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LHC injection optics measurements at commissioning (2015)

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Summary

This report describes the measurement and correction process followed during the 2015 LHC injection optics commissioning which extended into Machine Developments (MDs). Results have been analyzed and compared to the 2012 measurements.

Contents

1 Introduction

Optics measurements and corrections at injection energy were part of the 2015 LHC commissioning and the MDs of the LHC. These measurements were performed over several shifts during commissioning: 08/04/15, 09/04/15, 10/04/15, 23/04/15 and during the second MD block the 28/08/15.

The main objective of these studies is to correct the LHC optics. The data being recorded consist of vertical and horizontal beam position as a function of the number of turns. The maximum number of turns in the AC-dipole plateau has been upgraded from 2200 (2012) to 6600 (2015) and, furthermore, BPMs can now acquire up to approximately 50000 turns. During these measurements three experimental kickers were used: the tune kicker (MKQ), aperture kicker (MKA) and AC-dipole.

2 Results

2.1 First optics measurements

During the first attempts to measure the optics, on 08/04/2015, more than 50% of the BPMs were faulty. Figure 1 shows an example of bad turn-by-turn (TbT) data in both horizontal and vertical planes. Moreover, the beam intensity was not high enough and the AC-dipole amplitude had to be increased during the measurements causing some beam losses (especially in Beam 1) and limiting the resolution of optics measurements.

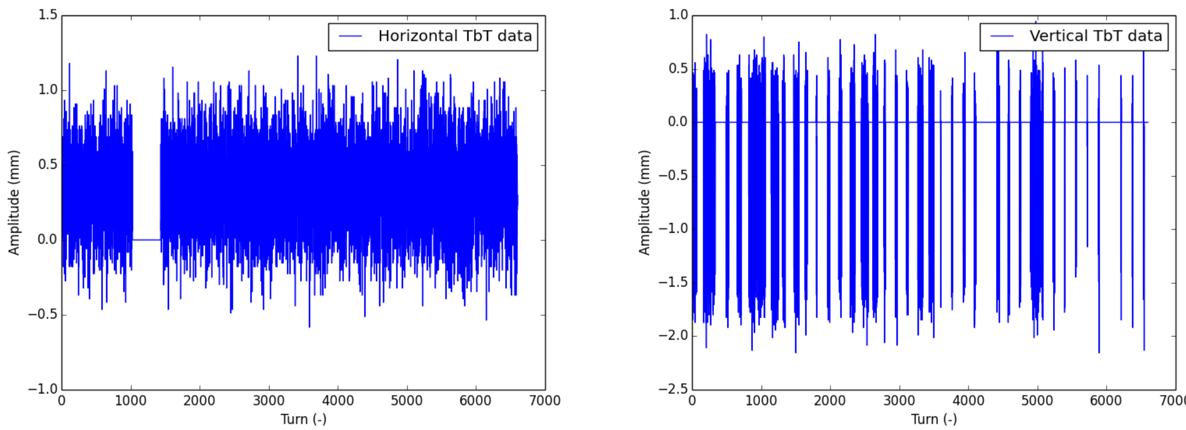

Figure 1: Bad TbT data acquired horizontal at the beginning of the commissioning

The problems with BPM acquisition combined with the poor beta-beating and coupling resolution, did not allow us to calculate either the beta-beating or the coupling corrections.

2.2 Second beta-beating measurements

A second set of measurements were performed on 09/04/2015. The fill number was 3607 and the beam process was RAMP-6.5TeV-2015_V1@0_[START] with the crossing angles and separations set to zero.

During the second day of measurements issues were observed when exciting the beam with the AC-dipole. The vertical TbT data amplitude suddenly increased at turn= 4500 as can be observed in Figure 2. When analyzing the data using the FFT (Fast Fourier transformation) unexpected shifts on the vertical natural tunes were observed.

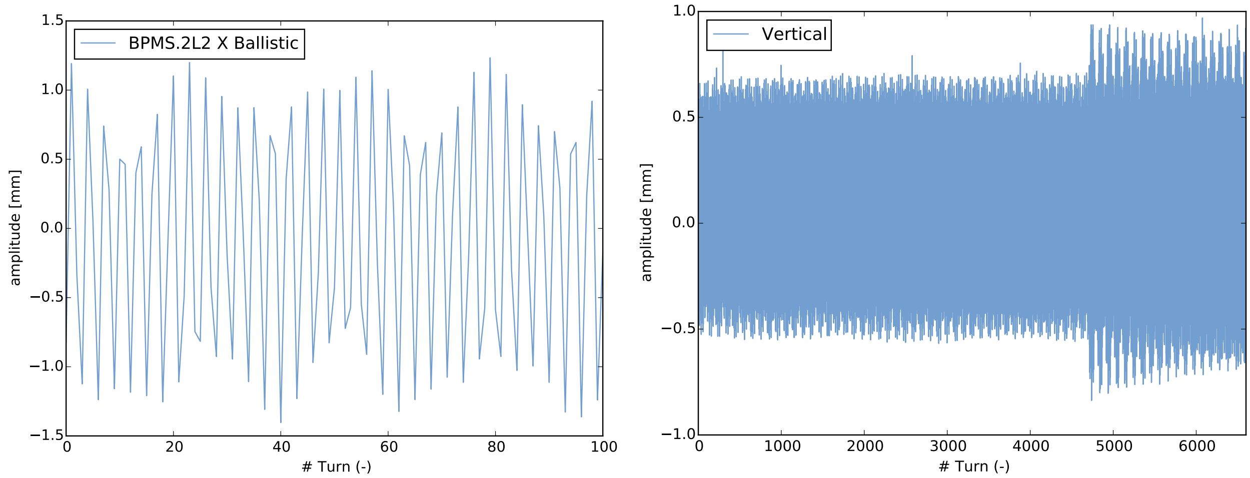

Figure 2: Bad TbT data acquired

The presence of those jumps was related to a bad electrical connection that probably was leading to an irregular ramp during the AC-dipole cycle that can be observed in Figure 3 [1] [2].

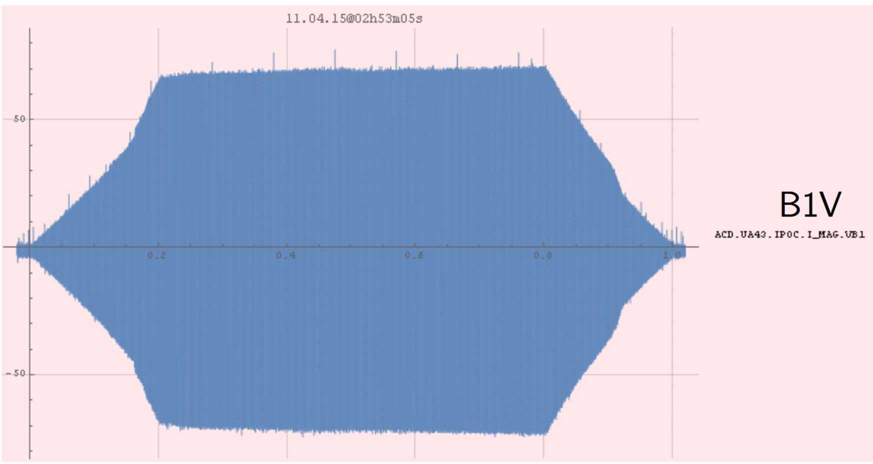

Figure 3: AC-dipole waveform showing deviations from ideal shape

Some TbT data recorded by several BPMs were presenting amplitude spikes (values larger than 20 mm). The BPMs that were recording bad TbT data were rejected for the analysis. Two main conclusions were drawn: on one hand, the number of BPMs with spikes increased linearly with the number of turns (so, the problem was not related to the increase in the maximum number of turns that are being acquired) and, on the other hand, it seemed to be random which BPMs were affected for a certain measurement. Finally, after some studies, this problem was identified as an incompatibility between the TbT mode and the average orbit acquisition.

2.3 Local coupling corrections

Local coupling corrections were performed on 09/04/2015. These corrections were applied in the interaction regions 1, 2, 5 and 8 in three iterations. In the last iteration the tunes were moved to the collision values in order to enlarge the coupling signal.

The skew quadrupole strength (k) set in 2012 and 2015 are compared in Table 1

		2012	2015
IR 1	kqsx3.r1 [10^{-4} m^{-2}]	8	8
	kqsx3.l1 [10^{-4} m^{-2}]	8	8
IR 2	kqsx3.r2 [$10^{-4}m^{-2}$]	-9	-16
	kqsx3.l2 [10^{-4} m^{-2}]	-9	-16
IR 5	kqsx3.r5 [10^{-4} m^{-2}]	6	7
	kqsx3.l5 [10^{-4} m^{-2}]	6	7
IR 8	kqsx3.r8 [10^{-4} m^{-2}]	-7	-5
	kqsx3.l8 [10^{-4} m^{-2}]	-7	-5

Table 1: Skew quadrupole strengths: 2012 vs 2015

A comparison of the coupling after local corrections were applied at injection tunes and at collision tunes can be observed in Figures 4 and in 5

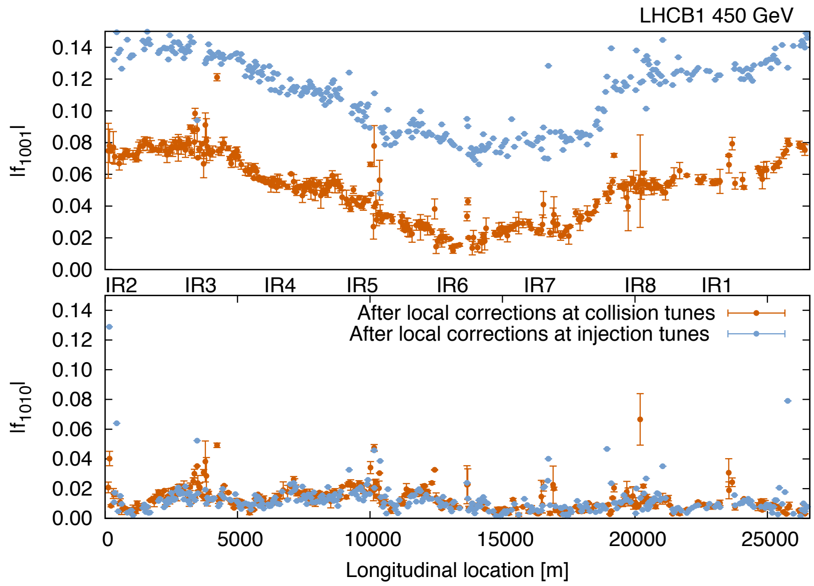

Figure 4: Coupling for Beam 1 (09/04/2015).

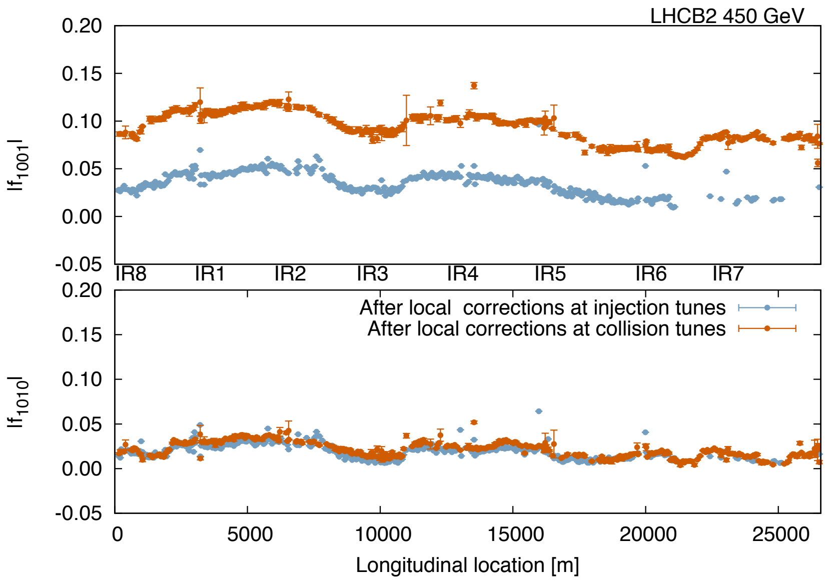

Figure 5: Coupling for Beam 2 (09/04/2015).

2.4 Global optics corrections

The goals of this session (09/04/2015) were to analyze the beta-beating measurements (both phase and amplitude) using the AC-dipole and to apply global corrections. Several correction knobs were applied at the same time for beam 2. Those corrections were created one by one in order to reduce the large beta-beating. The corrections are stored at "/afs/cern.ch/eng/sl/lintrack/LHC_commissioning2015/EXP_15-04-10_commissioning_inj_3" . The global corrections used were:

- Global_Corre_Beam1_inj_2015_v2
- Global_Corre_Beam2_inj_2015
- Global_Corre_Beam2_inj_2015_it2
- Global_Corre_Beam2_inj_2015_it3

A comparison of the the corrections that have been applied to the MQMs, MQTs and MQYs during the commissioning in 2012 and 2015 can be observed in Figures 6 and 7 .

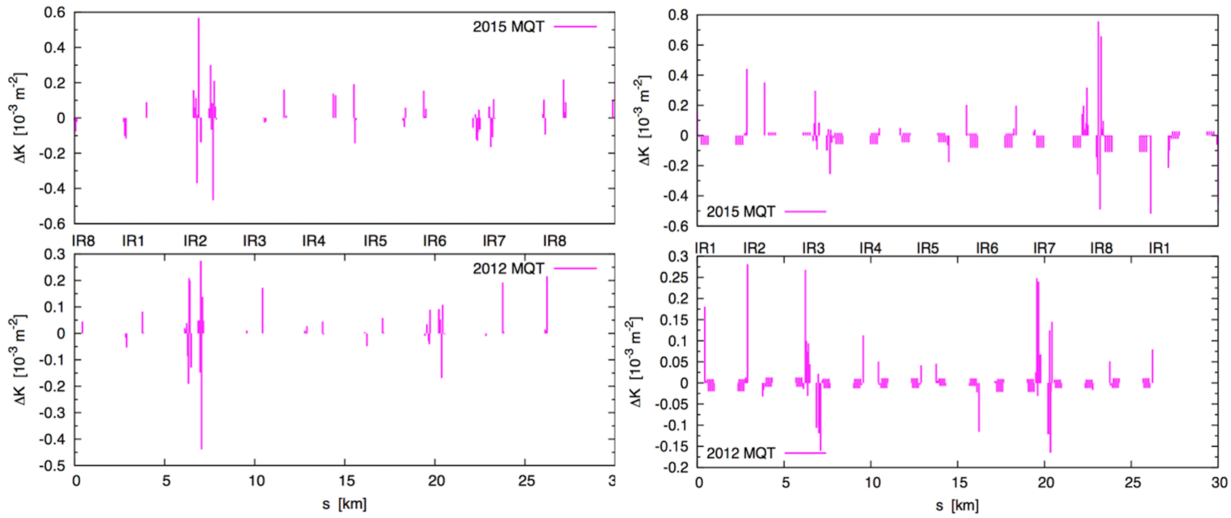

Figure 6: Corrections applied to the MQTs in 2012 and 2015 (Beam 1 left and Beam 2 right).

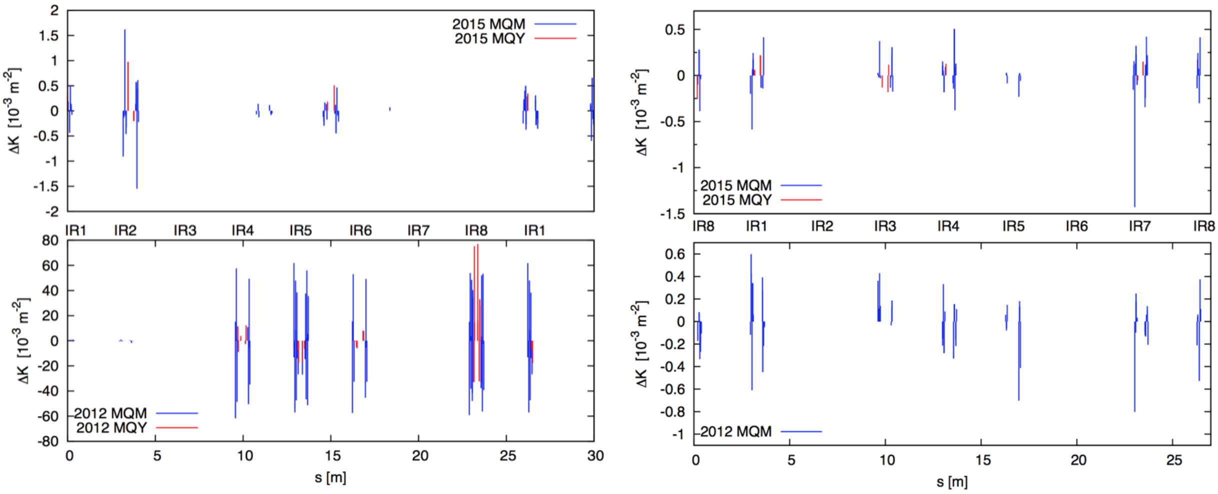

Figure 7: Corrections applied to the MQMs and MQYs in 2012 and 2015 (Beam 1 left and Beam 2 right).

Figures 8 and 9 show a comparison between measurements before and after corrections, Figure 10 and Figures 11 show a comparison between data from 2015 and data from 2012 before the corrections were applied. Finally, comparisons between data from 2015 and 2012 with corrections applied are shown in Figures 12 and 13.

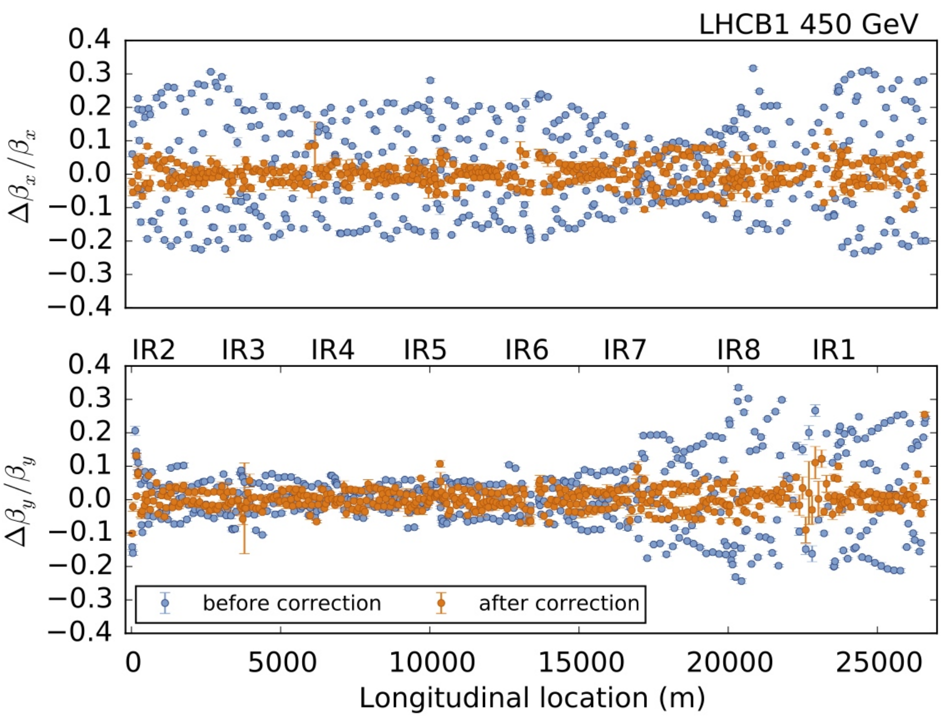

Figure 8: Beta-beating before and after corrections were applied (2015 Beam 1)

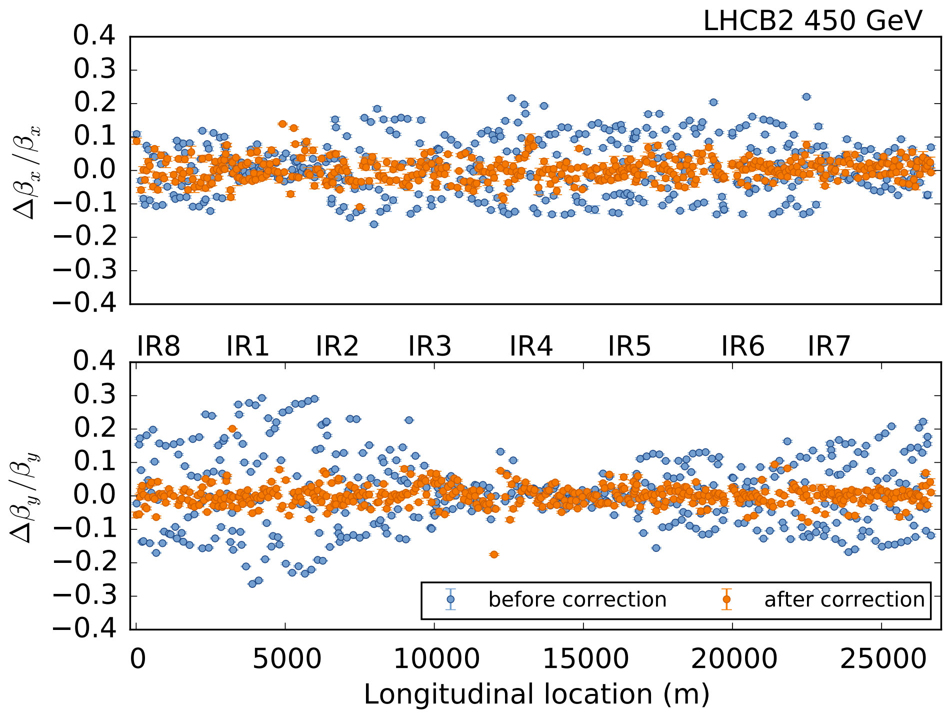

Figure 9: Beta-beating before and after corrections were applied (2015 Beam 2)

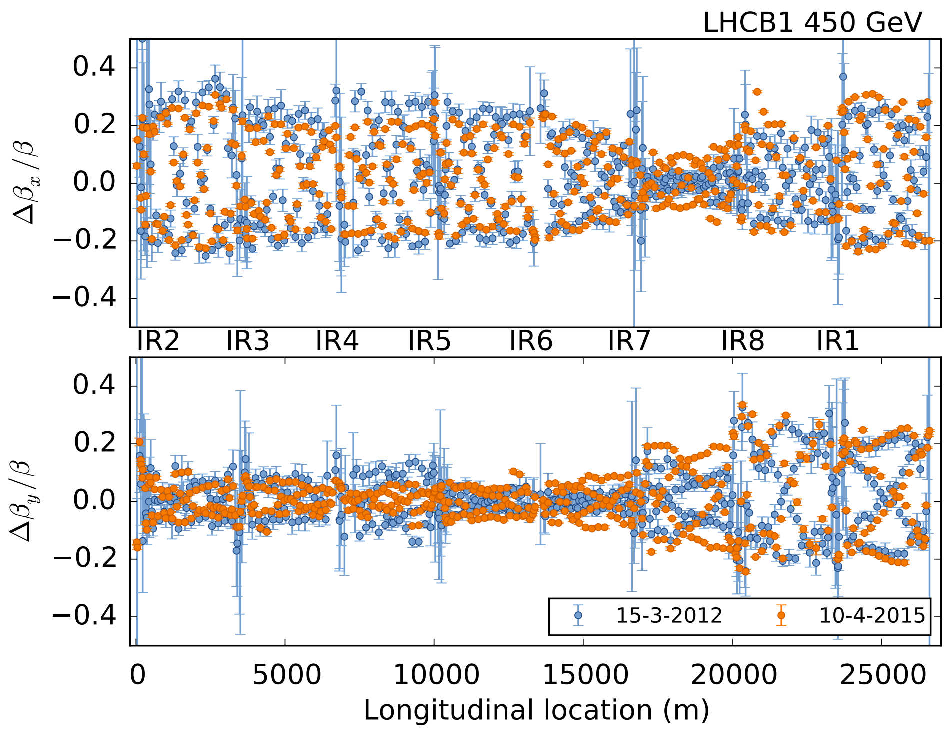

Figure 10: Beta-beating from 2012 and 2015 before corrections were applied (Beam 1)

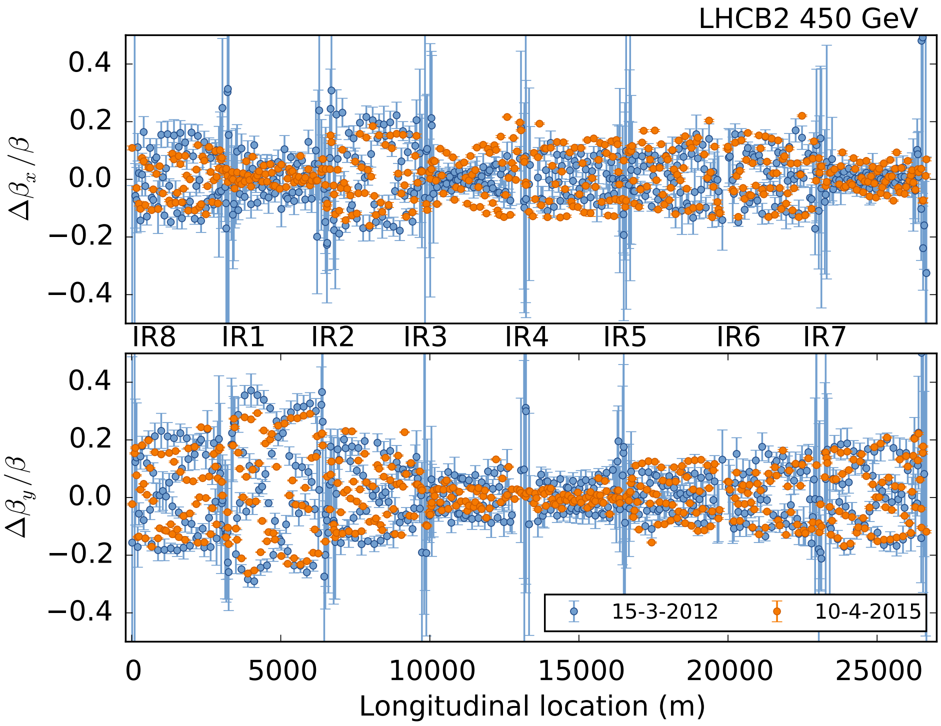

Figure 11: Beta-beating from 2012 and 2015 before corrections were applied (Beam 2)

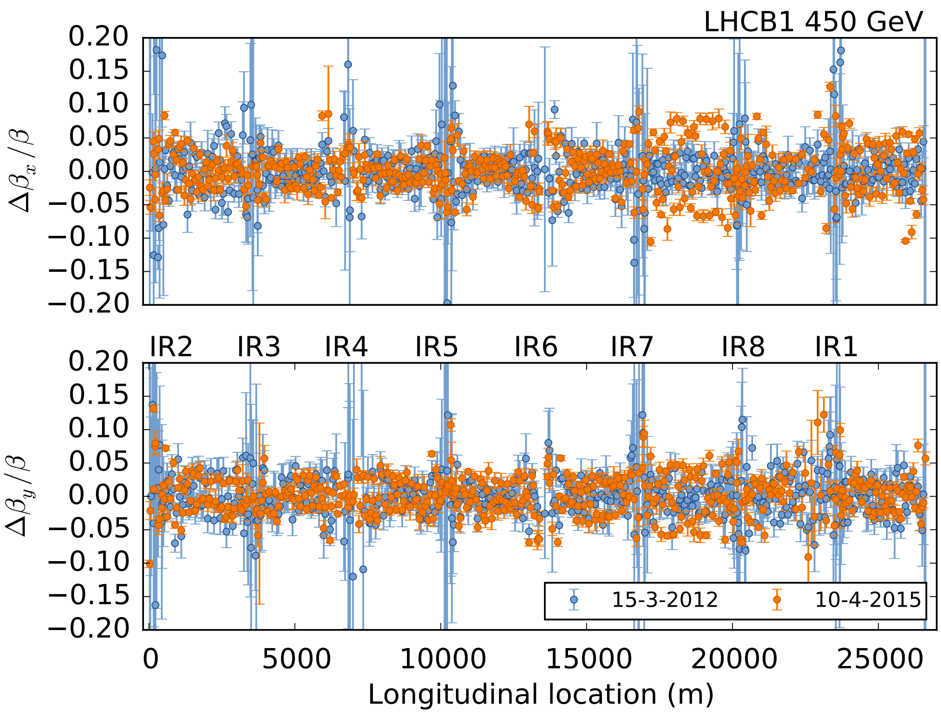

Figure 12: Beta-beating from 2012 and 2015 after corrections were applied (Beam 1)

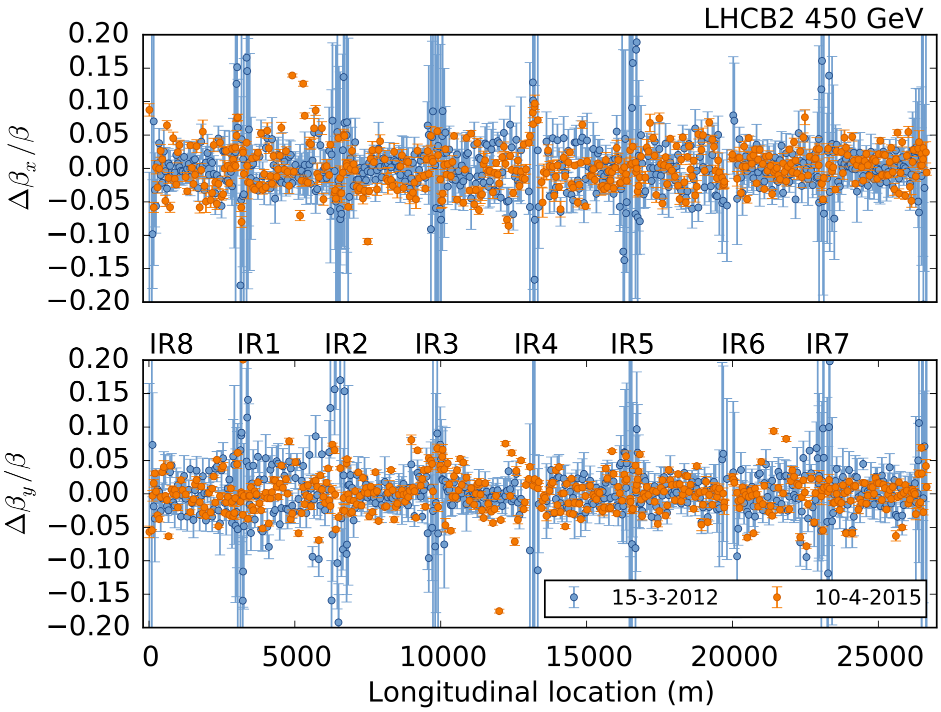

Figure 13: Beta-beating from 2012 and 2015 after corrections were applied (Beam 2)

The phase method used during this commissioning was an improved version of the three BPM phase-advance method [3] (used during the 2012 commissioning). The new method N-BPM is a more sophisticated algorithm that takes into account both the statistical and systematic errors involved in this measurement [4]. This makes it possible to combine more beam position monitor measurements for deriving the optical parameters and demonstrates to significantly improve the accuracy and precision.

2.5 Beta-beating measurements during MD750

During the second block of the machine development (MD750) [5] some optics measurements were made. The goals of this MD were to analyze the response of the new BPMs (DOROS) and also to review the optics at injection. The β-beating measurements for both beams are shown in Figures 14 and 15.

2.6 Dispersion

Figures 16 and 17 show the normalized dispersion measured during the commissioning and the MD respectively. As it can be seen in Figure 18 the normalized dispersion of Beam 1 was not measured during the commissioning. The dispersion measured during the MD shows large uncertainties values for Beam 2. The large values of the error bars was caused by a movement on the IR8 triplets.

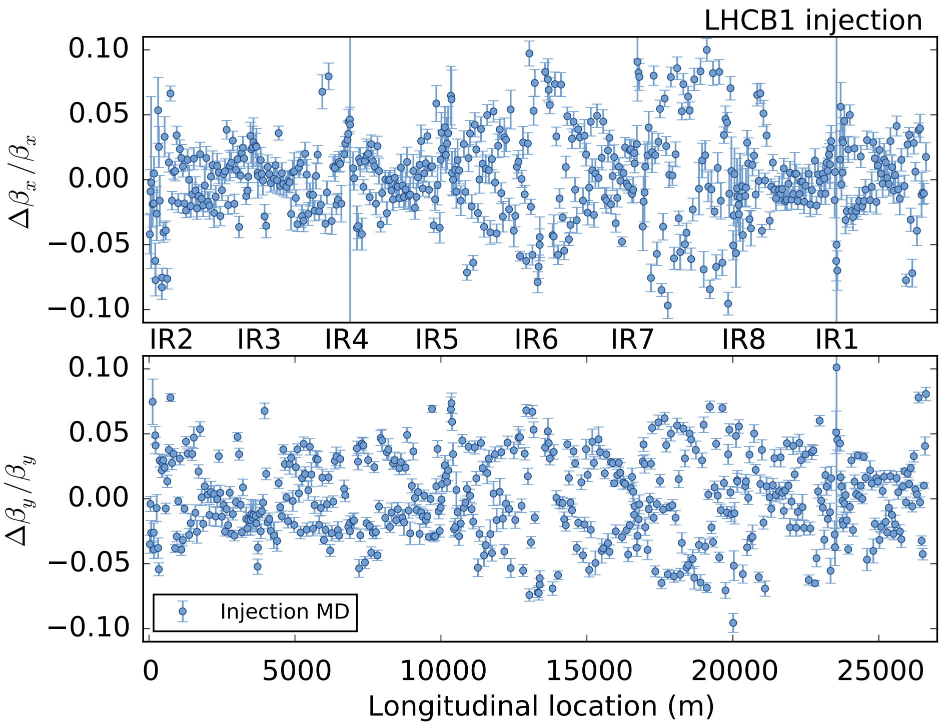

Figure 14: Beta-beating from 2015 MD (Beam 1)

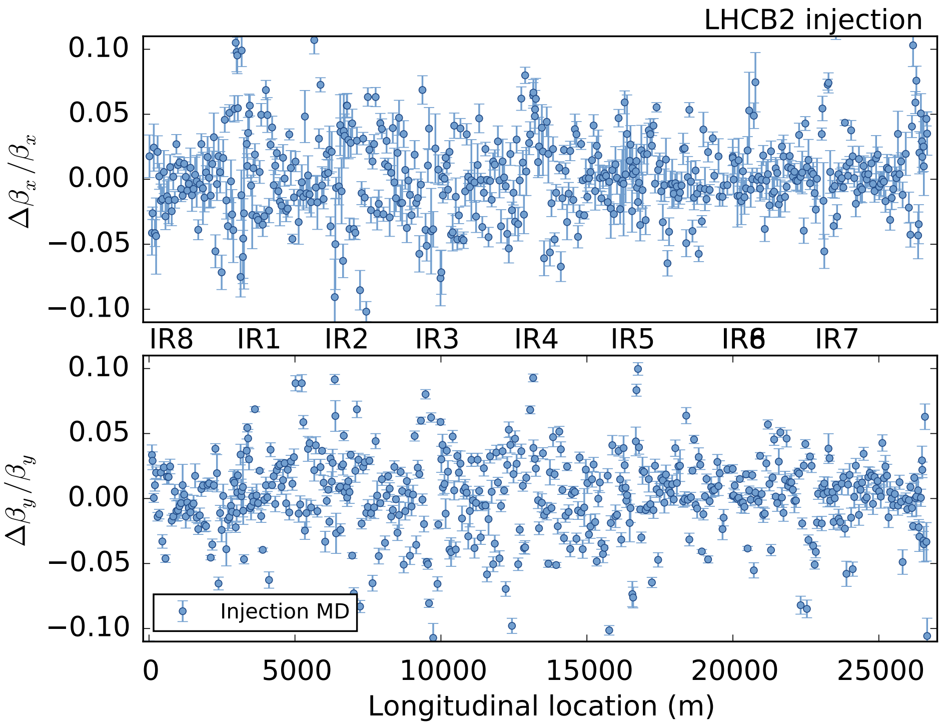

Figure 15: Beta-beating from 2015 MD (Beam 2)

A considerable decrease of the error bars amplitude can be observed in Figure 17 in Beam 2. Nevertheless, the measured dispersion of Beam 1 is still showing a large uncertainties.

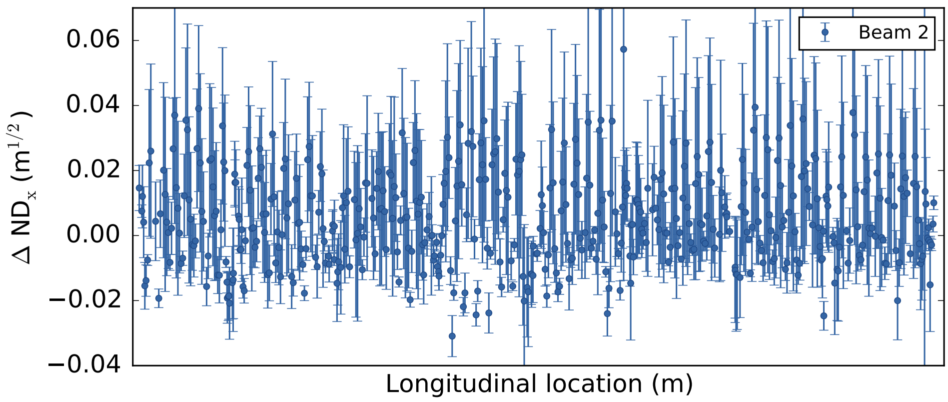

Figure 16: Normalised dispersion for Beam 2 (commissioning 23/04/2015)

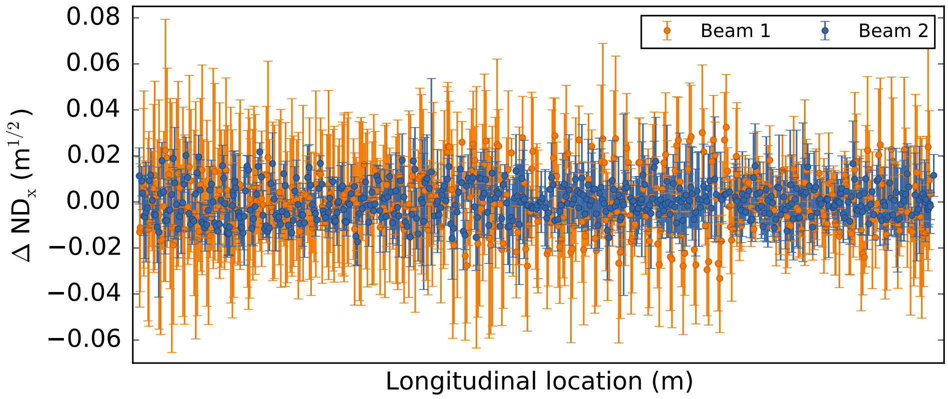

Figure 17: Normalised dispersion for Beam 1 and Beam 2 (MD 28/08/2015)

2.7 Chromaticity corrections

Finally, the aim of the last measurements during the commissioning (23/04/2015) was to apply non-linear corrections computed using data from previous days. Two knobs were created, one for Q" (beam 1 and beam2) and other for Q"" but the last one was not finally not applied. A more detailed analysis of non-linear chromaticity can be found at [6]

3 Conclusions

The injection commissioning has allowed to detect several problems in hardware devices: BPMs and AC-dipole and also in the analysis software (beta-beating GUI). This process led to a more stable framework (software and hardware).

The software upgrades in the beta-beating calculations together with a large AC-dipole excitation have led to more precise results. A large decrease in the values of the beta-beating error bars have been observed.

Results of optics measurements at injection energy have been shown in this report. Beta-beating has been successfully corrected using global corrections.

Also a better values of coupling have been achieved through the application of local corrections. Finally, in terms of non-linear chromaticity, the corrections applied have generated an improvement in the decoherence by a factor 3 approximately.

References

[1] N. Magnin, Private comunication.

[2] R.Tomás, LHC Commissioning. In *LHC Machine Committee (LMC) https://indico.cern.ch/event/401875/* , 2015.

[3] P. Castro. Luminosity and beta function measurement at the electron-positron collider ring LEP. Ph.D. thesis, University of Valencia (1996).

[4] A. Langner, R. Tomás, Phys. Rev. ST Accel. Beams 18, 031002 (2015)

[5] T.H.B. Persson, M.Gasior, A.S. Langner, T. Lefevre, E.H. Maclean, L. Malina, J. Olexa, P.Skowronski, A. Garcia-Tabares Valdivieso, J.M. Coello de Portugal, R.Tomás. “Towards automatic copulic corrections with DOROS BPMs” (2015). CERN-ACC-NOTE-2015-0033

[6] E.H. Maclean, R. Tomás, F.S. Carlier, A. Langner, L.Malina, T.H.B Persson, J.Coello de Portugal, P.K. Skowronski, A. Valdivieso. “Commissioning the non linear chromaticity for the LHC Run II” (2016). CERN-ACC-NOTE-2016-0013