

Status of the LHCb Experiment

Report to April 2006 RRB
by the LHCb Collaboration

1. Introduction

The preparation of the experiment is proceeding steadily. The commissioning of the magnet has been completed and that of ECAL and HCAL is advancing. Construction of the other large detector systems such as Preshower/SPD and Outer Tracker modules is also progressing well and their installation will start soon. Production of the muon chambers is progressing now according to the plan and installation of the muon system infrastructure is going well. The installation of RICH-2 has been completed, and construction of RICH-1 is moving fast. The construction of the VELO mechanics is close to completion and the series assembly of the sensor modules is about to start. Detector modules for the Trigger Tracker and Inner Tracker are now being steadily produced. The overall schedule remains very tight, but installation of the detector is expected to finish in time to be ready for collisions in Summer 2007. Syracuse University has signed the Memorandum of Understanding (MoU) for the Construction of the LHCb Detector and Brazil still remains the only country that has not yet signed. A funding strategy is in place, which ensures the timely completion of the detector system but with a funding shortfall for CPU's used for the High Level Trigger and event monitoring at the start-up. Although this is not a serious problem for 2007, the collaboration is actively looking for special contributions for the CPUs, in order to ensure successful physics exploitation starting from 2008.

2. Detector Subsystems

2.1 Beam Pipe

The second section of the beryllium beam pipe, UX85/2, was delivered to CERN in February 2006 and tested. A separate bellow section was introduced to allow for easier replacement during operation. The construction of the third beryllium section, UX85/3, has been completed at Komposit (Russia) and is undergoing vacuum tests. Fabrication of the VELO exit window and a spare has been completed at CERN. The welding of the first beryllium section, UX85/1, to the VELO window has been completed. New material has been procured and the fabrication procedures have been revised for the aluminium bellow and flange sections, in order to improve their reliability, and a new series is currently being manufactured. The stainless steel section of the beam pipe, UX85/4, has been manufactured at TTM (Spain) and was delivered to CERN in January 2006 and tested. The stainless steel bellows and flange section has been fabricated by SKODOCK (Germany) and delivered to CERN in March 2006. The aluminium spare beam pipe has been ordered and is being fabricated at TTM. All beam pipe supports and installation tooling have been conceptually designed and details are being finalized. The section of beam pipe upstream of the VELO tank, RB84, is being manufactured.

Changes: Delivery of the UX85/3 beryllium section has been shifted from December 2005 to April 2006.

Concerns: Short time available for tests and assembly on the surface after the delivery of the beam pipe sections, before the installation in the cavern. Reliability of aluminium bellows.

Plans: Perform acceptance and vacuum tests of UX85/3 and of the stainless steel bellows and flange section. Perform NEG coating of all delivered components. Start fabrication of supports and fixed points. Fabricate of permanent bake-out equipment at CERN and place order for removable bake-out equipment. Finalise the installation procedures for all sections, to be agreed with the detectors concerned. Define the alignment procedures on the basis of the accuracy to be achieved. Install the beam pipe in the experiment at Point 8 in Summer 06.

2.2 Magnet

In November and December 2005, complete field maps were measured for both polarities of the magnet, with all iron structures in position. Although the full analysis of the data is still in progress, a preliminary study shows that the measurements are in good agreement with the results obtained by simulation.

Changes: None.

Concerns: None.

Plans: Make a few service and maintenance interventions after the summer.

2.3 Vertex Locator (VELO)

All electronics boards have passed their production readiness reviews. Approximately 75% of the required silicon sensors are in hand. The production readiness review for the silicon modules has been held and their series production is expected to start in April. Construction of the structures which support the detector boxes was completed, and they have been installed into the vacuum vessel. The right-side module support has been fabricated and assembled together with the CO₂ evaporator. The left side is being fabricated. A first RF box was made successfully and coated with Torlon. A second RF box is under fabrication. The tools for assembling modules to the support at CERN are ready. The delivery of all kapton cable interconnects has been delayed due to manufacturing problems which create too large an inhomogeneity between trace resistances.

Changes: Completion of module PRR was delayed to mid April 2006. Detector commissioning with test beam in North Hall will need both a June and October beam period due to module production delays.

Concerns: Delivery of kapton cable interconnects and 42 tested detector modules in time for detector assembly and full-system test.

Plans: Complete production and test of all electronics boards. Start and complete production of detector modules. Assemble both left and right detector halves at CERN. Carry out a full-system test with each detector half in the lab and with a test beam. Complete second RF box and perform NEG-deposition on both boxes at CERN. Install and commission vacuum, cooling and positioning systems in the pit. Install all long distance cables.

2.4 Silicon Tracker

Production of the silicon sensors for Inner Tracker (IT) and Trigger Tracker (TT) is almost complete: only thirteen out of 1680 ordered sensors are still missing. The quality

of the received sensors is excellent. Production of IT and TT front-end hybrids is also almost complete. The series production of detector modules is ongoing and produced modules undergo an extensive QA test. Quality of the modules produced so far is very good. The series production of digitizer boards has been delayed due to adjustments in the overall production schedule, but will start soon. There is good progress in the development of the Service Box control card and a pre-series board has been integrated and is used in the IT module test stand. A set of support frames for one IT station has been produced and those for the second and third station will be assembled soon in Lausanne. A custom-designed readout cable for the IT has been introduced to reduce the amount of dead material in front of the Outer Tracker. Support frames for the Trigger Tracker station will be installed in April 2006 and almost all materials for the detector box are in hand. The detector box will be assembled in Zürich and mechanical and thermal measurements will be performed there throughout the summer.

Changes: None.

Concerns: No contingency left in the production schedule of detector modules and TT detector box. Lack of manpower for developing detector-specific software such as configuration and conditions databases. Funding profile for Germany (MPI) and Spain.

Plans: Complete the production of detector modules. Finalize the integration plan of detectors. Complete the production of the support frames and install them in IP8. Produce the full readout electronics.

2.5 Outer Tracker

The production of all detector modules has been completed in 2005 at all production sites. All modules have been tested with radioactive sources and the desired yield of functional modules, including spares, has been achieved. The interface to the gas supply lines is being installed on the modules before shipment to CERN to simplify the installation procedure. The first batch of the FE electronics has been produced and successfully tested: boards are first individually tested and finally, after assembly, a global functionality test is performed, to check the threshold and noise characteristics as well as the timing performance. The rest of the mass production has started and it is foreseen to take place in two batches. The production of the aluminium C-frames supporting the detector modules has been completed. In order to simplify the installation procedure, the C-frames are equipped with all services (gas, cooling, HV, LV, fast and slow control etc.) at NIKHEF, before shipment to CERN; 50% of the frames have already been pre-assembled and the completion of the project is expected in time for the installation. A significant delay in the production of the detector support structures could be recuperated and all structures are now produced and shipped to CERN.

Changes: None.

Concerns: Delay in the mass production of the FE electronics. Gain loss unexpectedly observed when testing some of the production chambers, which has not been observed before in the dedicated ageing tests.

Plans: Install the support structures followed by the detector modules. Continue tests to understand how to protect against loss of gain.

2.6 RICH

For the RICH-1 detector, the two magnetic shielding boxes have been installed in the pit and tested with the LHCb magnet at full field. The gas enclosure has been leak tested and has arrived at CERN, ready for installation in May. An 80% price increase in the cost of beryllium and concerns about the delivery schedule led to the cancellation of

the order for the spherical beryllium mirrors, despite the good optical performance of the prototype. Beryllium has now been replaced with a carbon-fibre technology. Prototype mirrors have been ordered and the design work is in progress. For RICH-2, the spherical and planar glass mirrors have all been mounted in the detector and RICH-2 has been successfully transported and installed in the LHCb pit; the mirror stability during the move was verified. The production of the HPD mounting assemblies has been completed and the columns are ready for HPD and electronics installation. For the HPD photon detectors, the production is now well underway and 25% of the 484 tubes have been delivered and tested at the two test centres. The steady-state production rate of 30 HPD's per month has been achieved and to date only five tubes have been rejected. We now have all bump-bonded sensor assemblies in hand to complete HPD production. The delivery of the final batch of tubes to CERN, fully tested, is now scheduled for February 2007. For the electronics, full production of the Level-0, LV and HV boards has started, with the 20% milestone reached for Level-0. A system test in a Frascati test beam has been completed using production HPD's and electronics. Level-1 electronics prototypes have been extensively tested and the first pre-production prototypes will be ready in May.

Changes: RICH-1 beryllium mirror order cancelled and replaced by one using carbon-fibre technology.

Concerns: The tight schedules for the completion of RICH-1 carbon-fibre mirrors and the production of the HPD's.

Plans: Complete the R&D for the carbon-fibre mirrors and finalize the mirror mechanical design in May. Install the RICH-1 gas enclosure at CERN in May. Start commissioning of RICH-2 in October. Complete the full electronics production by November.

2.7 Calorimeter

Following their assembly and cabling in the experimental cavern, the ECAL and HCAL detectors have entered their first commissioning phase. Pre-series modules of the LED monitoring systems are used for first quality control checks after assembly. The production and installation of the LED monitoring distribution system in the ECAL chariots is well on schedule. The prototypes of the ECAL and HCAL readout Front-End electronics have successfully undergone the quality control tests and the Production Readiness Review was made at the end of March 2006. The assembly of the Preshower/SPD super-modules has been finalized in February 2006. The electronic cards for the LED monitoring systems have been delivered. The installation and tuning of the LED monitoring system on the super-modules is progressing well, and the quality control with cosmic particles is on schedule to allow for installation of the first Preshower/SPD detector half in April 2006. The installation of the Preshower lead converter has been finalized at the beginning of March 2006. The qualification tests of final prototypes for the Very-Front-End cards for Preshower and SPD have almost been completed. The production of the electronic cards for the Cockcroft-Walton HV system of the Preshower/SPD is well under way. The tests of the prototype Front-End card for the Preshower are still ongoing.

Changes: None.

Concerns: The tight production and testing schedule of the Preshower/SPD FE cards.

Plans: Proceed with commissioning of ECAL and HCAL. ECAL/HCAL Front-End cards series-production to start in April 2006. Start installation of Preshower/SPD super-modules in experimental cavern in April 2006.

2.8 Muon

All raw materials for stations M2-M5 have been delivered to the production centres. Their global production rates are as planned and more than 1000 MWPC's of good

quality have been produced. Production of M1 chambers has started at LNF and CERN and the initial problems with the honeycomb panel preparation are being solved. Production of the triple-GEM detectors has also started in both production sites (LNF and Cagliari). The mass production of the CARDIAC FE-boards has started and a burn in procedure has been agreed upon. The first MWPC's have been completely dressed, which includes the Faraday Cages, FE-boards, LV-boards and HV-filters. Dressing is proceeding at full steam at LNF for the chambers build in the INFN centres, and has started at CERN for the chambers built at PNPI and CERN. All Transition Boards, Intermediate Boards and Service Boards have been produced and are now being tested. For the Off Detector Electronics Boards the validation of the preproduction is ongoing. After modification of the area downstream of the muon system, the installation of the general support structures could be carried out and is close to completion. The acceptance of the suspended platforms for chamber installation is in progress and the installation of the chamber support walls is starting on the cryogenics side. Design of the M1 support structures has started as well. The software has been upgraded to have more realistic description of the detector and a new data format implemented following the 1 MHz DAQ scheme. The work on the ECS system is entering into an active phase and new manpower has been assigned to it.

Changes: None.

Concerns: Delay in the on-detector cabling due to late delivery of cable connectors and cables. Delay in M1 support structure design and integration.

Plans: Reach nominal rate of 10 chambers/day for chamber dressing, followed by a final chamber test. Mount all chamber support structures and install services (mainly cables and gas pipes). Start M2-M5 chamber installation and commissioning on the cryogenics side. Complete production of electronics boards.

2.9 Trigger

The final design is in progress for the output board of the Pileup system. Several prototypes are under test: the vertex finder board for the Pileup system, the validation card and selection board for the Level-0 calorimeter, and the Level-0 decision unit. The production readiness review has been successfully completed for the optical mezzanine boards, the hybrid for the Pileup system, the Level-0 muon processing board, the controller board and backplane. Their production is starting. A new HLT-flow has been introduced, which combines the old L1 and HLT and treats the different trigger objects more coherently. A new algorithm of the so-called Generic selection has been worked out. It works with an output rate of 4 kHz and has a better signal efficiency than what was described in the Trigger System TDR, that gave an output rate of ~ 10 kHz. A single-hadron trigger has been introduced, which reduces trigger-induced systematics in measuring the mistag rate with control channels. The inclusive single-muon trigger has been expanded with an algorithm requiring both a muon and an associated hadron, which improved the signal purity of this trigger. It was found that the majority of non-signal events accepted by the exclusive triggers was due to non-reconstructed primary vertices (PV). This problem was remedied with a new PV reconstruction algorithm. Work has started to prepare methods to monitor the trigger performance with real data.

Changes: None.

Concerns: Tight time schedule for production of the Level-0 trigger electronics.

Plans: Organize production readiness review for pileup boards, validation card and selection board, and Level-0 decision unit. Produce all boards and test them. Investigate ways to profit more from the 1 MHz readout, by using tracking stations, muon stations

and ECAL information at rates larger than 40 kHz. Introduce new trigger summary blocks, which will allow a redundant monitoring of the trigger performance. Implement mechanism to steer the HLT from the on-line Condition Data Base.

2.10 Online

All TFC modules have been produced and will be tested piecemeal before distribution to the client groups. To date there are about a dozen TFC systems in use by groups inside and outside CERN. Emphasis in the ECS system work is moving from the development of basic building blocks to integration and system building, and guidelines for subdetector systems are being established. Tools for describing electronics boards in terms of controls and monitoring are also being introduced. Some development effort is still underway to finalize the SPECS software and also to harmonize the interfaces of the SPECS and the Credit Card PC (CC-PC). Controls PCs (1U size) for CC-PCs and CAN have been acquired and PCs (2U size) holding the SPECS cards have been ordered. The farm infrastructure control and monitoring is continuously being improved and has gathered a lot of interest from the other LHC experiments. In the DAQ area, the changes in conjunction with the adoption of the 1 MHz readout scheme are now being implemented. This includes the development of buffer manager software and an even-building task. The performance of the latter was measured to be $\sim 8.5\%$ CPU usage at the expected rate of ~ 30 kHz of Multi-Event Packets. This confirms the earlier estimates of the number of CPU-equivalents needed for this function. Also large-scale (one-quarter LHCb) switch tests were performed at the Force10 company in California and showed the expected performance, so that the choice of this equipment is confirmed.

Changes: A new sub-project has been defined to cover the aspects of histogram handling and data quality monitoring.

Concerns: Lack of manpower for the data quality monitoring and histogram-handling project.

Plans: Complete the additional cabling necessary for the 1 MHz readout in May. Set-up and operate a wedge of the Online system (ECS, TFC, DAQ) in April, in the framework of the preparations for the VELO test beam, and then commission it in IP8.

2.11 Computing

The recommended changes from the Subdetector and Core software review in September 2005 have now been implemented. In addition a more realistic geometry of the detectors, including the tilting of the detectors with respect to the beam-pipe, has been completed. Core developments in Gaudi have made use of the developments in the LCG application area following the merging of ROOT and SEAL. We have stopped the use of the CLHEP library from the LHCb-specific parts of the applications and LHCb has contributed to testing and improving the new ROOT geometry and Linear Algebra packages. Work has continued on evaluating the conditions database service for LHCb, using an ORACLE backend. Studies on the replication of the database have started, based on the LCG-3D developments, using instantiations at RAL and CERN. The VELO produced a report detailing their alignment procedure; the other tracking detectors are now also studying their alignment strategies. Work has commenced to understand how to perform the global alignment. LHCb participated in the Service Challenge 3 in order to study data replication. Tools were developed for data management, in particular a transfer agent that interacts with the FTS (file transfer system) from the LCG. The stripped datasets required for analysis were distributed to all LHCb Tier-1 centres and analysis is now possible at CERN and five of the LHCb Tier-1 centres. The

LHCb Workload and Data Management System (DIRAC) was reviewed in readiness for the 2006 Data Challenge. The tools are being finalized to allow automated processing to be triggered as data files become available. Ganga, the interface to the Grid for analysis, was successfully used for submitting jobs to the Grid through the DIRAC system. Over 20 users have been submitting their analysis jobs through Ganga, for which the most recent release allows automatic job splitting, and thus an improved turnaround.

Changes: Pre-production for DC06 will commence in April 2006 rather than January.

Concerns: Stability of the LCG infrastructure and development of middleware, particularly issues associated with data access.

Plans: Evaluate computing model during DC06. Start implementing the final alignment strategy.

3. Experimental Area and Detector Installation

RICH-2 has been installed in its final position, and both muon electronics towers have been assembled. One side of the muon support structure is complete and the area has been prepared for the installation of muon panels. The traction system for the muon filter has been fixed to the trolley and tested. Two access platforms close to the magnet have been assembled and will serve to provide access for the Vertex Locator vessel. Support structures between the magnet and upstream wall are in place for the installation of additional cranes. All four Preshower lead modules have been mounted on the gantry. Several DSS sensors have been installed and connected to the DSS system. The main structure supporting the cable trays in the front of the counting house has been completed, and the installation of the cable trays for the long distance cabling started in March 06 as scheduled.

Changes: Vertex Locator installation has been moved to May following delay of the delivery of two additional cranes, which have to be installed first. Beam pipe installation will start in July 2006.

Concerns: Increase of parallel activities in the experimental area due to delays.

Plans: Install the detector services such as cable trays for the long distance cables, cooling units, gas systems and safety devices such as ODH System in order to have the UX85 equipped before the first cool-down of the 8-7 Sector. Install Outer Tracker support structure until May and VELO vacuum tank in May. Complete muon support structure on side A and fix the gantry to the main crane support structure. Start PS/SPD super module installation in April 2006 and install the first part of TT support structure.

4. Cost and Funding

As discussed during the past RRB meetings, the current cost of the experiment is 75.341 MCHF, practically unchanged from the estimate given in the MoU (75.045 MCHF) while the MoU signed contributions amount only to 70.257 MCHF. This generated a funding shortfall of 5.084 MCHF spread over various subsystems. During the last RRB meeting in October 2005, the LHCb collaboration proposed a strategy where all the subsystems would be fully funded except for CPU's installed at IP8 for the High Level Trigger and event monitoring. This has been achieved, partly by requesting from some funding agencies extra contributions to the subsystems which are funded by them, and partly by shifting funds. For the requested extra contributions, we received either approvals or very encouraging responses during the last meeting, which was highly appreciated. Assuming that all of the previously mentioned extra contributions to the

subsystems were approved, the remaining problem on the CPU's would become a shortfall of 2.632 MCHF. After taking the contribution from the USA into account (400 kCHF), we still need to find 2.232 MCHF, which corresponds to roughly 65% of the required CPU cost. Starting up the experiment in 2007 with the 1/3 of the required CPU power will be sufficient. However, this will soon become a problem for physics exploitation in 2008, and we are now investigating the possibilities to obtain special contributions to fill this gap. Already the French representatives have informed us of their decision to provide an additional contribution of 500 kCHF. Requests for new contributions, 450 kCHF and 600 kCHF, have been submitted to Germany (BMBF) and US (NSF), respectively, and we are also approaching other funding agencies. At the forthcoming meeting we hope to present a solution to the remainder of the CPU shortfall.

LHCb Milestone Plot

