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Collecting amplitude detuning measurements from 2012

Rogelio Tomás, Javier Barranco, Xavier Buffat, Ewen H. Maclean, and Simon White

Keywords: optics, AC dipole, amplitude detuning, non-linear optics

Summary

This note collects the amplitude detuning measurements during 2012 with model extrapolations to the main operational configurations.

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Contents

IR 1		IR 5	
MAD var.	k_4 [m^{-4}]		
KCOX3.L1	0.835788		
KCOX3.R1	-1.049153		
MAD var.	k_3 [m^{-3}]	MAD var.	k_3 [m^{-3}]
KCSX3.L1	-0.000618	KCSX3.L5	-0.000157
KCSX3.R1	0.000464	KCSX3.R5	0.000481
KCSSX3.L1	0.009267	KCSSX3.L5	-0.002082
KCSSX3.R1	0.007192	KCSSX3.R5	-0.004514

Table 1: Interaction region correctors used during the measurement at β^*=0.6 m.

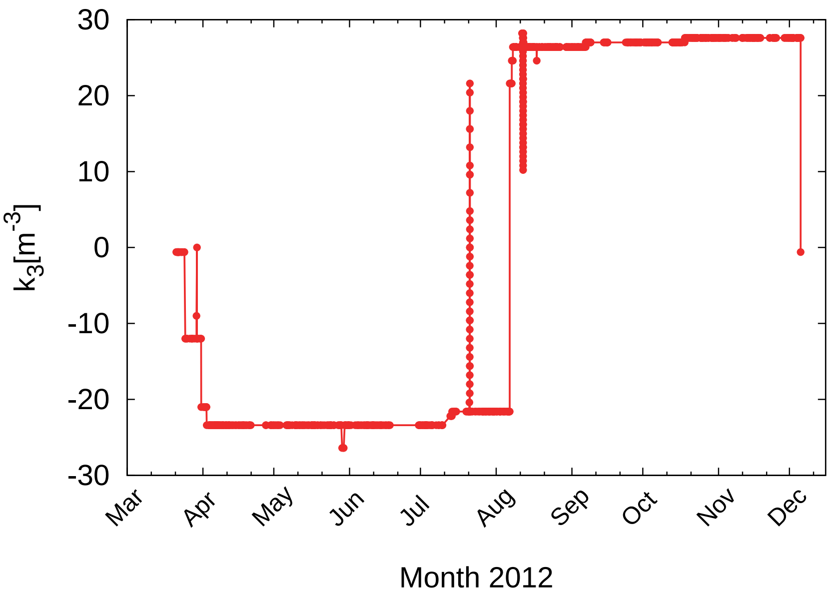

Figure 1: Octupole settings (MO) at the end of the squeeze during 2012.

1 Experiment conditions and results

Amplitude detuning measurements were carried out at injection on June 24, 2012 [1], at β^*=0.6 m on October 12 [2] and at flat-top (β^*=11 m) on November 27 [3] during dedicated MD sessions.

The following arc octupolar corrector circuits were not operational during 2012: KCO.a12B2, KCO.a78B2, KCO.a81B2 and KCO.a12B1. Arc skew sextupoles were not used in 2012, with the exception of a dedicated MD [4].

The measurements at injection were performed with nominal operational settings while at top energy the Landau octupoles were depowered. At β^*=0.6 m the amplitude detuning measurement was performed with Landau octupoles also set to zero but after powering the triplet correctors as shown in Table 1.

The Landau octupole settings changed during the year both in sign and absolute value. Figure 1 shows the Landau octupole settings at the end of the squeeze along 2012. Table 2 shows what is used in this report as *nominal* settings of the Landau octupoles for the two halves of 2012.

At injection single kicks were applied to excite betatron motion, which provides direct access to the amplitude detuning terms. However at 4 TeV the only way to perform this measurement is forcing betatron oscillations adiabatically with the AC dipole to be able to reuse the beam. The

	Before August k_3 [m^{-3}]	After August k_3 [m^{-3}]
Injection	-3	3
Flat-top	-23.4	26.4
β^* =0.6m	-23.4	26.4

Table 2: Most used octupole settings (MO) for the two halves of 2012. The two LHC beams had the same powering. To roughly compute the corresponding current setting in Amps the k_3 provided in the table should be multiplied by -2.16 at injection and -19.3 at 4 TeV.

		Beam 1		Beam 2		
	k_3 [m^{-3}]	$\partial Q_x/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_y/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_x/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_y/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_y/\partial 2J_y$ [10^3m^{-1}]
Injection	-3	-	-	-29±7	21±4	-32.8±0.4
Flat-top	0	-0.1±0.2	0.5±0.7	1±1	3±1	-
β^* =0.6m	0*	-	-	9±1	-17±4	-

Table 3: Measured amplitude detuning coefficients ($\partial Q_{x,y}/\partial 2J_{x,y}$) for both LHC beams together with the corresponding octupolar setting (k_3) during the measurement. The direct terms $\partial Q_x/\partial 2J_x$ and $\partial Q_y/\partial 2J_y$ at 4 TeV have been corrected with the factor 1/2 expected from the AC dipole. *For the squeeze case (β^* =0.6m) triplet octupolar correctors were powered as shown in Table 1.

observed amplitude detuning via forced oscillations has to be corrected as described in [2].

Table 3 shows the existing measurements of the amplitude detuning terms (cross and direct) with the appropriate correction factors. The corresponding model predictions are shown in Table 4. The largest discrepancies are observed at the end of the squeeze, followed by injection, probably suggesting that triplet non-linear errors are not well understood.

2 Model extrapolations to nominal settings

Tables 5 and 6 show the extrapolations to the operational settings shown in Table 2 by adding or removing the differential effects of the Landau octupoles and the IR correctors used in the measurements at β^* =0.6 m, Table 1.

		Beam 1		Beam 2		
	k_3 [m^{-3}]	$\partial Q_x/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_y/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_x/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_y/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_y/\partial 2J_y$ [10^3m^{-1}]
Injection	-3	-	-	-27	21	-30.5
Flat-top	0	1.4	-1.0	2.6	-1.8	-0.1
β^* =0.6m	0*	-	-	23	-5.5	-

Table 4: Model amplitude detuning corresponding to the configuration of the measurements shown on Table 3.

	Beam 1		Beam 2		
	$\partial Q_x/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_y/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_x/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_y/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_y/\partial 2J_y$ [10^3m^{-1}]
Injection	-	-	-29±7	21±4	-32.8±0.4
Flat-top	-192±0.2	141±0.7	-191±1	144±1	-
β^* =0.6m	-	-	-173±1	128±4	

Table 5: Best estimate of amplitude detuning during normal operation using both measurements and model predictions corresponding to the octupole settings before August 2012.

	Beam 1		Beam 2		
	$\partial Q_x/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_y/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_x/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_y/\partial 2J_x$ [10^3m^{-1}]	$\partial Q_y/\partial 2J_y$ [10^3m^{-1}]
Injection	-	-	14±7	-4.6±4	13.5±0.4
Flat-top	216±0.2	-159±0.7	217±1	-156±1	-
β^* =0.6m	-	-	235±1	-155±4	

Table 6: Best estimate of amplitude detuning during normal operation using both measurements and model predictions corresponding to the octupole settings after August 2012.

3 Injection corrections and higher orders

The experimental settings to cancel second order chromaticity and amplitude detuning at injection are shown in Table 7. In this note we have restricted to first order amplitude detuning terms. Second order amplitude detuning was measurable only at injection [1]. Figure 2 shows the considerable impact that the second order amplitude detuning has specially for the setting after August 2012.

References

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[4] T. Persson, Y. Levinsen, R. Tomás, E. Maclean, "Chromatic coupling correction in the Large Hadron Collider", Phys. Rev. ST Accel. Beams **16**, 081003, September 2013.
http://journals.aps.org/prstab/abstract/10.1103/PhysRevSTAB.16.081003

circuit	I_{meas}[A]	circuit	I_{meas}[A]
RCO A12	0	RCD A12	-85.41
RCO A23	4.692	RCD A23	-100.43
RCO A34	4.692	RCD A34	-94.14
RCO A45	4.692	RCD A45	-88.05
RCO A56	10.693	RCD A56	-75.60
RCO A67	10.693	RCD A67	-100.22
RCO A78	0	RCD A78	-149.85
RCO A81	-	RCD A81	-110.88

Table 7: Beam 2 measured currents in the octupolar and decapolar spool pieces MCO and MCD correcting for the second and third order chromaticities.

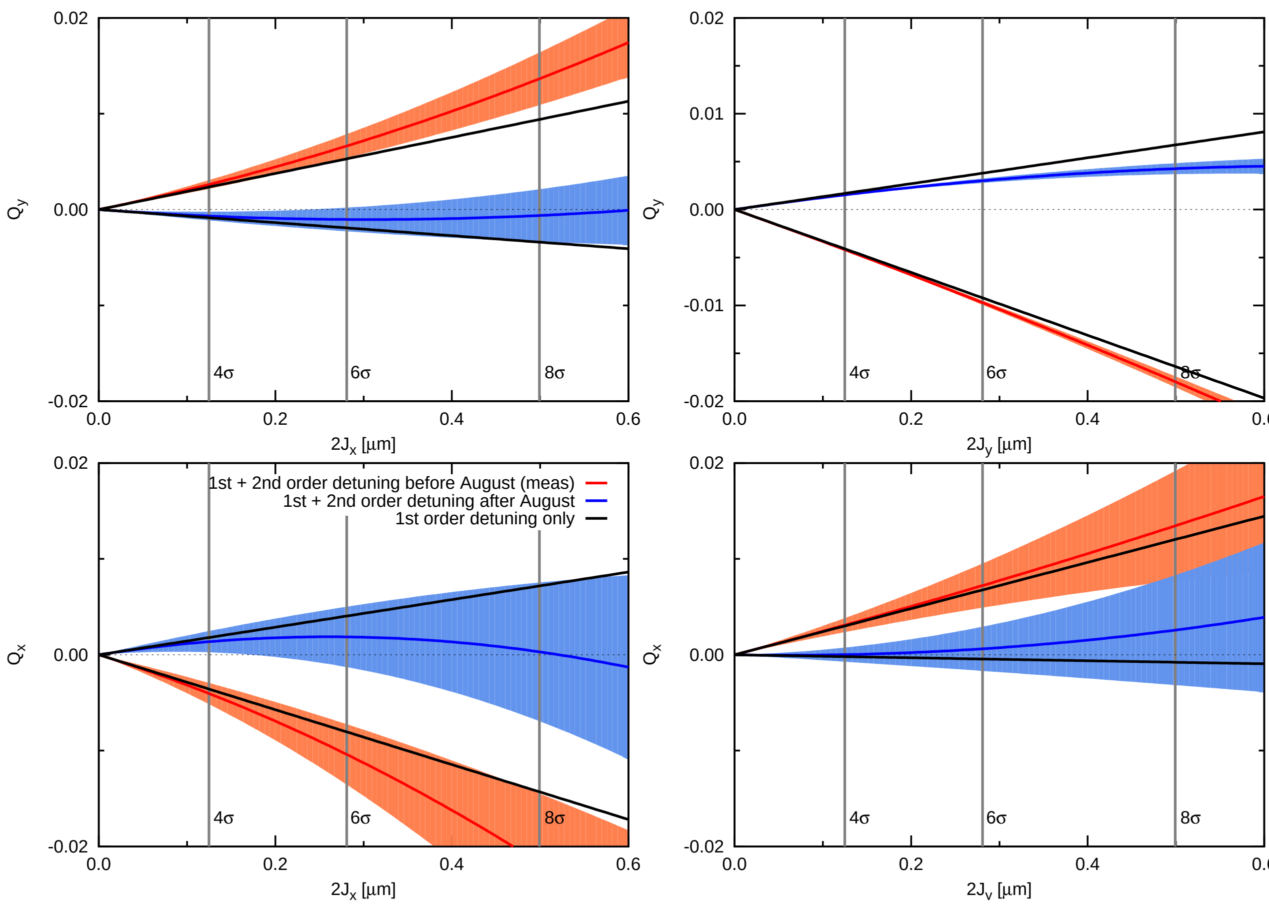

Figure 2: Beam 2 amplitude detuning at injection including higher order terms with measured uncertainties and an extrapolation for the configuration after August 2012.