SIMULATIONS OF COLLIMATION CLEANING PERFORMANCE WITH HL-LHC OPTICS*

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Abstract

The upgrade of the LHC from the current set-up to high luminosity performances will provide new challenges for the protection of the machine. The different optics considered might create new needs for collimation, and require new collimation locations. In order to evaluate the cleaning performances of the collimation system, different halo cleaning simulations were performed with the particle tracking code SixTrack. This paper presents the cleaning performance simulation results for the high luminosity Achromatic Telescopic Squeeze (ATS) optics considered as baseline for the HL-LHC. The new limitations observed and possible solutions are discussed.

INTRODUCTION

The High-Luminosity LHC (HL-LHC) upgrade project aims to increase the peak luminosity to $5 \times 10^{34}\,\mathrm{cm}^2 \cdot \mathrm{s}^{-1}$ [1]. This can be done by decreasing the size of the beam at the Interaction Point (IP), with values of the beta function down to $\beta^* = 10\,\mathrm{cm}$. One way to achieve this is the so-called *Achromatic Telescopic Squeeze (ATS)* scheme [2]. Its main characteristics is to use a beta beating in the arcs adjacent to the IPs where the low β^* values must be obtained to reduce it further, as shown in Fig. 1.

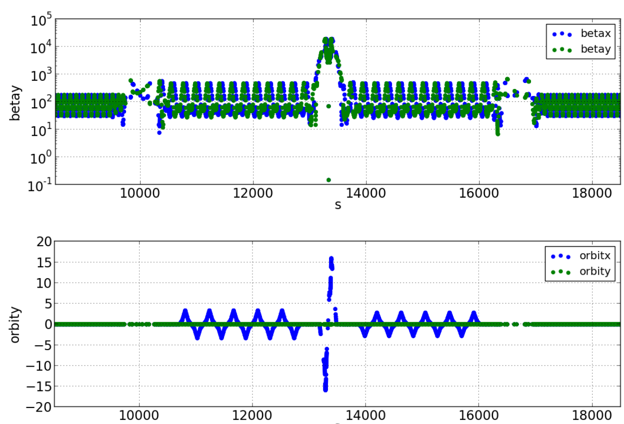

Figure 1: Examples of orbits (top) and beta functions (bottom) in the transverse planes in the arcs 4–5 and 5–6 around IP5, illustrating the differences with the other arcs.

The values of crossing angles and beta functions at the different Interaction Points (IPs) are given in Table 1. While the basic feasibility of this new scheme was successfully addressed during machine development periods at the LHC [4], other aspects need to be studied to see the overall feasibility for HL-LHC. This paper presents the first results of collimation cleaning with ATS.

Table 1: IP Parameters for the ATS Optics SLHCV3.1b [3]

IP	x'[mrad]	y' [mrad]	β_x^*, β_y^* [m]
IP1	0.	0.295	0.15
IP2	0.	0.240	10
IP5	0.295	0.	0.15
IP8	-0.305	0.	10

SIMULATION SET-UP

The cleaning performance simulations were performed using the tracking code SixTrack with the collimation routine [5], for the ATS layout and optics version `SLHCV3.1b` [3] which give the IP parameters in Table 1. The associated aperture model was updated to follow the modifications in IR1/5. The aperture model at the location of the separation dipoles in IR1/5 is still preliminary and does not model the aperture offsets. The nominal 7 TeV collimator settings are used for this first study (cf. Tab. 2). They ensure an adequate protection of the triplets for the optics considered.

The initial particle distribution is a halo at the setting of the primary collimator: 6 units of betatronic standard deviation called σ, in the considered phase space (horizontal or vertical); a normal distribution cut at $3\,\sigma$ for the other plane, and no variation of energy. This is the standard configuration for halo cleaning simulations [5]. A total of 30 millions protons at 7 TeV were tracked per simulation, for the perfect machine with no error.

Table 2: Setting of the Collimators by Type

Type	Location	Setting [σ]
TCP	IR3	12.
TCSG	IR3	15.6
TCLA	IR3	17.6
TCP	IR7	6.
TCSG	IR7	7.
TCLA	IR7	10.
TCSG	IR6	7.5
TCDQ	IR6	8.
TCT	IR1/5	8.3
	IR2/8	30.

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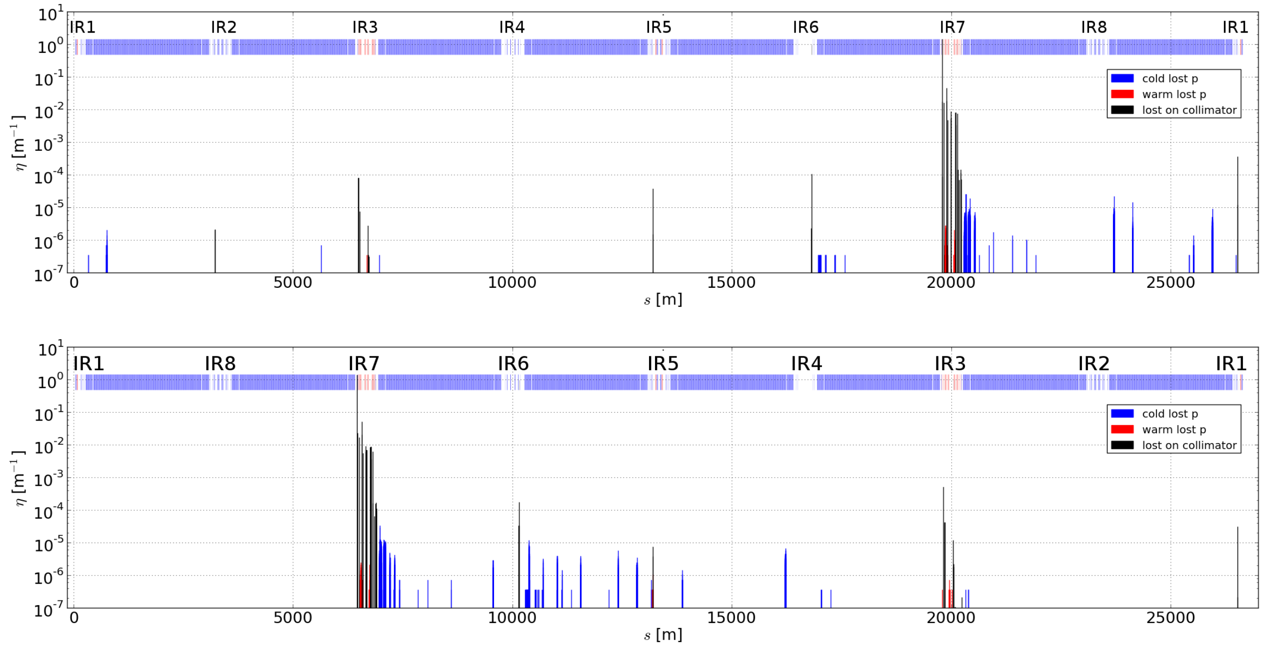

Figure 2: Horizontal loss map for the entire LHC Beam 1 (top) and for Beam 2 (bottom), for 30 million p. The red and blue boxes at the top give the position of warm and cold magnets respectively.

CLEANING SIMULATION RESULTS

The simulated loss map for a horizontal halo shows the local inefficiency around the ring, in Fig. 2 top. The results are the same for the vertical loss map. The local inefficiency η is defined as the loss per meter at a given location, normalised by the total number of protons lost.

The highest losses in cold elements occur in the Insertion Region 7 (IR7), similarly to standard optics, giving the highest inefficiency. The most critical area is the cold magnets in which the inefficiency is the highest (blue peaks right of IR7, see Fig. 3). These losses in the Dispersion Suppressors (DS) are also present in other schemes. However, other peaks, at the same level of the DS peaks (inefficiency $\eta \simeq 10^{-5}\,\mathrm{m}^{-1}$), appear in the arcs, as seen on Fig. 4. This is a specific feature of the ATS scheme which was never observed before with nominal collision optics. These losses, if proven to be above the quench limits, would be concerning because of their numbers: they could not all be cured locally, as the DS losses would.

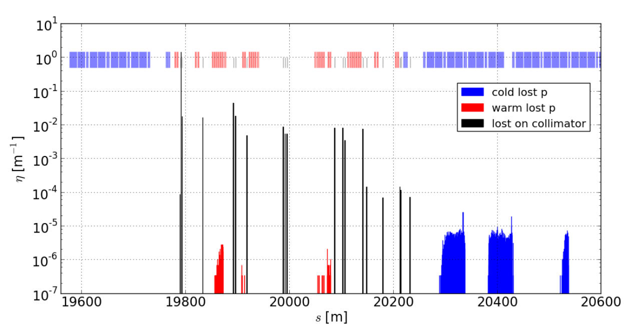

Figure 3: Horizontal loss map for IR7. Every peak in the DS corresponds to a maximum of the dispersion.

The same simulations were performed for beam 2 (cf. Fig. 2 bottom). In the arcs downstream IR7, losses occur at negative minimums of the dispersion (maximum in absolute); and always above a certain value of $\delta p/p$.

CHARACTERISATION OF THE LOSS PEAKS DOWNSTREAM IR7

In order to characterise the loss peaks, lost particles have been grouped by loss location. The transverse distribution of the DS losses in IR7 are illustrated in Fig. 5 top. Parti-

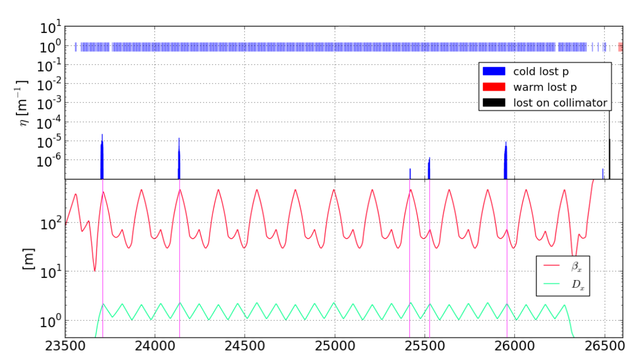

Figure 4: Loss map (top) and values of the beta and dispersion function (bottom) for the arc 81. Every peak inthe arc corresponds to a maximum of the dispersion.

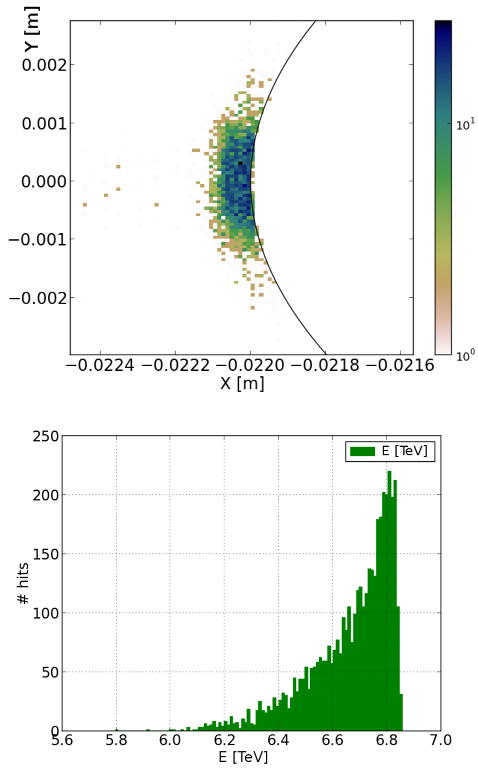

Figure 5: Transverse (top) and energy (bottom) distribution of the losses corresponding in the first peak in the dispersion suppressor right of IR7: 20270 m $< s <$ 20350 m. The black circle represents the aperture of the arc. The highest energy for a lost particle is 6.86 TeV, giving $\delta p/p = -0.02$.

cles are lost on the cold beam screens on the side of positive dispersion function. This is the typical distributions of dispersive losses dominated by single-diffractive interactions at the primary collimator. The energy distribution is also given in Fig. 5 bottom.

All the peaks discussed in the previous section, for both beams, have the same signature: they appear at local maximums of the dispersion function, as shown on Fig. 4. The distributions of the energy of the particles lost in each peak were gathered in Fig. 6. All the lost particles show a $\delta p/p < -0.005$, that is $E < 6.965$ TeV.

POSSIBLE SOLUTIONS

Since all limiting locations are induced by dispersive losses, a natural choice to cure the cleaning issues observed with the ATS optics is to consider local DS collimators in IR7, provided that the achievable momentum cut is sufficient to catch all the critical halo particles.

Solutions involving the installation of local DS collimators in IR7, in association with the new technology of the 11 T dipoles [6], are being considered. Preliminary optics considerations indicate that with collimators at the Q8, Q9 or Q10 locations, already considered in previous scenarios [7], one could achieve momentum cuts of -0.005 to

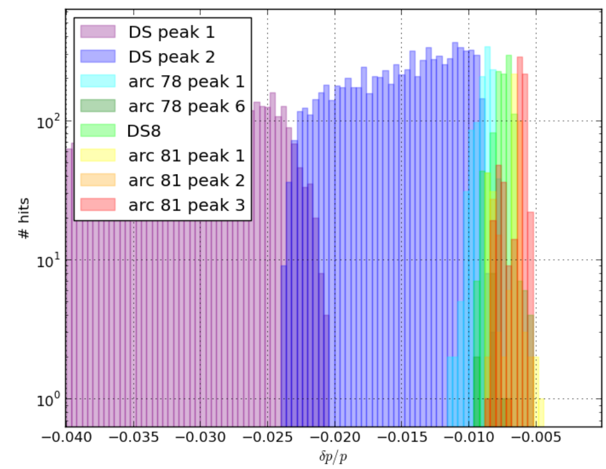

Figure 6: Distributions of the $\delta p/p$ of the particles lost in the main peaks downstream IR7, grouped by peak. The names are arbitrary. There is a clear limit of $\delta p/p$ under which the particles are lost.

-0.02 which would reduce losses around the ring. Detailed simulations for different layouts are ongoing.

CONCLUSIONS

The results for simulation of collimation cleaning with the ATS optics were presented. They indicated a new limitation due to losses in the arcs downstream IR7. Even for a perfect cleaning without optics, orbit and collimator errors, critical loss locations are observed in the arc used for the telescopic squeeze. This is a new feature that is not present in the standard optics, which is limited at the DS locations only. Preliminary studies indicate that DS collimation in IR7 could cure the observed limitation because losses around the ring have a dispersive nature. More simulation works are ongoing to address this.

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