Nuclear Instruments and Methods in Physics Research A 596 (2008) 13–16

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

The CMS Tracker End-Caps integration

Gaëlle Boudoul [a,b,*]

[a] IPNL, Université de Lyon, Université de Lyon 1 IN2P3/CNRS, 4 Rue E. Fermi, 69622 Villeurbanne cedex, France
[b] CERN 1211, Genève, Switzerland

On behalf the CMS Tracker Collaboration

A R T I C L E I N F O

Available online 29 July 2008

Keywords:
LHC
CMS
Tracker

A B S T R A C T

The two CMS Tracker End-Caps (TECs) consist of nine disks each, totalling 6400 silicon modules mounted on 288 intermediate sub-structures: the "petals", a carbon fiber plated honeycomb support which carries up to 28 modules arranged in seven radial rings. One of the TECs has been integrated at CERN by IPN Lyon, while the second one was assembled in RWTH-Aachen I. This contribution describes in detail the integration procedures, including: the qualification of petals before insertion, the sector by sector (18 petals) mechanical integration inside the TEC structure and the commissioning at room temperature and in the cold at -20°. The problems encountered during the whole assembly procedure and their solutions will be reported as well as the final performance of the two TECs. Both are now integrated in the CMS Tracker tube together with the Inner and Outer Barrel part. We will show the noise performance obtained under these conditions.

1. The CMS tracker end caps presentation

CMS (Compact Muon Solenoid) [1] is one of the two general purpose experiments at the Large Hadron Collider (LHC) at CERN. With more than 15 000 silicon strip modules and a silicon area of about 200 m^2, the CMS silicon strip tracker is the largest one ever built. It is composed of four subdetectors: the inner barrel (TIB) with four cylindrical layers of modules, the inner disks (TID) consisting of three disks on each side of TIB, the outer barrel (TOB) with six cylindrical layers, and the two end caps (TECs) called TEC+ and TEC− according to their location with respect to the interaction point. Each TEC is composed of nine disks.

A TEC covers a pseudorapidity region between 0.9 and 2.5, with the disks located at distances between 1.2 and 2.8 m from the interaction point. Both TECs represent more than half of the tracker volume and carry about 42% of the total number of modules.

2. Petal qualification

A TEC petal is a structure with a mean area of 0.3 m^2 of silicon strip detectors divided into 17–28 individual modules positioned with a 20 μm precision on two sides of a carbon-fibre honeycomb structure. The modules are of 10 different types arranged in seven rings concentric to the beam pipe.

Petals can be individually removed from the end caps without uncabling or disassembling the entire structure. The silicon modules [2], analog opto-hybrids (AOHS) and control modules (CCUM) on the petals are connected to printed boards, called InterConnect Boards (ICB), which are mounted on both sides of the petal. Once assembled, they undergo a qualification test which consists of six temperature cycles between room temperature and -20° over 3 days.

Cooling is provided by means of a 7 m long titanium cooling pipe with an inner diameter of 3.4 mm running below the modules inside the honeycomb structure. Each module is screwed onto up to four aluminium inserts that are milled to a relative mechanical precision of 5 μm and are glued to the cooling pipe, thus providing the thermal contact to the C_6F_{14} coolant.

Two hundred and ninety-two petals have been built at an average rate of 1 per day by seven institutes: RWTH-Aachen 1, RWTH-Aachen 3, IIHE (ULB-VUB)-Brussels, Hamburg-Univ., IEKP-Karlsruhe, FINU/UCL-Louvain, IPHC-Strasbourg [3]. In order to speed up the production and qualification of the petals, a new center was installed at CERN in 2006. Two kinds of set-up were entirely developed for the construction: one for the assembly including a partial functionality test; the other for the detailed qualification, including full petal read-out (for about 15 000 channels per petal).

* Corresponding author at: IPNL, Université de Lyon, Université de Lyon 1 IN2P3/CNRS, 4 Rue E. Fermi, 69622 Villeurbanne cedex, France.
E-mail address: Gaelle.Boudoul@cern.ch

0168-9002/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2008.07.128

3. TEC integration

Prior to the petal integration, the TEC structure was fully equipped with their cooling, electrical and optical services. As well, each petal, already fully qualified, underwent a last test consisting of an optical inspection and a basic readout before being mounting onto the disks of the TEC structure. Aachen-I assembled the TEC+ while Lyon integrated the TEC− at CERN. The same integration procedures were used for both TECs:

The petal insertion was performed by sectors consisting of nine front petals and nine back petals, in total 400 modules and 944 optical fibers (Fig. 1). Those 18 petals share nine readout control rings and four cooling circuits. The nine back petals are the first integrated, slided on the disks to their final position with the TEC in horizontal position, they are then fixed with a three point fixation mechanism. After a 180° rotation of the TEC, the operation is repeated for the nine front petals to complete a sector. The rotation operation can be easily done manually in the custom made craddle holding the TEC. Due to geometrical constraints in the petal fixations, back petals can only be removed if the associated front petal on the other disk side is first extracted. This feature makes the exchange of a back petal more complicated and risky.

Once all petals of a sector are inserted, the 944 fibers of a sector have to be carefully cleaned and plugged to 12 fibre ribbons running along the side of the TEC up to a patch panel connection to final optical cables. The power groups and the cooling pipes are also connected to the petals at the edge of the disks. The validation test of each sector consists of 10 main steps: a check of the read-out control ring stability, a test of the I^2C bus communication, a connection run (to debug missing optical connections), a timing run, a gain scan, a longer timing run (to debug low gain fibers), a HV test up to 450 V, pedestal runs in peak and deconvolution mode, readout of DCUs, and laser alignment.

To speed up the whole integration process, this sequence was modified at some point by integrating two sectors at once (insertion and cabling of 18 back petals, rotation of the TEC then insertion and cabling of the 18 corresponding front petals). The commissioning sequence was then being run but for two sectors at the same time.

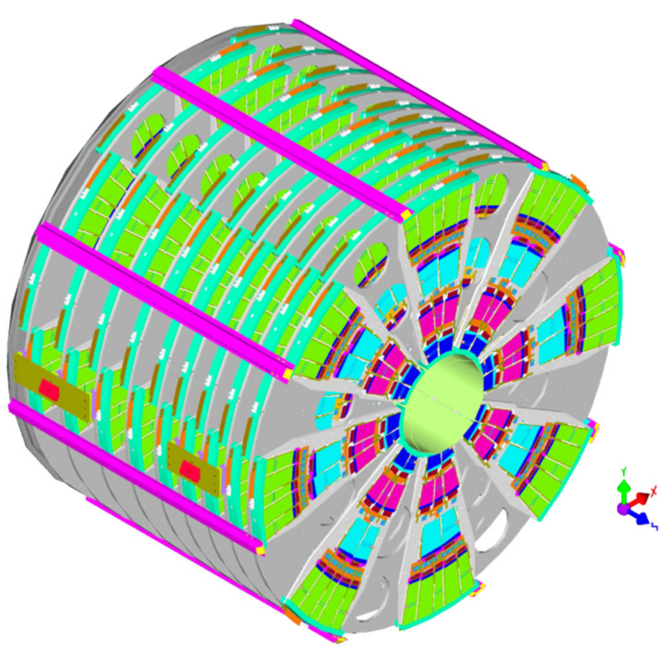

Fig. 1. The tracker end cap design, highlighting a tower (nine front petals + nine back petals).

Once the TECs were fully equipped and qualified, they underwent a cold test inside a dedicated room installed at CERN. Commissioning tests were performed in a temperature range from 20 to −20°. A dry air supply flushed the TEC volume and the cold room itself with a dew point at the output of −70°. This system was connected to an Uninterruptible Power Supply and a second spare dry air system was also installed in case of failure. Three electrical heaters were installed inside the cold room to speed up the warm-up phase. A dedicated system of temperature and humidity control was installed both outside and inside the TEC envelop of carbon fiber skins in order to monitor the operating conditions with the slowcontrol system. In addition to the standard slowcontrol provided by the CMS tracker team, alarms (red flags on the slowcontrol screen, SMS sent on the shifter mobile phones) allowed the shifters to react quickly in case of any kind of problems. Moreover interlocks were also installed directly on the dry air supply in case of the presence of humidity in the flow. Fig. 2 shows the hybrid and the silicon temperature histogram obtained in the cold configuration (−20° in the cooling liquid and in the environment).

4. Problems encountered and solutions

4.1. TEC cable problem

During the test of the fourth sector (sector #7) in Aachen, some unreliabilities were observed on LV connections (the noise on one

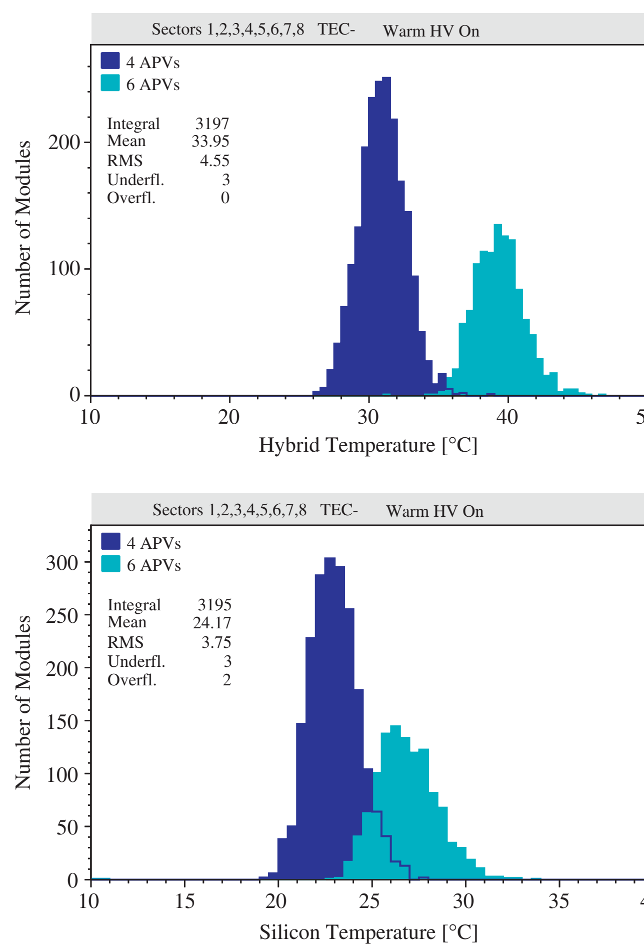

Fig. 2. Temperature measured on the hybrid (up) and in the silicon modules during cold tests (−20°). The two peaks corresponds to modules with 4 APVs and 6 APVs.