

# *Present Status of BDS study*

*Optics design for ILC FFS*

*Beam tuning simulation for various QF1 and QD0 L\*(CR2 )*

*BDS Tunnel Layout*

*Toshiyuki OKUGI, KEK*

*2015/04/14*

*BDS meeting*

*Beam Optics Design  
of  $ECM=250\text{GeV} / 500\text{GeV}$*

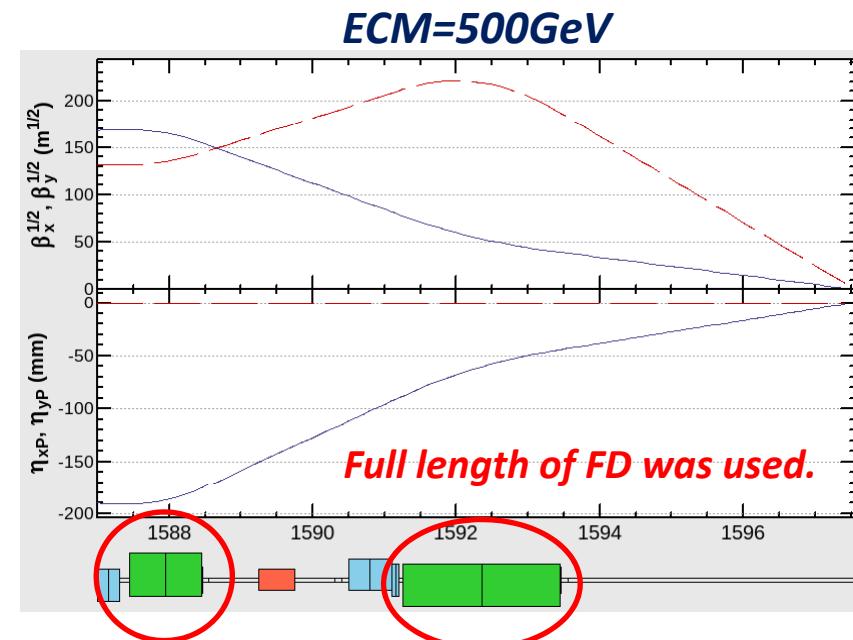
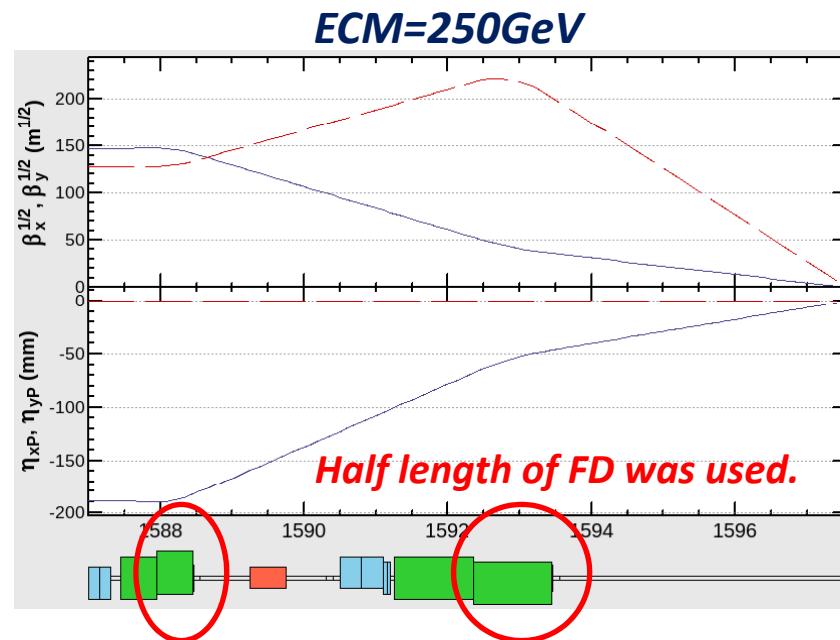
# *Procedure of the optics optimization*

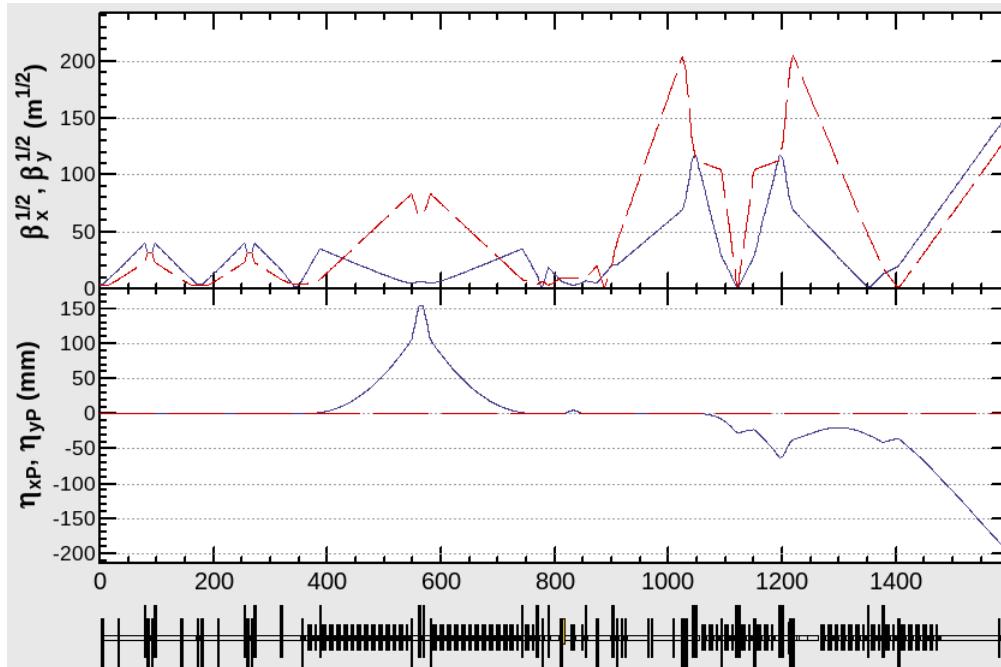
*The optics for  $ECM=250\text{GeV}$  was only used **the half of FD magnets** in order to increase the collimation depth.*

*Therefore, the magnet arrangement for  $ECM=250\text{GeV}$  was different to others*

*Since the nonlinear effects of the beam optics for  $ECM=250\text{GeV}$  is stronger than others, I optimized the magnet arrangement for  $ECM=250\text{GeV}$  first.*

*Then,  $ECM=500\text{GeV}$  optics was designed with the constraint of the arranged magnet to  $ECM=250\text{GeV}$ .*





*Beam Optics for **ECM=250GeV***

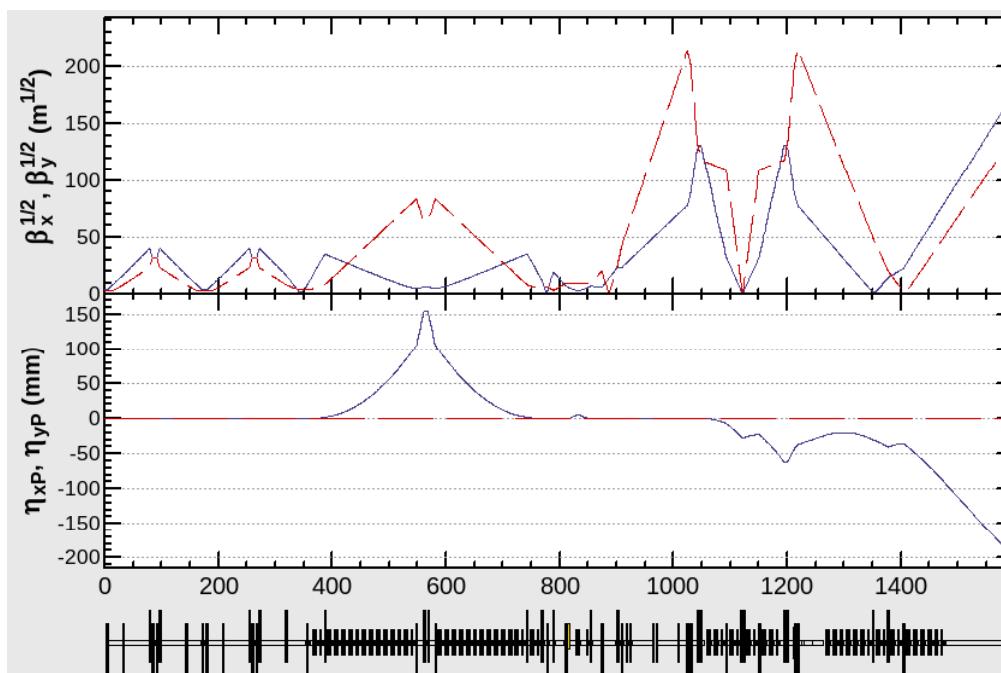
*The half length of FD magnets were used.*

$$\text{betaX}^* = 13 \text{ mm}$$

$$\text{betaY}^* = 0.41\text{mm}$$

*The **magnet arrangement and strengths***

*( 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.*

$$\text{betaX}^* = 11 \text{ mm}$$

$$\text{betaY}^* = 0.48\text{mm}$$

*The magnet arrangement  
was same to  $\text{ECM}=250\text{GeV}$ .*

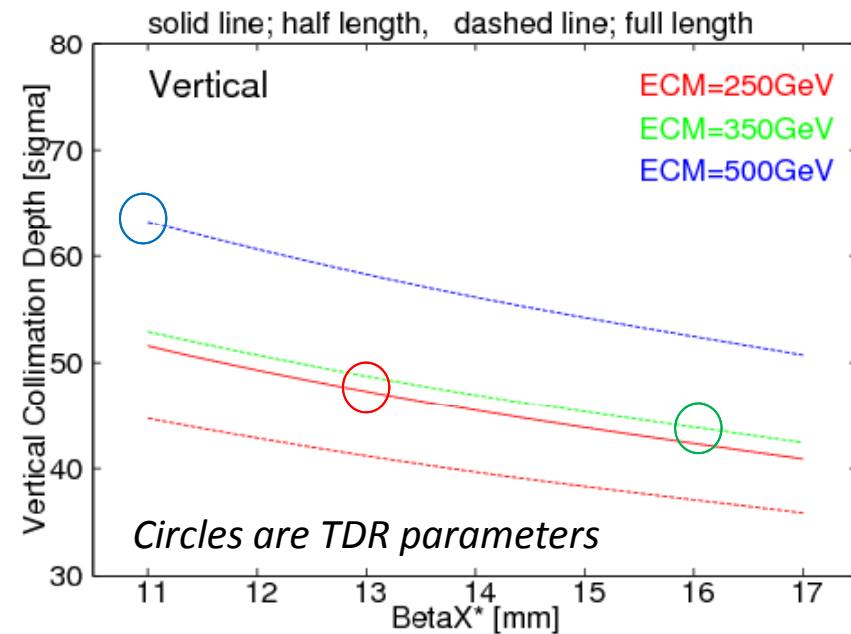
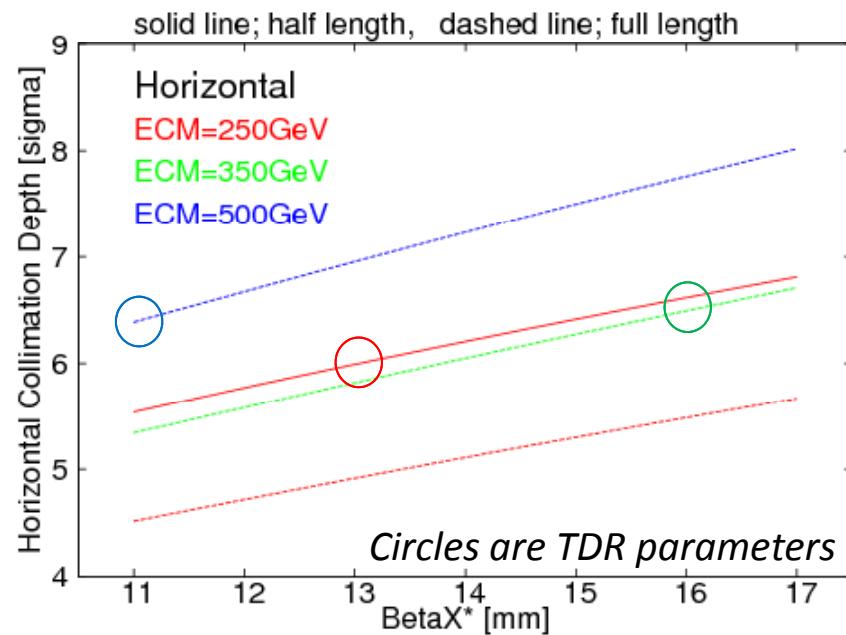
*The **strengths** were changed to optimize.*

# *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

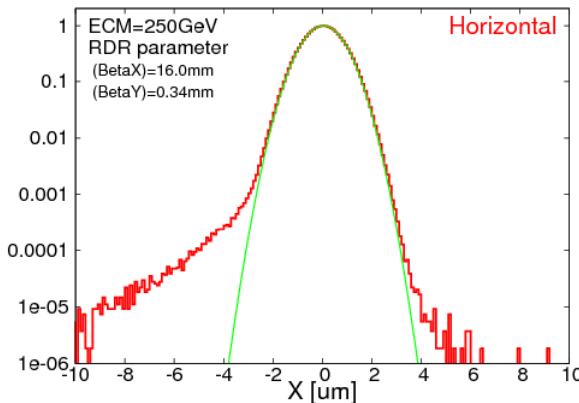
*TDR IP Parameters*

$$(QF1 L^*) = 9.1m$$

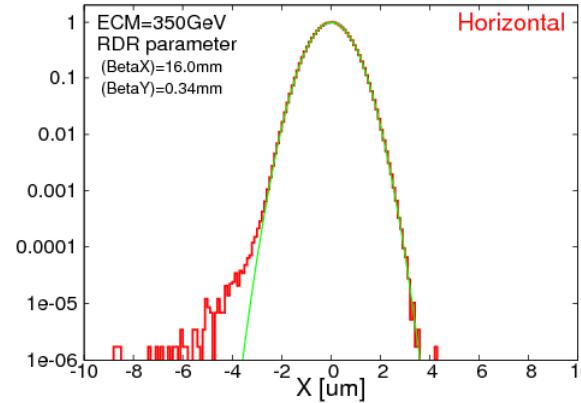
$$(QD0 L^*) = 4.1m$$

## IP Horizontal Profile

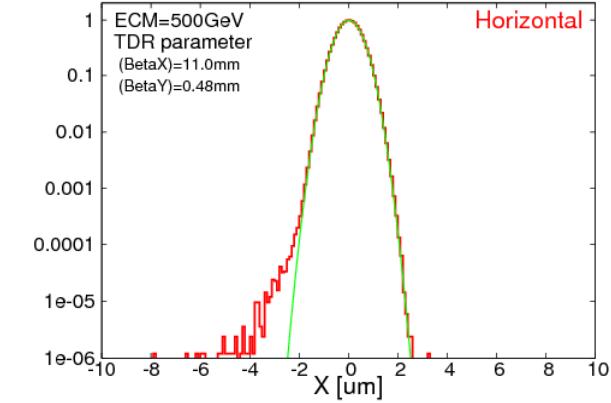
ECM=250GeV



ECM=350GeV

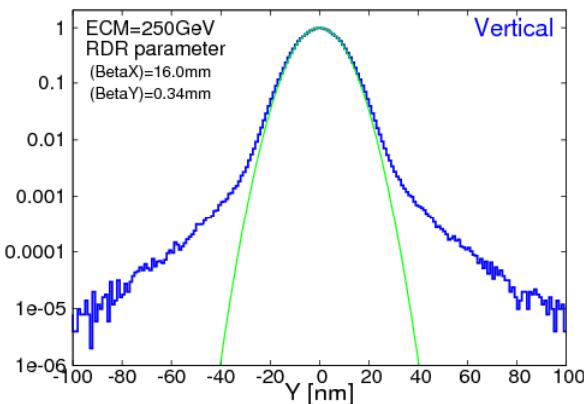


ECM=500GeV

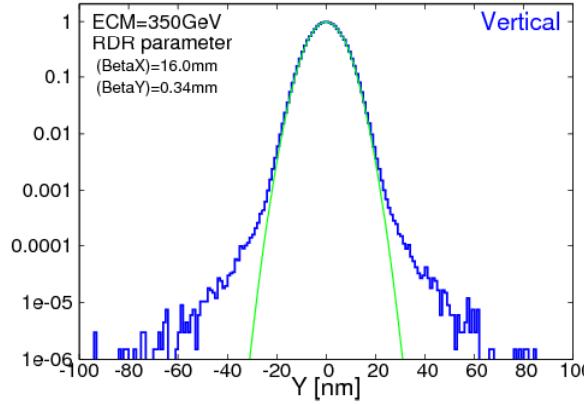


## IP Vertical Profile

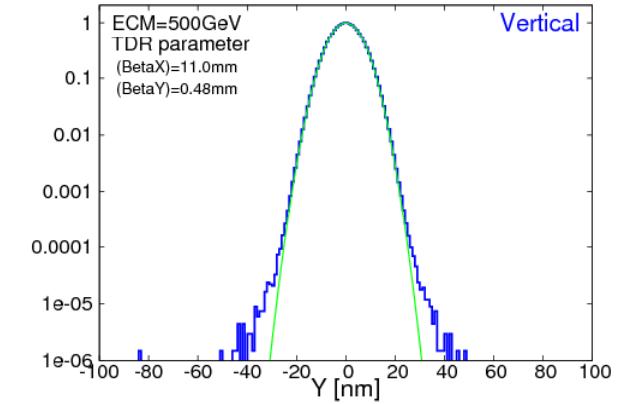
ECM=250GeV



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	<b>design</b>	0.729 um	0.684 um	0.474 um
	<b>core</b>	0.749 um	0.685 um	0.478 um
	<b>rms</b>	0.756 um	0.705 um	0.489 um
Vertical beam size	<b>design</b>	7.66 nm	5.89 nm	5.86 nm
	<b>core</b>	7.84 nm	5.99 nm	5.90 nm
	<b>rms</b>	8.03 nm	6.08 nm	5.93 nm
<b>Relative Luminosity (L/L<sub>0</sub>)</b>		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.

*Performance of (QF1 L\*)=9.1m, (QD0 L\*)=4.1m optics*

# *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.

# *Tolerances evaluation by IP-beam size tuning*

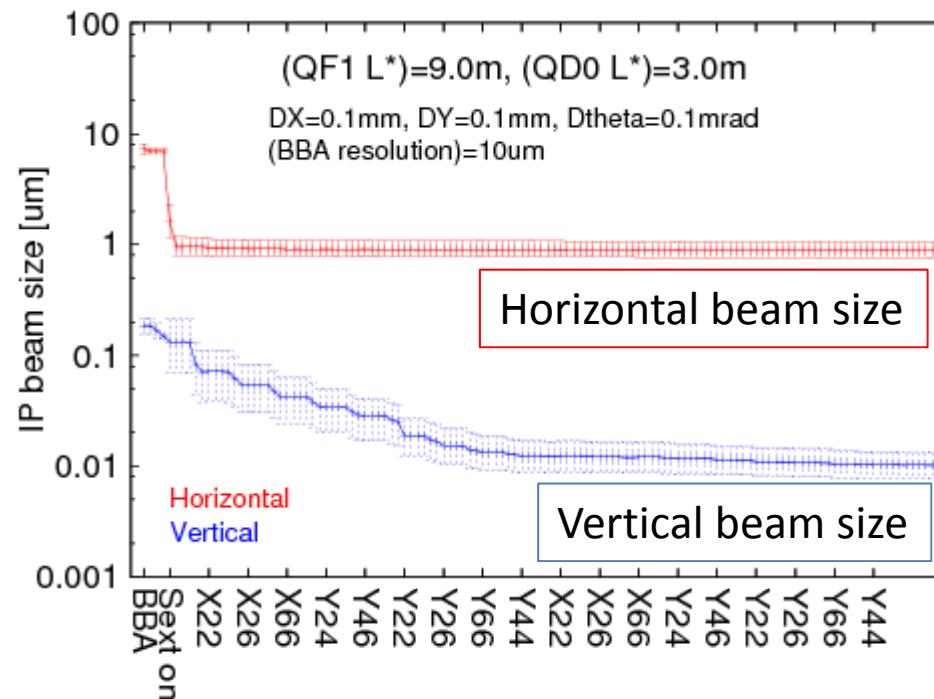
## *Procedures*

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 2<sup>nd</sup> order optics tuning

## *Example of the beam size minimization by the beam tuning simulation*

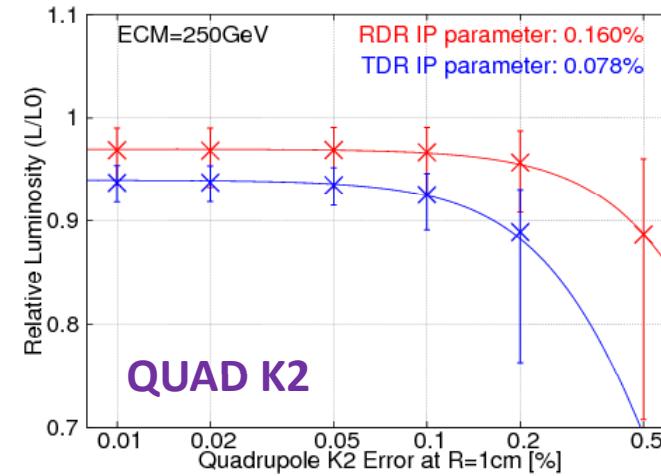
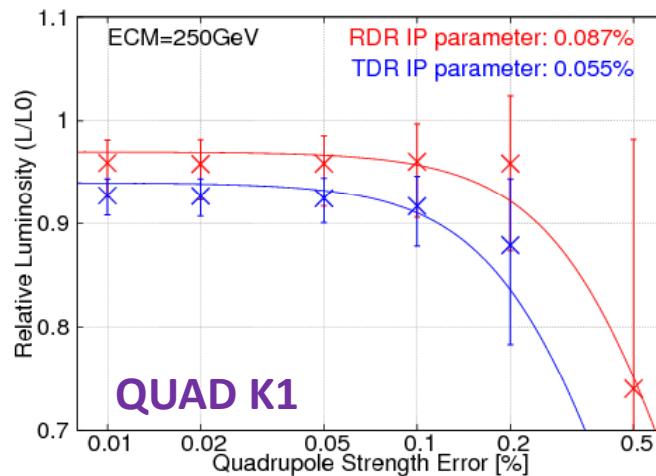
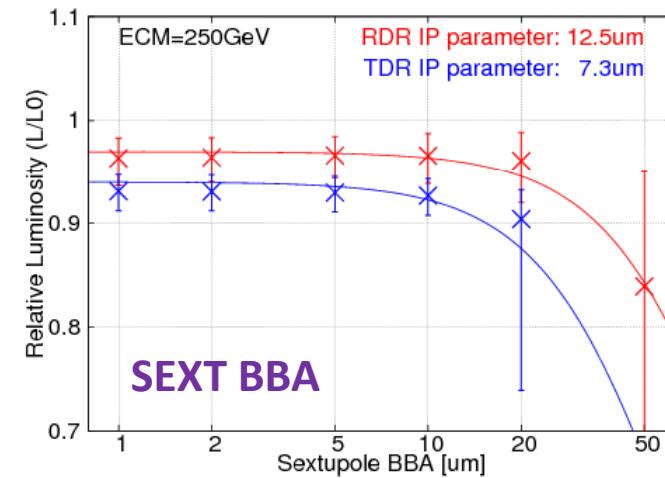
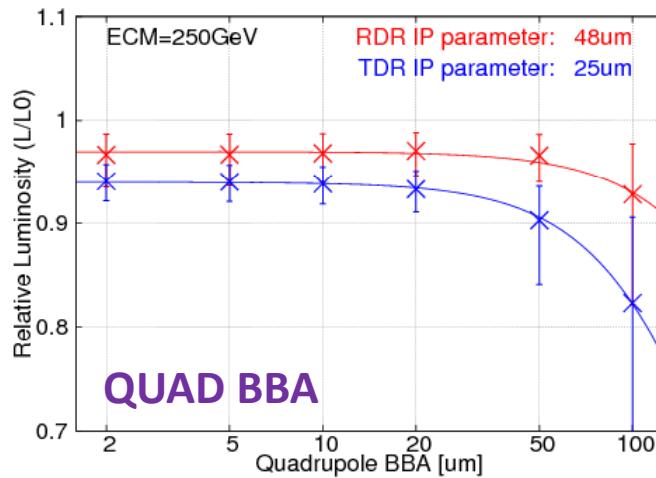
### *Alignment errors*

	Bend	Quad	Sext
$\Delta K$	0.1%	0.1%	0.1%
$\Delta X$	N. A.	0.1mm	0.1mm
$\Delta Y$	N. A.	0.1mm	0.1mm
$\Delta \theta$	0.1mrad	0.1mrad	0.1mrad



# *Example of tolerance evaluation*

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



# Summary of BDS Alignment Tolerances (ECM=250GeV)

*1% average luminosity reduction*

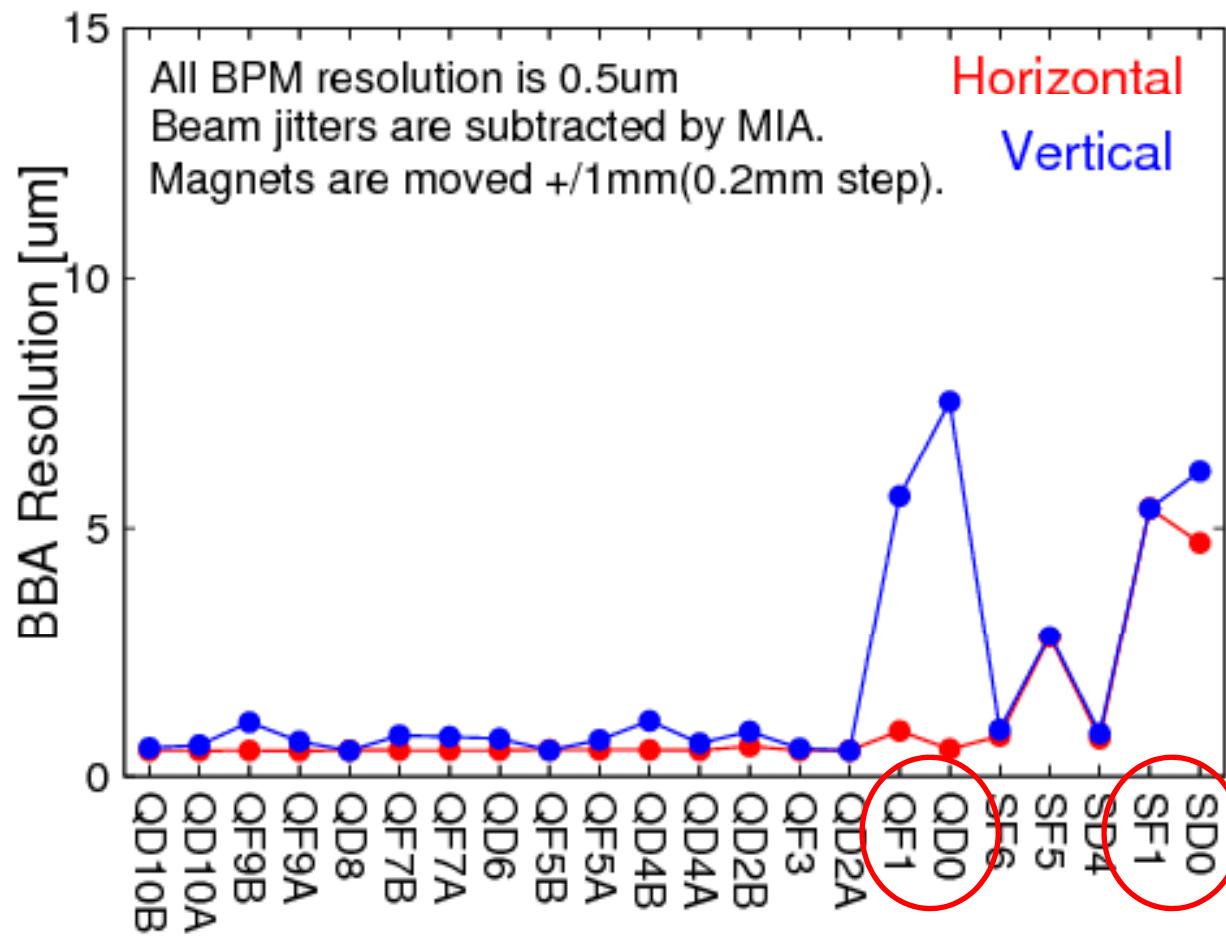
*Red seems difficult.*

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

*Simulation results said that*

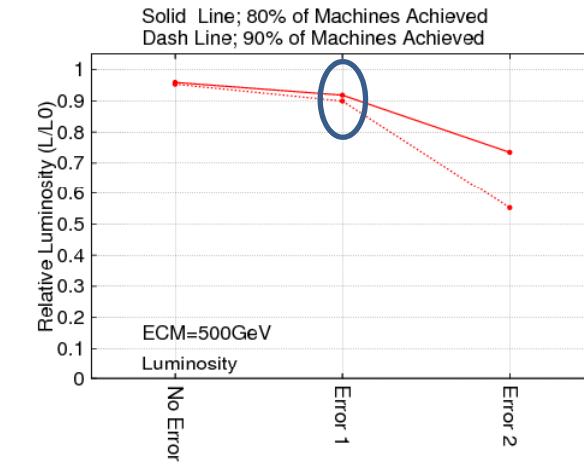
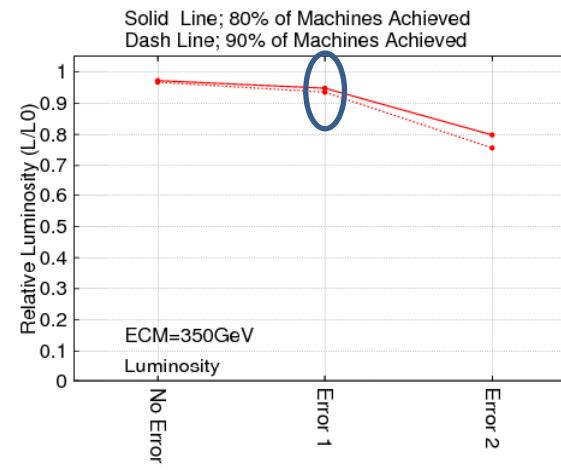
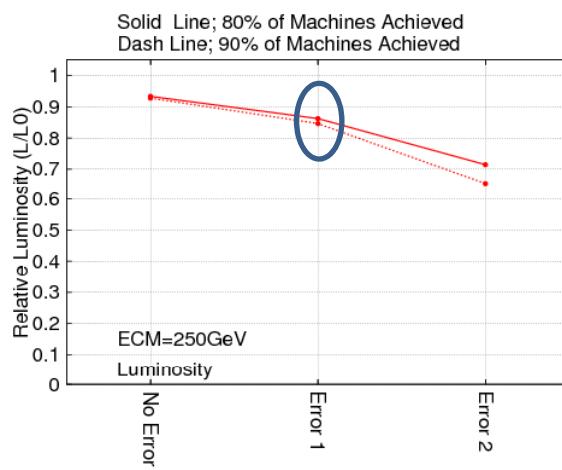
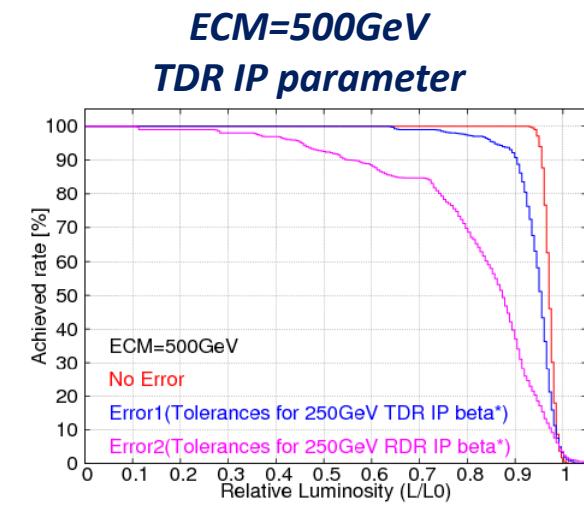
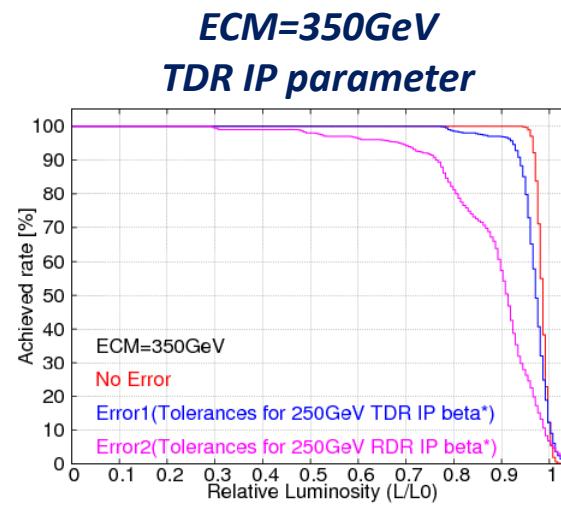
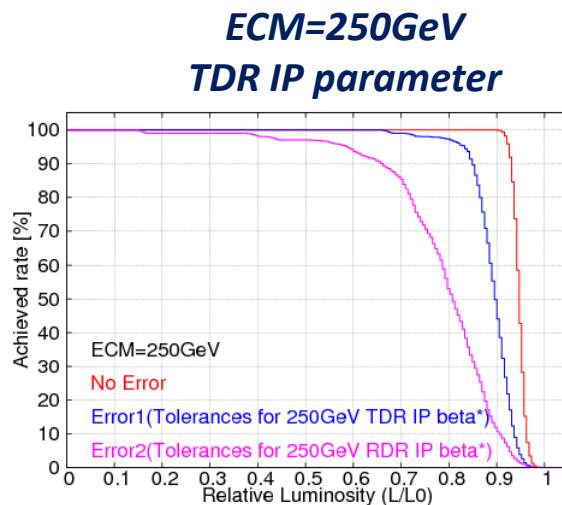
- the tolerances for TDR is 1.4times difficult to RDR for the errors related to linear optics .
- the tolerances for TDR is 2.0times difficult to RDR for the errors related to 2<sup>nd</sup> order optics.

## *Evaluation of the BBA resolution*



*The BBA resolutions for FD quadrupoles and sextupoles are large to others.*

# *IP tuning simulation by putting total alignment errors*



*Tolerances for ECM=350GeV, 500GeV are easier than ECM=250GeV.*

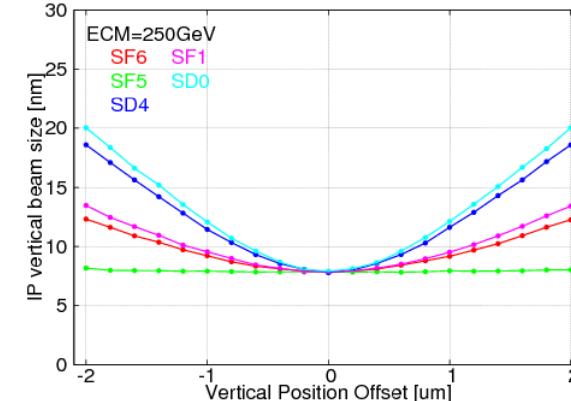
*When the alignment error is increased by the factor 1.4/2.0,  
the achieved luminosity is reduced so much.*

# *Requirement of the magnet movers*

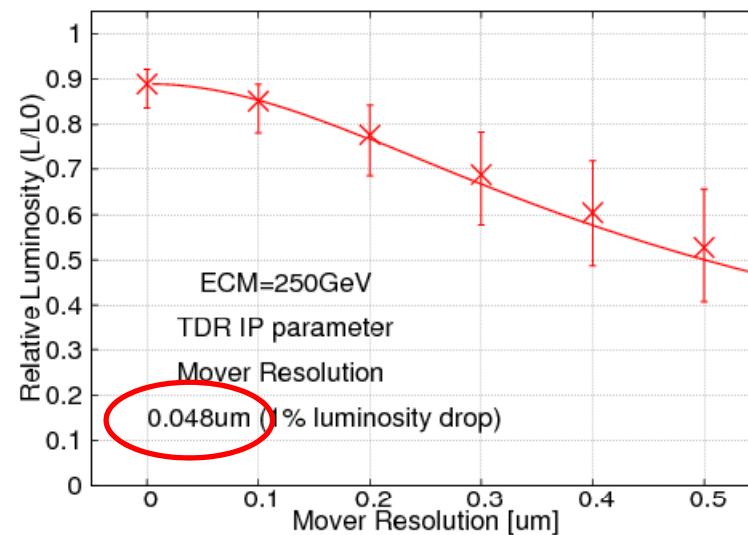
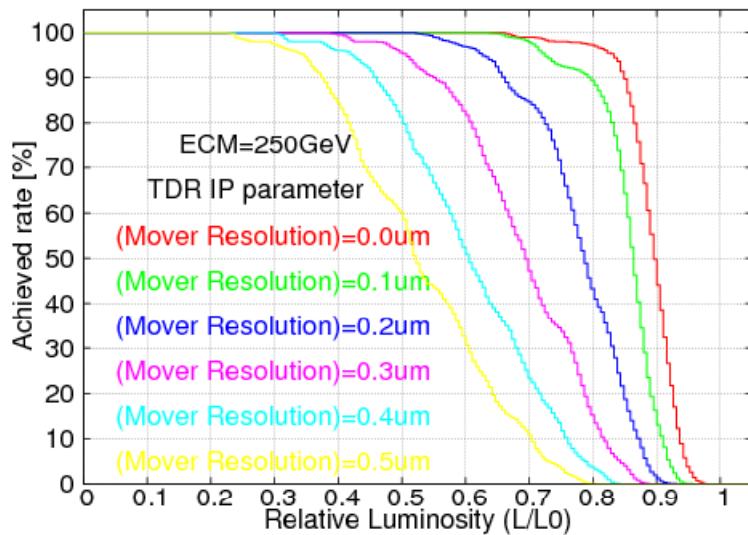
*When the position of the sextupoles were moved by sub-micron,  
IP-beam size was increased so much.*

*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.*

# *Requirement of Luminosity monitor resolution*

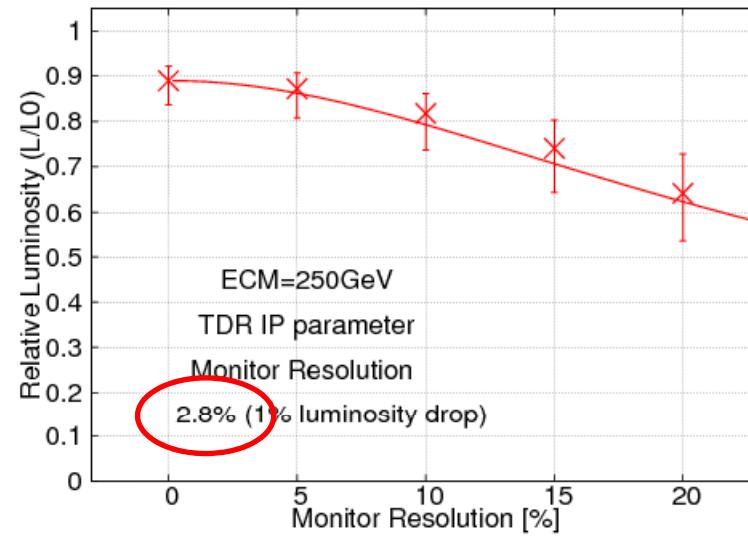
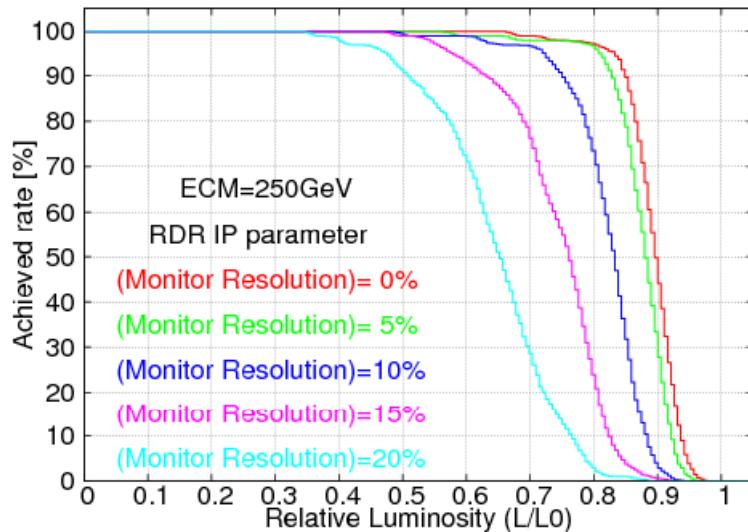
*In present MDI-BDS design, the luminosity monitor will be*

- Beamstrahlung monitor for large beam
- Incoherent pair monitor for small beam

*The resolution requirement for IP beam size tuning also evaluated.*

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

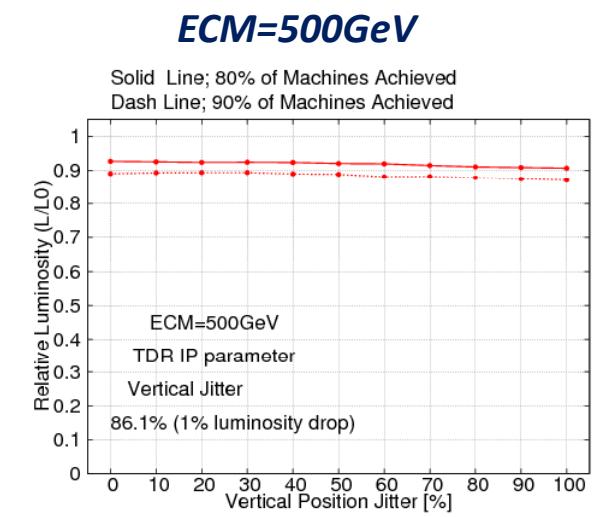
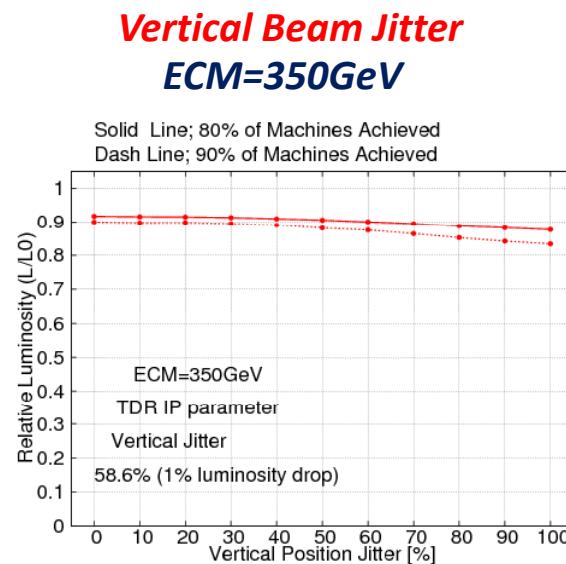
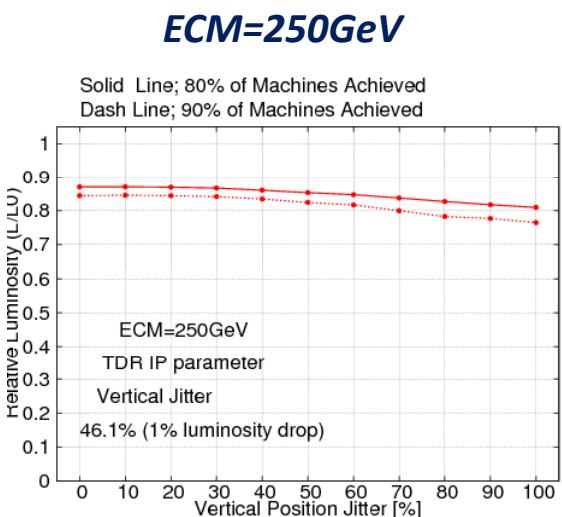
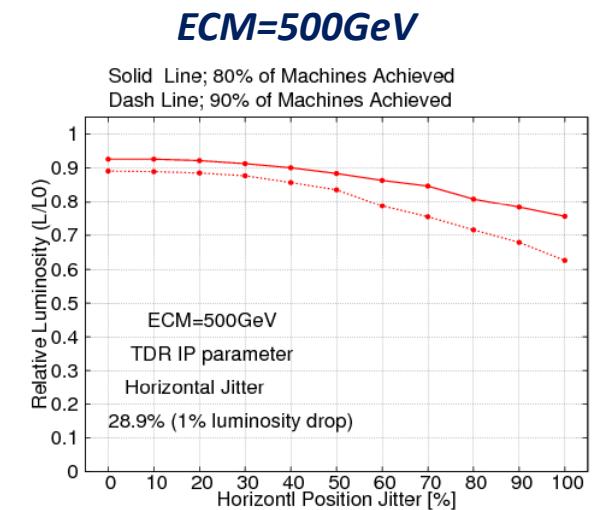
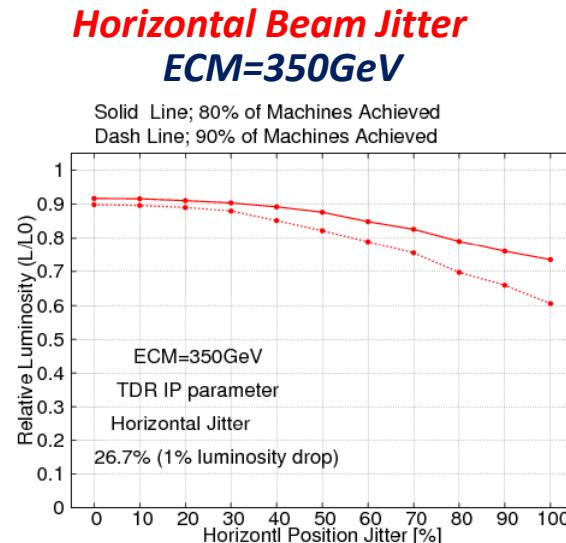
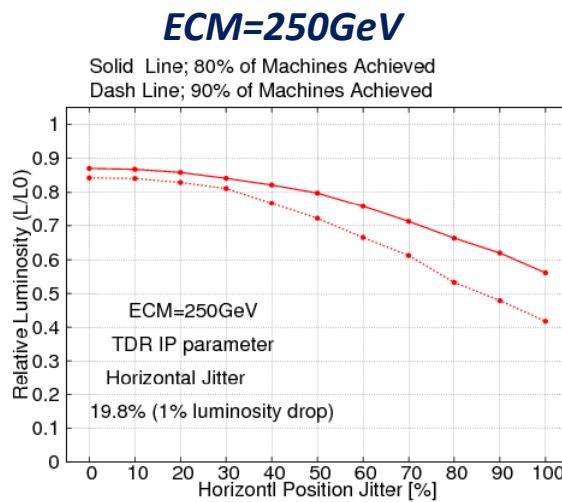
*The alignment error is set to the tolerance for 250GeV TDR parameter.*



*Resolution of luminosity monitor should be less than 3%.*

# Tolerance of the beam jitter

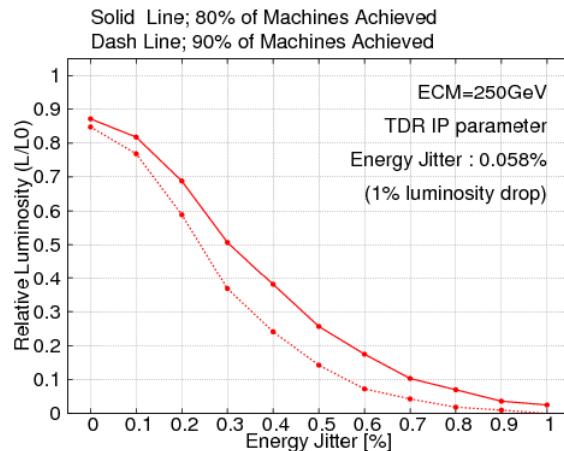
The tolerance is evaluated for  $ECM=250\text{GeV}$ , and TDR IP beta functions ( $\beta_X^*/\beta_Y^*=13\text{mm}/0.41\text{mm}$ ).  
 The alignment error is set to the tolerance for  $250\text{GeV}$  TDR parameter.



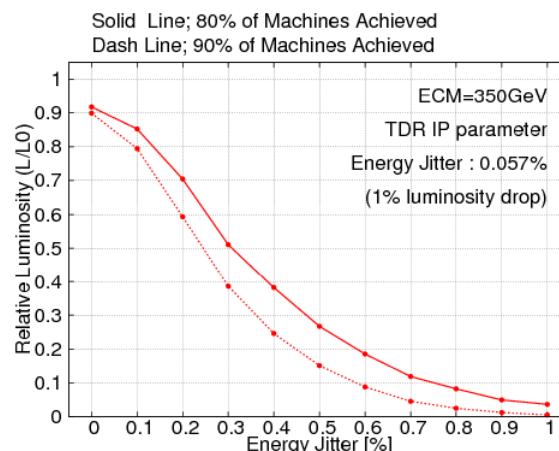
# *Tolerance of the beam jitter 2*

## *Beam Energy Jitter*

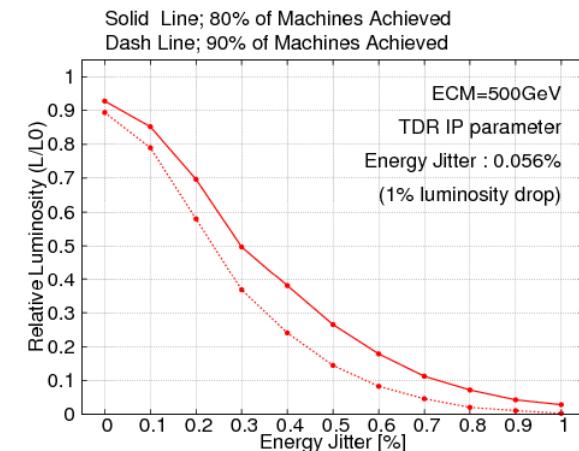
*ECM=250GeV*



*ECM=350GeV*



*ECM=500GeV*



## *Summary of tolerances for beam jitter*

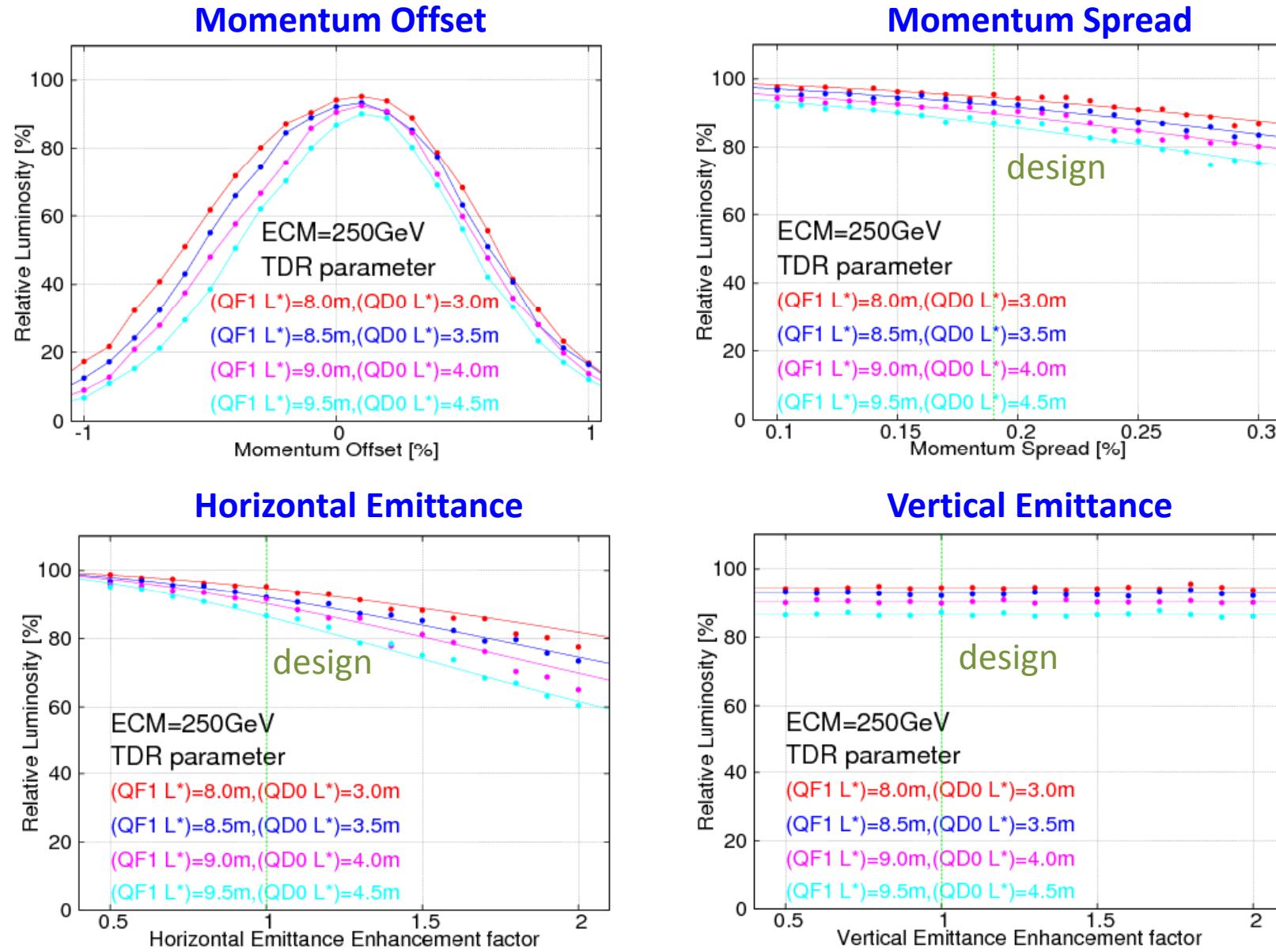
	<i>ECM=250GeV</i>	<i>ECM=350GeV</i>	<i>ECM=500GeV</i>
Horizontal	19.8%	26.7%	28.9%
Vertical	46.1%	58.6%	86.1%
Energy	0.058%	0.057%	0.056%

*Requirement of horizontal and vertical jitters for lower energy are tight, but not so tight.  
Energy jitter should be 0.06% for all energy range.*

*The results of beam tuning simulation  
for various QF1 and QD0 L\*  
( Information of CR2 )*

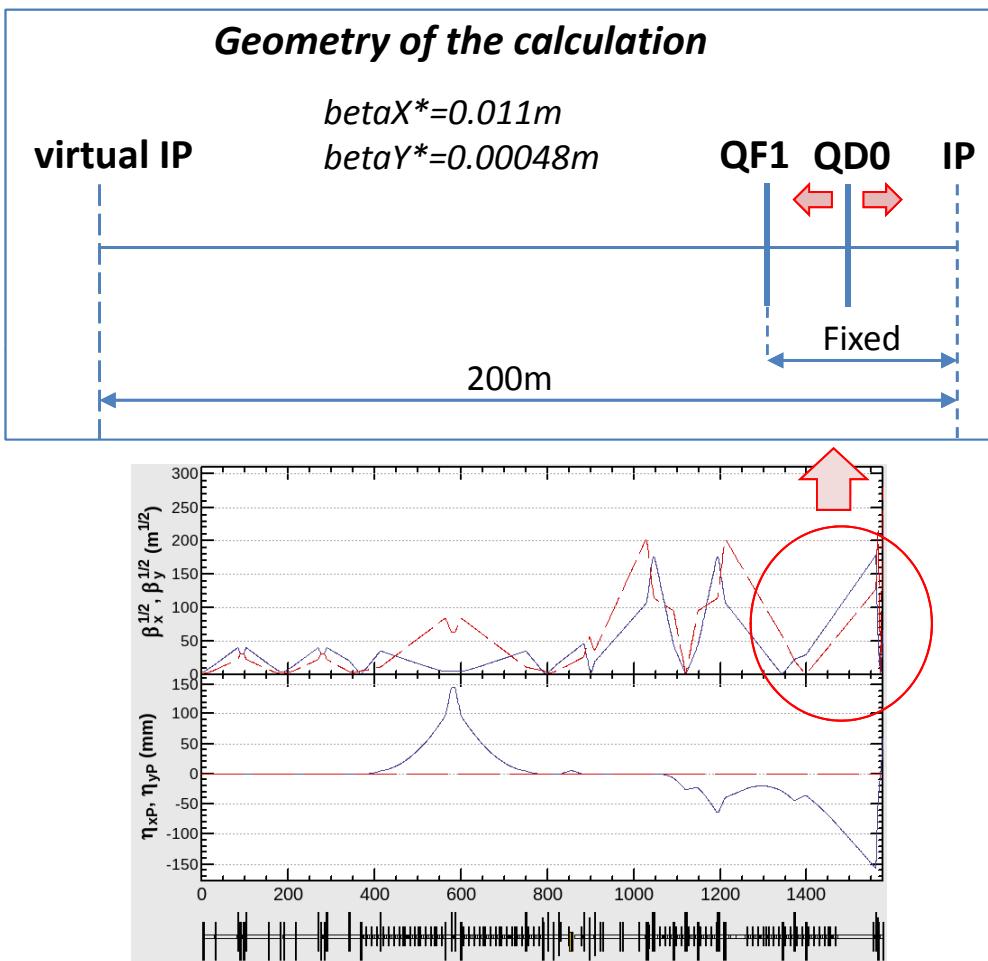
*Since I have no presentation at CR2 session,  
I will not present the issues at ALCW2015.*

# *$L^*$ dependence for same distance between QF1 and QD0*



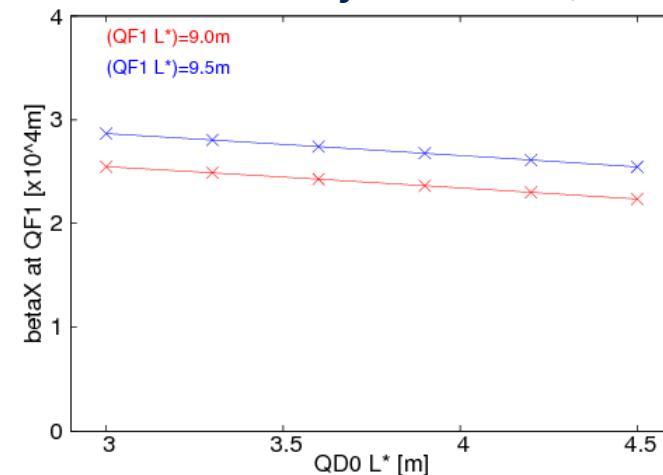
*In generally, the performance of FF beamline is better as small  $L^*$  as possible.*

# *QD0 L\* dependence, when QF1 position is fixed*



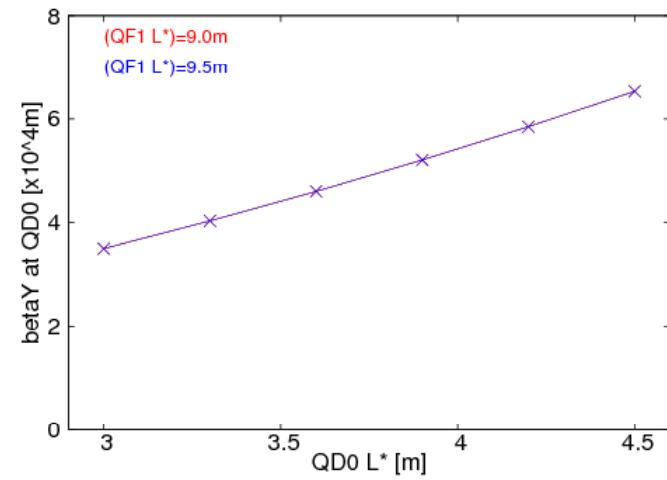
*When QD0 is move to be closer to IP,  
the horizontal beta function at QF1 is increased.*

**Horizontal beta function at QF1**



*Affect to the horizontal collimation depth*

**Vertical beta function at QD0**

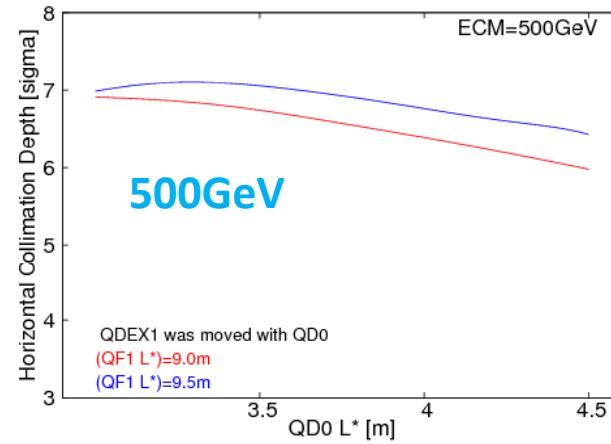
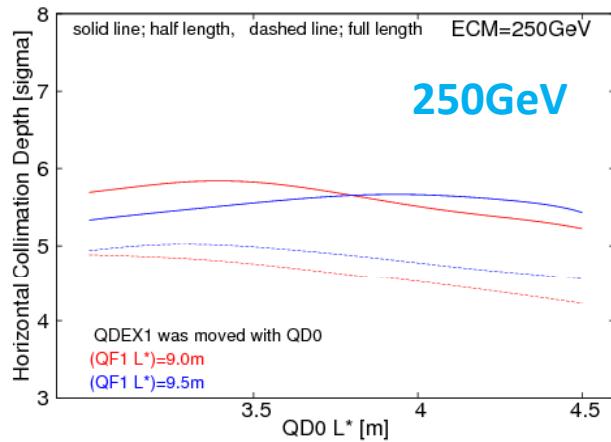


*Affect to the vertical collimation depth*

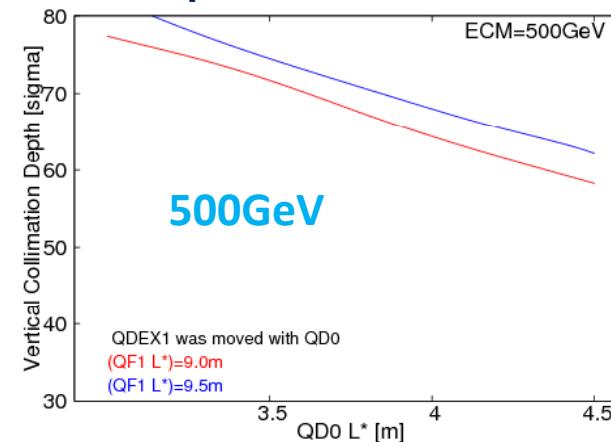
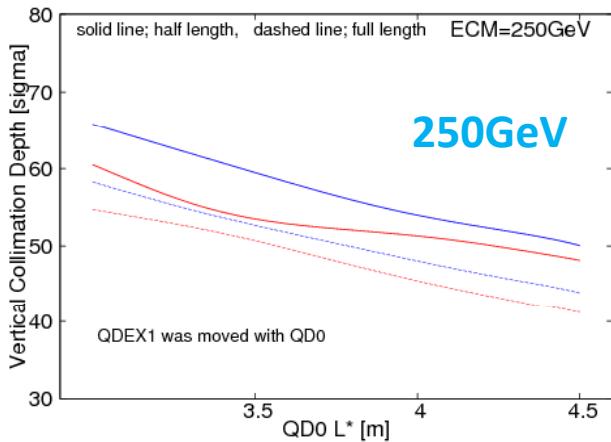
# *Effect of (QD0 L\*) to collimation depth*

$\beta^* (x/y) = 11\text{mm} / 0.48\text{mm}$  both for  $ECM=250\text{GeV}$  and  $500\text{GeV}$

## Horizontal Collimation Depth



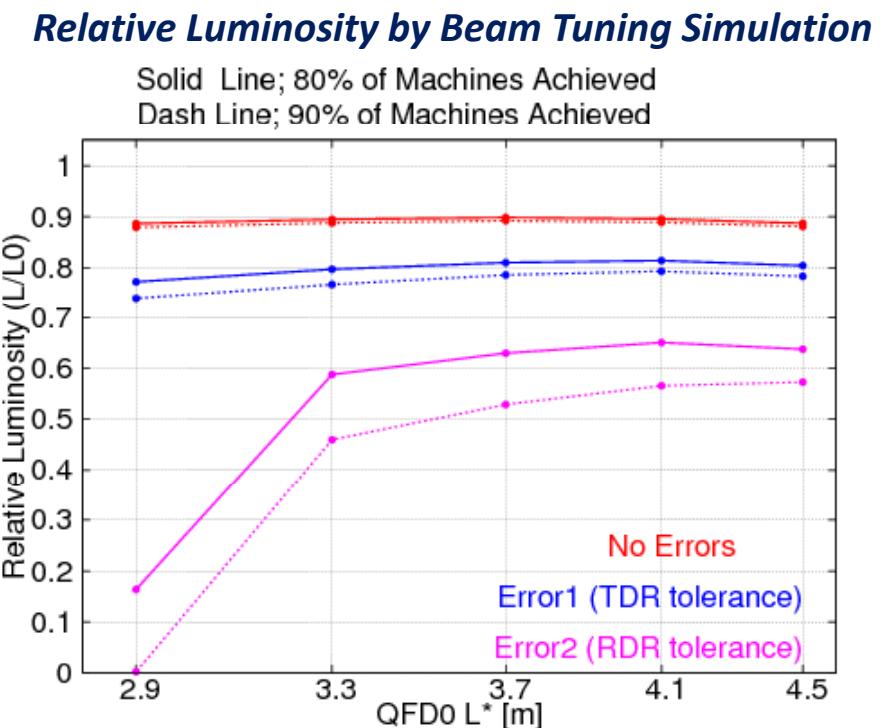
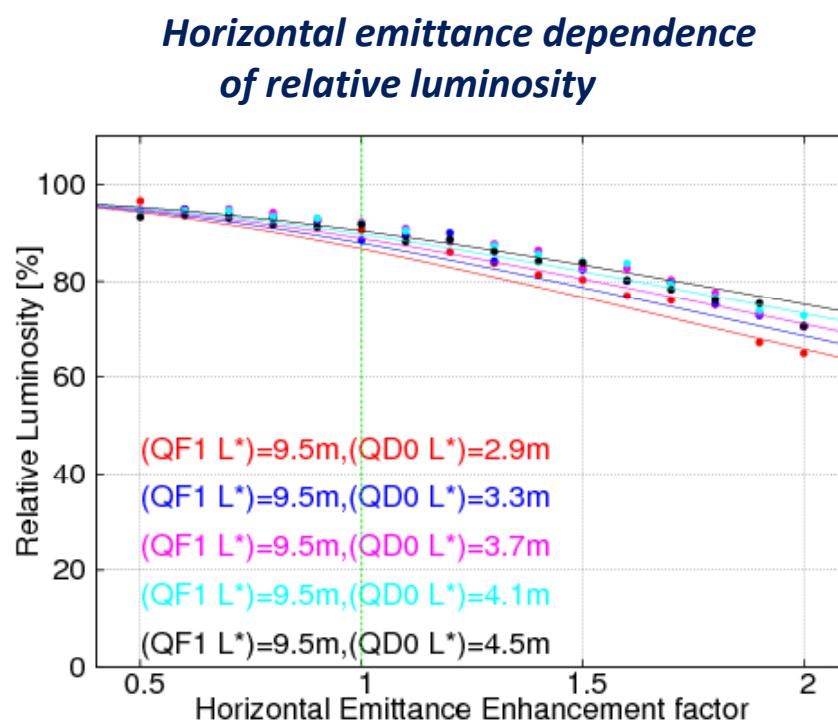
## Vertical Collimation Depth



The horizontal collimation depth have small dependence to QD0 L\*.  
The vertical collimation depth is larger for smaller QD0 L\*.

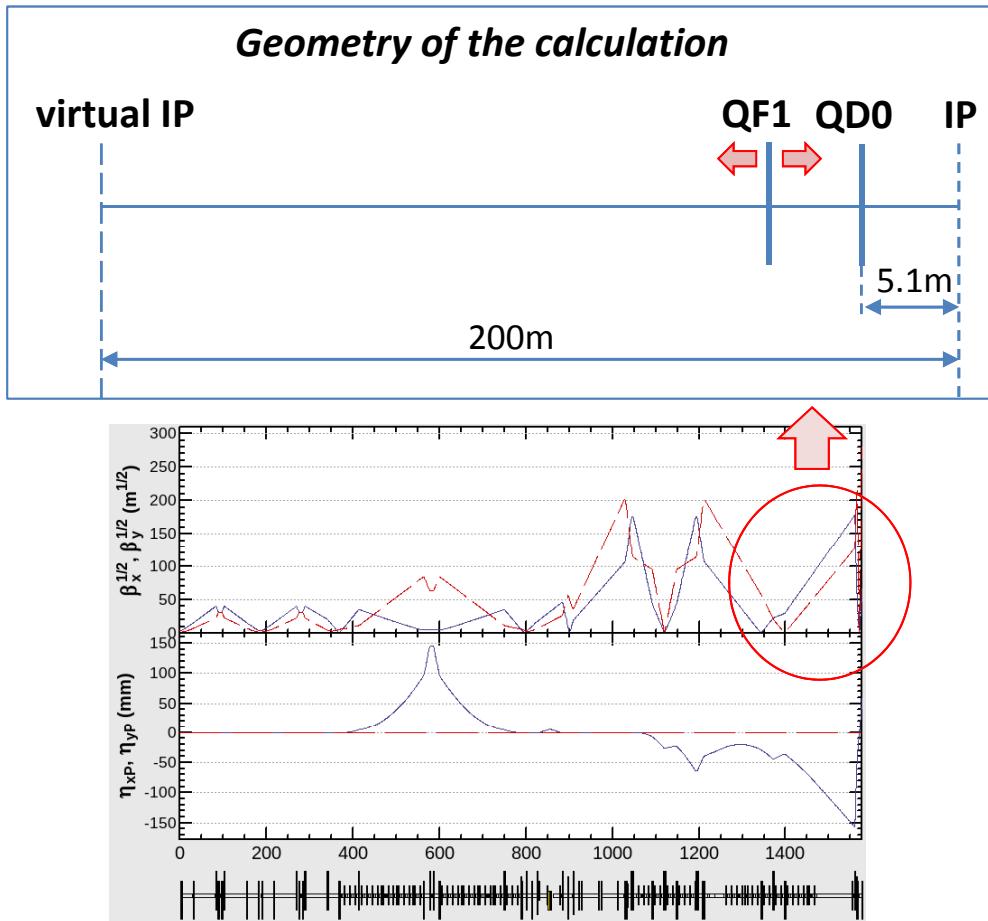
# *Effect of (QD0 L\*) to Luminosity*

$ECM = 250\text{GeV}$   
 $\text{beta}^*(x/y) = 13\text{mm} / 0.41\text{mm}$   
 $(QD0 L^*) = \text{variable}, (QD0 Length) = 2.2\text{m}$   
 $(QF1 L^*) = 9.5\text{m}, (QF1 Length) = 1.0\text{m} (\text{half length of TDR design})$

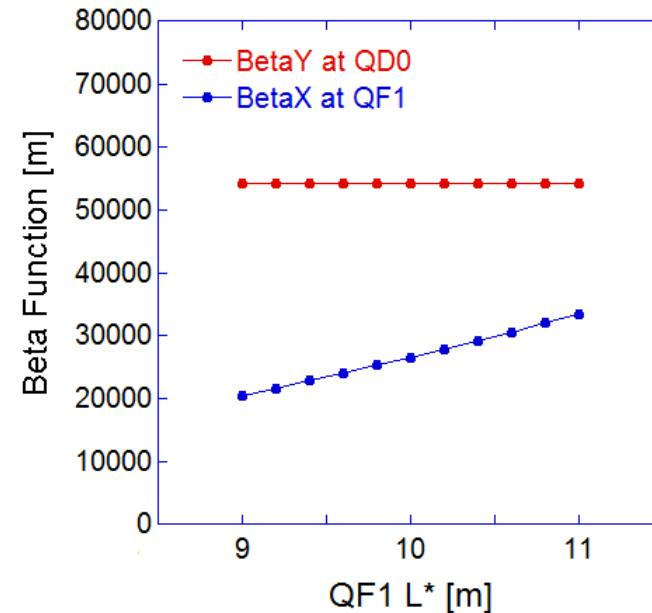


- When the horizontal beam size at FF beamline is increased, the luminosity reduction is small for longer QD0 L\*.
- The IP beam tuning simulation also said the longer QD0 L\* is better.

# *QF1 L\* dependence, when QD0 position is fixed*



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

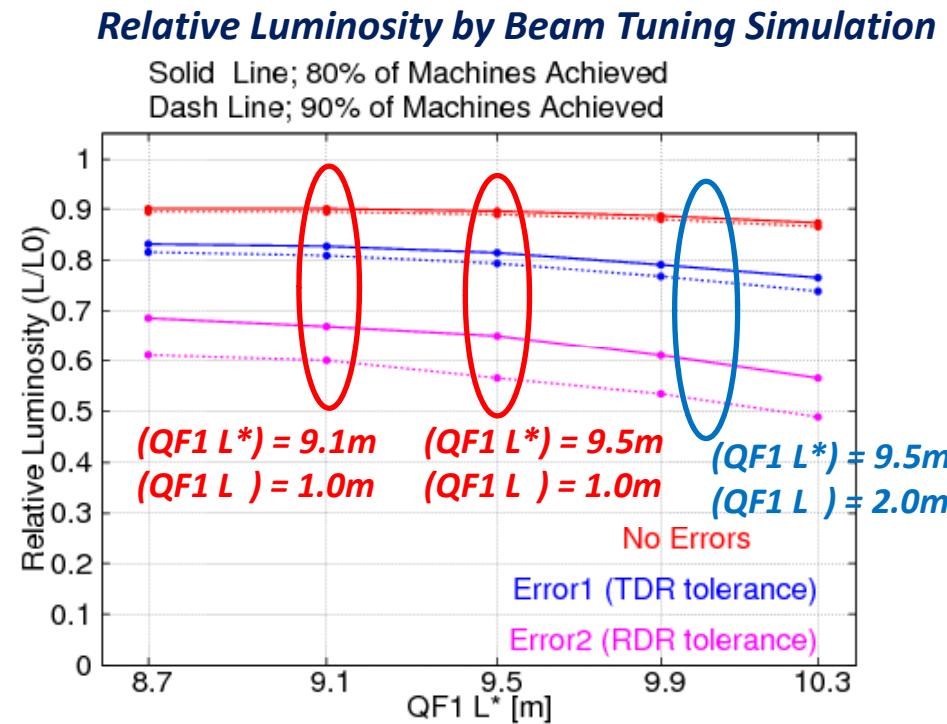
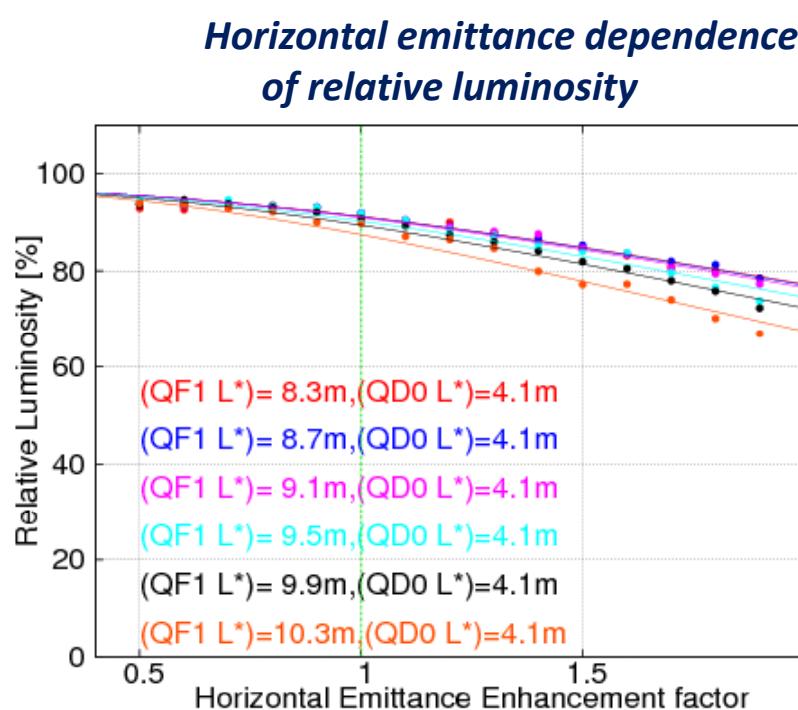


When QF1 is move to be closer to IP, the horizontal beta function at QF1 is decreased, by keeping the vertical beta function at QD0.

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

# Effect of (QF1 L\*) to Luminosity

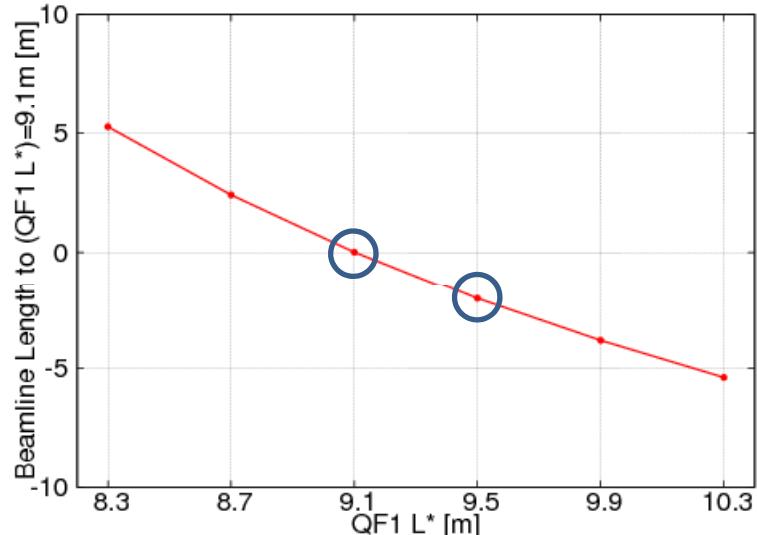
$ECM = 250\text{GeV}$   
 $\beta^*(x/y) = 13\text{mm} / 0.41\text{mm}$   
 $(QD0 L^*) = 4.1\text{m}, (QD0 Length) = 2.2\text{m}$   
 $(QF1 L^*) = \text{variable}, (QF1 Length) = 1.0\text{m} (\text{half length of TDR design})$



- When the horizontal beam size at FF beamline is increased, the luminosity reduction is small for shorter QF1 L\*.
- The IP beam tuning simulation also said the shorter QF1 L\* is better.

## *Other Consideration for $(QF1 L^*)=9.1m$ and $9.5m$*

*FF Beamlne Length*

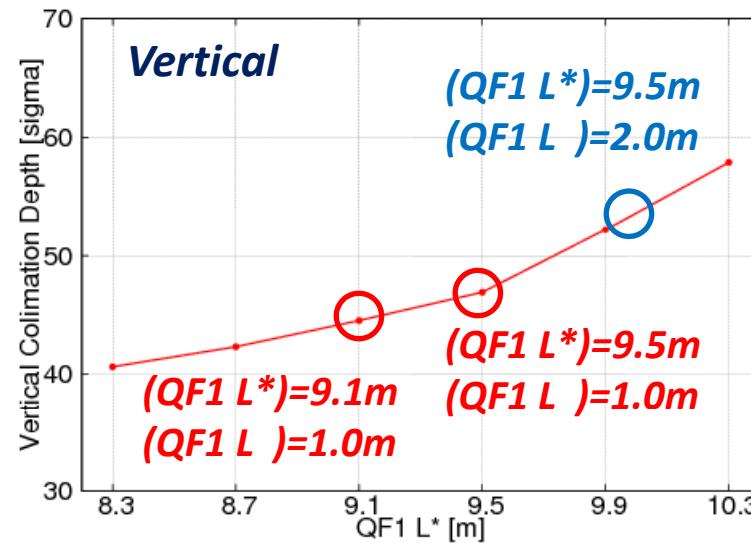
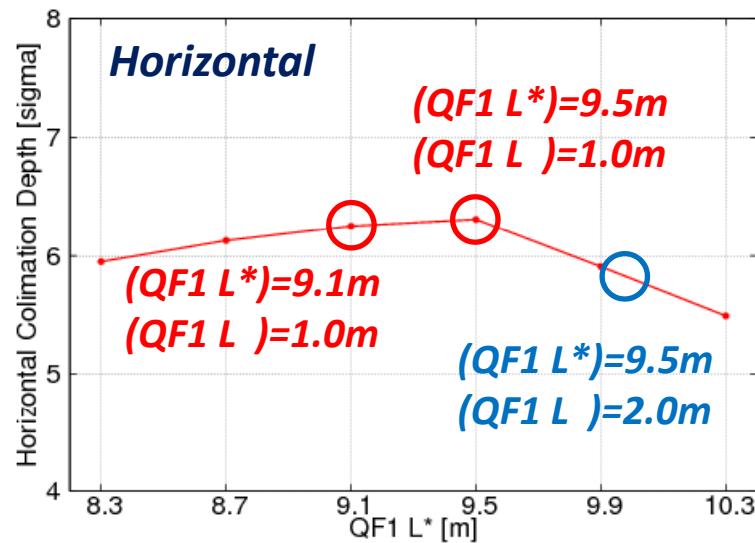


*Optics for  $(QF1 L^*)=9.5m$   
is about 2m shorter than  $(QF1 L^*)=9.1m$ .*

*The X and Y collimation depths both for  $(QF1 L^*)=9.5m$   
are a little bit larger than  $(QF1 L^*)=9.1m$ .*

*When we use the full length of QF1 magnet,  
the horizontal collimation lengths are smaller.*

*Collimation Depth*



## *Summary of $L^*$ issue*

*When we change (QF1  $L^*$ ) and (QD0  $L^*$ ) simultaneously,  
the FF performances are better for shorter  $L^*$ .*

*When we change (QD0  $L^*$ ) by keeping (QF1  $L^*$ ),  
the IP beam tuning performance is better for longer (QD0  $L^*$ ).*

*When we change (QF1  $L^*$ ) by keeping (QD0  $L^*$ ),  
the IP beam tuning performance is better for shorter (QF1  $L^*$ ).*

*The shorter QF1 is helpful to improve the performance of FF beamline.*

*Comparison of (QF1  $L^*$ )=9.1m and 9.5m with shorter QF1.*

- *The tolerances for horizontal emittance growth and IP beam size tuning  
are a little bit better for (QF1  $L^*$ )=9.1m.*
- *The horizontal and vertical collimation depths are a little bit better for (QF1  $L^*$ )=9.5m.*
- *The beamline length is different only by 2m for (QF1  $L^*$ )=9.1m and 9.5m.*

## ***BDS Tunnel Layout***

*We are collecting the information  
of BDS, RTML, electron and positron sources  
(not only beamline, but also PS and how to install the equipment)  
to design BDS tunnel.*

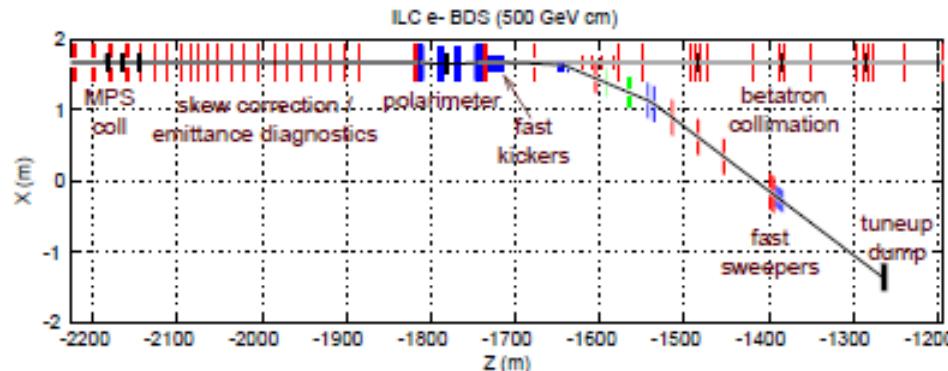
*I will present at ALCW2015 at 4/23 (Thu) session.*

# BDS Total Length

We must fix the beamline length of BDS, not only timing issue, but also design the BDS tunnel layout.

## The bending system for polarimeter and energy spectrometer

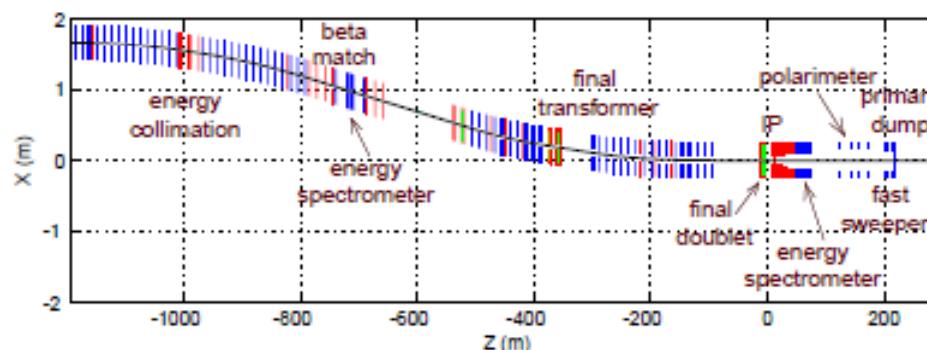
(Horizontal emittance growth)=12% when  $ECM=1\text{TeV}$  -> 3% V  
i.e.) that of Dog-leg is 4% (J.Jones and D.Angal-Kalinin at IPAC10 )



The beamline length in collimator section was lengthened by 50m from TDR.  
The specification of kicker is still difficult, we'd better to lengthen more.

## kickers for extraction

- 9 kickers to abort -> 4 kickers to abort
- Magnetic field of 1.3kG. -> 0.8kG
- Pulse length of 1ms
- 300ns rise time to full strength for emergency abort.



## FF sextupole magnets

- The magnet length is 1m
- 28mm $\phi$  of maximum bore diameter for  $ECM=1\text{TeV}$  (20mm $\phi$  of Inner pipe diameter )
- All of FF quadrupoles are more than 50mm $\phi$

Magnet length is increased to 3m long.

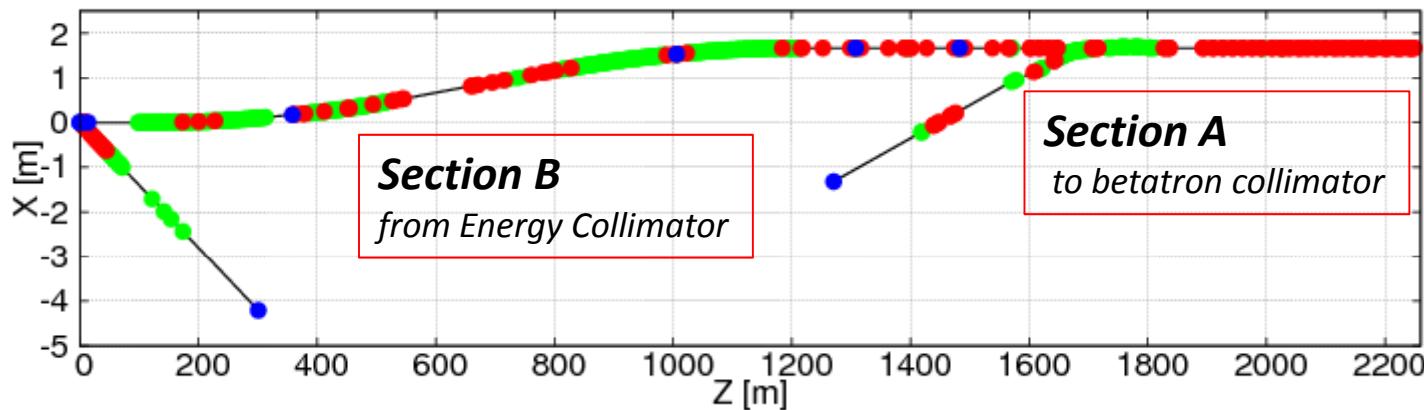
The beamline length of FF section was lengthened by 10m from TDR.

# *Magnet and PS arrangement of BDS*

*ECM= 500GeV optics can be increased the beam energy up to 300GeV (ECM=600GeV)*

*The beam optics can be increased to ECM=1TeV by using same geometory.*

*The most of the magnet for ECM=500GeV can reuse to 1TeV optics.*



	Energy [GeV]	# of BEND	# of QUAD	# of SEXT	# of Steer	# of PS	# of Mover	# of BPM
Section A	500	16	64	0	19	73	70	78
	1000	43	108	0	19	115	108	116
Section B	500	63	33	7	55	46	40	101
	1000	176	41	7	55	56	48	112

*No count to dumpline*

## *Cooling Water*

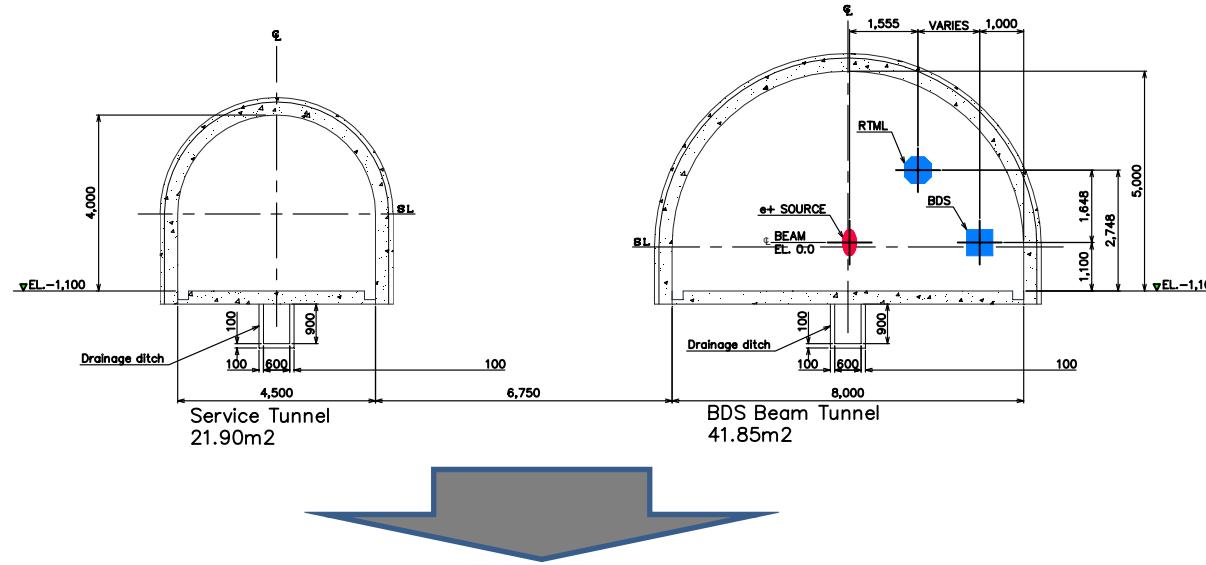
1300 l/min/line (500GeV)

2400 l/min/line (1TeV)

# Under Discussion

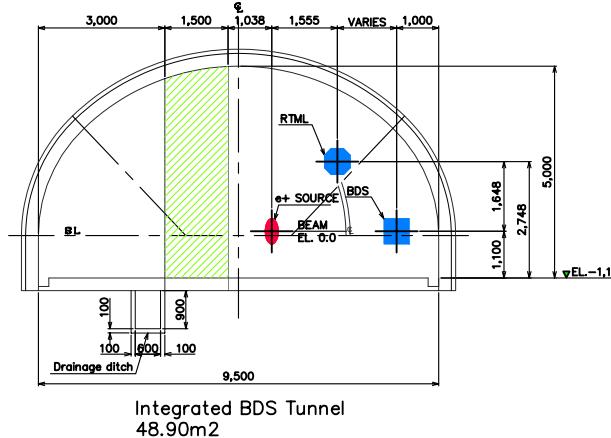
## TDR BDS Tunnel

- 2 tunnel ( based on American RDR design )
- High Cost
- Difficult to cable hole  
in between tunnels



## Integrated option

- We need 2 separate area  
to make emergency access path.
- No access when beam on.



Shield wall width : 1.5 m  
BDS gallery : 5.0 m  
Service gallery : 3.0 m  
Total 9.5 m

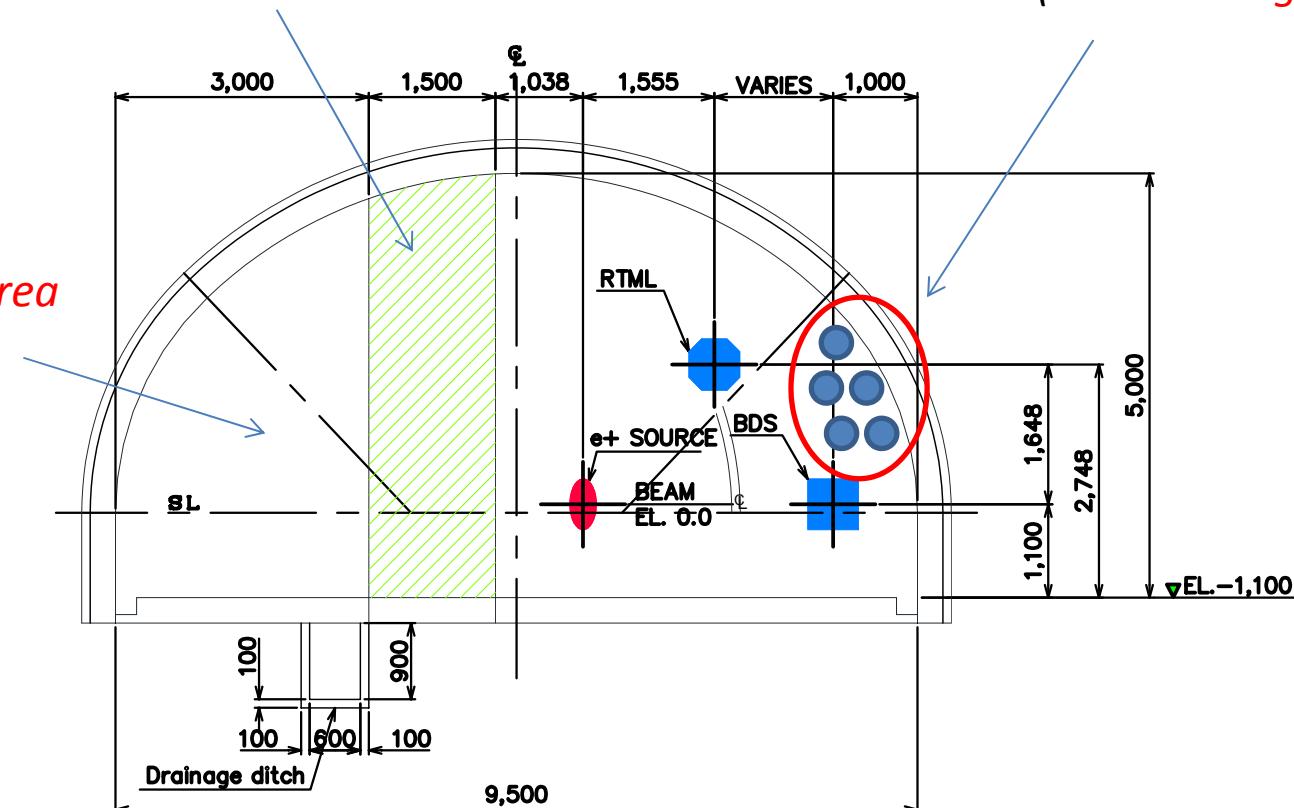
# BDS tunnel design

**Can we remove the concrete shield ?**

( Main linac is necessary  
for protection from dark current at aging  
even when we will not access at beam on . )

The cooling water pipe  
should be arranged.  
( 1m is enough ? )

*Is the service area  
enough ??*



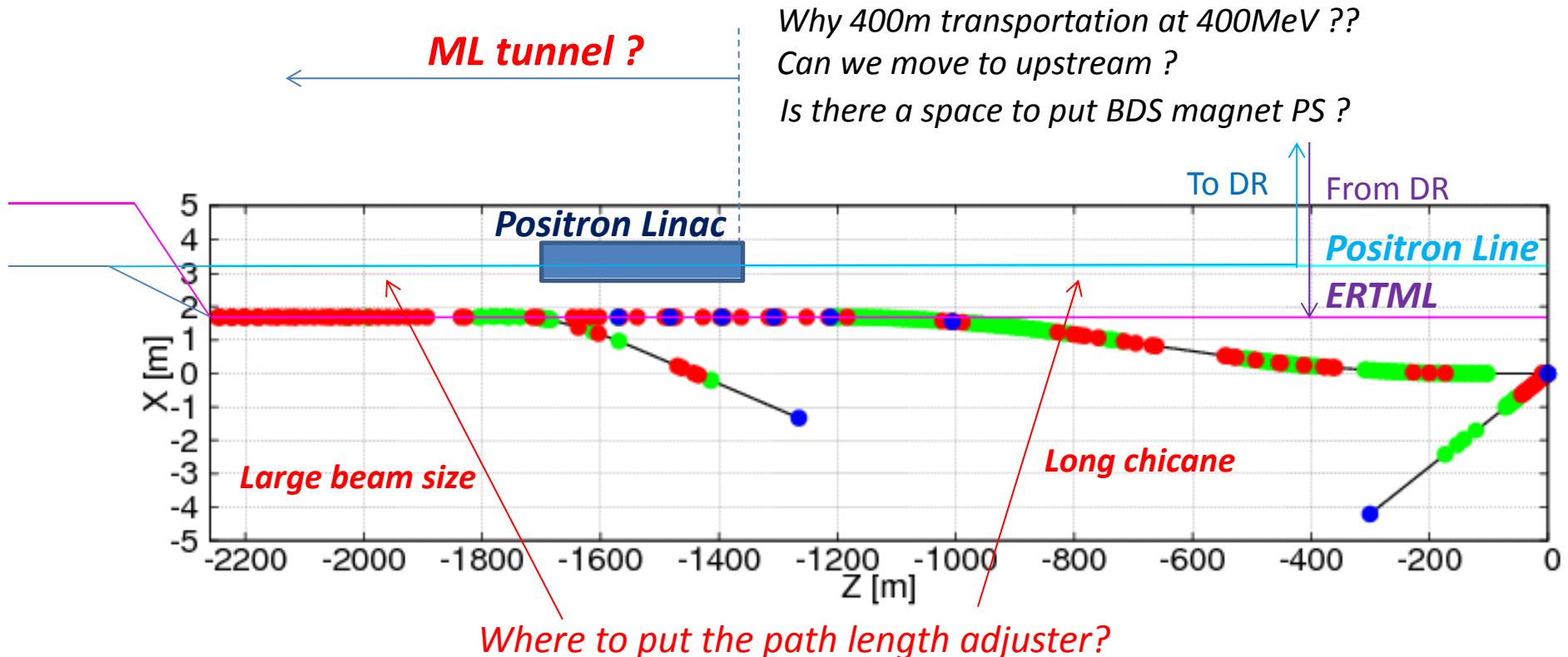
Integrated BDS Tunnel  
48.90m<sup>2</sup>

# Integration of Positron Source

*Integration of positron source is necessary.*

*(not only accelerator tunnel, but also PS station and installation of equipment)*

- Tunnel layout for positron source area, and how to share the service tunnel to BDS
- The arrangement of the components
- Installation scheme and plan
- conventional facilities for positron source



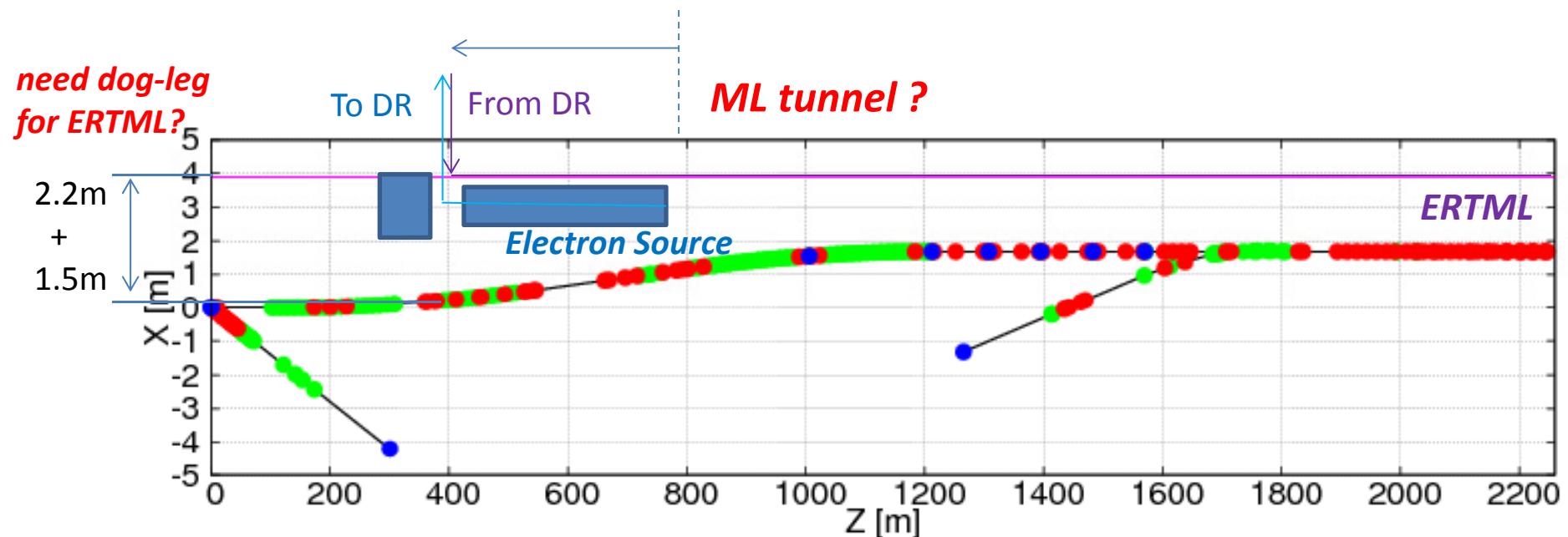
*Will we make the compatible tunnel design of undulator and conventional positron sources?*

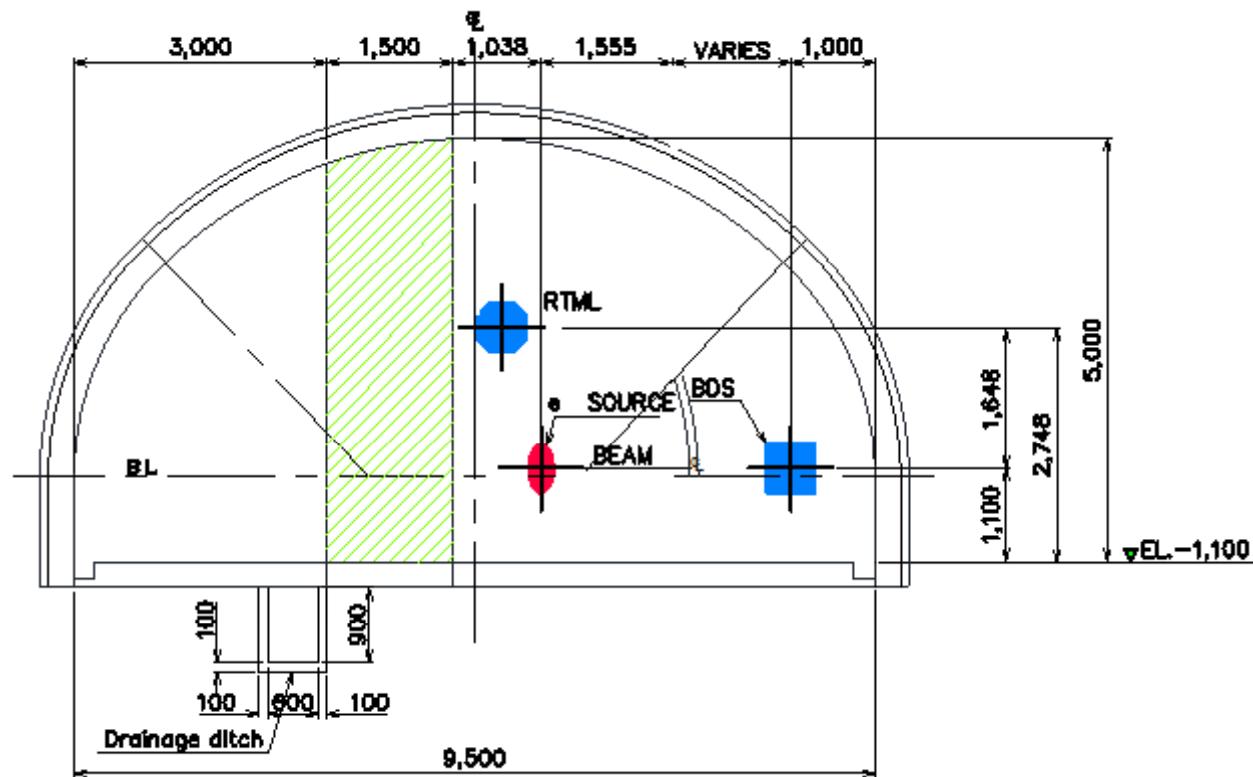
# *Integration of Electron Source*

***Integration of electron source is necessary.***

*(not only accelerator tunnel, but also PS station and installation of equipment)*

- Tunnel layout for electron source area, and how to share the service tunnel to BDS
  - The arrangement of the components
  - Installation scheme and plan
  - conventional facilities for electron source





Integrated BDS Tunnel  
48.90m<sup>2</sup>