

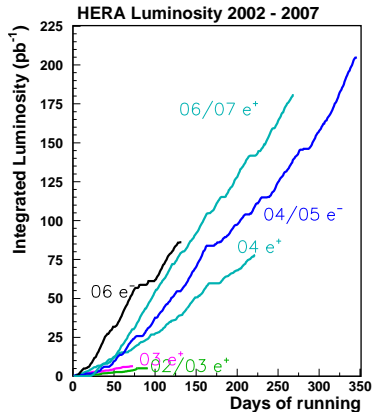
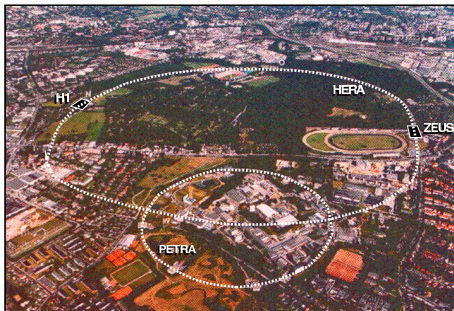
# Events with Isolated Leptons and Missing Transverse Momentum at HERA

J. Ferrando

University of Oxford  
On behalf of the H1 and ZEUS collaborations

DIS2008 April 9<sup>th</sup>, 2008





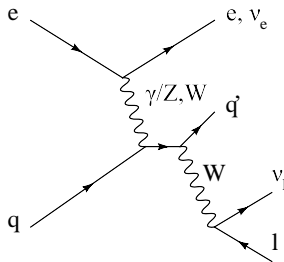
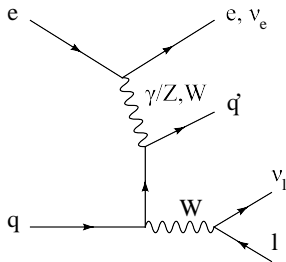
- HERA collided  $e^\pm$  (27.5 GeV) and protons (820,920,460,575 GeV) at largest  $\sqrt{s} \approx 318$  GeV
- $\sim 0.5 \text{ fb}^{-1}$  per experiment



# Isolated Lepton Production

Introduction  
Searches  
Summary

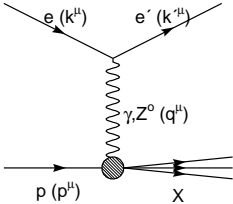
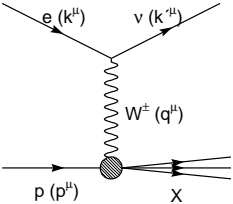
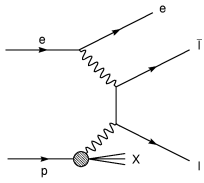
HERA  
Isolated Leptons  
Backgrounds  
Example  $e$  Event  
Example  $\mu$  Event  
History



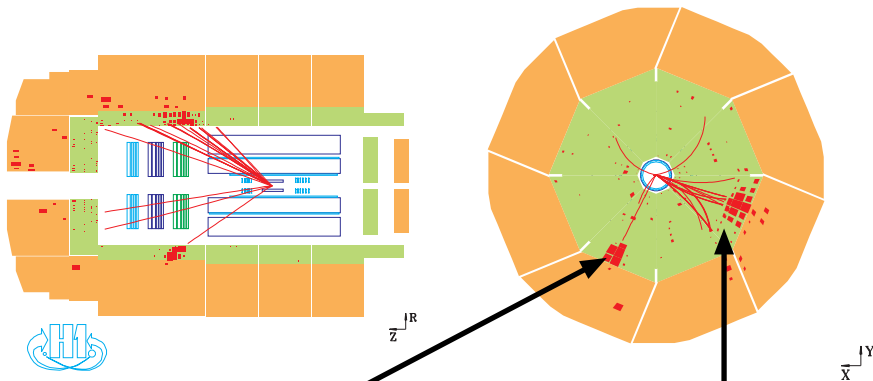
Main SM physics source of isolated leptons in events with missing transverse momentum at HERA is single  $W$  production ( $\sigma \approx 1.3\text{pb}$ ) via  $\gamma p$

- Modelled using **EPVEC** generator
- **NLO QCD corrections** applied leaving theoretical error  $\sim 15\%$
- Hadronic system typically has low transverse momentum ( $P_T^X$ )



NC DIS	CC DIS	Dilepton production
		
Genuine electron and fake $P_T^{\text{miss}}$ due to mismeasurement	misidentified lepton and genuine $P_T^{\text{miss}}$	Genuine $\mu$ and fake $P_T^{\text{miss}}$ due to mismeasurement
$\sigma \approx 8000 \text{ pb}$	$\sigma \approx 40 \text{ pb}$	$\sigma \approx 30 \text{ pb}$

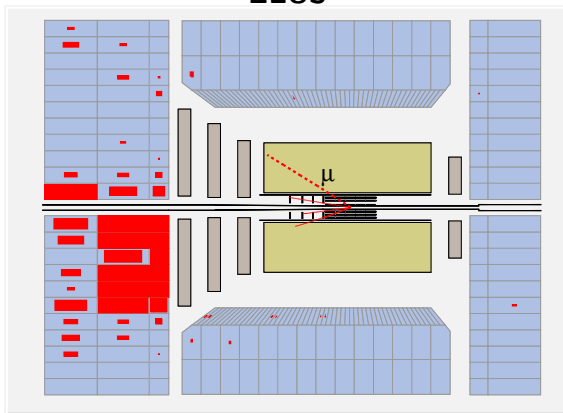




- Well isolated electron
- Large hadronic activity not back-to-back with electron



## ZEUS



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%)
	$p_T^X > 25\text{GeV}$	5 / 1.76 $\pm$ 0.30 (82%)	6 / 1.68 $\pm$ 0.30 (88%)
	$p_T^X > 40\text{GeV}$	3 / 0.66 $\pm$ 0.13 (80%)	3 / 0.64 $\pm$ 0.14 (92%)

- In isolated lepton Searches in HERA I data H1 observed an excess over the SM 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  $P_T^X > 25\text{ GeV}$



In this talk I present recent results on Isolated lepton Searches:

- H1 Isolated ( $e, \mu$ ) searches with full HERA luminosity  
([H1prelim-07-063](#))
- ZEUS Isolated ( $e, \mu$ ) searches with full HERA luminosity  
([ZEUS-prel-07-021](#))
- Combined H1+ZEUS Isolated Lepton ( $e, \mu$ ) searches  
([H1prelim-07-162/ZEUS-prel-07-029](#))
- H1 Isolated  $\tau$  results ([H1prelim-07-064](#))

Related but covered by other talks at DIS2008:

- H1 Single  $W$  production results
- Single top Production at HERA
- Lepton flavour violation





Variable	Electron	Muon
$\theta_l$	<b><math>5^\circ &lt; \theta_l &lt; 140^\circ</math> (H1), <math>15^\circ &lt; \theta_l &lt; 120^\circ</math> (ZEUS and COMMON)</b>	
$P_T^l$	$> 10$ GeV	
$P_T^{\text{calo}}$	$> 12$ GeV	
$P_T^{\text{miss}}$	$> 12$ GeV	
$P_T^X$	-	$> 12$ GeV
$D_{\text{jet}}$	$> 1.0$	
$D_{\text{track}}$	$> 0.5$ for $\theta_e \geq 45^\circ$	$> 0.5$
$\xi_1^2$	$> 5000 \text{ GeV}^2$ for $P_T^{\text{calo}} < 25 \text{ GeV}$	-
$V_{\text{sp}}/V_p$	$< 0.5$ ( $< 0.15$ for $P_T^e < 25 \text{ GeV}$ )	$< 0.5$ ( $< 0.15$ for $P_T^{\text{calo}} < 25 \text{ GeV}$ )
$\Delta\phi_{l-X}$	$< 160^\circ$	$< 170^\circ$
$\delta_{\text{miss}}$	$> 5 \text{ GeV}$	-
# isolated $\mu$	0	1

} Analysis phase space selection.  
H1: extended polar angle range

} Isolation of lepton

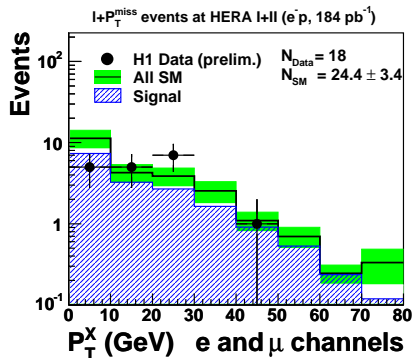
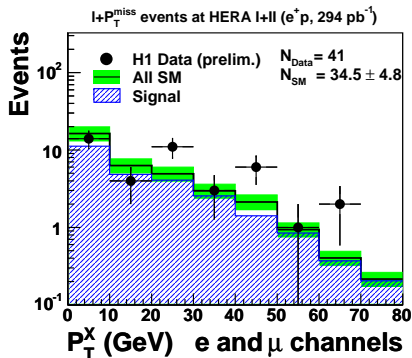
} Cuts designed to reduce SM background, whilst preserving large signal purity

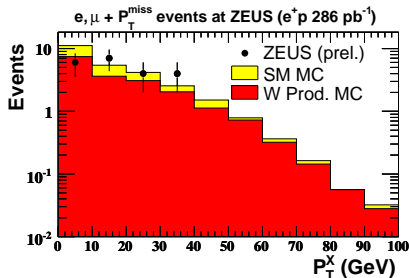
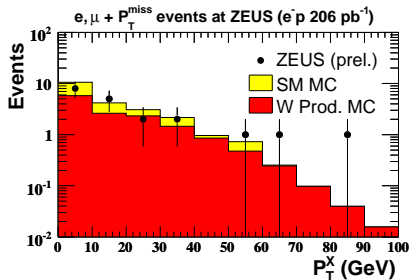
A large amount of work has been done by H1 and ZEUS analysis teams to ensure compatibility of searches



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







- No excess visible in ZEUS search in either  $e^+p$  or  $e^-p$  data set
- SM (dominated by W production) describes data well



Isolated e Candidates	$P_T^X < 12$ GeV	$12 < P_T^X < 25$ GeV	$P_T^X > 25$ GeV
ZEUS (prel.) $e^-p$ 206 pb $^{-1}$	9/11.3 $\pm$ 2.0 (55%)	5/3.4 $\pm$ 0.8 (62%)	<del>3/3.2</del> $\pm$ 0.6 (69%)
ZEUS (prel.) $e^+p$ 286 pb $^{-1}$	7/12.3 $\pm$ 1.9 (66%)	5/4.1 $\pm$ 0.7 (67%)	<del>3/3.9</del> $\pm$ 0.6 (76%)
ZEUS (prel.) $e^\pm p$ 492 pb $^{-1}$	16/23.6 $\pm$ 3.8 (60%)	10/7.5 $\pm$ 1.4 (65%)	<del>6/7.1</del> $\pm$ 1.1 (73%)

Isolated $\mu$ Candidates	$12 < P_T^X < 25$ GeV	$P_T^X > 25$ GeV
ZEUS (prel.) $e^-p$ 206 pb $^{-1}$	1/1.7 $\pm$ 0.3 (77%)	<del>2/2.4</del> $\pm$ 0.4 (85%)
ZEUS (prel.) $e^+p$ 286 pb $^{-1}$	3/2.3 $\pm$ 0.3 (82%)	<del>3/3.6</del> $\pm$ 0.5 (81%)
ZEUS (prel.) $e^\pm p$ 492 pb $^{-1}$	4/4.1 $\pm$ 0.6 (80%)	<del>5/6.0</del> $\pm$ 0.8 (82%)



- In 2006 H1+ZEUS working groups were formed with a view to producing final combined results on important topics
- One such group was assembled with a view to producing combined results on searches
- Comparisons of phase space explored by different experiments were made
- Having established compatibility of searches, the results were combined

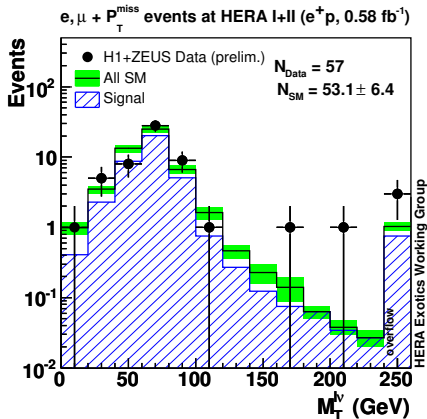
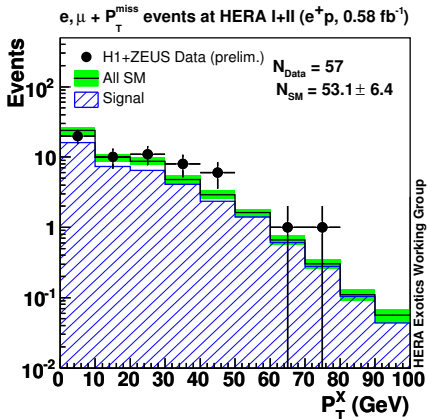
<http://www.desy.de/h1zeus/exotics/isolated-leptons/>



# Combined results $e^+p$ data

Introduction  
Searches  
Summary

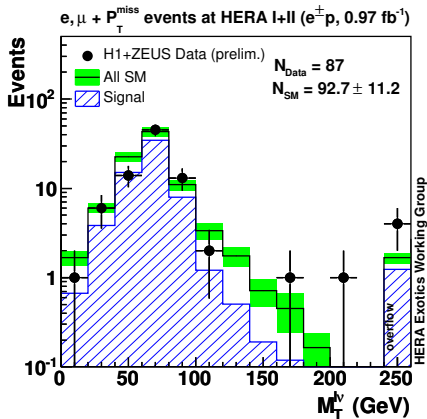
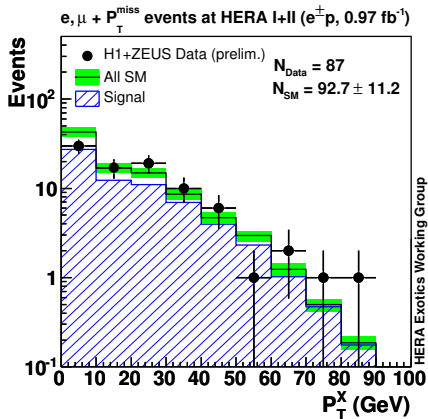
H1 results  
ZEUS results  
H1 + ZEUS Working Group Results  
H1 Isolated Tau



# Combined results $e^\pm p$ data

Introduction  
Searches  
Summary

H1 results  
ZEUS results  
H1 + ZEUS Working Group Results  
H1 Isolated Tau





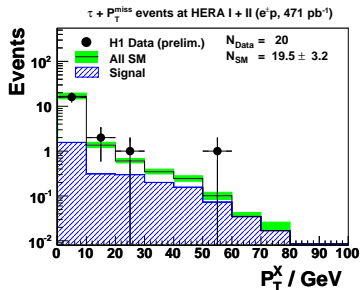
# Combined Results Summary

Introduction  
Searches  
Summary

H1 results  
ZEUS results  
H1 + ZEUS Working Group Results  
H1 Isolated Tau

H1+ZEUS Preliminary $l+P_T^{\text{miss}}$ events at HERA I+II		Electron obs./exp. (Signal contribution)	Muon obs./exp. (Signal contribution)	Combined obs./exp. (Signal contribution)
1994-2007 $e^+p$ $0.58 \text{ fb}^{-1}$	Full Sample	39 / $41.3 \pm 5.0$ (70%)	18 / $11.8 \pm 1.6$ (85%)	57 / $53.1 \pm 6.4$ (73%)
	$P_T^X > 25 \text{ GeV}$	12 / $7.4 \pm 1.0$ (78%)	11 / $7.2 \pm 1.0$ (85%)	23 / $14.6 \pm 1.9$ (81%)
1998-2006 $e^-p$ $0.39 \text{ fb}^{-1}$	Full Sample	25 / $31.6 \pm 4.1$ (63%)	5 / $8.0 \pm 1.1$ (86%)	30 / $39.6 \pm 5.0$ (68%)
	$P_T^X > 25 \text{ GeV}$	4 / $6.0 \pm 0.8$ (67%)	2 / $4.8 \pm 0.7$ (87%)	6 / $10.6 \pm 1.4$ (76%)
1994-2007 $e^\pm p$ $0.97 \text{ fb}^{-1}$	Full Sample	64 / $72.9 \pm 8.9$ (67%)	23 / $19.9 \pm 2.6$ (85%)	87 / $92.7 \pm 11.2$ (71%)
	$P_T^X > 25 \text{ GeV}$	16 / $13.3 \pm 1.7$ (73%)	3 / $12.0 \pm 1.6$ (86%)	29 / $25.3 \pm 3.2$ (79%)





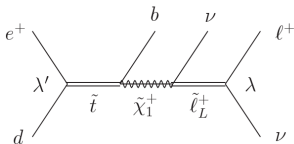
- CC background dominates over most  $P_T^X$
- 1 event observed compared to 1 expected for  $P_T^X > 25$  GeV

H1 Preliminary $\tau + P_T^{\text{miss}}$ events		Tau obs./exp. ( $W^\pm$ )
$e^\pm p$ 471 pb $^{-1}$	Full sample	20 / 19.5 $\pm$ 3.20 (14%)
	$P_T^X > 25\text{GeV}$	1 / 0.99 $\pm$ 0.13 (63%)

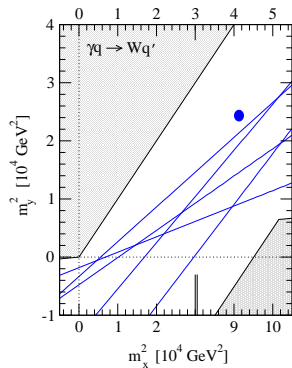
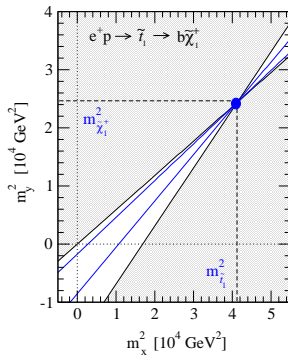


- Searches have been performed for isolated leptons in events with large missing transverse momentum using the full HERA data set ( $0.5 \text{ fb}^{-1}$  per collaboration)
- Excess over the standard model at high  $P_T^X$  observed by H1 in HERA I data remains in  $e^+p$  data
- ZEUS has not confirmed the H1 excess
- H1 and ZEUS have set up a working group to produce final combined results on isolated leptons:
  - W production cross section
  - BSM limits





- Possible interpretation of excess
- For many RPV scenarios:



$$m_{\tilde{\chi}_1^\pm}^2 = m_{\tilde{t}_1}^2 [1 - (E_b - p_b^z)/2E_e] - 2E_e(E_b + p_b^z) \quad (1)$$

Eur. Phys. J. C51 543 (2007)



- The  $e + p$  preliminary H1 only has a significance  $3.0\sigma$
- In the common phase space  $e + p$  preliminary H1 only has a significance  $2.9\sigma$
- Combining with ZEUS one obtains  $2\sigma$  !

