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ISOLATED LEPTONS, *W* AND SINGLE TOP AT HERA*

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Standard Model W production in ep collisions is characterised by a high p_{T} isolated lepton and missing overall p_{T} in the leptonic decay channel and three high p_{T} jets in the hadronic decay channel. These topologies are also the final state of single top production via a FCNC $\kappa_{tu\gamma}$ vertex. Results of searches for these topologies are presented and consequent upper limits on the $\kappa_{tu\gamma}$ coupling are derived.

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1. Introduction

Each of the HERA ep collision experiments have now collected over 100 pb^{-1} of data, at centre of mass energies in excess of 300 GeV. This gives access to the production of rare heavy particles, such as the W boson (within known Standard Model (SM) processes) or the top quark t (via a Flavour Changing Neutral Current (FCNC) vertex), as illustrated in figure 1. Both processes have the same final state topology — an isolated high p_{T} lepton with missing overall p_{T} for the leptonic decay channel of the W, and three high p_{T} jets for the hadronic decay channel of the W. In the case of t production, the jet originating from the beauty quark b will have particularly large p_{T}.

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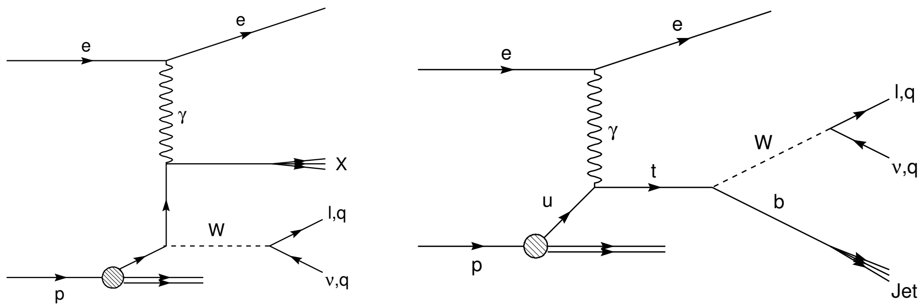

(a) (b)

Fig. 1. (a) SM W production and (b) single top via FCNC $k_{tu\gamma}$ vertex.

2. Isolated leptons from SM *W* production

W production with subsequent leptonic decay is the only known SM process which can produce a final state topology contain an isolated high $p_{\rm T}$ lepton, overall missing $p_{\rm T}$ and a hadronic jet. However, other Standard Model processes may produce a similar signal in the detector through measurement fluctuations. Given that at leading order (LO) the Standard Model predicts a W production cross section in ep collisions of only ≈ 1 pb, careful selection criteria must be employed to isolate this process. The predominant backgrounds are Neutral Current processes where missing $p_{\rm T}$ arises from a measurement fluctuation, Charged Current processes where a particle in the current jet is mis-identified as an isolated lepton, or inelastic lepton pair production where one lepton is not identified and a measurement fluctuation produces significant missing $p_{\rm T}$.

The selection criteria used by each experiment are detailed more fully in [1, 2] and [3]. However, both experiments base their selection on cuts on the measured calorimetric $p_{\rm T}$, the polar angle and $p_{\rm T}$ of the isolated lepton, the acoplanarity[1] of the event, and the distance of the isolated track from the nearest other track or jet.

3. Results

ZEUS observe event rates in good agreement with the SM expectation. H1 observe more events than expected, intriguingly at high $p_{\rm T}^{X}$ (see figure 2).

H1 observe no events in the low luminosity (13.6 pb^{-1}) $e^{-}p$ data sample in agreement with 1.46 ± 0.30 (e) and 0.32 ± 0.09 (μ) expected.

[1] The angle by which the isolated lepton-jet system differs from a back-to-back configuration.

ZEUS preliminary 1994-2000	Electrons Obs'd / expected (W)	Muons Obs'd / expected (W)
e^+p 114 pb^{-1}	7 / 9.9 ± 1.6 (2.4)	7 / 4.6 ± 0.6 (1.1)
e^-p 16 pb^{-1}	3 / 1.1 ± 0.4 (0.3)	0 / 0.8 ± 0.1 (0.2)
Total 130 pb^{-1}	10 / 11.0 ± 1.6 (2.7)	7 / 5.4 ± 0.7 (1.3)

ZEUS preliminary 1994-2000 $e^{\pm}p$	Electrons Obs'd / expected (W)	Muons Obs'd / expected (W)
$p_{\mathrm{T}}^{X} > 25$ GeV	1 / 1.14 ± 0.06 (1.10)	1 / 1.29 ± 0.16 (0.95)
$p_{\mathrm{T}}^{X} > 40$ GeV	0 / 0.46 ± 0.03 (0.46)	0 / 0.50 ± 0.08 (0.41)

Electron and Muon events	H1 Prel. e^+p Data	SM expectation	W	Other SM processes
$p_{\mathrm{T}}^{X} > 0$ GeV	18	10.48 ± 2.53	8.19 ± 2.46	2.29 ± 0.59
$p_{\mathrm{T}}^{X} > 12$ GeV	13	5.14 ± 1.31	4.22 ± 1.27	0.92 ± 0.33
$p_{\mathrm{T}}^{X} > 25$ GeV	10	2.82 ± 0.73	2.34 ± 0.70	0.48 ± 0.18
$p_{\mathrm{T}}^{X} > 40$ GeV	6	0.99 ± 0.28	0.93 ± 0.28	0.06 ± 0.04

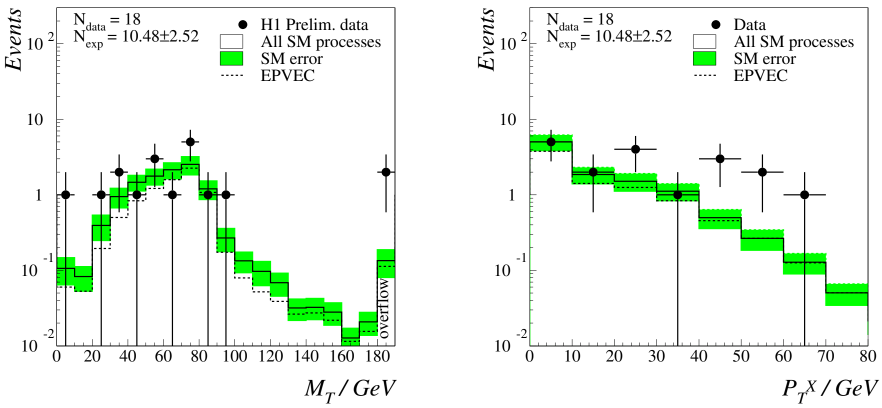

Fig. 2. The H1 events as a function of transverse mass and p_{T}^{X}.

4. Standard Model *W* production at NLO

At leading order (LO) in QCD, SM W production is dominated by diagrams such as that shown in figure 1(a). However at Next-to-Leading Order (NLO), virtual (loop) and real (radiative) corrections must be considered. Much of this work is now complete [4]. The calculation splits the phase space into a photo-production and DIS part. Only the QCD corrections to the (smaller) DIS part remain unknown. The NLO corrections to the LO cross section are of the order of 30% at low p_{T} and of the order of 10% at high p_{T}. Significantly, the NLO corrections are shown to greatly reduce the factorisation scale dependency. This is illustrated in figure 3. These results are yet to be included in the results of Section 3, yet lend confidence to the SM prediction, and they do not significantly affect the data/SM comparison.

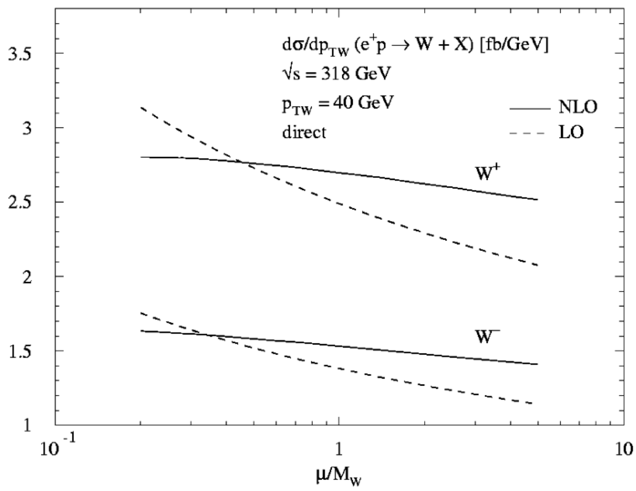

Fig. 3. The factorisation scale dependence of LO and NLO calculations [4].

5. Single top production

Both H1 and ZEUS have searched for evidence for single top production in both the hadronic and leptonic decay channels. The leptonic decay of a singly produced top quark has the same final state as W production. Furthermore, the decay of the heavy b quark will result in a hadronic jet with high transverse momentum (high p_{T}^{X}). Seeing no candidate events with this topology (see Section 3), ZEUS correspondingly set an upper limit (at 95% C.L.) for the coupling at the FCNC vertex of $k_{tu\gamma} < 0.257$ (leptonic decays only). H1 refine their sample requiring $p_{\mathrm{T}}^{\mathrm{Jet}} > 25$ GeV, $M_{\mathrm{T}}^{l\nu} > 10$ GeV and only positively charged leptons. This selects 3 (2) events in the electron (muon) channel compared with a SM expectation of 0.75 ± 0.18 (0.77 ± 0.21). This corresponds to $k_{tu\gamma} < 0.32$.

In the hadronic decay channel of a single top quark, 3 high energy jets are expected. ZEUS (H1) require the jets to have 40, 25 and 14 (20) GeV respectively. The reconstructed mass of two of the jets is required to be compatible with the W mass, and that of all three jets to be compatible with the top mass. H1 also cut on the angle between the W decay jets.

In this way H1 (ZEUS) select 14 (19) events compared to an expectation of 19.6 ± 7.8 (20.0) expected. Finally, these rates combined with those in the leptonic decay channel, give upper limits (95% C.L.) on $k_{tu\gamma}$ of 0.22 for H1 and 0.19 for ZEUS. These results are shown in figure 4, where the vertical scale represents the FCNC coupling at a tuZ vertex to which the HERA experiments have no sensitivity. The limit for H1 from leptonic decays alone is also illustrated, indicating the effect of the observed isolated lepton events by H1.

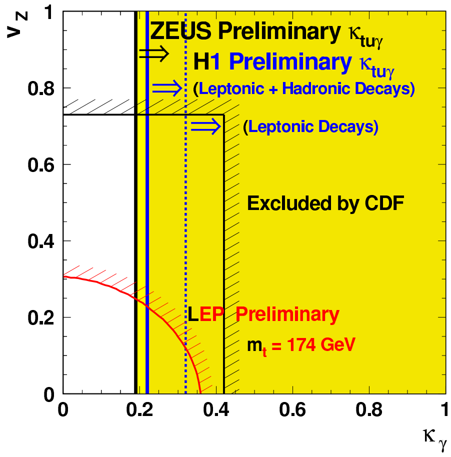

Fig. 4. Exclusion limits for FCNC couplings from H1, ZEUS, CDF and LEP.

6. Conclusion

The HERA ep collision experiments have both compared the predictions of the SM for real W production with their observations. Whilst these predictions agree well with ZEUS's observations, H1 observe notably more events in the leptonic decay channel, particularly at higher p_{T}^X. Recent extensions of the SM prediction to NLO are well controlled and confirm this discrepancy. Identification of such events as single top production allows upper limits to be set on the FCNC coupling $k_{tu\gamma}$.

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