SIMULATION OF THE LHC COLLIMATION SYSTEM USING MERLIN

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Abstract

The LHC Collimators are designed to remove halo particles such that they do not impinge onto either detectors or other vulnerable regions of the storage ring. However, the very high 7 TeV energy means that their design is critical, as is the modelling of the absorption, scattering and wakefield effects upon the passing bunches. Existing simulations are performed using Sixtrack and K2. We report preliminary results using the MERLIN code, which allows a fuller description of the scattering and wakefield processes, and in principle other physics processes.

INTRODUCTION

The Large Hadron Collider (LHC) requires a total number of 3×10^{14} protons in 2835 bunches for its target luminosity of 10^{34} cm^{-2}s^{-1} [1], and also has an operating mode in which two counter-rotating lead ion beams are stored. All four major experiments (ATLAS, CMS, LHCb, ALICE) and the storage ring itself must be protected from the potentially-damaging intense beam halo fed from the stored beam over many hours of stored beam, in the storage ring particularly the superconducting dipole cold masses, but also the warm vessels and detectors. Because of the large stored beam energy (360 MJ for 7 TeV protons), and the low quench limit of the superconducting magnets of only 8.5 W/m, dedicated cleaning insertions are required to limit the loss from the outer halo to less than 10^{-3}, implying a very good local cleaning efficiency. Primary (TCP) and secondary (TCS) collimators are composed of reinforced carbon to progressively spoil the incident halo prior to absorption on tungsten tertiary (TCT) absorbers, as well as auxiliary elements for protection at particular locations. The overall LHC layout is shown schematically in Figure 1, and the collimation system is described elsewhere [2, 3].

COLLIMATION MODELLING

At present, the primary modelling of the collimation system involves tracking of halo rings of charge with initial impact parameter around 1μ m to just impact the primary collimators, the halo being repopulated from the core beam [5]. SixTrack [7] is used with K2 [8, 6] to model the collimator scattering including elastic/inelastic scattering and single diffractive nuclear scattering [5], but not including the wakefield effects of the collimators. In this paper, we instead use MERLIN [9, 10] as a framework for simulations: MERLIN is a C++ package that may be extended to include additional physical processes. Here we present preliminary simulations where we have included normal (single plane) and angled collimators, which give rise to either elastic scattering or complete absorption.

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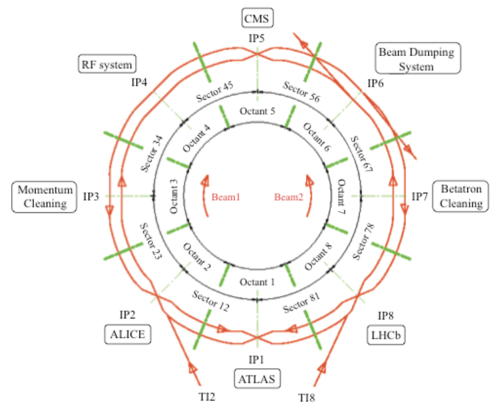

Figure 1: LHC schematic showing arrangement of experiments and collimation system.

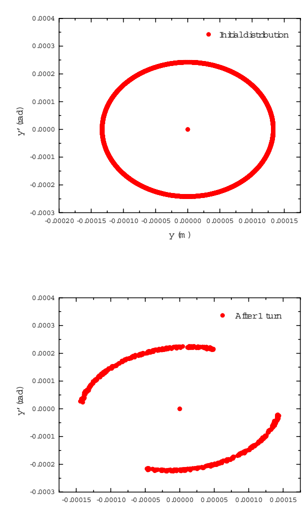

Figure 2: Test of MERLIN code, showing action of primary collimators on a thin ring of particles with distribution in vertical phase space at 8σ from the beam centre, with all collimators set to be perfectly absorbing.

As a test of the LHC optics (V6.503 in collision) we first confirm that collimation takes place for an overly large halo of 8σ with collimators set to their nominal values [11] (Figure 2). The primary collimator TCP.D6L7.B1 is the first to be struck, and this is confirmed to be at approximately correct aperture in Figure 3. By adjusting the halo size, we can set the impact parameter to approximately 1μm simi-

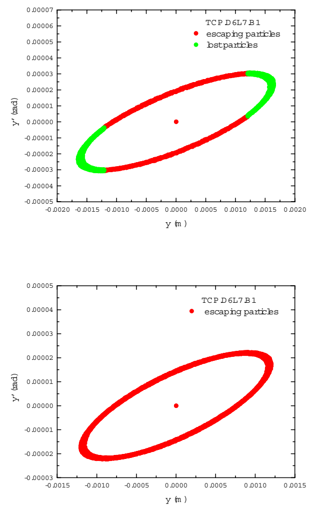

Figure 3: Observation of collimation at primary collimator TCP.D6L7.B1 (set to be perfectly absorbing) for vertical phase space distributions of rings at 8σ (above) and 5.8σ (below).

lar to the procedure used in SixTrack [5]; this is shown in Figure 4, and varies with turn number as shown in Figure 5.

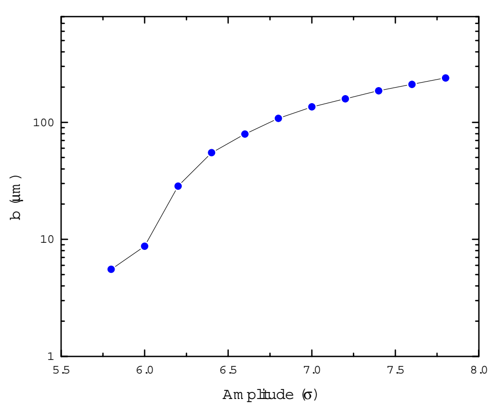

Figure 4: Variation of impact parameter TCP.D6L7.B1 with size of halo distribution in vertical phase space.

COMPARISON OF PARTICLE LOSS LOCATIONS

To adequately model particle loss in the LHC, particles must be followed for a few hundred turns to allow the primary and secondary spoilers to act to blow up the halo. In Figure 6 we show the particle loss on TCP.D6L7.B1 (the principal primary collimator in this simulation) as a function of turn number for perfectly-absorbing collimators, for an initial halo population of 100,000 particles where 80,770

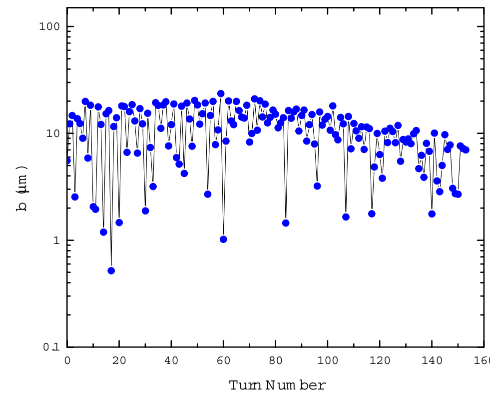

Figure 5: Average impact parameter at TCP.D6L7.B1 as a function of turn number for vertical phase space distribution of 5.875σ, into perfectly-absorbing collimator, showing that charge ring is approximately the correct size for collimator simulation.

are absorbed over 200 turns. Clearly, with elastically-scattering primary and secondary collimators the loss is transferred onto the absorbing tertiaries. To compare with SixTrack, we compare the impacts on the primaries and secondaries between the two codes: this is shown in Figure 7. Reasonable agreement is obtained given the differences in the codes and physics; similar collimation inefficiencies [4, 5] are found in the primary collimators. Losses in the tertiaries cannot be compared without the addition of inelastic scattering to the primary collimators.

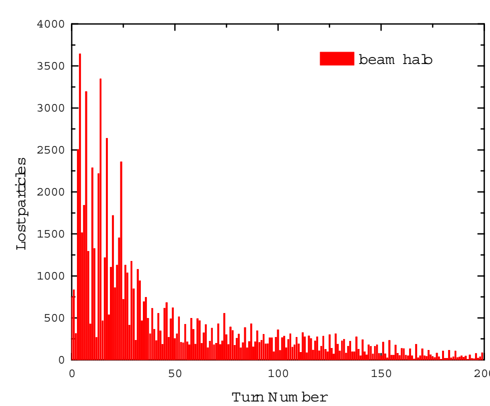

Figure 6: Particle loss into TCP.D6L7.B1 as a function of turn number, with all collimators set to be perfectly absorbing. The vertical tune is visible via the Fourier transform of the loss.

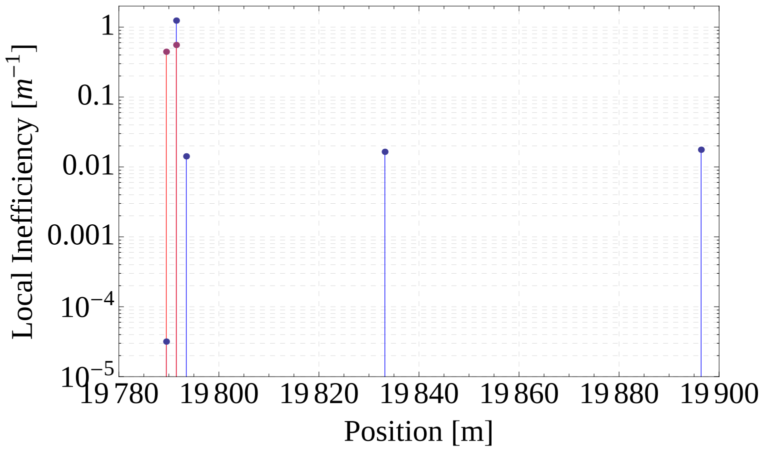

Figure 7: Collimator impact locations for initial distribution in both planes with impact parameter 1μm, comparing MERLIN (with perfectly-absorbing collimators, in red), and SixTrack (with elastic/inelastic and nucleon scattering included, in blue) [12]. Approximate agreement is obtained considering the different physics: primary collimators are impacted

FURTHER WORK

We have shown that MERLIN may be used to replicate the essential features of collimation modelling in the LHC. It is planned to augment this preliminary work with sufficient physics to correctly model the spoiler/absorber process, and to add wakefield effects to this.

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