Status of ATF2 Commissioning

for ATF2 International Collaboration

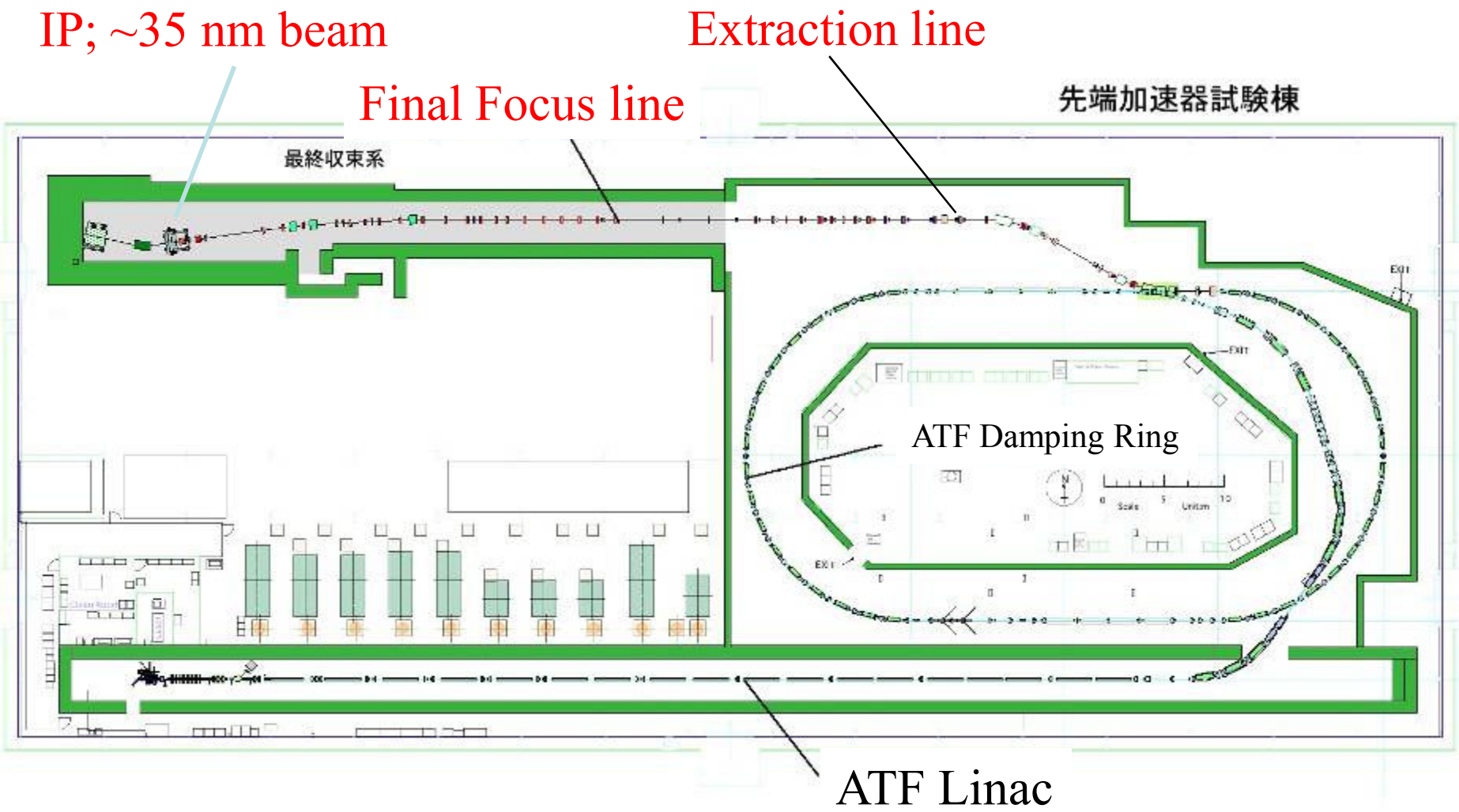
ILC-CLIC LET Beam Dynamics Workshop

CERN

2009 / 6 / 24

Slides prepared by T. Okugi
(modified and presented by K. Kubo)

ATF (KEK)


IP; ~35 nm beam
Extraction line
Final Focus line
先端加速器試験棟
最終収束系
ATF Damping Ring
ATF Linac

ATF2 parameters & Goals A/B

Beam parameters achieved at ATF and planned for ATF2, goals A and B. The ring energy is E0 = 1.3 GeV, the typical bunch length and energy spread are σ_z =8 mm and $\Delta E/E$ = 0.08 %.

	Measured	(A)	(B)
Single Bunch			
N_{bunch} [10^{10}]	0.2 – 1.0	0.5	0.5
DR $\gamma\varepsilon_y$ [10^{-8}m]	1.5	3	3
Extr. $\gamma\varepsilon_y$ [10^{-8}m]	3.0 – 6.5	3	3
Multi Bunch			
$n_{bunches}$	20	1 – 20	3 – 20
N_{bunch} [10^{10}]	0.3 – 0.5	0.5	0.5
DR $\gamma\varepsilon_y$ [10^{-8}m]	3.0 – 4.5	3	3
Extr. $\gamma\varepsilon_y$ [10^{-8}m]	~ 6	3	3
IP σ_y^* [nm]		37	37
IP $\Delta y/\sigma_y^*$ [%]		30	5

ATF2 proposed IP parameters compared with ILC

Parameters	ATF2	ILC
Beam Energy [GeV]	1.3	250
L^* [m]	1	3.5 – 4.2
$\gamma\,\varepsilon_x$ [m-rad]	3×10^{-6}	1×10^{-5}
$\gamma\,\varepsilon_y$ [m-rad]	3×10^{-8}	4×10^{-8}
β_x^* [mm]	4.0	21
β_y^* [mm]	0.1	0.4
η' (DDX) [rad]	0.14	0.094
σ_E [%]	~0.1	~0.1
Chromaticity W_y	~ 10^4	~ 10^4

ATF2 Operation Status

2009 February – March

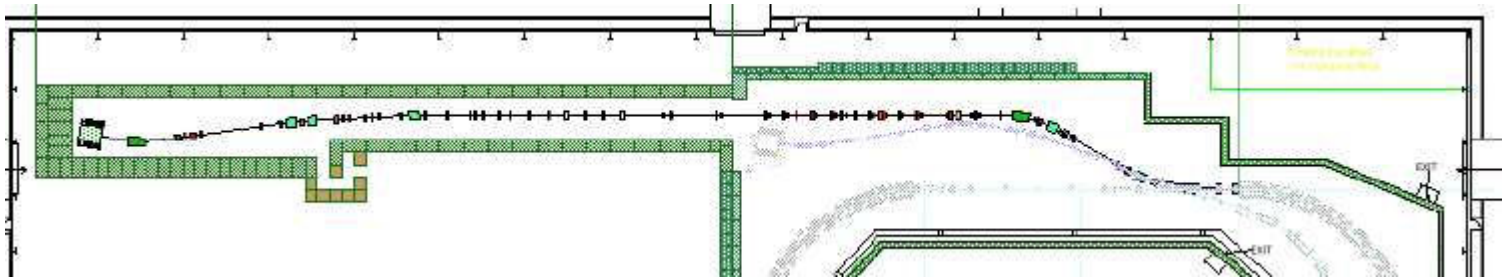
- Operation of ATF2 beam line was started.
- IP-BSM was commissioned for the horizontal laser wire mode.
- Since IP-BSM group required the horizontal beam size of 10-20micron, beam optics was the high beta optics (bx=0.08m, by=0.04m).
- Beam size tuning was concentrated only for the horizontal direction.
- Most of the beam time was spent for hardware and software commissioning.

2009 April – May

- IP-BSM was commissioned for the vertical interference mode as well as the horizontal laser wire mode
- Since IP-BSM group required the vertical beam size of 1micron, beam optics was changed to new high beta optics (bx=0.08m, by=0.01m).
- Both horizontal and vertical beam size tunings were applied.

Beam Tuning Sequence

1. Orbit tuning
2. Dispersion correction at Matching Section
3. Coupling minimization with WSs in EXT line
4. Emittance measurement at EXT line
5. Matching to post-IP WS
6. Vertical beam size minimization at post-IP WS
7. Set the final doublet to focus to IP
8. Beam size measurement by IP-BSM



Skew quads for corrections

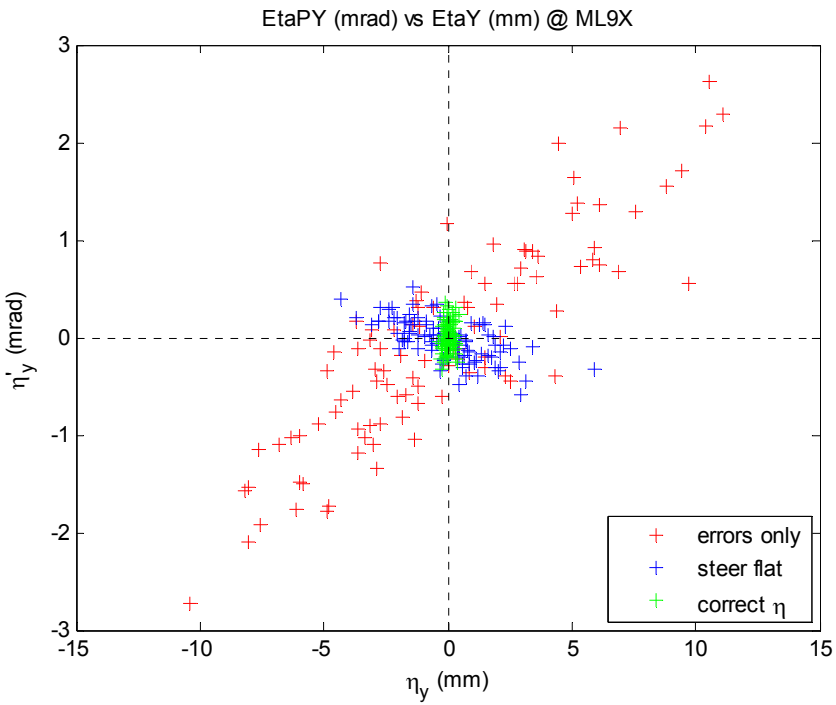
- 2 skew quads for vertical dispersion correction (QS1X, QS2X)
  - at high horizontal dispersion region
  - phase advance almost pi. (makes coupling correction easier, but dispersion may not be corrected well. -> see next slides)
- 4 skew correctors for coupling correction
  - at dispersion free region

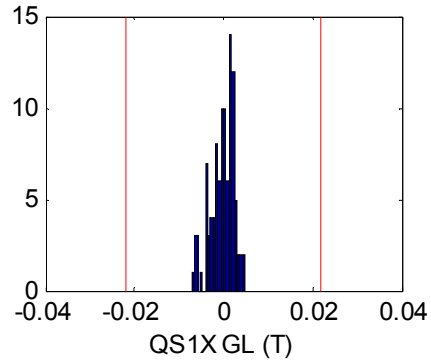
Vertical Dispersion Correction with sum-knob (Design)

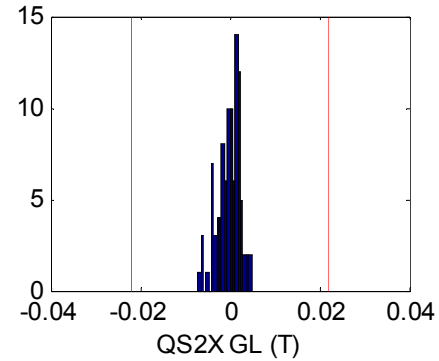
3rd ATF2 project meeting (2007) M.Woodley

Errors;

vertical dipole misalignments: 0.10mm (rms)
horizontal quadrupole misalignments: 0.05mm (rms)
vertical quadrupole misalignments: 0.03mm (rms)
quadrupole rolls: 0.30mrad (rms)







QS1X, QS2X
GLmax = 0.022 T
(20% IDX @ 5 amp)

When the dispersion sources are only in the extraction line, we can correct the vertical dispersion with single sum-knob.

Coupling Correction (Design)

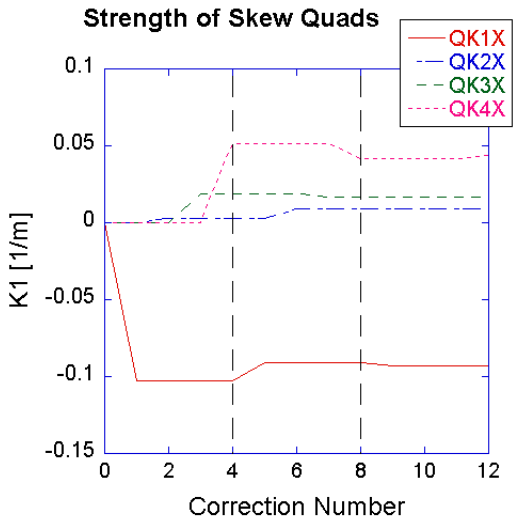
3rd ATF2 project meeting (2007) T.Okugi

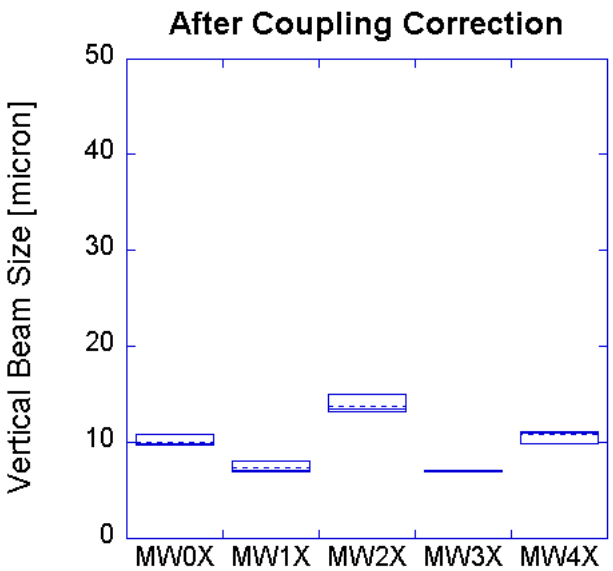
Example of the 1-by-1 correction

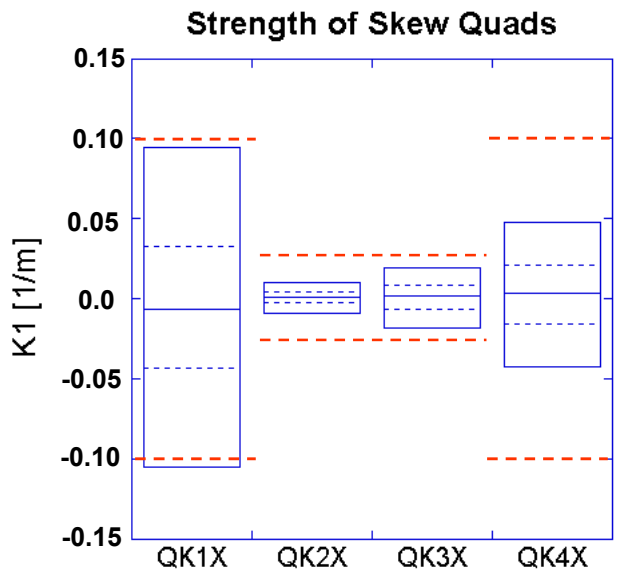
Coupling can be corrected with 1-by-1 correction

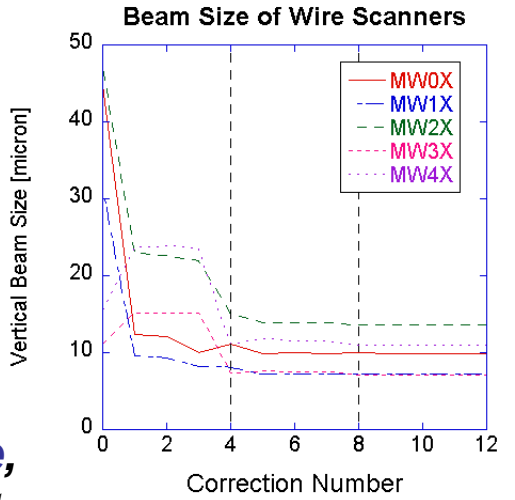
Errors;

vertical dipole misalignments: 0.10mm (rms)
horizontal quadrupole misalignments: 0.05mm (rms)
vertical quadrupole misalignments: 0.03mm (rms)
quadrupole rolls: 0.30mrad (rms)







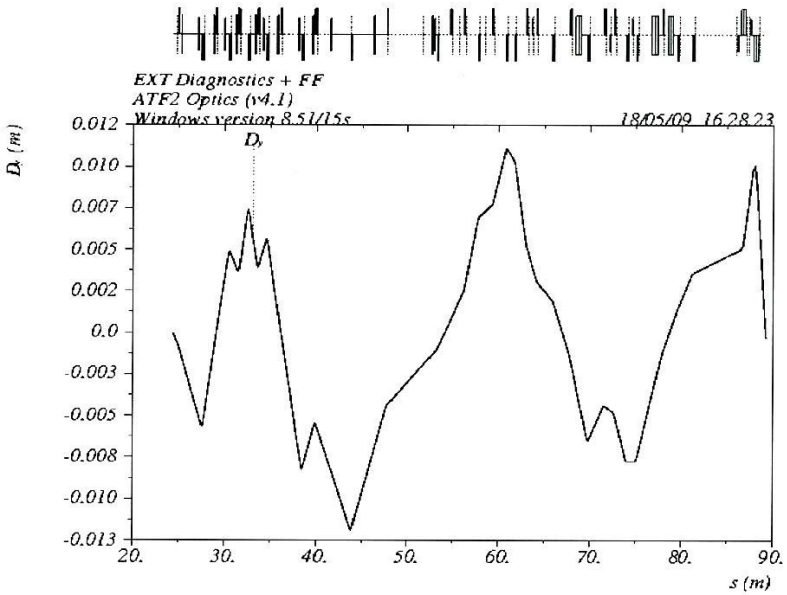


When the coupling sources are only in the extraction line, we can correct the coupling within skew-Q strength limit.

Vertical Dispersion correction (experiment 05/14)

Dispersion Correction with sum-knob

QS1X = +0.455A
QS2X = +0.455 A

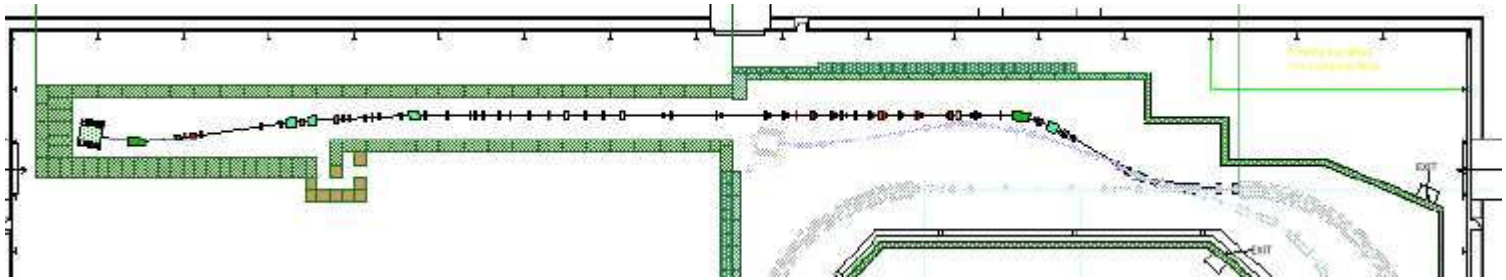


Dispersion cannot be corrected with single sum-knobs,
It probably means the incoming vertical dispersion (from DR or septum) is large and the phase is not on the phase of the sum-knob.
(On this day.)

Dispersion correction by skew quads can make large x-y coupling, which cannot be corrected by following 4 skew quads.

Beam Tuning Sequence

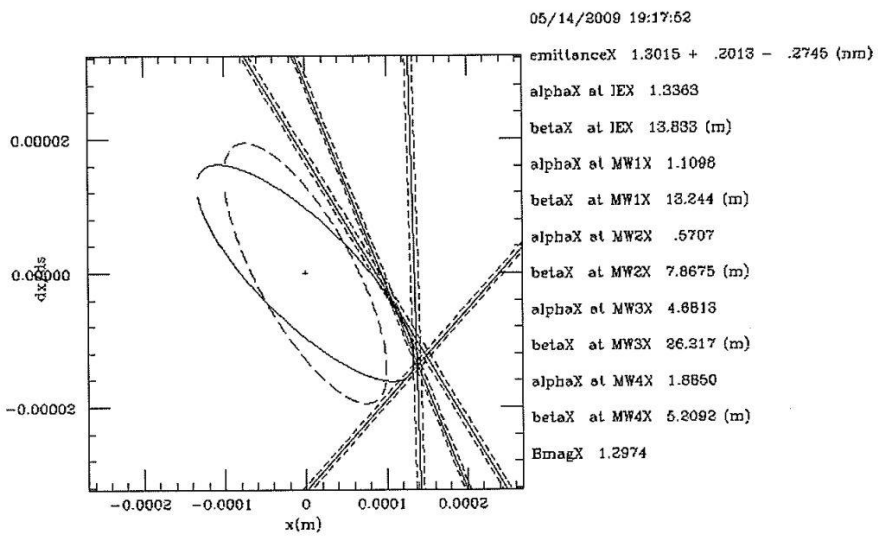
1. Orbit tuning
2. Dispersion correction at Matching Section
3. Coupling minimization with WSs in EXT line
4. Emittance measurement at EXT line
5. Matching to post-IP WS
6. Vertical beam size minimization at post-IP WS
7. Set the final doublet to focus to IP
8. Beam size measurement by IP-BSM



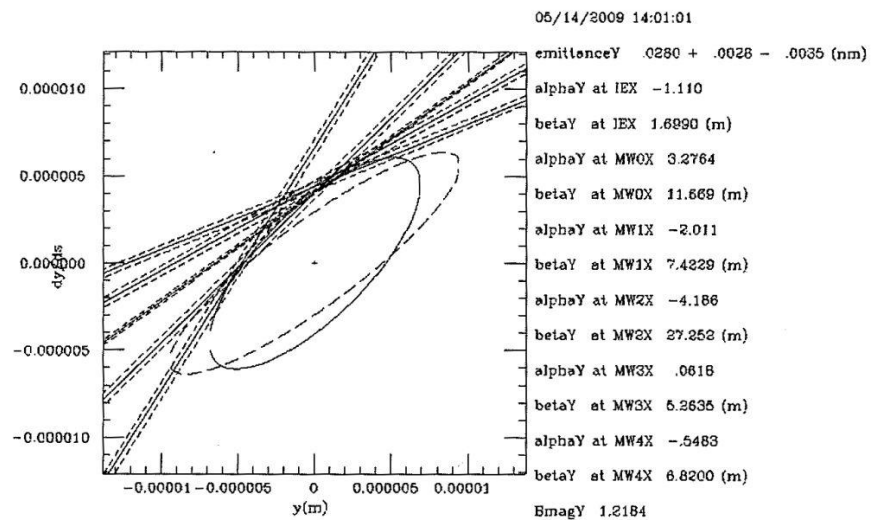
Emittance Measurement in Extraction Line (05/14)

Using 4 or 5 wire scanners, measurebeam size at different lacations.
→ fit emittance and Twiss parameters

Horizontal Emittance
1.302nm



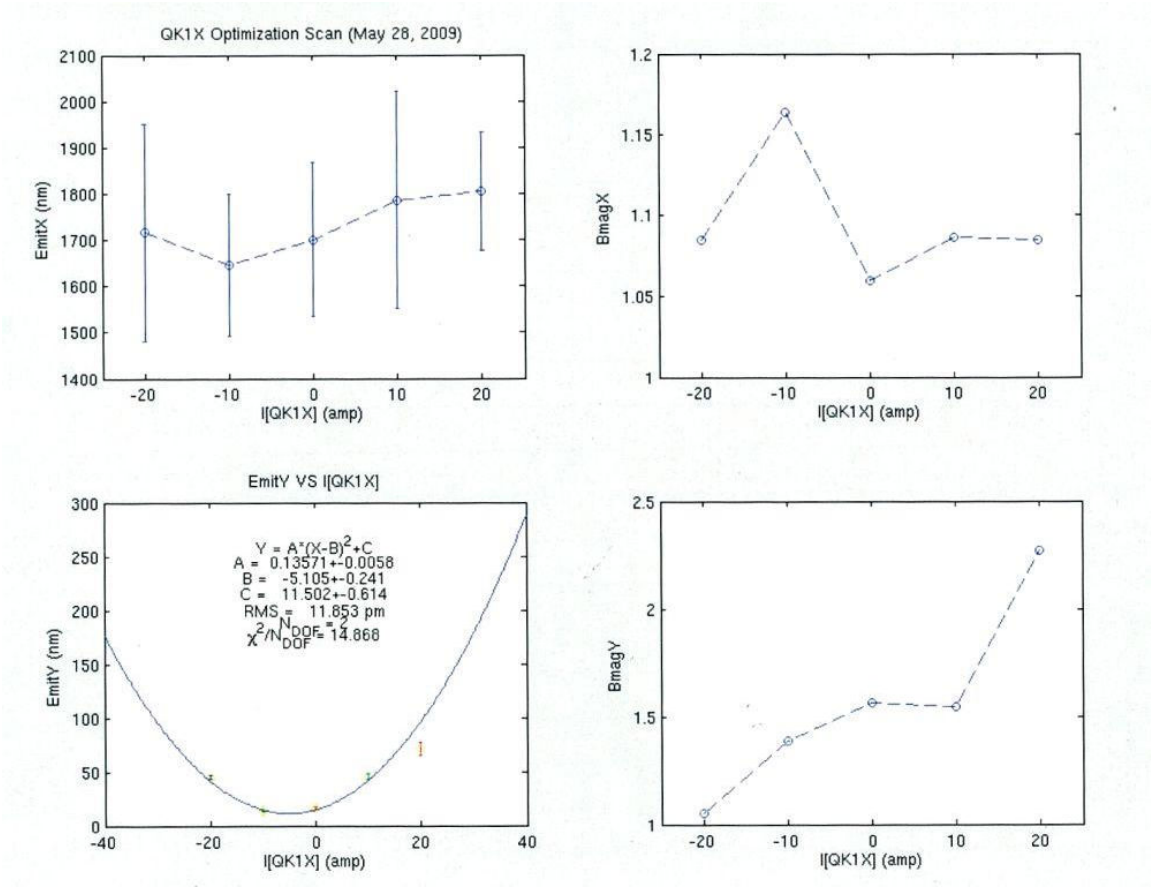
Vertical Emittance
0.028nm



Dispersion - coupling correction not satisfactory due to skew-Q strength limit.

Emittance Measurement in Extraction Line (05/28)

Horizontal Emittance
1.7nm



Vertical Emittance
0.011nm

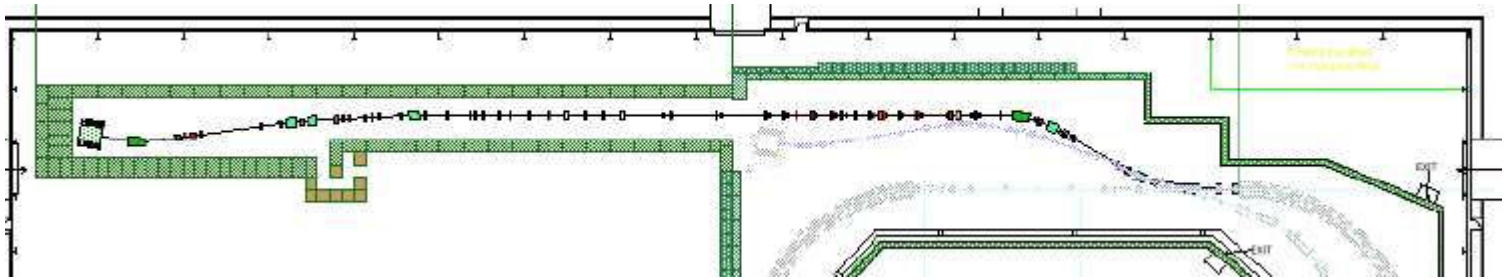
This day, dispersion - coupling could be corrected within skew-Q strength limit.

Sum knob

QS1X	**-**	**0.42A**
QS2X	**-**	**0.42A**
QK1X	**-**	**5.11A**
QK2X		**0.00A**
QK3X		**0.00A**
QK4X		**0.00A**

Beam Tuning Sequence

1. ***Orbit tuning***
2. ***Dispersion correction at Matching Section***
3. ***Coupling minimization with WSs in EXT line***
4. ***Emittance measurement at EXT line***
5. ***Matching to post-IP WS***
6. ***Vertical beam size minimization at post-IP WS***
7. ***Set the final doublet to focus to IP***
8. ***Beam size measurement by IP-BSM***

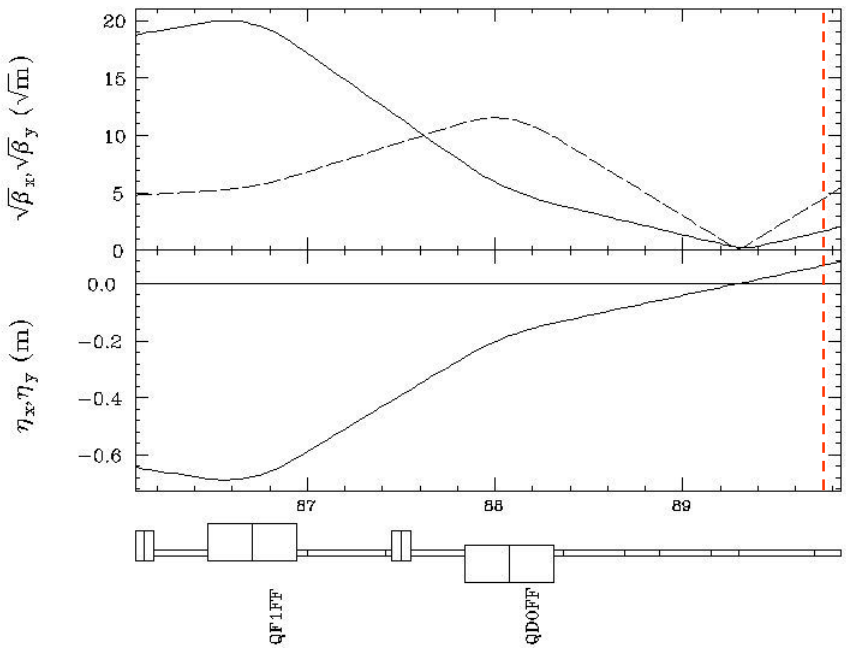


Beam Size Measurement at post-IP wire scanner (05/15)

beam waist at IP

QF1FF = 70.84A

QD0FF = 130.33A



σ_x = 74.3μm -> σ_x^* = 7.0μm

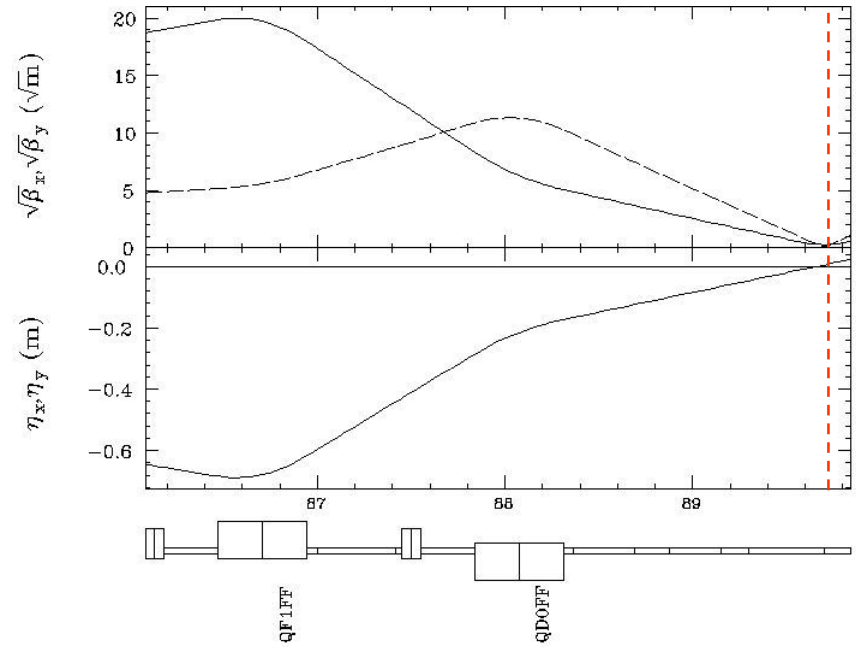
σ_y = 20.4μm -> σ_y^* = 0.5μm

(If α_x=0, α_y=0 at IP, ε_x=1.3nm, ε_y=28pm)

beam waist at MW1IP

QF1FF = 66.87A

QD0FF = 105.24A



σ_x^* = 11.4μm

σ_y^* = 4.1μm

Design Beam Size at IP

σ_x^* = 10.1μm

σ_y^* = 0.53μm

Horizontal beam size was consistent with the design.

Vertical Beam Size Tuning at MW1IP

(5 /20) by using FF multi-knobs (sextupole movers)

5.8μm (5.8 ,6.1 ,5.5) -> 4.1μm (3.9, 4.2, 4.1)

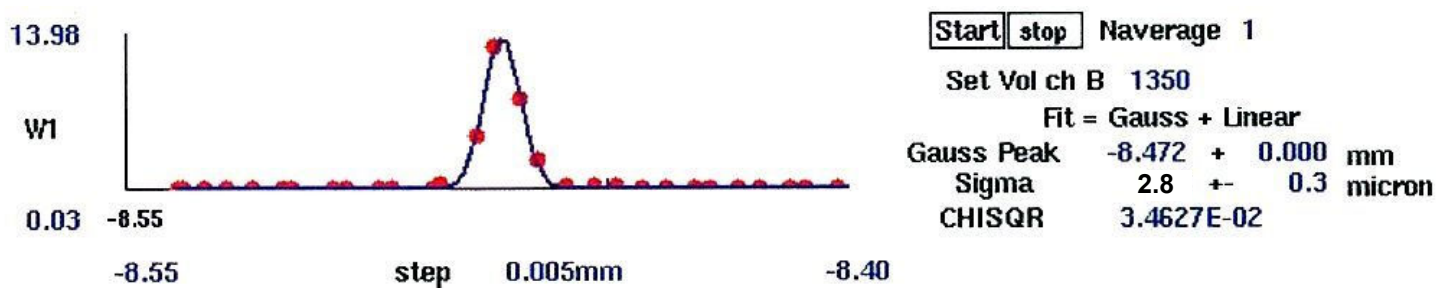
-***Residual vertical dispersion was dominant for the vertical beam size***

- Vertical dispersion was larger than correctable range for multi-knobs

(5 /26) - All sextupoles off
- QSs scan (skew-Q for vertical dispersion correction)
- QKs scan (skew-Q for coupling correction)
- QF6X scan (normal-Q for horizontal dispersion correction)

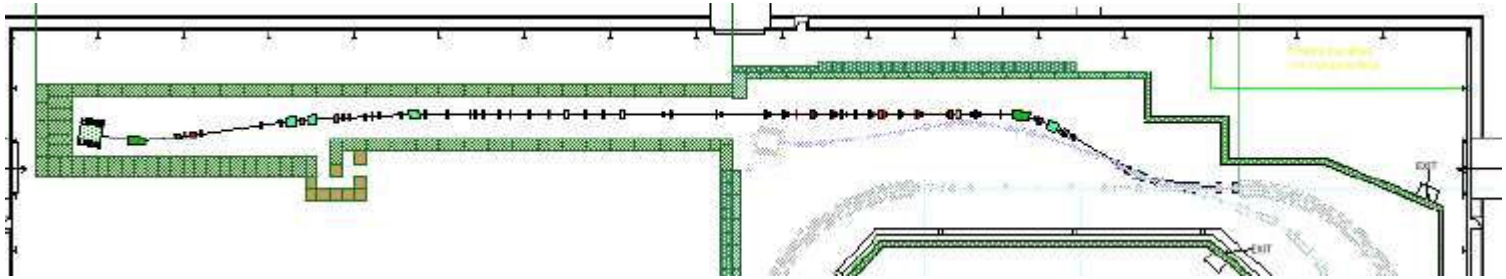
5.0μm (4,7 ,5.2, 5.2) -> 2.9μm (3.0, 2.8, 2.9)

Effect of wire size (10μm diameter) is dominant



Beam Tuning Sequence

1. Orbit tuning
2. Dispersion correction at Matching Section
3. Coupling minimization with WSs in EXT line
4. Emittance measurement at EXT line
5. Matching to post-IP WS
6. Vertical beam size minimization at post-IP WS
7. Set the final doublet to focus to IP
8. Beam size measurement by IP-BSM

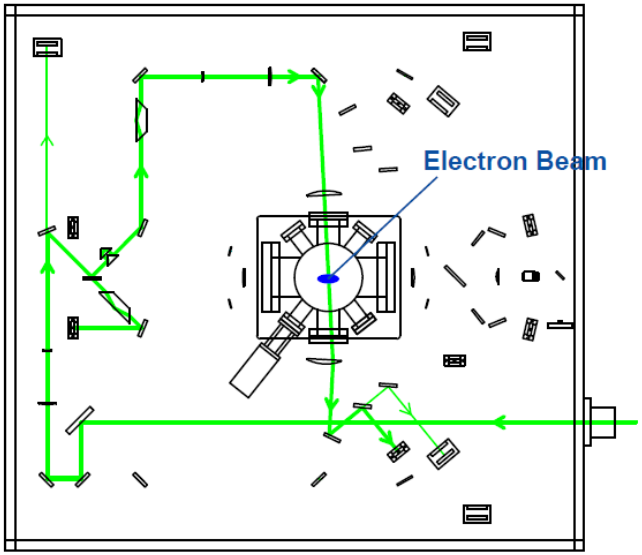


Horizontal Measurement (Laser Wire Mode)

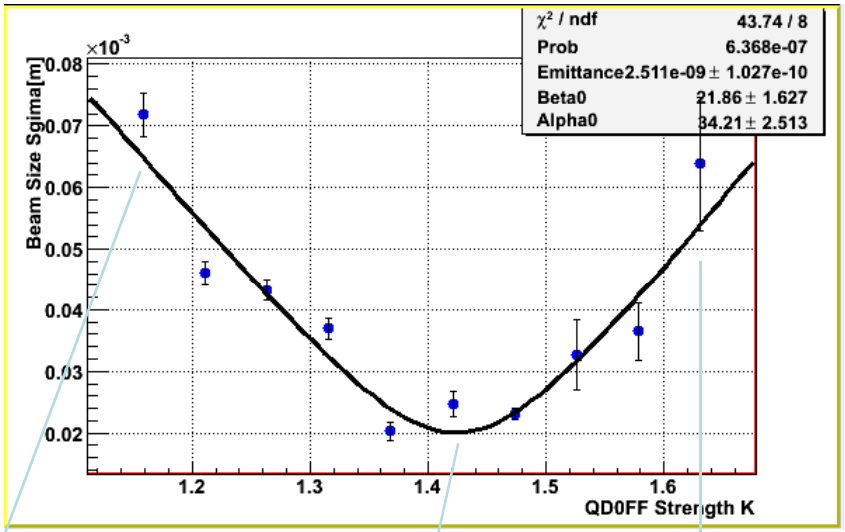
-*First Compton signal was observed in February.*

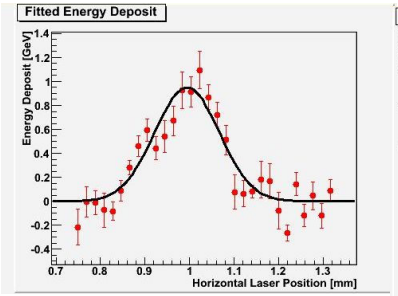
-*Beam size and emittance measurement was done in May.*

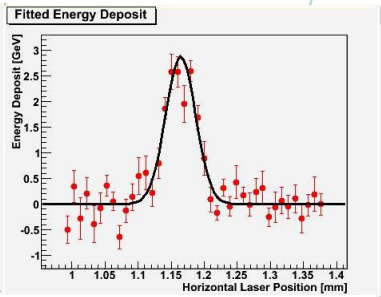
- *horizontal beam size at MW1IP was 20um.*
- *laser beam size 10um assumed.*
- *fitted horizontal emittance was 2.5nm.*

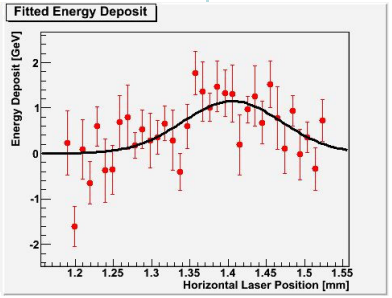


laser wire mode optics
(horizontal measurement)







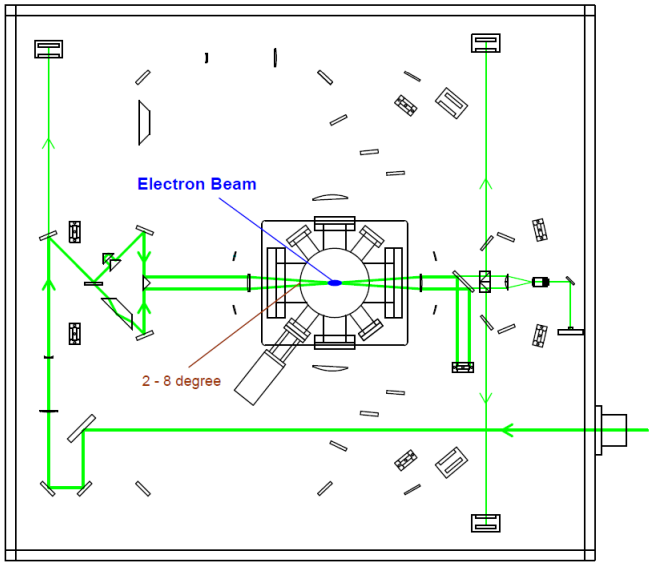


Vertical Measurement (Interference Mode)

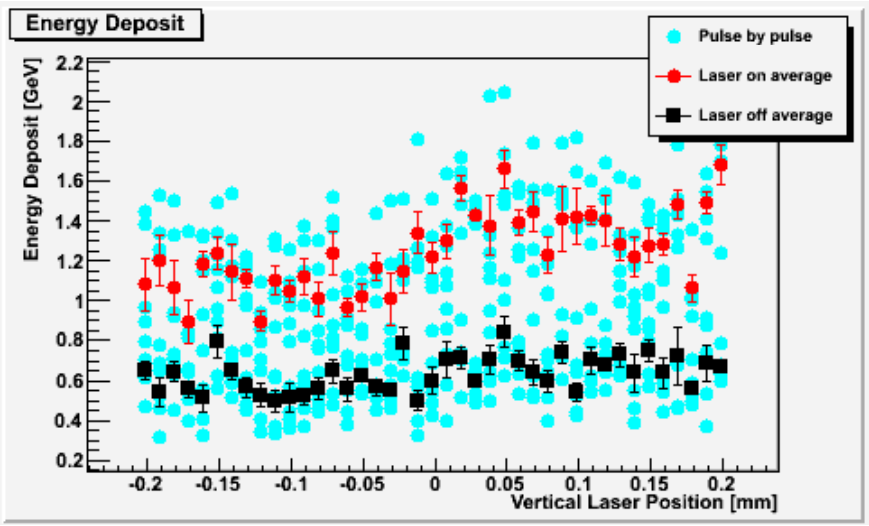
-***2-8 degree crossing angle was used to measure several um vertical beam.***

-Signal was detected in the first week of April.
But, the clear peak was not observed.

-***We need more accurate laser-beam collision tuning (alignment) procedure***
(additional screen monitor will be installed in this summer shutdown).



low crossing angle interferometer optics
(vertical measurement)



measured on 9 April, 2009

Summary

-*Incoming vertical dispersion is sometimes large and difficult to correct with sum-knob.*

-*Then, correction of vertical dispersion with independent skew quads makes large coupling and the coupling cannot be corrected by following skew quads.*

-*The measured minimum vertical emittance at extraction line was 11pm.*
(In this case ,vertical dispersion could be corrected by single sum-knob)

-*We confirmed design horizontal beam size for high beta optics at the post-IP wire scanner.*

-*We achieved the vertical beam size of 2.9μm at post-IP wire scanner.*
This includes effect of the wire size (10μm diameter) which is dominant.
(But not by the designed beam size tuning method with sextupole mover)

-*We did horizontal beam size measurement by IP-BSM (laser wire mode).*

-*We have not yet measured vertical beam size by IP-BSM (interference mode).*

Back Up

Vertical Dispersion Correction (Design)

3rd ATF2 project meeting (2007) M.Woodley

When we apply the sum-dispersion correction knob, only small betatron coupling is generated by the vertical dispersion correction with skews.

$$R = \begin{bmatrix} R_{11} & R_{12} & R_{13} & R_{14} \\ R_{21} & R_{22} & R_{23} & R_{24} \\ R_{31} & R_{32} & R_{33} & R_{34} \\ R_{41} & R_{42} & R_{43} & R_{44} \end{bmatrix} \equiv \begin{bmatrix} \mathrm{A} & \mathrm{B} \\ \mathrm{C} & \mathrm{D} \end{bmatrix}$$

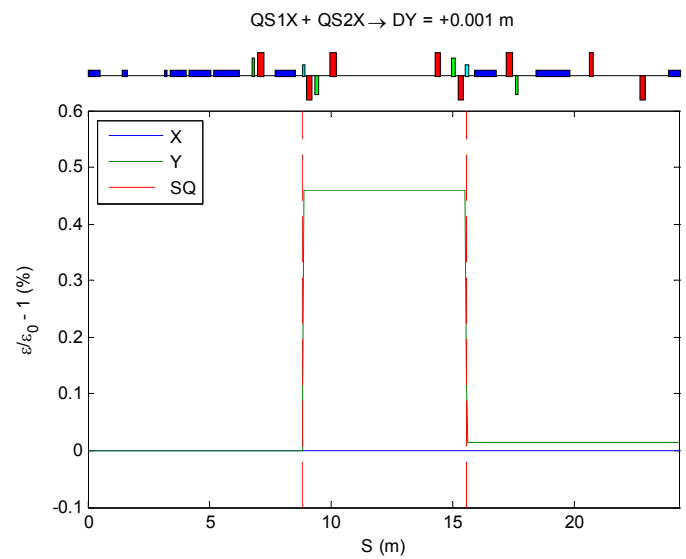
$$\mathrm{Q}_{x,y} \equiv \frac{1}{\sqrt{\beta_{x,y}}} \begin{bmatrix} \beta_{x,y} & 0 \\ -\alpha_{x,y} & 1 \end{bmatrix}$$

$$\mathrm{P} \equiv \mathrm{Q}_x^{-1} \mathrm{A}^{-1} \mathrm{B} \mathrm{Q}_y$$

$$\lambda = \mathrm{tr}\left(\mathrm{P}\mathrm{P}^{\mathrm{T}}\right)$$

$$\varepsilon_x^2 = |\mathrm{A}|^2 \varepsilon_{x0}^2 + |\mathrm{C}|^2 \varepsilon_{y0}^2 + |\mathrm{A}|^2 \varepsilon_{x0}\varepsilon_{y0}\lambda$$

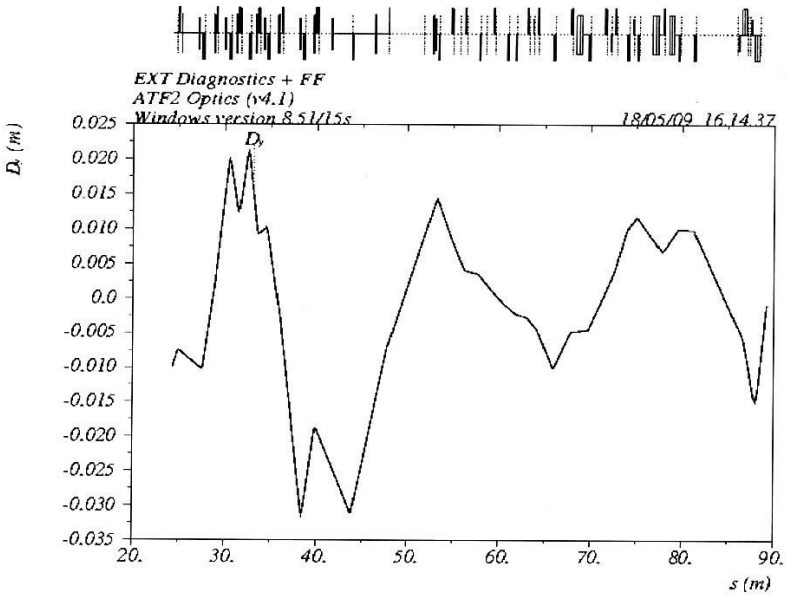
$$\varepsilon_y^2 = |\mathrm{C}|^2 \varepsilon_{x0}^2 + |\mathrm{A}|^2 \varepsilon_{y0}^2 + |\mathrm{A}|^2 \varepsilon_{x0}\varepsilon_{y0}\lambda$$



		QS1X	QS2X
βx	=	9.005	9.005
αx	=	-9.192	9.192
ηx	=	0.203	-0.203
βy	=	102.805	102.805
αy	=	-41.677	41.677
Δμx	=	-	7.710
Δμy	=	-	173.207
kl/klmax	=	0.121	0.121
residual	=	0.0001	

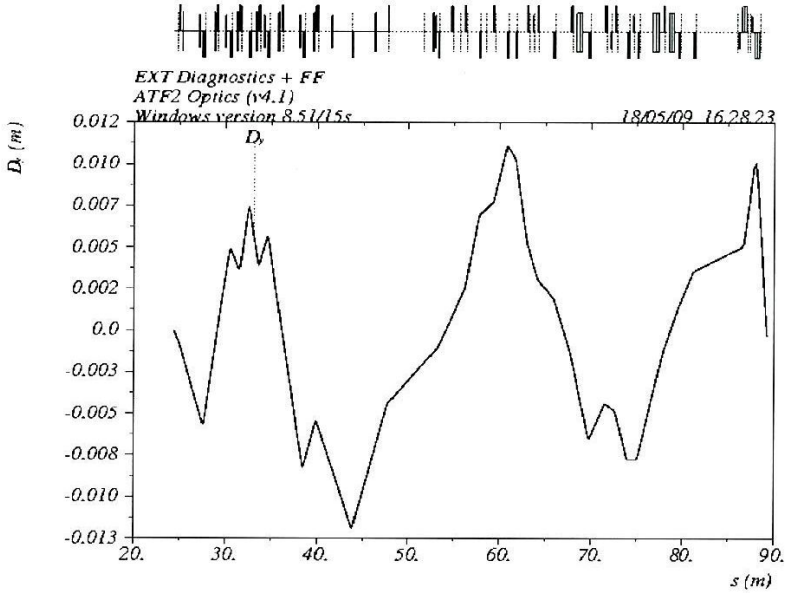
Vertical Dispersion Measurement (05/14)

Before Dispersion Correction



Dispersion Correction with sum-knob

QS1X = +0.455A
QS2X = +0.455 A

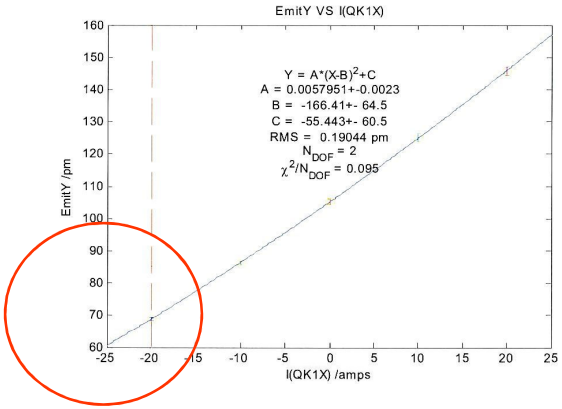


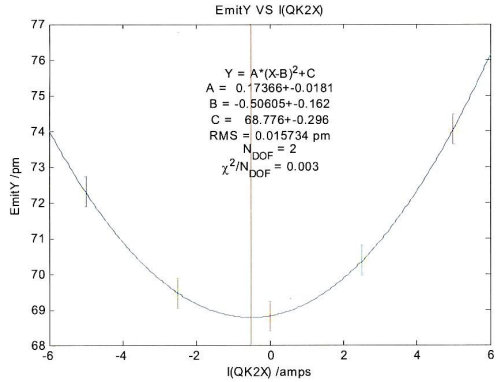
The measured dispersion cannot be corrected with single sum-knobs, It probably means the incoming vertical dispersion (from DR) is large and the phase is not on the phase of the sum-knob.
(In this example.

Simulation for the coupling correction with independent QSs

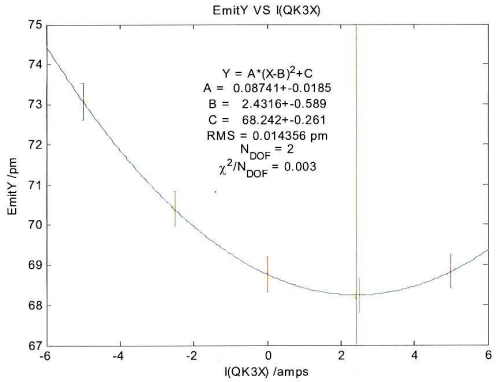
Calculated by M.Woodley

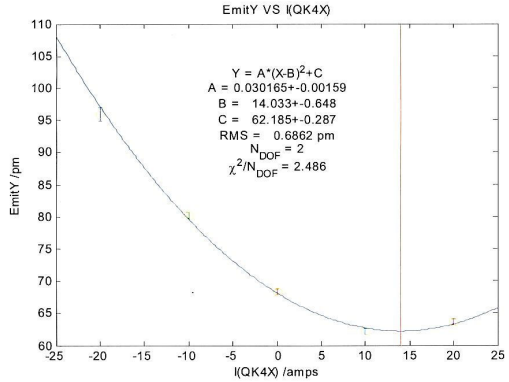
In order to correct the dispersion with QSs, we must apply large opposite fields to QSs, and it make large betatron coupling.





QS1X = - 6.295 A
QS2X = +6.359 A



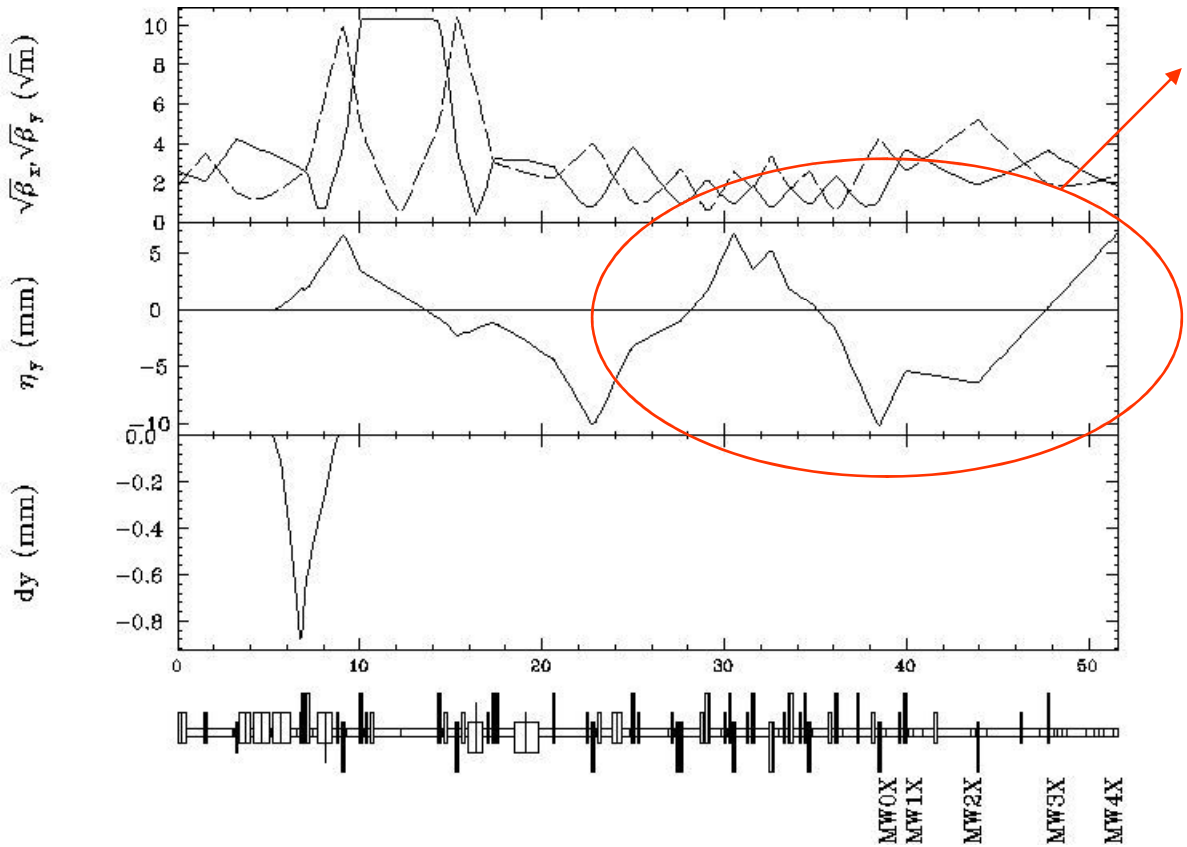


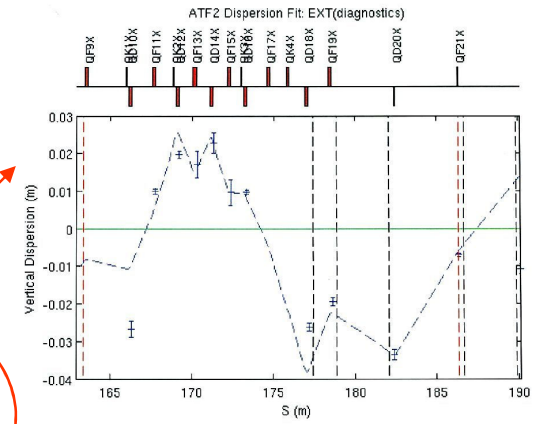
Dispersion correction by skew quads made large x-y coupling, which cannot be corrected by following 4 skew quads.

Candidate of the incoming dispersion source

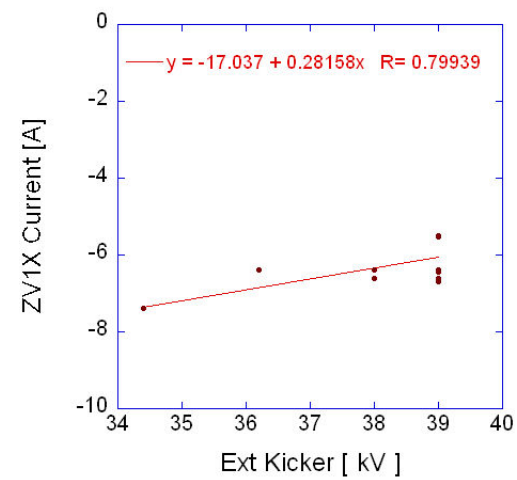
-*ZV1X must be apply huge field to pass the beam.*

-*When we assumed the vertical kick at septum and ZV1X and ZV2X, we can simulate the residulal vertical dispersion.*





Measured dispersion



Vertical kick at septum was smaller for higher kicker voltage