INTEGRATION OF A NEUTRAL ABSORBER FOR THE LHC POINT 8 *

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Abstract

The LHCb detector will be upgraded during the second long shutdown (LS2) of the LHC machine, in order to increase its statistical precision significantly. The upgraded LHCb foresees a peak luminosity of $\mathscr{L}_{HL} = 1 - 2 \times 10^{33}$ cm^{-2}s^{-1}, with a pileup of ~ 5. This represents ten times more luminosity and five times more pile up than in the present LHC. With these conditions, the *pp*-collisions and beam losses will produce a non-negligeable beam-induced energy deposition in the interaction region. More precisely, studies [1] have shown that the energy deposition will especially increase on the D2 recombination dipoles, which could bring them close to their safety thresholds. To avoid this, the placement of a minimal neutral absorber has been proposed. This absorber will have the same role as the TAN in the high luminosity Interaction Regions (IR) 1 and 5. This study shows the possible dimensions and location of this absorber, and how it would reduce both the peak power density and total heat load.

INTRODUCTION

With $\mathscr{L}_{HL} = 2 \times 10^{33}$ cm^{-2}.s^{-1} and the inelastic cross section σ_{pp} = 85mb, there will be 1.7×10^8 inelastic collisions per second at the LHCb. The inelastic collision power is carried off by neutrals (mostly neutrons and photons) and charged particles (mostly pions and protons), that leave in both directions from the Interaction Point (IP). The neutral particles are to a large extent intercepted by the TAN, at IR1 and IR5.

During the LHC design stage, it was estimated that absorbers would become only necessary for luminosities above $\mathscr{L} = 10^{33}$ cm^{-2}s^{-1}.The original request by LHCb has been for luminosities of up to $\mathscr{L} = 4 \times 10^{32}$ cm^{-2}s^{-1}, such that IR8, where the LHCb experiment is located, could be designed without absorbers. More detailed studies on energy deposition in IR8 [1] have been made recently, to see to which extent absorbers are required for the luminosity upgrade of IR8 up to $\mathscr{L}_{HL} = 2 \times 10^{33}$ cm^{-2}s^{-1}. It was found that the LHCb luminosity upgrade is compatible without TAS. The same study recommended the installation of a warm protection, or "minimal TAN", in IR8 to keep the energy flow into the D2 magnet well below the quench level.

The objective of this study is to propose a first rough design for this absorber.

CROSSING SCHEMES FOR LHCB

The LHCb spectrometer and its compensator magnets create an internal horizontal crossing angle bump of ±2100 μrad at injection, and ±135 μrad at collision, the sign depending on the spectrometer's polarity (+1 or -1). The external horizontal crossing angle bump is created by the orbit corrector dipoles to avoid parasitic encounters of the bunch trains, and the parallel vertical bump provides beam separation at the IP during injection, acceleration and squeeze to avoid collisions at the IP. We call the *effective angle* the sum of the internal and external crossing angles. At operation, no energy ramping for the spectrometer is desired since it causes mechanical stress to the magnets. This means that the spectrometer will be at full field at all times. Enough beam-beam separation is also needed for any bunch spacing ($\geq 10\sigma$).

A horizontal crossing scheme has been proposed by S. Fartoukh [2] taking these factors into account, with vertical parallel separation and a horizontal external crossing. The parameters of this scheme are presented in Table 1.

Table 1: Proposed Horizontal Crossing Scheme

Polarity	**Inj. [μrad]**	**Coll. [μrad]**
0	$p_x = -170$ $p_y = -30$	$p_x = -250$ $p_y = 0$
1	$p_x = 1930$ $p_y = -2$	$p_x = -115$ $p_y = -1.8$
-1	$p_x = -2270$ $p_y = -58$	$p_x = -385$ $p_y = -1.8$

	Inj.	**Squ.**	**Coll.**
β^* [m]	10	3	3
Δy [mm]	3.5	1.0	0.0

A vertical crossing scheme for LHCb has also been proposed in the past [3]. Ideally the effective horizontal crossing angle should be the same independently of the LHCb polarity, in order to avoid any systematic uncertainty in the vertex reconstruction of the LHCb detector. The advantages of a vertical crossing angle is that the external crossing angle will be decoupled from the dipole polarity and that the effective crossing angle for both magnet polarities would have the same absolute value. This would imply that the effective crossing angle will be in a tilted plane [4]. Further studies should asses if this scheme is still a possible option in the future, and simulate the impact it would have in the design of the absorber.

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As a first approach, we will consider tungsten (W) as the main material due to its absorption properties determined by its high density and atomic number.

PLACEMENT IN THE TUNNEL

The configuration of the beam line will impose some constraints in dimensions of the absorber, and placement with respect to the D2 magnet. The nearest longitudinal space to D2 is around 113-114 m from the IP. A clearance of 5 mm in the x direction with respect to the beam pipes is also assumed. Taking into account these considerations we define the absorber's dimensions, increasing its length in order to assess the maximal achievable protection by using all the longitudinal space available (see Table 2).

Table 2: Absorber's dimensions and longitudinal position from IP fitted to the beam line, where s(m) indicates the longitudinal position of the center of the absorber.

s [m]	**Δx [cm]**	**Δy [cm]**	**Δz [cm]**
113.8	9.0	12	90

Currently there is a BRAN (Beam RAte of Neutrals) detector monitor placed at 113.96 m from the IP. This element will interfere with the ideal absorber. If the BRAN would be kept in its current location after LS2, then the absorber's length might have to be reduced to $\sim 30-40$ cm (see Table 3).

Table 3: Longitudinal Positions of the BRAN and Absorber in Meters from the IP

Element	**Start**	**Middle**	**End**
BRAN	113.96	114.11	114.26
Absorber	113.35	113.80	114.25

HEAT LOAD AND POWER DEPOSITION

Collision debris particles, produced in inelastic and diffractive collisions at the IP, have been simulated using the FLUKA [5, 6] built-in interface to DPMJET III [7]. Beam divergence and vertex position distributions have been implemented. For the final normalisation, 85 mb *pp* cross-section was assumed.

The energy deposition in the coils is scored using a 3D cylindrical mesh with about 10 cm longitudinal bins, 2-degree azimuthal bins. Steady-state heat loads are estimated via the peak power density averaged over the radial dimension of the D2 coil layer.

The simulations have been done at collision energy, considering the horizontal crossing scheme presented in Table 1 and the spectrometer's polarity set to negative. The absorbers have been simulated following the parameters given in Table 2. The results presented are from the left side of IP8, where the D2 magnet is more exposed. This study considers an updated optics configuration with respect to [1]. The larger crossing angle results in a decrease of total power in D2 since more energy is deposited in the upstream elements. The nominal LHC optics were considered in the simulations. Further studies should include the Achromatic Telescopic Squeezing (ATS) scheme [8], which is the baseline scheme chosen for the optics and layout for the high luminosity LHC project (HL-LHC), although no significant differences are expected.

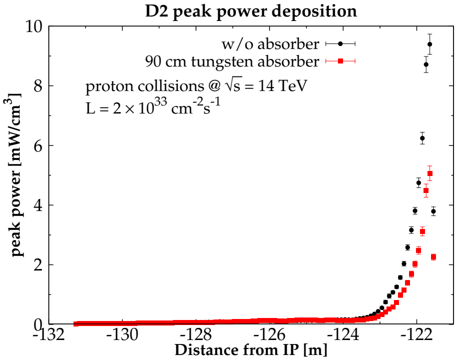

Figure 1: Longitudinal profile of peak power density along the D2 left side P8: w/o absorber (black points); with 90 cm tungsten absorber (red points). Results are normalised to $\mathscr{L}_{HL}$. Error bars indicate statistical uncertainties.

Figure 1 shows the comparison of the peak power density in D2 coils between the cases with and without absorber. We can see that the absorber reduces by half the maximum load on D2, from 9.5 mW/cm^3 to 5 mW/cm^3. The present recommended limit of 4.3 mW/cm^3 (the design limit) for NbTi magnets is slightly exceeded. To alleviate this, additional protection devices should be considered, such as masks around the beam pipes.

Comparing Figures 2 and 3 we can see the reduction of the power density transverse distribution at D2. The simulations show that the proposed absorber can reduce the total power by a factor of $\sim$ 3, as shown in Table 4.

Table 4: Total Power Deposited [W]

Absorber	**None**	**W**
Absorber	-	19
D2	24	8.6

CONCLUSIONS

We present a first study of a "minimal TAN" neutral absorber for IP8. We find that a tungsten absorber of 90 cm length would reduce the energy deposition into the D2 magnet by a factor of $\sim$ 3, and the maximum peak power density by half. This will assure safe operation with luminosities up to $\mathscr{L} = 2 \times 10^{33}$ cm^{-2}s^{-1} as requested by LHCb, provided that additional protection devices such as masks are considered. If the BRAN would be kept in its

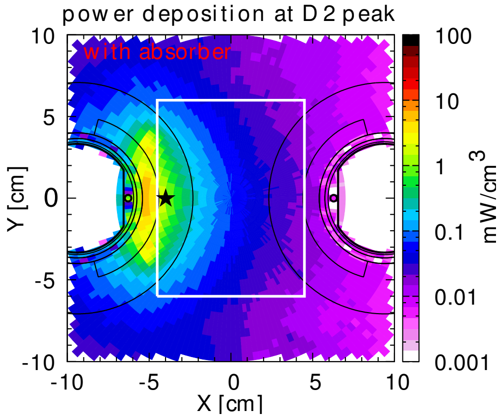

Figure 2: Power density transverse distribution at D2 longitudinal peak with 90 cm long tungsten absorber. The star indicates the point where debris particles travelling along the crossing angle direction impinge the D2 in case of an effective crossing angle of -385 μrad. The white rectangle represents the section of the absorber. Details of the magnet (beam screen, coil, collar...) are shown.

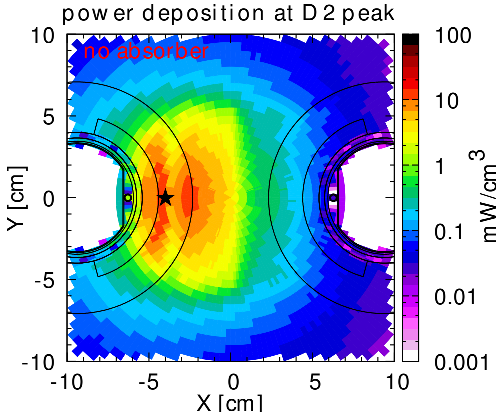

Figure 3: Power density transverse distribution at D2 longitudinal peak in case of no absorber. For the meaning of star refer to Fig. 2.

current location after LS2, the length of the absober will have to be reduced. In that case, further heat deposition studies will be needed in order to asses the load deposited in D2 with a shorter absorber.

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