SUMMARY OF SESSION 2: OPERATIONS

G. Papotti, J. Wenninger, CERN, Geneva, Switzerland

Abstract

The second session of the 6th LHC Operations Workshop, Evian2015, was dedicated the analysis from the OP point of view. The session included the following five talks:

1) **Cycle**, by M. Solfaroli Camillocci;
2) **Injection**, by D. Jacquet;
3) **Feedbacks**, by L. Ponce;
4) **Q and Q' snapback, decay**, by M. Schaumann;
5) **Optics model**, by A. Langner.

For each presentation of the session, summaries of the presentation and of the discussion that followed are given. A summary of the critical points and open actions is also given.

CYCLE

M. Solfaroli presented the analysis for the time spent in the different phase of the cycle. The analysis was carried out looking only at proton physics fills, and the beam mode changes were taken from the logging. Beam dump, rampdown and setup modes were not analyzed in details as most information can be found in *A. Apollonio*'s presentation in these same proceedings. The Turn-Around Time (TAT) is defined as the time from the end of Stable Beams to the start of the next Stable Beams. The most common TAT is between 6 and 7 hours (50 ns beams had shorter TATs on average). The mean time spent in Injection Probe mode is 24 minutes, while Injection Physics lasted twice as long; longer times are spent at injection depending on a number of independent factors (transfer line steering, beam availability from the injectors, ...). The time spent in Prepare Ramp is 10 minutes on average, but long tails in the distribution are observed and are mostly due to allow cryo transients to stabilize. The length of Ramp and Squeeze coincides with the length of the beam processes. The mode Adjust lasts ≈14 minutes on average and the large spread observed is probably due to different strategies applied by different shift crews. More agreement among shift crews is encouraged, e.g. concerning optimizations to be done before or after Stable Beams are declared. The comparison with 2012 indicates very small differences. Among the proposals for changes in 2016, the Combined Ramp and Squeeze (CR&S) is put forward. It was successfully proven in MD time in 2015 and used operationally in the intermediate energy run. A possibility is to squeeze until 3 m, as only at that beta* optics corrections are starting to be needed. As optics corrections in the ramp were performed, a more aggressive scenario would allow squeezing down until 1.2 m, feasible both for aperture and optics. This would allow a gain of ≈6–10 minutes. *M. Lamont* asked about the TAT outliers: while the fastest possible TAT is <3 hours, he wondered how the extra 3–4 hours are spent. *G. Arduini* agreed, pointing out that *A. Apollonio*'s analysis indicated 6–7 hours of average fault time. *M. Solfaroli* replied that it is spent solving problems and performing precycles. *W. Hofle* suggesting deepening the analysis distinguishing what is operational efficiency or procedural, and removing time dedicated to other studies and setups. *J. Jowett* stressed that CR&S is very promising, but also indicated worries about the ion setup: the IP2 squeeze needs to be added, and the total commissioning time is short. *M. Solfaroli* replied that IP2 could be pre-squeezed earlier in the ramp, and the commissioning time should be equivalent to the one for a squeeze. After a question by *M. Pojer*, *R. Tomas* recalled very good results in MDs concerning optics measurements during the ramp, that could be achieved despite limited BPM performance, and indicate no issues there.

INJECTION

D. Jacquet analyzed the time spent at injection. The time spent injecting physics beams is about twice more than the theoretical one calculated multiplying the number of injections and the length of the SPS supercycle (e.g. 1h30 vs 37 min for proton physics fills). A supercycle fully dedicated to LHC injection is not possible as 3-4 extra seconds are needed for the case of interleaved injections (10 extra seconds for single ring injection as the results for the IQC analysis are required to generate the next injection request). In case of stops or delays, a dedicated supercycle would penalize too much the SPS North Area (NA) physics. In case beam setup and physics filling can be sped up, then an advantage of the dedicated supercycle would be a better quality for the NA beams. A total of 28 h we spent in setting up beams at the injectors; 3 different types of beams for each filling certainly did not help. A better synchronization between LHC and injectors coordination would also help bring down this component. It is also noted that the TIDV intensity interlock worsen with 288 bunch trains. About 20% of nominal beam requests are dumped by the SPS BQM. An additional penalty was due to the limit to 144 bunches/injection, which required more injection requests. An optimization of the filling schemes is also envisageable to reduce the number of supercycle changes at the SPS (each change takes a few minutes). The use of two trains at the beginning of filling allowed steering the transfer lines on the fly instead of dumping for dedicated fills. This allowed gaining several hours, as 50% of steering was done while filling! The IQC gave unreliable analysis throughout the year, and the many warnings and errors resulted in a big risk to disregard real problems. The main issues are with the warning for injection losses that come too often (appropriate scaling is required!), and the detection of successful injections which worsened with respect to Run1 due to a less reliable BQM LHC. It was noted that the wire scanner measurements are too slow and with the improved BSRT they are questionable, while Q and Q' measurements have much improved since Run 1. A few intensity limitations appeared: from cryogenics for beam screen cooling, TDI.B2 vacuum and MKI.B2 vacuum, instabilities (partly solved by ADT setup). Note that dumps at injection at times generated additional delays due to the need to wait for cryo to stabilize. ADT diagnostics is missing. *C. Bracco* commented that 2015 was a transitional year for the IQC: it is now an operational tool, but more input would have been required from ABT. *V. Kain* and *C. Bracco* highlighted different scaling of the TDI losses depending on the cause being transverse or longitudinal. *V. Kain* added that the IQC thresholds were based on the 2012 experience and should have been updated in 2015. *M. Lamont* asked whether the response time could be reduced and *V. Kain* replied that the analysis itself is fast, but the data collection is not. *S. Redaelli* and *R. Schmidt* questioned whether the injection process was safe or not given the ignored IQC warnings. *D. Jacquet* and *J. Wenninger* recalled that the IQC is not there to protect, and the BLM warnings in the IQC are discussed, not the BLM threshold themselves. *B. Goddard* added that the IQC has information on the transfer line steering quality, which might have been disregarded. The general agreement is that this issue should be followed up by OP and ABT. *M. Lamont* asked about the 20% rejection rate of the SPS BQM. *G. Papotti* mentioned that a new interlock is now present, to check the injected intensity, and that a quick chat with *T. Bohl* highlighted that he was called less often for beam setup. *M. Pojer* stressed the importance of communication between coordinators of LHC and injectors. The injector chain should be included and informed of the planning, to help reducing beam setup time. *B. Goddard* highlighted the good results on time at injection, which did not substantially increase in 2015 despite the TDI hardware limitations.

FEEDBACKS

The LHC in 2015 profited from 4 tune systems, and 1 orbit feedback system (composed of one service unit and one controller). During LS1, main refactoring took place for the BFSU and the OFC, including the use of new hardware, the migration to FESA3 (which took ≈4 months, and was mostly manual), and code clean up. A major improvement was the creation of a testing framework, such that BI will probably use the same test model for the migration of the BLM and BPM systems to FESA3. A functionality that is still missing is the BFSU dependence on timing: at present, a linear interpolation between different optics is performed, but ideally an actual "play" of function should be performed. The feedbacks are now used reliably through the nominal cycle, and thanks to the increased BPM accuracy and the OFB reliability, the OFB is now used in Stable Beams (allowing to correct for the IR8 triplet-induced orbit drifts, with low number of eigenvalues and reduced gain). Only 3 dumps were caused by the QFB, mostly due to a bad measurement quality, while problems with the OFB could always be recovered. The Q signal has much improved with protons with respect to Run 1, while more issues were observed with ions. The coexistence with the abort gap cleaning during the squeeze is still a problem. The orbit reproducibility was ≈50 μm over 3 months, slightly worse in the H plane because of the IR8 triplet issue. *O. Bruening* asked to clarify the orbit reading movement in IR3. *J. Wenninger* and *L. Ponce* replied that it is clearly correlated with temperature and with the crate in which the electronics is housed. Concerning the IR8 triplet movement, *J. Wenninger* added that is it still under investigation: the movement is measured by the wire position system, and as soon as the triplet is emptied of helium, the movement stops, but no correlation with cryo actions could be found; the period of the oscillations is 8 hours, very predictable and reproducible.

Q AND Q' SNAPBACK, DECAY

The magnetic field multipoles drift when the magnets are on a constant current plateau, giving a decay of Q and Q', and a snap-back at the start of the ramp. Out of the many parameters that describe the decay, only the initial value and amplitude decay are used as fit parameters. The Laslett tune shift could be measured, with a clear proportionality to intensity. The fit parameters show a large spread between fills; the corrections are reproducible to 30%. The snap back is characterized by an exponential decay to the original hysteresis curve; it lasts 30–60 s depending on the initial amplitude of the injection plateau. A parameter drift during the year is observed, even after removing the correction for the Laslett tune shift which affects the offset, but is not as much correlated to the time constant. It was noted that only one time constant for the whole year is applied, and the offset is not fed forward. The Q' was measured only for a few fills and it is suggested to repeated it more often along the year. The curves are reproducible to ±2 units. A small imperfection in the persistent current model exists below 3 kA, but it does not impair the Q' control. The tunes at injection are under control, although the decay is not fully reproducible and influenced by beam intensity. Concerning the snap-back, the manual trims are linearly incorporated, but contain a certain leakage of the FiDeL model. It was noted that the higher beam intensity degrades the snap back correction and there is an unexplained drift of the time constant with beam intensity. *M. Lamont* asked whether for the Laslett Q shift the 1/energy dependence is included, and *M. Schaumann* answered positively, adding that some drift is still present for the time constant. *A. Siemko* asked whether, thanks to the improved corrections, the time-consuming precycle is still mandatory. *M. Solfaroli* stressed the need for the reproducibility of the Q' decay. *M. Lamont* was positively interested, proposing the option of, for example, a short precycle when coming out of access. *R. Schmidt* agreed, suggesting avoiding going to 0 current in the case of spurious quenches (when the switches don't open). *A. Siemko* promised TE-MPE will study that (only energy extraction without actual quench, at injection current). After a question by *E. Todesco*, *M. Schaumann* replied that in the first few seconds of the snapback, a disagreement with the model in V is still measured. After a comment by *M. Lamont*, *M. Schaumann* replied that the higher intensity takes a longer time to inject, but this is taken into account by the higher initial amplitude. *O. Bruning* asked about the possibility to use the HT for Q' measurements, *R. Jones* replied that the required kick excitation would be prohibitive.

OPTICS MODEL

The achieved peak beta-beating is <10%, with a record <6% in the V planes. The actual beta* was larger than design (82–88 cm), and a waist shift by ≈20 cm is present. For a waist shift correction in 2016, the team needs to update the codes, and fully online k-modulation measurements are also required. It was reported that the IR8 triplet movement disturbed the dispersion measurements. The updated strategy for optics commissioning includes calculating local corrections from turn-by-turn and k-modulation measurements, then another campaign of measurements, and finally global (and local) corrections. The ballistic optics was tested in MD time, and it looks promising for the 2016 commissioning as it allows disentangling triplet errors from other IR errors, and calibrating the IR BPMs. It should be carried out as early as possible. The optics team supports the CR&S. It is unclear if the optics stability is sufficient to reuse optic corrections from one year to the next one. The non-linear IR errors could be corrected (note that at RHIC this increased the integrated luminosity by 4%); this could be done at the end of the optics campaign. In 2016, a total of 7–8 shifts for optics measurements and corrections should suffice. After a question by *J. Wenninger*, *R. Tomas* replied that the main measured optics are available in the database: *D. Jacquet* prepared the upload, while *L. Malina* prepared the download. *V. Kain* asked about the availability of the measured optics at any machine element (e.g. at BPMs, collimators), and *T. Persson* replied that that part is included in the online model. On the subject of optics reproducibility, *J. Wenninger* suggested for extra measurements to be collected by OP for the OMC team parasitically. *J. Wenninger* speculated that the quality of the dispersion measurement is possibly impaired by the slow speed of the measurement, and suggested using the 1 Hz orbit data. *R. Tomas* replied that for the turn-by-turn data is required for the normalized dispersion, otherwise the calibration error of the BPMs is not sufficient. *J. Wenninger* suggested running the OFB during the measurement if the IR8 triplet movement is too disruptive. *R. Bruce* asked to confirm that for the MKD-TCT phase advance change there would no overhead in commissioning time.

MAIN POINTS TO BE FOLLOWED UP

Here the list of main points that require a follow up (in no particular order):

- The IQC requires major follow-up by OP and ABT, especially concerning the BLM warning thresholds. Additionally the BQM LHC is to recover its reliability.
- K-mod online measurements are required for optics commissioning.
- The implementation of CR&S for proton physics is widely supported.
- The analysis for longer turn-around times can be improved to highlight possible common causes and delays.
- The phase of the nominal cycle where improvements could bring the biggest gain is injection, both in terms of procedures (e.g. coordination, filling schemes, supercycle optimization, transfer line steering) and software (IQC, BQM SPS thresholds, wire scanner speed). The two initial short trains allowed online steering while filling, and they should be maintained as much as possible to avoid dedicated steering fills.
- The Q and Q' measurement, and the Q and orbit feedbacks have greatly improved since Run 1, especially for what concerns their reliability. Still missing is the handling of functions by the OFB.
- The possibility of skipping the precycle or carrying it out to reduced currents should be studied further.
- It is desirable to devise a new piece of software to correct the intensity dependent Q shift based on the BCT measurement. This would additionally improve the situation for what concerns minimum distance between the H and V tunes, coupling and instabilities that were observed in 2015.
- The IR8 triplet movement should be understood.