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Resistive plate chamber commissioning and performance in CMS

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ABSTRACT

The CMS muon system is conceived for trigger and muon track reconstruction. The redundancy and robustness of the system are guaranteed by three complementary subsystems: drift tube in the barrel, cathode strip chamber in the end-cap and resistive plate chamber in barrel and end-cap. The installation of muon stations and read-out trigger electronic has been completed in middle 2007. Since than, a remarkable effort has been addressed to the detector commissioning in order to ensure the readiness of the hardware/software chain for the LHC start up operation. At the end of 2007, a test of an entire CMS slice has been performed, involving about 5% of muon stations. Several thousand cosmic muons events have been collected. Performance of the barrel chambers are reported.

1. Introduction

The resistive plate chambers (RPC) trigger system for the CMS experiment at LHC will be one of the largest ever built based on RPCs [1,2]. It will have the crucial role of providing a first level muon trigger [3] with unambiguous bunch crossing assignment and coarse transverse momentum evaluation. In this paper we will report results only on the RPC barrel system.

In Section 2 studies on the noise rate level as function of the applied front end threshold are presented.

In Section 3 a muon track reconstruction technique is described. Results of the algorithm for local and global detector performances with cosmic rays are also discussed.

2. Noise studies

The use of RPCs as trigger detector requires an extreme low intrinsic noise rate to allow the proper functioning of the

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algorithm and to limit the number of fake triggers [4] in the output data flow. The noise level of the detector has been evaluated with running condition similar to the final one. One of the purpose of this commissioning phase is to optimize the threshold value in order to minimize the number of noisy strips.

An online evaluation has been obtained reading out the strip signals during a time window of 1 s. All the wheels (in the following denoted as W_i, $i = -2, -1, 0, +1, 2$) [5] were operated at 9.2 kV and the threshold was varied in the range 200–250 mV. We remind, as a reference, that a threshold of 200 mV correspond to a minimum charge signal of about 0.1 pC.

An example of a noise profile for a given chamber at 220 mV threshold is shown in Fig. 1.

In Fig. 2 the average noise as a function of the applied threshold is reported for a given chamber.

The overall noise distribution for all the W_0 chambers is shown in Fig. 3 at different threshold values. Few noisy strips (over 10 Hz/cm^2) can be easily suppressed by a slight increase in the threshold.

According to the previous results, a 220 mV threshold seems to be the most appropriate value for safe operation. This is in agreement with results on chambers performance obtained during quality assurance, which showed that a threshold of

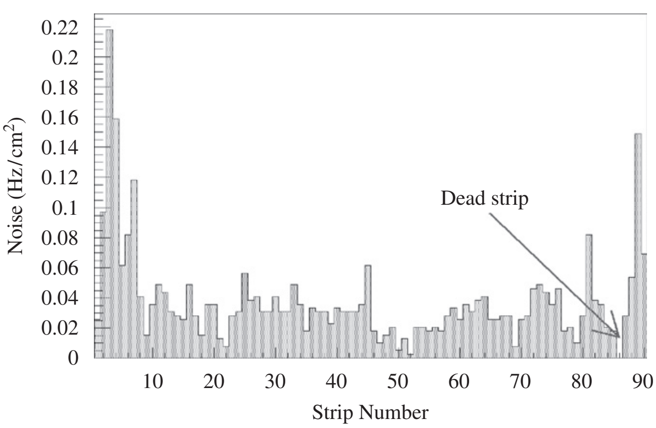

Fig. 1. Chamber noise profile at Th = 220 mV.

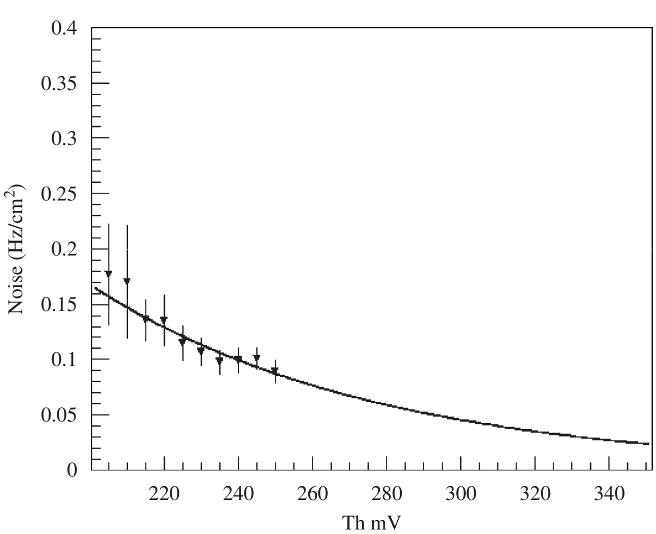

Fig. 2. Average noise for different Th values.

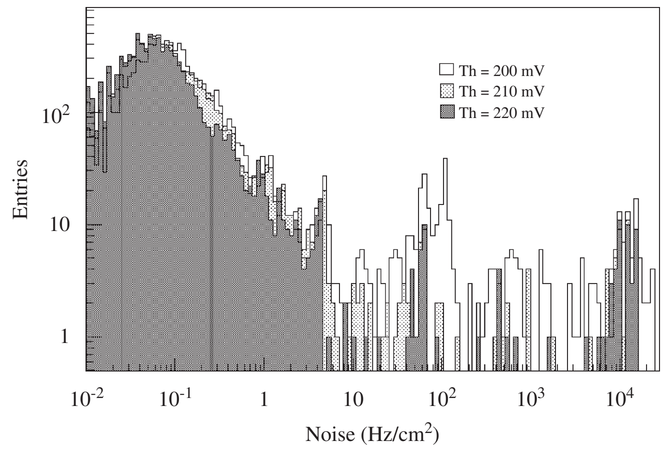

Fig. 3. Overall noise distribution of all the W_0 chambers at different Th values.

Table 1
Average noise values for all the tested wheels at Th = 220 mV.

	Noise (Hz/cm^2)	RMS (Hz/cm^2)	Strips over 10 Hz/cm^2 (%)
W_{-2}	0.58	10.25	0.79
W_{-1}	0.48	15.63	0.67
W_{+0}	0.49	8.29	0.63
W_{+1}	0.12	1.32	1.14
W_{+2}	4.20	41.72	4.00

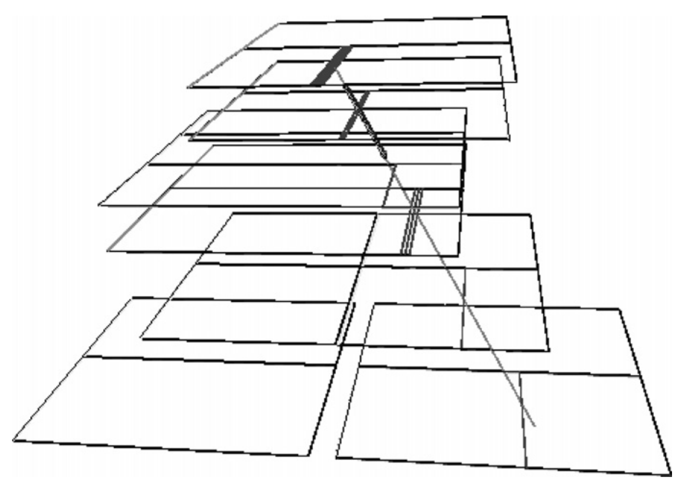

Fig. 4. Muon candidate reconstructed in sector 10 of W_0.

220 mV threshold was the most effective one to optimize efficiency and noise rate [6].

Noise summary for all wheels are given in Table 1. It can be noted that wheel W_{+2} has an average noise value significantly higher than the others. The reason was traced back to nine noisy front-end boards. By masking those channels the average noise value decrease to 0.51 Hz/cm^2 (0.2% of noisy strips), in agreement with the overall behavior.

3. Efficiency studies

3.1. Muon track reconstruction

The development of a tracking algorithm to reconstruct muon candidates is crucial for the evaluation of the local and global detector efficiencies. This information is relevant to determine the muon trigger efficiency and the muon reconstruction efficiency with high precision.

Tracks in the muon system are built using the Kalman filter technique by combining information coming both from RPC and DT/CSC [7]. This technique is recognized as the stand-alone muon reconstruction and it is also the basis of level-2 muon trigger.

Based on the Kalman filter technique, track reconstruction starts with the estimation of the seed state from track segments in the off-line reconstruction and from the trajectory parameters estimated by level-1 trigger [3]. The track is then extended using an iterative algorithm which updates the trajectory parameters at each step and reduces the possible bias from the seed. Once the hits are fitted and the fake trajectories removed, the remaining tracks are extrapolated.

The candidate muon track will also be propagated to the central tracker. A global muon candidate will than be reconstructed making use of information of both the muon system and the tracker system. Muon reconstruction is further completed by matching information with the energy deposits in the calorimeters.

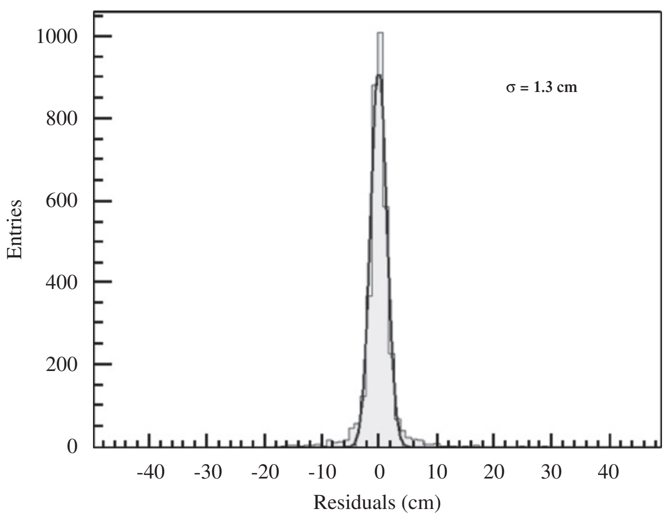

Fig. 5. Typical residuals distribution for a single chamber.

3.2. *Efficiency results*

The track reconstruction handles the DT, CSC and RPC reconstructed segments/hits and it can be configured in such a way to exclude the measurements from one or more muon subsystems. In our case is relevant the possibility to reconstruct a track using only DT information and to extrapolate it to the nearest RPC detector surface. Residuals distributions of the track coordinates with respect to the RPC hits position can be calculated. In Fig. 4 an example of a track extrapolation through sector 10 of W_0 is shown. RPC fired strips are also highlighted.

Distribution of residuals between RPC hit position and coordinates of track extrapolation is shown in Fig. 5. The sigma of the distribution $\sigma = 1.3\,\mathrm{cm}$ is compatible with the expected space resolution.

Local efficiencies can also be measured. Event by event, the chamber is considered efficient if a strip is fired exactly in the same eta-partition where the hit was predicted, in a fiducial region of ± 2 strips around the predicted one.

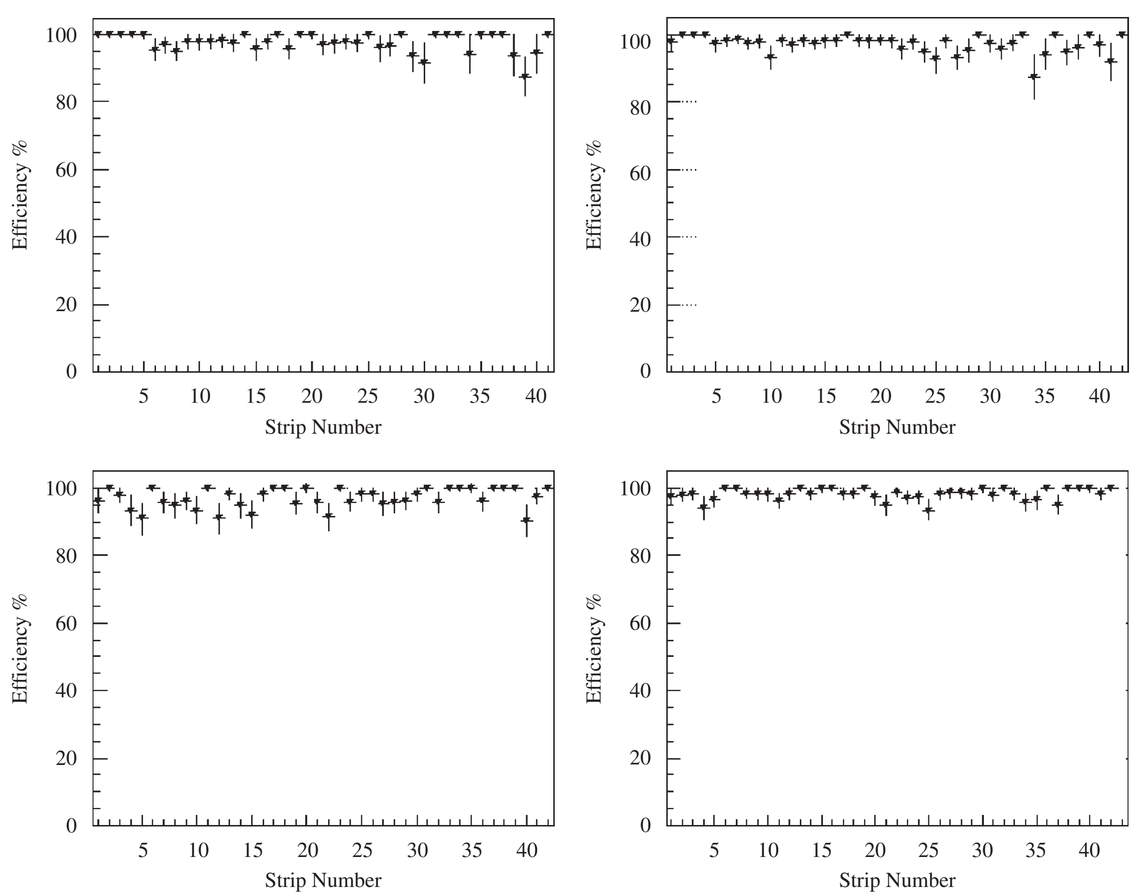

Fig. 6. Local efficiency for the third station of sector 10, W_0 at HV = 9.2 kV and Th = 220 mV.

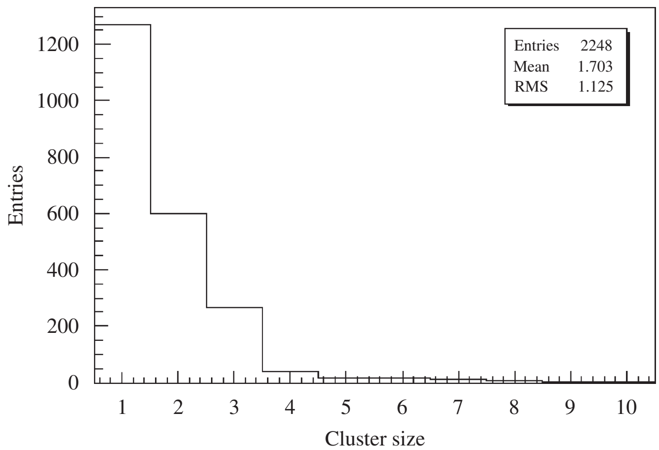

Fig. 7. Cluster size distribution for all chambers at HV = 9.2 kV.

In Fig. 6, local efficiency for an entire station (four RPC chambers in sector 10, W_0) is reported.

The RPC trigger performance depends also on the hit cluster size, defined as the number of adjacent fired strips. A large (greater than 2) cluster size could introduce uncertainty in the muon pattern recognition algorithm and originate a significant number of ghost events [8,9]. In Fig. 7 an overall cluster size distribution is shown considering simultaneously for all W_0 chambers.

4. Conclusion

The RPC group is proceeding toward a systematic commissioning with cosmic rays to determine noise and efficiency performance of the detector. The study of the noise level has allowed the discover of hot areas (noisy chips and front-ends) and the determination of the most effective front-end threshold. The development of track reconstruction algorithm in the muon system has furthermore allowed the evaluation of the detector efficiency. The system behaved steadily with excellent performance and all tested chambers have shown an efficiency greater than 95% and an average cluster size below 2.

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