CHAMONIX 2014 CONCLUSIONS: MAIN POINTS AND ACTIONS

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Abstract

The summary session of the LHC Performance Workshop in Chamonix, 22-25 September 2014 [1], held at CERN on 8 October 2014 [2] synthesized one week of presentations and intense discussions on the near-, medium- and long-term strategy for the LHC, including the upgrades of the LHC and its injectors.

In particular, Chamonix 2014 discussed the lessons from, and the end of the Long Shutdown 1 (LS1) up to powering tests and cold checkout, the injector status, the beam commissioning in 2015, the challenges and strategy for LHC Run 2, the LHC Injector Upgrade (LIU), the High-Luminosity LHC (HL-LHC), the consolidation of accelerator and non-LHC experiment areas through Long Shutdown 3 (LS3), as well as the strategy and preparation for the Long Shutdown 2 (LS2).

We report the main points and actions which have emerged at the Chamonix 2014 workshop.

PREPARATION PROCESS

The 1st preparation meeting for Chamonix 2014 was held on 21 March 2014. This meeting identified the key topics to be addressed:

- How to restart the machine?
- Strategy for first year and for all of Run 2
- Consolidation strategy
- LS2 preparation
- HL-LHC & LIU

In total 6 general preparation meetings had been organized between March 2014 and the end of the summer.

It had been decided that the spirit of the workshop would be not to encourage status reports, but rather to address open questions and options.

The selection of the participants through the Department Heads and Session Chairs proved difficult. Finally, there were about 130-140 attendees per session.

WORKSHOP STRUCTURE

The following session structure had been worked out during the preparation phase:

Session 1: "LS1, HW Commissioning, Powering Tests and Cold Check-out - Coming out of LS1." Chair: Mirko Pojer, Scientific secretary: Laurette Ponce

Session 2: "Injector Status and Beams for LHC, Dry Runs, Sector Tests with Beam." Chair: Rende Steerenberg; Scientific Secretary: Reyes Alemany

Session 3: "2015 Commissioning with Beam." Chair: Mike Lamont, Scientific secretary: Giulia Papotti

Session 4: "LHC: Challenges and Strategy for Run2." Chair: Markus Zerlauth, Scientific secretary: Belen Maria Salvachua Ferrando

Session 5: "LIU (LHC Injector Upgrade)." Chair: Malika Meddahi, Giovanni Rumolo

Session 6: "HL-LHC (High-Luminosity LHC)." Chair: Oliver Brüning; Scientific secretary: Paolo Ferracin

Session 7: "Accelerators and non LHC Experiment Areas Consolidation up to LS3." Chairs: Michael Benedikt, Florian Sonnemann

Session 8: "Long Shutdown 2 Strategy and Preparation." Chair: José Miguel Jiménez; Scientific secretary: Jean-Philippe Tock

The session organization and specific topics addressed at Chamonix 2014 reflect the timing of this workshop with respect to the short-term schedule of the LHC and its injector complex, which is illustrated in Fig. 1. Chamonix 2014 took place 3 months before the end of the Long Shutdown 1, which had extended from 16 February 2013 to December 2014. The PS and PS Booster were already operating for physics, and beam commissioning had just started in the SPS.

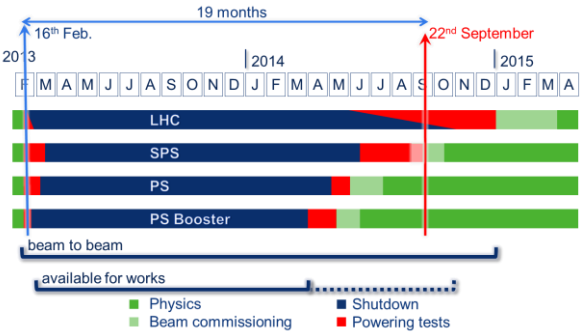

Figure 1: Timing of Chamonix 2014 with respect to the LHC Long Shutdown 1 and the schedule of the LHC injectors [3].

PS PHYSICS

The PS physics programme was already ongoing.

A run of nTOF originally planned for 15 July 2014 had been slightly delayed due to EAR2 installation work. The first beam had been on target by 25 July 2014. Since then, physics had been scheduled during night and weekends while installation continued during day time.

The East Area operation had also been planned to begin on 15 July. Here, indeed the first beam had been available

as scheduled, and physics had started on the following day (16 July).

Concerning the AD beam, in March 2014, the beam on target had been delayed by 3 weeks due to a horn strip line problem, which had resulted in 1 August 2014 as the revised new optimistic date for beam on target. In the end, the first AD beam had been delivered on 5 August and the AD physics had begun on 16 September.

The starting date of ion beam preparation for the 2015 run had been 25 August 2014. Argon ions had been successfully injected, accelerated and extracted from PS the following day.

As one **important conclusion**, for the PS a **better definition is needed for the different periods allocated to shutdown, hardware commissioning, cold checkout, and beam commissioning., respectively, together with a clear definition of roles and responsibilities** for each period and for the interfaces. The IEFC will follow up this issue.

SPS STARTUP

The SPS start-up with beam had been more or less on schedule. The beam had been foreseen for Monday 8 September. Despite longer than expected conditioning of injection and dump kickers after LS1, hardware testing of main circuits and debugging of converter software issues after updates during LS1, and a water leak on water cooled main bus bar in SPS point 3 (detected on 8 September), the first beam had been injected into the SPS on Saturday 13 September. The North Area was going to start physics on 6 October, and HiRadMat would commence its first run on 13 October. Beam would be sent to the LHC only in 2015.

LHC STATUS

Figure 2 illustrates that all LHC sectors were being cooled down. The LHC schedule version 4.1 is shown in Figure 3. This schedule was developed respecting the rule "safety first, quality second, schedule third". The first beam in the LHC was expected for week 11 (starting 9 March 2015).

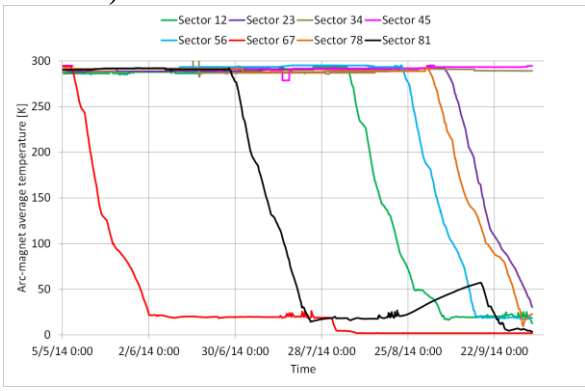

Figure 2: Temperature in LHC sectors from May to September 2014 [Courtesy L. Tavian].

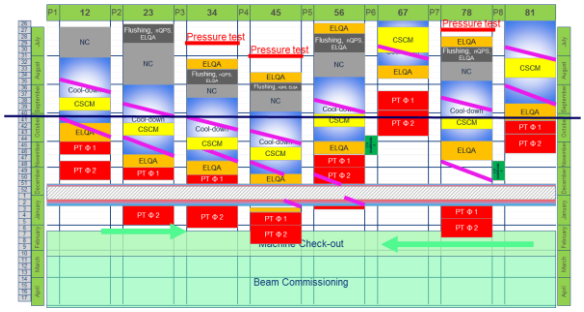

Figure 3: LHC schedule version 4.1 (Courtesy K. Foraz) [4].

MAXIMUM BEAM ENERGY IN 2015

The centre-of-mass energy for 2015 has been fixed at 6.5 TeV. Namely the decision had been taken to run at a maximum energy of 6.5 TeV per beam during the powering tests and during 2015. A total of 10 to 15 training quenches per sector were expected to be needed to reach this energy.

There had also existed a risk that results from late quench tests could force running at lower energy. This risk had been accepted by the experiments [5].

In summary, there will be NO change of the target beam energy for 2015. A decision regarding the possibility of increasing the energy will be taken later in 2015, based on the experience gained in all eight sectors at 6.5 TeV per beam during the powering tests and in operation with beams.

LHC STRATEGY FOR 2015

The strategy for 2015 pursues the following objectives:

1. Restart with beam parameters similar to those in 2012 and a relaxed β* (80 cm) (ALICE 10 m, LHCb 3 m), and establish as soon as possible collisions at 13 TeV with 50 ns bunch spacing, without a combined collide & squeeze, without a combined ramp & squeeze, etc.
2. Fulfil the LHCf request and perform VdM scans with the same optics.
3. Perform a first scrubbing run (50 ns + 25 ns; 7-9 days) and to accumulate up to 1 fb^{-1} with 50 ns bunch spacing (taking around 20 days).
4. Establish the running with 25 ns, and allocate sufficient time for the scrubbing (10-15 days and without any pressure for physics production).
5. Run at 25 ns bunch spacing at a β* of 80 cm during 2 months (45 days), and then decrease the β* to 60 cm or 40 cm, so as to have around 45 days of operation in the latter conditions in preparation for 2016 and 2017.
6. Allocate one month for heavy-ion collisions.

The schedule of Fig. 4 meets all these objectives.

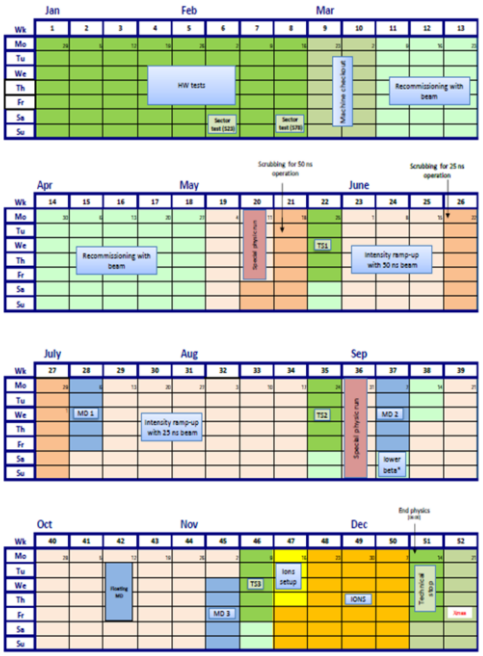

Figure 4: LHC schedule for 2015 [6].

RADIATION TO ELECTRONICS

The radiation-to-electronics (R2E) project was, and is, a major effort. From 2008 to 2011 it analysed and mitigated all safety relevant cases and limited the global impact. In 2011-2012, the emphasis was on avoiding long downtimes and on adding shielding. The LS1 period (2013/2014) was used for final relocation and more shielding. During LHC Run 2 through LS2 (2015-2018) the R2E effort will focus on tunnel equipment and power converters. Figure 5 illustrates the large past and future improvement resulting from this effort.

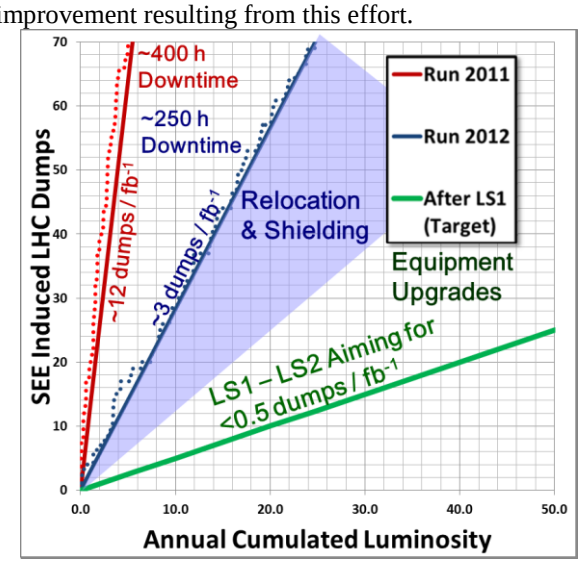

Figure 5: LHC beam dumps due to single-event upsets as a function of integrated annual luminosity for 2011 and 2012, together with a forecast for the post-LS1 period [7].

UFOS

The UFO situation may get worse at higher beam energy, where the UFO rate is expected to increase. The UFO rate is further known to be higher with 25 ns spacing than for 50 ns. In addition the energy loss per UFO increases at 6.5 TeV, while the quench margin is reduced. As a further complication, for higher beam energies the duration of the UFOs decreases and the rise time becomes faster; see Fig.6.

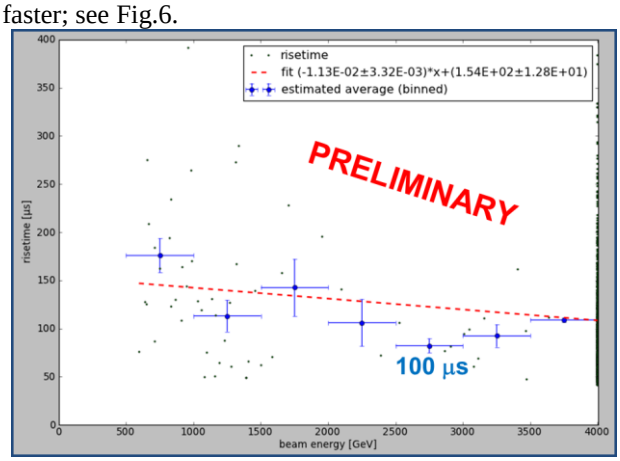

Figure 6: UFO rise time versus beam energy extracted from 683 UFO events observed in the arc (≥ cell 12) during operation with 1374 or 1380 bunches until 20.08.2012, considering signals with BLM running sum 4 above $2 \cdot 10^{-4}$ Gy/s. Only datasets with $R^2 \geq 0.95$ are included [8].

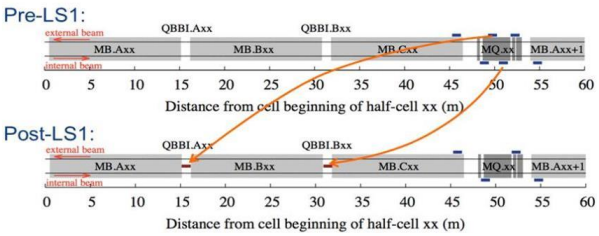

Figure 7: Relocation of BLMs during LS1 [9].

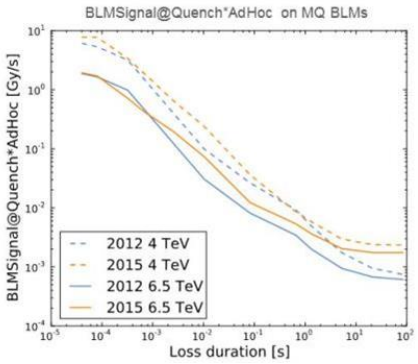

Figure 8: BLM thresholds vs. loss duration in 2012 and 2015 at beam energies of 4 and 6.5 TeV [9].

During LS1 there had been no mitigation measures to reduce UFO activity. However, two other measures were adopted:

(1) BLMs had been relocated for 100% coverage of SC magnets to allow localizing and quantifying UFOs. Specifically, BLMs were moved from the centre of MQ to a position above MB-MB interconnects (Fig. 7). The initial numbers of UFO events will be larger than in 2012, but conditioning should help.

(2) BLM thresholds had been refined, based on quench tests, to avoid unnecessary triggers and quenches; this is illustrated in Fig. 8.

LHC GOALS FOR 2015, RUN 2 AND RUN 3

The priorities for the 2015 run are to establish proton-proton collision at 13 TeV with 25 ns and low β^*, to prepare a production run in 2016, and to optimize the physics-to-physics duration (i.e. to minimize the "turn-around" time). One of the present limitations of the turnaround time is illustrated in Fig. 9. Later in 2015 there would be a decision on timing and duration on the special runs, e.g. 90 m optics. These would not be scheduled in the first part of the year. An LHCC recommendation was awaited. The 2015 run will also include a *Pb-Pb* run of one month.

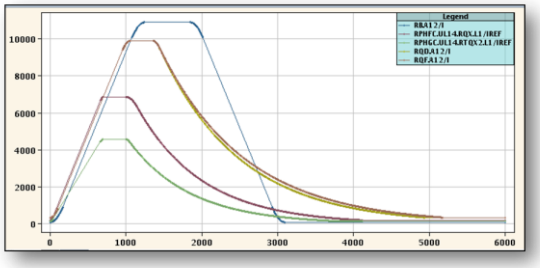

Figure 9: Ramp up and down cycles of the main LHC magnet circuits, indicating a possible improvement for the ramp down, and a shortening of the overall turnaround time, through the use of 4-quadrant power converters [10].

The goal for Run 2 is to reach a luminosity of 1.3×10^{34} $cm^{-2}s^{-1}$ in operation with 25 ns bunch spacing (2800 bunches), corresponding to a pile-up of ~40 events per bunch crossing. A maximum pileup of ~50 is considered to be acceptable for ATLAS and CMS. **The integrated luminosity goal for 2015 is 10 fb^{-1}, until the end of Run 2 ~100-120 fb^{-1}** (a better estimate will be available by the end of 2015), **and 300 fb^{-1} by LS3** (Fig. 10).

Figure 10: LHC run schedule with luminosity goals through 2025 [11].

THE LIU & HL-LHC PROJECTS COST AND SCHEDULE REVIEW

A cost & schedule review will be organized from 9 to 11 March 2015, in the frame of CERN-MAC meeting no. 10 (CMAC10). The review will be chaired by Norbert Holtkamp of SLAC. The goal of this cost and schedule review is to assess the status and risks of both projects.

Presently four major activities are ongoing in parallel at CERN: the operation of the accelerator complex, the Accelerator Consolidation Program, the LHC Injector Upgrades (LIU), and the High Luminosity LHC upgrade. The Cost & Schedule Review will cover the LIU and HL-LHC projects, taking into consideration their working hypotheses linked to the Consolidation project and to the operation of the CERN accelerator complex. However this review will not assess the cost and schedule of the Consolidation project nor the operation of the accelerator complex.

The following specific questions will be addressed:

- Is the estimated budget of the two projects adequate (for the baseline scenarios)?
- Are there any options to reduce the budget and does the review team see opportunities for savings? What is the possible scope contingency?
- What are the areas of high risk for scope, schedule or cost overrun? What would be the adequate related contingency, testing, mitigation measures…?
- Is the schedule well developed, credible and synchronized between the ongoing activities (operation, consolidation, diversity program, as well as the LHC experiments)?
- Are the foreseen resources correctly evaluated?
- Will the expertise (managerial and technical) be available when needed?

LS2 STRATEGY AND PREPARATION

The goal for Run 2 was to reach a luminosity of 1.3×10^{34} $cm^{-2}s^{-1}$ in operation with 25 ns bunch spacing (2800 bunches), corresponding to an estimated pile-up of 40 events per bunch crossing. A maximum pileup of ~50 is considered to be acceptable for ATLAS and CMS. Figure 11 shows the injector schedule through the end of LS2. Figure 12 presents preliminary estimates of injector downtimes required during LS2.

Figure 11: Injector schedule through the end of LS2 [12].

LIU MASTER SCHEDULE

A preliminary plan and time requirements for the LIU project during LS2 is presented in Fig. 13. This is still to be detailed by machine and coordinated across projects (for resource levelling).

A few first remarks can, however, already be made:

- The **PSB upgrade represents the critical path of the LIU project** in terms of workload on site.
- The **connection of the Linac4 has to be scheduled at the most appropriate time** according to the manpower needs.
- **Radioprotection conditions** to work in the various machine areas according to beam operation and other constraints will have to be identified (Linac3, dismantling of Linac2?)

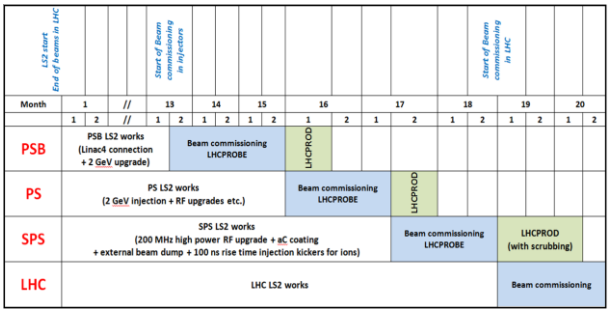

Figure 12: Preliminary estimates of shutdown time required for the LHC injectors during LS2.

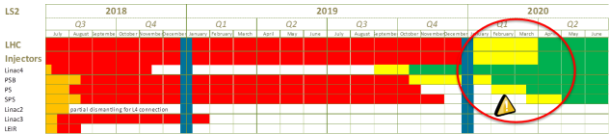

Figure 13: Preliminary LIU master plan [13].

LHC ACTIVITIES IN LS2

A proposal for a first **draft skeleton of LHC activities during LS2** is shown in Fig. 14. Details will depend on the cool down and warm up sequence. The time windows available for the activities vary between 9 and 13 months.

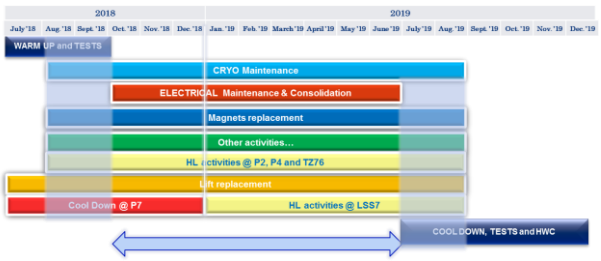

Figure 14: Skeleton of LHC Master Schedule for LS2 (indicative) [14].

CMAC9 RECOMMENDATIONS

CMAC9 issued the following 10 recommendations:

- R1: **The re-commissioning time for Heavy Ions** should be clarified with well-defined milestones.
- R2: Develop **integrated luminosity evolution plan for 2015 and Run 2** as a whole.
- R3: Schedule sufficient **study time** to resolve the luminosity limitation due **to instabilities during LHC commissioning** in 2015.
- R4: Develop a robust system to identify and prevent the unnecessary beam aborts due to UFOs.
- R5: Prepare a **minimum SPS upgrade plan** that satisfies the beam performance requirements of the HL-LHC project as soon as possible.
- R6: Investigate the **loss mechanism during the first hour of LHC stores** and develop mitigating efforts for the HL-LHC project.
- R7: Document the **scope, schedule and cost estimates for the HL-LHC in time for the cost & schedule review planned in March 2015** and pick one scenario for the purpose of costing and scheduling. Clearly distinguish the options from the baseline and define the advantages/ risks/ cost/ timelines
- R8: Perform a **sensitivity study from beginning to end (LINAC → HL-LHC) that demonstrates the margins/losses/beam requirements system by system** (accelerator by accelerator) in synchronization with LIU planning.
- R9: Perform **"the return on investment" analysis for the proposed consolidation activities** and take that into account when deciding what to fund when.
- R10: Determine the **effects of recent and expected changes in radiation regulations on the material handling in LS2**. Extend the estimation of radiation safety beyond LS2 through the entire HL-LHC to evaluate the impact on the project and the inevitable cost.

OUTLOOK

After huge work during LS1, the hardware & beam commissioning and the operation of the LHC machine at higher energy will be an absorbing and captivating period.

Beams are back in the injectors and are knocking at the door of the LHC.

ACKNOWLEDGEMENTS

Chamonix 2014 was a very fruitful workshop with very good proposals, overviews and strategies, with valuable information and discussions, and with an active participation of the LHC experiments.

We thank all the session chairs and scientific secretaries for a high-quality programme, the speakers together with all the persons involved in the preparation for their excellent presentations, as well as all participants for the open and lively discussions. We warmly thank Evelyne Delucinge for the practical organization of the Chamonix 2014 workshop.

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