Integration and Installation of the CMS Electronics system

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Abstract

The electronics systems used to control, trigger, and acquire data from the four experiments at LHC are, for the field of High Energy Physics, of unprecedented level of complexity and sophistication.

In the case of CMS, the users are gaining access to the underground counting room (USC55) at a late stage with respect to the official LHC start-up date.

Measures taken to reduce the time required between when the access is granted for installation and the experiment is ready for physics are presented along with the current status and plans.

I. INTRODUCTION

When it became obvious that the CMS cavern was going to be delivered to the collaboration at a very late stage, measures were taken to cope with the situation. In fact, neither the underground counting room USC55, nor the underground experimental cavern UXC55, is fully available for electronics installation to date.

In order to allow pre-integration of subsystems prior to installation in USC55 an Electronics Integration Centre (EIC) has been put in place.

All subsystems have also means to make internal tests between on-detector electronics and the part of the electronics system to be installed in USC55. As an example, the integration centre of the silicon tracker in building 186 has a quarter of the readout electronics installed in order to fully test the detector before it is transported to the experimental cavern for final installation and commissioning.

II. THE ELECTRONICS INTEGRATION CENTRE

An Electronics Integration Centre (EIC, in building 904, CERN), used by all electronics subsystems across CMS, was created in order to allow system integration to take place during the year before any electronics could be installed in the underground counting room. The goal is to use, as far as practical, the same technology and the same techniques in the EIC as will be used in the underground counting room.

The electronics integration centre is currently being intensively used by practically all subsystems, including the Detector Security System (DSS) which is, as in USC55, responsible for the safety in the racks where the electronics modules under test are located.

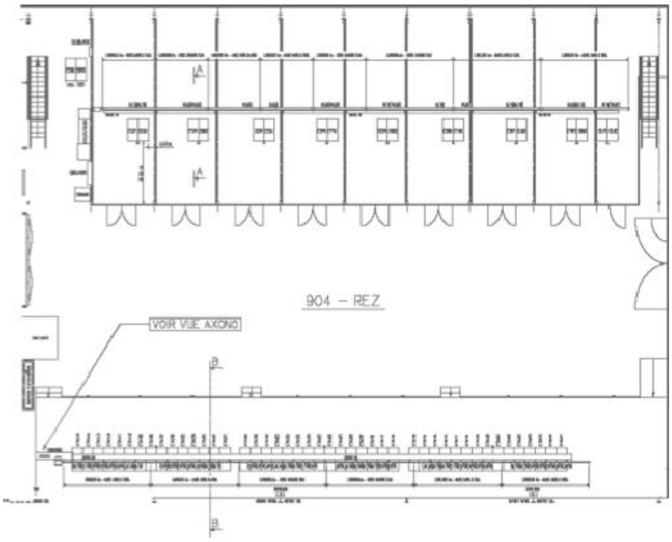

Figure 1: Drawing of the EIC: The “private” labs on top and the integration area on the bottom

Every subsystem has a “private” room allocated in which two standard racks, a cupboard, and a workbench is available. The “private” room is intended for test and development of the electronic modules used in the subsystem.

The integration centre provides also three rows of 15 standard LHC racks with water cooled heat exchangers. One row is used for system integration, one for sub-system burn-in, and the last row for burn-in of low voltage power supplies.

Figure 2: The integration area in the CMS Electronics Integration Centre; the first 15 racks are for system integration, the second 15 are for burn-in, and the last 15 racks are being used for burn-in of the low voltage power supplies.

III. THE COSMIC CHALLENGE DURING THE CMS MAGNET TEST

As an additional test, most subsystems contribute to an integration test attached in time to the CMS magnet test with the goal to detect, trigger, and read out events originating from cosmic particles. The event goes under the name Magnet Test Cosmic Challenge (MTCC).

Fractions of the sub-detectors have been mounted in the final positions inside and outside the large solenoid which contributes with the S in CMS. A complete slice of the electronics for the control, trigger, and readout systems is deployed, providing the opportunity to test and verify the interoperability of the sub-detector electronics systems with the level 1 trigger and the DAQ system before the experiment is lowered and installed in the and the CMS electronics system is finally installed for commissioning in the underground control room.

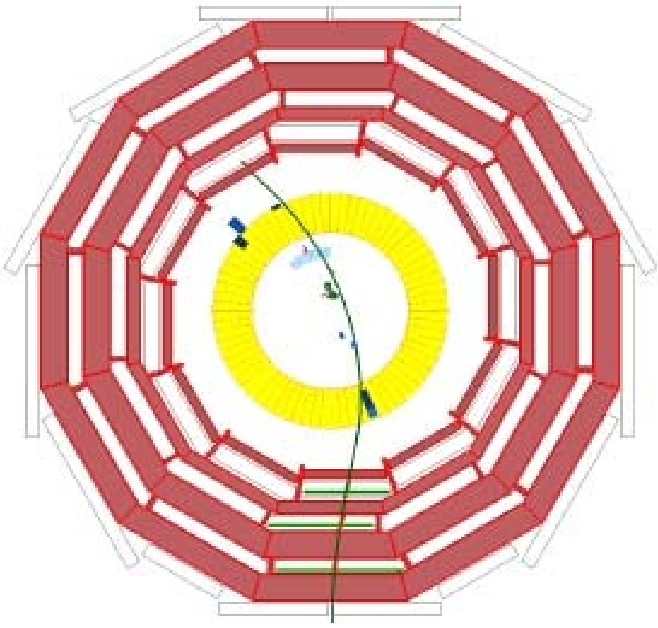

Figure 3: MTCC event display showing a cosmic muon making a trace through the HCAL, the ECAL, and the tracker, and out through the barrel muon detector (DT) on the bottom, actually proving that these sub-systems perform together in a magnetic field of 3.8T.

IV. INSTALLATION OF ELECTRONICS SUBSYSTEMS IN USC55

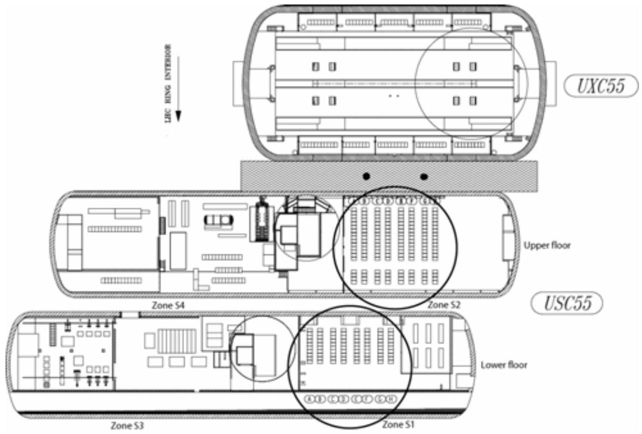

Figure 4: Point 5 Underground Area; The experimental cavern UXC55 with the adjacent, albeit a 7 meter thick concrete wall, underground counting room USC55, consisting of two floors.

A. *Installation readiness*

After a successful integration in the EIC, every subsystem has to go through an installation readiness review where every system having a direct interface has to agree that no visible problem exist. This review is estimated to be a useful preparation for installation, leaving only the new interconnects to verify during and after installation. Obviously, if a sub-detector has successfully participated in MTCC, the sub-system is considered as being ready to be installed.

B. *The overall plan*

The overall plan for installation of support infrastructure at point 5 is vast and very difficult to overlook. It integrates the day to day work of external subcontractors performing a large variety of tasks, including installation of cables, cooling and gas pipes, security systems, etc. The responsibility for the overall plan and the coordination of the work is with the CERN group TS-LEA.

C. *The Electronics installation plan*

The plan for the electronics installation in USC55 has initially been developed together with TS-LEA. As the site becomes ready, the actual plan for the electronics installation is detached.

Currently, the only resource considered in the plan for the electronics installation is space. It has been assumed that, on average, the time needed to install one rack of electronics in USC55 is one week. During this time, the access to the front and to the rear of the row of racks is prohibited to other groups. The outcome of the planning exercise is that the whole counting room should be possible to install and test in three months, including internal testing with local DAQ.

The result is a detailed day to day program. It is to be understood that the planning only provides an indication about the priority between the subsystems. In fact, almost half of the S1 level of USC55 is housing the readout and control system for the tracker, one quarter the global and muon triggers and the TTC (Trigger, Timing and Control), and the last quarter the readout of pixels, barrel muon drift tubes (DT), and end-cap muon chambers (CSC). The S2 level has mainly ECAL readout and high voltage, HCAL readout and high voltage, and the regional calorimeter trigger (RCT).

As can be noticed in figure 4 and figure 5 the S2 floor is more advanced than S1. There are several reasons. First of all, before any useful tests can be done involving readout electronics the PC area, located in S2, has to be ready and powered. This is actually possible only since one week. The real reason, however, is a problem with failing cooling manifolds. When the bad quality of the manifolds was discovered during a final reception test in June 2006 it was decided that the S2 floor had to be dealt with first since any leaking water could damage equipment installed in S1.

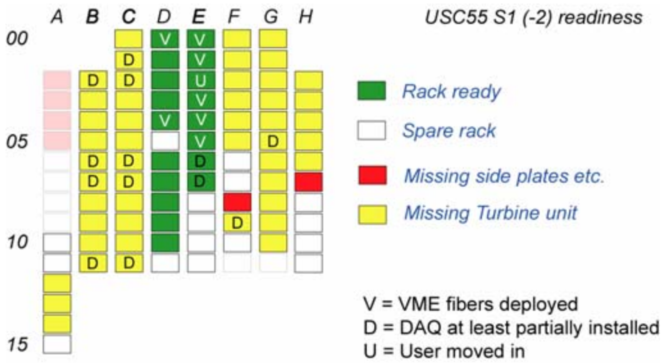

Figure 5: Electronics installation readiness of the USC55 S1 floor

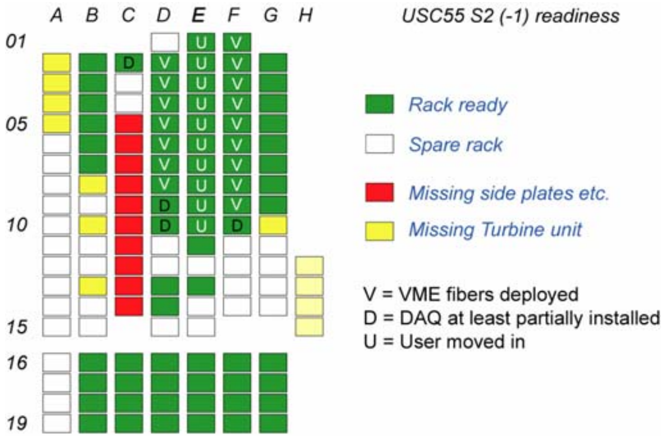

Figure 6: Electronics installation readiness of the USC55 S2 floor

Considering that that point 5 is a construction site only partially in the hands of the users, the installation of each subsystem has to follow the program with great precision, i.e. start and finish on time. Failing to do so, the user might see the access to the underground control room refused the next morning due to some scheduled event.

V. Installation Status

Considering the Electronics installation readiness of the underground control room it is easy to understand that not much electronics has been installed to date in USC55. The electronics subsystem are, however, practically all ready for installation, several in their entirety. The approximate production and integration status for different subsystems can be found in table 1.

Table 1: Subsystem production and integration status

Subsystem	Production Status	Integration Status
Pixel	Preseries	No
Tracker	100%	MTCC OK
ECAL readout	75%	MTCC OK
Preshower	Prototype	No
HCAL	100%	MTCC OK
DT readout	75%	MTCC OK
DT Track Finder	75%	MTCC OK
RPC trigger	In production	MTCC OK
CSC readout	100%	MTCC OK
CSC Track finder	100%	MTCC OK
RCT	100%	MTCC II
GCT	Prototype	No
GT	100%	MTCC II
TTC	100%	MTCC OK
DAQ	100%	MTCC OK

The status of the physical installation in the USC55 can be found in table 2. Please note that so far no electronics integration has been possible due to lack of power in the PC racks.

Table 2: Subsystem physical installation status

Subsystem	items	Integration
HCAL	HTR crate	5%
RCT	Infrastructure	100%
TTC	Infrastructure	25%
DAQ	User interface	75%

The official target dates for different levels of operation can be found in table 3. Considering the installation readiness of the subsystems, these target dates are considered reasonable.

Table 3: Installation target dates

Milestone	Target date
Ready for powered crates	October 2006
Electronics installation	October – December 2006
System commissioning	January to March 2007

VI. Maintenance of Electronics Systems in EIC

After completion of the electronics system commissioning, the EIC facility will continue to serve as a centre for hardware, firmware, and software development. This development may be either for upgrades, or to achieve the design performance of the experiment.

The task to develop new firmware builds, actually solving more problems than they create, is likely to become major. No guarantees can be given that the initial developers, who have the detailed knowledge about how and why the system actually works, are available even one year after the first physics run. Thus one important task may be to educate new experts, capable of understanding the detailed behaviour of the hardware and firmware. The value of having a complete slice of the experiment, at least for the level 1 trigger system, cannot be overestimated.

The plan is to provide such a slice in EIC, after the CMS electronics system has been commissioned, throughout the lifetime of the experiment.

VII. References and Acknowledgements

This paper is based on information obtained through private communication with Jordan Nash (CERN PH/CME), Tim Christiansen (CERN PH/CMM), Jan Troska (CERN PH/MIC), Wesley Smith (University of Wisconsin), and information obtained during numerous meetings and through work at the CMS experimental site (Point 5, Cessy, France).

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