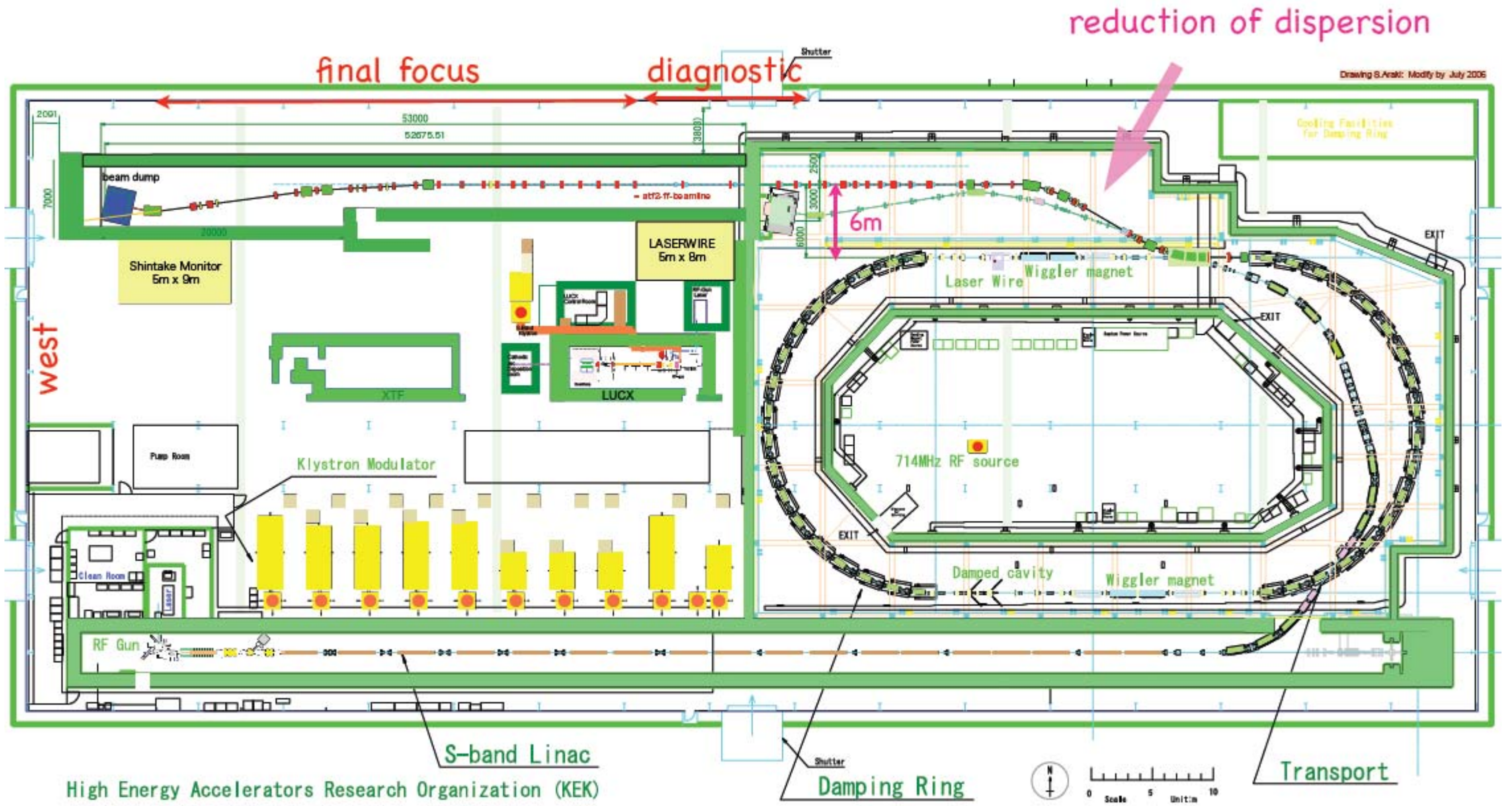
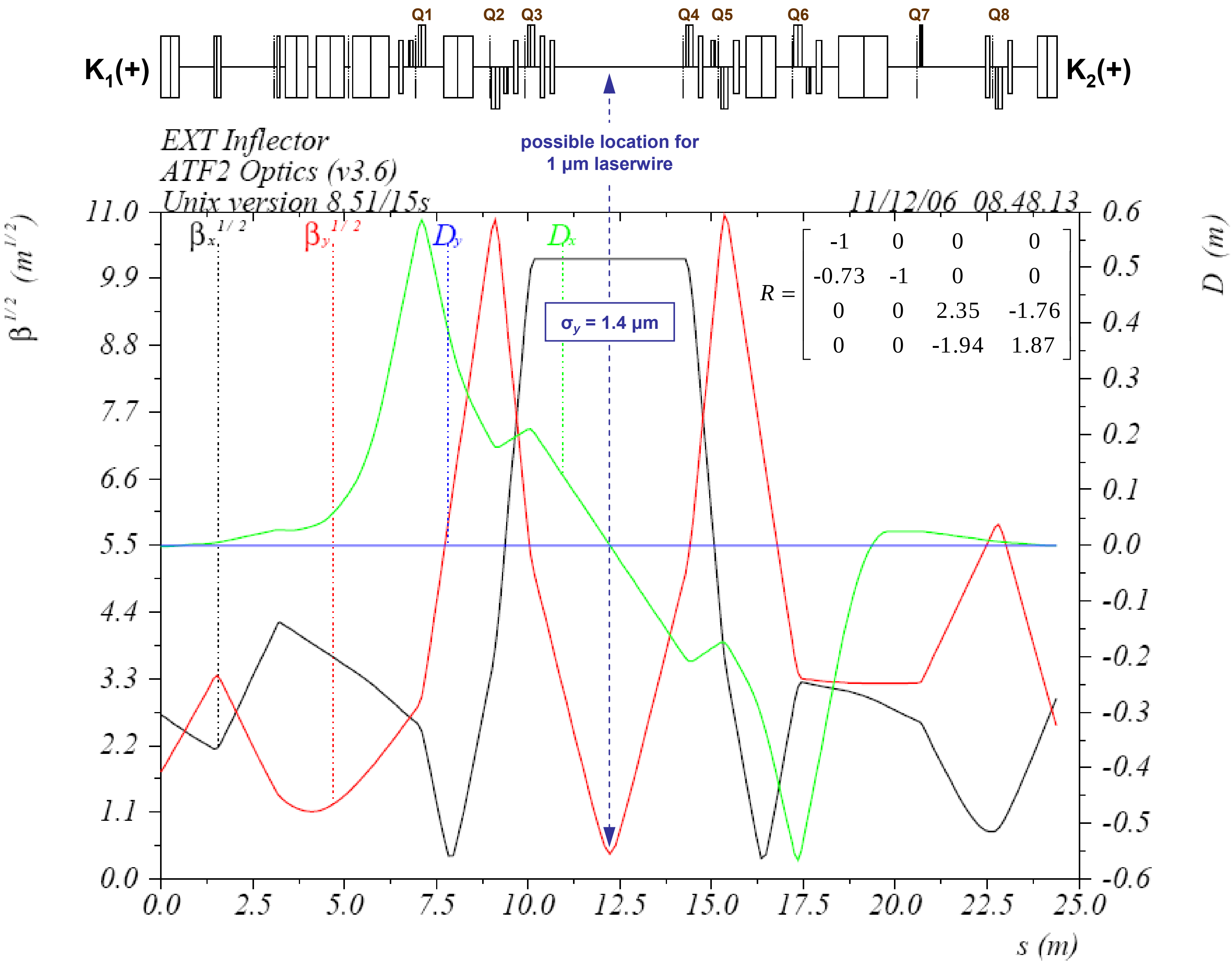
International Linear Collider at Stanford Linear Accelerator Center

Correction of Anomalous Vertical Dispersion in the ATF2 EXT Line (v3.6)

Optics v3.5, 1 July 2006





For MAD files see http://www.slac.stanford.edu/~mdw/ATF2/v3.6

Simulation Parameters

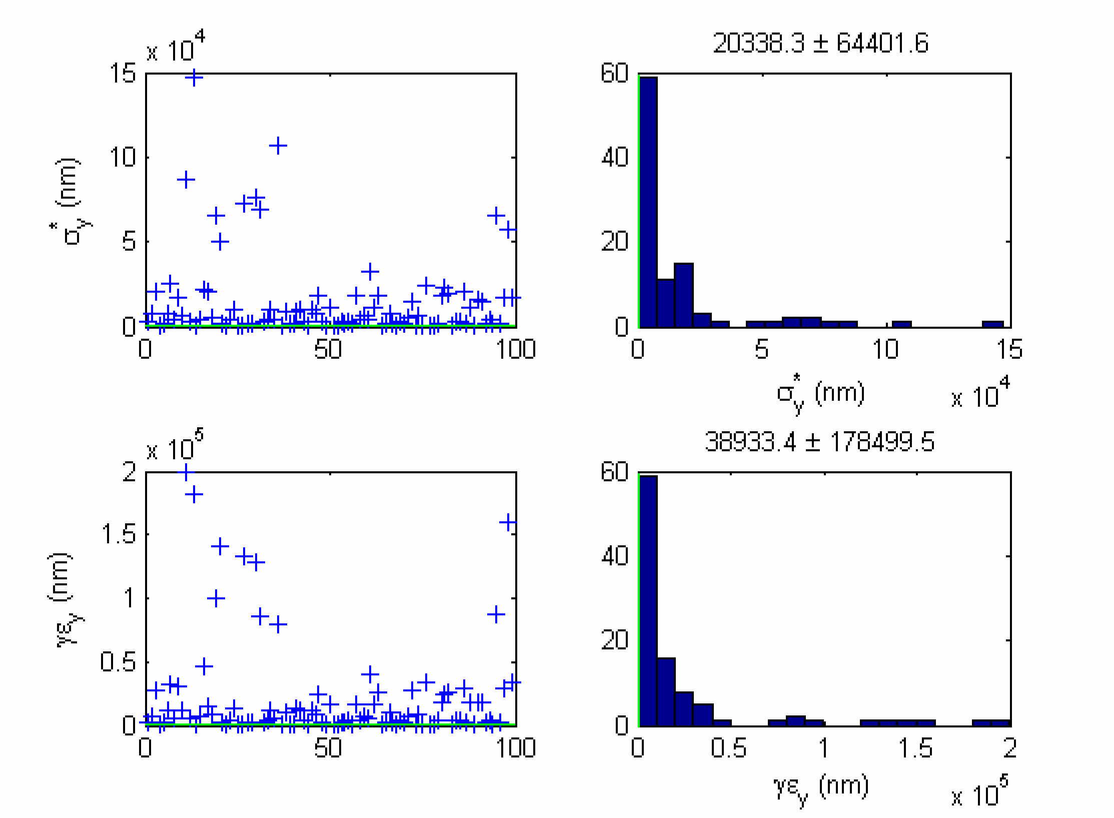
- use Peter Tenenbaum's Lucretia[1] simulation code
- included
  - perfect beam from Damping Ring (ε_x=2×10^{-9} m, $\gamma\varepsilon_y$=3×10^{-8} m) … errors begin after extraction septa, unless otherwise noted
  - perfect Final Focus
  - dipole errors[2]: ΔY = 100 μm (rms)
  - quadrupole errors: ΔX = 50 μm, ΔY = 30 μm, Δθ = 0.3 mrad (rms)
  - sextupole errors: ΔX = 50 μm, ΔY = 30 μm, Δθ = 0.3 mrad (rms)
  - BPM resolution: 5 μm (rms)
- *not* included
  - wire scanner rolls: $|\theta| \le 0.2°$ (uniform)
  - wire scanner beam size errors: $\sigma = \sigma_0(1+\Delta\sigma_{relative})+\Delta\sigma_{absolute}$
  - quadrupole strength errors (ΔK/K)
  - BPM offsets
  - BPM rolls
  - tuning in FF

[1]http://www.slac.stanford.edu/accel/ilc/codes/Lucretia/
[2]EXT dipoles BH1 and BH2 are assumed to have nonzero sextupole components

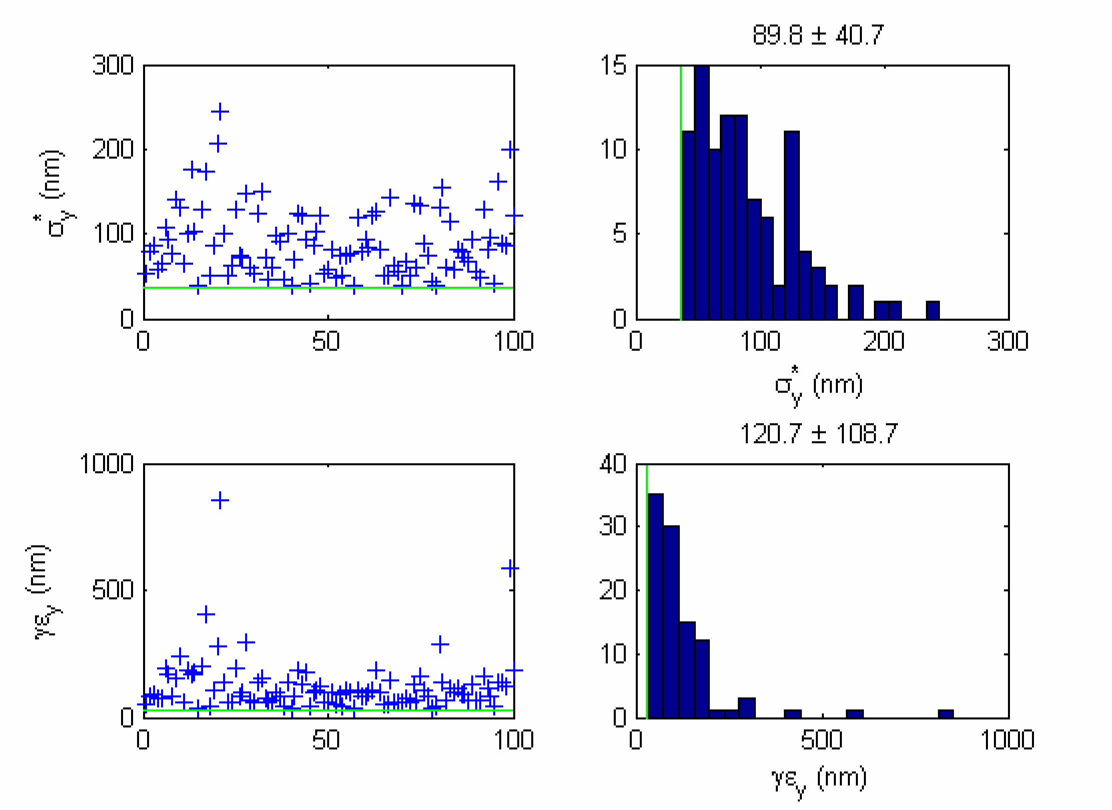
Simulation Procedure

1. apply errors
2. steer flat (EXT only)
3. launch into FF
   - use 2 virtual correctors
   - steer to 2 virtual BPMs (one at the IP and one 90° upstream)
   - virtual BPMs are perfect
4. measure dispersion in diagnostic section
   - scan input beam energy
   - measure orbits
   - fit position vs energy at each BPM
5. correct dispersion in diagnostic section
   - back-propagate measured η to start of diagnostic section to get η_0 and η'_0
   - use QF1X + QF6X multiknobs for η_x and η'_x
   - correct η_y and η'_y using skew quads in inflector (thin lenses at quad centers)
6. correct coupling
   - scan 4 skew quadrupoles sequentially
   - deduce projected ε_y from wire scanner measurements
   - set each skew quad to minimize projected ε_y

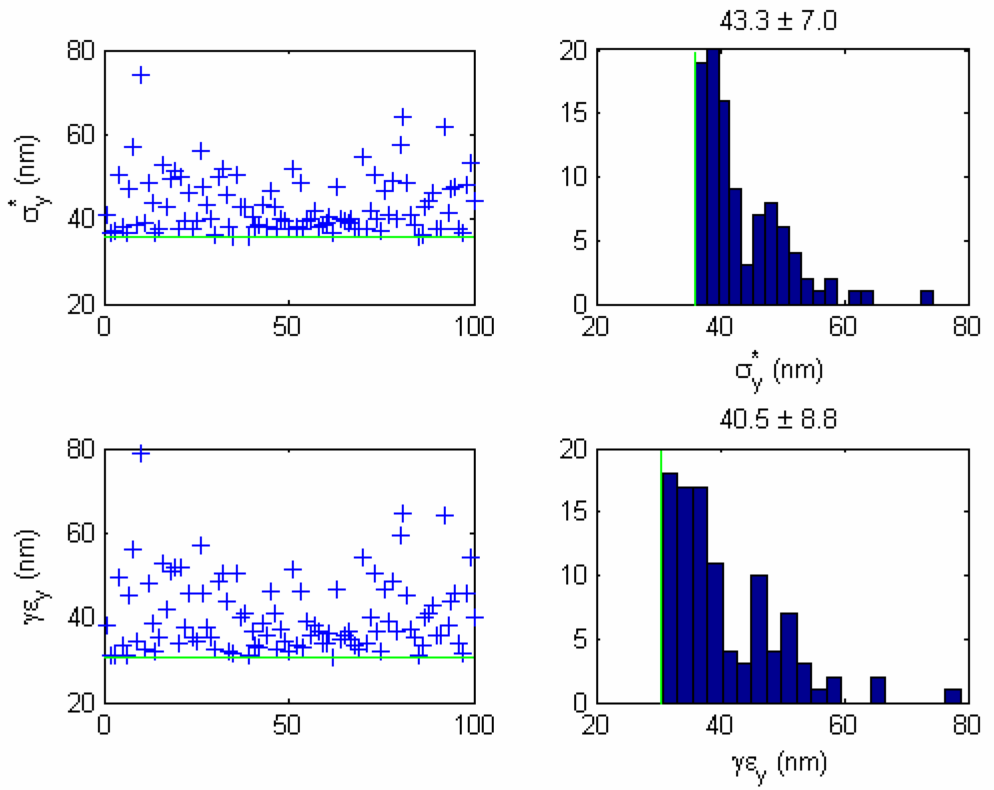
errors only (100 seeds)



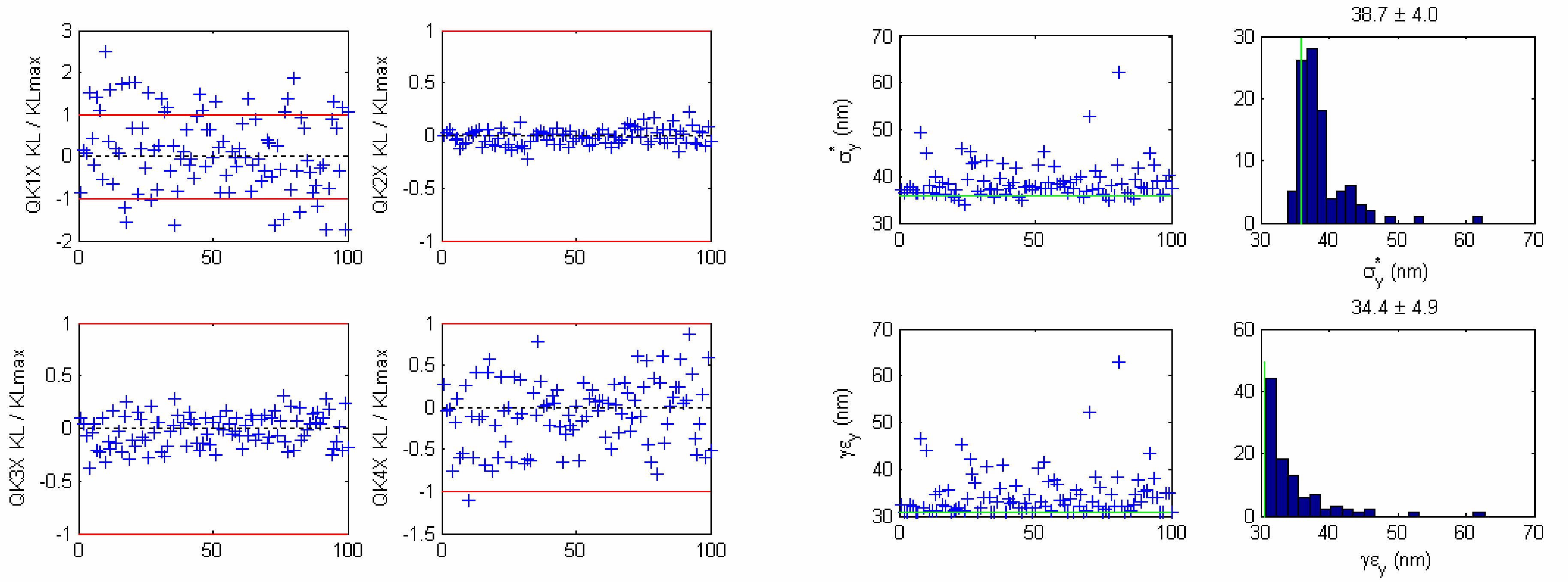
errors, FF launch



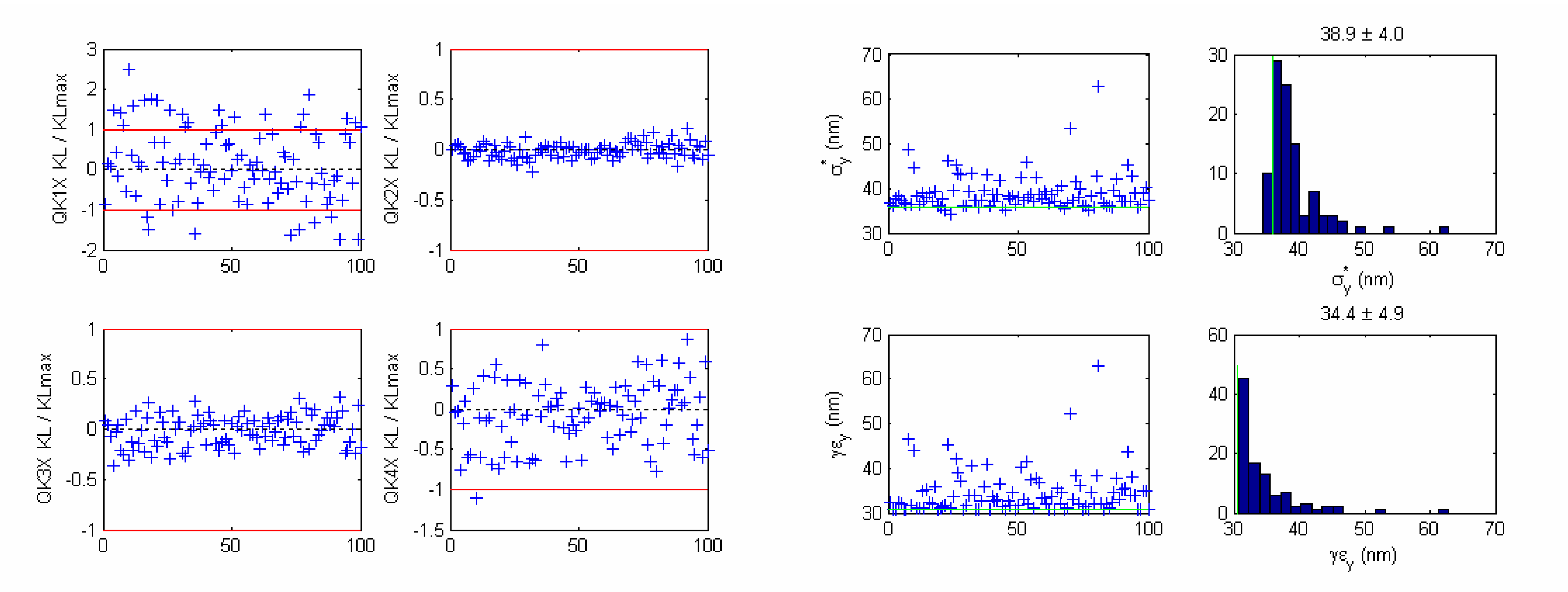
errors, steer flat, FF launch

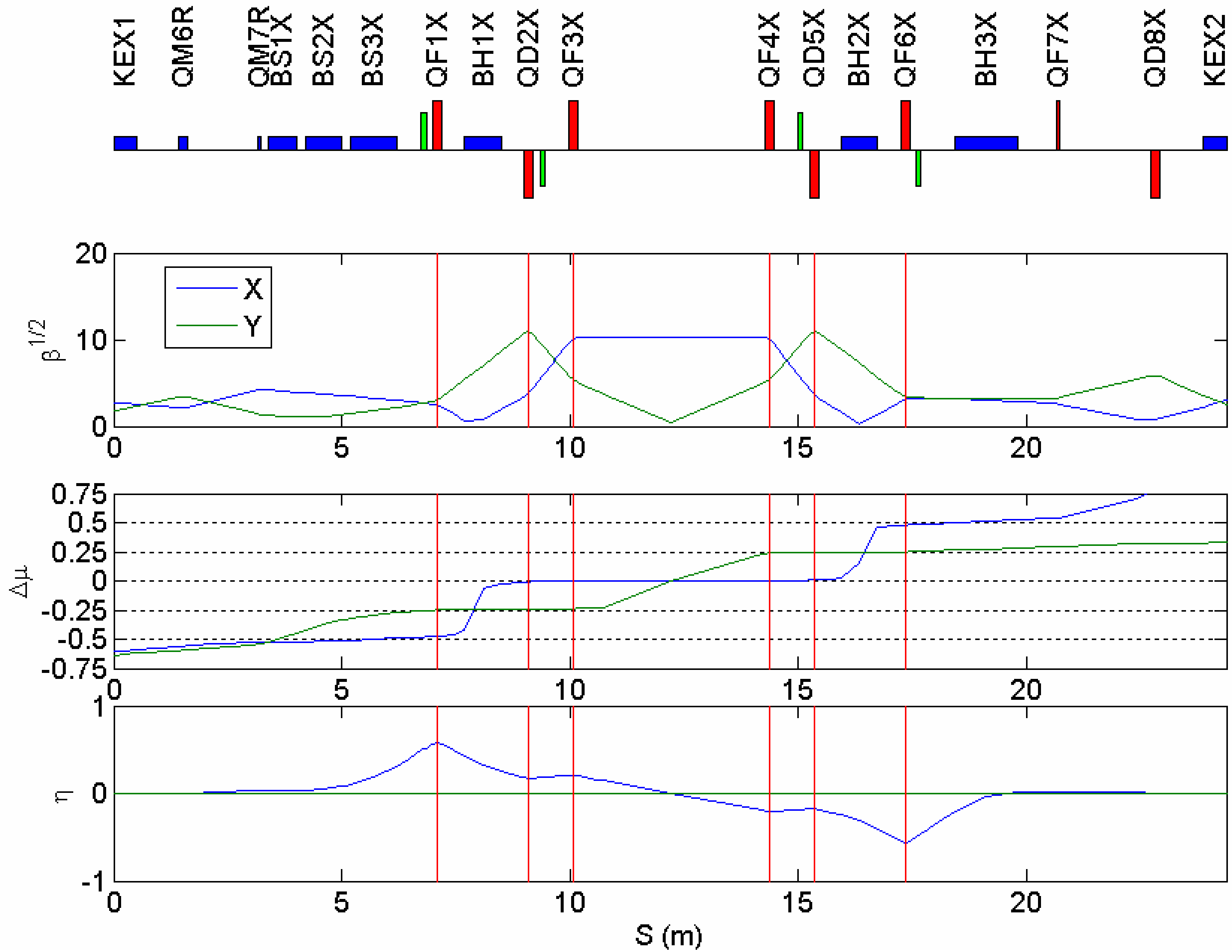


errors, steer flat, correct coupling, FF launch



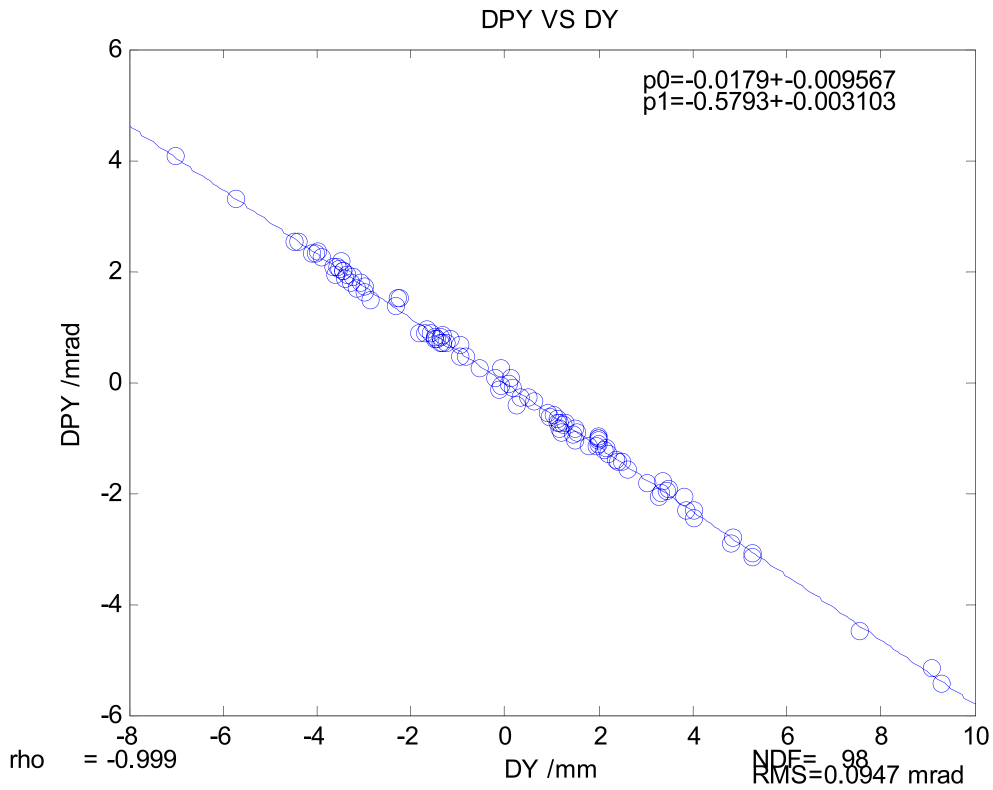
Note: red lines represent maximum integrated strength of IDX skew quad (KLmax ≈ 0.1 T) errors, steer flat, correct η_x, correct coupling, FF launch



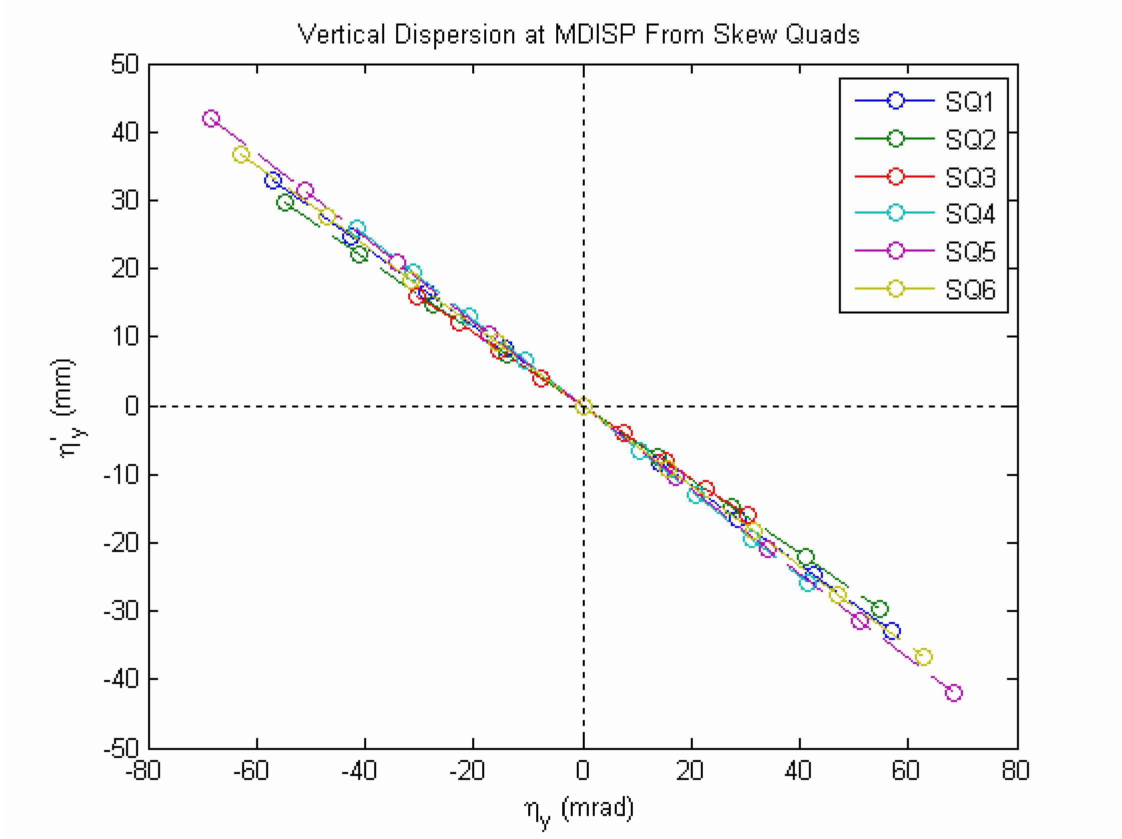


KEX1
QM6R
QM7R
BS1X
BS2X
BS3X
QF1X
BH1X
QD2X
QF3X
QF4X
QD5X
BH2X
QF6X
BH3X
QF7X
QD8X
KEX2
X
Y
$\beta^{1/2}$
$\Delta\mu$
η
S (m)

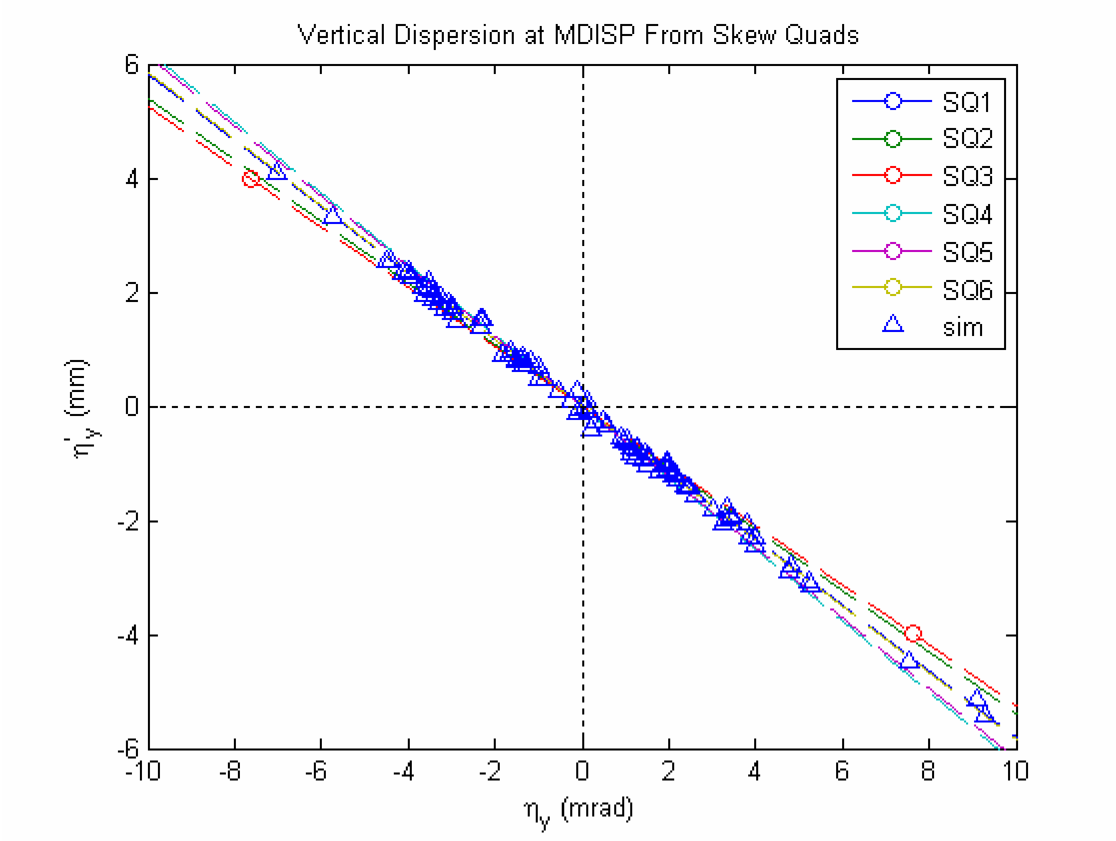
η_y vs η'_y at exit of KEX2 (start of diagnostic section)
100 seeds after steering EXT



η_y vs η'_y at exit of KEX2 (start of diagnostic section) perfect EXT; scan each skew quad



both η_y and η'_y can be corrected with any single skew quad!



η_y correction: residual *x*-*y* coupling

$$R = \begin{bmatrix} R_{11} & R_{12} & R_{13} & R_{14} \\ R_{21} & R_{22} & R_{23} & R_{24} \\ R_{31} & R_{32} & R_{33} & R_{34} \\ R_{41} & R_{42} & R_{43} & R_{44} \end{bmatrix} \equiv \begin{bmatrix} \mathrm{A} & \mathrm{B} \\ \mathrm{C} & \mathrm{D} \end{bmatrix}$$

$$\mathrm{Q}_{x,y} \equiv \frac{1}{\sqrt{\beta_{x,y}}} \begin{bmatrix} \beta_{x,y} & 0 \\ -\alpha_{x,y} & 1 \end{bmatrix}$$

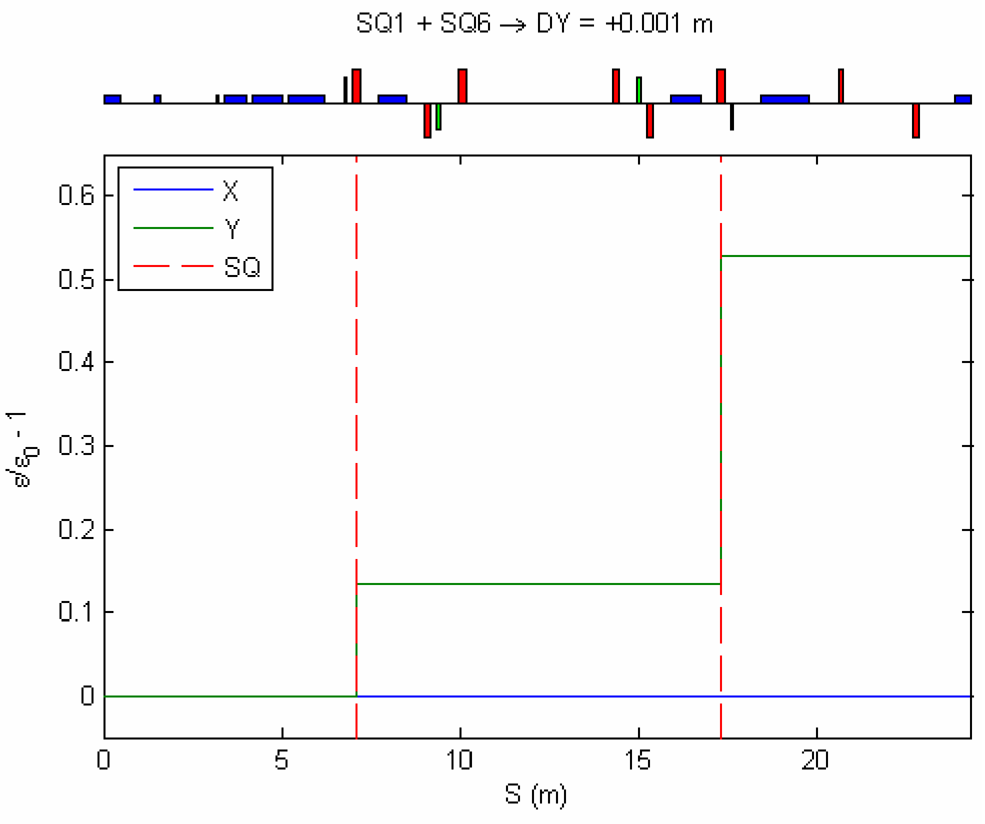
$$\mathrm{P} \equiv \mathrm{Q}_x^{-1} \mathrm{A}^{-1} \mathrm{B} \mathrm{Q}_y$$

$$\lambda = \mathrm{tr}\left(\mathrm{P}\mathrm{P}^{\mathrm{T}}\right)$$

$$\varepsilon_x^2 = \left|\mathrm{A}\right|^2 \varepsilon_{x0}^2 + \left|\mathrm{C}\right|^2 \varepsilon_{y0}^2 + \left|\mathrm{A}\right|^2 \varepsilon_{x0} \varepsilon_{y0} \lambda$$

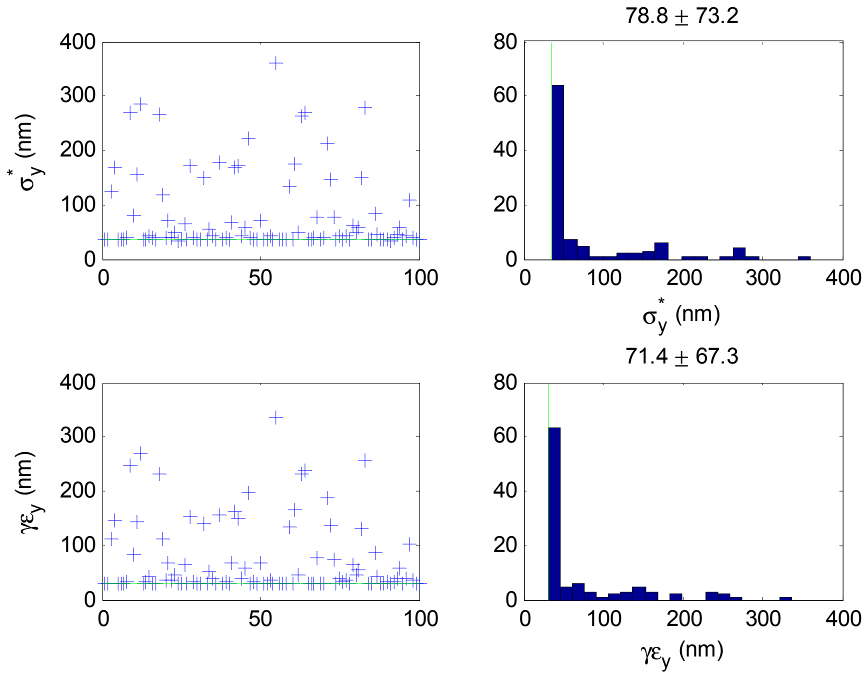
$$\varepsilon_y^2 = \left|\mathrm{C}\right|^2 \varepsilon_{x0}^2 + \left|\mathrm{A}\right|^2 \varepsilon_{y0}^2 + \left|\mathrm{A}\right|^2 \varepsilon_{x0} \varepsilon_{y0} \lambda$$

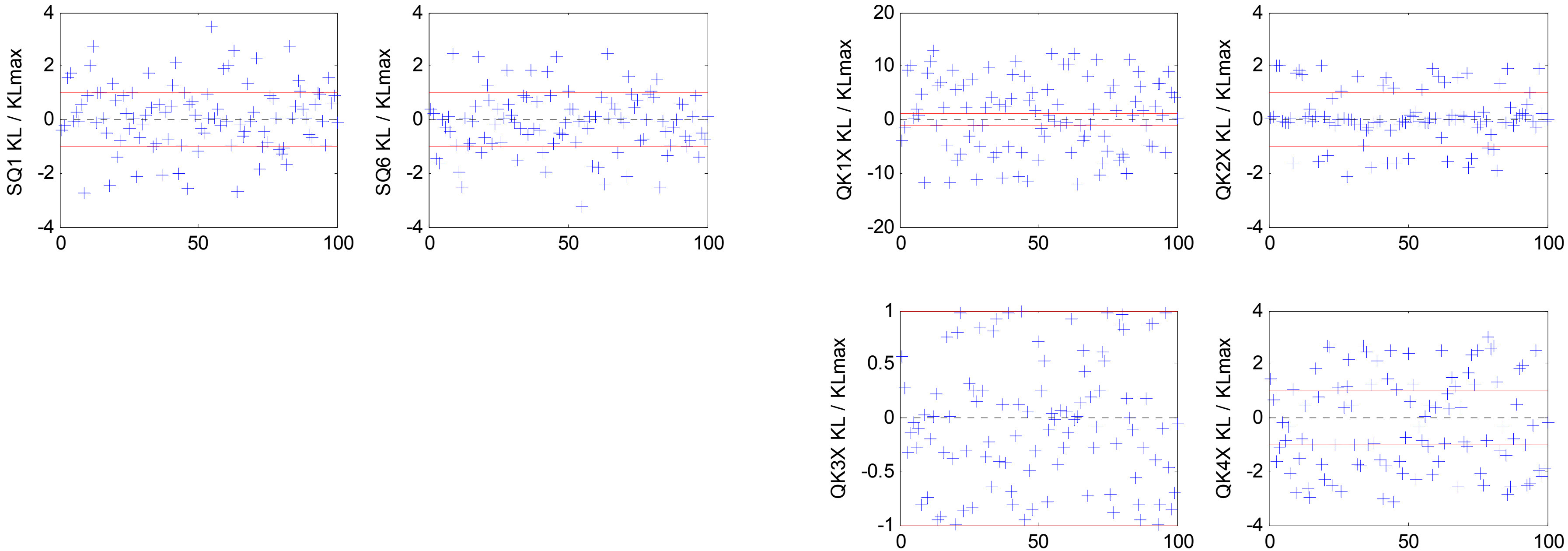
Scheme 1: 2 skew quads



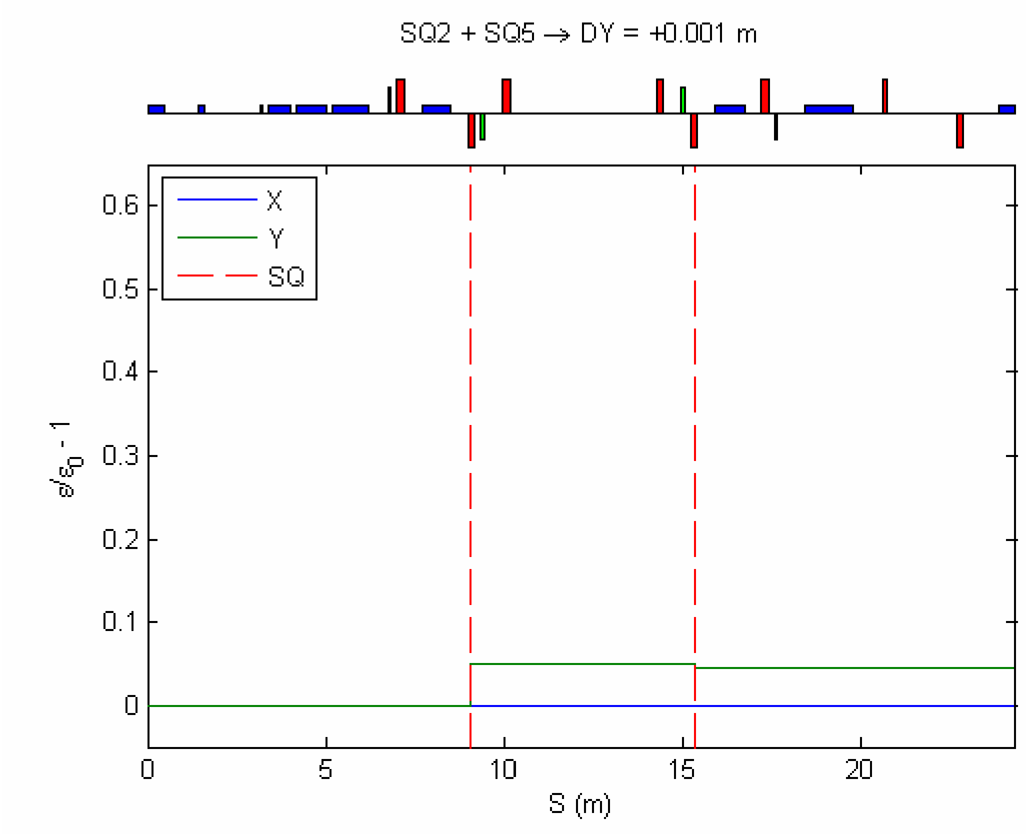
		SQ1	SQ6
		-------	-------
βx	=	5.920	10.036
αx	=	4.480	-5.320
ηx	=	0.585	-0.566
βy	=	9.053	11.557
αy	=	-7.212	6.631
Δμx	=	-	343.575
Δμy	=	-	179.568
kl/klmax	=	0.221	-0.178
residual	=	0.5288	

Scheme 1


78.8 ± 73.2
σ_y^* (nm)
σ_y^* (nm)
71.4 ± 67.3
$\gamma\epsilon_y$ (nm)
$\gamma\epsilon_y$ (nm)

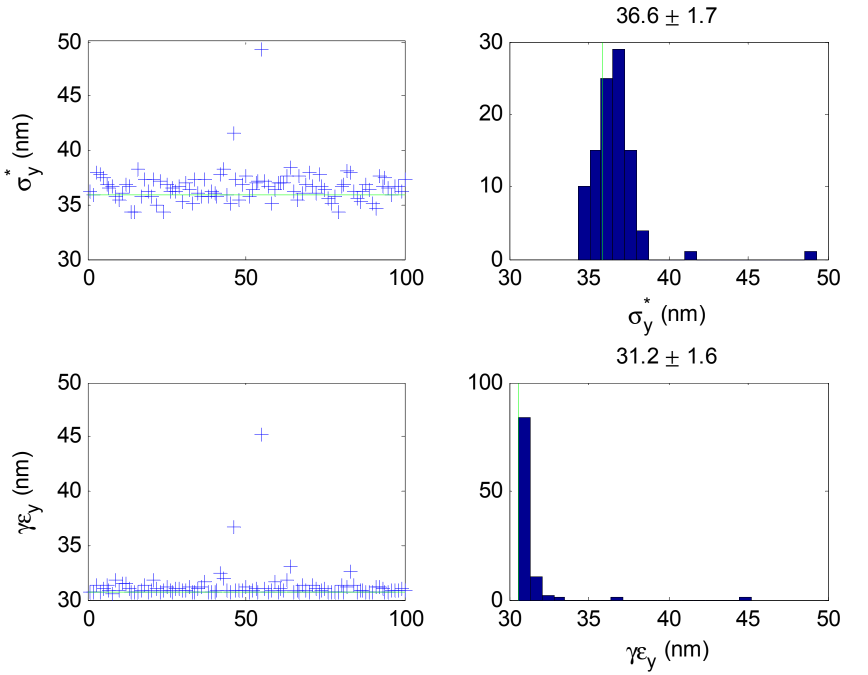

SQ1 KL / KLmax
SQ6 KL / KLmax
QK1X KL / KLmax
QK2X KL / KLmax
QK3X KL / KLmax
QK4X KL / KLmax

Scheme 2: 2 skew quads

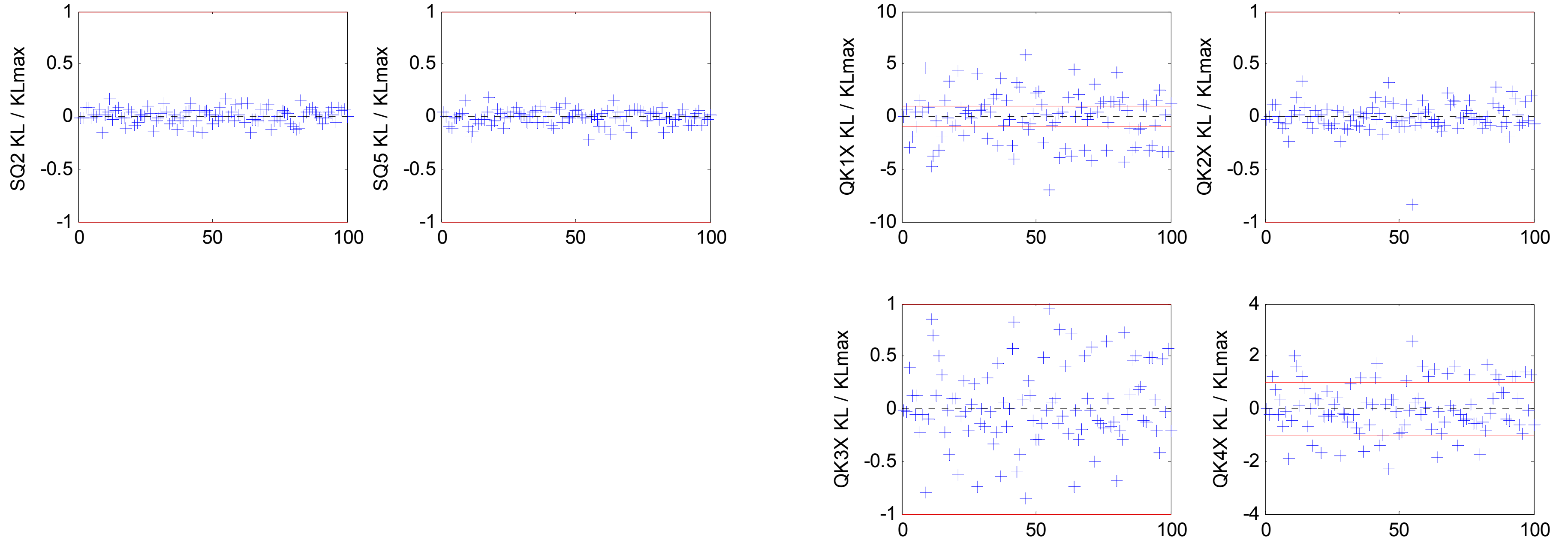


		SQ2	SQ5
βx	=	14.557	13.494
αx	=	-18.187	18.354
ηx	=	0.177	-0.174
βy	=	118.109	119.830
αy	=	10.711	-12.069
Δμx	=	-	5.337
Δμy	=	-	172.957
kl/klmax	=	0.023	0.001
residual	=	0.0442	

Scheme 2

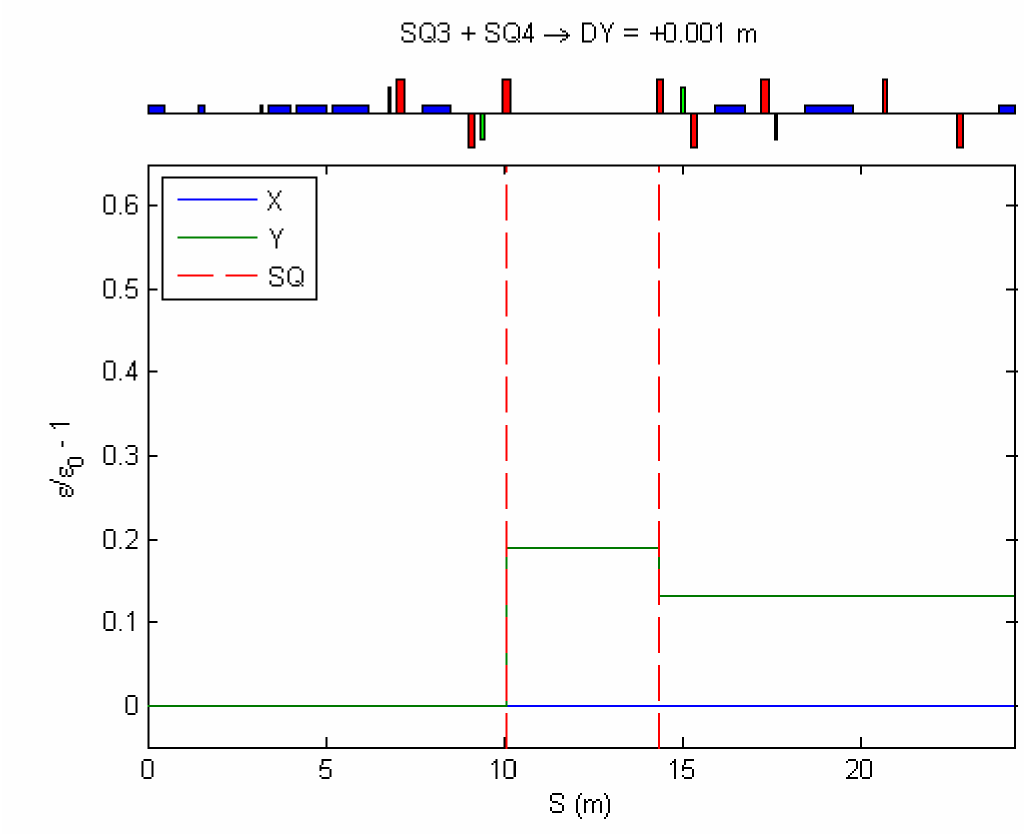


36.6 ± 1.7
σ_y^* (nm)
31.2 ± 1.6
$\gamma\epsilon_y$ (nm)

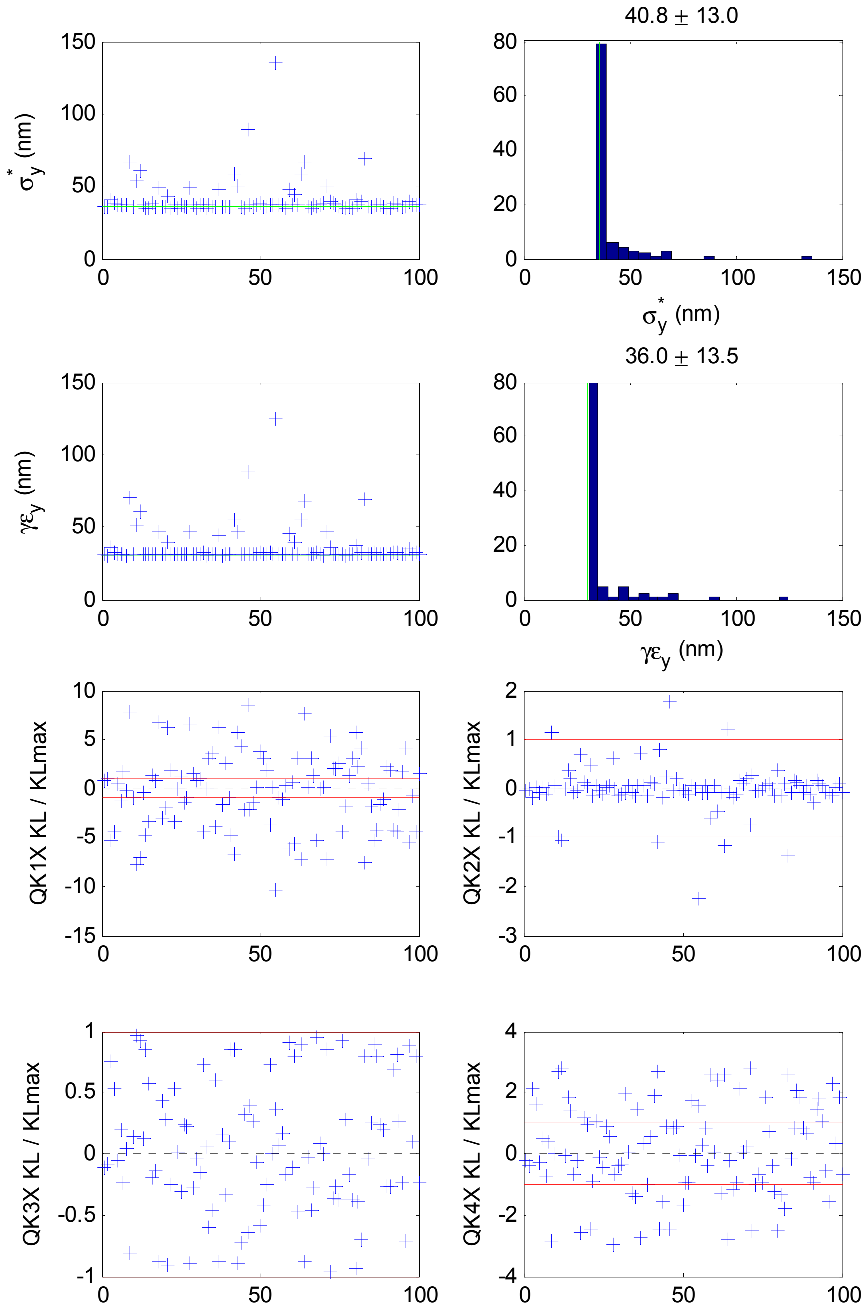


SQ2 KL / KLmax
SQ5 KL / KLmax
QK1X KL / KLmax
QK2X KL / KLmax
QK3X KL / KLmax
QK4X KL / KLmax

Scheme 3: 2 skew quads

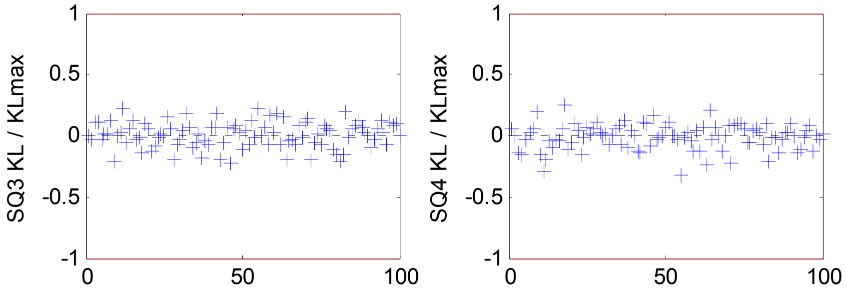


	SQ3	SQ4
βx =	101.073	101.000
αx =	-34.197	34.920
ηx =	0.209	-0.209
βy =	28.629	28.649
αy =	22.275	-22.484
Δμx =	-	2.362
Δμy =	-	171.062
kl/klmax =	0.036	0.006
residual =	0.1318	



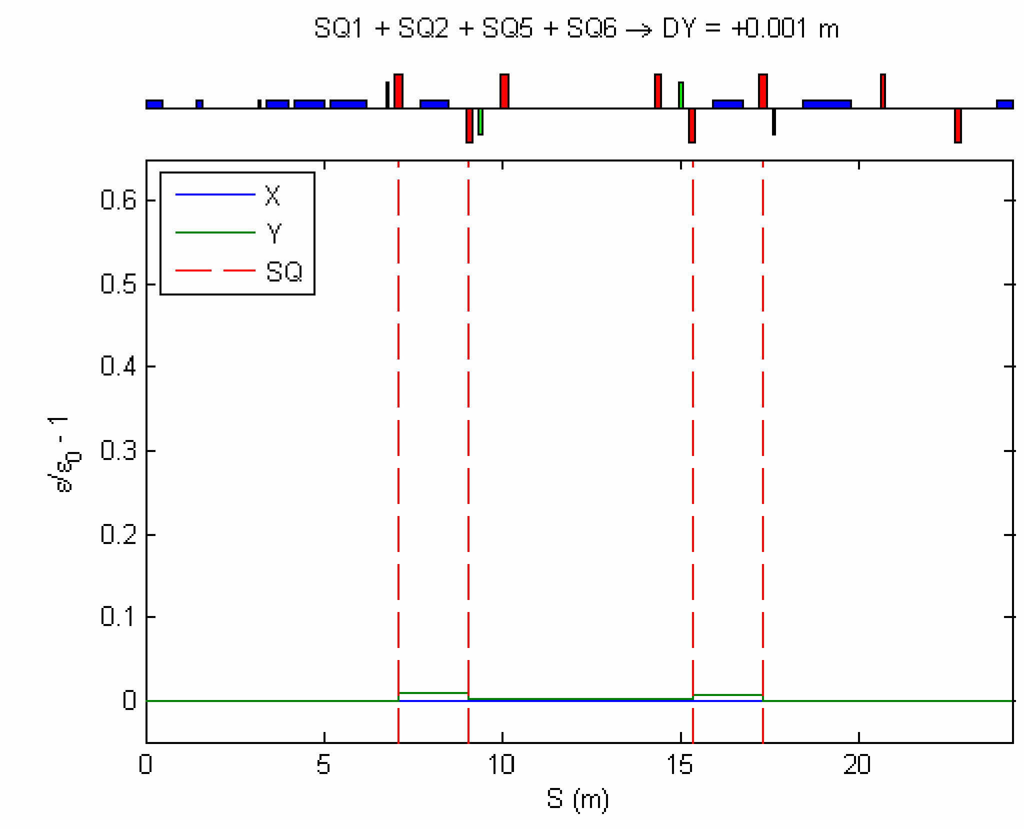
40.8 ± 13.0
σ_y^* (nm)
36.0 ± 13.5
$\gamma\epsilon_y$ (nm)
QK1X KL / KLmax
QK2X KL / KLmax
QK3X KL / KLmax
QK4X KL / KLmax

Scheme 3



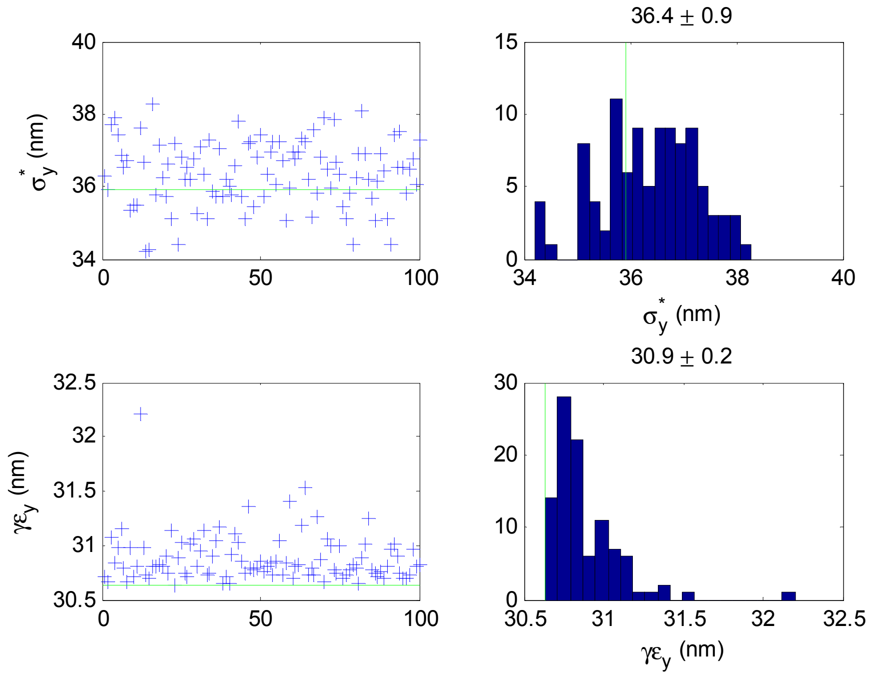
SQ3 KL / KLmax
SQ4 KL / KLmax

Scheme 4: 4 skew quads

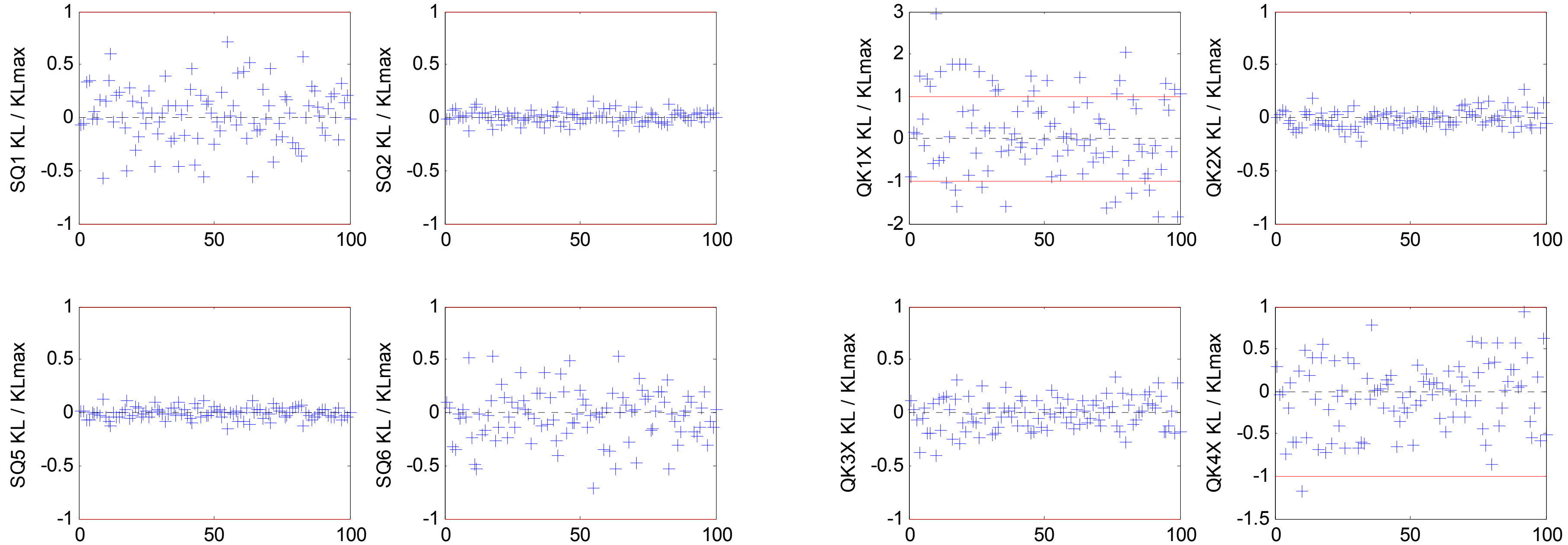


		SQ1	SQ2	SQ5	SQ6
βx	=	5.920	14.557	13.494	10.036
αx	=	4.480	-18.187	18.354	-5.320
ηx	=	0.585	0.177	-0.174	-0.566
βy	=	9.053	118.109	119.830	11.557
αy	=	-7.212	10.711	-12.069	6.631
Δμx	=	-	167.871	173.208	343.575
Δμy	=	-	3.516	176.473	179.568
kl/klmax	=	0.058	0.008	-0.010	-0.027
residual	=	1.8430e-004			

Scheme 4

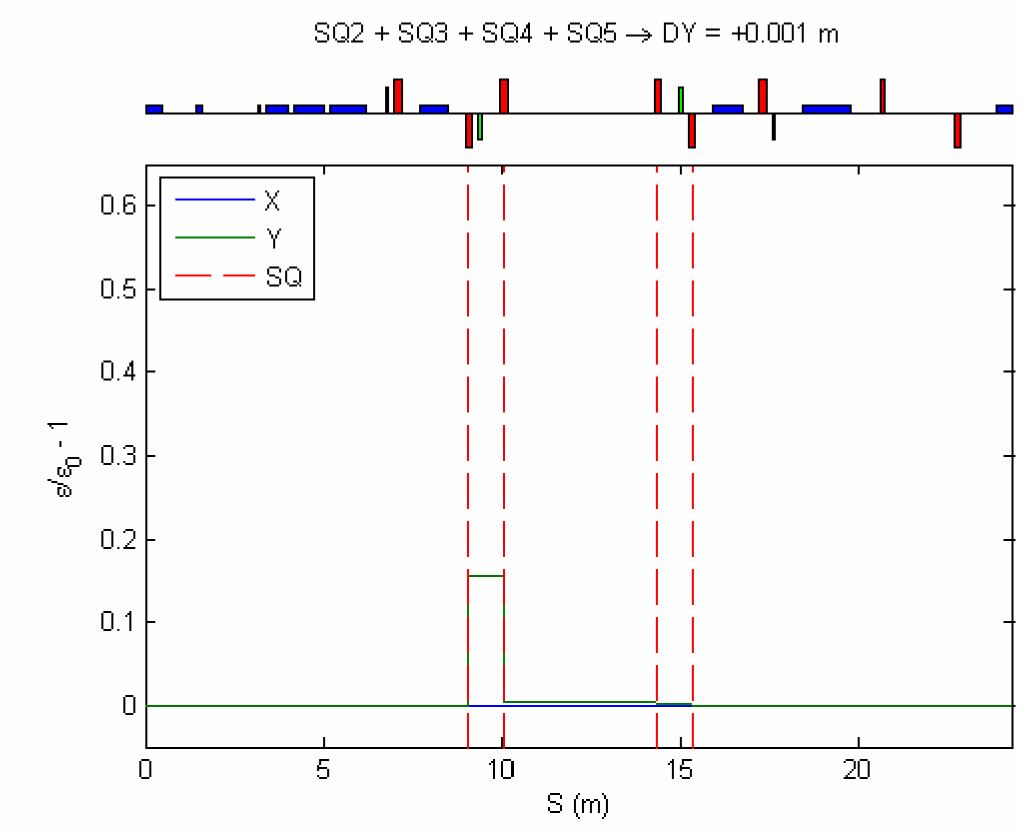


36.4 ± 0.9
σ_y^* (nm)
30.9 ± 0.2
$\gamma\epsilon_y$ (nm)



SQ1 KL / KLmax
SQ2 KL / KLmax
QK1X KL / KLmax
QK2X KL / KLmax
SQ5 KL / KLmax
SQ6 KL / KLmax
QK3X KL / KLmax
QK4X KL / KLmax

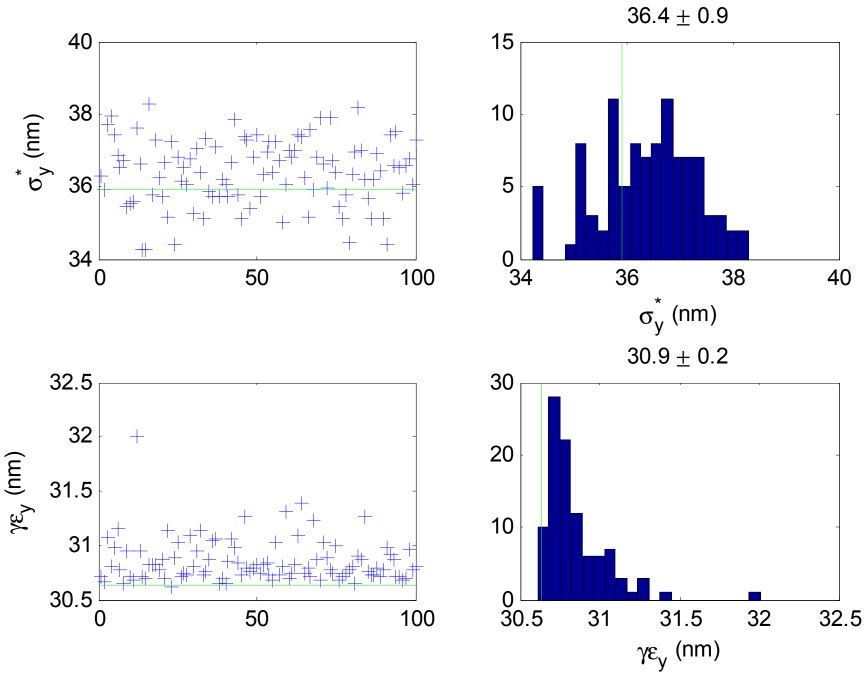
Scheme 5: 4 skew quads

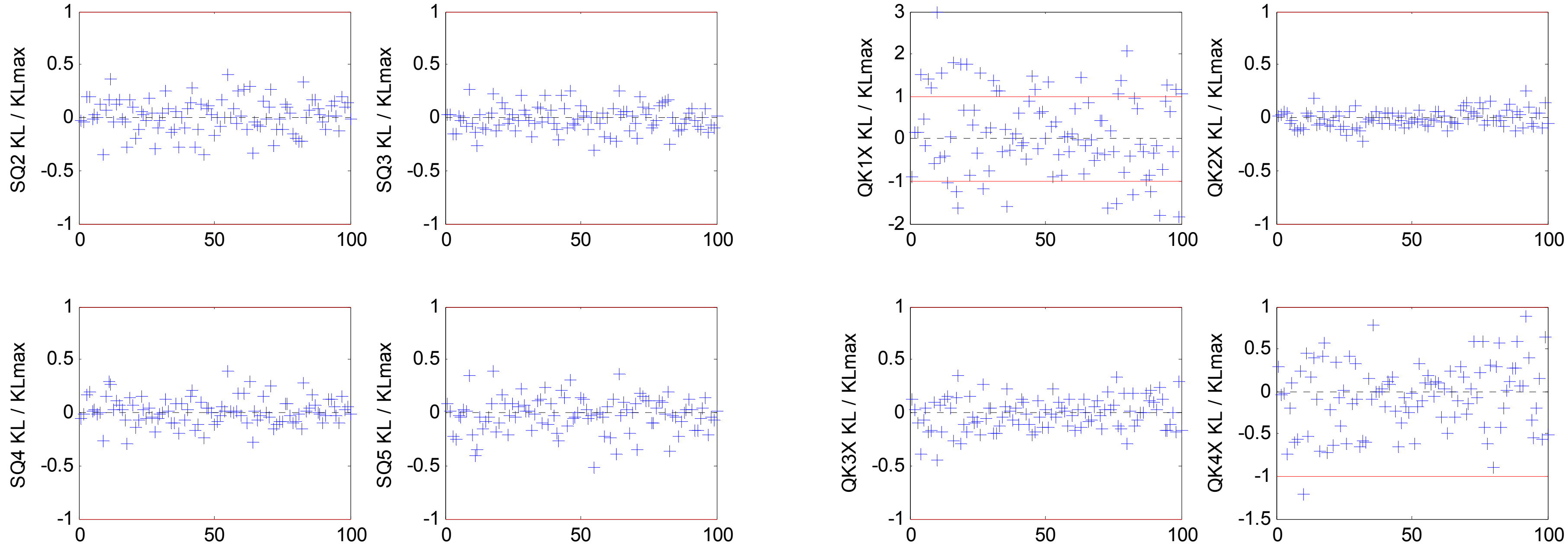


	SQ2	SQ3	SQ4	SQ5
βx =	14.557	101.073	101.000	13.494
αx =	-18.187	-34.197	34.920	18.354
ηx =	0.177	0.209	-0.209	-0.174
βy =	118.109	28.629	28.649	119.830
αy =	10.711	22.275	-22.484	-12.069
Δμx =	-	1.460	3.822	5.337
Δμy =	-	0.951	172.013	172.957
kl/klmax =	0.042	-0.028	0.007	-0.005

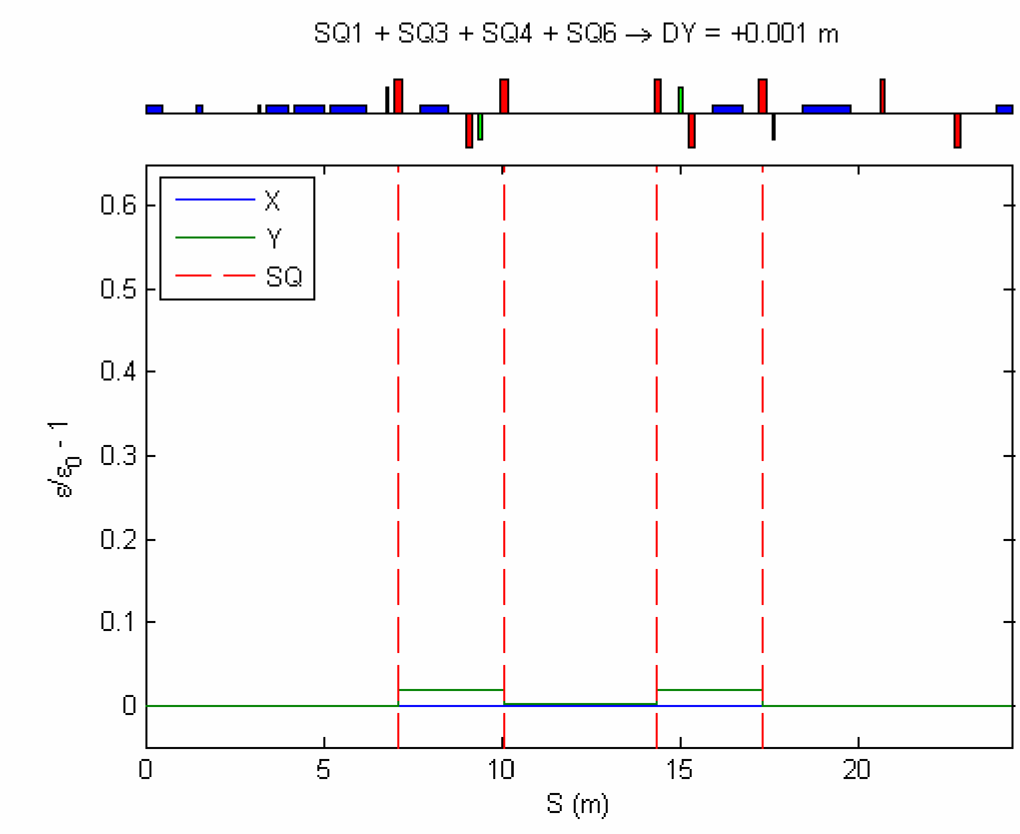
residual = 4.3953e-004

Scheme 5


36.4 ± 0.9
σ_y^* (nm)
30.9 ± 0.2
$\gamma\varepsilon_y$ (nm)

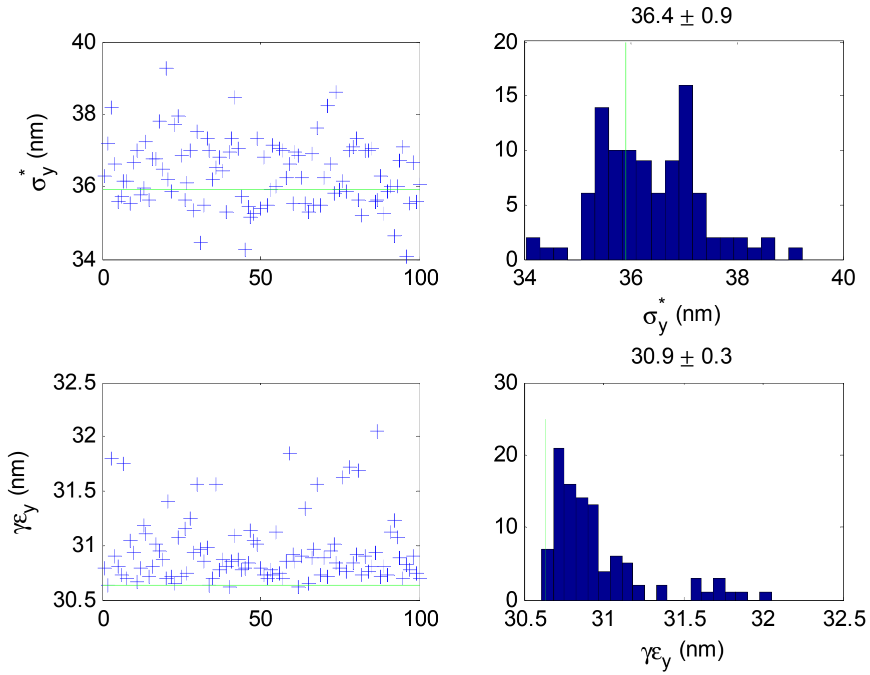

SQ2 KL / KLmax
SQ3 KL / KLmax
QK1X KL / KLmax
QK2X KL / KLmax
SQ4 KL / KLmax
SQ5 KL / KLmax
QK3X KL / KLmax
QK4X KL / KLmax

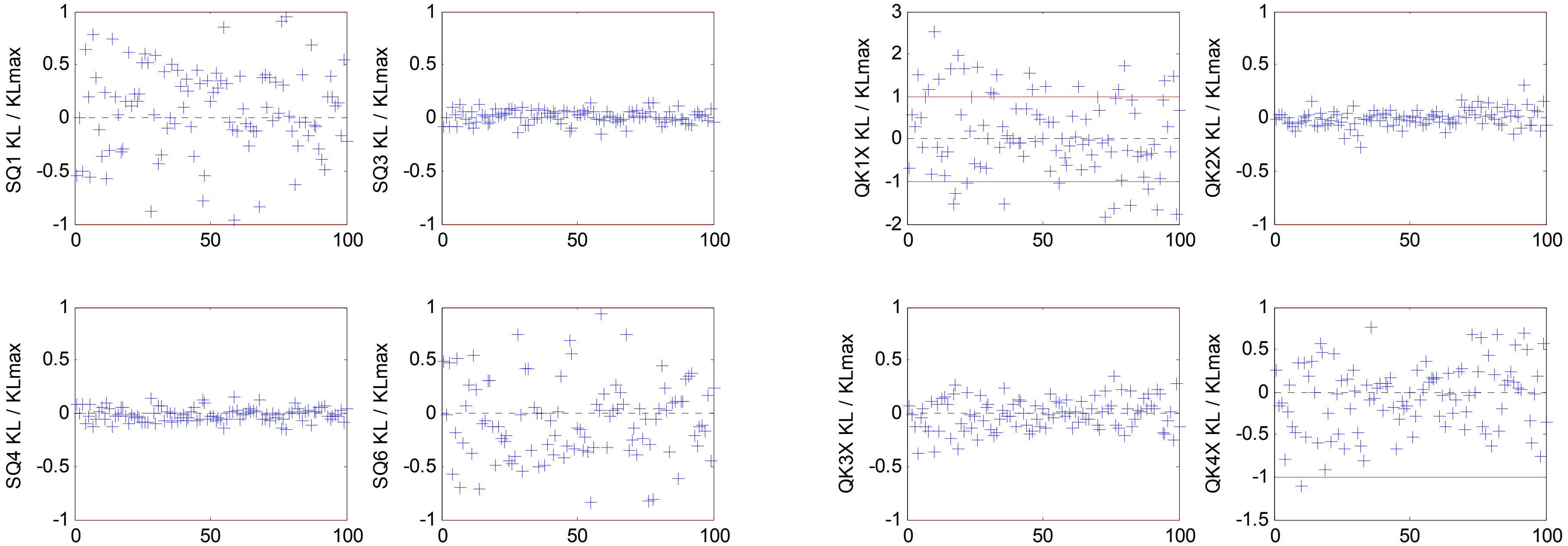
Scheme 6: 4 skew quads



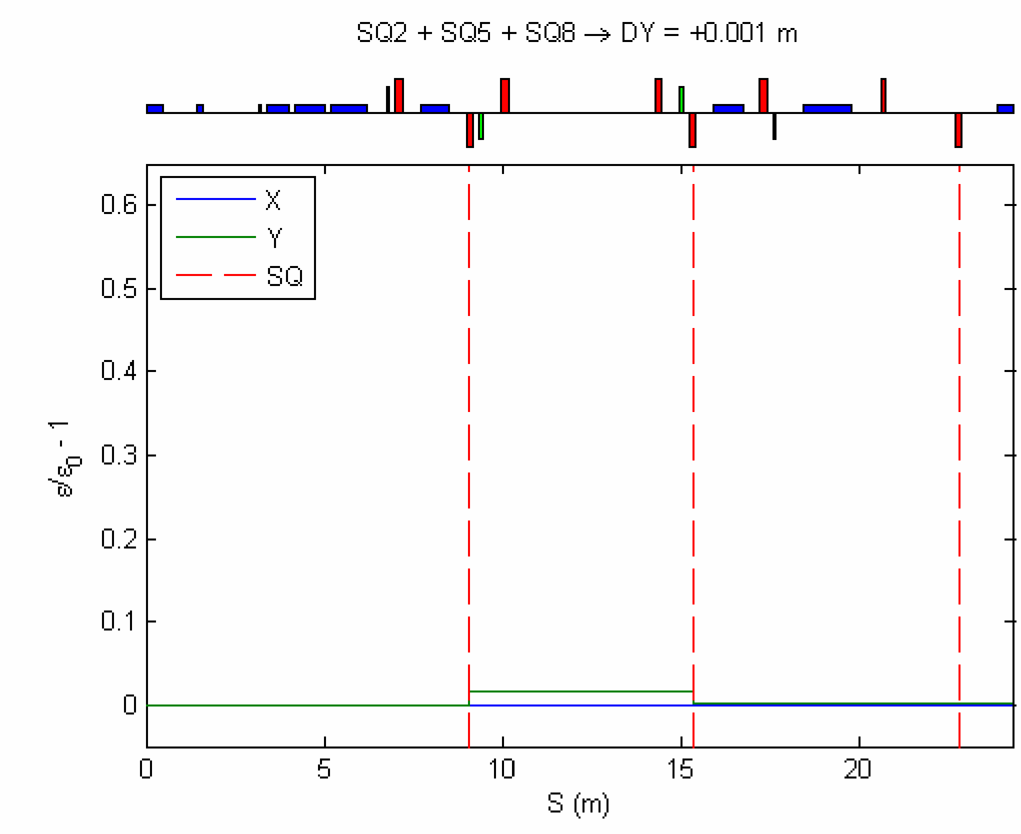
	SQ1	SQ3	SQ4	SQ6
	-------	-------	-------	-------
βx =	5.920	101.073	101.000	10.036
αx =	4.480	-34.197	34.920	-5.320
ηx =	0.585	0.209	-0.209	-0.566
βy =	9.053	28.629	28.649	11.557
αy =	-7.212	22.275	-22.484	6.631
Δμx =	-	169.330	171.693	343.575
Δμy =	-	4.467	175.529	179.568
kl/klmax =	0.080	0.010	-0.011	-0.048
residual =	2.1308e-004			

Scheme 6


36.4 ± 0.9
σ_y^* (nm)
30.9 ± 0.3
$\gamma\epsilon_y$ (nm)

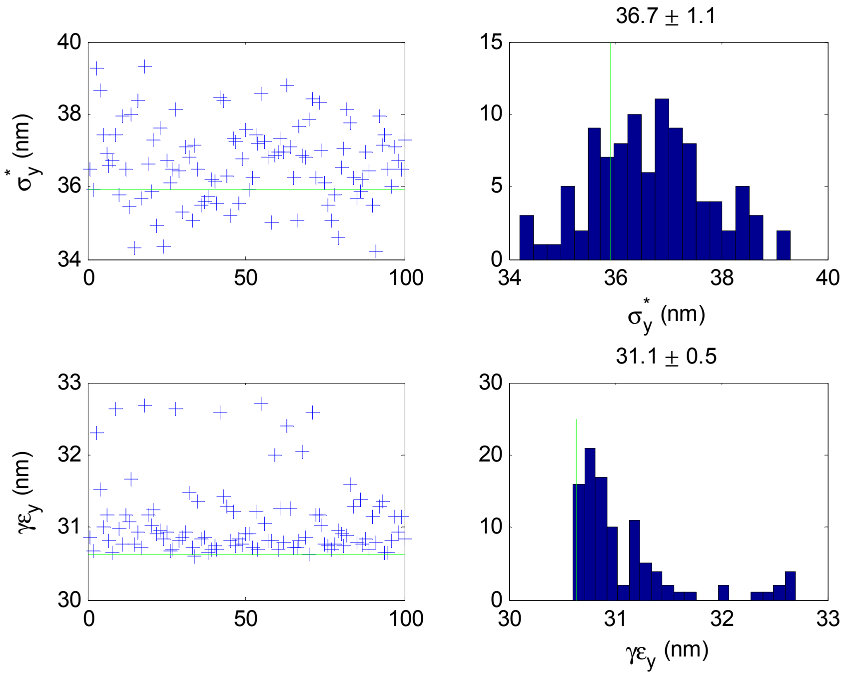

SQ1 KL / KLmax
SQ3 KL / KLmax
QK1X KL / KLmax
QK2X KL / KLmax
SQ4 KL / KLmax
SQ6 KL / KLmax
QK3X KL / KLmax
QK4X KL / KLmax

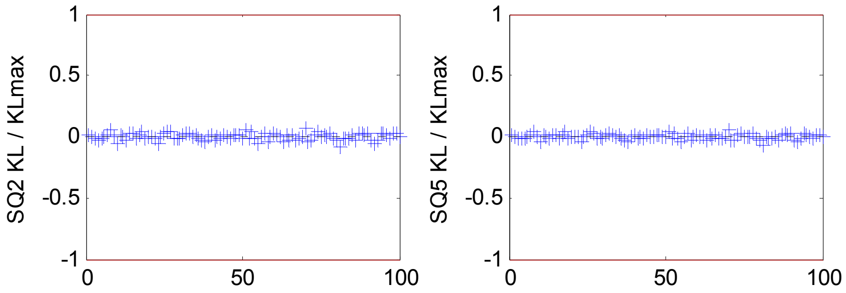
Scheme 7: 3 skew quads

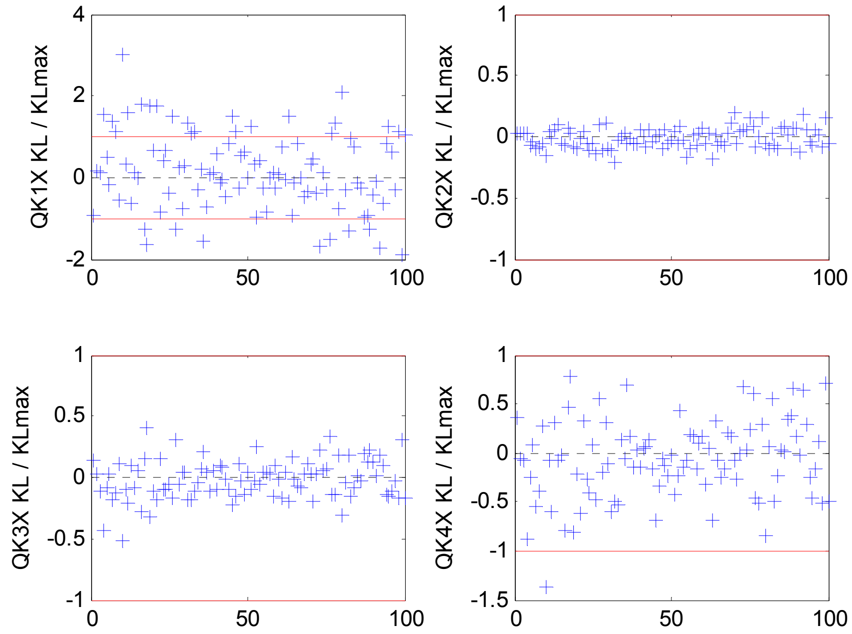


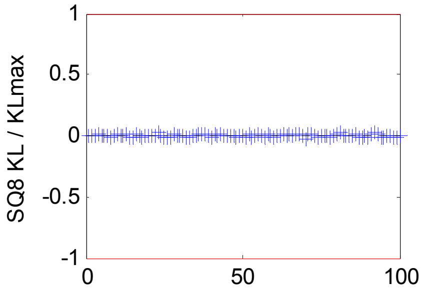
		SQ2	SQ5	SQ8
βx	=	14.557	13.494	0.696
αx	=	-18.187	18.354	-0.561
ηx	=	0.177	-0.174	0.007
βy	=	118.109	119.830	34.124
αy	=	10.711	-12.069	2.668
Δμx	=	-	5.337	289.667
Δμy	=	-	172.957	200.657
kl/klmax	=	0.013	0.010	-0.005
residual	=	0.0016		

Scheme 7



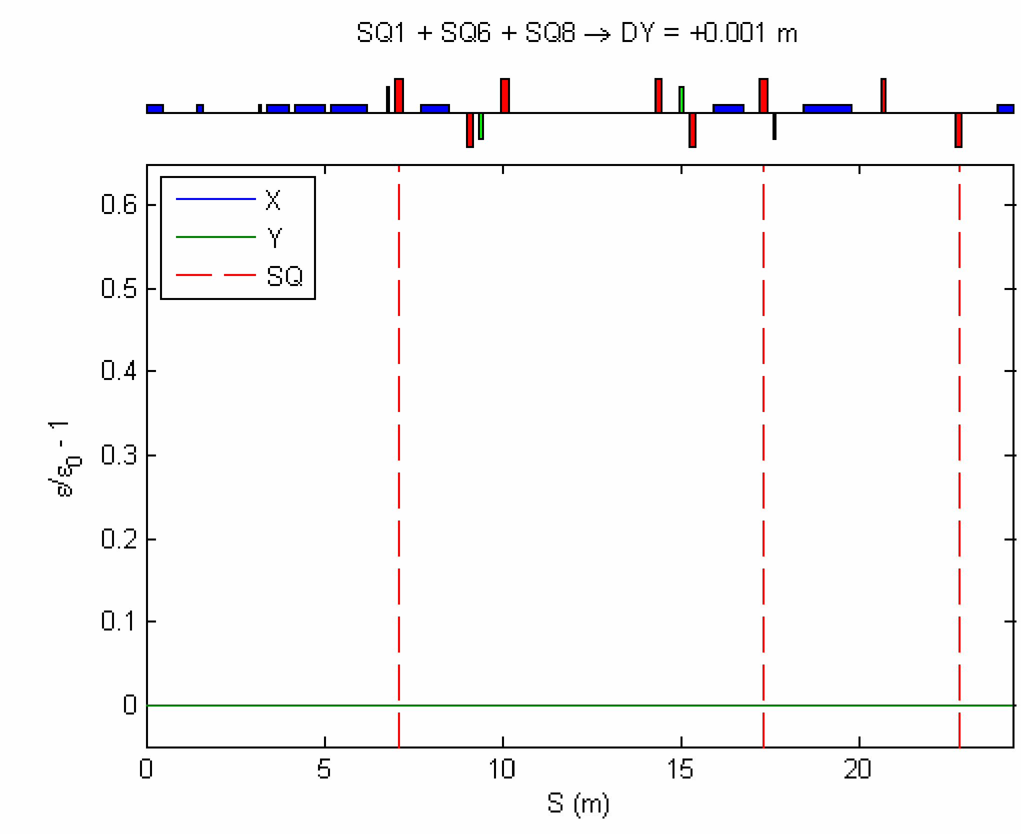






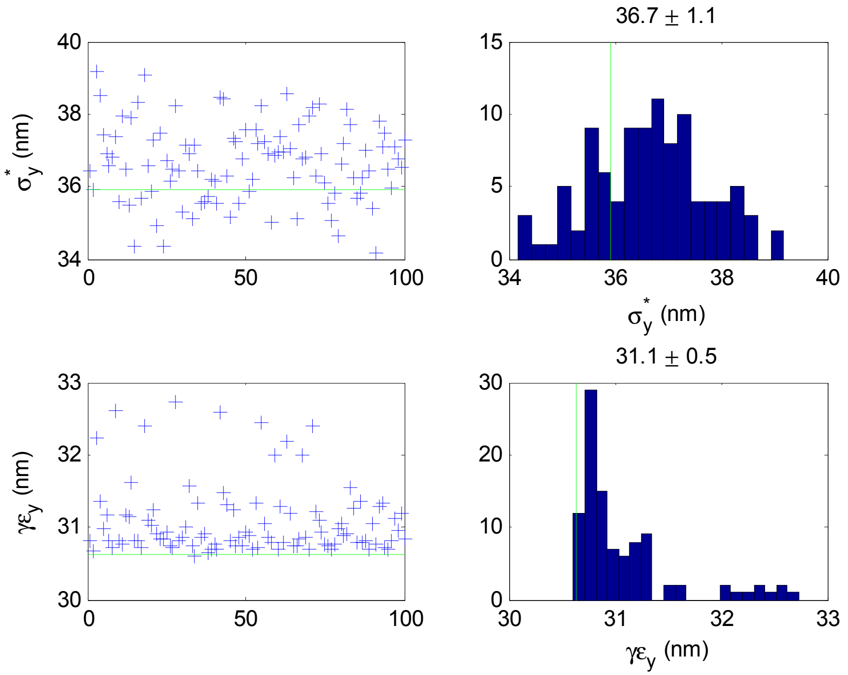
max(|KL|)=0.0022

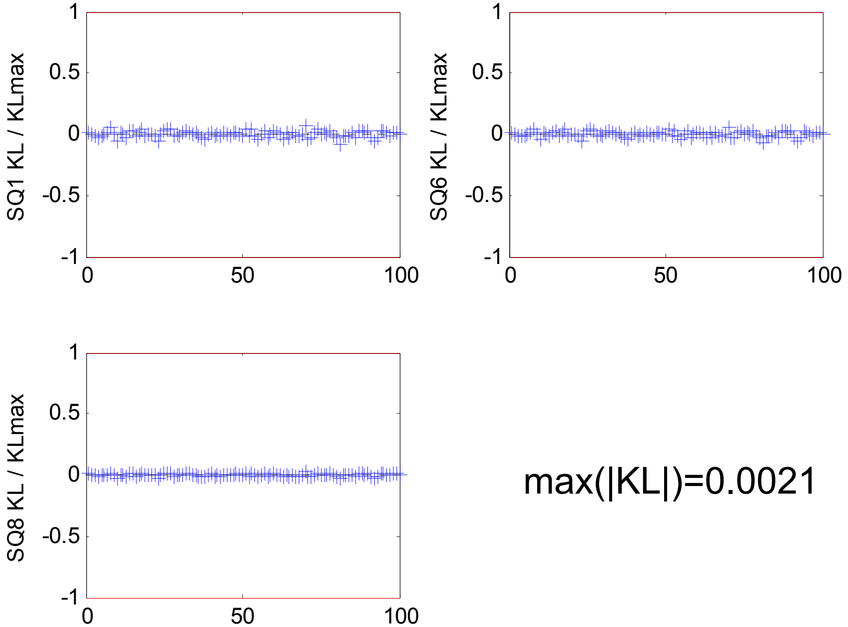
Scheme 8: 3 skew quads



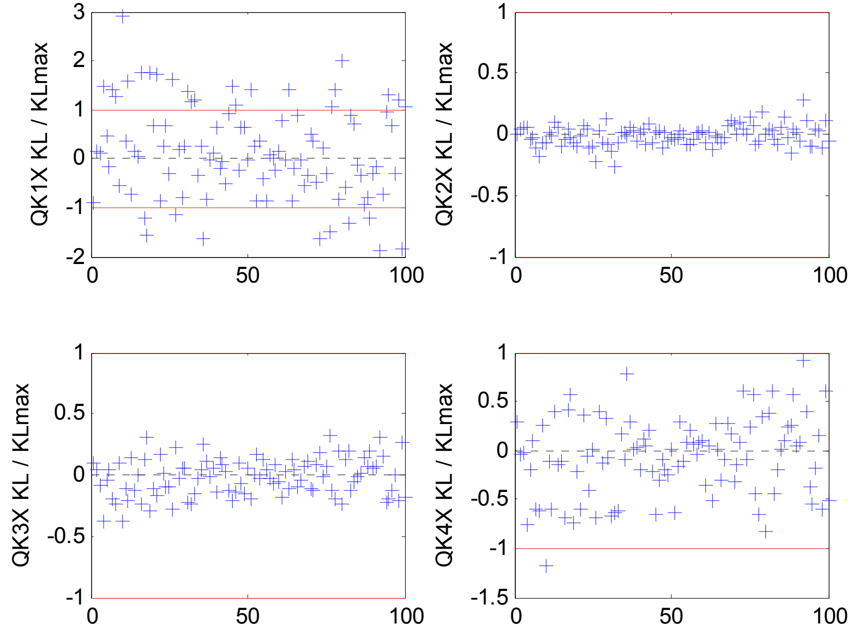
		SQ1	SQ6	SQ8
βx	=	5.920	10.036	0.696
αx	=	4.480	-5.320	-0.561
ηx	=	0.585	-0.566	0.007
βy	=	9.053	11.557	34.124
αy	=	-7.212	6.631	2.668
Δμx	=	-	343.575	457.538
Δμy	=	-	179.568	204.174
kl/klmax	=	0.013	0.011	0.005
residual	=	0.0000		

Scheme 8





max(|KL|)=0.0021



Conclusions

- simulated system performance is adequate for the achievement of ATF2 goal “A” (35 nm IP σ_y)
- if small assumed quadrupole roll errors and vertical dipole misalignments are the only sources of coupling, skew correction seems unnecessary
- if quadrupole roll errors are increased by a factor of 10, coupling correction provides 20% improvement in IP σ_y