Sextupole Multiknobs in practice and IP Tuning Plan

- Calculation and application of Sext multiknobs
- Stability of knobs with errors
- Tuning process and analysis of incoming dispersive errors

Glen White, SLAC
8th ATF2 Meeting
June 2009

IP Tuning

- Orbit restore, steering
- BBA
- EXT dispersion + coupling correction
- IP beta match
- IP y beamsize optimisation with QS1X/QS2X sum knob and QK1-4X
  - Hope to get IP beam sigma matrix within capture range of sextupole multiknobs.
- Compute sextupole multiknobs using online FS model.
- Iteratively apply multiknobs for lowest y beamsize.

Sextupole Multiknobs

- Use horizontal and vertical moves of SF6FF, SD4FF, SF1FF, SD0FF to generate orthogonal knobs to control IP aberrations (dispersion, waist, coupling).
- Also use roll of all 5 sextupoles to address non-linear terms (just scan these).
- Track beam through online FS model, scan all knob DOF, invert response matrix with scaling terms to get approx orthonormal knobs.

Linear Knobs for Design Lattice

Vertical IP Waist

	SF6FF	SD4FF	SF1FF	SD0FF
x	0.4593	-1	0.2049	0
y	0	0	0.0056	0.0045

Vertical IP Dispersion

	SF6FF	SD4FF	SF1FF	SD0FF
x	0.0055	-0.011	0.0021	0
y	0	-0.8433	0	1

IP <x'y>

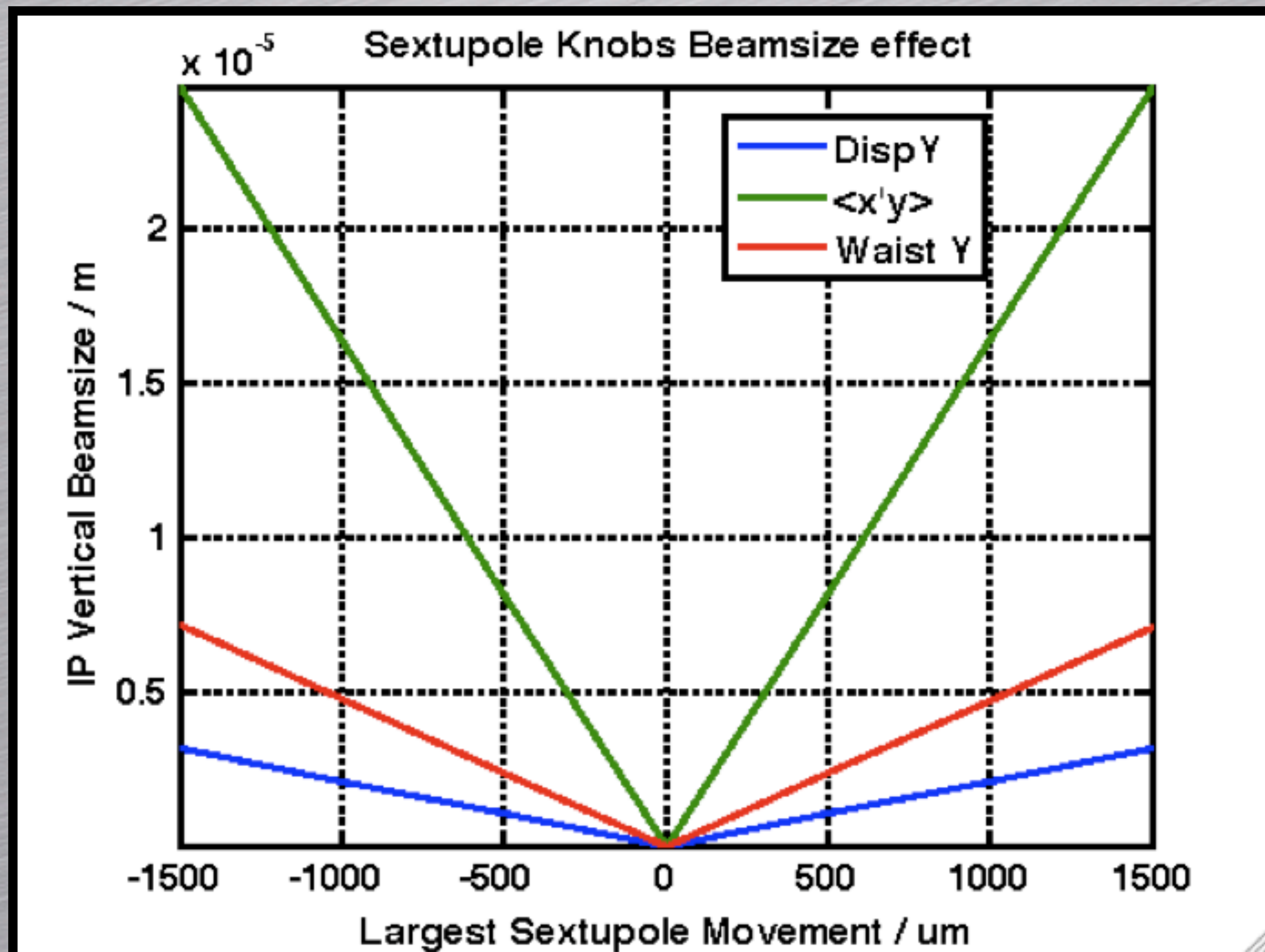
	SF6FF	SD4FF	SF1FF	SD0FF
x	0.0276	-0.0513	0.0109	0
y	0	1	0	0.8054

EXT Skew Quadrupole Knobs

These are the skew quadrupole knobs for correcting IP coupling terms (normalized):

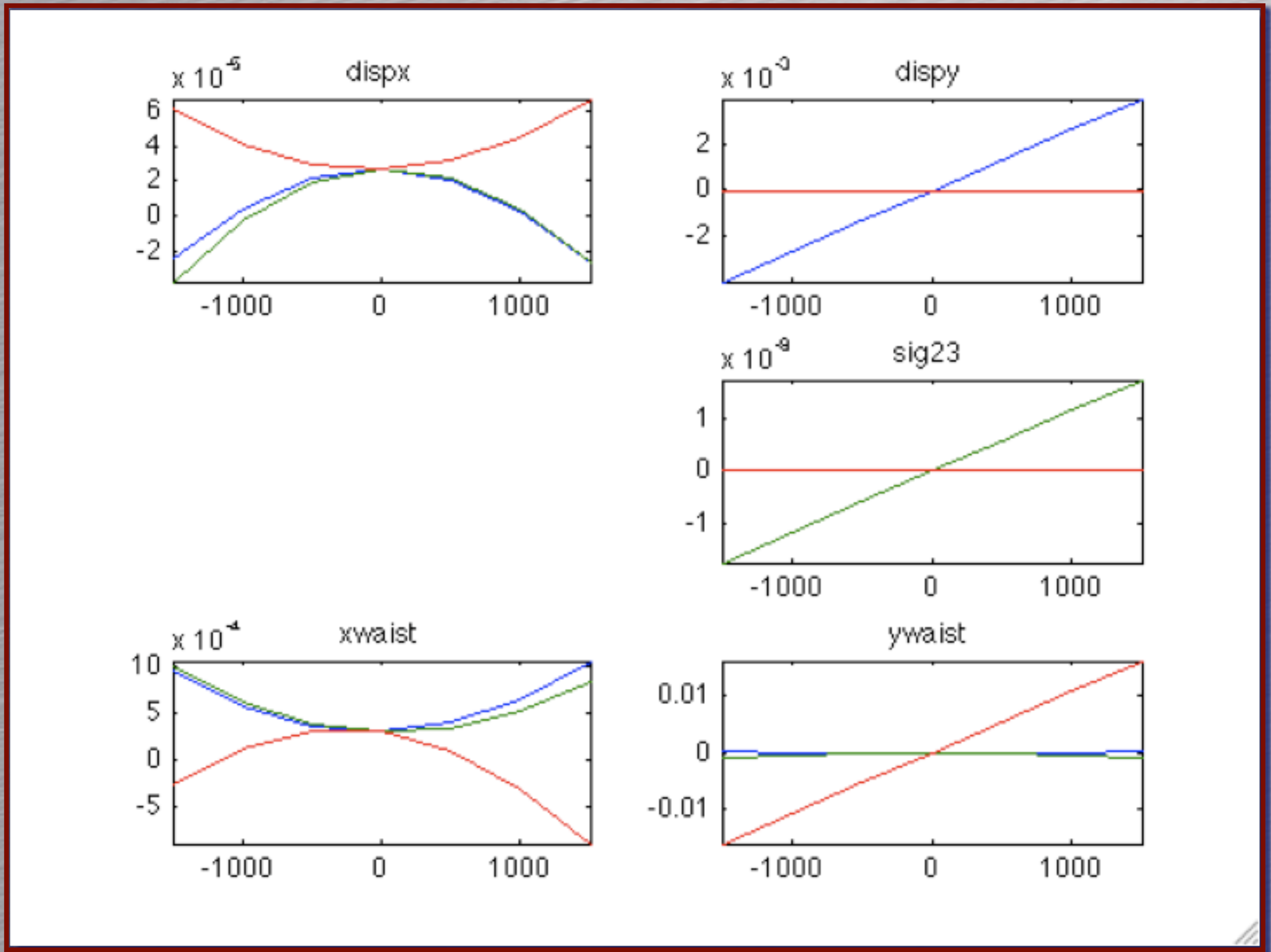
Knob	QK1X	QK2X	QK3X	QK4X
<xy>	-0.2032	-1	-0.9574	0.1927
<xy'>	0.1348	-1	0.6867	0.2015
<x'y>	0.9585	-0.3029	-0.3088	-1
<x'y'>	-0.2318	-0.3058	0.0735	-1

Effect of Knobs on Beamsize



- Effect of linear sextupole knobs on vertical beam spot size at the nominal IP.

Knob Orthogonality and Ranges



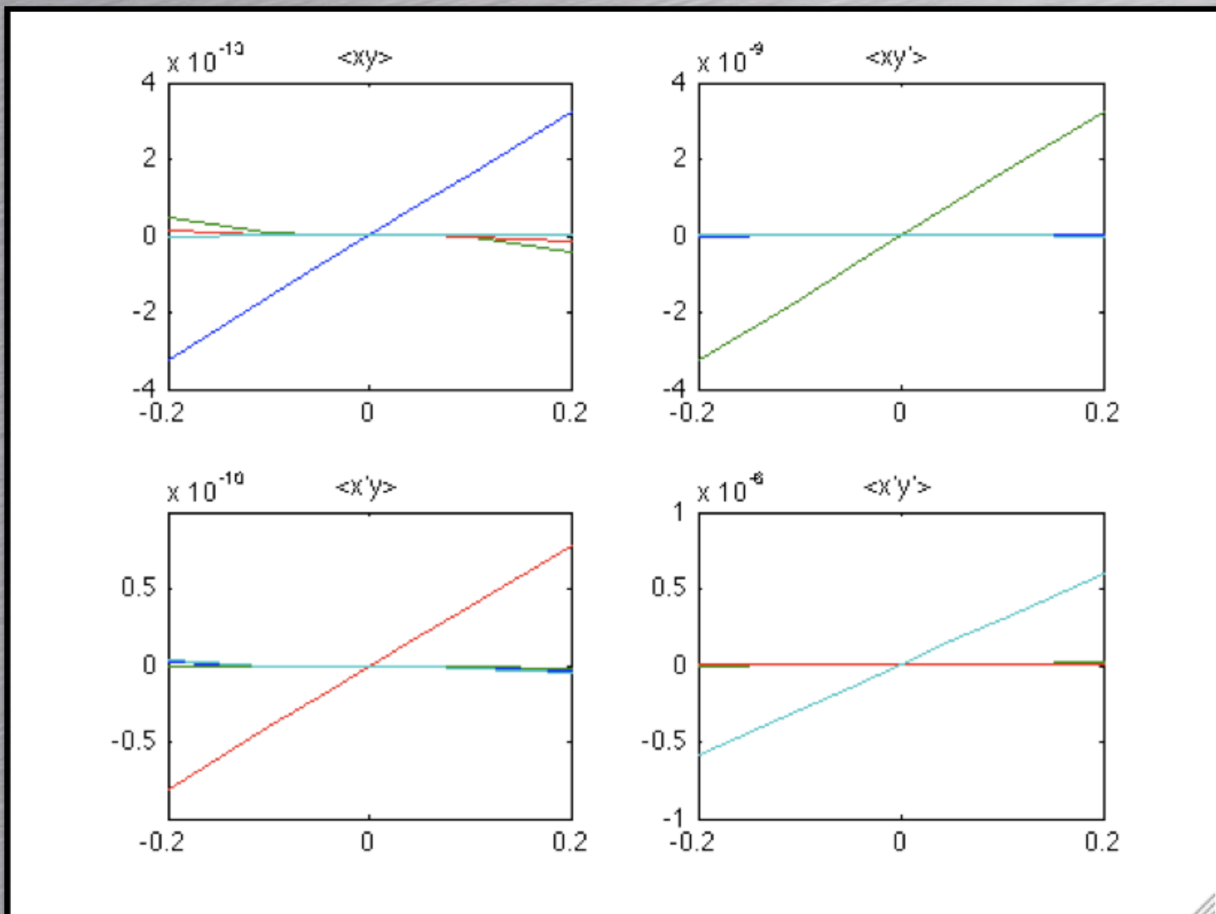
- Nominal optics
- Scan each knob over max range.
- Good orthogonality with perfect conditions

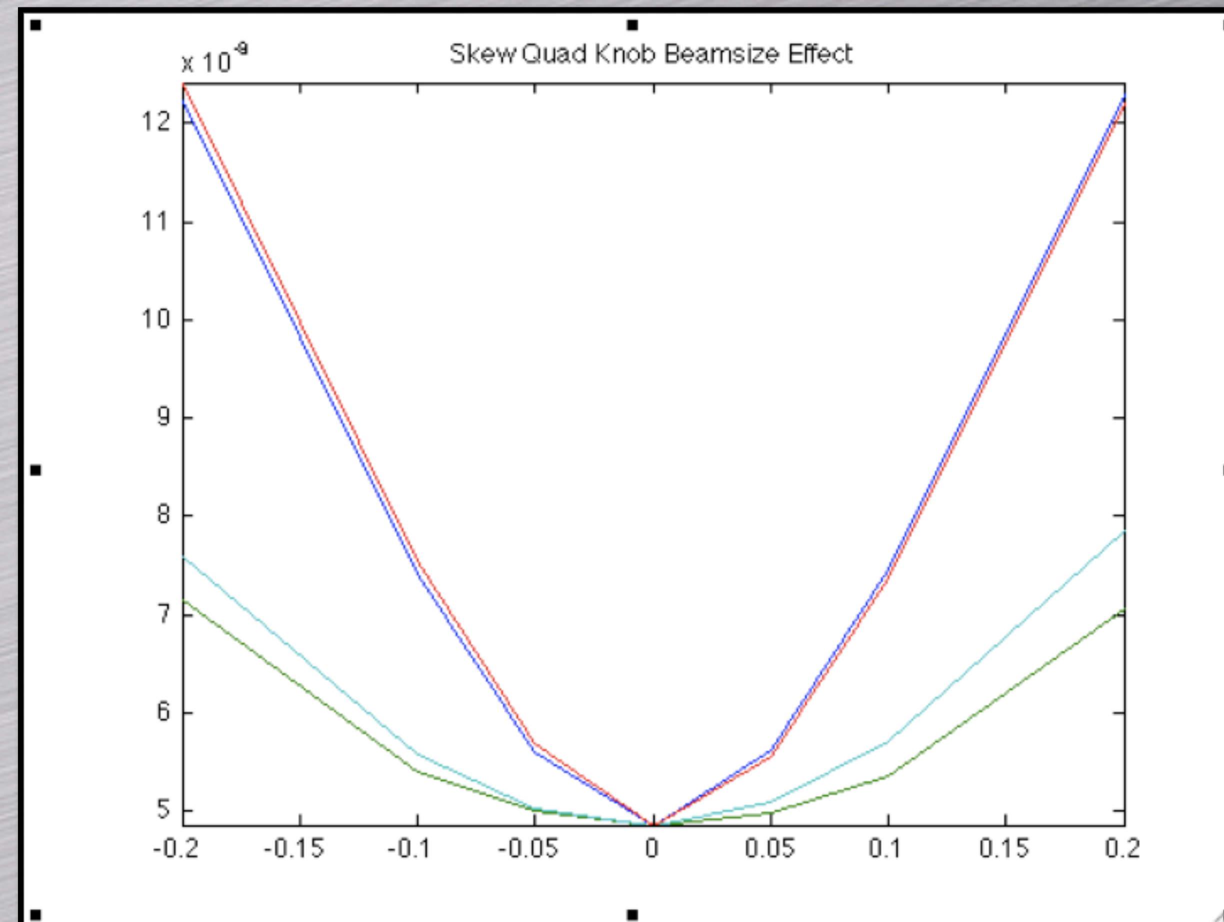
Max range of Knobs:
- DispY = 4mm
- <x'y> = 2e-9
- Y Waist = 2cm

Non-orthogonality (max % effect by other knob)

Disp Y	<x'y>	Waist Y
0.06 %	0.004%	5.9%

Coupling Knob Orthogonality





<xy>	<xy'>	<x'y>	<x'y'>
14.3%	0.6%	5.6%	3.1%

- Response of scanning 4 coupling knobs, IP coupling terms and effect on beamsize.
- Shown level of non-orthogonality across max correction range

Horizontal Sext Misalignment

RMS x Misalignment / um	Disp Y (%)	<x'y> (%)	Waist Y (%)
10	0.07 +/- 0.01	0.02 +/- 0.006	6.0 +/- 0.006
50	0.08 +/- 0.03	0.04 +/- 0.03	6.0 +/- 0.02
100	0.1 +/- 0.05	0.07 +/- 0.05	6.0 +/- 0.04
200	0.17 +/- 0.1	0.13 +/- 0.09	6.0 +/- 0.07
500	0.4 +/- 0.3	0.3 +/- 0.3	6.0 +/- 0.2

- Misalign all sextupoles in x by RMS values shown.
- Results show extent of non-orthogonality (mean and RMS spread from 50 seeds).
- Up to (and maybe beyond) 500um misalignment acceptable.

Vertical Misalignment

RMS y Misalignment / um	Disp Y (%)	<x'y> (%)	Waist Y (%)
10	0.13 +/- 0.00	0.02 +/- 0.01	6.1 +/- 0.2
50	0.13 +/- 0.01	0.09 +/- 0.05	6.7 +/- 0.6
100	0.14 +/- 0.02	0.16 +/- 0.09	7.4 +/- 0.9
200	0.16 +/- 0.06	0.26 +/- 0.20	8.8 +/- 2.2
500	0.37 +/- 0.25	0.64 +/- 0.59	13.3 +/- 6.6

- Aim to keep non-orthogonality <10%
- 200um probably max acceptable misalignment.

Roll Misalignment

RMS Roll Misalignment / mrad	Disp Y (%)	<x'y> (%)	Waist Y (%)
0.1	0.13 +/- 0.00	0.02 +/- 0.01	6.0 +/- 0.0
0.2	0.13 +/- 0.01	0.04 +/- 0.02	6.0 +/- 0.1
0.5	0.14 +/- 0.01	0.08 +/- 0.06	6.0 +/- 0.1
1	0.15 +/- 0.04	0.15 +/- 0.11	6.1 +/- 0.2
5	0.55 +/- 0.49	0.74 +/- 0.62	7.1 +/- 1.0

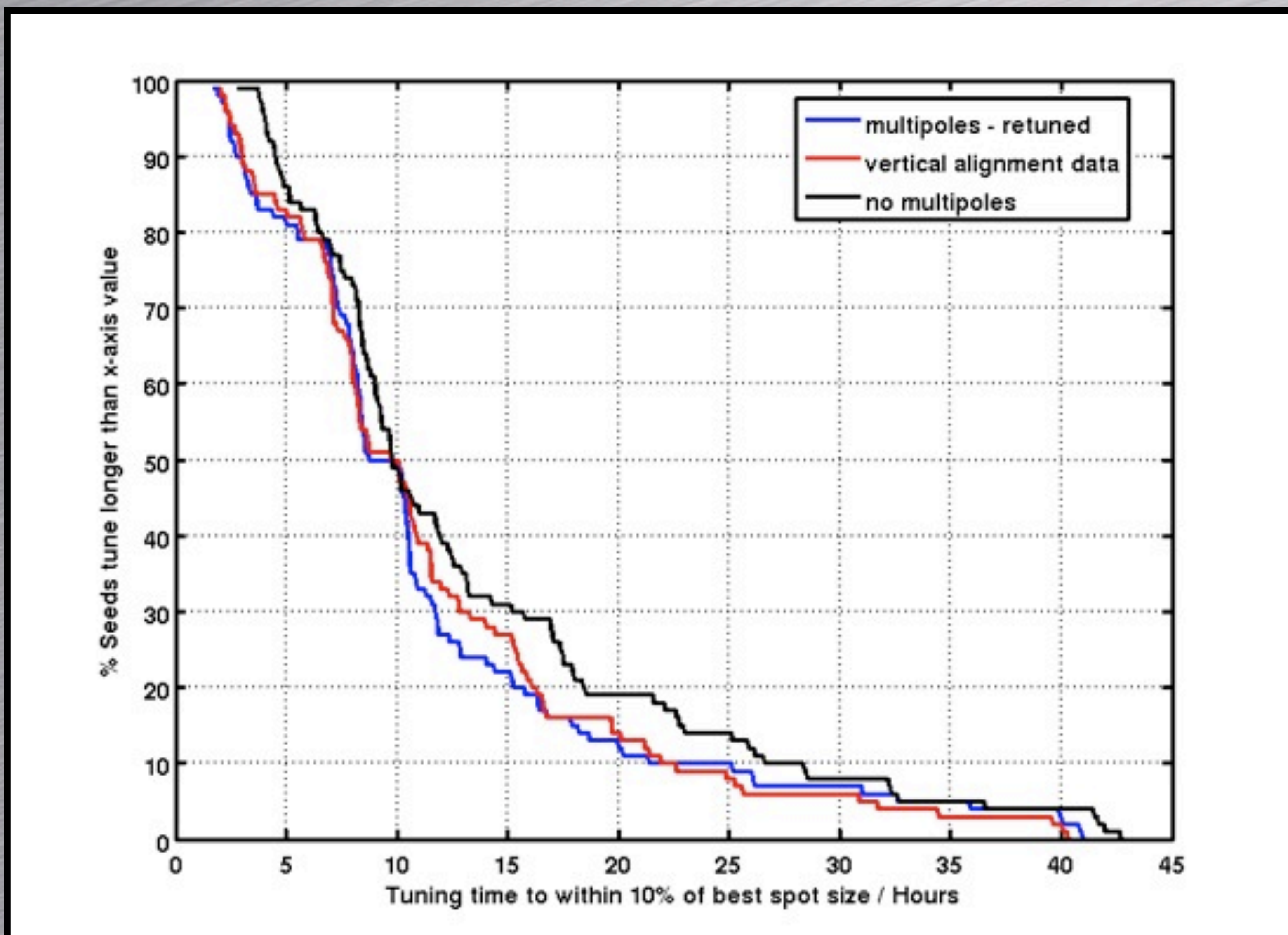
- Up to 5mrad acceptable from linear knob orthogonality standpoint.
- More like 0.1mrad for reduction of higher-order aberrations.

Magnet Field Error

% Magnetic field strength error	Disp Y (%)	<x'y> (%)	Waist Y (%)
0.01	0.1 +/- 0.0	0.02 +/- 0.01	6.1 +/- 0.03
0.1	0.3 +/- 0.1	0.1 +/- 0.1	6.3 +/- 0.7
0.5	1.0 +/- 0.7	0.7 +/- 0.5	8.9 +/- 5.4
1	1.9 +/- 1.3	1.5 +/- 1.0	8.9 +/- 6.0
5	10.1 +/- 6.4	8.3 +/- 26.1	7.4 +/- 85.7

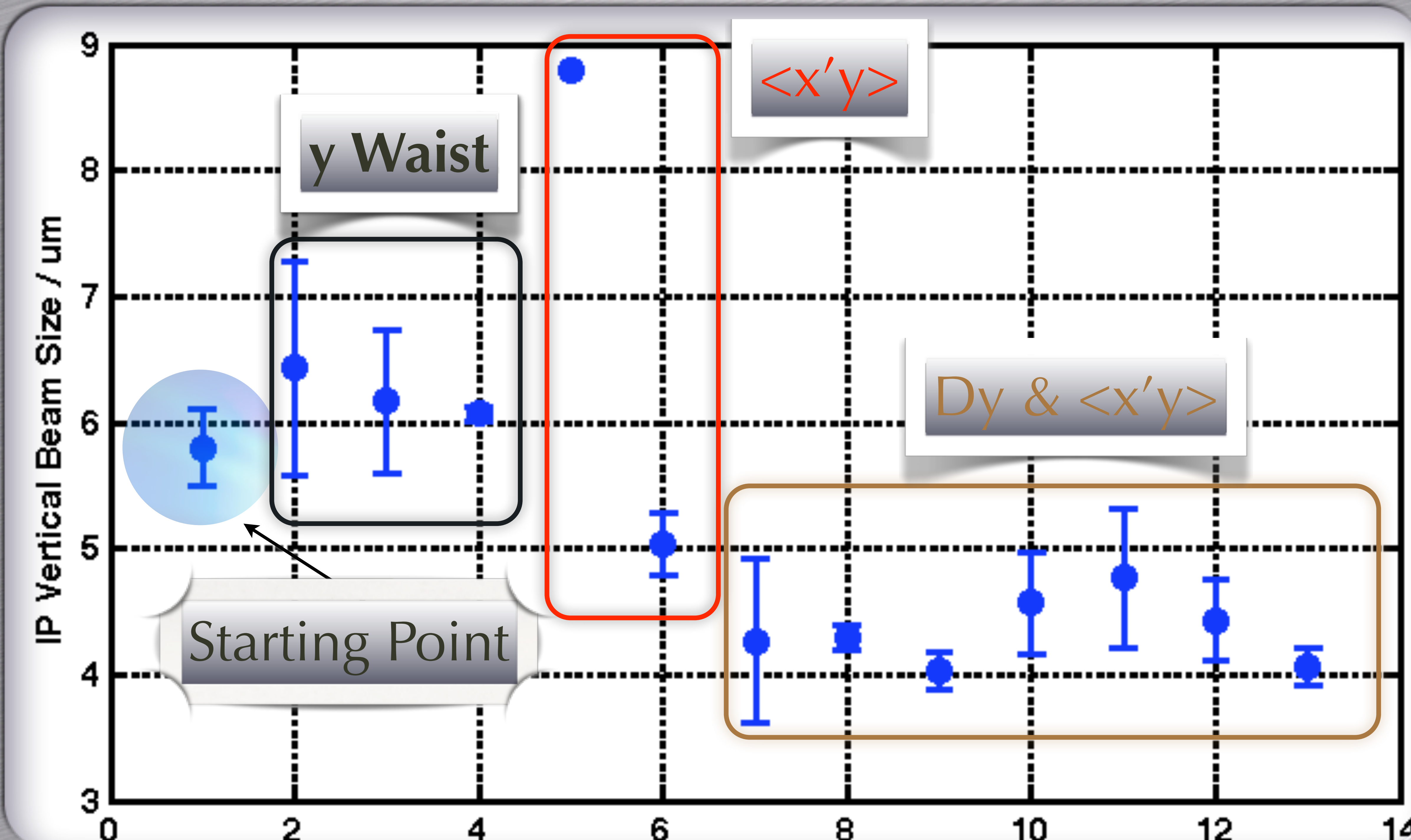
- 1% field error maybe ok for orthogonality.
- 0.1% better, especially for non-linear knobs

Expected Tuning Time from Simulation for 35nm Optics

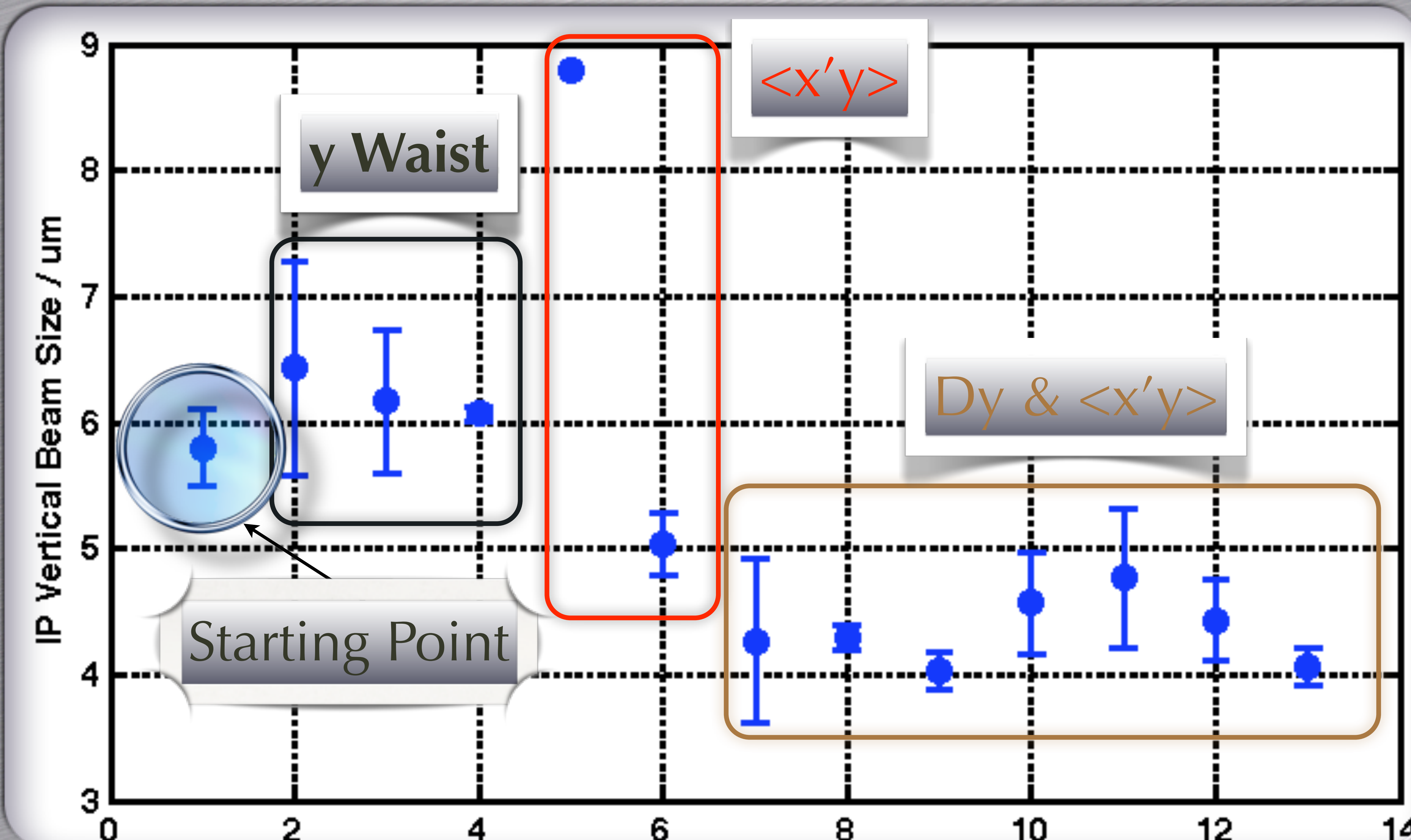


- 90% seed tune <1 day
- Continuous, no trips, perfect orthogonality of movers.

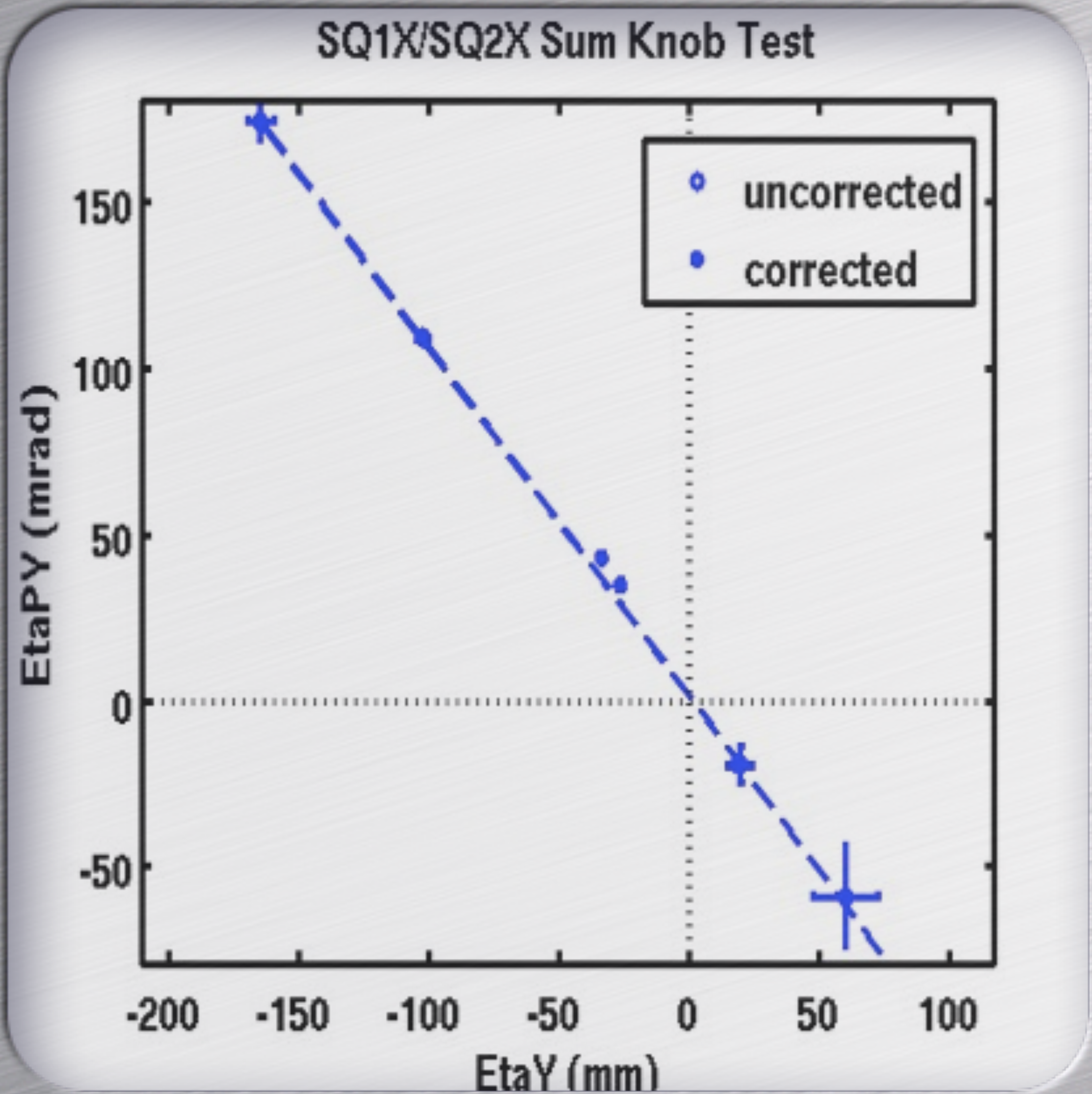
Application of Multiknobs on 1cm β_y Optics in May Run



Application of Multiknobs on 1cm β_y Optics in May Run

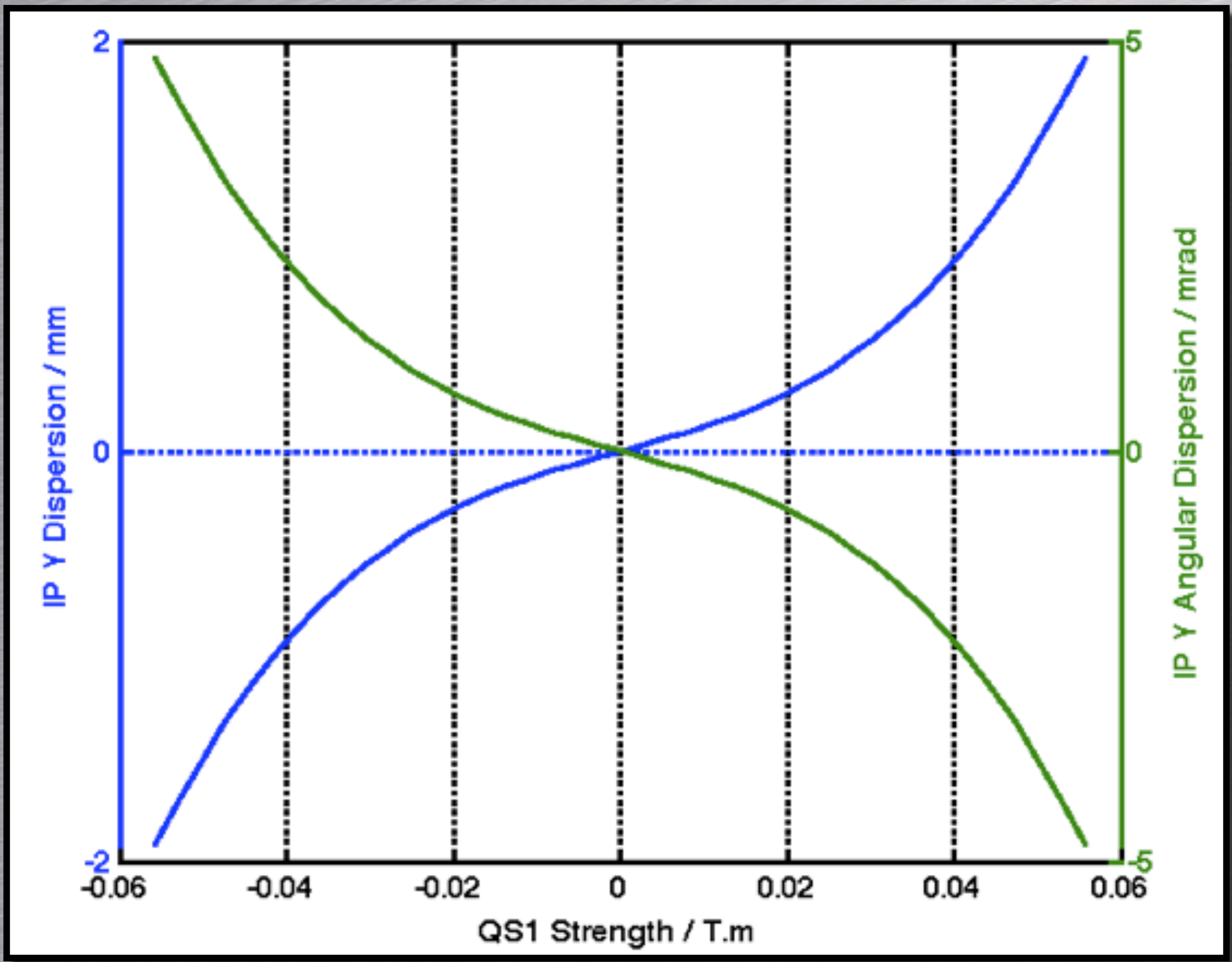


Dispersion Correction



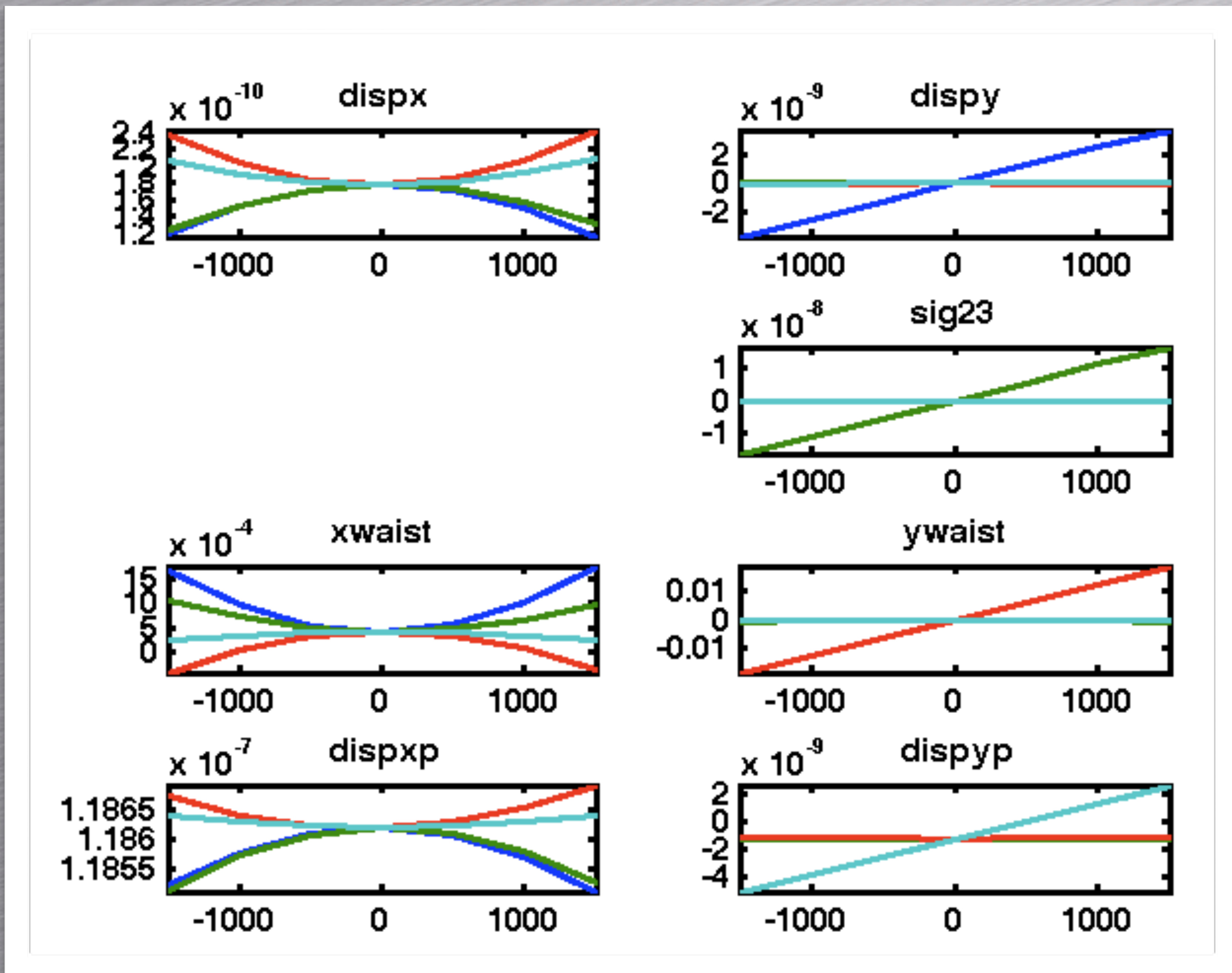
- EXT QS1X+QS2X sum knob designed to simultaneously correct etay + etay′
- Fine as long as dispersion errors originate in EXT
- Has been the case, this from April run.

IP Response to Sum Knob



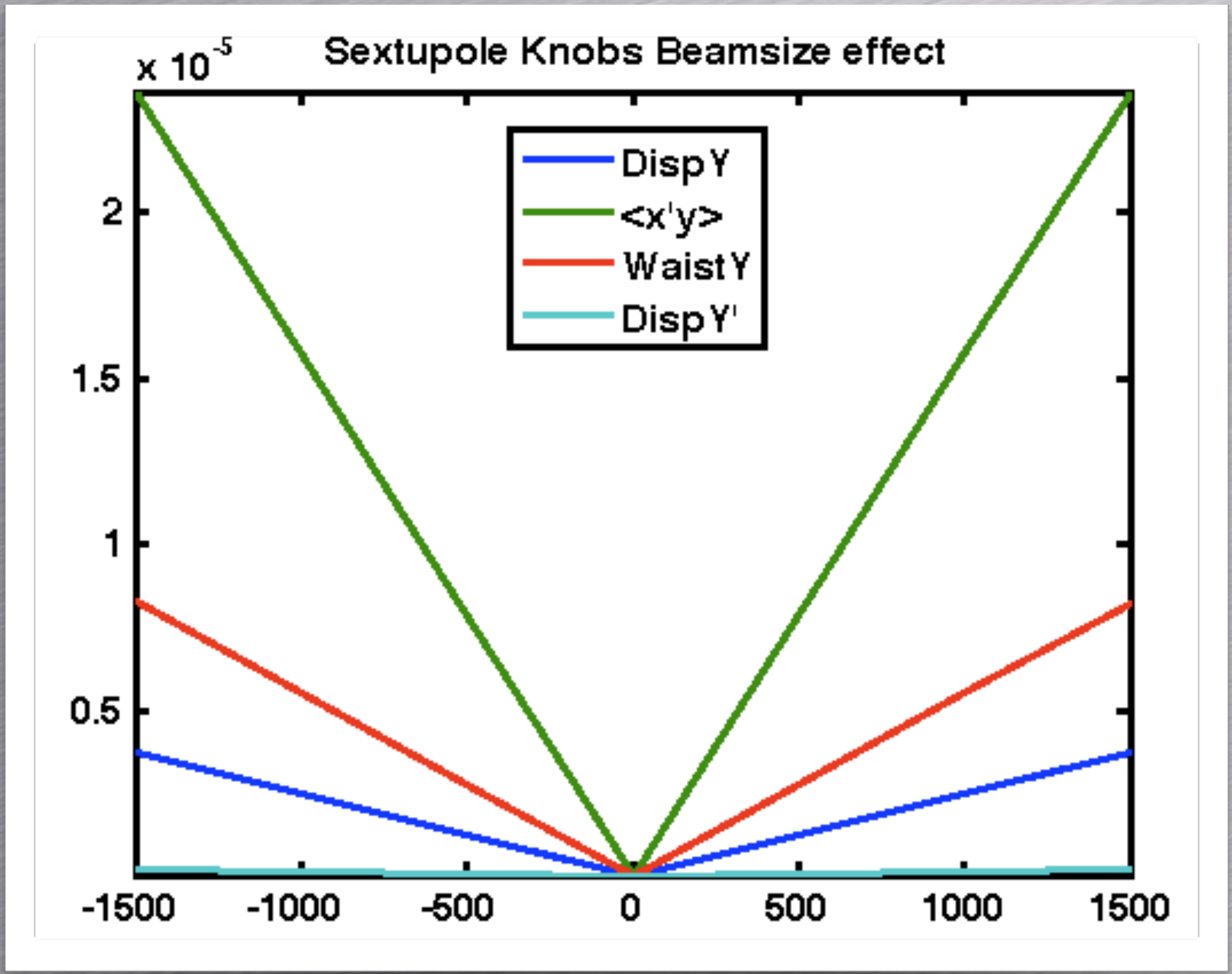
- Response of sum knob at IP with no incoming dispersion to EXT.
- Shown is +/- max strength of QS1X/ QS2X

Knob Response



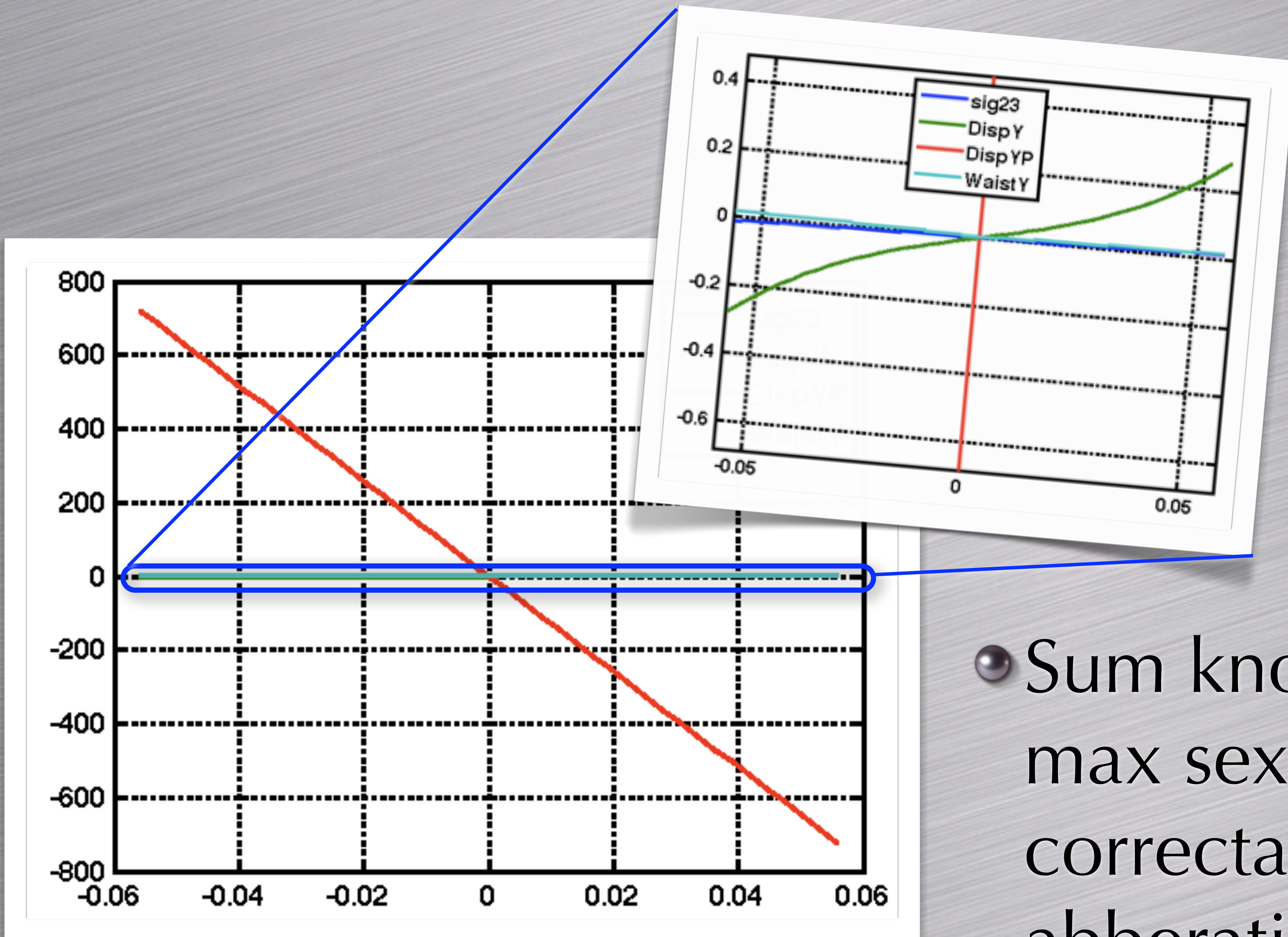
- Add knob for D′
- Important to generate knobs including fitted incoming Dispersion and QS settings otherwise orthogonality lost

Beamsize Effect of Knobs



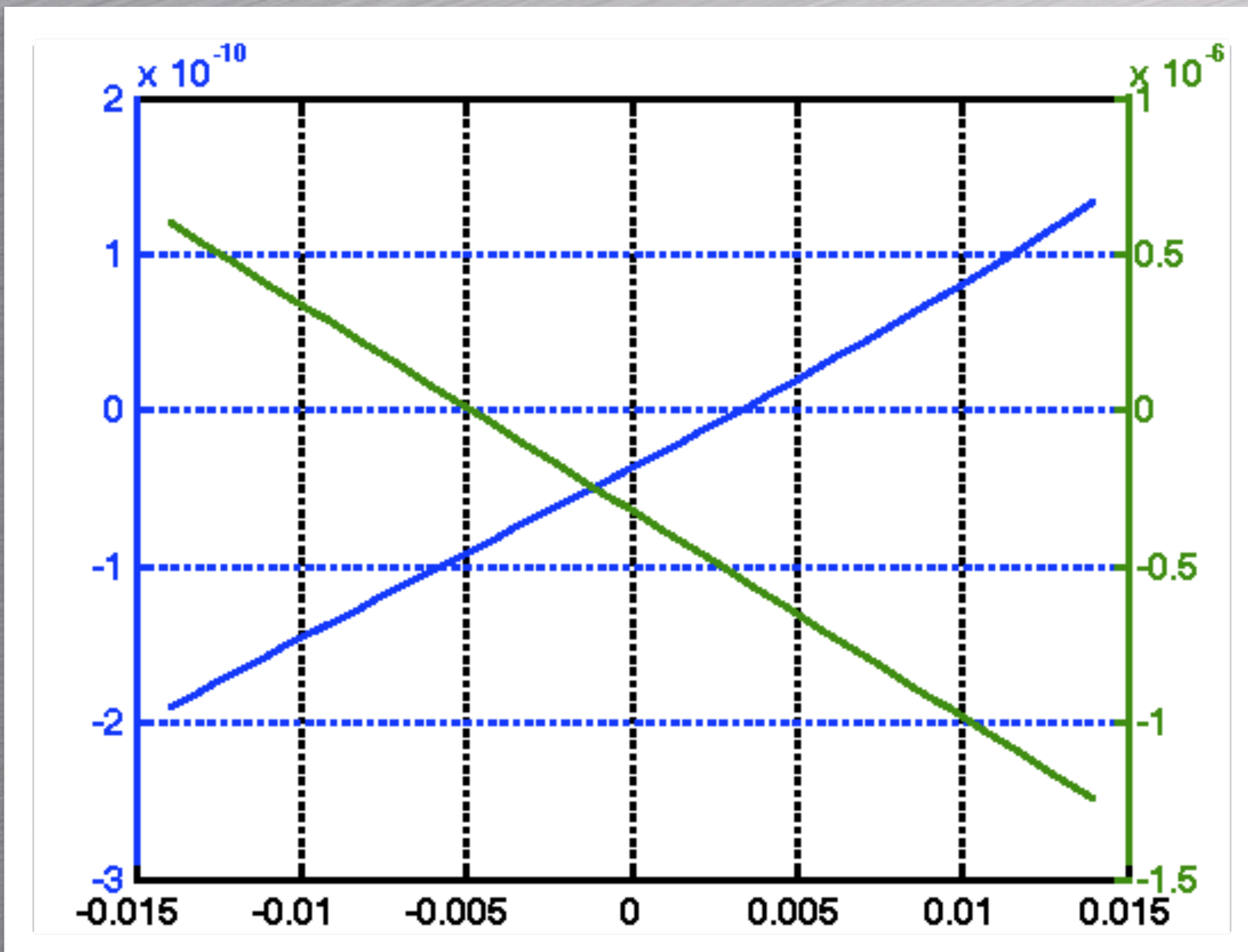
- D′ knob has minimal effect on IP beamsize

Sum Knob vs. IP Aberrations



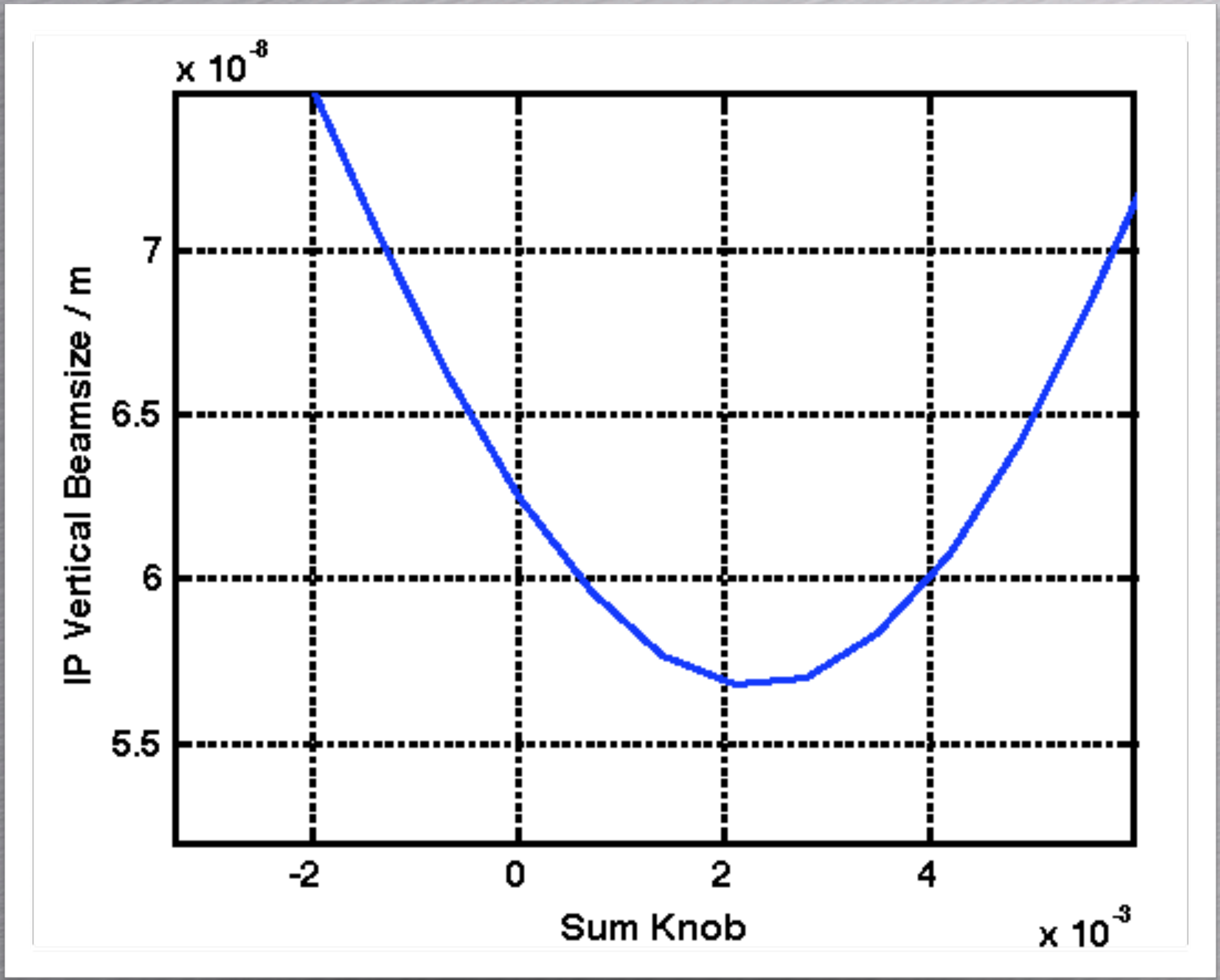
- Sum knob vs % max sext correctable IP abberations

ETA_Y @ IEX = 5mm



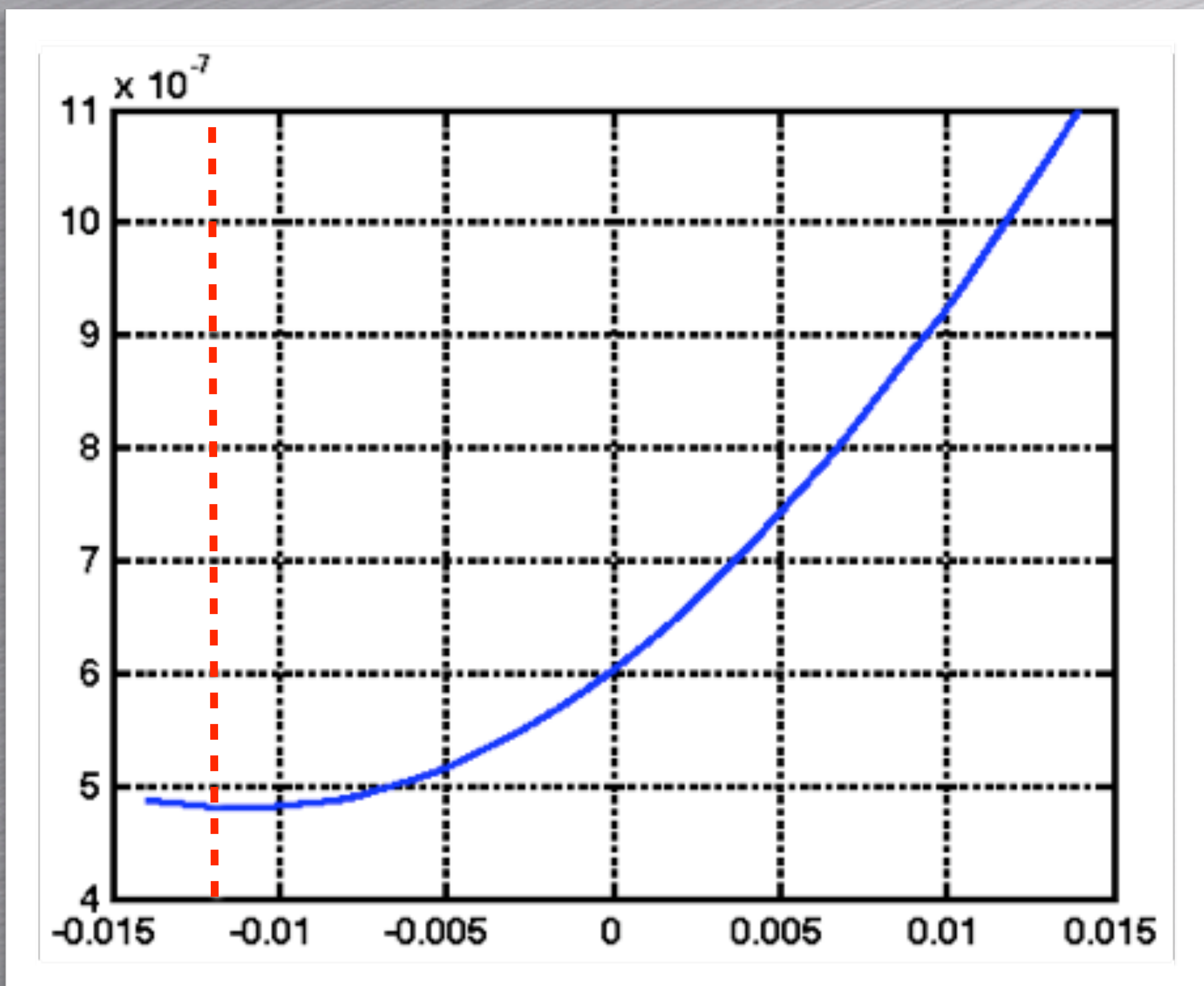
- SIGMA_36 (blue)
- SIGMA_46 (green)
- Correction no longer at 0/0

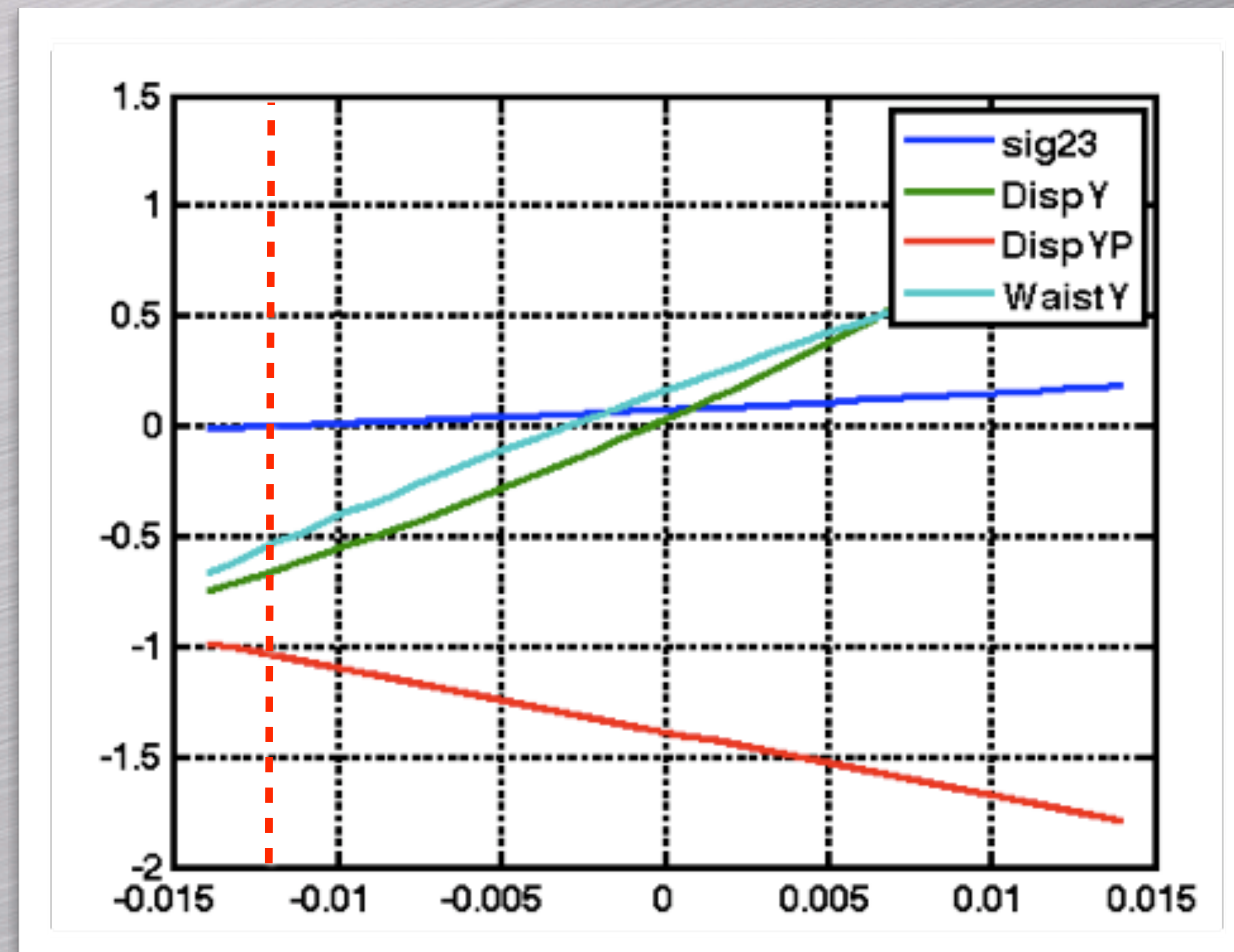
Sum Knob vs. IP sig_y



- Sum Knob does not restore nominal beam size

Capture Range @ IP After Sum Knob - IEX Dy = 50mm





Summary

- For the design optics in simulation
  - With reasonable misalignment and error conditions, SEXT linear knobs are orthogonal.
  - Tuning time is of order of 1 day
  - Range of knobs is enough to handle cases modelled - error conditions quoted in past from inside EXT & FFS + expected levels of twiss mismatch from DR.
- Incoming dispersion from DR could be a problem
  - Need to include in detailed simulations for 35nm optics to asses performance.
  - Also asses use of QS1X + QS2X as independent knobs, if we can deal with the coupling and how the simulation results compare with the sum knob method.