Fermi National Accelerator Laboratory

FERMILAB-Conf-97/143-E
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May 1997

Published Proceedings of the *QCD and High Energy Hadronic Interactions, XXXII Rencontres de Moriond*, Les Arcs, France, March 22-29, 1997

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy

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CDF / PUB / TOP / PUBLIC / 4167

TOP PROPERTIES AT THE TEVATRON

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Abstract

We present the latest results associated with top properties at the Tevatron. The large data set collected in four years of running has allowed, after top discovery, the study of various top properties. The results presented here include the measurement of the CKM matrix element $|V_{tb}|$, the search for top FCNC, the study of properties of the W in t decays and the search for heavy states decaying to $t\bar{t}$ pairs. Future measurements in top physics at the Tevatron are briefly discussed.

To appear in Proceeedings of the XXXII Rencontres de Moriond, QCD and Hadronic Interactions

1 Introduction

Both the CDF and D0 collaborations, after the top discovery,[1,2] have moved to precision measurements of its properties. Other talks in this Rencontres[3] discuss the measurement of top mass and of the production cross section for $t\bar{t}$ pairs in $p\bar{p}$ collisions. Here I will concentrate on the studies of top branching fractions and decays.

The top quark has a unique property related to its heavy mass, as its width

$$\Gamma_{top} = \frac{G_F|V_{tb}|^2}{8\pi\sqrt{2}} {m_t}^3 (1 - \frac{M_W^2}{m_t^2})^2 (1 + 2\frac{M_W^2}{m_t^2}) \simeq 1.8\, GeV/c^2$$

implies that it decays before hadronizing.

The CDF experiment has studied several properties of top events and in particular the structure of the vertex $t \to Wb$. In the following I will show results relative to the:

- measurement of the branching fractions ratio: $\mathcal{B} = \Gamma(t \to Wb)/\ \Gamma(t \to Wq)$;
- search for FCNC decays;
- measurement of the fraction of W's longitudinally polarized in top decays;
- search for $t\bar{t}$ resonant states and study of the kinematical properties of the top.

2 $\mathcal{B}$ and V_{tb} Measurement

The top quark branching fraction $\mathcal{B} = \frac{\Gamma(t\to Wb)}{\Gamma(t\to Wq)}$ is predicted to be almost 1 in the Standard Model(S.M.) framework. Its measurement directly provide a result for the CKM matrix element $|V_{tb}|$ through the relation $\mathcal{B} = \frac{|V_{tb}|^2}{|V_{tb}|^2+|V_{ts}|^2+|V_{td}|^2}$, after neglecting small phase space effects, If one also assumes unitarity, this reduces to $\mathcal{B} = |V_{tb}|^2$. Furthermore a large deviation of $\mathcal{B}$ from its S.M. value has been predicted in several non-standard models.

CDF has already reported preliminary results in the past, using part of the full data set. The analysis presented here is based on the whole Run 1 data (110 pb^{-1}), where a combination of kinematical selection (aimed to get a sample enriched in top candidates) and of b-tagging -needed to extract $\mathcal{B}$- is used.

The data set is made of two independent ensembles: the dilepton (DIL) sample, and the $W+$ $\geq$4 jets sample. 9 $t\bar{t} \to l\nu l\nu b\bar{b}$ candidates, selected with the cuts discussed in[1*], constitute

*In this analysis when applying the $75 < M_{ll} < 105$GeV/c^2 cut, photons with $P_t > 10$ GeV/c are included in the invariant mass calculation to remove radiative Z decays.

the DIL sample. The W4J sample is obtained from the $W+\ \geq 3$ jets sample[1] with the additional requirement of a fourth jet with $E_T > 8$ GeV and $|\eta|$ <2.4. 163 $t\bar{t}$ candidates constitutes the final data set in this channel. During this selection b-tagging information is not used in the DIL or in the W4J sample.

Each data set is separately divided in subsamples according to the b-tagging status (0,1,2 tags) of each event. While only SVX[1] tagging is applied to the dilepton candidates (with the events divided into 3 separate bins according to the number of tags), both SLT[1] and SVX tagging are applied to the $W+$jets events. In this case the sample is divided in four bins: events with no tag (SVX or SLT),events without SVX tags but 1 (or more) SLT tags, events with 1 SVX tag, events with 2 SVX tags. In the last two bins the SLT tagging status is not considered. In this way all subsamples are orthogonal (by construction).

Using a likelihood technique, data is compared to a model in which the content of each bin is described in terms of top and background. Acceptances and efficiencies are obtained from Monte Carlo, and $\mathcal{B}$ is left as a free parameter of the fit. After taking into account the systematic uncertainties (mostly coming from the tagging efficiency and the background subtraction), the fit result is $\mathcal{B} = 0.99 \pm 0.29$ (see fig. 1).

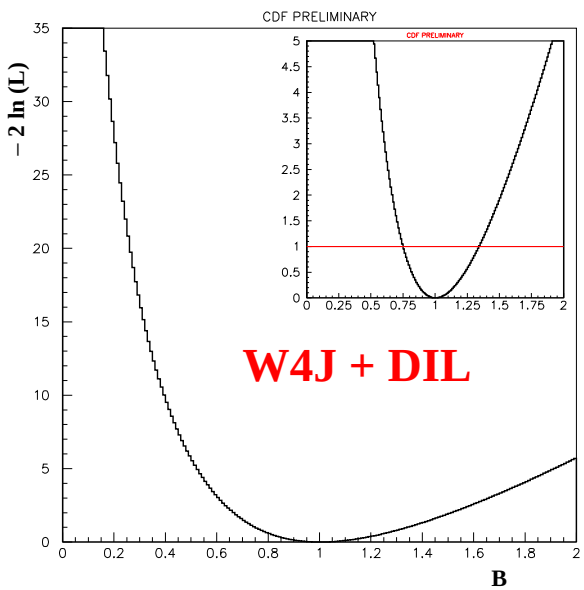

Figure 1: Plot of $-2\ln L$ as a function of B. Inset is a blow-up of the region of the minimum.

The confidence level limits are obtained by numerical integration of the likelihood, and are $\mathcal{B}$ >0.64 (0.58) at 90 (95) % C.L.. Assuming unitarity ($|V_{tb}|^2 + |V_{ts}|^2 + |V_{td}|^2 = 1$), the corresponding results on $|V_{tb}|$ are: 0.99±0.15(stat.+syst.) and $|V_{tb}|$ >0.8(0.76) at 90(95) % C.L.

3 FCNC decays of top

Within the Standard Model flavour changing neutral current decays of the top quark, are suppressed at the level of $10^{-10} \div 10^{-12}$. Given the present sensitivity of the experiments, the small branching fractions are completely out of reach at the Tevatron. The same situation holds for several non-S.M. sources of FCNC decays.[4] Reversing the argument, the observation of FCNC decays of top would signal the appearance of non-SM physics. With this in mind, the CDF collaboration has searched its data for signatures of $t \to q\gamma$ and $t \to qZ$ (where q indicates a u or c quark). Both analyses assume that one of the two t's decays according to the SM into Wb. $t\bar{t} \to Wbq\gamma$ is searched for in the lepton $+\gamma$ data sample and $t\bar{t} \to Wb\gamma jj$ is searched for in the $\gamma + 4$ jets events.

$t \to q\gamma$ candidates are selected by requiring an identified W (e or μ with $P_T >$ 20 GeV / c and $\not{E}_t >$ 20 GeV), a photon with $E_T^\gamma >$ 20 GeV and at least 2 jets with $E_T >$ 15 GeV.

$\gamma + 4$ jets candidates are selected by requiring a photon with $E_T^\gamma > 50$ GeV, $\sum E_T^{jets} >$ 140 GeV and at least one jet tagged as b by the SVX algorithm.

Expected background is mostly due to $W\gamma$ events, and is estimated at $\simeq 0.5$ evts. / channel. One event is observed (in the $l + \gamma$ sample). Although it survives all FCNC requirements, its kinematic [†] is also consistent with a $t\bar{t}$ event in which one of the top decayed to $Wb\gamma, W \to \nu\mu$. CDF does not subtract the background (a conservative choice), moreover as there is little (or none) capability to separate light quarks from charm, the limit is set by combining the two channels. The observation of a single candidate, after taking into account efficiencies, acceptancies and related uncertainties, converts in a 95 % C.L. limit: $\mathcal{B}(t \to \gamma u + t \to \gamma c) < 2.9\%$.

CDF has also searched for FCNC decay $t \to Zq$ (q indicates u or c). The topology investigated is $t\bar{t} \to ZqWb$,$Z \to ll$ (l e or μ). Events are required to have: $75 < M_{ll} < 105$ GeV / c^2 and at least 4 jets with $E_T >$ 20 GeV and $|\eta| < 2.4$. One event survives all cuts. The biggest background sources are Z+jets (0.5 events), $t\bar{t} \to l\nu l\nu b\bar{b}$ (0.6 events) with a smaller contribution from dibosons (0.1 events). As in the previous case, no background subtraction is performed, and the 95 % C.L. combined limit is: $\mathcal{B}(t \to Zu + t \to Zc) < 33\%$.

[†] The event has a 77 GeV / c muon, an 88 GeV photon, 3 jets and 24 GeV of $\not{E}_t$.

4 W polarization in top decays

Due to the large top mass, W's from top decays can be either transverse (W_T) or longitudinally (W_L) polarized. The fraction of longitudinally polarized W's is $\mathcal{F} = \frac{1/2 \cdot m_t^2/M_W^2}{1+1/2 \cdot m_t^2/M_W^2}$, and for M_{top}= 175 GeV/c^2 $\mathcal{F} \simeq 70\%$.

CDF extracts the W polarization from the angular distribution of the lepton from W decay in the W rest frame, which exhibits a peak at 90° (180°) if it is coming from longitudinal (transverse) W's. The angle θ_{lW} is measured in the mass sample data set[1] where the event kinematics are completely reconstructed.

Selection cuts strongly bias the sample, eliminating the characteristic 180° peak present in W_T decays. SVX tagging is used to reduce contribution from background as it distorts the angular distribution. After selection, the final data set is 20 events, with an estimated background of 1.6±1.0 events and is fitted, using a likelihood technique, to a mixture of top and background. The CDF preliminary result for the fraction of longitudinally polarized W's in top decays is: $\mathcal{F} = 55^{+48}_{-53}(stat.)\,\%$.

5 $M_{t\bar{t}}$ and top kinematics

Comparison of top kinematics observed in data with expectations from Monte Carlo is of the utmost importance as one not only looks for effects due to new physics but also checks the Monte Carlo programs which are heavily used in all studies.

CDF has studied a number of variables, finding good agreement between data and expectations. In fig. 2 angular distance between tops and the invariant mass of the $t\bar{t}$ system in tagged events is shown. While there had been suggestions of $t\bar{t}$ production being due to the decay of a heavy state, the data do not support such a hypothesis.

6 Future measurements

Both the CDF and D0 experiments are undergoing upgrades to be ready for Run II, when integrated luminosity of the order of 2 fb^{-1} will be delivered. This will allow M_{top} and $\sigma_{t\bar{t}}$ precision measurements, as well as $|V_{tb}|$ and $\mathcal{F}$ measurement to 5% precision. FCNC sensitivity will be in the 10^{-3} region.[5] This increased capability will allow the exploration of new aspects of top physics. One of the most important will be the observation of single top

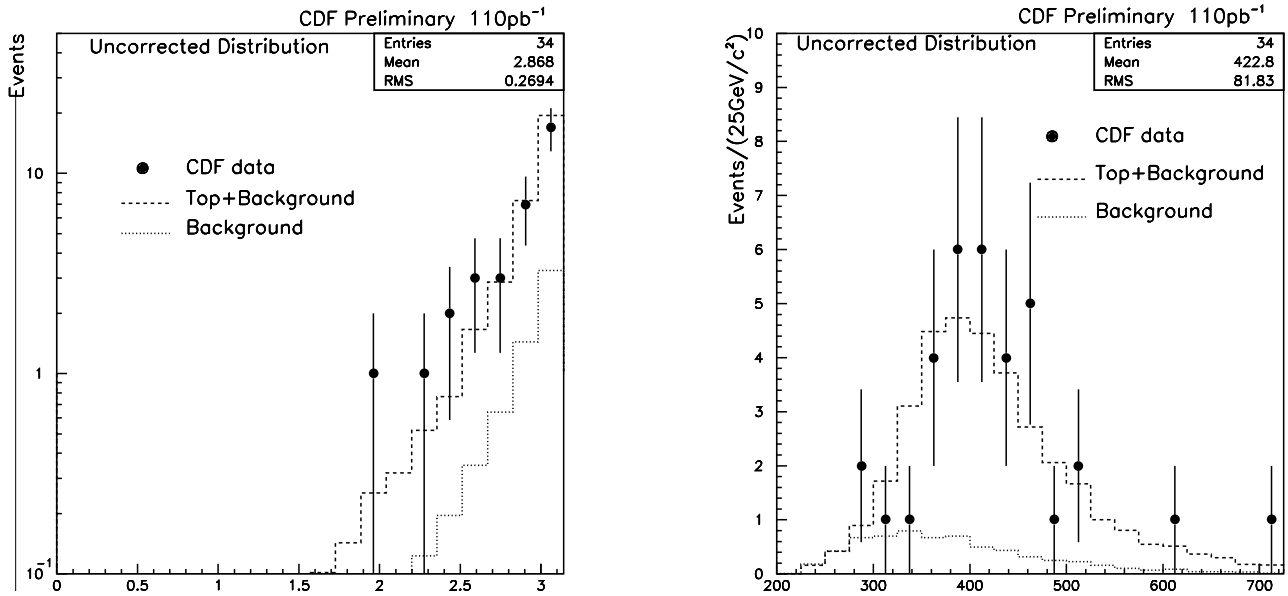

Figure 2: $\Delta\varphi$ t-$\bar{t}$ and invariant mass of the $t\bar{t}$ system in tagged events

events that will provide a direct measurement of Γ_{top}, as its cross section is proportional to $\Gamma(t \to Wb)$. This channel, not yet observed at the Tevatron, constitutes an important physics background in the Higgs searches in associated WH production, and understanding it will become increasingly important in the future.

7 Conclusions

The Tevatron is the place where top was discovered, and is the place where, at the moment, the study of top is taking its first steps. Although with still limited sensitivity due to the small statistics, CDF and D0 are exploring its properties. I presented results associated with the tWb vertex structure and of the search for a resonant $t\bar{t}$ state. With the start of Run II, the improved sensitivity of CDF and D0, and expecially with the much increased luminosity, Tevatron will be the place where top physics will be explored in detail.

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