FIRST RESULTS FROM THE LHC LUMINOSITY MONITORS*

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Abstract

The LHC Luminosity Monitor (BRAN) is ready for operation during the planned 2009-2011 run. The device is a gas ionization chamber designed to resolve bunch-by-bunch luminosity in the high luminosity regions IP1 and IP5 whilst surviving extreme radiation levels. Two devices are installed in the TAN absorbers located ±140m downstream the IPs and monitor the energy associated to the showers produced by high energy neutrons originating from the *pp* collisions. Designed to provide real time information on the relative luminosity the instruments are used as a collider operations tool for optimizing the luminosity at ATLAS and CMS. A photo-multiplier-based PMT system is also used at low luminosities. We present early test results, noise and background studies and correlation between the BRAN and the PMT monitors. Comparison with ongoing modelling efforts is included.

INTRODUCTION

The *pp* interactions in the LHC high luminosity regions generate high energy particle showers with an intensity proportional to the luminosity. Argon ionization chambers capable to detect the particle showers while withstanding high radiation levels are installed in the Neutral absorbers (TAN) at both sides of IP1 and IP5 [1,2].

The devices are intended to provide relative bunch-by-bunch luminosity information and are supposed to be calibrated against absolute information from the ATLAS and CMS detectors.

The main requirements for the devices, optimized for a collisions energy of 7 TeV per beam, are to operate in a 10^{28} –10^{34} cm^{-2} s^{-1} luminosity range and resolve the 40 MHz bunch separation. This involves the capability of measuring a signal from 1 to 100 *pp* interactions per bunch crossing at 40 MHz with a signal-to-noise ratio large enough to cope with the 1 *pp* interaction signal.

One of the challenging goals for this system is that the peak flux of particles at the TAN shower maximum for the 10^{34} cm^{-2} s^{-1} LHC design Luminosity is in the range of 5×10^{9} to 10^{12} cm^{-2} s^{-1} for neutrons and photons respectively and a radiation hard detector is needed.

SYSTEM DESCRIPTION

We developed a gas ionization chamber, using Argon mixed with 6% of nitrogen, allowing for bunch-by-bunch monitoring in an extremely high radiation environment (180 Gr/yr) at the nominal LHC operation [3,4].

The detector consists of six parallel layers each divided into four quadrants for possible collision rate monitoring during LHC operation with non-zero collision angles. Image charges of the electrons produced in the ionization process are collected and integrated by a fast front-end amplifier, followed by a shaper and a digitizing system. This signal processing chain has been designed to support the nominal 40 MHz bunch rate.

In light of these expected operating condition during this run, we set the gas pressure fixed at 6.5 atm, while the bias voltage can be controlled remotely. Due to the differences in absorbers, the experimental conditions at ATLAS and CMS will differ due to the relative position in the TAN and the amount and king of absorber materials. In the case of ATLAS, this detector depends upon the LHCf experiment to be in its inserted position in order to have the necessary material to create the hadronic shower.

The photomultiplier tube (PMT) system, provided by CERN to monitor collisions at very low luminosities, is used as a reference for cross calibration and sometimes as an external trigger.

LHC OPERATIONS

The LHC beam commissioning resumed in November 2009. To this date, the top energy has been limited to 3.5 TeV, beta-function at the interaction point to 2 m, bunch intensity to 2 x 10^{10} protons per bunch with a maximum of 6 bunches, giving luminosities of the order of 10^{29} and the collision rate on the order of 1 kHz. In 2010 and 2011, the maximum luminosity and collision rate per bunch crossing are estimated to 10^{32} and 10 kHz respectively [5].

BACKGROUND NOISE

In preparation for operations with beam, we established the noise baseline of the detector.

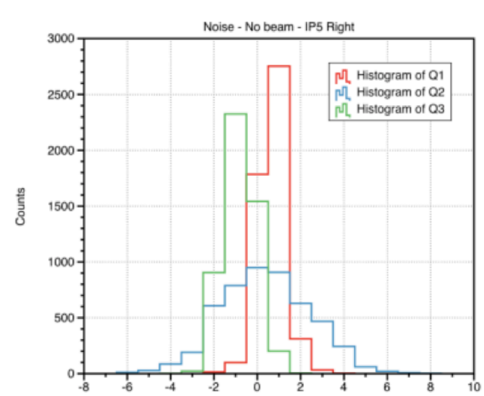

Figure 1: Histogram of background noise with no beam and no high voltage.

*This work partially supported by the US Department of Energy through the US LHC Accelerator Research Program (LARP).
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Figure 1 shows the noise histograms for three of the four quadrants of the detector on the right side of IP5, when the system bias was off and Figure 2 shows one of the quadrants biased at 1.2 kV with noise increased to σ≈4 ns. The other channels behave similarly. The noise does increase with beam and bias on the detector. Nevertheless, in both cases we see that the noise levels are quite reasonable and should allow us to operate the devices. It must be noted that unlike the other systems, the installation at the left side of point 5 presents a ~100 kHz pulsed noise.

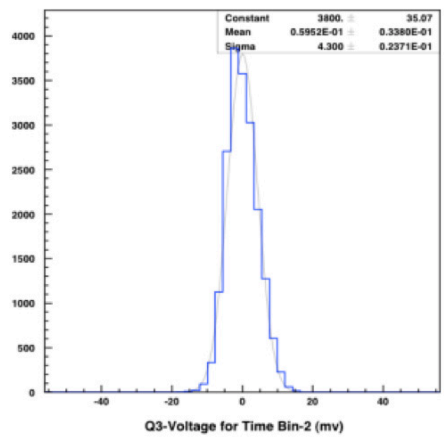

Figure 2: Histogram of background noise with no beam and 1.2 kV bias.

SIGNAL ANALYSIS

With the first collisions we started recording analog data. For the purposes of this analysis we used the nearby photomultiplier system as the trigger to this system.

Pulse Height Histograms

Figure 3 shows the 2D histogram of the maximum pulse height of the detector when triggered by the local PMT.

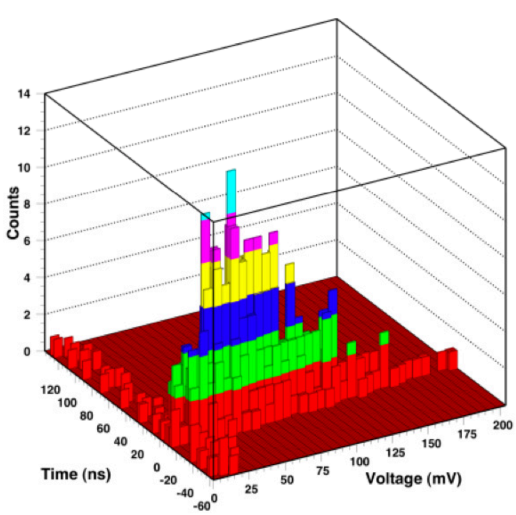

Figure 3: Histogram of maximum voltage for an event.

Pulse Vs. Bias Voltage and Detector Peaking Time

Given the fixed gas pressure, we scan the bias voltage to verify our expected speed optimizing bias. Figure 4 shows the response of Channel 3 of the detector to the right of CMS when we changed the bias from 200 to 1400 V in 200 V increments. As expected the system is faster as the bias increases.

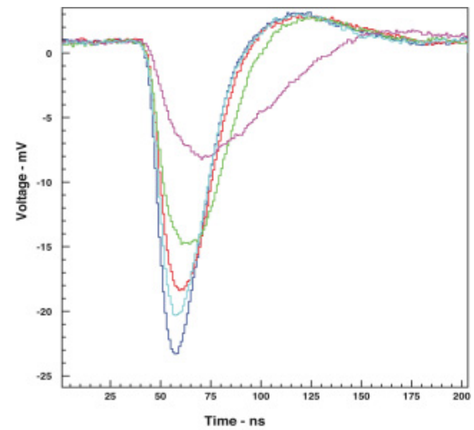

Figure 4: Average Ch. 3 waveform with biased from 200 V (magenta) to 1400 V (blue).

With the voltage scan it is possible to verify the peaking time of the chamber, which is an important parameter to reach ultimate performance at 25 ns bunch spacing.

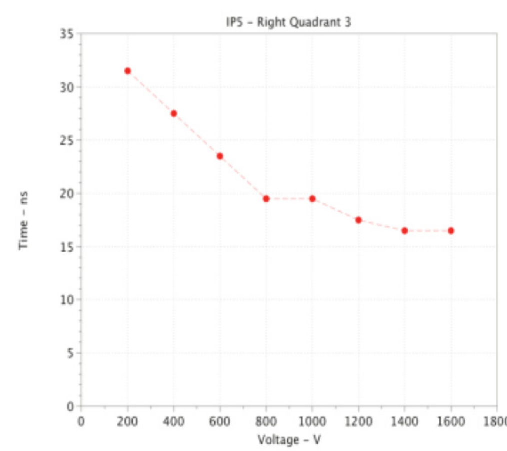

Figure 5: Detector peaking time as a function of bias voltage.

Figure 5 shows the peaking time diminishing with increased bias with its optimal value between 1200 and 1400 V, consistent with the 200V/atm bias expected to optimize detector speed.

Pulse Analysis

Taking the average of 1000 shots at the observed pulses it is possible to fit a Gaussian to the measured curve. Figure 6 shows a pulse width of about 30 ns, which will result in minimal pileup only at 40 MHz. This can be corrected with a simple deconvolution of two adjacent pulses.

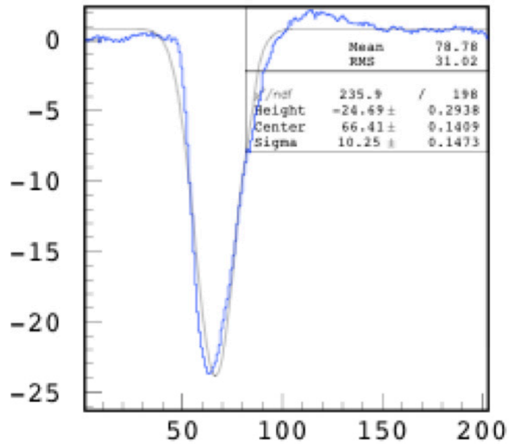

Figure 6: Pulse shape analysis at optimal bias voltage.

COMPARISON WITH MODELING

We can now also compare these results with the simulations of the system performance. Figure 7 shows the comparison between the sum of all quadrants in simulation and the measurements with an arbitrary constant. In spite of the limited pulse counts in the measurements, there is a pretty good agreement between the two curves [6].

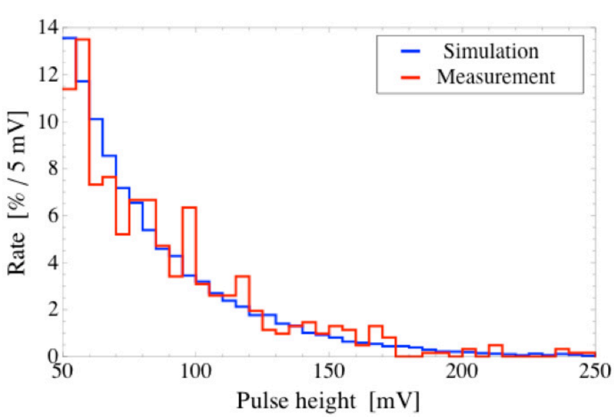

Figure 7: Comparison between modelling and data for single pp collisions at 3.5 GeV.

COUNTING RATES

The detector readout system has also been tested in counting mode. We acquired data during a luminosity scan and compared our rates with those observed by CMS and by the PMT system. Figure 8 shows a very good agreement between this monitor and the other two devices. A slightly better agreement with the PMT is explained by the proximity of the two monitors.

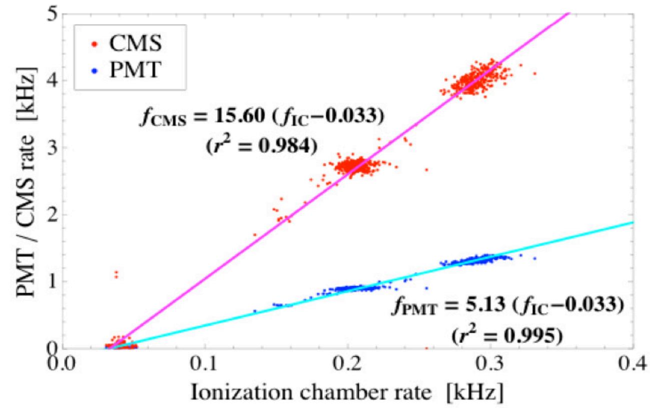

Figure 8: Counting rates correlations with CMS and the PMT system.

CONCLUSIONS

The gas ionization chamber has successfully started running during the first weeks of LHC operations and delivering collision signals from both IPs. Experimental data show a very good agreement with modelling and calculations. Count rates also compare very well with those from both the CMS experiment and the photomultiplier system. We will continue developing the system as the LHC performance will increase towards nominal intensities and energy.

ACKNOWLEDGMENTS

The authors are grateful for the continuous support of A. Drees (BNL), M. Placidi (LBNL) and the BE-BI/PM group at CERN. In addition, we would like to acknowledge the help of the LHCf collaboration that provided very accurate input files for our modelling efforts. Last, the US LARP program that supported this effort.

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