Optimization of ILC BDS optics for wide energy range

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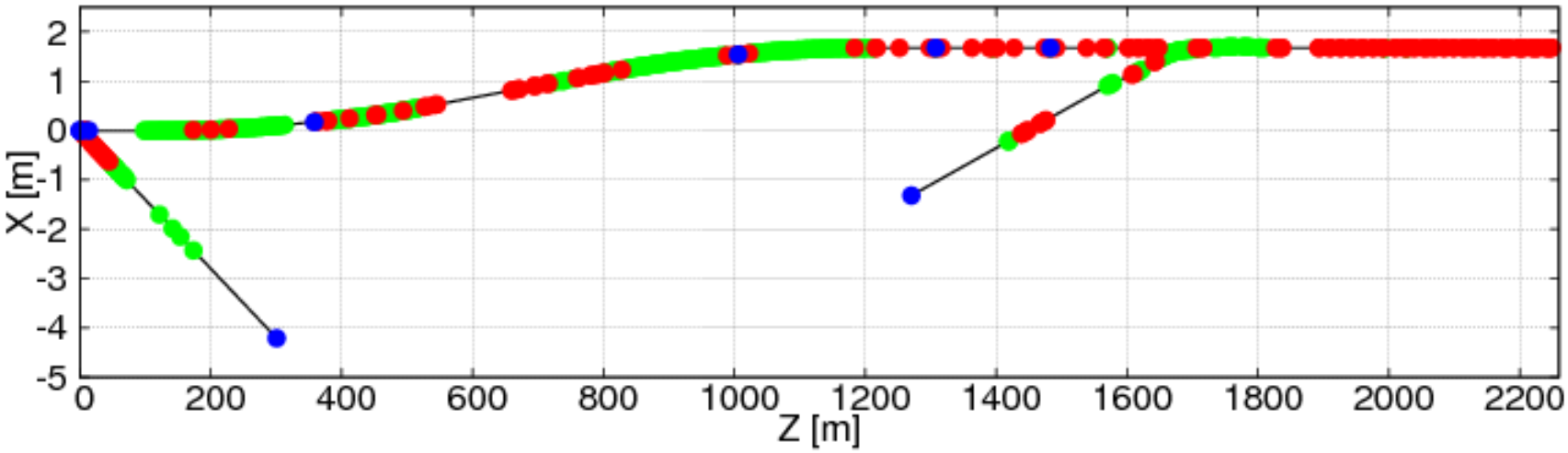
ILC BDS Beamline

Base design of ILC BDS beamline was presented by T.Okugi at ALCW2015, KEK.

In ILC design,

BDS beamline was designed ***from ECM=250GeV to ECM=1TeV with same geometry****.*

The several magnets will be added for ECM=1TeV operation.

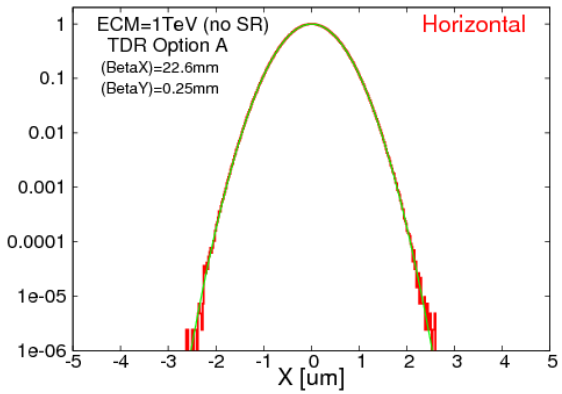


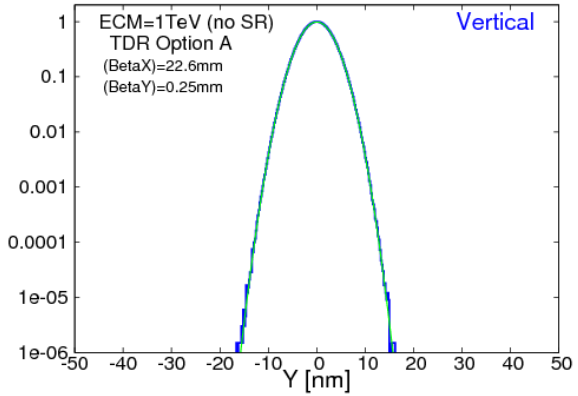
In order to use the same beamline to very wide energy range,

the performance for low energy and high energy optics is not good*.*

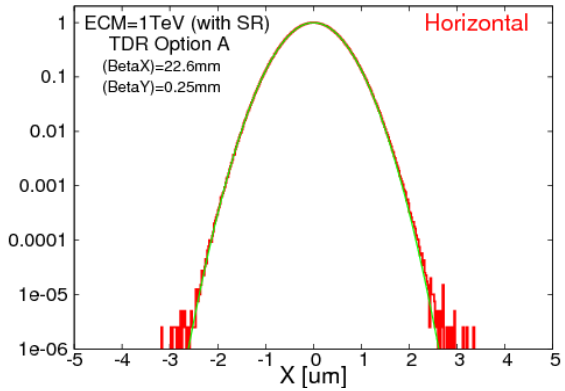
IP beam profile for ECM=1TeV

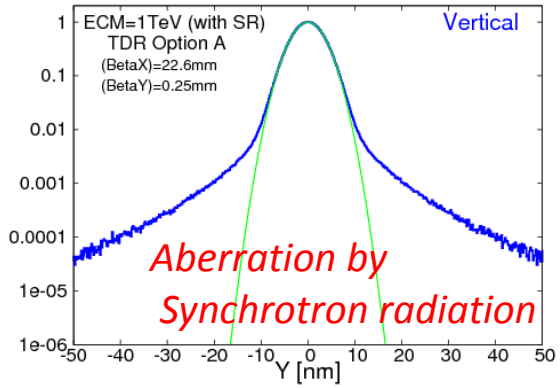
<< no SR >>





<< with SR >>





Large aberration by Synchrotron radiation

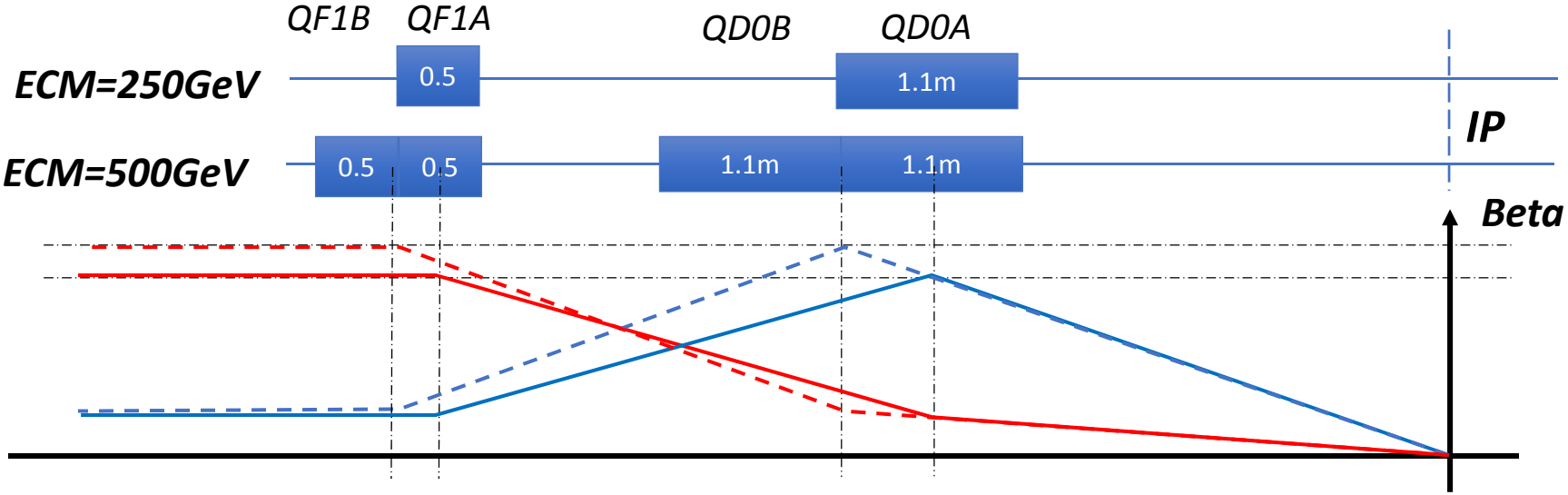
The luminosity is reduced by 5-6% by the aberration of Synchrotron radiation in ECM=1TeV. Therefore, it is difficult to increase the bending angle anymore in ECM=1TeV.

In order to make compatible design to ECM=1TeV,
the geometry of low energy optics also limited to the Synchrotron aberration of ECM=1TeV.

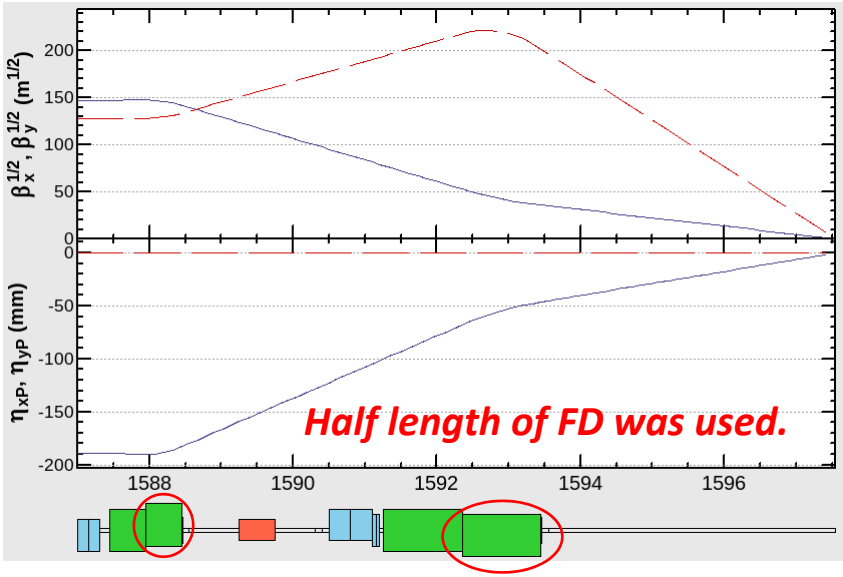
Low Energy Operation (E_{CM}=250GeV)

We need strong sextupole magnets to correct the chromaticities for their small dispersion.

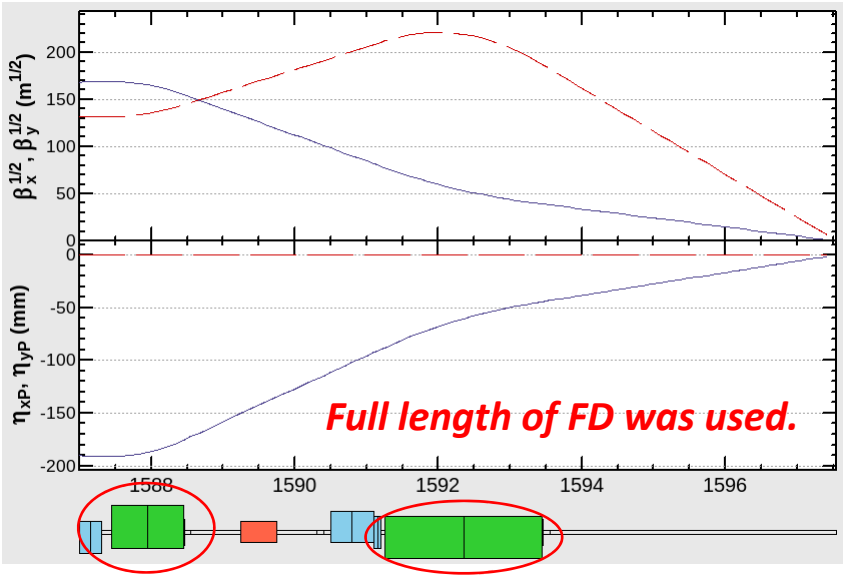
Then, the geometrical aberration is large by their large beam size at sextupoles in low energy region.



ECM=250GeV



ECM=500GeV

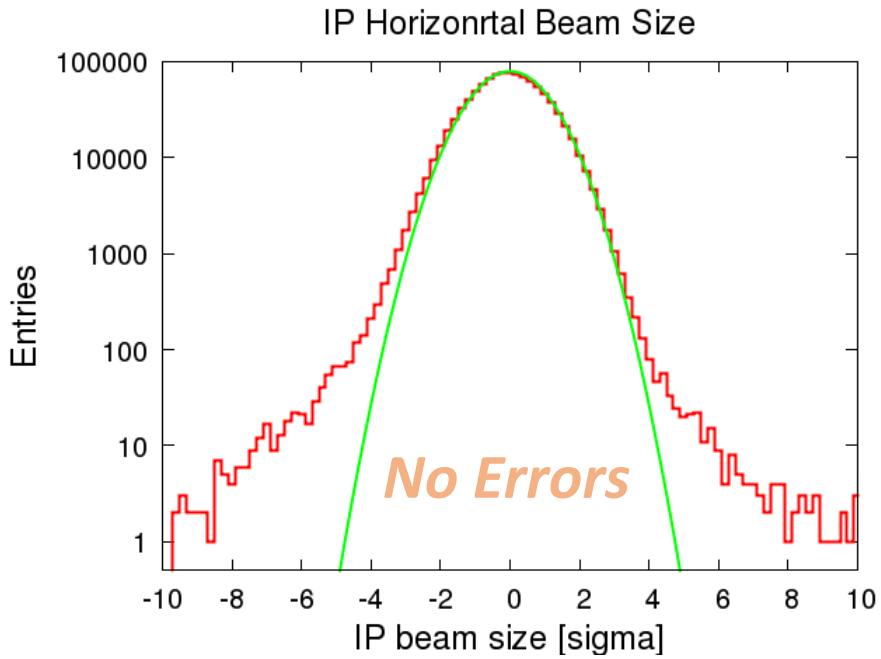


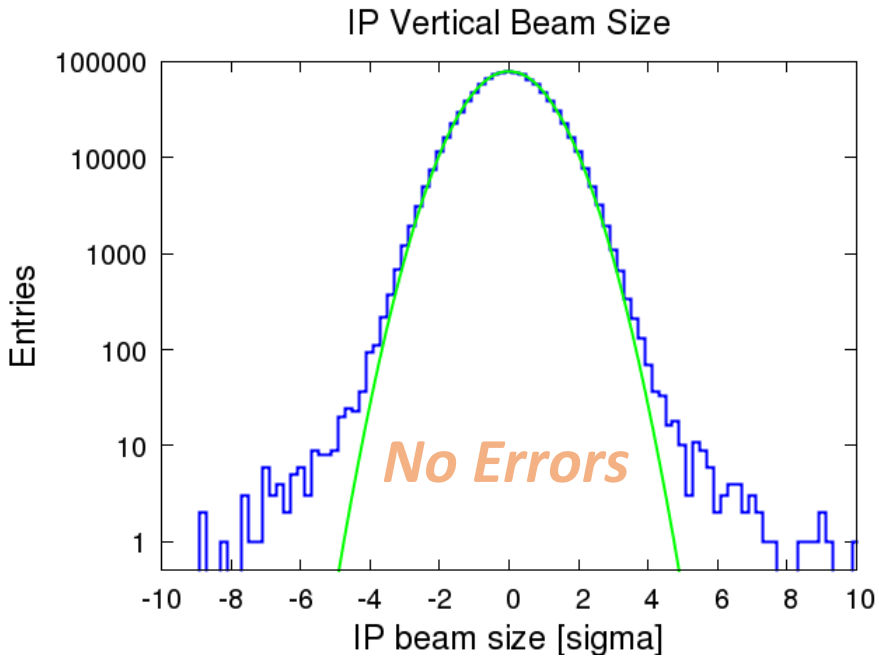
IP beam profile for ECM=250GeV

Simulated IP beam profiles for ECM=250GeV optics

$$\sigma_p/p = 0.188\%$$

$$\beta_x^* = 0.013\ \mathrm{m}\ , \beta_y^* = 0.00041\ \mathrm{m}$$





Even if we use the half length FD magnets,
the effect of the 2nd order aberrations by sextupoles are large.

- IP beam size growth (design luminosity is reduced by 7-8%)
- Large beam tail is generated.

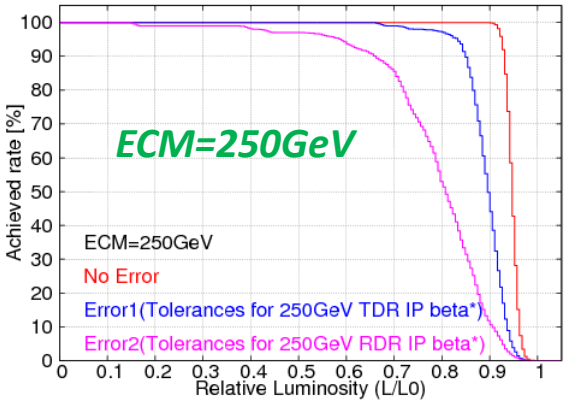
Alignment Tolerances for ECM=250GeV

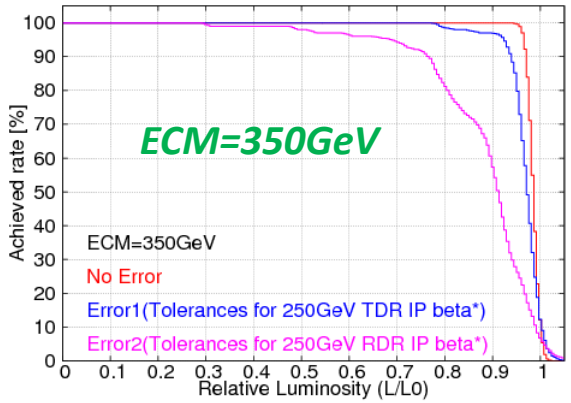
Evaluated by IP beam size using SAD tracking simulation

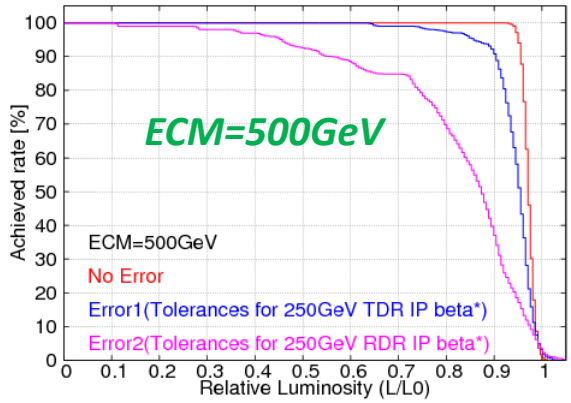
1% average luminosity reduction *Red seems difficult.*

Parameters			RDR (Error 2) (BX=21.0mm, BY=0.40mm)	TDR (Error 1) (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

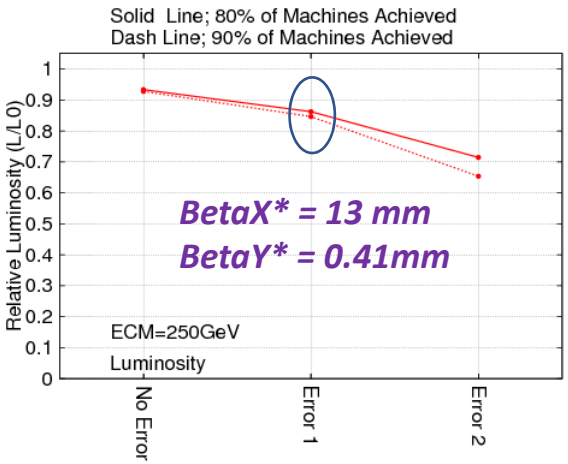
Beam tuning simulation for various beam energy

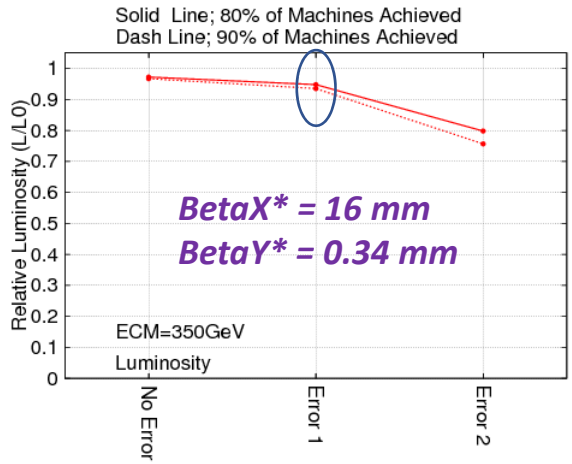


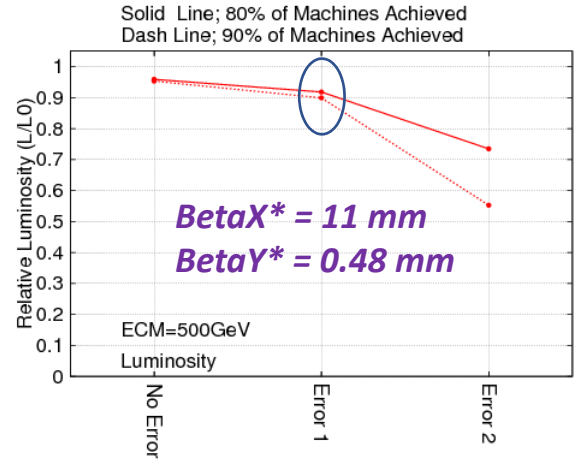




Simulation result of luminosity with all magnet errors of TDR & RDR tolerances







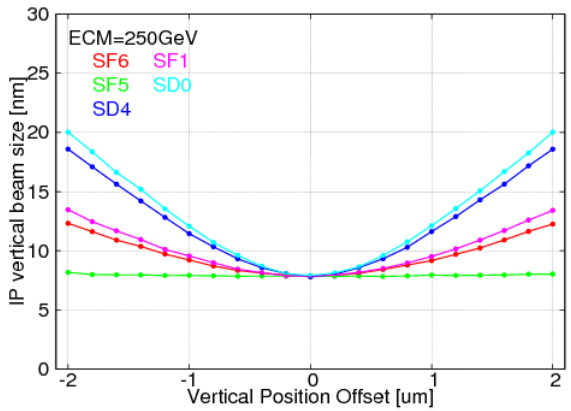
Tolerances for ECM=350GeV, 500GeV are easier than ECM=250GeV for their small horizontal beam size at FF sextupoles.

Requirement of the magnet movers

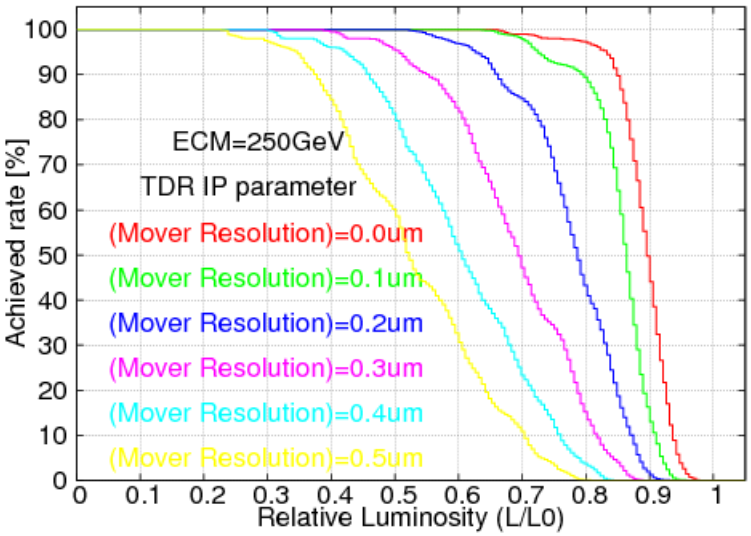
When the position of the sextupoles were moved by sub-micron, IP-beam size was increased so much.

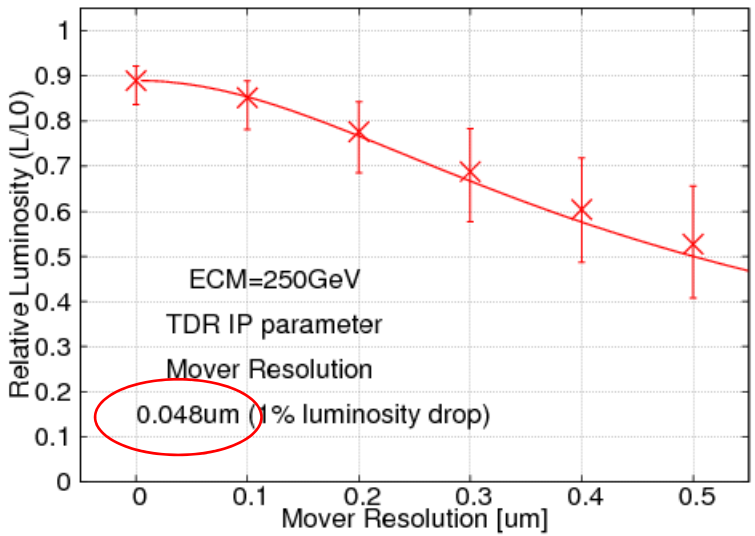
Therefore, the mover tolerances also evaluated by IP tuning simulation.

The tolerance is evaluated for ECM=250GeV, and TDR IP beta functions (betaX/betaY*= 13mm/0.41mm).*



The alignment error is set to the tolerance for 250GeV TDR parameter.





This is one of the difficult requirement of ILC FF.

Performance improvement for low energy operation

Present ILC BDS is not good for low energy
to keep the compatible design to ECM=1TeV beamline.

The beam tuning simulation says

- *most of machines (80-90%) can be focus the IP beam size with 10-20% luminosity loss by assuming the magnet errors of TDR tolerances.*
- *the tolerances of magnet mover resolutions are less than 50nm (ATF; 100nm).*

Since some TDR tolerances are still tight,
it is better to relax the tolerances at the low energy region.

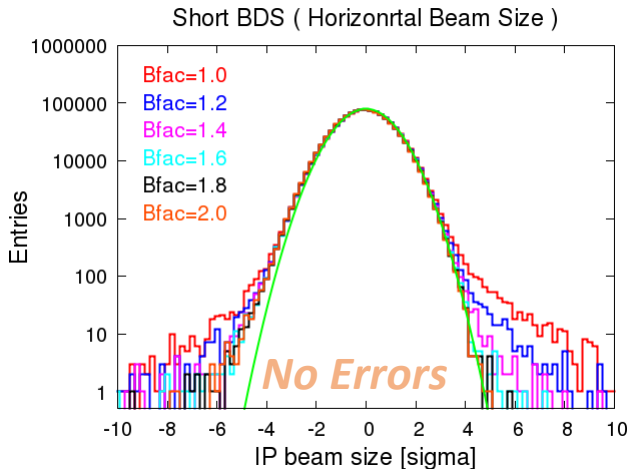
It is better to optimize the BDS optics to the low energy range especially for the 1st stage.

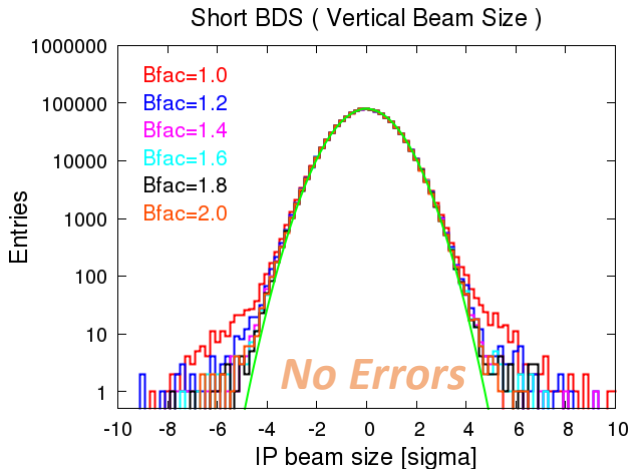
Therefore, the performance of the FF beamline with ***"strong bending magnet"*** *was evaluated.*

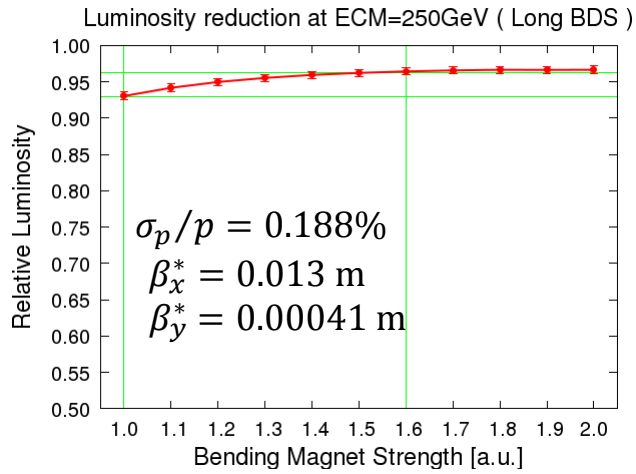
IP beam profile at ECM=250GeV for BDS with strong BEND

The stronger sextupoles makes the FF dispersion stronger.
Then, the geometrical dispersion will be reduced.

=> The luminosity and beam tail was improved.

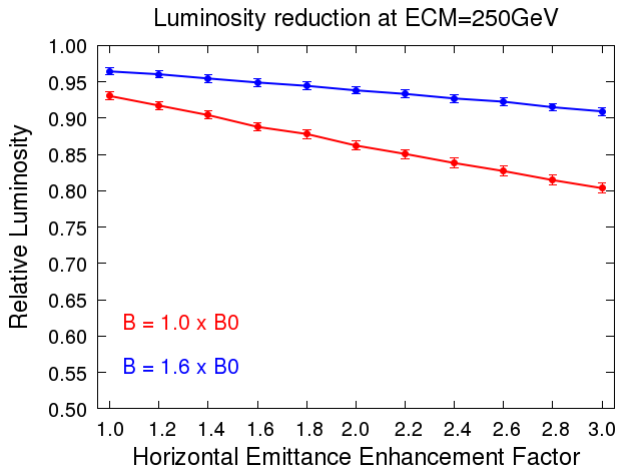




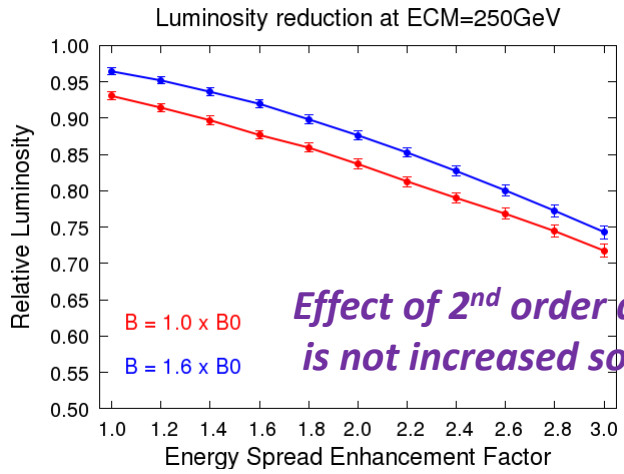


When we set to the bending magnet strength to be 1.6 times larger than design.

Horizontal emittance is larger than design



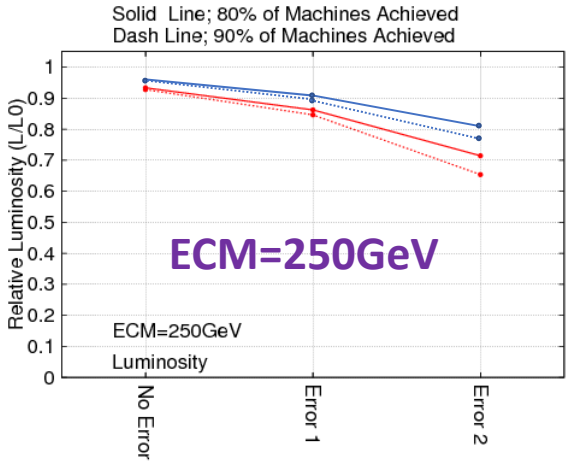
Energy spresd is larger than design

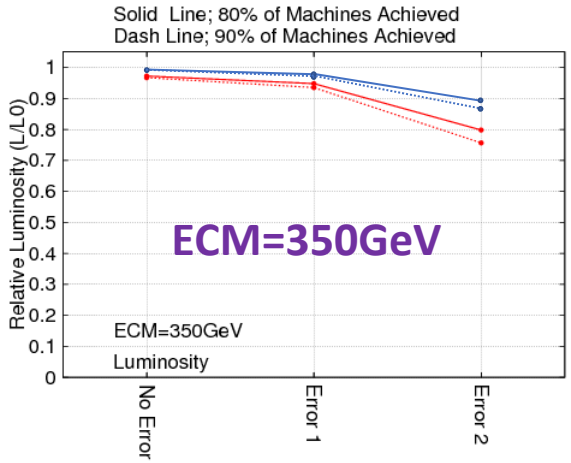


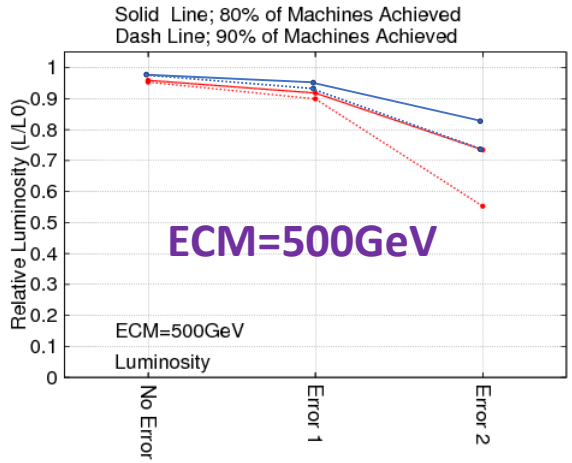
Effect of 2nd order dispersion is not increased so much

Beam tuning simulation for strong bend BDS

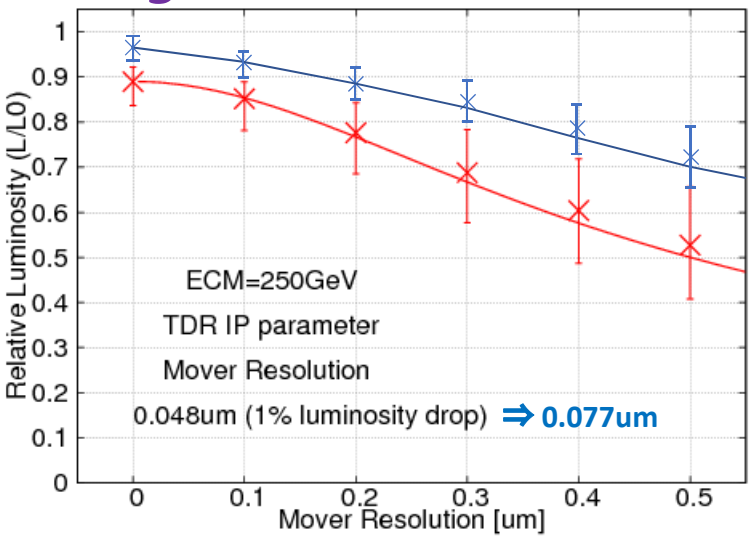
Tuning simulation with errors







Magnet Mover Tolerance



Red ; Original TDR

Blue ; Strong Bend TDR
(1.6 times stronger)

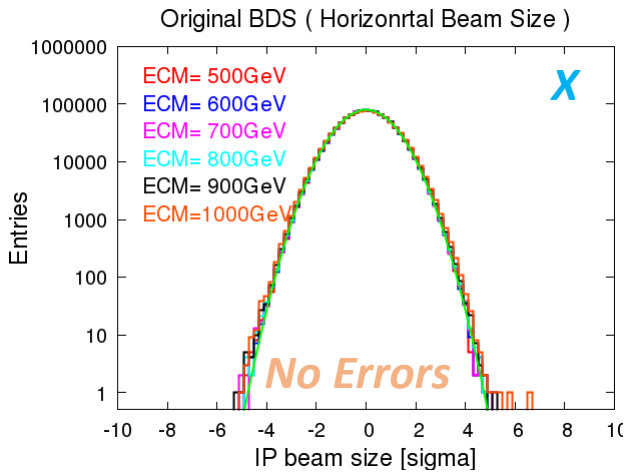
0.1um for ATF2 movers

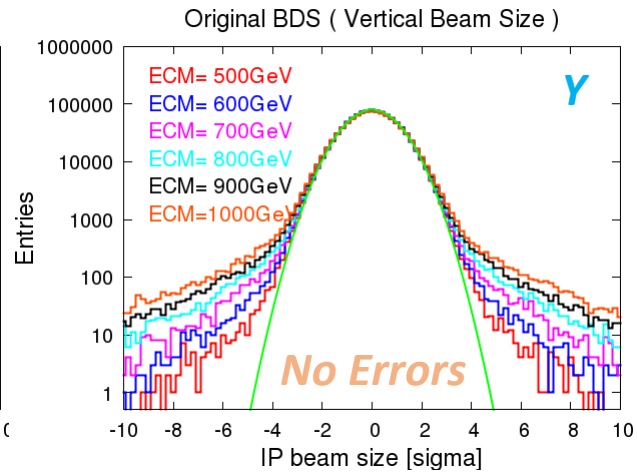
*Performance for BDS optics will be improved for the BDS beamline with **"strong bend".***

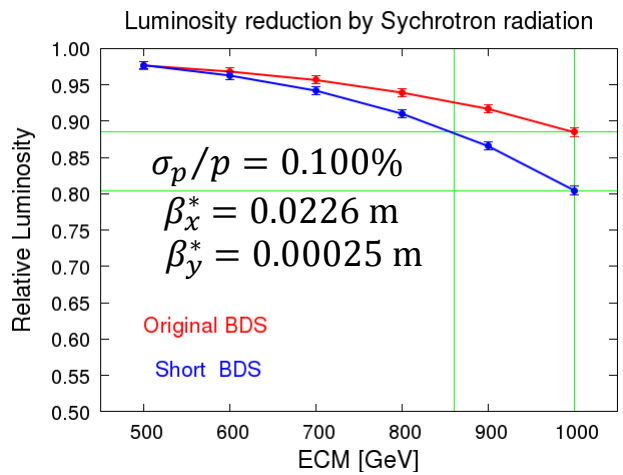
IP beam profile at ECM=1TeV with strong BEND

Luminosity reduction for original BDS and BDS with 1.6times strong bend

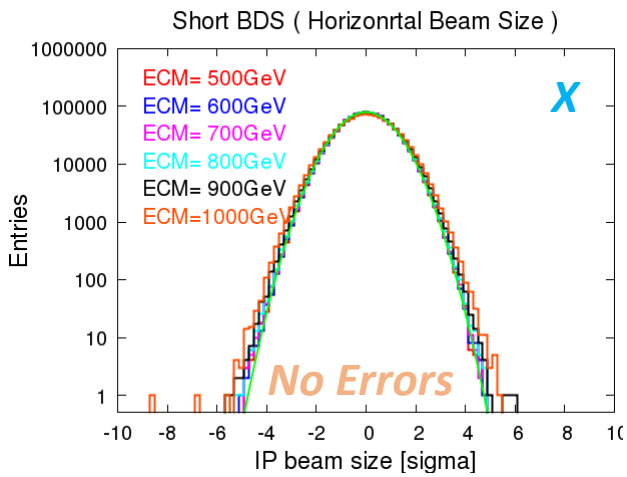
ORIGINAL BDS

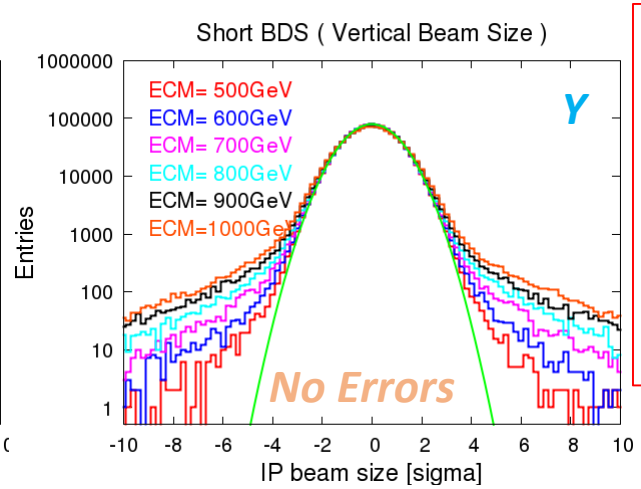






BDS with strong FF bending magnets (1.6 times strong)





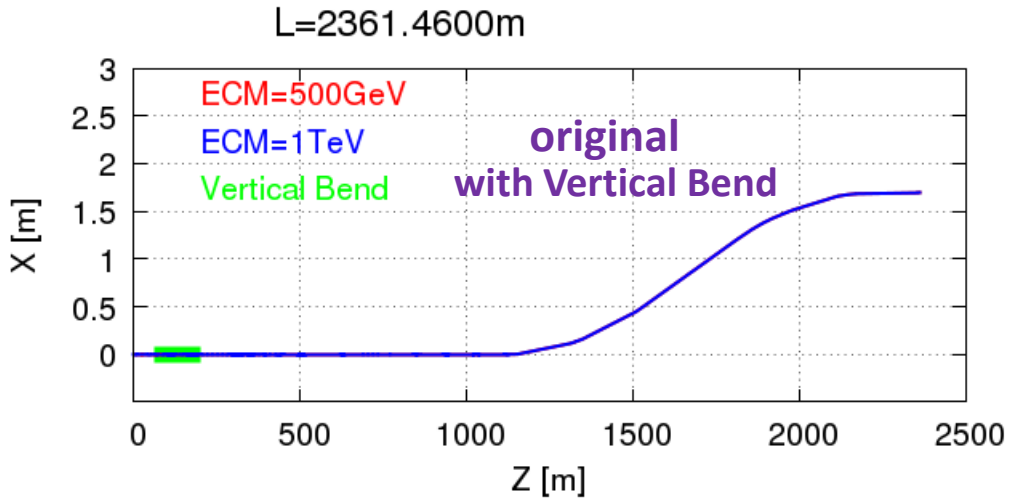
SR Luminosity reduction
at ECM=1TeV for original BDS
is 860GeV for BDS with strong bend.

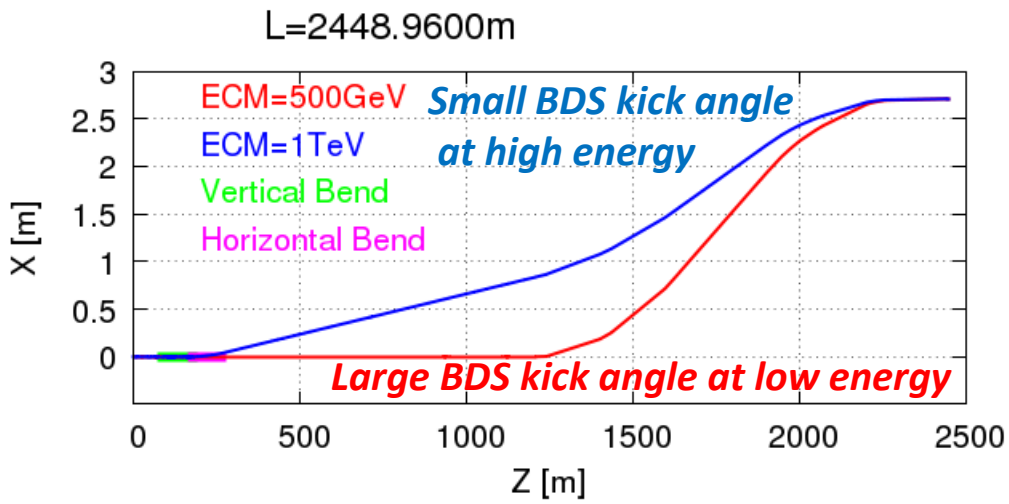
Luminosity reduction at ECM=1TeV
for BDS with strong bend
is approximately 20%.

Idea to optimize the luminosity reduction at ECM=1TeV

Put the horizontal bend system at the entrance of BDS.

The BDS kick angle at ECM=1TeV will be adjusted by changing the kick angles of H-bend and energy collimator.



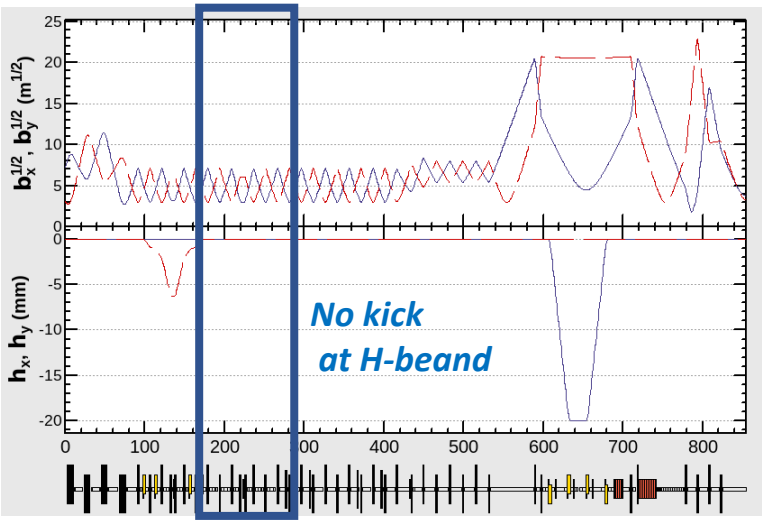


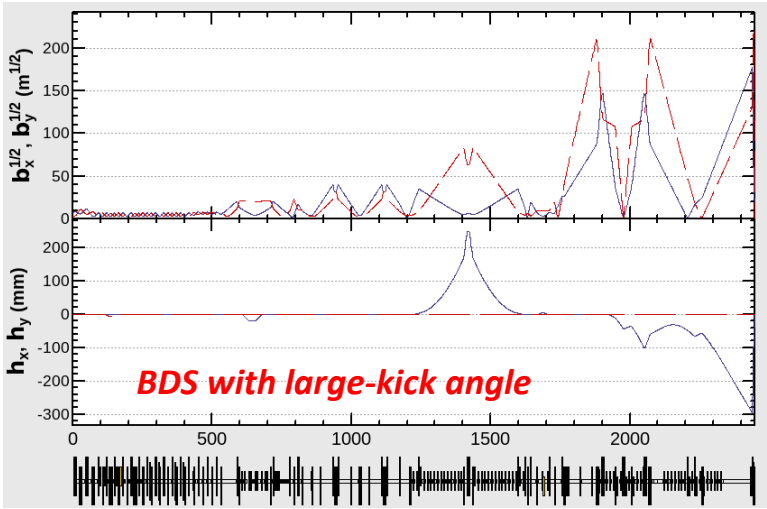
The total BDS beamline will be lengthened by 87.5m of horizontal bend system.

The horizontal beamline will be extended by 1m for large BDS angle kick.

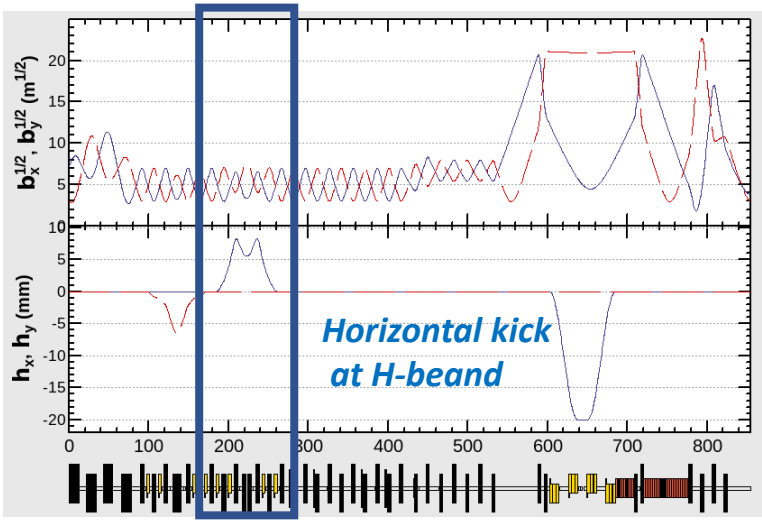
Beam optics for ECM=500GeV and ECM=1TeV

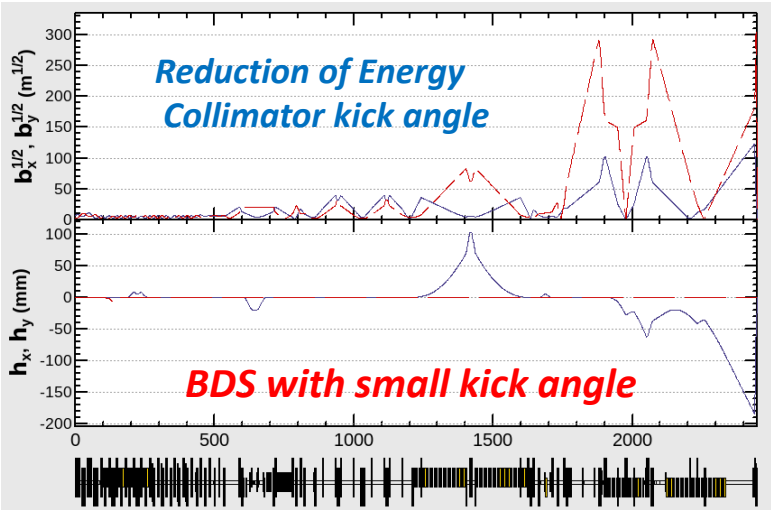
Upstream beamline **ECM=500GeV** **Overall beamline**



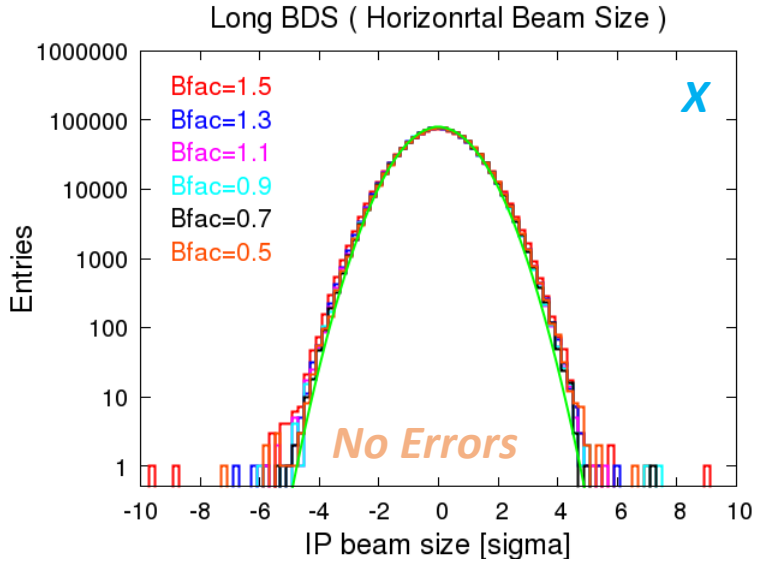


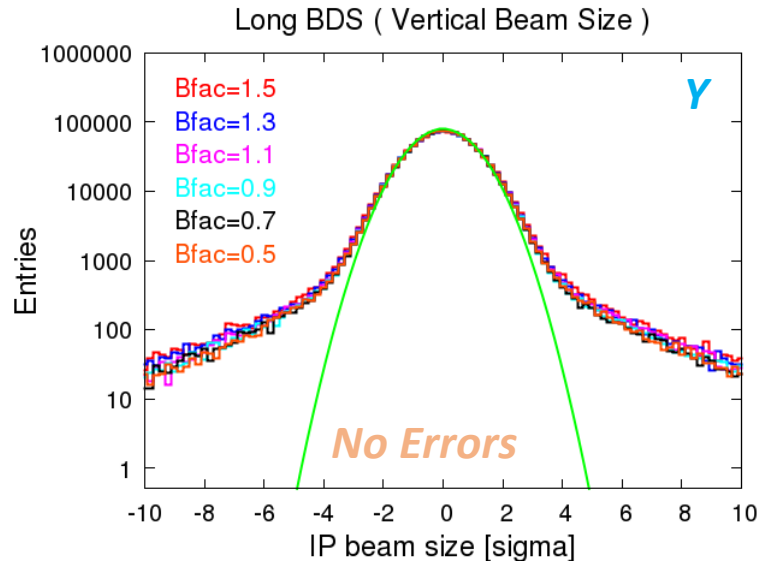
Upstream beamline **ECM=1TeV** **Overall beamline**

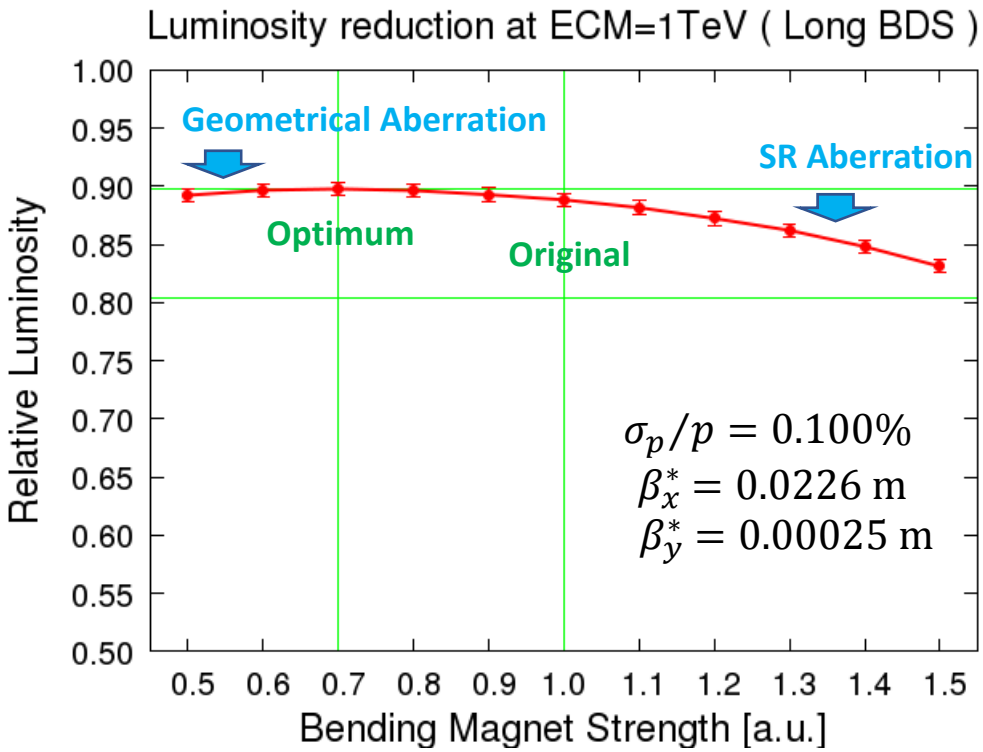




Optimization of bending angle for ECM=1TeV







Optimum bending angle is 70% of original.

(balanced geometrical aberration and SR aberration)

Summary

When the strength of the FF bending magnets are increased,
the performance of the low energy range (ECM=250-500GeV) will be improved.

But, the horizontal offset will be increased by 1m.
The aberration by synchrotron radiation at ECM=1TeV will be increased.

By putting the horizontal bending magnet system at the entrance of BDS beamline,
we can adjusted the BDS bending angle to be

- *larger for lower energy*
- *smaller for higher energy .*

The beamline will be increased by 87.5m.

Backup

IP Beam size tuning Simulation

Beam size minimization was simulated for the following conditions

Tuning knobs

1) Orbit correction

- movers for quadrupoles .

- dipole correctors for bending magnets.

2) IP-beam size tuning

- sextupole position shift for linear optics

- skew and normal sextupole strength for 2nd order optics

(same procedures to ATF2 tuning)

Monitors ; *Luminosity monitor (informations for X and Y are coupled)*

IP beam parameters

Beam Energy	125 GeV
gamma * emit (x/y)	10um / 35pm
momentum spread	0.19%
RDR IP beta function (x/y)	21 mm / 0.40mm
TDR IP beta function (x/y)	13mm / 0.41mm

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

Beam Based Alignment (BBA)

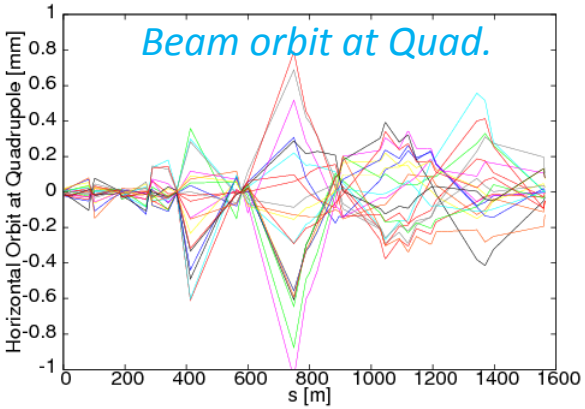
BPMs are moved with quadrupole magnets.

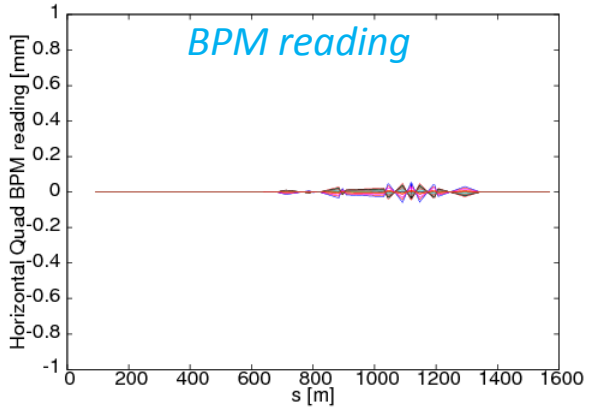
Since there are some BPMs, which are not on mover, the beam orbit was clipped.

Alignment Errors

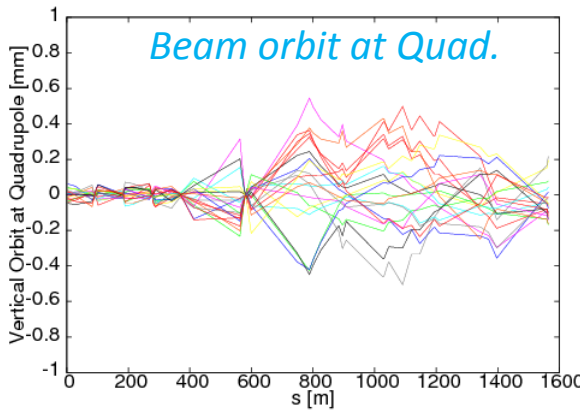
	Bend	Quad	Sext
ΔK	0.1%	0.1%	0.1%
ΔX	N. A.	0.2mm	0.2mm
ΔY	N. A.	0.2mm	0.2mm
Δθ	0.1mrad	0.1mrad	0.1mrad
BBA X	200um	50um	50um
BBA Y	200um	50um	50um

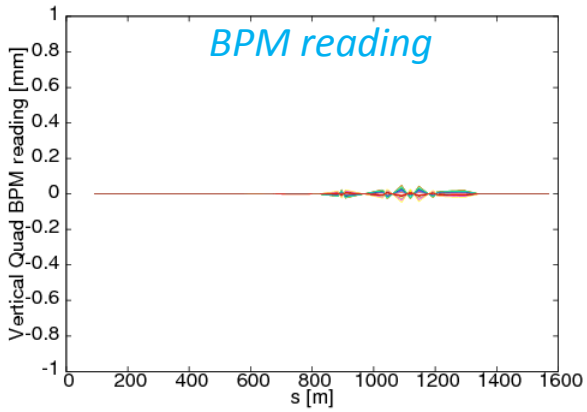
Horizontal





Vertical





We should check whether the orbit is acceptable to resistive wall kick or not.
If No, we should increase the fixed BPM and correctors.

Tolerances evaluation by IP-beam size tuning

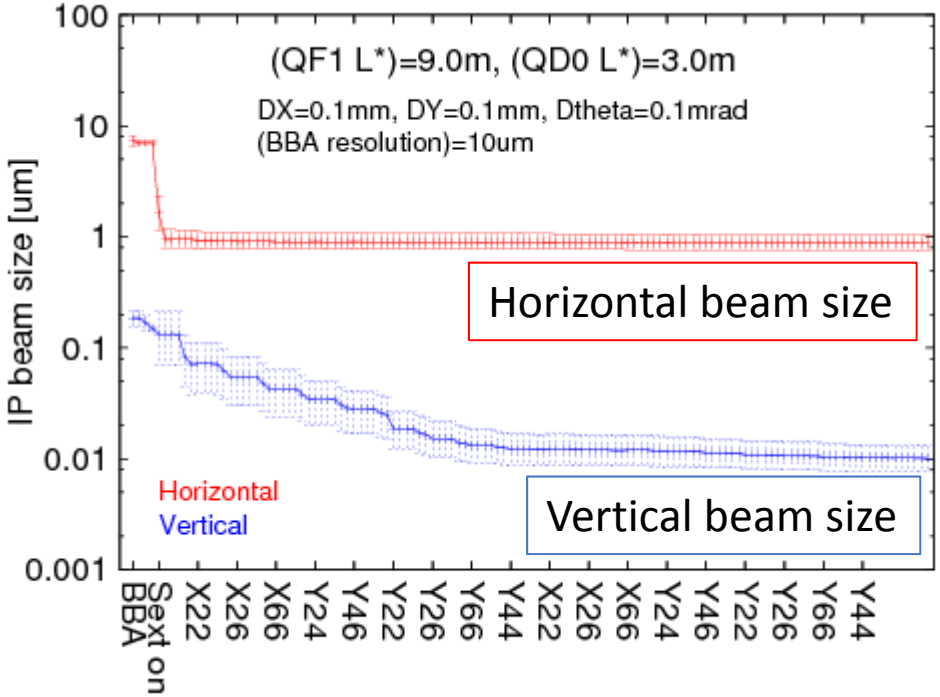
Procedures

1. *Put the errors for single parameter*
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



Example of tolerance evaluation

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