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The Compact Muon Solenoid Experiment

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# The Compact Muon Solenoid detector

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**Abstract**

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After a brief overview of the Compact Muon Solenoid experiment, the final detector installation and its commissioning in 2008 is reviewed. Preliminary results from the subdetectors commissioning during the long Cosmic muon Run At Four Tesla (CRAFT) field are shown together with few results from the first beam events.

*Key words:*
LHC, CMS, Commissioning

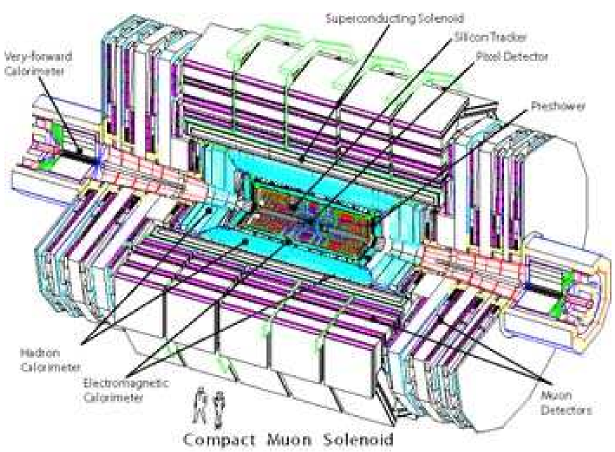


Figure 1: Schematic view of CMS

## 1. Introduction

The **C**ompact **M**uon **S**olenoid[1] (figure 1) is one of the two multi-purpose experiments at the CERN **L**arge **H**adron **C**ollider. At design luminosity ($10^{34} cm^{-2} s^{-1}$), the 7 TeV proton beams will cross inside CMS every 25 ns providing and average of 20 collisions per crossing, leading to up to 1000 tracks in the detector . In order to sustain such a rate, a high granularity detector is built around the 3.8 T superconducting coil. Inside it, the inner tracking comprises a pixel detector ( 3 barrel layers of and 2 end cap disks on each side) surrounded by the Si Strip detector (10 barrel layers,9 disks on each side). Its high granularity (70 millions pixels, 10 millions strips) and precision ensures good track reconstruction efficiency. It is surrounded by Electromagnetic calorimeter made of 76000 lead tungstate crystals grouped in 36 barrel supermodules and 4 endcap "D"s. The brass-scintillator sampling hadron calorimeter completes the in-coil detectors. Both calorimeters cover a range of pseudo-rapidity $|\eta| < 3$ and contribute towards the level 1 trigger. They are extended, away from the central detector, by the hadron outer detector and a quartz fiber very forward calorimeter to cover $|\eta| < 5$. The magnet return yoke is equiped with 4 stations of muon chambers (**D**rift **T**ube in the barrel region, **C**athode **S**trip **C**hambers in the endcap, **R**esistive **P**late **C**hambers in both parts, providing muon detection redundancy ) that are also part of the level 1 trigger. This level 1 trigger reduces the event rate from 40 MHz to 100 kHz. The events are then collected and reconstructed and filtered by the High Level Trigger PC farm down to 100 Hz of event stored on disk. The only missing subdetector in 2008 was the End cap Preshower that is currently being installed.

## 2. Detector status in 2008

The beam pipe was installed during spring 2008 while the Si Strip tracker was cabled and commissioned. The pixel detector was then installed and commissioned beginning of summer. The ECAL barrel was in operation since autumn 2007 and the two end caps were installed and commissioned during last summer. The HCAL is fully operational and the forward calorimeter (HF) was raised to its final position before the first beam. The solenoid coil was on during the autumn run at its nominal 3.8 Tesla field. All muon chambers were operational but the end cap RPC still being commissioned. The Level 1 trigger and data acquisition are commissioned and several tests of high rate and bandwidth were performed successfully. The High Level Trigger infrastructure is deployed and tested and was used to filter cosmic muon events.

## 3. Results with first beam

In September 2008 LHC ran up to the $19^{th}$ when an interconnection between 2 magnets broke leading to a pre-

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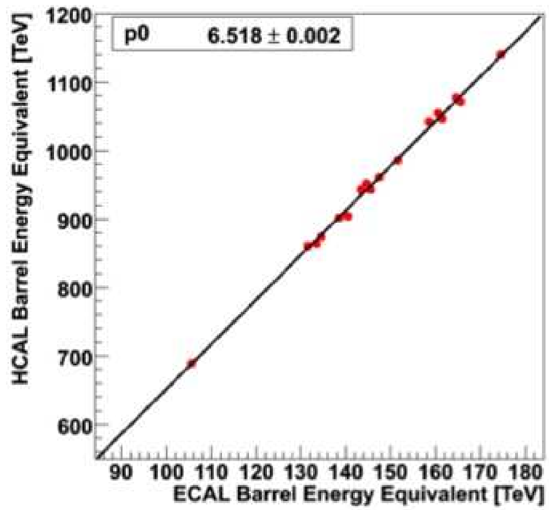


Figure 2: Correlation between ECAL and HCAL energy reconstructed for beam splash Event

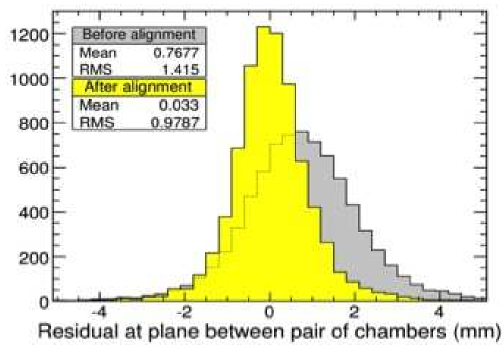


Figure 3: CSC alignment residuals with beam halo events

mature shutdown. Two kinds of data sample were collected before, beam splash and beam halo events. Beam splashes are created by single shot of LHC beam 1 onto the collimator placed 150 m upstream to CMS. These shots generated several hundred of thousands of muons. They were first used to synchronize our beam monitoring system to the beam timing and further to use the beam monitoring system as a trigger. With such trigger we were able to record events with all CMS sub detectors apart from the tracking devices. More than 99 % of the ECAL channels were fired and can be aligned in time within 1 ns . Figure 2 shows the correlation between reconstructed energy in ECAL and HCAL for such events where up to 1100 TeV was deposited in the calorimeters.

Once the beams circulated, muons generated in beam halo interactions were collected. Mainly parallel to the beam they were used both for timing studies and CSC alignment. Figure 3 shows the alignment procedure that reached a resolution of 1 mm for the chambers using such

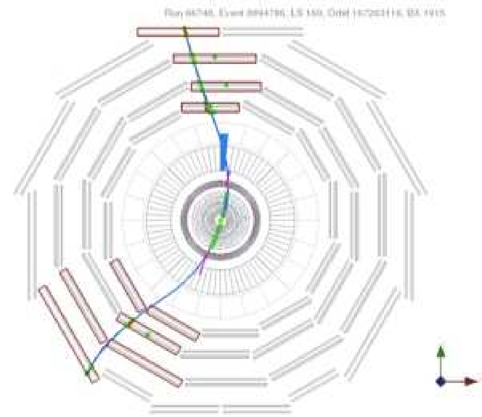

Figure 4: A typical cosmic muon event taken during the CRAFT event.

## 4. Cosmic Run AT Four Tesla

After the LHC shutdown it was decided to operate CMS for one month at nominal magnetic field (3.8 Tesla) in order to study data collection efficiency and to collect large statistics of cosmic muons for calibration purposes.The data taking lengthened by 4 weeks collected 370 million of events, and 290 millions with magnetic field on, where both tracking detectors and drift tube chambers were read out. The overall acquisition efficiency is around 60 %. Figure 5 shows the evolution of the statistics collected during CRAFT. Long stable runs of more than 24 hours were taken. Figure 4 shows a typical event where the DT, HCAL, ECAL and the tracker are hit.

The Si Strip Tacker was commissioned with this data set. 97 % of the inner barrel ( ˜ 1.5 % recovered since CRAFT), 98.9 % of the outer barrel and 99.3 % of the end cap modules were operational. The signal to noise ratio measured of 32 on 500 μm wafers and 25 on 320 μm fitted to the expectations. 99.2 % of the 66 millions pixels of the barrel functioned. In the endcap 6 % were lost due to a power supply cable problem during the installation and have been recovered later during the winter shutdown. The average noise measured on Barrel and End cap pixels is 200 e- and 130 e- respectively. Tracks are reconstructed using three different algorithms tuned for cosmic muon reconstruction . On selected pointing particles all three exceed 99 % efficiency on the whole momentum range. The alignment is based on the Millipede algorithm[2]. With the available statistic the precision of the procedure is 14 μm in the barrel pixel and between 10 and 30 μm in the strip tracker.

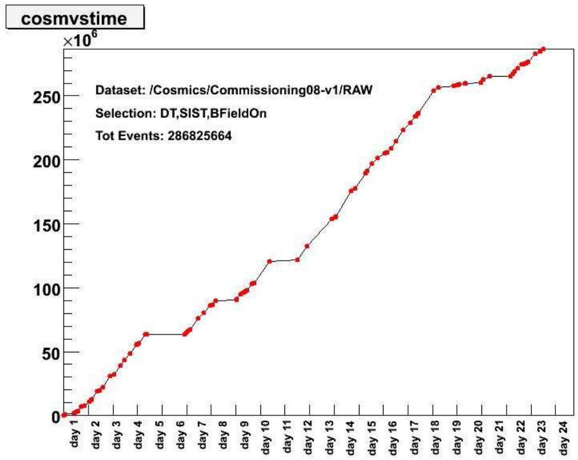


Figure 5: Integrated statistic collected during the CRAFT

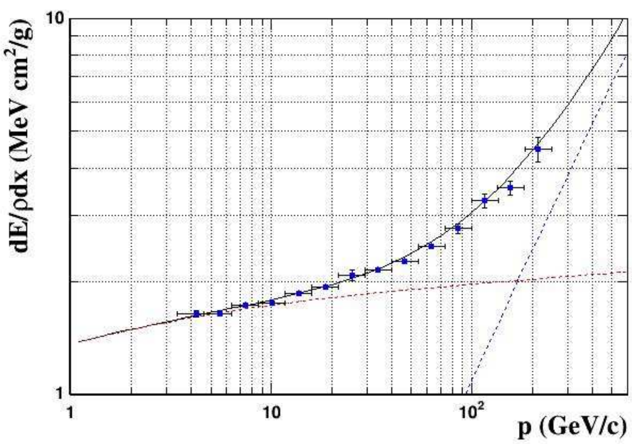


Figure 6: Energy deposit in the ECAL versus track momentum. The path length is estimated from the propagation of the track in the crystals

The ECAL was operated with an higher gain (x4) than in normal LHC operation. Figure 6 shows the stopping power of the ECAL, confirming the correctness of the tracker momentum scale and of the energy scale in ECAL calibrated with electron at test beams. Similar comparison was achieved with the HCAL mean deposit energy and good agreement with Monte Carlo expectation was observed.

The average Drift Tube single cell efficiency exceeds 98.5 % and the measured resolution ranges between 200 and 260 μm in reasonably good agreement with Monte Carlo expectation.

## 5. Conclusion

The year 2008 saw the achievment of almost 20 years of development and building of CMS. The detector was almost completed, fully commissioned and ready to acquire the first LHC event in September 2008. A long cosmic data taking then confirmed that all components are operational and close to their performance design specifications. After the End cap preshower installation, cosmic runs are currently resumed to recommission the detector in order to be ready for the first LHC collisions expected this autumn.

## References

[1] G. L. Bayatian et al., CMS technical design report, volume II: Physics performance, J. Phys. G 34 (2007) 995.

[2] G Flucke et al., CMS silicon tracker alignment strategy with the Millepede II algorithm,2008 JINST 3 P09002