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claudia.tambasco@cern.ch

MD 382: Beam Transfer Function and diffusion mechanisms

C. Tambasco, J. Barranco, X. Buffat, M. Crouch[*]*, T. Pieloni, A. Boccardi, K. Fuchsberger, M. Gasior, R. Giachino, G. Kotzian, T. Lefevre, T. Levens, M. Pojer, B. Salvachua, M. Solfaroli*
CERN, Geneva, Switzerland

Abstract

The Beam Transfer Function (BTF) measurements have been previously tested in the LHC during MD block 1 and 2. Different machine configurations (i.e. energy, beam intensity, emittance etc...) have been tested to determine a safe set-up (excitation amplitude) of the system to be completely transparent to the beam (no emittance blow-up neither losses). The aim of this experiment in MD block 3 was to characterize the Stability Diagram (SD) in the presence of diffusion mechanisms induced by excited resonances due to beam-beam long range and Landau octupole interplay. During the experiment, BTF measurements have been acquired at flat top for different settings of Landau octupole current, different chromaticity values and transverse feedback gains. In this note the description of the experiment is presented together with some preliminary results.

Keywords: Accelerator Physics, beam-beam effects, beam instabilities

[*]University of Manchester, Manchester, U.K / The Cockcroft Institute, Daresbury, U.K.

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1 Motivation and introduction

The Beam Transfer Function (BTF) measurements have been set-up and tested during MD block 1 and 2 as described in [1]. Several instabilities were observed during the 2012 LHC physics run during the betatron squeeze where beam-beam interactions become stronger and change the total tune spread. A possible explanation could be related to the deprecation of the stability area due to noise [2] and/or excited resonances [3, 4].
The aim of this Machine Development study, devoted to BTF measurements in the presence of diffusion mechanism, was to characterize the Stability Diagram (SD) in presence of strong beam-beam long range interactions. This will be done by measuring the SD with Landau octupoles while reducing the long range beam-beam separation. In this note the full experimental procedure will be presented together with some preliminary results of the experiment.

2 MD Procedure

The MD activity was carried out the 8th of November 2015. Because of a beam dump due to a software problem right after the end of the squeeze, unfortunately BTF measurements could not have been performed for different beam-beam long range separations. Furthermore, at the beginning of the MD some disabled settings of the ADT have required the intervention of several teams delaying the start of the MD. Therefore due to the restricted time, we decided to perform only measurements at top energy of 6.5 TeV.
One train of 1 nominal and 36 bunches was injected for Beam 2 (B2) and a single bunch for Beam 1 (B1) of lower intensity with respect to the nominal value to avoid coherent modes while beams in collision. The single bunch in B1 allowed us to reduce the ADT gain from nominal values to zero. This is necessary to avoid the feedback response component in the BTF measurements. Therefore all BTF measurements were acquired only for B1 (both in horizontal and in vertical plane). At flat top we performed BTF measurements with the following machine configurations:

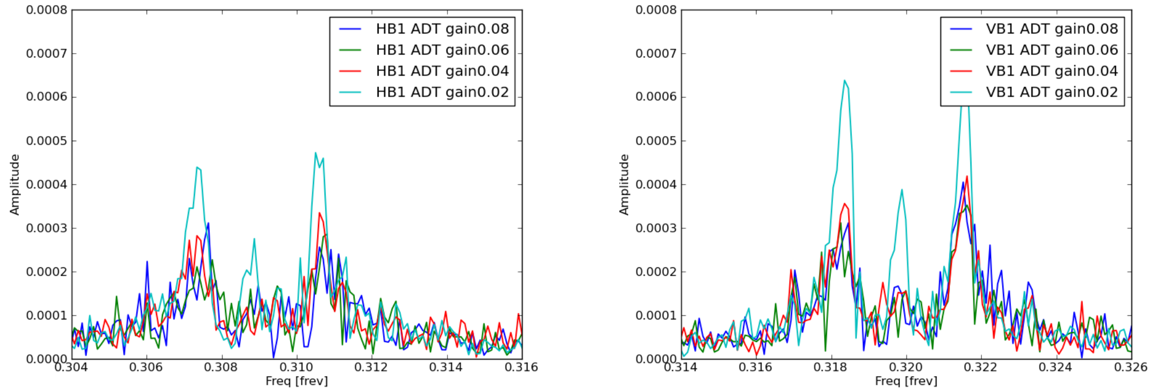
– for different ADT gains acting on B1 with nominal Landau octupole current of 550 A and chromaticity $Q' \sim 15$ units;
– for different units of chromaticity with the ADT switched off on B1 and nominal Landau octupole current of 550 A;
– for several Landau octupole currents, with chromaticity $Q' \sim 6$ units and ADT switched off on B1.

After the octupole scan, the nominal value of the octupole of 550 A was restored and BTF measurements were acquired just before going through the Betatron squeeze. At the end of the squeeze we took only one BTF measurement right before the machine dump. Some preliminary results of these measurements are presented in the next section.

3 Preliminary results

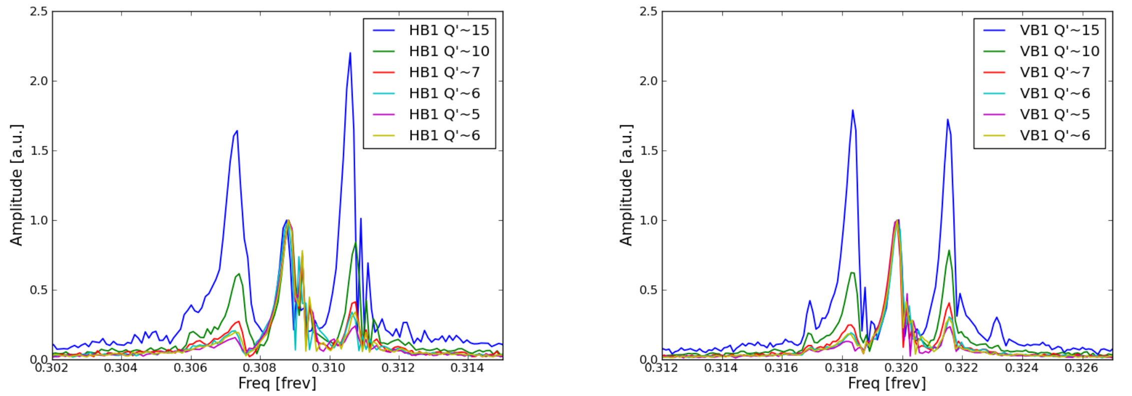
At flat top, BTF measurements have been performed for different ADT gains acting on B1. The chromaticity was set to $Q' \sim 15$ units and the nominal octupole current of 550 A was applied. Measurements of the BTF amplitude response as a function of the ADT gain are shown in Figure 1. Due to the high value of the chromaticity, the height of the synchrotron sidebands (expected at $\pm 2 \times 10^{-3}$ from the coherent tune at flat top) exceed the coherent peak of the tune. The BTF amplitude response results to be noisy due to the transverse feedback acting on the beam. As expected, lowering the ADT gain, the coherent response of the beam emerges from the signal: the synchrotron sidebands and tune peak are well visible for an ADT gain of 0.02, corresponding to a damping time of 100 turns.

To investigate the impact of chromaticity on the sidebands, a chromaticity scan, from $Q' \sim 15$ units to $Q' \sim 5$ units, was carried out with the ADT switched off on B1. Results of the BTF measurements are shown in Figure 2. The BTF amplitude response is normalized to the height of the coherent tune peak for both the horizontal and vertical plane. A reduction of the sidebands is visible in the BTF amplitude response while reducing the chromaticity. The ratio between the height of the tune peak (S_0) and the



(a) B1 horizontal plane. (b) B1 vertical plane.

Fig. 1: Measured BTF amplitude response in function of the ADT gain.



(a) B1 horizontal plane. (b) B1 vertical plane.

Fig. 2: Measured BTF amplitude response in function of the chromaticity.

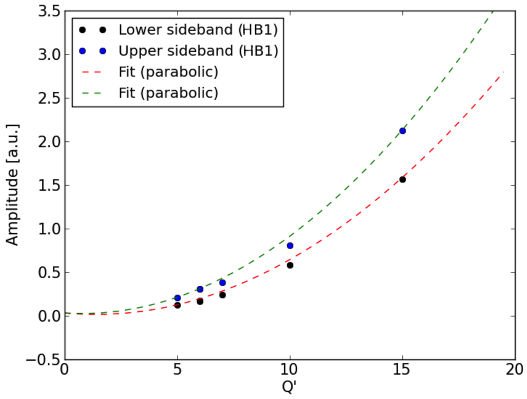
height of the sidebands (S_1) is plotted in Figure 3. The ratio S_0/S_1 has a quadratic dependence as a function of the chromaticity and this is shown in Fig. 3.

Before going through the Betatron squeeze, the chromaticity of Beam 1 was set back to a value of $Q' \sim 6$ and BTF measurements were acquired for Landau octupole currents of 550 A, 450 A, 360 A and 260 A. Figure 4 shows the BTF amplitude response of B1 as a function of the Landau octupole currents.

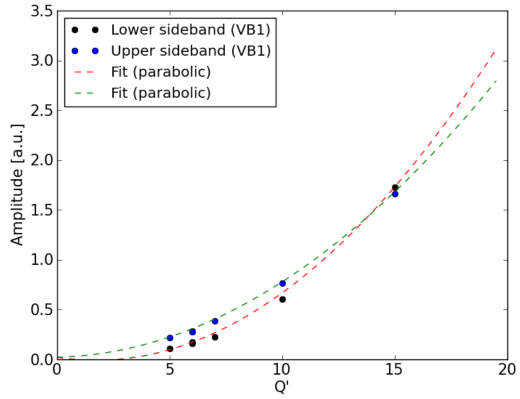
Afterwards, the nominal value of the octupole at flat top at 550 A was restored and BTF measurements were acquired just before the Betatron squeeze. At the end of the squeeze we took only one BTF measurement right before the beam dump. The correspondent beam-beam long range separation at the end of the Betatron squeeze was $d_{lr} \sim 14\sigma$. Figure 5 shows the measurements of the beam amplitude response before (blue solid line) and after (green solid line) the Betatron squeeze. For sake of clarity, the dashed green line corresponds to measurements after the squeeze, and is overlapped to the BTF response before the Betatron squeeze for comparison between the two cases. A slightly increase of the width of the response just after the Betatron squeeze is observed in the horizontal plane. The long range contribution in the spread is expected to be small therefore no important variations are observed on the amplitude response.

4 Summary

The procedure of the MD have been presented in this note together with some preliminary results. Unfortunately we could not manage to reach the goal of the MD due to a beam dump at the end of the

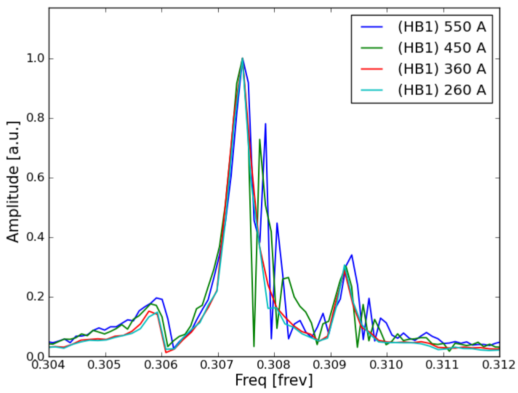


(a) B1 horizontal plane.

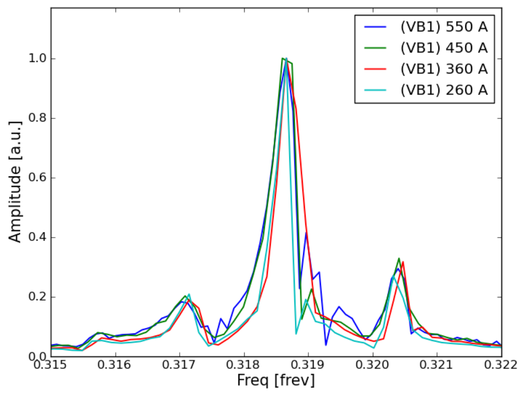


(b) B1 vertical plane.

Fig. 3: The ratio S_0/S_1 as a function of the chromaticity.

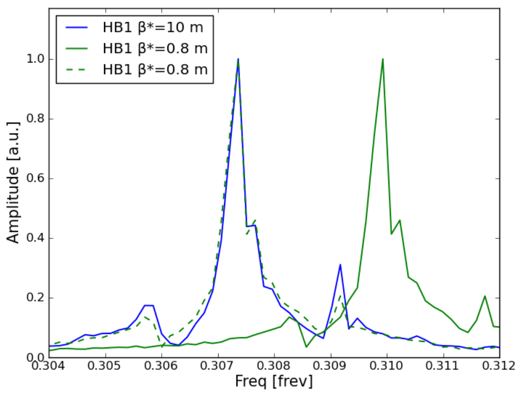


(a) B1 horizontal plane.

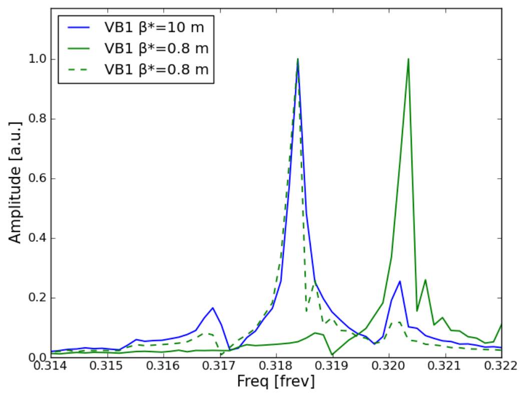


(b) B1 vertical plane.

Fig. 4: Measured BTF amplitude response for different Landau octupole currents.



(a) B1 horizontal plane.



(b) B1 vertical plane.

Fig. 5: Measured BTF amplitude response just before (blue solid line) and after (green solid line) the Betatron squeeze. The dashed green line corresponds to measurements after the squeeze, and is overlapped to the BTF response before the Betatron squeeze just for comparison between the two cases.

Betatron squeeze. However, we performed at flat top several tests to understand the impact of the ADT gain and the chromaticity on the BTF response. In addition, a Landau octupole current scan has been carried out to measure the contribution to the Landau damping from different octupole magnet currents at flat top. The impact of the beam-beam long range interactions has been evaluated by comparing the BTF measurements before and after the Betatron squeeze with the same machine configuration in terms of Landau octupole current. A slightly increase on the width of the BTF response has been observed in the horizontal plane compatible with the beam-beam long range contribution. For future MDs it would been interesting to investigate the effects of diffusion mechanisms due to noise or excited resonance driven by the beam-beam interaction and compare the SD predicted by the model with measurements.
Some other tests would be required in the future for a better set-up of the system:

- the calibration of the excitation amplitude is needed since the excitation amplitude is directly related with the height of the measured SD and was unknown for this preliminary tests
- for B2 vertical plane the BTF system is not responding this needs to be investigated
- a higher resolution for the BTF signal would be useful to better reproduce the simulated SD.

5 Acknowledgements

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6 References

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