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Coupling Measurements and Corrections for the Combined Ramp and Squeeze

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Summary

In operation of the LHC the ramp and the squeeze process have been independent beam processes up to now. Making them into a combined process would save time to reach the point where the beams are brought to collision. This would increase the integrated luminosity provided by the LHC. One possible source of problems could be deviation from the ideal optics and in particular the control of the transverse coupling. In this report we focus on the coupling measurements that were taken during the Combined Ramp and Squeeze (CRS) MD.

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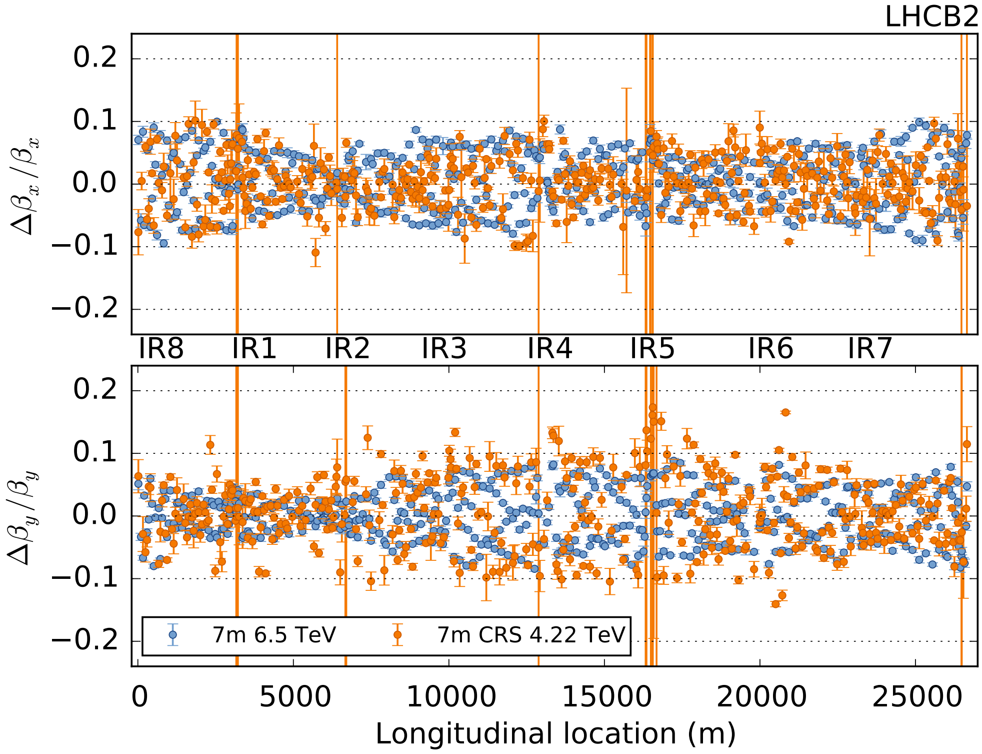

Figure 1: A comparison between the β-beat measured during the commissioning and CRS for a β^*= 7 m.

1 Introduction

A detailed description of the procedure during the MD can be found in [1] During commissioning, the squeeze process was stopped at matched β^*s to measure the optics. For the CRS we do not have this possibility and instead we measured while the beam process was played. We tried to kick as close as possible to the matched points to easily compare to our model.

2 Results

2.1 β^*-beat

The procedure to measure the optics in the LHC is described in [2]. Here we only present a comparison between the normal squeeze and the CRS. Figure 1 shows a comparison between the optics for 7 m measured during the CRS and normal commissioning. Figure 2 shows the β-beat for the 4 m, this point was not measured during the 2015 commissioning and hence lack a comparison.

In figure 3 the β-beat for the 3m is shown. Also here we lack a direct comparison but the β-beat is comparable to the 2 m during commissioning.

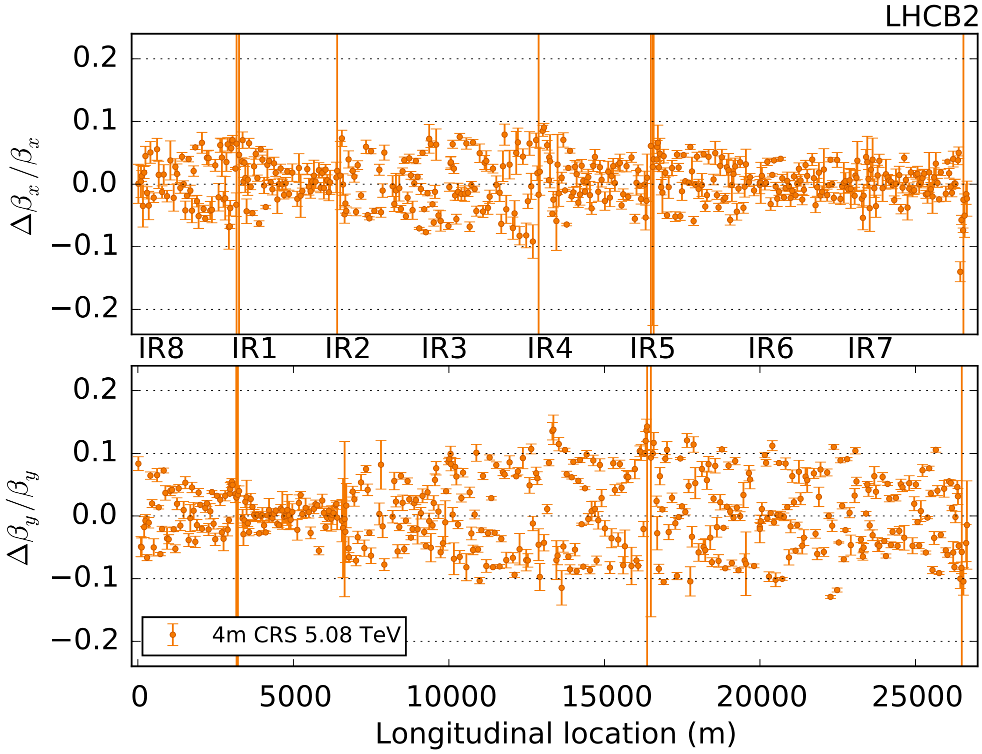

Figure 2: The β-beat measured during the CRS for a β^*= 4 m.

2.2 Coupling

It is important to control the transverse coupling during the CRS. In case the coupling would get to big it could lead to problems for the tune feedback and possibly cause instabilities. Figure 4 displays the evolution of the amplitude of the f_{1001} during the CRS.

In figure 5 the evolution of the real and imaginary part is shown. From the f_{1001} it is possible to calculate the $|C^-|$. The way to calculate it is described in [3].

In table 1 the settings of the knobs to correct the transverse coupling as well as the $|C^-|$ are shown. We observe that the $|C^-|$ is actually decreasing as the lower β-functions. However, we should also stress here that the energy was also increasing as the optics was squeezed.

β^*	Δb2_re_ip7	Δb2_im_ip7	$\lvert C^-\rvert$
7	-0.00146	-0.0079	0.0082
4	-0.0005	-0.0067	0.00665
3	-0.0017	-0.0031	0.00378

Table 1: Table showing the settings of the coupling knobs needed to correct the coupling as well as the value of the $|C^-|$ before any dedicated corrections.

Figure 7 shows the evolution of the $|C^-|$ measured with the BBQ during a normal ramp. We observe that for beam 2 there is a clear decrease of the coupling as the ramp continues.

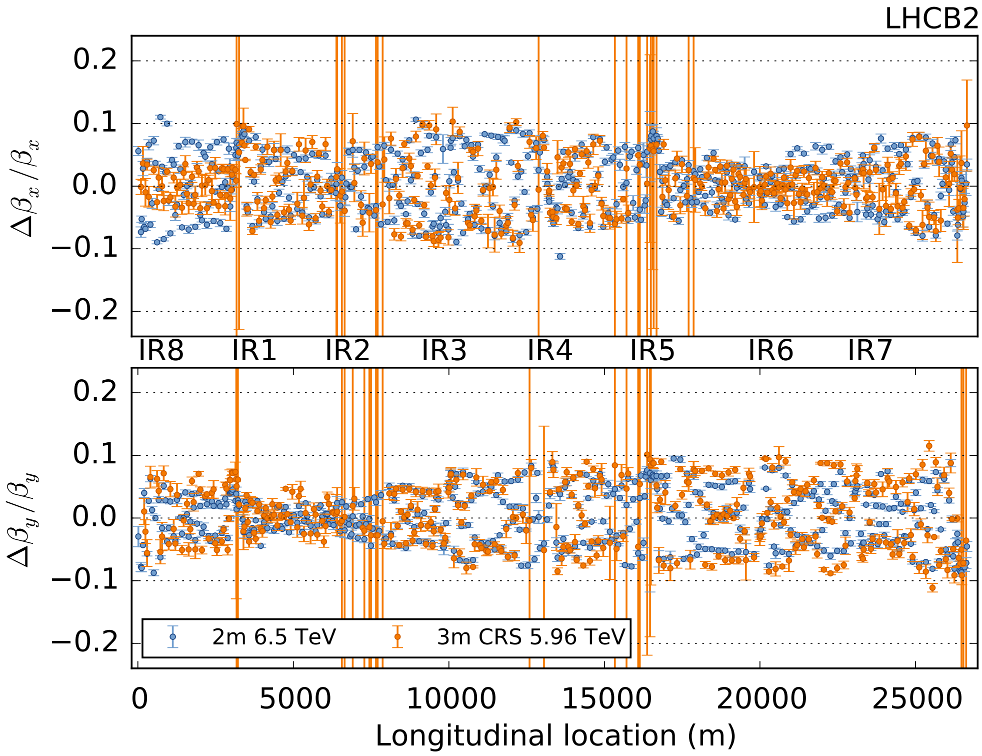

Figure 3: The β-beat measured during the commissioning at β^{*}= 2 m and for CRS for a β^{*}= 3 m.

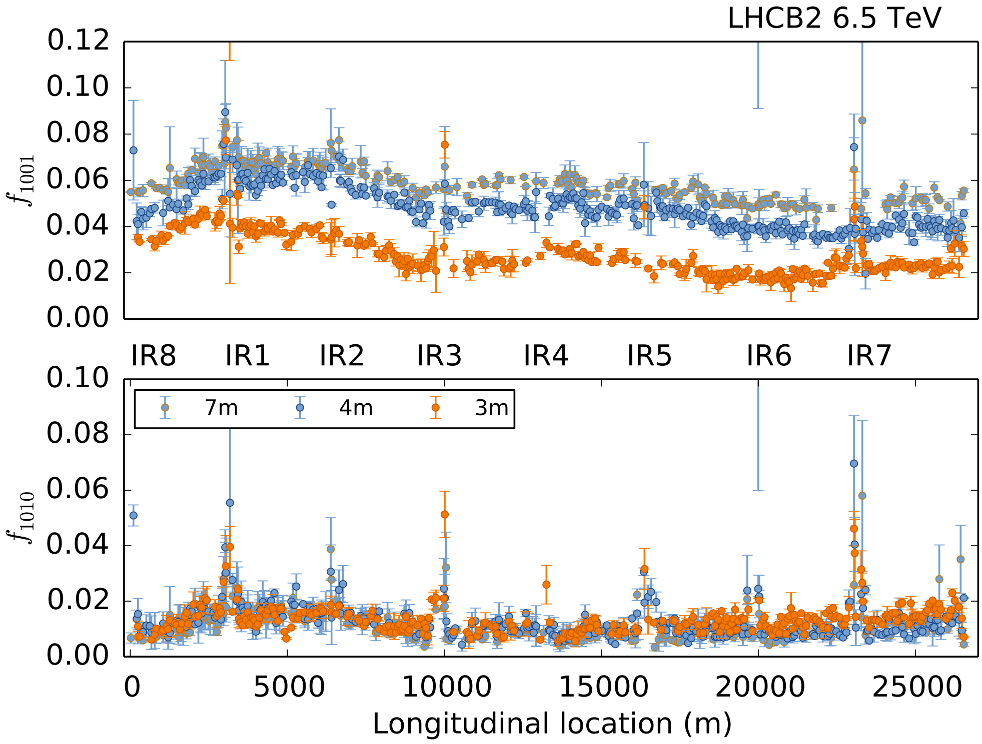

Figure 4: The amplitude of the f_{1001} at β^*=7 m, 4 m, 3 m.

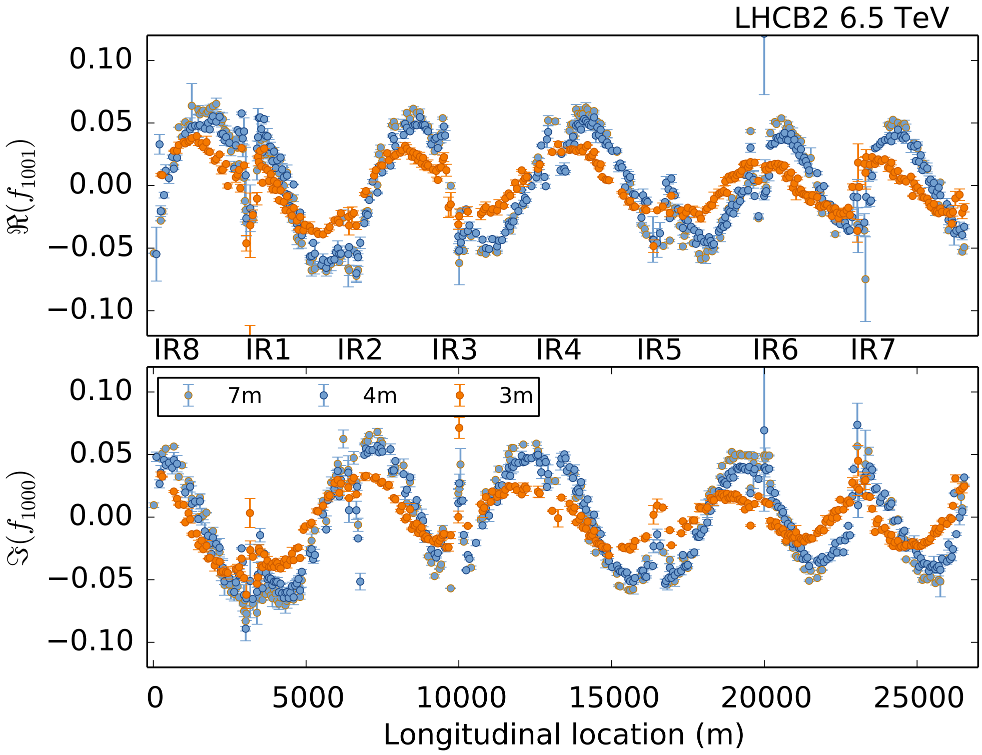

Figure 5: The real and imaginary part of the f_{1001} at β^*=7 m, 4 m, 3 m.

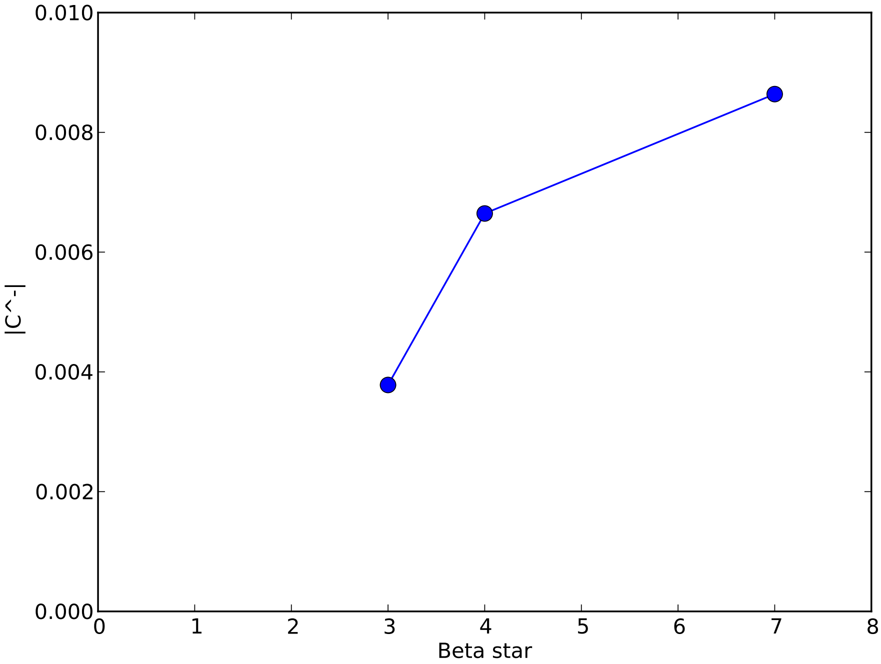

Figure 6: The $|C^-|$ for the different β^*.

This is the same behavior observed during the ramp and squeeze. This makes it likely that the decrease of coupling is related to the energy rather than the squeeze of the β^*.

3 Conclusion

The optics measurement during the CRS revealed no issues. The β-beat is comparable the normal squeeze and the coupling remains well controlled during the period. The coupling was, however, varying during the CRS but decreased along the ramp and squeeze. However, a complete measurement of beam 1 is needed to completely validate the optics.

References

[1] J. Wenninger, First beam test of a combined ramp and squeeze at LHC, "CERN-ACC-NOTE-2015-0023", http://cds.cern.ch/record/2049886

[2] R. Tomas, T. Bach, R. Calaga, A. Langner, Y. I. Levinsen, E. H. Maclean, T. H. B. Persson, P. K. Skowronski, M. Strzelczyk, G. Vanbavinckhove, and R. Miyamoto "Record low beta beating in the LHC"

[3] T. Persson and R. Tomas "Improved control of the betatron coupling in the Large Hadron Collider" Phys. Rev. ST Accel. Beams 17, 051004 (2014)

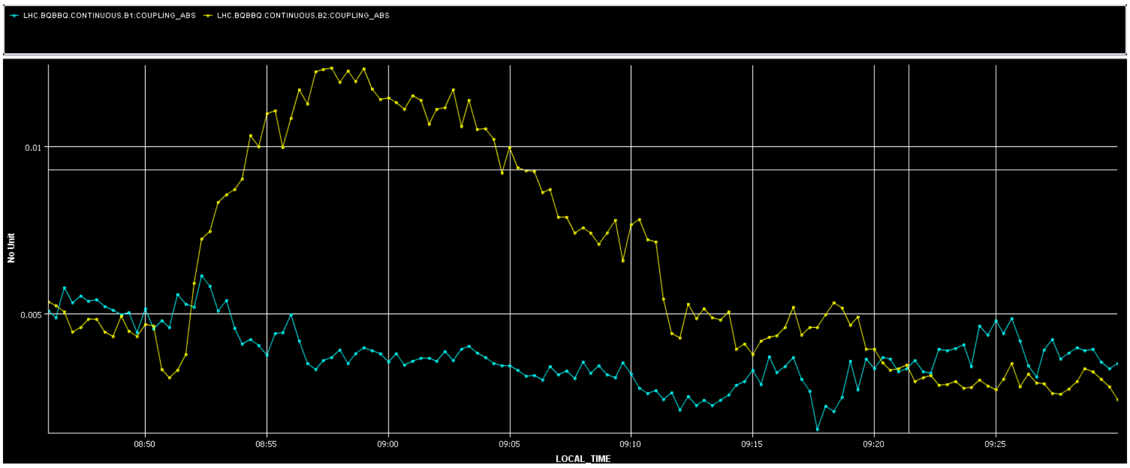

Figure 7: Figure showing the evolution of the $|C^{-}|$ measured with the BBQ for beam 1 and beam 2 during a normal ramp.