A4 Beam Delivery System

2nd day lectures

Toshiyuki OKUGI, KEK

LC school 2016
2016/12/16
Fuji, Japan

Contents of the Lecture

2nd day lectures

ILC final focus beamline optics for various beam energy
Tolerance evaluation for ILC final focus system
Introduction of ATF2 (Test facility of ILC final focus system)
IP position feedback
ILC machine detector interface
ILC beam diagnostic section
ILC beam extraction line

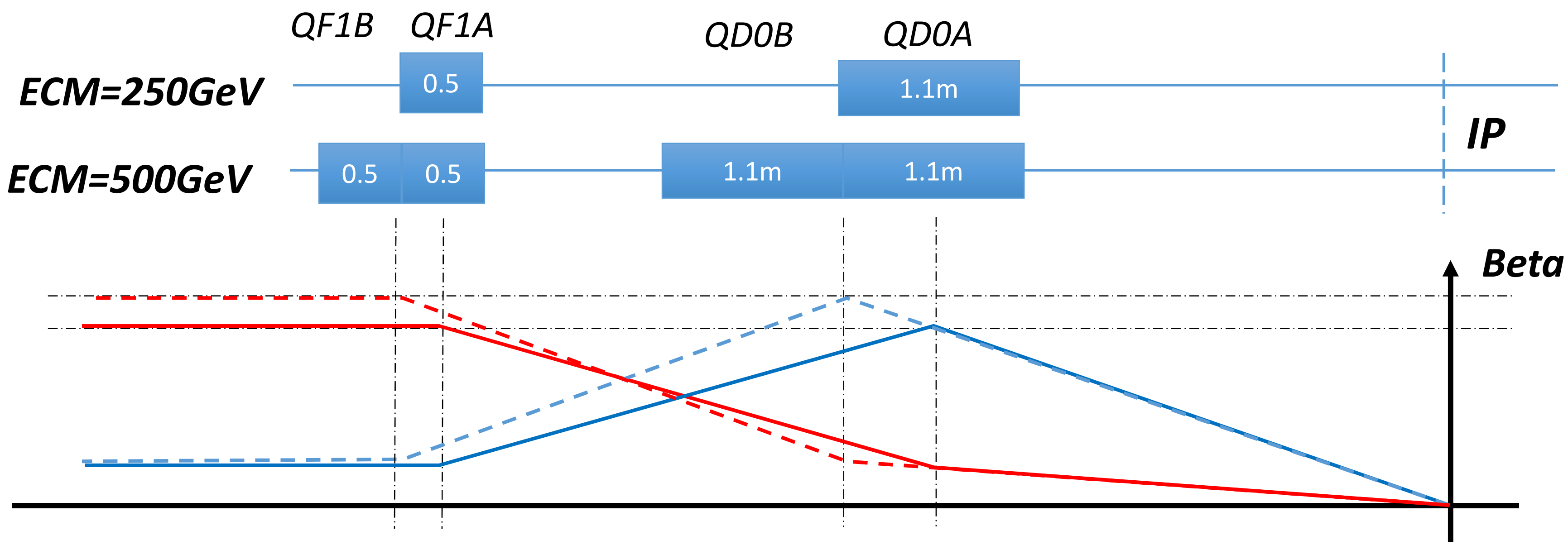
ILC Final Focus beamline optics for various beam energy

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

The field strength for ECM=250GeV is a half to ECM=500GeV.

When we only use a half of FD magnets,
the beta functions at FD magnets are decreased.

Therefore, the collimation depth can be increased.



This idea was proposed in TDR, but there were no beam optics by LCWS2014.

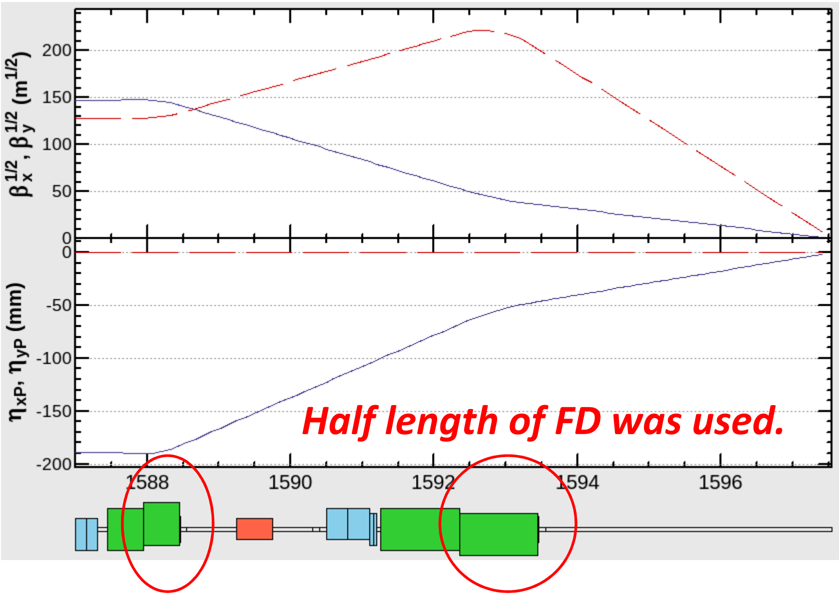
Procedure of optics optimization

Since the optics for ECM=250GeV was used ***half of FD magnets (0.5m QF1 and 1.1m QD0),***
the magnet arrangement for ECM=250GeV was different to others,
and the nonlinear effects of the beam optics for ECM=250GeV is stronger than others.

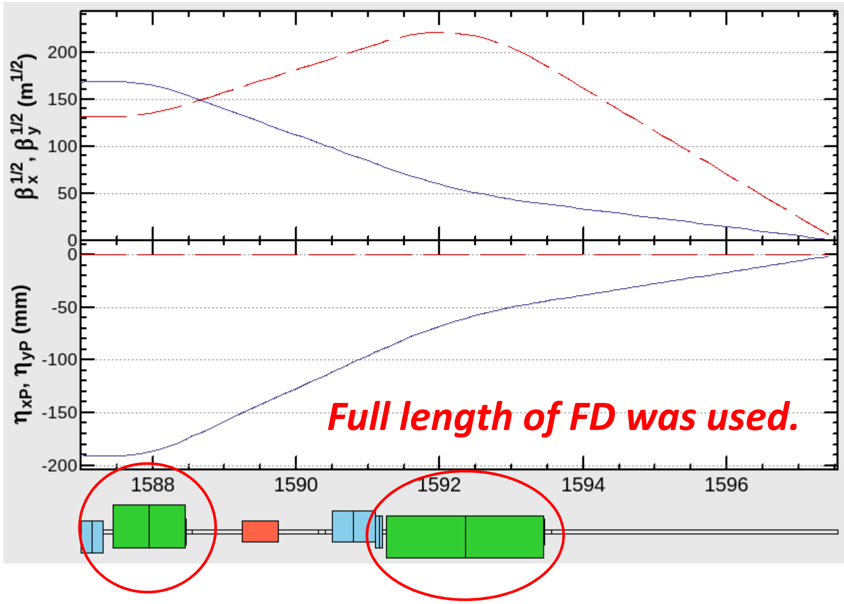
Therefore, I optimized ***the magnet arrangement for ECM=250GeV first****.*

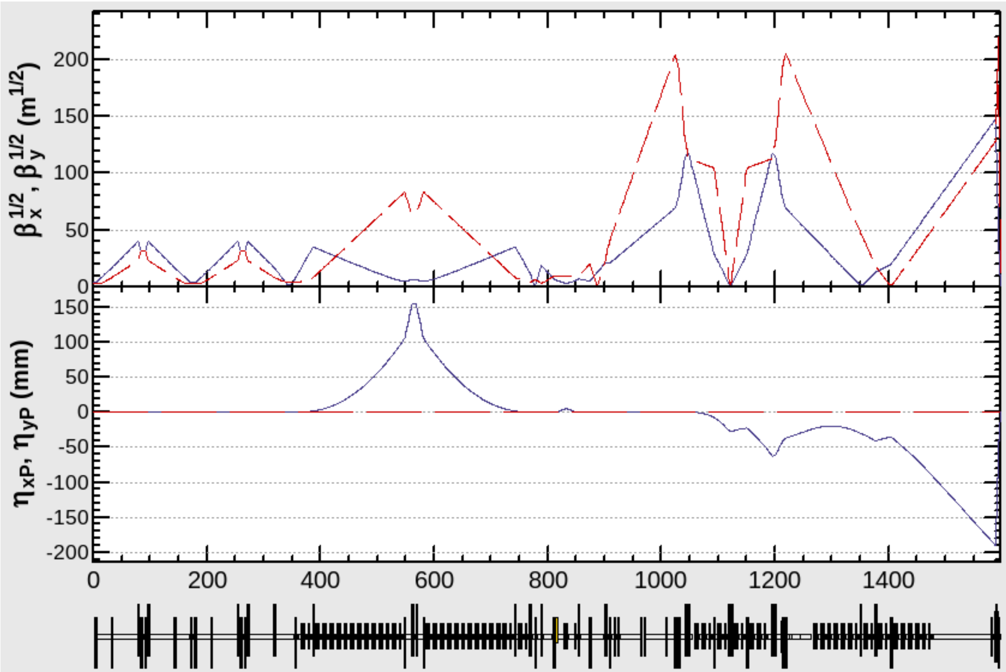
Then, ECM=500GeV optics was designed
with constraint of the arranged magnet to ECM=250GeV*.*

ECM=250GeV



ECM=500GeV

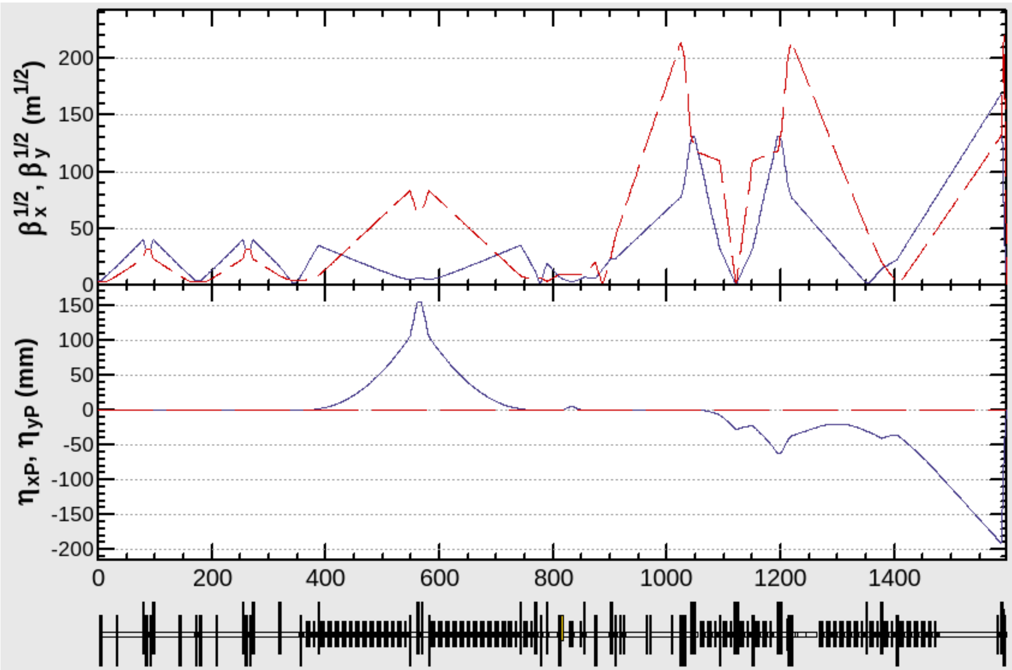




Beam Optics for ***ECM=250GeV***
The half length of FD magnets were used.

betaX* = 13 mm
betaY* = 0.41mm

The ***magnet arrangement 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.

betaX* = 11 mm
betaY* = 0.48mm

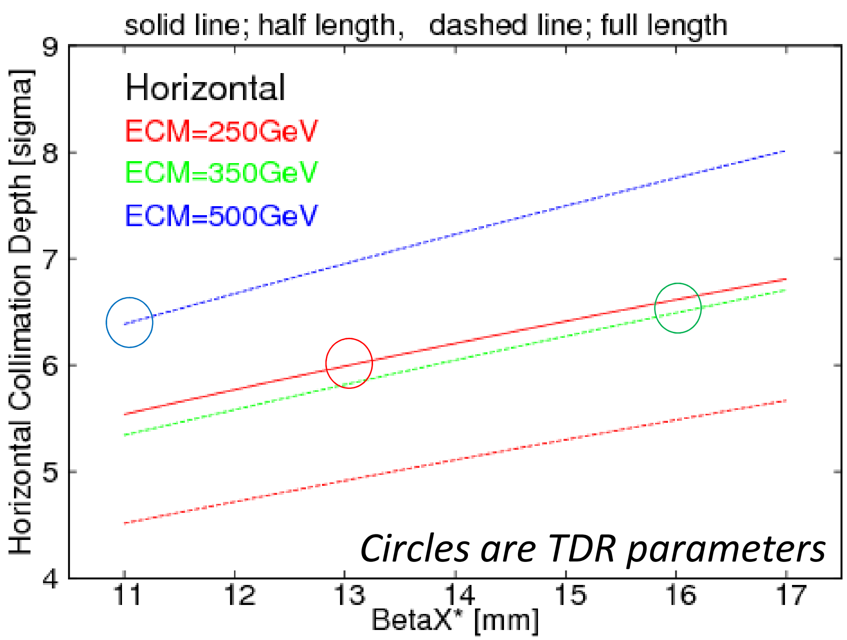
The magnet arrangement
was same to ECM=250GeV.

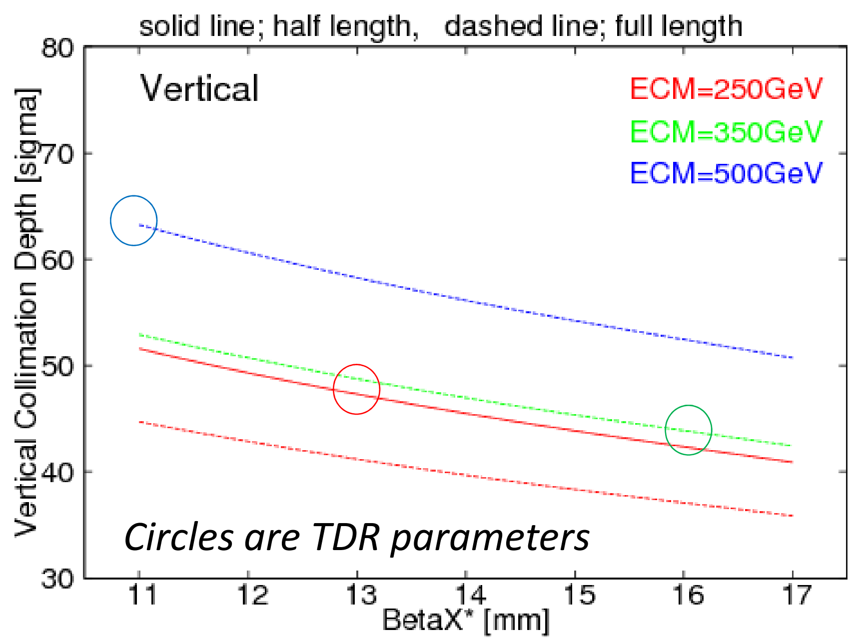
The ***strengths*** *were changed to optimize.*

The collimation depth for various beam energy

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

(QF1 L) = 9.5m*
(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

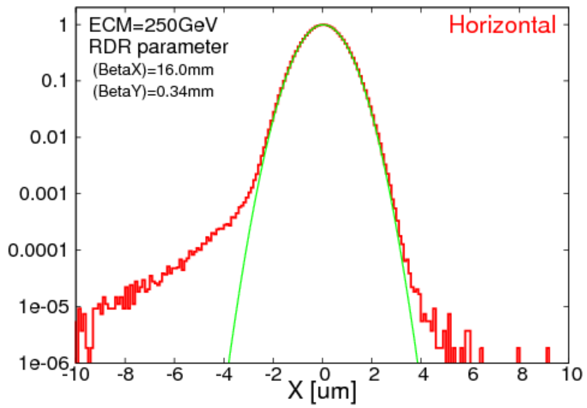
TDR IP Parameters

(QF1 L) = 9.5m*

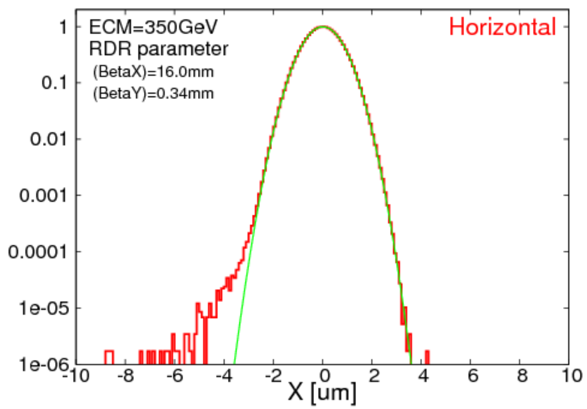
(QD0 L) = 4.1m*

IP Horizontal Profile

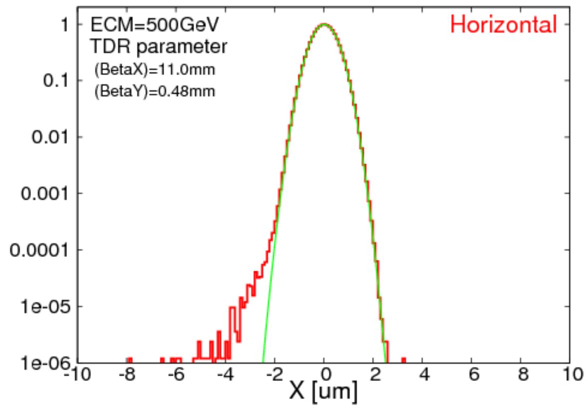
ECM=250GeV



ECM=350GeV

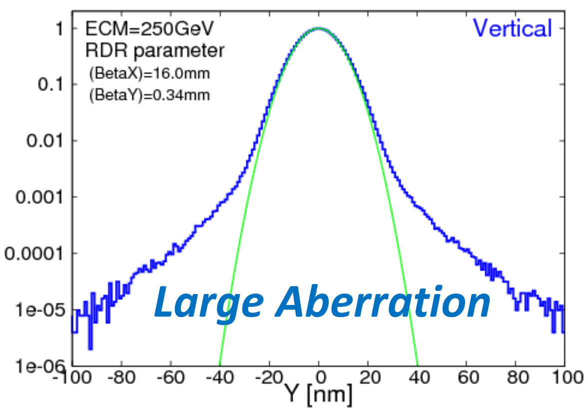


ECM=500GeV

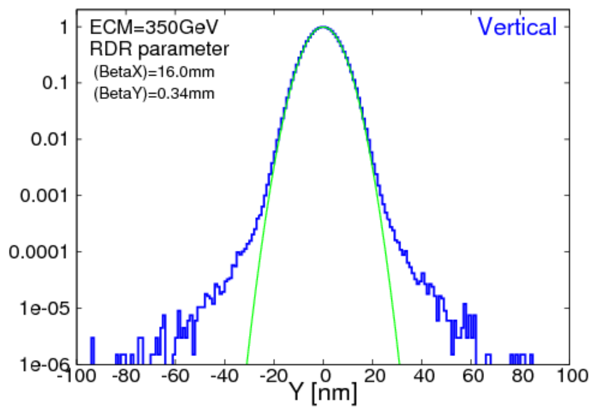


IP Vertical Profile

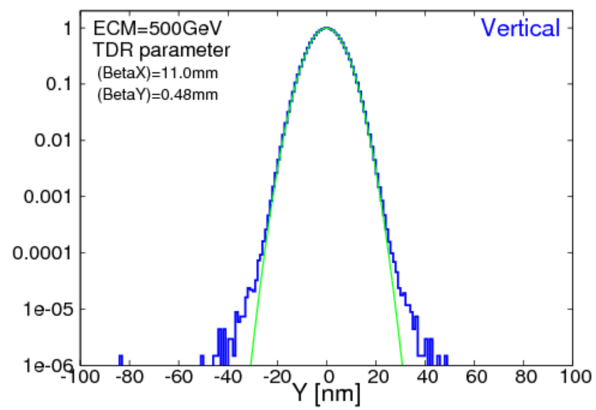
ECM=250GeV



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.

IP beam size of various beam energy

		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.

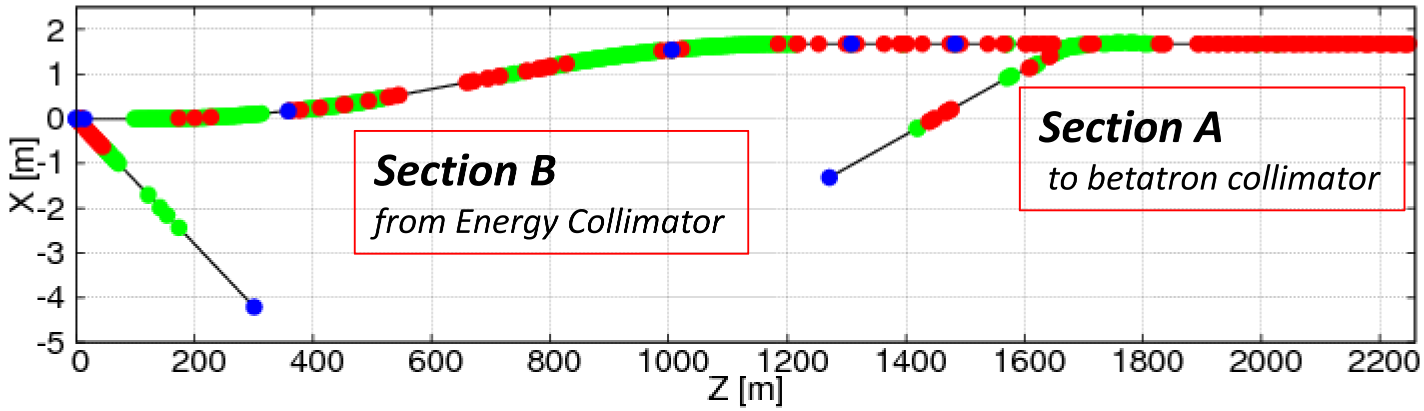
BDS optics for ECM=1TeV operation

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 magnets for ECM=500GeV can reuse to 1TeV optics.

- Some new magnets should be installed to extend to ECM=1TeV.



The number of components both for ECM=500GeV and ECM=1TeV

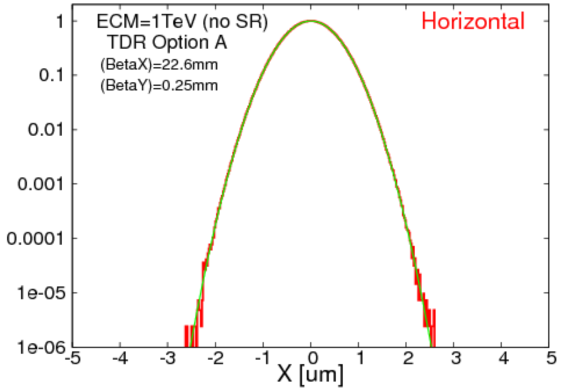
(not include the dumpline)

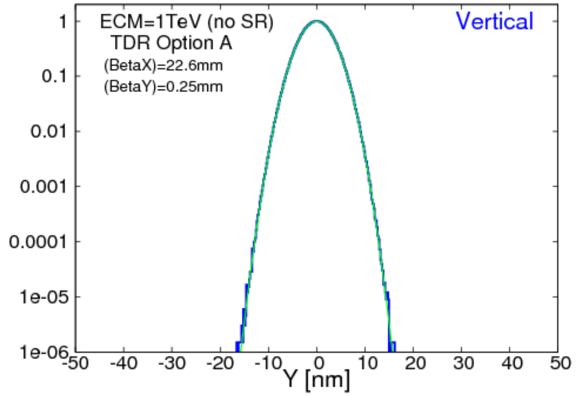
	Energy [GeV]	# of BEND	# of QUAD	# of SEXT	# of Steer	# of PS	# of Mover	# of BPM
Section A	500	16	64	0	19	73	70	78
	1000	43	108	0	19	115	108	116
Section B	500	63	33	7	55	46	40	101
	1000	176	41	7	55	56	48	112

Simulation Results for ECM=1TeV optics

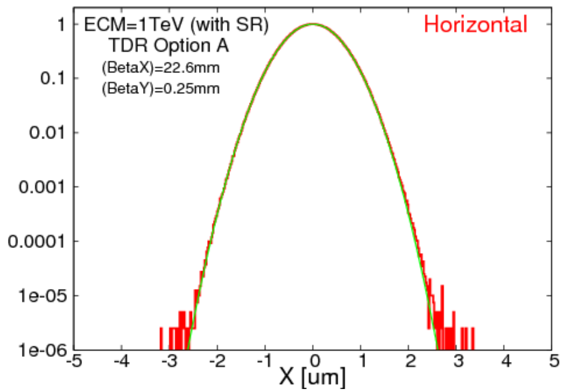
Large Aberration by Synchrotron radiation

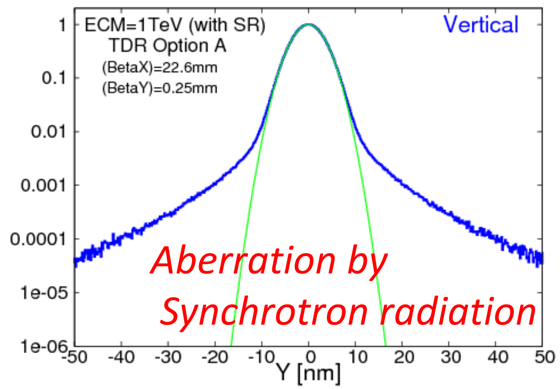
<< no SR >>





<< with SR >>





	Horizontal			Vertical			Relative Luminosity
	design	rms	core	design	rms	core	
no SR	0.481um	0.481um	0.481um	2.99nm	2.99nm	2.99nm	99.8%
with SR		0.499um	0.498um		3.71nm	3.15nm	91.7%

For $E_{CM} = 1\ TeV$ ILC Final Focus beamline,
the luminosity reduction of the aberration by Synchrotron radiation is smaller than 10%.

Summary of ILC FF Optics for various beam energy

The beam optics for low energy is difficult for its large aberration.
The final doublet for $E_{CM} = 250\ GeV$ is used only a half length of magnets to shorten L.*

The beam optics of ILC final focus system is optimized for $E_{CM} = 250\ GeV$.
Then, the optics for $E_{CM} = 500\ GeV$ is optimized only by changing the magnet strength.

Some magnets will be installed for $E_{CM} = 1\ TeV$ operation.
But, the magnet arrangement is basically same to that for $E_{CM} = 500\ GeV$.

The design luminosity for $E_{CM} = 1\ TeV$ is greater than 90% to the ideal luminosity, even if we take account of the Synchrotron radiation.

Present ILC final focus beam line
was designed by taking account of above issues.

Tolerance Evaluation for ILC Final Focus System

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)

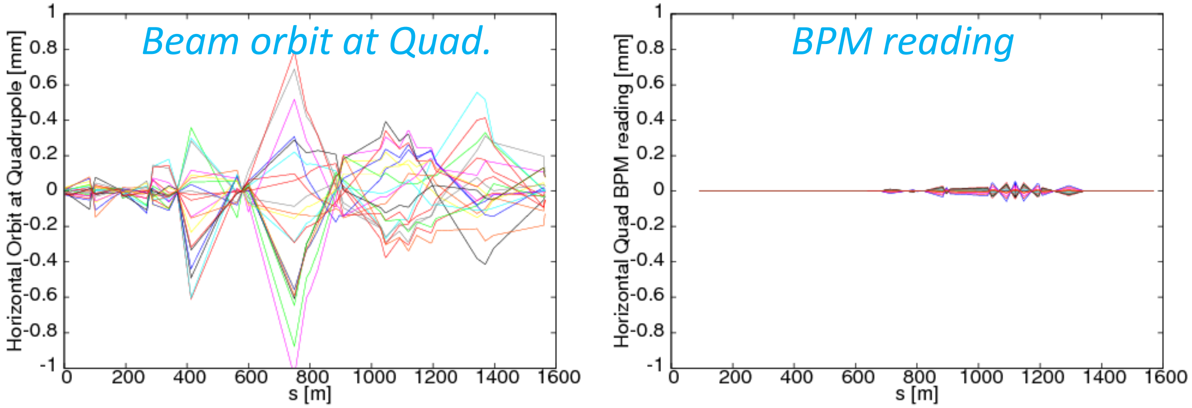
BPMs are moved with quadrupole magnets.

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

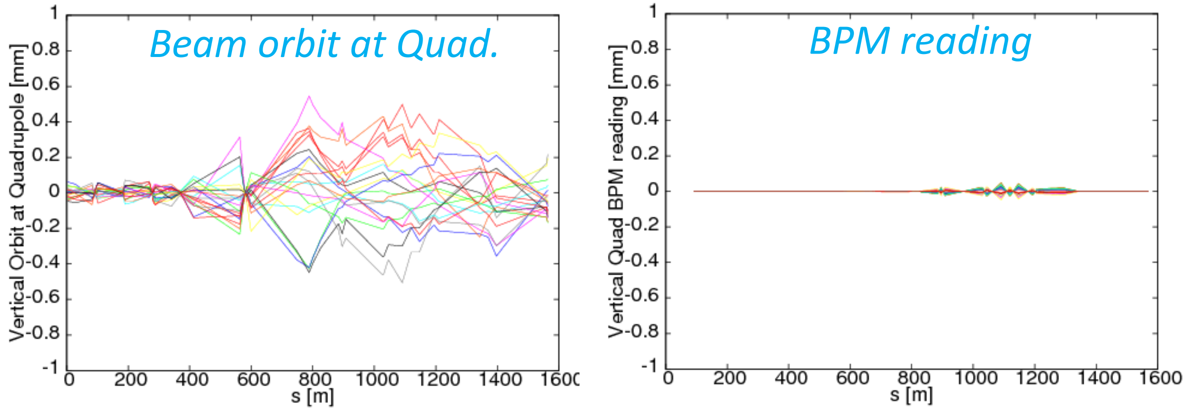
Alignment Errors

	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

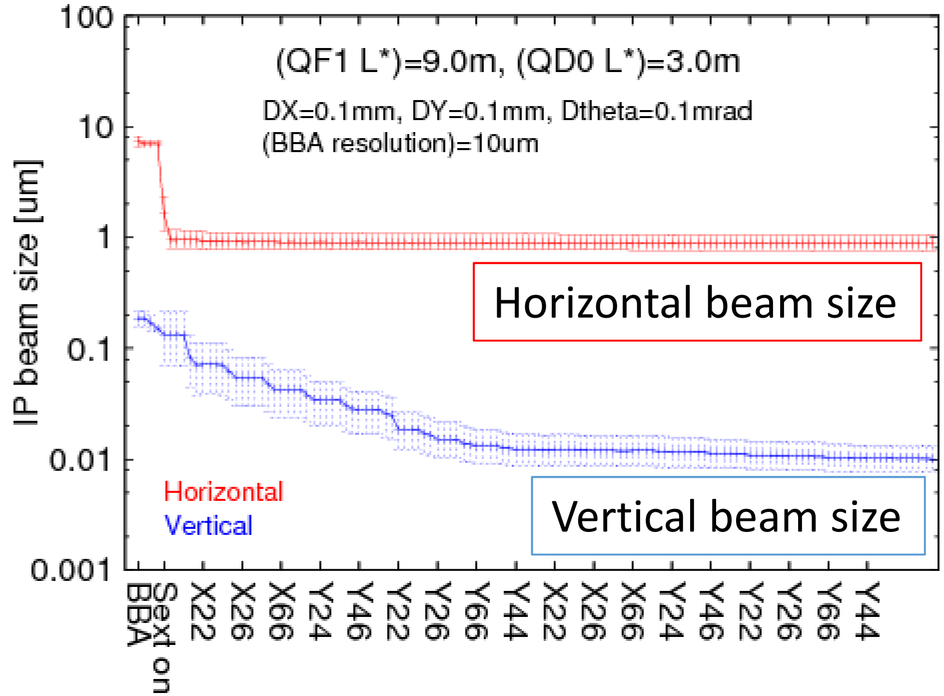
Procedures

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

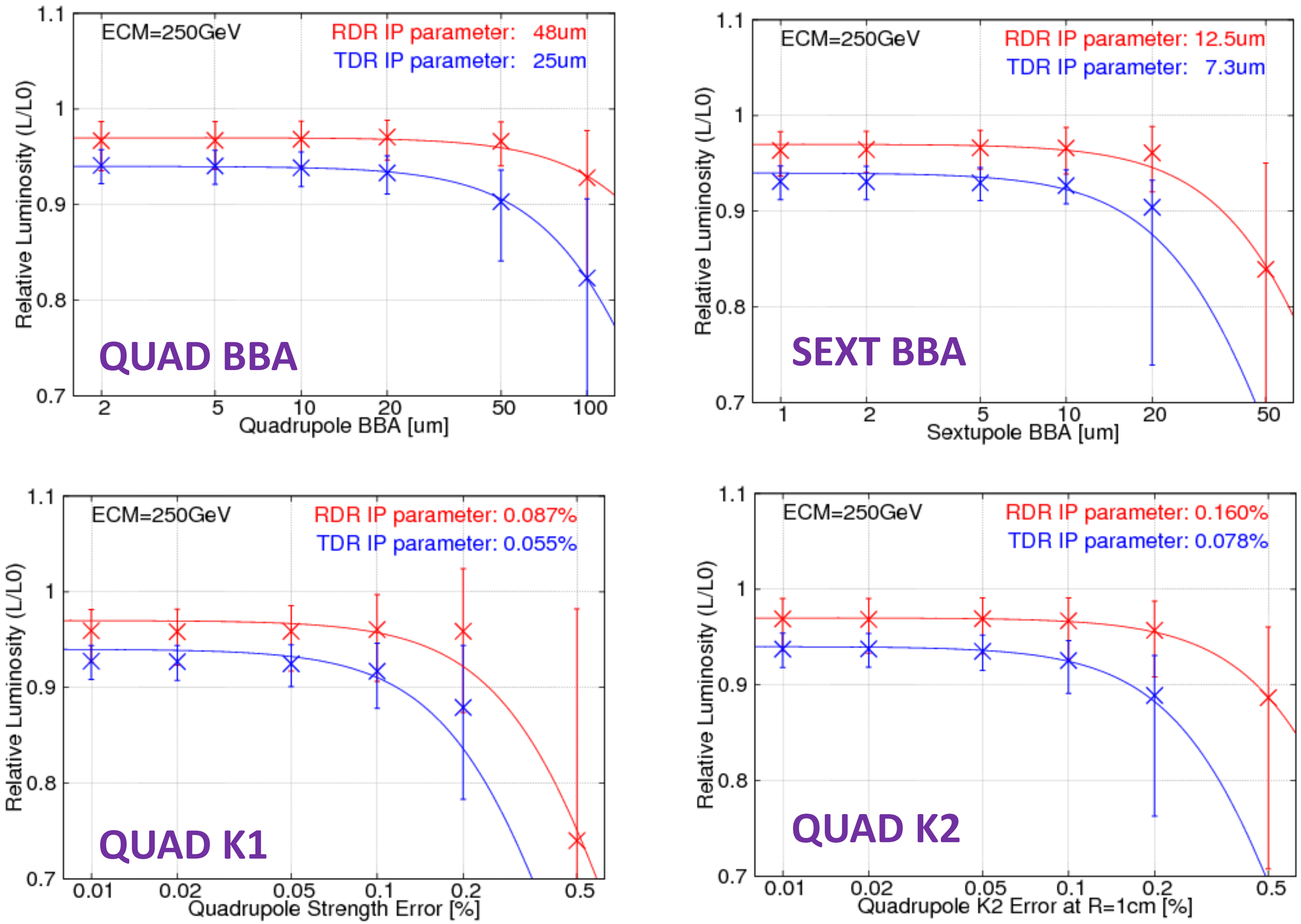
Alignment errors

	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**.*



Summary of Alignment Tolerances (ECM=250GeV)

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

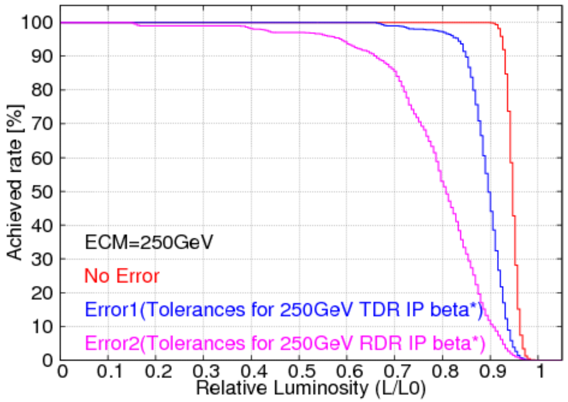
Simulation results said that

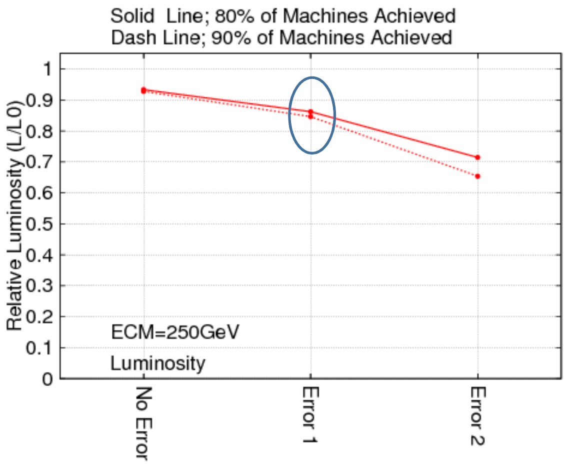
- the tolerances for TDR is 1.4times difficult to RDR for the errors related to linear optics .

- the tolerances for TDR is 2.0times difficult to RDR for the errors related to 2nd order optics.

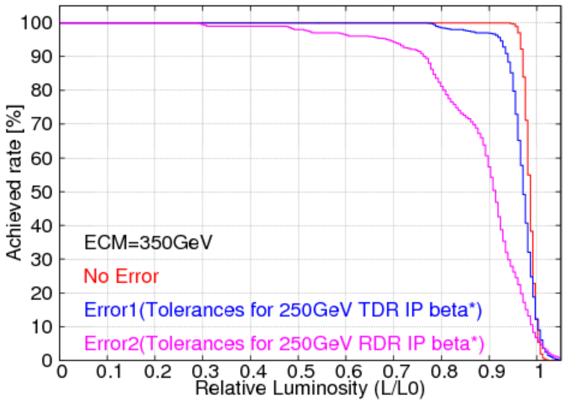
Beam tuning simulation for various beam energy

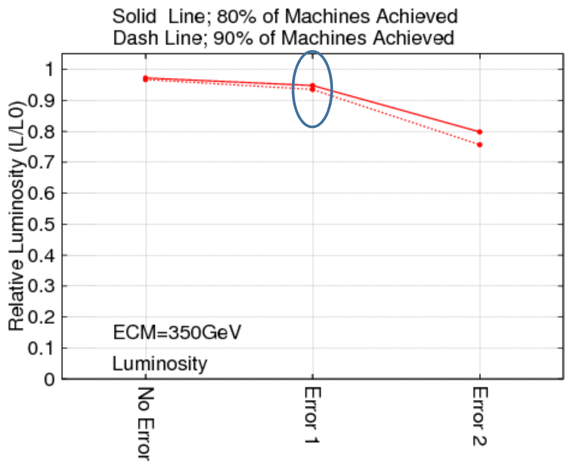
ECM=250GeV TDR IP parameter



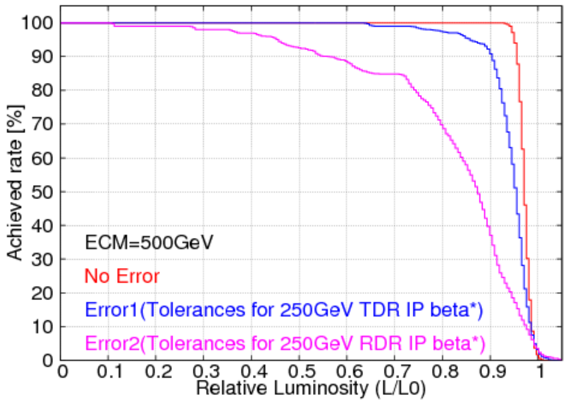


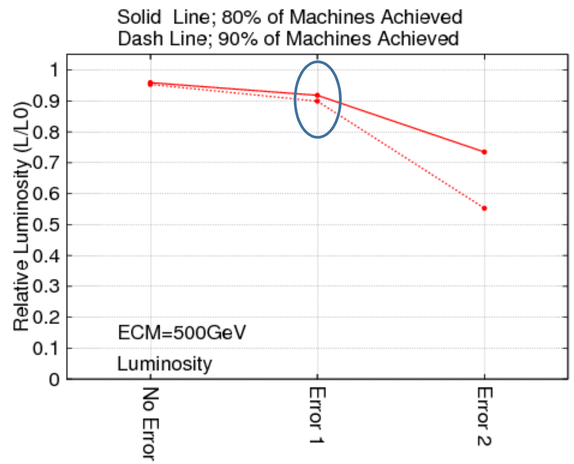
ECM=350GeV TDR IP parameter





ECM=500GeV TDR IP parameter





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

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

Beam tuning simulation with BBA errors

Procedures of beam tuning simulations

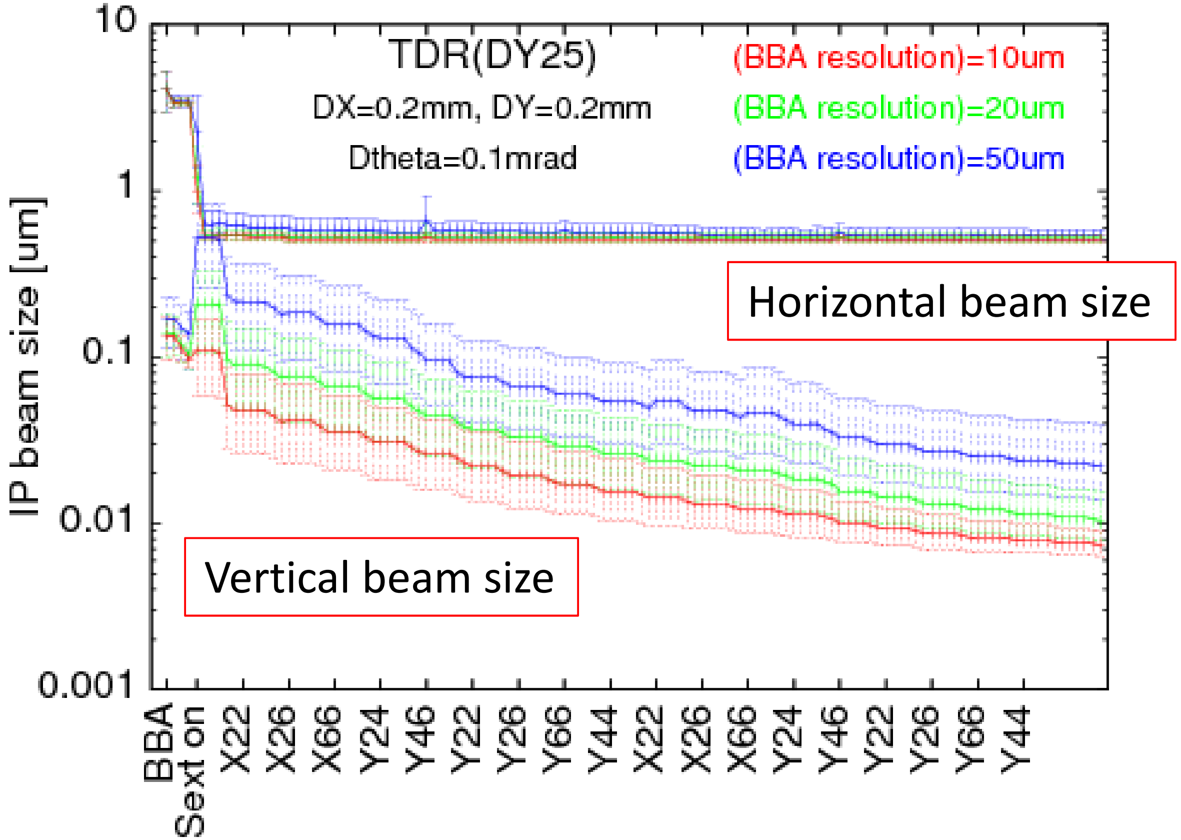
- 2 iterations for 2^{nd} order optics knobs

- 5 set of linear knob scan was done every after 2^{nd} 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
Δθ	0.1mrad	0.1mrad	0.1mrad

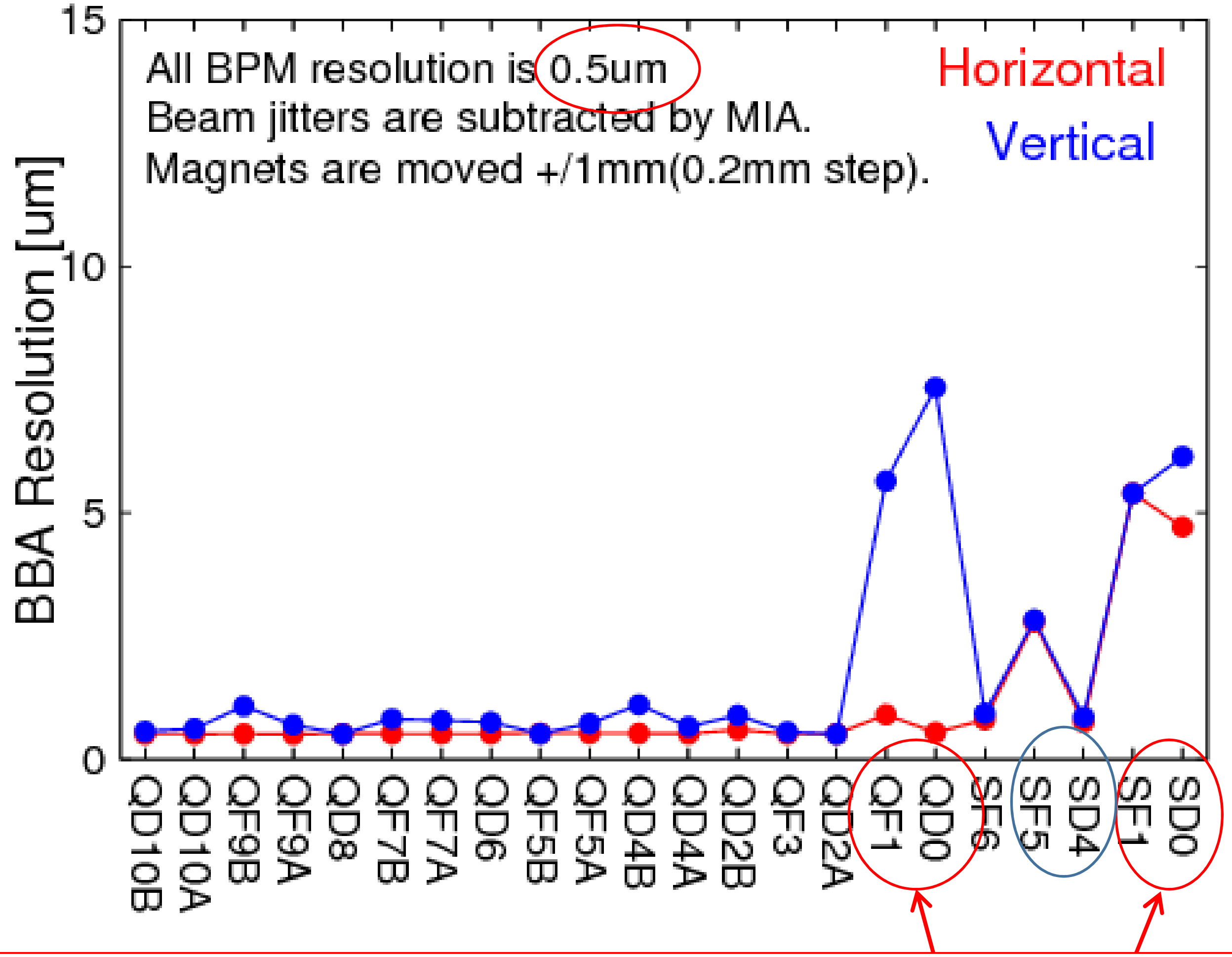


After the sextupole turned on, the beam size increased especially for large BBA error.

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

Evaluation of the BBA resolution

(*) The resolutions of C-band cavity BPMs are typically around 0.2um for normal beam operation .



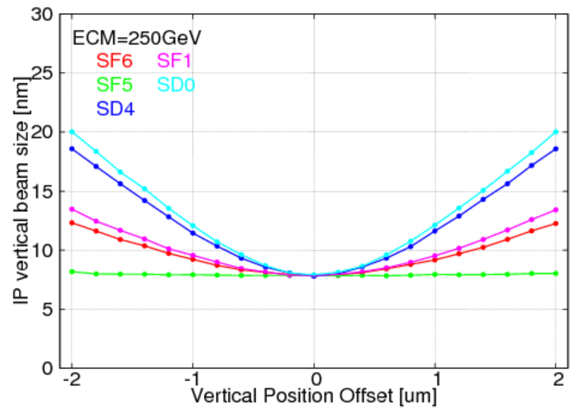
The BBA resolutions for FD quadrupoles and sextupoles are large to others, because there are no IP phase BPMs after the magnets.

Requirement of the magnet movers

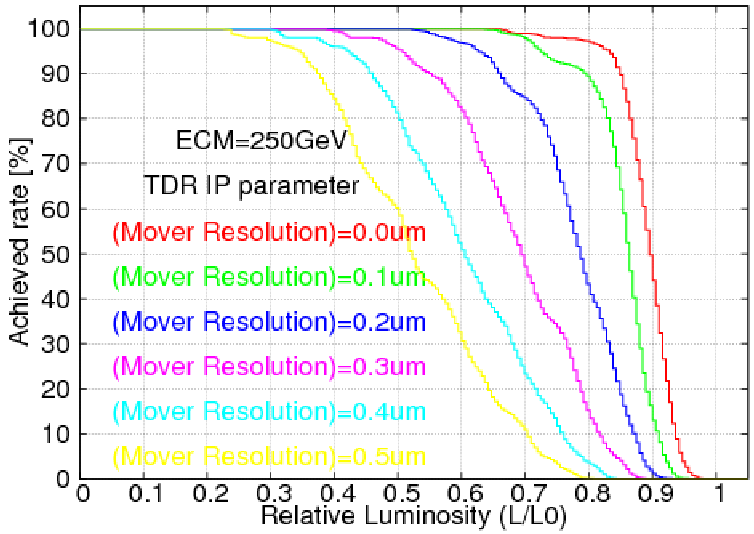
When the position of the sextupoles were moved by sub-micron, IP-beam size was increased so much.

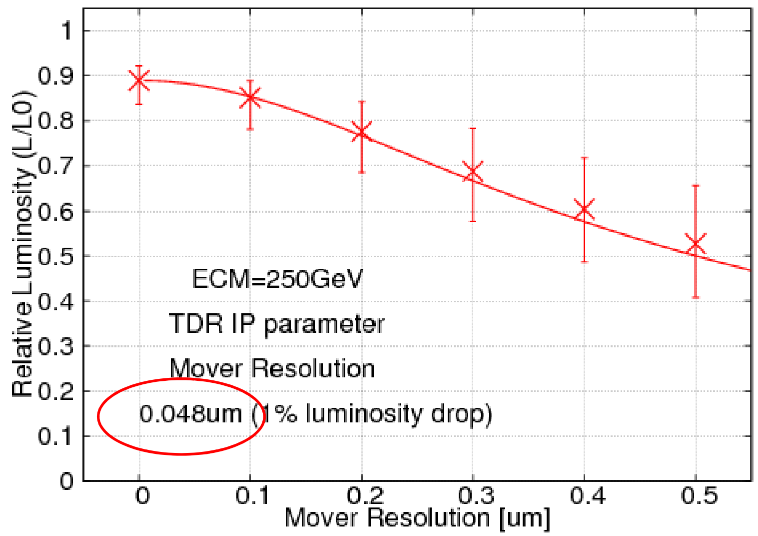
Therefore, the mover tolerances also evaluated by IP tuning simulation.

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.

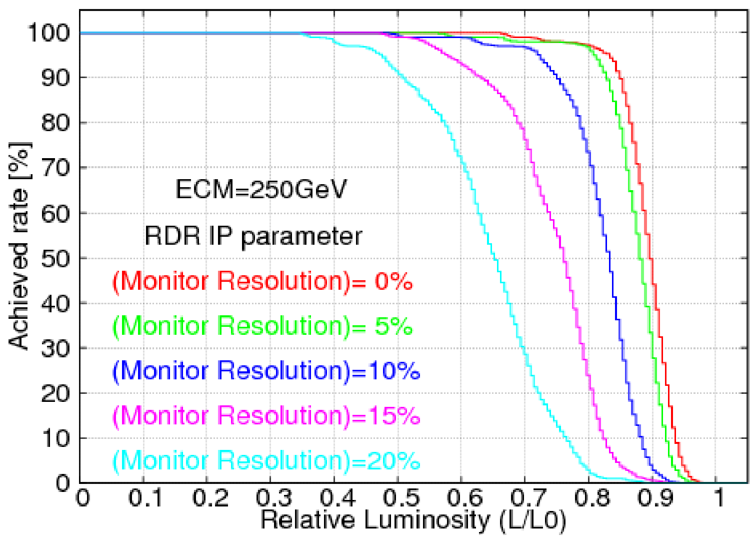
Requirement of Luminosity monitor resolution

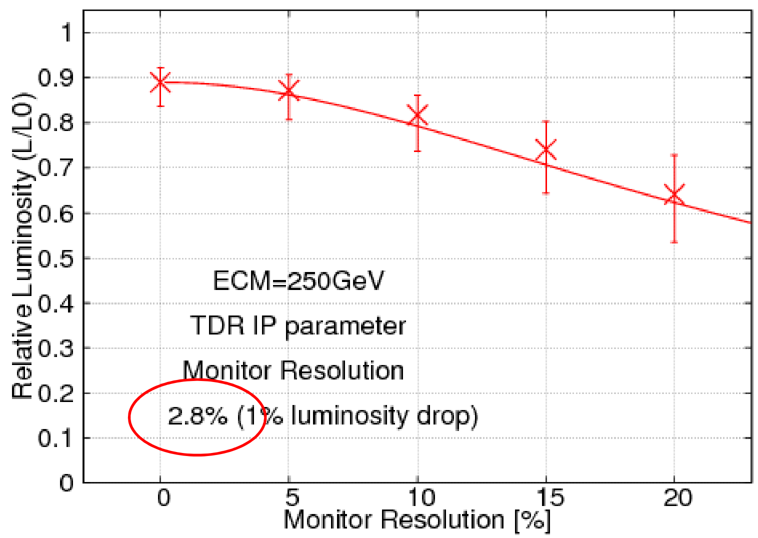
In present MDI-BDS design, the luminosity monitor will be
- Beamstrahlung monitor for large beam
- Incoherent pair monitor for small beam

The resolution requirement for IP beam size tuning also evaluated.

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

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



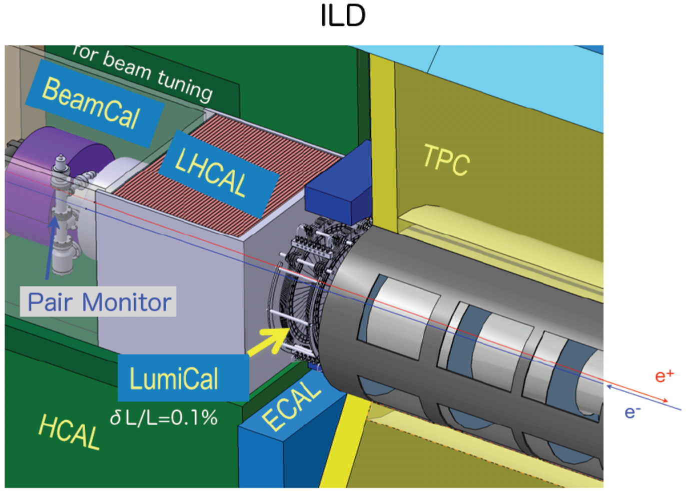


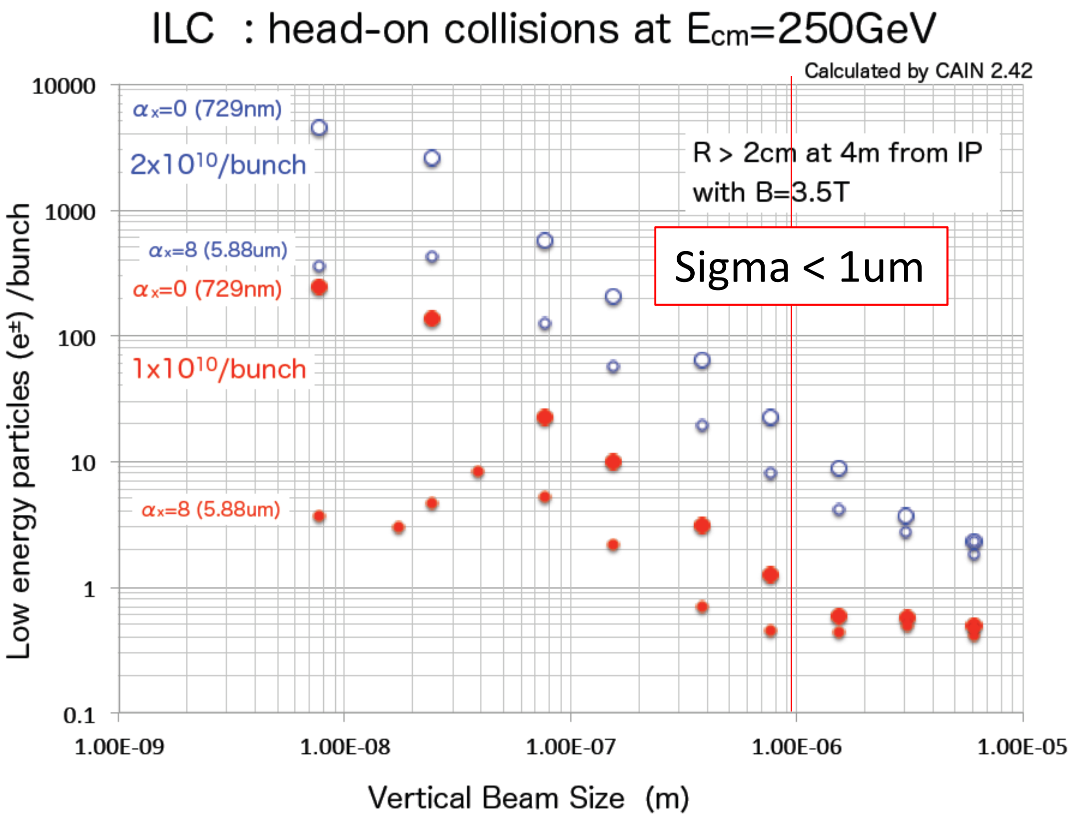
Resolution of luminosity monitor should be less than 3%.

Incoherent Pair Monitor

The beam size will be optimized by monitoring the Luminosity monitor in actual ILC beam operation.

Forward Calorimeter System for MDI





presented by T.Tauchi (KEK) at AWLC2014

High sensitivities for small beam (smaller than 1 um)

Beamstrahlung Monitor

High sensitivities for larger beam (larger than 1 um)

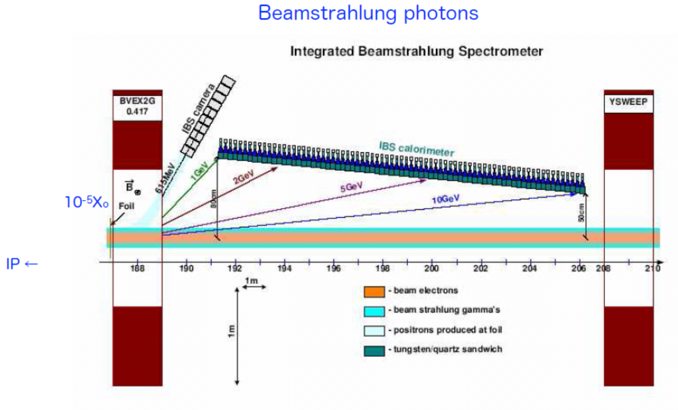
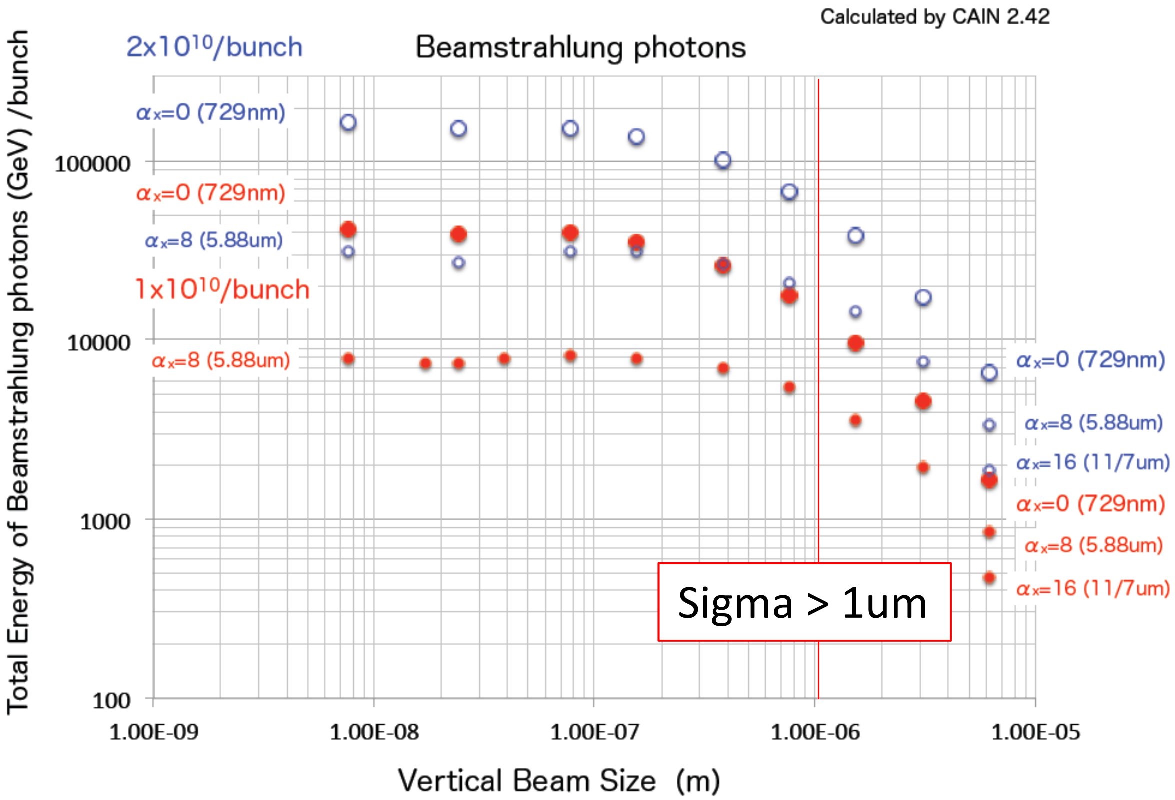


Figure 1: Concept for the GamCal.

W.M. Morse, GamCal - A Beamstrahlung Gamma Detector for Beam Diagnostics, LCWS07

ILC : head-on collisions at E_{cm}=250GeV



presented by T.Tauchi (KEK) at AWLC2014

We will optimize the IP beam size by monitoring the incoherent pair monitor and the beamstrahlung monitor.

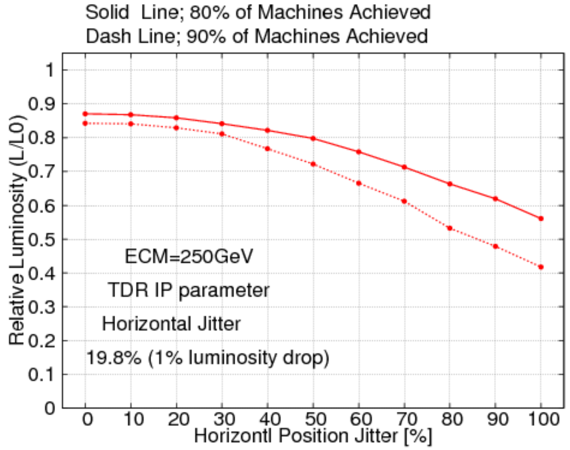
Tolerance of the beam jitter

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

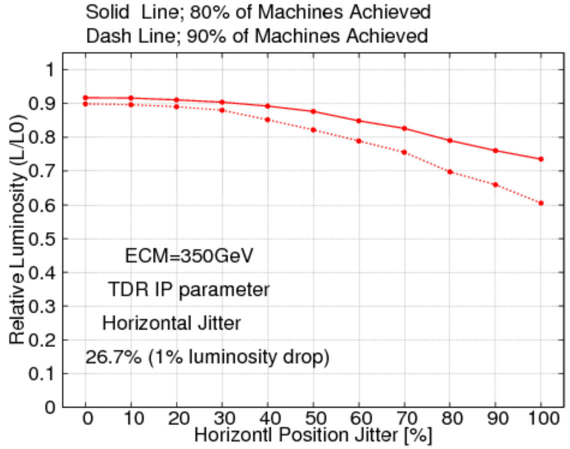
The alignment error is set to the tolerance for 250GeV TDR parameter.

Horizontal Beam Jitter

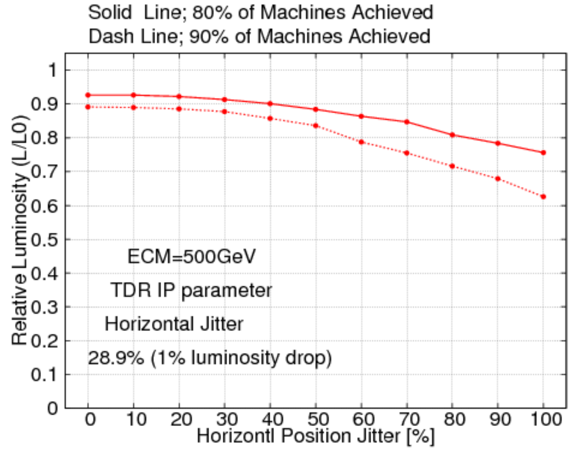
ECM=250GeV



ECM=350GeV

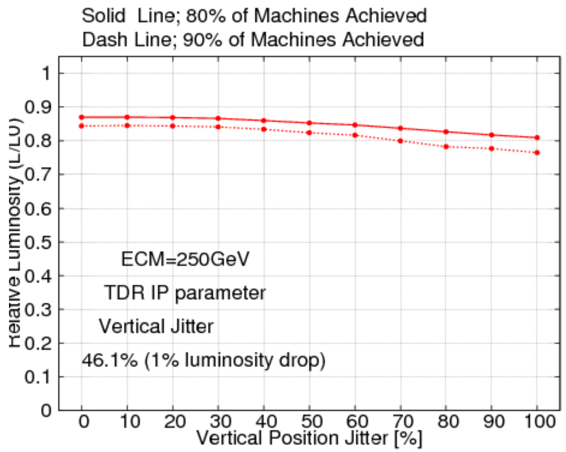


ECM=500GeV

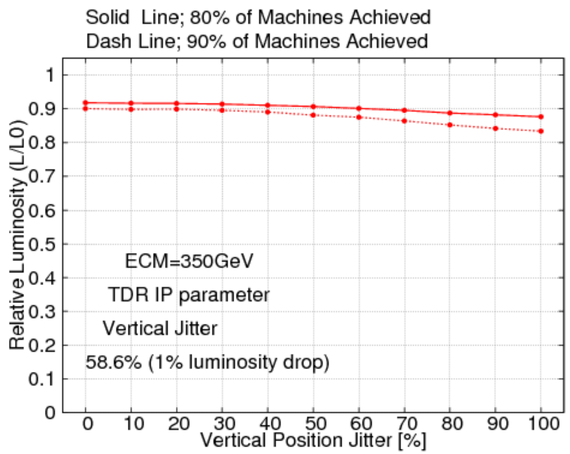


Vertical Beam Jitter

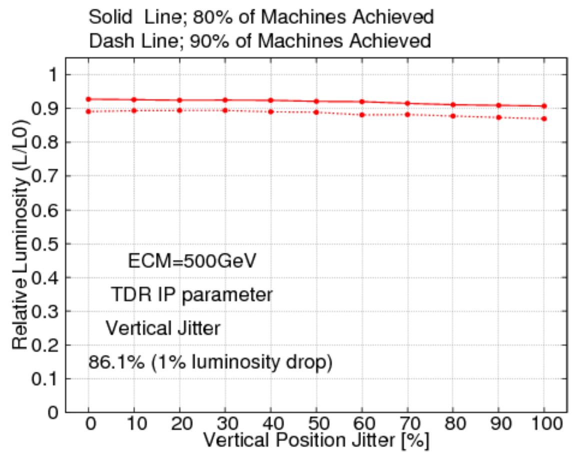
ECM=250GeV



ECM=350GeV



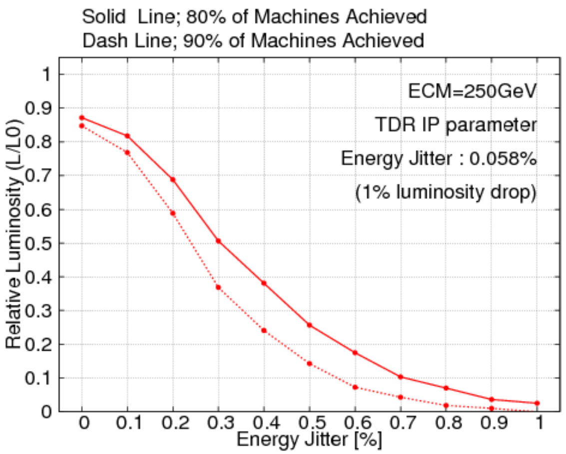
ECM=500GeV



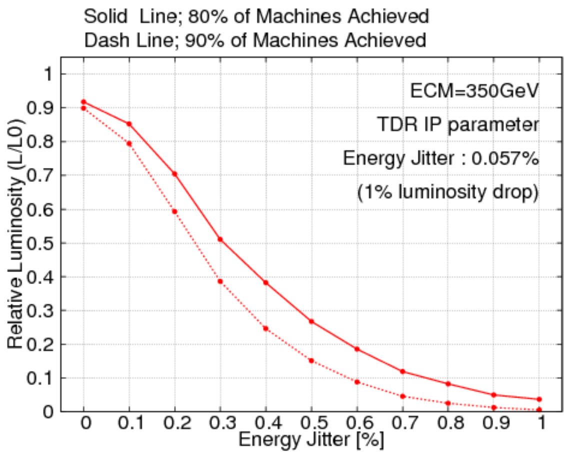
Tolerance of the beam jitter 2

Beam Energy Jitter

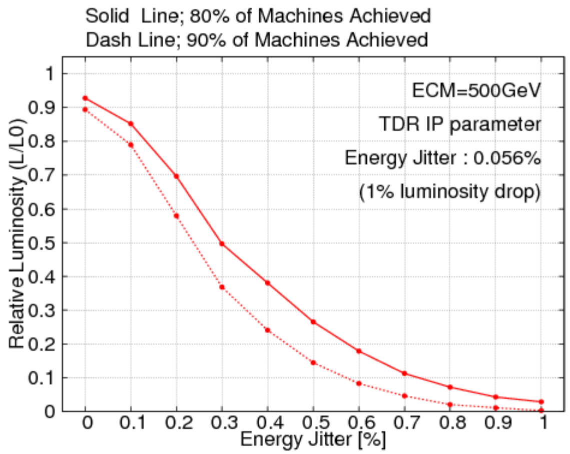
ECM=250GeV



ECM=350GeV



ECM=500GeV



Summary of tolerances for beam jitter

	ECM=250GeV	ECM=350GeV	ECM=500GeV
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.

Summary of Tolerance for ILC FF system

We evaluated the tolerances of magnet alignment, field errors, magnet mover accuracy, BBA accuracy, monitor accuracy and beam jitters.

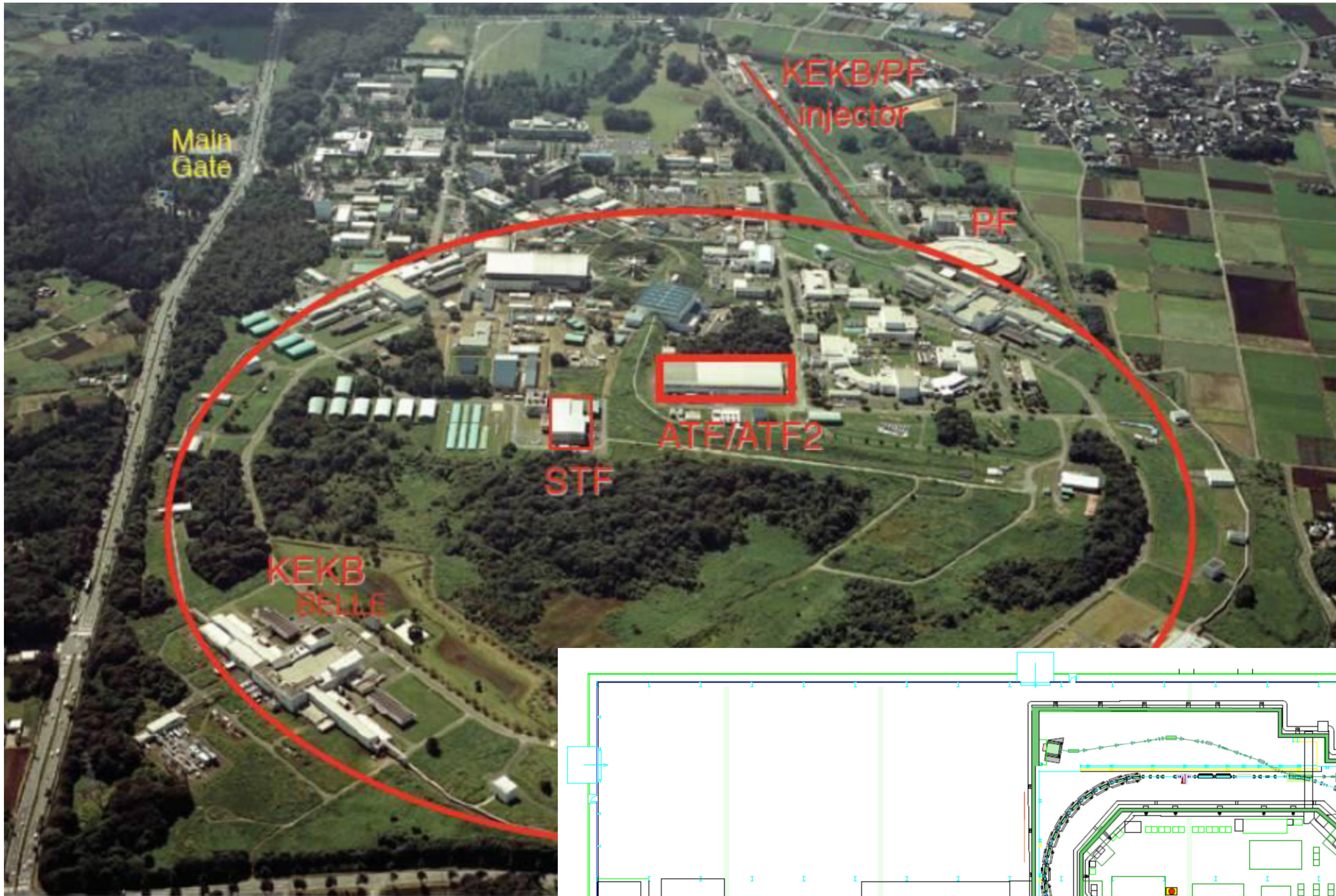
- *The field qualities (K1, K2 errors for quadrupoles)*
- *The magnet mover resolution*
- *BBA resoultion*
- *The beam size monitor resolution*
- *Horizontal beam jitter*

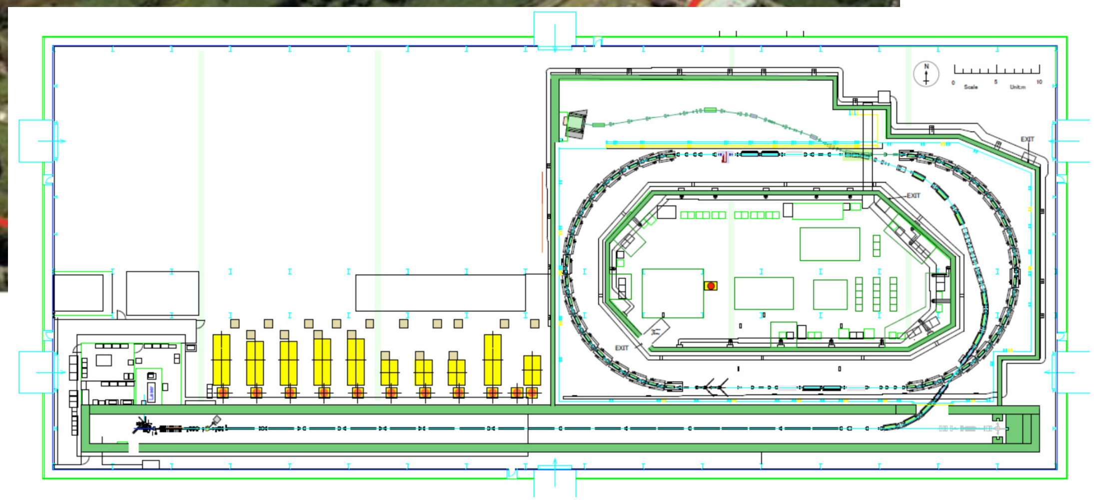
are tight tolerances, but are not impossible to realize.

The most of tolerance is tighter for lower beam energy.

Introduction of ATF2
(Test Facility of ILC Final Focus System)

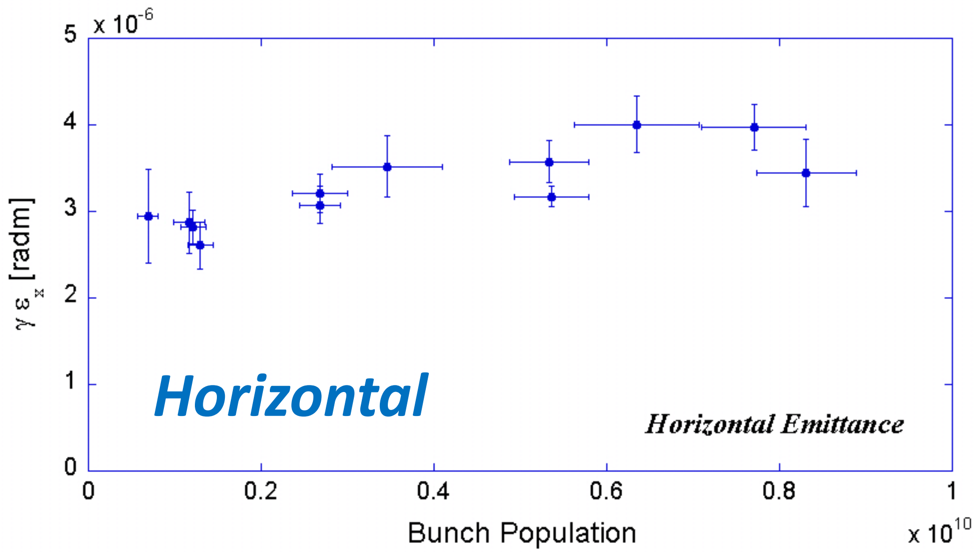
KEK-ATF (KEK Accelerator Test Facility)

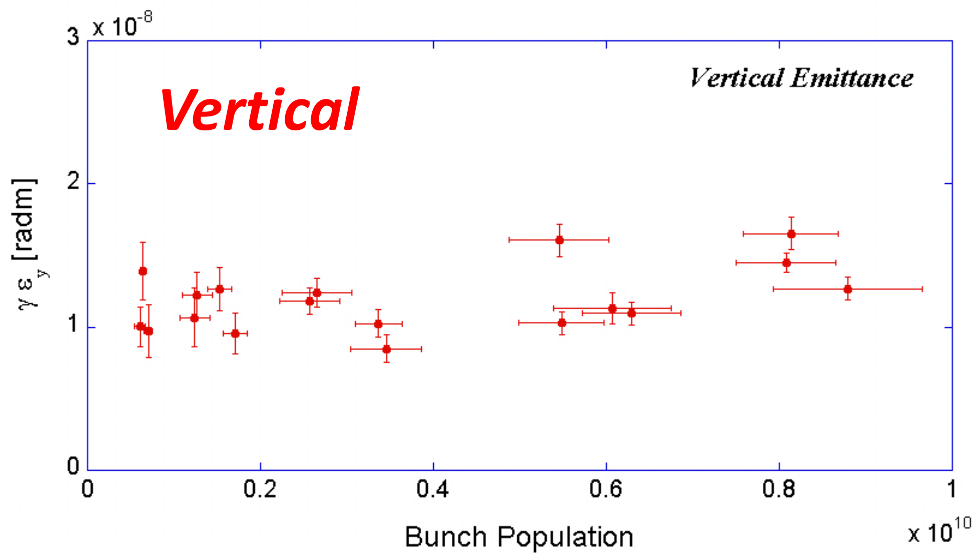




KEK-ATF damping ring was constructed to generate a low emittance beam for linear colliders from 1996.

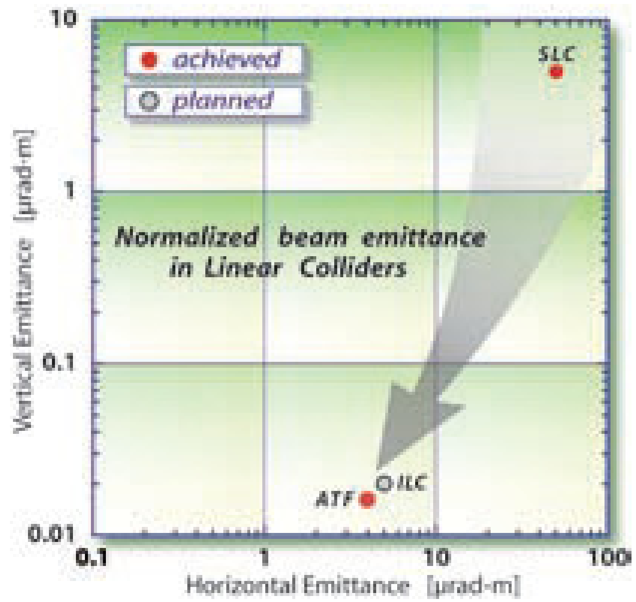
Beam emittance in ATF damping ring





Requirement of ILC emittance at DR

	Normalized emittance
Horizontal ($\gamma\varepsilon_x$)	5.5×10^{-6} rad · m
Vertical ($\gamma\varepsilon_y$)	2.0×10^{-8} rad · m

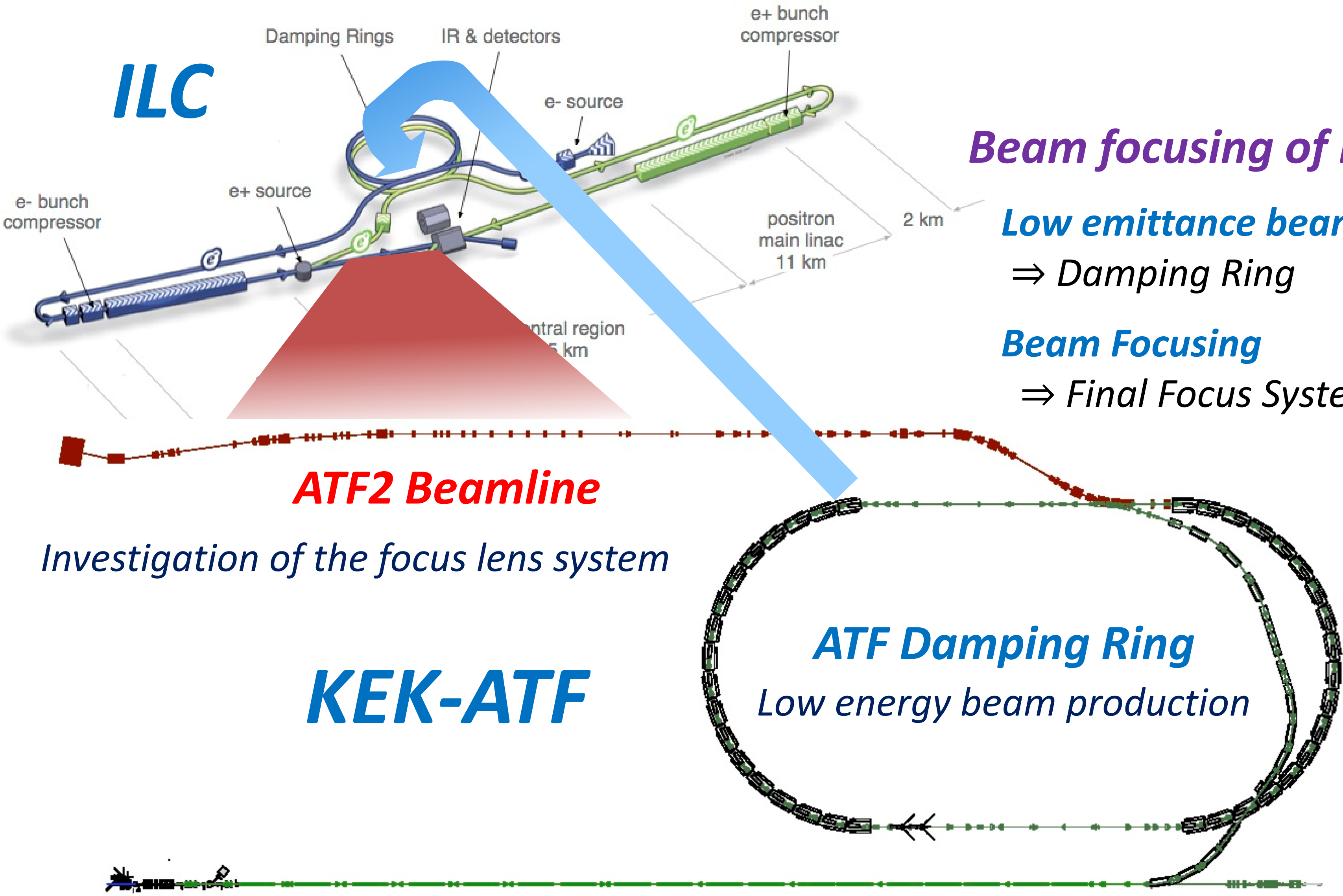


ATF damping ring was achieved the smaller emittance than ILC requirement.

ATF2 Project

Final focus test with ATF low emittance beam.

ATF2 project was proposed at 1st LCWS (2004 November).



Beam focusing of ILC

Low emittance beam

⇒ Damping Ring

Beam Focusing

⇒ Final Focus System

ATF2 Beamline

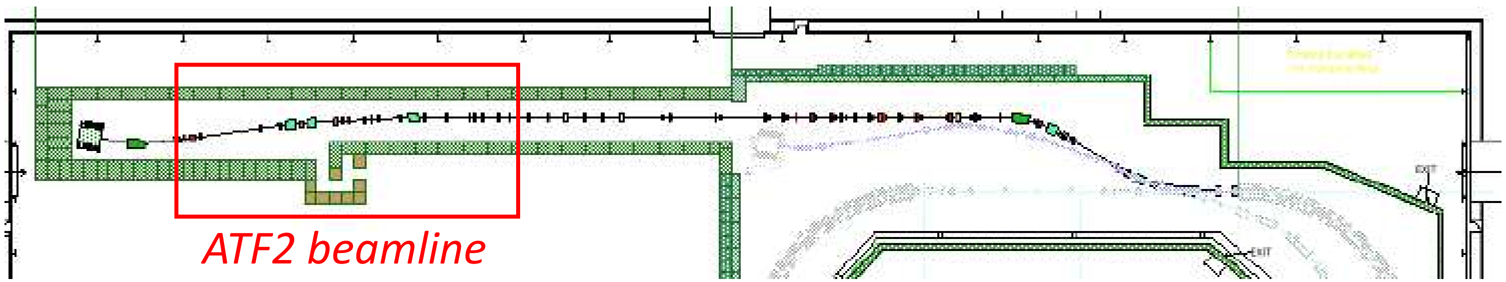
Test beamline for ILC final focus test

Start construction at 2007

Design and construction were done by international collaboration.

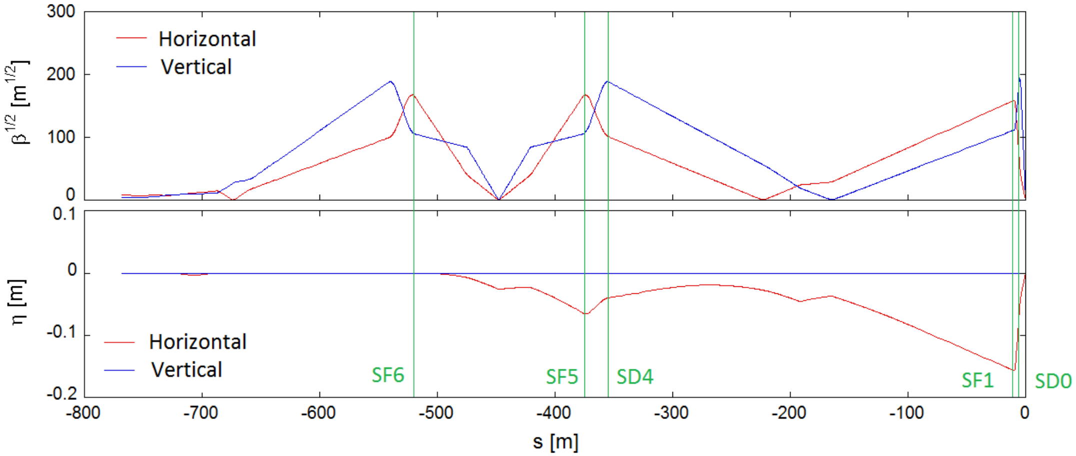
ATF has been operating by international collaboration.

ATFに参加している代表的研究機関
－ ATF International Collaboration －



Beam Optics of ILC & ATF2

Beam optics of ILC final focus system

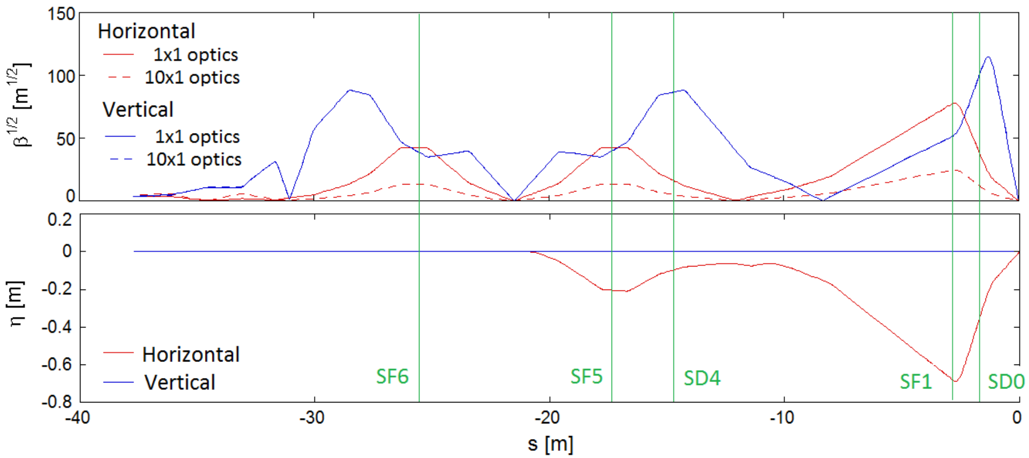


ILC final Focus System

- *ILC final focus systemand ATF2 beamline are both based on the Local Chromaticity Correction.*

- *Same magnet arrangement*

Beam optics of ATF2 beamline



ATF2 Beam Optics

1x1 optics

X&Y chromaticities are comparable to ILC FF.

10x1 optics

Since betax is 10 times larger than 1x1 optics, X chromaticity is one order smaller than ILC .*

Same concept of beamline design to ILC !

Chromaticity of ILC/ATF2

We can expressed the beam size at the final focus quadrupole as $\sigma_{x,y} \cong L^* \sqrt{\dfrac{\varepsilon_{x,y}}{\beta^*_{x,y}}}$,

Furthermore, the strength of the quadrupole is expressed as $K_1 \approx \dfrac{1}{L^*}$

The beam size generated the beam size generated by chromaticity as

$$\sigma_{126} = L^{*2}\sigma_\delta \sqrt{\frac{\varepsilon_x}{\beta^*_x}} K_1 \approx \frac{L^*}{\beta^*_x}\sigma_\delta\sigma^*_x$$

$$\sigma_{346} = L^{*2}\sigma_\delta \sqrt{\frac{\varepsilon_y}{\beta^*_y}} K_1 \approx \frac{L^*}{\beta^*_x}\sigma_\delta\sigma^*_x$$

	ILC		ATF2
	RDR	TDR	1x1 optics
$\xi_x = \sigma_{126}/\sigma^*_x\sigma_\delta$	248	473	313
$\xi_y = \sigma_{346}/\sigma^*_y\sigma_\delta$	13000	10833	12500

IP parameter of ATF2 1x1 optics is designed to be comparable to ILC.

IP beam size growth of the magnetic field error

When we have the multipole field error at final doublet,
IP beam size growth is generated by the higher order aberration.

When we assume the amount of relative magnetic field error as

$$b_{nN} \equiv \frac{\Delta B_{nN}}{B_1} = \frac{k_{nN} r_0^{n-1}}{n!\, k_1} \qquad b_{nS} \equiv \frac{\Delta B_{nS}}{B_1} = \frac{k_{nS} r_0^{n-1}}{n!\, k_1}$$

The IP beam size growth by the higher order aberration by magnet error is expressed as

2nd order X

$$\Delta\sigma_{122} = \frac{2\, L^{*2} \varepsilon_x}{\beta_x^*} \frac{b_{2N}}{r_0}$$

$$\Delta\sigma_{126} = 4\, L^{*2} \eta_x' \sigma_\delta \sqrt{\frac{\varepsilon_x}{\beta_x^*}} \frac{b_{2N}}{r_0}$$

$$\Delta\sigma_{166} = 2\, L^{*2} \eta_x'^2 \sigma_\delta^2 \frac{b_{2N}}{r_0}$$

$$\Delta\sigma_{144} = \frac{2\, L^{*2} \varepsilon_y}{\beta_y^*} \frac{b_{2N}}{r_0}$$

$$\Delta\sigma_{124} = 4\, L^{*2} \sqrt{\frac{\varepsilon_x \varepsilon_y}{\beta_x^* \beta_y^*}} \frac{b_{2S}}{r_0}$$

$$\Delta\sigma_{146} = 4\, L^{*2} \eta_x' \sigma_\delta \sqrt{\frac{\varepsilon_y}{\beta_y^*}} \frac{b_{2S}}{r_0}$$

2nd order Y

$$\Delta\sigma_{324} = 4\, L^{*2} \sqrt{\frac{\varepsilon_x \varepsilon_y}{\beta_x^* \beta_y^*}} \frac{b_{2N}}{r_0}$$

$$\Delta\sigma_{346} = 4\, L^{*2} \eta_x' \sigma_\delta \sqrt{\frac{\varepsilon_y}{\beta_y^*}} \frac{b_{2N}}{r_0}$$

$$\Delta\sigma_{322} = \frac{2\, L^{*2} \varepsilon_x}{\beta_x^*} \frac{b_{2S}}{r_0}$$

$$\Delta\sigma_{326} = 4\, L^{*2} \eta_x' \sigma_\delta \sqrt{\frac{\varepsilon_x}{\beta_x^*}} \frac{b_{2S}}{r_0}$$

$$\Delta\sigma_{366} = 2\, L^{*2} \eta_x'^2 \sigma_\delta^2 \frac{b_{2S}}{r_0}$$

$$\Delta\sigma_{344} = \frac{2\, L^{*2} \varepsilon_y}{\beta_y^*} \frac{b_{2S}}{r_0}$$

5th order Y

$$\Delta\sigma_{322222} = \frac{5!\, L^{*5} \varepsilon_x^2}{\beta_x^{*2}} \sqrt{\frac{\varepsilon_x}{\beta_x^*}} \frac{b_{5S}}{r_0^4}$$

Allowed component of quadrupoles

Multipole error tolerances of ILC/ATF2

The beam energy of ATF2 is much smaller than that of ILC,

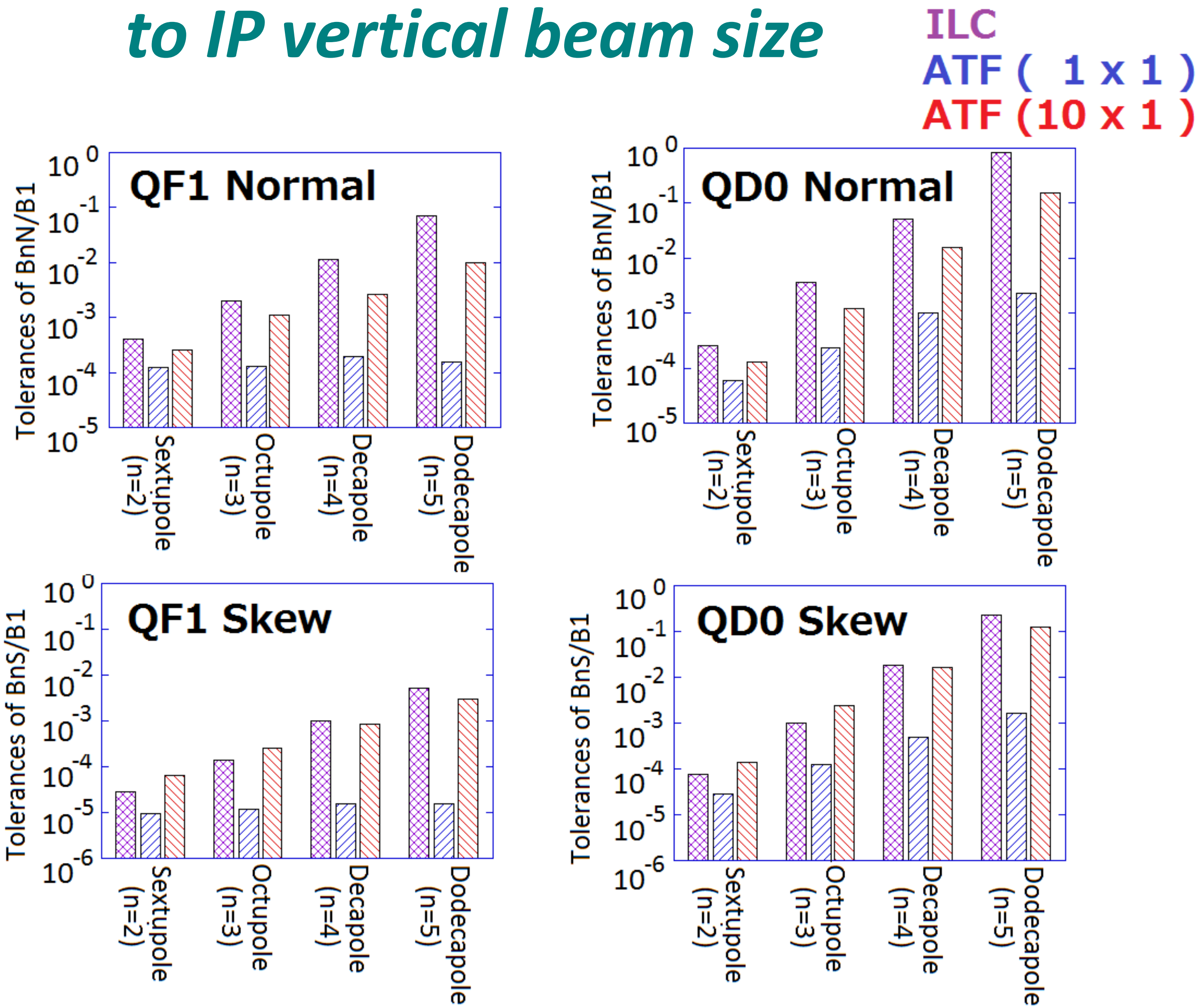
⇒ Beam size at quadrupole is much larger than ILC.

		ILC TDR	ATF2(1x1)	ATF2(10x1)	
2nd order	σ_{346}/σ_y^*	1	1.86	1.86	*Y chromaticity*
	σ_{324}/σ_y^*	1	4.60	1.45	*Y geometrical aberration*
	σ_{322}/σ_y^*	1	2.66	0.27	
	σ_{326}/σ_y^*	1	1.08	0.34	
	σ_{366}/σ_y^*	1	0.44	0.44	
	σ_{344}/σ_y^*	1	7.96	7.96	
$\sigma_{322222}/\sigma_y^*$		1	168.44	0.53	*Allowed component of quadrupoles*

Geometrical aberrations for ATF2 1x1 optics
is much stronger than ILC final focus beam line.

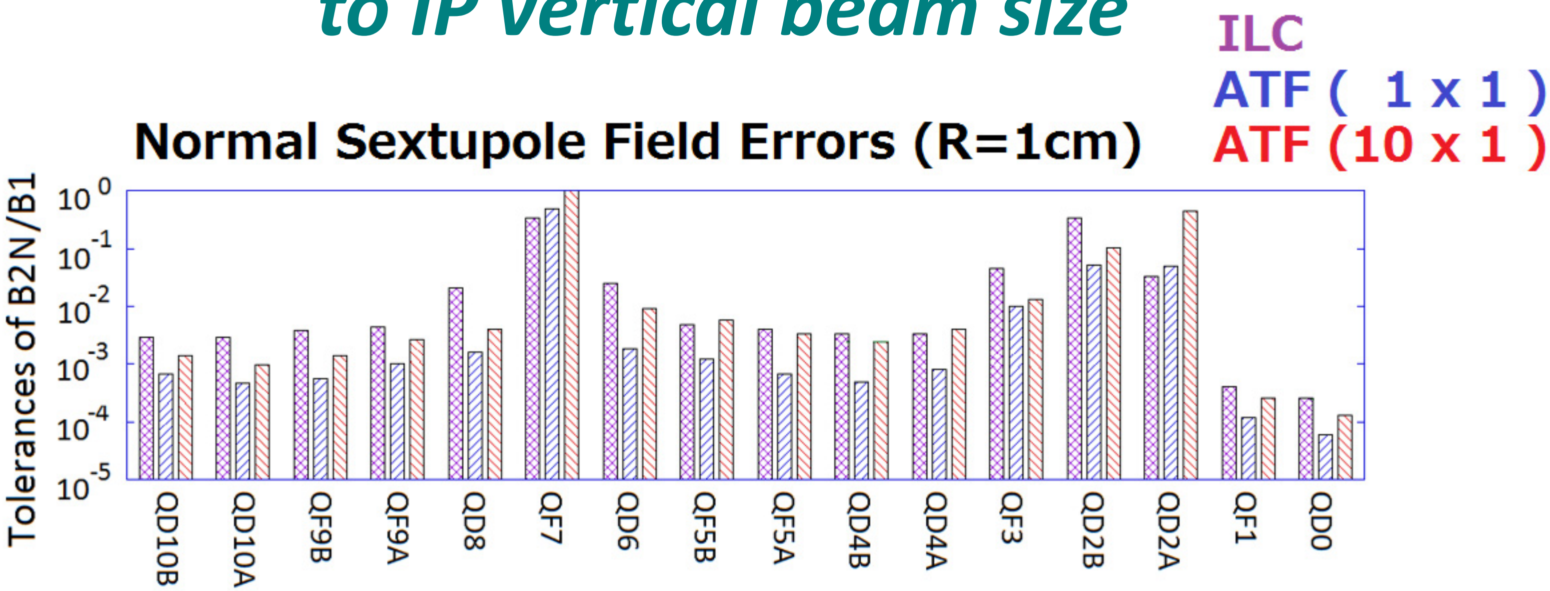
⇒ ATF2 10x1 optics (set to the comparable tolerance for field multipole errors.)
⇒ Tuning difficulty of IP vertical beam size is also comparable.

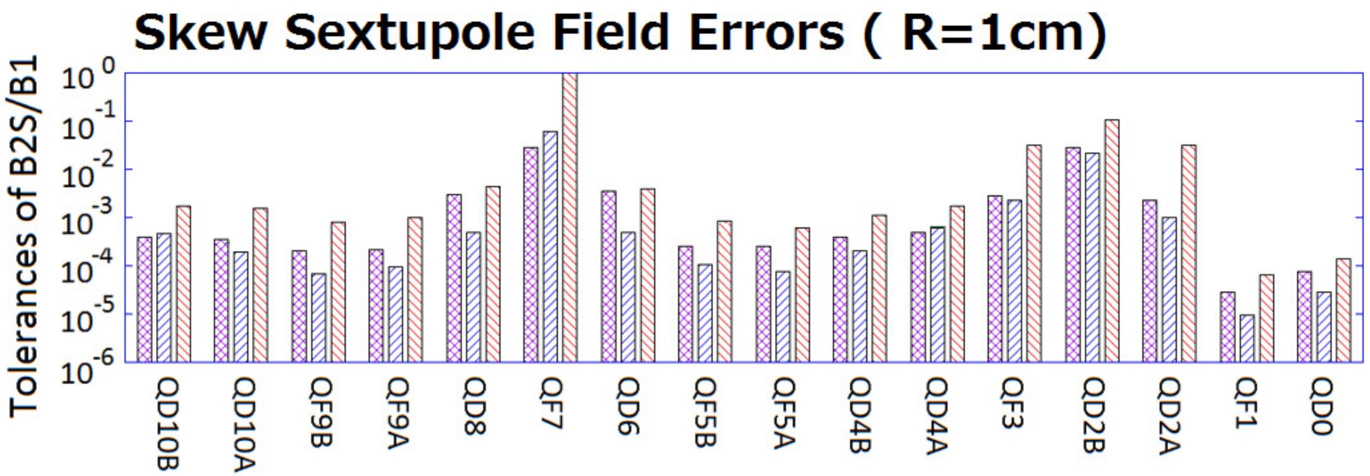
Tolerances of FD multipole field error to IP vertical beam size



The tolerances of FD multipole errors for ATF2 10x1 optics is comparable to ILC.

Tolerances of sextupole field error to IP vertical beam size





The tolerances of sextupole errors for ATF2 10x1 optics is comparable to ILC.

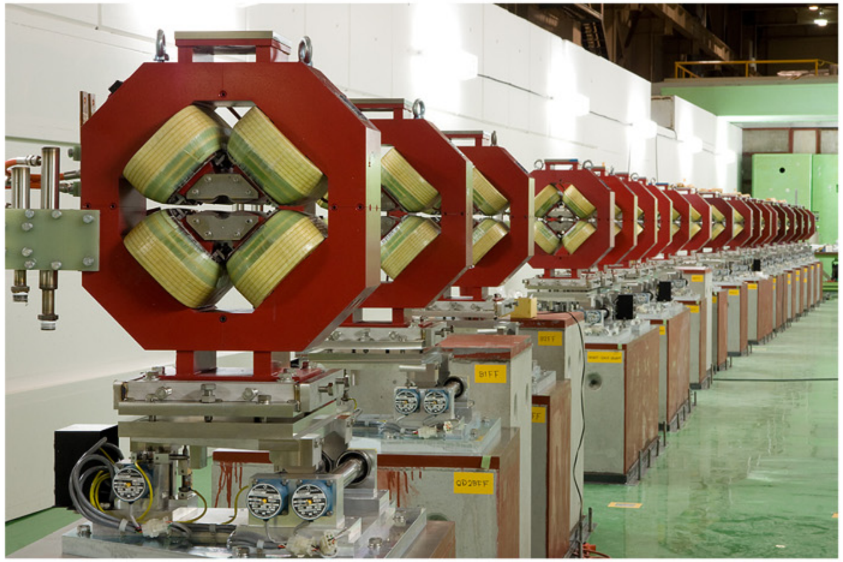
Flour construction

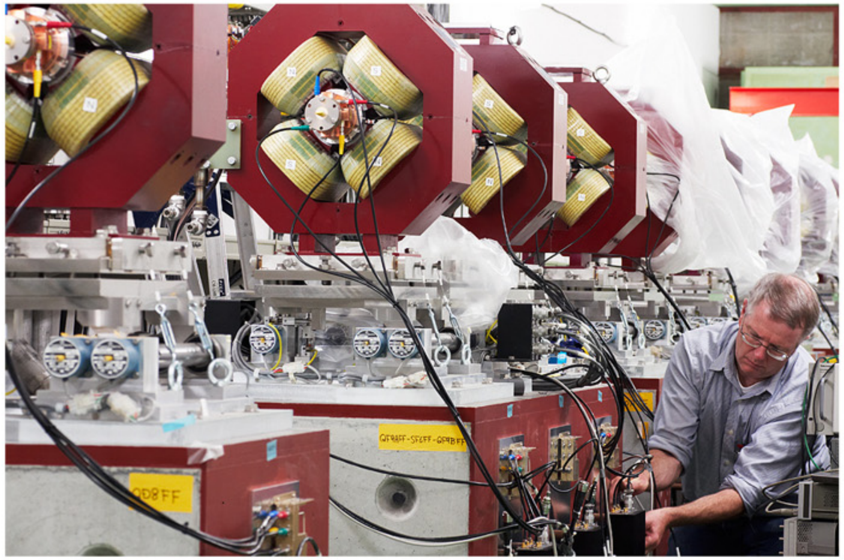
The construction was started from 2007.



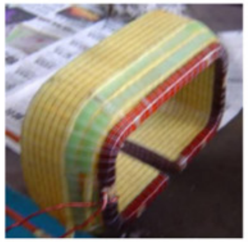


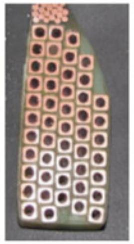
Magnet Installation

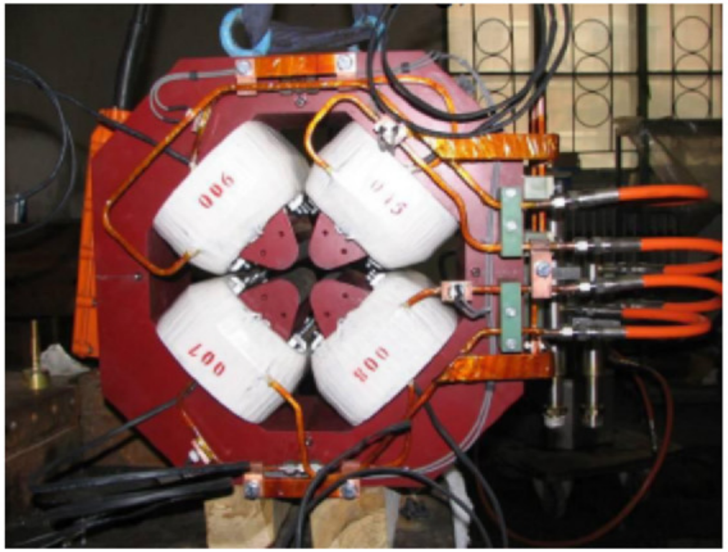




Magnet System (World –wide collaboration)



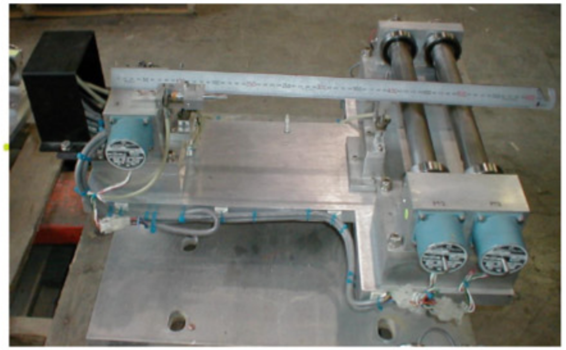




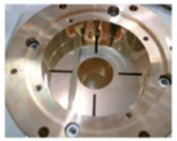
Magnet was designed by SLAC.
Magnet was constructed by IHEP (China).
Magnets were tested by IHEP and KEK.

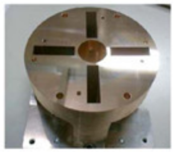
BPM readout electronics
were made by SLAC.

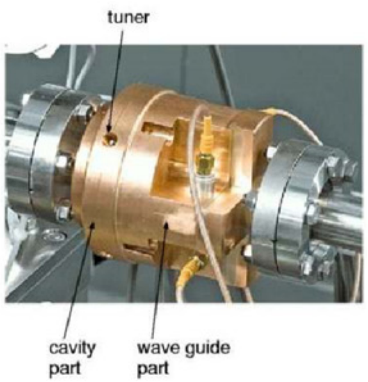
BPM readout software
were made by RHUL (UK).



FFTB movers (SLAC)
were reused.

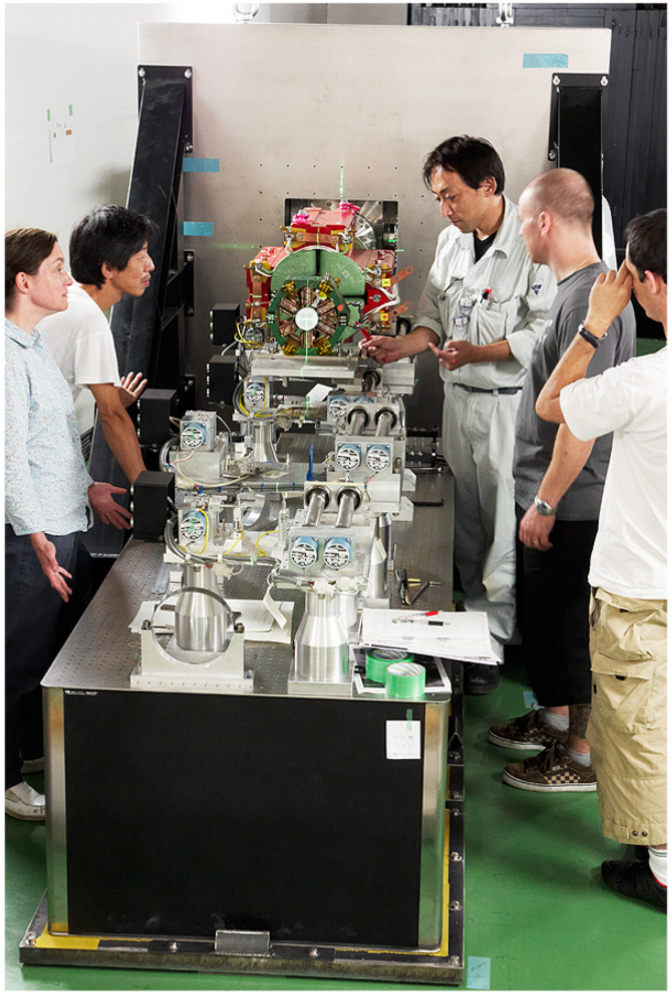


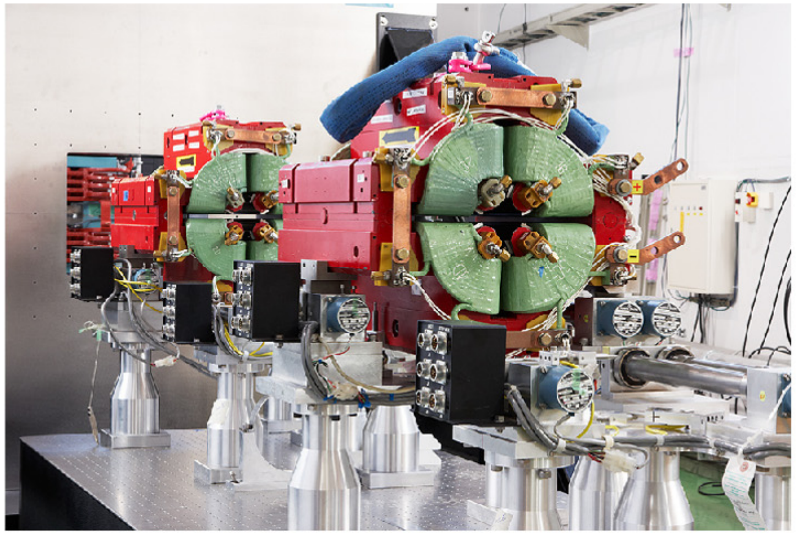




Prototype BPM was tested by KEK.
BPMs for ATF2 were constructed
by PAL(Korea).

Final Doublet





FFTB magnets (SLAC) were reused.

Support table was prepared by CERN.

Magnet support was constructed by LAPP (France).

Support with small vibrations designed by LAPP.

Beam operation was started from 2009

1st ATF2 project meeting after ATF2 beam line construction

ATF2 beamline was constructed as a world-wide project,
by many scientists and engineers, who are interested in ILC.

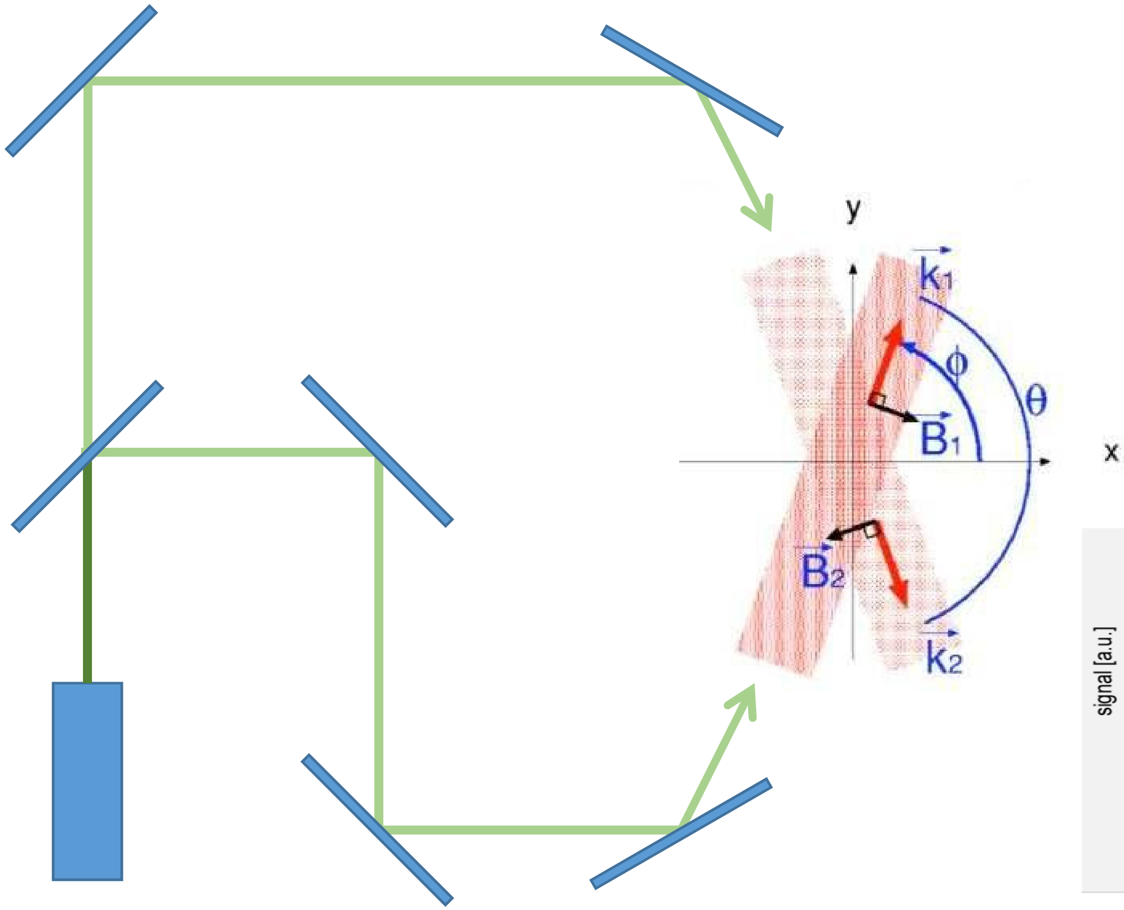
ATF2 are still operating as world-wide project !

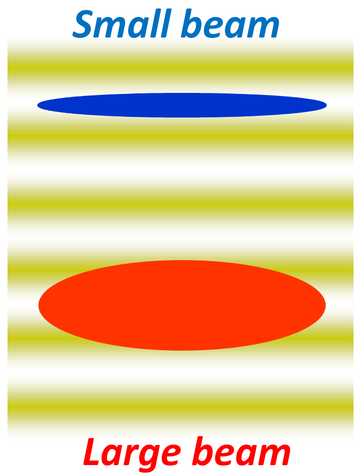
Shintake Monitor

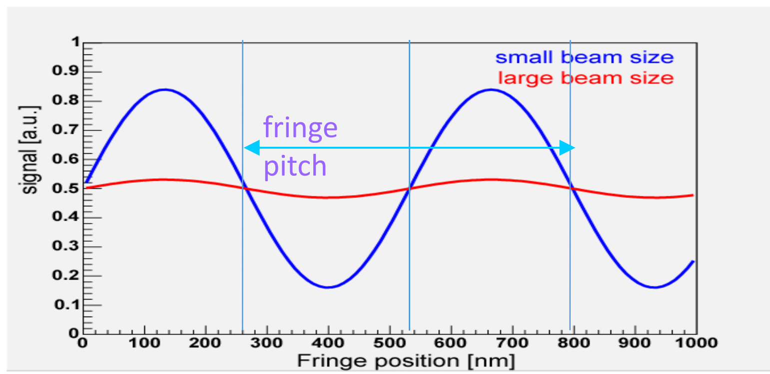
Laser light is divided by half-mirror.

The divided lights are crossed at IP.
⇒Interference pattern is generated st IP

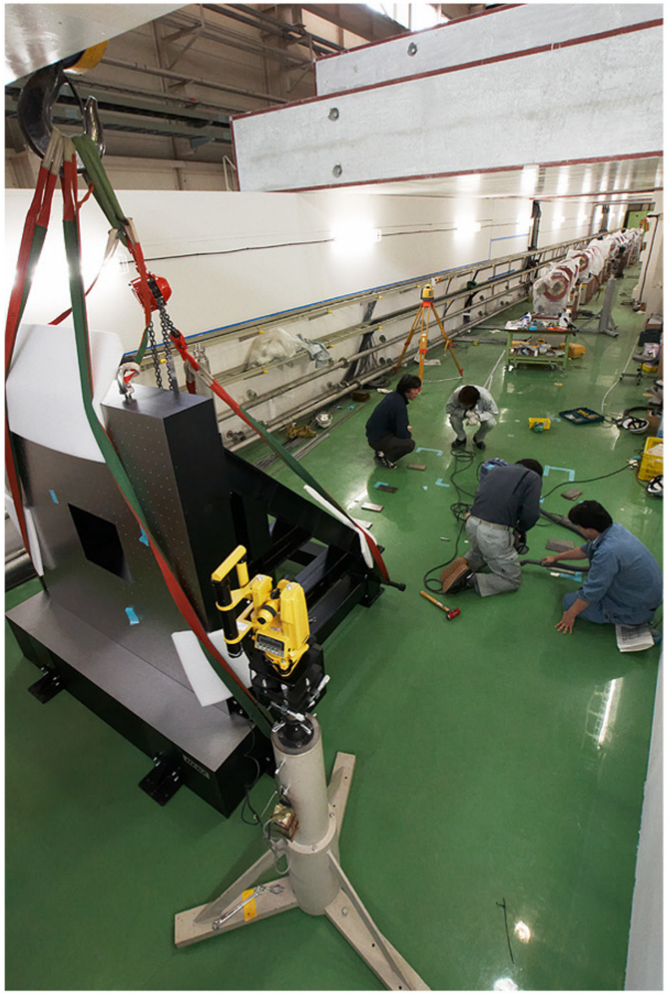
By comparing the beam with the interference pattern, the beam size can be evaluated.

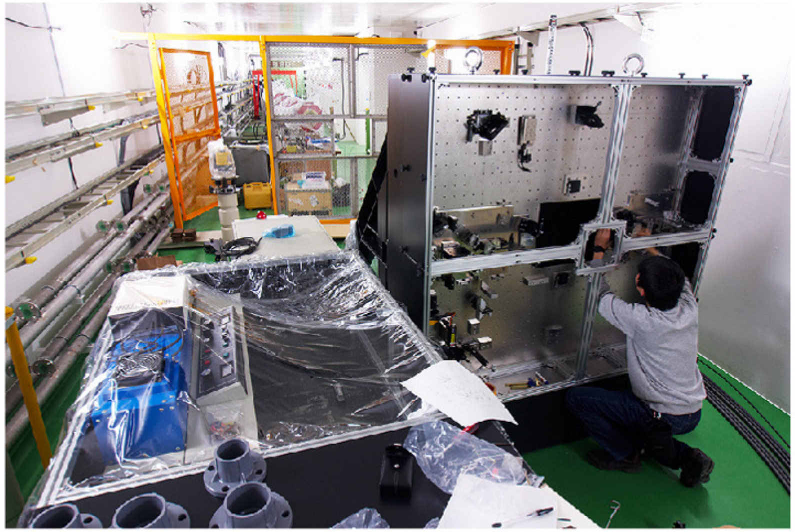




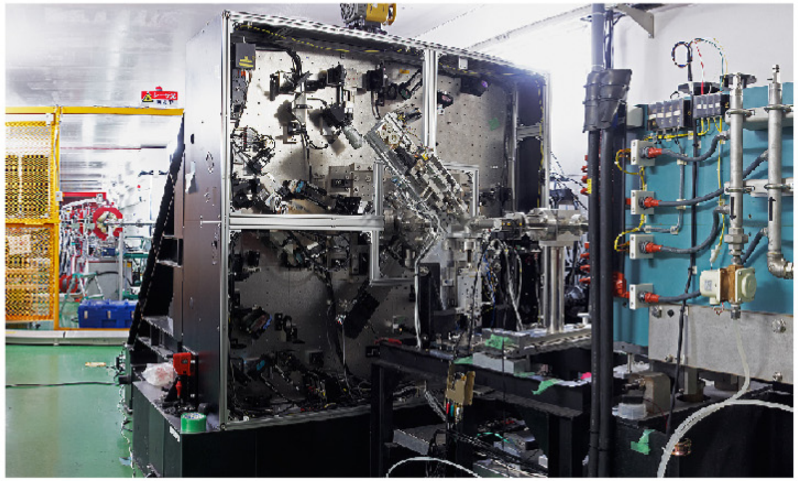


IP-BSM Installation





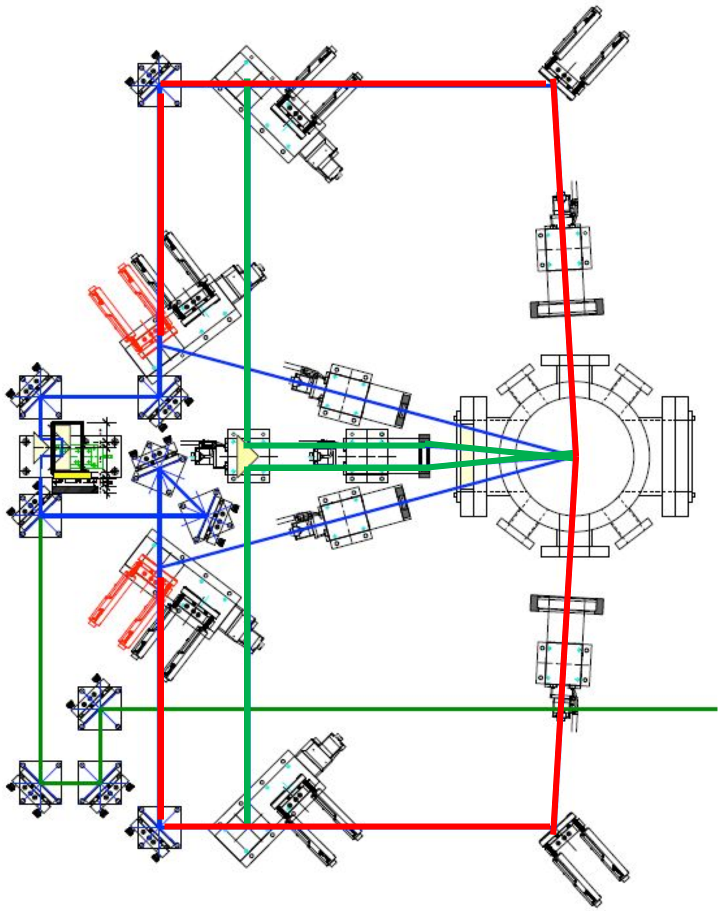
Laser system was reused for FFTB (SLAC).



For the initial test, laser system was put beside of monitor.

Collaboration with the University of Tokyo

IP-BSM (Shintake Monitor) for ATF2



Laser wave length was changed.

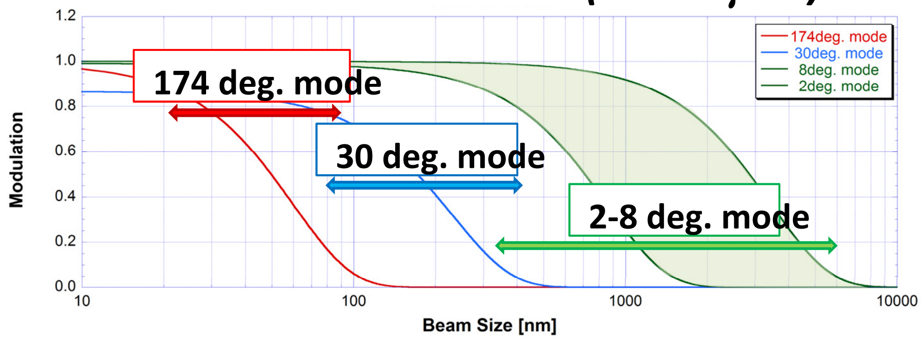
FFTB ; Nd:YAG fundamental mode (1064nm)

ATF2 ; Nd:YAG harmonic doubler (532nm)

Add the collision mode

FFTB	ATF2
174deg mode	174deg mode
30 deg mode	30 deg mode
	2-8deg mode

ATF2 IP-BSM (20 – 6μm)



ATF2 beam tuning procedures of IP beam size

FF sextupoles turned OFF

- *Orbit tuning*
- *QF1FF strength optimization (Carbon wire; Horizontal beam size)*
- *QD0FF strength optimization (Carbon wire; Vertical beam size)*
- *QD0FF rotation optimization (Carbon wire; Coupling)*
- *FF normal and sextupole BBA (Magnetic center)*

FF sextupoles turned ON

Carbon Wire
AY knob
EY knob
Coup2 knob

→

IP-BSM 8degree
AY knob
EY knob
Coup2 knob

→

IP-BSM 30degree
AY knob
EY knob
Coup2 knob
Y24 knob
Y46 knob

→

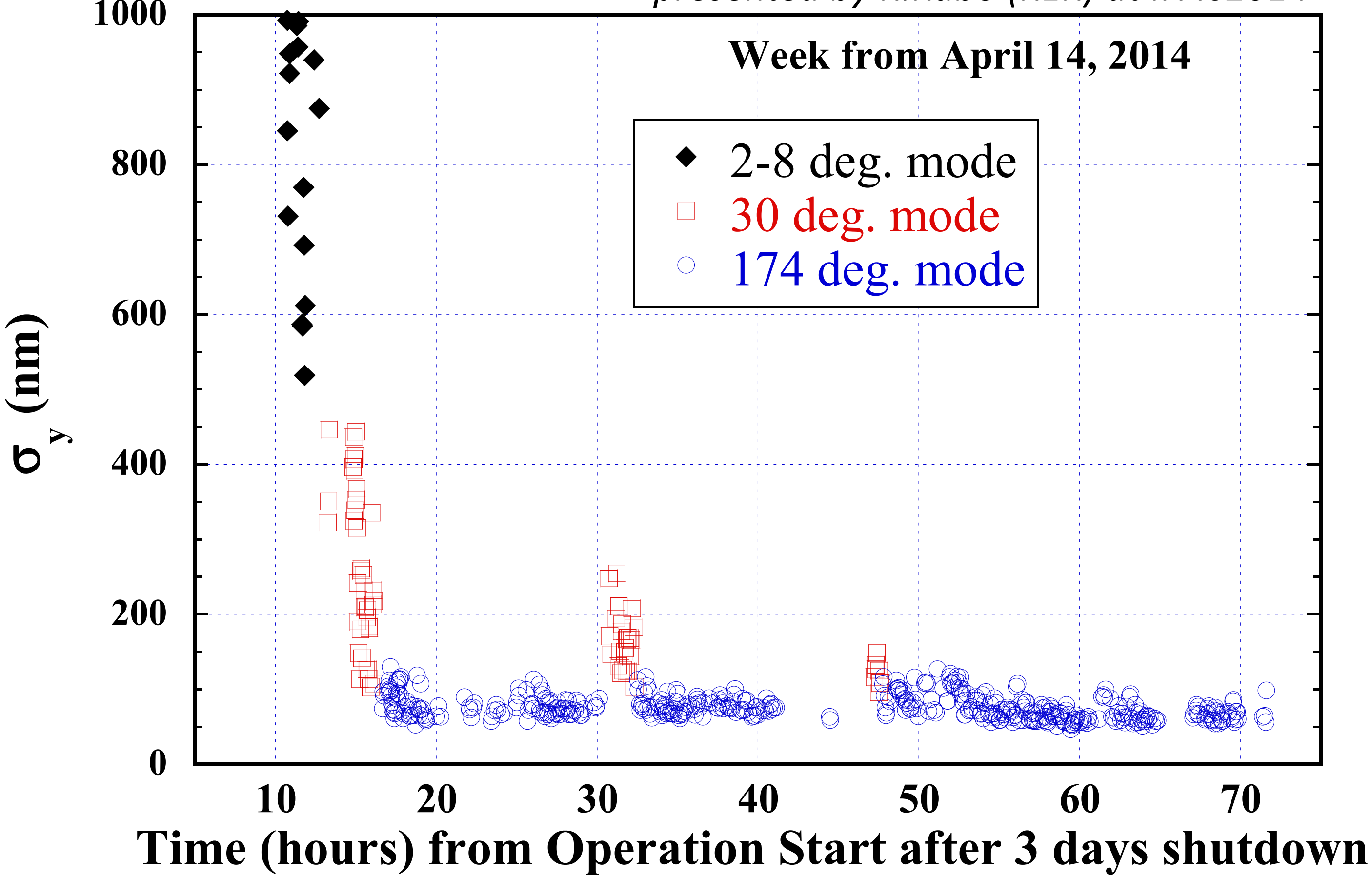
IP-BSM 174 degree
AY knob
EY knob
Coup2 knob
Y24 knob
Y46 knob
Y22 knob
Y26 knob
Y66 knob
Y44 knob

The ATF2 tuning procedure is same to ILC final focus beam line.

IP vertical beam size tuning in ATF2 beamline

Beam size history after 3 days shutdown

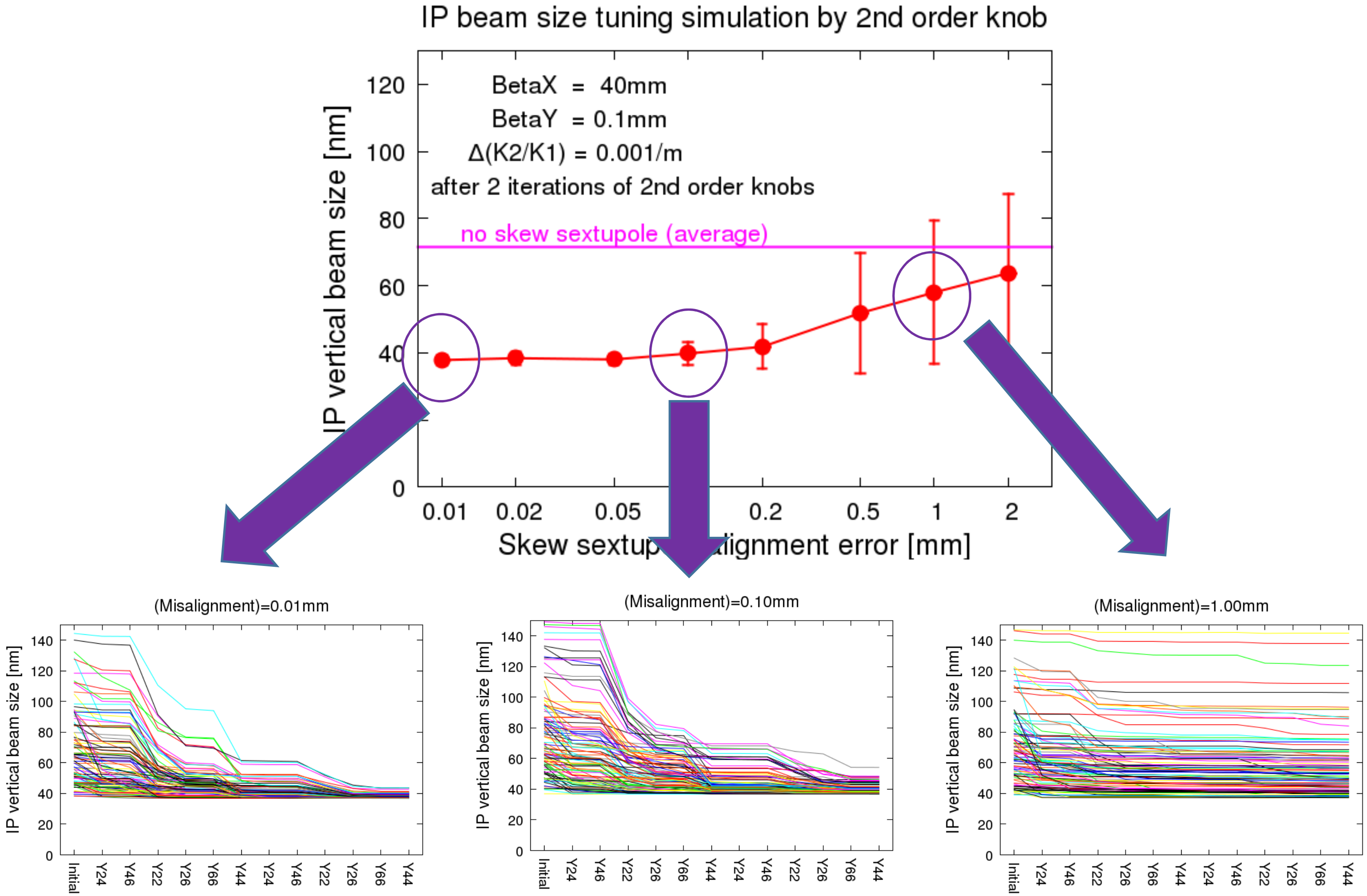
presented by K.Kubo (KEK) at IPAC2014



Good training for ILC FF bam size tuning.

Initial alignment for skew sextupole magnets

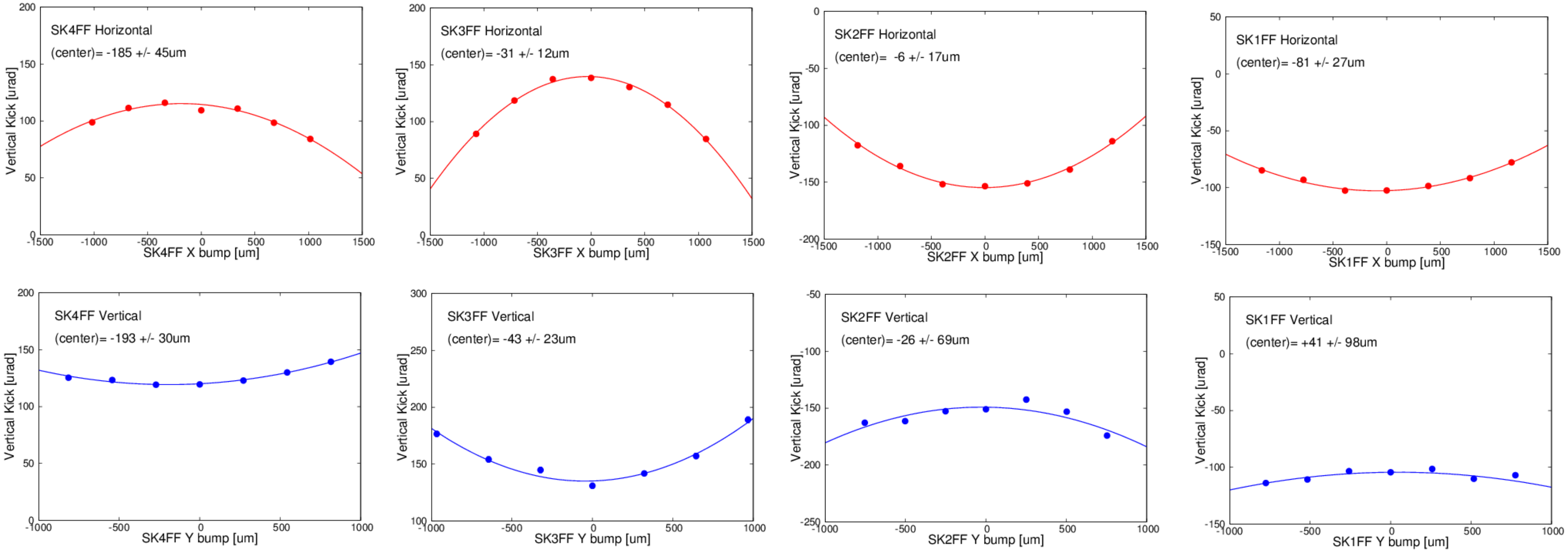
Beam tuning simulation to evaluate the requirement of initial alignment of skew sextupoles.



In order to apply the 2nd order knob effectively, we must align the magnets within 100um.

Beam based alignment of skew sextupoles

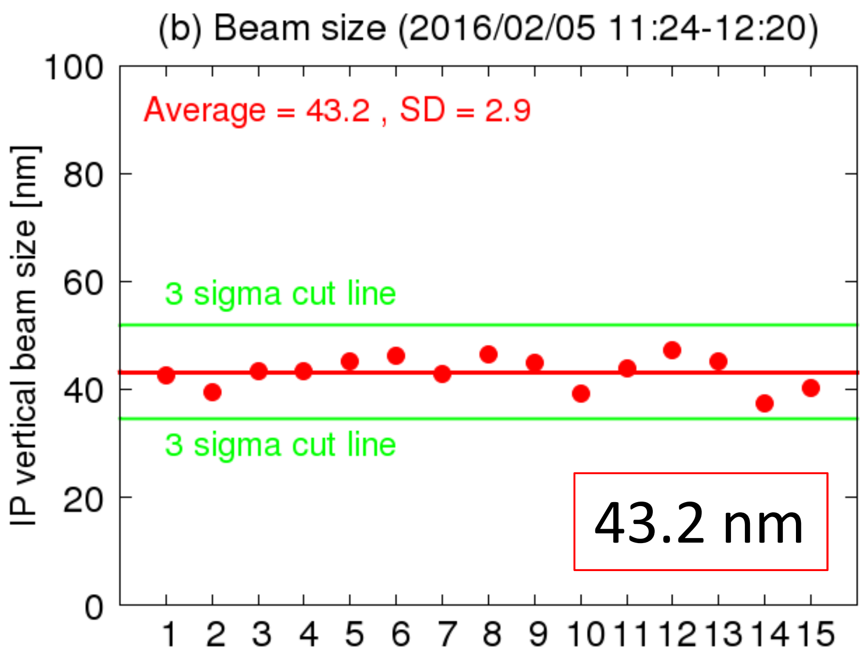
Since the magnets don't have movers,
we did the mechanical position alignment of FF skew magnet
by using the offset information of beam measurement.

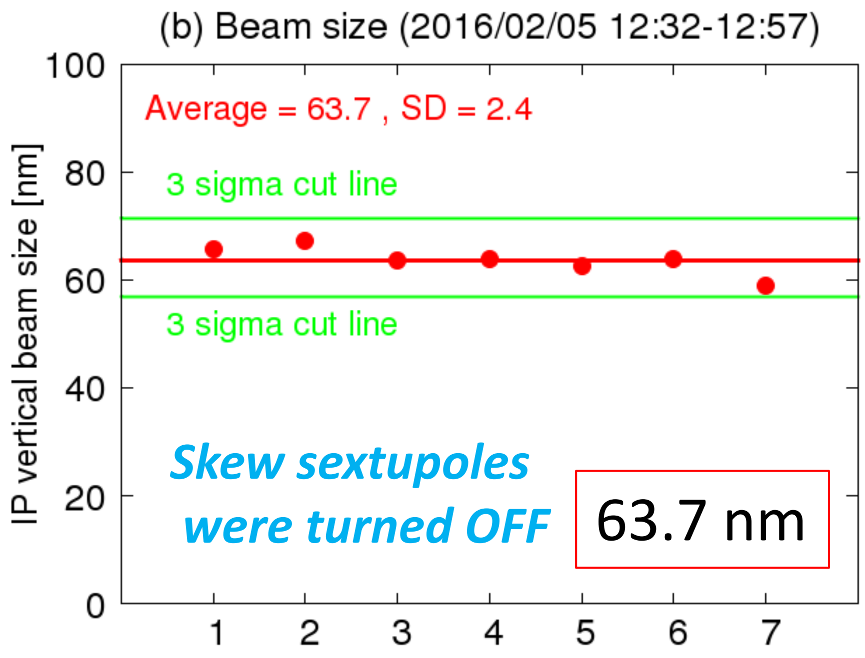


	SK4FF		SK3FF		SK2FF		SK1FF	
	X [um]	Y [um]	X [um]	Y [um]	X [um]	Y [um]	X [um]	Y [um]
2016/01/28	+527	+69	-94	-762	-12	-138	-137	+282
2016/02/03	-185	-193	-31	-43	-6	-26	-81	+41

Good training for ILC FF bam size tuning.

Beam size tuning results on 2016/02/05





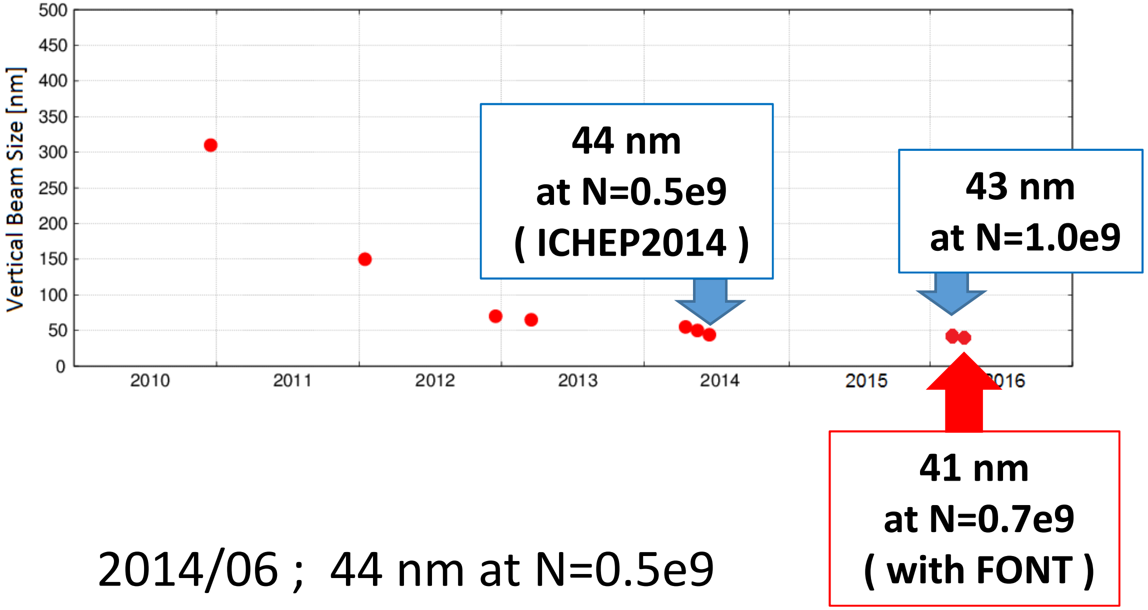
- *The correction with skew sextupoles worked well (same scheme of ILC).*
- *IP beam sizes were evaluated by assuming the perfect laser fringe contrast.*

Good training for ILC FF bam size tuning.

IP beam size trend of ATF2 beam size

Minimum beam size of 41 nm was measured on 2016/03/10 by using FONT orbit jitter correction at N=0.7e9.

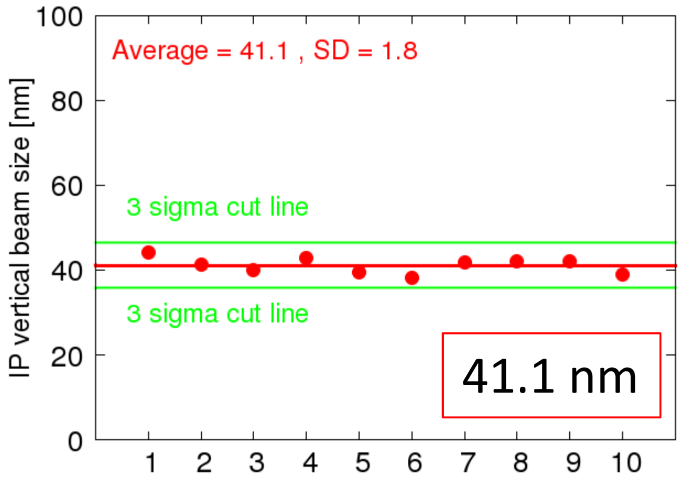
ATF design beam size is 37 nm.



2014/06 ; 44 nm at N=0.5e9
2016/02; 43 nm at N=1.0e9
2016/03; 41 nm at N=0.7e9 with FONT

Minimum beam size

presented by Y. Kano and T. Okugi at ECFA LC workshop 2016.



The beam jitter was subtracted with FONT(*) feedback

Present status of ATF2 beam focusing

	ILC - 500GeV	***ATF2***		***FFTB***	
	Design	Model	Achieved	Model	Result
Correction Method	Local Chromaticity Correction	Local Chromaticity Correction		Global Chromaticity Correction	
Beam Energy	250 GeV	1.28 GeV		46.6 GeV	
L^*	5.20m	1.25 m		0.65 m	
σ_δ	0.12%	0.06%		0.05 %	
β_x^* [mm] $\times$ β_x^* [mm]	11 $\times$ 0.48	40 $\times$ 0.10		10 $\times$ 0.1	
ε_x [nm] $\times$ ε_x [pm]	0.02 $\times$ 0.07	1.5 $\times$ 12		0.33 $\times$ 20	
σ_y^* [nm]	5.9	37	41	45	70
$\xi_y \sigma_\delta$	13.5	7.5		3.25	

Strength of chromatic aberration

Summary of ATF2 beamline

ATF2 beamline was constructed at KEK for the ILC final focus test by international collaboration.

The ATF2 operation has also been carrying out by the international collaboration.

The ATF2 optics is local chromaticity correction scheme as well as ILC design.

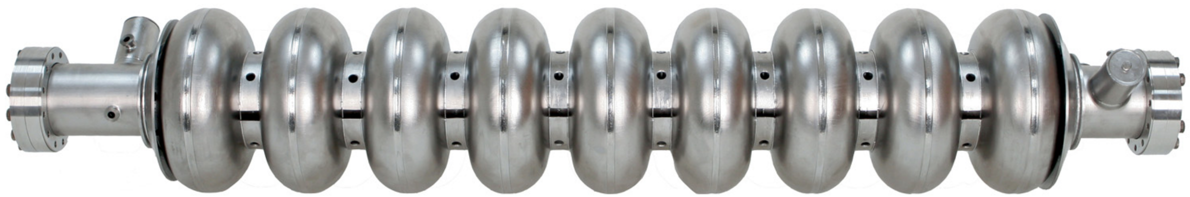
Present ATF2 IP parameter was set to the same difficulty of ILC final focus.

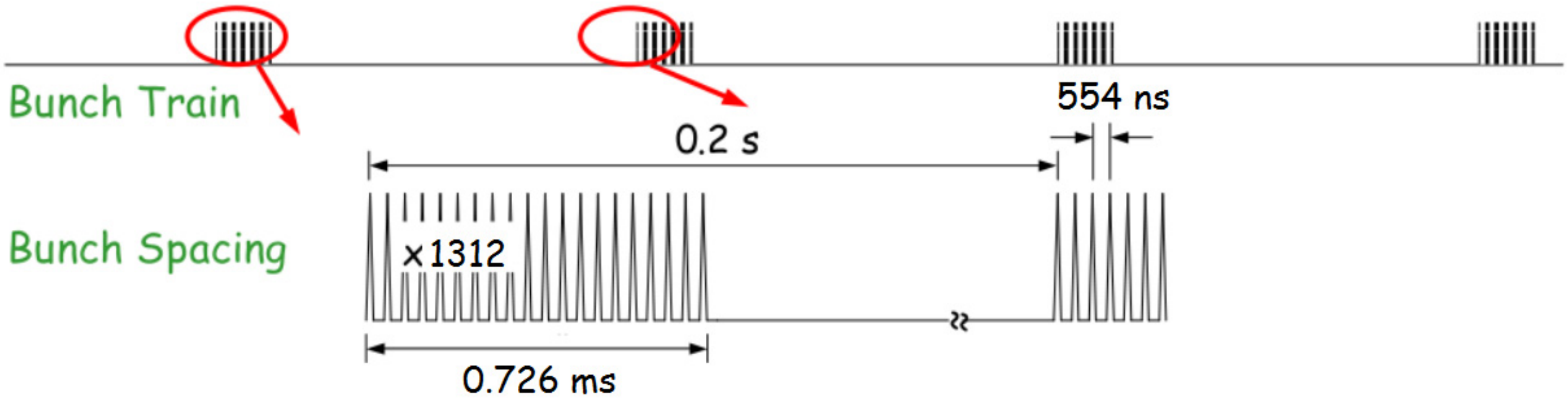
The IP beam size was focused at IP to be less than 41nm.
The number is very close to the design beam size of 37 nm.

Intra-train IP position feedback

Beam position change in the bunch train

ILC RF structure (2a = 70 mm)



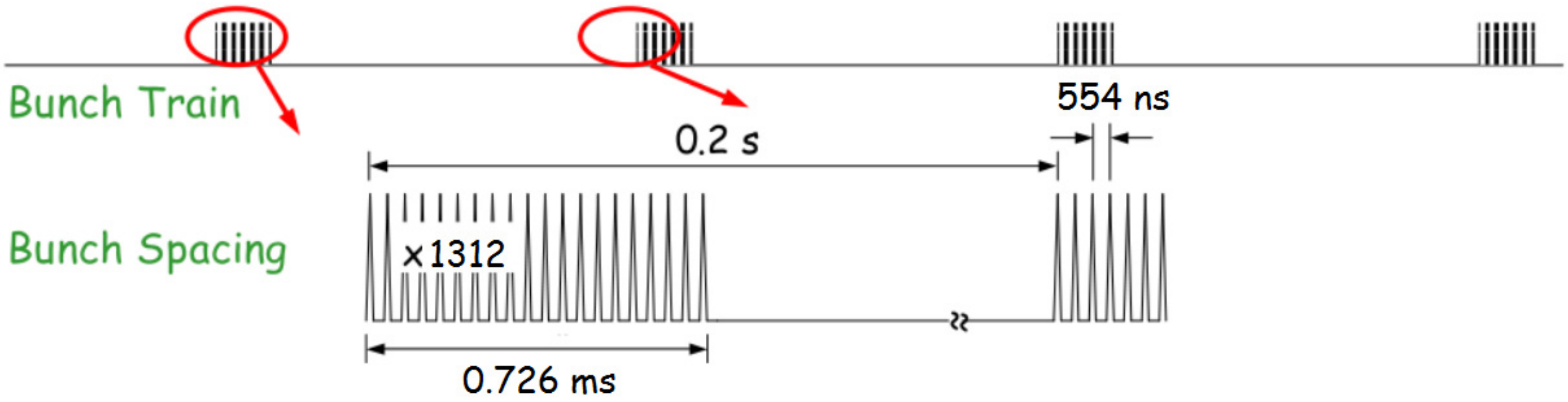


Since the bunch separation is 554 ns for ILC bunch structure, the multi-bunch wake is small effect to ILC beam (dominant for short-range wake).

Bunch-by-bunch position change via wakefield is small.

ILC bunch structure

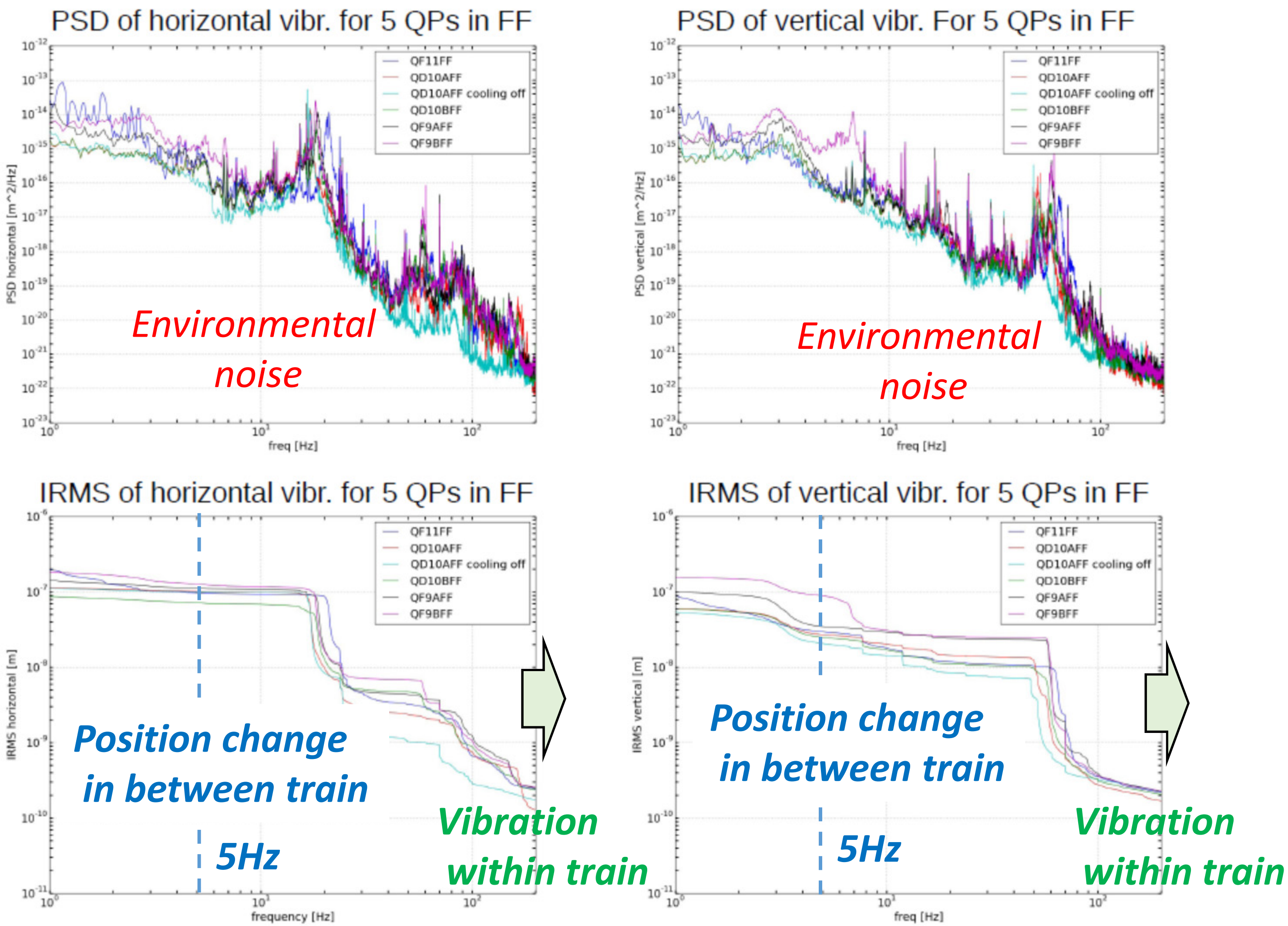
Since the train interval is 0.2 s,
the pulse-by-pulse position difference
affect the vibration above 5Hz.



Since the train length is less than 1 ms,
the position difference within train
affect the vibration above 1 kHz.

Vibration of environmental noise

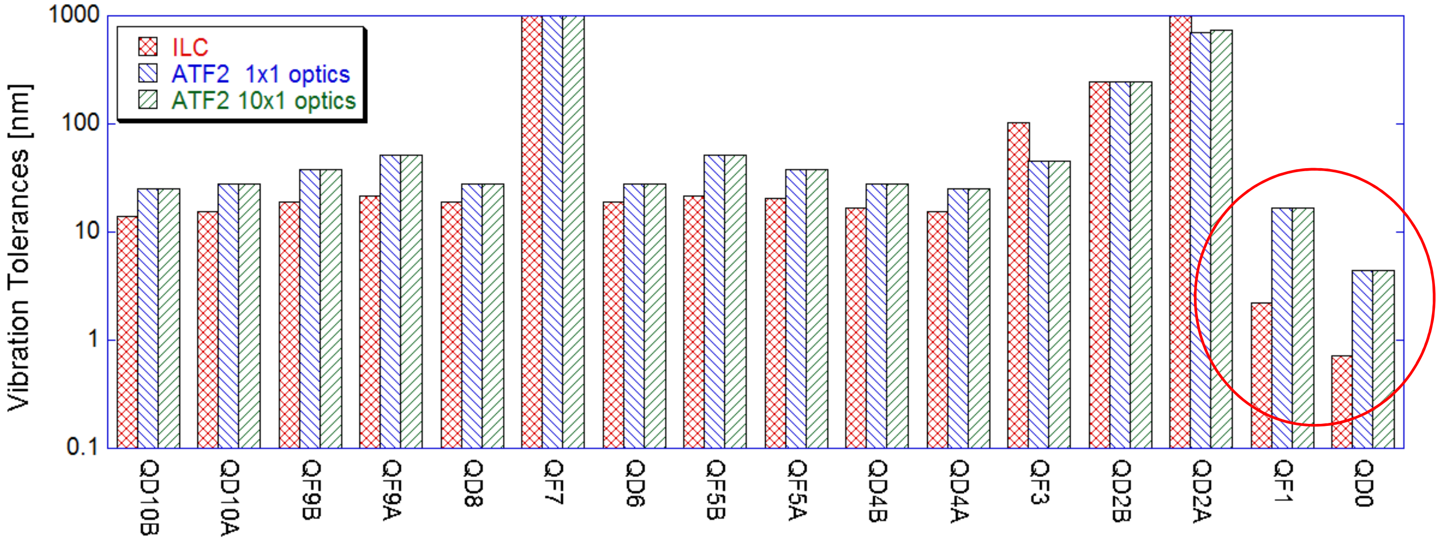
Most of the environmental noises are a few 10Hz.
The amplitude is changed by the ground environment.



Position feedback for 5Hz pulse interval is important for ILC.

Tolerances of magnet vibrations

The tolerances of ILC final doublet are tight.



Tolerance of magnet vibration without feedback

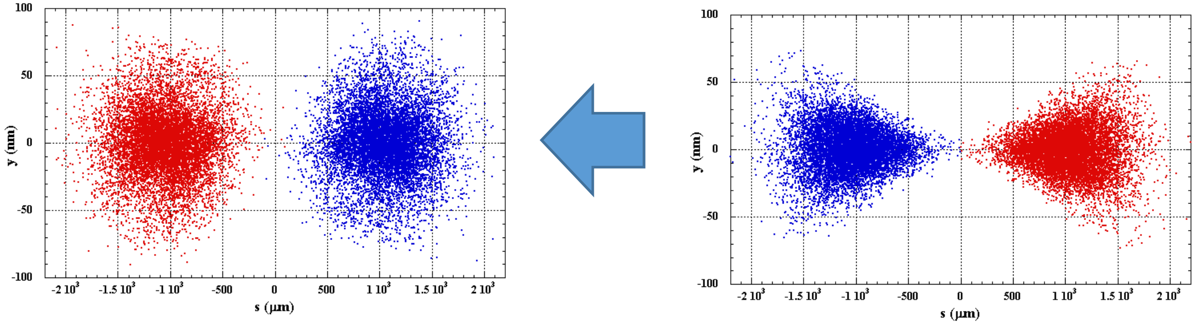
	QF1	QD0
ILC	2.2 nm	0.7 nm
ATF2	16.6 nm	4.5 nm

The vibration tolerances for final doublet are very tight.

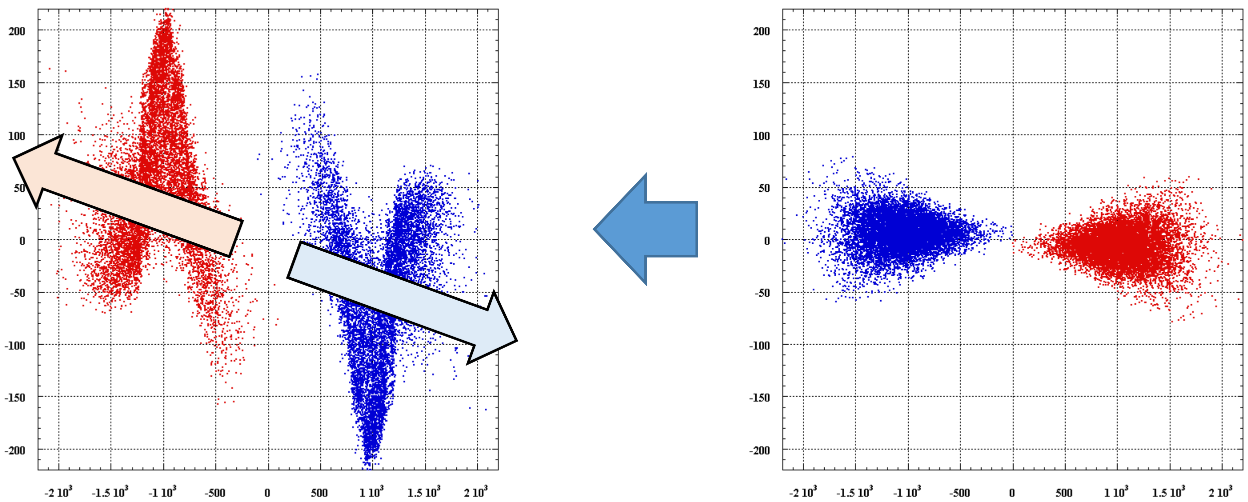
How to monitor the IP beam position

When the beams have large IP offset, the beams are diffracted by beam-beam effect.

ILC 500GeV (Beam offset) = 0

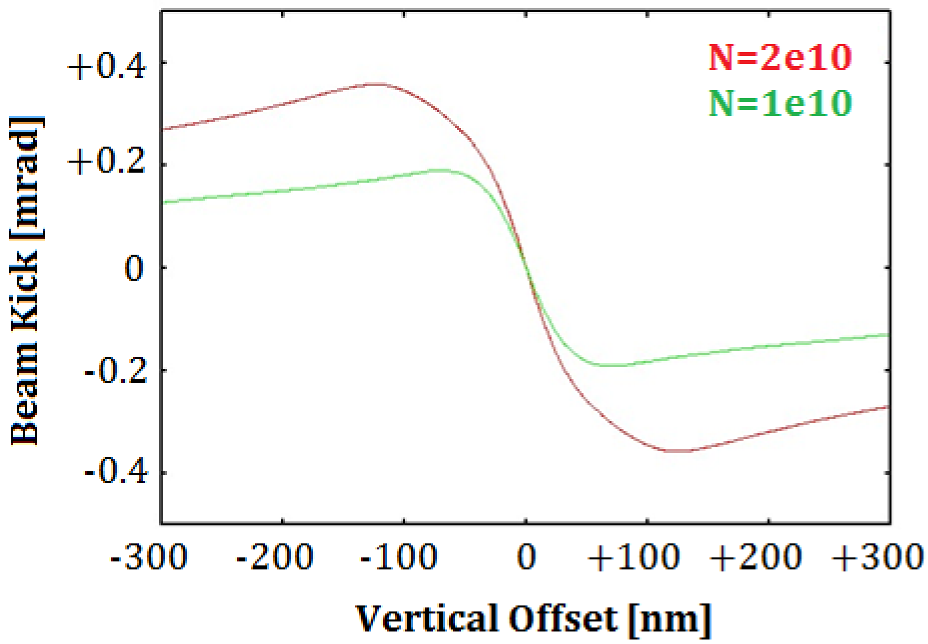


ILC 500GeV (Beam offset) = 1 σ



We can know the IP beam offset from the beam diffraction angle.

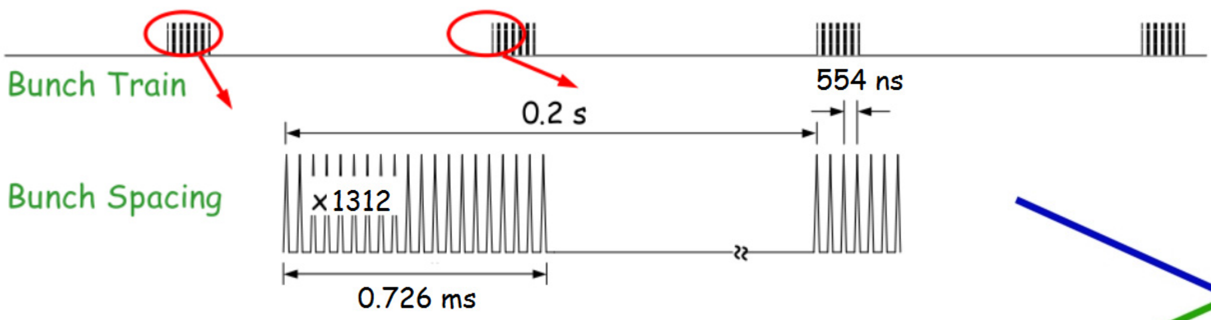
Intra-train position feedback

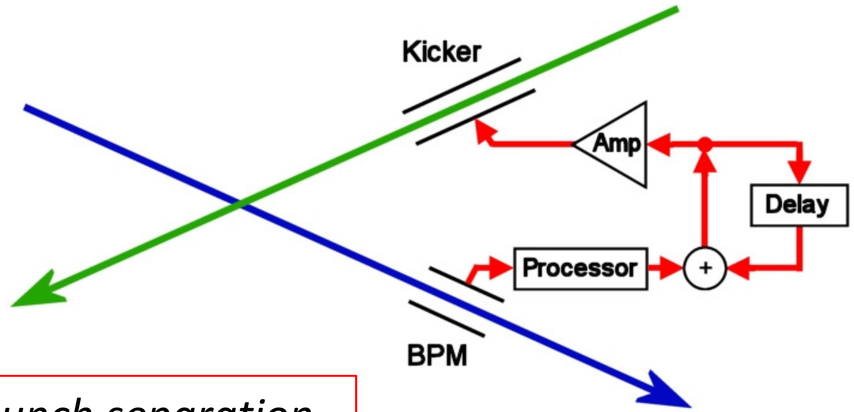


Kick angle at N=2e10 is 4urad/nm.

When BPM is put to R34=5m, the position difference is 20um/nm.

We can correct IP position within 1nm with 20um resolution BPM.



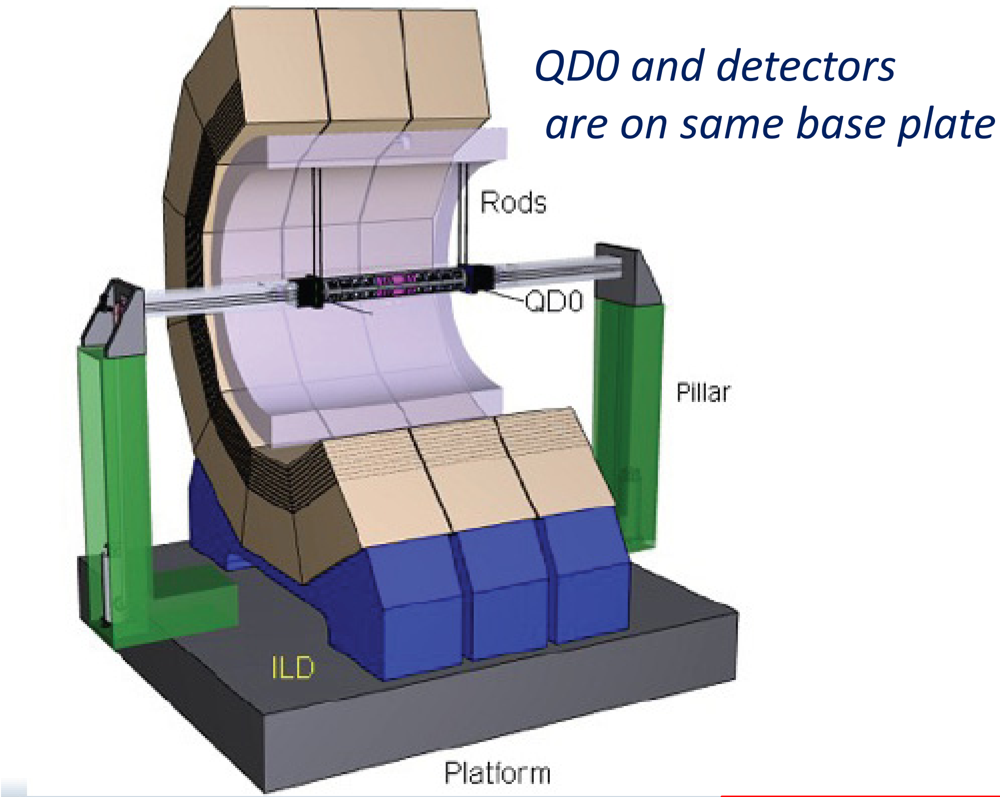


Requirement of latency of feedback is within bunch separation.

Vibration Sources 1

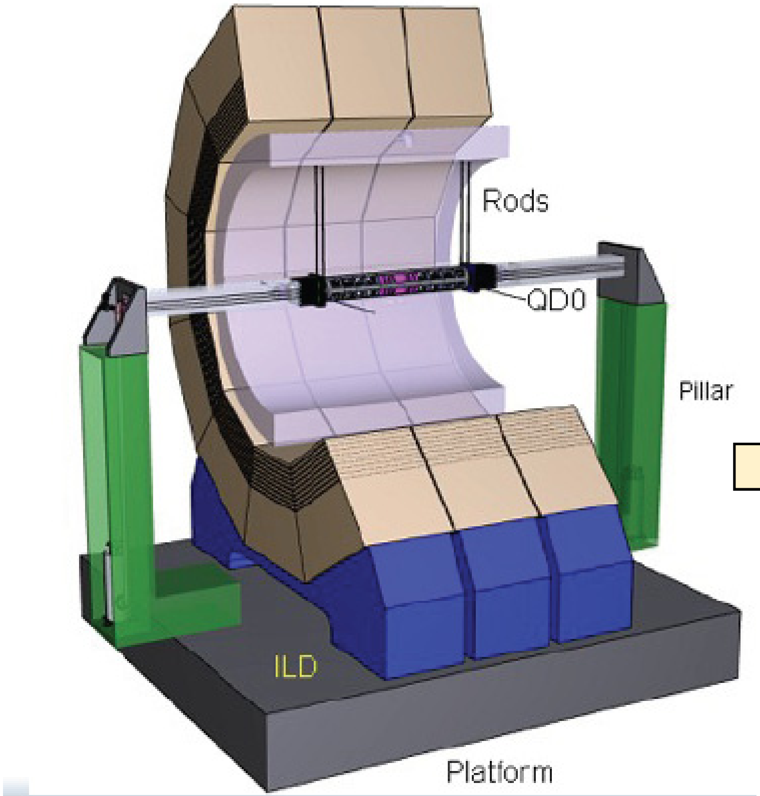
The QD0 vibration generate the IP beam vibration.

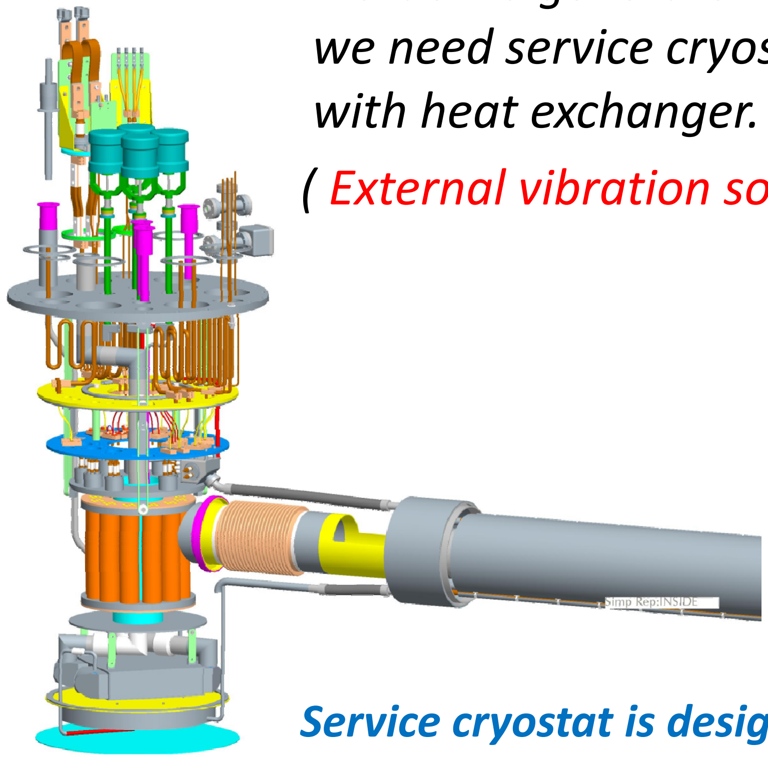
The QD0 is supported by using long pillars,
the vibration of the cryogenic transfer line is a problems for ILC.



In order to avoid the liquid Helium vibration,
ILC designed to use 2K helium to be super-fluidity.

Vibration Sources 2





In order to generate 2K Helium, we need service cryostat with heat exchanger.

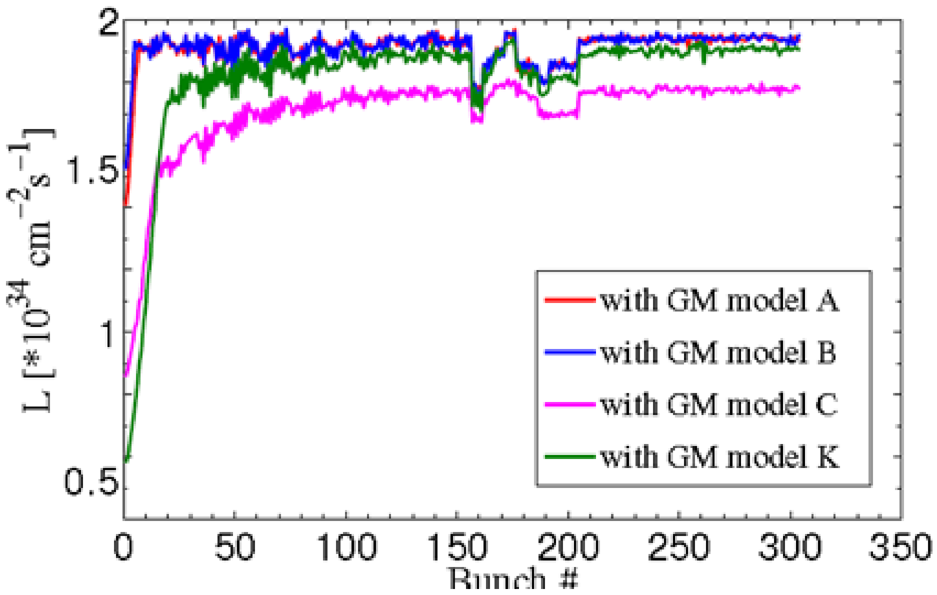
(External vibration source ??)

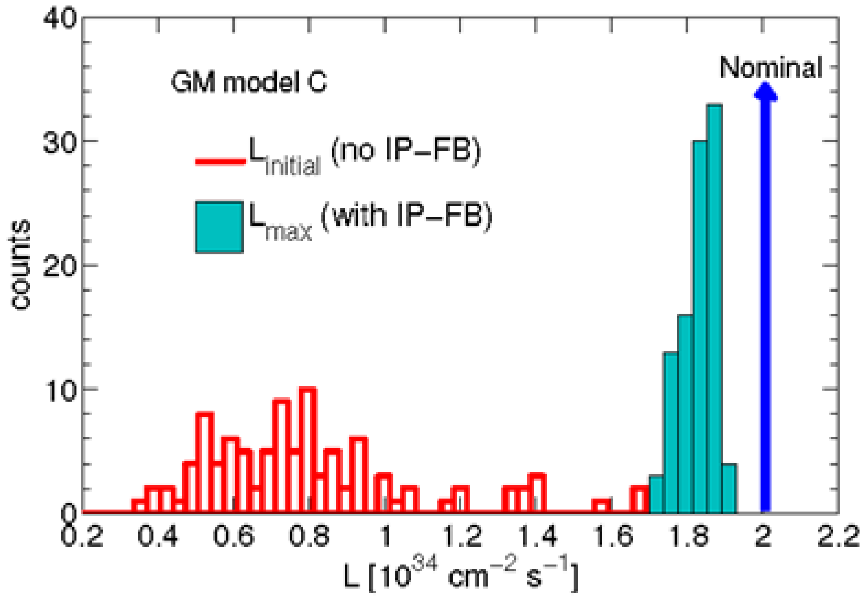
Service cryostat is designed to locate into the pillar.

The tolerance of QD0 vibration is 50 nm by using intra-train FB.

ILC Intra-train feedback simulation

Simulated by G. White with ground motion model A,B,C:
International Linear Collider Technical Review Committee,
Second Report, SLAC-R-606, 2003.



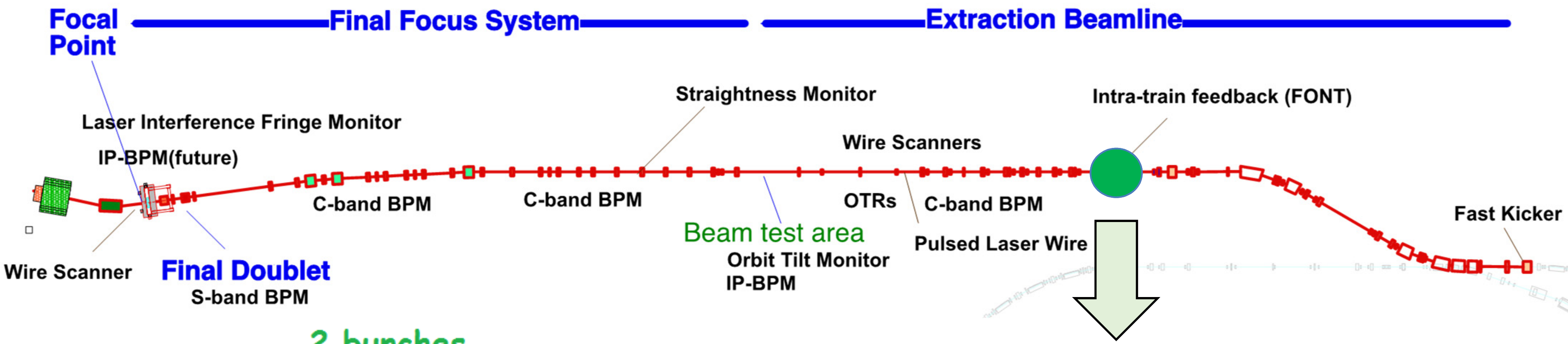


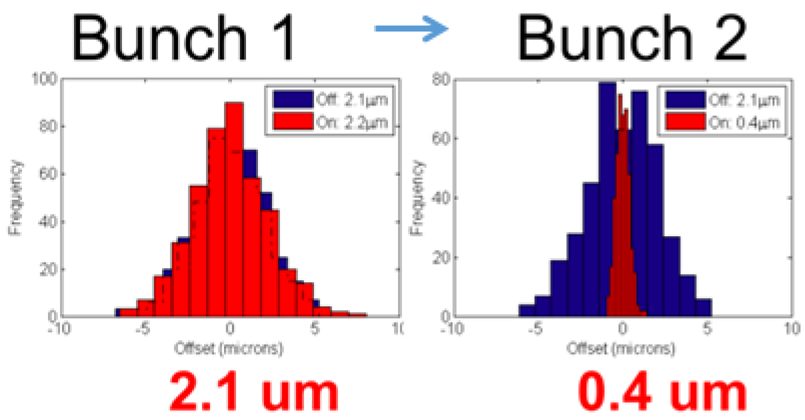
The luminosity is reduced by the ground motion.

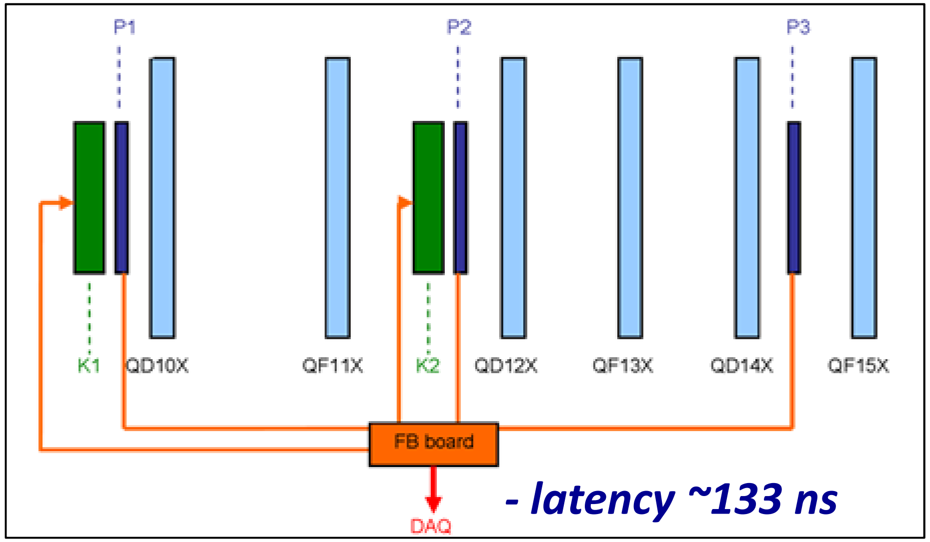
But, the luminosity can be recovered by using intra-train feedback.

FONT (Feedback On Nanosecond Time scale)

developing by Oxford Univ,
the detail of FONT is in " N. Kraljevic et al., Proc. of IPAC16, THPOR035".



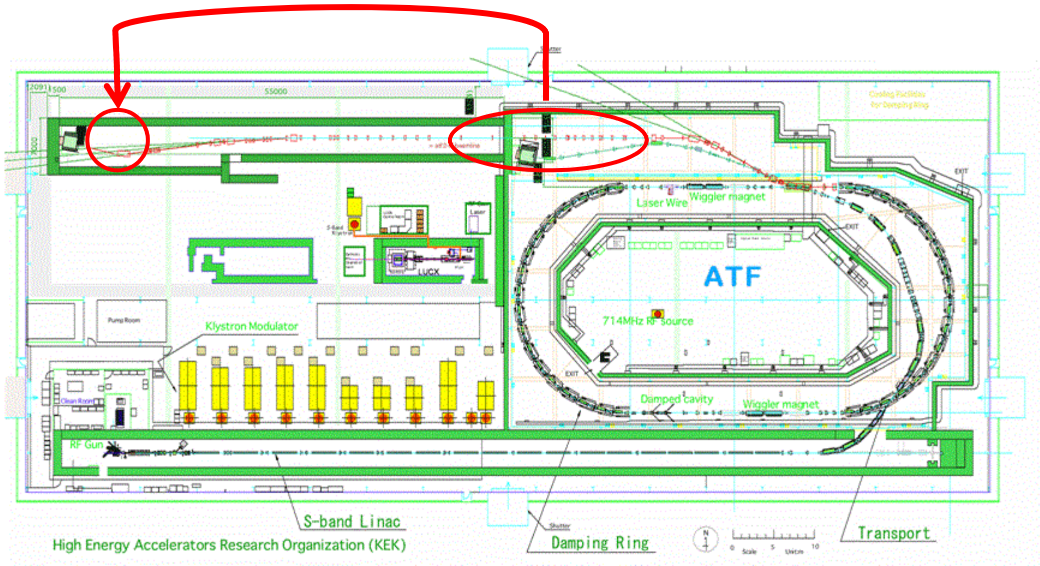


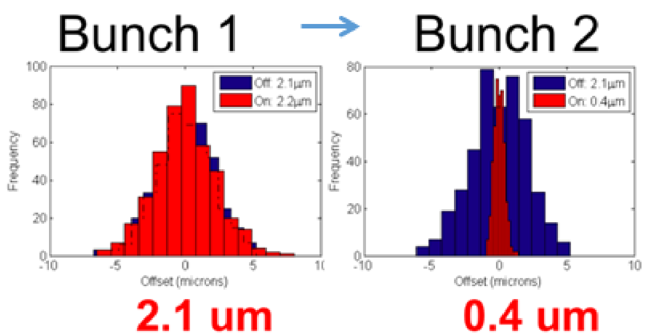


(y, y') *2-dimensional feedback with 2 BPMS ans 2 kickers*

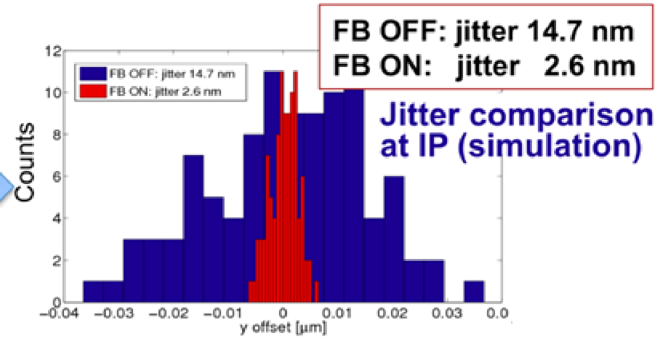
Propagation to IP position jitter

The position jitter, stabilized by FONT was propagated to ATF2 IP.





Assuming perfect lattice, no further imperfections (!)



The IP position jitter was reduced to 2.6 nm by using FONT.
(180 ns bunch spacing)

ILC is 554 ns

Summary of Intra-train IP position feedback

In general, the vibration tolerance of final doublet is very tight for linear colliders.

Therefore, we will use the intra-train IP position feedback for ILC.
We will correct the IP beam position within the bunch spacing.

When the 2 beams has offset at IP,
the large diffraction angle is generated by beam-beam interaction.
The IP position will be corrected by measuring the diffracted angle.

The simulation said the luminosity can be recovered with intra-train feedback,
even if we assumed the ground motion.

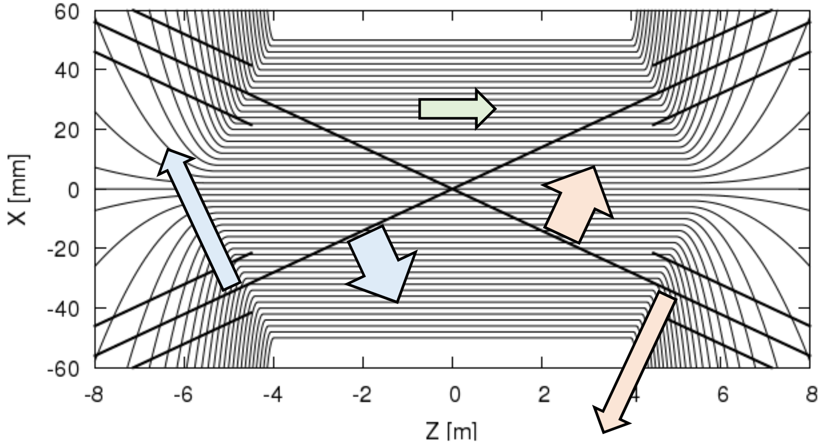
The FONT (feedback On Nanosecond Time scale) has been tested in ATF.
The IP beam position stability by FONT was evaluated to be 2.6 nm.

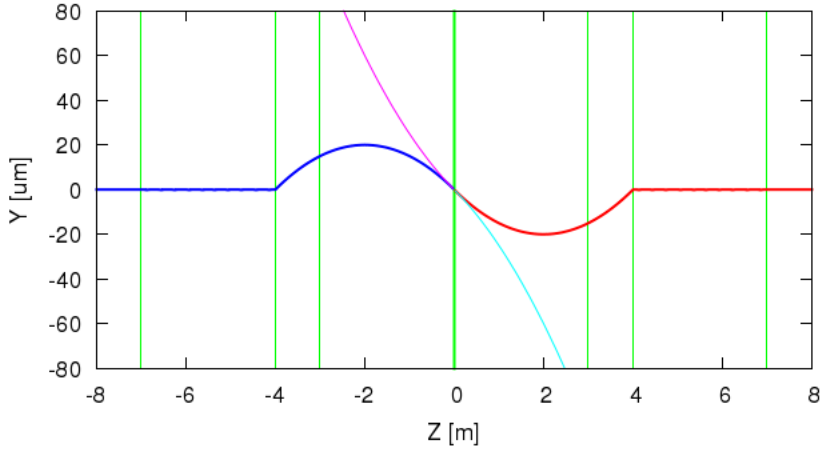
ILC Machine Detector Interface

Detector solenoid field with IP crossing angle

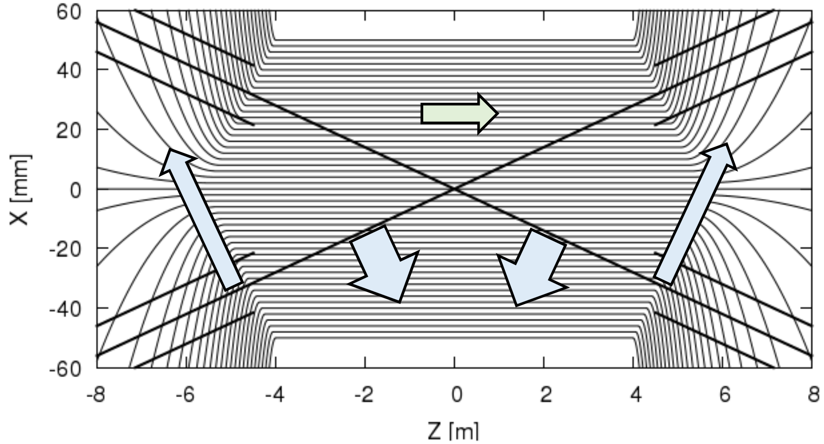
Detector solenoid field affect to the vertical beam orbit,
when the beams are collided with IP crossing angle.

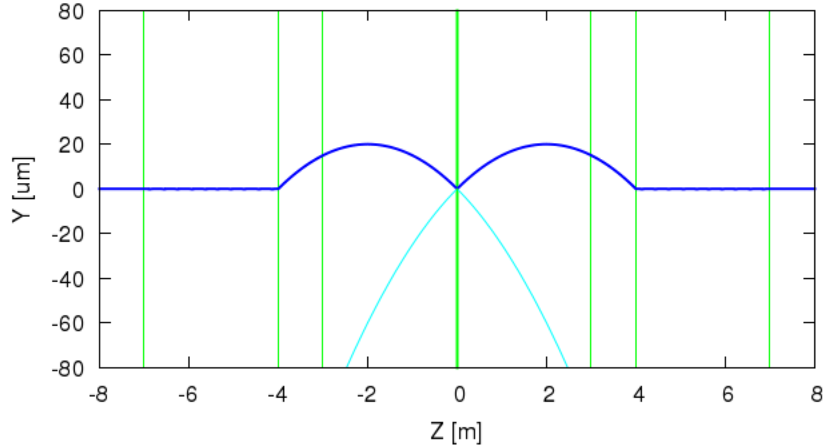
Electron-positron collision





Electron-electron collision





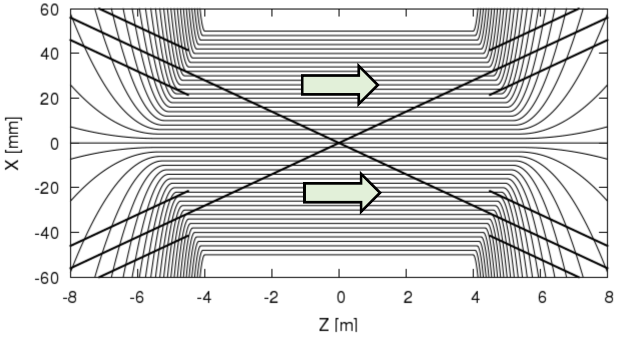
No head on collision

Detector Integrated Dipole (DID)

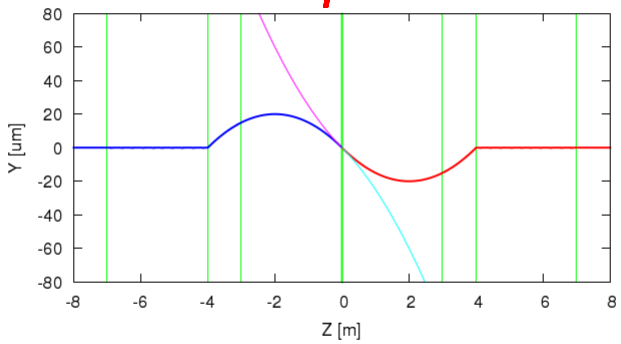
Idea to compensate the dipole field, generated by detector solenoid.

Without DID

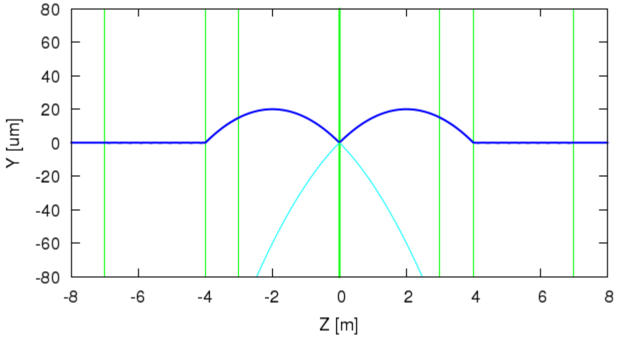
Magnetic field



Electron-positron

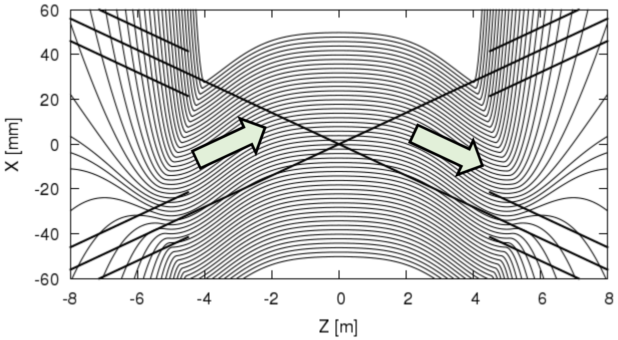


Electron-electron

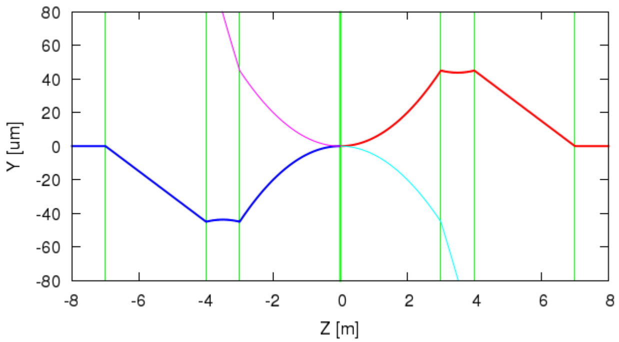


With DID

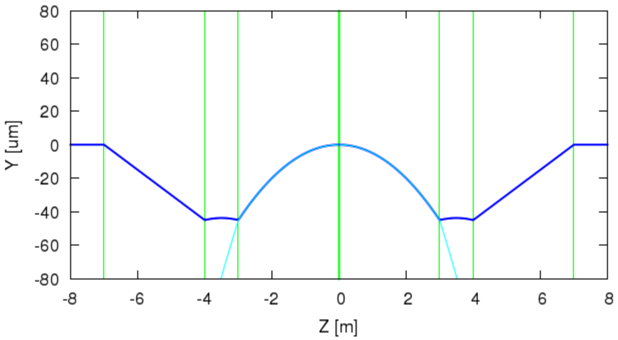
Magnetic field



Electron-positron



Electron-electron



Magnetic field will be parallel to incoming beam direction.

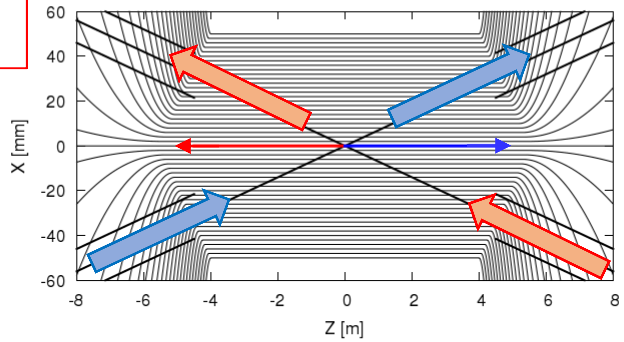
The electron-electron collision is also head-on collision.

The large number of low energy particles (incoherent pairs) will be generated after the collision. In order to reduce the detector background, it is very important to transport the low energy particles to extraction line

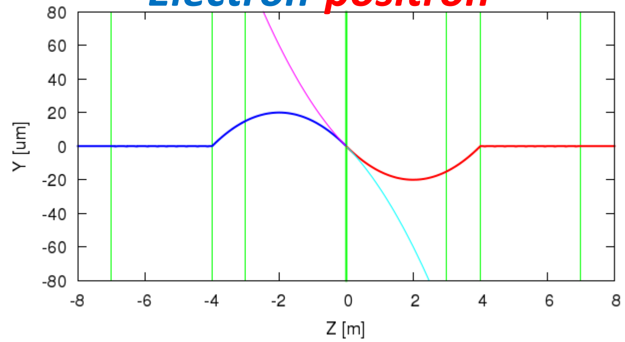
Large angular spread after collision

Without DID

Particle orbits after collision



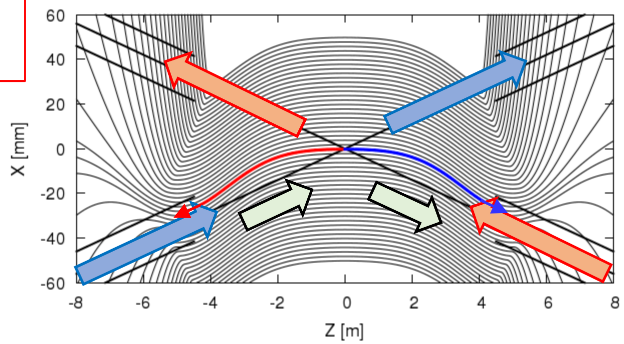
Electron-positron



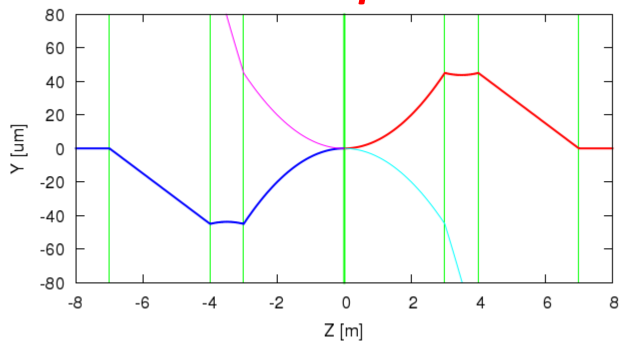
Angular spread will be enhanced.

With DID

Orbit of low energy particles



Electron-positron

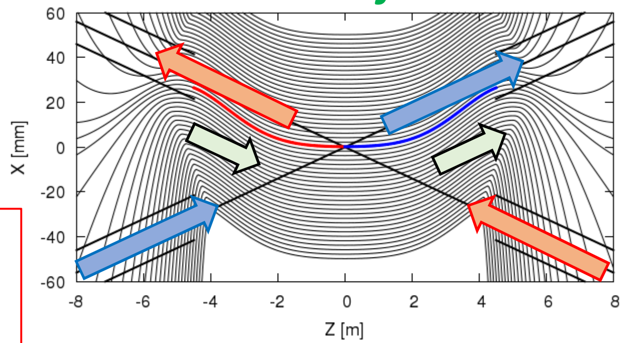


Anti-DID

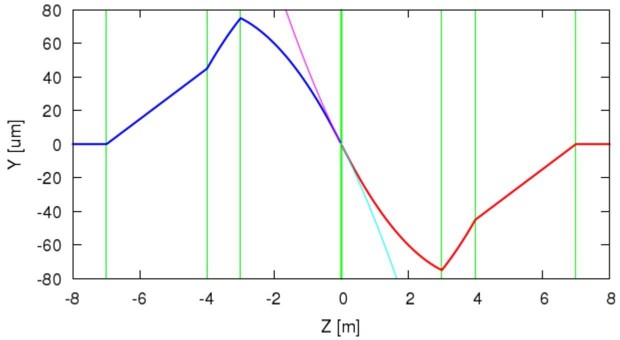
By applying the opposite field of DID,
the magnetic field direction will be able to set to be along the out-going beam line.

With anti-DID (Present ILC design)

Particle orbits after collision



Electron-positron

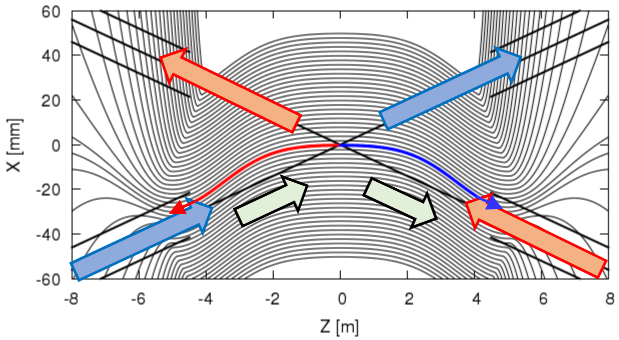


Angular spread and detector background will be reduced.

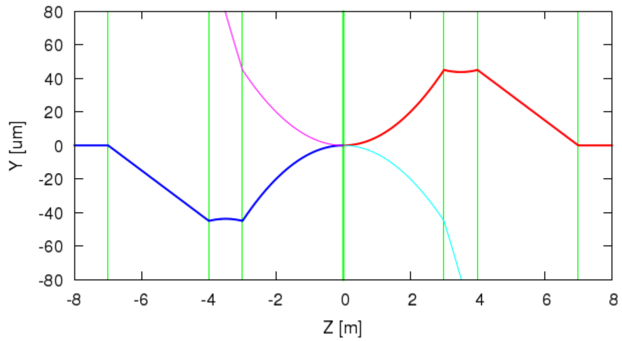
Vertical angular offset will be enhanced

With DID

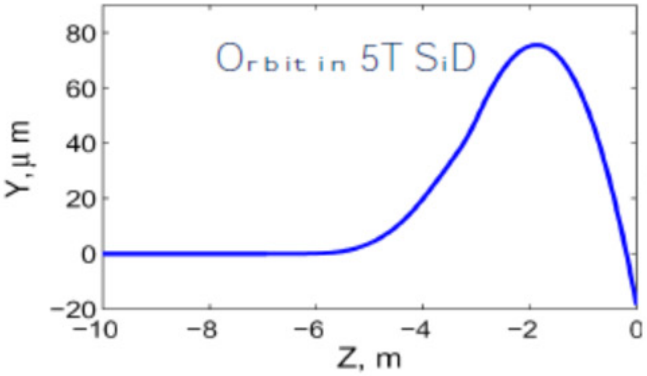
Orbit of low energy particles

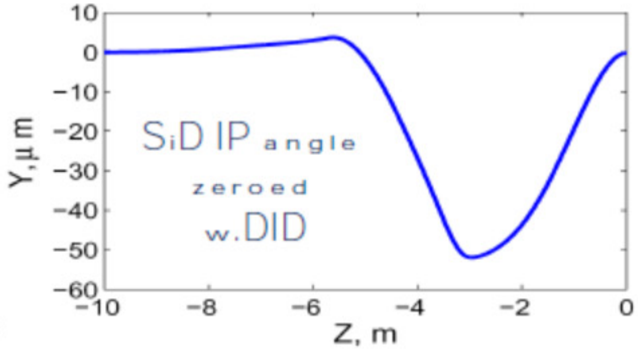


Electron-positron



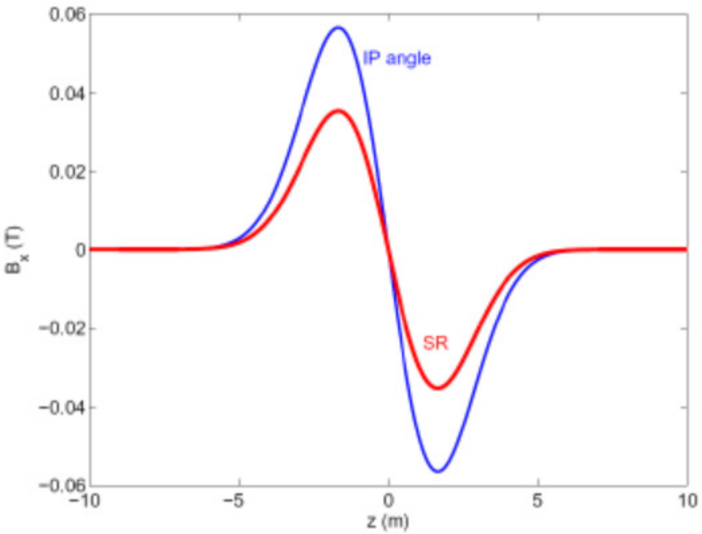
Use of DID or anti-DID

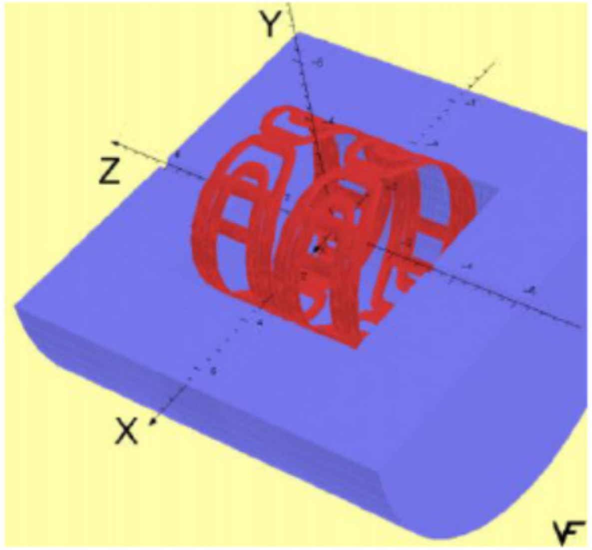




DID case

DID field shape and scheme





- The negative polarity of DID is also possible (called anti-DID)

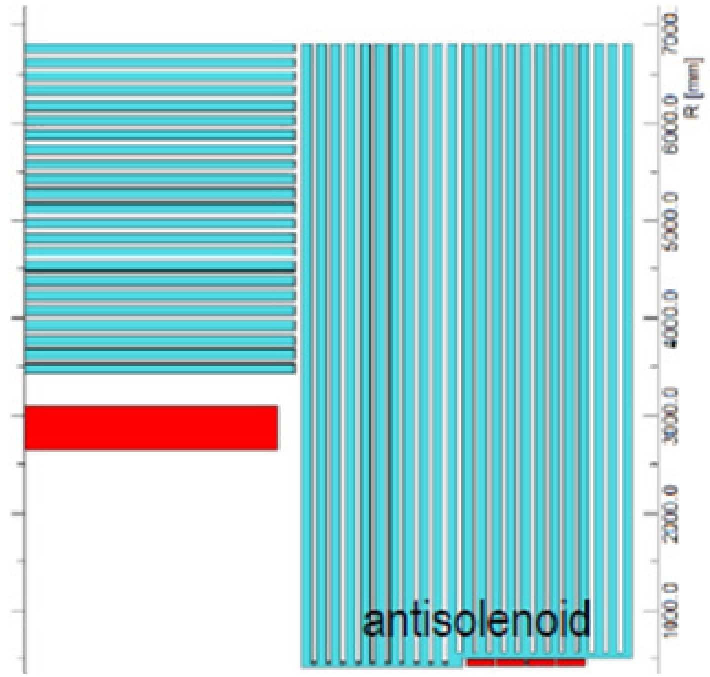
- In this case the vertical angle at the IP is somewhat increased, but the background conditions due to low energy pairs (see below) and are improved

Anti-solenoid Magnet around QD0

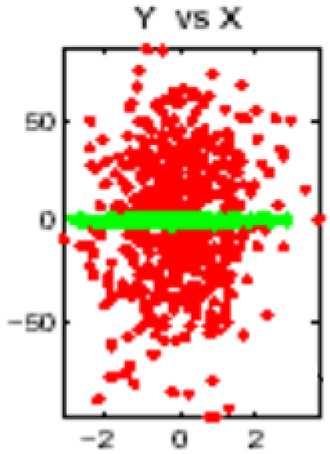
Detector is covered by strong solenoid magnet.

QD0 magnet was located within the solenoid field.

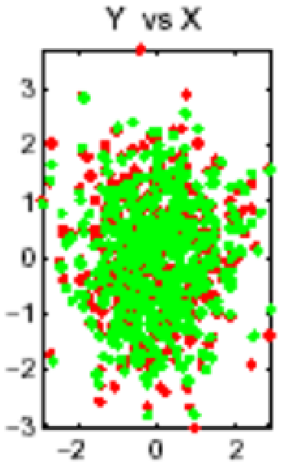
The solenoid field generate strong x-y coupling to beam.



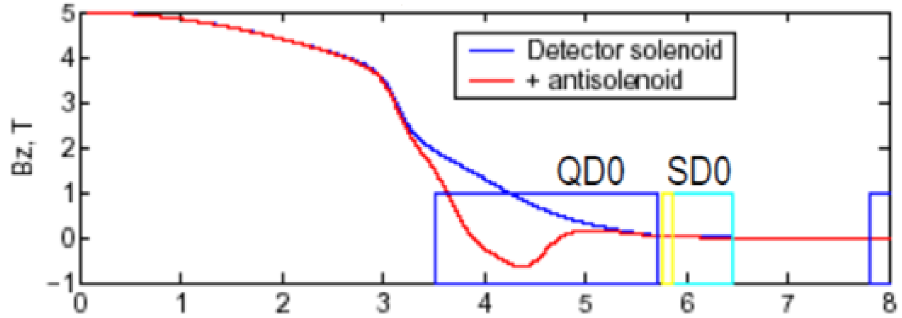
w/o anti-solenoid

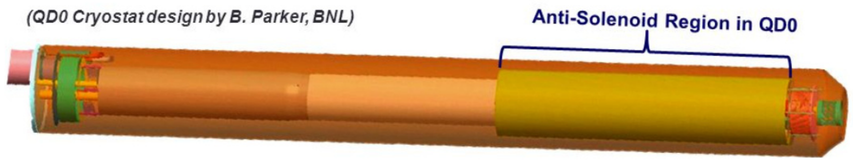


with anti-solenoid



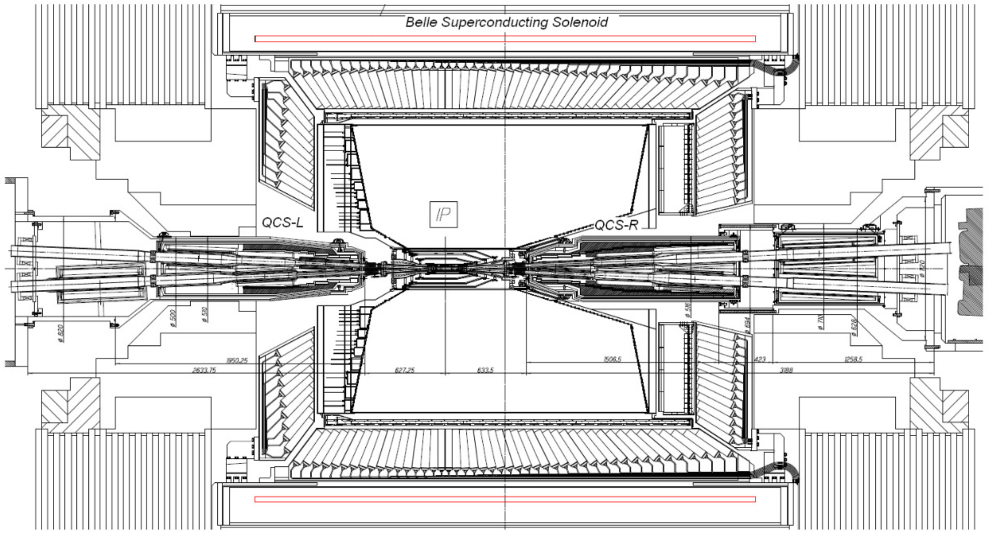
Green ; no field
Red ; with field

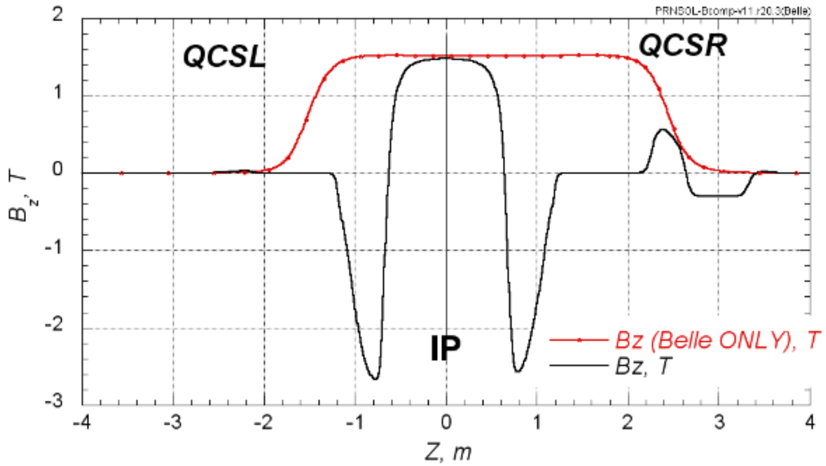


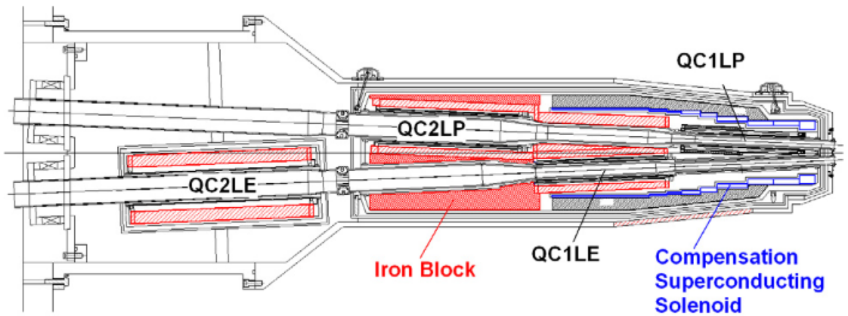


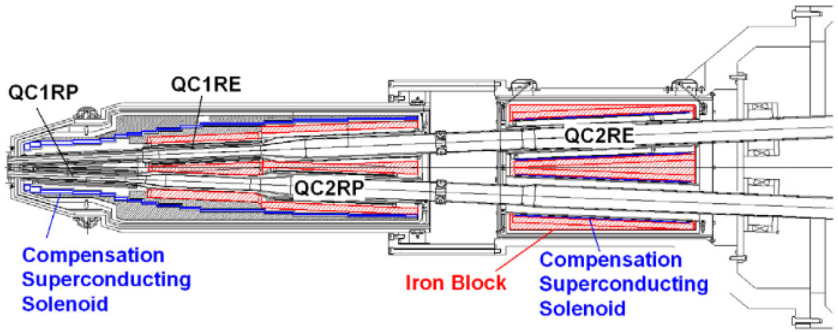
Example of IR magnets (SuperKEKB)

H.Yamaoka et al., Proceedings of IPAC2012, New Orleans, Louisiana, USA





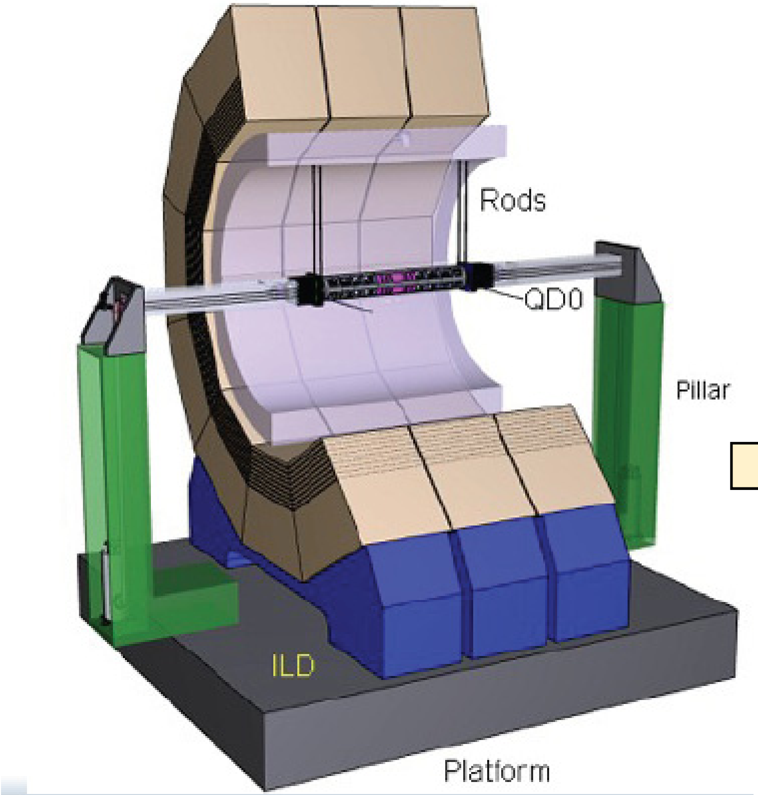


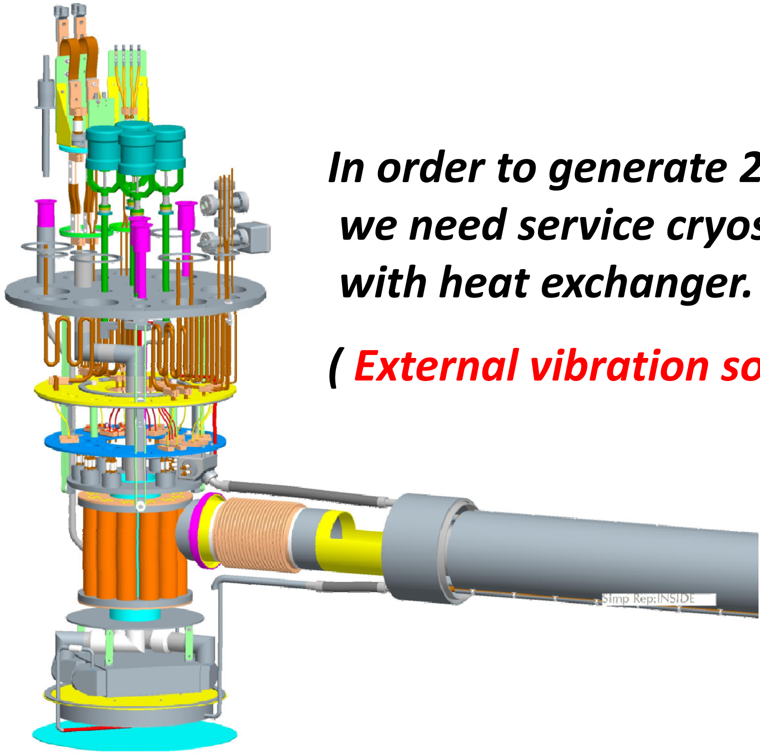


The actual hardware makes a lot of multipole field component.
The tolerances will also be reduced for the actual interfaces.

Vibration of ILC QD0 magnet

In order to avoid the liquid Helium vibration,
ILC designed to use 2K helium to be super-fluidity.





In order to generate 2K Helium,
we need service cryostat
with heat exchanger.

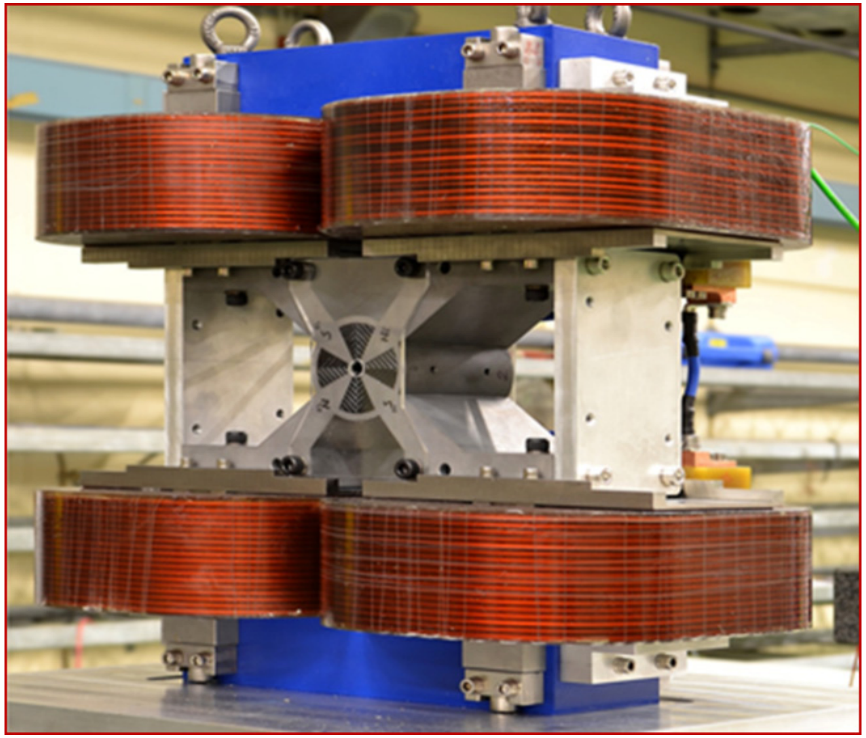
(External vibration source ??)

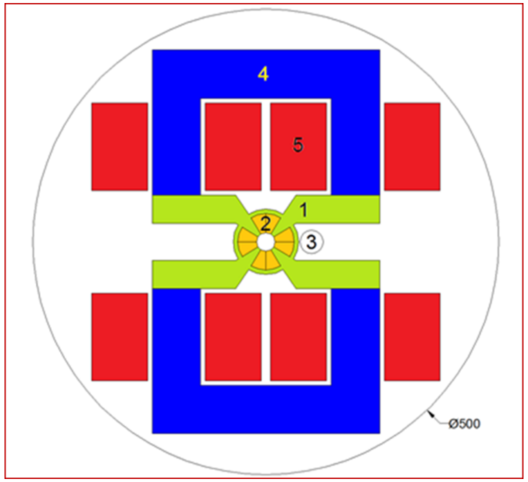
The tolerance of QD0 vibration is 50 nm by using intra-train FB.

Larger L* Optics (Optional)

If we will be able to put QD0 outside of detector solenoid,
we can use simple and rigid IP devices.
- can avoid the solenoid field.
- can reduce the vibration of QD0

i.e.) CLIC Hybrid magnets
permanent and electro-magnetic coil

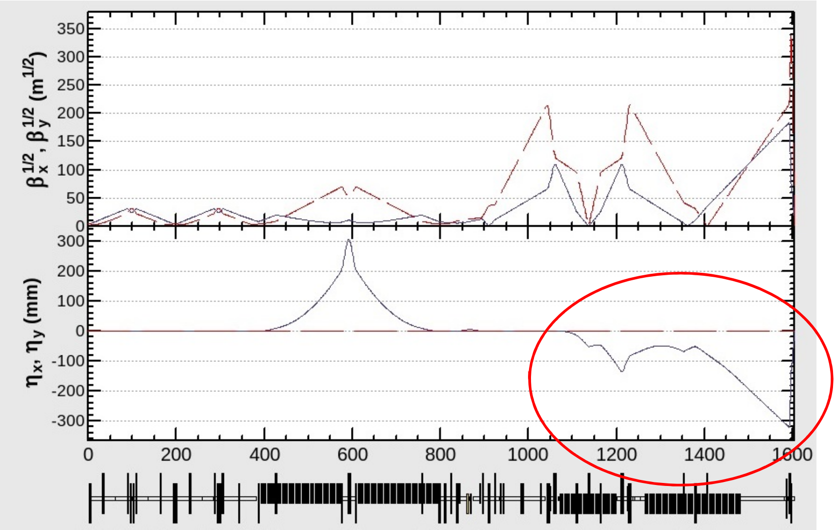




NI [A]	0	1250	2500	3750	5000
G [T/m]	34.494	42.807	68.333	98.196	127.30
b6	63.206	46.397	20.332	7.049	0.021
b10	0.219	0.166	0.083	0.041	0.022
b14	-0.001	0.000	0.001	0.001	0.001
b18	0.027	0.020	0.009	0.003	0.000

Long L* Optics with Local Chromaticity Correction

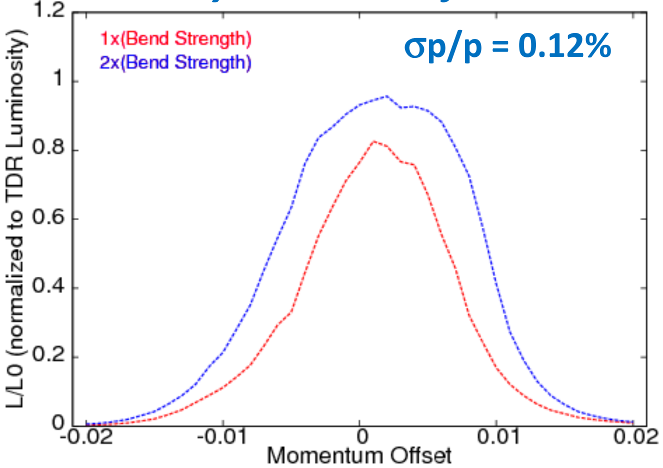
presented by T. Okugi (KEK) at AWLC2014



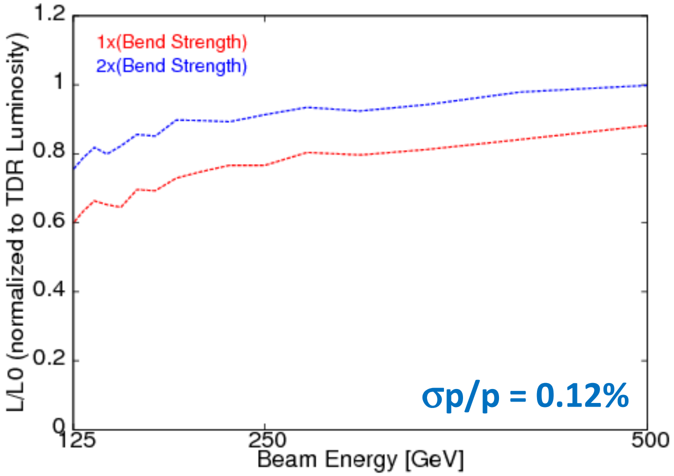
The strength of bending magnet was increased to twice to increase dispersion and strength of sextupoles.

IP Beam Size at E=250GeV	sigmaX*	sigmaY*
w/o Synchrotron Radiation	0.50um	5.81nm
with Synchrotron Radiation	0.50um	5.95nm

Luminosity Bandwidth for E=250GeV



Energy Dependence of Luminosity

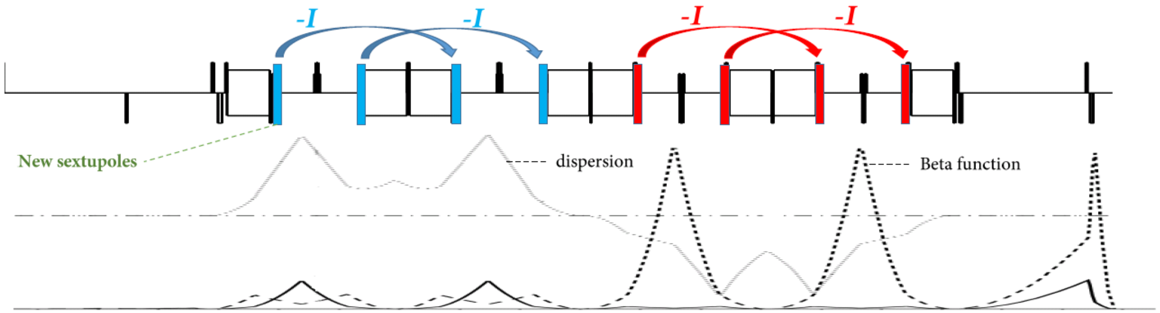


The geometry of BDS beamline is changed.

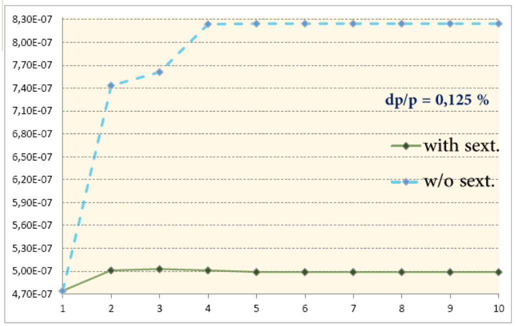
L*=8m optics based on "Traditional Optics"

presented by Marcin Patecki (CERN) at AWLC2014

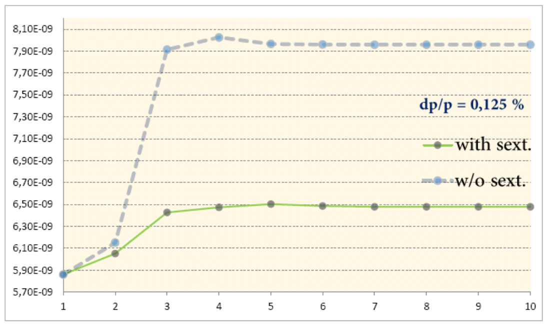
- Nonlinear aberrations cause high **loss of luminosity induced by L*=8m** ⟹ Need to add extra sextupoles
- Chromaticity is corrected by placing sextupoles magnets in phase in **regions of dispersion and high beta function**
- Adding sextupoles provide 3rd-order geometric aberration which can be cancelled by **placing them in pairs** and by **separating them by a $-I$ transformation** ⟹ $-I = \begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix}$



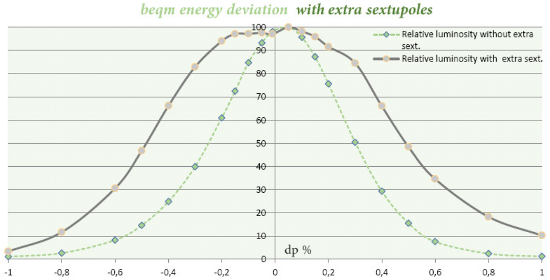
Horizontal beam sizes at the IP compared with traditional design



Vertical beam sizes at the IP compared with traditional design



Relative Lumininosity with synchrotron radiation as function of beqm energy deviation ***with extra sextupoles***



Influence of synchrotron radiation on beam sizes and Luminosity ***(dp/p= 0,125%)***

RMS w/o. sync. $\sigma_x{}^*$ RMS w. sync. $\sigma_x{}^*$	498,2 nm 502,81 nm
RMS w/o. sync. $\sigma_y{}^*$ RMS w. sync. $\sigma_y{}^*$	6,45 nm 9,36 nm
w/o. sync. . $L_{1\%}^{peak}$	$0{,}87 \times 10^{34}\ cm^{-2}.s^{-1}$
with sync. . $L_{1\%}^{peak}$	$0{,}85 \times 10^{34}\ cm^{-2}.s^{-1}$
w/o. sync. L_T	$1{,}41 \times 10^{34}\ cm^{-2}.s^{-1}$
with sync. L_T	$\boxed{1{,}38 \times 10^{34}\ cm^{-2}.s^{-1}}$

Higher order aberrations are cancelled by using 4 sextupole pairs.

Comments for Large L* Optics

The large L optics makes simple final focus magnet scheme.*

The large L optics can use the small vibrating magnet to QD0.*
The minimization of the QD0 vibration is very important for CLIC.
ILC can correct the QD0 position jitter (<50um) by using intra-train FB.

The preliminary optics was designed for ECM=500GeV.

But, the optics is only still conceptual design stage, and must take care of

- *beamline geometry as a total system.*
- *optimization of collimation depth.*
- *application for lower and higher beam energy etc.*

We have a lot of works to realize the technical design of the large L optics.*

It means that we can enjoy to design the large L optics !*

Summary of ILC Machine Detector Interface

When the beam has the crossing angle,
the beam was kicked to vertical direction by detector solenoid field.

For electron-electron collision,
the beams will not be collide head-on for the vertical kick.

- *DID helps to compensate the kick angle, and establish the head-on collision.*
- *But, it makes large angular spread for out-going beam.*
  The angular spread makes the large background to detector.

In order to reduce the background for out-going beam,

- *Anti-DID helps to transport the beams with large energy spread to extraction line.*
- *Anti-DID adopted to the present ILC design.*

Detector solenoid also make the large XY coupling to beam.

- *Anti-solenoid will be used to compensate the XY coupling by the detector solonoid.*

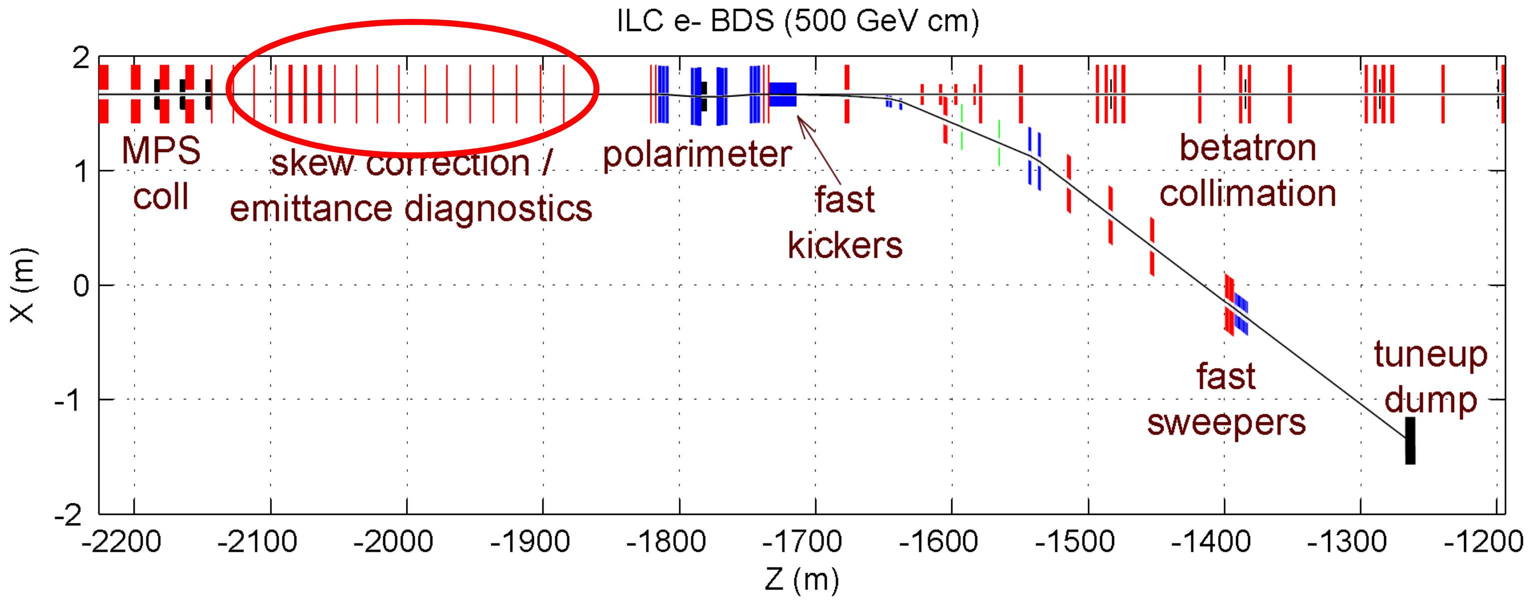
One of the idea to make the machine detector interface simple is large L optics.*

I suggest that the design of other concept final focus system is very nice start-point
to investigate the final focus optics for linear colliders.

The large L optics is a candidate of it.* ***Please enjoy !***

ILC Beam Diagnostic Section

Schematic Overview of ILC Beam Diagnostic Section

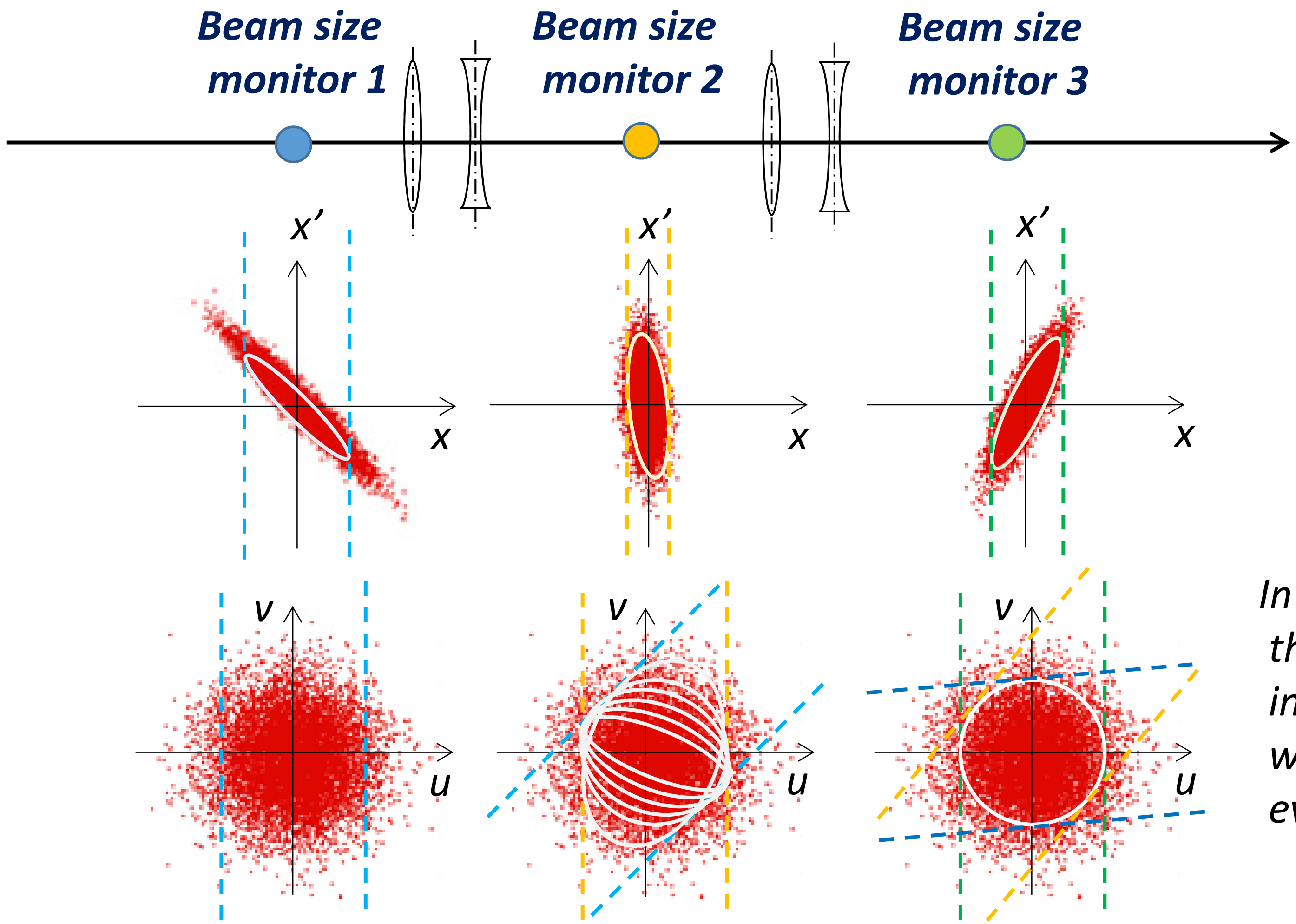


In ILC beam diagnostic section,
we will measure and correct the following beam properties.

- *beam emittance measurement.*
- *matching of beam parameters to following beam line.*
- *coupling correction.*
- *polarity measurement.*
- *Beam energy measurement.*

The measurement and correction will be done at the red circle in above figure.

Emittance and Twiss parameter Measurement



can not draw the circle only one measurement

still have ambiguity for 2 measurements

In order to make the measurement independent, we must put monitors every 30degree or more.

We need 3 or more monitors to evaluate emittance and Twiss parameters.

Coupling Correction

2D Beam Matrix

$$\Sigma_x = \begin{pmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{pmatrix} = \varepsilon_x \begin{pmatrix} \beta_x & -\alpha_x \\ -\alpha_x & \gamma_x \end{pmatrix}$$

$$\Sigma_y = \begin{pmatrix} \sigma_{33} & \sigma_{34} \\ \sigma_{43} & \sigma_{44} \end{pmatrix} = \varepsilon_y \begin{pmatrix} \beta_y & -\alpha_y \\ -\alpha_y & \gamma_y \end{pmatrix}$$

Propagation of beam matrix can be expressed with Transfer Matrix.

$$\Sigma_{x,2} = M_x \Sigma_{x,1} M_x^{-1}$$

$$\Sigma_{y,2} = M_y \Sigma_{y,1} M_y^{-1}$$

$$\sigma_{12} = \sigma_{21}$$

$$\sigma_{34} = \sigma_{43}$$

3 independent parameters both for x and y.

6 independent parameters in total.

4D Beam Matrix

$$\Sigma = \begin{pmatrix} \multicolumn{2}{c}{\Sigma_x} & \sigma_{13} & \sigma_{14} \\ & & \sigma_{23} & \sigma_{24} \\ \sigma_{31} & \sigma_{32} & \multicolumn{2}{c}{\Sigma_y} \\ \sigma_{41} & \sigma_{42} & & \end{pmatrix}$$

$$\sigma_{13} = \sigma_{31}$$

$$\sigma_{14} = \sigma_{41}$$

$$\sigma_{23} = \sigma_{32}$$

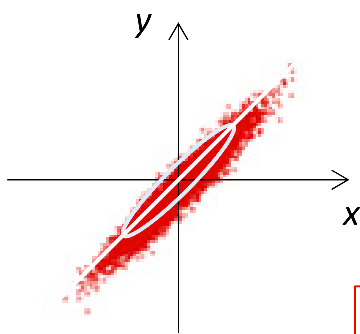
$$\sigma_{24} = \sigma_{42}$$

4 more independent parameters.

10 independent parameters in total by taking account of xy coupling.

We need 10 independent measurements to evaluate the 4D Beam Matrix.

We need 4 independent coupling sources to correct the x-y coupling.



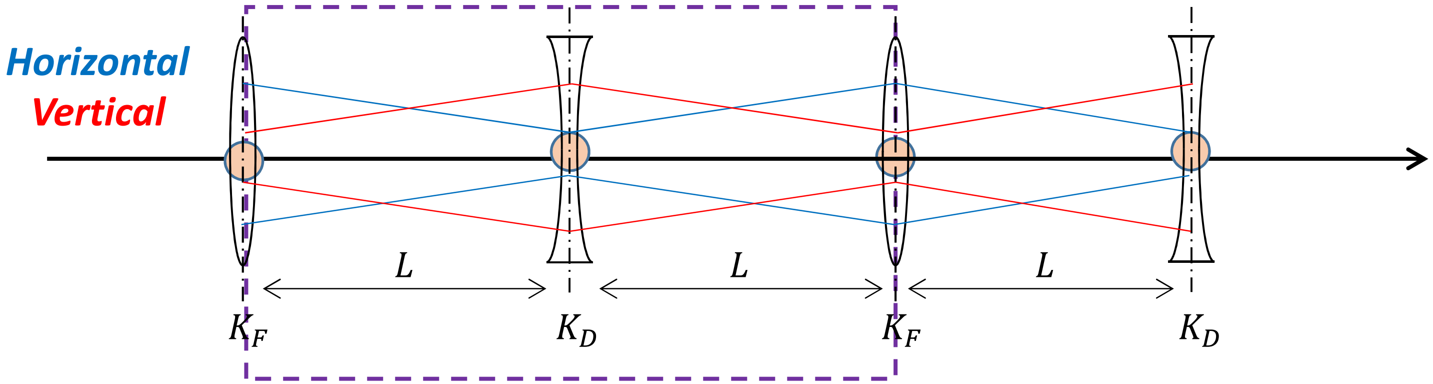
1 monitor can have 3 information.

- X beam size σ_x
- Y beam size σ_y
- XY correlation coefficient $\frac{\langle xy \rangle}{\sigma_x \sigma_y}$

At least 4 profile monitors

FODO cells for beam diagnostics

Periodic condition of FODO cell is useful for beam diagnostics.



Periodic condition with $\alpha_x = \alpha_y = 0$

Transfer Matrix for single FODO cell is

$$M_x = \begin{pmatrix} 1 & 0 \\ -K_F/2 & 1 \end{pmatrix} \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ +K_D & 1 \end{pmatrix} \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ -K_F/2 & 1 \end{pmatrix} = \begin{pmatrix} \cos\theta_x & \beta_x \sin\theta_x \\ -\sin\theta_x/\beta_x & \cos\theta_x \end{pmatrix}$$

$$M_y = \begin{pmatrix} 1 & 0 \\ +K_F/2 & 1 \end{pmatrix} \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ -K_D & 1 \end{pmatrix} \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ +K_F/2 & 1 \end{pmatrix} = \begin{pmatrix} \cos\theta_y & \beta_y \sin\theta_y \\ -\sin\theta_y/\beta_y & \cos\theta_y \end{pmatrix}$$

For $\theta_x = \theta_y = \theta$

$$K_F = K_D = \frac{\sqrt{2(1-\cos\theta)}}{L}$$

$$\beta_{\max} = \frac{L\left(2 + \sqrt{2(1-\cos\theta)}\right)}{\sin\theta}$$

$$\beta_{\min} = \frac{L\left(2 - \sqrt{2(1-\cos\theta)}\right)}{\sin\theta}$$

Laser wire monitor tested in ATF extraction line

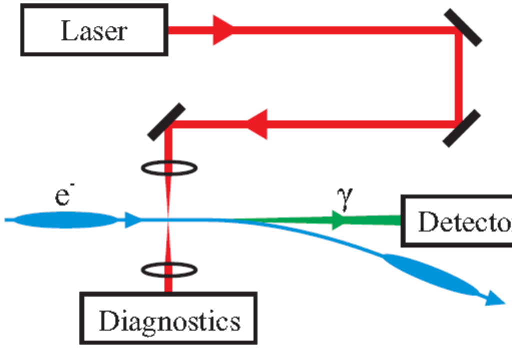
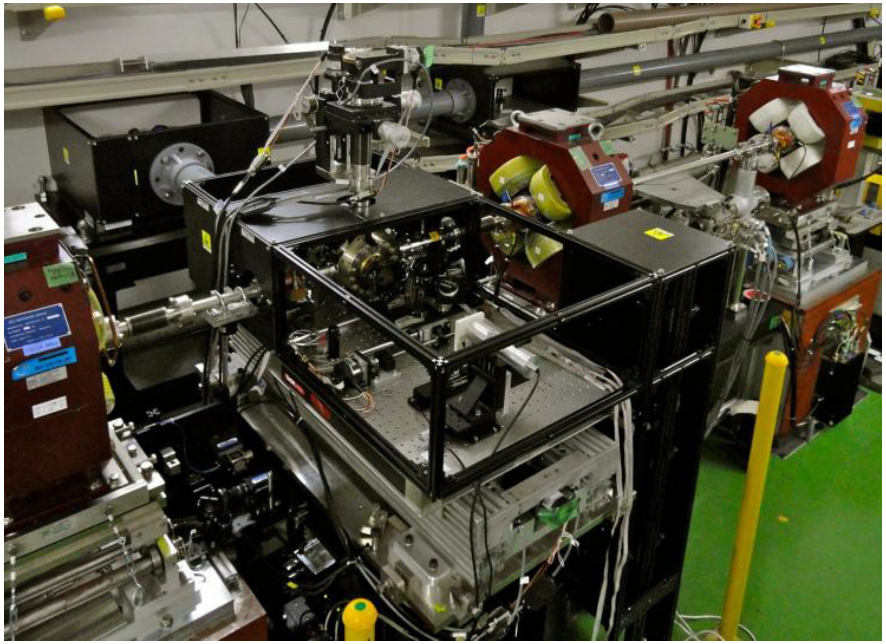


Figure 1: Schematic layout of the laser-wire.

L. Nevay, et.al., IPAC2011, TUPC158

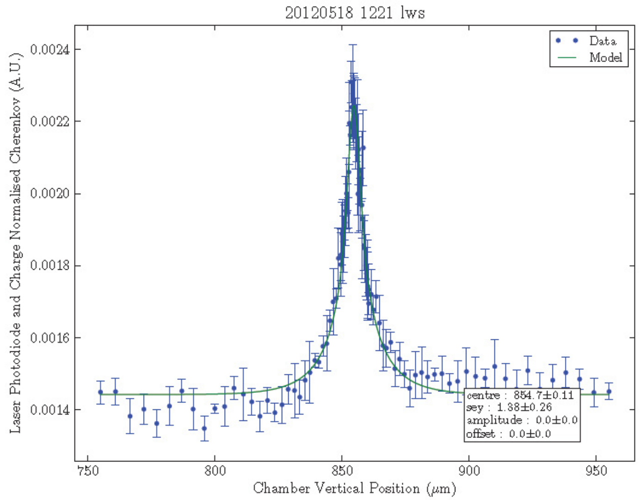
Laser wire monitor is un-destructive monitor.

We must take account for beam loss for high energy beam.



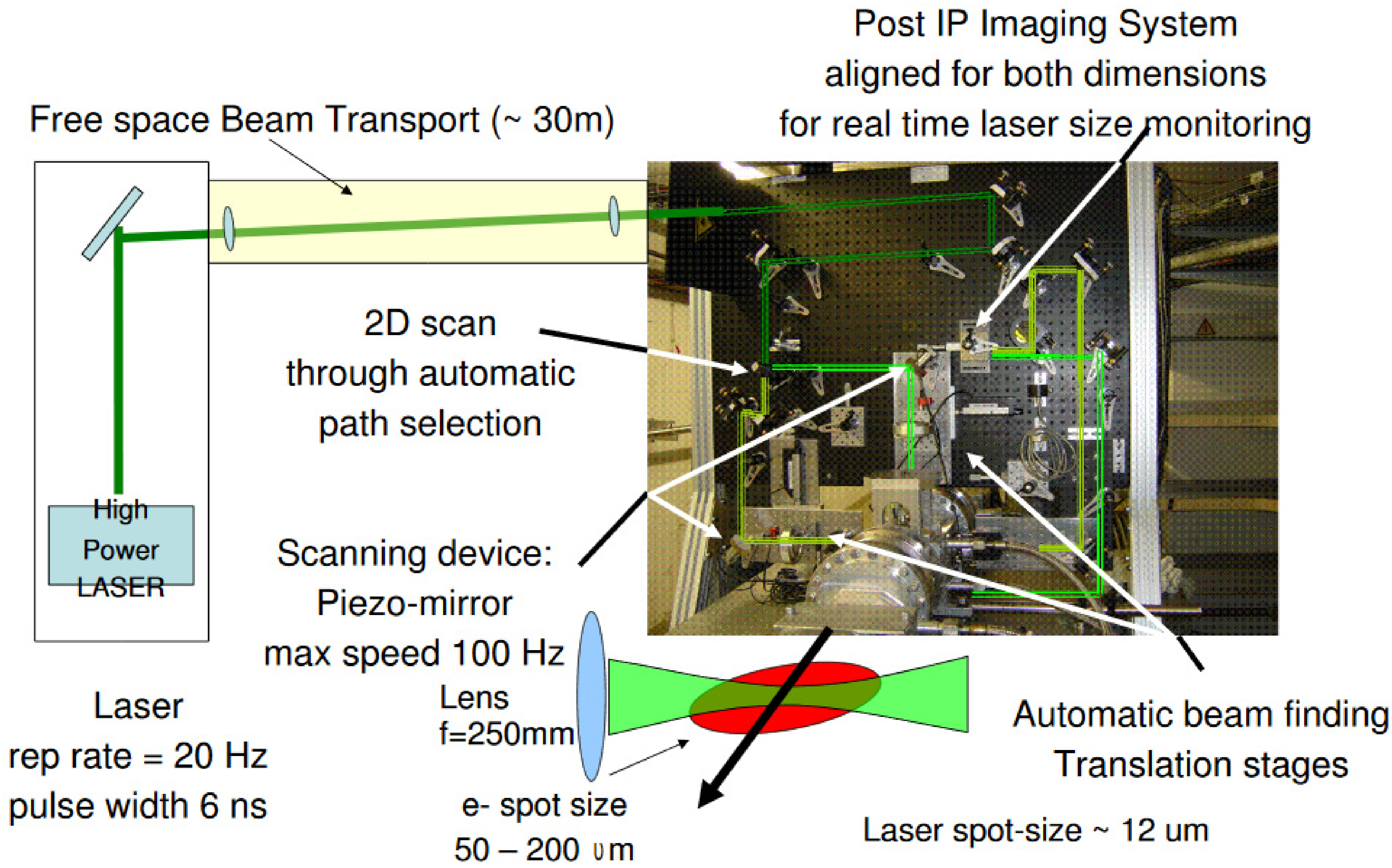
L. Corner, et.al,. ATF2 project meeting 11th Jan 2012

1μm of resolution is achieved in ATF.



L. Nevay, et.al., ATF meeting 18th May 2012

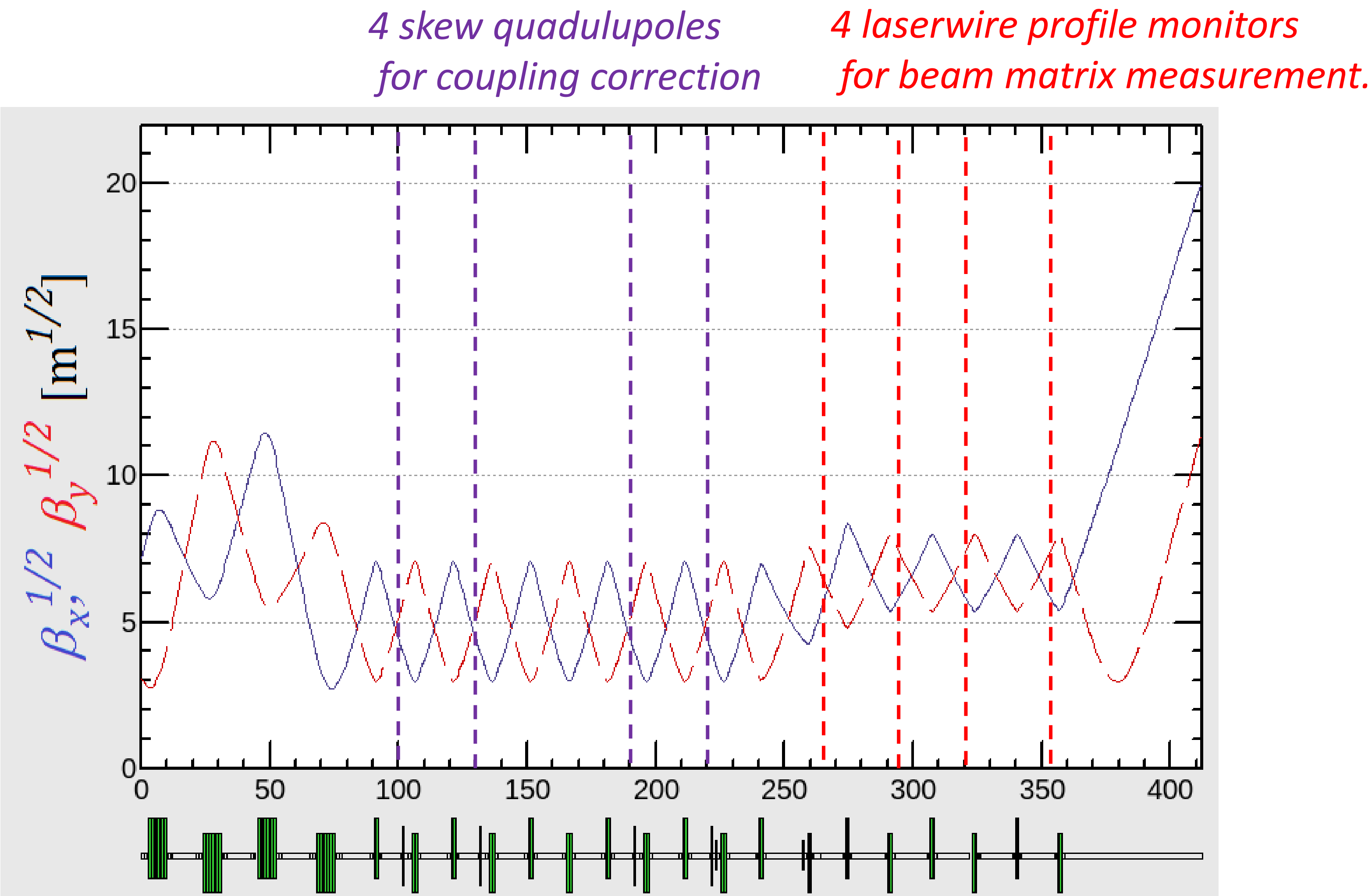
2D LW scanner at PETRA



We need one more axis
to measure the XY correlation for ILC.

Slide by M. Price, A Bosco et al

Beam Optics of ILC Beam Diagnostic Section



Energy Spectrometer

Requirement of the beam energy measurement is 100 ppm for ILC.

In order to measure the chicane with 5 mm dispersion,
we must evaluation the position difference at monitor by

$$\delta x = 5\ \mathrm{mm}\ \times (1 \times 10^{-4}) = 0.5\ \mu\mathrm{m}$$

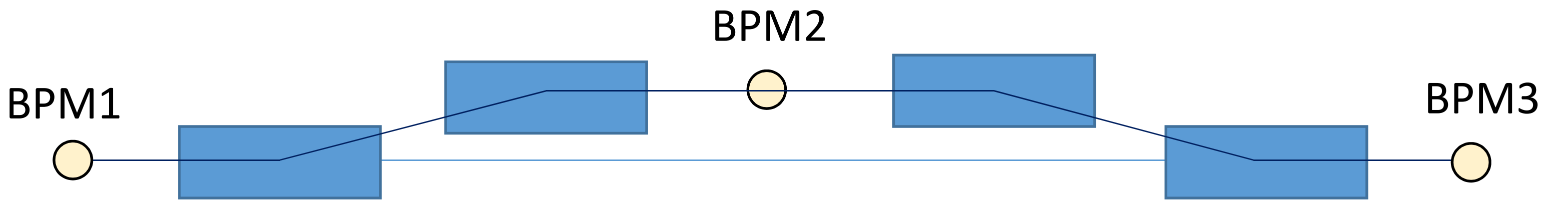
Furthermore, since the orbit jitter also should be subtracted from position information,
we use at least 3 fine resolution BPMs for energy spectrometer.

The beam energy information can be evaluated from the following relation

$$\Delta x_{ENERGY} = x_{BPM2} - \frac{x_{BPM3} - x_{BPM1}}{2}$$

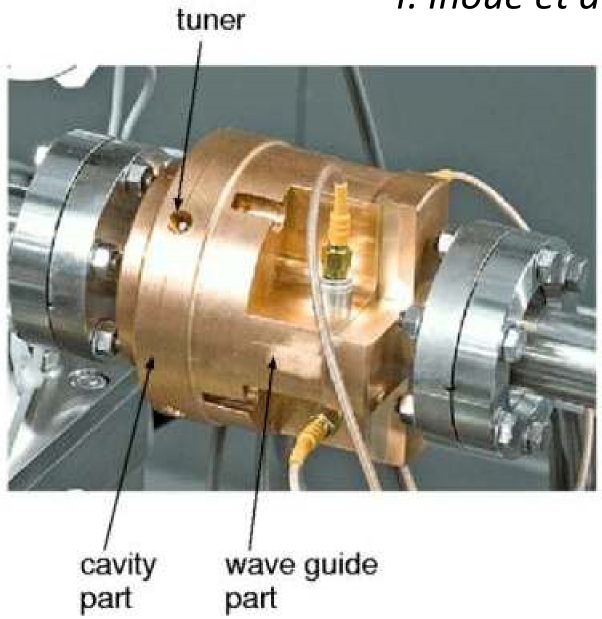
$$\sigma_{x_{ENERGY}} = \sqrt{\frac{3}{2}}\sigma_{BPM} \quad , \qquad \sigma_{BPM} \ll 0.4\ \mu\mathrm{m}$$

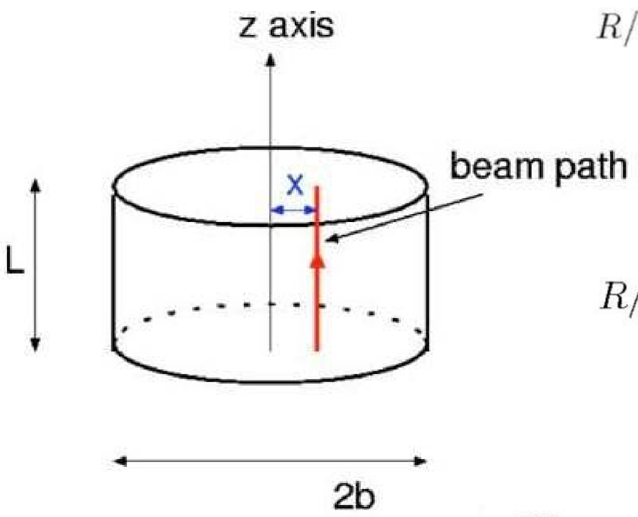
ILC requirement
$\sigma_{BPM} = 0.1\mu\mathrm{m}$



High Resolution RF BPM test at ATF

Y. Inoue et al., 3rd Annual Meeting of Particle Accelerator Society of Japan (2006).





$$R/Q(x) = \frac{|V|^2}{\omega U}$$

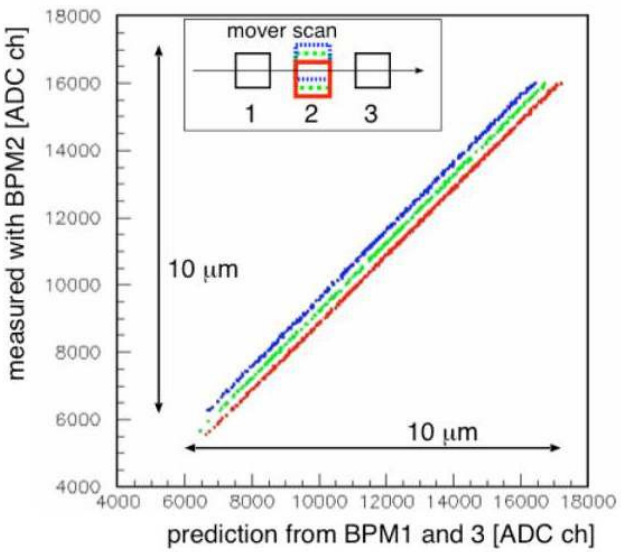
$$V(x) = \int_0^L E_z dz$$

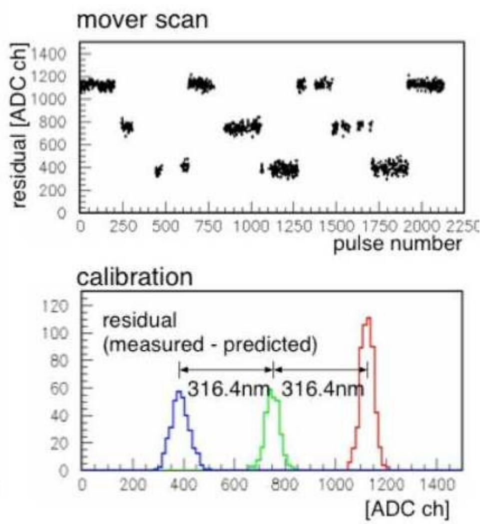
$$U = \frac{1}{2}\int \epsilon_0 |E_z|^2 dV$$

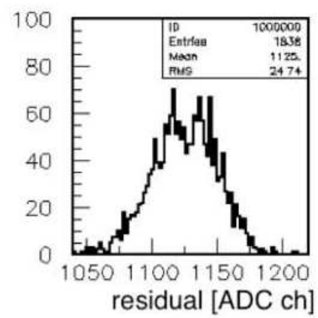
$$R/Q = 50.5 \times (\frac{\omega}{c})^3 L T^2 \underline{\underline{x^2}}$$

Dipole mode

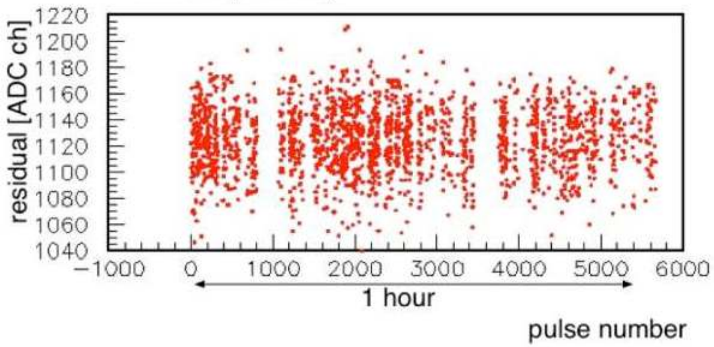
$$T = \frac{\sin \frac{\omega L}{2c}}{\frac{\omega L}{2c}}$$



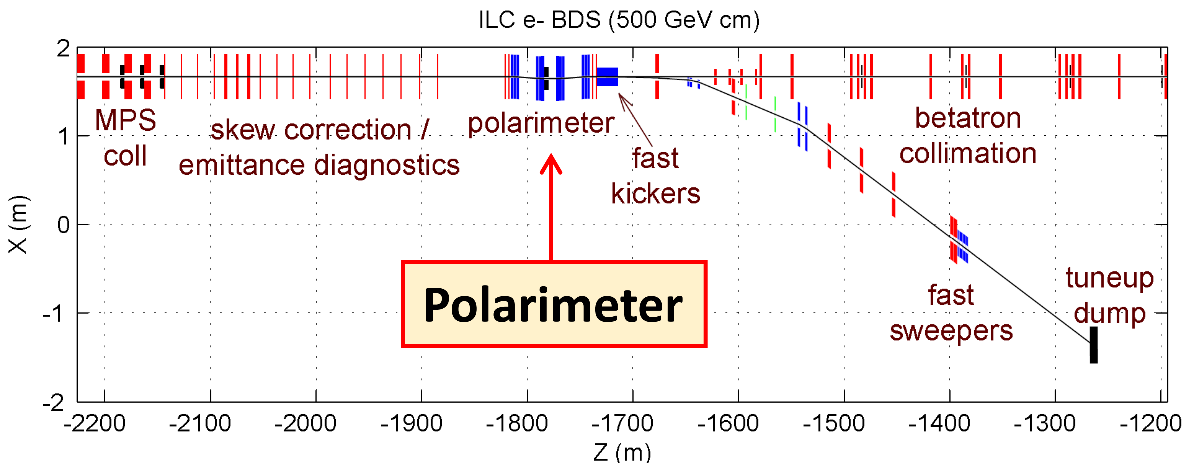


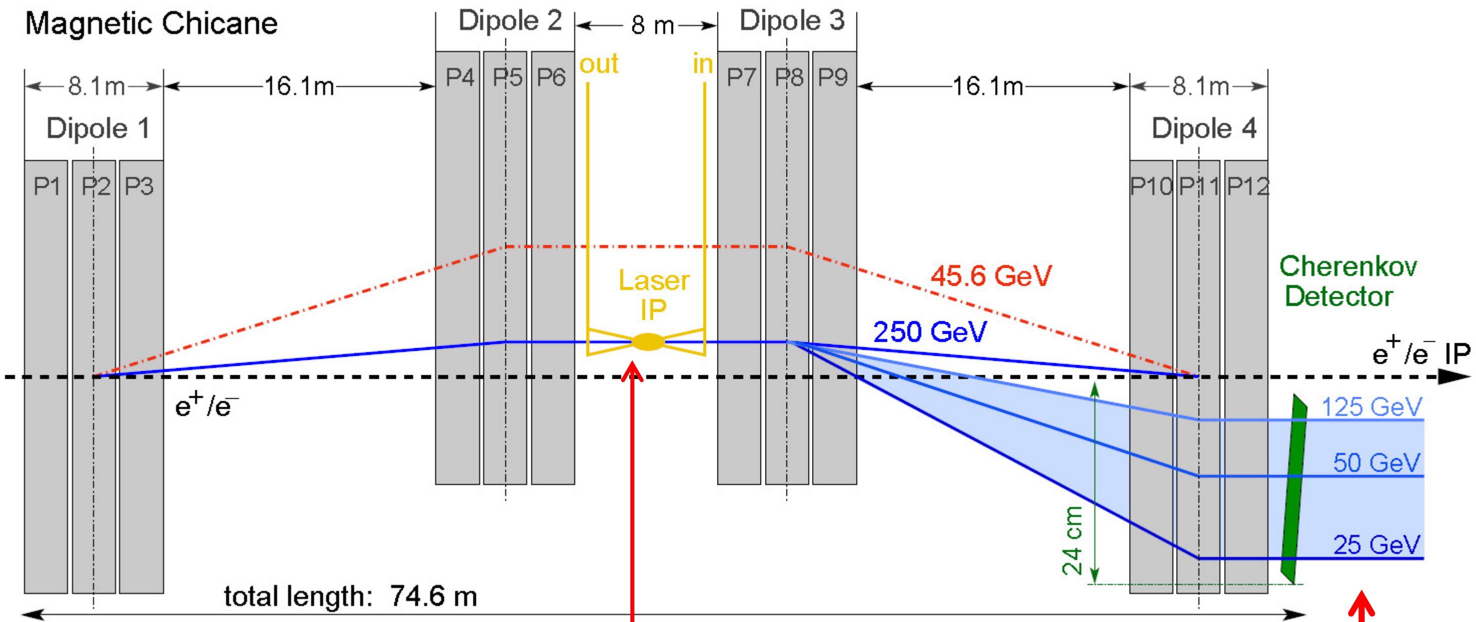


RMS of the residual
= 21.2 nm
resolution of the BPM
$=\sqrt{2/3}$ x RMS
= 17.3 nm



ILC polarimeter (Upstream)





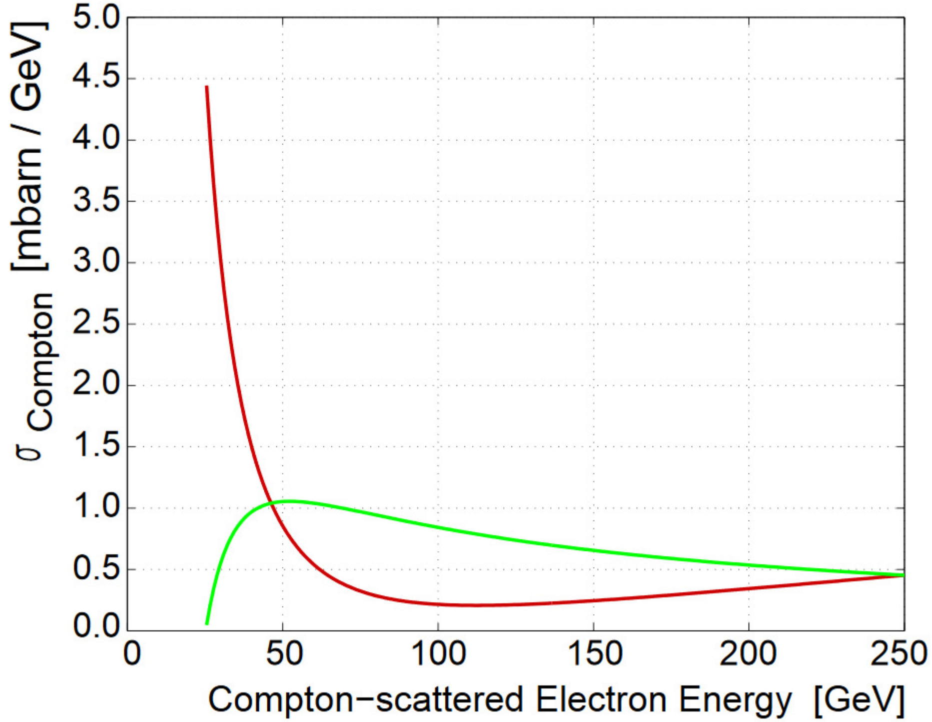
Electron-laser collision

Energy spectrum measurement of Compton scattered electrons.

Cross Section of Laser Compton Scattering

Differential cross section of polarized electron beam and laser light is different for right-hand and left-hand circular polarized laser.

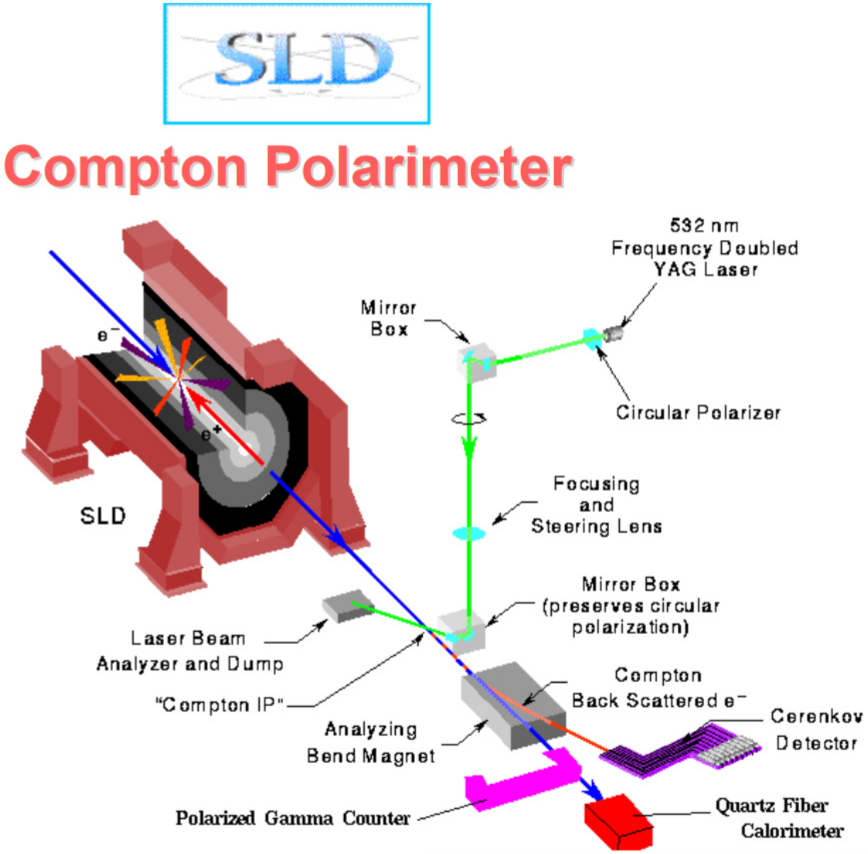
Spectrum of Compton scattered electron

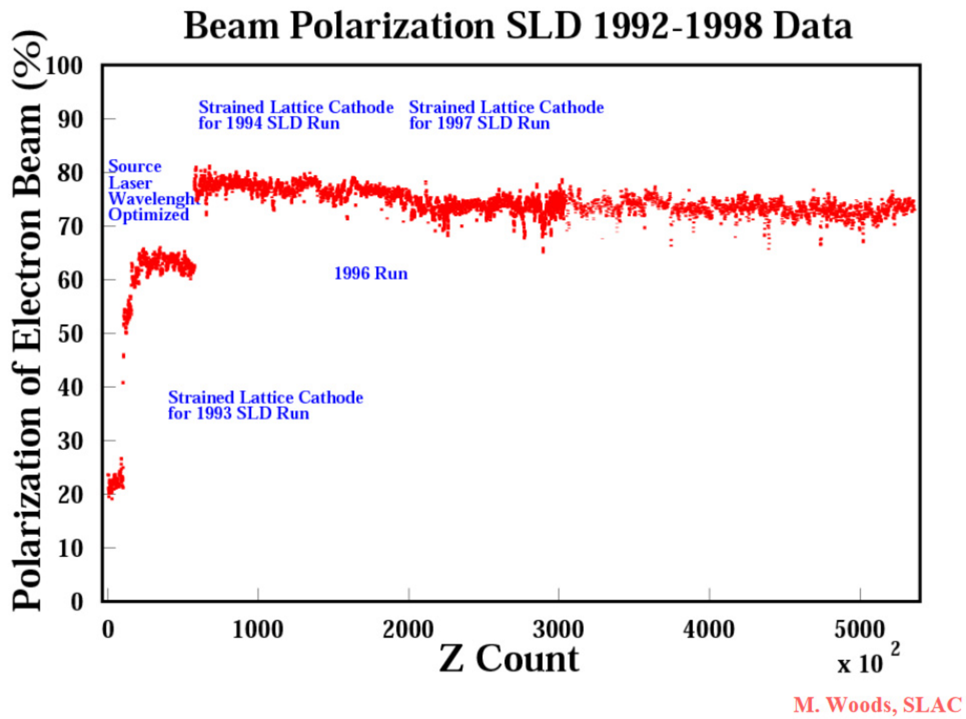


By counting the scattered electron number difference with right-hand and left-hand circular polarized laser especially for low energy electron, we can evaluate the electron beam polarization.

SLC electron polarimeter

The laser Compton based polarimeter was already used in SLC.





70-80% of electron polarization was realized at SLC.

Summary of ILC Beam Diagnostic Section

In ILC beam diagnostic section,
we will measure and correct the following beam properties.

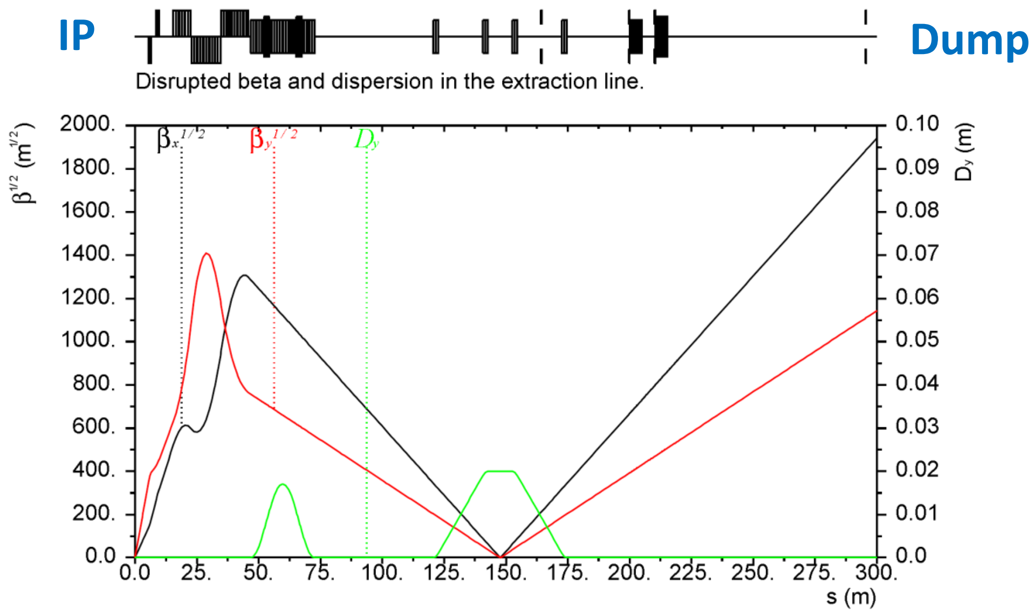
- *beam emittance measurement.*
- *matching of beam parameters to following beam line.*
- *coupling correction.*
- *polarity measurement.*
- *Beam energy measurement.*

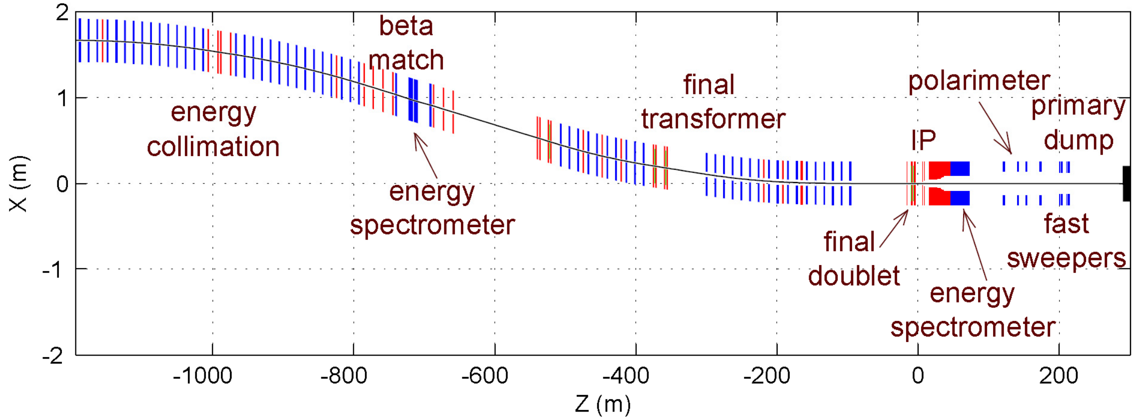
The prototype test of the monitor devices were already done for

- *Laserwire beam profile monitor for beam size measurement.*
- *High resolution beam position monitor for energy spectrometer.*
- *Laser Compton based polarimeter*

ILC Beam Extraction Line

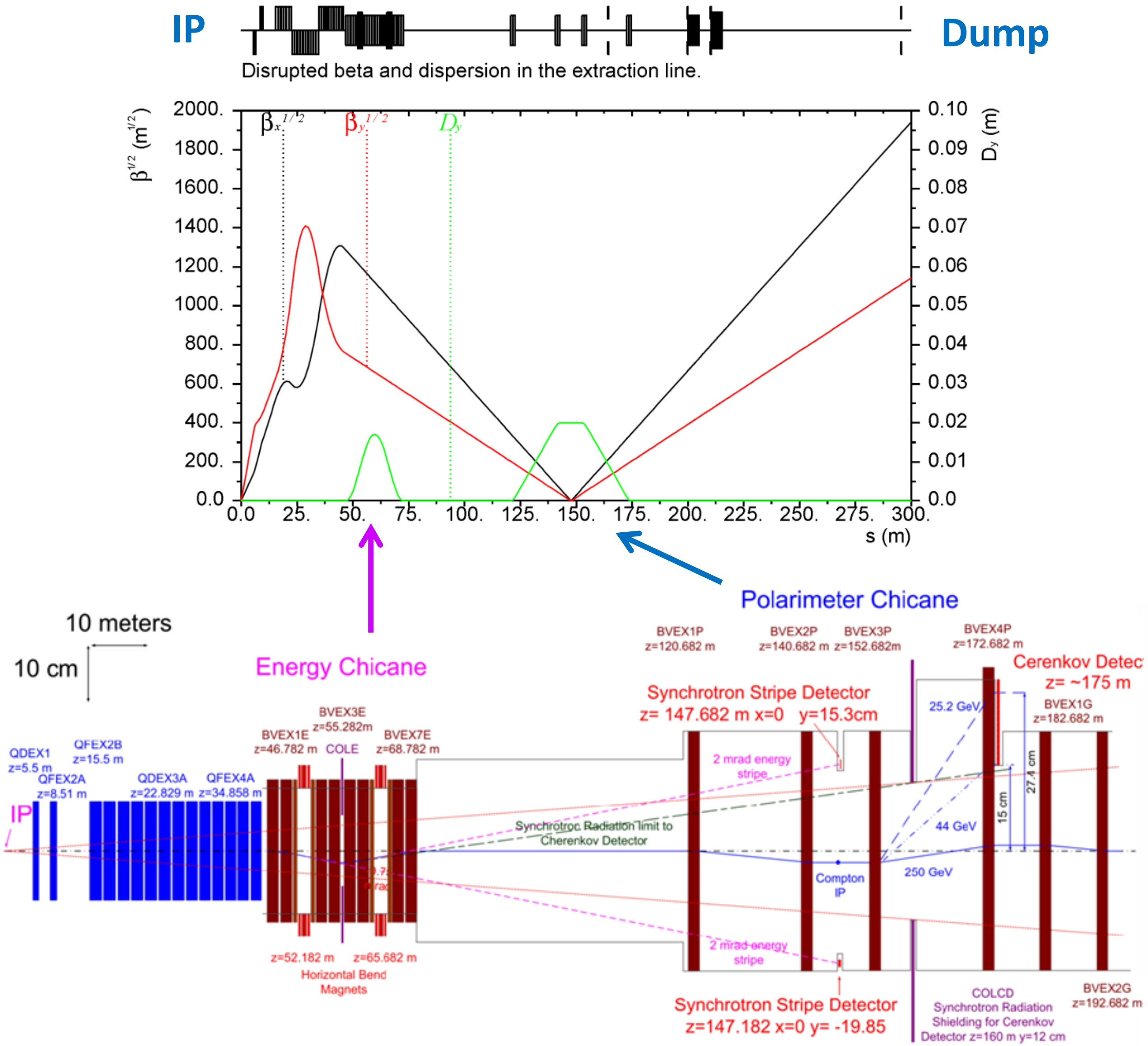
Schematic Overview of ILC Beam Extraction line



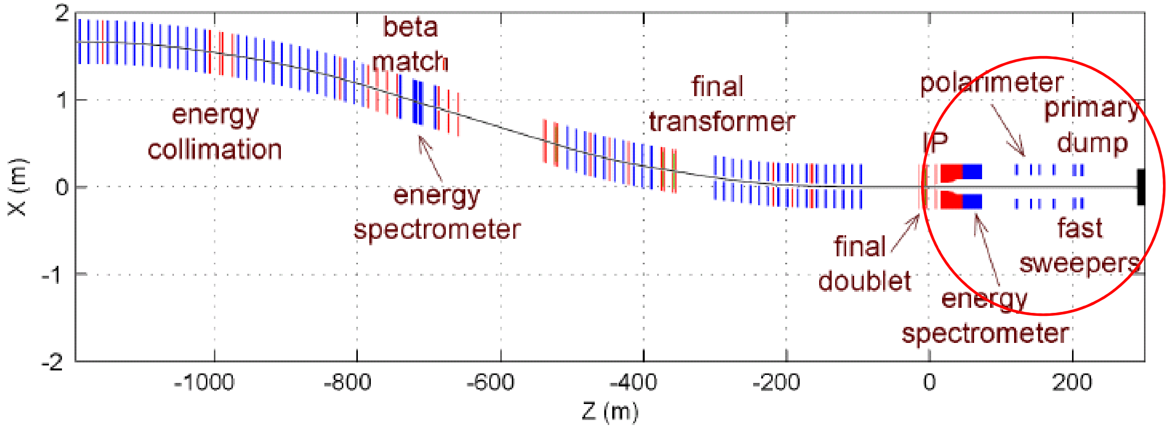


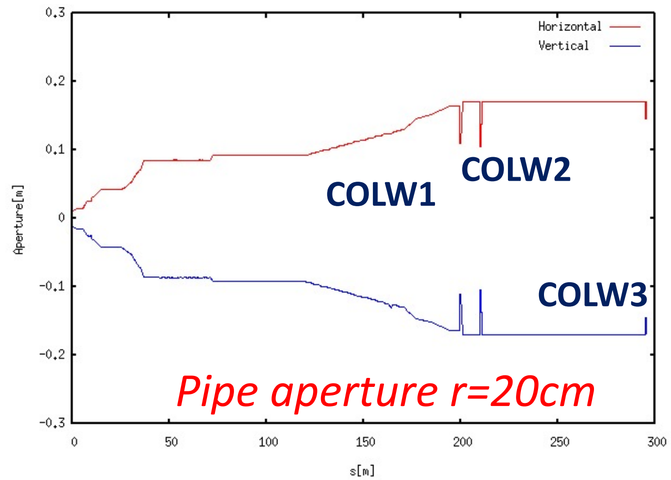
Beam Diagnostics after IP for ILC

We have an energy spectrometer and polarimeter after IP.



Beam Loss at Extraction Line





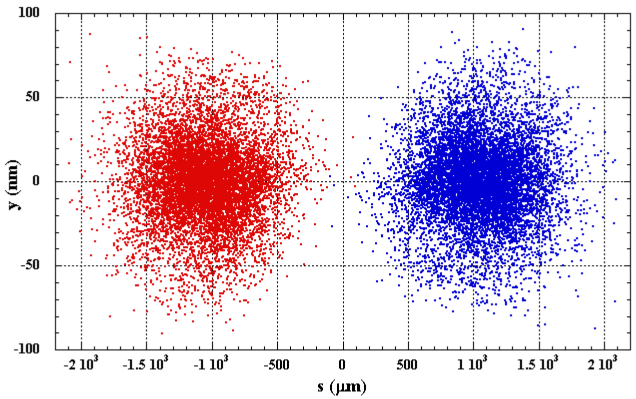
Beam loss at extraction line for head-on collision

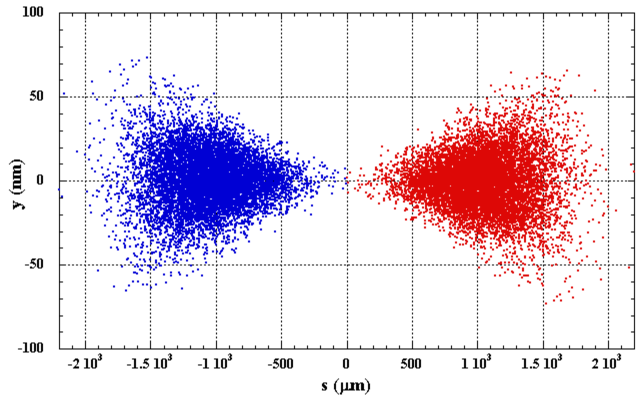
Yuri Nosochkov at LCWS2014

Parameter option	Warm magnets	Pipe	Detectors		Collimators				
			Synch-rotron	Cheren-kov	Energy	Cheren-kov	Dump-1	Dump-2	Dump-3
500 GeV	12 W/m	5 W/m	30 W	132 W	22 W	256 W	2.8 kW	1.9 kW	3.0 kW
500 GeV w/o DID	21 W/m	14 W/m	66 W	209 W	68 W	436 W	3.7 kW	2.1 kW	3.2 kW
1 TeV A1	85 W/m	48 W/m	279 W	642 W	88 W	1.8 kW	5.9 kW	2.5 kW	1.5 kW
1 TeV A1 w/o DID	206 W/m	92 W/m	679 W	819 W	376 W	3.3 kW	9.2 kW	3.5 kW	2.3 kW
1 TeV B1b	1.6 kW/m	0.9 kW/m	4.0 kW	4.6 kW	3.5 kW	16.7 kW	43.3 kW	18.5 kW	14.8 kW
1 TeV B1b w/o DID	2.7 kW/m	1.4 kW/m	5.9 kW	5.3 kW	7.6 kW	24.0 kW	57.8 kW	22.0 kW	17.4 kW

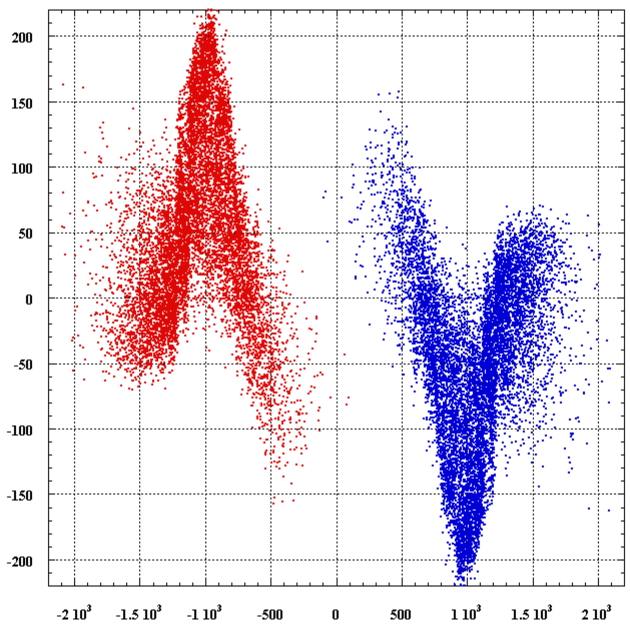
Beam distribution after beam-beam collision

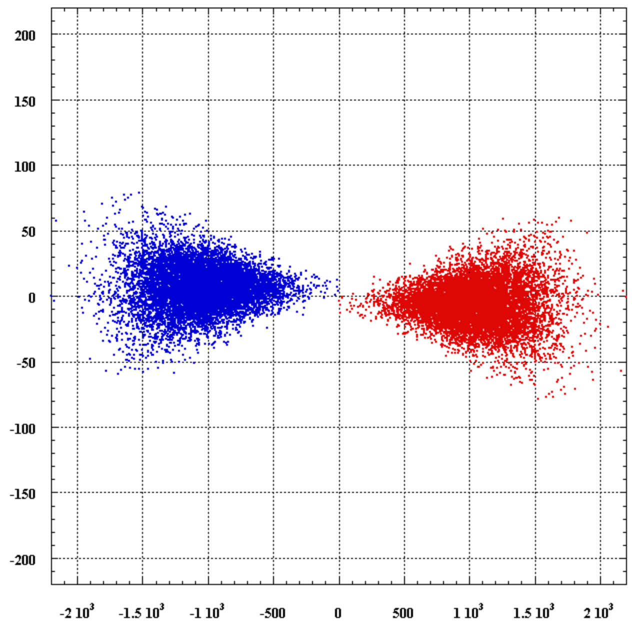
ILC 500GeV (Beam offset) = 0





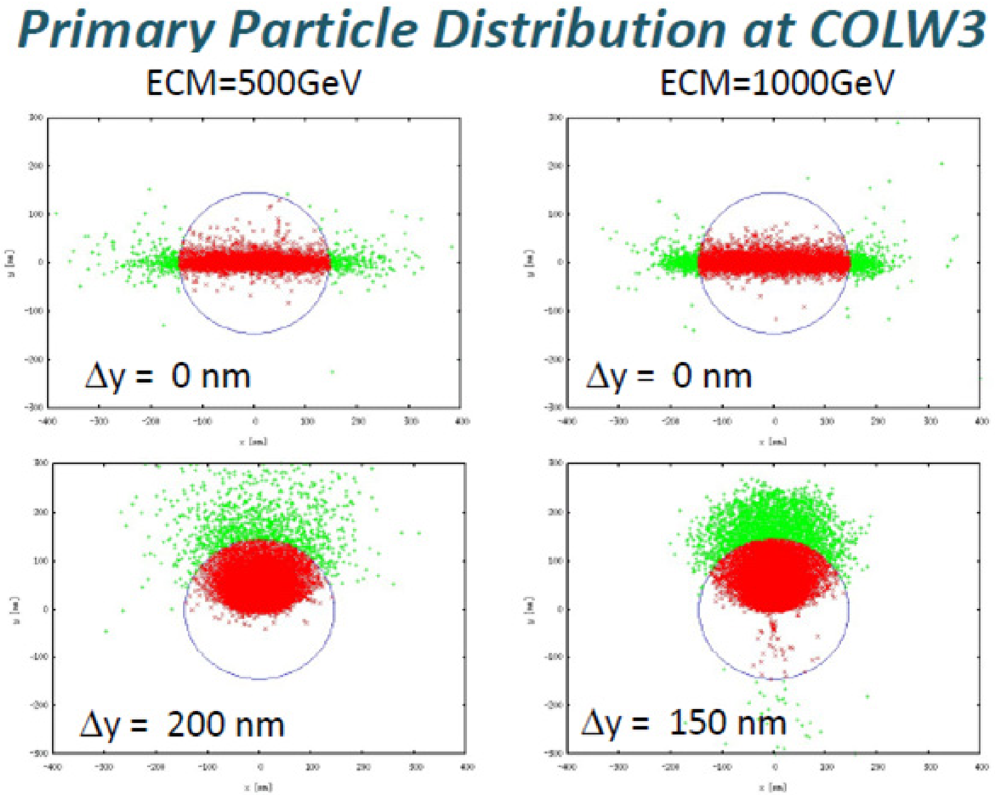
ILC 500GeV (Beam offset) = 1 σ





Beam distribution with IP beam offset

presented by T. Okugi (KEK) at AWLC2014



The beam loss at extraction line makes beam loss larger.

Head-on collision at IP is important not only to get large luminosity,
but also reduce the beam loss at extraction line.

⇒ *The IP offset will be corrected by intra-train FB (important).*

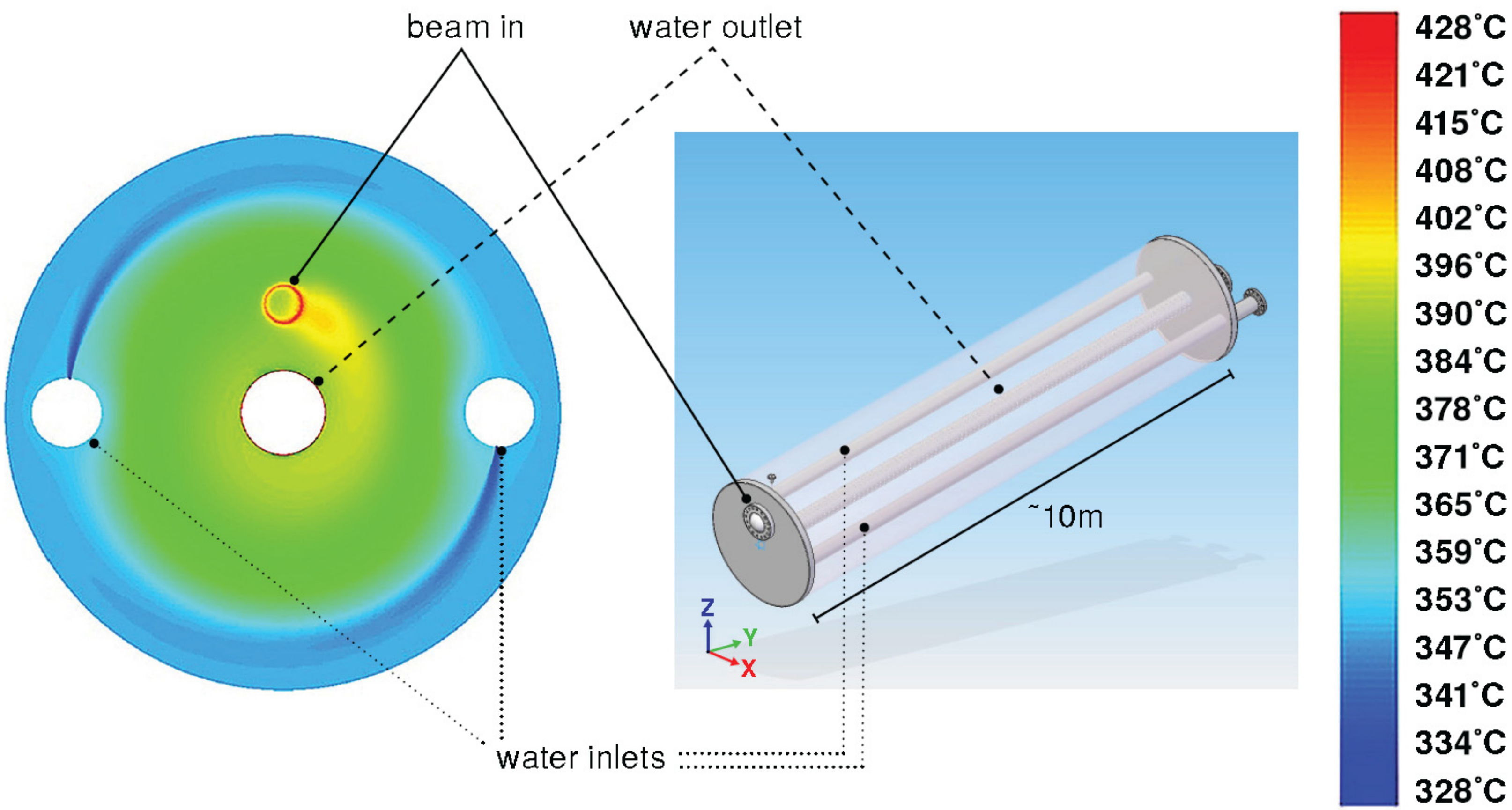
We need careful consideration of power loss and chamber cooling in extraction line.

Beam Dump

Designed beam power for ILC is more than 10MW for 1TeV operation (SLC; 2MW).

The beam dump is designed SLC-type water dump.

In order to avoid the temperature rise and the dump window damage.
The beam position at dump window will be rotated with beam sweeper magnets.



Summary of ILC Beam Extraction Line

The energy spectrometer and beam polarimeter will be arranged in the bam extraction line, too.

The beam loss at ILC extraction line is designed to be small beam loss to less than a couple 10 kW.

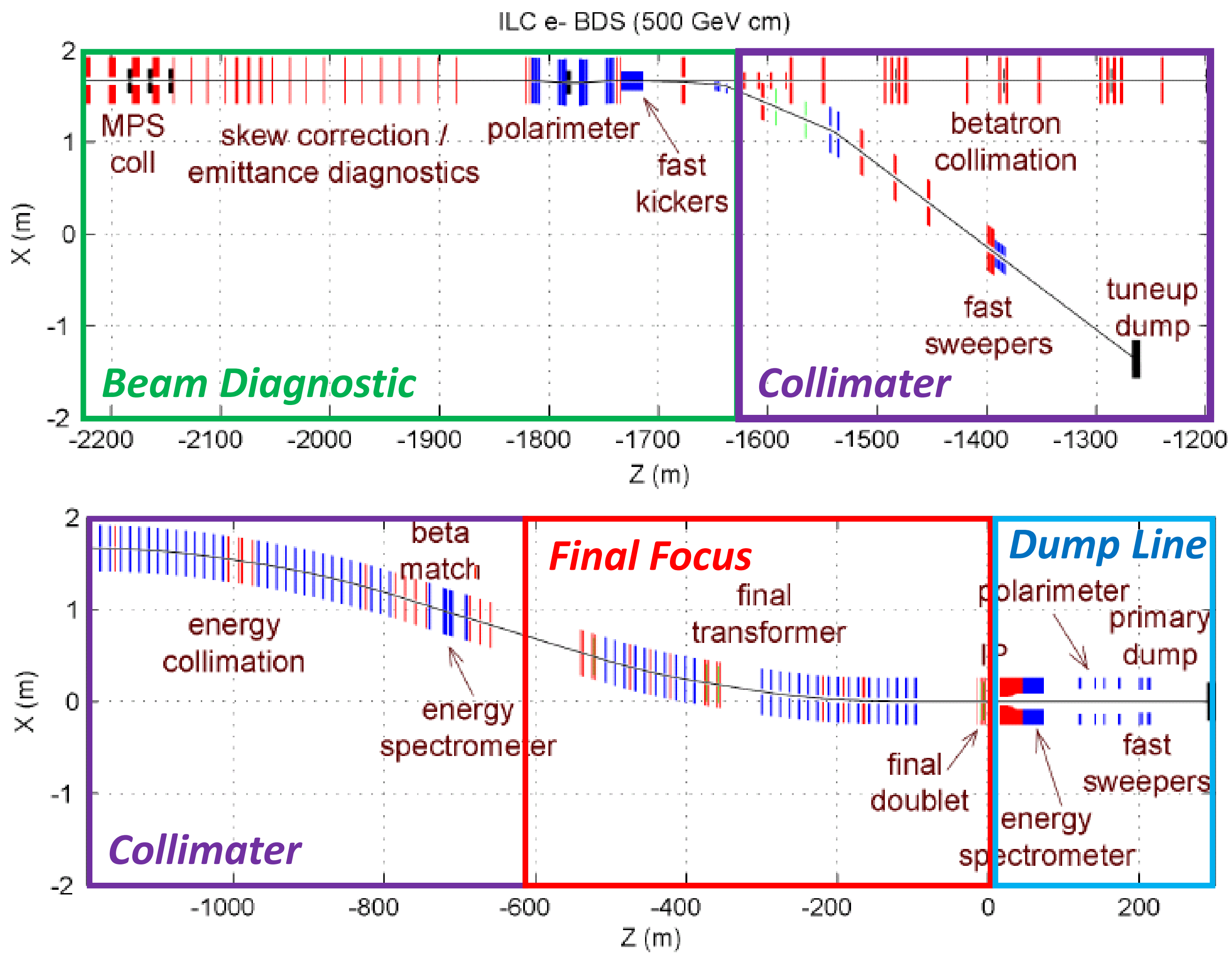
In order to reduce the beam loss, the beam pipe aperture was very large r=20cm.

When the IP beam has large offset , the beam distribution after IP is large.
Since the position offset is corrected by Intra-beam FB,
the intra-train FB is very important to ILC.

The total beam power for ILC is more than 10MW for 1TeV operation.
The beam dump design is also important.
Present ILC beam dump is designed based on SLC beam dump.

BDS (Beam Delivery System) Overview

In the lecture, I introduced all section of BDS beamline, especially for final focus beamline.



NOW,

you can design

Beam Delivery System

for linear colliders !

Thank you for your attention !