TOP PAIR PRODUCTION CROSS SECTION AT $\sqrt{S}$=1.96 TEV AND A SEARCH FOR $V+A$ CURRENT IN TOP QUARK DECAY.

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Possible effects from physics beyond the Standard Model have been investigated in top quark decays from a data sample enriched in $t\bar{t}$ events produced in $p\bar{p}$ collisions at $\sqrt{s}=1.96$ TeV with an integrated luminosity of approximately 700 pb^{-1}and collected with the CDF II detector.

The combined $t\bar{t}$ production cross section measurement 7.3±0.9 pb agrees with the QCD NLO predictions: 6.7±0.8 pb assuming m_{top}=175 GeV/c^2 .

The fraction of the $V+A$ current in top quark decay, f_{V+A}, is determined using the invariant mass of the charged lepton and the bottom quark jet in the decay chain $t \to Wb \to \ell\nu b$ (where ℓ = e or μ). The measured value $f_{V+A} = -0.06\pm0.25$ under the assumption m_{top}=175 GeV/c^2 is in agreement with the Standard Model. We set an upper limit on f_{V+A} of 0.29 at the 95% confidence level.

1 Introduction

Since the beginning of Run II, the Tevatron $p\bar{p}$ collider has delivered more than 1 fb^{-1}of $p\bar{p}$ collisions at $\sqrt{s}=1.96$ TeV. With this increasing data set the top quark properties can be exhaustively measured. Deviation from their predicted Standard Model values could signal new physics in the production rate of top quark pairs and in the $V-A$ weak decay $t \to W^+ b$.

2 $\sigma_{t\bar{t}}$ measurements.

The best single measurement is performed in the lepton plus jets channel, $\sigma_{t\bar{t}} = 8.2 \pm 0.6(stat) \pm 0.9(syst) \pm 0.5(lum)$. The measurement in the dilepton channel provides an independent and complementary result: $\sigma_{t\bar{t}} = 8.3 \pm 1.5(stat) \pm 1.0(syst) \pm 0.5(lum)$ that will weight ~10% in the combination.

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The CDF combined result of these two measurements and 4 others [1]: $\sigma_{t\bar{t}} = 7.3 \pm 0.5(stat) \pm 0.6(syst) \pm 0.4(lum)$, improves 15% with respect to the best single measurement. The experimental precision reaches the 12% theoretical accuracy of the QCD NLO predictions 6.7±0.8 pb [2].

2.1 The dilepton channel

The dilepton sample is enriched with $t\bar{t} \rightarrow W^+bW^-\bar{b}$ events where both W bosons decay leptonically. The CDF technique providing the $\sigma_{t\bar{t}}$ result with highest S/B ratio [3] (see figure 1) and no need of b-tagging selects two identified leptons, electrons (or muons), with opposite electric charge and $E_T(P_T)$ >20 GeV, $\not\!\!E_T$ above 25 GeV, and at least 2 jets with $E_T > 15$ GeV.

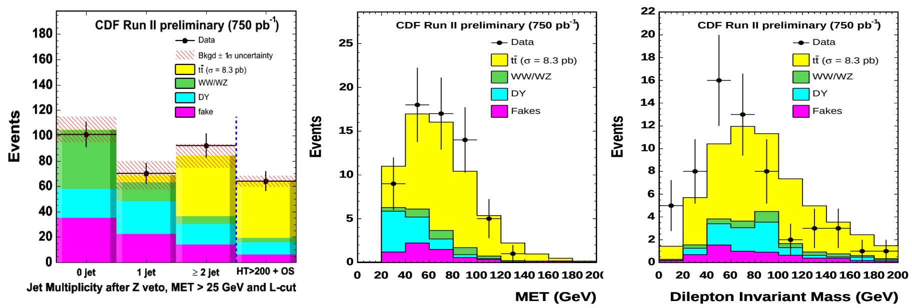

Figure 1. Left plot: Signal and background composition of the high P_T CDF dilepton sample (750 pb^{-1}) in different N_{jets} bins [3]. Central plot: $\not\!\!E_T$distribution categorized by source (stacked histograms) and the total number from data (points).Right plot: P_T distribution

The contributing backgrounds are: Drell-Yan ($Z^*/\gamma \rightarrow e^+e^-, \mu^+\mu^-$), $W+$ *jets* with one jet misidentified as a lepton, WW and WZ and $Z^*/\gamma \rightarrow \tau^+\tau^-$ with associated jets. The main systematics come from the instrumental background method determination and jet energy scale. The $Z^*/\gamma \rightarrow e^+e^-, \mu^+\mu^-$ background relies on both data and MC. The background from *fake* lepton in $W+$jets is driven purely from data.

2.2 The lepton plus jets channel

The lepton plus jets sample is enriched with $t\bar{t} \rightarrow W^+bW^-\bar{b}$ events where only one W boson decay leptonically. The lepton plus jets signature consist of only one isolated electron (μ) with E_T (P_T) > 20 GeV, $\not\!\!E_T > 25$ GeV and 3 o more jets with $E_T > 15$ GeV. The ratio S/B is almost 3 by requiring at least one b-tagged jet with the secondary vertex technique and $H_T{}^a > 200$ GeV [4]. The dominant background is $W+$jets followed by the instrumental QCD background, with one jet misidentified as a high P_T lepton and $\not\!\!E_T$ from mismeasurements. The main systematic comes from the knowledge of the b-tagging efficiency. The QCD background evaluation relies 100% on data. $W+$ heavy flavour : b, b$\bar{\text{b}}$, c is determined with data and MC and $W+$light flavour is based on mistags found in data.

3 Search for $V + A$ current in top quark decay.

In the Standard Model, the top quark decays with an almost 100% branching ratio via the weak decay $t \to bW^+$. Neglecting the b-quark mass, the V-A structure of this weak interaction predicts a fraction f_0 of W^+ bosons with longitudinal polarization at leading-order: $f_0 = m_t^2/(m_W^2 + m_t^2) = 0.70$ for $M_W = 80.4$ GeV/c^2 and $m_t = 175$ GeV/c^2. The left handed fraction of W^+ bosons is $f_- = 0.30$ and the right handed is $f_+ = 0.00$ [5]. However, theoretical models exist including a non-zero admixture of V+A weak current that could modify the predicted polarization of the top quark decay products [6], for instance non-zero values of f_+, indicating new physics.

The observable $M_{\ell b}^2$, the invariant mass of the charged lepton and the b-quark in the decay chain $t \to Wb \to \ell\nu b$, provides discrimination between $t\bar{t}$ V+A and V-A (see left plot in figure 2). $M_{\ell b}^2$ is related to the polar angle, ψ^*, of the charged lepton in the rest frame of the W boson (the z-axis is defined to be the direction of motion of the W boson in the rest frame of the top quark) through the relation: $M_{\ell b}^2 = \frac{1}{2}(m_t^2 - m_W^2)(1 + \cos\psi^*)$, that is exact in the limit $m_b \to 0$. The fraction f_{V+A} of non-standard right-(left-) handed $W^+(W^-)$ bosons from top quark decay is measured by comparing the $M_{\ell b}^2$ distribution in data with Monte Carlo $M_{\ell b}^2$ templates built for backgrounds and $t\bar{t}$ with two assumptions: $f_{V+A} = 0$ and 1. Three independent samples are studied. For all the samples we model the hard $t\bar{t}$ process with the MC ALPGEN and PYTHIA for hadronization.

In the lepton+jets sample with a single b-tagged jet, the observable $M_{\ell b}^2$ is a 1-D distribution where the b-tagged jet is from the same top quark decay as the charged lepton in approximately half of the $t\bar{t}$ events (see Fig. 2). The background $M_{\ell b}^2$ distribution is a combination of 85% W+jets, modeled by ALPGEN $Wb\bar{b}$, and 15% multi-jet events, modeled by non-isolated lepton+jets data events. In 695 pb^{-1}, 304 candidates are observed with a total expected background of 88.5±11.2 events.

In lepton+jets sample with two b-tagged jets, the observable $M_{\ell b}^2$ is a

[a] H_T is the scalar sum of all jets E_T, $\not\!\!E_T$ and lepton, electron (or μ) E_T (or P_T)

2-D distribution built with the two possible M_{lb}^2 values of the charged lepton with either the highest or the second highest E_T b-tagged jet. The multijet background is negligible. In 695 pb^{-1}, we find 75 candidates with a total expected background of 9.1±1.8 events.

The last sample is the dilepton one, where again the observable $M_{\ell b}^2$ is a 2-D distribution built with the two possible M_{lb}^2 values for a charged lepton with either the highest or the second highest E_T jet, that are assumed to be produced by the fragmentation of the b quarks. The background $M_{\ell b}^2$ distribution is the combination of three background types: 50% from $Z/\gamma^* \to \ell^+\ell^-$ with associated jets, 30% from $W \to \ell\nu$ with associated jets where a jet is misidentified as a lepton, and 20% from massive diboson pairs, WW/WZ. The Z/γ^* and diboson background M_{lb}^2 distributions are modeled by ALPGEN. The fake lepton background is based on a dilepton sample where the second lepton is instead a jet or charged particle track weighted by a probability for misidentification as a lepton. In 750 pb^{-1}, we observe 64 candidates (12 ee, 24 $\mu\mu$ and 28 $e\mu$) with a total estimated background of 19.9±4.2 events.

A binned log likelihood fit procedure is used to extract f_{V+A}. Nuisance parameters are the accepted background cross section for each sample, σ_{bg}, and the $t\bar{t}$ cross section, $\sigma_{t\bar{t}}$. For each sample, the likelihood is the product over all N bins in $M_{\ell b}^2$ of the Poisson probabilities of observing n_i entries in a given bin i, where the average expected bin content is μ_i, and Gaussian constraints on the estimated background and the predicted $t\bar{t}$ production cross section [2]. The μ_i are given by: $\mu_i = N^{data}[x_{V+A}\hat{T}^i_{V+A} + x_{V-A}\hat{T}^i_{V-A} + x_{bg}\hat{T}^i_{bg}]$ where N^{data} is the observed total number of data events for the sample, x_{V+A}, x_{V-A}, and x_{bg} are the expected fractions of $t\bar{t}$ production with $V+A$ top quark decay, $t\bar{t}$ production with $V-A$ top quark decay, and background, respectively. These fractions depend on f_{V+A}, $\sigma_{t\bar{t}}$, σ_{bg} and the acceptances $\mathcal{A}_{V+A}$ and $\mathcal{A}_{V-A}$. The $\hat{T}^i_{V+A}$, $\hat{T}^i_{V-A}$, and $\hat{T}^i_{bg}$ are the probabilities for an event to occupy bin i of the $M_{\ell b}^2$ distribution for $t\bar{t}$ production with $V+A$ top quark decay, $t\bar{t}$ production with $V-A$ top quark decay, and background, respectively. By construction $\sum_i \hat{T}^i = 1.0$. The combined likelihood is the product of the likelihoods of the three samples, but with one common Gaussian constraint on the $t\bar{t}$ cross section.

The robustness of the fitting procedure has been tested with pseudo-experiments. An expected statistical uncertainty of 0.22 on f_{V+A} is found for the case of all samples combined in the same likelihood. For each separate sample it is found 0.36, 0.41 and 0.49 for lepton+jets single b-tagged events, lepton+jets double b-tagged events, and dilepton events, respectively. The main systematics are jet energy scale, the background shape and normalization, and limited MC statistics.

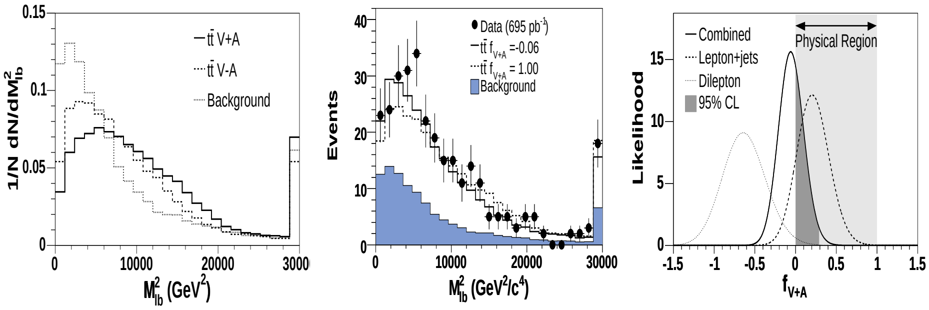

Figure 2. Left plot: $M^2_{\ell b}$ discrimination between V+A and V-A in $t\bar{t}$ for lepton+jets single b-tagged sample. Central plot: agreement in $M^2_{\ell b}$ between data and MC with best f_{V+A} fitted result also for lepton+jets single b-tagged sample. Right plot: The likelihood distribution for all samples combined. The maximum likelihood fit provides $f_{V+A} = 0.21 \pm 0.28$ for the lepton+jets sample (single and double b-tagged) and $f_{V+A} = -0.64 \pm 0.37$ for the dilepton sample. Both results are compatible at about 2.3 standard deviations.

4 Conclusions

Combining all samples and including all systematics the fraction of $V + A$ current in top quark decay is $f_{V+A} = -0.06 \pm 0.25$ (stat.+syst.) assuming m_{top}=175 GeV/c^2 , in agreement with the Standard Model. In the absence of a signal, we set an upper limit on a $V + A$ current in top quark decay of $f_{V+A} < 0.29$ at 95% CL. For a ± 2.5 GeV/c^2 shift in m_{top}, the shift in the upper limit (measurement) for f_{V+A} is ± 0.07 (± 0.09). The results in terms of the fraction of right-handed W^+ bosons are: $f^+ = -0.02 \pm 0.07$ and $f^+ < 0.09$ at 95% CL (for more details of these analysis see reference [7]).

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