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Status of the LHCb Experiment

Report to October 2009 RRB
by the LHCb Collaboration

1. Introduction

The installation of the LHCb detector has been fully completed including the first muon station (M1). All detector elements are commissioned and ready for data taking.

The commissioning activities have resumed after expanding the readout network to its nominal readout performance. All detectors were successfully readout at 1 MHz. The test of the transfer line (TED run) in June was used again to provide secondary tracks almost parallel to the beam-pipe in all detectors, allowing time and position alignment of the high granular detectors such as Vertex detector (VELO), Inner tracker (IT) and Trigger tracker (TT). They were timed to a few nanoseconds with spatial resolution in the expected range. For the Cherenkov RICH1 detector a dedicated cosmics trigger has been set-up using scintillators to observe rings of Cherenkov light emitted by the tracks traversing the detector in the proper direction. Time alignment was also performed. The Outer tracker (OT), the Calorimeters and Muon detectors have already been time aligned using cosmics.

The Full-Experiment-System-Test (FEST), which is able to inject (MC)-data in the Event Filter Farm (EFF), is being used regularly to exercise the HLT commissioning.

After some maintenance work in spring and summer, all detectors are now back to an operational state and have been included in global readout tests. All sub-detectors reached the nominal read-out rate of 1 MHz except M1 that remains to be tuned in.

In order to complete the tuning of the VELO and silicon detectors in their final configuration, another TED run is planned in the middle of October followed by the injection test at the end of October. From then on, LHCb will be in stand-by and ready for first beams expected by mid November.

2. Detector Subsystems

2.1 Vertex Locator (VELO)

The VELO detector hardware was successfully commissioned in 2008. During Q2 2009 improvements to the system were made in preparation for data taking. These capabilities were tested in a successful June 2009 TED run where once again (c.f. Aug

2008) the VELO was able to immediately record hits and reconstruct tracks – this time with fully tuned pedestals and thresholds. The system is now 100% operational with only 0.1% loss of readout-strips (due an intermittent front-end chip) since construction.

The vacuum and cooling systems have continued to function without any major fault. Until September 2009 the coolant temperature has been kept at -5° C. This minimized the severity of the thermal cycling experienced by the VELO modules during commissioning. For the planned TED run in October the temperature will be lowered to the nominal -25° C in readiness for full data taking. Data taken during this run will be used to “fingerprint” the system in its final configuration.

The LV and HV system are operating stably. We note the LV spares situation has been substantially improved due to delivery of spares from CAEN.

The Data Acquisition System has been fully integrated with LHCb and can be read out at 1 MHz. The ECS system is now complete,

The VELO group has finalized its improved “2009” online and offline monitoring. All key plots that can identify potential problems in the VELO are in place. Ongoing work, due to be completed before data-taking starts, will ensure the monitoring of critical parameters put into the data base.

The build of the VELO replacement, which mitigates the impact of beam related accidents to LHCb, continues. The problem of pitch adaptors supply and robustness has been solved. A meeting is planned for October 2009 to finalize responsibilities for full construction and system testing of the replacement.

Changes: None.

Concerns: TELL1 spares and reliability

Plans: Continuous running from Mid October 2009

2.2 Outer Tracker

The analysis of the 2008 data, taken with cosmics and secondary particles from a TED run, has shown that the OT detector is in good shape for the 2009 data taking. In particular, the data showed that the initial time and space alignment are within expectations, and that the procedures for further offline corrections give the expected results.

The detector commissioning has continued throughout 2009. Remaining faults shown by few Front End (FE) electronics boxes when running at full rate (1 MHz) have been located. All faulty FE Boxes have been first exchanged and then repaired. All spares are available.

The anti-aging treatment of all detector modules at 40 degrees in situ has been completed. The gas system has been modified to allow an oxygen admixture, if necessary.

Changes: None.

Concerns: Uncertainty in the long-term behavior of the gain loss remain a concern, most notably the differences in the behavior of different modules observed during the latest irradiation campaign in March.
Plans: Commissioning of the Data Quality Monitoring and online data archiving, and study of the aging evolution with irradiations in situ.

2.3 Silicon Tracker

During the winter shutdown repair work was carried out to replace malfunctioning components in the Service boxes located close to the detectors. After this repair work over 99.5 % of the readout channels in both IT and TT are operational. Both sub-detectors have participated regularly and successfully in global commissioning efforts and have been read out at a trigger rate of 1 MHz. During the June 2009 TED run a sample of 50,000 reconstructed tracks was collected. This sample has been used to make detailed studies of the detector performance. The Inner Tracker ladders have been aligned to a precision of better than 20 microns and the detector S/N ratio found to be within the expectations from test-beam.

A remaining concern is the broken bonds that have appeared on seven TT modules. The majority of these problems occurred just after installation. The exact cause of this problem is still under investigation. Four of the effected modules have been replaced with spares for the coming 2010 run. Three modules have been left in-situ in order to study the evolution of the problem at the pit. It is planned to order new hybrids in the next months to allow the repair of modules.

Changes: None

Concerns: Broken wire bonds on some TT front-end hybrids, reliability of TELL1 boards.

Plans: Further improve control and monitoring software. Continue detector performance studies.

2.4 RICH

Both RICH1 and RICH2 detectors are complete and routinely taking laser-data, online monitoring and DAQ are also exercised using FEST.

An important achievement in August has been the observation of rings from the two RICH1 radiators, the gas C_4F_{10} and the solid aerogel (obtained by means of a trigger using scintillators). These data demonstrated the excellent S/N of the HPDs (only 2-3 channel were noisy out of the ~100000 active) and the number of detected Cherenkov photons is as expected. The exercise was also extremely useful to test the offline software reconstruction as well as the online monitoring chain.

The detailed studies of the evolution of each HPD in terms of its ion feedback rate (IFB) has proven to be a reliable indicator of the HPD lifetime; those and only those tubes predicted to glow have in fact done so. The repair process has been somewhat slower than expected (partially because of the summer shut down of the producer), and at present 14 tubes are available for replacing the 21 tubes identified to be replaced for the 2009/2010 run. The repaired tubes, installed during the intervention of March 2009 continue to behave very satisfactorily.

An instability problem in the HV power supplies was identified as a manufacturing problem, all units have been repaired by the manufacturer. Since then, the RICH detector has been successfully re-commissioned, the HV units behave correctly as indicated by continuous monitoring.

During the summer, the commissioning of the Magnetic Distortion Monitoring System (MDMS) installed in RICH1 was completed. Two sets of scans with B field off and B field on were taken and analyzed. Corrections to the distortions induced by the field for each HPD were determined.

The RICH reconstruction software, as well as the online and data quality monitoring took advantage from the cosmic induced rings in RICH1. The software is now performing well in reconstructing real rings from cosmics.

Changes: None.

Concerns: Availability of repaired HPD's is not as expected.

Plans: Prepare for the LHC startup

2.5 Calorimeters

The four calorimeter systems SPD/PS/ECAL/HCAL were commissioned using cosmic events and the LED calibration system. During this commissioning the 4 detectors were aligned in time within 3 ns. To improve the stability of the ECAL PMT response the 6000 PMT channels have been modified during the 2008-2009 shutdown. The stability tests performed using LED signals show that all the modified PMTs are performing very well and have the expected stability. The ECAL PMT gain measurements are in agreement within 5% with the expected value from earlier PMT test measurements. We therefore expect an inter-calibration of the ECAL PMTs better than 10% at start-up. For HCAL, the Cesium source calibration run provides an inter-calibration better than 4%. PS and SPD detectors are fully functioning as well, including the LED monitoring system. All calorimeters are successfully readout at 1 MHz rate.

The channel-to-channel time alignment for ECAL/HCAL and PS has been further improved using TED runs.

An emphasis has been given during the last months to the on-line control including the use of the calibration farm, detector quality tests, calibration procedure in order to be able to give fast answer on detector status, timing and calibration at start-up.

Changes: Improvement of the ECAL PMT HV system. Maintenance on all sub-detectors SPD/PS/ECAL/HCAL

Concerns: None

Plans: Record cosmic and calibration data; check the time alignment with the coming TED run and cosmics. Exercise on-line monitoring tools and setup a calibration strategy, which can be tested using FEST data.

2.6 Muon Detector

The installation of the M1 station has been completed in time by July 7 and the closing procedure has been successfully tested. The station had been closed on September 15 for the forthcoming LHC run. The commissioning of the station is well advanced and M1 has been successfully included in the global LHCb DAQ system.
The HV systems are operational, including the custom equipment for the GEM detectors. The control software has been improved on various levels and integrated in the PVSS tree of the global LHCb Experiment Control System (ECS). All the M1 chambers have been powered and the conditioning is ongoing. The custom made part of the HV system for the MWPCs has been improved and problematic resistors affecting the stability of the HV modules have been replaced.

Commissioning of the stations M2-M5 has been completed and the system is fully tested and surveyed. The faulty readout channels have been fixed and the four stations are now fully operational. A few remaining problems, mostly related to the communication with the L0 trigger are still being fixed.

The ECS has evolved substantially. New tools for noise analysis and system configuration have been put in place. A substantial improvement in the system configuration time has been achieved. Studies and acquisition runs for optimal configuration of the system for data taking are in progress.

Changes: None.

Concerns: None

Plans: Continue commissioning of M1. Continue acquisition runs and tests to set the optimal working point for data taking.

2.7 Trigger

Following the improvements of the Calorimeter and Muon detectors as well as of the data acquisition system, the Level-0 (L0) trigger has been checked carefully. Error detection and reporting, as well as monitoring have been improved. The integration of the M1 station started. Software tools are in preparation in order to determine running parameters on real data.

Using MC data produced at nominal conditions, i.e. luminosity of 2×10^{32}, a full trigger chain, including two stages of the off-line High Level Trigger HLT, L0xHLT1xHLT2 has been tuned to give output rates below 2 kHz with efficiencies for the LHCb key channels larger than those published in the Trigger System TDR. In this configuration,

the HLT1 CPU consumption is around 5 ms/event/core, which will allow us to run at the required L0-rate of 1 MHz within the Event Filter Farm (EFF) budget. The HLT2 timing is being worked on to allow an HLT1 rate of around 40 kHz.

The FEST data is being used regularly to exercise the HLT commissioning. Newly produced MC data, which should mimic the 2010 conditions, is being used to tune the trigger settings for the start-up and first physics runs next year. The results show that the trigger is capable to efficiently select charm-physics in addition to our B-physics program during the expected low luminosity conditions next year.

Changes: None.

Concerns: Manpower to tune and operate the Level-0 Pile-up detector.

Plans: Prepare and operate the Level-0 and HLT triggers for the 2009/10 data taking period. Continue to use FEST to exercise the system until real data arrives.

2.8 Online

The HLT farm has been increased to 550 processing units (dual quad-core units), sufficient to receive 1 MHz of trigger rate at nominal event size. The readout network was expanded to nominal capacity, acquiring 14 90-port line cards for the central router. The line cards are currently still being debugged and mechanical problems have been identified and are being addressed by the manufacturer. Minor software issues are dealt with by the manufacturer as well. Nevertheless, successful tests have been made with all detectors at 1 MHz trigger rate.
The TTC transmission system has been upgraded and the resulting time-jitter at the receiving end has been significantly reduced which improves the reliability and stability of the system.
The Controls system is continuously improved and consolidated and the functionality increased.
The data monitoring infrastructure is being improved and is being used on a regular basis by the subdetector experts for debugging and commissioning.

Changes: None
Concerns: Long-term manpower coverage
Plans: Prepare for LHC startup.

2.9 Computing

After a thorough commissioning of the simulation application (based on latest Geant4 version) during spring ’09, LHCb has started early June the campaign of Monte-Carlo simulation for preparing the 2009-10 data taking (MC09). Since then more than 3

million simulation jobs have been run on the Grid, generating 10^9 minimum bias events and several 100's million signal events at the beam energy of 5 TeV. Many improvements have been brought to the LHCb production system at this occasion, allowing to run over 45,000 jobs per day (over 25,000 jobs simultaneously). LHCb has also participated in the STEP'09 activity in June, during which data was sent from the Online system to Tier0 and Tier1's, triggering reconstruction at all sites automatically, after thorough Data Quality checking. Simultaneously data distributed earlier was reprocessed in order to simulate concurrent activity, including staging from tape. Simulation and analysis activities continued unchanged. A system for checking performance of Tier1s for analysis has been developed and is being integrated in Ganga, which should allow a better feedback to the sites for that activity. Analysis on the Grid through DIRAC and Ganga is on average at the level of 100,000 jobs per month.

Concerning Computing resources, LHCb modified slightly its requirements, following recommendations from the C-RRB Scrutiny Group.

Changes: None

Concerns: Stability of Tier1s, in particular regarding storage and Data Access. Manpower for running the Computing Operations.

Plans: Fully commission stripping including multiple streams, on simulated minimum bias events with various conditions of selection in preparation for the 2009-10 run. Run continuously dataflow from the pit to the offline reconstruction and stripping. Continue MC09 analysis on the Grid.

3. Experimental Area

The radiation shielding plugs have been completed with the iron blocks on both sides (RB84 & RB86 areas) of the LHCb detector in June 09 as scheduled.

The tightness between the LHC tunnel and the detector area (UX85B) has been improved in August 09, in order to cope with a possible helium leak with a pressure of 40 mbar from the LHC tunnel.

In parallel to the detector shutdown activities, the infrastructure and the safety consolidation projects have been achieved as planned. In particular, the re-structuring of the chains of the emergency stops in the UX85 cavern has been achieved in order to improve safety around the detector.

Two workshops (2 x 20 m^2) dedicated to repair the slightly radioactive components such as electronic boards, have been built in the UX85A (protected area), the rooms will be available from December 09.

At surface, the new LHCb bungalow (3894) with the four offices and the new videoconference room is in use since June 09. The laboratories in the SX8 building have been also refurbished, giving more working space to the LHCb sub-detector users.

Changes : None

Concerns : None

Plans : All the consolidation projects foreseen in the detector area will be achieved as scheduled.

4. Cost and Funding Issues

The overall cost of the detector remains unchanged with 75 MCHF. The underfunding in 2005 of about 2.6 MCHF for the DAQ CPU Farm, has been covered through extra contributions from BMBF, Brazil, France, MPI Germany, Spain, UK, US and CERN. The status of the accounts is healthy and there is no cash flow problem foreseen. Based on extrapolations of the spending profile until end of August and the experience from previous years, we expect that the M&O Cat. A budget forecast for this year is correct for all the items apart from Online computing and Power estimates [CERN-RRB-2009-117].

The procurement of a replacement beam pipe UX85/3B is well on its way and it is fully budgeted from CERN funds. The VELO replacement financing mechanism is working well. With most of the contributions received for 2009, we do not expect cash flow problems.

5. Collaboration Issues

The Collaboration Board of LHCb has discussed two applications for Technical Associates: the Catholic University of Rio de Janeiro, Brazil and the Tier-1 centre, CCIN2P3, Lyon, France. They will be hosted by UFRL, Rio de Janeiro and CPP, Marseille respectively. The final decision is expected at the next Collaboration Board in December 2010.

Guy Wilkinson (University of Oxford) has been elected as the next Physics Coordinator for one year starting from January 2010.