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The Compact Muon Solenoid Experiment

Conference Report

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Commissioning of the CMS Detector

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Abstract

The status of the commissioning of the CMS detector is summarized and some of the achievements of the past year are highlighted. Preliminary results presented in this note used the big amount of cosmic data collected during 2008 and events produced by the first LHC beams.

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Commissioning of the CMS Detector

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1 Introduction

The Compact Muon Solenoid [1] (CMS) is one of the four experiments operating at the CERN Large Hadron Collider (LHC). A schematic view of the detector is shown in Fig. 1. The tracking system is made of a pixel detector close to the beam pipe surrounded by a silicon strip detector: its high granularity (70 millions pixels, 10 millions strips) and precision ensures good track reconstruction efficiency. It is placed inside a 3.8T superconducting solenoid together with the electromagnetic calorimeter (ECAL), made of lead tungstate crystals, and the brass-scintillator sampling hadronic calorimeter (HCAL). Forward sampling calorimeters increase the pseudo-rapidity coverage up to $|\eta| \leq 5$. The magnet return yoke is instrumented with 4 stations of muon chambers: Drift Tubes (DT) in the barrel region, Cathode Strip Chambers (CSC) in the endcap, Resistive Plate Chambers (RPC), providing a better time resolution, in both; they cover most of the 4π solid angle.

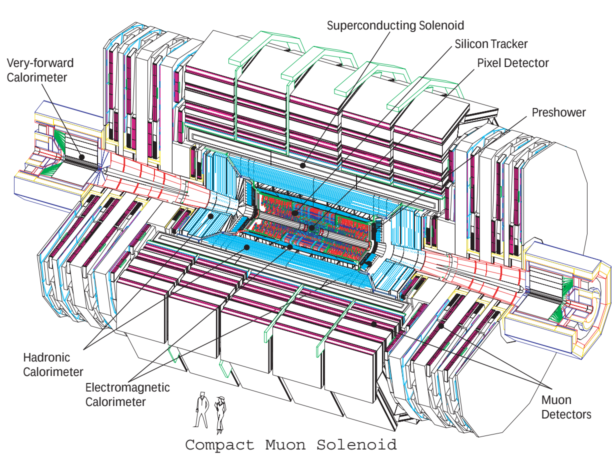

Figure 1: Schematic view of the CMS Detector

2 Data collected during 2008

A total of 350M events were collected with magnet off in common (with all the available subdetectors) data taking configuration, the majority between May and August during the four cosmic data taking campaigns called CRUZETs (Cosmic RUn at Zero Tesla), but some events were also recorded during the circulation of LHC beams between the 10^{th} and the 19^{th} of September. In October, during the four weeks of CRAFT (Cosmic Run At Four Tesla), 290M events were collected with magnet at 3.8T.
During the first half of 2008 there was a frenetic activity to complete the installation of all subdetectors in the underground cavern and by the time of the fourth CRUZET only the Preshower and the RPCs of one endcap were missing; they are currently being installed.

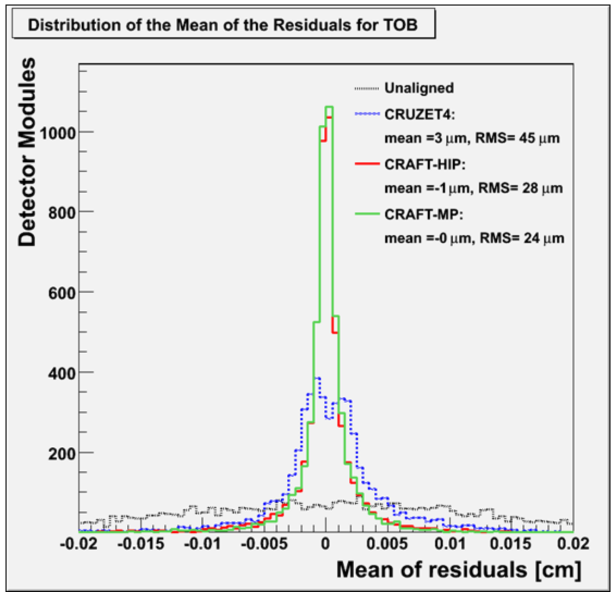

Figure 2: Residual distribution for the Tracker Outer Barrel (TOB)

3 Studies using cosmic muons

The big amount of cosmic data available was really useful to spot problems, exercise the full hardware/software chain, from the on-detector electronics to the GRID-based data analyses, and verify performances of the different subdetectors. Some preliminary results are summarized in the following paragraphs.

3.1 Track reconstruction systems

Measurements of occupancies and efficiencies in detecting the crossing muons were performed both in the muon chambers and the tracking system in order to verify the hardware status and settings (power and trigger systems, front end electronics, etc.). The efficiencies obtained were almost 100% in all the layers in operation.
Space resolutions were evaluated from the standard deviation of the residual distributions $(X_{FitTrack} - X_{RecHit})$. In Fig. 2 the residual distribution for the TOB (Tracker Outer Barrel) is shown for two different track-based alignment algorithms: a local iterative method called HIP [2] and a global method, accounting for global correlations, called MillePede [3]. The best resolution obtained is $\sigma = 24\mu m$ and the mean value, sensitive to module displacements, is $0\mu m$.

In the DTs the worst resolution values, $\sigma \sim 200-260\mu m$ (however compatible with Monte Carlo simulations), were obtained in the chambers of the external wheels, where the magnetic field has a large radial component.
This component of the magnetic field, perpendicular to the chambers, also causes a smaller effective drift velocity, due to the fact that particles have to travel longer paths to reach the wire, because of the transverse Lorentz force; this effect was clearly observed, especially in the innermost stations of the outer wheels.

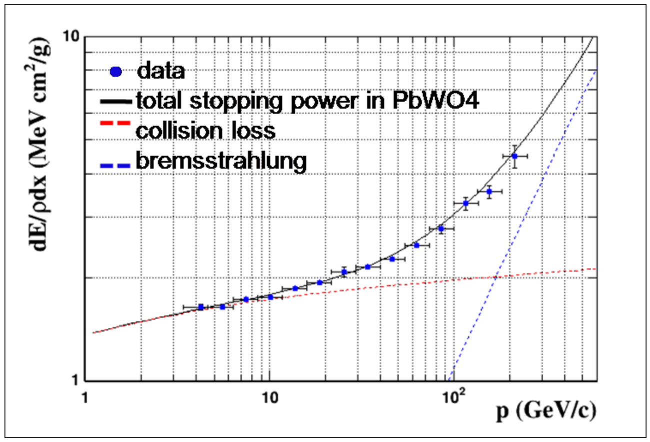

Figure 3: ECAL Stopping power

3.2 Calorimeters

The stopping power (energy deposit corrected for the muon path length) for muons crossing the ECAL is shown in Fig. 3 as a function of the muon momentum as measured by the tracker. The good agreement between the data and the theoretical curve proves the correctness of both the tracker momentum scale and the ECAL energy scale, calibrated with e^- at test beams. Similar good results were also obtained for the HCAL energy scale.

Cosmic muons were also used to perform some physics analysis, like a measurement of the charge ratio, of the moon shadow (the moon screens the cosmic rays flux) and others. For instance, the angle distribution was measured: an excess of muons in certain regions was found and understood as due to an increased acceptance through the access shafts of CMS.

4 Events produced by the first LHC beams

Two types of events were produced when beams were circulating in LHC:

- *Beam-Splash* events: the beam (2x10^9 protons) was deviated against one collimator placed 150m upstream of CMS

Hundreds of thousands of muons were produced in these events and passed through the detector. During LHC collisions this will never happen, but this type of events offered the possibility to stress our system. Hits in the detectors were recorded also in these extreme conditions and meaningful measurements were possible, as it can be seen in Fig. 4(a) where the good linear correlation between reconstructed energies in the Barrel HCAL and ECAL is shown.

- *Beam-Halo* events: caused by interactions of the beam protons with beam gas

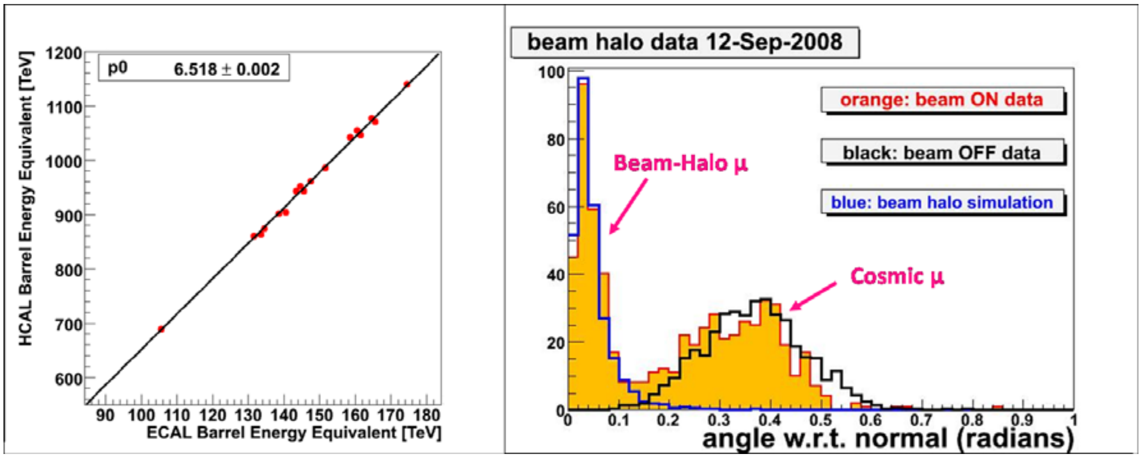

Figure 4: (a) Linear correlation between reconstructed energies in HCAL and ECAL in Beam-Splash events; (b) Angle distributions of reconstructed muon tracks

Usually one muon (rarely two) was produced and crossed the whole detector. While cosmic muons in CMS are mainly vertical tracks, beam-halo muons made a small angle with respect to the beam direction (see Fig 4(b)). They were particularly useful for subdetectors placed vertically in the endcaps (like CSCs), since their direction is more similar to what these subdetectors were designed to detect during collisions.
For example, CSCs could perform track-based alignment using these events, achieving accuracies of $270\mu m, 0.35 mrad$, comparable to the photogrammetry results, with just 9 minutes of LHC beam.

5 Conclusions

The commissioning of the CMS detector is at a very good stage. Several tests performed during last year confirm that our subdetectors work as expected. During the winter shutdown the needed repairs were performed and the missing parts (Preshower and the RPC endcap) will be completed soon. In the summer, more cosmic data will be collected, also with the magnet on, while waiting for LHC to start.

References

1. CMS Collaboration (R. Adolphi *et al*) *JINST* **3**, S08004 (2008).
2. V. Karimäki *et al*, *The HIP Algorithm for Track Based Alignment and its Application to the CMS Pixel Detector*, CMS NOTE 2006/018.
3. P. Schleper *et al*, *Alignment of the CMS silicon tracker using Millepede II*, CMS NOTE 2008/029.