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Energy deposition calculations for the betatron cleaning insertion of LHC

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Summary

This work is a part of the radiation studies for the IR7 betatron cleaning insertion of LHC. Energy deposition in the collimators and radiation doses in the magnet coils are presented.

Hadronic and electromagnetic cascade calculations with a detailed model of the betatron cleaning section of LHC have been made recently [1], [2] to obtain hadron fluence and absorbed dose around the beam lines. The same model of the cleaning section and the MARS code [3] are used here for the energy deposition calculations.

The betatron cleaning section is shown schematically in Fig.1. Every collimator tank consists of a pair of jaws in a vacuum box. The primary collimators TCP have 200 mm long aluminium jaws and the secondary collimators TCS have 500 mm long copper jaws. Each separation dipole D3 and D4 consists of two warm magnet modules MBW. Corrector dipoles MCH and MCV are made of one module MCBW. The quadrupoles Q4, Q5 and Q6 consist of several warm magnet modules MQW. The dipole and quadrupole modules are described in [4], [5]. The modules of one magnet are marked individually by an alphabetic index in Table 2 (not shown in Fig.1). In the left part of the insertion they are arranged in the antialphabetic order with respect to the direction of the Ring 1 beam.

The transversal cross-sections of the collimators and magnets can be found in [1]. All the long drift spaces between magnets are covered by shielding. The typical transverse cross-section of the shielding can be found in [2].

The calculated energy deposition in the collimators is presented in Table 1.

It can be seen that all the collimators together absorb 24% of the primary proton energy both at injection and in collision. Secondary particles escaping into the tunnel carry only a few percents of the primary energy [1]. Therefore approximately 70% of the primary energy is absorbed in the magnets and in the shielding.

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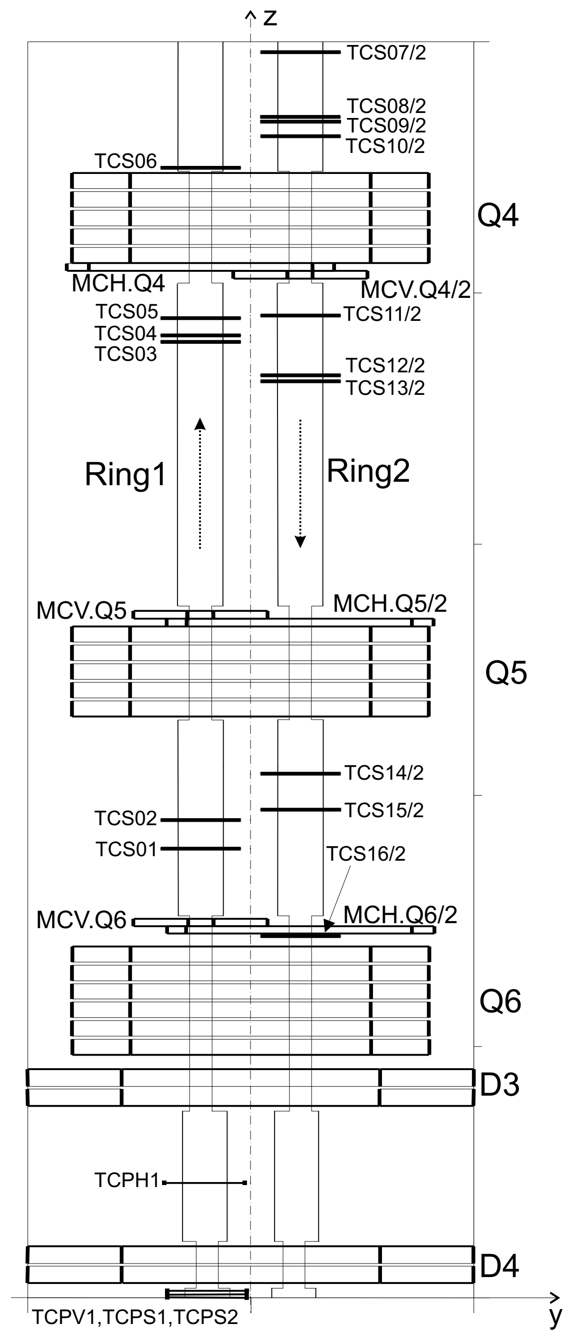

Figure 1: Layout of the left half of the cleaning section.

Table 1: Energy deposited in the collimators and power dissipated in the tanks. A collimator tank is a pair of jaws in a vacuum box. The energy deposition corresponds to one proton lost in the collimators of one ring. Total power corresponds to a peak loss rate of 3×10^9 protons/s at collision energy [6].

Collimator	*injection* **Energy [GeV/proton]**		*collision*		**Power [W]**
	jaws	tank	jaws	tank	
TCPV1	0.17	0.21	0.80	0.93	0.5
TCPS1	0.65	1.03	4.67	5.95	2.9
TCPS2	1.26	2.36	13.49	17.96	8.6
TCPH1	0.46	1.47	9.70	27.81	13.4
TCS01	28.90	30.79	671.00	697.00	334.6
TCS02	10.10	12.22	308.00	331.80	159.3
TCS03	9.61	10.26	99.90	106.26	51.0
TCS04	9.00	10.93	84.40	90.72	43.6
TCS05	3.89	4.41	41.40	44.61	21.4
TCS06	2.96	3.14	28.60	29.82	14.3
TCS07	2.25	2.65	38.50	40.43	19.4
TCS08	4.49	4.98	47.70	50.89	24.4
TCS09	3.30	3.80	42.90	45.39	21.8
TCS10	1.61	1.90	28.90	31.37	15.1
TCS11	5.10	5.44	34.60	35.71	17.1
TCS12	2.21	2.45	26.30	28.32	13.6
TCS13	2.07	2.36	26.10	28.24	13.6
TCS14	2.51	2.69	29.80	30.84	14.8
TCS15	2.33	2.59	22.00	23.77	11.4
TCS16	0.95	1.02	11.66	12.00	5.8
All	93.8	106.7	1570.4	1679.8	806.3

Mechanical and electrical properties of the organic insulation of the magnet coils deteriorate under irradiation. The maximum allowed dose of radiation in the coils of MBW, MCBW and MQW modules is specified as 50 MGy [7]. The first calculations with the simple shielding configuration [1] have shown that the dose in the coils of the modules D3.B and Q6.F can reach 4 MGy per year while for the other modules of D3 and Q6 it is at least 3 times lower. This value is therefore too large to ensure a lifetime of more than 10 years.

The fact that the beam pipes inside the magnets have smaller diameter than in the long drift spaces can be used for a better protection of the edge modules which are most exposed. If the small beam pipes are extended 1 metre upstream and 1 metre downstream of each dipole and quadrupole assembly, then a tighter shielding can be placed around them. In addition the space between the extended beam pipes can be filled with iron insertions.

The results of the dose calculations with this improved shielding are presented in Table 2. The annual doses were obtained under the assumption of 10^{16} and 1.6×10^{16} protons lost in collimators of one ring per year for injection and collisions [8] respectively. Even the higher doses for D4 which is very close to the set of three primary collimators are low enough compared to the limit of 50 MGy.

Table 2: Maximum absorbed dose in the magnet coil with the improved shielding option discussed in the text. The annual dose corresponds to 10^{16} protons/year at injection and 1.6×10^{16} protons/year in collisions.

Magnet	**injection [Gy/proton]**	**collision [Gy/proton]**	**annual [MGy/year]**
D4.B	2.8×10^{-12}	6.0×10^{-11}	1.0
D4.A	2.8×10^{-12}	6.2×10^{-11}	1.0
D3.B	9.2×10^{-13}	3.5×10^{-11}	0.58
D3.A	7.5×10^{-13}	3.5×10^{-11}	0.58
Q6.F	3.7×10^{-13}	2.1×10^{-11}	0.34
Q6.E	1.9×10^{-13}	1.4×10^{-11}	0.23
Q6.D	1.4×10^{-13}	1.4×10^{-11}	0.23
Q6.C	1.3×10^{-13}	1.1×10^{-11}	0.18
Q6.B	1.2×10^{-13}	1.1×10^{-11}	0.18
Q6.A	9.2×10^{-14}	5.9×10^{-12}	0.10
MCH.Q6	8.0×10^{-13}	2.5×10^{-11}	0.41
MCV.Q6	1.7×10^{-13}	4.6×10^{-12}	0.08
Q5.E	1.6×10^{-13}	3.8×10^{-12}	0.06
Q5.D	6.5×10^{-14}	2.4×10^{-12}	0.04
Q5.C	5.1×10^{-14}	3.1×10^{-12}	0.05
Q5.B	4.7×10^{-14}	2.9×10^{-12}	0.05
Q5.A	4.3×10^{-14}	2.3×10^{-12}	0.04
MCH.Q5	2.1×10^{-13}	4.2×10^{-12}	0.07
MCV.Q5	4.4×10^{-13}	1.0×10^{-12}	0.02
MCH.Q4	2.9×10^{-13}	2.5×10^{-12}	0.05
MCV.Q4	6.5×10^{-15}	1.1×10^{-13}	0.002
Q4.E	3.1×10^{-13}	6.2×10^{-12}	0.10
Q4.D	5.0×10^{-14}	1.2×10^{-12}	0.02
Q4.C	4.0×10^{-14}	6.2×10^{-13}	0.01
Q4.B	3.0×10^{-14}	9.8×10^{-13}	0.02
Q4.A	2.7×10^{-13}	1.2×10^{-12}	0.02

Conclusions

We present the peak power deposition in the tanks of the collimators of the LHC betatron cleaning insertion. We propose a way of shielding the entrance of the warm dipoles and quadrupoles of the same insertion which allows to keep the absorbed dose of radiation in the coils down to a level which corresponds to a lifetime of more than 10 years of operation.

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