Search for new physics in top decays at DØ

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Abstract. The results of search for new processes, performed with top quark events at DØ are summarized in this paper. It presents three updated DØ results : search for heavy W' resonances, search for fourth generation t' quark and search for flavor changing neutral current. Neither of these measurements reveal any deviation with respect to the standard model predictions.

Keywords: Top quark, DØ, W', fourth generation t' quark, FCNC
PACS: 14.65.Ha Top quarks -14.65.Jk Other quarks (e.g., 4th generations) - 14.70.Pw Other gauge bosons

INTRODUCTION

The Tevatron $p\bar{p}$ collider at Fermilab operates with a center-of-mass energy of 1.96 TeV. This review is focused on the search for new physics performed with top quark events in DØ, one of the two multipurpose detectors located on the Tevatron. It presents three updated or new DØ results.

SEARCH FOR $W' \to tb$ RESONANCES WITH LEFT- AND RIGHT-HANDED COUPLINGS TO FERMIONS

Many models of physics beyond the standard model (SM) predict the existence of additionnal charged bosons, generally called W', that are more massive than the W boson of the SM. Independent of specific models, the most general, lowest-dimension lagrangian for the interaction of a W' boson with fermion fields f is given by [1]

$$\mathscr{L} = \frac{V_{ij} g_w}{2\sqrt{2}} \bar{f}_i \gamma_\mu (a_{ij}^R (1+\gamma^5) + a_{ij}^L (1-\gamma^5)) W'^\mu f_j + \text{h.c.}, \quad (1)$$

where $a_{ij}^{L/R}$ are the left/right-handed couplings of the W' boson to the fermion doublet f_i and f_j and g_w is the weak coupling constant of the SM. If the fermions are quarks, the V_{ij} are the element of a 3x3 identity matrix.

A search for a W' boson that decays to a top quark and an anti-bottom quark (or charge conjugates) has been performed by the DØ collaboration using 2.3 fb^{-1}[2]. The top quark decays to Wb and the W boson is required to decay to $e\nu$ or $\mu\nu$. Thus the final state contains an electron or muon, missing transverse momentum ($\not\!\!E_T$) from the undetected neutrino, and two jets from the fragmentation of the two b-quarks. The selection is analogous to the single top selection [3]. The dominant backgrounds arise from $W+$ jets production and from $t\bar{t}$ pairs.To improve discrimination multivariate discriminants based

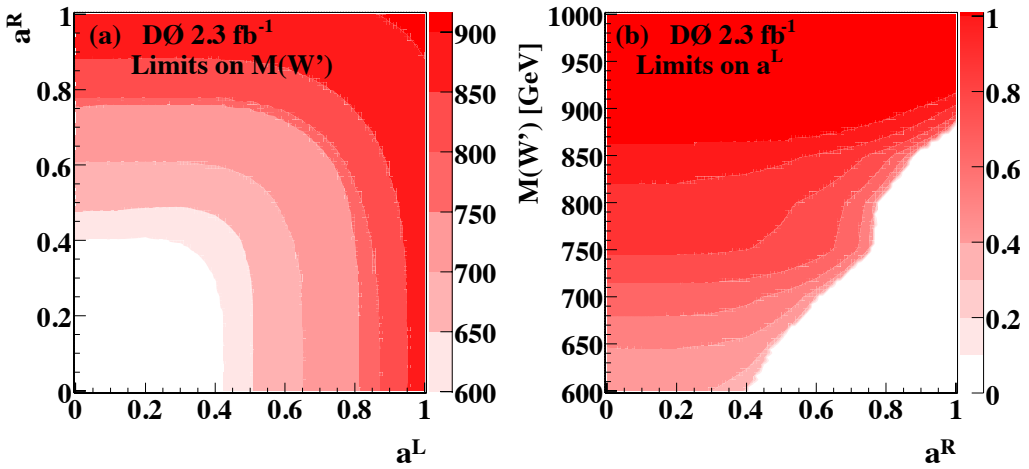

FIGURE 1. (a) Contour plots of 95 % C.L. lower limits on $m(W')$ in the (a_L, a_R) plane, and (b) 95 % C.L. upper limits on the coupling a^L in the $(a^R, M(W'))$ plane.

on boosted decision trees are trained. No significant deviation from SM predictions is found and limits are set on the production cross-section times branching fraction for such W' bosons. For the first time they are translated into limits for arbitrary combination on left- and right-handed gauge couplings. Each of the combinations of a_L, a_R and $M(W')$ is considered as a model. Values for any two of the three parameters a_L, a_R and $M(W')$ are assumed and the cross section limit is interpolated in the third parameter value. Figure 1(a) shows contours of lower limits for the W' mass in the (a^L, a^R) plane, while Fig. 1(b) shows contours of upper limits for the coupling a^L in the $(a^R, M(W'))$ plane. In the case of $M(W') > m(\nu_R)$, $M(W') < 863(885)$ GeV are excluded at 95 % C.L. for purely left(right)-handed couplings, and $M(W') < 916$ GeV if both left-and right-handed couplings are present. The limit for right-handed coupling improves to 890 GeV if $M(W') < m(\nu_R)$.

SEARCH FOR A FOURTH GENERATION t' QUARK

A search for pair production of a fourth generation t' quark and its antiparticle, followed by their decays to a W boson and a jet, based on an integrated luminosity of 5.3 fb^{-1} has been performed by the DØ collaboration [4]. Events with one isolated muon or electron, with high transverse momentum, a large imbalance in transverse momentum and at least four jets corresponding to events in which one of the W bosons decays to quarks are selected. The two main SM processes that produce such events are $t\bar{t}$ and $W+$ jets production. The third most important source of events arises from mismeasured multijet events in which a jet is misidentified as an electron or a muon from heavy flavor decay appears isolated. Two-dimensional histograms of H_T, the scalar sum of $\not\!\!p_T$ and of the transverse momenta of all jets and the charged lepton, versus m_{fit}, the mass of the t' quark reconstructed with a kinematical fit to the $t'\bar{t}' \to \ell\nu bq\bar{q}'\bar{b}$, are used to test for the presence of signal in data and to compute 95 % C.L. upper limits on the $t'\bar{t}'$ production

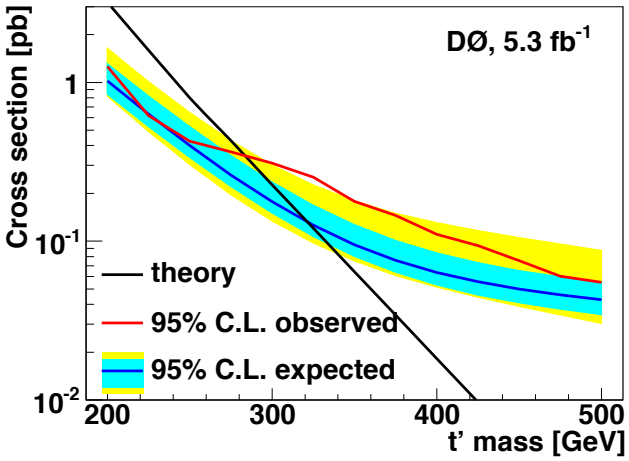

FIGURE 2. Observed and expected upper limits and predicted values for the $t'\bar{t}'$ production cross section as a function of the mass of the t' quark. The shaded regions around the expected limit represent the $\pm$ 1 and $\pm$ 2 standard deviation bands.

cross section as a function of mass. Figure 2 shows the resulting cross section limits compared to the limits expected in the absence of $t'\bar{t}'$ production and to the predicted NLO t' pair production cross section as a function of the t' mass. $t'\bar{t}'$ production for t' quark mass values below 285 GeV are excluded at 95 % C.L.

SEARCH FOR FLAVOR CHANGING NEUTRAL CURRENTS IN DECAYS OF TOP QUARKS

A search for flavor changing neutral currents (FCNC) in decays of top quarks based on an integrated luminosity of 4.1 fb^{-1} been performed by the DØ collaboration [5].

FCNC allow for transitions between quarks of different flavors but same electric charge. As they are highly suppressed in the SM, FCNC are sensitive indicators of physics beyond the SM. The search has been performed in top pair production, where either one or both of the top quarks decay via $t \to Zq$ or their charge conjugate. We assume that the $t \to Zq$ decay is generated by an anomalous FNCN term added to the SM lagrangian:

$$\mathscr{L}_{FCNC} = \frac{e}{2\sin\theta_W \cos\theta_W}\bar{t}\gamma_\mu(v_{tqZ} - a_{tqZ}\gamma_5)qZ^\mu + \text{h.c.}, \tag{2}$$

where q, t, and Z are the quantum fields for up or charm quarks, top quarks, and for the Z boson respectively, e is the electric charge, θ_W the Weinberg angle, and v_{tqZ} and a_{tqZ} are dimension-4 vector and axial-vector couplings as defined in [6]. For the first time, the search is performed in channels where W and Z bosons decay leptonically, giving rise to a final state with three charged leptons (e or μ),$\not\!\!E_T$ and zero, one or two jets. It provides a distinct signature with low background albeit at the cost of statistical power. Pair of electrons or muons with opposite electric charges are used to identify the Z boson decay.

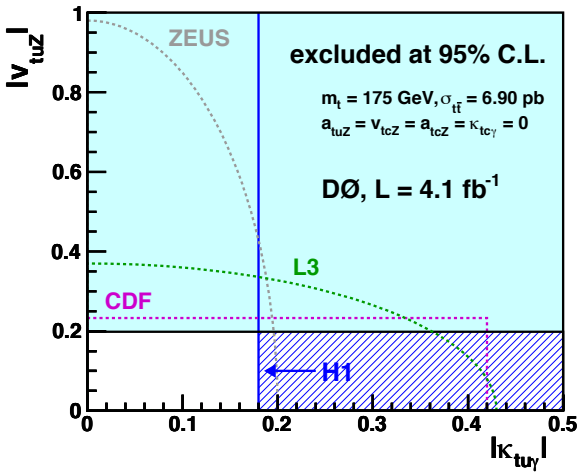

FIGURE 3. Upper limits at the 95% C.L. on the anomalous $\kappa_{tu\gamma}$ and v_{tqZ} couplings assuming $m_{top} = 175$ GeV. Limits obtained at LEP by the L3 experiment, at HERA by the ZEUS experiment , and at the Tevatron by CDF are also shown. The region above or to the right of the respective lines is excluded.

The main backgrounds arise from SM WZ production, ZZ and $t\bar{t}$. In events with more than one jet, the invariant mass m_t^{reco} is reconstructed from the 4-momenta of the jet and the identified Z boson. As no deviation to SM is observed, limits on the branching ratio $B(t \to Zq)$ are obtained and converted to limits at the 95 % C.L. on the FCNC vector v_{tqZ} and axial-vector a_{tqZ} couplings as defined in Eq. (2) using the relation given in [6]. This can be done for any point in the (v_{tqZ}, a_{tqZ}) parameter space and for different quark flavor. Assuming only one non-vanishing v_{tqZ} coupling ($a_{tqZ} = 0$) we derived an observed (expected) limit of $v_{tqZ} < 0,19 (< 0.21)$ for $m_{top} = 172.5$ GeV. Figure 3 shows current limits from experiments at the LEP, HERA, and Tevatron colliders as a function of the FCNC coupling $\kappa_{tu\gamma}$ (defined in Ref. [6]) and v_{tqZ} for $m_{top} = 175$ GeV.

SUMMARY

This contribution reports the most recent results on searches for new physics in top decays at DØ. No significant data excess has been observed and the results have been interpreted as 95 % C. L. exclusion limits.

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