PROCEEDINGS OF SCIENCE

Observation of $\Lambda_b^0 \to \Lambda \mu^+ \mu^-$ Decay and Updated Search for Non-SM Physics in $B \to K^{(*)} \mu^+ \mu^-$ Decays at CDF

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CDF has studied the flavor-changing neutral current (FCNC) decays $\Lambda_b^0 \to \Lambda\mu^+\mu^-$, $B_s^0 \to \phi(1020)\mu^+\mu^-$, $B^+ \to K^+\mu^+\mu^-$, $B^0 \to K^*(892)^0\mu^+\mu^-$, $B^0 \to K_S^0\mu^+\mu^-$, and $B^+ \to K^*(892)^+\mu^+\mu^-$ in 6.8 fb^{-1} of data collected with a dimuon trigger. CDF reports the first observation of $\Lambda_b^0 \to \Lambda\mu^+\mu^-$ with 24 signal events and a statistical significance of 5.8 standard deviations. The inclusive and differential branching ratio as function of the di-muon mass squared for exclusive $b \to s\mu^+\mu^-$ decays are measured. CDF also measures the angular distributions in $B \to K^{(*)}\mu^+\mu^-$ decays. The transverse polarization asymmetry $A_T^{(2)}$ and the triple-product asymmetry of the transverse polarizations A_{im} are measured for the first time, together with the K^* longitudinal polarization fraction F_L and the muon forward-backward asymmetry A_{FB}, for the decays $B^0 \to K^{*0}\mu^+\mu^-$ and $B^+ \to K^{*+}\mu^+\mu^-$. The results are among the most accurate to date and consistent with those from other experiments. No significant departure from the standard model has been found.

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The decays $B \to K^{(*)}\mu^+\mu^-$ [1], which proceed via the flavor-changing neutral current (FCNC) process $b \to s\mu^+\mu^-$, are among the most promising probes of the standard model (SM) and its extensions [2]. In the SM the decays occur with $\mathcal{O}(10^{-6})$ rates and their decay amplitudes are sensitive to a broad class of new physics beyond the SM, especially as a function of dimuon mass. Exclusive decays of $B \to K^{(*)}\mu^+\mu^-$ have been observed by BaBar [3], Belle [4], and CDF [5]. Belle reports that the cumulative difference of the muon forward-backward asymmetry A_{FB} from the SM prediction of their measurement corresponds to 2.7 standard deviations, but there are no conclusive measurements so far. CDF also reported the observation of $B_s^0 \to \phi(1020)\mu^+\mu^-$ [5] recently. However there is no experimental search result for b baryon FCNC decay $\Lambda_b^0 \to \Lambda\mu^+\mu^-$, although the decay is considered a promising channel to extend FCNC decay measurements [6].

CDF measures the exclusive $H_b \to h\mu^+\mu^-$ channels, where H_b stands for Λ_b^0, B_s^0, B^+, and B^0, and h stands for Λ, ϕ, K^+, K_S^0, K^{*0}, and K^{*+}. For Λ, ϕ, K^{*0}, and K^{*+} reconstruction, CDF collects $p^+\pi^-$, K^+K^-, $K^+\pi^-$, and $K_S^0\pi^+$ combinations, respectively. The K_S^0 meson is reconstructed in the mode $K_S^0 \to \pi^+\pi^-$. Corresponding resonant decays, where dimuon originate from J/ψ, are reconstructed as normalization modes.

CDF uses a data sample corresponding to an integrated 6.8 fb^{-1} of $p\bar{p}$ collisions at a center-of-mass energy of $\sqrt{s} = 1.96$ TeV, collected with the CDF II detector between March 2002 and June 2010. The CDF II detector is described in detail elsewhere [7]. After the signal candidates are loosely selected from the dimuon trigger events, an artificial neural network technique is applied to obtain further optimized event selection. For rare decays, dimuons are required to have $q^2 \equiv M_{\mu\mu}^2 c^2$, where $M_{\mu\mu}$ is the dimuon invariant mass [8], outside the range of the charmonium (J/ψ and $\psi(2S)$) resonances dominant regions.

Figure 1 shows the invariant mass distributions of the rare decays. The signal yield is obtained by an unbinned maximum log-likelihood fit. CDF observes 24 ± 5, 49 ± 7, 234 ± 19, 164 ± 15, 28 ± 9, and 20 ± 6 signal yields for $\Lambda_b^0 \to \Lambda\mu^+\mu^-$, $B_s^0 \to \phi\mu^+\mu^-$, $B^+ \to K^+\mu^+\mu^-$, $B^0 \to K^{*0}\mu^+\mu^-$, $B^0 \to K_S^0\mu^+\mu^-$, and $B^+ \to K^{*+}\mu^+\mu^-$ decays, respectively. The statistical significance of $\Lambda_b^0 \to \Lambda\mu^+\mu^-$ decays corresponds to 5.8 standard deviations. This is the first observation of a b baryon FCNC decay.

CDF then measures the branching ratio of each rare channel H_b, relative to the corresponding resonant channel $H_b \to J/\psi h$:

$$
\begin{aligned}
\mathcal{B}(\Lambda_b^0 \to \Lambda\mu^+\mu^-) &= [1.73 \pm 0.42(\mathrm{stat}) \pm 0.55(\mathrm{syst})] \times 10^{-6},\\
\mathcal{B}(B_s^0 \to \phi\mu^+\mu^-) &= [1.47 \pm 0.24(\mathrm{stat}) \pm 0.46(\mathrm{syst})] \times 10^{-6},\\
\mathcal{B}(B^+ \to K^+\mu^+\mu^-) &= [0.46 \pm 0.04(\mathrm{stat}) \pm 0.02(\mathrm{syst})] \times 10^{-6},\\
\mathcal{B}(B^0 \to K^{*0}\mu^+\mu^-) &= [1.02 \pm 0.10(\mathrm{stat}) \pm 0.06(\mathrm{syst})] \times 10^{-6},\\
\mathcal{B}(B^0 \to K^0\mu^+\mu^-) &= [0.32 \pm 0.10(\mathrm{stat}) \pm 0.02(\mathrm{syst})] \times 10^{-6},\\
\mathcal{B}(B^+ \to K^{*+}\mu^+\mu^-) &= [0.95 \pm 0.32(\mathrm{stat}) \pm 0.08(\mathrm{syst})] \times 10^{-6}.
\end{aligned}
$$

Besides the total branching ratio, CDF measures the differential branching ratio as a function of q^2. The results are consistent with other experiments and the previous CDF results [3, 4, 5].

From the full differential decay distribution for decays $B \to K^*\mu^+\mu^- \to K\pi\mu^+\mu^-$ as a function of q^2, one can project the decay distribution into three simpler relations each involving just

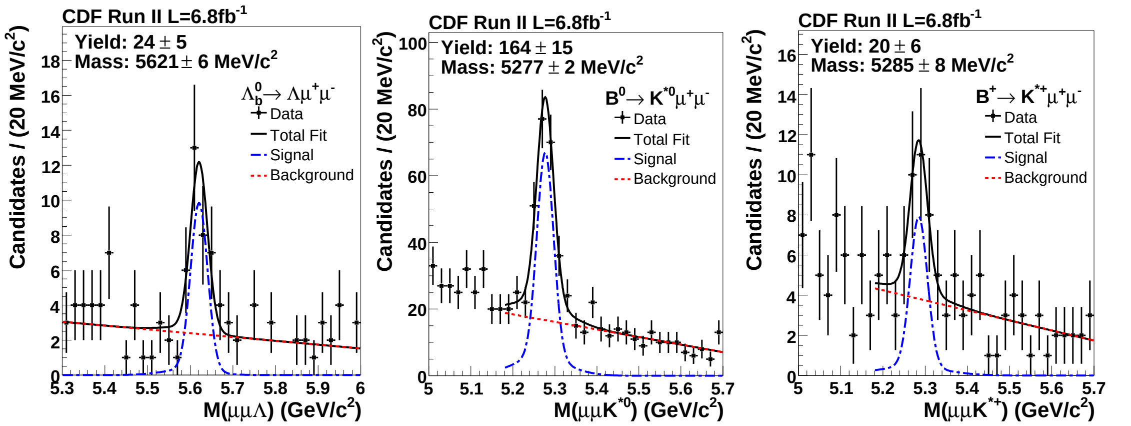

Figure 1: From left to right, invariant mass of $\Lambda_b^0 \to \Lambda\mu^+\mu^-$, $B^0 \to K^{*0}\mu^+\mu^-$, and $B^+ \to K^{*+}\mu^+\mu^-$ with fit results overlaid, respectively.

one of the angles and obtain the following observables; The muon forward-backward asymmetry (A_{FB}) and K^* longitudinal polarization (F_L) are extracted from $\cos\theta_\mu$ and $\cos\theta_K$, respectively, where θ_μ is the helicity angle between μ^+ (μ^-) direction and the opposite of the B ($\overline{B}$) direction in the dimuon rest frame, and θ_K is the angle between the kaon direction and the direction opposite to the B meson in the K^* rest frame. The transverse polarization asymmetry ($A_T^{(2)}$) and the T-odd CP asymmetry (A_{im}) are extracted from ϕ, where the angle ϕ is the angle between the two decay planes of the dimuon pair and K-π decay pair.

To extract the angular observables above, CDF performs likelihood fits to the distributions of $\cos\theta_K$, $\cos\theta_\mu$, and ϕ for candidates in each q^2 range. The values of F_L in individual q^2 ranges are extracted in advance to A_{FB}, $A_T^{(2)}$, and A_{im} fits, and then used as fixed inputs in the fits of other observables. CDF also has measured A_{FB} using the decay $B^+ \to K^+\mu^+\mu^-$. Figure 2 shows the fit results in combined $B \to K^*\mu^+\mu^-$ as a function of q^2.

All results shown in this document and also in Refs. [8] are among the most precise from a single experiment to date. CDF does not observe a discrepancy from the SM, although our results are consistent with all recent measurements from the other experiments [4, 9, 10].

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[1] $K^{(*)}$ denotes $K^\pm$, $K^*(892)^0$, or $K^*(892)^\pm$. Charge-conjugate modes are implied throughout this document.

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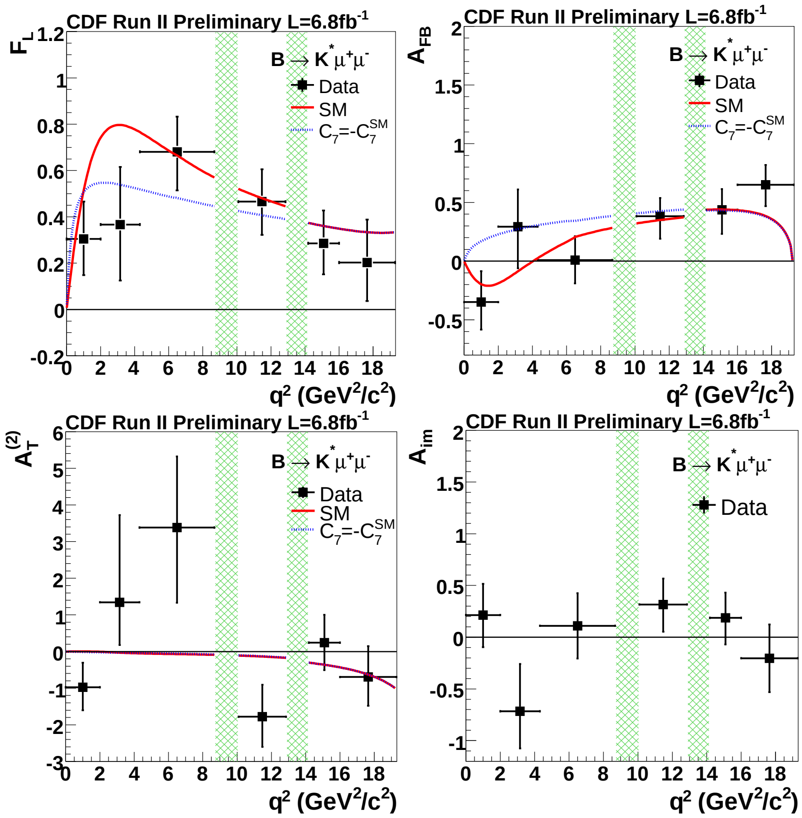

Figure 2: From top-left to bottom-right, measurements of longitudinal K^* polarization fraction F_L, forward-backward asymmetry A_{FB}, transverse polarization asymmetry $A_T^{(2)}$, and T-odd CP asymmetry A_{im} in the combined decay mode $B \to K^*\mu^+\mu^-$, all presented as a function of q^2. The points are the fit results from data. The solid curves are the SM expectation [11]. The dotted curves are the $C_7 = -C_7^{\mathrm{SM}}$ expectation. Hatched regions are resonant (charmonium) decay regions.

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