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Results from a complete simulation study of the RPC based muon trigger system for the CMS experiment

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Abstract

The performance of the Resistive Plate Chambers-based muon trigger of the CMS detector has been studied by means of a full simulation of the system under realistic operating conditions. Requirements on the performance of the chambers are deduced.

1. Introduction

The CMS muon trigger system [1] based on the Resistive plate chambers (RPCs) [2] will have to fulfill two basic requirements, namely, efficient detection of high transverse momentum (p_t) muons and high rejection of uninteresting events. The achievement of the former goal mainly depends on the efficiency and timing properties of RPCs. On the other hand, the RPC cluster size and the random hits, due to both the spurious hits in the chambers and to the severe background expected at the LHC, represents a major source of fake triggers.

2. The RPC trigger for CMS and its simulation

The RPC trigger relies on the 4 T strong solenoidal magnetic field of the apparatus to estimate the muons transverse momentum (p_t) from the track bending. Four RPC planes are used in the trigger which is based on a pattern recognition algorithm [3]. Each valid pattern is associated a maximal p_t value. In the simulation of the RPC trigger [4], the RPCs have been assumed to be uniformly efficient and to have a gaussian time response. The contribution to the time jitter from the front-end electronics and cables has been also assumed to be Gaussian with an r.m.s. of 1 ns. The signal propagation speed along the strips has been set to $0.66c$. In this study, the width of the time windows in which the signals are accepted is 20 ns for all chambers, but the opening time varies according to the chamber location in CMS. The

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cluster size has been parametrized according to the distribution function $\exp(-x/cs_{RPC})$, where cs_{RPC} is a parameter given in units of strips. The experimentally observed [2] time delay between strips of a cluster has been parametrized with the distribution function $\exp(-t/\Delta T)$ where the value $\Delta T = 3$ ns has proven to fit well experimental data. Both the rate due to the RPC spurious hits ($noise_{RPC}$) and to the hits produced by neutral particle fluxes have been assumed to be poisson distributed. The rate of the latter source has been parametrized according to the distributions that can be found in [5] multiplied by the factor rate_fac.

3. Results of the simulation

In Fig. 1 it is shown the RPC trigger efficiency for various combinations of the RPC time resolution (σ_{RPC}) and RPC efficiency (ε_{RPC}). The plot refers to $50 < p_t < 70$ GeV/c muons in the pseudorapidity region $-0.06 < \eta < 0.06$. The applied transverse momentum cut (p_t^{cut}) is 5 GeV/c. It is evident that the drop of the trigger efficiency is not particularly dramatic even in a very pessimistic scenario: $\sigma_{RPC} = 4.5$ ns and $\varepsilon_{RPC} = 90\%$. Fig. 2 shows the integrated single prompt muon spectrum expected in CMS [6] together with the calculated RPC trigger rate on these prompt muon events as a function of the p_t^{cut}. The trigger rate has been obtained by convoluting the muon spectrum with trigger efficiency curves for each p_t^{cut} bin value reported on Fig. 2. Three different scenarios are presented: (a) ideal trigger ($\varepsilon_{RPC} = 100\%$, $\sigma_{RPC} = 0.0$ ns, $cs_{RPC} = 0$ strips, $noise_{RPC} = 0\,\mathrm{Hz\,cm^{-2}}$, rate_fac = 0), (b) realistic conditions ($cs_{RPC} = 1.3$ strips, $noise_{RPC} = 10\,\mathrm{Hz\,cm^{-2}}$, rate_fac = 1), (c) pessimistic realistic conditions ($cs_{RPC} = 2.0$ strips, $noise_{RPC} = 50\,\mathrm{Hz\,cm^{-2}}$, rate_fac = 5). In cases (b) and (c) it has been used $\sigma_{RPC} = 2.5$ ns and $\varepsilon_{RPC} = 98\%$. The cut in p_t starts having some effect at about 3 GeV/c and is quite selective up to 30 GeV/c after which only tiny reductions in the trigger rate can be obtained. In fact, the RPC space resolution does not allow to easily distinguish 30 GeV/c from higher p_t tracks. For $p_t^{cut} > 20$ GeV/c the trigger rate under realistic conditions is increased by about a factor 2 with respect to the ideal case and the difference grows with p_t^{cut}. This can be understood if one recalls that the logic of the algorithm is such that higher p_t patterns are preferred. Cluster size hits or an aligned random hit can give rise to a pattern which is straighter than the actual one and therefore the

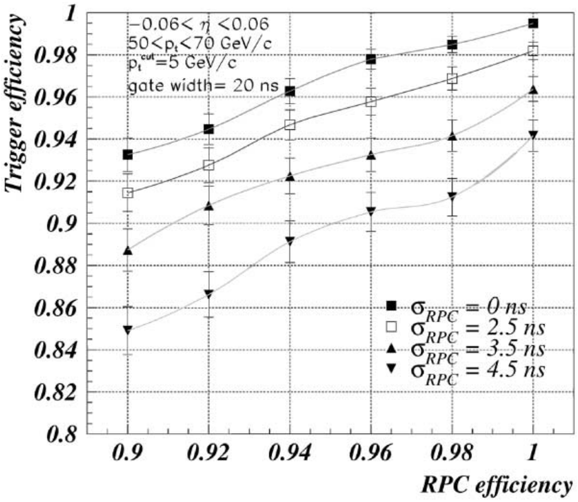

Fig. 1. Trigger efficiency versus RPC efficiency for various values of the RPC time resolution.

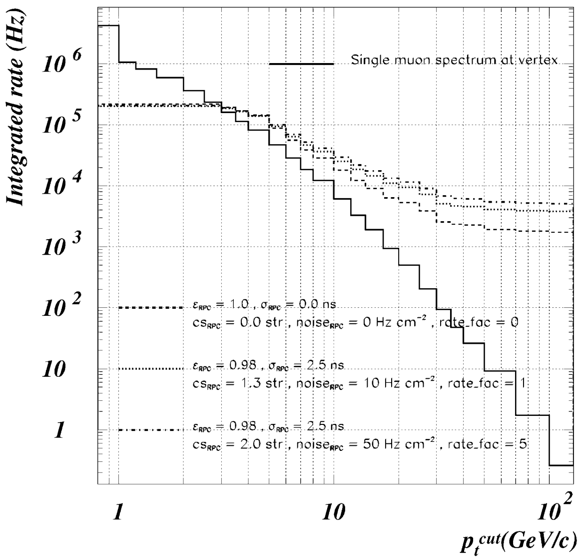

Fig. 2. Integrated spectrum of single muon produced at the vertex (full line) versus p_t^{cut} and RPC trigger rate in three different scenarios as indicated on the picture.

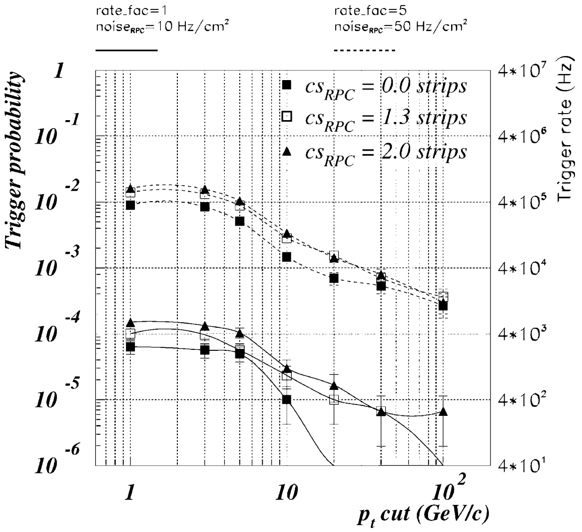

Fig. 3. RPC fake trigger probability and corresponding trigger rate versus muon p_t^{cut}.

muon will be assigned a higher p_t. The trigger rates shown in Fig. 2 only results from the rare events having a muon produced at the vertex. This rate is increased by the fake triggers on those events with no muon at the vertex. Fig. 3 shows the fake trigger probability as a function of the p_t^{cut} under different conditions from the point of view of rate and cluster size. Again $\sigma_{RPC} = 2.5$ ns and $\varepsilon_{RPC} = 98\%$. The main conclusion one can draw is that values of noise$_{RPC}$ sensibly greater than 10 Hz cm^{-2} would result in an unacceptably high total trigger rate. In conclusion, the results of this study show that in order to avoid efficiency losses of the trigger greater than 10% of the value attainable with ideal detectors RPCs are required to have an intrinsic time resolution not exceeding 3.5 ns and an efficiency greater than 90%. Moreover, it has been shown that the cluster size and the RPC intrinsic noise may become quite critical for the trigger system. Further studies should be done to understand the effects of muons coming from pions and kaons decay on the trigger rate. Nevertheless, one must remember that the final word on the CMS muon trigger system should be given after combining the RPC trigger with the DT + CSC trigger and the calorimeter trigger. Future studies are also expected in this direction.

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