Betatron halo machine induced background for LHCb at 7 TeV

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Abstract

The physics performance of the LHCb experiment of the LHC will be affected by the experimental background conditions arising from the machine. In this note, calculations are presented of the betatron halo contribution at 7 TeV to the machine induced background, arising from betatron halo loss on the tertiary collimators in the experimental insertion. The resulting secondary particle cascade produces a stream of background particles into the LHCb cavern. The fluxes of particles are presented for beam 1 and beam 2 and the spatial and energy distributions analyzed. The calculations presented include the EM component of the background and the arrival time information for background species.
1 \ Introduction

The performance of the Large Hadron Collider and the associated experiments is
dependent on an understanding and control of particle rates arising in the machine and
streaming to the experimental caverns and detectors. This machine induced background
(MIB) will be seen with the first few bunches in the machine, and is generally proportional
to beam current and dependent on the machine optics, filling scheme, collimation scheme
and so on. The various sources of MIB in the LHC can be classified as,

1. Halo scattering, and subsequent showering, on the tertiary TCT collimators. This
contribution, arises from beam halo collimation in the long straight sections (LSSs).
It depends on the optics and collimation apertures, and varies greatly depending on
the proximity of the experiment from the betatron and momentum cleaning sections
of the machine.

2. Beam-gas interactions in the long straight section (LSS) of the machine. This con-
tribution depends of the local gas pressure profile, and the produced secondary
particles generally have a visible line-of-sight to the interaction point (IP).

3. Elastic beam-gas events in the arc. These events will modify the proton loss distri-
bution on the tertiary collimators.

4. Cross-talk from other experiment. This background is proportional to luminosity,
and is possibly only be a problem for ATLAS and CMS providing a background to
the lower luminosity LHCb and ALICE.

This note will focus on the background streaming into LHCb from the betatron halo
collimation in IR7 for both beam 1 and beam 2.

The LHC will need to be nominally operated with a collimation system to protect
elements of the machine from beam damage and to avoid quenching of superconducting
elements. A further role of the collimation system is to protect the experiments from any
machine induced background. The inherent inefficiencies when scattering a 7 TeV proton
in a 1 m Carbon collimator mean the LHC collimation system is designed to be multi-
phase and multi-turn, with a staged collimator hierarchy at increasingly further distances
from the beam, collimating protons over successive turns. The system is further divided
into momentum cleaning collimation, where the beam is cleaned in momentum space in a
dispersive region, and betatron cleaning designed to clean the horizontal and vertical phase
space of the beam. The betatron collimation region is designed to be dispersion free, and
the collimators of the betatron cleaning section are closest to the beam and most relevant
for beam halo, and hence halo induced background,creation. The primary beam halo is
intercepted and rescattered by betatron primary collimators made of Carbon, which have a
jaw 6 \( \sigma \) (where \( \sigma \) refers to the betatron beam size) from the beam. The scattered secondary
halo is intercepted by a betatron secondary collimators, again made of Carbon with a jaw
7 \( \sigma \) from the beam. The cleaning inefficiency of the secondary collimators produces a
tertiary halo, which is cleaned by tertiary halo collimators located on the incoming beam
either side of each experiment. The tertiary collimators hence provide protection to the
superconducting final triplet magnets from the tertiary halo, and the collimator jaws are
set to 8.3 \( \sigma \). The cascades initiated in the tertiary collimators shower into the detector
caverns and are a principle source of MIB at the LHC. There are two tertiary collimators
per beam per experiment, each with a high Z Tungsten jaw insert to intercept the halo:
a vertical TCTV and a horizontal TCTH. The collimators are one-beam collimators in
every IR apart from the TCTVs for IR 2 and 8 (ALICE and LHCb), which are located
in a shared beam pipe region and are a design variant with both beams in the collimator
aperture.
The MIB background fluxes from the tertiary collimators has been calculated for ATLAS and CMS [1] and some studies made for LHCb [2]. In this note, we present new and up-to-date calculations of the betatron halo background for LHCb from the tertiary collimators. The study updates previous work [3] and extends the scope to study time correlations in the background fluxes. The work also includes the impact of collimator offsets and alignments on this background source. The fluxes are calculated for 7 TeV nominal optics [4], for both beam 1 and beam 2, and the full background phase space (following the LHCb format described in [5], is available for LHCb detector studies at [6]).

2 LHCb background fluxes

2.1 Tertiary collimator proton inelastic event rate

The rate of proton loss on a given collimator is calculated using a Sixtrack multi-turn tracking calculation, for nominal optics and collimator layout and jaw setting. The machine parameters can be found in the LHC design report [7], and were taken to be nominal (for example beam energy of 7 TeV, $1.15 \times 10^{11}$ protons per bunch etc). An initial transverse halo distribution, either in the vertical or horizontal plane, is tracked for several hundred turns with a complete model of the machine and collimator apertures. Recattering of protons occurs on the collimator jaws, with elastically interacting protons allowed to continue tracking until they interact inelasticly with a collimator jaw or intersect the machine aperture. The resulting distribution of lost protons around the ring is localised on the primary and secondary collimators in LSS7 but losses are also seen on all tertiary collimators, with a different loss pattern for beam 1 and beam 2 determined by the proximity to the betatron cleaning (and to a lesser extent) the momentum cleaning section [7]. The fraction of total lost protons at a given collimator is termed the cleaning inefficiency. Table 1 shows the cleaning fractions for a Sixtrack calculation of $5 \times 10^6$ protons with nominal optics at 7 TeV, a LHCb $\beta^*$ of 10 m and the tertiary collimators set to $8.3 \sigma$ (equivalent to 1.35mm half-gap for the TCTVB in IR8). The asymmetry between beam 1 and beam 2 of the losses arises because the tertiary halo is dominantly produced in IR7 (betatron cleaning), which is adjacent to IR8 for beam 1 and very far around the LHC ring for beam 2. As discussed in the previous section, the halo type refers to the initial halo distribution in the Sixtrack calculation, with a pure vertical or horizontal halo referring to the possible extremes of the true halo distribution.

<table>
<thead>
<tr>
<th>Halo type</th>
<th>Beam 1</th>
<th>Beam 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical</td>
<td>TCTVB</td>
<td>TCTH</td>
</tr>
<tr>
<td>Horizontal</td>
<td>4631</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td>Horizontal</td>
<td>13</td>
<td>918</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>153</td>
</tr>
</tbody>
</table>

Table 1: The number of simulated particles inelastically interacting with the tertiary collimators of LHCb, for $5 \times 10^6$ total particles. The calculations were carried out with Sixtrack for nominal optics at 7 TeV and $\beta^*$ of 10 m.

The cleaning fractions can be normalised to a proton loss rate through the total beam lifetime. The decay of protons in the LHC is related to the beam lifetime $\tau$ by,

$$N(t) = N_0 \exp(-t/\tau),$$

(1)
implying the maximum decay rate of proton number is found at $t=0$,

$$\dot{N} = \frac{N}{\tau}.$$  \hspace{1cm} (2)

Therefore the maximum rate of total proton loss is related to the beam life and the total number of proton in the LHC. In this work the betatron halo beam lifetime is assumed to be 30 hours and the total number of proton in the LHC is assumed to be $3 \times 10^{14}$, giving a total loss rate (integrated around the machine) to be $2.78 \times 10^9$ protons per second. This can be combined to give the proton loss rate at a given collimator, which is shown in table 2 for the LHCb tertiary collimators for the cleaning fractions in table 1 for the case of beam 1.

<table>
<thead>
<tr>
<th>Halo type</th>
<th>Beam 1</th>
<th>Beam 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical</td>
<td>$2.57 \times 10^6$ p/s</td>
<td>$0.10 \times 10^6$ p/s</td>
</tr>
<tr>
<td>Horizontal</td>
<td>$7.23 \times 10^3$ p/s</td>
<td>$0.51 \times 10^6$ p/s</td>
</tr>
</tbody>
</table>

Table 2: The proton loss rate on the tertiary collimators of LHCb for beam 1, for a beam lifetime of 30 hours (equivalent to a total loss rate of $2.78 \times 10^9$ p/s). The rates are computed for nominal optics at 7 TeV and $\beta^*$ of 10 m.

2.2 Hadronic and electromagnetic showers from the tertiary collimator

The hadronic and electromagnetic (EM) showers initiated by the collimated proton inelastic interactions in the collimators were calculated using FLUKA [8]. A geometrical model of the LSS of LHCb was constructed, comprising of tunnel, beam pipe, all accelerator elements and the tunnel shielding, and is documented in [9]. The mass distributions were taken from the relevant engineering drawings, collimators included according to the design. The magnetic fields were included through explicit field maps for the final triplet elements and idealised fields for other quadrupoles, dipoles and correctors. The accuracy of the magnetic fields was checked against the reference orbit. The tertiary collimators are modelled as an LHC one-beam TCS collimator for the TCTH and an LHC two-beam collimator for the TCTVB (due to this collimator being close to the shared beam pipe region and the magnet D1). The forward region shielding of LHCb is modelled in terms of blocks of Iron and Concrete in the tunnels. On the left-hand side of the IP (RB84) [10], the shielding is grouped in three regions, 80 cm of concrete closest to the IP, 80 cm of Iron and 120 cm of Concrete in the tunnel, and then 80 cm of Iron and 120 cm of Concrete forming a tunnel chicane. On the right-side of the IP (RB86) [11], there is 120 cm of Concrete and 80 cm of Iron of shielding grouped around Q1 as a tunnel plug beginning 24.6 m from the IP, and a further chicane piece composed of 120 cm of Concrete and 80 cm of Iron. Note the RB84 shielding is consequently closer to the beam, while the RB86 shielding is located around the large diameter cryostat of Q1. The role of the shielding is to screen the LHCb detector from the MIB particle fluxes, and is expected to be most effective for the charged hadron contribution. The shielding is illustrated in figure 1, which shows the RB84 shielding on the left side of LHCb. The FLUKA model is shown in figure 2.

The EM and hadronic showers themselves are initiated in the Tungsten insert block of the tertiary collimators. The Sixtrack tracking calculation gives the distribution of inelastic events in the block, and so the cascade was initiated with a proton-Tungsten
nuclear interaction at the relevant location in the collimator block. This interaction forcing was done with an explicit DPMJETIII [12] calculation and an appropriate boost to the frame of the collimator, or implicitly in the FLUKA source routine. Both methods give the same results.

The showers were propagated with a 20 MeV cut on kinetic energy of all charged hadrons, electromagnetic particles and muons, whilst allowing neutrons down to thermal energies. The multiplicity of the EM cascade was controlled with a leading particle bias on the cascade below 1 GeV. The choice of cut or bias was checked not to impact the LHCb background fluxes scored above 20 MeV.

The secondary particle products from the showers are scored at -2.1 m from the IP for beam 1 and 19.9 m from the IP for beam 2 [5]. All particle species are recorded, with energy, weight (to account for the use of biasing in the cascades), phase space coordinates, arrival time (with $t=0$ corresponding to the loss on the collimator and with respect to the reference particle), the longitudinal position of the original loss location and the species of the parent interaction atom.

3 LHCb background flux rates and distributions

In this section the LHCb background fluxes will be presented and the impact of collimator and source alignment will be discussed.

3.1 TCTVB backgrounds and alignment

The TCTVB is a two-beam collimator located around 74 m from the LHCb interaction point on the incoming beams. Its purpose is to screen the final triplet from particle fluxes and prevent quenching. The close proximity of the two beams at the collimator location means the collimator is a two-beam type, consisting of a large aperture to accommodate both beams and a shaped collimator block with a Tungsten insert, designed to ensure only the beam heading towards the IP impacts the Tungsten and is collimated. The two-beam collimator variant (TCTVB) is used in IRs 2 and 8, while the TCTV in IRs 1 and 5 are the one-beam TCTVA variant. The collimator is equipped with alignment sensors and motors, and has a horizontal degree of freedom to move the collimating block.
The setup procedure of the collimator is to adjust the vertical jaws to give the collimator half-gap, and then adjust the horizontal motor to give sufficient clearance to the non-collimated beam whilst still collimating the incoming beam tertiary halo. This means that the vertical collimator position is known, but there remains a degree of freedom in the horizontal TCTVB position. Note this change in the collimator alignment is equivalent to a change of the beam position on the collimator jaw. To understand the impact, the production mechanism of muons entering LHCb needs to be considered. The 7 TeV proton interacts with a nucleus in the Tungsten, producing up to multi-TeV charged hadrons, particularly charged pions, which are boosted in the forward direction. These pions scatter through the Tungsten, with the shower growing transversely, emerging energy-moderated and propagate towards the experiment. Hence the transverse thickness of Tungsten seen by the scattering pions determines the mean energy of exiting pions, the pion distribution and so the resulting flux of muons and charged hadrons at the experiment. The distribution of pions is therefore sensitive to the interaction location in the Tungsten (equivalent to collimator alignment), and additionally suppressed in the forward direction regardless of the alignment. To evaluate the MIB impact of the relative position of the beam to the Tungsten block, the LHCb backgrounds were calculated for several beam-Tungsten alignments, with the different alignments obtained by scanning the beam over the fixed Tungsten geometry. The horizontal offset of the beam at the TCTVB is comprised of a geometric part arising from the beam separation dipoles, and a beam orbit part from the transverse beam orbit around the reference trajectory. For the background fluxes, the cases considered were 1/4, 1/2 and full geometric offset (with 1/4 geometric offset presenting the least Tungsten transverse to the beam and hence the largest fluxes) and the case of the sum of the full geometric offset and beam orbit. The Tungsten is assumed to be aligned to the centre of the collimator aperture in all cases.
Figure 3: The TCTVB tertiary collimator, rotated to collimate in the horizontal plane.

The range of cases considered will give a feeling for the range of background fluxes from the collimator and the range of detector response.

3.2 Beam 1 and beam 2 background rates

The muon and charged hadron flux rates at -2.1 m from the IP for beam 1, integrated over transverse space, are shown in table 3. The calculations were done for 7 TeV nominal optics with $\beta^*$ of 10 m at the IP of LHCb, for a vertical halo in the LHC, a 8.3 $\sigma$ vertical setting of the TCTVB and the four horizontal alignment cases. The fluxes were normalised to 30 hours total beam lifetime, and the calculations were done for the case of no LHCb forward region shielding and the case of full shielding to allow an assessment of shielding impact.

<table>
<thead>
<tr>
<th>Alignment</th>
<th>Full shielding</th>
<th>No shielding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>muon rate [s]</td>
<td>CH rate [s]</td>
</tr>
<tr>
<td>Geometric + beam</td>
<td>0.20E6</td>
<td>0.24E6</td>
</tr>
<tr>
<td>Geometric</td>
<td>0.24E6</td>
<td>0.17E6</td>
</tr>
<tr>
<td>Half geometric</td>
<td>0.34E6</td>
<td>0.14E6</td>
</tr>
<tr>
<td>Quarter geometric</td>
<td>0.41E6</td>
<td>0.16E6</td>
</tr>
</tbody>
</table>

Table 3: The beam 1 LHCb background fluxes coming from the TCTVB collimator for a vertical halo source. The beam 1 fluxes are quoted for four different horizontal alignments of the beam with the collimator jaw. The rates are computed for nominal optics at 7 TeV, $\beta^*$ of 10 m and a lifetime of 30 hours.

The impact of the horizontal alignment of the TCTVB can be seen on the rate of IP background particles, and the difference of up to a factor of two in muon and charged...
hadron flux is obtained. This difference may be small compared to other uncertainties but shows the relativity sensitivity to collimator alignment. The largest fluxes are seen at the IP when the beam is close to the edge of the Tungsten, and the pion mean energy exiting the collimator is larger than for other cases. The case of full geometrical and beam orbit offset gives the smallest flux, although for this case the beam is 2.22 cm from the Tungsten edge and essentially in the horizontal middle of the Tungsten insert. Taking the largest fluxes as an estimate of the approximate worst case, the LHCb beam 1 background fluxes from the TCTVB with a vertical halo are 1.85E6 muons/s and 2.62E6 charged hadrons/s, or 1.85 MHz and 2.62 MHz respectively. Note that this rate is much less than the LHCb rate of proton-proton interactions at the IP. The calculations also indicate a factor of two in fluxes arising from variable beam-collimator alignment. The impact of the forward region shielding can also be seen from the flux numbers in table 3. The efficiency of the shielding can be seen to be high, with the total fluxes reduced due to the Concrete and Iron shielding. This shielding removes most of the charged hadrons, with a contribution left in the beam pipe, and the (more penetrative) muons are reduced by a factor or 2-3.

<table>
<thead>
<tr>
<th>Collimator</th>
<th>Halo</th>
<th>Full shielding</th>
<th>No shielding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>muon rate</td>
<td>CH rate</td>
<td>muon rate</td>
</tr>
<tr>
<td></td>
<td>/s</td>
<td>/s</td>
<td>/s</td>
</tr>
<tr>
<td>TCTVB</td>
<td>Vertical</td>
<td>0.41E6</td>
<td>0.16E6</td>
</tr>
<tr>
<td>TCTVB</td>
<td>Horizontal</td>
<td>neg.</td>
<td>neg.</td>
</tr>
<tr>
<td>TCTVB</td>
<td>Total</td>
<td>0.41E6</td>
<td>0.16E6</td>
</tr>
<tr>
<td>TCTH</td>
<td>Vertical</td>
<td>0.15E5</td>
<td>0.98E4</td>
</tr>
<tr>
<td>TCTH</td>
<td>Horizontal</td>
<td>0.75E5</td>
<td>0.67E5</td>
</tr>
<tr>
<td>TCTH</td>
<td>Total</td>
<td>0.89E5</td>
<td>0.76E5</td>
</tr>
</tbody>
</table>

Table 4: The beam 1 LHCb background fluxes for the tertiary collimators, for a beam lifetime of 30 hours (equivalent to a total loss rate of 2.78E9 p/s). The rates are computed for nominal optics at 7 TeV and β* of 10 m, and the rates coming from the TCTVB are quoted for a quarter geometrical offset and no beam offset.

Table 4 is a complete summary table for the LHCb beam 1 tertiary background fluxes at the -2.1 m scoring plane. The table includes the TCTH induced background and fluxes for the shielding and non-shielding case. The total flux is computed as the sum of the horizontal and vertical halo (to give an upper bound); as these initial distributions represent extremes of the initial distribution, the sum represents an upper limit on the betatron halo contribution to the total background. The horizontal halo loss on the TCTVB is very small, and so the total flux from the TCTVB is taken to be the contribution from the vertical halo alone.

The background fluxes at 19.9 m for beam 2 are shown in table 5, including the TCTVB and the TCTH contribution and all for the case of full shielding. Tables 4 and 5 taken together give the complete background flux rates from the betatron halo into both sides of the LHCb cavern.

3.3 Beam 1 distributions: no shielding

Figures 4 to 12 show the distribution of the muon and charged hadron background species at the LHCb1 beam 1 interface plane at 2.1 m from the IP for the case of no forward region shielding.
Table 5: The beam 2 LHCb background fluxes coming from the TCTVB collimator for a vertical halo source. The beam 1 fluxes are quoted for four different horizontal alignments of the beam with the collimator jaw. The rates are computed for nominal optics at 7 TeV, $\beta^*$ of 10 m and a lifetime of 30 hours.

<table>
<thead>
<tr>
<th>Case</th>
<th>Full shielding</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>halo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCTVB Geometric + beam</td>
<td>vertical</td>
<td>0.56E4</td>
<td>0.67E4</td>
</tr>
<tr>
<td>TCTVB Geometric</td>
<td>vertical</td>
<td>0.45E4</td>
<td>0.80E4</td>
</tr>
<tr>
<td>TCTVB Half geometric</td>
<td>vertical</td>
<td>0.47E4</td>
<td>0.47E4</td>
</tr>
<tr>
<td>TCTVB Quarter geometric</td>
<td>vertical</td>
<td>0.53E4</td>
<td>0.71E4</td>
</tr>
<tr>
<td>TCTVB</td>
<td>horizontal</td>
<td>neg.</td>
<td>neg.</td>
</tr>
<tr>
<td>TCTH</td>
<td>horizontal</td>
<td>0.62E4</td>
<td>0.71E4</td>
</tr>
<tr>
<td>TCTH</td>
<td>vertical</td>
<td>neg.</td>
<td>neg.</td>
</tr>
</tbody>
</table>

The correlation between the secondary particle arrival time with respect to the reference particle (for all secondary species) with production location is shown in figure 4, where most particles are close to a time delay of zero from the reference particle, and there is a tail to around 10 ms delay. The long time tail is dominated by low velocity particles, primarily neutrons. Therefore the majority of background particles arrive with the bunch, but there is a long tail of arrival times associated with lower energy particles. The largest spike in the production location is at the tertiary collimator at 74 m, although there are large contributions from the iron mass of the separation dipole D1 and the final triplet.

The arrival time distribution for all particles (left) and for background particles (right) is shown in figure 5. The distribution for all particles has a long tail arising from low energy particles, while the background particles arrive much more in time with the reference particle.

Figure 6 shows the correlation between arrival time and production location for the particles contributing to the main background (charged hadrons and muons) in the left-hand plot, and the right-hand plot shows the correlation between arrival time and kinetic energy for the background particles. The background particles tend to arrive closer to the reference particle due to their relatively high kinetic energy.

The spatial distribution of muons (left) and charged hadrons (right) at the -2.1 m interface plane are shown in figure 7. The outline of the tunnel is clearly visible in both plots. The left-hand plot shows the penetrating nature of the muons outside the tunnel, and the right-hand plot clearly shows the greater sensitivity of the charged hadrons to the material distribution of the geometry and also shows peak of the charged hadrons in the vacuum of the beam pipe.

Figure 8 shows the kinetic energy distribution of the muons, with a zoom at low energy shown in the right-hand plot. The corresponding plots for the charged hadrons are shown in figure 9. Both the background particle types have a energy tail down to several hundred GeV, with peaks at low energy. The muons and charged hadrons are peaked at around 200 MeV kinetic energy. Figure 10 shows the kinetic energy distribution of the neutrons (left) and the electromagnetic particles (right) at the interface plane. Note the neutrons are dominated by very low energy particles.

The horizontal spatial distribution of the tertiary background muons (left) and
charged hadrons (right) is shown in figure 11. The distributions are fairly flat across the tunnel, with a drop-off outside the tunnel in the Concrete surround. A peak is seen at x=0 in the charged hadrons distribution, corresponding to the beam pipe location. Note there is no peak at x=0 for the muons, which are generally flatter.

Figure 12 shows the corresponding radial density distributions in the tunnel, with both plotted with equal binning and vertical axis. The plots show the tertiary halo background gives an equal contribution at small and large radii, and is expected to provide the dominant contribution at large radii where other background contributions are generally lower.

3.4 Beam 1 distributions : full shielding

In this section, the distribution of the muon and charged hadron background species at the LHCb beam 1 interface plane at -2.1 m from the IP for the case of full forward
The spatial distribution of muons (left) and charged hadrons (right) at the -2.1 m beam 1 interface plane are shown in figure 13. The left-hand plot shows the penetrating nature of the muons outside the tunnel, and the right-hand plot clearly shows a significant reduction of the charged hadrons with respect to the non-shielded case, figure ??.

Therefore the muons distribution is flat for the shielded case, and the charged hadron distribution is much more peaked at r=0 for the shielded case than for the unshielded case.

Figures 14 and 15 show the energy distribution of the muons and the charged hadrons respectively, with low energy zoom shown in the right-hand plot in both cases. Both the background particle types have a energy tail down to several hundred GeV, with
peaks at low energy, which is similar to the unshielded case.

The radial distribution of the tertiary background muons (left) and charged hadrons (right) is shown in figure 16. The muon distributions is flatter across the tunnel than the charged hadron distribution, and both are more peaked at r=0 with respect to the unshielded case. This peak is more pronounced for the changed hadrons than the muons.

Finally the arrival time distribution is shown in figure 17, with all particles on the left and only the background (muons and charged hadrons) on the right. The effect of the shielding can be seen by comparing to figure 5, with the shielding removing a large amount of the long arrival time tail (which arises from the lower energy particles).

4 Conclusion and summary

In this note, new calculations of the betatron halo machine induced background for LHCb are presented and analysed. The calculations expand and update previous calculations, and include a detailed analysis of the background time structure, EM component, neutron component and are done for both beams. The Sixtrack halo distributions are showered from the tertiary collimators to the experimental cavern using a new FLUKA model of the IR8 long straight sections, which includes all machine elements, fields and shielding. This model was created specially for the background calculations. The calculations were done at 7 TeV for a nominal collimation scheme and an IP8 $\beta^*$ of 10 m.

For the beam 1 betatron halo background arising from the TCTVB, it was shown that the horizontal alignment of the collimator changed the muon and charged hadron
background flux at the -2.1m scoring plane by up to a factor of two. Furthermore, the impact of the shielding was shown to be significant for the charged hadron component and effective by about a factor of 2-3 for more penetrating muons. The shielding also reduces the EM component reaching the cavern, and narrows the distribution of the arrival time.

A complete set of background rates into the LHCb cavern from both beam 1 and beam 2 were presented, along with the associated distribution. The spatial distribution of charged hadrons shows a peak at the beam position, while the muon distribution is flatter. In the time domain, the background shows a spike arriving with the bunch, and a long tail of lower energy background particle arriving many bunches after the reference particle.
Generally, the rate of background particles is small compared to the rate of particles from IP proton-proton collisions.

The full phase space of the betatron halo background for LHCb has been made available at [6], for studies of showering and detector response. The analysis for the betatron halo background at 450 GeV, 3.5 TeV and 5 TeV will be performed and made available to the experiments as soon as the collimation scheme and loss maps are available from the collimation working group.

References
Figure 16: The muon (left) and charged hadron (right) tertiary halo background flux (right) radial density distribution at the LHCb beam 1-2.1m interface plane for the quarter geometrical orbit LHCb tertiary halo background for the case of full shielding.

Figure 17: The particle arrival time distribution for all particles (left) and the background (charged hadron and muons) particles (right). The distribution for all particles has a long tail arising from low energy particles, while the background particles arrive much more in time with the reference particle.


[10] CDD/LHCJR840001