

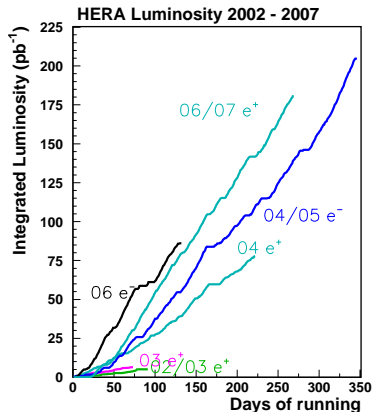
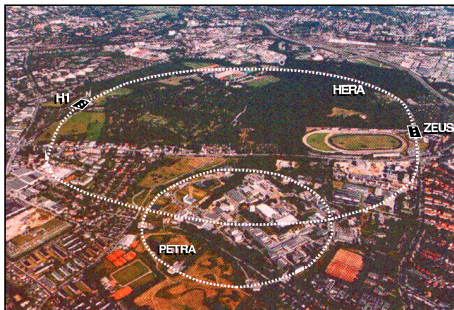
Events with Isolated Leptons and Missing Transverse Momentum at HERA

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On behalf of the H1 and ZEUS collaborations

DIS2008 April 9th, 2008





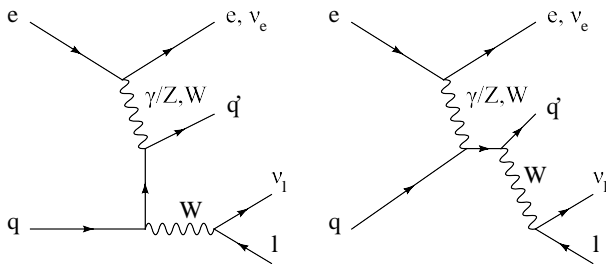
- HERA collided e^\pm (27.5 GeV) and protons (820,920,460,575 GeV) at largest $\sqrt{s} \approx 318$ GeV
- $\sim 0.5 \text{ fb}^{-1}$ per experiment



Isolated Lepton Production

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HERA
Isolated Leptons
Backgrounds
Example e Event
Example μ 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 γp

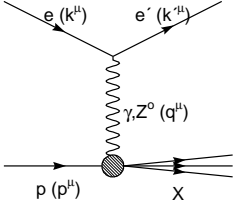
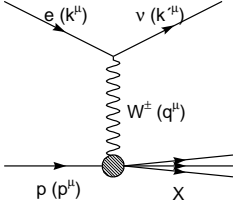
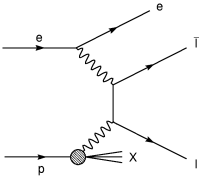
- Modelled using **EPVEC** generator
- **NLO QCD corrections** applied leaving theoretical error $\sim 15\%$
- Hadronic system typically has low transverse momentum (P_T^X)



Backgrounds

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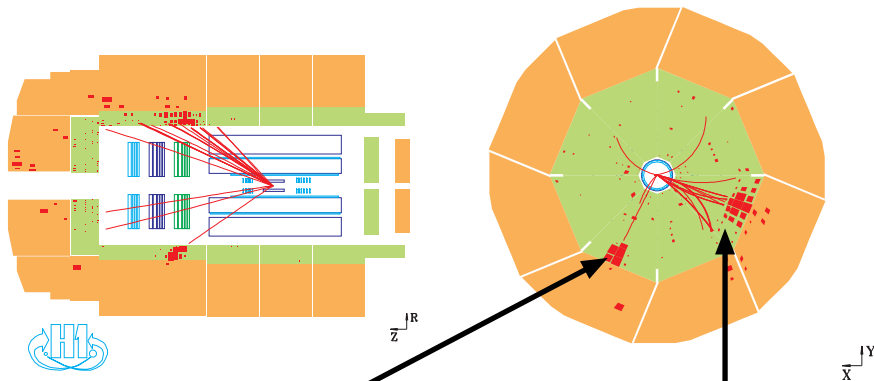
NC DIS	CC DIS	Dilepton production
		
<p>Genuine electron and fake P_T^{miss} due to mismeasurement</p>	<p>misidentified lepton and genuine P_T^{miss}</p>	<p>Genuine μ and fake P_T^{miss} due to mismeasurement</p>
<p>$\sigma \approx 8000 \text{ pb}$</p>	<p>$\sigma \approx 40 \text{ pb}$</p>	<p>$\sigma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



e Candidate

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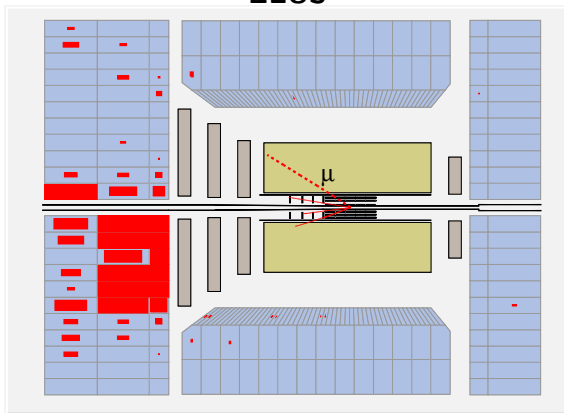
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- Well isolated electron
- Large hadronic activity not back-to-back with electron



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 τ 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, μ) searches with full HERA luminosity
([H1prelim-07-063](#))
- ZEUS Isolated (e, μ) searches with full HERA luminosity
([ZEUS-prel-07-021](#))
- Combined H1+ZEUS Isolated Lepton (e, μ) searches
([H1prelim-07-162/ZEUS-prel-07-029](#))
- H1 Isolated τ 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
θ_l	$5^\circ < \theta_l < 140^\circ$ (H1), $15^\circ < \theta_l < 120^\circ$ (ZEUS and COMMON)	
P_T^l	> 10 GeV	
P_T^{calo}	> 12 GeV	
P_T^{miss}	> 12 GeV	
P_T^X	-	> 12 GeV
D_{jet}	> 1.0	
D_{track}	> 0.5 for $\theta_e \geq 45^\circ$	> 0.5
ξ_1^2	> 5000 GeV ² for $P_T^{\text{calo}} < 25$ GeV	-
V_{sp}/V_p	< 0.5 (< 0.15 for $P_T^e < 25$ GeV)	< 0.5 (< 0.15 for $P_T^{\text{calo}} < 25$ GeV)
$\Delta\phi_{l-X}$	$< 160^\circ$	$< 170^\circ$
δ_{miss}	> 5 GeV	-
# isolated μ	0	1

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

} Isolation of lepton

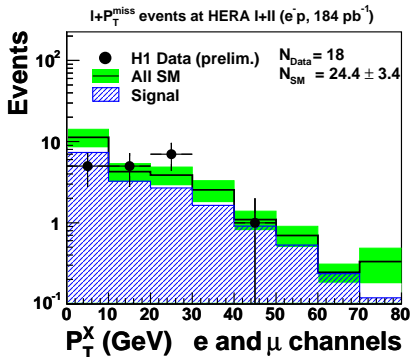
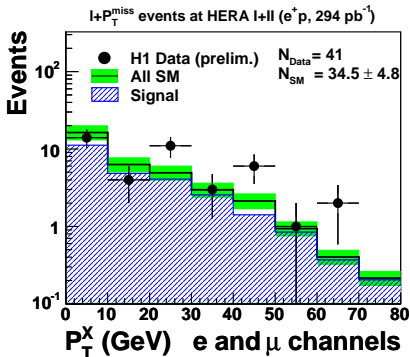
} Cuts designed to reduce SM background, whilst preserving large signal purity

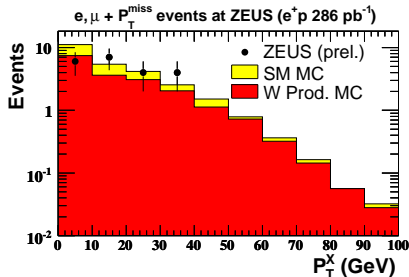
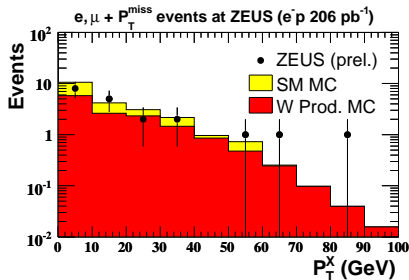
A large amount of work has been done by H1 and ZEUS analysis teams to ensure compatibility of searches



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 ⁻¹	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 ⁻¹	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 ⁻¹	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%)	3/3.2 \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%)	3/3.9 \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%)	6/7.1 \pm 1.1 (73%)

Isolated μ 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%)	2/2.4 \pm 0.4 (85%)
ZEUS (prel.) e^+p 286 pb $^{-1}$	3/2.3 \pm 0.3 (82%)	3/3.6 \pm 0.5 (81%)
ZEUS (prel.) $e^\pm p$ 492 pb $^{-1}$	4/4.1 \pm 0.6 (80%)	5/6.0 \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

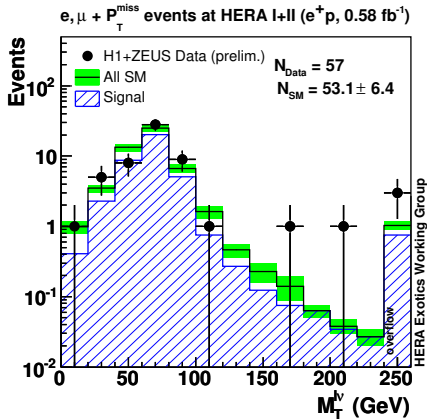
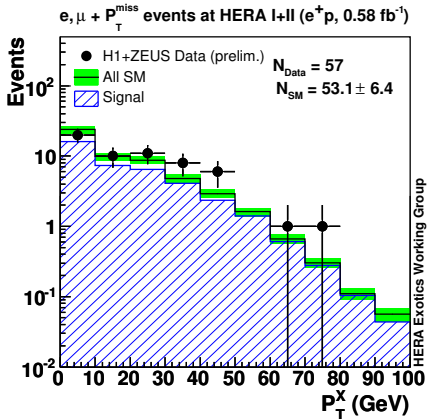
<http://www.desy.de/h1zeus/exotics/isolated-leptons/>



Combined results e^+p data

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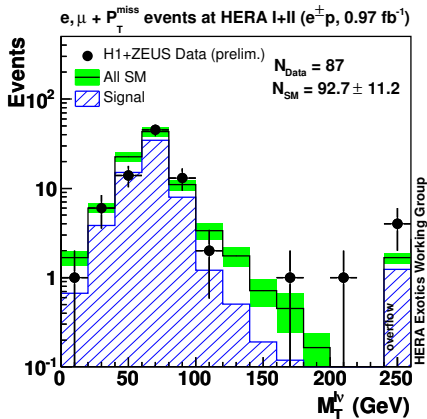
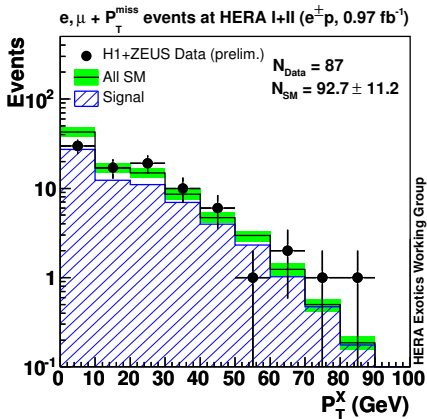
H1 results
ZEUS results
H1 + ZEUS Working Group Results
H1 Isolated Tau



Combined results $e^\pm p$ data

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H1 Isolated Tau



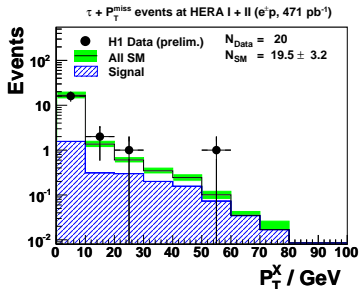
Combined Results Summary

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H1 results
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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	Full Sample	39 / 41.3 \pm 5.0 (70%)	18 / 11.8 \pm 1.6 (85%)	57 / 53.1 \pm 6.4 (73%)
0.58 fb $^{-1}$	$P_T^X > 25$ 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	Full Sample	25 / 31.6 \pm 4.1 (63%)	5 / 8.0 \pm 1.1 (86%)	30 / 39.6 \pm 5.0 (68%)
0.39 fb $^{-1}$	$P_T^X > 25$ GeV	4 / 6.0 \pm 0.8 (67%)	2 / 4.8 \pm 0.7 (87%)	6 / 10.6 \pm 1.4 (76%)
1994-2007 $e^\pm p$	Full Sample	64 / 72.9 \pm 8.9 (67%)	23 / 19.9 \pm 2.6 (85%)	87 / 92.7 \pm 11.2 (71%)
0.97 fb $^{-1}$	$P_T^X > 25$ GeV	16 / 13.3 \pm 1.7 (73%)	3 / 12.0 \pm 1.6 (86%)	29 / 25.3 \pm 3.2 (79%)





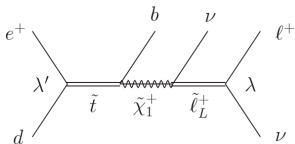
- CC background dominates over most P_T^X
- 1 event observed compared to 1 expected for $P_T^X > 25$ GeV

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%)

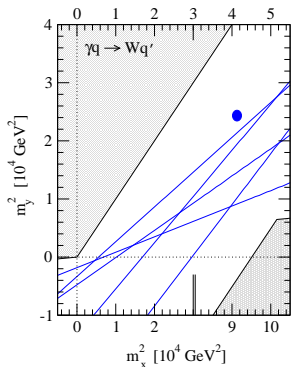
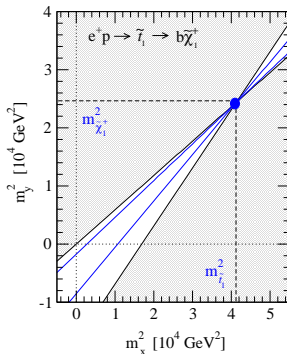


- Searches have been performed for isolated leptons in events with large missing transverse momentum using the full HERA data set (0.5 fb^{-1} per collaboration)
- Excess over the standard model at high P_T^X observed by H1 in HERA I data remains in e^+p data
- ZEUS has not confirmed the H1 excess
- 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:



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

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

