MEASUREMENTS OF TOP PRODUCTION AND DECAY AT THE TEVATRON

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Presented in this paper are the latest results from CDF and D0 in the study of top quark production and decay, including measurements of the top pair cross section, searches for resonant top production, charged Higgs production, and fourth generation top quarks. These results were presented at the 2009 Moriond EWK conference.

1 Introduction

The top quark was discovered in 1995 by the CDF and D0 collaborations [1 2]. Over 30 times more massive then any other quark, the top quark could play some special role in electroweak symmetry breaking, and is an excellent probe for high energy new physics. Though few measurements of top properties outside the mass have been measured with precision, the Tevatron has now produced over 10 times the statistics since top's discovery. During this time, measurement techniques have advanced at a rapid pace. Now, with several fb^{-1} of collected data and new advanced methods, precision measurements are a reality, allowing us to finally test the top quark's place in the standard model.

2 Measurements

2.1 Measurement of the Top Pair Production Cross Section

The top pair production cross section has been measured by the CDF collaboration in 2.8 fb^{-1} of collected data [3 4]. Two measurements have been performed: a more traditional b-jet identification measurement and a topological approach. The b-jet measurement reduces background by identifying a bottom quark from top decay using an algorithm SECVTX[5]. Secvtx searches for a long lived b-hadron which creates a secondary vertex displaced from the primary interaction. As opposed to b-tagging, the topological measurement uses event kinematics fed into an artificial neural network to distinguish the top signal from background. The results are $\sigma_{t\bar{t}} = 7.1 \pm 0.4_{stat} \pm 0.6_{syst} \pm 0.4_{lumi}$ pb for b-tagging and $\sigma_{t\bar{t}} = 6.9 \pm 0.4_{stat} \pm 0.4_{syst} \pm 0.4_{lumi}$ pb for the topological measurement using a mass of 175 GeV/c^2. Both measurements are systematically limited, with the dominant systematic being the uncertainty in the integrated luminosity.

To reduce the systematic uncertainty from luminosity, the top cross section can be measured relative to the Z cross section. The Z cross section is measured using opposite-signed dilepton events in an invariant mass range 66 GeV $< M_{ll} <$116 GeV. The ratio of the top cross section to the Z cross section is calculated. The top cross section is extracted from the ratio by multiplying by the theoretical Z cross section, effectively replacing the luminosity systematic with an uncertainty on the theoretical Z cross section. This technique has been performed for both the b-tagging and topological measurements. The results are $\sigma_{t\bar{t}} = 7.0 \pm 0.4_{stat} \pm 0.6_{syst} \pm 0.1_{theory}$ pb for b-tagging and $\sigma_{t\bar{t}} = 6.9 \pm 0.4_{stat} \pm 0.4_{syst} \pm 0.1_{theory}$ pb for the topological measurement using a mass of 175 GeV/c^2.

2.2 Search for Resonant Top Production

Because of the relatively large mass of the top quark, it serves as an excellent probe for new physics. The D0 collaboration has performed a direct search for new massive gauge bosons (Z$'$) which could be contributing to top production [6]. The search is performed in the invariant mass spectrum of the $t\bar{t}$ system ($M_{t\bar{t}}$). For each event, $M_{t\bar{t}}$ is fully reconstructed using an algorithm that depends on the topology of the event. Narrow resonance templates are formed from a topcolor monte carlo simulation, and fit to the data across several mass points. Limits are placed on the mass of a new narrow resonance gauge boson, $M_{Z'} >$ 760 GeV at 95% CL [7].

2.3 Search for Charged Higgs

New physics signals could appear in measurements focusing on the decay of the top quark. If the top quark were to decay to an unexpected state, the relative rates of top production would change across decay channel. The D0 collaboration has performed a search for top decay to charged Higgs by analyzing events across three different channels: lepton + jets, dilepton, and tau + jets [8]. Two possible models are considered in the search, models where charged Higgs decays to a tau and neutrino, and where charged Higgs decays to a charm and strange quark. Cross sections across the three channels are compared and limits set on the these two models in the $tan\beta$ and mass of charged Higgs phase space.

2.4 Search for $t\bar{t}H$ Production

The D0 collaboration has performed a search for the production of standard model Higgs in association with top pairs [9]. At the Tevatron, the cross section times branching ratio is very low for this process, but this remains an interesting channel to search for deviations from the standard model. The $t\bar{t}H$ signal is distinguished from background using multiple variables, including the scalar sum of transverse energy, the total number of jets in the event, tracking parameters, and the number of b-jets identified through a neural network identification technique. After a likelihood fit is performed, no deviation from the standard model is observed. The observed limit at $M_H = 115$ GeV is 64 times larger then standard model prediction.

2.5 Search for Fourth Generation Top Quarks

The CDF collaboration has performed a direct search for a fourth generation heavy top-like quark (t$'$) decaying to a W-boson and quark final state. Such a fourth generation particle exists in several new physics models such as little Higgs and beautiful mirrors [10] [11]. The search is performed by reconstructing the mass of the top from it's decay products using kinematic constraints. The reconstructed mass, along with the scalar sum of the transverse energy in the detector (H_T), are used to discriminate a t′ signal from standard model top as well as other backgrounds. A binned 2D likelihood fit is performed, and in the absence of a signal, a limit is placed on the mass of the t′, $M_{t'} < 311$GeV at 95% CL [12].

3 Conclusion

The CDF and D0 collaborations continue towards the goal of mapping out the top quark's place in the standard model. With several fb^{-1} collected, precision top quark physics is now possible. In this paper, it has been demonstrated that the cross section is now a precision measurement, as well as several stringent limits have been set on new physics models. In no way does this encompass all the results produced by the top groups at CDF and D0. More results can be found at both groups public web sites [13] [14].

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