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B physics at DØ

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Abstract. An overview of progress in B physics studies with the DØ Detector at the Fermilab Tevatron is presented, based on approximately 114 pb^{-1} of Run II data. Results on the performance of the upgrade DØ tracking system are shown. Signals for many exclusive $B^{\pm}$, B_d^0, and B_s decay modes are shown, along with preliminary results for b-hadron lifetimes and b-quark production cross sections.

1 Introduction

As a basis for B physics studies, the Tevatron provides an experimental environment complementary to that of the e^+e^- B factories at SLAC and KEK. The enormous b production cross section ($\sim 150\mu$b in the central detectors) and high energy make available b hadrons not accessible at the B factories, such as B_s, B_c and Λ_b, and lead to the collection of a number of rare B decay modes. At DØ, b hadrons are selected by single or di-lepton triggers, which, through the semileptonic or J/ψ decay modes, providing clean samples. All results presented here are preliminary.

2 The DØ detector and its performance

The DØ detector has been largely upgraded for Run II. Substantial improvements have been made to the muon system and the calorimeter readout electronics. The trigger and data acquisition systems have been replaced. The central detector is also new, comprising a 2-T superconducting solenoid, a scintillating fiber Central Fiber Tracker (CFT), and a Silicon Microstrip Tracker (SMT). The reliability of these systems has been excellent: 91% of SMT channels, 99.5% of CFT channels, and $> 99.9\%$ of calorimeter and muon channels are available at all times. The trigger menu in Run II has included jets, multi-jets, lepton + jets, and single and di-lepton triggers. Particularly important for the results presented here has been the single and di-muon triggers, with coverage out to $|\eta| < 2$ and momentum thresholds $p_T > 2.5 - 3.5$ GeV/c.

2.1 Detector performance

Since many of the studies presented here rely on the quality of the tracking system, some parameters are shown that give an indication of its performance to date. Figure 1 shows the invariant mass of muon pairs from $Z \to \mu\mu$ decays, with a resolution of 7.8 GeV. Figure 2 shows the Monte Carlo prediction of the impact parameter resolution in the plane perpendicular to the beam axis (the $x-y$ plane) compared with that measured in the data. Good agreement is seen over the whole range of momentum. Figure 3 exemplifies the tracker performance for reconstructing high-impact parameter tracks. Shown is the mass peak for the Ξ, reconstructed in the decay $\Xi^{\pm} \to \Lambda\pi^{\pm}$. This final state, containing multiple tracks with centimeter-sized impact parameters, is reconstructed cleanly with very low fake rate. Also shown is a reconstructed Ω signal.

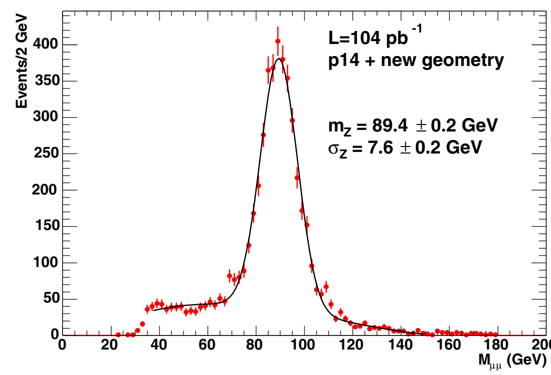


Fig. 1. Invariant Z mass resolution from the decay $Z \to \mu\mu$. The width of the distribution is 7.8 GeV

3 The b production cross section

A preliminary measurement of the b hadron production cross section at $\sqrt{s} = 1.98$ TeV has been made using a small (3.4 pb^{-1}) dataset[1]. Events containing b hadrons are selected using a μ+jets trigger. The cross section for μ+jets is then measured by determining the trigger efficiency and acceptance corrections. The measured μ+jets cross-section is shown in Fig. 4a as a function of the transverse energy E_T of the jet associated with the muon. The

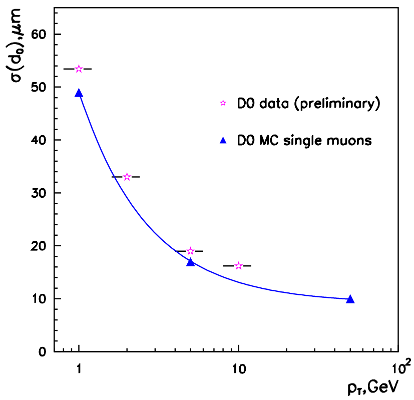


Fig. 2. Impact parameter resolution, measured in the plane perpendicular to the beam axis. The solid curve is the prediction from single-muon Monte Carlo, the points are measured in multi-jet events in data

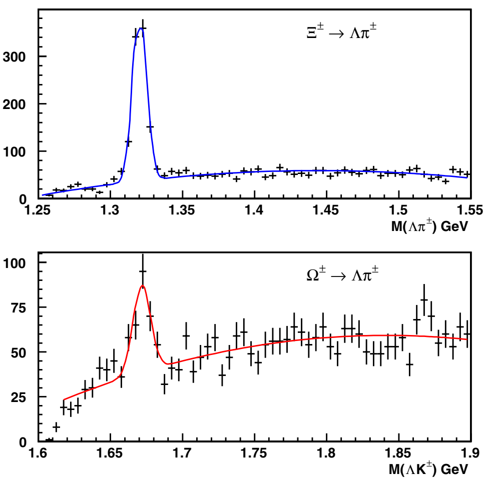


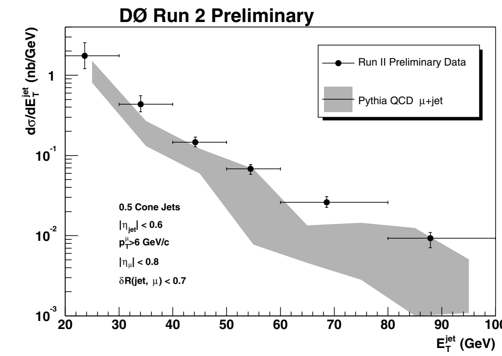
Fig. 3. Reconstructed mass peaks for $\Xi^{\pm}$ and $\Omega^{\pm}$

b hadron production cross section is then obtained by determining the fraction of jets containing b hadrons in the μ+jets sample, where the b flavor content depends on the jet E_T. The final result is shown in Fig. 4b. The trend of the measured cross section lying above the QCD predictions continues at this higher center-of-mass energy.

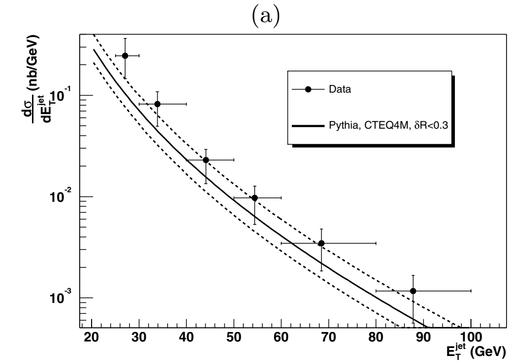
4 Exclusive B reconstruction

The selection of a large J/ψ sample has allowed the exploration of many exclusive b hadron final states. The b hadron decay modes can then be easily reconstructed by combining the J/ψ with other charged particles to find decay modes with all charged particles in the final states.

The J/ψ selection is rather simple: 1) tracks with transverse momentum greater than 1.5 GeV that are identified as muons by matching to hits in at least one chamber of the muon system are required to have at least 3 SMT hits and at least 4 CFT hits. 2) The muons are fit to a common vertex, and the χ^2 of the vertex fit must be less



(a)



(b)

Fig. 4. a the μ+jets cross section at 2 TeV as a function of the E_T of the leading jet. **b** The measured b hadron production cross section *vs.* the E_T of the leading jet.

than 20. These cuts result in a J/ψ sample of approximately 290k events, with a mass resolution of 74 MeV/c^2.

Table 1 summarizes the signals observed so far, including the cut requirements for the particle(s) added to the J/ψ to form the given final state. The cuts are rather simple; no particle-id is required (besides the muons from the J/ψ) anywhere in the analyses. As an example of the quality of the reconstruction, the $B_s \to \psi\phi$ reconstructed mass is shown in Fig. 5. Note that the B_s and Λ_b modes are only accessible at the Tevatron at this time. The exclusive modes have been used for lifetime measurements, which will be described in the following section. Publication of particle masses awaits the reduction of systematic errors in the absolute momentum scale of the tracking system.

5 Lifetime measurements

The exclusive modes have been used to measure the lifetimes of the various b hadrons, as summarized in Table 2. The dominant systematic errors are typically from verification of fit bias with Monte Carlo and tracking efficiency uncertainties. Having all-charged final states gives a very precise measure of the decay length and the proper time, since there is no missing energy which must be determined in order to calculate the boost of each hadron. One case for which this is not true is the inclusive B lifetime measurement using only the decay length of the J/ψ[2]. Here, the di-muon vertex gives an accurate B decay length, but

Table 1. A summary of the exclusive b hadron decay modes reconstructed using the J/ψ sample as a basis. Cuts on the additional tracks and the b hadron system are included. Here, $\theta_{\mathbf{p},\mathbf{L}}$ is the angle between the vertex momentum and the vertex line of flight, $b(B)$ is the three-dimensional impact parameter of the reconstructed B hadron to the event primary vertex, and σ_b is the error on b. All results use an integrated luminosity of 114 pb^{-1}

Mode	Track cuts	"B" cuts	Yield
$B^\pm \to \psi K^\pm$	$p_T(K) > 0.5$ GeV	$L/\sigma_L > 3.0$	1235 ± 52
	$b(K^\pm)/\sigma_b > 3$	$\cos\theta_{\mathbf{p},\mathbf{L}} > 0.9$, $b(B^\pm)/\sigma_b < 8$	
$B_d^0 \to \psi K_s^0$	$p_T(\pi) > 0.5$ GeV	$L/\sigma_L > 3.0$	157 ± 20
	$\Delta\chi^2_{\text{vtx}}(\text{trk}) < 36$	$\cos\theta_{\mathbf{p},\mathbf{L}} > 0.9$, $b(B^0)/\sigma_b < 6$	
$B_d^0 \to \psi K^{0*}$	$p_T(K,\ \pi) > 0.5$ GeV	$L/\sigma_L > 3.0$	509 ± 37
	$\Delta\chi^2_{\text{vtx}}(\text{trk}) < 36$	$\cos\theta_{\mathbf{p},\mathbf{L}} > 0.9$, $b(B^0)/\sigma_b < 8$	
$B_s \to \psi\phi$	$p_T(K) > 1.0$ GeV	$L/\sigma_L > 3.0$	133 ± 17
	$\Delta\chi^2_{\text{vtx}}(\text{trk}) < 36$	$\cos\theta_{\mathbf{p},\mathbf{L}} > 0.9$	
$\Lambda_b \to \psi\Lambda$	$p_T(p)[\pi] > (1.8)[0.25]$ GeV	$\chi^2_{\text{vtx}} < 20$	56 ± 14
	$b(p,\ \pi)/\sigma_b > 3$	$\theta_{\mathbf{p},\mathbf{L}} < 1.2$, $n^{\text{cone}}_{\text{trk}} < 14$	

Table 2. A summary of the b hadron lifetimes measured at DØ. A description of additional cuts is also included. All results use an integrated luminosity of 114 pb^{-1}

Particle	Mode Used	Track cuts	"B" cuts	Lifetime (ps)
B	Incl. J/ψ	$p_T(\mu) > 1.5$ GeV	$p_T(J/\psi) > 2.0$ GeV	$1.562 \pm 0.013 \pm 0.044$
		$b(K^\pm)/\sigma_b > 3$	$\cos\theta_{\mathbf{p},\mathbf{L}} > 0.9$, $b(B^\pm)/\sigma_b < 4$	
$B^\pm$[3]	$B^\pm \to \psi K^\pm$	$p_T(\psi) > 4.0$ GeV	$p_T(B^\pm) > 5.0$ GeV	$1.65 \pm 0.08 \pm 0.13$
		$p_T(K) > 1.5$ GeV	$\Delta\chi^2_{\text{Kaon}}(\text{vtx}) < 10$, $\chi^2_{\text{vtx}}(B) < 20$	
B_d^0[4]	$B_d^0 \to \psi K^{0*}$	$p_T(K,\ \pi) > 2.0$ GeV	$p_T(B^0) > 6.0$	$1.51^{+0.19}_{-0.17} \pm 0.20$
		μ iso: $2 < n^{\text{cone}}_{\text{trk}} < 15$	$\sigma_L(J/\psi) < 0.02$ cm	
B_s[4]	$B_s \to \psi\phi$	$p_T(K) > 1.0$ GeV	$p_T(B_s) > 6.0$, $\sigma_L(\phi) < 0.2$ cm	$1.19^{+0.19}_{-0.16} \pm 0.14$
		μ iso: $2 < n^{\text{cone}}_{\text{trk}} < 15$	$\sigma_L(J/\psi) < 0.02$ cm	
Λ_b	$\Lambda_b \to \psi\Lambda$	$p_T(p)[\pi] > (1.8)[0.25]$ GeV	$\chi^2_{\text{vtx}} < 20$	$1.05^{+0.21}_{-0.18} \pm 0.12$
		$b(p,\ \pi)/\sigma_b > 3$	$\theta_{\mathbf{p},\mathbf{L}} < 1.2$, $n^{\text{cone}}_{\text{trk}} < 14$	

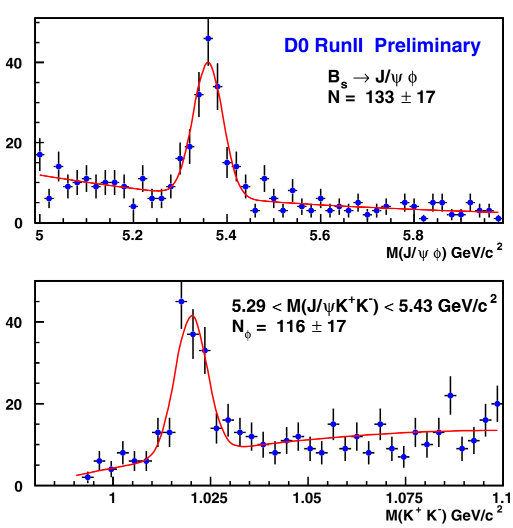


Fig. 5. *Top:* The reconstructed B_s mass in the $\psi\phi$ final state. *Bottom:* The reconstructed KK mass around the ϕ

a correction to the J/ψ boost is required in order to obtain the true B boost.

6 Inclusive B semi-leptonics

We have also observed large yields of semi-leptonic B decays using our single muon trigger, which has coverage out to $\eta < 2$. We have reconstructed sizeable sigals for $B \to D^0\mu X$ (2537 ± 88), $B \to D^\pm\mu X$ (1067 ± 66), $B \to D^{*\pm}\mu X$ (1132 ± 50), and $B_s \to D_s^\pm\mu X$ (279 ± 32), where the number of events is quoted for a sample of only 6.2 pb^{-1}. These events will be used for lifetime and mixing studies.

References

1. Further documentation for all results is available at: www-d0.fnal.gov/Run2Physics/ckm/
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3. P. Podesta-Lerma et al.: DØ Note 4273, Oct. 2003
4. C. Luo and D. Zieminska: DØ Note 4221, Jul. 2003