ISBN: 978-3-95450-249-3 ISSN: 2673-5350 doi: 10.18429/JACoW-IBIC2024-THP24

DESIGN AND FIRST RESULTS OF A CRYOGENIC BEAM LOSS MONITOR INSTALLED AT THE LHC

E. Effinger*, S. Morales Vigo, B. Salvachua, J. Storey, C. Zamantzas, CERN, Geneva, Switzerland
E. Griesmayer[1], TU Wien
[1]also at CIVIDEC, Vienna, Austria

Abstract

The Large Hadron Collider (LHC) is equipped with NiTb superconducting magnets operating at the cryogenic temperature of 1.9 K. A tiny fraction of proton beam at 7 TeV impacting the beam screener has the potential to generate enough heat, to cause the loss of superconductivity in the magnet (a magnet quench). Consequently, it is imperative for machine performance to detect such beam losses before the quench event occurs. To enhance the sensitivity of magnet quench detection through the measurement of beam losses, ongoing efforts focus on the development of cryogenic beam loss monitors (CryoBLM). This contribution outlines the design improvements made to a semiconductor-based beam loss detector installed inside the magnet cryostat, positioned just outside the vacuum vessel of the superconductive LHC dispersion suppressor magnets.

Detector Locations

The location for the detectors has been chosen according to the expected losses and loss scenarios from the experience during Run 1 of the LHC. The initial installation was performed during the Long Shutdown 1 (LS1) and first measurements were done during run 2. Two different locations for the detectors were chosen. The first location is in the Insertion Point 5 (IP5) in half-cell 9L5, about 350 m from the colliding point, at the interconnect between a quadrupole MQM and a dipole MBB, which was chosen due to the measured high integrated dose in this area. This location allows to measure the luminosity losses from the physics debris of the CMS experiment.

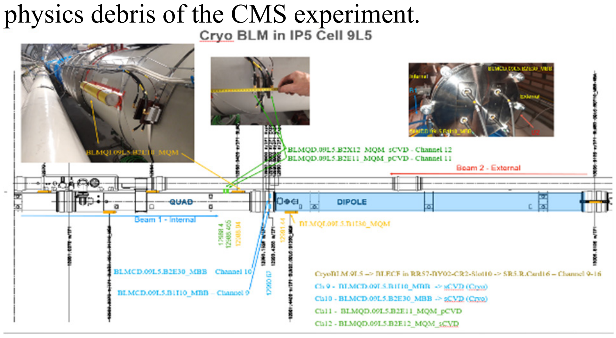

Figure 1: CryoBLM installation in IP5 half-cell 9L5.

The second location is in the Insertion Point (IP7), in half-cell 9R7, between the dipole MBA and dipole MBB interconnect. The main collimation system is located in IP7, thus, the detectors in IP7 will be able to measure the losses from the betatron halo cleaning. Additional information, concerning the detector installation during LS1 can be found in [1]. During the LHC Long Shutdown 2 (LS2), the complete design and installation of these detector types was reviewed and improved [2]. The location of the new CryoBLM remained the same. Figure 1 andFigure 2 show the installation pictures including a diagram showing the neighbouring elements. Outside the cryostat, two additional diamond detectors, one single-crystal Chemical Vapor Deposition (sCVD), one polycrystalline Chemical Vapor Deposition (pCVD) and one ionisation chamber were added to compare the signals with the CryoBLM which is based on a sCVD.

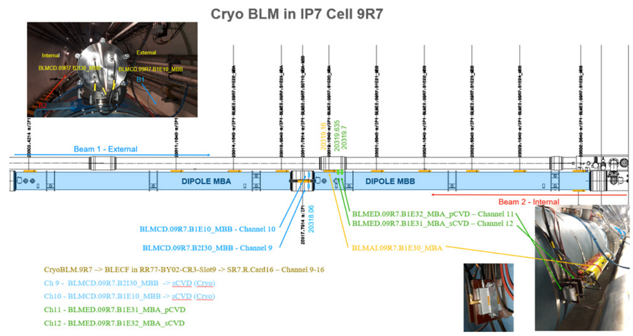

Figure 2: CryoBLM installation in IP7 half-cell 9R7.

Detector Positions

The CryoBLM detectors are located inside the cryostat and placed on the endcaps of the dipoles. In LS2, the mechanical holder was re-used from the LS1 installation, see Figure 3. The 4 rectangles in the central vertical and horizontal axis identify the possible location of the detectors.

Four holders have been welded on the endcap of the dipole, which allow fixing of the CryoBLMs on the cryostat close to the beam pipe.

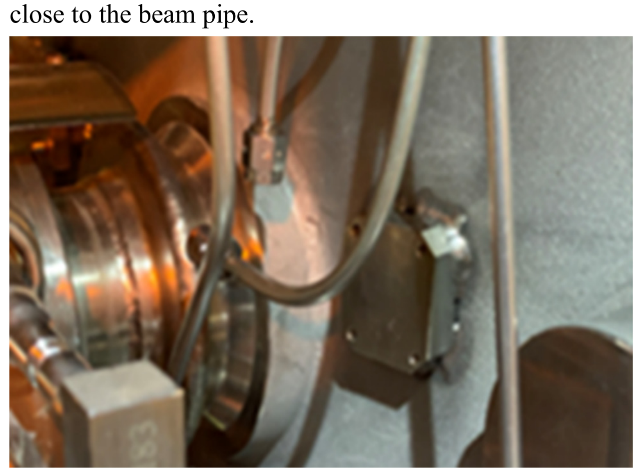

Figure 3: Picture of the welded detector holder on the dipole endcap.

* Ewald.Effinger@cern.ch

ISBN: 978-3-95450-249-3 ISSN: 2673-5350 doi: 10.18429/JACoW-IBIC2024-THP24

For the detector signal and bias voltage supply, a DN200 flange was welded onto the vacuum vessel. On the flange, an elbow with 90 degrees and a special DN200 flange with SMA feedthrough connector were installed. For the connection of the feedthrough and the CryoBLM, 16 special high-performance semi-rigid SiO2 cables (AA9790 from Times Microwave Systems) were used. The original setup included on each location, two diamond based and two silicon based detectors. In the LS2 setup, it was reduced to two diamond detectors per location. The two fixations on the horizontal axis, which can be clearly associated with losses for beam 1 and beam 2, were selected to install the new CryoBLMs, see Figure 4.

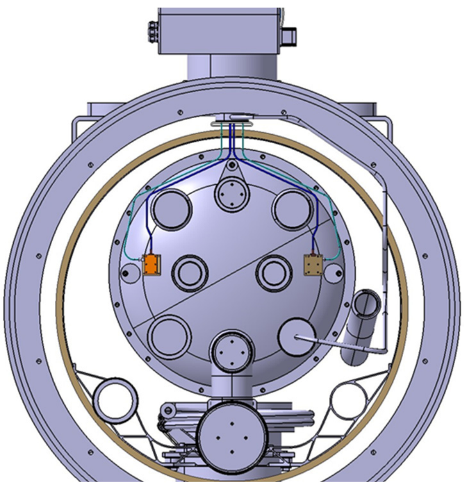

Figure 4: Layout of CryoBLMs mounted on the endcap of MB cold mass.

CryoBLM Fixation

The dimension and the fixation holes of the new Cry oBLM are different from the previous detectors. To be able to reuse the welded fixation an adapter plate was designed. The adapter plate allowed the possibility of a flexible mounting of the detector avoiding obstacles from the cabling. The orientation of the welded holder between the 9R7 and 9L5 is rotated 90 degrees and therefore also the detector. Figure 5 shows the orientation in 9L5.

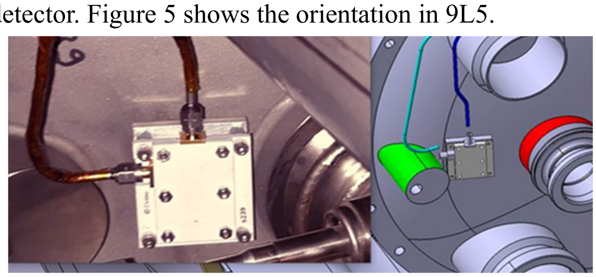

Figure 5: CryoBLM BLMCD.09L5.B2E30_MBB on the end cap of MBB 9L5.

Improvements and Changes

After the installation during LS1, several measurements were attempted, but it was not possible to extract a useful signal since the noise level was dominating the measurement. Different connecting schemes and additional filters were applied to improve the situation, but the signal-to-noise ratio did not improve. It was finally decided to redesign the installation after an internal review [3]. During LS2 the entire installation was completely redone with several parts revised. Among others, the printed circuit board (PCB) was redesigned, the holes for the fixation were isolated from the ground and a resistor on the signal connector can allow if necessary to open the ground between the bias voltage connector and the signal connector. All diamond detectors, including the CryoBLM, are produced by CIVIDEC Instrumentation GmbH [4].

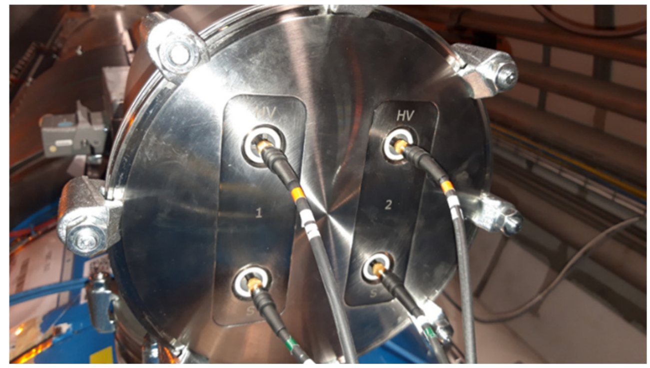

Figure 6: Installed DN200 Flange with CeramTec SMA 19604-01-W.

The DN200 flange was redesigned, and special floating SMA feedthroughs from CeramTec were used to isolate the detector ground from the machine ground, see Figure 6. To ensure the isolation of the ground from the thermal shield and surrounding parts, the high-performance semi-rigid SiO_2 cables were isolated using Kapton tape.

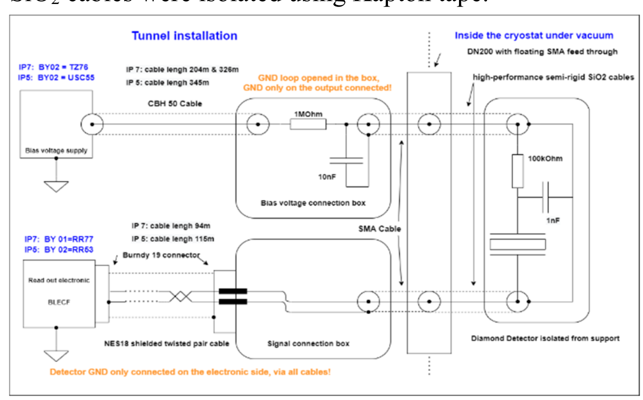

Figure 7: Connection diagram of the CryoBLM.

During the entire installation process and the closing phase of the interconnect, the isolation resistor between the machine ground and detector ground was regularly checked. All these measurements resulted in an isolation resistance above 100 GΩ. This is very important for the setup and allows to have a star grounding at the front-end electronic side. Figure 7 shows the diagram of the connections.

The functionality of the detector itself was verified in the classified radioactive workshop and before the closing of the interconnect with a radioactive ^{90}Sr source.

The signal and bias voltage connection boxes were replaced by a modified version. The new version includes an

ISBN: 978-3-95450-249-3
ISSN: 2673-5350
doi: 10.18429/JACoW-IBIC2024-THP24

additional filter but also a path without a filter, to be able to switch it easily to a different connection scheme.

All the external cabling outside the cryostat was redone and special care was taken not to create ground loops, which can interfere with measured signal.

The two existing bias voltage supplies were also replaced by a simpler version, to avoid problems due to the communication protocol. Additional filters were added in the bias voltage connection box.

First Measurements of the CryoBLM

Figure 8 shows the beam current and luminosity signals for several LHC fills. Figure 9 shows the CryoBLM signal in blue installed in location 9L5 and the additional signals from the diamond detectors and the standard ionisation chamber. The figure shows that the signals are highly correlated to the luminosity measurement as expected. It is observed that the signal from the detector BLMCD. 9L5. B1I10_MBB only shows noise. Since the detector was working in the workshop and after the installation, we assume that it got damaged during the cooldown of the superconductive magnets.

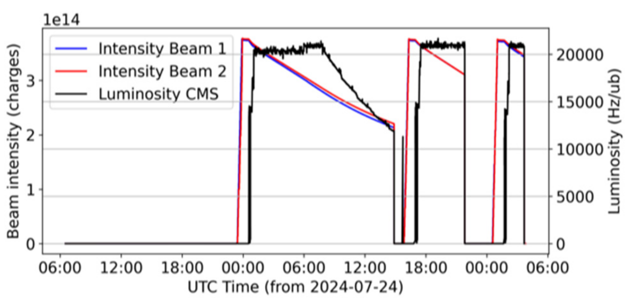

Figure 8: Beam current and luminosity.

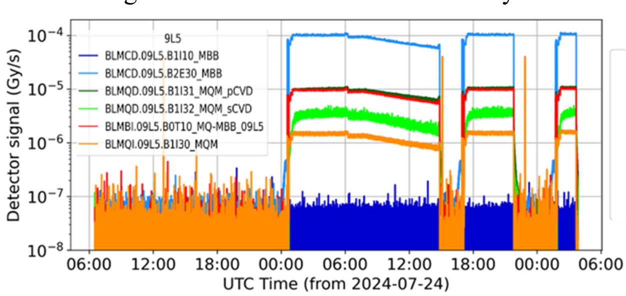

Figure 9: CryoBLM signal for 9L5.

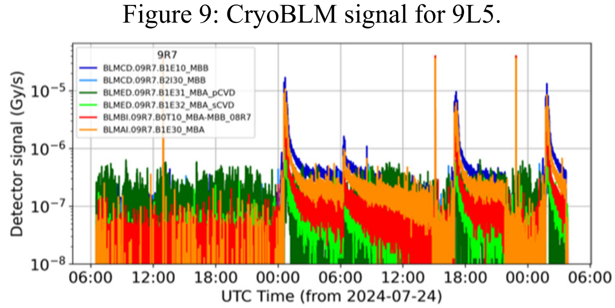

Figure 10: CryoBLM signal for 9R7.

Figure 10 shows the detector signals for the installation in 9R7. In this location, the signals are only correlated to the beam intensity losses, which are higher at the start of the energy ramp and before luminosity production starts.

The first measurements prove the functionality, the sensitivity and the proper location of the CryoBLMs. A repair of the BLMCD. 09L5. B1E10 will only be possible during a long shutdown and needs to be verified if it can be useful. The BLMCD. 09L5. B2E30, BLMCD.09R7.B1E10 and BLMCD.09R7.B2I30 will be further analysed and compared with the surrounding BLMs.

First Comparisons of the Different Detectors

Comparison of the measured losses during fill 9921 in half-cell 9L5 with the CryoBLM, the LHC Ionisation Chamber (IC), sCVD and pCVD detectors, which are located at the same position, is shown in Figure 11. The measured signal of the CryoBLM is a factor 3 higher than that of the ionization chamber, a factor of 7.3 to the pCVD and a factor of 40 to the sCVD. Due to the higher measured signal of the CryoBLM, there is more information and structure indicated. Similar behaviour is observed in 9R7.

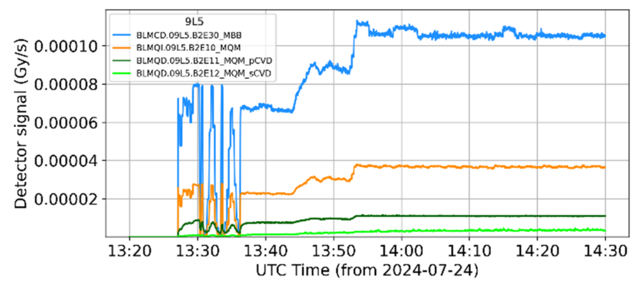

Figure 11: Comparison of CryoBLM, IC, sCVD and pCVD measurements during fill 9921 in half-cell 9L5.

Conclusion and Outlook

A more profound analysis of these detectors has been initiated to gain further insights into the CryoBLMs. This study encompasses various loss scenarios, as well as sensitivity and robustness of the detectors. The latest redesign has been successful, and the on-going measurements show already the vast potential of such detectors. With additional FLUKA simulations, along with comparative analyses of the surrounding detectors, we can confidently recalculate the calibration factors of the pCVD, sCVD and Cryo-BLMs.

REFERENCES

[1] M. Sapinski *et al.*, "Installation of cryogenic beam loss monitors on MBs in IR5 and IR7", *Engineering change request*, EDMS No. 1324259, Ref. LHC-LB-EC-0003, CERN, 2014 https://edms.cern.ch/document/1324259

[2] Engineering Change Request, "LHC BLM System Changes During LS2", EDMS#2643023, LHC-BLM-EC-0015 v.1.0.

[3] C. Zamantzas, "CryoBLM: LS2 Modification", CERN, Geneva, Switzerland, Rep. HL-LHC WP13 BI Meeting, Jun. 2018. https://indico.cern.ch/event/727027

[4] Product Certificate, PK/316: CIVIDEC Instrumentation GmbH, Vienna, Austria, Nov. 2018.