CDF/PHYS/TOP/PUBLIC/10776

Search for top+jet resonances in $t\bar{t}$+jet(s) at CDF.

The CDF Collaboration
URL http://www-cdf.fnal.gov
(Dated: February 9, 2012)

We present a search for a heavy new particle M produced in association with a top quark ($p\bar{p} \to Mt/M\bar{t}$) and decaying via $M \to \bar{t}q/tq$, leading to a resonance in the $\bar{t}/t$+jet system of $t\bar{t}$+extra jet events. We use events with exactly one lepton, missing transverse energy and at least five jets in data with an integrated luminosity of 8.7 fb^{-1}. We find the data to be consistent with the Standard Model and set cross-section upper limits from 0.61 pb to 0.02 pb for resonances ranging from 200 GeV to 800 GeV. We reinterpret these cross-section limits for specific physics models as exclusions in mass-coupling space.

I. INTRODUCTION

We present a search for top+jet resonances in $t\bar{t}$+jet events using the CDF detector [1]. Recently, CDF reported a measurement of the top-quark production forward-backward asymmetry (A_{FB}) that is significantly larger than predicted by the SM [2]; DØ sees a consistent result [3].

A wide class of models [4] have been built to explain such a discrepancy, most involving the production of a new heavy mediating particle M that enhances A_{FB}. Such new particles may also be singly produced in association with a top(antitop)-quark and further decay to a anitop(top)-quark and an additional jet.

$$p\bar{p} \to Mt(\bar{t}) \to \bar{t}jt(tj\bar{t})$$

Such a decay would look like a top+jet resonance in $t\bar{t} + jet$ events.

II. SIGNAL AND SELECTION

Our signal is similar to $t\bar{t}$ with an additional jet, in the lepton + jets channel the detector signature is $\ell + \nu + qq' + bb' + q$. To isolate such a final state we require:

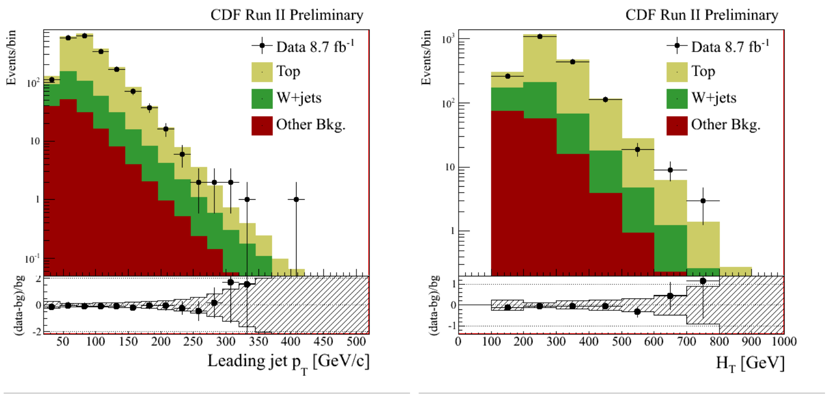


FIG. 1: Validation in the $t\bar{t}$ region, with exactly four jets and at least one b-tag.

- Exactly one tight electron or muon with p_T >20GeV
- At least 5 jets with E_T >20GeV and $|\eta| < 2.0$
- At least 1 SECVTX [5] tag
- $\not\!\!E_T \geq 20$ GeV.

III. MODELING AND BACKGROUNDS

We model the M resonance signal using MADGRAPH [6] to describe the hard process and PYTHIA [7] for the showering. The dominant backgrounds with our selection are $t\bar{t}$ and W+jets. The $t\bar{t}$ and dibsoson background samples are generated using PYTHIA, W+jets and Z+jets using ALPGEN [8]+PYTHIA, and the QCD sample is modeled from jet events in the data.

We validate our background in three control regions:

- $t\bar{t}$ region: Exactly four jets and at least one b-tag. This validates the overall background normalization, as well as the modeling of m_{tj}; the requirement of exactly four jets depletes the sample of potential signal contamination, Figure 1.
- $t\bar{t} + j$ region: At least five jets and exactly zero b-tags. This validates the modeling of additional jet radiation, which is the source of SM events with at least five jets. The requirement of exactly zero b-tags suppresses the signal, Figure 2.
- Low H_T region: At least five jets and small H_T ($<$ 225 GeV). This region directly probes the $t\bar{t}$+ jet contribution, which is partially suppressed in the $t\bar{t}$+jet region by the low H_T requirement, Figure 3.

Our signal region is then defined as $N_{jets} \geq 5$ and at least 1 tag.
We consider several sources of systematic uncertainty, including jet energy scale, contributions from additional interactions, uncertainty in descriptions of initial and final state radiation, differences in Monte Carlo generators for $t\bar{t}$ background and the Q^2 systematics for W+jets backgrounds. The impact of these systematics are listed in Table I.

IV. RECONSTRUCTING THE RESONANCE MASS.

We construct the resonance mass, m_{tj}, using the top kinematic fitter. From the N (>= 5) jets we pick the 4 jets that have highest likelihood match to a $t\bar{t}$ topology, the remaining $N-4$ are paired with the $t/\bar{t}$, the highest invariant mass of a jet + $t/\bar{t}$ is chosen as our analysis variable, m_{tj}. Figure 4 shows this reconstruction for the backgrounds, data and example signal resonances of 300, 500 and 800 GeV/c^2 in the signal region.

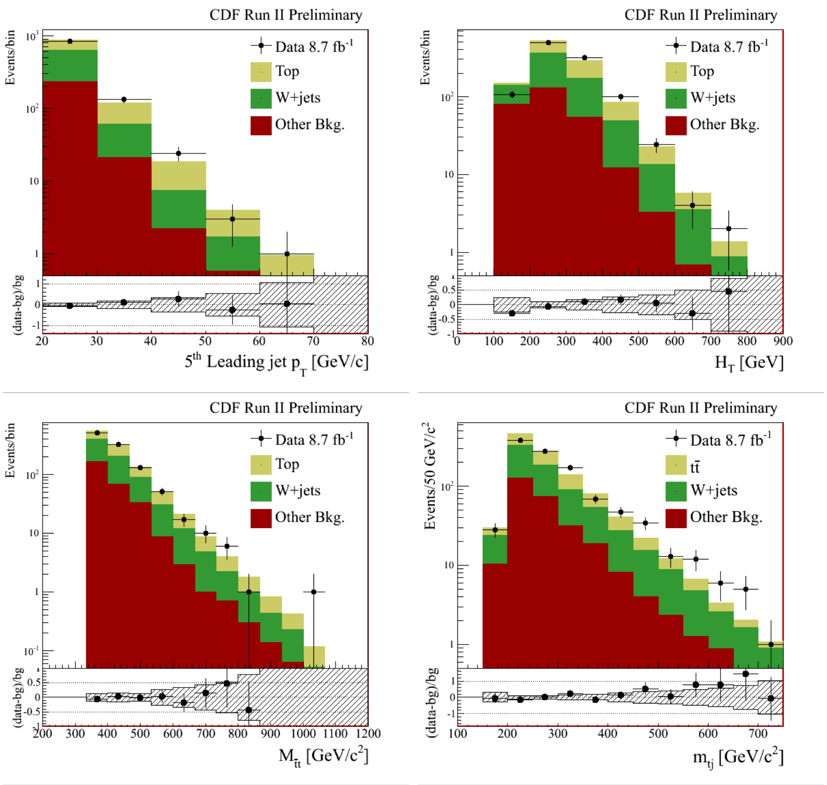


FIG. 2: Validation in the W+jets region, with at least 5 jets and exactly 0 b-tag.

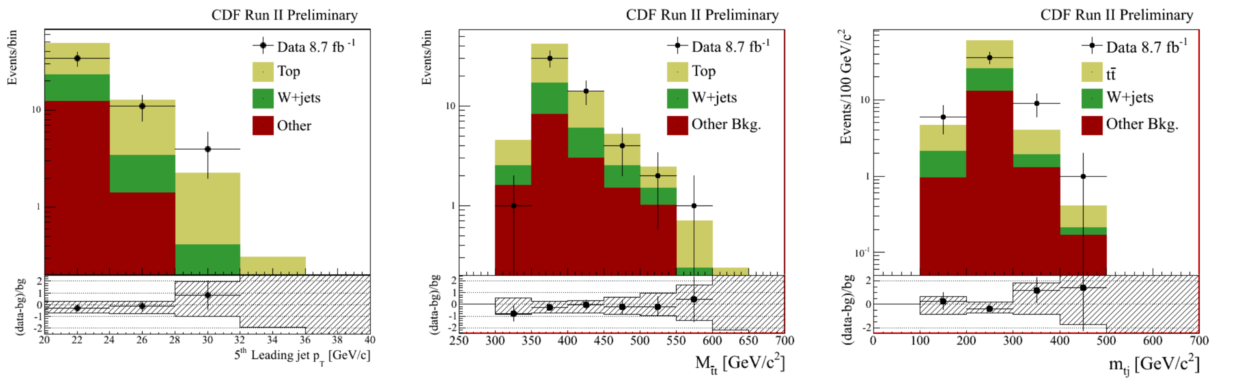


FIG. 3: Validation in the $t\bar{t}+j$ region, with at least 5 jets, at least 1 b-tag, and $H_T < 225 GeV$.

TABLE I: Impact of systematic uncertainties on each background source and an example signal of 500 GeV in the signal region.

Systematic	$t\bar{t}$	W+jets	Total	M (500 GeV)
Nominal	550.55	78.64	669.17	339.69
JES	17%	15%	16%	9%
Radiation	6%	-	5%	4%
Q^2	-	19%	2%	-
Nvtx	3%	2%	3%	2%
$t\bar{t}$ Generator	6%	-	5%	-
Normalization	10%	30%	12%	-
Total Uncertainty	22%	38%	21%	10%

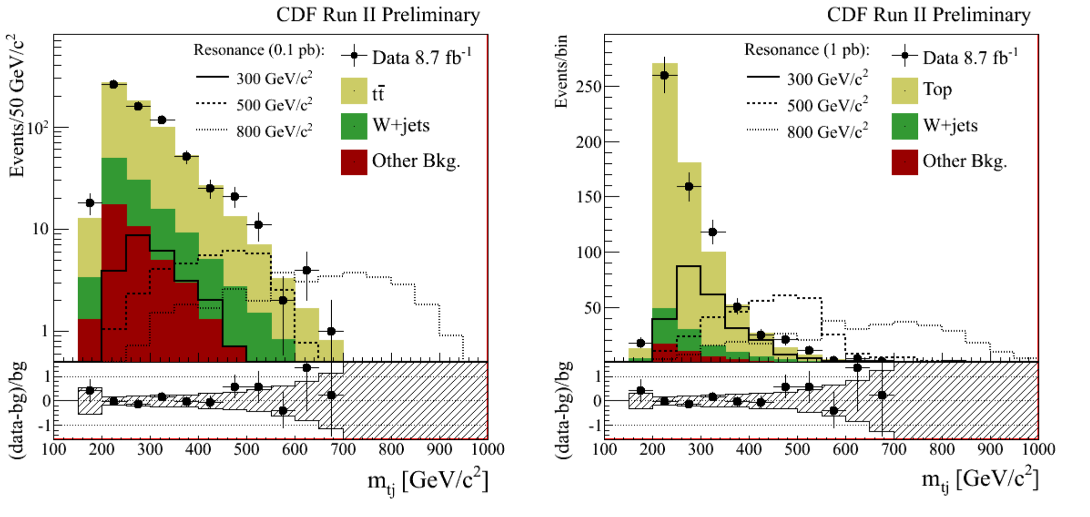


FIG. 4: Resonance mass reconstruction, m_{tj}, for backgrounds, data and example signal resonances of 300, 500 and 800 GeV/c^2 in the signal region scaled to a cross-section of (left) 0.1 pb with log-scale and (right) 1 pb on a linear scale.

V. RESULTS: LIMITS ON CROSS SECTION

To extract the most likely signal cross-section, we perform a binned maximal-likelihood fit to the m_{tj} distribution, varying each background rate within uncertainties, allowing shape and rate variation due to systematic uncertainties described above. The signal and background rates are fitted simultaneously. The CLs method [9] is used to set 95% cross-section upper limits. The median expected upper limit is extracted in the background-only hypothesis.

We find that the observed limits are consistent with what we would expect if the data were drawn from the standard model. We estimate 95% C.L. upper limits on the cross-section of such resonances, see Figure 5.

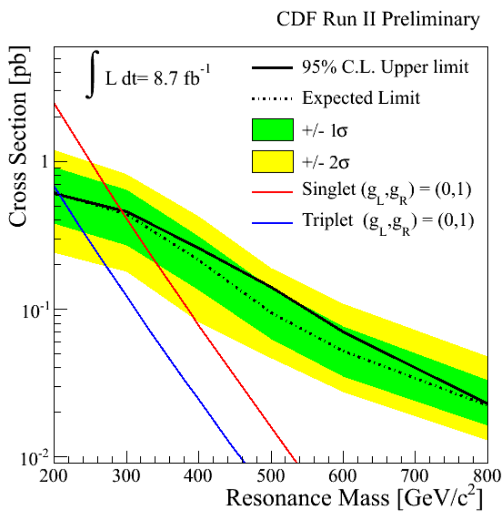
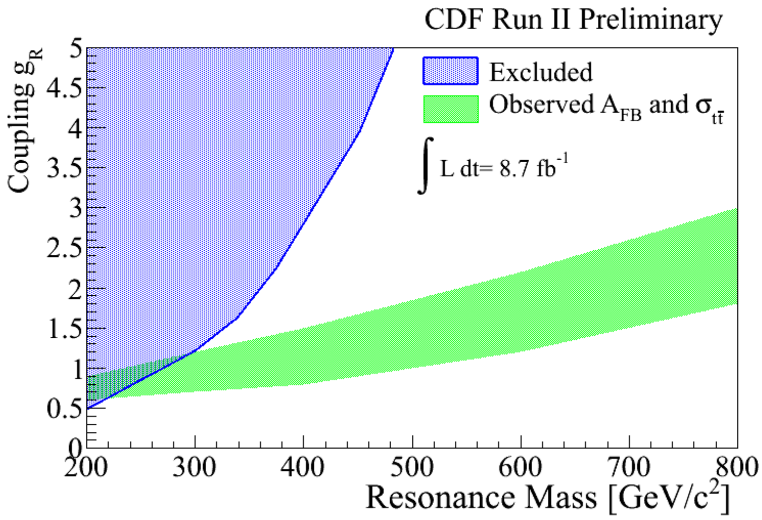


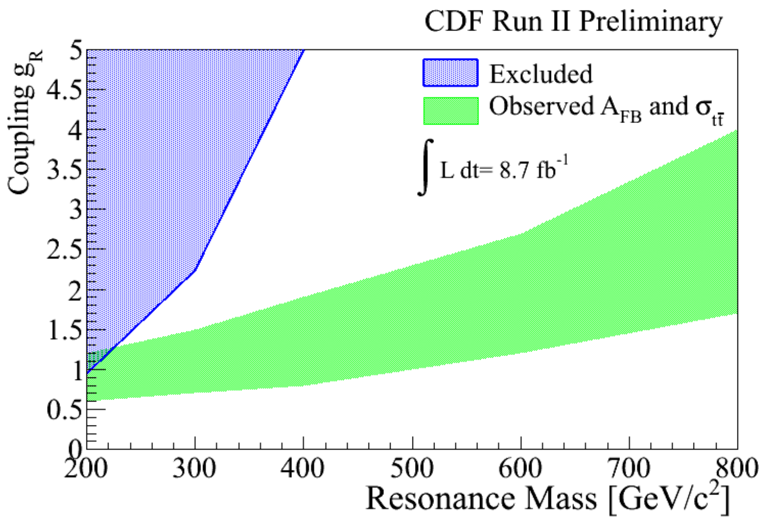
FIG. 5: Upper limits at 95% CL on $t\bar{t}+j$ production via a heavy new mediator M, as a function of the mediator mass. Also shown are theoretical predictions, assuming a unit coupling.

VI. RESULTS

We convert limits on top+jet resonance to exclusion of specific models in mass-coupling space, see Fig. 6



(a) Singlet models.



(b) Triplet models.

FIG. 6: Excluded region in mass-coupling space for two specific models, where the M particle is part of a new singlet (a) or colored triplet [4] (b). Also shown are regions [10] which are consistent with the observed anomalous $A_{\rm FB}$ and constraints from top-quark pair production and single-top production cross-section measurements.

[1] A. Abulencia *et al.*, J. Phys. G **34**, 2457 (2007).,
[2] T. Aaltonen *et al.* (The CDF Collaboration), Phys. Rev. D **83**, 112003 (2011).
[3] V. M. Abazov *et al.* (The D0 Collaboration), Phys. Rev. D **84**, 112005 (2011).
[4] Zurek et al, arXiv:1102.0018v1 [hep-ph] (2011)
[5] A. Abulencia *et al.* (The CDF Collaboration), Phys. Rev. D **74**, 072006 (2006).
[6] J. Alwall *et al.* JHEP 0709:028,(2007).
[7] T. Sjostrand *et al.*, Comput. Phys. Commun. 238 135 (2001).
[8] M. M. *et al.*, arXiv:0206293 [hep-ph](2003) 2006).
[9] CDF Note 8128, `http://www-cdf.fnal.gov/~trj/mclimit/mclimit_csm.pdf`
[10] This region simultaneously satisfies the observed high-$m_{t\bar{t}}$ $A_{\rm FB}$, low-$m_{t\bar{t}}$ $A_{\rm FB}$, and the $t\bar{t}$ cross-section better than the Standard Model. Mathematically, it is defined as the region with $\chi^2 < 2.8$, where χ^2 is defined in Equation 22 in Ref. [4]. χ^2 for the Standard Model is 2.8.