Comparison the tolerances of ILC and ATF2 beamline

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Contents

Tolerance of Multipole Field Errors

Tolerance of Magnet Vibrations

Tolerance of Vertical Misalignments of Magnets

Multipole Field Errors

Tolerances were defined by 2% of IP beam size growth

1.1 Tolerances of Sextupole Field Errors for Quadrupole Magnets

Tolerances were calculated with/without 2nd order optics correction used at ATF2.

1.2 Tolerances of Higher Order Multipole Errors for Final Doublet

2^{nd} Order Optics Corrections (same as ATF2 tuning)

When the strengths of Final Focus Sextupole magnets were changed

$$\Delta X_{IP} = \frac{R_{12} K_2}{2} \left(\underbrace{\Delta x^2}_{X_{22}} + \underbrace{2\eta \Delta x \frac{\Delta p}{p}}_{X_{26}} + \underbrace{\eta^2 \frac{\Delta p^2}{p^2}}_{X_{66}} - \underbrace{\Delta y^2}_{X_{44}} \right)$$

ignore (effect is small)

$$\Delta Y_{IP} = R_{12} K_2 \left(\underbrace{\Delta x \Delta y}_{Y_{24}} + \underbrace{\eta \Delta y \frac{\Delta p}{p}}_{Y_{46}} \right)$$

Y24, Y46, X22, X26, X66 *are orthogonal to change the strengths of the* ***5 normal sextupole magnets****.*

We put 4 skew sextupole magnets in the beamline.

When the strengths of skew sextupole magnets were changed

$$\Delta y_{IP} = \frac{R_{34} K_{2S}}{2} \left(\underbrace{\Delta x^2}_{Y_{22}} + \underbrace{2\eta \Delta x \frac{\Delta p}{p}}_{Y_{26}} + \underbrace{\eta^2 \frac{\Delta p^2}{p^2}}_{Y_{66}} - \underbrace{\Delta y^2}_{Y_{44}} \right)$$

Y22, Y26, Y66 and Y44 *are orthogonal to change the strengths of the* ***4 skew sextupole magnets.***

SAD Deck of ILC beam delivery system

The ILC2006e optics (RDR optics) was translated to SAD deck.

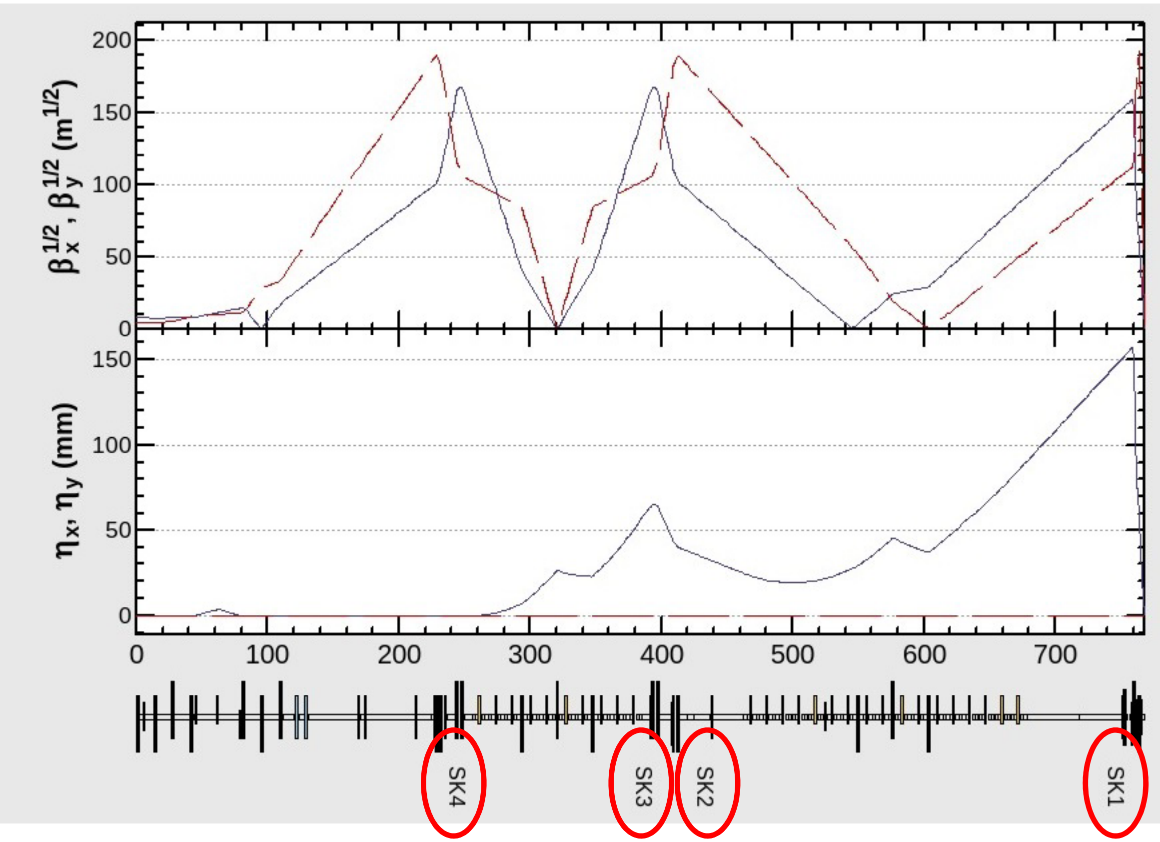
- The optics was ***matched to the ILC TDR IP parameters*** *to*

- betax = 11mm (21mm original)*

- betay = 0.48mm (0.40mm original)*

- ***4 skew sextupoles*** *were put to the beamline as well as ATF2.*

- The tolerances of ILC FF and ATF2 were compared with same code.

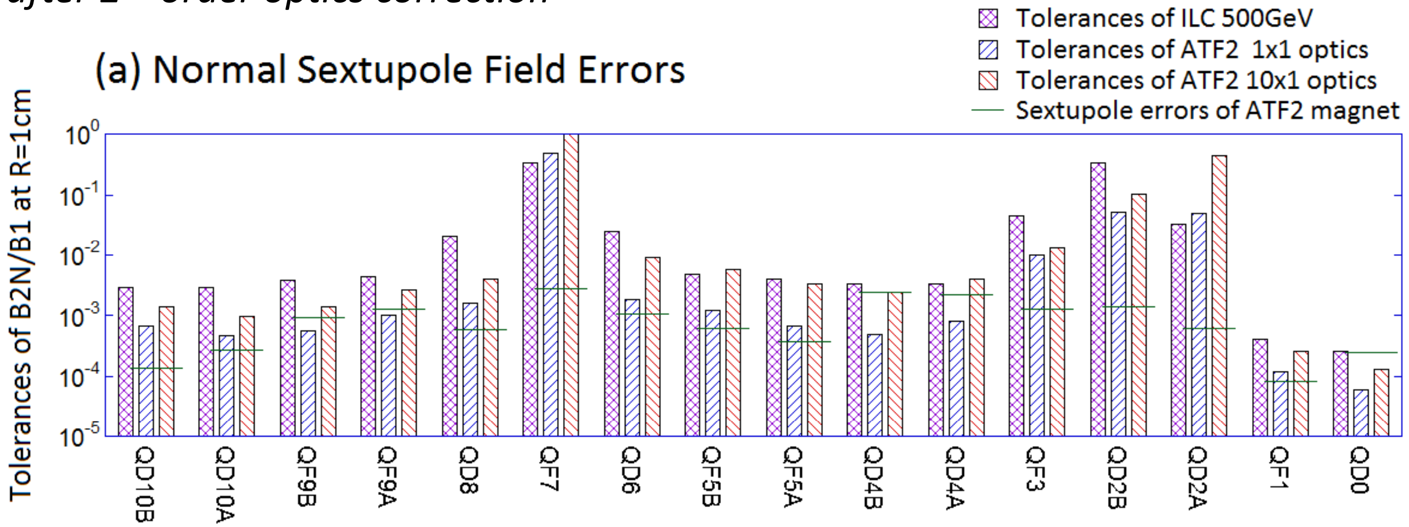


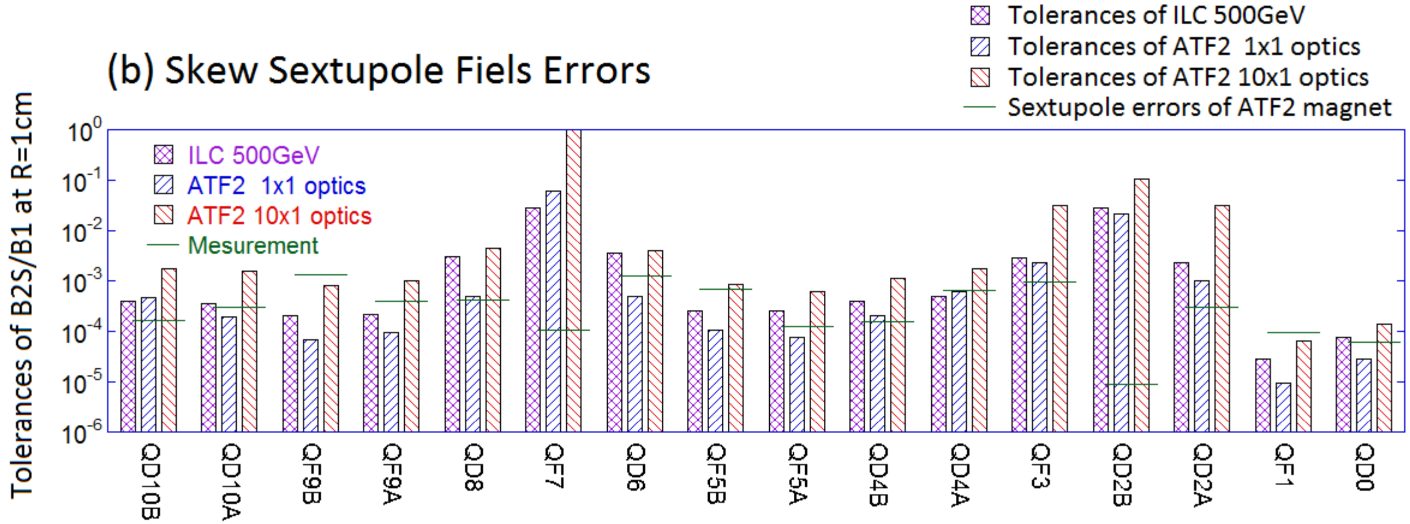
Comparison the multipole Errors of ILC and ATF2

Purple ; ILC TDR
Blue ; ATF2 1x1 optics
Red ; ATF2 10x1 optics

1-1. Tolerance of the Sextupole Field Errors

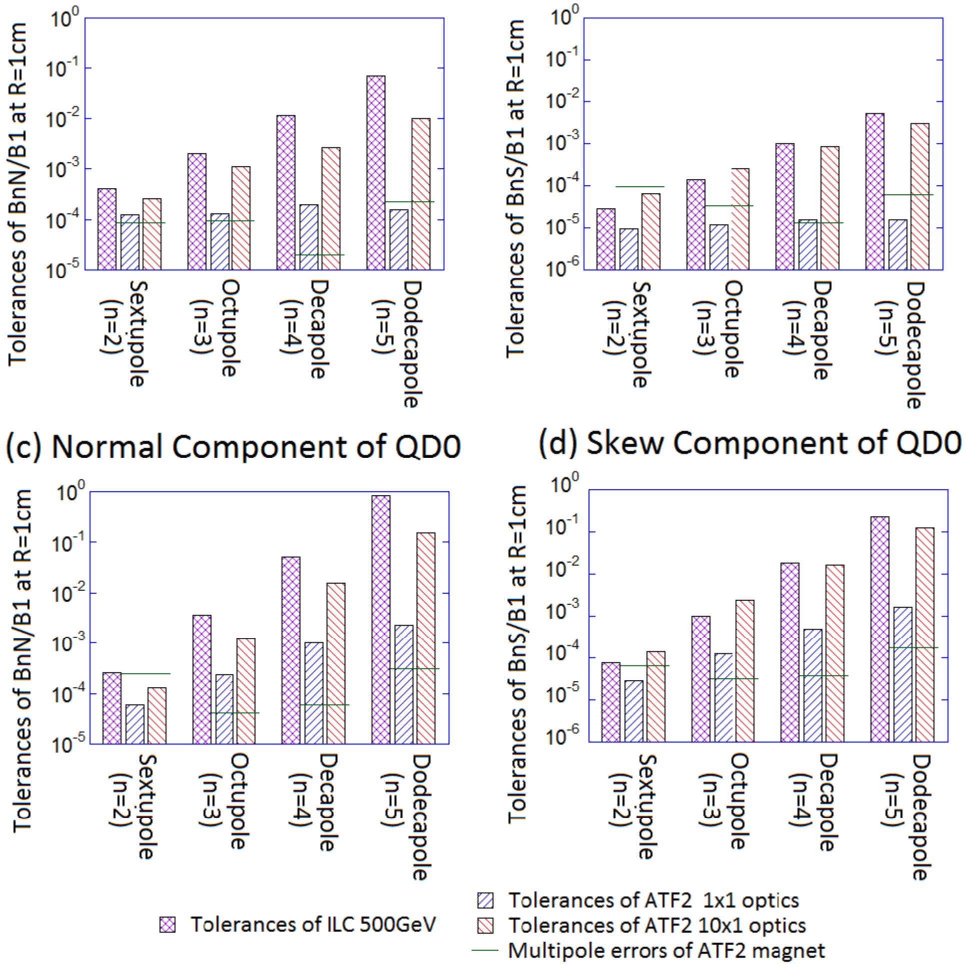
after 2nd order optics correction





The tolerance are comparable to ATF2 10x1 optics and ILC final focus system.

1-2. Tolerance of the Multipole Field Errors of Final Doublet



Purple ; ILC TDR

Blue ; ATF2 1x1 optics

Red ; ATF2 10x1 optics

The tolerance are comparable to ATF2 10x1 optics and ILC final focus system.

Since the difference of the bore diameter for ATF2 QF1 and ILC QF1, the fabrication of the ILC QF1 is much difficult to ATF2 QF1.

Rough Evaluation of Nonlinear Component in ATF2 Beamline

When we assumed the beam size at quadrupoles as $\sigma_{x,y} \propto L^* \sqrt{\dfrac{\varepsilon_{x,y}}{\beta^*_{x,y}}}$,

the effect of multipole field to IP beam size can be roughly scaled as

$$Y_{24} \propto L^{*2} \sqrt{\frac{\varepsilon_x \varepsilon_y}{\beta^*_x \beta^*_y}} \Big/ \sqrt{\varepsilon_y \beta^*_y} = L^{*2} \varepsilon_y \sqrt{\frac{\varepsilon_x}{\beta^*_x}} \qquad (5th\ order\ aberration) \propto L^{*5} \frac{\varepsilon_x^2}{\beta_x^{*2}} \sqrt{\frac{\varepsilon_x}{\beta^*_x}} \Big/ \sqrt{\varepsilon_y \beta^*_y} = L^{*5} \frac{\varepsilon_x^2}{\beta_x^{*2}} \sqrt{\frac{\varepsilon_x \varepsilon_y \beta^*_y}{\beta^*_x}}$$

etc.

		ILC	ATF2(1x1)	ATF2(10x1)
2^{nd} order	Y46	1	0.91	0.91
	Y24	1	6.50	2.05
	Y22	1	3.76	0.38
	Y26	1	0.52	0.16
	Y66	1	0.07	0.07
	Y44	1	11.14	11.14
3^{rd} (horizontal)		1	17.80	0.56
4^{th} (horizontal)		1	84.33	0.84
5^{th} (horizontal)		1	399.55	1.26

Chromatic aberration (Y46)

Generate by Sextupole (Y24)

Allowed component of quadrupoles (5th)

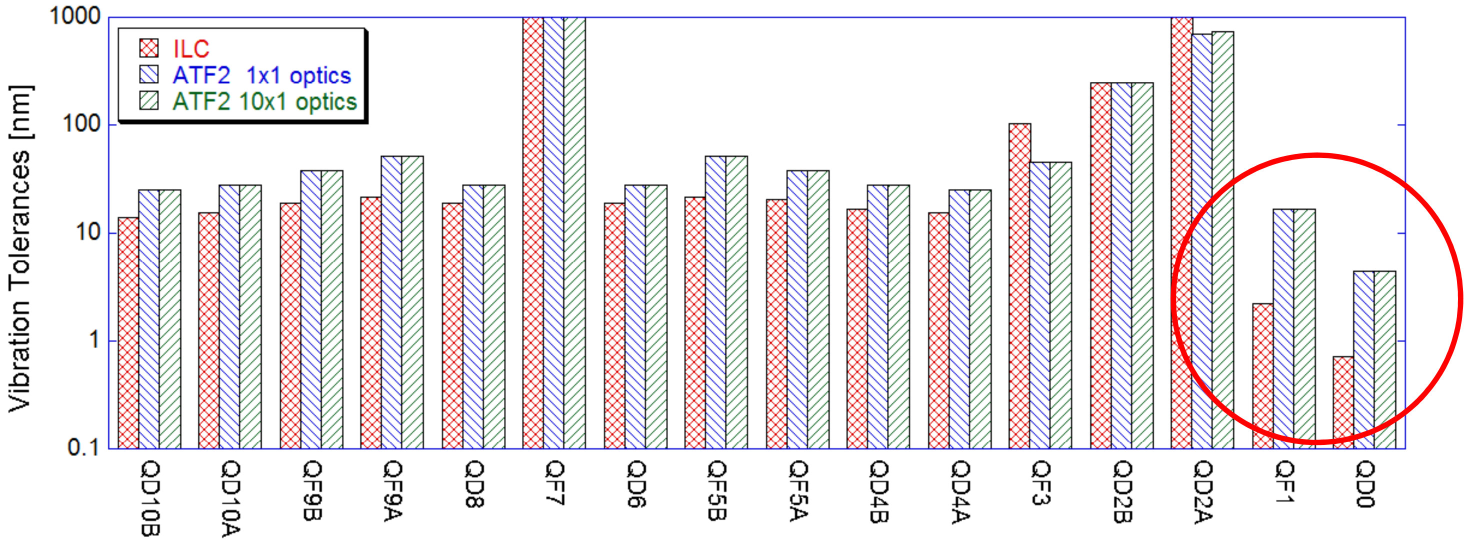
The effect of ILC higher order multipole field is comparable to ATF2 10x1 optics.

Vibrations of Quadrupole Magnets

Tolerances were defined by 2% of IP beam size growth.

2. Tolerances of the vibration of magnets

Since the magnet settings for 1x1 optics and 10x1 optics are same, the tolerances of the vibration are exactly same.



The tolerances for final doublet were much different.

Since the tolerances are only defined by quadupole strength and L, the tolerances are not sensitive to the optics design.*

	QF1	QD0
ILC	2.2nm	0.7nm
ATF2 1x1 optics	16.6nm	4.5nm
ATF2 10x1 optics	16.6nm	4.5nm

Stability of ATF2 Final Doublet

Andrea Jeremie (LAPP) presented the FD magnet position jitter at ATF2 meeting on 8/30/2013

2013 by Andrea JEREMIE (same analysis)	Tolerance	Measurement (between QD0)	Measurement (between new QF1)
Vertical	7 nm (for QD0) 20 nm (for QF1)	4.8 nm	30 nm
Parallel to the beam	~ 10,000 nm	25 nm	290 nm

Outside tolerance for 2% effect on beam!

A.Jeremie ATF2 Meeti 11

After we replaced the QF1 magnet, the vibration was increased.

***The stabilization of the magnet support is not enough*.**

The magnet position jitter was converted to the IP vertical beam size contribution

	QD0	QF1
Vertical	7.3 nm	12.6 nm
Parallel	0.4 nm	0.8 nm

Total IP vertical beam size contribution of magnet position jitter is 14.6 nm.
37.0 nm -> 39.8 nm (7.5% of IP vertical beam size growth)

Vertical Position Misalignments of Quadrupole Magnets

Tolerances were defined by 2% of IP beam size growth.

Tolerances were calculated with/without Linear optics correction used at ATF2

Linear Optics Corrections (same as ATF2 tuning)

Linear knobs are calculated by changing the positions of FF sexts.

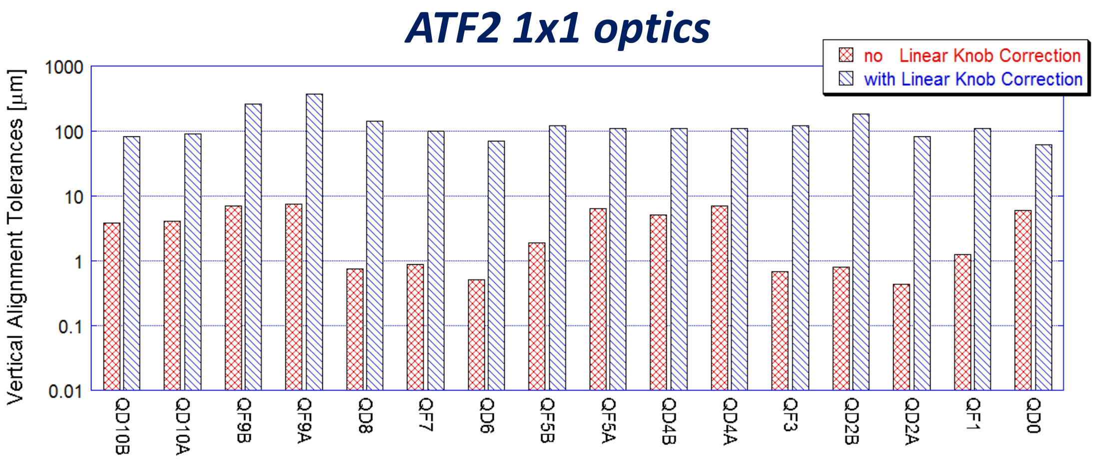
ΔX for FFsext -> change the alphaX, alphaY, etaX, etaX'

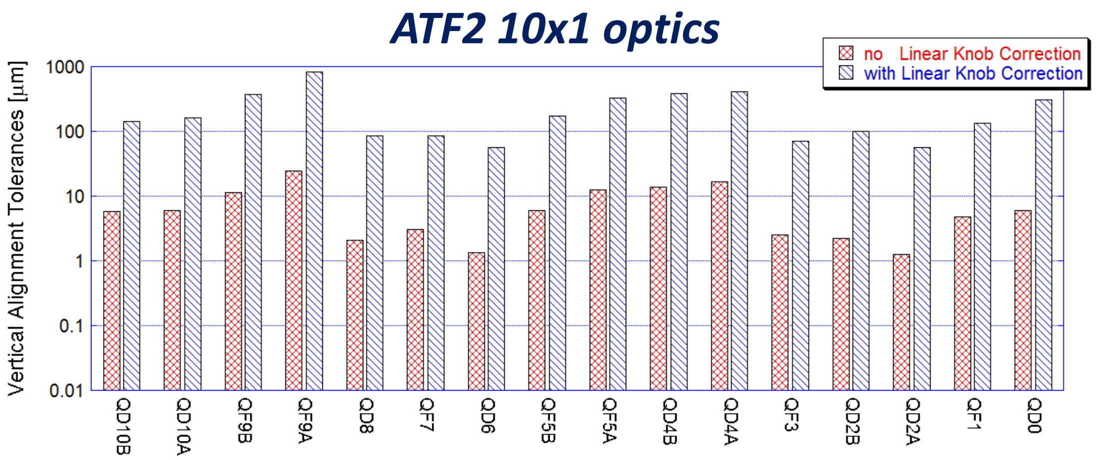
- *ΔX for SF6, SF5, SD4, SF1, SD0 are orthogonal to make alphaX, alphaY, etaX, etaX' knobs .*
- *One other free parameter is adjusted to make a large dynamic range of knobs.*

ΔY for FFsext -> change the etaY, etaY', <x'y>

- *ΔY for SF6, SF5, SD4, SF1, SD0 are orthogonal to make etaY, etaY', <x'y> knobs .*
- *Two other free parameters are adjusted to make a large dynamic range of knobs.*

3-1. Comparison with ATF2 1x1 optics and 10x1 optics (Vertical Misalignment)





no Linear knob correction

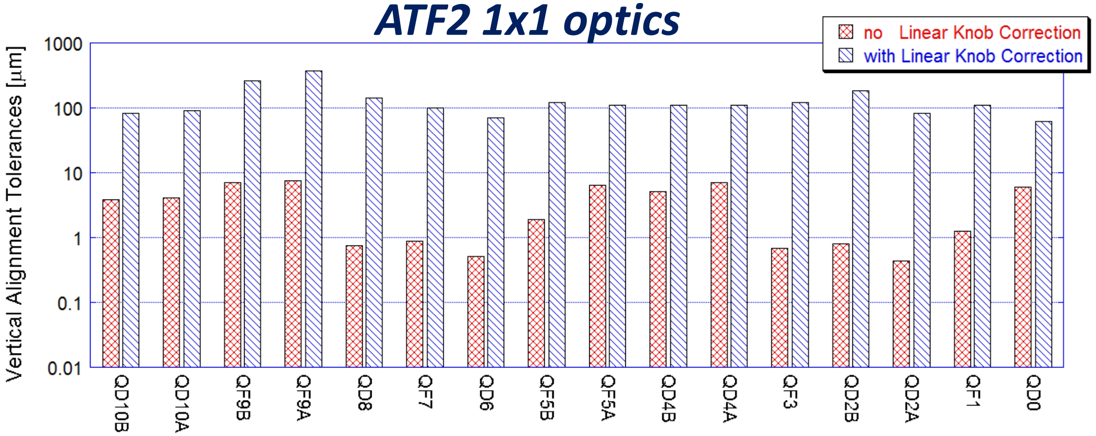
with Linear knob correction

The tolerances after linear knob correction were defined by nonlinear aberrations of off-center orbit at sextupole magnets.

The tolerance for 10x1 optics is a little bit larger than 1x1 optics, but ***the tolerances are around 100um for both optics.***

3-2 Comparison with ATF2 1x1 optics and ILC FF (Vertical Position Misalignment)

ATF2 1x1 optics

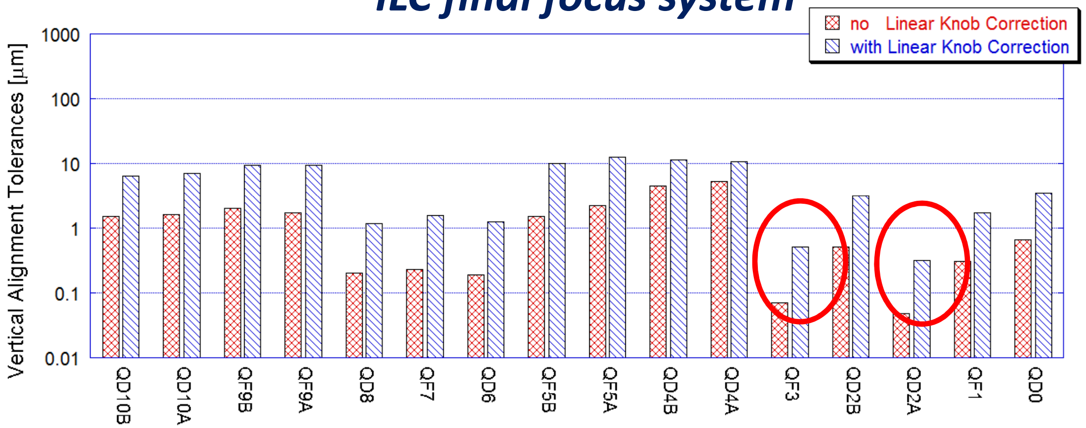


no Linear knob correction

with Linear knob correction

*The tolerances for most of the magnet are **around 100um after correction**.*

ILC final focus system



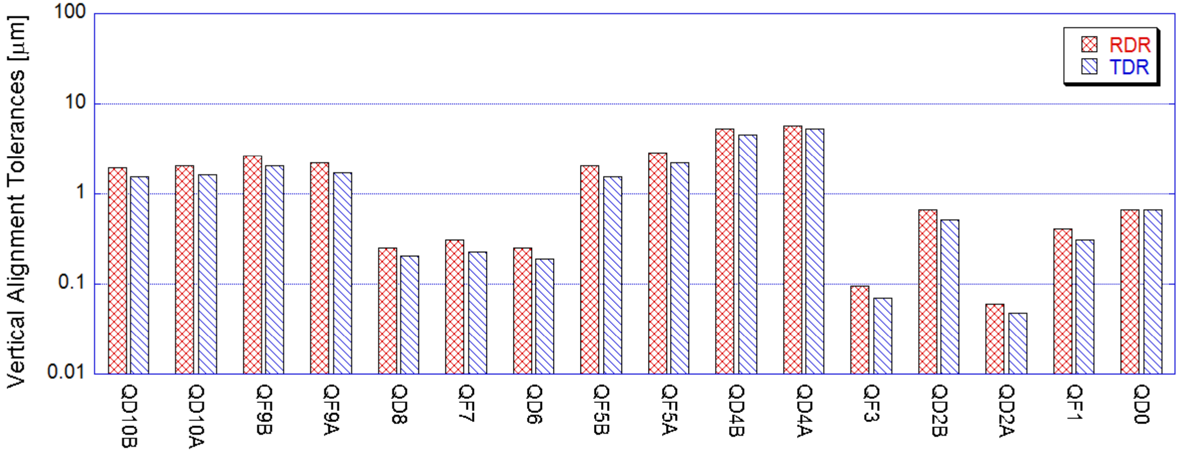
*The tolerances for most of the magnet are **less than 10um after correction.***

*The tolerances **for QF3 and QD2A are less than 1um**, even if we correct with linear knob.*

It seems difficult to apply the present ATF2 orbit tuning to ILC FF, and the precise BBA is required for the ILC FF.

3-3. Comparison with ILC RDR FF and ILC TDR FF

Tolerance of Vertical Misalignment (no Linear Knob Correction)



RDR parameter

βx^* = 0.021 m

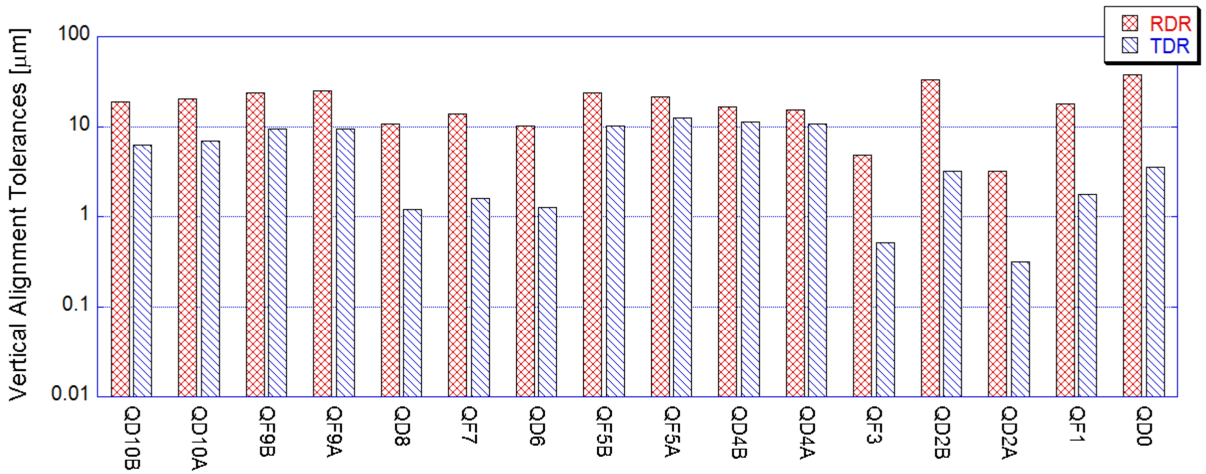
βy^* = 0.00040 m

TDR parameter

βx^* = 0.011 m

βy^* = 0.00048 m

Tolerance of Vertical Misalignment (with Linear Knob Correction)



	RDR	TDR
QF3	4.8µm	0.5µm
QD2B	33.3µm	3.2µm
QD2A	3.2µm	0.3µm

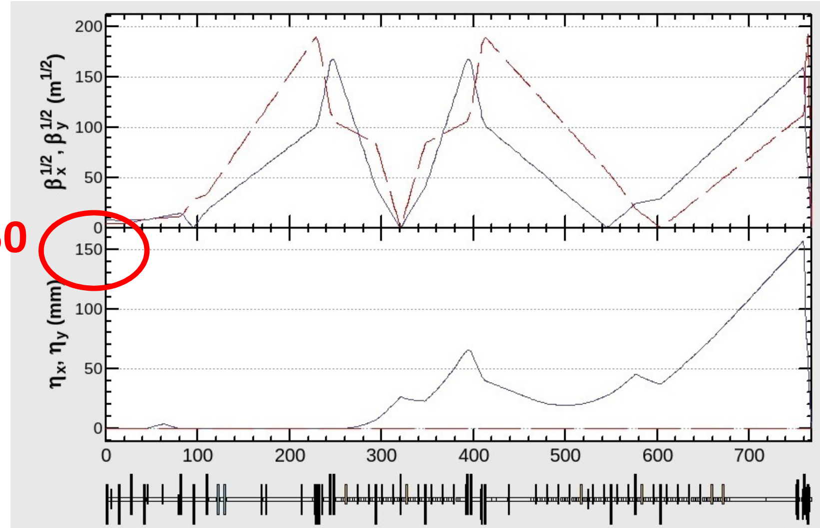
Tolerance after linear knob tuning were much different.

The tolerance for RDR is also still smaller than ATF2.

Are the sextupole fields too strong for ILC TDR parameters to make large vertical misalignment tolerances???

Temporal optics with small sextupole strength

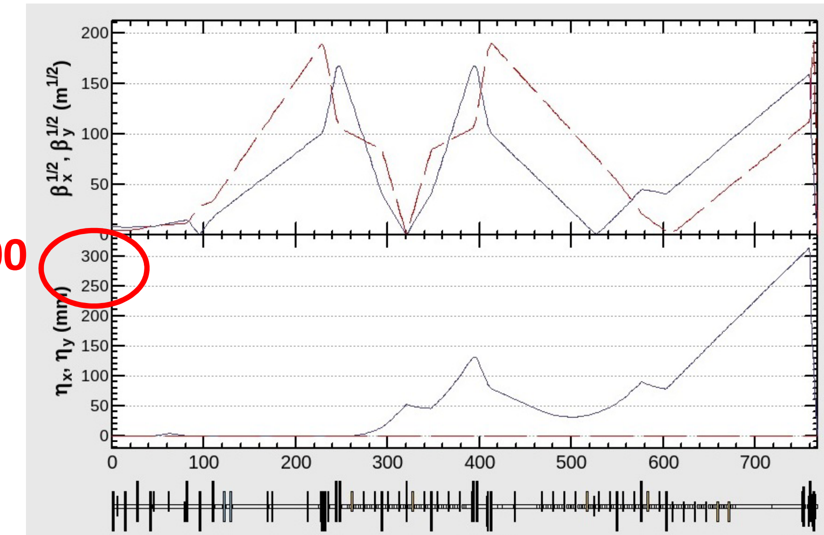
150



ILC TDR Final Focus

βx = 0.011 m*
βy = 0.00048 m*

300



Small K2 Optics

B5, B2, B1 are 2 times stronger than TDR parameter
(don't think about the synchrotron radiation)

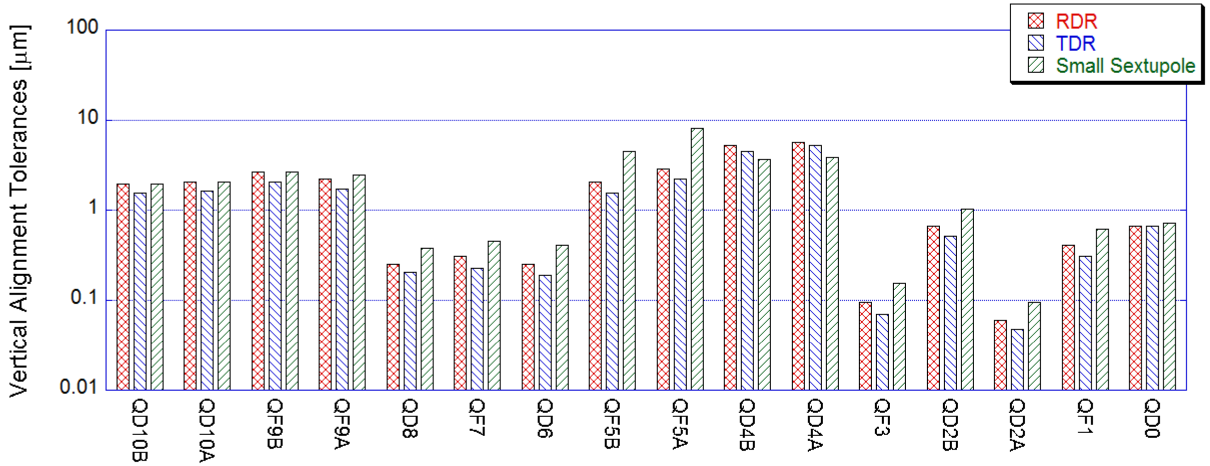
Sextupole strengths are a half to TDR parameter.

Quadrupoles are matched to ***same IP parameter to TDR.***

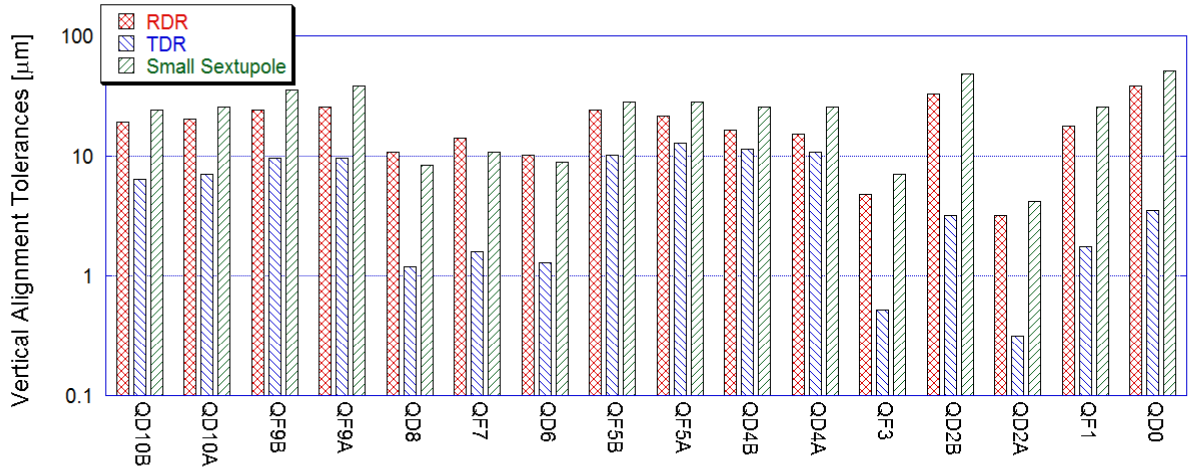
βx = 0.011 m*
βy = 0.00048 m*

3-4. Comparison with Small Sextupole Optics

Tolerance of Vertical Misalignment (no Linear Knob Correction)



Tolerance of Vertical Misalignment (with Linear Knob Correction)



RDR parameter

$\beta x^* = 0.021$ m

$\beta y^* = 0.00040$ m

TDR parameter

$\beta x^* = 0.011$ m

$\beta y^* = 0.00048$ m

Small Sextupole Optics

$\beta x^* = 0.011$ m

$\beta y^* = 0.00048$ m

By reducing the sextupole field,

tolerances are much improved

even if we set same beta !*

It was found that the sextupole fields are too strong at least for ILC TDR IP parameters to make large vertical misalignment tolerances.

We should optimize the IP parameters or beam optics for the ILC Final Focus Beamline.

Summary

Tolerances for multipole field errors

*Since the **bore diameter of ILC FF magnet are smaller than ATF2**,*
***the fabrication of ILC FF magnet is more difficult** than ATF2 Final Focus magnets.*
Not enough only by ATF2 results

However, the tolerances of ILC FF are comparable to ATF2 10x1 optics as aspect to the beam tuning.
The difficulty of ILC beam size tuning are comparable to ATF2 10x1 optics, if we make the tolerable magnets.
OK by ATF2 10x1 optics tests

Tolerances for magnet vibrations

***The tolerances of ATF2 final doublets are 16.6nm for QF1 and 4.5nm for QD0**,*
and the measured vibrations are a little bit larger than the tolerances (7.5% beam size growth)

*The tolerances of ILC magnet are smaller than ATF2, especially for final doublet (**sub-nm level**).*
*We must **make very stable floor, support, water and helium flow systems** for ILC final doublet.*
Not enough only by ATF2 results

Tolerances for vertical magnet alignments

TDR FF beamline is same as RDR FF beamline, and matched the beta to TDR IP parameters.*
*Tolerances for ILC TDR are **not only smaller than ATF2, but also much smaller than RDR.***
*The tolerances are **limited by the strong sextupole fields**.*
We should optimize the IP parameters or FF beam optics of ILC Final Focus Beamline.

*The most of the tolerances for **ATF2 magnets are around 100um** after linear knob tuning,*
*on the other hands, most of tolerances for **ILC magnets are 10um** even for RDR optics.*
We should improve BBA technique from ATF2 orbit tuning procedure.
However, since all of ATF2 magnets are on mover, ATF2 have a capability to develop the BBA technique .

We should compare the CLIC final focus beam line too.