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Charm Physics at CDF

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Abstract

A survey of recent results in charm physics from CDF is presented.

Talk delivered at *DIS 2008*
University College, London

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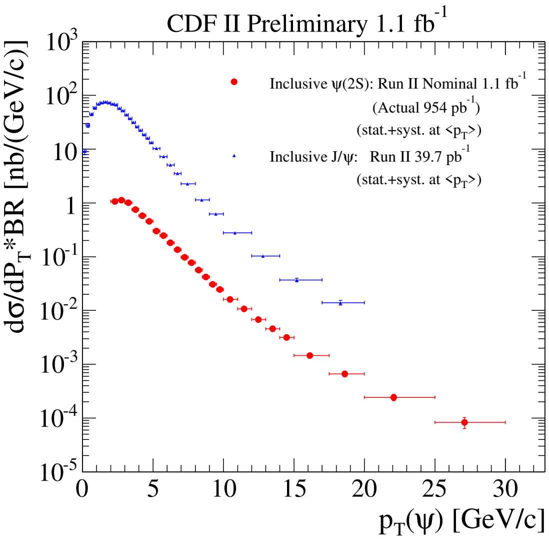

Figure 2: Inclusive cross sections for ψ' production at CDF, as in Fig. 1, compared to the J/ψ cross section.

1 Introduction

Since the start of the Tevatron Run II running at 1.96 TeV in 2001, the CDF experiment has accumulated extremely large samples of charm-containing events. These have been taken with several triggers, and especially the so-called "two track trigger" which selects tracks displaced from the main vertex at an early stage of the trigger process. Other useful triggers have been based on muon identification. In this talk I present three recent analyses which illustrate different facets of the CDF charm program.

2 Inclusive $\psi(2s)$ production

In Run I, CDF published inclusive cross sections for both J/ψ and ψ' production [1], and an earlier CDF II paper [2] presented inclusive cross sections for J/ψ production. These results have now been complemented with a new measurement of the inclusive ψ' cross section using 1.1 fb^{-1} of Run II data. The central drift chamber and muon detection system were used to detect the dimuon decay of the ψ', selecting on dimuon masses in the range 3.5 - 3.8 GeV/c^2, with the ψ' rapidity in the range ± 0.6, and transverse momentum in the range 2.0 - 30.0 GeV/c, giving a clear improvement on the Run 1 lower limit of 5.0 GeV/c.

The signal was extracted from the background by means of an unbinned maximum likelihood fit using parametrized functions for the background and the signal. The signal and background both have a prompt ψ' component and one arising from B decays, which are distinguished by means of the distance of the dimuon vertex from the beamline as measured using the Silicon Vertex Detector. The prompt component was modelled as a Gaussian in terms of the distance of the vertex from the beamline, and the decayed component by convoluting this with an exponential decay distribution.

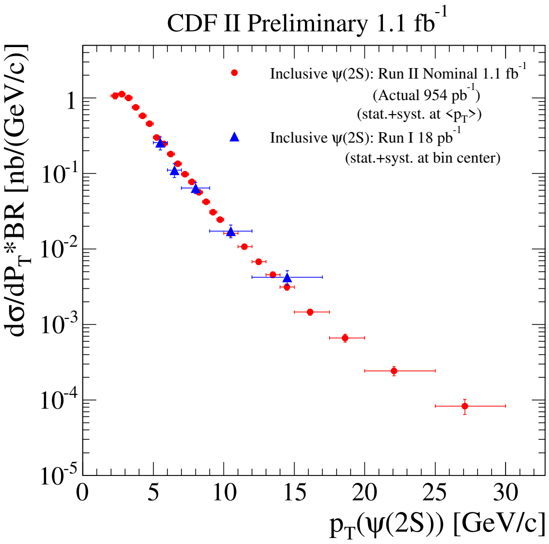

Figure 1: Inclusive cross sections for ψ' production compared with the Run I results

The results are shown in Figs. 1 - 3. The total integrated ψ' cross section is $3.141 \pm 0.038(\text{stat})^{+0.225}_{-0.218}(\text{sys})$ nb. There is good agreement with the Run I results. In comparison with the J/ψ cross section, that of the ψ' is lower by one to two orders of magnitude.

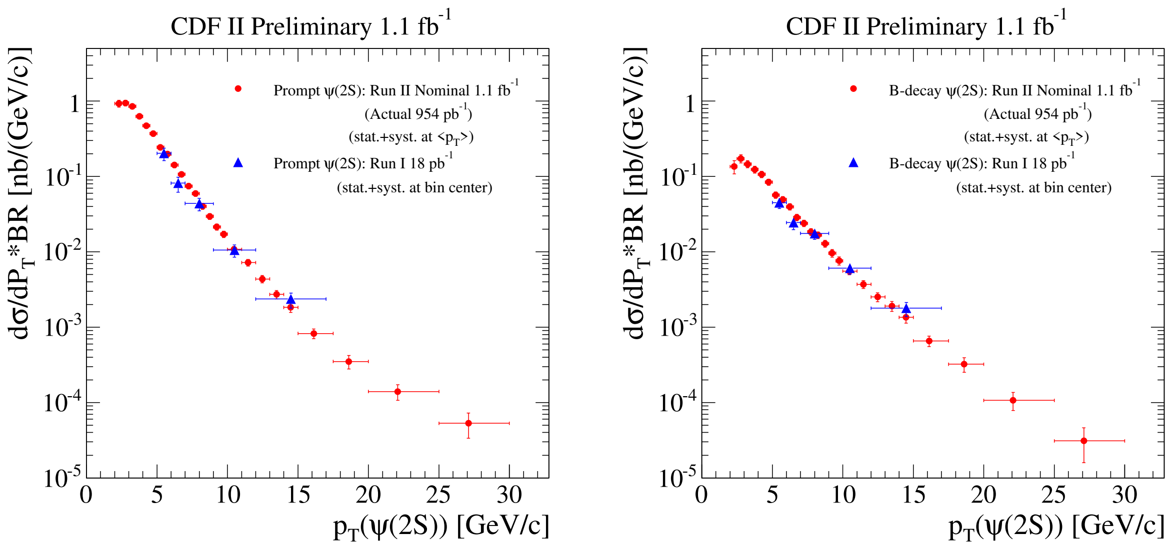

Figure 3: Inclusive cross sections for ψ' production at CDF, showing the prompt (upper) and B-decay (lower) components separately, compared to the Run I results.

3 D^0 mixing at the Tevatron

There have recently been significant developments in extending the studies of mixing into the charm sector. BELLE have obtained evidence that the lifetime for D^0 decay into CP eigenstates, such as K^+K^- and $\pi^+\pi^-$ is different from CP-mixed states, such as $K^+\pi^-$ [3]. BaBar, meanwhile, have found a difference in the decay time between the decays $D^0 \to K^+\pi^-$ and $D^0 \to K^-\pi^+$. CDF have now found evidence for the latter of these two effects, for the first time in D mesons produced by hadronic collisions. [5].

The approach followed is first to define the quantity $R(t)$ as the ratio of the observed numbers of $K^+\pi^-$ and $K^-\pi^+$ decays undergone by D^0 under experimental conditions. The similarity of the kinematic acceptances means that the systematic uncertainty on this measured ratio is small. Then, with reasonable assumptions, it can be shown that

$$R(t) = R_D + \sqrt{R_D}y't + \frac{1}{4}(x'^2 + y'^2)t^2,$$

where R_D is the "direct" ratio, t is the decay time and x', y' are linear combinations of $x = \Delta m/\Gamma$ and $y = \Delta\Gamma/2\Gamma$, namely the scaled mass and width differences between the two physical eigenstates.

Using 1.5 fb^{-1} of data, the initial D^0 or $\overline{D}^0$ mesons are identified in D^* decays, using the sign of the soft pion to tag the D state. The ratio $R(t)$ of the"wrong sign / right sign" decays (Cabibbo doubly suppressed / allowed, in the absence of oscillations) is then plotted as a function of decay time. The result, when fitted with a quadratic curve, is suggestive that $R(t)$ rises with t (Fig. 4). Bayesian probability contours were now constructed in the x', y' space using a flat prior. A value of x', y' significantly different from the no-mixing point at the origin indicates D^0-$\overline{D}^0$ mixing. The no-mixing point is found to lie on a contour corresponding to a probability level of 1.5×10^{-4} or 3.8 σ. This is claimed as evidence for mixing.

4 Search for the rare decay $D^0 \to \mu^+\mu^-$

The decay $D^0 \to \mu^+\mu^-$ is strongly suppressed in the Standard Model. Figure 5 shows two short-range SM decays (top) a long-range SM decay (middle) and a possible SUSY decay (bottom). The predicted SM rates are very low and correspond to a branching ratio of approximately 4×10^{-13}, far below foreseeable experimental measurements. However the SUSY decays can give branching ratios of up to 3.5×10^{-6}, well within present experimental capabilities. Earlier in Run II, CDF published a branching ratio limit of 2.5×10^{-6} (90% CL) [6], which has since been reduced to 1.3×10^{-6} by BaBar [7]. Here using a larger data sample, we present a new result which improves substantially on the previous values.

In order to reduce backgrounds, which arise principally from muon pairs from B meson decays, both decay muons are required to have good identification within the CDF central muon detector system (CMU, CMX). An illustration of the mass peak obtainable in CDF is given in Fig. 6, which shows $\pi^+\pi^-$ decays of D^0 meson in which the pions have been relabelled as muons and point into the central muon detectors. The muons arising

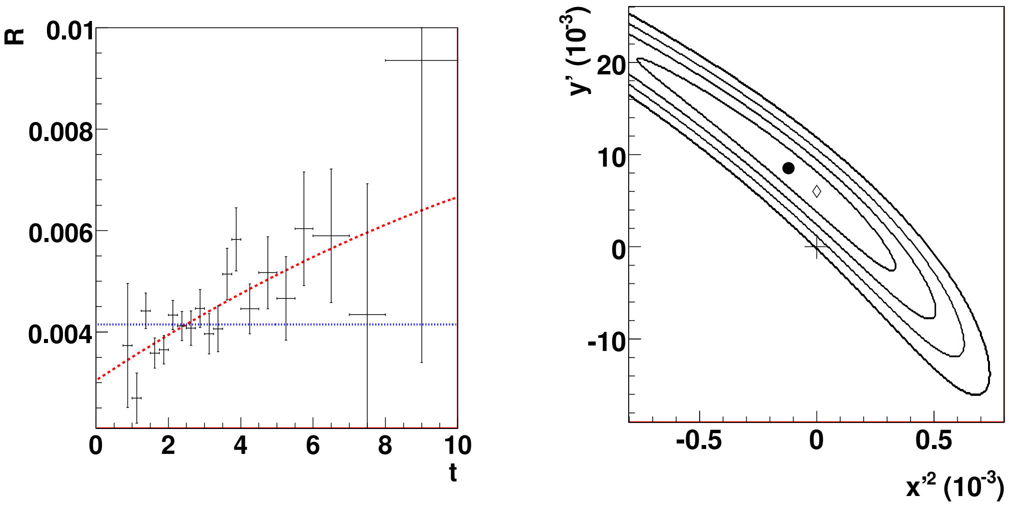

Figure 4: Left: "wrong / right sign" ratio for D^0 decays, plotted against proper decay time in units of the mean decay time, with a fitted quadratic curve. Right: probability contours in x', y', corresponding to 1 - 4 Gaussian standard deviations. The closed circle and open diamond, show central results from an unconstrained and a physically allowed fit. The cross shows the no-mixing point. The parameter R_D is removed by a Bayesian integration.

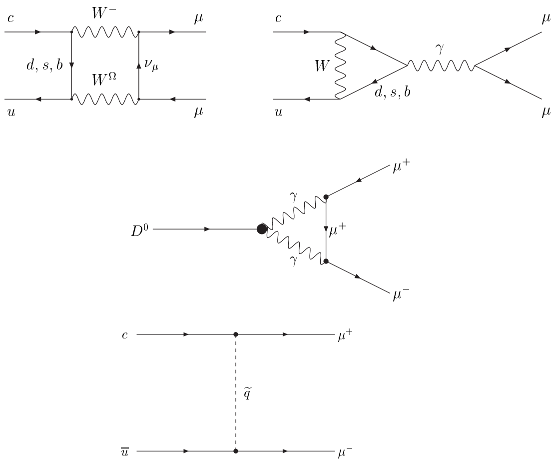

Figure 5: Feynman diagrams for the decay $D^0 \to \mu^+\mu^-$.

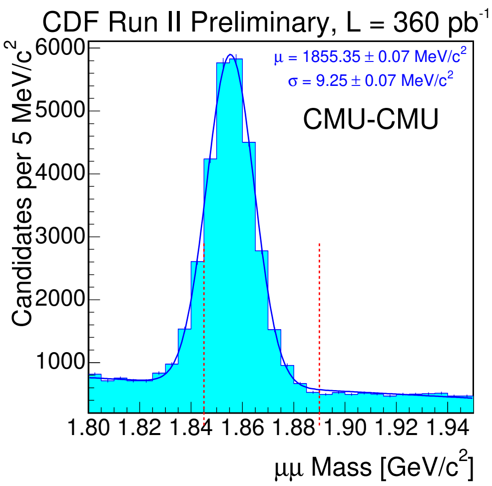

Figure 6: Reference peak for the $\pi^+\pi^-$ decay, indicating the $D \to \mu^+\mu^-$ mass region.

from B decays are removed by cuts on the vertex position and pointing of the muon pair as measured in the Silicon Vertex Detector. A total of 4 candidate events were observed, with an expectation of 8.6; using a Bayesian approach this gives an upper limit on the branching ratio of 4.3×10^{-7} (90% CL) or 5.3×10^{-7} (95% CL). Using just 360 pb^{-1} of data, this is currently the world's best result for this channel, and translates into significant constraints on the R-parity violating couplings within SUSY.

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