Fermi National Accelerator Laboratory

Single Top Production in $e\gamma$ Collisions *

Eran Yehudai
Theoretical Physics Group, M.S. #106
Fermi National Accelarator Laboratory
P.O. Box 500, Batavia, IL 60510

and

Stephen Godfrey and K. Andrew Peterson
Ottawa Carleton Institute for Physics,
Department of Physics, Carleton University,
Ottawa, Ontario CANADA K1S 5B6

ABSTRACT

We study single top production in high energy $e\gamma$ collisions. The process $e\gamma \to \nu b\bar{t}$ can serve as a unique tool for measuring the Wtb coupling. We show that allowing for realistic luminosity and backgrounds, the size of this coupling can be determined to within 10 (5)% in an $e\gamma$ collider built around a 500 (1000) GeV e^+e^- collider.

The top quark mass can be accurately determined in a high energy e^+e^- collider, using either continuum top decay or threshold top production.[1] The top width, however, is much more difficult to measure. In the Standard Model, this width is proportional to the Wtb coupling which, in turn, is proportional to the KM element $|V_{tb}|^2$. If $|V_{tb}|$ is found to be significantly less than 1, it could serve as evidence for mixing with a fourth generation of quarks.

It has been proposed[2] that the process $e\gamma \to b\bar{t}$ could be used to directly measure V_{tb}. The total cross section for the process is directly proportional to $|V_{tb}|^2$. In this work we examine this claim in detail, by considering realistic luminosity, cuts and backgrounds.

The Feynman diagrams contributing to the process $e^-\gamma \to \nu b\bar{t}$ are given in Fig. 1. The top quark is not observed directly. Rather, it decays into a W and a b. In looking for appropriate cuts and potential backgrounds, one has to take into account the correlation between the top production and subsequent decay. We chose to do that by including the top decay as part of the Feynman diagram. By appropriately selecting the W polarization vectors we included correlations with the subsequent $W \to q\bar{q}'$ decay.

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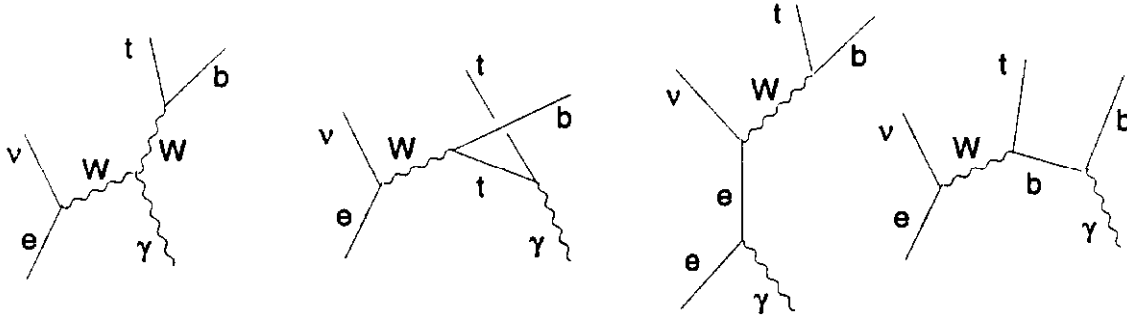
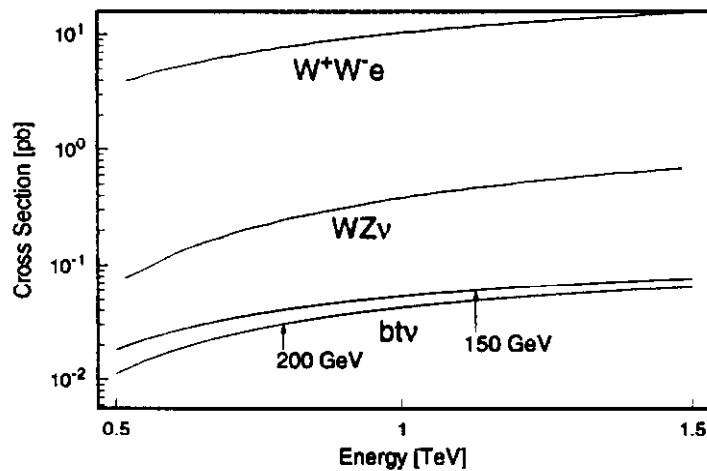Fig. 1. The Feynman diagrams contributing to the process $e\gamma \to \nu b\bar{t}$.

Fig. 2. Total cross section for $e\gamma \to \nu b\bar{t}$ and its important backgrounds.

An analytic formula for the differential cross section of $e\gamma \to \nu b\bar{t}$ is given in ref. 1. We have used this formula to check our results by integrating over top decay phase-space. The actual calculation was carried out using the Vector Equivalence Technique[3] and was checked using the helicity amplitude techniques of Hagiwara and Zeppenfeld.[4]

The major backgrounds we are concerned with are $e\gamma \to \nu W Z$ and $e\gamma \to e W^{+}W^{-}$. Fig. 2 shows the energy dependence of the total cross sections of the process $e\gamma \to W b\bar{t}$ and the various backgrounds.[5]

If the Z or one of the W bosons decays hadronically, its two jet decay products could look like the two jets coming from the b and $\bar{b}$. The most effective method of eliminating these backgrounds is by imposing a cut on the $b\bar{b}$ invariant mass $m_{b\bar{b}}$:

$$\min\left(|m_{b\bar{b}} - m_Z|, |m_{b\bar{b}} - m_W|\right) > 10 \text{GeV}. \tag{1}$$

A small number of hadronically decaying Ws or Zs could have a measured invariant

mass far enough from m_W or m_Z. A future study should address the question of whether those could still constitute a significant background.

In addition to cuts necessary to elliminate backgrounds, we also have to require that both the top decay products and the b jet are observed. We assume that no detection is possible less than $10°$ away from the beam pipe. Table 1 presents the effect of these cuts on the observed signal cross section. The numbers represent the signal reduction due to each cut separately, as well as the final cross section when all cuts are imposed. The number of events represents an integrated luminosity of 10fb^{-1} at 500 GeV and 40fb^{-1} at 1 TeV.

	$m_t = 150\text{GeV}$ $E_{cm} = 500\text{GeV}$		$m_t = 200\text{GeV}$ $E_{cm} = 1000\text{GeV}$	
	$\sigma[\text{fb}]$	Events	$\sigma[\text{fb}]$	Events
Uncut Total	18.1	180	42.4	1700
Visible Top Decay Products	17.0	170	38.8	155
$m_{b\bar{b}} < 70\text{GeV}$ or $m_{b\bar{b}} > 100\text{GeV}$	14.4	145	36.2	1450
b Jet Visible	11.1	110	22.0	880
All Cuts	8.8	90	17.4	700

Table 1. Cross Section of $e\gamma \to \nu b\bar{t}$ with the various cuts as described in the text.

It is possible to increase available event sample by relaxing the demand that the b jet is observable. The experimental signature in this case would consist of the decay products of a single top, and nothing else. While this seems like a very distinct signature, it precludes the possibility of using the $m_{b\bar{b}}$ cut to eliminate the backgrounds. Additional study is required to determine the cross section of relevant background in that case.

As demonstrated by the figures in Table 1, it seems that the total cross section for a single top production can be determined to within 20%. Since this cross section is proportional to $|V_{tb}|^2$, it follows that V_{tb} itself can be determined to within roughly 10%.

In the case of a 1 TeV collider, the cross section can be determined to within 10%, and V_{tb} to within 5%.

References

1. U. Stiegler, Report No. INFN-AE-91-09 (1991); K. Fujii, Report No. KEK-PREPRINT-92-6 (1992); Y. Sumino et al., Phys. Rev. **D47**, 56 (1992); K. Fujii, Report No. KEK-PREPRINT-92-159 (1992).
2. G. Jikia, Nucl. Phys. **B374** 83 (1992).
3. E. Yehudai, Report No. FERMILAB-PUB-92/256-T (1992).
4. K. Hagiwara and D. Zeppenfeld, Nucl. Phys. **B274** 1 (1986).
5. K. Cheung, Report No. NUHEP-TH-92-24 (1992).