Use of octupoles to achieve lowest beam sizes in ATF2

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Outline

Local Chromaticity Correction

ATF2 was meant to demonstrate FFS based on the local chromaticity correction[a].

Project	Status	Energy [GeV]	$\gamma\epsilon_y$ [nm]	σ_y^* [nm]	β_y^* [mm]	L* [m]	ξ_y
FFTB	Designed	46.6	2000	52	0.1	0.4	4000
FFTB	Measured	46.6	2000	70	-	0.4	-
ATF2 Nominal	Designed	1.3	30	37	0.1	1.0	10000
ATF2 $10\beta_x 1\beta_y$	Measured	1.3	30	65	0.1	1.0	10000
ILC	Designed	250	35	5.9	0.48	3.5	7500
ATF2 Ultra-low β^*	Proposed	1.3	30	23	0.025	1.0	40000
CLIC L*= 3.5 m	Designed	1500	20	1	0.069	3.5	50000

More details on ATF2: *"ATF2 status and plans" presented by Dr. Kiyoshi KUBO.*

[a] *G. White et al. Phys. Rev. Lett. vol 112 - 014801 (2013)*

Impact of Multipoles

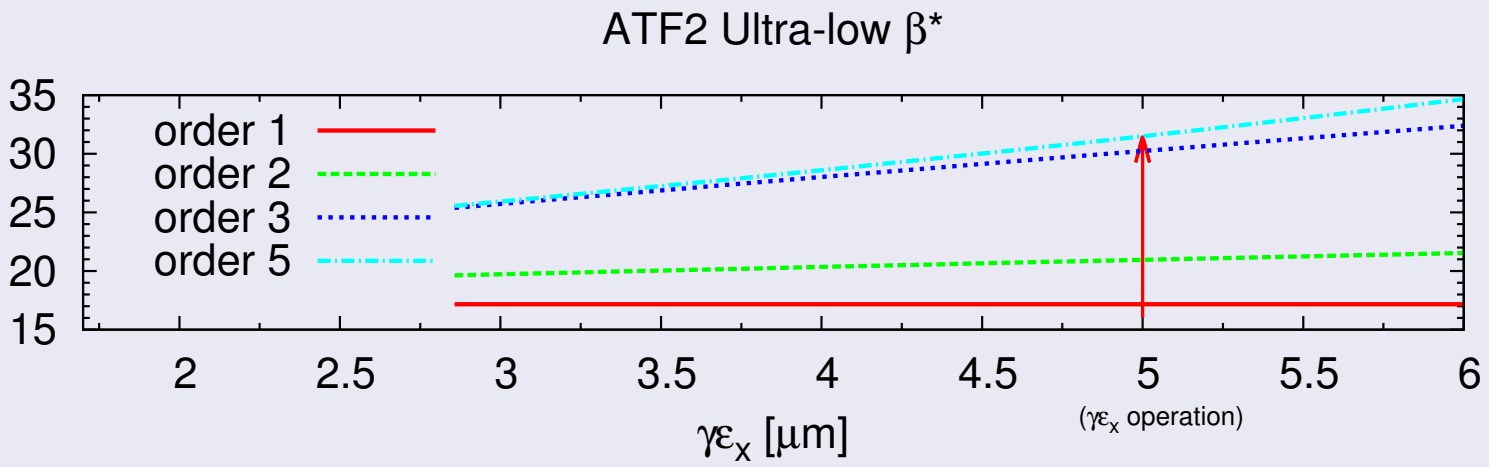
Presently ATF2 is running with a modified optics in order to:

- lower the backgrounds at the IP
- minimise the potential impact of the magnetic errors

Project	Magnetic Errors	β_x^* [mm]	σ_x^* [μm]	β_y^* [μm]	σ_y^* [nm]
ATF2 Nominal	OFF	4	3.2	100	37
ATF2 Nominal	ON	4	3.2	100	38
ATF2 $10\beta_x^* 1\beta_y^*$	ON	40	9.0	100	37
ATF2 Ultra-low β^*	OFF	4	3.2	25	23
ATF2 Ultra-low β^*	ON	4	3.2	25	31
ATF2 $10\beta_x^*$ $\frac{1}{4}\beta_y^*$	ON	40	9.0	25	22

Beam size growth

The MAPCLASS analysis reveals which order is the most responsible of the evaluated $\Delta\sigma_y^*$.



If $\delta p/p$=0 $\rightarrow$ σ_y^*=19.5 nm

Chromatic Skew Octupole Aberration

SOLUTIONS

QD0 Field quality

Relative tolerances at R = 0.01 cm for the multipole content of QD0FF. Each tolerance represents a $\Delta\sigma_y^*$=2%.

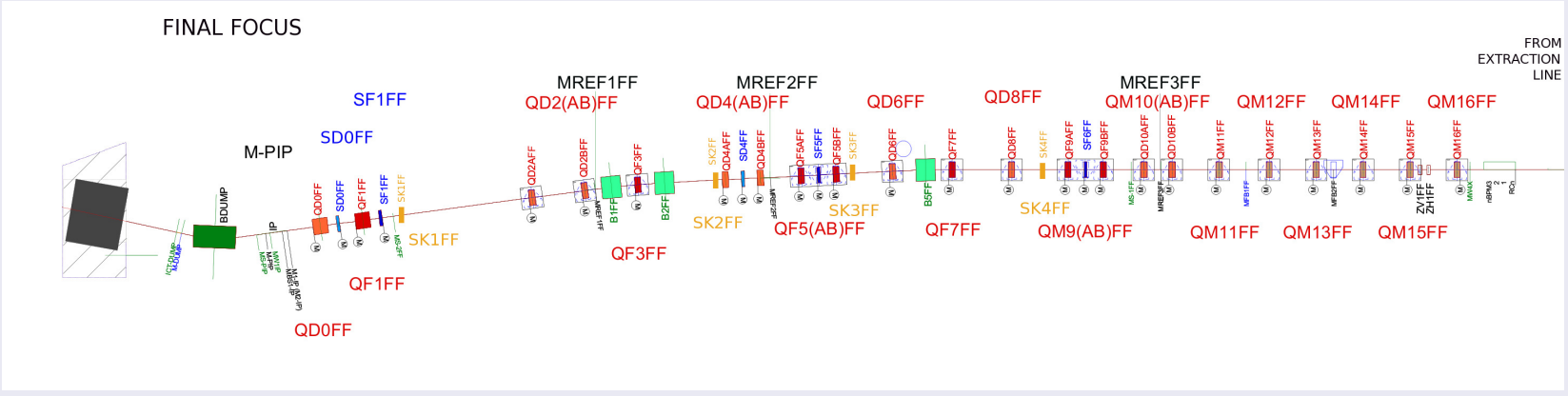
QD0FF		Normal [10−4]			
		6-pole	8-pole	10-pole	12-pole
	Tol.	0.2	1.8	3.1	15.0
	Meas.	1.8	0.4	2.9	3.5
	PM	-1.8	-0.3	-0.5	1.2
		Skew [10−4]			
QD0FF		4-pole	6-pole	10-pole	12-pole
	Tol.	0.2	0.8	0.6	9.0
	Meas.	1.8	0.3	0.3	0.2
	PM	0.2	0.1	-0.1	-0.2

The obtained IP spot sizes are:

σ_x^* = **3.3 μm** σ_y^* = **27 nm**

Octupoles Insertion

We have inserted 2 octupoles of 10 cm (magnetic length) separated by a phase advanced of π.



Option A:

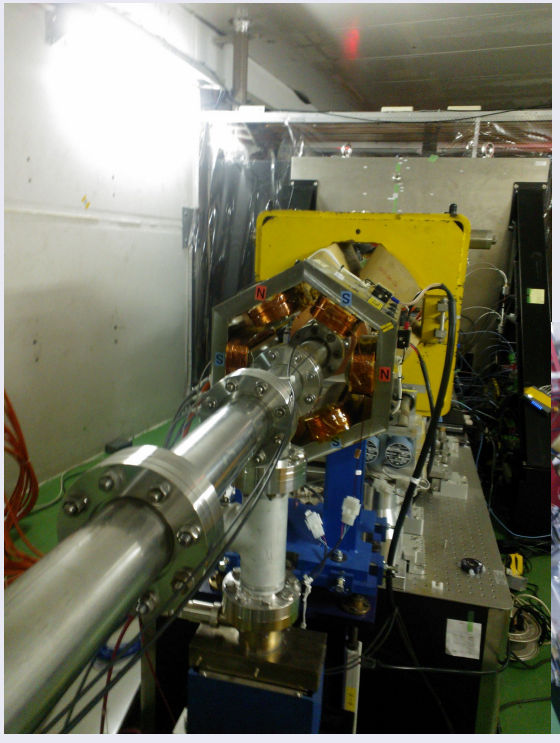
OCT2FF located in between of QD4BFF and QD4AFF (0.4 m).
OCT1FF located in between of SD0FF and QD0FF (0.3 m)

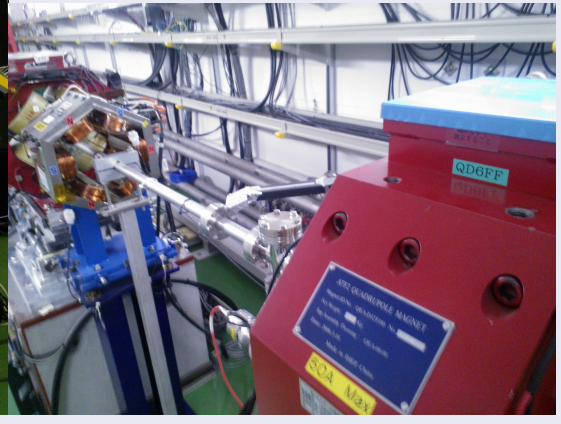
Option B:

OCT2FF located in between of QD6FF and SK3FF (1.0 m).
OCT1FF located right before SK1FF (3.8 m).

ATF2 FFS Beam line

Upstream of SK1FF Downstream of QD6FF





High Order Multipoles Optimisation

The Simplex algorithm has been used for optimisation of

- Octupole magnets
- Octupole Tilts
- Normal sextupole magnets
- Skew sextupole magnets

Obtained Integrated strength for the OCTs:

Option-A: $KL_{(OCT1FF)}$ = 1238 m^{-3} $KL_{(OCT2FF)}$ = -359 m^{-3}
$Tilt_{(OCT1FF)}$ = -1.6 deg $Tilt_{(OCT2FF)}$ = -0.9 deg

Option-B: $KL_{(OCT1FF)}$ = 1526 m^{-3} $KL_{(OCT2FF)}$ = -567 m^{-3}
$Tilt_{(OCT1FF)}$ = -2.0 deg $Tilt_{(OCT2FF)}$ = -1.5 deg

The obtained IP spot sizes are:

Option-A: σ_x^* **= 3.3** μ**m** σ_y^* **= 22 nm**

Option-B: σ_x^* **= 3.4** μ**m** σ_y^* **= 22 nm**

Octupole Field Quality (Option-A)

Relative tolerances at R = 0.02 cm for the multipole content of the octupole magnets. Each tolerance represents a $\Delta\sigma_y^*$=2%.

OCT1FF	Normal [10−0]			
	4-pole 0.001	6-pole 0.013	10-pole 0.4	12-pole 1.7
OCT1FF	Skew [10−0]			
	4-pole 0.001	6-pole 0.007	10-pole 0.2	12-pole 0.7
OCT2FF	Normal [10−0]			
	4-pole 0.002	6-pole 0.01	10-pole 1.5	12-pole 2.4
OCT2FF	Skew [10−0]			
	4-pole 0.0006	6-pole 0.008	10-pole 0.9	12-pole 4.8

10-pole and 12-pole tolerances do not represent a difficulty from a magnet design perspective[a].

[a] see Talk by M. Modena, *Magnet Studies (CLIC, ILC QD0 and BDS, ATF2)*

Tuning Study (Option-A)

Error Conditions

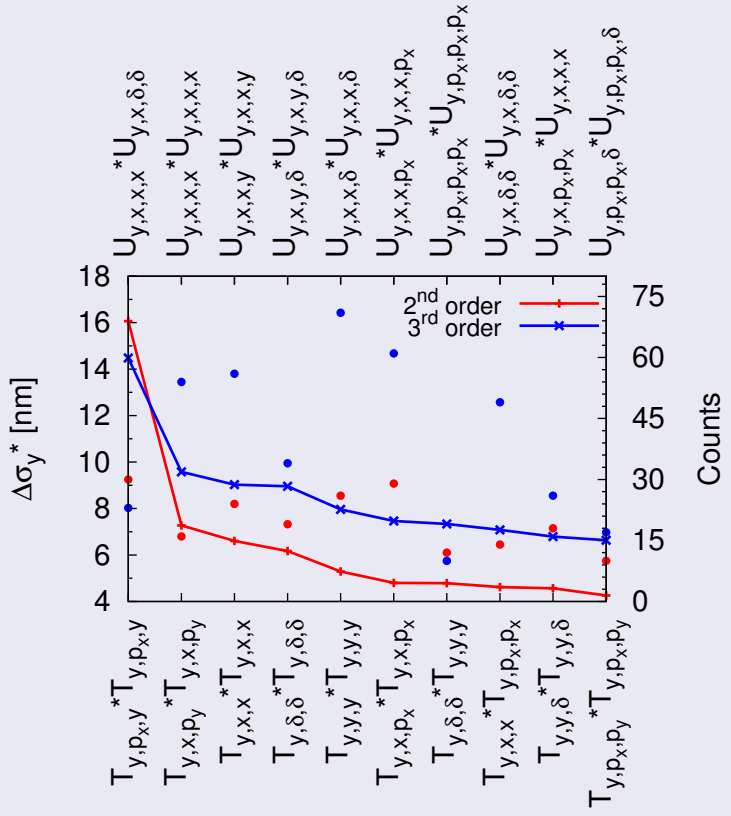
The tuning study considers 100 machines with different initial error conditions.
Errors are randomly assigned following a Gaussian distribution.

Error	Unit	σ_{error}
Horizontal misalignment	[μm]	100
Vertical misalignment	[μm]	100
Tilt along *s*-coordinate	[μm]	300
Strength	[%]	0.1
IP measurement	[%]	10
Magnetic errors		ON

Tuning Results II

Knobs

Linear knobs that target $\alpha^*_{x,y}$, $\eta^*_{x,y}$ and $< u_{x,p_x}, u_{y,p_y} >^*$.
Only 33% of machines reach a $\sigma^*_y \leq 1.2\sigma^*_{y,0}$.
Residual IP aberrations:



T-knobs:

$T_{y,p_x,y}$, T_{y,x,p_y},
$T_{y,\delta,\delta}$, $T_{y,x,x}$

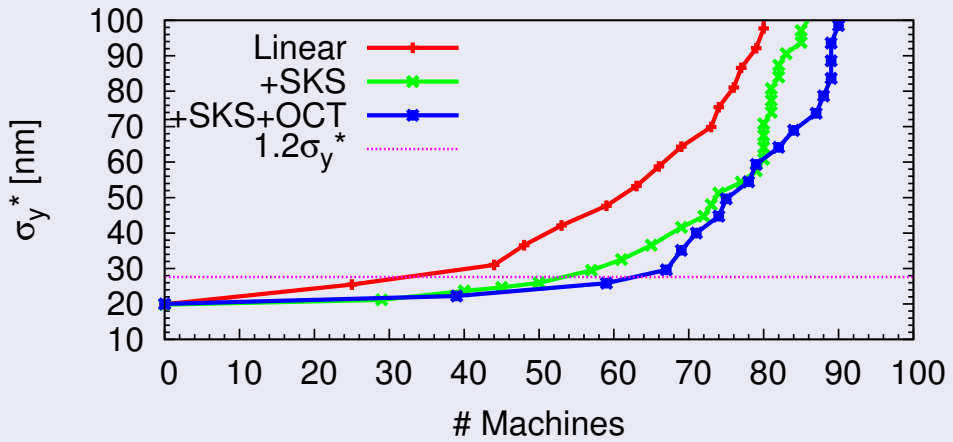
U-knobs:

$U_{y,x,x,x}$, $U_{y,x,\delta,\delta}$.

Tuning Results II

High Order Knobs

Taking advantage of the skew sextupole and octupole magnets new knobs are obtained.



Linear knobs: 33% of machines reach a $\sigma_y^* \leq 1.2\sigma_{y,0}^*$.
Linear + *T-knobs: 54% of machines reach a* $\sigma_y^* \leq 1.2\sigma_{y,0}^*$.
Linear + T+U-knobs: 63% of machines reach a $\sigma_y^* \leq 1.2\sigma_{y,0}^*$. [a]

[a] more details: *TUPBA25, Proceedings of PAC2013, Pasadena, (USA)*

Summary and Outlook

Summary

- The insertion of 2 octupole magnets permits the exploration of higher chromaticity lattices at ATF2.
- Preliminary designs of the octupoles meet the requirements from an optics perspective.
- Better tuning results are obtained implementing the octupole magnets.

Outlook

- Make a proposal to insert 2 octupole magnets during the 17^{th} ATF2 Project meeting (next week).

Thank you for your attention!!