Anomalous *t-c-g* coupling: The connection between single top quark production and top quark decay

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Continuing earlier work, we examine the constraint on an anomalous *t-c-g* coupling from top quark decay. We find that from current CDF measurements of the branching ratio $t\to Wb$, the minimum scale at which new physics can strongly modify the *t-c-g* coupling is $\Lambda_{tcg}\geqslant$ about 950 GeV. At the upgraded Fermilab Tevatron, single top quark production can constrain $\Lambda_{tcg}\geqslant 4.5$ TeV. The connection between *t-c* production and the decay $t\to cg$ is examined, showing how constraints on one lead to a constraint on the other. [S0556-2821(97)04311-7]

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As shown in [1], an anomalous coupling between top quark, charm quark, and gluon fields can have a large effect on single top quark production at the Fermilab Tevatron.[1] The operator which produces this anomalous coupling is dimension five, and thus contains a parameter Λ, which characterizes the scale of the new physics which strongly modifies the *t-c-g* coupling. This anomalous operator can be written as

$$\frac{g_s}{\Lambda}\left[\bar{t}\frac{\lambda^a}{2}G^a_{\mu\nu}\sigma^{\mu\nu}c+\bar{c}\frac{\lambda^a}{2}G^a_{\mu\nu}\sigma^{\mu\nu}t\right], \tag{1}$$

where we have assumed that the left-handed and right-handed *t-c-g* couplings are equal. In that work, it was mentioned that the *t-c-g* operator can also be studied from the decay $t\to cg$. This decay mode has been studied in [2], and the results are similar to those presented here.

In [1] the ratio of the partial widths is presented:

$$R_{tcg}=\frac{\Gamma(t\to cg)}{\Gamma(t\to W^+b)}=\frac{\sqrt{2}\,64\alpha_s\pi m_t^2}{3\Lambda^2G_F[1-m_W^2/m_t^2]^2[1+2m_W^2/m_t^2]}. \tag{2}$$

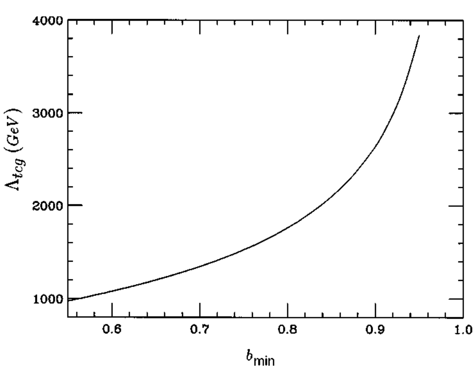

FIG. 1. The constraint on λ_{tcg} as a function $b_{\min}$.

[1]The notation and conventions used in this work are the same as those presented in [1]. A full discussion of the effective operator which generates the *t-c-g* coupling can be found therein.

Assuming that there is no other new physics modifying the top quark decays, the branching ratio $B(t\to Wb)$ can be expressed as

$$B(t\to Wb)=\frac{\Gamma(t\to Wb)}{\Gamma(t\to Wb)+\Gamma(t\to cg)}. \tag{3}$$

From these results, one may determine Λ_{tcg} (the minimum value of Λ from experimental constraints) which corresponds to a given lower limit on $B(t\to Wb)$, $b_{\min}$. The results are plotted in Fig. 1.

The current Collider Detector at Fermilab (CDF) measurement of $B(t\to Wb)$ [3],

$$B(t\to Wb)=0.87^{\pm0.13\pm0.13}_{\pm0.30\pm0.11}, \tag{4}$$

leads to the 1σ limit $b_{\min}=0.55$. From this we derive a constraint on $\Lambda_{tcg}\geqslant 950$ GeV. As shown in [1], the maximum effect to the top-charm quark production rate (99% C.L.) is

$$\sigma_{tc}^{\max}=616\left(\frac{\text{TeV}}{\Lambda_{tcg}}\right)^2\text{fb}, \tag{5}$$

including some basic acceptance cuts. From the constraint on Λ_{tcg} discussed above, this implies $\sigma_{tc}^{\max}\leqslant$ about 0.6 pb. The relation between $b_{\min}$ and $\sigma_{tc}^{\max}$ is plotted in Fig. 2. At the

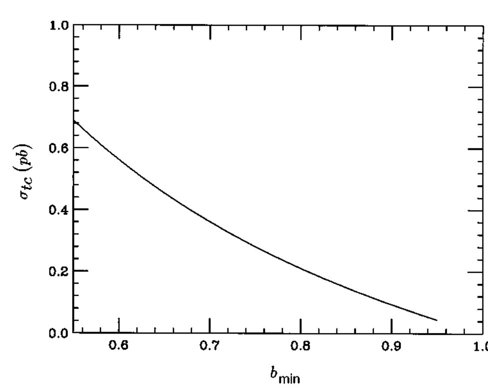

FIG. 2. The maximum cross section, $\sigma_{tc}^{\max}$ as a function of $b_{\min}$.

upgraded Tevatron (run II), the integrated luminosity is expected to be 2 fb^{-1} per year. As shown in [1], if no t-c signal events are observed in 2 fb^{-1} of integrated luminosity, this would imply $\Lambda_{tcg} \geqslant 4.5$ TeV, and from Fig. 1, this requires $b_{\mathrm{min}} = 96.3\%$ $[B(t \rightarrow cg) \leqslant 3.7\%]$.

The connection between $\sigma_{tc}^{\mathrm{max}}$ and b_{min} is interesting, because it gives a prediction of one quantity in terms of the other one. This can serve to help identify this type of new physics effect from other possible effects, and shows how a constraint derived from one process has implications for another one.

Recently detailed work has been done on studying the measurement of Λ_{tcg} from top quark decays, including kinematic cuts to optimize the signal-to-background ratio [4]. These results show studying top quark decays to be a promising way to constrain Λ_{tcg}, almost as promising as studying single-top-quark production for the current data sample, and possibly providing even stronger constraints at the upgraded Tevatron.

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