B Physics at CDF

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Due to the large $b\bar{b}$ cross section at 1.96 TeV $p - \bar{p}$ collisions, the Tevatron is currently the most copious source of B hadrons. Recent detector upgrades for Run II have made these more accessible, allowing for a wide range of B and $Q\bar{Q}$ physics with B hadrons of all flavours. In this paper we present B-physics results, and, using the versatile hadronic Two Track Trigger, a search for $\Xi(1860)$, from up to 240 pb$^{-1}$ of data.

1 Introduction

CDF has been taking data at Tevatron Run IIa for about two years. For $p\bar{p}$ collisions at 1.96 TeV, the $b\bar{b}$ production cross section is $\sigma_{b\bar{b}} \sim 0.1$ mb. CDF has undergone major upgrades for Run II, optimising its B physics potential. The upgrades most relevant for CDF’s B physics program include a new tracking system with a new, faster drift chamber, and new Silicon vertex trackers providing excellent proper time resolution, sufficient to resolve the expected fast oscillations in the $B_0$ system. The excellent impact parameter resolution is used for triggering on B-events. The muon coverage has been increased. A di-muon trigger efficiently finds $B \to J/\psi X$ decays.

Here we present some of the wide range of analyses of the current CDF B physics program, which includes a wide range of studies, involving all types of B-hadrons, including leptonic as well as fully hadronic decays of $B_d, B^+, B_s, B_c, \Lambda_b$. The impact-parameter based trigger also provides a very large sample of long-lived $\Xi^-$. This has been used for a sensitive search for $\Xi^0(1860) \to \Xi^- \pi^+$ and $\Xi^{--} \to \Xi^- \pi^-$, which have been observed at NA49$^1$ and are often interpreted as pentaquark states.
Table 1: Lifetimes and lifetime ratios in Run II from $B^+_s \rightarrow J/\psi(\mu^+\mu^-)K^+$ (240 pb$^{-1}$), $B^0_d \rightarrow J/\psi(\mu^+\mu^-)K^{(*)0}$ (240 pb$^{-1}$), $B^0_s \rightarrow J/\psi(\mu^+\mu^-)\phi$ (240 pb$^{-1}$), $\Lambda_b \rightarrow J/\psi(\mu^+\mu^-)\Lambda$ (65 pb$^{-1}$) compared with world average (HFAG results for PDG 04, and, for $\Lambda_b$, results for PDG 02), Run I results and HQE predictions. Run I results are from all channels combined, Run II results from fully reconstructed $J/\psi(\mu\mu)X$ only.

| Channel | Result (ps) |
|---------|-------------|
| $B^+_s \rightarrow J/\psi(\mu^+\mu^-)K^+$ | $1.662 \pm 0.022 \pm 0.008$ |
| $B^0_d \rightarrow J/\psi(\mu^+\mu^-)K^{(*)0}$ | $1.539 \pm 0.051 \pm 0.008$ |
| $B^0_s \rightarrow J/\psi(\mu^+\mu^-)\phi$ | $1.369 \pm 0.100^{+0.008}_{-0.010}$ |
| $\Lambda_b \rightarrow J/\psi(\mu^+\mu^-)\Lambda$ | $1.25 \pm 0.25 \pm 0.10$ |

Note that the Run II result for $B_s \rightarrow J/\psi\phi$ is dominated by the (shorter) lifetime of the CP-even component.

2 Results from the Di-Muon Trigger

2.1 $b$ Production Cross Section

The inclusive $b$-hadron production cross-section is measured from the $b$-fraction in the reconstructed $J/\psi$ sample up to February 2002 (37 pb$^{-1}$). Combining this number with the inclusive $J/\psi X$ cross section, and the appropriate branching fractions, allows to calculate the absolute $b$ production cross section. The long lifetime of $B$-hadrons is used to discriminate between prompt $J/\psi$ and $J/\psi$ from $B$-hadron decays. The total single $b$-quark cross section integrated over one unit of rapidity is

$$\sigma(p\bar{p} \rightarrow \bar{b}X : |y| < 1.0) = 29.4 \pm 0.6 \text{(stat)} \pm 6.2 \text{(sys)} \mu\text{b}$$

where the largest contributions to the systematic error come from uncertainties in the acceptance and the inclusive $B$-hadron to $J/\psi$ branching ratio.

2.2 Lifetimes

Life time measurements in the heavy quark sector gain specific significance due to the precise predictions of Heavy Quark Expansion thus providing a testing ground for this theoretical tool that is frequently used, for example to relate experimental measurements to CKM parameters like $\Gamma_d$ to $|V_{tb}|$ or $\Delta m_s/\Delta m_d$ to $|V_{ts}/V_{td}|$.

Fully reconstructed hadronic $B \rightarrow J/\psi X$ decays, found with CDF’s di-muon trigger, provide a clean method for measuring $B$ lifetimes, free from the systematic uncertainties associated with semileptonic decays due to the missing momentum of the $\nu$, and free from the lifetime bias in impact parameter-based trigger samples. Of specific interest at CDF are the lifetimes of the $B_s$ and $\Lambda_b$, which are currently produced in large quantities only at the Tevatron. Lifetime results, and lifetime ratios, compared to theory predictions, Run I results, and world averages, are summarised in Table 1.

2.3 CP content of $B_s \rightarrow J/\psi\phi$

The measurement of the average lifetime in $B_s \rightarrow J/\psi\phi$ constitutes a first step towards a measurement of $\Delta T_{av}$, the width difference between the long and short lived CP eigenstates, which has some sensitivity to new physics, especially when compared to the mass difference, $\Delta m_s$, which is also going to be measured at the Tevatron. The CP-even and odd contribution in $B_s \rightarrow J/\psi\phi$ can be disentangled by analysing the decay in terms of transversity angles, leading
Table 2: Transversity-angle analysis in \( B_s \to J/\psi \phi \) and \( B_d \to J/\psi K^{*0} \). \( A_0 \) and \( A_\parallel \) are CP even decay amplitudes, \( A_\perp \) is CP-odd, normalised such that \( |A_0|^2 + |A_\parallel|^2 + |A_\perp|^2 \approx 1 \).

| \( B_s \to J/\psi \phi \) | \( B_d \to J/\psi K^{*0} \) |
|------------------|------------------|
| \( A_0 = 0.762 \pm 0.044 \pm 0.07 \) | \( A_0 = 0.796 \pm 0.022 \pm 0.012 \) |
| \( A_\parallel = (0.433 \pm 0.199 \pm 0.011) e^{i(2.08 \pm 0.51 \pm 0.06)} \) | \( A_\parallel = (0.433 \pm 0.037 \pm 0.014) e^{i(3.10 \pm 0.50 \pm 0.06)} \) |
| \( |A_\perp| = 0.481 \pm 0.104 \pm 0.025 \) | \( |A_\perp| = 0.422 \pm 0.050 \pm 0.027 \) |

(a) Discriminating Variables: Mass, lifetime, \( \Delta \phi \) and isolation \((p_t(\mu) \text{ divided by all } p_t \text{ in a cone around the } \mu)\). (b) 1 event found in overlap of search windows - consistent with bkg estimate of \( 1.05 \pm 0.30 \) (\( B_d \)), \( 1.07 \pm 0.31 \) (\( B_s \)), \( 1.75 \pm 0.34 \) (combined). (c) Projected and current sensitivity to \( B_s \to \mu \mu \) at CDF, not including expected improvements due to increased \( \mu \) coverage.

Figure 1: Search for \( B_{d,s} \to \mu^+ \mu^- \)

The CDF Run II results for \( 192 \text{ pb}^{-1} \) are shown in Table 2 for both \( B_s \to J/\psi \phi \) and, as a cross check, \( B_d \to J/\psi K^{*0} \). The \( B_d \) results are consistent with those from BaBar \(^8\) and CLEO \(^9\). The phases of the amplitudes provide an interesting test of factorisation, which predicts the relative phases to be either 0 or \( \pi \). The amplitude measurements imply a CP-even content in \( B_s \to J/\psi \phi \) of \( 77\% \pm 10\% \). Work is in progress to combine this technique with the lifetime analysis for a \( \Delta \Gamma_s \) measurement.

2.4 Search for New Physics with \( B_{d,s} \to \mu^+ \mu^- \)

While in the Standard Model, the branching ratio of \( B_{d,s} \to \mu^+ \mu^- \) is \( \mathcal{O}(10^{-9}) \), which is below the sensitivity of the Tevatron, many New Physics models predict enhancements of this mode by several orders of magnitude, for example mSUGRA \(^1\) and SO(10) Symmetry breaking models \(^2\). In mSUGRA, the \( B_{d,s} \to \mu^+ \mu^- \) branching ratio is approximately \( 10^{-6} \cdot \tan^6 \beta \frac{M_1^2 \text{ GeV}^4}{(M_1^2 + M_0^2)^3} \), which increases rapidly with large \( \tan \beta \).

The search for \( B_{d,s} \to \mu^+ \mu^- \) was performed as a blind analysis. The cuts were optimised using Monte-Carlo generated signal events and background events from real data. Signal and background distributions for the most important cuts are shown in Figure 1 (a). After all cuts are applied, \( 1.05 \pm 0.30 \) background events are expected in the \( B_d \) mass window and \( 1.07 \pm 0.31 \)
Figure 2: The CDF hadronic 2-Track-Trigger. $\Delta \phi$ is the angle between the tracks in the transverse plane. IP is the 2-D impact parameter of each of the two tracks. $L_{xy}$ is the decay length in the transverse plane. The table on the left lists the trigger requirements. The figure on the right shows the IP resolution at trigger level.

| L1: 2 XFT tracks, $p_t > 2$ GeV, $\Delta \phi < 135^\circ$, $p_{t1} + p_{t2} > 5.5$ GeV. |
| L2: |
| 2-body: | Multi-body: |
| e.g. $B^0 \rightarrow \pi\pi$ | e.g. $B^0_s \rightarrow D_s\pi$ |
| $100 \mu m < IP < 1$ mm | $120 \mu m < IP < 1$ mm |
| $20^\circ < \Delta \phi < 135^\circ$ | $2^\circ < \Delta \phi < 90^\circ$ |
| $L_{xy} > 200 \mu m$ | $L_{xy} > 200 \mu m$ |
| IP of $B < 140 \mu m$ | - |
| L3: Same with refined tracks & mass cuts. |

$B_s$ mass window, both are 200 MeV wide, and overlap. The number of background events predicted for the combined mass window is $1.75 \pm 0.34$. Several cross checks in real data have been performed before unblinding, for example using wrong-sign di-muon events ($\mu^+\mu^+$ and $\mu^-\mu^-$), which yielded consistent results. The total number of events found after unblinding is 1 event in the overlap region of the two mass windows, as shown in Figure I (b), resulting in the following 90% confidence limits:

$$\text{BR}(B_d \rightarrow \mu^+\mu^-) < 1.5 \cdot 10^{-7} \ (90\%\text{CL})$$

$$\text{BR}(B_s \rightarrow \mu^+\mu^-) < 5.8 \cdot 10^{-7} \ (90\%\text{CL})$$

which is, for the $B_d$, similar to the results from BaBar and BELLE, and more than a factor of 3 better than the previous best limit for $B_s \rightarrow \mu\mu$, which was provided by CDF Run I. The projected performance as a function of integrated luminosity, ignoring future improvements due to the expected increase in muon coverage, is shown in Figure I (c).

3 Results from the Impact Parameter-Based Hadronic B Trigger

3.1 CDF’s Two Track Trigger

One of the most innovative improvements for B physics at CDF is the large-bandwidth hadron trigger, which triggers on the impact parameters of tracks at Level 2. The trigger requirements for the two scenarios, 2-body and multi-body B decays, are given in Figure 2. CDF’s Two Track Trigger provides a unique sample of hadronic bottom and charm decays, that would otherwise be inaccessible, for example $B^0 \rightarrow \pi\pi$ and $B_s \rightarrow D_s\pi$.

3.2 $B \rightarrow hh$

Figure 3 (a) shows the invariant mass of reconstructed B to two-hadron events (assuming the hadrons are pions). About 900 events are found. In order to discriminate the different decay modes, pions and kaons are separated using their specific energy loss, $dE/dx$. The $\pi/K$ discrimination using $dE/dx$ has been measured using $D^*$ decays and has been found to be $1.16\sigma$, as shown in figure 3 (b). Further discrimination between the different $B \rightarrow hh$ decay modes is achieved using decay kinematics, as shown in 3 (c). The plot shows the reconstructed B mass in Monte Carlo simulated $B \rightarrow hh$ events vs $(1 - p_1/p_2) \cdot q_1$ for different decay modes. Here, $p_1$ is the smaller of the two momenta, $q_1$ is the charge of the particle with momentum $p_1$, and the mass is calculated assuming the decay products are pions. This led to the first observation of the decay
vanish in the Standard Model: This allows a precise measurement of time-integrated CP asymmetries, which are expected to be reconstructed D∗.

The Two Track Trigger also provides a huge charm signal, where the same methods can be applied. In the analysis presented here, only D∗ mesons from D∗ decays are used, which has two advantages: a very clean signal due to the highly effective cut on the difference between the reconstructed D∗ and D0 mass, and the flavour of the D0 is known from the charge of the D∗.

This allows a precise measurement of time-integrated CP asymmetries, which are expected to vanish in the Standard Model:

- \( A_{CP}^{KK} = \frac{\Gamma(B_s^0 \rightarrow K^+K^-) - \Gamma(B_s^0 \rightarrow K^0\pi^0)}{\Gamma(B_s^0 \rightarrow K^+K^-) + \Gamma(B_s^0 \rightarrow K^0\pi^0)} = 2.0% \pm 1.2% \pm 0.6% \)

- \( A_{CP}^{\pi\pi} = \frac{\Gamma(D^0 \rightarrow \pi^+\pi^-) - \Gamma(D^0 \rightarrow \pi^0\pi^0)}{\Gamma(D^0 \rightarrow \pi^+\pi^-) + \Gamma(D^0 \rightarrow \pi^0\pi^0)} = 1.0% \pm 1.2% \pm 0.6% \)

Branching ratios of D0 mesons are also of some interest, for example \( \frac{\Gamma(D^0 \rightarrow K^+K^-)}{\Gamma(D^0 \rightarrow \pi^+\pi^-)} \), which is consistently larger experimentally, than theoretically predicted. The following summarises the ratios of B.R. results:

- \( \frac{\Gamma(D^0 \rightarrow K^+K^-)}{\Gamma(D^0 \rightarrow \pi^+\pi^-)} = 9.96% \pm 0.11% \pm 0.12% \)

- \( \frac{\Gamma(D^0 \rightarrow \pi^+\pi^-)}{\Gamma(D^0 \rightarrow K^+K^-)} = 3.608% \pm 0.054% \pm 0.12% \)

- \( \frac{\Gamma(D^0 \rightarrow K^0\pi^0)}{\Gamma(D^0 \rightarrow \pi^+\pi^-)} = 2.762% \pm 0.040% \pm 0.034% \)

B\(_s^0 \rightarrow K^+K^-\). A summary of the results from analysing B → hh events in 65pb\(^{-1}\) of data are given below:

- First observation of B\(_s^0 \rightarrow KK\): 90 ± 24 out of 300 B → hh events.
- Search for \( \Omega_P \) in time-integrated rates
  \[ A_{CP} = \frac{\Gamma(B_d^0 \rightarrow K^-\pi^+)}{\Gamma(B_d^0 \rightarrow K^-\pi^+)+\Gamma(B_d^0 \rightarrow K^+\pi^-)} = 0.02 \pm 0.15 \pm 0.017 \]
- Ratios of B.R.:
  \[ \frac{\Gamma(B_s^0 \rightarrow \pi^+\pi^-)}{\Gamma(B_s^0 \rightarrow K^+K^-)} = 0.26 \pm 0.11 \pm 0.06 \]
  \[ \frac{\Gamma(B_s^0 \rightarrow K^+K^-)}{\Gamma(B_s^0 \rightarrow K^0\pi^0)} = 2.71 \pm 0.73 \pm 0.35(f_s/f_d) \pm 0.81 \]

where \( f_s/f_d \) refers to the uncertainty due to the B\(_s^0\)/B\(_d\) production ratio.

Results for 195pb\(^{-1}\) should follow, soon. In the long term, these methods can be used to extract the CP-violating phase \( \gamma \) from a combined analysis of time-dependent decay rate asymmetries in B\(_d\) → \( \pi\pi \) and B\(_s^0 \rightarrow KK\).[13]

### 3.3 D\(_0^0 \rightarrow hh\)

The Two Track Trigger also provides a huge charm signal, where the same methods can be applied. In the analysis presented here, only D\(_0^0\) mesons from D\(*\) decays are used, which has two advantages: a very clean signal due to the highly effective cut on the difference between the reconstructed D\(*\) and D\(_0^0\) mass, and the flavour of the D\(_0^0\) is known from the charge of the D\(*\). This allows a precise measurement of time-integrated CP asymmetries, which are expected to vanish in the Standard Model:

- \( A_{CP}^{KK} = \frac{\Gamma(D^0 \rightarrow K^-\pi^+)}{\Gamma(D^0 \rightarrow K^-\pi^+)+\Gamma(D^0 \rightarrow K^+\pi^-)} = 2.0% \pm 1.2% \pm 0.6% \)

- \( A_{CP}^{\pi\pi} = \frac{\Gamma(D^0 \rightarrow \pi^+\pi^-) - \Gamma(D^0 \rightarrow \pi^0\pi^0)}{\Gamma(D^0 \rightarrow \pi^+\pi^-) + \Gamma(D^0 \rightarrow \pi^0\pi^0)} = 1.0% \pm 1.2% \pm 0.6% \)

Branching ratios of D\(_0^0\) mesons are also of some interest, for example \( \frac{\Gamma(D^0 \rightarrow K^+K^-)}{\Gamma(D^0 \rightarrow \pi^+\pi^-)} \), which is consistently larger experimentally, than theoretically predicted. The following summarises the ratios of B.R. results:

- \( \frac{\Gamma(D^0 \rightarrow K^+K^-)}{\Gamma(D^0 \rightarrow \pi^+\pi^-)} = 9.96% \pm 0.11% \pm 0.12% \)

- \( \frac{\Gamma(D^0 \rightarrow \pi^+\pi^-)}{\Gamma(D^0 \rightarrow K^+K^-)} = 3.608% \pm 0.054% \pm 0.12% \)

- \( \frac{\Gamma(D^0 \rightarrow K^0\pi^0)}{\Gamma(D^0 \rightarrow \pi^+\pi^-)} = 2.762% \pm 0.040% \pm 0.034% \)
3.4 \( B_s \rightarrow D_s \pi \)

The decay of \( B_s \) to the flavour-eigenstate \( D_s \pi \) is the “flagship mode” for \( B_s \) mixing at CDF. Being fully reconstructible (no missing \( \nu \)), it provides for excellent time resolution - in topologically similar decays, CDF currently achieves \( \sim 67 \text{ fs} \), and hopes to improve once the innermost Si layer has been fully commissioned and aligned. In \( 119 \text{ pb}^{-1} \), \( 84 \pm 11 \) \( B_s \rightarrow D_s \pi \) have been reconstructed with a signal to background ratio of \( \sim 2 \). The reconstruction efficiency has been increased since data taking has started and is now at \( \sim 1.6 \) events per \text{ pb}^{-1}. These data can be used to calculate the relative production \( \times \text{B.R.} \) in \( B_s \rightarrow D_s \pi \) and \( B_d \rightarrow D \pi \):

\[
\frac{f_s \cdot BR(B^0_s \rightarrow D^-_s \pi^+)}{f_d \cdot BR(B^0_d \rightarrow D^- \pi^+)} = 0.35 \pm 0.05 \pm 0.04 \pm 0.09(BR)
\]

where the last error is due to the uncertainty in the B.R. of the charm mesons.

3.5 \( B_d \) mixing

A further step towards measuring \( B_s \) mixing is to make the somewhat easier measurement in the \( B_d \) system and check for consistency with the well-established results from the B factories, and Run 1. About \( 1k \) \( B_d \rightarrow J/\psi K^* \) and \( 5k \) \( B_d \rightarrow D \pi \) events from \( 270 \text{ pb}^{-1} \) were used for this measurement. The mass difference is extracted by measuring the oscillation frequency in time-dependent decay rate asymmetries. The asymmetries are between \( B \) decays that did not change flavour (e.g. \( B^0 \rightarrow \bar{D}^0 \pi^- \), neglecting Cabbibo suppressed decays), and those that did (e.g. \( B^0 \rightarrow D^0 \pi^+ \)). In the measurement presented here, the flavour of the \( B^0 \) at birth was determined using same-side tagging only, which is based on the correlation of the \( B^0 \) or \( \bar{B}^0 \) flavour at birth, and the charge of the pion produced alongside, picking up the “left over” \( d \) or \( \bar{d} \) quark. (The same principle can be applied to \( B_s \) mesons, using Kaon tags.) The tagging efficiency and dilution are measured using charged \( B \) decays. The tagging power for same-side pion tagging is

\[
\varepsilon D^2 = (1.0 \pm 0.5 \pm 0.1) \%
\]

where \( \varepsilon = (63 \pm 0.6)\% \) is the tagging efficiency (fraction of tagged events) and \( D = (12.4 \pm 3.3)\% \) the “dilution” defined as \( D \equiv (1 - 2\omega) \), where \( \omega \) is the mis-tag fraction. Note that a large “dilution”, according to this definition, is a good thing. The tagging power \( \varepsilon D^2 \) describes the statistical power of the tag: \( N \) events before tagging are statistically equivalent \( \varepsilon D^2 \times N \) perfectly tagged events. A simultaneous fit to the time-dependent decay rate asymmetries in \( B_d \rightarrow J/\psi K \) and \( B_d \rightarrow D \pi \), shown in Figure 4, yields for the mass difference in the \( B_d \) system:

\[
\Delta m_d = (0.55 \pm 0.10 \pm 0.01) \text{ ps}^{-1}
\]
Opposite side tagging In independent studies, other tagging methods have been investigated. Opposite side muon tagging yields a tagging power of $\varepsilon D^2 = (0.660 \pm 0.093)\%$, jet charge tagging $\varepsilon D^2 = (0.419 \pm 0.024(stat))\%$. Further taggers are under investigation.

3.6 Pentaquarks

The impact-parameter based trigger does not only provide large numbers of bottom and charm mesons, but of all long lived particles, including the $\Xi^-$. Combining this with a pion allows to search for the $\Xi^0(1860)$ and $\Xi^{--}$ observed at NA49, which is often interpreted as a pentaquark.

CDF searches for the $\Xi^0(1860)$ and $\Xi^{--}$ in the decay modes $\Xi^0(1860) \to \Xi^-\pi^+$ and $\Xi^{--} \to \Xi^-\pi^-$ with $\Xi^- \to \Lambda(p\pi)\pi^-$. The $\Xi^-$ lives long enough to leave hits in the Si detector before decaying. Requiring hits from the $\Xi^-$ in the Si provides a very efficient cut. Figure 5(a) shows the mass distribution a sample of 36,000 $\Xi^-$. The tiny background contribution, estimated from wrong-charge combinations, is superimposed as the shaded histogram.

In a second step, the $\Xi^-$ is combined with a $\pi^\pm$. Figure 5(b) shows the invariant mass distribution for same charge (shaded histogram) and opposite charge (black crosses) combinations of $\Xi^-$ and pions. The line represents a fit to the opposite charge mass distribution. There is a clear peak at the well-known $\Xi^0(1530)$ resonance, that is used as a reference in this analysis. However, neither the same sign nor the opposite sign combination show any evidence of a resonance at 1860 MeV. As a cross check, the analysis was repeated using the Jet20 trigger sample, that is not affected by an impact parameter cut. For 4k $\Xi^-$ in the Jet20 sample, no evidence of a $\Xi(1860)$ was found. The 95% upper confidence limits for the ratio of $\Xi(1860)$ to the known $\Xi^0(1530)$ are:

| $\Xi^-\pi^+(\text{search}) / \Xi(1530)(\text{control})$ | 0.07 |
|----------------------------------------------------------|------|
| $\Xi^-\pi^-(\text{search}) / \Xi(1530)(\text{control})$ | 0.04 |

4 Conclusion

Large numbers of $B$ hadrons of all flavours are produced at the Tevatron. CDF has measured the $b$ production cross section in $b \to J/\psi X$ events. Fully reconstructed $B \to J/\psi X$ events have been used for precise lifetime measurements of $B_d, B_s$ and $\Lambda_b$ hadrons, which will provide a test of Heavy Quark Expansion. The CP content of $B_s \to J/\psi\phi$ has been measured using a transversity angle analysis, which will be combined with the lifetime measurement to extract $\Delta \Gamma_s$. Data from
the leptonic B trigger were also used to obtain the best current limit on the B.R. of $B_s \to \mu\mu$, one of the most sensitive probes of new physics at the Tevatron.

CDF’s high bandwidth Two Track Trigger provides a unique sample of hadronic B and Charm decays, including $B \to hh$, which led to the first observation of $B_s \to KK$, and will be used for CP violation studies as more data become available. First steps towards a $B_s$ mixing measurement have been taken with the reconstruction of $B_s \to D_s\pi$ events, and mixing measurements in the $B_d$ system.

The huge sample of $\Xi^-$ found in the Two Track Trigger has been used for a sensitive search for $\Xi(1860)$, which was not found. The B triggers will be used for many more pentaquark searches, especially those decaying to $J/\psi$ or D and baryons.

References

1. C. Alt et al. [NA49 Collaboration], Phys. Rev. Lett. 92, 042003 (2004) [arXiv:hep-ex/0310014]
2. N. Uraltsev, [arXiv:hep-ph/9804275]
3. M. A. Shifman, [arXiv:hep-ph/0009131]
4. Heavy Flavour Averaging Group. Method:
   D. Abbaneo et al. [ALEPH, CDF, DELPHI, L3, OPAL, SLD], June 2001, CERN-EP/2001-050, [arXiv:hep-ex/0112028] Results for PDG-2004: http://www.slac.stanford.edu/xorg/hfag/osc/PDG2004/index.html Results for PDG-2002: http://lepbosec.web.cern.ch/LEPBOSC/combined_results/PDG2002/
5. F. Abe et al. [CDF] Phys. Rev. D 57 (1998) 5382 Phys. Rev. D57, 5382; Phys. Rev. Lett. 76, (1996) 4462; Phys. Rev. D 58 (1998) 092002; Phys. Rev. Lett. 77, (1996) 1945; Phys. Rev. D 57, (1998) 5382; Phys. Rev. Lett. 77 (1996) 1439; See also: http://www-cdf.fnal.gov/physics/new/bottom/blife_summary/blife_summary.html
6. M Battaglia, AJ Buras, P Gambino and A Stocchi, eds. Proceedings of the First Workshop on the CKM Unitarity Triangle, CERN, Feb 2002, [arXiv:hep-ph/0304132]
7. A. S. Dighe, I. Dunietz, H. J. Lipkin and J. L. Rosner, Phys. Lett. B 369, 144 (1996) [arXiv:hep-ph/9511363]
8. B. Aubert et al. [BABAR Collaboration], Phys. Rev. Lett. 87 (2001) 241801 [arXiv:hep-ex/0107049]
9. C. P. Jessop et al. [CLEO Collaboration], Phys. Rev. Lett. 79 (1997) 4533 [arXiv:hep-ex/9702013]
10. T. W. Yeh and H. n. Li, Phys. Rev. D 56 (1997) 1615 [arXiv:hep-ph/9701233]
11. A. Dedes, H. K. Dreiner and U. Nierste, Phys. Rev. Lett. 87 (2001) 251804 [arXiv:hep-ph/0108037]
12. R. Dermisek, S. Raby, L. Roszkowski and R. Ruiz De Austri, JHEP 0304 (2003) 037 [arXiv:hep-ph/0304101]
13. R. Fleischer, Phys. Lett. B 459 (1999) 306 [arXiv:hep-ph/9903456]