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Fully Reconstructed Hadronic B-decays at CDF

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Abstract

The CDF detector at the Tevatron Collider (Fermilab) has collect data from 1992 to 1995. During these years we performed several measurements by using B hadronic decays. All the analysis exploited lepton triggers. The new measurements we present here are on radiative B decays $B \to K^{0*}\gamma$, $B \to \varphi\gamma$ and $\Lambda_b \to \Lambda\gamma$. We show also preliminary study for the determination of the branching ratios $B \to J/\psi K^+\pi^+\pi^-$ and $B \to \chi_c(1P)\,K^+$. In view of Run II we discuss CDF reaches using fully reconstructed B hadronic decays. This is done by scaling the number of events and the efficiencies found in Run I without rely on Monte Carlo simulation whenever it is possible.

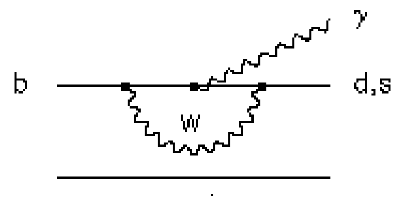

Figure 1: *Feynman diagram for $b \to s, d$ transition.*

1 Introduction

The study of hadronic B decays became one of the main task at CDF when we understood that they are necessary for many physics study. For example the measurement of $B_s^0 - \bar{B}_s^0$ oscillation frequency can be done only in a sample of fully reconstructed hadronic decays as we will discuss in detail later. While we were optimizing an hadronic trigger to study CP violation in $B_d \to \pi^+\pi^-$ decay, we realized that many other measurements in the CP violation sector would be possible by exploiting different hadronic decay channels, as for example $B_s \to D_s^{\mp} K^{\pm}$. Moreover, in certain hadronic decays ($B_s \to J/\psi\phi$ for examples) the Standard Model (S.M.) predicts a very small CP asymmetry, and, if on the contrary, the experimental measurements will point out a large asymmetry this will be a sign of new physics.

At the Tevatron the B production cross section is large, $\sigma = 3.52 \pm 0.38 \pm 0.48$ μb (measured using $B^+ \to J/\psi K^+$)[1], compared to 1.05 μb [1)] at the $\Upsilon(4S)$. Since the ratio σ_B/σ_{tot} is unfavorable at $p\bar{p}$ collider ($\sim 10^{-3}$), respect to dedicated machine (~ 0.28), an efficient trigger is needed. At CDF in Run I we did not have a trigger for hadronic B decays and the major part of these events are identified using J/ψ or leptons. Since the branching ratios is usually low our measurements in these channels are statistically limited. In Run II we will have a hadronic trigger which will require tracks with impact parameter greater than a given threshold. With this trigger we could select any B decays without rely on the presence of leptons in the final state.

2 Search for Radiative decays

We searched for $B \to K^{0*}\gamma$, $B \to \varphi\gamma$ and $\Lambda_b \to \Lambda\gamma$ in Run I data. In the Standard Model these decays can proceed through the so-called "electromagnetic penguin", a $b \to s$ or $b \to d$ transition. The dominant particle in the loop (see fig. 1) is the top quark if the nature is completely explained by S.M. If not, non-S.M. heavy particles could affect the branching ratio and enhance direct CP violating effects. Precision measurement of $B_d \to K^{*0}\gamma$, $B_s \to \varphi\gamma$ branching ratio can be used to test

[1] Charge conjugate decays are always implied throughout the paper unless mentioned otherwise

non perturbative QCD effects and reduce theoretical uncertainty in the extraction of $|V_{ub}|$, one of the Cabibbo-Kobayashi-Maskawa (CKM) matrix element [2],from $B \to \rho l \nu$ decay. But our final goal is to compare $B_d \to K^{*0}\gamma$ with $B_s \to K^{*0}\gamma$ in order to set limit on $|V_{td}| / |V_{ts}|$, other two elements of CKM matrix..

While the branching ratio $\mathcal{B}\left(B_d \to K^{*0}\right) = \left(4.55^{+0.72}_{-0.68} \pm 0.34\right) \times 10^{-5}$ has been measured by CLEO [3], for $B_s \to \varphi\gamma$ there is only one upper limit set by the DELPHI Collaboration [4] $\mathcal{B}\left(B_s \to \varphi\gamma\right) < 7.0 \times 10^{-4}$ at 90% CL. No measurement or limits are available for $\Lambda_b \to \Lambda\gamma$ decay. This search is supported by several theoretical works done recently [5]. They suggest to measure not only the decay rate but also the polarization. The expected branching ratio is $0.2 - 5 \times 10^{-5}$.
Our searches use two different sample of data:

- direct photons

- photons from conversion

2.1 Direct photon analysis

A trigger was specially designed which required an electromagnetic cluster plus two oppositely charged tracks. In Run IB with a threshold in transverse energy (E_T) at 10 GeV we collect $\sim 300k$ events in 22.3 pb^{-1} of data, in Run IC ($E_T > 6$ GeV) we had $\sim 500k$ in 6.6 pb^{-1} of $p - \bar{p}$ collisions.

The sensitivity of this method to Λ_b is low and we do not search for this decay in this data set.

2.1.1 Event reconstruction

In the events with at least one γ we search for $K^{*0} \to K^+\pi^-$ and $\varphi \to K^+K^-$ We loop over all oppositely charged tracks with $P_T > 2$ GeV/c and we retain combinations consistent with K^{*0} and φ by requiring $\left|M\left(K^+\pi^-\right) - M_{K^{*0}}\right| < 80$ MeV/c^2 and $\left|M\left(K^+K^-\right) - M_{\varphi}\right| < 10$ MeV/c^2. Because the lifetimes of the φ and K^{*0} mesons are much smaller than the B meson lifetime, the secondary vertex found by vertexing the two tracks indicates the point where the parent B meson decayed. We then require $c\tau$, the proper decay length, $0 < c\tau < 3$ mm and the isolation $I_B > 0.7$ ($I_B \equiv \frac{P_T(B)}{P_T(B)+\sum_{R\leq 1} P_T}$ where $P_T(B)$ is the transverse B momentum and $\sum_{R\leq 1} P_T$ is the transverse momentum of all tracks within a cone of $R = 1$ in the $\eta - \phi$ space around the B meson direction). The B mass resolution obtained is 110 MeV/c^2, dominated by the energy resolution of the photon.

To improve our sensitivity to the radiative decays we optimize our cuts by maximizing signal to noise ratio. The noise is constituted by events in the high mass region, $6 < M\left(K^{*0}\gamma, \varphi\gamma\right) < 10$ GeV/c^2. The requirements are:

- B consistent with coming from primary vertex;
- charged daughters of K^{*0} or φ decays be inconsistent with coming from the primary vertex.

We remain with 1 candidate in the signal region for $B \to K^{*0}\gamma$ and no event for $B_s \to \varphi\gamma$ with the expected background $N_{bg} < 0.1$ events.

2.1.2 Results

In order to calculate the branching ratio we use the ratio with a known branching ratio, $\mathcal{B}\left(B \to e^+\bar{D}^0 X\right)$:

$$\frac{N_{K^{*0}\gamma}}{N_{eD^0}} = \frac{f_d}{f_u + f_d} \times \frac{\mathcal{B}(B_d \to K^{*0}\gamma)\mathcal{B}(K^{*0} \to K\pi)}{\mathcal{B}(B_u \to e^- D^0 X)\mathcal{B}(D^0 \to K^-\pi^+)} \times \frac{\epsilon(K^{*0}\gamma)}{\epsilon(eD^0)} \cdot \frac{\mathcal{L}_{rad}}{\mathcal{L}_{eX}} \qquad (1)$$

$$\frac{N_{\varphi\gamma}}{N_{eD^0}} = \frac{f_s}{f_u + f_d} \times \frac{\mathcal{B}(B_s \to \varphi\gamma)\mathcal{B}(\varphi \to KK)}{\mathcal{B}(B_u \to e^- D^0 X)\mathcal{B}(D^0 \to K^-\pi^+)} \times \frac{\epsilon(\varphi\gamma)}{\epsilon(eD^0)} \cdot \frac{\mathcal{L}_{rad}}{\mathcal{L}_{eX}} \qquad (2)$$

In the ratio the b-quark production cross section cancels and the effect of systematic uncertainties is reduced.

It is important to reconstruct $B \to e^+\bar{D}^0 X$ using almost the same trigger used for the radiative search. We used the inclusive electron, where the main difference is the requirement of a track which extrapolate to the electromagnetic cluster. In this sample we search for $D^0 \to K^-\pi^+$ and the B is reconstructed in a such a way that its P_T is comparable with which of radiative decays. We then apply the same cuts used for radiative decays ending up with 40.7 ± 7.3 (27.4 ± 6.2) events in Run IB (Run IC).

In the equations 1 and 2 we use: $N_{K^{*0}\gamma,\varphi\gamma}/N_{eD^0X}$, the ratio of the observed number of events for radiative decays and $B \to e^+\bar{D}^0 X$, $\mathcal{L}_{rad}/\mathcal{L}_{eX}$, the ratio of the measured integrated luminosities; the ratio of fragmentation functions, $f_d/(f_u + f_d)$ and $f_s/(f_u + f_d)$, are taken respectively 1/2 and 0.213 ± 0.034 [6] and for the known branching ratios, $\mathcal{B}(K^{*0} \to K\pi)$, $\mathcal{B}(B_u \to e^- D^0 X)\mathcal{B}(D^0 \to K^-\pi^+)$ and $\mathcal{B}(\varphi \to KK)$ we refer to the PDG values [7]. The efficiencies ratios, $\epsilon_{K^{*0}\gamma,\varphi\gamma}/\epsilon_{eD^0X}$ have been evaluated using Monte Carlo data.

Since we do not have enough events in the signal region to perform a measurement, we set an upper limit conservatively without background subtraction:

$\mathcal{B}(B_d \to K^{*0}\gamma) < 1.6 \times 10^{-4}$ at 90% CL and 2.0×10^{-4} at 95% CL; $\mathcal{B}(B_S \to \varphi\gamma) < 2.4 \times 10^{-4}$ at 90% CL and 3.3×10^{-4} at 95% CL.

2.2 Conversion photon analysis

Given a photon conversion probability for our detector of 6% we can identify a sample of photons by an electron-positron pair produced through the external photon conversion before the central drift chamber. A data sample of ~ 74 pb^{-1} collected with the electron trigger with $E_T > 8$ GeV is used as a starting sample. The second electron is an oppositely charged track with $P_T > 0.5$ GeV/c.

2.2.1 Event reconstruction

The $B \to K^{*0}\gamma$ and $B_s \to \varphi\gamma$ identification is similar to the direct photon analysis. We apply the same cuts on the K^{*0}, φ invariant mass and on the isolation. The main difference is in the B decays products P_T. In the direct photon analysis we had a cut at 2 GeV/c due to the trigger while in this case we can go down to 0.5 GeV/c. Since the photon reconstruction is based on the tracking system the invariant mass resolution is 45 MeV/c^2 and it is dominated by the momentum resolution of the trigger electron.

The $\Lambda_B \to \Lambda\gamma$ has the Λ identified as $p\pi^-$. The minimum P_T required is 1.5 GeV/c for proton and 0.4 GeV/c for pion and their dE/dx information must be consistent with the expectations. A minimum impact parameter significance is required for pion and proton. We apply the isolation and the proper decay length cuts to improve the sample purity.

In order to improve our sensitivity to the radiative decays we optimize the selection cuts by maximizing the ratio $\epsilon_{sig}/\sqrt{\epsilon_{bg}}$ where ϵ_{sig} and ϵ_{bg} are our efficiencies for signal and background. The optimization is based on decay products P_T and impact parameter significance. At the end we have: 1 candidate for B_d with an expected background of 0.6 ± 0.3 events, no candidate in the B_s signal region with expected background of 0.1 ± 0.1 and 2 candidates for the Λ_B with expected background of 3.4 ± 0.6 events.

2.2.2 Results

As for the direct photon analysis we normalize ourselves to a known decay $B_u \to J/\psi K^-$:

$$\frac{N_{K^{*0}\gamma}}{N_{J/\psi K}} = \frac{f_d}{f_u} \times \frac{\mathcal{B}(B_d \to K^{*0}\gamma)\mathcal{B}(K^{*0} \to K\pi)}{\mathcal{B}(B_u \to J/\psi K^-)\mathcal{B}(J/\psi \to e^+e^-)} \times \frac{\epsilon(K^{*0}\gamma)}{\epsilon(J/\psi K)} \tag{3}$$

$$\frac{N_{\varphi\gamma}}{N_{J/\psi K}} = \frac{f_s}{f_u} \times \frac{\mathcal{B}(B_s \to \varphi\gamma)\mathcal{B}(\varphi \to KK)}{\mathcal{B}(B_u \to J/\psi K^-)\mathcal{B}(J/\psi \to e^+e^-)} \times \frac{\epsilon(\varphi\gamma)}{\epsilon(J/\psi K)} \tag{4}$$

$$\frac{N_{\Lambda\gamma}}{N_{J/\psi K}} = \frac{f_{\Lambda_B}}{f_u} \times \frac{\mathcal{B}(\Lambda_B \to \Lambda\gamma)\mathcal{B}(\Lambda \to p\pi^-)}{\mathcal{B}(B_u \to J/\psi K^-)\mathcal{B}(J/\psi \to e^+e^-)} \times \frac{\epsilon(\Lambda\gamma)}{\epsilon(J/\psi K)} \tag{5}$$

The $B_u \to J/\psi K^-$ decay is reconstructed exactly on the same data set used for radiative decays, with $J/\psi \to e^+e^-$. For this reason besides the b-quark production cross section also the integrated luminosity cancels in the ratio and many systematic uncertainties are reduced.

A $J/\psi \to e^+e^-$ is formed by the electron trigger and an oppositely charged track with $P_T > 1$ GeV/c. The B candidate is reconstructed by combining a track with $P_T > 2$ GeV/c with a J/ψ. We then apply the same cuts used for radiative decays reconstruction. In figure 2 we show the invariant mass distribution for the radiative decays and for $B_u \to J/\psi K^-$ after background subtraction. Only B_d and B_s are show, the Λ_B distributions are similar.

As in the direct photon measurement in the equations 3, 4 and 5 we use the PDG values for the known branching ratios and the CDF measurements for the fragmentation functions [6]. The efficiencies are evaluated using Monte Carlo data. The upper limits obtained with this method are 1.9×10^{-4}, 2.4×10^{-4}, 6.5×10^{-4} at 90% CL and 2.4×10^{-4}, 3.3×10^{-4}, 1.1×10^{-3} at 95% CL for $B_d \to K^{*0}\gamma$, $B_s \to \varphi\gamma$ and $\Lambda_B \to \Lambda\gamma$ respectively.

2.3 Combined Limits

The two methods are statistically independent and to combine the two measurements we simply add the number of candidates in each analysis. There are 2 candidates for B_d, 0 for B_s with expected backgrounds of 0.6 ± 0.3 and 0.1 ± 0.1 events respectively. We have 18% and 24% as combined systematic uncertainties for $B_d \to K^{*0}\gamma$ and $B_s \to \varphi\gamma$. The upper limits on the branching ratios without background subtraction are 1.1×10^{-4} and 1.2×10^{-4} at 90% CL, and 1.4×10^{-4} and 1.5×10^{-4} at 95% CL for $B_d \to K^{*0}\gamma$ and $B_s \to \varphi\gamma$ respectively.

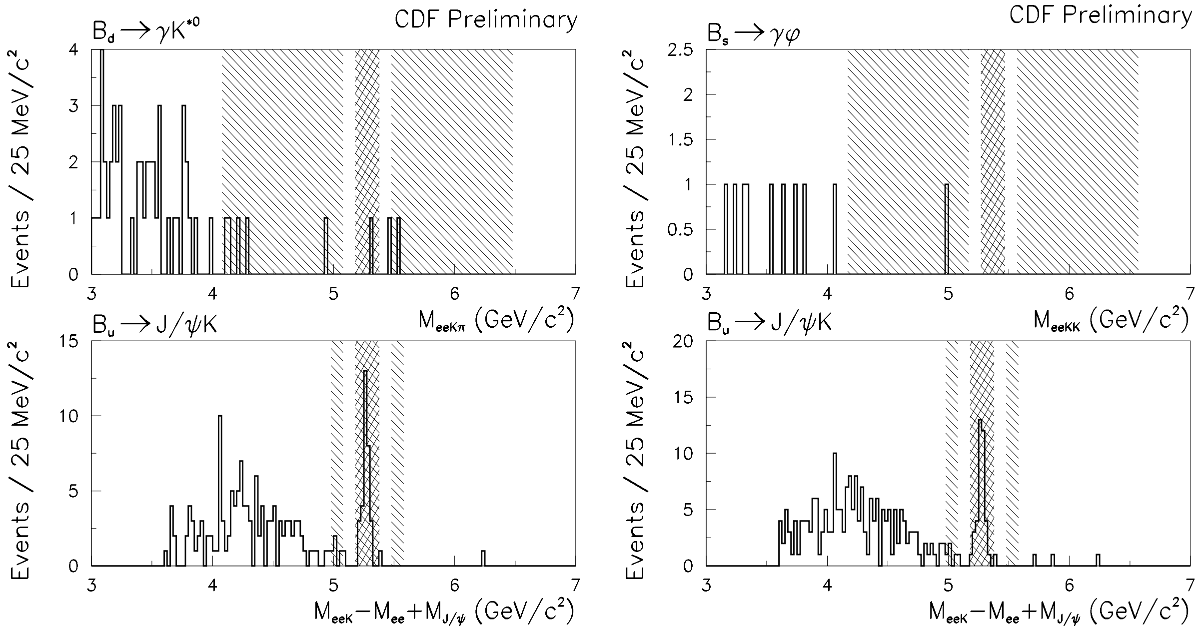

Figure 2: *Invariant mass distributions for* $B_d \to K^{*0}\gamma$ *(left) and* $B_s \to \varphi\gamma$ *(right). The bottom plots show the invariant mass of* $B_u \to J/\psi K^-$*, the reference signal.*

3 Search for $B^+ \to J/\psi K^+\pi^+\pi^-$ and $B^+ \to \chi_{c1}(1P)\,K^+$ decays

Since at CDF we have a huge sample of $J/\psi \to \mu^+\mu^-$, $\sim 63,000$ events, we can search for hadronic decay with a low branching ratio which have a J/ψ in the final state. The $B^+ \to J/\psi K^+\pi^+\pi^-$ branching ratio has been measured by CLEO [8] using only 6 events and it is $(1.4 \pm 0.6) \times 10^{-3}$. Also the $\mathcal{B}(B^+ \to \chi_{c1}K^+) = (1.0 \pm 0.4) \times 10^{-3}$ is poorly known even if it has been measured by CLEO [9] and ARGUS [10]. These branching ratios will be determined by measuring the ratio of our decays and $B^+ \to J/\psi K^+$, by using the last decay as reference signal.

We reconstruct $B^+ \to J/\psi K^+$ and $B^+ \to J/\psi K^+\pi^+\pi^-$ by performing a vertex-constrained fit of 1 and 3 tracks respectively with the J/ψ candidate. We then require a $c\tau > 80$ μm, $P_T(B) > 6$ GeV/c and impact parameter respect to the beam line less then 100 μm. To improve our sensitivity to $B^+ \to J/\psi K^+\pi^+\pi^-$ we also impose the B to be isolated by using the momentum and the topological event configuration. In figure 3(left) the invariant mass distribution for the events which pass the cuts is shown. We have 14 events in the signal region.

$B^+ \to \chi_{c1}K^+$ branching ratio will be also infered by using $B^+ \to J/\psi K^+$ as reference decay. χ_{c1} is reconstructed into $J/\psi\gamma$. We apply the standard CDF cuts on the photon and then we require the invariant mass of the $J/\psi\gamma$ candidate to be within 100 MeV/c^2 of the PDG χ_{c1} mass. $B^+ \to \chi_{c1}K^+$ events are reconstructed with the following requirements: $P_T(B) > 5$ GeV/c, $c\tau > 120\mu$m, and B impact parameter less then 80 μm. These cuts are optimized to have the higher sensitivity on

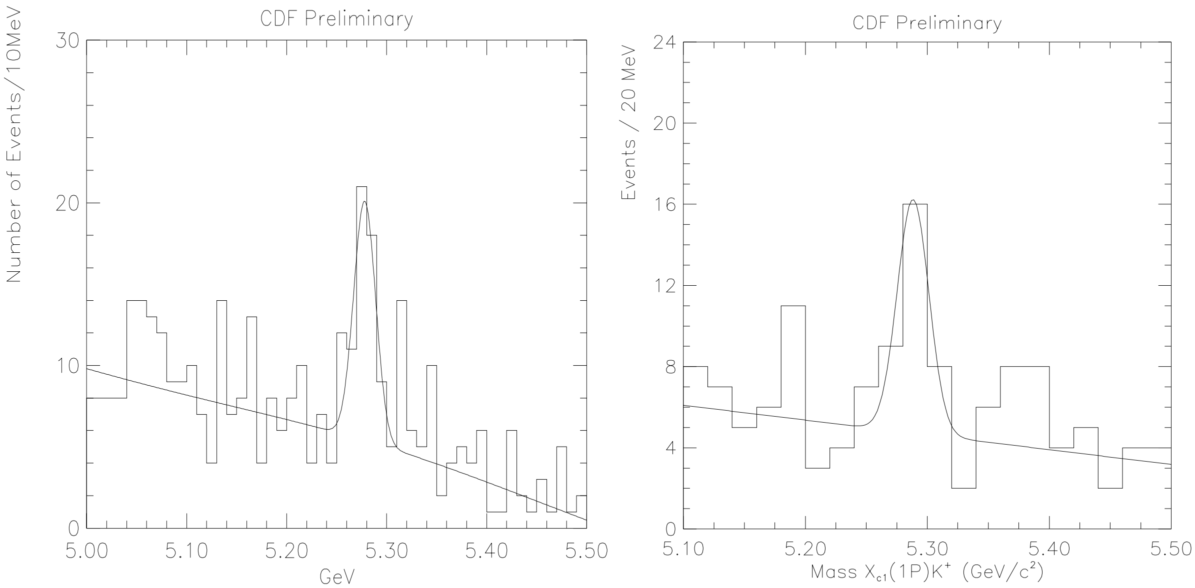

Figure 3: *Invariant mass distribution for* $B^+ \to J/\psi K^+$ *(left) and* $B^+ \to \chi_{c1} K^+$ *(right) .*

the signal. There are 10 events in the signal region obtained by fitting the invariant mass distribution shown in figure 3(right). The branching ratios evaluation is in progress and these results have to be considered preliminary.

4 Hadronic B decays in Run II

Hadronic B decays in Run II will be one of the major B physics item. We extrapolate results obtained in Run I to Run II by multiplying the number of events by: factor 20 for the integrated luminosity, 2 fb^{-1} of data expected in 2 years; other factors due to the improved geometrical acceptance and new trigger which depend on specified decay channel. We use, whenever it is possible our data and we rely on Monte Carlo simulation only for minor things.

4.1 Radiative decays

The plan for radiative decays trigger is still based on electrons. At level 1 we will ask for an electron with $P_T > 4$ GeV/c, then at level 2 we will use the hadronic trigger by requiring 2 tracks, one of which with large impact parameter. In 2 fb^{-1} of data we expect: ~ 1000 $B_d \to K^{*0}\gamma$, ~ 400 $B_s \to \varphi\gamma$ and ~ 10 $B_s \to K^{*0}\gamma$.

With the new tracking system we expect to have an invariant mass resolution $\sigma_B \sim 30$ MeV/c^2 that means we can separate B_d from B_s in $K^{*0}\gamma$ at the level of 3 standard deviations and we could measure the relative branching ratio.

With 1000 events of $B_d \to K^{*0}\gamma$ and by assuming the detector performances we had in Run I we can search for the CP violating asymmetry $\mathcal{A}_{CP} \approx$

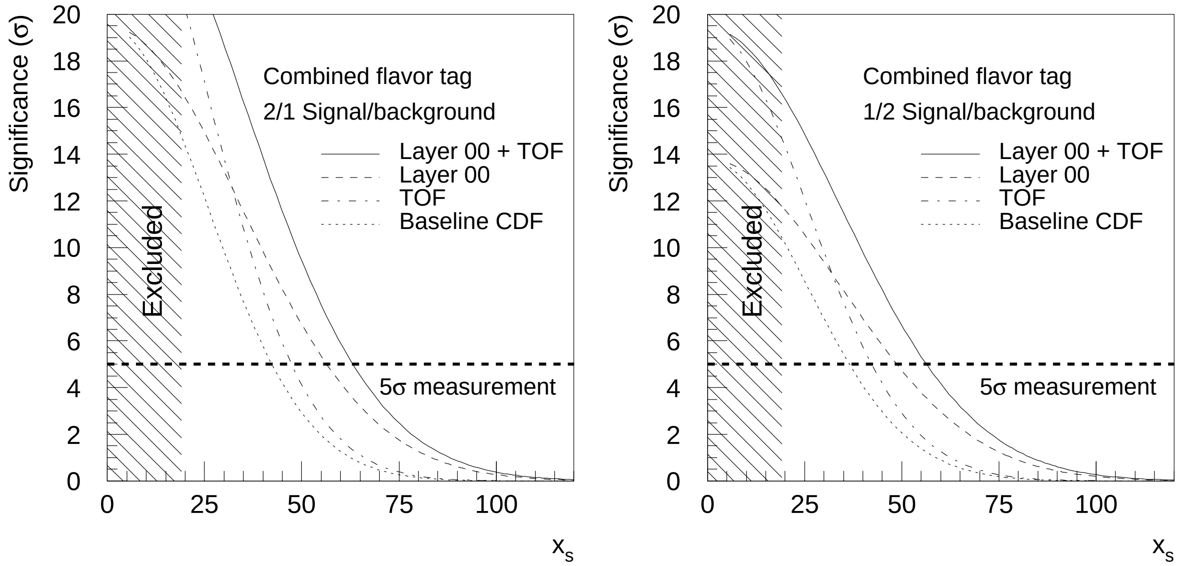

Figure 4: *Significance on $x_s$in standard deviations versus x_s.*

$$\left(N\left(\bar{B}\to \bar{K^{*0}}\gamma\right)-N\left(B\to K^{*0}\gamma\right)\right)/\left(N\left(\bar{B}\to \bar{K^{*0}}\gamma\right)+N\left(B\to K^{*0}\gamma\right)\right)$$

4.2 $B_s^0-\bar{B}_s^0$ oscillations

One of the unitarity test may come from the measurement of $\sin(2\beta)$(one angle of the unitarity triangle) and $|V_{td}/V_{ts}|$. At the Tevatron we have the unique capability to do both.

In order to measure the oscillation frequency, Δm_s, we need the precise decay time $t=m_B\frac{L}{P}$ (where m_B is the B mass, P its momentum and L the decay length) and the B flavor identification at decay and production time. In Run I we set a limit on $\Delta m_s>5.8$ ps^{-1} at 95% CL using $B_s\to\varphi l X\nu$ [11)] The significance on $x_s=\Delta m_s/\tau$ can be written :

$$Sig\left(x_s\right)=\sqrt{\frac{N\epsilon D^2}{2}}e^{-(x_s\sigma_{ct}/\tau)^2/2}\sqrt{\frac{S}{1+S}} \tag{6}$$

which depend on the flavor tagging effectiveness, ϵD^2, on the signal events S and on the proper time resolution σ_{ct}, the most critical parameter when Δm_s becomes very high. In order to be able to resolve B_s oscillations we need a good proper time resolution. This is possible only with fully reconstructed decays where we precisely measure the momentum. By using the hadronic trigger we can have 20,000 events of $B_s^0\to D_s^-\pi^+$ and $B_s^0\to D_s^-\pi^+\pi^-\pi^+$ with $D_s^-\to\varphi\pi^-$. In these events we can reach $\epsilon D^2=11.3\%$ and $\sigma_t=0.045$ ps $\oplus\, t\cdot\sigma_{P_T}/P_T$ which is dominated by the constant term for fully reconstructed decays. In figure 4 we plot the significance as function of x_s for a signal to noise ratio of 1:2 and 2:1. In Run II we will have a sensitivity up to $x_s=63$ for a 5σ measurement.

4.3 Expectations for CP violation

4.3.1 $\sin(2\beta)$

In order to evaluate which will be the error on $\sin(2\beta)$ we scale the errors we had on Run I [12]. What we measure $\mathcal{A} = D\sin(2\beta)$ and the error on $\sin(2\beta)$:

$$\sigma\left(\sin\left(2\beta\right)\right) = \frac{\sigma\left(\mathcal{A}\right)}{D} \oplus \sin\left(2\beta\right)\frac{\sigma\left(D\right)}{D} \tag{7}$$

The first error term is statistical and the second one is systematic due to the imperfect tagging. In Run I we had 198 $J/\psi K_s^0$ with precise decay time determination, in Run II we expect 10,000 events if we consider the increase in the integrated luminosity and the improvements in the detector. The statistical error becomes 0.078 and 0.067 if we include the benefit of the time of flight system (TOF). The better detector will help also in tagging the events. The expected tagging effectiveness is $\epsilon D^2 = 6.7\%$, 9.1% with TOF. To understand the tagging we use samples of $B \to J/\psi K^+$ and $B \to J/\psi K^{*0}$. In Run II we will have bigger samples also of these decays and we will better determine the mistagging rate. At the end what we called systematic error will scale with the number of events. We will have $\frac{\sigma(D)}{D} = 0.031$ or 0.027 by making use of the time of flight. The final error is, assuming $\sin(2\beta) = 1$, $\sigma(\sin(2\beta)) = 0.084$ or 0.072 with TOF.

4.3.2 $\sin(2\alpha), \sin(2\gamma)$

The measurement of $\sin(2\alpha)$, and $\sin(2\gamma)$ will be much more difficult even if we neglect the theoretical problems. To evaluate $\sin(2\alpha)$ we plan to use $B_d \to \pi^+\pi^-$. We expect to collect $10,000$ events in 2 fb^{-1} of data with the hadronic trigger. To separate the signal from the physics background, mainly $B_d \to K\pi$, $B_s \to K\pi$ and $B_s \to KK$, we exploit the different mass distribution and the different asymmetry oscillation frequencies. With the mass resolution achievable in Run II we can measure the asymmetry with an error $\sigma(\mathcal{A}) \sim 0.01$. The study for $\sin(2\gamma)$ ate the moment is based on Monte Carlo data. We are studying how to extract $\sin(2\gamma)$ from $B_s \to D_s^{\mp}K^{\pm}$. We are considering also a method proposed by R.Fleischer [13] to extract $\sin(2\gamma)$ from the measurement of asymmetry in the decays $B_d \to \pi^+\pi^-$ and $B_s \to KK$. With the first method we can reach $\sigma(\sin(\gamma \pm \delta)) \approx 0.7$ where δ is a strong phase present in the decay. For the second method the sensitivity is under evaluation.

4.3.3 *CP violation beyond Standard Model*

The asymmetry in $B_s \to J/\psi\varphi$ will measure the weak phase of V_{ts} which is expected to be small. Observing a large asymmetry would signal new physics beyond the Standard Model. Based on Run I data experience [14] we expect that the yield of $B_s \to J/\psi\varphi$ in Run II will be about 60% of $B \to J/\psi K_s^0$. With a tagging effectiveness of 9.7% we can reach an error on the asymmetry $\mathcal{A} \sim 0.1$ for $x_s \sim 25$. For large x_s the resolution worsen but not dramatically.

5 Summary

CDF had done several measurements using Run I data by exploiting fully reconstructed B decays. With the experience gained in these analysis and the planned capabilities of Run II detector we are able to project our expectation for Run II. We expect to measure $\sin(2\beta)$ with a precision of 0.072 and the asymmetry in $B \to \pi^+\pi^-$ with an error of 0.1. We will have a 5 standard deviation sensitivity for $B_s^0 - \bar{B}_s^0$ oscillations up to $x_s = 63$. Beyond the Standard Model we can search for CP violating effect in radiative decays and we will have an uncertainty of $\sim 10\%$ in the asymmetry of $B_s \to J/\psi\varphi$ for $x_s \sim 25$. Many important tests to Standard Model and Models beyond that will be done uniquely at the Tevatron using fully reconstructed hadronic B decays in the next years.

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