Abstract
The goal of Long Shutdown 1 (LS1) is to perform the full maintenance of equipment and the necessary consolidation and upgrade activities in order to ensure reliable LHC operation at nominal performance from mid-2014.

LS1 not only concerns the LHC but also its injectors. To ensure resources will be available an analysis is in progress to detect conflict/overload and decide what is compulsory, what we can afford, and what can be postponed until LS2. The strategy, time key drivers, constraints, and draft schedule are presented here.

INTRODUCTION
LS1 will be the first Long Shutdown (LS) of the LHC, and is part of the 10 year draft plan, which foresees the following LS and Operational Periods (OP):
- LS1 to perform all activities needed for a safe and reliable operation of the accelerator complex at nominal energy.
- OP2 at nominal energy (around 7 TeV/beam) and intermediate luminosity ($10^{34}$ cm$^{-2}$ s$^{-1}$) for 3 years, including proton runs, ion runs and technical stops.
- LS2 in order to perform all activities for a safe and reliable operation of the accelerator complex at nominal energy and luminosity.
- OP3 at nominal energy and nominal luminosity ($2.10^{34}$ cm$^{-2}$ s$^{-1}$) for 3 years, including proton runs, ion runs, and technical stops.
- LS3 in order to perform all activities for a safe and reliable operation of the accelerator complex at nominal energy and ultimate luminosity.

This paper focuses on the strategy, activities, and constraints to be performed during LS1, both in the LHC and in the injectors’ complex.

STRATEGY
LS1 is scheduled to last 20 months. This has been agreed with the technical coordination of the experiments and of the different machines. This time frame will be sufficient to perform all the consolidation and upgrades needed to achieve the goal of LS1, as well as perform the full maintenance of the different systems. Although activities foreseen by equipment groups are usually planned in term of resources, it is necessary to check whether the support needed from other groups is available.

It is therefore important to understand each request in terms of goals, time constraints, and support needed from other groups in order to detect conflicts or overloads and decide what is compulsory or what can be postponed until OP2 or LS2. In this respect, the project leader of LS1, F. Bordry, held meetings with the different stakeholders to obtain a clear and complete picture of the activities related to the accelerator complex and LHC experiments. All the information is compiled in a database and the four following priorities have been set:
- Priority 1: all the activities which will allow the LHC to run at nominal energy,
- Priority 2: all activities which will allow the reliable operation of OP3 (i.e. maintenance),
- Priority 3: CERN approved projects,
- Priority 4: non-CERN approved projects.

INJECTORS
The shutdown of the injectors during LS1 will last about 14 months as illustrated in Fig. 1.
It will include two general Christmas breaks of about 3 months, at the end of 2012 and 2013 to perform the usual maintenance programme and Christmas break activities. In addition, the 2013 break will be used to consolidate and upgrade the injectors.

Figure 1: Skeleton schedule for the injectors’ complex

Main Activities in the SPS
- Vacuum coating of 16 dipoles for e-cloud mitigation;
- Upgrade and reduction of the impedance of the kicker systems;
- Major upgrade of RF systems (power increased up to 4 MW);
- Major capacity upgrade for EN-CV to allow the above RF upgrade tests and later operation (for LS2);
- Cable clean-up necessary for the above activities as well as the BA5 cable clean-up campaign;
- 18 kV transformers consolidation;
- Alignment works.
Main Activities in the PS and PS Booster
- Preparatory works for 2 GeV upgrade for LS2 in the PS Booster (e.g. new Beam Dump to handle Linac4 type beams, etc.);
- Renovation of the PS vacuum control system;
- Installation and commissioning of the new access system;
- Alignment works.

LHC MACHINE

Time Key Drivers
In the LHC machine, the total period is driven by:
- The consolidation of the superconducting circuits;
- The Radiation to Electronics (R2E) mitigation measures;
- The maintenance programme.

Typical Sequence of One Sector
In each sector, the following sequence will be followed:
- Powering tests prior to the warm-up in order to qualify the circuits, except the main one, up to 7 TeV, and therefore be able to repair or consolidate these circuits if necessary. The preliminary tests will also help localize existing electrical faults;
- Warming-up the cryomagnets and cryogenic line to room temperature with a standby period of one week (above 20 K and with constant header pressures) in order to localize the existing leaks;
- Consolidating the superconducting circuits and maintenance works;
- Preparing for cool-down including pressure tests, electrical quality assurance tests (ELQA), flushing, etc.;
- Cooling-down and cryogenic tuning;
- Hardware commissioning.

Consolidation of the Superconducting Circuits
Three main teams will consolidate the superconducting circuits. One team in charge of the opening and closing of the interconnection, which will intervene before the team in charge of consolidating the main splices, and after the closure of the interconnections. A third team will be in charge of the special interventions, for instance the cryomagnets exchange, y line repair in sectors 78 and 81, etc.

Maintenance
After more than 3 years of operation a full maintenance programme of the different systems is needed. The maintenance of a cryogenic plant will last 18 weeks, mainly driven by the maintenance of the compressor stations. In light of the cryogenic maintenance, the cooling towers will be completely cleaned, and their electrical and mechanical maintenance fully carried out. As underlined by F. Duval, during Chamonix 2011, a lot of important maintenance has been delayed because of the non-ability of stopping the systems (in order to reduce the time dedicated to technical stops, and thus to increase the time dedicated to operation) [6].

Mitigation Measures for R2E
Mitigation measures for R2E will mainly occur at Points 1, 5, 7, and 8. Except for Point 7, the schedule of each point is ready. In order to better understand and anticipate the conflicts in logistics an animated schedule was edited (showing the exact location of the works at each point, week by week).

Point 1
The first schedules edited for the implementation of mitigation measures at Point 1 before running at nominal energy had an important impact on the schedule of the adjacent sectors. To relax the schedule, some activities were anticipated during the 2011-2012 Christmas Break. The total duration is now of 62 weeks and the impact on adjacent sectors has been reduced, but there is still a 2-week delay for the cool-down of sector 81.

Point 5
There is also a heavy workload for the implementation of mitigation measures at Point 5. Indeed, most of the equipment installed on the first floor of UJ56, as well as in the electrical safe room of UJ56 will be relocated elsewhere. To not impact the overall schedule and especially that of adjacent sectors, several teams will work in shifts. The actual duration is 57 weeks and the impact on the adjacent sectors is reduced, but there is still a 2-week delay for the cool-down of sector 56, as well as the powering tests.

Point 7
The schedule for point 7 is being established and shall be finalized by March 2012.

Point 8
Most of the work has been anticipated during the last Christmas Breaks and technical stops. The workload for Point 8 concerning R2E is therefore light and the schedule will be adapted according to the resource levelling exercise.

Other Activities
Many other activities are foreseen, and were already presented and accepted by the project leader. These activities will be scheduled in detail in 2012, including the associated logistics.

Skeleton Schedule
The 20 months of shutdown will be followed by a period of cold-check-out and beam commissioning which will last about 4 months as shown in Fig. 2. With a start date at the end of 2012, the physics at ~7 TeV per beam shall commence at the end of 2014. The machine will therefore be ready to start physics just before the annual Christmas Break so it has been decided to cancel the 2014-2015 Christmas Break to not stop the machine when it has just started. In order to keep the level of reliability, a second slot of maintenance of the main systems has
been foreseen during the period of hardware commissioning.

Figure 2: The LHC during LS1 – skeleton schedule

Risks

During the installation we observed the slow start of the different worksites. Indeed, the implementation of the worksites (especially in matters of organization) and the unavailability of the materials or resources caused delays. On average the first 25% of the works took about 20% longer than foreseen; this, regardless of the nature of the works.

Splices Consolidation: When this average delay is applied to the interconnection train in Fig. 3, one can see that this has no direct impact on the end date. Indeed, in the last sector, the train will finish before the closure team starts. However, one has to pay attention to the fact that the leak detection and electrical tests performed during the last steps of the interconnection period can reserve bad surprises, and engender delays.

Figure 3: Impact of the delay in the IC trains

R2E Mitigation Measures: If the activities at Points 1 and 5 are 6 weeks longer then, again, this has no direct impact on the start date of the LHC, but it will delay the start of commissioning in several sectors and pile-up the tests in the last months.

Additional Activities: The scope of the LS1 has been defined and the amount of work must therefore not evolve as it could be another important source of delays by disorganizing the tight plan. Particular attention must be focused on the additional requests that require the support from other groups. As a matter of fact, some support groups are already overloaded and with some works having started.

CSCM Tests: it is envisaged to perform the Copper Stability and Continuity Measurements in the eight sectors of the machine. This additional activity will cost around one month for the beam start up.

ORGANIZATION

Preparation is crucial for a good worksite progress:

- Orders have to be placed in due time, meaning the reverse schedule for the administrative part has to be done properly;
- Engineering Change Requests have to be approved prior to the works;
- Depending on the type of work and/or the radioprotection environment, DIMRs have to be prepared;
- Materials have to be ready. This last point was often a source of delay during the installation of the machine and technical stops.

Preparation meetings will be held throughout 2012 for the organization, scheduling, and coordination of the different areas.

CONCLUSION

The analysis of the requests for the accelerator complex is well advanced. This is done with respect to priorities and resources. For the complex, skeleton schedules are ready, but detailed schedules are now to be implemented. This will be done during 2012, as well as the detailed preparation and organization of LS1.

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