MACHINE INDUCED BACKGROUND SOURCES ANALYSIS FOR THE IP1 INTERACTION REGION OF THE LHC

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Abstract

Analysis of the machine induced radiation background is presented for the IP1 interaction region of the LHC collider, where ATLAS experiment will be performed. Absolute value and relative importance of the different background generation mechanisms are estimated by means of the Monte Carlo simulation of the beam losses and cascades inside LHC lattice.

INTRODUCTION

The fluxes of the secondary particles, which reach the zones where the high energy physics experiments will be performed from the machine tunnel, compose *machine induced background* — secondary radiation which results from the nuclei-electromagnetic cascades initiated in the accelerator structure by the beam particle losses. The formation of the machine induced background in a particular experimental region depends on the scenario of machine operation and on the position of the given experimental insertion in the accelerator structure with respect to the other machine insertions.

Large hadron collider LHC at CERN [1] will be the proton accelerator with the design beam current of 530 mA and beam energy of 7 TeV. The high intensity of the accelerator beam dictates the exceptional importance of the solution for the radiation problems of the LHC project, with the problem of the machine induced background among them. Below we analyze different background sources and evaluate their relative importance in the study of the machine induced background phenomenon in the region of the beam interaction point IP1 of the LHC.

THE STRUCTURE OF LHC

The general view of LHC structure is given in Figure 1. The structure of collider includes eight sectors with the beam interaction points between them, in the middle of the corresponding straight section of the insertion. The beam interactions with the high luminosity of 10^{34} cm^{-2} s^{-1} will be organized in the insertion regions of points IP1 and IP5, while in the points IP2 and IP8 the design luminosity will be a few orders of magnitude lower. Two located at each side of the collider cleaning insertions SS3 and SS7 are featured by the maximal restrictions on the beam size. The symmetry of LHC structure allows considering the results obtained for the beam losses in the ring one also valid for the ring two. The presence of two beams in each interaction region doubles the values given below for the total background particle fluxes.

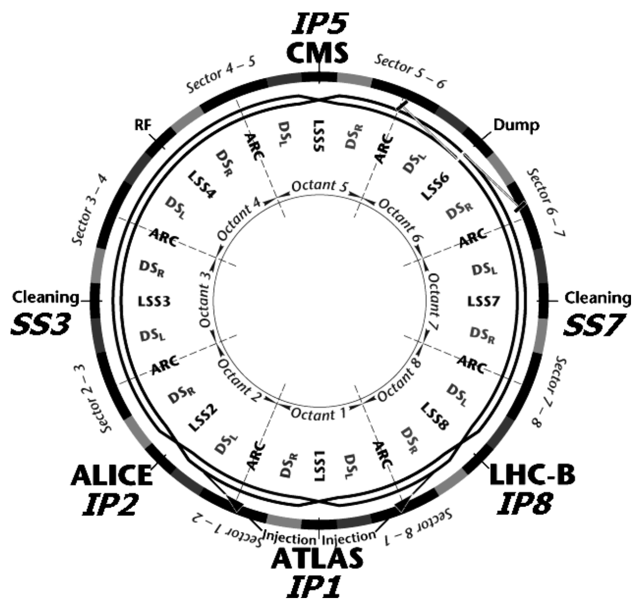

Figure 1: The scheme of the LHC collider.

THE ORIGIN OF THE BACKGROUND

The generic origin of the machine induced background is the losses of the beam particles which continuously occur along the whole length of the machine ring. In general case the loss happens when the particle falls out the phase space of the beam [2]. This does not imply that the secondary cascade will be instantly initiated at the point of the loss. The deflected beam particle can be successfully transported downstream by the machine optics if particle parameters are close to the parameters of the equilibrium particle. Such particles are supposed to be intercepted and absorbed by the collimators of the cleaning insertions but may interact with the material of the accelerator components before they will be cleaned. The result of these interactions will the background produced far downstream from the point of the loss in the regions with the large size of the beam and maximal restrictions on the beam size.

THE SOURCES OF THE BACKGROUND

The loss of the particle from the phase space of the beam results from the several mechanisms which can be consid-

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ered as acting independently. One of these mechanisms is the continuous drift of the circulating particles in the transverse plane due to the non-linearity of the accelerator magnetic structure or machine imperfections. These escaped from the beam envelope particles are absorbed by collimators of cleaning insertions. However there always exists the portion of the deflected particles that will not be intercepted by primary and secondary collimators due to the cleaning inefficiency. If these particles will interact with the material of the machine elements in the region close to the experimental insertion, the resulting secondary cascades will contribute to the machine induced background [3].

Another source of the background is elastic and inelastic interactions of beam particles with the nuclei of the residual gas which remains inside the accelerator vacuum chamber during all stages of the machine operation. The secondary products of the inelastic interaction have the characteristics that differ significantly from the ones of the beam particles. These secondaries are then scattered by the machine optics in the region close to the point of production and hence can not contribute to the background at a large distance from the point of loss. To account for this kind of the background particle interactions with the residual gas in the straight sections only has to be considered [4].

Elastic interactions with the residual gas give particles with the characteristics close to the properties of the beam particles which can be transported by the machine optics far downstream from the point of interaction. Because of this feature this source of the background can be also called a distant one. These deflected particles have also to be absorbed in the cleaning insertions. This means that considering this kind of the background with respect to particular interaction point elastic interactions only on the machine length between this point and the adjacent upstream cleaning insertion have to be taken into account [5].

As the third kind of the machine induced background source the beam-beam interactions in the adjacent interaction points is mentioned [6]. This source consists of the particles produced in the interactions at the interaction point with the relatively small changes in the momentum and small scattering angle. These particles have in principle a chance to be transported by the machine optics to the adjacent insertion region and produce there a secondary cascade which will contribute to the background.

BACKGROUND IN THE IP1 REGION DUE TO THE BEAM-GAS INTERACTIONS

As seen from Figure 1, the region of interaction point IP1 is located at the distance of two sectors of LHC from the adjacent cleaning insertions SS3 and SS7. For the LHC ring one the primary collimators at SS7 limit the beam aperture to $6\,\sigma$ in their nominal position. At the same time the aperture of the inner triplet quadrupoles is equal to $10\,\sigma$ in the insertion region of IP1 itself for the nominal value of β^* in the IP1 [7]. So the collimators of cleaning insertion effectively isolate the IP1 region from the elastic component of the beam gas source of the background except for the elastic interactions that occur in the Ring one structure downstream from the SS7. This allows limiting the length of the machine on which the elastic interactions of protons with the residual gas will be simulated to the distance between cleaning insertion SS7 and IP1 region.

The various machine parameters which affect the formation of the background were taken into account in the calculations by using a specially developed methodical approach to the study of the machine induced background problem [5]. Elastic interactions of beam protons with the residual gas on the machine length between SS7 insertion and IP1 point were simulated by the STR00 version of the STRUCT program [8]. The Monte-Carlo simulation of the particle cascades evolution in the machine structure on the length of the straight section of the IP1 region was performed using the IHEP MARS program [9]. The calculation of the machine induced background in the IP1 region done for the period of the nominal LHC operation showed the dependence of the resulting particle fluxes on the optics, the mechanical layout and the residual gas dynamics in the considered region of the machine structure [10].

Calculated resulting particle fluxes for charged hadrons and muons at the entrance to the experimental region of point IP1 are given in Figures 2 and 3. In these figures the dashed line gives the background produced in the straight section of the IP1 region by beam particles deflected in the elastic interactions in the machine structure between IP1 and SS7 insertion. The solid line gives the sum of the background from this source with the one generated due to the interactions on the length of the straight section SS of the IP1 region. As can be seen already for charged hadrons the contribution from the distant source of the background in the IP1 region is visible, on the level of 10 % from the total particle flux. For muons this contribution is significantly larger up to 30 % even with the assumed value very low residual gas density in the machine [11]. The total values calculated for the background particle flux generated by the beam-gas interactions are 1.77×10^6 and 1.04×10^5 particles/s for hadrons and muons respectively [12].

THE MINOR BACKGROUND SOURCES

Contribution to the background in the experimental insertion due to the cleaning inefficiency was first analyzed for the case of the particle leakage from the collimators of the insertion SS7 with the subsequent interaction in the next interaction point region IP8 [3]. Since the IP8 region precedes to the region of IP1 in the direction of the LHC ring one the obtained conclusions can be used for the estimation in the case studying here. The estimated rate of particle losses in the straight section elements of the interaction point region due to the nominal cleaning inefficiency was found ~ 40 times lower than the rate of the losses due to the beam-gas interactions [13]. Such comparison allows to conclude that this source of the background is a minor one, in the case of the nominal operation of the beam cleaning

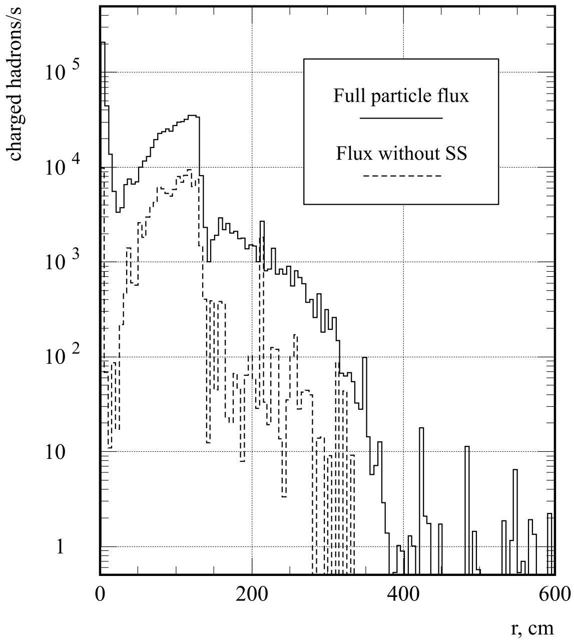

Figure 2: Radial distributions of charged hadron flux at the entrance to the IP1 experimental region.

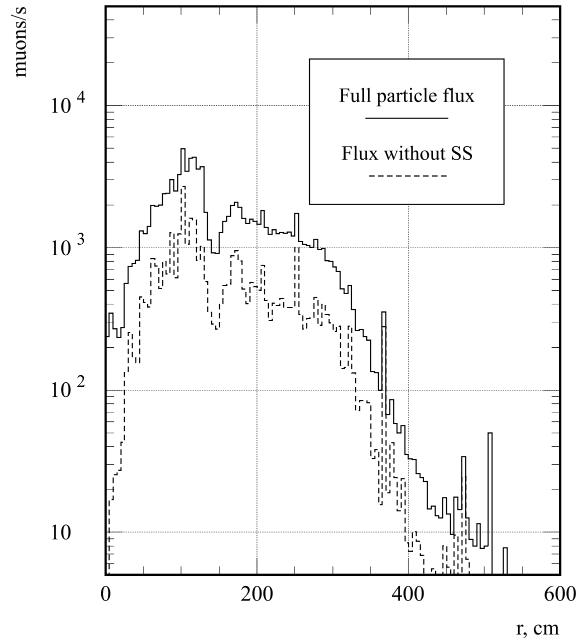

Figure 3: Radial distributions of muon flux at the entrance to the IP1 experimental region.

system.

To estimate the contribution to the background from the beam-beam interactions in the adjacent interaction point, the probability of the proton with relatively small change in momentum to be lost in the neighboring insertion region was calculated [3]. Already for the high luminosity of the beam-beam interactions in the adjacent point, the value several orders of magnitude lower than the rate of the beam-gas interactions was obtained for the rate of the losses due to this mechanism [13]. This leads to conclusion that for the contribution from the neighboring to the IP1 points with low luminosity IP2 and IP8 this value will be even lower. Taking into account that from the another high luminosity insertion the IP1 region is separated by the cleaning insertions SS3 and SS7, the total rate of this kind of losses in the IP1 region and hence the contribution to the background from this source can be estimated as negligible.

CONCLUSION

The evaluation of the different sources of the machine induced background in the region of the interaction point IP1 of the LHC shows that the main source of the background during the nominal machine operation is the inelastic and also elastic interactions that occur in the straight section of the IP1 region. Nevertheless a visible potion of the background in the IP1 region is produced due to the elastic losses of the beam protons in the machine structure between this region and the cleaning insertion SS7. The possible contribution to the background in the considered region from the adjacent interaction point can be estimated as negligible while the contribution from the scattering in the cleaning insertion itself can be important in the case of the cleaning inefficiency significantly higher than the designed one.

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