Beam Extraction Line of ATF2
(from Damping Ring to Final Focus)

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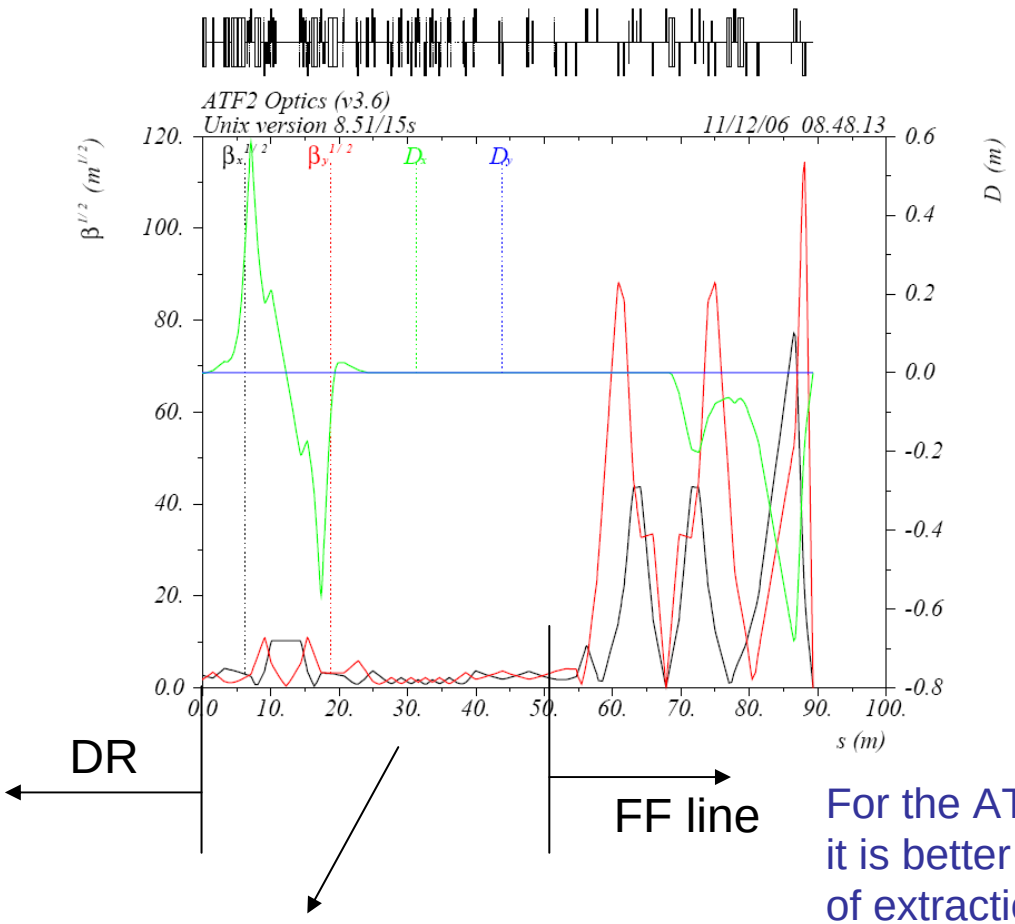
Beam Optics of ATF2 ver3.6



For the ATF2 FF study,
it is better to separate the problems
of extraction line and FF line.

Beam Extraction Line

Requirements to make an ideal beam to FF line

- Betatron coupling correction to FF
- Dispersion correction to FF
- Other nonlinear corrections in beam transport line
- …

Betatron coupling correction

In ATF2 beam extraction line, we will prepare 4 skew quadrupoles and 5 wire scanners for betatron coupling correction.

Strength of skew quads estimation with SAD simulation.

- Put 0.3mrad rotation errors (rms.) for QD*X, QF*X (extraction line quads) only.
  (No errors in FF line, No position errors for all magnets.)

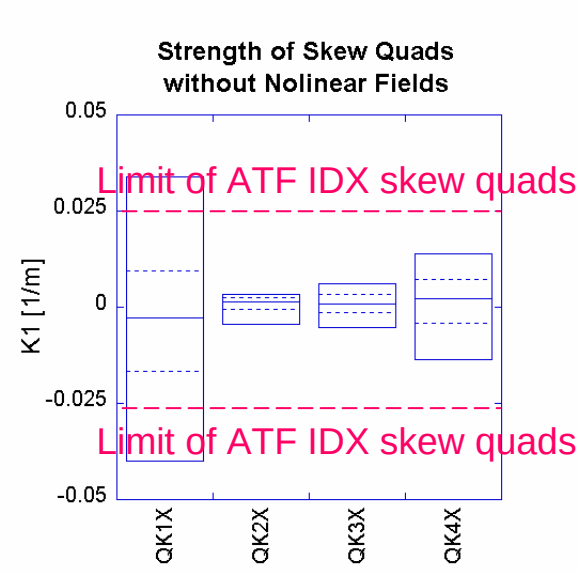
- Dispersion correction in extraction line was done by local bump.
  ZH1X ZH2X ZX1X ZX2X for horizontal
  ZV1X ZV2X ZV3X ZV4X for vertical
  (No effect of the skew quads for dispersion correction)

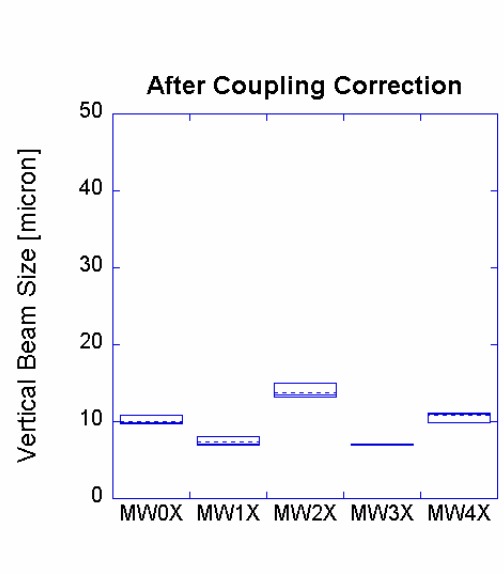
- Coupling correction was done with QK*X (4 skew quads for coupling correction)
  by monitoring wire scanner beam size at diagnostic section.

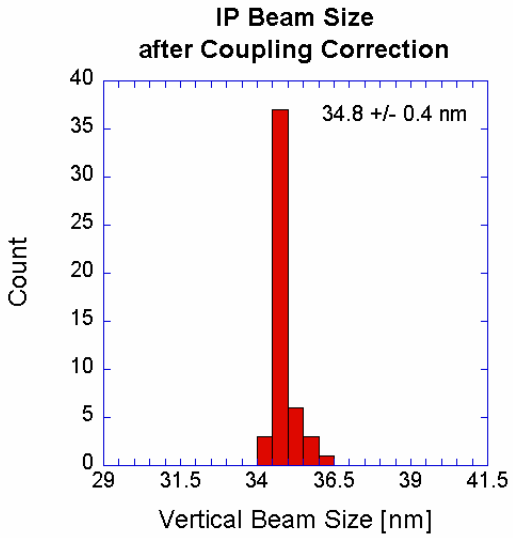
- Betatron matching was done with QM*X. (matching quads to FF line)

Coupling correction with QK*X (4 skew quads for coupling correction) by monitoring wire scanner beam size (MW0X-MW4X)

Strength of the Skew Quads



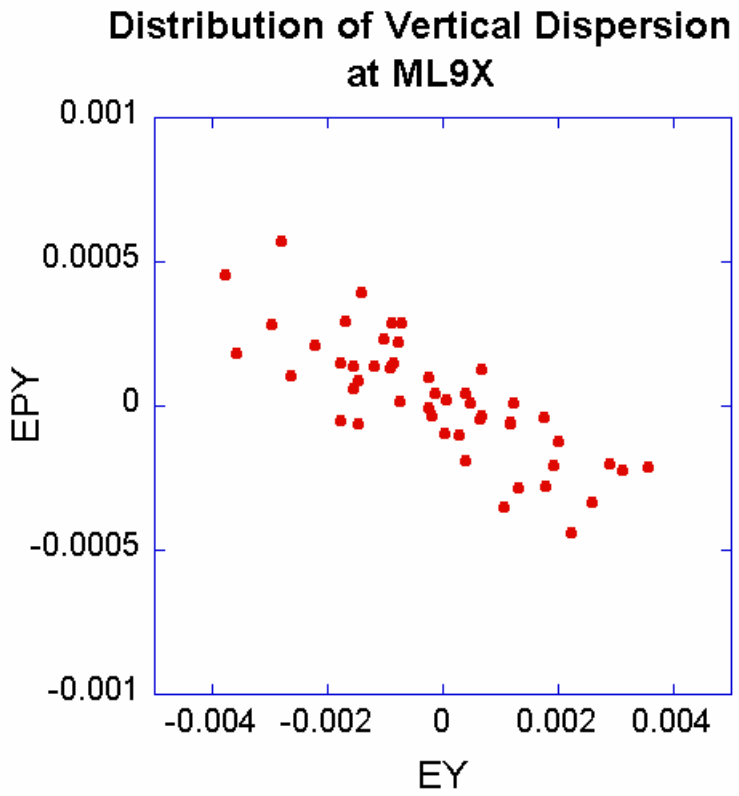




QK1X is out of limit
for 0.3mrad rotation errors

We can correct the betatron coupling with QKs

Residual vertical dispersion for 0.3mrad rotation errors at the straight section of ATF2 beam extraction line



-Dispersion correction with local bump.
(No betatron coupling generation)

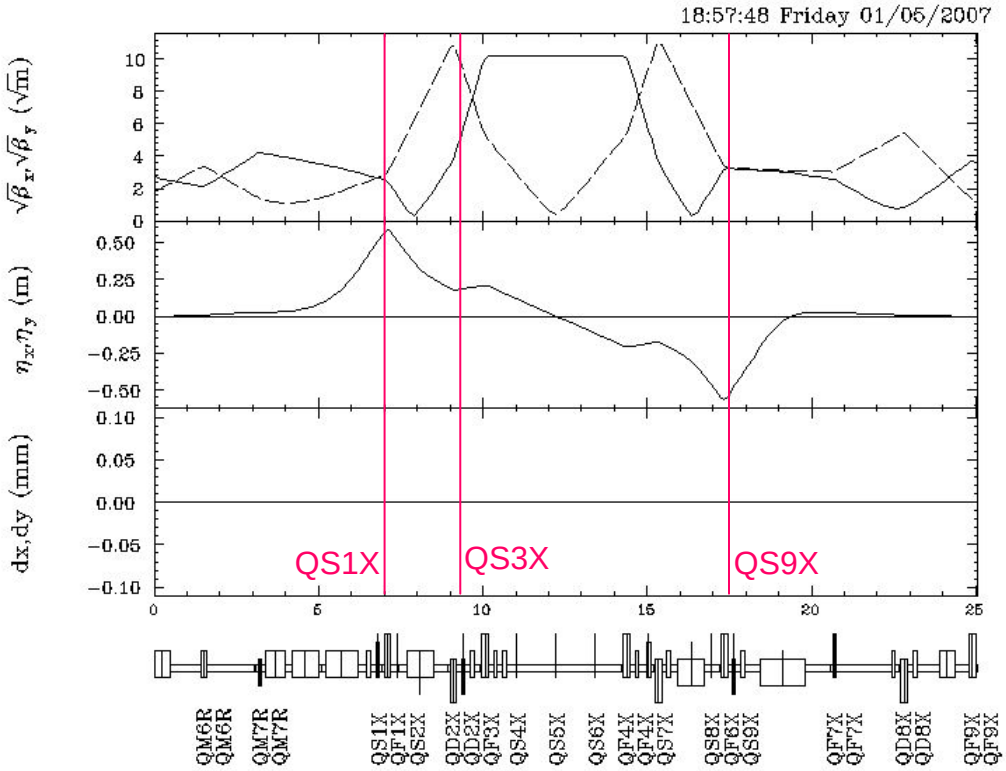
-But, the amount of the bump was 1-2mm
to correct the +/-5mm vertical dispersion.

-The range of the dispersion correction
with local bump was +/-5mm

We need the additional dispersion correction knobs,
because we have other dispersion sources

- residual dispersion from DR
- quads position errors
- position correctors in transport …

Horizontal Dispersion Correction with QF3X, QF4X
Vertical Dispersion Correction with Skew Quads

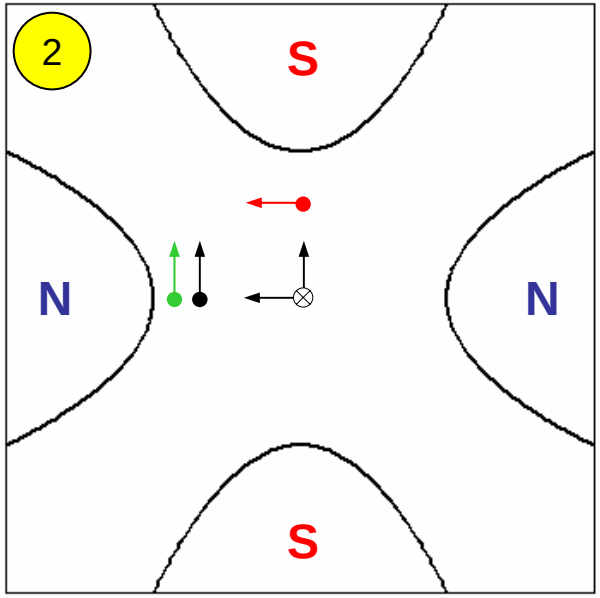


Candidate location of skew quads for vertical dispersion correction.

QS1X, QS3X
- Minimum strength of skews

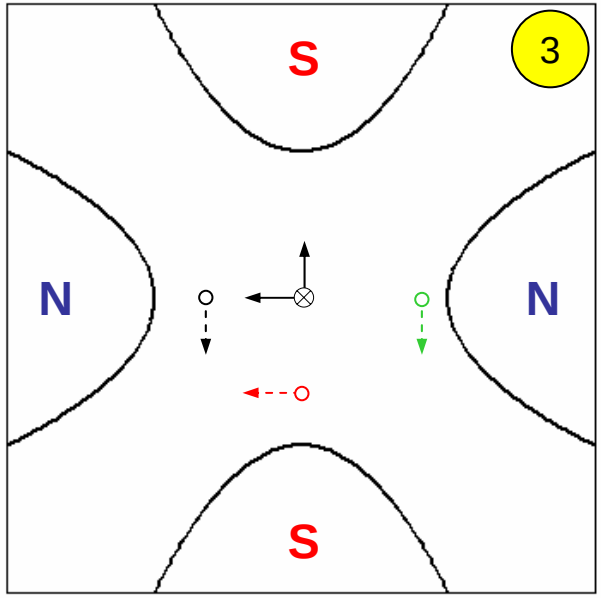
QS1X, QS9X NuX=2Pi, NuY=Pi
- Betatron coupling was cancelled for “SUM KNOB”.

after 1st skew quad



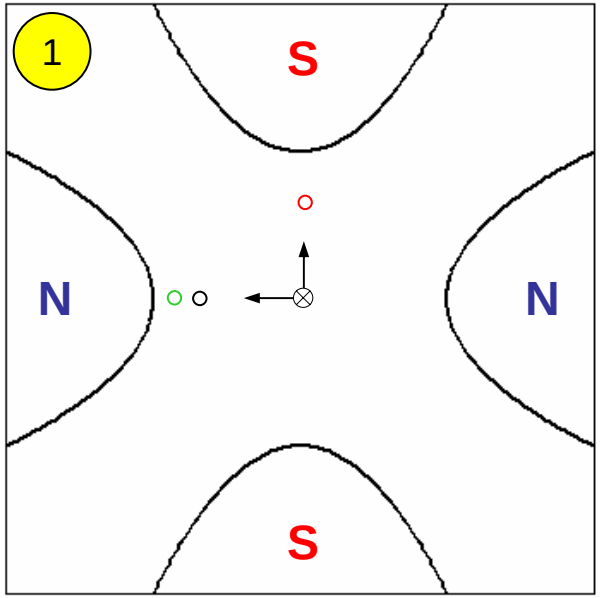
$\Delta \mu_x = 0{,}360^\circ$
$\Delta \mu_y = 180^\circ$
$+ \eta_x \rightarrow - \eta_x$

before 2nd skew quad



how to generate η_y without introducing coupling

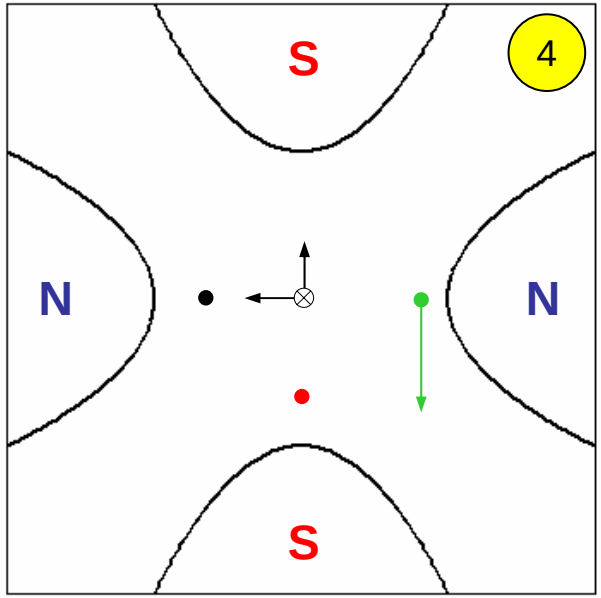
before 1st skew quad



β_x (on-energy)
β_y (on-energy)
η_x (off-energy)

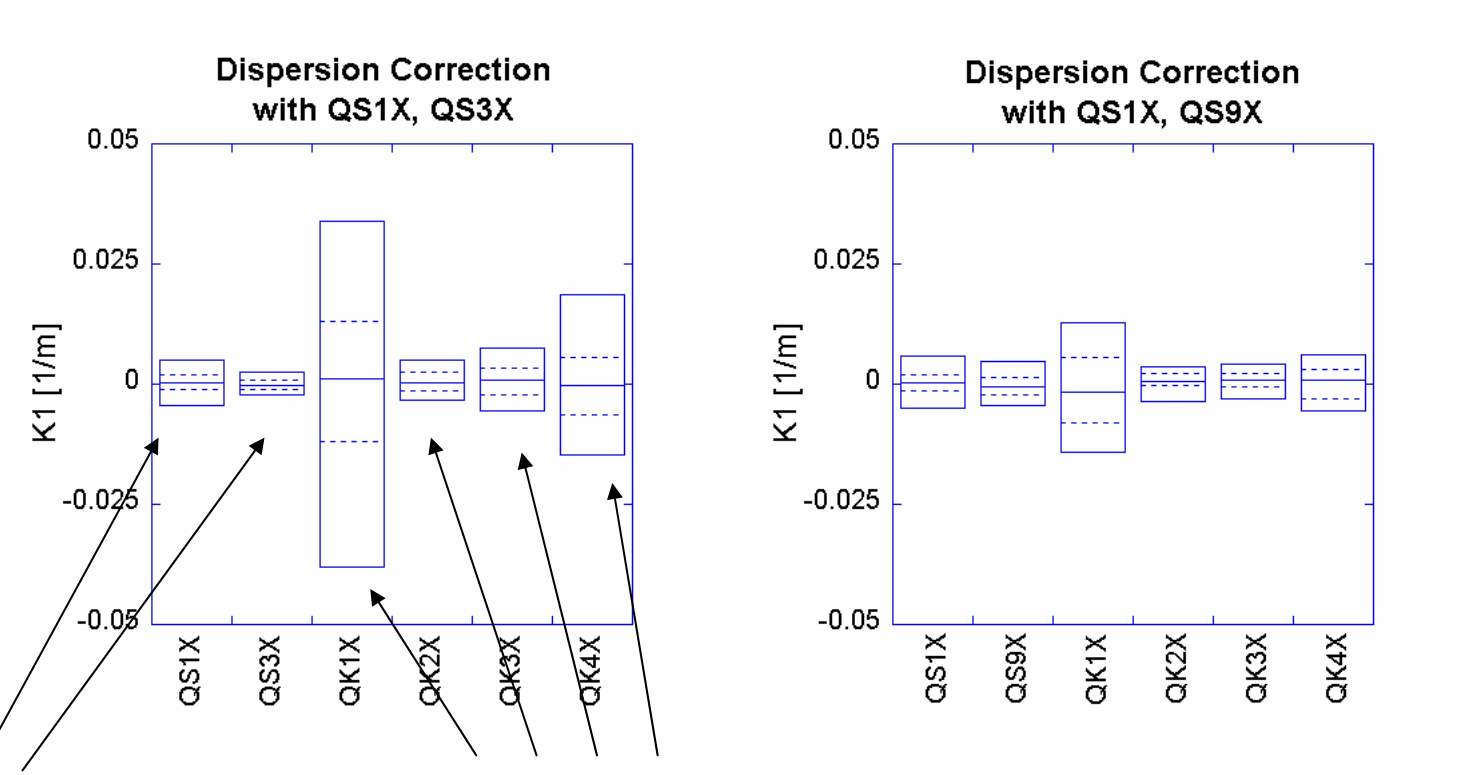
skew quads have equal strengths ("sum knob")

after 2nd skew quad



Presented by M.Woodley (SLAC) at 3rd ATF2 project meeting.

Strength of skew quads for vertical dispersion correction



Dispersion correction

Betatron coupling compensation
for dispersion correction skew quads.

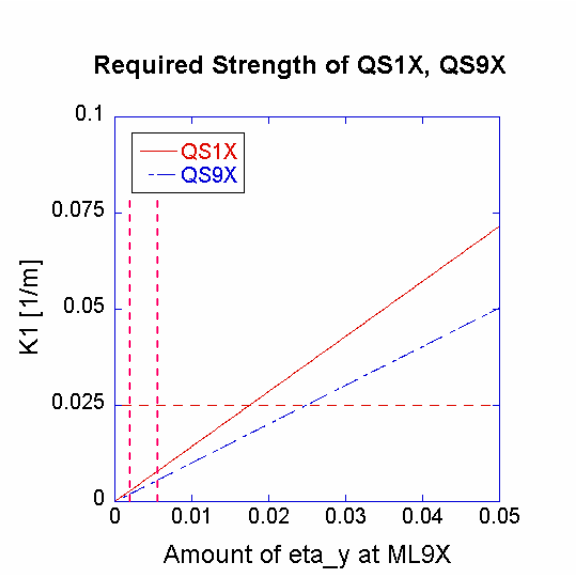
The set of QS1X, QS9X is small betatron coupling by canceling “SUM” part,

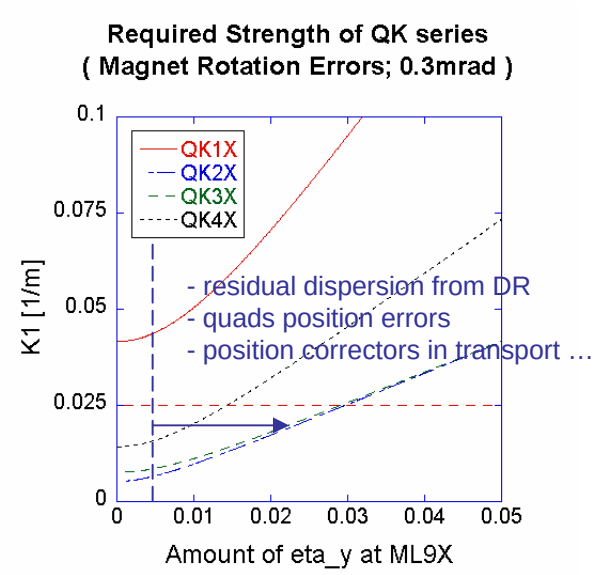
but there remain some residual betatron couplings.

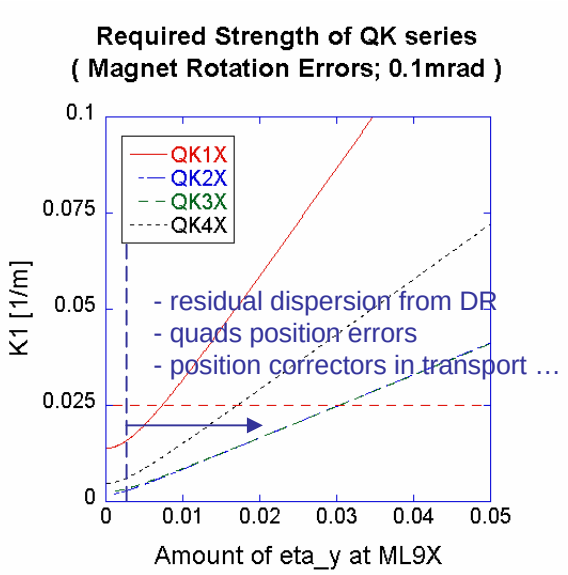
Strength of skew quads for ATF2

Skew quads for dispersion correction

Skew quads for betatron coupling







The required strength of skew quads of ATF2 strongly depends on the amount of vertical dispersion correction.

We need the evaluation of the requirement of the amount of the correction to determine the strength of skew quads, QSs and QKs.

Nonlinear Field 1 - Sextupole Component of Bending Magnet.

- The sextupole component of bending magnets for ATF was roughly evaluated by SLAC collobarators (ATF report 00-06).

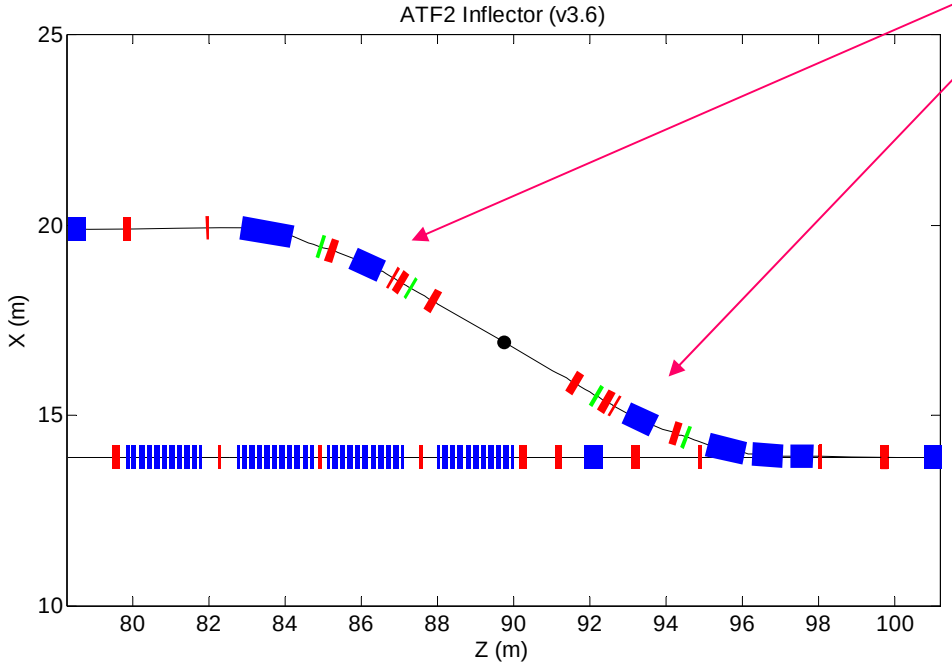
  K2 = 0.365

- In the ATF2, the same bending magnets are used.

- The same amount of sextupole fields are assumed to the bend in ATF2 transport line.

SBH2X K2 = +0.365

SBH1X K2 = - 0.365

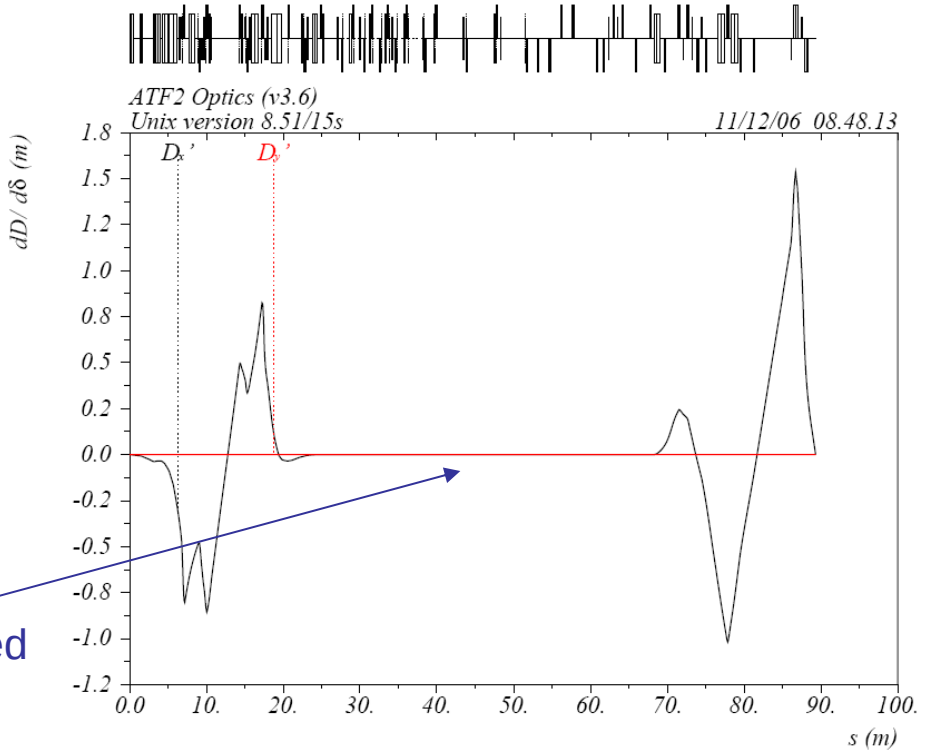


Presented by M.Woodley (SLAC) at 3rd ATF2 project meeting.

Nonlinear Field 2 - Sextupole Magnets for 2nd order Dispersion Correction.

- The 2nd order dispersion can be corrected by using 4 sextupoles.

SF1X K2 = +3.55
SD2X K2 = - 3.15
SD3X K2 = +3.15
SF4X K2 = - 3.72



2nd order dispersion is corrected at the entrance of FF line.

Presented by M.Woodley (SLAC) at 3rd ATF2 project meeting.

However, the strength of sexts are extremely strong, comparable for the sexts in FF.

Both sextupole components affect to the betatron coupling,
depends on the beam position at the magnets.

In order to evaluate the nonlinear effects, SAD simulations were done.

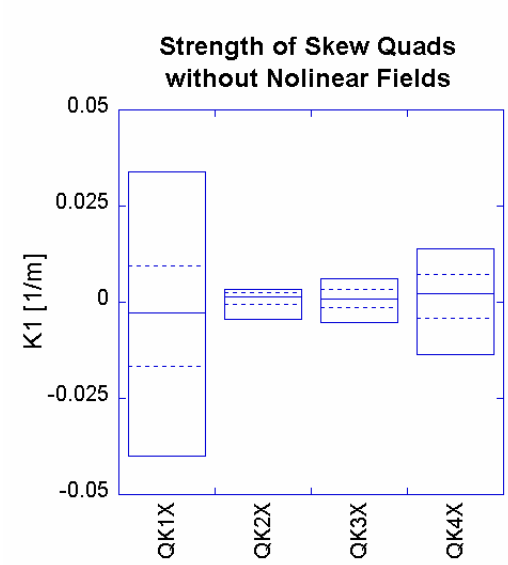
- Put 0.3mrad rotation errors (rms.) for QD*X, QF*X (BT line quads) only.
  (No errors in FF line, No position errors for all magnets.)

- Dispersion correction in extraction line was done by local bump.
  ZH1X ZH2X ZX1X ZX2X for horizontal
  ZV1X ZV2X ZV3X ZV4X for vertical ← It makes 1-2mm vertical offset at bends and sexts.
  We can evaluate the effects of nonlinear field.

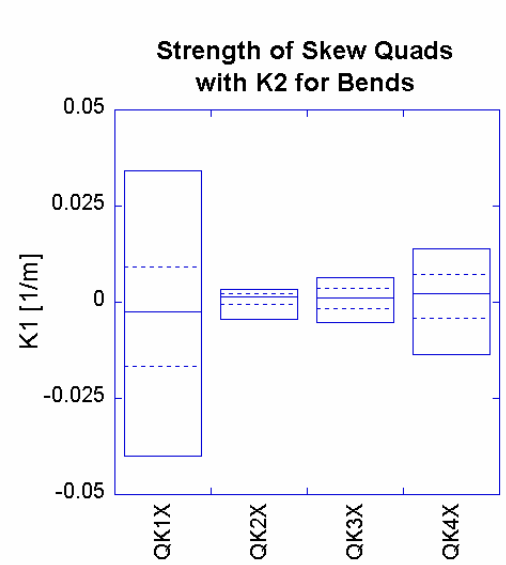
- Coupling correction was done with QK*X (4 skew quads for coupling correction)
  by monitoring wire scanner beam size at diagnostic section.

- Betatron matching was done with QM*X. (matching quads to FF line)

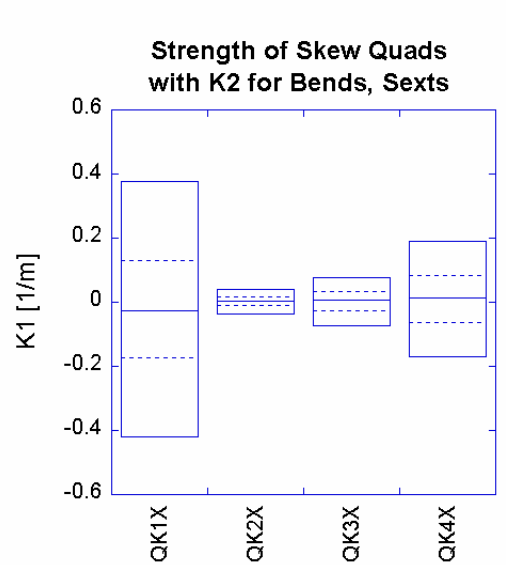
No Nonlinear Field



with Bends K2



with Bends, Sexts K2



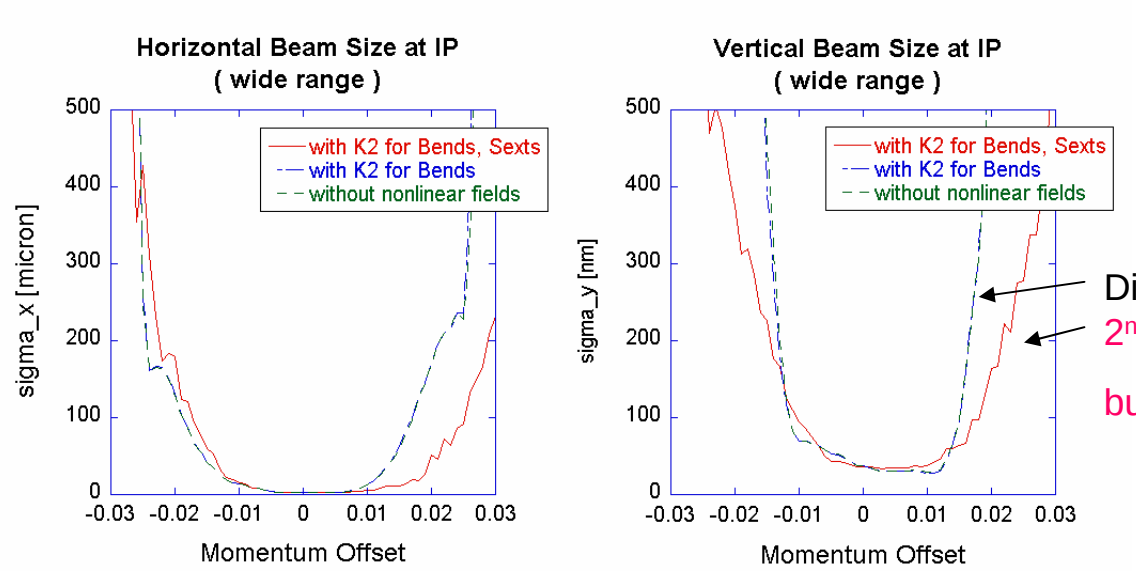
Sextupole components of bending magnets
are no effects for betatron coupling
at 1-2mm beam position offset.

We don't have to take care of the K2 component
of bending magnets.

Sextupole magnets for 2nd order dispersion correction
make the strength of the skew quads
for betatron coupling correction 10 times more strong,
even if we have 1-2mm beam position offset at magnets.

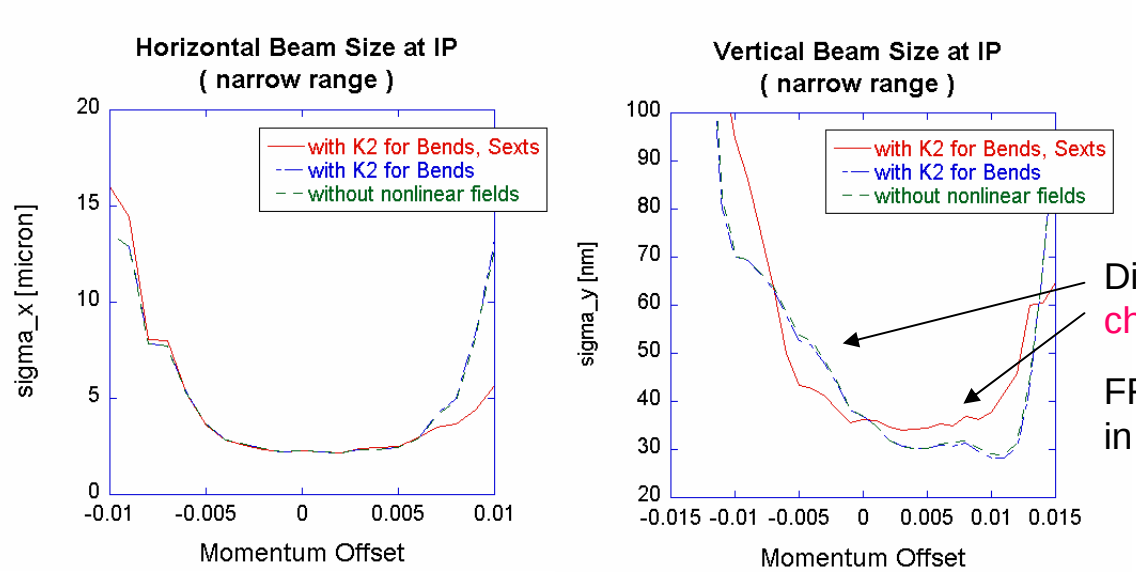
If we put the sextupole magnets in the transport line,
The requirement of beam orbit tuning will be rapidly tight.

Bandwidth of the IP beam size of ATF2



Difference come from that of
2nd order dispersion at extraction line.

but no change within +/-1%.



Difference come from that of
chromaticity at extraction line.

FF line is optimized with Sexts
in extraction line.

Summary

Betatron coupling correction to FF
- with 4 skew quadrupoles, QK1X-QK4X
- required strengths are 0.05-0.40 1/m for 0.3% rotation errors
- the strength of QK1X is stronger than the present ATF skew quads

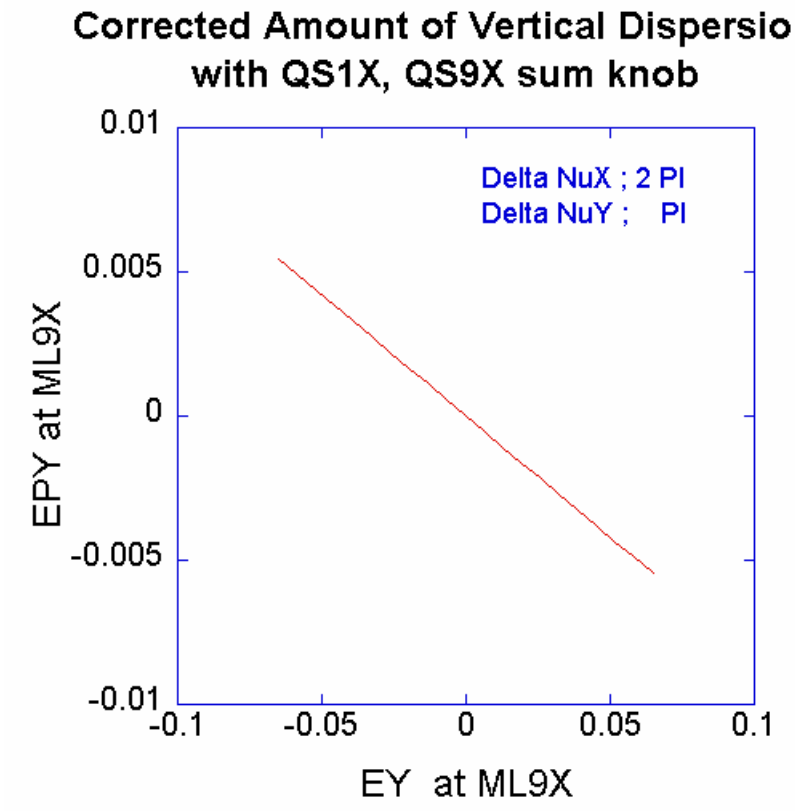
Dispersion correction to FF
< 5mm residual vertical dispersion correction
We can correct local bump.
> 5mm residual vertical dispersion correction
We need to put additional skew quads.
- The skew quads affect no only dispersion, but also betatron coupling.
- We need the evaluation of the requirement of the amount of the correction to determine the strength of skew quads, QSs and QKs.
- We need find appropriate position to put QSs.

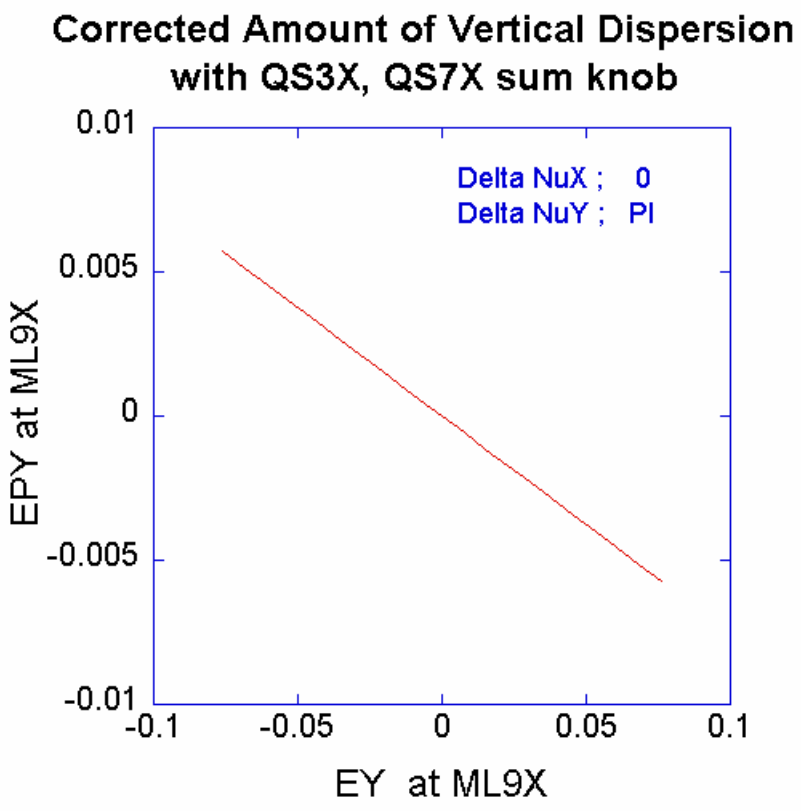
Other nonlinear corrections in beam transport line
1) Sextupole component of bending magnet
No effect both for betatron coupling generation and bandwidth at IP beam size

2) 2nd order dispersion
- We can correct 2nd order dispersion with sextupole magnets.
- The sexts make the beam orbit tuning tolerance too tight.
- Residual 2^{nd} order dispersion is no effect the bandwidth of IP beam size within +/-1%.
- We don't have to take care the 2^{nd} order dispersion at first.

End of presentation

Dispersion Correction with 2 set of “SUM KNOB”s

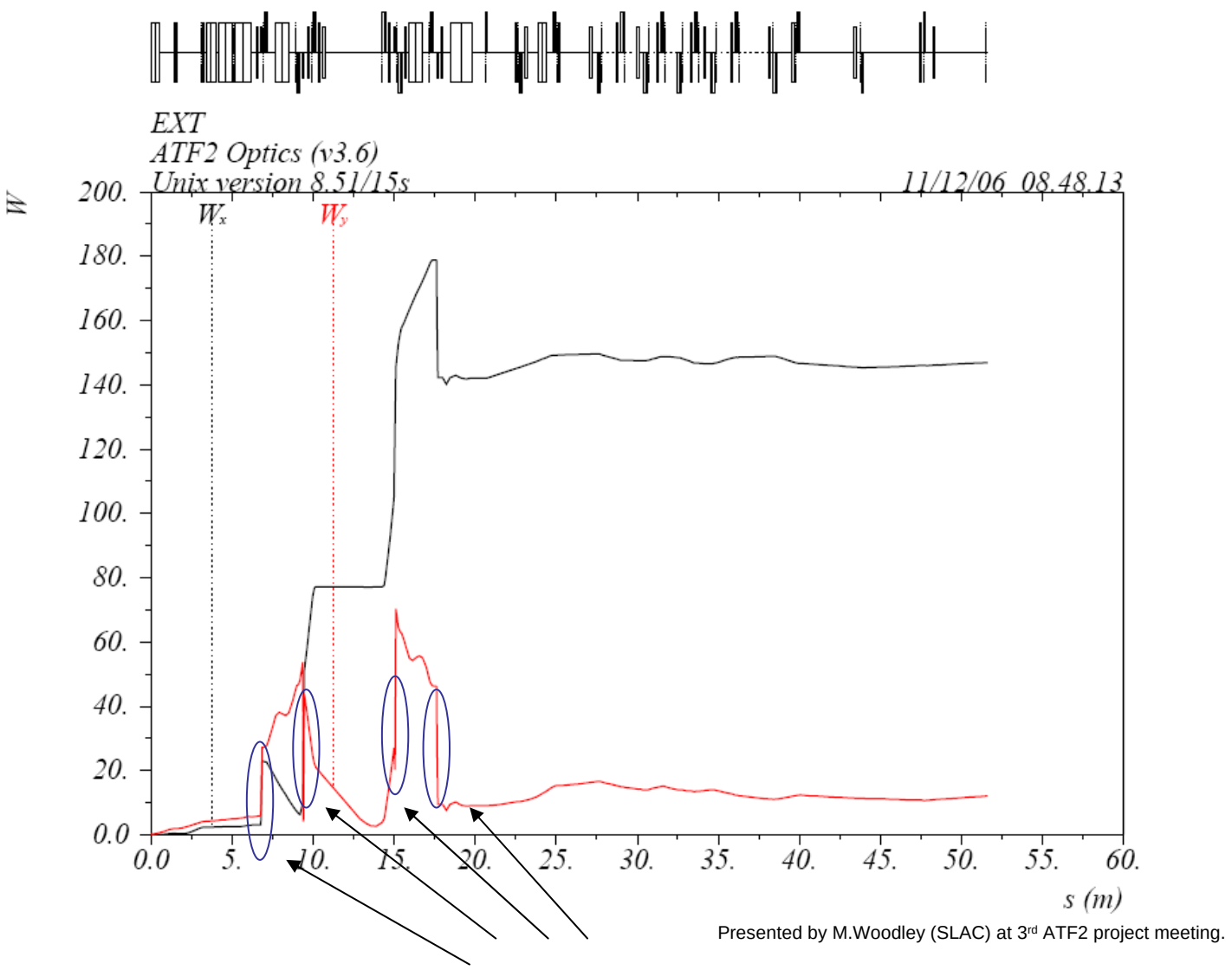




Dispersion Response of each “SUM KNOB” is not independent !

Dispersion correction with 2 set of “SUM KNOB”s is not effective in ATF2 extracion line.

Chromaticity in ATF2 extraction line



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Effect of sextupoles