DISCUSSION SUMMARY OF SESSION 4: OPERATIONAL PERFORMANCE

B. Holzer (Chairman) and S. Redaelli (scientific secretary), CERN, Geneva, Switzerland

Abstract

This paper summarizes the discussions that followed the presentations of the "Operational Performance" session of the the LHC Beam Operation Workshop, EVIAN2011.

INTRODUCTION

The forth session of LHC Beam Operation Workshop was dedicated to the review of the operational performance in 2011. The section included the following contributions:

1) **Aperture and optics measurements and conclusions**, by Stefano Redaelli (BE-OP);

2) **Emittance preservation in LHC**, by Verena Kain (BE-OP);

3) **Intensity ramp-up: 2011 experience**, by Markus Zerlauth (TE-MPE);

4) **Transverse feedback**, by Daniel Valuch (BE-RF).

For each presentation of the session, summaries of the main content of the contributions and of the discussion that followed the presentations are given. In the last session, a summary of the open points and items to be followed up is also given.

APERTURE AND OPTICS (S. REDAELLI)

Summary of the presentation

The presentation gave a complete overview about the beam optics that had been applied during LHC operation in 2011 and the aperture measurements resulting from machine studies. In an instructive table the main parameters that have been used in different periods of the 2011 running during were summarized: The beta functions at the 4 IPs, the crossing angles and the time needed for the different procedures: a very valuable piece of information. In addition, different scenarios were proposed to gain time during the squeeze procedures by reducing the number of intermediate beam optics that are applied between flat top and collision.

The results of beam optics measurements were presented in detail and it has been emphasized that the beta-beat in the case of the different luminosity optics that have been used in 2011 could be limited to about $\Delta\beta/\beta \approx$10%. The correction of coupling as well as feed-forward corrections for the tune drift during the squeezing were explained. In this context it has been proposed to perform a part of the squeeze procedure already during the acceleration and establish a combined "ramp & squeeze" operation.

The second part of the presentation dealt with the aperture measurements. Summarizing briefly the results here the available aperture at 450 GeV injection energy is in the order of 12-13 sigma in both transverse planes with values of 15-16 sigma in the triplet regions. At 3.5 TeV operation, the interaction regions at IP1 and IP5 have been studied in detail. The values of 18-19 sigma that are measured are considerably larger than had been expected and give very comfortable space for further improvements of the machine performance via smaller values of β^* or increased crossing angles for a possible 25 ns bunch spacing. In particular, the additional margins found in 2011 allowed to push the β^* in IP1/5 from 1.5 m to 1.0 m for a 50 % increase of luminosity that was essentially transparent for the beam operation.

It has to be mentioned however that the aperture measurements were performed on one side of the bump geometry only and for completeness and safety a full measurement will be needed during the re-commissioning period in 2012.

Summary of the discussion

J. Jowett asked if we could merge the settings after the commissioning of the squeeze in IP2 to achieve simultaneous squeeze in all IPs, which would allow saving the additional 13 minutes that the squeeze took in IP2 in 2011 (the IP2 functions follow after the other IPs, so the times add up). *S. Redaelli* replied that it is certainly possible to recommission the squeeze for the ion operation with simultaneous functions in all IPs, to avoid the problem of consecutive squeeze. On the other hand, this requires building a new "beam process" that affects also the setting functions in the other IPs. There is therefore a potential the risk to repeat the MP setup in case the machine is not reproducible. *S. Redaelli* reminded that in 2011, this option was considered but finally disregarded because the time gained per fill with simultaneous squeeze in all IP did not justify the additional commissioning time required for validating a new beam process. The modular approach to add the IP2 squeeze without changes in the other IPs was considered overall more efficient. This should be re-discussed for 2012.

O. Brüning asked why the aperture in units sigmas is different between injection and top energy. *S. Redaelli* replied that the optics, orbit and energy are different but the aperture computed in mm is the same within a couple of millimeters. The aperture in unit sigma is expressed for conve-

nience and for direct comparison with the collimators settings.

J. Wenninger commented that, in view of collisions between main and satellite bunches in ALICE, we might consider a partial squeeze in IP2 during the proton run. *S. Redaelli* replied that this will pose no problems (we did the same in IP8 in 2011). The length of the squeeze will be dominated by IP1 and IP5 anyway (to be confirmed by detailed setting preparation).

R. Assmann commented that measurements at 3.5 TeV are done at one side only and should be repeated on both sides. S. Redaelli agreed and indeed he had this comments in his slides (not shown due to lack of time).

R. Assmann also commented that loss maps cannot be used for aperture measurements. There could be complicated single-side halo building up in some cases, so we cannot always guarantee that the aperture is probed on both sides with loss maps.

EMITTANCE PRESERVATION IN LHC (V. KAIN)

Summary of the presentation

The talk summarized the emittance measurements that had been performed during machine studies and routine LHC operation. Starting from the wire scanner data in SPS flat-top, the emittance data during / after LHC injection, the ramp and finally the data obtained from luminosity runs were compared to investigate possible sources of emittance blow up in LHC. It had been pointed out that during the most critical procedure, i.e. the injection of the two beams no emittance blow up could be observed within the measurement tolerances. However a steady slow increase of ϵ in the two transverse planes has been seen during the injection plateau, which is in reasonable agreement with the expectations from intra beam scattering processes. A slow lengthening of the bunches during the 30 minutes of beam injection also had been observed and as in this case it is stronger than can be expected from pure IBS it has been pointed out that further investigation will be needed to follow up this effect.

For a number of fills the emittance has been measured during the ramp and unlike to the injection case or the stable fills at collision an unexplained blow up of ϵ of up to 20 % is observed. In machine studies this effect has been investigated in more detail and using test-ramps with bunches of different initial emittances it is concluded that the absolute increase of ϵ is independent of its initial value.

It has been concluded that the problem will need further investigation during routine fills and dedicated machine studies in 2012. As a prerequisite a faster and well-calibrated BSRT system will be indispensable, a reliable rest gas ionisation monitor and improved settings for the wire scanners to obtain better fits.

Summary of the discussion

Y. Papaphilippou commented that a possible solution to improve the spread on SPS wire scanner measurements is to look offline into the database and not in the application (error on fit and settings of the user). Yannis also asked which models are used for the IBS evolution. *J. Jowett* replied that simulations assume Gaussian bunches transversally but non Gaussian longitudinal. Yannis thinks that this is a good approach.

Triggered by a question from *O. Brüning*, *V. Kain* commented that the blowup during the ramp takes place at all energies and not only at the beginning of the ramp, so it cannot be related (only) to dynamic effects at the beginning of the ramp.

G. Arduini stated that we need definitely to be able to trigger wire scanner measurements during the ramp with finer time resolution.

E. Bravin commented that it is normal that the BSRT and the WS measurements give the same blowup because the BSRTs are calibrated with respect to the wire measurements.

INTENSITY RAMP-UP: 2011 EXPERIENCE (M. ZERLAUTH)

Summary of the presentation

The presentation reviewed the steps in single bunch intensity and mainly in stored number of bunches that had been performed during the 2011 LHC running period: Starting with three bunches for machine protection tests and collimator loss maps, the intensity was increased following a well defined procedure in steps of 8, 32, 64, 136 and then 200 bunches, requiring 20 hours of stable running per step. This procedure required a minimum of 3 fills yielding a total of 20 hours of running in stable beams per step and was accompanied by checks by the rMPP team to assure machine protection. The procedure lasted 10 days, then a further intensity increase had been performed in steps of 200 bunches.

In mid April – after another period of 10 days – 1020 bunches could been stored in the machine for the first time. The final intensity that could be stored in 2011 has been reached after switching to 50 ns bunch spacing and the first successful fill storing 1380 bunches could be delivered end of June. The major problems that had been encountered during this period of intensity increase were summarized: They were mainly related to UFOs and R2E related problems. Other difficulties like false positives in the RF input coupler system or tight BLM thresholds could be over come soon by technical means.

The conclusion of the presentation was, that the main delays of intensity increase in 2011 were related to the follow up, understanding and mitigation of the intensity related problems (UFO, vacuum, SEUs). It was concluded that a similar procedure of intensity increase and machine protection checks in 2012 will be followed, but based on the

positive experience the full bunch pattern of 1380 bunches should be available in the machine within three weeks.

Summary of the discussion

The issue of BLM threshold settings for 2012 triggered some discussions. *B. E. Holzer* proposed to keep them as they are at startup and only change them if needed. *R. Schmidt* commented that, if we go to 4TeV in 2012, we will gain on experience with BLM threshold scaling and this will provide valuable information for higher energies.

R. Assmann stressed that the BLM thresholds are too tight in collimation regions and can be relaxed. This should be followed up in preparation for the 2012 operation.

R. Assmann wondered why we should still spend about 20 h for the steps in stored energy where we have been already. *M. Zerlauth* replied that we could indeed gain in this reset. The details for the time to be spent at each step will be re-discussed once the baseline for 2012 has been defined in this respect. Also note that the 20 hour request only applied for beam intensities higher than 640b.

B. Goddard reminded that the 2012 ramp-up strategy must take into account the granularity of number of bunches per train in order to avoid too big jumps. The required tests for the transfer lines must be taken into account.

R. Assmann requested to have special BLM threshold configurations for quench tests. These tests are essential to understand the LHC performance and presently it is very difficult to perform them because we are limited by dumps triggered by BLMs.

TRANSVERSE FEEDBACK (D. VALUCH)

Summary of the presentation

The talk summarized in a clear and understandable way the technical set up of the ADT system, its layout seen from the CCC and the different ways how it is/can be used for LHC operation: To damp injection oscillations and oscillations from beam instabilities and to clean the injection and abort gaps. It has been pointed out that while the injection gap cleaning is working without any draw backs, the first tests concerning the abort gap cleaning in 2011 showed a slight excitation of bunches outside the abort gap. This might result from possible signal reflections and still has to be understood. A strategy of how to apply the cleaning procedure on beam during collision runs will have to be defined for the next LHC run period.

A proposal for a further very promising application of the ADT system has been presented: the batch selective excitation of the beam. Using white noise to excite a certain number of bunches, fully controlled steady particle losses can be created. Possible applications are the measurement of aperture limits, quench tests and mainly to provide a fast and very elegant way to measure loss maps that are needed to check routinely the hierarchy of the LHC collimation system.

On a mid term basis it will be studied whether the ADT system can also be used for tune measurements, using either the residual noise in the beam or witness bunches that will be damped less - or will even be excited - for diagnostic issues.

Summary of the discussion

B. Holzer commented that, if the gain switch mechanism will not be implemented, ADT pilot settings will not be adequate.

W. Hofle commented that the cables were identified as source of noise. But there is additional noise coming from the satellite bunches. In response to a question by *E. Shaposhnikova*, Wolfgang stated that the threshold of satellite bunch population to avoid problems is in the range of 1e-4 of the main bunch intensity (for the satellite bunches the main bunches). Wolfgang therefore recommends to take this aspect into proper account before deciding on satellite bunch schemes for physics fills with high intensities.

B. Holzer asked whether the problems with the cables can explain the effect of damper on the luminosity lifetime. *D. Valuch* replied that this is not the case because they are pickup cable (on the other hand, there could be some reflection on the drive cables).

OPEN POINTS AND FOLLOW-UP ITEMS

Optics and aperture

- Do we start the 2012 commissioning with combine ramp and squeeze?
- What is the desired β^* value for physics fills in LHCb?
- Do we start with an intermediate β^* value in IP2 for main-satellite collisions?
- Requirements for aperture measurements in 2012: (1) Repeat injection measurements, global and local in the triplet region; (2) Perform off-momentum measurements at injection; (3) Perform local IR measurements at top energy with the final value of β^*, for both sides of the triplet aperture.

Emittance preservation in LHC

- Setup automatic triggers of wire scanners at defined ramp times
- How to improve the calibration of the BSRT (at least for relative measurements)?
- We need to schedule dedicated beam tests for emittance blow-up studies as it is not possible to perform them with the wire scanner with large beam intensities.

Intensity ramp-up

- We need to establish a strategy for the setup of BLM threshold in 2012. Should we keep the same values than at 3.5 TeV even if we operate at 4.0 TeV and only change them if it is needed?
- We need to increase BLM thresholds in collimator regions.
- It would be useful to setup global ”relaxed” threshold conditions for special quench tests.
- How many hours in stable beams do we need to validate intermediate intensity steps that were already validated in 2011?

Transverse damper

- It was agreed that the controlled blow-up technique for loss maps will be commissioned as a part of the initial beam commissioning in 2012 and not during MD time.
- The ADT team requested that dedicated commissioning time must be scheduled for the transverse damper for every significant step of single bunch intensity.
- The requirements for new OP applications for the ADT controls are required.
- Strategy for abort gap cleaning: do we really need it?
- How can we exploit in the best way the available ADT diagnostics (many data buffers could be useful for various purposes)?