TECHNICAL STOPS: WHAT WERE THE ISSUES IN 2011, MINIMIZING IMPACT AND IMPROVING RECOVERY

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Abstract

As any other accelerator, the LHC has to undertake periods of stop for maintenance. Five technical stops have been performed during the 2011 run and sometimes a quite long recovery time was experienced. An analysis of the reasons is presented paying particular attention to the interventions carried out during the stop. Following this analysis, an outlook on the future that aims to increase the LHC availability and to diminish the downtime is also considered. Further consideration is put on the possibility to perform maintenance only once the machine undergoes a problem, instead of during planned stops.

2011 TECHNICAL STOPS OVERVIEW

5 Technical Stops (TS) have been performed on LHC in 2011 from March to November, for a total duration of 23 days (the winter break has not been taken into account). The details are presented in table 1.

Table 1: 2011 Technical Stops

	Start Date	End date	Length	Days before next TS
TS#1	28/03	31/03	4	38
TS#2	09/05	12/05	4	52
TS#3	04/07	08/07	5	51
TS#4	29/08	02/09	5	65
TS#5	07/11	11/11	5	26

At the end of each TS 1 day was allocated for partial re-commissioning and recovery of the LHC.

ANALYSIS METHODOLOGY

The present analysis has been performed with 3 objectives in mind:

- Spot out possible correlations between actual recovery time of a technical stop and interventions performed;
- Identify the major issues and factors influencing the recovery period;
- Investigate and propose a strategy for improvement.

For each Technical Stop, the list of performed interventions was screened and the recovery period examined. All periodic tests meant to re-check the status of the machine whose execution is not due to TS, (i.e. loss maps) have been considered as part of the recovery time.

Each technical stop has been then divided in three phases:

1. TECHNICAL STOP: from Monday 7am (when tunnel activities begin) to the moment the first Hardware re-commissioning test is performed;
2. MACHINE RECOVERY: after the Technical Stop till the moment the first beam commissioning test is carried out;
3. BEAM COMMISSIONING: after Machine Recovery till the goal of the week is accomplished.

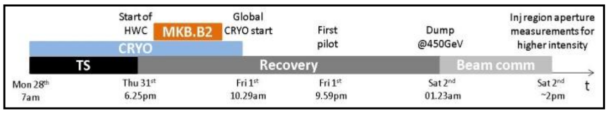
THE TECHNICAL STOPS

TS#1 (28 - 31 March 2011)

The first Technical Stop took place just after a period of 1.38 TeV operation; the last 3.5 TeV fill had 200 bunches, with an intensity of 1.22 E^{11} p/bunch. The goal of the week was declared as “TS, recovery from TS and start preparation for high intensity”. During the 4 days of technical stop many activities were performed: 60% of them were due to maintenance or measurement on systems, 30% to installation or modification aimed to improve the performances and the remaining 10% to fix problems that appeared during the first month of operation.

Figure 1 shows the time line of the three phases of the first technical stop.

Figure 1: timeline of TS#1



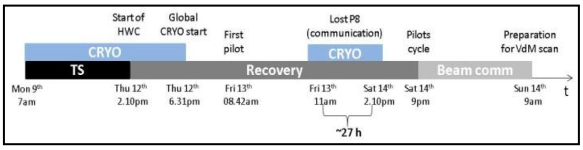
During the recovery period, around 14.5 hours were spent to solve issues that were blocking the LHC operation. 62% of this time was spent to solve HW issues and the remaining 38% for SW problems. It is important to notice that 52% of the global time loss was related to problems that are a consequence of interventions performed during the TS.

TS#2 (09 - 12 May 2011)

The second Technical Stop took place during operation with protons at 3.5 TeV. The last fill had 768 bunches with an intensity of 1.25 E^{11} p/bunch. The goal of the week was declared as “TS, re-establish physics conditions, alignment of Roman Pots, Van der Meer scan”. During the 4 days of the technical stop many activities were performed: 60% of these activities were due to maintenance or measurement on the systems, 24%

to installation or modification aimed to improve the performances and the remaining 16% to fix problems that appeared during operation. During TS#2 some HW studies on the quench propagation on a busbar were performed by provoking quenches on the dipoles circuit of sector 56 (RB.A56). In the same sector a series of Fast Power Aborts at different current levels was also provoked on the quadrupole circuits (RQD.A56 and RQF.A56) in the context of a simulation study of the electrical property and behavior of the circuit.

Figure 2: timeline of TS#2

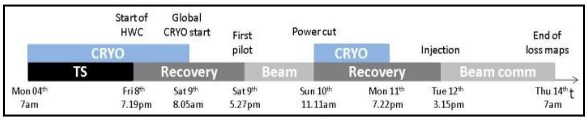


During the recovery period, around 15.5 hours were spent to solve issues that were blocking LHC operation; 90% of this time was spent to solve HW issues and the remaining 10% for SW problems. It’s important to notice that only 6% of the global time loss was related to problems that are a consequence of interventions performed during the TS.

TS#3 (04 - 08 July 2011)

The third Technical Stop took place during operation with p at 3.5 TeV. The last fill had 1380 bunches with an intensity of 1.16 E^{11} p/bunch. The goal of the week was declared as “TS, continue with the satellite collision scheme (264 bunches and higher)”. Five days were allocated for this technical stop and many activities were performed: 65% of them were due to maintenance or measurement on systems, 26% to installation or modification aimed to improve the performances and the remaining 9% to fix problems that appeared during operation. During TS#3 some more HW studies on the quench propagation on a busbar were performed on the dipoles circuit of sector 56 (RB.A56). Some special boards for the Quench Protection System were also installed on the dipoles circuit of sector 81 (RB.A81), tested, then removed.

Figure 3: timeline of TS#3



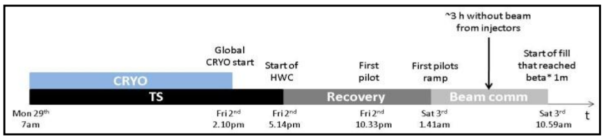
On Sunday the 10th July, when the LHC was almost ready for operation, a power cut hit the CERN network. (the cryogenic conditions were lost in 5 sectors). As a consequence a full series of test was organized to check that no major problem had happened on critical systems. This activity required much more time than foreseen by the normal recovery. This time has been, therefore, excluded from this analysis.

During the recovery period, around 19.5 hours were spent to solve issues that were blocking LHC operation; 85% of this time was spent to solve HW issues and the remaining 15% for SW problems. It is important to notice that 54% of the global time loss was related to problems that are a consequence of interventions performed during the TS.

TS#4 (29 August – 02 September 2011)

The fourth Technical Stop took place during operation with protons at 3.5 TeV. The last fill had 1380 bunches with an intensity of 1.29 E^{11} p/bunch. The goal of the week was declared as “TS, recovery from TS, 1 m beta*, Alice polarity change”. During the 5 days allocated, several activities were performed in the LHC tunnel: 69% were due to maintenance or measurement on systems, 24% to installation or modification aimed to improve the performances and the remaining 7% to fix problems that appeared during operation. During the TS#4 some additional HW studies on the quench propagation on a busbar were performed on the quadrupole circuit of sector 56 (RQD.A56 and RQF.A56).

Figure 4: timeline of TS#4



During the recovery period, around 6.5 hours were spent to solve issues that were blocking LHC operation; 8% of this time was spent to solve HW issues and the remaining 92% for SW problems. It is important to notice that 85% of the global time loss was related to problems that are a consequence of interventions performed during the TS.

TS#5 (07 - 11 November 2011)

The fifth Technical Stop took place during operation with protons at 3.5 TeV. The last fill had 1380 bunches with an intensity of 1.5 E^{11} p/bunch. The goal of the week was set as “TS, recovery form TS, ions (stable beams) over the weekend”. During the 5 days allocated, several activities were performed in the LHC tunnel: 70% were due to maintenance or measurement on systems, 24% to installation or modification aimed to improve the performances and the remaining 6% to fix problems appeared during operation. During TS#5, some additional HW studies on the quench propagation on a busbar were performed on the quadrupole circuit of sector 56 (RQD.A56 and RQF.A56).

Figure 5: timeline of TS#5

During the recovery period, around 4 hours were spent to solve issues that were blocking LHC operation; 62% of this time was spent to solve HW issues and the remaining 38% for SW problems. It's important to notice that only 50% of the global time loss was related to problems that are a consequence of interventions performed during the TS.

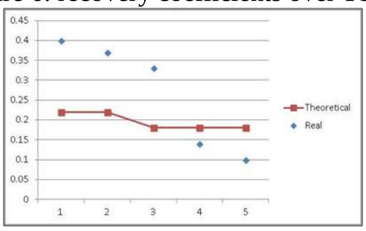
General statistics

Looking at the analysis presented on the previous chapter, a general trend can be identified. On every technical stop about 65 % of the tunnel activities were due to maintenance of the systems. This means that a reduction of the number of technical stops (if possible), would necessarily result in an increase of length. A constant effort is put in place to increase the reliability of the LHC by improving the quality of the systems. This is what about 25% of tunnel activities are meant to do. The remaining 10% are due to solutions of problems that appeared during LHC operation, indicating a very high level of reliability of the LHC.

Another interesting statistic is related to the issues encountered in the recovery phase. In general it is possible to see that only around 50 % of the time loss is a consequence of changes due to interventions performed. Looking at the time lost for SW and HW issues that appeared during recovery, it is important to remark that the time necessary to solve a single HW problem is in average bigger than the one spent for SW issues, as it could require an access. Consequently, the higher amount of time spent to solve HW problems doesn't necessarily mean a larger number of issues.

It is also very interesting to look at the recovery time over the 5 Technical Stops that took place in 2011. It is immediately clear that the recovery time diminishes along the year passing from 43 hours for the TS#1 to 13 hours for the TS#5. As the time allocated for the first technical stops is shorter than the one allocated to the last ones, a recovery coefficient has been calculated; a theoretical coefficient is calculated by dividing the 24 hours allocated for recovery by the total time allocated for the technical stops and the real one using the real time spent for recovery. Both coefficients are shown in Figure 6. A clear tendency of improvement is visible.

Figure 6: recovery coefficients over TSs



STRATEGY

In order to minimize the impact of the TSs, different strategies have been investigated. To do this, the first step is to identify the main user requirements:

- **Cryogenic system:** no systematic maintenance is done anymore during technical stops; from their point of view there is no showstopper to go to 4 (or even 3) TSs, provided that a minimum of 5 days is allocated to each of them. The 2011 configuration was anyway very good, as it provided the time needed for maintaining the system in a good shape.
- **Quench Protection System:** a minimum of 3 stops should be performed (ideally in May, August and October) with a minimum duration of 4.5 days each, as in 2011.
- **Electrical Power Converters:** no systematic maintenance is needed on the power converters, but at least 1-2 days every 9-10 weeks are needed to cope with necessary calibration and problem solving.
- **Electrical system:** TSs are extremely important to repair/reset/maintain some systems that are not in good shape. Nevertheless, there is no particular constraint not to wait till problems actually appear.
- **Cooling and ventilation:** the global stop time is already at the limit. The system needs systematic maintenance then increased time between technical stops could result in mayor faults of the system that require longer time to be fixed. A period of operation longer than 8-9 weeks risks decreasing the global efficiency.
- **Injectors:** from the injectors point of view it is difficult to reduce the stops to less than 4 as continuous maintenance is necessary.

Considering the user requirements, a reduction to 4 technical stops can be taken into account (it has been planned for 2012), but a further reduction could compromise the performances of the LHC.

The possibility to use the strategy of operating the LHC till the moment a blocking issue appears and only then stop for few days to perform the needed maintenance has also been considered. This strategy has been already successfully adopted by other accelerators and could theoretically reduce the downtime of the LHC to its minimum. Unfortunately different points have to be taken into account in this evaluation.

The complexity of the LHC suggests that this strategy would increase rather than reduce the downtime. When a major fault appears, in fact, many systems are affected and a long time could be needed to fix the problem. Due to the large number of different systems working on the LHC, spare parts are not available for all equipment. A regular maintenance is needed to prevent some systems from breaking.

Another problem is the fact that most of the work done on the LHC is performed by contractors. For this reason, it is also important to properly schedule the stops and the work to be done so to use the time efficiently and effectively.

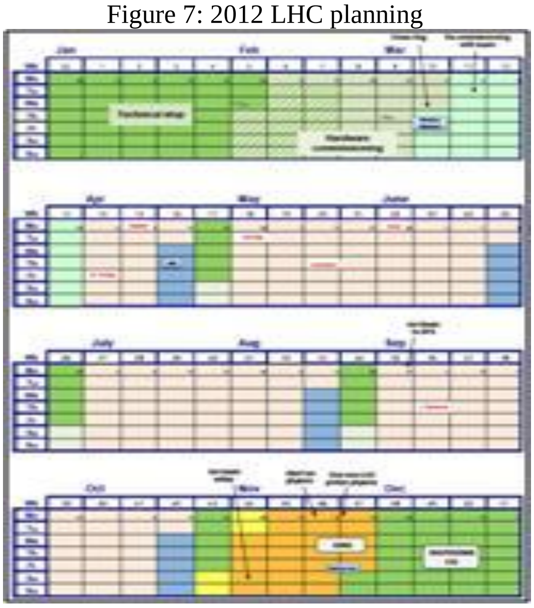
CONCLUSIONS

The analysis performed highlighted some important points that can improve the reliability and the efficiency of the LHC:

- There is an ongoing campaign to improve the activity tracking. Keeping this clear would result in reduced time to spot out the source of problems encountered during recovery, thus increasing the efficiency.
- The issues appeared during recovery after technical stops show that there is no systematic source of issues over the 5 TSs.
- There is a clear trend of improvement in the time needed to restart the LHC operation after a technical stop, but some important considerations have to be made:
  - A reduction in the recovery time was already observed during 2012.
  - In the effort of increasing the activity tracking it is essential to apply a control to SW as well as HW changes. Both of them, indeed, strongly contribute to a slow down in the recovery process. This could also improve the changes by coordinating them as well as increase the operational efficiency, by making the identification of the source of problems easier.

The possibility of further reducing the number of TSs in 2012 (at present 4 TSs are scheduled) pushing some maintenance forward to the Long Shutdown (LS1) foreseen for the end of 2012 has been also discussed. Nevertheless, as the time between the TSs cannot be drastically reduced for the reasons already discussed it is not possible to run the LHC with 3 TSs only.

Figure 7: 2012 LHC planning



The last TS, scheduled just before the Ions run (thus making the period of operation before the long shutdown very short), cannot be cancelled nor anticipated as needed for the Zero Degree Calorimeter installation. This device needs to be installed right before the Ion run to avoid high intensity p beams as it could be damaged. As a result the configuration of TSs stops scheduled for 2012 (Figure 7) is already optimized.

AKNOWLEDGEMENTS

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