DØ Results and Run II Status

Brad Abbott representing the DØ collaboration

440 West Brooks St. Norman OK 73019

Abstract. Run II at the Tevatron has begun. The DØ detector is expected to collect nearly 2 fb^{-1} of data at $\sqrt{s}$=2.0 TeV for Run II in approximately 2 years with a design instantaneous luminosity of 2×10^{32} cm^{-2} s^{-1}. This large data set will allow precision measurements in a number of important B physics areas and new measurements in B decays. This paper describes the prospects for several important B physics measurements, including sin(2β) using B $\rightarrow$ J/ψ K_s^0 decays, Δm_s using B_s mixing, the Λ_b lifetime and rare B decays.

INTRODUCTION

In this era of asymmetric e^+e^- B factories, the Tevatron provides an important and complimentary tool for studying b physics. Although the environment at the B factories is much cleaner and the backgrounds at the Tevatron are much larger, the Tevatron will play an important role in many areas of b physics. The Tevatron has a number of advantages over e^+e^- machines with sit at the $\Upsilon(4S)$. The b cross section in $\mathrm{p\bar{p}} \rightarrow \mathrm{b\bar{b}}$ at $\sqrt{s}$ = 2.0 TeV is orders of magnitude larger (150 μb) than at the B factories (1 nb). Additionally, with the larger center of mass energy available at the Tevatron, all flavors of B hadrons are produced including B_u, B_d, B_c, B_s, and Λ_b. This provides DØ a large sample for many different B physics measurements.

The DØ detector has recently undergone a number of important upgrades [1] to allow much improved performance in this high luminosity environment. The detector has enhanced its strengths of excellent calorimetry and extended muon coverage by installing a much improved tracking system. A silicon vertex detector consisting of both barrels and disks resides closest to the beam pipe. The silicon detector provides excellent vertexing capabilities with a primary vertex resolution of σ=15-30 μm in r-ϕ and σ=75-100 μm in z. A secondary vertex resolution of σ=40 μm in r-ϕ will allow DØ to accurately reconstruct and measure displaced vertices. A new tracker consisting of 74,000 scintillating fibers mounted on 8 carbon fiber cylinders provides tracking at larger radii. Both of these trackers reside in a 2 Tesla magnetic field. The combination of the silicon and fiber tracker provide excellent tracking capabilities. Tracks with $|\eta| < 3$ can be reconstructed with a momentum resolution of σ_{p_T}/p_T^2=0.002.

Other important upgrades include an improved muon system, a new preshower detector and an improved trigger system. These upgrades will allow DØ to trigger on muons with P_T of 1.5 GeV for $|\eta| < 2$ and to trigger on electrons with P_T of 1 GeV for $|\eta| <$ 2.5.

CP VIOLATION

Sin2β

One of the primary measurements expected from DØ is an accurate measurement of sin(2β). We expect to use the "Golden" decay mode B→ J/ψ K_s^0 with the J/ψ → $\mu^+\mu^-$ and the $K_s^0 \to \pi^+\pi^-$. Figure 1 shows the invariant mass of the B for Monte Carlo B → J/ψ K_s^0 decays after a constrained fit was performed. DØ expects to reconstruct nearly 40,000 events in this decay mode with an additional 30,000 events in the mode J/ψ → e^+e^-. The time dependent asymmetry

$$A(t) = \frac{\Gamma(\bar{B}^0 \to J/\psi K_s^0) - \Gamma(B^0 \to J/\psi K_s^0)}{\Gamma(\bar{B}^0 \to J/\psi K_s^0) + \Gamma(B^0 \to J/\psi K_s^0)}$$

can be related to the CKM parameter β by

$$A(t) = \sin(2\beta)\sin(\Delta m_d t)$$

In order to measure this asymmetry, the flavor of the B at production must be known. Many different flavor tagging techniques will be used in order to maximize the tagging performance. The flavor of the B will be determined using the charge of the lepton from semileptonic decays, the charge of the "away side" jet, and the charge of the soft pion nearest to the $B^0 \to$ J/ψK_s^0 decay. With these tagging techniques, studies have shown that an effective tagging efficiency εD^2 of 10% can be achieved, where ε is the tagging efficiency and D is the dilution factor D=2P-1, where P is the probability to determine a correct tag. We can estimate the expected measurement accuracy of sin(2β) using:

$$\sigma(sin2\beta) \approx e^{x_d^2\Gamma^2\sigma_t^2}\sqrt{\frac{1+4x_d^2}{2x_d}}\frac{1}{\sqrt{\varepsilon D^2 N}}\sqrt{1+\frac{B}{S}}$$

where Γ and $x_d = \Delta m_d/\Gamma$ are the decay width and mixing parameter of the B, N is the number of events, B/S is the background to signal ratio and σ_t, the proper time resolution, is approximately 100 fs. Using a S/B ratio of 0.75, an uncertainty on sin(2β) of 0.04 is expected after collecting 2 fb^{-1} using J/ψ → $\mu^+\mu^-$. A similar accuracy is expected for J/ψ → e^+e^- giving a combined accuracy on sin 2β of 0.03 after only 2 years of data.

DØ will also study CP violation in $B_s \to$ J/ψ φ decays which have similar trigger and reconstruction efficiencies as B→ J/ψ K_s^0. The asymmetry in this channel is expected to be small so any measured asymmetry could be a signal for new physics.

α and γ

By measuring an asymmetry in the decays $B_d \to \pi^+\pi^-$ and $B_s \to K^+K^-$, a measurement of α and γ may be possible [2]. One difficulty which arises in this measurement is the background due to $B_d \to K^+\pi^-$ and $B_s \to \pi^+K^-$ decays. DØ has limited particle ID

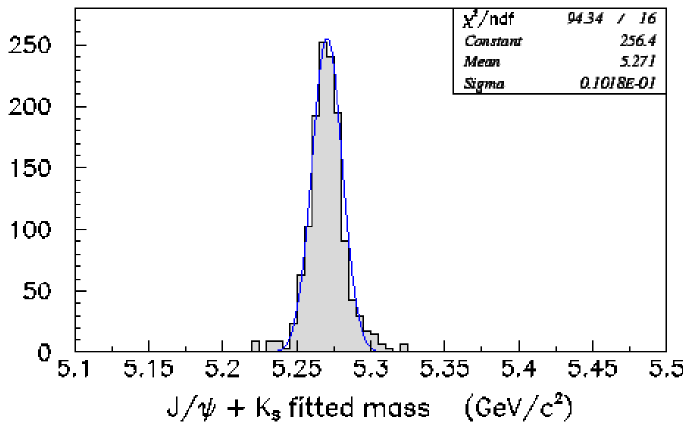

FIGURE 1. Reconstructed B mass using a constrained fit to B$\rightarrow$ J/ψ K_s^0.

capabilities so separating pions from kaons cannot be done. Therefore we expect large backgrounds in this measurement. Also triggering on these hadronic decay modes of the B will prove challenging. Due to limitations in our trigger bandwidth, DØ cannot trigger on two tracks with low p_T. The additional presence of a lepton in the event must be required to reduce the trigger rate. Since the flavor of the B must be known in order to measure an asymmetry and a lepton provides a very good flavor tag, DØ will require the opposite side B to decay semileptonically. Although this constraint seems harsh, it allows for a much easier method of triggering and flavor tagging. Simulations have shown a detection efficiency of $\sim$ 0.5% which includes both trigger and reconstruction efficiency. With 2 fb^{-1}, DØ expects to reconstruct approximately 500 $B_d \rightarrow \pi^+\pi^-$ events and 1000 $B_s \rightarrow K^+K^-$. Figure 2 shows the reconstructed B mass for four different decays. By combining the reconstructed mass and lifetime information, CP asymmetries can be extracted. Another difficulty which arises in determining α and γ are theoretical uncertainties due to possible large penguin contributions. A measured asymmetry may not directly translate into a measurement of α or γ. Due to these difficulties a determination of α and γ may be possible, but the level of uncertainty on these measurements is not yet known.

B_S MIXING

One of the measurements not possible at the e^+e^- B factories is B_s mixing. Measuring Δm_s is one of the highest priorities of DØ's B physics program. The oscillation frequency for B_s is expected to be much higher than for B_d ($\Delta m_d/\Delta m_s \approx$ 1/20) making this measurement challenging. Due to the high frequency of oscillation, one needs both very good decay length resolution and momentum resolution in order to measure the proper time with sufficient accuracy. There are many different decays which can be used to measure B_s mixing. The mode providing the easiest triggers are semileptonic

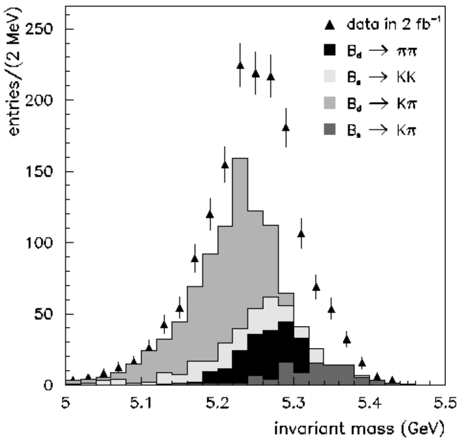

FIGURE 2. The reconstructed B mass for four different B decays, $B_d \rightarrow \pi\pi$, $B_d \rightarrow K\pi$, $B_s \rightarrow KK$, and $B_s \rightarrow K\pi$. Since DØ cannot separate kaons from pions, in all cases the pion mass has been assigned to the two tracks coming from the B vertex.

decays of the B_s such as $B_s \rightarrow \phi l^+ X\nu$. By requiring the other B in the event to decay semileptonically, one can trigger on the two leptons in the event. Tagging of the initial flavor and final flavor of the B is achieved by using the sign of the leptons. Large event samples are expected even using more exclusive decays of the B_s such as $B_s \rightarrow D_s^- l^+ \nu X$ where $D_s \rightarrow \phi X$ and $\phi \rightarrow K^+K^-$. In 2 fb^{-1} of data, we expect to reconstruct $\sim$ 40,000 events. However, due to the presence of the neutrino the B_s momentum is not accurately measured, limiting the Δm_s reach. It is expected that DØ can measure $x_s < 30$ using semileptonic decays of the B_s.

To more accurately measure the B_s momentum, hadronic decays of the B such as $B_s \rightarrow D_s\pi$ and $B_s \rightarrow D_s\pi\pi\pi$ must be used. Because the trigger rates will be too high without requiring a lepton in the event, the other B in the event must decay semileptonically. The initial flavor of the B is tagged by the charge of the lepton and the final flavor of the B by the charge of the D_s. Due to the strict restrictions required by the trigger, DØ expects to fully reconstruct $\sim$ 1000 hadronic B_s decays. Although this event sample is much smaller than in the semileptonic decay of the B_s, the superior momentum resolution allows a much more accurate measure of the proper time. A reach of $x_s < 30$ for the hadronic decays of the B_s is expected with 2 fb^{-1} of data.

RARE B DECAYS

With 2 fb^{-1} of data, DØ will have enough data to search for rare and exotic B decays. Flavor Changing Neutral Currents processes such as the decay $\mathrm{b} \rightarrow \mathrm{d}l^+l^-$ are forbidden at tree-level in the Standard Model. These processes require loop diagrams and are, therefore, sensitive to new physics making them very interesting.

The decay $B_d \rightarrow K^*\mu^+\mu^-$ with $K^* \rightarrow \pi K$ has a Standard Model branching ratio of

(1-1.5) $\times$ 10^{-6}. Non Standard Model physics will change the branching ratio and decay asymmetry. Since there are two muons in the event, these events can be triggered by requiring a two muon trigger. Requiring a secondary vertex well displaced from the primary and removing events with the dimuon mass around known resonances, will allow DØ to reconstruct approximately 700 events. Additionally $B_d \rightarrow K^* e^+ e^-$ and $B^+ \rightarrow K^+ \mu^+ \mu^-$ will be studied.

The rare decay $b \rightarrow s\mu^+\mu^-$ is theoretically very interesting but experimentally very difficult. Large backgrounds are difficult to separate from signal. To reduce background only a small dimuon mass window can be used. Assuming a Standard Model branching ratio of 6 $\times$ 10^{-6}, DØ expects to reconstruct about 1000 events in this channel. However, there will remain a large signal to background ratio of nearly 1:100. With this large background and theoretical uncertainties this measurement will be challenging.

Very rare decays such as $B_s \rightarrow \mu^+\mu^-$ will also be studied. Assuming the ratio between B_s and B_d is 40%, and assuming the Standard Model branching ratio of 4 $\times$ 10^{-9}, less than 10 events are expected to be found. However since the Standard Model branching ratio is so small for this decay, any signal cannot be Standard Model physics and may be a hint for physics beyond the Standard Model.

B_c decays will also be studied in the channel $B_c \rightarrow$ J/$\psi l \nu$. By triggering on the leptons from the J/ψ, we expect to reconstruct approximately 600 events which will allow much improved measurements on the mass and lifetime of the B_c .

Λ_B^0 LIFETIME

Current measurements of the Λ_b^0 lifetime show $\tau(\Lambda_b^0)/\tau(B^0)$=0.79$\pm$0.05 [3] while naive spectator model predicts this ratio to be unity. In the standard model, non spectator processes such as final state quark interference and W-boson exchange are too small to account for this deviation. Previous measurements often used semileptonic decays of the Λ_b^0 in order to achieve a large event sample. These measurements have the disadvantage that the momentum of the Λ_b^0 cannot be directly measured due to the presence of the neutrino. With the large data available in Run II, it is expected that DØ will be able to fully reconstruct nearly 15,000 events in the decay mode $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$. Using fully reconstructed events a lifetime resolution for the Λ_b^0 of 0.11 ps is expected (see Figure 3). It will be very interesting to see if the discrepancy between theory and data is present in this measurement.

CONCLUSIONS

The newly upgraded DØ detector is ready to collect high quality physics data. Many exciting B physics measurements are planned. In the next 2 years, we expect to measure Sin(2β) to an accuracy of better than 0.04. We can measure B_s mixing if x_s is less than 30. Rare decays will be studied with increased precision. Mass and lifetimes of b baryons will be accurately measured. These new results will significantly constrain the Standard Model or perhaps indicate previously unknown physics.

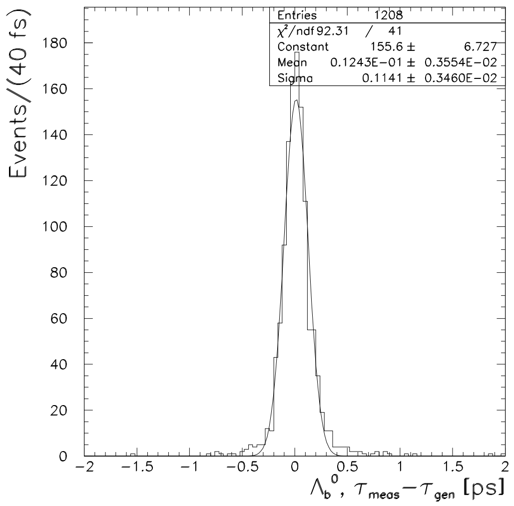

FIGURE 3. Distribution of measured minus generated lifetime for $J/\psi\Lambda^0$ candidates.

REFERENCES

1. The DØ upgrade, http://www-d0.fnal.gov/hardware/upgrade/upgrade.thml
2. R.Fleischer, Phys. Lett B **459** 306 (1999).
3. LEP B Lifetime Working Group, http://home.cern.ch/∼claires/lepblife.html