LHC Project Note 427

robert.appleby@cern.ch

The FLUKA model of IR8

R.B. Appleby, EN/MEF, CERN
A. Mereghetti, EN/STI, CERN

Keywords: LHC, IR8, FLUKA

Summary

The study of machine induced background (MIB), the radiation environment and beam dynamics of the LHC requires a detailed model of the machine tunnel, elements and electromagnetic fields. In this note, a specially created model of IR8 in FLUKA is described, including the tunnel, vacuum chambers, magnets, collimators, injection elements and shielding. The inclusion of all relevant machine elements in the LSS of IR8 results in a very flexible model suitable for a large variety of calculations and studies. The validation of the model is discussed, and some example applications described.

LHC-Project-Note-427
08/02/2007

1 Introduction

The performance and ultimate success of the LHC requires a detailed understanding of the charged and neutral particle environment induced by beam in the machine. This study of radiation and particle background is necessary to understand the radiation dose to machine components and the impact of secondary particles in the experimental detectors (MIB). For these reasons, a detailed model of the IR8 LSS has been made in FLUKA [1] and presented in this note. The model consists of the LHC tunnels, all machine elements contained in the tunnels and a model of the electromagnetic fields seen by the beams, and is described in the following sections.

2 Layout of the model

The model is divided into separate pieces for the left side and the right side of the IR (IR8-left and IR8-right respectively) for computational simplicity and because of the presence of the LHCb detector around the IP. The model consists of the long straight section from $\pm$ 280 m from the IP to the interface plane between the machine and experiment at -2.1 m for beam 1 (IR8-left) and +19.9 m for beam 2 (IR8-right) (although the origin is taken as the interaction point in both cases and the model extends to positive s). Taken together, the two halves of the model provide a complete picture of the IR8 LSS, with a gap in the middle for the detector. The LHC layout database [2] and optics web-page [3] was used to produce the layout, and engineering drawings were taken from the CDD [4].

The model of the LSS of LHCb was constructed using the machine layout, the optics and the engineering drawings of the components, and is comprised of the tunnel, beam pipe, all accelerator elements and the tunnel shielding. The tunnels and caverns are modelled around the beam, and in detail for the cable feedthroughs and mazes from RA83 to UA84.

The model is plotted in figures 1 and 2 for IR8-left and in figure 3 for IR8-right.

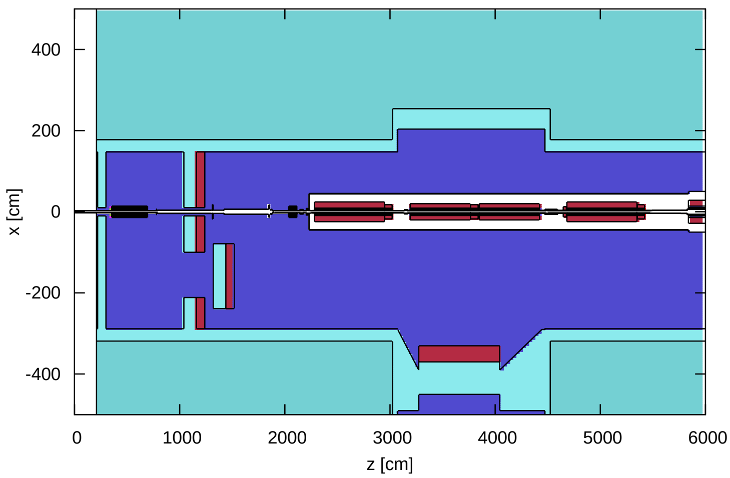

Figure 1: The first 60 m of the IR8-left model, showing the tunnel and the forward region shielding. The final triplet and the corrector MBXWS can also be seen, as well as the mobile shielding plug in UJ84.

The following subsection describe the various components of the model on the left and the right sides.

2.1 Magnets

The final triplet magnets are adapted from the final triplet model for IR1 [5]. The magnetic field in the final triplet is modelled with an explicit field map in the quadrupoles Q1 to Q3. The model for D1 is adapted from the superconducting D2 in the IR1 FLUKA model [5], and the Q4-Q7 quadrupoles are models of the standard LHC MQY/MQM components [5]. In the separation dipoles (D1 and D2) and Q4-Q7, the field are ideal fields and localised to the vacuum chamber. For IR8, new models were made of the correctors MBXWH and MBXWS, which are part of the LHCb inner crossing angle bump. The fields for these elements are ideal.

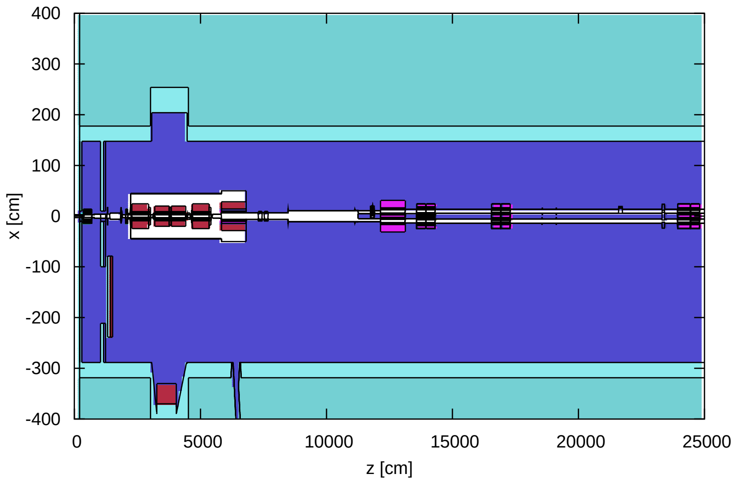

Figure 2: The IR8-left mode, showing the tunnel and the separation of the vacuum chambers.

The reference orbit for an incoming and also and outgoing nominal proton was checked against the LHC reference optics and agreement achieved.

2.2 Collimators

The collimators in the LSS of IR8 which are not injection-related are the tertiary halo collimators (TCTS). These are designed to intercept the tertiary beam halo before it hits the superconducting final triplet magnets and also provide protection in the event of anomalous beam dump events. They are located on the incoming beams, with one collimator with vertical jaws and one collimator with horizontal jaws, with a Tungsten jaw inset for proton collimation. The horizontally collimating TCTH is derived from a standard LHC TCS one-beam collimator [5, 6] and is located around 118 m from the IP.

The TCTVB is a two-beam collimator located around 74 m from the LHCb interaction point on the incoming beams. 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 incoming beam 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 TCTVB is shown in figure 4, where the Tungsten insert can be seen. The model of the TCTVB is a specific two-beam collimator model, adapted from the one-beam TCS standard collimator.

The collimators are aligned with the incoming beams, and the jaw position set by the optics and beam energy.

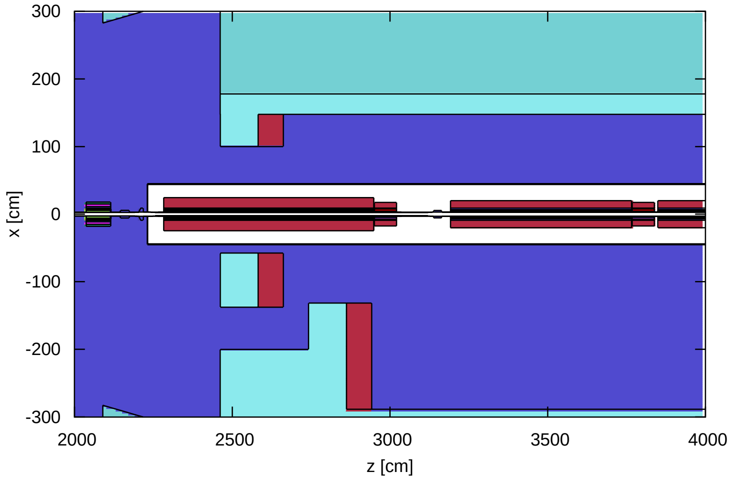

Figure 3: The first 40 m of the IR8-right model, showing the tunnel and the forward region shielding. The final triplet and the corrector MBXWS can also be seen.

2.3 Injection elements

IR8 of the LHC is the injection region for beam 2, and so there are several injection-related elements on the left and right side of the model. Beam 2 is injected in the right-side of the IR from the outside of the accelerator ring and from below and five Lambertson type septum magnets (MSI) deflect the beam in the horizontal plane by 12 mrad onto the horizontal orbit. The MSI also has an aperture for the circulating beam 1, and a new model of the elements was created. Together with the gaps between the magnets, the septum stretches over 21.8 m. After the MSI the beam continues off-center through the superconducting quadrupole Q5 and is kicked vertically by 0.85 mrad onto the orbit by the four kicker modules of the MKI, the injection kicker. The kicker is currently modelled in a simple way, and a more detailed MKI will be included in a future version of the geometry.

The IR8-right model also contains two injection-related collimators. The first is the TDI, which provides vertical injection protection and is retracted during circulating beam operation. Close to the TDI is located the TCDD, which is a fixed injection mask. This was modelled with a simple, cylinder based, new model.

The IR8-left model contains three injection-related collimators. The first is a two-beam collimator called the TCLIA, which is modelled with the new TCTVBt two-beam tertiary collimator described in this note. The other two are one-beam collimators TCLIB, based on the standard TCS collimator model, and the TCLIM, which is an injection mask and modelled in terms of collimating cylinders. The TCLIM engineering drawing used to derive the model is shown in figure 5.

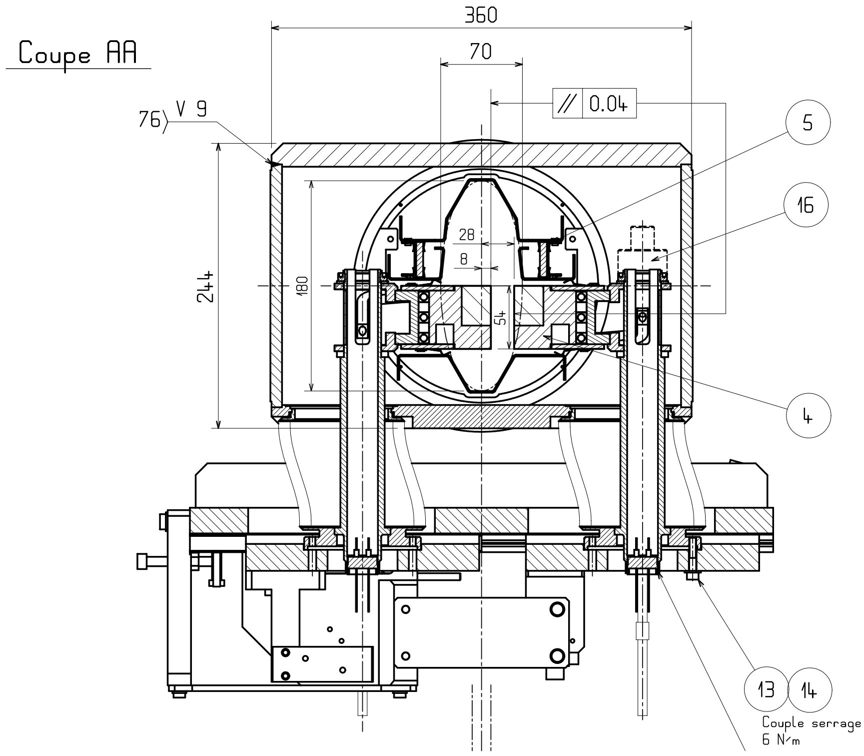

Figure 4: The TCTVB tertiary collimator.

2.4 Shielding

The tunnel shielding of LHCb is modelled in terms of blocks of Iron and Concrete in the tunnels. 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. On the left-hand side of the IP (RB84), 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. This shielding can be seen in figures 1 and 2, and is illustrated in figure 6.

On the right-side of the IP (RB86), there is 120 cm of Concrete and 80 cm of Iron of shielding grouped around Q1 as a tunnel plug beginning 24.622 m from the IP, and a further chicane piece composed of 120 cm of Concrete and 80 cm of Iron. This shielding can be seen in figure 3.

Note the RB84 shielding is consequently closer to the beam, while the RB86 shielding is located around the large diameter cryostat of Q1. Also included in the model is the shielding plug in UJ84. This mobile shielding consists of a 2 m concrete base, with 0.4 m of Iron and 0.8 m of concrete on top. This shielding is designed to protect the electronics in UA83 from radiation exposure.

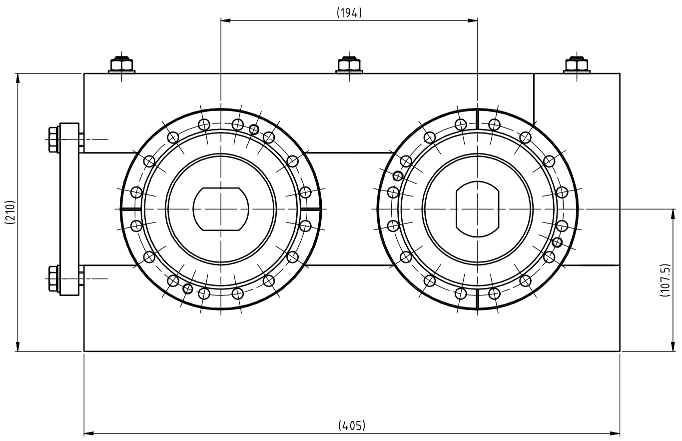

Figure 5: The TCLIM injection mask.

3 Example of the use of the model

In this section, an example of the model is shown for a calculation of the 20 MeV charged hadron fluence in the IR8-left region. The source used is proton-proton collision at the IP with $\sqrt{s}$ equal to 14 TeV. Figure 7 shows a map of the 20 MeV charged hadron fluence (integrated over y) in the tunnel region, with hot spots at the collimators, and also shows the fluence in the cable feedthroughs to UA64 and the maze in UJ84. The hadron fluence hot-spots are behind the shielding plug in UJ83, through the maze and at the exit of the cabling ducts. The map is calculated for 1.E7 proton-proton events per second (corresponding to nominal LHCb luminosity) and normalised to a year.

Figure 8 shows the neutron fluence down to thermal energies in the tunnel, and in the start and end regions of the first transverse cabling duct from the tunnel to the parallel UA83. The attenuation of the neutrons by the duct can be seen. The plot is normalised to a year of IP proton-proton collisions.

4 Summary

This note describes the FLUKA model of IR8, comprising the tunnel and machine elements in the LSSs left and right of the IP. The flexible model allows study of the machine induced background of LHCb and radiation environment studies in the LSSs around IR8. An example of the use of the model was shown, with a calculation of 20 MeV hadron fluence and neutron fluence in the left side of IR8. For further details and information on how to use this model, please contact the authors of this note.

References

[1] "The FLUKA code: Description and benchmarking" G. Battistoni, S. Muraro, P.R. Sala, F. Cerutti, A. Ferrari, S. Roesler, A. Fasso', J. Ranft, Proceedings of the Hadronic

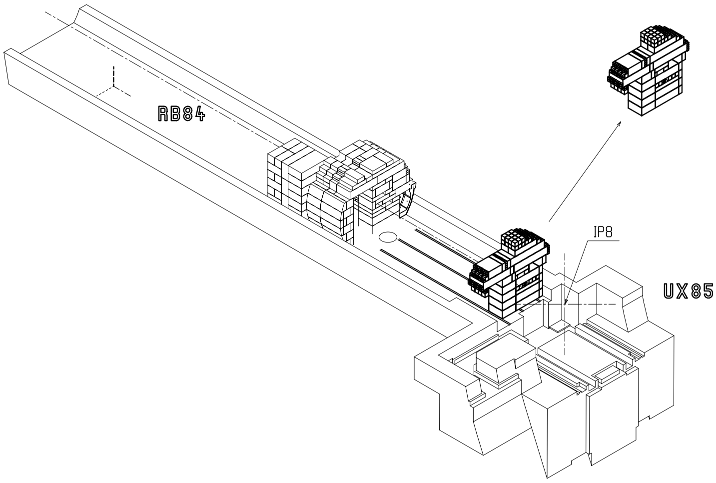

Figure 6: The TCTVB RB84 shielding.

Shower Simulation Workshop 2006, Fermilab 6–8 September 2006, M. Albrow, R. Raja eds., AIP Conference Proceeding 896, 31-49, (2007)

"FLUKA: a multi-particle transport code" A. Fasso', A. Ferrari, J. Ranft, and P.R. Sala, CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773

[2] http://layout.web.cern.ch/layout/

[3] http://www.cern.ch/lhcoptics

[4] http://est-div.web.cern.ch/est-div/CDD/

[5] C. Hoa, F. Cerutti, E. Wildne, LHC Project Report 1167

[6] M. Magistris, M. Santana Leitner, K. Tsoulou, M. Brugger, F. Cerutti, A. Ferrari and V. Vlachoudis, CERN-AB-Note-031-ATB

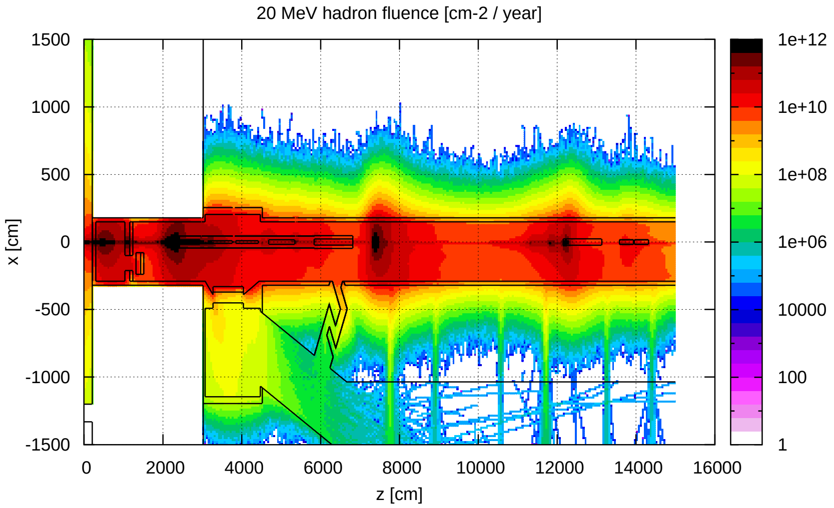

Figure 7: The 20 MeV charged hadron fluence in the left-hand side of IR8, calculated for 1.E7 proton-proton events per second (corresponding to nominal LHCb luminosity) and normalised to a year.

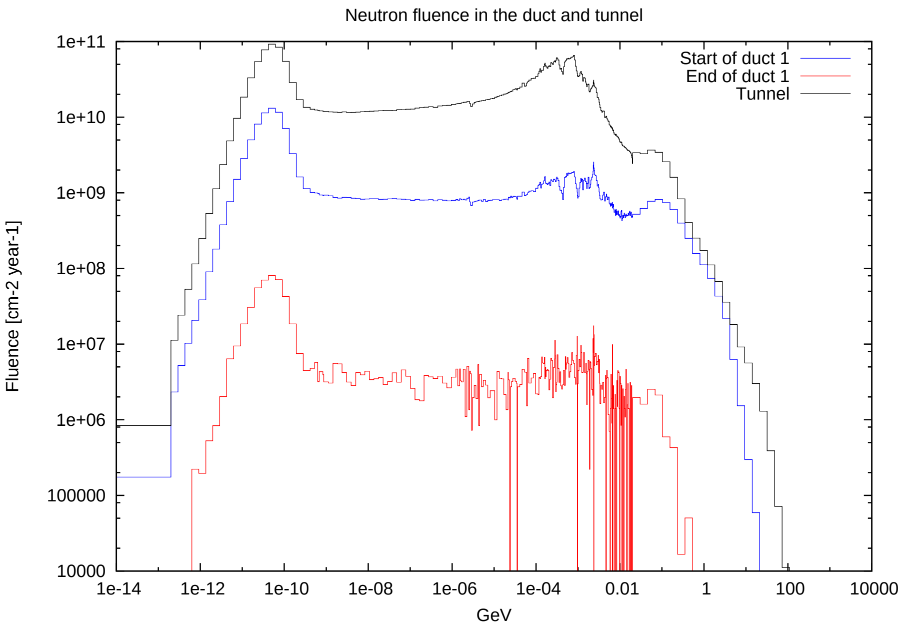

Figure 8: The neutron fluence (normalised to 1 year) in the tunnel region, and in the start and the end of the first transverse cabling duct from the tunnel to the parallel UA83. The attenuation of the neutron fluence due to the duct can be seen.