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First results on RB2 muon barrel RPC detector for CMS

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Abstract

The first CMS MB2 station, with one RPC and one DT module, has been tested with a muon beam under a high intensity photon flux at the CERN Gamma Irradiation Facility during the Autumn 2001 test. Results on efficiency, rate capability, cluster size and spatial resolution, for the RPC detector, are reported here. Studies with a small percentage of SF_6 in the gas mixture, in order to decrease the noise rate, have also been carried out.

Keywords: RPC; CMS; Noise rate; Spatial resolution; Streamer fraction; SF_6

1. Introduction

The CMS detector has a redundant muon system based on Drift Tube (DT) wire chambers in the barrel, Cathod Strip Chambers (CSC) in the End Caps, and an additional dedicated trigger system, built with Resistive Plate Chambers (RPC) in both regions [1]. The muon system will work in a very high background environment: in the barrel region the flux of low-energy photons will reach the level of 10^3 cm^{-2} s^{-1}, while in the forward will be 10^5 cm^{-2} s^{-1}. CMS will use the independent and complementary information of the two subsystems (the excellent spatial resolution of wire chambers and the superior time resolution of RPC) in order to build a highly efficient first-level trigger with high flexibility and powerful background rejection. During the Autumn 2001, for the first time, a barrel muon station (MB2) has been tested. The basic MB2 station (second muon station in the barrel) consists of two RPCs (RB2s) and one DT module. The DT module is composed of three superlayers (SL) each one split into four layers of staggered drift tubes. Two SLs measure the coordinate in the bending plane (ϕ view), the other in the longitudinal plane (θ view). The RPCs are double gap chambers with the readout strips running along the beam line (ϕ view). Since RPC and DT chambers are mechanically combined in a single detector, one of the major issue of the test has been the check of their electrical compatibility. In this

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paper, we report the results on the performance (efficiency, rate capability and spatial resolution) of one RB2 chamber while operating in combination with the DT at the CERN muon X5 beam in the presence of gamma background. The effectiveness of adding a small fraction of SF_6 to reduce the streamer probability has also been studied.

2. Experimental setup

The GIF is located downstream the final dump of X5 beam line at CERN. Inside the zone a 740 GBq ^{137}Cs gamma source creates background conditions similar to the ones expected during the LHC machine operation. The ^{137}Cs isotope emits 661 keV photons: a system of lead filters, that can be moved in front of the source, allows to reduce the flux by up to a factor 10^4. The tests were performed with source off, absorption (ABS) 1 (i.e. source open and no filters), ABS 2, 5, 10, 50, 100 (ABS N indicates a nominal absorption factor N with respect to ABS 1). During the test the MB2 station was positioned vertically inside the irradiation area, 4 m away from the source. The chamber was operating under a photon flux ranging from $5.6 \times 10^3\ cm^{-2}\ s^{-1}$ (ABS 100) to $2.8 \times 10^5\ cm^{-2}\ s^{-1}$ (ABS 1). A system of scintillators was used to trigger on the beam particles. The RPC chamber had a bakelite resistivity $\simeq 7 \times 10^{10}\ \Omega$ cm, and the sensitive volume was filled with a 96.5% $C_2H_2F_4$, 3.5% iso-C_4H_{10} mixture. Some data were also taken with a mixture enriched with a small percentage (0.2%) of SF_6. The internal bakelite surfaces were coated with linseed oil. The signals were picked-up by $2.9 \times 124\ cm^2$ aluminum strips located between the two gaps, terminated at one end with a 40 Ω resistor. The strips were readout by eight channels chip front-end electronics, designed and manufactured in 0.8 μBiCMOS technology by AMS [2]. The amplifier charge sensitivity was $2\ mV\ fC^{-1}$ and the discrimination threshold was 100 fC. A 100 ns pulse shaper followed the discriminator. The signals were read-out by home-made multi-hit common stop TDC modules with 25 ns resolution. The signals from the DT chambers were fed to multi-hit common stop CAEN TDCs with 0.8 ns resolution.

3. Experimental methods and results

During the operation no electrical interference between DT and RPC was observed. Also the mechanical integration fulfilled the requirements. The TDC data have been used to study the time and spatial properties of the RPC chamber under different irradiation fluxes. In the following, to account for temperature T and pressure P variations during the data taking, the applied voltage is normalized at the reference values $T_0 = 293$ K and $P_0 = 1000$ mbar, according to Ref. [3].

3.1. Efficiency

In the following, the RPC is considered efficient if there is at least one hit in a time window of 50 ns around the average time response. Fig. 1 shows the efficiency curves at various absorption factors. The probability of accidental coincidences has been taken into account by measuring the number of times a signal is registered in the same time window but out of trigger (200 ns before the muon

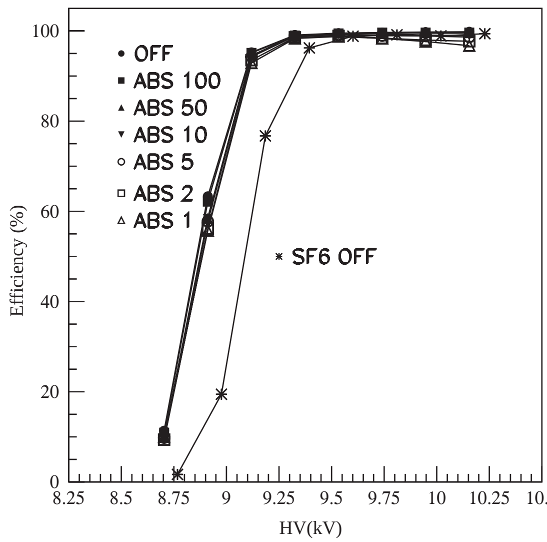

Fig. 1. Efficiency curves at different absorption factors. The cross markers show the efficiency curves with the SF_6 mixture.

trigger signal from the scintillators). At increasing background a slightly loss of efficiency is observed at high voltages ($\approx$97.5% at ABS 1 and HV > 10.0 kV). In the same figure the efficiency curve when 0.2% SF_6 is added to the mixture is also shown: a shift of about 150 V is observed.

3.2. Cluster counting

Both minimum ionizing particle and Compton electrons coming from the photons emitted by the source may produce detectable signals in several adjacent strips, forming a cluster. A cluster is defined by grouping adjacent strips with signals inside a time window of fixed width, Δt. We studied how the cluster multiplicity is affected by the choice of the time window and gas mixture by analyzing the same events using two values of Δt for the clustering algorithm, 25 and 50 ns. In Fig. 2 the average cluster size is shown for the case of SF_6 free mixture and with the $\Delta t = 25$ ns window. Results are given for muon triggered events under different source conditions and operating voltages. Fig. 3 shows the comparison between the mean cluster size when windows of $\Delta t = 25$ or 50 ns are used, for muon trigger events. A decrease of the cluster size at higher voltage is observed when the

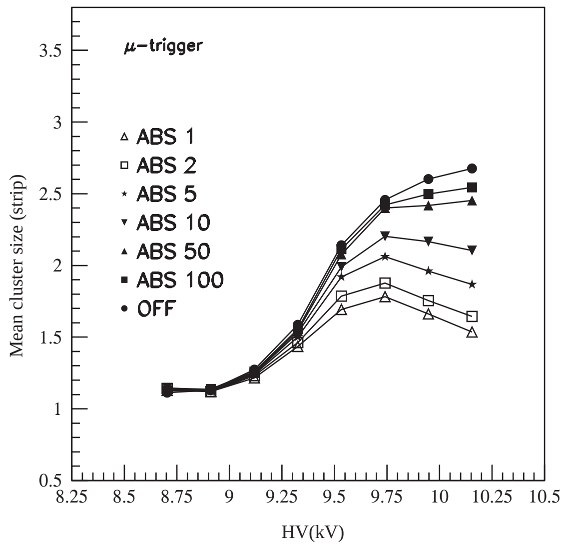

Fig. 2. Average cluster size in 25 ns time gate vs. applied voltage at different ABS factor and no-source.

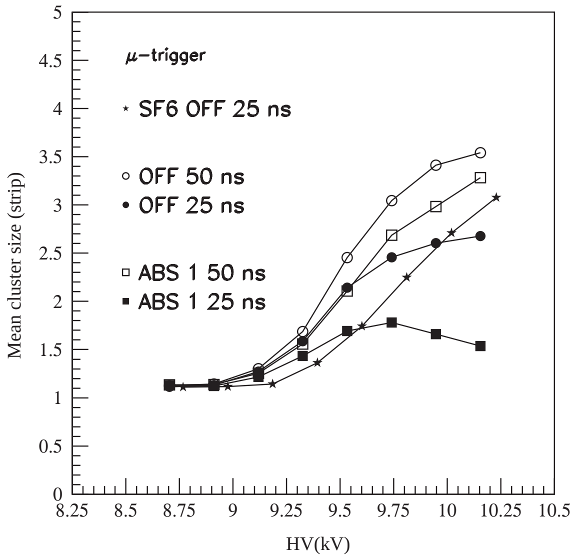

Fig. 3. Average cluster size vs. applied voltage under different experimental conditions.

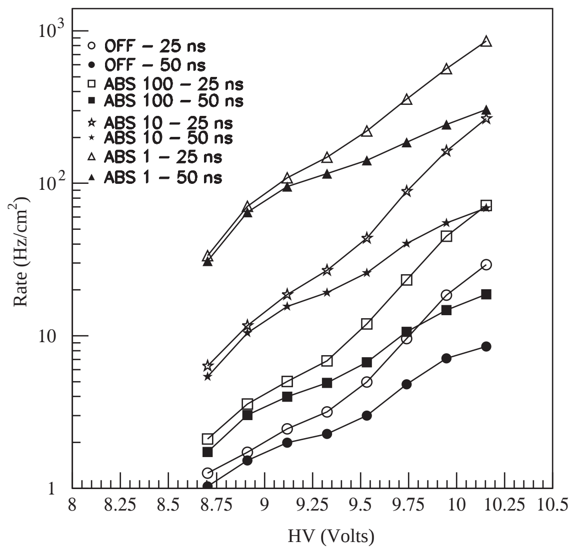

Fig. 4. Counting rate vs. applied voltage under different experimental conditions.

25 ns time gate is used. This can be explained as due to the fragmentation of the clusters in smaller ones if the time spread of the strips signals is larger than the applied window. The fragmentation affects also clusters from Compton electrons and noise. In Fig. 4 the rate of clusters, computed out

of muon trigger events, is shown as a function of HV, both for 25 and 50 ns time window. It can be seen that higher cluster rate is always found with the $\Delta t = 25$ ns window. The cluster fragmentation could affect the RPC bunch crossing assignments and therefore the trigger performance by increasing the rate of false trigger. It is known [4] that a small percentage of SF_6 decreases the cluster size: a lower cluster size values with respect to the SF_6 free mixture might help to reduce the effect of the fragmentation and allow the full cluster reconstruction in 25 ns. In fact, Fig. 3 shows a smaller cluster size and no effect of fragmentation when SF_6 is used at operating voltages well above the knee of efficiency plateau.

In Fig. 5 we show the fraction of clusters with more than six strips as a function of the voltages. The two cases are considered so that, as explained previously, fragmentation is minimized:

- SF_6 free mixture and cluster reconstruction in 50 ns time window;
- SF_6 mixture and cluster reconstruction in 25 ns time window.

It can be seen that the SF_6 enriched mixture reduces the fraction of clusters with large strip

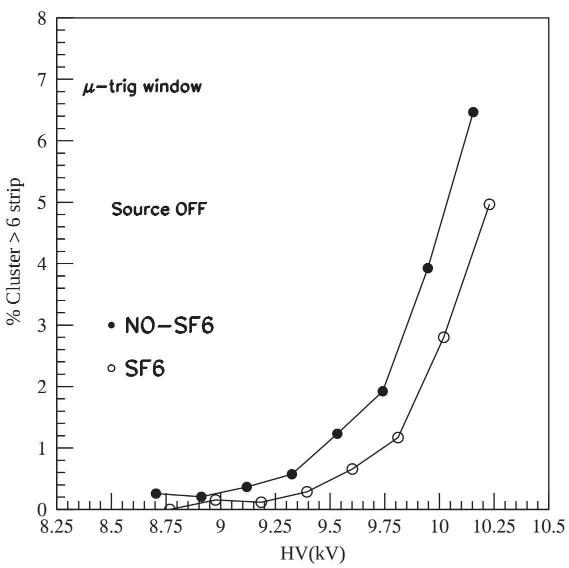

Fig. 5. Fraction of clusters with average strip multiplicity larger than 6 for the two different gas mixtures and with source off.

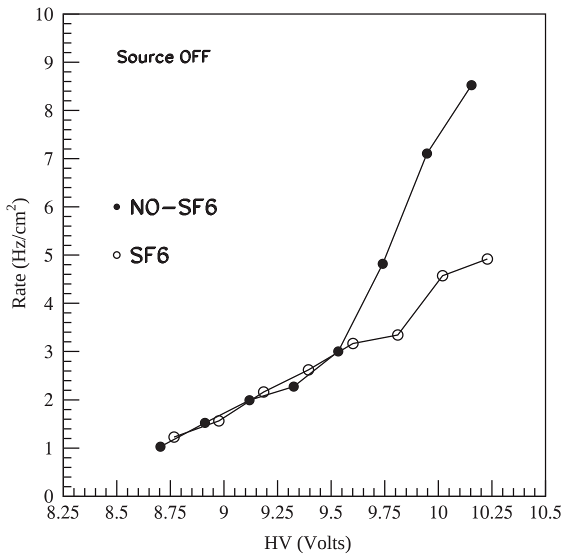

Fig. 6. Noise rate as a function of the high voltage for the SF_6 and SF_6 free mixture.

multiplicity, up to the higher voltages. The results reflect the know capability of a very small percentage of SF_6 in the binary mixture ($C_2H_2F_4$iso-C_4H_{10}) to suppress the streamer probability [4]. During the source off operation the noise rate has also been measured by counting the number of clusters not associated with the extrapolated muon tracks: from Fig. 6, where the rate is plotted vs. HV, a lower noise rate is observed at high HV values when the SF_6 mixture is used.

3.3. Spatial resolution

The median strip in the cluster, computed as the centre of gravity of the fired strips, has been used as an estimator of cluster position [5]. In order to correlate the cluster multiplicity to the muon impact point on the detector we used the independent reconstruction of the muon as given from the DT module. The DT performs local reconstruction of track segments in each SL. In Fig. 7 the reconstructed muon trajectory has been extrapolated to the RPC local reference system and the distribution of its position across the strip is shown for cluster with strip multiplicity one, two and three. When the muon hits the RPC in

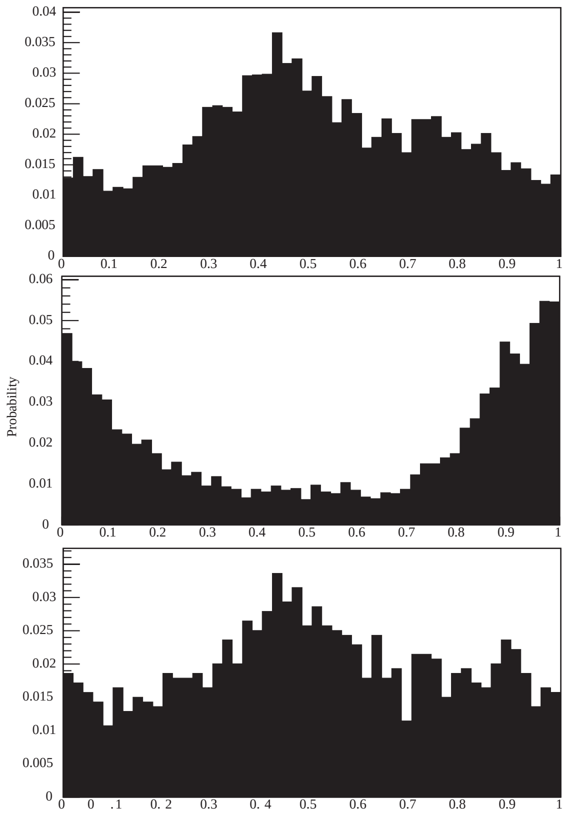

Fig. 7. Probability distribution of the muon impact point along the strip when the cluster size is one (top), two (middle) and three (bottom) (SF_6 free mixture and 25 ns cluster gate).

the middle of the strip we register, with high probability, cluster size one or, due to large induced charge on the neighboring strips, cluster size three; on contrary cluster size two occurs with high probability when the muon hits the edge of the strip.

4. Conclusions

The performance of the first CMS MB2 station have been studied during the 2001 beam test under different rate conditions with muons and photons. The results of the RPC detector have been reported. The crucial role of gas mixture have been pointed out: in order to optimize L1 triggering performance, where the RPCs play a crucial role, a very small percentage of SF_6 is needed. It allows to work in a regime of lower streamer probability up to the higher voltages with lower noise rate, better cluster rencostruction, lower strip multiplicity in the cluster.

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References

[1] The Muon Project, Technical Design Report, CERN/LHCC 97–32.
[2] M. Abbrescia, et al., Nucl. Instr. and Meth. A 456 (2000) 143.
[3] M. Abbrescia, et al., Nucl. Instr. and Meth. A 359 (1995) 603.
[4] P. Camarri, et al., Nucl. Instr. and Meth. A 414 (1998) 317.
[5] M. Abbrescia, et al., Nucl. Instr. and Meth. A 456 (2000) 103.