Results of the beam line optimization for ILC FFS (QF1 L)=9.1m and (QD0 L*)=4.1m*

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Procedure of the optics optimization

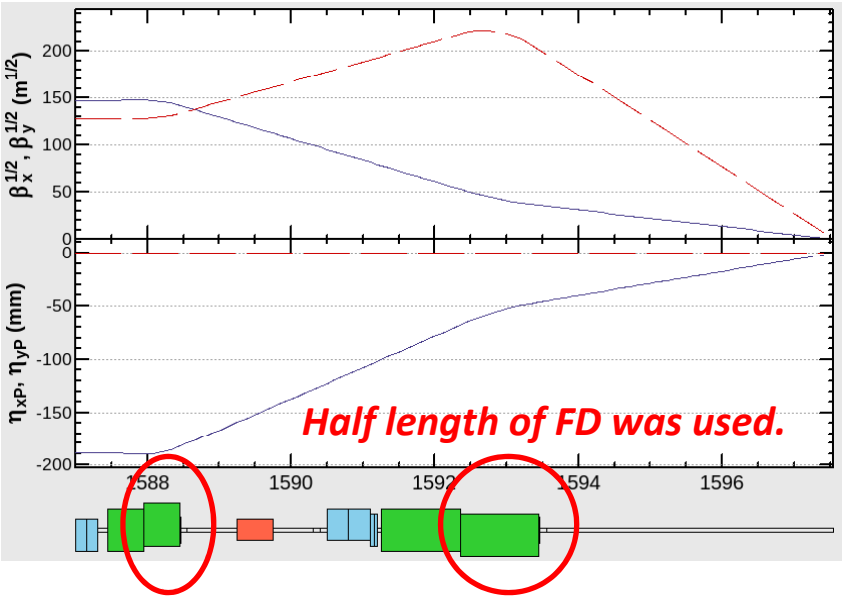
The optics for ECM=250GeV was only used the half of FD magnets in order to increase the collimation depth.

Therefore, the magnet arrangement for ECM=250GeV was different to others

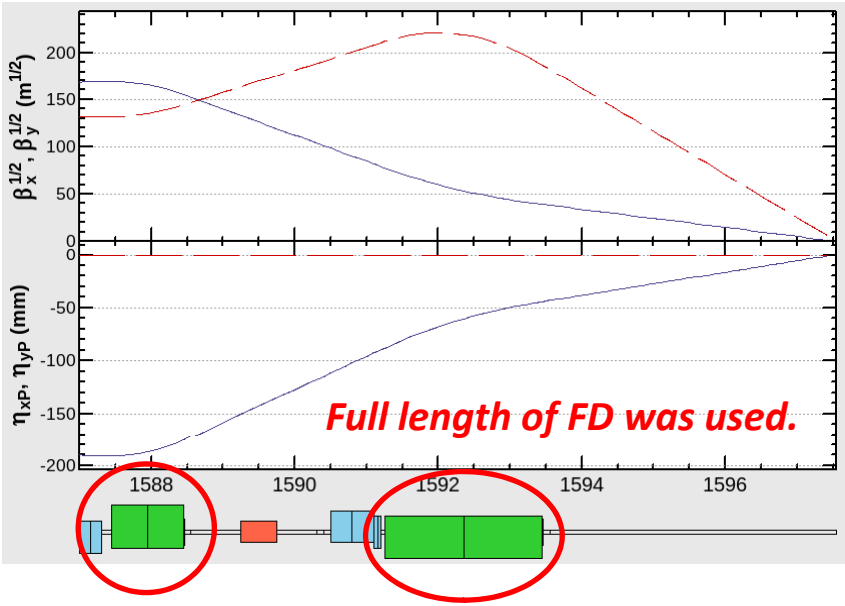
Since the nonlinear effects of the beam optics for ECM=250GeV is stronger than others, I optimized the magnet arrangement for ECM=250GeV.

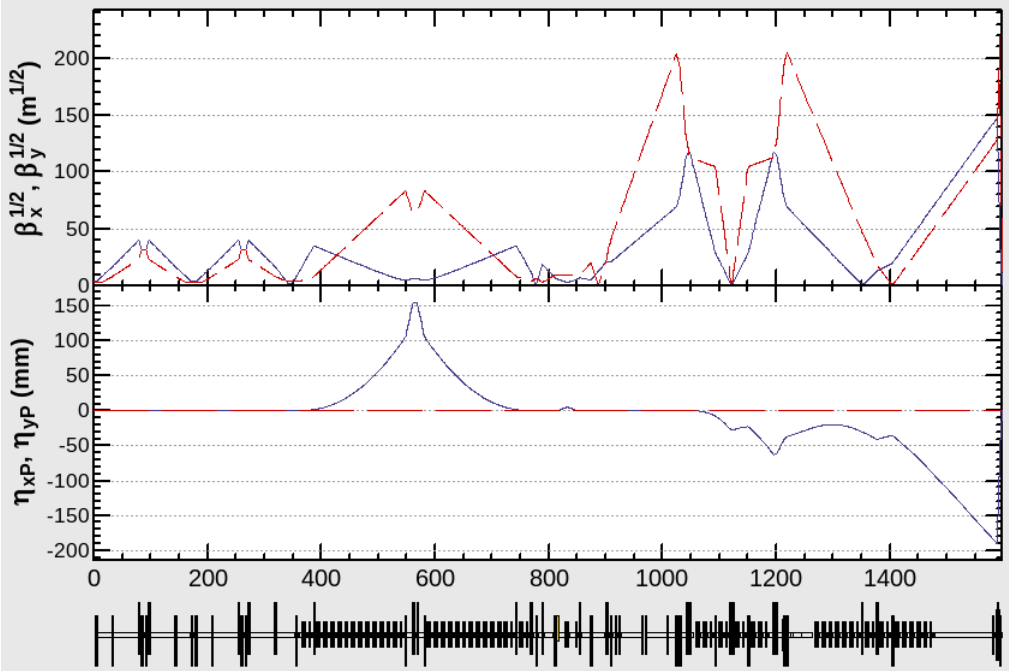
Then, ECM=500GeV optics was designed with the constraint of the arranged magnet to ECM=250GeV.

ECM=250GeV



ECM=500GeV

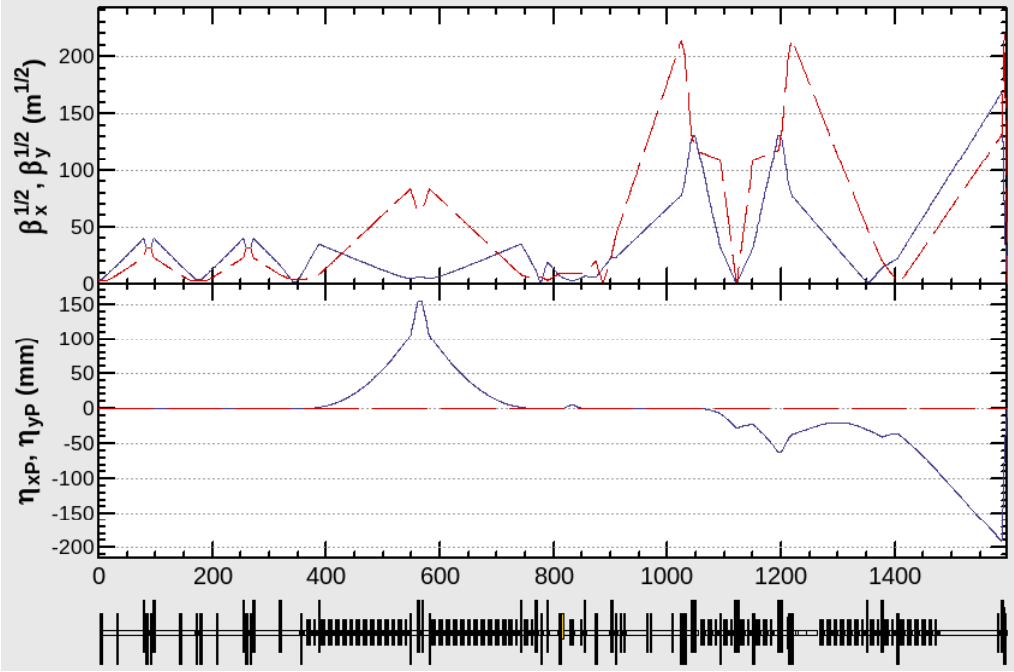




Beam Optics for ECM=250GeV
The half length of FD magnets were used.

betaX* = 13 mm
betaY* = 0.41mm

The magnet arrangement
(balances of beta and dispersion at sextupoles)
was optimized for this condition.



Beam Optics for ECM=500GeV
The full length of FD magnets were used.

betaX* = 11 mm
betaY* = 0.48mm

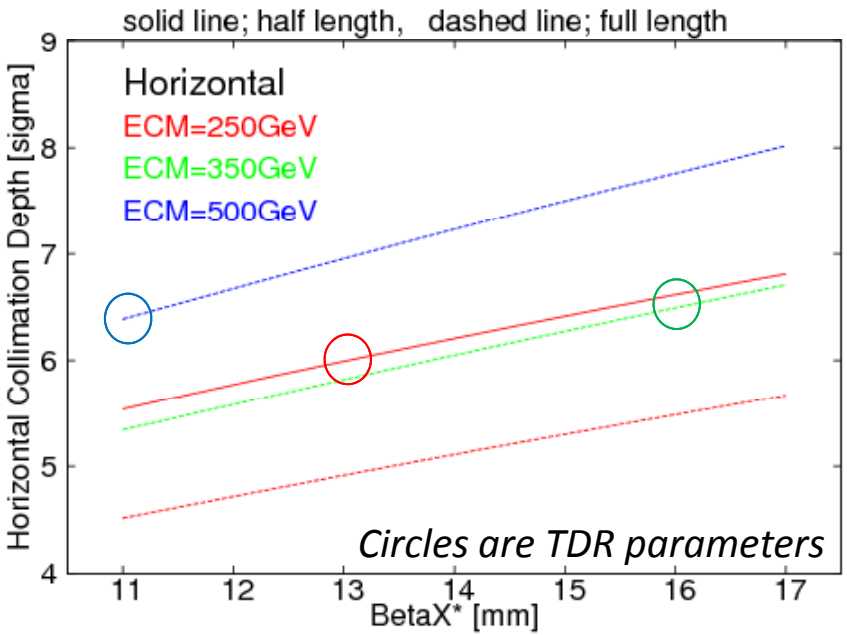
The magnet arrangement
was same to ECM=250GeV.

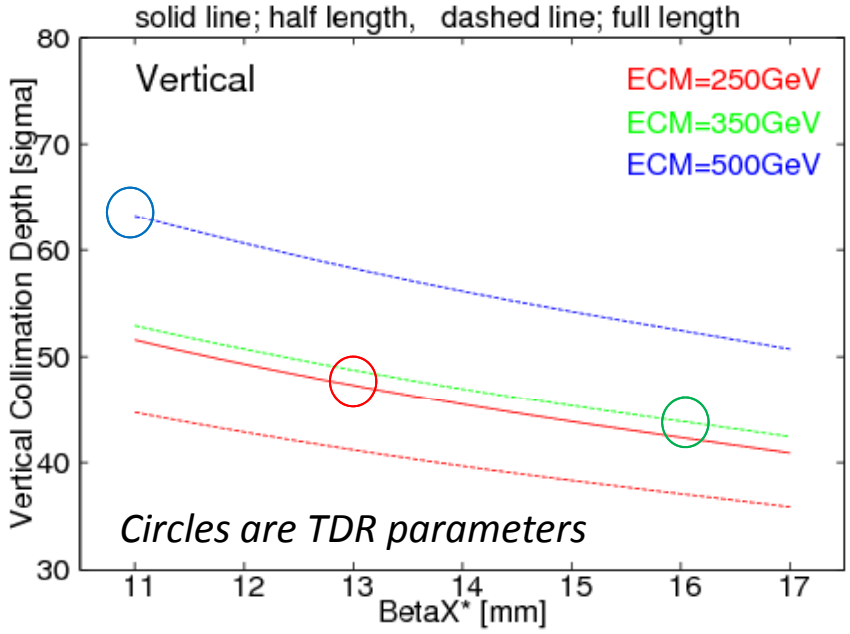
The strengths were changed to optimize.

The collimation depth for various beam energy

ECM	BetaX*	BetaY*
250GeV	13mm	0.041mm
350GeV	16mm	0.034mm
500GeV	11mm	0.048mm

(QF1 L) = 9.1m*
(QD0 L) = 4.1m*





The collimation depths for ECM=250GeV is comparable to ECM=350GeV and 500GeV, because we can focus the beam only with half of final doublets for ECM=250GeV.

But, the horizontal beam size at FF sextupoles are much larger than ECM=350GeV.

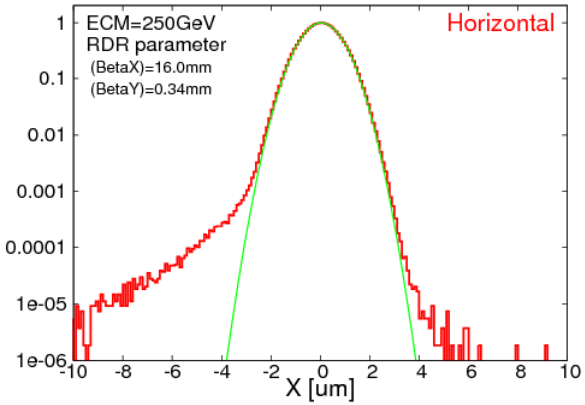
IP beam profile

TDR IP Parameters

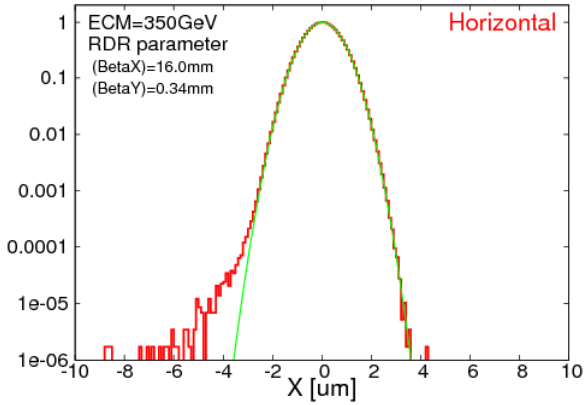
(QF1 L) = 9.1m*
(QD0 L) = 4.1m*

IP Horizontal Profile

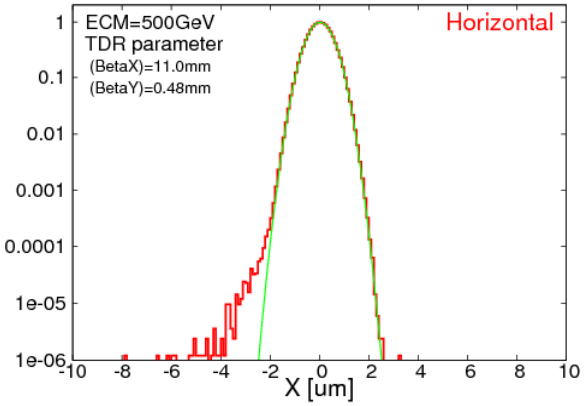
ECM=250GeV



ECM=350GeV

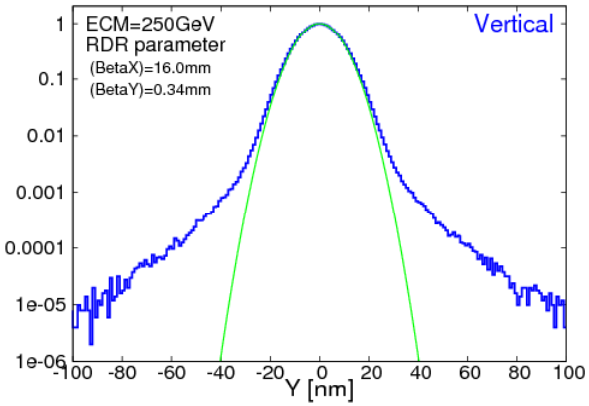


ECM=500GeV

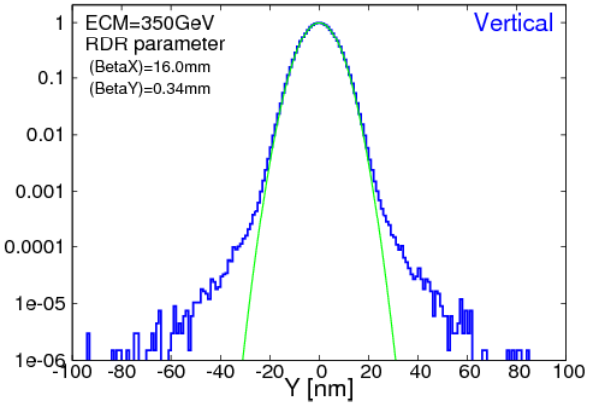


IP Vertical Profile

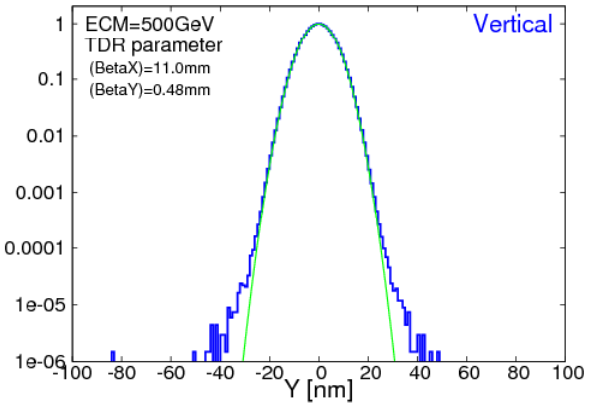
ECM=250GeV



ECM=350GeV



ECM=500GeV



The multipole effect for ECM=250GeV is huge compared to other parameters.

Since the horizontal profile was asymmetric, we could not correct with octupoles.

Summary of the IP beam size of the ILC BDS optics

		ECM=250GeV	ECM=350GeV	ECM=500GeV
Horizontal beam size	**design**	0.729 um	0.684 um	0.474 um
	core	0.749 um	0.685 um	0.478 um
	rms	0.756 um	0.705 um	0.489 um
Vertical beam size	**design**	7.66 nm	5.89 nm	5.86 nm
	core	7.84 nm	5.99 nm	5.90 nm
	rms	8.03 nm	6.08 nm	5.93 nm
Relative Luminosity (L/L0)		95.1 %	98.2 %	98.6%

-The TDR IP parameters was used for each beam energy.

-The beam size simulation was not included the effect of Synchrotron radiation.

-The multipole effects for ECM=250GeV was larger than others,
and the final luminosity for ECM=250GeV is also smaller than others.

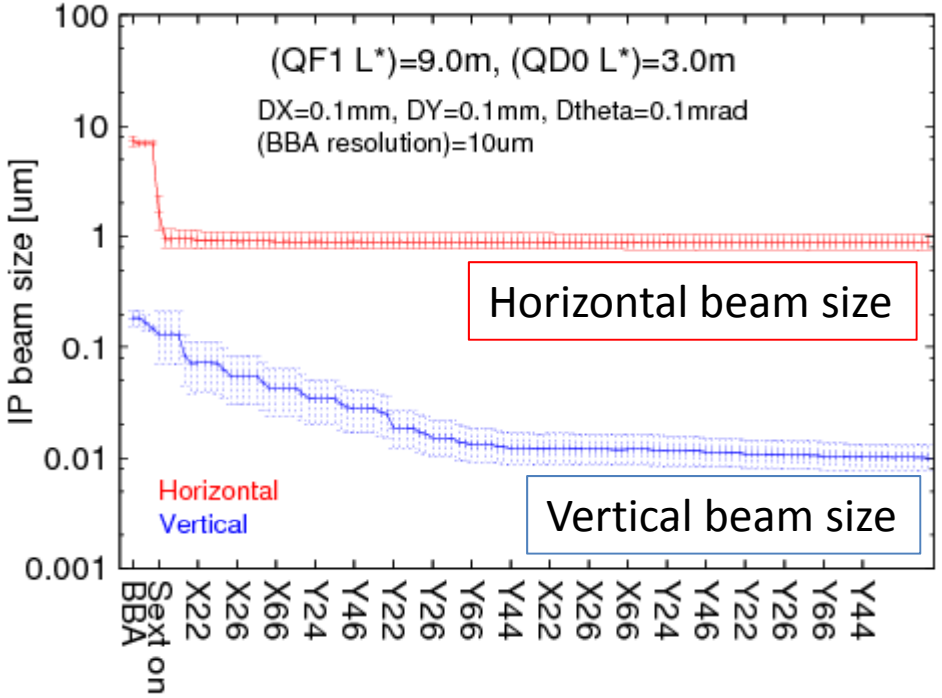
Tolerances for ECM=250GeV was evaluated by using IP beam size tuning simulation

Since ECM=250GeV is difficult to others,
I evaluated the tolerances for ECM=250GeV.

Procedures

1. *Put the errors*
2. *Apply the orbit tuning*
3. *Tuned on the sextupole after sextupole BBA*
4. *Apply the linear and 2nd order optics tuning*

Example of the beam size minimization by the beam tuning 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

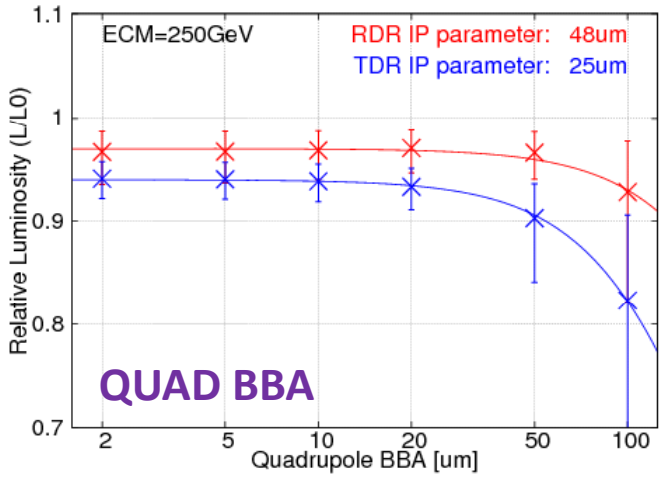
1 by 1 error input

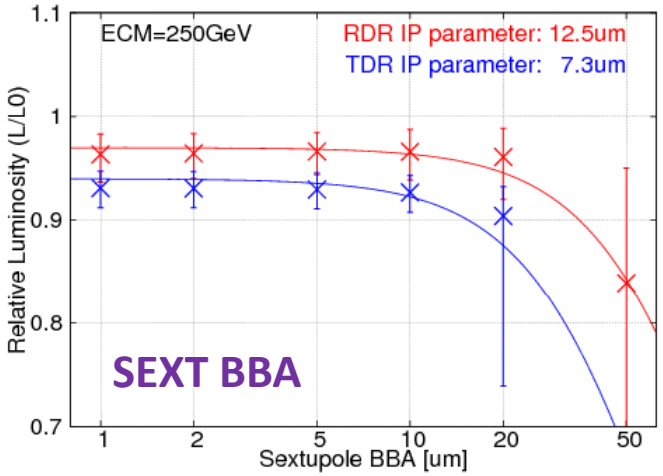
Since the beam focusing for ECM=250GeV is most difficult,
The tolerances for ECM=250GeV was evaluated.

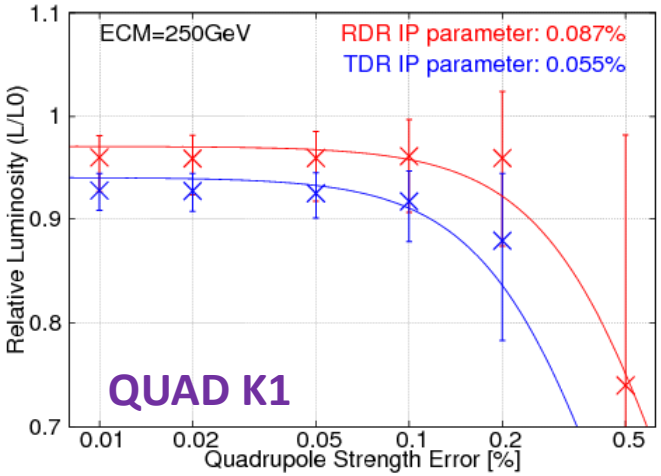
The tolerances were defined to
1% luminosity reduction of 100 seed average.

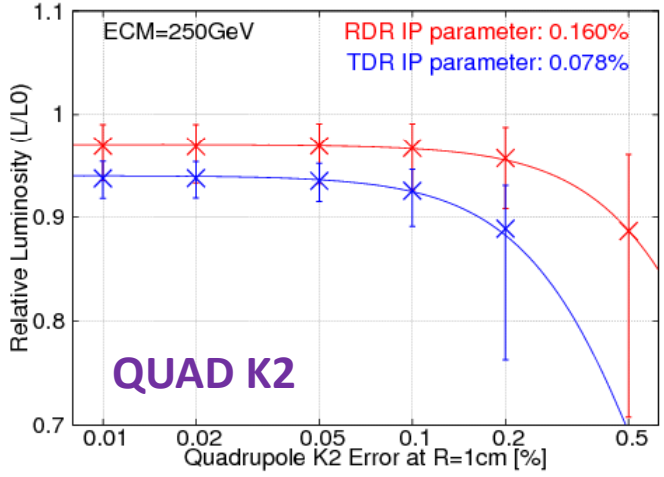
(QF1 L) = 9.1m*
(QD0 L) = 4.1m*

*gamma*emitX = 10um*
*gamma*emitY = 35nm*
sigmaP/P = 0.19%









Summary of BDS Tolerances (ECM=250GeV)

(QF1 L) = 9.1m*
(QD0 L) = 4.1m*

1% average luminosity reduction

Parameters			RDR (BX=21.0mm, BY=0.40mm)	TDR (BX=13mm, BY=0.41mm)
Quadrupole	Initial Alignment	Position	> 200um	> 200um
		Roll	0.20mrad	0.16mrad
	Strength	K1	0.087%	0.055%
		K2 at R=1cm	0.160%	0.078%
	BBA		48um	25um
Sextupole	Initial Alignment	Position	> 200um	> 200um
		Roll	> 1mrad	> 1mrad
	Strength		> 1%	0.60%
	BBA		12.5um	7.3um
Bending Magnet	Initial Alignment	Position	> 200um	> 200um
		Roll	> 1mrad	> 1mrad
	Strength		> 1%	> 1%
	BPM Alignment		103um	73um

IP beam size simulation with total error inputs

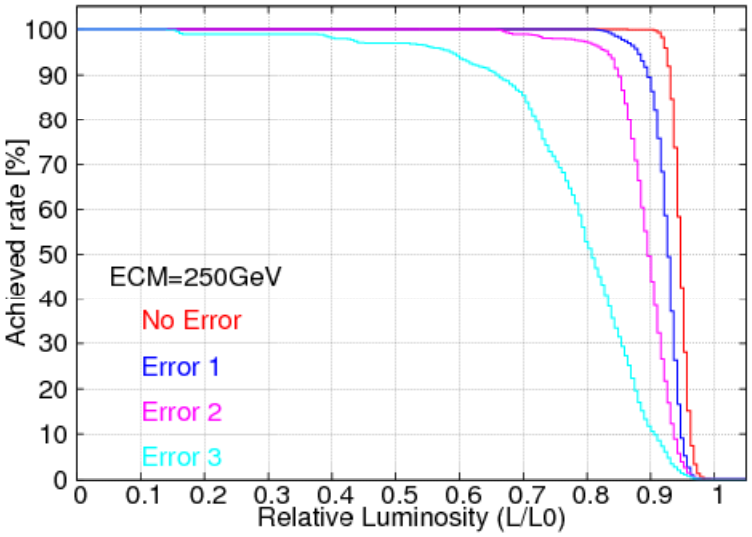
I assumed 3 errors for the IP beam tuning simulation.

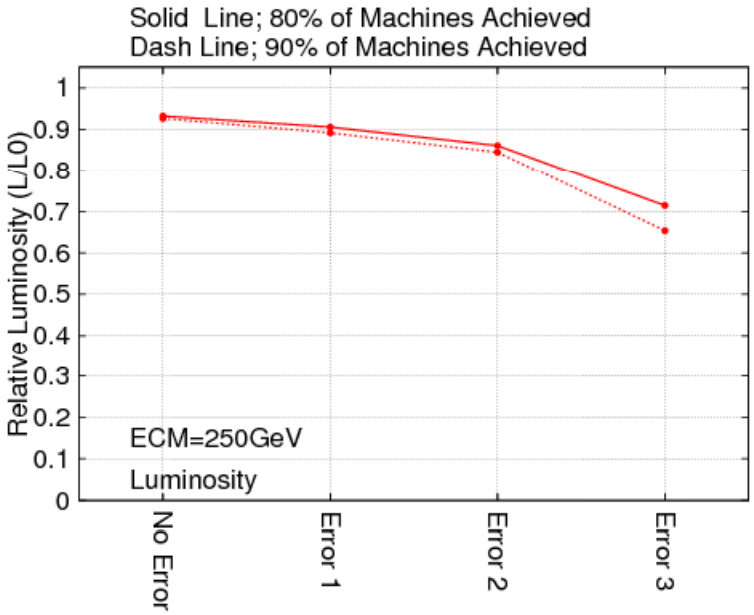
Parameters			Error 1 (Edu's simulation)	Error 2 (TDR 250GeV tolerance)	Error 3 (RDR 250GeV tolerance)
Quadrupole	**Initial Alignment**	**Position**	100um	200um	200um
		Roll	0.30mrad	0.16mrad	0.20mrad
	Strength	**K1**	0.010%	0.055%	0.087%
		K2 at R=1cm	0.010%	0.078%	0.160%
	BBA		5um	25um	48um
Sextupole	**Initial Alignment**	**Position**	100um	200um	200um
		Roll	0.3mrad	1mrad	1mrad
	Strength		0.010%	0.600%	1.000%
	BBA		5 um	7.3um	12.5um
Bending Magnet	**Initial Alignment**	**Position**	100um	200um	200um
		Roll	0.3mrad	1mrad	1mrad
	Strength		0.01%	1.00%	1.00%
	BPM Alignment		5 um	73um	103um

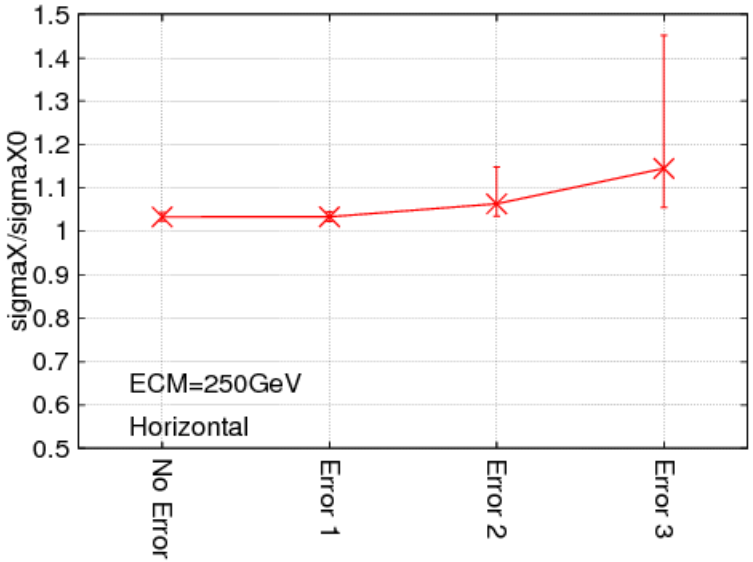
The errors for Edu's simulation was easier than others, except for roll error of quads.

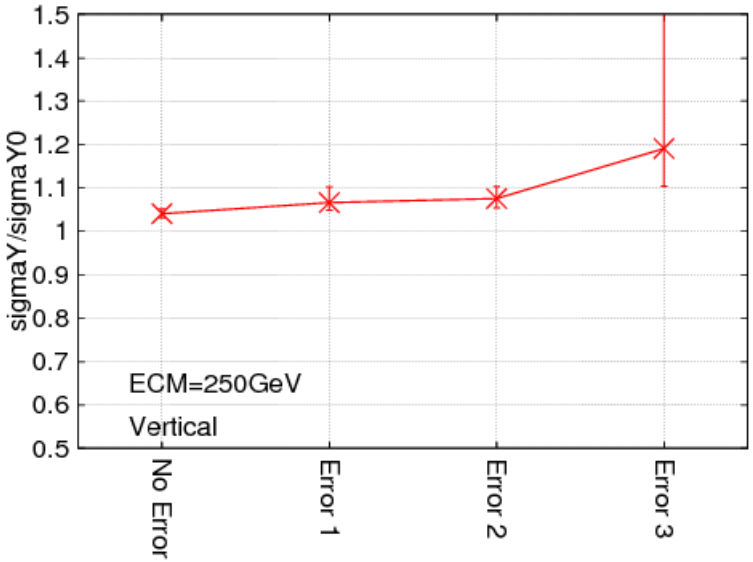
IP beam size tuning results for ECM=250GeV

Maximum luminosity was about 95% of design



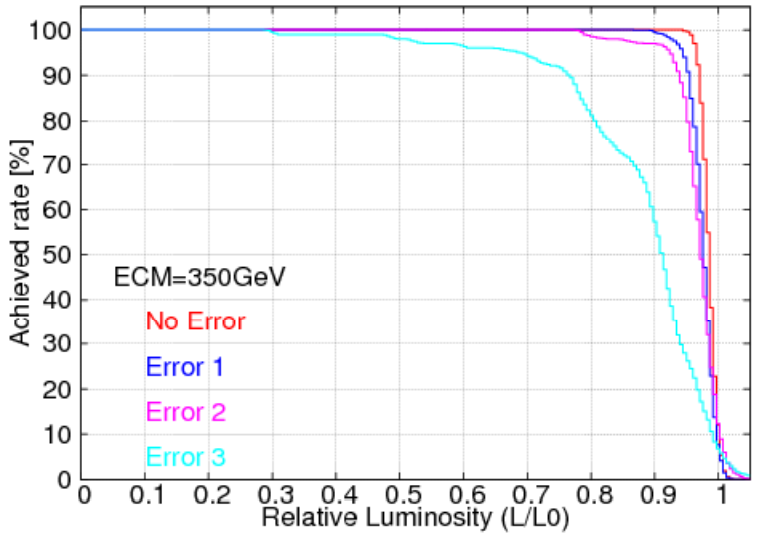


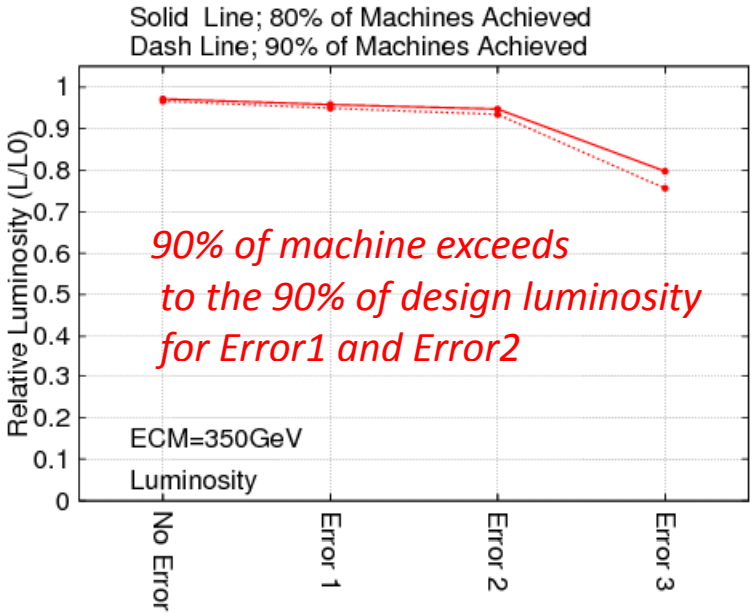


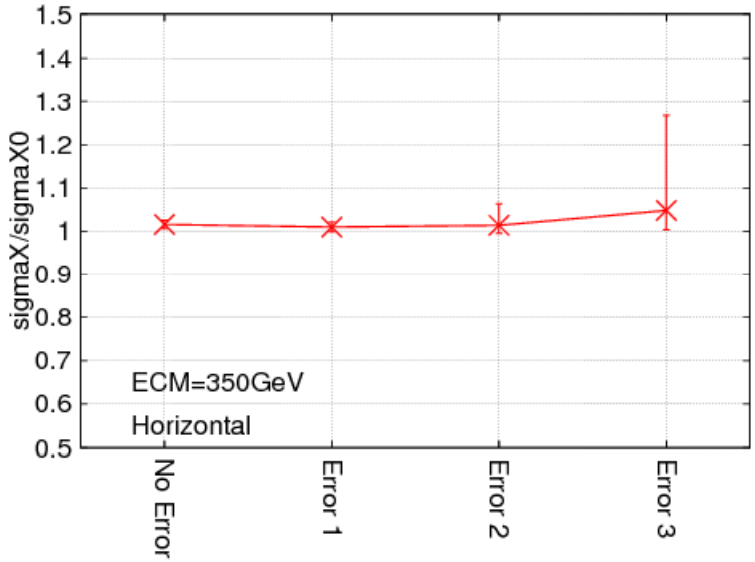


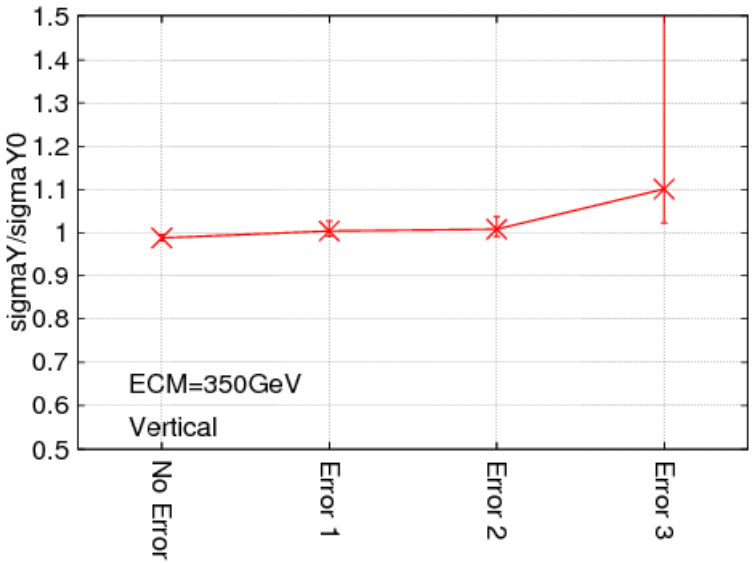
We observed not only vertical beam size growth, but also the horizontal beam size growth.

IP beam size tuning results for ECM=350GeV



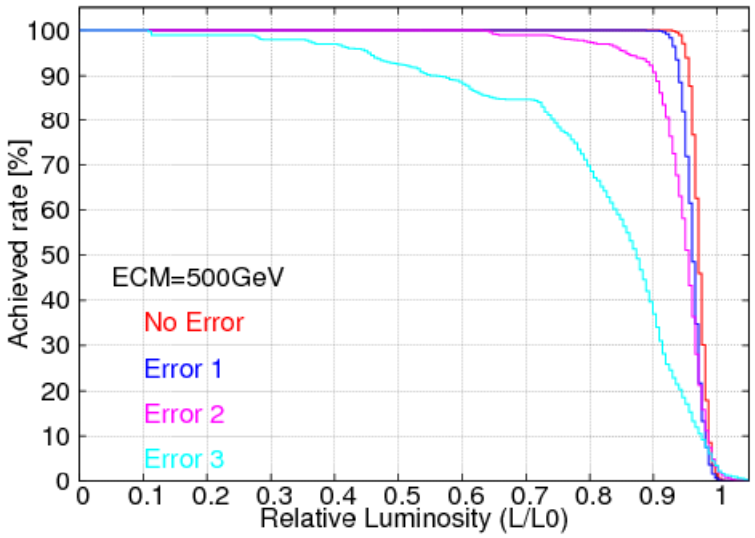


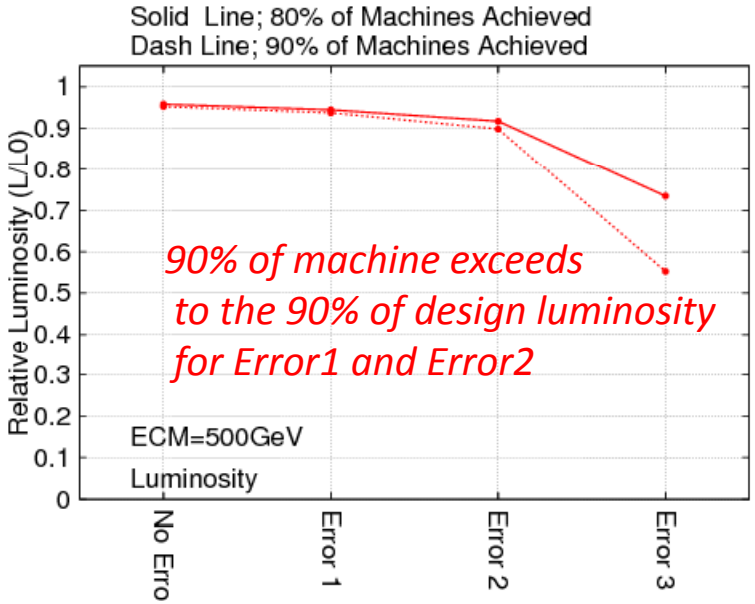


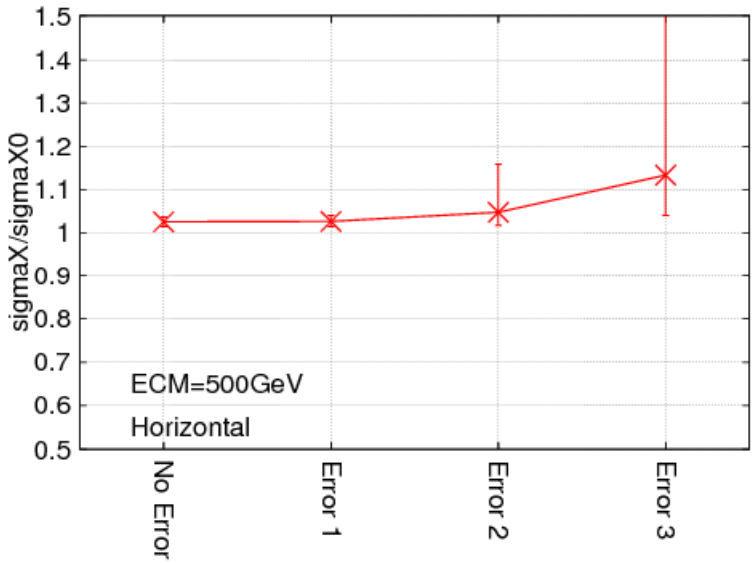


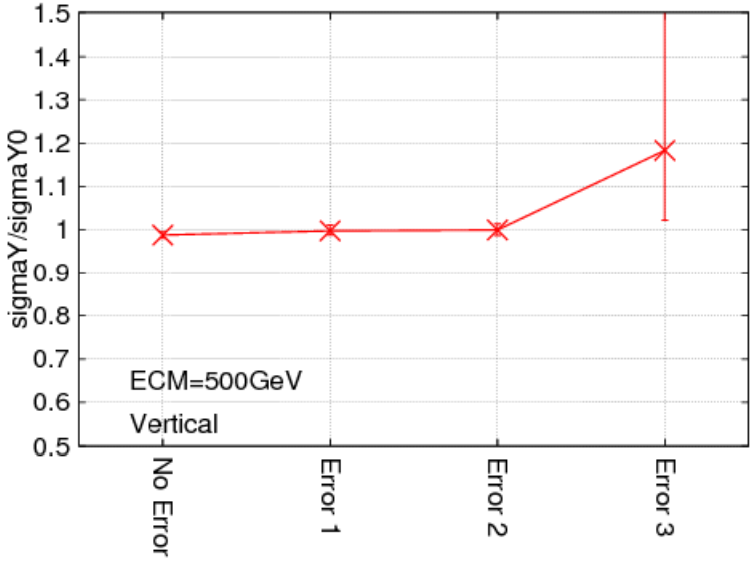
We observed not only vertical beam size growth, but also the horizontal beam size growth.

IP beam size tuning results for ECM=500GeV









The horizontal beam size growth is stronger than ECM=350GeV.

Summary

Simulation results say it is possible to correct the IP beam size only with sextupoles.
When we optimized the linear and 2nd order optics carefully,
we don't need the octupoles for IP beam size tuning.

When we use the octupoles to the core beam size minimization,
the tail particles will be spray with the beam line and it makes the collimation depth small.
Therefore, it is better to design the optics only with lower order optics correction, if possible.
(The octupoles are better to use the tail folding.)

Furthermore, when the machine has the large errors,
not only vertical beam size, but also horizontal beam size was increased.

Since the horizontal profile was asymmetric,
we could not correct the horizontal beam size with octupoles (see the IP beam profile).