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STATUS AND PLANS FOR THE UPGRADE OF THE CERN PS BOOSTER

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Abstract

CERN's Proton Synchrotron Booster (PSB) is undergoing a major upgrade program in the frame of the LHC Injectors Upgrade (LIU) project. During the first long LHC shutdown (LS1) some parts of the upgrade have already been implemented, and the machine has been successfully re-commissioned. More work is planned for the upcoming end-of-year technical stops, notably in 2016/17, while most of the upgrade is planned to take place during the second long LHC shutdown (LS2). We report on the upgrade items already completed and commissioned, the first Run 2 beam performance and give a status of the ongoing design and integration work.

INTRODUCTION

The upgrade of the PS Booster consists of two major parts. With the connection of Linac4, the injection scheme will be upgraded to charge exchange injection of H- ions. This change will significantly reduce beam loss in the injection area and allow for tailoring the transverse emittance by means of phase space painting. At the same time, the injection energy will be increased from 50 MeV to 160 MeV [1]. With this increase of beam energy the relativistic $\beta\gamma^2$ factor increases by a factor of 2. The incoherent space charge tune shift at Booster injection can be expressed as

$$\Delta Q_x = \frac{R_p N_b}{2\pi^{3/2}\gamma^3\beta^2\sigma_z}\oint\frac{\beta_x(s)ds}{\sigma_x(s)[\sigma_x(s)+\sigma_y(s)]}$$

$$\Delta Q_y = \frac{R_p N_b}{2\pi^{3/2}\gamma^3\beta^2\sigma_z\sqrt{\varepsilon_y}}\oint\frac{\sqrt{\beta_y(s)}ds}{\sigma_x(s)+\sigma_y(s)}$$

where R_p is the classical proton radius and N_b is the number of protons per bunch. With the increase of injection energy the space charge tune shift decreases by a factor 2, thus doubling the intensity that can be accumulated within a given emittance. The second component of the upgrade program is the increase of the extraction energy from presently 1.4 GeV to 2.0 GeV. The underlying idea is to reduce space charge effects at injection into the downstream Proton Synchrotron (PS), thus removing this bottleneck. The expected gain can again be deduced from the ratio of the $\beta\gamma^2$ factor at 1.4 GeV and 2.0 GeV, which is 1.63 and corresponds to an intensity increase of 60% within given emittance values.

LS1 WORK

While most of the upgrade activities are scheduled to be implemented during LS2, a number of LIU activities could be performed in the PSB during LS1 in 2013/14. Activities that could be completed comprise:

- implementation of the new digital RF controls
- installation of 5 additional prototype Finemet cavity cells (Fig. 1)
- upgrade of diagnostics (new beam loss monitors, new orbit measurement, new pick-ups and transformers in the transfer lines)
- renovation of the multipole power supplies
- installation of a new external dump
- limited cabling campaign and identification of obsolete cables
- controls upgrades (change of many front-end computers)
- consolidation of handling and lifting equipment
- new hardware interlock at extraction (Beam Interlock System - BIS)

Figure 1: Prototype Finemet cavity modules installed in Ring 4 of the PSB.

COMMISSIONING OF UPGRADE ITEMS

The PS Booster was re-started after LS1 in June 2014. Unlike in previous years, much more than standard

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maintenance had been performed during the shutdown, and several systems were completely new and needed to be commissioned. A major effort represented the successful commissioning of the new, digital low-level RF system. This system was put fully in place and the old RF controls were phased out. On the high-level RF side, additional cavity cells were installed and commissioned (Figs 1 and 2). This is part of the prototyping for the full replacement of the existing first and second harmonic cavities in the frame of the LIU project. A major milestone could be reached when the LLRF team succeeded to accelerate 650E10 protons in a pure h=1 using only the Finemet system (ferrite cavities were disabled). Using the ferrite cavities to back up the power 790E10 protons could be accelerated [2].

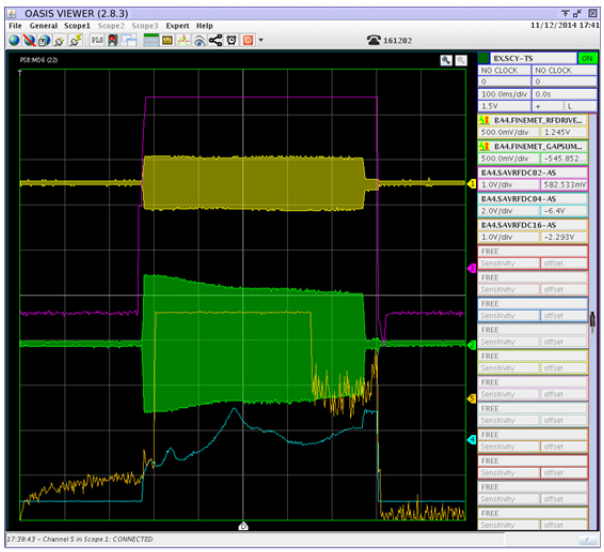

Figure 2: Finemet drive and return. First harmonic ferrite cavity on, second harmonic ferrite cavity disabled.

Other hardware installed during LS1 could also be successfully commissioned, as for example the new external dump, new power supplies and new beam instrumentation.

RUN2 MACHINE PERFORMANCE

Throughout the year 2014 beams were set up with the primary goal to recover pre-LS1 performance. Besides the beams for CERN's fixed-target physics program, the different LHC-type beams were set up (Figs 3 and 4). These comprise the low-intensity single-bunch beams used for setting up of the LHC, as well as the multi-bunch beams with 25 ns and 50 ns bunch spacing.

By early 2015 and well in time for the start-up of the LHC after LS1, all LHC type beams are available in the injector complex with pre-LS1 performance.

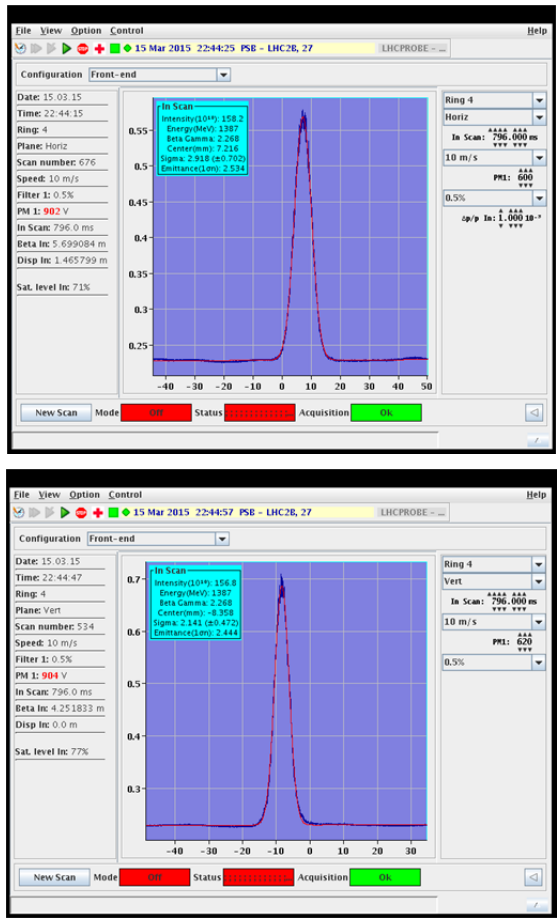

Figure 3: Measured transverse characteristics of the 25 ns bunch spacing LHC physics beam in the PSB.

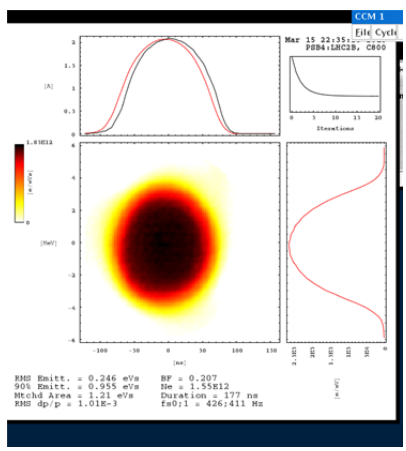

Figure 4: Measured longitudinal characteristics of the 25 ns bunch spacing LHC physics beam in the PSB.

ONGOING UPGRADE WORK

As the machine is running again for the fixed-target physics program and the LHC, work continues in various areas of the LIU upgrade. This comprises the new injection line with the distribution system which splits up the incoming beam into the four levels of the PSB, as well

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as the injection period itself with the foil mechanism and associated magnets, diagnostics and beam dumps. Since the area is very confined and had originally not been designed for such an injection system, a very demanding integration work is necessary. Figure 5 shows the injection period of the PSB after the upgrade.

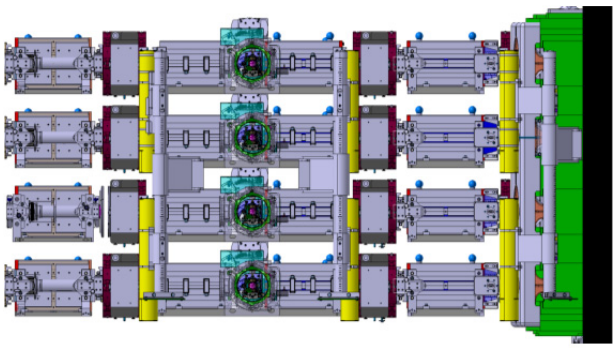

Figure 5: Integration drawing of the new injection region with injection chicane magnets and foil changer units (center).

Important input for the assembly and commissioning of the new injection scheme will come from the Half Sector Test. This test set-up consists of half of the injection period, which will be temporarily installed in the Linca4 transfer line. It will allow to gain practical experience with the new injection hardware, thus saving time during the commissioning in the PSB. In addition to the Half Sector Test, a stripping foil test stand will be installed in the Linac4 transfer line [3].

On the side of the 2 GeV energy upgrade, the technical specifications for the new main power supply have been finalised and procurement is in progress. The new power supply will be housed in a dedicated building the construction of which will start in the first half of 2015. The new building includes cooling and handling equipment, and will house the reference magnet.

Other magnets required for 2 GeV operation are in the final design phase or already being procured.

For the new Finemet cavity system studies are ongoing and a final review is planned for September 2015. This will also mark the final decision point on whether to opt for this new system (baseline) rather than to consolidate the existing RF cavities (fall-back scenario).

WORK PLANNING

As the PSB is operating as part of the LHC proton injector chain, all upgrade work is constrained by the stops of the LHC. Limited work (e.g. inspection of cables) is possible during the end-year technical stops (YETS), for example 2015-16. Here it is also planned to install the KSW16L1 kicker [4]. There will be an extended technical stop in 2016-17 which will allow for clean-up of unused cables, a prerequisite for new installations. The bulk of the upgrade work is planned for LS2, with both Linac4 connection and 2 GeV upgrade happening simultaneously. This planning has been endorsed by a review in October 2013 [5]. A detailed planning of all the coactivities is presently being performed by CERN's Machines & Experimental Facilities group.

CONCLUSION

The upgrade of CERN's PS Booster in the frame of the LIU project is well under way. A limited number of upgrade items have been installed during LS1 and have been successfully commissioned. For the other items, all technical design choices have been made and manufacturing and procurement of equipment is in full swing for installation during LS2. The complete LIU upgrade has been documented in detail in a Technical Design Report published in 2014 [6]

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