CMS Muon System Status

Marcos Fernández García

Instituto de Física de Cantabria, Avda. los Castros, s/n, E-39005 Santander, Spain

E-mail: Marcos.Fernandez@cern.ch

Abstract.
The status of the Muon System of the Compact Muon Solenoid (CMS) is presented in this paper. First, the design parameters for the spectrometer are quoted. Then, a brief description of each detection technology (Drift Tubes in the barrel region, Cathode Strip Chambers in the endcaps and Resistive Plate Chambers both in barrel and endcaps) precedes an update of its current status. A short term forecast of the expected dates of completion is given.

1. The Muon System Design parameters

The CMS muon system [1] has been designed to provide redundant and fast identification (trigger) and momentum measurement of the muons traversing it. The ultimate momentum resolution $\Delta p_T/p_T$ will be obtained later, when the muon track tailored by the Global Muon Trigger (>96% efficiency), is complemented with the more precise tracker measurement (including the vertex constraint) [2]. Roughly a factor 3-5 (depending on the muon energy and pseudorapidity) is gained in this process. Thus, a momentum resolution down to 2% is obtained for p_T <100 GeV (all pseudorapidities) or 18% for the most forward 1 TeV muon measurable by the spectrometer.

Three types of gaseous detection technologies (see Fig. 1) have been chosen according to the different background rates and magnetic field the detectors will have to withstand. Where neutron background (muon signal) is small 1-10 (1) Hz/cm^2 drift tube chambers (DT) are used. In the endcap region where the background (signal) rate is higher 1000 (200) Hz/cm^2 and the magnetic field is more intense than in the barrel, cathode strip chambers (CSC) were selected. DTs and CSCs, both with self-trigger capabilities, can be used to measure the momentum and the time of crossing of the muon. Still, unambiguous bunch crossing (bx) identification is obtained using Resistive Plate Chambers (RPCs) both in the barrel and endcaps, providing a fast and accurate ($\sim$1 ns) time measurement.

2. The Barrel Muon System: Drift Tube Chambers

The barrel system is divided into 5 independent wheels. Each wheel (see Fig. 1 and 2) is geometrically segmented into 12 sectors, 60° each. Each sector is equipped with 4 chambers, except the horizontal top and bottom sectors with 6 chambers each.

Each chamber from the 3 innermost rings performs 2 independent ϕ and one θ measurements. Chambers from ring 4 measure only the ϕ coordinate. Each chamber provides a muon vector in space with precision $\phi \sim 100$ μm, $\theta \sim 150$ μm and $\sim$1 mrad in direction. Each (ϕ or θ) measurement is provided by the so-called chamber SuperLayer (SL). A SL is in turn a stack of

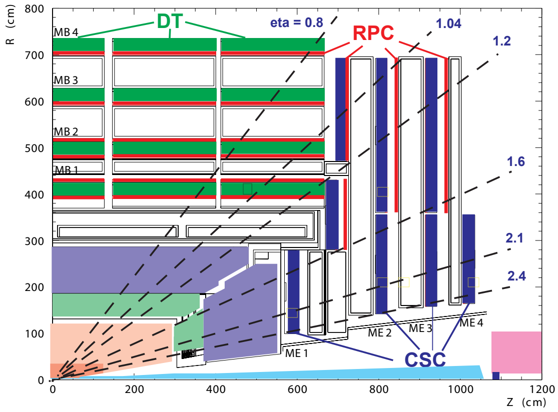

Figure 1. One quarter of the CMS experiment for the initial low luminosity run. The Muon Barrel system extends $|R| > 350$ cm and $|Z|$ <700 cm (chambers are shown in green color). In the endcap part CSC chambers (noted as ME) are clearly visible (blue color). RPCs are displayed in red color in the barrel and endcap parts.

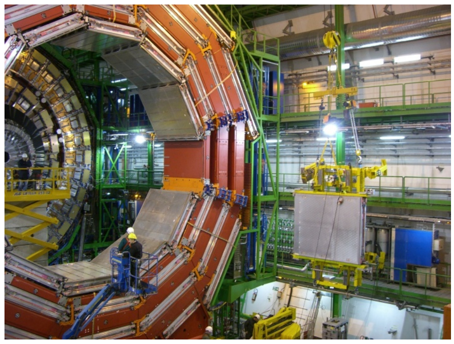

Figure 2. Insertion of one of the last DT chambers (coming from the right) in the horizontal sector 1 of wheel +2. Counted anticlockwise, sectors 1 to 6 (top) and 9-12 are seen. Within sector 1, one can observe the different size of the DT chambers and the overlap between sectors. DT have RPCs attached before being installed.

4 staggered layers of drift cells (250 μm cell resolution). The drift cell design provides a linear space-time relationship of the drift electrons. The gas mixture employed is Ar(85%)/CO_2(15%).

Each DT holds its readout and part of the L1 trigger electronics embedded in a custom electronics crate, so-called MiniCrate (MC), physically attached to the chamber. Inside the MC, Bunch and Track Identifier chips (BTI) for each layer try to find time alignment of hits compatible with a muon crossing. These chips provide track parameters and are able to assign the correct bx to the event. Segments provided by both ϕ-SL are combined at the TRACO, which tries to correlate them, suppressing noise hits. The best 2 segments are delivered by the TS to the regional trigger.

Status of the DTs
All chambers were individually commissioned at the ISR facility at CERN prior to installation on surface. All chambers are now installed except 8 of them whose pockets are used to attach the gantry cables to lower the wheel (Fig. 2). Once installed, the chambers were commissioned in the wheels. Afterwards the wheels are dressed with cables (HV, LV, cooling, gas,...) and chambers are recommissioned as part of their sectors. At the time of writing, only negative wheels stay on the surface. In parallel, installation of tower electronics and cabling to USC is ongoing. Underground commissioning ending date will happen most likely one month after the negative wheels are lowered.

3. The Endcap Muon System: Cathode Strip Chambers

CSCs are multiwire proportional chambers comprised of 6 anode wire planes interleaved perpendicularly to 7 cathode panels with strips milled on them. Strips run radially according to CMS coordinates. By interpolating charges induced in the strips from the avalanche of positive ions near a wire, a precise ϕ localization 75 (inner ring)-150 μm is obtained. Angular resolution in ϕ is of order 10 mrad. The wire signals give fast and precise time information ($\sim$ 4.5 ns) with coarser spatial resolution $16-54mm$. For the 72 smallest ME1/1, anode wires are rotated by 29° to compensate the Lorentz force under the 4T, avoiding electron charge to be spread along the wires. Each wire plane is sub-divided by spacer bars into 5 independent HV segments. Nominal operation point is 3.6 kV. The nominal gas mixture is Ar(30%)+CO_2(50%)+CH_4(20%)

FPGA based anode trigger boards are placed on the top face of the chambers. Wire patterns compatible with a track (Anode Local Charged Tracks or ALCT) are already trigger primitives. The corresponding cathode trigger boards are in crates around each disc. Up to 2 matched anode and cathode LCTs per bunch crossing and chamber are sorted out by Trigger Mother Boards. The 3 best candidates are forwarded to the Track Finder.

Status of the CSCs
All 468 chambers have been mounted (See Fig. 3). All on chamber electronics, peripheral crates and electronics from discs have been installed and commissioned. Chamber commissioning and slice tests continues. After negative discs are lowered, cabling and other critical activities will run in parallel. Ready by March 08.

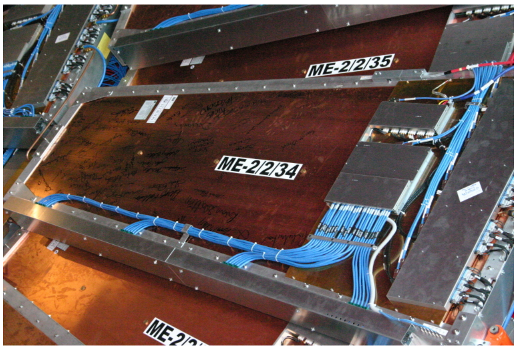

Figure 3. One of CSC mounted in wheel -2

Figure 4. RPC mounted on a DT chamber.

4. Resistive Plate Chambers

Resistive Plate Chambers are made of 2 gas gaps read out by one set of copper strips placed in the middle of the gaps. Each gap is in turn made out of 2 bakelite plates filled with a closed-loop gas mixture of $C_2H_2F_4$(96.2%), i-C_4H_{10}(3.5%), SF_6(0.3%). Chambers are operated in avalanche mode ensuring proper operation at rates of up to 10 kHz/cm^2. They guarantee a precise bunch crossing assignment thanks to their fast response and good time resolution. Muons are reconstructed from correlated patterns of hits in several stations.

There are 2 RPC chambers in stations 1 and 2 in the barrel, and 1 for stations 3 and 4 (see Fig. 1 and 4). There are 3 rings of 4 stations in the endcaps. For the low luminosity phase the innermost ring and the outermost stations have been staged ($|\eta| > 1.6$).

Status of the RPCs
Barrel and forward chambers are installed (except in the horizontal sectors), cabled and precommissioned (gas tightness, HV/LV tested). Barrel (forward) full commissioning expected by Feb 08 (Nov. 07). Long term tests of gas parameters ongoing at the ISR facility.

References

[1] The CMS Collaboration, *CMS physics: Technical Design Report*, CERN-LHCC-2006-001 ; CMS-TDR-008-1
[2] The CMS Collaboration, *The TriDAS Project Technical Design Report, Volume 1:The Trigger Systems*, CERN/LHCC 2000 - 38, CMS TDR 6.1, December 15, 2000