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Status of the LHCb Experiment

Report to April 2009 RRB
by the LHCb Collaboration

1. Introduction

The LHCb collaboration is successfully completing a list of activities planned for the 2008-2009 shut-down period including the replacement of a few modules of the Silicon tracker where the broken bonds have been identified, the installation of the Magnetic distortion monitoring system for the Ring Image Cherenkov detector RICH1 and replacement of HPDs in the RICH2 detector, the modification of the Cockroft-Walton bases of the Electromagnetic calorimeter phototubes and the installation of the M1 Muon station.

In general, the LHCb detector should be fully operational for the LHC start-up. LHCb plans to take TED data during summer and use them effectively in order to test the time and spatial alignment of the whole detector.

A new activity called FEST (Full Experiment System Test) was started in December 2008. FEST consists in injecting simulated events at the entrance of the Event Filter Farm (EFF) at the highest possible rate, to exercise all systems from High Level Trigger (HLT) onwards, i.e. online monitoring and reconstruction, express stream, transfer to CERN storage, data distribution to Tier1s, reconstruction and data quality validation.

For the analysis of the first LHC data a strategy of the trigger and subsequent physics analysis is being prepared.

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 has been under vacuum from June 2008 to Ocober 2008, since then it is filled with ultrapure Neon at atmospheric pressure. 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 the tender process the order for a replacement of the UX85/3 Beryllium beam pipe was placed, the delivery is expected in the second half of 2010.

Changes: None.

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

Plans: Start the development of beam pipe supports with further reduced material.

2.2 Magnet

The magnet had been powered in September ’08 just before the LHC ‘dry’ run for final test. Everything went well. Since then, the magnet has not been switched on again. Cooling water is running continuously through the coils. Yearly maintenance checks have been performed.

Changes: None

Concerns: None

Plans: Perform magnet test in June 2009 and verify position stability of the Trigger Tracker and the RICH 1. Another run with the magnet is planned just before the closure of the experimental area for LHC operation in late August 2009.

2.3 Vertex Locator (VELO)

Following commissioning of the VELO hardware in 2008, and the reconstruction of tracks from the beam synchronization tests in August 2008, the VELO has concentrated on extending the existing monitoring packages and improving its software infrastructure. Full software readiness, for the 2009/2010 run, is expected to be achieved by mid April 2009. The software will be tested in its final configuration with target data (TED) in during summer 2009. Online and offline monitoring has been extended and consolidated to ensure rapid diagnosis of faults that could occur during operation. The development of basic “expert” systems that can identify potential problems in the VELO is expected before September 2009.

The procedures to determine the correct timing of the electronics has been improved and will allow the VELO to be correctly timed, using first collisions, within a few minutes. Online software to analyse the tracks from collisions and to integrate this data with the ECS system is now in place and is undergoing final tests; this will make closing of the VELO a simpler and safer process.

During operation in 2008 a major issue was the availability of spare readout boards (TELL1) and their reliability. This problem has been mitigated by the provision full complement of new TELL1 boards and spares.

Detector safety remains of paramount concern to the VELO. The existing hardware interlock system has been improved and spare interlock system constructed to minimize down-time should the interlock system itself fail.

The build of the VELO replacement, which mitigates the impact of beam related accidents to LHCb, continues. All hybrids and mechanical components have been completed. Approximately 45% of the sensors have been received and problems with the glass pitch adaptors resolved. The group expects to attain its planned output rate for replacement modules by June 1st 2009 confirming that, at present, the rebuild is proceeding according to schedule.

Changes: Return to nominal cooling temperatures for 2009 run.

Concerns: Low level leak in the RF foil; availability of LV spares which have been ordered.

Plans: Develop “expert” system for monitoring. Full tests of VELO with TED data prior to first collisions.

2.4 Outer Tracker

After the installation phase (completed before the 2008 LHC run), the focus has been on analyzing the 2008 data (cosmic and beam) and on continuing the detector commissioning for the 2009 data taking period.

In the data analysis, the main activities were time alignment (hardware and software corrections) and space alignment. The cosmic and beam data allowed a debugging of the OT geometrical description and the development and test of the software space alignment procedure and we are under way to achieve the expected space resolution.

The production and test of the FE electronics spares has been completed. Various problems with the FE electronics were also tackled and solved in situ, while few still remains. The anti-aging treatment of the detector modules at 40 degrees was carried on and at present the entire side C and one out of 6 C-Frames on the side A have been treated. This activity will proceed, hopefully until completion.

Changes: None.

Concerns: Uncertainty in the long term behaviour of the gain loss remain the main concern. Recent local ageing tests indicated possible reaction difference to the heating. This effect is currently under investigation.

Plans: Heat-treatment of all modules in situ and commissioning of the DAQ and ECS systems.

2.5 Silicon Tracker

The commissioning of both Inner Tracker (IT) and Trigger Tracker (TT) detectors is making good 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. For TT the majority of the faults has been fixed whilst for the IT it is planned to fix the remaining problems in the coming weeks. A significant number of wire bonds have broken on eight out of the 280 TT front-end readout hybrids. The majority of the problems occurred a few weeks after the module installation and no further problems have developed since November last year. Studies are ongoing to understand the origin of the problem. Although it seems to be limited to these hybrids we are preparing for the production of spares for the case this spreads to other hybrids. Both IT and TT participate regularly and successfully in the global commissioning efforts. Data taken during LHC synchronization tests has been used to adjust the readout timing within the subsystem as well as with respect to the rest of LHCb. With the same data, initial spatial alignment studies were also performed and the detector survey performed before installation verified. 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 RICH1 and RICH2 detectors are complete and are routinely taking continuous-laser and cosmic data. An important achievement of the recent months has been the accurate work of investigation performed to characterize the effects due to the vacuum degradation of some HPDs, mostly installed in the RICH2 detector. The main outcome is that the evolution in time of every individual tube is predictable: a rate of 2% /year (= 11 HPDs per year) of tubes is expected to need replacement in the next 5 years. The already degraded tubes (57 in total) have been replaced with spares or are going to be replaced in August-September 2009. In case however, of missing spare HPDs, these will be at the very periphery of the RICH2 detector, and therefore stability of RICH2 operations as well as physics performance in particle identification will not be significantly affected.

In RICH1 the major intervention has been the installation of the Magnetic Distortion Monitoring System (MDMS). To install the two final, full coverage systems, the removal of the RICH1 HPD arrays and photon funnels was necessary. This intervention also provided the opportunity to make some repairs and improvements based on what had been learned during initial commissioning. These included: the replacement of 4 HPDs with short predicted lifetimes, replacement of one failing level 0 board, the optimisation of the position alignment of the two HPD arrays, optimisation of the position of the fibres providing illumination of the HPDs e.g. for timing alignment, replacement of patch panels where connection problems had been identified, installation of improved plumbing for column cooling, repair of one light-leak PMT etc. This part of the shutdown work has been completed and the RICH1 detector is being successfully re-commissioned.

The RICH reconstruction software is ready and data quality monitoring is in place. RICH calibration procedures using physics data are well advanced.

Changes: None.

Concerns: Availability of repaired HPD's of RICH2 before the LHC start-up.

Plans: Replacement of a further set of HPDs in RICH2.

2.7 Calorimeters

The calorimeter detector installation was completed and the system was operational for data taking in September 2008. The four calorimeter elements SPD/PS/ECAL/HCAL were commissioned during the full 2008 year, in particular with cosmic events and LED calibration events. During this commissioning detector elements were aligned in time within 3ns. The stability of PMT response was studied using the LED system, showing some instability for the ECAL calorimeter. To improve the stability of the ECAL PMT response it has been decided to modify the bases of the 6000 PMT channels. During the shut-down the 6000 PMT of ECAL have been removed, the bases modified and installed back. The stability tests performed using LED signal show that all the modified PMT are performing very well and have the expected stability.

Tests on radiation effects on the electronics have been performed in IHEP

(Protvino) and lead to a small modification of the inner ECAL and HCAL PMT bases.

Maintenance work on HCAL solved the very few remaining problems. The HCAL calibration system with a Caesium source is used regularly to monitor the gain calibration.

The commissioning of the LED system for PS/SPD resulted in an operational LED system. Maintenance work on PS/SPD solved few connectivity problems.

As foreseen, serializers on the front-end ECAL/HCAL cards, concerning the trigger path, have been exchanged successfully.

Changes: ECAL/HCAL bases modified; serializers for the trigger path modified.

Concerns: None

Plans: Record cosmic and calibration data in order to check the time alignment. Further develop on-line monitoring tools and setup of a calibration strategy.

2.8 Muon Detector

The four stations M2-M5 have been fully commissioned with the cosmic ray data acquired in September 2008. Taking into account that neither the HV nor the threshold were at the nominal value, the performance of the chambers is found to be within the expectations. An intense debugging activity has been organised to fix a number of bad readout channels (about 4% of the total). All the problems are now understood and most of them already fixed. To fix the remaining missing channels (<1% of the total) an access (already planned) to the chambers is needed.

The HV system is operational since spring last year. Three gaps out of 4416 do not hold nominal high voltage and 6 gaps draw large dark current. Other occasional problems are found in additional 3 gaps. In total less than 0.3% of the gaps are under investigation. Some of these chambers will be replaced during the access.

The installation of the services and infrastructure for M1 is completed and chamber installation has started in mid February with a delay of about two months due to several unforeseen problems in the preparatory work. A very detailed schedule has been devised and is being followed strictly in order to complete the M1 station in time. The alignment of the station is progressing as planned. All the readout electronics is in place and tested. The links with the DAQ and the L0 trigger has been successfully tested and the DAQ boards (TELL1) are operational.

The tests of the M1 front-end electronics are progressing at full speed thanks to the dedicated ECS tools developed in the past months. The control through the global ECS system is operational. The HV system is already in place and tested and the control through the ECS is operational.

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. Complete installation and commissioning of the M1 station.

2.9 Trigger

The FEST system allows full scale HLT testing in an environment as realistic

as possible. The HLT has successfully tested fast run changes using FEST. Monitoring histograms are being produced both in the Event Filter Farm and in the Monitoring Farm.

There has been a change in the strategy adopted for the last phase of the HLT (HLT2). While originally HLT2 was an "or" of many exclusive selections, channels have now been grouped in a small number of inclusive selections. Most of these selections have already been prototyped.

Efforts are ongoing to improve the track reconstruction for the high level trigger, for example: fast fit using simplified geometry and ghost track reductions.

Changes: The HLT2 strategy

Concerns: None

Plans: The HLT will continue to use FEST to exercise the system.

2.10 Online

The LHCb Online system is operated routinely for all activities in the detector commissioning.

The CPU Farm is being upgraded to a level that allows the full 1 MHz readout at nominal event size. Currently 550 Processor Elements are installed. The final upgrade is foreseen for beginning of 2010. First beam will show the needed capacity. The readout network will be upgraded to full capacity during summer 2009 with the latest generation of router line cards.

Improvements in the control system, especially configuring the system, are being worked on.

Changes: None

Concerns: Dropping manpower level.

Plans: Network upgrade in summer. CPU upgrade in beginning of 2010.

2.11 Computing

LHCb have been completing the commissioning of DIRAC3 for both production and user analysis activities. The Ganga user interface for Grid analysis has been adapted accordingly and the number of users has been steadily increasing to reach currently a level of 60 users active every week. Specific tests on sites' services, in particular for storage have been improved and put in production in order to provide precise and reliable information to service providers in WLCG. Data access remains though the main concern and this is being extensively worked on with Data Management developers and service providers. Actions have been taken by LHCb within the LCG for restarting common effort between experiments, developers and service providers. Two weeks of FEST have been successfully carried out, including data distribution, reconstruction and Data Quality checks (new). Further FEST weeks have been planned on a monthly basis until LHC start-up. The Computing infrastructure was stress-tested with simulation jobs and is ready for starting the large simulation productions needed for preparing the coming data taking. The overall activity (production and analysis) is on average running 10,000 jobs per day with peaks over 40,000, covering a total of 111 Grid sites. New estimates of Computing Requirements for 2009-10 have been prepared. Main features are: increase of resource

needs at CERN; smaller CPU needs at Tier1s in 2009 but stable in 2010; smaller storage needs at Tier1s (less data in 2009); smaller CPU needs at Tier2s (less simulation).

Changes: DIRAC3 in full production

Concerns: Data access and storage services stability at Tier1s; Limited manpower for Core Software and Computing Operations.

Plans: Run extensive simulation productions over the whole year. Run monthly FEST weeks (including one week in common with the other LHC experiments).

3. Experimental Area

The first stage of the installation of the radiation shielding plugs in the LHC tunnel, both sides of the LHCb detector was achieved in 2007 as scheduled. The procurement of the missing iron blocks (~30 %) has been launched in February 09. The delivery of the non-standard iron blocks is expected by June 09. And the installation is scheduled for the end of June 09.

In the background of the detector shut-down activities, a few infrastructure items such as accesses, additional fences, grounding, safety panels have been improved in the experimental area.

In addition, two small workshops (roughly 20 m^2 each) dedicated to the repair of slightly radioactive components such as electronic boards, are also under construction in the PZ alcoves of the UX85-A area.

Changes **:** None

Concerns **:** None

Plans **:** Completion of the radiation shielding plugs in the LHC tunnel on both sides of the LHCb detector is scheduled for June 2009. An improvement of the air tightness of the concrete shield located just in front of the VELO detector is also foreseen in order to reduce the air flux coming from the LHC tunnel.

4. Commissioning

The commissioning activities during the winter are somewhat reduced, as the various detectors are working on fixing problems identified with the 2008 data. Monthly commissioning weeks are continuing in order to keep the system together, and will gain again momentum from April onwards. Cosmic data were already taken mid March after the modification of the ECAL CW bases, showing the expected improvement in noise.

More detailed alignment studies using Cosmic events of Outer Tracker, Muon detector and Calorimeter revealed some small inconsistencies between the geometry described in the software and reality. VELO alignment using data from the TED events is in good agreement with metrology measurements performed prior to installation.

A first session of the FEST activity took place in January and dedicated weeks are now scheduled monthly. The injection rate is about 2 kHz sustained and all systems were shown to work at this rate, including distributed reconstruction on Tier1s.

Data quality procedures are exercised in regular FEST weeks.

Simulation software is ready for launching new productions with 2009/2010 conditions as well as with ultimate beam conditions. Beta versions had been used to simulate sets of events for the FEST exercises.

Changes: None

Concerns: None

Plans: Continue exercising and establishing data quality procedures. Continue alignment work with cosmics and new TED runs during summer 2009 for the VELO/IT/TT. Monthly commissioning weeks and FEST weeks to identify and fix remaining imperfections.

5. Cost and Funding Issues

5.1 Overall Funding Situation

The overall cost of the detector remains unchanged at 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.

6. Collaboration Issues

The groups from the University of Manchester, led by Professor David Bailey, and from the University of Warwick, led by Professor Tim Gershon, were accepted as new members of the LHCb Collaboration in November 2008. The participation of each group in LHCb will be at the level of about 3 FTE in 2009. They will also bring new students and possibly PDRAs.

The Manchester group will work on the interface between the LHC machine and the LHCb detector, elements for the beam quality monitoring, CORE computing and the VELO replacement and upgrade. The Warwick group will assume responsibilities on the HLT2 and offline data stripping network, data quality monitoring and integration of the EvtGen event generator within the LHCb software framework.

It is understood that both groups will also contribute to the M&O category A fund of LHCb. The Collaboration Board of LHCb has recognized the physics expertise of the Manchester and Warwick groups group based on their participation in the BaBar physics analysis. It should be noted that their participation is fully supported by the UK LHCb groups.