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Status and Commissioning of the CMS experiment

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Abstract

The construction status of the CMS experiment at the Large Hadron Collider and strategies for commissioning the subdetectors, the magnet, the trigger and the data acquisition are described. The first operations of CMS as a unified system, using either cosmic rays or test data, and the planned activities until the startup of the LHC are presented.

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1. Introduction

Compact Muon Solenoid (CMS) [1] is a multi-purpose experiment designed for the study of new physics which may manifest itself in proton-proton or heavy-ion collisions delivered by CERN's Large Hadron Collider (LHC). The detector features an inner tracker, which consists of a pixel detector and a silicon strip tracker, a lead tungstate crystal electromagnetic calorimeter (ECAL), a brass-scintillator central hadronic calorimeter (HCAL), a superconducting magnet coil, and a muon system made of drift tube (DT), cathode strip (CSC) and resistive plate chambers (RPC). A forward hadronic calorimeter (HF) consisting of two steel and quartz-fibre elements located on both sides of the experiment, close to the beam pipe, completes the apparatus. A custom-developed level-1 trigger and a high-level trigger and data acquisition (DAQ) based almost entirely on industrial components serve to select the collisions in real-time and to read out the corresponding detector data. CMS is located in a newly constructed cavern of the LHC. In order to make use of the time needed for completing the cavern civil engineering, the detector has been pre-assembled and tested in a hall on the surface. A scheme using a rented gantry crane to lower big units of CMS has been developed. More than half of the large wheels, including the heaviest central wheel weighing 1900 tons, have already been successfully lowered into the cavern (Figs. 1 and 2). Final assembly and commissioning takes place underground. Calibration and commissioning tools before the availability of collisions include cosmic rays, lasers, LED's, test pulses and patterns as well as test beams.

2. Inner Tracker

Silicon detectors fulfill the requirements of good spatial resolution, high speed and radiation tolerance. Therefore CMS has chosen an all-silicon solution for its inner tracking detectors. The inner tracker consists of two basic components, the pixel detector close to the beam pipe and the silicon strip tracker surrounding it.

The pixel detector has three layers in the central region located at radii of 4.4, 7.3 and 10.2 cm. Forward layers are located at ± 34 cm and ± 46 cm from the interaction point. The silicon pixel pads, 100 μm $\times$ 150 μm in area, provide a spatial resolution better than 20 μm.

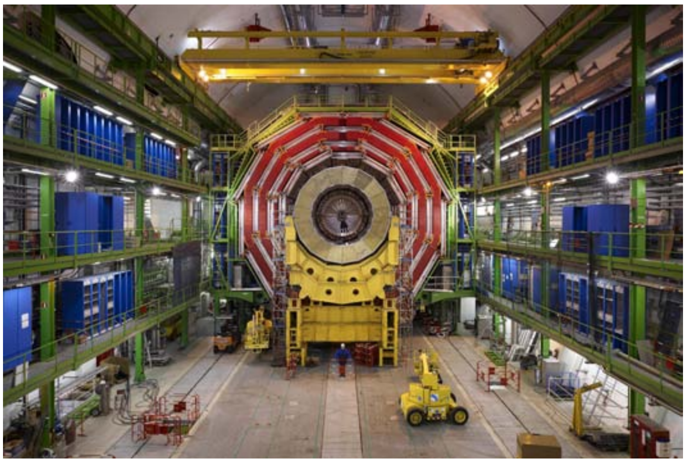

Figure 1. Part of CMS in cavern.

Figure 2. Lowering of central wheel with magnet coil.

Readout chips in 0.25 μm CMOS technology, 16000 in total, are bump-bonded to the silicon sensors. The radiation environment is challenging. During ten years of LHC operation a dose of 1 MGy is expected, which makes it necessary to replace the innermost pixel layer after a few years. The pixel module production is completed to 75%, and a system test of 12 modules is under way. The construction of the support tube is finished. The barrel supply tube delivering power, cooling, controls and housing auxiliary electronics is also completed. The first quarter of the endcaps has been delivered in May 2007. The last endcap quarter is expected by Oct. 2007. The final pixel detector will be available by Jan. 2008, in time for the first LHC collisions.

The silicon strip tracker (SST) occupies the region with radii between 20 cm and 1.10 m. The sensors, covering a total area of 220 m^2, are p-in-n type microstrips. SST assembly at a dedicated clean-room area at CERN, the Tracker Integration Facility, including insertion in the support tube was terminated in March 2007. Tests with cosmic muons have been performed, with several million events recorded. The operating temperature ranged between room temperature and -15^0C. Only a few per mille of dead or noisy strips were found, and the signal-to-noise ratio was always better than 25:1. The laser alignment system has been successfully commissioned. The goal for alignment until April 2008 is to achieve a value better than 100 μm for tracker and pixels combined. This number is foreseen to decrease to fewer than 30 μm after about two months of collisions. Installation of the SST electronics in the CMS cavern has begun. The tracker is expected to be operational by Nov. 2008.

3. Calorimetry

All $PbWO_4$ crystals for the barrel part of the electromagnetic calorimeter have been delivered. They are housed in 36 supermodules, which have all been installed in the cavern. Cabling should be terminated in Sep. 2007. The delivery of endcap crystals manufactured in China and Russia is foreseen to end in March 2008. The first endcap Dee will be ready for installation in March 2008. Construction of the second one should finish by summer 2008. In the endcap regions a preshower detector will help to separate photons from π^0's and identify diphoton vertices. It is a two-layer sampling calorimeter each consisting of a lead absorber and silicon microstrip detectors behind. Completion is planned for March 2008.

The barrel and endcap parts of the central hadron calorimeter consist of alternating plates of brass and plastic scintillator read out by photodiodes through wavelength shifting optical fibres. Most HCAL modules are installed underground. A test beam for electromagnetic/hadronic ratio measurements in the endcaps has been underway since July 2007. Commissioning of the barrel modules underground starts in Aug. 2007. The forward hadronic calorimeter consists of steel absorber plates sampled by quartz fibres due to their good radiation tolerance, read out by conventional photomultipliers as the magnetic field is much lower than in the central region. HF was the first subdetector to record cosmic particles in the cavern at the end of March 2007.

4. Magnet

The superconducting solenoid is the characterizing piece of CMS. It achieves a magnetic flux density of 4 T, with a current of 19.5 kA. It first reached its nominal magnetic field during the so-called Magnet Test and Cosmic Challenge performed in the surface hall in summer 2006. Commissioning of the coil in its final location has started, after installation of sevices. Cooldown will be possible from Sep. 2007. Testing at low current will be be performed in Nov. 2007, and one week of final commissioning up to the nominal current as well as one slow dump at 14 kA will be undertaken in March 2008.

5. Muon System

All 468 CSC and all DT and RPC except a few chambers are installed on the wheels. Commissioning with cosmics is going on underground for the central and negative side wheels, and in the surface hall for the remaining positive side wheels until their lowering between Oct. and Dec. 2007.

6. Trigger and Data Acquisition

The installation of the trigger hardware in the underground control room next to the experimental cavern is mostly completed. The trigger and timing control distribution is also almost done. Commissioning with test patterns and cosmics is ongoing. The current emphasis is on integrating and testing all subdetectors with the trigger. The front-end of the data acquisition located underground and the links between the cavern and the DAQ building on the surface are installed and tested. The readout and builder units on the surface are being deployed. Gigabit Ethernet switches are installed. Mass storage components with 22 TB capacity are ordered.

7. Commissioning and Startup Schedule

Since May 2007 so-called Global Runs using cosmics and test data take place at the end of each month. Subdetectors are being successively brought in. All detectors except the ECAL endcaps and the pixel detector will be tested between Oct. and Dec. 2007. After closing and baking out the LHC beam pipe, the Pixel Detector and one ECAL endcap will be installed during Feb. 2008. Testing of CMS with all subdetector types present will be possible afterwards. Closing of the experiment for initial collisions is planned for Apr. 2008. The first first physics run will start in summer 2008.

8. Conclusions

CMS construction is coming to an end. Extensive tests of the complete detector are ongoing and will continue throughout the first semester of 2008.

Acknowledgments

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References

[1] `http://cms.cern.ch`