Design and first results of a cryogenic beam loss monitor installed at the LHC

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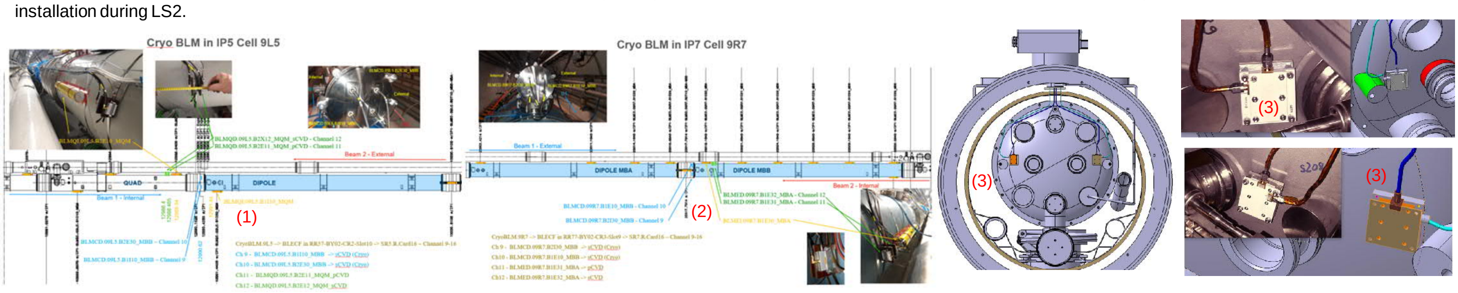
Abstract: The Large Hadron Collider (LHC) is equipped with NiTb superconducting magnets operating at the cryogenic temperature of 1.9 K. A tiny fraction of proton beam at 7 TeV impacting the magnet coils has the potential to generate enough heat, leading to the loss of superconductivity in the magnet (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. 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.

CryoBLM Installation Overview

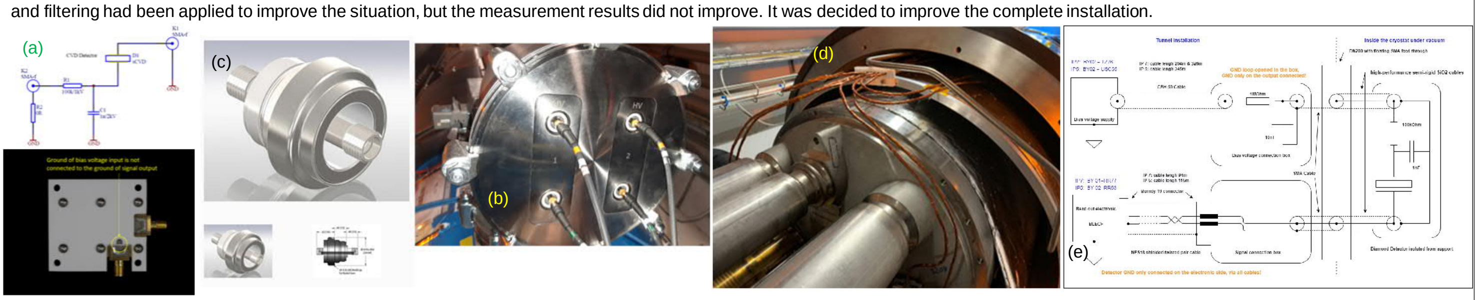
The location for the detectors has been chosen according to the expected losses and loss scenarios, from the experience during the run 1 of the LHC. The first installation was realized during the Long Shutdown 1 (LS1) and first measurements were foreseen during run 2. Two different locations were chosen for the detectors in the LHC, one in cell 9L5 (1) and the second in 9R7 (2). In IP5, the location of the detectors are at the interconnection between a quadrupole and a dipole in cell 9L5, to measure the luminosity losses from physics debris. In IP7 the detectors will measure the losses from the betatron halo cleaning and are located at the dipole-dipole interconnection in cell 9R7. The detector locations and the positions remained the same for the new installation during LS2.



The detectors are located inside the cryostat and placed on the endcaps of the dipoles (3). The original installation included 2 diamond based and 2 silicon based detectors, which was reduced to 2 diamond detectors per location. Four holders have been welded on the end cap of the dipole, which allows to fix the detector PCBs. The signal and bias voltage connection boxes were replaced by a modified version and all the cabling was redone precisely not to create GND loops. Outside the cryostat two additional diamond detectors, one single-crystal Chemical Vapor Deposition (sCVD) and one polycrystalline Chemical Vapor Deposition (pCVD) were added to compare the signals with the sCVD used as CryoBLM. All diamond detectors, including the CryoBLM, are produced by CIVIDEC Vienna.

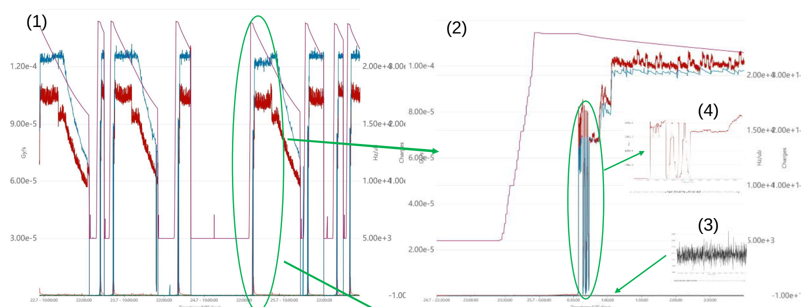
Improvements and changes on the CryoBLM detector and installation

After the installation during LS1 first measurements were conducted, but it was not possible to measure a proper signal since the noise level was too elevated. Different connecting schemes and filtering had been applied to improve the situation, but the measurement results did not improve. It was decided to improve the complete installation.

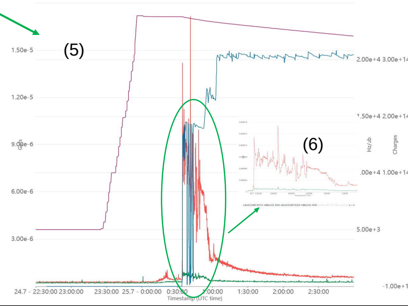


During LS2 the complete installation was revised. The detector PCB (a) of the CryoBLM was redesigned, the holes for the fixation are now isolated from GND and a resistor on signal connector allows to open the GND loop. The flange (b) was redesigned, and special floating SMA feed throughs (c) are used to isolate the detector and machine GND. To insure the GND isolation, the high-performance semi-rigid SiO2 cable (d) was isolated with Kapton tape. During the entire installation and the closing phase of the interconnect, the isolation resistor between the machine and detector was continually checked. All this measurements resulted in an isolation resistor above 100GOhms and allowed to have a single GND connection at the electronic side (e). The functionality of the detector itself was verified before the closing of the interconnect with a SR90 source. The bias voltage supply was replaced by a new type and additional filter added in the bias voltage connection box.

First measurements of the CryoBLM and comparisons of the different detectors



The 4 CryoBLM (BLMCD) signals of Fills 9923 to 9934 are displayed in diagram (1) together with the luminosity and the beam current from the BCT. Three detectors are working perfectly, but one detector shows only noise, it most probably got damaged while the cool down of the magnet. Diagram (2) shows the signals of the 2 detectors in cell 9L5. Diagram (3) shows the noise of the broken detector. Diagram (4) shows zoom of the losses while luminosity scan. In cell 9R7 the two CryoBLMs are showing the losses while the beam adjustment (5). Diagram (6) is a zoom of the same signal. The first measurements prove the functionality and the sensitivity of three new CryoBLMs.



Comparison of the measured losses during Fill 9921 in cell in 9L5 with the CryoBLM, the Ionisation chamber, sCVD and pCVD detectors are shown. The signal of the CryoBLM is a factor 3 higher than of the ionization chamber, factor 7.3 to the pCVD and factor 40 to the sCVD. Due to the higher signal, there is more information and structure indicated. A more profound analysis of these detectors is started to learn more of the CryoBLM, the calibration factors of the different detectors and the loss scenarios in the LHC.