The CMS RPC project, results from 2009 cosmics data taking

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Abstract

The Resistive Plate Chambers are used in the CMS experiment as a dedicated muon trigger both in barrel and endcap system. About 4000 square meter of double gap RPCs have been produced and have been installed in the experiment since 2007. The full barrel system and a fraction of the endcaps have been extensively commissioned with millions of cosmic rays collected by the full CMS experiment. Making use of the redundant muon system composed by Drift Tube in the barrel and CSC in the endcaps that provide independent tracking and trigger informations, the performances of the RPCs have been studied in terms of efficiency, cluster size multiplicity, spatial resolution and trigger response. Moreover during the long period of detector operations the stability of the system has been monitored to study the dark currents and noise behavior as a function of time. First results obtained using the cosmic rays data taken in the 2008 and 2009 will be reported here.

Presented at RPC 2010: X workshop on Resistive Plate Chamber and related detectors
The CMS RPC project, results from 2009 cosmic-ray data
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Abstract

The Resistive Plate Chambers (RPCs) are used in the CMS experiment as dedicated muon triggers both in the barrel and the endcaps system. About 3000 square meters of double-gap RPCs were produced and have been installed in the experiment since 2007. The full barrel system and part of the endcaps have been extensively commissioned with millions of cosmic rays collected by CMS. Making use of the redundant muon system composed by drift tubes in the barrel and CSCs in the endcaps which provide independent tracking and trigger information, the performance of the RPCs has been studied in terms of efficiency, cluster size multiplicity, spatial resolution and trigger response. Moreover during this long period of detector operations the stability of the system has been monitored to study the dark current and noise behavior as a function of time. First results obtained using the cosmic ray data taken during 2009 will be reported.

Key words: CERN, CMS, RPC, DT, CSC, Efficiency, Cluster Size

1. The CMS Experiment

The Large Hadron Collider (LHC), the biggest and most powerful particle accelerator ever built is a double ring accelerator that collides beams of protons at a center-of-mass energy of 7 TeV. The LHC is projected to reach a peak luminosity of \(10^{34}\) cm\(^{-2}\) sec\(^{-1}\), will operate with a bunch crossing rate of 40 MHz (25 ns). At this luminosity about 20 interactions per crossing are expected producing 2000 charged particles on average. Severe radiation conditions are expected, corresponding to a flux of \(10^{18}\) hadrons per year from interaction point.

Located in one of the interaction points is the CMS experiment, where three types of gaseous detectors are used to identify and measure muons. The choice of the detector technologies has been driven by the very large surface to be covered and by the different radiation environments. In the barrel region (|\(\eta\)| < 1.2), where the neutron induced background is small, the muon rate is low, and the residual magnetic field is low drift tubes (DT) chambers are used. In the 2 endcaps, where the muon rate as well as the neutron induced background rate is high, and the magnetic field is also high, cathode strip chambers (CSC) are deployed and cover the region up to |\(\eta\)| < 2.4\([1]\). In addition to this, resistive plate chambers (RPC) are used in both the barrel and the end-cap regions. These RPCs are operated in avalanche mode to ensure good time resolution at high rates (up to \(10kHz/cm^2\) ) RPCs also provide a fast response therefore they can identify unambiguously the correct bunch crossing.

2. The CMS RPC system

![Sketch of an RPC chamber in CMS](image)

Each RPC detector consists of a double-gap Bakelite chamber, operating in avalanche mode\([1]\). The gaps have a 2 mm width; see figure 1. Trigger requirements demand that in each station the strips, which run along the beam direction, be segmented into 2 parts for stations MB1,MB3, and MB4; in the MB2 station, either the innermost or the outermost layer is segmented into 3 parts, depending on the position in the wheels and sectors. The strip length is thus 130 cm, except in the MB2 station where it is either 85cm or 130cm. There are 480 RPCs in the Barrel, for a to-
otal of 1020 double-gap modules, while in the endcap there are 432 chambers. The total RPC active area is 2953 m$^2$ distributed in 109608 strips (channels).

3. Cosmic Ray Runs 2009

From July to September 2009 the CMS continuously collected cosmic data. This period of data taking was named Cosmic Run At Four Tesla 2009 (CRAFT09). It was recorded about 500 million events distributed in 360 runs were recorded. The CMS RPC system participated actively in this data taking.

4. RPC Performance Studies with Cosmic Rays

The cosmic ray data taking was an important source of information for the commissioning of the RPC system. Studies of the stability, synchronization, efficiency, cluster size and other working parameters were performed, as explained in the following subsections.

4.1. Stability

During the cosmic data taking the stability of the system was monitored. The trigger rate for different muon triggers, gas gap currents and temperature of the chambers are show in Fig. 3, 4 and 5 repetitively.

4.2. Synchronization

The CMS experiment has 3 types of muon detectors, two calorimeters and a complex tracker system. The synchronization is a crucial factor for all the subdetectors. The CRAFT09 data was used to “tune” the RPC system in order to get the best internal synchronization. The bunch crossing assignment for the RPC reconstructed hits with respect to the RPC global trigger time is shown in Fig. 6, the background caused by noisy strips and detector electronics is illustrated by dashed line.

The timing between the Technical Trigger Unit (TTU) and Pattern Comparator Trigger (PAC) is shown in Fig. 7. The peak at 0 shows the overall good performance of the TTU trigger with respect to the PAC trigger.

4.3. Efficiency

Each muon sub detector in CMS has its own local trigger and its own local reconstructed products. In order to estimate the efficiency for muon detection we get the infor-
information about the drift tube segments, which is basically a point and direction of the muon track in a given DT chamber, a linear extrapolation is done to the RPC surface. After this “impact prediction” we checked for any RPC reconstructed hits in the RPC chamber. Residuals between the predicted point and the reconstructed RPC hit are shown in Fig. 9. A global sketch of the algorithm is shown in Fig. 8.

The RMS expected for the distribution shown in Fig. 9 is related to the cluster size and the mean strip width for the system;

$$RMS_{expected} = \frac{\langle strip \ width \rangle \times \langle cluster \ size \rangle}{\sqrt{12}}$$  \hspace{1cm} (1)$$

which agrees with the obtained value for the data used:

$$RMS = 1.334 \text{ cm}$$

We assume that a given extrapolation is efficient if the closest RPC reconstructed hit is not farther than two strips from the extrapolated point. During CRAFT09 efficiency scans were performed for different high voltages and thresholds and the results are shown in Fig. 10 and 11.

With the same technique, segment extrapolation, it is possible to perform studies of local efficiency chamber by chamber as shown in Fig. 13. There the lower efficiency spots are due to the presence of the RPC spacers on a grid of 10 cm pitch.
The plot in Fig. 13 validates the method that has been used for RPC efficiency and allows detailed monitoring of the RPC chambers.

4.4. Cluster Size Multiplicity

The DT/CSC segment also contains the incident angle of the muon on the RPC chamber, which allows the study of the dependency between this angle and the cluster size, as shown in Fig. 14.

The incident angle of muons produced from collisions is expected to be less than $20^\circ$.

5. Conclusions

Data collected during the CRAFT 2009 period have been very useful for RPC commissioning. The performance of the barrel and the endcaps system has been measured using cosmic ray data with good results. Thanks to the cosmic data taking we understand our detector with detail up to 1 cm resolution and the results have shown that the CMS-RPC system is ready for proton-proton collisions in 2010.

6. Acknowledgements

The author(s) would like to thank the Colombian Administrative Department of Science, Technology and Innovation COLCIENCIAS, the School of Science and the Physics Department of Universidad de Los Andes and the HELEN program for their financial support during this research.

References