ILC FFS optics optimization

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ILC BDS meeting

Low Energy Operation

Collimation Depth

*Performances for the FF optics with various QF1 and QD0 L*s*

Beam Size Simulation

(*) ECM=250GeV was calculated with IP parameters (Bx=11mm, By=0.48mm) not (Bx=13mm, By=41mm in TDR) .

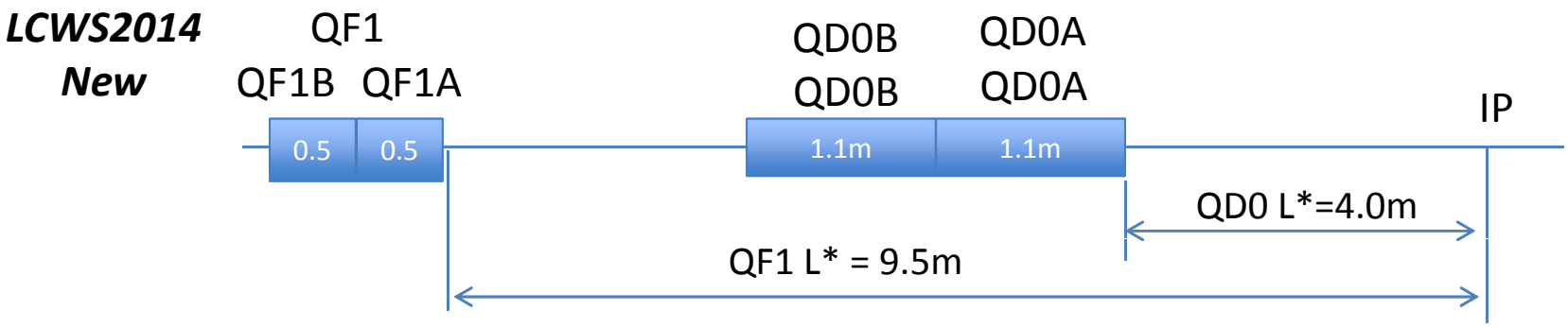
Low Energy Operation (E_{CM}=250GeV)

In LCWS2014, I tried to optimize the low energy FF optics by dividing only QD0 magnet.

Therefore, not only QD0, but also QF1 magnet s were divided to 2 pieces in order to increase the collimation depth.

The first study was done for

- *(QF1 L*) = 4.0m*
- *(QD0 L*) = 9.5m*
- *(QF1 Length) = 1.0m*
- *(QD0 Length) = 2.2m .*



Performance of E_{CM}=250GeV Optics

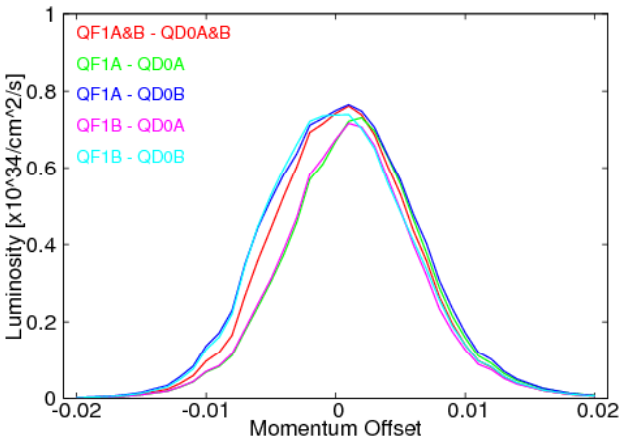
Magnet location was optimized the bandwidth at E_{CM}=500GeV (full length FD magnets)

We compared the performance of the optics, which were used only several half FD magnets.

Each optics was optimized the bandwidth by changing the magnet strengths for

- *QF5, QD4, QD2B, QF3, QD2A QF1 and QD0*
- *SF6, SF5, SD4, SF1 and SD0.*

Luminosity Bandwidth
(no waist shift)

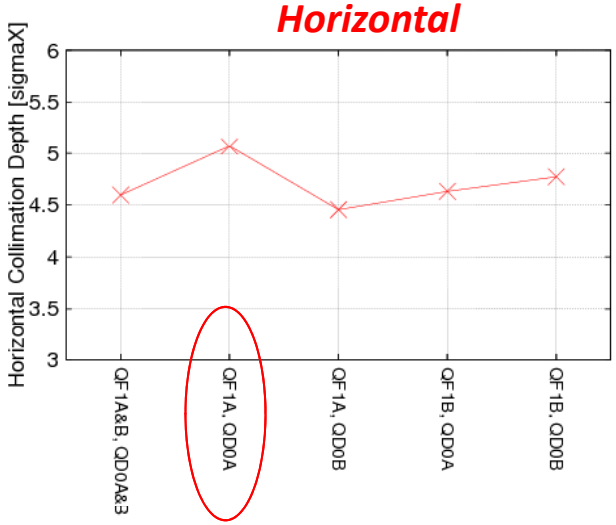


Good for QF1A&QD0B
QF1B&QD0B

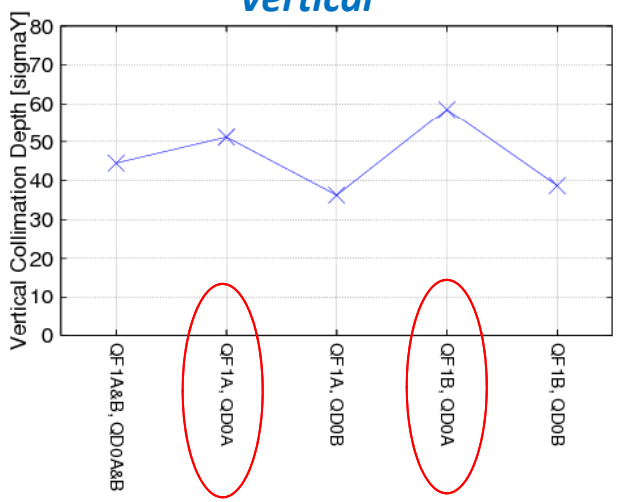
Bad for QF1A&QD0A
QF1B&QD0A

Collimation Depth

Horizontal



Vertical

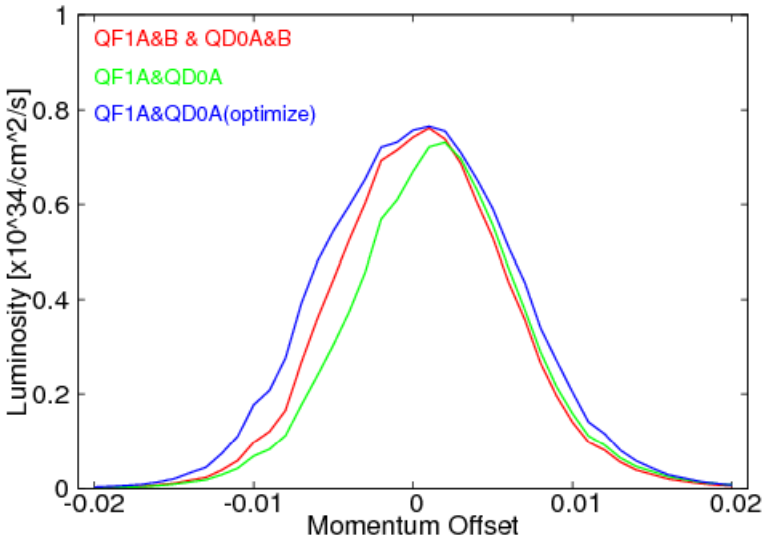


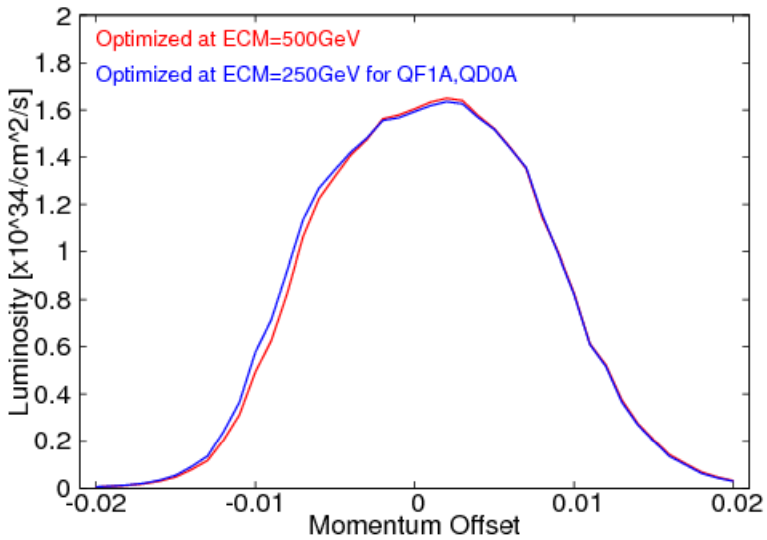
Good for QF1A&QD0A

Magnet location was optimized for QF1A&QD0A at E_{CM}=250GeV

Optics at E_{CM}=500GeV was optimized the bandwidth by changing the magnet strengths for

- *QF5, QD4, QD2B, QF3, QD2A QF1 (full-length) and QD0 (full-length)*
- *SF6, SF5, SD4, SF1 and SD0.*



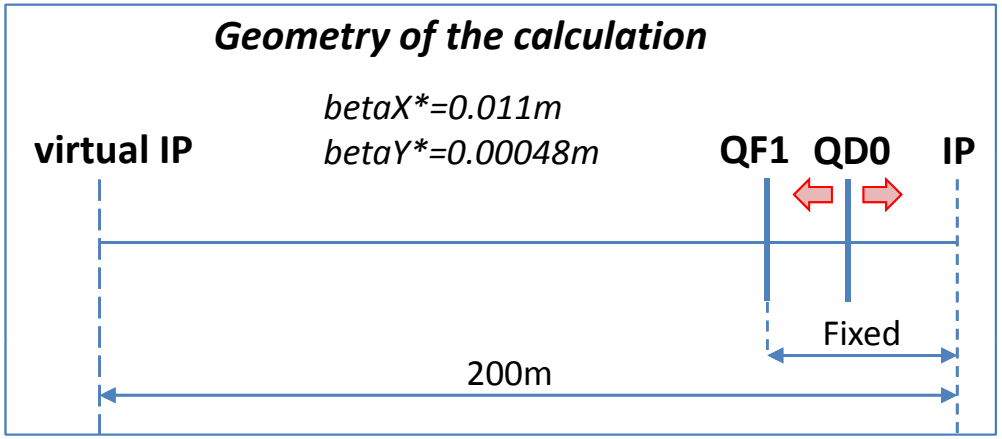


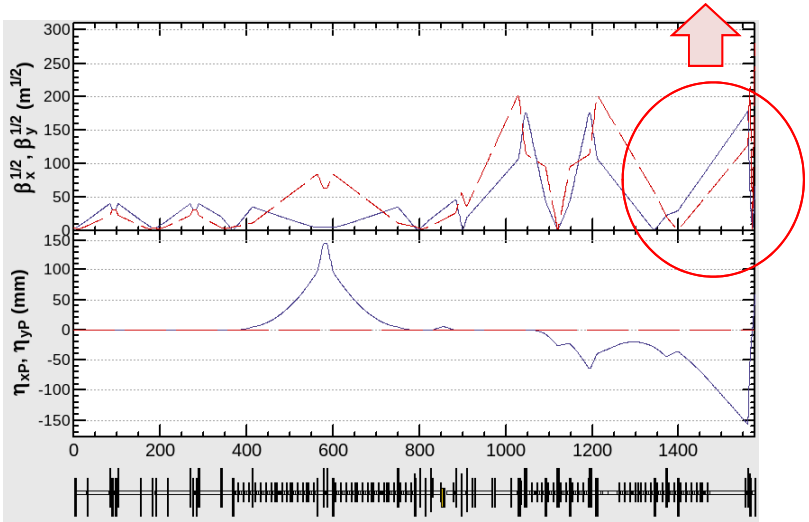
The bandwidth for E_{CM}=250GeV is larger than the original optics.

The bandwidth for E_{CM}=500GeV is also comparable to the original optics.

Collimation Depth

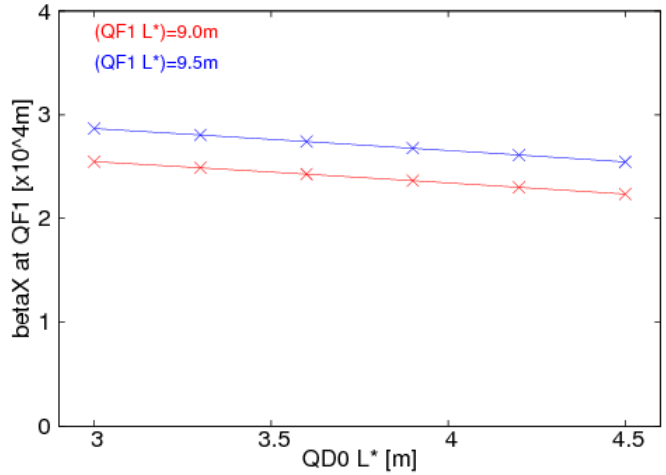
Beta functions at Final Doublet, when QF1 position is fixed





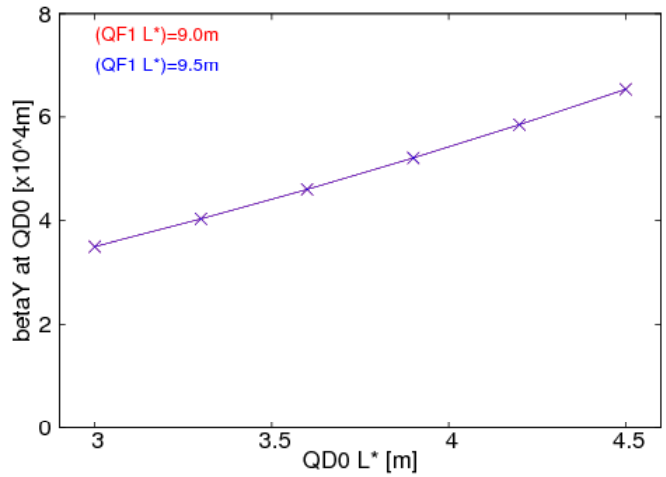
When QD0 is move to be closer to IP,
the horizontal beta function at QF1 is increased.

Horizontal beta function at QF1



Affect to the horizontal collimation depth

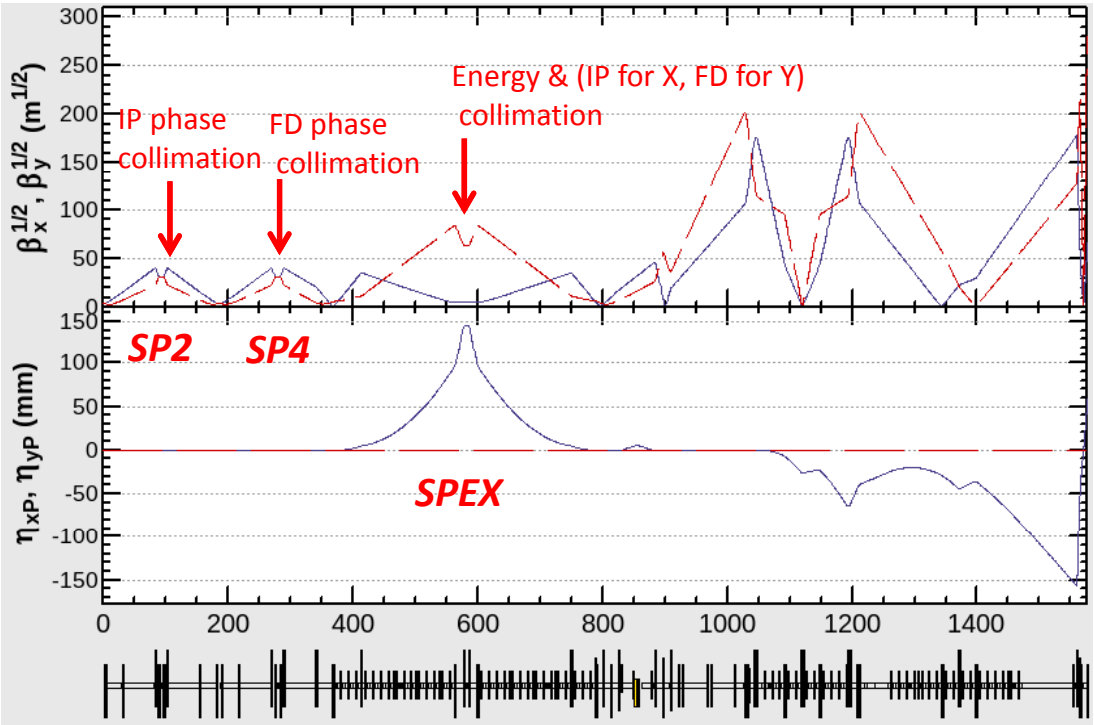
Vertical beta function at QD0



Affect to the vertical collimation depth

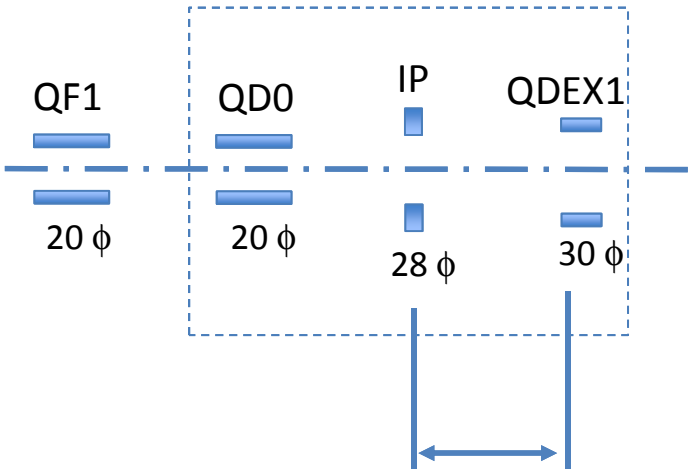
Configuration of the collimators and apertures

Beta Function at SP2/SP4 = (X; 1000m / Y; 1000m)
Beta Function at SPEX = (X; 36m / Y; 4000m)
Phase Advance (SP2 / IP) = (X; 7.0 pi / Y; 6.0 pi)
Phase Advance (SP4 / IP) = (X; 6.5 pi / Y; 4.5 pi)
Phase Advance (SPEX / IP) = (X; 5.0 pi / Y; 3.5 pi)
EtaX at SPEX = 0.145m



*1) Fixed QDEX1 L**

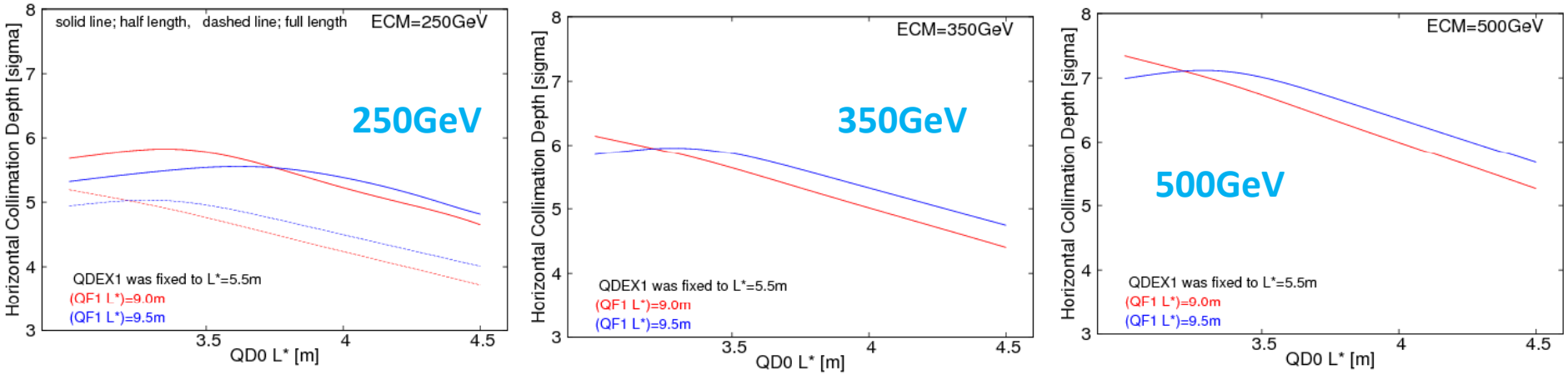
Detector apertures



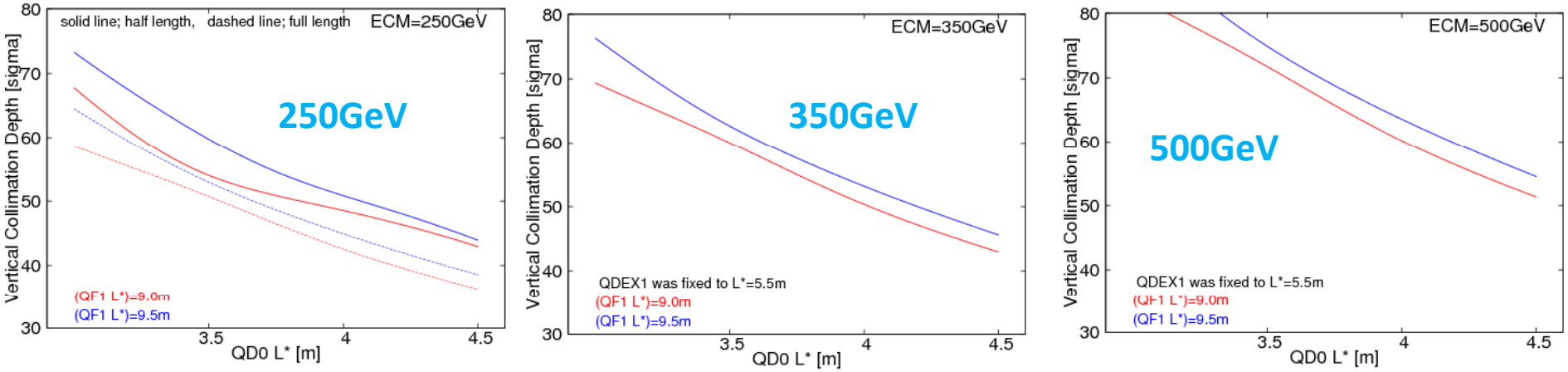
QDEX1 L was fixed to L*=5.5m*

The collimation depth were defined to 70% of aperture limit for safety margin.

Horizontal Collimation Depth



Vertical Collimation Depth

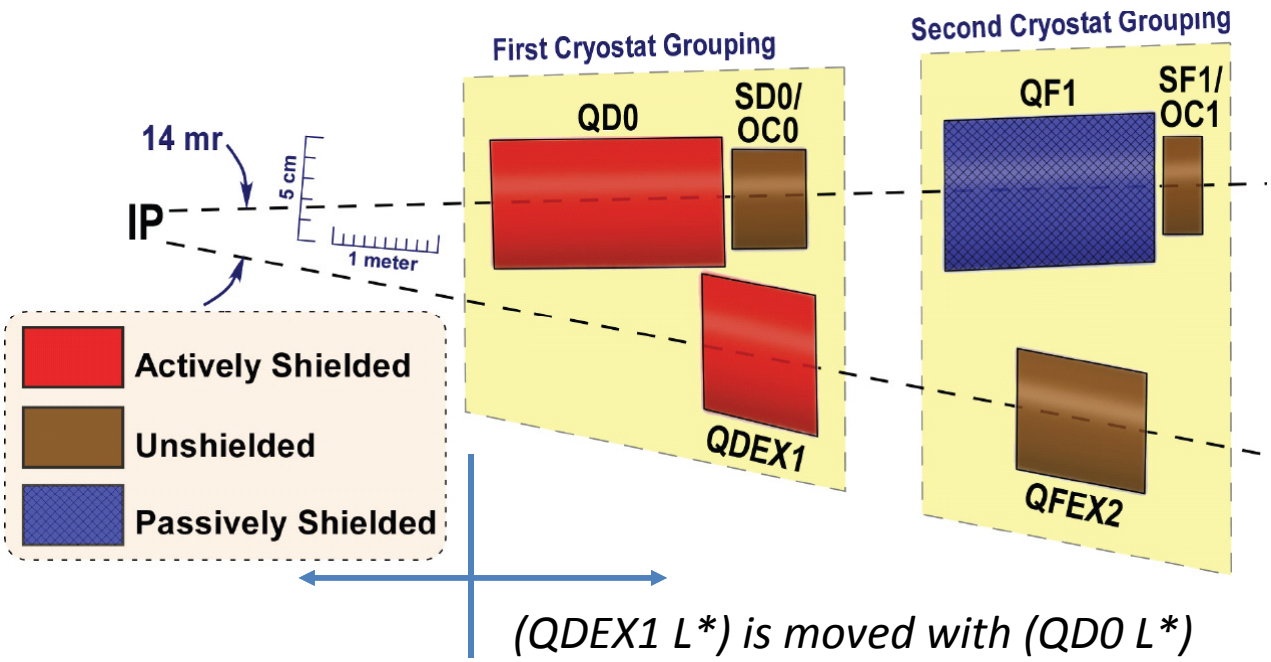


By using the special optics at ECM=250GeV only with QF1A & QD0A,
the collimation depths at ECM=250GeV can be increased to comparable to ECM=350GeV.

(more than 4.3 sigma for horizontal and 42 sigma for vertical at minimum)

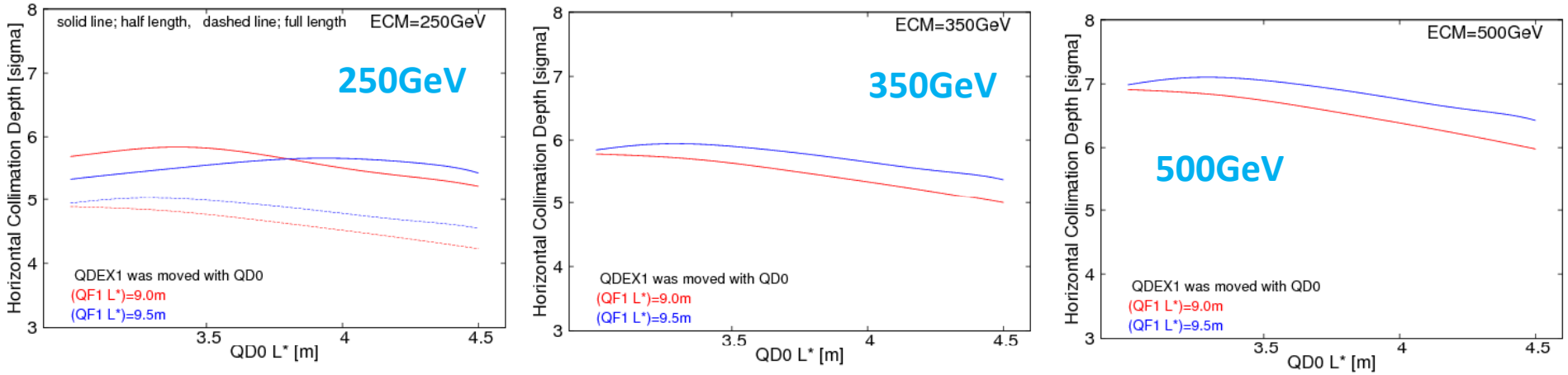
(2) (QDEX1 L) is moved with (QD0 L*)*

(QDEX1 K_1) x (QDEX1 L) = (constant)*
(QDEX1 B_{max}) = (same)
(inner diameter of coil) = (magnet aperture) + 8mm

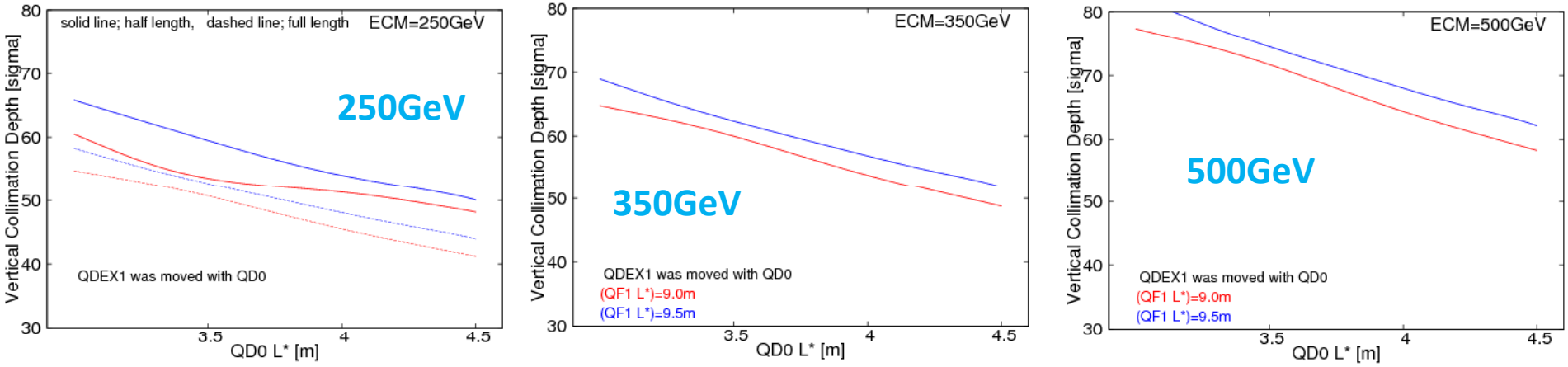


(QDEX1 L)=5.0m, A=27mm at (QD0 L*)=3.0m*
(QDEX1 L)=6.5m, A=36mm at (QD0 L*)=4.5m*

Horizontal Collimation Depth



Vertical Collimation Depth



*The apertures for shorter L*s were decreased.*
*The apertures for longer L*s were increased.*

Horizontal collimation depths are greater than 5.0 sigma for all cases .
Vertical collimation depths are greater than 48 sigma for all cases.

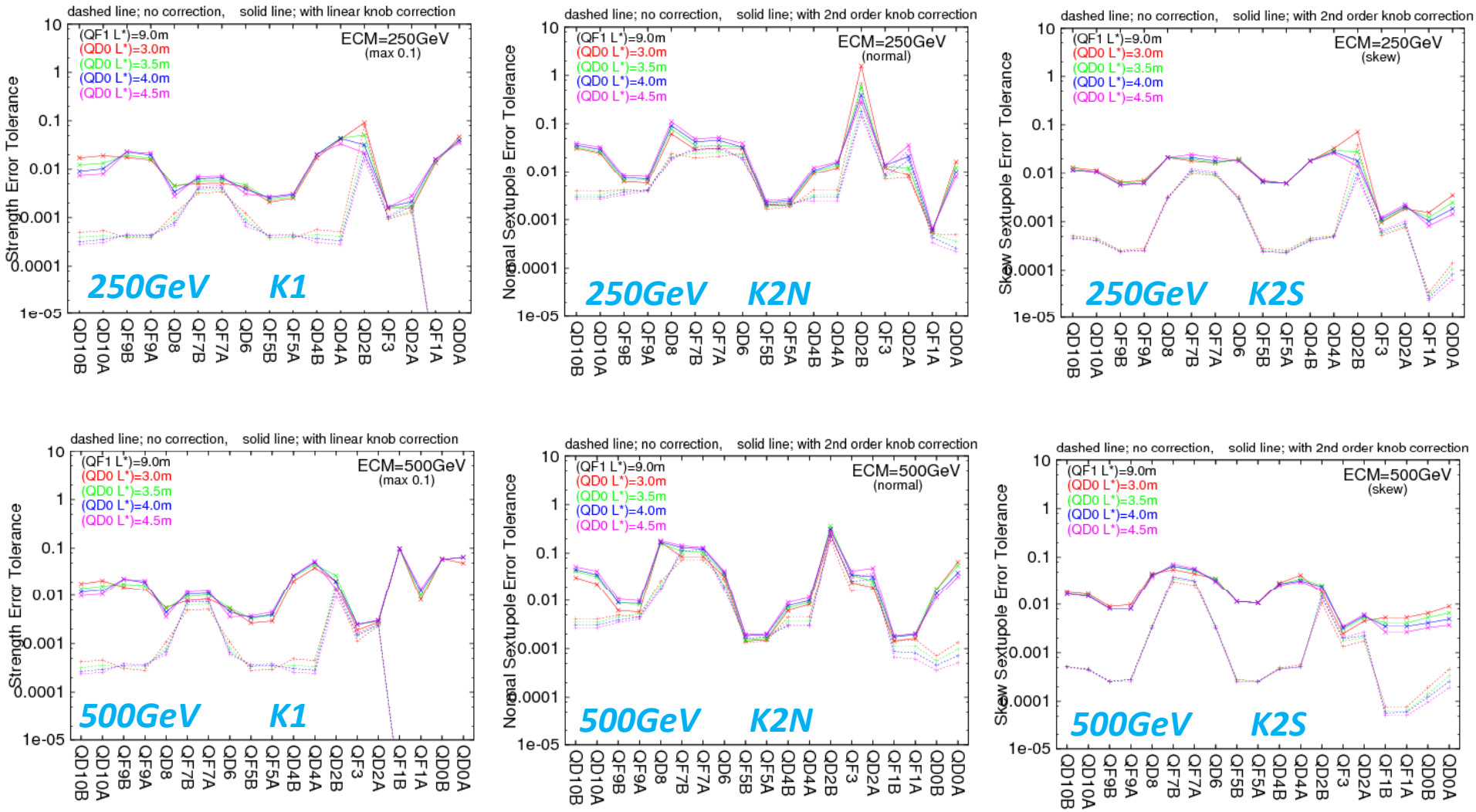
*Performances for the FF optics with various QF1 and QD0 L*s*

I prepared the following FF optics.

(QD0 L) = 3.0m, 3.5m, 4.0m, 4.5m*
(QF1 L) = 9.0m, 9.5m*
(ECM) = 250GeV, 500GeV

Total 4x2x2=16set of FF optics were prepared.

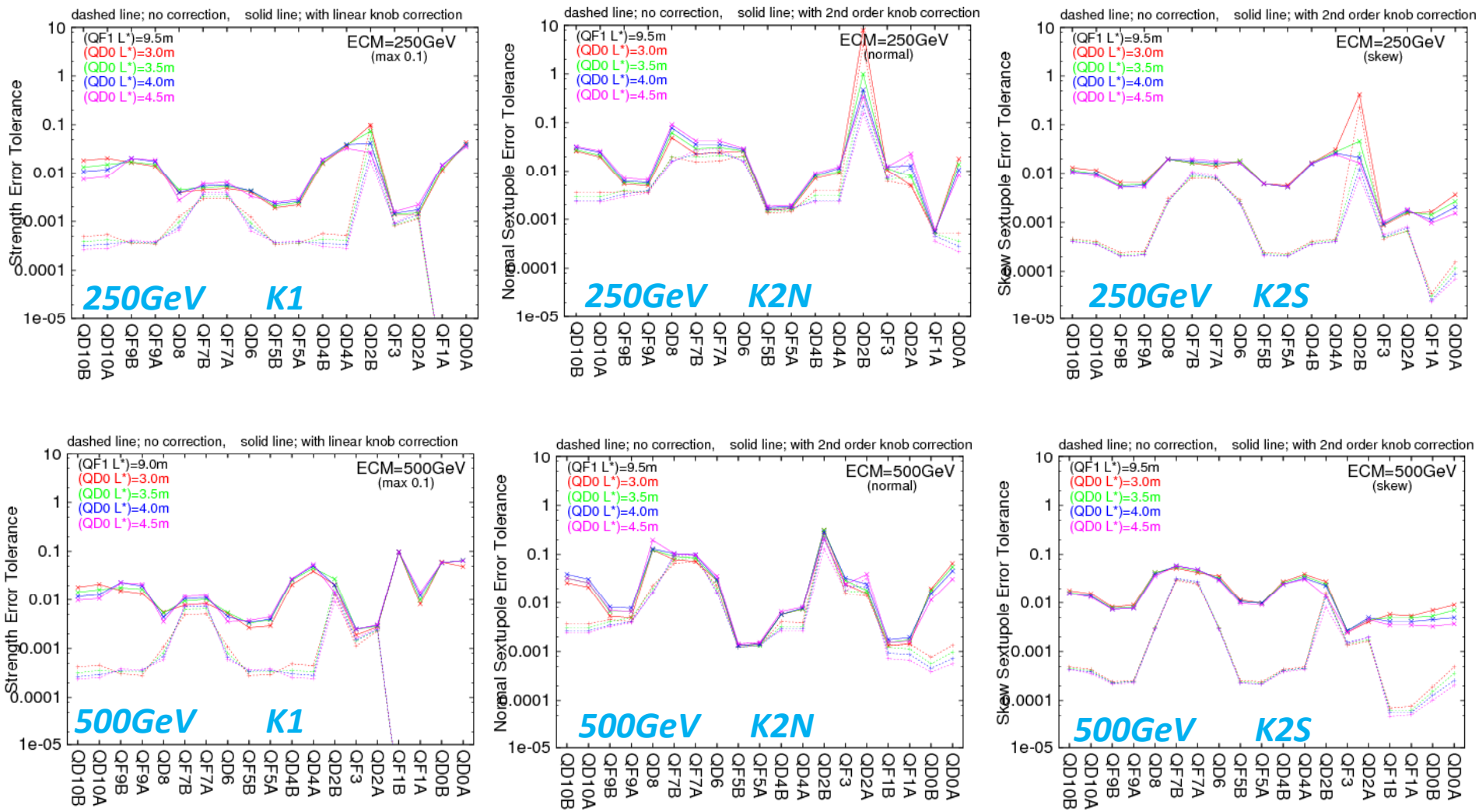
Requirement of magnet qualities for (QF1 L*)=9.0m



By applying the linear and 2nd order optics correction, the tolerances will be increased.

The typical tolerances after corrections were more than 1e-3 for K1, K2 (at R=1cm).

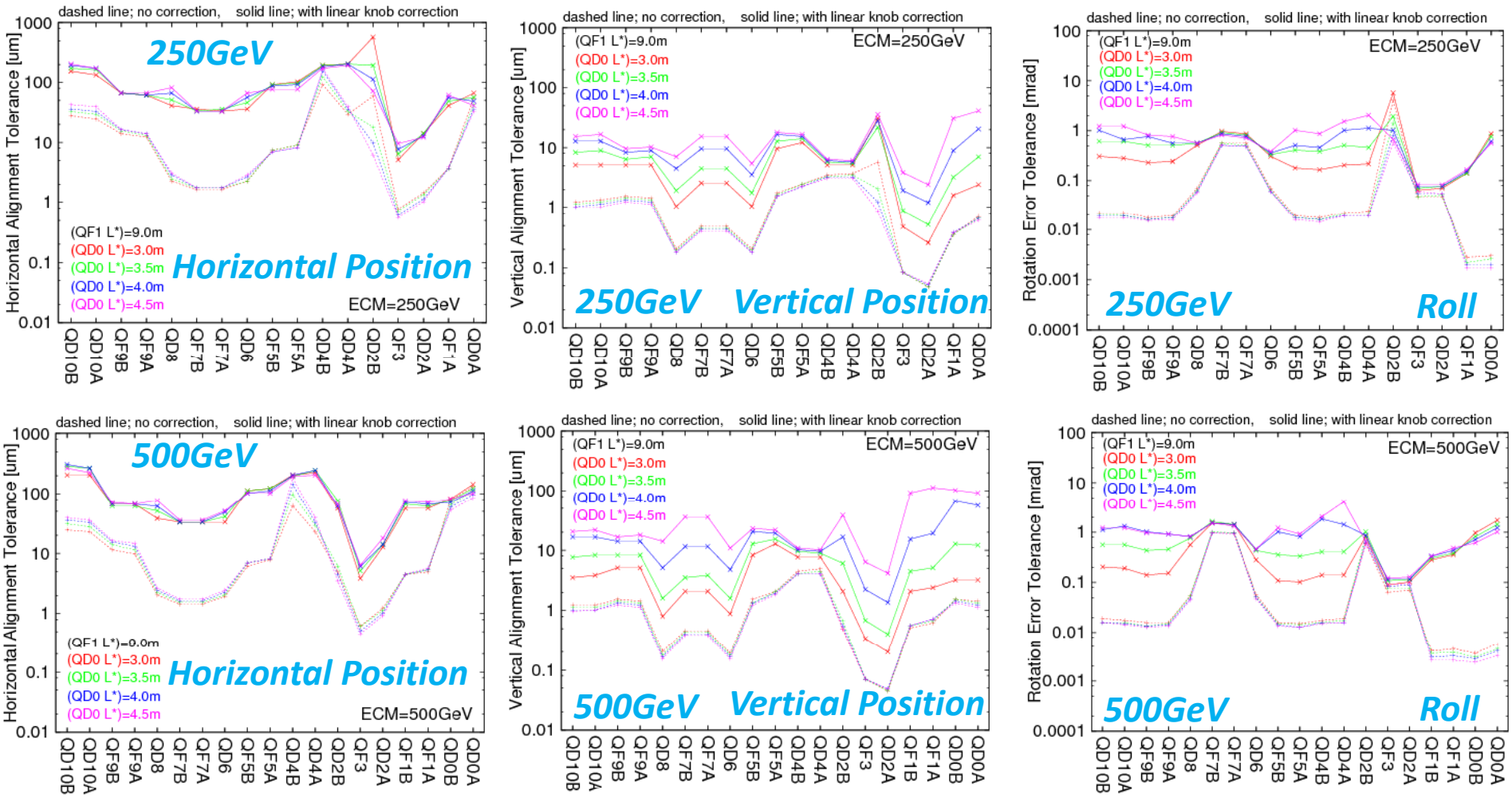
Requirement of magnet qualities for (QF1 L*)=9.5m



By applying the linear and 2nd order optics correction, the tolerances will be increased.

The typical tolerances after corrections were more than 1e-3 for K1, K2 (at R=1cm). (almost same to (QF1 L)=9.0m).*

Requirement of Alignment for (QF1 L*)=9.0m

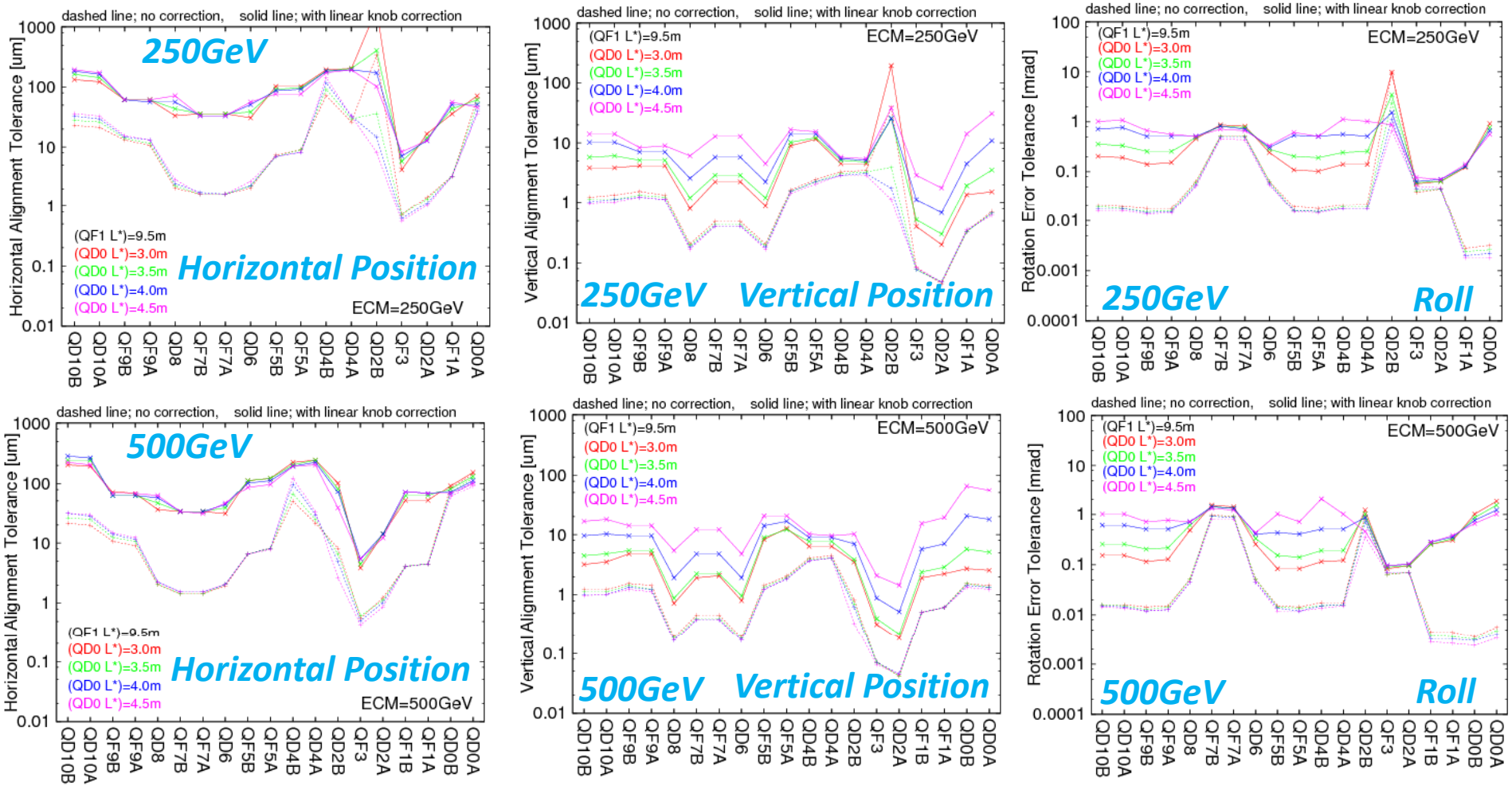


By applying the linear optics correction, the tolerances will be increased.

The tolerances for vertical alignment and roll after correction was tighter for shorter (QD0 L) for strong sextupole.*

The typical tolerances after corrections were more than 0.1mrad for roll and 1-10um for vertical position alignment .

Requirement of Alignment for (QF1 L*)=9.5m

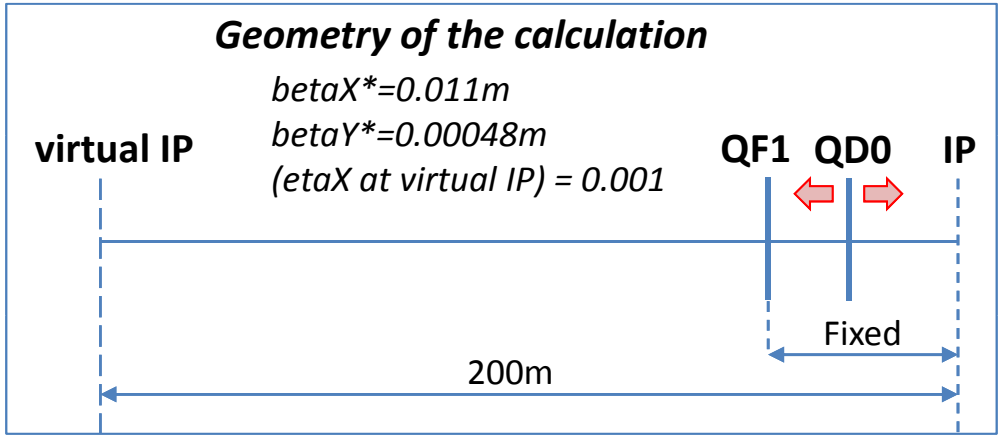


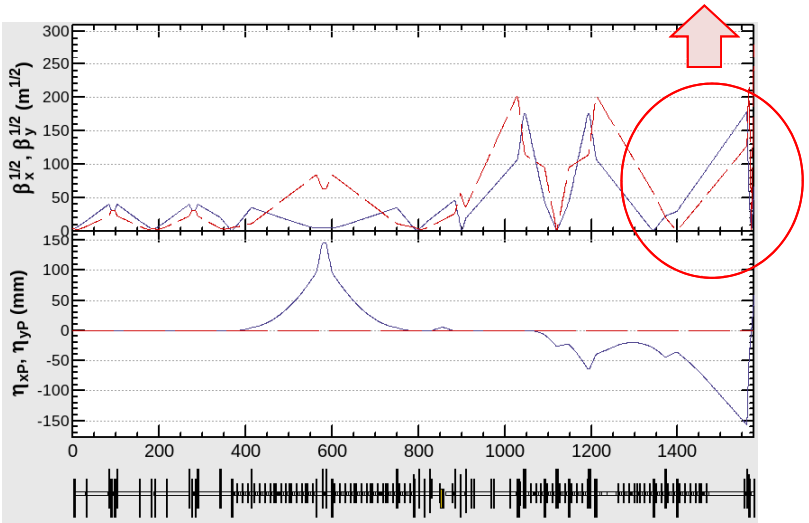
By applying the linear optics correction, the tolerances will be increased.

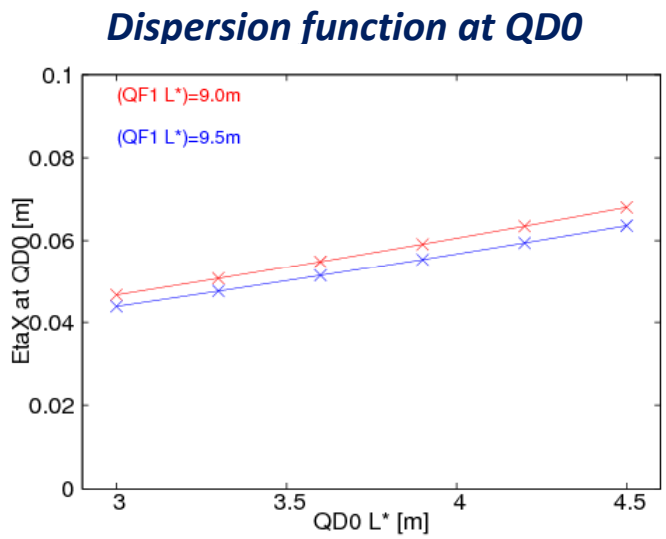
The tolerances for vertical alignment and roll after correction was tighter for shorter (QD0 L) for strong sextupole.*

The typical tolerances after corrections were more than 0.1mrad for roll and 1-10um for vertical position alignment (same order to (QF1 L)=9.0m).*

Dispersion at QD0, when QF1 position is fixed





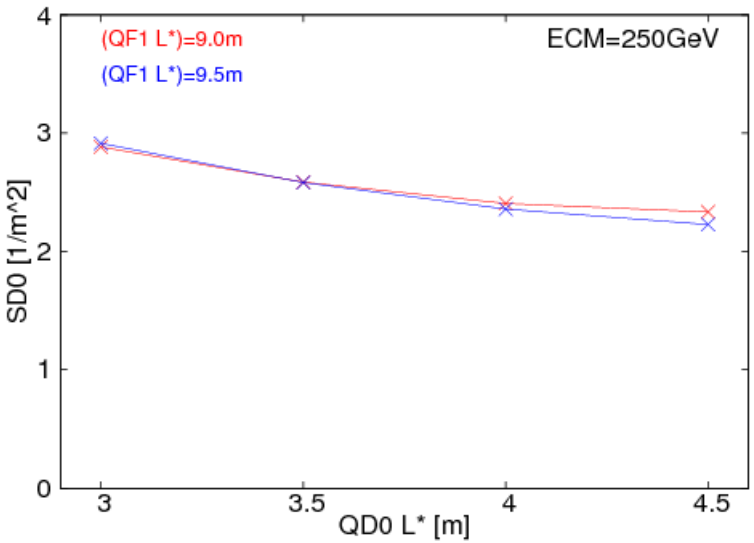


Affect to the strength of SD0

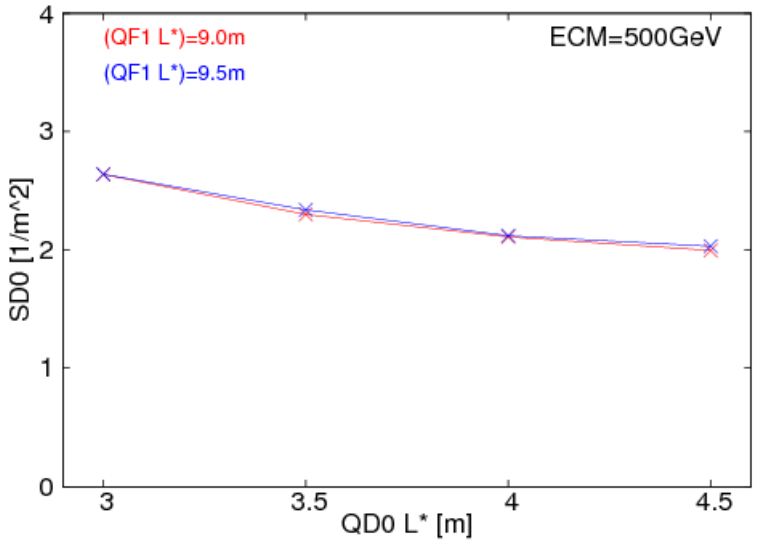
When QD0 is move to be closer to IP, the dispersion function at QD0 is decreased. Therefore, the strength of SD0 will be stronger.

Strength of SD0 for actual optics

The strength of SD0 for the beam optics at ECM=250GeV

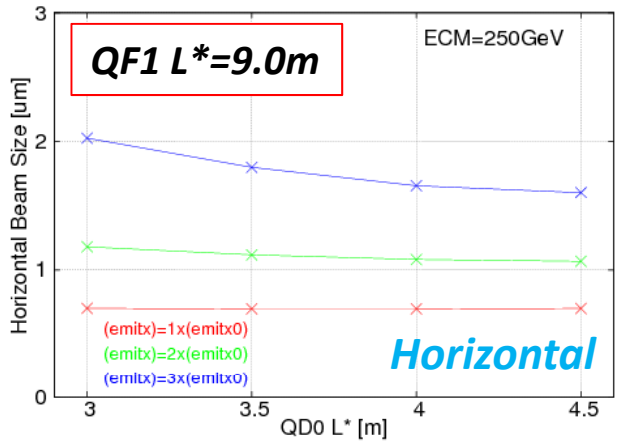


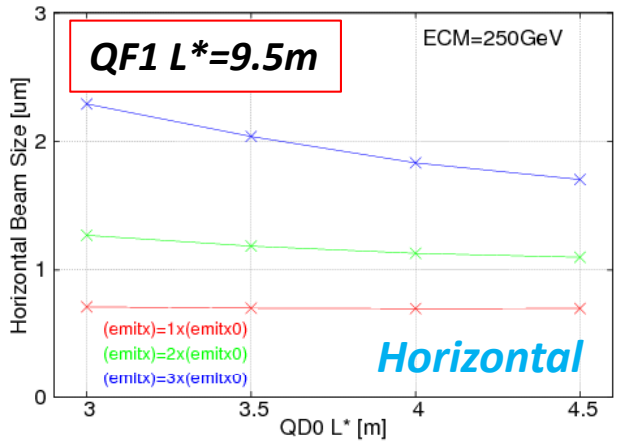
The strength of SD0 for the beam optics at ECM=500GeV

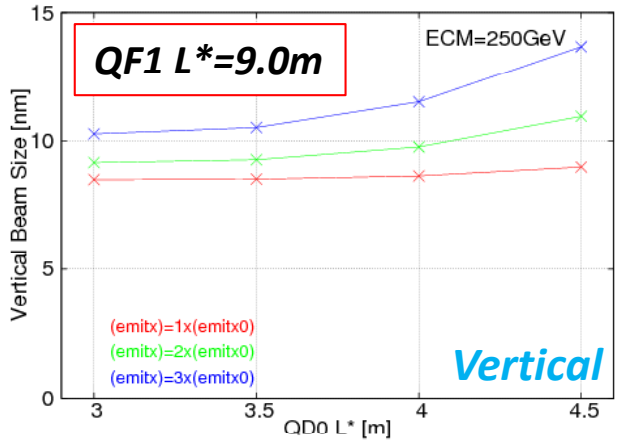


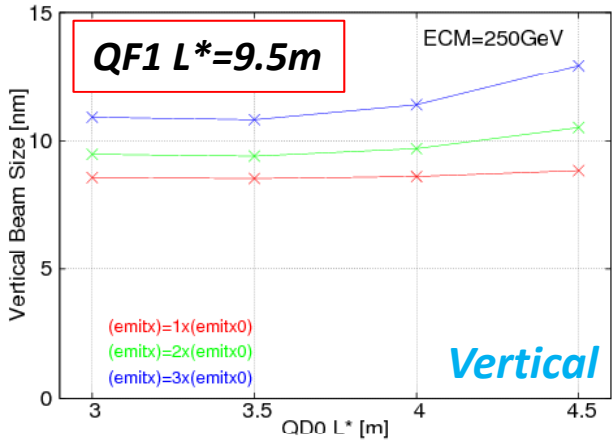
The strengths for SD0s were stronger for smaller QD0 L for the actual beam optics.*

Responses for horizontal emittance for ECM=250GeV





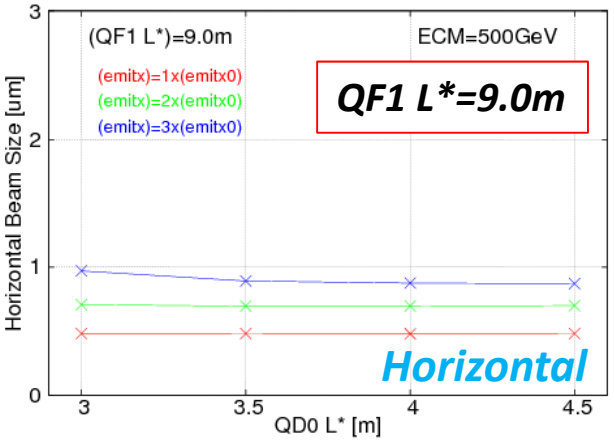


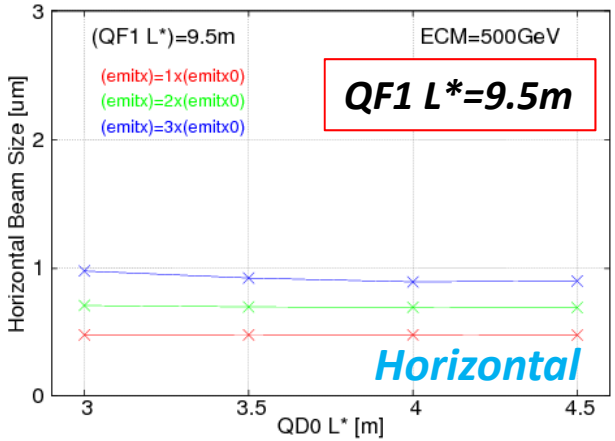


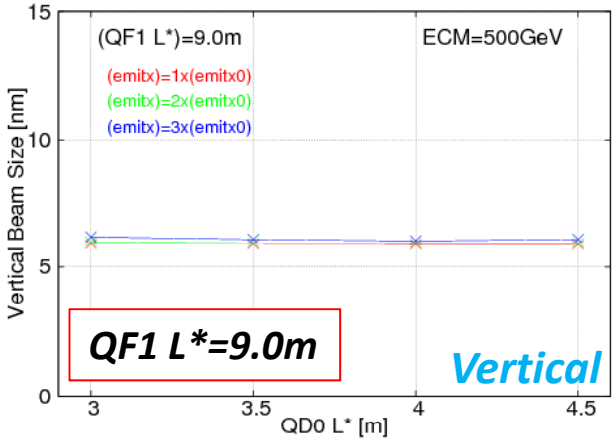
Since the horizontal beam size at sextupoles are large for the low energy, the horizontal emittance is sensitive to the IP beam size, especially for

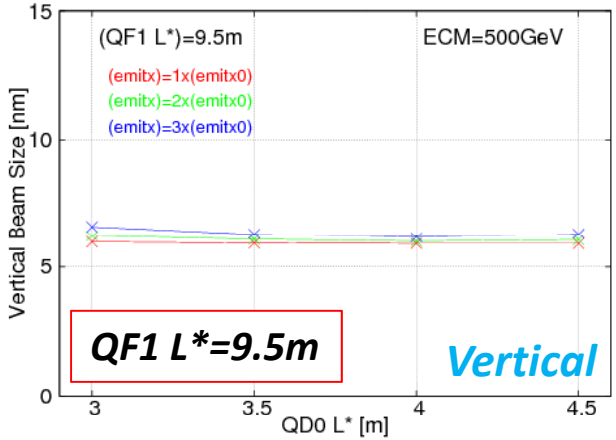
- *the IP horizontal beam size is sensitive for shorter QD0 L*.*
- *the IP vertical beam size is sensitive for longer L*.*

Responses for horizontal emittance for ECM=500GeV









The responses are same to ECM=250GeV.
- *the IP horizontal beam size is sensitive for shorter QD0 L*.*
- *the IP vertical beam size is sensitive for longer L*.*

But, the response is smaller than lower energy.

Beam Size Simulation

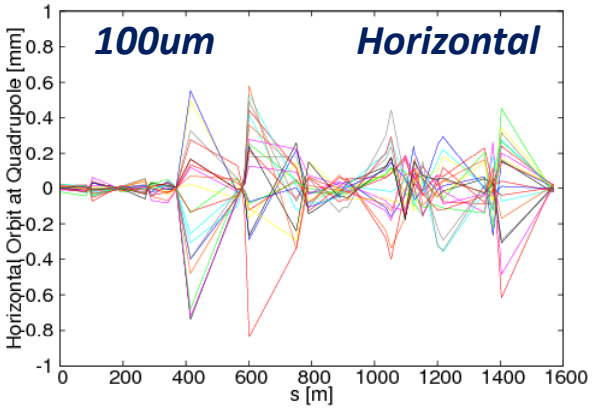
Example of the BBA in beam tuning simulation

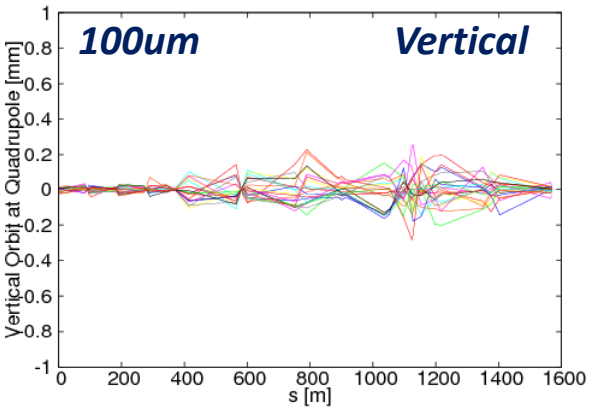
BPMs are moved with Quadrupole Magnet.

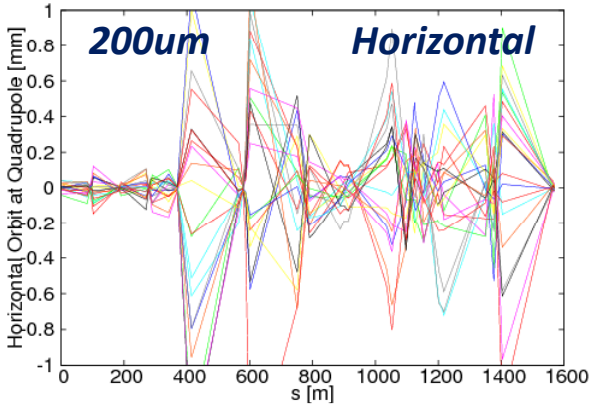
Since there are some BPMs, which are not on mover, the beam orbit was clipped.

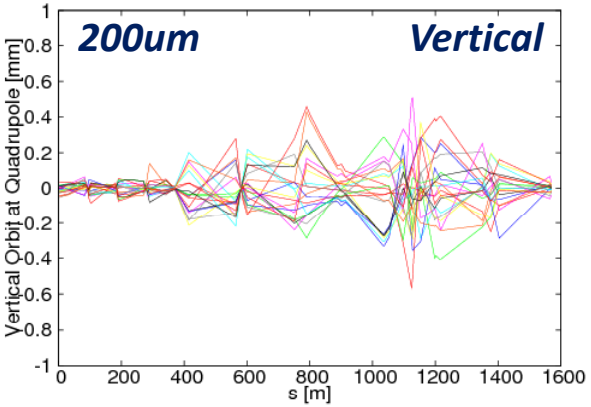
Alignment Errors

	Bend	Quad	Sext
ΔK	0.1%	0.1%	0.1%
ΔX	N. A.	0.1mm	0.1mm
ΔY	N. A.	0.1mm	0.1mm
Δθ	0.1mrad	0.1mrad	0.1mrad









Example of the beam tuning simulation

Procedures of beam tuning simulations

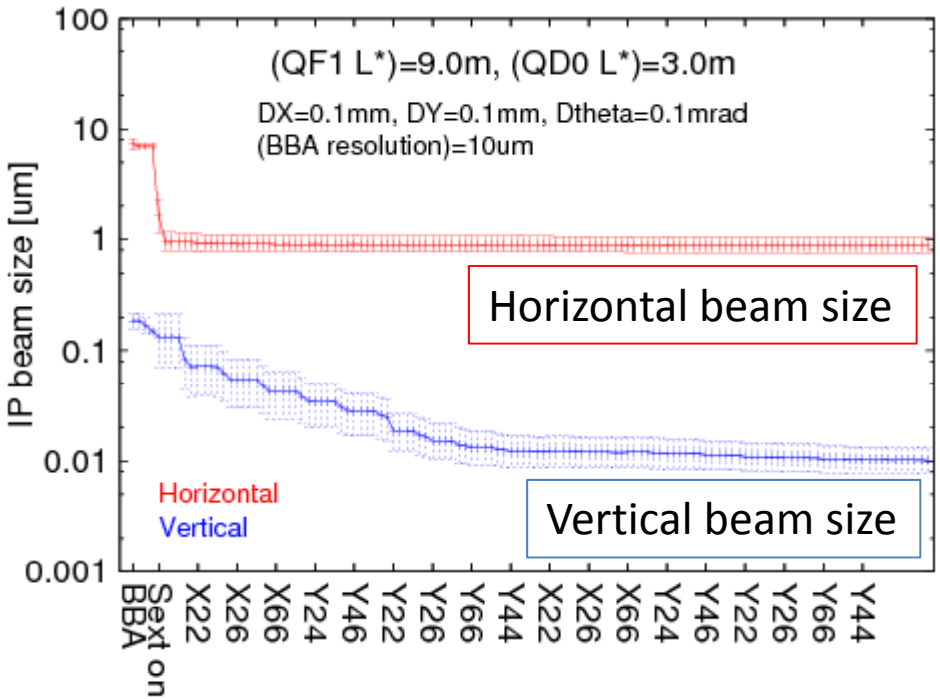
- 2 iterations for 2nd order optics knobs

- 5 set of linear knob scan was done every after 2nd order knob scan.

- 10um, 20um and 50um of BBA resolutions were assumed in the simulation

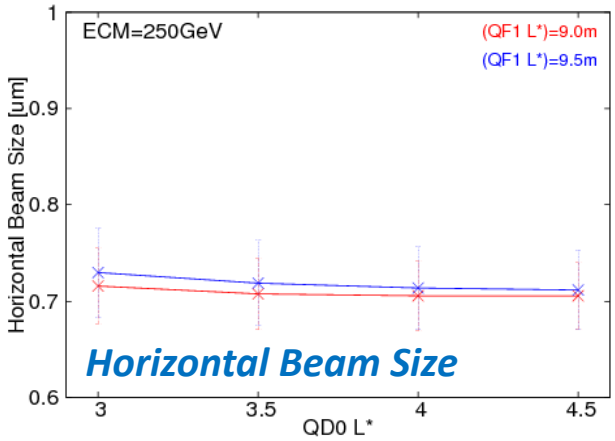
Alignment errors

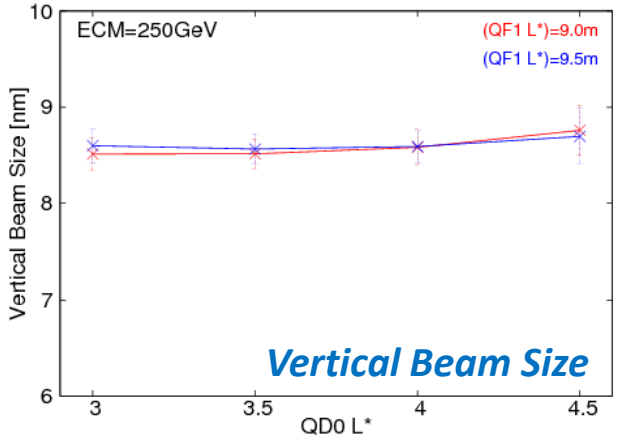
	Bend	Quad	Sext
ΔK	0.1%	0.1%	0.1%
ΔX	N. A.	0.1mm	0.1mm
ΔY	N. A.	0.1mm	0.1mm
Δθ	0.1mrad	0.1mrad	0.1mrad



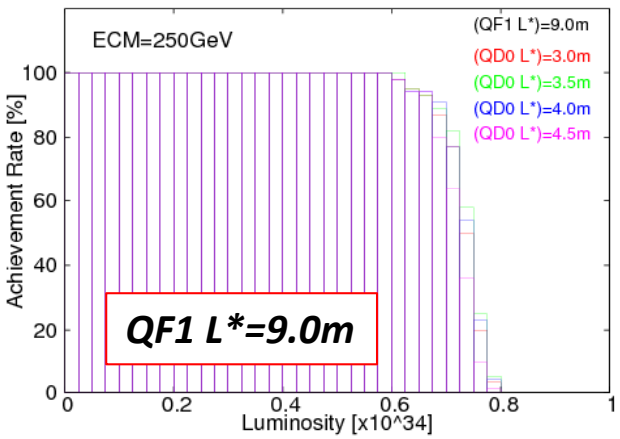
Simulation result for very precise alignment error

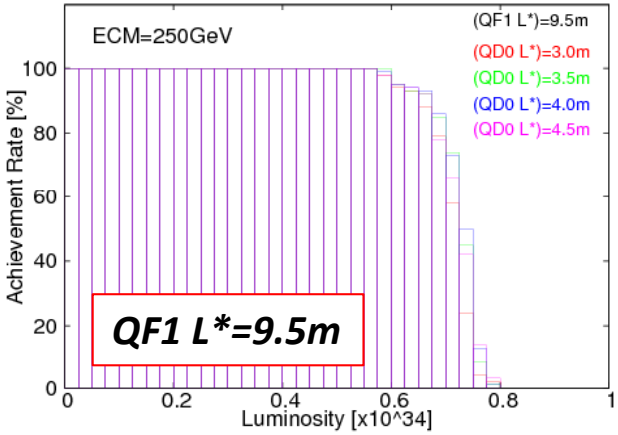
(ECM=250GeV, Alignment Error 10um, BBA resolution 1um)

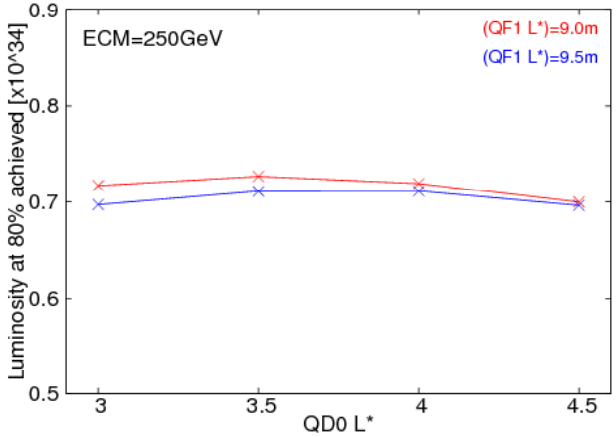




Luminosity



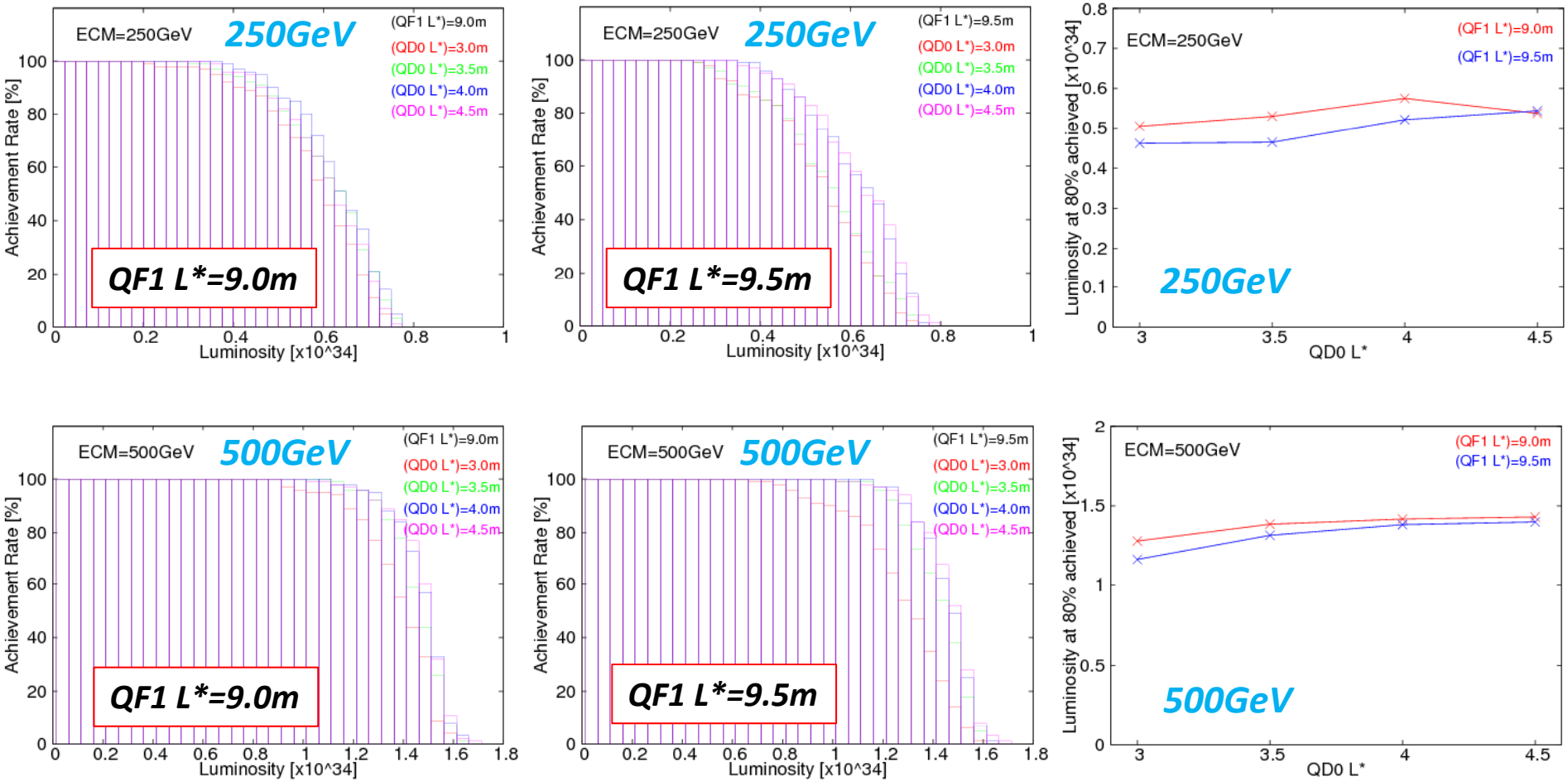




When we can align the magnets are very precisely,
the maximum luminosities can be achieved
(QD0 L) = 3.5m for (QF1 L*) = 9.0m*
(QD0 L) = 4.0m for (QF1 L*) = 9.5m*

Simulation Result with reliable alignment errors

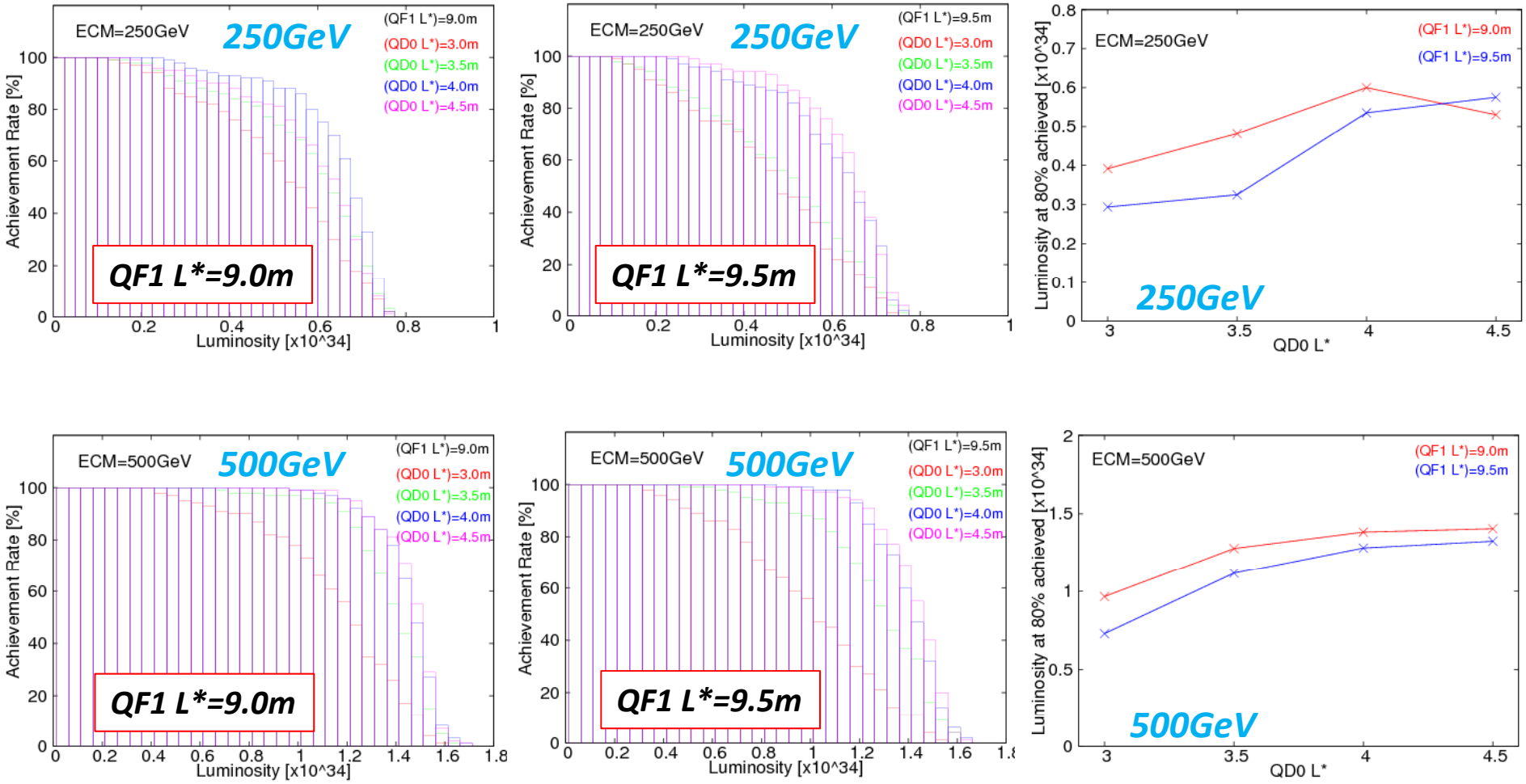
(Alignment Error 100um, BBA resolution 10um)



The luminosity was reduced for shorter QD0 L both for ECM=250GeV and ECM=500GeV.*

Simulation Result with reliable alignment errors

(Alignment Error 100um, BBA resolution 20um)



*The luminosity was reduced for shorter QD0 L**
both for ECM=250GeV and ECM=500GeV.

The BBA resolution is sensitive to the luminosity, especially for shorter QD0 L.*

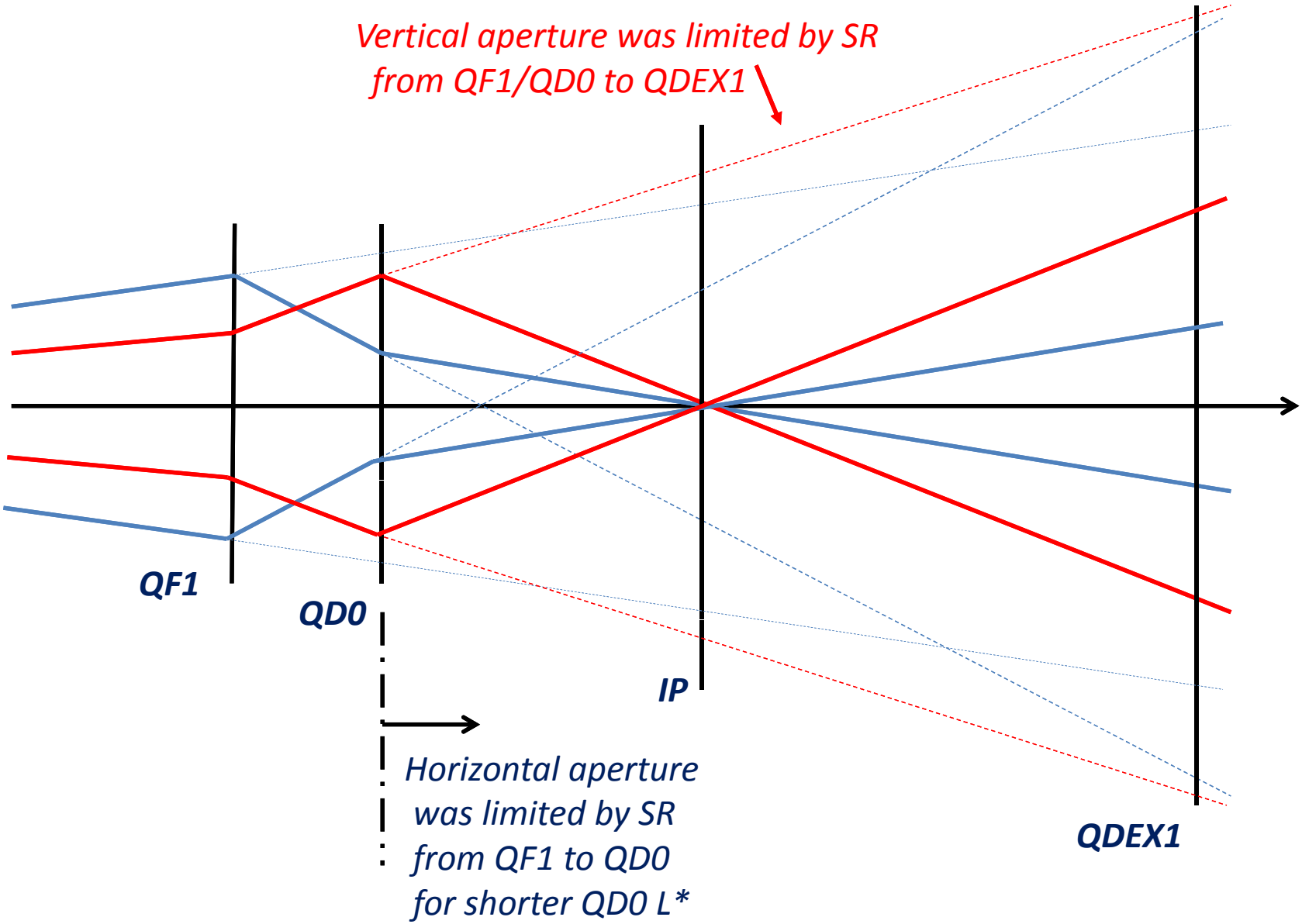
Summary

QF1 L is better to be shorter for all parameters.*

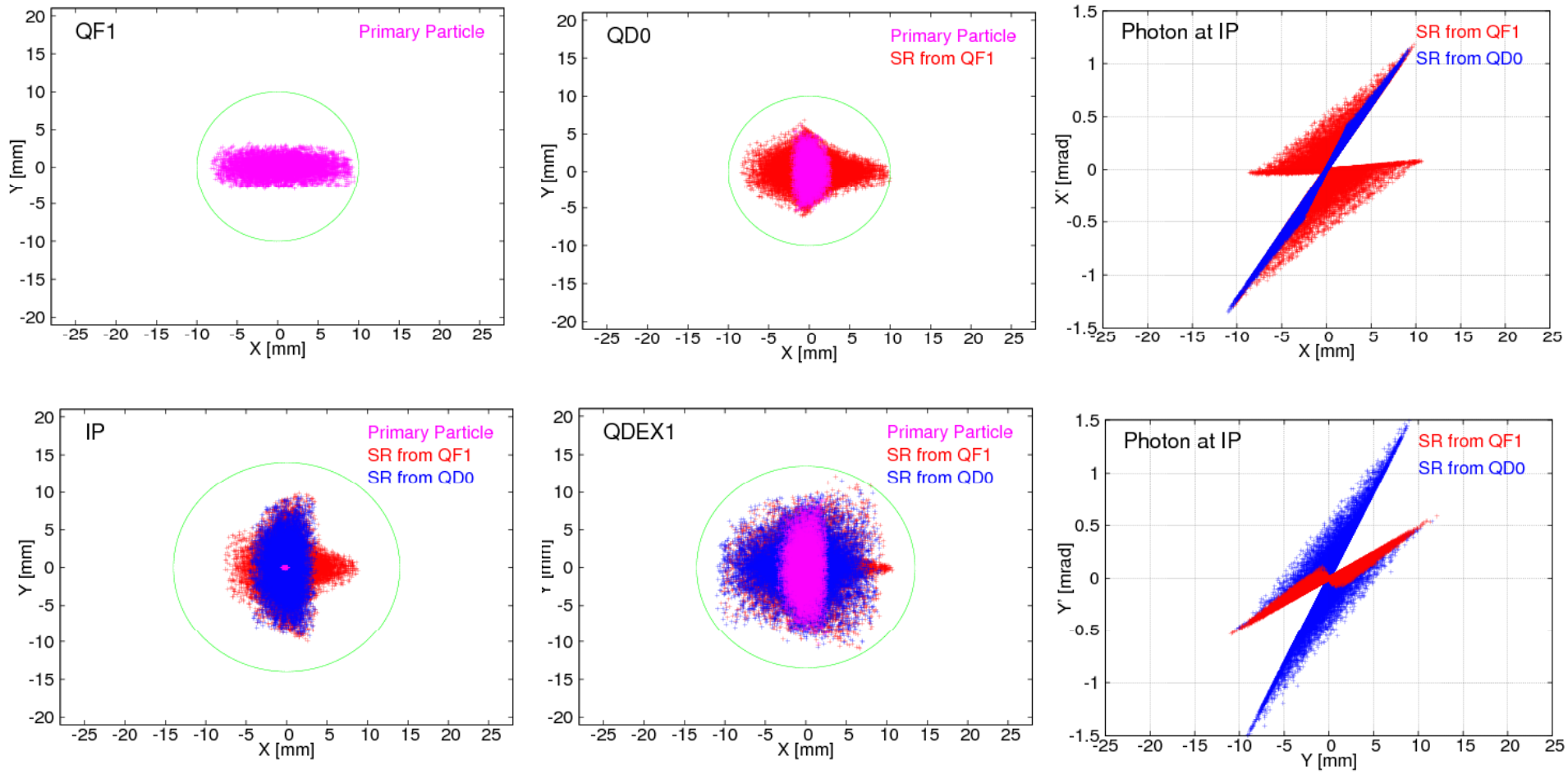
When we fix the QF1 L to be finite location,*

- *The horizontal collimation depths were not changed so much.*
- *The vertical collimation depth were better to be shorter L*.*
- *The alignment tolerance were better to be longer L*.*
  Therefore, the beam tuning simulation said
  that the higher luminosities were achieved to longer L.*

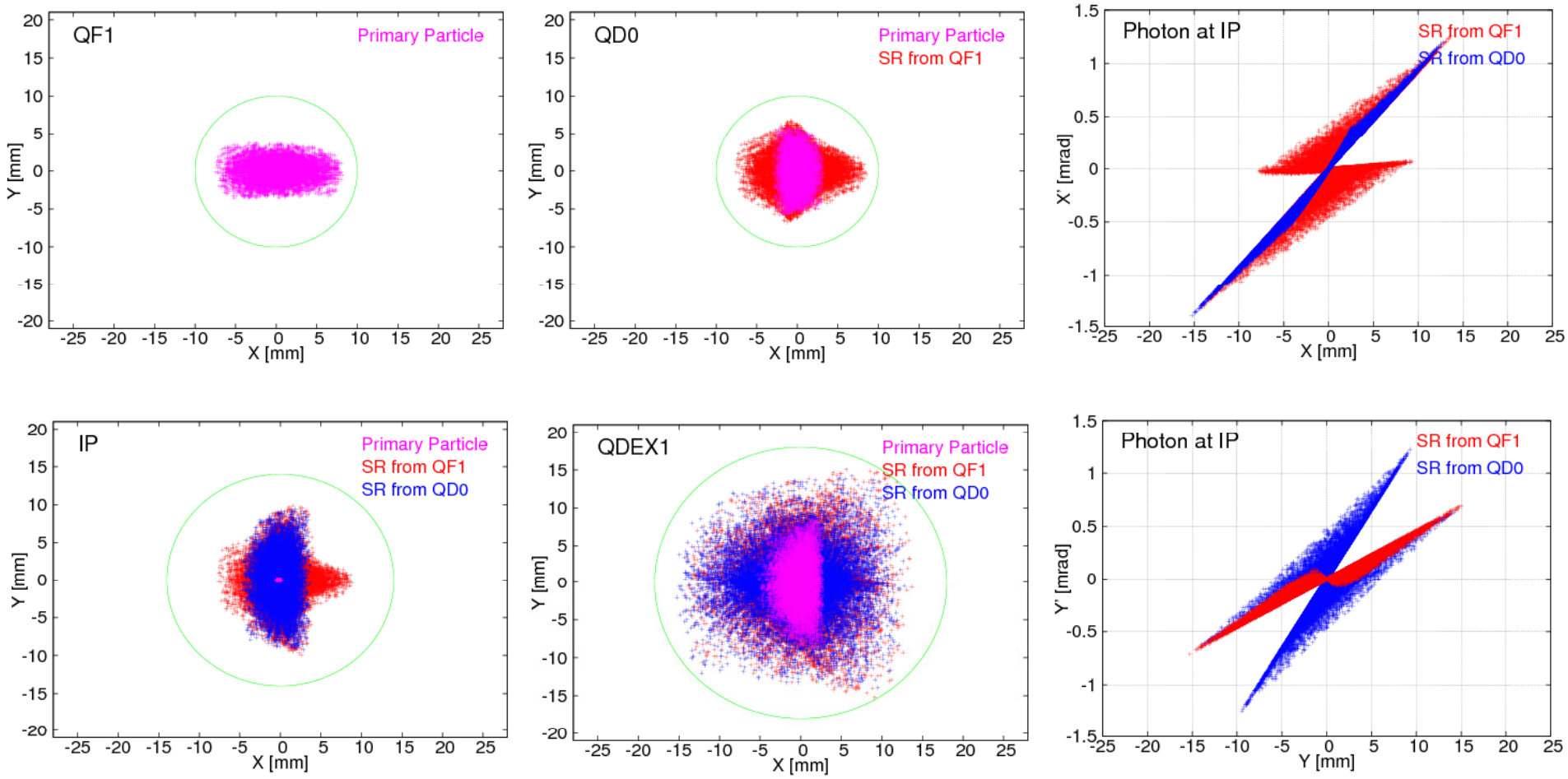
Backup


Vertical aperture was limited by SR
from QF1/QD0 to QDEX1
QF1
QD0
IP
QDEX1
Horizontal aperture
was limited by SR
from QF1 to QD0
for shorter QD0 L*

(QD0 L*)=3.0m , (QF1 L*)=9.0m



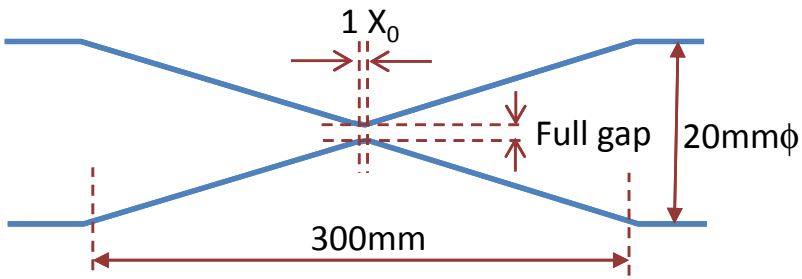
(QD0 L*)=4.5m , (QF1 L*)=9.0m

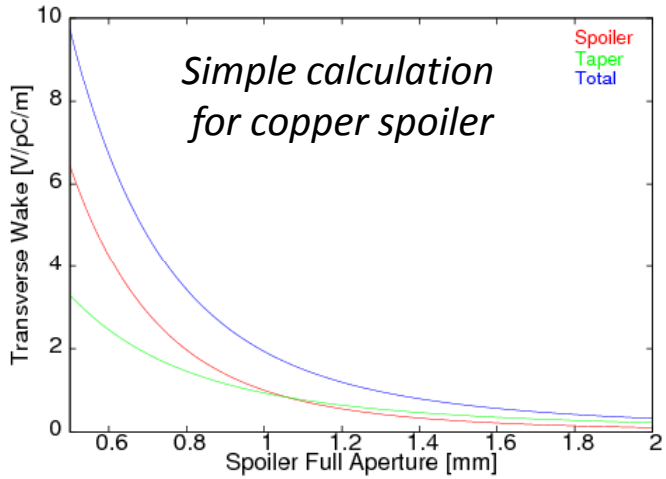


Consideration of the spoiler wake

RDR scheme must collimate at SP2/SP4 (betaY=1000m) for vertical direction.
New scheme can collimate at SPEX (betaY=4000m).
We can increase the vertical gap of spoiler.

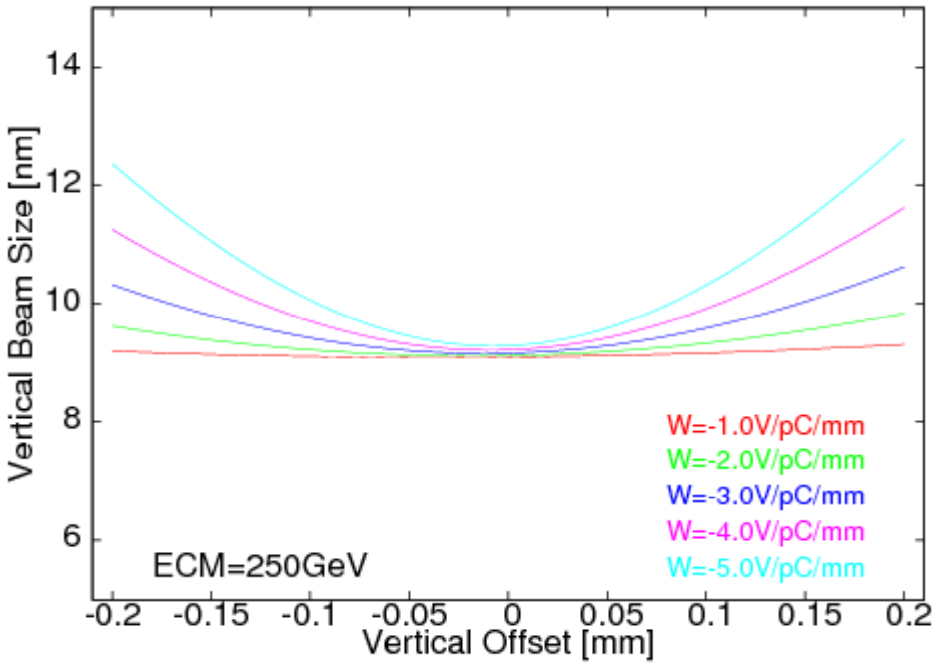
Example of resistive wall





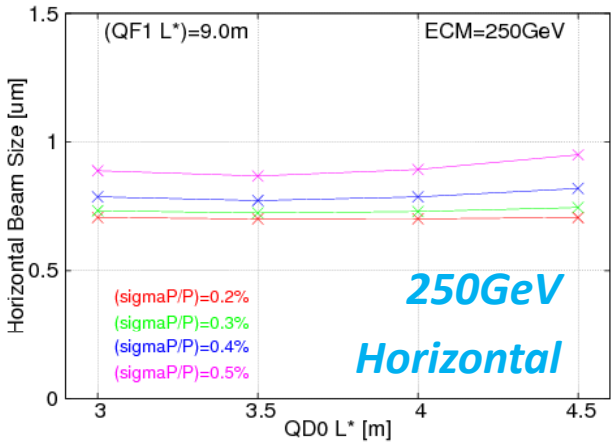
Example for the effect of resistive wall

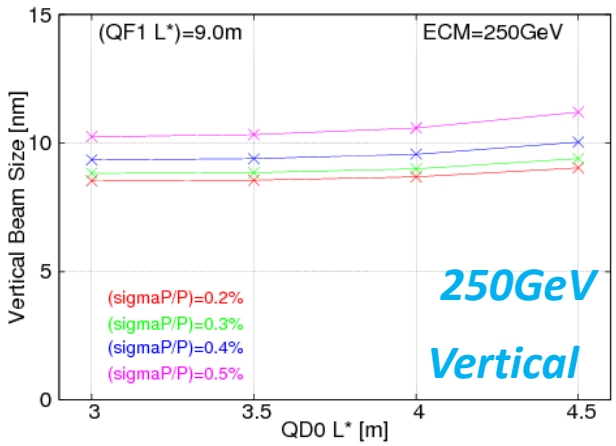
IP beam size simulation with wake for E_{CM}=250GeV
Wake source was put to SPEX

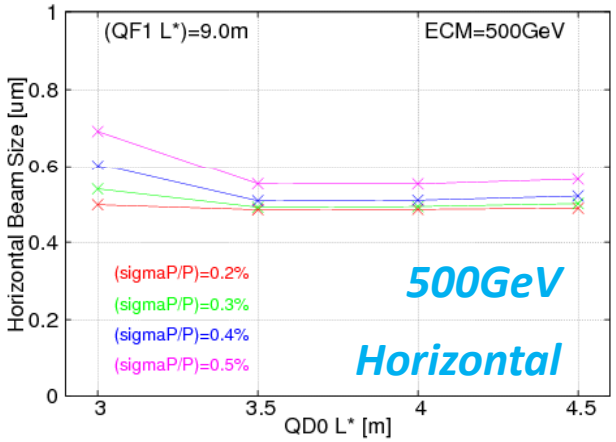


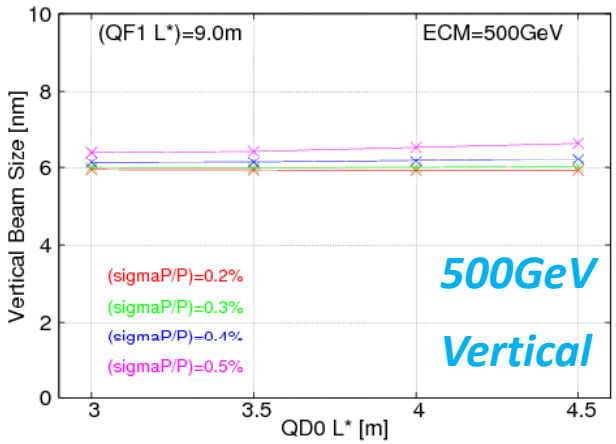
Material and geometry are different from ILC design.
see B. D. Fell et al., Proc. EPAC 08, 2883 (WEPP168).

Responses for energy spread for (QF1 L)=9.0m*









Horizontal beam size for shorter L* at ECM=500GeV is sensitive to energy spread.
(The distance between QD0 and QF1 we

Responses for energy spread for (QF1 L)=9.5m*