11 Particle Physics with LHCb

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The full LHCb collaboration consists of 63 institutes from Brazil, China, France, Germany, Ireland, Italy, Pakistan, Poland, Romania, Russia, Spain, Switzerland, The Netherlands, Turkey, Ukraine, the United Kingdom and the United States of America.

(LHCb - Collaboration)

The main goal of the LHCb experiment [1] at CERN's Large Hadron Collider (LHC) is the search for possible contributions from "New Physics" (NP) beyond the Standard Model (SM) by performing precision measurements of *CP* violating observables and rare decays of hadrons containing a b quark or a c quark. Of special interest are processes that involve loop diagrams with internal quark lines, such as box or penguin diagrams. Heavy new particles, which are predicted by most NP models, can appear in the internal lines of these loop diagrams and modify the observables with respect to SM predictions. Precision measurements of these observables therefore can reveal the presence of NP. The Zurich group has made important contributions to several key analyses of rare B decays.

The unique acceptance coverage of the detector and the ability to trigger on particles with moderately high transverse momentum, p_{T}, gives LHCb very interesting possibilities in particle production studies. The Zurich group has a leading role in measurements of W, Z and low mass Drell-Yan production. These constitute a test of QCD at LHC energies and will provide valuable input to the knowledge of the parton density functions (PDF) of the proton in a previously unexplored kinematic region.

Several members of the Zurich group have taken up leadership roles in the collaboration: U. Straumann completed his term as chair of the LHCb Collaboration Board; O. Steinkamp served as chair of the Speakers' Bureau; K. Müller acts as co-convener of the "QCD, Electroweak & Exotica" physics working group, while J. Anderson and N. Serra are co-conveners of the sub-working groups "Electroweak bosons" and "Rare electroweak penguin decays", respectively.

11.1 The LHCb experiment

The LHCb detector[1] is a single-arm forward spectrometer with pseudo-rapidity coverage in the range 2 to 5. The detector has excellent vertex and momentum resolution to separate primary and secondary vertices and provides good invariant mass resolution. It is able to trigger on particles with p_{T} down to a few GeV. Two Ring Imaging Cherenkov detectors (RICH) allow discrimination between pions and kaons over a wide momentum range. The detector and its performance have been described in previous annual reports [2].

The experiment has performed outstandingly well during the first three years of LHC operation. Many competitive and world-best measurements have been obtained from the analysis of the 2011 data set, corresponding to an integrated luminosity of 1.0 fb^{-1} of pp collisions collected at a centre of mass energy of 7 TeV. An additional 2 fb^{-1} of good quality data at a centre of mass energy of 8 TeV have been collected in 2012 and are being analysed. The total integrated luminosity in the forthcoming period (2015-2017), following the first long shutdown (LS1) of the LHC, is expected to be about 5 fb^{-1}. A comprehensive upgrade of the LHCb apparatus is then foreseen for the second long shutdown (LS2) of the LHC accelerator in 2018/2019. The main goals of the LHCb upgrade are to operate the experiment at higher instantaneous luminosities and to improve further the trigger efficiency for heavy quark decays to purely hadronic final states.

[1] A. A. Alves Jr. *et al.* [LHCb collaboration], JINST 3 S08005 (2008).

[2] Physik-Institut, University of Zürich, Annual Reports 1996/7 ff.; available at *http://www.physik.unizh.ch/reports.html*.

11.1.1 LHCb detector performance and operation

The LHCb experiment continued to demonstrate excellent running performance in 2012. Data taking efficiency exceeded 95%. The centre-of-mass energy of 8 TeV in 2012, lead to a 15 % higher $b\bar{b}$ production cross section compared to 2011. The output rate of the LHCb high-level trigger (HLT) could be increased from 3.5 kHz in 2011 to

5 kHz in 2012 by an upgrade of the HLT farm (which was partially funded by a special contribution from the SNF) and the introduction of a deferred trigger scheme. About 10 % of the events were temporarily stored on local disks and then processed during the gaps in between two proton fills in the LHC. The increased HLT output rate permitted to further reduce p_T thresholds, benefiting in particular charm and production particle studies.

LHCb also participated in the LHC proton–ion runs at the end of the data taking period in February 2013. About 2 nb^{-1} of proton-lead collisions were recorded with very loose trigger settings. The study of these data will help to gain better understanding of nucleus-nucleon collisions.

The LHC accelerator is now undergoing a two-year shutdown for maintenance and consolidation work, which will allow to operate at a centre-of-mass energy of $\sqrt{s} = 13$ TeV from 2015 onwards.

11.1.2 The Tracker Turicensis

N. Chiapolini, Ch. Elsasser, C. Salzmann, S. Saornil, M. Tobin

The Zurich group continued to be responsible for the operation and maintenance of the Tracker Turicensis (TT), a large planar silicon-strip tracking detector located in front of the LHCb dipole magnet. The TT had been designed and constructed in Zurich. A description of this detector can be found in previous annual reports [1]. At the end of the 2012 data taking period, 99.7 % of the 143 360 readout channels of the TT were fully operational. This is still the highest reliability figure of any silicon tracking detector at the LHC.

Ageing effects in the detector were studied using two complementary methods. One method makes use of the well understood relation between the detector leakage current and the fluence the detector is exposed to. The second method uses charge collection efficiency (CCE) scans which are used to estimate the full depletion voltage V_{fd} of the sensors. The full depletion voltage V_{fd} is related to the received fluence through the so-called Hamburg model [2]. Such CCE scans have been regularly performed every few months. As shown in Fig. 11.1, the results of the analysis are in good agreement with expectations from the Hamburg model.

[1] Physik-Institut, University of Zürich, Annual Reports 1996/7 ff.; available at *http://www.physik.unizh.ch/reports.html.*

[2] M. Moll, *Radiation Damage in Silicon Particle Detectors*, DESY-THESIS-1999-040.

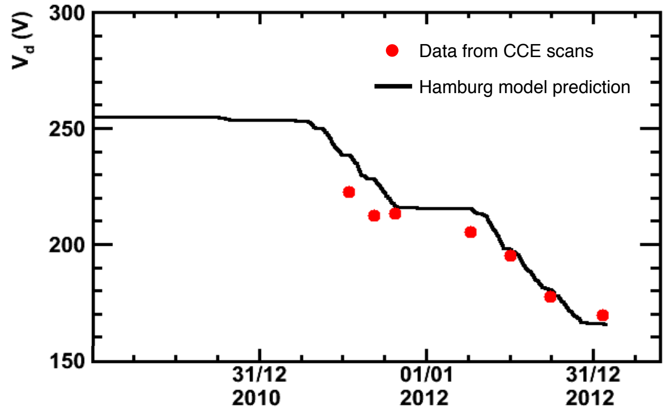

FIG. 11.1 – The full depletion voltage V_{fd} in the inner most region of TT measured from Charge Collection Efficiency scans compared with the evolution expected from the Hamburg model [2].

11.2 The LHCb upgrade

Assuming that LHCb will collect about 5 fb^{-1} during the LHC run following LS1, and taking into account the factor of two higher heavy quark production cross sections at 13 TeV, the size of the collected event samples will have increased by more than a factor of ten by the time of LS2 compared to the 2011 data set used for the currently published results.

The LHCb collaboration is then preparing a comprehensive upgrade of the detector and its readout for LS2. The physics case and details of the upgrade plans are described in the Letter of Intend [1] and the Framework Technical Design Report [2] for the upgrade. The Framework TDR was submitted to the LHCC in May 2012 and endorsed by the committee in September. In its November 2012 session, the CERN Research Board approved the upgrade of LHCb to be part of the long-term exploitation of the LHC. Sub-system Technical Design Reports are scheduled for the end of 2013.

The upgrade plan contains two main components: to prepare the detector for operation at a five times increased instantaneous luminosity compared to 2011 and to read out the full detector at the LHC bunch crossing rate of 40 MHz. By overcoming the limitations of the current hardware based trigger level, the 40 MHz readout will gain a factor of two in trigger efficiencies for b hadron decays to fully hadronic final states. Together with the increased heavy quark production cross section, the expected gains in event yields per year, compared to 2011, are a factor 10 in channels involving muons in the final state and a factor 20 in channels to fully hadronic final states. In total, the upgraded experiment is expected to collect an integrated luminosity of 50 fb^{-1} over 10 years of operation. The upgrade will significantly increase the physics reach in very rare decays, provide unique opportunities for NP searches in B_s^0 decays and be competitive in B^0 decays, and will deliver unprecedented charm yields.

[1] R. Aaij *et al.* [LHCb collaboration], *Letter of Intent for the LHCb Upgrade* CERN-LHCC-2011-001, LHCC-I-018.

[2] I. Bediaga *et al.* [LHCb collaboration], *Framework TDR for the LHCb Upgrade: Technical Design Report*, CERN-LHCC-2012-007, LHCb-TDR-12.

11.2.1 Upgrade studies

E. Bowen, O. Steinkamp and B. Storaci

The present TT detector will need to be replaced as part of the LHCb upgrade foreseen for LS2 since its front-end electronics is not compatible with the foreseen 40 MHz readout. The main purpose of the upgraded TT (UT) will be to improve the speed of the track reconstruction at trigger level by providing an early momentum estimate for track candidates. The Zurich group is responsible for the optimisation of the relevant reconstruction algorithms. These studies will also provide important input for the optimisation of the layout of the UT.

No significant changes to the LHCb detector are foreseen for LS1. The HLT strategy will, however, be revised and optimised to prepare for the higher particle densities and detector occupancies expected at 13 TeV collision energy. As part of the upgrade studies performed by the Zurich group, we also investigate the possibility of reducing the processing time of the HLT by using information from the existing TT to provide an early momentum estimate for track candidates. The momentum estimate could be used to reject track candidates that are expected to miss the tracking stations after the magnet and to optimise search windows in these tracking stations for the remaining candidates.

11.3 Physics Results

The LHCb collaboration has submitted more than 100 papers for publication and almost 80 preliminary results to conferences. Some highlights are the first evidence for the very rare decay $B_s^0 \to \mu^+\mu^-$ [1] and the first measurement of the zero crossing point of the forward-backward asymmetry in the rare decay $B^0 \to K^{0\star}\mu^+\mu^-$ [2], two measurements in which the Zurich group made significant contributions as described below; the world's most precise measurement of the *CP* violating phase ϕ_s in the decays $B_s^0 \to J/\psi K^+K^-$ and $B_s^0 \to J/\psi\pi^+\pi^-$ and the first observation of a non-zero lifetime difference $\Delta\Gamma_s$ between the two mass eigenstates in the $B_s^0\overline{B}_s^0$ system; the determination of the sign of this lifetime difference; the first observation of the doubly Cabibbo suppressed decay $B^- \to DK^-$ with $D \to K^+\pi^-$ and a competitive measurement of the CKM angle γ from a combination of $B^\pm \to DK^\pm$ decay modes; and the observation of $D^0 - \overline{D}^0$ oscillations with a statistical significance of 10 σ. In addition, a wealth of results has been obtained in the field of heavy quark production and spectroscopy, including a first determination of the quantum numbers of the $X(3872)$ state. The full list of papers and conference contributions can be found at the LHCb web site [3], implications of the first measurements on classes of extensions to the SM are discussed in [4].

[1] R. Aaij *et al.* [LHCb collaboration], Phys. Rev. Lett. 110,‘ 021801 (2013).

[2] R. Aaij *et al.* [LHCb collaboration], *Differential branching ratio and angular analysis of the decay* $B^0 \to K^*\mu^+\mu^-$, arXiv:1304.6325 [hep-ex].

[3] `http://lhcbproject.web.cern.ch lhcbproject/CDS/cgi-bin/index.php`

[4] R. Aaij *et al.* [LHCb Collaboration], *Implications of LHCb measurements and future prospects*, arXiv:1208.3355 [hep-ex].

11.3.1 The decays $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$

Ch. Elsasser, N. Serra and O. Steinkamp

The decays $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ are predicted to be very rare in the Standard Model of particle physics. Possible contributions from NP could be of the same order of magnitude as the contributions from the SM. The determination of the branching fractions of these decays strongly constrains the allowed parameter space for various NP models and is one of the key measurements for LHCb.

A combined analysis of 1.0 fb^{-1} collected in 2011 at a centre-of-mass energy of $\sqrt{s} = 7$ TeV and 1.1 fb^{-1} collected in 2012 at $\sqrt{s} = 8$ TeV, has yielded the first evidence for the decay $B_s^0 \to \mu^+\mu^-$. The observed excess of $B_s^0 \to \mu^+\mu^-$ candidates with respect to the background expectation (see Fig. 11.2) has a statistical significance of 3.5 standard deviations, and corresponds to a probability of $5.3 \cdot 10^{-4}$ for a background fluctuation [1]. The measured branching fraction is

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.2^{+1.4}_{-1.2}(\text{stat})^{+0.5}_{-0.3}(\text{syst})) \times 10^{-9},$$

in very good agreement with the the SM prediction of $(3.23 \pm 0.27) \times 10^{-9}$ [2].

The sensitivity for B^0 decays is four times larger than for B_s^0 due to the different hadronization fractions ($f_s/f_d = 0.256 \pm 0.020$). For $B^0 \to \mu^+\mu^-$, the observed number of candidates is consistent with the background expectation, and yields the world's best

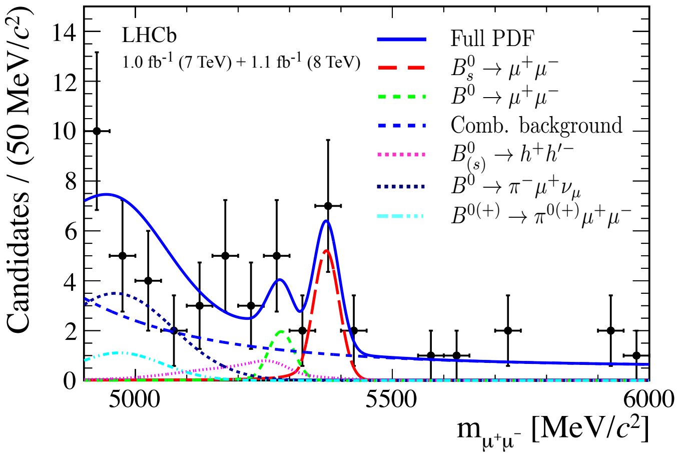

FIG. 11.2 – Invariant mass distribution of $B^0 \to \mu^+\mu^-$ and $B_s^0 \to \mu^+\mu^-$ event candidates. The result of a fit including the various sources of background is shown as well. Most background involves at least one hadron mis-identified as a muon. The $B^0 \to \mu^+\mu^-$ branching fraction obtained from the fit is statistically insignificant.

upper limit on the branching fraction of

$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 9.4 \times 10^{-10}$$

at 95 % confidence level [1]. The predicted SM branching fraction is $(1.07 \pm 0.10) \times 10^{-10}$ [2].

The Zurich group has made significant contributions to this measurement. The main responsibilities of our group are the calibration of the invariant di-muon mass and the multivariate classifier used to distinguish signal from background. The distributions of both variables were determined from the measured exclusive $B^0_{(s)} \to h^+h^-$ decays, where $h^\pm$ is a kaon or a pion. Information from the RICH detectors is used to separate kaons and pions. The particle identification efficiencies were evaluated using the control channels $B^\pm \to J/\psi(1S)K^\pm$ and $B_s^0 \to J/\psi(1S)\phi$. An alternative method to estimate the invariant mass resolution for $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ is the interpolation between the observed resolutions for the di-muon resonances J/ψ, $\psi(2S)$, $\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(3S)$. The result from this method is in perfect agreement with that from the analysis using $B^0_{(s)} \to h^+h^-$.

[1] R. Aaij *et al.* [LHCb collaboration], Phys. Rev. Lett. 110,' 021801 (2013).

[2] A. J. Buras, J. Girrbach, D. Guadagnoli, and G. Isidori, Eur. Phys. J. C72 (2012) 2172.

11.3.2 Other very rare B-decays

Ch. Elsasser, N. Serra and O. Steinkamp

The LHCb experiment also offers unprecedented sensitivity to other very rare B-decays such as $B^0_{(s)} \to \tau^+\tau^-$ and to Lepton Flavour Violating (LFV) decays such as $B^0_{(s)} \to e^\pm\mu^\mp$ and $B^0_{(s)} \to \mu^\pm\tau^\mp$. LFV decays are practically forbidden in the SM but can be accommodated in several NP scenarios. In the Pati-Salam model [1], for example, lepto-quark exchange mediates these decays already at tree level.

Our group makes important contributions to studies of the reconstruction and selection of τ leptons in LHCb. As a first step, more frequent decays involving τ leptons, such as $B_c^\pm \to J/\psi(1S)\tau^\pm\nu_\tau$ and $Z \to \tau^+\tau^-$ are investigated. We collaborate with other analysis groups that study semi-leptonic B decays involving τ leptons.

[1] J. Pati and A. Salam, Phys. Rev. **D10** (1974), 275.

11.3.3 $B^0 \to K^\star\mu^+\mu^-$

M. De Cian, N. Serra and M. Tresch

The rare decay $B^0 \to K^{0\star}\mu^+\mu^-$ is a flavour-changing neutral current process that proceeds via box and loop diagrams. This decay has been widely studied in literature from the theoretical point of view, since its angular distributions and differential branching fraction are sensitive to a large number of NP scenarios (see Ref. [1] and references therein). Particularly interesting is the forward-backward asymmetry $A_{\rm FB}$, described by the opening angle between the μ^- and the B^0 in the $\mu^+\mu^-$ rest frame. The A_{FB} as a function of the di-muon invariant mass squared, q^2, changes sign at a well defined value in the SM and is sensitive to NP contributions. The so-called *transverse asymmetry* A_T^2, built using the angle between the $K^{0\star}$ and the di-muon decay planes in the B^0 rest frame, is sensitive to extensions of the SM with right-handed currents. A measurement of A_{FB} and $A_T^{(2)}$ was performed based on the dataset of 1.0 fb^{-1} collected in 2011 [2]. The results are shown in Fig. 11.3. In addition to these observables, world's best determinations have been performed for longitudinal polarisation, F_L, of the $K^{0\star}$, the differential branching ratio and the CP asymmetry A_9. All results show good agreement with SM predictions.

Our group played a key role in designing a strategy for this analysis. One of the challenges was to account for detector acceptance effects in a model independent way. This was achieved using a Monte Carlo (MC) based procedure after the simulation was properly tuned using a set of control channels. Our group contributed to the tuning of the MC and the

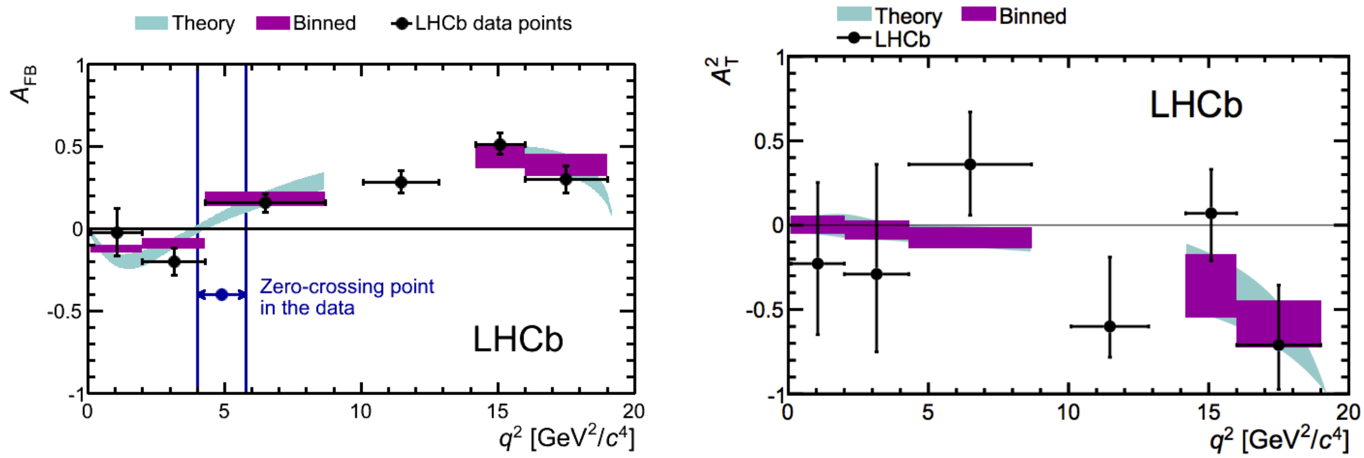

FIG. 11.3 – Left: A_{FB} as a function of the di-muon invariant mass squared q^2. The 68% CL region for the zero-crossing point is indicated. Right: The observable $A_T^{(2)}$ as a function of q^2. The turquoise band is the SM prediction. The violet bands indicate the rate weighted SM predictions in the same bins as chosen for the measurement [3].

extraction of the acceptance corrections. The procedure was validated using the decay $B^0 \rightarrow J/\psi K^{0*}$, with $J/\psi \rightarrow \mu^+\mu^-$. This decay has the same final state as $B^0 \rightarrow K^{0\star}\mu^+\mu^-$ but is more abundant by a factor of 50. Our group has also contributed to the development of the maximum likelihood fit used to the extract the results for the angular observables and the differential branching ratio. Finally, we have been responsible for the first measurement of the zero-crossing point of $A_{\rm FB}$. The result was extracted using a novel "unbinned counting" technique which avoids biases introduced by assumptions on the shape of A_{FB} as a function of q^2. The result is in agreement with SM predictions but its statistical uncertainty is still large and significant contributions from NP cannot be excluded so far. Significant improvements are expected from the analysis of the 2012 data set which is currently ongoing.

Other angular observables of interest in $B^0 \rightarrow K^{0\star}\mu^+\mu^-$, which had not been measured so far, are known as P_4' and P_5' in literature. These are particularly sensitive to possible NP contributions since they result from the interference of different transversity amplitudes [4]. We proposed a new method that allowed early measurements of P_4' and P_5' using the 2011 dataset. This work has been documented in the Ph.D. thesis of M. De Cian [5] and is currently under review in the collaboration.

[1] J. Matias *et al.*, *Complete Anatomy of $\bar{B}_d \rightarrow \bar{K}^{*0}(\rightarrow K\pi)l^+l^-$ and its angular distribution*, JHEP 04 (2012) 104.

[2] R. Aaij *et al.* [LHCb collaboration], *Differential branching ratio and angular analysis of the decay $B^0 \rightarrow K^*\mu^+\mu^-$*, arXiv:1304.6325 [hep-ex].

[3] C. Bobeth *et al.*, *More Benefits of Semileptonic Rare B Decays at Low Recoil: CP Violation*, arXiv:1105.0376 [hep-ex].

[4] S. Descotes-Genon *et al.*, *Optimizing the basis of $B^0 \rightarrow K^*\mu^+\mu^-$ observables in the full kinematic range*, arXiv:1303.5794 [hep-ph].

[5] M. De Cian, *Track Reconstruction Efficiency and Analysis of $B^0 \rightarrow K^*\mu^+\mu^-$ at the LHCb Experiment*, Ph.D. thesis.

11.3.4 Electroweak boson and low mass Drell-Yan production

J. Anderson, A. Bursche, N. Chiapolini, and K. Müller

W and Z boson production cross sections and their ratios have been measured by LHCb in the $W \rightarrow \mu\nu$ and $Z \rightarrow \mu\mu$ decay channels [1] using 36 pb^{-1} of data collected in 2010. Z boson production has also been measured in final states with two electrons [2] or two taus [3] using the much larger dataset collected in 2011 with 1 fb^{-1}. These measurements provide valuable input to the knowledge of the parton density functions (PDF) of the proton

A preliminary measurement of Z boson production in the di-muon channel based on the 2011 dataset has just been released [4]. All the efficiencies are calculated from data using a tag and probe method. Our group played a leading role in this measurement which will be published this summer. Figure 11.4 shows the differential Z cross section as a function of $p_{\rm T}$ of the Z boson. The next-to-next-to-leading order (NNLO) prediction from FEWZ [5] fails to describe the shape of the distribution. Resbos [6], which interfaces a NLO calculation to PYTHIA [7], and Powheg [8], which resums the leading contribution to next-to-next-to-leading logarithms and matches the result to a NLO QCD calculation, describe the data reasonably well.

A method was developed in our group to compare the LHCb results to the published results of ATLAS and CMS [9]. As the fiducial volumes of the measurements are slightly different, extrapolation factors are needed. These factors are calculated at NLO. Figure 11.5 shows the differential W boson cross section as a function of the pseudorapidity of the muon together with the results from ATLAS [10]. The plot illustrates the complementarity of the two experiments.

The analysis of Z boson production is being extended to events containing jets in the final state (A. Bursche in close collaboration with the Cambridge group). Measurements of Z boson production together with a jet are sensitive to the gluon content in the proton. The dominant uncertainty originates in the jet energy scale. The relative cross section as a function of the rapidity y of the Z boson is shown in Fig. 11.6. These results have been presented at a conference [11] and a publication is being prepared.

In order to further exploit the unique phase space region of LHCb a measurement is performed of Z bosons with associated production of charmed mesons and baryons using the final states $D^0 \to K^-\pi^+$, $D^+ \to K^-\pi^+\pi^+$, $D^+ \to K^-K^+\pi^+$ and $\Lambda_c^+ \to p^+K^-\pi^+$. These processes may give insight into the correlations of the partons in double parton scattering events. This measurement is performed by A. Bursche and a master student (E. Crivelli).

The analysis of low mass Drell-Yan production in the di-muon channel is performed by the Zurich group (J. Anderson, N. Chiapolini, K. Müller). This measurement is sensitive to Bjorken-x values as low as 8×10^{-6} where x is the momentum fraction carried by the struck quark. A preliminary result has come out in spring 2012 [12]. The analysis has been updated since to include the full 2011 dataset. A precise measurement at low masses is challenging as the backgrounds are very high; the ≈30% uncertainty on the purity at low masses was the dominant systematic uncertainty in [12]. A new variable for the fit of the purity, based on the total p_T in the cone around the muon, was studied. It does not depend on the mass and can therefore be extracted from the Z sample which is almost background free. Also the background templates are extracted from data. A toy study confirmed the reliability of the new method down to di-muon masses of 10 GeV/c^2. It is planned to publish the 2011 results within the next months. An analysis of the 2012 dataset will allow to extend the kinematic reach to even lower x due to the higher centre of mass energy.

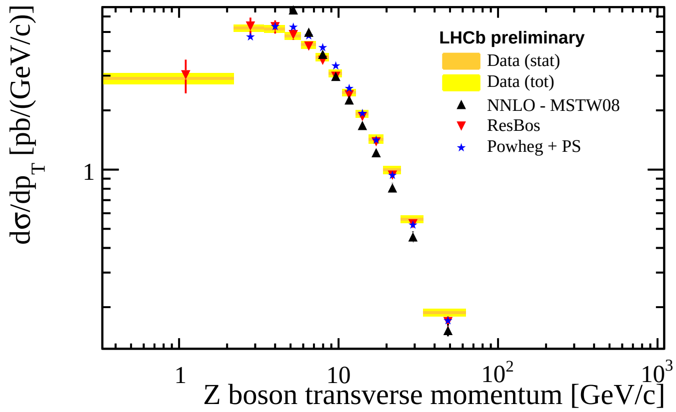

FIG. 11.4 – Differential Z production cross-section as a function of p_T of the Z boson as observed in the $Z \to \mu\mu$ channel. Statistical and total uncertainties are indicated. Superimposed are the predictions from FEWZ [5] (NNLO), Resbos [6] and Powheg [8].

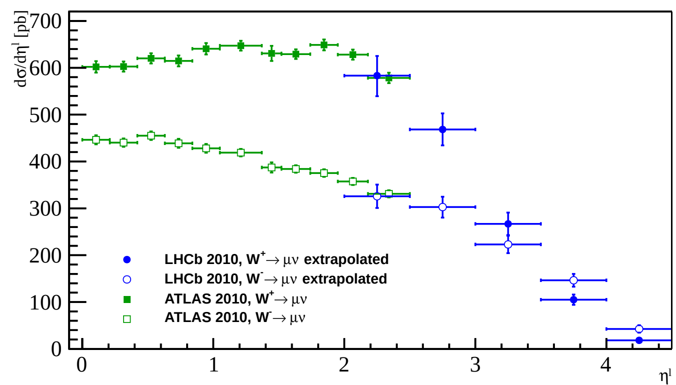

FIG. 11.5 – Differential cross-section for W boson production observed in the $W \to \mu\nu$ channel as a function of the pseudorapidity of the muon. LHCb results, corrected for the different definition of the fiducial volumes, are shown together with results from ATLAS.

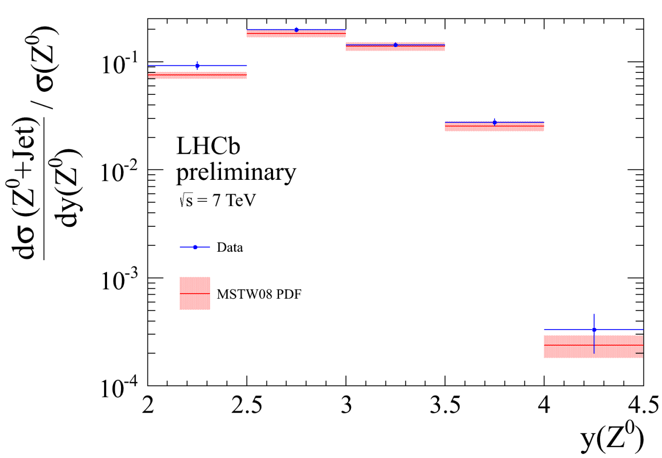

FIG. 11.6 – Rapidity distribution of Z production with associated jets normalised to the inclusive Z production cross section.

[1] R. Aaij *et al.* [LHCb Collaboration], JHEP **1206** (2012) 058.

[2] R. Aaij *et al.* [LHCb Collaboration], JHEP **1302** (2013) 106.

[3] R. Aaij *et al.* [LHCb Collaboration], JHEP **1301** (2013) 111.

[4] LHCb collaboration, *Measurement of the cross-section for $Z \to \mu\mu$ production with 1 fb^{-1} of pp collisions at $\sqrt{s}$=7 TeV*, LHCb-CONF-2013-005.

[5] Y. Li and F. Petriello, Phys. Rev. D **86** (2012) 094034.

[6] G. A. Ladinsky and C. P. Yuan, Phys. Rev. D **50** (1994) 4239.

[7] T. Sjostrand, S. Mrenna and P. Z. Skands, JHEP **0605** (2006) 026.

[8] P. Nason, JHEP **0411** (2004) 040.

[9] LHCb collaboration, *Graphical comparison of the LHCb measurements of W and Z boson production with ATLAS and CMS*, LHCb-CONF-2013-007.

[10] ATLAS collaboration, Phys. Rev. D **85** (2012) 072004.

[11] LHCb collaboration, *Measurement of jet production in $Z/\gamma^* \to \mu\mu$ events at LHCb in $\sqrt{s} = 7$ TeV pp collisions*, LHCb-CONF-2012-016.

[12] LHCb collaboration, *Inclusive Drell-Yan production in the forward region at $\sqrt{s} = 7$ TeV*, LHCb-CONF-2012-013.

11.4 Summary and Outlook

The LHCb experiment has performed very well throughout the 2012 LHC run. More than 2 fb^{-1} of data have been recorded, with a data taking efficiency exceeding 95%. The results obtained from data collected so far have allowed the LHCb experiment to take a leading role in the field of b and c-physics; to considerably reduce the parameter space for many models beyond the SM and to show world best and world first measurements of B-hadron branching ratios.