DESIGN AND OPERATION OF THE HIGH INTENSITY LUMINOSITY MONITORS OF THE LHC*

H.S. Matis,# S. Hedges, M. Placidi, A. Ratti, W. C. Turner, LBNL, Berkeley, CA, U.S.A.
R. Miyamoto, ESS, Lund, Sweden, E. Bravin, CERN, Geneva, Switzerland

Abstract

We have built a high-pressure ionization chamber (BRAN) for the IR1 (ATLAS) and IR5 (CMS) regions of the LHC. This chamber is designed to measure the relative bunch-by-bunch luminosity of the LHC from beam commissioning all the way up to the expected full luminosity of 10^{34} cm^{-2}s^{-1} at 7.0 TeV.

INTRODUCTION

The BRAN, which is used as a high intensity gas ionization detector has been described in several recent papers [1-4]. It is located in the TANs, which are absorbers made up of steel and copper and are located on either side of the IR1 and IR5 interacting regions. It measures the neutrons and photons from the collisions in the forward direction. The detector (currently running at 7 bar) has four quadrants, which are distributed around the center of each IR.

MODELING

Method

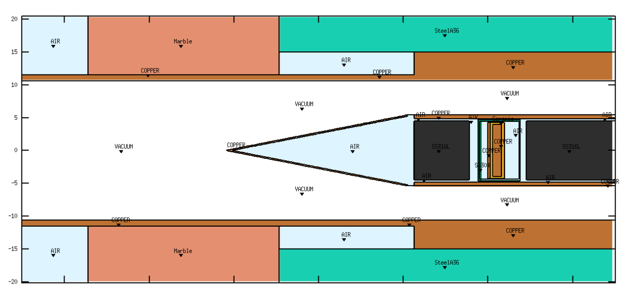

Figure 1: Top view of the BRAN in the CMS TAN. The color white indicates the regions of vacuum.

We have used the modeling program called FLUKA [5-6] to simulate collisions in the LHC. The model simulates half of the IP. The full detail of the beam line is included up to the TAN in which the detector rests. The geometry of the TAN is shown in Figure 1. The TAN is an absorber, which shields the first LHC dipole from the forward neutral particles produced at the intersecting region (IR). The TAN is about 140 m from the IR. The model includes the materials in the TAN at the beginning of the 2012 run.

Using the DPMJET [7] option of FLUKA, we have simulated the following reactions pp, pPb and PbPb over the expected operating range of the LHC. We can see how the shower forms by looking at Figure 2.

*Work supported by the US-LARP program.
#hsmatis@lbl.gov

This figure shows how the shower develops for pp (which is dominated by gamma ray showers) and PbPb (which is dominated by neutron showers).

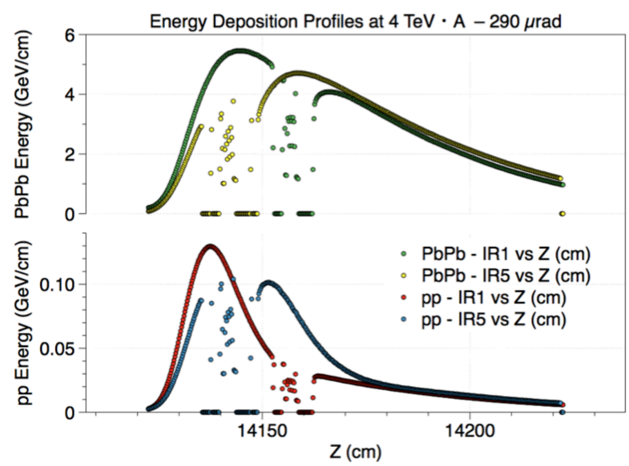

Figure 2: Energy deposited in the TAN for pp and PbPb collisions. The region in the center for each detector is where the BRAN is located. The different material in from of the BRAN produces the difference between the shower deposition between the IR regions.

The simulations show how the energy is deposited in the detector as a function of energy and crossing angle of the beams. For instance, Figure 3 shows the predicted behavior at the nominal full crossing angle of 290 μrad, which is used for the 2012 LHC run. Figure 4 shows the sensitivity to crossing angle for both pp and PbPb collisions. The crossing angle ratio, χ_r is the difference in energy between the top and bottom quadrants divided by the total energy. Note, the simulation predicts that the quantity χ_r is higher in PbPb collisions.

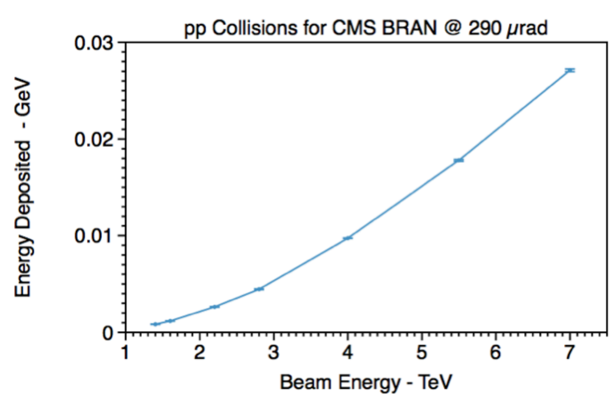

Figure 3: Energy deposited in the IR5 BRAN as a function of the energy of one of the beams in pp collisions.

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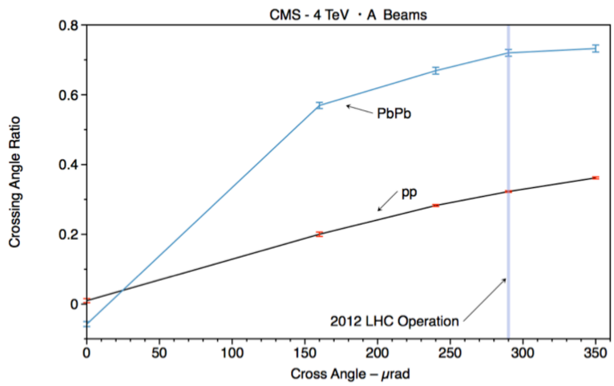

Figure 4: χ_r for pp and PbPb collisions.

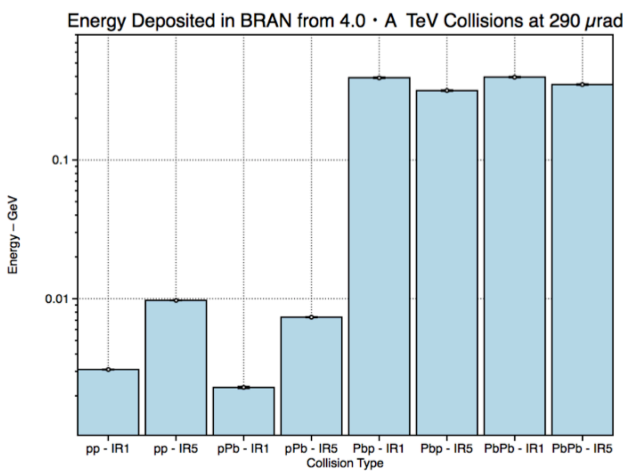

Figure 5: Comparison between the amount of energy deposited in the detector between pp, pPb, and Pbp and PbPb collisions. The first particle indicates the particle headed toward the BRAN.

Figure 5 shows the relative amount of energy in the BRAN for different combinations of colliding particles. When the LHC collides p on Pb, the signal strength from the BRAN will be more than a factor of ten higher on the side that the Pb beam approaches.

OPERATION OF THE DETECTOR

The BRAN is used in two different ways. On the left side of the IR (viewed from inside of the LHC ring), a hit for each bunch crossing is declared every time the voltage exceeds a threshold. This method, called "Counting Mode" works well at low luminosity, but saturates as the intensity increases. The second method is called "Pulse Height Mode" where the average pulse height from each collision is recorded. "Pulse Height Mode" is linear but is tends to be dominated by system noise at low luminosity.

Van der Meer Results

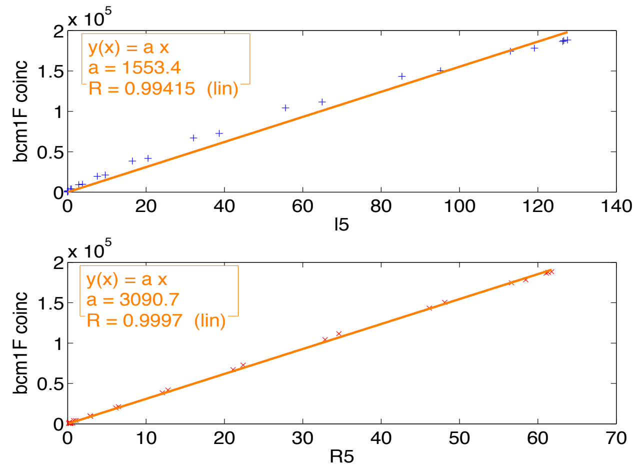

Figure 6: Comparison between the performance of the BRAN detector and the CMS Beam1F coincident detector.

On April 16, 2012, CERN took a Van der Meer Scan of the LHC Beams when it was operating at 4 TeV and a full crossing angle of 290 μrad. A comparison of the BRAN detector with the corresponding CMS detector is shown in Figure 6. The left detector, which operates in "Counting Mode", saturates as expected, while the right detector is very linear with the CMS detector.

The results, which are depicted in Figure 7, show that with a Gaussian fit, the right BRAN detector has a width of 31.94 ± 0.14 μm compared to 32.06 ± 0.06 μm from the CMS HF detector and 32.95 ± 0.07 μm from the CMS BeamqF detector. The error in the BRAN is slightly higher and can be improved by integrating longer. The results from the left detector show a smaller beam width. However, since it is saturating, it should not be used. This analysis is very simple and should not be construed to measure the size of the LHC beam. We use these measurements to show that the BRAN's accuracy is comparable to the CMS detectors.

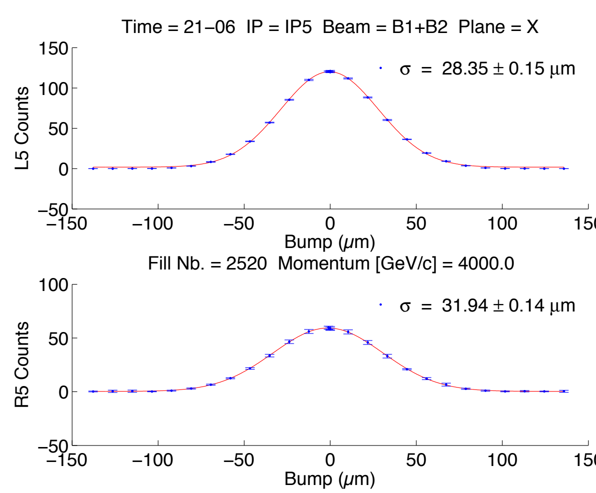

Figure 7: Fit of the Van der Meer scan for the IR1 and IR5 detectors in pulse height mode.

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Crossing Angle Comparison

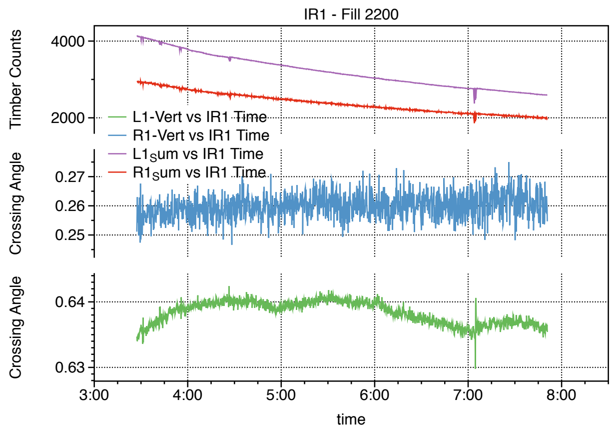

Figure 8: Measurement of the "Crossing Angle" for Fill 2200. R1 varies more because it is in "pulse height mode".

Figure 8 shows χ_r for the 2011 LHC run when the nominal LHC crossing angle was 240 µrad. The time plot shows fluctuations and one instance when the ratio changes at the same time as the luminosity. Examination of the LHC BPMs show that there were changes at the same time.

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REFERENCES

[1] H.S. Matis, et al., "Results from the LHC BRAN Luminosity Monitor at Increased Luminosities", IPAC'11, TUPC168 (2011).

[2] R. Miyamoto, et al., "Operational Results from the LHC Luminosity Monitors", PAC'11, WECN3 (2011).

[3] H.S. Matis, et al., "Simulations of the LHC High Intensity Luminosity Detectors at Beam Energies from 3.5 TeV to 7.0 TeV", PAC'11, MOP202 (2011).

[4] H.S. Matis, et al., "The BRAN Luminosity Monitor: Modeling and Experimental Results at CMS and ATLAS", Contribution to LUMI Days 2012, CERN (2012).

[5] G. Battistoni et al., "The FLUKA code: Description and benchmarking", Proceedings of the Hadronic Shower Simulation Workshop 2006, Fermilab 6–8 Sept. 2006, M. Albrow, R. Raja eds., AIP Conference Proceeding 896, 31-49, (2007).

[6] A. Fasso et al., "FLUKA: a multi-particle transport code", CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773.

[7] S. Roesle et al., "The Monte Carlo Event Generator DPMJET-III" in Proceedings of the Monte Carlo 2000 Conference, Lisbon, October 23-262000, Springer-Verlag Berlin, 1033-1038 (2001).

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