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MD 402: Head-on limits. Separation leveling.

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Abstract

HL-LHC will operate in a large beam-beam head-on tune shift regime and as well as is the LHC considering to reach higher luminosity levels. A clear understanding of colliding high brightness beams is fundamental to guarantee the successful operation of such beams and to anticipate problematics that might appeared in that scenario. The beam dynamics of high brightness colliding beams are to be explored in this MD with intensities close to 2e11 ppb and smallest emittances possible. Beam lifetimes and emittance evolution around the nominal working point for full head-on collisions as well as collisions with small transverse offsets will be monitored. The study aims to highlight emittance growth driven by beam-beam and possible issues with instabilities due to mode coupling at injection energy.

Keywords: CERN LHC, Beam-Beam Effects.

Contents

1 Motivation

The present MD was proposed to assess the beam parameters evolution, mainly emittances and intensities, while colliding high brightness beams applying different small transverse offsets. The measurements will be then compared with the predictions of transverse emittance blow up due to small static offsets at the head-on collisions presented in [1]. This is fundamental to guarantee no extra emittance growth in case luminosity leveling by transverse separation is applied to the HL-LHC operation.

2 Experimental conditions

The MD was planned for 6 hours, that finally were 5.5 hours due to accumulated delays.

The general procedure for this MD included:

- Inject 3 bunches (2 to be collided and 1 not) with different high brightness.
- At injection energy the tunes are rematched to the ones of collision.
- Bunches brought into collision simultaneously at IP1 and 5.
- Collisions optimized looking mainly at luminosity signals of ATLAS and CMS.
- Applied small transverse offsets in both IPs and monitor the beam parameters for around 15 minutes/step.

However due to several unforeseen events this procedure was not successful.

The actual MD started with the need of rematching the tunes since they had drifted significantly from the previous MD (they were already at collision tunes). Chromaticity as well needed to be rematched to 4 units in both planes since it had drifted to negative values. Afterwards there were a couple of wrong injections as shown in Fig. 1. In the first one the bunches were injected in wrong RF buckets with a 2.5 ns shift for beam 1 and 5 ns for beam 2. In a second injection synchro delays were off by one bucket for beam 1 and 2 buckets for beam 2 due to a load of wrong settings left in from the previous MD. Once this was fixed there was some additional waiting time due to some issues in the injector chain.

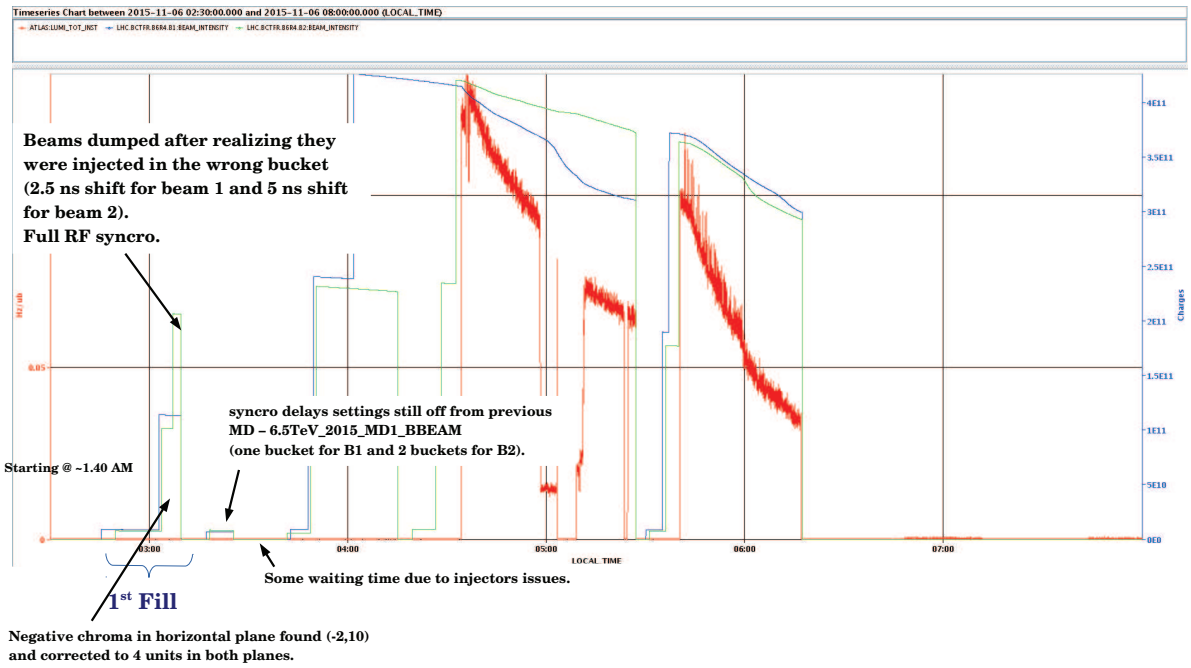

Fig. 1: RF synchronization issues at the beginning of the MD.

Once solved the synchronization issues we started the set-up procedure looking for collisions at IP1 and 5. However at this moment it was realized that the luminosity signal published by CMS was too noisy to be used in the optimization process. In Fig. 2 the attempts to find and optimize collision

are shown (top) and the BBQ signal (bottom) shows the effects of this 'blind' attempts on the coherent modes. Of course all of this are post-processed info not available during the MD. Around 5.03 AM it can be seen how collision at ATLAS were fully separated to try to find collisions at CMS looking at the tune shift measured. However this was not successful because there was no luminosity signal from CMS.

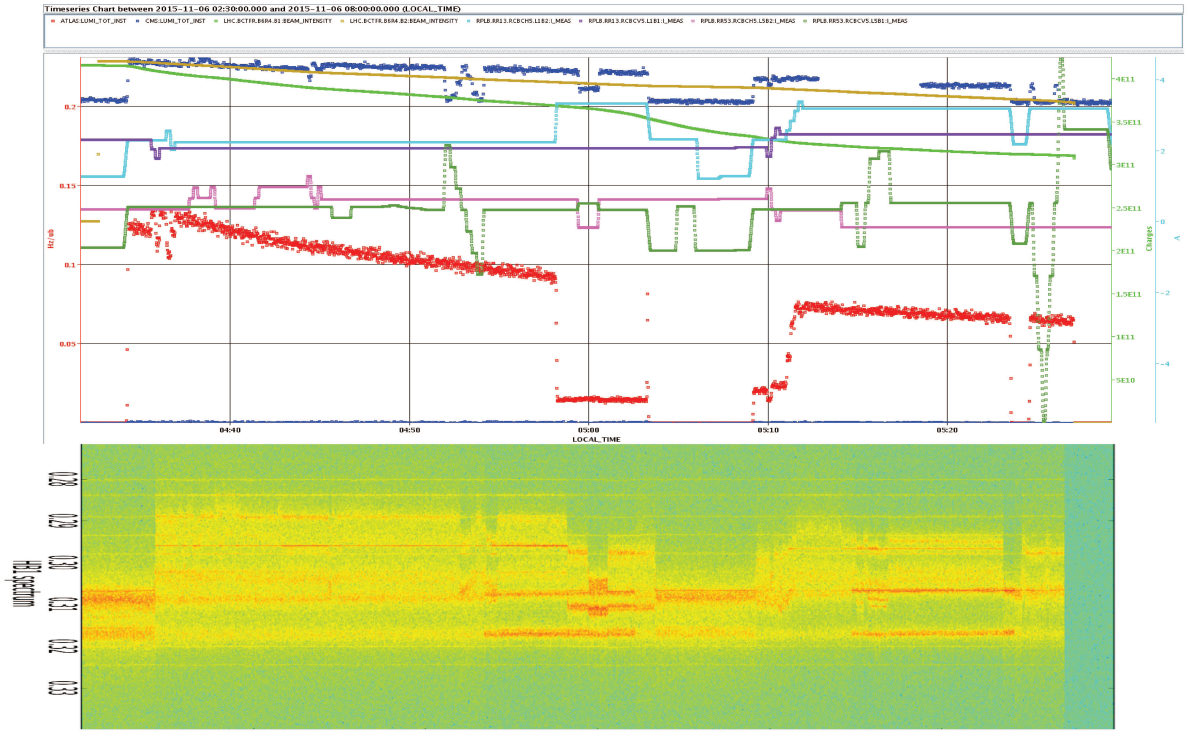

Fig. 2: Attempt to find and optimize collisions at IP1 and 5. Luminosity and orbit correctors (top) and BBQ signal (bottom) CMS was not publishing a clean signal of their measured luminosity for this reason blind attempts had to be done. The CMS lumi signal (blue dots) have cleaned in this plot during the MD it was unusable.

In the last fill we decided to perform the measurements just with collisions at IP1 although if this meant less beam-beam parameter. In Fig. 3 again it is shown the luminosity and orbit correctors signals (top) with a full head on collision from 5.40 to 6.00 AM and a 0.5 σ from 6.00 to 6.16 AM. Since we ran out of MD time this was the only useful data acquired. During this measurement the ADT was on, but it was not possible to test different gains.

3 Observations

In Fig. 4 the analysis of the last fill is shown. As explained before we had time to only do one step in separation around 20 min after the beginning of the fill. As in other beam-beam MDs at injection we observe that the non-colliding bunches present a large emittance growth which point to other energy related processes dominating the evolution. As well we can see some small effect on the non-colliding when the offset was introduced that might be caused by some non-orbit closure but to be further understood. The intensity for beam 2 drops with the orbit change which points to some losses due to this orbit bump. Regarding the colliding bunches there is an emittance growth visible after the offset but only in beam 1, the reason for that is still not clear. As well an intensity drop in beam 2 is observed so there could be a difference in orbit closure for the two beams.

The MD was not successful and a request to repeat it in the future has been submitted. From the little data finally acquired at first sight is not possible to draw any conclusion.

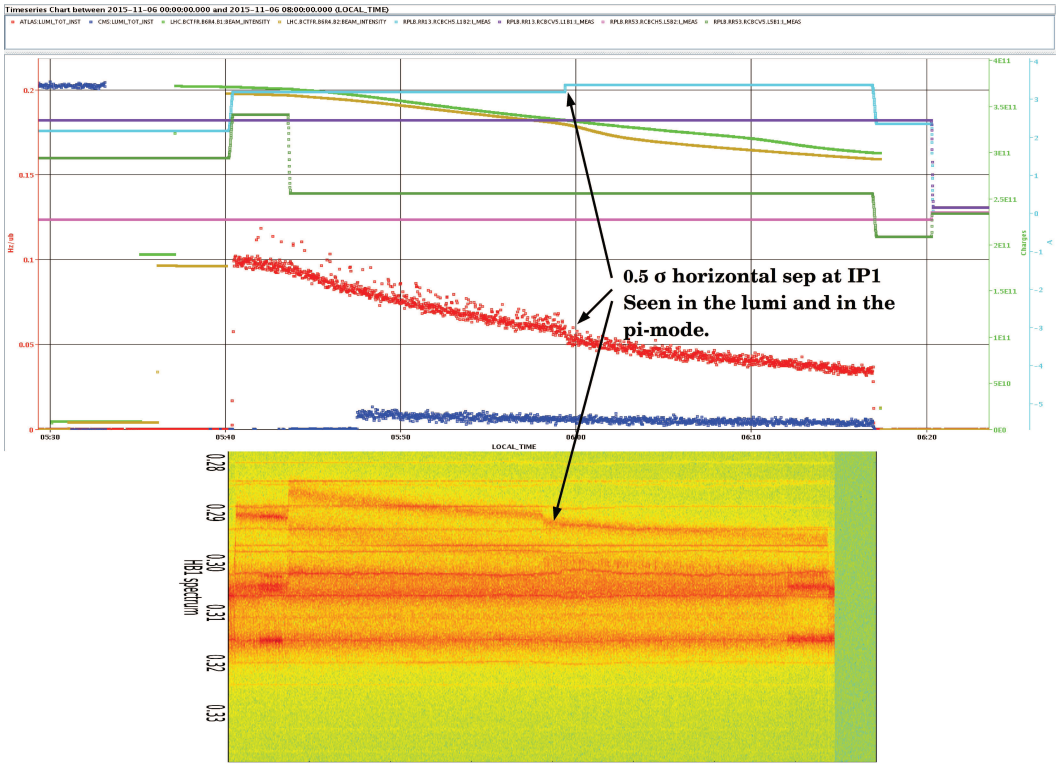

Fig. 3: In the last fill it was decided to collect some data colliding only at IP1. There was time for only two steps of 15-20 min. From 5.40 to 6.00 full head-on and form 6.00 to 6.16 AM with a transverse offset of 0.5 σ.

4 Conclusions

The MD time was mainly lost in correcting for wrong settings and to establish collisions which was not possible due to the fact that CMS was not publishing useful luminosity data. For the single offset measured of 0.5 σ it is visible that a change in growth rate of beam 1 and not on beam 2. The non colliding bunch behavior is unchanged with or without the offset at the IP as expected but a larger emittance growth rate occurs due to other mechanisms. The experiment should be repeated to verify the findings and quantify for different offsets.

5 References

[1] T. Pieloni, W.Herr and J.Qiang, *"Emittance growth due to beam-beam effects with a static offset in collision in the LHC"*. Proceedings of PAC09, Vancouver, BC, Canada.

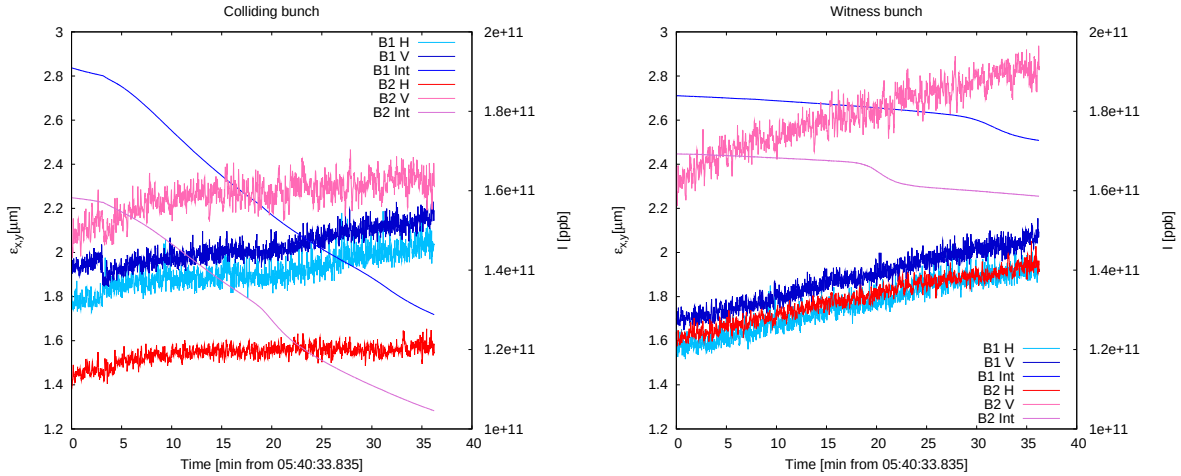

Fig. 4: Emittance growth (from BSRT) and intensity evolution for colliding (left) and non-colliding bunches (right). The maximum beam-beam parameter in both colliding bunches is $\xi_{bb} \approx 0.02$. A transverse offset of 0.5 σ was introduced after 20 min and a visible change in growth rate is observed for the colliding bunch.