Tevatron B-Physics: Recent Results and Prospects

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Between 1992 and 1996, the CDF and D0 experiments have collected data samples of 110 pb^{-1} each of $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV at the Fermilab Tevatron. In the year 2001 the Tevatron commenced $p\bar{p}$ collisions again at $\sqrt{s} = 1.96$ TeV with the goal of delivering an integrated luminosity of 1 fb^{-1} per year. In the mean time the CDF and D0 detectors have undergone substantial upgrades which allow for a rich B physics program with unique capabilities. In this paper we discuss recent results and the B Physics prospects at the Tevatron with 2 fb^{-1} of data (Run IIa) or 15 fb^{-1} of data (Run IIa+Run IIb).

1. INTRODUCTION

In this paper we discuss the B Physics prospects for the CDF and D0 experiments at the Fermilab Tevatron in Run II. From August 1992 to February 1996, the CDF and D0 detectors collected a data sample of 110 pb^{-1} each of $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV and we refer to this period as Run I. The Tevatron commenced $p\bar{p}$ collisions again at $\sqrt{s} = 1.96$ TeV in the Spring of 2001 with an initial goal of delivering an integrated luminosity of 1 fb^{-1} per year, corresponding to approximately 10^{11} $b\bar{b}$ pairs produced per year. This current data taking period is referred to as Run II. The first phase of Run II is expected to last about three years yeilding a data sample of 2 fb^{-1}. Ultimately a data sample of approximately 15 fb^{-1} is expected to be collected before the turn-on of the LHC at $\sim$ 2007.

The main goals of the B Physics program at CDF and D0 for Run II are to provide precision measurements of the angles β and γ of the Unitarity Triangle as well as to exploit the B_s^0 and B_c^+ mesons and b baryons which are currently a unique feature of hadron colliders. CDF and D0 will also attempt to provide a measurement of the angle α of the Unitarity Triangle. A precision measurement of B_s^0 flavor oscillations will be very important for testing the unitarity of the Cabibbo-Kobayashi-Maskawa (CKM) mixing matrix and the exploration of CP violation in B_s^0 decays could manifest Physics beyond the Standard Model.

This paper is organized as follows. In section 2 we describe the Run II environment; in section 3 we present the prospects for the measurement of the angles of the Unitarity Triangle and of B_s^0 flavor oscillations. We also present plans for further studies of the B_s^0 meson as well as studies of the B_c^+ system and of rare B decays that are sensitive to new physics. Finally in section 4 we present our conclusions.

2. Run II environment

The rate of $b\bar{b}$ production at the Tevatron is considerably high, approximately 100 μb, and this, together with the fact that all b species are produced at the Tevatron, makes it a unique place for the study of b production and decay. Although the $b\bar{b}$ production cross section is only one part per thousand of the inelastic cross section, the CDF experiment has shown [1] that exclusive B channels can be succesfully reconstructed in a harsh hadron environment.

The new crucial accelerator components for Run II are the Main Injector, a new 150 GeV accelerator which injects protons and antiprotons into the Tevatron, and the Recycler which is an 8 GeV ring of permanent magnets which will collect the antiprotons after a store and re-use them. The Main Injector has been commissioned successfully and is expected to increase the rate of production of antiprotons by at least a factor of three above previous rates. The Recycler, to be used later in the Run, is in the commissioning phase. Detector issues are driven by the luminosity, the number of bunches and the time between crossings of the protons and antiprotons. In Run I the crossing time was 3.5 μs for 6 bunches and the typical luminosity of order 10^{31} cm^{-2}sec^{-1}. The crossing times that are expected in Run II are currently 396 ns for 36 bunches and later 132 ns for 103 bunches. The corresponding expected typical luminosities are 0.86×10^{32} cm^{-2}sec^{-1} and 1-2 $\times$ 10^{32} cm^{-2}sec^{-1} with peak luminosities of 2.0×10^{32} cm^{-2}sec^{-1} and 4.0×10^{32} cm^{-2}sec^{-1} respectively. So far, the typical luminosities are $\sim 10^{31}$ cm^{-2}sec^{-1}.

At CDF [2] and D0[3] the detector changes are to the tracking systems, to the calorimeters, to the muon systems, to the front-end electronics and the trigger electronics. In addition, D0 added a new 2 Tesla solenoidal superconducting magnet and CDF improved its particle identification capabilities.

CDF has constructed a new central wire drift chamber (COT), which has a drift time that is reduced by a factor of eight from Run I. dE/dx information for the tracks is also provided by the COT. There is also a new 7 layer (8 layers for 1< $|\eta|$ <2) silicon system in a barrel geometry that extends from a radius of r = 1.6 cm from the beam line to r = 28 cm. The layer closest to the beam pipe is a radiation-hard, single-sided detector called Layer 00 which employs recent LHC designs for sensors supporting high bias-voltages. This enables good signal-to-noise performance even after extreme radiation doses. The remaining seven layers are radiation-hard, double-sided detectors. This system allows track reconstruction in three dimensions and is expected to have an impact parameter resolution better than 30 μm for tracks with transverse momentum of 1 GeV/c. CDF has also replaced the gas calorimeters in the pseudorapidity region $|\eta| \geq 1.0$ with a new scintillating tile calorimeter. In the muon system some gups are closed in the azimuthal coverage for $|\eta| \leq 1.0$ and a new muon system has been built which is covering the region $1.0 \leq |\eta| \leq 1.5$. Finally a Time-of-flight (TOF) detector with expected resolution of 100 ps has been built which will allow a 2σ K/π separation for track momentum of less than 1.6 GeV/c.

D0 has constructed a new scintillating fiber tracker and a new silicon vertex detector with 4 barrel layers and disks which extend the tracking up to $|\eta|$ =2.5. New scintillating strip electromagnetic preshower detectors have been also built for the central and forward regions to help with the electron identification. D0 has improved as well its muon detection system in general, and has completely rebuilt its forward muon coverage.

To accomodate a 132 ns bunch-crossing time both experiments have essentially replaced all the front end electronics. CDF and D0 have had significant data acquisition and trigger updates as well.

Both experiments use versions of the SVX readout chip. CDF uses un upgraded version of the SVX chip (dead timeless readout) which allows a 50 kHz bandwidth into the Level 2 vertex trigger. This trigger is crucial for efficient triggering on two body decay modes of the B meson such as $B^0 \to \pi^+\pi^-$ and the B^0_s decay modes like $B^0_s \to D^-_s\pi^+$ and $B^0_s \to D^-_s\pi^+\pi^-\pi^+$. At CDF, fast tracking is now available at Level 1 with the XFT track processor which can find tracks of transvere momentum p_T > 1.5 GeV/c with good momentum and azimuthal resolutions. Information from the silicon detectors is available at Level 2. The SVT trigger processor [2] associates clusters formed from axial strips in the silicon detectors with tracks of p_T > 2 GeV/c found by the XFT, providing a measurement of the impact parameter of the track in the plane transverse to the beam axis. This way it becomes possible to trigger on tracks originating from the decay of long-lived b hadrons and therefore coming from vertices different than the primary vertex of the $\bar{p}p$ collision. This allows triggering on "all-hadronic" decays of b hadrons which are important for B^0_s mixing studies and for the measurement of CP violation.

In Fig. 1 we show the D^+ and D^+_s mass distributions based on the two-track trigger selection using the SVT at CDF.

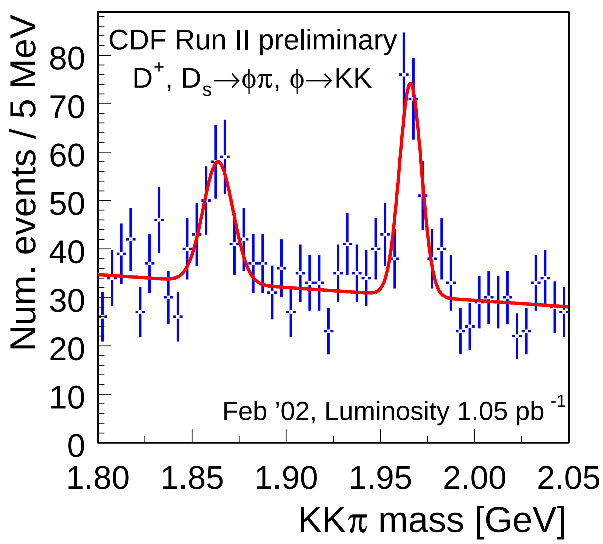

Figure 1. D^+ and D_s^+ mass distribution in 1.05 pb^{-1} of Run IIa data at CDF.

3. B Physics Expectations for Run II

CDF and D0 will address many important questions in B Physics in Run II. Many of the relevant measurements have already been investigated by CDF using the Run I data. In the following subsections we summarize some recent results and the expectations for Run II.

3.1. Measurement of sin(2β)

In the B system the measurements of CP violation that are related (without large theoretical uncertainties) to angles of the Unitarity Triangle are from asymmetries in the decays of neutral B mesons to CP eigenstates. For the measurement of the angle β the most popular mode is $B^0/\bar{B}^0 \to J/\psi K_s^0$. CP violation is expected to manifest itself as an asymmetry in the particle decay rate versus antiparticle decay rate to $J/\psi K_s^0$:

$$A_{CP} = \frac{N(\bar{B}^0 \to J/\psi K_s^0) - N(B^0 \to J/\psi K_s^0)}{N(\bar{B}^0 \to J/\psi K_s^0) + N(B^0 \to J/\psi K_s^0)}$$

where $N(\bar{B}^0 \to J/\psi K_s^0)$ is the number of mesons decaying to $J/\psi K_s^0$ that were produced as $\bar{B}^0$ and $N(B^0 \to J/\psi K_s^0)$ is the number of mesons decaying to $J/\psi K_s^0$ that were produced as B^0. In the Standard Model the CP asymmetry in this decay mode is proportional to sin2β: $A_{CP}(t) =$ sin2βsin(Δm_dt), where β is the angle of the Unitarity Triangle and Δm_d is the mass difference between the heavy and light B^0 eigenstates. Even though the time integrated asymmetry can be used to extract sin2β, measuring the asymmetry as a function of proper decay time is more advantageous. For the measurement of $A_{CP}(t)$ we need to reconstruct the decay mode $B^0/\bar{B}^0 \to J/\psi K_s^0$ with good signal-to-background ratio, measure the proper decay time t and determine whether the meson that decayed was produced as a B^0 or as $\bar{B}^0$. This last component is known as "b flavor tagging". The performance of the b flavor tags can be quantified by their efficiency ϵ and dilution D. The efficiency is the fraction of B candidates to which the flavor tag can be applied. The dilution is related to the probability P that the tag is correct: $D = 2P - 1$, that is, a perfect tag has $D = 1$ and a random tag has $D = 0$. The experimentally measured asymmetry or observed asymmetry is reduced by the dilution of the tag: $A_{CP}^{obs} = DA_{CP}$. The uncertainty in the asymmetry is inversely proportional to the square root of $\epsilon D^2 N$ where N is the number of events before the flavor tagging. The product ϵD^2 is usually called "flavor tag effectiveness". The CDF experiment using the entire Run I data of $B^0/\bar{B}^0 \to J/\psi K_s^0$; $J/\psi \to \mu^+\mu^-$ decays and three tagging algorithms (same-side tagging, soft-lepton tagging and opposite-side tagging) has found that sin2$\beta = 0.79\ ^{+0.41}_{-0.44}$(stat.+syst.) [4]. CDF has recently updated this measurement. The new measurement is based on 402±37 $B^0/\bar{B}^0 \to J/\psi K_s^0$; $J/\psi \to \mu^+\mu^-$, $K_s^0 \to \pi^+\pi^-$ events and 60±19 $B^0/\bar{B}^0 \to \psi(2S)K_s^0$; $\psi(2S) \to \mu^+\mu^-, J/\psi\pi^+\pi^-$, $K_s^0 \to \pi^+\pi^-$ events. In addition, the opposite-side jet tag has been improved by adding to the jet-charge tag a jet-kinematics tag and a kaon dE/dx tag. The new value is sin2β = 0.91 $^{+0.37}_{-0.36}$(stat.+syst.).

In Run IIa, the signal size at CDF is expected to increase to $\sim$ 20,000 $B^0/\bar{B}^0 \to J/\psi K_s^0$ decays where $J/\psi \to \mu^+\mu^-$ and $K_s^0 \to \pi^+\pi^-$. By triggering on $J/\psi \to e^+e^-$, the number of $J/\psi K_s^0$ events is expected to increase by approximately 50% [2].

The expected combined flavor tag effectiveness for Run II based on "same-side tagging", "soft-lepton tagging" and "jet-charge tagging" [2] is $\epsilon D^2 = 6.7\%$. The TOF detector will make it possible to use a new flavor tag based on kaons, since the decays of b hadrons containing $\bar{b}(b)$ quarks usually produce $K^+(K^-)$. With this additional flavor tag, the total flavor tag effectiveness is expected to increase to ϵD^2 =9.1% [1], resulting in an error on sin2β of 0.05 using the dimuon channel only in 2 fb^{-1} of data. Using ϵD^2 =9.8% [1] derived from CDF's Run I experience in B flavor tagging and the upgrades of the D0 detector, D0 expects δ(sin2β) = 0.04 using the dimuon channel only. The two experiments expect an error on sin2β of of approximately 0.02 with 15 fb^{-1} of data.

In Fig. 2 we show the J/ψ and ψ(2S) mass distributions from 6 pb^{-1} of Run II a data from CDF for $p_T^\mu > 1.5$ GeV/c, which is the muon transverse momentum cut at the trigger level.

In Fig. 3 we show the K_s mass distribution based on $\sim$ 1 pb^{-1} of Run IIa data from the D0 experiment, using silicon tracking only.

3.2. Extracting sin2α

CDF and D0 have considered extracting sin2α from the measurement of the asymmetry in the decay $B^0 \to \pi^+\pi^-$. The greatest challenge in this measurement is the trigger requirement.

At CDF, the trigger uses two oppositely charged tracks found by the XFT processor at Level 1, and at Level 2 it uses the SVT. The SVT measures the impact parameter of the tracks sufficiently precisely to distinguish tracks coming from heavy flavor decays from tracks coming from QCD jets. Tracks from QCD jets have non-zero impact parameter only due to measurement resolution.

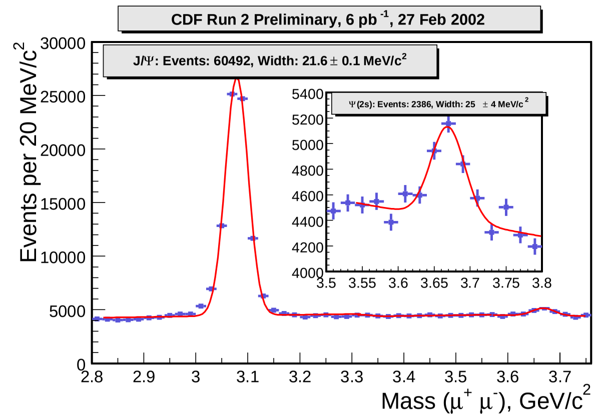

Figure 2. The J/ψ and ψ(2S) mass distributions in 6 pb^{-1} of data of Run IIa.

The $B^0 \to \pi^+\pi^-$ signal yield is obtained from Monte Carlo simulation [1,5]. Assuming $BR(B^0 \to \pi^+\pi^-) = (4.3^{+1.6}_{-1.4} \pm 0.5) \times 10^{-6}$ [6], CDF expects 5060 to 9160 fully reconstructed $B^0 \to \pi^+\pi^-$ events in 2 fb^{-1} of data. Combinatorial backgrounds have been studied using specialized test trigger data from Run I. To measure the CP asymmetry in $B^0 \to \pi^+\pi^-$ events one needs to study as well the *physics* backgrounds from $B^0 \to K\pi$, $B_s^0 \to K\pi$ and $B_s^0 \to KK$ decays. These backgrounds can be extracted from the untagged sample by making use of the invariant $\pi\pi$ mass distribution as well as the dE/dx information provided by the COT. We expect a $K - \pi$ separation of 1.3 σ for track momentum $p_T >$ 2 GeV/c. An initial simulation [2] indicates that the invariant mass resolution at $p_T(B)$ of 6 GeV/c will be about 20 MeV/c^2. The $B_s^0 \to K^+K^-$ peak lies directly under the $B^0 \to \pi^+\pi^-$ signal and it requires particle identification through dE/dx and TOF as well as a time dependent analysis. The relative yields expected are: $(B^0 \to K\pi)$:$(B^0 \to \pi\pi)$:$(B_s^0 \to KK)$:$(B_s^0 \to \pi K)$ $\sim$ 4:1:2:0.5 and they are expected to be measured with an uncertainty of a few percent. D0 expects about 1400 $B^0 \to \pi^+\pi^-$ reconstructed events in 2 fb^{-1}.

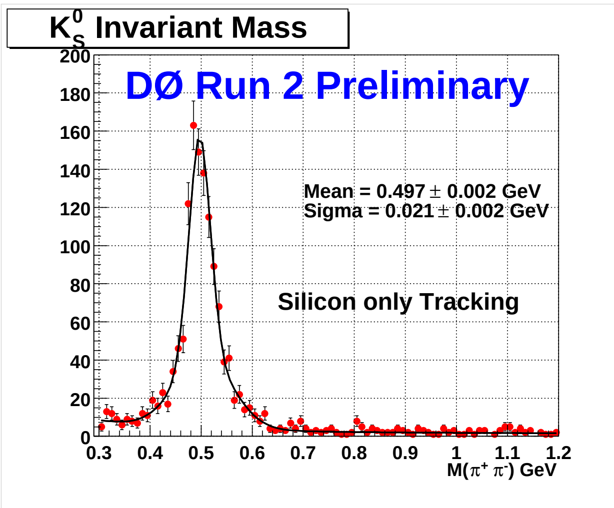

Figure 3. K_s mass distribution with the D0 detector in $\sim 1\ pb^{-1}$ of Run IIa data.

The final issue related to the extraction of the angle α from the measured time dependence of the CP asymmetry is the extraction of possible penguin contributions, in addition to the tree level diagrams, requiring theoretical input. As discussed in reference [7], the decay $B^0 \to \rho\pi^0 \to \pi^+\pi^-\pi^0$ provides enough observables to determine α from an analysis of the time-dependent three-pion Dalitz plot. This method provides a promising alternative way to determine sin2α, however, the reconstruction of low momentum π^0 mesons from their decays into two photons will be very challenging for CDF in Run II.

3.3. Prospects for $B^0_s - \bar{B}^0_s$ mixing

In the Standard Model, $B^0_s\bar{B}^0_s$ oscillations occur dominantly through top quark contributions to the electroweak box diagram. The size of the mixing is expressed in terms of the parameter x_s which is related to the mass difference between the two mass eigenstates and the average lifetime of the states by $x_s = \Delta m_s \tau(B^0_s)$. The value of x_s depends on the top quark mass, the B_s decay constant, the QCD bag parameters and corrections due to the breaking of SU(3) flavor symmetry.

A precision measurement of B^0_s flavor oscillations, combined with existing measurements of B^0 oscillations, will be very important for testing the unitarity of the CKM mixing matrix. The combined world average lower limit in B^0_s flavor oscillations [8] is currently $\Delta m_s > 14.9$ ps at 95% C.L. The currently favoured value of the Standard Model for x_s [9] is in the range $22.55 < x_s < 34.11$ at 95% C.L. If the value of x_s is small, less than 30, then both CDF and D0 can use semileptonic decay modes to measure the mixing by early 2003. If the value of x_s is significantly greater, then the exclusive modes will be needed.

The exclusive B^0_s decay modes used in such studies at CDF are $B^0_s \to D^-_s\pi^+$ and $B^0_s \to D^-_s\pi^+\pi^-\pi^+$ where the D^-_s is reconstructed as $\phi\pi^-$, $K^{*0}K^-$ or $K^0_sK^-$. For the determination of the signal yield it was assumed that $BR(D^-_s\pi^+) = (0.30 \pm 0.04)\%$ and $BR(D^-_s\pi^+\pi^-\pi^+) = (0.80 \pm 0.25)\%$ [5]. The data collection of B^0_s decay modes is based on the two-track trigger used for the collection of $B^0 \to \pi^+\pi^-$ events. CDF expects 75,000 reconstructed B^0_s decays in 2 fb^{-1} of data using all the above decay modes. For the extraction of the signals from combinatorial background CDF estimates a signal-to-background ratio in the range 1:2 to 2:1 [5].

Layer 00 and TOF play an important role for the evaluation of the sensitivity to $B^0_s - \bar{B}^0_s$ oscillations at CDF. The addition of Layer 00 provides more precise decay length measurements which improves the proper time resolution from σ_t = 60 fs to σ_t = 45 fs. The TOF system is expected to improve the ϵD^2 flavor tag effectiveness from 5.7% to 11.3%. Figure 4 shows the integrated luminosity required to achieve a five standard deviation observation of $B^0_s - \bar{B}^0_s$ mixing for three different signal-to-background ratios. The curves shown in the figure assume that excellent trigger and reconstruction efficiency was achieved and 75,000 reconstructed B^0_s decays. They also assume the excellent proper time resolution and flavor tagging efficiency CDF is aiming for. The x_s reach is expected to be 74 for S/B=2:1 and 69 for S/B=1:2. Therefore, the expected CDF reach in Run II covers very well the currently favoured values of x_s within the Standard Model.

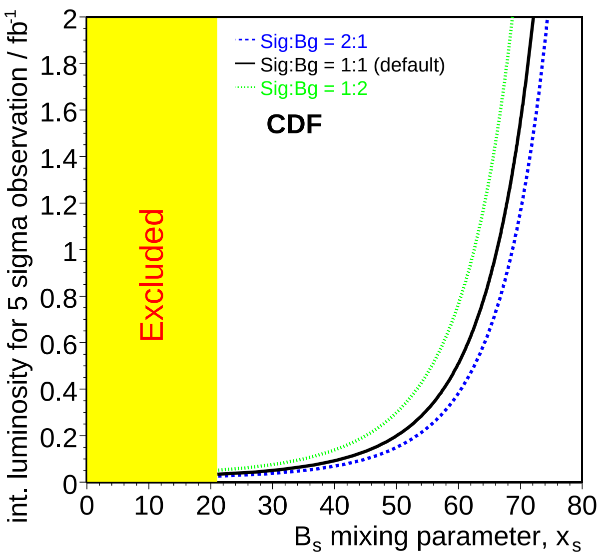

Figure 4. Integrated luminosity required to achieve a five standard deviation observation of $B_s^0 - \bar{B}_s^0$ mixing.

3.4. CP asymmetry in $B_s^0 \to J/\psi\phi$

While the CP asymmetry in $B^0/\bar{B}^0 \to J/\psi K_s^0$ measures the weak phase of the CKM matrix element V_{td}, the CP asymmetry in $B_s^0/\bar{B}_s^0 \to J/\psi\phi$ measures the weak phase of V_{ts} which is expected to be very small within the Standard Model. Observing an asymmetry in $B_s^0/\bar{B}_s^0 \to J/\psi\phi$ would signal the existence of an anomalous CP violating phase [7].

On the basis of the Run I experience, CDF expects that the yield of $B_s^0 \to J/\psi\phi$ in Run II will be about 60% of the $B_s^0 \to J/\psi K_s$ yield. The flavor tagging efficiency for $B_s^0 \to J/\psi\phi$ is expected to be 9.7% with the TOF detector. An angular analysis may be necessary to separate the different possible CP eigenstates contributing to this final state. If we neglect any loss of sensitivity due to this procedure, with the assumptions stated above and for x_s =25, CDF expects to measure the CP asymmetry in $B_s^0 \to J/\psi\phi$ with a resolution of about 0.1 with 2 fb^{-1}. A resolution between 0.03 and 0.06 is expected with 15 fb^{-1}, depending on the CP content of the final state. This is close to the Standard Model expectation of roughly 0.02, allowing for a sensitivity to new CP-violating physics in this mode.

3.5. Measurement of the angle γ

One of the best tools to extract the angle γ are measurements of the time-dependent asymmetries in B_s^0 decays. CDF has considered measuring γ using the decays $B_s^0 \to D_s^- K^+$ and $B^\pm \to DK^\pm$.

Data for the first decay mode will be collected at CDF with the same two-track trigger as for $B^0 \to \pi^+\pi^-$ and $B_s^0 \to D_s^-\pi^+$. In 2 fb^{-1} of data CDF expects to have about 850 $B_s^0 \to D_s^- K^+$ signal events before flavor tagging. In order to estimate the signal-to-background ratio CDF considered physics backgrounds and combinatorial background. The main physics background is from $B_s^0 \to D_s^{*-}\pi^+$ decays. Studies of Run I data indicate that the signal to background ratio should be between 0.5 and 2, not including improvements that may be coming from dE/dx and TOF information and three-dimensional vertexing.

To estimate the CDF reach for sinγ, Monte Carlo studies generated pseudo-experiments which included signal, backgrounds, resolution smearing as well as mistagging. Each pseudo-experiment was subjected to a fitter extracting $\sin(\gamma+\delta)$ and $\sin(\gamma-\delta)$ as fit parameters where δ is the strong phase. Within the first 2 fb^{-1}, the expected error on $\sin(\gamma \pm \delta)$ is around 0.4 to 0.7 depending upon what the backgrounds turn out to be. With 15 fb^{-1}, an uncertainty near 0.1 may be achievable.

Another way to extract the CKM angle γ had been originally suggested by Gronau, London and Wyler [10]. It is based on measuring $B^\pm$ decay rates involving $D^0/\bar{D}^0$ mesons and requires the interference between two amplitudes that are significantly different in magnitude causing the resulting asymmetries to be small. A refinement of this method has been suggested by Atwood, Dunietz and Soni [11] using decays to final states that are common to both D^0 and $\bar{D}^0$ and that are not CP eigenstates. In particular, large CP asymmetries can result from the interference of the decays $B^- \to K^-D^0$ and $B^- \to K^-\bar{D}^0$ with $D^0 \to f$ being a doubly Cabibbo suppressed decay while $\bar{D}^0 \to f$ is Cabibbo allowed. The measurement of interference effects in these modes allows the extraction of γ without the knowledge of $BR(B^- \to K^-\bar{D}^0)$.

In a preliminary study, CDF has investigated the two D^0 final states $K^-\pi^+$ and $K^-\pi^+\pi^-\pi^+$. The $B^- \to K^-D^0$ data samples would be collected using the two-track hadronic trigger used for $B^0 \to \pi^+\pi^-$ or hadronic B_s^0 decays. In 2 fb^{-1}, 100 to 140 events are expected to be recorded for $B^- \to K^-D^0$ with $D^0 \to K^-\pi^+$ and about the same number for $D^0 \to K^-\pi^+\pi^-\pi^+$. The studies indicate that if the combinatoric backgrounds can be controlled and if the necessary branching ratios are known with an uncertainty of 20%, a resolution on γ of $\sim 15^\circ$ could be possible with 15 fb^{-1}.

The angle γ can be also measured [1] by relating the CP violation observables in $B^0 \to \pi^+\pi^-$ and $B_s^0 \to K^+K^-$ and using U-spin symmetry to relate the ratio of hadronic matrix elements for penguin and tree diagrams. Detailed studies show that by using this technique, γ can be measured to $\sim \pm 10^\circ$ with a four-fold ambiguity in Run IIa, assuming that $\sin(2\beta)$ is pecisely known from $B^0 \to J/\psi K_s^0$. By allowing 20% SU(3) symmetry breaking, the theoretical uncertainty is expected to be $\sim \pm 3^\circ$. With 15 fb^{-1} of data, the statistical uncertainty should be $\sim \pm 3^\circ$, making this a very promising method for measuring γ.

3.6. B_c^+ Mesons and Rare B decays

We expect three major contributions to the B_c^+ decay width: $\bar{b} \to \bar{c}W^+$ with the c as a spectator, leading to final states like $J/\psi\,\pi^+$ or $J/\psi\,\ell^+\nu$; $c \to sW^+$, with the $\bar{b}$ as spectator, leading to final states like $B_s^0\,\pi^+$ or $B_s^0\,\ell^+\nu$; and $c\bar{b} \to W^+$ annihilation, leading to final states like $D\,K$, $\tau\,\nu_\tau$ or multiple pions. CDF searched for the decay channels $B_c^+ \to J/\psi\,\mu^+\,\nu$ and $B_c^+ \to J/\psi\,e^+\,\nu$ followed by $J/\psi \to \mu^+\mu^-$. $20.4^{+6.2}_{-5.5}$ events were observed in these decay channels and the B_c^+ mass and lifetime were measured to be $6.40 \pm 0.39(stat.) \pm 0.13(syst.)$ GeV/c^2 and $0.46^{+0.18}_{-0.16}(stat.) \pm 0.03(syst.)$ ps respectively[12].

The increase of statistics expected in Run II of the Tevatron Collider (increase in yield by a factor of ~50 in the J/ψ decay modes for the first 2 fb^{-1}), combined with refinement in technique and investigation of additional decay channels for the B_c^+ meson, should allow CDF to measure the B_c^+ mass, lifetime and production cross section with much better accuracy than the one achieved with the Run I data. It should also allow to measure ratios of branching ratios of the B_c^+ for various decay channels. Let us note here that for CDF the mass uncertainty from the B_c^+ hadronic channels involving a J/ψ is about 8 MeV/c^2, to be compared with the 411 MeV/c^2 uncertainty achieved in Run I with the semileptonic decay modes.

Rare B decays provide a stringent test of the Standard Model for possible new physics effects, such as an anomalous magnetic moment of the W and the presence of a charged Higgs. Experimentally, these rare decays are accessible at CDF via the dimuon trigger, which is one of the most important B physics triggers. CDF has performed a search for the decay modes $B^\pm \to \mu^+\mu^-K^\pm$, $B^0 \to \mu^+\mu^-K^{*0}$ and $B^0_{d,s} \to \mu^+\mu^-$ [13] using Run I data. The sensitivity of Run II CDF for the rare-decay modes $B_{d(s)} \to K^{*0}\gamma$, $\Lambda_b \to \Lambda\gamma$, $B_d \to \mu^+\mu^-K^{*0}$ and $B_{d(s)} \to \mu^+\mu^-$ are:

$$N(B_d \to K^{*0}\gamma) =$$
$$(170 \pm 50) \times \frac{\int L}{2fb^{-1}} \times \frac{Br(B_d \to K^{*0}\gamma)}{4.5 \times 10^{-5}}$$

$$N(B_s \to K^{*0}\gamma) = (12 \pm 4) \times \frac{\int L}{2fb^{-1}} \times \frac{Br(B_d \to K^{*0}\gamma)}{4.5 \times 10^{-5}}$$

$$N(\Lambda_b \to \Lambda\gamma) = (4.0 \pm 1.7) \times \frac{\int L}{2fb^{-1}} \times \frac{Br(\Lambda_b \to \Lambda\gamma)}{4.5 \times 10^{-5}}$$

$$N(B_d \to K^{*0}\mu\mu) =$$
$$(59 \pm 12) \times \frac{\int L}{2fb^{-1}} \times \frac{Br(B_d \to K^{*0}\mu\mu)}{1.5 \times 10^{-6}}$$

$$Sensitivity(B_d \to \mu\mu) = 3.5 \times 10^{-9} \times \frac{2fb^{-1}}{\int L}$$

$$Sensitivity(B_s \to \mu\mu) = 1.0 \times 10^{-8} \times \frac{2fb^{-1}}{\int L}$$

CDF expects to observe $\sim$440 $B_d \to \mu^+\mu^-K^{*0}$ events with 15 fb^{-1} with the dimuon plus displaced track trigger. This data will most probably allow to study both the invariant mass distribution of the dimuon pair as well as the forward-backward charge asymmetry in the decay. Both of these distributions are sensitive to physics beyond the Standard Model [14].

4. Conclusions

CDF has established a rich and competative B Physics program in Run I and has shown that the study of B Physics is possible in a hadron collider environment. Both CDF and D0 have upgraded detectors with unique capabilities for B-Physics measurements in Run II.

The expectations are: measurement of sin2β with an uncertainty of 0.04 in Run IIa and 0.02 in Run IIa+IIb; measurement of the CP aymmetry in the decays $B^0 \to \pi^+\pi^-$ and $B_s \to K^+K^-$; measurement of the angle γ to better than 10° in Run IIa and to about 3° in Run IIa+IIb; a five standard deviation sensitivity for a $B_s^0 - \bar{B}_s^0$ mixing measurement up to about $x_s = 60$ in Run IIa; measurement of the CP asymmetry in the decay $B_s^0 \to J/\psi\phi$ with about 10% uncertainty for $x_s = 25$ in Run IIa and between 3% and 6% in Run IIa+IIb; observation of exclusive B_c^+ meson decays; observation of b baryons and of rare B decays.

With these and other measurements that CDF and D0 will pursue in Run II, we expect to impose severe constraints on the Standard Model of weak quark mixing and CP violation and be sensitive to new physics.

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