PROCEEDINGS OF SCIENCE

Studies of charmed hadronic B decays with early LHCb data and prospects for γ measurements

Susan Haines[*†]
University of Cambridge
E-mail: haines@hep.phy.cam.ac.uk

We present the first studies of decays of the type $B \to DX$, where D represents a charmed meson (D^0, $D^{(*)+}$ or D_s) from the LHCb experiment at CERN. Our studies use data accumulated during the first months of the 2010 run of the LHC. This work represents the first steps on a programme towards a precision measurement of the angle γ of the CKM Unitarity Triangle. The prospects for this γ measurement are reviewed.

35th International Conference of High Energy Physics
July 22-28, 2010
Paris, France

*Speaker.
†On behalf of the LHCb Collaboration.

PoS(ICHEP 2010)239

1. Introduction

The CKM angle $\gamma = arg(-(V_{ud}V^*_{ub})/(V_{cd}V^*_{cb}))$ is the least well-constrained of the angles in the Unitarity Triangle. The current tightest experimental constraints on γ come from loop processes; however, these processes are expected to be sensitive to new, non-Standard Model (SM), physics contributions. γ can also be measured directly in tree-level Feynman diagram processes such as charmed hadronic B decays ($B \to DX$), which have no penguin loop corrections, thus allowing benchmarking of the SM. The value of γ from direct measurement presented at this conference is 71^{+21}_{-25}[1]. The large uncertainty on this value can be reduced by performing at LHCb the analyses summarised below[2]. The event yields and sensitivities quoted are based on studies of a realistic Monte Carlo (MC) simulation of the LHCb experiment, reconstructed with software very similar to that which is used for real data.

2. Time integrated measurements

Time integrated measurements studied at LHCb include ADS/GLW analyses[3][4] and GGSZ (Dalitz) analysis[5], using $B^{\pm} \to DK^{\pm}$ and self-tagging $B^0 \to DK^{*0}(K\pi)$ decay modes. D indicates a D^0 or $\overline{D}^0$ meson. The amplitudes of $B \to DK^{(*)}$ decays are sensitive to γ at tree level due to interference effects when D^0 or $\overline{D}^0$ decays to the same final state. Corrections on γ coming from neutral D meson mixing are calculated to be very small[6] and can be neglected.

2.1 ADS/GLW studies

Two-body decays of the D from $B \to DK^{(*)}$ include decays to CP even final states such as KK or $\pi\pi$ (used in the GLW method), or to flavour-specific final states such as $K\pi$ (used in the ADS method). The GLW analysis involves measurement of two rates; the ADS analysis of four $B \to D(K\pi)K^{(*)}$ rates, two favoured (final state kaons same sign) and two suppressed (kaons opposite sign). At LHCb, a χ^2 fit will be performed on the six rates together in order to overconstrain the system and extract γ[7]. The two-body D decay analyses for the charged and neutral B cases are similar; the flavour of each neutral B can be determined from the charge of the K from the K^* decay[8]. Related decays involving four-body D decays to $KK\pi\pi$ and $K\pi\pi\pi$ with D from charged B have also been studied[9]. These analyses involve an extension of the two-body decay cases to take account of the multi-body D decay which can proceed through different resonant states.

2.2 GGSZ (Dalitz) studies

The three-body D decay mode $B^{\pm} \to D(K_s\pi\pi)K^{\pm}$ allows γ to be extracted from the amplitude differences between the Dalitz plots of $D \to K_s\pi\pi$ coming from B^- and from B^+. Two fitting methods have been investigated at LHCb[10]: an unbinned, model-dependent likelihood fit and a binned, model-independent fit. The unbinned fit requires a model of the $D \to K_s\pi\pi$ decay with its associated error ($3-9°$[11][12]), but makes full use of the available statistics. The binned fit has lower statistical precision and requires external input of the difference in strong phase between D^0 and $\overline{D}^0$ decays within each bin; this input measurement has been performed at CLEO-c and gives an error on γ of $\approx 2°$[13].

Table 1 shows approximate expected event yields for the time integrated decay channels with 1 fb^{-1} of integrated luminosity at $\sqrt{s} = 7$ TeV.

Decay channel	Expected event yield
$B^{\pm} \to D(KK)K^{\pm}$, $B^{\pm} \to D(\pi\pi)K^{\pm}$	2000, 750
$B^{\pm} \to D(K\pi)K^{\pm}$ suppressed, favoured	400, 20000
$B^{0} \to D(KK)K^{*0}$, $B^{0} \to D(\pi\pi)K^{*0}$	70, 25
$B^{0} \to D(K\pi)K^{*0}$ suppressed, favoured	70, 800
$B^{\pm} \to D(KK\pi\pi)K^{\pm}$	300
$B^{\pm} \to D(K\pi\pi\pi)K^{\pm}$ suppressed, favoured	100, 13000
$B^{\pm} \to D(K_s\pi\pi)K^{\pm}$	> 1600

Table 1: Approximate expected event yields for time integrated measurement channels, with 1 fb^{-1} of integrated luminosity at $\sqrt{s} = 7$ TeV. Charged decay channel yields are for the sum of B^+ and B^- decays; neutral decay channel yields are for the sum of B^0 and $\overline{B}^0$ decays.

3. Time dependent measurements

At LHCb, time dependent *CP* asymmetry measurements of $B_s^0 \to D_s^{\pm}K^{\mp}$ and $B^0 \to D^{\pm}\pi^{\mp}$ have been considered[14]. The tree-level sensitivity to γ in these decays arises from interference between $B^0/\overline{B}^0$ or $B_s^0/\overline{B}_s^0$ decays to the same final state either directly or after mixing[15]. The decay $B_s^0 \to D_s^{\pm}K^{\mp}$ allows for extraction of $\gamma - \phi_m$, where ϕ_m is the B_s^0 mixing phase (which will be well constrained from $B_s^0 \to J/\psi\phi$ decays). $B^0 \to D^{\pm}\pi^{\mp}$ allows $\gamma + 2\beta$ to be determined, however the result for γ in this case has ambiguities. In order to reduce or remove these ambiguities, measurements from related channels with different strong phases, such as $B^0 \to D^{*\pm}\pi^{\mp}$, can be used, or a joint U-spin analysis with $B_s^0 \to D_s^{\pm}K^{\mp}$ can be performed. Approximate expected event yields for the time dependent channels with 1 fb^{-1} of integrated luminosity at $\sqrt{s} = 7$ TeV are shown in Table 2.

Decay channel	Expected event yield
$B_s^0 \to D_s^{\pm}K^{\mp}$	3500
$B^0 \to D^{\pm}\pi^{\mp}$	300000

Table 2: Approximate expected event yields for time dependent measurement channels, with 1 fb^{-1} of integrated luminosity at $\sqrt{s} = 7$ TeV.

4. First experimental results

Charmed hadronic B decays are challenging to distinguish from background in the hadronic environment present at the LHC. Analyses must therefore make use of the excellent track impact parameter resolution, primary vertex resolution and particle identification (PID) available at LHCb[16]. In particular, the time integrated $B^{\pm} \to DK^{\pm}$ channels have large potential backgrounds from $B^{\pm} \to D\pi^{\pm}$ events, where the branching fraction of the latter process is an order of magnitude higher than that of the signal[17]. $(K - \pi)$ PID is vital to allow separation of the signal decays from these backgrounds. Signal event selection criteria also make use of the common topology of B meson decays, such as the long lifetime of the B and high transverse momenta and large impact parameters of the B decay products. The early proton-proton collision data at $\sqrt{s}=7$ TeV has been used to study and improve calibration and alignment of the LHCb detector systems and work is still ongoing.

With the first 14 nb^{-1} of data, B meson candidates have been observed for $B^0 \to D^{\pm}(K\pi\pi)\pi^{\mp}$ and $B^{\pm} \to D(K\pi)\pi^{\pm}$; the candidate mass distribution is shown in Figure 1. As expected, B candidates in other channels have not yet been observed, however the D decays which form the lower part of the B decay chains of interest have been observed in several cases[18]. The early data has been used to study detector and trigger effects and background contributions[19].

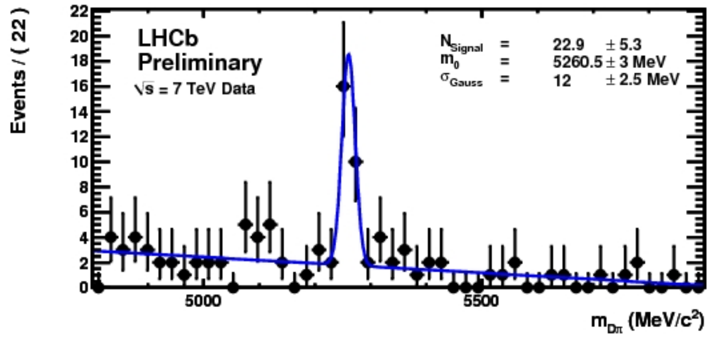

Figure 1: B mass distribution, $B^0 \to D^{\pm}(K\pi\pi)\pi^{\mp}$ and $B^{\pm} \to D(K\pi)\pi^{\pm}$ combined, for integrated luminosity 14 nb^{-1} at $\sqrt{s}=7$ TeV.

5. Combined sensitivity to γ

A combined sensitivity for γ has been estimated[20], including the binned model-independent $B^{\pm} \to D(K_s\pi\pi)K^{\pm}$ analysis, the charged and neutral B ADS/GLW analyses, the ADS-type $B^{\pm} \to D(K\pi\pi\pi)K^{\pm}$ analysis and the $B_s^0 \to D_s^{\pm}K^{\mp}$ and $B^0 \to D^{\pm}\pi^{\mp}$ analyses. The estimated combined uncertainty on γ was found to be $1.9-2.7^{\circ}$ for 10 fb^{-1} of integrated luminosity at $\sqrt{s}=14$ TeV. This includes uncertainties on external inputs such as the CLEO-c measurement for the $B^{\pm} \to D(K_s\pi\pi)K^{\pm}$ analysis, but not experimental systematic uncertainties, which will be estimated from control channels in data. Other channels such as $B^{\pm} \to D(K_sKK)K^{\pm}$, which have not been included here, can be exploited; these should further improve the LHCb sensitivity from large data sets. Scaling the estimate of [20] to 1 fb^{-1} of data at $\sqrt{s}=7$ TeV gives an expected sensitivity on γ of $6-8^{\circ}$.

6. Conclusion

The study of charmed hadronic B decays at LHCb will allow a direct measurement of the CKM angle γ to be made. The combined expected sensitivity from these channels with 1 fb^{-1} at $\sqrt{s}=7$ TeV is $6-8^{\circ}$. In the longer term, it is expected that 10 fb^{-1} of data collected at $\sqrt{s}=14$ TeV will give a sensitivity of $1.9-2.7^{\circ}$. This is an order of magnitude improvement on the current direct measurement. The first data at $\sqrt{s}=7$ TeV has been used to study the detector, trigger and backgrounds and has allowed the first B candidates in these channels to be observed.

References

[1] CKMfitter Group (J. Charles et al.), Eur. Phys. J. C 41 1-131 (2005), updated results and plots available at: http://ckmfitter.in2p3.fr; S. T'Jampens, these proceedings.

[2] The LHCb Collaboration, B. Adeva et al., arXiv:0912.4179 (2009).

[3] D. Atwood, I. Dunietz and A. Soni, Phys. Rev. Lett. 78 3257 (1997); D. Atwood, I. Dunietz and A. Soni, Phys. Rev. D 63 036005 (2001).

[4] M. Gronau and D. London, Phys. Lett. B 253 483 (1991); M. Gronau and D. Wyler, Phys. Lett. B 265 172 (1991).

[5] A. Giri, Y. Grossman, A. Soffer and J. Zupan, Phys. Rev. D 68 054018 (2003); A. Bondar, Proceedings of BINP Special Analysis Meeting on Dalitz Analysis, 24-26 Sep. 2002, unpublished; A. Bondar and A. Poluektov, Eur. Phys. J. C 47 347 (2006); A. Bondar and A. Poluektov, Eur. Phys. J. C 55 51 (2008).

[6] Y. Grossman, A. Soffer and J. Zupan, Phys. Rev. D 72 031501 (2005).

[7] M. Patel, CERN-LHCb-PUB-2008-011; M. Patel, CERN-LHCb-PUB-2009-011.

[8] J. Nardulli and S. Ricciardi, CERN-LHCb-PUB-2008-038.

[9] P. Hunt and M. John, CERN-LHCb-PUB-2009-002.

[10] V. Gibson, C. Lazzeroni and J. Libby, CERN-LHCb-PUB-2007-48; V. Gibson, C. Lazzeroni and Y.-Y. Li, CERN-LHCb-PUB-2008-28.

[11] The BABAR Collaboration, P. del Amo Sanchez et al., arXiv:1005.1096 (2010).

[12] The Belle Collaboration, A.Poluektov, A. Bondar, B. D. Yabsley et al., Phys. Rev. D 81 112002 (2010).

[13] G. Wilkinson, these proceedings.

[14] V. V. Gligorov and G. Wilkinson, CERN-LHCb-PUB-2008-035; V. V. Gligorov, CERN-LHCb-PUB-2007-044; J. Borel, L. Nicolas, O. Schneider and J. Van Hunen, CERN-LHCb-PUB-2007-017; S. Cohen, M. Merk and E. Rodrigues, CERN-LHCb-PUB-2007-041.

[15] R. Aleskan, I. Dunietz and B. Kayser, Z. Phys. C 54 653 (1992); I. Dunietz and R. Sachs, Phys. Rev. D 37 3186 (1998), 39 3515(E) (1989); I. Dunietz, Phys. Lett. B 427 179 (1998).

[16] A. Powell, S. Borghi, these proceedings.

[17] K. Nakamura et al. (Particle Data Group), J. Phys. G 37, 075021 (2010).

[18] I. Belyaev, these proceedings.

[19] E. Van Herwijnen, these proceedings.

[20] K. Akiba et al., CERN-LHCb-PUB-2008-031.

PoS(ICHEP 2010)239