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The Compact Muon Solenoid Experiment

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Beam test of the first production forward RPC

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Abstract

The production of the first set of forward Resistive Plate Chambers (RPC) for the CMS experiment at the Large Hadron Collider (LHC) has started at CERN since June 2004. The detectors are assembled with gas gaps made in Korea, mechanics made in China and are equipped with the final front-end electronics, high/low-voltage distribution and threshold control. After testing and validating, one of the pre-series RE1/2 chambers was coupled to the corresponding Cathode Strips Chamber (CSC), ME1/2, and exposed to muons at the X5A beam area at CERN. Its performance in terms of detection efficiency, noise and cluster size in this beam with 25 ns bunch structure is presented.

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1 Introduction

The CMS forward muon system [1] consists of three iron yoke disks equipped with gaseous tracking chambers as illustrated in Fig. 1. The wedge shaped Cathode Strip Chambers (CSC) [2] contain 6 multiwire layers with cathode strips running radially. Four CSC stations cover the forward-backward part up to eta=2.4. Per station they are arranged in concentric rings of staggered chambers. They are complemented by three stations of RPC detectors covering eta up to 1.6 for the initial CMS detector. Their role is to identify unambiguously the bunch crossing and help with CSC ghost reduction when running at the anticipated high luminosity of the LHC. In the first station both detector types have to coexist on the same face of the YE1 iron yoke. For the intermediate ring, called ME1/2-RE1/2, the RE1/2 RPC is mated to the corresponding ME1/2 CSC. This mating and simultaneous running of both detector types was achieved for the first time in this beam test.

The major goal of this beam test for the RPC project was the validation of the Link Board System [3] for the CMS level 1 muon trigger. In addition its monitoring capabilities permitted the investigation of the RPC chamber. Only the results concerning the RPC performance will be given here. Results from the test of the Link system and the CSC chambers will be given in separate notes.

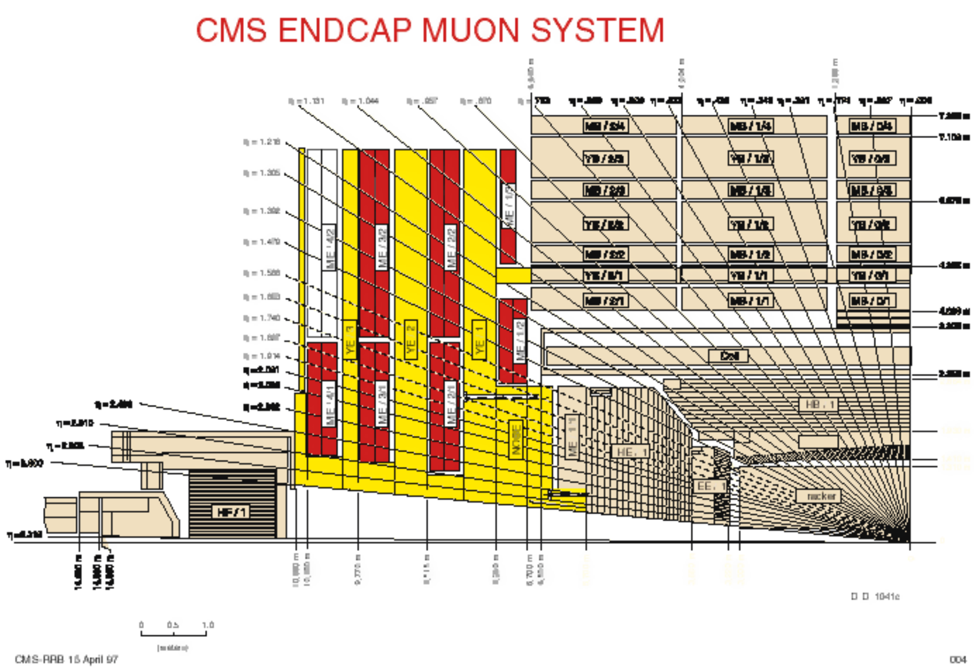


Fig. 1 CMS Endcap Muon System

2 Chamber design

The double gap RPC developed for CMS [4] is schematically shown in Fig. 2. For the forward part, the RPCs are wedge shaped with readout strips running radially.

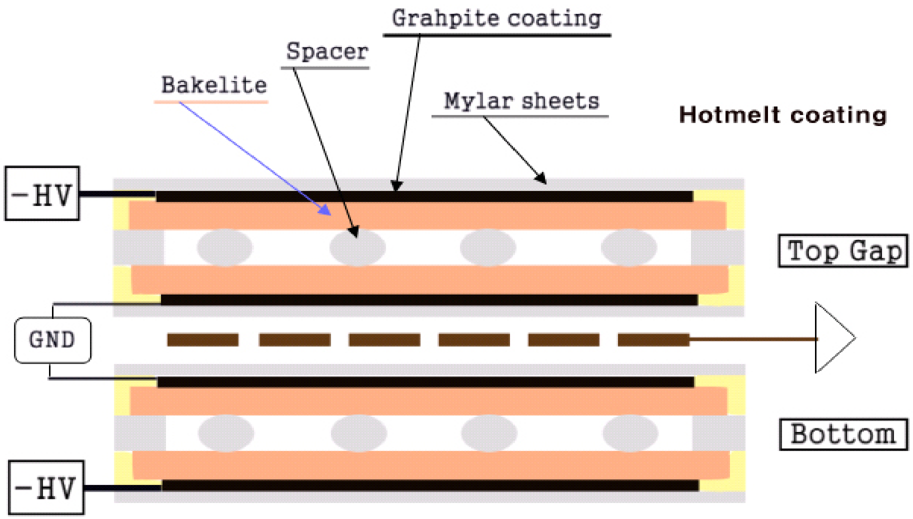


Fig. 2 Schematic of the double gap RPC.

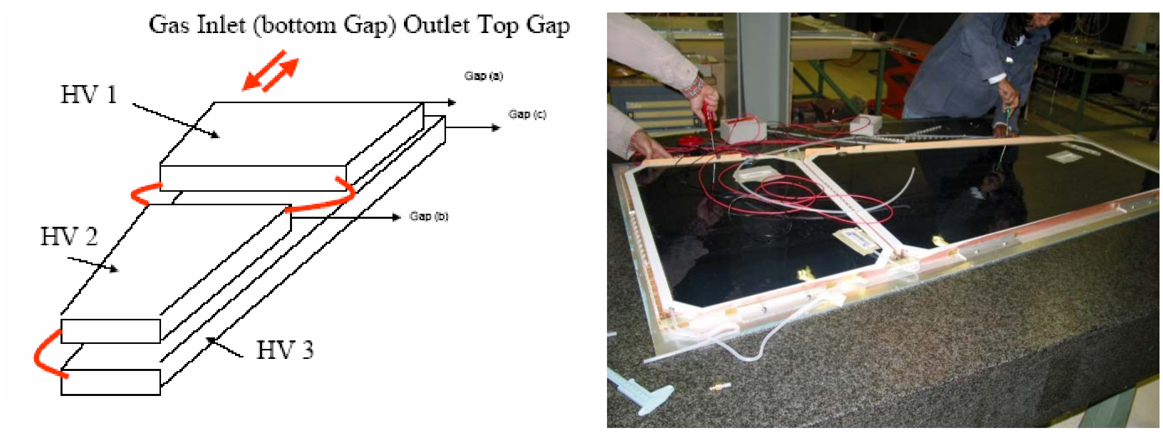


Fig. 3 Gas pipe connections for the three gaps of one RE1 chamber; in the photo the two top gaps can be seen.

Strips are about 2 cm wide and are segmented in three trigger sections for the RE1/2 detector. The split gas gap on top, as shown in Fig. 3, allows the connection to these trigger sections. The total surface of RE1/2 is ~ 15930 cm^2.

The mechanical assembly surrounding the RPC gas gaps is based on aluminum honeycomb top and bottom panels and aluminum edge profiles yielding an RPC enclosure of only 28 mm thick. The front-end electronics is located on top of the top panel as shown in Fig. 4 and then covered by an aluminum screening box of 20 mm height.

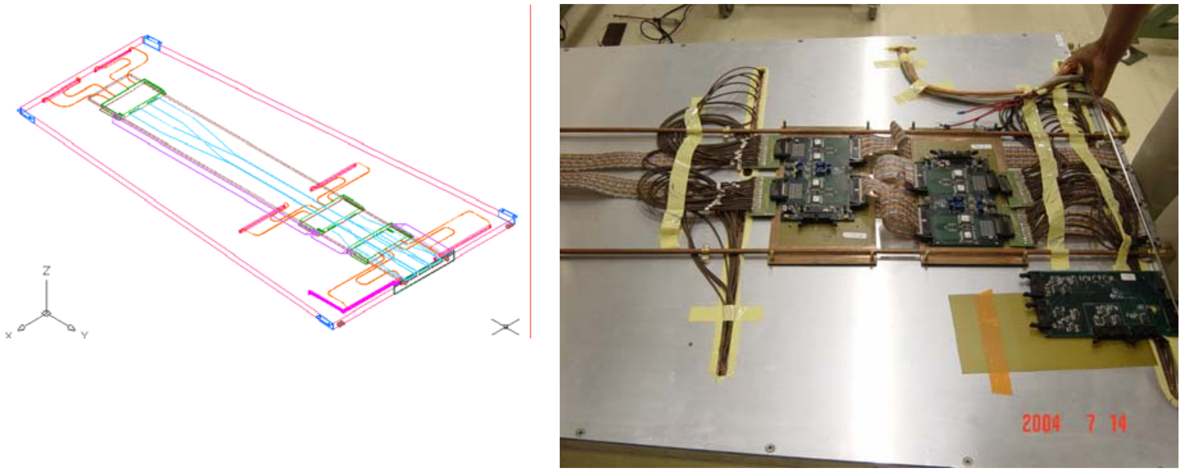


Fig. 4 Placement of the Front-end Electronics and cooling on the chamber, the right side picture shows a photo of the same.

3 Gas Gap construction

Bakelite sheets are purchased, cut and cleaned in Italy and then shipped to the Kodel Institute in Seoul, Korea, where the gas gaps are assembled and tested. The 2mm thick gas gap is obtained by gluing a regular pattern of 2 mm thick polycarbonate spacers in between 2 bakelite sheets of 2 mm thickness each. The inter column and inter row pitch between spacers is 10 cm. The outer edge is obtained by gluing polycarbonate edge profiles along the bakelite sheet periphery. Injection molded gas in and outlet pieces are inserted at the four corners of the gas gap. The graphite coating, applied by silk screening, on the outer bakelite surfaces of the gas gaps is covered by a 0.2 mm thick mylar sheet laminated via a hot melt procedure. The inner surfaces of the bakelite are covered with a thin layer of linseed oil (5 micron thick) by filling and subsequently emptying the gaps via the gas in and outlet pieces. Flushing the gaps with hot dry air cures the linseed oil layer. Prior to their shipment to CERN, all gas gaps are tested with a 20 mbar overpressure for gas tightness and the absence of popped spacers. The High Voltage test consists of monitoring the currents drawn by the gaps at nominal operating voltage (9.4 kV). Nominal stable currents are typically few micro-amps, and are not allowed to exceed 10 micro-amps. Fig.s 5, 6 and 7 respectively show the silk screening, the hot melt facility and the oiling set up at Kodel.

Figs. 5 and 6: The silk screening and linseed oil coating facility at Kodel, respectively.

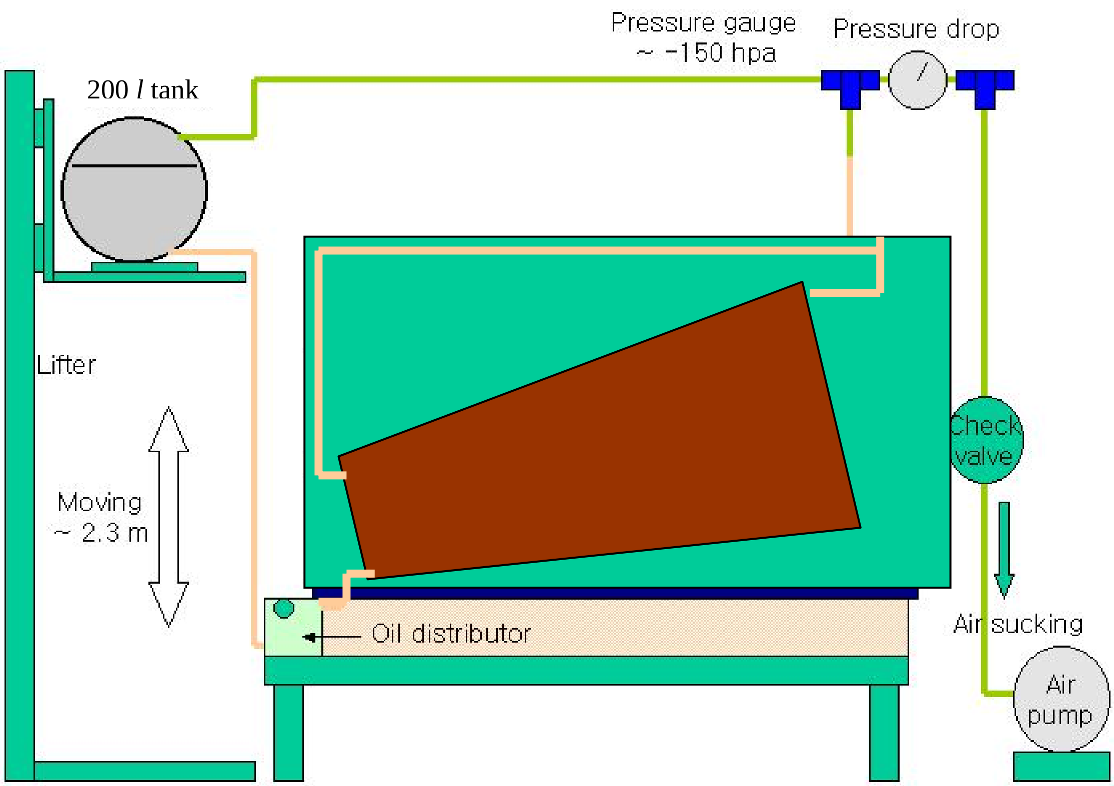


Fig. 7 Scheme for oiling of the Bakelite Gaps.

4 Chamber assembly

Upon arrival at CERN, all gas gaps are subject once more to the two basic quality control procedures concerning gas tightness, popped spacers and HV behavior; the former tests are performed by filling argon in the gaps while the HV tests are done with the RPC gas namely Freon 95%, Isobutane 4%, SF6 0.3% and water. Three gas gaps are then arranged as shown in Fig. 3 inside the box assembled from aluminum honeycomb panels, edge profiles and miscellaneous pieces procured by Peking University in China and shipped to the CERN RPC assembly laboratory. The main tasks concern the connection of the read out strips to the Front End Boards (FEB), the installation of the gas and cooling circuits and the connections to high and low voltage. The strip to FEB connection is achieved using 50 Ohm coax cables via an adaptor board.

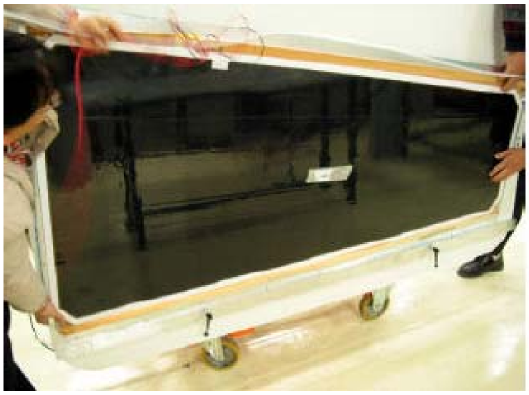


Fig. 8 Gas Gap transported vertically using the scissor table during the assembly process

Fig. 9 Gas inlets of the top gas gaps, the readout strip and ground copper sheet can be seen below.

Fig. 10 Ready for top cover the after closing the Faraday cage with top Copper sheet.

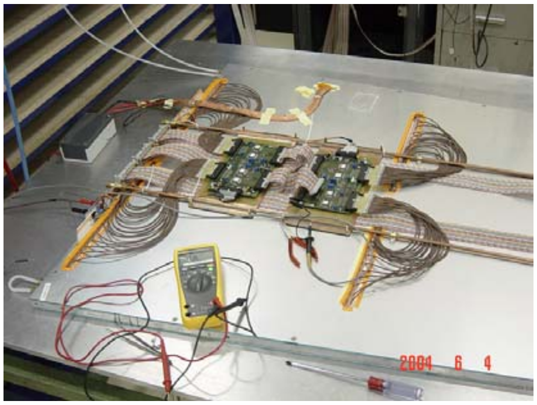


Fig. 11 Electronics and signal cables on the top surface of the chamber.

The three gas gaps are at this stage individually connected to the HV supply and current monitoring system. The top and bottom gaps are kept on separate gas channels.

Connection of all services to the RPC is achieved via the patch panel on the wide base of the trapezoid. Figures 8-11 illustrate some steps in this assembly.

Assembled detectors are tested for the integrity of all connections and the singles rate noise as well as the dark current is monitored at nominal operation voltage. Ready RPCs are then stacked, up to 10, inside a cosmic hodoscope for the precise control of their performance as shown in Fig. 12.

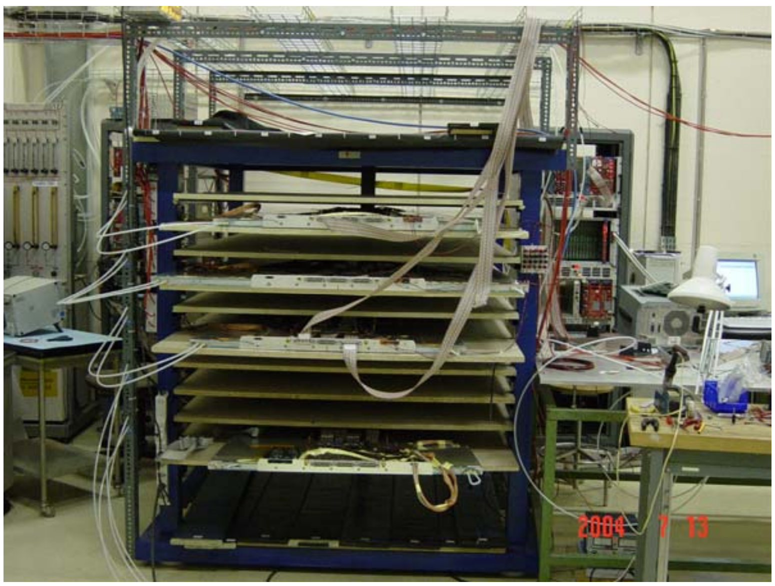


Fig. 12 The cosmic stand with chambers and DAQ for QC

5 Beam test results

For the beam test an RE1/2 RPC assembled with all final components and close to final procedures was mated to an ME1/2 CSC detector in the X5A SPS beamline at CERN. The mechanical mating was flawless and no electronic interferences have been observed throughout the beam test lasting one week. As pointed out before the major goal of this beam test was the validation of the Link Board system for the CMS first level muon trigger. Data concerning the RPC detector performance was recorded via the monitoring capability of the Link Board.

The RE1/2 RPC detector was flushed with the RPC gas mixture. Fig. 13 shows the RE1/2 mated at the back of the ME1/2 CSC, the FEB side of the RPC facing the CSC. Dark currents of the gaps, in between spills, ranged from a fraction of a micro amp to a maximum of 3 micro amp, depending on the gap, the HV setting and time. In Fig. 13 are shown some typical monitoring plots such as noise and strip hit distributions at two nominal voltages 8.7 and 9.0 kV on each of the three gaps. The detector efficiency with respect to the muon trigger, provided by a triple scintillator coincidence, is shown in Fig. 14 as a function of the HV setting.

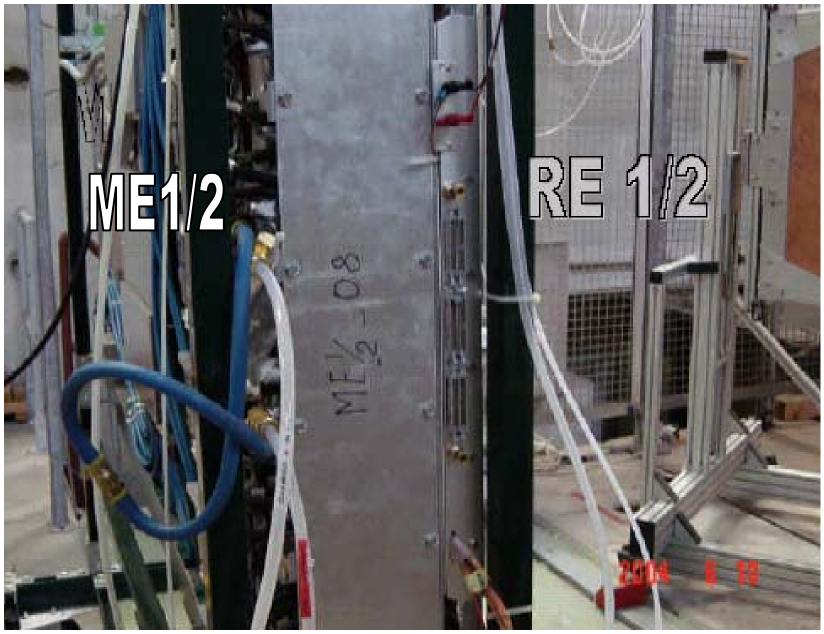
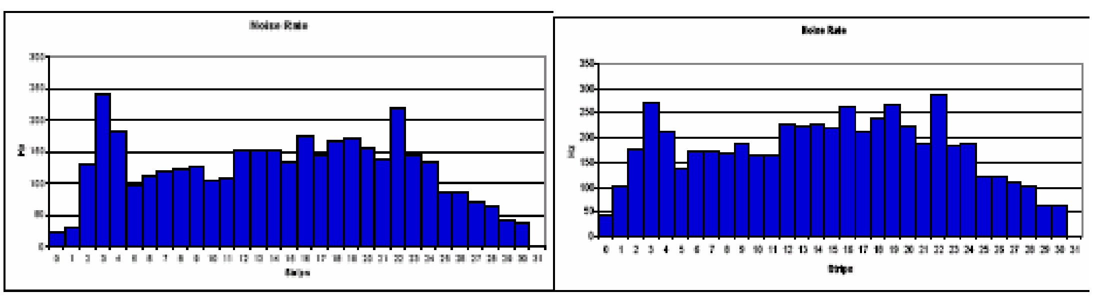
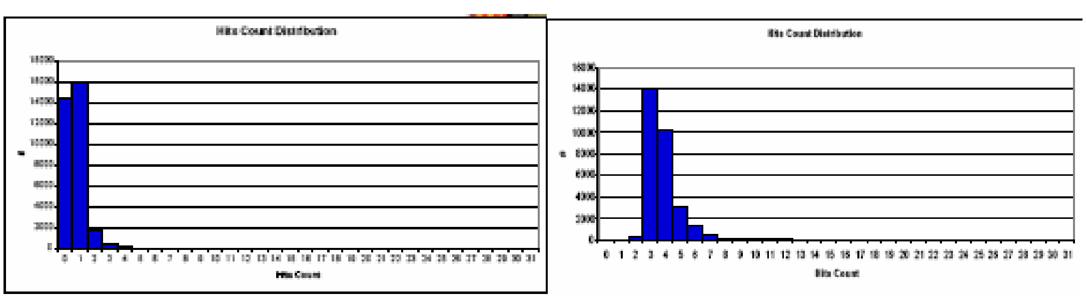


Fig. 13 – RE1/2 Chamber mated with ME1/2 on beam in X5



Noise at 8.7 kV and 9.0 kV



Strip Hit at 8.7 kV and 9.0 kV

Fig. 14

The upper curve corresponds to the double gap configuration, the lower curves to the efficiency curves for single gaps powered in turn. It is seen that the double gap reaches the start of the plateau at a 9 kV setting. With an efficiency close to 100% and an average cluster size of 2.9 the noise plot exhibits a typical value of noise hits per strip of about 1 Hz/cm^2. Finally the evolution of the average cluster size as a function of the HV is shown in Fig. 15 for the double gap conFig.uration. Clearly beyond 9.3 kV, the cluster size becomes large indicating the onset of a sizeable streamer fraction. But even at 9.4 kV settings the dark currents never exceeded 5 micro-amps on spill and the noise rate remained unaffected as shown in Fig. 16.

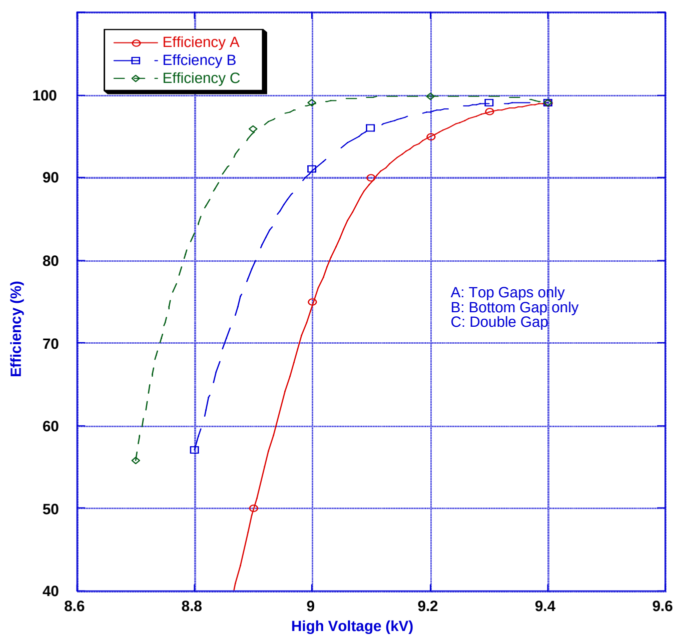


Fig. 15 Efficiency curves for (A) both gaps, (B) bottom and (C) top gaps only.

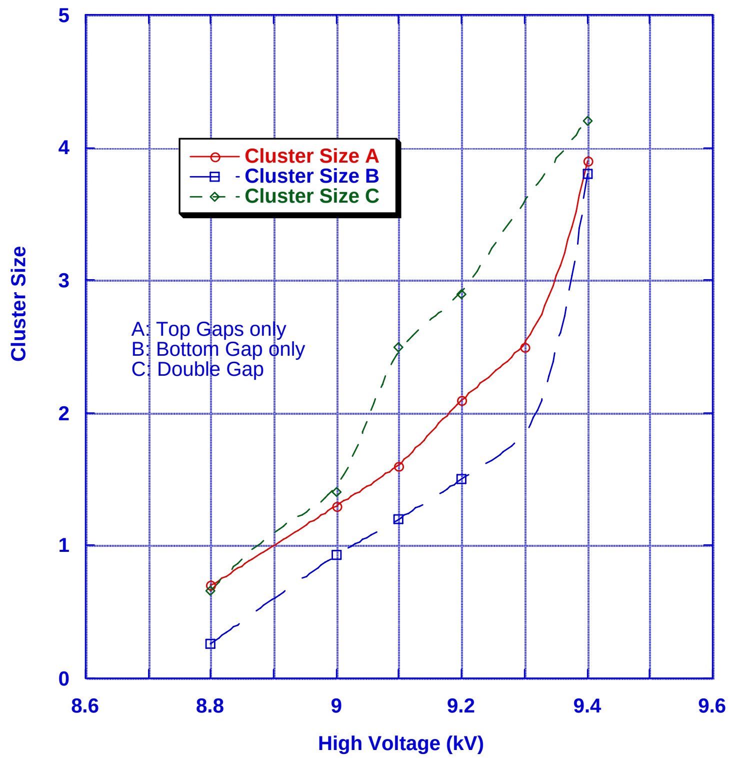


Fig. 16

6 Conclusions

The first RE1/2 RPC detector has been assembled at CERN using all final components: gas gaps produced in Korea, mechanics produced in China and the final Front End Electronics boards designed and built in Italy. It has been successfully mated to the corresponding ME1/2 CSC chamber and exposed, as a system, to the X5A beam with 25 ns bunch structure. The performance results of the RPC were obtained using the monitoring capability of the Link Board. In terms of muon detection efficiency, noise rates, dark currents and cluster sizes, this first production RE1/2 has fullfilled all the requirements for the CMS detector at the LHC.

7 Acknowledgments

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