Tolerances for ATF3 Final Doublet and swapping studies

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Outline

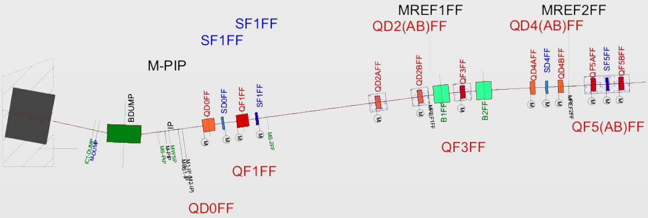
ATF2 lattices

Project	σ_y^* [nm]	β_y^*[mm]	L*[m]	L*/β_y^*	ξ_y
ATF2 Nominal	37	0.1	1.0	10000	19000
ILC	5.7	0.4	3.5	8750	15000
ATF2 Ultra-Low β^*	23	0.025	1.0	40000	76000
CLIC	1	0.068	3.5	51000	63000

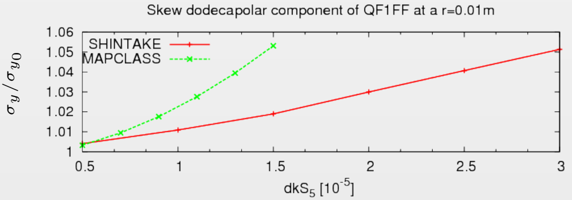
- ATF2 Nominal lattice is the scale-down version of the ILC-Final Focus System lattice.
- ATF2 Ultra-low β^* is a proposal to reduce β_y^* a factor 4 of the Nominal design.

Multipolar errors

- Extraction kickers.
- Bendings.
- Quadrupoles: Sextupolar and octupolar. Until order 9 in the FD.
- Sextupoles: 3rd-9th order.

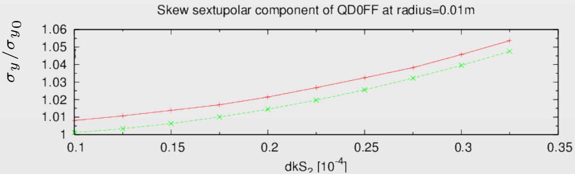


FD multipolar components



QF1 skew dodecapolar comp. at $r = 0.01$m

$$dkrs = 2.3 \cdot 10^{-4}$$



QD0 skew sextupolar comp. at $r = 0.01$m

$$dkrs = 1.76 \cdot 10^{-4}$$

- The measured multipoles of QF1/QD0 are well above the tolerances for the ATF2 Ultra-low lattice.
- For the ATF2 Ultra-low β^* is required to replace the Final Doublet.
- A new final doublet will help to reach smaller beam sizes and to keep $\beta_x = 4$mm.

Final doublet tolerances for the ATF2 Ultra low beta*

- We consider only the UL lattice because is more sensitive to multipolar components.
- The tolerances are evaluated assuming an error-free lattice.
- Each normal and skew components are increased until $2\%\Delta\sigma_y$.
- The most restrictive tolerances from QD0 and QF1 are considered.

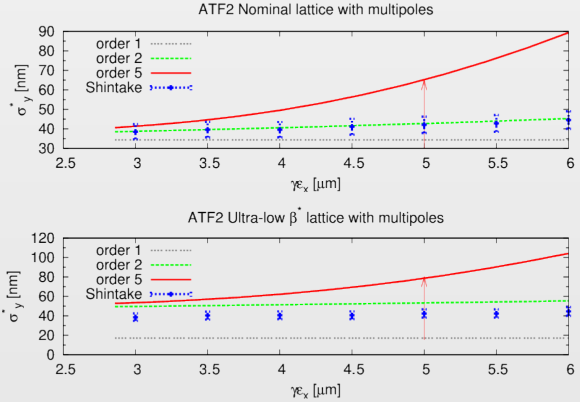
Tolerances for QD0FF and QF1FF at a $r_a = 0.02$m

Multipole	Sextupolar $[10^{-4}]$		Octupolar $[10^{-4}]$	
Component	Normal	Skew	Normal	Skew
QF1/QD0	0.83	0.109	2.61	0.304

Multipole	Decapolar $[10^{-4}]$		Dodecapolar $[10^{-4}]$	
Component	Normal	Skew	Normal	Skew
QF1/QD0	3.04	0.542	8.11	1.28

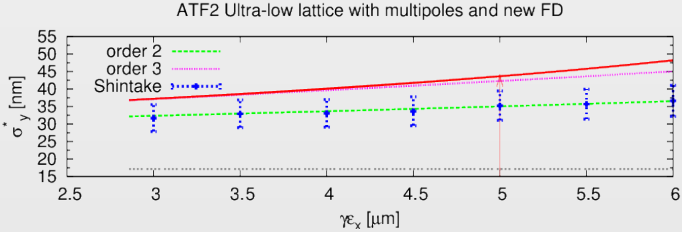
- Skew tolerances are more restrictive than the normal tolerances.
- More relaxed tolerances are found for higher orders.
- We see that the tolerances are tight but not impossible.

Impact of the multipoles in the ATF2 lattices



- It is not possible to achieve very small beams due to the magnet imperfections.
- The effect of the multipoles is notable at order 2 and at order 5.

- For the ATF2 Nominal lattice with the new FD the calculated spot sizes are:
  $\sigma_y^*(RMS)$ =45.5nm $\sigma_y^*(SHI)$ =41.0nm
- For the ATF2 Ultra-low lattice with the new FD:

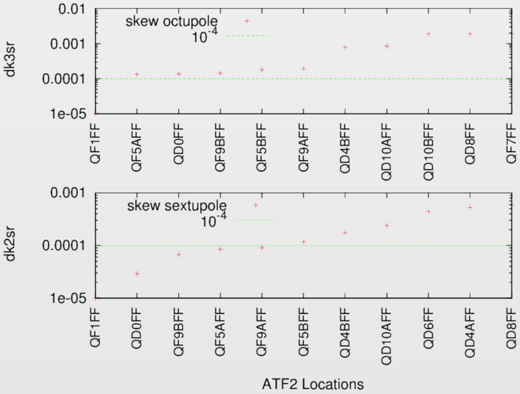


The 2^{nd} (*sextupolar component*)and 3^{rd}(*octupolar component*) orders are the most relevant contributors to the observed $\Delta\sigma_y^*$.

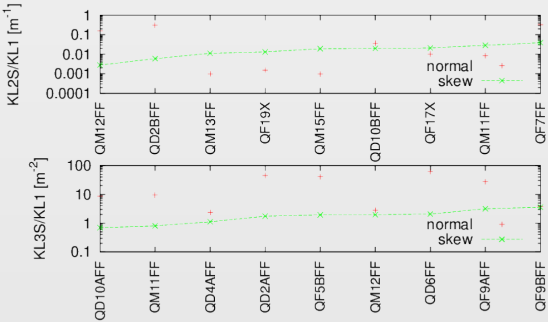
$\Downarrow$

Swapping the quadrupoles

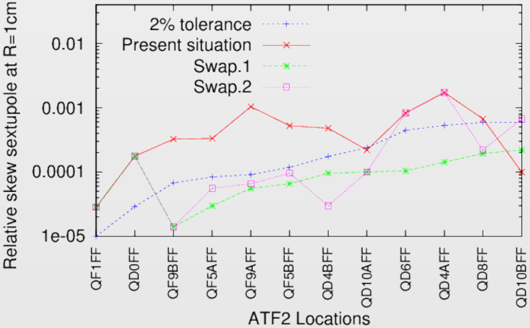
- To spot the most sensitive location to the presence of skew sextupolar and octupolar component



- To sort the quadrupoles according to their skew sextupolar and octupolar component



- The quadrupoles are distributed according only to their skew sextupolar component.

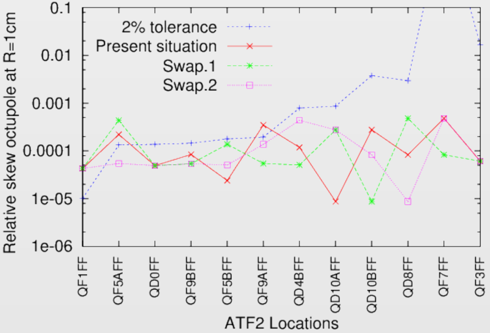


[1]

SWAPPING:
(... replaced by ...)
QF9B ⇔ QM12
QF5A ⇔ QD2B
QF9A ⇔ QM13
QF5B ⇔ QF19X
QD4B ⇔ QM15
QD10A⇔ QD10B
QD6 ⇔ QF17X
QD4A ⇔ QM11
QD8 ⇔ QF7

[1] *Comparable swapping is proposed by S.Bai*

- The quadrupoles are distributed according to their skew sextupolar and skew octupolar component.



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QD6 ⇔ QF17X
QD4A ⇔ QM11
QD8 ⇔ QD10A

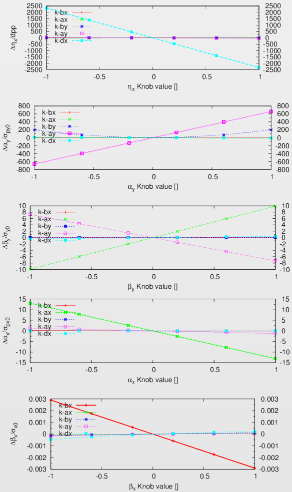
	σ_y^* [nm]		
Lattice	Present	Swap.1	Swap.2
ATF2 Nominal	45	39	41
ATF2 Ultra-low	44	31	35

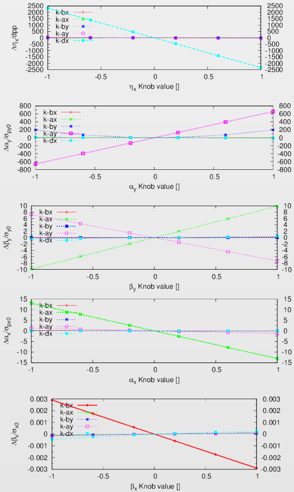
- Swap.1
  - For the ATF2 Nominal lattice σ_y^* is reduced below 40nm.
  - For the ATF2 Ultra-low lattice σ_y^* is notably reduced but not sufficient.
- Swap.2
  - A gain is observed for both lattices but smaller than the obtained by swap.1

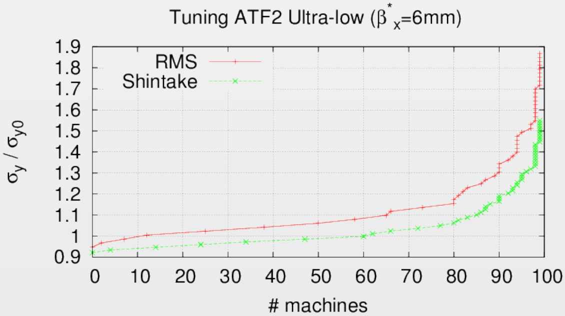
- By relaxing β_x^* the impact of the multipoles is minimised.
- Two different values have been studied: β_x^*=6mm and β_x^*=8mm .

	σ_y^* [nm]	
ATF2 Ultra-low lattice	RMS	SHI
β_x^*=6mm	27.5	25.5
β_x^*=8mm	25.1	24.0

The tuning is based on knobs to modify orthogonally the following aberrations at the IP: $<x,y>$, $<p_x,y>$, $<p_x,p_y>$, η_y, η_{py}, α_x, α_y, η_x







The tuning study for the ATF2 Ultra-low lattice shows that:

ATF2 Ultra-low	% machines with $\sigma_y^*/\sigma_{y0}^* < 20\%$	
	RMS	Shintake
σ_x^*=6mm	65	87 (30 nm)
σ_x^*=8mm	67	84 (29 nm)

- Similar tuning performance is observed for the ATF2 Ultra-low with different β_x^*.

- For the ATF2 Nominal lattice with the new FD and swapping the quadrupoles a σ_y^* below 40m is obtained.
- Replacing the FD, is not sufficient to reach a satisfactory vertical spot size for the ATF2 Ultra-low lattice.
- Swapping the quadrupoles according to their sextupolar component benefits to both lattices.
- For the ATF2 Ultra-low β^* lattice is necessary to swap the quadrupoles and to increase β_x^* up to 6 or 8mm to reach a vertical spot size of 27.5nm and 25.1 respectively.
- The ATF2 Ultra-low tuning studies show an equivalent tuning performance between β_x^*=6mm and 8mm. In terms of the Shintake monitor, 85% of the machines reach a final σ_y^* below $1.2 \cdot \sigma_{y_o}^*$