Introduction of recent studies for ATF2 beamline

Introduction of the ATF2 beamline

Effect of the multipole fields for FF quadrupoels

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CLIC BDS meeting
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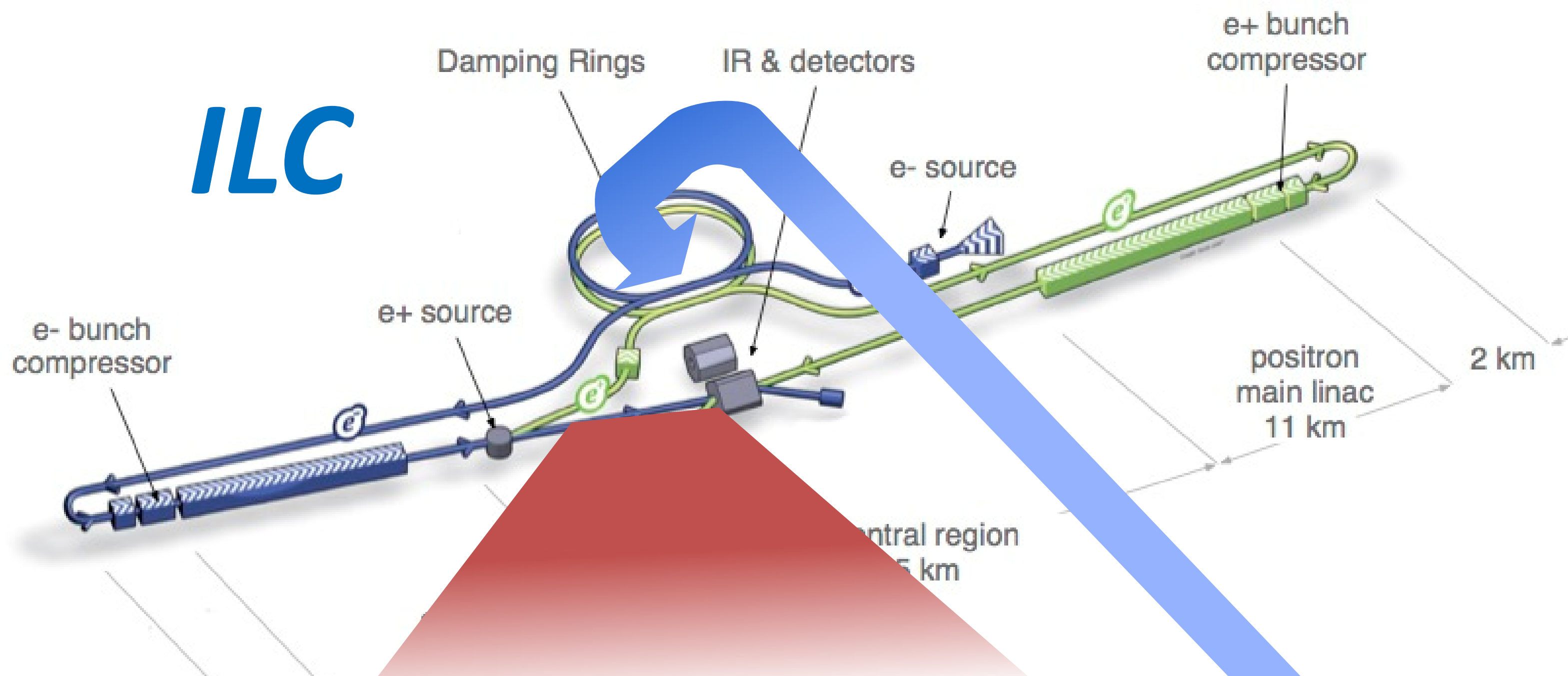
ATF2 Project

Final focus test with ATF low emittance beam.
ATF2 project was proposed at 1st LCWS (2004 November).

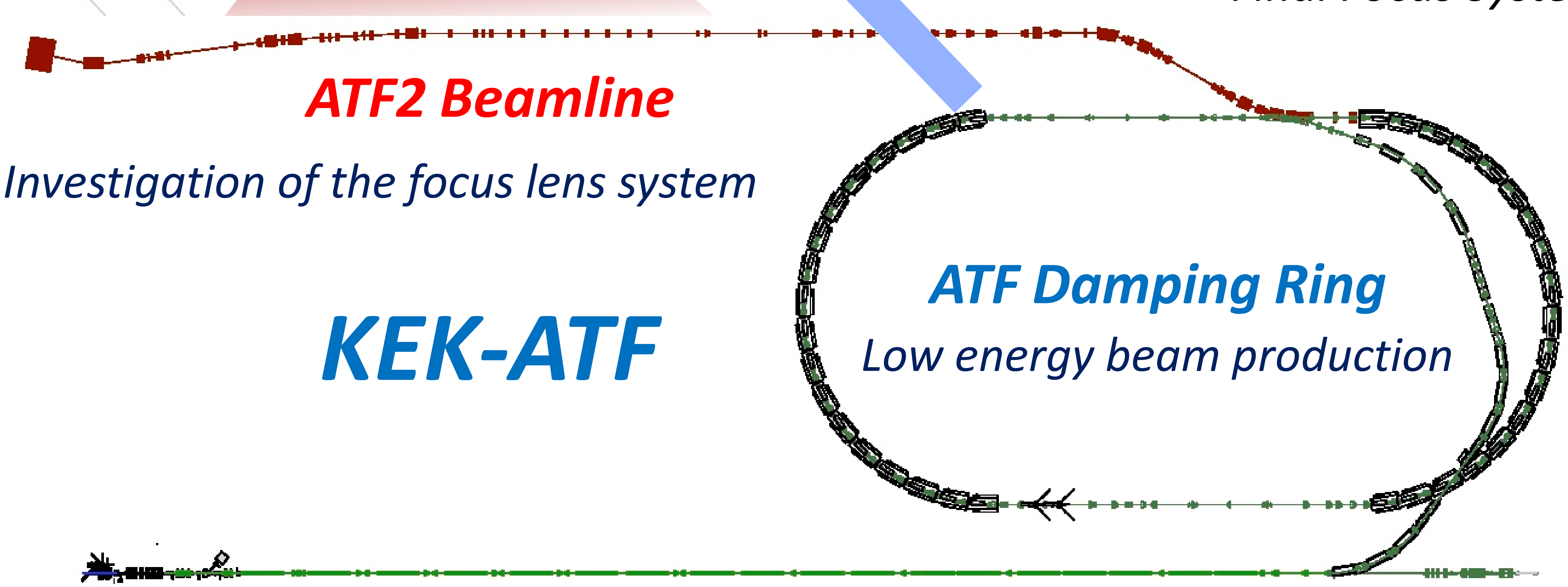
ILC



Beam focusing of ILC

Low emittance beam
⇒ *Damping Ring*

Beam Focusing
⇒ *Final Focus System*



ATF2 Beamline

Investigation of the focus lens system

KEK-ATF

ATF Damping Ring

Low energy beam production

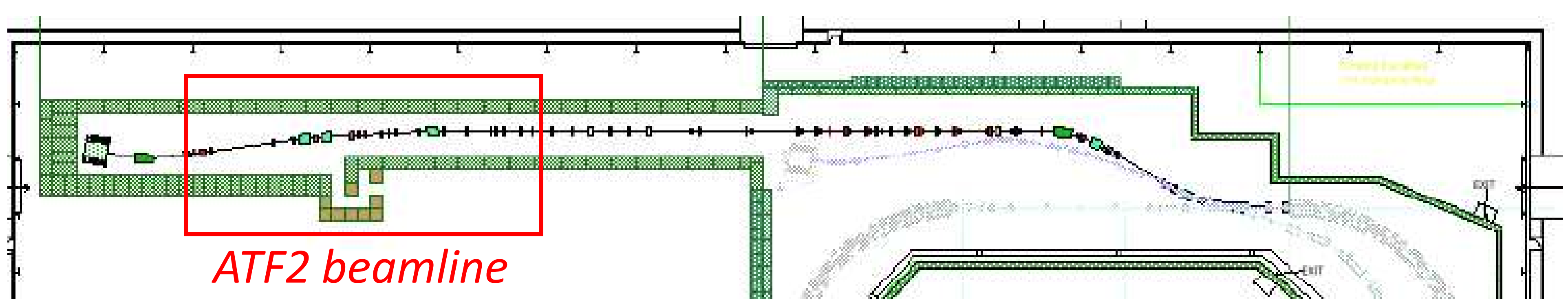
ATF2 Beamline

Test beamline for LC final focus test

Start construction at 2007

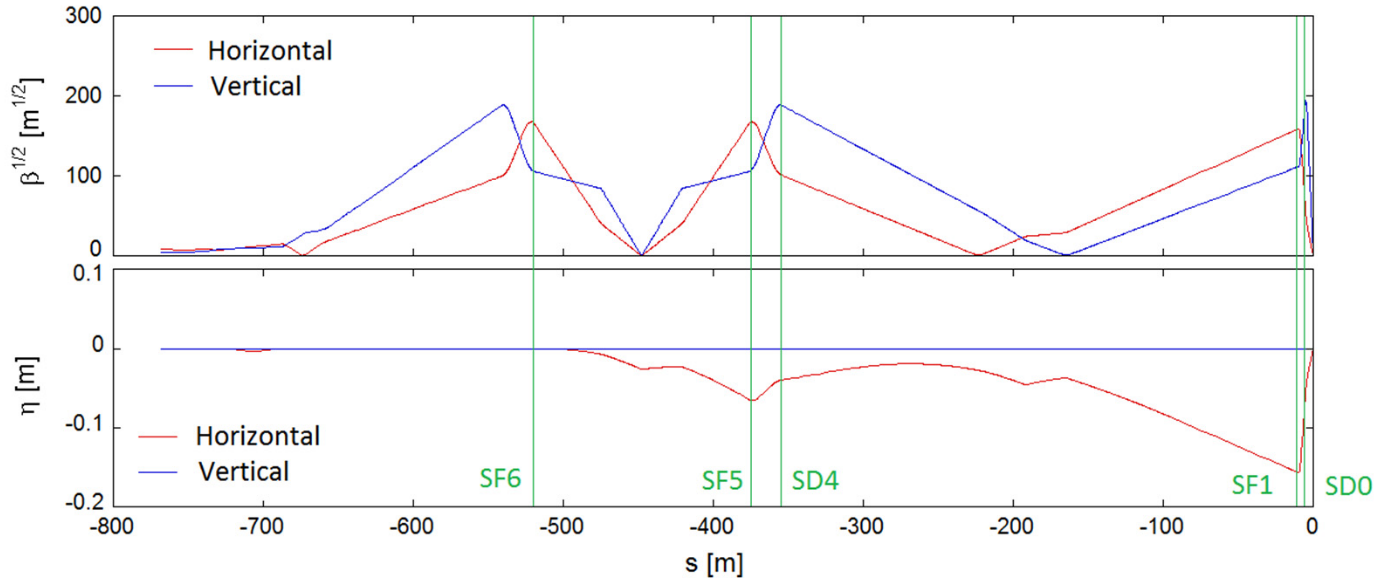
Design and construction were done by international collaboration.

ATF has been operating by international collaboration.



Beam Optics of ILC & ATF2

Beam optics of ILC final focus system

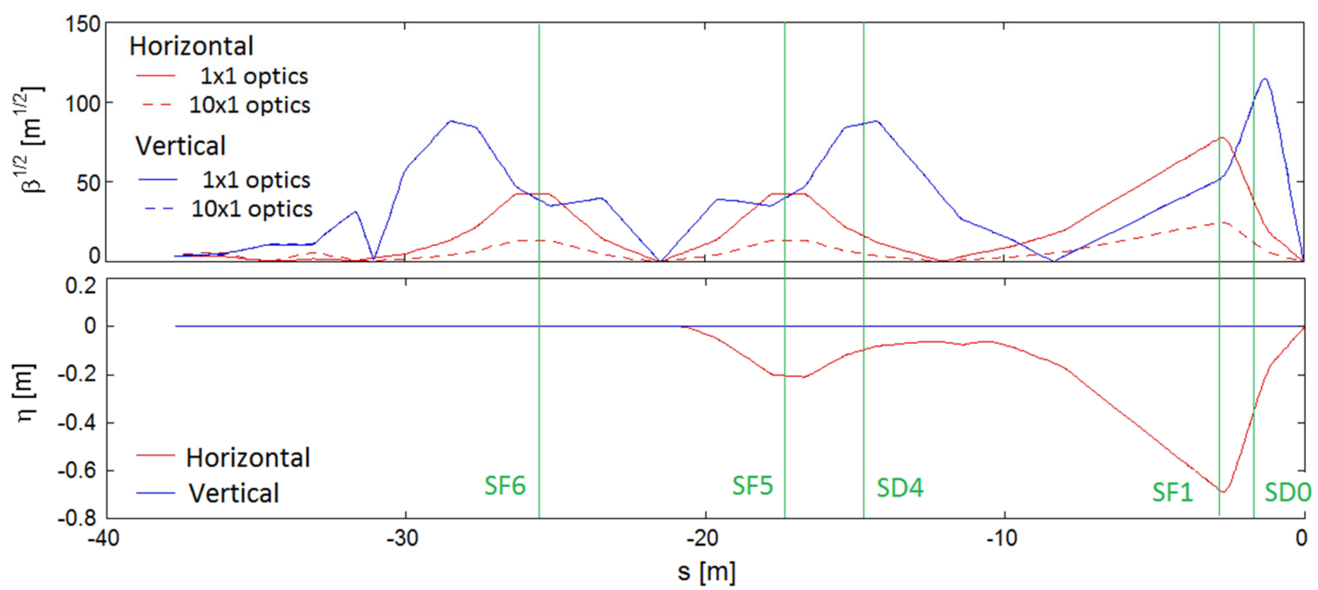


ILC final Focus System

- *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

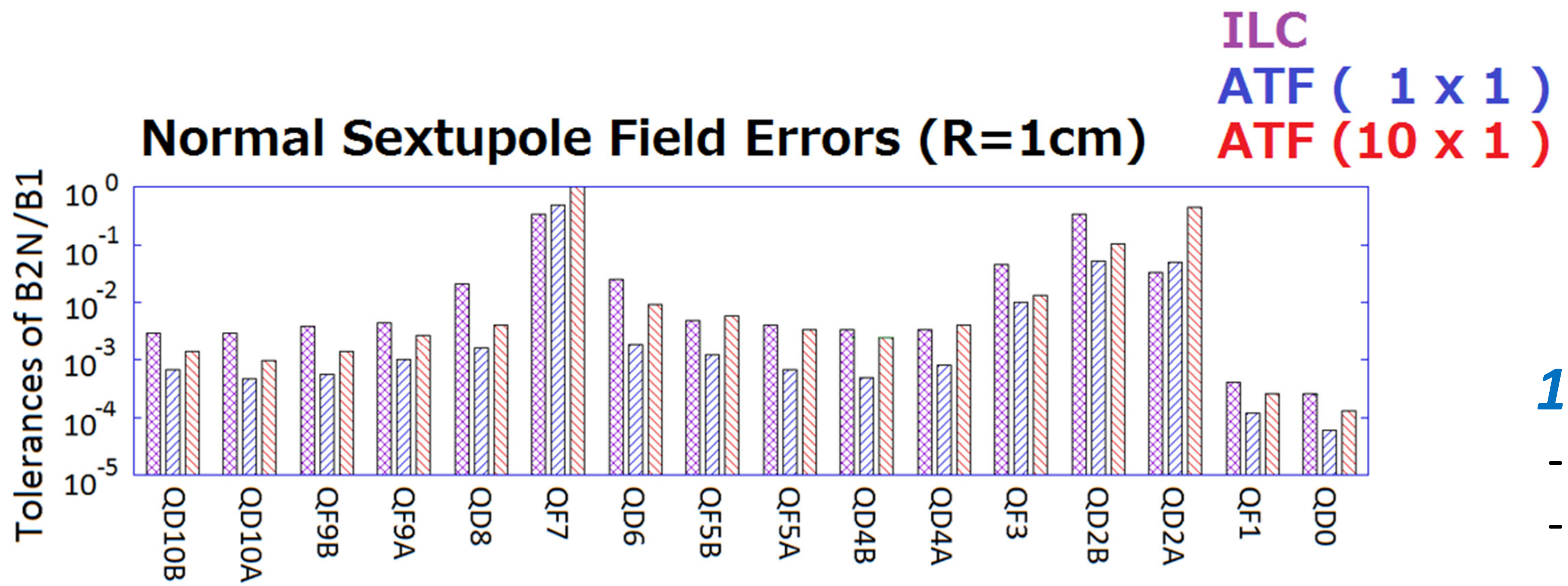
X&Y chromaticities are comparable to ILC FF.

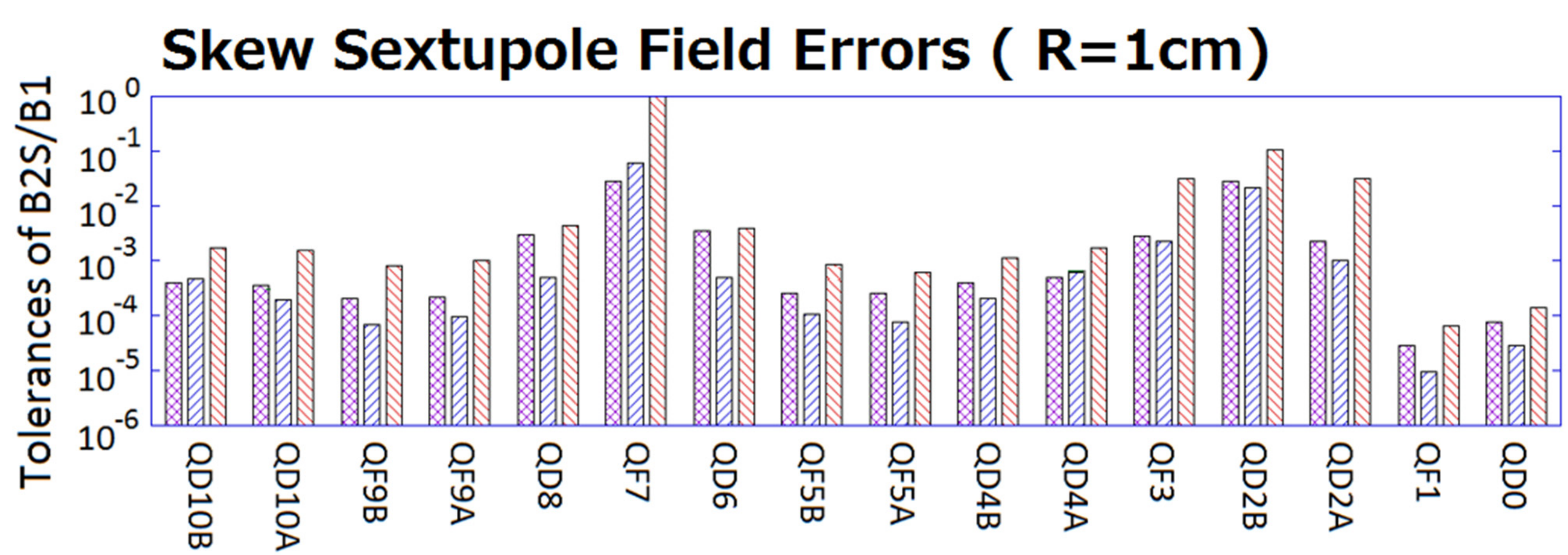
10x1 optics

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

Same concept of beamline design to ILC !

Tolerances of sextupole field error to IP vertical beam size



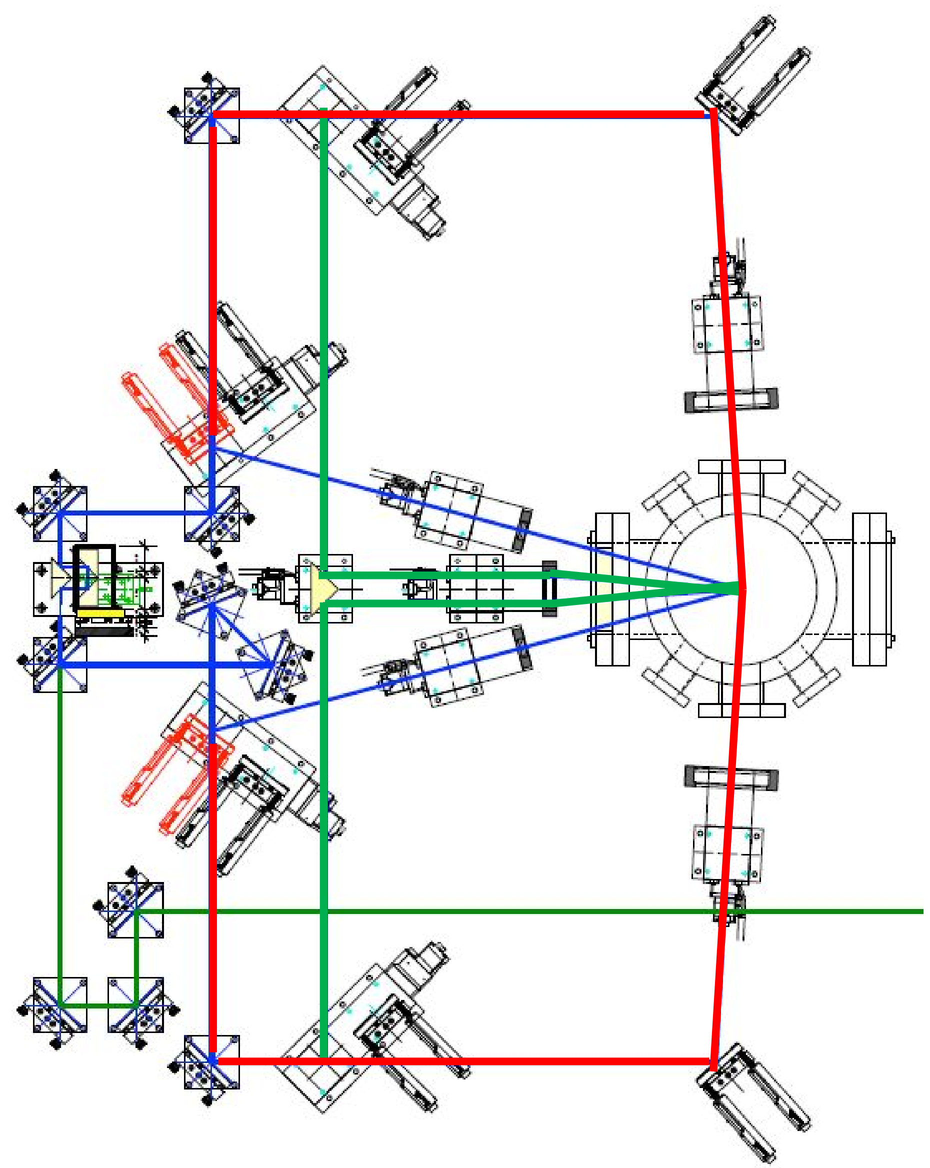


10x1 optics

- betaX* = 40mm
- betaY* = 0.1mm

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

IP-BSM (Shintake Monitor) for ATF2



Laser wave length was changed.

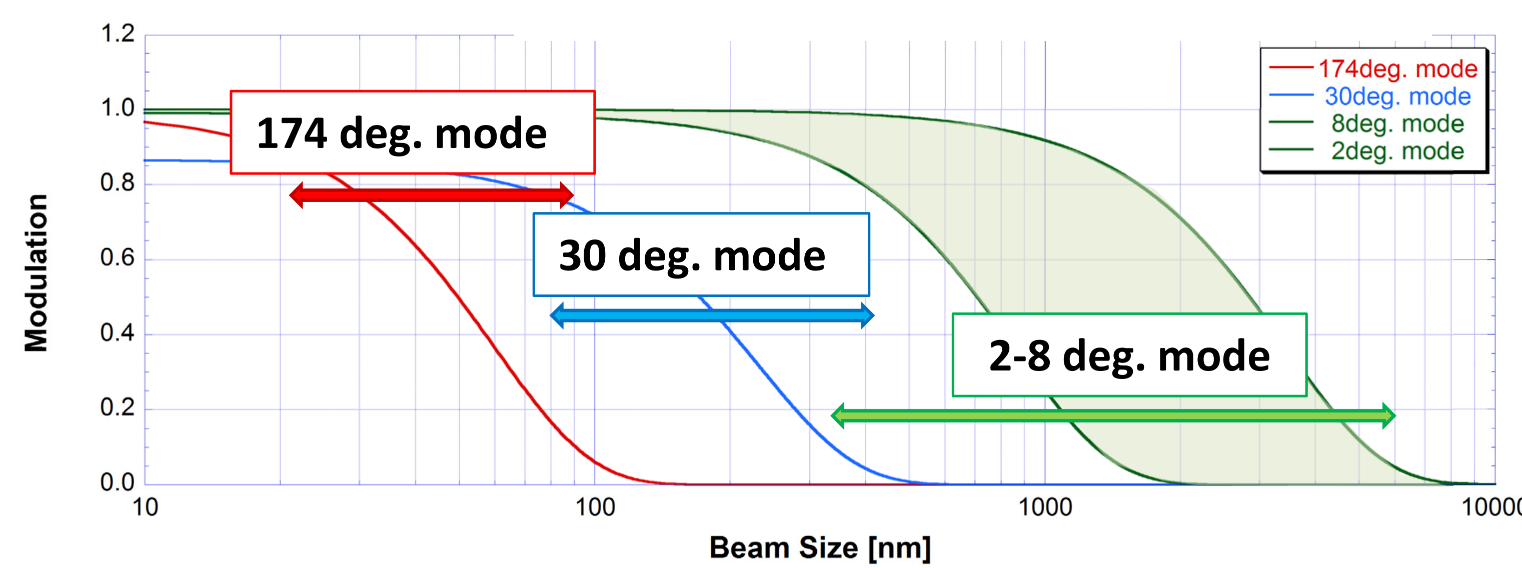
FFTB ; Nd:YAG fundamental mode (1064nm)

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 – 6mm)



Remaining studies planned for the next few years at "ATF review 2020 report"

Our main study items in the near future are:

- ***Study of higher order aberrations and corrections***
  - ✓ *Study of 2nd order aberrations and corrections*
  - ✓ *Study of the energy bandwidth of the final focus*
  - ✓ *Study of the different optics that enhance the effects of aberrations (smaller beta/larger L*)*
- ***Study of intensity dependence***
  - ✓ *Qualitative agreement of our observations and simulations/calculations*
- ***Improvement of IPBSM laser system***
  - ✓ *New laser system*
- ***Stabilizing beam orbit and reducing beam jitter***
  - ✓ *Specify the main source of the orbit drift*
  - ✓ *Routine operation of the upstream FONT feedback system*

ATF3 proposal

Building on the achievements of the ATF2 project a follow-on, upgraded facility ('ATF3') for pursuing R&D aimed at maximising the luminosity potential of ILC is necessary. ATF3 would comprise an overhaul and upgrade of the existing ATF2 beamline so as to model more accurately the energy-scaled ILC final-focus system.

Time-critical WPs by the IDT WG2

WP-prime-15 : ATF (Priority A)

- *ATF is the only existing test accelerator in the world to test the final focus beamline of the linear collider, and the study of the final focus beamline at ATF is important for ILC.*
- *However, since some of the items listed in the TPD can be performed in the Pre-Lab period, it is appropriate for the time-critical WP to narrow down the items and to perform only the higher priority research topics.*
- *Therefore, the time-critical WP of theWP-15 is not be selected some items from the items listed in the technical preparation document, but be restricted the following three research topics to be carried out at ATF before the pre-lab starts. Then, the budgets that are evaluated to be necessary for these items.*

  1) ***wakefield mitigation***
  2) ***mitigation and correction of higher-order aberration***
  3) ***training for ILC beam tuning (ML etc.)***

- *As candidates for research laboratories, we decided to list all the laboratories that were also listed as candidate laboratories in TPD WP-15.*

Introduction of recent studies

- ***Effect of the multipole fields for FF quadrupoels***
- *IP-BSM improvement*
- *Wakefield study*
- *DR injection / IP beam size tuning with machine learning technique*

➢ *Today we only present "Effect of the multipole fields for FF quadrupoels".*

➢ *The rest of the topics will be introduced at the ATF2-3 project meeting (tentative name) scheduled in March this year.*

Observation of the dependence of the IP vertical beam size for the horizontal and vertical IP beta functions

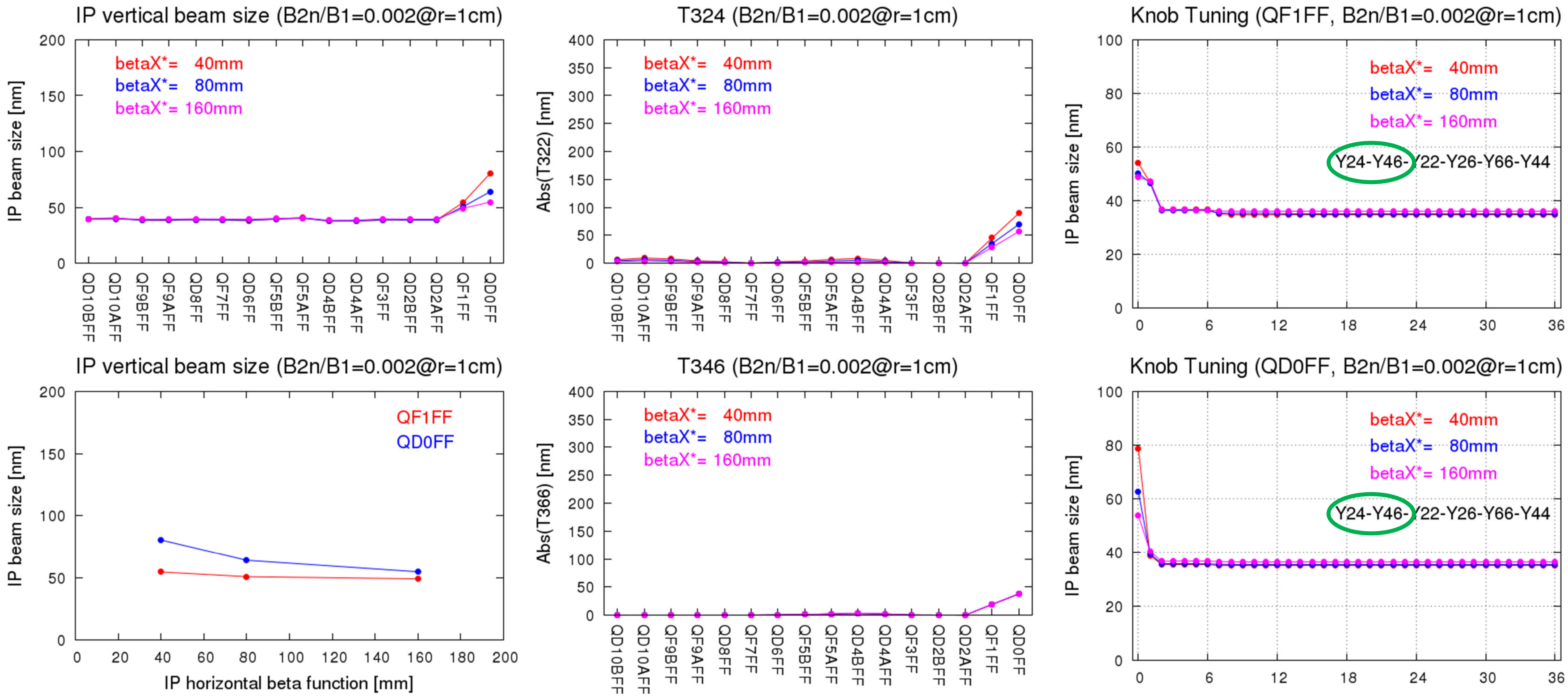
We investigated how much we could reduce the IP vertical beam size while changing the IP horizontal and vertical beta functions ***without using nonlinear knob beam size with FF skew sextupoles (Y22, Y26, Y66 and Y44 knobs)*** *during the spring 2022 operation.*

Summary tale of the IP beam size squeezing

βx, mm	βy, mm	M30, %	M174, %	
30-40	0.15	50	0	(roughly > 150um)
80	0.15	65	15	(roughly 100um)
180	0.08	70	25-30	(roughly < 70um)
180	0.15	75	25-30	

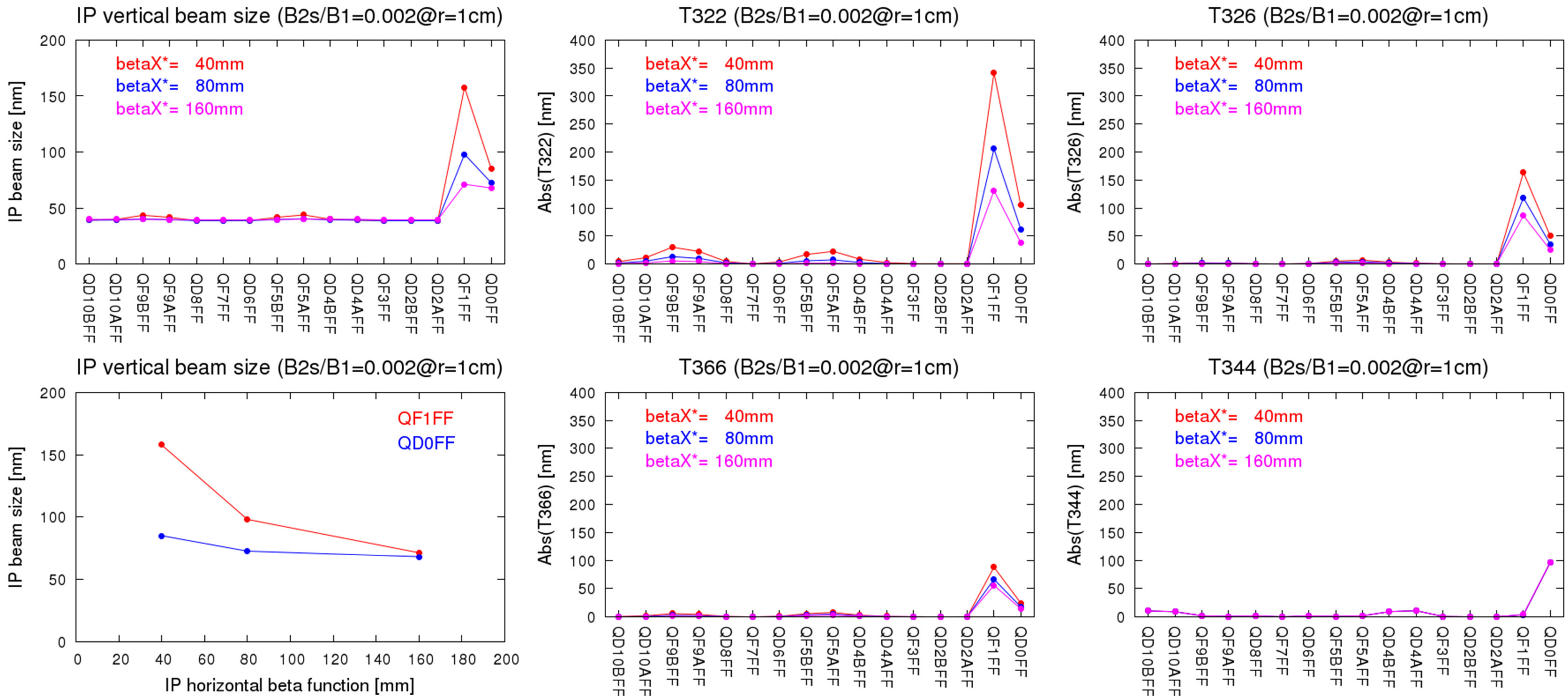
- *In particular, the IP vertical beam size seems to change significantly when the horizontal beta function is changed.*
- ***Is the effect of IP beam size due to nonlinear field error larger than expected?***

Normal sextupole field errors for FF quadrupoles



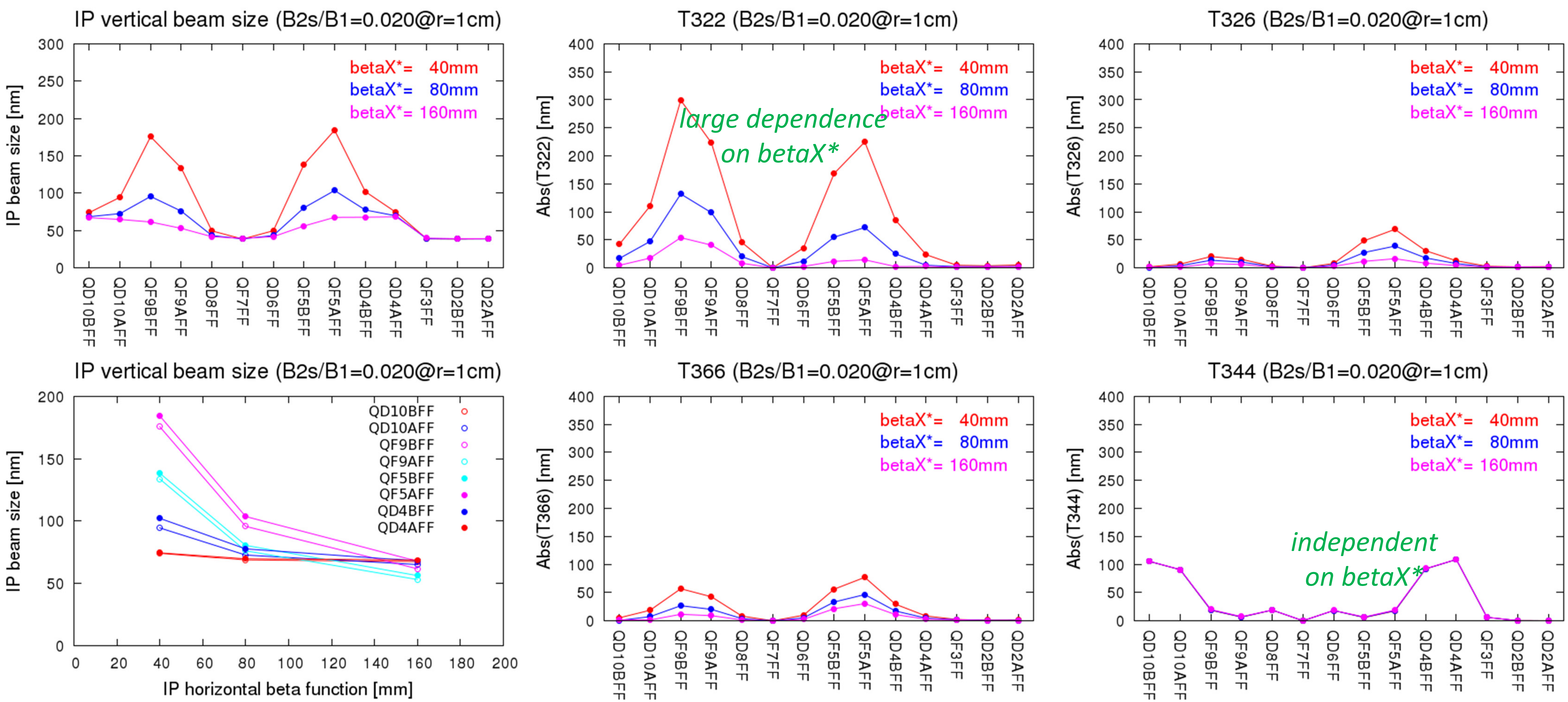
- *Assuming **normal sextupole field errors of about 0.002** to the FD to make significant IP beam size growths.*
- *The change when changing the IP horizontal beta function is larger for QD0 (mainly come from **T324**).*
- ***The effect can be corrected by nonlinear knob (Y24, Y46 once each). => This process was done in the operation.***

Skew sextupole field errors for FF quadrupoles



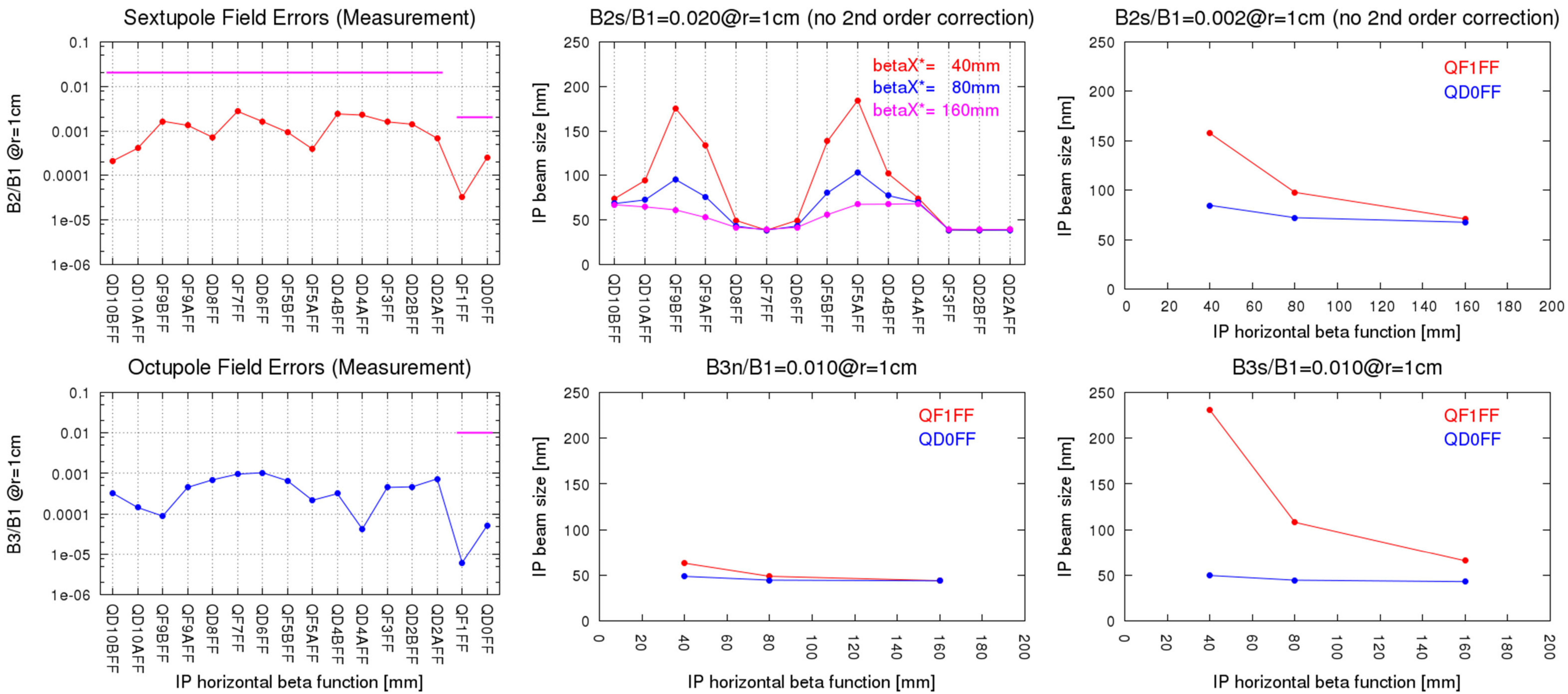
- *Assuming* ***skew sextupole field errors of about 0.002*** *to the FD to make significant IP beam size growths (larger than normal sextupoles component).*
- *The change when changing the IP horizontal beta function is larger for QF1 (mainly come from* ***T322****).*

Skew sextupole field errors for FF quadrupoles (larger errors)



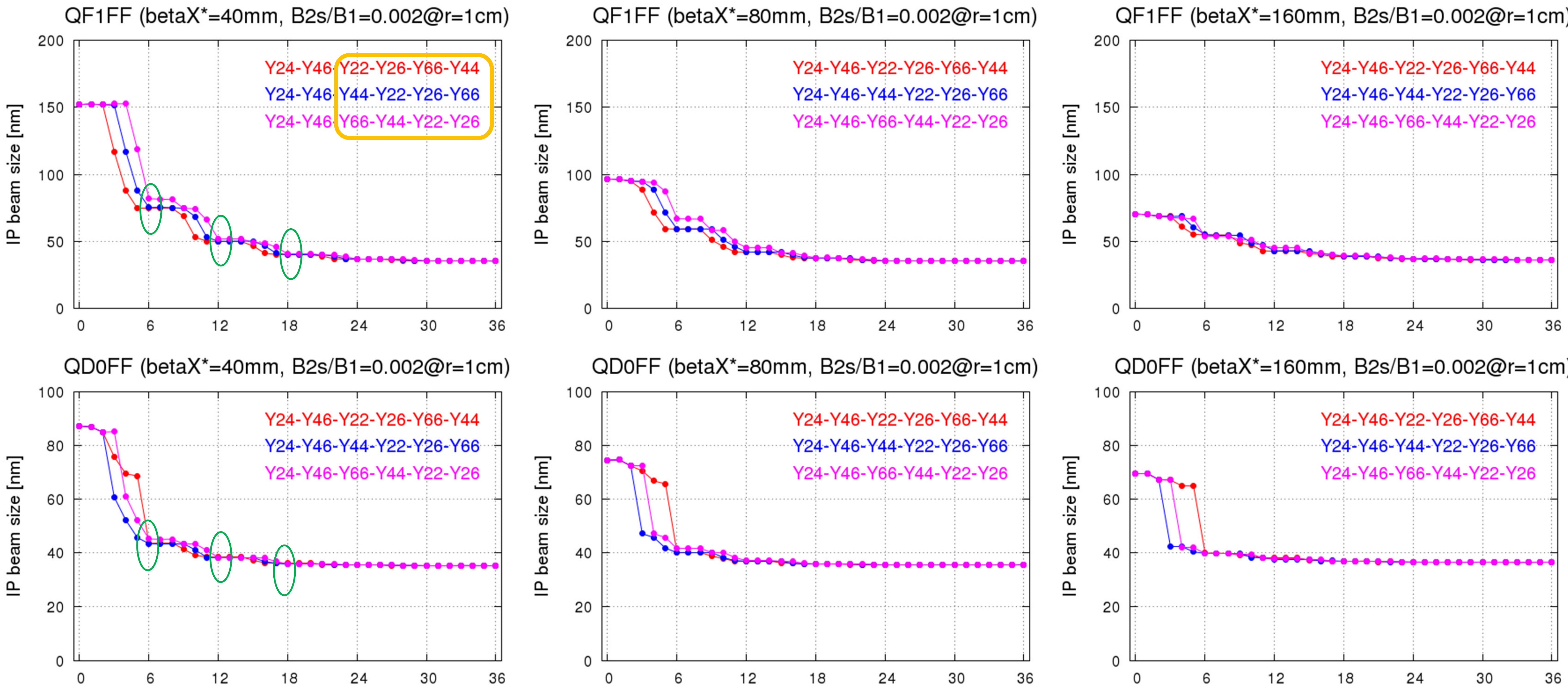
- *Assuming* ***skew sextupole field errors of about 0.02****, significant IP beam size growth occurs for magnets with large beta functions even though the final doublet, when the magnets have large field errors.*
- *The change in the beta function depends on the location (depends on the dominant components).*

Measurement of multipole field errors for the FF quadrupoles



- *Assuming a sextupole error that is an order of magnitude higher than what is measured (more than 10 years ago), we can reproduce the IP beam size growth that depends on betaX*. This effect can be corrected to less than 40 nm with nonlinear knob.*
- *The octupole error also causes IP beam size growth, but requires a larger error. The dependence of octupole error on betaX* is larger than that of sextupole error and cannot be corrected by the current nonlinear knob.*

Correction of the skew sextupole field errors for Final Doublet



- ***The effect can be corrected by repeating the nonlinear knob 2 or 3 times.***
- *Changing the order of the nonlinear knobs does not seem to change the number of iterations for convergence.*

Summary of the study
for the effect of the multipole fields for FF quadrupoels

If the multipole error of some quadrupole magnets in ATF2, not only Final Doublet, becomes one order of magnitude worse after the beamline construction, the IP beam size may be affected as it is now.

- *Even if these errors can be compensated for in the simulation with the 2nd order knob, the dynamic range of the 2nd order knob makes it difficult to find the first modulation observation in the 174 degree mode.*

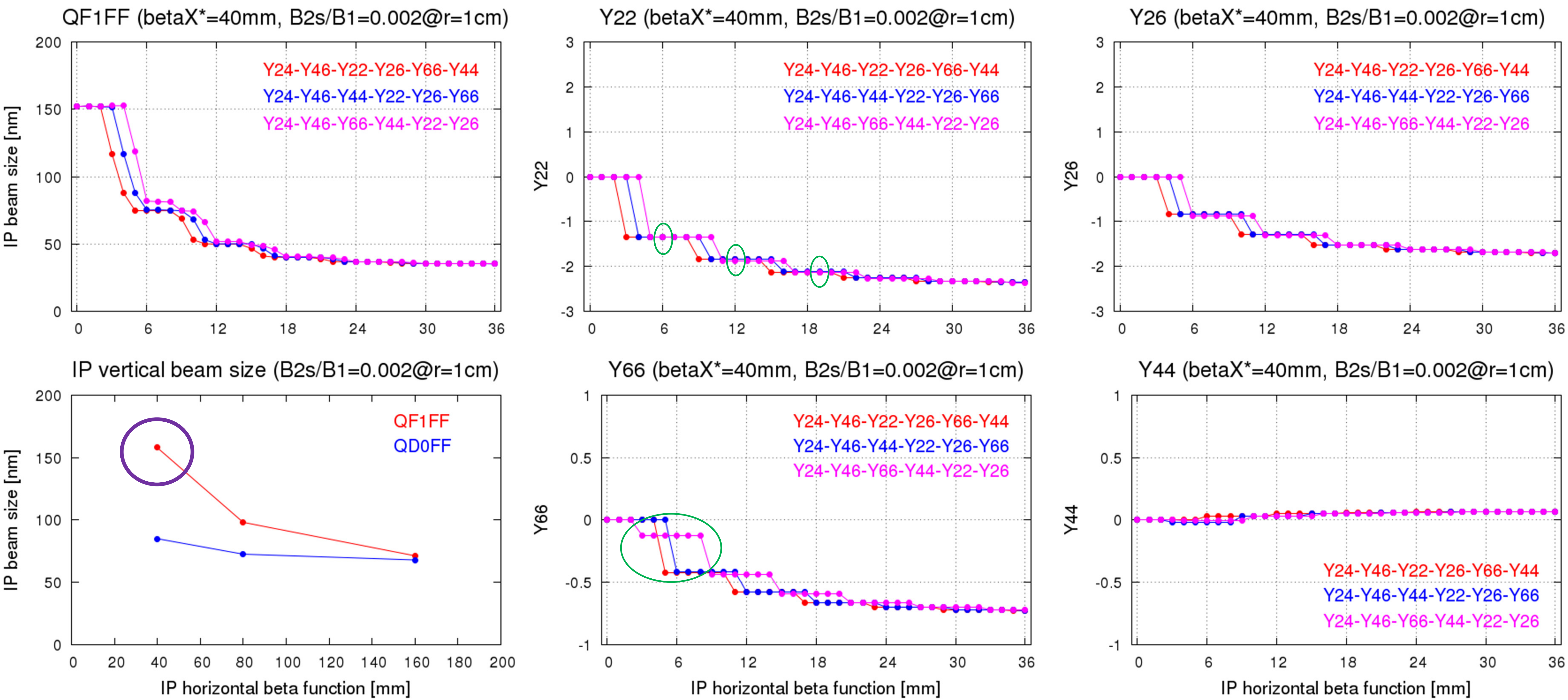
- *Note that this effect is expected to be even greater in ultra-low beta optics.*

  - *QF1FF has been replaced by the large diameter magnet used in SLAC's PEP-II.*
  - *One of the coils in QD0FF has been replaced due to water leakage.*
  - *One new magnet is being made to back up the FD magnet (to be delivered in the next fiscal year).*

We are planning beam experiment in February to confirm the effect of changing the IP horizontal beta function on the IP vertical beam size.

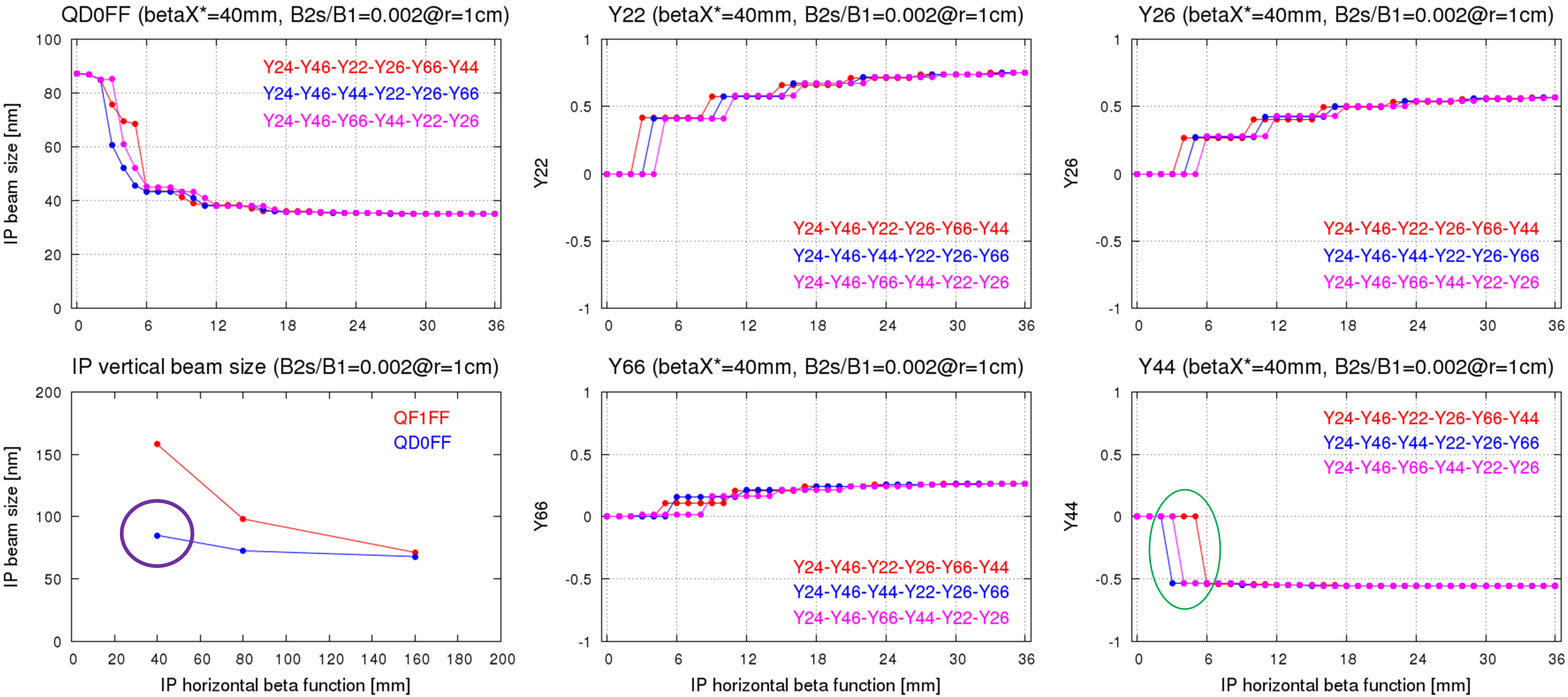
backup

Detail for the QF1FF skew sextupole field error correction



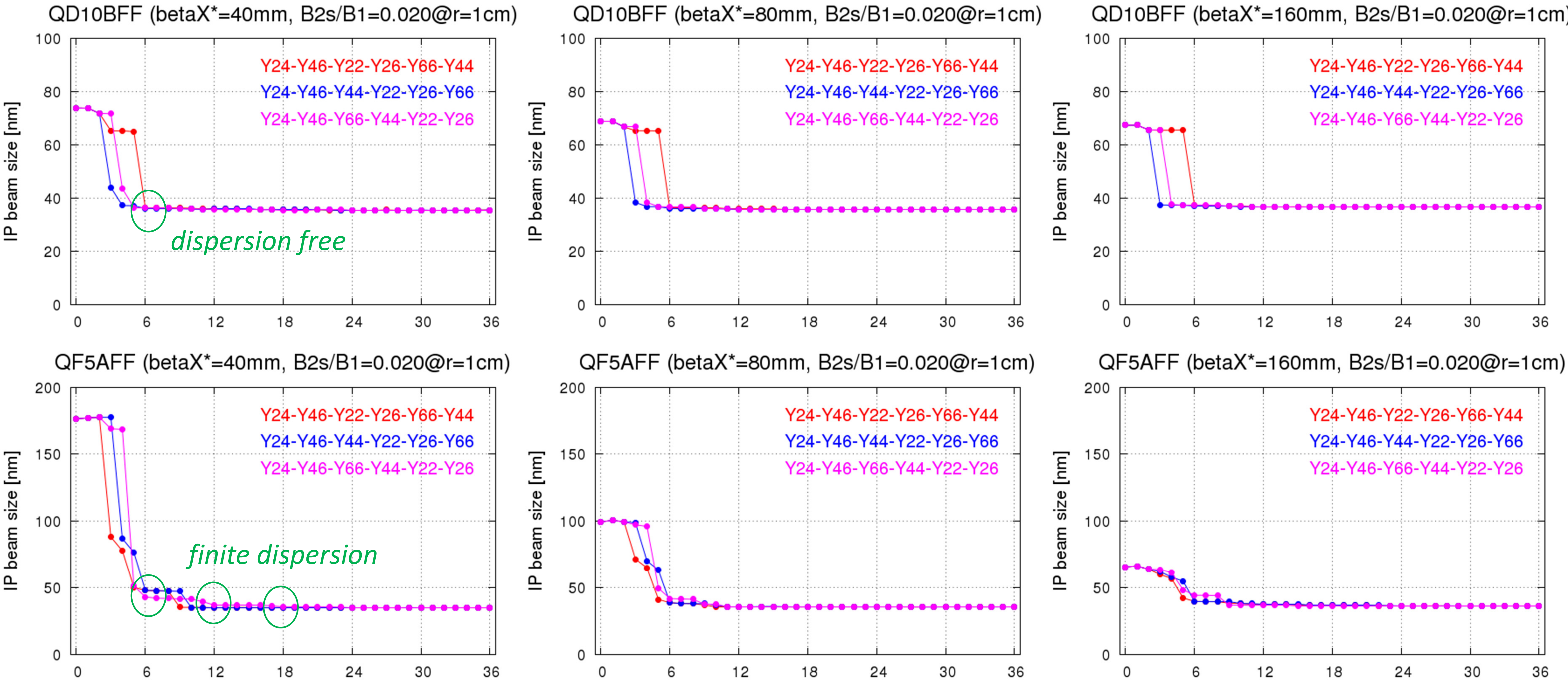
- ➢ *Looking at the changes in the individual knobs, there does not seem to be any over-correction, then back.*
- ➢ *In some conditions, as a result of coupling between knobs, changing the order of knobs changes the speed of convergence at the beginning, but it does not make much difference at the end.*

Detail for the QD0FF skew sextupole field error correction



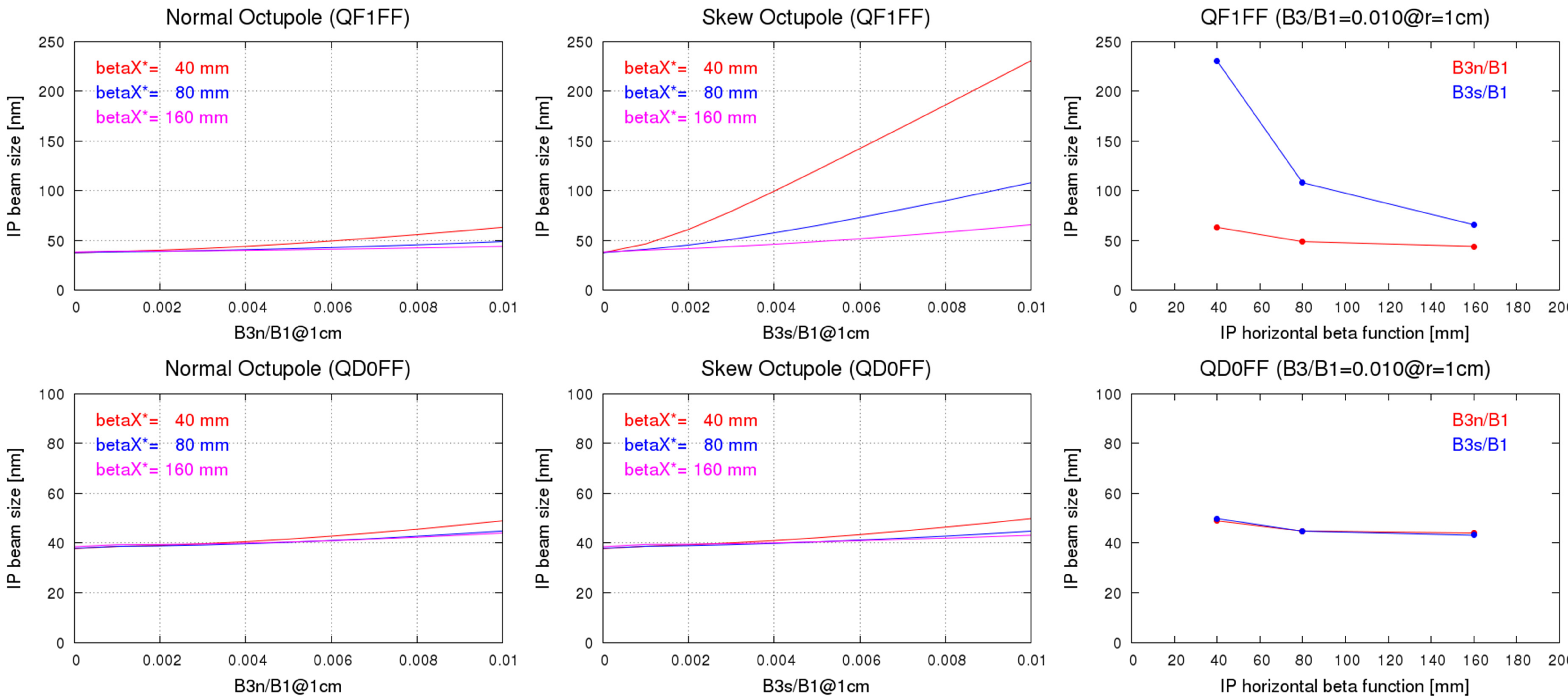
- *Since **Y44 is dominant**, Y22, Y26 and Y66 have little effect, and the largest beam size decreases at the timing when Y44 changes.*
- *Then, the IP beam size converges after the iterations of Y22, Y26 and Y66.*

Examples for the skew sextupole field error correction



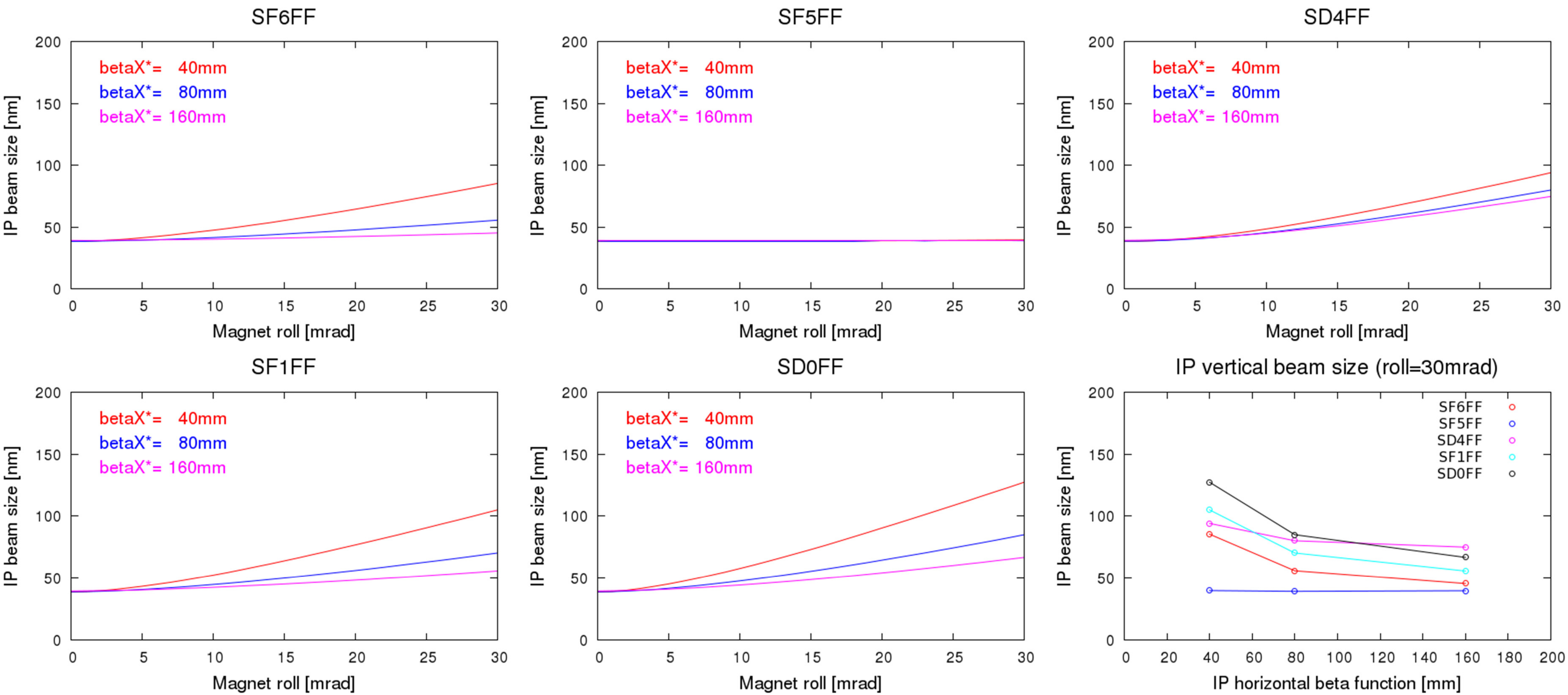
- *In the dispersion free region, the correction converges after a single iteration.*
- *In the region with finite dispersion, the correction converges after 2 or 3 iterations.*

Octupole field errors for final doublet



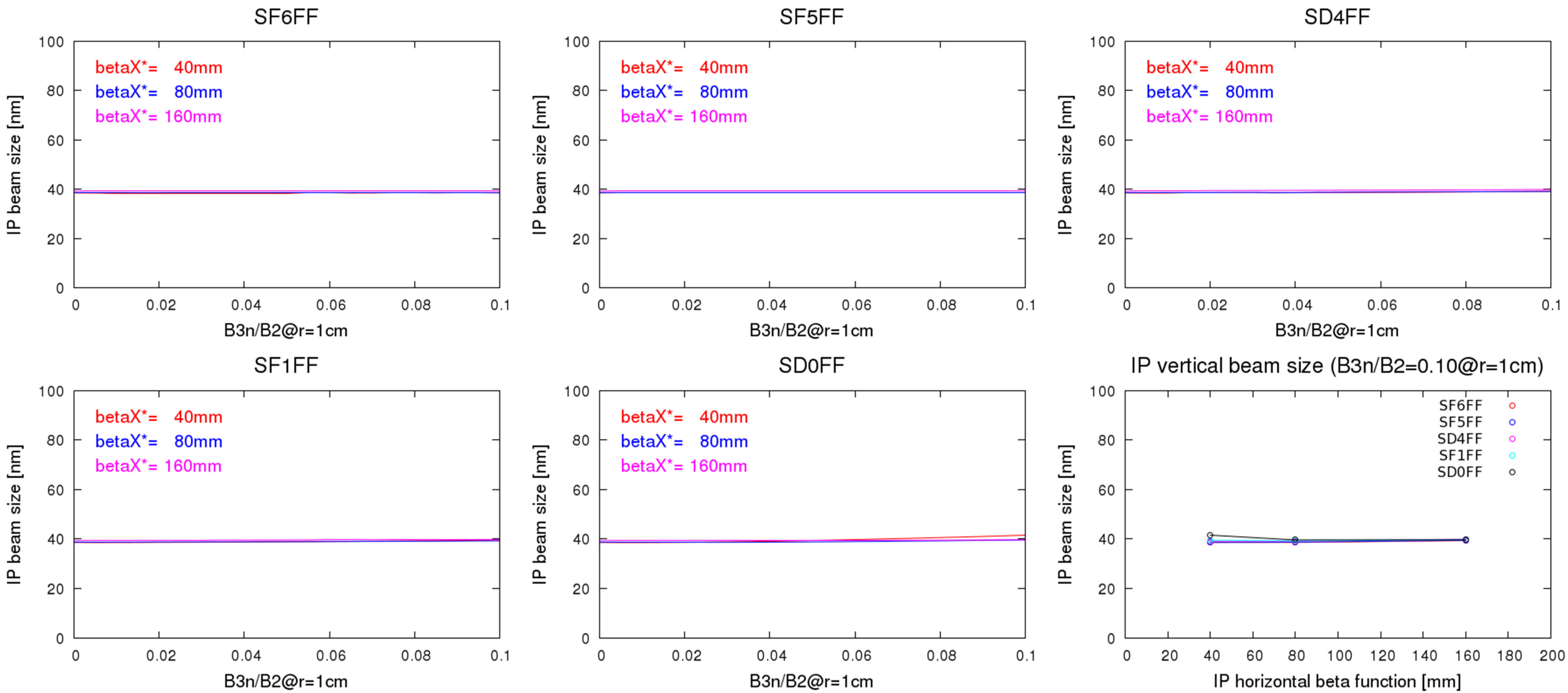
- *Assuming a skew octupole field error of the order of 0.001 in QF1FF, significant IP beam size growth occurs.*
- *Assuming 0.01 of the normal component of QF1 and the octupole errors for QD0 does not produce significant beam size growth.*
- *The change when changing the beta function is larger than the sextupole error.*

Roll errors for FF sextupoles



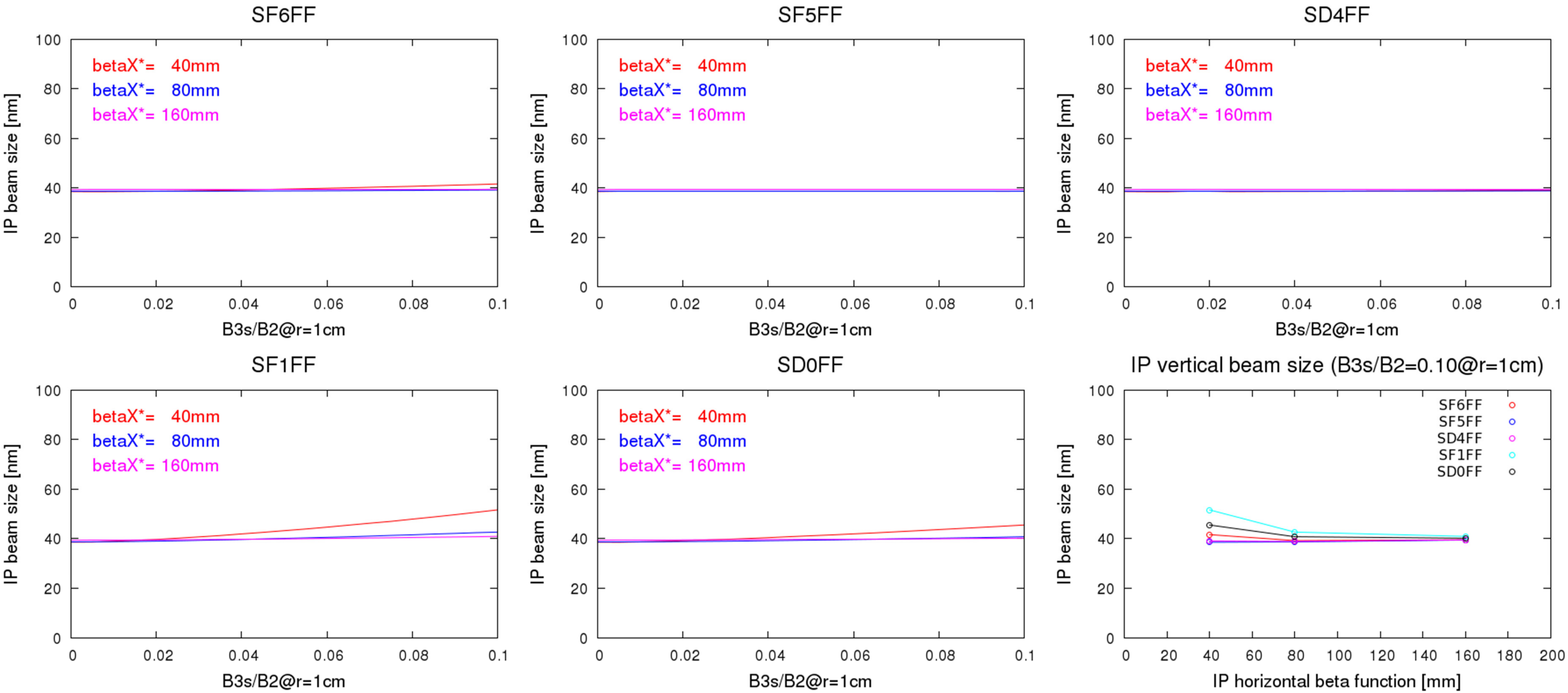
- ➢ *To reproduce the IP's beam sizegrowth with FF sextupole roll error, an error of a few 10mrad is required.*
- ➢ *Since the main cause of the beam size growth is skew sextupole field error, it should be possible to correct it with a nonlinear knob (I have not done any simulation).*

Normal octupole errors for FF sextupoles



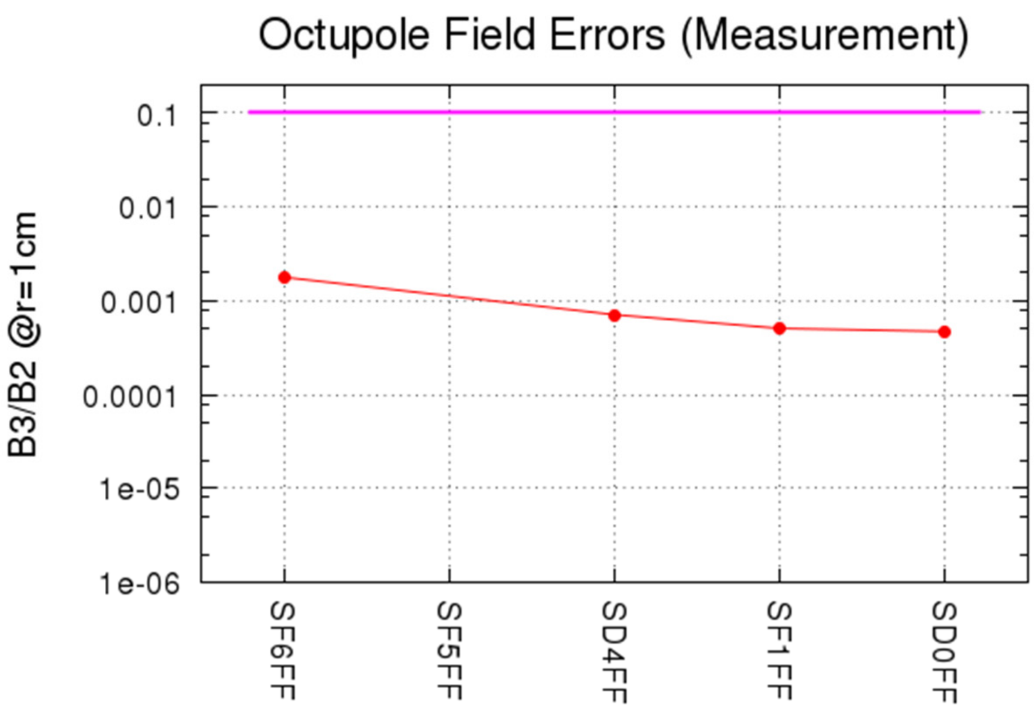
- *Assuming 0.1 of the normal octupole field errors of FF sextupoles does not produce significant beam size growth.*

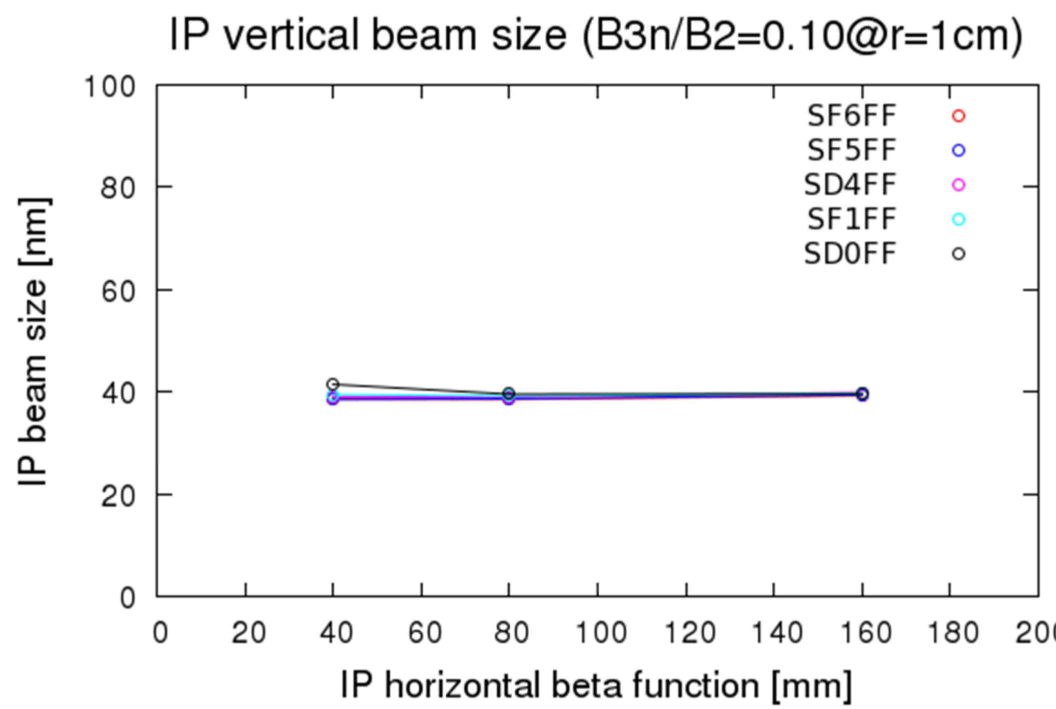
Skew octupole errors for FF sextupoles

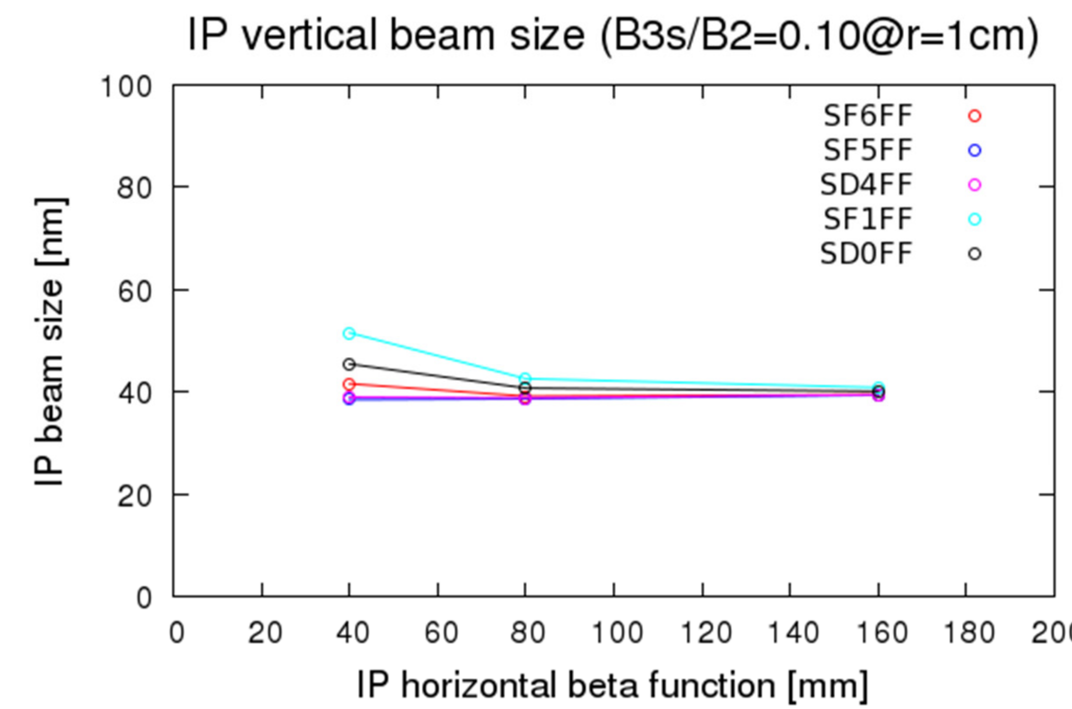


- *Assuming 0.1 of the skew octupole field errors of FF sextupoles does not produce significant beam size growth (a little bit for SF1FF).*

Summary of multipole field errors for the FF sextupoles







- *Even assuming an octupole error sufficiently higher than what is measured (more than 10 years ago), significant IP beam size growth cannot be reproduced.*