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Estimation of the material budget of the LHCb detector

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Abstract

The material budget of the LHCb detector at the time of the DC 06 data challenge is estimated.

1 Introduction

The detectors located upstream of RICH2 contain a sizable amount of material. At the time of the re-optimization TDR [1] this constituted around 40% of a radiation length. Search windows in pattern recognition algorithms and the momentum resolution in the detector were found to be dominated by the multiple scattering that this material caused. In addition, a sizable fraction of photons converted before the start of RICH2. For DC '06 [2] several sub-detectors have implemented more realistic descriptions of the detector geometry [3, 4]. Therefore, it is important to update the estimates of the material budget so that the impact of any increase on the detector performance can be judged.

To estimate the radiation length between two points a python script is used. The GaudiPython module provides access to the TransportSvc and to the LHCb detector description. Hence, a material scan of the full LHCb geometry description can be performed. For these studies, the LHCb acceptance is divided into 200×200 bins in pseudorapidity (η) and azimuthal angle (ϕ). For each bin a test particle is traced from the origin through the elements of the detector and the radiation length estimated. The scan has been used to estimate the material before the first measured point, before the start of the spectrometer magnet and up to the end of the tracking system. For completeness the radiation length in regions corresponding to each sub-detector is given in Section 3.

2 Results

The resolution on the track impact parameter has a significant contribution due to the material before the first measured point. Fig. 1 shows the radiation length seen by a particle before the first measured point. The material of the RF foil can clearly be seen. Averaging over $1.8 < \eta < 4.8$ this amounts to 2.7 % of a radiation length. This is similar to the value found in previous studies.

In Fig. 2 the radiation length up to z= 270 cm, the start of the LHCb magnet, is plotted as a function of η and ϕ. Fig. 3 shows the radiation length as a function of η. It can be seen that:

- For η between 1.9 and 3.5 a particle sees just over 30 % of a radiation

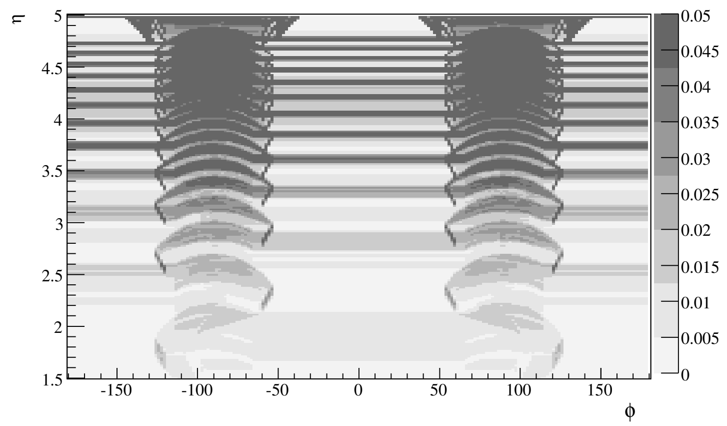

Figure 1: Radiation Length versus η and ϕ before the first measured point. Note the truncated scale.

length.

- The material of the detector frames and other dead material outside the acceptance gives a large increase in the amount of material below $\eta = 1.9$.
- Between $\eta = 3.6$ and 4.3 a particle sees $40 - 50$ % of a radiation length. The increase compared to low η is due to the interface section between the VELO vacuum tank and the beam-pipe.
- A prominent spike can be seen at $\eta = 4.3$. This is due to the 25 mrad section of the beam-pipe.

At the time of the reoptimization TDR the material between 1.9 and 3.5 amounted to just under 30 % of a radiation length. The increase that is observed is due to the change in the thickness of the VELO sensors from 200 to 300 μm and the changes to the TT geometry description discussed in [4, 5]. Compared to the reoptimization TDR a 4 % increase in the amount of material above $\eta = 4.5$ is also seen. This is mainly attributed to the increase in the amount of material in the TT station around the beam-pipe. Finally, a scan was made to see what fraction of an interaction length this radiation length corresponds to. On average a particle see 12 % of an interaction length.

Fig. 4 and 5 show the material integrated up to the end of the LHCb tracking system, z = 930 cm. It can be seen that a particle sees around $50 - 70$ %

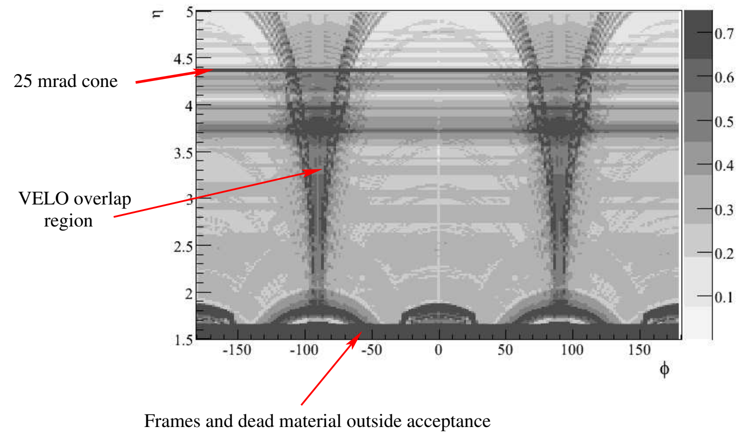

Figure 2: Radiation Length as a function of η and ϕ integrated up to z = 270 cm. Note that the radiation length scale is truncated.

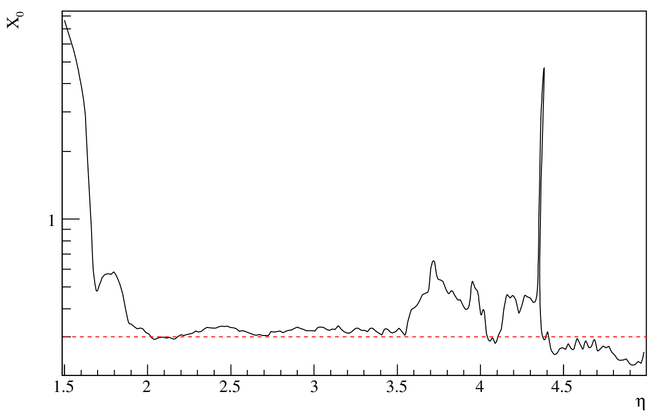

Figure 3: Radiation Length versus η integrated up to z = 270 cm. The dotted line corresponds to 30 % of a radiation length.

of a radiation length up to the end of the tracking system. In addition, the material of the beam-pipe supports together with the cooling rods and cables of the Inner Tracker can clearly be seen. Finally, it should be noted that a particle sees 20 % of an absorption length before the end of the tracking system.

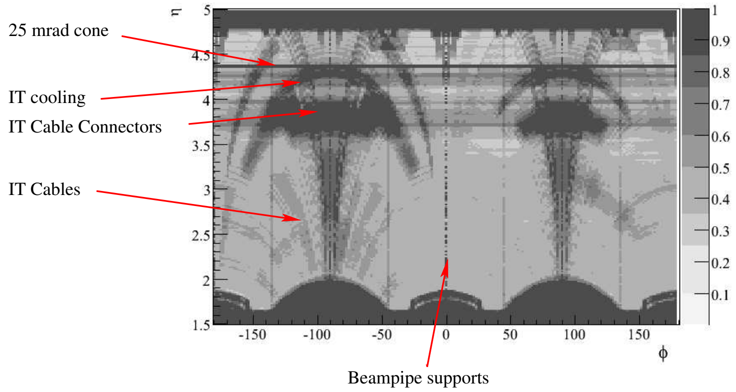

Figure 4: Radiation length as a function of η and ϕ integrated up to z = 930 cm. Note that the radiation length scale is truncated.

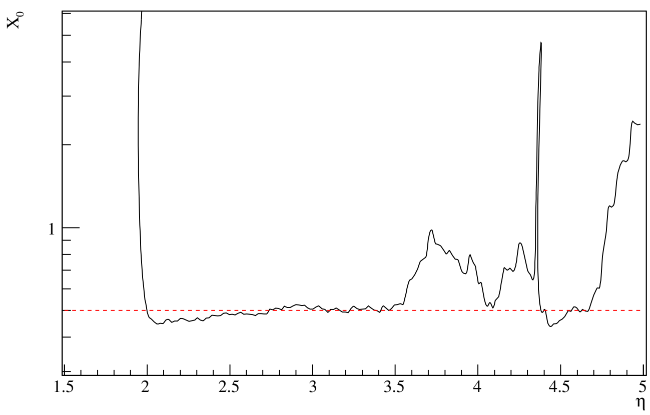

Figure 5: Radiation Length versus η integrated up to z = 930 cm. The dotted line corresponds to 50 % of a radiation length.

3 Scans as a function of z

For completeness scans have been made to estimate the material in each of the sub-detectors in the tracking system. The z ranges for the six scans made are summarized in Table 1 together with the radiation length in that region averaged over ϕ and for $2.0 < \eta < 4.8$. Fig. 6 shows the results of the scans as a function of η and ϕ. Fig. 7 shows the shows the results of the scans averaged over ϕ as a function of η.

Region	z_{min}/cm	z_{max}/cm	X_0/%
VELO	0	83	16.2
VELO-RICH1 interface	83.0	97.8	6.8
RICH1	97.8	225	9.5
TT	225	275	5.1
Magnet	275	760	5.3
T	760	930	17.8

Table 1: Average radiation length, X_0, in different regions of the detector.

4 Missing material

Unfortunately there is still some material missing from the Monte Carlo. For example:

- The VELO constraint system [7].
- The diamond based radiation monitor located immediately in front of the TT station [8].
- The supports for the TT half modules located directly above and below the beam-pipe.
- The section of the IT cooling pipes closest to the detector box [3].
- The beam-pipe approach system of the IT [9].
- The additional material due to the changes to the IT cabling.

Compared to the increase in the X_0 seen in going from the reoptimization TDR to DC 06 it is expected that the effect of these changes will be small.

5 Summary

In this note the material in the LHCb detector at the time of the DC 06 data challenge has been estimated. Compared to the reoptimization TDR the material in the detector has increased. On average a particle sees 60% of a radiation length up to RICH2, compared to $40-50\%$ at the time of the reoptimization TDR. This additional material will lead to increased multiple

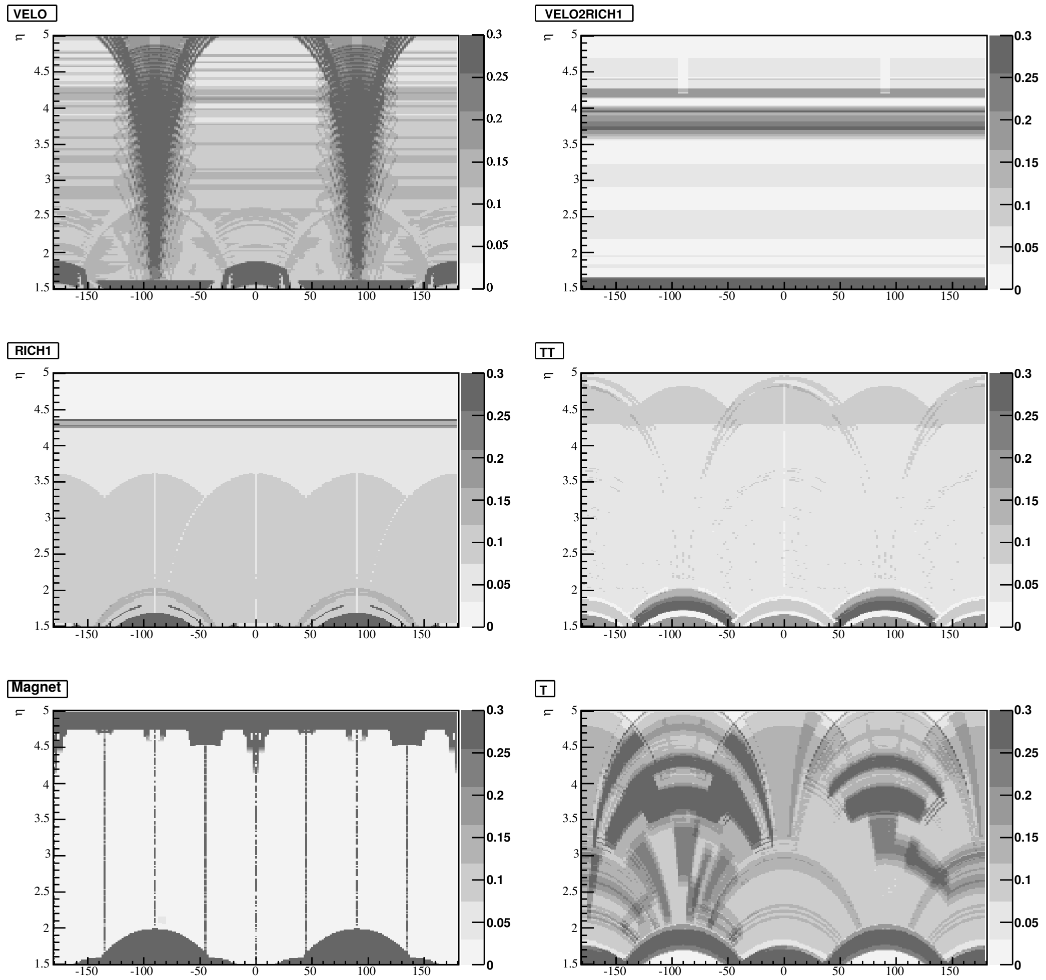

Figure 6: Radiation length as a function of η and ϕ integrated over various regions in z.

scattering which will complicate the pattern recognition and degrade the momentum resolution. The size of the latter effect can easily be estimated. As shown in [6] the momentum resolution scales with $\sqrt{X_0}$. Therefore, a 20 % increase in the amount of material will degrade the momentum resolution by 10%.

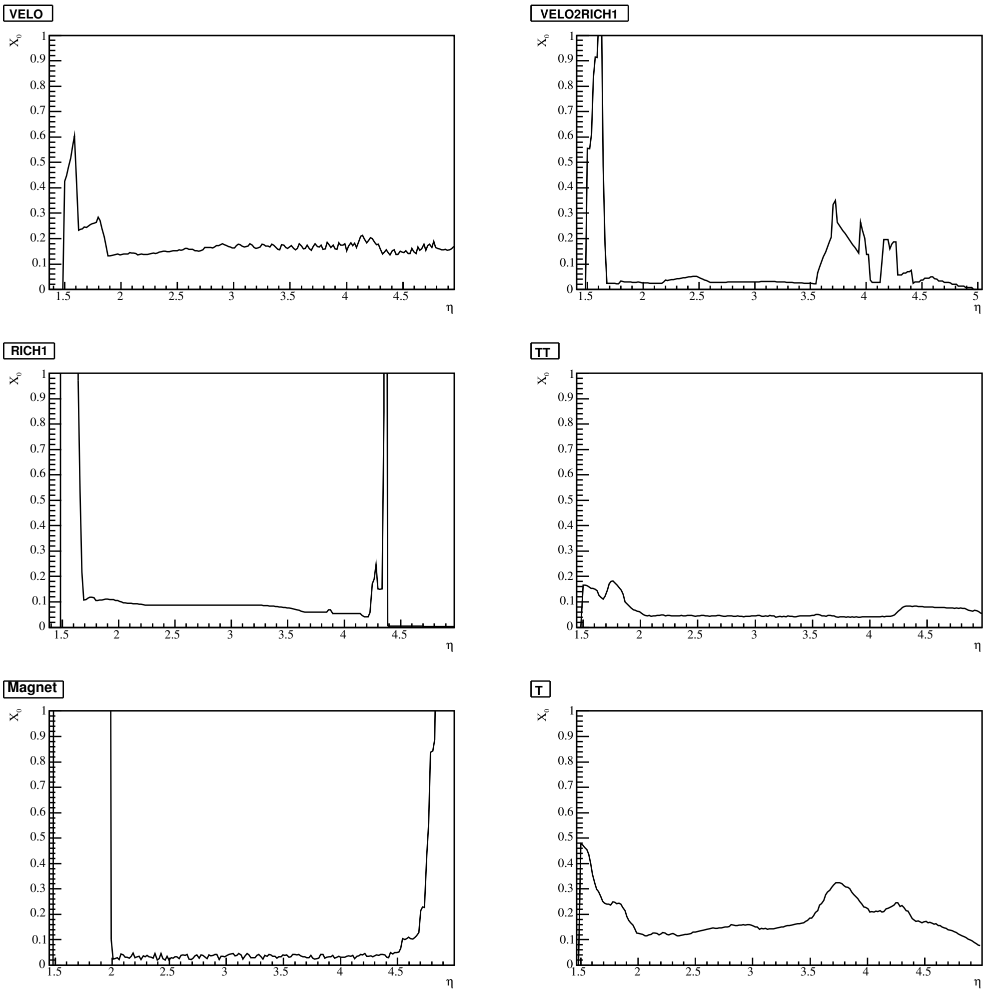

Figure 7: Radiation Length as a function of η averaged over ϕ for various regions in z.

References

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