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MEASUREMENT OF $B(t \to Wb)/B(t \to Wq)$

MONICA TECCHIO

Physics Department, University of Michigan, 500 E. University
Ann Arbor, MI 48105/1120

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We measure the ratio $R = B(t \to Wb)/B(t \to Wq)$ in top-quark decays at CDF. R is determined from the relative rates of identified b jets in $t\bar{t}$ decays reconstructed both in the lepton-plus-jets and dilepton final states. We obtain $R > 0.62$ at the 95% CL, consistent with Standard Model expectations.

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1. Introduction

The ratio of branching fractions $R = B(t \to Wb)/B(t \to Wq)$, where q is any quark, can be expressed as a ratio of Cabibbo-Kobayashi-Maskawa (CKM) matrix elements $R = |V_{tb}^2|/(|V_{tb}^2| + |V_{ts}^2| + |V_{td}^2|)$. If the CKM matrix is unitary and one assumes only three generations of quarks, the current best estimate of $|V_{tb}| > 0.999$ [1] leads to $R > 0.998$ at 90% confidence level. A measurement of R significantly different from unity would imply a failure of the Standard Model, implicit in the assumptions above.

We describe a measurement of R in 161 pb^{-1} of data collected by the CDF detector[2] at the Fermilab Tevatron $p\bar{p}$ collider. The relative rates of $t\bar{t}$ events with zero, one and two identified b quarks can be used to overconstraint the product $R\epsilon_b$. Here ϵ_b is the efficiency to identify, or "tag", the jet produced in the b quark decay, which can be estimated from $t\bar{t}$ simulation and calibrated with independent control sample. In order to predict the number of events $N_{\mathrm{exp},i}$ with $i = 0$, 1 or 2 tagged jets, one must know the backgrounds $N_{\mathrm{bkg},i}$ in each tagged bin as well as the efficiency to tag events with i b-jets as a function of $R\epsilon_b$. Using a likelihood technique, we extract the value of $R\epsilon_b$ that maximizes the probability to observe $N_{\mathrm{obs},i}$ events given the predictions. This method is independent of the top production cross-section.

2. Data Sample and Event Selection

For this analysis we use the same $t\bar{t}$ candidate events used to measure the top cross-section in the dilepton (LL) channel [3] and in the lepton-plus-jets [4]. For our purposes, the latter is further divided into events with exactly three jets (L3J) or at least four jets (L4J). Jets are tagged as coming from b quarks using the SECVTX algorithm [5], which searches for tracks in jets with large impact parameter and tries to constraint them to a common vertex displaced from the event primary vertex. The SECVTX efficiency is measured to be $\epsilon_b = 0.44 \pm 0.03$; the rate at which this algorithm falsely tags, or "mistag", generic jets is ≈ 0.5 %. Table 1 shows the events counts separate for the different number of tagged jet and for the different categories considered in this analysis.

Table 1. Event counts and background estimates in each tagged jet bins for the different samples used to measure R in this analysis.

	$N_{\mathrm{obs},i}$			$N_{\mathrm{bkg},i}$			
Sample	LL	L3J	L4J	LL	L3J(DE)	L4J(DE)	L4J(NN)
0-tag	5	358	79	2.0 ± 0.6	-	-	$62.4^{+8.5}_{-9.3}$
1-tag	4	26	23	0.2 ± 0.2	16.0 ± 2.4	4.2 ± 0.7	$5.8^{+5.6}_{-5.2}$
2-tag	2	3	5	0	0.8 ± 0.2	0.2 ± 0.1	$0.1^{+0.9}_{-0.0}$

2.1. *Backgrounds*

The backgrounds are evaluated using different techniques for the LL and L3J/LJ4 samples. For the LJ4 sample alone, two independent estimate of the background are available.

For the LL sample, we have an estimate of the total background before tagging, as the dilepton top cross-section selection does not require the presence of SECVTX tags. This background is dominated by Z and diboson events produced in association with jets, and events with a W-plus-jets in which a jet fakes the second lepton. We assume that the tagged background from these events can be evaluated using the SECVTX generic jet "mistag" rate. This leads to the background estimates shown in Table 1.

For the top lepton-plus-jets sample, the presence of a SECVTX tagged jets is imposed as part of the selection to improve the signal to background ratio. The residual background is dominated by W production in association with heavy-flavor jets ($Wb\bar{b}$,$Wc\bar{c}$,Wc), W production with light-flavor jets for which one jet is a mistag and non-W events containing a fake lepton. A direct estimate (DE) of the background in the L3J/LJ4 1-tag and 2-tag subsample, which uses a combination of data-driven and simulation based-techniques, gives the background estimates shown in Table 1.

For the L4J sample we also use a kinematic based neural net (NN) analysis to extract the fractions of top signal and background in the different tagged bins. The single outptut NN is trained on nine kinematic variables indepedent of SECTVX tagging. The background estimates coming from this method are also shown in Table 1.

2.2. *Event Tagging Efficiencies*

We consider various sources of tagged jets. If $R < 1$, b quarks from $t \to Wb$ and light (*i.e.* non-b) quarks from $t \to Wq_l$ contribute to the total efficiency to tag a jet with terms like $R\epsilon_b$ and $(1 - R)\epsilon_l$, respectively. We also consider other sources of tagged jets; from hadronic decays of the W, with efficiency ϵ_W; and from "other" jets in the event, with efficiency ϵ_o.

All of these tagging efficiencies apply to jets that are taggable, *i.e.* inside the SECVTX fiducial acceptance. The final event tagging efficiencies for each tagged jet bin, ϵ_i, are parameterized in terms of $R(\epsilon_b - \epsilon_l) = R\Delta\epsilon$, ϵ_W, ϵ_o and F_{bWo}, where F_{bWo} are the fractions of evens with taggable jets from different sources. All of these parameterd are extracted from $t\bar{t}$ simulation. In particular, jet tagging efficiencies other than ϵ_b are typically about 1% .

2.3. *Likelihood Function*

The likelihood function is the product of three terms (for the LL, L3J and L4J samples), each of the form $\mathcal{L} = \Pi_i \mathcal{P}(N_{\mathrm{obs},i}, N_{\mathrm{exp},i})$, where $\mathcal{P}$ are Poisson probability to observe $N_{\mathrm{obs},i}$ events with i tags given the expected number of events $N_{\mathrm{exp},i}$. Using the background estimates of Table 1 and the event tagging efficiencies ϵ_i described above, we extract the value of $R\Delta\epsilon$ that is most consisten with the data.

Systematic uncertainties in the measurement are folded into the likelihood by multiplying the Poisson functions by a set of Gaussian functions that constrain various parameters to their expected values with some uncertainty.

3. Results

Figure 1 shows the likelihood distribution that results from using the best background rates available for each tagged bin, that is the DE estimated for the 1-tag and 2-tag L3J/L4J subsamples and the NN estimate for the 0-tag L4J subsample. From the position of its peak, we estimate $R\Delta\epsilon = 0.49^{+0.09}_{-0.08}$, or $R = 1.11^{+0.21}_{-0.19}$. The L3J and L4J samples alone yield $R = 1.04^{+0.24}_{-0.21}$, and the LL sample alone gives $R = 1.40^{+0.45}_{-0.38}$. The measured value is thus independent of the decay modes of the W in the $t\bar{t}$ events. Focusing in on the lepton-plus-jets samples, if we only use the 1-tag and 2-tag samples and the DE backgrounds, we find $R\Delta\epsilon = 0.94 \pm 0.32$. If instead we use the NN backgrounds throughout, we find $R = 1.06^{+0.27}_{-0.24\mathrm{stat}} \pm 0.16_{\mathrm{sys}}$. These values are less precise than, but consistent, with what we obtain when we combine the two methods.

To set a limit on R, we turn to the Feldman-Cousins procedure [6]. For each input value of R_{true}, we determine the 95% confidence bands given different R_{obs} by changing various input quantities to the analysis (*i.e.* backgrounds and efficiencies) within their appropriate systematic uncertainties. Given $R = 1.11^{+0.21}_{-0.19}$, we find $R > 0.62$ at the 95% confidence level. Using results from the NN analysis only, we obtain $R > 0.57$ at the 95% confidence level. This limit is stronger than that from

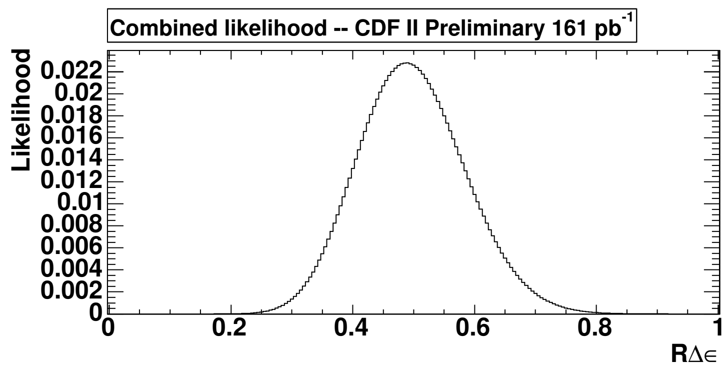

Fig. 1. Combined likelihood for all three data samples as a function of $R\Delta\epsilon$.

the previous measurement using CDF data from Run I at the Tevatron, $R > 0.56$ [7]. While not sufficiently precise to test the standard-model predictions for R in any stringent way, we have still placed the strongest constraints on R to date.

References

1. S. Eidelman *et al.*, Phys. Lett B **592**, 1 (2004).
2. F. Abe, et al., Nucl. Instrum. Methods Phys. Res. A **271**, 387 (1988); D. Amidei, et al., Nucl. Instum. Methods Phys. Res. A **350**, 73 (1994); F. Abe, et al., Phys. Rev. D **52**, 4784 (1995); P. Azzi, et al., Nucl. Instrum. Methods Phys. Res. A **360**, 137 (1995); The CDFII Detector Technical Design Report, Fermilab-Pub-96/390-E.
3. D. Acosta *et al.*, Phys. Rev. Lett. **93**, 142001 (2004).
4. D. Acosta *et al.*, FERMILAB-PUB-04-275-E
5. T. Affolder *et al.*, PRD **64**, 032002 (2001).
6. G. Feldman and R. Cousins, PRD **57**, 3873 (1998).
7. T. Affolder *et al.*, PRL **86**, 3233 (2001).