

ILC IP parameter optimization

T. Okugi, KEK

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LCWS14

Inn Vinca (SERBIA)

ILC IP parameter and luminosity

Basic performance comparisons for various IP parameters

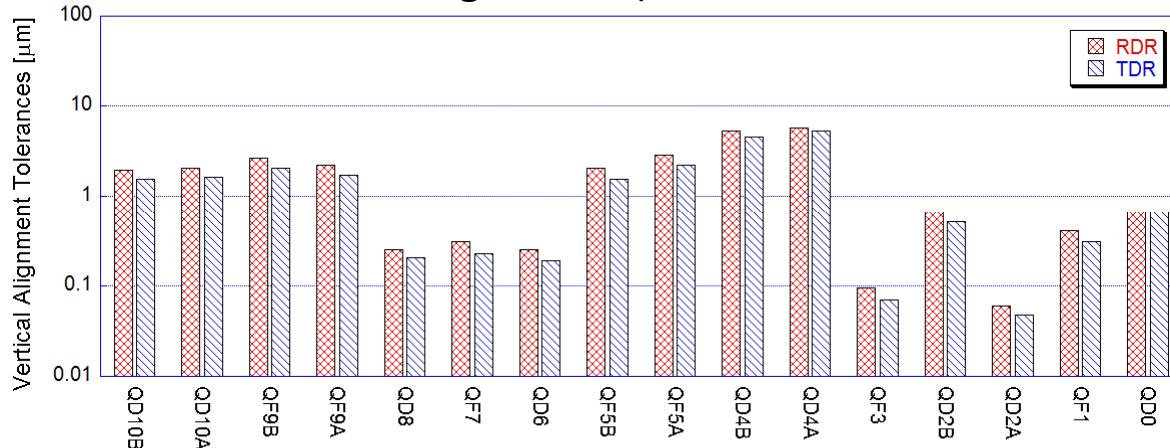
Beam tuning simulation

Introduction

Comparison with ILC RDR FF and ILC TDR FF

Presented at LCWS13 by T.Okugi

Tolerance of Vertical Misalignment (no Linear Knob Correction)



RDR parameter

$$\beta x^* = 0.021 \text{ m}$$

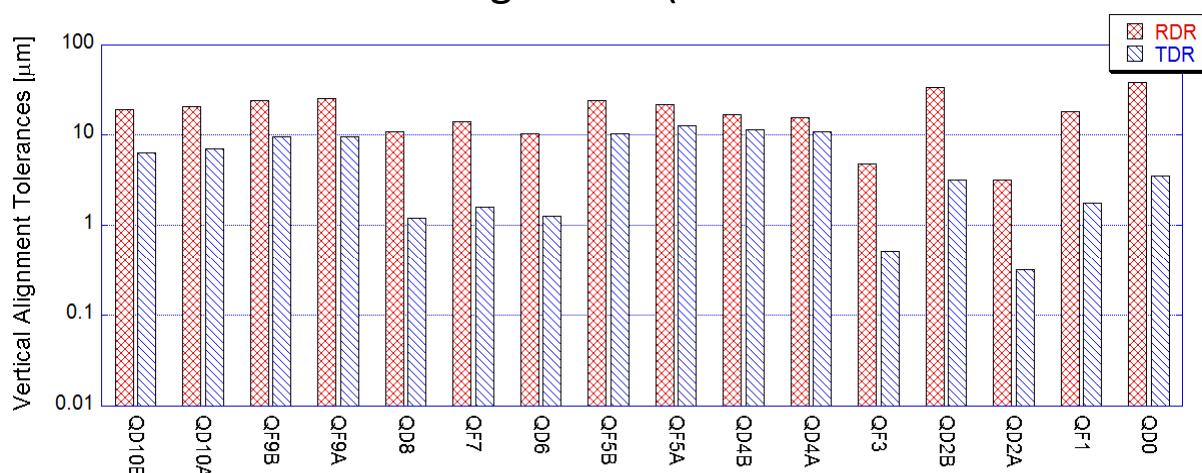
$$\beta y^* = 0.00040 \text{ m}$$

TDR parameter

βx^* = 0.011 m (circled)

$$\beta y^* = 0.00048 \text{ m}$$

Tolerance of Vertical Misalignment (with Linear Knob Correction)



	RDR	TDR
QF3	4.8μm	0.5μm
QD2B	33.3μm	3.2μm
QD2A	3.2μm	0.3μm

Tolerance after linear knob tuning were much different.

Therefore, I checked the optics performance for various IP parameters.

List of ILC IP parameters

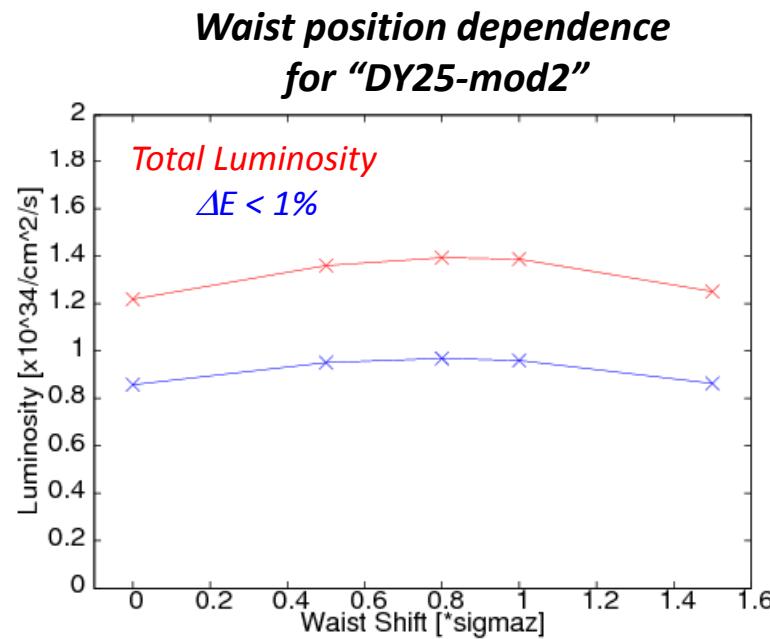
RDR, TDR and 2 more new IP parameters are assumed in this presentation.

	RDR	TDR	DY25-mod1	DY25-mod2
Beam Energy	250 GeV	250 GeV	250 GeV	250 GeV
Nb	1312	1312	1312	1312
frep	5 Hz	5 Hz	5 Hz	5 Hz
betaX*	21 mm	11 mm	14 mm	17 mm
betaY*	0.40 mm	0.48 mm	0.38 mm	0.32 mm
sigmaZ	0.30 mm	0.30 mm	0.30 mm	0.30 mm
emitx (normalized)	10um	10um	10um	10um
emity (normalized)	0.035um	0.035um	0.035um	0.035um
sigmaX*	655 nm	474 nm	535 nm	589 nm
sigmaY*	5.35 nm	5.86 nm	5.21 nm	4.79 nm
Geometric Luminosity L0 [1/cm^2/s]	0.60e34	0.75e34	0.75e34	0.74e32
Dy	19.6	24.6	24.5	24.3
Ay = sigmaZ/betaY*	0.750	0.625	0.787	0.938
Luminosity (no waist) [1/cm^2/s] [*]	1.05e34	1.55e34	1.36e34	1.23e34
Luminosity (waist) [1/cm^2/s] [*]	1.17e34	1.71e34	1.54e34	1.39e34
L / LTDR	0.68	1	0.90	0.81

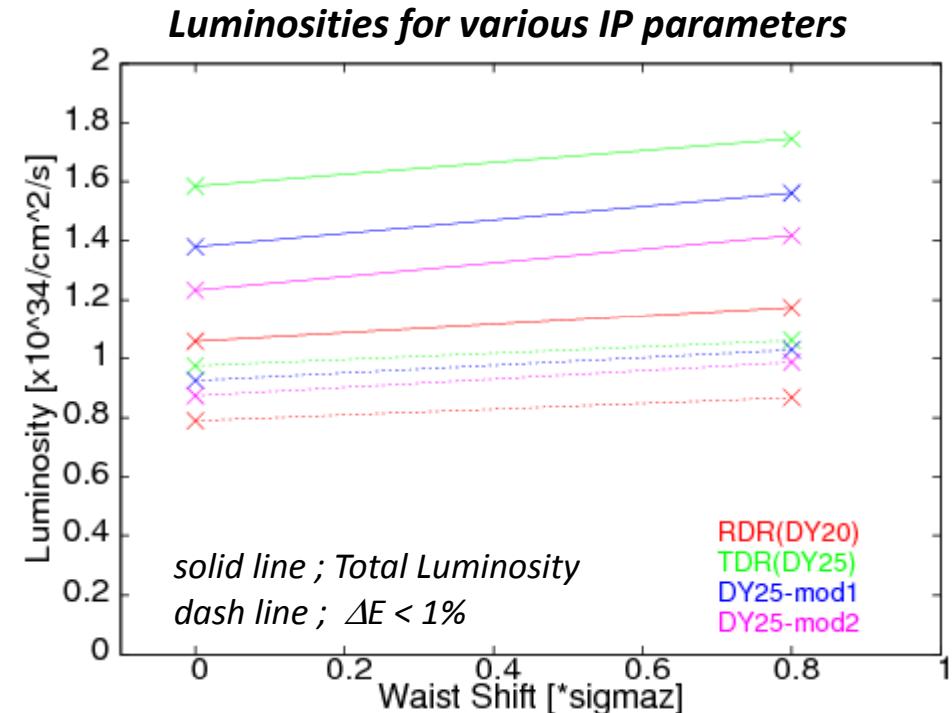
[*] calculated by K.Yokoya with CAIN

Luminosity calculation with waist shift

Calculated by K.Kubo with CAIN



Luminosity was maximized,
when the IP waist was shifted by 0.8 σ_{maz} .
TDR adopted the luminosity with waist shift.



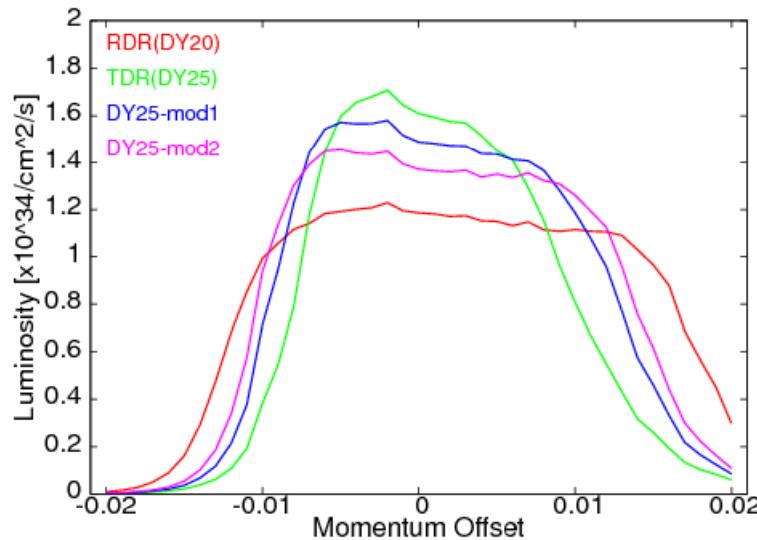
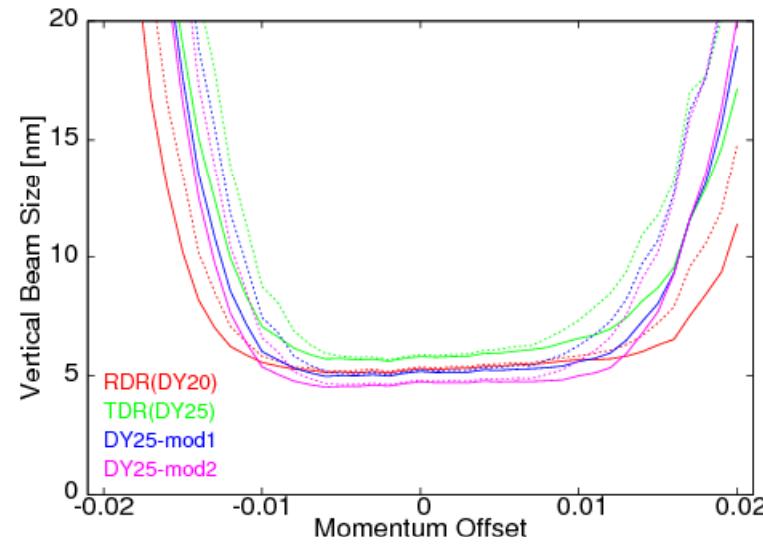
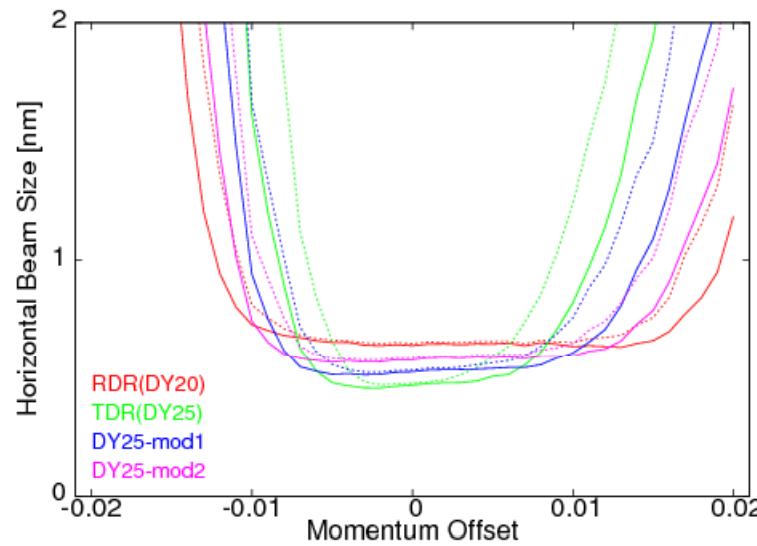
Luminosities with waist shift

	RDR	TDR	DY25-mod1	DY25-mod2
Peak Luminosity [$\times 10^{34}/\text{cm}^2/\text{s}$]	1.174	1.743	1.560	1.417
Ratio to TDR parameter	0.674	1	0.895	0.813
$\Delta E < 1\%$ Luminosity [$\times 10^{34}/\text{cm}^2/\text{s}$]	0.869	1.061	1.030	0.988
Ratio to TDR parameter	0.819	1	0.971	0.931

ILC luminosity status for $E_{CM}=500\text{GeV}$

1. *Disruption parameter was increased from RDR ($Dy=20$) to TDR($Dy=25$).*
2. *The aspect ratio at IP beam size was reduced (make β_X^* small) in order to reduce hour glass effect for TDR.*
3. *The total luminosity is increased by factor 1.48 from RDR to TDR.*
4. *The luminosity within $\Delta E < 1\%$ is increased by factor 1.22 from RDR to TDR.*
5. *When we change the aspect ratio at IP beam size by keeping $Dy=25$, the total luminosity is changed a lot, but the luminosity within $\Delta E < 1\%$ is not changed so much.*

Energy bandwidths for various IP parameters



The bandwidth for TDR parameter was a half of RDR parameter.

The 2 set of DY25 parameters were in between TDR and RDR.

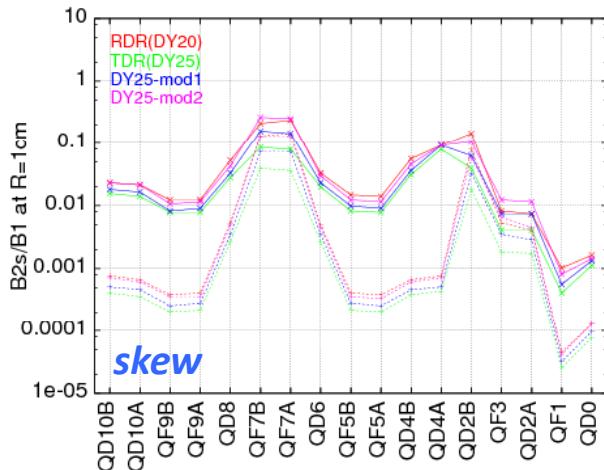
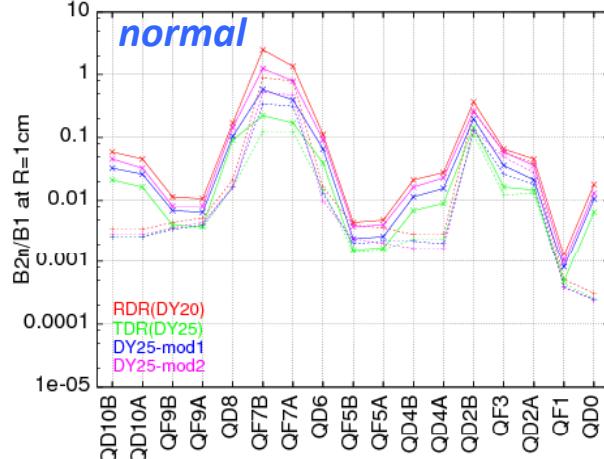
The bandwidth is better for larger beta X^ .*

[*] calculated based on K. Yokoya and P. Chen, "Beam-Beam Phenomena in Linear Colliders", in *Frontiers of Particle Beams: Intensity Limitation. Lecture Notes in Physics 400* (1991) 414.

Multipole error tolerances for various IP parameters

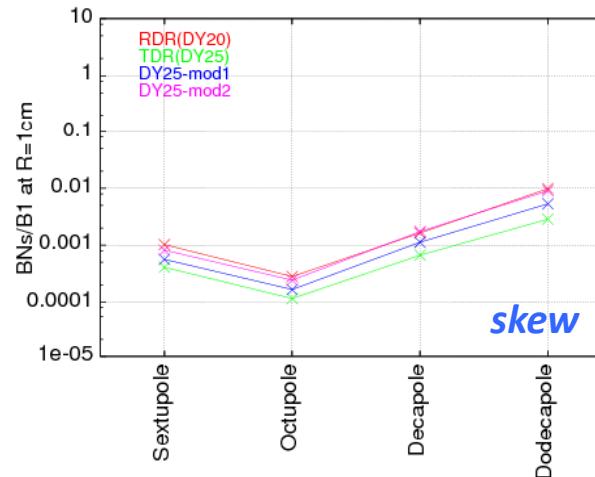
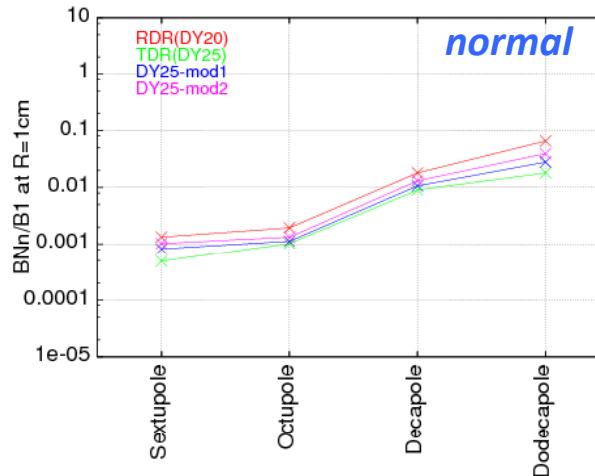
Alignment tolerance was defined as $\text{Min}(\Delta\sigma_x=0.02\sigma_{x0}, \Delta\sigma_y=0.02\sigma_{y0})$.

**Sextupole component
for FF quadrupoles**

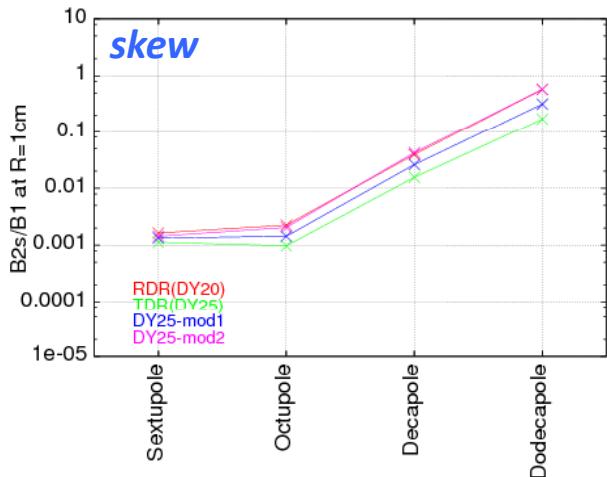
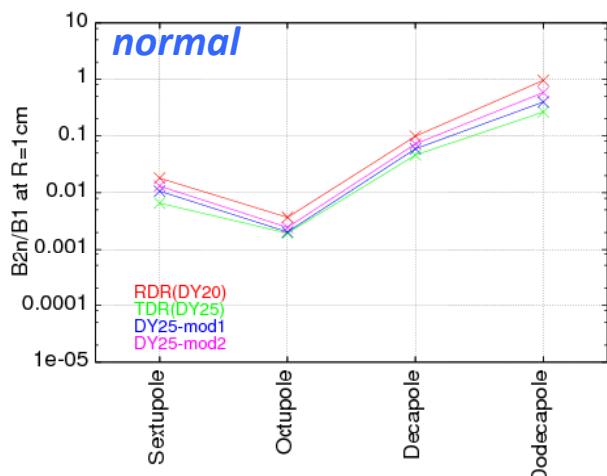


*solid line ; with 2nd order knob correction
dash line ; no 2nd order knob correction*

Multipole components for QF1



Multipole components for QD0



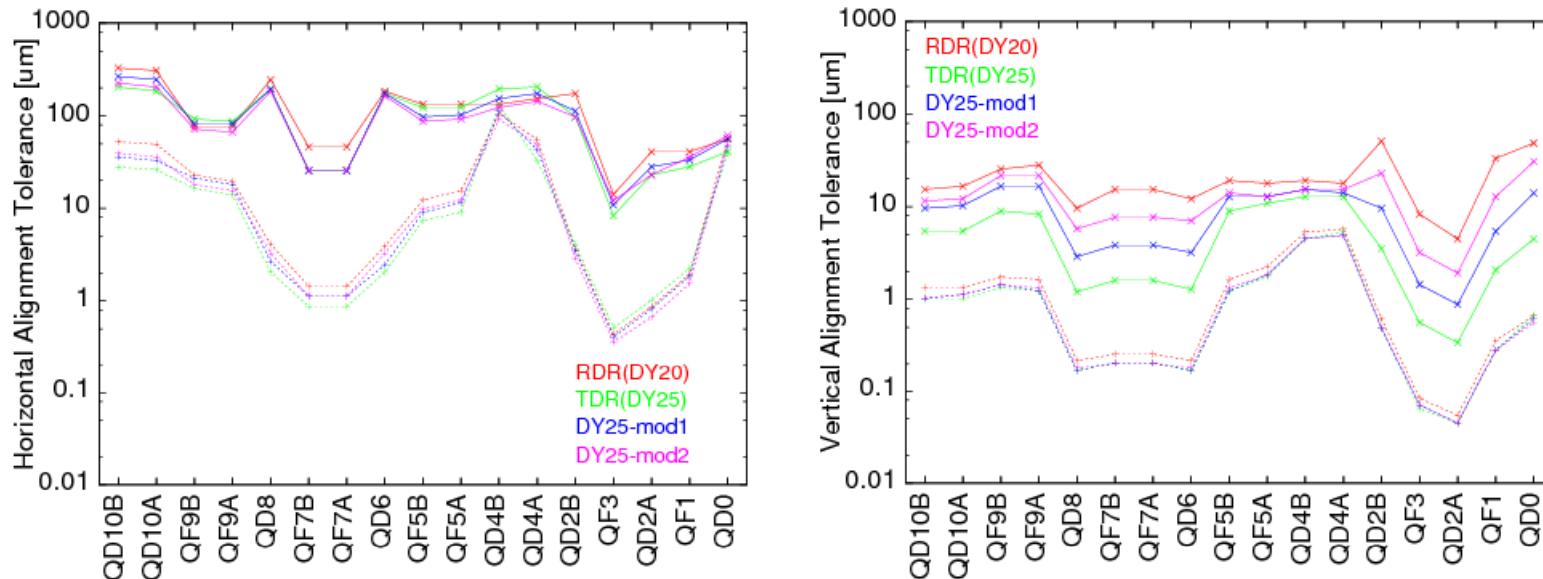
*The tolerances are also better for larger betaX**

Alignment tolerances for various IP parameters

Alignment tolerance was defined as $\text{Min}(\Delta\sigma_x=0.02\sigma_{x0}, \Delta\sigma_y=0.02\sigma_{y0})$.

solid line ; after 2 iteration of linear knob correction

dash line ; no linear knob correction



Vertical alignment tolerances (with linear knob correction)

	QD2B	QF3	QD2A	QF1	QD0
RDR	51.2um	8.32um	4.48um	33.3um	48.6um
TDR	3.52um	0.56um	0.34um	2.08um	4.48um
DY25-mod1	9.60um	1.44um	0.88um	5.44um	14.1um
DY25-mod2	23.0um	3.20um	1.92um	12.8um	30.7um

The alignment tolerance is also much better for larger betaX*

Optimization of the phase advances for collimators

Horizontal phase advance of SPEX is different from F. Jackson's optimization,
but other phase advances are set to optimized without additional quadrupoles.

see F. Jackson et. Al, Proceedings of PAC07, THPMN073

Beta Function at SP2/SP4 = (X; 1000m / Y; 1000m)

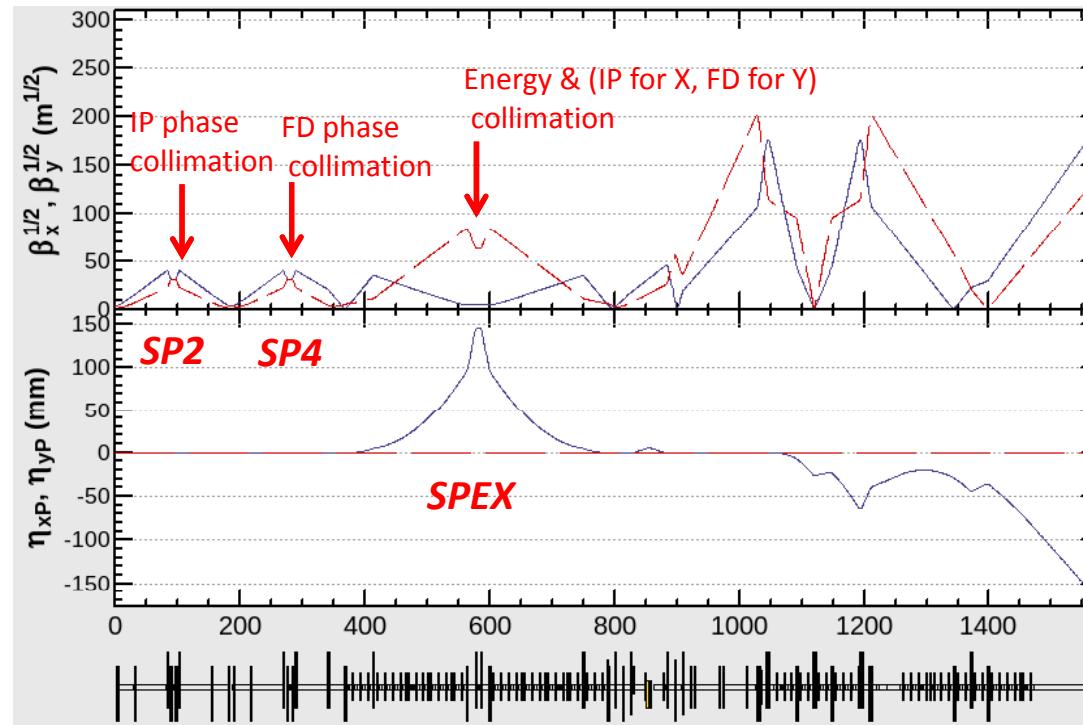
Beta Function at SPEX = (X; 36m / Y; 4000m)

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



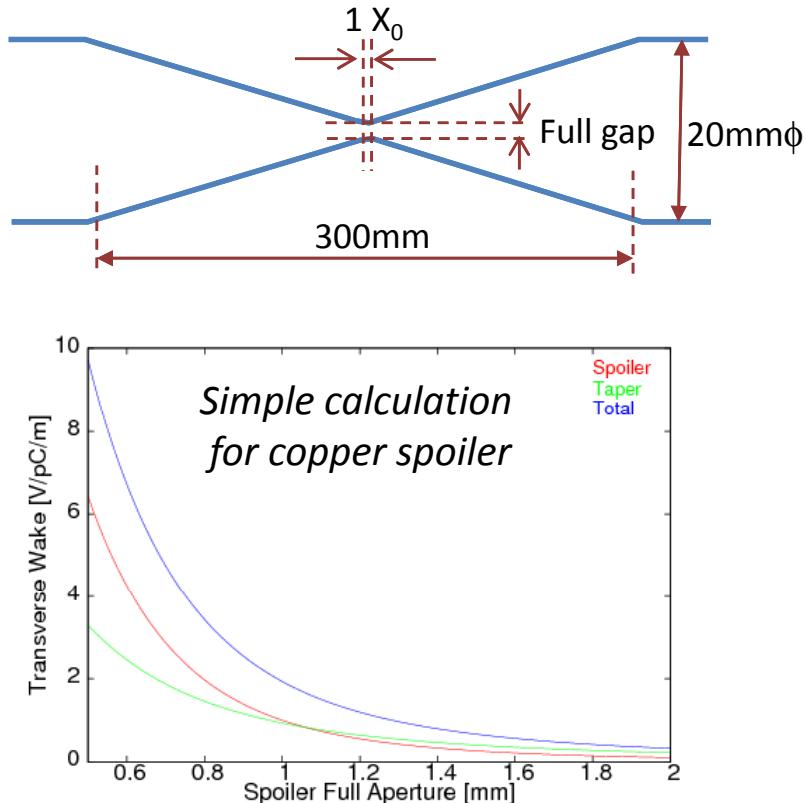
Consideration of the spoiler wake

RDR scheme must collimate at SP2/SP4 ($\beta Y=1000m$) for vertical direction.

New scheme can collimate at SPEX ($\beta Y=4000m$).

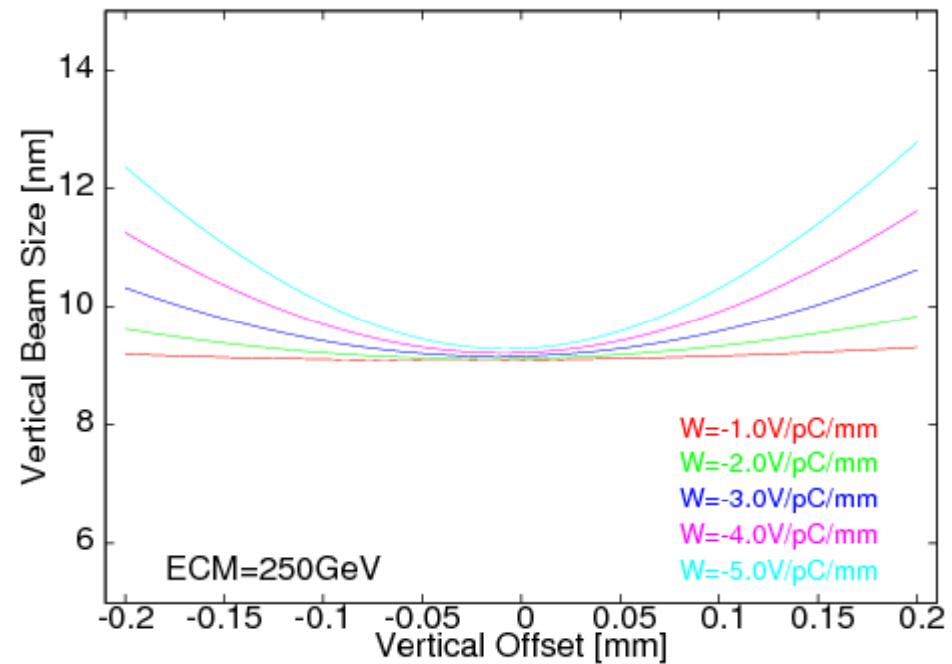
We can increase the vertical gap of spoiler.

Example of resistive wall



Example for the effect of resistive wall

IP beam size simulation with wake for $E_{CM}=250\text{GeV}$
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).

Collimation depths for various IP parameters

Collimation depth was calculated for $E_{CM}=500\text{GeV}$.

$$(\text{QF1 L}^*) = 9.5\text{m} (\text{L} = 1.0\text{m})$$

$$(\text{QD0 L}^*) = 4.0\text{m} (\text{L} = 2.2\text{m})$$

$$(\text{X half aperture of SPEX}) = 1.50 \text{ mm} (\Delta p/p = 1\%)$$

IP Parameters	btaX*	betaY*	Collimator Half Aperture	
			X collimator (SP2/SP4)	Y collimator (SP2/SP4/SPEX)
Old collimator	11mm	0.48mm	0.66mm (4.7 σ)	0.57mm (68 σ)
RDR	21mm	0.40mm	1.19mm (8.4 σ)	1.19mm (71 σ)
TDR	11mm	0.48mm	0.86mm (6.1 σ)	1.30mm (78 σ)
DY25-mod1	14mm	0.38mm	0.98mm (6.9 σ)	1.15mm (69 σ)
DY25-mod2	17mm	0.32mm	1.07mm (7.6 σ)	1.06mm (64 σ)

By using new collimator system, the collimation depths were increased.

Horizontal collimation depth is wider for larger btaX .*

*The vertical aperture is about 1.0mm (half gap) at SPEX,
and the collimation depth is 64σ even for "DY25-mod2".*

ILC BDS SAD deck modification for beam tuning simulation

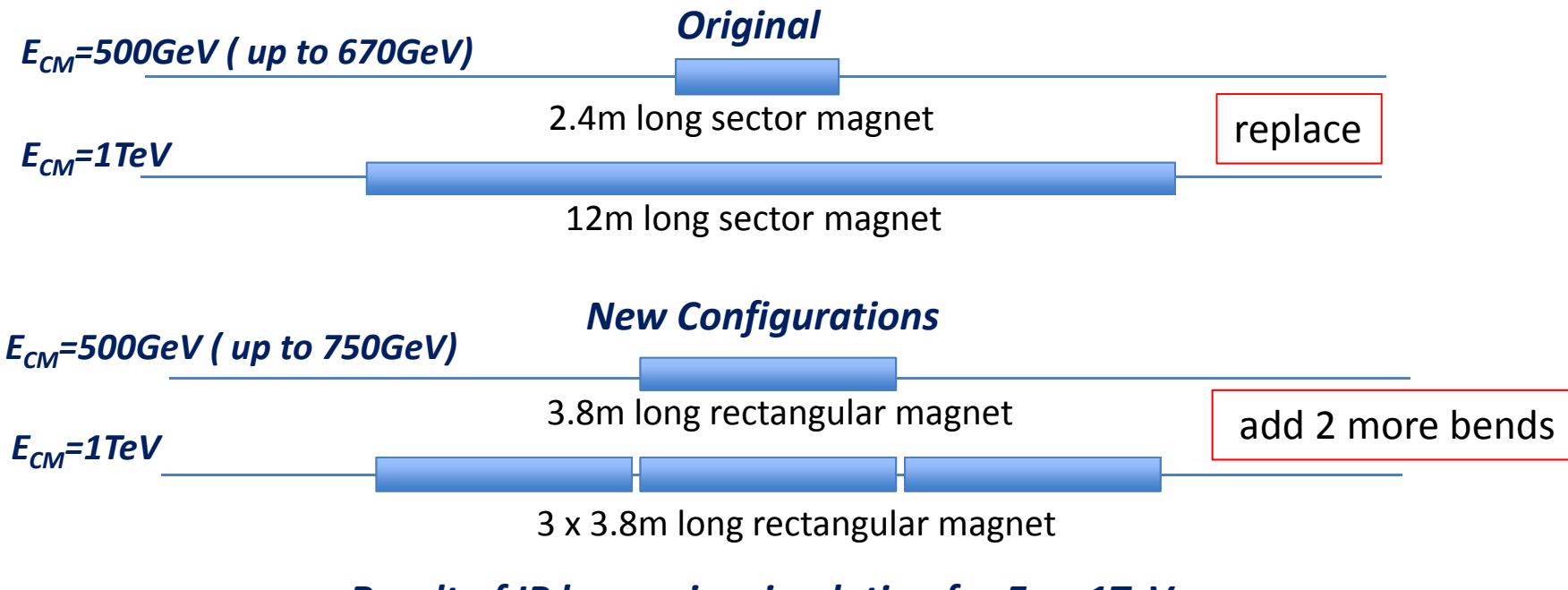
1. Individual names for all bending magnets, quadrupoles are named to put initial alignment errors.
i.e.) $B1 \rightarrow B101 - B106$,
 $QB0 \rightarrow QB0A, QB0B, QB0C$ and $QB0D$,
 $QD10 \rightarrow QD10A, QD10B$ etc.
2. BPMs are put to 0.1m upstream of quadrupoles, sextupoles and so on.
 - These BPMs are moved with magnets by movers.
 - The name of quadrupoles are “MQD10B” for the BPM of “QD10B”.
 - “MQF1” and “MQD0” are put to downstream of “QF1” and “QD0”.
3. Skew sextupole magnets SK1-SK4 are put in beamline for 2nd order knob correction.
(already used to calculate the tolerance of the sextupole field error)
4. The vertical correctors are put in the bending section
to correct the rotation errors of bending magnets.
5. QF7 is split, and put the beam monitor in between QF7s (QF7A and QF7B).
Several BPMs are put to bending section.
 - Since these BPMs are not moved when BBA orbit tuning,
they are used to clip the beam orbit at BBA orbit tuning.
6. The bending magnets are replaced
from 2.4m long sector magnets to 3.8m long rectangular magnets .

Bending magnet replacement

The bending magnet for $E_{CM}=500\text{GeV}$ cannot use for 1TeV beamline.

It is difficult to make and transport the 12m long magnet.

The effective lengths are shorten, when it will divide several components.



Result of IP beam size simulation for $E_{CM}=1\text{TeV}$

	Original		New	
	X	Y	X	Y
no SR	330nm (327nm)	4.10nm (4.05nm)	332nm (330nm)	4.18nm (4.14nm)
with SR	339nm (333nm)	4.96nm (4.36nm)	346nm (340nm)	4.75nm (4.36nm)

Simulation result shows no clear difference.

In theoretically, horizontal emittance growth by SR at $E_{CM}=1\text{TeV}$ was increased by 10% from original 12m long bending magnet.

Example of the BBA in beam tuning simulation

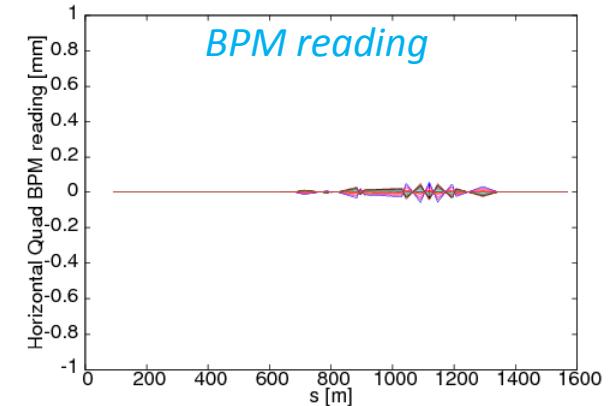
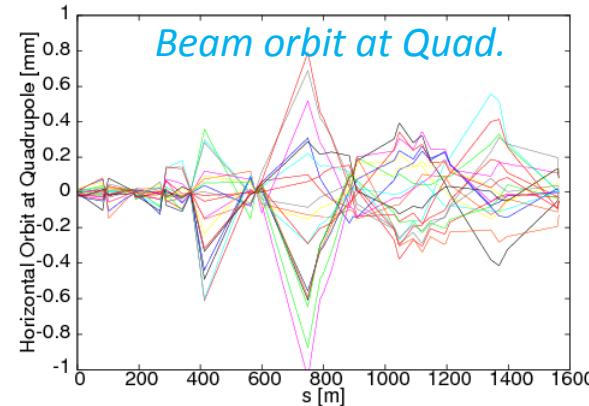
BPMs are moved with Quadrupole Magnet.

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

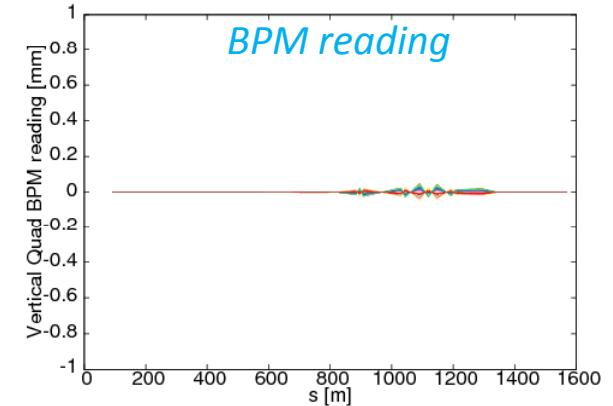
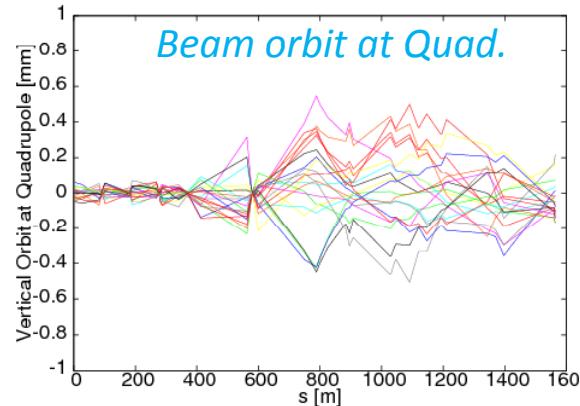
Alignment Errors

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

Horizontal



Vertical



We are ready to evaluate
the collimation depth with alignment.
(not yet, but will be soon)

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

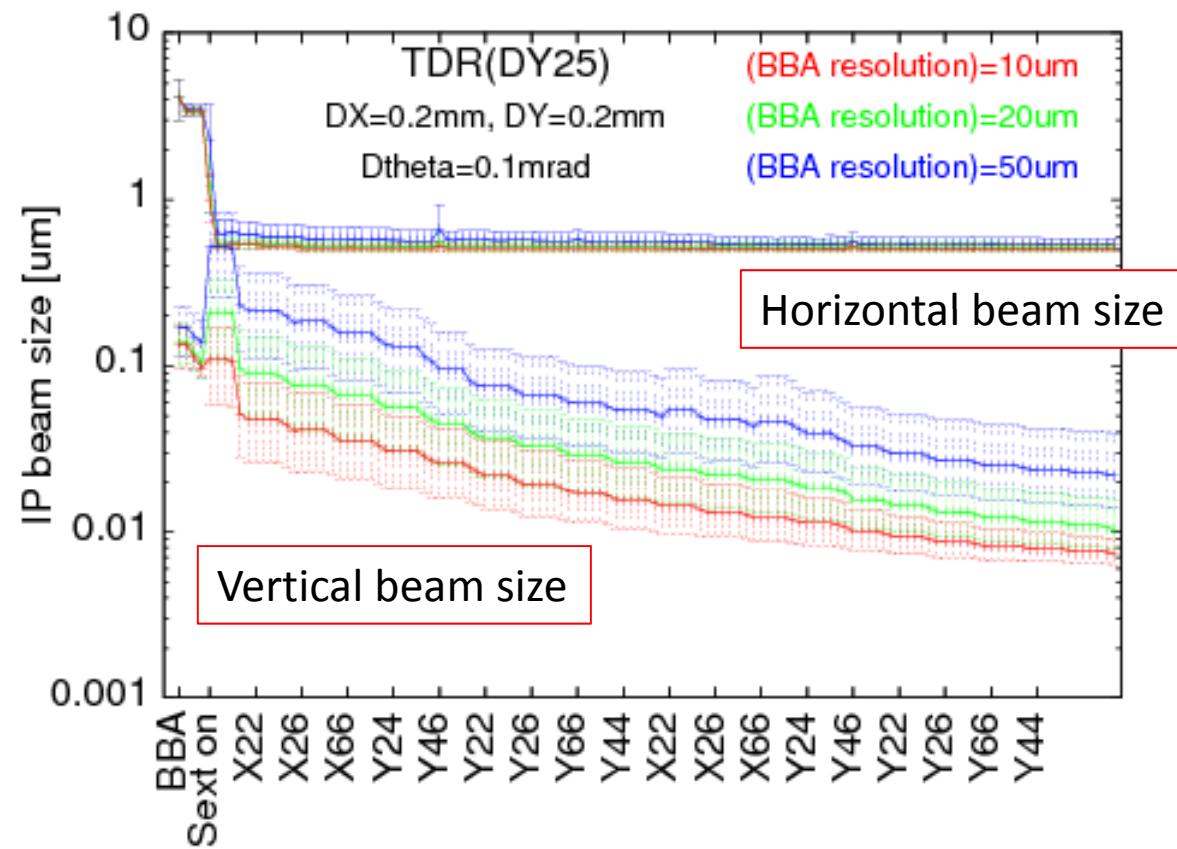
Example of the beam tuning simulation

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

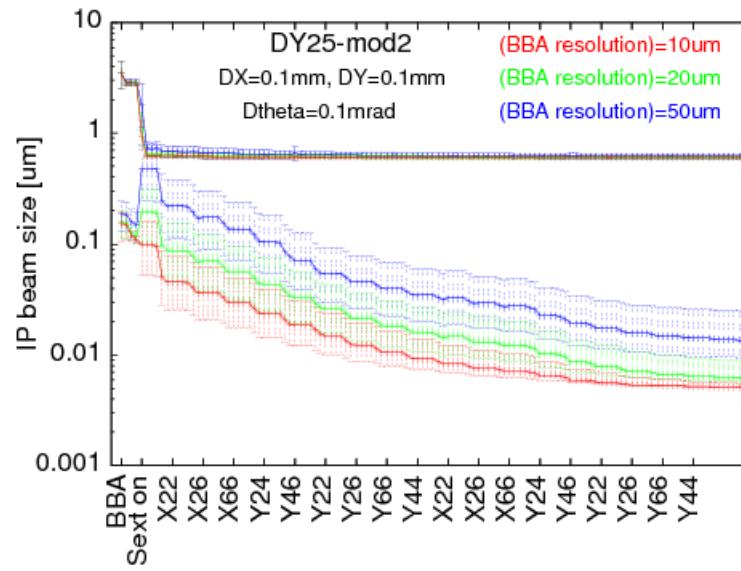
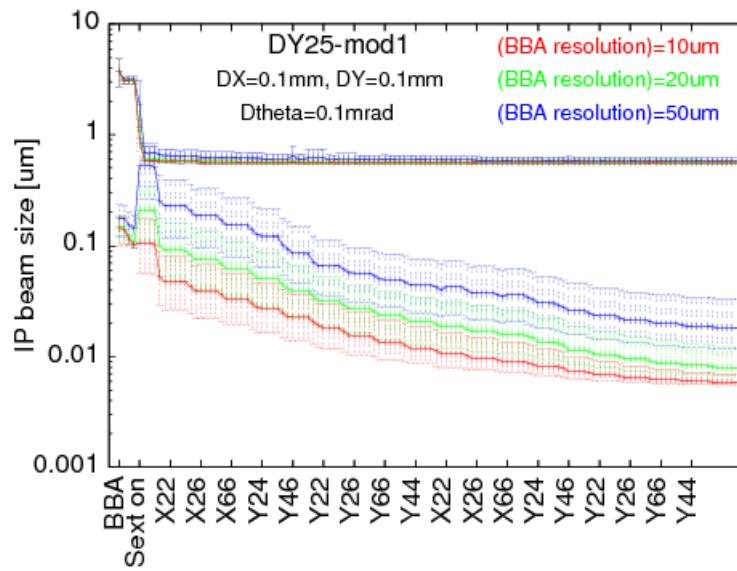
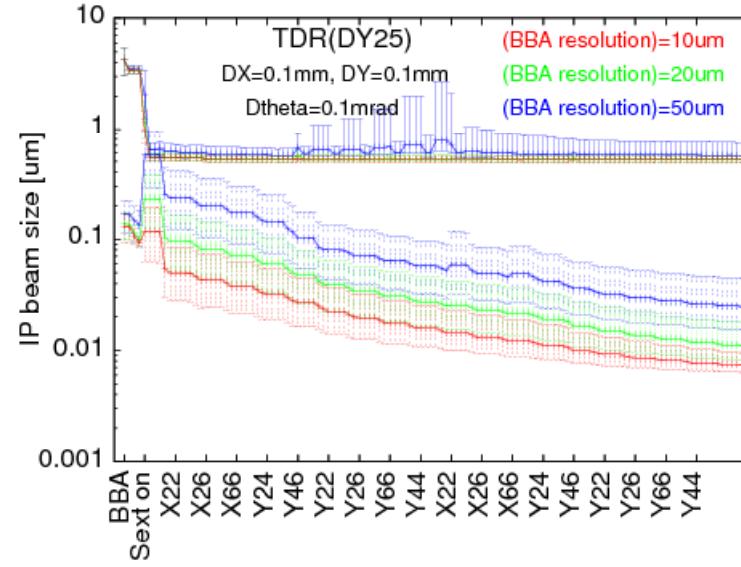
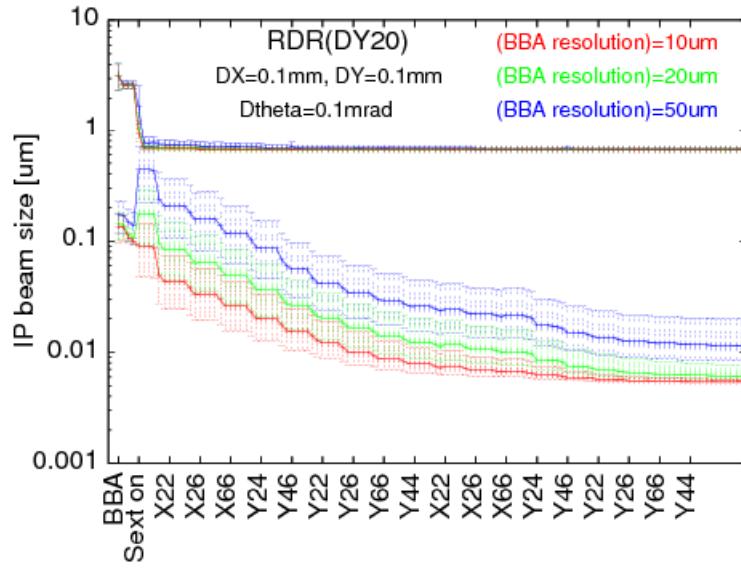
	Bend	Quad	Sext
ΔK	0.1%	0.1%	0.1%
ΔX	N. A.	0.2mm	0.2mm
ΔY	N. A.	0.2mm	0.2mm
$\Delta \theta$	0.1mrad	0.1mrad	0.1mrad



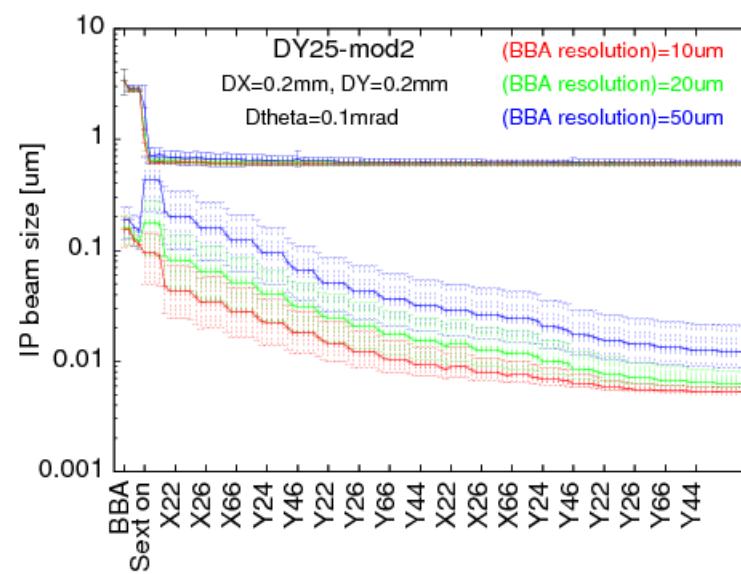
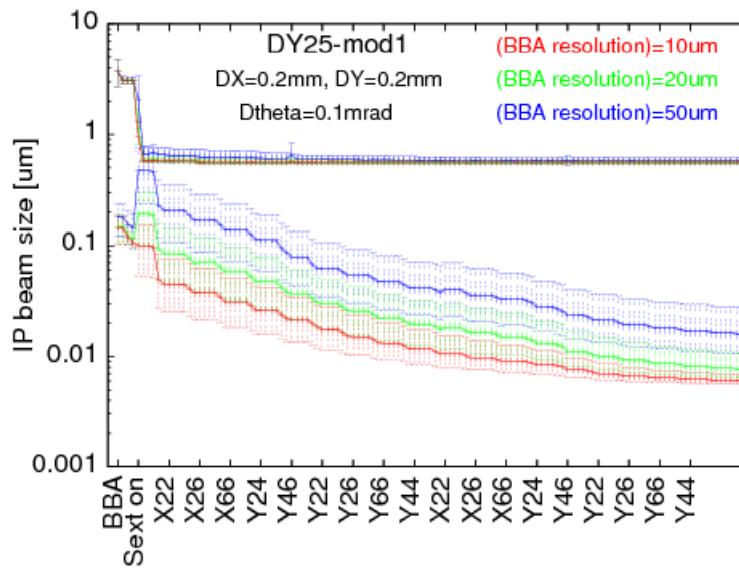
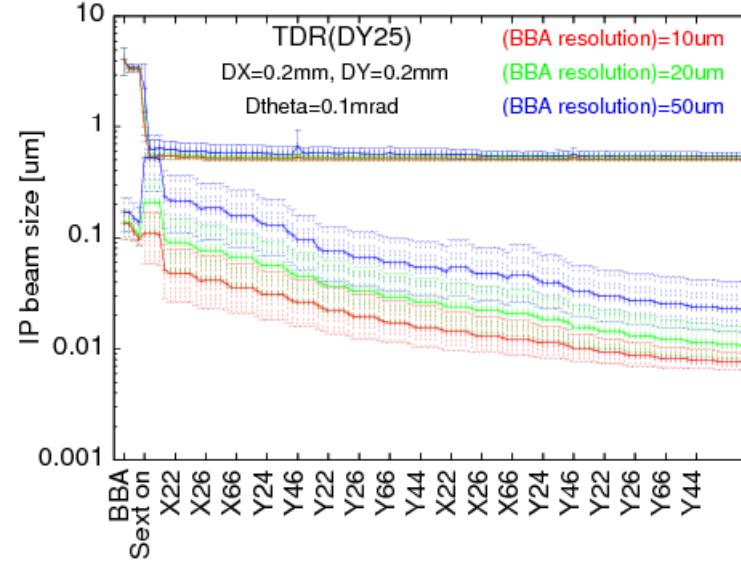
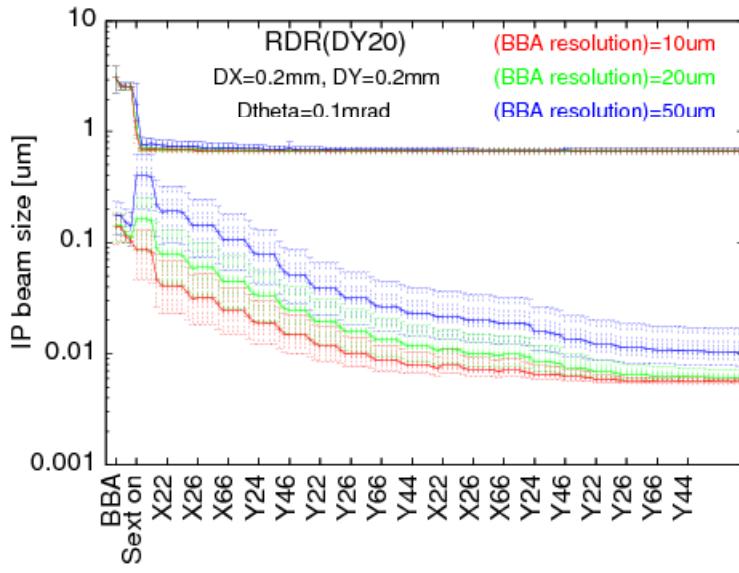
After the sextupole turned on, the beam size increased especially for large BBA error.

Final vertical beam size is larger for large BBA error (strongly affect the error for sextupoles).

Simulations of 4 IP parameters with 100um initial alignment error

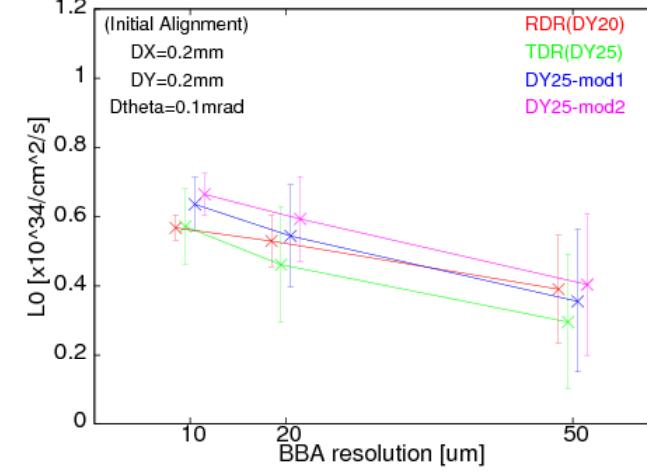
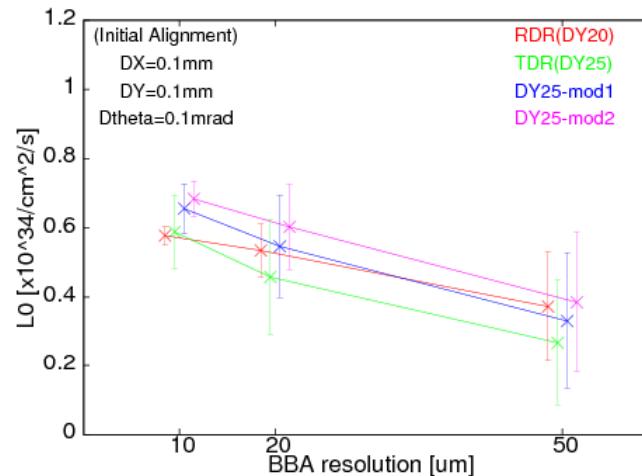
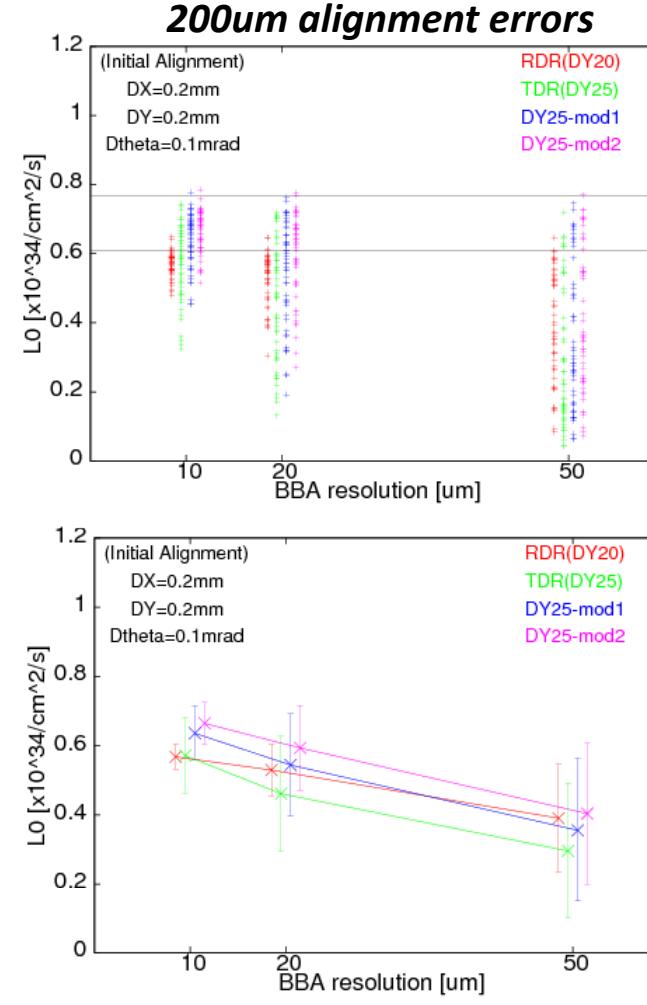
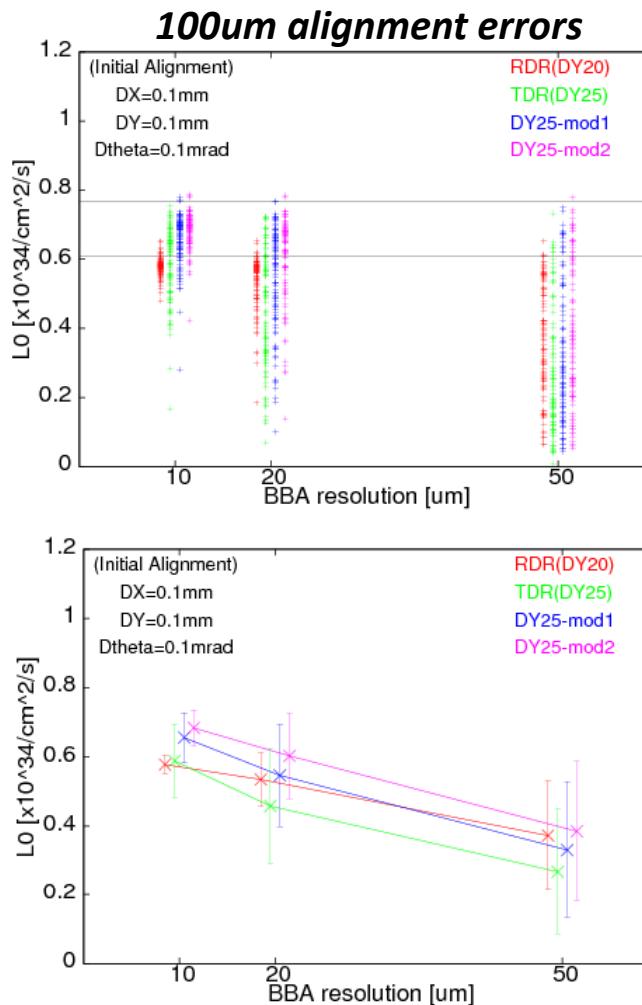


Simulations of 4 IP parameters with 200um initial alignment error



Luminosities after IP beam size simulations

The luminosity was calculated only for the geometrical luminosity L_0 .



- DY25-mod2 is larger for all BBA resolution
- The final luminosity is strongly depends on BBA resolution (especially for sextupole).
- There were no clear dependence to initial alignment error.

Summary

Luminosity and IP parameter

- Disruption parameter was increased from RDR ($Dy=20$) to TDR($Dy=25$).
- The aspect ratio at IP beam size was reduced to reduce hour glass effect for TDR.
- The total luminosity is increased by factor 1.48 from RDR to TDR.
- The luminosity within $\Delta E < 1\%$ is increased by factor 1.22 from RDR to TDR.
- When we change the aspect ratio at IP beam size by keeping $Dy=25$ for $E_{CM}=500\text{GeV}$, the total luminosity is changed a lot, but that within $\Delta E < 1\%$ is not changed so much.
- We should check other energy. i.e.) $E_{CM}=125\text{GeV}$ etc.

IP parameter and optics performance

- When we change the aspect ratio at IP beam size by keeping $Dy=25$, the bandwidth, the tolerances and the horizontal collimation depth will be improved.

Beam tuning simulation

- Optics deck preparation was finish for beam tuning simulation.
- The beam tuning simulation said the final beam size after beam tuning is better for large aspect ratio (DY25-mod2).
- The final beam size after tuning is determine by the accuracy of the sextupole BBA.
- We should evaluate the collimation depth with orbit .
- We should check whether the beam orbit is acceptable for resistive wall kick or not.
- We should check the tuning performance for other optics and for lower energy beam.

Collimator Issue

- The phase advances from collimators to IP was optimized.
- We should make a wake model for collimators, and should check the effect.
- After the collimation depth is decided (strongly depend on optics and IP parameters), we should determine the length of muon spoiler.