

LARGE HADRON COLLIDER COMMITTEE

LHCb COMPREHENSIVE REVIEW

February 2006

1. EXECUTIVE SUMMARY

The fourth of the LHCC Comprehensive Reviews of LHCb took place on 13-14 February 2006. The LHCC referees addressed the following areas: Inner Tracker, Trigger Tracker, Outer Tracker, Vertex Locator, RICH Detectors, Calorimeter System, Muon System, Trigger & DAQ, Computing, Physics and the issues of Management, Technical Coordination and Schedules.

Since the previous Comprehensive Review in February 2005, the LHCb Collaboration has made very significant progress towards the realisation of an experimental set-up ready to record proton-proton collisions at the LHC. The LHCC expects LHCb to have a working detector installed in time for the beginning of LHC operation in 2007 provided the timely delivery of the sub-detectors and the smooth advancement of the production schedules is ensured.

Construction of final components is well underway. The spectrometer dipole magnet has been successfully commissioned and its magnetic field has been mapped. The Electromagnetic Calorimeter (ECAL), Hadronic Calorimeter (HCAL) and RICH-2 Ring Image Cherenkov Detector have been installed in the UX85 cavern. Installation of the infrastructure and technical services in the experimental area are well advanced. Issues concerning interference due to the installation of LHC Machine components around the LHCb experimental hall have been successfully handled. The LHCC noted as a concern the delays and resulting tight schedules in the production of the Vertex Locator (VELO), Inner Tracker, Trigger Tracker, RICH-1 Detector, Muon System, and in the Outer Tracker and Calorimeter front-end electronics.

The principal conclusions and concerns of the LHCC are summarised below. They will allow the Committee to follow up the outstanding issues and to monitor future progress of this project in forthcoming sessions of the LHCC prior to the next LHCb Comprehensive Review one year hence.

2. OVERVIEW

- Good progress was reported on the Inner Tracker, Trigger Tracker and Outer Tracker. The tight schedules for Inner Tracker and Trigger Tracker and for the Outer Tracker front-end electronics remain as the major outstanding issues.
- Good progress was reported on the VELO, RICH Detectors and Calorimeters. Production of all detectors is either underway or complete and installation in the UX85 cavern has started. The major outstanding issues regard the tight schedules for the completion of the VELO module production, the RICH-1 spherical mirrors and the Calorimeter front-end electronics.
- Good progress was reported on the Level-0, High-Level Triggers, Data Acquisition and Experiment Control System.

- Impressive progress was made in the Muon System and the Computing project since the previous LHCb Comprehensive Review. However, the schedule for the production of modules and electronics for the Muon System remains tight, increasing the risk that the ready-for-installation milestone will not be met.
- The LHCC took note of the new organization structure for the physics activities and plans until the start of LHC data-taking and requests further details on the physics commissioning strategy for the initial LHC operation phase.
- Much progress was reported on the work in the UX85 experimental cavern. The LHCC considers that although the schedule is tight, it is realistic to expect LHCb to have a working detector installed in time for the beginning of LHC operation in 2007.

3. INNER TRACKER, TRIGGER TRACKER OUTER TRACKER

Production of the Silicon Trackers, consisting of the Inner Tracker and Trigger Tracker, is advancing, albeit with a slower-than-expected start. All sensors for the Silicon Trackers are available and the quality of the first produced modules is good. Fabrication of the front-end electronics and the mechanical support frame are advancing well and will be completed on time. The problems reported at the previous LHCb Comprehensive Review have been resolved. The Silicon Tracker production and installation schedule is feasible but tight.

Excellent progress was reported on the production of the Outer Tracker. The detector is now on-time for installation in LHCb. Ageing tests on the ArCO₂ baseline counting gas should be completed and a report submitted to the LHCC. Production of the front-end electronics is progressing but the schedule to complete the electronics is tight.

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4. VERTEX LOCATOR, RICH DETECTORS AND CALORIMETERS

Good progress was reported on the VELO, with many of the technical problems at the time of the previous LHCb Comprehensive Review having been resolved. However, the Production Readiness Review for module production has been delayed by 8 months, resulting in a very tight schedule for the completion of module fabrication. The on-time delivery of kapton cables and RF boxes remains critical.

Good progress was also reported on the RICH detectors. The RICH-2 Detector has been installed in the UX85 cavern and the mirror alignment is stable. Excellent progress was reported on the Hybrid Photon Detectors (HPDs), with 133 out of 485 tubes having been delivered, almost all of which are of good quality. Production of RICH-1 is underway, albeit on a tight schedule, and the magnetic shielding has been installed. A significant cost increase in the beryllium spherical mirrors was reported. Together with the large uncertainty in their fabrication time, this resulted in the decision to pursue carbon-fibre technology instead, for which further tests are required. The issues regarding the spherical mirrors and the tight schedule for completing production of RICH-1 remain a concern.

Installation of the ECAL and HCAL modules in the UX85 cavern is complete, including the Photomultiplier Cockcroft-Walton high voltage bases and cables, and commissioning of these calorimeters has started with LED and a temporary ADC system. Good progress was also reported on the Preshower (PS) and Scintillator Pad Detector (SPD), with the respective module and supermodule assembly and Multi-Anode Photomultiplier (MAPMT) production completed. Installation of the PS and SPD in the UX85 cavern is scheduled to start in April 2006. The major outstanding issue is with the timely delivery of the front-end boards for all the above calorimeter systems, as appreciable delays have been accumulated owing to the additional iterations on prototypes. Production has now started on several components and LHCb has submitted a revised schedule, which is

consistent with the commissioning with the final front-end electronics in the second half of 2006.

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5. TRIGGER, DATA ACQUISITION AND EXPERIMENT CONTROL SYSTEM

Progress was reported on the Level-0 Trigger and HLT. No outstanding technical issues were reported for the Level-0 Trigger, although delays were accumulated in the project due to lack of manpower. Prototypes and pre-series elements of the Level-0 Trigger are under test for most boards. Production Readiness Reviews for several boards are pending and will be held shortly. Commissioning of individual L0 sub-systems will start in the autumn of 2006 and that for the complete L0 Trigger is scheduled for early 2007. The Committee will monitor progress of the Level-0 Trigger closely. Promising studies were shown for improvements to the HLT, which exploit the improved flexibility due to the new 1 MHz read-out. Preparations for the second stage of the Real Time Trigger Challenge are underway.

The underlying assumptions for the Data Acquisition RTTC run control have been verified and the move to the 1 MHz read-out scheme is reasonable and is well-underway.

Very good progress was reported on the Experiment Control System (ECS) and the Timing and Fast Control System (TFC).

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6. MUON SYSTEM AND COMPUTING

Impressive progress was made in the Muon System since the previous LHCb Comprehensive Review. Production of Multi-Wire Proportional Chambers (MWPCs) is advancing at the nominal rate at all sites and fabrication of the 3-GEM detectors has started. All quality tests so far are positive. Good progress was reported on the ancillary systems, such as the Muon System infrastructure and the Muon Filters in the UX85 cavern, beam plugs in the LHC machine tunnel, the general Muon System support structure, the gas system, the cooling services, and the cabling. Further details on the cabling plan are requested by the LHCC. Production of all electronics components is now in production. However, the schedule for the production of modules and electronics remains tight, increasing the risk that the ready-for-installation milestone will not be met.

Good progress was also reported on all aspects of the Computing, including the software framework, simulation alignment and reconstruction. The achievements of 2005 include the provision of software and trigger applications for the Real Time Trigger Challenge, the start of demonstrating alignment of sub-detectors, the commissioning of the conditions database and its integration in the sub-detector systems and the optimization of the pattern recognition algorithms. The performance of user tools for the analysis of Monte Carlo data is excellent. Preparations for Data Challenge 2006, the production challenge using the LHC Computing Grid (LCG) production services, are underway, and the availability of 3D database tools must be closely monitored.

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7. PHYSICS

The Committee took note of the new organization of the physics activities and plans until the start of data-taking. The structure of the working groups should reflect the needs for the initial LHC operation phase. The tau lepton physics programme and the assessment of its impact on the trigger should be developed. The LHCC requests further details on the physics commissioning strategy for the initial LHC operation phase.

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8. MANAGEMENT, TECHNICAL COORDINATION, AND SCHEDULES

Much progress was reported in the UX85 experimental hall. The field mapping of the Dipole Magnet is complete for both polarities and the measurements are within specifications. The final magnetic field map will be used in the reconstruction software. LHCb intends to reverse the polarity of the spectrometer magnet during LHC runs, perhaps at a frequency of once per week, to control systematic effects in CP asymmetries. The reversal is an added complication for the LHC Machine operation but during the initial LHC running period the reversal will not be necessary.

Installation of the LHCb beam pipe will start in May 2006 and is needed to be completed by the LHC Sector Test at the end of 2006. The last two beryllium sections have accumulated significant delays at the production phase. Owing to this and in order to meet the installation milestone, the pre-assembly and test of the complete beam pipe in the laboratory will not be carried-out.

A Commissioning Task Force has been put in place with representatives from all sub-systems. This body will define the mode of operation for data-taking, coordinate the commissioning of the sub-systems and prepare the LHCb detector for LHC data-taking.

Good communication between the LHCb Collaboration and the LHC Machine groups installing elements of the accelerator around Point 8 has continued, mitigating risk to the installation schedules. However, delays in the installation of the LHC Machine cryoline and subsequent tests, together with LHCb internal delays, have resulted in a shift of up to four months to several LHCb installation tasks. Nevertheless, it is reasonable to expect LHCb will be ready for the LHC Sector Test at the end of 2006, which is the preferred date for the Sector Test by the experiment as long as the LHC start-up date does not change. The issue of ensuring the radiation tolerance of electronics components of the LHC machine cryogenics is being addressed by the relevant LHC Machine groups.

Much progress was reported on the work in the UX85 experimental cavern. The LHCC considers that although the schedule is tight, it is realistic to expect LHCb to have a working detector installed in time for the beginning of LHC operation in 2007.

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