BDS Tuning Optimisation

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Accelerator: BDS-II: Optics
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Outline

TDR Parameters

Energy-dependent parameters of the Beam Delivery System

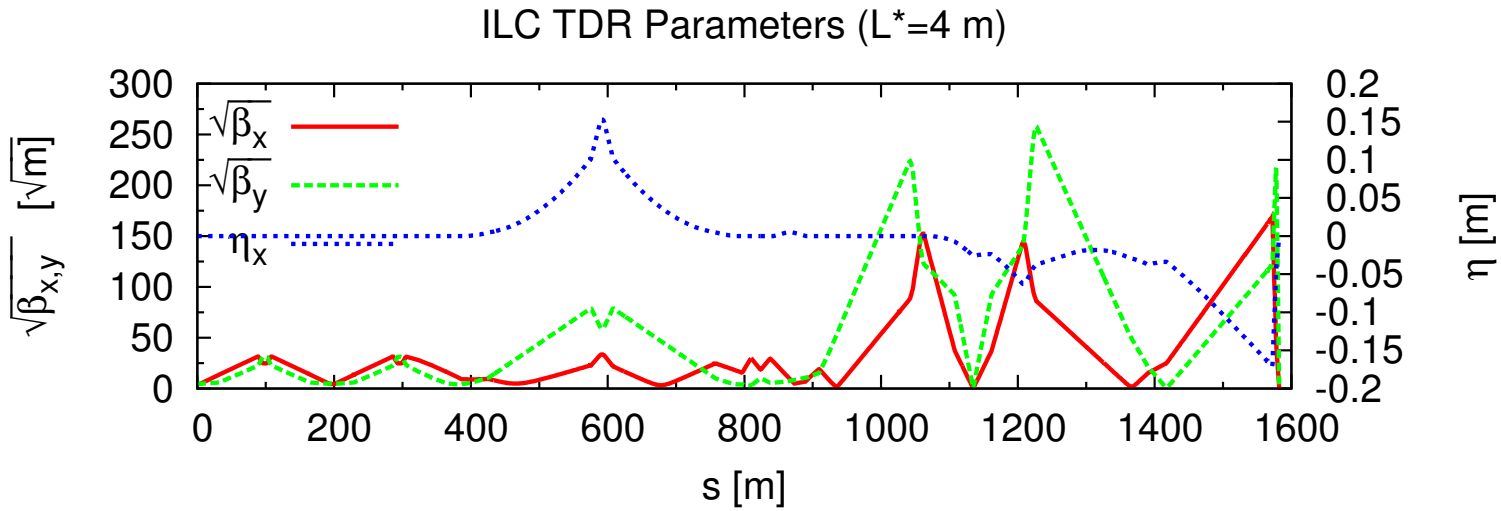
Parameter	Unit	E_{CM}[GeV]		
		250	500	1000 (A1)
β_x^*	[mm]	13	11	22.6
β_y^*	[mm]	0.41	0.48	0.25
$\delta E/E$ (e^-)	[%]	0.19	0.124	0.083
σ_x^*	[nm]	729	474	481
σ_y^*	[nm]	7.7	5.9	2.8
$\mathcal{L}$	$[10^{34} cm^{-2} s^{-1}]$	0.75	1.8	3.6

FD location:
QF1 @ 9.5 m, QD0 @ 4.0 m upstream IP

ILC BDS
$E_{CM} = 250$ GeV

Lattice Design

FD magnets split, only using half of QF1(A) and QD0(A)
Optimization done by MAPCLASS using sextupole and octupole magnets



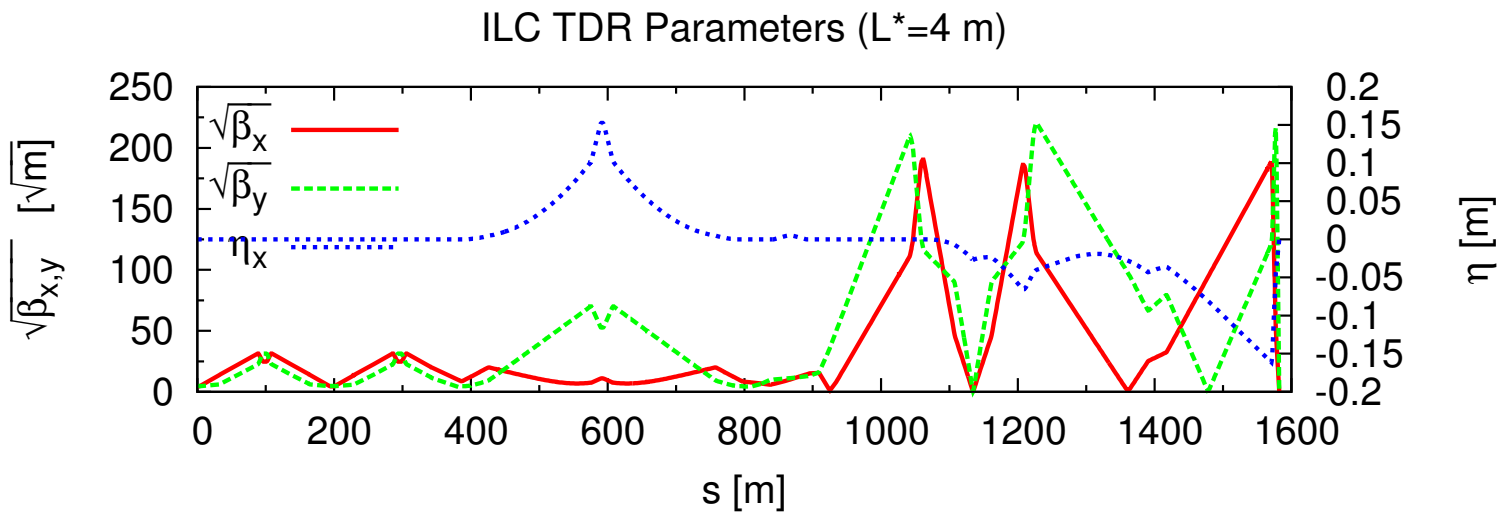
$\sigma_x^* = 770$ nm (RMS)

$\sigma_y^* = 7.7$ nm (RMS)

ILC BDS
$E_{CM} = 500$ GeV

Lattice Design

Optimization done by MAPCLASS using sextupole and octupole magnets



$\sigma_x^* = 483$ nm (RMS)

$\sigma_y^* = 5.8$ nm (RMS)

Tuning Framework

Monte-Carlo study of 100 different machines

Errors assigned following a Gaussian distribution (3σ-cut):

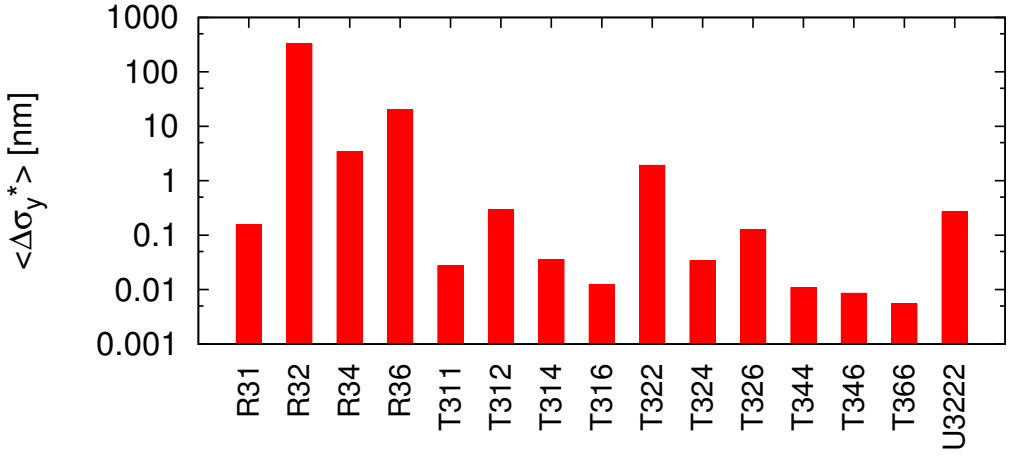
- Alignment (x/y) error: 100 μm
- Tilt error: 300 μrad
- Relative strength error: 10^{-4}
- BPM reading error: 1 μm
- BPM-to-Quad error: 0.3 μm
- Mover error: 2 μm

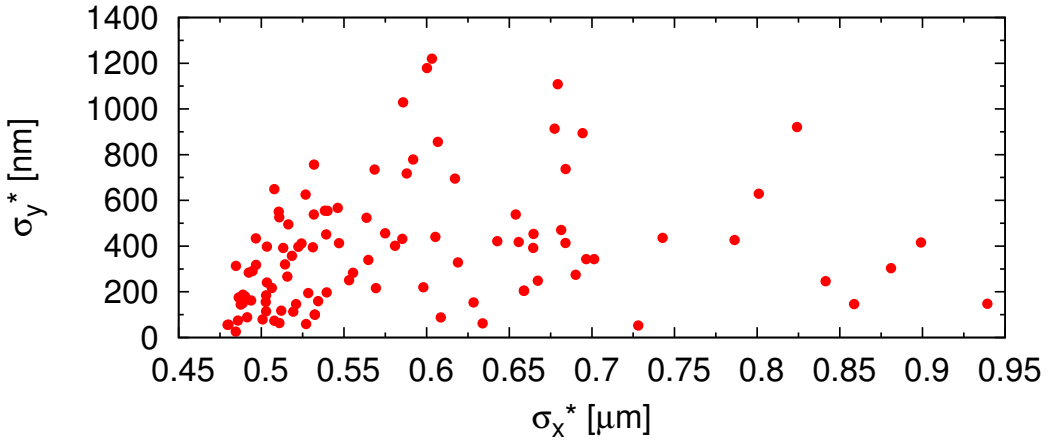
Tuning Procedure:

- 1-to-1 Steering
- BBA of Sextupole & Octupole magnets
- Knobs scan

Spot Sizes before Knobs

Aberrations present after steering and BBA

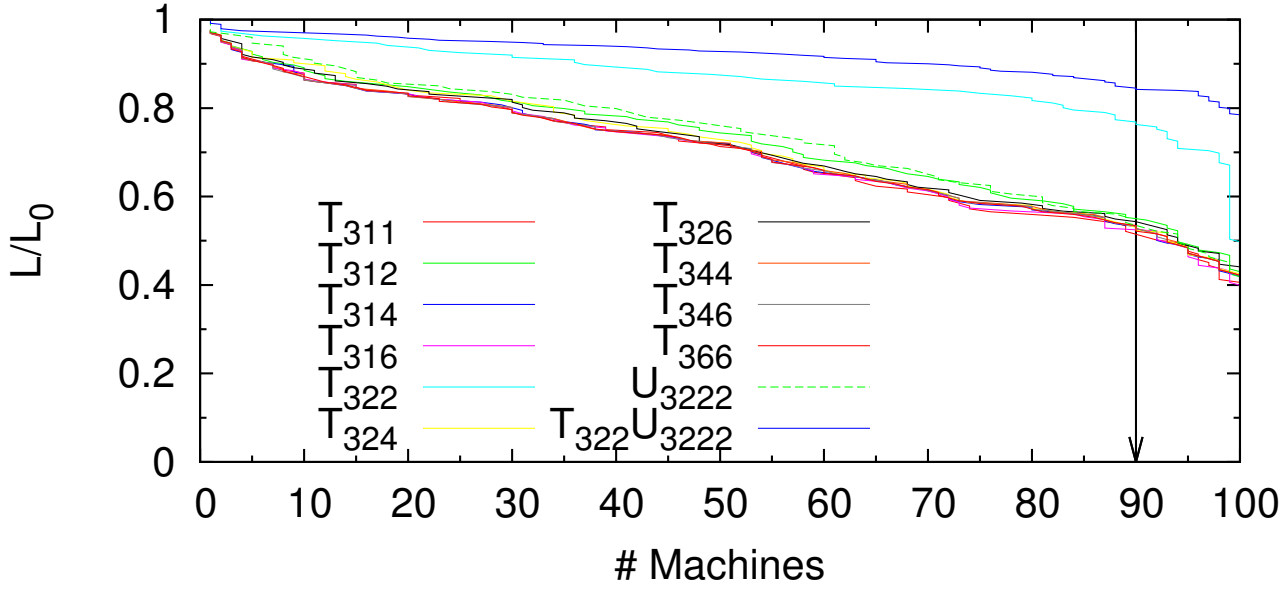




$$< \sigma_x^* >= 587 \pm 104\text{nm}$$
$$< \sigma_y^* >= 377 \pm 265\text{nm}$$

Required Tuning Knobs

Confidence level obtained by "artificially" removing the correlations from the beam distributions

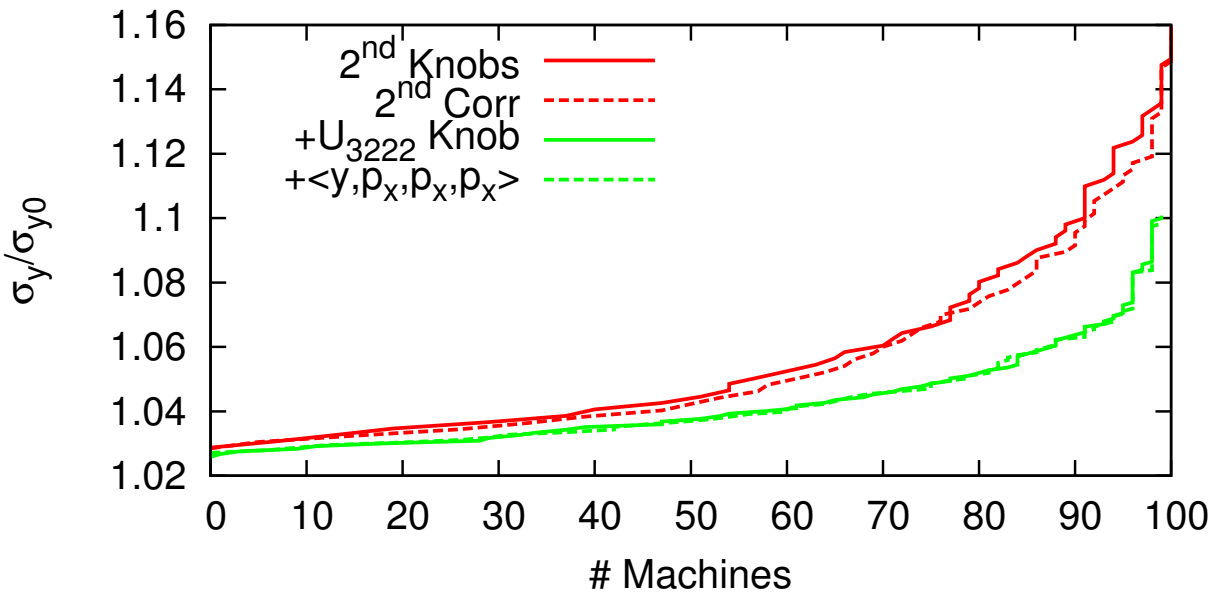


This exercise defines the required set of high order knobs:

T_{312}, T_{322}, T_{324}, T_{326} and U_{3222}

High Order Knobs

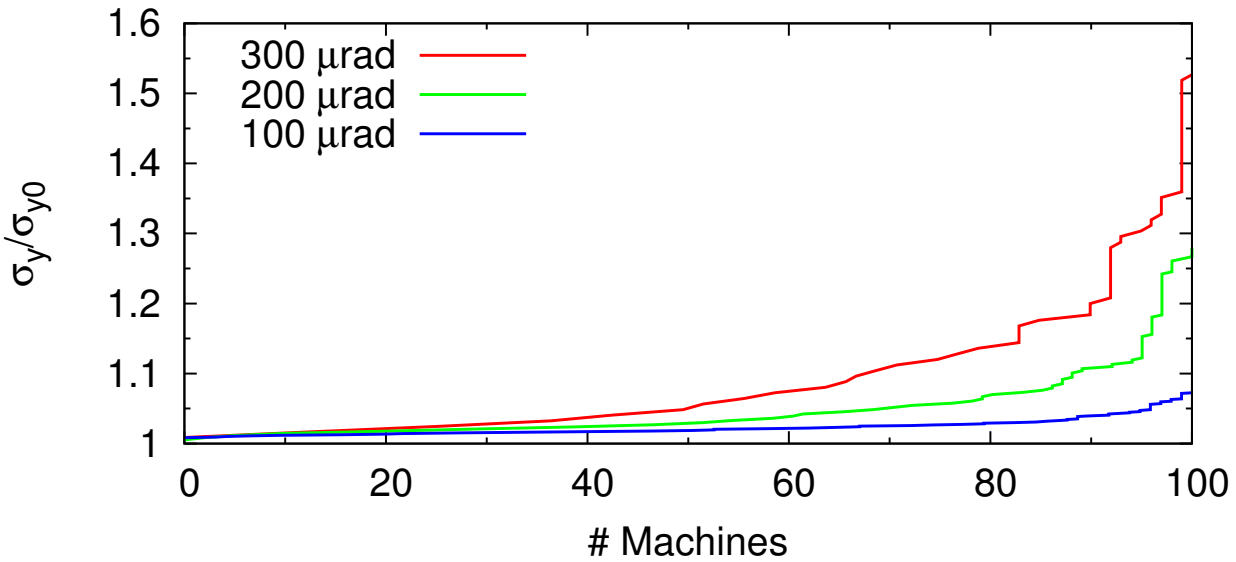
2^{nd} order knobs T_{312}, T_{324}, T_{322} and T_{326} are constructed by means of 4 skew sextupoles
U_{3222} knob is obtained by adding the octupole (OCM10) to the skew sextupoles



Comparable performance is obtained by applying the knobs or "artificially" removing the correlations

Who introduces U_{3222}?

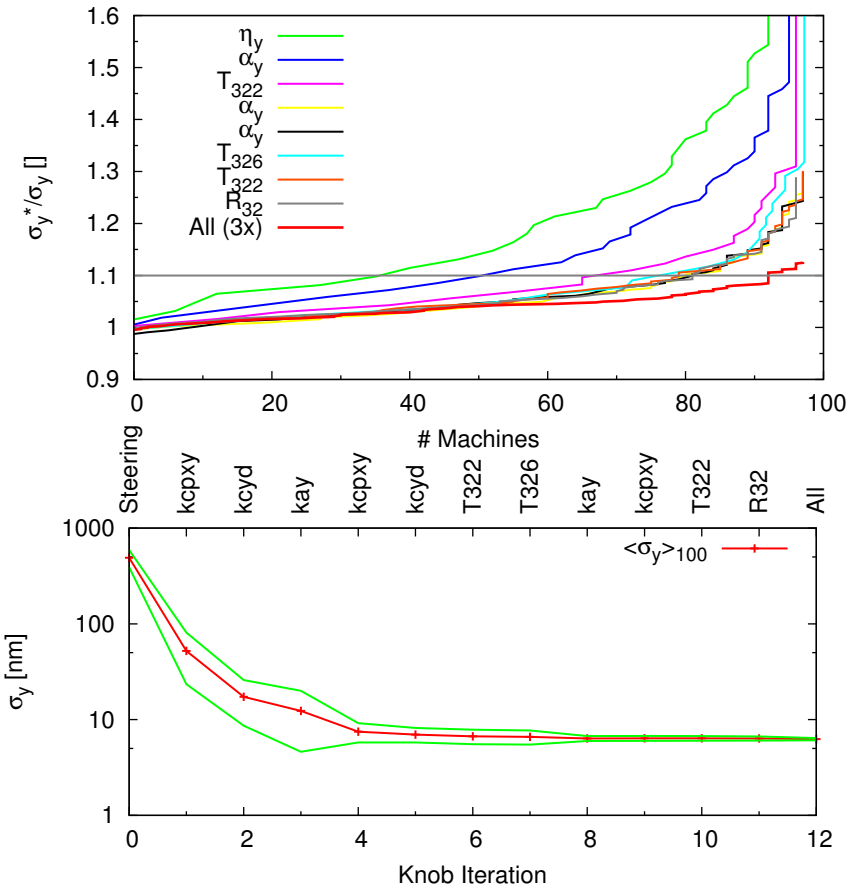
Assuming only tilt errors on quadrupole magnets
Confidence level after removing 1st and 2nd order correlations



Rotational alignment of the quadrupoles might be relaxed by using the U_{3222} knob

Integral Tuning Procedure

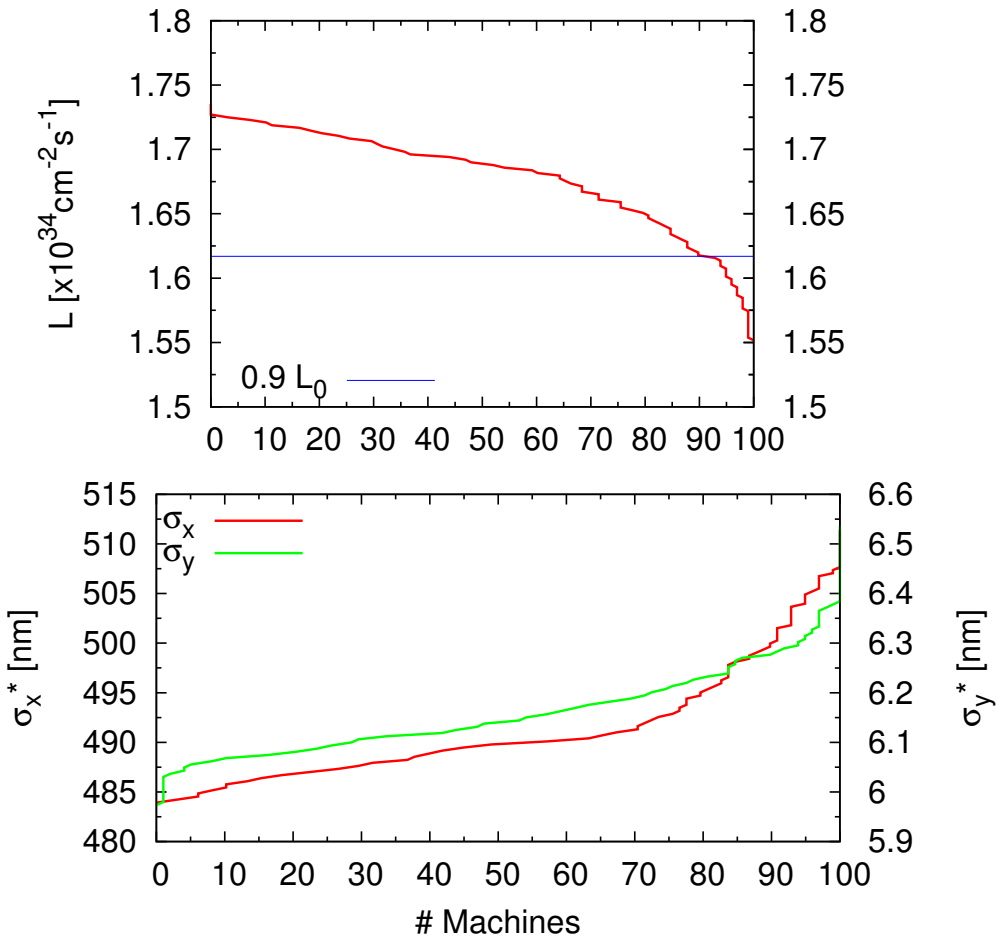
Tuning Procedure: **Steering + BBA + Knobs**



Tuning Results

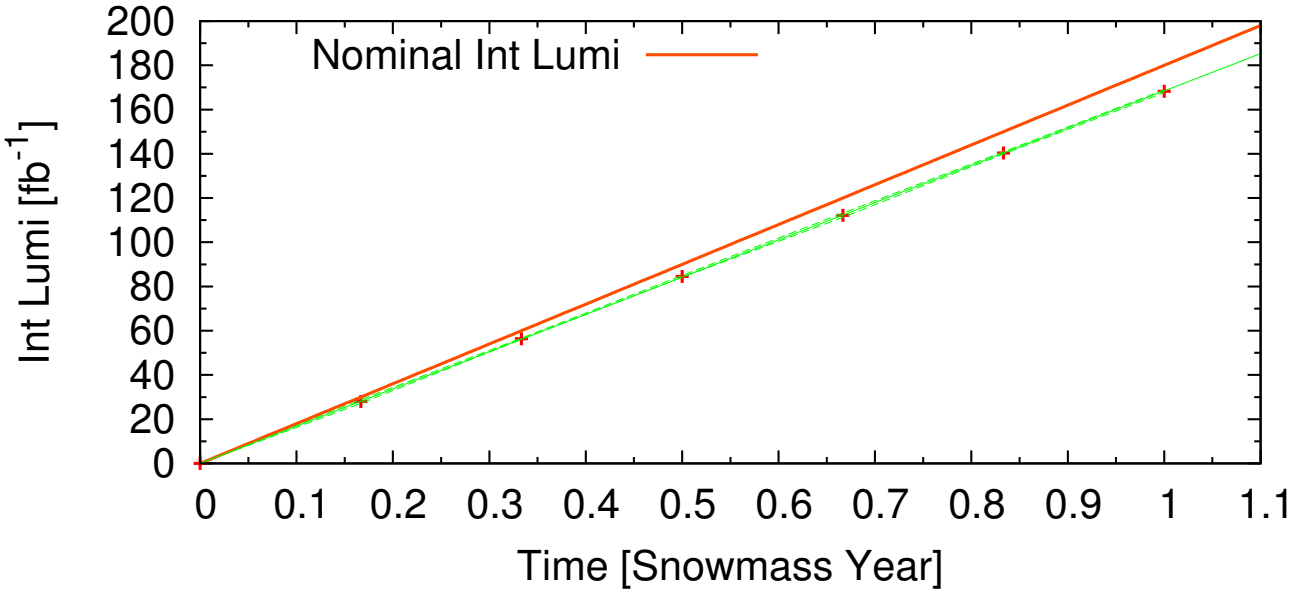
$\sigma^*_{x,y}$ and $\mathcal{L}$ obtained for ILC BDS L*=4 m @ E_{cm}=500 GeV

$$\mathcal{L} \sim \frac{1}{\sigma^*_x \sigma^*_y} \rightarrow (\Delta\mathcal{L})^{-1} = \frac{\delta\sigma_x}{\sigma^*_{x0}} + \frac{\delta\sigma_y}{\sigma^*_{y0}} + \frac{\delta\sigma_x \delta\sigma_y}{\sigma^*_{x0}\sigma^*_{y0}}$$



Integrated Luminosity

Expected luminosity delivered over 1 Snowmass year, assuming 6 re-seedings

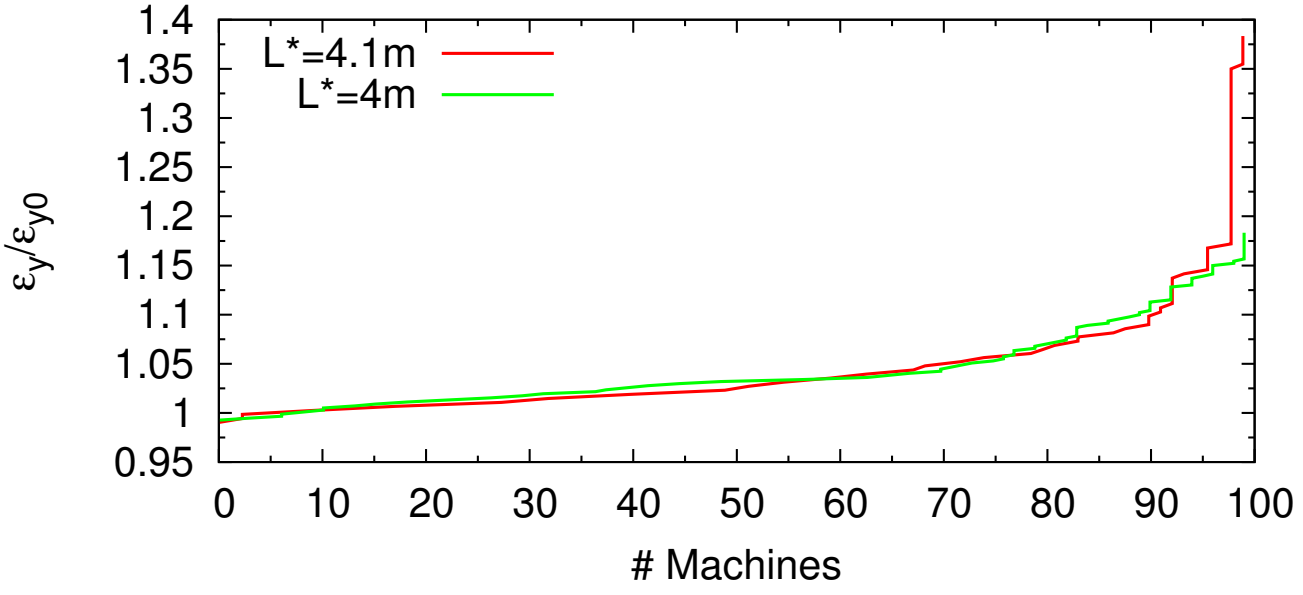


$$< \text{Int } \mathcal{L} >_{100} = 166 \pm 1.7 \text{ fb}^{-1}$$

Note: Tuning time after re-seeding: 1000 $\mathcal{L}$ measurements

L* Tuning Comparison

New lattice design of the FFS with QF1 @ 9.1 m and QD0 @ 4.1 m upstream IP has been obtained

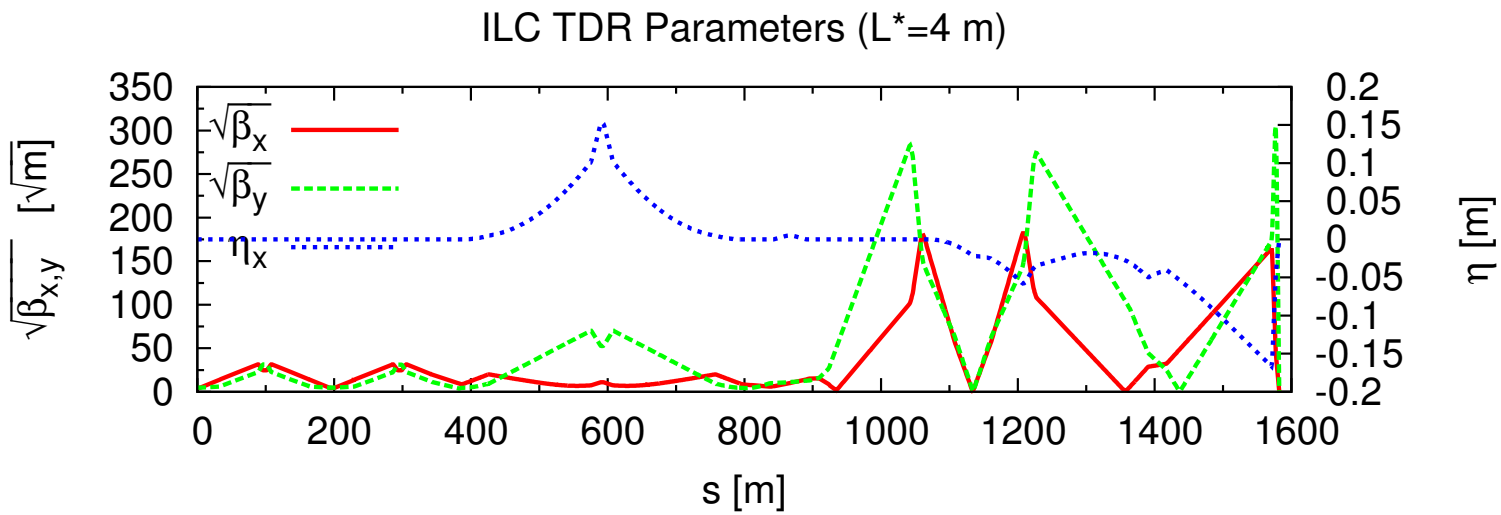


No significant difference is observed with respect to previous design (QD0 @ 4.0m and QF1 @ 9.5m)

ILC BDS
$E_{CM} = 1000$ GeV

Lattice Design

Optimization done by MAPCLASS using sextupole and octupole magnets



$\sigma_x^* = 481$ nm (RMS)

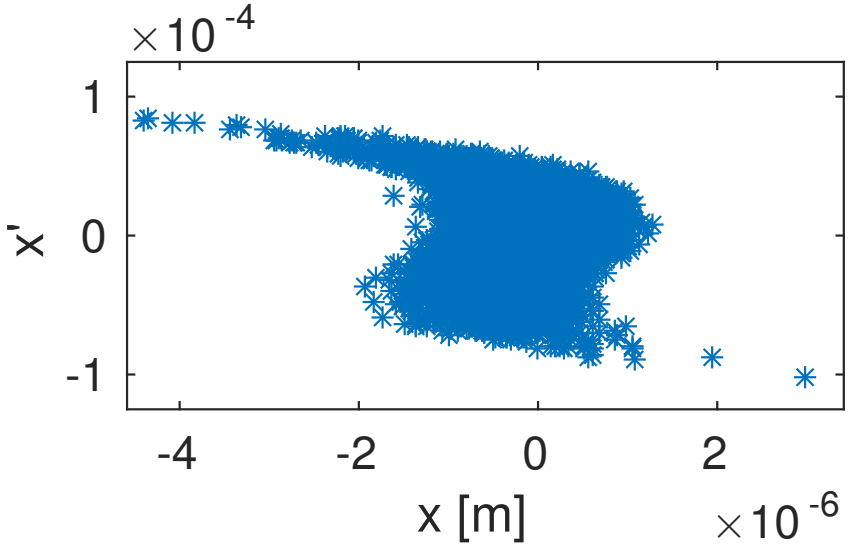
$\sigma_y^* = 3.0$ nm (RMS)

ILC BDS E_{CM}=1 TeV

	σ_x^*	σ_y^*
	[nm]	[nm]
Design	481	2.8
SR OFF		
RMS	481	3.0
CORE	460	3.0
SR ON		
RMS	485	3.3
CORE	462	3.3
Sext & Octs Optimization		
RMS	480	3.3
CORE	440	3.1

Residual $\Delta\sigma_y^*$ after optimization: 3.3%

Horizontal phase space after high-order optimization



SUMMARY

Summary and Outlook

- Obtained lattice designs for E_{CM}'s 250, 500 and 1000 GeV
- Tuning Study on ILC BDS E_{CM}=500 GeV
  - >90% machines reach 90% of the nominal luminosity by applying 1st,2nd and 3rd order tuning knobs
  - No significance difference is observed between two different configuration of the FD locations
  - Rotational alignment of the quadrupoles could be relaxed by using octupole OCM0
- E_{CM}=1000 GeV
  - Optimization of the high order magnets taking into account SR. $\Delta\sigma_y$ reduced to almost 3%
  - FD Octupoles could be used for further reduction of σ_x^*

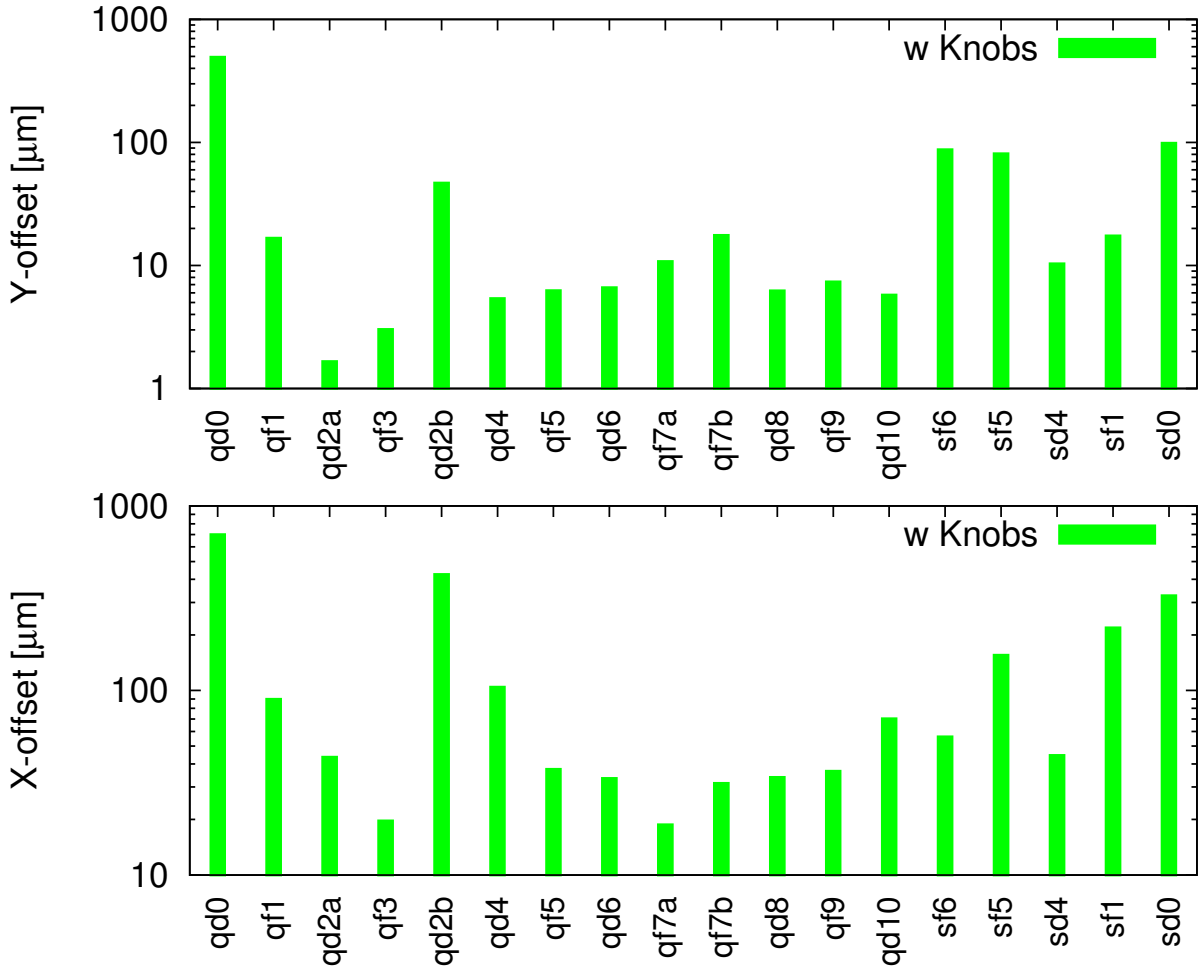
Outlook:

- Re-design FFS lattices with L* = 4.1m for E_{CM}'s 250 and 1000 GeV

BACK-UP

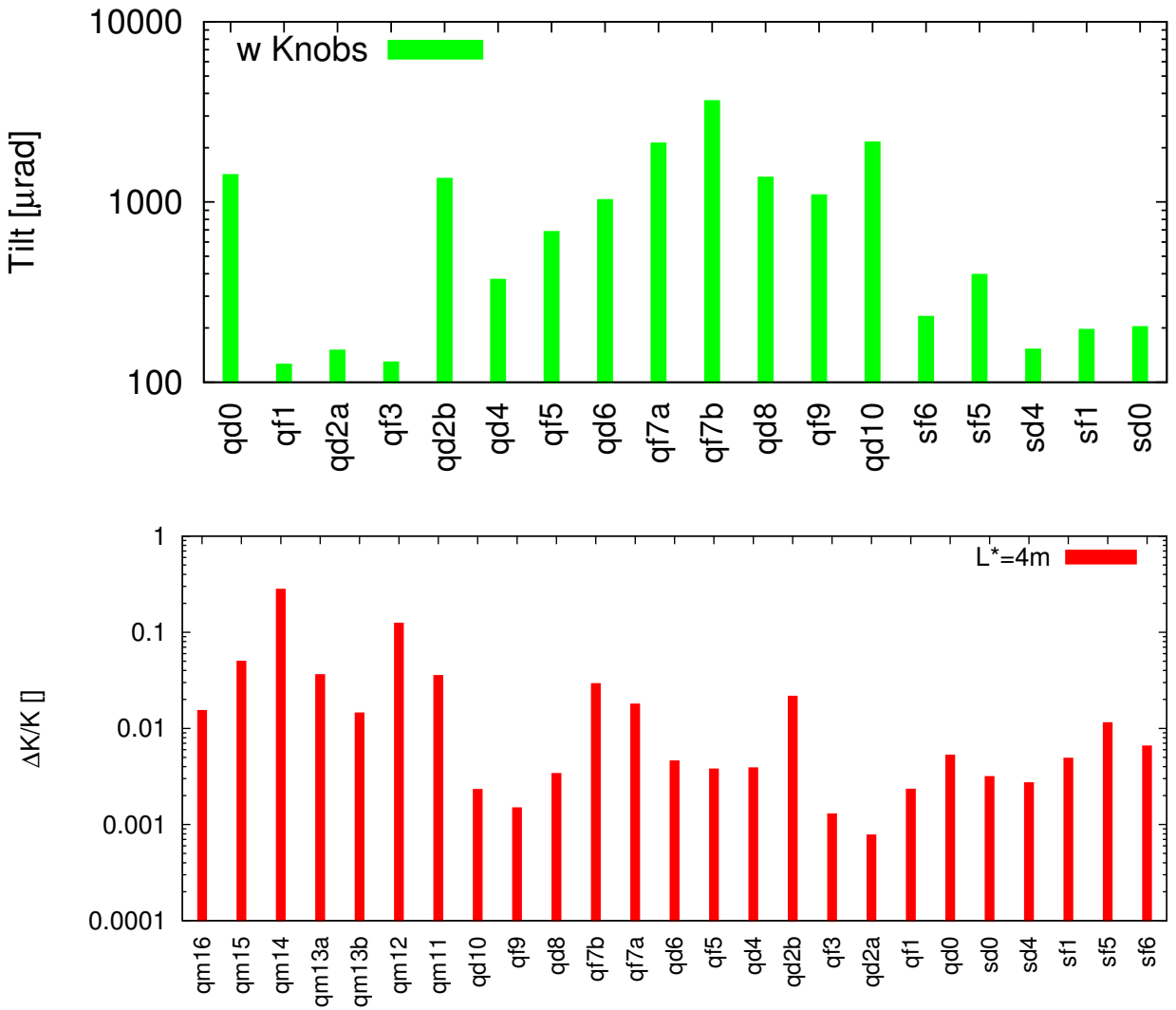
Tolerances I

Transverse alignment tolerances ($\Delta\mathcal{L} = 2\%$)
(Linear correlations are removed)

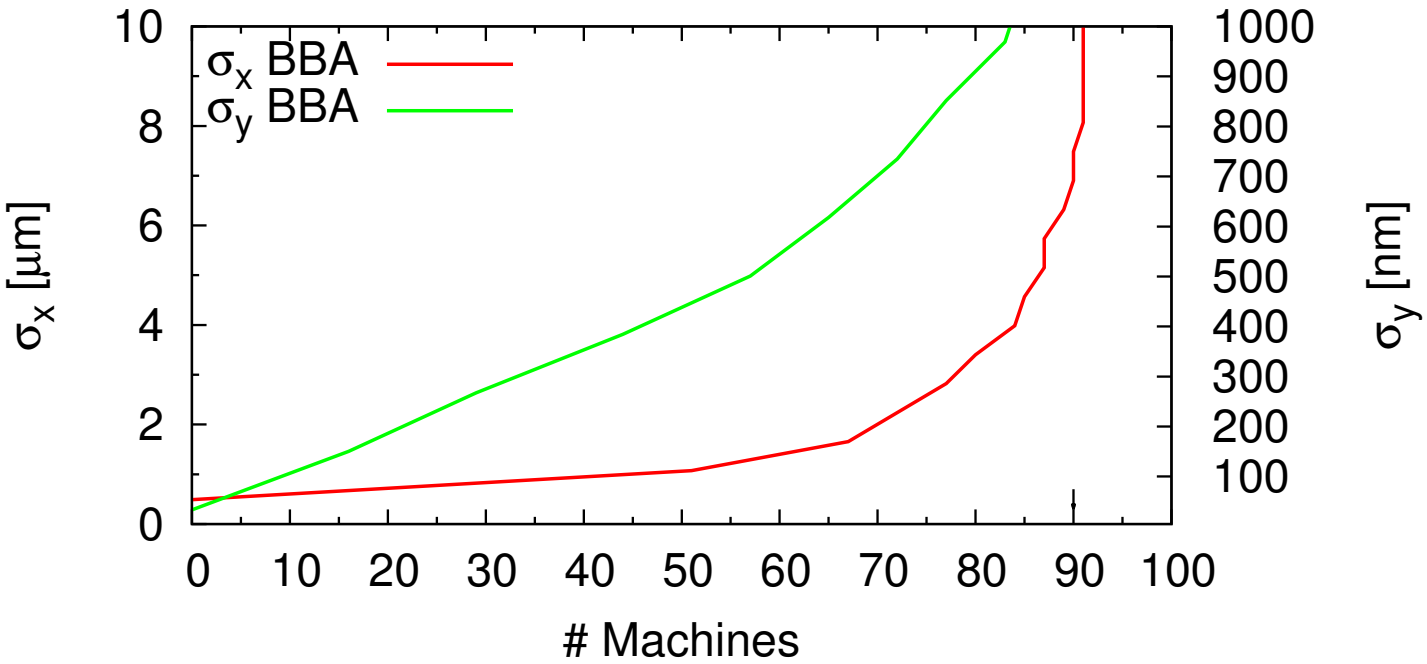


Tolerances II

Tilt and strength tolerances ($\Delta\mathcal{L} = 2\%$) (Linear correlations are removed)

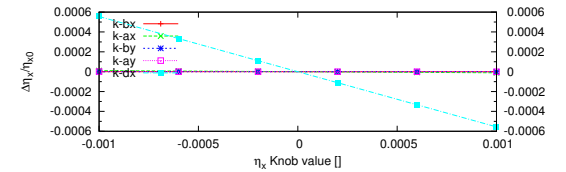


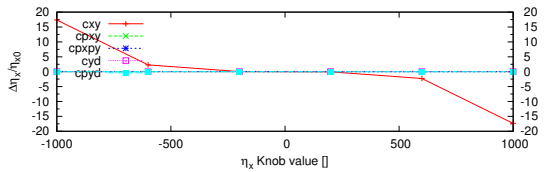
Obtained confidence level after BBA

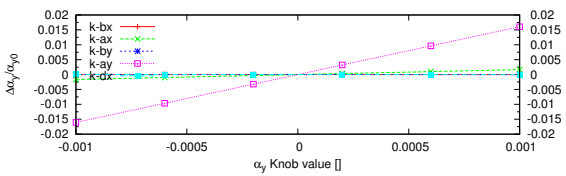


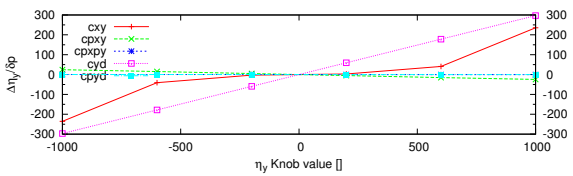
Linear Knobs

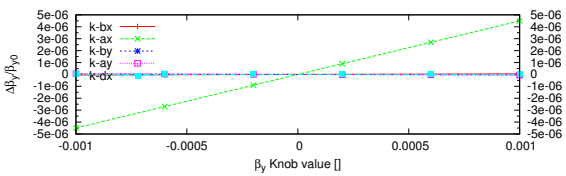
Linear Knobs constructed by means of transverse displacements of normal sextupole magnets to target α_x,α_y,η_x,η_y,$< p_x, y >$ and $< x, y >$

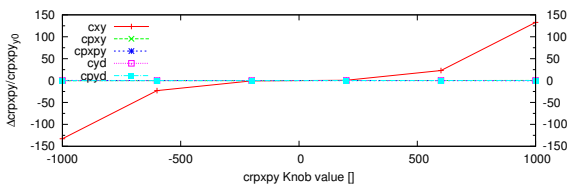


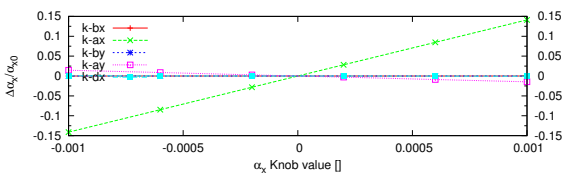


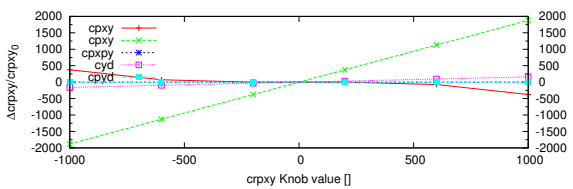


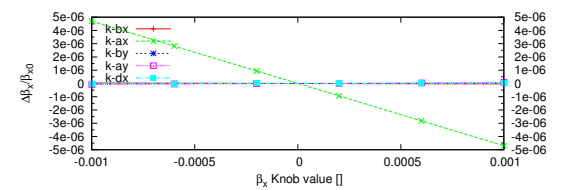


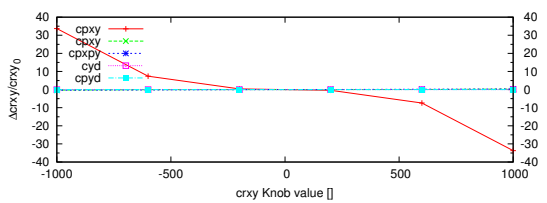




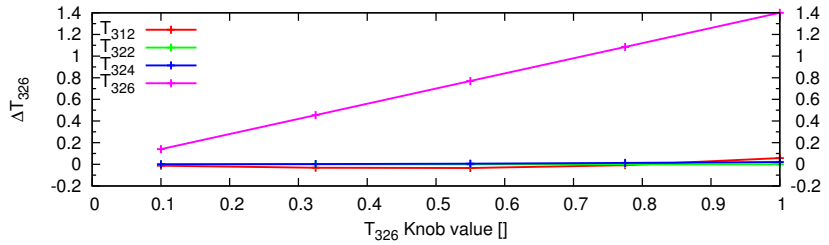


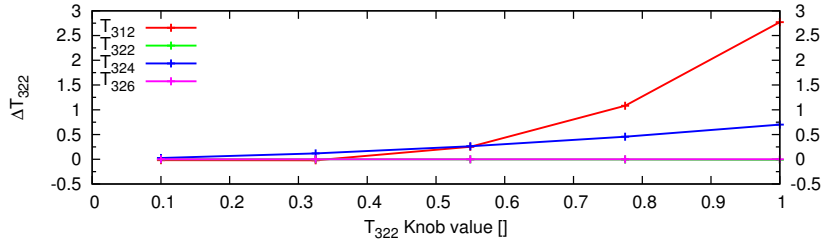


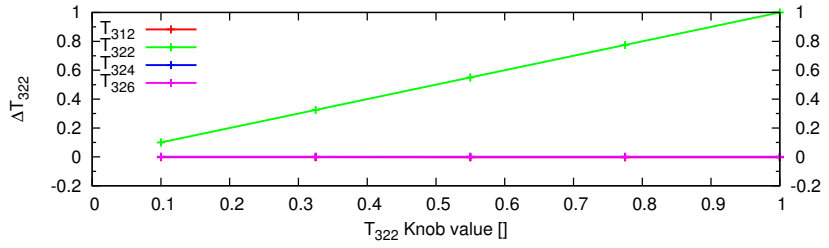


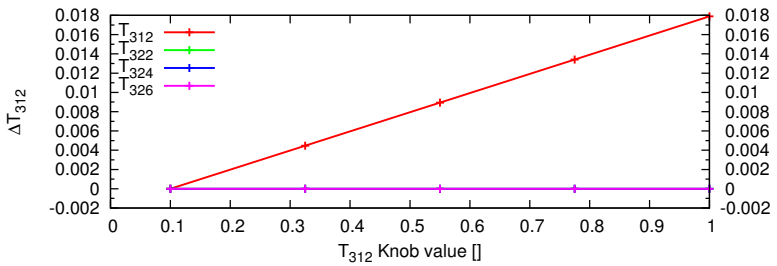


2nd Order Knobs









Knobs Range

Increasing η_x throughout the FFS reduces the strength of the sextupole magnets which relax the alignment tolerances for the quadrupoles magnets
In addition it increases the capability range of the tuning knobs which potentially could ease the tuning process