B_c AT CDF*

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We report CDF results on the B_c^- meson [1] in Run II. The B_c^- meson has been observed in semileptonic decays, $B_c^- \to J/\psi\ \ell^- \nu X$, where $\ell = e, \mu$ at a significance greater than 5σ in both channels. The $B_c^- \to J/\psi\ \ell^- \nu X$ observations have resulted in measurements of the relative production times branching ratio with respect to $B^- \to J/\psi\ K^-$ decays and a precise determination of the lifetime of the B_c^-: $\tau(B_c^-) = 0.474\ ^{+0.073}_{-0.066}$ (stat.) $\pm$ 0.033 (syst.) ps. Also, an observation of $B_c^- \to J/\psi\ \pi^-$ decays at a significance exceeding 6σ results in a precise determination of the mass of the B_c^-: $\mathrm{M}(B_c^-) = 6275.2 \pm 4.3$ (stat.) $\pm$ 2.3 (syst.) MeV/c^2.

1. INTRODUCTION

1.1. *B Physics at Hadron Colliders*

The study of the B_c^- meson relies on the large production cross section at hadron colliders, triggerable low background decay modes, and the powerful capabilities of the modern multipurpose collider detectors.

1.2. *Tevatron in Run II*

The Tevatron at Fermilab is currently operating the Run II physics program where protons and anti-protons collide at energy $\sqrt(s) = 1.96$ TeV with over 1.5 fb^{-1} of integrated luminosity recorded. The CDF detector is instrumented with an inner silicon tracking system including Layer00 [2], which is mounted directly onto the beam pipe.

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1.3. B_c^- properties

The B_c^- meson is a special B meson composed of two distinct heavy quarks with different flavors. The presence of both such quarks impacts the production [3], decay [4], and mass properties [5],[6] of the B_c^-. All of these theoretical ideas require testing through experimental measurements.

1.4. B_c^- in Run I

The observation by CDF in Run I [7] of a significant number of semileptonic candidates was hailed as the discovery of the last meson. The observation of $20.4\ ^{+6.2}_{-5.5}$ signal events suggested that the study of B_c^- decays would be a fruitful enterprise in Run II.

2. Semileptonic B_c^- Decays

$B_c^- \to J/\psi\ \ell^-\nu X$ decays with $\ell = e$ or μ are not fully reconstructed due to the missing neutrino and possible missing particles, X. However, a $B_c^- \to J/\psi\ \ell^-\nu X$ signal can be identified over background and measurements of some of the B_c^- properties can be made. Understanding the background is a key component of the $B_c^- \to J/\psi\ \ell^-\nu X$ analyses with expected background contributions arising from $b\overline{b}$ events where one of the B mesons decays into a J/ψ and the other anti-B meson decays semileptonically. Backgrounds also include electrons and muon candidates that are "fake" in the sense that the lepton candidate comes from a hadronic track that happens to pass the lepton selection criteria. Fortunately, the study of the backgrounds can be performed both with Monte Carlo simulation and with the data itself. In particular, the larger J/ψ + *track* sample and the reference $B^- \to J/\psi\ K^-$ decay sample provide a means to help determine residual background.

3. $B_c^- \to J/\psi\ \ell^-\nu X$ in CDF

The CDF experiment has results of semileptonic B_c^- decays in both the final state μ [8] and e [9] channels. In the $B_c^- \to J/\psi\ \mu^- X$ channel, CDF uses 0.36 fb^{-1} of integrated luminosity in which over 2.7 M J/ψ decays into dimuons are identified. Both the general J/ψ + *track* and $B^- \to J/\psi\ K^-$ samples are used to understand the sample composition. Fake muon backgrounds for B_c^- are estimated from the number of expected J/ψ + *track* combinations that have an invariant mass, M($J/\psi\mu$), in the 4-6 GeV/c^2 signal region where the track is mis-identified as a muon. The π, K, and p

composition as a function P_T is studied using dE/dx and time-of-flight particle identification capabilities of CDF. The fake rate can then be extracted using large samples of fully reconstructed $K^0_s \to \pi^+ \pi^-$, $D^0 \to K^- \pi^+$ and $\Lambda^0 \to p \pi^-$ decays. The $b\overline{b}$ background studies use Monte Carlo simulation normalized to $B^- \to J/\psi K^-$ decays. Finally, the sidebands of the J/ψ are used to estimate the contribution arisings from fake-J/ψ events. Of the 106 events in the signal region, the three backgrounds are estimated to contribute approximately 16 (fake μ), 13 ($b\overline{b}$), and 19 (fake J/ψ) events resulting in a 5.3σ signal consisting of 60.0 ± 12.6 B_c^- candidates. A measurement is made of R, the production times branching ratio relative to $B^- \to J/\psi K^-$ decays with $P_T(B) > 4$ GeV/c and $|y| < 1$:
$R = 0.249 \pm 0.045$ (stat.) $\pm$ 0.069 (syst.) $^{+0.082}_{-0.033}$ (lifetime).

CDF has also studied semileptonic decays $B_c^- \to J/\psi e^- X$ where backgrounds are further complicated by the presence of conversion photons. The conversion background as a function of M($J/\psi e$) is estimated by studing a sample of conversion photons and understanding the efficiency for identifying the electron track as a function of P_T. The conversion background contributes approximately 15 of the total 64 event background estimate. The remaining signal excess has a 5.9σ significance and contains $114.9 \pm 15.5 \pm 13.6$ B_c^- candidates. In this channel, a measurement of R is made for $P_T(B) > 4$ GeV/c and $|y| < 1$:
$R = 0.282 \pm 0.038$ (stat.) $\pm$ 0.035 (yield) $\pm$ 0.065 (acceptance).

The $B_c^- \to J/\psi e^- X$ sample is also used to measure the lifetime of the B_c^- meson. Figure 1 shows the pseudo-proper decay length distribution with superimposed signal and background contributions. With relaxed requirements on the pseudo-proper decay length compared with the R analysis, the fit finds a total of 238 signal events over 545 ± 55 background events in the M(J/ψe) range between 4 and 6 GeV/c^2. From the fit, the B_c^- lifetime is measured to be: $c\tau(B_c^-) = 0.474\ ^{+0.073}_{-0.066}$ (stat.) $\pm$ 0.033 (syst.) ps.

4. $B_c^- \to J/\psi\ \pi^-$ in CDF

CDF reported initial evidence of $B_c^- \to J/\psi\ \pi^-$ decays with 0.36 fb^{-1} [10]. We now describe an independent analysis [11] using the full 0.8 fb^{-1} of collected and processed data available for analysis at the end of 2005. This search for $B_c^- \to J/\psi\ \pi^-$ uses a strategy that studies the effects of various selection criteria on the reference $B^- \to J/\psi\ K^-$ decay and the sideband background events below 5.5 GeV/c^2. The selection requirements include requiring the K candidate track to have an impact parameter that is sig-

nificantly displaced from the primary vertex while pointing to a displaced J/ψ secondary vertex defined by the two muons. Only after the selection was approved internally by CDF was the K hypothesis changed to a π and the region of interest in M($J/\psi\pi$) examined. A small excess is observed in this analysis with 0.36 fb^{-1} of data and has become more signifiant with the full 0.8 fb^{-1} where a fit to a Gaussian signal and linear background gives 38.9 B_c^- signal events and 26.1 background events in the mass range between 6.24 and 6.30 GeV/c^2 - an observation with a significance greater than 6σ based upon simulations that include random fluctuations over a wide search window. Figure 2 shows the invariant mass distribution of $J/\psi\pi$ candidates in the range between 5.6 and 7.2 GeV/c^2. An unbinned likelihood fit is used to measure the mass of the B_c^-: M(B_c^-) = 6275.2 (stat.) $\pm$ 4.3 $\pm$ 2.3 (syst.) MeV/c^2.

5. Summary and Conclusions

Measurements of the B_c^- meson are happening at CDF and DØ using Run II data. The B_c^- is an unique system whose properties are currently best studied at the Tevatron collider where relatively large production rates, triggerable decays modes, and powerful detectors combine to provide the current best measurements of this meson. In particular, new precise measurements of the lifetime and mass of the B_c^- are challenging theoretical predictions.

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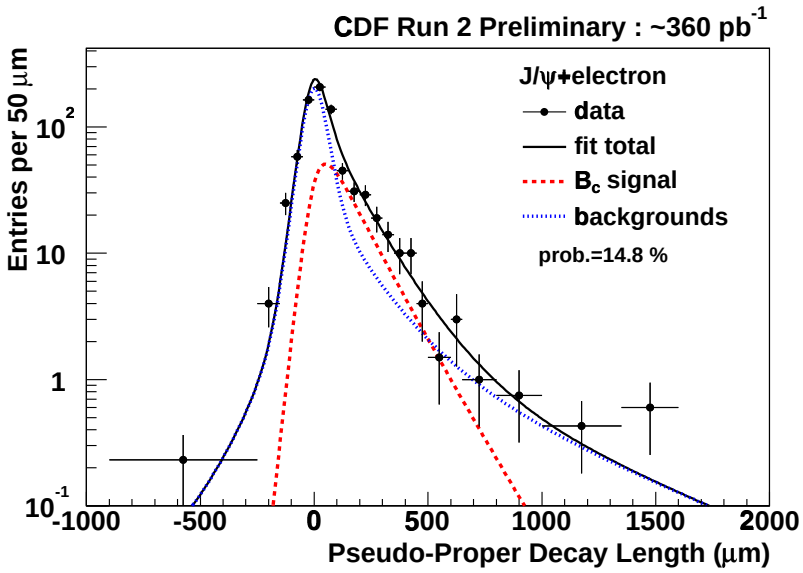

Figure 1. The pseudo proper lifetime distribution of $B_c^- \to J/\psi\ e^- X$ candidates in the CDF Run II data showing the contributions of background and B_c^- signal.

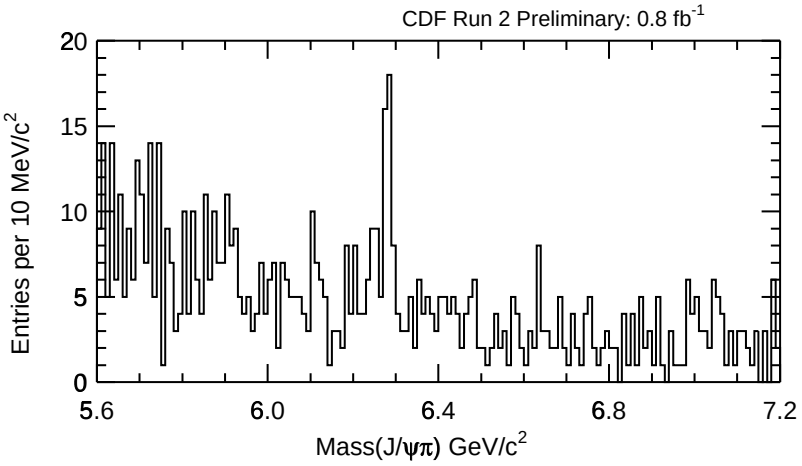

Figure 2. Invariant mass distribution of $J/\psi\ \pi^-$ in 0.8 fb^{-1} of CDF data.