W and Anomalous Single Top Production at HERA

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The analysis of W production and the search for anomalous single top production is performed with the H1 detector at HERA with an integrated luminosity of 0.5 fb^{-1}, consisting of the complete high energy data from the HERA programme. Production cross section measurements of single W production, as well as W polarisation fractions in events containing isolated leptons and missing transverse momentum are also presented. In the context of a search for single top production an upper limit on the top production cross section $\sigma_{ep\to etX} < 0.16$ pb is established at the 95% confidence level, corresponding to an upper bound on the anomalous magnetic coupling $\kappa_{tu\gamma} < 0.14$.

1 Events with Isolated Leptons and P_T^{miss}

Events containing a high P_T isolated electron or muon and associated with missing transverse momentum have been observed at HERA [1, 2]. An excess of HERA I data events (1994–2000, mostly in e^+p collisions) compared to the SM prediction at large hadronic transverse momentum P_T^X was reported by the H1 Collaboration [2].

The main SM contribution is the production of real W bosons via photoproduction with subsequent leptonic decay $ep \to eW^{\pm}(\to l\nu)X$, where the hadronic system X is typically of low P_T.

The event selection employed by the H1 [4] analysis may be summarised as follows: The identified lepton should have high transverse momentum $P_T^l > 10$ GeV, be observed in the central region of the detector and be isolated with respect to jets and other tracks in the event. The event should also contain a large transverse momentum imbalance, $P_T^{miss} > 12$ GeV. Further cuts are then applied, which are designed to reduce SM background, whilst preserving a high level of signal purity.

The analysis has recently been performed on the electron and muon channels using the complete HERA I+II data sets, which corresponds to 478 pb^{-1} [4]. A total of 59 events are observed in the data, compared to a SM prediction of 58.9 ± 8.2. For

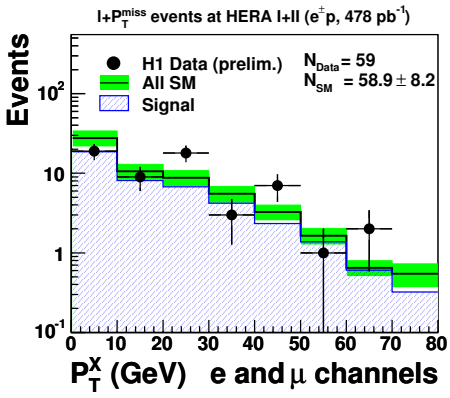

Figure 1: The P_T^X distribution of the data (points) compared to the SM expectation (open histogram). The signal component of the SM expectation is given by the hatched histogram. N_{Data} is the total number of data events observed, N_{SM} is the total SM expectation. The total error on the SM expectation is given by the shaded band.

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$P_T^X > 25$ GeV, a total of 24 events are observed compared to a SM prediction of 15.8 ± 2.5, of which 21 events are observed in the e^+p data compared to a SM prediction of 8.9 ± 1.5. The observed data excess in the HERA I e^+p data thus remains at the 3.0σ level for the complete H1 e^+p dataset. The results of the analysis are summarised in Table 1.

Figure 1 shows the P_T^X distribution of the $e^\pm p$ data for the combined electron and muon channels. The signal contribution, dominated by real W production, is seen to dominate the total SM expectation in all data samples. Overall there is good agreement with the SM expectation. A possible contribution from anomalous single top production would be expected to contribute at high P_T^X

2 Cross Sections and W Polarisation Fractions

The selection results described in section 1 are used to calculate production cross sections for events with an energetic isolated lepton and missing transverse momentum ($\sigma_{\ell+P_T^{miss}}$) and for single W boson production (σ_W), for which the branching ratio for leptonic W decay is taken into account [7]. The results are shown below with statistical (stat) and systematic (sys) uncertainties compared to the SM prediction, quoted with a theoretical systematic error (th.sys) of 15%.

H1	HERA I+II Data	SM
$\sigma_{\ell+P_T^{miss}}$	$0.24 \pm 0.05\,(\text{stat}) \pm 0.05\,(\text{sys})$	$0.26 \pm 0.04\,(\text{th.sys})$
σ_W	$1.23 \pm 0.25\,(\text{stat}) \pm 0.22\,(\text{sys})$	$1.31 \pm 0.20\,(\text{th.sys})$

A measurement of the W polarisation fractions is also performed since new physics may modify the SM polarisation fractions of Ws from single top decays [6] and is described in [7]. Additional selection criteria are applied to ensure good reconstruction of the W and the missing ν. Using a 2D fit, optimal values of the left-handed (F_-) and longitudinal (F_0) fractions are extracted, as shown in figure 2 (left) compared to the SM and a FCNC single top model [8]. The data are in agreement with the SM expectation albeit within large experimental uncertainties.

3 Search for Single Top Quark Production

The excess of events at high P_T^X may be interpreted in terms of anomalous single top production via flavour changing neutral currents with coupling $\kappa_{tu\gamma}$ between t and u quarks and the exchange photon. Such a search has been reported by H1 previously [9, 10].

In this analysis, decays of top quarks into a b quark and a W boson with subsequent decay of the W in the leptonic electron and muon channels are studied. Therefore a top preselection is applied by requiring good top mass reconstruction and a lepton charge compatible top production.

A multivariate analysis is then performed to discriminate top from SM background (dominated by real W production) using the transverse momentum of the reconstructed b quark candidate P_T^b, the reconstructed top mass $M_{\ell\nu b}$, and the W decay angle $\cos\theta_W^\ell$ calculated as the angle between the lepton momentum in the W rest frame and the W direction in the top quark rest frame. A multivariate discriminator is trained using ANOTOP [8] as the

signal model and EPVEC [11] as the background model. The discriminator is based on a phase space density estimator using a range search algorithm [12].

The observed data distributions of these quantities agree well with the SM expectation within the uncertainties. No evidence for single top production is observed. Using a maximum likelihood method an upper limit on the anomalous top production cross section of $\sigma_{ep\to etX} < 0.16$ pb is established at 95% CL. The corresponding H1 limit on the coupling $\kappa_{tu\gamma} < 0.14$ is shown in figure 2 (right) and is currently the best limit compared to those from other colliders [13, 14].

References

[1] C. Adloff *et al.* [H1 Collaboration] 1998 *Eur. Phys. J.* C **5** 575 (*Preprint* hep-ex/9806009)

[2] V. Andreev *et al.* [H1 Collaboration] 2003 *Phys. Lett.* B **561** 241 (*Preprint* hep-ex/0301030)

[3] S. Chekanov *et al.* [ZEUS Collaboration] 2003 *Phys. Lett.* B **559** 153 (*Preprint* hep-ex/0302010) —

[4] H1 Collaboration, contributed paper to *HEP-EPS 2007*, Manchester, abstract **228**, H1prelim-07-063

[5] H1 Collaboration, contributed paper to *HEP-EPS 2007*, Manchester, abstract **227**, H1prelim-07-064

[6] K. Hagiwara, R. D. Peccei, D. Zeppenfeld and K. Hikasa *Nucl. Phys.*B **282**1987253.

[7] H1 Collaboration, contributed paper to *HEP-EPS 2007*, Manchester, abstract **775**, H1prelim-07-161

[8] E. Perez, unpublished.

[9] A. Aktas *et al.* [H1 Collaboration] 2004 *Eur. Phys. J.* C **33** 9 (*Preprint* hep-ex/0310032)

[10] H1 Collaboration, contributed paper to *HEP-EPS 2007*, Manchester, abstract **776**, H1prelim-07-163

[11] U. Baur, J. A. Vermaseren and D. Zeppenfeld, *Nucl. Phys.*B**375** 1992 3.

[12] A. Höcker *et al.* TMVA Users Manual, [physics/0703039v4].

[13] P. Achard *et al.* [L3 Collaboration] 2002 *Phys. Lett.* B **549** 290 (*Preprint* hep-ex/0210041)

[14] CDF Collaboration, CDF Public Note 9202, 2008

[15] CDF Collaboration, CDF Public Note 8888, 2007; Amnon Harel, *et al.*

H1 Preliminary l+$P_T^{\rm miss}$ events at HERA I+II		Electron obs./exp. (Signal contribution)	Muon obs./exp. (Signal contribution)	Combined obs./exp. (Signal contribution)
e^+p	Full Sample	26 / 27.3 ± 3.8 (71%)	15 / 7.2 ± 1.1 (85%)	41 / 34.5 ± 4.8 (74%)
294 pb^{-1}	$P_T^X > 25$ GeV	11 / 4.7 ± 0.9 (75%)	10 / 4.2 ± 0.7 (85%)	21 / 8.9 ± 1.5 (80%)
e^-p	Full Sample	16 / 19.4 ± 2.7 (65%)	2 / 5.1 ± 0.7 (78%)	18 / 24.4 ± 3.4 (68%)
184 pb^{-1}	$P_T^X > 25$ GeV	3 / 3.8 ± 0.6 (61%)	0 / 3.1 ± 0.5 (74%)	3 / 6.9 ± 1.0 (67%)
$e^\pm p$	Full Sample	42 / 46.7 ± 6.5 (69%)	17 / 12.2 ± 1.8 (82%)	59 / 58.9 ± 8.2 (72%)
478 pb^{-1}	$P_T^X > 25$ GeV	14 / 8.5 ± 1.5 (68%)	10 / 7.3 ± 1.2 (79%)	24 / 15.8 ± 2.5 (73%)

Table 1: Summary of the H1 results of searches for events with isolated electrons or muons and missing transverse momentum for the e^+p data (294 pb^{-1}), e^-p data (184 pb^{-1}) and the full HERA I+II data set (478 pb^{-1}). The results are shown for the full selected sample and for the subsample at large $P_T^X > 25$ GeV. The number of observed events is compared to the SM prediction. The signal component of the SM expectation, dominated by real W production, is given as a percentage in parentheses. The quoted errors contain statistical and systematic uncertainties added in quadrature.

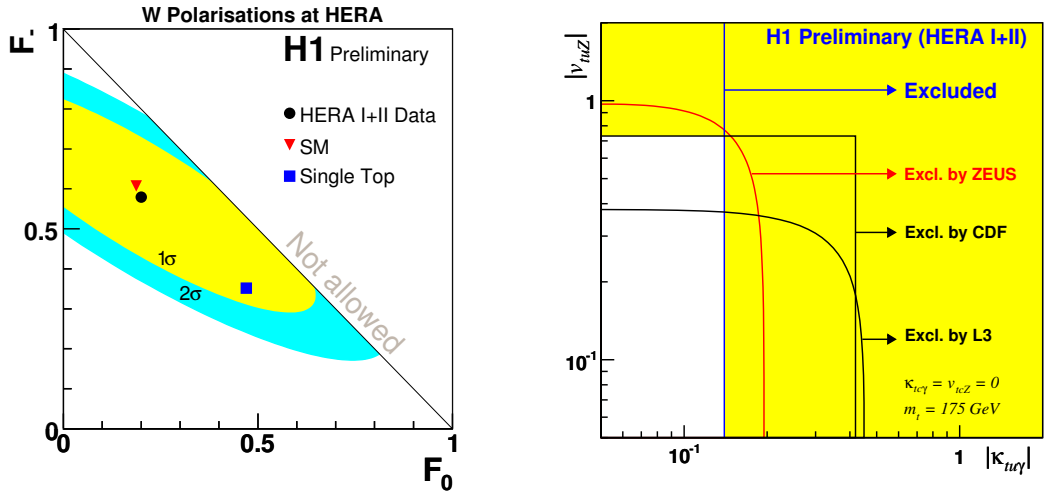

Figure 2: Left: The fit result for the simultaneously extracted left handed (F_-) and longitudinal (F_0) W boson polarisation fractions (point) at 1 and 2σ CL (contours). Also shown are the values for the SM prediction (triangle) and anomalous single top production via FCNC (square). Right: Exclusion limits at the 95% CL in the search for single top production on the anomalous $\kappa_{tu\gamma}$ and v_{tuZ} couplings obtained at LEP (L3 experiment [13]), the TeVatron (CDF experiment [14], the result shown is from [15]), and HERA (H1 [10] and ZEUS [3] experiments). Anomalous couplings of the charm quark are neglected $\kappa_{tc\gamma} = v_{tcZ} = 0$. Limits are shown assuming a top mass $m_t = 175$ GeV.