The Compact Muon Solenoid Experiment
Conference Report

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24 June 2015 (v2, 27 July 2015)

Cherenkov Detector for Beam Quality Measurement

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Abstract

A new detector to measure the machine induced background at larger radii has been developed and installed in the CMS experiment at LHC. It consists of 40 modules, each comprising a quartz bar read out by a photomultiplier. Since Cherenkov radiation is emitted in a forward cone around the charged particle trajectory, these detectors can distinguish the directions of the machine induced background. The back-end consists of a microTCA readout with excellent time resolution. The performance of the detector modules measured in several test-beam campaigns will be reported. The installation in CMS will be described, and first results about operating the detector during data taking will be given.

Presented at *Elba2015 13th Pisa Meeting on Advanced Detectors*

Cherenkov Detector for Beam Quality Measurement

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Abstract

A new detector to measure the machine induced background at larger radii has been developed and installed in the CMS experiment at the LHC. It consists of forty modules, each comprising a quartz bar read out by a photomultiplier tube. Since Cherenkov radiation is emitted in a forward cone around the charged particle trajectory, these detectors can distinguish between the arrival directions of the machine induced background and the collision products. The back-end electronics consists of a uTCA readout with excellent time resolution. The installation in the CMS is described and first commissioning measurements with the LHC beams in Run II are presented.

Keywords: Beam Instrumentation, BHM, Cherenkov Detector, Beam Halo, CMS

1. Overview

The Beam Halo Monitor (BHM) [1] is a new detector to measure bunch-by-bunch beam background at larger radius in the CMS experiment at the LHC. The BHM will provide feedback to the LHC on the beam quality and beam conditions. Each BHM unit is comprised of a quartz bar read out by a photomultiplier tube. The BHM can distinguish the low rate of machine induced background (MIB) from the vast flux of collision products. The electronics is based on the Phase 1 upgrade of the CMS Hadronic Calorimeter [2], with firmware and readout adapted to the beam monitoring requirements [3].

2. Detector concept

Figure 1: A BHM detector unit. The arrows indicate the direction of the expected particles from machine induced background (forward) crossing the quartz bar and the collision products (backward).

A BHM detector unit is composed of a quartz bar coupled to a fast photomultiplier tube (Hamamatsu R2059) at one end and painted with black paint at the opposite end, see Figure 1. Beam background particles move in the forward direction and give rise to a large signal, while particles from the collision products move in the backward direction and the Cherenkov light produced is mostly absorbed. The directional sensitivity of the detector allows for forward (MIB) and backward-going

Figure 2: Pictures of the installation of the detector units in the CMS experimental cavern (left, middle) and the electronics rack in the CMS service cavern (right).

particles (collision products) to be distinguished by the amplitude of the signal. The placement of the BHM units was chosen so that the separation in time between beam-background and collision signals is at the maximum value, 12.5 ns, providing an additional selection criterion for beam-background particles.

3. Installation in CMS during LHC Long Shutdown 1

Twenty detectors were installed on each of the CMS detector ends (later referred as plus and minus end, referring to the sign of the z coordinate in the CMS cavern) and distributed azimuthally as shown in Figure 2. The units are orientated parallel to the beam pipe, around the CMS rotating shielding, at a radius of 180 cm from the beam pipe and 20.6 m from the interaction point. The detectors installed at the minus end are more sensitive to the beam 2 background and vice versa.

4. Electronics readout chain

The analog signal from each BHM channel is readout by the front-end digitizer cards, which integrate the charge over 25 ns, find the rising edge of the signal with 0.5 ns resolution and send the digitized values to the back-end histogramming units, which

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produce occupancy histograms by binning hits above threshold into four sub-bins for each bunch crossing based on the rising edge information. The histogram of each channel is readout by a back-end module via IPbus protocol every 2^{14} LHC orbits. The electronics during first steps of commissioning are synchronized to the CMS clock, which arrives from the TCDS of CMS to the back-end uTCA crate and gets distributed from there to the front-end crate.

5. First results during LHC beam splashes and collimators settings

Figure 3: A single scope trigger during beam 2 splashes from two detector units installed at the opposite ends of CMS.

The first BHM data were recorded during the LHC “beam splash” events in April 2015. During a splash event one bunch is directed onto the TCT collimators producing a shower of particles arriving in CMS. The flux of particles is much larger than the one expected under normal operating conditions. Figure 3 shows the signal from a beam 2 splash event from two detectors installed on opposite ends. The amplitudes are significantly different due to the directional nature of the detector. Figure 4 shows the distribution of the charge measured in a detector unit installed at the minus end. The increased fraction of entries with a larger charge (green) corresponds to the beam-background from Beam 2, whereas the response to the Beam 1 splashes (red) is similar to the one with no beam (black). These measurements demonstrate for first time with LHC beams full

Figure 4: Distribution of the charge measured in a detector installed at the minus end of CMS during splashes.

Figure 5: The BHM response to collimators movement.

functionality of all electronics components, including the prototype front-end cards and the high-speed 5 Gbps asynchronous link to the histogramming units used.

The sensitivity of BHM to the movement of the collimators is demonstrated in Figure 5, which depicts the BHM rates as a function of the collimator position. The red (black) dashed lines show the collimator aperture for beam 1 (2). The solid lines show the average background rate in the BHM detectors. The increase in BHM rate occurs for each end, when the collimator gap of the respective beam is reduced, while the rate of the BHM at the opposite end remains at the same levels as before.

6. Software

The BHM readout software is part of BRIL-DAQ, a xDAQ architecture for independent readout of the central CMS data taking. A xDAQ application collects histograms from the back-end electronics via IP bus and publishes them to a bus every 2^{14} LHC orbits. A second xDAQ application collects and aggregates the histograms from the bus and calculates the bunch-by-bunch background per beam. It publishes the background information to the LHC and CMS every 23 s, corresponding to 2^{18} LHC orbits.

7. Summary

A novel Beam Halo Monitor has been developed and installed during LS1 and is currently being commissioned. Data taken with first beams demonstrate the expected functionality of both detector units and electronics. The system will soon be fully operational, ready to provide prompt feedback to the LHC machine on the beam conditions.

References

- [1] S. Orfanelli, et al., Design of a novel Cherenkov detector system for Machine Induced Background monitoring in the CMS cavern, IBIC2013, (Oxford, UK, 2013) 33–36.
- [2] J. Mans, et al., CMS Technical Design Report for the Phase 1 Upgrade of the Hadron Calorimeter. Technical Report CERN-LHCC-2012-015, CMS-TDR-10 CERN (Geneva, Switzerland, 2012).
- [3] N. Tosi, et al., Electronics and Calibration system for the CMS Beam Halo Monitor, PoS TIPP 2014 (2015) 411.