Status of ATF2 Beam Tuning

Toshiyuki Okugi (KEK)

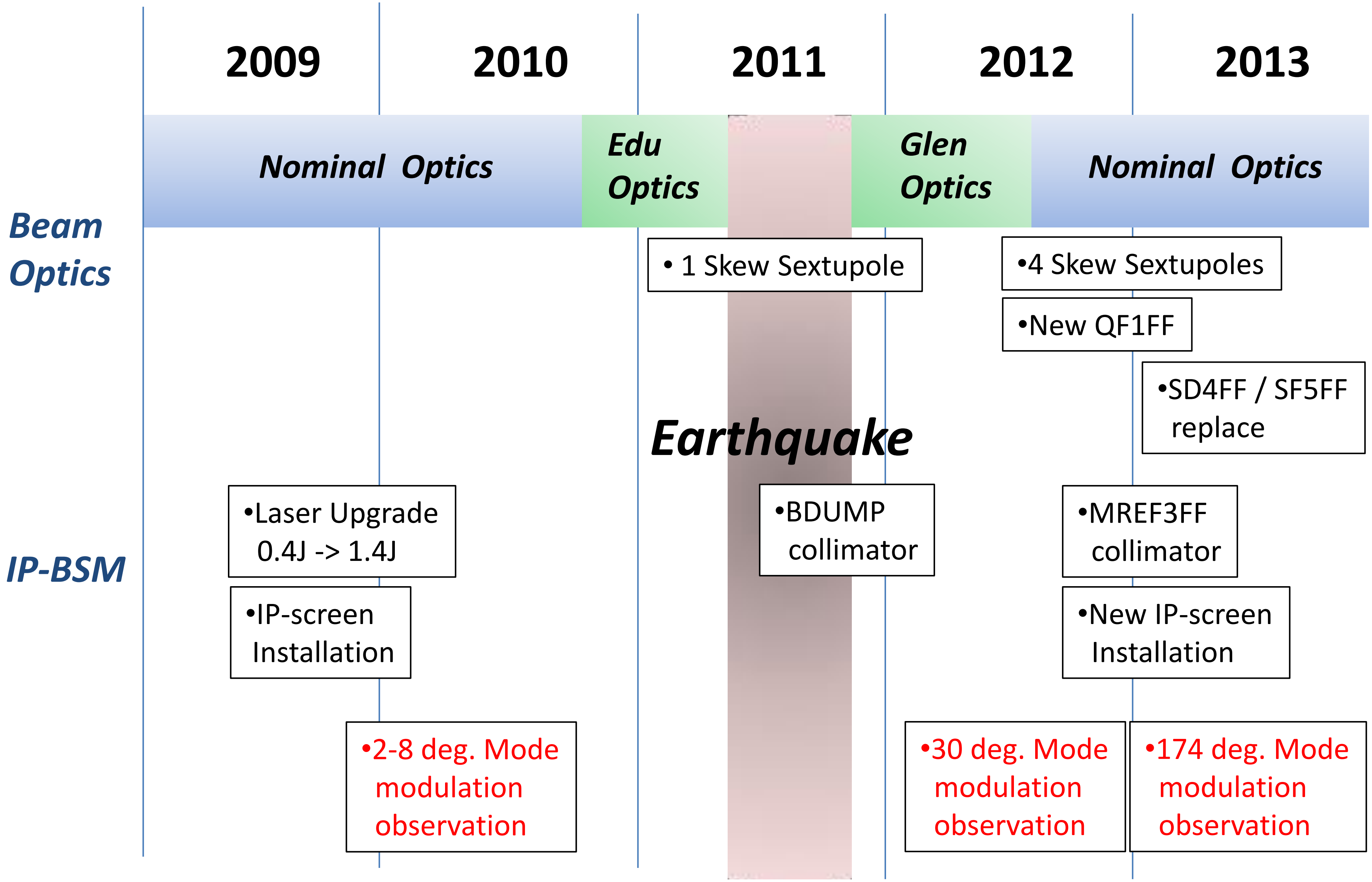
2013/04/03

ATF2 Technical Review for GDE

Contents

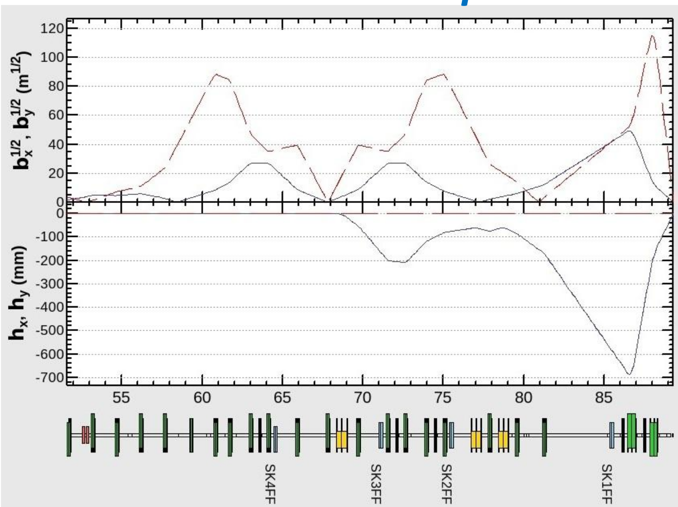
Beam Optics for ATF2 Beamline

History of ATF2 beam tuning

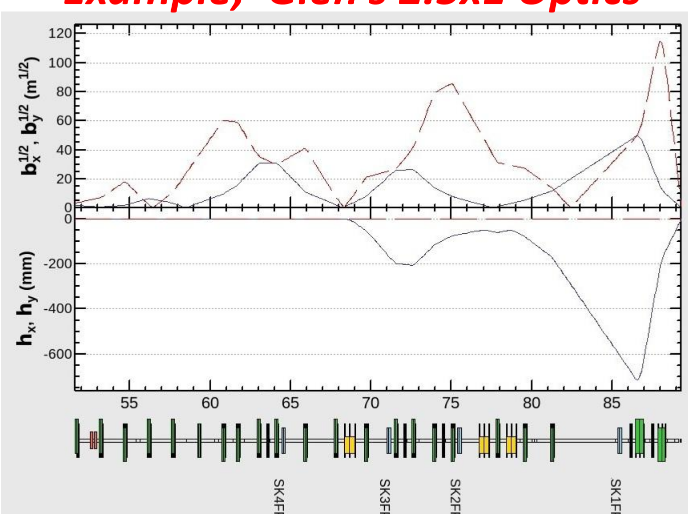


Special Final Focus Optics
to be cancelled the multipole errors

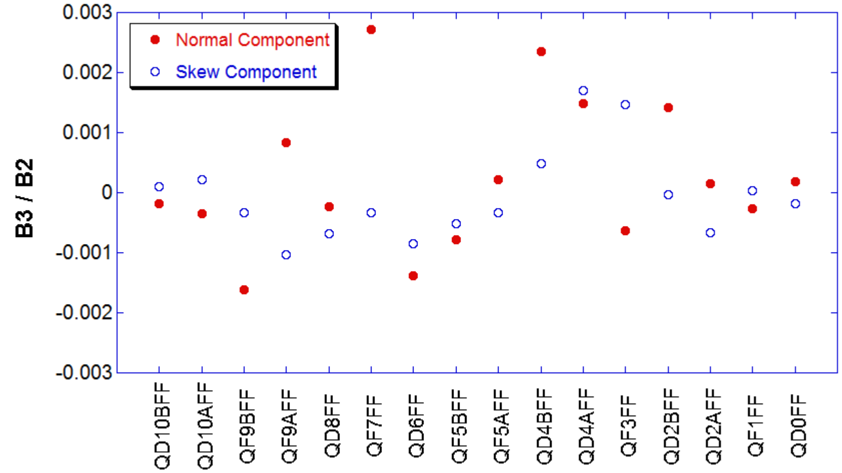
Nominal2.5x1 Optics



Example; Glen's 2.5x1 Optics



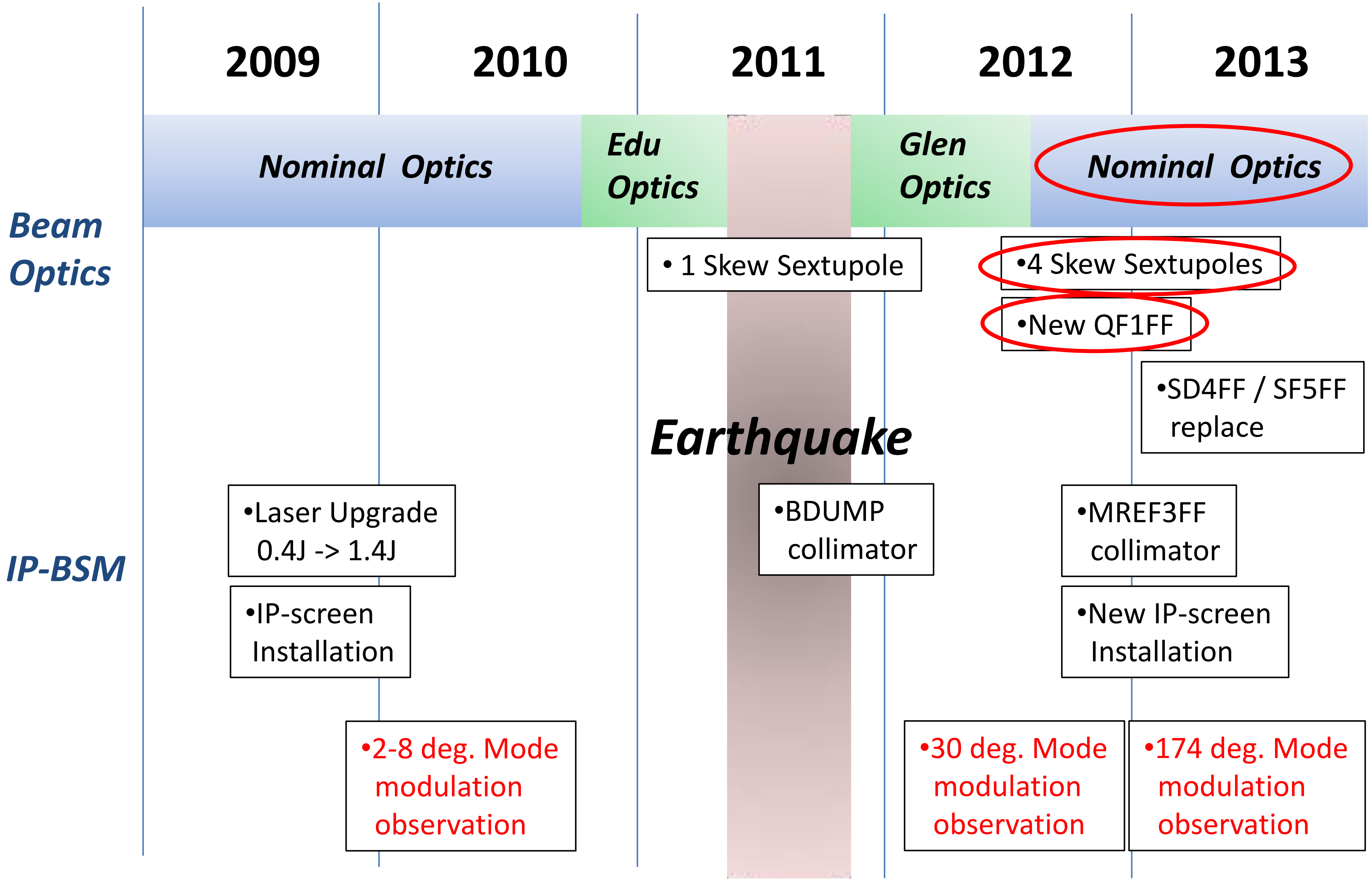
Sextupole Field Errors
for the quadrupoles in ATF2 beam line



From 2010 Dec. to 2012 June

We used some special FF optics
to be cancelled the multipole field errors
in ATF2 final focus beam line.

History of ATF2 beam tuning

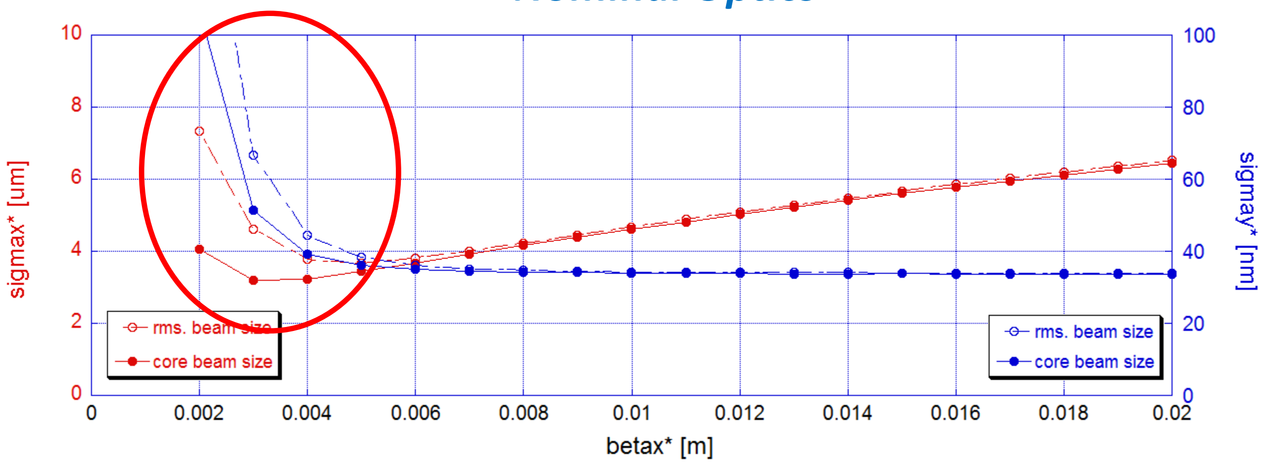


Now, we use the nominal FF optics

No significant difference after correction with 4 skew sextupoles.

We switched back to Nominal Optics in October 2012.

Nominal Optics

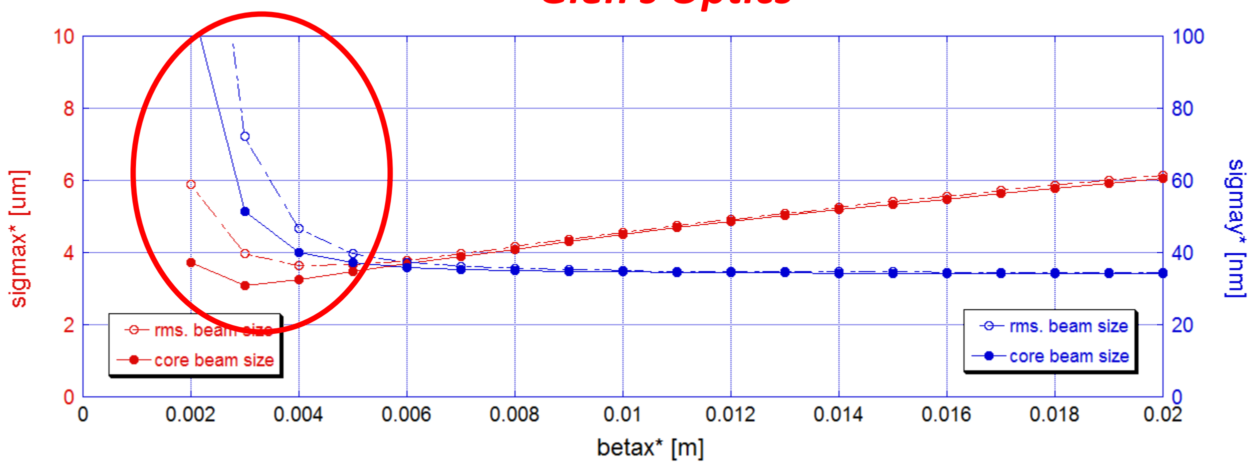


emitx = 2nm
emity = 12pm
betay = 0.1mm*

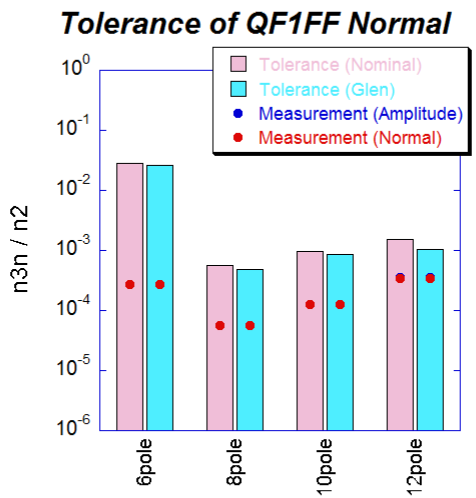
after Y24 Y46 Y22 Y26 Y66 Y44 correction

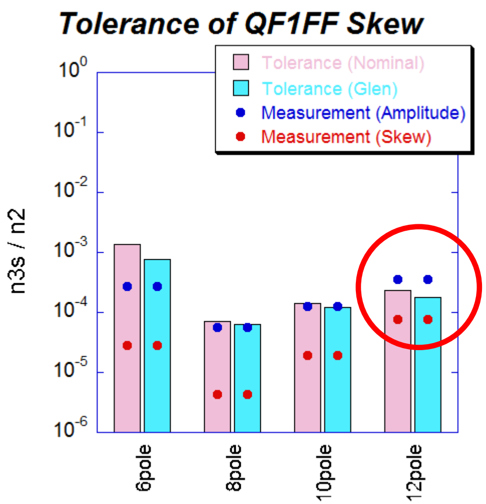
betax's are changed by changing matchng quads.*

Glen's Optics



QF1FF Magnet Replacement in November 2012



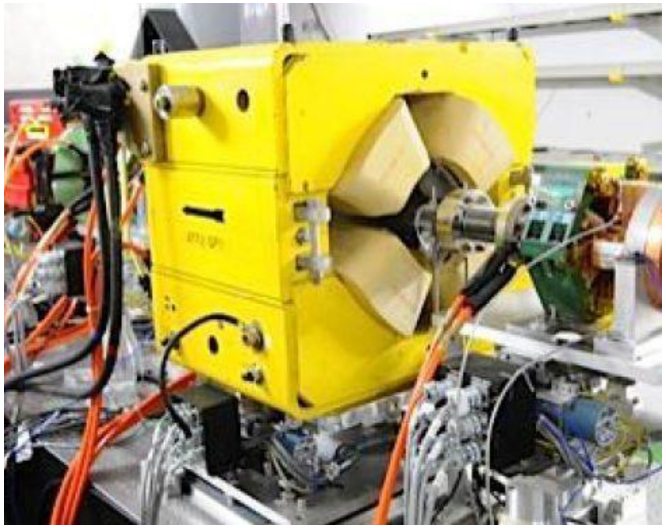


Red ; Nominal 2.5x1
Blue; Glen's 2.5x1

emitx = 2nm
emity = 12pm

with 4 skew sextupole correction

12pole of QF1FF was limited to reduce betax more.*



Therefore, we replaced QF1FF to the quadrupole magnet used in PEP-II.

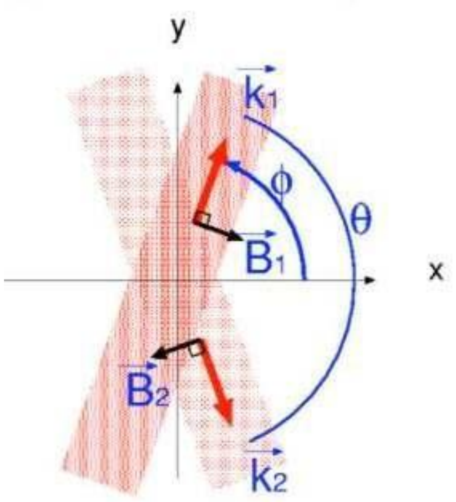
IP Beam Size Monitor in ATF2

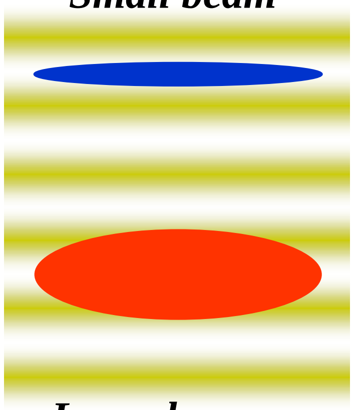
IP Beam Size Monitor (Shintake Monitor)

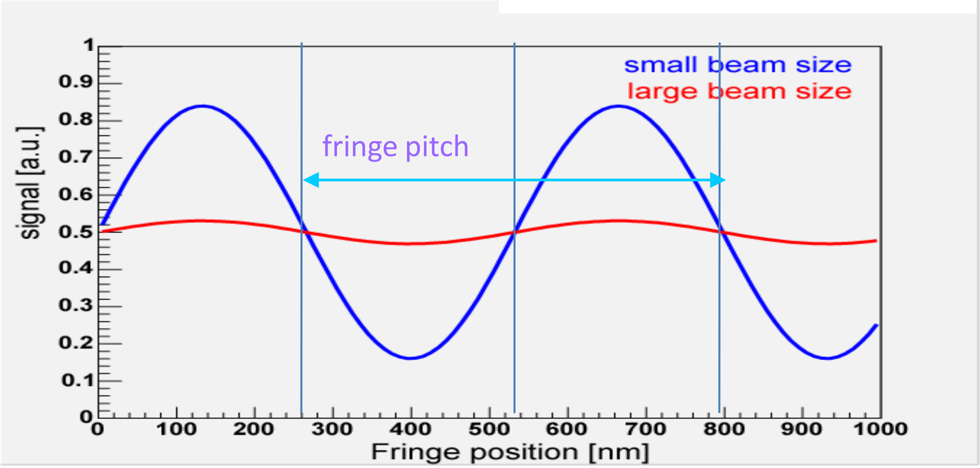
Laser is split into 2 paths.

The both laser paths
are collided at IP.

The interference pattern
is generated at IP.



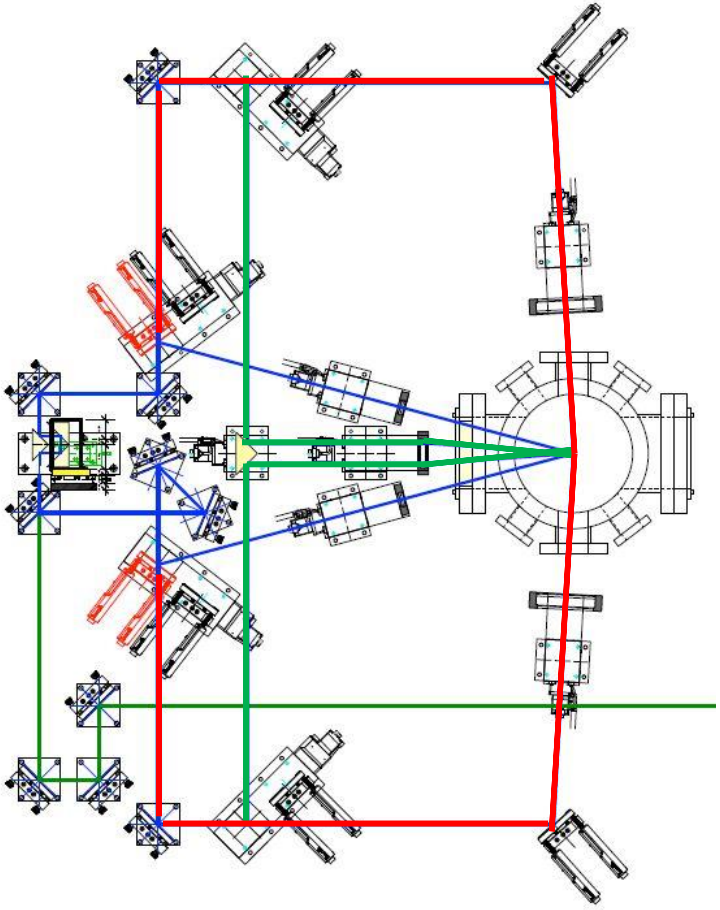




Modulation

$$M = \frac{N_{max} - N_{min}}{N_{max} + N_{min}}$$

IP-BSM for ATF2



Laser wave length was changed.

FFTB ; Nd:YAG fundamental mode (1064nm)

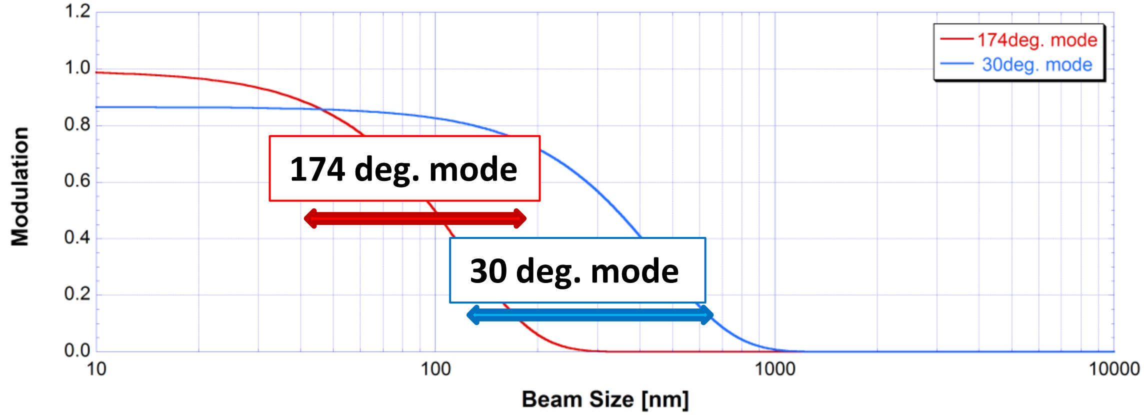
ATF2 ; Nd:YAG harmonic doubler (532nm)

Add the collision mode

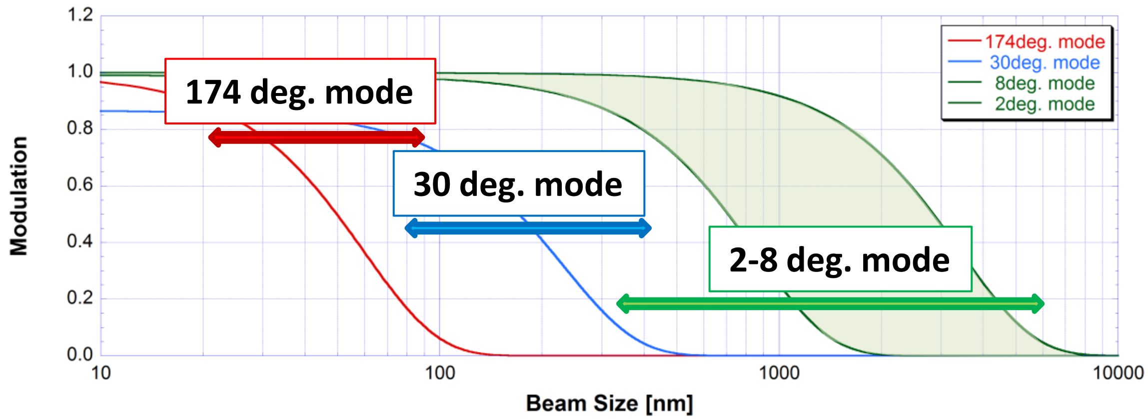
FFTB	**ATF2**
174deg mode	174deg mode
30 deg mode	30 deg mode
	2-8deg mode

Dynamic Range of IP-BSM

FFTB IP-BSM (40 – 600 nm)

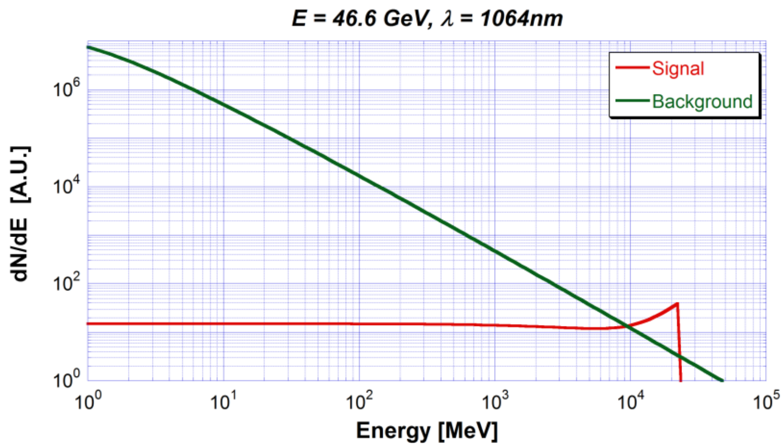


ATF2 IP-BSM (20 – 6μm)



S/N ratio of IP-BSM

FFTB
46.6GeV
λ = 1064nm

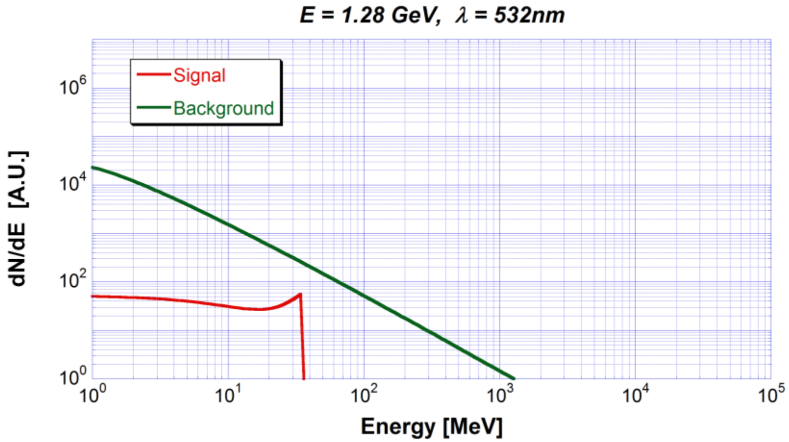


Maximum Compton Energy

$$E_{max} = 2\,\gamma^2\,E_l$$

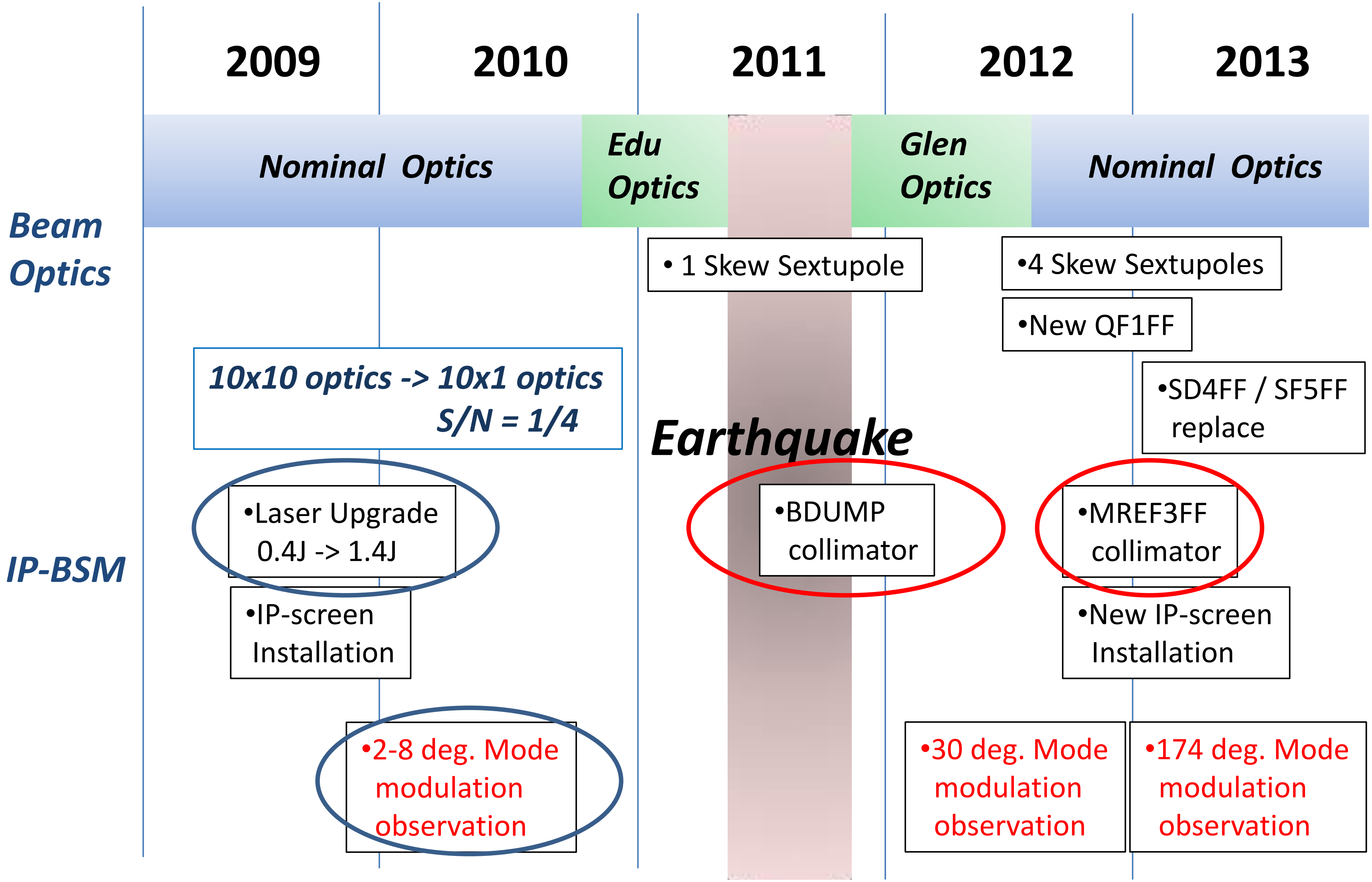
Low energy background
is larger than high energy BG.

ATF2
1.28 GeV
λ = 532nm

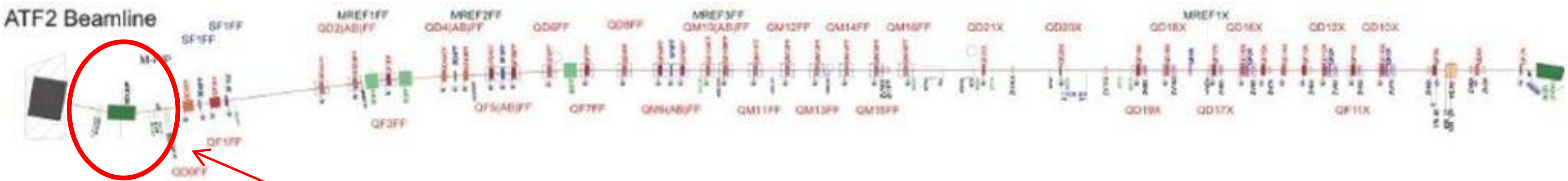


It is difficult to distinguish
Compton signal and Background
for the small beam energy in ATF.

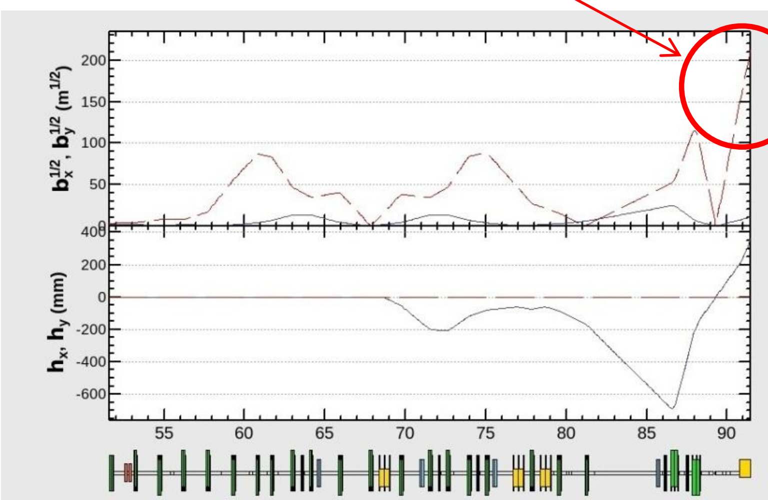
History of ATF2 beam tuning



Collimator at Dump Bend

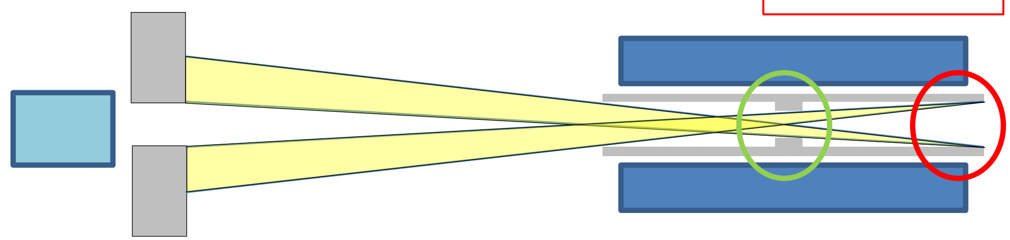


BG source



Since vertical aperture of dump bend was large BG source,

BG source

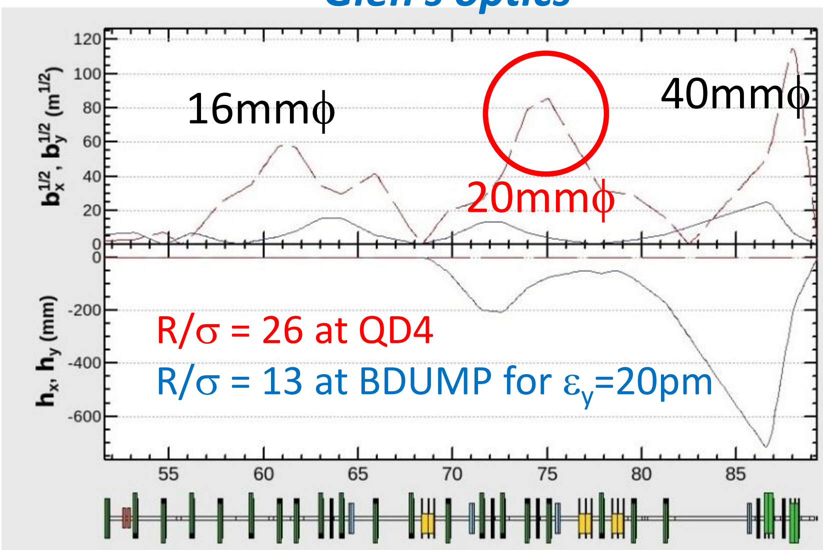


We put the collimator in the bend chamber.

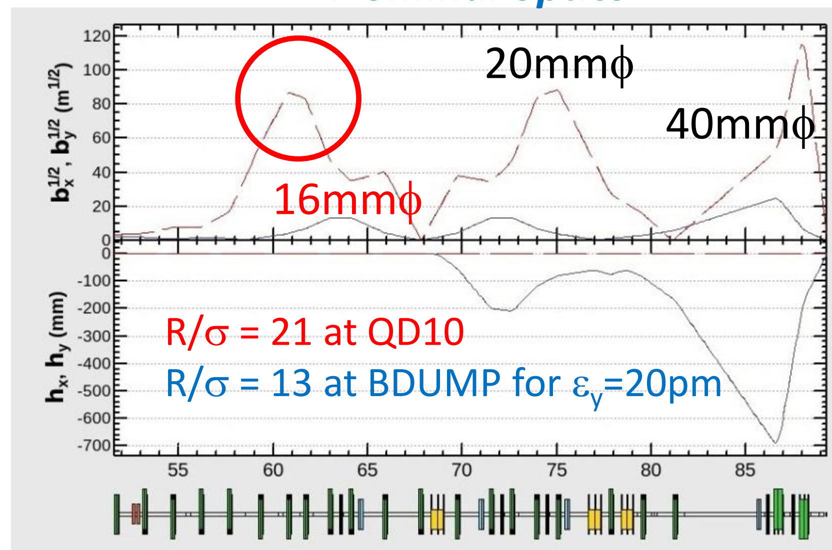
BG level was reduced 1/3 – 1/4.
Then, S/N = 1 for 10x1 optics

Optics dependence of IP-BSM background

Glen's optics



Nominal optics



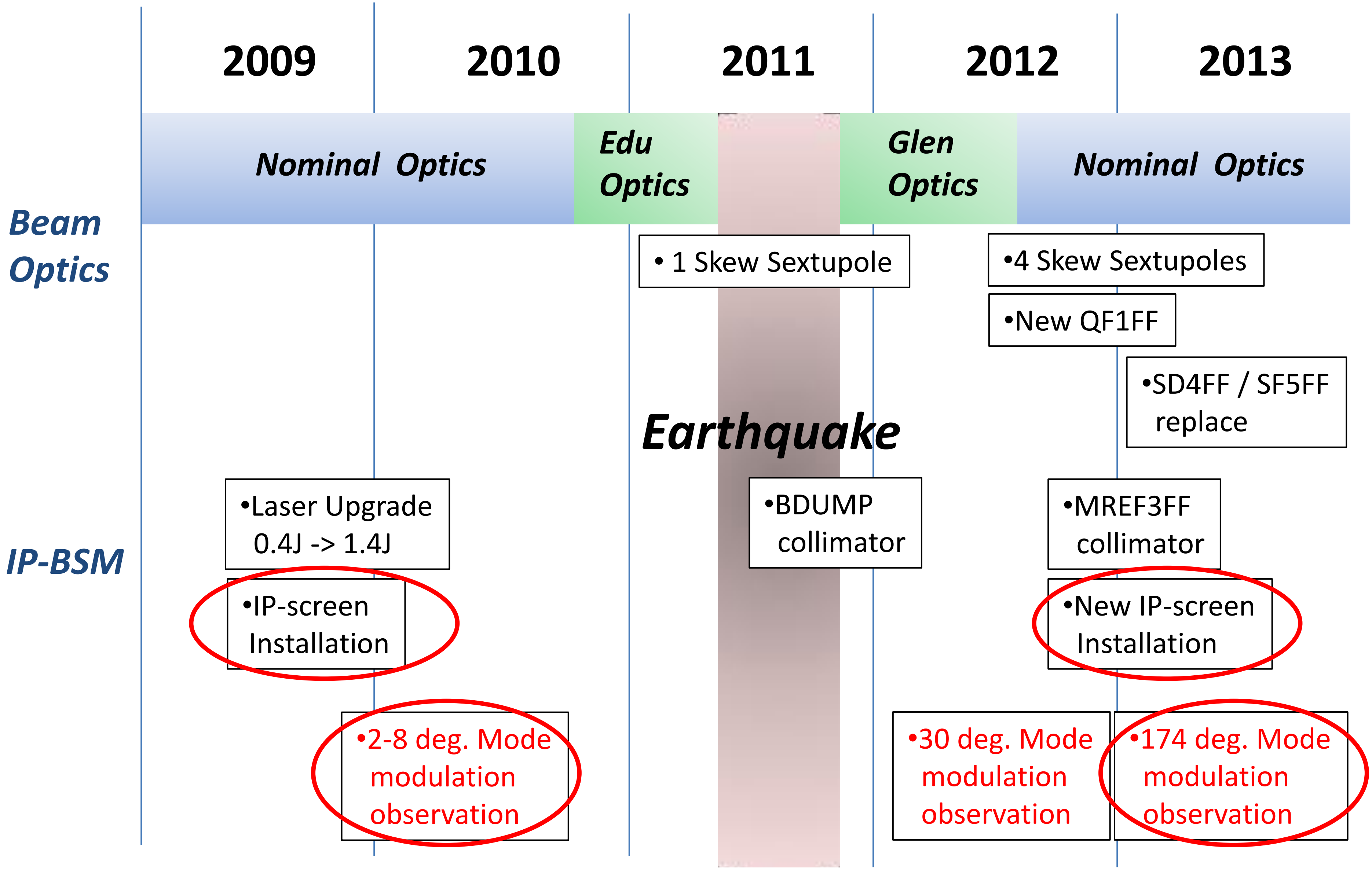
Reference cavity at high beta region affect as a collimator.

Reference cavity was on mover for wake study (see K.Kubo presentation).

The position of reference cavity is very sensitive to the IP-BSM BG.

The BG level was reduced by factor 2-3 to optimize the position of reference cavity after we switched back to nominal optics (S/N = 2-3).

History of ATF2 beam tuning



ATF2 IP-BSM Screen monitor

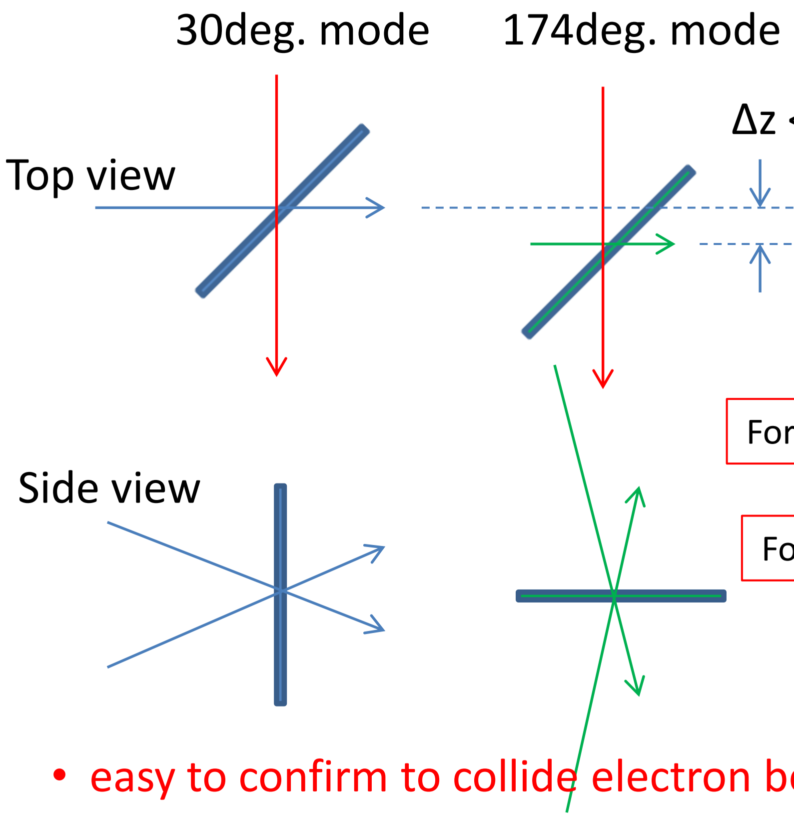
Old Screen System

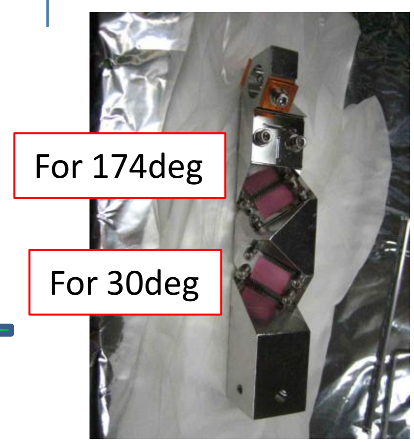
We have 2 screens.

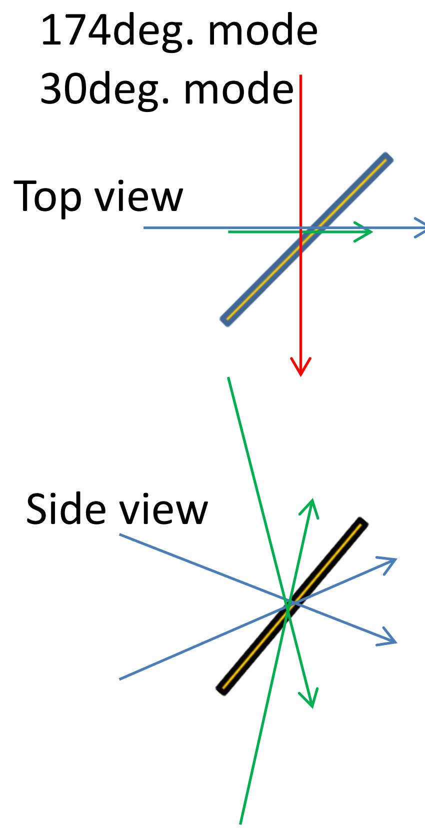
- 1 for 30 deg. mode
- 1 for 174 deg. mode

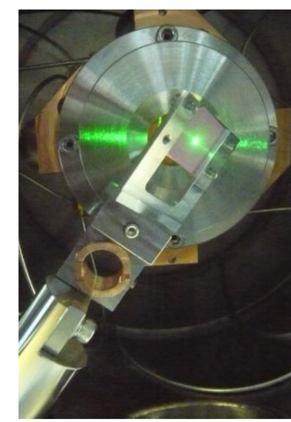
New Screen System

We adjust the laser paths both of 30 deg. and 174 deg. modes with 1 screen.







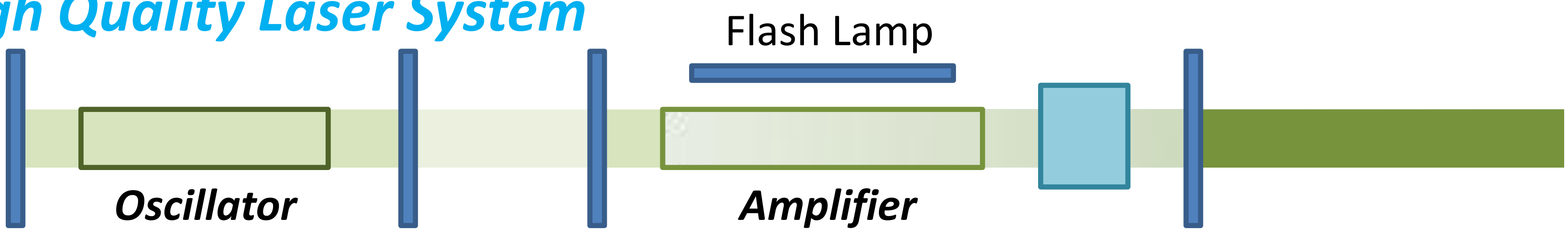


- easy to confirm to collide electron beam and laser.
- easy to confirm to collide two laser beams.
- difficult to confirm to set same z-position for 30deg & 174deg mode.

- easy to confirm to set same z-position for 30deg & 174deg mode.

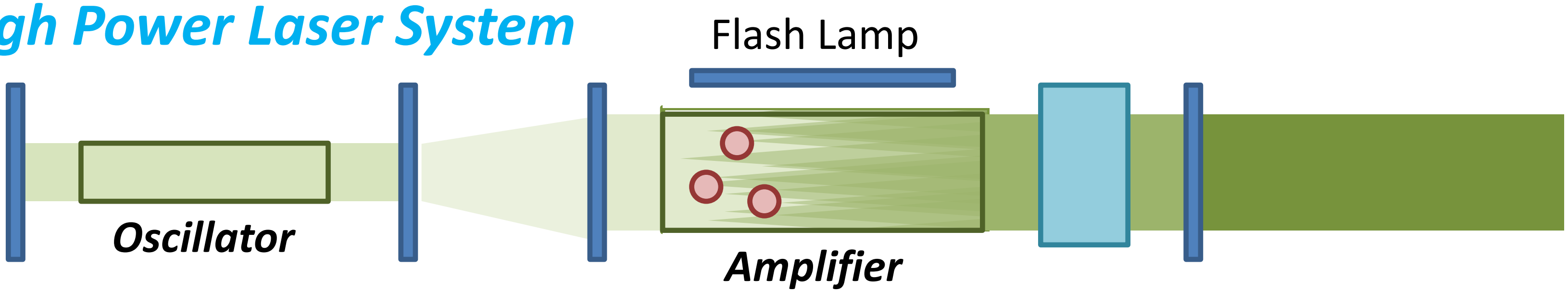
Present Problems of ATF2 IP-BSM laser

High Quality Laser System



- The YAG crystal of oscillator and amplifier are same diameter to keep a good laser profile and spatial coherency of seed laser.

High Power Laser System



- The YAG crystal of amplifier is larger than that of oscillator.
- Seed laser is expanded to inject the main laser amplifier in order to avoid to a damage from an extremely high laser density in YAG crystal.
- It makes several source points in YAG crystal -> reduce the spatial coherency.

In order to increase S/N, we use a high power type of laser in ATF2 IP-BSM.

2012 February ; Maximum modulation was almost 80%.

- The good mode lock condition kept only 1 or 2 weeks.
- The optical components (viewports and mirrors) were broken by hot spot of laser.
- We frequently called the laser expert from laser company to tune the laser.

2012 March ; Maximum modulation was reduced to almost 60%.

- We expand the laser diameter in the laser amplifier.
- We exchanged the mode lock circuit.
- We put a half mirror to decrease the laser intensity at viewports.
- The good mode lock condition kept several weeks without the laser expert tuning.
- The optical components did not have sevire damage.

2012 November ; Maximum modulation was increased to 80-90%.

- The laser diameter in the laser amplifier was back to the original diameter.
- The stable mode lock condition kept without the laser expert tuning.

2013 February ; Maximum modulation was decreased to about 70%.

- The flash lamps were changed for their lifetime.
- The laser profile was changed (by thermal lens effect in crystal ??).

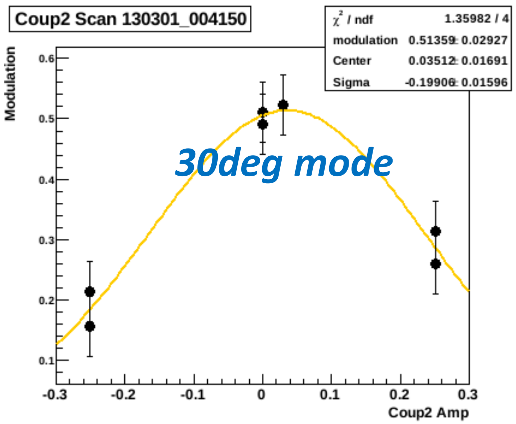
2013 March (next week); Maximum modulation was increased to above 85%.

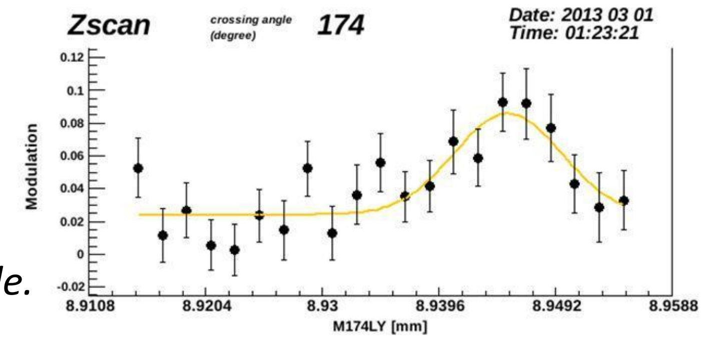
- The laser expert tune the laser profile.

The spatial coherency strongly depends on the laser profile.

The week of 2/25 – 3/01

Require to 174deg mode ; > 73%
Max modulation ; 51%





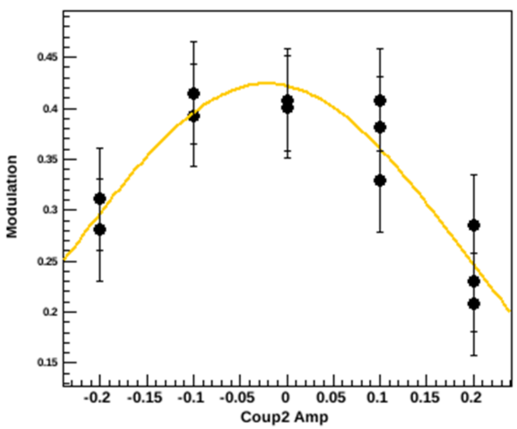
We could find the IP-BSM modulation of 174 deg mode.

We can use the IP-BSM for beam tuning, even if the maximum modulation is small.

But, it is difficult to evaluate the beam size from IP-BSM modulation.

The week of 3/04 – 3/08

30deg mode (3/6)

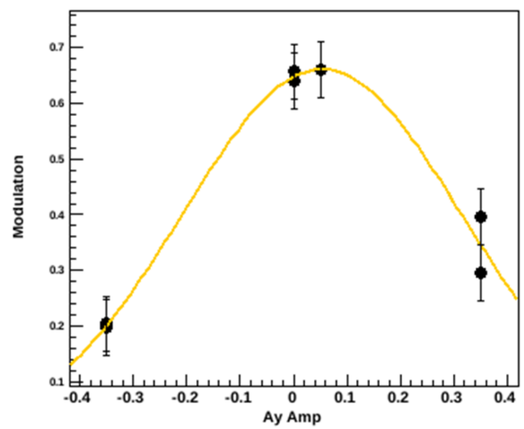


Max modulation ; 42%

Laser profile tuning by laser expert.

Maximum modulation was increased.

30deg mode (3/7)



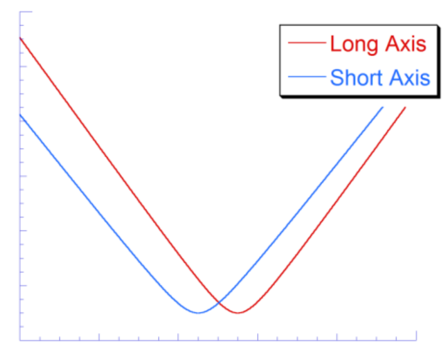
Max modulation ; 66%

The laser divergences for horizontal and vertical were different.

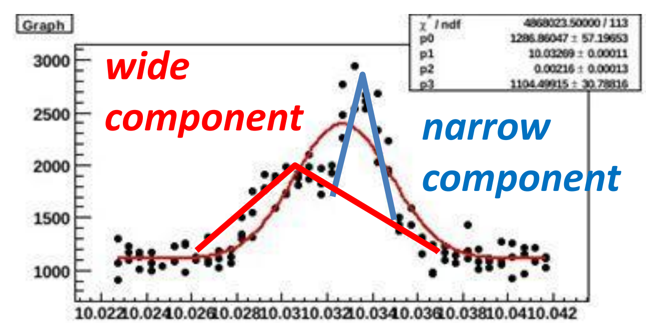
The laser profile of vertical and longitudinal plan was rotated at IP.

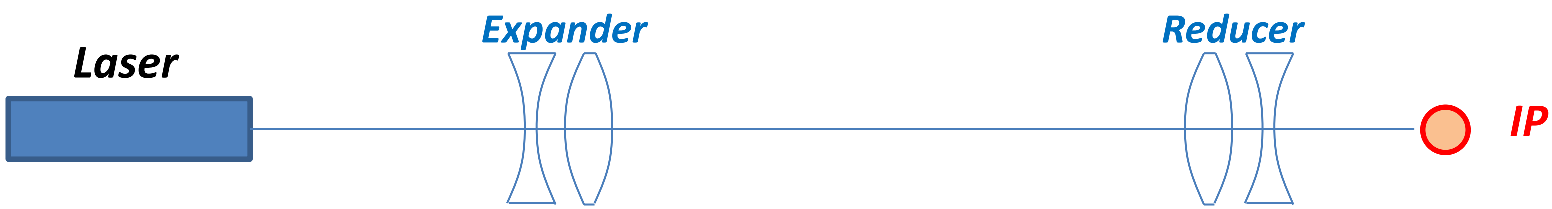
Since the laser focus was checked by measuring the projected beam size to vertical axis, it is difficult to focus to the laser waist.

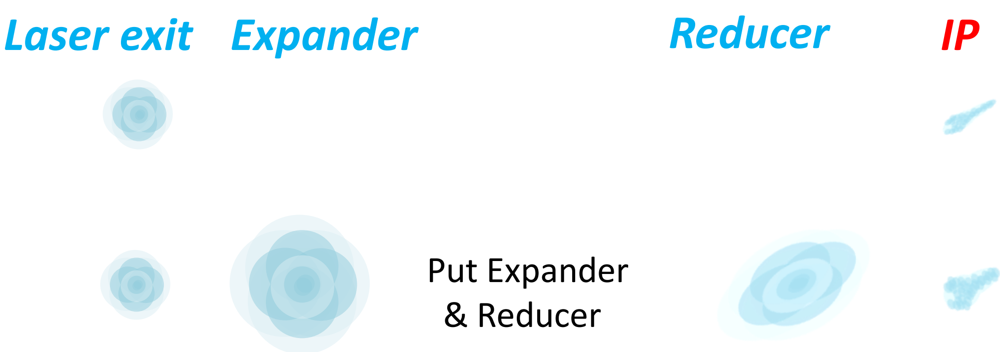
The laser overlap for upper and lower path was smaller than the expectation from laser wire scan in vertical axis.

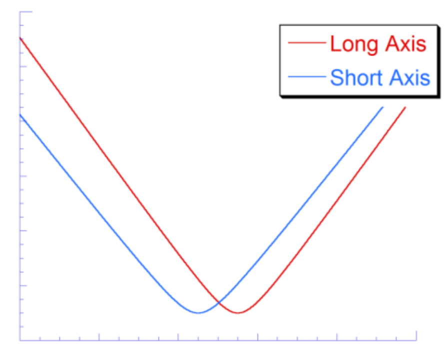


Vertical and longitudinal profiles are the projection of these axis.



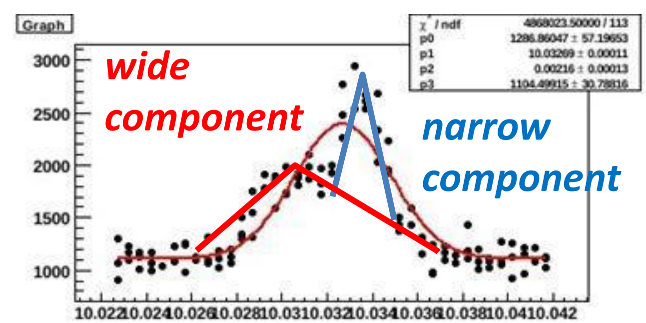


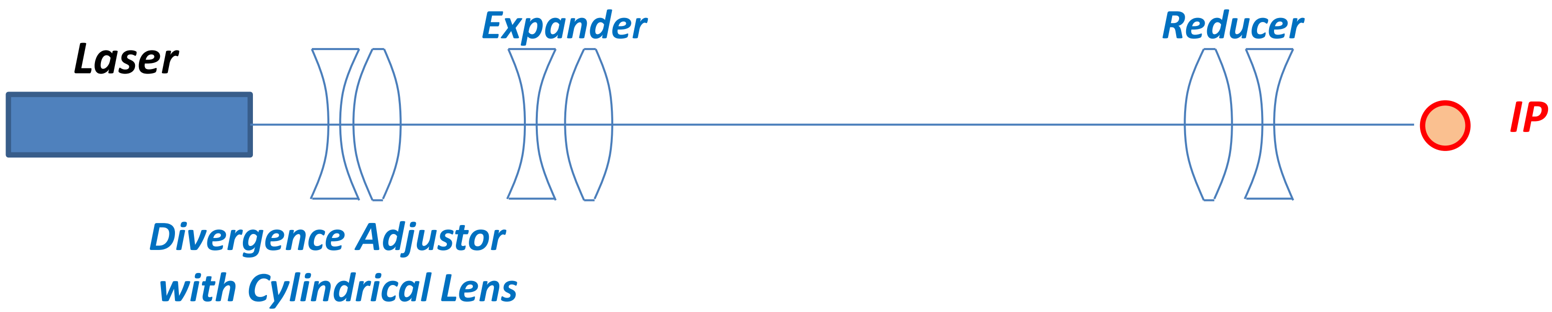


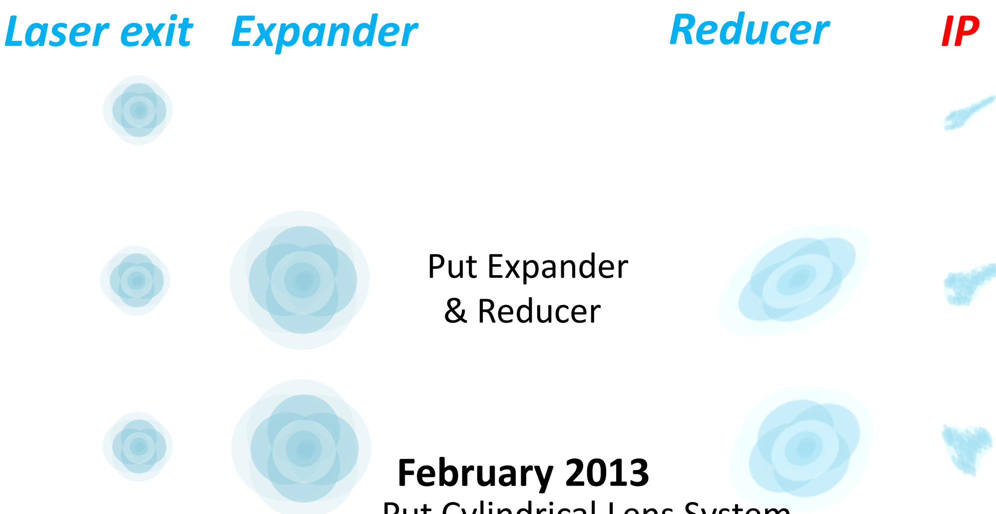


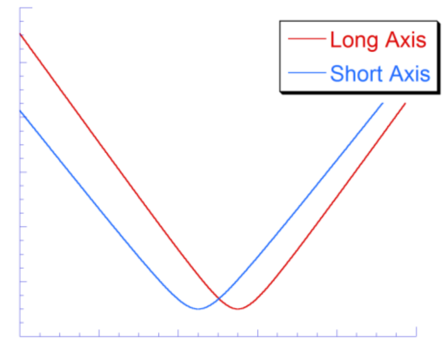
Shorten the effective laser path length

Vertical and longitudinal profiles are the projection of these axis.







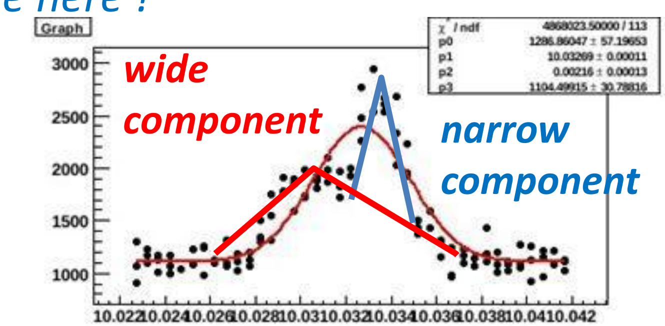


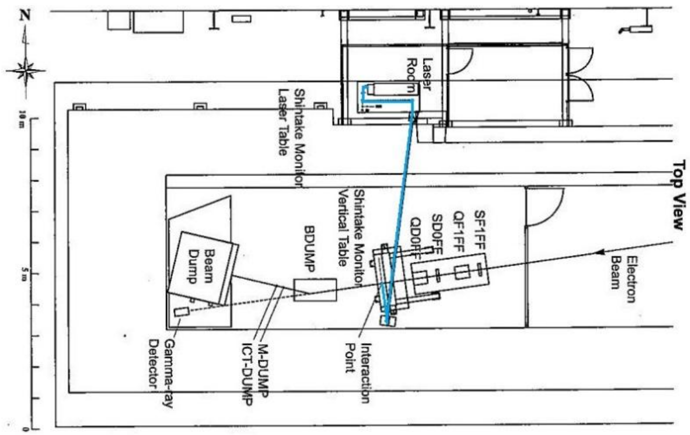
Vertical and longitudinal profiles are the projection of these axis.

Change the aspect ratio of laser.

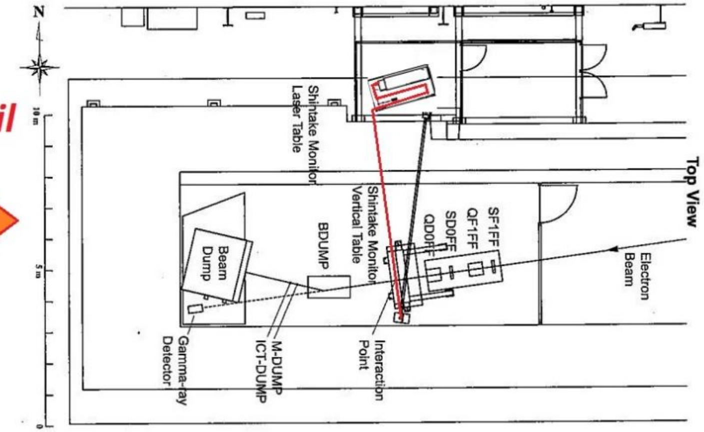
The focal points for 2 axis were closed.

We are here !

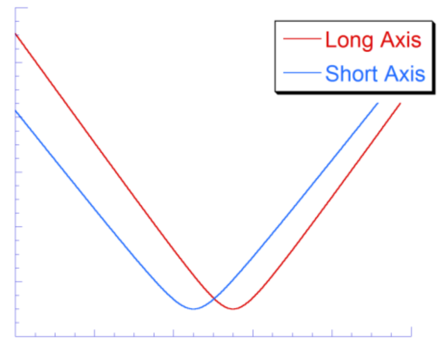




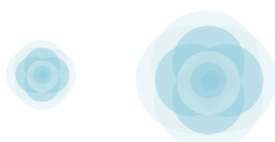
2013 April



Laser exit | Expander | Reducer | IP



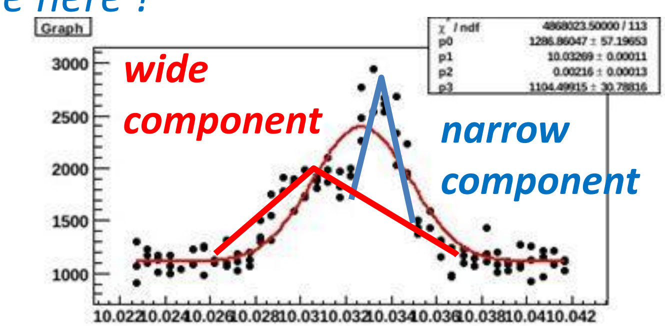
Vertical and longitudinal profiles are the projection of these axis.

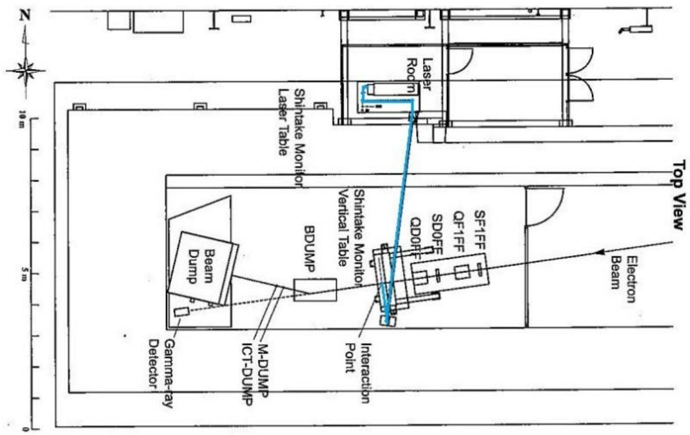


April 2013
Change Laser Transport

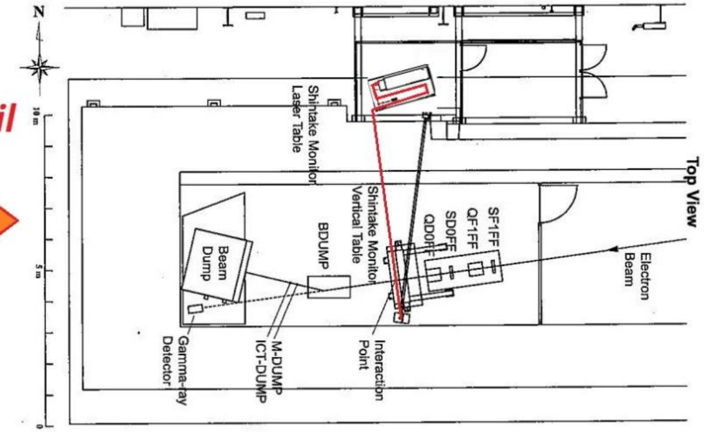
Correct the rotation of laser at IP

We are here !

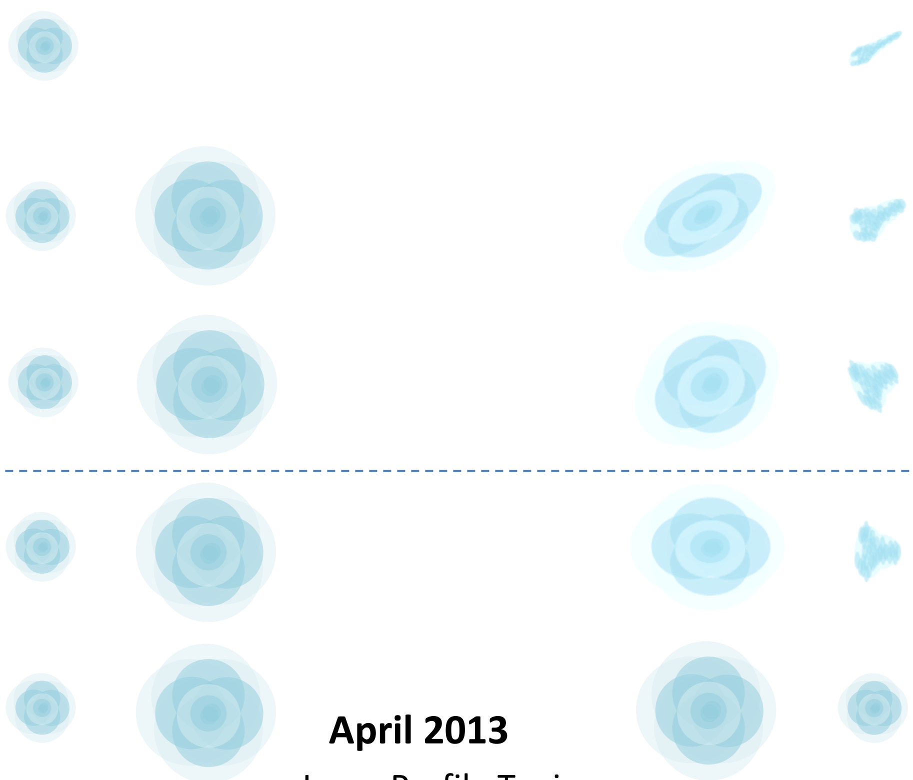


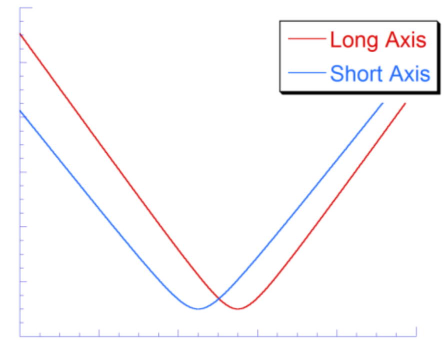


2013 April



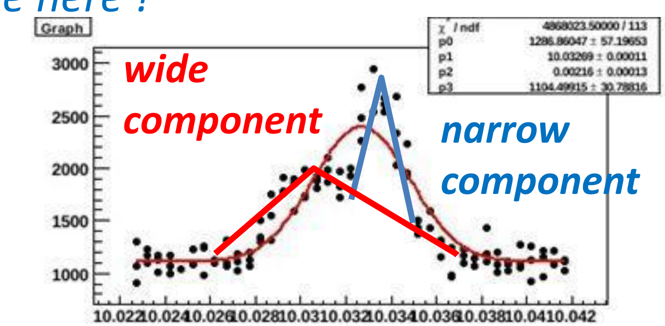
Laser exit *Expander* *Reducer* *IP*





Vertical and longitudinal profiles are the projection of these axis.

We are here !



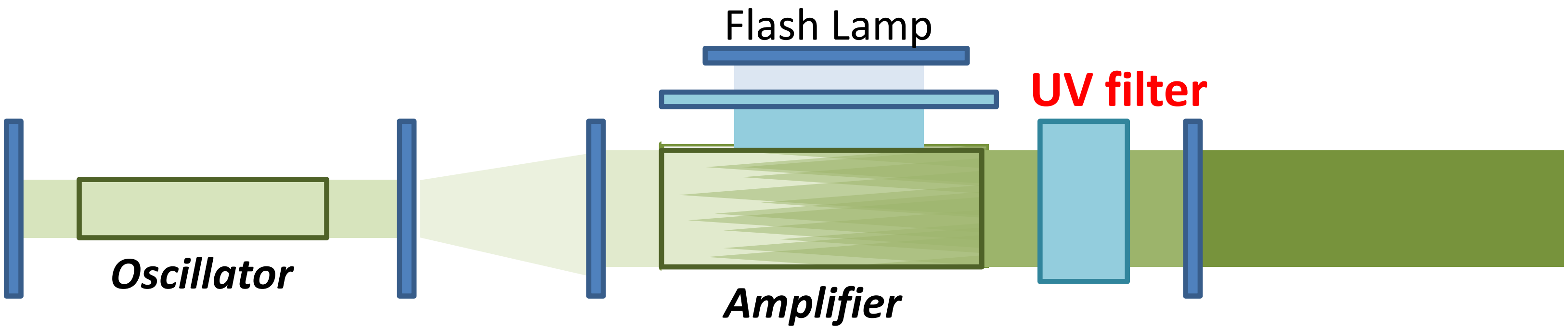
April 2013

Laser Profile Tuning

Profiling the IP-BSM Laser

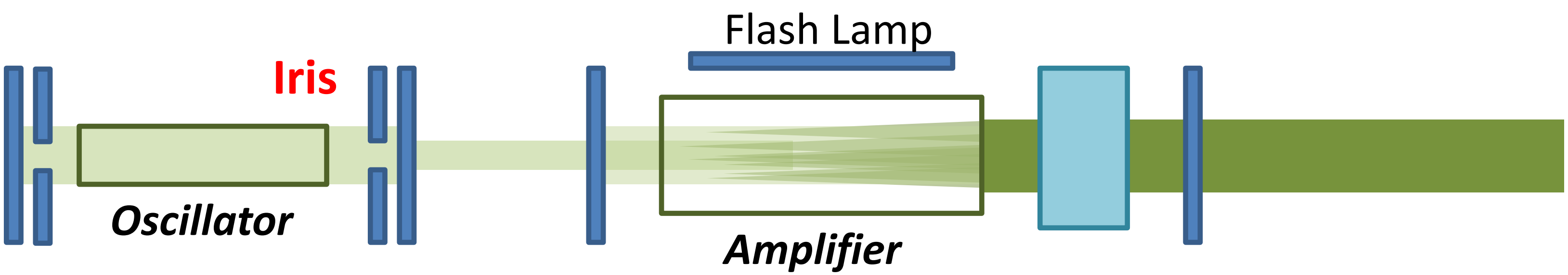
1) Put UV filter in between flash lamp and YAG crystal.

The thermal expansion of YAG crystal was suppressed.



2) Put an iris in laser oscillator.

Laser light in amplifier was centered.



The laser intensity was reduced to be 75%, but the laser profile was improved so much.

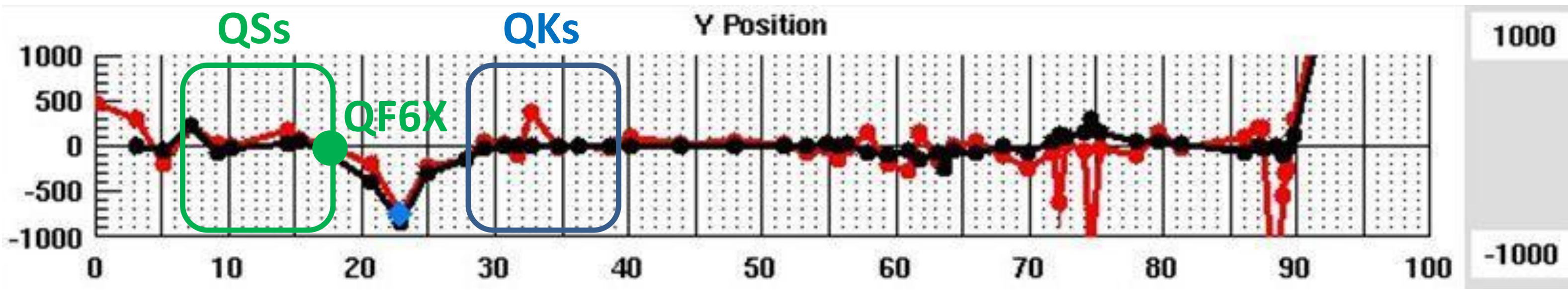
We expect to have a good spatial coherancy in next beam operation

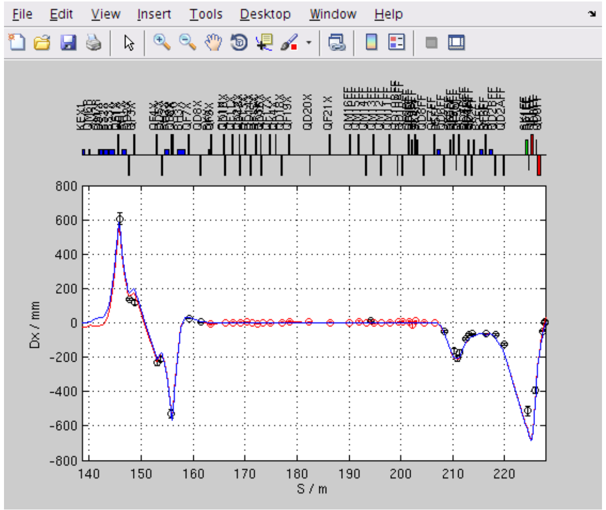
Linear Optics Tuning

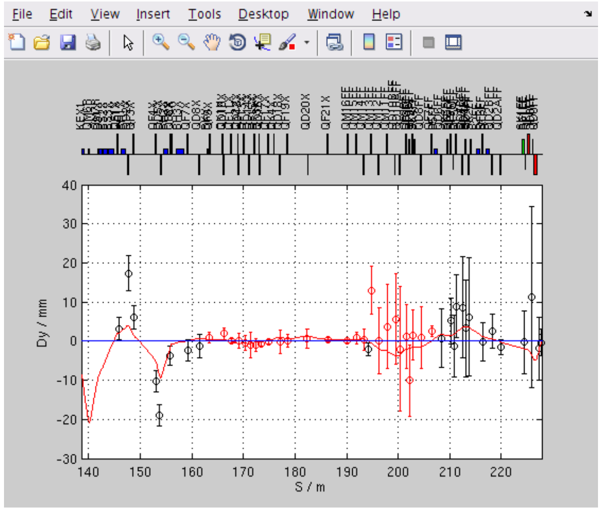
Dispersion Correction in Extraction Line

(see M.Woodley's presentation)

EXT vertical dispersion correction was done with
- QS1X, QS2X sum-knob
- *ZV4X, ZV7X, ZV8X local bump (from February 2013)*
  - small orbit change around QF6X, QSs and QKs



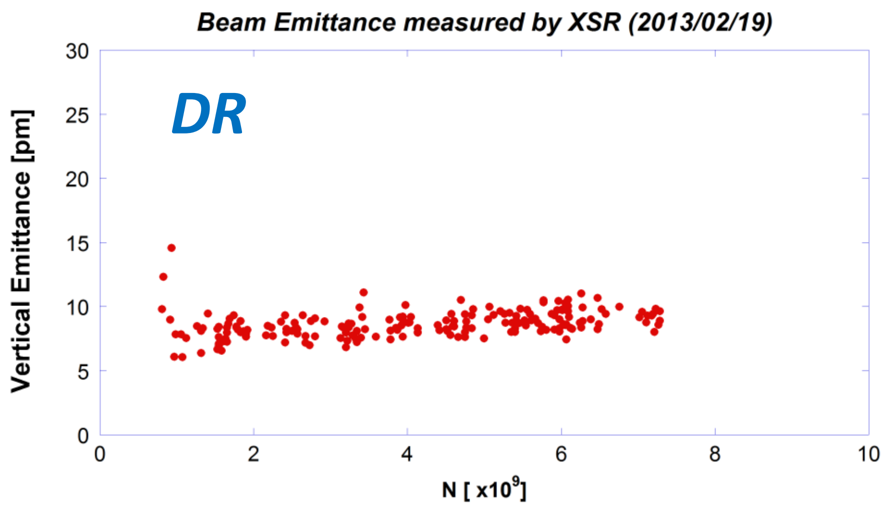


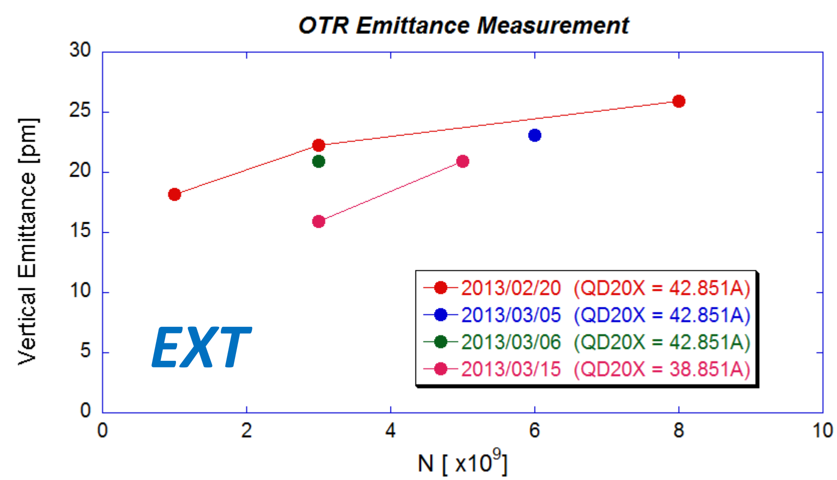


Coupling Correction in Extraction Line

Coupling correction was not used QKs, but QS1X/QS2X difference knob (from 2013 Fubruary).

- We could correct only single coupling component (almost <x'y> at IP), but coupling correction to OTR monitors worked well.
- The amplitude of skew quadrupoles are smaller than QKs correction.
  typical strength of QS correction ; 1-2A
  maximum strength of QK correction; more than 10A
- QK magnets are used for coupling knobs at IP.





The emittance by OTR measurement was still larger than that in DR.

Coupling Knob with QKs (Extraction Line)

(from 2013 March)

The strength of QK1X, QK2X, QK3X, QK4X are orthogonal to make <xy>, <x'y>, <xy'>, <x'y'> knobs.

<xy> ; the IP position correlation (beam tilt).

<xy'> ; the main coupling source at IP, but can be correct with linear knob .

<x'y'> ; possibility to change the IP divergence.

QK coupling knobs for the beam optics of 2013/02/05.

	<xy>	<x'y>	<xy'>	<x'y'>
QK1X	+2.57A	- 3.60A	- 2.00A	+3.80A
QK2X	+2.79A	+2.28A	+5.00A	+3.68A
QK3X	+5.00A	+5.00A	- 3.14A	- 3.12A
QK4X	- 2.43A	+3.82A	- 3.26A	+5.00A

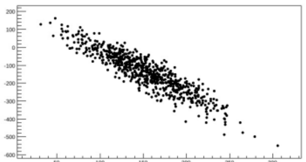
<x’y’> coupling confirmation

(15 March 2013)

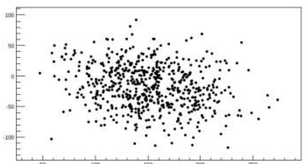
<x’y’> evaluation by QF9FF-X and QD10FF-Y jitter analysis

(entrance of FF)

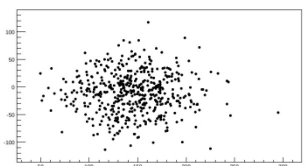
QK4X = +15A



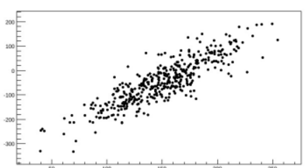
QK4X = 0A



QK4X = -0.8A
(Optimum)

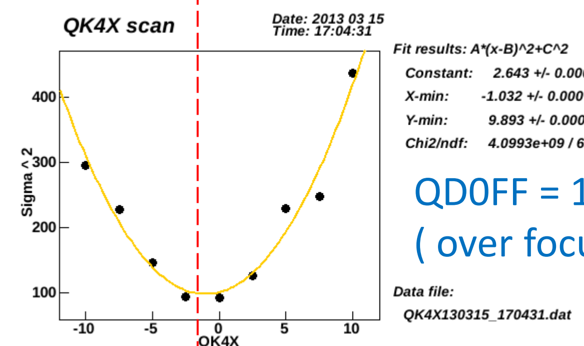


QK4X = -15A



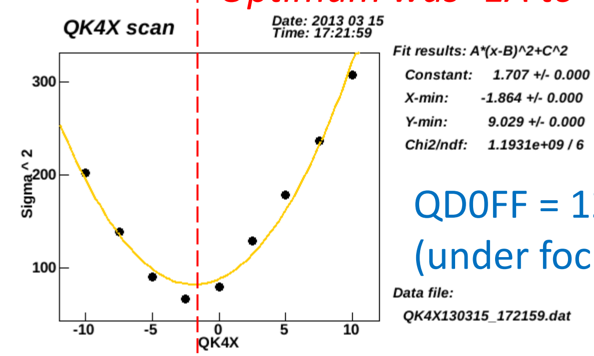
The optimum was very close in between EXT and IP.

<x’y’> evaluation by IP beam divergence



QD0FF = 131.069A
(over focusing)

Optimum was -1A to -2A.



QD0FF = 127.469A
(under focusing)

It was found from the <x’y’> knob test,

- Not only <x’y>, but also <x’y’> are small after the coupling correction of QS difference knob.
- No strong <x’y’> coupling source in FF beam line.

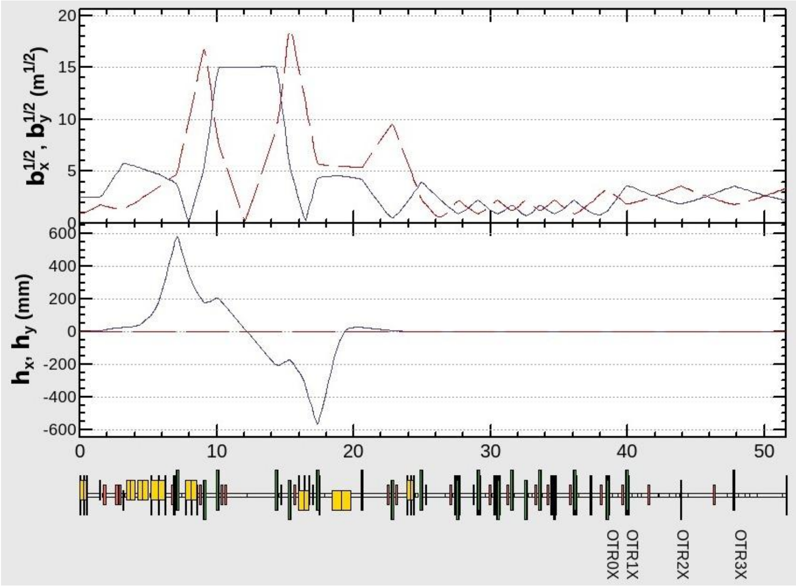
Optics Matching from EXT to IP

The Twiss parameters at the entrance of extraction line was drifted.

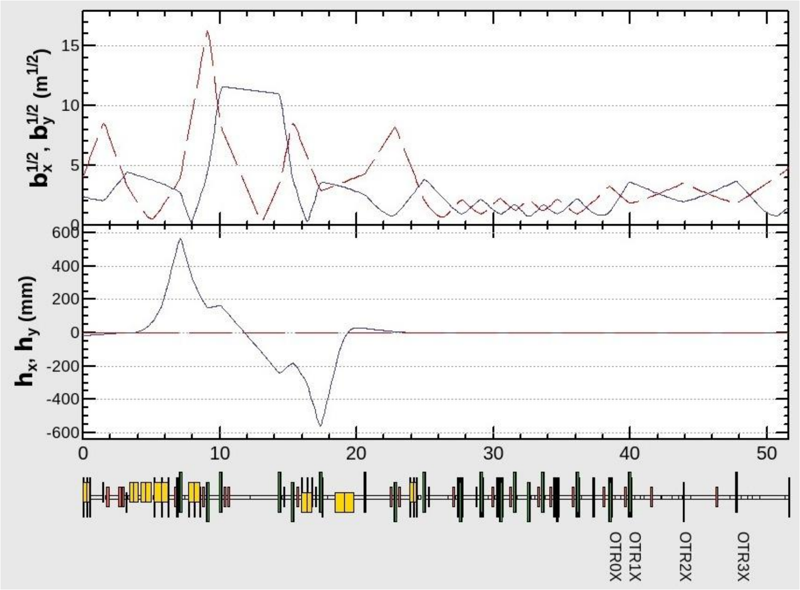
Now, the matching to FF was done by changing not matching quadrupoles, but the quadrupoles in extraction line (see M.Woodley's presentaion) .

- Matching to αx, αy, βx, βy at OTR0X.
- Matching to ηx=0, $\eta x'$=0 at OTR0X.
- Matching to (|ηx|at QF1X) = (|ηx|at QF6X).

Extraction Line Optics in 2012 December



Extraction Line Optics in 2013 February

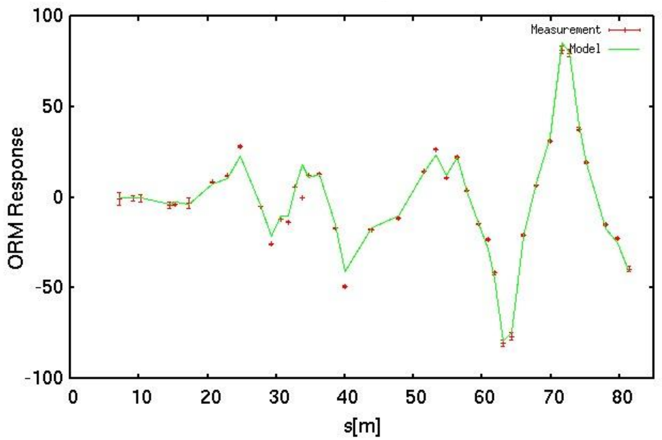


Optics Diagnostics

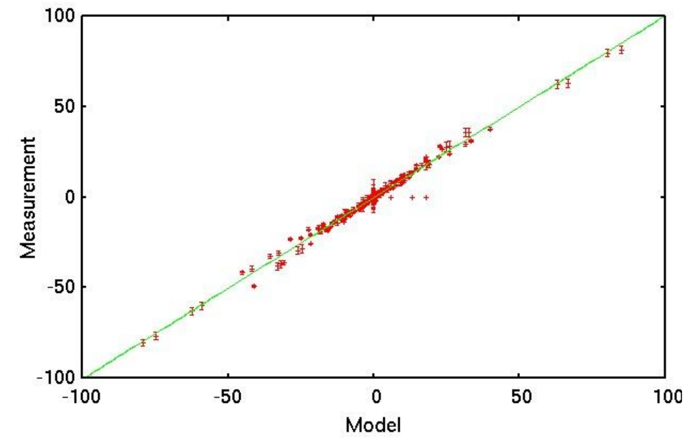
•We checked the ORM, the orbit response was good agreement with model without any fudge factors.

Horizontal

Example of ZH1X

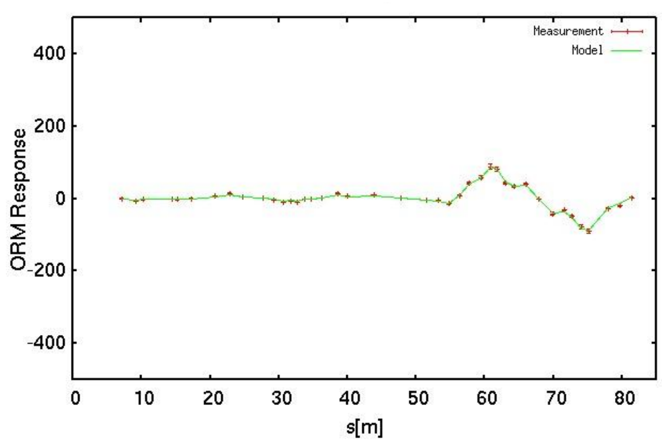


All vertical steering

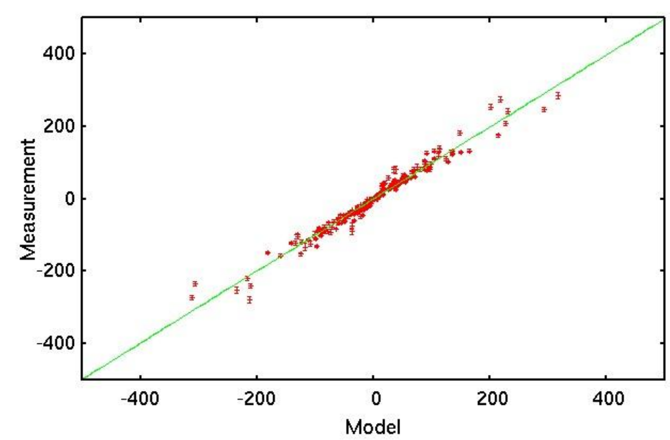


Vertical

Example of ZV1X



All horizontal steering



Linear knob (Linear Optics Correction at IP)

Linear knobs are calculated by changing the positions of FF sexts.

ΔX for FFsext -> change the alphaX, alphaY, etaX, etaX'

- ΔX for SF6FF, SF5FF, SD4FF, SF1FF, SD0FF are orthogonal to make AX, AY, EX, EPX knobs .
- One other free parameter is adjusted to make a large dynamic range of knobs.

ΔY for FFsext -> change the etaY, etaY', <x'y>

- ΔY for SF6FF, SF5FF, SD4FF, SF1FF, SD0FF are orthogonal to make EY, EPY, Coup2 knobs .
- Two other free parameters are adjusted to make a large dynamic range of knobs.

$$\sigma^2 = \sigma_0^2 + (C_\alpha^2 Ay^2 + C_\eta^2 Ey^2 + C_c^2 Coup2^2)$$

C_α ; Effect of beam waist position (depends on vertical divergence)

C_η ; Effect of vertical dispersion (depends on momentum spread; basically constant)

Cc ; Effect of coupling (<x'y>) (depends on horizontal divergence)

Beam Size Tuning with Linear Knob

Measured Modulation by IP-BSM

$$M = C \cos\theta \exp\left[-2(k_y\sigma)^2\right]$$

C ; Modulation Reduction Factor
(IP-BSM related)

If each knob is not coupled,

$$M = C \cos\theta \exp\left[-2(k_y\sigma_0)^2\right]$$ Constant for linear knob tuninig

$$\exp\left[-2(k_y C_\alpha Ay)^2\right]$$ Effect of Ay knob

$$\exp\left[-2(k_y C_\eta Ey)^2\right]$$ Effect of Ey knob

$$\exp\left[-2(k\ Cc\ Coup2)^2\right]$$ Effect of Coup2 knob

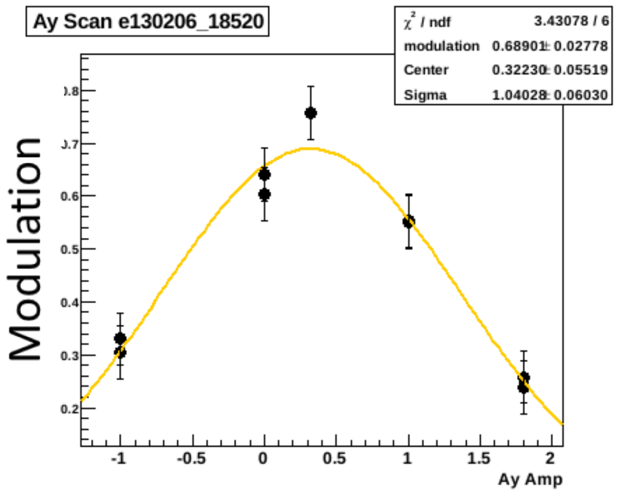
We can optimize each knob independently.

Example of Linear Optics Tuning with IP-BSM

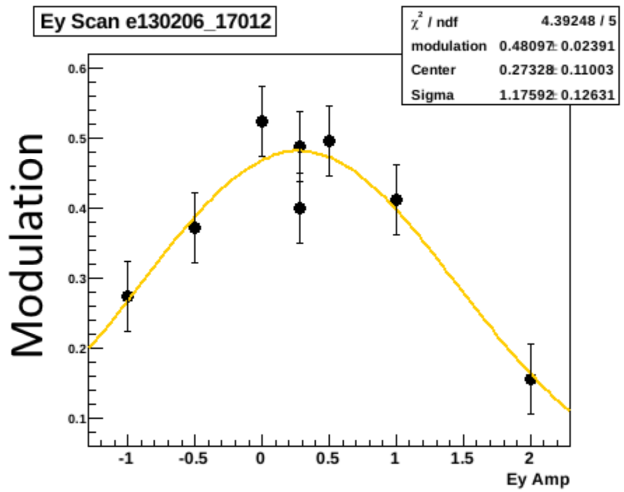
- We can optimize each knob by finding the maximum modulation
- Since it is difficult to find the optimum knob setting
  only by scanning around peak for IP-BSM stability,
  we scan the wide range (typically +/- 1.5σ) for the knob optimization.

Linear Knob Optimization for IP-BSM 30 deg mode

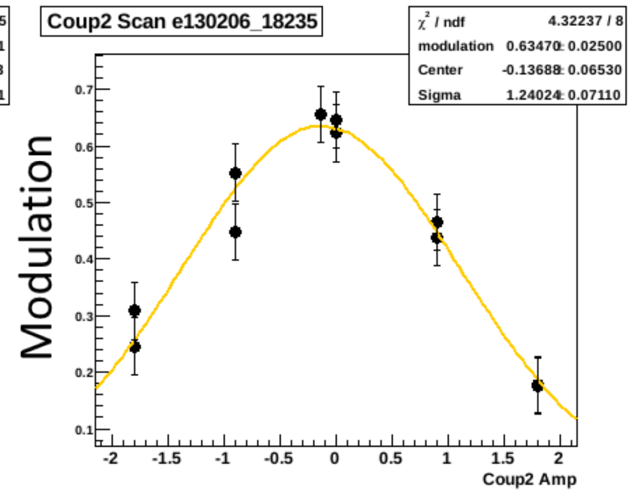
Ay knob (beam waist)



Ey knob (dispersion)



Coup2 knob (<x’y> at IP)



Correction of Higher Order Multipole Field Errors

Effect of Nonlinear Component in ATF2 Beamline

We need extremely good quality quadrupoles for ATF2 1x1 optics.

Therefore, we are now operating the ATF2 by 10x1 optics.

		ILC	ATF2(1x1)	ATF2(10x1)
Linear	αy	1	1.37	1.37
	ηy	1	0.04	0.04
	<x y>	1	1.01	3.19
	<x'y>	1	0.79	0.25
2^{nd} order	Y46	1	1.14	1.14
	Y24	1	6.43	2.03
	Y22	1	3.72	0.37
	Y26	1	0.66	0.21
	Y66	1	0.12	0.12
	Y44	1	11.12	11.12
3^{rd} (horizontal)		1	17.41	0.55
4^{th} (horizontal)		1	81.62	0.82
5^{th} (horizontal)		1	382.53	1.21

Chromatic aberration

Generate by Sextupole

Allowed component of quadrupoles

Normal Sextupole Field Correction Knobs

Sextupole field correction knobs by changing the strength of FF sexts.

Sextupole field

$$B_y = \frac{B^{(2)}}{2}(x^2 - y^2)$$

$$B_x = B^{(2)} x y$$

$$\Delta X_{IP} = \frac{R_{12} K_2}{2} \left(\Delta x^2 + 2\eta \Delta x \frac{\Delta p}{p} + \eta^2 \frac{\Delta p^2}{p^2} - \Delta y^2 \right)$$

X_{22} X_{26} X_{66} X_{44}

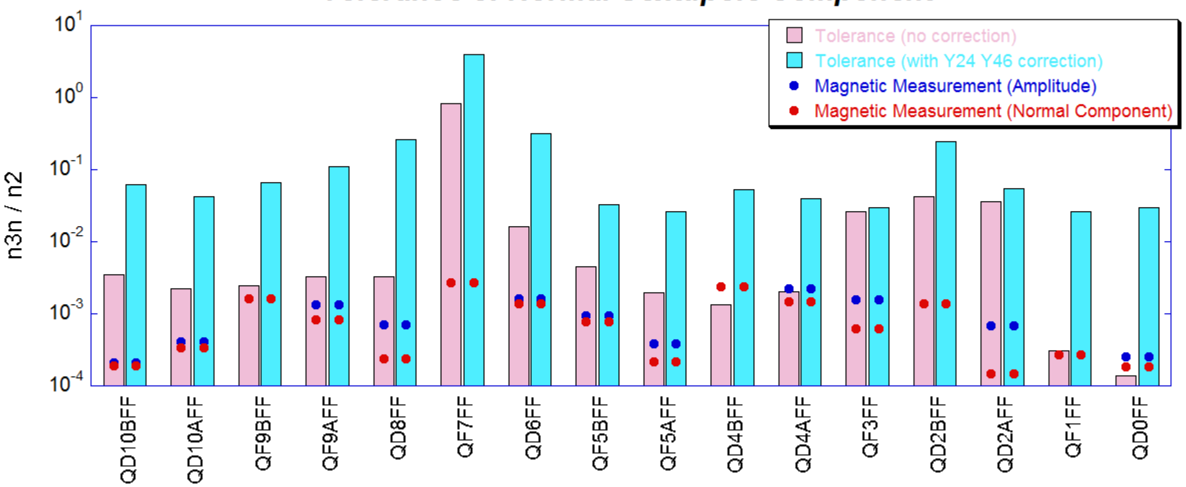
ignore (effect is small)

$$\Delta Y_{IP} = R_{12} K_2 \left(\Delta x \Delta y + \eta \Delta y \frac{\Delta p}{p} \right)$$

Y_{24} Y_{46}

ΔK2 for SF6FF, SF5FF, SD4FF, SF1FF, SD0FF are orthogonal to make X22, X26, X66, Y24, Y46 knobs

Tolerance of Normal Sextupole Component



Definition of tolerance

$$\Delta\sigma = 0.05\,\sigma$$

with Glen's 2.5x1 FF optics

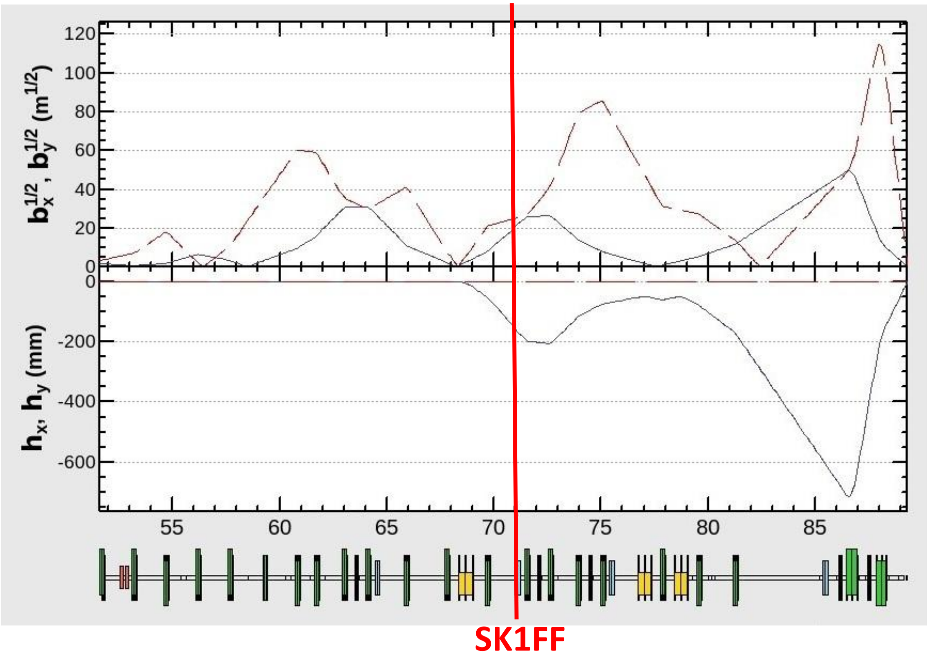
betax*= 0.0100m, emitx = 2nm

betay*= 0.0001m, emity = 12pm

Red ; No correction

Blue; with Y24 Y46 correction

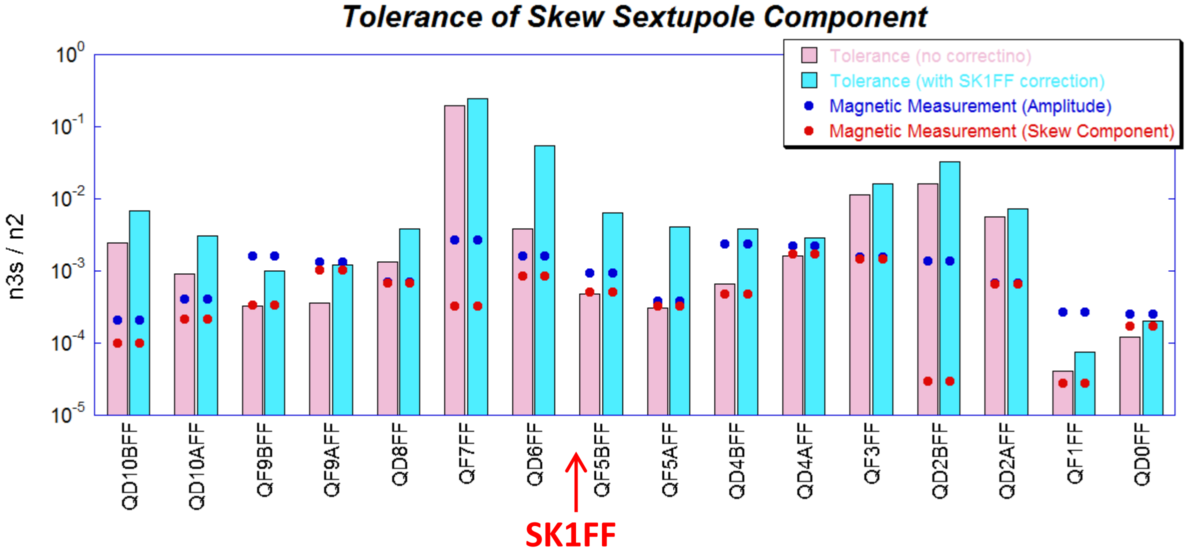
Skew Sextupole Field Correction Knob



In order to relax the tolerance of skew sextupole errors, we put the skew sextupole magnet (SK1FF)

(borrowed from KEKB)

Location of the skew sextupole was optimized by E. Marin.



Definition of tolerance

$$\Delta\sigma = 0.05\ \sigma$$

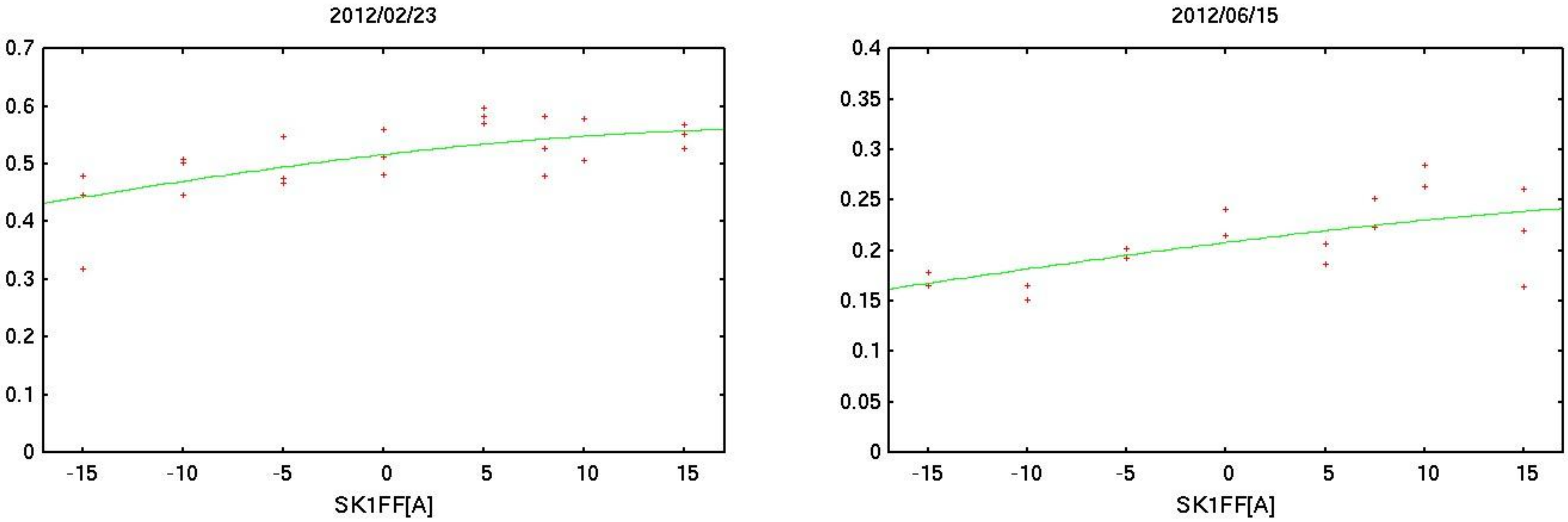
with Glen's 2.5x1 FF optics
betax*= 0.0100m, emitx = 2nm
betay*= 0.0001m, emity = 12pm

Red ; No correction

Blue; with SFD correction

Abnormal Skew Sextupole Field

- *We observed huge skew sextupole field in Feb. and June 2012.*
  (Minimum SK1FF was around 20A ; design was 2A)
- *We measured same response of SK1FF strength scan in Feb. and June 2012.*



We must find the error source of skew sextupole field.

Present Correction Scheme of Skew Sextupole Field (from 2012 Autumn Operation)

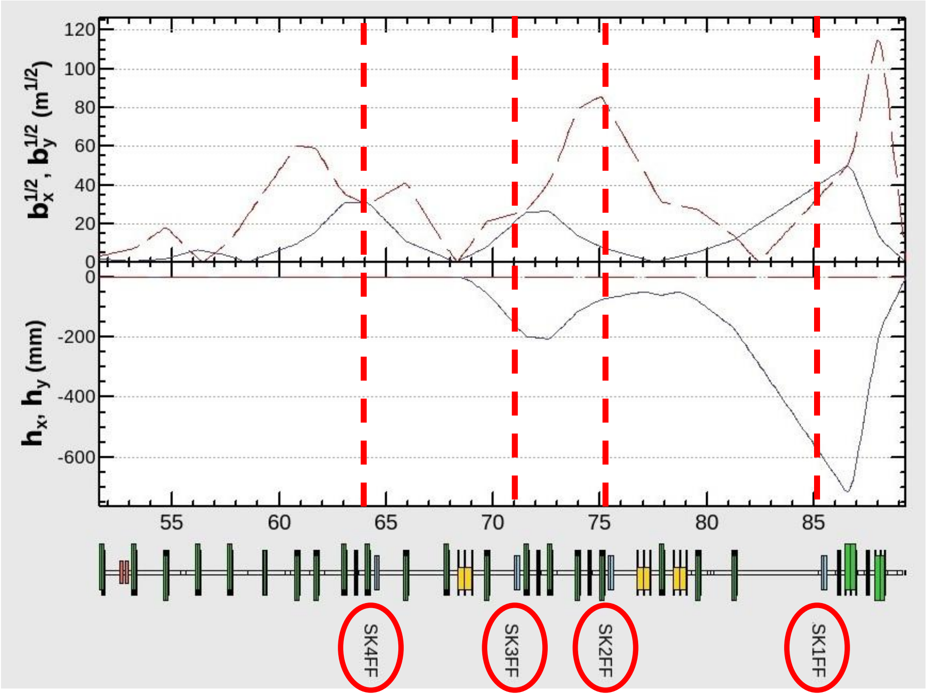
Skew sextupole field

$$B_x = \frac{B_s^{(2)}}{2}(x^2 - y^2)$$

$$\Delta y_{IP} = \frac{R_{34} K_{2S}}{2}\left(\Delta x^2 + 2\eta\Delta x\frac{\Delta p}{p} + \eta^2\frac{\Delta p^2}{p^2} - \Delta y^2\right)$$

Y_{22} Y_{26} Y_{66} Y_{44}

We will put 4 skew sextupole correctors



SK1FF ; sensitive to Y22, Y26, Y66

SK2FF ; sensitive to Y44

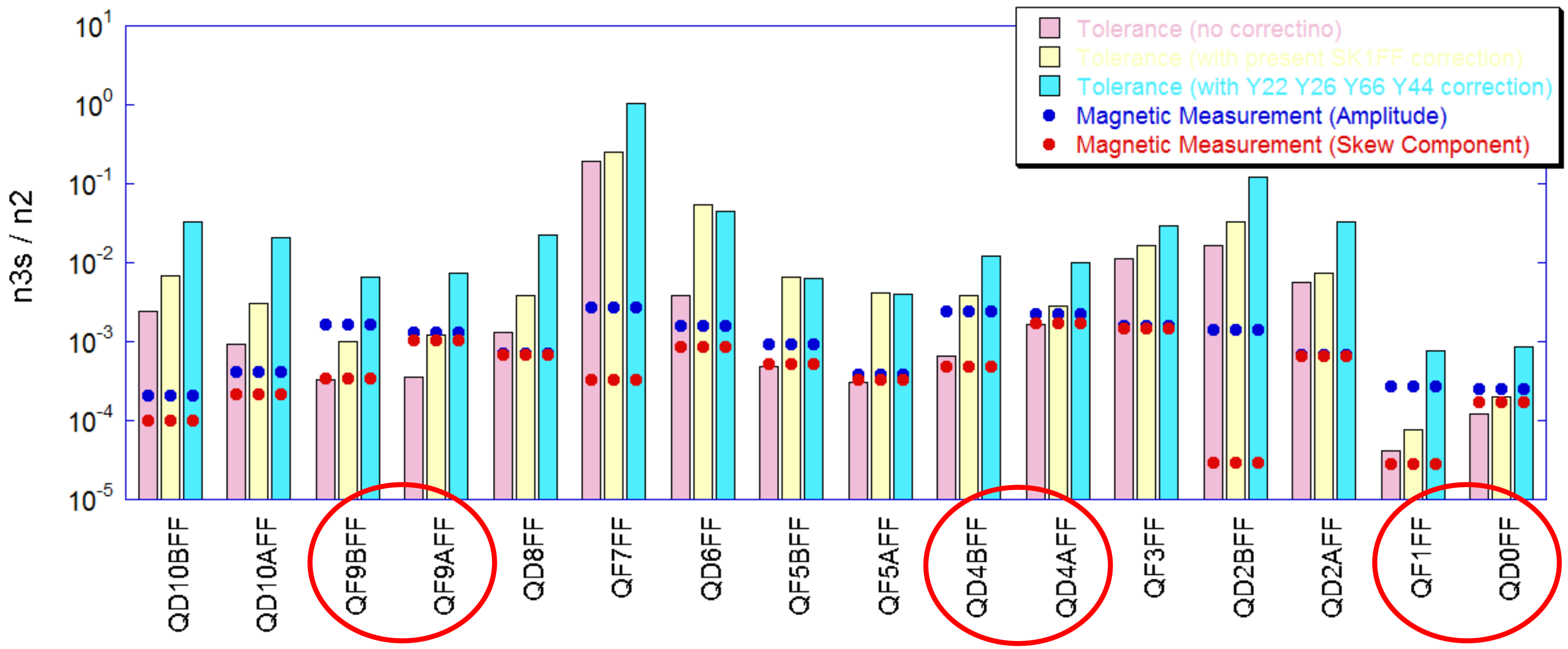
SK3FF ; sensitive to Y22, Y26, Y66

SK4FF ; sensitive to Y22

Y22, Y26, Y66, Y44 knobs are calculated by the combination of SK1FF, SK2FF, SK3FF, SK4FF.

Performance of New Correction Scheme

Red ; No correction
Yellow ; with SK1FF correction
Blue;   with 4 SKs correction
(10A maximum)

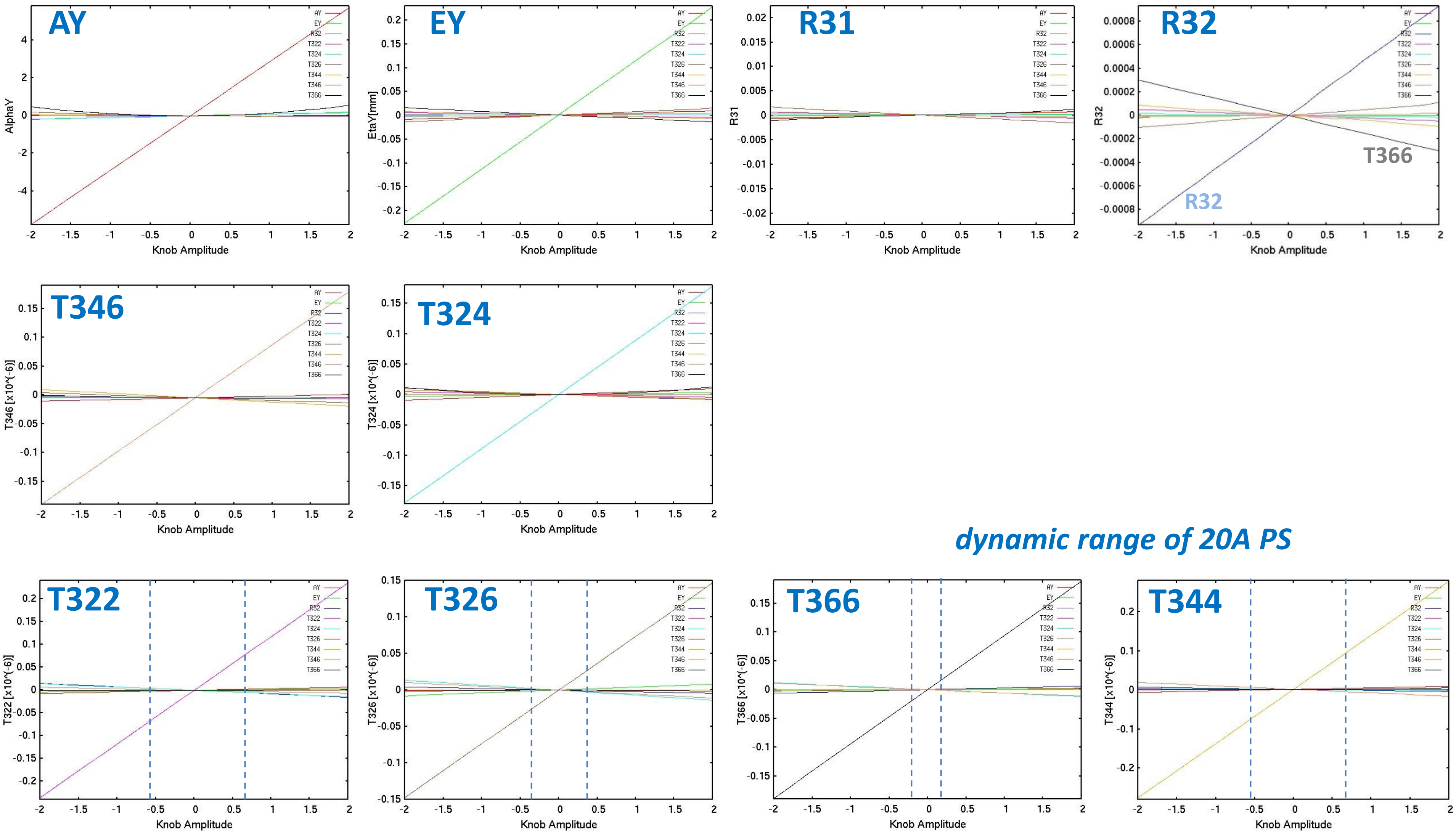


By using 4 SKs correction,

- *Tolerances for all quadrupoles are increased.*
- *We can investigate the error source of skew sextupole field.*

Multiknob Response

Each knob is normalized to (knob=1 -> $\Delta\sigma y$ = 100nm).
Maximum vertical axis of plots are scaled to $\Delta\sigma y$ = 200nm.



Summary of Beam Tuning Method in ATF2

$$M = C \cos\theta \; \exp\;[-2\,(k_y \sigma)^2]$$

C ; Modulation Reduction Factor
(IP-BSM related)

$$\sigma^2 = \beta\,\varepsilon + (C_\alpha^2 Ax^2 + C_\eta^2 Ey^2 + C_c^2\, Coup2^2) + Ct^2 \langle xy\rangle^2$$

Correct with linear knobs **Correct with QKs**

$$+ (C_{24}^2 Y_{24}^2 + C_{46}^2 Y_{46}^2) + (C_{22}^2 Y_{22}^2 + C_{26}^2 Y_{26}^2 + C_{66}^2 Y_{66}^2 + C_{44}^2 Y_{44}^2) + \sigma_{6pole,res}^2$$

Correct with normal sextupole knobs **Correct with skew sextupole knobs**

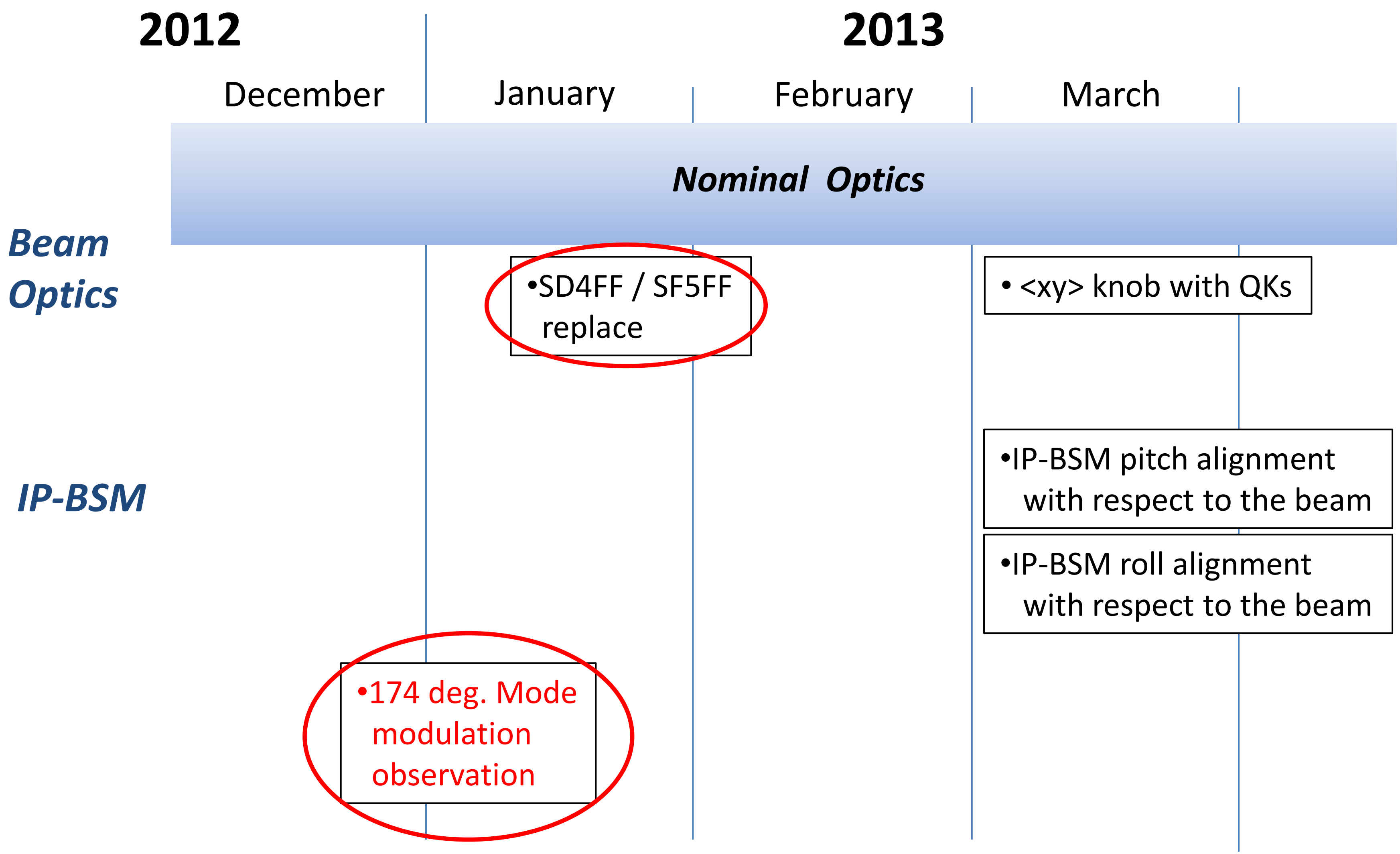
$$+ \sigma_{8pole}^2 + \sigma_{10pole}^2 + \sigma_{12pole}^2 + \ldots\ldots$$

-can not correct with any tuning knobs
-But, since the effect strongly depend on the beam size at quads, we can control the effect by changing $\sigma_{x'}^*$

If the beam size was reached to the limit, we should increase the betax.*

Recent Status of ATF2 Beam Tuning
(From December 2012)

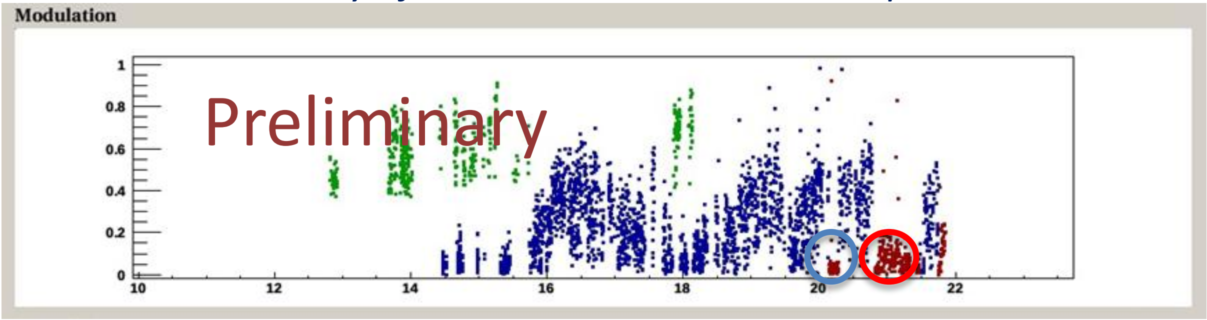
Recent History of ATF2 beam tuning

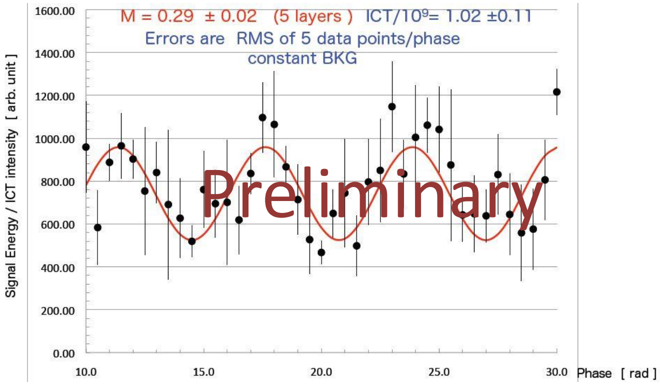


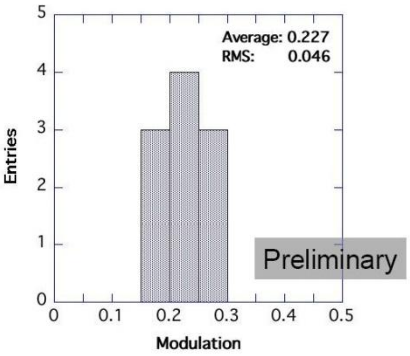
First Observation of modulation of IP-BSM 174deg mode

2012/12/19 ; We tried the 1st 174 mode measurement, but we could not observe clear modulation.
2012/12/20 ; We tried the 2nd 174 mode measurement, we could observe clear modulation.

History of last 2 weeks in 2012 Dec. operation







If we assume (modulation reduction factor)=1,
the modulation corresponds to 73nm (upper limit) beam size.

The difference of the settings for 12/19 and 12/20 are the set of nonlinear knobs only.

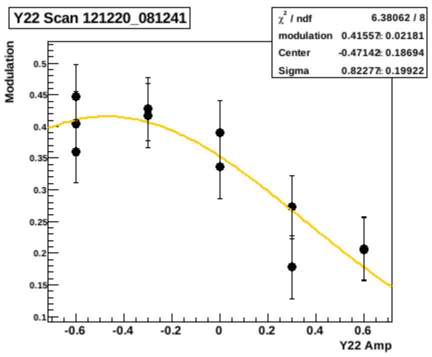
2012/12/19 ; Y22=-0.6, Y26= 0.0, Y44= 0.0
2012/12/20 ; Y22=-0.2, Y26=-0.2, Y44= 0.0

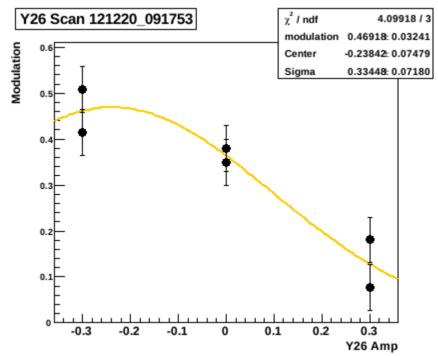
Error source of multipole field

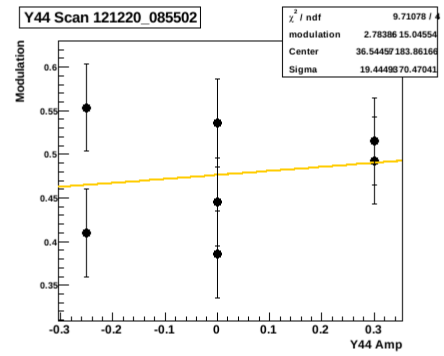
When we assumed the be large errors both for SK magnet and FF sextupoles, we could reproduce the measured IP vertical beam size in simulation.

In simulation, I assumed the roll for SF6FF by -50mrad to make a large T322.

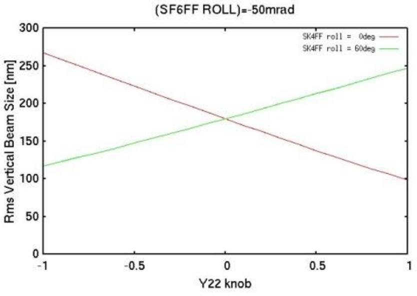
Measurement (origin is knob zero)

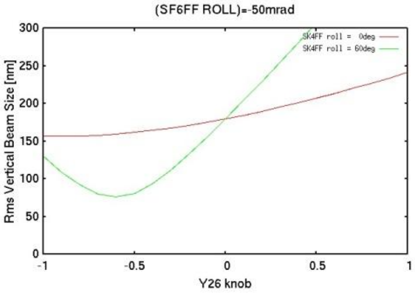


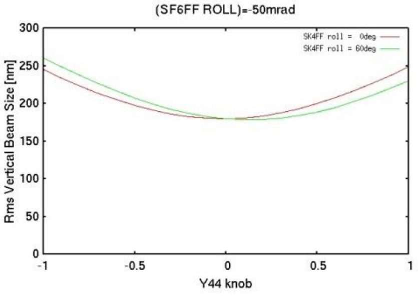




Model Response with errors

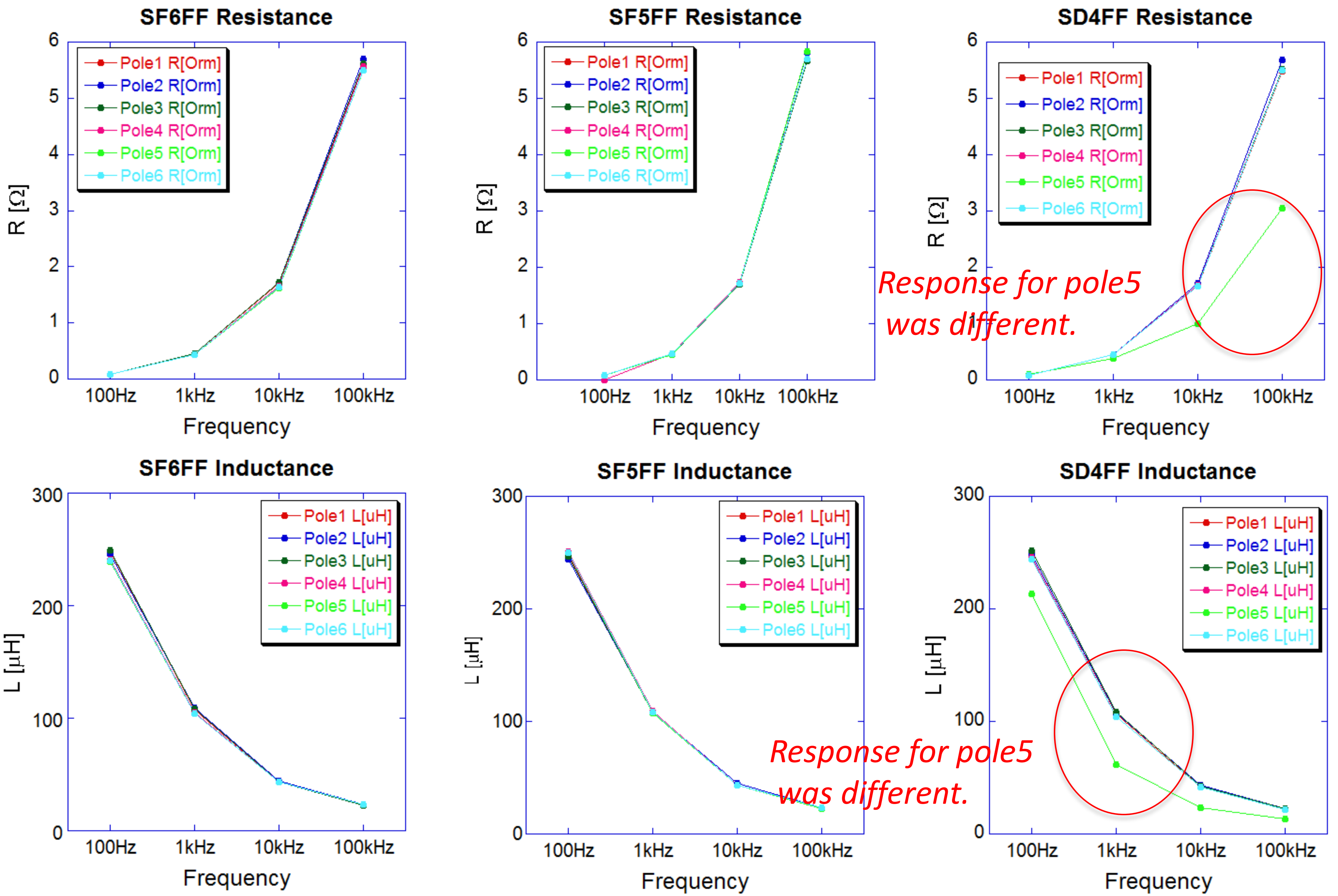




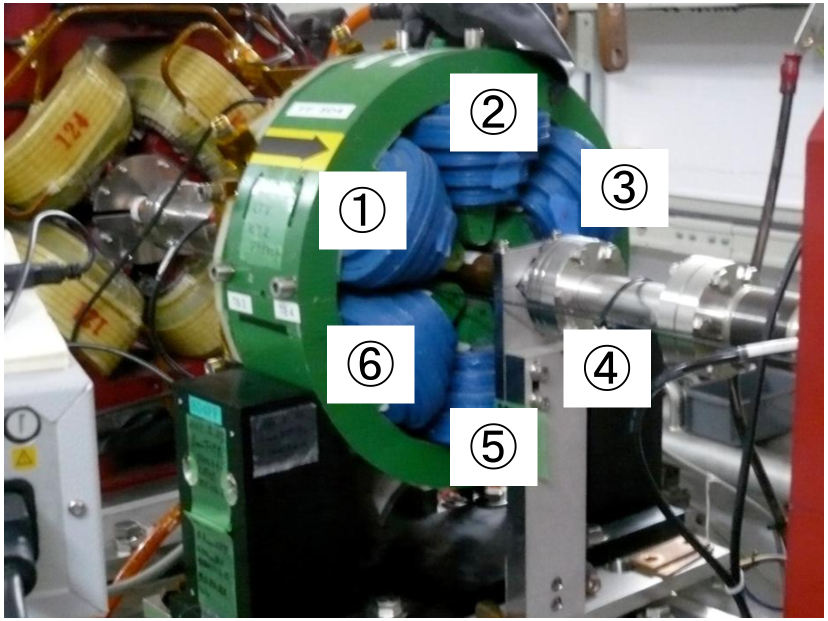


When we assumed the large rotation of SD4FF and SK4FF field, we could reproduce same response of the nonlinear knob in 2012 Dec. operation.

Impedance Measurement of FF Sextupoles



The effect of the small current of pole5 for SD4FF



When the current of pole5 was smaller than those of others,

- *-Generate the horizontal kick*
- *-Generate the skew quadrupole field*
- *-Reduce the sextupole field*
- *-Generate the higher multipole fields.*

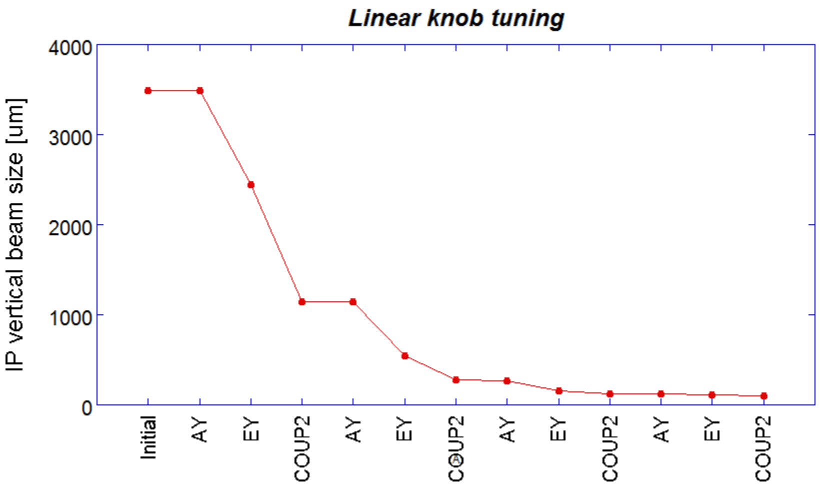
The effect of the skew quadrupole field of SD4FF

-Generate the vertical dispersion (can be corrected with Ey knob)

-Generate the <x'y> (can be corrected with Coup2 knob)

-Converted T122 from SF6FF to the IP vertical beam size
-> generate T322
-> almost same effect to the roll of SF6FF

IP beam size simulation with skew quadrupole field in SD4FF



- *emitx=2nm, emity=12pm*
- *put K1S= -0.015 at SD4FF*
- *rotate the SK4FF by -44.4 deg.*

The IP vertical beam was 3.5um by effect of <x'y> and ηy* for skew quad of SD4FF.

The beam size was smaller by applying the linear knob tuning

3.5um -> 100nm

	rms beam size	core beam size	
No errors	55.4nm	51.7nm	
With errors, linear knob	111.1nm	101.5nm	
Y22=-0.6, Y26= 0.0	96.4nm	91.1nm	***12/19 setting***
Y22=-0.2, Y26=-0.2	71.1nm	67.0nm	***12/20 setting***

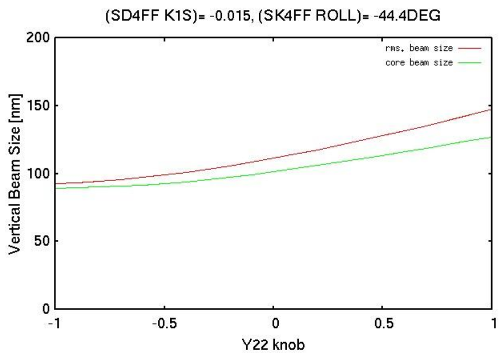
There is a clear difference between the setting of 12/19 and 12/20.

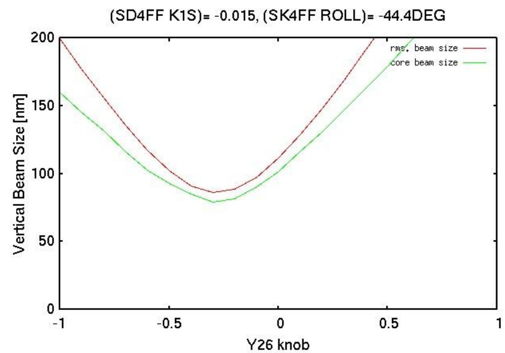
The estimated beam size on 12/20 setting was smaller than that of no correction, but larger than that for no multipole errors.

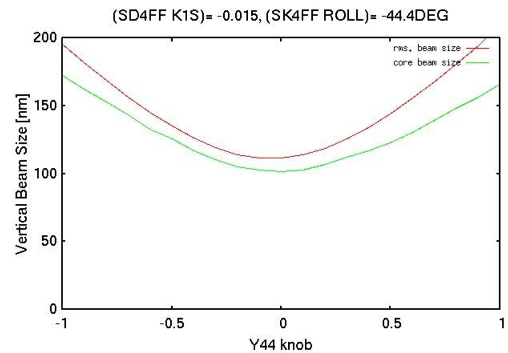
The effect of skew quadrupole field of SD4FF

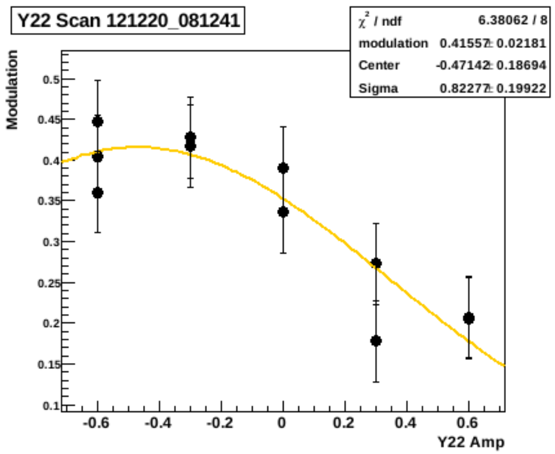
Simulation

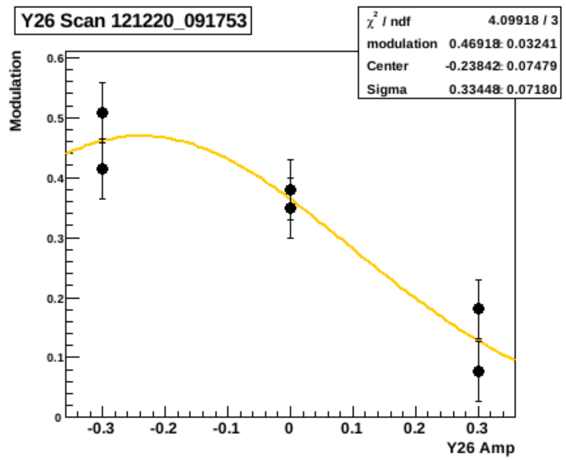
-Put K1S=-0.015 at SD4FF
-Rotate the SK4FF by -44.4 deg.
-Optimize the linear knobs (Ay, Ey, Coup2)
-Evaluate the nonlinear knob response

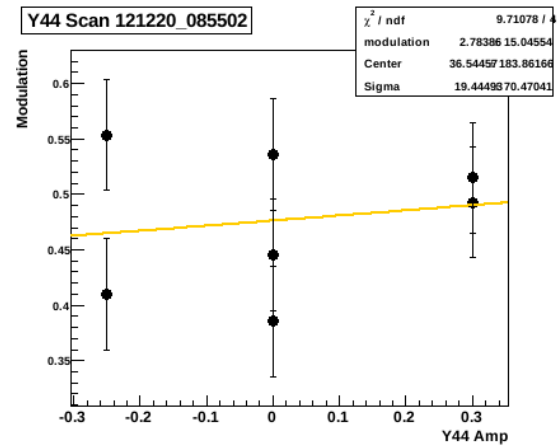












Same response to the measurement

IP beam size with/without FF sextupoles

2012/11/08

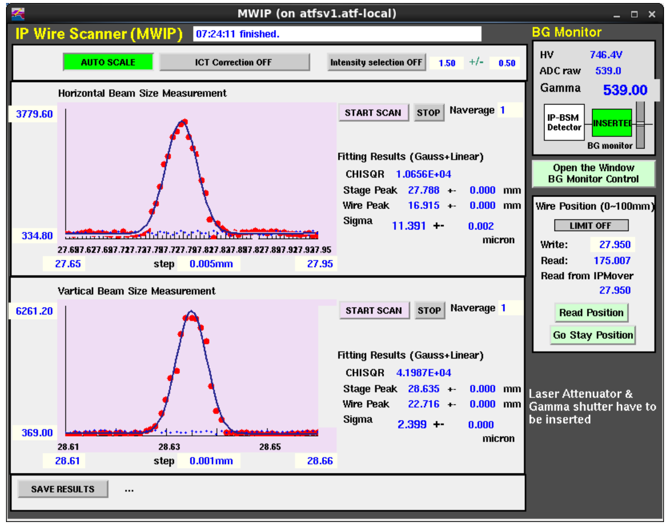
(before SF5FF/SD4FF swap)

Vertical beam size

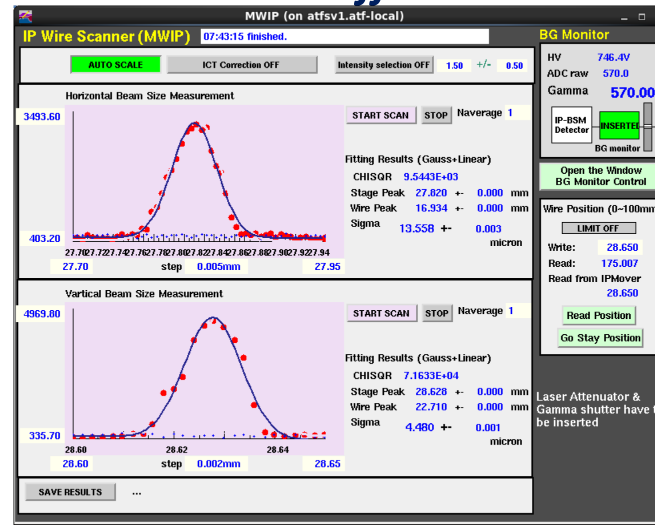
Sexts OFF 2.4um

Sexts ON 4.5um

FF sextupoles turned off



FF sextupoles turned on with BBA offset



2013/02/06

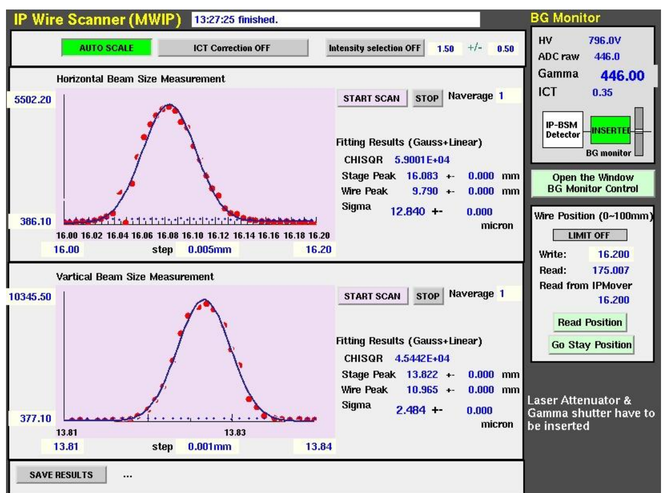
(after SF5FF/SD4FF swap)

Vertical beam size

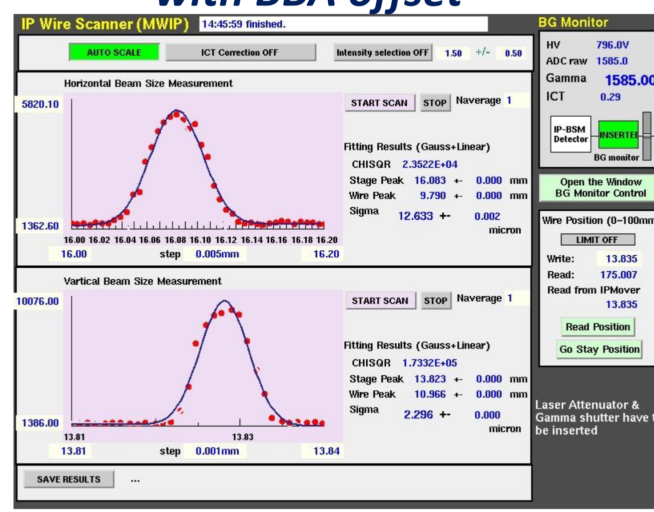
Sexts OFF 2.5um

Sexts On 2.3um

FF sextupoles turned off

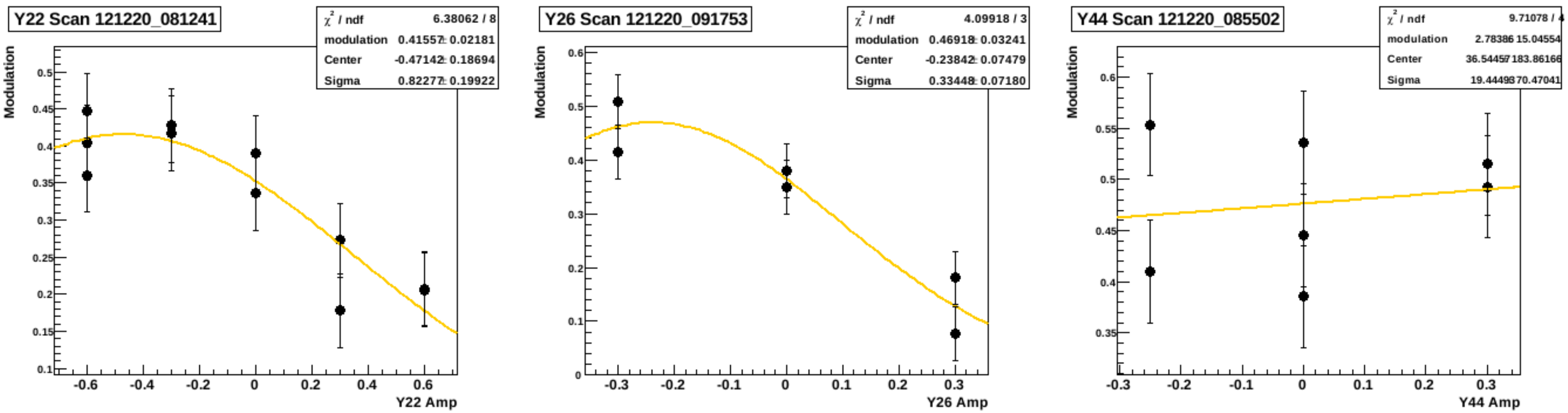


FF sextupoles turned on with BBA offset

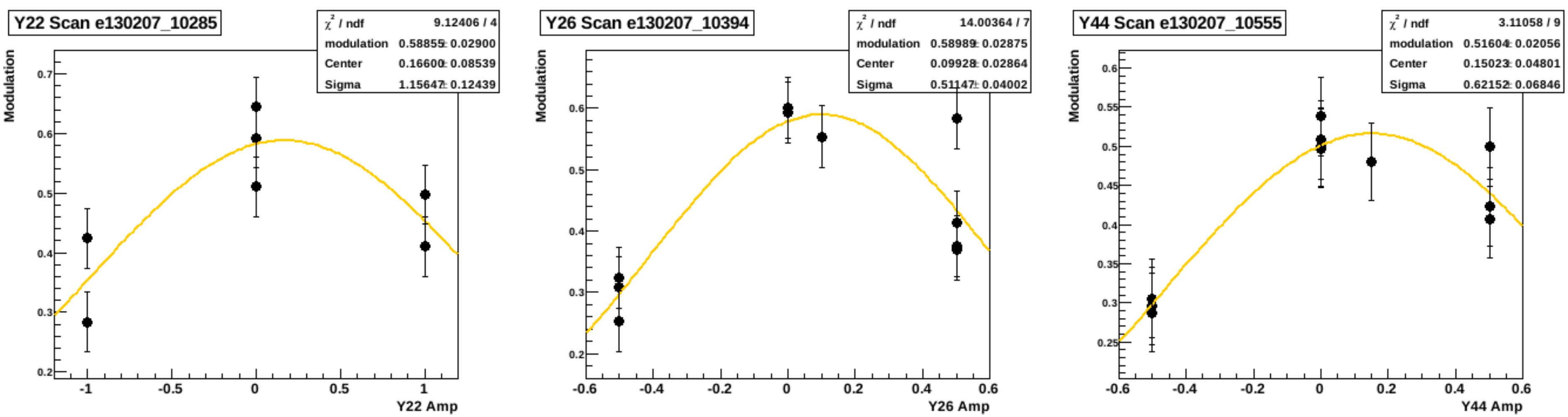


Response of nonlinear knob in IP-BSM 30deg. mode

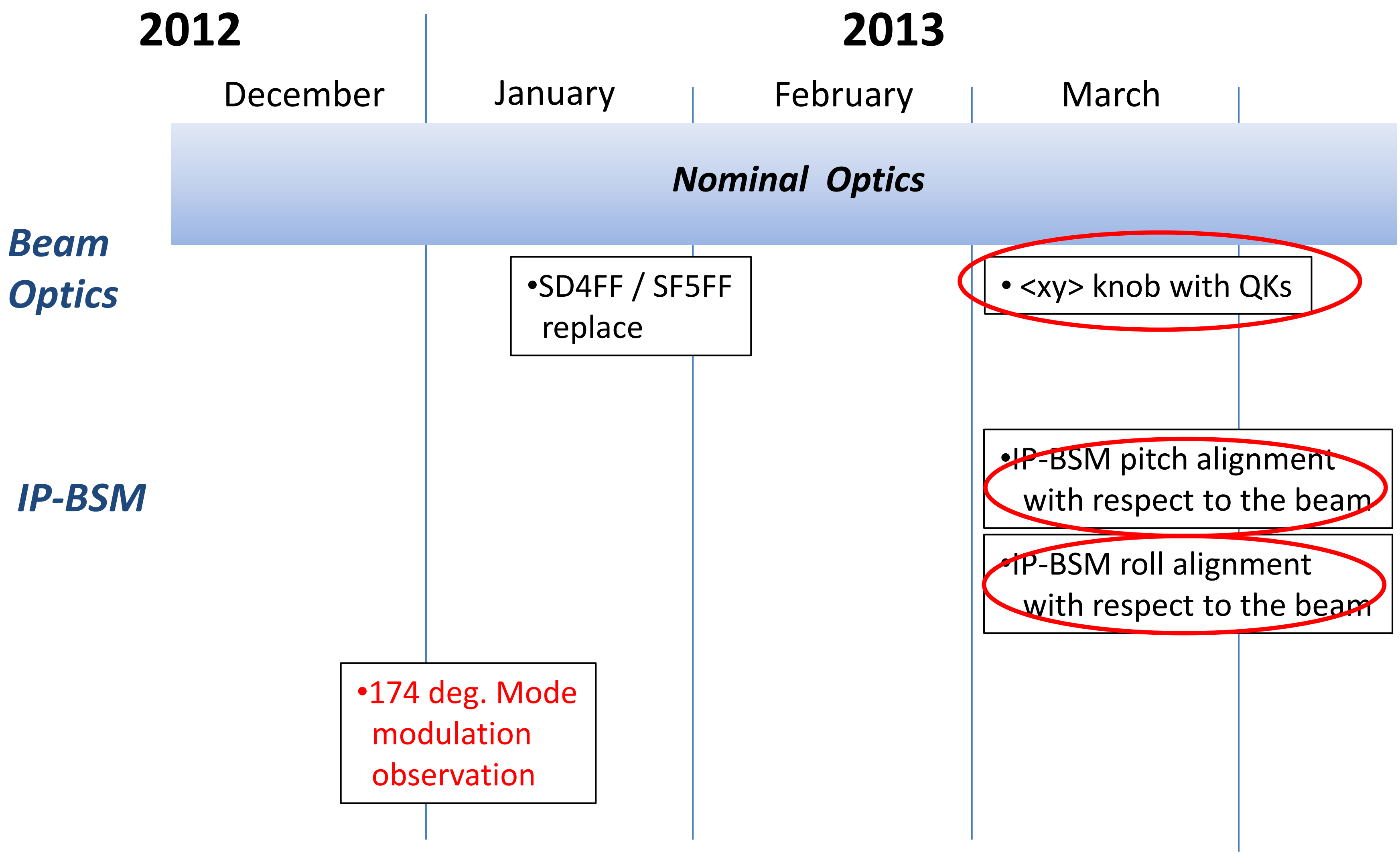
2012/12/20 (before swapping of SD4FF and SF5FF)



2013/02/07 (after swapping of SD4FF and SF5FF)

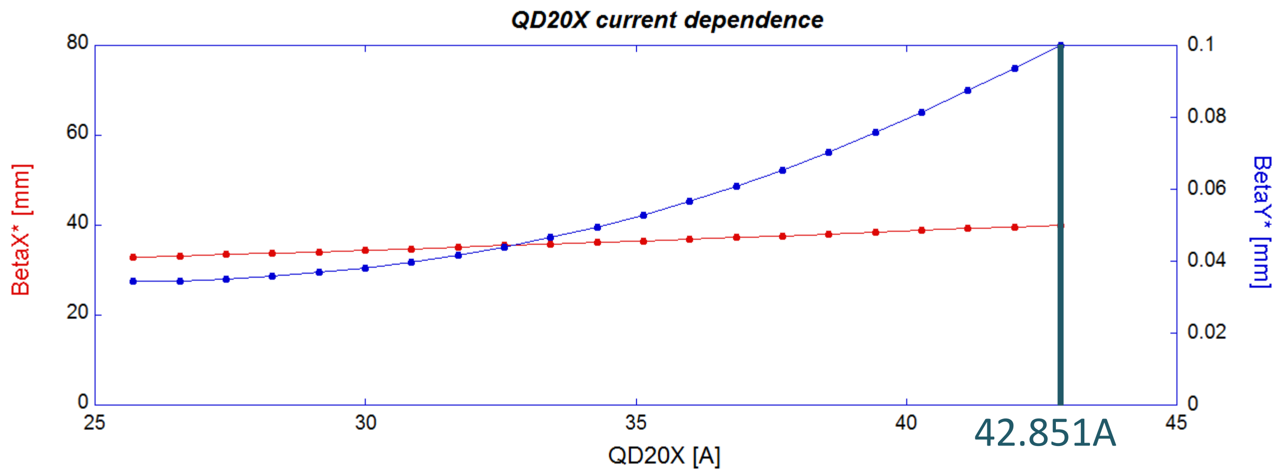


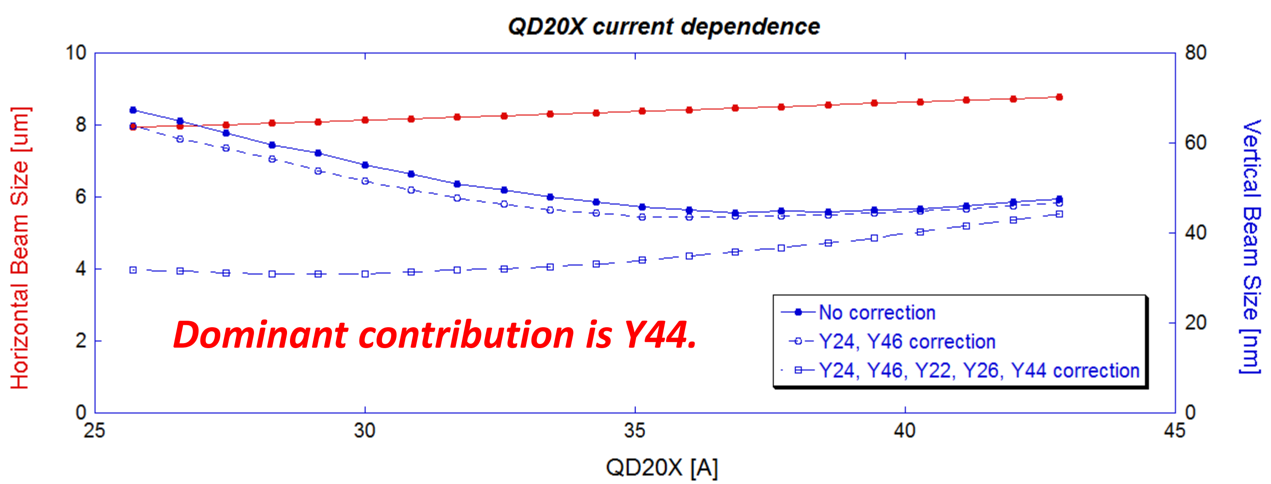
Recent History of ATF2 beam tuning



Betay* Matching with QD20X Strength Scan

- We could change the betay* by changing QD20X strength.
- The effect of betax* was small for QD20X strength change.
- We confirmed the beam waist was on MFB2FF for all QD20X current.





Beam size simulation

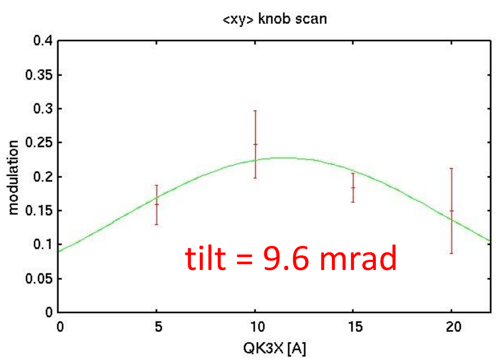
emitx = 2nm
emity = 20pm
Dp/p = 0.08%

<xy> coupling correction at IP

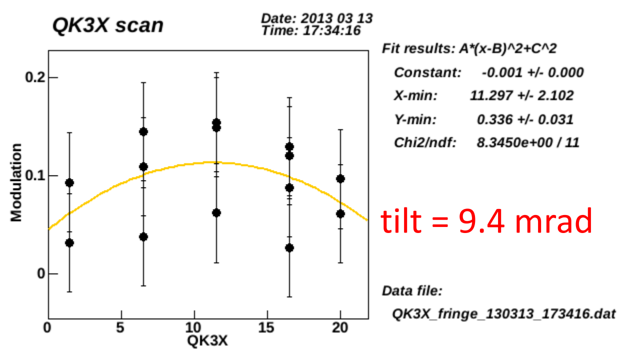
We applied <xy> knob scan for 3 different QD20X settings.

The combination of QKs for <xy> knob was calculated for each QD20X setting.

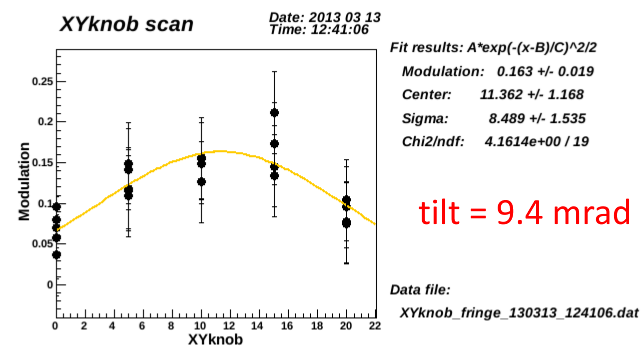
QD20X = 42.581A (3/05)



QD20X = 38.581A (3/13)



QD20X = 34.581A (3/13)



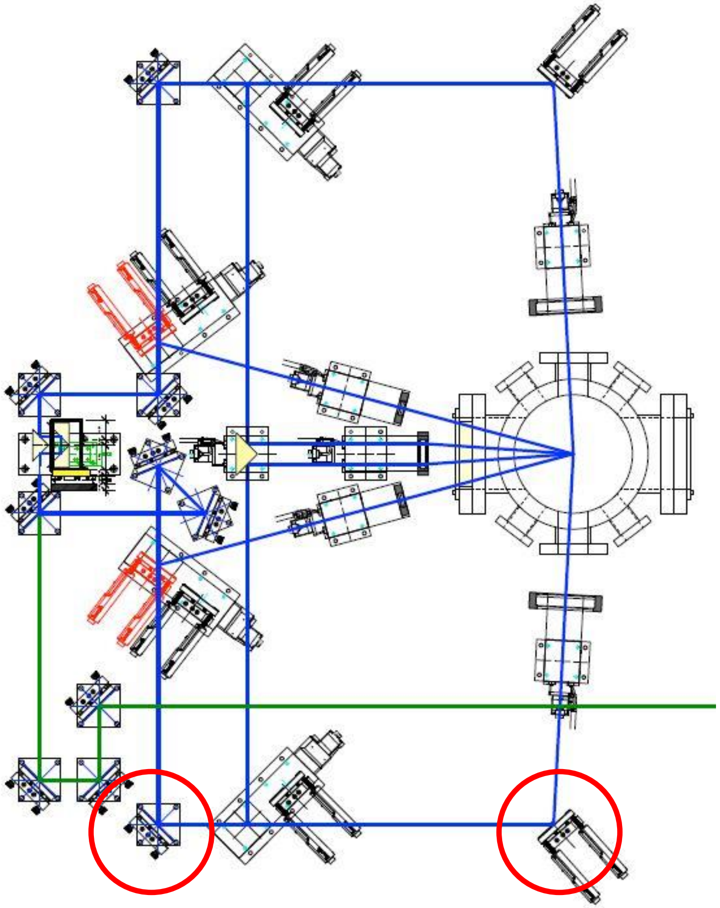
9.5mrad -> $\Delta\sigma y$ = 85.5nm

The optimum setting was almost same for these 3 setting.

Therefore, we think the roll was not beam, but IP-BSM fringe.

Laser Alignment with respect to the beam

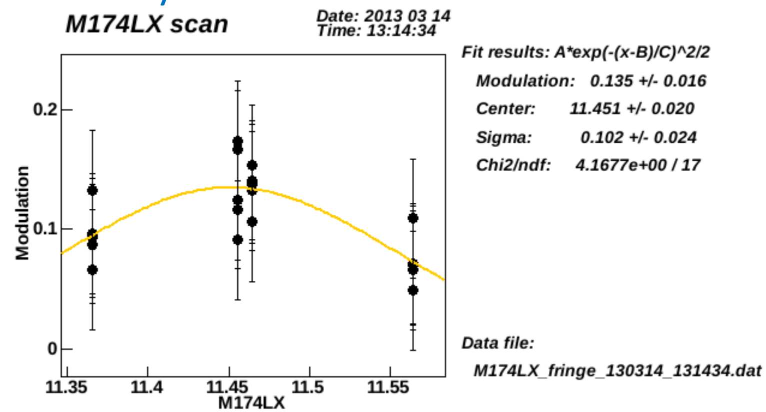
Laser path was adjusted to make a maximum modulation



We changed the IP-BSM fringe roll & pitch by changing the two mirrors

Fringe Roll Adjustment

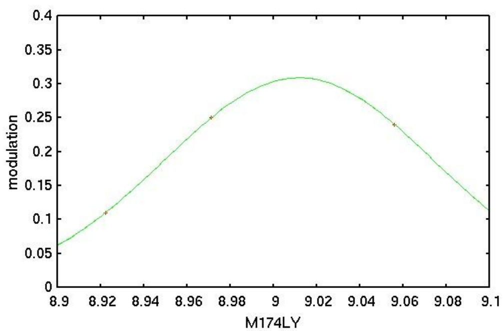
<xy> knob was reset to 0.



Tilt = 9.8mrad

Maximum modulation was same the correction with <xy> knob.

Fringe Pitch Adjustment



Pitch = 3.9mrad

If laser waist=20μm,

$\Delta\sigma y$ = 78nm

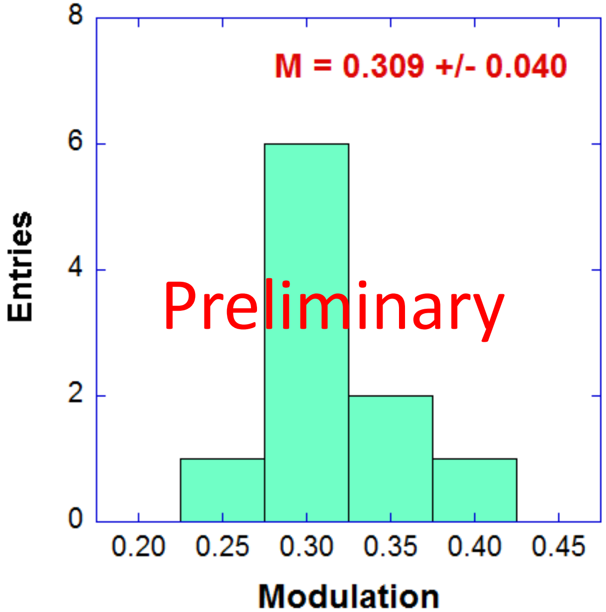
Result of Beam Size Measurement

- QD20X = 42.581A (nominal).
- When we changed QD20X strength, the maximum modulation was not changed.
- *We could not apply Y24, Y46 (normal sextupole) knobs for the current limit (>0.88A) of SF5FF PS.*
- *We could not apply Y26 (skew sextupole) knobs for current limit of SK2FF PS (replaced to use QK knobs).*

These knobs will be able to use from April 2013.

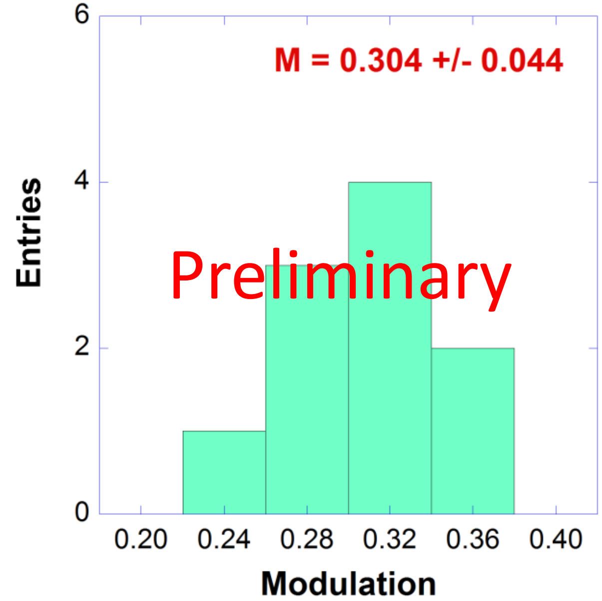
2013/03 /08

after IP-BSM roll alignment
with QK <xy> knob



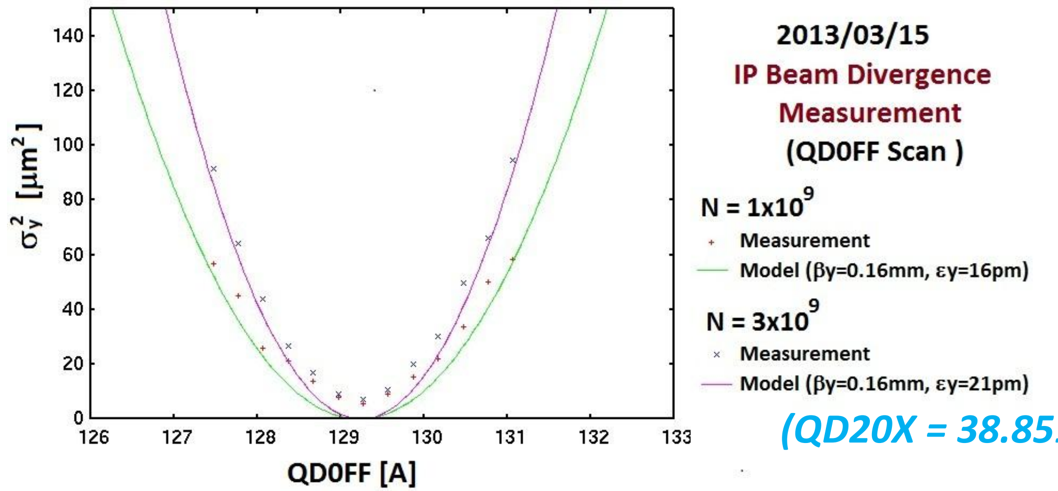
2013/03 /14

after IP-BSM roll alignment
after IP-BSM pitch alignment

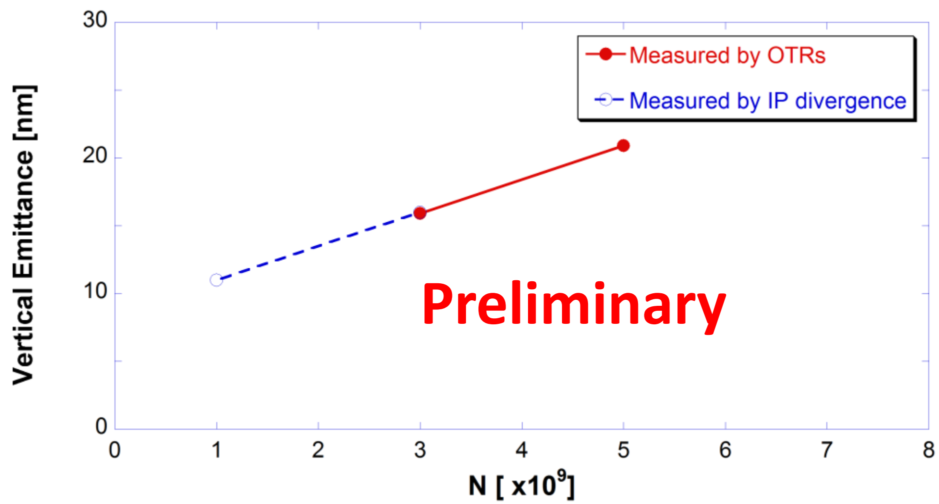


If we assume (modulation reduction factor)=1,
the modulation corresponds to 65nm (upper limit) beam size.

Emittance Measurement in 2013 March Operation



(QD20X = 38.851A)



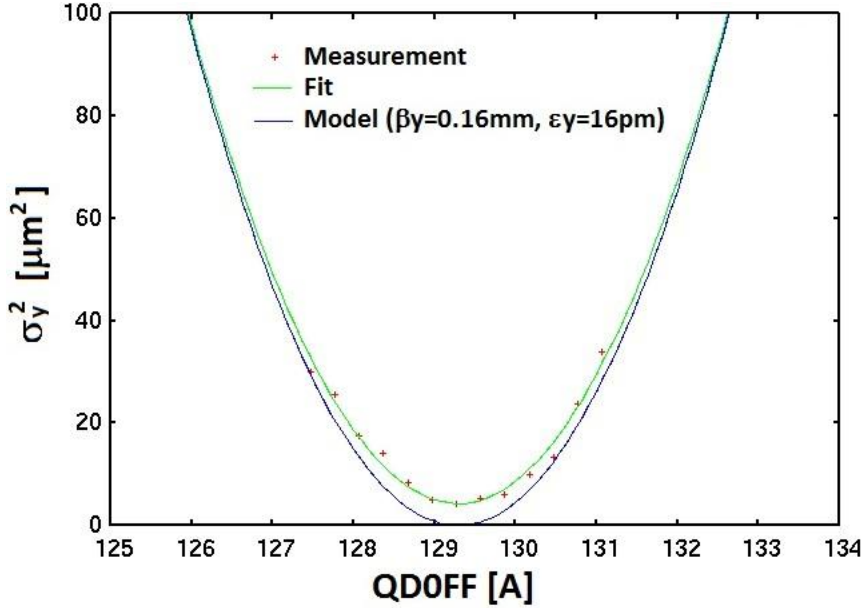
ε_y = 11pm at N = 1x10^9

(We need to check!)

- The light intensity of OTR3X was too weak to measure the beam size in low intensity.
- Therefore, we evaluated the emittance in low intensity region by measuring the intensity dependence of IP beam divergence in March 2013.

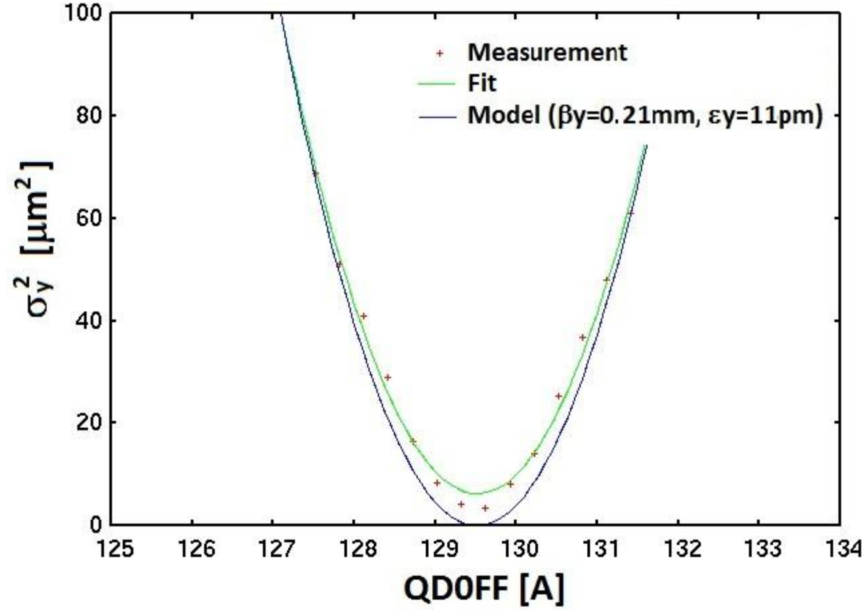
Beta Function Evaluation from IP Beam Divergence Measurement

2013/03/06



If emity = 16pm at N = 3e9,
betay = 0.16mm.*

2013/03/15



If emity = 11pm at N=1e9,
betay = 0.21mm.*

- These measurement was done with same matching parameters (QD20X=42.851A).
- The matching from DR was changed within 2 weeks ??

Present status of ATF2 beam focusing

Preliminary

	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*	3.50m	1.00 m		0.40 m	
$\sigma p/p$	0.12%	0.06%		0.05 %	
βx^*[mm] × βy^*[mm]	11 × 0.48	40 × (0.16 - 0.21)		10 × 0.1	
εx[nm] × εy[pm]	0.02 × 0.07	2.0 × 11		0.33 × 20	
σy^* [nm]	5.9	42 - 48	< 65	45	70
$L^*/\beta y^* \times \sigma p/p$	8.75	2.86 - 3.75		2.0	

Strength of chromatic aberration

- ATF2 achieved to focus the beam to less than 65nm by using with the local chromaticity correction scheme

Summary (1/2)

Beam Optics for ATF2 Beamline

We used some special FF optics to be cancelled the multipole field errors in ATF2 final focus beam line from 2010 Dec. to 2012 June.

We operate the ATF2 by using nominal FF optics, after we installed 4 skew sextupoles and replaced the QF1FF to be small multipole errors.

IP Beam Size Monitor in ATF2

The beam tuning status has been improved with IP-BSM improvement.

We had a problem for laser profile by 2013 March.
Therefore, we have a laser transport change and a drastic profile improvement .

Linear Optics Tuning

We have a tuning knobs and tools both in extraction line and IP for

- *Twiss parameter and beam waist position*
- *dispersion function*
- *xy coupling (<xy>, <x'y>, <x'y'> ...) .*

Summary (2/2)

Correction of Higher Order Multipole Field Errors

We operate the ATF2 FF to be matched to bx=4cm, by=0.1mm (10x1 optics) to reduce the tolerance of 12pole errors (allowed component) for quadrupoles.

We have a tuning knobs for the correction of normal and skew sextupole errors (Y24, Y46, Y22, Y26, Y66 and Y44) for beam tuning and for finding the error sources .

Recent Status of ATF2 Beam Tuning (From December 2012)

We succeeded to find the IP-BSM modulation in 2012 December, and found the impedance difference of 1 pole in SD4FF.

We can squeeze the beam within the dynamic range of IP-BSM 174deg mode, after we swapped the SD4FF and SF5FF.

We could correct the IP-BSM fringe pitch and roll, and we could squeezed the beam to less than 65nm.

We could not use the Y24, Y46 and Y26 knobs in 2013 March operation for the problem of magnet PSs (We can use the knobs in 2013 April).