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CDF

Prospects for Measuring B_s Mixing at CDF

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1. INTRODUCTION

1.1 CDF B Physics Potential

The original design of the Collider Detector at Fermilab (CDF)[1] was optimized for high p_T physics measurements associated with W and Z boson, top quark, and QCD jet production. This choice resulted in an emphasis on the central pseudorapidity region ($|\eta| < 1.0$) for detector coverage. Thus, CDF has excellent tracking ($\Delta p_T/p_T = 0.0066 \oplus 0.0014 p_T$), good calorimetry, and a suitable muon system in the central region. Even with this limited coverage, the large $\bar{p}p \rightarrow bX$ cross section of nearly 100 μbarns for $|\eta| < 1.0$ has allowed the CDF experiment to make many B physics measurements[2]. In addition, with the successful operation of the CDF silicon vertex detector (SVX)[3], the capability for making time-dependent B_s mixing measurements becomes a reality. Upgrade plans, which include extending the tracking and lepton identification into the forward region and the implementation of a high-rate DAQ system, make a time-dependent B_s mixing measurement an attractive goal during the anticipated high-luminosity Main Injector collider runs. We discuss here the feasibility and potential of making a B_s mixing measurement based on extrapolations of the current CDF detector performance using colliding beam data and the expected upgrade plans.

1.2 Physics Motivation

The physics motivation for measuring the B_s mixing parameter X_s has been discussed many times[4]. First, it allows an independent measurement of the CKM matrix element V_{ts}, which is expected to be equal in magnitude to V_{cb}. Equation (1) gives the standard expression for X_s (there is a similar expression for X_d), in which top quark exchange in the box diagrams is assumed to be dominant:

$$X_s \equiv \frac{(\Delta M)_{B_s}}{\Gamma} = \tau_{B_s}\frac{G_F^2}{6\pi^2}M_W^2 M_{B_s}(f_{B_s}^2 B_{B_s})\eta_{B_s} y_t f_2(y_t) \mid V_{ts}^* V_{tb} \mid^2, \qquad (1)$$

where τ_{B_s} and M_{B_s} are the lifetime and mass of the B_s meson, B_{B_s} and f_{B_s} are the B_s bag parameter and decay constant, η_{B_s} is a QCD correction factor and $y_t f_2(y_t)$ depends on the

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top quark mass. We see here the dependence on the B_s mass and lifetime; the former has been measured recently in the $B_s \rightarrow J/\psi\phi$ decay mode at CDF[5], and the latter is expected to come from the same channel in the near future.

A measurement of the ratio of X_s to X_d allows cancellation of the top quark mass dependence and reduced dependence on the bag parameter-decay constants. This results in an improved measurement of V_{td}, as shown in Equation (2):

$$\frac{X_s}{X_d} \propto \frac{f_{B_s}^2 B_{B_s} \mid V_{ts} \mid^2}{f_{B_d}^2 B_{B_d} \mid V_{td} \mid^2}. \tag{2}$$

V_{td} of course contains the phase of the CKM matrix, which is thought to be the source of CP-violation in the Standard Model. Calculation of the ratio $f_{B_s}^2 B_{B_s}/f_{B_d}^2 B_{B_d}$ is believed to be more reliable and have less error than determining $f_{B_s}^2 B_{B_s}$ or $f_{B_d}^2 B_{B_d}$ alone[6]. Finally, the value of X_s is necessary for asymmetry measurements related to the unitary triangle angle γ in the B_s decay modes.

Standard model prediction of X_s places it in the range $10 - 30$ for a top mass less than 200 GeV[7]. These large values of X_s correspond to rather rapid oscillations of the B_s meson flavor and provide an experimental challenge to measure time-dependent B_s mixing. This is in contrast to the X_d measurements performed by ARGUS[8] and CLEO[9] which result in combined average[10] $X_d = 0.665 \pm 0.088$.

2. EXPERIMENTAL APPROACH

2.1 Precursor Measurements

We see the CDF approach to measuring B_s mixing as a "walk before you run" strategy. Although the current priority for CDF is the study of high P_t phenomena, steady progress has been achieved in the identification of B decays and in the use of the silicon detector and lepton-identification tools. CDF has already made a measurement of time-integrated B^0 mixing[11]. This will be improved on in the data sample taken in Run 1A ($\sim$ 20 pb^{-1}) and in the soon to be acquired Run 1B data (an additional 60 pb^{-1} or more is expected on tape).

Run 1A data may also allow a time-integrated B_s mixing measurement through lepton-D_s, lepton charge correlation. Such a measurement would have little X_s reach but might shed some light on the $b \rightarrow B_s$ and $b \rightarrow B_d$ fractions at CDF when combined with the time-integrated B^0 measurement. Another possibility in the present Run 1A data is a time-dependent B_d mixing measurement using lepton-secondary vertex, lepton correlations. In this case, no clear charm signal is identified (to maintain statistics), but the lepton associated secondary vertex position is plotted for same and opposite sign lepton pairs. Since the B_d oscillation is so slow, rather poor resolution in the decay time may still yield a time-dependent measurement of X_d . The LEP experiments have already demonstrated time-dependent B_d mixing in lepton-associated charm modes[12].

2.2 General Considerations

The general method for any mixing measurement requires determining the flavor of a neutral B meson (B_d or B_s) at production and decay. The B meson flavor is usually determined through the associated lepton from B semileptonic decay. The lepton from the other B gives the flavor of the first B at production, and the lepton from the B itself gives its flavor at decay. There is, of course, dilution of the lepton tag due to B_d, B_s oscillations, charm cascade decays, and fake leptons. The effects of dilution on the B_s mixing measurement are discussed elsewhere[13]. Other tagging methods include the charge sign tagging from associated strange particle ($K^\pm$) production in the $b \rightarrow c \rightarrow s$ cascade, charge counting of tracks associated with the B decay vertex, and resonant or non-resonant tagging of the first generation hadron produced in the $b \rightarrow B$ hadronization[14].

The time dependent oscillation of neutral B meson is given by the following mixing probabilities:

$$Prob(B \rightarrow \overline{B}) = \frac{1}{2}e^{-t/\tau}(1 - cos(Xt/\tau)), \tag{3}$$

$$Prob(B \rightarrow B) = \frac{1}{2}e^{-t/\tau}(1 + cos(Xt/\tau)), \tag{4}$$

where X is the mixing parameter. So, given a set of events which are tagged as either $B \rightarrow \overline{B}$ or $B \rightarrow B$ events, the distribution of these events should follow the exponentially-damped cosine dependence given above. The specific cosine dependence can be isolated by taking the difference of mixing probability equations and dividing by the sum:

$$\frac{Prob(B \rightarrow B) - Prob(B \rightarrow \overline{B})}{Prob(B \rightarrow B) + Prob(B \rightarrow \overline{B})} = cos(Xt/\tau). \tag{5}$$

The ability to resolve the cosine oscillations for a given mixing parameter X depends on the proper time resolution σ_t/τ. The decay time $t = L/\beta\gamma c = Lm/pc$ depends on the decay length, momentum, and mass. This relation also holds in the transverse plane, which is more suitable for solenoid geometry central collider detectors like CDF, so that $t = L_T m/p_T c$. The proper time resolution σ_t/τ is then given by:

$$\frac{\sigma_t}{\tau} = \sqrt{(\frac{\Delta L_T}{L_{0T}})^2 + (\frac{t}{\tau}\frac{\Delta p_T}{p_T})^2}, \tag{6}$$

where $L_{0T} = p_T c\tau/m$. The proper time resolution σ_t/τ thus depends on the transverse decay length resolution of the B vertex and the B momentum resolution. For a detector like CDF, with a transverse decay length resolution of ~ 50 microns and $\Delta p_T/p_T \sim 0.2\% p_T$, the proper time resolution is dominated by the transverse decay length resolution for fully reconstructed B_s decays and is dominated by the B_s momentum resolution for partially reconstructed decays.

The maximum X_s reach for a given proper time resolution can be derived rather simply from the cosine dependence[15]. If the product of $X_s\sigma_t/\tau$ is greater than $\pi/2$, then there will be smearing between the positive and negative amplitudes of the cosine and the cosine dependence will be washed out. This constraint thus sets the maximum X_s reach for a given proper time resolution:

$$X_s^{max} = \frac{\pi}{2}\frac{\tau}{\sigma_t}. \tag{7}$$

So, for example, the maximum X_s reach for $\sigma_t/\tau = 0.10$ is ~ 16. Different B_s decay modes have different proper time resolutions and X_s sensitivities depending on whether the decay is fully or partially reconstructed. Purely hadronic B_s decays such as $B_s \rightarrow D_s\pi$, which are so far less easily identified in $\overline{p}p$ collisions, offer the best proper time resolution and thus the largest range of probing for X_s . Unfortunately, the clean $B_s \rightarrow J/\psi\phi$ signature offers no help for measuring B_s mixing since the flavor of the B_s at decay cannot be determined from the final state particles. As mentioned above, this mode will however eventually yield a precision measurement of the B_s lifetime, which will be needed for a B_s mixing analysis. For the present CDF tracking chamber and vertex detector, the proper time resolution for fully reconstructed B_s decays is ~ 0.08, allowing X_s to be measured up to 20 before resolution effects significantly smear out the oscillations. The addition of an inner layer of silicon pixels to improve the decay length resolution is a possible way to extend the X_s reach.

In Table 1, we list the product branching ratios for exclusive B_s mixing decay modes. We consider here only the $B_s \to D_s\pi\pi\pi$ and $B_s \to D_s\pi$ decays. For the decay branching ratios, we used the $s \to d$ interchanged $B_d \to D\pi\pi\pi$ and $B_d \to D\pi$ Particle Data Group[16] (PDG) values. These B_s decay modes have the advantage of containing a D_s, which can be cleanly identified in its $\phi\pi$ (already seen at CDF[17]) or K^*K final states. Neither of these B_s decays has been reconstructed yet at CDF, but several purely hadronic B_s decays have been seen at LEP[12]. Run 1A or Run 1B data at CDF should yield several of these events. Of course, in order to obtain large samples of these exclusive B_s events on tape, the single lepton threshold (on the lepton trigger from the other B) will have to be lowered and the detector coverage improved, or these purely hadronic decays will have to be triggered directly with a secondary vertex trigger. CDF is now planning a secondary vertex trigger for the Run II collider run and beyond[18]. Initially this trigger will select on high impact parameter tracks and look for $B^0 \to \pi^+\pi^-$ decays. Improvements to this trigger should allow online triggering of separated secondary vertices Summing up the two B_s decay modes with the 3 D_s final states, we find a combined product branching ratio of 4.2x10^{-4}.

Table 1: Branching Ratios for Exclusive B_s Mixing Modes.

Decay Mode	Branching Ratio	Comment
$D_s \to \phi\pi$	$(2.8 \pm 0.5)\%$	PDG, 1992
$D_s \to \phi\pi\pi\pi$	$(1.2 \pm 0.4)\%$	PDG, 1992
$D_s \to K^*K$	$(2.6 \pm 0.5)\%$	PDG, 1992
$\phi \to KK$	$(49.1 \pm 0.8)\%$	PDG, 1992
$K^* \to K\pi$	$(67.0 \pm 0.0)\%$	PDG, 1992
$B_s \to D_s\pi\pi\pi$	(8.0 ± 2.5)x10^{-3}	from B_d mode, PDG, 1992
$B_s \to D_s\pi$	(3.2 ± 0.7)x10^{-3}	from B_d mode, PDG, 1992
$B_s \to D_s\pi\pi\pi, D_s \to \phi\pi, \phi \to KK$	(1.1 ± 0.4)x10^{-4}	product branching ratio
$B_s \to D_s\pi\pi\pi, D_s \to \phi\pi\pi\pi, \phi \to KK$	(4.7 ± 2.2)x10^{-5}	product branching ratio
$B_s \to D_s\pi\pi\pi, D_s \to K^*K, K^* \to K\pi$	(1.4 ± 0.5)x10^{-4}	product branching ratio
$B_s \to D_s\pi, D_s \to \phi\pi, \phi \to KK$	(4.4 ± 1.2)x10^{-5}	product branching ratio
$B_s \to D_s\pi, D_s \to \phi\pi\pi\pi, \phi \to KK$	(1.9 ± 0.8)x10^{-5}	product branching ratio
$B_s \to D_s\pi, D_s \to K^*K, K^* \to K\pi$	(5.6 ± 1.6)x10^{-5}	product branching ratio
$B_s \to D_s\pi\pi\pi, D_s \to$ 3 modes	(3.0 ± 0.7)x10^{-4}	sum of 3 modes
$B_s \to D_s\pi, D_s \to$ 3 modes	(1.2 ± 0.2)x10^{-4}	sum of 3 modes
$B_s \to$ 2 modes, $D_s \to$ 3 modes	(4.2 ± 0.7)x10^{-4}	sum of 6 modes

Table 2 lists the product branching ratios for inclusive B_s mixing modes. Here, the semileptonic decay of the B_s is required, and then the reconstruction of the D_s or ϕ is necessary to tag the presence of a B_s decay. There are, of course, backgrounds from the decays of other B hadrons to a D_s or ϕ. Due to the missing neutrino or lack of a reconstructed D_s, the B_s is only partially reconstructed, and the X_s reach is limited due to the uncertainty on the B_s momentum. These exclusive decay modes can be examined in either single lepton or dilepton triggered samples. In the single lepton case, the flavor of the B_s at production has to be provided by some tagging method, while in the dilepton sample the lepton from the other B is conveniently triggered on and provides the flavor tag.

Table 2: Branching Ratios for Inclusive B_s Mixing Modes.

Decay Mode	Branching Ratio	Comment
$D_s \to \phi\pi$	$(2.8 \pm 0.5)\%$	PDG, 1992
$D_s \to \phi\pi\pi\pi$	$(1.2 \pm 0.4)\%$	PDG, 1992
$D_s \to \phi\pi\pi^0$	$(6.7 \pm 3.3)\%$	PDG, 1992
$D_s \to \phi\rho$	$(5.2 \pm 1.6)\%$	PDG, 1992
$D_s \to \phi l\nu$	$(1.4 \pm 0.5)\%$	PDG, 1992
$D_s \to \phi X$	$(17.3 \pm 3.8)\%$	PDG, 1992
$B_s \to D_s l\nu$	$(10.5 \pm 0.5)\%$	B mode e,μ ave., PDG, 1992
$B_s \to D_s l\nu$,$D_s \to \phi\pi$,$\phi \to KK$	(1.4 ± 0.3)x10^{-3}	product branching ratio
$B_s \to D_s l\nu$,$D_s \to \phi\pi\pi\pi$,$\phi \to KK$	(6.2 ± 2.1)x10^{-4}	product branching ratio
$B_s \to D_s l\nu$,$D_s \to K^*K$,$K^* \to K\pi$	(1.8 ± 0.4)x10^{-3}	product branching ratio
$B_s \to D_s l\nu$,$D_s \to$ 3 modes	(3.8 ± 0.5)x10^{-3}	sum of 3 modes
$B_s \to D_s l\nu$,$D_s \to$ 2 phi modes	(2.0 ± 0.4)x10^{-3}	sum of 2 modes
$B_s \to D_s l\nu$,$D_s \to \phi X$,$\phi \to KK$	(8.9 ± 2.0)x10^{-3}	product branching ratio

2.3 Expected Rates

We now consider the expected Run 1A, Run 1B, Run 1A+1B combined and Run II+ (1000 pb^{-1}) data samples obtained at CDF relevant for B_s mixing studies. In each case the listed numbers correspond to the data samples after applying lepton identification and fiducial cuts. We assume no drastic changes or improvements to the present Run 1A trigger, which had single electron and muon triggers for $p_T(l) > 6$ GeV/c (prescaled) and $p_T(l) > 9$ GeV/c (independent from the 6 GeV/c trigger and not prescaled) and dimuon ($p_T(\mu) >\sim 2.5$ GeV/c), $e-\mu$ ($E_T(e) > 5$ GeV, $p_T(\mu) > 3$ GeV/c), and dielectron ($E_T(e) > 5$ GeV) triggers. This is *rather conservative* given the large increase in data samples possible by improving the DAQ system and lowering the trigger p_T thresholds. For all of the following numbers, we have required that secondary vertex information be available (50% efficiency for Run 1A and 1B, 100% efficiency for Run II+) for the partially reconstructed B_d and B_s decays and the reconstructed D_s, D_0 and ϕ decays; for each of the latter we assume a reconstruction efficiency of 40%. However, we have not included a vertex separation efficiency. For the dilepton samples, the number of reconstructed D_0 and ϕ events is based an observed rate of $\sim 5/\text{pb}^{-1}$ in the dimuon sample[19]. This extrapolates to $\sim 100/20\text{pb}^{-1}$ in the dimuon sample, $16/20\text{pb}^{-1}$ in the $e-\mu$ sample and $3/20\text{pb}^{-1}$ in the dielectron sample, all before requiring secondary vertex information. Because of large uncertainties in the identification and reconstruction efficiencies, we have not included here estimates for reconstruction of purely hadronic B_s decays[20].

Table 3 lists the expected (after full analysis) single lepton and dilepton data samples after fiducial and lepton id cuts for the Run 1A data. For the partially reconstructed B_d and B_s decays in the single lepton sample, we have included a low p_T lepton (e,central μ) tagging efficiency[21] (including the semileptonic branching ratio) of 1.8%. A tagging efficiency of a few percent is not unexpected given the soft p_T and broad rapidity distributions of B mesons and the present CDF detector coverage.

For Run 1B, we have assumed a x2 increase in the number of recorded $p_T > 6$ GeV/c electron events due to an improvement in the single electron trigger[22]. We have also assumed an increase in the low p_T lepton (e,μ) tagging efficiency from 1.8% → 2.5% due to improved understanding of the larger angle muon system.

Table 3: Run 1A CDF Single Lepton and Dilepton Data Samples.

Decay Mode	$P_T(l) > 6$	$P_T(l) > 9$	Combined
$B \rightarrow e\nu DX$	100,000	200,000	300,000
$B \rightarrow \mu\nu DX$	100,000	50,000	150,000
$B \rightarrow l\nu DX$	200,000	250,000	450,000
$B \rightarrow l\nu DX; B \rightarrow lX$	3,600	4,500	8,100
$B \rightarrow l\nu D^0X, D^0 \rightarrow K\pi; B \rightarrow lX$	4	5	10
$B_s \rightarrow l\nu D_sX, D_s \rightarrow \phi\pi, \phi \rightarrow KK; B \rightarrow lX$	1	2	3
$B_s \rightarrow l\nu D_sX, D_s \rightarrow$ 3 modes; $B \rightarrow lX$	4	5	9
$B_s \rightarrow l\nu D_sX, D_s \rightarrow \phi X, \phi \rightarrow KK; B \rightarrow lX$	9	11	20

Decay Mode	$\mu\mu$	$e\mu$	ee	Combined
$B \rightarrow l\nu X; B \rightarrow l\nu X$	40,000	6,600	1,340	47,940
$B \rightarrow l\nu X; B \rightarrow l\nu D^0X, D^0 \rightarrow K\pi$ events	50	8	2	60
$B \rightarrow l\nu X; B \rightarrow l\nu X, \phi \rightarrow KK$ events	50	8	2	60

Including these improvements combined with the expected x3 increase in the luminosity for Run 1B, there is a significant increase in the number of tagged partially reconstructed B_d and B_s decays (Table 4), and lower limits on the value of X_s might be determined in both the single and dilepton samples.

Table 4: Run 1B CDF Single Lepton and Dilepton Data Samples.

Decay Mode	$P_T(l) > 6$	$P_T(l) > 9$	Combined
$B \rightarrow e\nu DX$	600,000	600,000	1,200,000
$B \rightarrow \mu\nu DX$	300,000	150,000	450,000
$B \rightarrow l\nu DX$	900,000	750,000	1,650,000
$B \rightarrow l\nu DX; B \rightarrow lX$	22,500	18,750	41,250
$B \rightarrow l\nu D^0X, D^0 \rightarrow K\pi; B \rightarrow lX$	27	23	50
$B_s \rightarrow l\nu D_sX, D_s \rightarrow \phi\pi, \phi \rightarrow KK; B \rightarrow lX$	9	8	17
$B_s \rightarrow l\nu D_sX, D_s \rightarrow$ 3 modes; $B \rightarrow lX$	25	21	45
$B_s \rightarrow l\nu D_sX, D_s \rightarrow \phi X, \phi \rightarrow KK; B \rightarrow lX$	56	47	103

Decay Mode	$\mu\mu$	$e\mu$	ee	Combined
$B \rightarrow l\nu X; B \rightarrow l\nu X$	120,000	19,800	4,020	143,820
$B \rightarrow l\nu X; B \rightarrow l\nu D^0X, D^0 \rightarrow K\pi$ events	150	24	6	180
$B \rightarrow l\nu X; B \rightarrow l\nu X, \phi \rightarrow KK$ events	150	24	6	180

For completeness, we have combined the Run 1A and Run 1B expected rates in Table 5. We assume here that the increased 2.5% low p_T lepton tagging efficiency can be applied to the entire single lepton sample. Again, observable signals of tagged B_d and B_s decays should be seen. This data should receive thorough analysis by the time Run II data taking begins, and all of the lessons learned from reconstructing B_d and B_s decays should be available immediately on the Run II sample.

Table 6 lists the projected Run II+ (1 fb^{-1} data sample), assuming no major changes to the present single lepton and dilepton trigger, but including improvements to the detector and tagging efficiencies. These improvements include a doubling of the secondary vertex detection coverage, resulting in nearly 100% acceptance and increase in the lepton (e, μ) coverage for tagging, not triggering, out to $|\eta| < 2$. This results in an increase in the low p_T lepton tagging efficiency from 2.5% to 3.9%.

Table 5: CDF Run 1A+1B Combined Single Lepton and Dilepton Data Samples.

Decay Mode	$P_T(l) > 6$	$P_T(l) > 9$	Combined
$B \to e\nu DX$	700,000	800,000	1,500,000
$B \to \mu\nu DX$	400,000	200,000	600,000
$B \to l\nu DX$	1,100,000	1,000,000	2,100,000
$B \to l\nu DX; B \to lX$	27,500	25,000	52,500
$B \to l\nu D^0X, D^0 \to K\pi; B \to lX$	33	30	63
$B_s \to l\nu D_sX, D_s \to \phi\pi, \phi \to KK; B \to lX$	11	10	22
$B_s \to l\nu D_sX, D_s \to$ 3 modes; $B \to lX$	30	28	58
$B_s \to l\nu D_sX, D_s \to \phi X, \phi \to KK; B \to lX$	69	63	131

Decay Mode	$\mu\mu$	$e\mu$	ee	Combined
$B \to l\nu X$;$B \to l\nu X$	160,000	26,400	5,360	191,760
$B \to l\nu X$;$B \to l\nu D^0X$,$D^0 \to K\pi$ events	200	32	8	240
$B \to l\nu X$;$B \to l\nu X$,$\phi \to KK$ events	200	32	8	240

The secondary vertex detection improvement to the CDF detector should be ready for the start of Run II, but the lepton coverage upgrade is likely to come later in the Run II+ running. Nevertheless, we assume these modifications in our rate estimates, which really correspond to CDF operating with an increased B physics priority. Of course, now the rates are very large and an X_s measurement in the partially reconstructed B_s decay modes, with an X_s reach up to possibly 10, is likely. A measurement of X_s in fully reconstructed B_s decay modes is also possible and this is discussed elsewhere[20].

Table 6: CDF Run II+ (1000 pb^{-1}) Single Lepton and Dilepton Data Samples.

Decay Mode	$P_T(l) > 6$	$P_T(l) > 9$	Combined
$B \to e\nu DX$	8,750,000	10,000,000	18,750,000
$B \to \mu\nu DX$	5,000,000	2,500,000	7,500,000
$B \to l\nu DX$	13,750,000	12,500,000	26,250,000
$B \to l\nu DX; B \to lX$	536,250	487,500	1,023,750
$B \to l\nu D^0X, D^0 \to K\pi; B \to lX$	1287	1170	2457
$B_s \to l\nu D_sX, D_s \to \phi\pi, \phi \to KK; B \to lX$	440	400	839
$B_s \to l\nu D_sX, D_s \to$ 3 modes; $B \to lX$	1180	1073	2252
$B_s \to l\nu D_sX, D_s \to \phi X, \phi \to KK; B \to lX$	2681	2438	5119

Decay Mode	$\mu\mu$	$e\mu$	ee	Combined
$B \to l\nu X$;$B \to l\nu X$	2,000,000	330,000	67,000	2,397,000
$B \to l\nu X$;$B \to l\nu D^0X$,$D^0 \to K\pi$ events	5000	800	200	6000
$B \to l\nu X$;$B \to l\nu X$,$\phi \to KK$ events	5000	800	200	6000

3. CONCLUSION

Based on a preliminary analysis of the Run 1A data sample, we have made estimates for the expected number of partially reconstructed B_d and B_s events at CDF for Runs 1A, 1B and II+ (1 fb^{-1}). These estimates are based on an extrapolation from the present Run 1A sample and assume *no major changes* to the B physics triggers and modest improvements to the present detector. From these estimates, we expect observable B_d and B_s time-dependent mixing signals in the Run 1B data and measurements of X_s (up to $\sim$ 10) in the Run II+

sample using partially reconstructed modes. Fully reconstructed B_s decays in the $B_s \rightarrow D_s\pi$ and $B_s \rightarrow D_s\pi\pi\pi$ should be seen in Run 1B, and a precision measurement of the B_s lifetime in the $B_s \rightarrow J/\psi\phi$ mode is expected. Measurements of X_s up to 20 in fully reconstructed B_s decays using the Run II+ data sample are also conceivable[23].

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