Search for Single-Top Production in ep Collisions at HERA

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Results of a recent search for single-top production in $e^\pm p$ collisions at HERA are presented. The search for single-top production, $e p \rightarrow e t X$, has been performed with the ZEUS detector at HERA collider using data corresponding to an integrated luminosity of 0.37 fb$^{-1}$. No evidence for top production was found, consistent with the expectation from the Standard Model. Limits were computed for single-top production via flavour changing neutral current transitions. The result was combined with a previous ZEUS result yielding a total luminosity of 0.50 fb$^{-1}$. A 95% Credibility Level upper limit of 0.13 pb was obtained for the cross section at the centre-of-mass energy of $\sqrt{s} = 315$ GeV.
1. Introduction

In ep collisions at HERA, the production of single-top quark is possible due to the large centre-of-mass energy \( \sqrt{s} = 318 \text{ GeV} \). The dominant production process of single top quarks in the Standard Model (SM) is the charged current (CC) deep inelastic scattering (DIS) reaction \( ep \to \nu tX \) \([1, 2]\) which has a cross section of less than 1 fb.

No sizeable production is hence expected in our data sample and any excess can be attributed to new physics. In several extensions of the SM \([3]\), single-top production can happen via a flavour changing neutral current (FCNC) process mediated by an effective coupling which allows a \( u-t \) or \( c-t \) transition via a neutral vector boson (\( \gamma \) or \( Z \)), see Fig. 1.

Owing to the large \( Z \) mass, this process is more sensitive to a coupling of the type \( t\gamma \). Furthermore, large values of \( x \), the fraction of the proton momentum carried by the struck quark, are needed to produce a top quark. Since the \( u \)-quark parton distribution function (PDF) of the proton is dominant at large \( x \), the production of single top quark is most sensitive to the \( tu\gamma \) coupling.

The analysis has been performed with 0.37 fb\(^{-1}\) and extends the previously published ZEUS results \([4]\) corresponding to 0.13 fb\(^{-1}\). Limits for single-top production via FCNC were computed combining this result with the previous ZEUS one \([4]\) for a total luminosity of 0.50 fb\(^{-1}\).

2. Event selection

The event selection was optimised for single-top production via photon exchange, looking for the dominant decay \( t \to bW^+ \) and subsequent W decay to \( e \) and \( \mu \) and their respective neutrinos. The selection is based on requiring an isolated high-\( p_T \) lepton, large missing transverse momentum and high hadronic \( p_T \).

The main preselection cuts were the following:

- \( p_T,\text{miss} > 10 \text{ (12) GeV} \) \( \mu-\text{(e-)} \) channel;
- lepton \( p_T > 8 \text{ (10) GeV} \) \( \mu-\text{(e-)} \) channel;
- transverse mass \( M_T > 10 \text{ GeV} \) \( e \)-channel only;

The main final cuts where the following:

- hadronic \( p_T > 40 \text{ GeV} \) for both channels;
- \( p_T,\text{miss} > 15 \text{ GeV} \) \( e \)-channel.

\(^1\)Here and in the following, \( e \) denotes both the electron and the positron.
Figure 2 shows the preselection plots in the muon (left) and electron (right) channels. Black dots are data, green area is MC and the dark-shaded region is the $W$ contribution; reasonable agreement is observed in all cases.

3. Systematic uncertainties

The main contribution to the systematical uncertainties on the predicted SM events is due to the following sources:

- the theoretical uncertainty on the $W$ background normalisation; ±15%;
- the statistical uncertainty on the total SM prediction after the final selection; ±13% and ±9% for the $e$- and $\mu$-channel respectively;
- the uncertainty on the NC DIS background; ±15% for the preselection and ±6% for the final selection in the $e$-channel and negligible in the $\mu$-channel.

4. Limits evaluation

Since no excess of events above the SM expectations is observed, a further selection is made to evaluate the limit on FCNC cross section under the assumption of no signals. The 95% Credibility Level (C.L.) limit on the cross section is found to be: $\sigma < 0.24$ pb at $\sqrt{s} = 318$ GeV. The limit on the cross section is converted into a limit on the coupling $\kappa_\gamma < 0.18$ (95% C.L.). This limit has been combined with a previous ZEUS result [4] giving the following constraints: $\sigma < 0.13$ pb and $\kappa_\gamma < 0.13$ (95% C.L.) [5]. Constraints on the anomalous top branching ratios $t \rightarrow u\gamma$ ($Br_{u\gamma}$) and $t \rightarrow uZ$ ($Br_{uZ}$) were also evaluated assuming a non-zero $v_Z$. Figure 3 shows the ZEUS boundary in the ($Br_{u\gamma}$, $Br_{uZ}$) plane compared to limits from H1 [6], ALEPH [7], CDF [8], D0 [9]. For low values of $v_Z$, resulting in branching ratios of $t \rightarrow uZ$ of less than 4%, this paper provides the current best limits.
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S. Antonelli

5. Conclusions

A search for possible deviations from the Standard Model predictions due to flavour-changing neutral current top production in events with high-\(p_T\) leptons and high missing transverse momentum was performed using an integrated luminosity of 0.37 fb\(^{-1}\), collected by the ZEUS detector in 2004-2007. Since no significant deviation from the expectation was observed, the results were used to set limits on the anomalous production of single top at HERA. A 95% C.L. upper limit on the cross section of \(\sigma < 0.24\) pb at a centre-of-mass energy of 318 GeV was obtained. The limit was combined with a previous ZEUS result [4], obtained using HERA I data, for a total integrated luminosity of 0.50 fb\(^{-1}\), giving a combined 95% credibility-level upper limit of \(\sigma < 0.13\) pb at \(\sqrt{s} = 315\) GeV. This limit, assuming a vanishing coupling of the top quark to the Z boson (\(v_Z\)), corresponds to a constraint on the coupling of the top to the \(\gamma\) of \(\kappa_\gamma < 0.13\). Constraints on the anomalous top branching ratios \(t \to u\gamma\) and \(t \to uZ\) were also evaluated assuming a non-zero \(v_Z\). For low values of \(v_Z\), resulting in branching ratios of \(t \to uZ\) of less than 4%, see Fig. 3, this paper provides the current best limits.

References