High Mass Dijet and $t\bar{t}$ Resonance Searches

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We present searches for dijet and $t\bar{t}$ mass resonances using between 0.68 and 2.1 fb$^{-1}$ of Tevatron Run II data collected by the CDF and D0 detectors. No evidence of new physics is found, and 95% C.L. limits are set on a number of new physics hypotheses, such as excited quark, Randal-Sundrum graviton, $Z'$, $W'$, color-octet technirho, axigluon and flavor-universal coloron, $E_6$ diquark, quark compositeness, ADD and TeV$^{-1}$-sized LED, massive gluon.

1. INTRODUCTION AND OVERVIEW OF ANALYSES

Of all high $p_T$ processes at a hadron collider, QCD processes have the largest cross-section. Large data samples accumulated by the CDF and D0 detectors in RunII allow precise measurements of the shapes of the observables that describe Standard Model QCD processes. Therefore deviations from the Standard Model could be easily detected.

The top quark, due to its large mass, that is not yet understood, may have a special connection with the electroweak symmetry breaking and new physics. At Tevatron the $t\bar{t}$ pairs are predominantly produced via the s-channel gluon annihilation. However this may not be the only production mechanism. A new neutral heavy particle produced in a proton-antiproton collision would decay into $t\bar{t}$, adding a resonant component to the Standard Model spectrum. An example of such particle is a heavy resonance, $Z'$, which appears in theories with a new strong gauge force coupling to third generation. Besides, a top and anti-top quarks may form a bound state before decaying. This would also create a bump in the $t\bar{t}$ invariant mass spectrum.

Six searches are presented in this paper, two analyses in the dijet final state and four analyses in the $t\bar{t}$ final state. In the dijet final state, CDF looked for a bump in the invariant mass spectrum with 1.13 fb$^{-1}$, while D0 exploited the shapes of dijet angular distributions with 0.7 fb$^{-1}$. In the $t\bar{t}$ final state there is one analyses by D0 with 2.1 fb$^{-1}$, and three analyses by CDF with 0.96 [1], 0.68 [2], and 1.9 fb$^{-1}$ respectively. Important aspect of the $t\bar{t}$ analyses is the reconstruction of top-antitop invariant mass. D0 uses direct mass reconstruction, without constraint fit. CDF analyses employ template method, matrix method, and dynamic likelihood method, respectively. Analyses by both CDF and D0 $t\bar{t}$ use lepton+jets final state.

2. DIJET SEARCHES

2.1. CDF Dijet Analysis

Jets are reconstructed with the midpoint cone 0.7 algorithm within rapidity of 1.0. Events with dijet masses above 180 GeV are selected. Cosmic event background is removed using missing transverse energy significance cut. Dijet mass spectrum is fitted with the parameterized shape that was derived from the full detector simulation spectrum. No significant indication of resonant structure is observed. Uncorrected data are used to set limits using Bayesian approach. The results are shown in Figure 1.

2.2. D0 Dijet Analysis

Jets are reconstructed by RunII midpoint cone 0.7 algorithm. Data are corrected for instrumental effects such as detector response, resolution, out-of-cone showering, additional energy, vertex mis-identification, and jet reconstruction inefficiencies. Dijet angular distributions at particle level are studied. Dijet variable $\chi_{dijet} = \exp(|y_1 - y_2|)$, where $y_1$, $y_2$ are rapidities of two leading jets, is directly sensitive to the dynamics of the underlying reaction. It is expected to have different shape between QCD and new physics. Particle level data distributions overlaid with QCD
Figure 1: Observed limits on resonant dijet production (CDF).

Figure 2: $\chi_{dijet}$ angular distributions for data, QCD, and new physics models (D0).

and several new physics models are shown in Figure 2. Data do not show significant deviations from QCD. Limits on three new physics models are set using Bayesean approach. Quark compositeness, ADD, and TeV$^{-1}$-sized Large Extra Dimensions (LED) models are considered. The parameters of these models are energy scale $\Lambda$, fundamental Planck Scale $M_S$, and compactification scale $M_C$ respectively. The observed limits on $\Lambda$, $M_S$, and $M_C$ are $2.58$, $1.56$, and $1.42$ TeV.
3. \( t \bar{t} \) SEARCHES

3.1. D0 \( t \bar{t} \) Analysis

An isolated electron with \( p_T > 20 \) GeV and \( |\eta| < 1.1 \) or an isolated muon with \( p_T > 20 \) GeV and \( |\eta| < 2.0 \) is required. Missing transverse energy is required to be above 20 GeV (25 GeV) for electron (muon) channel. Three or more leading jets, with one or more being b-tagged, are selected. \( t \bar{t} \) invariant mass is reconstructed directly, without top quark mass constraint fit. Main backgrounds are \( t \bar{t} \), Z+jets, single top, dibosons, W+jets, and multijet. Signal is modelled with the the high mass \( Z^0 \), whose width is equal to 1.2\% of its mass. No resonant structure is observed. Limits are set using Bayeasian approach. The results are shown in top left plot of Figure 3. Leptophobic \( Z' \) is excluded up to 760 GeV.

3.2. CDF \( t \bar{t} \) Analysis with Template Method

Event selection requires a central lepton with \( p_T > 20 \) GeV, missing transverse energy above 20 GeV, and four jets with \( |\eta| < 2.0 \), of which three must have \( p_T > 15 \) GeV, a fourth must have \( p_T > 8 \) GeV, and at least one contains a secondary vertex b-tag. \( t \bar{t} \) invariant mass is reconstructed using the mass fit algorithm with top and W mass constraints. Same signal model as described in previous section is used. No evidence for resonances is observed. Limits are set using Bayeasian approach. The results are shown in the top right plot of Figure 3. For example, leptophobic \( Z' \) is ruled out below 720 GeV.

3.3. CDF \( t \bar{t} \) Analysis with Matrix Method

Very similar event selection as in the previous analysis is used. Matrix-element technique is used to reconstruct \( t \bar{t} \) invariant mass in each event. Same signal model as in previously described \( t \bar{t} \) analyses is used. In the absence of resonances, limits are set using Bayeasian approach. The results are shown in the bottom left plot of Figure 3. For example, leptophobic \( Z' \) is ruled out below 725 GeV.

3.4. CDF \( t \bar{t} \) Analysis with Dynamic Likelihood Method

This is a search for the new color-octet particle called massive gluon. The parameters are mass, width, coupling strength. Mass range between 400 and 800 GeV is explored. Several width scenarios between 5\% and 50\% of the mass are considered. Exactly four jets with \( p_T > 20 \) GeV and \( \eta < 2.0 \), reconstructed with the 0.4 cone algorithm are required. Muon or electron with \( p_T > 18 \) GeV and missing transverse energy above 20 GeV are required. The data are fit for the coupling strength and found to be consistent with the Standard Model. Limits on the coupling strength are set. Exclusion contours for the case when width is equal to 30\% of the mass are shown on bottom right plot of Figure 3.

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References

[1] CDF Collaboration, T. Aaltonen et al., Phys. Rev. D 77, 051102(R) (2008).
[2] CDF Collaboration, T. Aaltonen et al., Phys. Rev. Lett. 100, 231801 (2008).