

STATUS OF THE FCC-HH COLLIMATION SYSTEM

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Abstract

The future circular hadron collider (FCC-hh) will have an unprecedented proton beam energy of 50 TeV, and total stored beam energy of 8.4 GJ. We discuss current developments in the collimation system design, and methods with which the challenges faced due to the high energies involved can be mitigated. Finally simulation results of new collimation system designs are presented.

INTRODUCTION

The FCC-hh collimation system must protect the other accelerator components from beam losses which could cause serious issues such as magnet quenches, radiation damage, and high experimental backgrounds. The system must be highly efficient due to the high per-particle energy of 50 TeV, and stored beam energy of 8.4 GJ [1]. It must provide a higher cleaning efficiency over that produced by the current state of the art machine, the LHC. The accelerator has undergone a number of layout changes relevant to the collimation system since previously reported papers. In addition, previous layouts did not yet meet the required cleaning inefficiency target. Changes that have been made, and their effect on the performance on the system will thus be reported.

THE NEW ACCELERATOR LAYOUT

The current FCC-hh lattice has undergone a number of subtle changes since the previously reported version. Due to civil engineering constraints, the size of the accelerator has been reduced in order to fit within new geological boundaries. Previously in the extended straight sections, the beam dump system was followed by the betatron collimation system in order to protect against an asynchronous dump. Due to the decrease in available accelerator size, and the increase in length of the beam dumping system, the systems have now been split. The beam dumping system is now placed in one extended straight section and the betatron collimation insertion is placed in the opposite extended straight section. This was previously occupied by the energy collimation system and a beam diagnostics section. The energy collimation system has now been moved to a shorter straight section.

The experimental insertions are also updated. Two high luminosity experiments and two lower luminosity experiments now exist. The beam is injected in the same insertions as the lower luminosity experiments. This is shown in Fig. 1. Another major change is that each IR now has 2 collimators (TCLD) installed within the dispersion suppressor (DS) re-

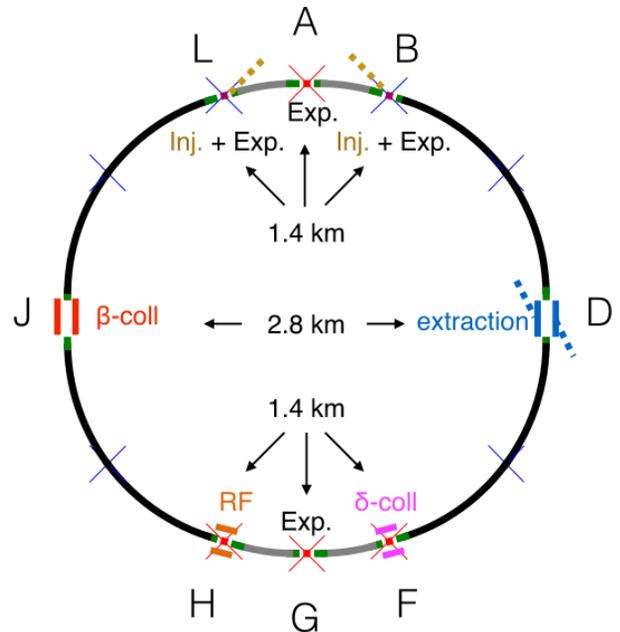


Figure 1: A diagram showing the updated FCC-hh accelerator layout.

gion by default. This follows an analogous scheme as to that which is foreseen to be implemented for the HL-LHC [4–6] upgrade to the LHC. These DS collimators are designed to catch off energy protons exiting the straight insertion regions, be they a collimation insertion or experiment [7]. Previous studies have shown that DS losses are an important issue for the FCC-hh [2, 3]. For the current layout, studies have been performed using protons generated by SixTrack/K2 and Merlin and have been transferred to FLUKA for full showering calculations in the DS. Different locations, collimator lengths, and masks have been tested, and it has been found that two 1 m tungsten collimators should be sufficient to prevent quenches, assuming the same minimum beam lifetime as the LHC.

SIMULATIONS OF THE NEW LAYOUT WITH DS COLLIMATORS

Beam loss simulations have been performed with the tracking code SixTrack [8, 9]. In [10], a number of simulations on the updated layout have been performed with a selection of simulation codes. In this paper, we have restricted ourselves to only using geant4 with the FTFP_BERT physics list, since it gave the highest rate of cold losses (excluding

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K2). A horizontal beam halo was generated - a ring in the x, x' plane (horizontal), a gaussian distribution cut at 3σ in the y, y' plane (vertical), and no spread in the longitudinal plane. The ring was generated with a size of $7.57 \pm 0.0015\sigma$ (the primary horizontal collimator opening). 12.8M particles were then tracked for 200 turns. Collimators were set as listed in Table 1.

Table 1: A Table showing collimator settings used for FCC-hh simulations. Values are given in beam sigmas.

Collimator family	Gap ($n\sigma$)
β TCP	7.57
β TCSG	8.83
β TCLA	12.61
δ TCP	18.06
δ TCSG	21.67
δ TCLA	24.08
IR TCT	10.47
DS TCLD	35.14

The first run was performed with no DS collimators. In the second run, DS collimators were set at 35.14 sigma in the betatron and energy collimation insertions, and also following the high luminosity experiments, IPA and IPG. The results of these simulations are shown in Figs. 2 and 3 for the full ring and the betatron collimation insertion.

The top pane of each image shows the optical functions, including the transverse beta functions in red (x) and blue (y), and the horizontal dispersion function in green. Directly below the optical plot is a small band showing the elements at each location in the lattice, blue denotes dipoles, red quadrupoles, and green shows collimators. The lower two panes show the cleaning inefficiency at each point, defined as

$$\eta = \frac{n_{\text{lost}}}{n_{\text{total}}\Delta s},$$

where Δs is the binning size, in this case 0.1 m for aperture losses, and the collimator length for collimators, n_{lost} is the number of particles lost in a bin, and n_{total} is the total number of particles.

The losses are colour coded depending on the location - losses in collimators are shown in green, losses in warm regions of the machine are shown in red, and those into cold superconducting magnets are shown in blue. These cold losses are to be avoided, and can lead to magnet quenches and radiation damage. The upper loss plot shows the simulation without DS collimators and the lower shows with them enabled as described.

It is highly promising that the DS collimators in the betatron collimation insertion remove almost all losses in the following cold regions. This extends to the arcs following IPA - between 0 and 43 km there are no cold losses with DS collimators inserted. It should be noted that even with DS collimators, not all cold losses are prevented. Cold losses

occur before the DS collimators after the energy collimation, and before the TCTs in the high luminosity experiments. The TCTs in future designs will need to be moved closer to the arcs, and the DS collimator placement may also need to be adjusted. It is also considered as an option to make a full redesign of the collimation system, rather than using the current scaling of the LHC system.

CONCLUSIONS

The current FCC-hh layout with dispersion suppressor collimators does provide a much higher cleaning efficiency over the lattice without any DS collimators in place. With the usage of DS collimators and some future placement adjustments, the required levels of cleaning inefficiency [11] of 3×10^{-7} could finally be achieved. Potential issues still exist about power loads and power density on to collimators [12]. These will have to be addressed in future redesigns of the collimation system.

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Figure 2: An image showing the current FCC-hh loss map with and without DS collimators using geant4 FTFP_BERT for the entire ring. A full description is given in the text.

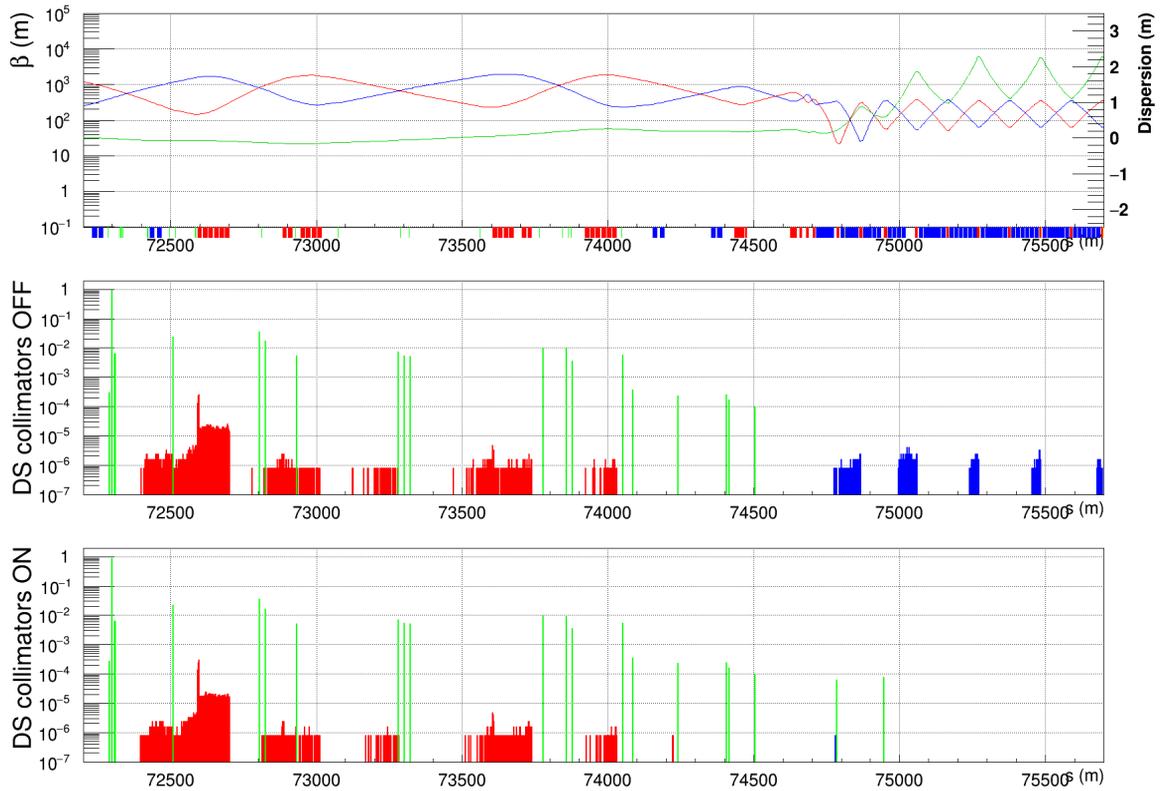


Figure 3: An image showing the current FCC-hh loss map with and without DS collimators using geant4 FTFP_BERT for the betatron collimation insertion. A full description is given in the text.

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