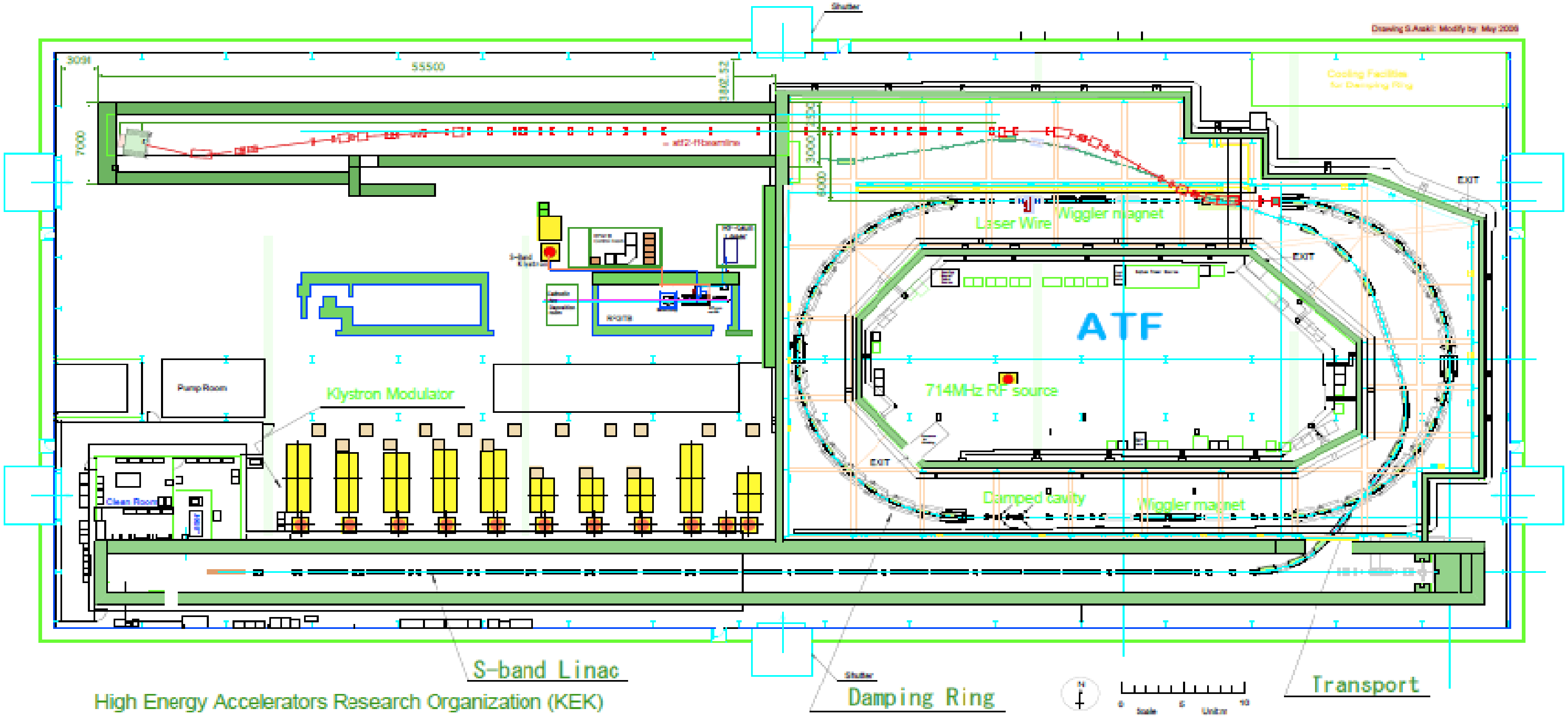
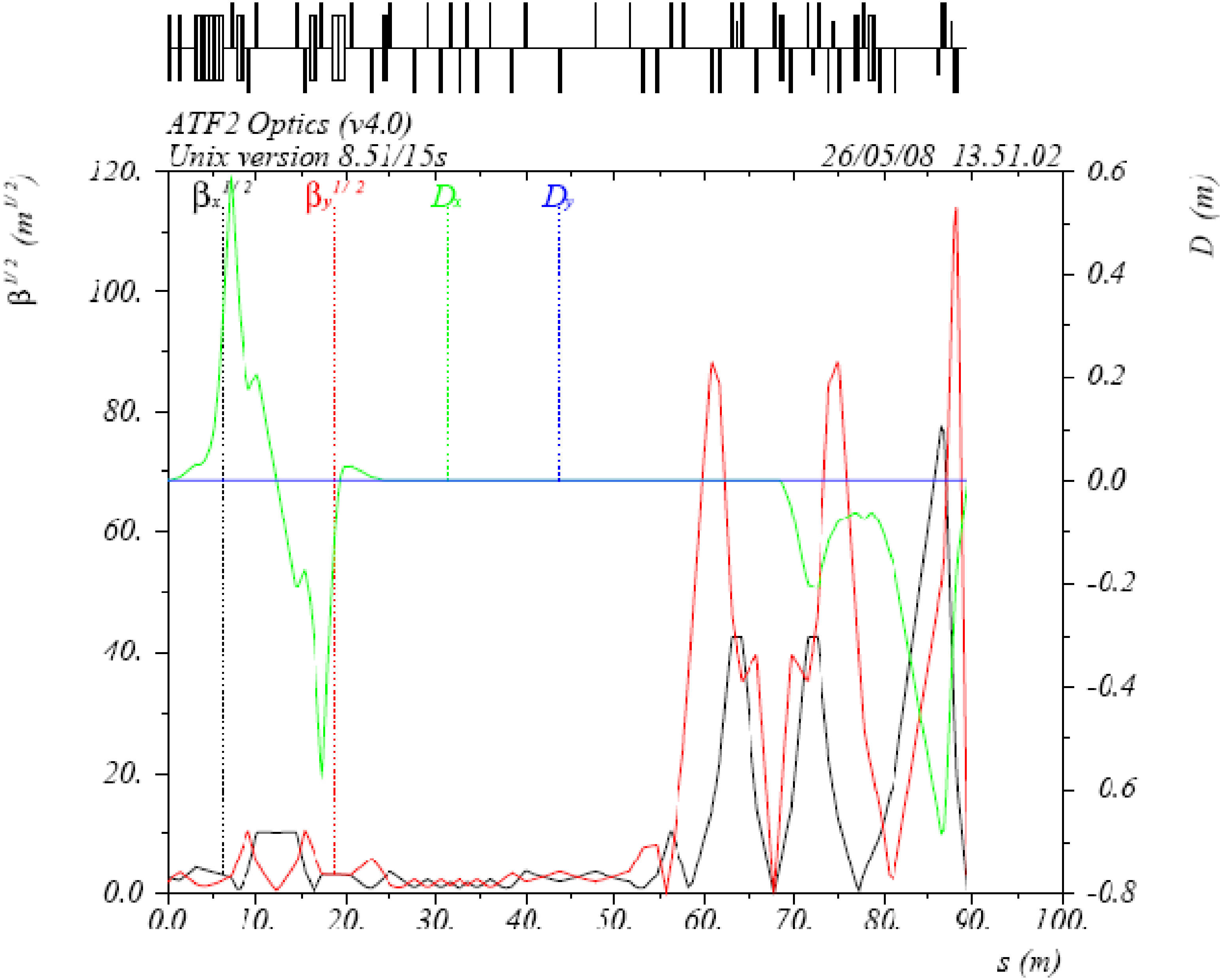
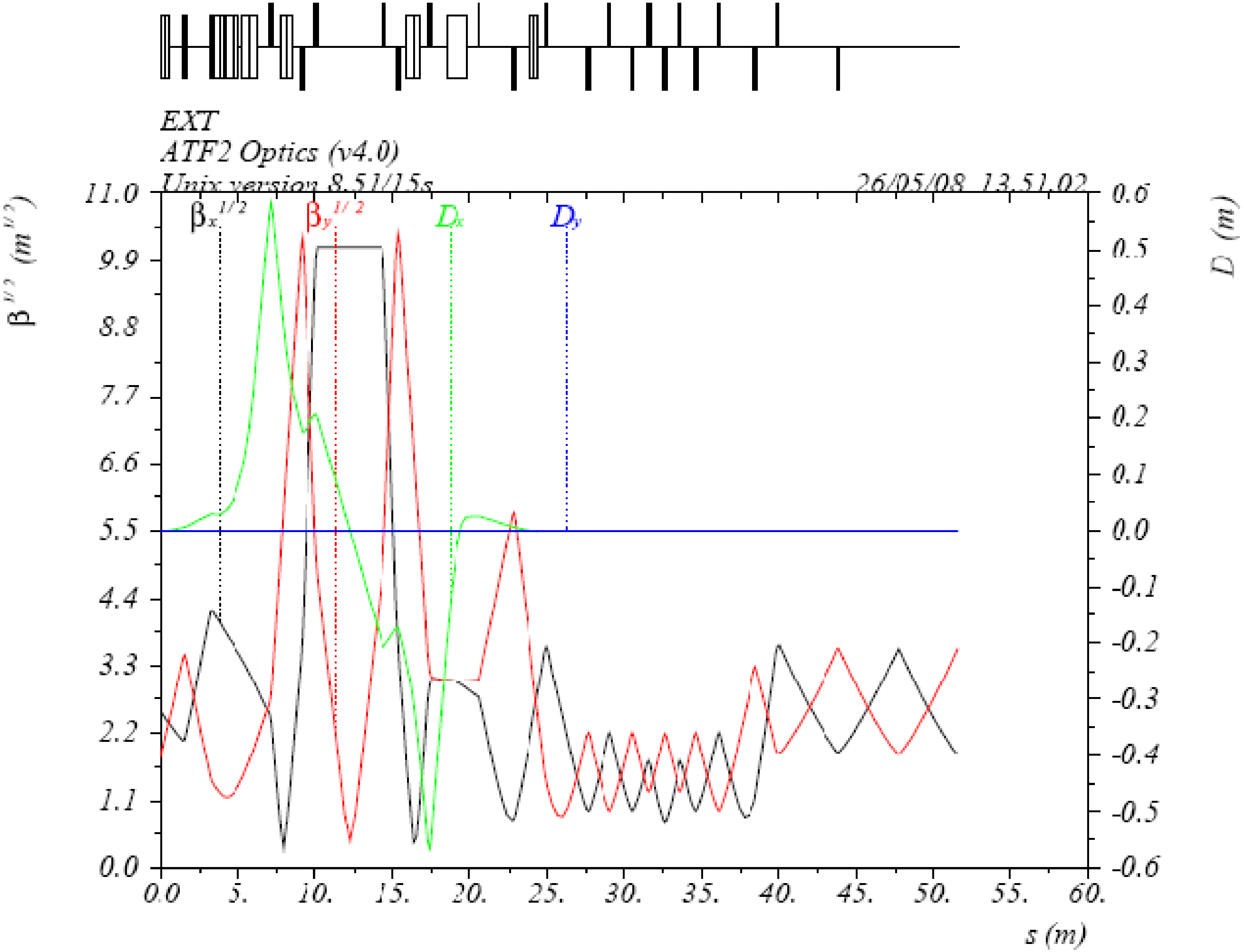
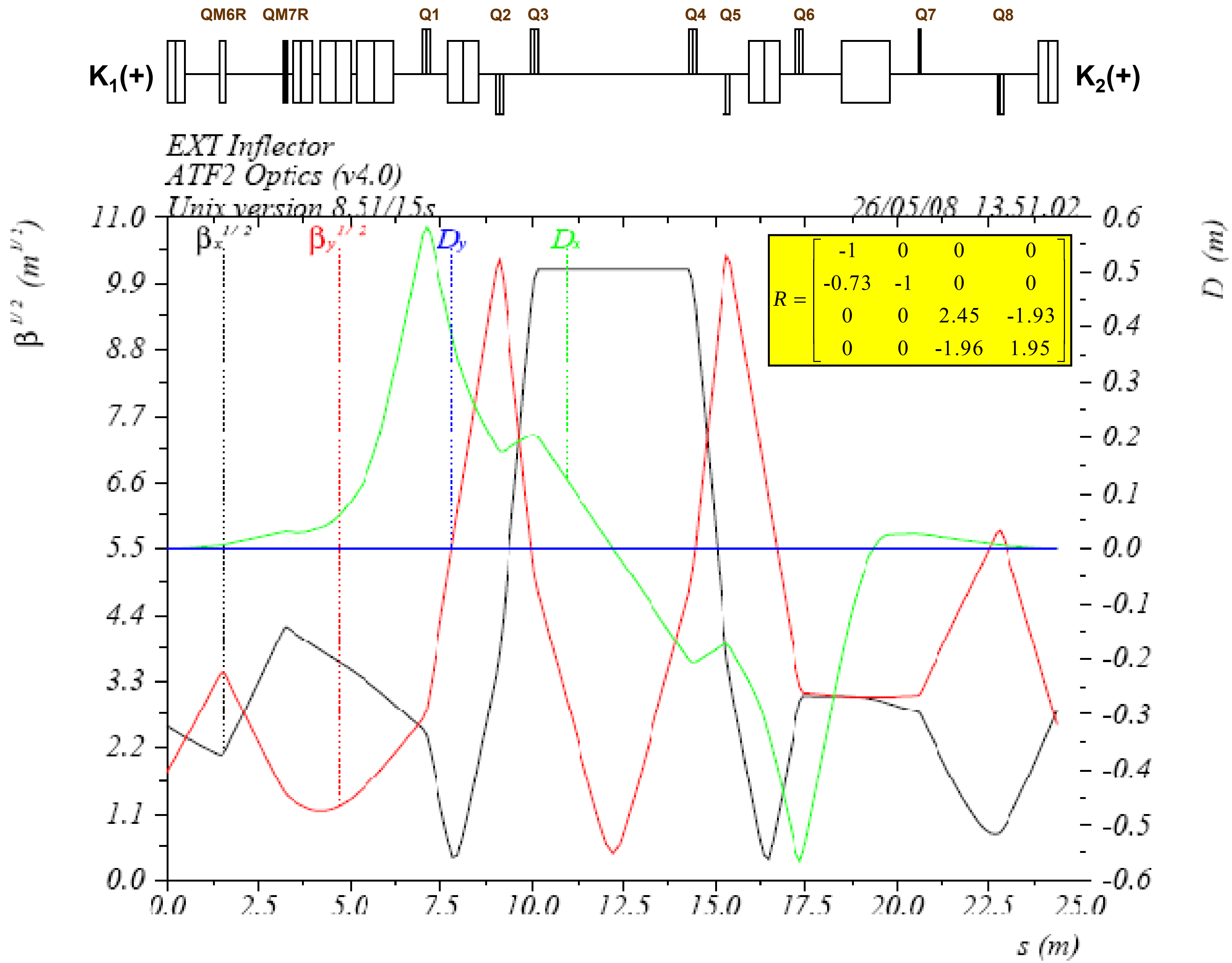
Simulation of Performance of ATF2 EXT Line (v4.0)




ATF2 Optics (v4.0)
Unix version 8.51/15s
26/05/08 13.51.02
$\beta_x^{1/2}$
$\beta_y^{1/2}$
D_x
D_y
$\beta^{1/2}$ $(m^{1/2})$
120.
100.
80.
60.
40.
20.
0.0
D (m)
0.6
0.4
0.2
0.0
-0.2
-0.4
0.6
-0.8
0.0
10.
20.
30.
40.
50.
60.
70.
80.
90.
100.
s (m)

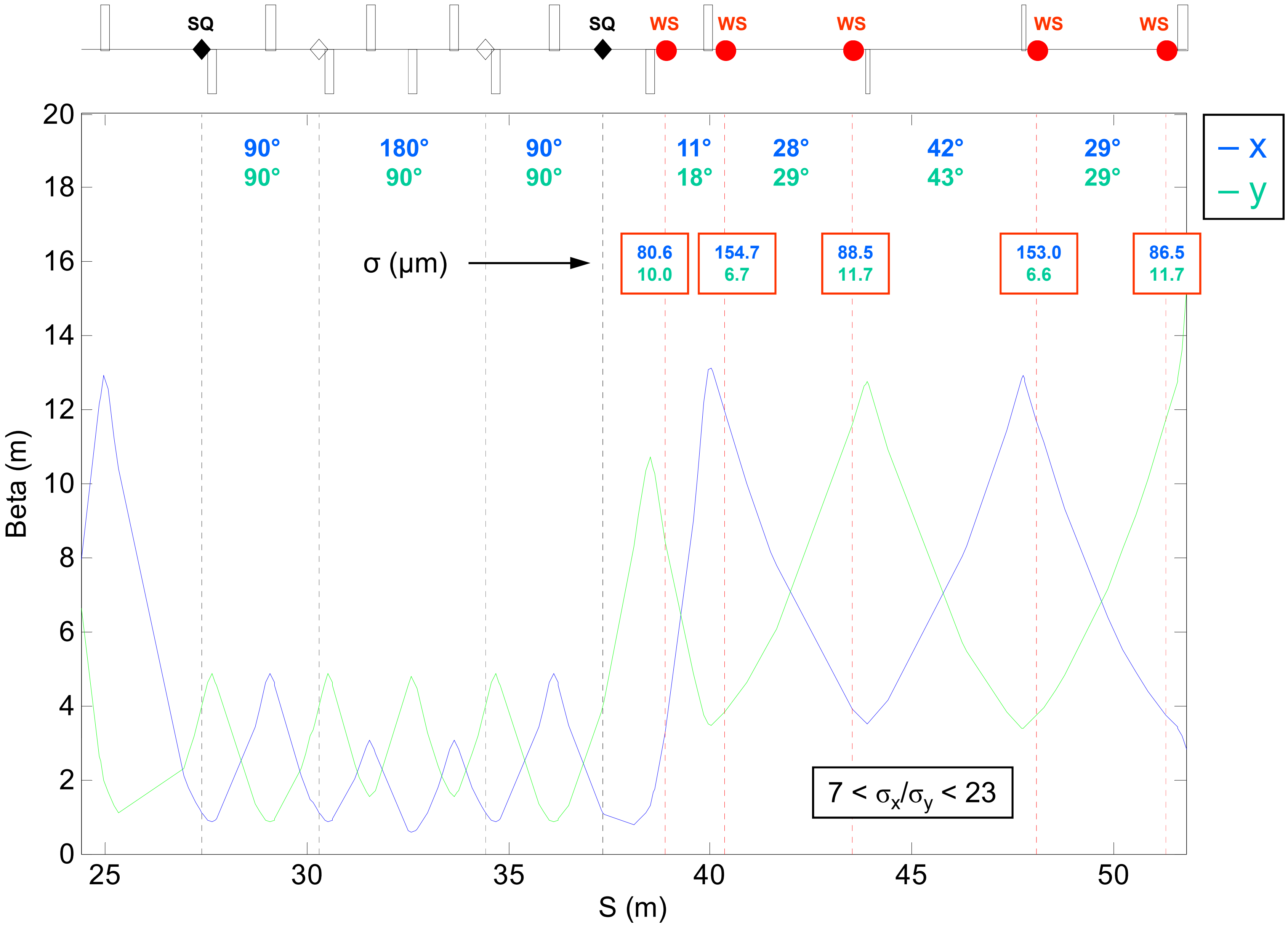

EXT
ATF2 Optics (v4.0)
Unix version 8.51/15s
26/05/08 13.51.02
$\beta_x^{1/2}$
$\beta_y^{1/2}$
D_x
D_y
$\beta^{1/2}$ ($m^{1/2}$)
D (m)
s (m)
11.0
9.9
8.8
7.7
6.6
5.5
4.4
3.3
2.2
1.1
0.0
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0.0
5.
10.
15.
20.
25.
30.
35.
40.
45.
50.
55.
60.



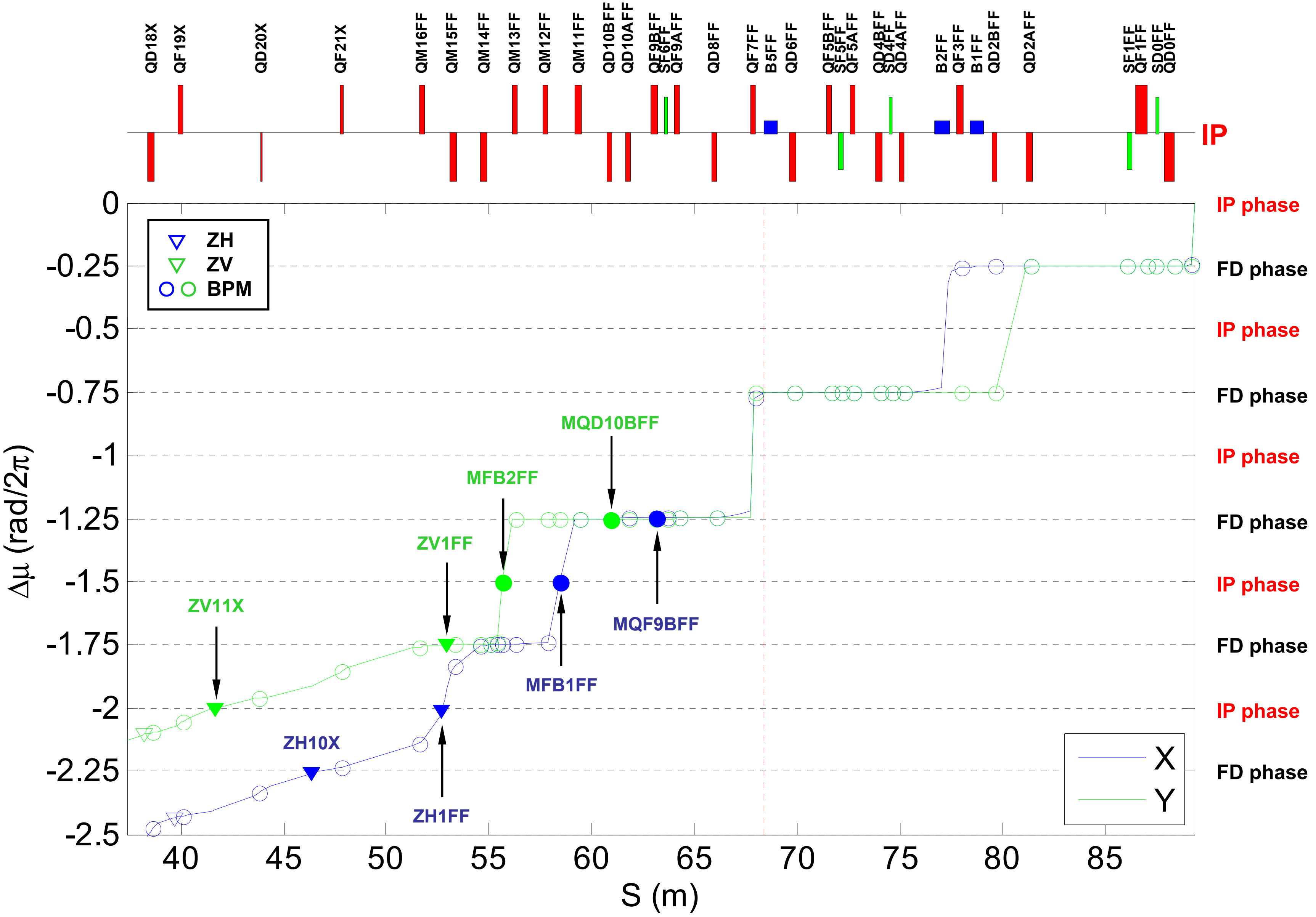
$$R = \begin{bmatrix} -1 & 0 & 0 & 0 \\ -0.73 & -1 & 0 & 0 \\ 0 & 0 & 2.45 & -1.93 \\ 0 & 0 & -1.96 & 1.95 \end{bmatrix}$$

For MAD files see http://www.slac.stanford.edu/~mdw/ATF2/v4.0

EXT Diagnostic Section (version 4.0)

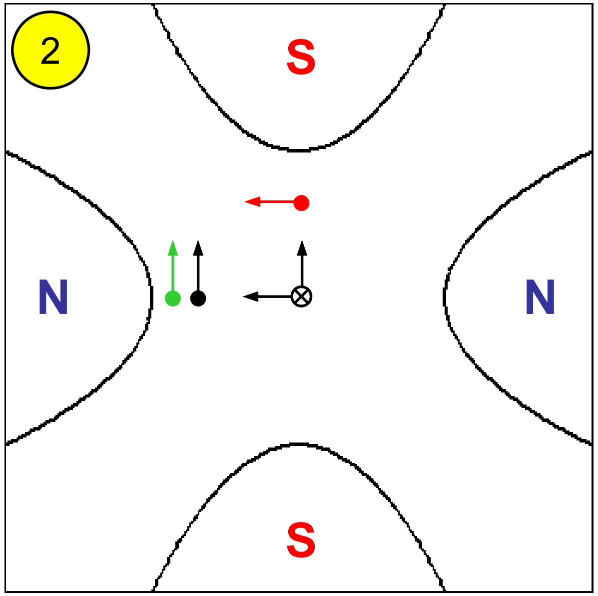


ATF2 pulse-to-pulse feedback devices (v4.0)



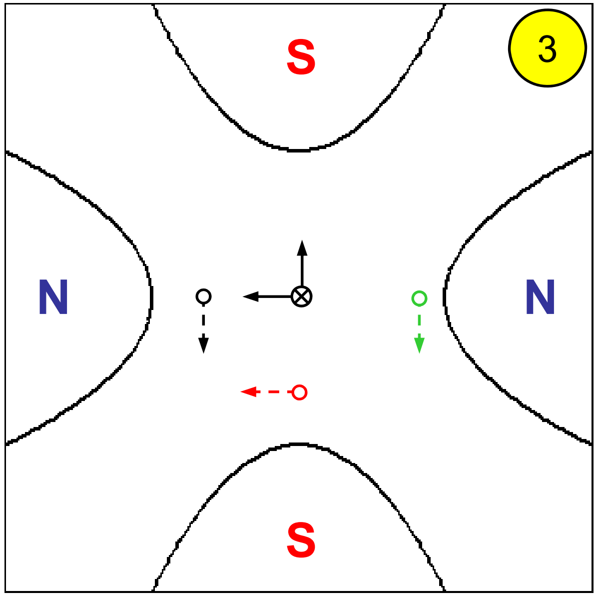
Vertical Dispersion Correction

after 1st skew quad



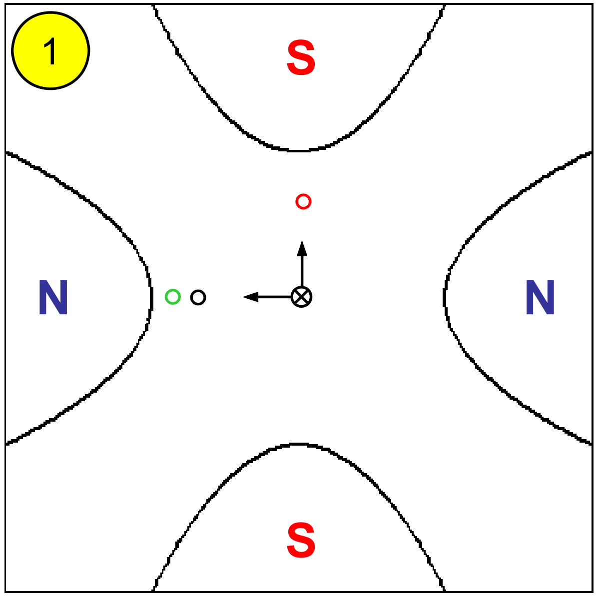
$\Delta\mu_x$ = 360°
$\Delta\mu_y$ = 180°
$+\eta_x \rightarrow -\eta_x$

before 2nd skew quad



how to generate η_y without introducing coupling

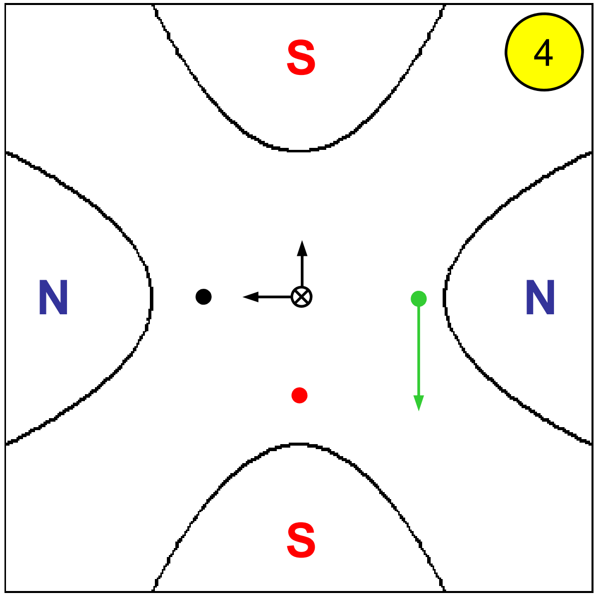
before 1st skew quad



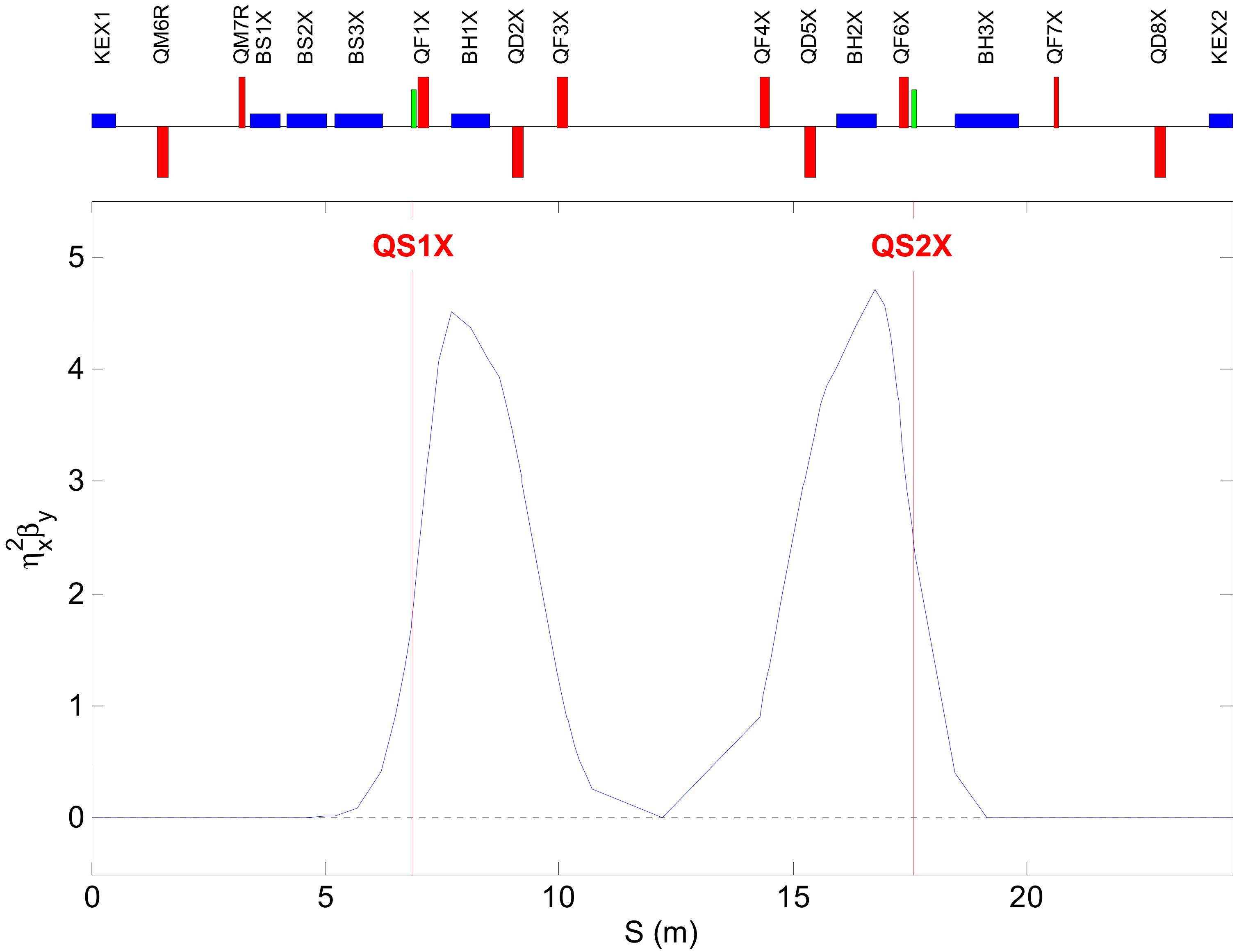
β_x (on-energy)
β_y (on-energy)
η_x (off-energy)

skew quads have equal strengths (“sum knob”)

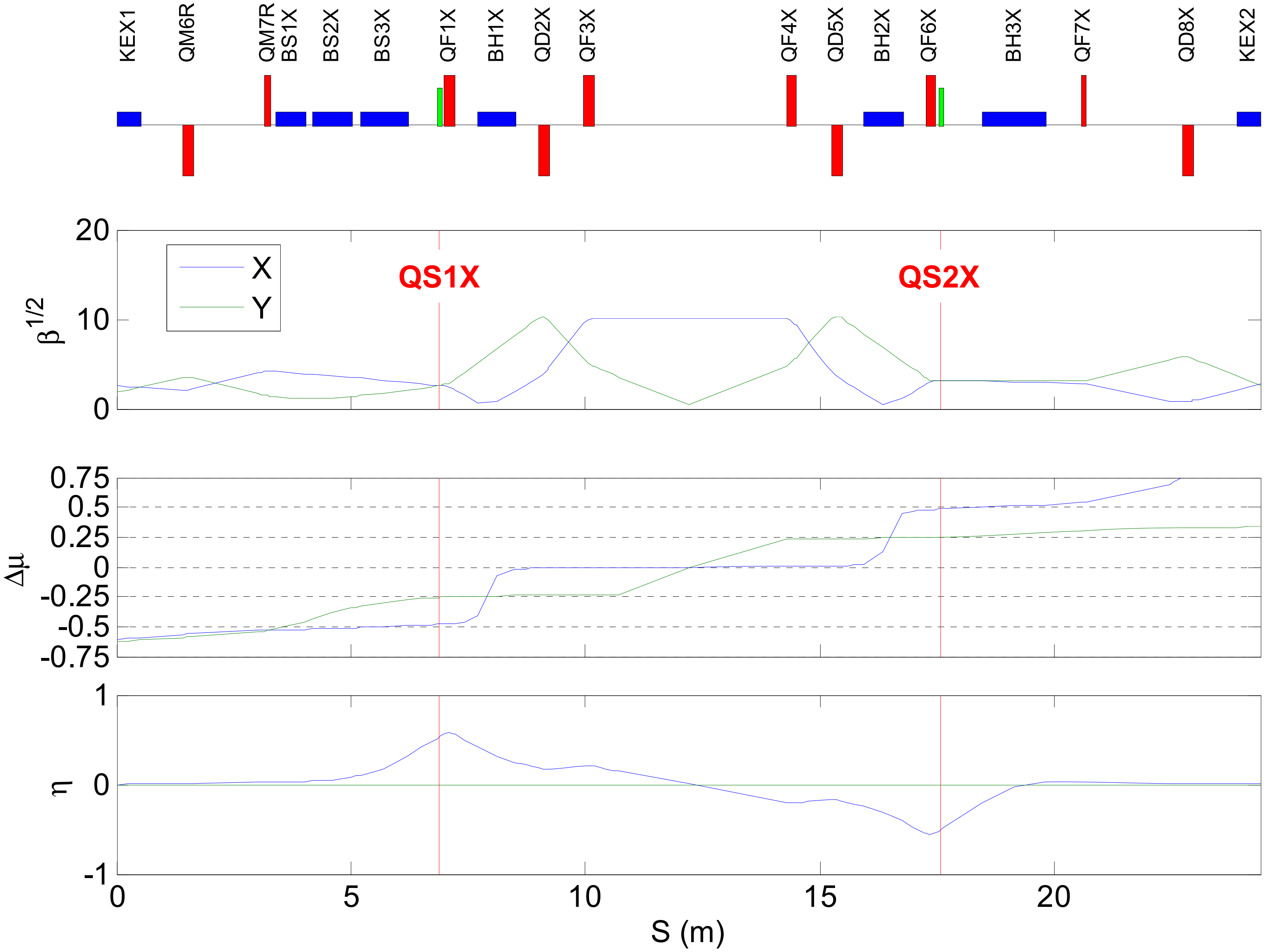
after 2nd skew quad



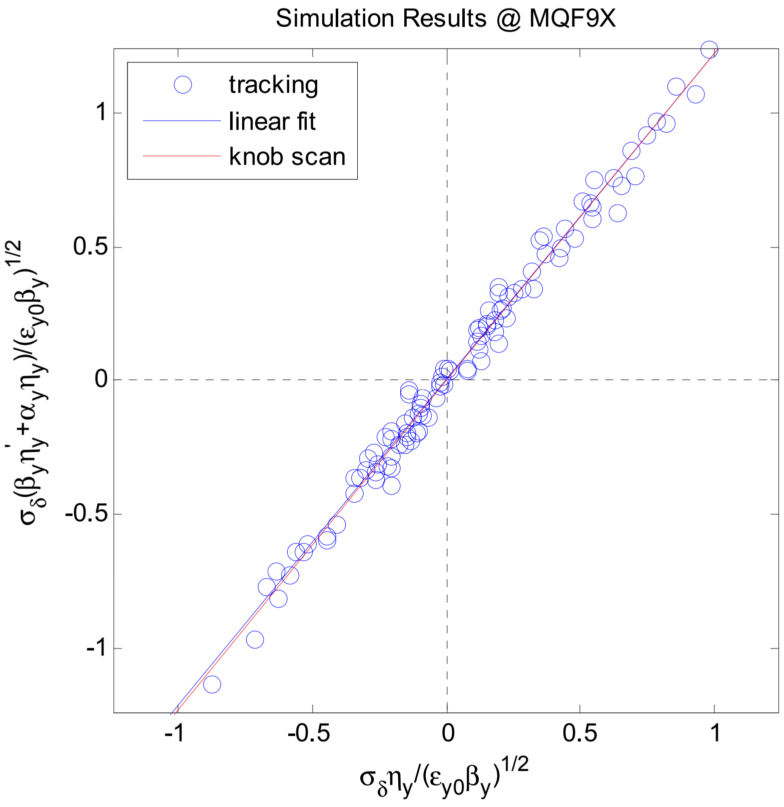
Vertical Dispersion Correction: Effectiveness



Vertical Dispersion Correction: Twiss at Skew Quadrupoles



η_y and η'_y at MQF9X (start of diagnostic section) after steering EXT flat (100 seeds)



$$\frac{\varepsilon_y}{\varepsilon_{y0}} = \sqrt{1+\sigma_\delta^2\left\{\frac{\eta_y^2+\left(\beta_y\eta'_y+\alpha_y\eta_y\right)^2}{\varepsilon_{y0}\beta_y}\right\}}$$

@ MLQFX: β_y = 2.624 m, α_y = 3.299

Vertical Dispersion Correction: Residual *x-y* Coupling

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

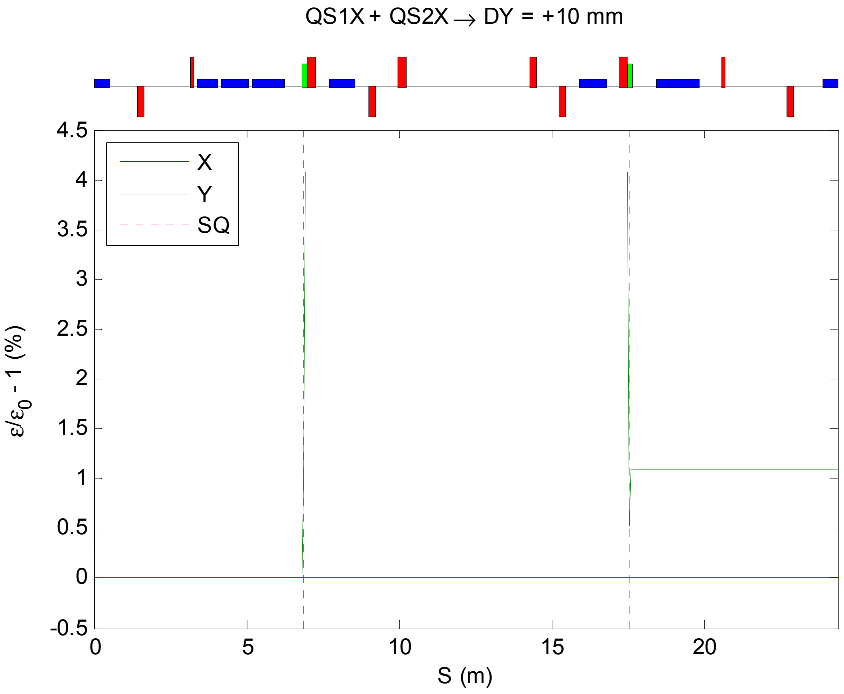
$$\mathrm{Q}_{x,y} \equiv \frac{1}{\sqrt{\beta_{x,y}}} \begin{bmatrix} \beta_{x,y} & 0 \\ -\alpha_{x,y} & 1 \end{bmatrix}$$

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

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

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

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


QS1X + QS2X → DY = +10 mm

```
                     QS1X     QS2X
                   -------  -------
βx  (m)          =   6.504    9.358
αx               =   1.309    0.054
ηx  (m)          =   0.540   -0.521
βy  (m)          =   6.890    9.643
αy               =  -2.059    0.208
Δμx (degree)     =     -    345.536
Δμy (degree)     =     -    182.022
kl/klmax         =   0.131    0.131

residual (%)     =   1.097
```

EXT Tuning Simulations

Simulation Parameters

- use Lucretia[1] simulation code
- included
  - perfect beam from Damping Ring ($\varepsilon_x=2\times10^{-9}$ m, $\gamma\varepsilon_y=3\times10^{-8}$ 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, $\Delta\theta$ = 0.3 mrad (rms)
  - sextupole errors: ΔX = 50 μm, ΔY = 30 μm, $\Delta\theta$ = 0.3 mrad (rms)
  - BPM resolution: 5 μm (rms)
- *not* included
  - wire scanner rolls: $|\theta| \leq 0.2°$ (uniform)
  - wire scanner beam size errors: $\sigma = \sigma_0(1+\Delta\sigma_{relative})+\Delta\sigma_{absolute}$
  - quadrupole strength errors ($\Delta K/K$)
  - BPM offsets
  - BPM rolls
  - tuning in FF

---

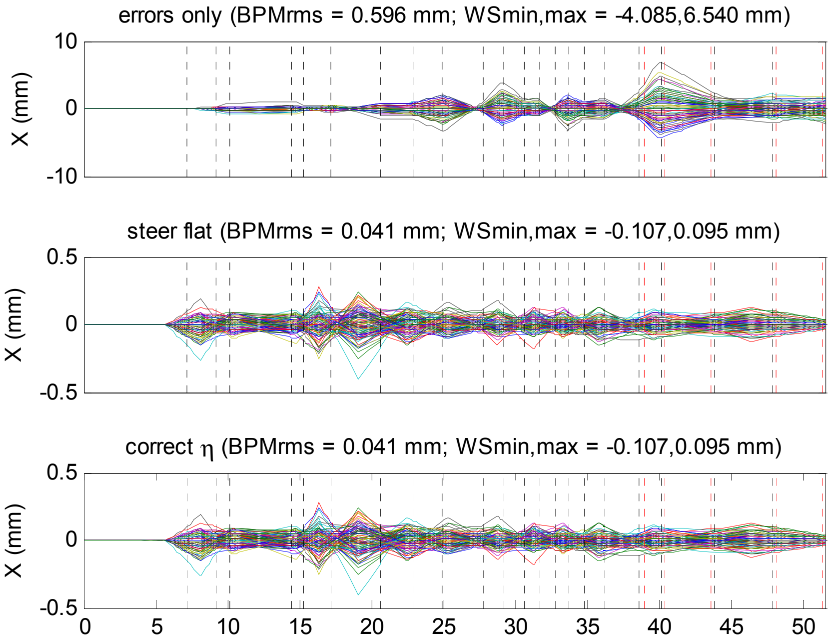
[1] http://www.slac.stanford.edu/accel/ilc/codes/Lucretia/

[2] EXT dipoles BH1 and BH2 are assumed to have nonzero sextupole components

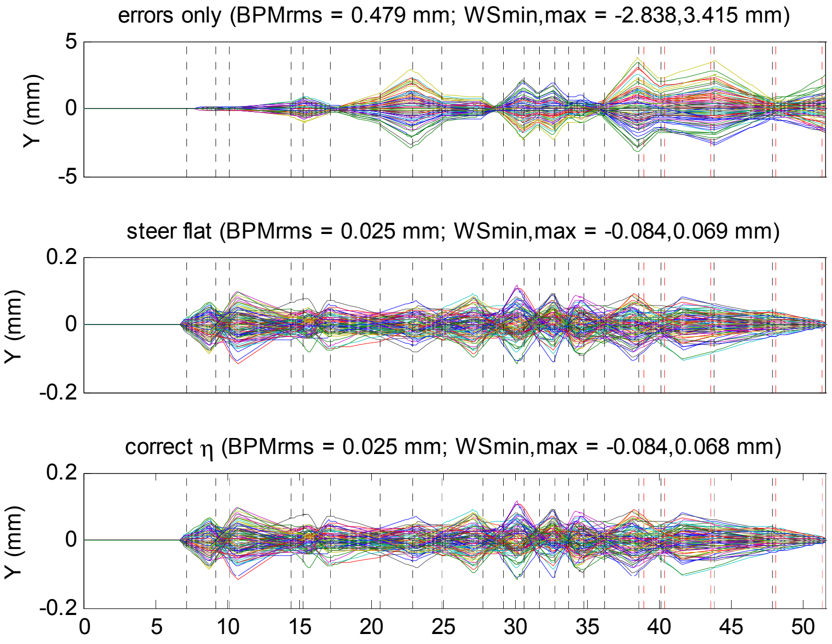
Simulation Procedure

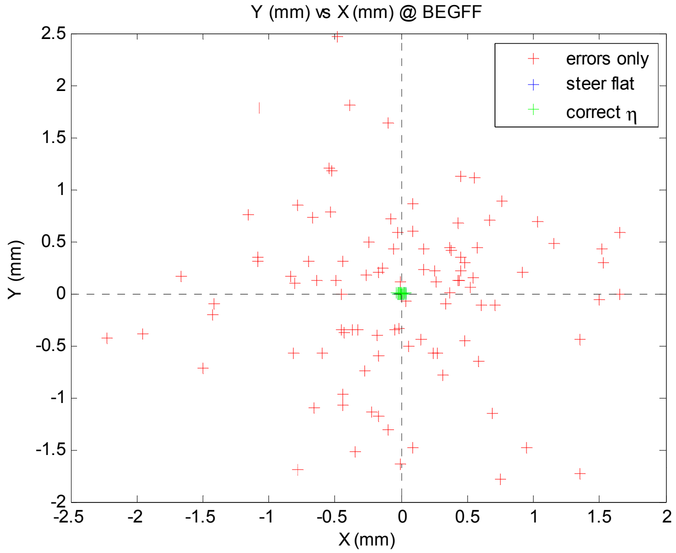
1. apply errors
2. steer flat (EXT only)
3. launch into FF
    - use pulse-to-pulse feedback correctors and BPMs
    - BPMs are perfect
4. measure dispersion in diagnostic section
    - scan input beam energy
    - measure orbits
    - fit position vs energy at each BPM … linear correlation is η
    - back-propagate measured η to start of diagnostic section to get η_0 and η'_0
5. correct dispersion in diagnostic section
    - use QF1X + QF6X multiknobs for η_x and η'_x
    - correct η_y using QS1X + QS2X “sum knob”
6. correct coupling
    - scan skew quadrupoles sequentially
    - deduce projected ε_y from wire scanner measurements
    - set each skew quad to minimize projected ε_y

horizontal orbit

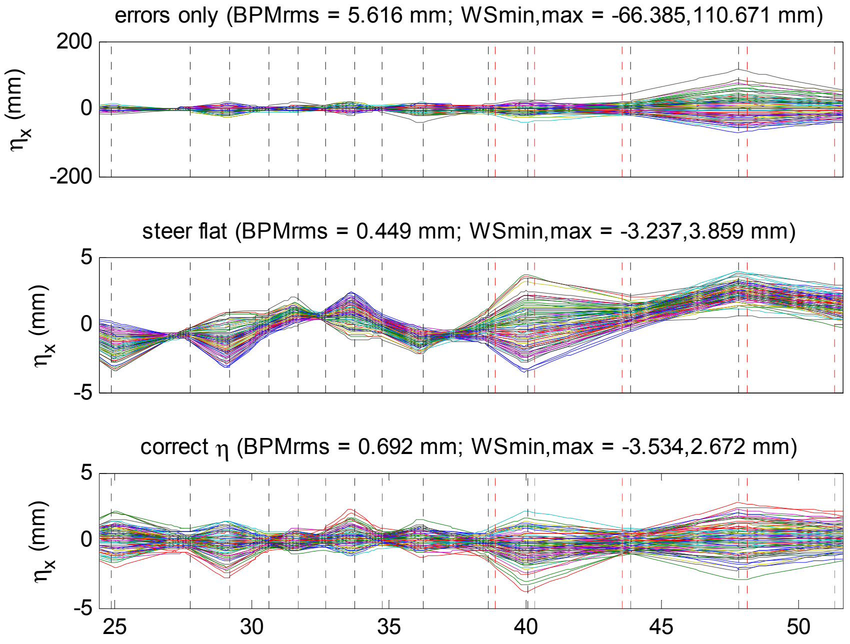


vertical orbit

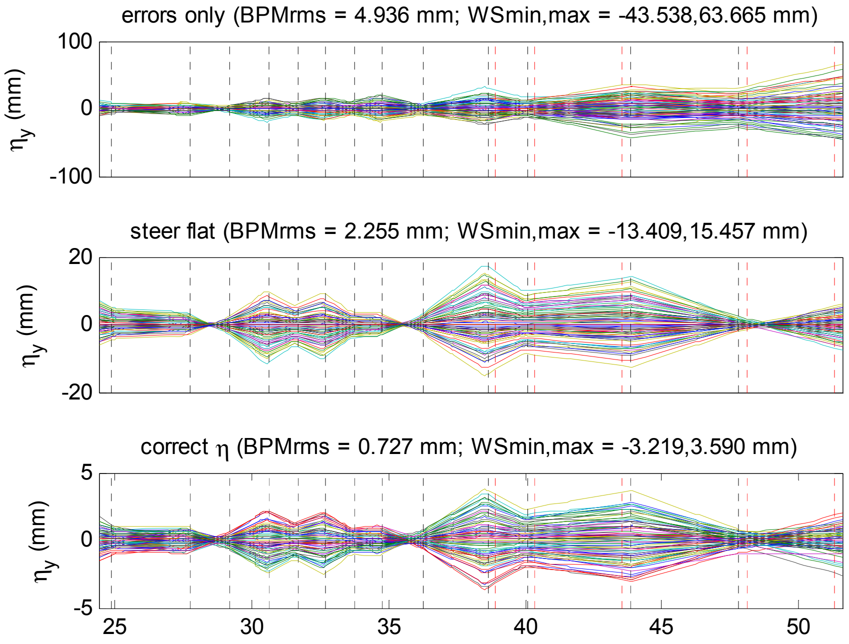


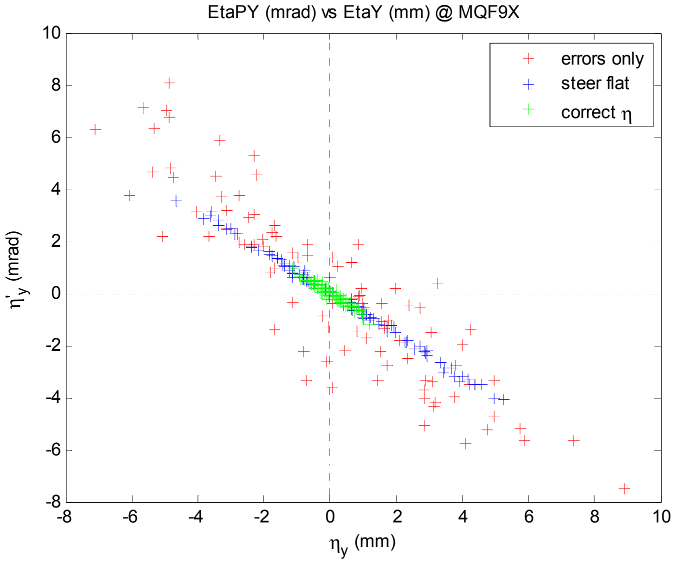


horizontal dispersion

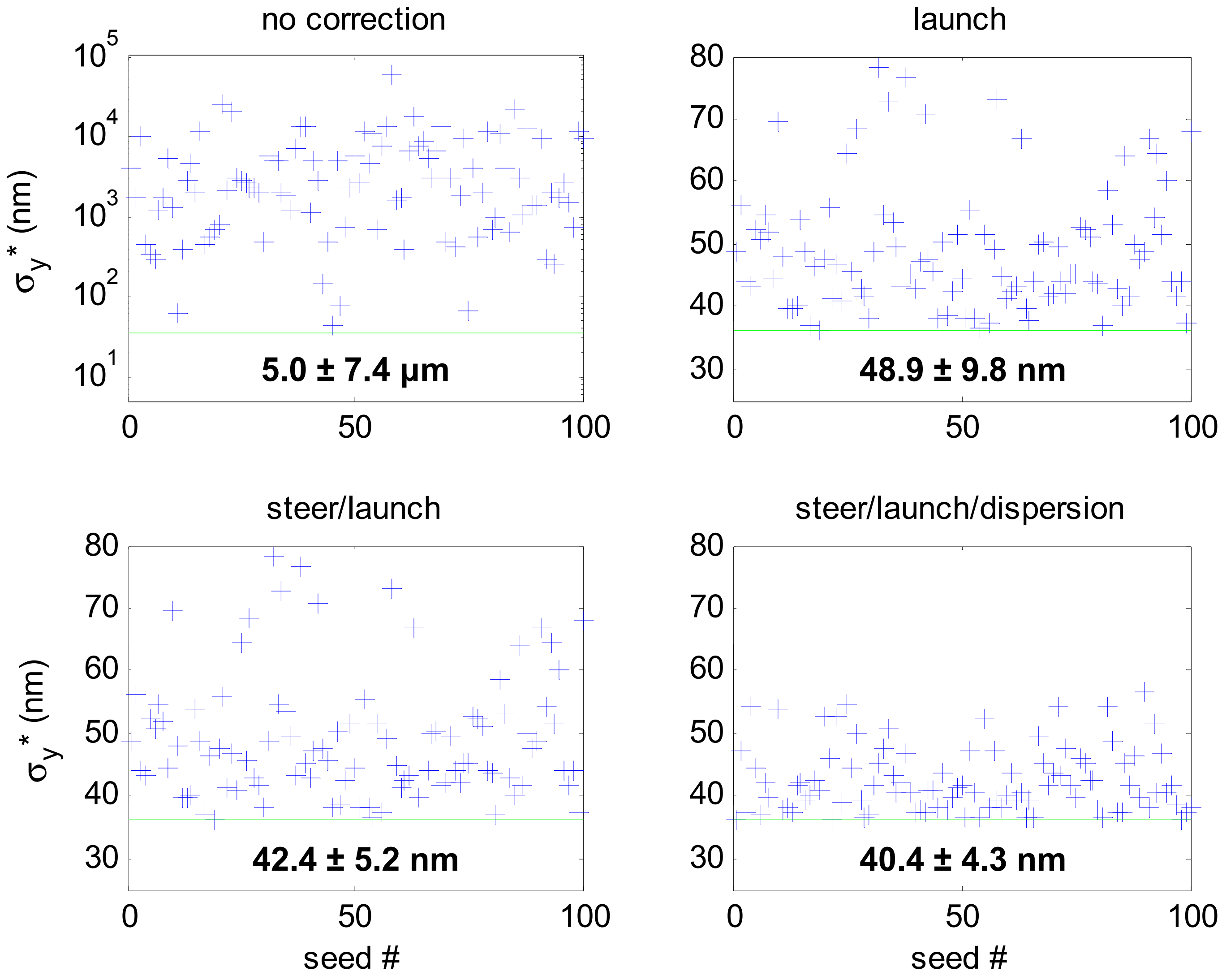


vertical dispersion



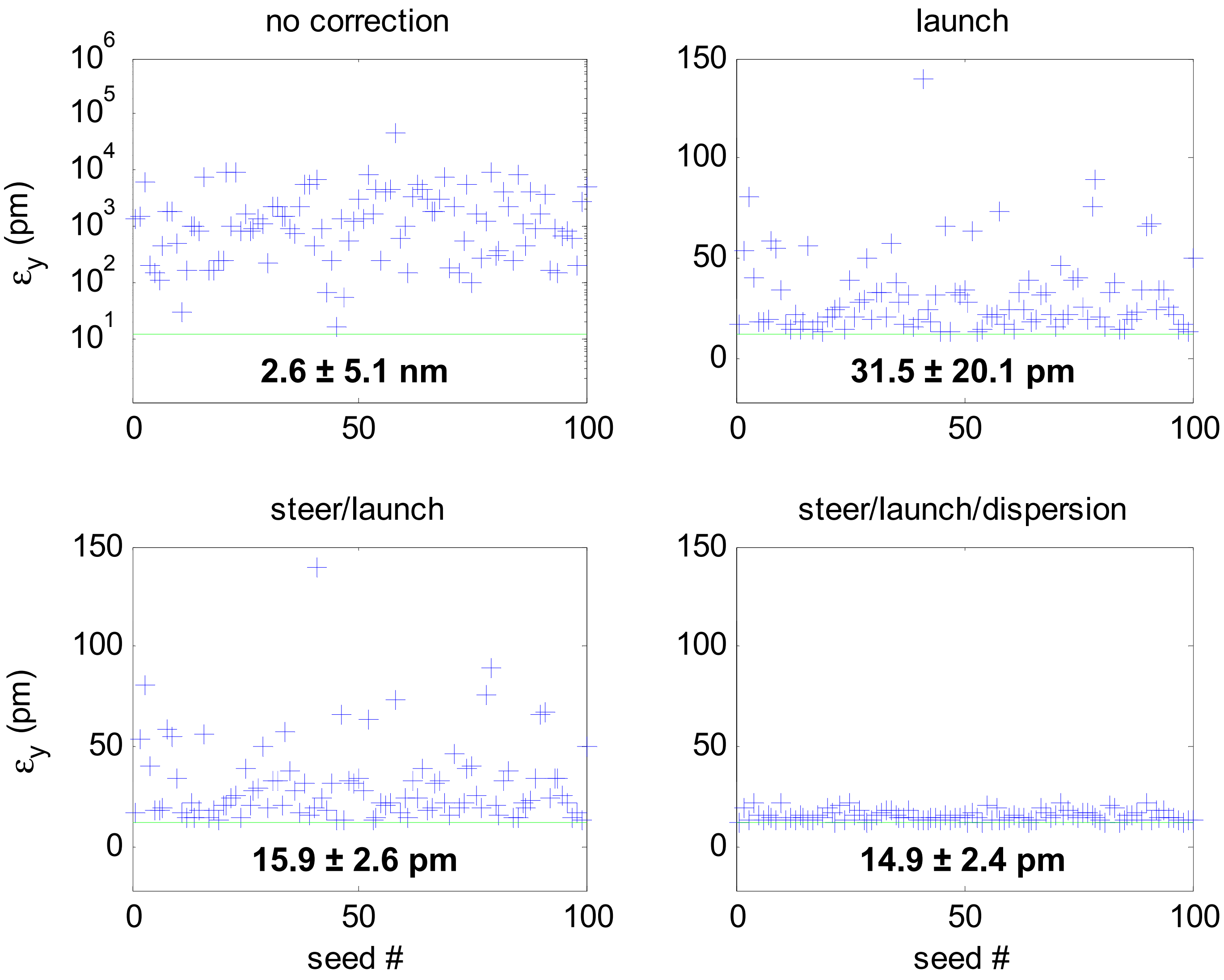


Simulation Results: σ_y^*

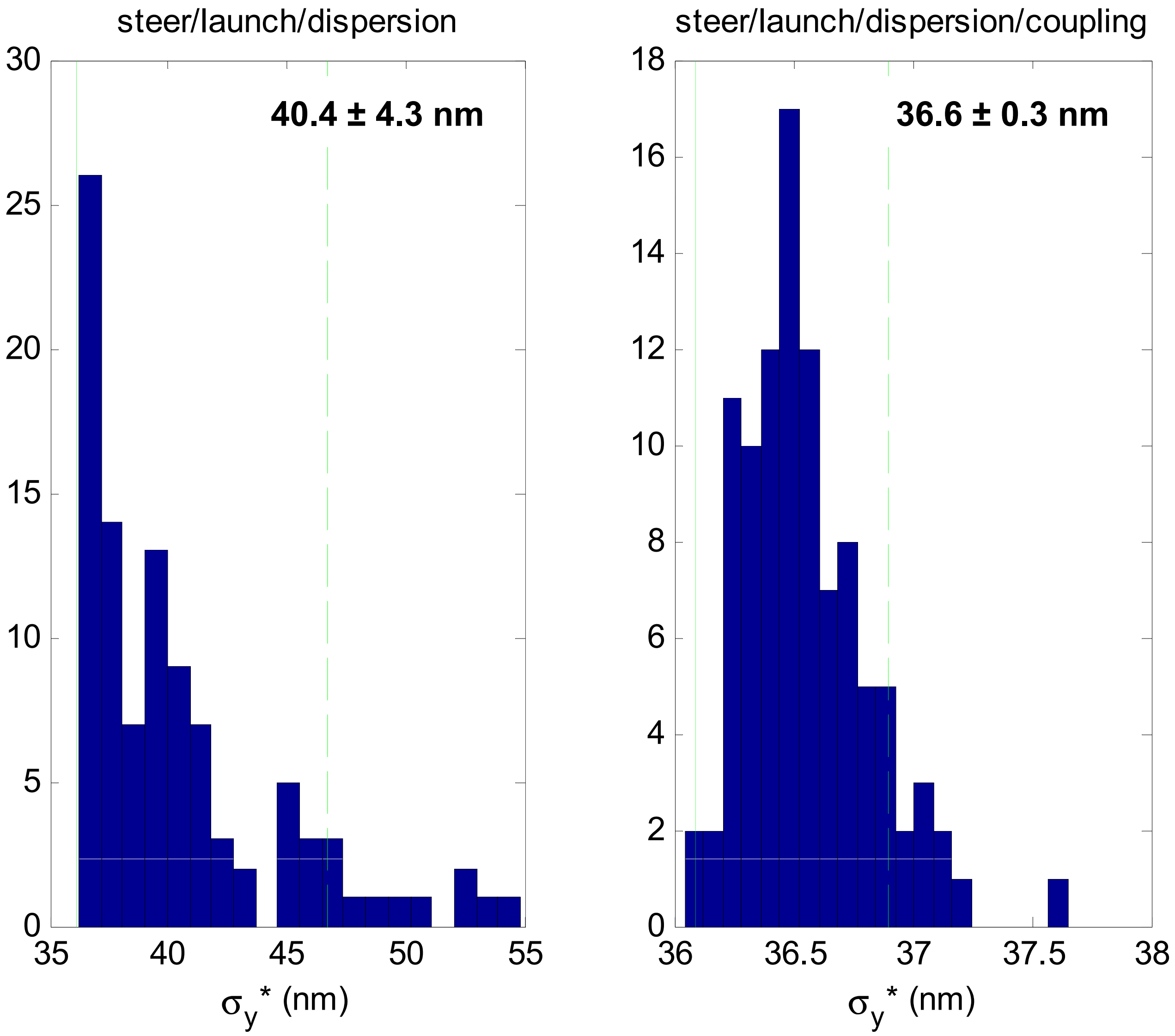


note: green lines show tracking for perfect machine (no errors, no corrections)

Simulation Results: ε_y



Simulation Results: σ_y^*

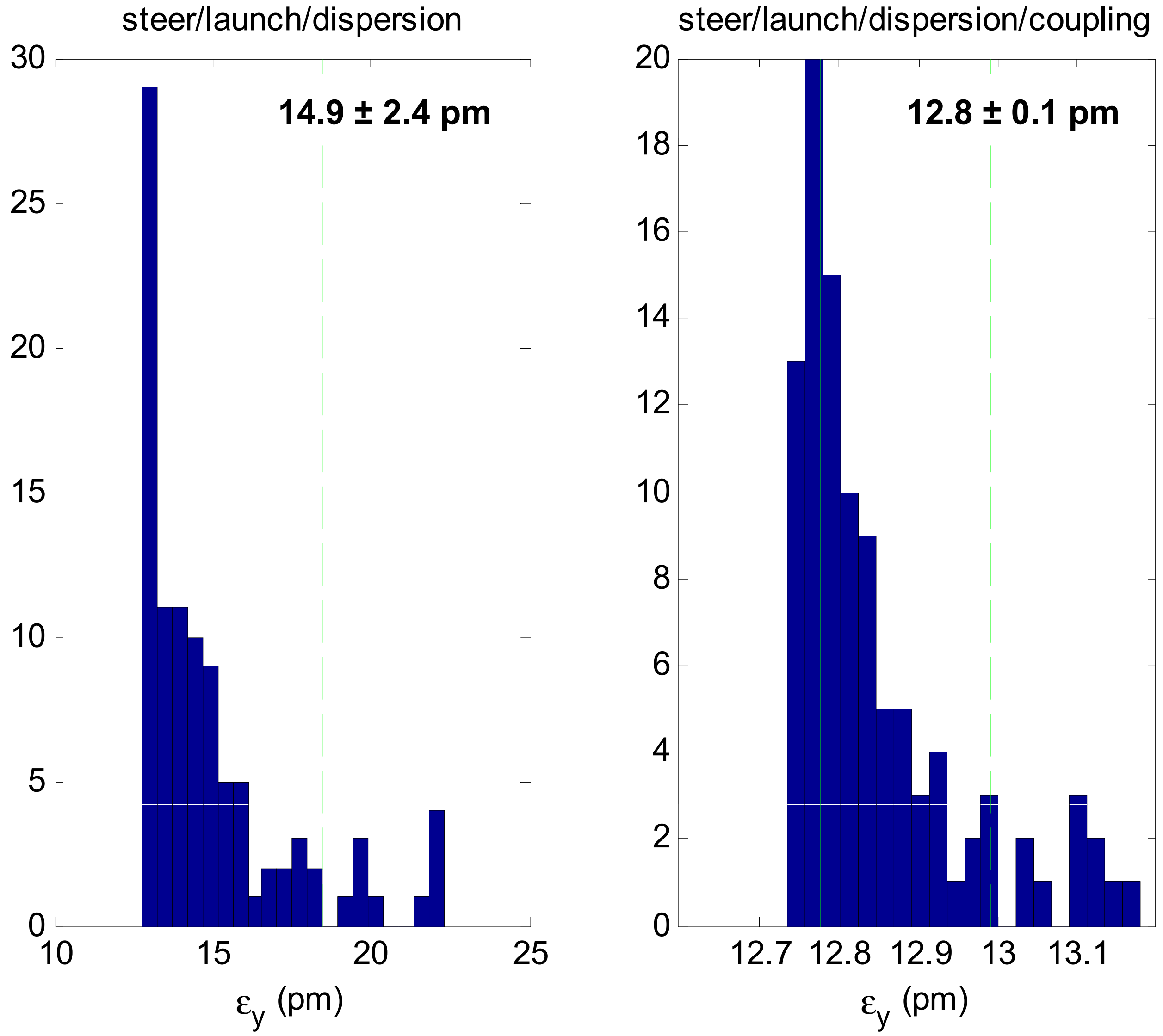


perfect wire scanners (no measurement errors) were used during coupling correction

4 skew quads used for coupling correction (QK1-4X)

note: green dashed lines show 90% limits (90% of seeds less than value at dashed line)

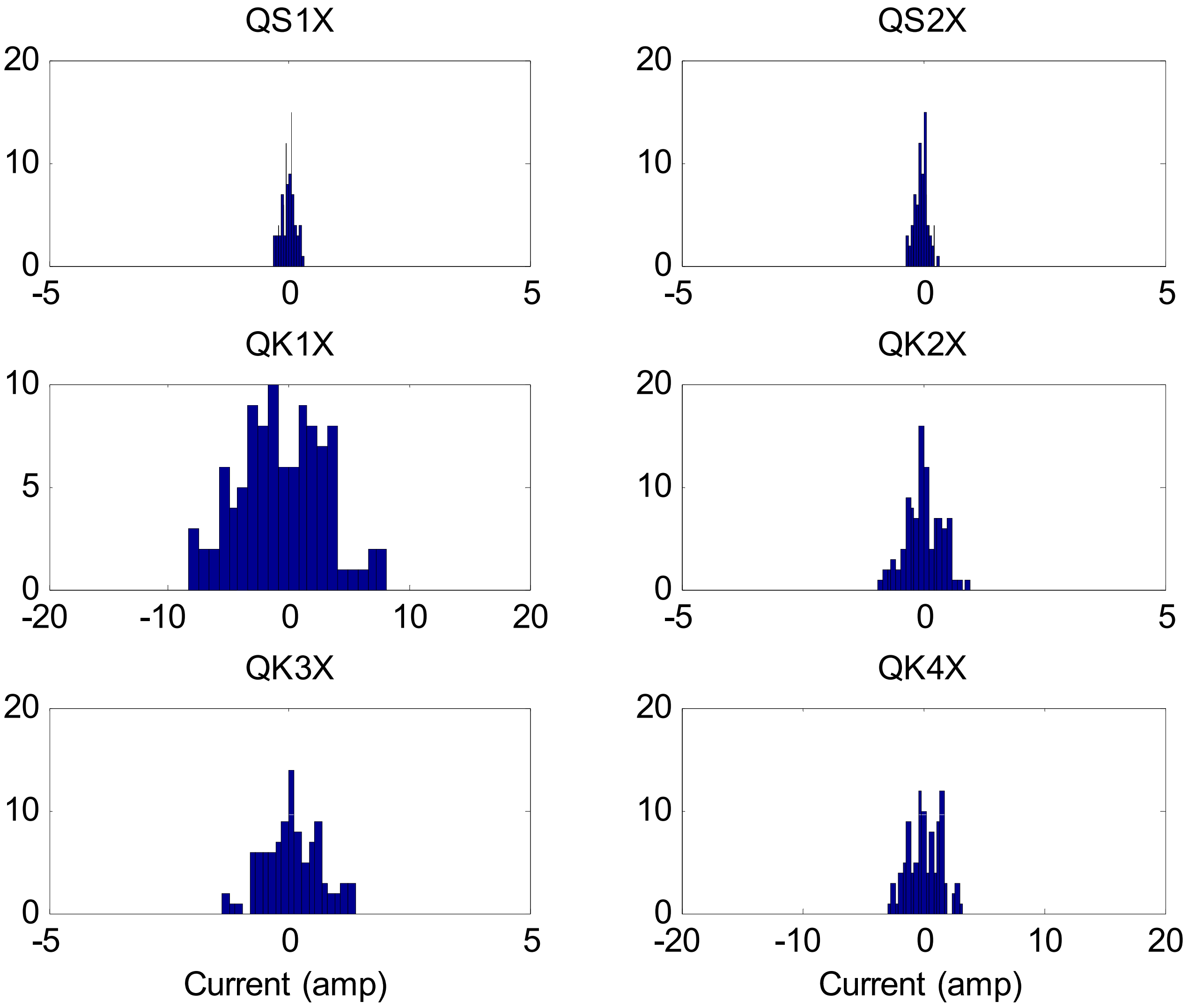
Simulation Results: ε_y



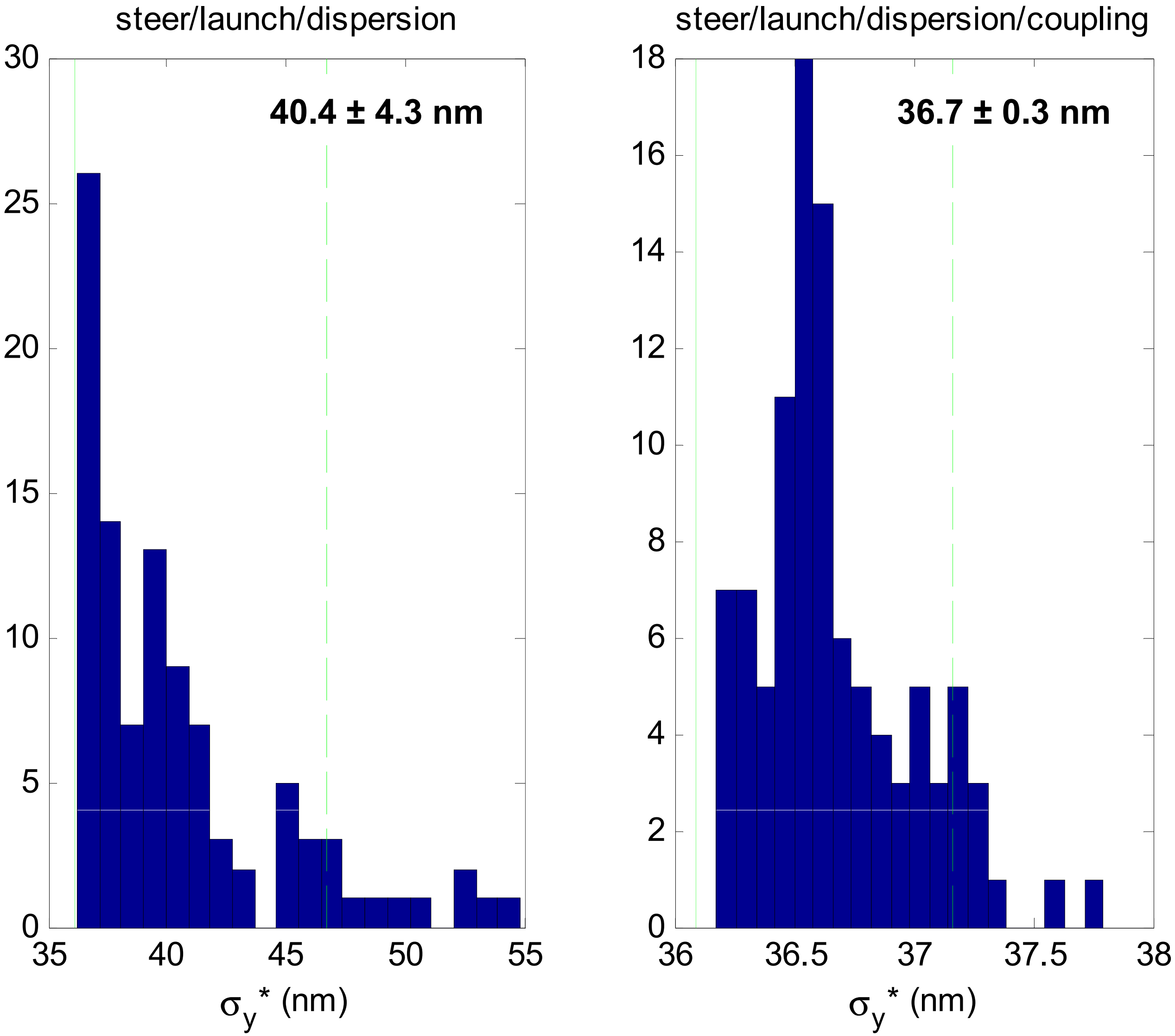
perfect wire scanners (no measurement errors) were used during coupling correction

4 skew quads used for coupling correction (QK1-4X)

Skew Quadrupole Currents



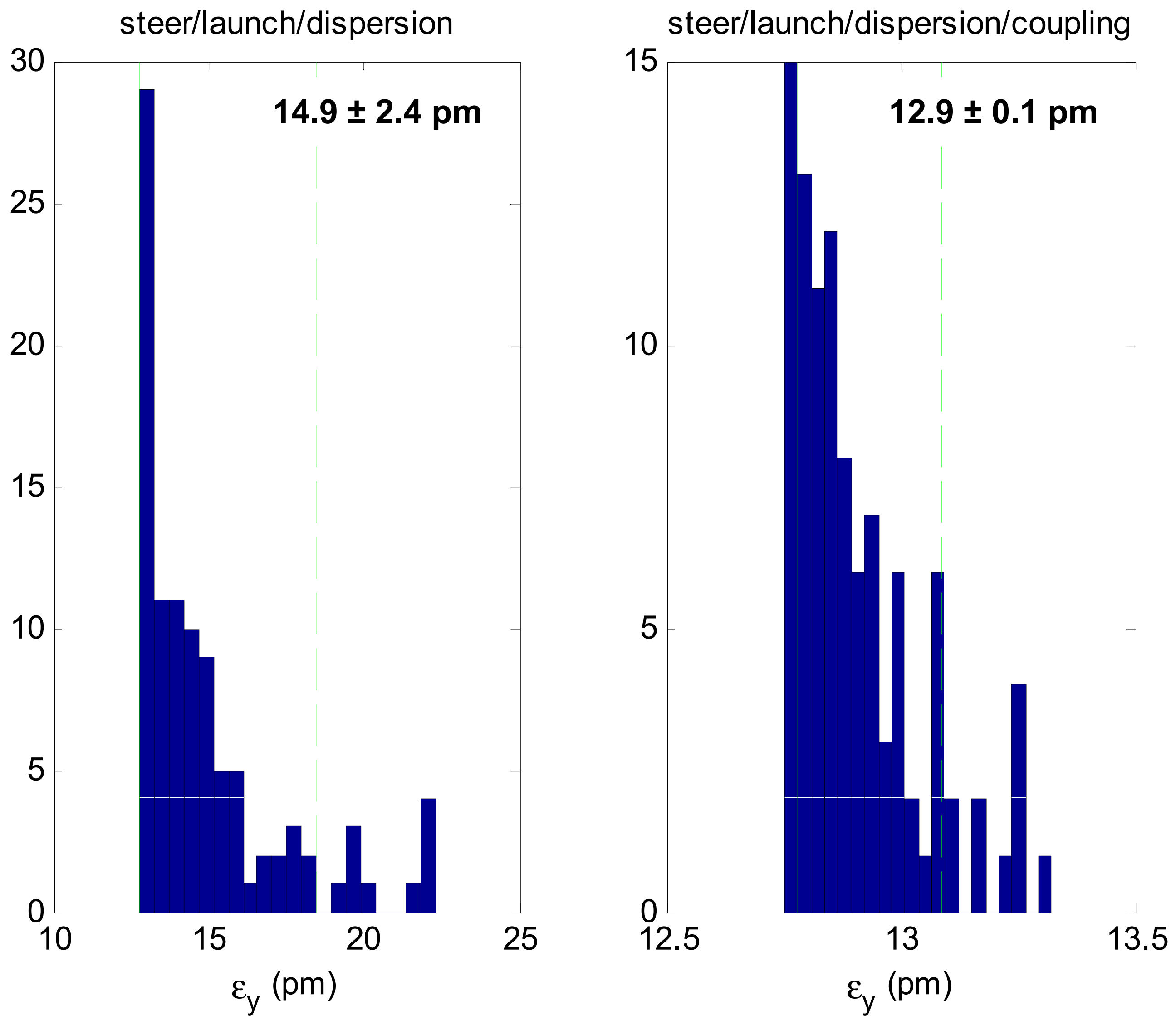
Simulation Results: σ_y^*



perfect wire scanners (no measurement errors) were used during coupling correction

2 skew quads used for coupling correction (QK1,4X)

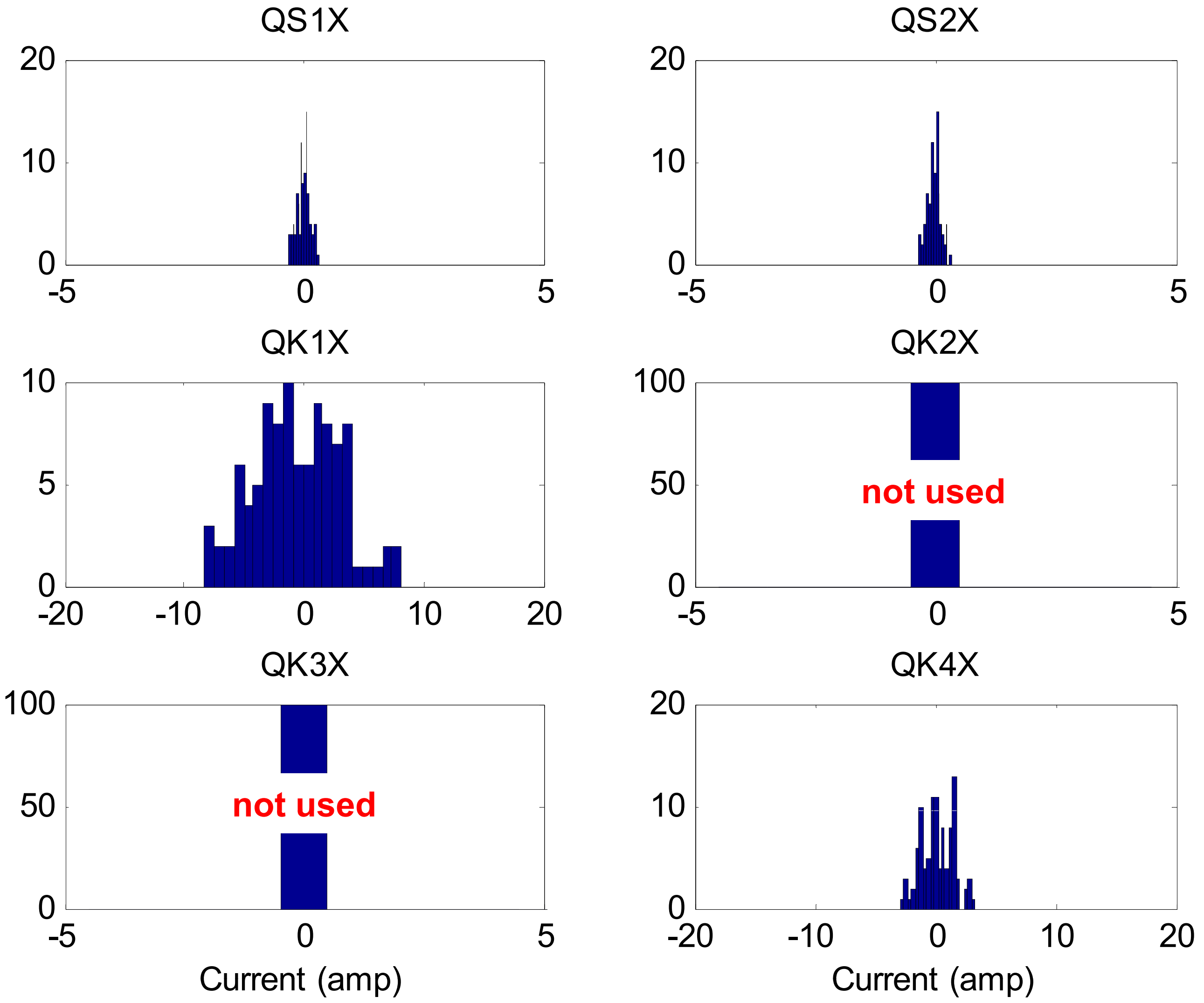
Simulation Results: ε_y



perfect wire scanners (no measurement errors) were used during coupling correction

2 skew quads used for coupling correction (QK1,4X)

Skew Quadrupole Currents



Conclusions

- simulated system performance, for the given errors and diagnostic resolution, is adequate for the achievement of ATF2 goal “A” (37 nm IP σ_y)
- including vertical dispersion correction provides 5% improvement in IP σ_y (10% in ε_y), and can be achieved with two skew quadrupoles (near QD2X and QD5X) with maximum integrated strengths of ≈ 0.02 T (corresponds to an IDX skew quad at 1 amp)
- coupling correction provides 10% improvement in IP σ_y (15% in ε_y)
- QK1X, because it is in phase with all errors in the inflector that cause coupling, requires up to 3 times the strength of an IDX skew quadrupole at 5 amps, at least in these simulations … a 20 amp (bipolar) power supply will provide plenty of overhead
- coupling correction without QK2X and QK3X seems OK

Continuing Work

- correction of vertical dispersion from the inflector is done by running QS1X and QS2X in “sum mode” (both with the same strength), which generates dispersion but no coupling … running these skew quadrupoles in “difference mode” (opposite strengths) should generate coupling but no dispersion; because these skew quadrupoles are in phase with the coupling errors in the inflector, perhaps this effect can be used to reduce the required strength of QK1-4X?
- the effects of finite wire scanner resolution on the tune-up scheme must be studied
- magnet strength errors, BPM offsets, and BPM rolls should be included
- it should be possible to correct the vertical dispersion by minimizing the projected vertical emittance, similar to scanning one of the coupling correction skew quadrupoles, rather than by changing the DR energy, measuring dispersion on BPMs, and back-propagating … these two methods should be compared

QM7R Errors

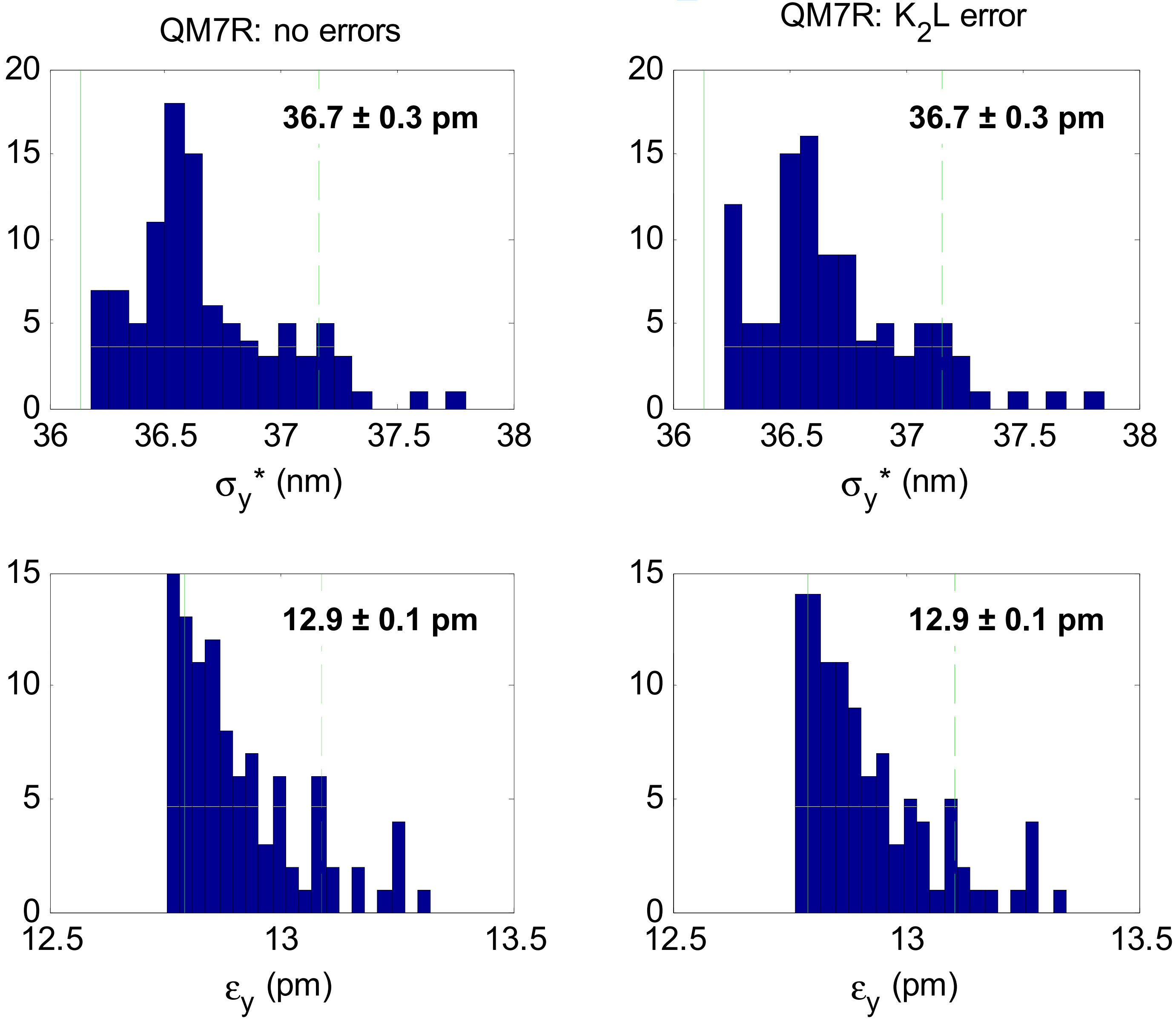
Simulation Parameters

- use 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)
  - 20% gradient reduction in QM7R (1D fit to POISSON)
  - sextupole component in QM7R K2L = 44.179 m-2 (1D fit to POISSON)
- *not* included
  - wire scanner rolls: $|\theta| \leq 0.2°$ (uniform)
  - wire scanner beam size errors: $\sigma = \sigma_0(1+\Delta\sigma_{\text{relative}})+\Delta\sigma_{\text{absolute}}$
  - quadrupole strength errors (ΔK/K)
  - BPM offsets
  - BPM rolls
  - tuning in FF

Simulation Procedure

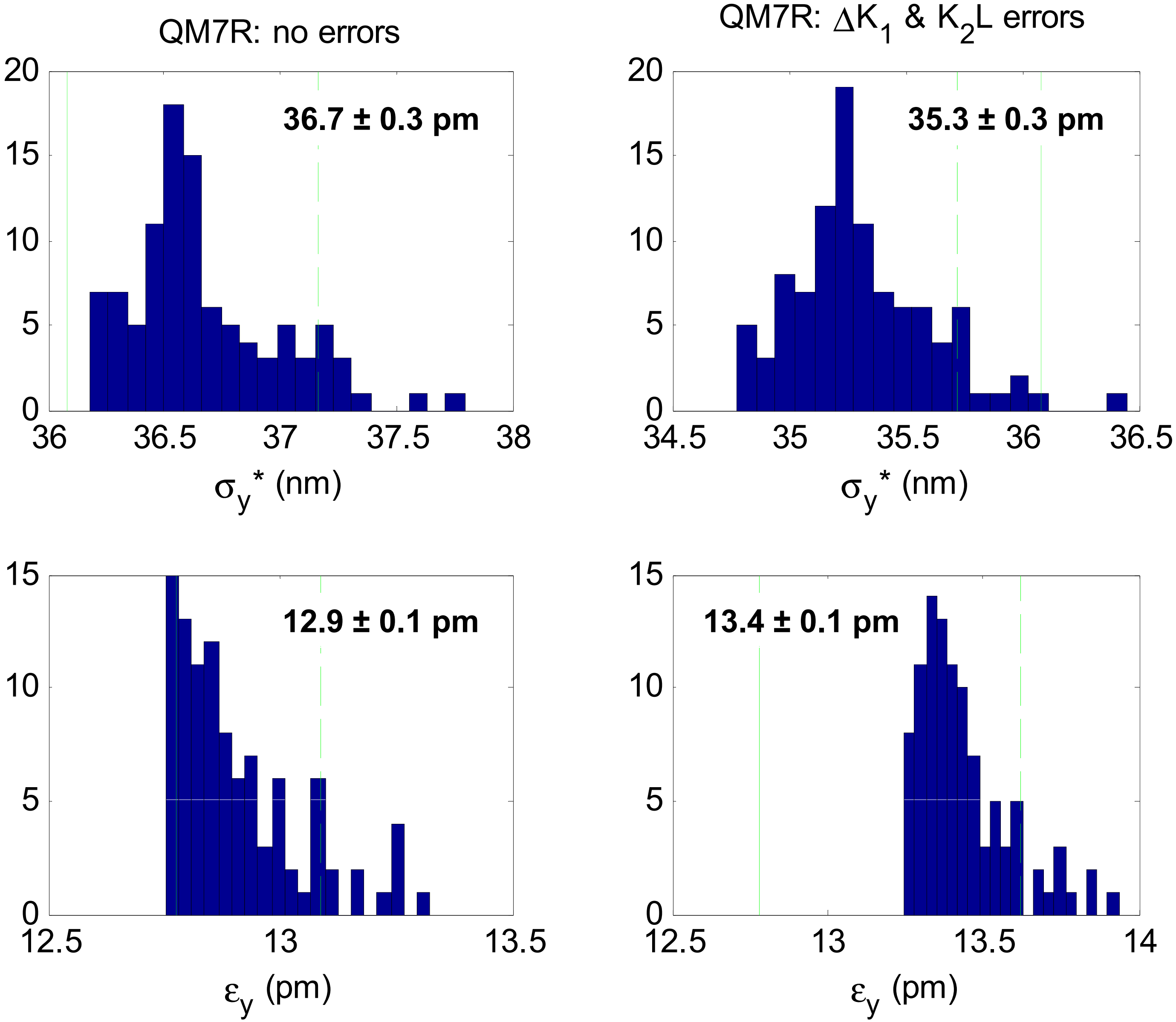
1. apply errors … scan QM7R vertical offset from -1 mm to +1 mm
2. steer flat (EXT only)
3. launch into FF
    - use pulse-to-pulse feedback correctors and BPMs
    - BPMs are perfect
4. measure dispersion in diagnostic section
    - scan input beam energy
    - measure orbits
    - fit position vs energy at each BPM … linear correlation is η
    - back-propagate measured η to start of diagnostic section to get η_0 and η'_0
5. correct dispersion in diagnostic section
    - use QF1X + QF6X multiknobs for η_x and η'_x
    - correct η_y using QS1X + QS2X "sum knob"
6. correct coupling
    - scan skew quadrupoles sequentially
    - deduce projected ε_y from wire scanner measurements
    - set each skew quad to minimize projected ε_y

QM7R: K_2L



no effect when beam passes through QM7R on the midplane

QM7R: ΔK_1 & K2L

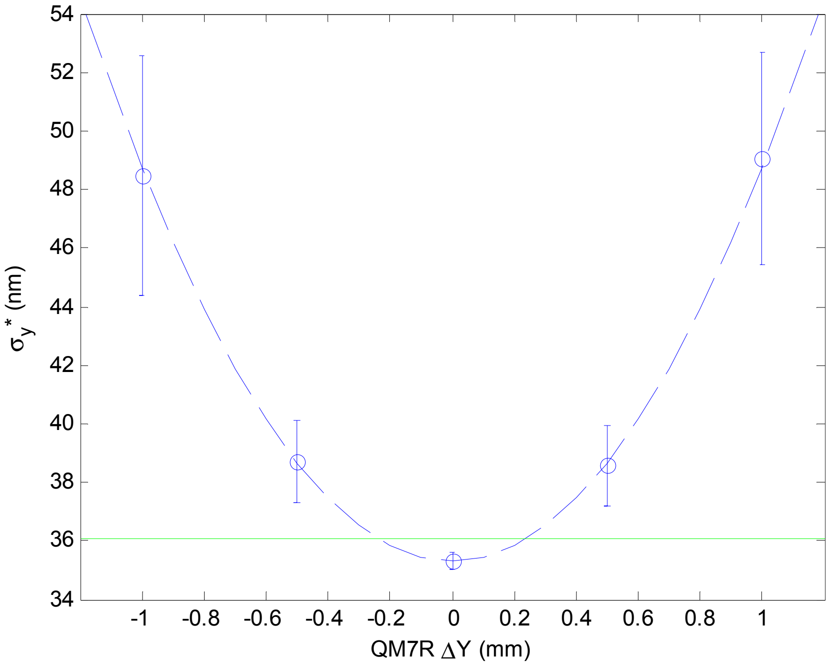


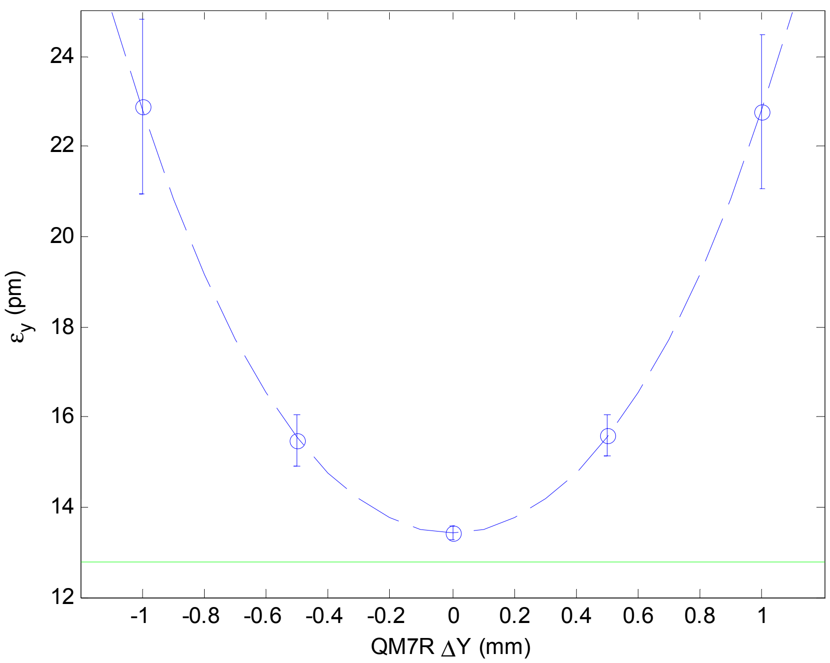
smaller β_y^*

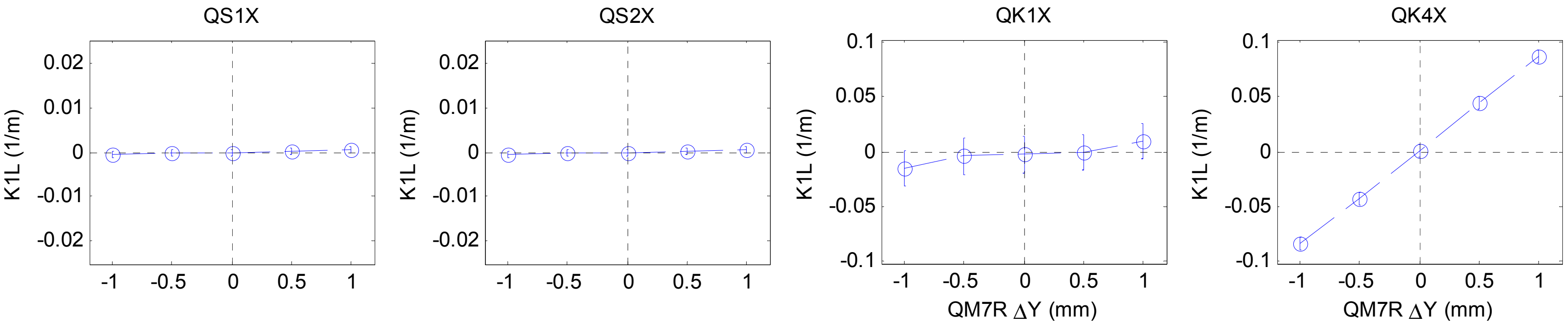
nonorthogonality in
coupling correction
(iterate?)

QM7R Offset

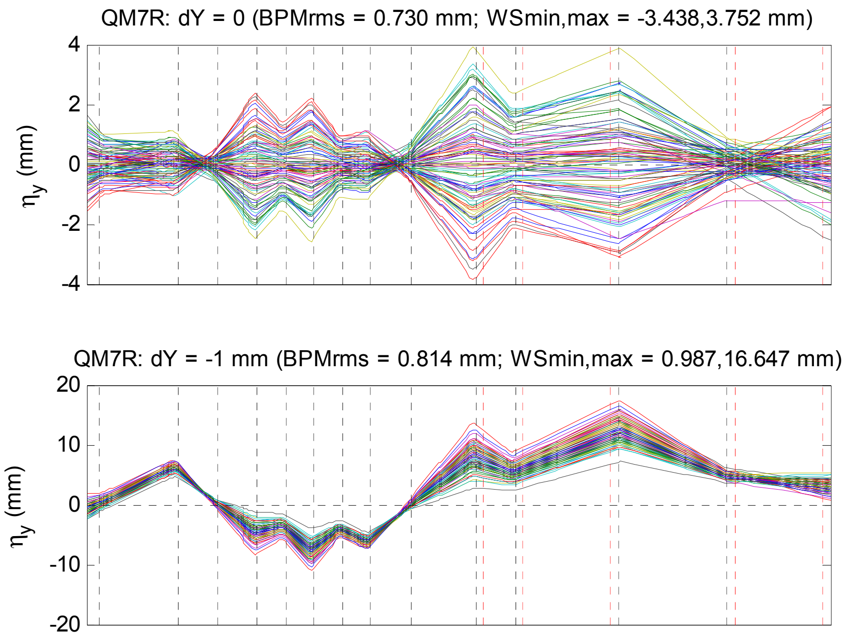
QM7R: ΔK_1 & K2L; scan Y-offset; full tuning

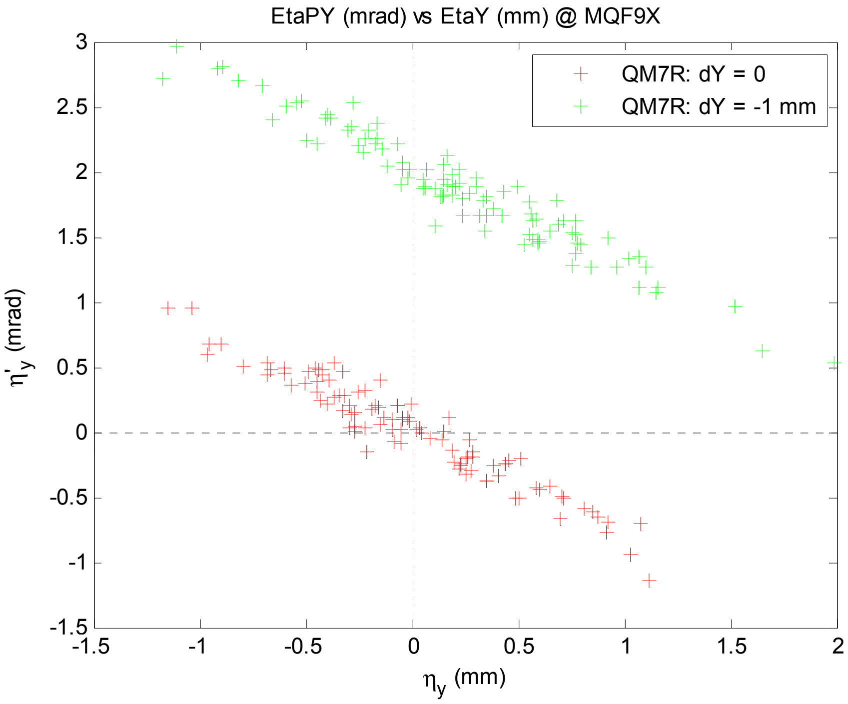






QM7R: ΔK_1 & K2L; scan Y-offset; full tuning





Conclusions

- given simple 1D fits to POISSON predictions for ΔK_1 and K_2L in QM7R, standard EXT tuning works when the beam passes through QM7R on the magnetic midplane
- however, standard EXT tuning does *not* work when the beam passes through QM7R off the magnetic midplane vertically
- the problem appears to be a net shift in η_y' which is not corrected by the QS1X-QS2X “sum knob” when η_y is corrected … it’s still unclear exactly why this is true
- QK4X seems to be in phase with the coupling caused by QM7R under these conditions (note: using 4 skew quads for coupling correction makes things worse!)
- at this point it’s unknown if Glen’s FF tuning process can deal with the incoming η_y under these conditions

Continuing Work

- understand why η_y correction breaks down
- can we use QS1X and QS2X independently to correct both η_y and η_y' simultaneously? if so, how strong do they get? how will this affect the coupling correction?
- verify that the blowup in σ_y^* and ε_y are due to uncorrected η_y / η_y'
- try to rematch EXT optics for QM7R dK1
- and …
- and …