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Time-integrated measurements of γ at the Tevatron and prospects

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The measurement of CP-violating asymmetries and branching ratios of $B \to DK$ modes allows a theoretically-clean extraction of the CKM angle γ. We report recent CDF measurements with Cabibbo suppressed ($\pi\pi$, KK) or doubly Cabibbo suppressed ($K^+\pi^-$) D decays. These measurements are performed for the first time in hadron collisions.

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1 Introduction

Using $B \to DK$ decays γ could be extracted by exploiting the interference between the tree amplitudes of the $b \to c\overline{u}s$ and $b \to u\overline{c}s$ processes. In Fig. 1 the diagrams of these processes are shown, on the left the $B^- \to D^0 K^-$ ($b \to c\overline{u}s$) and on the right the $B^- \to \overline{D}^0 K^-$ ($b \to u\overline{c}s$). γ is the relative weak phase between the two diagrams, and in principle can be probed by measuring CP-violating effects in B-decays where the two amplitudes interfere. This can be obtained in several ways, using different choices of D decay channels [1, 2, 3].

The precision of current experimental data [4] is still far from theoretical uncertainties and is statistics–limited, so the current knowledge of γ can be significantly improved by additional experimental measurements.

All mentioned methods for extracting γ from $B \to DK$ modes require no tagging or time-dependent measurements, and many of them only involve charged particles in the final state. They are therefore particularly well–suited to hadron collider environment, where the large production can be exploited. The use of specialized trigger based on online detection of secondary decay vertexes (SVT trigger [5]) allow the selection of pure B meson samples.

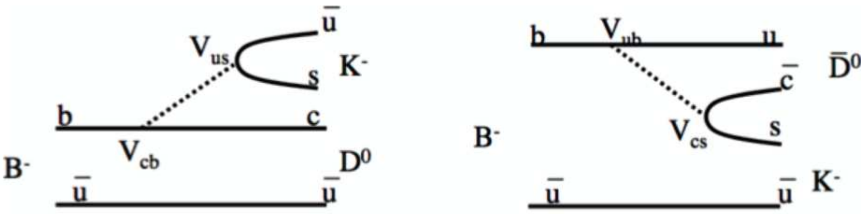

Figure 1: Diagrams contributing to $B \to DK$ and related modes. The diagram on the left proceeds via V_{cb} transition, while the diagram on the right proceeds via V_{ub} transition and it is color suppressed.

2 Atwood-Dunietz-Soni method

We report the first measurement of branching ratios and CP asymmetries of $B \to D_{DCS}K$ modes performed in hadron collisions, based on an integrated luminosity of 5 fb^{-1} collected by CDF. Events where the D meson decays to the flavor specific mode $K^-\pi^+$ (D_{CF}) or the doubly Cabibbo suppressed mode $K^+\pi^-$ (D_{DCS}) are reconstructed.

From these modes, the following observables can be defined [2]:

$$R_{ADS} = \frac{\mathcal{B}(B^- \to [K^+\pi^-]_D K^-) + \mathcal{B}(B^+ \to [K^-\pi^+]_D K^+)}{\mathcal{B}(B^- \to [K^-\pi^+]_D K^-) + \mathcal{B}(B^+ \to [K^+\pi^-]_D K^+)} \quad (1)$$

$$A_{ADS} = \frac{\mathcal{B}(B^- \to [K^+\pi^-]_D K^-) - \mathcal{B}(B^+ \to [K^-\pi^+]_D K^+)}{\mathcal{B}(B^- \to [K^+\pi^-]_D K^-) + \mathcal{B}(B^+ \to [K^-\pi^+]_D K^+)}. \quad (2)$$

These quantities are related to the CKM angle γ by the equations [2] $R_{ADS} = r_D^2 + r_B^2 + 2r_D r_B \cos\gamma \cos(\delta_B + \delta_D)$ and $A_{ADS} = 2r_B r_D \sin\gamma \sin(\delta_B + \delta_D)/R_{ADS}$, where r_B is the magnitude of the ratio of the amplitudes of the processes $B^- \to \overline{D}^0 K^-$ and $B^- \to D^0 K^-$, and δ_B is their relative strong phase; r_D is the magnitude of the ratio of the amplitudes of the processes $D^0 \to K^-\pi^+$ and $D^0 \to K^+\pi^-$, and δ_D is their relative strong phase. We measure R_{ADS} and A_{ADS} also for the $B \to D_{DCS}\pi$ decay mode because also for this mode sizeable asymmetries may be found [4].

The invariant mass distributions of CF and DCS modes, with a nominal pion mass assignment to the track from B, are reported in Fig. 2 where an obvious CF signal is visible, while the DCS signal appears to be buried in the combinatorial background. Due to the smallness of the DCS branching ratio (0.3% of the CF rate), the main issue for this analysis is the suppression of the combinatorial background.

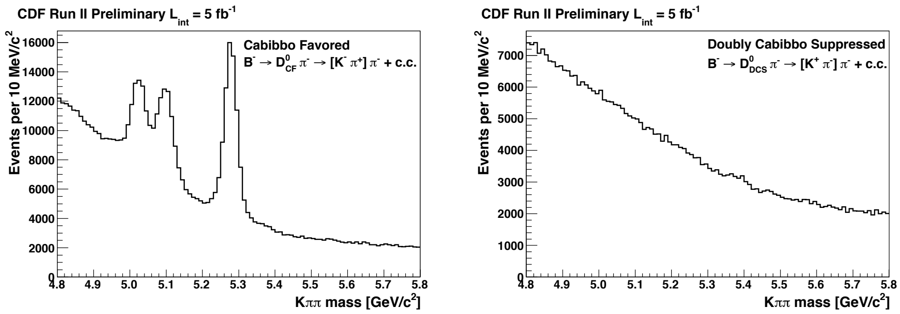

Figure 2: Invariant mass distributions of $B \to Dh$ candidates for each reconstructed decay mode. The pion mass is assigned to the track from the B decay.

We performed a cuts optimization focused on finding a signal of the $B \to D_{DCS}\pi$ mode. Since the $B \to D_{CF}\pi$ mode has the same topology of the DCS one, we did the optimization using signal (S) and background (B) from the CF mode. We maximized the figure of merit $S/(1.5+\sqrt{B})$ [6]. The variables used in the optimization and the threshold values for all the requirements are described in [7]. The resulting invariant mass distributions of CF and DCS modes are reported in Fig. 3 where the combinatorial background is almost reduced to zero and an indication of the DCS peak is now visible.

The dominant physics backgrounds for the DCS mode are $B^- \to D^0\pi^-$, with $D^0 \to X$; $B^- \to D^0 K^-$, with $D^0 \to X$; $B^- \to D^{*0} K^-$, with $D^{*0} \to D^0\gamma/\pi^0$;

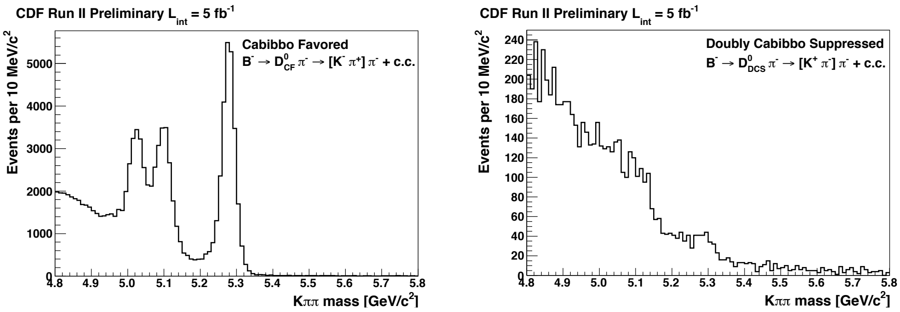

Figure 3: Invariant mass distributions of $B \to Dh$ candidates for each reconstructed decay mode after the cuts optimization. The pion mass is assigned to the track from the B decay.

$B^- \to K^-\pi^+\pi^-$ and $B^0 \to D_0^{*-}e^+\nu_e$ as determined by a study on CDF simulation described in [7].

An unbinned likelihood fit, exploiting mass and particle identification information provided by the specific ionization (dE/dx) in the CDF drift chamber, is performed to separate the $B \to DK$ contributions from the $B \to D\pi$ signals, from the combinatorial background and from the physics backgrounds.

Fig. 4 shows the DCS invariant mass distributions separated in charge. We obtained 34 ± 14 $B \to D_{DCS}K$ and 73 ± 16 $B \to D_{DCS}\pi$ signal events.

We measured the asymmetries $A_{ADS}(K) = -0.63 \pm 0.40(\text{stat}) \pm 0.23(\text{syst})$ and $A_{ADS}(\pi) = 0.22 \pm 0.18(\text{stat}) \pm 0.06(\text{syst})$ and the ratios of doubly Cabibbo suppressed mode to flavor eigenstate $R_{ADS}(K) = [22.5 \pm 8.4(\text{stat}) \pm 7.9(\text{syst})] \cdot 10^{-3}$ and $R_{ADS}(\pi) = [4.1 \pm 0.8(\text{stat}) \pm 0.4(\text{syst})] \cdot 10^{-3}$.

These quantities are measured for the first time in hadron collisions. The results are in agreement with existing measurements performed at $\Upsilon(4S)$ resonance [4, 8].

3 Gronau-London-Wiler method

We report the first measurement of branching ratios and CP asymmetries of $B \to D_{CP+}K$ modes performed in hadron collisions, based on an integrated luminosity of 1 fb^{-1} collected by CDF [9]. Events where the D meson decays to the flavor specific mode $K^-\pi^+$, or one of the CP-even modes K^-K^+ and $\pi^-\pi^+$ are reconstructed. From these modes, the following observables can be defined [1]:

$$A_{CP+} = \frac{\mathcal{B}(B^- \to D_{CP+}K^-) - \mathcal{B}(B^+ \to D_{CP+}K^+)}{\mathcal{B}(B^- \to D_{CP+}K^-) + \mathcal{B}(B^+ \to D_{CP+}K^+)}, \tag{3}$$

$$R_{CP+} = 2\frac{\mathcal{B}(B^- \to D_{CP+}K^-) + \mathcal{B}(B^+ \to D_{CP+}K^+)}{\mathcal{B}(B^- \to D_{CF}K^-) + \mathcal{B}(B^+ \to \overline{D}_{CF}K^+)}. \tag{4}$$

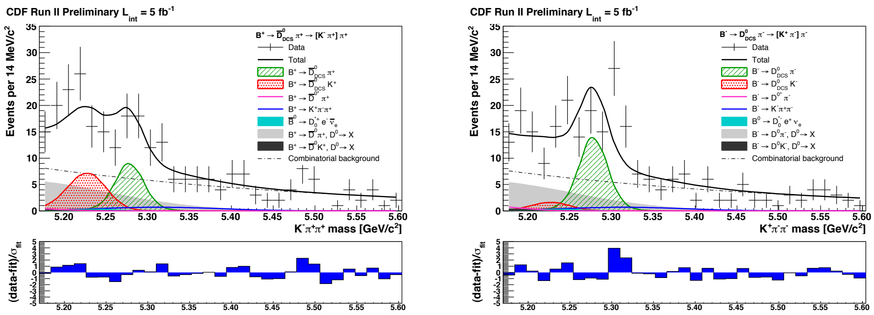

Figure 4: Left: Invariant mass distributions of $B^+ \to \overline{D}_{DCS}h^+$ candidates. Right: Invariant mass distributions of $B^- \to D_{DCS}h^-$ candidates. The pion mass is assigned to the track from the B decay. The projections of the likelihood fit are overlaid.

These quatities are related to the CKM angle γ by the equations [1] $R_{CP+} = 1 + r_B^2 + 2r_B \cos\delta_B \cos\gamma$ and $A_{CP+} = 2r_B \sin\delta_B \sin\gamma / R_{CP+}$. For every $B \to Dh$ candidate, a nominal invariant mass is evaluated by assigning the pion mass to the particle h coming from the B decay. The distributions obtained for the three modes of interest (where $D \to K\pi$, KK or $\pi\pi$) are reported in Fig. 5; a clear $B \to D\pi$ signal is seen in each. Events from $B \to DK$ decays are expected to form much smaller and wider peaks in these plots, located about 50 MeV/c^2 below the $B \to D\pi$ peaks, and as such cannot be resolved. The dominant backgrounds are combinatorial background and mis-reconstructed physics background such as $B \to D^{*0}\pi$ decay, and in the $D \to KK$ final state, the non resonant $B \to KKK$ decay, as determined by a study on CDF simulation. An unbinned likelihood fit, exploiting kinematic and particle identification information provided by the dE/dx, is performed to statistically separate the $B \to DK$ contributions from the $B \to D\pi$ signals, from the combinatorial background and from the physics backgrounds.

We obtained around 90 $B \to D_{CP+}K$ and we measured the double ratio of CP-even to flavor eigenstate branching fractions $R_{CP+} = 1.30 \pm 0.24(\text{stat}) \pm 0.12(\text{syst})$ and the direct CP asymmetry $A_{CP+} = 0.39 \pm 0.17(\text{stat}) \pm 0.04(\text{syst})$. These results are in agreement with previous measurements from $\Upsilon(4S)$ decays [10, 11].

4 Conclusions

CDF performed the first measurement of A_{ADS} and R_{ADS} at a hadron collider using a luminosity of 5 fb^{-1}. This supplements the recently published first GLW analysis in hadron collisions [9] within a CDF global program to measure γ angle from tree-dominated processes. At the moment we recorded 8 fb^{-1} and we will expect around 10-12 fb^{-1} by the end of 2011. CDF has demonstrated the feasibility of these mea-

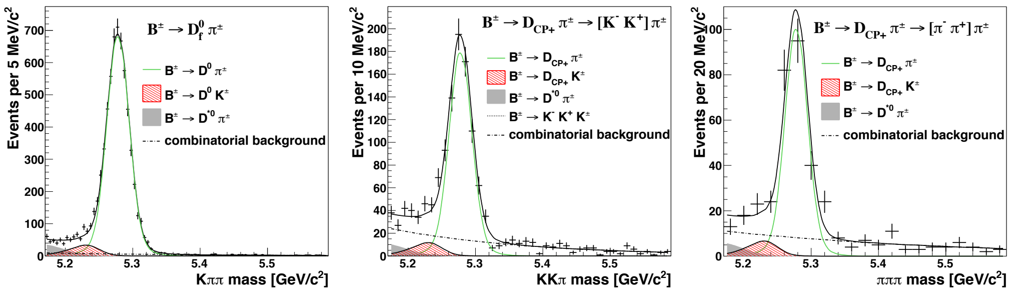

Figure 5: Invariant mass distributions of $B \to Dh$ candidates for each reconstructed decay mode. The pion mass is assigned to the track from the B decay. The projections of the likelihood fit are overlaid for each mode.

surements at a hadron collider and will obtain interesting and competitive results in the near future.

References

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

[2] 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).

[3] A. Giri, Y. Grossman, A. Soffer and J. Zupan, Phys. Rev. D **68**, 054018 (2003).

[4] The Heavy Flavor Averaging Group, arXiv:1010.1589v1 [hep-ex].

[5] Ashmanskas et al., Nucl. Instrum. Methods A **518**, 532 (2004).

[6] G. Punzi, arXiv:0808063v2 [physics.data-an] (2003).

[7] The CDF Collaboration, CDF Public Note 10309.

[8] P. del Amo Sanchez et al. (BaBar Collaboration), arXiv:1006.4241v1 [hep-ex] (2010).

[9] T. Aaltonen et al. (CDF Collaboration), Phys.Rev.D **81**, 031105 (2010).

[10] P. del Amo Sanchez et al. (BaBar Collaboration), Phys. Rev. D **82**, 072004 (2010).

[11] K. Abe et al. (Belle Collaboration), Phys. Rev. D **73**, 051106 (2006).