CERN-RRB-2006-092
6 October 2006

Status of the LHCb Experiment

Report to October 2006 RRB
by the LHCb Collaboration

1. Introduction

The LHCb spectrometer is being built up rapidly in the cavern. The spectrometer magnet, RICH-2 and the calorimeter system are now fully in place. Large panels to support the muon chambers have been placed between the iron filters for the Muon Stations 2 to 5 and are being prepared for the chamber mounting. A common support structure for the Outer Tracker and Inner Tracker frames has been erected between the spectrometer magnet and RICH-2, and is ready to accept them. Supporting rails for the Trigger Tracker frames have been mounted between RICH-1 and the magnet. The gas enclosure box for RICH-1 is now in place between the top and bottom iron shielding boxes for the Hybrid Photon Detectors, and has been connected to the Vertex Locator (VELO) vacuum tank whose exit window acts as an entrance window for the RICH-1. The VELO vacuum tank together with the first beryllium section of the beam pipe is now in its nominal position. The LHCb experiment should be fully installed and ready to take data during the 2007 pilot run. These data will be used to align and calibrate the detector.

2. Detector Subsystems

2.1 Beam Pipe

The first section of the beryllium beam pipe, a 25 mrad beryllium cone welded to the VELO exit window, has been connected to the VELO vacuum tank at the Interaction Point 8 (IP8) in August, and vacuum tests are being performed by the CERN AT/VAC group. The installation procedures of the remaining sections are being refined and agreed with the detectors concerned. NEG coatings of the second beryllium section, UX85/2, and of the stainless steel section, UX85/4, have been made. Leaks were observed in the third beryllium section, UX85/3, during the preliminary tests performed in Russia. They had been fixed by a varnish coating over the outside surface. The section will be delivered to CERN in October, and followed by acceptance tests by the CERN AT/VAC group in collaboration with NIKHEF. The stainless steel bellows and flange section have passed the acceptance tests. A new series of aluminium bellow and flange sections have been fabricated with a revised procedure and are being tested. The aluminium spare beam pipe is being fabricated at TTM (Spain) and is expected for delivery before the end of 2006. The removable bake-out equipment for UX85/1-2 and a part of UX85/3 has been delivered and the permanent bake-out equipment for the remaining section of UX85/3 is ready for assembly.

Changes: Installation of beam pipe sections UX85/2-4 and bellow sections has been delayed to the end of 2006.

Concerns: Short time available for tests before installation due to the delayed delivery of the last beryllium section. Reliability of varnish applied to a part of UX85/3 in high radiation environment.

Plans: Install the section of beam pipe upstream of the VELO tank, RB84, in October. Perform acceptance tests and make NEG coating for UX85/3. Finish tests of beam pipe supports and fixed points and fabrication of attachments to the detector structure. Install permanent bake-out equipment. Install the remaining sections of the beam pipe and bellows sections by the end of 2006 and commission in early 2007.

2.2 Magnet

The magnet was fully commissioned already in 2005.

Changes: None.
Concerns: None.

Plans: Test the combined operation with the compensator magnets.

2.3 Vertex Locator (VELO)

Delivery of production grade sensor modules to CERN started at the end of August and ~30% of the modules are already in hand. A burn-in set-up is now operational at CERN. The long Kapton interconnect cables were installed in the right-half module base and mounting of the sensor modules on the base has started at CERN. The first stage of VELO commissioning, a full vertical DAQ slice, was successfully carried out in April. In the second stage, three pre-production sensor modules were tested in a test beam in August. The VELO vacuum vessel was installed in IP8, aligned and surveyed. Some leaks on auxiliary equipment developed during transport, which are being repaired. The vacuum and positioning systems have been installed in the pit. Two left and two right RF boxes have been constructed and leak tested, and are currently being surveyed. Work is in progress on the construction of the left-half module, with all mechanical pieces already available.

Changes: Detector commissioning with test beam will take place with the right half only. Commissioning of left half will occur in assembly lab.

Concerns: Module delivery and detector half assembly on critical path. Delivery schedule of the long-distance signal cables. Delayed delivery for the CAEN Low Voltage power supplies.

Plans: Complete the production of all the electronics boards. Finish the assembly of the right and then left detector halves at CERN. Perform system test of right half in November test beam. Install the RF boxes inside the vacuum tank, make the NEG coating and commission the tank. Install HV, LV and signal cables in the pit. Install and commission the cooling system at IP8. Install detector halves into the vacuum tank.

2.4 Outer Tracker

Production and testing of the detector modules were completed and they are all now at CERN. A large stainless steel structure, the IT/OT bridge, has been assembled between the magnet and RICH-2 to hold the IT and OT in place. All the aluminium C-frames, which support the detector modules, were equipped with necessary services (gas, cooling, HV, LV, fast and slow control etc.) at NIKHEF and have been transported to CERN. After making test insertion into the IT/OT bridge, they are now being loaded with detector modules in the cavern using a specially constructed frame structure. Cabling of the C-frames to the patch panels in the cavern has started and will proceed in parallel with the detector installation. A second batch of Front-end electronics has been produced, which corresponds to about 25% of the total, and all the delivered individual boards have been tested. Currently, the fully assembled Front-end boxes are being

tested together with the control system and a first complete version of the Data Acquisition system.

Changes: None.

Concerns: Delay in the mass production of the FE electronics. Gain loss observed in OT modules when they are exposed to small doses of irradiation: various procedures for treating the modules have been investigated that substantially reduce the effect, but a definitive solution has not yet been established.

Plans: Continue the C-frame loading and installation to the support bridge. Start the installation of the Front-end boxes. Continue tests to establish the best procedure to protect against loss of gain.

2.5 Silicon Tracker

All the silicon sensors and readout hybrids for the Inner Tracker (IT) and the Trigger Tracker (TT) have been delivered and tested. A small number of additional spares were ordered to replace those lost in production and to make a few extra spare modules. The series production of detector modules is now proceeding smoothly at the planned speed and with good quality. IT module production is 60% complete, and TT module production more than 90%. The IT support frames have been produced, and a test insertion to the IT/OT support bridge has been successfully completed. The first IT detector box is currently being assembled with modules inside, and a test-stand for testing the fully equipped detector box is being set up. The support rails for the TT station have been installed and aligned in IP8. Production of the TT detector box is in progress. All the Service Box crates have been assembled and production of the electronics cards is advancing. Work on ST-specific slow-control software has started.

Changes: None.

Concerns: Tight schedule for IT module production. Very tight schedule for the assembly and testing of the TT detector box. Low level of manpower for the development of detector-specific software. Funding profile for Germany (MPI) and Spain.

Plans: Complete the production and testing of the sensor modules. Complete and install the detector boxes in IP8. Test and install the full readout electronics. Continue work on the development of detector-specific software. Start in-situ commissioning of the detectors in IP8.

2.6 RICH

For the RICH-1 detector, the gas enclosure has been leak-tested, installed in the pit, and the seal to the VELO has been connected. Samples of prototype carbon-fibre spherical mirrors, including one almost full-size mirror, have been successfully tested for radiation tolerance, reflectivity and fluoro-carbon compatibility. The order for the final spherical mirrors has been placed for an expected delivery by the end of this year. The flat mirrors for RICH-1 have been delivered and have excellent optical quality. The full aerogel production of 16 tiles has been completed. RICH-2 was installed in the LHCb pit a year ago and the optical system has remained stable throughout. The production of the HPD mounting assemblies for RICH-2 has been completed and seven of 18 columns have been fully mounted with HPDs and electronics. The HPD production is now more than halfway complete. Of the 484 tubes required, 286 have been delivered and 244 of these have been tested. The steady-state production rate of 30 HPDs per month has been maintained and to date only eight tubes have been rejected (3%). Problems with the delivery of quartz windows incurred a month's delay, but this time should be recovered so that the delivery of the final batch of HPDs to CERN and completion of testing by

February 2007 can be achieved. For the electronics, whilst there has been a slippage of a couple of months, production of the Level-0, LV and HV boards is well underway, with the 50% production point either reached or close to being reached. The Level-1 electronics pre-production has been successfully tested and the Production Readiness Review (PRR) has been completed. A system test of three production HPD columns at the CERN SPS with 25ns beam structure is currently underway.

Changes: None.

Concerns: The tight schedules for the completion of RICH-1 carbon-fibre mirrors, the fabrication of the RICH-1 HPD mechanics, and the production of the HPDs.

Plans: Begin commissioning of half-equipped RICH-2 in November. Complete the HPD mechanics by the end of the year. Complete the full electronics production by January 2007. Complete RICH-2, including all photon detectors, by January 2007. Complete RICH-1 by April 2007.

2.7 Calorimeter

The commissioning of the ECAL and HCAL modules using the LED monitoring systems is progressing. Following a successful PRR, the series production of the FE electronics modules for the ECAL and HCAL started in April 2006. The first 32 FE-modules have been delivered to CERN, to start their commissioning with the detector in October. Following calibration with cosmics, the installation of all 16 Preshower/SPD supermodules in the experimental cavern has been completed according to schedule in June 2006. Due to some delays in installing the necessary infrastructure of the Preshower system, the cabling of the 12,000 Preshower/SPD readout channels is expected to start in October 2006. The Preshower FE electronics underwent a PRR in June 2006 and series production has started. The production of the very-front-end (VFE) cards for Preshower and SPD, as well as the electronics cards for the Cockroft-Walton HV system, are on schedule.

Changes: None.

Concerns: Very tight schedule for cabling the Preshower and for the production and testing of the Preshower/SPD FE cards.

Plans: Proceed with commissioning of ECAL and HCAL with LED monitoring system and with testing of the ECAL/HCAL FE cards from series production. Continue the production and quality control of Preshower/SPD FE cards. Cable the Preshower from detector to FE cards.

2.8 Muon

Production of Muon chambers has progressed well on schedule and more than 1300 chambers, 90% of the total required, have been produced with good quality. Almost 700 chambers have already been delivered to CERN by INFN and PNPI, and are undergoing final tests prior to their installation. Production of triple-GEM detectors is ongoing. The delivery of CARDIAC FE boards is now progressing well, after some delay due to production problems identified during burn-in. A problem of bad resistors on the Spark Protection Boards (SPB) has been solved, which however caused a delay in chamber dressing and installation. Twenty pre-production ODE boards have been delivered for a final test. A test of the complete readout chain at 40 MHz has been successfully performed and is being repeated with chambers in a special 40 MHz test beam. The HV system has been ordered. All of the Muon system M2-M5 infrastructure (panels, chamber supports, gas and electronics racks) has been installed. Cables and gas pipes have already been installed on M5, which is now ready to accept chambers. Installation

of services for stations M2-M4 is in progress. Design of M1 infrastructure is ongoing, ready for an internal review in October.

Changes: More work being done in parallel during the installation phase.

Concerns: Manpower for services and chamber installation. Delays in M1 integration and installation.

Plans: Continue installation of services and start chamber installation in October. Complete production of ODE boards and install off-detector electronics. Begin system commissioning. Start dressing of GEM Chambers. Complete M1 design and integration and begin installation of M1 chambers. Install HV system and start commissioning. Order material for spare chambers.

2.9 Trigger

PRRs have been successfully completed for the Level-0 calorimeters and for the Level-0 Decision Unit. The remaining one is foreseen before the end of the year for the Level-0 Pile-up boards. Currently 20% of the Level-0 trigger boards have been produced and 3% tested. The new HLT-flow has been implemented in the software prepared for the ongoing data challenge, DC06, and first tests with the newly generated data are in progress. Studies of using the T-stations, Muon stations, and ECAL information at rates larger than 40 kHz are well underway, resulting in an increase of the trigger efficiency. All the setting parameters for the HLT have been defined. They are steered by the on-line Condition Data Base. Methods to determine these parameters using real data are under development.

Changes: None.

Concerns: Tight time schedule for production of the Level-0 electronics. Delayed production of the four Pile-up modules.

Plans: Produce and test all Level-0 trigger boards and install them in the experiment. Produce a version of the HLT which can be used to benchmark candidate CPUs for the EFF by early 2007. Introduce the L0-confirmation algorithms in the HLT flow.

2.10 Online

All additional cabling for the 1 MHz readout is finished. The barracks are now ready for receiving the subsystem's equipment. The Timing and Fast Control system is ready. The Beam Position and Intensity Monitor (BPIM) module has been designed and is now in production. While waiting for the cables between the detector and the barracks (long-distance cables), a small system allowing the detector groups to commission at least part of the installed equipment is being prepared. A first example of this Commissioning Rack (CRack) is now ready, and two others will follow for use by various detector groups. At the software level, the tasks running in the nodes of the HLT farm have been debugged and are ready for use. The basic components of the control system are ready, and now have to be deployed by the subsystems and integrated to make the overall LHCb control system. The TELL1 production is keeping pace with the needs, and currently approximately 40 cards are available for tests. A subproject to cover the aspects of histogram handling and data quality monitoring was established and has started.

Changes: A new subproject has been defined to cover the aspects of histogram handling and data quality monitoring. Delay the installation of the full DAQ system to 2008 in view of the new LHC plan.

Concerns: None.

Plans: Complete the Experimental Control System and start integrating the subsystems. Install a scaled down version of the DAQ hardware for the global commissioning of the detector and pilot run in 2007.

2.11 Computing

The initial subdetector internal- and global-alignment strategies have been completed and outlined in an LHCb note. Work has started to set up the software framework for the T-station alignment and is expected to be ready and tested by the end of this year. The VELO alignment is working in the test beam environment. The global alignment challenge has been postponed until the beginning of 2007. The tracking software is now functional after all the event model changes and improvement in detail of detector material. A detector performance similar to before, although slightly degraded due to the additional material (e.g. beam pipe supports), is achieved. Work is ongoing to tune the particle identification, charged and neutral, with the new tracking. Physics quality simulation has been in production since the summer in preparation for the LHCb physics analysis studies. Physics quality reconstruction software is expected to be ready in November. The latest data challenge, DC06, started in July, and the use of DIRAC tools to allow automated processing to be triggered as data files become available has worked smoothly. Issues associated with data access were identified at several Tier-1 sites; four Tier-1 sites were able to support the challenge at start-up and problems have been solved at an additional two. The prioritisation between simulation and reconstruction jobs occurred successfully and needs to be extended to analysis versus production jobs.

Changes: Global alignment challenge to January 2007.

Concerns: Delay in achieving stability of the LCG infrastructure and in development of LCG middleware associated with data access.

Plans: Continue evaluation of computing model and production for physics analysis.

3. Experimental Area and Detector Installation

The installation of the major metallic structures and supports for cable trays has been finished. The installation of the cable trays is well advanced, about 90% completed. Gas distribution system and cooling systems are also installed up to the proximity of the subdetectors. Installation of all the safety devices is progressing well. The Oxygen Deficit Hazard (ODH) system at the detector area is in operation since July as scheduled. The cabling (long distance) started in July and is progressing well. The VELO vacuum vessel has been installed and Outer Tracker support structure lowered and installed. All Preshower/SPD super-modules have been inserted and the RICH-1 gas enclosure mounted inside its magnetic shielding. The Trigger Tracker support structure has been installed with both of its rails aligned to 0.1 mm precision. All Muon support panels have been mounted and service installation is well advanced. The large Calorimeter access tower and bunker extensions have been assembled. Two cranes behind the magnet are in their final position and have been used for detector installation in this area. The RICH-1 gas enclosure has been sealed to the VELO and the first section of the beam pipe has been connected to the VELO vacuum vessel. Two Outer Tracker C-frames filled with modules have been moved inside the support structure. All Inner Tracker support frames have arrived at the experimental area. Muon beam plugs are mounted to the Muon filters on both sides. All long distance cable trays have been installed and cabling is well advanced.

Changes: Due to the cancellation of the sector test foreseen for December 2006, the installation of the upper part of the radiation-shielding wall in the UX85 cavern has

been rescheduled for November-December 2006. The installation of the front part has now been shifted to next year.

Concerns: Many parallel activities in the experimental area.

Plans: Install all the detector services and cabling. Make pre-commissioning tests of the cooling systems. Completion and start of operation of the new access control system at IP8. Install RICH-1 exit window in October and start with the remaining beam pipe installation at the end of October. Mount two platforms in the TT and RICH-1 areas, continue long distance cabling, and connect gas systems.

4. Cost and Funding

As reported at the last RRB meeting on 26th of April 2006, LHCb had an under-funding of 1.732 MCHF, after taking into account the special contribution from France (500 kCHF) and US (400 kCHF) for the CPU farm. As agreed at that meeting, construction of the LHCb detector has advanced by shifting all of the under-funding to the CPU farm in IP8. Since then, we have received the following approvals for special contributions for the missing parts of the CPU farm:

Germany	300 kCHF
US	130 kCHF

This makes the current under-funding 1.302 MCHF, which should be compared to the cost of the CPUs of 3.420 MCHF. This level of under-funding clearly does not introduce any problem for the pilot run in 2007 at a reduced energy of $\sqrt{s} = 900$ GeV, and neither for the initial period of the 2008 run. However for the second half of 2008, we should have all of the CPUs in order to fully exploit the physics potential of LHC, which should be able to deliver the nominal luminosity for the LHCb experiment. Decisions are expected in Spring 2007 for the requests to Italy and UK, for 200 kCHF and 400 kCHF respectively, and a new request of 450 kCHF has been made to US-NSF for the funding period of 2007 to 2009. In addition, Spain has already expressed their intention to make a contribution of 20 kCHF during the last RRB meeting. Effort is being made to seek countries that can make additional contribution, including Brazil.

LHCb Milestone Plot