LHC INJECTION SYSTEMS MODIFICATIONS IN LONG SHUTDOWN 1

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Abstract

Hardware changes of the injection and injection protection systems, foreseen in LS1, are presented. Proposals for improving the protection logic of the abort gap keeper, ensuring correct TDI and TCDI settings and its validation, avoiding SPS-LHC timing issues and the need for BLM 'sunglasses' after LS1 are discussed. Suggestions for safely steering the transfer line trajectories and improving the role of the Injection Quality Check (IQC) as an operational tool are presented.

MKI UPGRADES

Due to high voltage breakdown reasons, most of the presently installed injection kicker magnets MKI have 15 screen conductors to reduce the beam impedance, rather than the initially planned full complement of 24. For the upgrade after the Long Shutdown One (LS1) it is foreseen to equip all magnets with 24 screen conductors which shall reduce the beam induced heating by a factor of approximately 3-4. To achieve this, several modifications are being made to the beam screen. Some part of the metallization at the end of the ceramic tube will be replaced by a conducting cylinder which is spaced from the ceramic, Fig. 1. Preliminary test results indicate that this modification increased the PFN voltage at which surface flashover occurs by at least 50%. The copper bypass tubes for the counter-rotating beam will be NEG-coated in order to suppress electron cloud build-up, Fig. 2. Increased tank emissivity shall lead to better thermal radiation of the heat generated in the ferrites. The vacuum system for the cold-warm transitions in the MKI areas shall be upgraded with NEG-coating of the copper insert, installation of new domes on both sides of the sector valves with a D400 NEG cartridge and 2 ion pumps. All Beam Position Screens (BTVSI) and Beam Position Timing modules (BPTX) will be NEG coated. For the MKI interconnects, the ion pump shall be exchanged to a version including a NEG cartridge, and the copper insert of the warm bellow module will be NEG coated. In order to reduce dust particles (UFOs) which can lead to beam losses and hence beam dumps, the ceramic tubes will be even better cleaned, as already performed on the MKI8D unit (installed during the technical stop TS3 in 2012) with promising results. There are ongoing studies on a Cr_2O_3 coating of the ceramic tube to further increase the flashover voltage and reduce the Secondary Electron Yield (SEY). Figure 3 shows the analysis of a test coating in the scanning electron microscope. One coated ceramic tube could possibly be installed during LS1 to obtain

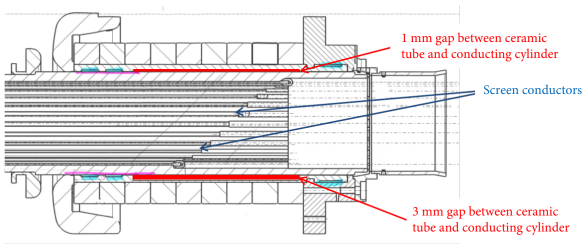

Figure 1: Upgrade of the MKI screen conductors.

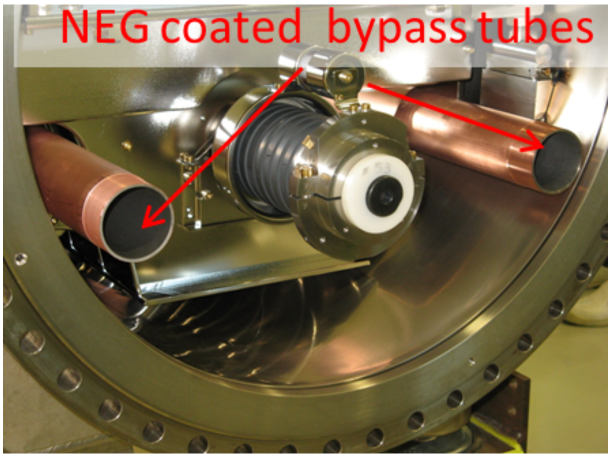

Figure 2: NEG coating of the MKI bypass tubes.

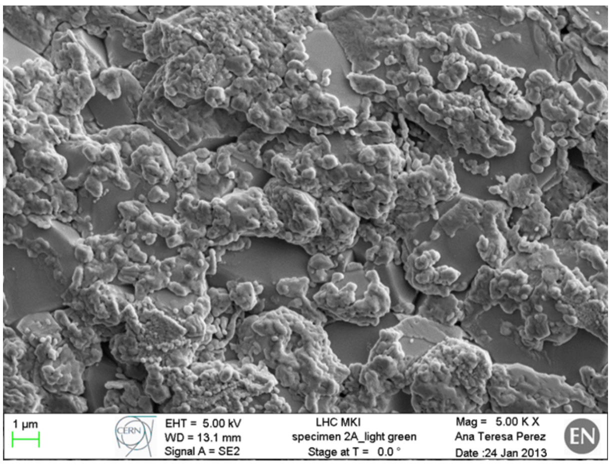

Figure 3: SEM analysis of the chromium oxide coating, courtesy of A. Perez.

operational experience; the magnet could be exchanged in case of detrimental effects. Further studies include the effect of vacuum pressure on the surface flashover voltage and measurements of the beam coupling impedance with comparison to simulations.

TDI CONSOLIDATION

During LS1 both injection protection dumps (TDI), in point 2 and 8, will be removed and consolidated. The existing spare will be adapted as well and a second spare will be constructed with lower priority. The beam screen will be made out of reinforced stainless steel with copper coating and a new supporting frame, Figures 4 and 5. Its sliding systems will be improved. The central RF fingers will be replaced by a mechanical connection and the RF extremities will be bolted instead of electron beam welded. 16 more temperature sensors shall be added. The grease of the gearbox will be replaced by a coating to avoid the risk of torque increase due to radiation induced stiffening of the grease. Concerning the TDI coating, studies are ongoing on vacuum and impedance perfomance.

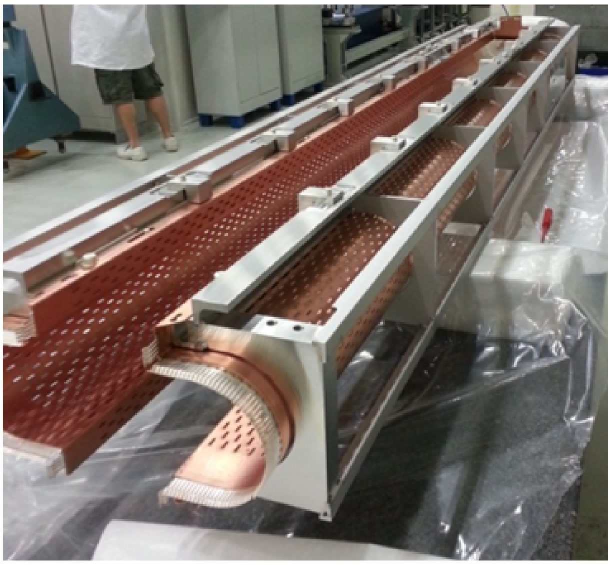

Figure 4: New reinforced TDI beam screen.

If the existing Ti coating can be removed, possibly a thin (1 μm) layer of Cu could be used with NEG coating to reduce the SEY. FLUKA simulations are ongoing to verify that copper does not sublimate in case of a grazing impact.

ABORT GAP KEEPER

Having the Abort Gap Keeper (AGK) not only connected to the MKI but also to the SPS extraction would avoid dumping the beam on the TDI in case of an inhibited MKI kick. However, this connection is impossible due to having different beam positions in the SPS with respect to the LHC. Improvements of the AGK will concern its monitoring; after each injection there shall be a measure of the delay between the end of the AGK and the trigger of the MKI and a measure of the delay between the trigger of the MKI and the beginning of the AGK. The sum of these two delays and the length of the abort gap should give the length of one turn.

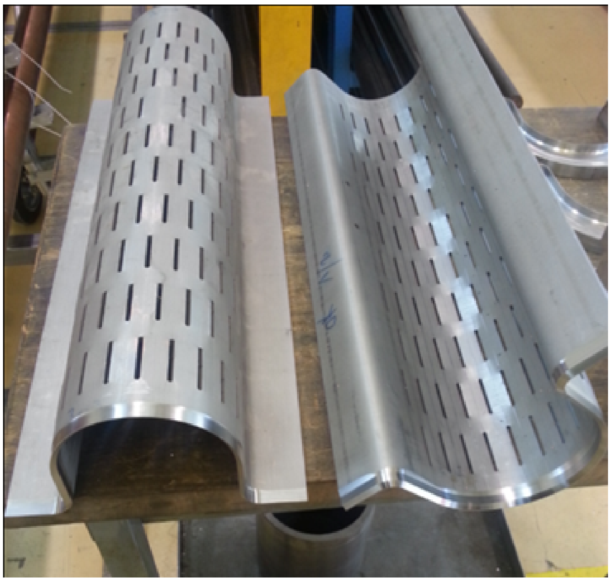

Figure 5: Prototype of new TDI beam screen.

INJECTION BETS CONNECTIONS

It is foreseen to interlock the current of the injection septum (MSI) with the Beam Energy Tracking system (BETS) applying a tolerance of a 1 σ beam oscillation. The BETS has to be connected to the injection Beam Interlock System (BIS). The injection BIS will stop the SPS extraction within a few microseconds which is acceptable compared to the expected timescale of MSI current changes. The interlock has to be maskable with the LHC Setup Beam Flag.

Also the TDI gap shall have a maskable BETS interlock with a ± 1 σ tolerance on the up- and downstream gaps. A reliable position monitoring is required in order not to compromise operational availability.

TCDI SETTINGS AND VALIDATION

After changing to the Q20 optics in the SPS and deploying a new optics also for the transfer lines TI-2 and TI-8 in September 2012 the gaps of the injection protection collimators (TCDI) were not adapted. To avoid such a failure in the future, a concept similar to the SIS β^* check as for the LHC ring is suggested. A TCDI Gap Control Parameter (TGCP) needs to be defined for the transfer line optics, just as β^* is defined for the squeeze functions. This will be used by the SIS-SMP-MTG chain to check the gaps in the TCDI, just as β^* is used for the gap control of the tertiary collimators (TCTs). For each transfer line optics the quadrupole currents have to be stored and associated with a unique TGCP value. The SIS reads reference settings, compares to published extraction currents for every cycle and in case the settings are within tolerance the value is published, otherwise zero is published.

On the TCDI side the TGCP value is read and checked if within limits.

The TCDI settings, TGCP values and optics are stored in a single beam process; if the beam process is wrong, the SIS check will fail.

Certain features need to be added to the existing infrastructure, like reference settings for the transfer line quadrupoles and TGCP values, TGCP limits for the TCDIs and additional SIS code.

TEMPORARY INHIBIT OF INJECTION BLMS

During RUN-1 of the LHC, beam loss induced showers from transfer line collimators were impacting the sensitive LHC ring Beam Loss Monitors (BLM) from the outside in the areas where the transfer line tunnel is adjacent to the ring. These losses trigger beam dumps already for low injected beam intensities. However, they are considered avoidable and therefore they unnecessarily limit the availability of the machine. Amongst other mitigations several options were studied to temporarily inhibit injection BLMs [1]. The option to be implemented in the BLM regrouping campaign during LS1 includes creating two crates (P2 and P8) dedicated to BLMs with the option to inhibit their interlock signal during injection (the option of blinding out dedicated BLMs is also known as the BLM 'sunglass' system).

In the 2012 run Little Ionization Chambers (LIC) were successfully tested with higher gas pressure [2]. LICs have a higher saturation level than standard ionization chambers and thus allow higher thresholds which could be used to avoid dumps at injection. However, these thresholds will be higher not only at injection but during the full time when the beam energy is at 450 GeV. A combination of standard ionization chambers with RC-filters and LICs will be selected to be connected to the dedicated crates. In selecting the monitors a trade-off has to be found between response time due to the RC-filters, noise limits in setting thresholds for different energies, and the reliability of the new monitors.

Monitor locations where injection losses could become critical for machine availability are described in detail in [3]. The aim is to have a factor 5 margin between maximum operational losses and the dump threshold. The data analysed is based on the 2011 run where the TCDIs had a 4.5 σ half-gap. Due to the increased number of avoidable dumps the TCDIs were opened during the run to 5 σ half-gap. For the restart after LS1 it is envisaged to come back to the original 4.5 σ opening.

It is foreseen to start the machine without blinding out these two crates, having the possibility to add the blind-out during the run in case avoidable dumps reduce the machine availability. Details on the implementation of the blind-out are described in [4].

OPERATIONAL CHANGES

A reproducible trajectory in the SPS to LHC transfer lines is mandatory to reduce injection losses which could lead to avoidable beam dumps as described in the section above. The main cause of shot-to-shot variations is the power converter ripple of the SPS extraction septum [5]. Work is ongoing to improve the stability of these power converters.

In order to facilitate a meaningful calculation of the trajectory corrections, the SPS extraction kicker timing has to be set up such that the trajectory of intermediate intensity beam (6 or 12 bunches) represents the behaviour of the full batch. The same kicker timing will be deployed for intermediate intensities and the full batch. In case corrections calculated on the full batch trajectory are sent to the hardware it is unavoidable to test the new trajectory with intermediate intensities. The same strategy must be applied for corrections to the ring orbit.

The Injection Quality Check (IQC) application is foreseen to become a more rigorous control for safety at injection. Possibly only one reset of injection oscillations per filling will be allowed and enforced by software. In terms of injection loss alarms, there shall be a warning level at 10% and an inhibit of further injections at 50% of the dump threshold.

SUMMARY

During LS1 modifications will be made to hardware and software of injection related systems. The upgrades of the MKI aim to reduce: high-voltage breakdowns of the screen, the beam induced impedance, the electron cloud build-up, and the UFO rate. The upgrades also aim to provide an improved cooling.

Both TDIs will be taken out and consolidated. Also the spare unit will be upgraded and another spare be constructed. The second spare might not be ready for the start-up.

Improved monitoring will be implemented for the AGK delays with respect to the MKI trigger.

The MSI current and the TDI gap will be connected to the injection BETS with a maskable BIS input to allow for the TDI setup.

TCDI settings will be validated by SIS using a β^* like check.

Two additional crates will be dedicated to the injection BLMs with the possibility of implementing their blind-out during the run to reduce the number of avoidable beam dumps at injection.

The transfer line trajectory stability is being improved by reducing the SPS MSE power converter ripple. Resetting injection oscillations and injection losses shall be limited by the IQC.

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