Search for narrow-width $t\bar{t}$ resonances in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV

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Abstract. We present a preliminary result on a search for narrow-width resonances that decay into $t\bar{t}$ pairs using 130 pb$^{-1}$ of lepton + jets data in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV. No significant deviation is observed from prediction of the standard model, and upper limits at 95% confidence on the product of the production cross-section and its branching fraction to $t\bar{t}$ are presented for narrow-width resonances, as a function of resonance mass $M_X$. We also use these limits to exclude the existence of a leptophobic top-color particle, $X$, with $M_X < 560$ GeV/c$^2$ and width $\Gamma_X = 0.012 M_X$.

Particles with narrow width that decay to $t\bar{t}$ pairs are predicted by several theories beyond the standard model [1,2]. For instance, one of the scenarios of the top-color assisted technicolor model in ref. [2], predicts a heavy $Z'$, that couples preferentially to the third quark generation, and not to leptons (leptophobic). The cross-section for the $Z'$ in this model is large enough for it to be observed over a wide range of masses and widths in data available from the 1.8 TeV $p\bar{p}$ Tevatron collider at the Fermi National Accelerator Laboratory.

In searches for these heavy particles or $t\bar{t}$ resonances in the distribution of the invariant mass of the $t\bar{t}$ decay products, one seeks an excess beyond that predicted by the standard model. Previous searches from the Tevatron have limited a leptophobic $Z'$ to a mass higher than 480 GeV/c$^2$ [3]. In this paper we present a preliminary result based on a direct search for $t\bar{t}$ narrow-width resonances in the inclusive decay modes $t\bar{t} \rightarrow \ell \nu + 4$ (or more) jets, where $\ell = e$ or $\mu$, using 130 pb$^{-1}$ of data recorded by the DØ experiment from 1992 to 1996.

We consider two orthogonal classes of events for this analysis, whose selection is based on: (a) a purely topological selection of lepton+jets events denoted as $e +$ jets and $\mu +$ jets, and (b) a selection based primarily in the presence of a muon contained within a jet ($\mu$ tag), and additional selections on the topology of the event. These events are denoted as $e +$ jets/$\mu$ and $\mu +$ jets/$\mu$. The principal sources of background correspond to standard model $t\bar{t}$ production, production of a $W$ boson in association with the requisite number of jets, with the $W$ boson decaying into a lepton and its corresponding neutrino, and production of multijets ($N_j \sim 5$), in which one of the jets is misidentified as a lepton, with instrumental effects simulating sufficient missing transverse energy ($E_T$) that satisfies the neutrino requirement. The selections used to reduce the contribution from non-$t\bar{t}$ sources are summarized in table 1.
Table 1. Summary of event selections.

| Lepton  | $E_T > 20$ GeV | $|p_T| < 2$ | $E_T > 20$ GeV | $|p_T| < 1.7$ |
|---------|----------------|------------|----------------|------------|
| Jets    | $E_T > 20$ GeV | $|p_T| < 2$ | $E_T > 20$ GeV | $|p_T| < 1.7$ |
| $\mu$ tag | No            | No         | Yes            | Yes         |
| Other   | $|E_T| + |E_T'| > 60$ GeV | $|E_T| + |E_T'| > 60$ GeV | $E_T > 35$ GeV, $\Delta\phi(E_T, \mu) < 170^\circ$, if $\Delta\phi(E_T, \mu) < 25^\circ$ |
| $|\eta| < 2$ | $|\eta| < 2$ | $\Delta\phi(E_T, \mu) < 170^\circ$, if $\Delta\phi(E_T, \mu) < 25^\circ$ |

Events selected: 42 41 4 3

Figure 1. The DØ Run I 95% confidence level upper limits on $\sigma \times B$ as a function of resonance mass $M_X$. Included for reference are the predicted top color assisted technicolor cross-sections for a width $\Gamma_X = 1.2\% M_X$.

We perform a three-constraint (3C) kinematic fit to the $t\bar{t} \rightarrow l +$ jets, decay hypothesis [4], and require $\chi^2 < 10$ to further reduce non-$t\bar{t}$ background, whereupon 41 events are left in the data sample, of which 4 are $\mu$-tagged.

We consider the resonance signal ($X \rightarrow t\bar{t}$) at nine different masses $M_X$ between 400–1000 GeV/$c^2$, with a width $\Gamma_X = 0.012 M_X$. We then use Bayesian statistics [5] to fit the data $m_T$ distribution to a three-source model comprised of signal ($X \rightarrow t\bar{t}$) at a resonance mass $M_X$, and the standard model backgrounds [4]. No significant
Search for narrow-width $t\bar{t}$ resonances

deviation is seen in the data $m_{T\bar{T}}$ distribution from standard model expectations for any of the resonance masses.

To conclude, after investigating 130 pb$^{-1}$ of the data, we find no statistically significant evidence for a $t\bar{t}$ resonance, and establish upper limits at 95% confidence on the product of the production cross-section ($\sigma_X$) of the resonance, $X$, and its branching fraction ($B$) to $t\bar{t}$, for $M_X$ between 400 and 1000 GeV/c$^2$. These limits are used to constrain a model of top-color assisted technicolor and exclude at 95% confidence, the existence of a leptophobic $Z'$ [2] with mass $M_X < 500$ GeV/c$^2$ and width $\Gamma_X = 0.012 M_X$, as shown in figure 1.

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References

[4] D0 Collaboration: V M Abazov et al, Search for narrow-width $t\bar{t}$ resonances in $p\bar{p}$ collisions at $\sqrt{s}$ = 1.8 TeV, to be submitted to Phys. Rev. Lett.