Status of CMS
Progress Summary Report for April 2006 RRB22

In the current CMS Master Schedule the initial detector will be ready for first collisions in late summer of 2007. Installation of the pixel tracker, (ready in summer 2007), and the ECAL endcaps is now foreseen during the 2007/2008 winter shutdown, in time for the first physics run in spring 2008. The staged items include the fourth endcap muon station ME4/2, RPC chambers at low angles ($|\eta|>1.6$), 60% DAQ online farm and third forward pixel disks.

Civil Engineering

Status

Civil engineering (CE) works at Point 5 (located at Cessy, France) have been completed. Installation of the infrastructure in the USC55 cavern (for the counting rooms and services) is advancing well. The infrastructure of the PM54 shaft has also been completed. The underground cavern UXC55 (for the experiment proper) was handed to CMS in February 2005 and the installation of infrastructure is advancing after the repair of leaks in the experiment cavern shaft PX56. Main ventilation ducts are in position, and the steel floor destined to receive the detector elements has been laid. The experiment cavern will thus be ready to receive detector elements in summer 2006 after completion of forward shielding for the two ends. The construction of the SDX5 building has also been completed as well as that of the surface control room building, SCX. The latter will be ready to receive the first elements of the computer farm in July 2006.

The shielding plug, which will also be used as a lifting platform for the transfer of the experiment underground, will be tested in April 2006 under a load of 2000 tons. The test of the gantry and the start of heavy lowering operations will follow.

Changes
None.

Plans for 2006
Continue installation of infrastructure in all buildings and caverns. The UXC cavern is expected be ready in time for lowering of CMS. Start equipping SCX.

Concerns
None.

Installation and Infrastructure

Status

Gas and cooling pipes for DTs, CSCs and RPCs have been installed on the six yoke disks and on the five barrel wheels. Deliveries of the cooling plants (water and fluoro-carbon) are nearing completion. The rack system is in position, and will be ready to receive crates in Spring 2006 before the start of the main cabling campaign. The plan for electrical distribution, including the Low Voltage system, has been completed, and this has allowed the finalization of the cabling plan.

The HF shielding for both the ends and the forward cylindrical shielding surrounding it, manufactured in Iran, have been fully assembled at CERN. The manufacture of the rotating shielding for both the ends has been completed and they have been tested. After filling with borated concrete they will be installed and hinged from the forward shielding before July 2006.

The contract for the heavy lifting tasks is operational, and the structure of the main gantry has been erected around the SX5 hall. The gantry will be tested before the first lowering operation that is foreseen to be for the HF detectors in July.

The cabling and final commissioning of chambers installed in YB0 will fall on the critical path after the test of the magnet.

Changes
None.

Plans for 2006
Complete installation of shielding and cable chains. Complete cabling from USC racks to cable chain patch panels.

Concerns
Cabling on YB0 in SX5.

Magnet

Status

All of the magnet yoke has been assembled at Point 5.

The five coil modules have been delivered to CERN and assembled into a single cold mass. After being brought to the horizontal position using the main swivelling tool, the cold mass has been inserted inside the outer vacuum tank from which it is suspended by titanium tie-bars. After swivelling, using the same tooling, the inner vacuum tank has been inserted inside the coil, and the two flanges have been welded to complete the vacuum enclosure.

The power converter has been delivered and the power circuit completed. The dump resistor has been installed in the position for the test of the magnet on the surface. The test of the proximity cryogenic system has been completed at Saclay, and the outer cryogenics has been tested using the dummy thermal load and the 6000-litre cryostat installed on the central wheel. Nominal cooling power has been reached.

Pumping of the cryostat started before Christmas 2005, and cooling of the coil commenced in the beginning of February. The coil reached its operating temperature (liquid helium – 4K) after 23 days of cooldown. The electrical test of the magnet in the surface building should be completed by June 2006. A period of stable operation for detector tests and detailed mapping of the magnetic field will follow the test proper.

Changes
The coil is sitting at the operating temperature.

Plans and milestones for 2006
The magnet will be tested to full current and the field mapped by August 2006.

Concerns
The critical path goes through coil test on the surface.

Tracker

Status

Three main phases can be identified in the construction of the Tracker: module production, assembly of modules into TOB-rods, TIB-shells, and TEC-petals and the integration of TOB rods, complete TIB and complete TEC structures into the Tracker Support Tube.

Hybrids have been in full production since the beginning of 2005 and deliveries were completed in December 2005. Deliveries of all sensors were completed by the end of 2005; the sensor quality is very impressive and assembled modules have bad strip rates well below 0.5% and very low electronic noise.

Assembly of modules has also progressed well. TIB module production is complete and TOB and TEC production will be complete in Spring 2006. Mechanical and electrical integration of the sub-detectors has been proceeding rapidly and the first half of the Tracker Inner Barrel is expected in CERN from Italy in May 2006. A trial run of transportation of the one endcap system from Aachen was carried out in preparation for its final delivery in September 2006.

A new ~400m^2 Tracker Integration Facility (TIF) was constructed for final assembly of the entire tracker. It was commissioned in CERN during the autumn and is now in full operation, with assembly of one endcap taking place there alongside construction of the outer barrel, using rods delivered from the USA. Once the tracker is complete, the facility will be used to carry out full testing of the entire tracker before it is installed underground at Point 5.

Recent optimisation (enlargement) of the Tracker Patch Panel 1, using space released by ECAL, should allow TEC, as well as TIB/TID and TOB cables to pass through interconnects on the inside of the vac-tank. This simplification is a vital ingredient introducing flexibility in the endgame planning, since it will partially decouple the actual Tracker delivery from the critical path activity of YB0 cabling.

The off-detector electronics are arriving steadily in CERN. A large fraction of the power supplies and more than half of the Front End Drivers have been delivered. Commissioning of the electronic systems has been well under way in the CMS Electronics Integration Centre in Prevessin since mid-2005. The required systems will then be transferred to the TIF to commission the completed tracker.

Considerable progress has been made in software development, both online and offline. The Tracker DAQ is well advanced and able to read out full crates of FEDs via VME; the high speed S-link connection to the CMS central DAQ was run successfully. Tracker trigger-related logic was verified once final modules of the TTC system became available and synchronization procedures have been demonstrated. Several software workshops were held during the year, which reviewed the state of the analysis and monitoring tools.

An engineering review of the pixel system was carried out in May 2005, which concluded that the barrel and endcap systems were ready for mass production, with the assembly line and test equipment in place at PSI and in the US, centered around FNAL. Beam tests of final pre-production modules were carried out in 2005. The final version of the 0.25-micron readout chip has been found to be satisfactory and manufacture of the production wafers has now been launched. Endcap sensors were successfully delivered in the final quarter of 2005.

Changes

Optimisation (enlargement) of the Tracker Patch Panel 1.

Plans and milestones for 2006
Through to autumn 2006 commission and test TIB, TOB and TEC in the TIF and then integrate into the Trcaker support tube.
Nov 06 to Jan 07 Commission Tracker inside the support tube in Bat 186
Feb 2007 Installation of the Tracker in UX5.

Concerns
The schedule for the completion of the tracker is very tight.

Electromagnetic Calorimeter

Status

About 47500 out of 61200 of the barrel crystals have been delivered and are being used to construct modules (400 or 500 crystals) in CERN and Rome. Ninety eight modules, out of 144, have been assembled. Twenty four bare supermodules (SM, each comprising 1700 crystals) have been assembled. The crystal production is now proceeding at the rate of about 1150 crystals per month.

The production of all 140,000 APDs is complete. The production runs of all ECAL ASICs in Deep Submicron (DSM) Technology have been received, packaged and tested. The production and testing of the 13,000 Very-Front-End boards, 2600 Front-End boards, 2500 regulator boards and 5000 Gigabit Optical Hybrids for the barrel has been completed. Some difficulties were encountered with the weld quality of the cooling elements inserted in the supermodules. The problem has now been overcome, but has induced a delay in the serial integration of the electronics, which restarted at the end of last year. The present integration rate is consistent with the general construction schedule of CMS. The performance of the integrated supermodules satisfies fully the design performance stipulated in the TDR.

Pre-series of all off-detectors readout modules are at hand. After a successful integration test with the Regional Calorimeter Trigger, the production of these modules has been launched.

The construction of the Endcap mechanics is progressing according to schedule. The large mechanical pieces needed for the four Dees have been delivered to CERN. Over eighty percent of the 15000 VPTs have been delivered and tested to 1.8T. The production of the endcap Very-Front-End boards has been launched, prototypes of the Front-End boards have been tested. The other electronics boards are identical to the Barrel ones and are being produced.

Preshower: All of the required silicon sensors have been produced. The specific Preshower DSM ASICs have been produced, packaged and their testing is 90% complete. Following system tests, the production of the front-end hybrid has been tendered and launched. Preseries of the readout motherboard were successfully tested and the serial production is expected to start during the next Spring.

Both Endcaps calorimeter and Preshower detector have been pre-cabled in CMS proper. The installation tooling for the Barrel supermodules has been delivered and tested.

Changes
None.

Plans and Milestones for 2005/2006
Continue integration of electronics into the SMs, integrate all EB+ modules by July 2006.
Calibration in test beam of around 5 supermodules.

Concerns
Crystal production remains on the critical path. The schedule for the completion of the ECAL is very tight.

Hadron Calorimeter

Status

All HCAL (HB, HE, HO and HF) absorber, optics, and front end electronics are completed.

Modules of all geographic parts of HCAL were tested more extensively in beam in 2004 using final electronics. This established the relationship between the calibrating radioactive source and the pion and electron beams. Data were also taken with low energy pions and electrons from 3 to 9 GeV, thus extending the available data from 3 to 300 GeV. The results are being used to tune the GEANT4-based simulation. A final test beam run before first LHC collisions is planned in 2006 with a production ECAL module and the existing HCAL test beam setup.

All HCAL devices now have established a calibration relationship between the response to a radioactive source and that from the test beam data on pions and muons which was taken for a few HB, HE, and HF towers. This calibration data establishes an initial calibration prior to first collisions with an accuracy estimated at 5%.

The front-end electronics has been produced and tested for linearity and other quality factors. After "burn-in" the electronics was delivered to CERN and installed. The HCAL slow controls are being inserted into the overall CMS framework prior to the magnet test.

Changes
Source calibration done of both HB, both HE and one of two HF.

Plans and milestones for 2006
Prepare HF for lowering into UX5 in the third quarter of 2006.
Beam test of combined ECAL+HCAL in CERN beam H2.

Concerns
None.

Muon Detector

Status
Endcap Cathode Strip Chambers: All of the chambers (a total of 496 including 6% spares) have been assembled and tested at sites in China (IHEP-Beijing), Russia (JINR-Dubna, PNPI-St Petersburg) and US (FNAL, UCLA, UF). All chambers have been shipped to CERN, and over 90% have been installed on endcap yoke disks. Most of the chambers have been commissioned. The remaining chambers will be installed after the magnet test.

Barrel Drift Tubes: Chamber construction is completed at three sites: CIEMAT, Aachen and Legnaro. A total of 245 chambers including some spares (~95%) are already at CERN. The production at the fourth site, Torino is on schedule, all the superlayers and 36 chambers (~90%) have been assembled, 33 are at CERN and 24 are already installed. The 'dressing' of chambers in the CERN-ISR is proceeding well. The installation of chambers in the yoke was completed for YB+2 and YB+1 in November 2005. Eighty-four chambers have been commissioned with cosmic trigger and data taking through the on-chamber

electronics housed in the Minicrates. Cabling is progressing in YB+2 and YB+1. Cosmic-ray muons were seen in December in four chambers in Sector 10 of YB+1.

Three sectors, S10, S11 in YB+2 and S10 in YB+1 will be fully operational for the Magnet Test Cosmic Challenge later this spring. Chamber installation resumed at the end of January on the central wheel, YB0, after the completion of the welding operation on the cryostat. The planned installation: 8 sectors on YB0 (31 chambers) were completed by end of February. Chamber installation in sectors S10 and S11 in YB-1 and YB-2 was also completed. These chambers are required for a full-scale test of the alignment system during the MTCC.

Barrel RPCs (RB): The gap production has been finished and 88% of the 480 chambers have been assembled. The assembly should finish in June 2006. Over 350 chambers have been delivered to CERN. Furthermore, 254 chambers have already been installed in the barrel yokes. The RPCs are coupled to the DTs before the combined packages are installed. The commissioning of the RPC chambers is underway.

Endcap RPCs (RE): An RPC gap factory has been installed in Korea and mass production of gaps is almost finished. Priority has been given to RE1 chambers. To date 75% of the RE1 RPCs (144 chambers in all) have been installed on the yoke, both at the plus and minus ends. Additionally 50% of these chambers have been successfully pre-commissioned. RE2 and RE3 RPCs are being assembled in Pakistan (288 in total); 36 RE2/2s and 36 RE2/3s have been shipped to CERN and are undergoing certification on the ISR cosmic stand, in addition to the QC already done in Pakistan. Seventy out of 72 RE2/2s have been installed on YE+2 yoke disk.

Alignment: The hardware for the Endcap and Link subsystems needed for the Magnet Test is about 90% complete. The electronics is ready, but not yet integrated and about half of it is at CERN. The software for alignment with tracks (in the muon barrel) is progressing well.

Changes
None.

Plans and milestones for 2005/2006
Barrel Drift Tubes and RPC's: Install and commission chambers in all five YB wheels before lowering.
Endcap CSCs: finish installation and commissioning of remaining CSC chambers before disks are lowered into UX.
Endcap RPCs: Continue production and installation of chambers.
Alignment: Prepare for the magnet test.

Concerns
CSCs: None.
DTs: Cabling of chambers, especially those on YB0 and their general integration.
RPCs: Cabling of chambers, as above.

Trigger and Data Acquisition

Status

Trigger: Production is either well underway or complete for most major trigger subsystems. All trigger subsystems are now operating test systems composed of mostly production electronics in the Electronics Integration Center (EIC) in Prevessin. Systems integration tests involving multiple trigger subsystems with central clocking and control are underway in this facility with data being sent from detector electronics through to the Global Trigger. The trigger software framework is being deployed across trigger subsystems and tested in the EIC. Preparations are well advanced for providing triggers for the Magnet Test Cosmic Challenge and for final installation into USC55.

The Global Calorimeter Trigger (GCT), a critical part of the CMS calorimeter trigger, had accumulated significant delays and remedial actions unfortunately did not lead to a significant enough improvement. Significant risks still remained and after thorough reviews by many experts it was decided in January 2006 to construct the GCT using newer technology, used in a conservative way, and building upon existing designs. It is anticipated that the new GCT will be ready by mid-2007. In order to advance the testing of the trigger system a limited-functionality temporary solution will be used. The resource implications are discussed later in this document.

DAQ: The 1:8 scale DAQ pre-series system consisting of a Readout Builder (64x64), 1/8 of Data-to-Surface (D2S) components, 1/64 of Filter Farm and 14 water-cooled racks has been installed in a computing room in a SCX barrack at Point 5. The latest on-line software developments, including Central DAQ, Run Control and DCS are integrated and tested in view of the Cosmic Challenge data taking during the Magnet Test (May to August 2006). End-to-end (from FED to Filter) data flow column have been implemented and tested with Muon, ECAL, HCAL and Tracker detectors. All the custom readout equipment (FRL and FMM) has passed the system tests in the EIC and the racks and DAQ PCs installation in USC has started in December 2005.

Changes

Three out of 8 slices will now be deployed at startup.
GCT will now be constructed using newer technologies. It should be ready by mid-2007.

Concerns

The time available for installation and commissioning in the underground area is short.

CPT

Computing and Core Software, Physics Reconstruction and Selection, Tridas

Status

The CMS Software and Computing Project is organised as a single Project called CPT: comprising Computing and Core Software, Physics Reconstruction and Selection (PRS).

The main achievements of the CMS computing project in 2005 were the documentation of its technical baseline in the Computing Technical Design Report (C-TDR); the initial implementation, integration and testing of many of the computing system components and the end-to-end system tests in the "Service Challenge" (SC3).

The C-TDR gives an extended description of the tiered organization of computing resources at CERN (Tier-0 center and the CERN Analysis Facility, CAF) and across the LHC Computing Grid (Tier-1 and Tier-2 centers). Many CMS regional computing centers came into operation and demonstrated good performance, well on track with a ramp that will reach the 2008 performance targets. Some sites were actually already able to demonstrate 2008-scale data throughputs. SC3 also re-confirmed the need for re-engineering the Event Data Model and Data Management system, as outlined in the C-TDR and Volume 1 of the Physics TDR.

An examination of the pledged and required computing resources at CMS Tier 1s shows that the number of CMS T1s with resources close to a standard CMS T1 capacity is small and that there is a significant shortfall in the amount of tape resources. This leads to a concern about the effectiveness of the CMS Computing Model. CMS is examining this and a "white" paper with an analysis has been requested by the LHCC.

During 2005 the software tools needed to finalize the physics TDR were completed. More than 100M events have been simulated with the Geant4 toolkit based simulation program OSCAR, and reconstructed with ORCA. The fast parameterized simulation FAMOS was tuned to the detailed simulation and deployed for analyses for the TDR.

A combined Computing Software and Analysis Challenge (CSA2006) is currently scheduled to start in September 2006. This will be an important step towards preparing the Collaboration in the use of the WLCG. The CSA2006 will be integrated test of the full end-to-end chain of the complete system, from (simulated) raw data to analysis at Tier-1 and Tier-2 centers.

Cosmic ray data have been taken by the HCAL and the Muon Chambers, and were calibrated and reconstructed in real time using the new framework and event data model.

The software related to the online selection of events in the Filter Farm (HLT) underwent a major revision in 2005, following the adoption by CMS of a new Software Framework. This revision is now complete and the new framework is fully integrated with the DAQ system. The complete readout chain was tested for the forward muon system (CSC) using cosmic triggers, and data were successfully analyzed both online, using the Data Quality Monitoring infrastructure, and offline using the new Software Framework. The last part of the year has seen good progress in the preparation for combined data taking from calorimeters, muon detectors, and the silicon tracker using cosmic ray triggers in a combined test of detector commissioning at SX5 (Magnet Test and Cosmic Challenge, MTCC).

The first volume of the CMS Physics TDR has been submitted. This is a culmination of several years of intensive effort to develop software, algorithms, and operational procedures for the data-taking era of the LHC. The content includes: validation and tuning of the detailed detector simulation with test-beam comparisons, detailed descriptions of the procedures to operate the detectors (calibration, alignment, synchronization, and monitoring), summaries of the physics object reconstruction algorithms (both online and offline) along with the expected performance of the algorithms based on detailed and realistic simulations, and an overview of the software framework, event data model, and services that form the basis of all of the above.

Volume 2 of the Physics TDR, due in mid-2006, will demonstrate the physics capability of CMS. To gauge the performance of CMS detailed analyses are being performed of a few challenging benchmark processes. These processes cover several Higgs boson decay channels, the production and decay of new particles such as Z' and supersymmetric particles, B_S production. The last part of Volume 2 will document the physics reach with ~10 and 30 fb^{-1}.

A third volume of the Physics TDR is planned for completion by January 2007. This work will document the actual startup of the experiment in 2007, along with the very early physics reach with 0.1 fb^{-1} and $1fb^{-1}$. It will also contain an update on the High Level Trigger, timings and the trigger tables for various luminosities.

Changes
The Physics TDR Vol. 1 was submitted to the LHCC in January 2006.

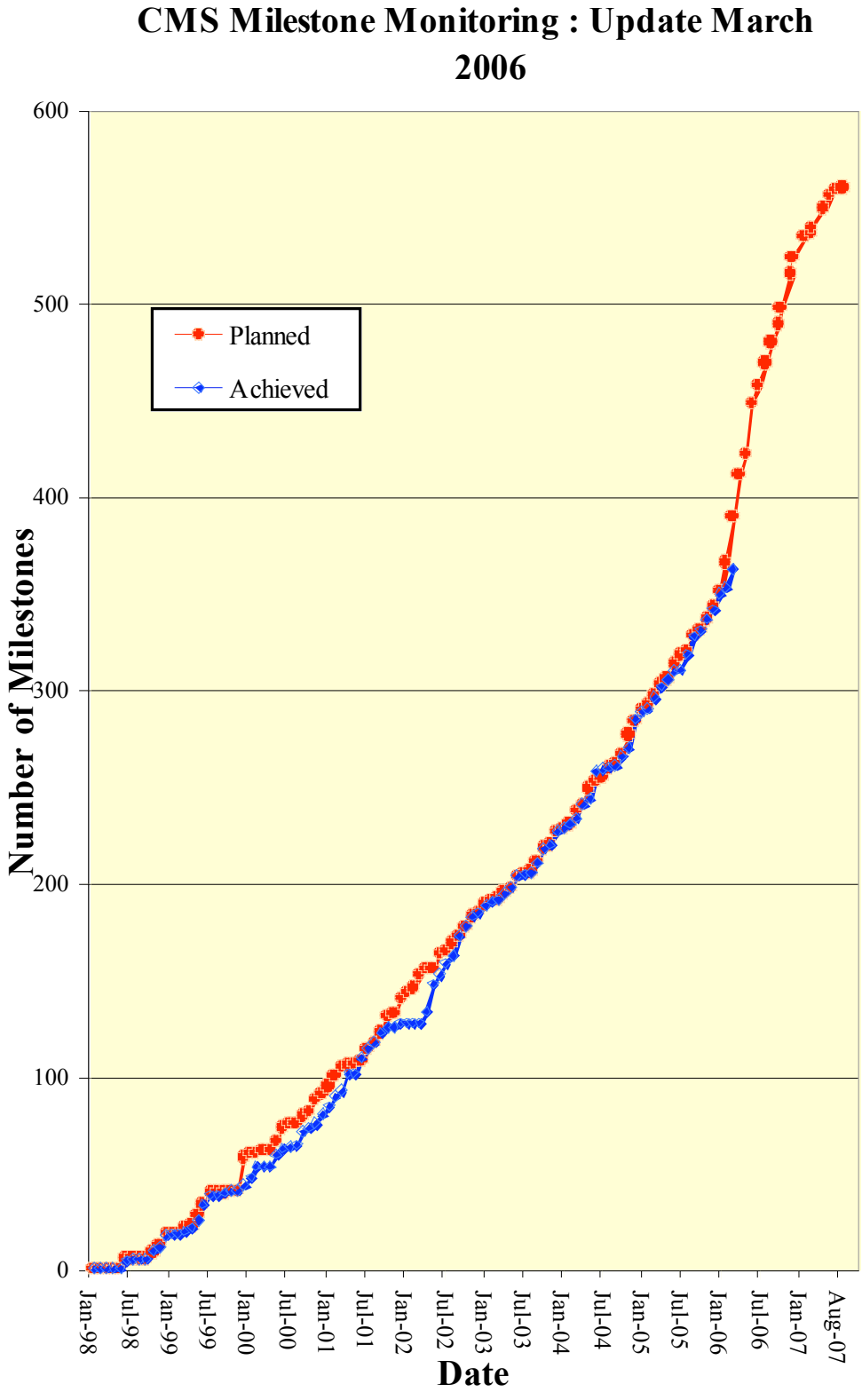
Plans and milestones for 2006
The Volume 2 of the Physics TDR will be submitted to the LHCC for its June meeting. Volume 3 will be submitted to the LHCC for its January 2007 meeting. A combined Computing Software and Analysis Challenge (CSA2006) is currently scheduled to run from September to November 2006.

Concerns
Availability of sufficient computing resources at the CMS T1s so that the CMS Computing Model can perform effectively.
Schedule for the Physics TDRs as well as CSA2006 is tight.

Overall Milestone Completion

In Figure 1, the intended and achieved integrated numbers of milestones completed are compared, month-by-month, with the CMS schedule. The assembly planning allows an initial detector to be closed on 30 June 2007.

Fig. 1



CMS Financial Plan

A financial plan was presented to the April 2005 Resources Review Board (RRB20), requesting extra resources at the level of ~ 32 MCHF. The current situation is shown in Table 1. It can be summarized by noting that there still exists a shortfall between the requests made and amounts committed or to be provided on a best-efforts basis. There is a shortfall of 3.7 MCHF split as follows: 1.5 MCHF for the ECAL crystals, 0.5 MCHF for the Tracker and 1.7 MCHF for the infrastructure and schedule consolidation.

As stated in the October 2005 RRB21, it was realized that the chances of timely delivery of a quality assured and debugged Tracker to Point 5 would be considerably improved if a large integration facility (TIF) could be set up. As funds for this were not foreseen, a fifth DAQ slice was staged to provide the necessary funds.

As stated in the section on Trigger and Data Acquisition the Global Calorimeter Trigger is now to be constructed using more recent technology. The additional cost to completion for this project is foreseen to be around 1.6 MCHF. The UK groups have requested access to UK contingency funds from PPARC. This is under urgent consideration. Furthermore, some expert manpower help will be provided by CERN. The limited functionality solution will be financed by the use of US_CMS contingency. CMS is very grateful to UK PPARC, CERN and the US Funding Agencies for responding positively.

The situation with respect to the construction of the staged items for High Luminosity operation has not changed since the April 2005 submission except that now 5 DAQ slices are staged instead of 4. It was noted that 2 of the staged DAQ slices will be restored using funds already foreseen in M&O Cat. A costs for the years 2009 and 2010.

In summary, CMS is grateful to the many Funding Agencies for their efforts to cover the extra costs, indicated in 2005, for the completion of the low-luminosity CMS detector. However, as the construction of this detector is coming to an end, even small remaining shortfalls have a serious impact on its timely completion. In particular the Tracker needs to be completed in 2006 and would remain short of ~0.5 MCHF. Furthermore, the funds foreseen for infrastructure and schedule consolidation (1.7 MCHF) are essential for the timely completion of the overall detector. **Hence, CMS requests the Funding Agencies to try to fully fulfill the requests made in the October 2005 RRB21.**

Table 1: Situation of the Requests presented in April and October 2005 RRBs, RRB20, RRB 21 (kCHF)

Funding Agency	Guideline	Reply	Committed/ Best Effort
Austria	275		
Belgium-FNRS	150	x	150
Belgium-FWO	150	x	150
Brazil			
Bulgaria	27		
CERN	4,800	x	4,800
China	300	x	300
Croatia	20		20
Cyprus	43		
Estonia	6	x	6
Finland	300	x	300
France-CEA	445	x	445
France-IN2P3	2,000		2,000
Germany	1,100	x	1,100
Greece	305		
Hungary	65		
India	500	x	500
Iran	74		
Ireland			
Italy	5,000	x	4,000
Korea	189	x	147
Mexico			
New Zealand			
Pakistan	149	x	149
Poland	183	x	
Portugal	140	x	140
RDMS-DMS			
RDMS-Russia	7,800	x	7,800
Serbia	24		
Spain	450	x	450
Switzerland-ETHZ			
Switzerland-PSI	500		
Switzerland-UNIV	200	x	200
Taipei	167		
Turkey	65		
United Kingdom	2,300		1,300
USA-DOE/NSF	4,750	x	4,750
TOTAL	**32,477**		**28,707**

Conclusions

CMS assembly planning allows an initial detector to be closed on 30 June 2007. A six-week delay is currently forecasted. Ways of recovering the six-week delay, after the lowering operation, are being investigated.

The initial detector will be without the previously staged items and the ECAL endcaps. The ECAL endcaps will be installed during the winter shutdown of 2007/2008 and be ready for the first physics run in 2008. The schedules for the completion of the Tracker and ECAL are tight.

CMS is indebted to the many Funding Agencies for their efforts to cover the extra costs-for the completion of the low-luminosity CMS detector. However, as the construction of this detector is coming to an end, even small remaining shortfalls have a serious impact on its timely completion. **Hence, CMS requests the Funding Agencies to try to fully fulfill the requests made in the October 2005 RRB21.**