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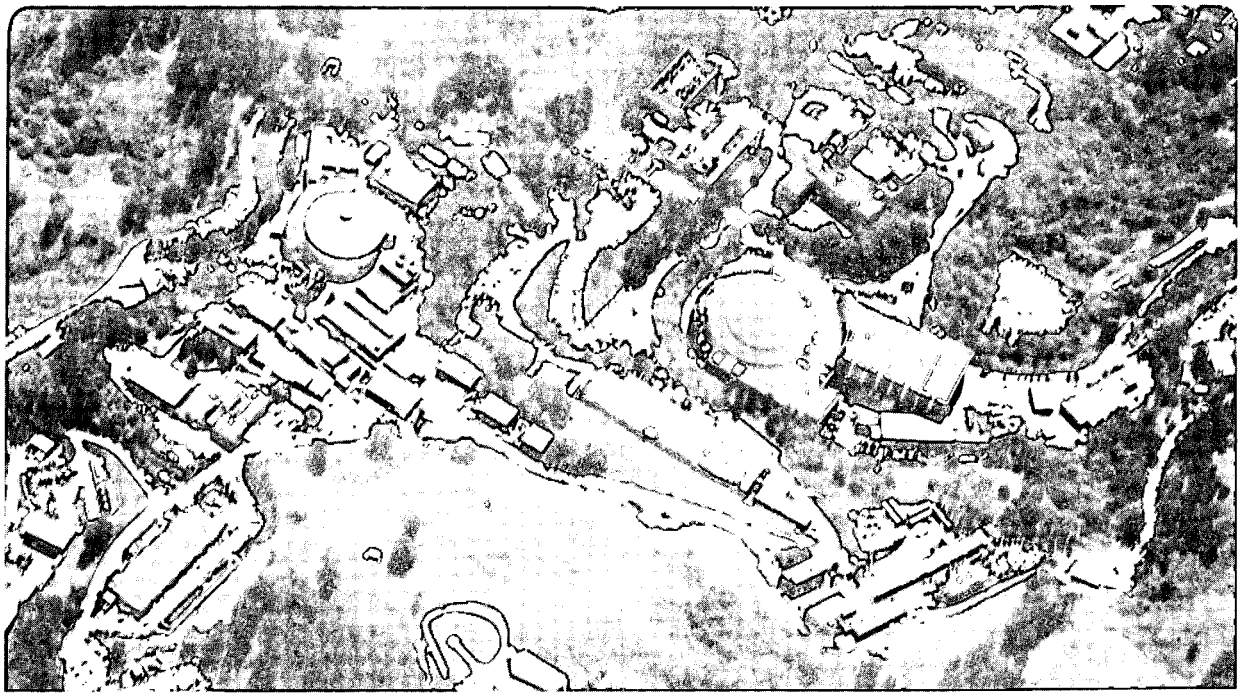
Physics Division

Presented at the Twenty-Eighth Rencontres de Moriond, QCD and High Energy Hadronic Interactions, Les Arcs, Savoie, France, March 20–27, 1993, and to be published in the Proceedings

B Production at DØ

T.G. Trippe

June 1993



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B PRODUCTION AT DØ

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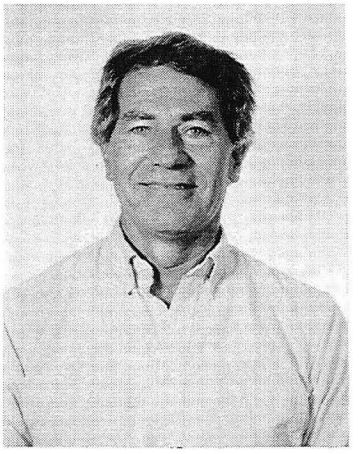
(for the DØ collaboration*)



ABSTRACT

The DØ detector is well suited for some aspects of B physics. The muon system is capable of triggering on muons with p_T down to 3 Gev/c, is dense and compact to suppress backgrounds from punchthrough and decay in flight, and covers a large pseudorapidity range $|\eta| < 3.3$. This allows the study of B production in muon and multimuon channels over a wide p_T and η range, which should provide information about gluon densities at small x. The muon inclusive p_T distribution is shown. Dimuon mass and charge correlations are analyzed to separate production and decay processes. B production in the inclusive mode $B \rightarrow J/\psi\ X$ as well as J/ψ and Υ production are discussed. $B\overline{B}$ mixing is studied using like-sign dimuon events.

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1. INTRODUCTION

While the DØ detector was designed primarily to do high p_T physics, it has some characteristics which allow it to make valuable measurements in low p_T physics, e.g. in $B\bar{B}$ mixing, B production cross sections, and direct J/ψ and Υ production. B production cross sections are of particular interest because next-to-leading order QCD hard scattering cross sections do not appear to fit the CDF bottom quark cross section.[1] Also, data on $p\bar{p} \rightarrow BX$ from UA1, CDF, and DØ will provide constraints on gluon density at small x.[2] DØ can cover a wide range of x because of it's large η coverage. Preliminary results on $B\bar{B}$ production and B mixing are presented.

2. THE DØ DETECTOR

DØ has central and forward tracking but no central magnetic field, so the charges of hadrons and electrons are not known and their energies are only determined by calorimetry, limiting the ability to measure exclusive final states. The muon system[3] has magnetized iron toroids between the first two of three muon drift tube layers, providing a measurement of the muon momentum and sign. The momentum resolution for B decay muons is dominated by multiple scattering and is $\Delta p/p = 20\%$ for $p < 60$ GeV/c.

The small size of the central detector, r= 75 cm, suppresses $\pi,K \rightarrow \mu$ background by limiting the decay path. The 13-19 interaction lengths of calorimeter and muon systems suppresses punchthrough, allowing the detection of muons inside jets. Because DØ can identify muons more cleanly than electrons inside jets, can measure muon sign and momentum, and can trigger over a wide range of η, B physics in DØ presently emphasizes muon channels. The muon system can trigger on muons with p_T down to about 3 Gev/c over a pseudorapidity range $|\eta| < 3.3$. This allows the study of muon and multimuon channels over a wide p_T and η range.

3. SINGLE MUON PRODUCTION

B production rates are high at the Tevatron; $\sigma(p\bar{p} \rightarrow b) \sim 50\ \mu b$ and $\sigma(p\bar{p} \rightarrow b \rightarrow \mu) \sim 5\ \mu b$ so that at luminosity $4 * 10^{30}\ cm^{-2}s^{-1}$ we expect muons from B decays at a rate of about 20 Hz compared with the total 2 Hz band width of DØ. Therefore to avoid huge prescales, the trigger strategy for single muons from B decay must be to trigger on muons only in those kinematic regions which are rich in muons from B decay compared to background muons. This is done mainly by using a muon p_T trigger threshold. Background muons from $\pi \rightarrow \mu$ and $K \rightarrow \mu$ decay in flight swamp muons from B decay at low p_T. The crossover where the muons from B decay exceed this background occurs at about 5 GeV/c p_T. Background muons from charm decay also contribute at low p_T but are expected to fall below those from B decay for $p_T \gtrsim 3$ GeV/c. Other significant backgrounds include cosmic ray muons and noise from spray near the beamline. The DØ muon p_T trigger threshold is about 3 GeV with full efficiency above about 5 GeV/c.

Above 5 GeV/c the geometric acceptance of the muon system, requiring muons to hit three layers, is about 75%. The trigger efficiency for these muons is about 85% at level 1, the hardware trigger level. Central muons ($\theta \sim 90°$) range out due to dE/dx losses before penetrating the muon system if p_T is less than about 4 GeV/c. Forward muons can penetrate the system at lower p_T. For example, at $\theta = 15°$, muons with p_T as low as 2 GeV/c can penetrate the muon system. This means that in the future DØ has the potential to lower it's p_T threshold in the forward regions.

DØ has shown a p_T spectrum for non-isolated muons with $|\eta| < 1$ and $p_T > 7$ GeV/c.[4] The shape of the spectrum was in agreement with lowest order QCD. The muon-jet separation and muon p_T relative to the jet axis were consistent with a sample rich in b decays. More recently DØ has extended its coverage into the forward region with its Small Angle Muon System (SAMUS). Fig. 1 shows the muon p_T spectrum for $2.2 < |\eta| < 3.3$ and $p_T > 2$ GeV/c. These data were from a short test run with integrated luminosity 6 nb^{-1}. The CDF data[5] for $1.95 < |\eta| < 2.8$ are also shown. The $b \rightarrow \mu$ curve is from ISAJET with $\sigma(b) = 40$ μb. A Monte Carlo estimate of the background from $\pi \rightarrow \mu$ and $K \rightarrow \mu$ decay is also shown. In this η range, the decay/b crossover is at ~3 GeV/c.

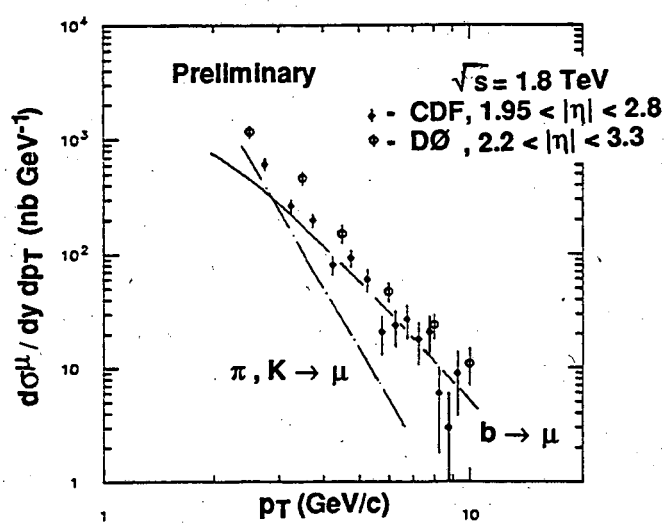


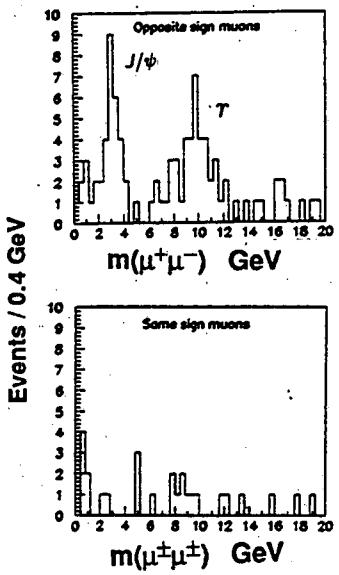
Fig. 1 Inclusive muon spectrum in the forward region

4. DIMUON PRODUCTION

Drell-Yan production of μμ and direct production of $J/\psi \rightarrow \mu\mu$ and $\Upsilon \rightarrow \mu\mu$ yield muons isolated from jet activity, while dimuons from heavy quark production and muonic decay yield non-isolated muons. Dimuons from $b\bar{b}$ production and semimuonic decays $b \rightarrow \mu^- X$ and $\bar{b} \rightarrow \mu^+ X$ yield opposite-sign non-isolated muons with high dimuon effective mass. $B\bar{B}$ mixing leads to like-sign dimuons with similar characteristics. $B \rightarrow \psi K$ with $\psi \rightarrow \mu^+\mu^-$ leads to opposite-sign dimuons associated with the same jet and with a ψ effective mass. Fig. 2 shows the isolated-dimuon mass spectrum for a sample with an integrated luminosity of 3.5 pb^{-1} and both muons with $p_T > 3$ GeV and $|\eta| < 1$. The muons have a good track fit and vertex projection, cosmic rejection, and calorimeter

energy consistent with 1 MIP. Neither muon has a jet within 0.7 in η,ϕ space, where a jet is defined as having $E_T > 8$ GeV in a 0.7 cone. The J/ψ and Υ are seen with widths consistent with a p_μ resolution of 20%. No peaks are seen in the like-sign dimuons.

Fig. 3 shows the non-isolated dimuon mass spectrum for the same sample except with at least one muon having a jet within 0.7 in η,ϕ space. There are 130+-28 J/ψ events in the peak. A roughly equal number of $J/\psi \rightarrow \mu\mu$ have been found in the single-muon-plus-jet triggers. The number of J/ψ events is small primarily because most $J/\psi \rightarrow \mu\mu$ events have at least one muon below our p_T threshold in the region $|\eta| < 1$. DØ is developing its μ triggers at high $|\eta|$ and low p_T to obtain more $B \rightarrow J/\psi \rightarrow \mu\mu$ events.



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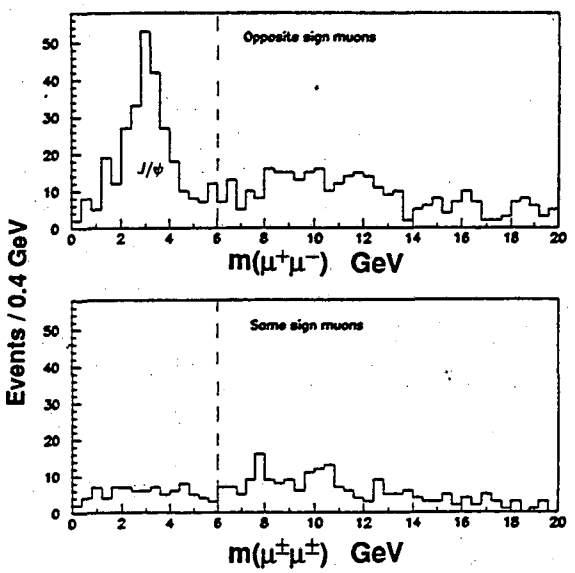

Fig. 2 Isolated dimuon mass spectrum

Fig. 3 Non-isolated dimuon mass spectrum

To study mixing we cut J/ψ events from the non-isolated dimuons by requiring $m(\mu\mu) > 6$ GeV (see Fig. 3) and then form the ratio R = N(same sign)/N(opposite sign) = 0.64 ± 0.05 (statistical error only). Other processes such as $b \rightarrow c \rightarrow \mu^+$, $\bar{b} \rightarrow \mu^+$, can also produce like sign dimuons. From ISAJET without mixing, $R = 0.35 \pm 0.06$. CDF reported $R = 0.556 \pm 0.048 + 0.035 - 0.042$ from their $e\mu$ sample. The preliminary DØ result indicates mixing and is consistent with the CDF result[6].

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