Isolated leptons in events with missing transverse momentum and the search for single top production

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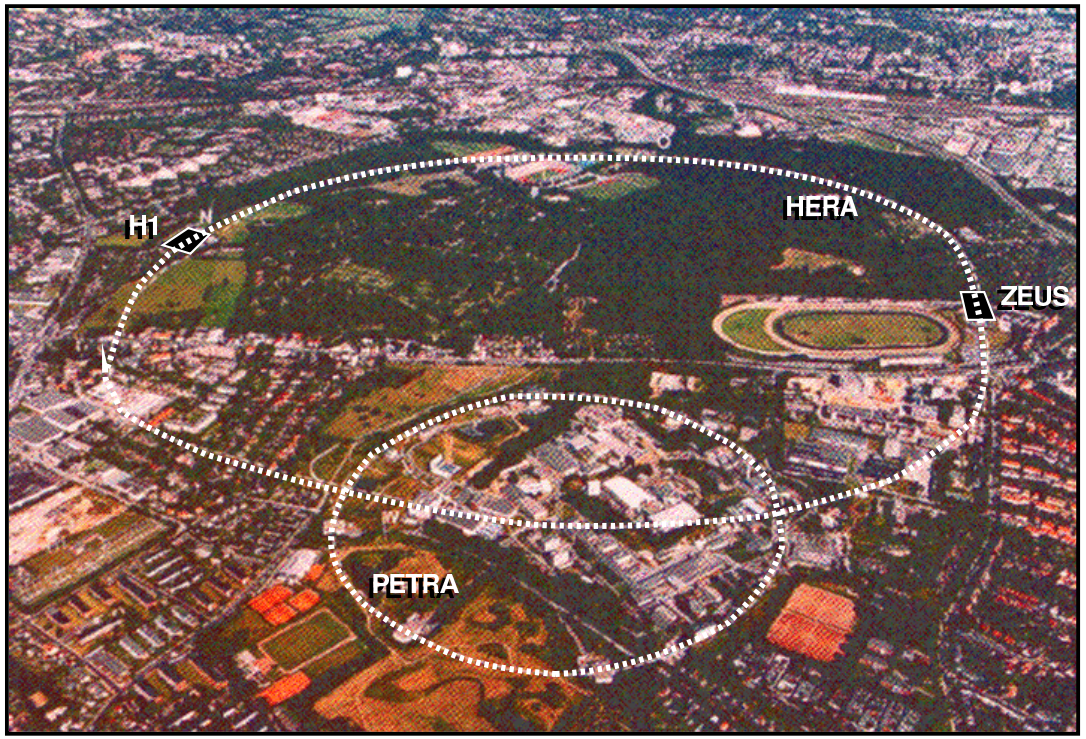
on behalf of the ZEUS and H1 collaborations

University of Glasgow

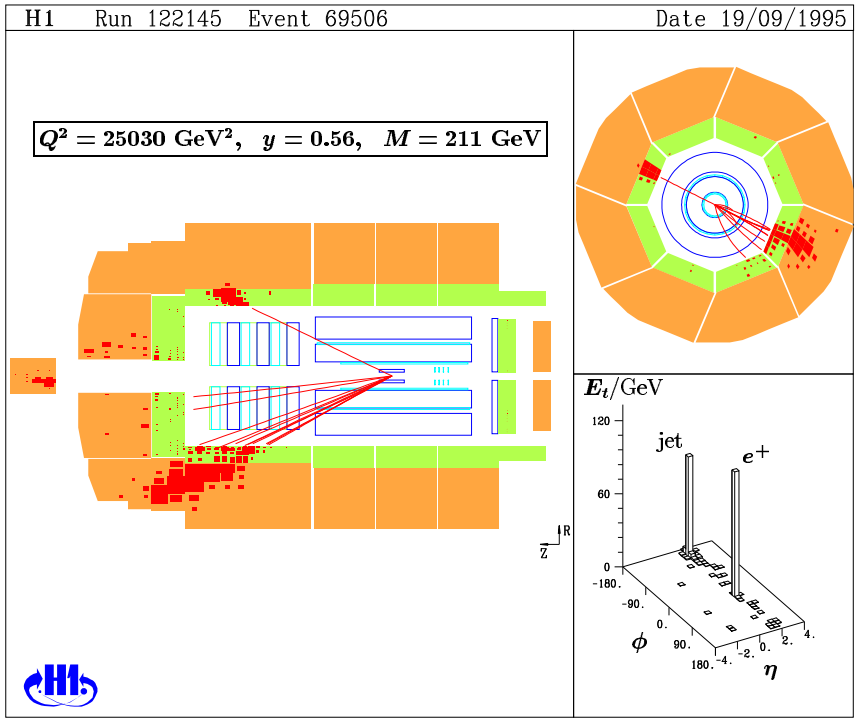
- **HERA**
- **ZEUS and H1**
- **Isolated Leptons**
- **Single Top Production**
- **Outlook**

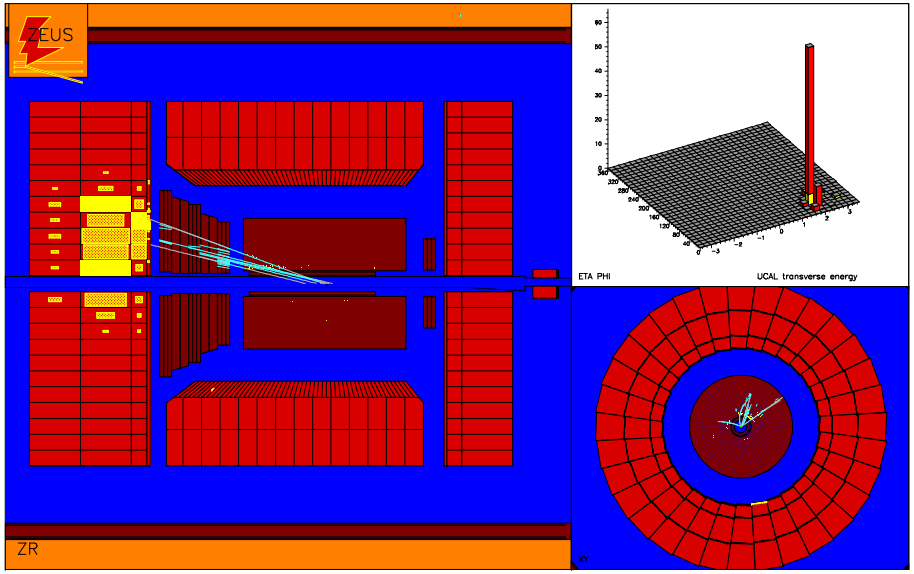
HERA : The Hadron-Electron Ring Accelerator



- **HERA collides $e^{\pm}$ (27.5 GeV) and protons (920 GeV) at $\sqrt{s} \approx 318$ GeV**
- **2 colliding beam experiments ZEUS + H1**
- **Also the fixed target experiment HERMES studies nucleon spin structure**
- **HERA underwent a luminosity upgrade 2000-2002**

H1 and ZEUS





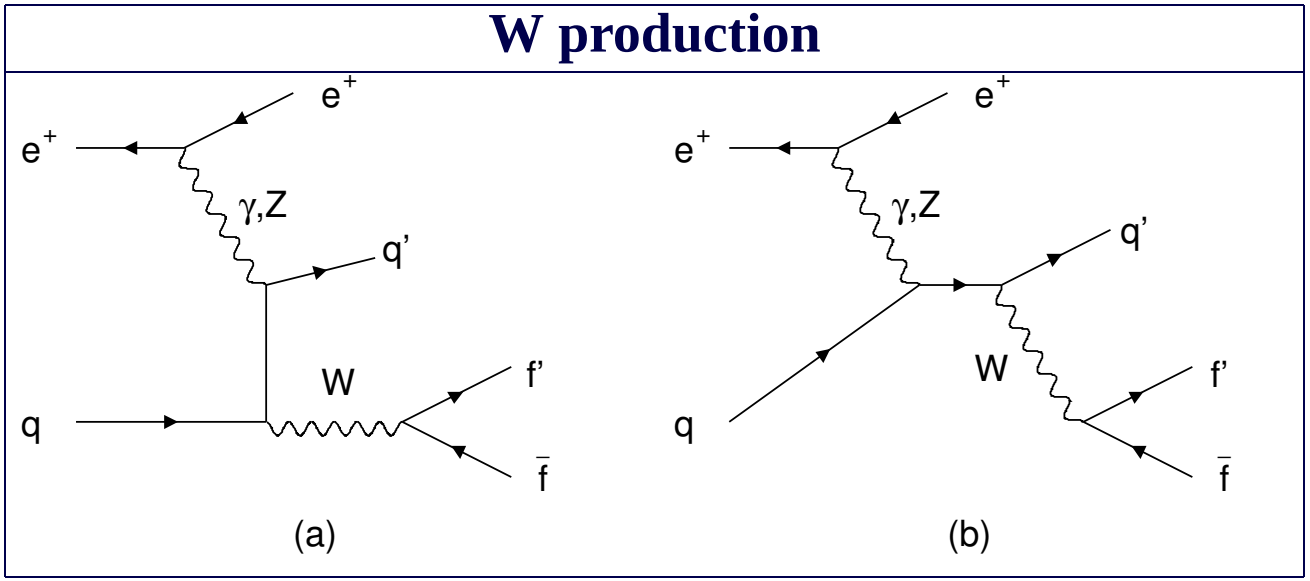
H1

- Liquid Argon Calorimeter
- Optimised for precision measurement of the scattered lepton

ZEUS

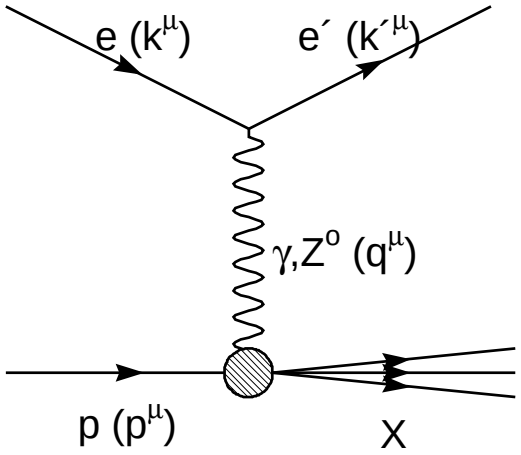
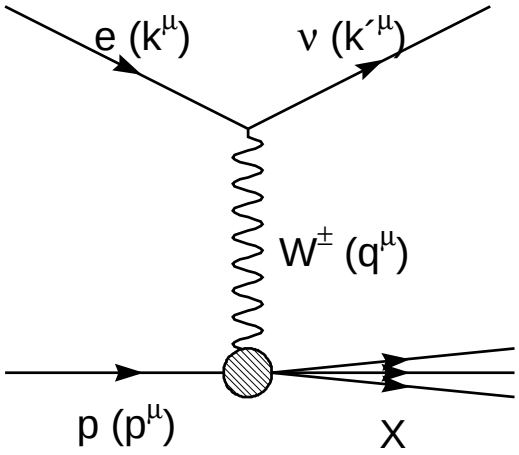
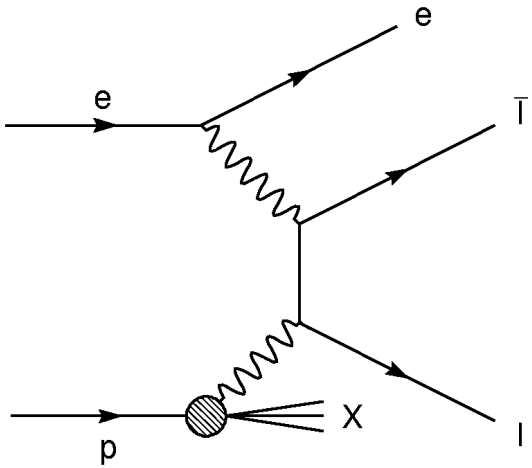
- Depleted Uranium Calorimeter
- Optimised for precision measurement of the hadronic final state

Isolated leptons with missing transverse momentum



- **The main physics source of isolated leptons in events with missing transverse momentum at HERA is single W production**
- **Total LO SM cross section ≈ 1.1 pb (318 GeV)**
- **SM Background arises mainly from badly reconstructed:**
  - **Neutral and Charged Current DIS**
  - **Dilepton production**

SM backgrounds to W production

NC DIS	CC DIS	Dilepton production
		
Genuine electron and fake P_T^{miss} due to mismeasurement	**misidentified lepton and genuine P_T^{miss}**	**Genuine μ and fake P_T^{miss} due to mismeasurement**

Searches for Isolated leptons in HERA I Data

1994-2000 $e^{\pm}p$		Electron obs./exp. ($W^{\pm}$ contribution)	Muon obs./exp. ($W^{\pm}$ contribution)
H1 118.4 pb^{-1}	Full sample	**11** / 11.54 $\pm$ 1.50 (71%)	**8** / 2.94 $\pm$ 0.50 (86%)
	$p_T^X > 25\,\mathrm{GeV}$	**5** / 1.76 $\pm$ 0.30 (82%)	**6** / 1.68 $\pm$ 0.30 (88%)
	$p_T^X > 40\,\mathrm{GeV}$	**3** / 0.66 $\pm$ 0.13 (80%)	**3** / 0.64 $\pm$ 0.14 (92%)

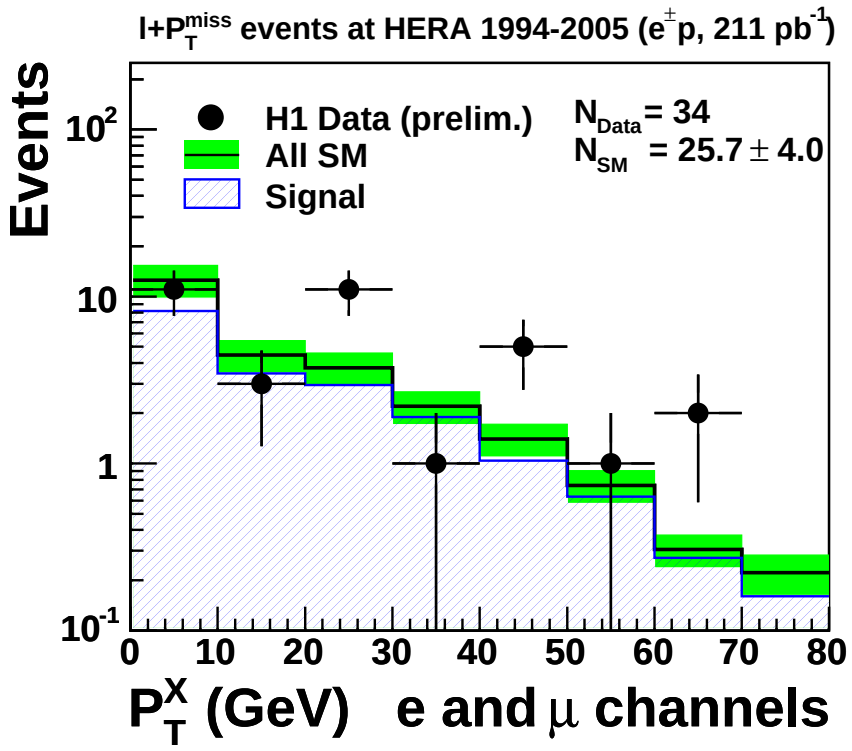
- **In searches for isolated leptons in HERA I data H1 observed an excess over the standard model predictions in both electron and muon channels**
- **Excess was not confirmed by ZEUS in similar analyses**
- **In the Tau channel ZEUS observed 2/0.2 $\pm$ 0.05 (45 %) events at $P_T^X > 25\,\mathrm{GeV}$**
- **This talk presents:**
  - **An update to the H1 search with twice the luminosity (abstract 637)**
  - **An H1 search for isolated tau particles (abstract 624)**
  - **A new search for isolated electrons by ZEUS, closer to the H1 selection (abstract 327)**

Isolated Lepton Searches Selection

	H1	**ZEUS**
Lepton within detector acceptance	$5^\circ < \theta < 140^\circ$	$\theta < 115^\circ$
High Transverse Momentum of Lepton	$p_T^l > 10\,\mathrm{GeV}$	$p_T^l > 10\,\mathrm{GeV}$
Lepton Isolation	$D_{\mathrm{track}} > 0.5$ $D_{\mathrm{jet}} > 1.0$	$D_{\mathrm{track}} > 0.5$ **implicit**
Large Missing Transverse Momentum	$P_T^{\mathrm{miss}} > 12\,\mathrm{GeV}$	$P_T^{\mathrm{miss}} > 12\,\mathrm{GeV}$
Acoplanarity	$e : \phi_{\mathrm{acop}} > 20^\circ$ $\mu : \phi_{\mathrm{acop}} > 10^\circ$	$e : \phi_{\mathrm{acop}} > 17^\circ$

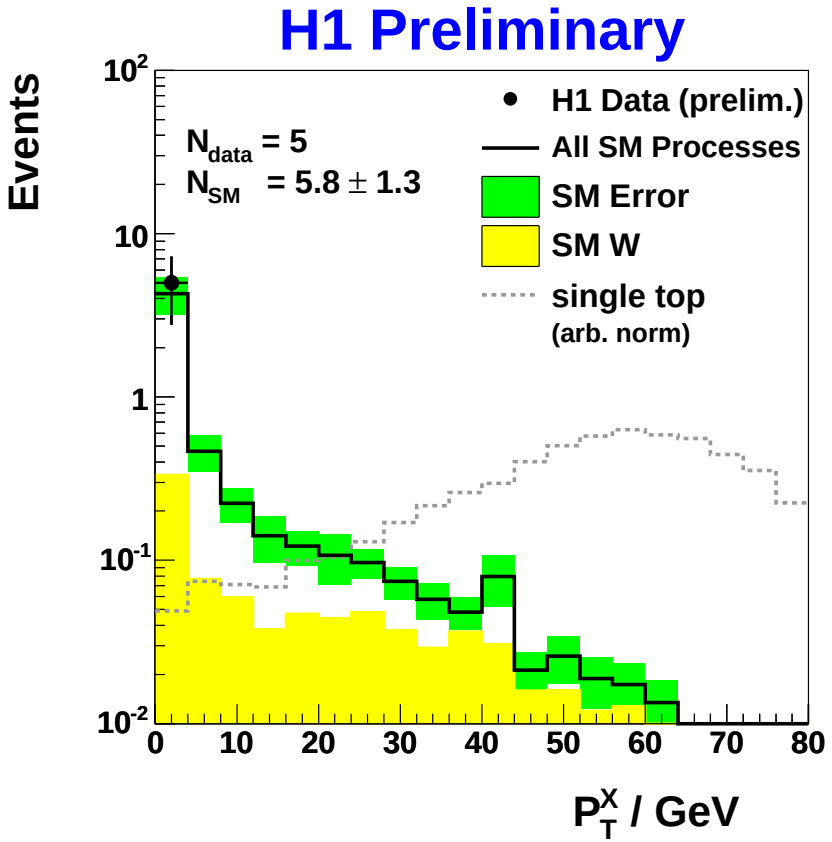
	H1 τ
τ-jet within detector acceptance	$20^\circ < \theta < 120^\circ$
High Transverse Momentum of Lepton	$p_T^{\mathrm{jet}} > 7\,\mathrm{GeV}$
One Prong Decay	$R_{jet} < 0.12$ **1 matching track**
Lepton Isolation	$D_{\mathrm{track,jet}} > 1.0$
Large Missing Transverse Momentum	$P_T^{\mathrm{miss}} > 12\,\mathrm{GeV}$
Acoplanarity	$\phi_{\mathrm{acop}} > 10^\circ$

H1 Isolated Lepton Search Results I



- **Excess at high P_T^X suggestive of heavy body decay**
- **Purity of e, μ search much higher than τ search**

- **Combined e, μ data show a clear excess over SM at high values of P_T^X**
- **Excess is not observed in τ search**



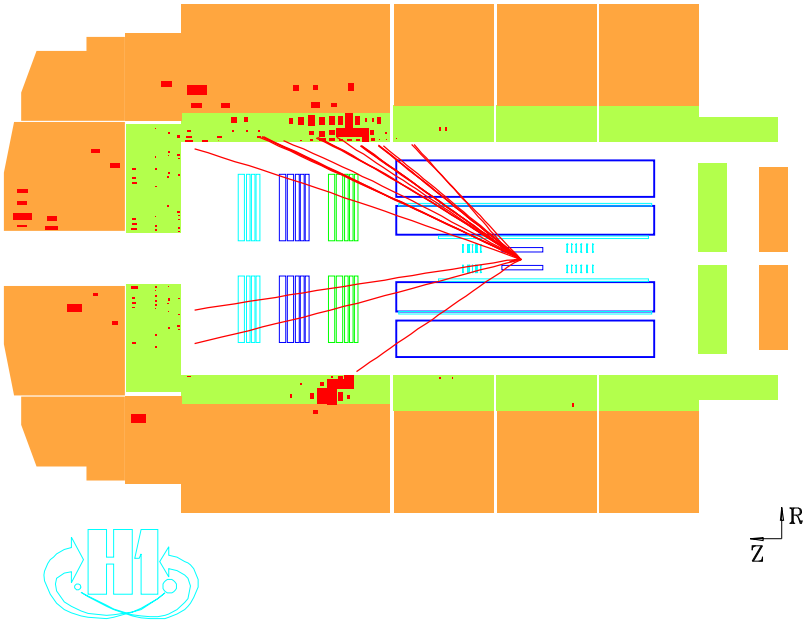
H1 Isolated Lepton Search Results II

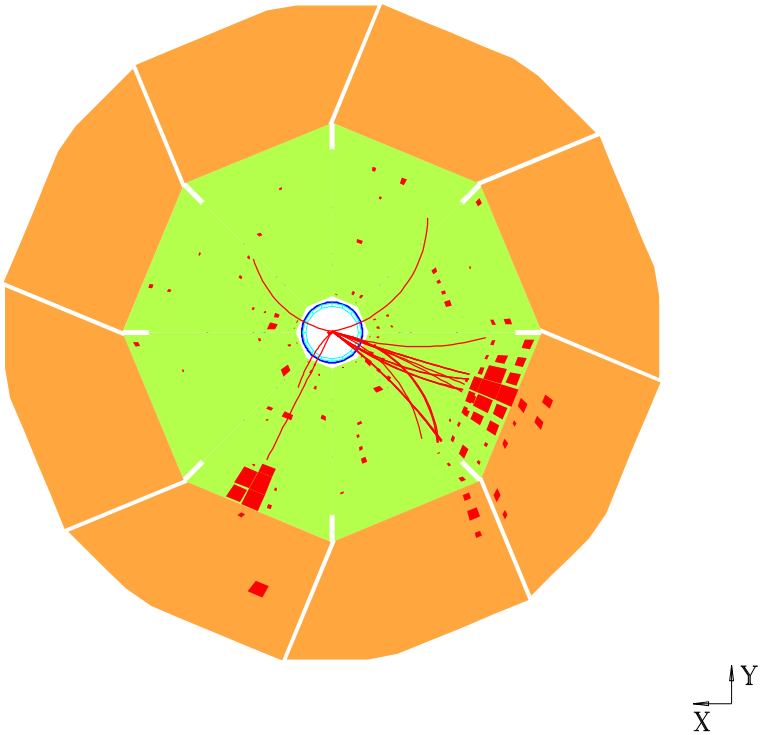
H1 Preliminary		Electron obs./exp.	Muon obs./exp.
1994-2004 e^+p 158 pb^{-1}	**Full sample**	**19** / 14.6 $\pm$ 2.0	**9** / 3.9 $\pm$ 0.6
	$p_T^X > 25$ **GeV**	**9** / 2.3 $\pm$ 0.4	**6** / 2.3 $\pm$ 0.4
1998-2005 e^-p 53 pb^{-1}	**Full sample**	**6** / 5.8 $\pm$ 0.9	**0** / 1.5 $\pm$ 0.5
	$p_T^X > 25$ **GeV**	**2** / 0.9 $\pm$ 0.2	**0** / 0.9 $\pm$ 0.2
1994-2005 $e^\pm p$ 211 pb^{-1}	**Full sample**	**25** / 20.4 $\pm$ 2.9	**9** / 5.4 $\pm$ 1.1
	$p_T^X > 25$ **GeV**	**11** / 3.2 $\pm$ 0.6	**6** / 3.2 $\pm$ 0.5

H1 Preliminary		Tau obs./exp.
1996-2000 e^+p 108 pb^{-1}	**Full sample**	**5** / 5.81 $\pm$ 1.36
	$p_T^X > 25$ **GeV**	**0** / 0.53 $\pm$ 0.10

- e **excess persists in HERA II** e^+p **data, no excess in** e^-p
- μ **excess comes only from HERA I** e^+p **data, no excess in** e^-p
- **Still a clear combined** e, μ **excess 17/6.4 .** τ **excess seen by ZEUS not confirmed**

Example High P_T^X Isolated Electron Candidate





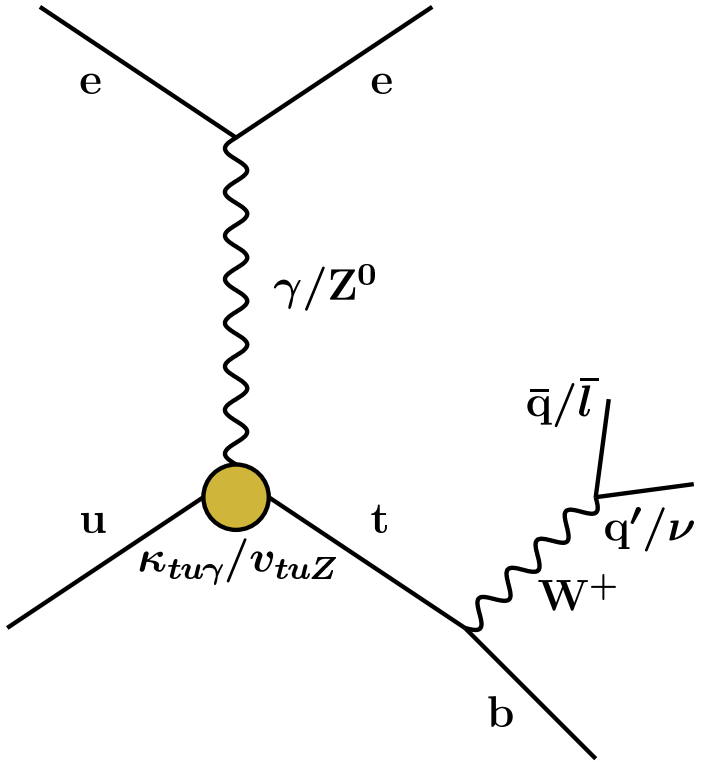
- **Well Isolated Electron**
- **Large hadronic activity not back-to-back with electron**

ZEUS Isolated Electron Search Results

Isolated e candidates	$12 < P_T^X < 25$ **GeV**	$P_T^X > 25$ **GeV**
ZEUS (prel.) 99-00 e^+p (66 pb^{-1})	**1**/$1.04 \pm 0.11(57\%)$	**1**/$0.92 \pm 0.09(79\%)$
ZEUS (prel.) 03-04 e^+p (40 pb^{-1})	**0**/$0.46 \pm 0.10(64\%)$	**0**/$0.58^{+0.08}_{-0.09}(76\%)$
H1 1994-2000 e^+p (104.7 pb^{-1})	**1**/$1.96 \pm 0.27(74\%)$	**4**/$1.48 \pm 0.25(86\%)$
H1 (prel.) 1994-2005 $e^\pm p$ (211 pb^{-1})	-	**11**/$3.2 \pm 0.6(77\%)$

- **Purity and expectations of ZEUS search similar to H1 at $P_T^X > 25$ GeV**
- **ZEUS 1/**1.5 **at $P_T^X > 25$ GeV (** 106 pb^{-1}**)**
- **ZEUS results in good agreement with the standard model**
- **Excess seen by H1 is not confirmed**

Single Top Production



- **Single Top Production (STP) via FCNC as a Standard Model Process:**
  - **Not a tree level SM process**
  - **Small σ (GIM mechanism): $\sigma < 1$ fb**
- **Events at HERA attributed to STP must be from anomalous couplings**

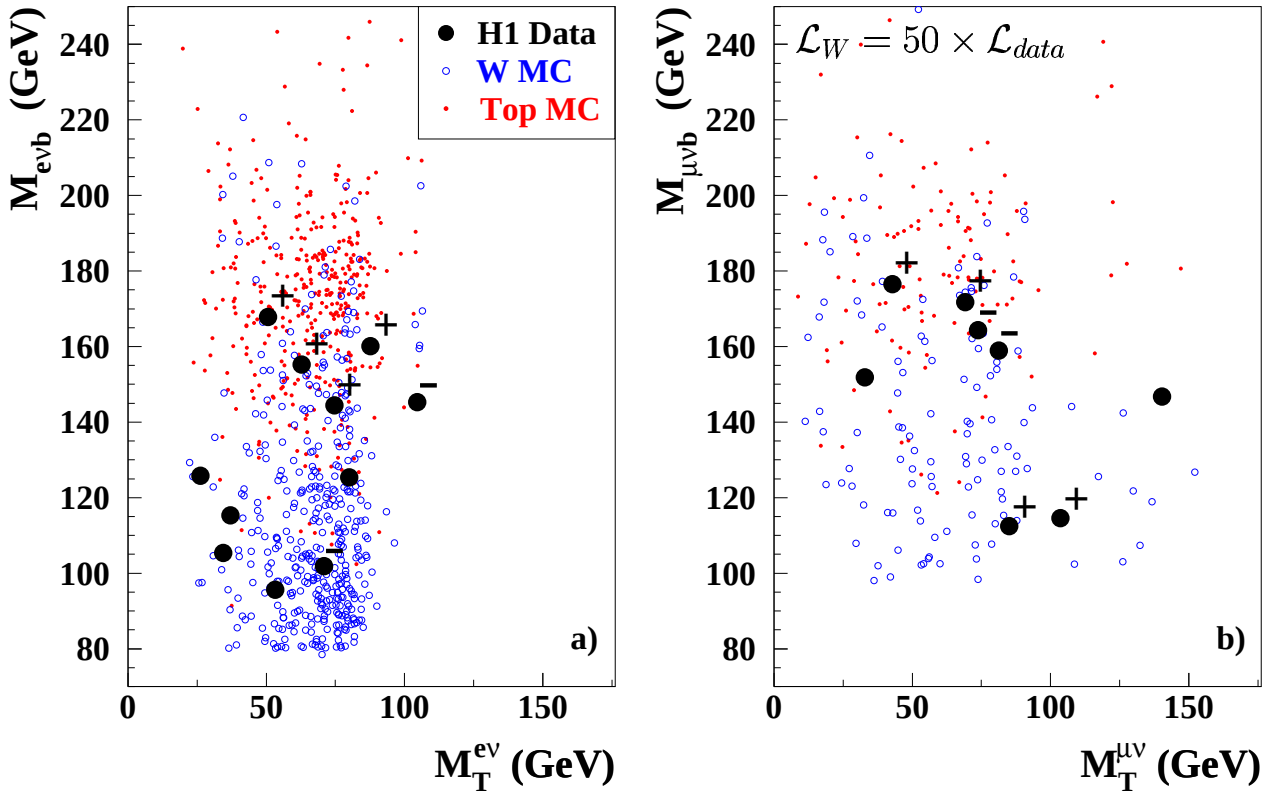
- **Single Top Production via Anomalous FCNC:**

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

Single Top Signature

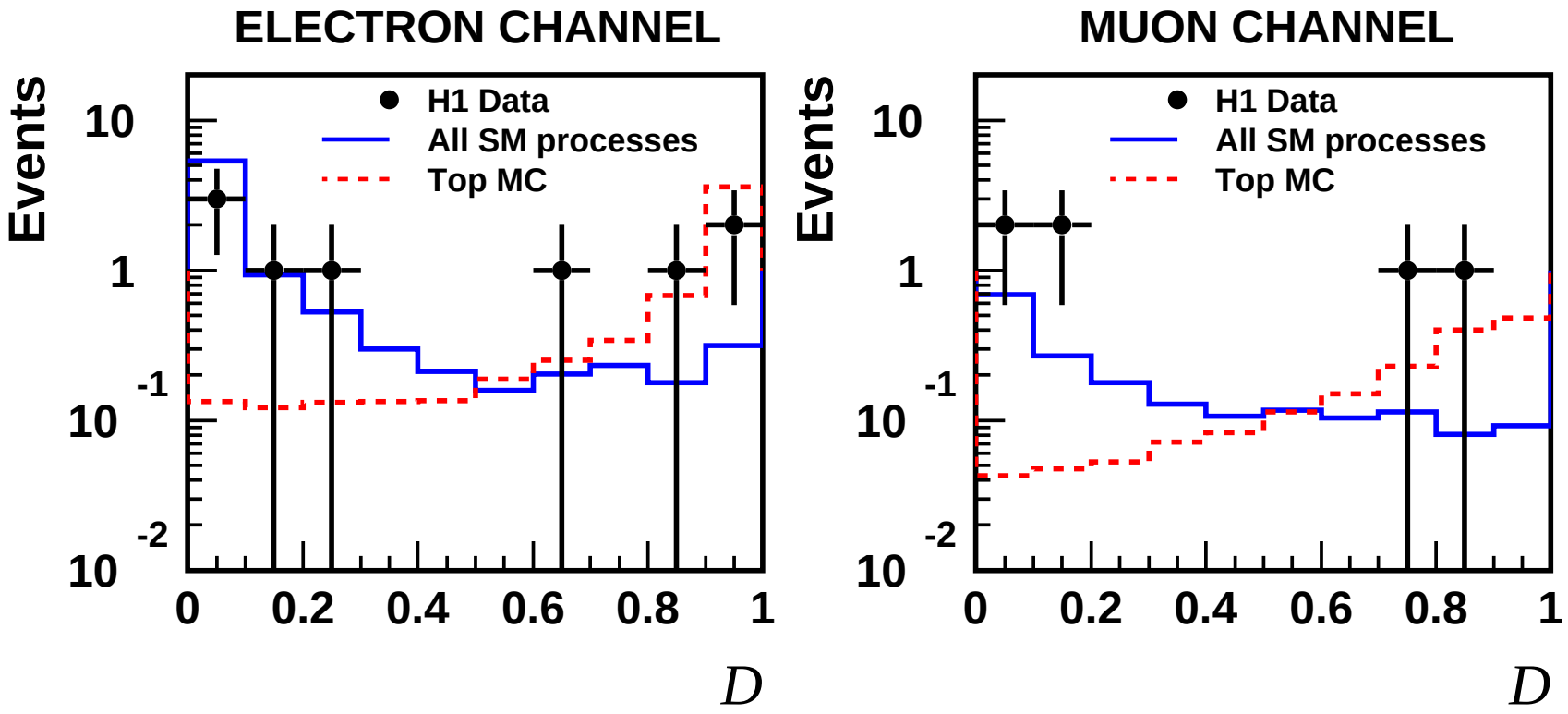
- **Signature of Single Top Production:**
  - **Isolated high p_T lepton in events with large missing transverse momentum)**
  - **Or 3 high E_T jets with , $M_{3j} \approx M_{\rm top}$, One pair with $M_{jj} \approx M_W$**
- **In leptonic channels main backgrounds are 2γ processes (μ), NC DIS and Single W Production**
- **In hadronic channel, main background is QCD**
- **H1 have performed searches in hadronic and leptonic decay channels using 118 $\rm pb^{-1}$ of data (abstract 607)**

H1 Single Top Production Search: I



- **b reconstructed from sum of all jets in event**
- **W mass constraint applied** $M_{l\nu} \approx= \sqrt{2 P_l p_\nu} \approx= M_W$

H1 Single Top Production Search: II

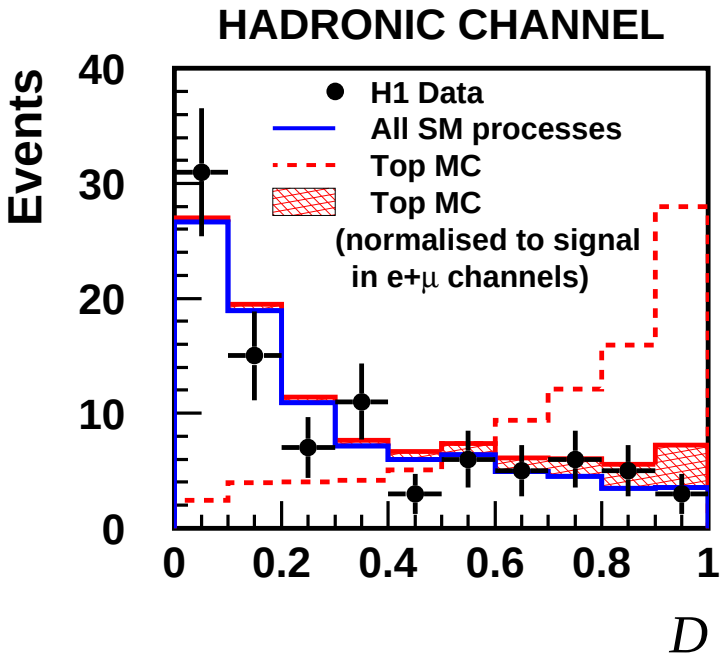


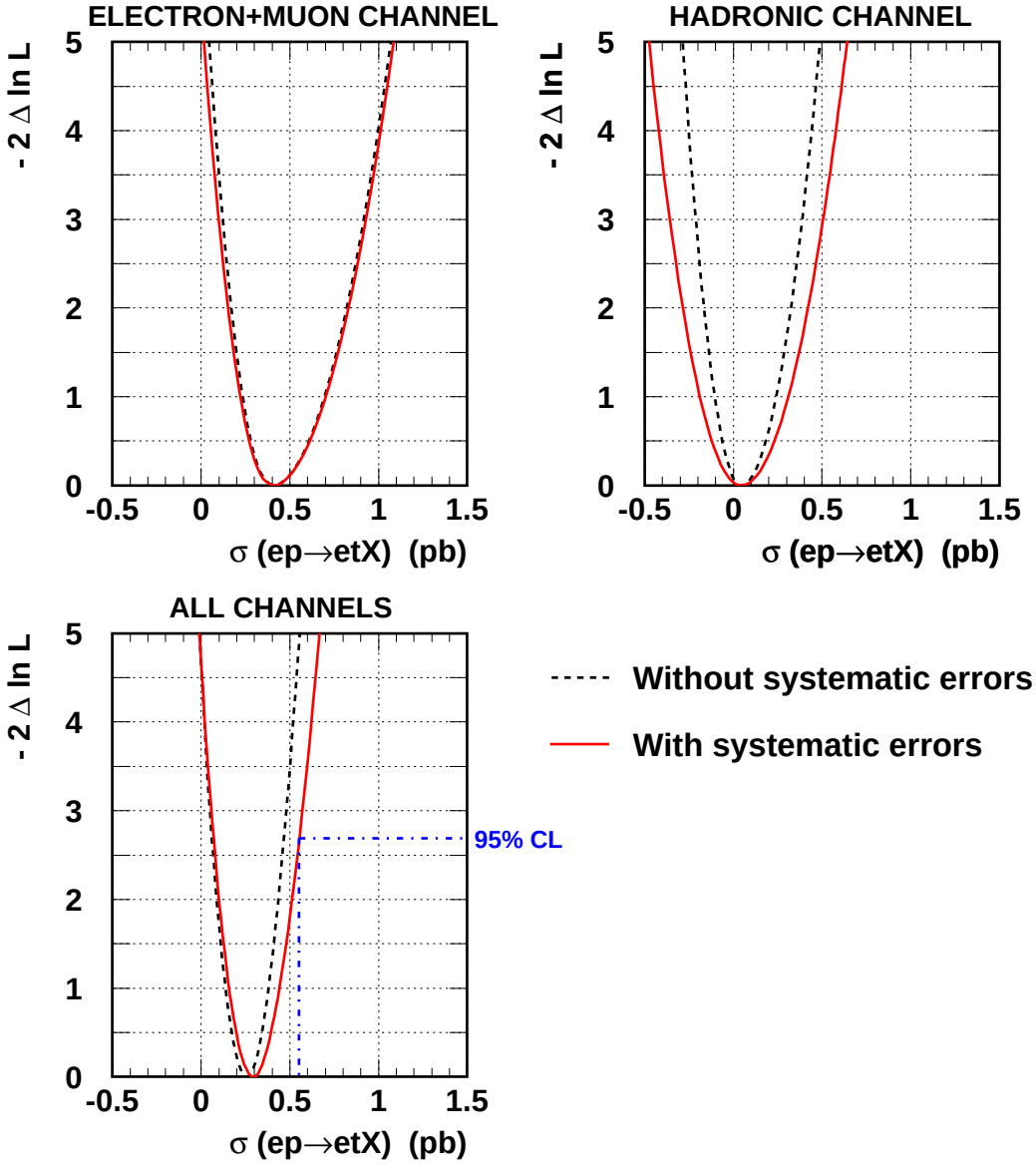
- **A multivariate likelihood analysis is used, based on the discriminator function:**

$$D(V) = \frac{\mathcal{P}^{\mathrm{sig}}}{\mathcal{P}^{\mathrm{sig}} + \mathcal{P}^{\mathrm{bkg}}}, \mathcal{P} = C(V)\Pi_i p_i$$

- **Discriminator is constructed from P_T^b, $M_{l\nu b}$ and the decay angle of the W relative to its momentum ($\cos\theta_W$)**

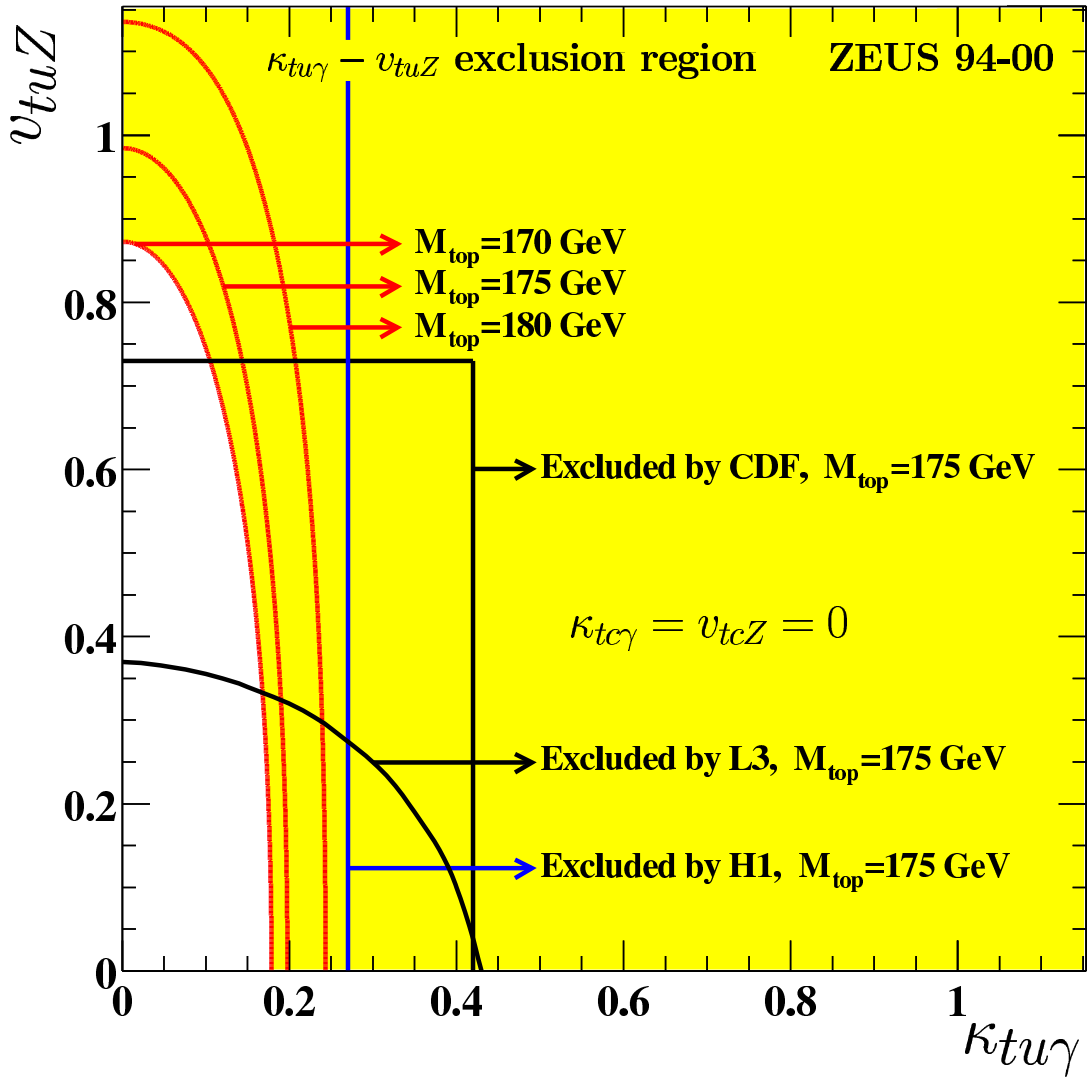
H1 Single Top Production Search: III





- **Preselection** $E_T^{\text{jet1}} > 40$ **GeV,** $E_T^{\text{jet2}} > 30$ **GeV,** $E_T^{\text{jet3}} > 15$ **GeV,** $E_{\text{tot}} > 110$ **GeV.** $65 < M_{jj} < 95$ **GeV for any two jets**
- **Discriminator constructed from** P_T^b**,** M_{jets} **and** $\cos\theta_W$

Exclusion limits for FCNC



Limits do not exclude interpretation of isolated lepton events as resulting from decays of top quarks produced via FCNC

Summary and Outlook

- **H1 continues to observe an excess of High P_T leptons in events with large missing total P_T**
- **This excess is not confirmed by ZEUS**
- **H1 does not confirm excess in the tau decay channel observed by ZEUS.**
- **The HERA experiments are able to set strong limits on the anomalous FCNC coupling constant $\kappa_{ut\gamma}$**
- **HERA experiments are taking more data at a faster rate than ever before, the new data will help us resolve this mystery**