

ILC FFS optics optimization

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LCWS14

Inn Vinca (SERBIA)

Introduction

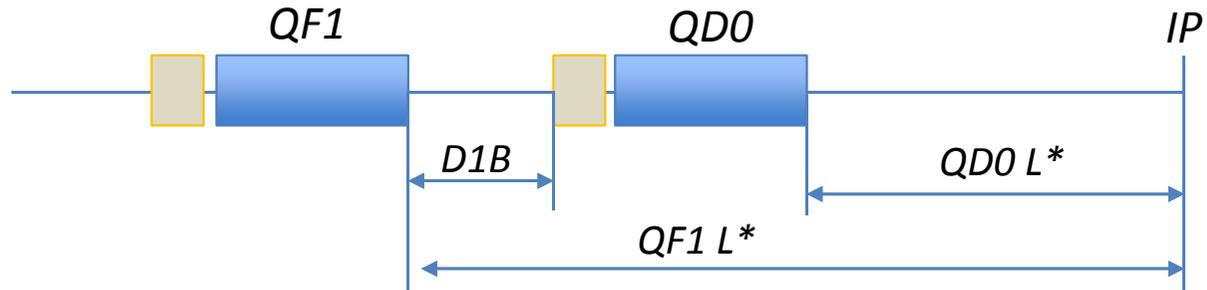
QD0 position dependence

QF1 position dependence

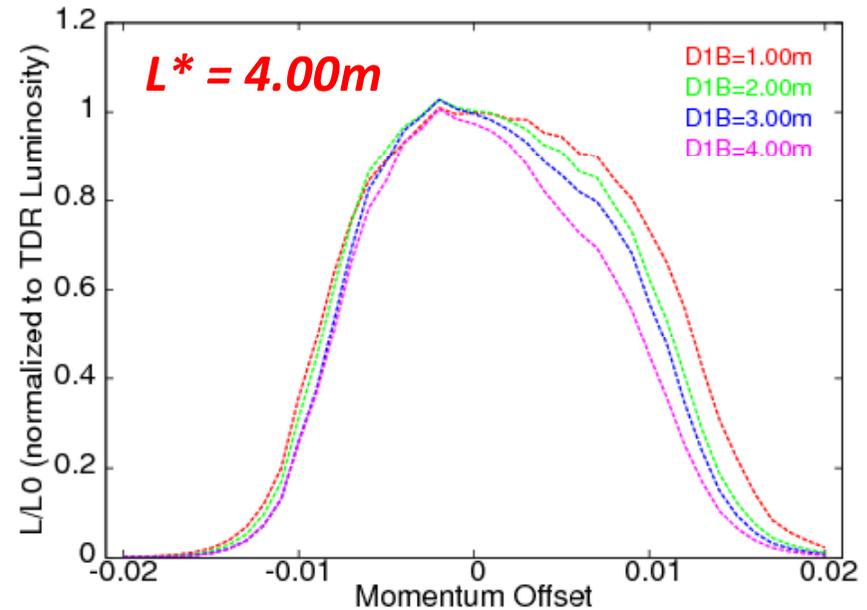
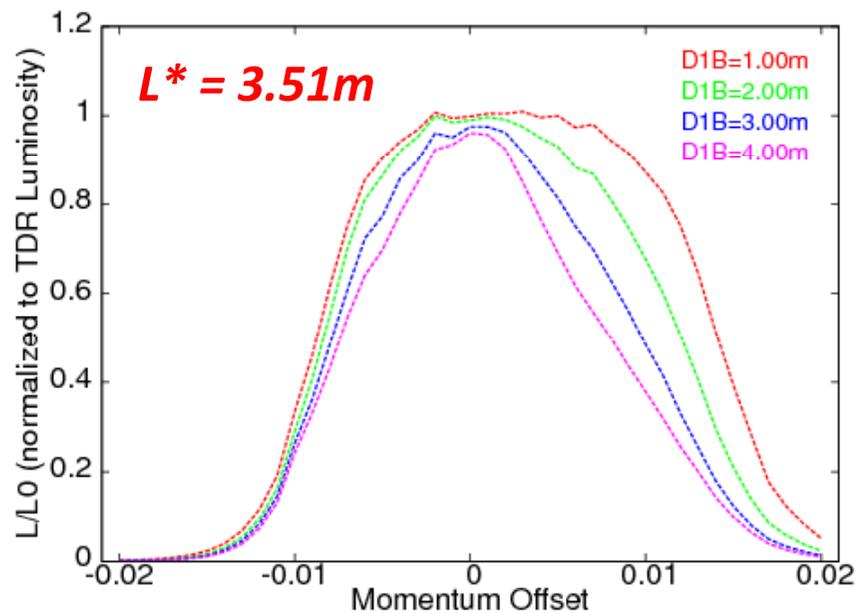
$E_{CM}=250\text{GeV}$ operation

Introduction

Presented at BDS meeting at 2014/09/04 by T.Okugi



Bandwidths for optimized optics (not only strength of quad, but also quad location)



Not only $QD0 L^*$, but also $QF1 L^*$ is important.
The $QF1 L^*$ is set to 9.5m for push-pull scheme.
Can the $QF1 L^*$ make shorter ?

Presentation from Detector Group

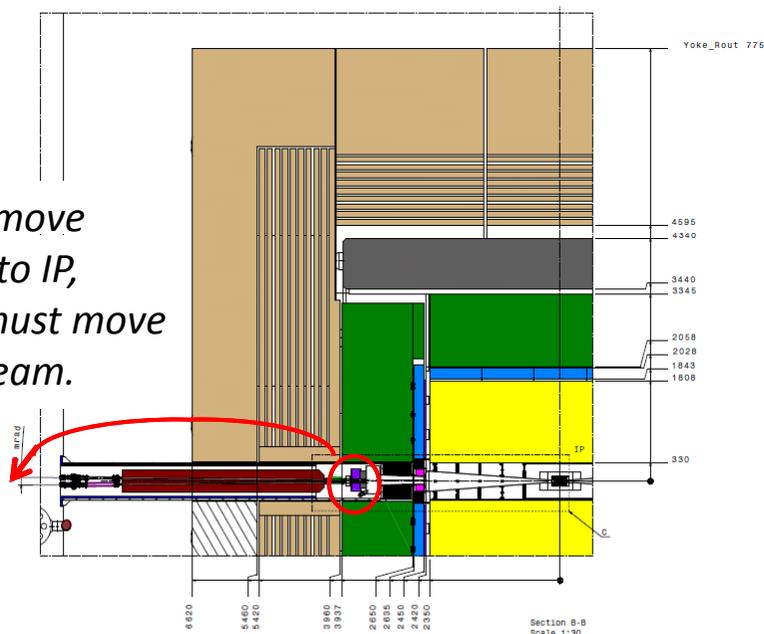
at MDI/CFS meeting at 2014/09/05 in Ichinoseki

ILD L* Issue

presented by Karsten Buesser

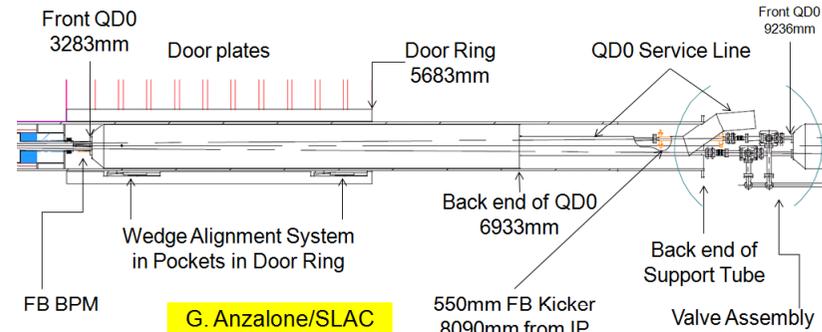
ILD Dimensions

When QD0 move to be close to IP, Ion pump must move to downstream.



SiD L* Issue

presented by Tom Markiewicz



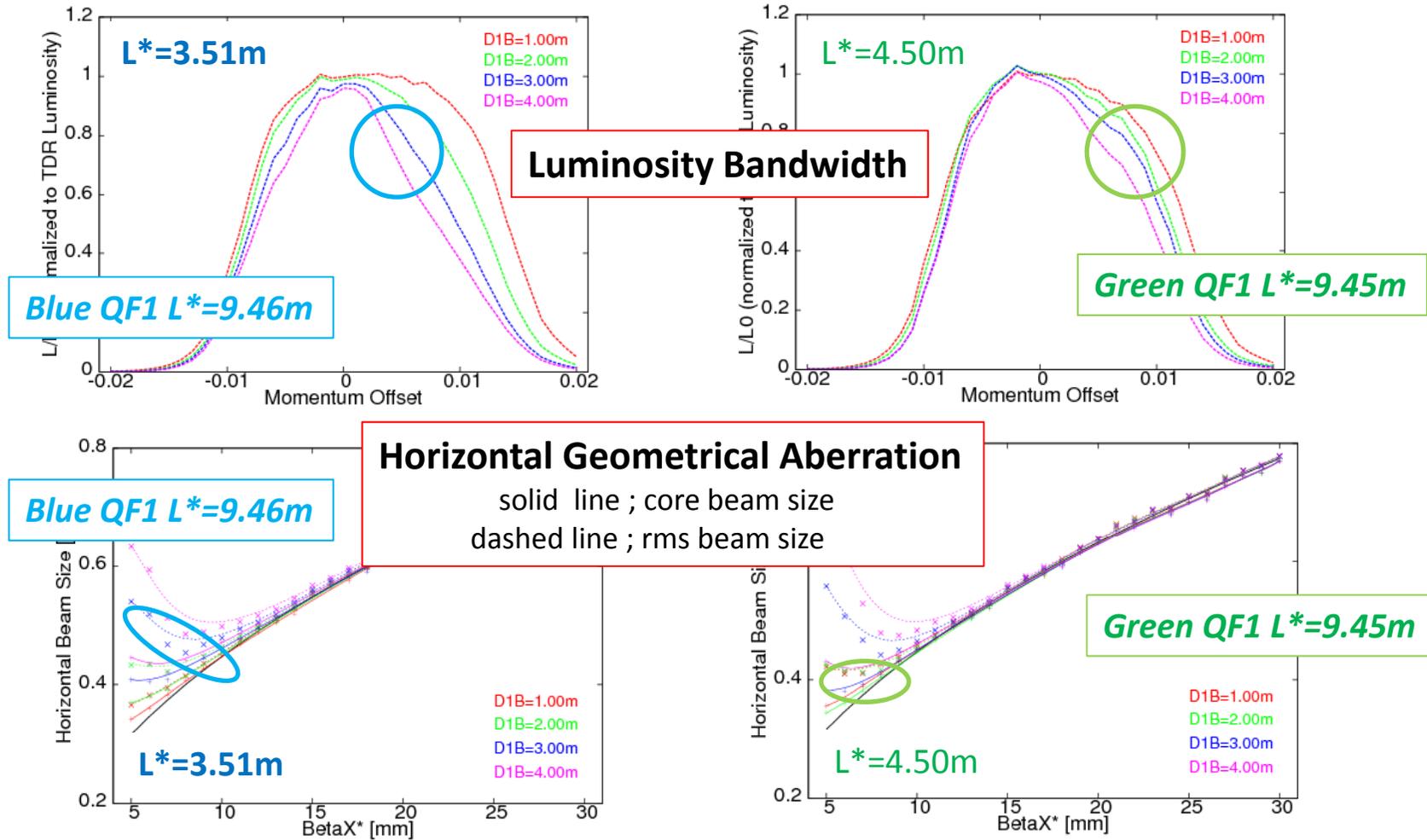
- Ion pump
 - Vacuum port
 - FB kicker
- must put in between SD0 and QF1 .

It is difficult to shorten QF1 L* so much for present design.

Therefore, we should optimize the FF optics to be fixed to around QF1 L*=9.50m at first.

Performances of the optics around QF1 $L^*=9.5m$

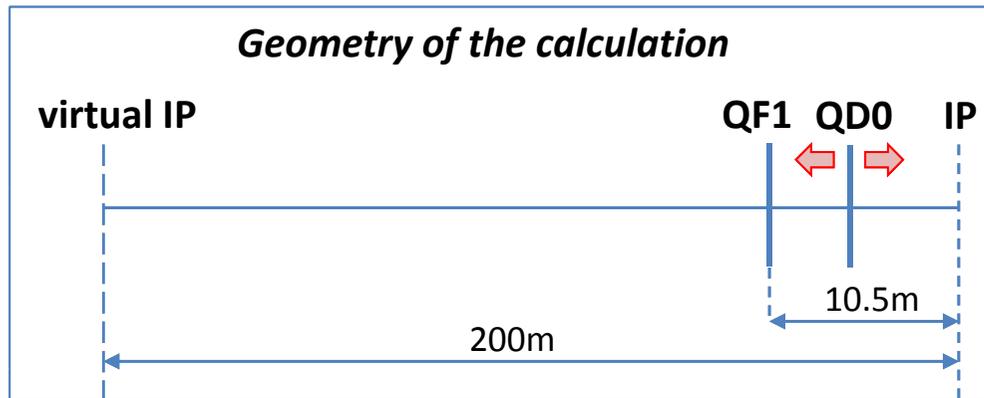
presented at the discussion at MDI/CFS meeting at 2014/09/06 by T.Okugi.
(same data was presented at BDS meeting at 2014/09/04.)



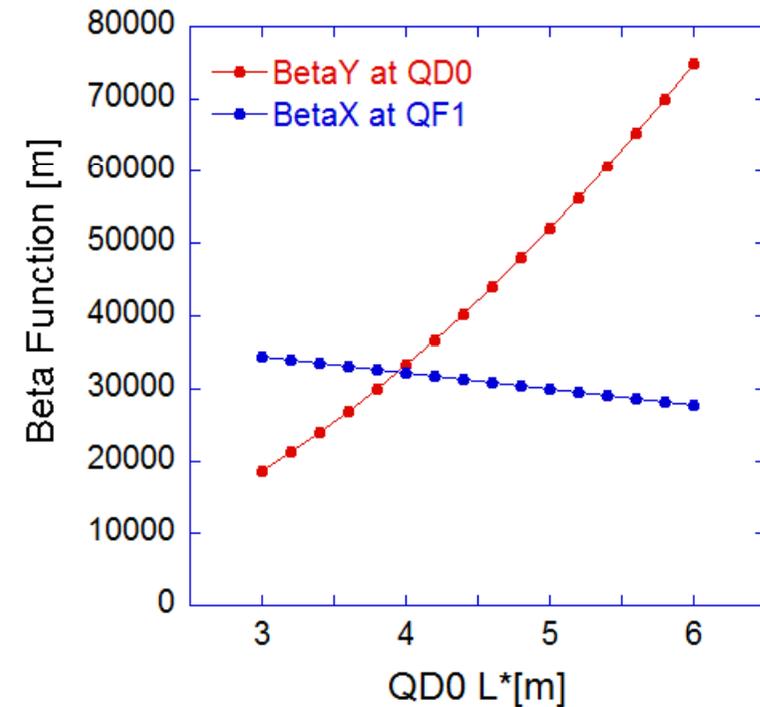
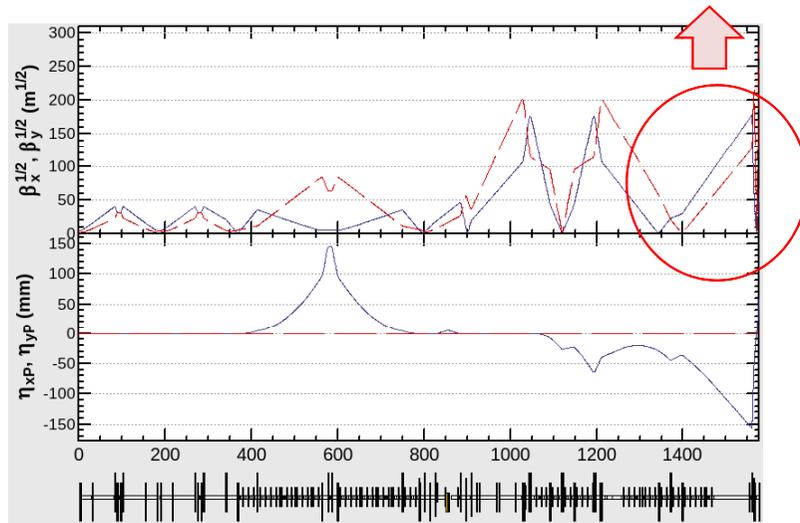
It seems better for $L^=4.50m$?*

We should check not only bandwidth and geometric aberration, but also others.

Beta functions at Final Doublet, when QF1 position is fixed



The beta functions at FD was calculated by thin lens approximation.



When QD0 is move to be closer to IP, the vertical beta function at QD0 is decreased.
On the other hand, the horizontal beta function at QF1 is increased.
Since most of difficulties come from the horizontal beam size at QF1,
we must optimize the QD0 location carefully.

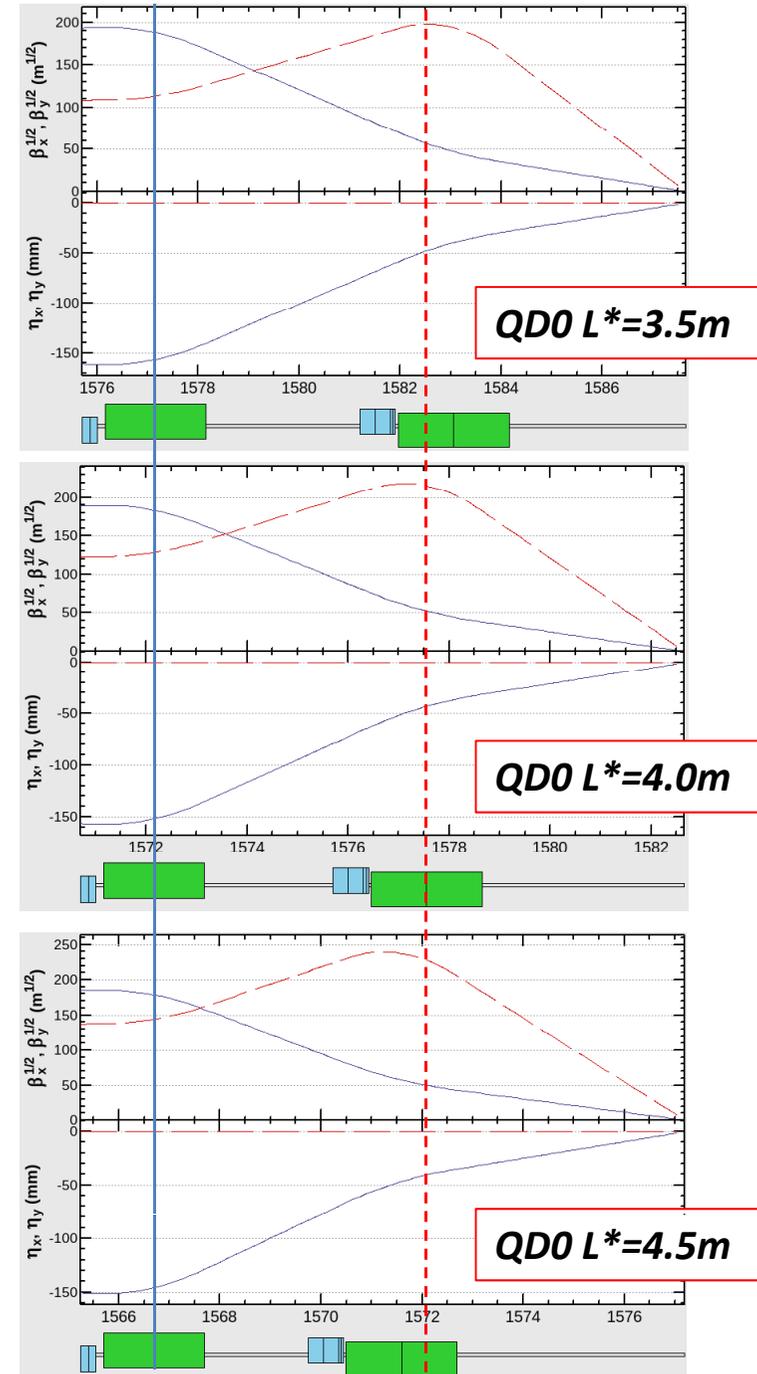
Optics was optimized with 3 different QD0 L*

Parameter list of optimized optics

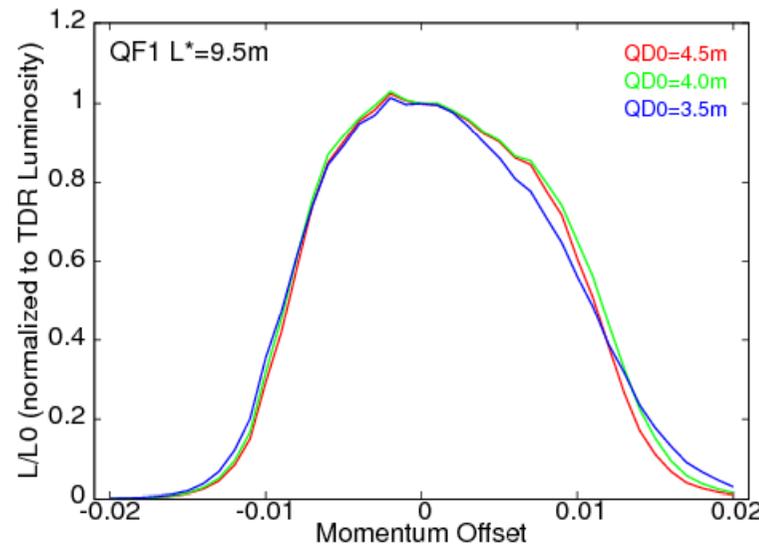
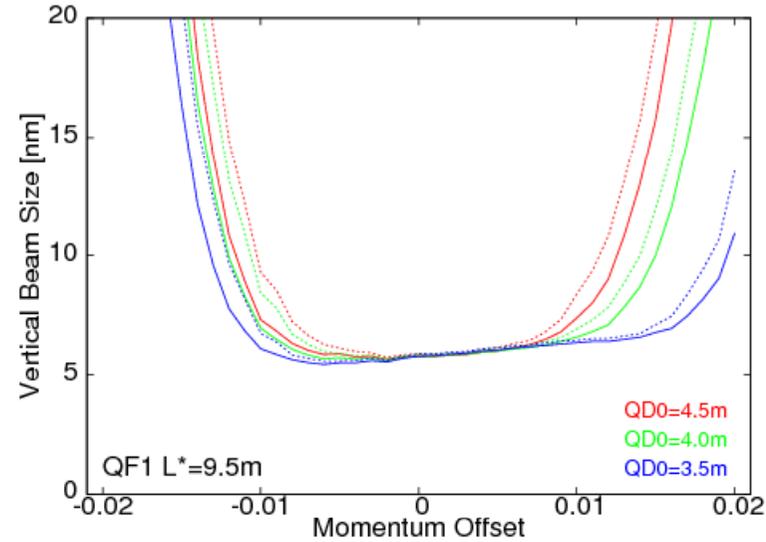
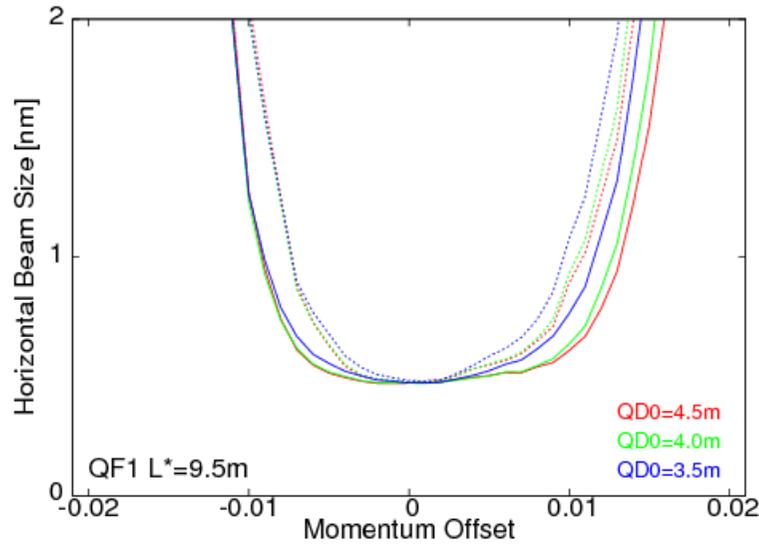
QD0	L*	3.5m	4.0m	4.5m
	Length	2.2m	2.2m	2.2m
	Center to IP	4.6m	5.1m	5.6m
	betaY	37,607m	46,523m	56,330m
QF1	L*	9.5m	9.5m	9.5m
	Length	2.0m	2.0m	2.0m
	Center to IP	10.5m	10.5m	10.5m
	betaX	35,343m	33,611m	31,977m

The length of beamline are different for all QD0 location, because the distances between QD4A and QD2B, QD2A and QF1 are adjusted to optimize the bandwidth.

When the QD0 L* is shorter by keeping QF1 L*=9.5m, the vertical beta function at QD0 is decreased, but horizontal beta function at QF1 is increased as expected.



Energy bandwidths for various QD0 locations



*The bandwidth for horizontal beam size will be wider, when we set to longer QD0 L^**

The bandwidth for vertical beam size will be wider, when we set to shorter QD0 L^ .*

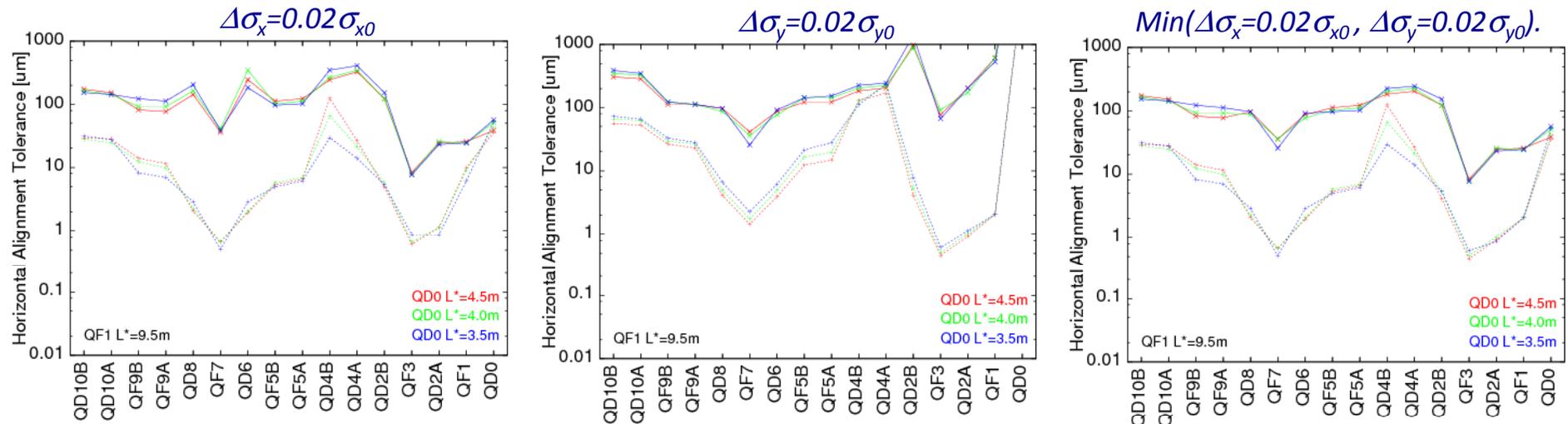
(agreement with the expectation !)

Luminosity bandwidth for $L^=3.5\text{m}$ is smaller than others, but not so much.*

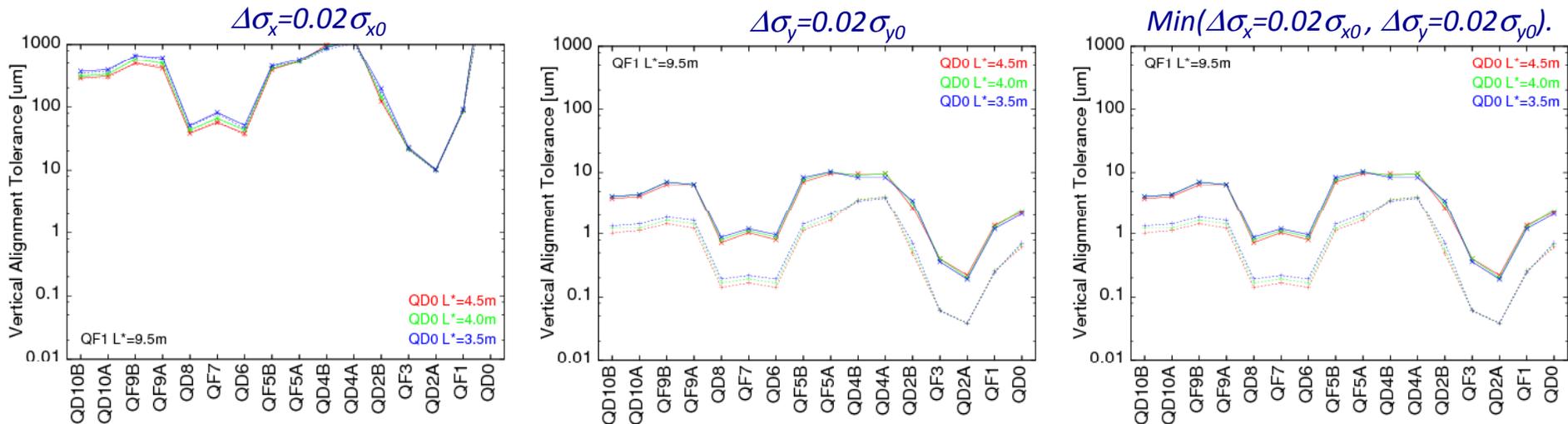
Alignment tolerances for various QD0 locations

Horizontal Alignment Tolerances

solid line ; after 2 iterations of linear knob correction
dash line ; no linear knob correction



Vertical Alignment Tolerances

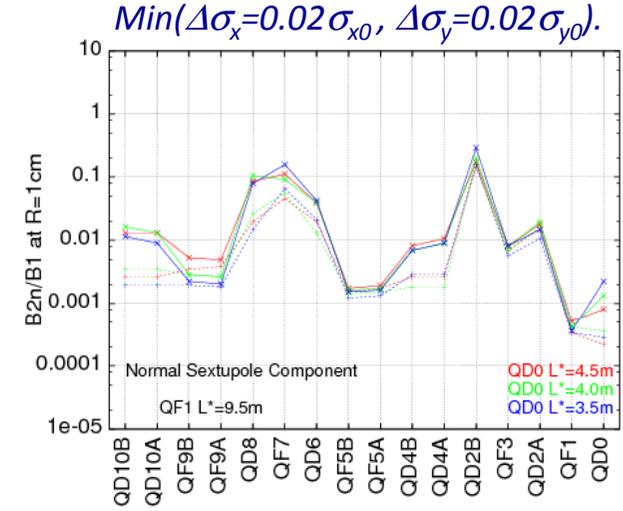
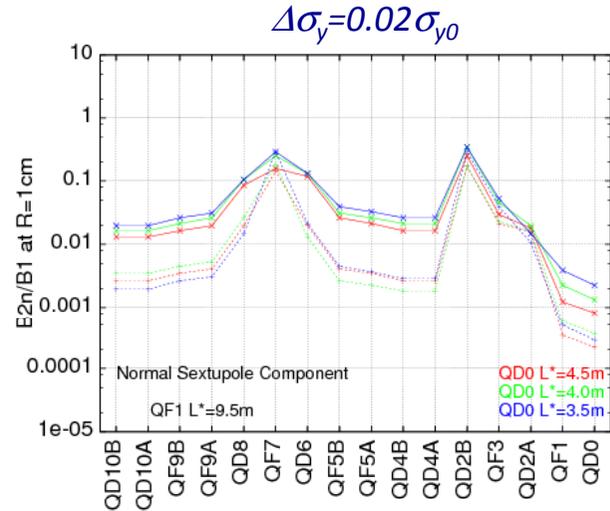
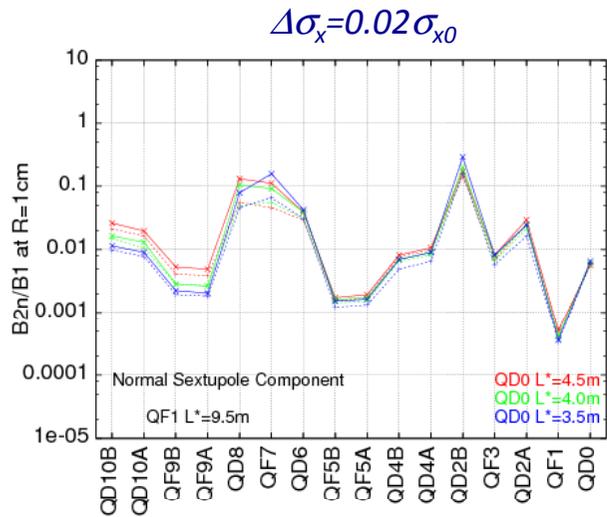


The alignment tolerance was not changed so much for QD0 location.

Sextupole field errors for various QD0 locations

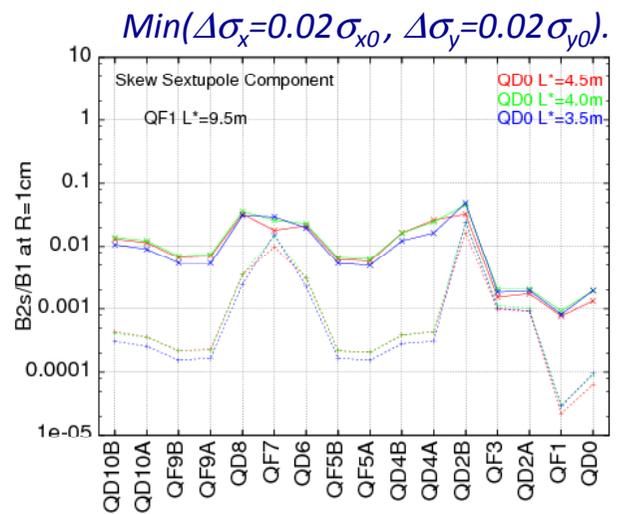
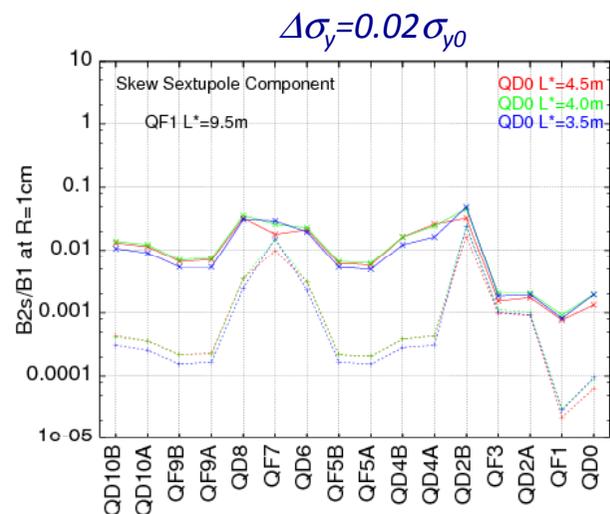
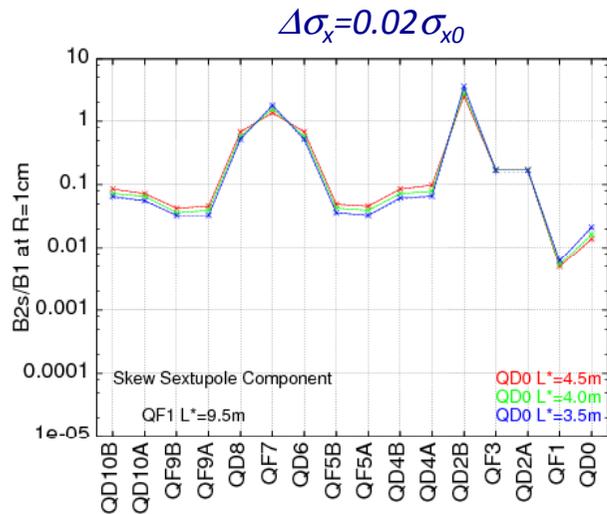
Tolerances for Normal Components

solid line ; after 2 iterations of 2nd order knob correction
 dash line ; no 2nd order knob correction



Tolerances for Skew Components

solid line ; after 2 iterations of 2nd order knob correction
 dash line ; no 2nd order knob correction

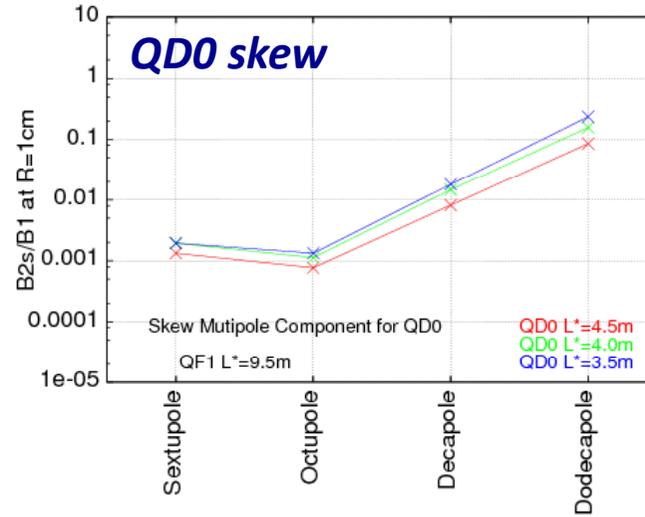
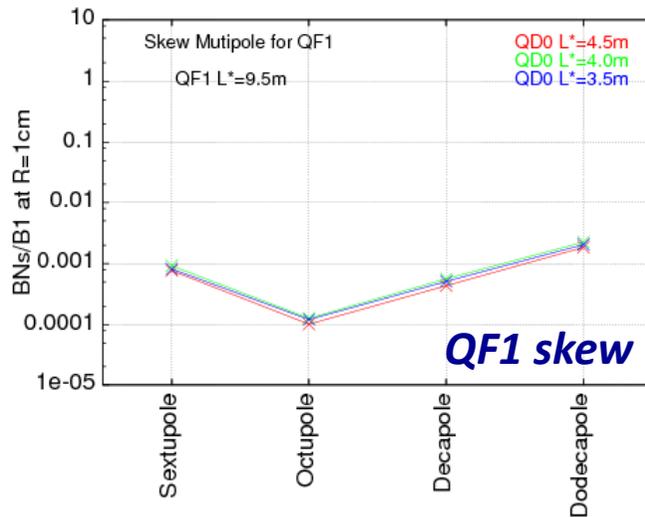
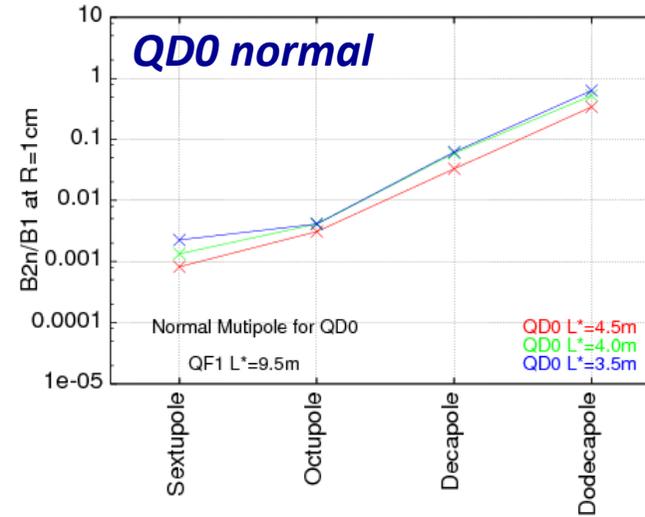
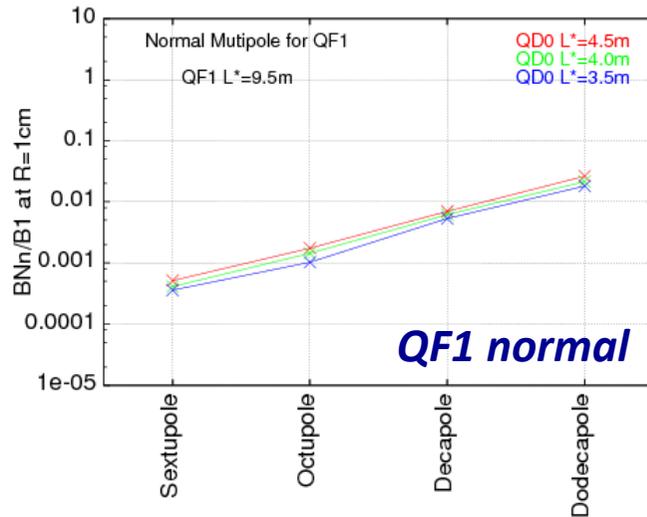


The tolerance of sextupole field error for FF quad was not so tight by applying 2nd order optics correction.

FD multipole tolerances for various QD0 locations

Tolerances were defined by $\text{Min}(\Delta\sigma_x=0.02\sigma_{x0}, \Delta\sigma_y=0.02\sigma_{y0})$.

The 2nd order optics correction was done twice for sextupole field errors.



Tolerances of QF1 was a little bit larger for longer QD0 L*.
Tolerances of QD0 was a little bit larger for shorter QD0 L*.
But, the tolerances were not so tight for every cases.

Consideration of collimation depth

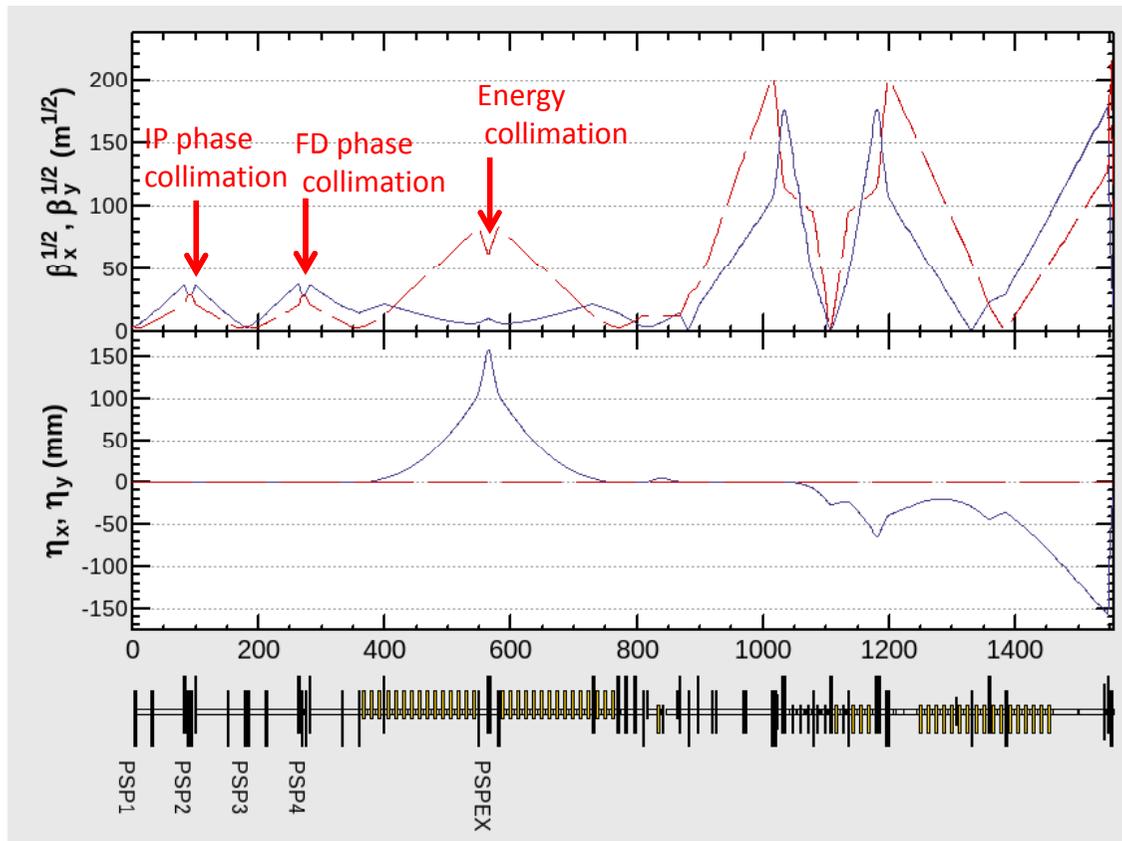
Arrangement of the Collimators

Beta Function at SP2/SP4 = (X; 1000m / Y; 1000m)

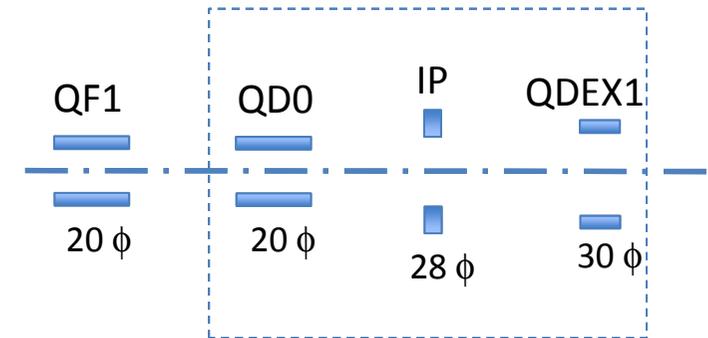
Phase Advance (SP2/SP4) = (X; 0.5π / Y; 1.5π)

Phase Advance (SP4/ IP) = (X; 5.5π / Y; 4.5π)

EtaX at SPEX = 0.158m



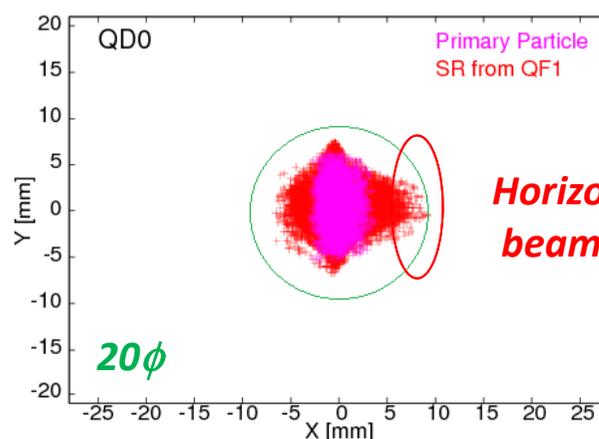
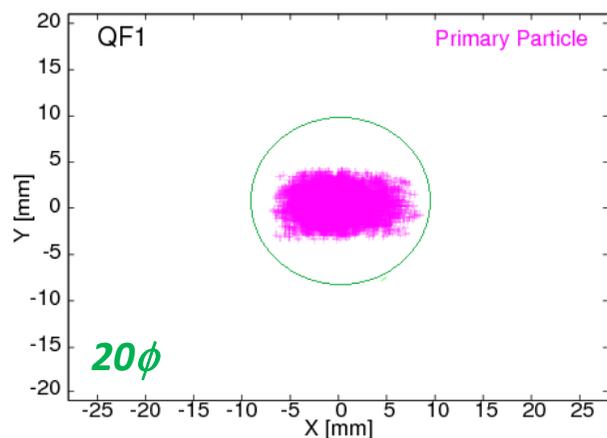
Detector apertures



Source for background

- 1) Halo particles
- 2) SR form halo particles

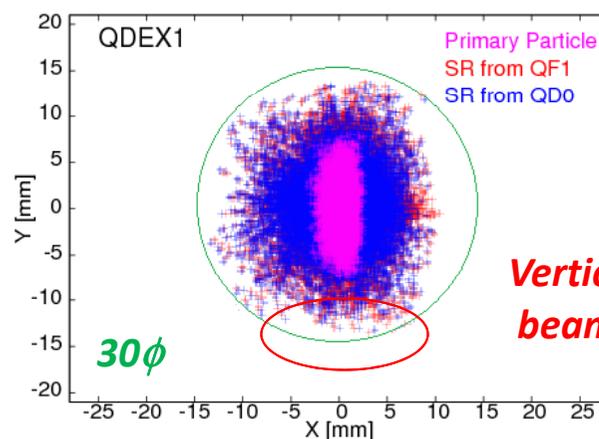
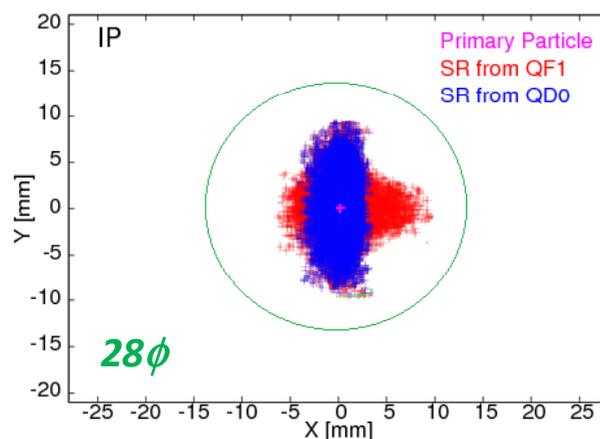
Example of beam halo simulation



FD locations

QD0 (2.2m) $L^* = 3.5m$

QF1 (2.0m) $L^* = 9.5m$



SP2/SP4 X ; 0.86mm

SP2/SP4 Y ; 0.98mm

SPEX X ; 1.60mm

($\Delta p/p = 1\%$)

Horizontal aperture was limited by SR at QD0.

Vertical aperture was limited by SR at QDEX1.

Since I did not yet include the beam orbit offset by the alignment errors and their tuning, the collimation depth is defined by **70% of aperture limit** (X; 0.60mm, Y; 0.69mm) here.

The actual collimation depth should be evaluated by simulation with alignment error and its correction.

Collimation depths for various QD0 locations

Collimation depth was calculated for $E_{cm}=500\text{GeV}$.

(QF1 L^*) = 9.5m ($L = 2.0\text{m}$)
(Half aperture of SPEX) = 1.60 mm ($\Delta p/p = 1\%$)

QD0 L^*	Collimator Half Aperture (SP2/SP4)	
	X collimator	Y collimator
$L^*=3.5\text{m}$	0.60mm (4.2 σ)	0.69mm (82 σ)
$L^*=4.0\text{m}$	0.62mm (4.4 σ)	0.59mm (70 σ)
$L^*=4.5\text{m}$	0.65mm (4.6 σ)	0.51mm (61 σ)

When the QD0 L^ is shorter by keeping QF1 $L^*=9.5\text{m}$,
the vertical collimation depth is relaxed, but horizontal collimation depth is tighter a little bit.*

We had better to keep the large horizontal collimation depth especially for small energy.

On the other hand, we can increased the vertical aperture by changing the betaY at SP2/SP4.

Summary of QD0 location

Energy bandwidth

- $L^* = 3.5\text{m}$ is smaller than others, but not so much
- $L^* = 4.0\text{m}$ and $L^* = 4.5\text{m}$ are almost same.

Alignment error tolerances

- Very tight (some magnets are less than $1\mu\text{m}$)
- No clear dependences in between $L^* = 3.5\text{-}4.5\text{m}$.

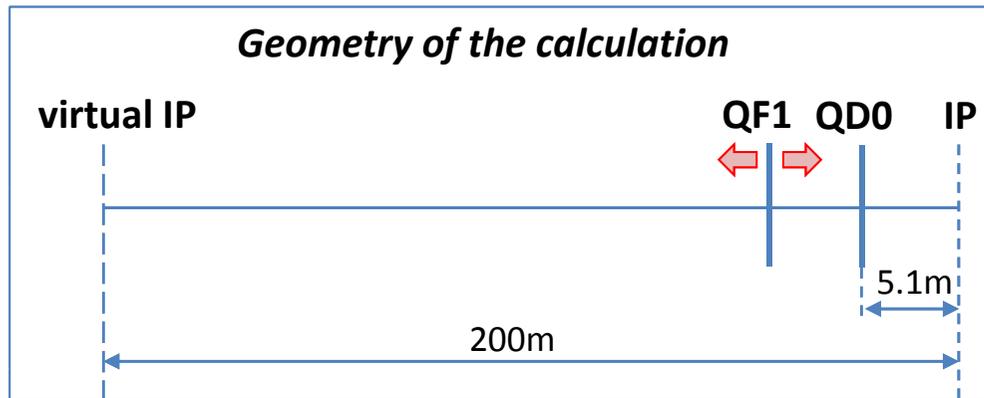
Multipole field error tolerances

- Not so tight after applying 2nd order optics correction.
- No clear dependence in between $L^* = 3.4\text{-}4.5\text{m}$.

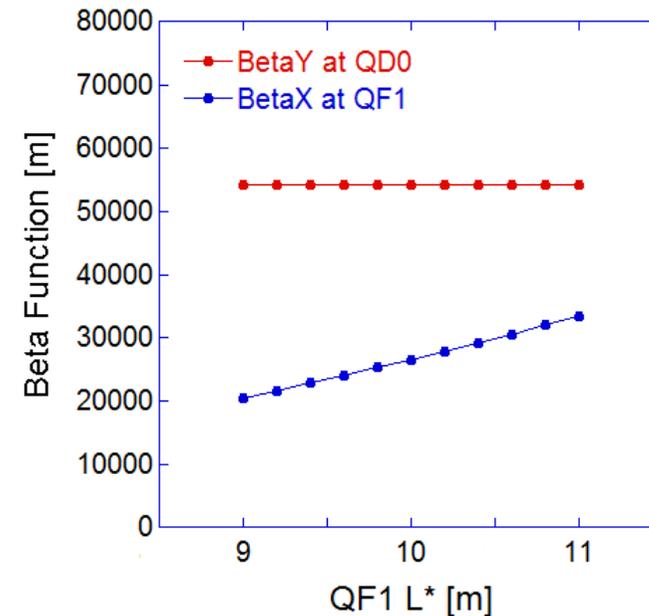
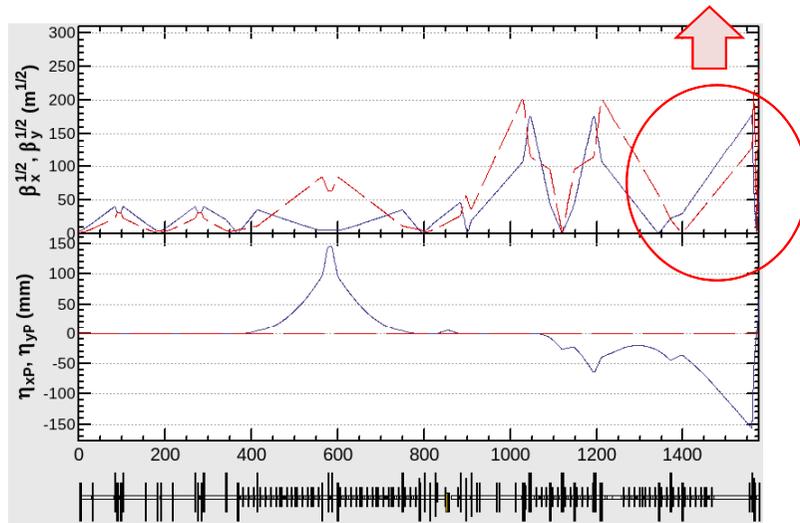
Collimation Depth

- Horizontal direction is better for $L^* = 4.5\text{m}$ (still less than 5σ).
- Vertical direction is better for $L^* = 3.5\text{m}$.
- The horizontal collimation depth is determined by SR at QF1.
- The vertical collimation depth is determined by SR at QDEX1.

Beta functions at Final Doublet, when QD0 position is fixed



The beta functions at FD was calculated by thin lens approximation.



When QF1 is move to be closer to IP, the horizontal beta function at QF1 is decreased, by keeping the vertical beta function at QD0.

Since most of difficulties come from the horizontal beam size at QF1, we must optimize not only QD0 location, but also QF1 location carefully.

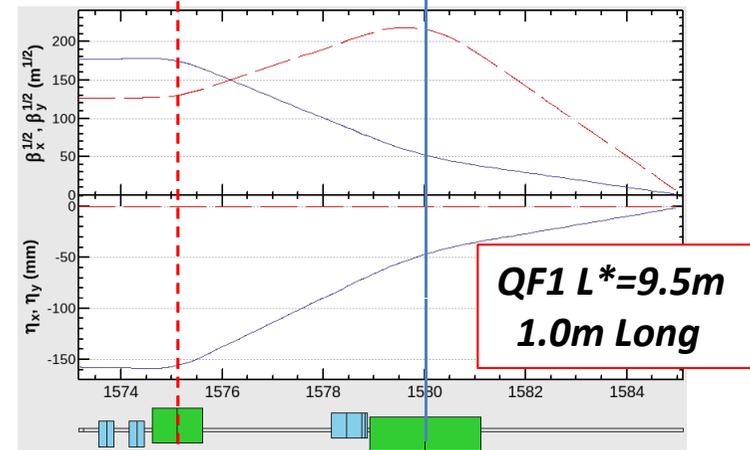
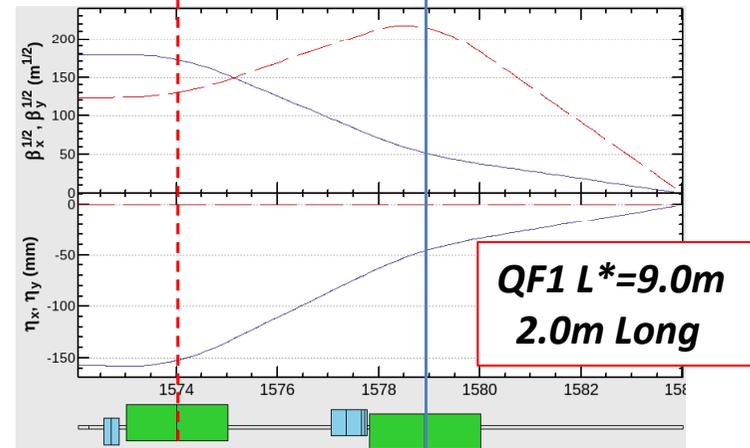
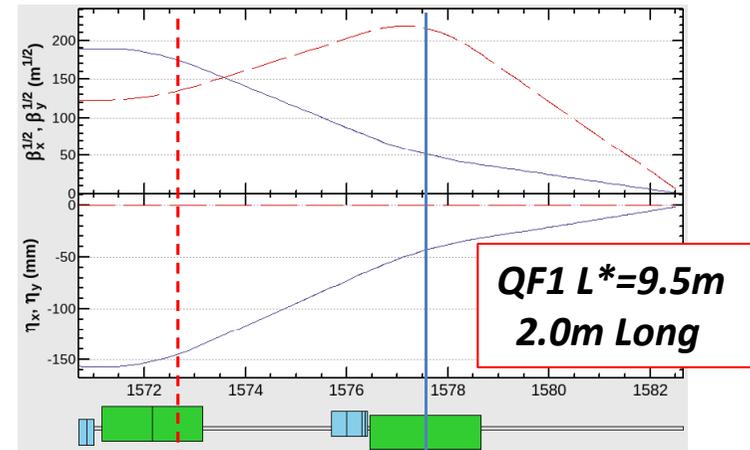
QF1 location dependence

Parameter list of optimized optics

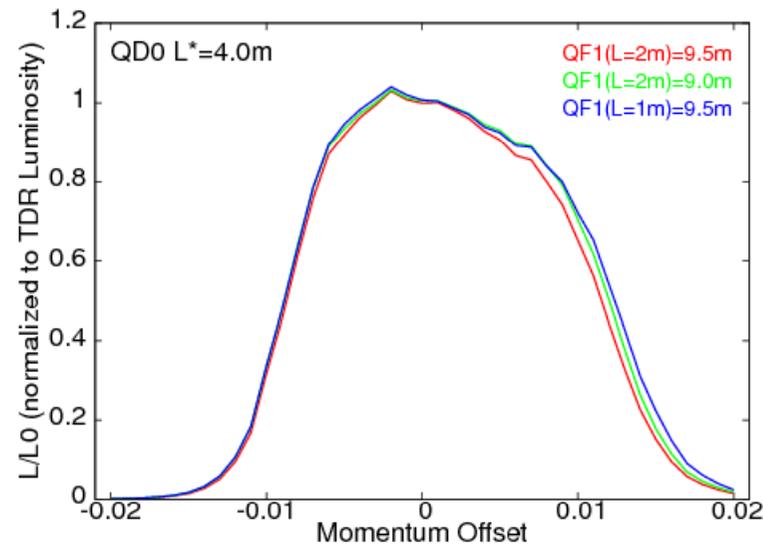
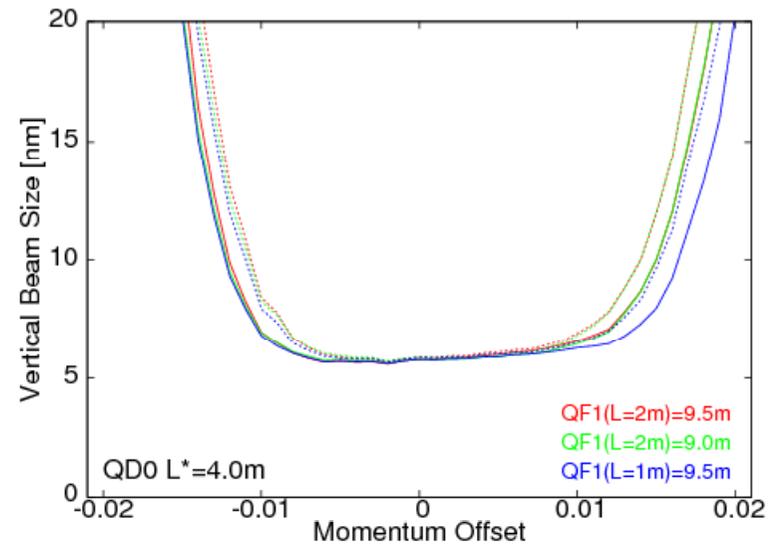
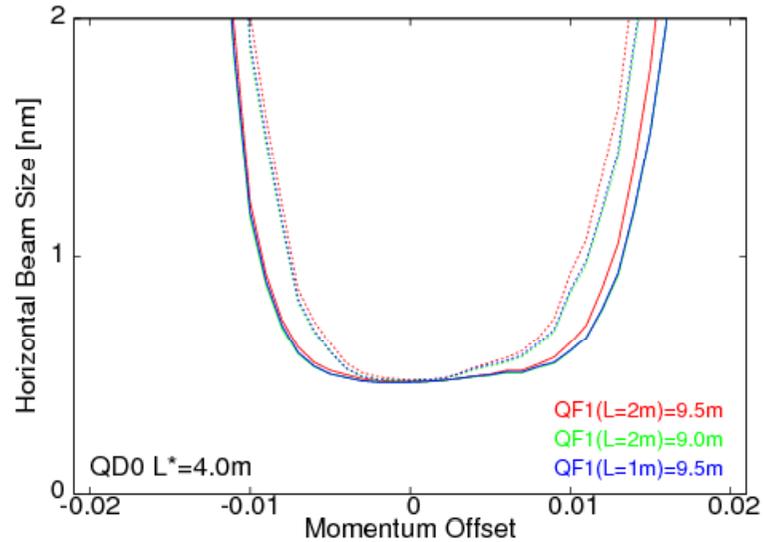
QD0	L*	4.0m	4.0m	4.0m
	Length	2.2m	2.2m	2.2m
	Center to IP	5.1m	5.1m	5.1m
	betaY	46,523m	46,291m	46,376m
QF1	L*	9.5m	9.0m	9.5m
	Length	2.0m	2.0m	1.0m
	Center to IP	10.5m	10.0m	10.0m
	betaX	33,611m	29,871m	30,630m

When the QF1 L* is shorter by keeping QD0 L*=4.0m, the horizontal beta function at QF1 is decreased.

B. Parker suggested to use shorter QF1 magnet to make QF1 location to be close to IP effectively at MDI/CFI meeting (2014/9/6).



Energy bandwidths for various QF1 locations



The bandwidth of the horizontal beam size was wider for shorter QF1 center position.

The bandwidths of vertical beam sizes was independent to QF1 L.*

But, short QF1 increased a little bit.

The luminosity bandwidth is better for

1) short QF1, QF1 L=9.5m*

2) long QF1, QF1 L=9.0m*

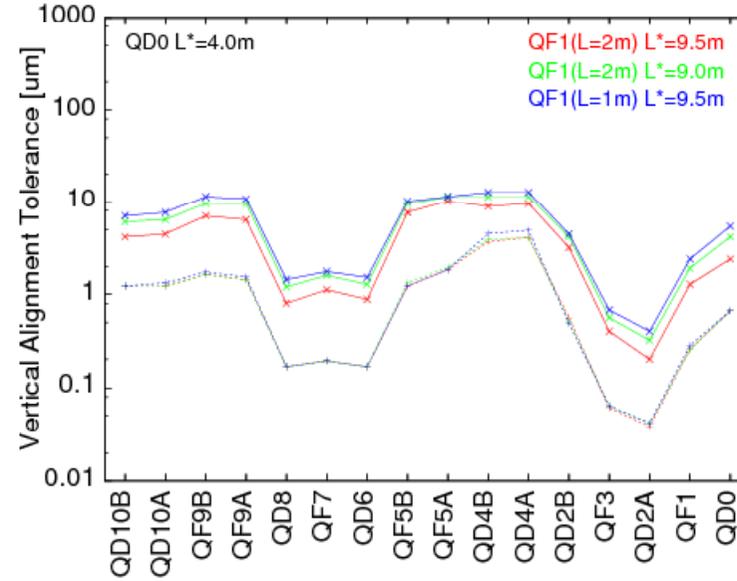
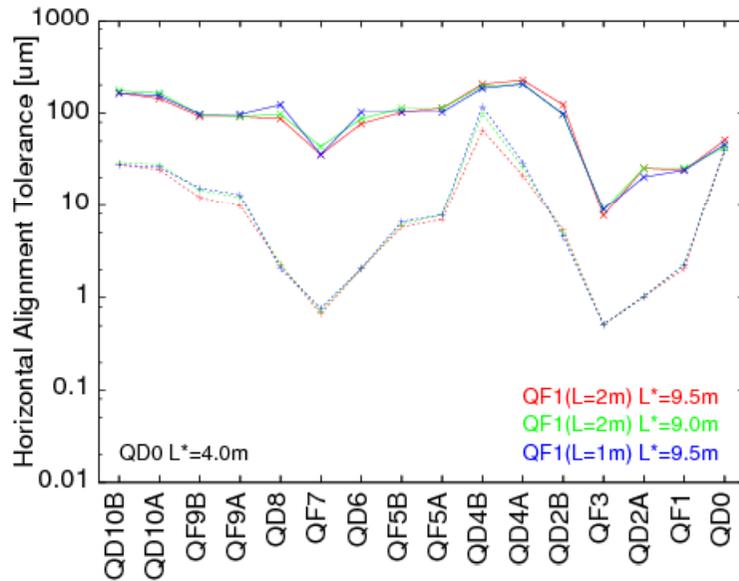
3) long QF1, QF1 L=9.5m*

, but the difference was not so much.

Alignment tolerances for various QF1 locations

Alignment tolerance was defined as $\text{Min}(\Delta\sigma_x=0.02\sigma_{x0}, \Delta\sigma_y=0.02\sigma_{y0})$.

solid line ; after 2 iterations of linear knob correction
dash line ; no linear knob correction



Vertical alignment tolerances (with linear knob correction)

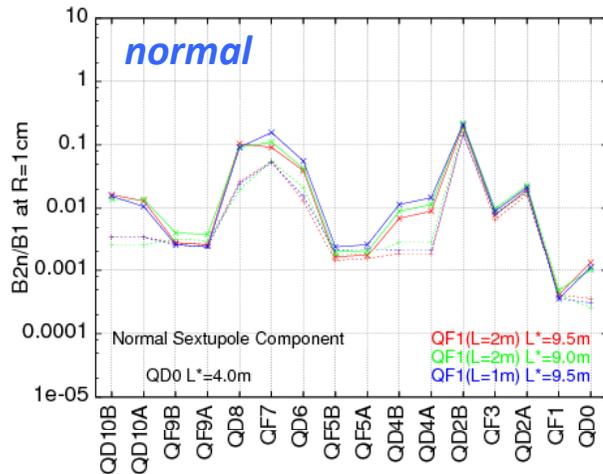
QF1 L*	QF1 L	QD2B	QF3	QD2A	QF1	QD0
9.5m	2.0m	3.20um	0.40um	0.20um	1.28um	2.40um
9.0m	2.0m	4.16um	0.56um	0.32um	1.92um	4.16um
9.5m	1.0m	4.48um	0.68um	0.40um	2.40um	5.44um

The QF1 L*=9.5m (L=1.0m) is best,
but the tolerances for some magnets are still less than 1um.

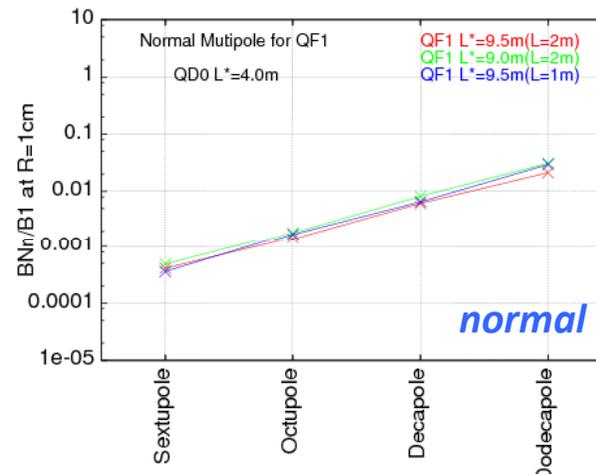
Multipole error tolerances for various QF1 locations

Alignment tolerance was defined as $\text{Min}(\Delta\sigma_x=0.02\sigma_{x0}, \Delta\sigma_y=0.02\sigma_{y0})$.

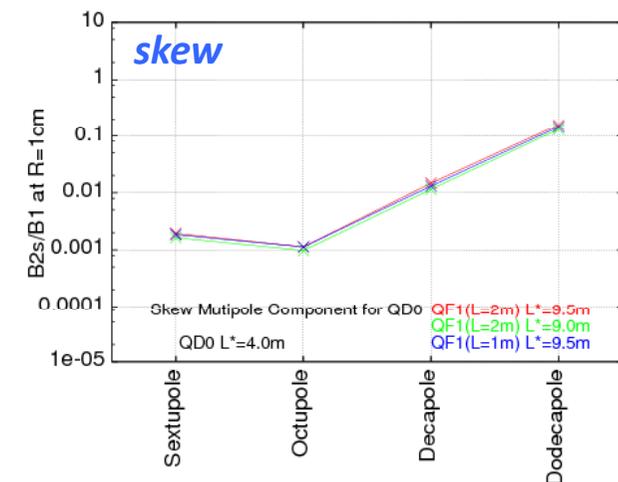
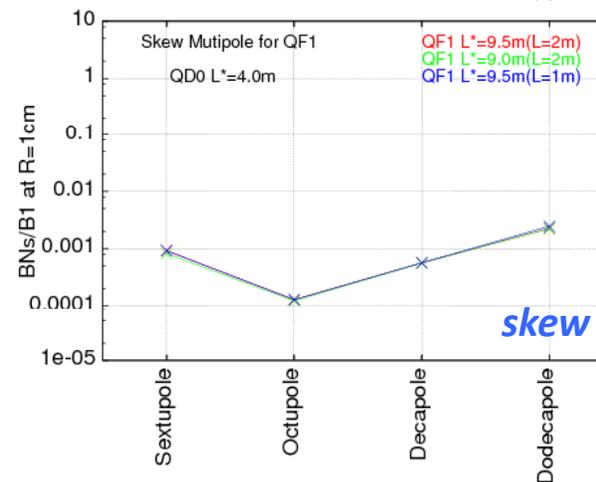
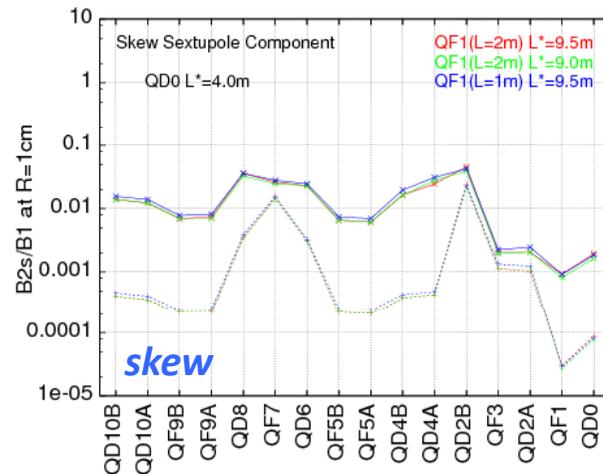
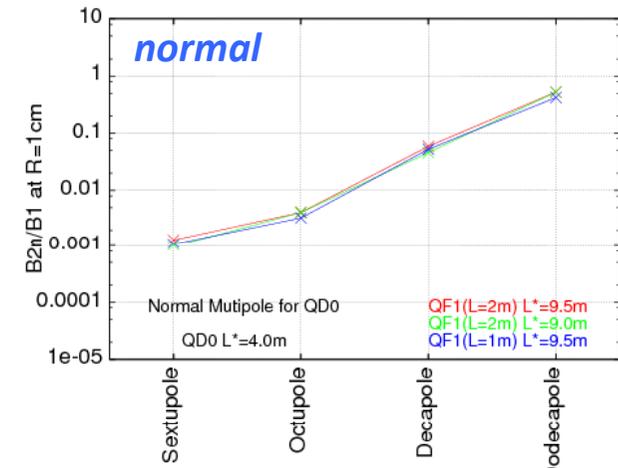
Sextupole component for FF quadrupoles



Multipole components for QF1



Multipole components for QD0



solid line ; after 2 iterations of 2nd order knob correction
dash line ; no 2nd order knob correction

The tolerances were not changed so much for QF1 location.

Collimation depths for various QF1 locations

Collimation depth was calculated for $E_{cm}=500\text{GeV}$.

(QD0 L*) = 4.0m

(Half aperture of SPEX) = 1.60 mm ($\Delta p/p = 1\%$)

QF1 L*	QF1 Length	Collimator Half Aperture (SP2/SP4)	
		X collimator	Y collimator
L*=9.5m	L=2.0m	0.62mm (4.4 σ)	0.59mm (70 σ)
L*=9.0m	L=2.0m	0.66mm (4.7 σ)	0.57mm (68 σ)
L*=9.5m	L=1.0m	0.67mm (4.7 σ)	0.58mm (68 σ)

Horizontal collimation depth will be wider, when the QF1 L is decreased.*

We had better to keep the large horizontal collimation depth especially for small energy.

Short QF1 is same effect to make QF1 close to IP.

Summary of QF1 location

Energy bandwidth

- QF1 should be located to be as close as possible to IP.
- Short QF1 magnet is effective to increase the bandwidth.

Alignment error tolerances

- QF1 should be located to be as close as possible to IP.
- Short QF1 magnet is effective to relax the alignment tolerance.
- But, still very tight (some magnets are still less than 1um)

Multipole field error tolerances

- Not so tight after applying 2nd order optics correction.
- No clear dependence for QF1 L* location.

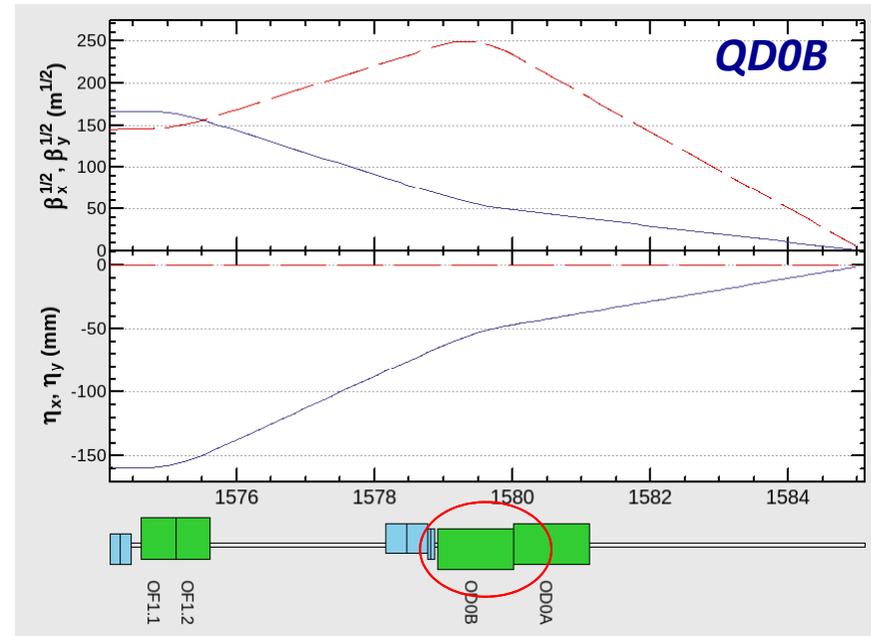
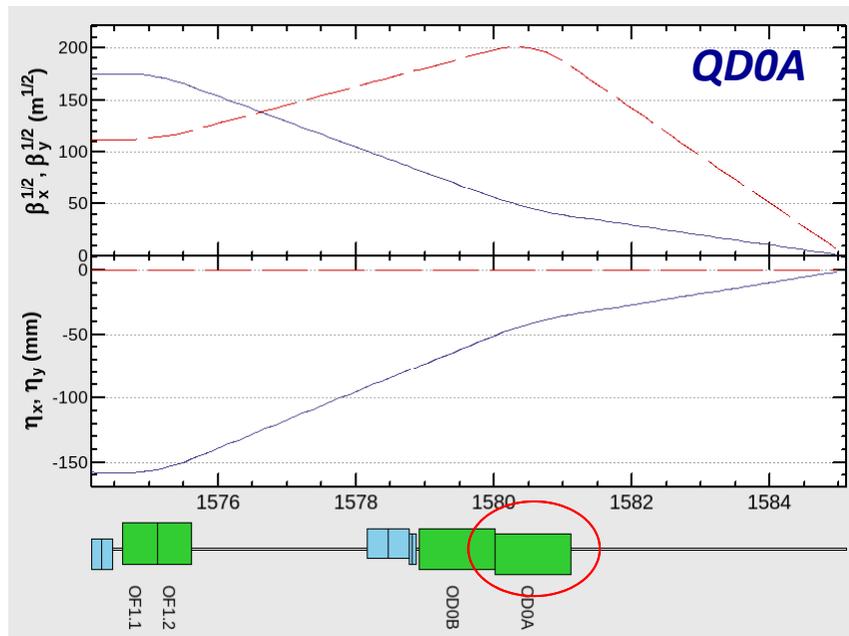
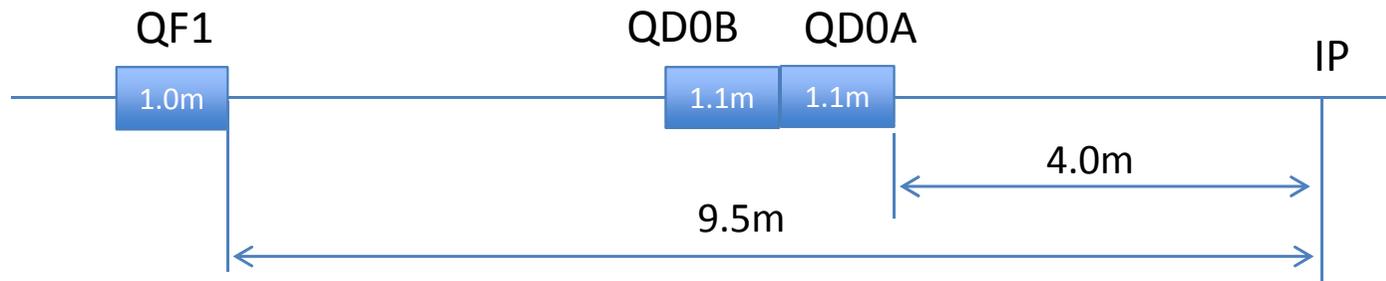
Collimation Depth

- Short QF1 L* is better for horizontal (still less than 5σ for $E_{CM}=500\text{GeV}$).
- The horizontal collimation depth is determined by SR at QF1.
- The vertical collimation depth is determined by SR at QDEX1.

Low Energy Operation ($E_{CM}=250\text{GeV}$)

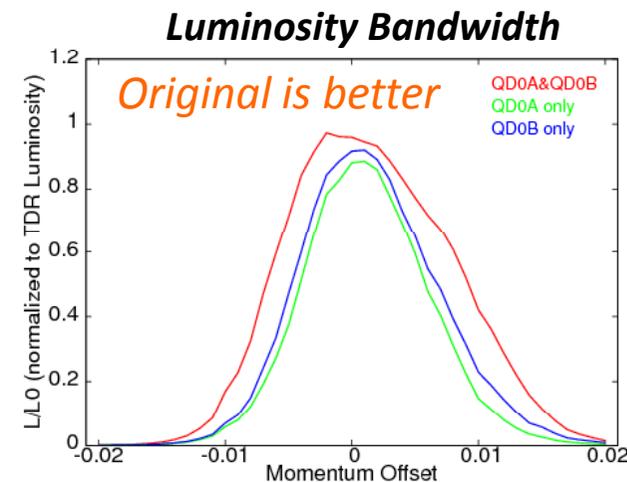
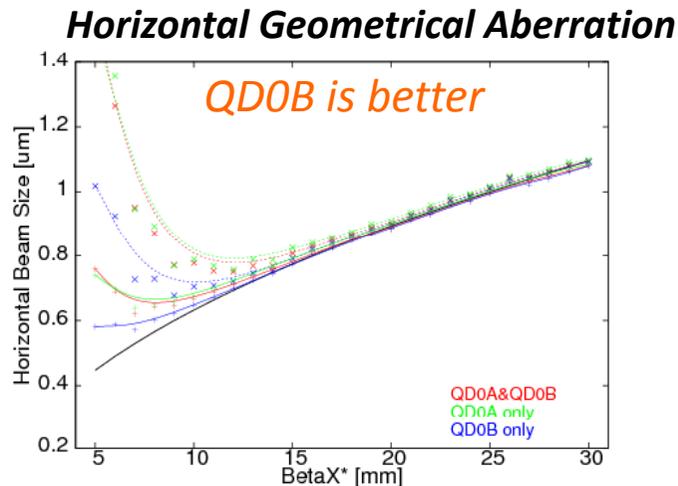
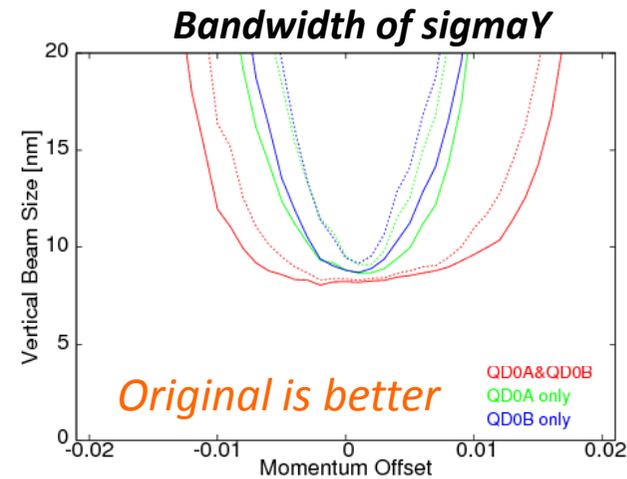
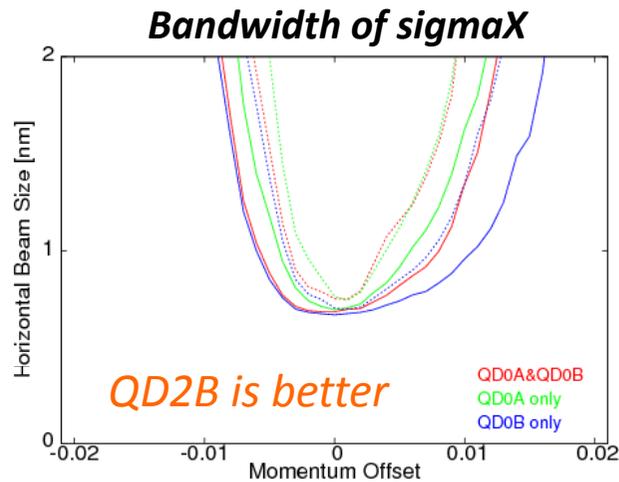
For the low energy operation, the collimation depth (especially for horizontal) is tight. Therefore, QD0 magnet was divided to 2 pieces to increase the collimation depth.

I tried to optimize the optics with QD0 $L^*=4.0\text{m}$, QF1 $L^*=9.5\text{m}$ (1m long).



Bandwidths for 3 set of optics at $E_{CM}=250\text{GeV}$

$\Delta p/p = 0.17\%$ (larger than $E_{CM}=500\text{GeV}$)

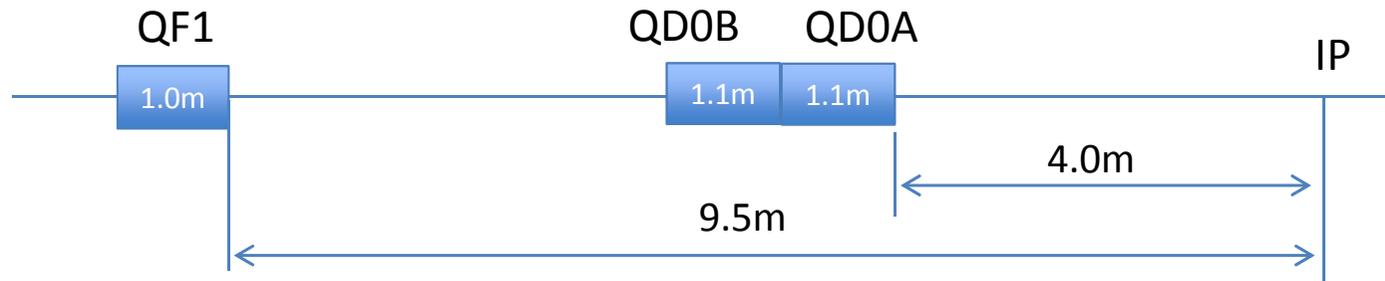


It was difficult to optimize the bandwidth under the fixed magnet position (especially difficult, when the distance between QF1 and QD0 is large).

Bandwidth for original optics is best for energy bandwidth.

But, the optics with QD0B (upstream) only is best for horizontal geometrical aberration

Collimation depth issues for $E_{CM}=250\text{GeV}$ operation



Simulation of the collimation depth for various QD0 arrangement

$$(QD0 L^*) = 4.0m$$

$$(Half\ aperture\ of\ SPEX) = 1.60\ mm\ (\Delta p/p = 1\%)$$

	QD0	QD0	QD0	BetaX at QF1	BetaY at QD0	Collimator Half Aperture (SP2/SP4)	
	Length	L*	Center			X collimator	Y collimator
QD0A	1.1m	4.0m	4.55m	29,660m	39,387m	0.65mm (3.2 σ)	0.67mm (58 σ)
QD0A & B	2.2m	4.0m	5.10m	30,630m	46,376m	0.66mm (3.3 σ)	0.57mm (48 σ)
QD0B	1.1m	5.1m	5.65m	26,713m	59,536m	0.68mm (3.4 σ)[*]	0.48 mm (40 σ)

[*] horizontal collimation depth also determined by QDEX1.

When we will use only QD0B, the horizontal collimation depth will be increased a little bit, but the vertical collimation depth, and energy bandwidth will be decreased.

Summary

- We must consider the L^* issue not only about QD0, but also combination of QF1.

QD0 location

- Most of the tolerances for QD0 $L^*=3.5-4.5m$ is comparable, when we set to QF1 $L^*=9.5m$.
- It is better to set $L^*=4.5m$ to make large horizontal collimation depth.

QF1 location

- QF1 should be set as close as possible to IP
to make better tolerances and horizontal collimation depth
(more effective than QD0 location).
- Short QF1 magnet is same effect to make QF1 close to IP.
- Since I only investigate only QD0 $L^*=4.0m$, I will check QD0 $L^*=4.5m$ after LCWS14.

Low energy operation ($E_{CM}=250GeV$)

- When we operate only with QD0A or QD0B,
the momentum bandwidths are smaller than original optics.
- When we operate only with QD0B (upstream; longer QD0 L^*),
the horizontal collimation depth is increased a little bit..
- It seems difficult to use the split QD0 option at least QD0 $L^*=4.0m$ optics.
- I will check the low energy optics for QD0 $L^*=4.5m$ after LCWS14.

Questions to detector group

Can we move QF1 to be close to IP (closer than 9.5m) ?

When QF1 or QD0 will be moved to be close to IP,

is the IP vacuum level acceptable to measure the small luminosity for beam tuning ?