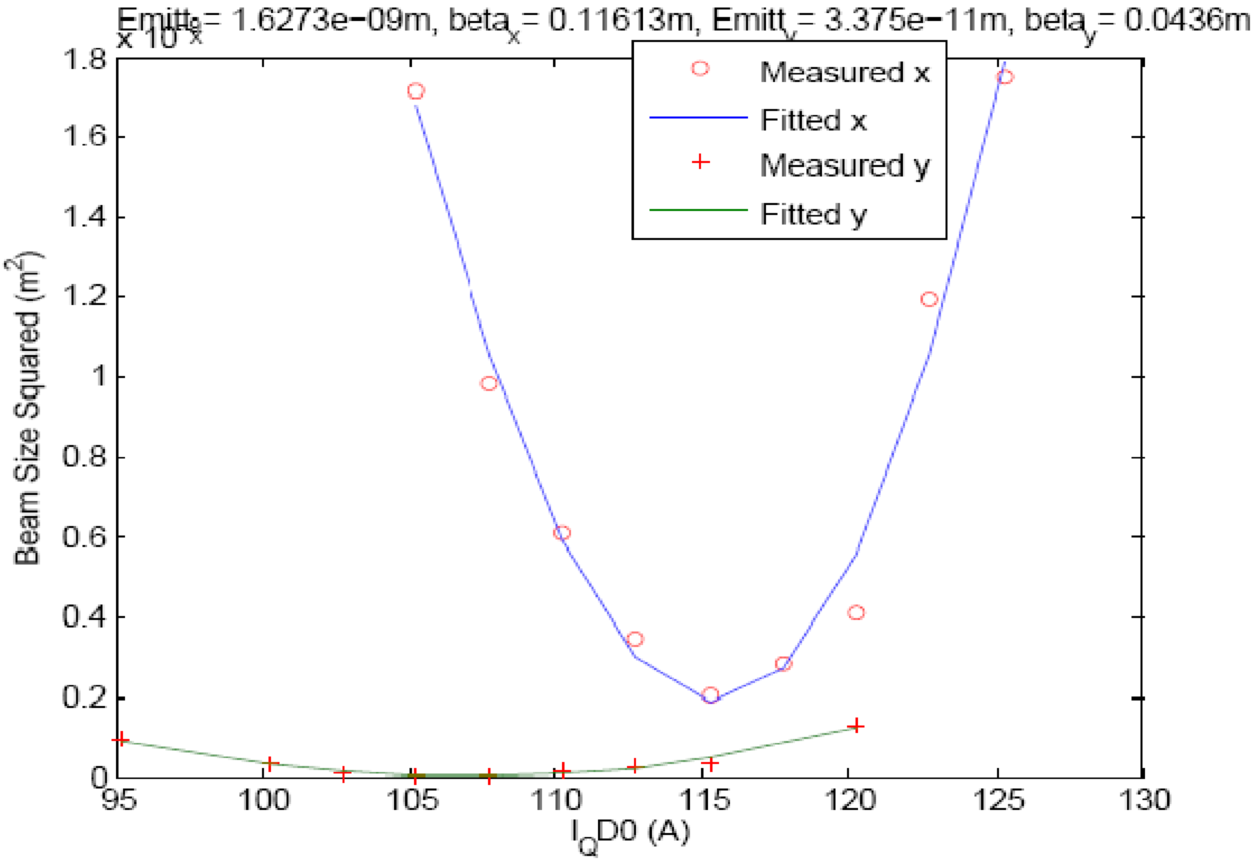




Fit with y=A*(x-B)^2+C
A = (1.016 ± 0.079)e-7
B = 1.206 ± 0.003
C = (1.489 ± 0.136)e-10
COV_{AC}= -0.251

Fit with y=A*(x-B)^2+C
A = (5.640 ± 0.778)e-9
B = 1.117 ± 0.005
C = (9.403 ± 3.418)e-12
COV_{AC}= -0.508

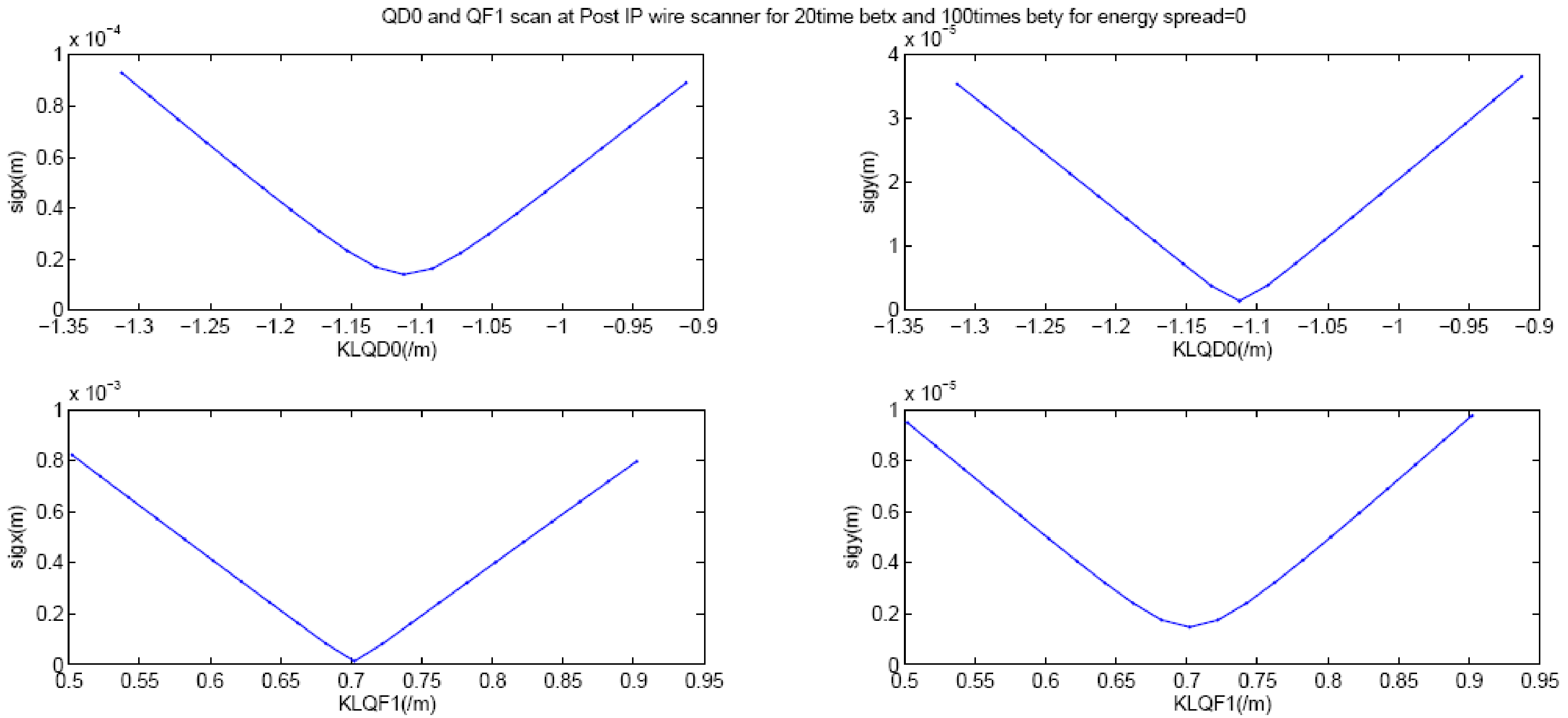
Beam size vs QD0 and fitting (by Feng Zhou)



Emittances and β at IP and B_{mag} at QD0 (by Feng Zhou)

- It is essential to measure x- and y-emittance and β at IP and B_{mag} at QD0; in principle, these parameters can be inferred from QD0 scan data using transfer matrix.
- With data of May 28, ε_x=1.63nm, β_x=11.6cm, and ε_y=25-65pm, β_y=4-6cm. The uncertainty of y parameters is caused by:
  - Uncertain wire resolution: 2.5-3um
  - No complete dispersion data at each QD0 setting
- Plans in the next runs:
  - To reduce the y-uncertainty:
    - To more accurately measure dispersion, and
    - To measure dispersion at each QD0 setting
    - To use higher-resolution carbon wire scanner
  - To record relevant parameters to get B_{mag} at QD0

- Estimate of “effective $R_{12,34}$” from simulation of QD0&QF1 scan when energy spread equals 0.
- “effective $R_{12,34}$” defined to avoid the thin lens approximation.



$$\sigma^2 = \varepsilon\beta(1+\triangle f^2 / \beta^2)$$

$$\triangle f = \triangle Q * a$$

“effective $R_{12,34}$” [m^2]

$a_x = 3.43 \quad a_y = 2.23$

There are two methods to estimate the Twiss parameters and emittance :

1. Use the measured emittances in EXT as input assumptions

$$\left.\begin{aligned}\sigma^2 &= \varepsilon\beta(1+a^2\Delta Q^2 / \beta^2) \\ &= A(Q-B)^2+C = A\,\Delta Q^2 + C\end{aligned}\right\} \Rightarrow A = \varepsilon_{EXT}\, a^2 / \beta \Rightarrow \beta = \varepsilon_{EXT}\, a^2 / A$$

2. The horizontal emittance and β can be obtained simultaneously from the horizontal measurements since the minimum beam size can be resolved

$$\left.\begin{aligned}\sigma^2 &= \varepsilon\beta(1+a^2\Delta Q^2 / \beta^2) \\ &= A(Q-B)^2+C = A\,\Delta Q^2 + C\end{aligned}\right\} \Rightarrow \left\{\begin{aligned}A &= \varepsilon a^2 / \beta \\ C &= \varepsilon\beta\end{aligned}\right.$$

$$\Rightarrow \left\{\begin{aligned}\varepsilon &= a^{-1}\sqrt{AC} \\ \beta &= a^*\sqrt{C/A}\end{aligned}\right.$$

With the wire scanner of 5 or 10 micron diameter (for the C and W wires respectively) and β_y = 0.01 m, the minimum vertical beam size can't be resolved. So method 2 is not reliable for the vertical case.

Horizontal Twiss parameters from the PIP wire scanner measurement and EXT propagation

		ε_x (m)	β_x (m)	α_x	Δf_x (m)
target@WS		2e-9	0.099	0	0
EXT propag-ation	May20	1.86e-9	0.1	-0.003	
	May28	1.7e-9	0.145	0.068	
BSM (May28)	Method1	1.7e-9	0.233	0.709	-0.209
	Method2	1.7e-9	0.234		
PIP WS measure -ment Method 1	May 20	1.86e-9	0.074	2.42	-0.176
	May 28	1.7e-9	0.19	1.804	-0.355
PIP WS measure -ment Method 2	May 20	1.88e-9	0.074	2.42	-0.176
	May 28	1.1e-9	0.13	1.804	-0.355

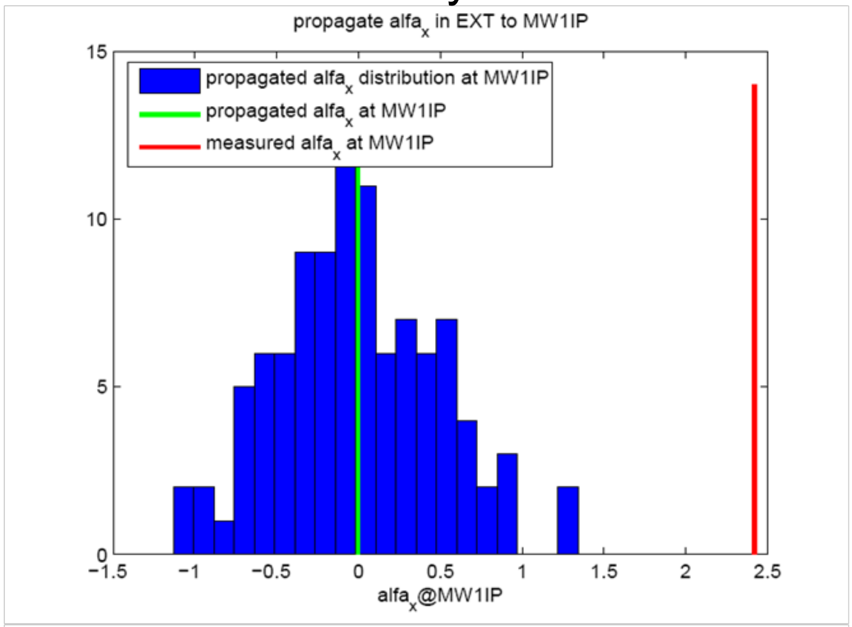
Vertical Twiss parameters from the PIP wire scanner measurement and EXT propagation

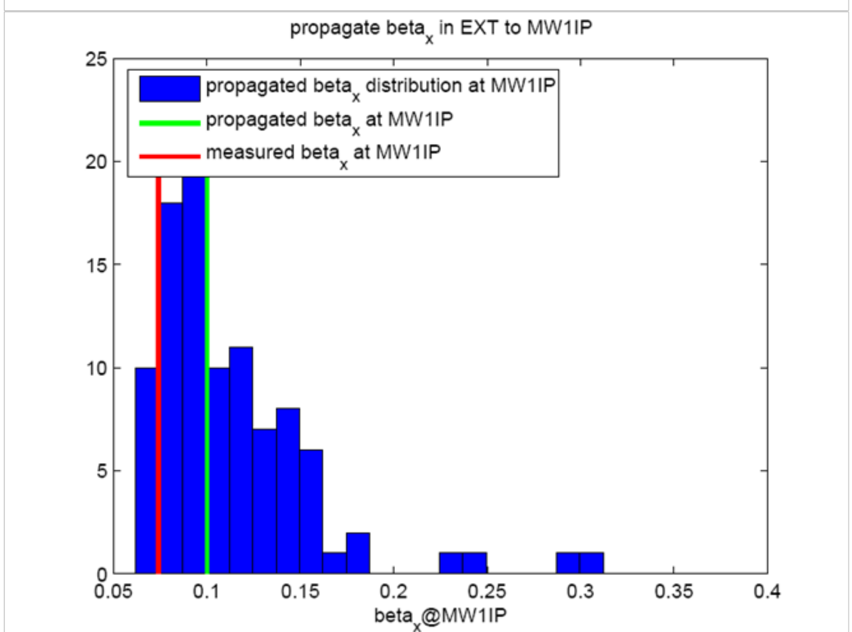
		ε_y (m)	β_y (m)	α_y	Δf_y (m)
target@WS		1.2e-11	0.018	0	0
EXT propag-ation	May20	2e-11	0.019	0.006	
	May28	1.6e-11	0.027	0.107	
BSM (May28)	Method1	1.6e-11	0.011	-6.11	0.037
PIP WS measure -ment Method 1	May 20	2e-11	0.005	-0.624	0.0032
	May 28	1.6e-11	0.014	-2.39	0.0337

- With the wire scanner of 5 or 10 micron diameter (for the C and W wires respectively) and β_y = 0.01 m, the minimum of the parabola can't be resolved. So method 2 is not reliable for the vertical case.

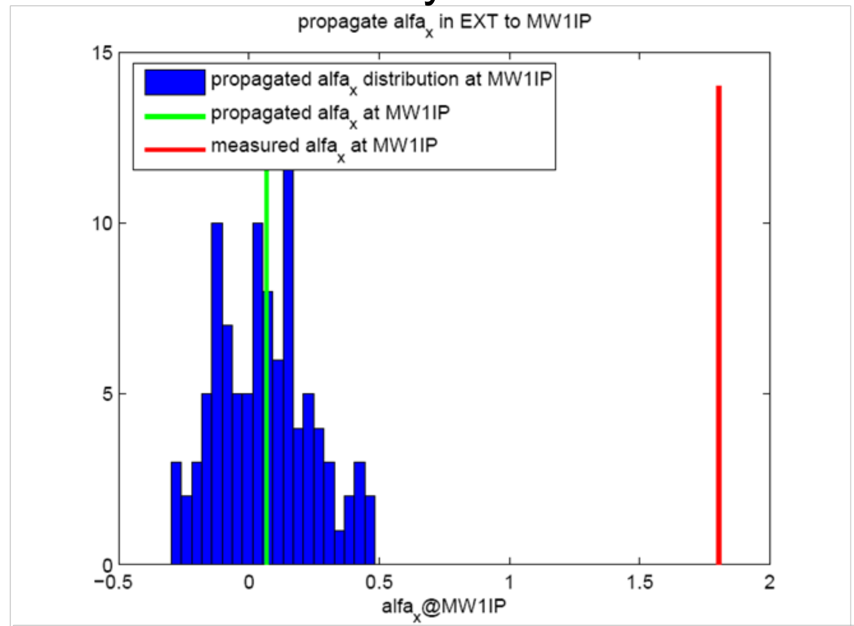
Propagation of Horizontal Twiss (measured on May20,28) to MW1IP

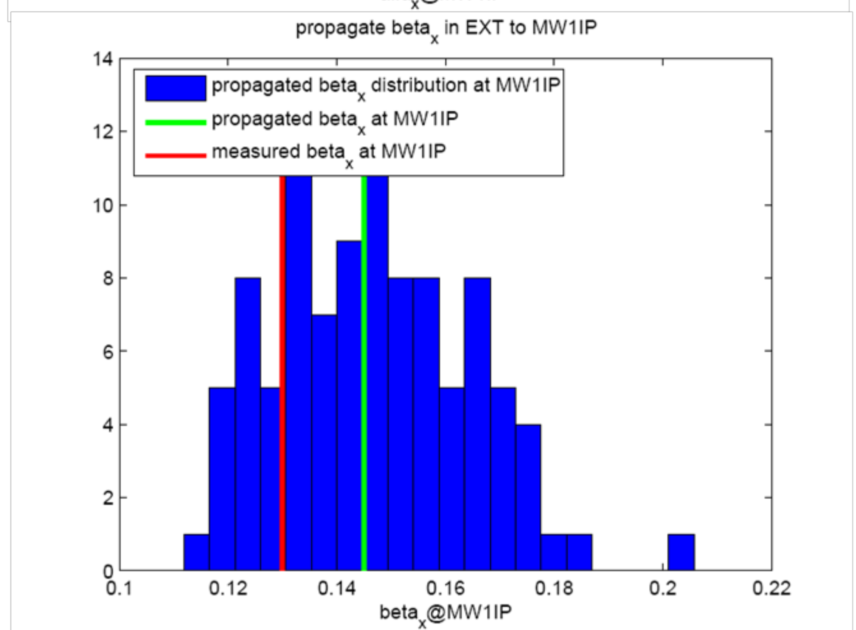
May20





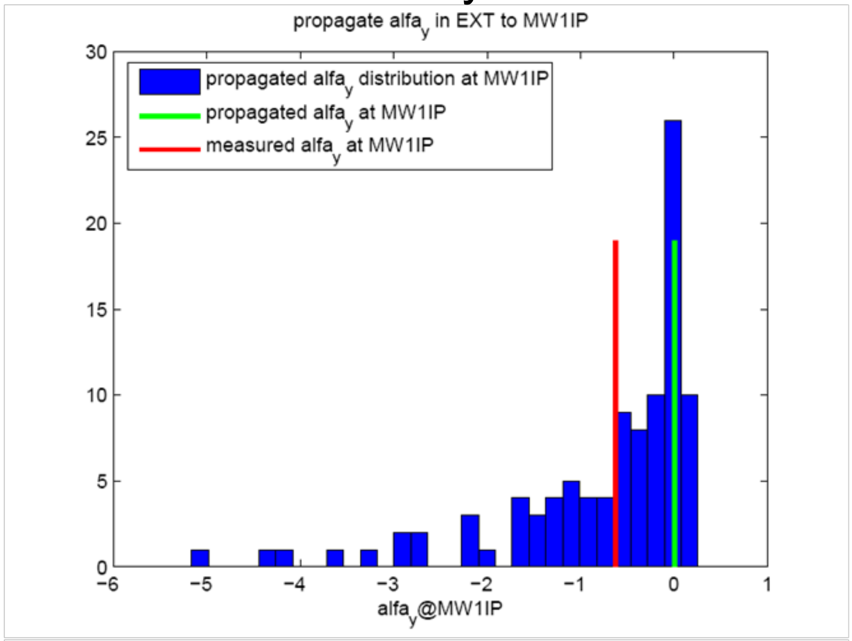
May28

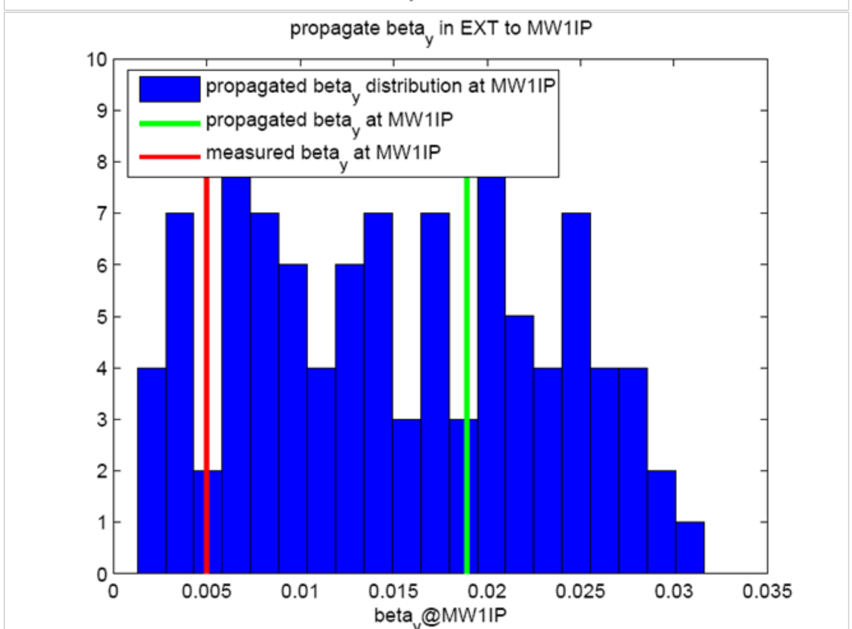




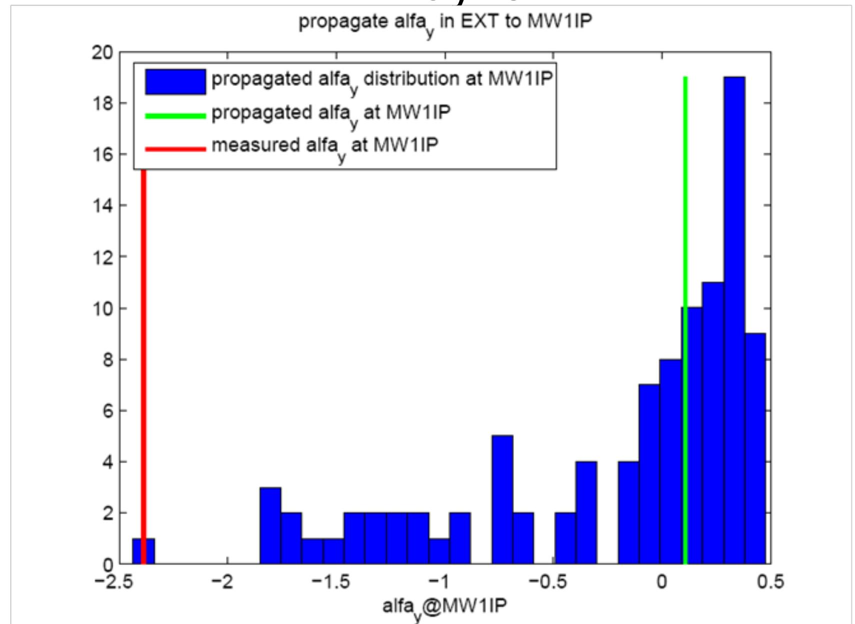
Propagation of Vertical Twiss (measured on May20,28) to MW1IP

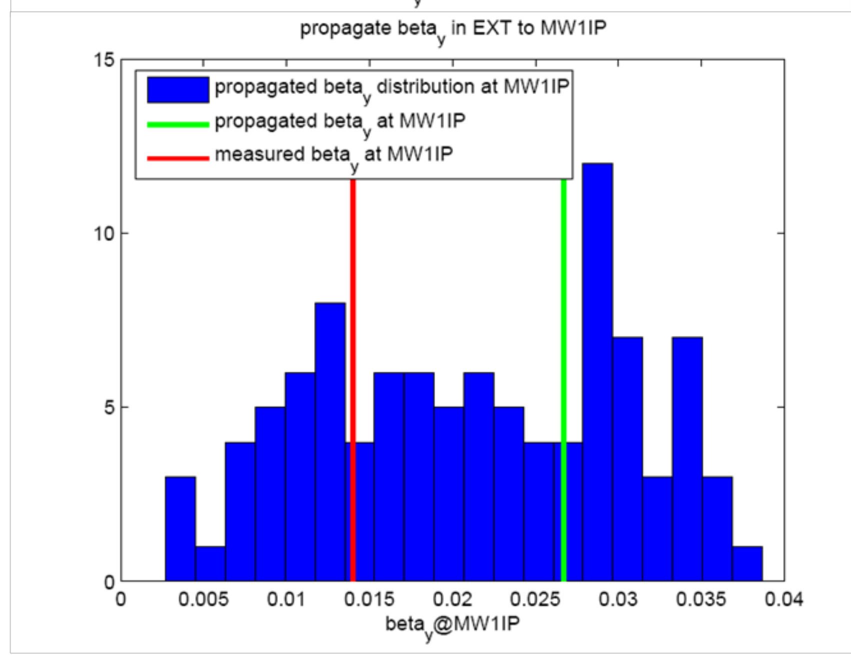
May20





May28





Conclusion

- Measured horizontal spatial and angular dispersions are mismatched compared to the design.
- Measured vertical dispersion was not fully corrected at IP.
- The measured horizontal emittance matches the design.
- The two measurements on shift May20 and May28 used same re-matched optics and have consistent features.
- Two independent analyses (May28) → similar results
- Propagation of measured Twiss in EXT to PIP WS, done at present without correlations, appears to give broader spreads than required for reliable re-matching → will be redone with full correlation matrix
- It could be better to use IP measurements as input for re-matching.
- In spite of large spreads of propagated EXT Twiss at PIP WS, there is a large systematic inconsistency with measured α_x while βvalues are systematically too low → this points to some error or incompatibility between the model and actual magnetic lattice (polarities of QM11-16 matching quads ???)