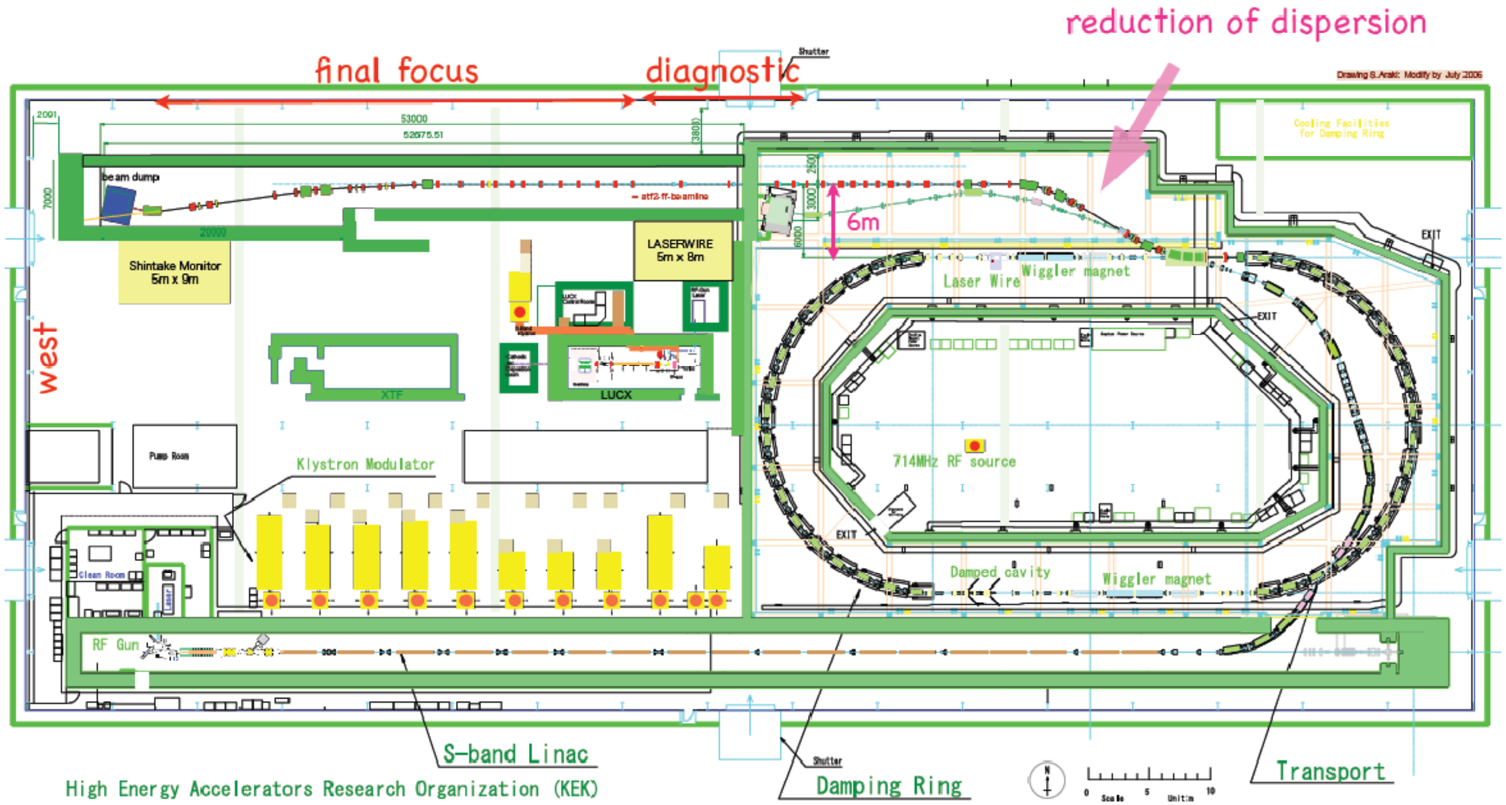
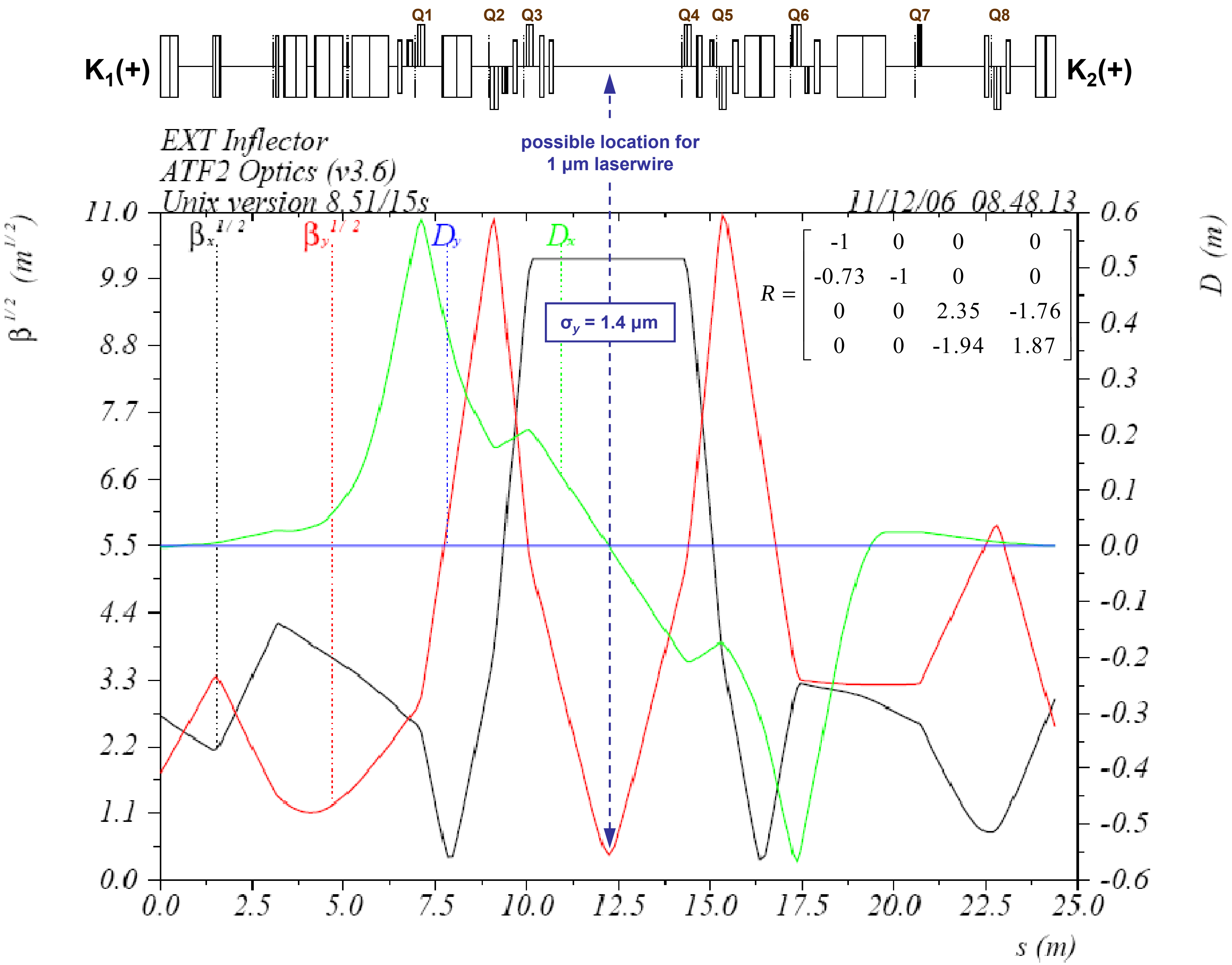
Vertical Dispersion and Coupling Correction in the ATF2 EXT Line (v3.6)

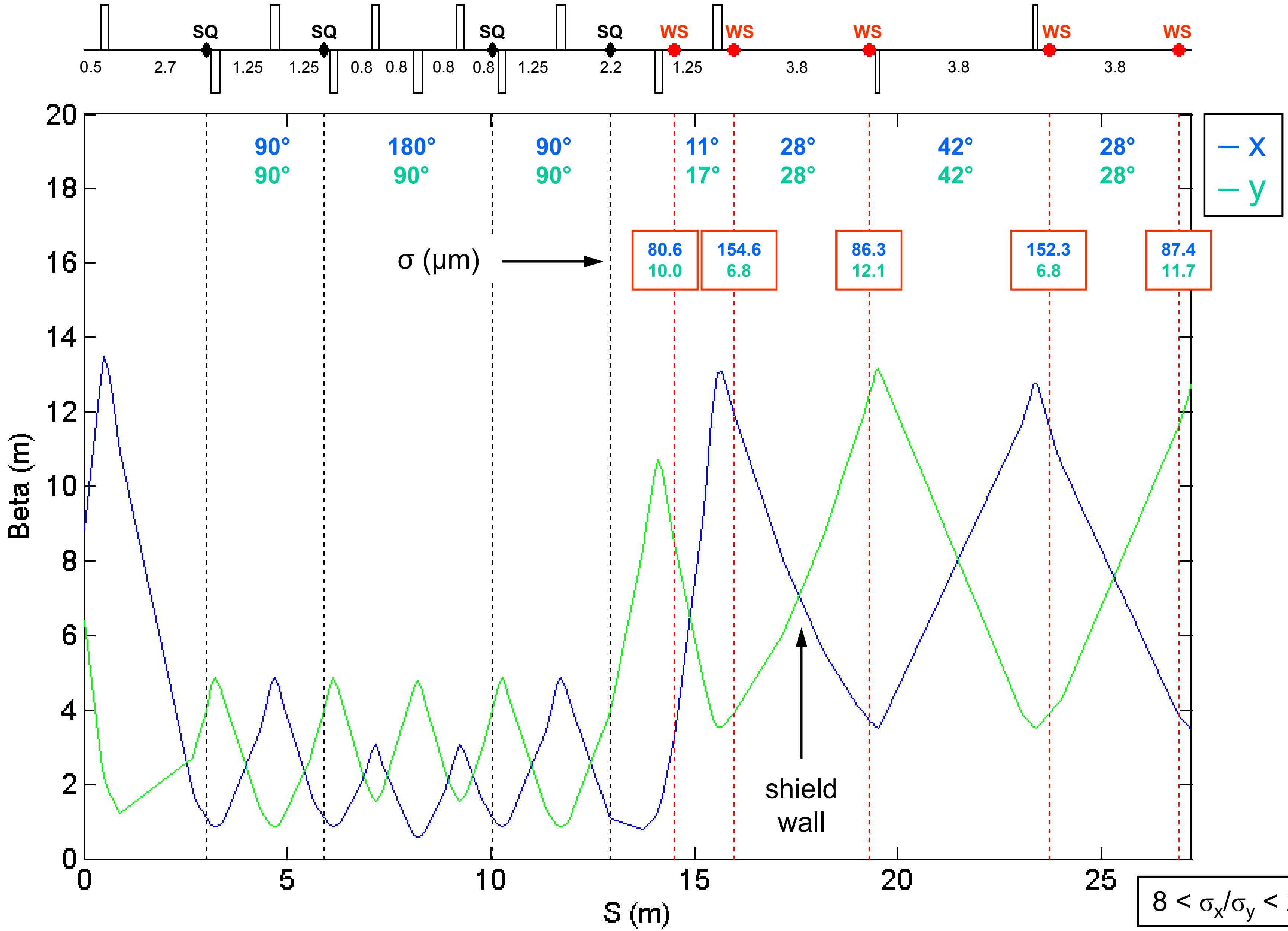
Optics v3.5, 1 July 2006



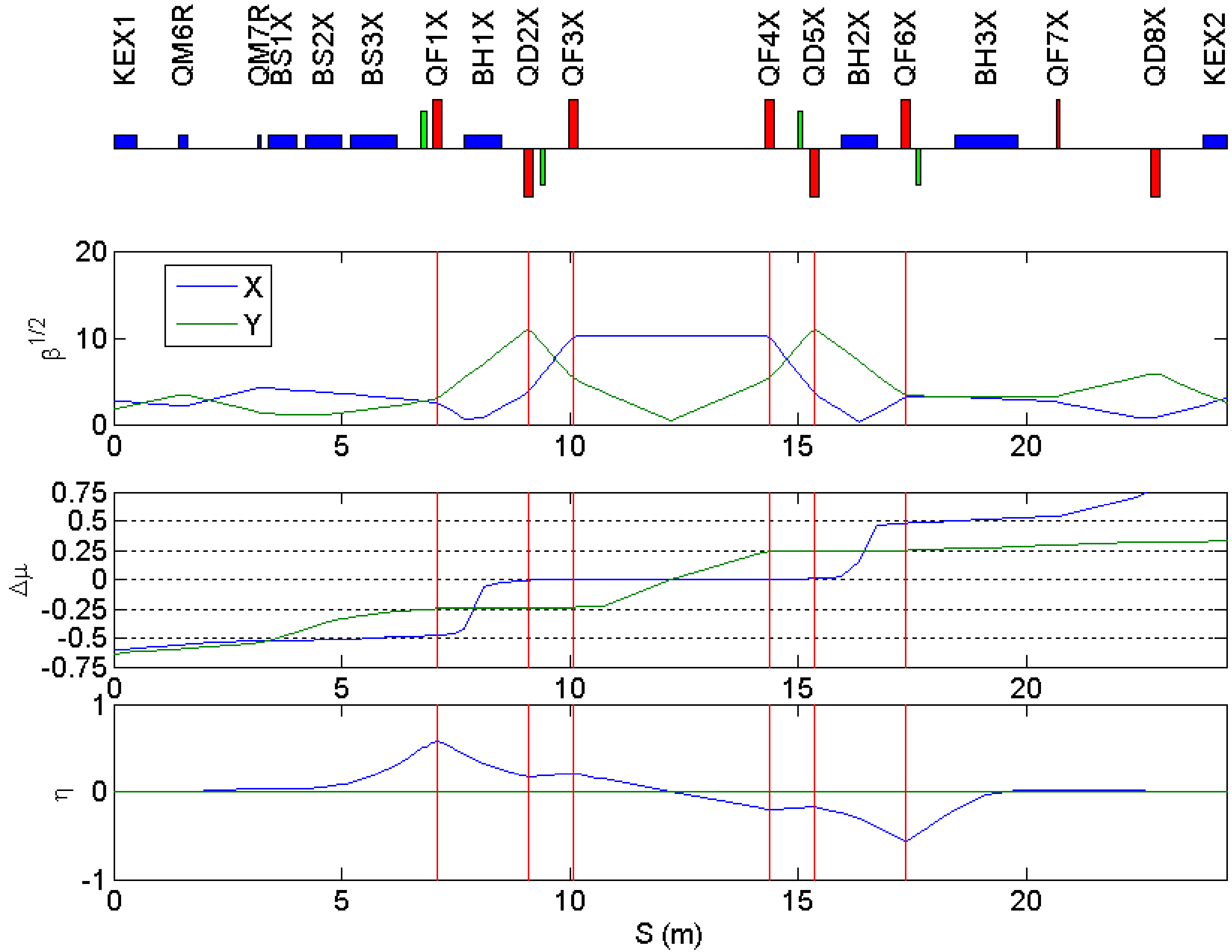


For MAD files see http://www.slac.stanford.edu/~mdw/ATF2/v3.6

EXT Skew Correction & Diagnostic Section (v3.6)



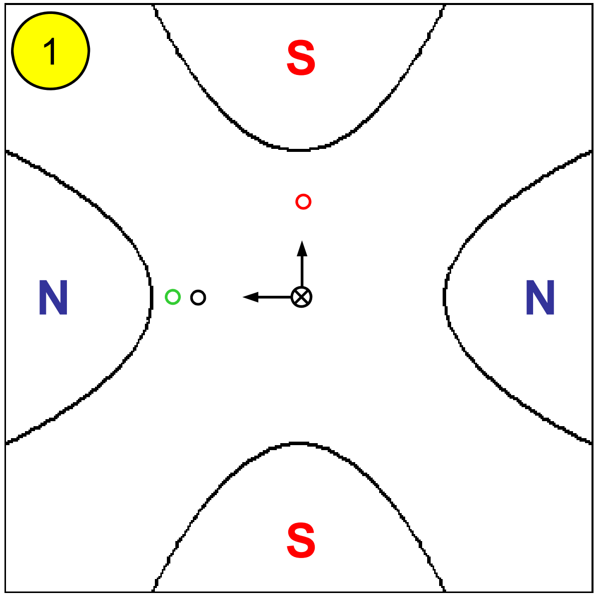
$8 < \sigma_x/\sigma_y < 23$



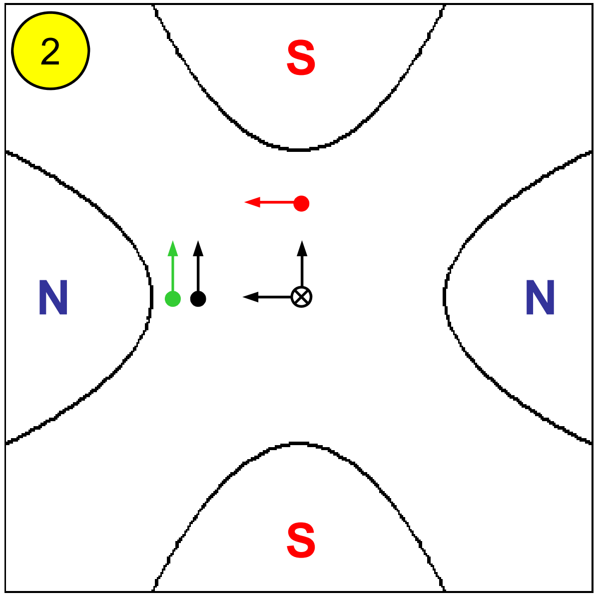
KEX1
QM6R
QM7R
BS1X
BS2X
BS3X
QF1X
BH1X
QD2X
QF3X
QF4X
QD5X
BH2X
QF6X
BH3X
QF7X
QD8X
KEX2
20
10
0
$\beta^{1/2}$
X
Y
0
5
10
15
20
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
$\Delta\mu$
1
0
-1
η
S (m)

how to generate η_y without introducing coupling

before 1[st] skew quad

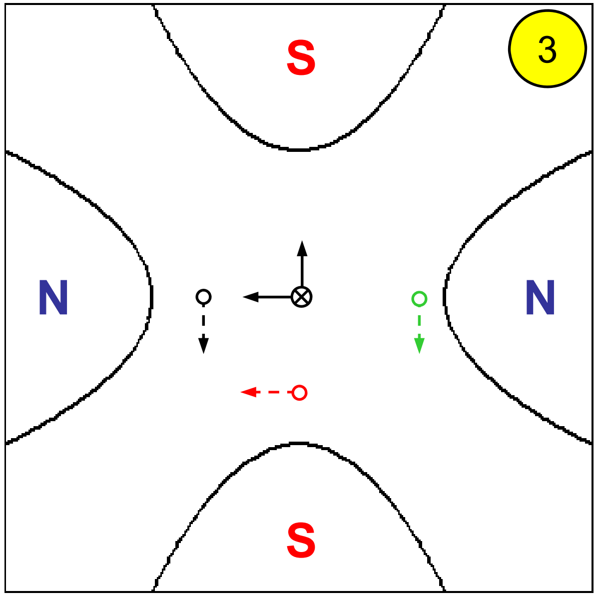


after 1[st] skew quad

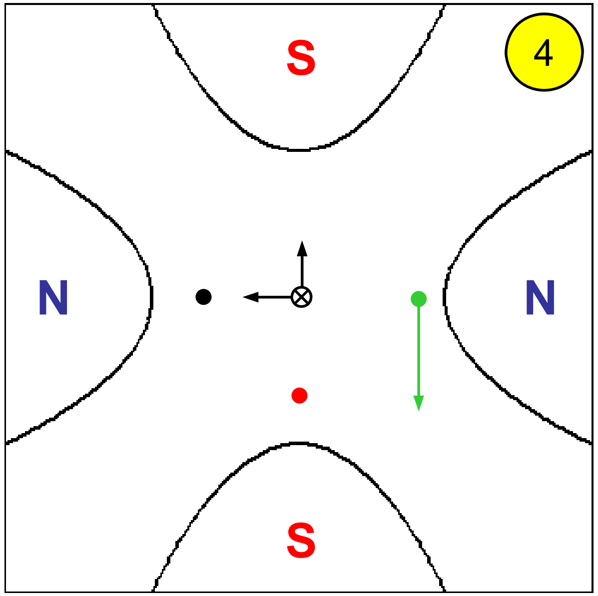


$\Delta\mu_x$ = 0,360°
$\Delta\mu_y$ = 180°
$+\eta_x \rightarrow -\eta_x$

before 2[nd] skew quad

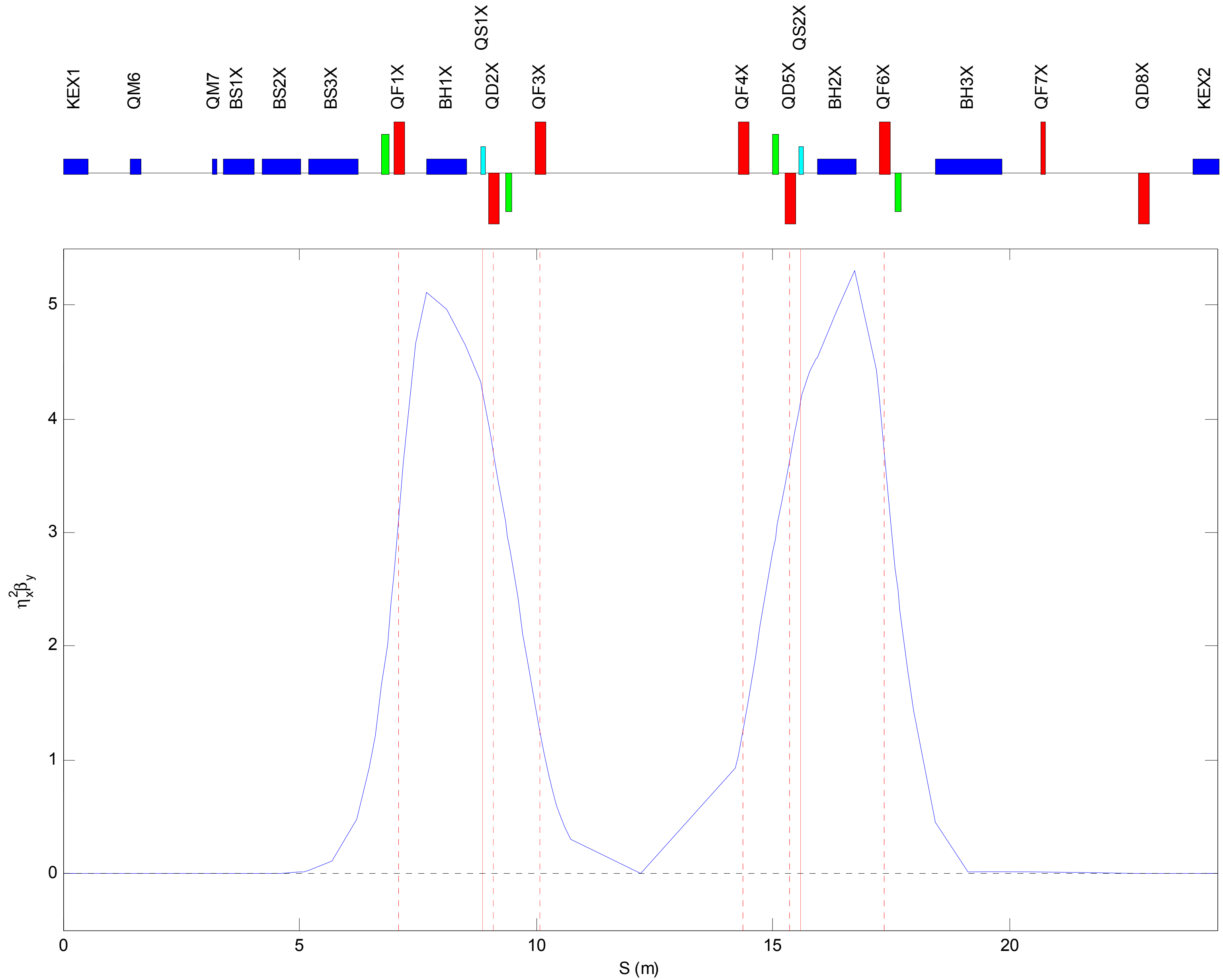


after 2[nd] skew quad



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

skew quads have equal strengths ("sum knob")


KEX1
QM6
QM7
BS1X
BS2X
BS3X
QF1X
BH1X
QS1X
QD2X
QF3X
QF4X
QD5X
QS2X
BH2X
QF6X
BH3X
QF7X
QD8X
KEX2
$\eta_x^2\beta_y$
S (m)
0
1
2
3
4
5
0
5
10
15
20

η_y correction: residual *x-y* coupling

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

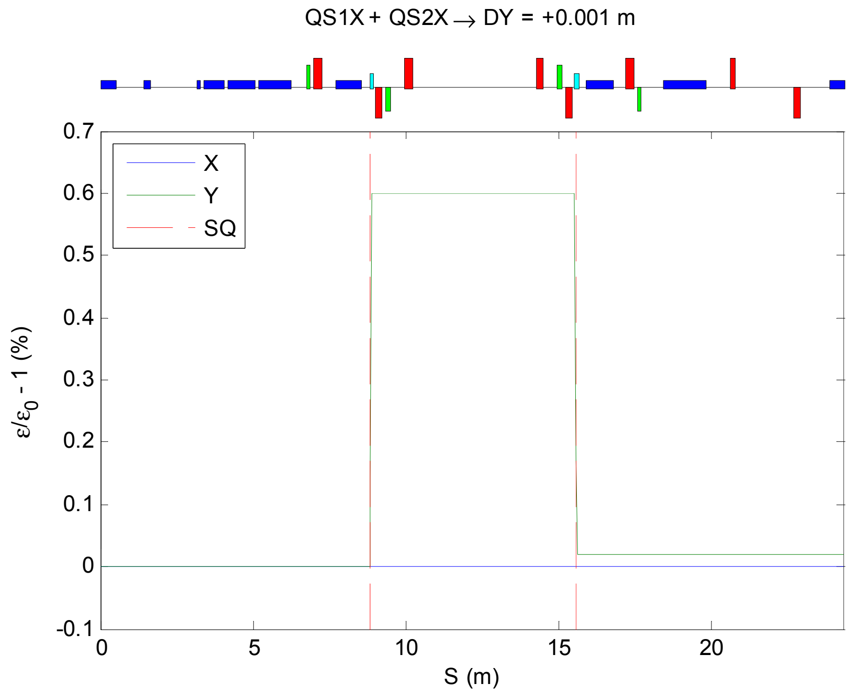
$$\mathrm{Q}_{x,y} \equiv \frac{1}{\sqrt{\beta_{x,y}}}\begin{bmatrix} \beta_{x,y} & 0 \\ -\alpha_{x,y} & 1 \end{bmatrix}$$

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

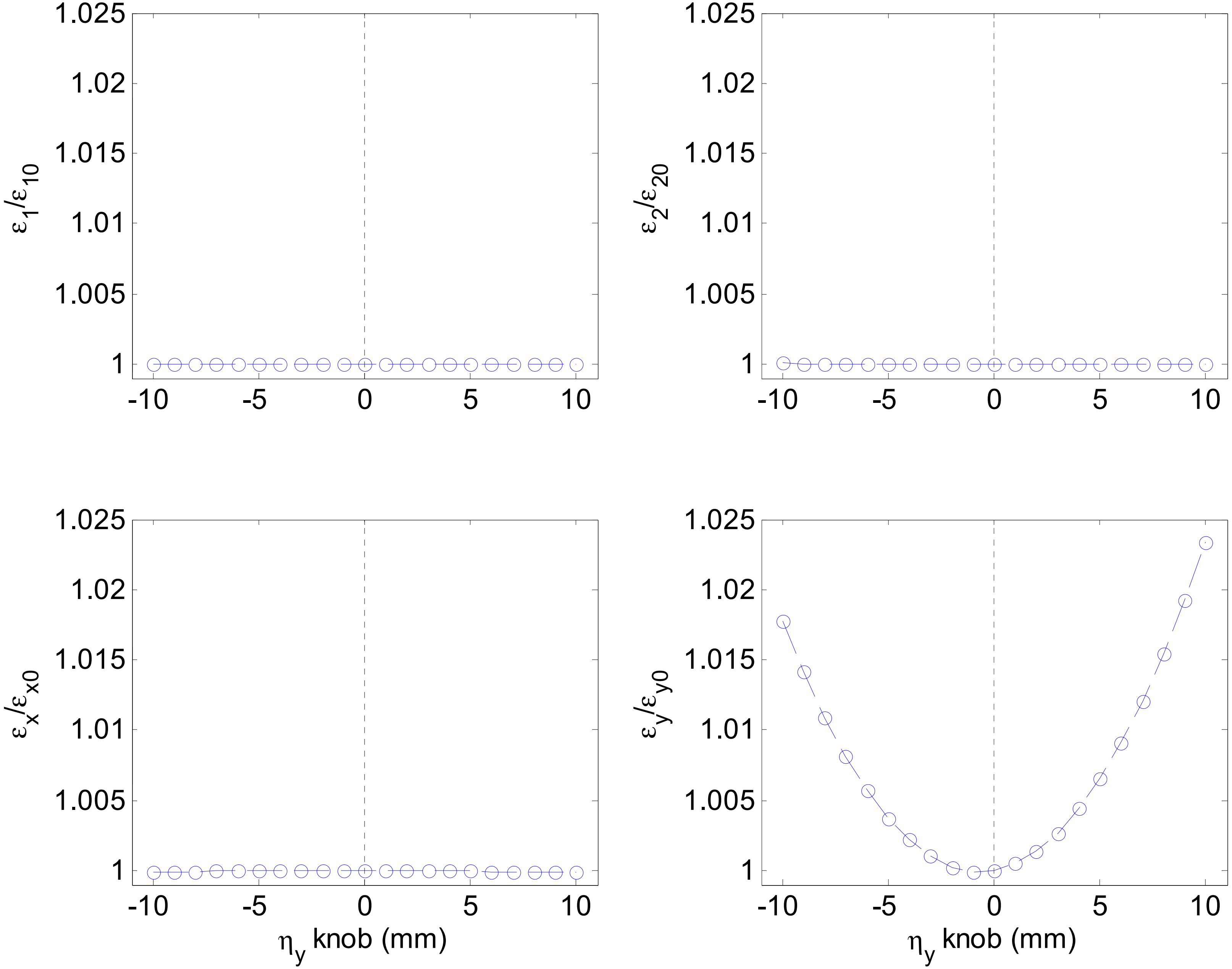
$$\lambda = \mathrm{tr}\left(\mathrm{P}\mathrm{P}^{\mathrm{T}}\right)$$

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

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



		QS1X	QS2X
		-------	-------
βx	=	9.005	7.762
αx	=	-9.192	9.438
ηx	=	0.203	-0.198
βy	=	102.805	105.110
αy	=	-41.677	40.608
Δμx	=	-	7.910
Δμ y	=	-	173.199
kl/klmax	=	0.139	0.139
residual	=	0.0002	


1.025
1.02
1.015
1.01
1.005
1
-10
-5
0
5
10
ε1/ε10
ε2/ε20
εx/εx0
εy/εy0
ηy knob (mm)

Simulation Parameters

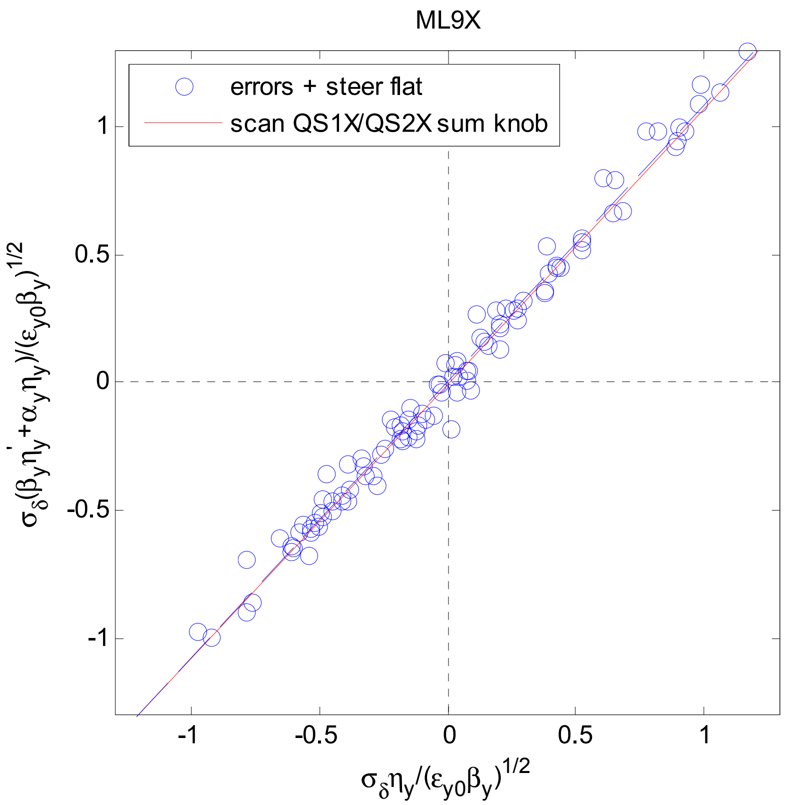
- use Peter Tenenbaum's Lucretia[1] simulation code
- included
  - perfect beam from Damping Ring (ε_x=2×10^{-9} m, $\gamma\varepsilon_y$=3×10^{-8} m) … errors begin after extraction septa, unless otherwise noted
  - perfect Final Focus
  - dipole errors[2]: ΔY = 100 μm (rms)
  - quadrupole errors: ΔX = 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 (η_{x0}, η'_{x0}, η_{y0})
   - use QF1X + QF6X multiknobs for η_x and η'_x
   - use QS1X + QS2X sum multiknob for η_y
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

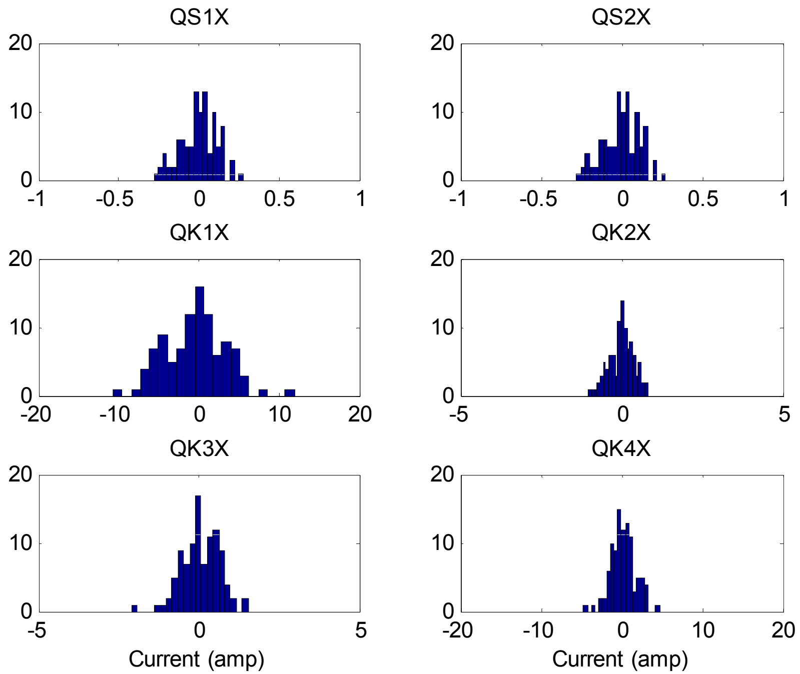
η_y and η'_y at ML9X (start of diagnostic section) after steering EXT flat (100 seeds)

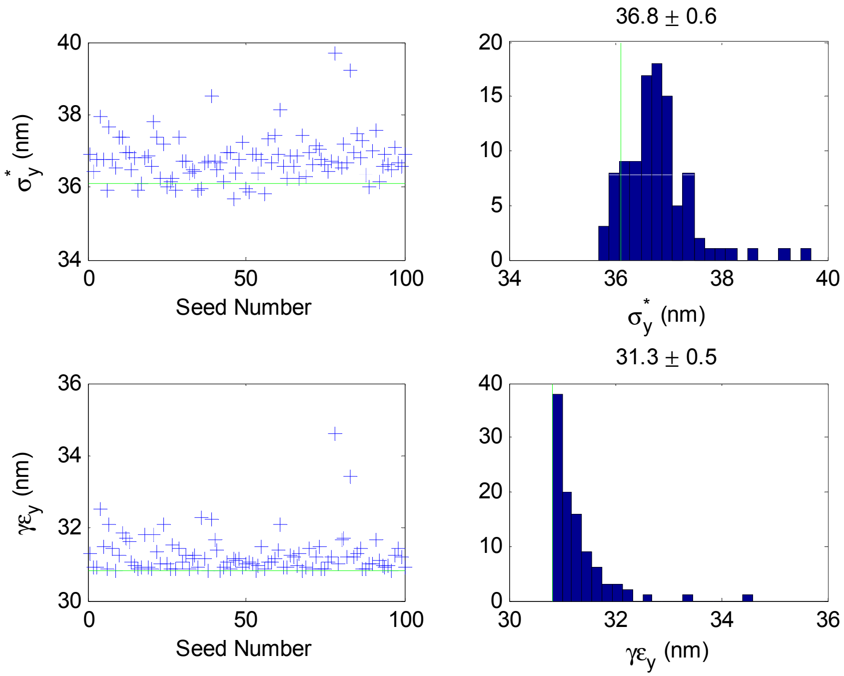


$$\frac{\varepsilon_y}{\varepsilon_{y0}} = \sqrt{1 + \sigma_\delta^2 \left\{ \frac{\eta_y^2 + \left(\beta_y \eta'_y + \alpha_y \eta_y\right)^2}{\varepsilon_{y0}\beta_y} \right\}}$$

@ ML9X: β_y = 1.675 m, α_y = 1.195

errors, steer flat, correct dispersion, correct coupling, FF launch



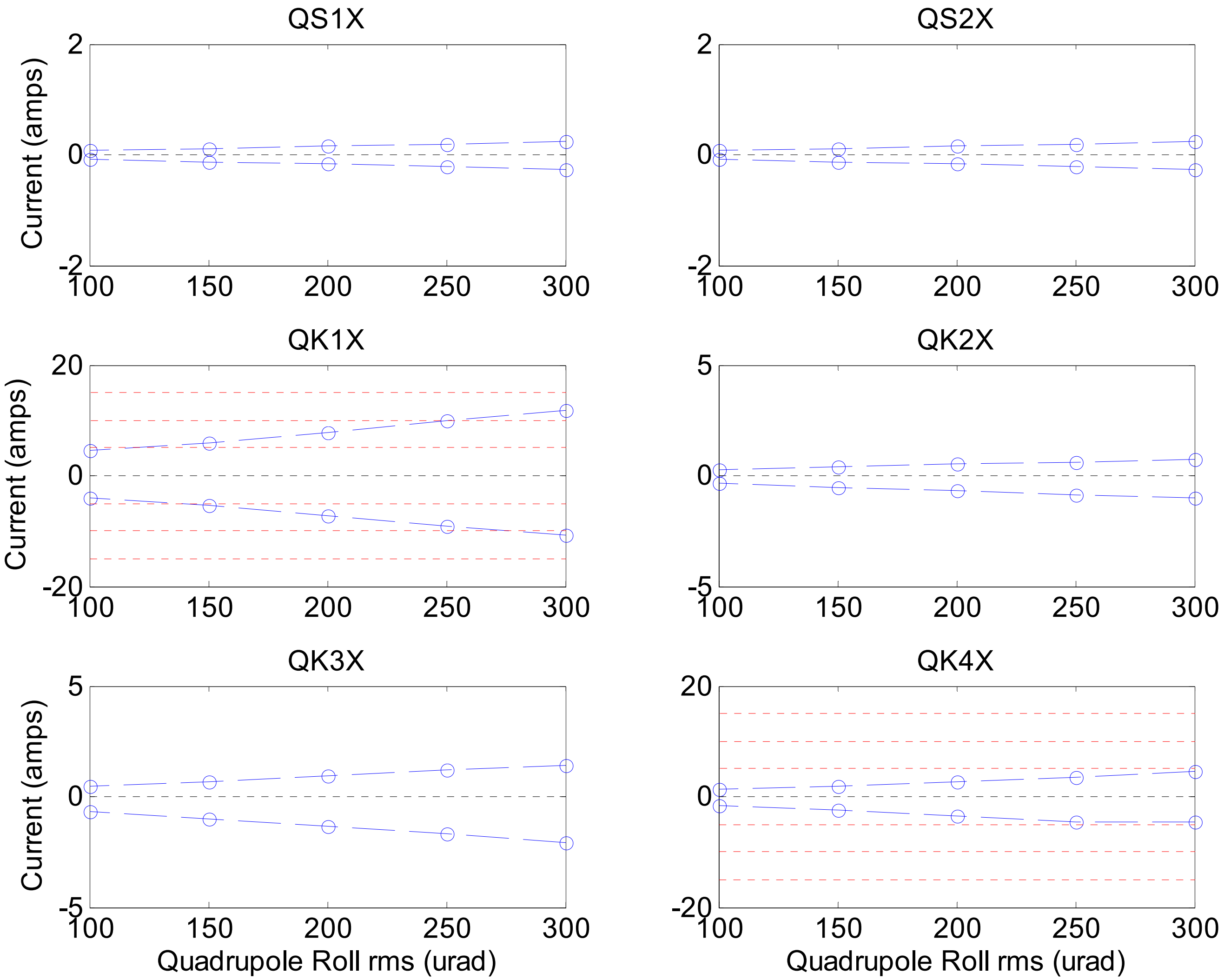


assume that all skew quads are IDX type

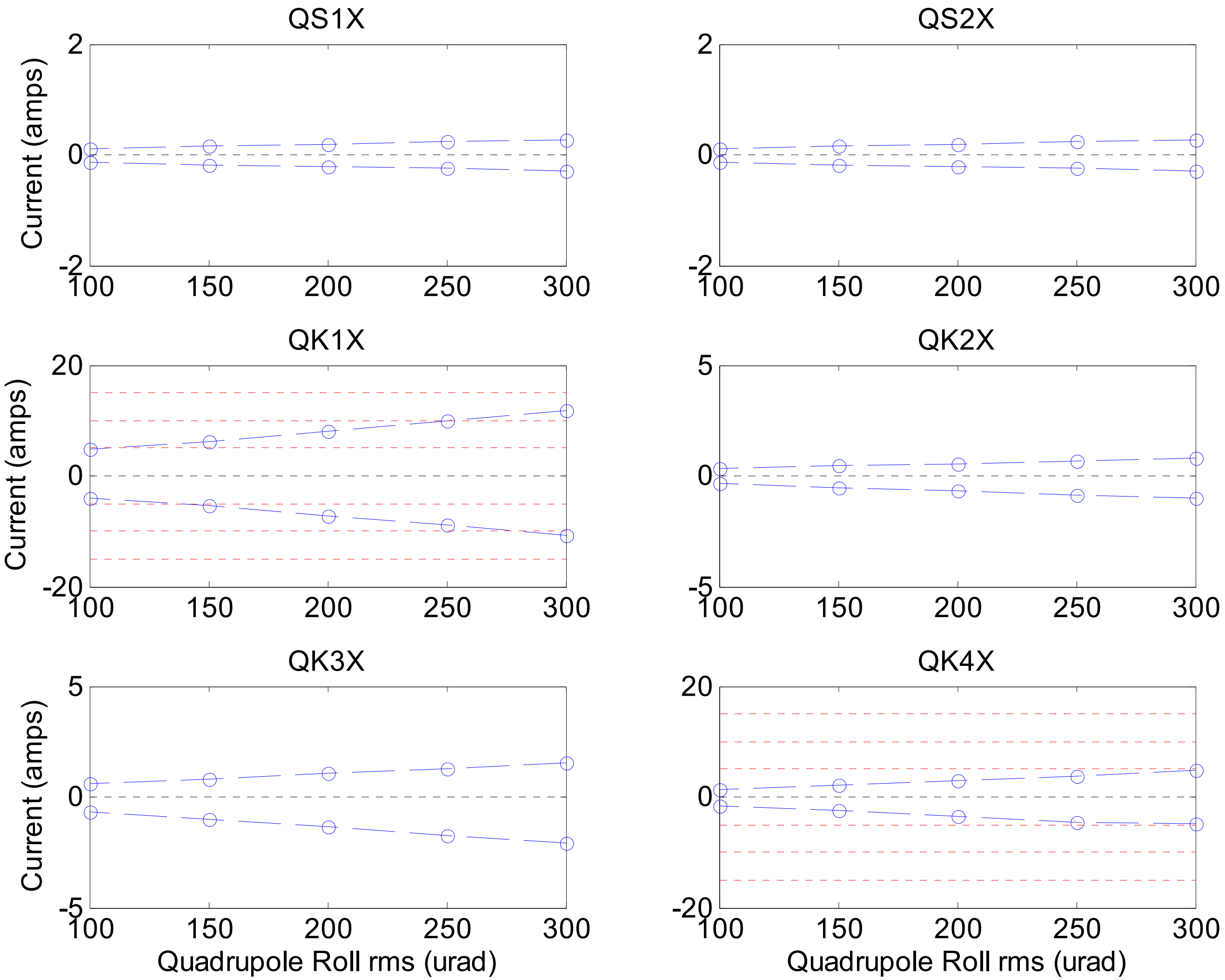
σ_y*(90%) = 37.4 nm

$\gamma\varepsilon_y$(90%) = 31.8 nm

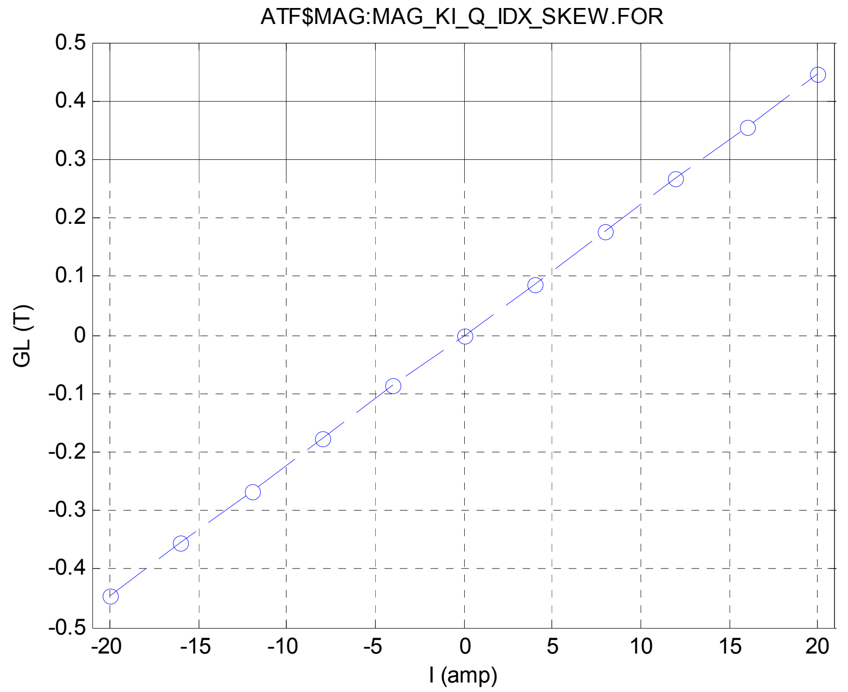
no errors except quadrupole rolls; correct dispersion and coupling; plot minimum and maximum skew quad currents (100 seeds)

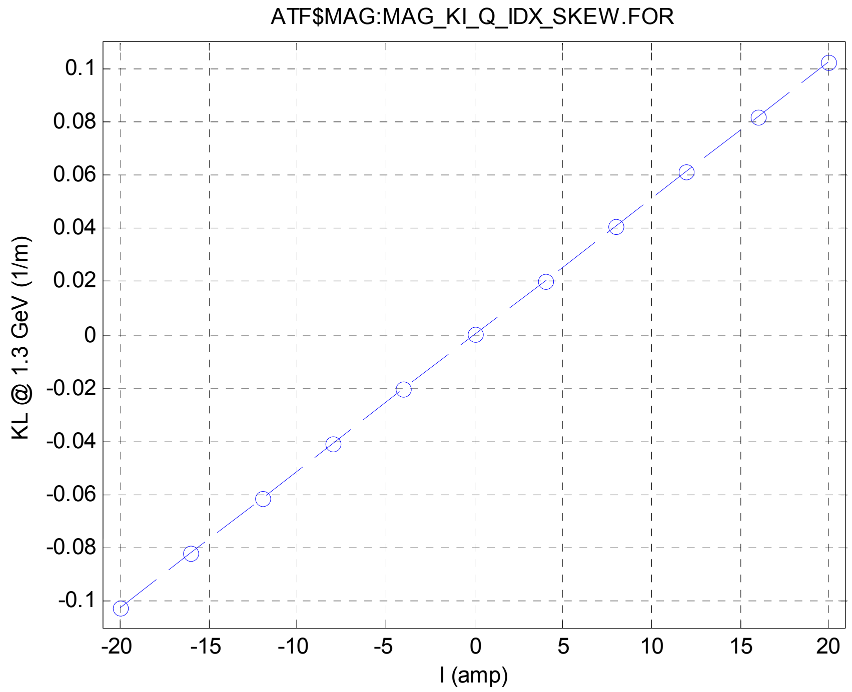


all errors including quadrupole rolls; correct dispersion and coupling; plot minimum and maximum skew quad currents (100 seeds)

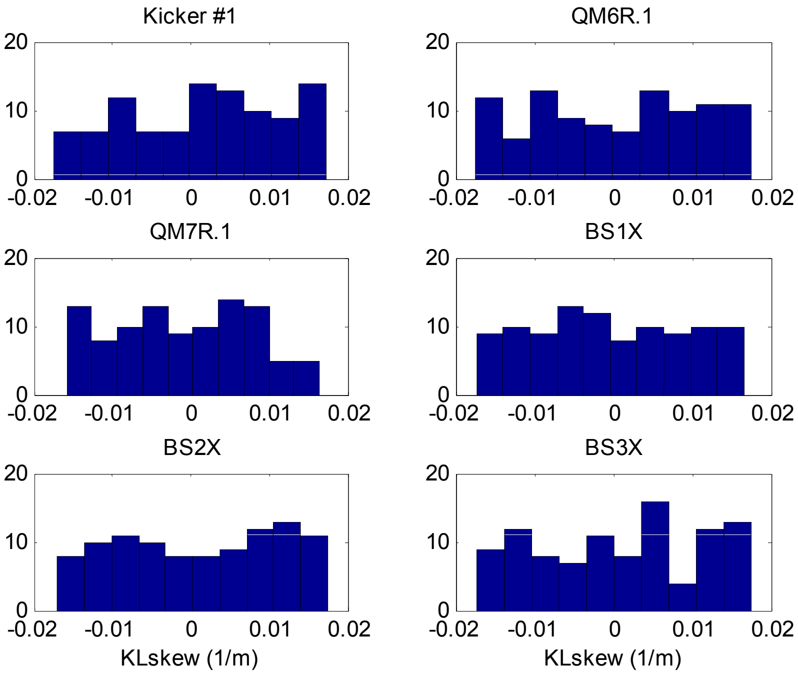


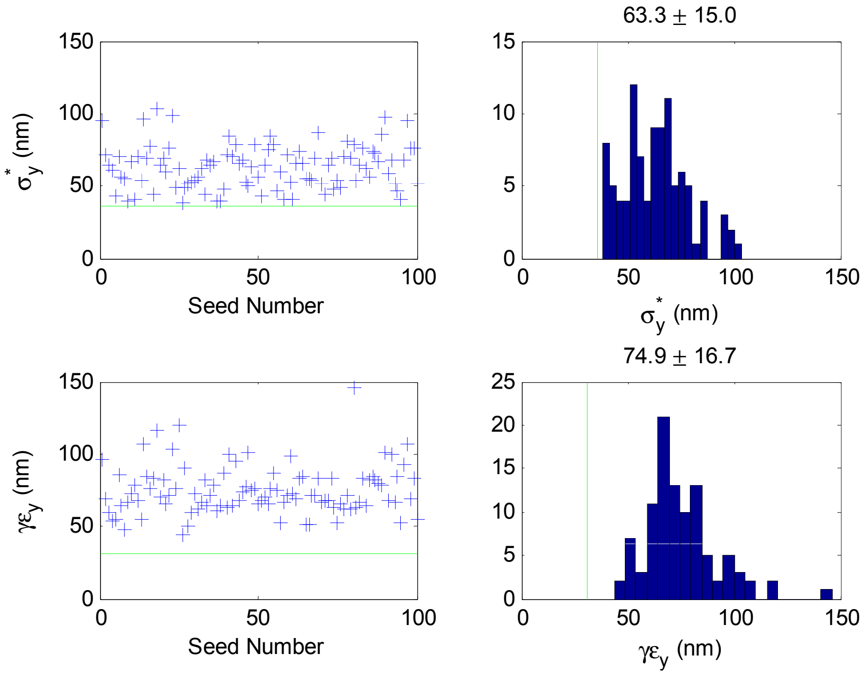
IDX skew quads have been measured to ±20 amps …
can we replace their ±5 amp power supplies with
±20 amp power supplies without modifying the magnets?





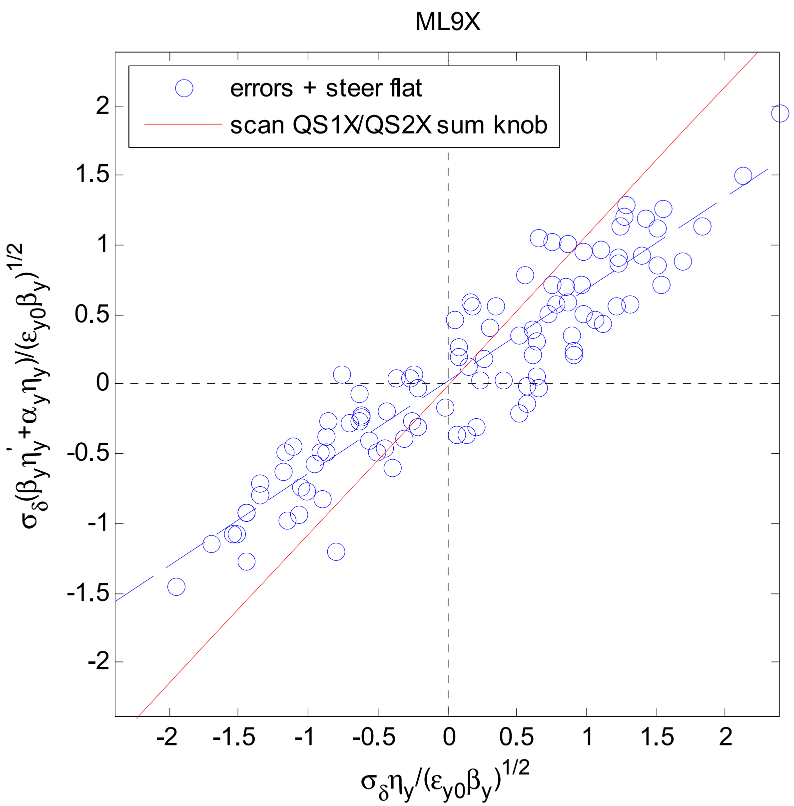
errors, steer flat, FF launch;
DR extraction channel skew errors included





|KLskew| < 0.0175
(like IDX @ 15 amps)

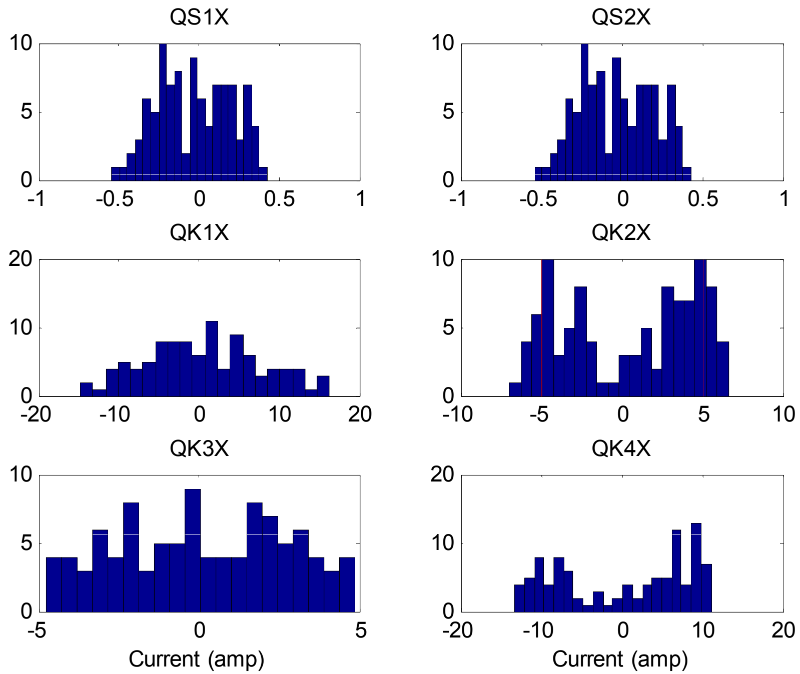
η_y and η'_y at ML9X (start of diagnostic section) after steering EXT flat (100 seeds); DR extraction channel skew errors included

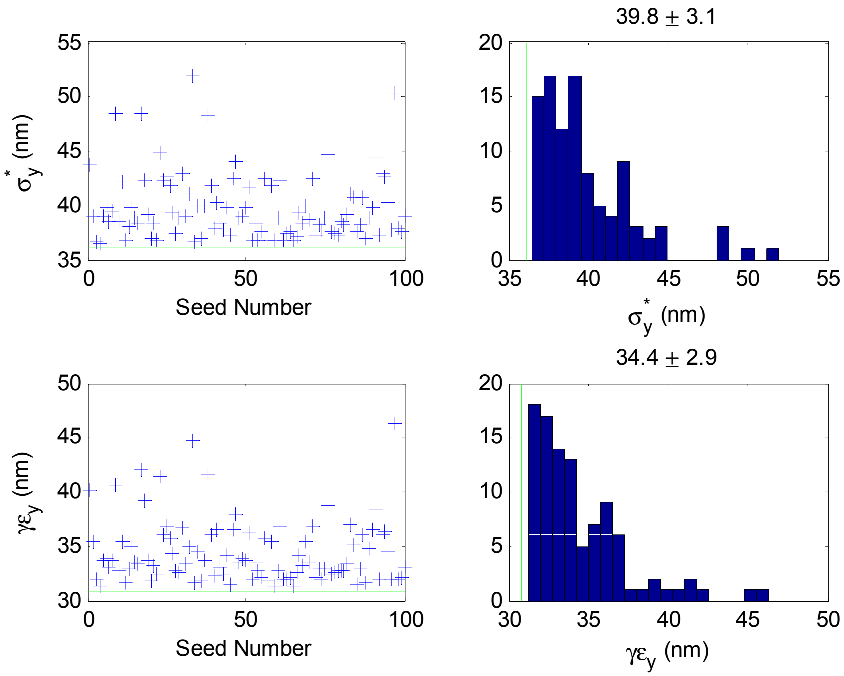


$$\frac{\varepsilon_y}{\varepsilon_{y0}} = \sqrt{1+\sigma_\delta^2\left\{\frac{\eta_y^2+\left(\beta_y\eta'_y+\alpha_y\eta_y\right)^2}{\varepsilon_{y0}\beta_y}\right\}}$$

@ ML9X: β_y = 1.675 m, α_y = 1.195

errors, steer flat, correct coupling, FF launch;
DR extraction channel skew errors included





assume that all skew quads are IDX type

$\sigma_y^*(90\%) = 43.0$ nm
$\gamma\varepsilon_y(90\%) = 38.0$ nm

Conclusions

- simulated system performance, for the given errors and diagnostic resolution, is adequate for the achievement of ATF2 goal “A” (~35 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 (QS1X just upstream of QD2X, and QS2X just downstream of 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 (20% in ε_y)
- two of the IDX skew quadrupoles for coupling correction (QK2X and QK3X) require ±5 amp power supplies (existing); the other two IDX skew quadrupoles (QK1X and QK4X) require at least ±10 amp power supplies (maybe better ±20 amp)
- anomalous skew fields in the DR extraction channel (Kicker #1, QM6R.1, QM7R.1, BSEP1, BSEP2, BSEP3) which cause 100% vertical emittance blowup can be mostly compensated with one iteration of correction

Continuing Work

- 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
- find better correction for η_y/η'_y coming for DR … EXT orbit bumps?
- iterate correction of anomalous skew fields in the DR extraction channel … can we get all the way back?

Woodley Homework

ATF2 MAD deck improvements needed for ATF2 v3.7

- turn EXT sextupoles OFF; rematch in FF
- use measured LEFF for QEA's
- use actual LEFF and APER values for FD quads (1.38Q17.72)
- use POISSON estimated LEFF and design HGAPs for FF bends
- use POISSON estimated LEFF and design APERs for FF sexts
- remove FF octupoles & decapoles
- add Q-BPMs to all quads from QD18X to IP
- add MOVERs to all FF quads and sexts
- add diagnostics stations (extLW,FONT,nBPM,IPBPM)
- add Glen's feedback devices
- add IP BSMs for commissioning (carbon wire scanners, Honda monitors)
- add sweeping magnets for IP position scan
- update parts list