CERN-RRB-2008-088
23 October 2008

Status of the LHCb Experiment

Report to November 2008 RRB
by the LHCb Collaboration

1. Introduction

The installation of the LHCb detector has been completed in time, except for the first muon station that will be completed as planned during the 2008/09 shutdown. Commissioning was proceeding well during the summer to the point that LHCb was ready to take data mid August, from which on 7 day 24 hour shift coverage was ensured. During the synchronization tests (TED runs) and during the first circulating beams data were successfully taken. These data proved to be very useful for fine time and space alignment of the detector. In the forthcoming winter shutdown the installation of the M1 station will be completed, the upgrade of the DAQ system to its full capacity will be undertaken as well as other improvements and maintenance work.

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 is under vacuum since June 2008. The aluminium spare sections, UX85/1, UX85/2 and UX85/3 are mechanically ready, the NEG coating has been put temporarily on hold, but can be performed on short notice. Following discussions with potential manufacturers a tender for a replacement of the UX85/3 Beryllium beam pipe was launched.

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

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

Plans: Proceed with procurement of the Be replacement for the UX85/3 section.

2.2 Magnet

The magnet was powered in April 2008 for one week and structures in the vicinity of the LHCb dipole have been surveyed again. Results have shown that the fixation of the RICH-1 lower shielding was sufficiently improved. However, the Trigger Tracker upper rail requires reinforcement of the support structure, which will be performed during winter 08/09. The symmetry of the B-field between the two polarities was measured to be better than 10^{-4}, a special demagnetizing cycle for switching the polarity is not necessary. Several sub detectors have been performing measurements with magnetic field. The beam dump trigger in case of a magnet failure has been tested together with the LHC operators. All the magnet ramping procedures have been controlled by the CERN Control Centre (CCC).

Changes: None

Concerns: None

Plans: Yearly maintenance work to be performed in the winter shut down. A powering test of the magnet will be performed before closing the experimental area for the 2009 run.

2.3 Vertex Locator (VELO)

The VELO detector hardware has been successfully commissioned. The VELO was able to record hits and reconstruct tracks from the beam synchronization tests in August 2008. The vacuum and cooling systems have functioned without fault. The nominal coolant temperature was set to -5° C for 2008. This minimizes the mechanical severity due to the thermal cycling that the VELO modules experienced during the commissioning period. The HV and LV systems are now fully checked out and installed although some problems have been identified with the HV firmware. We note that the lack of spares for the LV system remains critical. The VELO modules have operated in vacuum for extended periods of time and there exists, at this time, no evidence of vacuum related issues with the hybrids or silicon sensors. The Data Acquisition System has been integrated with LHCb. Hardware failures in the readout boards (TELL1s) remains an issue; consequently there is an acute shortage of TELL1 spares. The Experimental Control System (ECS) is now complete, although it is still being refined. This will include improved ease of automatically uploading pedestals and thresholds to the TELL1s. The majority of the software effort is now being invested in improving the online and offline monitoring, and in making the operation of the VELO more “user” friendly. The aim is to develop “expert” systems that can identify potential problems in the VELO. Procedures have been put in place to safely switch on power and to close the VELO modules in view of first collisions. The build of the VELO replacement, which mitigates the impact of beam related accidents to LHCb, is underway. The only outstanding problem, as with the original VELO build, is the supply of pitch adaptors. Prototype thin glass pitch adaptors (cheaper and easier to bond) have been supplied and are being evaluated.

Changes: Increased operating temperature for 2008 to minimize thermal cycling.

Concerns: Low level leak in the RF foil, TELL1 spares and hardware reliability; availability of LV spares, HV firmware needs revision.

Plans: Extend existing basic monitoring package; develop “expert” system for monitoring.

2.4 Outer Tracker

The detector installation was completed before the 2008 LHC run including detector services such as gas, cooling and Detector Safety System (DSS) interlocks. During the first data taking with cosmics and circulating beam, the online and offline data acquisition and monitoring systems were exercised. The results proved that the OT is operational. More detailed data analyses are ongoing, and preliminary results from tracking show that the detector alignment is according to the nominal values within +- 1 mm. Five C-detectors went through the heating treatment of the detector modules (up to 40°C) to reduce the gain-loss due to irradiation, and two more will be treated during the 2008/2009 shutdown. The HV training procedures to recover the gain-loss will be tested in situ. Studies in the laboratory brought new insight in the mechanism causing the gain deterioration. During irradiation, in addition to the out-gassing products that deposit on the anode wires, also ozone radicals are produced that have a cleaning effect on the deposit. This explains why the gain loss was not observed downstream of the irradiation area with respect to the gas flow.

Changes: None

Concerns: Production of spare FE Boxes still ongoing, but expected to complete by November 2008. Uncertainty in the long-term behaviour of the gain-loss.

Plans: Heat-treatment in situ and commissioning and debugging of the DAQ system.

2.5 Silicon Tracker

The installation of IT and TT is completed and the commissioning of both detectors is making excellent progress. Currently, about 97% of all readout channels in IT and 99% of all readout channels in TT are operational. The remaining problems are mostly due to individual malfunctioning components in the Service Boxes close to the detectors. They will be fixed in the coming weeks. A significant number of wire bonds have broken on six out of the 280 TT front-end readout hybrids. The problem occurred a few weeks after the module installation and is currently under investigation. Although this problem seems to be constraint to these six hybrids at the moment, we are preparing for the production of spares for the case this spreads to other hybrids. Both IT and TT have participated regularly and successfully in global commissioning efforts. Data taken during LHC synchronization tests were used to adjust the readout timing within the subsystem as well as with respect to the rest of LHCb. With the same data, the initial tests of the spatial alignment were also performed. Further progress has also been made in the development of detector control software and data quality monitoring software.

Changes: None

Concerns: Broken wire bonds on some TT front-end hybrids.

Plans: Fix remaining hardware issues and continue the commissioning of the detectors. Further improve control and monitoring software. Continue software alignment studies.

2.6 RICH

Both detectors are complete and are routinely taking laser-pulsed and cosmic data. Photon hits were observed with single circulating beams. However collision data are needed to observe clean and correctly focused Cherenkov rings. The relative adjustment of the readout timing within each RICH has been successfully completed and we will confirm the global timing of both RICHes to LHCb with colliding beams. The RICH reconstruction software is ready and data quality monitoring is in place. RICH calibration procedures using physics data are also well advanced and waiting for final verification with collisions. The deterioration of the vacuum inside of some Hybrid Photon Detectors (HPDs) still persists, however largely confined to the early batches of tubes, which are mostly installed in the RICH-2 detector. Around 40 HPDs out of 288 photon detectors in RICH-2 have developed this vacuum problem; around 20 of them have been replaced. The HPD performance is closely monitored during regular and routine operation, and the expectation is that an additional ~100 tubes will need to be replaced over the next 5 years of operation. Discussions with the HPD manufacturer are ongoing concerning the cause of the problem and eventual replacement of the tubes. A number of tubes have already been successfully re-processed. Work has been identified for this shutdown period including the installation of the final RICH-1 magnetic distortion monitoring system (MDMS) and the replacement of faulty HPDs in RICH-2.

Changes: None.

Concerns: Ongoing deterioration of the vacuum quality for some HPD's.

Plans: Installation of RICH-1 MDMS and replacement of HPDs.

2.7 Calorimeters

The calorimeter detector installation is complete and the system is operational for data taking. The commissioning of the four calorimeter elements SPD/PS/ECAL/HCAL has started in the first part of this year and they were used to trigger on cosmic events, which were recorded by most of the LHCb detectors. Using cosmic events, the readout timing was adjusted within 3 nsec for the HCAL and ECAL inter cells, as well as for PS within 2 nsec. The time adjustment of SPD is ongoing. The LED calibration system of each sub-detector is used extensively and corresponding data have been studied to monitor the photomultipliers stability. Developments were made in order to use the calibration farm to follow the PMT gains. The HCAL calibration system with a Cesium source has been used for the gain calibration. The tools for monitoring the calorimeters have been developed and tested with first data in September. During shut-down, the modification of the ECAL Cockroft-Walton HV system will imply an intervention on the 6000 ECAL PMT bases. The tests in progress show that the foreseen modification will reduce the CW noise to a negligible level and will improve the PMT stability. On the front-end ECAL/HCAL cards 3 serializers will be exchanged to more robust elements. The interventions will begin in October/November.

Changes: Modification of the Cockroft-Walton bases of the ECal.

Concerns: None

Plans: Repair the few channels in the different sub-detectors that are not working. Improve and tune the LED system for all sub-systems. Change the CW bases for ECAL and modify the serializers on the FE cards.

2.8 Muon Detector

Installation of the stations M2-M5 has been completed and all the system is fully tested and surveyed. The position accuracy is better than 1(2) mm in the x(y) direction respectively. The motorized system to open and close the stations in the direction perpendicular to the beam pipe is operational, and the position of the stations is reproduced within 1 mm after repeated operations. The production and testing of spare chambers is close to completion in PNPI and LNF. The gas system for the chambers is in operation. The complete HV system is in place and tested. The air-cooling system to cool the on-detector electronics in the inner part is also installed. The commissioning of the M2-M5 subsystem is well advanced. Only 3 gaps out of 4416 do not hold nominal high voltage and two other gaps draw large dark current. About 4% of the logical channels are under investigation to check the connectivity and optimize the signal timing. The readout timing of the system was adjusted with cosmic rays and with the first machine beams. Using reconstructed tracks, the chamber alignment has been cross-checked with cosmic rays and first results confirm the survey measurements. The communication with trigger and DAQ are working as expected. The ECS and the monitoring software are working and are routinely used in the commissioning. The installation of the services and infrastructure for M1 is close to completion and the installation of chambers will start in December 2008.

Changes: None.

Concerns: Delays in the completion of M1 due to the lack of manpower and interferences with parallel activities for the Calorimeter system.

Plans: Continue commissioning and debugging of M2-M5 with cosmic rays. Complete installation and commissioning of the M1 station.

2.9 Trigger

Commissioning of the Level-0 trigger was completed in October 2008. The Level-0 trigger selects routinely events with cosmics and beam induced events. The High Level Trigger (HLT) is being commissioned in the Event Filter Farm (EFF) using a version adapted for tests with cosmic and/or random L0-triggers. Using the EFF with about 15% of the CPU's installed that are finally needed, the scalability for configuring and running thousands of processes is being tested. It now takes about 40 s to configure the EFF and this seems almost independent from the number of sub-farms that need to be configured. Monitoring tools that collect the trigger monitoring histograms have been put in place and are being tested. Additional HLT-code was implemented to provide a relative luminosity measurement and the relative integrated luminosity for any selected data set used for analysis. The trigger strategy corresponding with the start-up scenarios of the machine have been defined, and the trigger is ready to be deployed.

Changes: None

Concerns: None

Plans: Integrate the M1 station in the Level-0 muon trigger. Install a system that is able to inject MC data in the EFF for full scale HLT testing in an environment as realistic as possible.

2.10 Online

The LHCb Online system including histogramming and monitoring was operated in a routine fashion during the entire summer and used by the subsystem groups for commissioning. The acquisition procedure for the rest of the HLT CPU farm has been initiated. The tender documents are sent out in October 2008 and replies are expected by beginning of December 2008. After evaluation, ordering of the PCs is planned for mid December. Delivery of the PCs is anticipated for mid February 2009 at latest with subsequent installation and commissioning. Beginning of December the decision will be taken which line cards for the Data Acquisition switch we will acquire. Delivery is expected middle of February 2009.

Changes: None.

Concerns: Very thin manpower coverage.

Plans: Acquisition, installation, and commissioning of final HLT farm and Readout network. Further improve performance of parts of the control system.

2.11 Computing

The track reconstruction program was successfully applied on data taken with cosmics, injection tests and beam splashes. The results were used to align the detectors and the first outcome looks very promising. A data quality team was put in place to develop procedures for monitoring the quality of the recorded data. The team takes appropriate actions, if something is out of specification. The simulation has been updated to the 2008 geometry and conditions. A large production for physics studies of first data will be launched in the beginning of November 2008.

LHCb has participated actively in the Common Computing Readiness Challenge (CCRC) in May 2008. Many fixes and improvements had been brought to DIRAC3 (the LHCb Community Grid Solution). Transfer rates above the nominal rate (70 MB) have been achieved and the behavior of Castor at CERN as well as that of the Storage Elements at Tier1s were satisfactory. The main concern remains the file accessibility from jobs running

on Tier1s affecting the overall job performance. Work continues with WLCG and Storage experts for solving these problems. The first data collected with cosmics and then with LHC beam went successfully through the transfer and registration chain, although not distributed to Tier1s since the amount of data was small. The new bookkeeping system is in place and the old system is planned to be retired before the end of the year. LHCb is preparing a Full Experiment System Test (FEST09) to start at the beginning of 2009. Simulated data will be injected into the HLT farm and follow the standard path, including L0 simulation and HLT processing and selection. This will allow testing the full system, including alignment and calibration as well as first physics analysis studies. LHCb is re-estimating its computing resource needs for 2009 in view of the new schedule of the machine as well as first experience with real data, in particular for calibration and alignment. Analysis requests will be reviewed as well with a better understanding of the needs obtained with the DC06 analysis. The new needs will be expressed in terms of the new computing power units decided in WLCG (Spec2006C++) and a first estimate should be available for the November Computing RRB.

Changes: None

Concerns: Limited file accessibility from jobs running on Tier1s. Manpower coverage of the core software.

Plans: Full experiment system test.

3. Experimental Area

The installation of the radiation shielding wall and commissioning of all the detector services has been completed. The beam and radiation monitoring system has been installed in order to ensure proper communication with the LHC machine. Beam induced background and radiation monitoring is performed by a diamond based Beam Condition Monitor, a metal foil Radiation Monitoring System located on the Inner Tracker, and Active Radiation Monitors. The Beam Condition Monitor has been in stable operation since May and performed as expected during the LHC synchronization tests and first beam. Being the main protective device of LHCb, the injection inhibit and beam dump mechanisms have been tested extensively. Having a long integration time for accumulated dose measurements, longer tests with beam is needed to commission the system fully. However, a few faulty readout channels have been found requiring repair during the shutdown. The Active Radiation Monitors have been developed in collaboration with Totem. The sensors are installed but the readout system remains to be installed. In addition, a Beam Loss Scintillator has been installed during the summer to detect fast beam losses close to the VELO, mainly following each injection but also during circulating beams. Currently it is readout with an oscilloscope but a fast 25ns continuous readout is in preparation using the acquisition board developed for the LHCb beam pickups.

The Beam Phase and Intensity Monitor acquisition cards connected to the LHCb beam pickups were commissioned and were operated successfully during the synchronization tests and first beam.

A framework of online graphics interfaces were prepared for the information from all the systems above and for all beam related information received from LHC via DIP (LHC modes and handshakes, beam loss monitors, collimators, beam position monitors, beam intensities etc).

Changes: None

Concerns: None

Plans: Repair RMS hardware. Prepare global synthesized background parameters for online use and publication to LHC, and co-relate information with machine settings. Continue integrating the LHC modes, handshakes and LHCb beam control into the overall experiment control system.

4. Commissioning

The commissioning activities converged into a fully operational detector during the summer. All detectors were included under central control and data taking was exercised during working hours in early summer, moving to a continuous operation from mid August with 24 hours shift coverage. A 70 kHz readout rate was sustained for several hours with random triggers. The Muon and Calorimeter cosmic triggers were used to get tracks in the detectors and to perform an initial time alignment of the large detectors. The first tests of the transfer line (TED runs) were invaluable to provide real tracks parallel to the beam in all detectors, allowing time and position alignment. VELO, IT, TT, OT were timed to a few nanoseconds, and the initial alignment with reconstructed tracks indicated no major problem and a resolution in the expected range. The RICH was also able to time align, even if particles were traversing LHCb in the wrong direction. Calorimeters and Muon were already time aligned with cosmics. The few hours of beam1 shots were recorded with great interest, as they were the first beam-induced tracks in the proper direction. The whole system behaved very smoothly and efficiently during these few days of LHC operation. We are now back to commissioning with cosmics, fixing identified problems and preparing for a more efficient 2009 run.

Changes: None

Concerns: Keep the system working while improvements and fixes are implemented.

Plans: Monthly commissioning week during the winter to keep the system in phase. Commission the central control of HV-LV. Restart global operations from early April.

5. Cost and Funding Issues

5.1 Overall Funding Situation

The overall cost of the detector remains unchanged with 75 MCHF. With the second contribution of 200 kUSD for the CPU's in the pit from US-NSF on behalf of the Syracuse group (93 kUSD have been paid, the remainder will be paid later this year), the LHCb experiment will be fully financed.

5.2 VELO Replacement Modules

The production of the spare VELO sensor modules has been launched in May. The project will be financed jointly by M&O Category A, splitting 500 kCHF among all of the funding agencies over a period of 5 years, UK from its Category B contribution and special 300 kCHF approved contribution from CH on behalf of the EPFL group. Approximately 75% of the hybrids, which include the carbon fibre coated TPG core, have been fabricated. Quality assessment procedures indicate they are well within specification and expected yield. About 15% of the phi sensors have been received and are under test. The first batch of r-sensors is due for delivery in late October. All ASICS have been inspected and are ready for mounting to the hybrids. The group also has procured and tested all replacement cables and cable

clamps. Substantial progress has been made in using alternative glass pitch adaptors. Glass pitch adaptors allow faster and more reliable bonding than kapton pitch adapters. Jigging has been built that allows bonding with either kapton or glass pitch adaptors. The biggest current concern for the VELO replacement is the availability of TELL1 readout boards. Full production cannot proceed without the deployment of 2 DAQ systems at Liverpool. As emphasized at the last RRB the speed of installation of the replacement modules depends on the availability of additional mechanics, cables and vacuum feedthroughs. No decision has yet been made, as to whether these components should be built.

5.3 Replacement Beam Pipe Section

A replacement of the third beryllium section of the beam pipe has to be procured, which was strongly recommended by the CERN Vacuum group. The cost will be covered by extra funding now granted by CERN.

6. Collaboration Issues

A group from the University of Bari, led by Professor Antimo Palano was accepted as a new member of the LHCb Collaboration, on July 7, 2008. The group is composed of a professor, a PhD researcher and a student, finishing his PhD thesis in Babar, and will fully integrate in our experiment before end 2009. Although no capital investment could be brought at present, their contribution to the physics software and the financial support already approved by the INFN, starting already in August 2008, were positively received. It is understood that the Bari group will also contribute to the M&O category A fund of LHCb. The Collaboration Board of LHCb has also unanimously recognized the physics expertise of the group, which will be particularly valuable in the search for CP violation in charm decays. It should be noted that their participation is fully supported by the Italian LHCb groups.

Werner Witzeling has been reappointed as the Technical Coordinator for a further term of three years.

Ulrich Straumann has been elected as the next chair of Collaboration Board for two years starting from November 2008.