INTERNATIONAL LINEAR COLLIDER

SLAC

Simulation of Alignment and Tuning of ATF2 FF

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ELC Workshop, Daresbury

Jan 2007

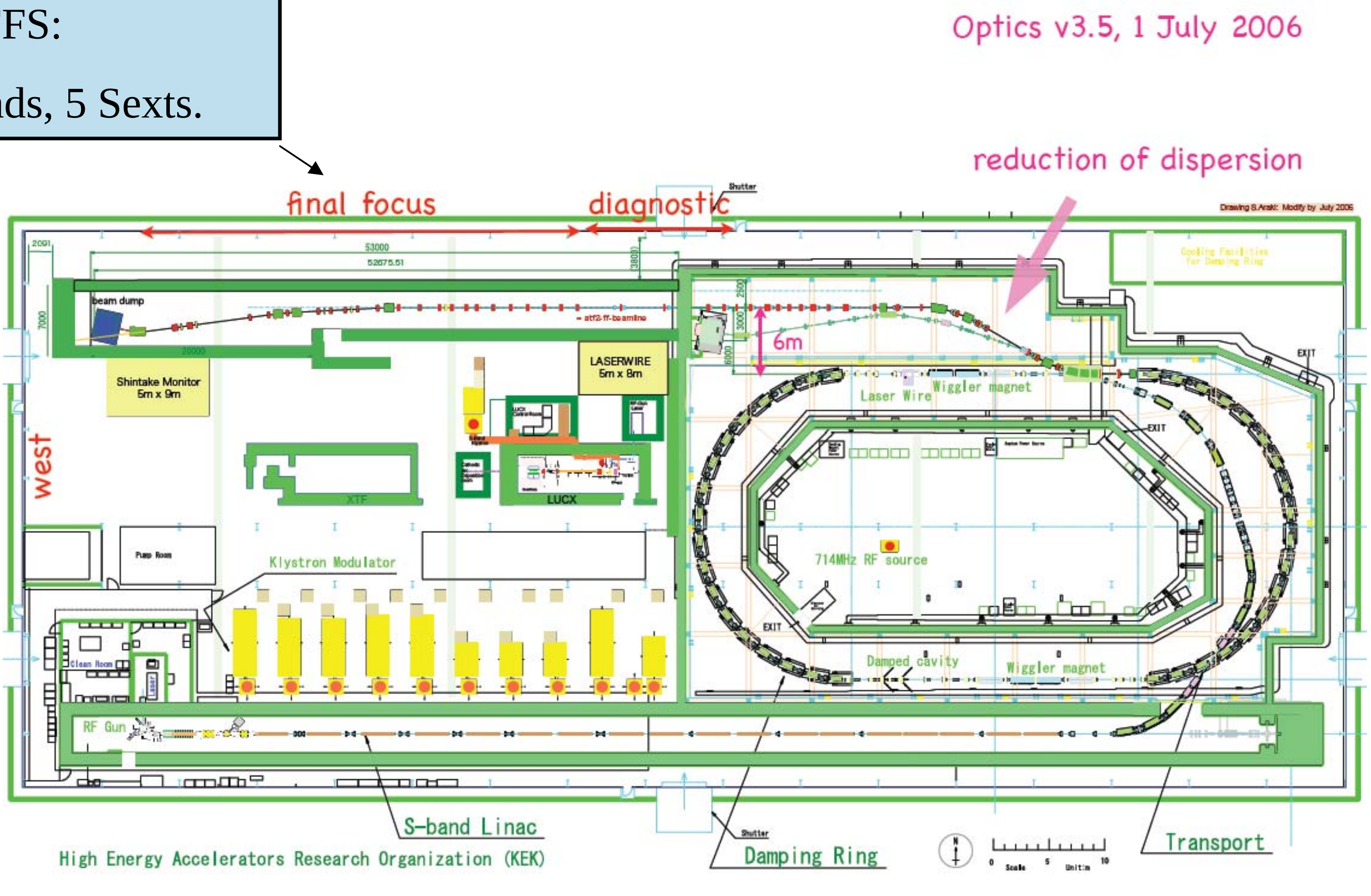
Overview

- Porting simulation developed for ILC alignment and tuning, first look at simulation of ATF2 tuning performance.
- Assuming set of initial starting errors, take 100 seeds of Woodley-tuned v3.6 lattice (dispersion and coupling fixed in diagnostic section).
  - Add FF errors.
  - Apply BPM alignment, BBA and sextupole tuning knobs for each of 100 seeds.
- Here, simulation is static- next step is to add dynamic imperfection to tuning (Ground Motion, component + incoming beam jitter, magnet and BPM drifts etc.).
- Lucretia used for simulations.

ATF2 Final Focus System

Tune FFS:

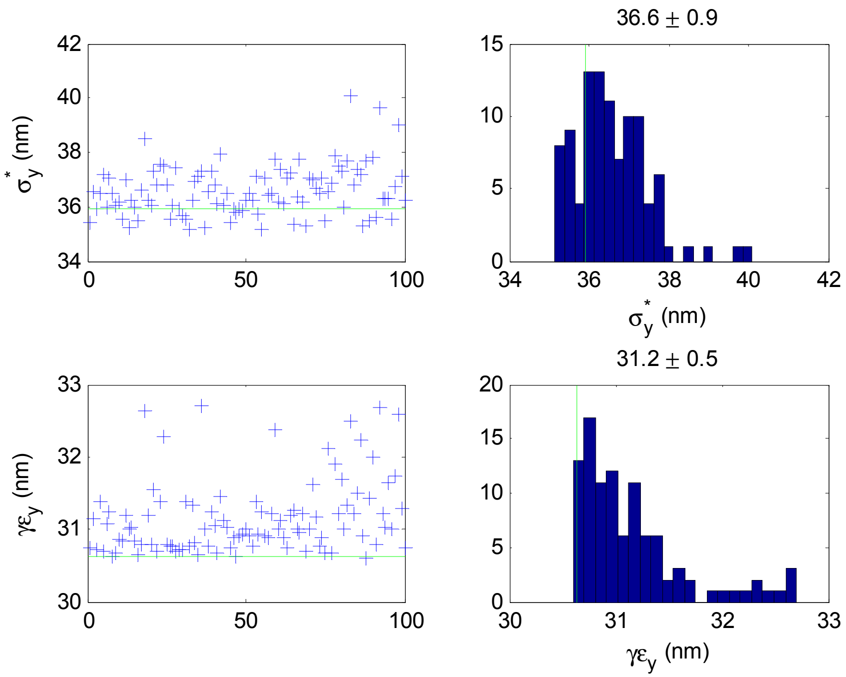
22 Quads, 5 Sexts.

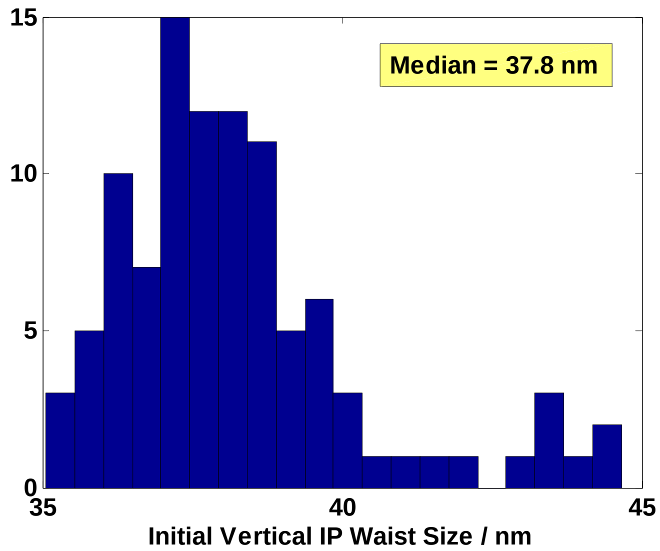


Initial Dispersion and Coupling Correction (MW)

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 … 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 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

Initial Beam Before Errors





- Initial set-up of MW ATF2 lattice with dispersion + coupling correction in diagnostic session gives IP sizes shown on left.
- Right plot after importing lattice into my simulation (using slice beam representation for simulation speed initially). Results relative to these starting conditions.

IP Beamsize Measurement

- Assume IP assembly of cavity BPM + shintake monitor for IP waist position + vertical size measurements.
- Shintake monitor measurement range 35nm – 350nm.
- Also assume presence of wirescanner for >1 micron waist sizes.
- Between 350nm and ~1um, proposal from Honda: use novel nano-pattern target film.
- So, assume a beamsize measurement all the way from initial few microns to target 35nm to tune on.

Initial Error Parameters

- Assume movers on all FF quadrupoles and sextupoles.
- Cavity BPMs fixed to all FF Quads + Sexts.
- Also assume IP BPM with 5nm RMS resolution.

Quad, Sext x/y transverse alignment	**50 um**
Quad, Sext roll alignment	**300 urad**
Initial BPM-magnet field center alignment	**30 um**
dB/B for Quad, Sexts	**1e-3 syst. + 1e-4 random**
Mover resolution (x & y)	**50 nm**
BPM resolutions	**100 nm**
Power supply resolution	**14 - bit**
Shintake Monitor Resolution	**2nm**

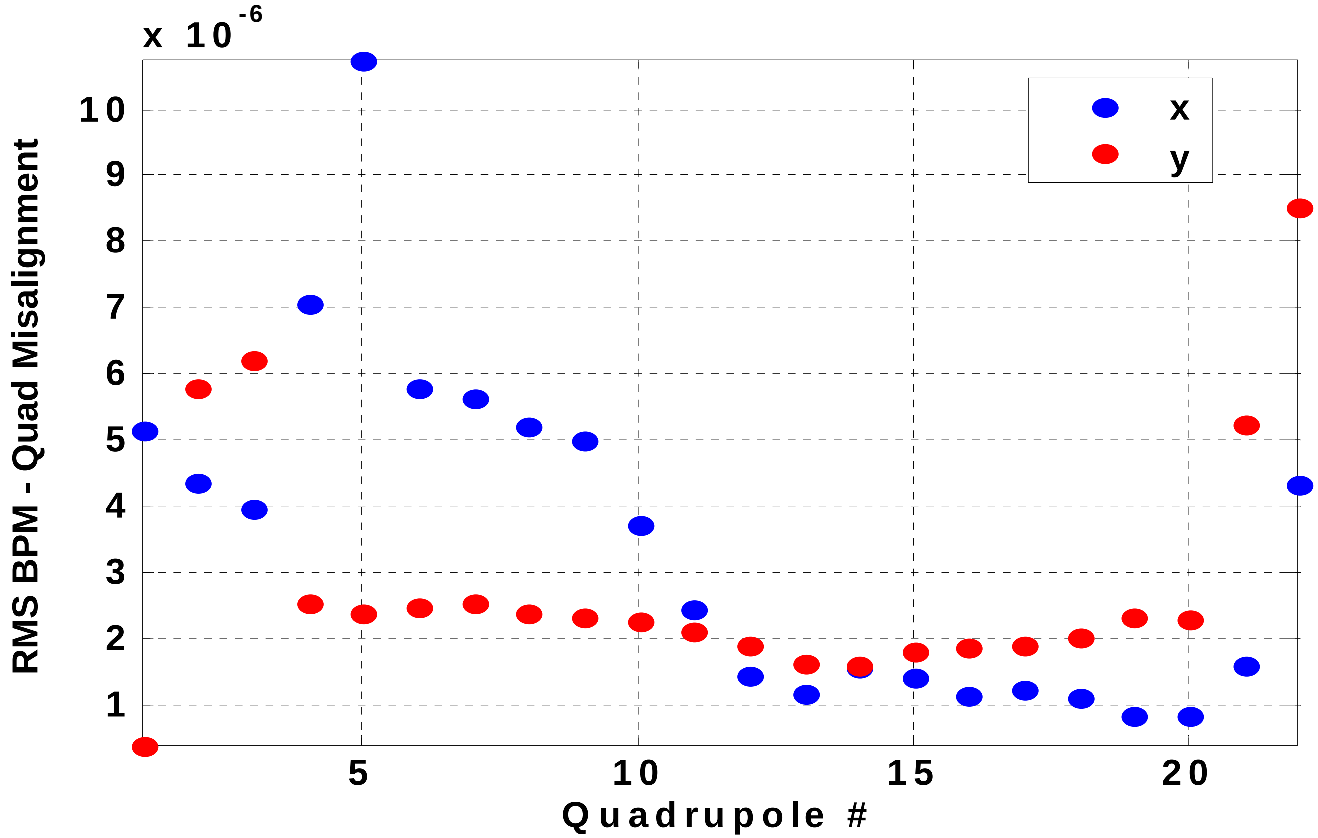
Alignment and Tuning Procedure

- Switch off Sextupoles.
- Perform initial BBA using Quad movers + BPMs to get orbit -> IP.
- Quadrupole BPM alignment (quad-shunting).
- Perform Quadrupole BBA. [See ILC talk for details]
- Align Sextupole BPMs (move through beam + downstream BPM fits).
- Activate sextupole magnets.
- Apply sextupole multiknobs to tune out IP aberrations.

Quadrupole BPM Alignment

- Nulling Quad Shunting technique:
- To get BPM-Quad offsets, use up to downstream 5 BPMs for each Quad being aligned (include IP bpm for last few quads).
- Quad dK 100-80 %, use change in downstream BPM readouts to get Quad offset.
- Move Quad and repeat until detect zero-crossing.
- For offset measurement, use weighted-fit to downstream BPM readings based on model transfer functions: $x_{Quad} = \Delta x_{BPM} / \left(\Delta R_Q(1,1) * R(1,1) + \Delta R_Q(2,1) * R(1,2) \right)$

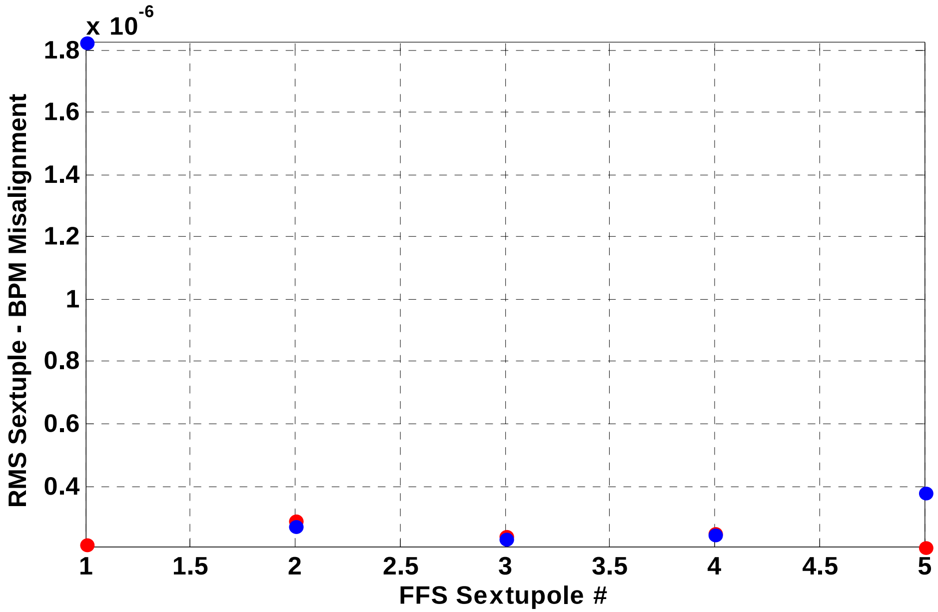
Quad BPM Alignment



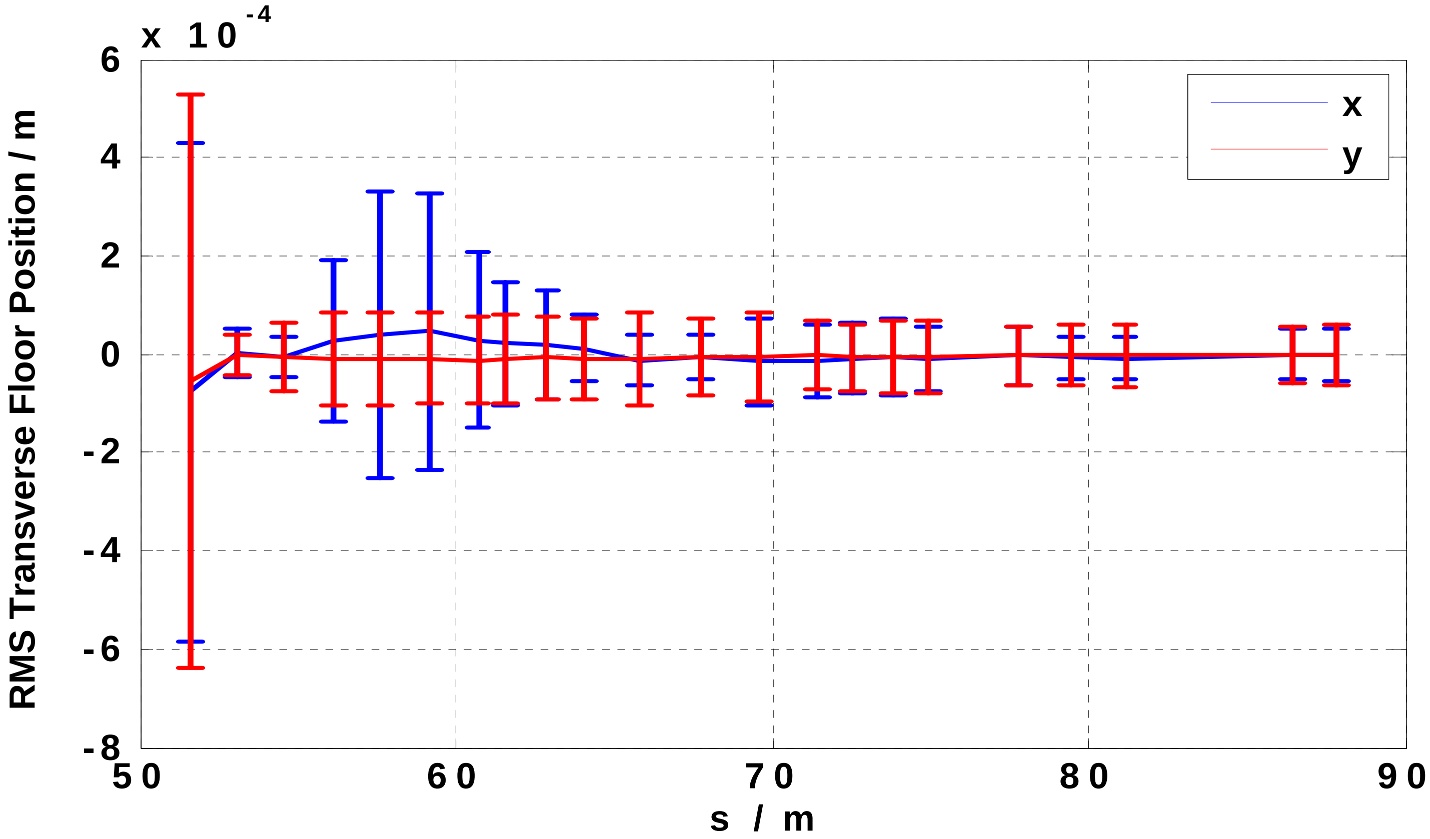
- RMS alignment of Quad field center – electrical center of Quad BPMs (100 seeds).

Sextupole BPM Alignment

- Move Sextupole +/- 0.5mm through beam.
- Fit quadratic function to IP BPM response.
- Alignment from minimum of fit.
- RMS alignment results below:

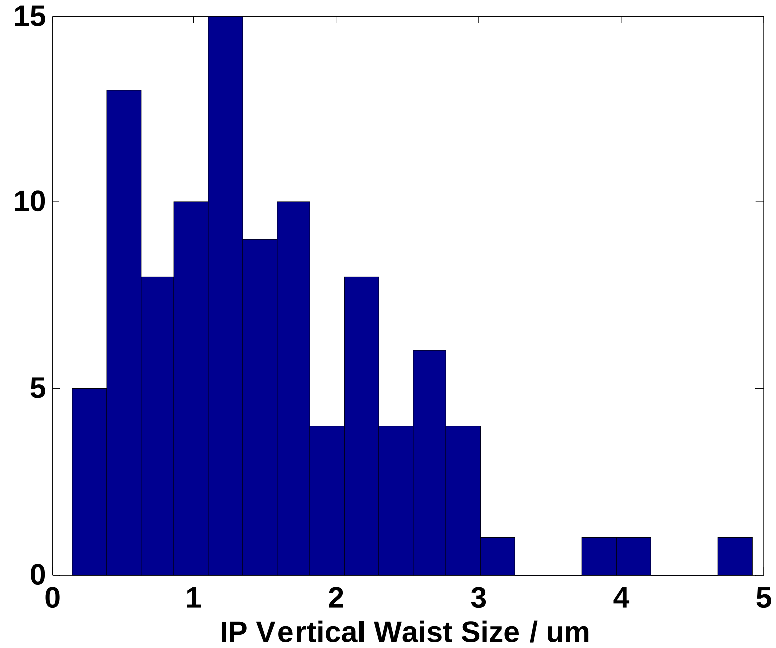


Quad BBA



- Quadrupole floor positions post BBA (mean and RMS from 100 seeds).

Beamsize After BBA



- IP waist size after BPM alignment and BBA.

Sextupole Multi-Knobs

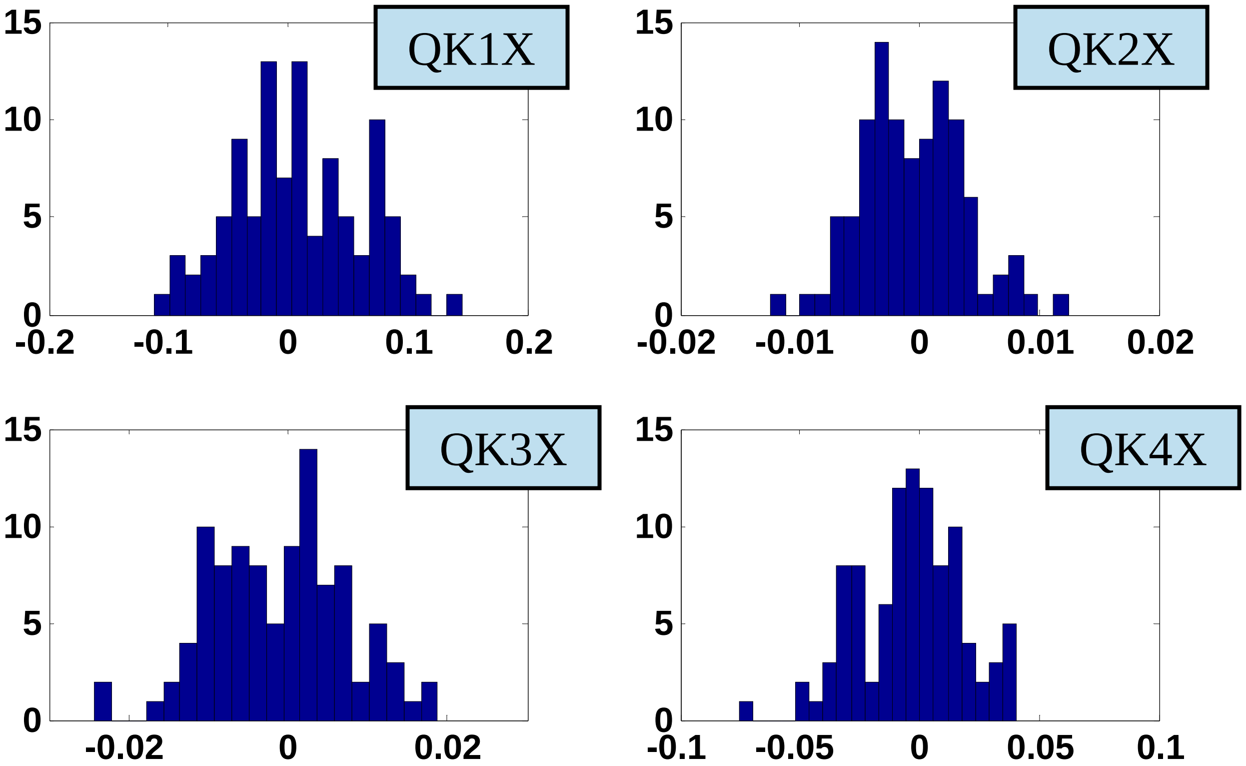
- Use orthogonalised x- and y-moves of FFS sextupoles to correct vertical waist and dispersion + <x’y> coupling term.
- Additionally use orthogonal moves of skew quads to tune <xy>.
- Higher-order IP aberration tuning performed by scanning sextupole tilts + strengths.
- In simulation, apply iteratively until beamsize within 10% of initial pre-error value.

Linear Sextupole Multi-Knobs

	SF5	SD4	SF1	SD0
Y Waist	-0.47(x)	1(x)	-0.2(x)	-
Y Disp.	-	-	-0.68(y)	-1(y)
<x’y>	-	-	1(y)	-0.99(y)

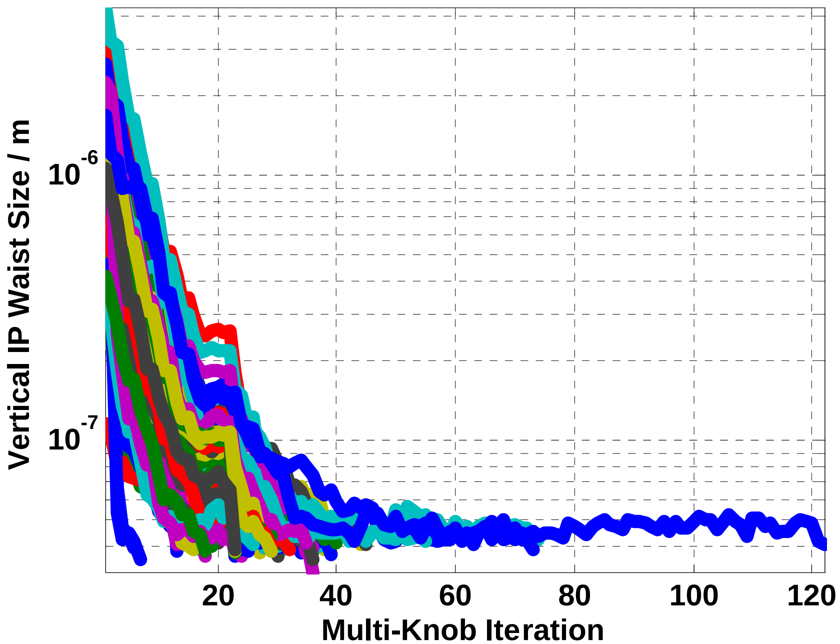
	QK1X	QK2X	QK3X	QK4X
<xy>	-0.92	0.21	0.20	1

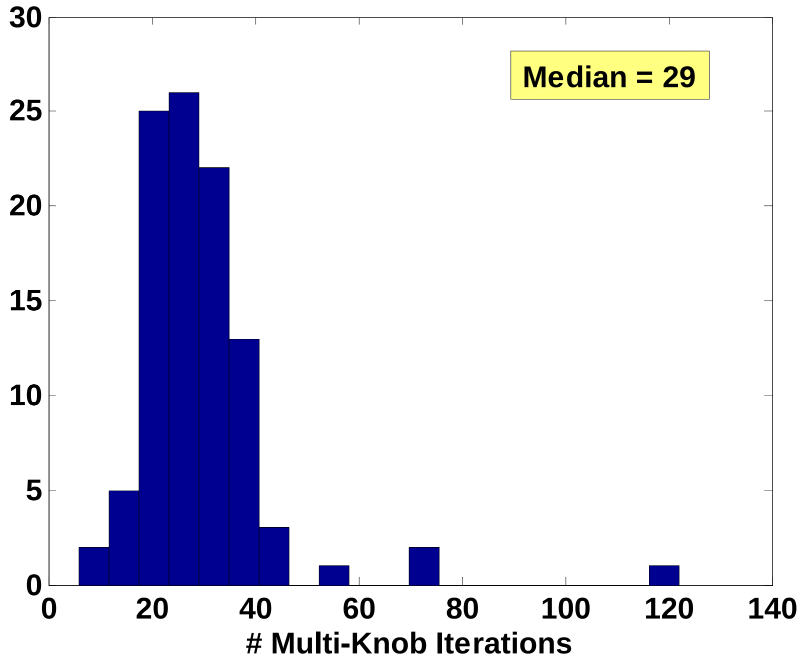
Final Skew Quad Strengths



- Final strengths of 4 skew quads after tuning (T).

Multi-Knob Tuning Results





- Multi-knobs iteratively applied until IP beamsize growth over initial conditions is <10% (~40nm).

Summary

- Median Convergence time ~ 30 iterations:
  - Assuming 1 min per IP spot-size measurement (90 bunches @ 1.5Hz), 10 scan points per knob iteration and 1 cycle through Sext tilt/dB scans:
  - If completely automated, tuning would take ~ 7 Hours.
- Need to add Ground Motion, component jitter, incoming beam orbit + energy jitter, BPM scale and magnet strength drifts…