New H1 Results on Isolated Leptons and Missing P_T at HERA

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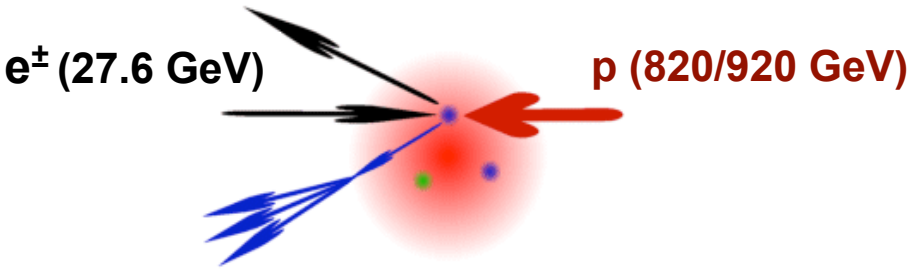
Outline

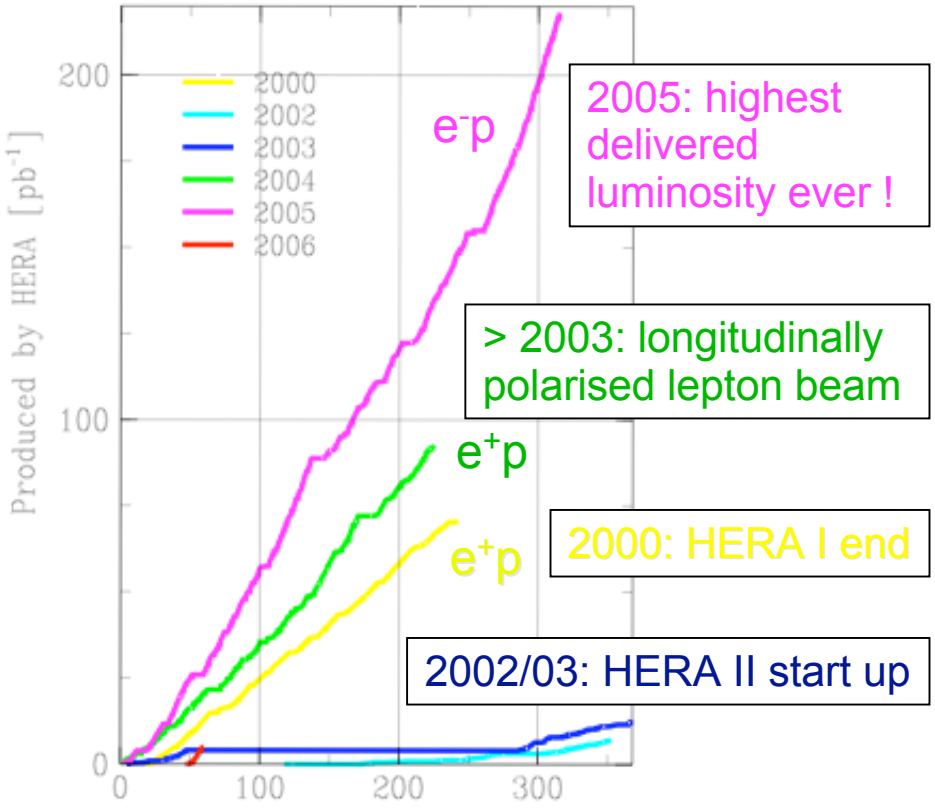
- Introduction to HERA, H1 and Isolated Leptons
- Standard Model Signal and Background Processes
- Isolated Lepton Selection
- Latest H1 Results
- Possible Interpretations and Future Prospects
- Summary and Conclusions

HERA and the H1 Experiment

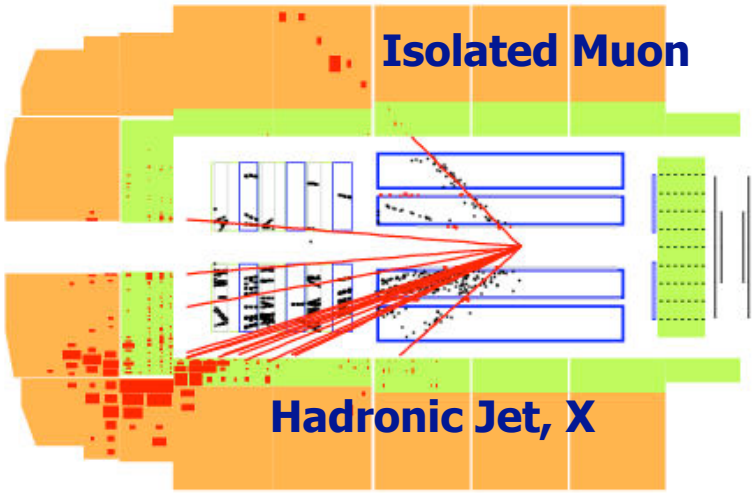


- At HERA electrons or positrons are collided with protons resulting in a centre of mass of up to 320 GeV
- Colliding experiments: H1 and ZEUS

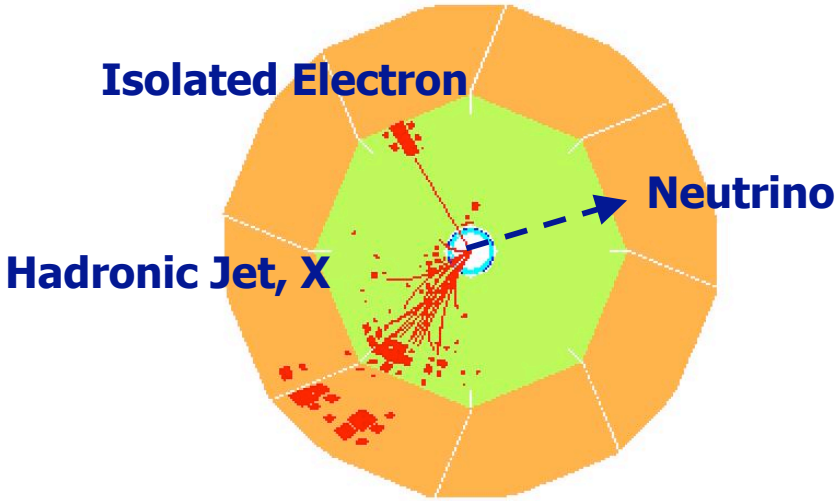
- HERA I (1994-2000)
  e^+p: L ~ 104 pb^{-1}; e^-p: L ~ 14 pb^{-1}
- HERA II (2003-2006)
  e^+p: L ~ 53 pb^{-1}; e^-p: L ~ 140 pb^{-1}



Introduction to Isolated Leptons



HERA I μ + P_T^{miss} event

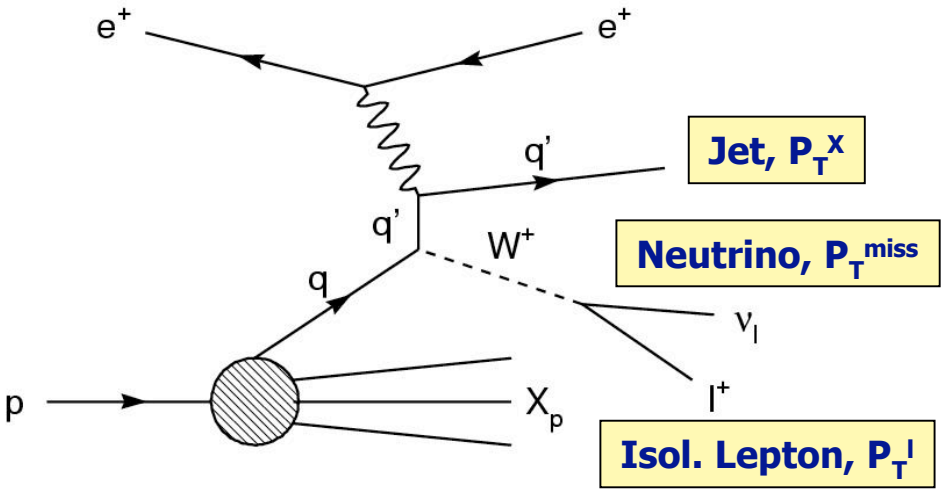


HERA I e + P_T^{miss} event

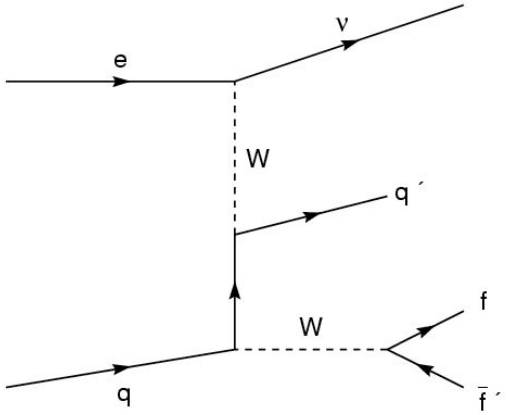
- H1 measurement of events containing P_T^{miss} and high P_T leptons (e or μ)
- HERA I analysis (118 pb^{-1}):
  - 19 events in the data (1 in e^-p) compared to 14.5 ± 2.0 expected from SM
  - An excess of data events is observed at large hadronic transverse momentum
- The events continue to be seen in the new HERA II data

Standard Model Signal Processes

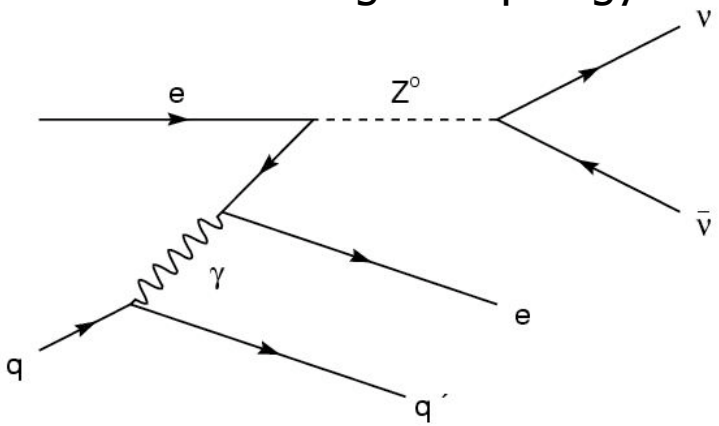
- Main SM contribution to signal from real W production via photoproduction with subsequent decay to leptons
  - Total cross section of order 1 pb, with 10% of W decays to each lepton flavour
  - Modelled using the EPVEC generator with a NLO QCD correction (Diener et. al.): modifies LO cross section by about 10%, reduces theoretical error to 15%



- Two additional processes included that contribute to the signal topology:



CC W Production



Cabibbo-Parisi Z^0 production (e channel only)

Phase Space Selection

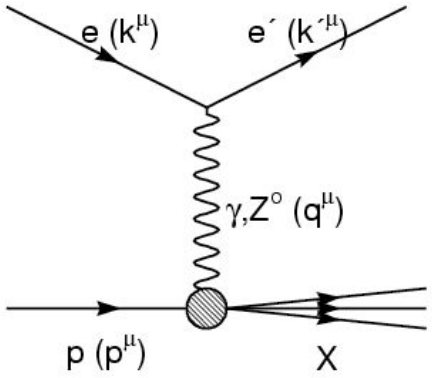
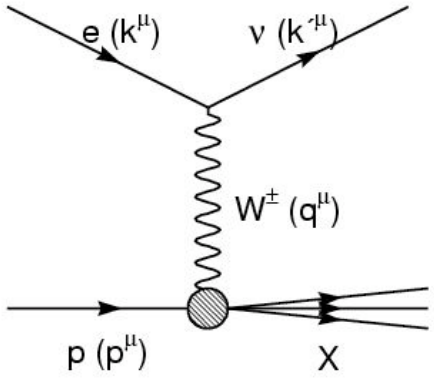
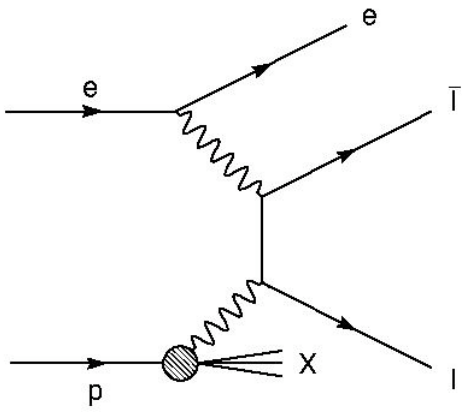
- Initial event selection:
  - NC / CC / muon triggers
  - Event timing requirements, clean event sample
  - Non-ep background finders
- Phase space selection for all subsequent selections employed:
  - Look for a high P_T lepton (electron or muon), in the main body of the detector (extends in polar angle to $\theta_l < 2.44$ rad), in events with large missing calorimetric transverse momentum

Phase Space Selection

$5^o < \theta_l < 140^o$, $P_T^l > 10$ GeV, $P_T^{calo} > 12$ GeV

Standard Model Background

- Main SM Background processes:
  - Neutral and Charged Current and lepton pair production (also photoproduction)

e: Neutral Current	e,μ: Charged Current	μ: Lepton Pair Production
		
real electron and fake missing P_T from mismeasurement	misidentified electron or muon and real missing P_T	real muon and fake missing P_T from mismeasurement

Dedicated study samples employed to ensure control of SM background

Isolated Lepton Event Selection

Variable	Electron	Muon
θ_l	$5^o < \theta_l < 140^o$	
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 $\theta_e \geq 45^o$	> 0.5
ζ_l^2	> 5000 GeV^2 for $P_T^{calo} < 25$ GeV	-
V_{ap}/V_p	< 0.5 (< 0.15 for $P_T^e < 25$ GeV)	< 0.5 (< 0.15 for $P_T^{calo} < 25$ GeV)
$\Delta\phi_{l\text{-}X}$	$< 160^o$	$< 170^o$
δ_{miss}	> 5 GeV	-
# isolated μ	0	1

Phase space selection

Only cut on hadronic P_T in muon channel

Isolation of lepton

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

 only if one e candidate is detected, with the same charge as the beam lepton

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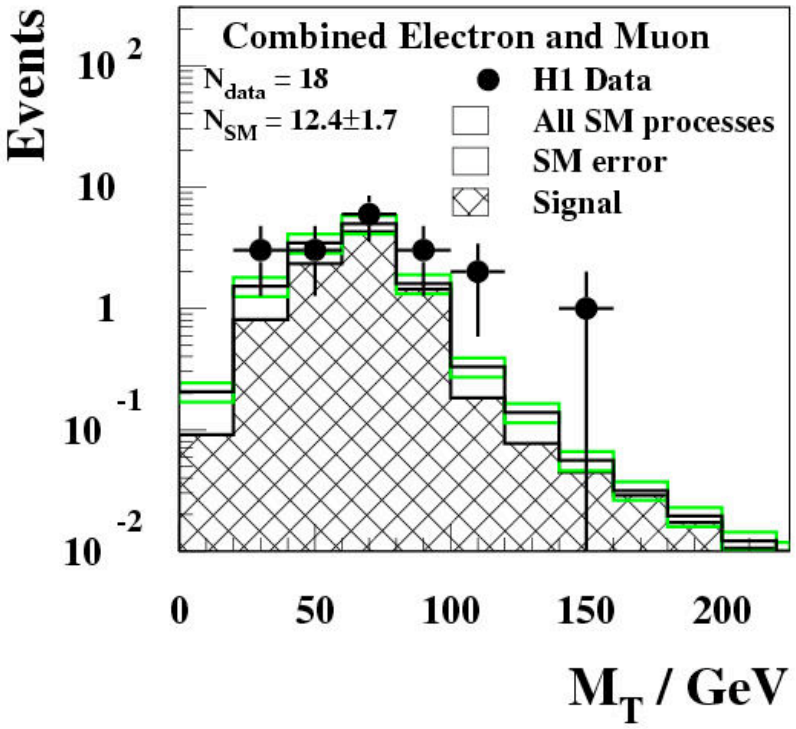
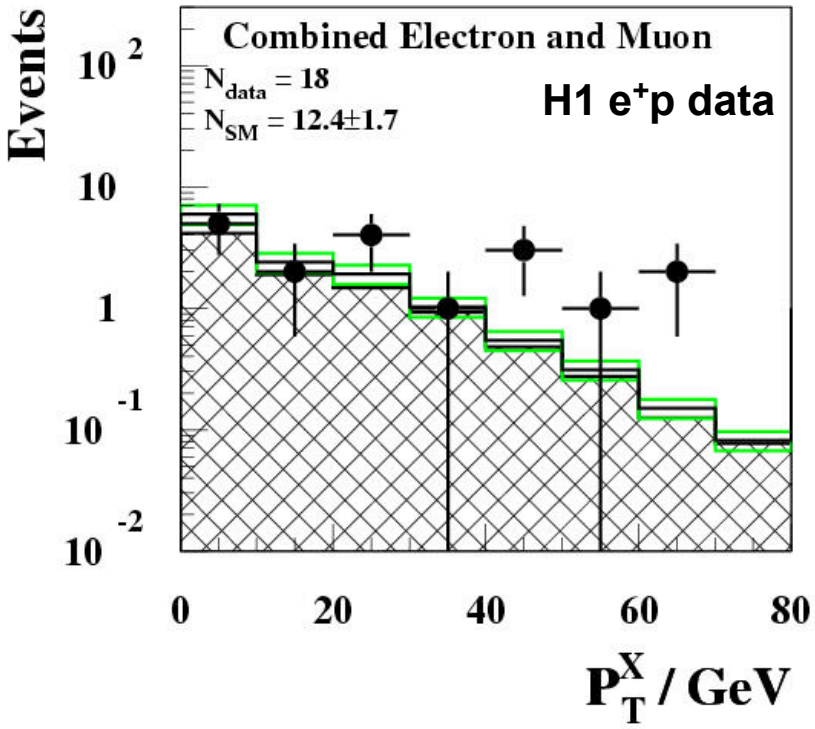
H1 Results from HERA I Analysis



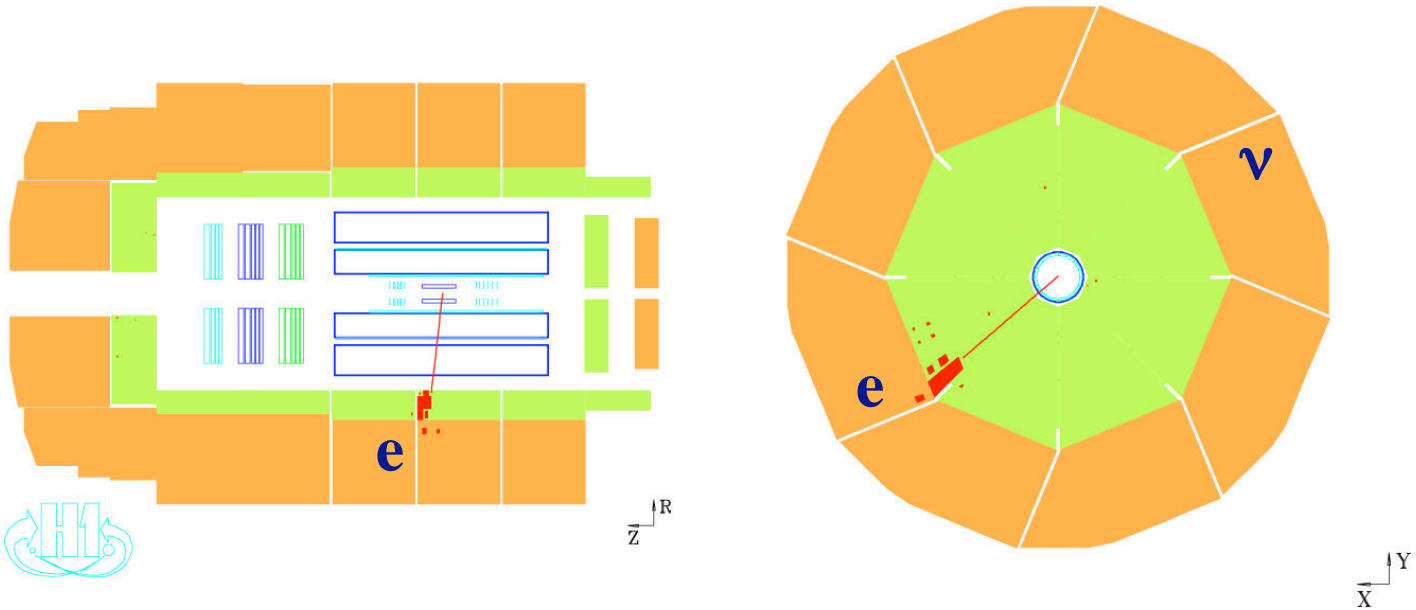


H1 $e^{\pm}p$ data HERA I (118 pb^{-1})	e channel obs. / exp.	μ channel obs. / exp.	e and μ channels obs. / exp.
Full sample	11 / 11.5 ± 1.5	8 / 2.9 ± 0.5	19 / 14.5 ± 2.0
P_T^X > 25 GeV	5 / 1.8 ± 0.3	6 / 1.7 ± 0.3	11 / 3.5 ± 0.6

Analysis of HERA II Data

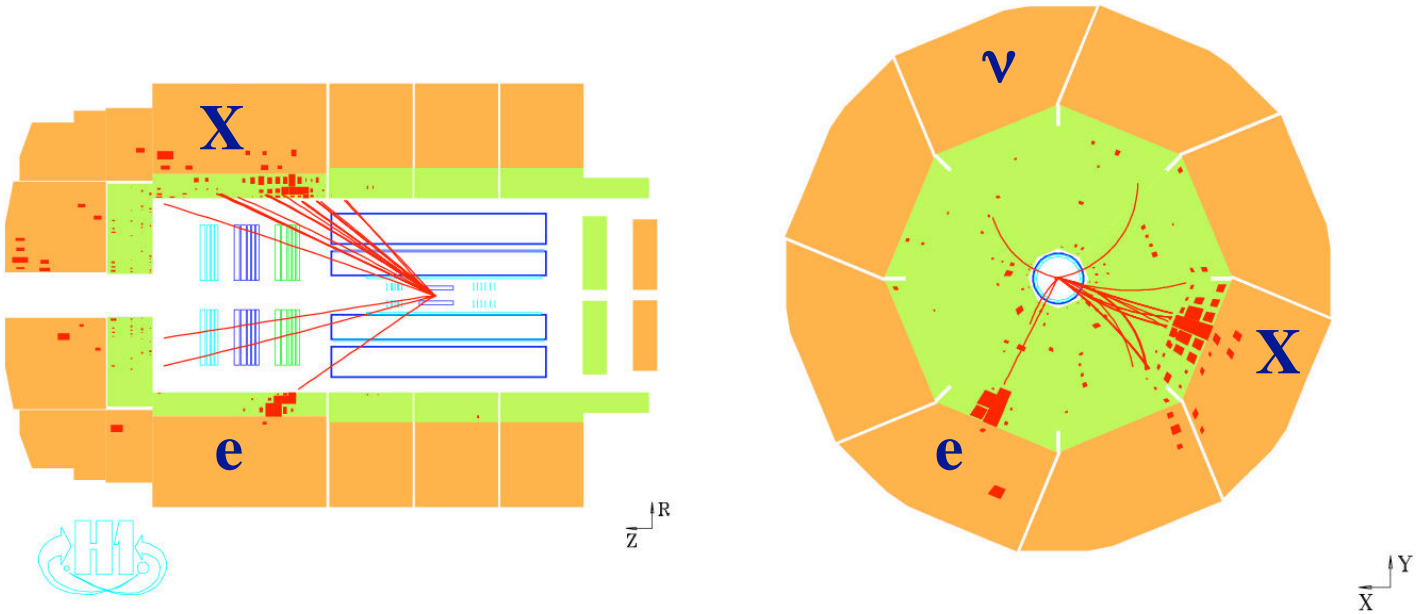
- HERA upgrade has provided and continues to provide a rich harvest of new data for analysis within H1
- The data is of good quality, providing new measurements of the polarisation dependence of the NC and CC cross sections
  - See talks by A. Nikiforov and B. Antunovic
- We now have a factor of 10 more e^-p data than in the HERA I phase - and more coming in right now
- The isolated lepton analysis has been performed on this new data, resulting in more than double luminosity than in the published paper

Isolated Lepton Event Display



- Elastic HERA II e + P_T^{miss} event in e^+p data
- P_T^e = 47 GeV, P_T^{miss} = 47 GeV, P_T^X = 0 GeV

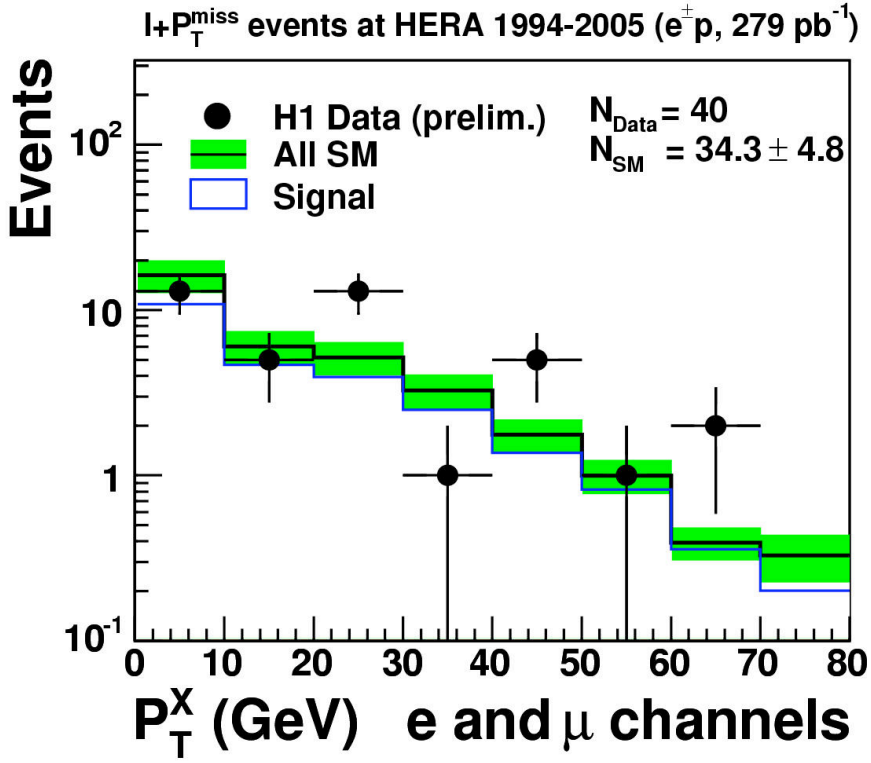
Isolated Lepton Event Display



- High P_T^X HERA II e + P_T^{miss} event in e^+p data
- P_T^e = 37 GeV, P_T^{miss} = 44 GeV, P_T^X = 29 GeV

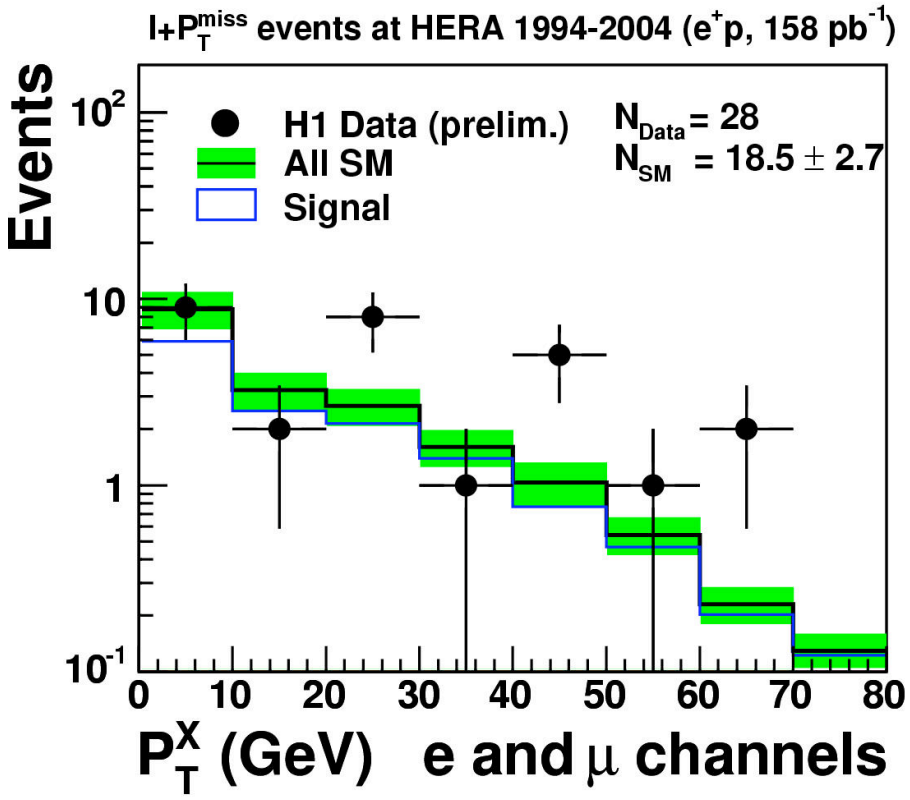
Results from H1 $e^{\pm}p$ data

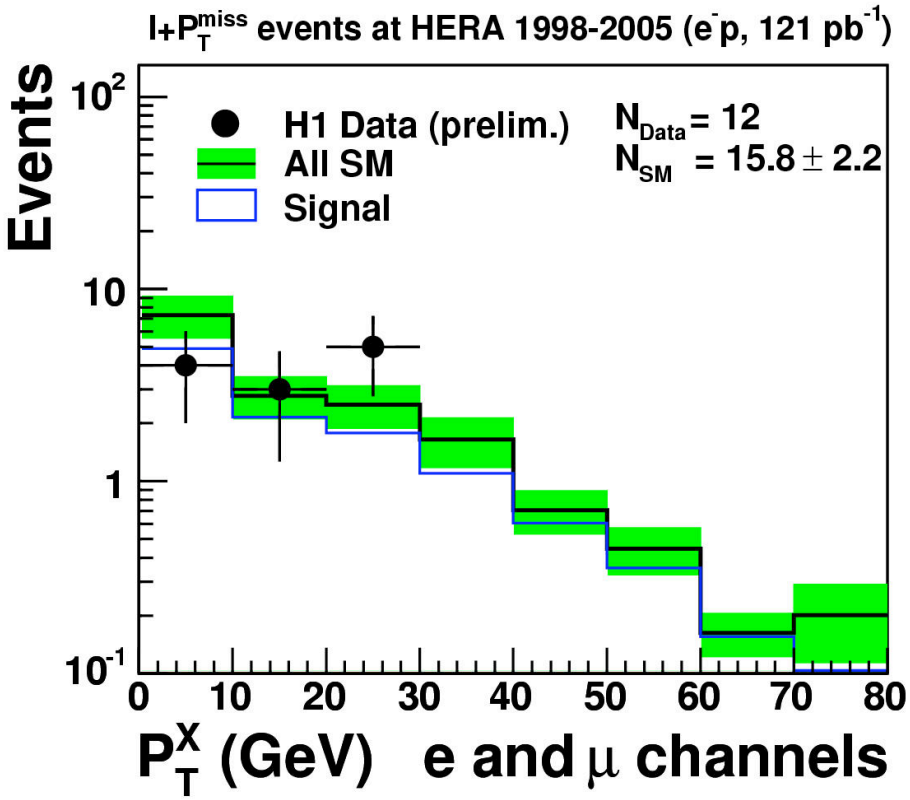
- Total analysed luminosity from HERA I and II datasets : **279 pb^{-1}**
  - 10 events (1 muon) observed in 53 pb^{-1} of HERA II $e^{+}p$ data, SM: 6.1 ± 0.9
  - 11 events (1 muon) observed in 107 pb^{-1} of HERA II $e^{-}p$ data, SM: 13.8 ± 1.9



H1 $e^{\pm}p$ data HERA I+II (279 pb^{-1})	e channel obs. / exp. (signal)	μ channel obs. / exp. (signal)	e and μ channels obs. / exp. (signal)
Full sample	30 / 27.2 ± 3.8 (68%)	10 / 7.2 ± 1.1 (81%)	40 / 34.3 ± 4.8 (71%)
P_T^X > 25 GeV	11 / 4.7 ± 0.9 (69%)	6 / 4.3 ± 0.7 (78%)	17 / 9.0 ± 1.5 (73%)

Results from H1 e^+p and e^-p data





HERA I+II e^+p data: 158 pb^{-1}

HERA I+II e^-p data: 121 pb^{-1}

Clear difference observed between e^+p and e^-p datasets

Summary of Isolated Lepton Results

$P_T^X > 25$ GeV	e channel obs. / exp. (signal)	μ channel obs. / exp. (signal)	e and μ channels obs. / exp. (signal)
H1 e^+p data 158 pb^{-1}	9 / 2.3 ± 0.4 (80%)	6 / 2.3 ± 0.4 (84%)	15 / 4.6 ± 0.8 (82%)
H1 e^-p data 121 pb^{-1}	2 / 2.4 ± 0.5 (62%)	0 / 2.0 ± 0.3 (76%)	2 / 4.4 ± 0.7 (68%)
H1 $e^\pm p$ data 279 pb^{-1}	11 / 4.7 ± 0.9 (69%)	6 / 4.3 ± 0.7 (78%)	17 / 9.0 ± 1.5 (73%)

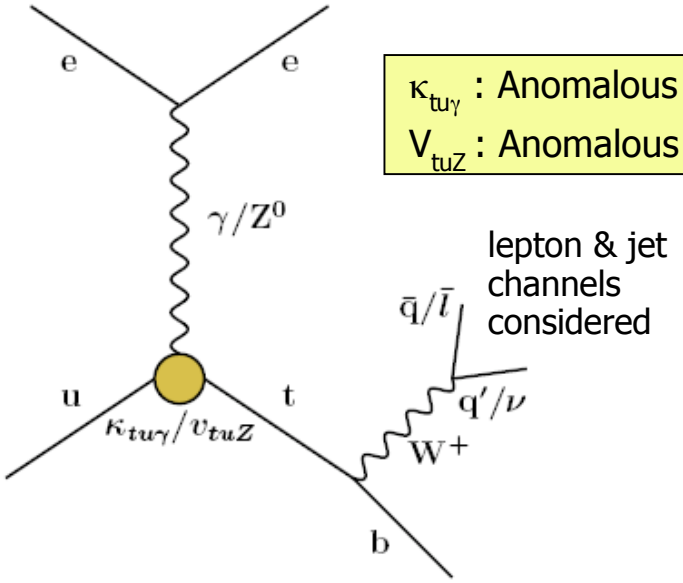
- Excess observed at large P_T^X in e^+p data but not in e^-p
- Probability in e^+p sample for SM to fluctuate up to observed number of data events = 3.4σ effect
- More information can be found in

http://www-h1.desy.de/psfiles/confpap/EPS2005/H1prelim-05-164_PRC_Nov05.ps

- For the H1 analysis of the τ channel, see talk by S. Xella

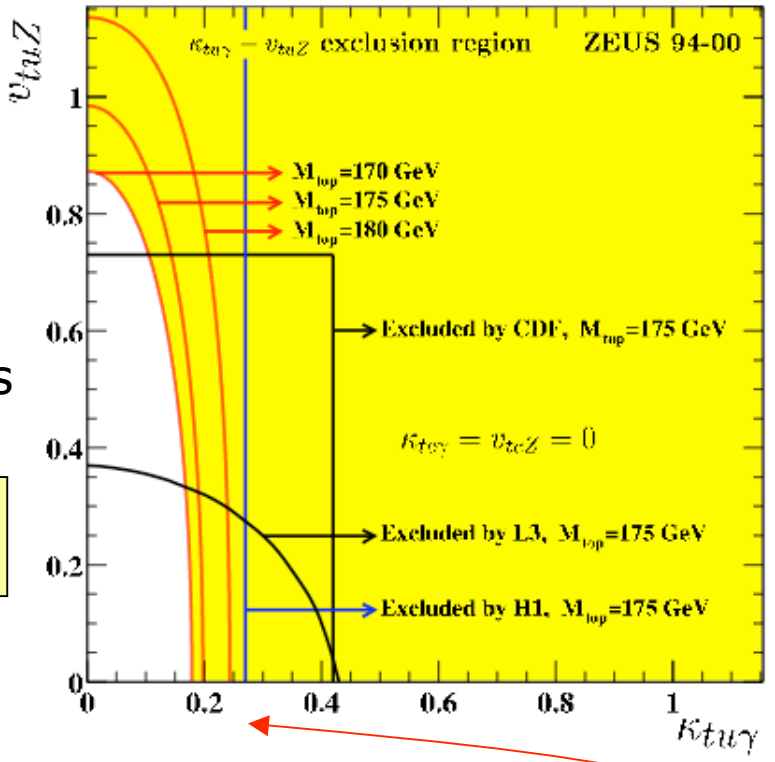
Single Top Production at HERA

- Excess of observed events at high P_T^X unlikely to be due to W production…
  - But! Typical signature of top decay t → bW
  - Tiny SM top production cross section < 1 fb
  - Anomalous top production via FCNC ?
  - Cannot explain asymmetry between datasets



$\kappa_{tu\gamma}$: Anomalous γ magnetic coupling
V_{tuZ} : Anomalous Z vector coupling

lepton & jet channels considered

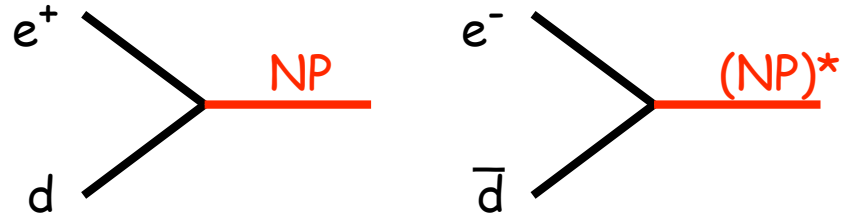


- HERA I analysis (118 pb^{-1}):
  - 5 / 1.31 ± 0.22 top like events
  - $\sigma(ep \rightarrow etX) < 0.55$ pb

HERA competitive!

Certain BSM Models could favour e^+p over e^-p

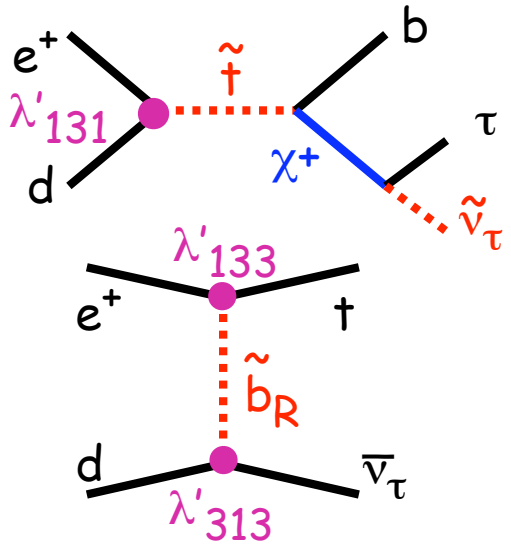
- Particle coupling to e-q with fermion number F=0 :



Large mass i.e. large x_{Bj}

$d >> \bar{d}$, hence $\sigma(e+) >> \sigma(e-)$

- Another example : Squarks in R-parity violating SUSY

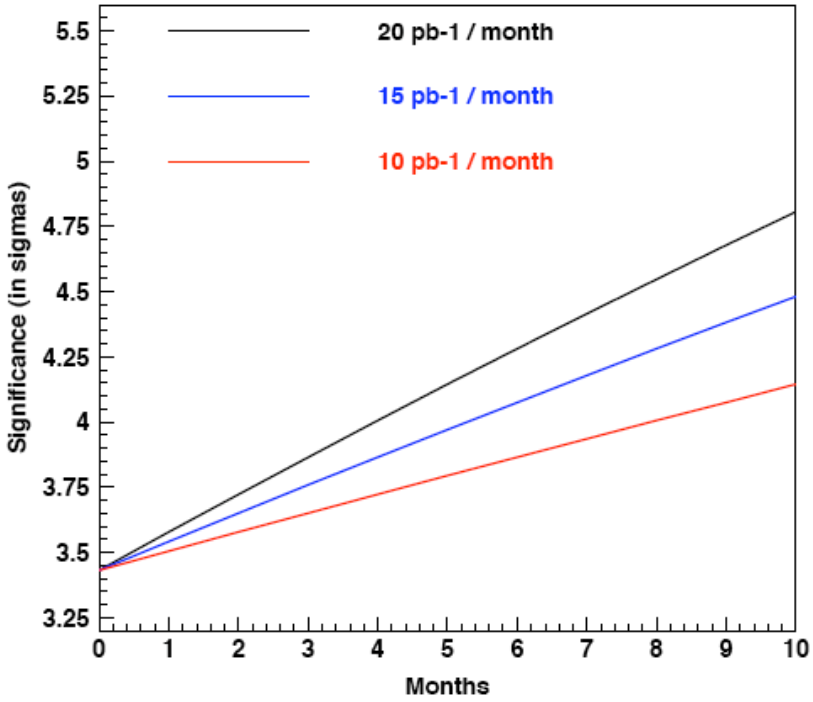


If LSP is $\tilde{\nu}_\tau$ and no large RpV coupling involving the τ : $\tilde{\nu}_\tau$ could be long-lived

RpV via couplings involving two 3rd generation fields, light sbottom. Large $M_{top} \rightarrow$ large x_{Bj}

Future Prospects from HERA II

- Extrapolation for e^+p data
  - Assume that events continue to show up at the rate observed in H1
  - A 4 - 5 σ effect is possible with ~ 8 further months of H1 e^+p data from HERA II, if 20 pb^{-1} / month



This analysis represents the best chance for a discovery at HERA

Conclusions

- An excess of events containing isolated electrons or muons with large missing P_T was observed by H1 in 118 pb^{-1} of HERA I data
  - This data was mainly e^+p collisions
- H1 has now analysed 279 pb^{-1} of data, which includes a substantial increase in statistics of e^-p data
- The observed HERA I excess persists in the e^+p data only
- Several BSM or exotic scenarios could provide the signal but no there is no definite candidate
- More (e^+p) data needed from HERA II to clarify the situation
  - **And it's coming in right now!**