ATF2 Dynamic Tuning Simulations

Glen White / SLAC

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- Simulation overview.
- Integration of EXT and FF tuning into single model with V.3.7 optics.
- Static and dynamic performance for standard error/misalignment set.

Overview

- Make a detailed dynamic simulation of ATF2 alignment and tuning steps to assess feasibility of getting and maintaining ~35nm spot size when considering all error sources.
- Updates since last report:
  - Move to V.3.7 optics.
  - Integrated MW EXT dispersion & coupling correction tuning with FFS simulation into unified model.
- Study of bunch model.
- Tuning performance studies
- Improvements to simulation reality. (S. Molloy).
- All simulations in Matlab with Lucretia.

Static Error Parameters

- Errors are normally distributed with mean=ref. orbit and quoted standard deviations.
- EXT BPM alignment not directly modeled yet, assume 10um quad-bpm alignment here.
- Model for SM measurement: mean spot size from 90 consecutive pulses +/- 2nm RMS error.
- Poisson-calculated multipole errors now added to FFS dipoles.

x/y/z alignment errors	**200 um**
Quad, Sext / Bend roll alignment	**300 / 1000 urad**
Initial BPM-magnet field center alignment	**30 um**
dB/B for Quad, Sexts	**1e-4 syst. + 1e-4 random**
Mover step size (x & y)	**50 nm**
BPM resolutions	**100**
Power supply resolution (FFS/EXT magnets)	**16/11 - bit**
Shintake Monitor Resolution	**2nm**

Dynamic Errors

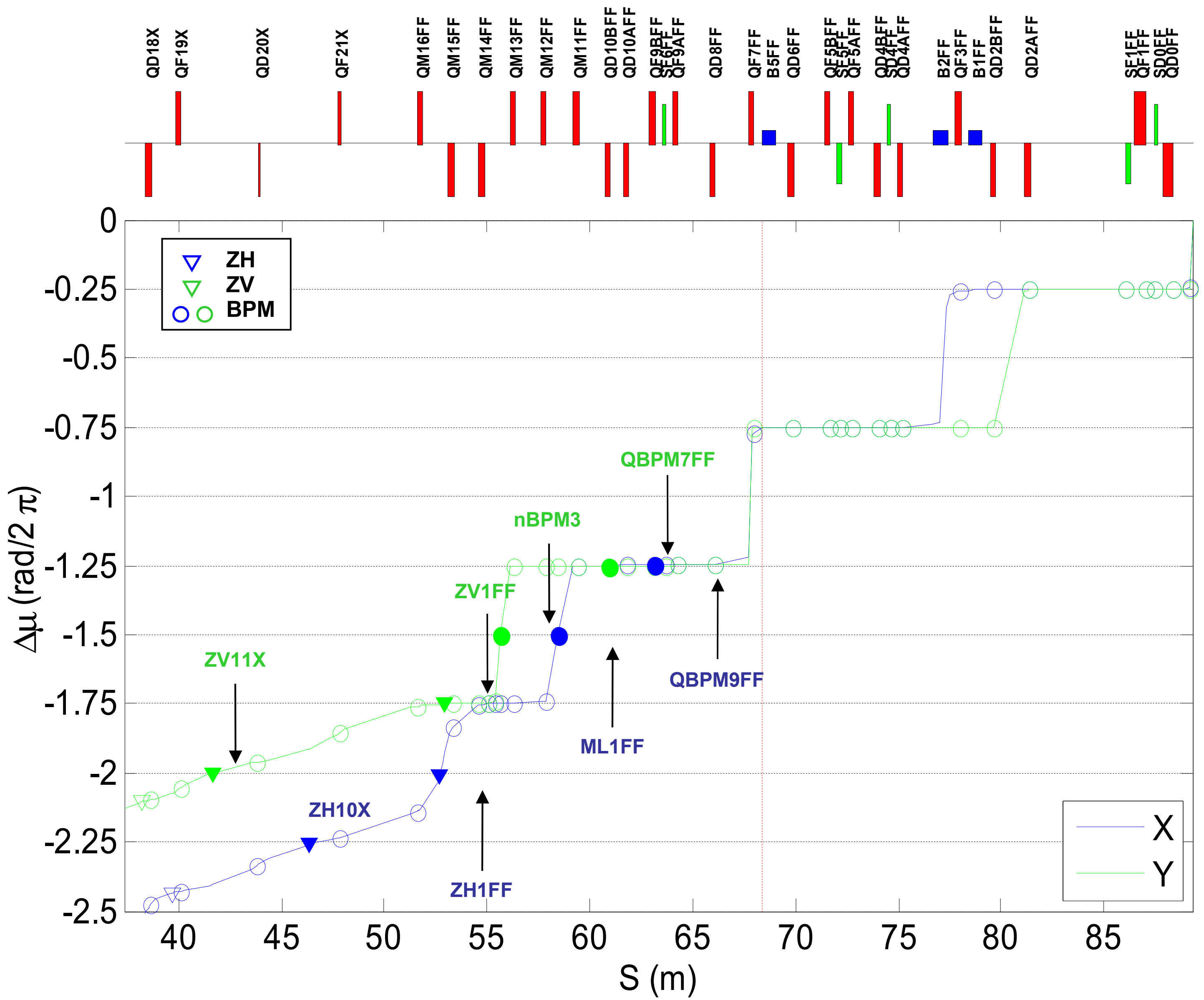
- RMS pulse-pulse errors:
  - Component jitter: 25 nm.
  - Energy error: 1E-4.
  - Ring extraction jitter: 0.1 sigma (x,x',y,y').
- Pulse-pulse feedback using FFS FB only.
- Ground motion: use modified model K from ATF measurements:

Ground motion ATF. Tentative version				K model
'Parameter A of the ATL law,	A [m**2/m/s]	'	1.00000E-17	
'Parameter B of the PWK,	B [m**2/s**3]	'	5.00000E-18	
'Frequency of 1-st peak in PWK,	f1 [Hz]	'	1.60000E-01	
'Amplitude of 1-st peak in PWK,	a1 [m**2/Hz]	'	4.00000E-13	1.00000E-11
'Width of 1-st peak in PWK,	d1 [1]	'	5.00000E+00	
'Velocity of 1-st peak in PWK,	v1 [m/s]	'	1.0000E+03	-1.0000E+03
'Frequency of 2-nd peak in PWK,	f2 [Hz]	'	2.50000E+00	
'Amplitude of 2-nd peak in PWK,	a2 [m**2/Hz]	'	3.00000E-15	1.00000E-15
'Width of 2-nd peak in PWK,	d2 [1]	'	3.00000E+00	
'Velocity of 2-nd peak in PWK,	v2 [m/s]	'	3.00000E+02	-4.0000E+02
'Frequency of 3-rd peak in PWK,	f3 [Hz]	'	9.00000E+00	
'Amplitude of 3-rd peak in PWK,	a3 [m**2/Hz]	'	3.00000E-17	1.00000E-17
'Width of 3-rd peak in PWK,	d3 [1]	'	2.80000E+00	
'Velocity of 3-rd peak in PWK,	v3 [m/s]	'	2.50000E+02	-4.0000E+02

Pulse-Pulse Feedback

- Use pulse-pulse feedback to get initial beam orbit through EXT and FFS and maintain orbit when GM drifts added.
- Use FFS FB mainly with EXT FB set to very low gain (orbit stability most important in FFS Sexts).
- EXT feedback "least-squares matrix-inversion" steering using all correction magnets (ZV*X & ZH*X) and quad BPMs.
- FFS feedback 2 kicker-BPM pairs for x & y feedback at 90-degree phase separations.

ATF2 pulse-to-pulse feedback devices (v3.7)



IP

IP phase

FD phase

IP phase

FD phase

IP phase

FD phase

IP phase

FD phase

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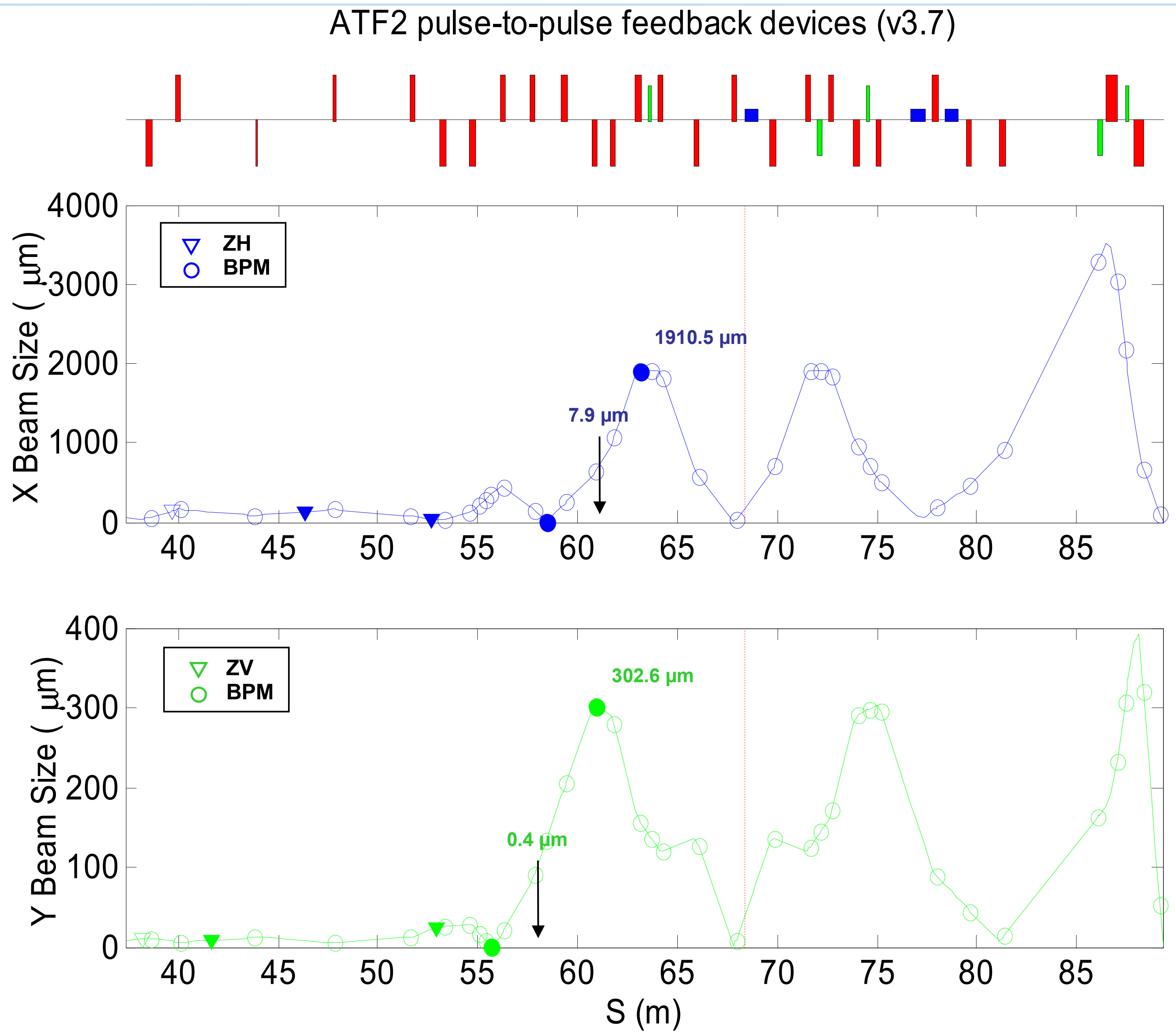
FD phase


ATF2 pulse-to-pulse feedback devices (v3.7)
ZH
BPM
X Beam Size (μm)
1910.5 μm
7.9 μm
ZV
BPM
Y Beam Size (μm)
302.6 μm
0.4 μm
S (m)

IP Beamsize Measurement

- Shintake monitor measurement range 35nm – 350nm.
- Wirescanner for >1 micron waist sizes.
- Between 350nm and ~1um, 'Honda Monitor'.
- So, beamsize measurement all the way from initial few microns to target 35nm to tune on.
- Complete new optics sets required to move between different IP locations? Here just use SM IP.
- After an initial look- maybe possible to shift between SM and DOWNSTREAM waist using final doublet + matching quads. Upstream waist more difficult?

Tuning Procedure Overview

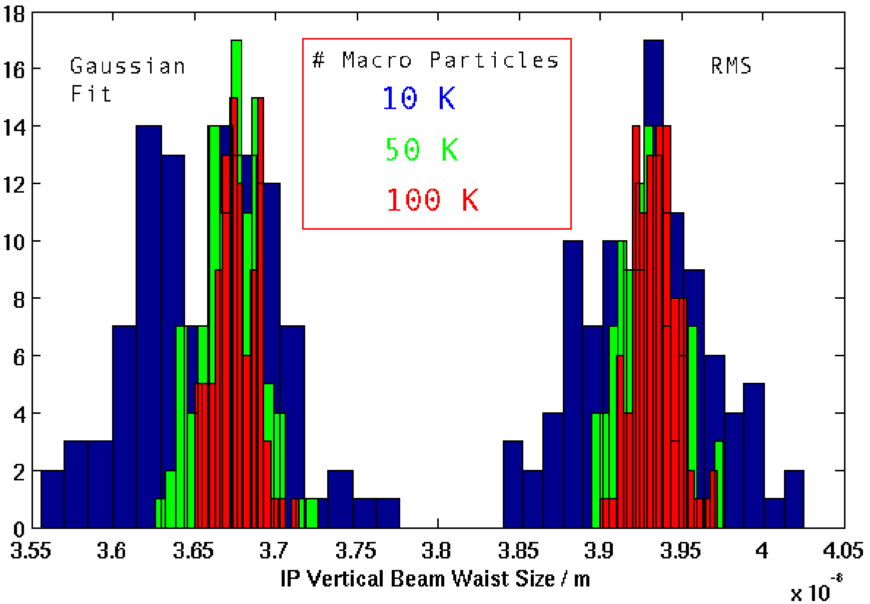
- Use EXT correctors + BPMs (EXT FB) to get orbit through EXT.
- Use FFS FB to get beam through FFS.
- First-order correction of systematic magnet strength error by scanning PS's for all magnets and minimising IP spot-size.
- Correct Dy/Dy' in EXT using skew-quad knobs.
- Correct coupling in EXT using coupling correction system.
- Use FFS FB for launch into FFS.
- FFS Quad BPM alignment using quad shunting with movers.
- FFS Quad mover-based BBA.
- FFS Sext BPM alignment using Sext movers and downstream BPMs.
- Waist optimisation with matching quad waist knob.
- Sextupole mover tuning knobs to get final spot size
  - Vertical IP dispersion and Waist
  - <x'y> coupling
  - Higher order terms collectively through Sext rolls + dK.
- Also use EXT skew-quads to tune other coupling terms.

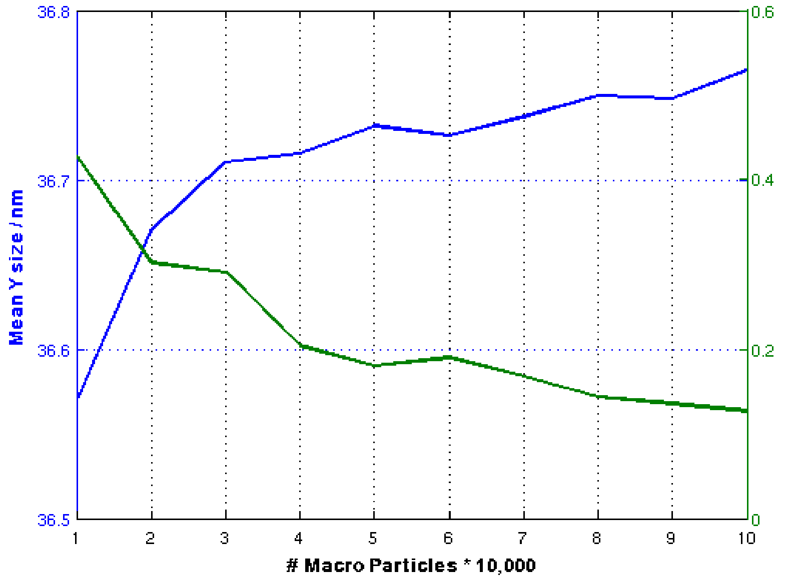
Simulation Notes

- Ideal simulation includes tracking every bunch, including inter-pulse jitter effects on IP size measurement (90 pulses per measurement).
- This takes a LONG time with macro-particle bunches.
- Simulation includes GM effects (ie. 90 / 1.5Hz GM added for every IP size measurement).
- Effect of fast jitter during 90 pulse IP size measurement is modeled as effective degradation of IP measurement resolution.
- For dynamic errors studied here, pulse-pulse jitter effects add 1.3nm (in quadrature) to 2nm SM measurement (giving res. ~2.4nm).

Beam Model

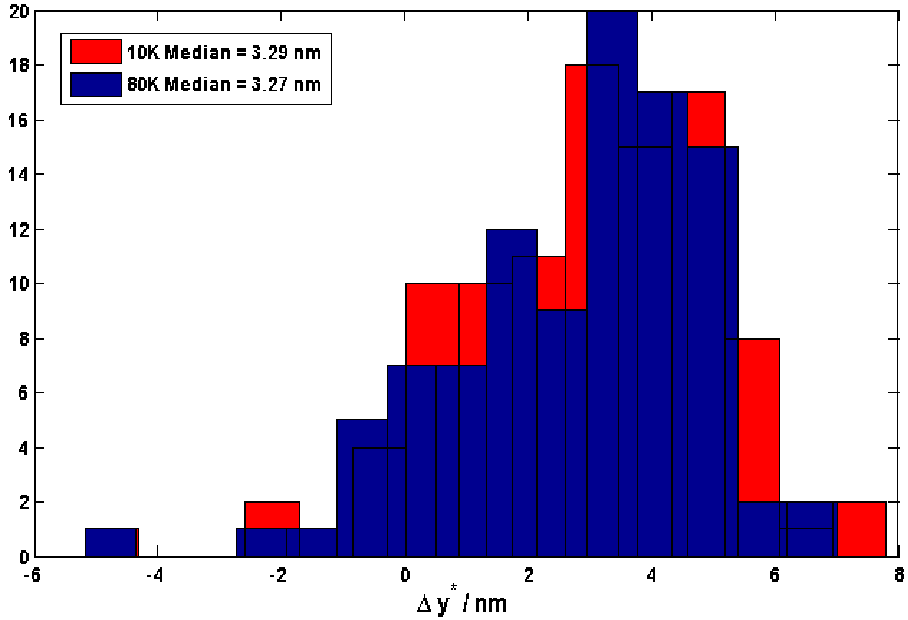
- Lucretia beam models:
  - 'Sparse' := 2nd order moment tracking in transverse
  - 'Macro-particle':= better for handling higher-order effects- non-Gaussian beam. Slower.





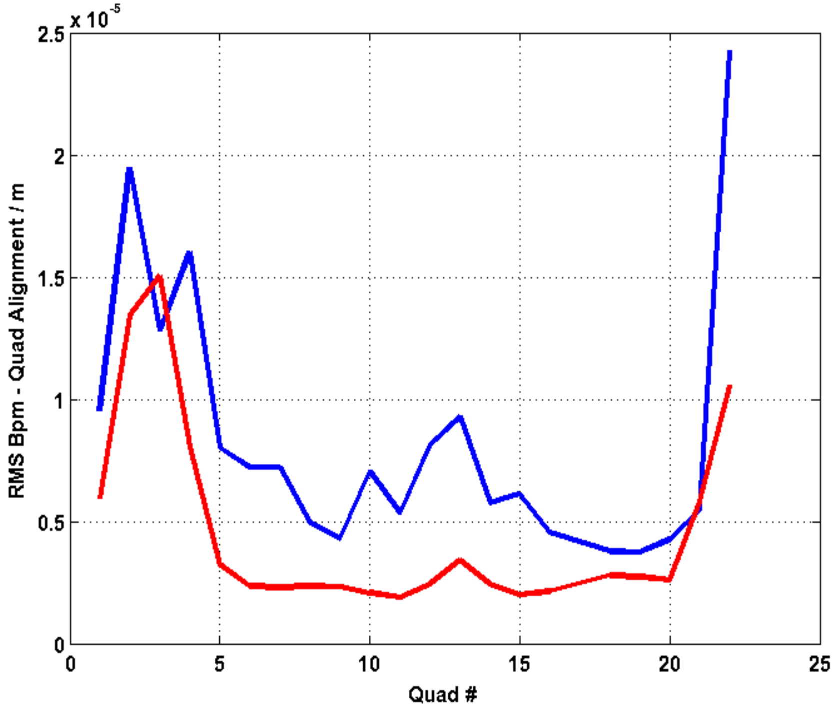
- Tracking through perfect lattice (100 generated bunches)
  - Sparse beam gives 35.0 nm
  - IP beam non-Gaussian, higher-order effects important as well as measurement of beam size.

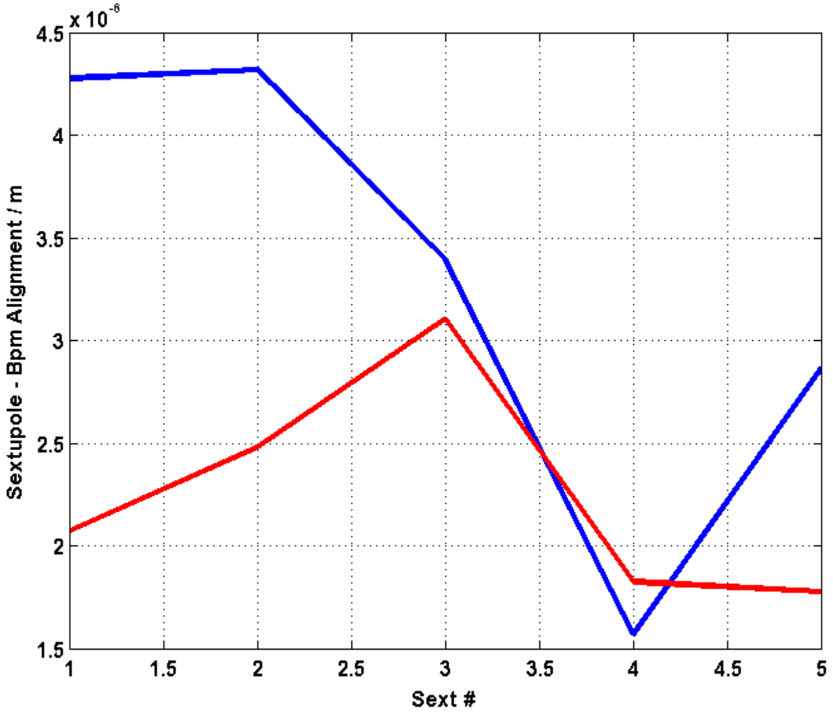
EXT Tuning Results



- With an error-free FFS, tune EXT with 10K and 80K macro-particle beams (100 seeds).
- Median results the same.
- Probably ok to do full tuning with 10K bunch with same perfect-lattice performance as the mean 100K-case.
- Use 10K bunch for simulation results shown in this talk.

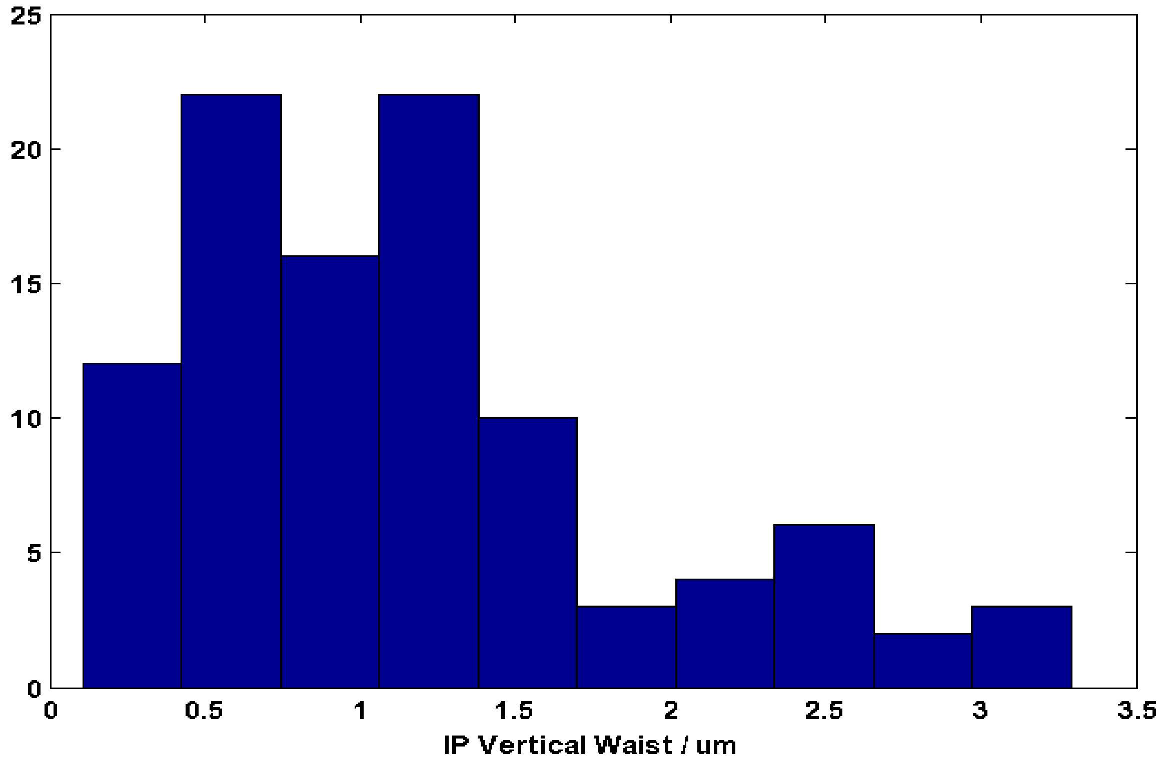
Quad & Sext BPM Alignment





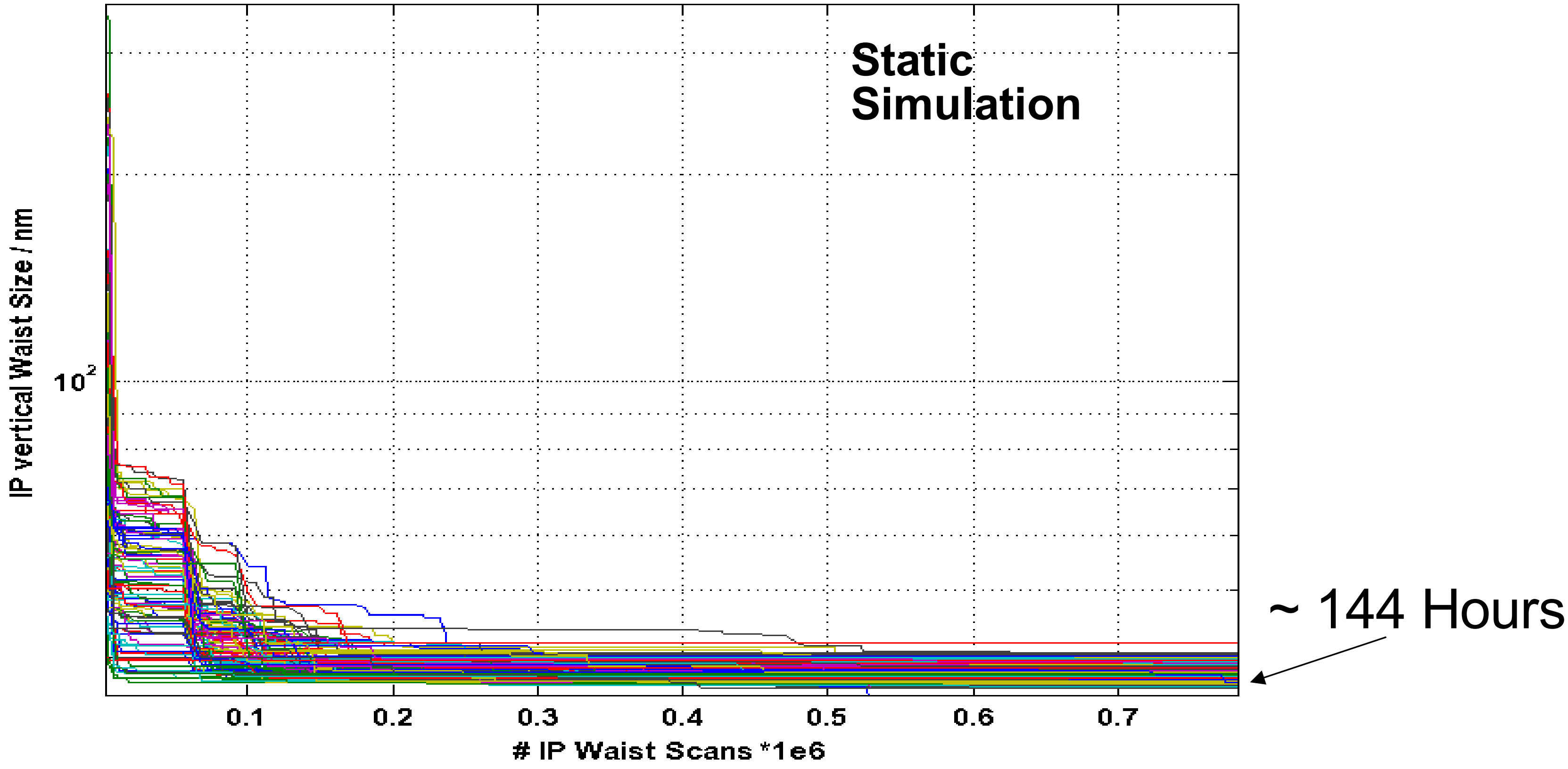
- RMS alignment of Magnet field centre – electrical centre of magnet BPMs (100 seeds).
- Blue = x Red = y.

Beamsize after BBA



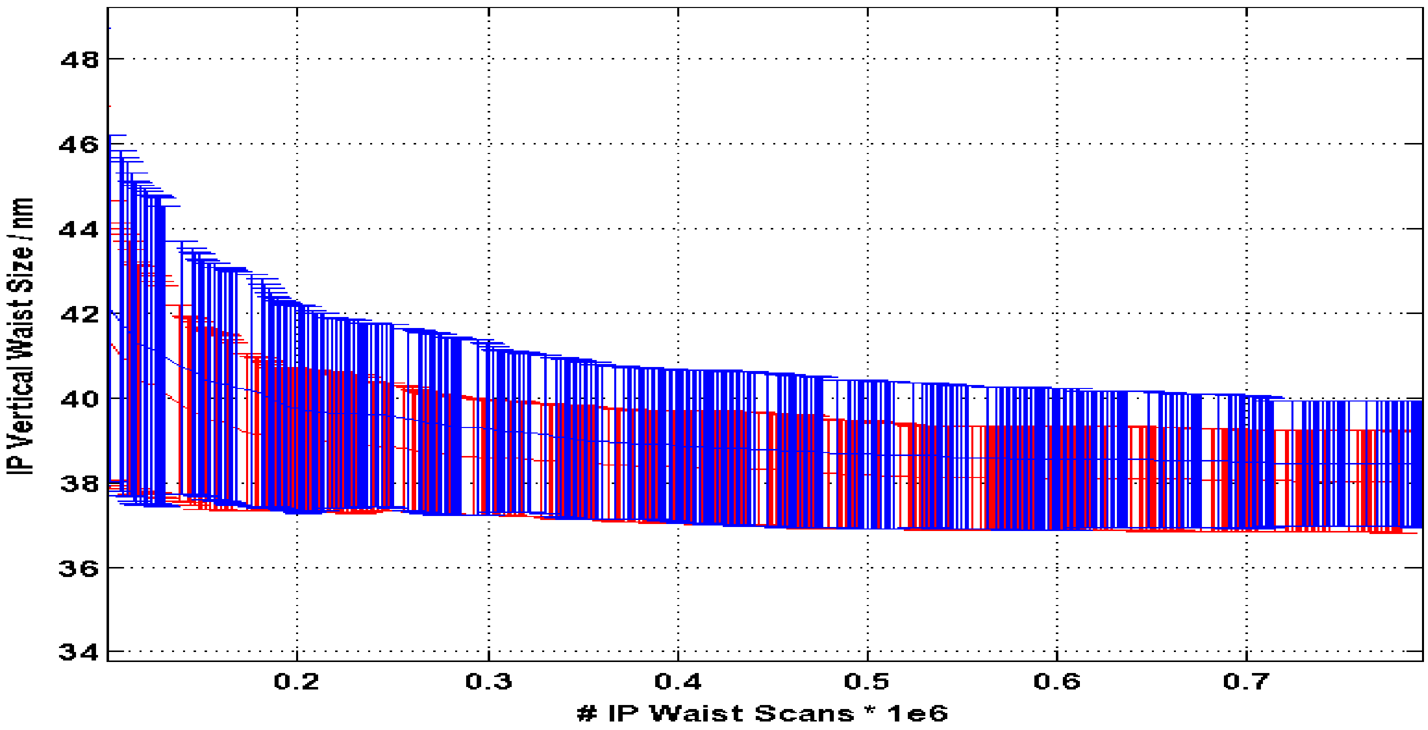
- IP waist size before sextupole FFS tuning knobs applied (100 seeds).

Multi-Knob Tuning Results



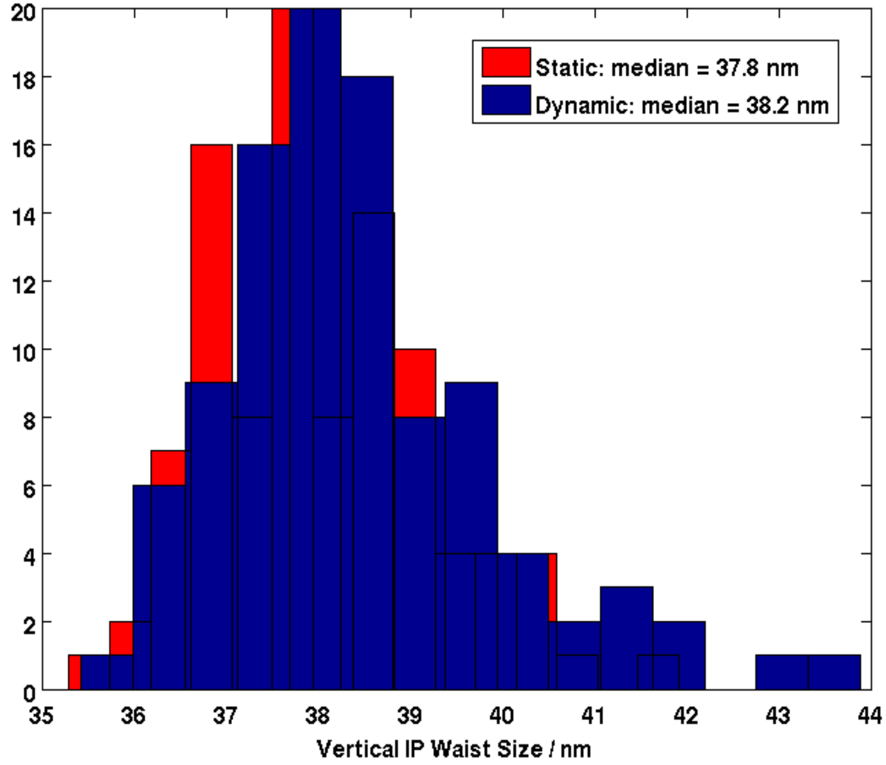
- IP spot size vs. # of pulses (assuming 90 pulses per IP size measurement).
- Fast convergence <100nm (after fixing waist + dispersion).

Best Spot Size Achieved



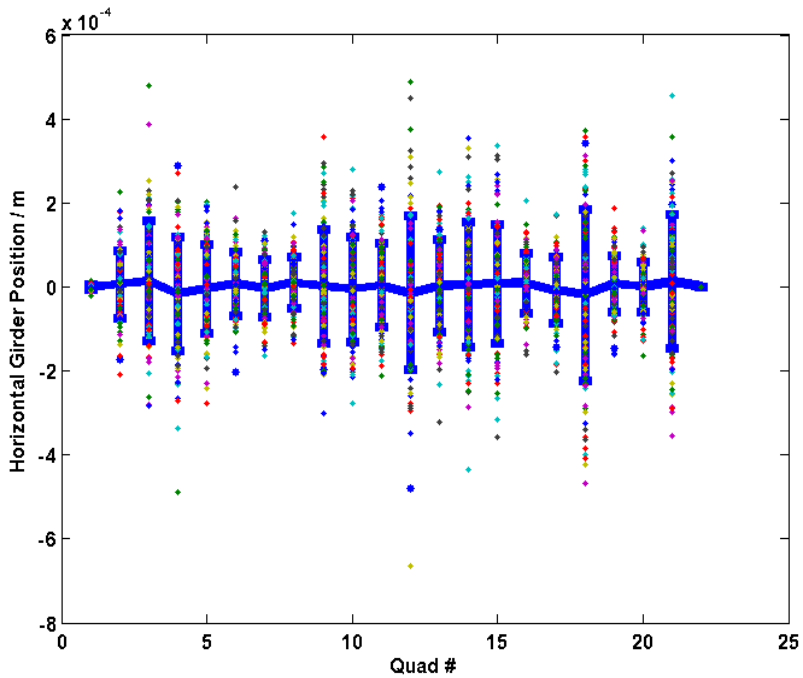
- Min IP waist size achieved vs. pulse #
- Mean and +/- 1 sigma plotted from 100 seeds.
- Red = static, blue = dynamic.

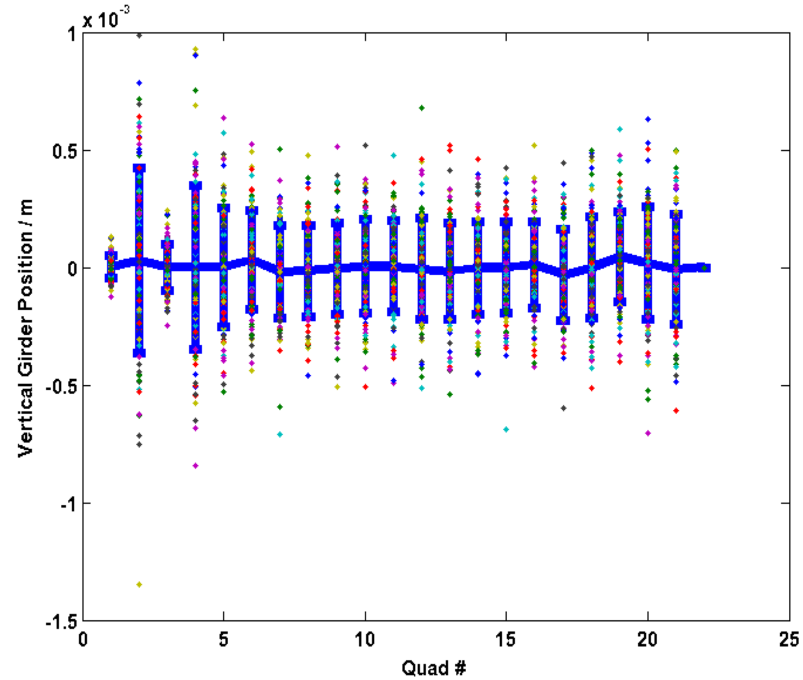
Tuning Results



- Best achieved spot-size (with perfect lattice = 36.7nm).
- In static simulation, median 1.1nm larger than with perfect lattice.
- Dynamic errors add 0.4 nm to median.

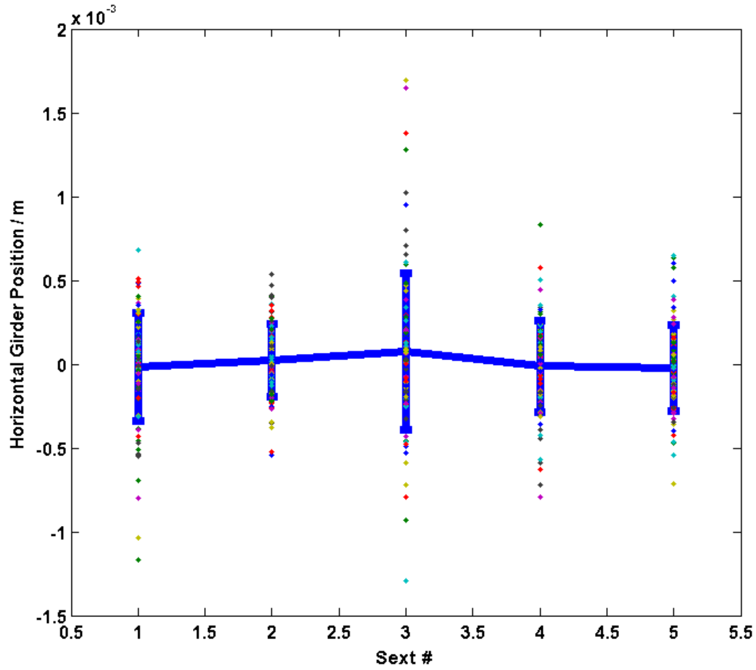
Final Quad Mover Positions

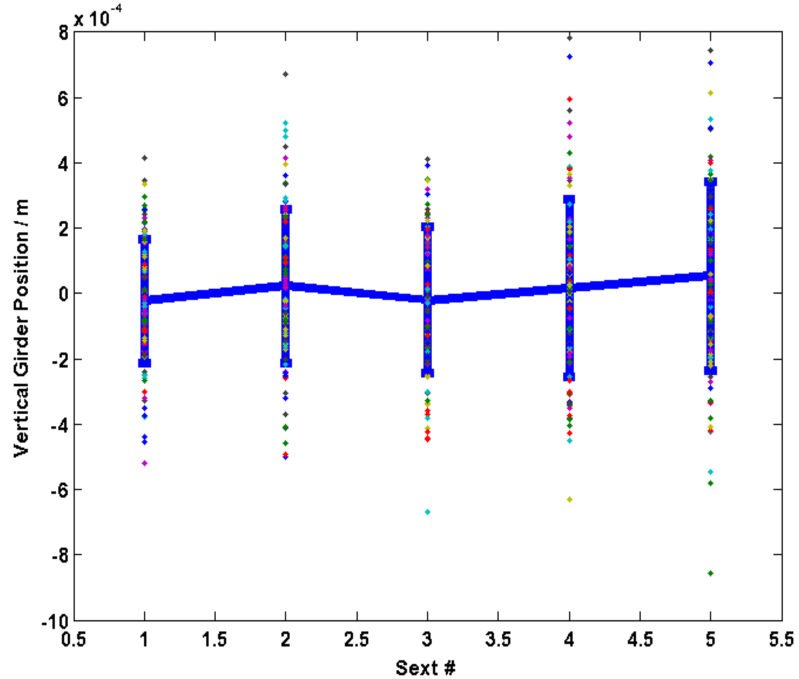




- Position of Quad Magnet Movers after tuning.
- x/y moves ~<2mm possible, but have to take into account map of x,y,roll phase space.
- Need to check don't try to move outside this phase space.

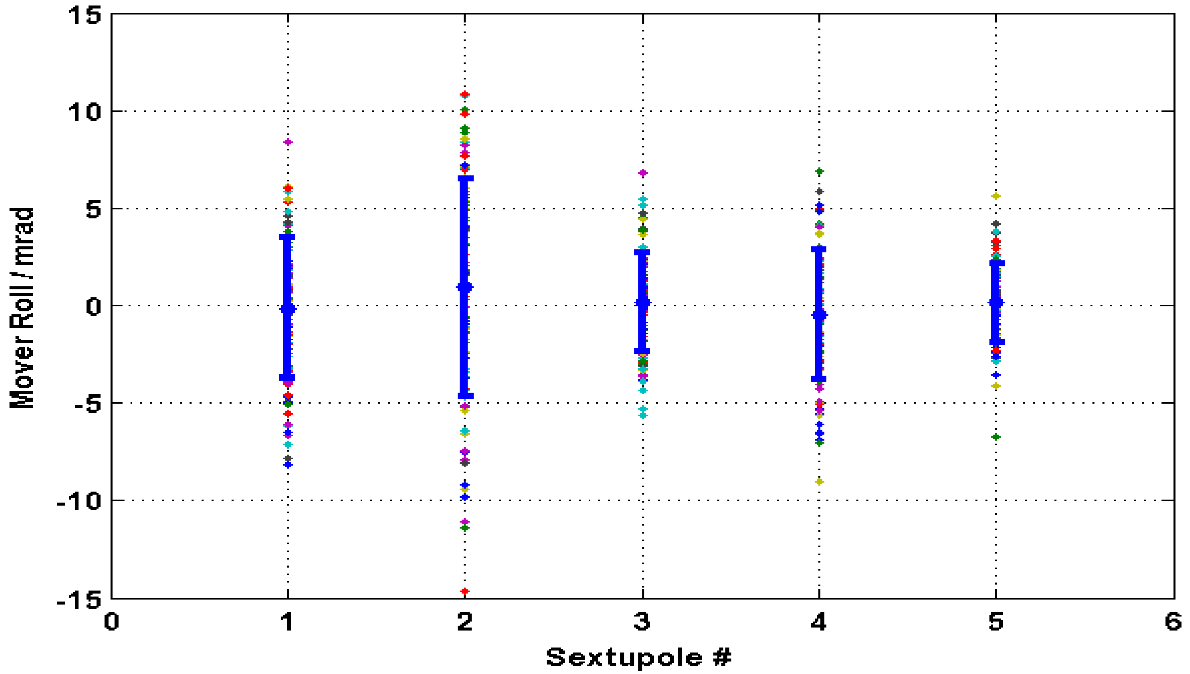
Final Sextupole Mover Positions





- x/y positions of Sext movers after tuning.

Final Sextupole Mover Rolls



- Final roll positions of sextupole movers.

Other Work

- Correct modeling of magnet mover dynamics + check range not exceeded at any time.
- Quad BBA modelled for EXT.
- Errors in EXT coupling correction.
- IP measurement simulation?
- Add more realistic constraints (S.Molloy)
  - Respect apertures
  - Radiation monitoring during BBA.