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Cosmic Ray Test Certification of the First 100 CMS Endcap RPCs and the Corresponding Construction Database

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In June 2004, production began for the first set of Resistive Plate Chambers (RPCs), which will be installed in the endcap of the CMS experiment at the CERN Large Hadron Collider (LHC). More than 140 such "RE" chambers have been produced and about 100 of them have been tested with cosmic rays. The detectors are assembled at CERN with gas gaps made in Korea and mechanics manufactured in China. They are equipped with the final front-end electronics, as well as, high/low-voltage distribution and threshold controls. The performance of these chambers in terms of detection efficiency, noise, and cluster size during cosmic ray testing will be described. After these tests, chambers are systematically put on a high voltage stand to monitor the dark current for a longer term. Once certified, the data from each chamber are organized in a MySQL construction database to ensure traceability of key chamber components and measured chamber performance parameters. The stringent quality control and assurance criteria that have been applied for each certified chamber to be installed in CMS will be described.

1. Introduction

As the name suggests, the Compact Muon Solenoid (CMS) at the European Center for Nuclear Research (CERN), relies heavily on muon signatures to identify the decay of various particles. Resistive Plate Chambers (RPC's) play an important roll in the detection of these muons. Their fast response time makes them a good choice to act as a dedicated trigger in CMS. RPC's can easily tag muon events corresponding to individual bunch crossings with a 25 ns separation [1].

RPC's at CMS are arranged in a segmented fashion to provide a multilayered triggering system in the detector. The main body is called the barrel and the endcaps are comprised of four disks on each end (Fig. 1). Each disk is further divided into three sectors of concentrically arranged RPC's (Fig. 2)[1].

In June of 2004, RE1/2 & 1/3 RPC production began at CERN. The chambers are assembled by workers from Peking University who follow as-

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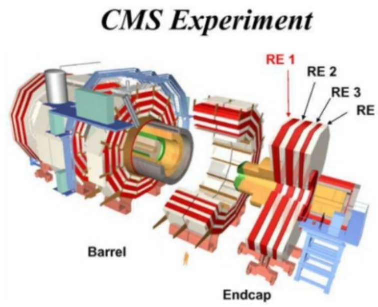

Figure 1. Compact Muon Solenoid (CMS) detector. The detector is divided into barrel and endcap regions. The endcap regions are further divided into four disks.

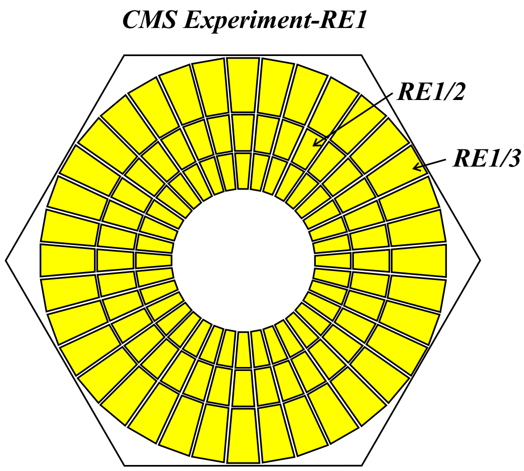

Figure 2. Endcap disk RE2. Endcap disks are divided into three concentric regions of RPC's. The numbering starts with the inner most sector (1) and increments outward. Sector 1 is staged and will be installed at a later date. Sector 2 has just been installed on the RE1 disks.

sembly and quality control procedures which is described in a separate article by Y. Ban, et al.[2]. After assembly, each chamber is certified prior to installation on the RE1 disk. This paper will describe this certification process and the subsequent storage of data into a MySQL database.

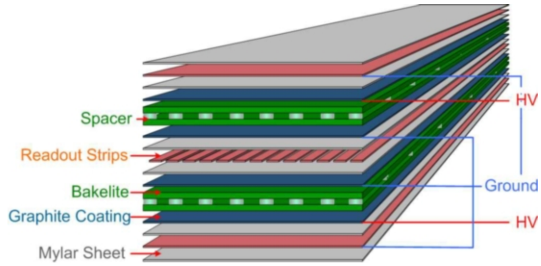

Figure 3. Endcap Resistive Plate Chamber

2. Materials and Methods

Endcap RPC's are double gap, parallel plate gaseous detectors. The overall chamber (Fig. 3) is comprised of an exterior container, readout strips, insulating sheets, and two inner gas chambers. One of these inner chambers is segmented in two pieces to allow cables to pass through to the readout strips. The inner chamber is commonly called a "gap".

The inner chamber is constructed from two sheets of resistive material (bakelite) with a resistivity ranging from $\rho = 10^{10}$ to $10^{11}\Omega \cdot cm$. The sheets are formed into a long narrow box with a separation of two millimeters between the two sheets of bakelite, which are two millimeters thick. A thin layer of material with moderate resistivity (graphite $\rho \approx 10^{-3}\Omega \cdot cm$), is applied to the top and bottom surfaces of the inner chambers. The gap is filled with a gas mixture composed of tetrafluoroethane (TFE)-95.5%, isobutane-3.5%, sulfur hexafluoride-0.3% and 50.0% relative humidity. Conducting strips are placed between the inner chambers, and ground sheets are placed to the outside. Separation between components is provided by insulating sheets of mylar.

In addition to numerous quality assurance checks, two primary tests are performed in the certification process. In each test the chambers are operated in avalanche mode. The first test, which utilizes cosmic muons, is a test to determine cluster size and efficiency for the chamber. A stand has been constructed to hold ten cham-

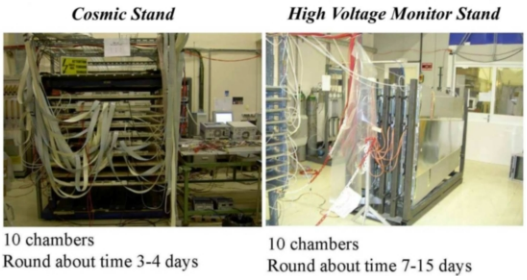

Figure 4. Certification Test Stands. The cosmic test stand (left) is used for determining efficiency and cluster size. The high voltage monitoring stand (right) is used for checking long term stability.

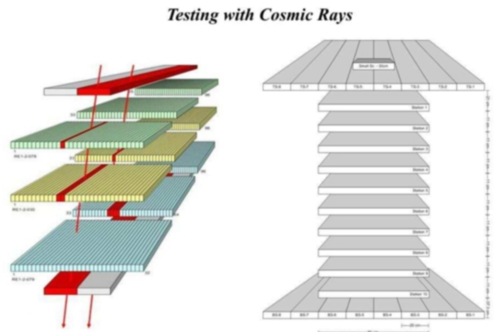

Figure 5. The cosmic test stand uses two planes of scintillators to tag cosmic rays.

bers in a stack between two planes of scintillators (Fig. 4 left). The scintillators provide a trigger for the RPC's. When a cosmic ray is incident on both planes of scintillators, the data taking process begins, and efficiency can be calculated based on the detection of the cosmic ray in the chambers (Fig. 5).

The second test performed during the certification process is the long term stability test. A high voltage stand has been constructed to hold ten chambers (Fig. 4 right). A voltage between 9300 and 9400 V is applied and the drawn current is recorded every two minutes over a two week period.

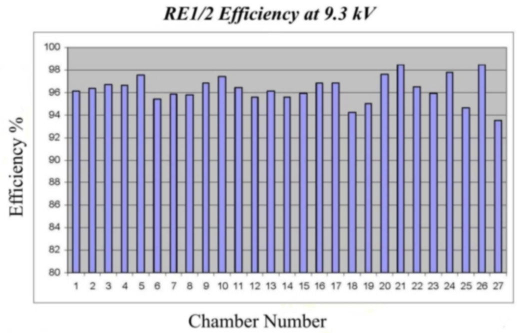

Figure 6. Efficiency for the first twenty-seven RE1/2 chambers tested

After data have been collected from each of these tests, they are stored in a MySQL relational database along with construction information. The database is accessed via an Apache web server.

3. Efficiency and Cluster Size

A minimum, acceptable efficiency of 95% has been set for chambers at 9300 V. Fig. 6 shows the results for first twenty-seven RE1/2 chambers tested. These results are typical for subsequent chambers that have been tested. When efficiency falls below the minimum, they are reopened and repaired accordingly. Since construction and testing occur in the same room, repairs are made quickly and the chamber is retested.

A cluster size (the number of strips which register an event) of three strips is set as maximum at 9400 volts. Fig. 7 shows the cluster size for a number of chambers at various voltages. For the first hundred chambers tested, all chambers have had cluster sizes below three at 9400 volts.

4. Long Term Stability

A maximum current draw of 10 μA is set at 9400 V for each gap in the chamber. If the current draw is exceeded during the two weeks of testing, the chamber is once again returned to the construction area, and the gap which failed the test is replaced. Figure 8 shows the current draw over

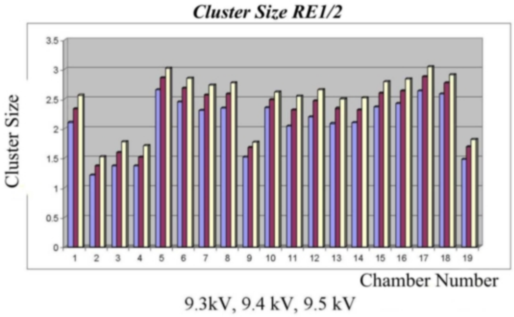

Figure 7. Cluster size for the first nineteen RE1/2 chambers tested. Each chamber was tested at 9.3 kV, 9.5 kV, and 9.5 kV (shown respectively by the three bars for each chamber)

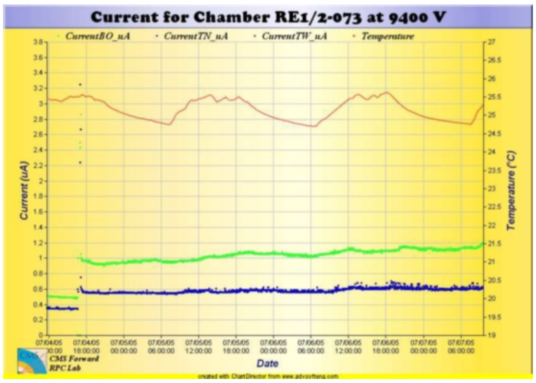

Figure 8. Current versus time for a RE1/2 chamber at 9400 V. The drawn current is well within the 10 μA limit.

a test interval for an RE1/2 chamber. The line graph is the temperature during the test, the upper data set (scatter plot) represents the bottom gap (BO) of the chamber. The lower data set is from the top gap, which is a split gap (TN & TW: top narrow and top wide). The two are tested on the same high voltage channel. Hence, the drawn current is for both sections.

5. Database

The data from construction and certification testing are stored in the construction database via PHP web page interfaces. These data are accessed at the URL:

http://forwardrpc.cern.ch/cms_forward_rpc/production_db/Main_db.htm

Here dynamic plots can be made for individual chambers. These include current plots, strip response, efficiency, and cluster size, as well as correlated plots with temperature and environmental humidity.

6. Results

Certification testing has revealed anomalous chamber performance in a few of the chambers. Since construction and testing occur in the same facility, these chambers have been repaired and retested. The result is certification of the first 100 chamber tested. These data have been stored and will be kept for the life of the experiment.

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