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Status of the LHCb Experiment

Report to April 2008 RRB
by the LHCb Collaboration

1. Introduction

Installation of the LHCb detector is close to completion, except for the first muon station where only the infrastructure and a limited number of chambers will be installed for the 2008 run. Commissioning of the installed subsystems is advancing well using the final DAQ and detector control system. The Muon, Calorimeter and Outer Tracker systems are taking data with cosmic rays. The cause of the Outer Tracker gain-loss with a specific irradiation level has been identified and preventative measures are being taken. The initial DAQ system sufficient for the expected LHC operation in 2008 has been purchased. This will be upgraded during the 2008-2009 winter shutdown to match the increasing event rate. Although more work is still needed, the Common Computing Readiness Challenge in February showed that there was no fundamental problem with the Grid based computing for the forthcoming data processing. The overall schedule remains tight, but we are confident to be ready for the first LHC collisions in 2008.

2. Detector Subsystems

2.1 Beam Pipe

Installation and commissioning of the 23 metre-long beam pipe going through the detector was completed in Summer 2007. The beam pipe was pumped down once more in November 2007 after installation of the VELO sensors. After successful verification of the vacuum quality, the beam pipe was again filled with ultra-pure neon to atmospheric pressure. During the magnet tests, the TS/SU group verified the position of the beam pipe with the field present. The fabrication of the aluminium spare sections, UX85/1, UX85/2 and UX85/3 was completed by the TS/MME group. The first two sections need still to undergo leak testing and NEG coating, and the third section NEG coating. Investigation of a replacement for the third section of the Be beam pipe has started and preliminary discussions have been carried out by AT/VAC with manufacturers.

Changes: Delay in the development of new beam pipe supports with further reduced material, due to priority of LHC installation activities.

Concerns: Mid- to long-term reliability of the UX85/3 varnish coating.

Plans: Prepare tendering procedures for a Be replacement for the UX85/3 section.

2.2 Magnet

The LHCb dipole has been switched on again in October 2007. During this period, the Magnet Control and Safety Systems (MCS and MSS) have been successfully commissioned, with all the control sensors and communication with the LHCb Detector Safety System (DSS). Positions of several sub-detectors, detector supports and access structures were surveyed as well. A small movement of the RICH-1 lower shielding during ramping of the magnet was measured and has been remedied by reinforcing the fixture. After the commissioning of the LHCb magnet under local control, the control was transferred to the CERN Control Centre (CCC). From the Control Centre the LHCb dipole was successfully operated together with all three compensator magnets.

Changes: None

Concerns: None.

Plans: A further period of magnet operation is foreseen in May 2008 during detector commissioning.

2.3 Vertex Locator (VELO)

The VELO detector halves have been successfully installed. The CO_2 cooling system is now operational at −25°C. The vacuum system has been commissioned and its control is due to be handed over to the LHC vacuum group before first collisions. All cables have been installed and tested. Delays due to the slow delivery of CAEN modules, and their recall, mean that the LV will not be fully operational before early April 2008. The firmware of the HV system (ISEG) was delivered with a significant delay and still has some minor problems. However, the HV should be fully functional by April 2008. An interlock box that permits application of LV and HV in safe conditions has been built and tested. About 15% of TELL1 boards, which digitize the analogue signals and perform zero suppression, developed a hardware problem that had not been present during the acceptance test. The cause of this problem has been identified to be a broken grounding connection of the board, and has been repaired. Investigation is in progress to examine whether this is due to a quality problem in the fabrication of the boards. Implementation of the Experiment Control System (ECS) framework is close to completion. Partial DAQ tests have been performed successfully. Purchase of some materials needed for the spare VELO modules has started.

Changes: Additional delays on the LV/HV deployment.

Concerns: Small leak developed in RF boxes, although not critical for the first years of operation. Long term reliability of the TELL1 board due to a possible quality problem in the fabrication.

Plans: Make the full VELO detector operational in Q2 of 2008.

2.4 Outer Tracker

The detector installation is complete with all the electrical, gas and cooling connections. The gas system and the cooling system have been commissioned, including DSS interlocks. The detector alignment has been completed. The LV and HV systems have been connected and commissioned. About 80% of the FE electronics has been installed and its commissioning is ongoing. Another 10% is being installed, while the remaining, including spares, is being produced and is expected before the end of April. All TELL1 boards have been installed and their commissioning is ongoing. Cosmic data are routinely taken with a special scintillator trigger. Ageing studies showed conclusively that the observed gain loss is due to the out-gassing of the Araldite used to seal the module boxes. A production module sealed with a different resin (TraBond 2115) has not shown any degradation under irradiation. For the present detectors, besides flushing, three C-Frames were warmed up to ~40 °C and gain-scan is being performed in situ to ascertain the results of the heat treatment. HV training procedures have been established for the recovery from the gain loss, in case of need.

Changes: None.

Concerns: Overall delay in the commissioning of the complete OT due to the delay of the FE electronics installation and to some lack of manpower for commissioning tasks. Uncertainty in the long-term behaviour of the gain-loss.

Plans: Complete electronics installation and commissioning and continue in situ heat treatment.

2.5 Silicon Tracker

All of the twelve IT detector boxes, along with their service boxes, and about 3/4 of the TT detector modules have been installed. The IT detector boxes and TT modules were tested and debugged in the laboratory prior to their installation in LHCb. High-voltage and readout tests have been performed on most of the installed detectors. The installation work is going smoothly and so far no major problems have been detected in the testing of the installed detectors. The C_6F_{14} cooling system has been routinely operated for several months. Significant progress has been made in the development of ECS and data-quality monitoring software. A part of the detectors was successfully included in global commissioning runs.

Changes: None.

Concerns: Funding profile for Germany, MPI Heidelberg.

Plans: Complete the installation and continue the commissioning of the detectors. Participate in LHCb global commissioning effort. Finalize ECS and improve user interfaces. Continue software alignment studies.

2.6 RICH

RICH-1 construction is now almost complete. All mirrors have been installed and aligned. The top photon detector (HPD) box has been installed and fully equipped with HPDs and readout electronics, and its commissioning is about to start. Fabrication of the bottom HPD box is essentially complete, together with all the necessary installation equipment. The HPD columns for the bottom box are ready to be installed. Manufacturing of the last remaining items, the upper and lower photon funnels, is being completed. The magnetic monitoring system has been shipped to CERN. Complete installation of the RICH-1 detector including the aerogel is expected to be completed in April. The RICH-2 detector, installed in the pit over two years ago, is fully equipped with the photon detectors and readout electronics, and included routinely in the globally commissioning. The magnetic monitoring system of RICH-2 has been successfully tested. All the HPDs (484+66 spares) were produced. Following commissioning of the RICH-2 detector, around 25 HPDs out of its 288 photon detectors had developed vacuum problems and have mostly been replaced. The HPD performance is now closely monitored during regular and routine operation of RICH-2. Discussion with the manufacturer has started concerning the possible causes and eventual replacement. RICH reconstruction software is in an advanced state of development and exercised with test-beam data. RICH calibration procedures, both in hardware and using physics data, are also well advanced.

Changes: None.

Concerns: The tight schedule for the installation of the final components of RICH-1. Deterioration of the vacuum quality for some HPDs.

Plans: Finish installation of the RICH-1 detector by April 2008. Finish global commissioning RICH-1 with full HV to 20 kV by the end of June 2008.

2.7 Calorimeters

Installation of the full system, comprising Scintillator Pad Detector (SPD), Preshower (PS), ECAL and HCAL, is complete. The commissioning is well advanced: all C-side detectors were able to participate in the global commissioning already at the beginning of March. Cosmic ray data, triggered by the coincidence of energy deposits in HCAL and ECAL calorimeters, have been recorded for SPD, PS, ECAL and HCAL. The LED calibration system of each sub-detector is currently used and corresponding data are regularly recorded. For the C-side, the remaining effort concentrates on the signal time alignment of the different sub-detectors. The A-side detectors are ready to be included in the global commission-

ing. This should be achieved quickly due to its similarity to the C-side. The caesium source for the HCAL calibration is ready and the calibration will take place in April. The real time calibration and monitoring software is being developed.

Changes: None.

Concerns: None.

Plans: Make the full calorimeter elements operational for mid-April 2008. Calibrate the HCAL with a caesium source in April 2008. Perform time alignment of the calorimeters. Take calibration events to survey PM's stability and prepare calibration procedure. Deliver a cosmic trigger for commissioning of the other sub-detectors.

2.8 Muon Detector

The 1084 installed chambers for stations M2-M5 were fully tested and aligned. The 20 missing chambers have been produced in PNPI and were delivered to CERN. They are now being equipped with the electronics, tested and installed. The production of more spare chambers is ongoing in PNPI and LNF. The gas system has been commissioned and is in operation. All the HV system is in place and tested. The air-cooling installation for the inner part of the chambers is in progress. The commissioning of the M2-M5 stations is well advanced. The connectivity of the electronics has been checked and corrected where necessary. The connections to trigger and DAQ are working. The signal time alignment of all electronics channels is ongoing. Half of the M2-M5 chambers have been operated successfully with HV and only 2 out of 2208 gaps are not working properly. The HV test of the other half is in progress. The ECS software is being fine-tuned and the global commissioning is in progress. Cosmic ray data, triggered by the coincidence of one quadrant of the stations M4 and M5, have been recorded. For M1, all the chambers are now under pre-installation tests and conditioning at GIF. The gas pipes and the LV cables were installed on the walls, and the installation of the cable chains and the mechanics for sliding the walls is ongoing.

Changes: None.

Concerns: Delays in M1 installation due to the lack of engineering manpower and many parallel activities with the SPD/PS detectors. Manpower for global commissioning and M1 installation.

Plans: Install the missing chambers on M2-M5 and complete the station alignment. Complete global commissioning of M2-M5. Deliver a cosmic trigger for commissioning of the other sub-detectors. Complete installation of M1 infrastructure, services and install some chambers. Complete production of spare chambers.

2.9 Trigger

Installation of the Level-0 trigger boards was completed in Summer 2007. Commissioning of the Level-0 Calorimeter and Level-0 Muon triggers is almost complete for Side-C. Commissioning of the Pile-up is starting. A cosmic ray trigger is running with ECAL and HCAL Level-0, Muon Level-0, and the Level-0 Decision Unit. The first complete version of the High Level Trigger (HLT) code has been released to allow benchmarking for the tender of the Event Filter Farm (EFF). This code is now running on some of the candidate computer nodes for the EFF, and its performance appears to be well matched to the EFF budget. The HLT code has been fully adapted to the new tracking framework. A first version to allow a quick and transparent changeover between different trigger configurations has been released, and is under test. A new Python based HLT software framework has been implemented to allow the physics working groups to make exclusive selections of their channels, and is under test.

Changes: None.

Concerns: None.

Plans: Complete the commissioning of the Level-0 Trigger. Start using the EFF to run the code and test the commissioning and monitoring tools.

2.10 Online

The installation of the online system is approaching completion to the planned level of the networking and CPU farm. The first slice of the HLT farm (~100 boxes, corresponding to ~15% capacity) has been ordered and is expected to be installed by middle of May at the latest. The installation of the final CPU and networking (currently ~20%) capacity is foreseen for the first quarter of 2009, in time for the 2009 data taking. The controls system is in operation, and minor performance issues have been addressed; functionality and operability is being improved continuously. The Timing and Fast Control system is complete and routinely used for detector commissioning. The final version of the Beam Intensity and Phase Monitor module is currently being mounted and should be ready soon. The Histogramming and Monitoring framework is being put in place, in conjunction with detector groups starting to implement their monitoring code.

Changes: None.

Concerns: Very thin manpower coverage for installation and setting-up.

Plans: Continue to commission, debug and improve the system.

2.11 Computing

The tracking and particle identification software is ready for real data. Tracks can be reconstructed with a reasonable efficiency and low ghost rate, even in the case of large initial misalignments, providing the starting point of the alignment procedure. Alignment working weeks with participation from all tracking detectors, including the muon system, have been organized at regular intervals. Implementation of the measured magnetic field to be used by the reconstruction software is ready for testing. LHCb has been extensively testing the latest release of ROOT released in January, and the LHCb framework has been built on this new series of LCG Application Area configurations. LHCb also collaborates actively with the Grid Middleware developers of the middleware client libraries in the LCG Application Area external software. Event simulation of signal samples has continued at a low pace. Stripping of b-inclusive background samples as well as signal samples demonstrated the lack of reliability of Storage Elements at sites where files were supposed to be present but were not accessible. Special LHCb-specific agents were developed to deal with this problem. DIRAC3 was used for data transfers and first-pass reconstruction during the two weeks of Common Computing Readiness Challenge that took place during the second half of February. Transfer and reconstruction at Tier1 sites was achieved at the LHCb nominal rate (70 MB/s) with a duty cycle for the LHC of 50%. Several issues were identified concerning SRM v2.2 during this challenge that were fed back to developers. A major effort to adapt the LHCb Bookkeeping system to real data has started. Analysis on the Grid using GANGA and DIRAC expects major improvements when moving to DIRAC3 and after the WLCG accepts the LHCb usage of multi-user pilot jobs.

Changes: none.

Concerns: Large manpower reduction from UK due to budget constraints. Manpower needs for organizing the LHCb Computing Operations team.

Plans: Perform alignment challenge in Spring 2008. Place DIRAC3 in full production for simulation, stripping and analysis before the May CCRC. Complete the developments on

Bookkeeping by July. Use latest developments in ROOT for handling data model schema evolution and data compression.

3. Experimental Area

The installation of the front part of the radiation shielding wall, started in July 2007, was interrupted from October until February 2008 due to the repair of the water cooling pipelines passing across the radiation shield via a chicane. Several micro-leaks were observed on the stainless steel pipelines in October and non-destructive inspections of the welds confirmed a very poor quality of the welds (micro-cracks, non-penetration, root-porosities). A crash programme with the supplier was set-up over December and January in order to repair all the water pipelines, which had been identified as non-compliant with the technical specifications. During this repair work the cooling for the electronics was interrupted which caused a delay of several weeks for the general progress of the commissioning of the detector. The installation of the shield re-started in February 2008 and will be completed by the middle of April. In the meantime, the concrete mobile radiation plug was produced and placed in final position including installation of the interlock system. Other detector services such as cooling systems (C_6F_{14} and demineralised water) are almost all connected to the sub-detectors (OT, IT, TT, RICH1&2, SPD/PS) and the commissioning is progressing now as scheduled. Construction of a special laboratory to handle irradiated detector components is being prepared.

Changes: The global completion of the radiation shield initially scheduled for December 2007 re-scheduled for April.

Concerns: None.

Plans: Completion of the radiation shielding wall and commissioning of all the detector services by June. Finish minor works such as installation of the sand bags for closing the small apertures around cable trays and pipelines.

4. Commissioning

The global commissioning of the detector is picking up speed. This is now done for one week every month with all experts available, with the aim of moving towards a more complete system and to solve problems as they are found. During the other weeks, each subdetector finishes the installation and commissioning of their own hardware. One day per week, integration of new parts or new features is tried. RICH2, the Calorimeter system, the Muon Detector, and the L0 Trigger are now integrated in the central system and some data were taken with a cosmic ray trigger, reading several consecutive readout cycles. Data have been taken with about 1/3 of the final number of readout boards for LHCb.

Changes: None.

Concerns: Delay due to the late installation of some detectors. Some instability in TELL1 hardware and software.

Plan: Increase the number of sub-systems, number of boards and rate. Take cosmic ray events.

5. Cost and Funding

5.1 Overall Funding Situation

As described during the last RRB in October 2007, with the second instalment of 200 kUSD for the CPU's in the pit from US-NSF on behalf of the Syracuse group, expected this year, the LHCb experiment is fully financed.

5.2 VELO Replacement Modules

As presented during the last RRB in October 2007, the VELO silicon sensors are expected to be replaced after an integrated luminosity of 6 fb^{-1} due to radiation damage. This was already indicated in the Technical Design Report and has again been endorsed by the LHCC during its February 2008 session. It is worth noting that 21 sensor modules, corresponding to the number housed in one detector half, would be needed as spares in case of the worst-case beam related accident. For this reason, we consider 21 sensor modules to be the usual spare modules to be taken care of by the subsystem. The remaining 21 modules are needed due to the expected radiation damage, which can be considered as a common item, as was specified in Appendix 9 of the MoU for M&O, to be financed by the whole collaboration. This was agreed by the Collaboration Board. The total material cost of the 21 modules is estimated to be 500 kCHF based on the experience of producing the first 42 modules. This would be split among all of the funding agencies over a period of five years with the same sharing as for the Category A M&O cost as common item. The actual amount per year would be small; less than 5% increase. The production of the remaining 21 modules as well as the necessary infrastructure of the production site at Liverpool would be basically covered by the UK from its Category B contribution and special contribution from CH (300 kCHF requested by EPFL). We would like to note that the high radiation dose expected in the region of VELO might impose a severe restriction on the module replacement work, defined by the CERN Radioprotection Regulations, which could make it difficult to finish the work during the annual shut down period. Possible loss of data taking could then be avoided by pre-installing all the sensor modules on replacement detector bases. We may indeed consider producing two detector bases, which would require a separate funding discussion. However, we need to gain more information on activation before concluding on the need for spare bases and making a definite proposal.

5.3 Replacement Beam Pipe Section

As reported in previous RRB meetings, the third beryllium section of the beam pipe was delivered with an inferior quality. The repair made by the CERN Vacuum Group was successful and it will be used for the initial period of the LHC operation. However, the CERN Vacuum Group expressed strong concern for the long-term reliability of the section as it will be subject to high irradiation doses when the LHCb runs with the nominal luminosity, and requested that a replacement should be produced. In order to provide the third section within the specifications, the production method must be changed. Recent investigation by the CERN vacuum group indicates that the cost could be covered by extra funding that has now been granted by CERN.

6. Collaboration Issues

The LHCb collaboration has welcomed Moscow State University (Russia), led by Prof. P. Ermolov, as a full member of the collaboration. Initially, the group will have three physicists and three PhD students. In addition to the obligatory contribution to the M&O, we are discussing possible technical contributions they could make in the areas of the muon system and VELO, where they have expertise and where help would be welcome. It should be noted that their participation is fully supported by the existing Russian groups.