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Search for a new Resonance decaying into Top-Antitop at Tevatron

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In this report a new search for a narrow-width heavy resonance decaying into top quark pairs ($X \to t\bar{t}$) in $p\overline{p}$ collisions at $\sqrt{s} = 1.96$ TeV has been performed using data collected by the DØ detector at the Fermilab Tevatron collider. The analysis considers $t\bar{t}$ candidate events in the lepton+jets channel using a lifetime tag to identify b-jets and the $t\bar{t}$ invariant mass distribution to search for evidence of resonant production. The analyzed dataset corresponds to an integrated luminosity of approximately 370 pb^{-1}. Since no evidence for a $t\bar{t}$ resonance X is found, upper limits on $\sigma_X \times B(X \to t\bar{t})$ for different hypothesized resonance masses using a Bayesian approach are set. Within a topcolor-assisted technicolor model, the existence of a leptophobic Z' boson with $M_{Z'} < 680$ GeV and width $\Gamma_{Z'} = 0.012 M_{Z'}$ can be excluded at 95% C.L..

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1. Introduction

The top quark has by far the largest mass of all known elementary particles. This suggests that the top quark may play a special role in the dynamics of electroweak symmetry breaking. One of the various models incorporating this possibility is topcolor [1], where the large top quark mass can be generated through a dynamical $t\bar{t}$ condensate, X, which is formed by a new strong gauge force preferentially coupled to the third generation of fermions. In one particular model, topcolor-assisted technicolor [2], X couples weakly and symmetrically to the first and second generations and strongly to the third generation of quarks, and has no couplings to leptons, resulting in a predicted cross section for $t\bar{t}$ production larger than the standard model (SM) prediction.

In this presentation a new model-independent search for a narrow-width heavy resonance X decaying into $t\bar{t}$ is presented. The analyzed dataset corresponds to an integrated luminosity of $366 \pm 24\,\text{pb}^{-1}$ in the e+jets channel and 363 ± 24 pb^{-1} in the μ+jets channel, collected between August 2002 and August 2004.

2. Search for $t\bar{t}$ production via new resonances

In the framework of the SM, the top quark decays into a W boson and b quark in nearly 100% of the cases. The $t\bar{t}$ event signature is fully determined by the W boson decay modes. In this analysis only the lepton+jets (ℓ+jets, where $\ell = e$ or μ) final state, which results from the leptonic decay of one of the W bosons and the hadronic decay of the other, is considered. The investigated event signature is one isolated electron ($|\eta| < 1.1$) or muon ($|\eta| < 2.0$) with high transverse momentum $p_T > 20$ GeV, large transverse energy imbalance $\not{E}_T > 20$ GeV due to the undetected neutrino, and at least four jets (defined using a cone algorithm with radius $\Delta\mathscr{R} = 0.5$) with $p_T > 15$ GeV and rapidity $|y| < 2.5$, two of which result from the hadronization of the b quarks. Further details of the event selection and of the following can be found in [3].

The signal-to-background ratio is improved by identifying b-jets using a lifetime based b-tagging algorithm. After b-tagging, the dominant physics background for a resonance signal is non-resonant SM $t\bar{t}$ production. Smaller contributions arise from the direct production of W bosons in association with four or more jets (W+jets), as well as instrumental background originating from multijet processes with jets faking isolated leptons.

The search for resonant production is performed by examining the reconstructed $t\bar{t}$ invariant mass distribution resulting from a constrained kinematic fit to the $t\bar{t}$ hypothesis. The used fit is similar to the one used for the measurement of the top quark mass in Run I [4]. The constraints to the fit are that two jets and the lepton+$\not{E}_T$ must each form the invariant mass of the W boson and that the masses of the two reconstructed top quarks have to be equal, and are set to 175 GeV. Only the four highest p_T jets are considered in the kinematic fit. From the resulting twelve possible jet-parton assignments, the one with the lowest χ^2 is chosen. This is found to give the correct solution in about 65% of the $t\bar{t}$ events. The expected $t\bar{t}$ invariant mass distribution for resonance masses of 400 GeV and 750 GeV are illustrated in Figure 1 (left).

The systematic uncertainties of the analysis rely on the prediction of the overall normalization as well as the shape of the reconstructed $t\bar{t}$ invariant mass distribution for both signal and the

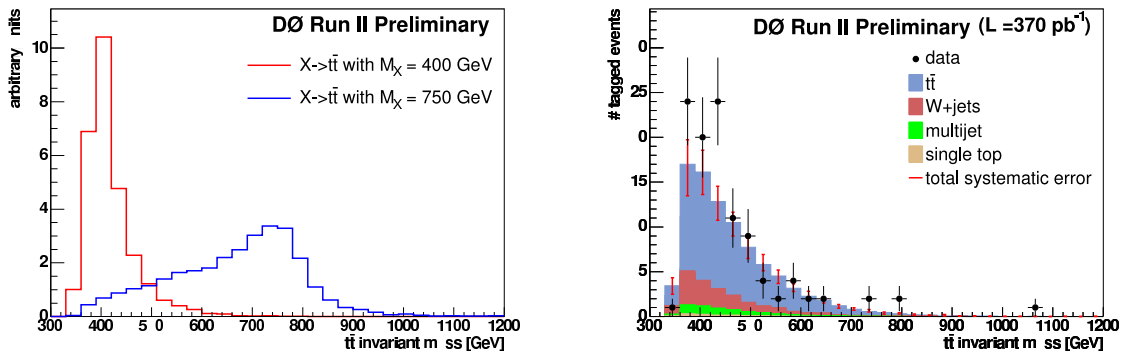

Figure 1: Comparison of the expected $t\bar{t}$ invariant mass distribution for a narrow-width resonance with mass $M_X = 400$ GeV and $M_X = 750$ GeV (left). The resulting $t\bar{t}$ invariant mass distribution for the combined ℓ+jets channels (right). The error bars drawn on top of the SM background indicate the total systematic uncertainty, which has significant bin-to-bin correlations.

different backgrounds. The systematic uncertainties can be classified as those affecting only normalization and those affecting both normalization and shape of the $t\bar{t}$ invariant mass distribution.

The systematic uncertainties affecting only the normalization include e.g. the experimental uncertainties on the MC-to-data correction factors, the theoretical uncertainty on the SM prediction for $\sigma_{t\bar{t}}$, $\sigma_{singletop}$ and the uncertainty on the integrated luminosity. The systematic uncertainties affecting the shape of the $t\bar{t}$ invariant mass distribution in addition to the normalization have been studied both on signal and background samples. These include e.g. uncertainties on the jet energy calibration, jet reconstruction efficiency, b-tagging parameterizations for b, c and light jets and the limited top quark mass accuracy as it enters the kinematic fit.

The systematic uncertainties associated with the estimation of the fractions for the different flavor components of the W+jets background have been taken into account as well as the uncertainty associated with the modeling of the SM $t\bar{t}$ background, in particular, gluon radiation effects.

3. Result

In the final selection 57 events remain in the e+jets channel and 51 events in the μ+jets channel. Figure 1 (right) shows the $t\bar{t}$ invariant mass for the combined ℓ+jets channels for the selected events in data and for the SM background predictions.

Assuming there is no resonance signal, a Bayesian approach is used to calculate 95% C.L. upper limits on $\sigma_X \times B(X \to t\bar{t})$ for different hypothesized values for M_X. A Poisson distribution is assumed for the number of observed events in each bin, as well as flat prior probabilities for the signal cross section. Systematic uncertainties on the signal acceptance and background yields are implemented via a convolution procedure of a multivariate Gaussian distribution implementing a full covariance matrix including correlations.

The expected and observed 95% C.L. upper limits on $\sigma_X \times B(X \to t\bar{t})$ as a function of M_X are displayed in Fig. 2. This figure also includes the predicted $\sigma_X \times B(X \to t\bar{t})$ for a leptophobic Z' boson with $\Gamma_{Z'} = 0.012 M_{Z'}$ which, combined with the experimental limits, allows to exclude $M_{Z'} < 680$ GeV at 95% C.L..

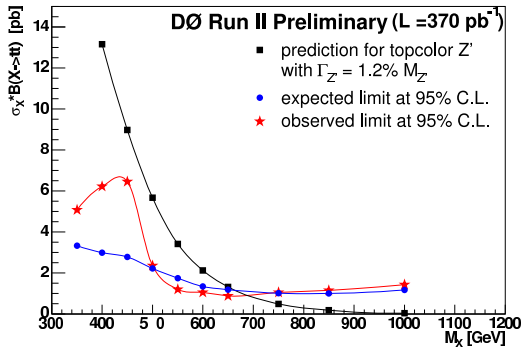

Figure 2: Expected and observed 95% C.L. upper limits on $\sigma_X \times B(X \to t\bar{t})$ compared with the predicted topcolor-assisted technicolor cross section for a Z' boson with a width of $\Gamma_{Z'} = 0.012 M_{Z'}$ as a function of resonance mass M_X.

Similar searches were performed at $\sqrt{s} = 1.8$ TeV by the CDF and DØ collaborations during Run I of the Tevatron collider analyzing a data set of 106 pb^{-1} (CDF) and 130 pb^{-1} (DØ), respectively. No evidence for a $t\bar{t}$ resonance was found. The resulting limits on $\sigma_X \times B(X \to t\bar{t})$, where σ_X is the resonance production cross section, were used to exclude a leptophobic Z' boson with $\Gamma_{Z'} = 0.012 M_{Z'}$. The excluded mass regions at 95% C.L. are, respectively, $M_{Z'} < 480$ GeV [5] and $M_{Z'} < 560$ GeV [6]. Thus the new Run II measurement presented here extends the DØ Run I exclusion on $M_{Z'}$ [6] by 120 GeV.

4. Conclusion

A search for a narrow width resonance in the ℓ+jets final states has been performed using data corresponding to an integrated luminosity of about 370 pb^{-1}, collected with the DØ detector during Run II of the Tevatron collider. By analyzing the reconstructed $t\bar{t}$ invariant mass distribution and using a Bayesian method, model independent upper limits on $\sigma_X \times B(X \to t\bar{t})$ have been obtained for different hypothesized masses of a narrow-width heavy resonance decaying into $t\bar{t}$. Within a topcolor-assisted technicolor model, the existence of a leptophobic Z' boson with $M_{Z'} < 680$ GeV and width $\Gamma_{Z'} = 0.012 M_{Z'}$ can be excluded at 95% C.L..

References

[1] C. T. Hill and S. Parke, Phys. Rev. D **49**, 4454 (1994).

[2] R. M. Harris, C. T. Hill and S. Parke, hep-ph/9911288 (1999).

[3] DØ Collaboration, "Search for a $t\bar{t}$ resonance in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV in the lepton + jets final state using a lifetime tag", HEP2005 Conference Note, DØ note 4880-CONF.

[4] DØ Collaboration, B. Abbot *et al.*, Phys. Rev. D **58**, 052001 (1998); DØ Collaboration, S. Abachi *et al.*, Phys. Rev. Lett. **79**, 1197 (1997).

[5] CDF Collaboration, T. Affolder *et al.*, Phys. Rev. Lett. **85**, 2062 (2000).

[6] DØ Collaboration, V.M. Abazov *et al.*, Phys. Rev. Lett. **92**, 221801 (2004).