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Search for single-top production in *ep* collisions at HERA

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Abstract

A search for single-top production, $ep \to etX$, has been made with the ZEUS detector at HERA using an integrated luminosity of 130.1 pb^{-1}. Events from both the leptonic and hadronic decay channels of the W boson resulting from the decay of the top quark were sought. Unlike the previously published results, the full simulation of the flavour-changing neutral current process, considering the anomalous tuZ (v_{tuZ}) and tuγ ($k_{tu\gamma}$) couplings both in the top production and decay, has been performed. The improved simulation allows the ZEUS exclusion limits to be substantially improved when large v_{tuZ} couplings are involved.

1 Introduction

The search for top-quark at HERA is motivated by the possibility that anomalous flavour-changing neutral current (FCNC) interactions substantially enhance the Standard Model (SM) expectation, resulting in a sizeable top-quark production.

Single top production can proceed via γ or Z exchange through the anomalous FCNC couplings $k_{tq\gamma}$ or v_{tqZ}, where q is a u- or a c-quark (fig. 1). At HERA, the sensitivity to couplings for the u-quark is much higher than that for the c-quark because of the smallness of the c-quark density in the proton. The present analysis assumes that only FCNC couplings involving u-quarks is different from zero.

The ZEUS experiment recently published [1] limits on the anomalous $tu\gamma$ coupling using positron-proton and electron-proton collisions, corresponding to an integrated luminosity of 130.1 pb^{-1}, at centre-of-mass energies, $\sqrt{s}$, of 300 and 318 GeV collected during the 1994-2000 running period. The results presented in this paper differ from the published results only in the use of an improved simulation of the Z-exchange process; the selection cuts and the data samples are the same. The new simulation allows the limits to be substantially improved at large v_{tuZ}.

2 Process description and Monte Carlo simulation

Deviations from the SM predictions due to FCNC transitions involving the top quark can be described by the following effective Lagrangian [2]

$$\Delta\mathcal{L}_{\text{eff}} = e\ e_t\ \bar{t}\ \frac{i\sigma_{\mu\nu}q^{\nu}}{\Lambda}\ \kappa_{tu\gamma}\ u\ A^{\mu} + \frac{g}{2\cos\theta_W}\ \bar{t}\ \gamma_{\mu}\ v_{tuZ}\ u\ Z^{\mu}\ + \text{h.c.}, \tag{1}$$

where e (e_t) is the electron (top-quark) electric charge, g is the weak coupling constant, θ_W is the weak mixing angle, $\sigma_{\mu\nu} = \frac{1}{2}(\gamma^{\mu}\gamma^{\nu} - \gamma^{\nu}\gamma^{\mu})$, Λ is an effective cutoff which, by convention, is set to the mass of the top quark, M_{top}, taken as 175 GeV, q is the momentum of the gauge boson and A^{μ} (Z^{μ}) is the photon (Z) field. In the following, it was assumed that the magnetic coupling $\kappa_{tu\gamma}$ and the vector coupling v_{tuZ} are real and positive. The values of $\kappa_{tu\gamma}$ and v_{tuZ} in the SM are zero at tree level and extremely small at the one-loop level.

The final states for the cases of $\gamma-$ and $Z-$exchange are quite different. For the former the polar angle distribution of the scattered electron is peaked towards the outgoing electron beam direction, while for the latter, the electron is in the detector acceptance in most of the cases. The interference term, being small, can be neglected.

In the previous publication, single top production was simulated using the HEXF generator [3]. This generator was designed to simulate excited fermion production at HERA but can be used also for single top production via γ-exchange, since the couplings involved in the two processes are of the same magnetic-type.

The present results use a full simulation of both γ- and Z-exchange processes performed in the COMPHEP [4] framework. The hard process $eu \to et$, simulated by COMPHEP, was used as input to PYTHIA6 [5] which provides proper treatment for the proton remnant, initial and final state QED and QCD radiation, hadronization and particle decays. Monte Carlo samples have been generated for the top decay channels $t \to bW$ and $t \to uZ$ while for the channel $t \to u\gamma$ a vanishing efficiency was assumed. Final results have been obtained using HEXF simulation for γ-exchange and COMPHEP for Z-exchange. It was checked that for γ-exchange HEXF and COMPHEP give consistent results. The interference between the two processes gives a contribution to the cross section of less than 1% in the whole range of the anomalous couplings considered in the analysis and was neglected.

3 Results

The search for single top production at HERA has been performed using both leptonic (electron or muon) and hadronic decay channels of the W or Z coming from a top decay. A detailed description of the data selection and of the detector components used in the analysis is reported in [1].

For the process mediated by a photon the selection efficiency in the leptonic channel is 7.1% (3.0%) for $t \to bW$ ($t \to uZ$) while for the hadronic channel it is 16.5% for $t \to bW$ and slightly higher for $t \to uZ$. The Z-exchange process was not simulated in [1] and the selection efficiency estimation was made using the conservative assumptions of vanishing efficiency for the hadronic channel and same efficiency as for the γ-exchange for the leptonic channel. The new simulation allows the evaluation of the efficiency for the Z-exchange process. In the leptonic channel it is 11.5% (10.6%) for $t \to bW$ ($t \to uZ$) while for the hadronic channel, it is much lower and is assumed to be vanishingly small. The reported efficiencies are for $\sqrt{s} = 318$ GeV and include the branching ratio of the W or Z in the considered decay channels; for $\sqrt{s} = 300$ GeV the efficiencies are very similar.

The derivation of the exclusion region in the $k_{tu\gamma} - v_{tuZ}$ plane was made using LO calculations for the process $ep \to etX$ obtained with the program COMPHEP (see [1] for details of the calculation). Corrections due to QED initial state radiation were taken into account using the Weiszacker-Williams approximation. Fig. 2 shows the 95% confidence level exclusion limits in the $\kappa_{tu\gamma} - v_{tuZ}$ plane obtained from this search, together with those from CDF [6] and L3 [8], which is the most stringent limit from LEP2 [7]. The limits have been obtained using a Bayesian approach as explained in [1].

It should also be noted that the Lagrangian used in the LEP analyses [7, 8] differs from that in Eq. (1) by a constant multiplicative factor such that $\kappa_{tu\gamma}^{\rm LEP} = \sqrt{2}\ \kappa_{tu\gamma}^{\rm ZEUS}$ and $v_{tuZ}^{\rm LEP} = \sqrt{2}\, v_{tuZ}^{\rm ZEUS}$. In Fig. 2, the limits from CDF and L3 are plotted using the Lagrangian convention of Eq. (1) and assuming $\kappa_{tc\gamma} = v_{tcZ} = 0$. The limit-setting procedure was repeated assuming $M_{\rm top} = 170$ and 180 GeV; the resulting exclusion regions are also shown in Fig. 2.

With respect to the previous ZEUS result, the full simulation of the single top production process allows a considerable improvement of the limits for large values of the anomalous vector coupling v_{tuz}.

4 Summary

A search fo single-top production via flavour-changing neutral current transitions has been made with the ZEUS detector at HERA in positron-proton and electron-proton collisions at centre-of-mass energies of 300 and 318 GeV using an integrated luminosity of 130.1 pb^{-1}. Present results are based on the previous ZEUS analysis reported in [1]. The improved simulation of the signal process allows a substantial improvement of the ZEUS limits when large values of the anomalous vector coupling v_{tuz} are involved.

References

[1] ZEUS Collaboration, S. Chekanov et al., Phys. Lett. B 559 (2003) 153 .

[2] T. Han and J.L. Hewett, Phys. Rev. D 60 (1999) 074015.

[3] H.J. Kim and S. Kartik, Preprint LSUHE-145-1993, 1993.

[4] A. Pukhov et al., Preprint INP-MSU-98-41-542, 1999. Also in hep-ph/9908288, 1999.

[5] M. Bengtsson and T. Sjöstrand, Comp. Phys. Comm. 46 (1987) 43.

[6] CDF Collaboration, F. Abe et al., Phys. Rev. Lett. 80 (1998) 2525.

[7] ALEPH Collaboration, R. Barate et al., Phys. Lett. B 494 (2000) 33;
ALEPH Collaboration, A. Heister et al., Phys. Lett. B 543 (2002) 173;
OPAL Collaboration, G. Abbiendi et al., Phys. Lett. B 521 (2001) 181.

[8] L3 Collaboration, P. Achard et al., Phys. Lett. B 549 (2002) 290.

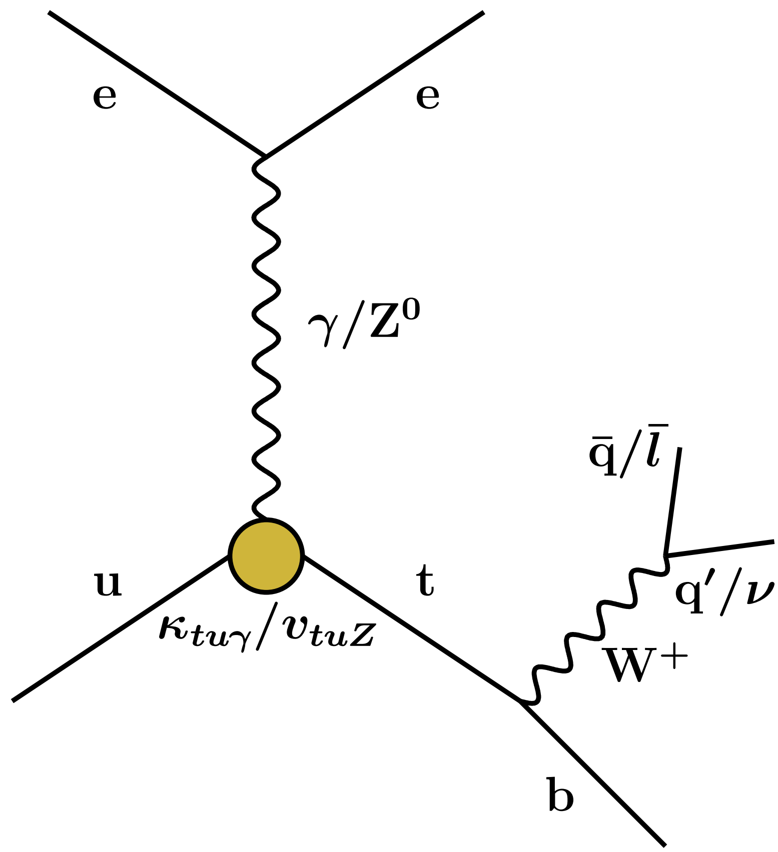

Figure 1: *Single-top production via flavour-changing neutral current transitions at HERA.*

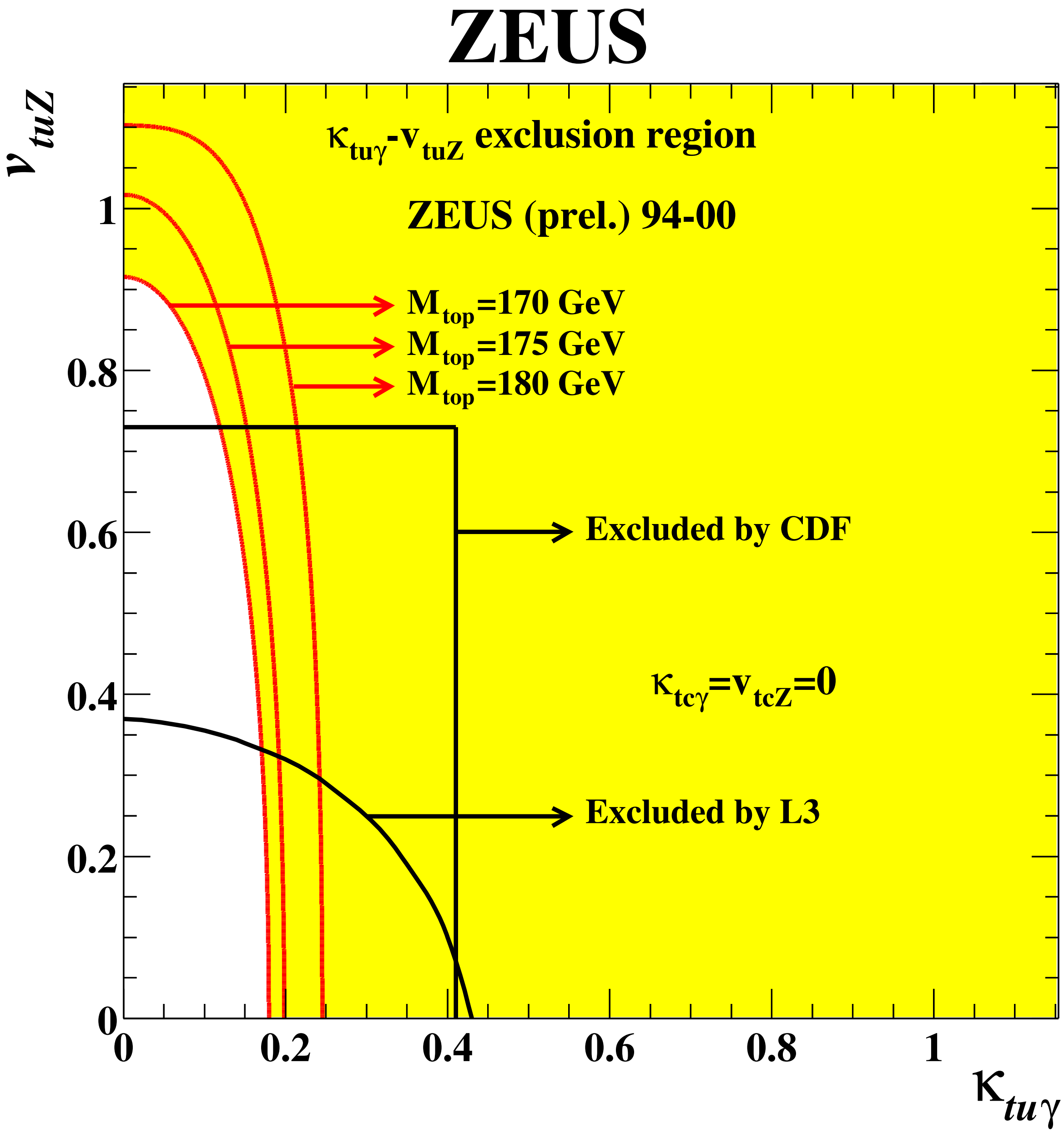

Figure 2: *Exclusion regions at 95% CL in the $\kappa_{tu\gamma} - v_{tuZ}$ plane for three values of $M_{\rm top}$ (170, 175 and 180 GeV) assuming $\kappa_{tc\gamma} = v_{tcZ} = 0$. The CDF and L3 exclusion limits are also shown.*