TUNE AND ORBIT FEEDBACKS PERFORMANCE : A USER PERSPECTIVE

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Abstract

The presentation will present the performance and issues of tune and orbit feedbacks seen from the user (operation) perspective. Some statistics on the beam dumps causes will be presented to emphasize the two main limitations of the system : the issue on the tune measurement and the triggering of the QPS system of RQTs circuits. The possible improvements for 2012 will then be discussed together with the foreseen software changes for the orbit reference management.

INTRODUCTION

Both the tune and orbit feedback systems are essential tools for the control of the LHC beams. From the point of view of operation, a major improvement has been introduced at the beginning of the 2011 run in the management of the reference orbit and proved to be very reliable over the run. Nevertheless, the feedbacks systems triggered several beam dumps. The goal of this talk is to review the cause and try to propose possible solutions to reduce the number of beam dumps.

SOME STATISTICS OVER THE YEAR

When analyzing the Post Mortem files over the all 2011 run, there are a total of 33 beam dumps which can be attributed to the feedbacks system (orbit or tune) for a total of 131 beam dumps happening in the phases when the feedbacks are ON, i.e ramp and squeeze. The repartition between the two different modes is shown in table 1.

Beam mode	**RAMP**	**SQUEEZE**
Total number of dumps	61	70
assigned to feedbacks	8	25
Percentage	13	37

Table 1: Distribution of the beam dumps due to feedbacks by beam modes

It is important to notice that 6 out of 8 beam dumps during the ramp happened in March, during the initial commissioning of the LHC cycle. Nevertheless, most of the beam dumps occurred during the Physics period, and mainly during the squeeze beam process, where the tune feedbacks is very active, see table 2.

Machine mode	**RAMP**	**SQUEEZE**
MACHINE DEVELOPMENT	1	4
BEAM SETUP	3	6
PHYSICS	4	15

Table 2: Distribution of the beam dumps due to feedbacks by machine modes and beam modes

MAIN DUMP REASONS

In order to improve the situation for the next run, it is important to identify the main cause of the beam dumps. When looking in the post mortem data, all the dumps can be classified in three different categories. The three main causes are:

- Triggering of the trim quadrupole (RQTFs and RQTDs) Quench Protection System (QPS)
- Wrong reference sent to the feedbacks controllers
- Instabilities of the tune measurements

The last cause can be divided in 2 different behavior of the feedback. The first one is the tune feedback controller driving the tunes towards the third order resonance during the squeeze and the beam is dumped by the beam loss monitor system. The second one is the orbit feedback not correcting during the ramp, leading to large orbit excursion and the beam is dumped by the Software Interlock System.

When looking at the repartition of the beam dumped according to the cause, table 3, one can see that the large majority (69 %) of the dumps attributed to feedbacks problems are due to the triggering of the QPS system.

	Number	**%of the total**
QPS triggering	23	69
Wrong reference	5	14
Instabilities	5	14

Table 3: Distribution of the beam dumps due to feedbacks by machine modes and beam modes

Looking again in more details in the dumps due to instabilities, it can be noted that 2 occurred during machine development time, 2 during proton physics and 1 during ion physics.

Wrong reference

Since the beginning of the run, the management of the change of references for the tune feedback and the orbit feedback is sequencer driven in order to limit the operator manual action and the risk of error. The references are stored in LSA and sequencer tasks are driving the settings to the feedbacks controller according to the played beam process. Orbit reference, tune reference and tune windows are managed through the sequencer.

Most of the errors happened when cloning hypercycles for machine developments or during the beam setup. These errors should be avoided with more consistency checks and test. More discipline is clearly required in the management of the settings.

QPS trips

The main cause of beam dump is the triggering of the QPS system of the trim quadrupoles. In these cases, the real trims sent by the feedbacks controller are oscillating rapidly or are too large, creating a U_{res} measured by the QPS system close to 100 mV. Above 50 A current in the converter, the QPS system triggers if the U_{res} measured is above the limit value of 100 mV for more than 190 ms. The following picture 1 shows a typical case of signal oscillating around the threshold, leading finally to a QPS trigger and a beam dump.

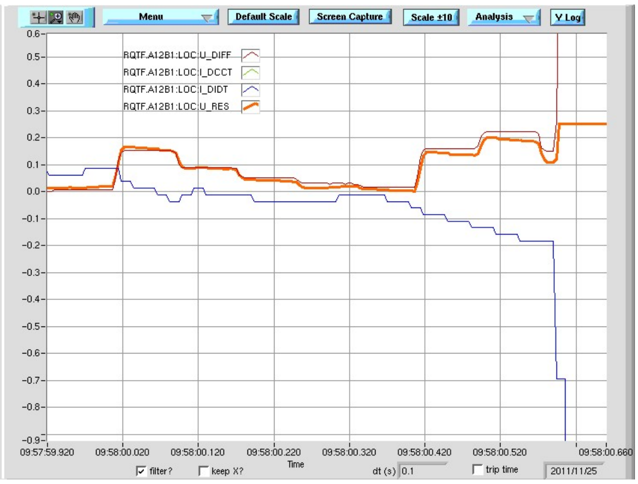

Figure 1: Typical example of real trims oscillating, leading to a beam dump by triggering the QPS system :U_{res} above 100 mV.

For the 2012 run, it has been proposed to increase the QPS U_{res} threshold. New simulation of the protection system have showed that the threshold could be relaxed [1]. Presently, the change of threshold between 2 V and 100 mV is done when current is going above 50A. It is proposed to keep the 2 V threshold up to 100 A, provided than the maximum current is hardware limited to 200 A. This proposal should reduce the number of false trigger for the next year, but will not worked for beam energy above 4.5 TeV as the current required in the tune trim quadrupoles may be above 200 A.

During the ion run, another solution has been tested in order to reduce in the real time trims and so limit the oscillation. The tune feedback response bandwidth has been reduced by a factor 5, allowing to have a much more stable demand on the current change. Figure 2 and 3 show the result of the reduction of the bandwidth with ion beams.

Figure 2: Example of noise produced on the RT trims due to high response bandwidth of the QFB controller

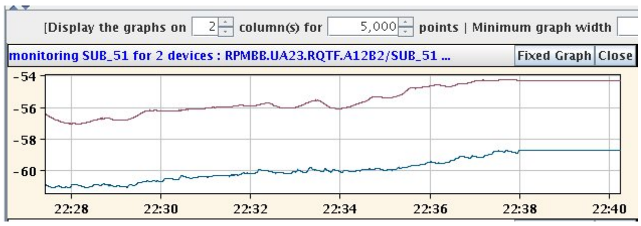

Figure 3: Reduction of the noise by reducing the FB response bandwidth by a fa

The possibility to reduce the bandwidth has to be tested with protons. The high bandwidth was motivated by the initial specification of keeping the tune shift below the per mil. It has to be tested if the setting could be relaxed during the new squeeze.

Tune measurement

During the 2011 run, the operation team experienced difficulties with the tune measurement. Indeed, two different problems appeared at different stage of the intensity increase during the year. The first problem has been observed when increasing the bunch intensity. Due to internal limitation of the instrument, the system saturated and the tune spectrum became completely flat, see figure 4. The tune peak is not detectable anymore and the feedback cannot work properly.

Hardware modifications are already planned for the Christmas break to adapt the dynamic range to higher bunch intensities and to allow a remote settings of the dynamic range (no more access needed for the setting). The modifications could lead to less sensitivity for the pilot, but the saturation of the detector should not be a problem anymore for 2012 run.

The second problem observed with the tune measurement was the apparition of a double peak instead of the

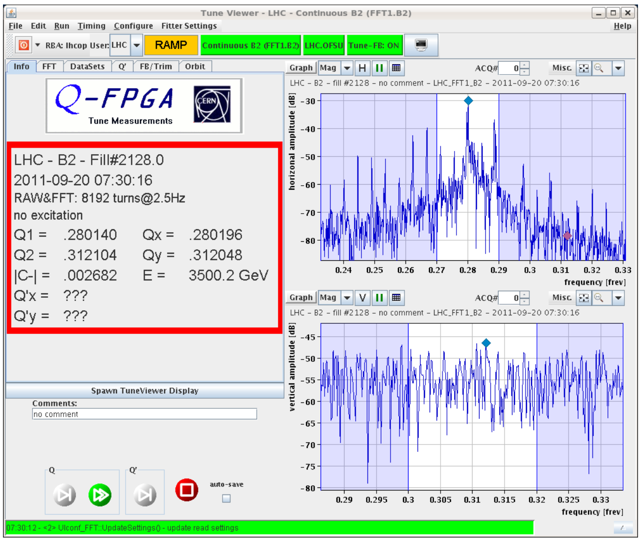

Figure 4: Example of saturation of the detector in the vertical plane.

tune peak, as in Figures 5. Due to the transverse dampers action, the tune peak is damped and the signal to noise ration became too bad to perform a correct tune detection.

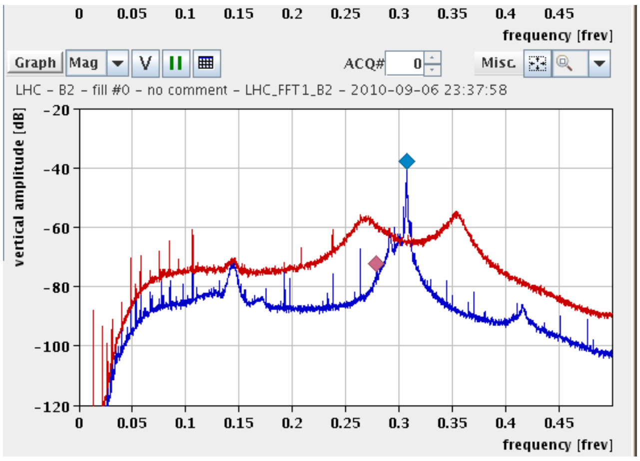

Figure 5: Example of transverse damper effect on the tune peak. The blue curve represents the tune signal without dampers, whereas the red one shows the tune signal with ADT on with maximum gain.

To limit the problem, the operation team had to use external excitation (CHIRP) to enhance the tune peak and allow using the feedback during the squeeze, but this cannot be generated to high intensity beam without approval of the Machine Protection Panel. The cohabitation between ADT and BBQ requires proper set-up time to define the working settings. It has to be repeated every time beam conditions are changed. There are not yet a clear solution to avoid the problem for 2012, other mean of tune measurement like using the ADT signal are under development, but not yet operational.

FURTHER IMPROVEMENTS FOR 2012 RUN

Gating on ADT and BBQ signal

At the end of 2011 run, bunch gating for the transverse damper has been successfully tested. The principle is to disable the ADT for a pre-defined bunch train and to also gate the BBQ to measure only the same bunch train. this method should allow to get rid of the competency between the 2 equipments. The ADT gating has been tested on train with 20 % more intensity than the rest of the machine. The main issue is that the BBQ signal is sensitive to bunch intensity, the more intense bunches contributes the more to the tune signal. The original idea to use the train of 12 bunches will have to be revisited as the intensity if the intermediate train is generally smaller than in the nominal train.

To be used in nominal operation, the ADT gating should be combined with the BBQ gating which is not yet fully ready. Machine development time will be required at the beginning of the run to commission it.

switching OFF feedback?

Beside the increase of the thresholds and the reduction of the noise on the RT trims to avoid the tripping of RQTF/Ds, a third solution has been used at the end of the run : switch off the tune feedback during the squeeze, when the signals were not stable enough. Several fills were put in physics with the tune feedback off. It is difficult to trace these fills in the statistics, but we estimated about 10 fills in ions and a couple of fills during the increase in bunch intensities were done with QFB manually switch off. To avoid big trims or oscillations when the tune signal is not stable, the tune feedback has put in place a self protection under the form of an automatic switch off with a tune stability measurement. In few cases, this protection was not enough and decision was made by the operator to switch off.

The Figure 6 shows an example of tune signal and RT trims applied when the decision to switch off was taken during the last part of the squeeze.

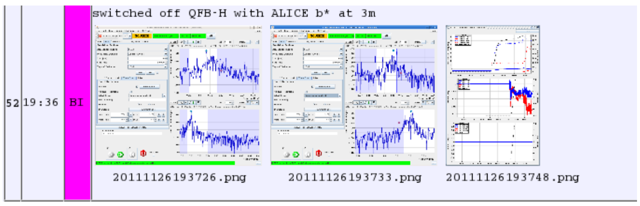

Figure 6: Example of tune signals and RT trims amplitude during a squeeze of ALICE where the QFB was manually switched off.

Feed Forward versus Feed Back

The extreme solution to switch off the QFB during the ramp and squeeze was working providing that the bigger part of the real time trims corrections were already incorporated in the played functions. A feed forward of the corrections has been regularly done during the commissioning of the beam processes, including incorporation of the RT corrections at the matched points, see Figure 7.

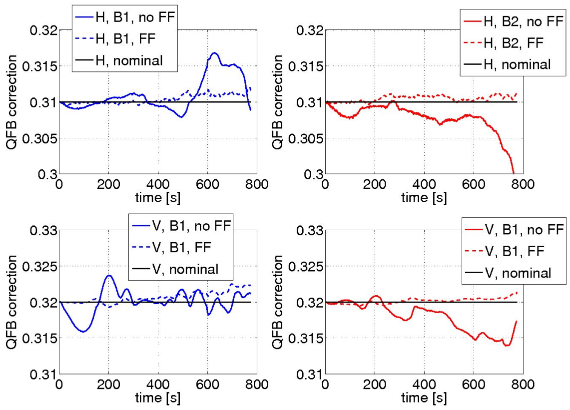

Figure 7: Example of the effect of feed forward during the ALICE squeeze, courtesy of N. Ryckx

For the orbit feedback, the feed forward has been also regularly done in the V plane, allowing a reduction of the strength of the RT trims from 10 to 3 μrad.

Unfortunately, the horizontal plane was not feed forwarded because of a not yet understood effect. The orbit feedback is pushing the orbit in the horizontal plane, inducing a drift of the tune in H which has to be compensated by the tune feedback, Figure 8 and 9

In this case, the tune feedback cannot be switched off and the real time trims cannot be incorporated.

High gain test

One of the beam dump attributed to orbit feedback instabilities was due to the test of a higher gain for the controller. The details of the tests have been presented by J. Wenninger[2]. During the squeeze, one can observed clear orbit excursion spikes, which will start to become a problem with tight collimators settings. When investigating possible cures, the orbit feedback was tested in operation with a higher gain, quite successfully in the first part of the squeeze where feed forward was performed, but driving instabilities during the squeeze of IP2 to 1 m. As a result of the test, it was proposed the following sequence of actions:

- perform a test squeeze with high gain and low intensity
- apply feed forward based on a high gain test to have good measurement
- if the feed forward is successful, operate the orbit feedback with lower gain and high intensity (more compatible with machine protection requirements.

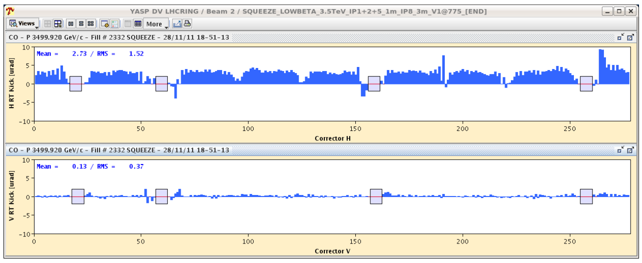

Figure 8: Example of real time trims during the ALICE squeeze, the H orbit is pushed outside.

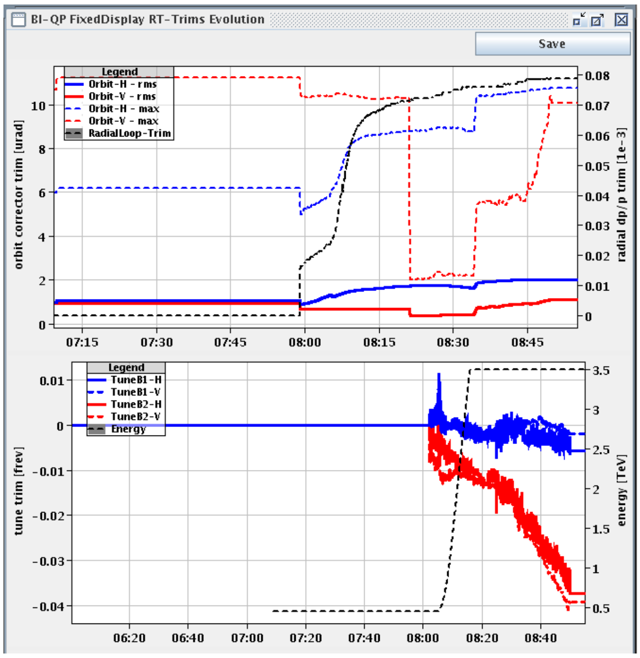

Figure 9: Corresponding compensation of the tune drift by the RT trims of the tune feedback.

SUMMARY

When looking at the statistics of the beam dumps, it is possible to identify the main problems related to tune and orbit feedback. Most of the dumps that occurred this year should be avoided next year thanks to a change of the QPS triggering threshold and a modification of the BBQ hardware to avoid the saturation effect. With the statistics of this year, we should be left with only 2-3 beam dumps due to problem of tune measurements. A new method, combining transverse damper gating and BBQ gating , is proposed to be tested at the beginning of the run to overcome the difficult cohabitation of the ADT and tune measurement system. The regular use of feed forward during the run allow to limit the amplitude of the real time trims and allowed to keep the beam stable even without feedbacks when the system was at the limit, but to be even more efficient the problem of the orbit feedback pushing the orbit in the horizontal plane will have to be sorted out.

ACKNOWLEDGMENTS

I would like to thank all the Operation group for the feedback on feedbacks and the help in the preparation of this presentation. I would like also to address a special thanks to M. Gasior, R. Steinhagen and M. Zerlauth for the inputs and explanations.

REFERENCES

[1] R. Denz, QPS - analysis of main problems, areas to target, possible improvements, presentation at this workshop in session 2

[2] J. Wenninger, presentation at LBOC meeting in December 2011.