

THE STUDY OF THE MACHINE-INDUCED BACKGROUND AND ITS APPLICATIONS AT THE LHC

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Abstract

We present the recent advances in the analysis of the machine-induced background generation and formation at the LHC. Different aspects of the study of the machine background problem at the LHC are reviewed, including the background production at the different stages of the machine operation, the role and influence on the background from the collimators in the experimental insertions and the background shielding. The potential use of the machine background for the purposes of detector testing and alignment is also discussed.

INTRODUCTION

The formation of the machine induced background in the structure of the machine depends on the combination of the different parameters of the operation such as machine optics, beam intensity, residual gas pressure, cleaning inefficiency, and for any experimental insertion is defined by the distribution of the sources of background with respect to a particular interaction point. In addition the background rates at the entrance to the experimental zones strongly depend on the mechanical layout of the straight section parts close to the interaction point.

The high luminosity insertion regions IR1 and IR5 of the Large Hadron Collider at CERN [1] house ATLAS and CMS experiments that will operate at the nominal luminosity of $L = 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$. The heavy shielding at the tunnel entrance to the zones of these experiments well protects the detectors from the secondary radiation from the tunnel down to a distance close to the beam. At the same time, at the machine start-up with the reduced luminosity in the IP, the use of the high energy muon component of the machine induced background is considered as one of the options for the commissioning of the detectors in both ATLAS and CMS [2].

In the LHC experimental insertions IR2 and IR8 two dedicated ion and B-physics experiments, ALICE and LHCb, are located. They will operate at the moderate luminosities of $L = 3 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$ and $2 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ respectively. At the nominal LHC beam intensity the problem of the machine induced background can be considered more relevant for these experiments. The betatron cleaning insertion IR7 is located upstream from IR8 in the direction opposite to the LHC beam 1 and another cleaning insertion IR3 — upstream from the IR2.

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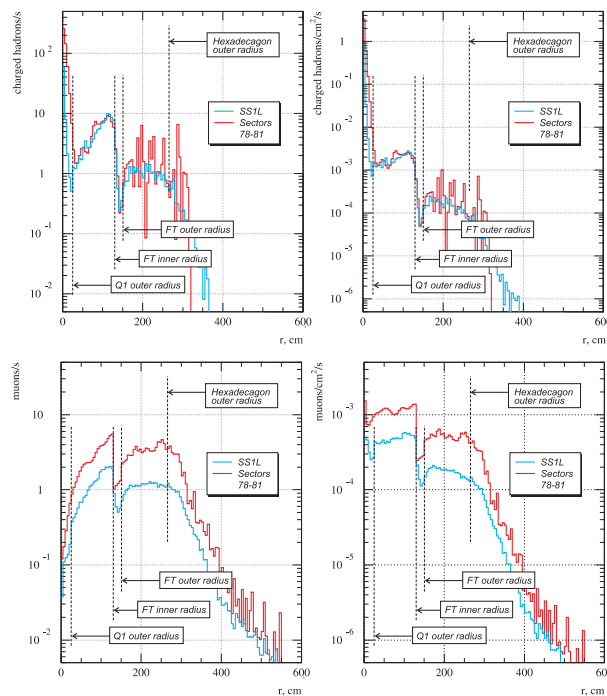


Figure 1: Charged hadron and muon flux (left) and flux density (right), at the UX15 entrance due to the beam-gas losses in SS1L (blue) and sectors 78-81 of the LHC (red) with two tertiary collimators in the IR1 for the case of machine start-up with the beam of 0.01 A.

MACHINE BACKGROUND AT THE LHC COMMISSIONING

The first estimates of the machine background for the purpose of the detector alignment in IR1 and IR5 were obtained by scaling the background rates, calculated for the conditions of the LHC nominal operation, to the cases of the lower beam intensity. Since then, the calculations of the residual gas pressures in the LHC experimental insertions were completed for different cases of the machine conditioning with a beam of reduced intensity [3]. Corresponding estimates of the machine background from the beam-gas losses in the IR1 insertion were done for the case of the machine commissioning with the beam current of 0.01 A (start-up with 43 bunches) [4].

Calculated radial distributions of charged hadron and muon flux are given in Figure 1. These distributions clearly reflect the structure of the inner shielding of the machine tunnel entrance to the UX15 cavern as shown in [5]. The total flux is estimated to be 2.2 kHz for all hadrons and

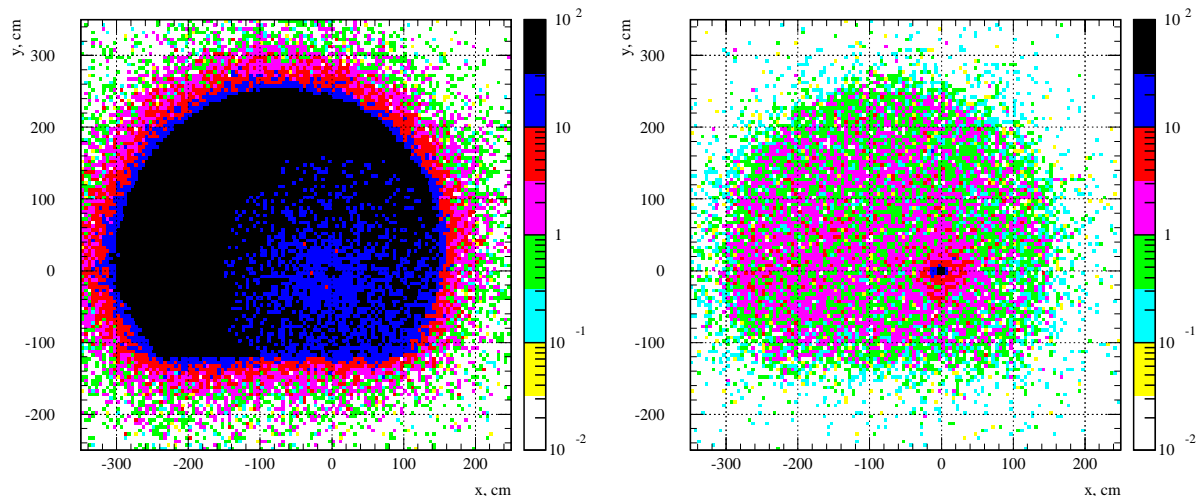


Figure 2: Hadron flux density [particles/cm²/s] at the entrance to the UX85 cavern without (left) and with (right) the shielding, for the halo losses on the vertical collimator at the IR7 side of IR8 and assumed beam lifetime of 30 h.

66.1 Hz for muons that is a factor of $\sim 10^3$ lower than the previously estimated levels for the nominal operation [6]. These estimates were obtained with two tertiary collimators TCTV/H which will be installed on both sides of the LHC interaction points [1].

On the same Figure 1 are given the distributions of the background fluxes due to the beam-gas losses in the two sectors 78-81 upstream from the IR insertion. The assumed pressure level in these cold sectors of the LHC were taken 30 times higher than the corresponding value for the Q6 magnet in IR1 from [3], following the somewhat pessimistic estimate given in [7], based on the conservative assumptions on the beam screen pumping speed and photon critical energy, flux rate and desorption. The observed contribution to the background fluxes in IR1 from the losses in the cold sectors was estimated to 1.13 kHz (55 %) for hadrons and 183 Hz (374 %) for muons.

The comparison of those new estimations for the particle fluxes with the earlier simulations [6] showed that up to 90 % of the protons out-scattered in the sectors 78-81 from the beam which were previously lost on the limiting apertures of the IR1 are now intercepted by tertiary collimators. The resulting cascades that are initiated in the material of the collimator jaws become an additional source of π^\pm and K^\pm flux which then decay to muons in the downstream drift space. The maximum of the observed difference between the muon fluxes from the two studied sources is obtained at the distance from the beam line corresponding to the outer radius of the UX15 inner shielding fixed tube FT where the secondary particles are attenuated only by the concrete layer. The resulting muon flux constitutes up to 80 % of the total muon machine background and becomes the dominant background component in the insertion.

BACKGROUND SHIELDING IN THE LOW LUMINOSITY IR'S

The shielding at the tunnel entrance to the experimental cavern is one of the ways required to reduce the machine background rates in the LHC experiments. In the LHC high luminosity insertions this role is performed by an inner/forward shielding located inside the experimental zones around the TAS absorber and the first inner triplet magnet, to protect the outer detectors of the experiments from the backslash from these machine elements. In the low luminosity insertions, due to the mechanical constraints of the installation such shielding has to be positioned in the LHC tunnel.

The model of such shielding for the IR8 experimental insertion was proposed in [8], and now the final configuration of this shielding whose design was done compatible with the overall structure of the machine elements and equipment is being installed. This realistic design was introduced in the model of the machine background simulations for IR8, and the efficiency of the shielding was evaluated versus the dominant source of the background in IR8 in the case of a reduced beam lifetime [2] — the background from the tertiary losses on the collimators at the IR7 side of IR8.

Simulated hadron flux density distributions at the entrance from the IR7 side to the UX85 experimental cavern of the interaction point IP8 are given in Figure 2, with and without the background shielding in IR8. The total rate of hadrons without the shielding was estimated to 9.2 MHz, for the assumed collimation beam lifetime of 30 h and corresponding rate of primary losses in the collimation system of 2.8×10^9 protons/s. The installation of the shielding decreases the hadron background rate to 0.27 MHz, effec-

tively removing charged hadron component of the background and leaving only the background fluxes close to the position of the beam unaffected.

MACHINE BACKGROUND IN THE LSS'S

Besides the case of the machine background formation along the LHC beam, incoming to the interaction point in the experimental insertion, we consider a few cases of the background, generated in the LHC long straight sections (LSS's) along the beam, outcoming from the IP. We estimate the beam-gas background in the sensitive areas of the Roman Pot detectors that will be located in the machine tunnel in the IR5 experimental insertion. We also study the variation of the beam-gas background in the LSS's for the case of an accidental leak or local pressure bump in the LHC vacuum chamber, for the purpose of vacuum diagnostics with the radiation monitors.

A set of Roman Pot detectors will be installed in IR5 for the forward physics programme of the TOTEM experiment at the LHC [9]. To estimate the background rates in these detectors, the correct identification of machine background sources in the region of detector installation is required. The analysis of the limiting apertures in IR5 showed that the p - p interactions in IP5 and the beam-gas losses on the machine sector between IP5 and Roman Pot stations had to be considered as the sources of the background. Estimates for the background from the p - p interactions during the TOTEM runs are obtained by scaling the numbers from [10] to the luminosity of $2.4 \times 10^{29} \text{cm}^{-2}/\text{s}$.

For the beam-gas background during TOTEM operation detailed simulations were performed [11]. Background rates were estimated for the specially developed high- β^* optics of the machine, most recent profiles of the residual gas density in IR5, calculated in [3] for the period of machine operation with the reduced beam intensity and the latest layout of the experimental insertion. Estimations showed that at the luminosity given above, the background rates from the two sources considered are on the same level of a few kHz. Full information on the background tracks, recorded in these simulations, allowed a thorough analysis of the background and the development of methods for the reduction of the background trigger rates [12].

For the purposes of vacuum diagnostics at the LHC we consider the possibility to evaluate the gas density profile in the room temperature part of the LSS via the variation in the radiation levels, caused by the beam-gas background in the insertion. We introduce a local pressure bump in the model of the LHC vacuum chamber and compare the estimates of the resulting background produced in proton interactions with the residual gas nuclei with the particle rates from the other sources of the secondary radiation in the LSS [13].

The estimates showed that the background produced along the beam, outcoming from the interaction point, from the local pressure bump in the region of the separation dipoles is a factor ~ 100 higher than the background level

for the predicted gas pressures during stable machine operation, in a few locations of IR5. Positioning of the radiation monitors in these locations would allow to detect this local increase of gas pressure in a reasonable time from a few to several minutes, during injection, ramp and squeeze.

REFERENCES

- [1] O. Brüning, P. Collier, P. Lebrun *et al.* (editors), "LHC Design Report. Volume I The LHC Main Ring", CERN 2004-003, Geneva, 2004.
- [2] G. Corti and V. Talanov, "Aspects of Machine Induced Background in the LHC Experiments", In: Proc. of the LHC Project Workshop — Chamonix XV, 2006, p.179–185.
- [3] A. Rossi, "Residual Gas Density Estimations in the LHC Insertion Regions IR1 and IR5 and the Experimental Regions of ATLAS and CMS for Different Beam Operations", CERN LHC Project Report 783, Geneva, 2004.
- [4] V. Talanov, "Estimation of the Machine Induced Background for the Commissioning Period with Tertiary Collimators in the IR1 of the LHC", CERN LHC Project Note 371, CERN, Geneva, 2005.
- [5] I. Azhgirey, I. Baishev, K.M. Potter *et al.*, "Machine Induced Background in the High Luminosity Experimental Insertion of the LHC Project", CERN LHC Project Report 722, Geneva, 2004.
- [6] I. Azhgirey, I. Baishev, K.M. Potter *et al.*, "Cascade Simulations for the Machine Induced Background Study in the IR1 of the LHC", CERN LHC Project Note 324, Geneva, 2003.
- [7] A. Rossi, "Expected Vacuum Performance in the Cold Arcs", LHC Machine Induced Background Working Group meeting, CERN, Geneva, June 2005, <http://cern.ch/lhc-background>.
- [8] I. Azhgirey, I. Baishev, K.M. Potter *et al.*, "Evaluation of Some Options for Shielding from Machine Induced Background in the IR8", LHC Project Note 307, CERN, Geneva, 2002.
- [9] The TOTEM Collaboration, "TOTEM Technical Design Report: Total Cross Section, Elastic Scattering and Diffraction Dissociation at the Large Hadron Collider at CERN", CERN LHCC 2004-002, Geneva, 2004.
- [10] A. Drozhdin, D. Macina, N. Mokhov *et al.*, "Accelerator Related Backgrounds in the LHC Forward Detectors", In: Proc. of the PAC'2003, Portland, OR, May 12–16 2003, p.1742–1744.
- [11] V. Avati, M. Deile, D. Macina *et al.*, "First Results of the Machine Induced Background Estimation for the Forward Physics Detectors in the IR5 of the LHC", CERN LHC Project Note 360, Geneva, 2004.
- [12] M. Deile, "Beam-Gas Background Studies for the TOTEM Roman Pots", LHC Machine Induced Background Working Group meeting, CERN, Geneva, June 2005, <http://cern.ch/lhc-background>.
- [13] V. Baglin, V. Talanov, T. Wijnands, "Radiation Monitors as a Vacuum Diagnostics for the Room Temperature Part of the LSS", CERN LHC Project Note 378, Geneva, 2006.