PROCEEDINGS OF SCIENCE

Forward-backward asymmetries of (B^-,B^+),($\Lambda_b, \bar{\Lambda}_b$) and ($\Lambda, \bar{\Lambda}$) in $p\bar{p}$ collisions at D0.

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We present a measurement of the forward-backward asymmetry in the production of $B^{\pm}$ mesons, Λ_b baryons and Λ baryons in 10.4 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s}$=1.96 TeV collected by the D0 experiment during RunII of the Tevatron collider. Nonzero asymmetries would indicate a preference for a particular flavor, i.e. b quark or b antiquark, to be produced in the direction of the proton beam. These measurements provide important constraints on the production mechanisms and hadronization processes of heavy quarks at hadron colliders.

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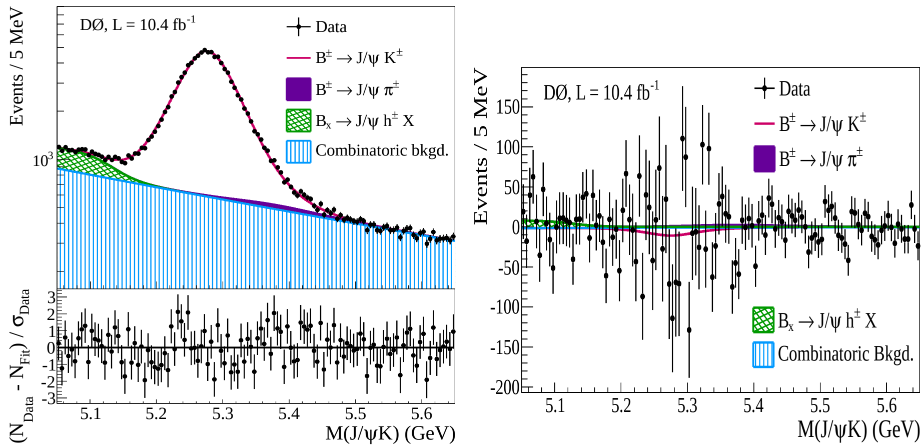

Figure 1: Fit to invariant mass $M(J/\psi K)$ distributions of forward+backward events (left) and forward-backward events (right).

1. Forward-backward asymmetries of (B^-,B^+)

Forward backward asymmetries have been measured in a number of various channels including $t\bar{t}$ [1] and a recent measurement by LHCb using $b\bar{b}$ [2]. The initial $t\bar{t}$ results showed an asymmetry larger than predicted by the Standard Model [3, 4], which created much interest in these types of measurements. Measuring the forward backward asymmetry in fully reconstructed $B^{\pm}$ decays has the advantage over $b\bar{b}$ in that it allows a direct measurement of the quark flavor and there is no need to take into account $B^0-\bar{B}^0$ oscillations. We reconstruct $B^{\pm}$ events in the decay mode $B^{\pm} \to J/\psi(\to \mu^+\mu^-)K^{\pm}$ and categorize it as forward or backward based on the variable $q_{FB} = -q_B sgn(\eta)$, where q_B is the charge of the $B^{\pm}$, $sgn(x)$ is the sign function, and η is the pseudorapidity of the reconstructed $B^{\pm}$. The forward backward asymmetry A_{FB} is defined as:

$$A_{FB}(B^{\pm}) = \frac{N(q_{FB}>0)-N(q_{FB}<0)}{N(q_{FB}>0)+N(q_{FB}<0)}.$$

Figure 1 shows the reconstructed $B^{\pm}$ mass along with a fit to both the forward+backward events and the forward-backward events. With an average B P_T of 12.9 GeV, the measured asymmetry is consistent with zero and is found to be $A_{FB}(B^{\pm}) = [-0.24 \pm 0.41(stat) \pm 0.19(syst)]\%$, providing the first measurement of this quantity. Figure 2 shows the measured $A_{FB}(B^{\pm})$ as a function of P_T and η compared to MC@NLO. The measured asymmetry is found to be systematically lower than MC@NLO for all η and for P_T=9-30 GeV. Recently a new calculation [5] shows much better agreement with the D0 data. Additional details of this analysis can be found in [6].

2. Forward-backward asymmetries of ($\Lambda_b, \bar{\Lambda}_b$)

Most measurements of forward-backward asymmetries have been made with bottom mesons and few with bottom baryons. Bottom baryons are sensitive to non-perturbative final state interactions and could produce a “string drag” effect [7] that could favor the production of a $\Lambda_b(\bar{\Lambda}_b)$ in the region containing the beam proton (anti-proton). In this analysis we study the forward backward asymmetry of $\Lambda_b, \bar{\Lambda}_b$ baryons using the decay chain $\Lambda_b \to J/\psi(\to \mu^+\mu^-)\Lambda(\to p\pi^-)$ and

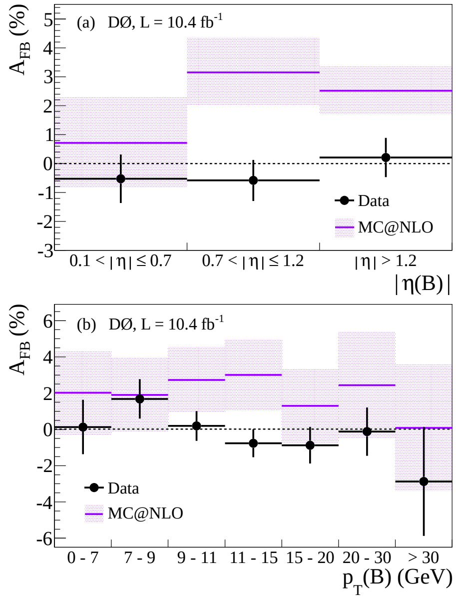

Figure 2: Comparison of A_{FB} as a function of $|\eta(B^{\pm})|$ (a) and $P_T(B^{\pm})$ (b) to MC@NLO. Data and MC bands include both statistical and systematic uncertainties.

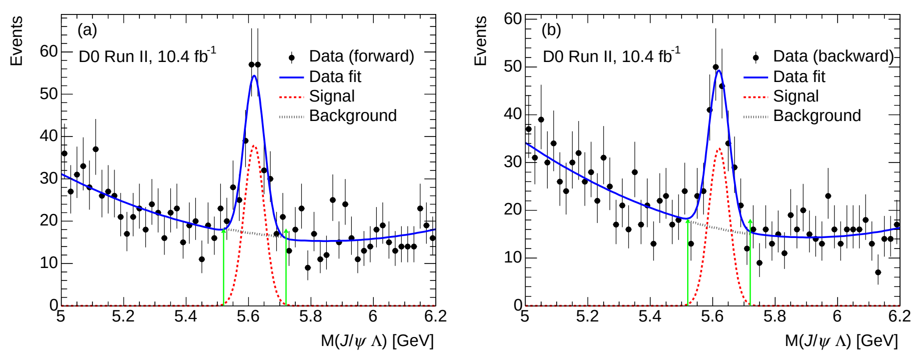

Figure 3: Reconstructed Λ_b and $\overline{\Lambda}_b$ candidates in the rapidity range $0.5 < |y| < 1.0$ for forward (a) and backward(b) events. A fit is superimposed along with vertical lines which define the signal region.

charge conjugate. Forward $\Lambda_b(\overline{\Lambda}_b)$ correspond to the baryons being emitted at $y > 0$ ($y < 0$), while backward $\Lambda_b(\overline{\Lambda}_b)$ correspond to the baryons being emitted at $y < 0$ ($y > 0$). The forward backward asymmetry can therefore be defined as

$$A_{FB} = \frac{N_{Forward} - N_{Backward}}{N_{Forward} + N_{Backward}}.$$

The data are separated into four rapidity regions to allow the asymmetry to be measured as a function of rapidity.

Figure 3 shows the reconstructed Λ_b mass in the rapidity range $0.5 < |y| < 1.0$ for both the forward and backward definitions along with a fit to the data.

Figure 4 shows the measured asymmetry as a function of rapidity compared to a Heavy Quark Recombination model [8] and a simulation showing the effects of the “beam drag” effect. Integrating over rapidity yields a forward backward asymmetry of A_{FB}=0.04 $\pm$ 0.07(stat.) $\pm$ 0.02(syst.).

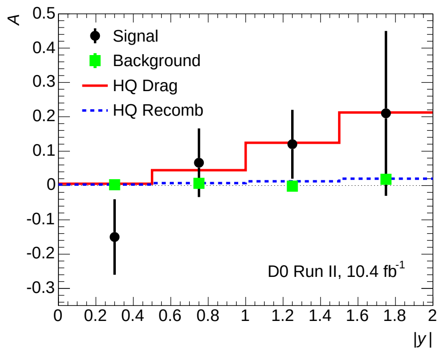

Figure 4: Forward backward asymmetry as a function of rapidity

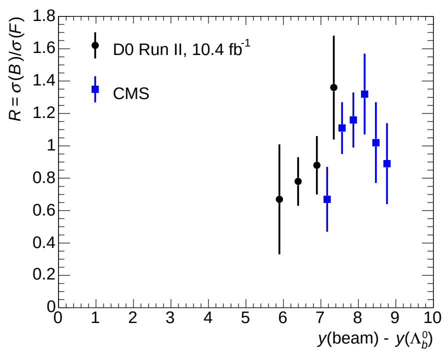

Figure 5: Ratio of the backward to forward production cross sections as a function of rapidity loss.

In addition to the forward backward asymmetry, the ratio of the backward to forward production cross sections ($R = \sigma(Backward)/\sigma(Forward)$) is measured. Figure 5 shows the ratio of the backward to forward production cross section as a function of rapidity loss ($y_{beam} - y(\Lambda_b)$) compared to CMS [9]. With an average P_T of 9.9 GeV for the Λ_b and $\overline{\Lambda}_b$ candidates we find R=0.92 $\pm$ 0.12(stat.) $\pm$ 0.04(syst.) Additional details on this analysis can be found at [10].

3. Forward-backward asymmetries of $(\Lambda, \overline{\Lambda})$

Searching for asymmetries in Λ and $\overline{\Lambda}$ mesons has the advantage of being able to determine small asymmetries due to the large data set available and the ability to control the systematic uncertainties. The definitions of forward, backward and A_{FB} are identical to the definitions used for the forward-backward asymmetries of $(\Lambda_b, \overline{\Lambda}_b)$. The forward backward asymmetry is measured in three separate samples: $J/\psi\Lambda(\overline{\Lambda})X, \Lambda(\overline{\Lambda})X$, and $\mu^{\pm}\Lambda(\overline{\Lambda})X$. Figure 6 shows A_{FB} as a function of rapidity for a minimum bias sample of $p\overline{p} \to \Lambda(\overline{\Lambda})X$ where the P_T of the $\Lambda(\overline{\Lambda})$ candidate is greater than 2 GeV. Integrating over rapidity yields $A_{FB} = 0.0015 \pm 0.0005$(stat.) $\pm$ 0.0006(syst.), showing a small but significant asymmetry.

A comparison of A_{FB} as a function of rapidity for three separate data sets is shown in Fig. 7 showing A_{FB} to be independent of the sample composition.

Figure 8 shows A_{FB} for three different P_T thresholds for the $\mu^{\pm}\Lambda(\overline{\Lambda})X$ dataset. A significant asymmetry with only a weak dependence on the P_T threshold is observed.

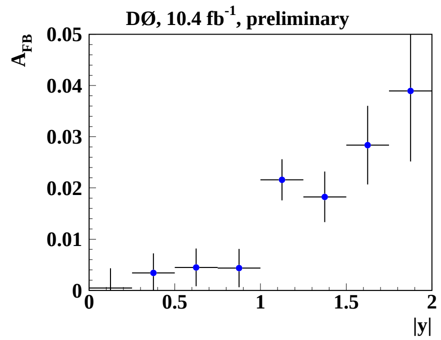

Figure 6: A_{FB} of $\Lambda(\overline{\Lambda})$ with $P_T > 2$ GeV as a function of rapidity for minimum bias data. The uncertainties are statistical only.

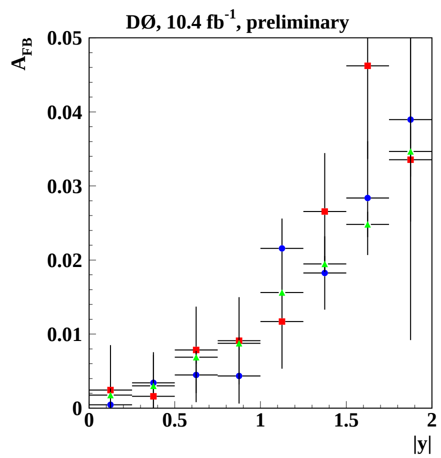

Figure 7: A_{FB} versus rapidity for $J/\psi\Lambda(\overline{\Lambda})X$ (red), $\Lambda(\overline{\Lambda})X$ (blue), and $\mu^{\pm}\Lambda(\overline{\Lambda})X$ (green)

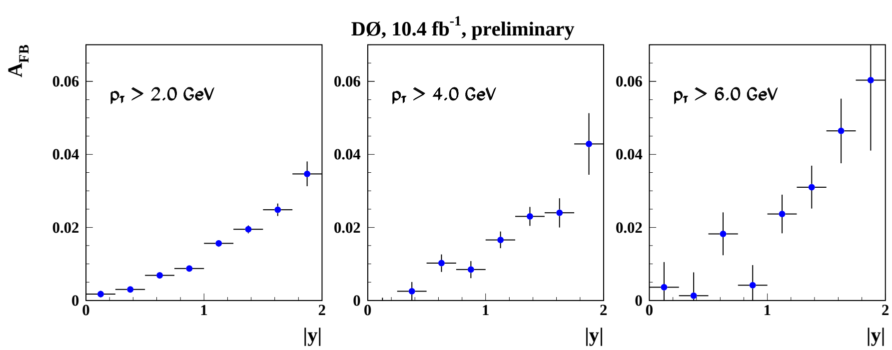

Figure 8: A_{FB} versus rapidity for $\mu^{\pm}\Lambda(\overline{\Lambda})X$ for three different P_T thresholds.

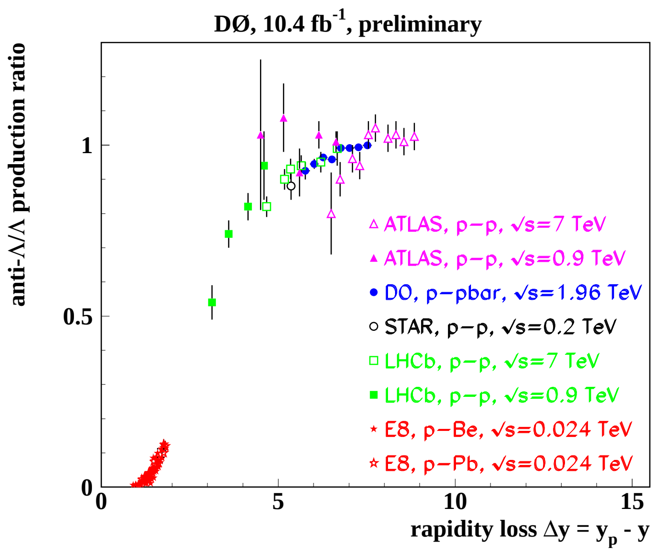

Figure 9: $\overline{\Lambda}/\Lambda$ production ratio as a function of rapidity loss for several experiments (see text).

Figure 9 shows the $\overline{\Lambda}/\Lambda$ production ratio as a function of rapidity loss for several experiments including ATLAS [11], STAR [12], LHCB [13], and Fermilab E8 [14] and D0 (this analysis). We find that $\overline{\Lambda}/\Lambda$ production ratio is approximately a universal function of rapidity loss.

4. Conclusions

The D0 experiment has measured the forward-backward asymmetry for three separate analyses. No significant forward backward asymmetry is observed for $B^{\pm}$ and some tension with MC@NLO is observed. However, a recent calculation shows much better agreement with the D0 data. A small but significant forward-backward asymmetry is found for $\Lambda, \overline{\Lambda}$ production. The $\Lambda/\overline{\Lambda}$ production ratio in $pZ \to \Lambda(\overline{\Lambda})X$ appears to be approximately a universal function of rapidity loss and the $\Lambda_b/\overline{\Lambda}_b$ production ratio follows a similar dependence on rapidity loss. The $\Lambda, \overline{\Lambda}$ production ratio does not depend significantly on the $\sqrt{s}$ from 0.025 TeV to 7 TeV for target $Z = p, \bar{p}$, Be or Pb. The forward-backward asymmetry for $\Lambda, \overline{\Lambda}$ does not depend significantly on the data set $p\bar{p} \to J/\psi\Lambda(\overline{\Lambda})X, \Lambda(\overline{\Lambda})X$, or $\mu^{\pm}\Lambda(\overline{\Lambda})X$ or the P_T threshold. The results suggest that a u-quark in some protons becomes replaced by an s or a b quark in the collision resulting in a Λ or Λ_b with the loss of some rapidity.

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