

Status of the LHCb Experiment

Report to April 2005 RRB
By the LHCb Collaboration

1. Introduction

Construction is advancing well for most of the subsystems (VELO, Outer Tracker, RICH, Calorimeters, and Muon system), and pre-production has started for the Inner Tracker and TT station. The overall schedule is very tight, but it is planned to complete the installation of the detector to be ready for collisions in summer 2007. The Memorandum of Understanding (MoU) for the Construction of the LHCb Detector has been signed by Poland. The only country that remains to sign the MoU is Brazil, whose requested contribution in the MoU is 1.6 MCHF, of which 1.22 MCHF is for the Muon system. In order not to slow down the construction of the Muon system, it is proposed to shift 1.22 MCHF from the Common Fund, originally assigned for the event filter farm CPU's, which could be bought later. In addition, the institutes responsible for the Muon system have requested additional funding to INFN and CERN in order to cover the cost increase of the Muon system, with encouraging responses. For the RICH system, negotiations are still in progress in order to find a solution for the increased cost of the RICH system with the funding authorities concerned, i.e. INFN, PPARC and CERN.

2. Detector Subsystems

2.1 Beam Pipe

Construction of the beryllium sections of the beam pipe is ongoing in Komposit (Russia). A prototype of the aluminium flange connecting the two long beryllium sections has been successfully qualified. Design of supports and fixed points is in progress: optimization of the amount of material is under study along with verification of the global mechanical analysis. Final design for the stainless steel section of the beam pipe has been approved and contacts with companies for fabrication are in progress. Manufacturing of the VELO exit window at CERN is in progress.

Changes: None.

Concerns: Short time available for tests after the delivery of the beam pipe sections before the installation.

Plans: Consolidate the designs of supports and fixed points. Perform tendering and place order for the stainless steel section of the beam pipe. Manufacture the aluminium bellow and flange section at CERN. Fabricate the stainless steel bellow and flange section. Start design of an aluminium spare chamber.

2.2 Magnet

The magnet has been switched on and successfully reached the nominal field for both polarities. At the same time, levels of magnetic field have been measured at various places including inside the temporarily located RICH2 shielding box, at the VELO region and at the cryogenics plant adjacent to the detector. Those measurements confirm the estimates based on simulation results. Before the end of 2004, a measurement of the field map inside the pole region was performed using a specially made measurement machine. The analysis of the measurements is in progress and a preliminary result shows good agreement with the simulation.

Changes: None.

Concerns: None.

Plans: Measure the field map over the entire tracking volume with the RICH1 box in position in May. Measure again the complete field map when all iron structures are in place in September.

2.3 Vertex Locator (VELO)

After the successful engineering run of the Beetle Front-end (FE) chips, the final production was launched and the chips received. The setup for the quality assurance of the produced chips is currently being commissioned in Heidelberg. Four prototype analogue digitizer mezzanines were produced and tested on a TELL1 board in Lausanne. Small pre-productions of the service board (repeater motherboard), low-voltage mezzanine and driver cards are currently being organised. The schematics for the Experiment Control System (ECS) boards are being defined. Pre-series silicon sensors were received and characterized in a test-beam run in November 2004. After the test-beam analysis, final sensor production was started. The hybrid design was finalized and a pre-series order placed. The cooling block interface was defined in February and production of the cooling system components was started in Amsterdam. The vacuum vessel was manufactured and the full vacuum system is now being assembled. Production of the detector mechanics has started. The first full-size rectangular bellow was produced and found to be leak tight. Prototyping of the RF box is continuing. Tests for deposition of NEG on the first prototype RF box have started at CERN.

Changes: Detector module Engineering Design Review (EDR) shifted to mid April 2005 and Production Readiness Review (PRR) to mid May 2005.

Concerns: Delivery time for tested detector modules, fabrication of final RF boxes, provision of sufficient DAQ for assembly and burn-in.

Plans: Qualify all the produced FE-chips. Complete pre-production and PRR of all readout boards by May to June and start production. Receive all ordered sensors and complete module EDR and PRR. Place an order and receive all hybrids. Start module production. Finish all mechanics and cooling system and produce two final rectangular bellows. Perform acceptance test of positioning system and cooling system.

2.4 Silicon Tracker

The EDR for the Inner Tracker and the TT station took place in December 2004. For the Inner Tracker, a pre-series of 50 silicon sensors was received and quality assurance tests have shown excellent results. The full production of the sensors has started and the next batch is expected in May. For the TT station, the contract for silicon sensors has been placed. The delivery of these sensors will be significantly delayed with respect to the original plan due to a saturation of the production lines at the vendor caused by the significant increase of the CMS sensor order. First detector modules have been built according to the final design and using final production tools. A small delay has been encountered in the testing of Beetle chips and the production of FE readout hybrids. This delay can be absorbed in the production schedule. Parts for the TT detector box have been produced, and the assembly of the station will start soon. A mechanical prototype of an Inner Tracker detector box is currently being tested in the laboratory. Design work on the interfaces for the TT station to the LHCb experiment is in progress and a prototype of the Inner Tracker support structure has been assembled in the laboratory. A prototype of the Service Box has been commissioned and will be used in burn-in tests during the module production. A full readout chain including all

components from FE hybrid to TELL1 board is operational in the laboratory. High-voltage and low-voltage systems have been defined.

Changes: None.

Concerns: Significant delay in the delivery of silicon sensors for the TT station.

Plans: Continue the pre-series module production and move gradually into full production. Assemble the TT detector box and perform mechanical and thermal tests. Start production of Inner Tracker detector boxes. Finalise the design of interfaces to the experiment. Order all components for the readout, HV and LV systems.

2.5 Outer Tracker

Module production is now running at a rate of two modules per week at NIKHEF and Warsaw, and one at Heidelberg. More than 50% of the total modules have been produced as planned, fully recovered from the previous delay. All materials received, except for the last 88km of wire, for which delivery is under way. All the kapton straws have been manufactured. First of two beam tests was done at DESY with a 6 GeV e^- beam using a Si telescope with 10 μm resolution, in order to determine the drift cell efficiency and resolution, and cross talk. Four modules were successfully operated for three weeks with FE electronics. On-line analysis of the data showed good results and detailed analysis is ongoing.

Changes: None.

Concerns: Necessary resources for the infrastructure (frames, cooling, etc.). Tight installation schedule, which may result in an increase of the cost.

Plans: Complete the system test of a C-frame with modules, cooling, gas, full FE and readout electronics system at NIKHEF. Fix the frame design and start the tendering. Perform electronics PRR in April and the second beam test in April.

2.6 RICH

For the RICH1 detector, the magnetic shielding boxes are currently under construction and will be installed at the end of April 2005. The PRR for the RICH1 gas enclosure was held in December 2004, and the tender is sent out. The full order for the RICH1 beryllium mirrors is currently being prepared, although there has been a 5-month delay in the delivery of the first full-scale prototype, now expected at the end of May. The aerogel performance and ageing properties have been verified. For RICH2, the assembly of the mechanical structure has been completed on schedule and the spherical glass mirrors are now being installed prior to alignment. The planar mirrors are in production. The PRR for the HPDs was held in December 2004, and the contract with DEP has now been signed. Nine pre-series HPDs have been tested in the laboratory and test-beam with excellent results. A total of 200 sensor assemblies have been delivered to CERN and $\sim 90\%$ are within specification. Full HPD production is now starting. The production of the mechanics for the RICH2 photon detector matrices and the on-detector electronics has started. Final prototypes of the Level-0 electronics together with the link module between the HPD and the Level-0 card are being tested. The low voltage and high voltage distribution cards are being tested in their final layout.

Changes: None.

Concerns: The tight schedules for the completion of RICH1 mechanics and the beryllium mirrors. The timescale for the production of the final HPDs, to be ready for installation in the RICH detectors.

Plans: Complete the PRRs for the remainder of the RICH1 mechanical components and beryllium mirrors. Install the RICH2 structure in the cavern in July. Make a system test

of a full column of 16 HPDs with the preproduction readout chain in May. Make a design review for the Detector Control System in June.

2.7 Calorimeter

All 3300 ECAL modules have undergone the final quality control with cosmic rays and are ready for installation. For the Hadron Calorimeter all 52 modules have been assembled with optics. Half of the modules are equipped with photomultipliers and Cockroft-Walton bases. Those modules have undergone successfully the final quality control check with a radioactive source and are ready for installation. All of the 7800 photomultipliers were delivered and tested. All the required Cockroft-Walton high voltage bases for ECAL and HCAL were produced and tested. For the Preshower and SPD four out of the required 16 super-modules have been assembled at CERN. After identification of problems with the fibre quality, the production of fibre bundles that transport the light from the Preshower modules to the Multi Anode Photomultiplier Tubes (MAPMT) at the detector periphery has resumed at CERN and Clermont. The 200 MAPMTs for the Preshower and SPD detectors have been delivered. Test-benches at Barcelona and Clermont for the MAPMT test have been commissioned. The installation of the ECAL and HCAL support chariots in the experimental cavern has been completed, and the installation of the ECAL detector modules has started at the beginning of March according to schedule. The design of the Preshower support structures and the lead converter has been finalized. A Market Survey has been launched for the lead converter. Final prototypes for the Very-FE cards for PS and SPD have been received and are under test. Prototypes of all the FE cards are being tested. All of the Calorimeter electronics have undergone successfully a Final Design Review in February 2005.

Changes: None.

Concerns: The tight schedules for the Preshower super-module production and the ECAL/HCAL and PS+SPD FE cards production and testing.

Plans: Complete ECAL module installation by mid 2005. Start HCAL module installation by April. Finish Preshower super-module production by end 2005. Begin ECAL/HCAL and SPD/PS FE card production in last quarter of 2005.

2.8 Muon

Production of panels is progressing with good quality, and material delivery to PNPI proceeds smoothly. Starting up of the PNPI-2 site took more time than expected. All the other production sites are operating at the planned production rates and more than 320 chambers have been produced with good quality. The EDR for the Triple-GEM detectors for the innermost region of the first muon station (M1) was completed. The NRE Run for the CARIOCA, DIALOG and SYNC chips has successfully produced six wafers. The chips are now being packaged and tested. The plan for the final packaging and testing is being worked out. Half of the Spark Protection Boards have been delivered. An order for the FE board is being placed. Production of other boards is also in progress. The three iron filters have been constructed in the cavern. The order for the chamber support walls is being placed.

Changes: None.

Concerns: Start up speed of the PNPI-2 site. Maintaining the stable production rates at all the production centres. Quality of spools for the anode wires. Manpower for the design and integration of the first muon station.

Plans: Start the Off Detector Electronics production. Launch the production run for the chips. Install the FE boards on the chambers. Install the chamber support structures for M2-M5 in the cavern. Start the production of Triple-GEM detectors.

2.9 Trigger

Level-0 electronics: A prototype of the calorimeter FE board is being tested and the trigger part will be debugged in the coming weeks. Prototypes of mezzanine boards driving optical links, a prototype of the Level-0 decision unit and the hybrid for the pile-up system are under test. The final design of the Level-0 muon processing and controller boards is progressing.

Level-1/HLT: On-line monitoring tools have been introduced in the Level-1 and HLT triggers, which will be tested during the Real Time Trigger Challenge (RTTC) in summer. A fully functional HLT algorithm has been produced and tested on large samples of minimum bias and signal events. Apart from the originally planned algorithms selecting B decay final states exclusively, more inclusive selection algorithms have been added to provide large statistics for calibration purposes and extend the physics scope of the experiment. These selections have increased the total output rate from 200 Hz to 2 kHz. A new particle identification algorithm has been developed tailored to the on-line needs, which in principle allows the use of the RICH information in the HLT trigger.

Changes: Add a spy mechanism at input and output of Level-0 calorimeter boards to check easily data exchange between boards. Increase of the output rate to 2 kHz.

Concerns: Tight time schedule for Level-0 calorimeter and muon triggers.

Plans: Test the prototype of the validation card and of the selection board for the Level-0 calorimeter. Produce two processing, one controller and one backplane boards for the Level-0 muon and test them. Test a first version of the pile-up system. Continue improving and extending the trigger algorithms. Test the on-line trigger monitoring tool during the RTTC in summer.

2.10 Computing

Online: The barracks in the pit are almost ready for receiving the electronics. Ethernet cabling is progressing and should be finished by the end of April. The cooling equipment for the CPU farm (Rack Cooler) has been delivered and is currently being installed in the racks. The Timing and Fast Control (TFC) equipment is in full production after some problems with the manufacturer and subsequent change of the manufacturer. The test stand and test procedures are ready to receive the production modules. Suitable candidates for the Sub Farm Controllers have been identified. Good understanding for the capabilities of modern Ethernet switches/routers have been achieved and a market survey for the LHCb networking will start soon. The first batch of 100 interface cards for the Credit Card PC has arrived. The implementation details of the SPECS system have been decided. Pre-production modules of the common TELL1 board were received and tested. All boards are working to specifications and are now distributed to the subdetector groups for further testing and integration.

Offline: The computing model was submitted to the LHCC for review in December. Several issues raised in the review, in particular the event size estimates and resource profiles, have been addressed and will be included in the computing TDR document. Limitations were revealed with the implementation of the Storage Resource Manager (SRM) within the LCG during Phase 2 of the Data Challenge, production analysis. Working closely with the LCG experts and the computing centres the majority of these problems have been understood and solutions implemented. Manpower to work in the area of the conditions database and the alignment framework has been provided through

CERN and the UK. INFN is providing additional manpower to work on the workload management system and data management. A major release of the software framework, Gaudi, has been made to incorporate changes to external software packages. Work is progressing well to provide the framework and production needs for the Real Time Trigger Challenge in the summer. A new VELO detector element has been implemented and the VELO tracking adapted, now using the same version online and offline. Also an updated track event model is being implemented and reviewed.

Changes: Computing Model adapted to an increased data output rate of 2 kHz.

Concerns: Tight manpower for the ECS system. Lack of manpower in some subsystem software teams.

Plans: Finish the installation of the power distribution for the barracks by June. Prepare necessary procedure for acquiring the online equipment gradually starting end 2005. Complete the CC-PC glue-card production and test by August. Submit the Computing TDR.

3. Experimental Area

Since October 2004, the main activity was the re-installation of the rails in the UX85 cavern for the calorimeters. The work has been completed as foreseen. The assembly of the chariots for ECAL and HCAL on rails started in February 2005 as scheduled. The installation of the part of the cryo-line (QRL) from the inter-connection box (QUI) located at the end of the UX85 up to the LHC tunnel (Sector 8-1) has been delayed until May to June 2005. However, the assembly of the last muon filter can be advanced due to a modification of the QRL design.

Changes: None.

Concerns: Cohabitation with the LHC QRL installation at UX85.

Plans: Install the Electrical Power Station in the PZ area by summer. Start the installation of the detector services such as cable trays, cooling pipes and gas piping.

4. Installation

The first three muon filters have been assembled and the support structure of the last filter (MF4) is in place. Handling tool for the MF4 installation has arrived. Support structure (80 tons) of RICH2 and the Outer Tracker has been installed in October 2004. All four Calorimeter chariots have been placed on rails and lateral beams are mounted and aligned. Assembly of the ECAL has started.

Changes: None.

Concerns: Very tight schedule and limited resources.

Plans: Complete ECAL and HCAL module installation and assembly of MF4 by May. Install the RICH1 shielding in May. Install the support structure for the first Muon station and Preshower in May. Transport and install RICH2 in the experimental area by August.

5. Organization

Below is the current organization of the LHCb collaboration.

Physics and Subsystem Projects

Physics Coordinator

O. Schneider (EPFL)

Subsystem Project Leaders

-VELO

J. v.d. Brand (NIKHEF)

-Silicon Tracker

O. Steinkamp (Zurich)

- RICH
- Outer Tracker
- Calorimeter
- Muon
- Level-0 trigger electronics
- Level-1 and High Level Trigger
- Online
- Computing

- N. Harnew (Oxford)
- A. Pellegrino (NIKHEF)
- A. Schopper (CERN)
- G. Carboni (Rome II)
- R. Le Gac (Marseille)
- H. Dijkstra (CERN)
- B. Jost (CERN)
- N. Brook (Bristol)

Management

- Spokesperson
- Deputy Spokesperson
- Technical Coordinator
- Resource Coordinator

- T. Nakada (CERN/EPFL)
- R. Forty (CERN)
- W. Witzeling (CERN)
- A. Smith (CERN)

Collaboration Board

- Chairperson

- E. Aslanides (Marseille)

6. Milestone Plot

Figure: Cumulative plot of the LHCb Milestones, as presented to the LHCC.

