Multipole components effect

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Accelerator physics issues on
ATF2 Technical Review

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SLAC NATIONAL ACCELERATOR LABORATORY

ATF

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Motivation

ATF2 is meant to demonstrate the feasibility of the FFS based on the local chromaticity correction scheme
To this end, 2 lattices have been designed:

- **ATF2 Nominal lattice**: it is the scale-down version of the ILC FFS
- **ATF2 Ultra-low β^* lattice** †: it is an even challenge β-optics with a chromaticity comparable to that one of CLIC

Ideal Lattice	β_x^*	σ_x^*(rms)	β_y^*	σ_y^*(rms)	L^*	$\xi_y \approx \frac{L^*}{\beta_y^*}$
	[mm]	[μm]	[μm]	[nm]	[m]	[]
ATF2 Nominal	4	3.2	100	37	1.0	≈10000
ILC ($E_{\mathrm{CM}} = 0.5$ TeV)	11	0.474	480	5.9	3.5	≈7300
ATF2 Ultra-low β^*	4	3.2	25	22	1.0	≈40000
CLIC ($E_{\mathrm{CM}} = 3$ TeV)	7	0.04	67	1.1	3.5	≈50000

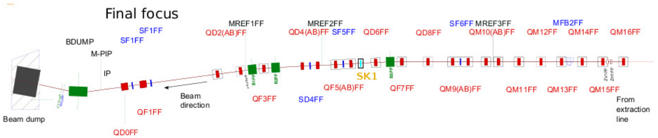
Both ILC & CLIC projects would benefit from experiencing with a higher chromaticity lattice

† **ATF2 Ultra-Low IP Betas Proposal**, Bambade, P. *et al*, CLIC-Note-792 (2009)

MULTIPOLE COMPONENTS OF ATF2 MAGNETS

The FFS of ATF2 is composed of 3 bending, 22 quadrupoles, 5 normal and 4 skew sextupoles magnets

Up to the 18^{th}-pole component of the FFS magnets are included into the model



ATF2 Lattice	β_y^* [μm]	σ_y^* [nm] (Mults OFF)	σ_y^*(rms) [nm] (Mults ON)	σ_y^* (Shi) [nm] (Mults ON)
Nominal	100	37	67	45
Ultra-low β^*	25	22	80 ‡	42

- the 6-pole and 12-pole components of QF1FF are the most important contributors to the evaluated $\Delta\sigma_y^*$ for the ATF2-NL
- in addition, the 6-pole component of QD0FF notably increases σ_y^* for the ATF2-UL

‡R. Tomás, H. Braun, J.P. Delahaye, E. Marín, D. Schulte, F. Zimmermann, "ATF2 Ultra-Low IP Betas Proposal", Proceedings of PAC09, Vancouver, May 2009, pp. 2540-2542

REPLACEMENT OF QF1FF

Replacement of QF1FF

In September 2012 it was proposed to replace the QF1FF magnet by a re-cycled 4Q17 quadrupole from PEP-II

	Unit	4Q17	QF1FF
Bore radius	[mm]	50	25
Iron length	[mm]	430	450
Total width	[mm]	646	450
Total height	[mm]	617	450
Weight	[Kg]	1181	400

Field quality of both quadrupole magnets

@ R=2 cm	Normal relative multipole component $[10^{-5}]$			
	Sextupolar	Octupolar	Decapolar	Dodecapolar
Tolerance[§].	30	12	11	3.1
QF1FF	54	23	100	560
4Q17	-2.3	0.76	-0.12	-1.2
	Skew relative multipole component $[10^{-5}]$			
Tolerance	0.8	2.1	0.6	1.9
QF1FF	2.8	0.9	7.6	6.1
4Q17	0.3	0.9	0.3	-0.1

[§] It represents a $\Delta\sigma_y^* = 2\%$

QF1FF field quality

The 4Q17 magnet was installed in November 2012

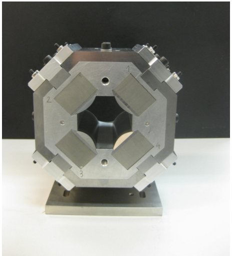
The motion capabilities of the QF1FF mover have been preserved thanks to a clever engineering design from the ATF staff

ATF2 lattices optimization

Obtained σ^* when replacing QF1FF by the 4Q17 quadrupole:

ATF2 Nominal lattice	ATF2 Ultra-low lattice
$\sigma_x^* = 3.2\ \mu$m	$\sigma_x^* = 3.2\ \mu$m
$\sigma_y^* =$ 37 nm	$\sigma_y^* =$ 31 nm

To further reduce σ_y^* of the ATF2 Ultra-low β^* lattice it would be required to replace QD0FF
Cern has designed a quadrupole based in Permanent Magnet technology ¶



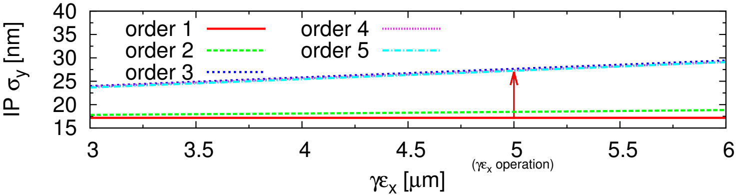
Permanent Material Magnet:
Aperture: 40 mm
Dimensions (h-w-l): 220x220x455 mm
Effective length: 474 mm
Gradient: 6.8 T/m
Tuning: 13%

¶A. Vorozhtsov et al. Design, manufacture and measurements of permanent quadrupole magnets for Linac4, Presented at MT-22, September 2011

ATF2 Ultra-low β^* lattice with PM QD0FF

@ R=2 cm	Normal relative multipole component $[10^{-4}]$			
	Sextupolar	Octupolar	Decapolar	Dodecapolar
Tolerance‖	0.2	2.5	26.3	190
QD0FF	3.7	1.8	5.2	56
PM	0.8	2.5	3.2	8.0
	Skew relative multipole component $[10^{-4}]$			
Tolerance	0.3	3.8	32.0	230
QD0FF	3.5	1.1	2.56	3.5
PM	0.1	0.3	0.5	1.3

Assuming the multipole components of the new PM QD0FF design:



ATF2 Ultra-low lattice with 4Q17 (QF1FF) and PM (QD0FF):

$\sigma_x^* = 3.2\ \mu m$ $\sigma_y^* = 26$ nm

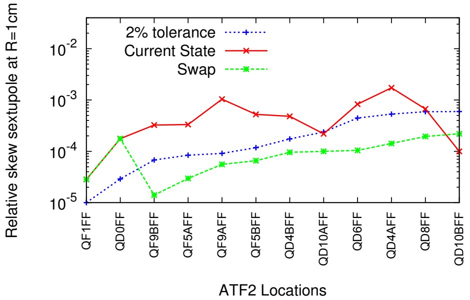
‖It represents a $\Delta\sigma_y^* = 2\%$

ATF2 Technical review

It has been investigated the benefits of swapping the quadrupoles according to their skew sextupole component **

QF9BFF replaced by QM12FF
QF5AFF replaced by QD2BFF
QF9AFF replaced by QM13FF
QF5BFF replaced by QF19X
QD4BFF replaced by QM15FF

QD10AFF replaced by QD10BFF
QD6FF replaced by QF17X
QD4AFF replaced by QM11FF
QD8FF replaced by QF7FF



ATF2 Ultra-low lattice with 4Q17 (QF1FF) and PM (QD0FF) and swap:

$\sigma_x^* = 3.2\ \mu m$ $\sigma_y^* = 26$ nm

** E. Marin et al, *Status of the ATF2 lattices*, IPAC-2011-TUPC016, San Sebastian

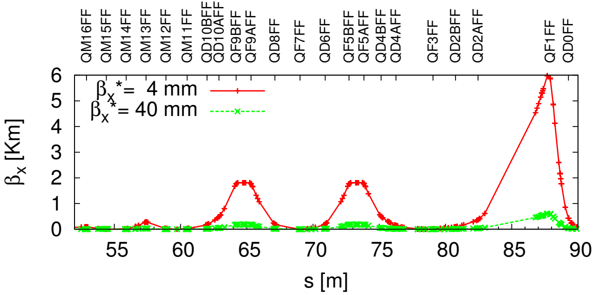
MODIFYING THE OPTICS

Increasing β_x^*

Alternatively the impact of the multipole components can be reduced by increasing the β_x^*

Additional benefits:

- bring down the background level
- reduction of tuning difficulties



The obtained σ_y^* when increasing β_x^* a factor 10, are:

ATF2 10Bx1.0By lattice[††]	ATF2 10Bx0.25By lattice
$\sigma_y^* = 36$ nm	$\sigma_y^* = 23$ nm

[††] This lattice was used during the last ATF2 run in December 2012

FD Tolernaces for ILC and CLIC

Comparison between the relative multipolar components of QF1 for ILC and CLIC
The tolerance is obtained by increasing the amount of the multipole until a $\Delta(\sigma_x^* \sigma_y^*)$=1% is observed

WARNING: using rms beam size!

@ R=3 mm	Normal relative multipole component $[10^{-5}]$			
	Sextupolar	Octupolar	Decapolar	Dodecapolar
ILC	7	3	12	7
CLIC	1	1	2	1
@ R=3 mm	Skew relative multipole component $[10^{-5}]$			
ILC	0.7	0.8	1	1.4
CLIC	0.15	0.15	0.2	0.2

Extremely tight skew tolerances are obtained for CLIC (10^{-6}!)

CONCLUSIONS AND FUTURE WORK

Conclusions and Future work

- Replacing the QF1FF magnet represents a step forward for the ATF2 Nominal lattice
- Additionally replacing the QD0FF magnet is necessary to reach a σ_y^*=27nm in terms of the ATF2 Ultra-low β^* lattice
- No significant beam size reduction is observed when swapping the quadrupole magnets according to their skew sextupole component
- Alternatively by increasing β_x^* a factor 10 leads to a satisfactory design of both ATF2 lattices
- The obtained tolerances of the QF1 multipole content required by the LC represent a challenge in terms of magnet design

Follow up:

- Calculate the multipole components tolerances of the FD for the LC using the luminosity as the criteria instead of the rms beam size