# Status of CMS

## Progress Summary Report for April 2009 RRB28

At the time of RRB27 six months ago, the initial CMS detector was operating at full magnetic field in a cosmics run including the following subsystems: barrel and endcap pixels; silicon strip Tracker, barrel and endcap crystal electromagnetic calorimeter (ECAL), hadronic calorimeter (barrel, endcap and forward HCAL), Muons (DTs, CSCs and RPCs), Level-1 Trigger, and 50 kHz DAQ. This run continued for six weeks, during which 300 million cosmic triggers were recorded, thus providing for a wealth of detector commissioning results discussed below. After the cosmics run ended, the detector was opened for a broad program of carefully selected maintenance and repair activities, as well as the installation of the preshower subdetector on both endcaps. This programme has been progressing according to the schedule laid down in November 2008. The highlights are:

a) the completion of the repairs to the barrel muon DT system
b) the removal and repair, and re-insertion of the forward pixel system
c) the completion and installation of the preshower (ES)
d) much progress with the maintenance and repair of other sub-systems
e) good progress with the revision of the tracker cooling plant
f) the maintenance of the general cooling and electrical systems

As the shutdown plan nears completion, re-commissioning of the CMS detector and full data-flow path has begun, with mid-week-global runs every two weeks interspersed with final maintenance and consolidation activities. Powering of the tracker awaits completion of the overhaul of the cooling system, the major element found last year to be sub-par for long-term operation, as reported at RRB27. Restart of running with cosmics with magnetic field on is scheduled for July, using the online and offline software releases foreseen for running with beam in the last quarter of 2009.

As also foreseen at RRB27, the forward region has been re-engineered in order to reduce risk. Planning for re-inserting CASTOR is well advanced. The schedule for inserting TOTEM is very tight and is the subject of scrutiny at this time.

As the next run will be much longer than the originally foreseen first run with beam at the end of 2008, considerable planning is being performed to understand the implications (person-power, spares, computing resources, expert availability, etc.) in order to ensure the sustainability of all activities of CMS during and after the 2009/2010 long run.

## Installation and Infrastructure

**Status**

The 2008-09 CMS shutdown repairs and installation proceeded in three main phases as planned. In the first two phases, the dominant activity (besides heavy logistics) was maintenance and repair of the barrel muon and alignment systems on all wheels and disks (but particularly YB0). The yoke wheels at both ends are once again closed over the vactank. Phase 3 was in full swing by mid-March and reached maximum complexity, with work-intensity similar that in summer 2008. The forward pixel tracker at the +z end (FPIX+) was extracted in early March and transported to the Meyrin site for maintenance, while the installation of preshower ES+, taking place in parallel, reached the stage where the active "Dee" elements were installed and the drum structures have just been moved

back along the beampipe and re-mated to the electromagnetic endcaps. This phase 3 activity required the large "20 ton" installation platform. To avoid the risks of once again lowering more than 100 concrete blocks into the cavern, a new light-weight support structure was designed and procured by CMS engineering teams.

Whilst the ES installation and commissioning were being finished at the +z end, the platforms and infrastructure for the same operation were being prepared in parallel at the –z end. FPIX- was removed while the ES- Dees were already transported from Meyrin and lowered into UXC. By the end of April the ES installation and commissioning should be finished. Both FPIX have been reinstalled. The schedule progression after removal of the platforms will be reviewed just before the Easter break.

In parallel with the above, the annual maintenance of detector services took place from mid-November to mid-January as planned. This involved a full stoppage of water-cooling circuits on November 24th with a gradual restarting from mid-January 09. The work included the cleaning of the two SF5 cooling towers, service of the chiller plants on surface, and service of the cryogenic plant serving the CMS Magnet. The overall site power was reduced from 8 to 2 MW, in order to cope with switching to the Swiss power network in winter, and full power was reinstated at the end of January.

A bypass for the endcap circuit was installed in order to limit pressure surges when one endcap is shut-off. Filters have been added on most of the cooling loops in UXC55 to better protect the muon chambers. At the same time a global cleaning campaign of all the filters (more than 500 pieces) was completed. As expected, the level of impurities in the circuits is progressively decreasing with time.

A large intervention underground is the installation in USC55 of two spare LV transformers that will be pre-cabled to assure a quick swap in case of failure of any of the six units actually operating in S4 for the CMS Low Voltage system. These two spare transformers have been delivered to CERN.

In order to increase the online monitoring of the temperature of the detector yoke, 80 new gauges are being installed on the barrel wheels and endcap disks.

The test campaign on the new model fan turbine for the electronics racks has been completed. It performs significantly better than the existing units. The new units can operate in magnetic fields of up to 1200 Gauss. CMS and other LHC experiments are interested in replacing their current fan turbines during the current shut-down; some 500 units in total with 230 units for CMS have been ordered.

Thus the repairs, installation, and maintenance have been proceeding as planned, within a few days of the schedule foreseen at the beginning of the shutdown. There remain several installation activities in the forward region (CASTOR, ZDC, TOTEM).

**Plans for the next months**

CMS will then be closed up and returned to a state of cosmics data-taking without and with magnet on, well before the re-start of the LHC.

**Concerns**

The installation schedule for TOTEM is tight. It is not yet fully clear how much of TOTEM can be installed and how much time will be available for testing after installation.

# Magnet

**Status**

Following the successful six-week cosmics run at full operating field of 3.8 T, the magnet was warmed to room temperature at the beginning of December, and a full maintenance was performed. This included a full inspection of the cryogenics which did not reveal any flaws. Some upgrades to magnet systems were performed, including some improved vacuum gauges and some improvements in the helium transfer system. The magnet control and safety systems were also upgraded and thoroughly retested.

**Plans for 2009**

The magnet subsystems are being put back into operation, starting with the vacuum pump-down. The cool down of the coil has started and the coil should be at the operating temperature in mid-May, leaving over a month before the field is ramped up.

# Commissioning

**Status**

The main commissioning event since the last RRB has been the long cosmic run in November with the field at the nominal value of 3.8 Tesla, the Cosmic Run At Four Tesla (CRAFT). The goals of the run were to operate continuously the detector for the order of a month in order to gain operational experience and to accumulate a sample of cosmic tracks matching the one collected through all the previous Zero-Tesla (CRUZET) runs (i.e. 300 Million cosmic triggers), or expressed in different terms, to run with an average operational efficiency close to 70%. Both goals have been achieved. Several firmware issues have been identified and fixed. Analysis of the CRAFT data has been a primary focus of the Detector Performance Groups (DPGs) for calibration, alignment, and detector performance studies.

The CRAFT run has been instrumental both for commissioning the alignment and calibration procedures as well as for determining the actual constants themselves. For tracker alignment, the first alignment results became available already three days after appearance of the corresponding data at the CERN Analysis Facility (CAF). The total sample yielded more than eight million tracker-specific events with more than 60000 tracks crossing the pixel detector. The presence of the magnetic field allowed for improved treatment of multiple scattering effects which resulted in a significantly improved alignment of the tracker. Very importantly, for the first time, the alignment of the pixel tracker at the module level has been possible. Stability of the tracker geometry throughout the CRUZET and CRAFT runs has been carefully investigated. For the muon system, both track-based and optical alignment methods are providing a wealth of geometry information, both of them showing, as expected, an overall longitudinal contraction of the muon detector due to the magnetic forces. Also, expected deformations of the CSC disks are clearly observed. For the first time with real data, the use of global muon tracks has allowed the cross-alignment between the muon system and the tracker. Furthermore, a wide range of calibration constants has been determined during the CRAFT run, including the timing of the muon chambers, the gain correction factors for tracker and calorimeters, and the various sets of pedestals. A regular validation and sign-off procedure is in place and has been extensively exercised during the CRAFT data-taking and subsequent analysis periods for prompt and efficient data reprocessing. For example, a reprocessing of CRAFT data with newly derived calibration and alignment constants was launched 2 weeks after the conclusion of the CRAFT run.

The synchronization of the readout to the muon trigger was improved both for the Pixel detector, where a latency scan allowed to improve the on-track hit collection efficiency by 30%, and for the Strip detector, where a study of the inter-calibration of the signal at the module level allowed to identify incorrect assumptions made on some associated fiber lengths. After making the Strip detector corrections, the signal to noise ratio reaches values close to expectation for all tracker components (nearly 30). The pixels were mostly immune to noise.

Availability of the specialized AlCaReco data skims in a time scale of days allowed for fast extraction of alignment constants. The number of aligned modules was significantly increased with respect to CRUZET, reaching a value of more than 95% for the Strip and 90% for the Pixel barrel, while pixel end-caps were aligned to the half-disk level (with far few tracks due to the natural angular distribution of cosmics). Improved alignment quality was also achieved, as observed in the rms of both the residuals and of their mean value distributions

Throughout CRAFT the ECAL calibration sequence was exercised, allowing for the acquisition of laser data for several hundred full cycles throughout the entire ECAL and consolidation of the sequence itself. The laser data processing farm has been improved and automated such that it can keep up with the data logging rate. In parallel, the LED pulsing system for the ECAL endcap also was commissioned. The LED data were acquired in different configurations to study the stability and the monitoring of the endcap photodetectors (Vacuum Photo Triodes).

In the reconstruction area, the reconstruction of the timing of the ECAL hits has been improved, leading to an improved precision (better than 1 ns for amplitudes larger than 2 GeV) and improved robustness of the local reconstruction. Notably, the internal synchronization of ECAL was determined very precisely from the first LHC circulating beam data collected by CMS. The events resulting from the dump of the circulating packet of protons onto the collimators 150 meters upstream of CMS gave signals in all the channels (5-10 GeV), and thus allowed for the extraction of the time settings. Finally, the effort in analyzing and categorizing problematic channels has been boosted in view of finalizing a strategy for their usage in LHC data analyses and in deploying automated diagnostic tools.

During CRAFT the HCAL DPG focused on 1) developing and testing the tools needed for fast data validation and run certification, and 2) fully integrating all configurations needed to initialize zero suppression, trigger look-up tables, etc. using central run keys. Alarms were displayed to HCAL shifters if there were RBX readout errors, HTR link errors, etc. The next steps include migrating to a central CMS alarm system, automating many procedures in order to help general shifters, and continuing to develop a fast feedback analysis team.

A number of detailed analyses of CRAFT HCAL data have taken place, for example: the measurement of the energy lost by muons in HCAL and the associated validation of the simulation; and the measurement of the scintillator brightening by comparing the muon response with magnet on and off. Additionally, during CRAFT we collected the data needed to produce an HPD noise library that can be overlaid onto physics simulation samples.

Analyses by the L1 Trigger DPG of the calorimeter trigger include: validation of the ECAL, HCAL, RCT and GCT processing for the electron and jet triggers using the corresponding trigger emulators; comparisons of L1 electrons and jets with offline reconstructed objects; analysis of the jet trigger rate; and a measurement of the electron trigger efficiency using cosmic muons that deposit energy in the ECAL. A similar measurement of the jet trigger efficiency has been performed. Muon trigger studies are focused on the comparison of objects from the L1 track finders with the reconstructed muons, on the

determination of the trigger efficiencies and on the measurement of trigger rates. The DT trigger emulation is being improved including the time measurement of muon tracks obtained from the DT local reconstruction.

The DT system proved to be quite stable during CRAFT, and the online DQM and prompt offline analysis showed good overall system performance.

Perhaps one the most relevant outcomes of the CRAFT run has been the identification of significant inaccuracy in the simulation of the CMS magnetic field map in the iron yoke. While the map is close to perfect inside the solenoid, several independent analysis based on the comparison of the tracker bending with the bending inside the return yoke and the comparison of the bending from one DT muon station to the next showed that the field map derived from a Tosca (finite element analysis) computation was out, especially in the last barrel iron layer where it was predicted to be higher by about 20%, indicating that the field escaping the iron was higher than the model predicted. Intense investigation has found that the source of this is in the Tosca treatment of the boundary conditions, and a much-improved map has been developed and implemented in the most recent version of the reconstruction software.

A very successful three-day workshop was held in Torino in March regarding the analysis results of the CRAFT data after a second reprocessing had occurred that had implemented the state of the art alignment constants. The impressive results can be summarized by noting that the CRAFT data allowed for an understanding as far as alignment is concerned that is comparable with what we had projected last year to be achieved after accumulating ~50 $pb^{-1}$ of LHC collision data.

Recent DPG activities have focused on the development of the reconstruction software to be implemented in the software version to be used for LHC data taking (and corresponding simulation)

The commissioning activities restarted the third week of January once the cooling was back after system maintenance. We have restarted periodic mid week global runs ( 2 days of global running every other week) involving all the subdetectors with the exception of tracker and pixel, whose cooling systems are not yet completely rebuilt and returned to service.

The focus of these early global runs has been to check the status of the data acquisition after the improvements (mainly on the firmware side) performed during the shutdown.

**Plans for next 6 months.**

Continue commissioning with midweek global runs. When CMS is closed, continue a with magnet-off cosmic run followed by a cosmic run at full field (CRAFT09) comparable to the 2008 run, with goal of increasing efficiency and rapid response to and problems encountered. Complete preparations for the long run with LHC beams and take first beam data.

# Tracker

**Status**

During the winter shutdown several parts of the Tracker system underwent maintenance, revision or upgrade. The main items were the revision of the strips and pixels cooling plants and removal and maintenance of Forward Pixel Detector (FPIX). The objectives

were to eliminate the large leaks experienced during 2008 cooling system operations and to assure the long-term reliability.

The revision of the cooling system involves the complete replacement of the tanks, distribution lines, valves and manifolds on the SS1 and SS2 strip tracker (182 circuits) and pixels (36 circuits) cooling plants. This work is proceeding smoothly under close supervision. Procurements are completed and the quality of delivered parts and the subsequent assembly work has been very good. Final connections of the Pixel cooling plant are now completed and this plant is now available to be used by the Pixel detector. For the strip Tracker, the new distribution lines and manifolds are being assembled in the cabinets on the surface before being put back onto the experimental cavern balconies for final connection. The first strip tracker cooling plant will be ready for commissioning starting the third week of April and the second plant is expected three weeks later.

The FPIX was carefully removed for maintenance and transported directly to Meyrin in March. This operation allowed the successful recovery of about 5.5% of the 6% bad channels and other minor improvements. Reinsertion was completed before Easter. The removal and reinsertion procedures have been carefully recorded in order to document the correct procedure for future maintenance scenarios, such as removal of pixels for the bake-out of the beam-pipe.

The early months of 2009 were also dedicated to finalize the analysis of the Tracker data taken during CRAFT. More precise calibrations and alignment constants were extracted and detailed comparisons were performed with cosmic Monte Carlo samples confirming that the performance of the Tracker fully meets the specifications defined in the CMS Technical Design Report.

**Plans for next months:**

Commission the refurbished Cooling System, re-commission the Tracker, participate in the cosmics data taking with CMS at 3.8T in the summer and prepare for beam collisions.

## Electromagnetic Calorimeter

**Status**

**Barrel:** The ECAL Barrel is now fully operational and has been running smoothly since the summer of 2008. There have been continuous developments of the DAQ and the trigger systems as the integration of the detector with the global systems of CMS advances.

The 37$^{th}$ (spare) supermodule has been assembled and a calibration with cosmic rays is planned for the second quarter of 2009.

**Endcaps:** The integration of the ECAL Endcap calorimeter has continued since last summer. The trigger and LED light pulser systems are being commissioned. The full trigger chain from the detector through to readout has been demonstrated with data on the Endcap calorimeter being used to trigger the readout of the detector. Triggering with both Endcaps is expected by June 2009.

**Preshower:** The construction of the Preshower was completed in December and went through a thorough testing before transfer to Point 5. There were only two defective strips out of a total of 137,000.

The two Preshower detectors, each consisting of two Dees, were transferred to point 5 for installation in March. This was completed when they were moved into their final position on March 20$^{th}$ one week ahead of schedule. The complete checkout to ensure all services

are correctly connected at both endcaps is scheduled to finish mid-April, with the next step of full integration into CMS global runs to follow.

The preshower readout boards DCC-ES are in the second round of fabrication after problems with the first and will delivered in May.

**Plans for the next weeks and months**
Complete the commissioning of the preshower while recomissioning the complete ECAL.

## Hadron Calorimeter

**Status**
All of the HCAL has been installed underground for more than a year. HCAL has participated in all global runs during 2008 and verified its calibration using cosmic rays. It has also participated in many of the Global Calorimeter Trigger and Global Trigger commissioning studies. HCAL timing was verified during the splash events of the LHC startup of September 9 and 10. Zero suppression of HCAL data has been implemented and HCAL has verified that it can accumulate triggers at the 100 KHz rate. A few channels exhibit random latency problems and are being investigated.

HPD noise has been studied extensively. The sources are ion feedback initiated by any electron hitting the silicon pixels as well as electric flashover noise in the walls of the HPD. This latter source is enhanced in intermediate magnetic fields but not at the CMS operating point of 3.8 T. During the CRAFT run of 2008 a number of HPD channels were flagged as having unacceptable noise rates (in HB, HE and HO). All of these HPDs have been replaced. The operating voltage for HB and HE has been set at an average value of 7KV, while that of HO Rings 2 and 3 at 6 KV. Ring 0 of HO continues to operate without problem at 8 KV. In the long run HCAL plans to replace the HO HPDs with silicon photodetectors (SiPMs). Two readout boxes worth of SiPMs will be installed during the current shutdown for a long range test of the devices under real operating conditions.

We have confirmed that the HF PMTs can operate in the fringe field when the CMS magnet is at the full value of 3.8 Tesla. The fringe field is well below the value for which the PMT shielding ceases to be effective (400 gauss). Under investigation are large PMT pulses induced by muons and other charged particles at the rate of 1 part in 10,000.

The integration of the ZDC into CMS continues. A novel engineering design for the ZDC lifting fixture has been tentatively approved. However, extensive testing is required before final acceptance.

CASTOR was removed during CRAFT as a precaution after some movement was observed in the magnetic field, and will be re-installed on a re-engineered table for 2009 running.

**Plans for the next weeks and months**
Install the forward detectors, complete re-commissioning.

## Muon Detector

**Status**
**Endcap Cathode Strip Chambers (CSC):** All services (gas, cooling, LV, HV) have been connected and are operational. The CRAFT run during Nov. 2008 was a success, with all 468 chambers having been commissioned by summer 2008 and with approximately 97% of the electronics operating in the CRAFT readout. Access to the few chambers that require maintenance on stations 2, 3, and 4 is scheduled for May 2009. Most of these

problems come from faulty cable connections. In mid-January the power and cooling systems became available so the operational features (startup, detector control, data quality monitoring, etc.) of the CSC system are being exercised and improved. Due to the high cost of the $CF_4$ gas, we have decreased the percentage from 10% to 5% for the shut-down period (most of '09), which will save a significant amount of money at no cost to performance (the $CF_4$ is primarily for aging in high radiation environments). For the next few months until the beam running in 2009, we will continue to refine the software and firmware for triggering and data acquisition.

**Barrel Drift Tubes (DT):** The maintenance work that started in November is completed. The interventions on chambers and on minicrates have been successful. The total fraction of cells that are disconnected from the HV is back to the 0.2% inherited from construction and installation.

Work on YB0 was not as difficult as anticipated. A basic requirement was to carefully plan and to set up the storage space for the displaced Barrel ECAL LV cables. Interventions on the Minicrates and FE on-chamber electronics have been performed in parallel to the chamber maintenance.

A Drift Velocity monitoring Chamber (VDC) built in Aachen was tested and installed; the software connection is being made so that the measurement is available to DCS; all DT chambers are sampled in turn. Five other VDCs (so to use one for each barrel wheel) are in preparation in Aachen.

A campaign of upgrades to the electronics firmware and on-line software is starting: a lot of work was done for getting ready for this period of firmware and software upgrade; the new FW and new DAQ are tested in Legnaro/Padova, with the local cosmics set-up using two DT chambers, before being deployed at CERN in late March and April.

In view of the 2009 run (CRAFT and LHC) improvements are being made to the DCS system to complete its integration into CMS, to the on-line and off-line DQM, to the Data Certification mechanism, which should eventually include also the DCS information. The calibration workflow is now well understood. The CRAFT 2008 data have provided very useful information on the performance of the muon barrel with the magnetic field on.

**Resistive Plate Chambers (barrel RB and endcap RE):**

Re-commissioning of RB and the positive RE endcap has been completed after the winter shutdown. Commissioning of RE on the minus end-cap will be completed by the end of April. In the past months, two main sources of concern were the unexpected increase of current in few RE chambers and some coherent noise in part of the detector producing improper high trigger rate.

Much effort has been invested to understand and solve these problems. The increase of current is suspected to be due to some unforeseen presence of polluting agents accumulated in the chambers during their long storage in the P5 cavern. Careful monitoring since then has shown low and stable currents.

Noise has been attacked by improving the grounding connection. Also the LV system ground is being revised.

Analysis of the CRAFT data has been extremely useful to validate the software and to spot hardware problem on the detector. Final results for the overall detector performance are encouraging.

Finally the tools for the detector configuration and running have been improved based on last year experience.

**Alignment:** Since December, the muon alignment community has focused on analyzing the data recorded so far in order to produce new DT and CSC Alignment Records.

Two independent algorithms, using cosmic muon tracks, were developed which align the DT chambers and provide a relative alignment of the barrel with respect to the tracker. The CSC chambers could not yet be included in the track-based alignment since only a few cosmics go through the tracker and the CSCs; instead the optical alignment, based on the LINK and endcap alignment systems, has provided alignment constants for CSC chambers, therefore complementing the track-based alignment.

A fully hardware-based relative alignment of the muon system with respect to the tracker is ongoing by means of the LINK system Alignment Rings, which are mechanically attached to the tracker endcaps and which link, via laser lines, the positions of external MABs and selected ME11 and ME12 chambers.

The analysis of DT data provided by the hardware barrel alignment system is being completed.

**Plans for the next months:**
Complete commissioning of the RPCs and re-commissioning of the DTs and CSCs.
Installation of additional Hall-probes in critical positions in the yoke, set up test systems at SX5 and Bldg. 904 in particular for fast feedback on firmware tests and modifications.

# Trigger and Data Acquisition

**Status**
**Level-1 Trigger:**
The trigger system has been in use in cosmic and commissioning data taking periods. During CRAFT running it delivered 300 million muon and calorimeter triggers to CMS. It has performed stably and reliably.

The production of the ECAL endcap trigger hardware is finished and the system commissioning in the underground cavern is being completed. The installation and commissioning of the RPC trigger link system on the negative side endcap is also being finalized. Various improvements in the trigger firmware suggested by the CRAFT running have taken place and are being validated in CMS global runs. This includes automated procedures for faster synchronization of trigger links and additional trigger algorithms requested by physics groups.

The L1 trigger software tools were improved based on the CRAFT experience. Priority was given to the conclusion of the scheme for transferring from online to offline (O2O) the trigger configuration data, including masks of noisy and dead channels. A revision of the L1 Trigger menu for start-up was implemented, following guidance from the reviews of the Trigger Tables.

**Trigger Coordination:**

The Trigger Studies Group collaborated with the Physics groups to produce a series of leaner trigger menus that are easier to manage, monitor and maintain. In addition, Primary Datasets and Express Selection bits have been defined that should address the detector commissioning, Data Quality Monitoring (DQM) and physics needs for the first LHC runs. The new menus contain triggers with optimized thresholds and other (e.g. isolation) cuts, and include newly estimated rates, efficiency calculations, backup triggers, monitoring samples, plans for evolution with increasing luminosity, and a clear definition of maintenance and responsibilities. These menus have been successfully run on the autumn 2008 CRAFT data. The first of the new trigger menus will be used online in the global runs.

There are new quality tests for online DQM in preparation for the global runs, comparison of higher level triggers online to offline and Level-1 reconstruction for offline trigger DQM, and integration of trigger DQM tests in reprocessing of the CRAFT data.

**DAQ:**

The installation of the 50 kHz DAQ system has been completed during 2008. The equipment consists of the full detector readout, 8 DAQ slices with a 1 Tbit/s event building capacity, an event filter to run the HLT comprising 720 8-core PCs, and a 16-node storage manager system allowing a writing rate up to 2 GByte/s and a total capacity of 300 TB. The 50 kHz DAQ system has been commissioned and has been put into service for global cosmics and commissioning data taking. During CRAFT, data was taken with ~600 Hz cosmic trigger rate. Often an additional 20 kHz of random triggers were mixed, which were pre-scaled for storage. The system was used, in addition to global data taking, for further commissioning and testing of the DAQ. Extensive stress testing of the event filter farm revealed problems with the PCs and infrastructure, which are being followed up with the manufacturers. As a result of the global and DAQ specific operation, areas for improvement have been identified and are being addressed.

Releases of the online software, including framework and services, run control, and central DAQ applications have been made. These addressed bug fixes, performance improvements, and functionality enhancements. An example of new functionality is the support for uniform reporting of errors and alarms.

The online cluster has been operational 24/7. Essential cluster services, such as file servers and network services, have been made more redundant. The network connections of the racks housing the cluster services and general servers, have been upgraded to 10 Gbit Ethernet. Performance of the installation of system and application software on 2000 nodes has been improved. Equipment has been added to the SCX5 surface control room.

The production online Oracle database has been operational 24/7. Equipment for a development and integration database has been delivered.

The central Detector Control System (DCS) has been operational 24/7, supervising the infrastructure and providing services to the sub-detector DCS systems. Progress has been made towards full integration of all sub-detector DCS systems into the global system. In addition to the Finite State Machine (FSM) control hierarchy following the geometrical configuration of the sub-detectors, an FSM control hierarchy reflecting the TTC partitions has been established. This enables in global operation to control detector elements according to the DAQ configuration.

A plan to rationalize the various setups used for testing and validating the DAQ has been prepared.

**Concerns**
End of contract effects on continuity of experienced man-power.

## Offline Software

**Status**

In the last 3 months development work has been focused on two development cycles (CMSSW_3_0_x and CMSSW_3_1_x). The main goals of the 3_0_x release are to provide a platform for integrating and validating the latest versions of major external software packages, in particular Geant4 (9.2) and ROOT (5.22). Its main purpose is to support

validation efforts and to produce a stable base for further development, without having to deal with production goals. This release includes an integration build for the new OS/compiler platform (SLC5/gcc4.3) that the LHC experiments will migrate to before data-taking commences. In contrast, the main focus of software developers in the detector and physics groups has been on the CMSSW_3_1_x cycle, which is targeted towards 2009 goals, namely a new Monte Carlo production cycle in spring and first data-taking with beam in autumn. Improvements have been introduced in all components of the offline software in terms of both functionality and performance, and in particular include changes that incorporate all the lessons learnt from data taking with cosmics in 2008.

In Full Simulation, the CMS Calorimetry Task Force has been working closely with the Geant4 team to introduce a number of new features in the modeling of physics processes and these are being exploited in the latest version of the CMS Full Simulation application. Further developments include the integration of the full simulation chain for the forward calorimeters (CASTOR, ZDC). Here the major goal is to complete the physics description of the forward region whilst avoiding an adverse impact on software performance through the adoption of shower libraries and parameterizations of the detector response.

Fast Simulation now includes further tuning and developments along with the integration of the latest improvements in High Level Trigger and Particle Flow reconstruction. This effort culminated in a large-scale Monte Carlo production of various signal and QCD background events during the Christmas break and a very good agreement with the Full Simulation was observed for nearly all physics variables.

Many new features have been introduced into event reconstruction. Calorimeter reconstruction now provides for the masking of hot cells and recovery of dead cells, giving improved performance of Jet and MET algorithms. The electron reconstruction sequence has been modified in order to benefit from Particle Flow algorithms. Additional iterative tracking steps have been added to recover displaced tracks and dedicated tools for V0 reconstruction have been added. The reconstruction application ran very stably at Tier-0 during the prompt processing of more than 300 M cosmic events with field on during CRAFT, and an inefficiency of less than 0.5% was observed due to program crashes. In addition, alignment and calibration algorithms were run at the CAF to produce constants for all sub-detectors providing a significant improvement to position residuals and energy resolutions. In the area of Visualization, both Iguana and Fireworks have now matured and are approaching an optimum level of functionality and stability.

The data and workflow management tools continue to evolve in support of CMS production workflows. At Tier-0, the Prompt Reconstruction workflow is now fully commissioned and the fully automated version of Alignment and Calibration skim production is also being exercised in production. The Express Stream processing system has also been designed and implemented and commissioning tests are in progress. The Express Stream is needed to meet the challenge of processing 10% of the data CMS takes within one hour in order to obtain rapid feedback from analysis and calibration tasks.

**Plans and milestones**

The CMSSW_3_1_0 production release will be made and deployed starting in early May. The month of May will be used for making an extensive round of physics validation tests and to measure the stability and performance of the software in realistic production environments. The release will be used for the large Monte Carlo production that starts in June and for a new round of data-taking runs with cosmics in July.

# Computing

**Status**

During the past months activities were focused on data operations; testing and re-enforcing shift and operational procedures for data production and transfers; MC production; and user support.

An Analysis Support task force worked on improving the reliability of analysis activities. It assessed and documented the effort and tools required to do Analysis Support and eventually Analysis Operations. User feedback on functionality and experience was collected by means of a user survey. The task force developed techniques and tools for providing user support and pro-actively address issues at sites. The existing monitoring tools and troubleshooting information were reviewed and metrics to assess analysis performance at the sites were developed. A reference platform for diagnostic of analysis problems will be set up. This task force will transition to a stable computing analysis operations group within the next months.

A monitoring framework was developed to assess the readiness of sites for conducting the CMS data processing workflows. Several tools are used to monitor site performance and test jobs are submitted periodically to check the availability of services. In addition, a few hundred jobs emulating analysis tasks are sent daily to each site. Data transfers at low rate between the CMS computing sites are continuously conducted in order to monitor network link availability and stability. The monitoring information is combined according to well-defined metrics based upon the recent history to flag sites as usable by CMS.

The production of large Monte Carlo samples completed in February. During late December and the first months of 2009 two reprocessing runs of all 2008 Cosmics data were performed with improved software versions and conditions.

In User Support, a comprehensive course "Using Physics Analysis Toolkit (PAT) in your Analysis" was organized in January-February based on e-learning technology. The CMS Offline SW Guide documentation is being reviewed by the Physics Object Groups and the review will continue with the CMSSW main domains and Physics Analysis Groups. The goal of the review is to make sure that the documentation of the most important software components is complete and accessible in a predictable place and properly linked. The review is done with the collaboration of experts in technical writing.

Together with the other experiments and the WLCG, it was agreed to schedule a set of scale tests in May and June with CMS and ATLAS, and possibly all the 4 experiments. This is to gain confidence in the sustained performance of the distributed computing infrastructure under the concurrent load of all experiments performing data production, transfers and analysis.

**Plans for 2009 and preparations for data taking**

Perform production of Monte Carlo event samples; a big production is planned with final software release for data taking.
Further consolidation of operations procedures with improved production tools.
Further improvement of monitoring and fault detection in the distributed computing infrastructure.
Dedicated functional tests together with ATLAS as preparation for 2009 data processing and analysis.
An end-to-end functionality test for processing and analysis with the aim to test the processing steps at Tier-0, Tier-1 and analysis access including luminosity and conditions information to verify the calculation of cross sections.

# Physics

**Status**

During the last six months, the CMS Physics program continued to be focused on readiness for initial data taking. The Physics Object and Physics Analysis groups strengthened their preparations for early LHC operation. Several important aspects of early running were revisited: as an example the trigger tables for very low luminosity were reviewed, the treatment of many physics objects was better adapted to initial conditions and data-driven techniques for early physics analyses were consolidated.

The physics and trigger groups carried out six joint reviews. Physics preparations for these reviews were coordinated by the object groups but had considerable involvement of the analysis groups. The outcome was a substantial advance in understanding critical triggering needs for collections of signal and control samples, as well as back up triggers, fallback options, evolution to higher luminosities and monitoring needs. The final products are lean but well-designed trigger tables and tools that will serve CMS well in early data-taking and allow quick changes to adjust to actual conditions and rates which are not assumed to be well predicted by Monte Carlo.

The treatment of physics objects advanced in several areas. One example is muon reconstruction and identification that could be tested and improved with the cosmic data collected in autumn 2008. Another example is the improved reconstruction of charged tracks by means of iterative procedures, allowing photon conversions, $V^0$'s and low pt tracks to be reconstructed with higher efficiency. The high granularity of the CMS detector has been exploited with particle flow techniques, and calorimeter information combined with charged tracking, obtaining sizeable improvements in jet reconstruction.

The considerable effort that started last year in the development of the Physics Analysis Toolkit (PAT) has continued, and the PAT is now the common analysis language for CMS analyses. Training on the PAT is taking place regularly, and has included a long tutorial that took place over a few weeks early this year. The PAT is acting as a bridge between the reconstruction-software domain and physics analysis. PAT objects are suited to physics analysis: analysis groups can trim the information to what is suited for their use cases, optimizing space consumption on disk and pre-computing quantities of common interest. A first large-scale test of PAT-tuple production (an analysis format compliant with the CMS Event Data Model) took place recently, as part of the general Monte Carlo production.

**Plans and milestones for 2009**

The physics groups are planning the production of large samples of events with full and fast simulation, based on the reconstruction software to be used for the forthcoming LHC data taking, and on the experience matured with cosmic data. These samples will be based on the new, revisited, trigger tables and will be aimed at preparing for the 2009/2010 LHC data taking.

# Conclusion

During the autumn 2008 cosmics run, the sub-detectors, online, offline, computing and analysis systems all performed well. The ensuing shutdown included broad maintenance activities and a programme of carefully selected repairs interleaved with installation of the preshower detector. The schedule defined in mid-November for this work is being held to within a few days. Preparations for another long cosmics run with magnet on prior to LHC beams are underway, as is planning for the long run with beam.

# CMS Financial Plan

The RRB is reminded that the foreseen deficit for CMS Construction was presented at the RRB23 meeting in October 2006. A request to cover this deficit in 3 steps was also presented. A plan (see Table 1 taken from CERN-RRB-2006-105) in three steps was proposed.

- The first priority is to complete the low luminosity detector requiring 17.5 MCHF.
- The second priority is to complete the DAQ. For this 8.4 MCHF are needed.
- The third priority is to upscope to design-luminosity detector needing a sum of 16.6 MCHF.

The restoration of the forward RPC (RE) system was also proposed.

In this short report we have concentrated on activities funded by the 3 steps.

## Step 1 Activities

The status was described in the November report (CERN-RRB-2008-095) and no change has occurred.

## Step 2 Activities

No expenses have yet been incurred. It is likely that we shall be able to attain the full DAQ/Filter Farm capability by using remaining Step 2 funds (see CERN-RRB-2008-095) and replacement slices funded via the M&O Cat. A during the next few years.

## Step 3 Activities

It is likely that some of the activities covered by Step 3 funds shall start this year, notably the construction of the up-scoped RE system.

## Infrastructure, Upscopes and Upgrades

Plans are being made to prepare for long and sustained periods of running and for upgrades. These include the continuation, and reinforcement, of the CMS Engineering Centre, in future including aspects of electrical and electronic systems. Bldg 904, which has been extensively used to test electronic chains, burn-in power supplies etc., especially before the underground cavern (USC55) was delivered to CMS, will play a similarly important role during the long phase of Upgrades. It is planned to have the complete electronics chains of sub-detectors so that improvements can be thoroughly tested prior to installation in Point 5. The question of how to finance theses activities is being addressed and a proposal shall be made at the October 2009 RRB.

CMS planning for the Upgrades is being firmed up taking account of the later than anticipated startup of the LHC. Two phases of the Upgrades are planned; Phase 1 will take the peak luminosity beyond $10^{34}$ cm$^{-2}$ s$^{-1}$ and the Phase 2 up to $10^{35}$ cm$^{-2}$ s$^{-1}$.

During the Phase 1 CMS will be upscoping or upgrading the following items: forward RPC system, ME4/2, items of infrastructure (e.g. YE4, etc), replacement of the pixels system, changes deemed necessary after first running (these could include e.g. some transducers in the HCAL system). Many of these items have previously been brought to

the attention of the RRB. Planning and costs of some of the above items are known whilst more time, and experience from first runs, are needed for the others.

The preparations for Phase 2 Upgrades necessarily require R&D, which has to be conducted in parallel with data-taking and work for Phase 1.

More details on the planning and costs of all of the above will be provided for the October 2009 RRB.

## Status of Requests for Additional Funding

CMS is very grateful to the many Funding Agencies that have already made commitments to the above-mentioned steps. The current situation is outlined in Tables 2 and 3.

To cover the deficits mentioned above, and the strategy that we are following requires all of the Funding Agencies to fulfill their obligations, at least for Steps 1 and 2.

In order to balance the income with the expenditure for the low luminosity detector, CMS again urgently requests all the Funding Agencies that have not yet made commitments with respect to the October 2006 Global Financial Plan to do so, at least for the Steps 1 and 2 and to the restoration of the first phase of the RE system (eta $< 1.6$).

# Table 1: Completing the Design Luminosity CMS detector in three steps (kCHF).

From October 2006 RRB (CERN-RRB-2006-105)

| | PhDs | MoU Funding 2002 | CTC1 RRB15 Oct02 | CTC2 RRB20 Apr05 | Constr. Funding 2006 | Low Lumi Constr. | DAQ 4 slices PhD | Low Lumi + DAQ | Upscope Rest PhD | Total Design Lumi | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | 11 | 3,900 | 600 | 275 | 4,775 | 211 | 45 | 256 | 171 | 427 | |
| Belgium | 27 | 5,000 | 870 | 300 | 6,170 | 272 | 111 | 384 | 420 | 803 | |
| Brazil | 9 | | | | 0 | 0 | 37 | 37 | 140 | 177 | |
| Bulgaria | 5 | 600 | 0 | 0 | 600 | 26 | 21 | 47 | 78 | 125 | |
| CERN | 72 | 85,200 | 13,500 | 4,800 | 103,500 | 4,569 | 297 | 4,865 | 1,119 | 5,984 | |
| *China* | 13 | 4,315 | 500 | 300 | 5,115 | | | | | *in kind RPC* | |
| Croatia | 7 | 280 | 49 | 20 | 349 | 15 | 29 | 44 | 109 | 153 | |
| Cyprus | 3 | 600 | 106 | 43 | 706 | 31 | 12 | 44 | 47 | 90 | |
| Estonia | 2 | 90 | 16 | 6 | 112 | 5 | 8 | 13 | 31 | 44 | |
| Finland | 12 | 5,000 | 870 | 300 | 6,170 | 272 | 49 | 322 | 187 | 508 | |
| France CEA | 14 | 5,600 | 1,687 | 445 | 7,732 | 341 | 58 | 399 | 218 | 617 | |
| France IN2P3 | 38 | 19,700 | 2,000 | 2,000 | 23,700 | | *2,000* | *2,000* | *0* | *2,000* | *Pledged* |
| Germany BMBF | 41 | 17,000 | 2,709 | 1,100 | 20,809 | 919 | 169 | 1,087 | 637 | 1,725 | |
| Germany DESY | 5 | | | | 0 | 0 | *2,000* | *2,000* | *0* | *2,000* | *New Collab.* |
| Greece | 17 | 5,000 | | 0 | 5,000 | 221 | 70 | 291 | 264 | 555 | |
| Hungary | 6 | 1,000 | 58 | 0 | 1,058 | 47 | 25 | 71 | 93 | 165 | |
| *India* | 26 | 4,400 | 300 | 500 | 5,200 | | | | | *in kind RPC* | |
| *Iran* | 3 | 510 | 700 | 0 | 1,210 | | | | | *in kind RPC* | |
| Ireland | 1 | | | | 0 | 0 | 4 | 4 | 16 | 20 | |
| Italy | 181 | 55,000 | 8,927 | 4,000 | 67,927 | 2,998 | 746 | 3,744 | 2,813 | 6,557 | |
| *Korea* | 14 | 1,315 | 500 | 147 | 1,962 | | | | | *in kind RPC* | |
| Mexico | 5 | | | | 0 | 0 | 21 | 21 | 78 | 98 | |
| New Zealand | 3 | | | | 0 | 0 | 12 | 12 | 47 | 59 | |
| *Pakistan* | 3 | 2,445 | 230 | 149 | 2,824 | | | | | *in kind RPC* | |
| Poland | 12 | 3,000 | | 0 | 3,000 | 132 | 49 | 182 | 187 | 368 | |
| Portugal | 5 | 2,000 | 300 | 140 | 2,440 | 108 | 21 | 128 | 78 | 206 | |
| RDMS | 72 | 18,862 | 2,211 | 1,657 | 22,730 | 1,003 | 297 | 1,300 | 1,119 | 2,419 | |
| Serbia | 3 | | 450 | 0 | 450 | 20 | 12 | 32 | 47 | 79 | |
| Spain | 34 | 6,000 | 1,350 | 450 | 7,800 | 344 | 140 | 484 | 528 | 1,013 | |
| Switzerland | 30 | 86,500 | | 200 | 86,700 | 0 | 124 | 124 | 466 | 590 | |
| Taipei | 11 | 2,330 | 410 | 0 | 2,740 | 121 | 45 | 166 | 171 | 337 | |
| Turkey | 18 | 1,000 | 58 | 0 | 1,058 | 47 | 74 | 121 | 280 | 401 | |
| UK | 49 | 9,100 | 918 | 3,000 | 13,018 | 575 | 202 | 777 | 762 | 1,538 | |
| USA | 418 | 104,320 | 12,800 | 1,868 | 118,988 | 5,252 | 1,722 | 6,974 | 6,497 | 13,471 | |
| **Sum** | **1170** | **450,067** | **52,119** | **21,700** | **523,843** | **17,530** | **8,400** | **25,930** | **16,600** | **42,530** | |
| **Requested** | | | **63,000** | **32,000** | | | | | | | |

# Table 2: Status of Pledged or Paid Additional Funding (kCHF)

| | Step 1 | Step 2 | Step 3 | Comment |
|---|---|---|---|---|
| **Austria** | 211 | 45 | 171 | |
| **Belgium-FNRS** | 136 | 56 | 311 | |
| **Belgium-FWO** | 136 | 56 | 109 | |
| **Brazil** | n.a. | 37 | | |
| **Bulgaria** | | | | Awaiting response |
| **CERN** | 4,569 | 297 | 1,119 | |
| **China** | Endcap RPC | Endcap RPC | Endcap RPC | |
| **Croatia** | 15 | 29 | 109 | |
| **Cyprus** | 31 | 12 | 47 | |
| **Estonia** | 5 | 8 | 31 | |
| **Finland** | 272 | 49 | | |
| **France-CEA** | 341 | 58 | 218 | |
| **France-IN2P3** | n.a. | 2,000 | n.a. | |
| **Germany BMBF** | 919 | 169 | 637 | |
| **Germany DESY** | n.a. | 2,000 | n.a. | |
| **Greece** | | | | |
| **Hungary** | | | | Discussing |
| **India** | Endcap RPC | Endcap RPC | Endcap RPC | |
| **Iran** | Endcap RPC | Endcap RPC | Endcap RPC | Discussing |
| **Ireland** | n.a. | 4 | 16 | |
| **Italy** | *1,000* | | | |
| **Korea** | Endcap RPC | Endcap RPC | **114** | |
| **Mexico** | n.a. | | | Awaiting Response |
| **New Zealand** | n.a. | 12 | | Discussing Step 3 |
| **Pakistan** | Endcap RPC | Endcap RPC | Endcap RPC | |
| **Poland** | 132 | 49 | | |
| **Portugal** | 108 | 21 | | |
| **RDMS-DMS** | | | | Discussing |
| **RDMS-Russia** | | | | Discussing |
| **Serbia** | 20 | 12 | | |
| **Spain** | 344 | 140 | | |
| **Switzerland** | n.a. | *141* | 466 | |
| **Taipei** | 121 | 45 | | |
| **Turkey** | 47 | 74 | **280** | |
| **U.K.** | 575 | 202 | 762 | |
| **USA-DoE/NSF** | 5,252 | 1,722 | | |
| **Sum** | **14,234** | **7,238** | **4,390** | |
| **Requested** | **17,530** | **8,400** | **16,600** | |
| **% covered** | **81%** | **86%** | **26%** | |

**Bold: Input since November 2008 RRB**
*Italic: Changed contributions*

## Table 3: The state of funding of the restoration of the forward RPC system.

| **FUNDING**<br>**Countries** | **Contributions**<br>**kCHF** | **Comments** |
|---|---|---|
| Belgium | 420 | Likely to use its Step 3 funds for RPC system |
| China | **500** | |
| India | 800 | In final stages of approval |
| Iran | | Discussing. Request for 800 kCHF made in RRB of Oct. 2006 |
| Korea | 405 | Also see Table 2 |
| Pakistan | 1250 | |