LHC DRY-RUNS AND MACHINE CHECK-OUT

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Abstract

During LS1 most of the equipment groups took the opportunity to upgrade, improve and refactor their hardware and software. A particular care is necessary for the operation team during the testing phase before beam commissioning. Some equipment and software tests from the control room have already started early in the year, including the communication with the experiments, RF frequency ramp, LBDS arming sequence etc… The results will be presented. In parallel, regular meetings between OP and the equipment's group have started for the establishment of a working plan for the final machine check-out. The strategy for the machine preparation from now to the beam commissioning will explained.

INTRODUCTION

Since March 2013 the LHC is in shutdown mode and most of its systems are undergoing major upgrades. This will improve their reliability, availability and performance for run II, which is scheduled to start with the beam commissioning phase in February 2015.

Because of the huge number of modifications which have been applied to the various LHC systems during the course of LS1, the 2015 start-up will be similar to the initial LHC start-up in September 2008 and its restart in November 2009. Therefore the same strategy, that had proved its efficiency then, will be adopted. Beside the essential individual system tests by the experts, early tests campaign of operational use-cases is performed by the operation team from the control room. Then a dedicated machine checkout period with full integration tests is planned after the end of LS1. This should ensure a smooth transition from LS1 to beam commissioning.

STRATEGY UNTIL BEAM COMMISSIONING

The operation team has started to organise systems tests from the control room already in May 2014. The aim of starting such a long time before beam is to detect the issues as soon as possible. Then equipment and software team have time for the corrective actions, even for a complete review of the system if need. In addition some equipment like collimators, beam dump and timing systems are running reliability run or stress tests from the control room for several weeks.

Nevertheless, starting systems tests very early also have drawbacks. Lots of the systems are not stable yet and most of the time only partial tests are possible. They will often have to be repeated once the situation is steadier. Finally with the priority given to the restart of the injectors, experts are not always available to help with the tests and solve the issues immediately.

A basic control environment needed to be available and operational already in May 2014 before the dry run. The LSA core applications and services where operational, used to check, trim and drive machine parameters. The LHC sequencer was made operational, and tests sequences could be created and run. The logging service was available so that the logged data for each system could be checked. Page one and DIP gateway were mandatory for communication with the experiments.

The timing system was up and running since the beginning of tests, events could be sent and timing tables triggered.

The period from now to beam commissioning will continue to be dedicated to system tests from the control room. More and more systems will be available and the control room tests more and more complete. The collaboration with the expert will then be essential. This will lead to the transfer line test that will take place at the end of week 6 and at the end of week 8.

SYSTEMS TO TEST

Continuous Interlock Systems Tests

The interlocks systems will need to be tested carefully and as soon as possible. All Beam Interlock System input will have to be tested one by one. There are almost 200 entries, for PIC, FMCM, vacuum, collimators, and experimental magnets, beam position monitors etc…

The tests will be organised following the readiness of the systems. For example, the vacuum interlock test is already planned at the end of September.

This is a huge systematic work that is essential to ensure the machine protection before any beam injection can be allowed.

The Software Interlock System (SIS), even if a bit less critical for safety, also needs intensive testing. The system is quite complex, with a lot of entries with each a proper logic.

RF systems

The RF resynchronisation sequence and RF frequency ramp have already been tested. More ramps are needed for the experiments to test their instrumentation and synchronisation systems, both for ions and protons.

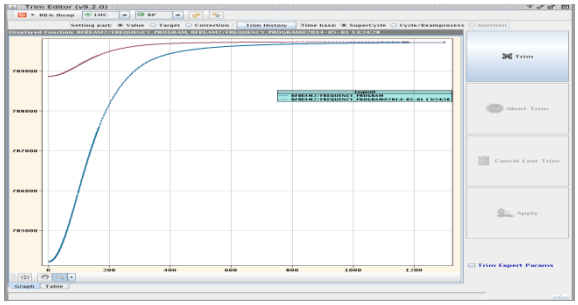

Figure 1: Proton and Ions frequency ramp to 6.5TeV

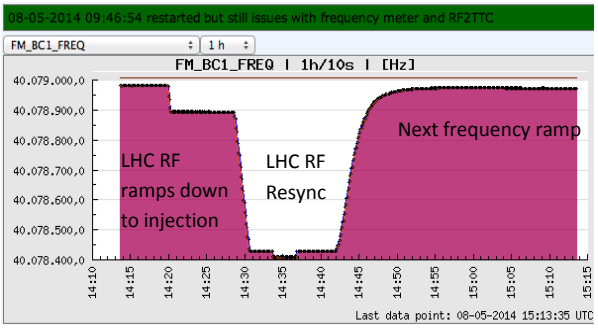

Figure 2: Signal from Alice Frequency meter

Tests of the SPS frequency rephasing with the LHC RF frequency will be organised. All the RF sequences to load and run the operational settings will be tested.

The ADT systems knows a major upgrade during LS1, dry runs will be organised to test the sequences and the control room applications.

Communication with the Experiments

A sequence has been prepared to mimic the consecutive handshakes and beam mode changes of the nominal sequence.

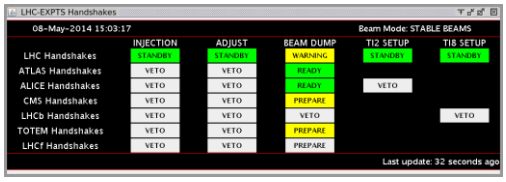

Figure 3: Beam dump handshake with experiments

The reception of the post mortem event by the experiment have been tested. The Safe Machine Parameter distribution to the experiments will need to be checked as well.

Collimators

The collimator tests from the control room have already started. Settings have been generated for the 6.5 TeV cycle, but the handling of critical settings still need to be sorted out. A sequence has been created to drive collimators to parking, injection and ramp position. This sequence is run continuously for several hours; collimators are added to the test pool as soon as available.

New collimators with embedded beam position monitor have been installed and will need to be tested.

The injection protection and transfer line collimator will be tested during the transfer line tests.

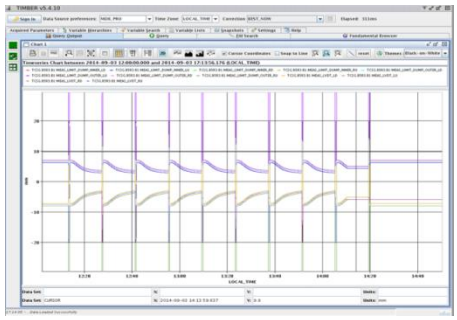

Figure 4: TCSG.B5R3.B1 jaw positions and threshold as logged in timber during reliability test.

Instrumentation

The instrumentation tests have started partially, mainly the BPM concentrators and the acquisition's trigger and synchronisation. Instruments are gradually coming together and the necessary tools will be ready for the transfer line tests. All systems should be ready for control room tests at the beginning of 2015.

Orbit and tune feedback will have a new implementation and intensive tests of the system will be needed.

Kickers

The arming sequence for the beam dump has been modified to adapt to the new interface between the beam dump and the BIS (Beam Interlock System) for the retriggering. A sequence for reliability run has been established, it arms the beam dump, simulate a ramp thanks to the BETS simulator and triggers a beam dump. This sequence is played continuously during several weeks. This first dry run campaign was done with a local BIS loop, it will have to be repeated with the global BIS (with all inputs bridged), and a new version of the TSU.

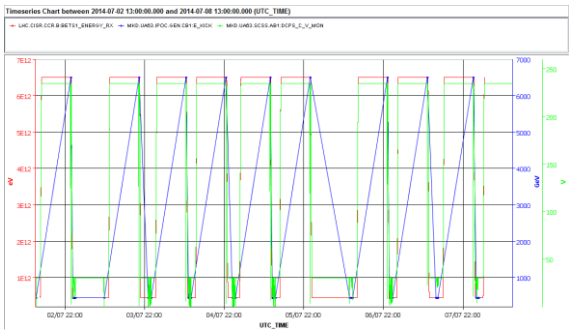

Figure 5: LBDS reliability run

The inject and dump sequence will have to be re-commissioned and the mechanism tested. It will be used during the transfer line tests.

For the MKI (injection kicker), test the pre-pulse from RF, the behaviour with the dynamic destination, the

system interlocks (i.e. the abort gap keeper) and the BIS interlocks.

The AC dipoles and MKQ have stated to be tested but still need some work before being fully operational.

Timing

The timing system has already been tested as needed since the first dry runs: send events, run tables, take mastership over SPS beam and request injection. These tests will need to be repeated after the major timing system upgrade foreseen at the end of October. A new protocol for injection requests will be deployed. A dedicated dry-run will be organised before the transfer line tests. It is expected to perform the beam request from the LHC injection sequencer or the LHC inject and dump sequence during the transfer lines test.

Access System Tests

The LHC access system needs to be tested and validated before any beam can be extracted down to TI2 and TI8.

The access tests are difficult to organise because the system has to be available all the time. Therefore, in June and July five dedicated Fridays have been planned. The aim of this first tests campaign was to check all the input/output signals, and test the new access powering interlock (software interlock that prevent the powering of magnets above a current limit when access conditions are unsafe). Once this validation made, the access system was secured for powering phase II.

To secure the access system for beam, two other tests are still needed. They will by organised during two dedicated week-ends.

During the first one, the system's experts will test the beam mode: ensures that the beam imminent warning sirens are working properly and test the redundant cable loop. The new maintenance doors that allow an access to the access devices while in beam mode will also be validated.

The second week-end, tests by the DSO (Department Safety Officer) will be organised. This is an independent verification of the access system validating that the access system ensures the protection and safety of the staff. This test is mandatory to allow beam in the LHC. If successful, the access system is ready for beam.

FINAL MACHINE CHECKOUT

End of LS1

LS1 stops at the end of week 6, before the dedicated machine checkout planned weeks 7 and 8. By this time, all equipment and systems need to be ready for beam and released to operations. The first week of machine check out will be in parallel with the last tests of circuit commissioning in sectors 45 and 78, this will request careful organisation of the different tests to progress on both activity in parallel.

Objective and Machine Conditions

The aim of this final machine checkout is to run full integration tests: the entire LHC systems will be tested together for the first time. It requires the LHC to be closed and the access system ready for beam. All systems have to be operational, i.e. the magnet circuits qualified individually, PIC (Power converter interlock controller) and QPS (Quench Protection System), beam vacuum system and BIS (Beam Interlock Controller).

Tests

- Final validation of the Beam Interlock System (BIS) verifying all hardware interlocks without beam.
- Final validation of the Software Interlock System (SIS) checking the logic of all software interlocks without beam.
- The beam dump energy tracking system (BETS) under real conditions using the four energy defining sectors and the additional magnets (extraction septa & Q4 quadrupoles).
- Final validation of the LHC beam dump system (LBDS). The test consists in arming and firing the LBDS, once the following conditions have been fulfilled:
    - LHC machine closed, access key in position "beam mode".
    - BIS loop closed.
    - BETS operational.
    - Injection BIS enabled.
- The beam vacuum valves and their interlock logic.
- Final tests of the injection, tune and aperture kickers and the AC dipole.
- Heat runs of all warm magnets.
- Testing the full operational LHC cycle (injection, ramp-up, squeeze, collision, ramp down and pre-cycle) driving all equipment.
- Final tests of all beam instrumentation and their associated applications.

Organisation

The machine checkout is coordinated by Rossano Giachino and Markus Albert of the operations team. There will be an EIC and an operator on shift 24/24 to perform the tests.

A daily 8:30 meeting in the CCC will be organised to:

- review the test results of the previous day
- define the test plan of the day
- negotiate access requests

CONCLUSION

Aside from individual system tests, the operations team has already organised various tests from the CCC with the equipment expert and experiments. It is aimed to start testing systems as early as possible from the CCC to anticipate on software bugs or hardware issues and get some time for fixes. A tight collaboration between OP

and the equipment specialists is mandatory for the tests organisation and follow-up. This will become even more important toward the beam commissioning as more and more systems will be tested together.

The readiness deadline for all equipment and controls is the start of the machine checkout period beginning in week 7.

During the final checkout period, full operational condition and machine closed are needed. The final tests without beam will hopefully lead smoothly to the beam commissioning.