CMS muon system performance

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Abstract

The CMS muon system is taking cosmic data since 2006 and is using them to study the performance of the three different detector technologies and triggers (drift tube, cathode strip chambers and resistive plate chambers). The muon system is described placing emphasis on the software tools that were developed and used to take data and to study, online and offline, the performance of the muon system. The results obtained analyzing up to 300 millions of cosmics acquired with the CMS detector will be described.

Presented at TIPP09, Tsukuba, Japan, March 12, 2009
1 Introduction

The aim of the CMS[1] muon system is to trigger, identify muons and to measure the transverse momentum. Using only the muon system, the expected transverse momentum resolution is around 9% at 200 GeV and will be contained between 15% and 40% for TeV muons. Combining with the tracker info, these resolutions can be reduced respectively to 1% for low pt muons and 5% for TeV muons[2]. To achieve this goal, three different technologies are used in the CMS detector: the drift tubes (DT) in the barrel, the cathode strip chambers (CSC) in the endcaps and the resistive plate chambers (RPC) in both barrel and endcaps[3].

2 The muon system

2.1 The drift tubes

The DT system covers a region up to \(|\eta|=1.2\) using 250 chambers, organized in five wheels. From the interaction point, a central muon will cross four stations. The first three stations are made of three superlayers (SL), two \(\phi\)-SLs and one \(\theta\)-SL, while the outermost stations are made of two \(\phi\)-SLs. Finally, each SL contains four single layers. For such a central muon, the maximum number of hits could be 44, with 32 in the r-\(\phi\) plane and 12 in the \(\theta\) direction.

The total number of DT cells is 172000, containing a mixture of Ar (85%) and CO\(_2\) (15%). The hit position is derived from the linear relation between the drift velocity (54.3 \(\mu\)m/ns) and the measured time of arrival of the electrons on the anode wire. The hit resolution reached in the r-\(\phi\) plane is contained between 200 and 250 \(\mu\)m.

2.2 The cathode strip chambers

The endcaps are equipped with 468 CSC chambers, covering the region between \(|\eta|=0.9\) and \(|\eta|=2.4\), overlapping with the DT system up to \(|\eta|=1.2\). At high pseudorapidity, a muon will cross three or four stations. The CSCs are multiwires proportional chambers, so as to be operated in large and inhomogeneous B fields. Each station contains six gas gaps, with wires perpendicular to the cathode strips, allowing the r-\(\phi\) and \(\theta\) measurements simultaneously.

The CSC system have more than 180000 read-out channels. The gas mixture chosen is Ar (40%), CO\(_2\) (50%) and CF\(_4\) (10%).

2.3 The resistive plate chambers

The RPCs are a complementary system, in order to trigger and to tag the bunch crossing time (25 ns) of an event without ambiguity. 480 RPC stations are located in the barrel, with the same coverage as the DT system and they are organized in six layers. 432 RPC chambers are currently in the endcaps, covering the region up to \(|\eta|=1.6\) and organized in three layers. In the high luminosity design, they will be extended to four layers, up to \(|\eta|=2.1\) using a total of 540 RPCs.

Each RPC station is made of a double gas gap and can operate at high rate, up to \(10^3\) Hz/cm\(^2\). They provide a fast response and a very good time resolution, of the order of one ns, using the following gas mixture: \(C_2H_2F_4\) (96.2%), iso - C\(_4\)H\(_{10}\) (3.5%) and SF\(_6\) (0.3%).

3 Performances of the muon system

3.1 Data taken with CMS

The CMS detector acquires cosmic data since 2006, starting with the Magnet Test and Cosmic Challenge (MTCC)[4] on surface. During 2007, all parts of the muon system were commissioned on surface and then in the pit. The first global run, with all other CMS subdetectors and without B field, took place in April and May 2008, so that CMS was ready in September 2008 for the first proton-proton beams. The next two months were employed for a “Cosmic Run At Four Tesla” (CRAFT) with the full CMS detector and nominal B field (3.8 T). During this period more than 290 millions cosmic data were recorded using the whole muon system.
3.2 Chamber efficiency

The first performance criteria is the detection efficiency. The cell efficiency is defined as the ratio of the number of hits over the number of reconstructed muons passing through this cell. The result obtained from the CRAFT data is shown in Fig.3.2 for the DT system. The average efficiency per SL is close to 99% for all SLs.

![Cell efficiency per SL in CRAFT data.](image)

Figure 1: Cell efficiency per SL in CRAFT data.

3.3 Muon reconstruction in the barrel

A selection is applied to ensure that the reconstructed muons contain at least two segments in both bottom and top sectors of the barrel muon system. The Monte Carlo (MC) simulation [5] is normalized to the number of events passing this selection. The direction of arrival is presented in Fig.2 and Fig.3 for the CRAFT data, representing respectively the $\phi$ and $\eta$ variables. Both distributions are using global muons, which is the combination of the muon system and tracker information.

![Direction of arrival $\phi$, shown for global muons (GLB mu).](image)

Figure 2: Direction of arrival $\phi$, shown for global muons (GLB mu).

![Direction of arrival $\eta$, shown for global muons (GLB mu).](image)

Figure 3: Direction of arrival $\eta$, shown for global muons (GLB mu).

The $\phi$ distribution is well symmetrized as expected. The $\eta$ distribution shows an asymmetry due to the CMS shaft. The data and the simulation are in good agreement, as well as the $\phi$ distribution.
3.4 Muon reconstruction in the endcaps

Two other distributions are shown for reconstructed endcap muons. First of all, in Fig.4 a quality criteria is presented: the number of hits per segment.

The distribution is peaked at six, which is the maximum number of hits in one CSC. The simulation agrees with the data.

Finally the transverse momentum of reconstructed endcap muons is shown in Fig.5. The whole spectrum up to several hundred GeV is reconstructed. There is a very good agreement between data and MC for both low momenta with high statistics, as well as in the tail of the distribution for high momenta.

4 Conclusion

Three different technologies (drift tubes, cathode strip chambers and resistive plate chambers) are used in the CMS muon system, so as to trigger, identify muons and perform the momentum measurement. Around 300 million cosmic events were recorded during the CRAFT run, using the full detector and the nominal B field. All subdetectors were fully installed, commissioned and worked very well. All distributions of basic quantities (numbers of hits, direction of arrival and transverse momentum) are in very good agreement between data and MC. Finally, the first p-p beams were also seen with beam halo muons passing through both barrel and endcaps.

Acknowledgments

This work was supported by the BMBF (Bundesministerium für Bildung und Forschung).

References

[1] The CMS Collaboration, Technical proposal, CERN/LHCC 94-038 (1994).
[2] The CMS Collaboration, The CMS experiment at the CERN LHC, JINST 3 S08004 (2008).
[3] The CMS Collaboration, The Muon Project, Technical Design Report, CERN/LHCC 97-31, CMS TDR2 (1997).
[4] The CMS Collaboration, The CMS Magnet Test and Cosmic Challenge (MTCC Phase I and II) Operational Experience and Lessons Learnt, CMS NOTE 2007/005.
[5] CMS Cosmic GENerator (CMSCGEN), https://twiki.cern.ch/twiki/bin/view/CMS/CMSCGEN.