

# *Layout of BDS beam line in ILC250*

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Fukuoka, JAPAN

***Introduction***  
***Present ILC BDS design***

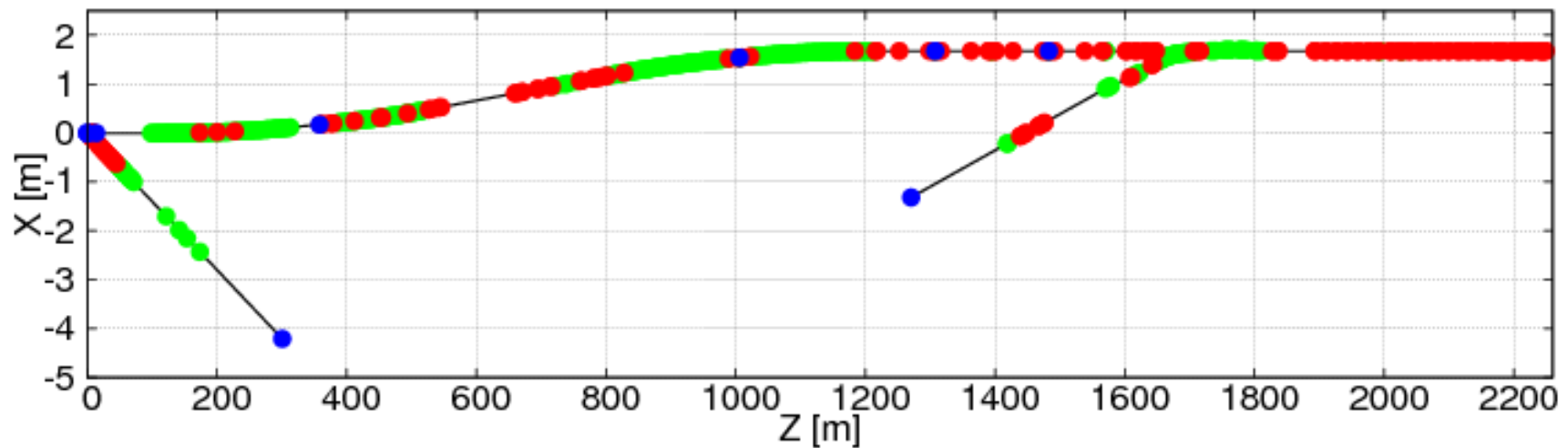
# ILC BDS Beamline

*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.*

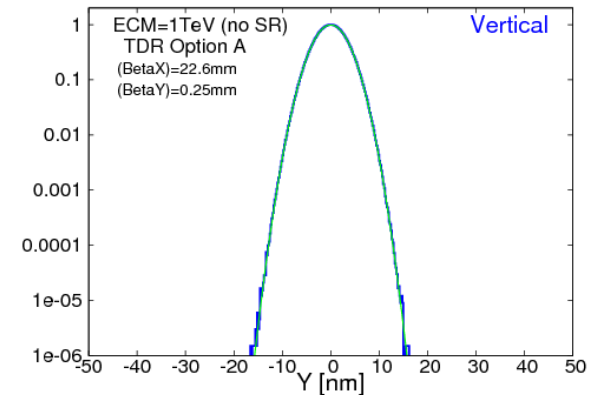
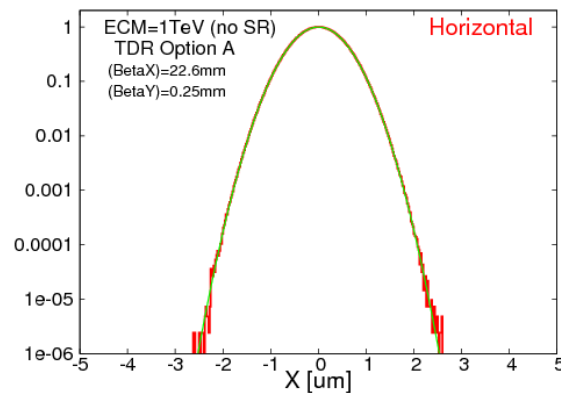


*In order to use the same beamline to very wide energy range,*

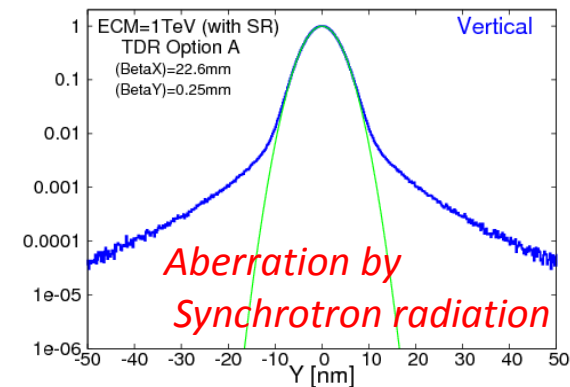
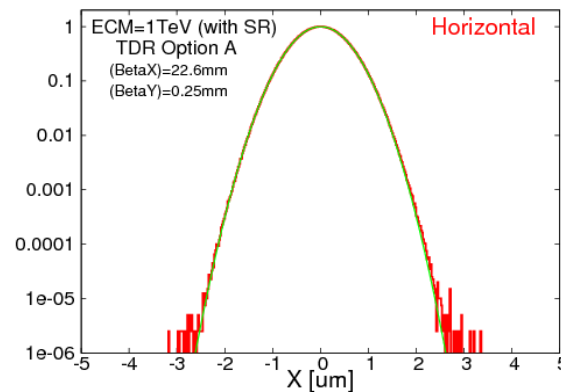
***the performance for low energy and high energy optics is not good.***

# IP beam profile for ECM=1TeV

<< no SR >>



<< with SR >>



*Large aberration by Synchrotron radiation*

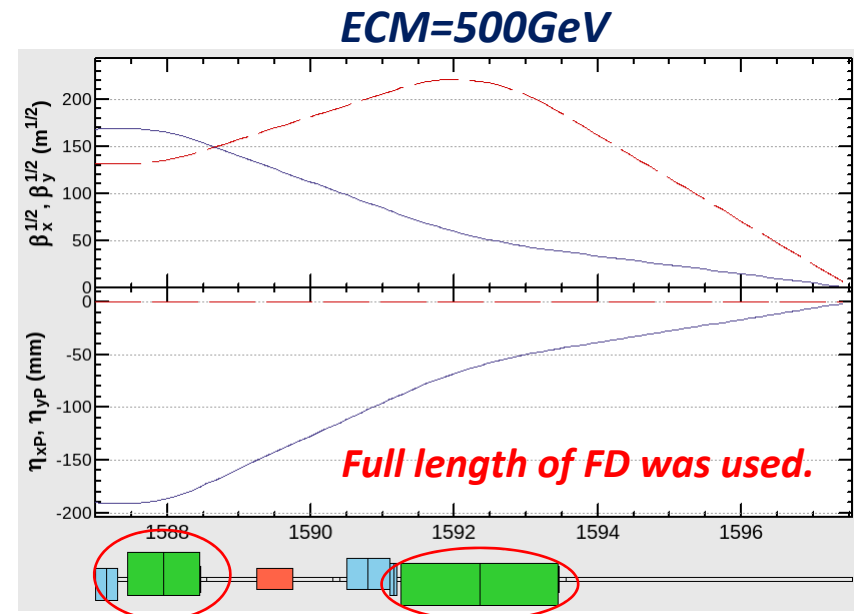
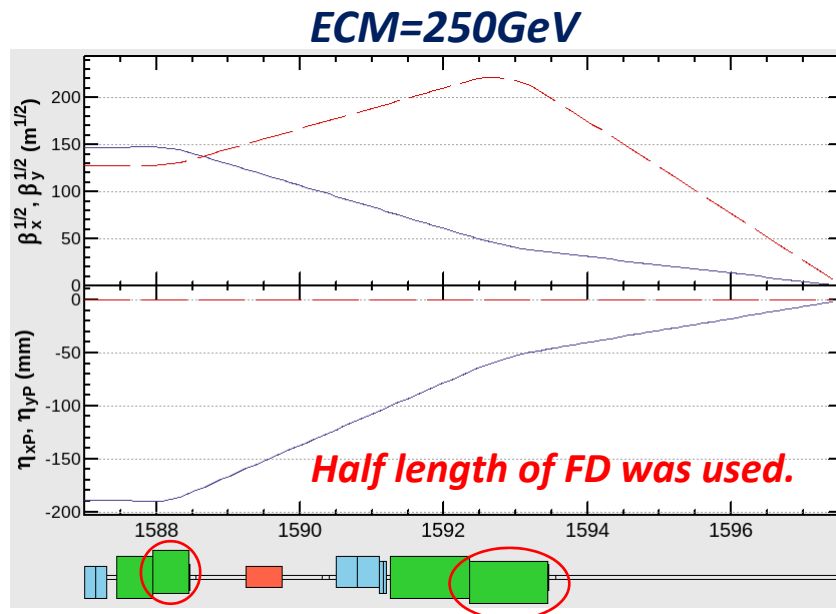
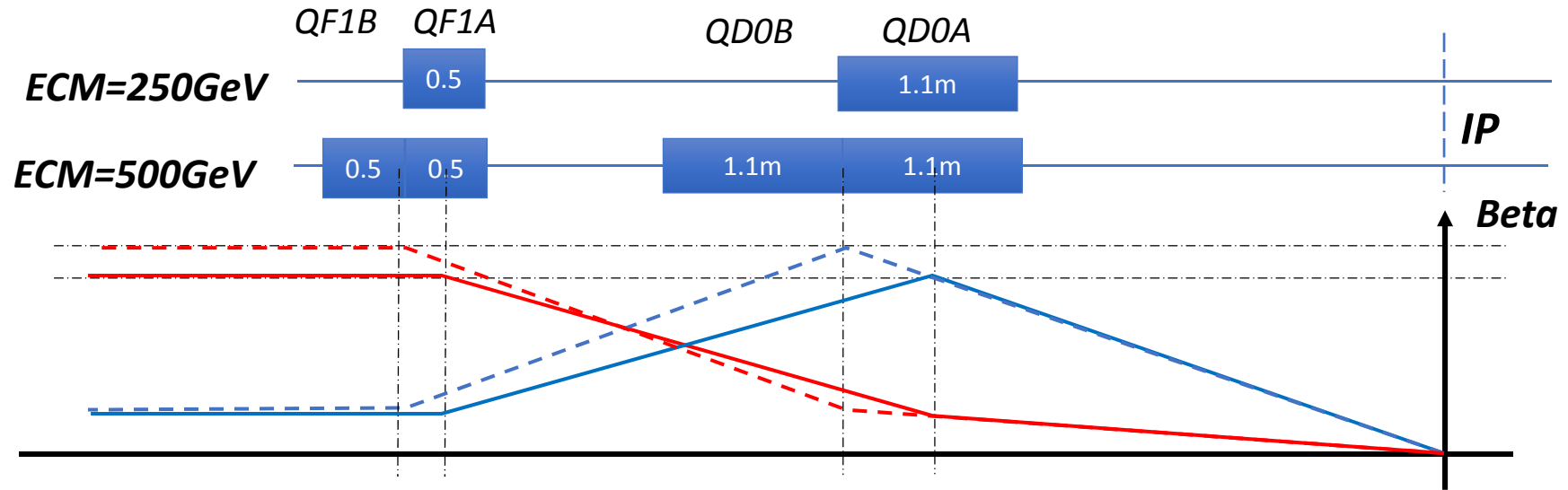
*The luminosity is reduced by 5-6% by the aberration of Synchrotron radiation in ECM=1TeV. Therefore, it is difficult to increase the bending angle anymore in ECM=1TeV.*

*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 ( $E_{CM}=250\text{GeV}$ )

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.

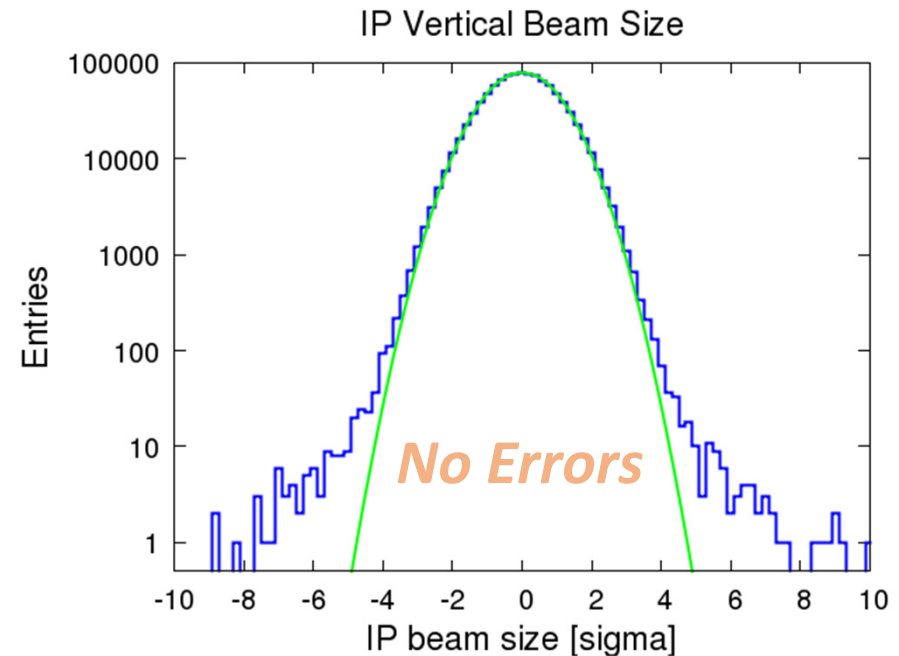
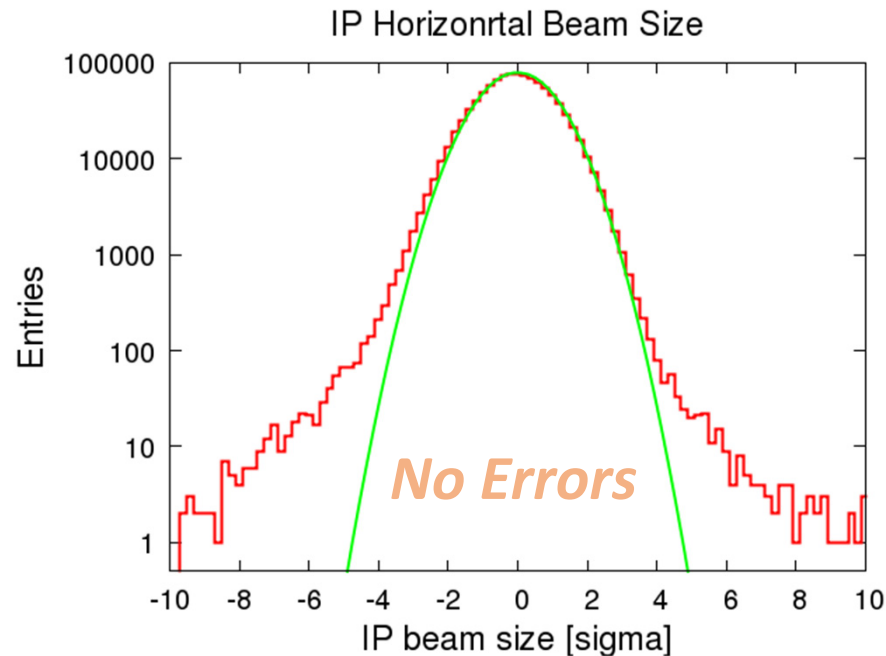


# IP beam profile for ECM=250GeV

## Simulated IP beam profiles for ECM=250GeV optics

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

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



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

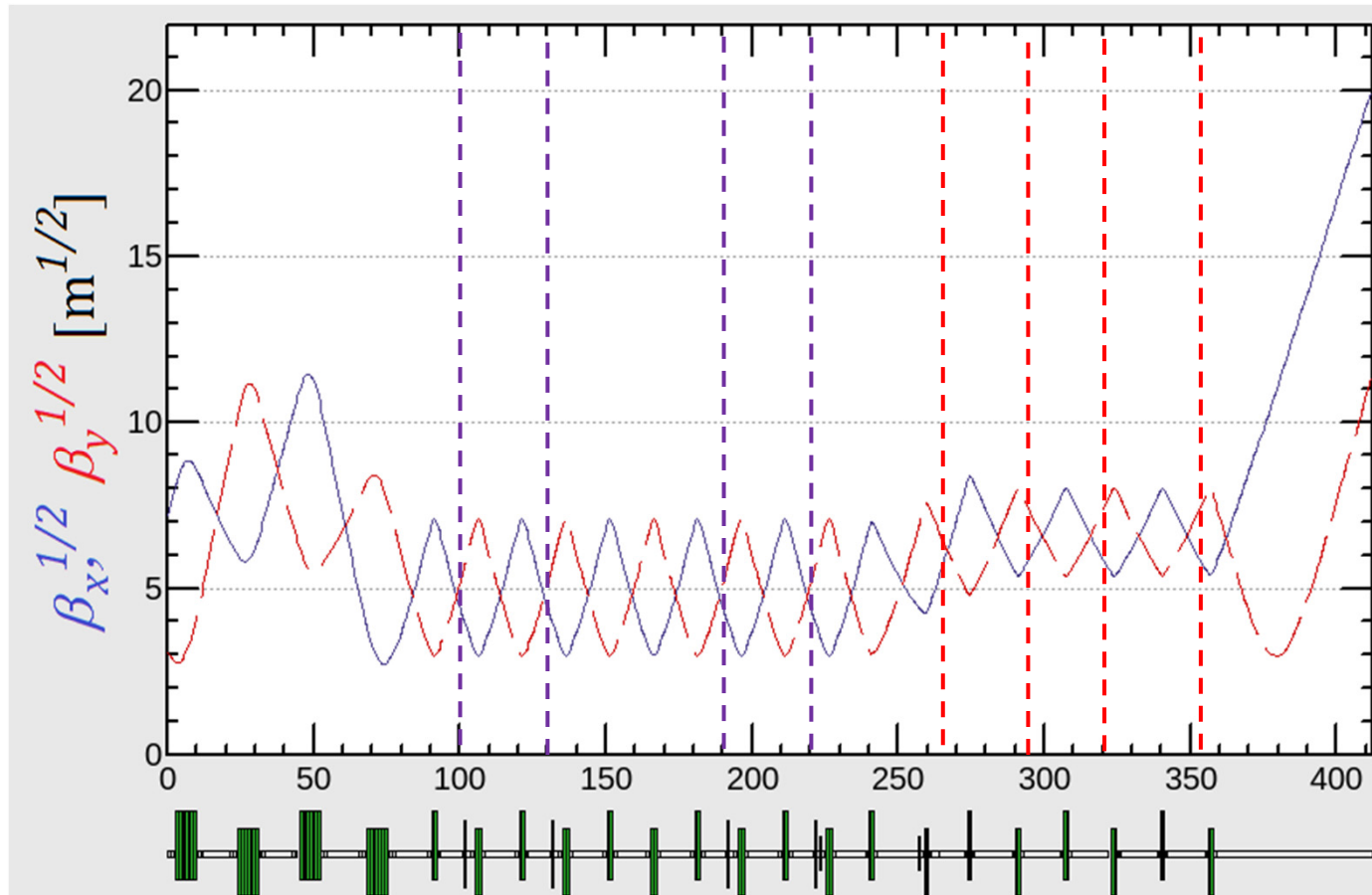
- IP beam size growth ( design luminosity is reduced by 7-8% )
- Large beam tail is generated.

***How much will the beamline length  
be shorten for ECM=250GeV specific optics ?***

# Beam Optics of ILC Beam Diagnostic Section

4 skew quadrupoles  
for coupling correction

4 laserwire profile monitors  
for beam matrix measurement.



2um at 250 GeV beam

100 m



2um at 125 GeV beam

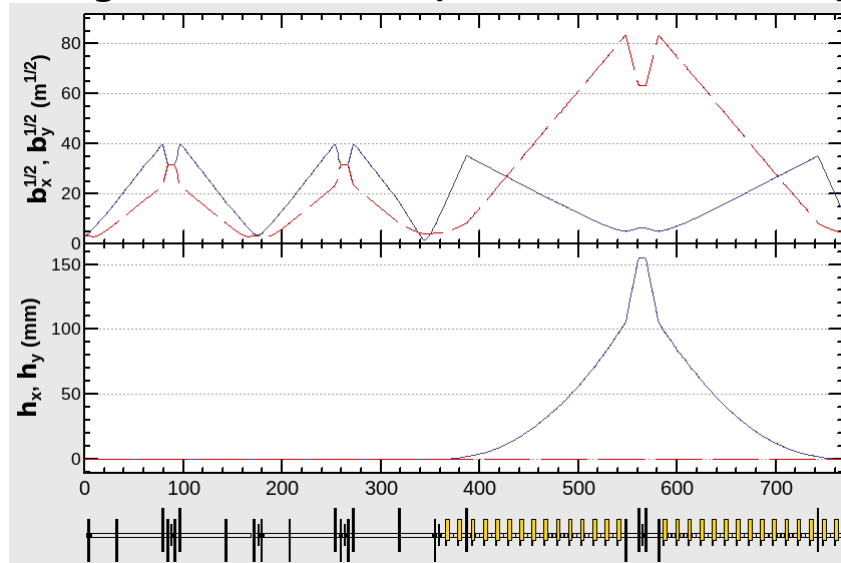
50 m

$\Delta L = 50$  m

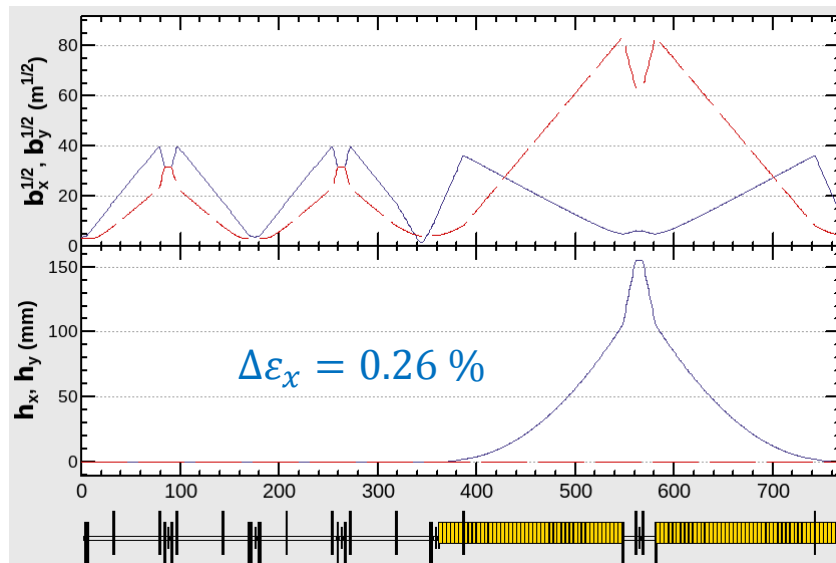


# Collimator Section

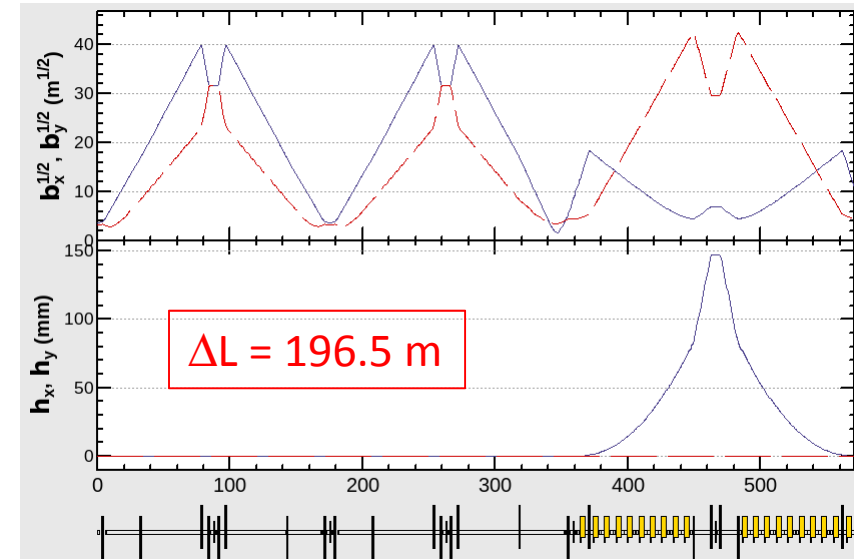
**Original Collimator ( ECM=250-500 GeV )**



↓ **ECM = 1 TeV**  
put additional bends



**Compact Energy Collimator for ECM=250GeV**



$$\Delta\epsilon_x = 14.8 \% \text{ for } E_{CM} = 1 \text{ TeV}$$

$$\Delta\epsilon_x = 0.004 \% \text{ for } E_{CM} = 250 \text{ GeV}$$

## Betatron collimators

In order to keep the beta functions at collimators by keeping the phase advance between collimators, it is difficult to make collimator system short.

## Energy collimator

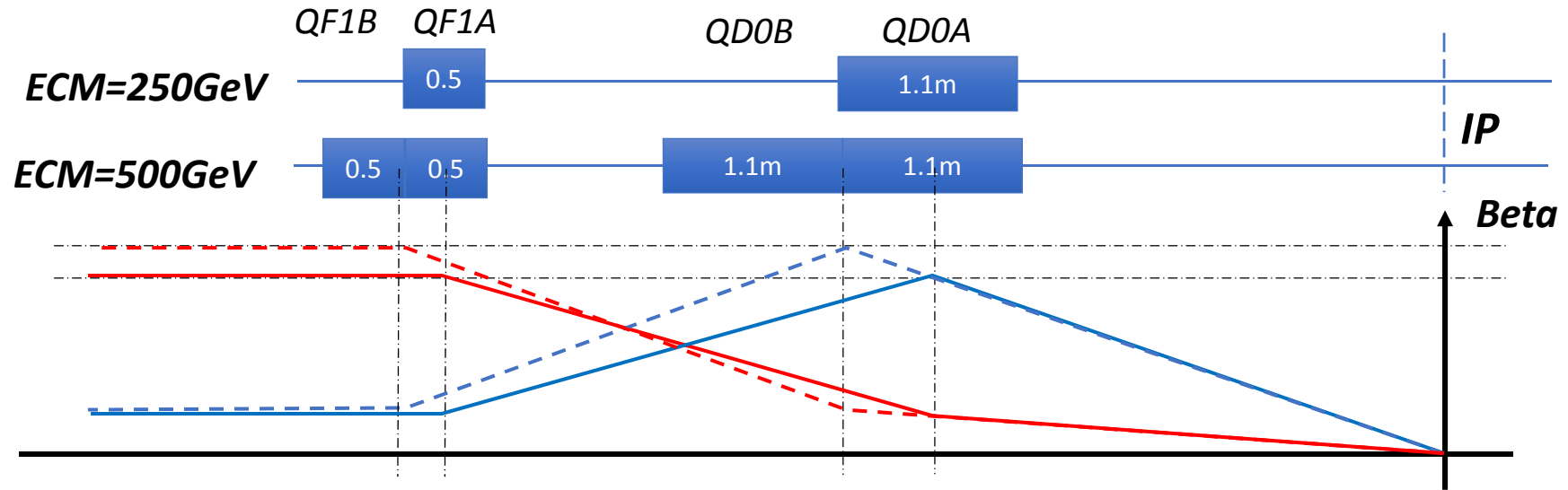
Present design of energy collimator was designed to minimize the horizontal emittance growth by SR at ECM=1TeV operation.

We can shorten the beamline length only for ECM=250GeV.

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

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.



$$(\text{Effective } L^*) = 5.20 \text{ m} \Rightarrow 4.65 \text{ m}$$

$$\Delta L = (1 - 4.65/5.20) \times 826.460 \text{ m} \approx 87 \text{ m}$$

## Total Beamline length reduction for $ECM=250\text{GeV}$ specific design

Diagnostic Section : 50 m

Collimator Section : 196.5 m

Final Focus Section : 87 m

( Total ) = 333.3 m

We can shorten the beamline length by almost 300m.

***Optimization the BDS optics  
for ECM=250GeV specific optics***

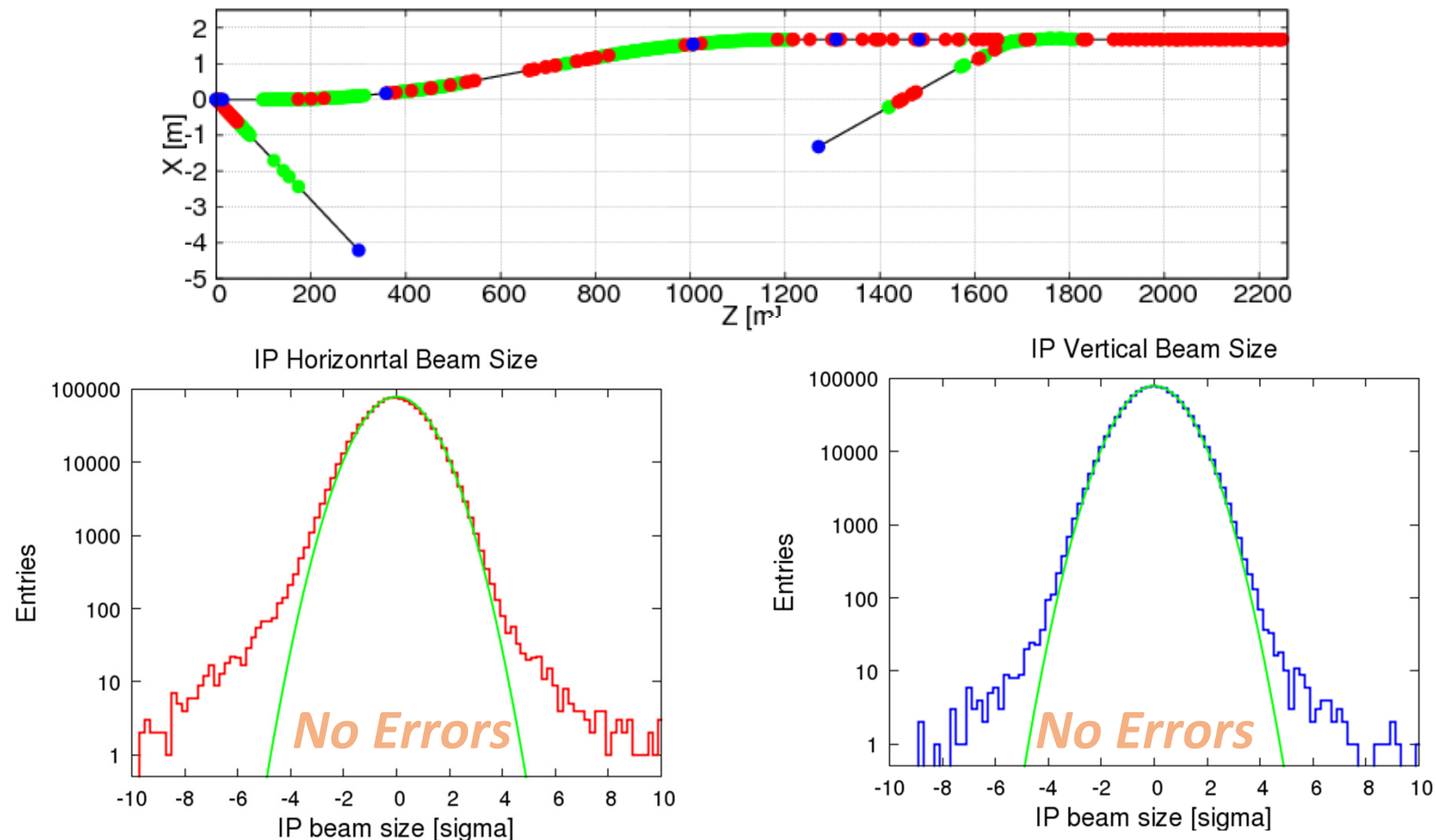
# Performance improvement for low energy operation

## Present ILC BDS is not good for low energy

to keep the compatible design to ECM=1TeV beamline (small bending angle) .

The bending angle was optimized to minimize effect of Synchrotron radiation in higher energy.

In order to optimize the performance for ECM=250GeV BDS,  
It is better to use “**strong bending magnet**” (presented at AWLC2017, SLAC).

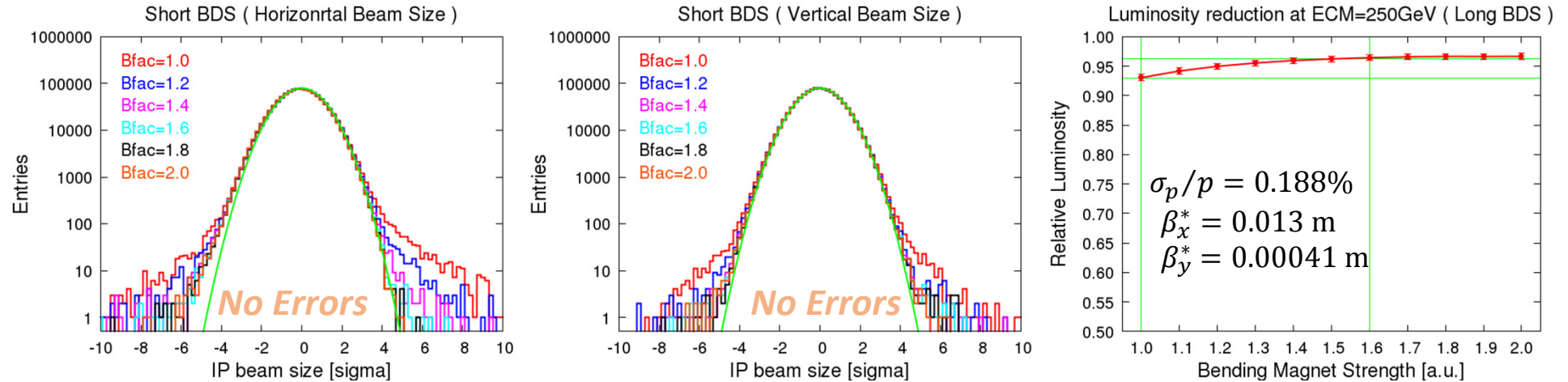


# IP beam profile at ECM=250GeV for BDS with strong BEND

The stronger sextupoles makes the FF dispersion stronger.

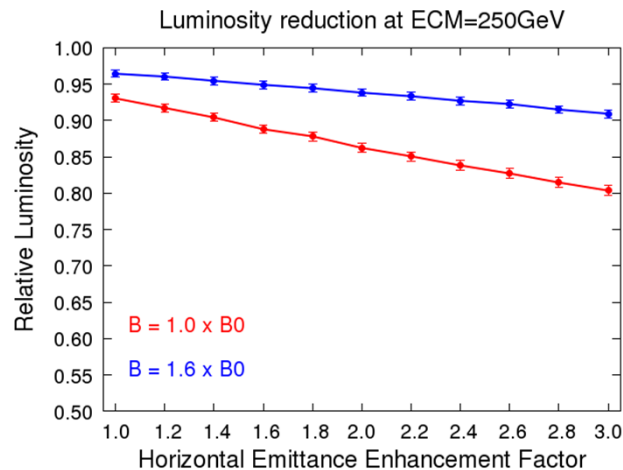
Then, the geometrical dispersion will be reduced.

=> The luminosity and beam tail was improved.

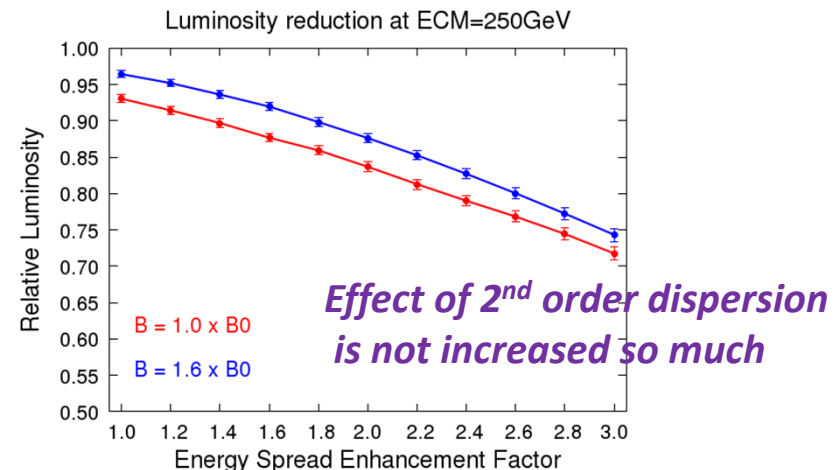


When we set to the bending magnet strength to be 1.6 times larger than design.

## Horizontal emittance dependence



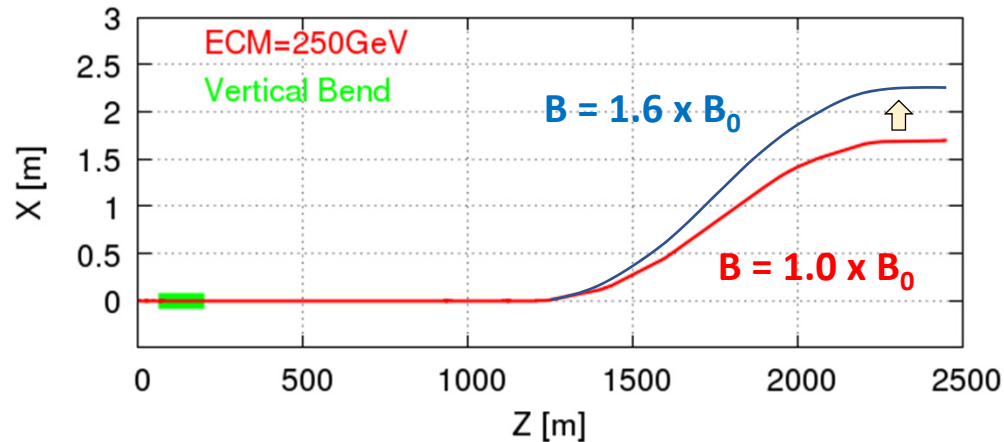
## Energy spread dependence



# Impact to beamline for the “Strong FF bend optics”

## Impact to the beamline geometry

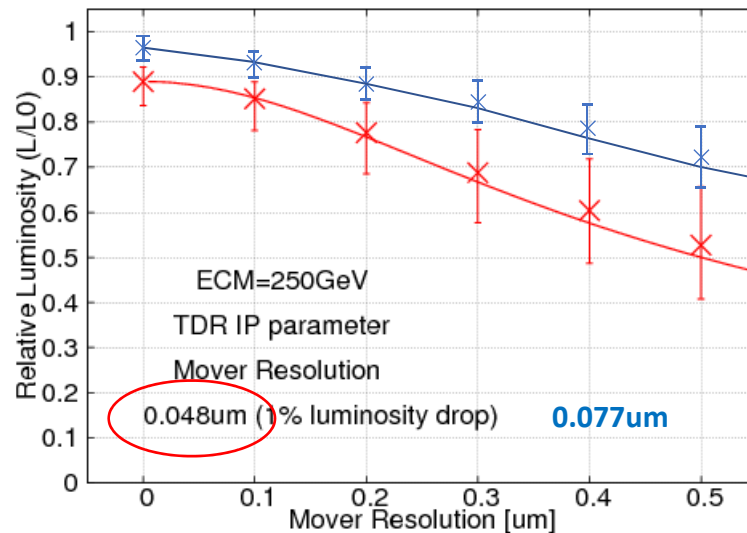
### Beamline geometry for “Strong BEND” BDS



Horizontal beamline  
was shifted by 0.7m.

## Impact to the tolerances for magnets

### i. e. ) Tolerance of magnet mover accuracy



Red ; Original TDR

Blue ; Strong Bend TDR  
( 1.6 times stronger )

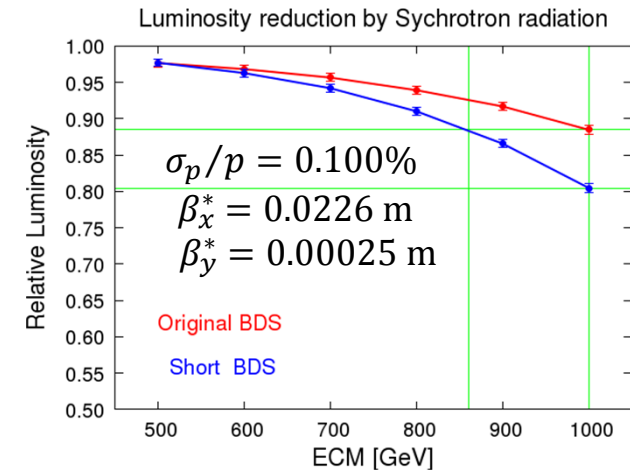
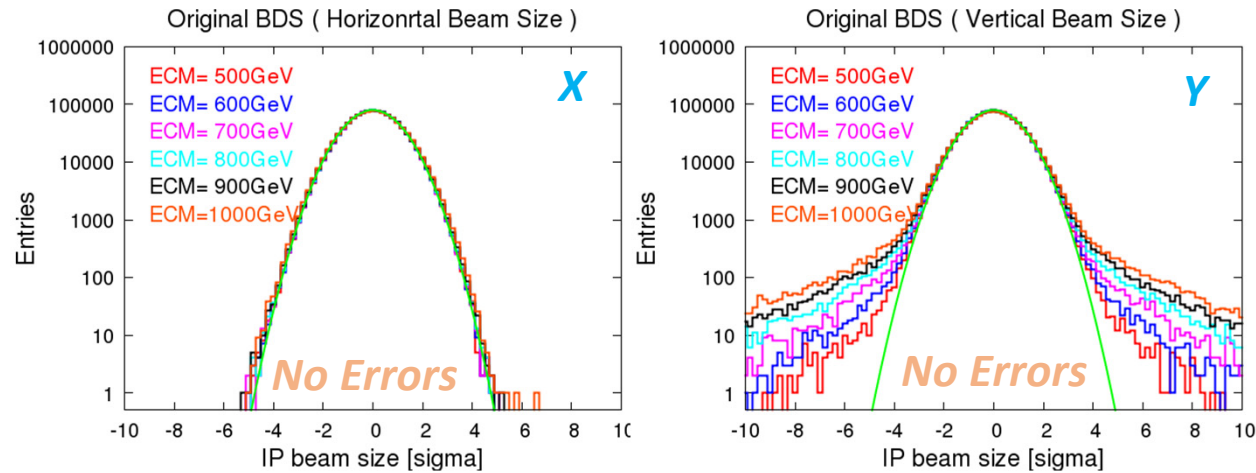
0.1um for ATF2 movers

The tolerance was  
relaxed by factor 1.6

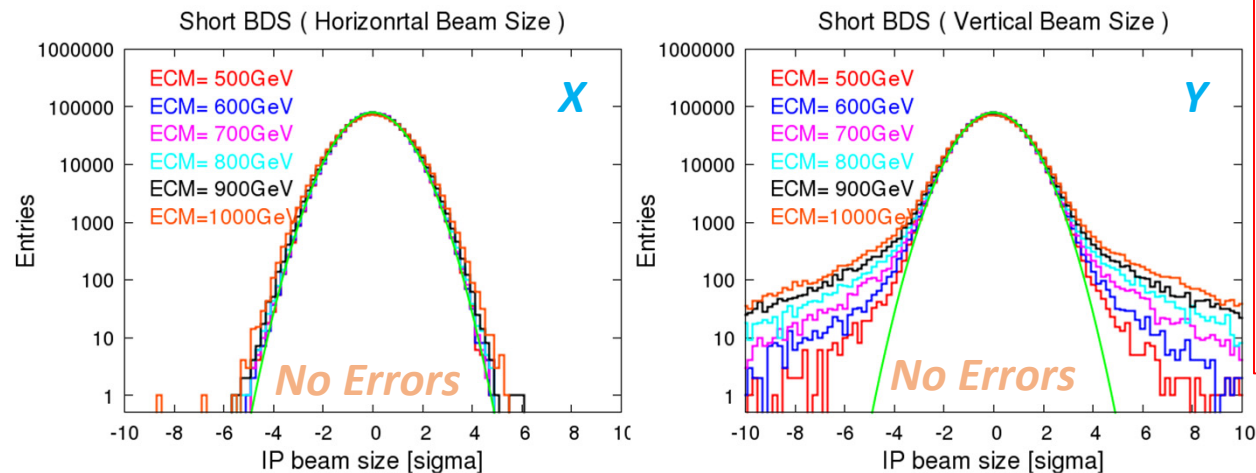
# IP beam profile at ECM=1TeV with strong BEND

*But, the beamline modification makes the performance for higher energy worse by SR effect.*

## 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.

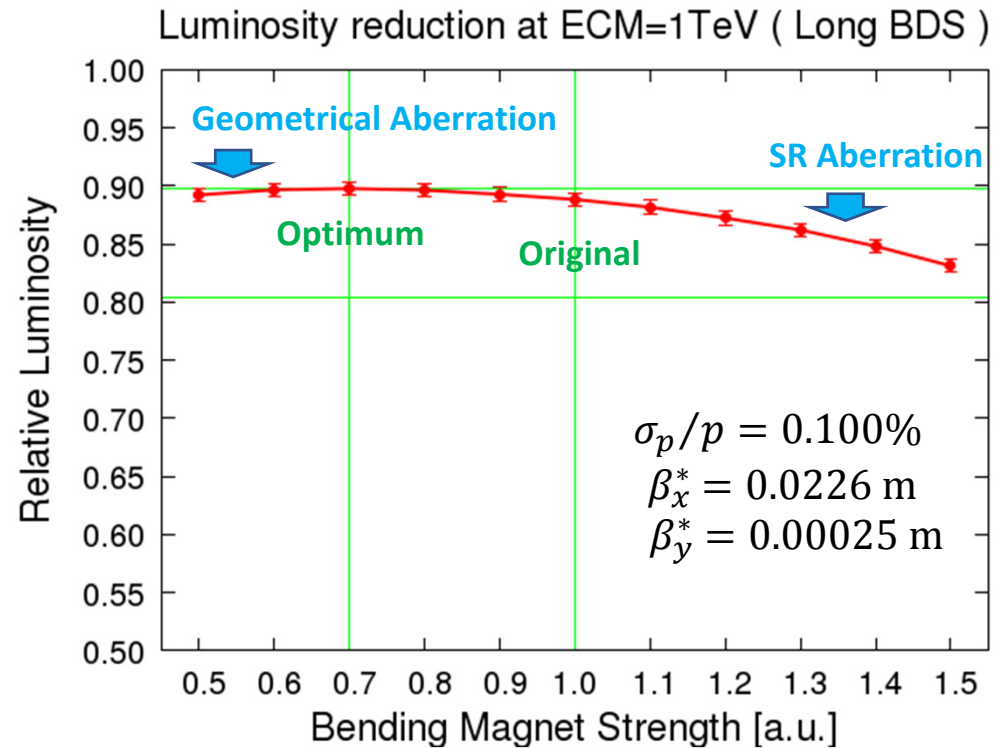
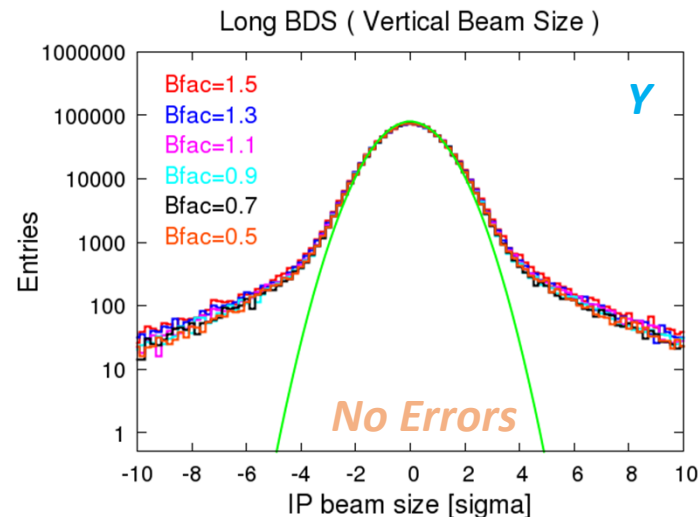
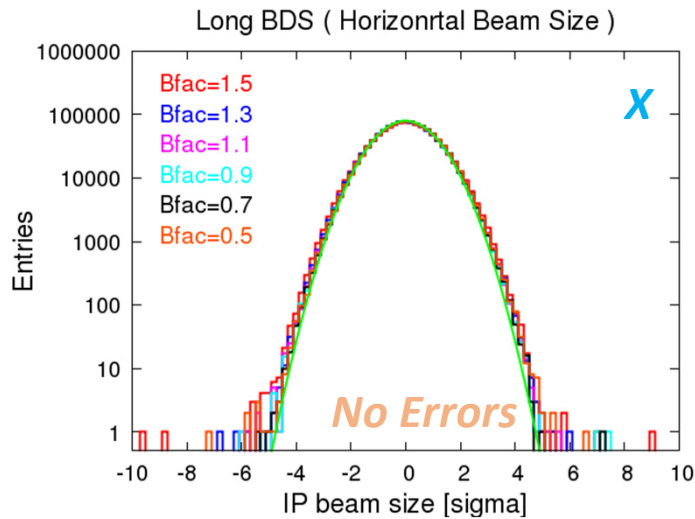
Luminosity reduction at ECM=1TeV for BDS with strong bend is approximately 20%.

# Optimization of bending angle for ECM=1TeV

The original bending angle is also not optimized for ECM=1TeV.

It is better to use weaker bend strength for ECM=1TeV.

But, we adopted to intermediate strength both for lower and higher energy in present BDS.



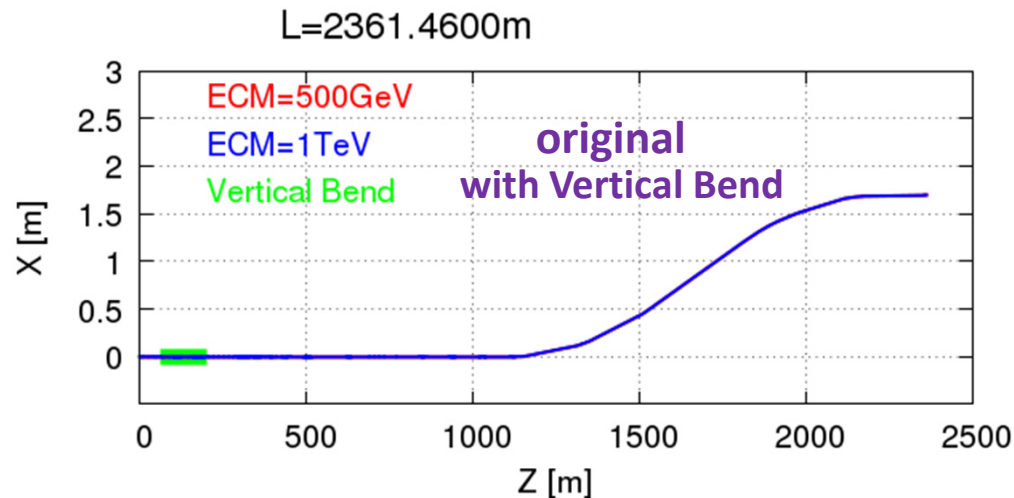
Optimum bending angle is 70% of original.  
( balanced geometrical aberration and SR aberration )



# Idea to optimize both for $ECM=500\text{GeV}$ and $ECM=1\text{TeV}$

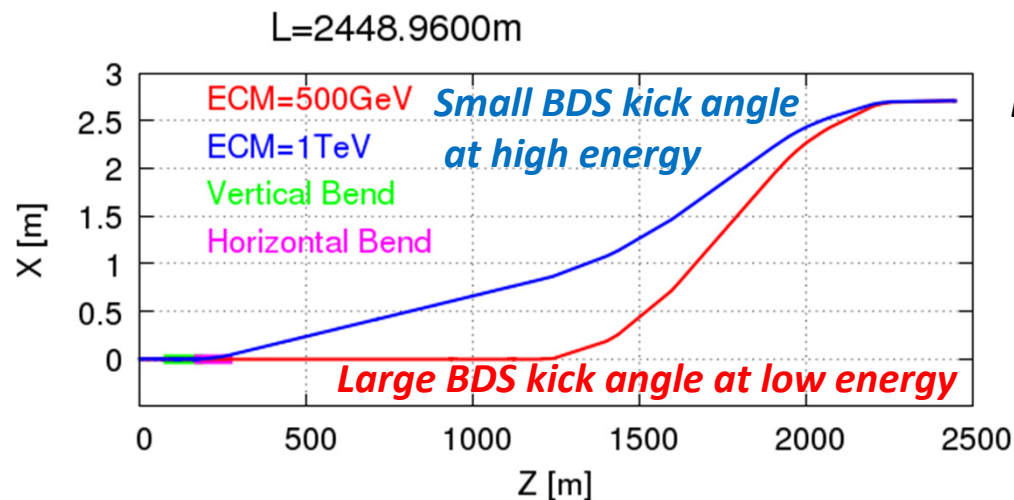
**Put the horizontal bend system at the entrance of BDS.**

The BDS kick angle at  $ECM=1\text{TeV}$  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 0.7m for large BDS angle kick.



Detector position and angle were set to same for all energy optics by adjusting

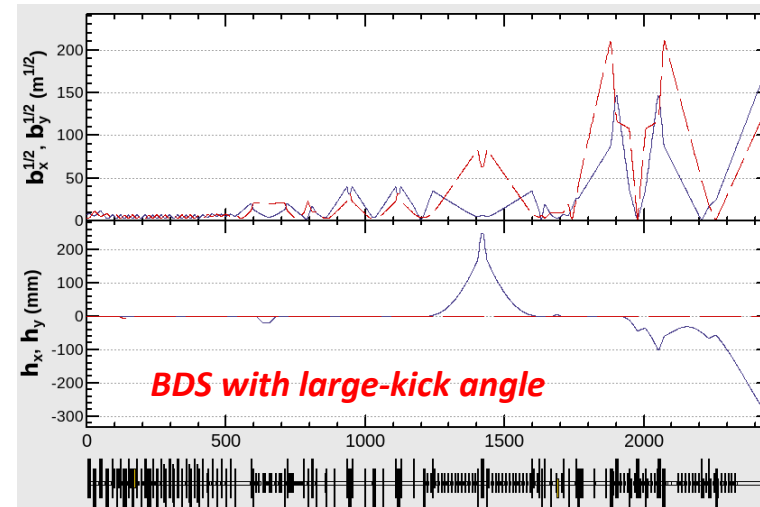
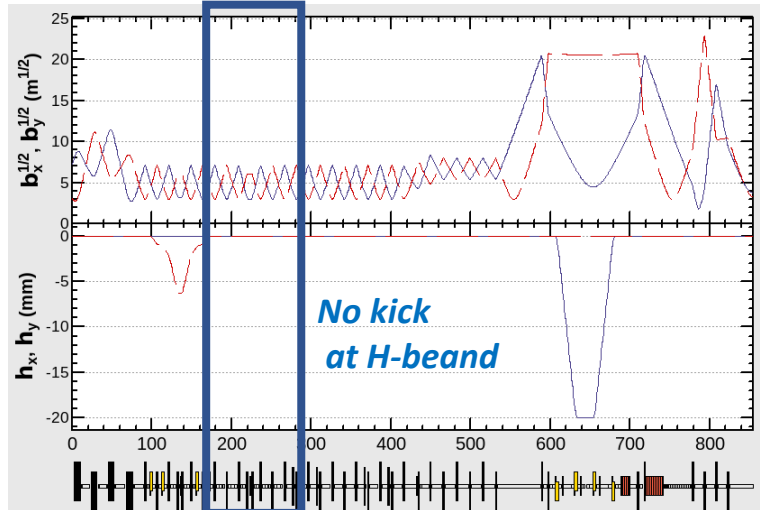
- Horizontal bend (newly introduced)
- Energy collimator
- FF bending magnet

# Beam optics for $ECM=250\text{GeV}$ and $ECM=1\text{TeV}$

Upstream beamline

$ECM=250\text{GeV}$

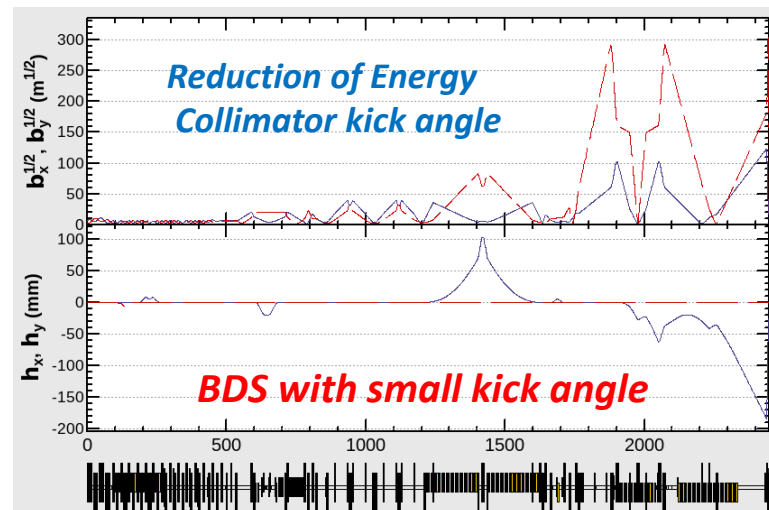
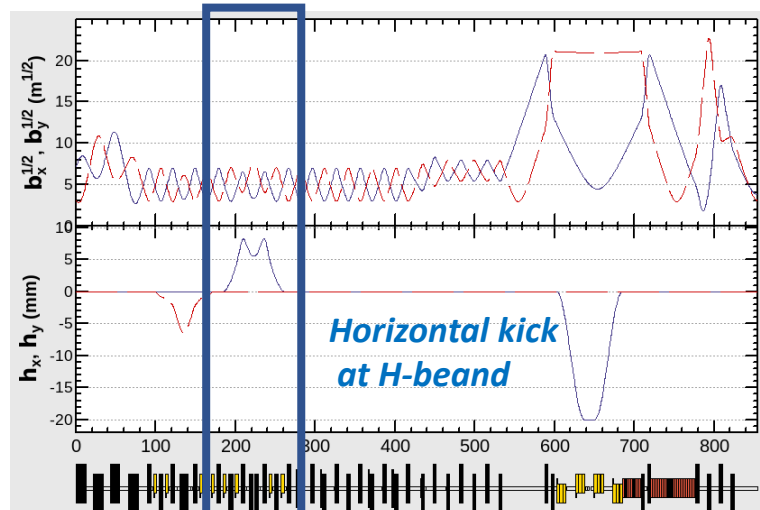
Overall beamline



Upstream beamline

$ECM=1\text{TeV}$

Overall beamline



# Summary

*We can shorten the beamline length of BDS by almost 300m for the ECM=250GeV specific optics.*

*But, it is difficult to use the BDS for higher beam energy.*

*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 0.7 m.*

*The aberration by synchrotron radiation for higher energy 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***

# Alignment Tolerances for ECM=250GeV

*Evaluated by IP beam size using SAD tracking simulation*

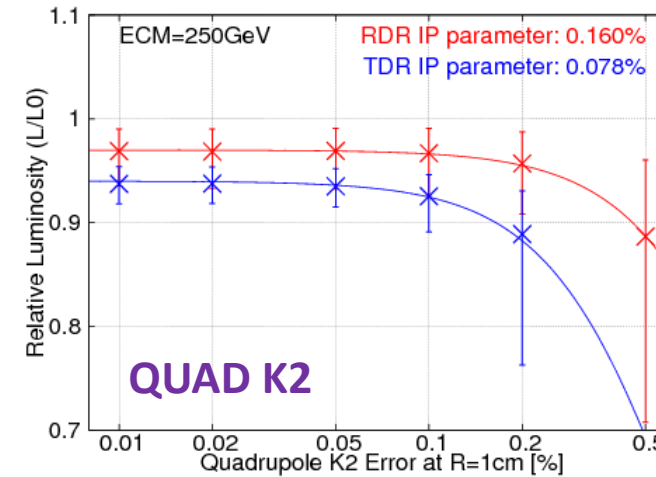
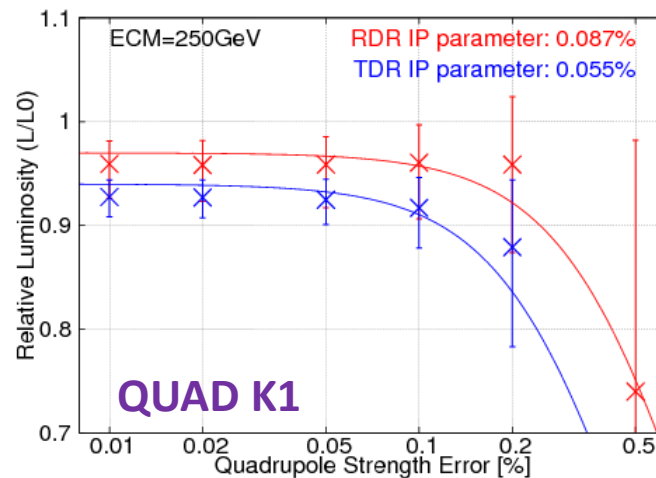
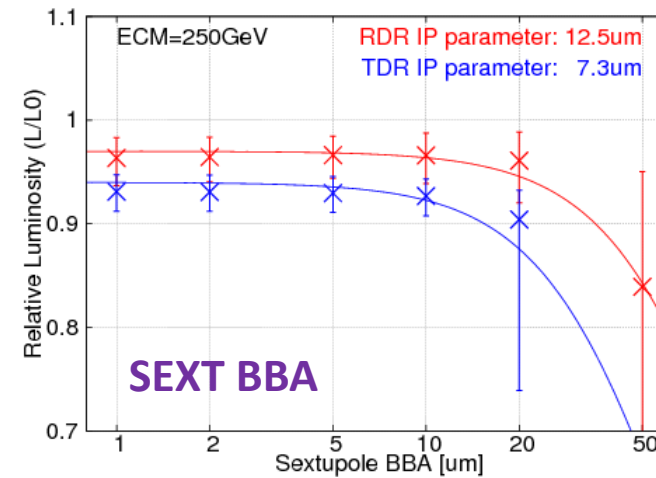
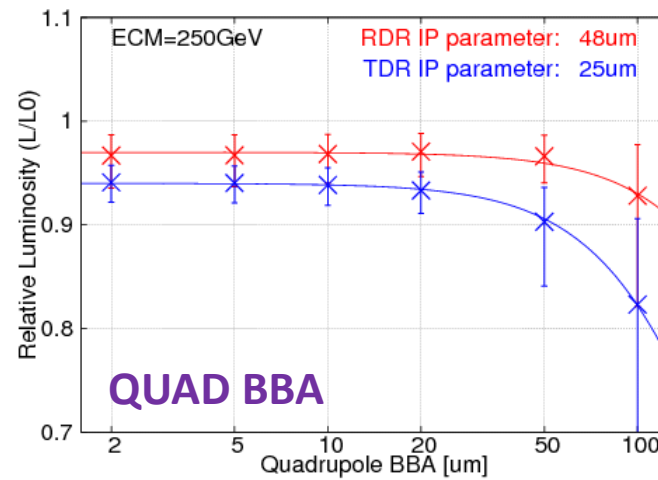
*1% average luminosity reduction*

*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

# Example of tolerance evaluation

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

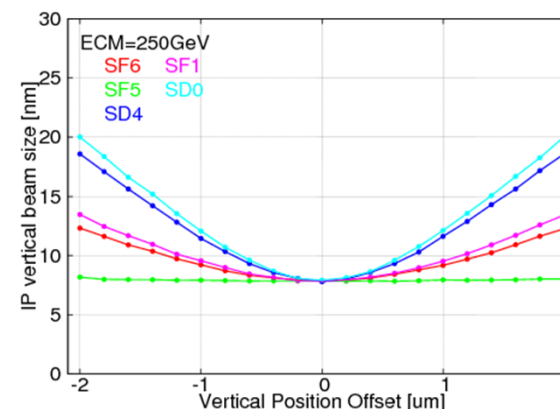


# Requirement of the magnet movers

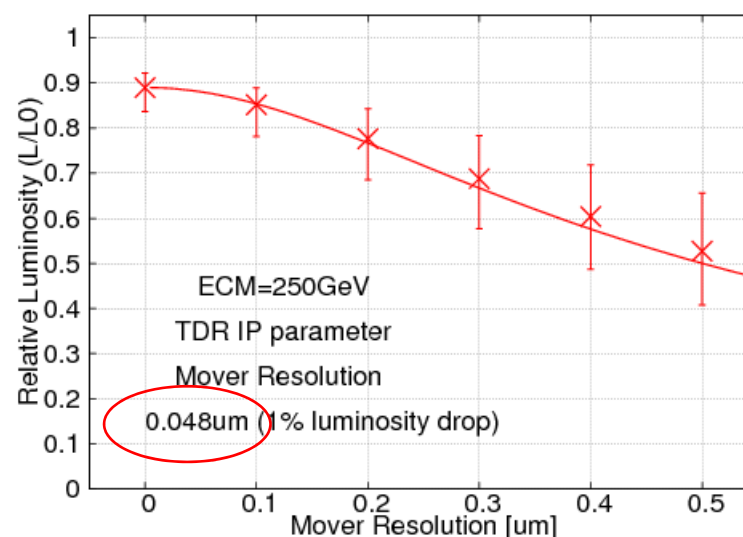
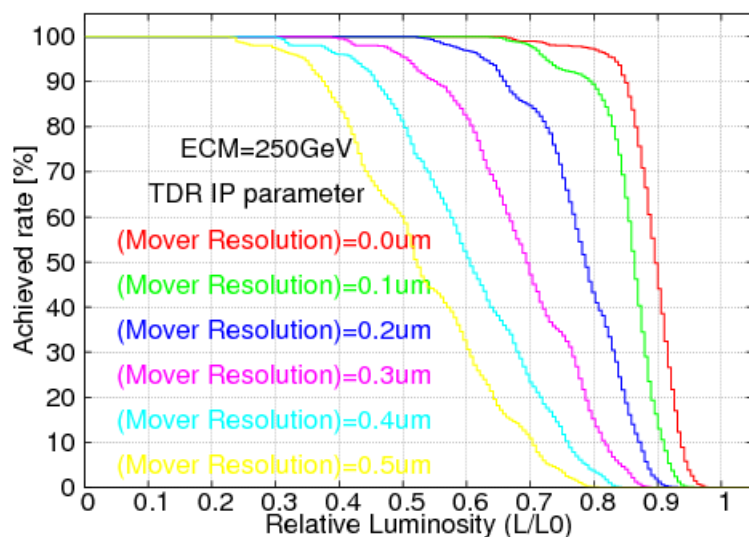
When the position of the sextupoles were moved by sub-micron, IP-beam size was increased so much.

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

The tolerance is evaluated for ECM=250GeV, and TDR IP beta functions ( $\beta_X^*/\beta_Y^* = 13\text{mm}/0.41\text{mm}$ ).



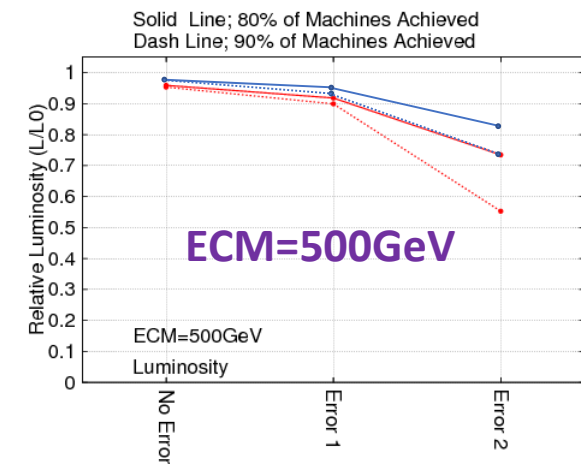
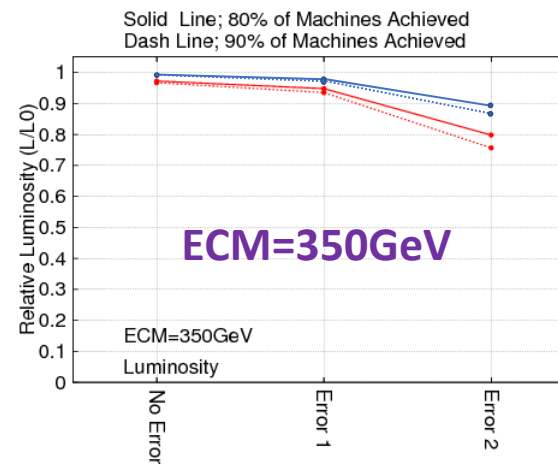
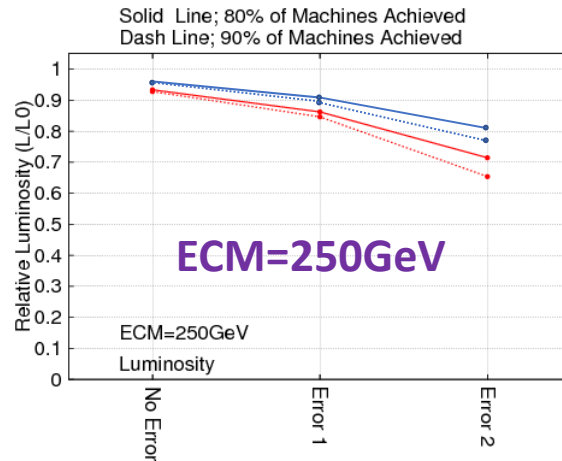
The alignment error is set to the tolerance for 250GeV TDR parameter.



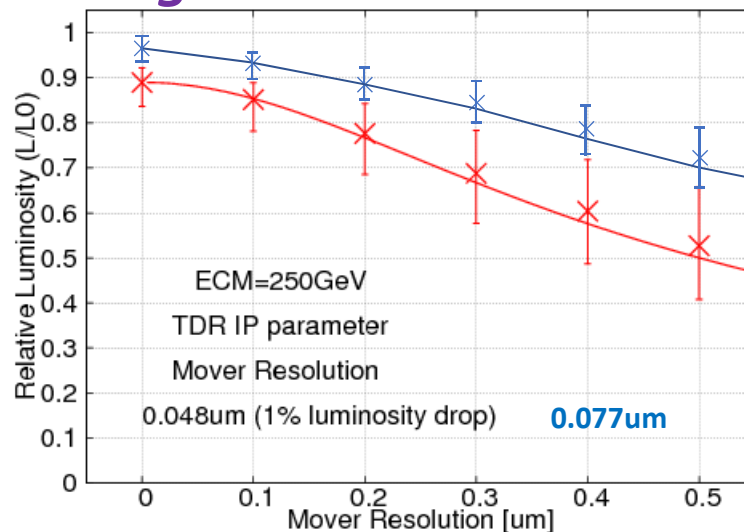
*This is one of the difficult requirement of ILC FF.*

# 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”.