LHC-Beam Commissioning Working Group

Notes from the meeting held on
8 June 2010

Present: Gianluigi Arduini, Ralph Assmann, Wolfgang Bartmann, Roger Bailey, Chiara Bracco, Andy Butterworth, Rama Calaga, Pierre Charrue, Ed Ciapala, Guy Crockford, Laurent Deniau, Lene Drosdal, Massimo Giovannozzi, Brennan Goddard, Per Hagen, Wolfgang Höfle, Lars Jensen, John Jowett, Malika Meddahi, Elias Metral, Gabriel Mueller, Giulia Papotti, Mario Pereira, Laurette Ponce, Bruno Puccio, Stefan Roesler, Adriana Rossi, Mariusz Sapinski, Rüdiger Schmidt, Elena Shaposhnikova, Katarina Sigerud, Matteo Solfaroli, Marek Strzelczyk, Benoit Salvant, Ezio Todesco, Joachim Tückmantel, Jan Uythoven, Daniel Wollmann.

Excused: Carmen Alabau, Reyes Alemany, Tobias Baer, Helmut Burkhardt, Oliver Brüning, Bernd Dehning, Octavio Dominguez, Lyn Evans, Stephane Fartoukh,Massimilano Ferro-Luzzi, Kajetan Fuchsberger, Rossano Giachino, E. Barbara Holzer, Werner Herr, Delphine Jacquet, Verena Kain, Mike Lamont, Thibaut Lefevre, Yngue Levinsen, Alick Macpherson, Ryoichi Miyamoto, Mirko Pojer, Stefano Redaelli, Ralph Steinhagen, Frank Schmidt, Rogelio Tomas, Glenn Vanbavinckhove, Walter Venturini Delsolaro, Jörg Wenninger, Simon White, Uli Wienands, Marco Zanetti, Frank Zimmermann.

1- Comments and follow-ups from last meetings

- Pierre Charrue: Since Monday 7 June, 16h00, the LHC "BEAM SETUP" accelerator mode is set to RBAC-OPERATIONAL. If there are any questions / concerns, or additional information needed about the current configuration for OPERATIONAL and NON-OPERATIONAL flags of the different LHC modes, please do not hesitate to contact <RBAC-support@cern.ch>.
- Lars Jensen and email from Rhodri Jones and Thibaut Lefevre: A bug in the software of the LHC abort gap monitor combined with insufficient hardware interlocks has led to severe damage of both of the installed photomultiplier tubes and associated electronics. This happened when the software detected an energy greater than 3.5 TeV, and set the bias voltage to its maximum value. With the currently installed power supplies this value is 10kV, over double the voltage that the PMT can handle. New power supplies were already on order to correctly adapt to the PMT range to avoid any such overvoltage and should arrive within the next week. A spare PMT and electronics was installed to replace the damaged system for Beam 2, but Beam 1 does not currently have a functional abort gap monitor. A second spare PMT is already on order, but delivery time is stated as being 2 months. Fortunately, colleagues at Lawrence Berkeley lab. have now shipped a similar PMT which will be tested and installed as soon as possible.
  First investigations on the missing signal on the B2 BSRA monitor seemed to indicate an alignment problem. An access in P4 was taking place at the time of the meeting to investigate the problem.
- Ezio Todesco: concerning the new ramp at 10 A/s, the measurements on the usual dipole at 2 A/s will be available next week. Meanwhile, it is advised to keep the b3 correction which is currently applied.

- Mariusz Sapinski: This morning, the commissioning of the LHC BGIs (on beam 2 only) has been started and led to excellent results. See the measured profile. It was done with gas pressure 2e-8 and two nominal bunches in the LHC.
- Lars Jensen: Beam time was devoted last night and this morning to continue the BI commissioning for high intensity. Measurements on low/high gains (switching at about 5-6e10) for the BPM system continued and more results will be available in the coming days.

2- Highlights / Issues from the last week of operation – Gianluigi Arduini (slide)

Most of the week end was spent in recovering from the Technical Stop and qualifying the ramp and squeeze for the 13 bunches.

Issues:

Orbit feedback: Although off, beams were lost twice at 3.5 TeV : i- due to reference going to zero suddenly during physics coast; ii- due to unwanted corrections during momentum scan for chromaticity measurements.

Temporary solution: Block the real time input of the FGC and real time output of the tune and orbit feedback at the end of the ramp. Stephen Page has prepared and tested a new version of the FGC gateway software with the feature to prevent changes to the real-time references. When enabled, the real-time references will be held and any values subsequently received will be ignored. At present there is no way for the feedback server to know that the gateways are ignoring the values that it sends. Therefore, care should be taken to only enable the feature when the feedback is off.

It was stressed that reliable operation of orbit and tune feedback is mandatory for operation at higher intensity so this needs to be understood and fixed. **Follow-up: Rhodri Jones**.

Investigations on what happened have started and seem to indicate a configuration/user-input related issue rather than an error in the OFC computation. Ralph Steinhagen proposed to 1) find and eliminate the source of the undesired user inputs to the OFC and/or to improve their reliability and 2) regularly incorporate the accumulated FB states and trims as LSA functions (e.g. before start/after end of ramp, squeeze, before physics, etc.).

A new optics including the Beam 2 dispersion orbit function is ready for deployment and test. This configuration error is exploited only in the case of OFB 'on' and if large dispersion orbits are generated (e.g. Q' measurements).

Revisiting the squeeze sequence: Last week end, following observed tune drifts leading to the loss of one fill (B2V), the squeeze has been re-established in steps (9, 7, 5, 3.5 and 2 m) with reduced intensity. Tune/chromaticity/coupling orbit corrections incorporated.

SW issues:

- Problems with the sequencer not stopping after the execution of a task;
- Actual Trim application: Mario Pereira removed the unintended systematic increment; Concerning the "Time Period" feature, investigation is in progress;
- Number rounding-off: Propagation of an LSA bug through some applications (e.g. Lumi-scan): being worked-on.

Operational procedure: An updated procedure is now available on the coordination web page.

Noisy nQPS board on A25L1 (caused two trips of Sector 81) – fixing on going.

Relative octupole sign for Landau damping: important to sort out in order to get sufficient strength for Landau damping –see Elias Metral's presentation.

To note: Technical stop of 4 days will lead us to re-start on Fridays, which might result to an even lengthier re-start. **Action: Mike Lamont**.

3- Single bunch instability studies at 3.5 TeV – Elias Metral (slides)

Elias Metral summarised the 3 experiments done during the ramp with high intensity.
A reminder on transverse single bunch instabilities was given. Head tail instabilities appear when Q' is different from 0. Q' has to stay as small as possible not to excite the high order head-tail modes, but be still positive (if no feedback is used). This is the regime in which the LHC operates, if the model of the impedance is correct, the machine is below the TMCI intensity threshold. If the Q' is a few units, the rise time will be much faster. The theory and the head tail simulations performed for the nominal case at 3.5 and 7 TeV were presented. The simulation is being checked for a larger number of turns.
The very interesting results from the LHC experiments were compared with the predictions and showed promising results for curing the observed instabilities.
In Summary:
It seems that the observed single-bunch instability with ~ 1E11 p/b at high energy is a Head-Tail instability of mode m = - 1 (as predicted for Q_x' ~ 6, as it was the case during the MD on 17/05/2010).

- Measured instability rise-time ~ 9.8 s (with 10 A in the octupoles): the simulation prediction with the correspondent beam and collimators settings at 3.5 TeV is ~ 4.3 s, with neither intrinsic nonlinearities nor Landau octupoles;
- The bunch can be stabilized by Landau damping with a current in the octupoles of ~ 20 A (with 10 A, B2 was unstable): We have some theoretical predictions for this as well but not yet for the MD case => HEADTAIL simulations are running and the results should come soon…
- **For the nominal beam at 7 TeV/c, a rise-time of less than 1 s is predicted for Q_x'~6.**

Elias Metral only presented the observed single-bunch instability. But good agreements were also obtained for the dedicated MDs on transverse coherent tune shifts vs. intensity.

Brennan Goddard: is the time between the decrease of the octupole strength and the start of the instability consistent with the simulations? tbc
Ezio Todesco: Octupoles have non-negligible hysteresis which is to be taken into account close to 0 current.
Elias Metral: Stabilisation mechanisms are: less intensity, larger beam size, as observed during the MD.
Elias Metral: there were good agreements between the model and the measurements, at the exception of the larger tune shift measured during the over injection. This discrepancy is not yet fully understood and could be measured again now that the conditions are cleaner.
Ralph Assmann: Can we now switch all octupoles during operation to prevent beam losses? Elias Metral: This is a trade-off with the non-linearity effects which arise from the resulting larger tune spread and can lead to beam losses (e.g. due to resonances). Also the octupole sign to be used is still under investigation, taking into account the optics constraints. Tests are to continue, and could be done as well with lower intensity during the upcoming ramps.

4- Controlled longitudinal beam blow up in the LHC– Elena Shaposhnikova (slides)

The LHC longitudinal emittance of the nominal beam is 0.7 eVs (inj.) and 1 eVs (after filamentation) at 450 GeV. It is 2.5 eVs at 7 TeV (controlled emit. blow-up during ramp). To have the same thresholds for longitudinal beam stability as at 450 GeV with 0.7 eVs and as at 7 TeV with 2.5 eVs, 1.75 eVs was proposed at 3.5 TeV.
Calculated loss of Landau damping due to low frequency inductive impedance does agree very well with observations made in the LHC.

This instability leads to undamped bunch oscillations (quadrupolar in the LHC -as dipolar instability is damped by phase loop). It has a weak dependence on the voltage but a strong dependence on the energy and on the longitudinal emittance.
Emittance of 0.6 eVs from the SPS is a good compromise to minimise losses at the Flat Bottom and to ease the controlled emittance blow-up during the ramp in LHC. A controlled emittance blow-up in the SPS is needed and now used during injection into the LHC.
For the LHC longitudinal emittance, 0.7 eVs will be sufficient for longitudinal bunch stability at 3.5 TeV, but there are other limitations (IBS). Also, controlled blow-up is more difficult for smaller synchrotron frequency spread (small bucket filling factor), but a small filling factor is required to avoid particle losses during blow-up and ramp. A relative incoherent synchrotron frequency shift for intensity of 10^{11} and short bunches (0.8 ns) is ~ 0.03, i.e. comparable to the spread at high energies (without blow-up).
Commissioning steps: The same method and noise generation as in SPS will be used - band-limited noise inside synchrotron frequency band injected through phase loop.
The experiments performed yesterday at 450 GeV were explained and the first results were very successful. The tests will continue tonight, this time during the ramp.
In summary:

- The noise generation hardware and software work as expected
- Successful first tests (at 450 GeV) of controlled blow-up to a given value by controlling
  - the frequency spectrum
  - the amplitude of the applied phase noise
  - time of noise application

Next step – Emittance blow-up during the ramp (tonight): phase noise with a bandwidth corresponding to the fixed relative synchrotron frequency spread (fixed filling factor) for low and high intensity bunches.

Rüdiger Schmidt: How this controlled longitudinal emittance blow up is coupled with the transverse instabilities observed? Elias Metral: if the bunch length is longer, the rise of transverse instability will take longer.

Elena Shaposhnikova: At flat bottom the beam can not be blown up as it already occupied the full bucket, otherwise beam loss will be generated.

5- A.O.B

Daily 8:30 HWC meeting in the CCC conference room (09:00 at weekends).

Daily 17:00 Beam commissioning meeting /OP, CCC glass box.

Next meeting: **15 June 2010,** 15:30, 874-1-01. Agenda will be sent in due time.

Malika Meddahi