# DRY RUNS AND MACHINE CHECK-OUT STRATEGY

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*Abstract*

The paper describes the structure, organisation and strategies which will be applied to prepare the LHC for beam commissioning in early 2015 after its first long shutdown. Equipment dry runs, sector test preparation and final machine checkout, which constitute the ingredients for a smooth start of beam commissioning, will be explained.

## INTRODUCTION

Since March 2013 the LHC is in shutdown mode and most of its systems are undergoing major upgrades in order to improve their reliability, availability and performance for run II, which is scheduled to start with the beam commissioning phase in February 2015. Although the tunnel work and equipment modifications are still ongoing, the preparations for beam operation have already started in parallel. Because of the huge number of modifications which have been applied to the various LHC systems during the course of LS1, two injection tests, one for each beam, have been scheduled for November 2014 in order to test the beam injection (1 pilot bunch per beam) and perform first measurements with a single pass bunch. Beam 1 will be stopped by a collimator in point 3 whereas beam 2 will go as far as the beam dump in point 6. As a considerable amount of systems has to be operational for those two injection tests, the preparation phase in the form of machine check-out tests and dry runs has already started. The combination of standard machine check-out tests and dry runs has proven to be a successful recipe to prepare the initial accelerator start-up of the LHC in September 2008 and its restart in November 2009. Therefore it will again be used to prepare the machine for its upcoming second run.

## MACHINE CHECK-OUT

The transition phase between shutdown and beam commissioning during which a CERN accelerator is prepared for beam operation is commonly called machine check-out. It consists of testing equipment that has passed all individual system tests (IST) remotely from the CCC (Cern Control Center) by operations in collaboration with equipment experts. Those tests comprise interlock tests without beam, equipment tests without beam as during normal beam operation and tests of the associated controls infrastructure by driving the equipment via the standard application programs. It is a vital ingredient for a smooth start of the beam commissioning phase as meticulous and exhaustive equipment testing generally guarantees high machine availability during the beam setup period.

As it was decided to perform two injection tests (one for each beam), scheduled for November 2014 before starting the general beam commissioning in February 2015, the whole machine checkout phase can be divided into three phases.

### *Phase I – Information collection and planning*

The initial phase which precedes any machine checkout period consists in collecting information about the status of each equipment system and the planned handover dates to operations after the individual system tests have been terminated. The operations coordination team organises meetings with the equipment representatives of all accelerator systems in order to establish a planning, which includes all readiness dates and planned system tests. This planning serves as the basis for the subsequent test phases. During this equipment status inventory phase it may occur that a first coordination takes place in case overlaps or interferences between the scheduled dates of two or more equipment groups are identified.

### *Phase II – Equipment checks for sector tests*

Once an accelerator system, like for example the RF acceleration system, has been released for operational checks, the operations group in collaboration with the equipment experts perform a well-defined and complete set of test sequences in order to make sure the equipment behaves as expected for the various operational scenarios. For the machine checkout exercise in 2014/2015 there will be two test periods due to the scheduled beam injection tests which are organised 3 months before the general beam commissioning period during the month of November. The tests which will be performed follow the machine check-out test planning which is established in the previous phase. As there will be an overlap between equipment testing and testing of the electrical circuits of the superconducting magnets (also known as “hardware commissioning”, HWC), certain equipment verifications can only be performed once all electrical circuit tests on a whole sector have been successfully passed.

As the injection tests are performed with beam, although only with a single bunch pilot beam, the personnel protection system of the LHC, also known as access system, will have to be fully functioning and will have to be certified for beam operation by the departmental safety officer (DSO). The test which provides this certificate is generally known as DSO test. It is scheduled to take place during the weekend of $11^{th}/12^{th}$ October.

### *Phase III – General machine check-out*

The final phase of the machine check-out is scheduled just before the beam commissioning period and will take place during the month of January 2015. During this phase all superconducting circuits will be fully qualified and released to operations to be extensively cycled together. In this final phase the aim is to perform tests of:

- The Beam Interlock System (BIS) verifying all hardware interlocks without beam.
- 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).
- 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.
- 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.
- All beam instrumentation and their associated applications.

During this phase a daily 8:30 meeting in the CCC will:

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

## DRY RUNS

In addition to standard machine checkout tests there will also be a series of dry runs in order to optimally prepare the various systems for beam operation and test the interplay of the various accelerator systems in conjunction with the high level control room applications. The emphasis of these tests is on the communication and controls chain, between low level equipment access and high level application software. Past experience, in particular the initial preparation for beam operation in 2008 and the preparation for the LHC restart in 2009, has shown, that the combination of general machine check-out and dry runs constitutes an ideal recipe to prepare the LHC for beam operation.

Dry runs are conducted by the operations group from the CCC in collaboration with the experts of the equipment being tested. First dry runs on the machine timing system, the B1 beam injection system and the B2 beam dump system have already started in May and shown good overall results. The dry runs will continue until the end of 2014 with a frequency of about one per month. The following table shows the list of scheduled dry runs.

| Date | Program |
|---|---|
| May, W19 | Timing, TI2 BI upstream, BPM concentrators, experiments handshake, beam mode changes, experiments frequency ramps, LHC RF re-synchronisation |
| May, W21 | LBDS arming of B2, new arming sequence, new CIBDS board |
| W24-W29 | LBDS reliability run (B1 & B2) |
| Jun, W25 | LHC re-synchronisation (Linux FECs), LHC mastership (dynamic destination in test mode), TI2 – BI with IQC (possibly also TI8), SDDS, AC dipole, tune & aperture kicker, MCS checks, SMP for beta* and energy |
| Jul, W29 | PM and XPOC |
| Parallel to HWC | Sequence to reset circuits, arm switches, LSA (trim, incorporation, etc.) |
| Aug, W33 | Collimators (+ similar devices), RF beam control, ADT settings, injection cleaning, abort gap cleaning, etc. |
| Sep, W38 | "old" implementation of feedbacks , BLM continuous, global permit loop + LBDS arming + XPOC, experiment interlocks & injection permits,<br>BI sequencer tasks, ALICE frequency ramp, BQM, LHC BTVs, BRANs<br>Start checking EVERY task in nominal sequence |
| Oct, W42 | Vacuum, BIS checks, BCTs, MKI, BLM triggered buffers, new timing system, sector test preparation (injection requests, inject & dump, set machine to injection…) |
| until end of 2014 | profile measurement systems (BSRT, WS), RF cavity control, ADT,<br>new feedbacks |

Table 1: LHC Dry Runs in 2014

## CONCLUSION

During the long shutdown 1 and nearly two years without beam in the LHC, there have been many modifications on the different accelerator systems. All groups have profited from the long stop to apply changes to their equipment in order to improve the reliability, availability and performance of their equipment for the upcoming run II of the LHC. In order to cope with the challenges related

to restart that modified machine, it was decided to perform two injection tests in order to have a first validation of the equipment around the injection regions, three sectors of the machine and the beam dump system for B2. It was also decided to start the machine check-out test campaign early in 2014 to have time for a detailed preparation of all accelerator systems before the start of beam commissioning which will coincide with an increase of the maximum beam energy from 4TeV to 6.5TeV. The way to prepare the LHC for operation with beam will be a combination of general machine check-out tests and dry runs, as this recipe has already successfully worked during past preparation periods.

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