Status of the LHCb experiment

CERN-RRB-2013-104

10 October 2013

1 Introduction

During the second part of 2013, the LHCb experiment has continued the analysis of data collected in Run 1, has started the activities for LS1 and the R&D preparatory for the upgrade phase. The status of the upgrade is described in detail in a separate document [1].

Since the last RRB, several new results have been presented at the Spring and Summer conferences, in particular Beauty, EPS and Charm. Some of the analyses are based on the full Run 1 statistics. Among them, the most important have included the following: the improved precision on $B^0_{(s)} \to \mu^+\mu^-$, the first observation of CP violation in B^0_s decays, the first LHCb results on J/ψ suppression in pA collisions, the precise measurement of the Λ_b lifetime, an unexpected resonant structure in $B^+ \to K^+\mu^+\mu^-$, an anomalous distribution in angular variables of $B^0 \to K^{*0}\mu^+\mu^-$ (that needs further cross-checks with higher statistics) and very precise measurements in mixing and indirect CP violation in D^0 hadronic decays. This intense scientific production has allowed LHCb to pass the milestone of its 150$^{\text{th}}$ paper based on LHC collision data, at the beginning of September.

Activities in LS1 are progressing well, with significant work of refurbishing the infrastructure (power distribution and UPS, cooling, ventilation, etc.), maintenance of sub-detectors, the online system, and the magnet. The beam pipe has been dismounted, to allow for its substitution. Two weeks in June and September have been devoted to re-commission and test the operation of the detector. A new infrastructure has been deployed for a better and safer access of visitors. LHCb has participated to the CERN Open Days, with nearly 2400 visitors underground and an exhibition on the surface comprising the two halves of the full spare VELO detector on display.

2 Detector sub-systems

Extensive consolidation and maintenance work for the LHCb experiment is in full swing and almost on schedule. Some minor delays have been accumulated, but not giving rise to any particular concern at this stage. The beam pipe has been dismounted completely, apart from the first section. The material required for the consolidation of the LHCb dipole has been defined and ordered, and preparation work to introduce the new material between coils and support clamps of the magnet has started. This heavy intervention will be completed by the end of this year. The new visitor platform is in place now and highly appreciated by the visitors. With this new structure, the experiment is nicely visible from a safe location and visit tours do not interfere with activities on the detector and its services. The heavy work for the additional iron filter downstream of the muon system has been completed recently. The very long maintenance period of the general cooling services are giving some difficulties to the commissioning weeks, where the whole readout chain of the LHC detector is tested. Nevertheless, with a temporary cooling plant and the attentive support from the technical departments this will be less of a concern in the future.

2.1 Beam pipe

A new solution for the cables to be used in the new support structures for sections UX85/2 and UX85/3 has been defined. The carbon fibre option chosen has been ordered, and delivery to CERN is expected in the coming months. A continuous monitoring of the tension of the cables is being finalized; sensors satisfying the requirement to work both in a high radiation environment and in a magnetic field have been identified to instrument three cables and will be ordered shortly. The remaining cables will be instrumented with sensors that stand only the magnetic field environment as required during the installation and commissioning of the system. Two different solutions for the electronics and software for the readout of the tension sensors are being evaluated. All of the beam pipe sections apart from UX85/1 were removed in Spring 2013. UX85/1 has been pumped down and is under vacuum. It will be filled with neon at atmospheric pressure when work on the magnet will take place close by. The two beam pipe sections to be reinstalled, UX85/2 and UX85/4, have been filled with nitrogen and are stored in the LHCb cavern at Point 8. All other elements, UX85/3, aluminium and stainless steel bellows and the beryllium support collars are ready for installation and stored by TE-VSC in their facilities. The re-installation of all beam pipe components is scheduled towards the second quarter of 2014.

2.2 Vertex Locator (VELO)

The VELO has performed exceptionally well during the first LHC run with very little down-time and produced data of high quality. The activities during the long shut down are primarily focussed on preventive maintenance and minor upgrades to ensure a continued successful operation. For example most crate and power supply fans and the LV bulk power supplies will be replaced and the LV connectors will be refurbished. The power supplies have been ordered and the fan repair has been arranged with the manufacturer. Similarly, preventive maintenance of the cooling, motion and vacuum system is performed. The migration of the control software to the new platforms has progressed well and is mostly completed. The new control interfaces to the hardware (SPECS and CAN) remain to be integrated in the control framework. There are substantial developments of the monitoring and data quality software. The monitoring framework is being re-built and further automation of the monitoring is being implemented. Agreement has been reached between the LHC vacuum group and LHCb that the VELO does not have to be removed for bake-out after the beam pipe replacement. A change in this decision would require a large effort to temporarily remove the VELO for bake-out. Some additional spares will be produced and tested during LS1. The two detector halves for the replacement are fully assembled but some costs still remain to be covered for the metrology and the storage and display of the replacement detector halves.

2.3 Silicon Tracker (ST)

The operation of the Inner Tracker (IT) and the Tracker Turicensis (TT) was extremely stable during the last run with only a few minor problems encountered. The ST performed very well at luminosities well above the design value throughout the whole period. The operation of the detectors was in the hands of the central shift crew and supported occasionally by an on-call ST piquet. Detailed monitoring of the detector status and performance ensured safe and efficient data taking. Since the start of LS1, the detectors have been switched to a safe state and are only powered for short tests or during the LHCb commissioning weeks. Additional temperature and humidity sensors have been installed to provide extra monitoring and security during the shutdown. A major upgrade of the cooling system has started. The system was not reliable during the last run and required daily attention (as discussed in previous RRB reports). A new chiller was installed in August 2013. New valves have been installed in TT and IT together with the new pipes and filters required for the new plant. Work is on-going to connect the new system and it should be fully commissioned by the end of 2013. The old system will remain as a backup and maintenance will be performed on this system during early 2014. Filters were installed in the cooling circuits to remove dirt responsible for the decrease in the flow of C_6F_{14} coolant. The replacement of the faulty flow switches and flow meters is scheduled for October 2013. The number of working channels is 99.61% and 98.41% in TT and IT respectively. Some of this inefficiency will be recovered during LS1 by the replacement of broken VCSEL diodes in both IT and TT, and the repair of two modules that are not configurable in the IT. A major rewrite of the control system code has started to simplify the code, improve maintainability, and significantly reduce the time needed to configure the front-end electronics. Most of the work is finished and has been tested in a virtual machine. It will be deployed and tested with the production system in the coming weeks.

2.4 Outer Tracker (OT)

The detector and readout electronics operated reliably at the instantaneous luminosity of $4 \times 10^{32}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ in 2012, and even up to $6 \times 10^{32}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ for a brief period at the end of 2012. The performance has been documented in detail in a paper draft, which is circulating within the collaboration for approval to submit for publication. A large analysis effort is continuously being made to allow for a timely determination of the onset of ageing effects. During LHC operation this is done by using charged particle tracks to map the stability of the detector. In the long shutdown, the response of a subset of the detector modules has been scanned with a ^{90}Sr source, and in addition one detector module has been irradiated for two months. No signs of radiation damage were observed. Furthermore, during LS1 the quality of the OT has been consolidated, by disconnecting three channels with short-circuits, by improving the grounding on a few front-end electronics boxes to further reduce noise, by tightening the screws of most low-voltage connectors, and by regularly exercising the data-acquisition. In the last commissioning week a problem with the cooling water of the low-voltage power supplies was observed, which is being investigated.

2.5 RICH systems

The planned work for the RICH system during LS1 is progressing well. New procedures for the refurbishment of HPDs have been established in collaboration with DEP-Photonis. Newly repaired HPDs with longer bake-out time and the addition of getter strips have much lower ion-feedback rate. All the indications show that HPDs repaired with the new procedures will last until LS2 (when they will be replaced for the LHCb upgrade). The campaign to replace some HPDs in the RICH detectors will start in early 2014. There has been good progress in understanding how the L0 trigger rate affects the performance of the HPDs. Some HPD settings were already optimised in 2012 for running at L0 rate of 1 MHz, however, small improvements may still be possible. There have also been measurements of the TTC fibre connectivity using Optical Time Domain Reflectometry (OTDR) in order to understand some front-end de-synchronisation problems. The performance of the RICH system for particle identification was excellent during 2012. During LS1 degraded HPDs will be replaced and the few issues with running efficiency will be addressed.

2.6 Calorimeters (SPD, PS, ECAL and HCAL)

Several activities are on-going during the shutdown. The maintenance of the SPD detector has been conducted and two VFE boards exchanged, the ones for the other sub-systems will be done over the next months. The migration of ECS software from PVSS to WinCC-OA has been performed and is now under test. A method based on raw occupancy and developed to follow the ageing was tested for the PS, ECAL and HCAL with 2012 data, with encouraging results. The final implementation for employing this method in an automated way to produce the online calibration constants for HLT2 has now to be studied. Tests of quartz fibres have been performed at UCL Louvain-La-Neuve with the support of AIDA in June 2013. The transparency loss was measured for $200\,\mu$m pure silica-high OH core from Polymicro to be well below 1% for 100 kRad, and it was decided to proceed with the replacement of fibres used for the ECAL monitoring system. The purchase of the different components (fibres, LED, ferrules, connectors, etc.) has been done. The preparation of the workshop is on-going and the production of the fibre bundles will start at CERN mid-October. The installation on the detector is scheduled to start in January 2014 and will need several months. During the high luminosity run tests performed end of 2012 it was observed that a few TELL1 boards were throttling, or close to throttling level. Therefore, it was decided to add two TELL1 boards for the PS/SPD and HCAL detectors to increase the margin. Consequently, one additional crate had to be added as the existing one was already fully equipped.

2.7 Muon system

The muon system activities at present are mainly focussed on the maintenance tasks scheduled for LS1, which are proceeding smoothly. The doubling of channels for the PNPI-HV system, which improves further the redundancy of the system, is progressing well. Almost all the hardware has been installed on the detector and software integration has started. We expect to complete this task by the end of 2013. The installation of the additional shielding behind the most downstream station M5, to protect the upper part of the station from back-splash of scattered particles, has been completed. The intervention on the problematic chamber gaps and the improvement of the grounding for some chambers in the inner part of stations M2 and M3 is on-going and will be completed by March 2014. The upgrade of the ECS system (at both hardware and software level) is starting and will be continued in 2014. In addition, the test of the spare MWPC chambers is continuing. We have two test stands working in parallel and we expect to complete the tests during the year 2014.

2.8 Online system

In the reference period the consolidation of the online system has proceeded. The controls infrastructure is being moved to virtual machines, partly running on retired farm PCs. The upgrade of the controls software to the new version of PVSS (now WinCC-OA) is on-going and all systems are expected to be upgraded by the end of the year. The farm control is being prepared for the future split of HLT and successful tests were performed with the new system. A test of a new router from Brocade for the DAQ system was successfully executed and the router performs well. This was done to have a fall-back solution in case the support from Force10 should cease before LS2.

3 Operations

During Run 1 LHCb has collected 3 fb^{-1} of integrated luminosity at centre-of-mass energies of 7 and 8 TeV. The data processing evolved significantly during this period and in particular the trigger rate increased from 2 to 5 kHz, placing a great load on offline computing. Most of our trigger bandwidth is dominated by signal b and c hadron events.

During Run 2 we anticipate running at energies of 13 to 14 TeV and similar instantaneous luminosity. The increased production cross-sections of of heavy flavour particles

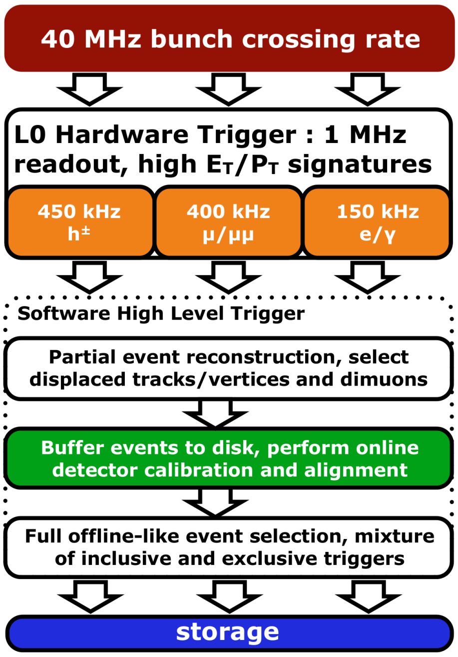

Figure 1: New split trigger architecture.

will reflect in a higher trigger rate of about 12 kHz. We are now in the process of reviewing the trigger and computing model in order to accommodate this additional rate [2].

3.1 Trigger

In 2012 we optimised the use of the available CPU by storing 20% of the L0-accepted data to local disk and deferring the trigger processing of that data to inter-fill periods. It was clear then that storing HLT1-accepted events would have allowed a better use of the available disk, but the available manpower did not allow for this change during the 2011–12 technical stop. We are now in the process of implementing this split between HLT1 and HLT2, which will allow us to buffer up to one week's worth of data locally on the trigger farm (see Fig. 1). Instead of storing only a small fraction of the data, all the HLT1-accepted events will be temporarily stored. We will use a delay of about one hour to run the RICH calibration and alignment, and to check the VELO and tracker alignment. The new calibrations will then be used in HLT2. This significant change in the trigger allows for a reliable use of particle ID (especially kaon ID) in HLT2, which will make the trigger selections more offline-like, in particular for charm physics.

3.2 Computing

The computing usage [3] and the consequences of these changes on the computing model [4] are described in separate documents. We outline here the main conclusions.

During the second half of 2012 we limited the prompt processing of the new data to about 40% of the rate, sufficient to perform data quality checks and run alignments and calibrations. These calibrations were then used for a reprocessing that ran a couple of weeks after data taking. This was then the final reprocessing of the 2012 data set. We are now confident that we can replace the current scheme (that has one "uncalibrated" prompt processing followed by an "end-of-year" processing) with a single processing, which would happen a few weeks after data taking. A small subset of the data would be used for the necessary calibrations during this period. No further processing would then be planned until LS2.

The anticipated 12.5 kHz of data from the trigger will be split in three datasets:

The full stream of 5 kHz will contain our core physics and follow the processing outlined above.

The parked stream of another 5 kHz is intended to be processed and analysed once computing resources are available, i.e. during LS2.

The turbo stream of 2.5 kHz will contain all necessary information to perform the analysis on triggered objects without the need for offline processing. A compact information format will be provided at the trigger output for further analysis and the raw data will be stored on tape. Studies have shown that some of our physics results could have been performed this way without loss of precision.

One recurrent issue is the shortfall of disk. To address this we introduce two measures. First we will make disk available at selected Tier-2 sites (T2-D). Second, to encourage analysts to move to the compact micro-DST format, we will store a backup DST for the selected micro-DST events on tape. This will allow missing information to be recovered without needing to wait for the next stripping of the whole dataset.

4 Physics results

Between April and October 2013, LHCb has continued a high rate of physics output. At the time of writing, LHCb has submitted a total of 156 papers for publication, of which 136 are already published. These numbers have both increased by 50 since the last RRB report—during this period the publication rate of LHCb exceeded those of the ATLAS and CMS collaborations. The collaboration is arranging another in its series of successful workshops together with theorists to discuss the latest results and prepare the final analyses on Run 1 data. In addition, an internal review of ongoing and planned analyses has been launched, in order to maximise the physics output that can be achieved with the Run 1 data. In the remainder of this section, some of the highlights of the most recent results are briefly described.

One of the most keenly anticipated results from LHCb was the update of the analysis of $B^0_{(s)} \to \mu^+\mu^-$ decays with the full Run 1 (2011 + 2012) data set. Indeed the previous publication [5] presenting the first evidence of the B^0_s decay is, according to the INSPIRE database, the most highly cited experimental particle physics paper of the last 12 months. The updated result [6] shown in Fig. 2 confirms the previous evidence and, together with a contemporaneous results from CMS [7], strengthens the significance to the $5\,\sigma$ threshold that is the standard for claiming observation. The LHCb limit on the $B^0 \to \mu^+\mu^-$ decay is the most restrictive to date. The timing of the release of the new results from LHCb and CMS was co-ordinated, and it was agreed that these landmark papers would be published back-to-back in Physical Review Letters. A preliminary combination of the results [8] was also prepared and presented in the plenary session of the EPS 2013 conference. The results are consistent with the Standard Model expectation, restricting the allowed phase space of new physics models, and motivating further improvements in the precision.

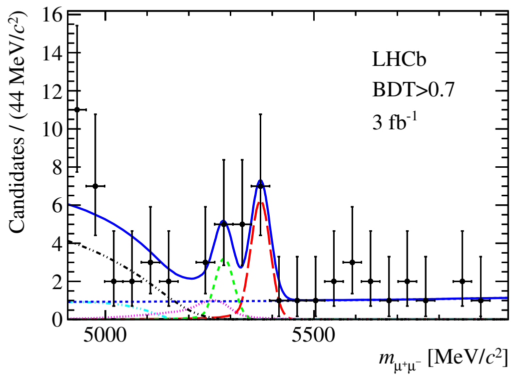

Figure 2: Invariant mass of dimuon candidates in the most signal-like region of the BDT classifier, showing the peak at the B_s^0 mass [6].

LHCb has the ability to study a wide range of $b \to s\mu^+\mu^-$ transitions, and has published several papers on exclusive decays including $B^0 \to K^{*0}\mu^+\mu^-$ [9], $B_s^0 \to \phi\mu^+\mu^-$ [10] and $\Lambda_b^0 \to \Lambda\mu^+\mu^-$ [11]. The angular distributions and CP asymmetries that can be studied in the decay modes offer a wider range of observables compared to $B_s^0 \to \mu^+\mu^-$. Moreover, for certain observables the theoretical uncertainties due to the hadronic form-factors can be minimised. An investigation of one such observable, referred to as P_5', has revealed an interesting deviation from the Standard Model prediction [12], as shown in Fig. 3. This result, although not yet at the level of significance that a strong claim can be made, has provoked considerable interest in the theoretical community, since it can be explained by well-motivated extensions of the Standard Model without causing conflicts with other experimental constraints.

Another very interesting new result among the $b \to s\mu^+\mu^-$ transitions has been the first observation of resonant structure at high dimuon invariant mass in $B^+ \to K^+\mu^+\mu^-$ decays [13]. The structure is fitted as shown in Fig. 4, and is found to have properties consistent with the so-called $\psi(4160)$ state, and therefore the result corresponds to the first observations of both $B^+ \to \psi(4160)K^+$ and $\psi(4160) \to \mu^+\mu^-$ decays. The contribution from the resonant structure to the $K^+\mu^+\mu^-$ final state is much larger than previously anticipated, and is therefore prompting theorists to re-evaluate their models of this B

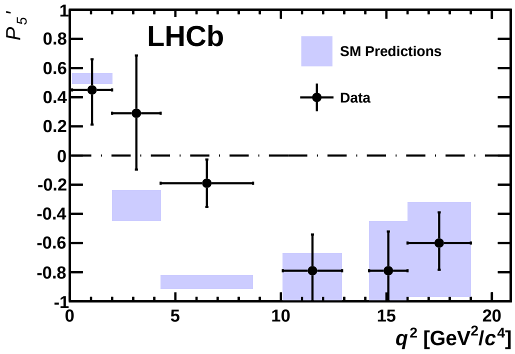

Figure 3: Measured values of the angular observable P_5' in bins of dimuon invariant mass squared q^2 in $B^0 \to K^{*0}\mu^+\mu^-$ decays (black points) compared with SM predictions (blue bands) [12].

decay. The result also shows that B decays can provide powerful methods to understand charmonium spectroscopy.

Studies of charmonium production in LHC collisions remain an important topic, with several unresolved issues needing to be addressed. LHCb has published its long-awaited measurement of J/ψ polarisation in pp collisions [14], which confirms that the polarisation is not well modelled by any of the theoretical descriptions in the literature. Another important result is a new study of χ_{cJ} production [15], where the significant improvement in mass resolution that comes from the use of photons from the $\chi_{cJ} \to J/\psi\gamma$ decay that convert to e^+e^- pairs in the detector material allows the first evidence of χ_{c0} production at a hadron collider. Charmonium production in proton-ion collisions has also been studied [16] using the data recorded by LHCb in early 2013. The comparison of proton-lead and lead-proton beam configurations, together with the forward geometry of the detector, allows interesting measurements to be made of the nuclear modification factor (i.e. the production rate relative to that in pp collisions at the equivalent centre-of-mass energy) as a function of rapidity, as shown in Fig. 5. A unique feature of LHCb in this

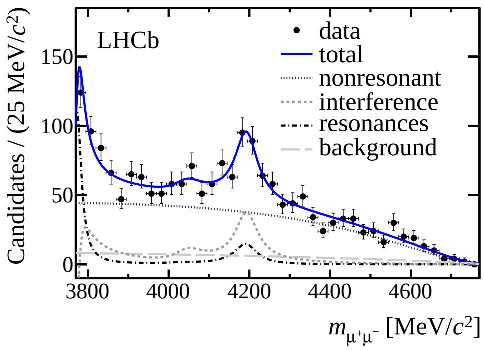

Figure 4: Dimuon mass distribution of $B^+ \to K^+\mu^+\mu^-$ data with fit results overlaid [13].

field is its ability to separate promptly produced J/ψ mesons from those originating from b hadron decays, due to the excellent vertex resolution.

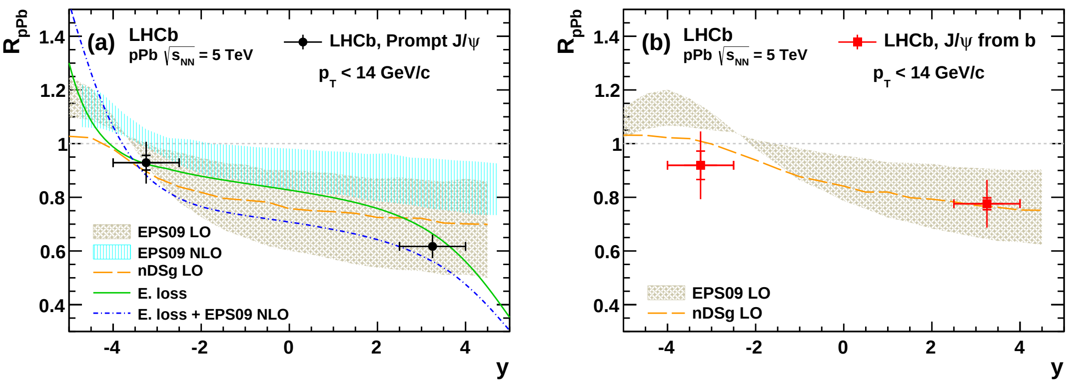

Figure 5: Nuclear modification factor $R_{p\mathrm{Pb}}$ as a function of rapidity y for (a) prompt J/ψ mesons and (b) J/ψ mesons produced in b hadron decays, together with the theoretical predictions [16].

LHCb has also been able to resolve a long-standing issue in b physics concerning the lifetime of the Λ_b^0 baryon. The heavy quark expansion predicts that all weakly-decaying hadrons composed of b quarks and light quarks should have lifetimes that are equal to within a few percent, however early measurements of the Λ_b^0 lifetime at LEP and Tevatron experiments gave an average value that was significantly below that of the B^0 meson. LHCb has been able to significantly improve the knowledge of the ratio of the Λ_b^0 and B^0 lifetimes, exploiting the kinematic similarity between a newly discovered but high yield decay mode, $\Lambda_b^0 \to J/\psi\, pK^-$, and the $B^0 \to J/\psi\, K^{*0}$ decay [17]. The result, $\tau(\Lambda_b^0)/\tau(B^0) = 0.976 \pm 0.012 \pm 0.006$, is consistent with the prediction of the heavy quark expansion.

A number of important new results in *CP* violation have been published. The precision of the determination of the angle γ of the CKM Unitarity Triangle has reached 12° by including the first analyses of $B \to DK$ decays based on the full Run 1 data set [18,19,20]. Significant further improvement is anticipated when more analyses of the full Run 1 data are completed. A major milestone was the first observation of *CP* violation in B_s^0 decays [21]. This was achieved using the $K^\pm\pi^\mp$ final state, where the rate asymmetry is found to balance that observed in B^0 decays, as expected due to flavour symmetries in the Standard Model. These results, shown in Fig. 6, can be used to together with other measurements of two-body B meson decays to kaons and pions to provide a complementary measurement of γ that can be compared to that from $B \to DK$ decays to test the Standard Model. The first results of the relevant parameters in $B_s^0 \to K^+K^-$ decays have recently been published by LHCb [22]. Similar analyses can also be done with three-body B decays, where LHCb has discovered unexpectedly large *CP* violation effects in some regions of the phase space [23, 24]. Understanding the origin of these effects is a high priority, and requires further work from theory as well as experiment.

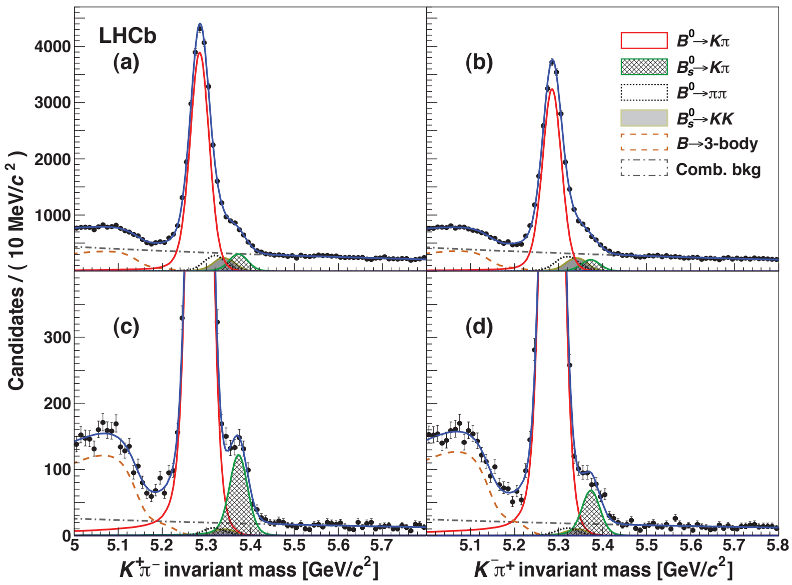

Figure 6: Invariant mass spectra for (a,c) $K^+\pi^-$ and (b,d) $K^-\pi^+$ with selection optimised for (a,b) B^0 and (c,d) B_s^0 decays [21]. The *CP* violation effects are visible as the different height of the peaks in the left and right hand plots.

The search for *CP* violation effects in the charm sector continues to be of great interest. Previous evidence for direct *CP* violation in two-body D^0 decays has not yet been confirmed, and new studies of four-body decays have also not revealed a significant effect [25]. Following the first $5\,\sigma$ observation of charm oscillations [26], it is now possible to look for *CP* violation phenomena associated to the mixing, also known as indirect *CP* violation. New results using the two-body decays $K^{\pm}\pi^{\mp}$ [27], K^+K^- and $\pi^+\pi^-$ [28] are consistent with the Standard Model expectation of negligible *CP* violation, and reduce the allowed parameter space by more than a factor of two. Further improvement of these measurements will allow highly precise tests of the Standard Model and are sensitive to small deviations that could be caused by plausible models of new physics.

5 Financial issues

The status of the accounts is healthy and there is no cash flow problem foreseen. For 2013 M&O Cat. A budget, the expenditures have generally respected our forecast. Year 2013 is the first LS1 year. As expected, “Detector related expenditures” and “General Services” have shown an increase in expenditures, due to LS1 maintenance and consolidation activities. Taking in account the Cat. A funds buffered in the previous years, we are confident to be able to satisfy our requirements during LS1 without budget increase.

6 Collaboration matters

At the LHCb Collaboration Board meetings of June and September 2013, a new group has been accepted as full member and two more as associates. The INFN and University of Milano Statale group, led by Dr. N. Neri, has interest in the area of charm physics and tracking studies and has expressed intention to take part to the UT detector for the upgrade. The group has been fully financed from INFN for its participation to the present experiment. The Milano group has been accepted as full member. The Valencia group, led by Dr. F. Martinez-Vidal, has interest in the area of radiative B decays and calorimetry. The group has been accepted as member associated to Barcelona. The Kurchatov Institute (Moscow) group, led by Prof. V. Shevchenko has interests in the computing area, and in technical participation to the R&D for the fibre tracker in the upgrade. The group has been accepted as member associated to ITEP (Moscow).

At the Collaboration Board of September 2013 it was also decided to suspend the association of Lahore (Pakistan), due to the lack of participation in LHCb from that institute, together with missing contribution to the M&O Cat. A fund. The Maryland and MIT groups have communicated that they have been fully funded by the NSF for their participation in LHCb. P. Koppenburg (NIKHEF) has been elected as Physics Coordinator, starting in January 2014.

The LHCb Collaboration is currently composed of 65 institutes from 17 countries, including 6 associates.

References

[1] LHCb collaboration, *Status of the LHCb upgrade*, CERN-RRB-2013-122.

[2] J. Albrecht *et al.*, *Implications of post-LS1 running conditions on LHCb's data processing*, LHCb-PUB-2013-008.

[3] P. Charpentier (ed.), *LHCb Computing Resource usage in 2013 (I)*, LHCb-PUB-2013-013.

[4] M. Cattaneo (ed.), *LHCb Computing Resources: 2014 re-assessment and 2015 request*, LHCb-PUB-2013-014.

[5] LHCb collaboration, R. Aaij *et al.*, *First evidence for the decay* $B_s^0 \to \mu^+\mu^-$, Phys. Rev. Lett. **110** (2013) 021801, `arXiv:1211.2674`.

[6] LHCb collaboration, R. Aaij *et al.*, *Measurement of the* $B_s^0 \to \mu^+\mu^-$ *branching fraction and search for* $B^0 \to \mu^+\mu^-$ *decays at the LHCb experiment*, Phys. Rev. Lett. **111** (2013) 101805, `arXiv:1307.5024`.

[7] CMS collaboration, S. Chatrchyan *et al.*, *Measurement of the* $B_s^0 \to \mu^+\mu^-$ *branching fraction and search for* $B^0 \to \mu^+\mu^-$ *with the CMS experiment*, Phys. Rev. Lett. **111** (2013) 101804, `arXiv:1307.5025`.

[8] CMS and LHCb collaborations, *Combination of results on the rare decays $B^0_{(s)} \to \mu^+\mu^-$ from the CMS and LHCb experiments*, Jul, 2013. CMS-PAS-BPH-13-007, LHCb-CONF-2013-012.

[9] LHCb collaboration, R. Aaij *et al.*, *Differential branching fraction and angular analysis of the decay $B^0 \to K^{*0}\mu^+\mu^-$*, JHEP **08** (2013) 131, `arXiv:1304.6325`.

[10] LHCb collaboration, R. Aaij *et al.*, *Differential branching fraction and angular analysis of the decay $B^0_s \to \phi\mu^+\mu^-$*, JHEP **07** (2013) 84, `arXiv:1305.2168`.

[11] LHCb collaboration, R. Aaij *et al.*, *Measurement of the differential branching fraction of the decay $\Lambda^0_b \to \Lambda\mu^+\mu^-$*, Phys. Lett. **B725** (2013) 25, `arXiv:1306.2577`.

[12] LHCb collaboration, R. Aaij *et al.*, *Measurement of form factor independent observables in the decay $B^0 \to K^{*0}\mu^+\mu^-$*, `arXiv:1308.1707`, to appear in Phys. Rev. Lett.

[13] LHCb collaboration, R. Aaij *et al.*, *Observation of a resonance in $B^+ \to K^+\mu^+\mu^-$ decays at low recoil*, Phys. Rev. Lett. **111** (2013) 112003, `arXiv:1307.7595`.

[14] LHCb collaboration, R. Aaij *et al.*, *Measurement of J/ψ polarization in pp collisions at $\sqrt{s} = 7\,\text{TeV}$*, `arXiv:1307.6379`, submitted to Eur. Phys. J. C.

[15] LHCb collaboration, R. Aaij *et al.*, *Measurement of the relative rate of prompt χ_{c1}, χ_{c2} and χ_{c0} production at $\sqrt{s} = 7\,\text{TeV}$*, `arXiv:1307.4285`, to appear in JHEP.

[16] LHCb collaboration, R. Aaij *et al.*, *Study of J/ψ production and cold nuclear matter effects in pPb collisions*, `arXiv:1308.6729`, submitted to JHEP.

[17] LHCb collaboration, R. Aaij *et al.*, *Precision measurement of the Λ^0_b baryon lifetime*, Phys. Rev. Lett. **111** (2013) 102003, `arXiv:1307.2476`.

[18] LHCb collaboration, R. Aaij *et al.*, *A measurement of γ from a combination of $B^\pm \to Dh^\pm$ analyses*, Phys. Lett. **B726** (2013) 151, `arXiv:1305.2050`.

[19] LHCb collaboration, *Model-independent measurement of CP violation parameters in $B^\pm \to (K^0_S h^+h^-)_D K^\pm$ decays*, LHCb-CONF-2013-004.

[20] LHCb collaboration, *A measurement of γ from a combination of $B^\pm \to DK^\pm$ analyses including first results using $2\,fb^{-1}$ of 2012 data*, LHCb-CONF-2013-006.

[21] LHCb collaboration, R. Aaij *et al.*, *First observation of CP violation in the decays of B^0_s mesons*, Phys. Rev. Lett. **110** (2013) 221601, `arXiv:1304.6173`.

[22] LHCb collaboration, R. Aaij *et al.*, *First measurement of time-dependent CP violation in $B^0_s \to K^+K^-$ decays*, `arXiv:1308.1428`, to appear in JHEP.

[23] LHCb collaboration, R. Aaij *et al.*, *Measurement of CP violation in the phase space of $B^\pm \to K^\pm\pi^+\pi^-$ and $B^\pm \to K^\pm K^+K^-$*, Phys. Rev. Lett. **111** (2013) 101801, `arXiv:1306.1246`.

[24] LHCb collaboration, R. Aaij *et al.*, *Direct CP violation in $B^+ \to K^+K^-\pi^+$ and $B^+ \to \pi^+\pi^-\pi^+$ decays*, LHCb-PAPER-2013-051, in preparation.

[25] LHCb collaboration, R. Aaij *et al.*, *Model-independent search for CP violation in $D^0 \to \pi^-\pi^+\pi^+\pi^-$ and $D^0 \to K^-K^+\pi^-\pi^+$ decays* , arXiv:1308.3189, to appear in Phys. Lett. B.

[26] LHCb collaboration, R. Aaij *et al.*, *Observation of D^0–$\overline{D}^0$ oscillations*, Phys. Rev. Lett. **110** (2013) 101802, arXiv:1211.1230.

[27] LHCb collaboration, R. Aaij *et al.*, *Measurement of D^0–$\overline{D}^0$ mixing parameters and search for CP violation using $D^0 \to K^+\pi^-$ decays*, arXiv:1309.6534, submitted to Phys. Rev. Lett.

[28] LHCb collaboration, R. Aaij *et al.*, *Measurements of indirect CP violation in $D^0 \to K^-K^+$ and $D^0 \to \pi^-\pi^+$ decays*, LHCb-PAPER-2013-054, in preparation.