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CDF

B Physics with CDF: Recent Results and Future Prospects

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B PHYSICS WITH CDF: RECENT RESULTS and FUTURE PROSPECTS

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Abstract

Using data collected during the 1992-1993 collider run, we report on measurements of the B^0, B^+, and B_s lifetimes. We also present our revised measurement of the B_s mass. Production studies involving inclusive modes decaying into J/ψ or $\psi(2S)$, semileptonic decays involving D^0 or D^{*+} mesons, and fully reconstructed B mesons are also presented. We present the prospects for future work with this data, as well as that being collected in the 1994-1995 collider run. Upgrades to the detector and estimates of physics capabilities for future collider runs are also presented.

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1 INTRODUCTION

The existence of working b experiments at hadron colliders is a vital component in planning for CP violation studies in the B system. Not only do they extend our current knowledge of the production and decay of the b quark, they reduce the amount of extrapolation necessary in making decisions for the future. As our experimental and theoretical prejudices confront the reality of data, we obtain benchmarks with which to better design new experiments and upgrade existing ones. In May 1992, the drought of CDF data ended, as the Fermilab Tevatron resumed operations. This began what turned out to be a very successful year of running. Between the completion of detector commissioning and the end of the run, CDF wrote ~ 20 pb$^-1$ of data to tape.

I will discuss the components of CDF[1] used for b physics in the 1992 run, as well as give a broad description on how we triggered on b events in CDF. I will discuss the measurements of the B^0, B^+, and B_s lifetimes. Then I will comment on a revised measurement from CDF on the B_s mass. The J/ψ and $\psi(2S)$ differential cross sections have been measured, and we use the lifetime information from the vertex detector to separate the prompt component from that arising from b decays. I will then discuss a measurement of the differential cross section made using fully reconstructed B mesons as well as semilepton decays to$\mu D(D^*)$. Finally, I give some indication of what, we hope, is yet to come from the data we have taken and will take in the coming year as well as prospect for the farther future.

1.1 CDF for Run 1A

Three systems inside the 1.4 T solenoid provide charged particle tracking. First is a silicon microstrip detector (SVX)[2]. This is a four layer DC coupled, single sided silicon device. The hit resolution is 13 μm, with radii ranging from 3 to 8 cm. This gives an impact parameter resolution of $(13 + 40/P_T)\mu$m. The rms size of the beam spot is 35μm. The SVX covers $|z| < 26$ cm, but since this is also the RMS spread of the interaction region in z, not all events in CDF have vertices within the fiducial volume of the SVX. The VerTeX Chambers (VTX) locate the longitudinal postion of the primary interactions. The Central Tracking Chamber (CTC) is an 84-layer cylindrical drift chamber. with radii ranging from 31 to 132 cm and a length of 321 cm. These are organized as five groups of 12 axial layers which are interleaved with four groups of 6 stereo layers. The momentum resolution for the CTC alone is $\delta P_T/P_T = 0.0014 P_T \oplus 0.0066$ and $\delta P_T/P_T = 0.0009 P_T \oplus 0.0066$ for the combined SVX-CTC system. The readout electronics for CTC were modified before the 1992 run to allow for dE/dX measurements.

Information on central electrons is provided by exterior calorimetry. Outside the solenoid is the Central PreRadiator multiwire proportional chambers (CPR). Following this is the Central ElectroMagnetic (CEM) and HAdronic (CHA) calorimeters, covering out to $|\eta| < 1.1$ with a segmentation of $\Delta\eta \times \Delta\phi = 0.1 \times 15°$. A proportional wire chamber (CES) is located at shower maximum in the CEM to provide shower profiles.

Three systems provide central muon identification. The Central MUon (CMU) is outside the calorimeters and covers the region $|\eta| < 0.6$. Behind the original muon chambers, extra steel has been added, followed by the Central Muon uPgrade chambers (CMP), increasing the number of absorption lengths in this region from 5 to 8. The Central Muon eXtension chambers (CMX) extend the η coverage from 0.6 to 1.0 with 6 absorption lengths of material in front of it.

The SVX, CPR, CMP, and CMX are new devices, installed for the 1992 run.

1.2 b Triggers for Run 1A

CDF is primarily a high P_T experiment. Triggers for low P_T physics must obey the rule, "Contribute no deadtime to the top search." A brief discussion of the triggers relevant for b physics may help people understand what physics might be done at CDF and on what time scale. These triggers are based on identification of electrons and muons.

The trigger is divided into three levels. At Level 1, at least one central muon stub or one CEM trigger tower ($\eta \times \phi = 0.2 \times 15°$) with a $P_T(E_T) > 6$ GeV is required. For events with two or more lepton candidates, the threshold is lowered to 4 for the CEM tower and 3 for the muon stub. Since the P_T of the muon stub is measured only in the muon chambers, the resolution is poor, and the trigger turns on slowly. For instance, the 3 GeV/c threshold has an efficiency that rises from 50% at 1.6 GeV/c to 90% at 3.1 GeV/c and reaches a plateau of 94%

At Level 2, hardware EM clustering, and track finding are run. The

Central Fast Tracker (CFT)[3] is a dedicated track finder. It provides information in the r-ϕ plane with a curvature resolution of $\sigma_{P_T}/P_T^2 \sim 4\%$ and a phi resolution better than 1°. The tracks are matched to the EM clusters or muon stubs, cuts are placed on the E_T of EM clusters and the P_T of tracks. The electron(muon) cuts are 9 GeV (9 GeV/c) for the single lepton triggers, and 5 GeV (3 GeV/c) for the ee, eμ and $\mu\mu$ triggers. In order to increase the acceptance for J/ψ events in the dimuon triggers, only one of the muon stubs was required to have a CFT matched to it. In addition, a lower threshold single lepton trigger was installed specifically for b physics. The threshold was 6 GeV, but not all events were written to tape. The fraction of these triggers that was passed by Level 2 was automatically adjusted to soak up any available bandwidth, without violating the rule stated above.

Level 3[4] consisted of a 1000 MIP microprocessor farm, in which a subset of the offline reconstruction software was run. The thresholds for the lepton triggers were matched to their Level 2 values, except the dimuon trigger, where the thresholds were lowered to 1.4 GeV/c. This matched the range out energy for muons passing through the calorimeter. In addition to filtering, Level 3 also selected 10% of the events for a special high priority data set. This stream mainly consisted of top candidates, W's, and other high P_T events. We were able to include a data set containing opposite sign dimuon events with mass between 2.8 and 3.4 GeV/c^2. Since this split was made in the trigger, these events were available to the collaboration within hours of the data being taken. Analyses using J/ψ events were thus able to proceed quickly, while those using other data sets have taken more time.

2 *B* LIFETIMES

The determination of the Cabbibbo-Kobayashi-Maskawa[5] matrix element V_{cb} involves three components; a theoretical calculation of a B decay partial width or distribution, an experimental measurement of a branching ratio or distribution, and a measurement of the B lifetime to relate the two. The most promising method employs Heavy Quark Effective Theory[6] to interpret exclusive semileptonic decays[7]. Since the individual B meson lifetimes are now known to better accuracy than the other two elements, it makes sense to use them rather than the inclusive "b" lifetime, which is just an average over all b hadrons. Exclusive lifetime measurements also allow comparisons between hadrons. The spectator model predicts that the B^0 and B^+ lifetime should be nearly equal, although this was not true in the charm system[8]. CDF has measured the inclusive b lifetime[9], and is now pursuing a program of individual measurements of bottom hadron lifetimes.

2.1 Exclusive Lifetimes

Measurements of the B^+ and B^0 lifetimes have been made[10] at LEP and PEP using partially reconstructed decays containing a lepton and a D^0 or D^*+. Although CDF is also pursuing this technique, the large cross section at the Tevatron allows us to measure the lifetimes directly using fully reconstructed B meson decays. Measuring the lifetime of B^+ and B^0 lifetimes using this method is, at the moment, statistically limited by the number of fully reconstructed B mesons. B mesons are reconstructed in eight decay modes:

$$\begin{array}{lll}
B^+ & \rightarrow J/\psi K^+ & \rightarrow \mu^+\mu^- K^+ \\
B^+ & \rightarrow J/\psi K^{*+} & \rightarrow \mu^+\mu^- K^0_s\pi^+ \\
B^+ & \rightarrow \psi(2S)K^+ & \rightarrow \mu^+\mu^-\pi^+\pi^- K^+ \\
B^+ & \rightarrow \psi(2S)K^{*+} & \rightarrow \mu^+\mu^-\pi^+\pi^- K^0_s\pi^+ \\
B^0 & \rightarrow \psi K^0_s & \rightarrow \mu^+\mu^- K^0_s \\
B^0 & \rightarrow \psi K^{*0} & \rightarrow \mu^+\mu^- K^+\pi^- \\
B^0 & \rightarrow \psi(2S)K^0_s & \rightarrow \mu^+\mu^-\pi^+\pi^- K^0_s \\
B^0 & \rightarrow \psi(2S)K^{*0} & \rightarrow \mu^+\mu^-\pi^+\pi^- K^+\pi^-
\end{array} \tag{1}$$

J/ψ events are found using di-muon combinations in the high priority trigger stream. K^0_S's are selected by combining two tracks with impact parameters greater than 2σ, where σ is the measurement error on the impact parameter added in quadrature with the size of the beam spot. The K^0_S is required to have a positive decay length, and an impact parameter with respect to the J/ψ vertex of less than 2 mm. $\psi(2S)$ and K^0_S candidates are required to be within 20 MeV of the world average[8], while J/ψ and K^* candidates are required to be within 80 MeV of the world average[8]. To be used for reconstructing B's, the K^+, K^0_S, or K^* candidates must have a $P_T \geq 1.25$ GeV/c.

In the final B reconstruction, all the decay tracks, except those from a K^0_S, are constrained to a common vertex, and the J/ψ and $\psi(2S)$ candidates are mass constrained to their known values. In order to increase efficiency, only the two muons are required to be well reconstructed within the SVX. Any

B's with $P_T < 6.0$ GeV/c are rejected. In the case of multiple candidates, we keep the one with the best χ^2 for the constrained fit. The mass distributions for these candidates are shown in Figure 1. The lower plot shows the same distribution for candidates with $c\tau > 100\mu m$. There are clear B signals, albeit with a large zero lifetime background. For the lifetime analysis, we define the signal region to be ±30 MeV of the world average[8] B mass. Sideband regions are are defined to be between 60 and 120 MeV away from the world average. This excludes the region where B's with a missing π would be reconstructed.

The decay length distributions for charged and neutral B's, for both the signal and sideband regions is shown in Figure 2. The superimposed curves are the results of separate unbinned likelihood fits for the B^+ and B^0. The signal is parameterized as an exponential convoluted with the gaussian resolution, while the background is gaussian plus asymmetric exponential tails. The signal and background distributions have been fit simultaneously. The fits indicate that there are 148 ± 16 charged and 121 ± 16 neutral B mesons in the signal regions. The measurement of the lifetimes of the B^+ and B^0 mesons is,

$$\begin{aligned} \tau(B^+) &= 1.61 \pm 0.16(\text{stat.}) \pm 0.05(\text{syst.})\text{ps} \\ \tau(B^0) &= 1.57 \pm 0.18(\text{stat.}) \pm 0.08(\text{syst.})\text{ps}. \end{aligned} \tag{2}$$

Accounting for the correlated systematic errors, we obtain the lifetime ratio

$$\tau^+/\tau^0 = 1.06 \pm 0.16(\text{stat.}) \pm 0.05(\text{syst.}). \tag{3}$$

This result is final, and between the time of the workshop and preparation of this manuscript, has been published[11].

2.2 B_s Lifetime

Although fully reconstructed decays provides the best measurement of the proper lifetime on an event-by-event basis, the statistics for fully reconstructed B_s decays within the fiducial volume of the SVX is still rather limited. Thus we follow the LEP technique[12] of using $B_s \rightarrow D_s^- l^+ \nu X$ events[13]. D_s candidates are reconstructed in events passing inclusive lepton triggers, with good e or μ candidates identified offline. The D_s is found with the decay mode, $D_s^- \to \phi\pi^-$. ϕ's are selected from two-track combinations, assuming the kaon mass that have an invariant mass within 8 MeV/c^2 of the ϕ mass and a combined $P_T > 2.0$ GeV/c. These are combined with a third track with $P_T > 0.8$ GeV/c, and the three tracks are constrained to a common vertex. Two of the three tracks as well as the lepton must have good SVX information. Figure 3 shows the $\phi\pi^-$ mass distribution for events with the correct charge correlation between the lepton and the π for B_s decays. A signal of 76 ± 8 events is seen, along with a hint of the Cabbibo suppressed D^- decay. The plot of the wrong sign charge correlation shows no enhancement. The signal region is defined to be within 14 MeV of the D_s mass. Events in the sidebands of the "right sign" $\phi\pi^-$ distribution, as well as events in the *signal* region of the "wrong sign" distribution are selected as the background sample.

The intersection of the lepton and the D_s^- candidate defines the B_s vertex. Since the true momentum is unknown, a "psuedo-$c\tau$" is calculated by correcting the observed decay length with $P_T(lD_s)/M(B_s)$. As in the B^0 and B^+ analysis, the $c\tau$ distributions of the signal and background are fit simultaneously. In this case, the shape of the signal distribution is also convoluted with the shape of the $P_T(B_s)/P_T(lD_s)$ distribution obtained from Monte Carlo. The distributions are shown in Figure 4. The preliminary result is,

$$\tau(B_s) = 1.42^{+0.27}_{-0.23}(\text{stat.}) \pm 0.11(\text{syst.})\text{ps} \qquad (4)$$

As a check, the proper distance between the B_s and D_s vertices was measured. We find $c\tau(D_s) = 0.45^{+0.13}_{-0.10}$ps, in good agreement with the world average.

3 The B_s Mass

The B_s meson is a bound state of a of a b-s quark-antiquark pair. Its mass is determined from the QCD potential between them. In 1993, CDF published a measurement of the B_s mass[14] using the data collected during the fall of 1992. We have now included the data from the second half of run 1A, collected during the spring of 1993, doubling the statistics. We have also improved the track reconstruction and tracking chamber alignments to improve the B_s mass measurement.

This analysis uses the decay mode $B_s \to J/\psi\phi$. We follow the general reconstruction procedures tuned on the $B_u \to J/\psi K^+$ and $B_d \to J/\psi K^*$ decays. To ensure high efficiency, all well matched muons are considered, and tracks are not required to be reconstructed in the SVX. We combine tracks, assigned the K mass, and keep combinations where the invariant mass is within 10 MeV of the ϕ mass. These are combined with $J/\psi \rightarrow \mu^+\mu^-$ candidates, where the four tracks are vertex constrained and the dimuon pair is mass constrained to the J/ψ mass. The probability of this fit must be greater than 1%. In order to reject combinatoric background, the resulting combination is required to have a positive decay length. The mass spectrum of the resulting events is shown in Figure 5. A signal is clearly visible and remains significant under variation of the selection criteria. A binned likelihood fit result gives 33 ± 7 B_s events at a mass of

$$M(B_s) = 5367.7 \pm 2.4(\text{stat}) \pm 4.8(\text{syst})\text{MeV}/c^2. \tag{5}$$

This is in good agreement with the ALEPH result[15] of $5368.6 \pm 5.6 \pm 1.5\text{MeV}/c^2$, but is lower than our published mass of $5383.3 \pm 4.5 \pm 5.0\text{MeV}/c^2$. We have studied the events in common between the two analyses, as well as the events which pass the selection criteria with one version of the tracking, but not the other. The statistics in the original sample is limited, and we have been unable to determine any systematic reason for the shift. The higher statistic measurements of the B^0 and B^+ masses are essentially unaffected,

$$\begin{aligned} M(B^+) &= 5279.6 \pm 1.7(\text{stat}) \pm 2.9(\text{syst})\text{MeV}/c^2 \\ M(B^0) &= 5279.9 \pm 2.5(\text{stat}) \pm 3.7(\text{syst})\text{MeV}/c^2, \end{aligned} \tag{6}$$

and are in good agreement with the world averages. Thus, it appears that the reason for the shift in the B_s mass is a rare statistical fluctuation. The dominant systematic uncertainty is due to the current uncertainty in the tracking calibration.

4 B PRODUCTION STUDIES

Measuring B spectra provide important engineering numbers for predicting the sensitivity of future experiments. NLO QCD calculations of b production exist[16, 17], but the strong dependence on the choice of renormalization scale may indicate that even higher order diagrams are important. These calculations are also only at the parton level, while the measurements examine some subset of the decay products of the physical b hadrons. CDF has used many methods of studying b production, and is using the new data to extend and refine these measurements. We have inferred the b quark cross section from these measurements, in order to compare different measurements and allow qualitative tests of the agreement with theory. Cross sections infered from measurements at lower energy[18] were in agreement with the predictions. Quantitative tests need to understand the correlations between the various inferred points. These would also probably be better done by comparing to the directly measured quantities.

Inclusive lepton cross sections[19] provide a high statistics estimate of the b cross section at the Tevatron. The systematic uncertainties in these measurements, come from our level of knowledge of the backgrounds. Using the detector improvements in the current data we will be able to greatly reduce these uncertainties. The CPR and dE/dX will allow us to better estimate and reduce the amount of hadron fakes in the electron sample, while the level of hadron punch-through in the muon sample can be reduced by requiring muon confirmation in the CMP. Studies of lepton impact parameters in the SVX will allow a more accurate determination of what fraction of the leptons candidates actually come from the decay of b hadrons. These analyses are underway and we hope to have results by the fall.

4.1 Charmonium Production

Studies of charmonium production provide an estimate of the b cross section at lower P_T. The excellent mass resolution of CDF allows us to separate J/ψ, χ_c, and $\psi(2S)$ states from the background. Converting charmonium cross sections to b cross sections requires knowledge of the fraction of these ψ states that come from b hadron decays. In previous measurements[20] we have used the theoretical assumption that charmonium production at the Tevatron is dominated by b and χ_c production. This predicts that 100% of the $\psi(2S)$ events come from b's. Using the measured J/ψ and χ_c cross sections we can also determine this model dependent b cross section. Recently, it has been suggested that other processes, such as gluon or charm quark fragmentation might also be important[22]. With the addition of the SVX we now have vertex resolutions that are small compared to the B lifetime. This allows us to separate the J/ψ's from prompt charmonium production from those from B decays in a model independent manner[21].

Figure 6 shows the result for the prompt and long-lived J/ψ's as well as the total. Comparison with the theory curves shows that the excess over the predicted cross section is due primarily to prompt J/ψ production. The measured values are about only a factor of two higher than the NLO predictions[16] for the b component when the renormalization scale, $\mu = \mu_0 = \sqrt{m_b^2 + P_T^2}$, is used. Better qualitative agreement is obtained using $\mu = \mu_0/4$, although a quantitative check has not yet been completed.

The situation with $\psi(2S)$ decays is even more amusing. In Figure 7, we see that the b component does not dominate the total $\psi(2S)$ production. In fact, the reverse appears to be true. The cross section for the prompt component is more than an order of magnitude higher than the theoretical prediction. The absence of a $\chi \rightarrow \psi(2S)$ component in the prediction makes the discrepancy more clear.

Much theoretical work is now going on in this area[23] to try and resolve the discrepancy. Higher order diagrams such as $gg \rightarrow J/\psi gg$ are being calculated[24] to determine their relative contribution to the J/ψ and $\psi(2S)$ rate. One can expect the theoretical curves shown in these figures to change over the next few months. On the experimental side, we can examine a few other measurements to contribute here. CDF is extending the measurements to the Υ system and should have differential cross sections for all three triplet S states by the end of summer. We are repeating our earlier measurement of the χ_c cross section with the Run 1A data. The increase in statistics over 1989 data by more than an order of magnitude will also allow this state to be separated as a function of P_T into prompt and b sources. This should be ready by the fall. Photon conversions provide the mass resolution needed to measure the relative rates of the individual χ_c states. This measurement may require extra data from the current collider run. Finally we can try to separate the prompt J/ψcross section into isolated and non-isolated components. This can help determine the contribution from direct vs. fragmentation production of charmonium.

4.2 $d\sigma_B/dPt$

The statistics available in the decay $B^+ \rightarrow J/\psi K^+$ allow us to directly measure the differential cross section of physical B mesons as a function of P_T[25]. Events were selected in a manner similar to the lifetime analysis except that they were not required to be within the SVX fiducial volume. In order to be in a region of well understood trigger efficiency, each muon was required to have $P_T \geq 1.8$ GeV/c, and at least one was required to have $P_T \geq 2.8$ GeV/c.

The data is divided into three bins in P_T, 6-9, 9-12, and 12-15 GeV/c, for the $J/\psi K^+$ events and two bins, 7-11, 11-15 GeV/c, for the $J/\psi K^{*0}$ events. The choice of bin size leads to comparable statistical and systematic uncertainties.

We also measure the B cross section[26] using the semi-exclusive decay $B \to \mu^- D^0 X$, and $B \to \mu^- D^{*+} X$. An analysis including electron triggers is still in progress. A Monte Carlo based correction is used to estimate the B P_T on an event by event basis using the measured P_T and mass of the $\mu^- D$ system. This results in a B P_T resolution of 15%. The data is divided into three bins, 18-22, 22-26, and 26-34 GeV/c. There is a large correlation between the D^0 and D^{*+} data.

The cross section is shown in Figure 8, along with a NLO calculation[17] convoluted with Peterson fragmentation[27]. Again, the data seems slightly high compared to the theory, but the qualitative agreement can be improved by using $\mu = \mu_0/4$.

5 Future prospects

Since the $b\bar{b}g$ processes are more sensitive to the choice of μ than the direct $b\bar{b}$ production is, $b\bar{b}$ correlations should yield more information on the correct way to make the theory agree with our data. We are studying these correlations by looking at P_T and ϕ correlations in di-lepton events, and in events with a lepton and another jet tagged as a b with vertex information from the SVX[28]. We are studying the structure of the $B \to J\psi X$ decay by measuring the ratio of branching fractions for various exclusive decays as well as the polarization[29] in the $J/\psi K^*$ decay. We have preliminary limits on B_c production and nonresonant $\mu^+\mu^- K/K^*$ decays[30], but we hope to improve them. We hope to measure the Λ_b lifetime using $\Lambda_c l\nu$ events, and continue to search for the $J/\psi\Lambda$ decay mode in order to measure its mass. We continue to study time-dependent B^0 mixing and hope to set limits on B_s mixing. We expect to have something to on this subject before *Beauty '95.*

Finally, we are using fully reconstructed decays and the $Dl\nu$ events to examine various tagging techniques with real data as compared to Monte Carlo. We are comparing lepton tagging, charged vertex tagging, and kaon tagging in the opposite jet. We are also trying to find the optimum way to "self-tag" the B by examining the primary particles in the jet arising from the $b \rightarrow B$ fragmentation. We expect to have something to say on this topic by *Beauty '95*. A final comparison of the relative prospects of these techniques for use in studying CP violation will benefit from the increased statistics available in Run 1B.

5.1 Run 1B

Fermilab is currently in the middle of what is termed "Run 1B". This collider run will continue until at least fall '95, and probably should continue after that until the Fixed Target experiments are ready to take data. During the summer shutdown between these runs, CDF made more improvements to the detector. A replacement for the SVX (SVX′) was installed. This employs AC-coupled rad-hard electronics to increase the lifetime of the device. It also has slightly better ϕ acceptance than its predecessor We studied the details of the CFT to determine a scheme for reducing the lowest tracking trigger threshold even further. This allows us to require a track match to both stubs in the dimuon trigger and thus keep the Level 2 trigger rate under control at higher luminosities without sacrificing any physics rate. We also installed trigger boards to check the CES in electron and photon triggers at level 2 (XCES)[31]. These boards allow us to cut the Level 2 electron trigger rate by roughly a factor of two, with little loss in efficiency.

With these improvements the factor of three to five (and possibly more) increase in Luminosity, we hope to greatly improve and extend our measurements of the production and decay of b-flavored hadrons. My estimate of the possible results from CDF by *Beauty '96* is given in Table 1. In addition to the improvement in the statistical errors on the measurements listed above, we can extend to other measurements such as;

- Set non-trivial limits on or observe the B_s(long)-B_s(short) lifetime difference by fitting the D_s lifetime distribution with two components.
- Observe the decay $\Lambda_b \rightarrow J/\psi\Lambda$ and measure the mass even if the true rate is an order of magnitude less than the UA1 published result[32].

5.2 Run II

After the end of Run I, the collider program will be off for probably at least three years while the fixed target experiments take data and construction of the Main Injector is completed. During this time, CDF will be making major upgrades to detector and DAQ systems.

- Gas Calorimeters in the plug region will be replaced by scintillating tiles. This is being done to accomodate the shorter bunch spacings in Run II. The Plug Upgrade will improve some of our QCD measurements, but any benefit to B physics will depend on our ability to extend tracking (both offline and in the trigger) into the higher η regions.

- A new silicon vertex detector will be installed (SVX II). The new detector will be nearly twice as long (96 cm) as the current device. It will cover the entire interaction region and essentially double the vertexing acceptance for centrally produced charged particles. The increased length will also maintain the high acceptance out to $|\eta| < 2.0$. SVX II will also have r-z information as well as r-ϕ. Having three-dimensional vertex information will greatly reduce the number of tracks whose origin might be ambiguous between the primary vertex and a nearby secondary decay. It may also allow us to reconstruct three dimensional tracks that fall outside of the full acceptance of the CTC.

- We will also install a pipelined DAQ system. This is being designed to provide a deadtimeless trigger with the possible 132 nsec bunch spacing of the later MI era. It will have a maximum rate capacity of 50 KHz out of the Level 1 trigger, 1 KHz out of Level 2, and 10 Hz for every tape stream being written out of Level 3. These rates are at least a factor of 20 greater than current limits at Levels 1 and 2. The rate to tape will be limited by the number of output streams we decide to set up.

- A new hardware track finder (XFT) will replace the CFT. It will improve the resolution (σ_{P_T}/P_T^2) from 4% to $< 2\%$. The minimum threshold will be reduced from 2 GeV to 1.5, which closely matches the range out for muons in the calorimeter. The results will also be available for trigger decisions in Level 1 instead of Level 2. At Level 2, information from the outermost stereo layer will be added to the r-ϕ track found at Level 1.

- At Level 2 a new trigger (SVT) will take tracks found in the XFT and associate them with hits in SVX II. The resulting tracks should have resolution of $< 50\mu$m on r-ϕ impact parameters, depending on how well we can track the beam.

The effect on CDF's B physics capability will be large[33]. We will be able to reduce the trigger thresholds for dilepton events down to 1.5 GeV for di-lepton events. Single leptons displaced from the primary vertex could be triggered down to 3 GeV. Lowering the di-mu thresholds and adding in the di-electrons will increase the triggered cross section for $b \rightarrow J/\psi$ events by a factor of four. Twice as many of the events will be within the SVX II acceptance. The integrated luminosity per year will be at least 0.5 fb^{-1} compared with 20 pb^{-1} in Run 1A. The increased size of the data set will obviously improve many of our current measurements. It will also, along with the 3-D vertexing in SVX II, make possible the observation and measurements of more rare B decays such as $K^*\mu^+\mu^-$, $K^*\gamma$, $\rho\gamma$, $\rho l\nu$, as well as measurements of the properties of the B_c meson.

This increase in statistics will also open up the possibility of observing CP violation in $B^0 \rightarrow J/\psi K_s$ decays. We conservatively estimate[34] the reach with the approved upgrades and *only* using lepton tagging to be $\delta(\sin 2\beta) = 0.4/\sqrt{L/1fb^{-1}}$. The other tagging techniques currently being studied could improve this by a factor of two or more.

The presence of tracking information at Level 1 and vertexing at Level 2 makes triggering on nonleptonic B decays possible. We have compared the decay mode $B^0 \rightarrow \pi^+\pi^-$ in Monte Carlo to real Minimum Bias triggers from 1A[35]. Simple cuts on P_T's and opening angles of tracks found by the XFT should keep the trigger rates under control. The efficiencies with these cuts seem high enough that, given the measured branching ratio from CLEO, we should be able to reconstruct the two-charged-hadron decay of the B at a rate comparable to $J/\psi K_s$. Given the current level of kaon identification in CDF, separating out the CP asymmetries due to individual components ($B^0 \rightarrow \pi^+\pi^-; K^+\pi^- : B_s \rightarrow K^-\pi+; K^-K^+$) may be difficult (see Figure 9). We also need to study other hadronic B decays, particularly from B_s, to understand possible improvements to mixing analyses. Most of the measurements done with hadronic B decays will also involve tagging its flavor at production. Thus the results of comparisons of various tagging techniques using 1B data will also affect the exact design of the topological trigger.

My opinions as to CDF's B physics prospects for the early Main Injector era are summarized in Table 1. It should be noted that these are large extrapolations from CDF's current experience with the Run 1A data. By *Beauty '96*, we should have gleaned much more information about our prospects from the 1A and 1B data. We will also have a better idea of the realities of scheduling and funding at Fermilab as well as the rest of the world.

5.3 Beyond Run II

Fermilab has begun the process of soliciting proposals for experiments to follow the first couple of years of Main Injector running. This is being termed Run III. Expressions-of-Interest were submitted in the week following this conference. The reader is encouraged to read our submission[34] as well as other's. I will only state a few of my own opinions.

- Until LHC turns on, there will be only two interaction regions where the top quark and other high P_T phenomena can be studied, B0 and D0 at Fermilab. This scarcity means that the detectors in these regions must maintain the ability to study the top quark and verify each others results.

- A detector capable of studying top must also be able analyze top's decay products, mostly B hadrons. The search for other exotic objects also often involves observing their decay to B hadrons. Thus in speaking of the difference between a high P_T detector and a B detector at the Tevatron one can be talking of small differences in optimization rather than designs that preclude one or the other.

- The major difference is that top events are rare and produce high P_T b jets. The detector must have fine enough granularity in the tracking chambers to identify B's in these dense jets. B's in B events are much lower P_T and the event rate is much higher. Minimizing material to reduce multiple scattering terms in the tracking resolution is important. A high rate DAQ system is also important for a B detector.

- An expensive new detector should not be built unless it can be shown to be competitive with experiments at LHC or brought on line *significantly* before the start of LHC running.

- Any upgrades to CDF that can be ready in time for Run II should be installed then rather than wait for Run III.

- A particle identification with good K/π separation would allow the use of kaon tagging in CP and mixing studies. A low-cost time-of-flight system could replace the Central Drift Tubes outside the CTC. This could substantially increase our CP reach and could be in place by the start of Run II. Separating $B^0 \to \pi^+\pi^-$ from $B_s \to K^+K^-$ would require a more sophisticated device capable of K/π identification up to $P = 5$ GeV.

- Multiple interactions cause increased occupancy in the inner layers of the CTC. This leads to degraded tracking efficiency and resolution at high luminosities. We have begun to study these effects by merging the data from top candidates or J/ψ events with the hits from additional Minimum Bias triggers. This will tell us the degradation with the current detector on b-tagging in top events and J/ψ and K_s reconstruction in B events. We are also beginning Monte Carlo studies to see how extra high granularity tracking devices added between the SVX II and CTC would alleviate potential problems. Such a device could also serve to extend the rapidity coverage for tracking and triggering. At some instantaneous luminosity, the occupancy will be so great the CTC should be replaced. If it is determined that the Tevatron will operate above this point, the design of the new tracker can consider using some of that space for a particle identification system.

A detailed discussion of the proposal should probably wait until further work has been done and we know which of CDF's upgrade options are technically, fiscally, and politically viable. Those studies should be ready when the Letter-of-Intent is due, sometime this winter. Again, I think we can look forward to some interesting presentations at *Beauty '95* and *Beauty '96*.

6 ACKNOWLEDGEMENTS

I would like to thank Jon Lewis for his help with the preparation my originally scheduled talk. I would especially like to thank Peter Wilson and Jim Hylen for their assistance in preparing the last minute additional talk on upgrade plans. Finally, I would like to express my gratitude to the people who made my time at Rutgers and CDF so pleasant and stimulating. I wish you all the luck in the future and hope that at least some of us can work together again.

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Projections of Future Results

	Beauty '96	Beauty 2000
$\tau(B^0)$	$\pm 5\%$	$< \pm 2\%$
$\tau(B^+)$	$\pm 5\%$	$< \pm 2\%$
$\tau(B_s)$	$\pm 10\%$	$\pm 3\%$
$\tau(\Lambda_b)$	$\pm 15\%$	$\pm 5\%$
$\tau(\Xi_b)$	$\pm 30\%$	$\pm 10\%$
$\tau(\Omega_b)$	no	?
x_s reach	5-10	10-20
B_c	?	Observe
Rare decays	?	Some observed
$\sin(2\beta)$	no	$\pm 0.2 - 0.4$
$\sin(2\alpha)$	no	?
$\sin(2\gamma)$	no	??

Table 1: Estimates of CDF results that could be presented in future meetings of this conference as well as the estimated timescale.

Figure 1: Mass distributions of the fully reconstructed B samples. ΔM is the difference between the measured mass and the world average B meson mass. The lower histograms are obtained by requiring $c\tau > 100\ \mu$m.

Figure 2: The proper decay length ($c\tau$) distributions of the fully reconstructed B samples. The fits (curves) are described in the text.

Figure 3: The $\phi\pi$ mass distribution for events where the lepton and pion have the opposite charge (upper plot) and same charge (lower plot).

Figure 4: The pseudo-$c\tau$ distribution for events in the B_s signal region. The solid curve is the result of the unbinned likelihood fit to the signal and background. The dashed curve indicates the background contribution as determined from the background sample (lower plot).

Figure 5: a)The J/ψ K^+K^- mass distribution for K^+K^- within 10 MeV/c^2 of the ϕ mass (solid). The dots are the normalized ϕ sideband region ($M_{K^+K^-}$ between 1050-1090 MeV/c^2). b) The K^+K^- mass distribution for J/ψ K^+K^- combinations within 20 MeV/c^2 of 5380 MeV/c^2.

Figure 6: The J/ψ differential cross section, along with the separation into prompt and B components as determined from the decay length distributions.

Figure 7: The $\psi(2S)$ differential cross section, along with the separation into prompt and B components as determined from the decay length distributions. The B and prompt points have been artificially offset along the x axis in order to make them easier to see.

Figure 8: The B meson differential cross section compared to a NLO calculation convoluted with Peterson fragmentation.

Figure 9: The mass distribution for the combination of $B^0 \to \pi^+\pi^-$, $B^0 \to K^+\pi^-$, $B_s \to \pi^+K^-$, and $B_s \to K^+K^-$ assigning the pion mass to all kaons. The rate corresponds to approximately 0.25 fb^{-1} of Monte Carlo.

Projections of Future Results		
	Beauty '96	Beauty 2000
$\tau(B^0)$	$\pm5\%$	$< \pm2\%$
$\tau(B^+)$	$\pm5\%$	$< \pm2\%$
$\tau(B_s)$	$\pm10\%$	$\pm3\%$
$\tau(\Lambda_b)$	$\pm15\%$	$\pm5\%$
$\tau(\Xi_b)$	$\pm30\%$	$\pm10\%$
$\tau(\Omega_b)$	no	?
x_s reach	5-10	10-20
B_c	?	Observe
Rare decays	?	Some observed
$\sin(2\beta)$	no	$\pm0.2 - 0.4$
$\sin(2\alpha)$	no	?
$\sin(2\gamma)$	no	??

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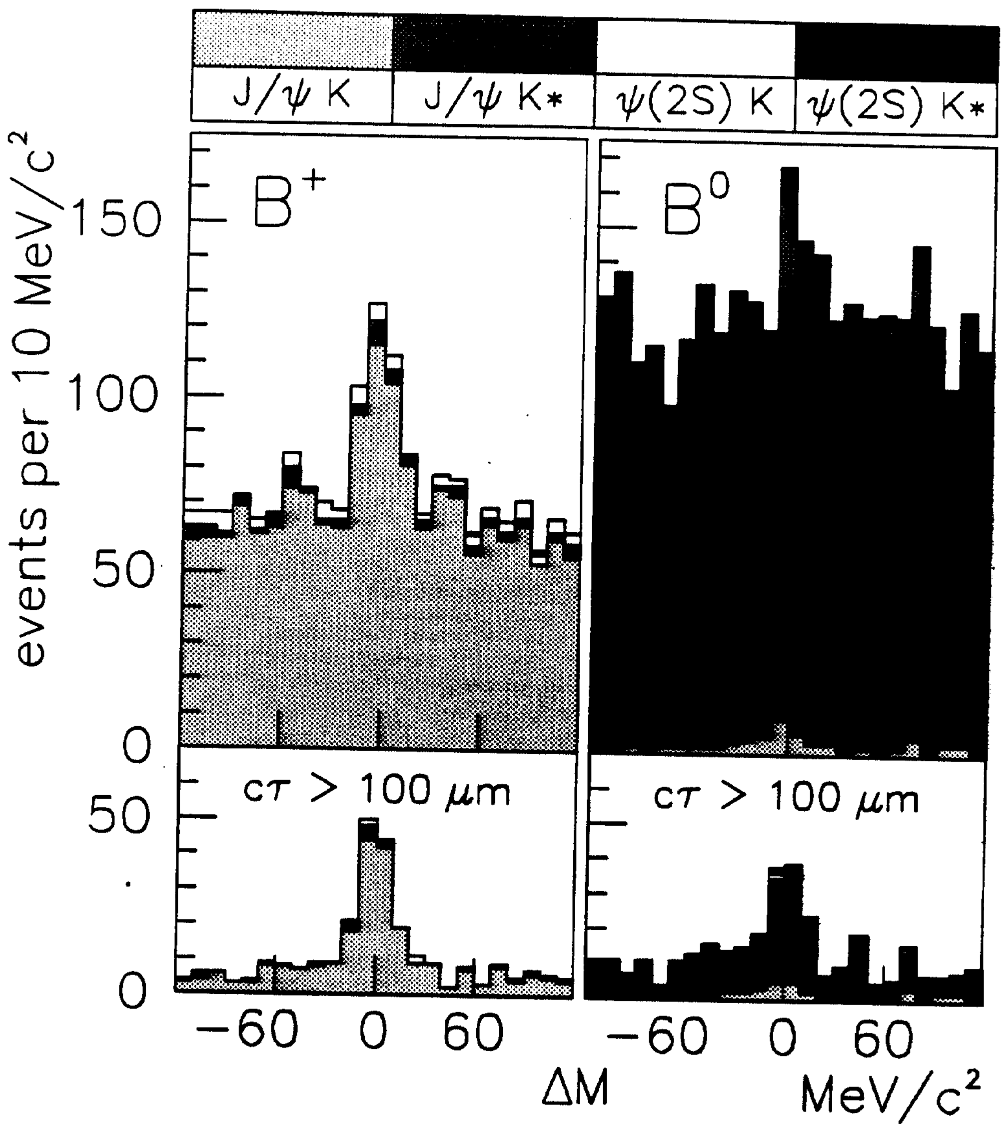

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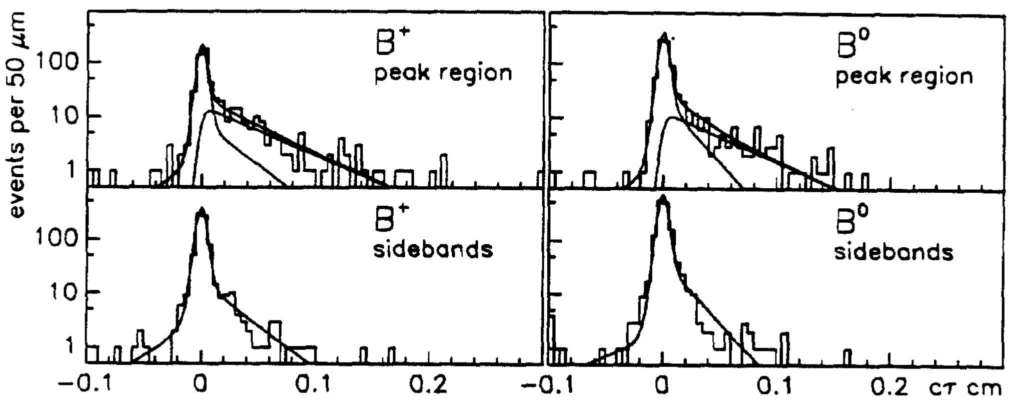

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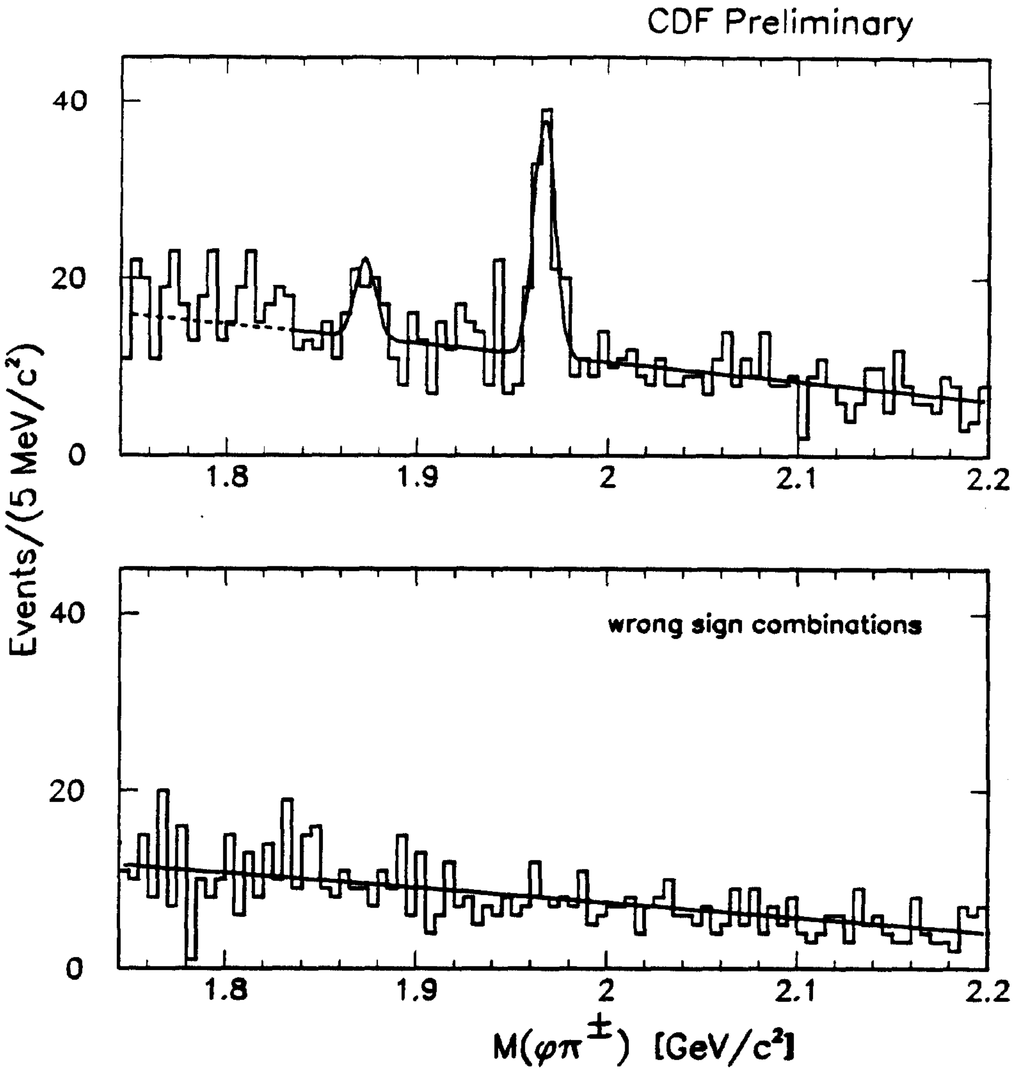

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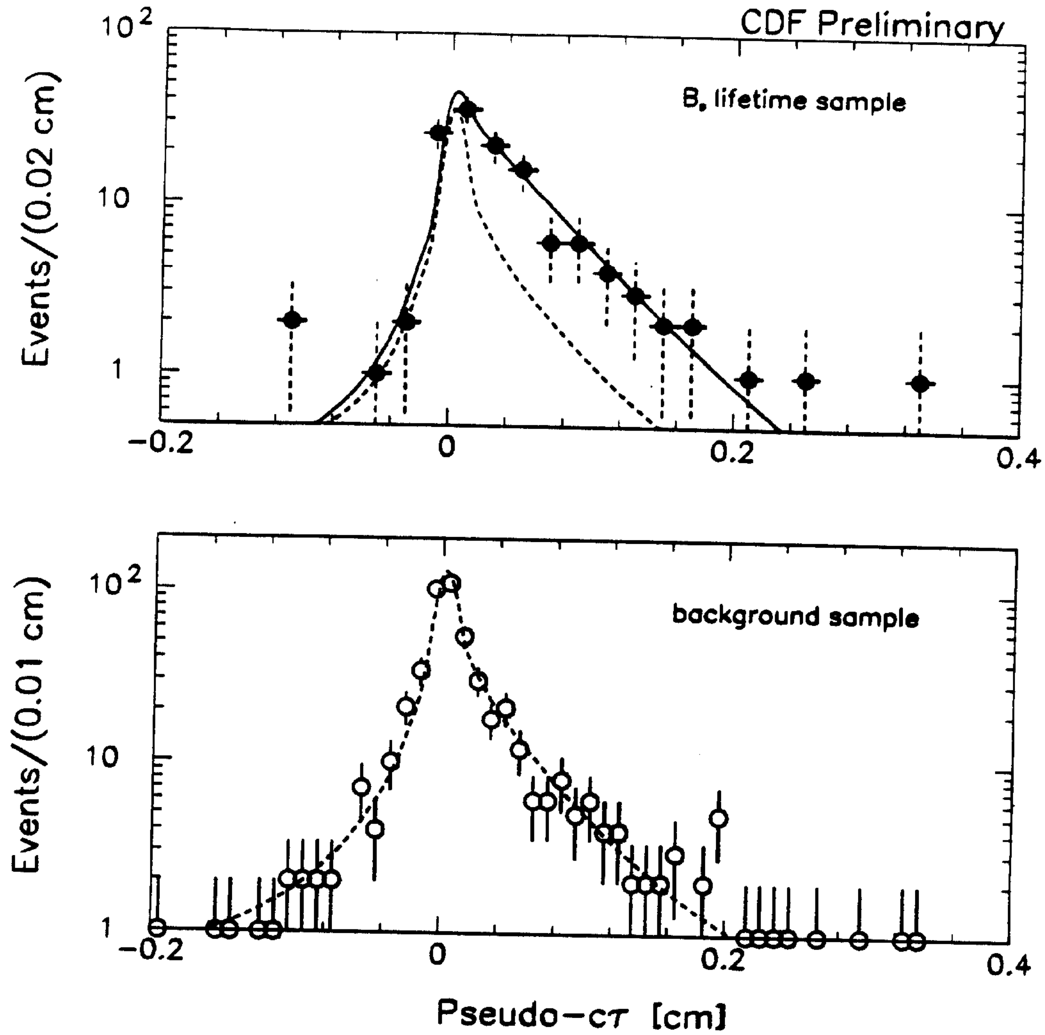

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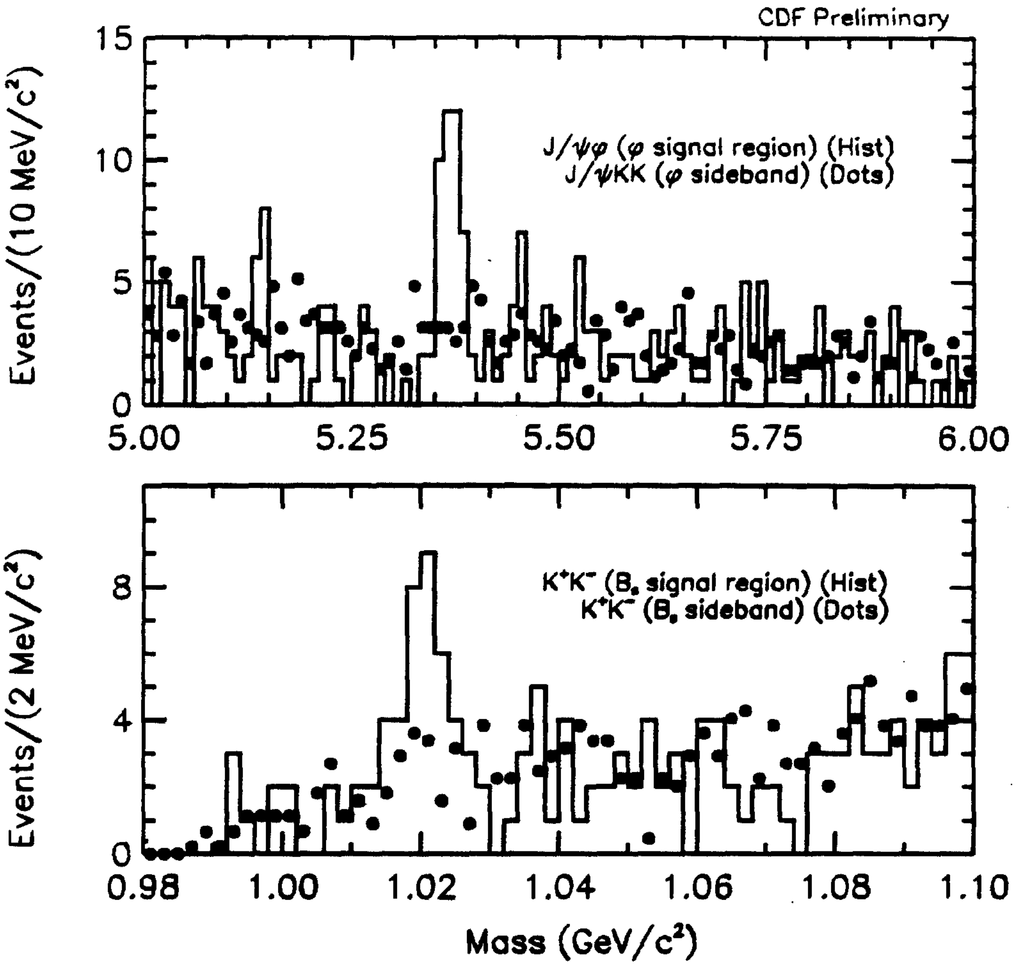

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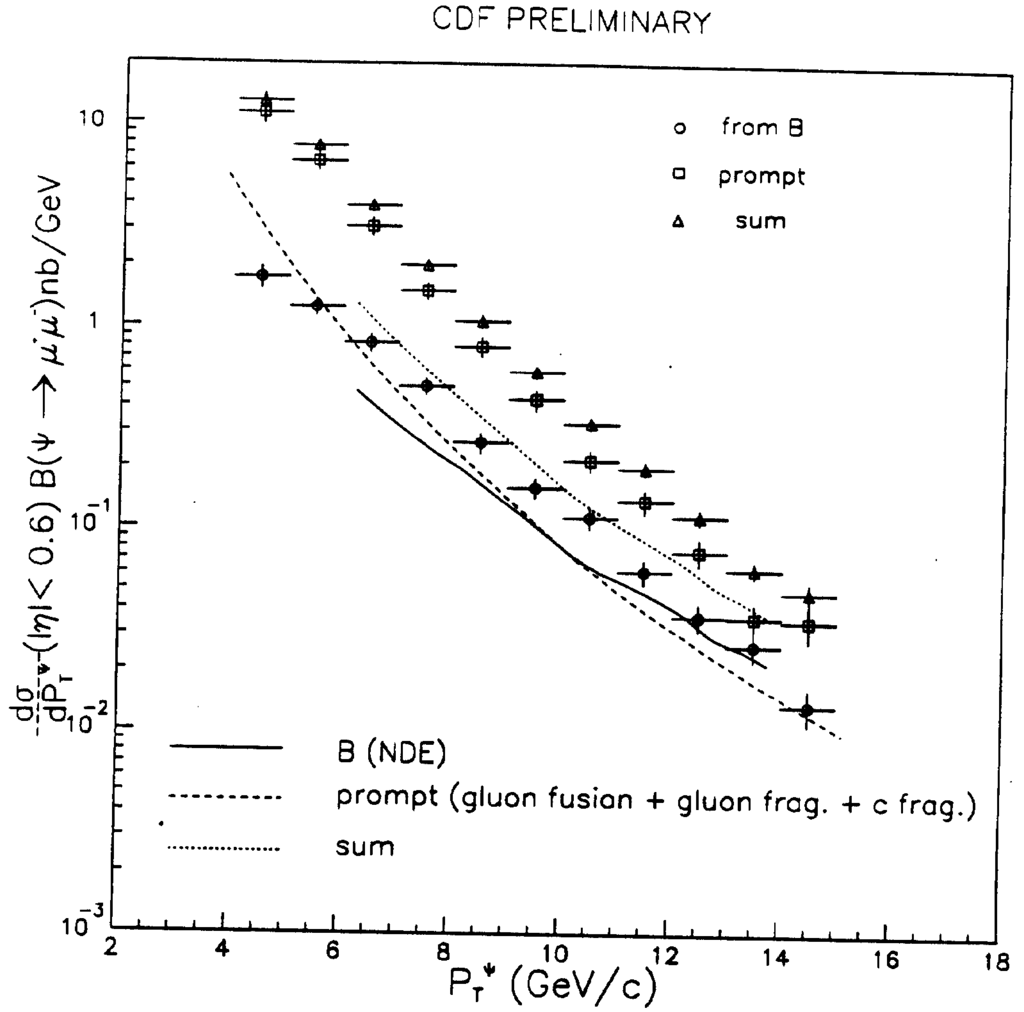

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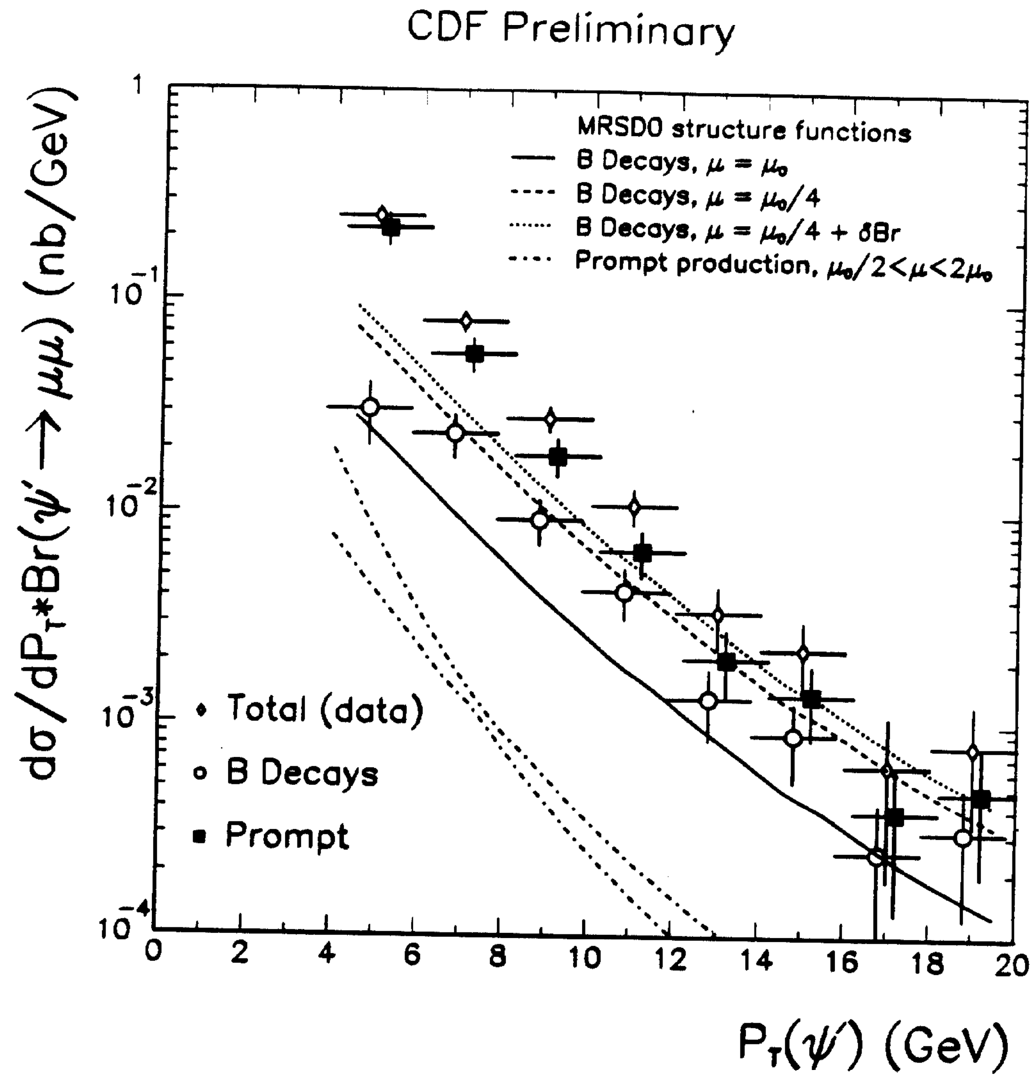

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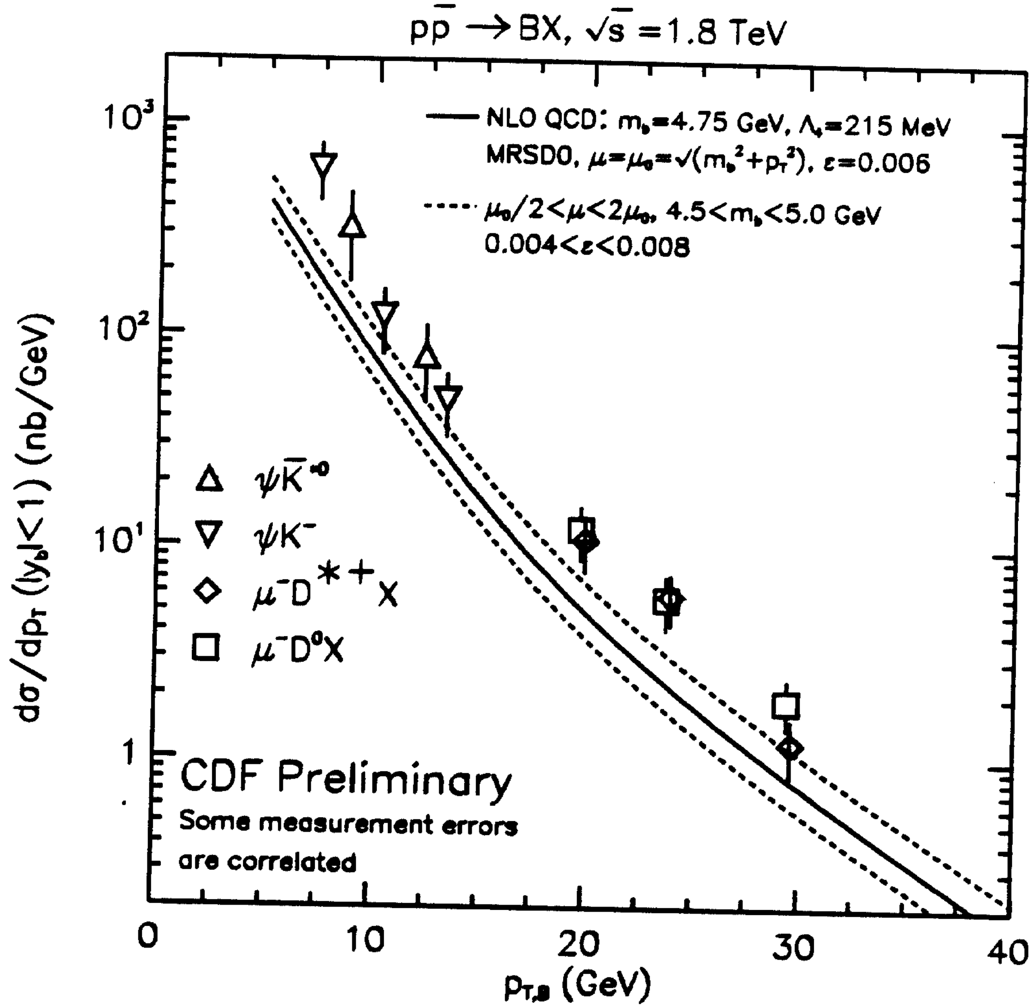

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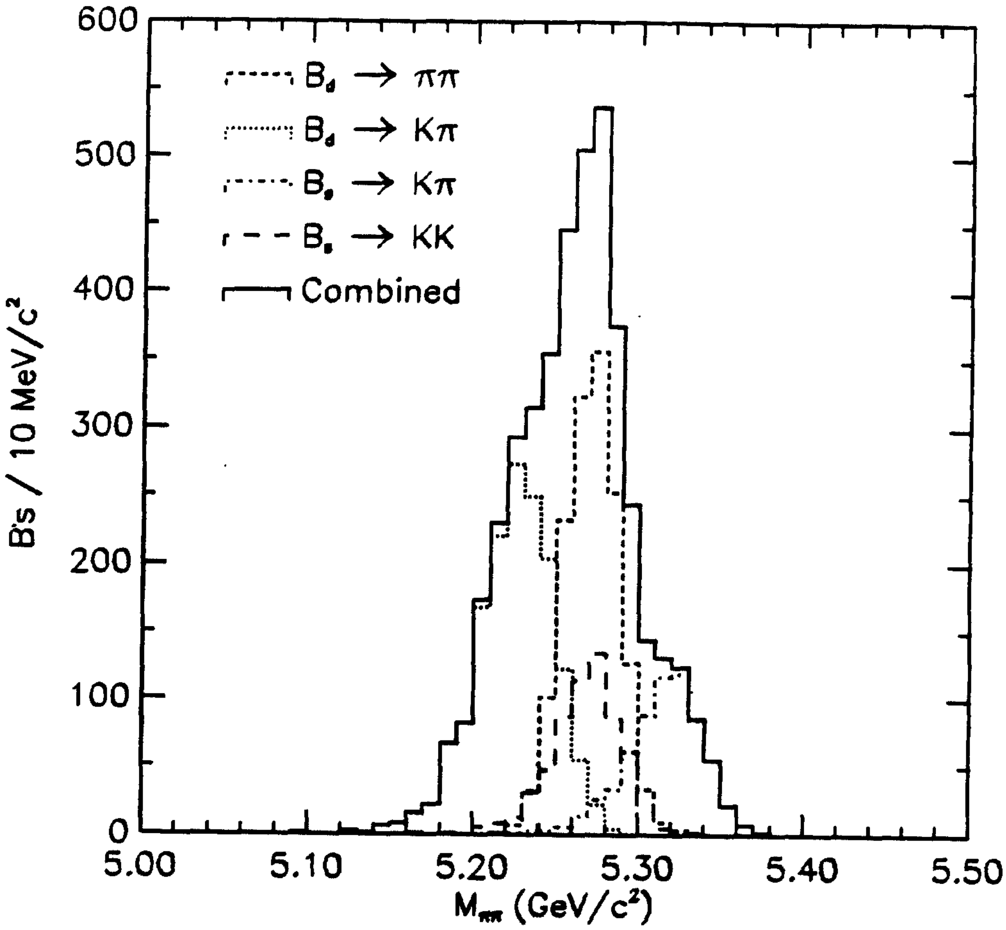

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