SESSION3: PICS AND UPGRADE SCENARIO 1

M.Meddahi, L.Rossi, CERN, Geneva, Switzerland

Abstract

This document summarizes the talks and discussion which took place in the third session of the RLIUP Review.

The session was devoted to Performance Improving Consolidation (thereafter PICs) and Upgrade scenario 1. The PICs were defined as the “Replacement or upgrade of a system justified by consolidation but with the goal of improving performance”. The PICs scenario goals were further defined as accumulating 70 fb^{-1} integrated luminosity per year over a period a 10 years of operation, reaching 1000 fb^{-1} (starting with an initial integrated luminosity of 300 fb^{-1}).

An ‘Upgrade’ was defined as the ‘Replacement or addition of a system to improve the performance, which would otherwise not be necessary’. The Upgrade scenario 1 goals were defined as accumulating 170 fb^{-1} integrated luminosity per year over a period a 10 years of operation, reaching 2000 fb^{-1} (starting with an initial integrated luminosity of 300 fb^{-1}). This scenario assumed no crab cavity, no levelling, and a crossing angle adjusted for 12 sigma long range beam-beam separation.

The aim of the session was to analyse which beam parameters can reach these targets and what are the related actions on the equipment.

In the first part of the session, the PICs were presented and discussed for both the LIU and the HL-LHC project. This part comprised three presentations: “Injectors: PICs: what are we talking about?” by K.Hanke; “LHC: PICs: what are we talking about?’ by P.Fessia and “LIU-HL-LHC: PICs: what do we gain in beam performances?” by G.Arduini. The second part of the session was devoted to the Upgrade scenario 1, with four presentations: ‘HL-LHC: How to achieve Upgrade Scenario 1 goals in the LHC?’ by O.Brüning; “Work effort in the LHC accelerator for upgrade scenario 1” by E.Todesco; “LIU: Which beams in the injectors fulfil HL-LHC US1 goals?” by S.Gilardoni and “Work effort in the LHC injector complex, including Linac4 connection, for upgrade scenarios” by J.-B.Lallement and B.Mikulec.

PICS IN THE INJECTORS: WHAT ARE WE TALKING ABOUT? – K. HANKE

K.Hanke emphasised that despite the fact that there is a clear PIC definition, some overlaps and grey zones persist with pure consolidation (defined as ‘Partial or complete replacement of a system to be performed in order to maintain the present level of performance/availability’) and Upgrade scenarios. A summary of all the PICs needed for the LIU project was given and the time driver activity for a minimum duration single block adds up to 12 months for the LIU-PSB, 3 months for the LIU-PS and 6 months for the LIU-SPS. It was stressed that all time estimates depend strongly on the available manpower and a consequent amount of work is indeed to be done in parallel for all machines. So the planning has to be weighted together with the consolidation and maintenance activities.

In terms of cost, 50 MCHF is needed for PICs in the LIU-PSB, 16 MCHF for the LIU-PS and 23 MCHF for the LIU-SPS.

It is important to note that the PICs are mandatory and must be fully implemented in the injectors in LS2 regardless of which upgrade scenario is chosen.

PICS IN THE LHC: WHAT ARE WE TALKING ABOUT – P.FESSIA

P.Fessia described the extensive LHC PIC activities which concern practically all the sectors of the machine and are spread between the 1st long technical stop after LS1 and LS3.

The interaction region interventions in IP 1 and 5 provide safe operation for 2025 to 2035 years and the required luminosity capacity.

The collimation interventions should reduce the whole machine impedance providing more robust collimators and ensure safe ion run in IP2.

The beam diagnostic interventions provide the necessary diagnostic capacity, with hardware compatible with the higher radiation dose.

The SC (superconducting) links provide a solution to radiation electronic issues for the Power converters, and (by removing also the DFBs from teh tunnel) are key for reducing collective dose and interventions time.

The Cryoplant at point 4 provides flexibility in the management of the RF interventions and eliminate the 1st machine bottleneck in term of cooling capacity. All cryogenics installation have to be performed with a long term view in the installation/integration perspective (foresee for future needs).

The high radiation dose calls for radiation management and possible reconfiguration to provide the best possible reliability and access conditions. Radiation tolerant electronic development (including R&D and testing) will affect several equipment groups (costs, resources).

PICS: WHAT DO WE GAIN IN BEAM PERFORMANCE? – G.ARDUINI

G.Arduini summarised the possible performance, depending of the beam parameter scenarios (cf. tables in G.Arduini’s presentation).

To be noted:

- The luminosity target can be reached with the standard 40cm/20cm optics;
- The BCMS (Batch Compression Merging and Splitting) gives a slightly higher performance

but is more sensitive than the standard scheme to additive sources of emittance blow-up;
- The 50/25 optics provides margin in aperture and offers a reduction of the pile-up density below 0.7 events/mm;

The key questions and studies required in Run 2 have been sketched, e.g. understanding and control of the sources of blow-up; confirmation of the feasibility of β*-levelling as a possible solution for IP8; confirmation of the feasibility of scrubbing the dipoles down to SEY=1.3-1.4 possibly with dedicated beams; full understanding of the stability limits for single and two-beams.

WHICH BEAMS IN THE INJECTORS FULFIL THE UPGRADE SCENARIO 1 GOALS? – S. GILARDONI

S.Gilardoni investigated all the different possible options in order to reach the Upgrade Scenario 1 goals, with the emphasis that large bunch intensity in LHC is more important than low emittances.

His investigation led to the conclusion that the 200 MHz RF Upgrade in the SPS is mandatory to match the goals of LHC-Upgrade scenario 1, with unchanged longitudinal parameters at LHC injection. Therefore, for the LIU project, there is no difference in terms of hardware strategy between Upgrade scenario 1 and 2.

HL-LHC: HOW TO ACHIEVE UPGRADE SCENARIO 1 GOALS IN THE LHC? – O.BRÜNING

O. Brüning derived the possible performance reach scenarios, using the beam parameters presented by S.Gilardoni, assuming the LIU SPS 200 MHz full upgrade ($1.9\ 10^{11}$ppb within 2.26 μrad emittance (> 70% blow-up wrt SPS extraction), at LHC collision energy).

For example, the following case could reach the Upgrade Scenario 1 goals and is possible from the IBS point of view, requiring TAS and TAN upgrades, as well as matching section upgrades.

- N at collisions = 2508 colliding pairs in IR1 and IR5 (revised BCMS filling scheme)
- flat beams with beta* = 0.4m / 0.1m
- beam separation of 10 sigma -> crossing angle of 310 μrad
- IBS growth rates of ca. 22h horizontally and 25h longitudinally (scaled)
- Peak Luminosity = $8\ 10^{34}\ cm^{-2}\ s^{-1}$
- Leveling time = 2.9 h; Luminosity decay time = 4 h; Turnaround time = 3 hours
- Total fill length (leveling + decay + turnaround) = 9.9h
- Integrated Luminosity per fill =1.06 fb^{-1}; Luminosity per year for perfect operation = 413fb^{-1}
- Required efficiency for achieving 170fb^{-1} per year = 41%

The following additional remarks were made:

- Beam-Beam Wire compensator is very important for Upgrade scenario 1. An optimum position at 10 sigma would require checking carefully the integration aspects with the Collimation System.
- The small emittance beams from LIU upgrade cannot really be utilized in the LHC due to IBS limitations.
- The Upgrade Scenario 1 goals are compatible with full SPS upgrade and HL-LHC PIC when operating with flat beams (40cm/20cm). Smaller β* (e.g. 40cm/10cm) can provide more performance (>20%) but requires some Matching Section upgrades.

WORK EFFORT IN THE LHC ACCELERATOR FOR UPGRADE SCENARIO 1 – E.TODESCO

E.Todesco described the LHC work effort to meet the upgrade scenario 1 goals.

The same peak luminosity as for the Upgrade scenario 2 will be reached (heat loads), and 2/3 of data (radiation damage) – many unknowns to be seen with 7 TeV operation

The new triplet/D1 as defined for PIC (larger aperture and W-shielding) allows swallowing larger heat loads (thanks to new cryoplant for the triplets), and radiation damage.

The Matching section becomes a bottleneck for β* (not lower than 30 cm), but can swallow heat load and radiation damage.

The scenario relies on the ability to increase beam intensity.

The main work effort lies in the collimators in IR7, IR1, IR5, in the superconductive link for matching sections in IR1 and IR5, and in the Beam-beam long range wire compensator. This equipment is essential, it is a new piece of hardware and a proof of principle for the LHC will be given in ~2017.

WORK EFFORT IN THE LHC INJECTOR COMPLEX, INCLUDING LINAC 4 CONNECTION, FOR THE UPGRADE SCENARIOS – J.-B.LALLEMENT, B.MIKULEC

J.-B.Lallement confirmed that 15 weeks are needed to deliver a Linac4 beam to the PSB (linac2/linac4 interface and LBE line activities, including beam commissioning). B.Mikulec investigated the overall Linac 4 connection to the PSB and about 9.3 months will be needed.

During LS2, the time line is driven by the PSB activities (a big amount of cabling work to be performed which inevitably will compete with cabling needed for other projects). The PSB first beam (LHCPROBE) will be sent to the PS after 17.5 months. The PS will be ready for beam from PSB already after 14.5 months. So clearly it is needed to gain 3 months in PSB planning. The SPS will be ready for beam from PS after 16.5 months. So the first injection of LHCPILOT into the LHC will take place after

~20.5 months and the minimum time for injection of LHC production beam into the LHC is estimated to ~22 months (due to scrubbing to be performed).

OVERALL SUMMARY OF SESSION 3 – M.MEDDAHI, L.ROSSI

- PICs
  - Need to be fully implemented in the LIU regardless of the chosen Upgrade Scenario;
  - PICs (new triplet+collimation upgrade+ Cryo…) are mandatory for future HL-LHC operation;
  - PICs provide at least 70 fb^{-1} / year and fulfil the 1000 fb^{-1} target sets for the PICs only scenario until 10 year operation to 2035.
- Upgrade scenario 1
  - Means Full Upgrade of the injectors (identical upgrade to scenario 2);
  - Allows reaching the set target of 2000 fb^{-1} (170 fb^{-1}/y) using 'smaller' emittance beams. However, in lack of Crab cavity, foreseen only in Upgrade scenario 2, the long range BB compensating wire is necessary in the LHC.
- Schedule
  - Coordinated effort to plan all the upgrade implementation is to be started, taking into account all needed resources for LIU, HL-LHC but also CONS and other requests;
  - Should cover a longer time span (few LS);
  - LS2: LIU implementation to be ready for post-LS3 operation;
  - LS2 should be at least 18 months (but for LIU is necessary to solve the cabling problem, by increasing resources and speed of laying)