

# LONG SHUTDOWN 2 @ LHC

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## *Abstract*

After a second period of operation of more than 3 years, the accelerator complex will be stopped for about 18 months, from July 2018. The main purpose of the Long Shutdown 2 (LS2) is the LHC injectors upgrade (LIU). Nevertheless LHC will profit from this period to perform full maintenance of all the equipment, to consolidate part of the machine and to anticipate activities, where possible, of the LHC High Luminosity (HL-LHC) project. During LS2 activities across LHC, Injectors and LHC Experiments will be performed. This paper reviews all the major LS2 activities (maintenance, consolidation and HL-LHC), identifying those which are on the critical path, those which can be anticipated during End of Year Technical Stops, and those which will have to be postponed to Long Shutdown 3. The support needed from infrastructure services and logistics will be highlighted, as well as those requiring technical expertise from the Accelerator and Technology sector. A preliminary LS2 schedule is proposed, including the driving activities and the critical path.

## INTRODUCTION

Long Shutdown 2 is scheduled to start in July 2018 and its duration is 18 months. This long shutdown will be mainly dedicated to Injectors, nevertheless important activities as maintenance and consolidation will be performed in the LHC machine. Moreover the Accelerator Consolidation Project and the HL-LHC will also implement important modifications during LS2.

## METHODOLOGY USED TO SELECT THE ACTIVITIES TO BE PERFORMED

To identify the activities to be performed during LS2, a systematic approach was used. The Group Leaders of TE, EN and some Group Leaders of IT and GS have been interviewed and some recurrent questions have been submitted. Part of the information around the activities related to LS2 is already available, part is related to the performances of Run 2, and will be disclosed only during 2017. In addition, some exchanges went on with the Project Leader of the accelerator consolidation project and the Technical Coordinator of the HL-LHC project. The typical set of questions was around the following areas:

- Description of activities foreseen during LS2 in the LHC; including the indication if the activities are related to safety, reliability, improvement or RP issues and the impact if they are not realised.
- Maintenance to be performed, impact on the machine and preliminary durations.

- Announcement of the activities: to identify if the activities are already declared in Impact, Plan or in different Workshops.
- Resources needed to realise the activities: human and material;
- Support needed from other groups;
- Need of surface & production areas at CERN;
- First duration of the announced activities.

Concerning the projects, the same set of questions has been asked, focusing on activities foreseen during LS2.

Following the information from the Group Leaders, Project Leaders and Coordinators, the activities have been analysed and three main areas of intervention have been identified. Activities related to: Projects, Maintenance and Consolidation. A detailed description of the activities corresponding to each area is given below.

## PROJECTS

The two main projects which foresee activities during LS2, are:

- Accelerator consolidation project;
- HL-LHC project.

Concerning the accelerators consolidation, the baseline around the LHC activities is being reviewed and in September 2014 the official baseline is not yet available.

Concerning the HL-LHC project, the activities are around the following areas:

- Point 2: the replacement of the 8T Dipole, with two 11T Dipoles and a warm collimator, in the dispersion suppressor regions;
- Point 4: the debottlenecking of the cold power and the increasing of the cryogenic redundancy; a first approximate duration is 8 months of work and 3 months for commissioning;
- Point 7: the displacement of the power converters and DFB in the TZ76, the installation of the superconducting link from TZ76 to the tunnel. This part of the project will include also the modification of cryogenics related to the installation of the superconducting link.
- Point 2 and Point 8:
  - Replacement of the TDI with new TDIS consisting of several tanks and new absorber materials to cope with intense LIU beam;
  - Replacement of TCDD and possible TCLIA and TCLIB to provide sufficient protection of superconducting elements in the case of injection failures.

## MAINTENANCE

The maintenance activities are specific to each group and listed below.

### *Technology Department:*

Cryogenics: the main maintenance of compressors and rotating machines will be performed with duration between 8 and 12 months; this activity is certainly on the critical path of LS2.

Vacuum: maintenance will be done around all the vacuum pumps, valves and instrumentation; the beam gas injection system in LSS4; the remote reconditioning of NEG cartridge across the ring; the exchange of ion pumps at MKBs; the corrective maintenance on defective PIMs; and other activities not related to maintenance, but to the test phase, as the leak tests on the whole LHC machine.

Electrical power converters: in this area, corrective and preventive maintenance will be performed according to the performance of Run 2; as baseline, all equipment will be maintained and the PCs situated in the RR will be replaced.

Machine protection equipment: all the systems will be maintained during LS2, such as Energy Extraction System, QPS, etc.; moreover ELQA tests will be performed at the beginning and at the end of LS2, in the test period phase.

### *Engineering Department:*

Cooling and Ventilation: regular maintenance of the ventilation system, on the surface and underground; including the special maintenance of UW, SU and SF; the maintenance of rotating machines as engines of pumps, ventilators, fans, etc...; replacement of valves, cleaning of heat exchangers and piping, replacement of defective equipment, cleaning of piping, etc...

Electrical: maintenance of 400kV and 66 kV, with duration of about 8 weeks and a maximum consumption during this period of 60 MW. Moreover corrective and preventive maintenance will be performed on all the LHC points with duration of 1 week per point.

Sources, Targets and Interactions: the maintenance or replacement of collimators in LHC will be done according to the performance during Run 2; moreover the dismantling of some collimators will be necessary to ease operation and co-activities in the collimation points, according to the requests from other groups. For STI group LS2 is a good opportunity to prepare activities to be performed during LS3, in particular the establishment of ALARA procedures.

### *Information Technology Department:*

Communication System: to prevent the deterioration of the internal insulation, it is foreseen to replace the present radiating cable on the whole LHC machine; this activity will generate some safety constraints, due to the fact that Tetra network is transmitted with the radiating cable. The replacement of the routers in the computing centre will be performed and will impact the technical and general services networks.

### *General Infrastructure Services Department:*

Access, Safety and Engineering tools: the maintenance of the fire detection systems, ODH, access system and evacuation is foreseen on the surface and underground, followed by a series of tests on the whole machine.

Other civil engineering work will be realised, most probably related to projects and consolidation activities. For the time being these activities are unknown, but will be defined in a second stage.

In September 2014 only part of the maintenance activities are known; the other will be disclosed during Run 2. Activities related to maintenance around RF, Kickers, Beam Instrumentation, Controls will be also realised.

## CONSOLIDATION

The consolidation activities are specific to each group; part of these activities will be included in the LHC Consolidation Project, but in September 2014 this is not yet defined.

### *Technology Department:*

Cryogenics: it is necessary, during LS2, to proceed to the mechanical consolidation of the support of the quench line, which will be used in case of major quench. The redundancy of the LHC warm compressors will be implemented, so to decrease the mean time to repair from one week to one day. Moreover, to reduce the storage of Helium from 90t to 30t, it is foreseen to equip the existing storage tanks with a small liquifier.

A subject to be discussed between the Cryogenics and Magnet Groups, is the need to replace the heat exchanger of the Inner Triplets at Points 1 and 5. According the cryogenics group, there is a need to increase the capability of heat extraction due to the increased beam parameters during Run 2.

Concerning the consolidation of the QRL bellows, it is not expected to discover non-conformities during LS2; only minor replacements are expected wrt? LS1.

Vacuum: the consolidation activities of the vacuum group are around the turbo pumps. In the LSS the turbo pumps will be replaced; in the arcs and QRL the control system of the turbo pumps will be moved to the REs, and this implies a major cabling campaign in the arcs. Other consolidation activities concern all the vacuum equipment around the LHC ring, for insulation and beam vacuum: valves, pressure gauges, pumping systems, ... An action plan should be defined around the Elastomer joints (o-ring) situated on the W bellow and on magnet feet; the reliability of the joints vs the radiation doses should be assessed.

Magnet: during LS2 it is foreseen to replace about 15 magnets. For the moment, the need to replace 4 magnets in sector 34 (3 SSS and 1 Dipole) is identified, but the final number of magnets to replace, will be assessed during run 2. Concerning the warm magnets, the screens to protect the coil from radiation, should be installed on about 35 units situated in Point 1 and Point 7. An

important work for TE-MS, is the preparation, of LS3 to ease dismantling and installation of Inner Triplets.

**Machine Protection Equipment:** TE-MPE group foresees the replacement and upgrade of all the DYPQ racks, to increase their reliability and reduce the downtime; to perform this activity, the support of the transport group is needed, as well as a surface storage. The obsolete electronics of the beam interlock system will be replaced; the activities will be performed mostly on the surface; nevertheless the upgrade involves 17 controllers between LHC and Experiments, and it is expected to have heavy commissioning and starting phase.

*Engineering Department:*

**Cooling and Ventilation:** several renewal and relocation activities will be realised during LS2. The interventions will be around the compressed air plant, the HVAC warm water for the underground ventilation, the firefighting water pipeline for surface Points, the air handling units of the TU and the cooling towers. During the consolidations and the maintenance the related networks will be out of service.

**Sources, Targets and Interactions:** in the frame of the consolidation activities, the Collimation project is ongoing in collaboration with BE-ABP. The project includes activities for the replacement of secondary collimators in Point 7 and for the improvement of tertiary collimators at Points 1 and 5; the support of TE-VSC, EN-EL, EN-CV and EN-MME is fundamental to reach the expected results. Moreover STI foresees the replacement of 12 TCDIs in the transfer lines, to increase their robustness and attenuation for the use with LIU beams. For STI, LS2 is a good opportunity, to develop ALARA procedures to apply during LS3.

Electrical group has a huge and heavy plan around consolidation. It is a long term plan, which will be implemented step by step during YETS, EYETS and Run 2. The plan has major activities also in the frame of LS2, as the consolidation of the Jura station, with a duration of 6 months minimum, the creation of an additional CERN station 400/66 kV near Bois Tollo [CERN 2 400kV\_220MVA], the installation of the new compensation on Meyrin Machine network (TE/EPC), the consolidation of the automatism of control and regulation for LHC Diesel. Moreover the partial replacement of 18 kV protection relays and 48VDC systems on LHC surface is foreseen. EN-EL group has a very tight and heavy schedule, which will be on the critical path of at LS2. The group is analysing the possibility to optimise the activity, anticipating as much as possible the interventions before LS2. Concerning the cabling, the activity of replacement of the water cooled cables will be completed during LS2; still 45% of cables need to be replaced. Moreover some optical fibre for LHCb will be installed. EN-EL-CF outlines the need to receive the requests of copper cabling at least 1 year before LS2, and to be informed of project requiring cabling, since the early phase.

**Handling Engineering:** it is foreseen to replace all the LHC lifts (machine and experiments) between 2015 and

the end of LS2. During LS2 it is scheduled to work on the replacement of PM15, PM25, PZ33, PZ45, PM56, PM65 and PM76; the duration of replacement is 3 months per lift. At Point 1 a temporary lift (Alimack) will be installed during the replacement of PM15, but the capacity is under investigation.

*Information Technology Department:*

**Communication System:** the installation of a second radiating cable is foreseen on the whole LHC machine; this will allow to increase the transmission rate with 4G+ and to download up to 100 Mbps. During LS2 no Wi-Fi will be available in the machine, but only the 4G+; therefore is it important for the users to validate the compatibility of the user’s device, before LS2.

*General Infrastructure Services Department:*

**Access, Safety and Engineering tools:** the alarm transmission system will be consolidated during LS2, with the installation of an anti-fire cable; moreover the access system will be upgraded and the access point in SZ6 (PZ65) will be refurbished to support the replacement of PM65 Lift. In addition, the recommendation of the Helium spill working group about the ODH detectors will be implemented during LS2.

In conclusion, already in September 2014, a lot of consolidation activities are declared, to be performed during LS2; nevertheless, the activities to be performed in the frame of the Accelerator Consolidation project, for LHC should be finalised.

**PRELIMINARY SCHEDULE**

The preliminary schedule of LS2 is composed of three main parts:

- The Warm up and test phase: the duration is about 3 months for the whole machine, nevertheless the first sector will be “released for activities” after about one month, from the beginning of the warm up. The access to LSS7, is related to its radiological cool down, which is estimated to 6 months.
- The maintenance and activities phase: this includes all activities related to maintenance, consolidation and projects. The critical path of this phase is related to the cryogenics maintenance in all the cryogenics points, and to the implementations of HL-LHC project in Points 2, 4 and 7.
- The cool down, tests and hardware commissioning phase: the duration of this phase is about 6 months, nevertheless, as for warm up; the sectors will be cooled down in sequence.



Figure 1 – snapshots of LS1-LHC dashboard

In conclusion, depending on the cool down and warm up sequence, the period available for maintenance and consolidation activities is between 9 and 13 months.

## **CONCLUSION**

Long Shutdown 2 is mainly dedicated to Injectors; nevertheless in the LHC and its Experiments, the Maintenance and Consolidation activities are important. Also for the projects, as the HL-LHC, LS2 is a good opportunity to prepare LS3, when all the modifications will be implemented. In addition LS2 is a good opportunity for all the groups to study and implement ALARA procedures, to be applied during LS3.

During LS2, the support group should manage a large amount of activities and the shutdown will be a challenge also for the coordination teams of LHC and Experiments. Due to the large involvement of all the groups during LS2, it is important that this will not compromise the preparation of LS3. The resource optimisation across the Accelerators and Experiments will be one of the main challenges of LS2.

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