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Beam losses in the dispersion suppressors of IR3 and IR7

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Summary

This work is a complement to the radiation studies for the IR3 and IR7 collimation insertions of LHC. In order to allow for dose calculations in the dispersion suppressors adjacent to these insertions, beam loss maps in these areas are presented and discussed.

1 Introduction

The calculation of a precise beam loss map downstream of a collimation insertion is more difficult and less precise than it can be downstream of a collision point where the source point is unique and of small size [1],[2]. In the collimation insertions, the source points are distributed in all collimator jaws where the secondary or tertiary fluxes are strongly absorbed for good efficiency. The rate of protons leaving the insertions with a longitudinal or transverse amplitude which is large enough to impact on the vacuum chamber is small, resulting in quite large statistical errors. We therefore first present integral loss rates obtained with different approaches, in order to confirm the global efficiency calculations. Then, we present a differential distribution of high momentum protons along the dispersion suppressors.

2 Integral fractional loss rates

In this paper, the integral fractional loss rate is the number of protons of large relative momentum offset, i.e. $|\delta_p| < 0.3$, which leave the cleaning section, divided by the rate of inelastic collisions summed on all collimators. This quantity was estimated by different methods, with their results listed in Table 1. The K2 code [3] is used to provide a map

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Table 1: Integral fractional loss rates.

Insertion	V5.0/K2/model	V5.0/K2/MARS	V6.2/K2/MARS	V5.0/STRUCT
IR7 β-coll.	5×10^{-4}	10×10^{-4}	-	4×10^{-4}
IR3 δ_p-coll.	-	-	5×10^{-4}	-

of inelastic interaction points in collimators and a set of protons leaving the collimation insertion. The map is later used with the shower code MARS [6] which computes on its own the flux of particle leaving the insertion. The results given in column 2 and 3 of Table 1 are deduced from former studies following this method [7],[8],[9],[10]. A crude analytic calculation is used to compute an average dilution [3], which can be integrated over an effective length of the dispersion suppressor (i.e. the length along which the dispersion is growing, approximately 50m), given in column 1 of Table1. Finally, the result in column 4 of Table 1 is obtained with the most recent version of the STRUCT code [11], which allows both precise tracking including edge scattering in the collimator jaws [12] and step tracking along the ring. All three methods give similar results, in spite of the limitations of each of them. We can thus be quite confident that our simulations are not too far from reality.

3 Differential distribution along the dispersion suppressor

We can now use with some confidence the method based on STRUCT in order to built a distribution of losses along the dispersion suppressor. Proton scattering in the collimator jaws is simulated first. The outscattered proton in the relative momentum offset range $-0.3 < \delta_p < 0$ are tracked through the arc sector 7/8 with aperture checking at each lattice element. A simple transfer matrix is used for the rest of the ring to return the surviving protons to the collimation section, thus allowing to simulate multi-turn contributions to collimation efficiency and proton losses. The results are given in both Table 2 and in Fig. 1. The shape of the curve is very similar to the one obtained near collision points [1],[2], because of the similar single diffractive differential cross-sections, which is almost independent of the centre of mass energy for not too small δ_p [4]. The similar integrated loss rates computed for the betatron and momentum collimation insertions allows to use the same differential distribution for both insertions. The sole difference will be the absolute normalisation of the results, which is beyond the scope of the present note. In Table 2, the column entitled 'Relative loss rate' is normalised to one proton which interacts inelastically in the collimation insertion. This value would change little if it would be normalised to the primary impact rate, because the collimation efficiency is high, at least in our model. The column entitled 'Loss density' is normalised to an inelastic rate of $\dot{n} = 3 \times 10^9$ p/s.

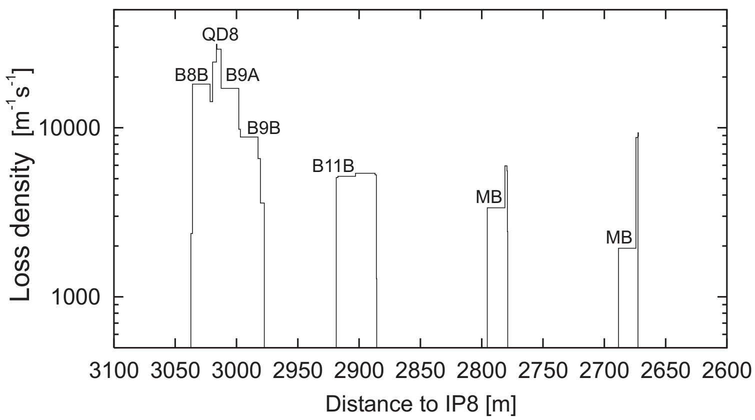

Figure 1: The map of losses along the dispersion suppressor, normalised to a primary flux of $\dot{n} = 3 \times 10^9$ p/s in the collimation insertion.

Table 2: The map of losses along the dispersion suppressor. The longitudinal coordinate s has an arbitrarily origin at IP8. For the other quantities, see text.

Name	s [m]	L [m]	Relative loss rate per element	Loss density [p/m/s]
B8A.R7	3051.554	14.300	0.900E-06	0.189E+03
drift	3037.254	1.360	0.107E-05	0.237E+04
B8B.R7	3035.894	14.300	0.864E-04	0.181E+05
drift	3021.594	2.060	0.979E-05	0.143E+05
QD8.R7	3019.534	3.100	0.254E-04	0.245E+05
drift	3016.434	0.450	0.468E-05	0.312E+05
QT.QD8.R	3015.984	1.150	0.112E-04	0.292E+05
drift	3014.834	2.345	0.228E-04	0.292E+05
B9A.R7	3012.489	14.300	0.817E-04	0.171E+05
drift	2998.189	1.360	0.445E-05	0.981E+04
B9B.R7	2996.829	14.300	0.420E-04	0.881E+04
drift	2982.529	2.060	0.452E-05	0.658E+04
QF9.R7	2980.469	3.100	0.371E-05	0.359E+04
B11A.R7	2932.959	14.300	0.169E-05	0.354E+03
drift	2918.659	1.360	0.230E-05	0.508E+04
B11B.R7	2917.299	14.300	0.246E-04	0.517E+04
drift	2902.999	15.930	0.286E-04	0.538E+04
QT.QF11.	2887.069	1.150	0.202E-05	0.527E+04
drift	2885.919	0.275	0.117E-06	0.128E+04
QF11.R7	2885.644	3.100	0.265E-06	0.257E+03

4 Beam gas losses

The rates given in Table 2 can be compared to a somewhat speculative beam gas interaction rate. In the absence of a better knowledge of the dynamic vacuum pressure in LHC, and also in the absence of quantified operational scenarios, we use the estimate deduced from [13] and for a beam-gas lifetime of 85 hrs. Adding the contribution of two beams, the beam gas loss rate per unit length shall be

$$\dot{n}_{bg} = 6 \times 10^4 \text{ p/m/s} . \qquad (1)$$

This value is larger then the largest value listed in Table 2. But of course after a few years of operation, the residual gas density shall decrease, while the cleaning rate by the collimation systems shall stay constant. On the other hand the quoted cleaning rate by the collimation system is high and corresponds more to peak luminosity operation than to average values.

5 Conclusions

Beam loss distributions induced by the collimation activity are given for the dispersion suppressors adjacent to the collimation insertions. The dispersion suppressors of the betatron and momentum collimation insertions are identical. Therefore, with similar integrated loss rates computed for the betatron and momentum collimation insertions, the differential distribution for both insertions must be nearly identical. The loss densities are comparable to expected loss rates associated to collisions between circulating protons and residual gas pressure.

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