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Estimation of the material budget of the Inner Tracker

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Abstract

The material budget of the LHCb Inner Tracker in July 2008 is estimated. Values are also given for the total material before the magnet and integrated to RICH 2.

1 Introduction

The material budget of the Inner Tracker at the time of the DC 06 data challenge [1] is discussed in [2]. At the beginning of 2008 the XML description of the detector has been updated to account for changes that have occured since then. The most relevant changes are:

- The description of the signal and HV cables has been improved. The total amount of material and its location has been estimated in [3].
- A simplified description of the service boxes and the cables outside the acceptance has been added.
- Some parts of the cooling system near the boxes were missing in the previous description. These have now been added.
- The steel connectors between the two cooling rods are now explicitly described, instead of being smeared out in other volumes.
- The properties of the materials of the PCB's and connectors have been updated.

The total mass for the detector boxes description matches the measured mass within $\mathcal{O}(2\ \%)$. For the cables and support frames, the precision is estimated to be $\mathcal{O}(5\ \%)$. Details of the materials and volumes can be found in [4].

To estimate the changes in radiation length, material scans were made. Two version of the geometry were compared, the first is the DC06 version used in [2], while the second is the July 2008 version tagged as 'head-20080716'. The radiation length is estimated using a python script. 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 400×400 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 script has been used to make scans of the material of the Inner Tracker, 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 4.

2 Inner Tracker Results

Fig. 1 and 2 show the material integrated for the whole T stations including IT. This corresponds to z = 7.6 m to 9.3 m. It can be seen that a particle sees around $15 - 20$ % of a radiation length across the T system. The material of the cooling rods and cables can clearly be seen in Fig. 3 and 4.

- For η below 1.9, the main contribution is the material of the signal cables connecting to the service boxes. As these cables are coiled they give a large increase in the radiation length outside the acceptance.
- Between $\eta = 1.9$ and 3.5 the radiation length rises from 12 % to 18 % of X_0
- In the region between $\eta = 3.5$ and $\eta = 4.1$ the radiation length incrases from 18 % to peak at 25 % of X_0. This is due to the PCBs of the signal boxes and the their steel connectors.
- In the region between $\eta = 4.1$ and 4.5 the radiation length makes a second peak of same amplitude than the previous one. This is due to the cooling rods and their steel connectors.
- In the region between $\eta = 4.5$ and 5.0 the radiation length decreases from 16 % to 8 % of X_0 as the particles see a decreasing part of the silicon sensors at high η values.

Differences in X_0 between the DC06 and July 2008 versions are clearly visible outside of acceptance. These are due to the better description of the cables. The total amount of cables in this region has been tuned to match as closely as possible the real setup observed during the cable survey [3]. In addition, differences can be seen in the peak at $\eta = 3.5$ to 4.1 corresponding to the PCB's and connectors of the boxes, it can be seen that the July 2008 version contains less material. This is because of a mistake in the DC06 version which caused this material to be overestimated by a factor of 4. Finally, the variations in X_0 within the $\eta = 1.9$ to 3.5 region are the consequence of the better description of the signal cables coming from the cable survey [3].

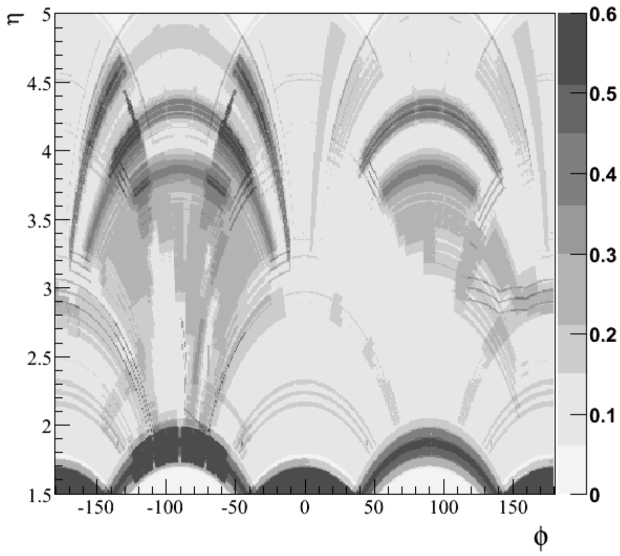

Figure 1: Radiation length versus η integrated over the whole IT.

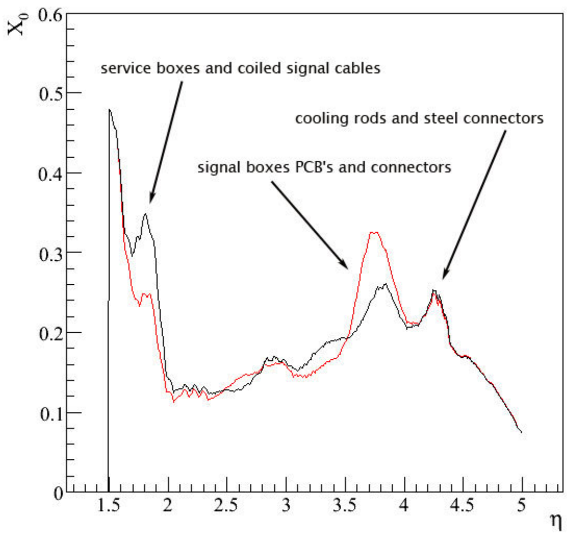

Figure 2: Radiation length versus η integrated for the whole IT region. The red line stands for DC06 and black for July 2008.

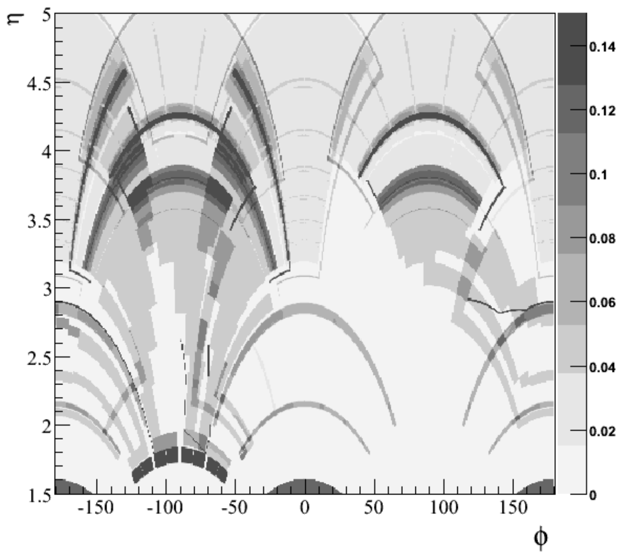

Figure 3: Radiation length versus η integrated for the Station 1 of IT.

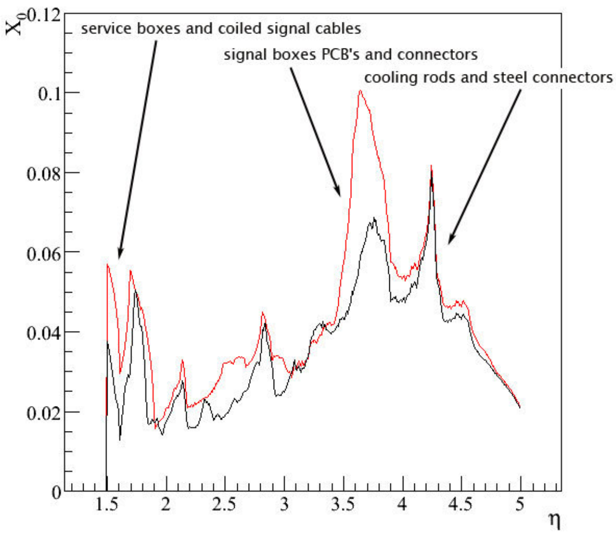

Figure 4: Radiation length versus η integrated for the Station 1 of IT. Red line stands for DC06 and black for July 2008.

3 Material in the detector

In Fig. 5 the radiation length up to z = 2.7 m, the start of the LHCb magnet, is plotted as a function of η and ϕ. Fig. 6 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 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.

There are differences between the July 2008 and the DC06 version both at high and low η. For low η values this comes from a better description of the cooling material of the TT outside the acceptance. At high η it is due to a more realistic description of the insulation jacket around the beampipe in the TT.

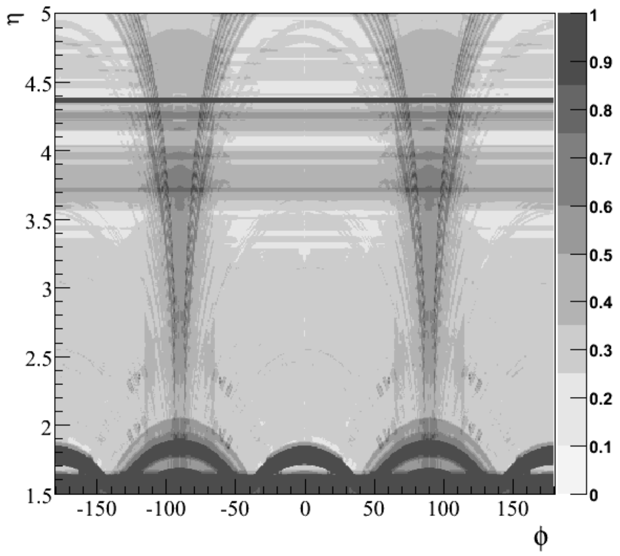

Figure 5: Radiation length as a function of η and ϕ integrated up to z = 2.7 m. Note that the radiation length scale is truncated.

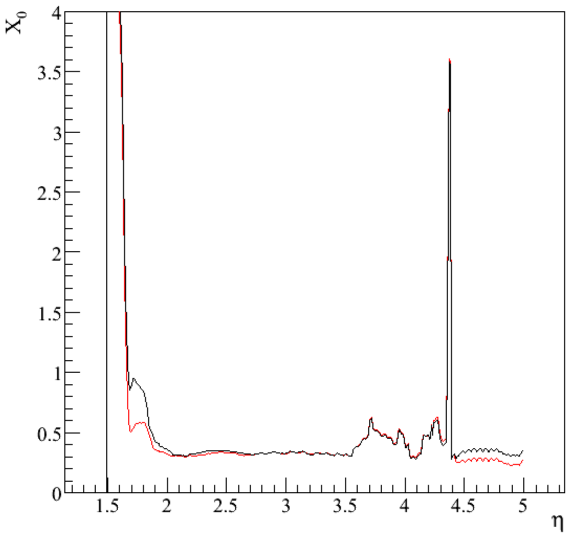

Figure 6: Radiation length versus η integrated up to z = 2.7 m. The red line stands for DC06 and black for July 2008.

Fig. 7 and 8 show the material integrated up to the end of the LHCb tracking system, z = 9.3 m. It can be seen that a particle sees around $50 - 70$ % 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.

- For η between 1.9 and 3.5 a particle sees 50 % of a radiation 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 $60 - 80$ % of a radiation length. The additional increase compared to the $0 < z < 2.7$ m region is $10 - 20$ % of X_0 and is mainly caused by the inner tracker boxes' connectors and the cooling rods.
- In the region between $\eta = 4.7$ and 5.0 sees a radiation length going up from 60 % to 250 %. This is due to the planges, bellows and collars around the beampipe inside the magnet region.

The average difference in X0 between DC06 and July 2008 version is of 0.75 % of a radiation length.

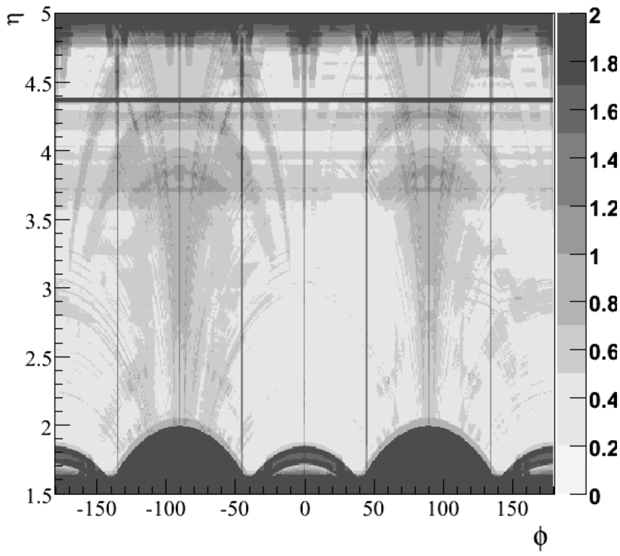

Figure 7: Radiation length as a function of η and ϕ integrated up to z = 9.3 m. Note that the radiation length scale is truncated.

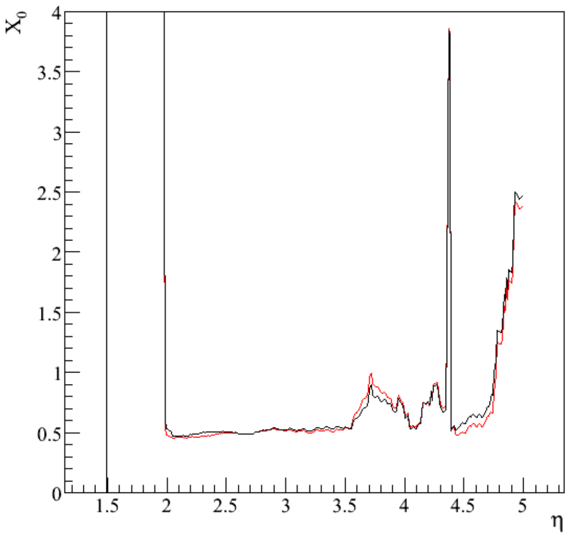

Figure 8: Radiation length versus η integrated up to z = 930 cm. The red line stands for DC06 and black for July 2008.

4 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 together with the radiation length in that region averaged over ϕ and for $2.0 < \eta < 4.8$. Fig. shows the results of the scans as a function of η and ϕ. Fig. 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	17.2
VELO-RICH1 interface	83.0	97.8	6.8
RICH1	97.8	225	9.1
TT	225	275	6.3
Magnet	275	760	5.9
T	760	930	17.5

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

5 Summary

In this note the material in the LHCb detector at the time of the before experiment start has been estimated. Compared to the DC06 version, the material in the detector is better described, but the total amount changed only by 0.75 % of a radiation length. Scans of the whole LHCb spectrometer have also been made. On average a particle sees 62.72 % of a radiation length up to RICH2. This value was of 61.97 % of a radiation length at the time of the DC06 version. This additional material will degrade the momentum resolution by 0.6 %, bringing it to 0.4527 % from the previous value of 0.45 %

References

[1] Gauss v25r7, Boole v12r10, Brunel v30r14, XmlDDDB v30r14.

[2] M. Needham and T. Ruf. Estimation of the material in the LHCb detector. LHCb-note 2007-025.

[3] V. Fave. Cable Survey ot the Inner Tracker. LHCb-note 2008-055.

[4] http://lhcb.physik.uzh.ch/ST/software/det/.