EDMS-1340718

Specification for Cryogenic BLMs

to be installed in LHC during LS1

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1. Introduction

This document describes the calculation of the signal levels expected in the two locations where the Cryogenic Beam Loss Moniotors (CryoBLM) are installed during LS1. The installation procedure and motivation for the chosen locations is described in LHC-LB-EC-0003 (EDMS 1324259). Here approximate calculations of the expected signals are presented.

2. Method of signal estimation

The estimation of the signal in Cryogenic BLM is based on a very general knowledge about the particle shower development due to beam loss. The base of the estimation are:

1. Signals in the closest ionization chamber registered in specific conditions (eg. loss maps).

2. The observation that in case of diamond detectors installed in IR7 the signals form Ionization Chamber (IC) and diamond are similar according to the document (Diamonds_IP7_20110527.xmct) summarized by the following points:

- dose seen by IC (dcum 20189 m) during UFO event with 72 bunches in the machine: $2.29 \cdot 10^{-6}$ Gy,
- therefore $3.2 \cdot 10^{-8}$ Gy/bunch,
- signal of 1 MIP in diamond: 3.78 fC, corresponding to 5.7 mV (ask Bernd),
- during the UFO event diamond registered 140 mV ie. 24.6 MIPs,
- each MIP leaves energy deposition of $4.93 \cdot 10^{-14}$ J, and diamond mass is: 0.18 grams, so the dose is 0.27 nGy,
- dose registered in diamond during the event: is: $6.7 \cdot 10^{-9}$ Gy/bunch,

- diamond sees $3.2 \cdot 10^{-8} / 6.7 \cdot 10^{-9} = 4.8$ times less dose than the IC,
- these measurements were done with pCVD, sCVD diamonds give twice as high signal as pCVD ones (source: Bernd, priv. Comm),
- this approximation is based on case of diamond detectors installed in the collimation region and does not have to be true for CryoBLM case,
- in the following it is assumed that Diamond detector gives 2 times less signal than IC.

3. In the very first approximation the lateral profile of the hadronic cascade can be expressed as a combination of an exponent and a gaussian (see for instance arXiv:hep-ex/9903052):

$$dE/dA = B_1 * \exp(-r/L_1)/r + B_2 * \exp(-r^2/L_2^2)/r$$

where:

r – is a distance from shower axis (in our case we'll assume center of the vacuum chamber as we are not sure where the losses may come from,

A – is the detector surface,

$B_1=1.69$,

$B_2=6.77$,

$L_1=14$ cm,

$L_2=4.24$ cm.

The obtained profile is shown in Figure 1.

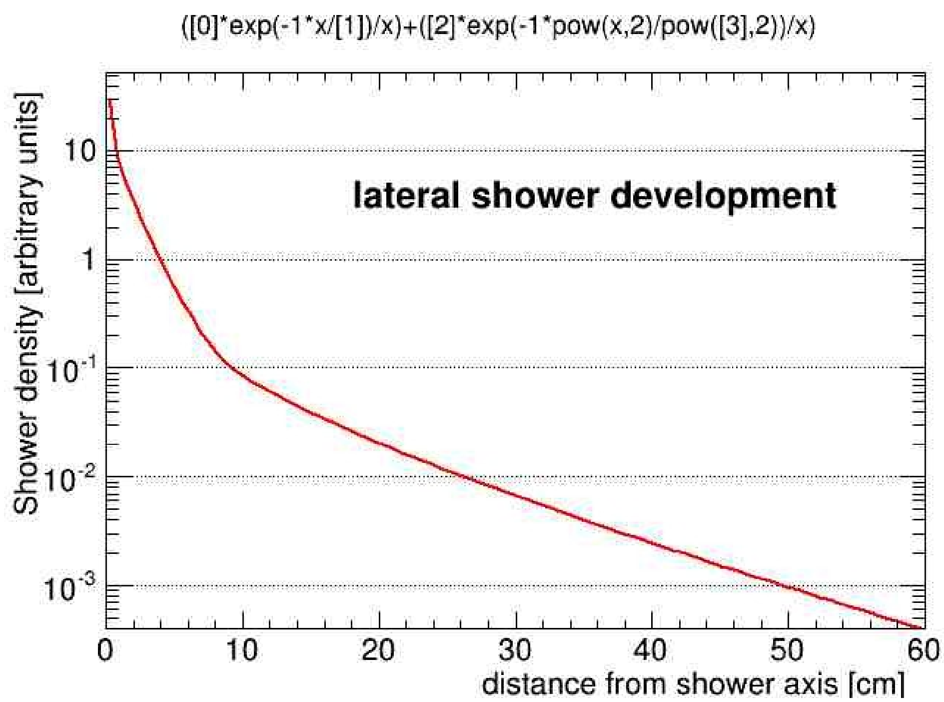

Figure 1: Lateral profile of hadronic shower.

3. Positions of detectors

The CryoBLMs are installed closer to the beams than ionization chambers. In Figure 2 transverse positions of Cryogenic BLMs are shown. To calculate the actual distances from the middle of the right beam vacuum chamber, where the losses are expected to come from, the geometer measurements (document EDMS 1334786) are used. The distances, referred to the center of the right beam are found to be:

- for the right detector horizontal distance from the beam is 78.4 mm and vertical 18.5 mm, so radial distance from beam axis is 80.6 mm,
- for the bottom detector horizontal distance is 94.5 mm and vertical 29.6 mm, so radial distance from the beam axis is: 99 mm,
- for the upper detector horizontal distance is 94.3 mm and vertical one 28.7 mm so radial distance is 98.6 mm,
- for the left detector the horizontal distance is 271.8 mm and vertical one 18.3 mm so radial distance is 272.4 mm.

The distance of the normal BLM installed on the right side of the magnet to the right beam pipe is 573.1 mm (only horizontal distance, vertical one is assumed zero).

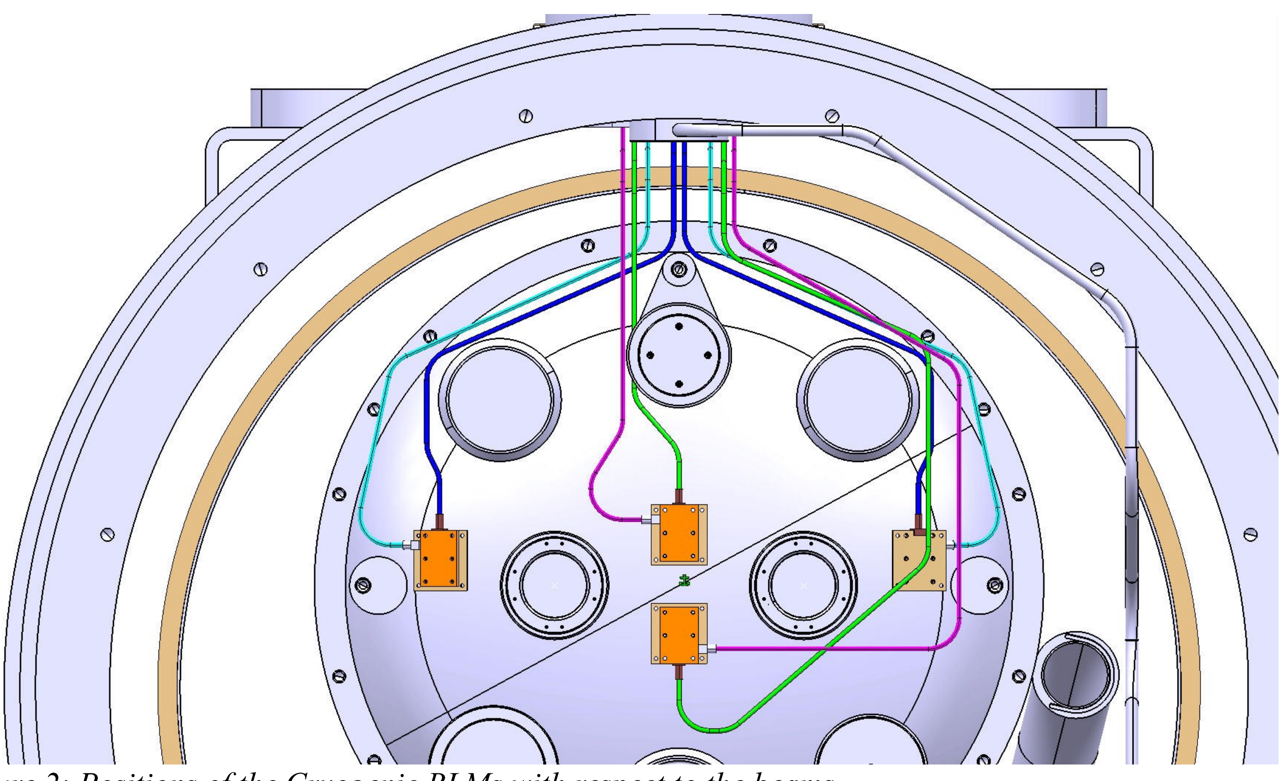

Figure 2: Positions of the Cryogenic BLMs with respect to the beams.

Using the above, very approximate approach (approximate because in the interconnect there is not much space where shower can develop) one can signal increase with respect to IC as in Table 1.

Detector	Radius [cm]	Relative signal
IC	57.31	1
right	8.06	286/2=143
bottom	9.9	177/2 = 89
left	27.24	18/2=9
upper	9.86	179/2=90

Table 1: Distances of various detectors from the center of the beam vacuum chamber and the signal expected there relative to the one in the ionization chamber outside.

It must be stated that these calculations are approximate and the particle shower simulation should be carried out in order to get precise results.

4. Location in cell 9R7

In cell 9R7 the losses expected during normal accelerator operation are relatively small. Revealed by study over month of November 2012 is the number of 365 mGy, which is not a lot, but this location receives relatively large signal when collimation loss maps are performed. For a typical collimation loss map (example used here 4 TeV horizontal loss map at 2012.09.25 hour: 12:04:24) the signal in the adjacent ionization chamber (first to the right cross in Figure 3, expert name is: BLMEI.09R7.B1E30_MBA) is 43 µGy/s.

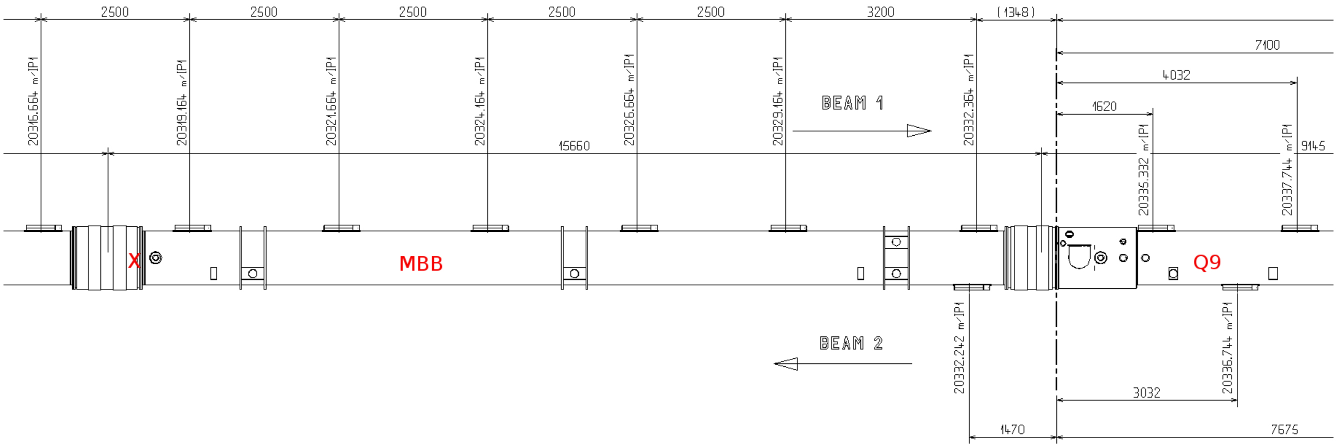

Figure 3: BLM layout in location of the CryoBLMs in cell 9R7.

In Table 2 the measured and expected signals for ICs and new detectors are shown. For new detectors assumed is 5x5x0.5 mm sCVD with conversion factor $3.4{\cdot}10^{-6}$ C/Gy (see EDMS-1340708, for IC the conversion factor is $5.4{\cdot}10^{-6}$ C/Gy is used, the conversion factor for 10x10x0.3 mm Silicon detector can reach $2{\cdot}10^{-5}$ C/Gy). For maximum current it is assumed that loss registered by the new detectors is compactified in 1 ns, instead of 25 ns, therefore current is multiplied by factor 25. Two assumed scenarios is a loss map and a quench test, which was performed in 2013 on the opposite side of IR, therefore mirror detector signal is used.

Obviously the calculated conversion factor for diamond ($3.4\ {\cdot}10^{-6}$ C/Gy) remains in disagreement with IR7 observations (suggesting value much higher, about $2.4\ {\cdot}10^{-5}$ C/Gy). This should be kept in mind as a needed margin when using the peak detector current.

detector	Loss map		Quench test	
	Average signal [Gy/s]	Peak detector current	Average signal [Gy/s]	Peak detector current
IC: BLMEI.09R7.B1E30_MBA BLMEI.09L7.B2I30_MBB	$43{\cdot}10^{-6}$	2 nA	0.0022	120 nA
right	$6.2{\cdot}10^{-3}$	530 nA	0.32	27 μA
bottom	$3.8{\cdot}10^{-3}$	325 nA	0.2	17 μA
left	$3.9{\cdot}10^{-4}$	33 nA	0.02	1.7 μA
upper	$3.9{\cdot}10^{-3}$	329 nA	0.2	17 μA

Table 2: Signals measured and expected during typical exercise of collimation loss map and during quench test.

4. Location in cell 9L5

CryoBLM installation in point 5 aims to observe signals from interaction debris in CMS. The signal level measured by the BLM on the MB (see Figure 4) integrated over the month of November 2012 (when luminocity production was stable and continous) is about 5.5 Gy and is the largest in this section. The luminosity signals are shown in Table 3.

detector	Average signal [Gy/s]	Peak detector current
IC (BLMQI.09L5.B2E10_MQM)	$1.2 \cdot 10^{-5}$	65 nA
right	$1.7 \cdot 10^{-3}$	146 nA
bottom	$1.1 \cdot 10^{-3}$	91 nA
left	$1.1 \cdot 10^{-4}$	9 nA
upper	$1.1 \cdot 10^{-3}$	92 nA

Table 3: Luminosity signals in location of installation in cell 9L5.

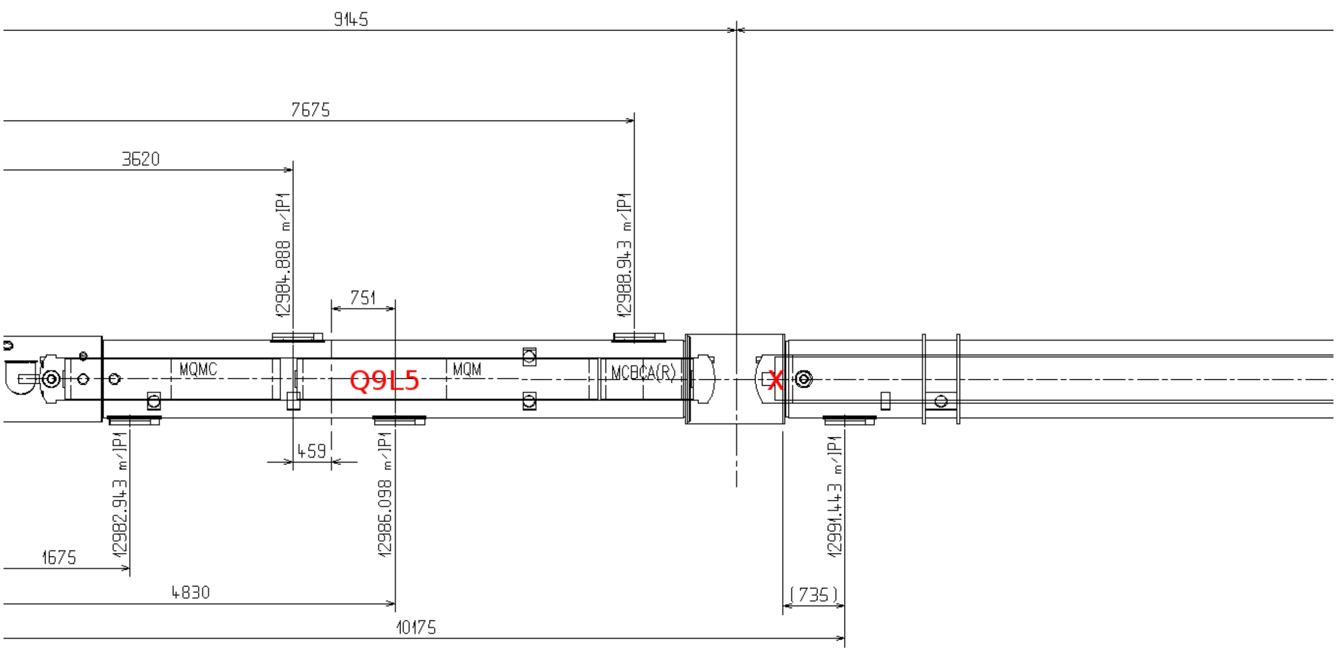

Figure 4: Layout of the existing BLMs and location of CryoBLMs in cell 9L5.

5. Conclusions

In this document it has been shown that the cryogenic detectors installed on the cold mass surfaces of the magnets will register peak currents between 9 nA (luminosity losses inn the least favourable location) and about 30 μA (losses during expected quench test). These calculations were done for a small diamond detector (and even there some uncertainty is present). In case of silicon detectors the currents are expected to be higher (200 μA).