Status of the LHCb experiment

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1 Introduction

In the last part of 2011 and at the beginning of 2012, the LHCb collaboration has worked for the preparation of 2012 run and in the continuation of the analysis of the data taken last year. On the detector side, the activities, as discussed in more detail later on, have been devoted to the installation of a gas-tight aerogel box, in the general maintenance of the infrastructure and of detectors, and in the preparation of a substantial upgrade of the HLT project. On the analysis side, several of the results presented at the summer conferences in 2011 have been updated for the winter conferences 2012, with the full statistics. These include the search for the $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ rare decays, the measurement of angular distributions in the $B^0 \to K^{*0}\mu^+\mu^-$ decay, and the determination of the CP-violating phase ϕ_s in B_s^0 decays. Several new measurements with the full 2011 statistics have also been produced, not only in the domain of b flavour physics, but also in charm sector, in quarkonia production measurements, in spectroscopy, in electroweak and in exotica searches. In particular, the evidence seen of a possible CP violation in the Cabibbo suppressed D^0 decays ($\Delta A_{CP} = A_{KK}^{CP} - A_{\pi\pi}^{CP}$) has triggered an enormous interest in the theoretical community concerning its possible origin from New Physics. The issue is still open and needs further confirmation, both experimental and theoretical. Over the last year the LHCb scientific production has considerably increased. In the recent period the collaboration has continued to work on the preparation of the LHCb upgrade, setting important milestones for its achievement.

2 Detector sub-systems

After successful data taking with an overall channel efficiency above 99% in 2011, LHCb has profited of the extended technical stop during the winter months. The electrical network at the experimental site, inherited from the LEP era, has undergone a major consolidation work, gaining more robustness. The cooling and ventilation controls system of the gas complex has been renewed. The yearly tests and maintenance work of safety systems were mostly performed during the Christmas CERN closure, not disrupting the activities required for the different sub-systems. All sub-detector groups requested access to their system and every system had been opened for repair, maintenance or modification. During this period the experiment has been prepared to run at an instantaneous luminosity of $4 \times 10^{32}\,\mathrm{cm^{-2}s^{-1}}$. All work has been completed, the cavern was closed well in time and the experiment is ready for data taking.

2.1 Beam pipe

The replacement part for the third section of the Be beam pipe (UX85/3) has been delivered to CERN. Metrology measurements and vacuum tests show excellent results. The beam pipe has been NEG coated and is ready for installation during the long shutdown 2013/14 (LS1). The qualification process for the new and lighter support structures of the section UX83/2 is progressing well. Irradiation tests are well advanced and an engineering design review will be held during June 2012. The tooling for the fabrication of the aluminium bellows between UX85/2 and UX85/3 has still to be prepared. The planning of the activities during the LS1 concerning the beam pipe has already started.

2.2 Vertex Locator (VELO)

Robustness issues were encountered with the low voltage system connectors during 2011 operation. The system was modified by the manufacturer, exchanged and recommissioned during the extended technical stop 2011/12. Periodic servicing of components, notably on the vacuum and cooling systems, was also performed during the shutdown. The VELO sensors received a very high radiation dose, being only 8 mm from the LHC beam, and significant studies on the radiation damage of the detector have been undertaken. The silicon sensor currents and the depletion voltage changes resulting from bulk radiation damage are at the expected level, with the inner parts of the n-in-in sensors having gone through type inversion. However, an unexpected radiation-induced charge loss to the second metal layer in the sensors has also been observed. Currently no degradation is seen on the track reconstruction efficiency and monitoring has been put in place for 2012 operation. The assembly of the first half of the VELO replacement system has been completed, and all modules for the second half have been delivered to CERN.

2.3 Silicon Tracker (ST)

The two detectors that constitute the Silicon Tracker: the Inner Tracker (IT) and Tracker Turicencis (TT) have performed very well throughout the 2011 run. The central LHCb crew is in charge of the operation of the detector with support from an on-call piquet. The performance of the detectors surpassed the design specifications and guarantees their operation well above the design luminosity. At the moment 99.8% of channels in the TT and 98.9% in the IT are operational. The very few channels that broke down during the operation of the detector were fixed in the extended technical stop 2011/12. Most of them required the opening of the detector, a major intervention which always has to be balanced against the risk of not improving the excellent detector performance further in an appreciable way. Modifications to the original design of the cooling plants were implemented and improved the reliability and robustness of the systems considerably. Furthermore, automatic actions were implemented to reduce to a minimum the downtime in case of failure. The installation of a very thin Kapton foil in the inner part of the TT detector Faraday cage greatly improved the situation with the high currents seen in the detector when beams are present. This motivated the installation of a second metallic foil on top that will further reduce the current by changing the electrostatic field. A survey of the IT detector along the beam axis confirmed the observed longitudinal movement of the detectors towards the magnet when switched on. Radiation damage has been monitored carefully and the results are so far fully consistent with the design predictions.

2.4 Outer Tracker (OT)

The OT detector and readout electronics operated reliably in 2011 with the amount of dead channels well below 1%. One out of the 432 VCSEL transmitters on the on-detector serializer boards failed in 2012, compared to 1 (5) in 2011 (2010). This has been repaired, together with two HV problems, resulting in a total of 8 disconnected straws out of a total of 53,760. In addition, the source of small noise problems has been localized. A large analysis effort has been 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 200 pb^{-1} of integrated luminosity, dedicated runs were performed to study the hit efficiency at elevated amplifier threshold values, which will be continued during the 2012 running. So far no reduced gain from ageing has been observed, but possible ageing remains a concern and will be watched closely.

2.5 RICH detectors

Both RICH detectors performed very well over the full year 2011 despite the very challenging LHCb running conditions. The CF_4 scintillation issue in RICH-2 was solved by injecting a small quantity of CO_2 into the radiator gas. In May 2011, increased luminosities indicated an anomalous throttling of the UKL1 (DAQ) board, limiting the maximum luminosity to 3.2×10^{32} $cm^{-2}s^{-1}$. This issue was solved by improving the efficiency of the firmware, demonstrating compliance with LHCb rate and event size specifications and providing a significant margin in the luminosity range. Beam-induced light emission, a background phenomenon appearing only with presence of beam and high luminosity, is being controlled by employing an electronegative gas (CO_2) around the HPD photodetectors, and by decreasing their high voltage from 18 kV to 16 kV, without affecting the excellent particle ID performance. Monitoring tools have been put in place to detect this phenomenon if it reappears. A new gas-tight aerogel box has been tested and mounted in RICH-1 during the technical stop. Operation of the system is made easier by a wealth of automated reactions for the detector control, DAQ and safety systems. The HPD replacement campaign is progressing according to expectations from ion feedback measurements, although we were disappointed with an unsatisfactory yield for a few of the repaired batches, which slightly reduced the number of available spares.

2.6 Calorimeters (SPD, PS, ECAL and HCAL)

The calorimeters are ready to take data in 2012 and all channels are functional. A single dead channel in HCAL has been registered during last years running and only very few minor hardware interventions were required during the extended technical stop. A few PMT which showed instabilities or an increased dark current have been exchanged. A slight increase in current was observed on some boards which are used to power the VFE (very front-end) electronics of the SPD. This was related to an increase of fuse impedance, and to prevent any future problem the fuses have been exchanged for a higher value. A new hardware system has been installed and tuned in order to measure phase changes of the calorimeter crates. A first paper reconstructing $B^0 \to K^{*0}\gamma$ and $B_s^0 \to \phi\gamma$ decay modes has been published. After ECAL calibration the achieved B mass resolution is about 100 MeV/c^2, close to the Monte Carlo expectation. To correct for the ECAL radiation effects, the PMT high voltages have been adjusted to make uniform the cells' transverse energy range, while for the HCAL the PMT gains have been reduced by a factor two. The gain of the HCAL readout chain is recovered at the front-end electronics level, at the price of a small increase of the electronics noise. Consequently, this increases the dynamic range of the HCAL up to $E_{\mathrm{T}}^{\mathrm{max}} = 30\,\mathrm{GeV}$. The radiation effects and calibration will be followed up over the next year, and a model describing the effect has been developed for the ECAL. Together with the LED monitoring system it will be used to update the calibration on a weekly basis, while a more precise calibration will be derived from a large sample of π^0 from two separated photons once a month. Concerning the HCAL, after every 200 pb^{-1} collected, or at a change of the magnet polarity, the LED system will be used to tune the photomultiplier high voltages to restore their initial gain. At each technical stop a more precise correction will be applied using calibration runs with a radioactive source.

2.7 Muon System

During the extended technical stop 2011/12 a lot of consolidation work has been performed on the Muon System. All the known hardware issues have been addressed and fixed. One GEM chamber, three MWPCs and a number of front-end boards have been replaced. After these interventions no dead channel is present in the Muon System, as demonstrated by the first data acquired at the beginning of the 2012 LHC run. The TELL1 firmware has been further improved in order to ensure a smooth running of the system up to the highest rates. Additional iron shielding has been installed downstream of the M5 station in order to reduce the background coming from particles backscattered in the LHC tunnel.

2.8 Online System

In the report period, which coincided with the extended technical stop, most of the activities were concentrated on implementing the Deferred HLT scheme, i.e. writing data to the local disk of the HLT farm PCs if there is no capacity available to perform the trigger algorithm. In the inter-fill time the data is then read back from the disk and processed by the HLT algorithm, and the output written to the output stream. This scheme has the potential to increase the effective computing capacity of the farm by 10–20%. It implied work on the data-flow system and the control system. Many tests have been made and the scheme is now ready for commissioning. Other activities involved improvements in the emulation of the behaviour of the front-end electronics in the TFC system. Also the further automation of the operation was implemented which will help the shift crew and improve the overall efficiency. Another upgrade of the farm by more than 3300 cores is in the pipeline and will be operational around mid-April 2012.

3 Operations

The tests at a luminosity of $4 \times 10^{32}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ performed during the last week of 2011 data taking were successful, and we plan to operate at this luminosity throughout the 2012 data taking period. Thanks to the luminosity levelling introduced last year the ratio of average to peak luminosities should be close to unity. We thus hope to achieve an integrated luminosity of $1.5\,\mathrm{fb}^{-1}$ this year by keeping the overall efficiency as high as possible.

The LHCb operations are driven by the needs of physics based on last year's experience. The evidence seen for CP violation in the charm sector [24] has highlighted the importance of charm in LHCb's physics programme. Important improvements in the trigger and offline computing have been implemented during the winter to increase the yields of charm decays. This included a campaign of optimisation of the HLT trigger. As a result, the trigger rate, already increased to 3 kHz in 2011 (from an original 2 kHz), will reach 4.5 kHz in 2012.

We are also planning to swap the magnet polarity more frequently, typically every $150\,\mathrm{pb}^{-1}$ to better cancel out any small detector instabilities.

3.1 Trigger

The Level-0 (L0) trigger has been run with stable thresholds throughout the year 2011. Only minor modifications are foreseen to cope with the increased luminosity and higher collision energy this year.

The HCAL gain drift is affecting the L0 rate as well as the L0 efficiency (especially for low-p_{T} charm). This will be mitigated by more frequent HCAL gain calibrations (typically every magnet polarity swap).

Considerable work was done to improve the emulation of the pipeline in the BEETLE front-end chip. This should allow us to reduce the dead-time by a few percent, and achieve the design 1 MHz L0 rate.

The high level trigger (HLT) was improved and reoptimised during the winter. The main additions are the use of track seeding in its second stage, which will allow the use of K_S^0 decaying outside of the VELO in the trigger decision. This is expected to considerably increase the trigger efficiency on charm decays to K_S^0, such as $D^0 \to K_S^0\pi^+\pi^-$. The tracking has also been retuned to increase efficiencies.

These improvements and changes running conditions have a CPU cost corresponding to about a 30% increase. This will be absorbed in roughly equal parts by improved software, additional CPUs, and the introduction of deferred triggering. In this new scheme to be commissioned with the first 2012 data we will be writing some fraction (about 10%) of the L0-accepted events to local disks and process them during the inter-fill gaps. Simulations based on last year show that we should only very rarely exceed the disk capacity because of too long fills or too short inter-fill gaps. In such cases we will lower the luminosity or apply a tighter trigger.

As a consequence of these changes the rate of charm decays recorded should increase from 1 to 2 kHz. We also expect the other triggers to have a larger rate due to the higher energy and luminosity. The total trigger rate will be set to 4.5 kHz. This high output rate, needed to accommodate our physics programme, sets stringent constraints on the offline computing.

3.2 Data processing (offline computing)

The computing resources pledged for 2012 will not allow to fully exploit the physics potential of the new trigger bandwidth, due to disk space limitations. Therefore, unless extra resources become available during the year, parts of the recorded data will have to be "locked" during 2012. This will be achieved by tuning the offline event selection ("Stripping") to produce the same output bandwidth as in 2011. The "locked" data will be "unlocked" during 2013 re-stripping passes by introducing additional channels and looser requirements, increasing by 50% the final output. This will allow both enhanced analyses as well as true data-mining searches.

In order to reduce the size of the data samples selected for physics by the Stripping, a new data format, MDST, has been introduced with a target size per event one order of magnitude smaller than the nominal DST format. This allows the number of events accessible for physics to be increased without increasing the size of the stripped sample. A further reduction in the total volume of the data will be achieved by keeping on disk only the last two (previously three) processing passes for each data sample. This will be accompanied by a reduction in the frequency of new passes.

Another important consequence of the expanded charm physics program is that the so-called "Swimming" will be run in production. To accurately determine the lifetime acceptance of the trigger, this involves re-running the trigger many times on the same event, varying the decay time. This is a very CPU-demanding task. While it can be done by individual users for typical B decays, it is not possible for the huge statistics of charm decays. It will this be run in production on the output of the Stripping, storing the result on the MDST.

The new physics analyses have generated new demands of simulated samples. The flexible LHCb production system has been able to produce them by making opportunistic use of non-pledged resources (at non-LHCb WLCG Tiers, using non-WLCG resources, going beyond the pledge at Tier2s, making use of idle resources at Tier0/1s, etc.). This has put further pressure on disk resources, which has been mitigated by reducing the number of disk replicas for the samples, from 4 to 3, and making periodic clean-ups of "old" simulated samples, requiring use to be made of the new samples when possible.

During the 2011/12 shutdown, the usage of the online Event Filter Farm (EFF) as additional computing resource has been commissioned. Its usage is fully integrated using DIRAC. For reprocessing, the usage of the EFF is limited by network bandwidth. However, scaling tests still need to be performed. It is also unclear for how long the EFF can be available during shutdowns, due to power and cooling shortage or maintenance. We prefer to keep its additional power as contingency until its possibilities have been determined.

It should be noted that 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 might interpret this as a comfortable situation and not provide the resources in 2013 needed to fully exploit the 2012 data. The disk request for 2012 assumes that pledged disk will be fully installed by April and distributed among the Tier1s according to the CPU shares. This will not be entirely the case since some Tier1s have pledged disk below their current CPU share, and others will not be installing their full pledge until later, some as late as autumn. This will lead to shortages at some sites in the second half of the year [1].

3.3 Calibration and alignment

Unlike in 2011 we do not have the resources to reprocess the early 2012 data with the correct alignment constants. This will affect the amount of data available for preliminary results shown at the summer conferences.

To mitigate this, work has been done to improve the real-time data quality monitoring, essentially by running the offline reconstruction on a 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, almost in real time. The plan is to use these constants already in the first pass processing, improving the quality of the data available before the winter 2012/13 reprocessing.

There is a continuous effort to improve the flavour tagging efficiency. Data-driven techniques are being developed to optimise the same side pion (for B^0) and kaon (for B_s^0) tagging.

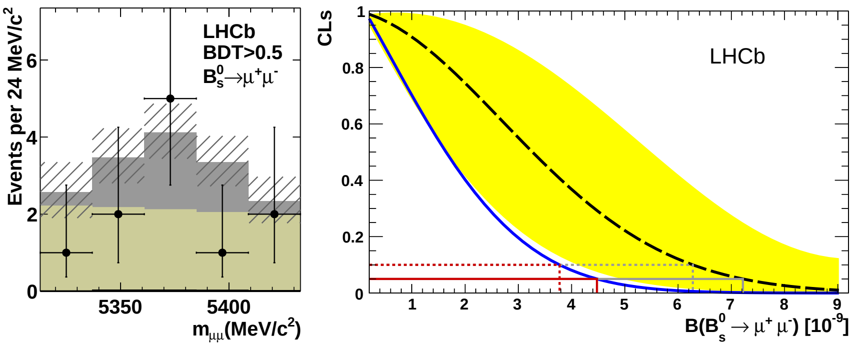

Figure 1: Results on $B_s^0 \to \mu^+\mu^-$ [4]. (Left) dimuon invariant mass distribution for $B_s^0 \to \mu^+\mu^-$ candidates: the histograms show the expected background and signal (at the Standard Model rate) distributions. (Right) extraction of limits using the CL_s method: the solid curve is the observed result while the dashed curve is that expected for background plus signal at the Standard Model rate.

4 Physics results

In the last few months there have been two main objectives for LHCb physics exploitation—converting preliminary results into publications, and producing new results using the full reprocessed $1.0\,\mathrm{fb}^{-1}$ data-set collected in 2011. Excellent progress has been made, with at the time of writing 46 journal papers submitted for publication and another ten well advanced in the internal review process. In addition, thirteen new conference notes describing preliminary results have been produced, though increasingly more of the new results are of sufficiently high quality to send directly for publication. In what follows some selected highlights from this harvest are summarized.

One of the golden channels for the potential observation of physics beyond the Standard Model is the $B_s^0 \to \mu^+\mu^-$ decay. The branching fraction is significantly suppressed, to the level of 3×10^{-9}, by the absence of tree-level flavour-changing neutral currents in the Standard Model, along with its helicity structure. However, extended models do not necessarily share these features, so that enhancements to the branching fraction may be possible. In particular, larger rates are predicted in supersymmetric models with high values of $\tan\beta$ (the ratio of Higgs' vacuum expectation values).

LHCb has continued to refine its analysis procedures, following two previous publications on this channel [2, 3], to optimise the sensitivity. The latest result [4] uses the full $1.0\,\mathrm{fb}^{-1}$ sample, with results that are shown in Fig. 1. The number and distribution of candidate events is consistent with the background expectation, and an upper limit on the branching fraction $\mathcal{B}(B_s^0 \to \mu^+\mu^-) < 4.5 \times 10^{-9}$ is set at 95 % confidence level using the CL_s method. This is the tightest limit on this decay to date—the LHCb analysis has better sensitivity than the CMS and ATLAS results that appeared almost contemporaneously and use up to five times more integrated luminosity. Although the result is consistent with the Standard Model, it has prompted some theorists to consider if the true value of the branching fraction might be smaller than predicted—a possible outcome

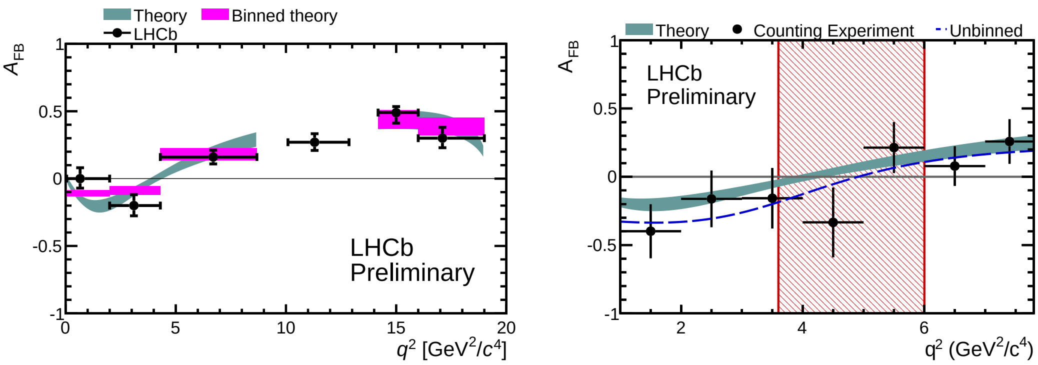

Figure 2: Measurement of the forward-backward asymmetry in $B^0 \to K^{*0}\mu^+\mu^-$ decays [6]. (left) $A_{\rm FB}$ over the full q^2 range compared to theory prediction (empty regions are vetoed due to the presence of charmonium resonances); (right) zoom around the zero-crossing point.

of some extended models.

Another rare decay that provides a sensitive laboratory to search for effects of new particles is $B^0 \to K^{*0}\mu^+\mu^-$. One of the key observables is the forward-backward asymmetry $A_{\rm FB}$, which arises due to interference between diagrams where the dimuon system is produced by virtual γ and Z^0 bosons. In particular, as the relative contributions from these diagrams vary with the dimuon invariant mass-squared (q^2), $A_{\rm FB}$ also varies and changes from negative to positive as q^2 increases. The value at which this occurs is cleanly predicted to be around $4\,{\rm GeV}^2/c^4$, but results from previous experiments (BaBar, Belle and CDF) indicated positive values of $A_{\rm FB}$ across the whole q^2 range, albeit with large uncertainties.

LHCb has published its first analysis of this channel [5], and the results of an updated analysis using the $1.0\,{\rm fb}^{-1}$ data-set [6] are shown in Fig. 2. The zero crossing point is measured for the first time to be $q_0^2 = \left(4.9\,^{+1.1}_{-1.3}\right)\,{\rm GeV}^2/c^4$. Additional observables, such as the transverse polarisation asymmetry, can also be studied with this large data-set. The new analysis provides the first significant constraints on these observables. While the measurements to date are consistent with the Standard Model, the results demonstrate the potential of LHCb to make unprecedented studies of these decays as more data is accumulated.

Among other results on rare decays that have attracted attention from the community are the world's best limits on the $D^0 \to \mu^+\mu^-$ decay ($\mathcal{B}(D^0 \to \mu^+\mu^-) < 1.3\times10^{-8}$ at 95 % confidence level—an improvement on the previous limit by an order of magnitude) [7], studies of the radiative decays $B_s^0 \to \phi\gamma$ and $B^0 \to K^{*0}\gamma$ [8,9], and the first observation of the decay $B^+ \to \pi^+\mu^+\mu^-$ [10]. The results are shown in Fig. 3. The latter has a branching fraction measurement of $\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-) = (2.4 \pm 0.6 \pm 0.2) \times 10^{-8}$ (the previous upper limit was 6.9×10^{-8} at 90 % confidence level), with signal significance of more than five standard deviations, and hence is the rarest B decay yet observed.

LHCb has not only observed new decays of known particles, but has also discovered new particles. First observations of excited B mesons have been reported [11], and an

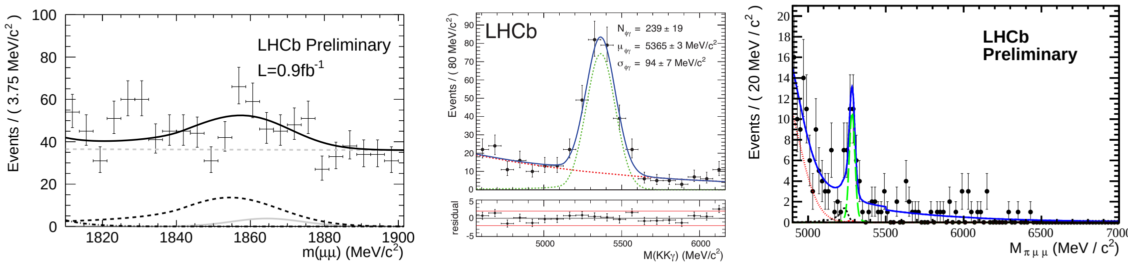

Figure 3: Results on (left) $D^0 \to \mu^+\mu^-$ [7] (note that the peak shown as the dashed curve is due to background from $D^0 \to \pi^+\pi^-$), (middle) $B_s^0 \to \phi\gamma$ [8], (right) $B^+ \to \pi^+\mu^+\mu^-$ [10].

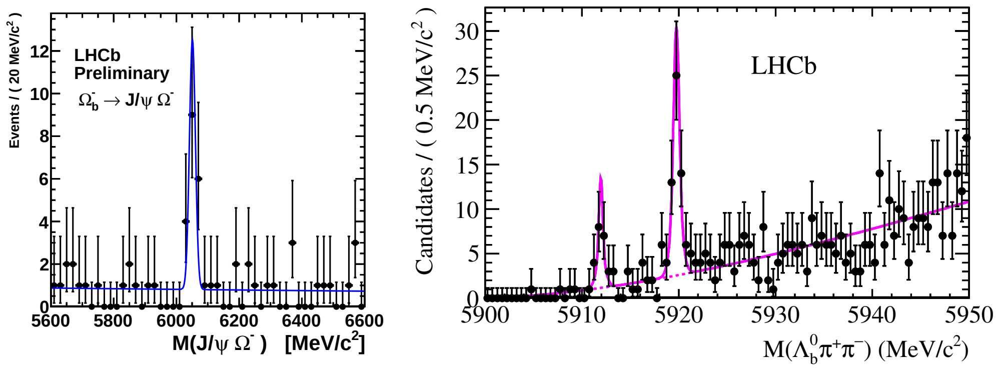

Figure 4: (Left) Signal for the Ω_b^- reconstructed in the $J/\psi\,\Omega^-$ decay channel [12]. Its mass is measured to be $M(\Omega_b^-) = 6050.3 \pm 4.5 \pm 2.2\,\mathrm{MeV}/c^2$. (Right) Observations of Λ_b^{*0} states in the $\Lambda_b^0\pi^+\pi^-$ spectrum [13].

analysis of the Ω_b^- baryon [12] resolved a long-standing discrepancy between previous measurements of its mass. The latest discovery is of two new b-baryons, observed in the $\Lambda_b^0\pi^+\pi^-$ spectrum, as shown in Fig. 4 (right) [13]. These are interpreted as the spin 1/2 and 3/2 Λ_b^{*0} states.

LHCb is designed to study violation of the *CP* symmetry that relates matter and antimatter in quantum field theories. Of particular interest is the measurement of the *CP*-violating phase (labelled ϕ_s) in the $B_s^0 \to J/\psi\,\phi$ process—the B_s^0 system counterpart of the measurement of $\sin(2\beta)$ from $B^0 \to J/\psi\,K_S^0$ decays, which was the golden channel for the BaBar and Belle experiments. Following the publication of the results based on $0.3\,\mathrm{fb}^{-1}$ [14, 15], several significant further developments have been made.

- The previous results suffered from an ambiguity in the results for ϕ_s, which is unavoidable in the case that $B_s^0 \to J/\psi\,\phi$ decays alone are used. Exploiting the quantum-mechanical interference with K^+K^- pairs in S-wave in the invariant mass region near the ϕ peak, it is however possible to resolve the ambiguity. This analysis has been performed for the first time by LHCb [16]—the solution that is consistent with the Standard Model is found to be the correct one. An interesting outcome of

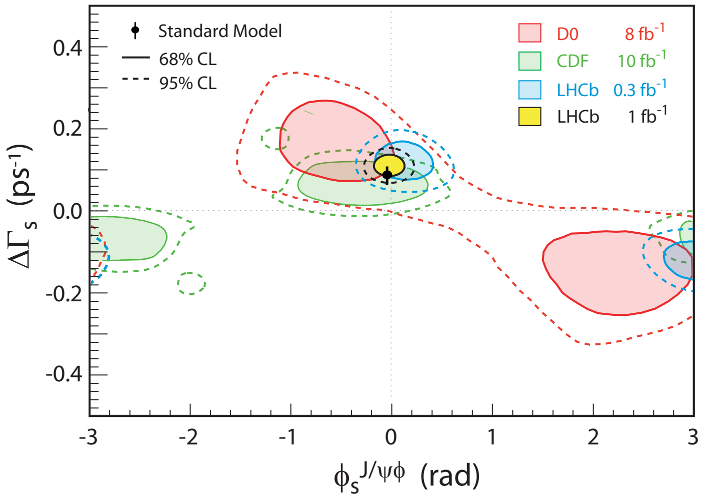

Figure 5: Latest constraints from LHCb in the ϕ_s–$\Delta\Gamma_s$ plane.

the analysis is that it is now known that the heavier of the two B_s^0 mass eigenstates has a longer lifetime than its lighter partner.

- A previous analysis [15] used the $B_s^0 \to J/\psi\, f_0(980)$ ($f_0(980) \to \pi^+\pi^-$) decay to complement the $J/\psi\,\phi$ final state. Now, for the first time, an angular analysis of the entire phase space of the $B_s^0 \to J/\psi\,\pi^+\pi^-$ decay has been performed [17]. The results of this analysis show that the *CP*-odd fraction of the final state is > 0.977 at 95 % confidence level, and therefore a large range of $\pi^+\pi^-$ invariant mass can be included in the measurement of ϕ_s. Exploiting this information, the *CP*-asymmetry analysis of $B_s^0 \to J/\psi\,\pi^+\pi^-$ has been performed with the 1.0 fb^{-1} data-set [18].

- The *CP*-asymmetry analysis of $B_s^0 \to J/\psi\,\phi$ decays has also been updated to use the full 1.0 fb^{-1} data-set [19].

Combining all the latest results, we obtain $\phi_s = -0.002 \pm 0.083 \pm 0.027$ rad, as shown in Fig. 5. The constraint is significantly improved compared to previous experiments, and the strong dependence on the value of the width difference between the B_s^0 mass eigenstates ($\Delta\Gamma_s$) is no longer visible. The result is consistent with the Standard Model prediction of small *CP* violation effects. Further improvements in precision, that will come as more data are analysed, will allow detailed comparison with the expected amount of *CP* violation.

The $B_s^0 \to K^+K^-$ channel allows the predictions of the Standard Model to be tested in several ways. As the final state is *CP*-even, measurement of the effective lifetime [20, 21] provides input on the width difference in the B_s^0 system. Moreover, a time-dependent asymmetry analysis allows to probe *CP* violation in B_s^0 oscillations and in the decay amplitudes. Combination of the results with those from $B^0 \to \pi^+\pi^-$ decays allows a novel determination of the phase γ of the CKM matrix, under certain theoretical assumptions.

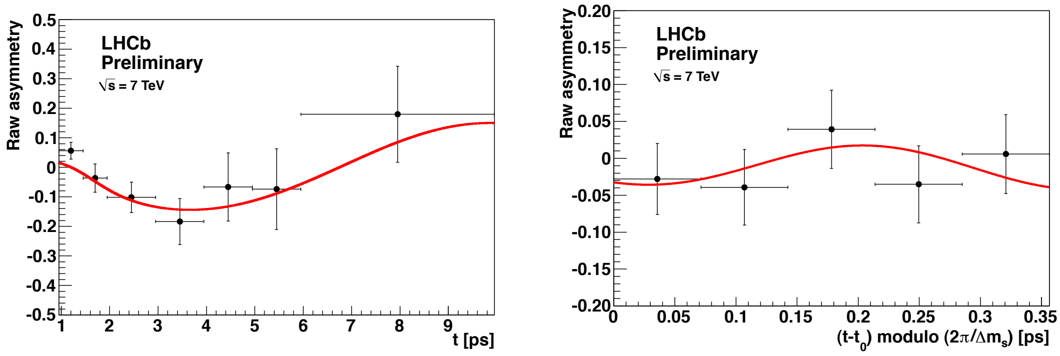

Figure 6: Raw asymmetries (differences between numbers of b and $\bar{b}$ tagged events divided by their sum) in bins of decay time for (left) $B^0 \to \pi^+\pi^-$ and (right) $B_s^0 \to K^+K^-$ [22].

Both K^+K^- and $\pi^+\pi^-$ final states have been studied at LHCb using $0.7\,\mathrm{fb}^{-1}$ of data [22], as shown in Fig. 6. The results in the $B^0 \to \pi^+\pi^-$ system are consistent with previous measurements, which provides confidence in the analysis. The results on *CP* violation in $B_s^0 \to K^+K^-$ are the first ever.

Another approach to measuring the *CP*-violating phase γ uses $B \to DK$ decays. These involve only tree-level diagrams, and therefore the measured value of γ provides a Standard Model benchmark and is unchanged in most extended models. New results from LHCb, using $1.0\,\mathrm{fb}^{-1}$ of data, provide the most precise measurements to date of the relevant observables when the neutral D meson in the decay is reconstructed in two-body final states [23]. This demonstrates that LHCb is well on the way towards making a precise measurement of γ, which is one of the fundamental free parameters of the Standard Model.

One of the most surprising results from the LHC to date concerns *CP* violation in the charm system. In the Standard Model, only very small differences between charmed and anti-charmed systems are expected, since effects of the third family of quarks via loop processes are suppressed. Strategies to search for very small effects are therefore necessary. To reduce potential systematic biases, LHCb has developed an approach in which the difference of *CP* asymmetries in neutral D decays to K^+K^- and $\pi^+\pi^-$ is measured: $\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$. After correcting for the slightly different kinematic acceptances of the two decays, production and detection asymmetries vanish in this observable. Using $0.6\,\mathrm{fb}^{-1}$ of data, and tagging the flavour of the decaying D meson using the charge of the pion emitted in $D^{*\pm} \to D\pi^\pm$ decay, samples of 1.4 million K^+K^- and 0.4 million $\pi^+\pi^-$ events are obtained, as shown in Fig. 7. These are significantly larger samples than those accumulated by previous experiments. LHCb measures $\Delta A_{CP} = -(0.82 \pm 0.21 \pm 0.11)\,\%$, providing the first evidence of *CP* violation in the charm sector [24]. This result has prompted a great deal of theoretical activity to see if such an unexpected effect could be explained in the Standard Model, or if not, what kinds of extended model could be responsible. Improving these measurements, and determining other observables in the charm system, is a high priority to help to resolve the situation. LHCb is uniquely

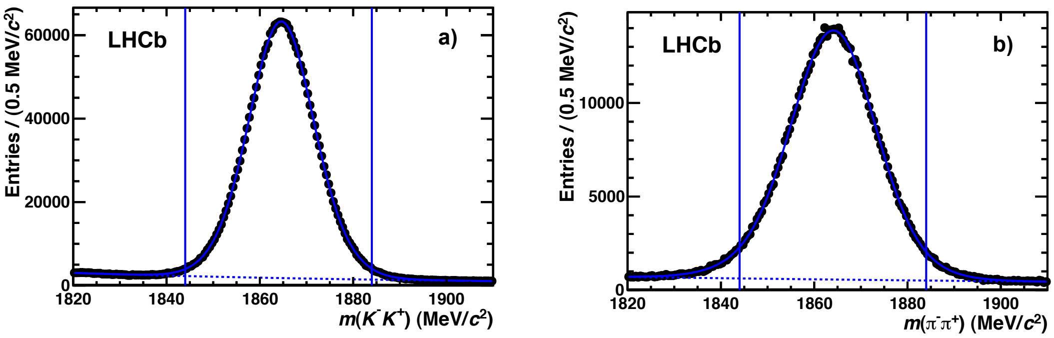

Figure 7: Samples of tagged D decays to (left) K^+K^- and (right) $\pi^+\pi^-$ used in the ΔA_{CP} measurement [24].

capable of providing the necessary experiment results: the large event samples needed to make the measurements shows the need for sophisticated trigger and analysis strategies, and optimal use of computing resources.

In the coming months LHCb will continue to produce new results and expand its physics programme. A continuous output of publications and preliminary results is anticipated through a series of spring conferences up to ICHEP 2012 in the summer. It is expected that the first results using 2012 data will be presented at ICHEP. These are likely to be mostly production measurements, where comparisons of the results with $\sqrt{s} = 8\,\text{TeV}$ data with previously published analyses at lower energies will be of great interest. Since the amount of data available for analysis prior to ICHEP will be fairly small compared to that collected in 2011, updates of the core physics channels such as $B_s^0 \to \mu^+\mu^-$, ϕ_s, etc. are likely to come somewhat later. With a target integrated luminosity of $1.5\,\text{fb}^{-1}$ over the year, accounting for the increased b production cross-section at $\sqrt{s} = 8\,\text{TeV}$, and with improved trigger efficiencies, the complete 2012 data set will allow further dramatic improvements across the LHCb physics programme.

5 LHCb upgrade

The collaboration has continued the activities in view of the preparation and submission of Technical Design Reports (TDRs) for the upgrade. In particular, several workshops on tracking issues and related simulation activities, on particle identification and on trigger and data processing have been organized, with a very high attendance and interest.

In agreement with the LHC Committee, the collaboration is preparing a "Framework TDR for the Upgrade of the LHCb Detector", to be submitted in June 2012, for a first assessment of schedule, global cost and institutes' interest for the LHCb upgrade. This document will describe the updates with respect to the Letter of Intent, including the physics potential of the experiment. There will be particular emphasis on the various technological options and on the set of milestones which will bring the collaboration through the decision process, in order to prepare the TDRs on various subsystems by the end of 2013.

For reasons of flexibility and to allow for possible evolution of the trigger, it has been decided to design those detectors that need replacement for the upgrade such that they can sustain a luminosity of $2 \times 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$. After detector prototypes have been validated and the TDRs have been approved, the years 2014 to 2016 will be used for the module production of the various sub-systems. The following 1–2 years are foreseen for quality control and acceptance tests, and the second long LHC shutdown, currently scheduled for 2018, for installation of the detector upgrade and its commissioning.

The Framework TDR will serve as a basis for a preliminary discussion on funding requests with various agencies.

6 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. We note an under-spending in the detector related line. Due to the fact that LHCb is running to optimize physics throughput and owing to the principle of keeping our budget as constant as possible over the years, this surplus should serve in covering the coming long shutdown years, while keeping the related line essentially constant, when important consolidation and maintenance on the detector general infrastructure is foreseen.

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

7 Collaboration matters

In the LHCb Collaboration Board of March, two new groups have been accepted as associate members, listed below. Syracuse University will act as host institute for both.

The University of Cincinnati, led by Prof. Mike Sokoloff, has shown interest in the charm sector as well as in the development of HLT trigger. Service work was agreed upon between LHCb and the Cincinnati group in the software sector, including upgrade activities. The group has submitted a funding grant request to NSF in October 2011 so as to participate in future as a full member of the LHCb Collaboration.

The University of Lahore, led by Prof. Shabana Nisar, has shown interest in studies of CP violation in b decays, and for data-quality monitoring as service task.

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