Status of the LHCb experiment

CERN-RRB-2012-106

10 October 2012

1 Introduction

During 2012 the LHCb experiment has been successfully collecting data since the beginning of April and so far has already achieved the goal of 1.5 fb^{-1}, which was the luminosity target for this year. Thanks to the extension of the pp run, LHCb should be able to collect about 2.2 fb^{-1} by the end of 2012.

The data taking is characterized by several new running conditions: the higher energy, that brings larger physics yields; an increased performance of the HLT trigger, thanks to software improvements and to the use of extra farm CPUs (both coming from new acquisitions and from the use of "deferred triggering"); a new configuration of collisions in IP8, with beams crossing each other in a vertical plane, to better control systematics using regular switches of magnet polarity; stable data taking at a constant luminosity of $\sim 4 \times 10^{32}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and L0 trigger rate of $\sim$ 1 MHz. On detector side, individual subsystems show excellent stability and very high operational efficiency, and so far there is no sign of ageing effects that affect the quality of the data. On the analysis side, several new results have been presented at the summer conferences and at the recent CKM workshop. Among them, the most important have been the measurement of the semileptonic asymmetry in B_s decays (a^s_{sl}) and the first measurement of the CKM variable γ to a precision already comparable with that of previous experiments. Several other results have been produced in flavour and non-flavour physics, bringing the total number of physics publications to 72.

The parallel ongoing reprocessing of 2012 data will allow the collaboration to present updated results at the 2013 winter conferences with fully calibrated data. The test performed in September with pA collisions in LHCb has been very successful, confirming the possibility of data taking in early 2013 with the pA and Ap beams. The plans for the LHCb upgrade have now developed into a well-defined project that is covered in a separate document [1].

2 Detector subsystems

All LHCb subsystems have operated very reliably over the past six months. The high channel efficiency has been kept almost constant over the full period. Data has been taken at an instantaneous luminosity of $4 \times 10^{32}\,\text{cm}^{-2}\text{s}^{-1}$, and some short tests are planned at a value up to $6 \times 10^{32}\,\text{cm}^{-2}\text{s}^{-1}$ at the end of this year's data taking period. The aim of this is to probe all subsystems at this high instantaneous luminosity, which will serve as a preparation for the data taking after the long shutdown. LHCb participated in the lead ion-proton test run during September and the experiment recorded data smoothly at a trigger rate of 160 Hz. Planning for the long shutdown (LS1), which will start in February next year, is progressing and extensive discussion with the technical departments and subsystem groups are well advanced. In addition to improvements for the beam pipe, major consolidation work for the LHCb dipole is scheduled for next year.

2.1 Beam pipe

The qualification process for the new and lighter support structures of sections UX85/2 and UX85/3 continue to progress well. An engineering design review took place in June 2012 with internal and external reviewers. All mechanical aspects of the design, tests and qualifications were reviewed as well as installation and safety aspects. The reviewers' report was very positive, highlighting a few aspects where further work was recommended. Following their recommendations, studies with an alternative methodology for evaluating safety factors for the beryllium collars have been carried out leading to minor modifications of their geometry, for a further increase of the safety factor. The material for the collars has been qualified for integrity by the supplier and the collars are being manufactured at Exotec. Their delivery is expected in the coming month. Irradiation tests of material for the remaining components of the supports are continuing. The materials retained following the gamma irradiation will be irradiated with protons at CERN in October. The aluminium bellows between UX85/2 and UX85/3 are being manufactured at CERN and tooling for the fabrication of the one between UX85/1 and UX85/2 is in progress. Procedures for the activities during LS1 concerning the beam pipe are being defined.

2.2 VELO

Operation of the VELO during the 2012 data taking period has in general been smooth with only minor problems encountered and resulting in a very modest loss in data taking efficiency. The quality has been high throughout the year with all modules operational close to 100% of the time. One noticeable loss in data quality was caused by an incorrectly prepared TELL1 recipe resulting in 45 pb^{-1} flagged as "VELO bad" in the data quality. The radiation effect on the VELO sensors is monitored closely and the degradation is in agreement with the predictions. The only unexpected effect is a loss of signal to the second metal layer of the sensors. The effect of the radiation is clearly measurable but still far from affecting the performance of the detector. No signs of radiation damage beyond the sensors have been observed and we see no reason to install the replacement detector during LS1. Maintenance and consolidation work is foreseen for LS1, distributed as many small- to medium-scale tasks across most parts of the VELO. Coordination with the beam pipe replacement will be necessary but the impact on the VELO will be minimized. Development of control and monitoring software will continue during LS1, this combined with the foreseen "commissioning weeks" will require continued presence of experts at CERN during LS1. The assembly of the two replacement detector halves is complete and the metrology is currently on-going. Preparations have started to prepare the long-term storage of the halves until they will be needed.

2.3 Silicon Tracker

The performance of the Tracker Turicensis (TT) and the Inner Tracker (IT), the two detectors which constitute the Silicon Tracker, has been extremely stable since April 2012. The operation of the detector is controlled by the central LHCb shift crew with support from an on-call piquet. The number of working channels is 99.7% and 98.7% in TT and IT respectively. The number of working channels for IT is lower, as accessing the read-out electronics for repairs requires the detector to be opened (a major intervention). These channels will be recovered during LS1. Radiation damage in the silicon sensors has been monitored carefully and the results are so far fully consistent with the design predictions. To investigate the problem with higher currents in the TT observed during 2011 and early 2012, various modifications were made to the system. Finally, the effect of the high currents was much reduced by the installation of a Kapton foil and the high currents have disappeared completely since mid-May following a change in the operating procedures. The behaviour of these channels will continue to be monitored, although the problem appears to be cured. There have been many difficulties with the reliable operation of the cooling for the Silicon Tracker. The temperature of the TT detector box together with one box in IT were found to be rising since the start of the year. This was due to a decrease in the flow of the C_6F_{14} coolant and was solved by an intervention on the regulator valves in June. A second problem has been seen which results in a loss of cooling power in the plant. The problem can be cured in the short-term by making a "re-circulation" of the cooling plant during an inter-fill period. However, this intervention is required every five days or so, which is clearly unsatisfactory. A major intervention is planned to upgrade the cooling system during LS1. It will involve the installation of an inverted chiller, a heat exchanger and a brine pump, and a brine circuit which will follow the route of the mixed water pipes from the chiller to the IT and TT cooling plants. This intervention will not start before May 2013.

2.4 Outer Tracker

The detector and readout electronics operated reliably at the instantaneous luminosity of $4 \times 10^{32}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ in 2012, with the amount of dead channels typically below 0.25%. One of the 432 VCSEL transmitters on the on-detector serializer boards broke in early

2012, before data-taking started, compared to 1 (5) in 2011 (2010). Furthermore, one HV cable, connected to 256 straws, supplied unstable HV values in June, and was cured by re-patching the affected straws to a spare HV channel. In July and August one of the 432 on-detector serializer boards exhibited synchronization problems and was disabled until replacement in September. At present, in total only 8 straws out of a total of 53,760 are unresponsive (disconnected), corresponding to 99.99% efficiency. A large analysis effort is continuously being made to allow for a timely determination of the onset of ageing effects, based on the usage of tracking to "map" the stability of the detector. Every 400 pb^{-1} dedicated runs are performed to study the hit efficiency at elevated amplifier threshold values. So far no reduced gain from ageing has been observed, but possible ageing remains a concern and will be watched closely.

2.5 RICH system

The RICH system is performing extremely well, in spite of the challenging LHCb running conditions. First data from 2012 confirm the excellent RICH single photon Cherenkov angle resolutions. All interventions, carried out in 2011 and aimed at improving, stabilizing and consolidating the RICH performance and reliability, have shown their effectiveness and durability. This allowed the RICH operation team to study in detail the behaviour of the front-end electronics (the LHCb pixel chip inside the HPDs, and the RICH L0 system) at very high trigger rates ($\sim 1\,\mathrm{MHz}$) and to further improve their settings, achieving up to $\sim 15\%$ improvement in hit densities. An improved MDCS scan (the RICH-1 system to correct for magnetic distortions) has also minimized small differences in magnet-polarity-dependent RICH-1 single-photon Cherenkov-angle resolutions. A new gas-tight aerogel box has been tested and mounted in RICH-1 during the winter technical stop. Results on aerogel PID performance are awaited in the coming data reconstruction phase. Operation of the system is made easier by a wealth of automated reactions for DCS, DAQ and safety systems. The HPD replacement campaign is progressing according to expectations from ion feedback measurements, although we have to lament an unsatisfactory yield for a few repaired batches, which has slightly reduced the amount of available spares. However, first results from improved HPD fabrication procedures seem to show very promising signs to further reduce (or even suppress) the onset of ion feedback.

2.6 Calorimeters

The calorimeters are running smoothly; all channels are functional. ECAL and HCAL radiation effects are scrutinized regularly. Due to the large bandwidth dedicated to the hadron trigger, the gain of the HCAL PMT has to be adjusted regularly to maintain a constant trigger rate at a level of a few per cent. The LED system is used to measure the ageing of the PMT. In addition, the plastic scintillator is being affected as well. The combined effect is measured with a Cs source scanning the entire HCAL. Radioactive source scans can only be performed during periods without beam in the LHC machine. With the recorded data a dedicated model has been derived and together with the result of the LED measurements radiation effects are frequently compensated. Typically, the HCAL HV is adjusted between once to twice per week, after a delivery of $\sim 100\,\mathrm{pb}^{-1}$ or a change of the magnet polarity. The bandwidth allocated to the electromagnetic trigger is lower and consequently the detector response of the ECAL is more concerned by the radiation effects. Every two months, a precise calibration is derived from a large sample of π^0 from two separated photons. Short-term effects are followed by monitoring electrons from conversions and evaluating the ratio of the deposited energy of the electron in the calorimeter to its momentum measured by the tracking system (E/p) in ranges of $\sim 40\,\mathrm{pb}^{-1}$. The initial performance of the electromagnetic calorimeter and its expected resolution are recovered for π^0 and B decays including photons. Using the same method, the impact of the ageing on the electromagnetic rate has been compensated by adjusting the gain of ECAL PMTs, after $\sim 1\,\mathrm{fb}^{-1}$. This will be done more frequently in the future. As the LED system of ECAL is also affected by radiation effects, it was not used to estimate the ageing of ECAL. The replacement of the plastic fibres of this system by quartz fibres is envisaged to be immune to radiation. As the diameter of these fibres is smaller, a brighter LED will be required and some R&D has started on the characterization and choice of new fibres and LEDs. The change of this system during LS1 is under study.

2.7 Muon system

Since the beginning of LHCb run in 2012, the muon system has operated smoothly with no major hardware problems. The fraction of working channels exceeds 99%. Despite the current LHCb higher instantaneous luminosity the wire chambers are performing well and the fraction of high voltage trips is well under control, with about one trip every two hours on average over more than 4900 wire planes. The GEM detectors are also performing well. Several monitoring tools have been improved especially for configuration and monitoring of the front-end electronics. The iron shielding installed behind station M5 during the extended technical stop 2011/12 has partially reduced, as expected, the background in the upper part of the station due to particles back-scattered by the LHC quadrupole magnet downstream in the tunnel. According to data and on-going simulation studies more shielding will be installed during LS1. The additional shielding will also be beneficial in view of the LHCb upgrade. The production of additional high voltage channels to have individual powering for each gap has been completed at PNPI; the high voltage modules have been delivered to CERN for testing and will be installed during LS1.

2.8 Online system

During the last six months most effort was invested to make the deferred HLT more robust and thus ease the task of the shift crew. In a first step 1 TB disks were added to the farm nodes susceptible to implement deferred processing. This increased the buffering capabilities by a factor of five. The total buffer space is now $\sim 1\,\mathrm{PB}$. On the control side, all the operations for the deferred HLT are now automated. The deferred HLT is started automatically when beams are lost and is automatically stopped (at latest) when stable

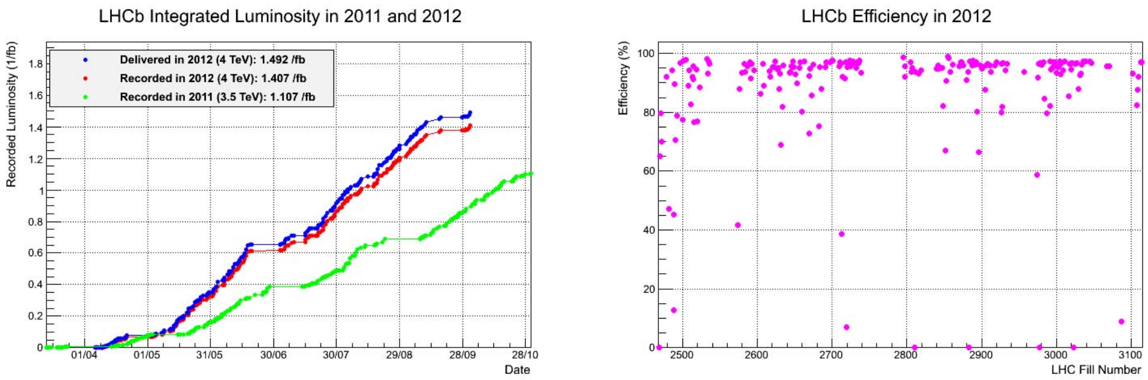

Figure 1: LHC delivered luminosity at LHCb interaction point and LHCb recorded luminosity for the first half of 2012 (left), and corresponding DAQ efficiency (right).

beams are declared again. This allows us to consistently defer around 20% of the input trigger rate with a very small probability of filling up the disk buffer. In addition, 10% of new CPU were installed, to increase the farm capacity. Planning is proceeding concerning the activities during the long shutdown, in particular the replacement of the controls PCs and the storage system.

3 Operations

Since the beginning of the LHC operations in April, LHCb has been steadily taking data with high efficiency and up to the end of September about 1.5 fb^{-1} of pp collisions had been recorded at a centre of mass energy of 8 TeV. Figure 1 shows the delivered luminosity during this period as well as the LHCb data collecting efficiency that has been on average almost 95%, with many of the fills very close to 100%.

During 2012, LHCb has taken data at a constant instantaneous luminosity of $4 \times 10^{32}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ (compared to an average of 3.7 in 2011). This results in a constant average number of visible pp interactions per bunch crossing (μ) of around 1.7 (1.5 in 2011), during the whole duration of the fills.

3.1 Trigger

The Level-0 (L0) trigger has been run with stable thresholds during the year 2012. Only minor modifications have been applied in order to adapt to the ageing of the calorimeters.

The high level trigger (HLT) was improved and reoptimized during the winter. The main additions are the use of track seeding in HLT2, which allows to use K_S mesons decaying outside of the VELO in the trigger decision. This considerably increases the trigger efficiency on charm decays to K_S such as $D^0 \to K_\mathrm{S}\pi\pi$, but adds more rate and costs CPU time. It should be noted that the high trigger output rate needed to accommodate our physics programme sets stringent constraints on our computing.

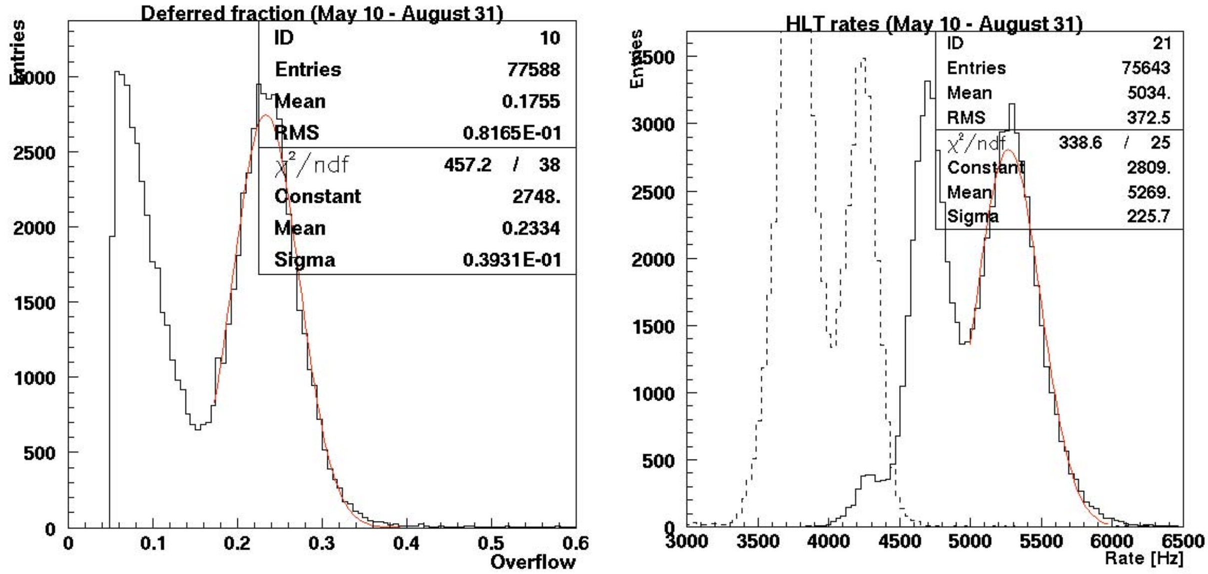

Figure 2: Fraction of HLT input events with deferred HLT triggering (left) and (right) HLT output rate with deferral (full curve) and prompt rate not corrected for deferral (dashed curve).

To accommodate these changes, LHCb has invested in a novel deferred triggering technique in its High Level Trigger (HLT) farm, that allows to store around 20% of the events at the input of the HLT for processing during the inter-fill periods when the HLT farm would otherwise be idle. This allows for a more efficient HLT trigger selection, at the expense of a higher effective HLT output rate of 5 kHz (3 kHz in 2011, 4 kHz without deferral), see Fig. 2.

3.2 Offline computing

Detailed reports on computing resources have been published about the 2011–12 usage [2], 2012–14 prospects [3] and 2015 estimates [4]. The following section copies the parts of their conclusions relevant for this report.

Until the end of August 2012, the LHCb experiment collected a total of 1.2 PB of Raw data that, according to the LHCb computing model, has been stored at the CERN mass storage system.

Tier1 sites pledged a substantially smaller amount of disk resources than originally requested, with the reduction mostly concentrated on two sites (IN2P3 and NL-T1) that now present a clear imbalance between CPU and storage. LHCb took measures to fit within the pledge, but the extension of the LHC running time has once more increased the needs. The usage of tape resources has exceeded the original estimates due to extra new data and the new Full-DST data format introduced to reduce the pressure on the staging system, which in the past had problems during stripping campaigns when Raw and SDST data had to be accessed in parallel. Balancing measures are being put in place, reducing the number of archival replicas for all other data sets. Sites have been invited to update their storage pledges to accommodate the extra data from the new running conditions.

The resource estimates have evolved since the previous ones due to the increased LHCb physics trigger rate, the extended LHC schedule, and mitigating actions we have taken to adapt to actual resources available in 2012. Overall we expect an increase of $\sim 40\%$ more data in 2012 than originally foreseen leading to a commensurate increase in storage and CPU requirements. The LHCb disk request already takes into account the compromises made to fit the forecast usage into the pledged resource. There is a risk that Tier1s will interpret this as a comfortable situation and not provide the resources in 2013 needed to fully exploit the 2012 data.

For CPU, simulation and processing of real data have shared the resources in approximately equal terms, the first being concentrated on Tier2s (with some contributions from Tier1s when there was no LHC activity) and the second on the Tier1s (with some help from selected Tier2s to cover the full CPU need). On average the usage of CPU resources has been about 50% of the power that is expected to be needed during the second half of the year when prompt reconstruction and full reprocessing of 2012 and 2011 data will run in parallel, requiring the full pledged power from the different sites.

3.3 Reprocessing and Data Quality

In 2011 we started the reprocessing of the data with updated alignment and calibration constants during the months of September to December, making the reprocessed data available in time for the 2012 Winter Conferences.

Due to the increase of trigger rate and the extension of the physics run we do not have the resources to do the same this year. In order not to delay the availability of reprocessed data too far into 2013, we decided to reduce the fraction of new data being processed to 50%. This is sufficient for data quality checks and to extract calibration constants. We foresee that this will allow to have the data taken up to the September technical stop reprocessed by Christmas. The remaining to be taken data would be available at a later stage.

Work is being done to improve the real-time data quality monitoring, essentially by running the offline reconstruction on an even smaller fraction of events in real time. Some of the data will also be used to monitor the global alignment parameters and the RICH refractive index in almost real time.

4 Physics results

Between April and October 2012, LHCb has focused on publishing results from its data sample of $1.0\,\mathrm{fb}^{-1}$ of $7\,\mathrm{TeV}$ pp collisions recorded in 2011. First studies have been performed on the 2012 data to assure the quality of the data and to make first measurements of production cross-sections at $8\,\mathrm{TeV}$ [5], but the majority of physics results based on the

2012 data are not anticipated until the reprocessed sample is available, *i.e.* in early 2013.

At the time of writing, LHCb has submitted a total of 72 papers for publication, of which all but 14 are already published. In addition, exactly 100 conference contributions, describing preliminary results, have been submitted. These results are having a significant impact on the landscape of heavy flavour physics, and indeed in the other areas covered by LHCb's broad physics programme. This can be seen not only in the publication record, but in the large number of conference talks given by LHCb speakers – there will have been in excess of 300 LHCb talks at international conferences and workshops during the calender year 2012. Among the most highly cited LHCb papers are the first measurement of the $b\bar{b}$ production cross-section at the LHC [6], the first evidence for *CP*-violation in the charm system [7] and the most restrictive limits to date on the branching fractions of the very rare decays $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ [8]. Following two workshops organized together with theorists, a detailed summary of the implications of LHCb results on theories of physics at the Terascale and beyond was prepared [9], and its executive summary submitted to the European Strategy Preparatory Group [10]. This document also complements the Framework TDR for the LHCb Upgrade [11], emphasizing the importance of the measurements that can be made with the upgraded LHCb detector.

In the remainder of this section, some of the highlights of the most recent results are briefly described.

Rare decays of b hadrons to final states containing muons provide an excellent hunting ground for new physics, that is experimentally well suited for LHCb due to the clean trigger signature. Previously presented results on the golden channel $B^0 \to K^{*0}\mu^+\mu^-$ [12,13] have been complemented with studies of its equally golden siblings, $B^+ \to K^+\mu^+\mu^-$ [14], $B^+ \to K^{*+}\mu^+\mu^-$ and $B^0 \to K^0_S\mu^+\mu^-$ [15]. Although the predictions for the differential branching fractions in each of the channels individually suffer from significant hadronic uncertainties, the so-called isospin asymmetries between the charged and neutral B decay rates have reduced uncertainty. Measurements of these isospin asymmetries therefore provide a promising approach to search for new physics models that may affect charged and neutral B decays differently. As shown in Fig. 3, while the asymmetry in $B \to K^*\mu^+\mu^-$ decays is consistent with zero as expected, there is evidence for an asymmetry in $B \to K\mu^+\mu^-$ decays. Integrated over all values of dimuon invariant mass squared, the significance of the effect is $4.4\,\sigma$. Intriguingly, less precise results from previous experiments also hint at such an asymmetry. However, the data is not conclusive so far, and the pattern of effects is hard to explain in many new physics models. Thus updated and improved measurements are keenly anticipated. Another important test for new physics in these decays is to search for *CP*-violation effects; LHCb has very recently presented first results in this area [16].

The excellent capability to trigger on final states containing muons also enables LHCb to pursue a programme of measurements related to production of electroweak gauge bosons. The centrepiece of this activity is the study of the production rates of W and Z bosons and their asymmetries. By determining these quantities in the unique forward acceptance of the LHCb spectrometer, essential input can be provided to improve knowledge of parton distribution functions (PDFs) that can lead to significant systematic uncertain-

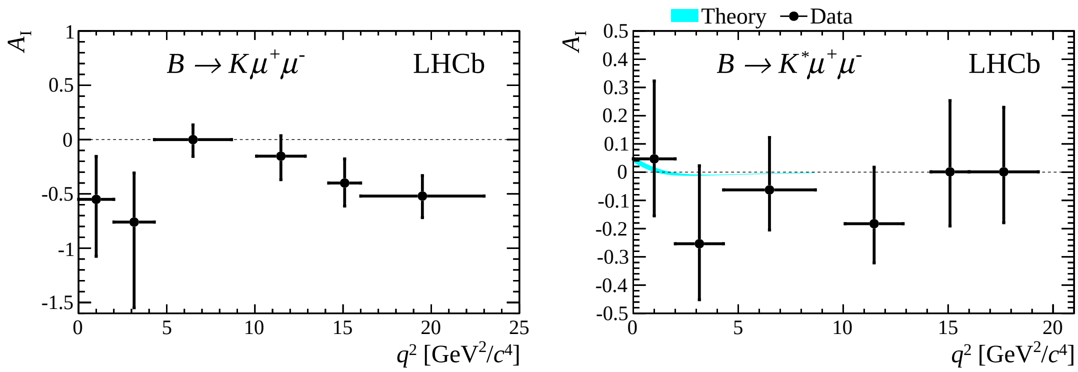

Figure 3: Isospin asymmetries as a function of dimuon invariant mass squared q^2, in (left) $B \to K\mu^+\mu^-$ and (right) $B \to K^*\mu^+\mu^-$ decays [15].

ties in certain analyses, also for the ATLAS and CMS experiments. The most striking demonstration of this is seen in the lepton charge asymmetry, determined from the difference in the inclusive production cross-sections for W^+ and W^-, as a function of muon pseudorapidity. The asymmetry changes sign in the LHCb acceptance, as shown in Fig. 4, which is based on the analysis of the 2010 data set ($37\,\mathrm{pb}^{-1}$) [17]. Work is in progress on an update of this analysis with more data, which will give very strong constraints on the PDFs and allow to distinguish between different parametrisations. The Z production measurements in the $\mu^+\mu^-$ final state have been complemented with preliminary results from a study of inclusive Drell-Yan production (also using the 2010 data set) [18] as well as results based on the $1.0\,\mathrm{fb}^{-1}$ collected in 2011 using the $Z \to e^+e^-$ [19] and $\tau^+\tau^-$ [20] channels. The results of first studies of Z production in association with jets have also been presented [21].

LHCb continues to provide world leading measurements in the field of *CP* violation. Although previous results from LHCb [22,23] significantly restrict the parameter space for new physics contributions in B_s^0 mixing, this area continues to attract theorists' attention due in part to results from the D0 collaboration [24] indicating anomalous semileptonic *CP* asymmetries, which are predicted to be negligibly small in the Standard Model (SM). At ICHEP, LHCb presented the world's most precise measurement of the semileptonic asymmetry in the B_s^0 system, $a_{\mathrm{sl}}^s = (-0.24 \pm 0.54 \pm 0.33)\%$ [25], consistent with zero and the SM prediction, but not ruling out small new physics contributions. Updated and improved measurements are needed to resolve the origin of the D0 anomaly. With this in mind, it is notable that the systematic uncertainties in the LHCb result, which is based on the 2011 dataset, are determined using data-driven approaches, and therefore significant improvements in precision can be anticipated with larger samples.

Among other interesting results in this area, LHCb has presented the most precise measurements of B_s^0 decays to $J/\psi\,\eta$ and $J/\psi\,\eta'$ [26], which demonstrate the performance of the electromagnetic calorimeter, as well as of $B_s^0 \to D_s^+ D_s^-$ [27]. These will be important channels for future *CP*-violation studies in the B_s^0 sector, complementing the $J/\psi\,\phi$ and $J/\psi\,\pi^+\pi^-$ final states that have been used so far.

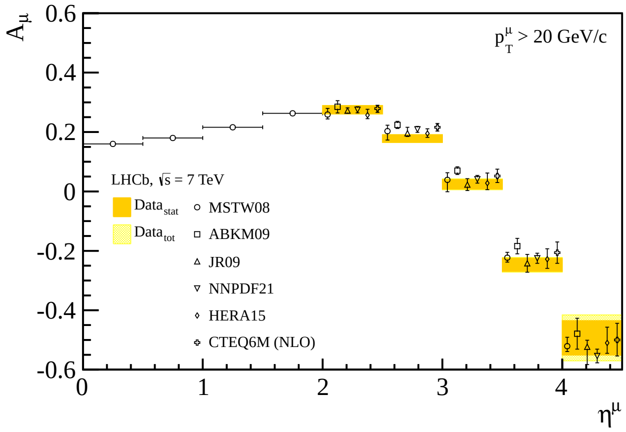

Figure 4: Lepton charge asymmetry A_μ as a function of muon pseudorapidity η^μ [17]. The dark shaded (orange) bands correspond to the statistical uncertainties, the light hatched (yellow) band to the statistical and systematic uncertainties added in quadrature. Superimposed are predictions with different parametrisations of the PDF.

As well as searching for small CP-violation effects in the B_s^0 and charm sectors, LHCb has discovered the largest matter-antimatter asymmetries seen to date. Results on B^+ decays to three tracks have uncovered dramatic effects [28, 29], that will require detailed investigations in order to understand their origin and establish whether or not they are consistent with the SM. The analyses carried out so far are model-independent, in that no attempt is made to describe the distribution of events across the phase space (or Dalitz plot) of the three-body decay, but instead the total yields, and binned Dalitz plot distributions, of B^+ and B^- decays are compared. The results for the integrated asymmetries are

$$\begin{aligned}
A_{CP}(B^\pm \to K^\pm\pi^+\pi^-) &= +0.034 \pm 0.009\,(\text{stat.}) \pm 0.004\,(\text{syst.}) \pm 0.007\,(J/\psi\,K^\pm)\,, \\
A_{CP}(B^\pm \to K^\pm K^+ K^-) &= -0.046 \pm 0.009\,(\text{stat.}) \pm 0.005\,(\text{syst.}) \pm 0.007\,(J/\psi\,K^\pm)\,, \\
A_{CP}(B^\pm \to \pi^\pm\pi^+\pi^-) &= +0.120 \pm 0.020\,(\text{stat.}) \pm 0.019\,(\text{syst.}) \pm 0.007\,(J/\psi\,K^\pm)\,, \\
A_{CP}(B^\pm \to K^+K^-\pi^\pm) &= -0.153 \pm 0.046\,(\text{stat.}) \pm 0.019\,(\text{syst.}) \pm 0.007\,(J/\psi\,K^\pm)\,,
\end{aligned}$$

where the last source of uncertainty is due to possible CP asymmetry in the $B^\pm \to J/\psi\,K^\pm$ channel that is used to remove effects of production asymmetry. The results give the first evidence (at more than $3\,\sigma$) of non-zero values of these parameters in all modes except $K^\pm\pi^+\pi^-$ (where the significance is $2.8\,\sigma$). However, from inspection of the variation of the asymmetries across the Dalitz plots, it is clear that much larger effects appear localized in some regions, as shown in Fig. 5. Further studies are underway to improve the understanding of the origin of these asymmetries.

Although the theoretical interpretations of many asymmetries involving loop processes suffer from significant uncertainties, the situation is quite different for processes dominated by tree amplitudes. For this reason the determination of the angle γ of the CKM Unitarity Triangle using $B \to DK$ decays has long been considered a standard candle of

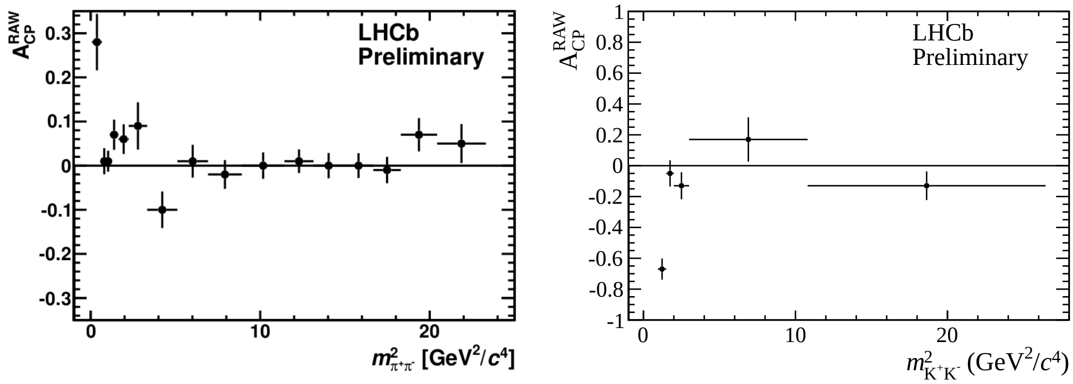

Figure 5: Raw *CP* asymmetries (not corrected for detector or production asymmetries) as a function of (left) $m^2(\pi^+\pi^-)$ in $B^\pm \to K^\pm\pi^+\pi^-$ decays [28], (right) $m^2(K^+K^-)$ in $B^\pm \to K^+K^-\pi^\pm$ decays [29].

heavy flavour physics, although previous experiments have not been able to reduce its uncertainty below 10° due to limited statistics. LHCb has recently complemented its most precise measurements of the parameters in $B^+ \to DK^+$ decays with two-body D decays [30] with analyses based on three- and four-body D decays [31, 32]. Combining these measurements gives the constraint [33]

$$\gamma = \left(71.1\,^{+16.6}_{-15.7}\right)^\circ \ ,$$

which is comparable to the final precision achieved by the BaBar and Belle experiments. The world average for the first time has sensitivity better than 10°. First results on important additional channels such as $B^0 \to DK^{*0}$ [34], $B^+ \to DK^+\pi^+\pi^-$ [35], $B^0_s \to DK^+K^-$ [36] and $B^0_s \to D^\mp_s K^\pm$ [37] have also been presented. In future it will be possible to include results from these modes in the combination. Therefore, considering also that results based on the much larger 2012 data sample will become available, there are excellent prospects for a significantly improved γ measurement within the next year.

5 Financial issues

The status of the accounts is healthy and there is no cash flow problem foreseen.

For the 2011 M&O Cat. A budget the expenditures have generally respected our forecast, and for 2012 we do not expect surprises. Year 2012 is our third full operations year, therefore we also expect a decrease in "Detector related expenditures" and "General Services", as in the previous two years.

In view of the long shutdown in 2013–14 and of the foreseeable important interventions on subdetectors and on general safety and infrastructure, LHCb has assessed in detail the expected M&O expenditures. Taking in account the Cat. A funds buffered in the previous years, we are confident to be able to satisfy our requirements during LS1 with essentially no budget increase.

No institute has indicated that it has additional requests for funds to be presented to the RRB.

6 Collaboration matters

At the LHCb Collaboration Board meetings of June and September, three new groups have been accepted as full members.

The Padova group (INFN and University), led by Prof. Donatella Lucchesi, has shown interest in the study of measurement of γ angle. Service work was agreed upon between LHCb and the Padova group for activities in the flavour tagging and the computing, including the upgrade. The participation and funding of the group has been approved by INFN in September 2012.

The Pisa group (INFN, University and Scuola Normale Superiore), led by Prof. Giovanni Punzi, has shown interest in the study of the hadronic decays of charm and beauty quarks. Service work was agreed upon between LHCb and the Pisa group for activities in the HLT and the tracking, including the upgrade. The participation and funding of the group has been approved by INFN in September 2012.

The University of Maryland, led by Prof. Hassan Jawahery, has shown interests in the study of *CP* violation in the b sector. Service work was agreed upon between LHCb and the Maryland group for the tracking and flavour tagging, including upgrade activities. The group has submitted a funding grant request to DOE in October 2012.

The NSF grant to Cincinnati University for their participation in LHCb has been attributed in June 2012.

References

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