DIS 2000, Liverpool

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W Production and high P_T isolated leptons at HERA

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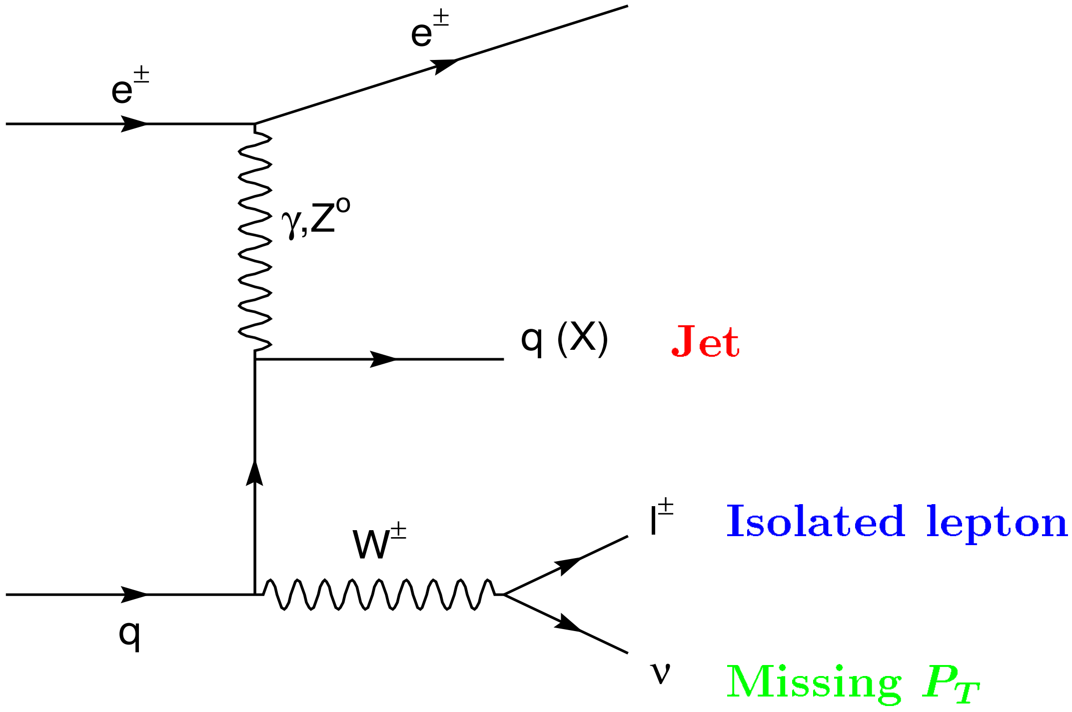
- Introduction
- 1994-1997 e^+p data
  - H1 isolated leptons and W search
  - ZEUS W analysis and cross section limits
- 1998-9 e^-p data - H1 / ZEUS
- Latest e^+p results ZEUS (1999) and H1 (1999/2000)
- Summary

Introduction(1)

The H1 and ZEUS detectors at the HERA ep collider have now each recorded $\approx 80pb^{-1}$ of data

$\rightarrow$ Sensitivity to rare SM physics processes e.g. W production :

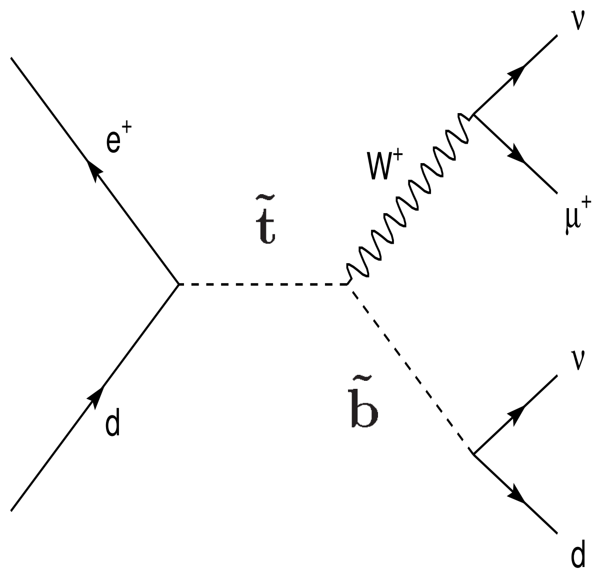


Standard Model (LO) predicts
$\sigma(ep \rightarrow eW^{\pm}X) \approx 1pb$
($\approx 60fb$ per charge state and leptonic decay channel)

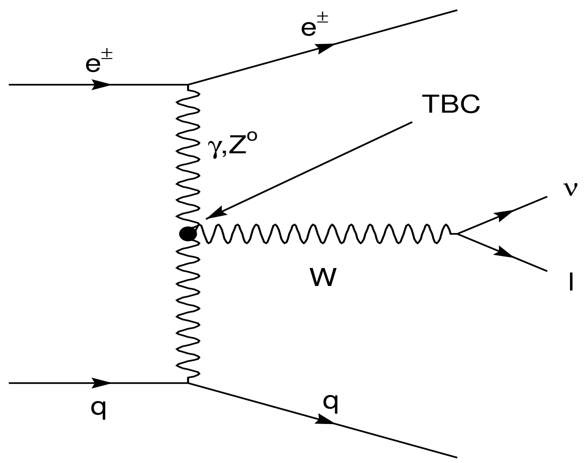
Uncertainties on proton/photon structure functions $\approx 5\%/10\%$
$5\% \rightarrow 10\%$ uncertainty on QCD scale

Introduction(2)

Beyond the Standard Model, W production is the background to other processes with a jet, an isolated lepton and missing P_T, e.g. $\not{R}$-parity **SUSY**, compositeness or stop decay:



Also sensitive to anomalous $WW\gamma$ couplings (λ,$\Delta\kappa$):



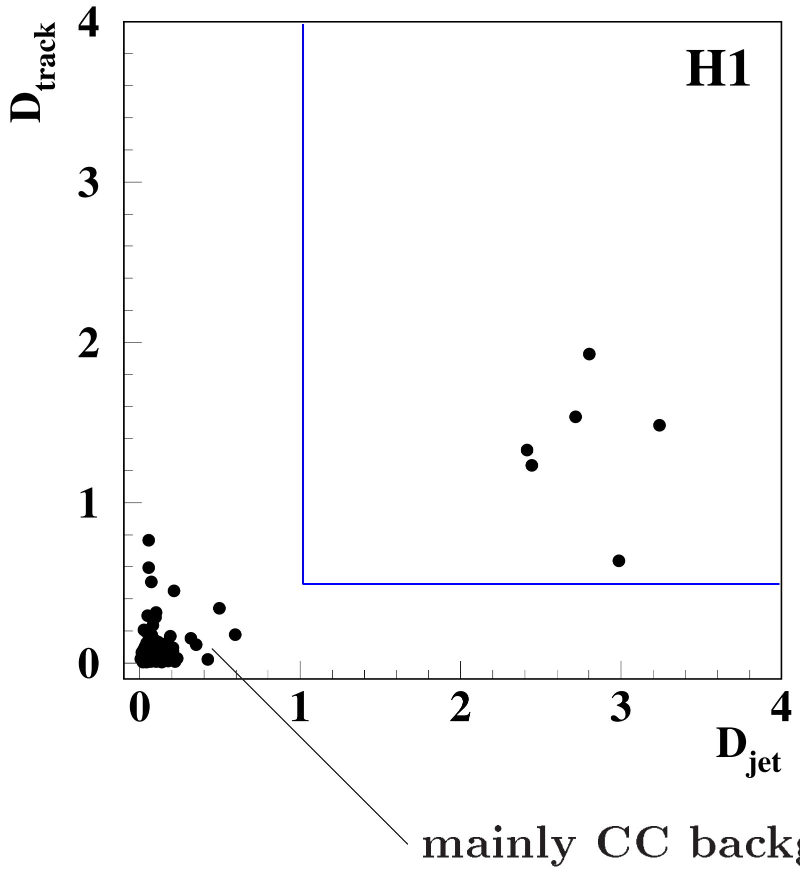
An important physics channel

H1 isolated lepton selection (94-7 e^+p data)

hep-ex/9806009

- $P_T^{calo} > 25$ GeV
- $\theta_{track} > 10^o$ and $P_T^{track} > 10$ GeV

(no identification required yet)



1994-1997 e^+p data
$36.5\ pb^{-1}$

124 events in total

all have at least
1 hadronic jet

D_{track} = Distance to nearest track in (η,ϕ) space
D_{jet} = Distance to nearest jet in (η,ϕ) space

- Final selection criteria:
  - $D_{track} > 0.5$
  - $D_{jet} > 1.0$

+ Timing requirements and Cosmic rejection

Apply lepton ID $\rightarrow$ 1 electron and 5 muons

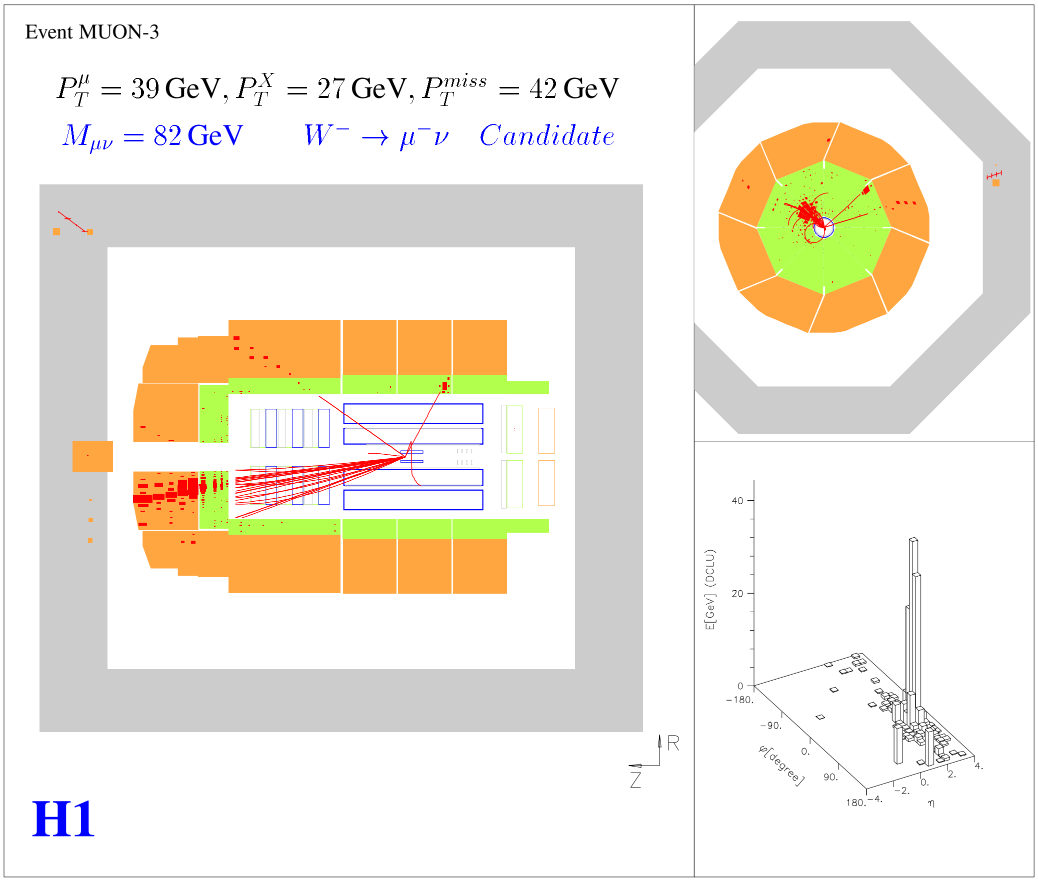
H1 94-97 result : 36.5 pb^{-1} e^+p

1998 Paper	Electron	Muon
Data	0 e^+,1 e^-	$2\mu^-$,2 μ^+,1 μ
W	1.65 $\pm$ 0.47	0.53 $\pm$ 0.11
CC - DIS	0.02 $\pm$ 0.01	0.01 $\pm$ 0.01
NC - DIS	0.5$\pm$0.10 e^+, 0.02$\pm$0.10 e^-	0.09 $\pm$ 0.06
L Pair	0.09$\pm$0.03 e^+, 0.04$\pm$0.01 e^-	$0.14^{+0.14}_{-0.07}$

($2\mu^+$, $2\mu^-$ and one muon at too great a P_T to allow accurate charge determination (stiff track))

Main background to W production is NC DIS

NB: e^- not beam lepton



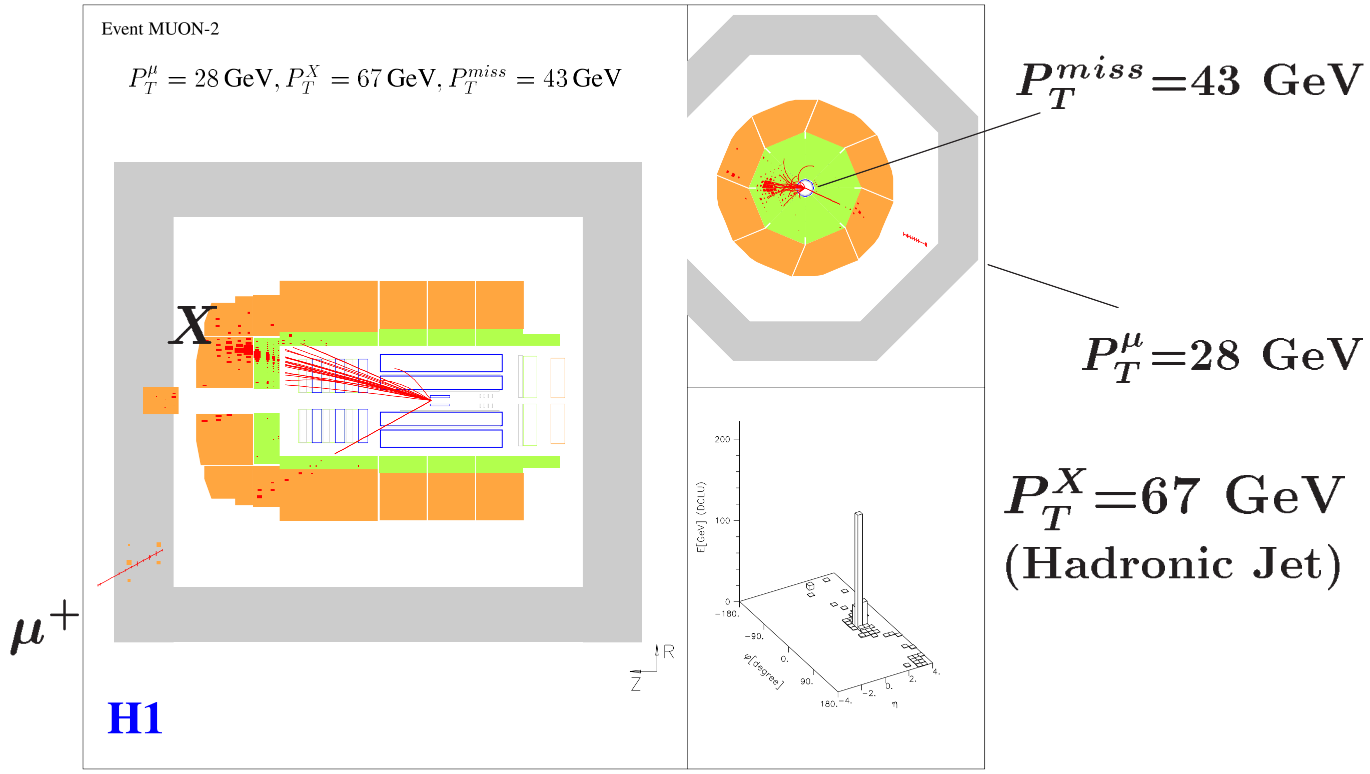
$M_{\mu\nu}$=82 GeV

P_T^X=27 GeV

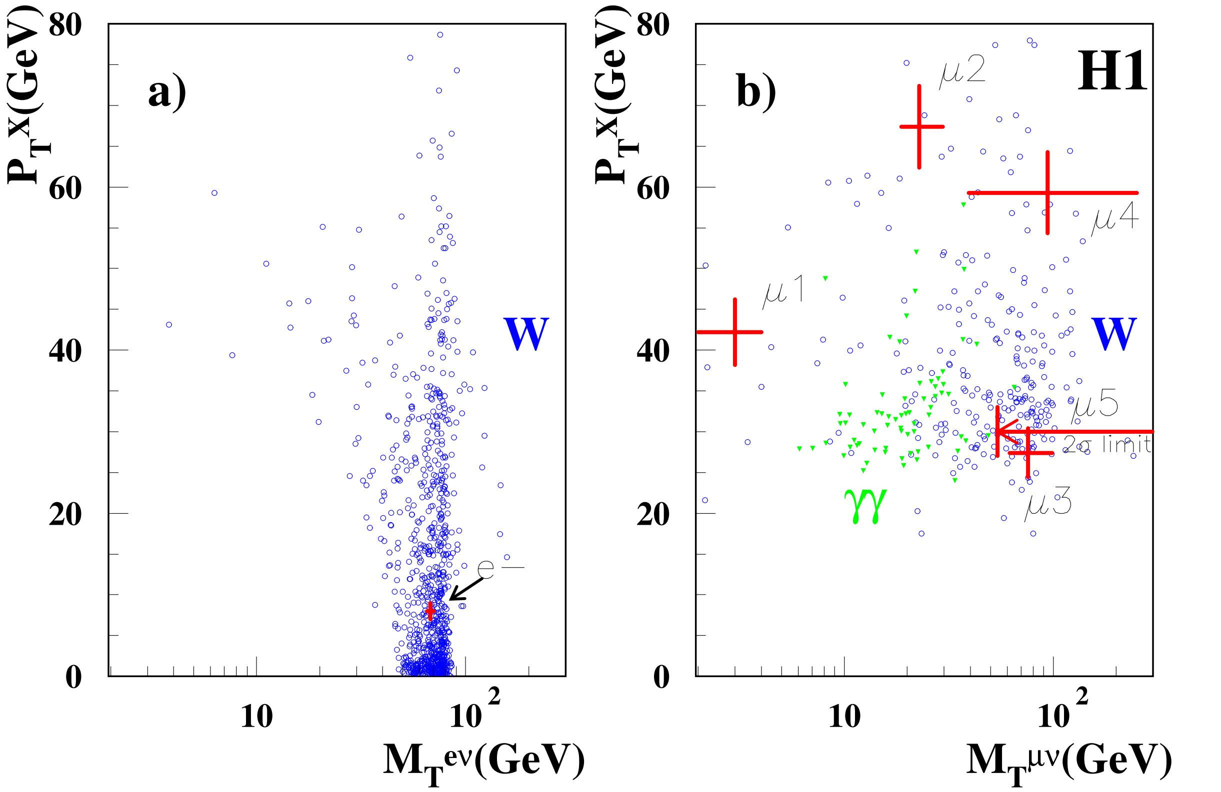
(Hadronic Jet)

Tagged positron allows well-reconstructed mass

H1 94-97 result : 36.5 pb^{-1} e^+p



MC lumi = 500 x data



3 muons are atypical of SM W production

H1 dedicated W analysis (94-7 e^+p data)

- Multivariate selection criteria
- Extend phase space (hadronic decay → S.Caron's talk ; tau decays investigated)
  - lower in P_T^{calo}
  - further "forward" ($\theta > 5^o$)
- Enhanced background rejection

Electron	Data	SM expectation	W
$P_T^X > 0$ GeV	3	3.12 ±0.70	2.24 ±0.67
$P_T^X > 12$ GeV	1	1.15 ±0.25	0.78 ±0.23
$P_T^X > 25$ GeV	0	0.50 ±0.12	0.38 ±0.11

P_T^X = Hadronic Recoil

Muon	Data	SM expectation	W
$P_T^X > 12$ GeV	5	1.01 ± 0.28	0.87 ± 0.26
$P_T^X > 25$ GeV	5	0.56 ± 0.15	0.49 ± 0.15

H1 Preliminary

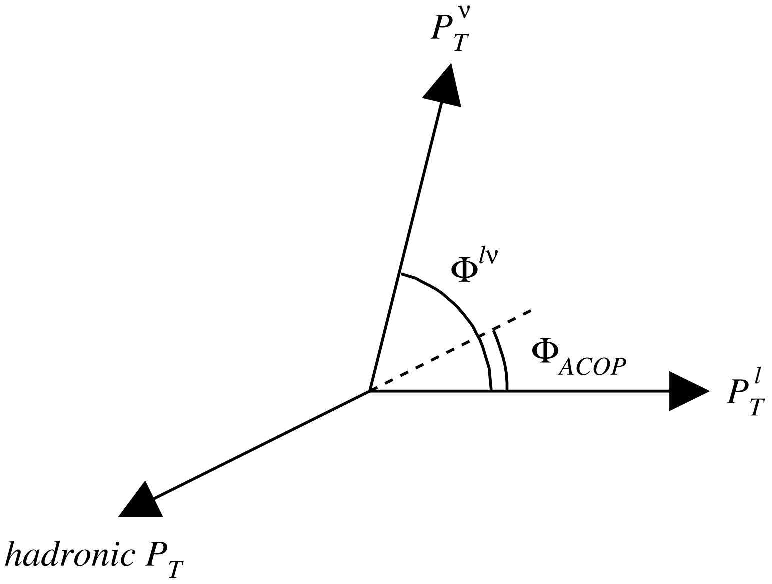
Same 5 muons as found in isolated lepton analysis

Extending lower in P_T^X find two more electrons in agreement with SM

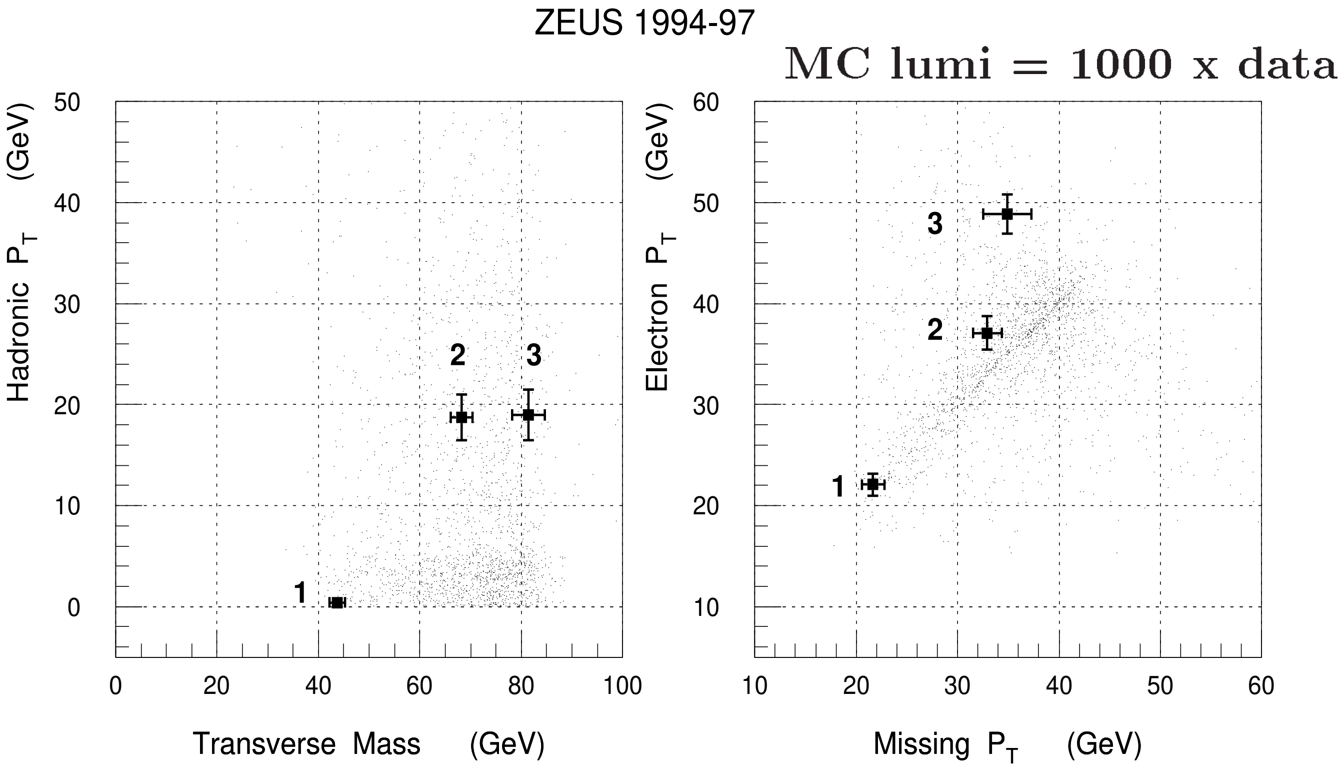
ZEUS 94-97 result : 46.6 pb^{-1}

Electron Channel

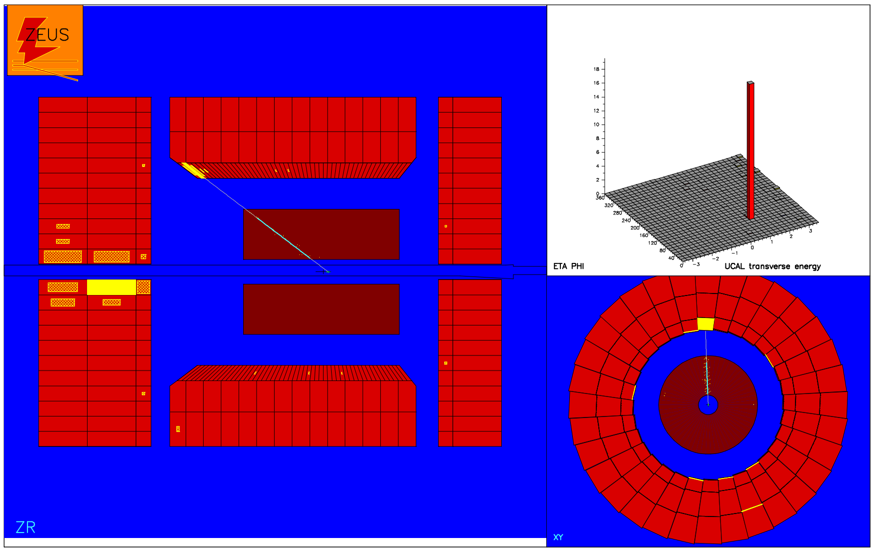
- $P_T^{calo} > 25$ GeV
- $\theta_e < 86^o$
- $P_T^e > 10$ GeV
- Acoplanarity $> 17^o$



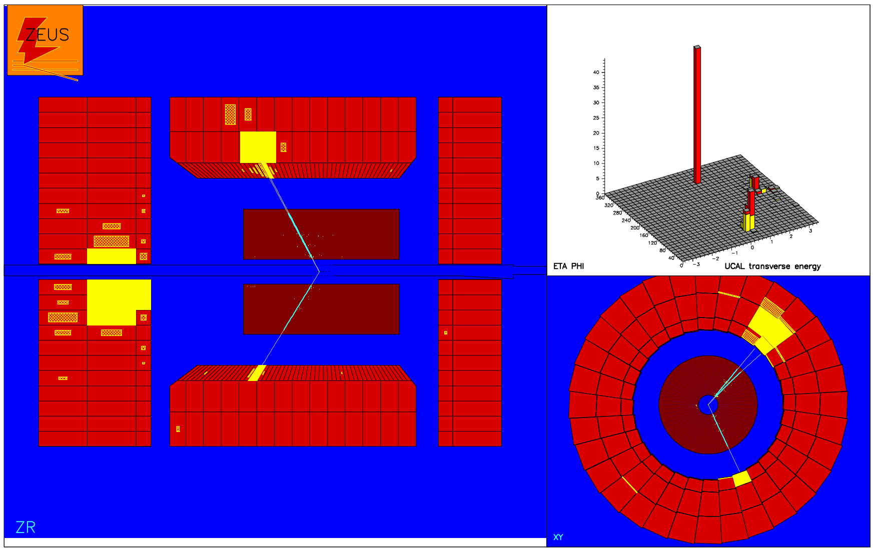
Results : 3 e^+ cf. 2.1 W and 1.1$\pm$0.3 background (mainly CC DIS and LPAIR)



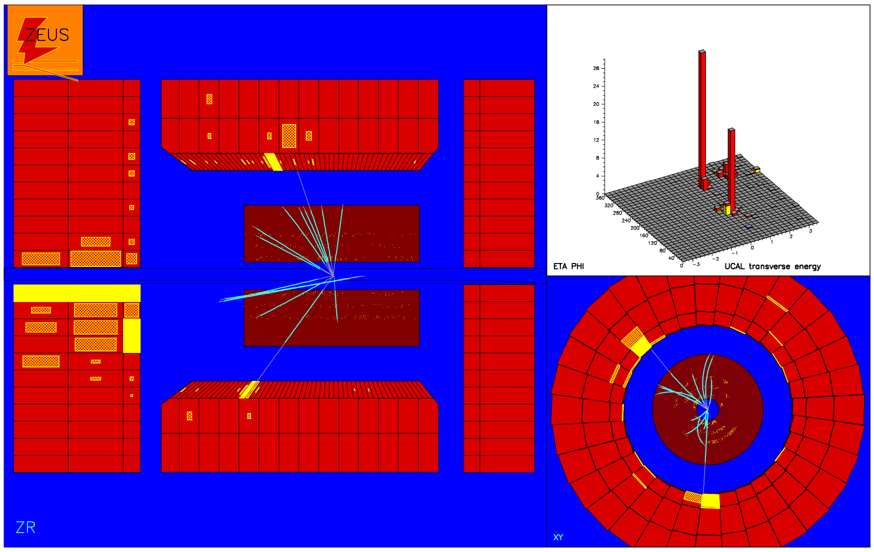
ZEUS 94-97 result : Electron kinematics



$$\theta^e = 37^\circ$$
$$E_T^e = 22.1 \pm 1.1$$
$$p_t^{track} = 22.3^{+6.8}_{-4.2}$$
$$\text{charge} = +1(4.3\sigma)$$
$$P_T^h = 0.4 \pm 0.1$$
$$P_T^{CAL} = 21.7 \pm 1.1$$
$$M_T = 43.7 \pm 1.6$$



$$\theta^e = 58^\circ$$
$$E_T^e = 48.8 \pm 2.0$$
$$p_t^{track} = 44.1^{+33.0}_{-13.2}$$
$$\text{charge} = +1(2.3\sigma)$$
$$P_T^h = 19.0 \pm 2.5$$
$$P_T^{CAL} = 34.9 \pm 2.4$$
$$M_T = 81.4 \pm 3.2$$



$$\theta^e = 54^\circ$$
$$E_T^e = 37.1 \pm 1.6$$
$$p_t^{track} = 35.9^{+13.8}_{-7.8}$$
$$\text{charge} = +1(3.6\sigma)$$
$$P_T^h = 18.7 \pm 2.2$$
$$P_T^{CAL} = 32.9 \pm 1.4$$
$$M_T = 68.2 \pm 2.2$$

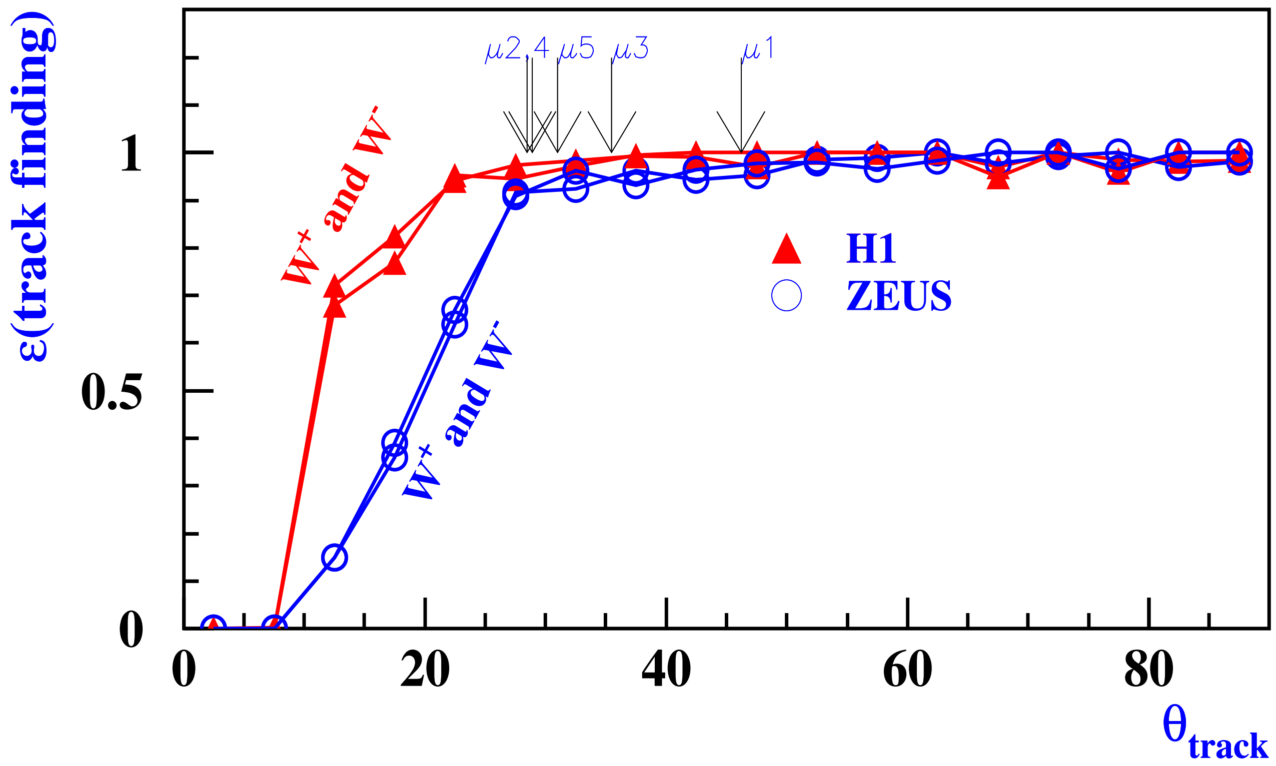
ZEUS 94-97 result : 46.6 pb^{-1}

Muon Channel

- $P_T^{calo} > 15$ GeV
- $\theta_\mu < 115^o$
- $P_T^\mu > 5$ GeV
- Track is a M.I.P.

Results : 0 candidates cf. 0.76 (W) and 0.65 $\pm$ 0.22 (CC / $\mu\mu$) $\rightarrow \sigma(W)$ <3.7pb 95% CL

Is there a detector difference between H1 and ZEUS? MC studies of muons with P_T >10 GeV have been made for each experiment:



hep-ph/9901335

ZEUS 94-97 result : 46.6 pb^{-1}

Electron results : 3 e^+ cf. 2.1 W and 1.1$\pm$0.3 background

$\rightarrow \sigma(e^+p \rightarrow e^+W^\pm X) = 0.9^{+1.0}_{-0.7}$(stat.)$\pm$0.2(syst.)pb

Also analysis procedure similar to original H1 publication yields 3 isolated tracks (e^+) cf. 5.7 $\pm$ 0.8 expected

Combine e and μ results for limits on cross section

P_T^X	data	Standard Model MC			95%
		W	backd	W eff.	C.L.
$> 15\ GeV$	2	1.4	0.62 ± 0.20	10%	$< 1.2pb$
$> 20\ GeV$	0	1.2	0.52 ± 0.18	11%	$< 0.58pb$
$> 25\ GeV$	0	0.89	0.49 ± 0.18	11%	$< 0.56pb$

The limits on σ for P_T^X >20GeV correspond to 95% C.L.:

$-4.7 < \Delta\kappa < 1.5$ $(\lambda = 0)$

and

$-3.2 < \lambda < 3.2$ $(\Delta\kappa = 0)$

(significantly larger limits than derived at TeVatron and LEP2)

In agreement with SM W production

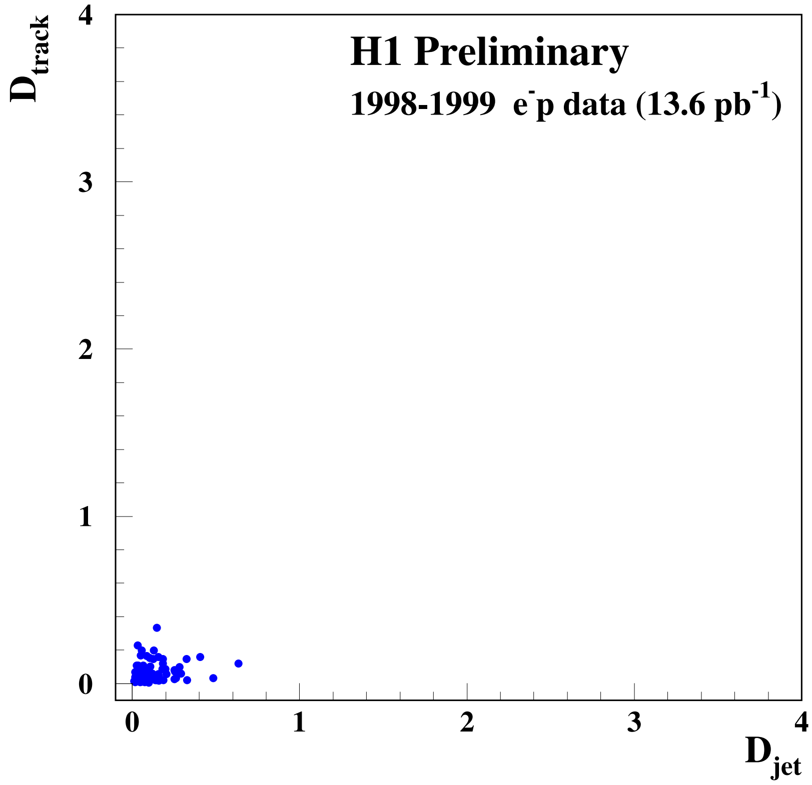
H1 W analysis (98-9 e^-p data)

Luminosity = 12.8 pb^{-1}

Electron	Data	SM expectation	W
$P_T^X > 0$ GeV	0	1.58 $\pm$0.32	0.95 $\pm$0.28
$P_T^X > 12$ GeV	0	0.61 $\pm$0.12	0.35 $\pm$0.10
$P_T^X > 25$ GeV	0	0.25 $\pm$0.06	0.18 $\pm$0.05

P_T^X = Hadronic Recoil

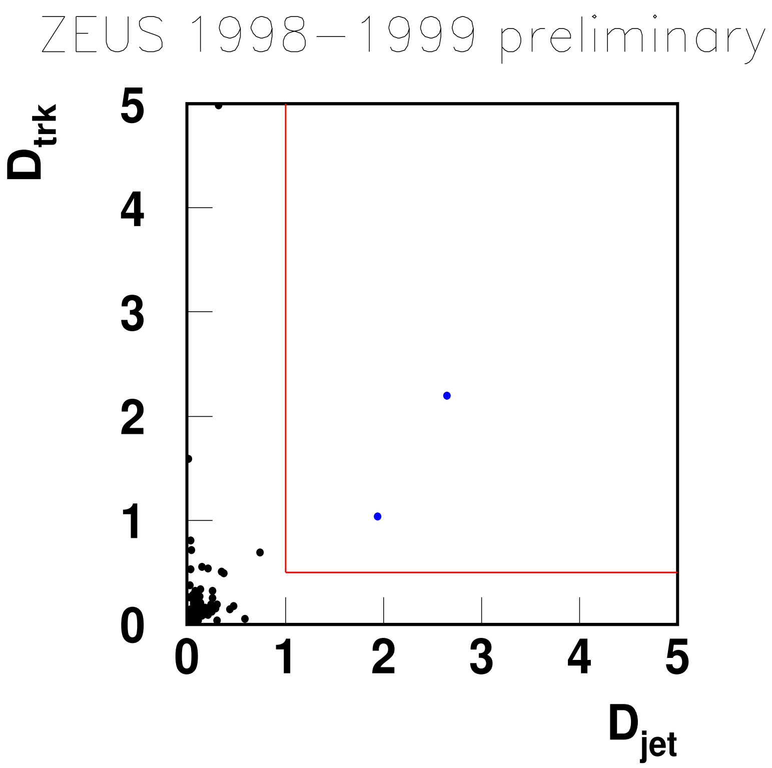
Muon	Data	SM expectation	W
$P_T^X > 12$ GeV	0	0.41 $\pm$ 0.11	0.35 $\pm$ 0.11
$P_T^X > 25$ GeV	0	0.24 $\pm$ 0.07	0.21 $\pm$ 0.06



Isolation plot using original isolated lepton cuts

ZEUS 98-99 result : 16 pb^{-1} e^-p data

Latest results:



2 isolated tracks identified as electrons cf. 1.6±0.4 from SM

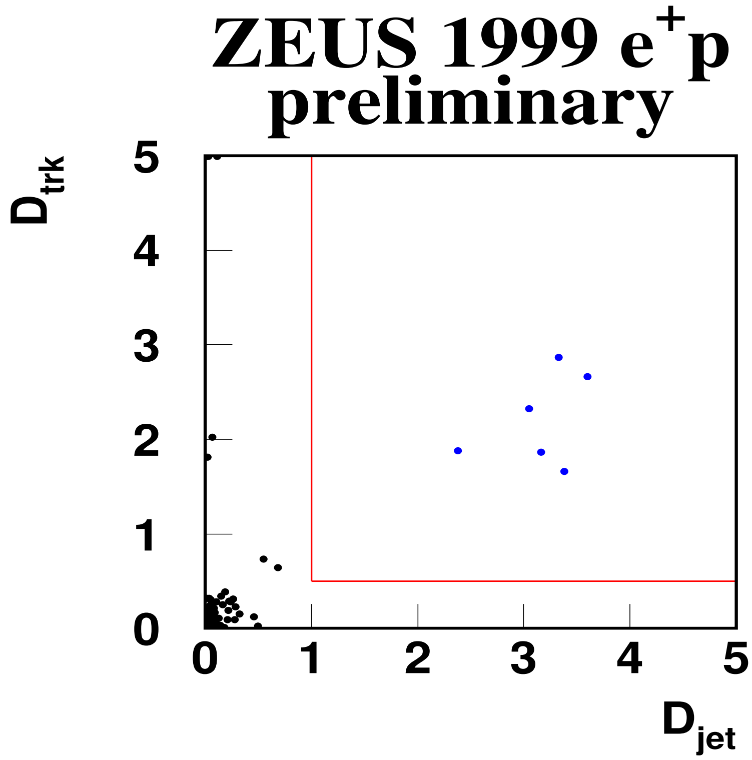
(of which 0.8±0.4 pass e and 0.8±0.1 pass mu ID)

The electrons are found in events with NC DIS topology

First has evidence of energy leakage into the backing calorimeter
Second has a muon within a hadronic jet ($\rightarrow P_T^{miss}$)

No evidence of an excess of events in this data set

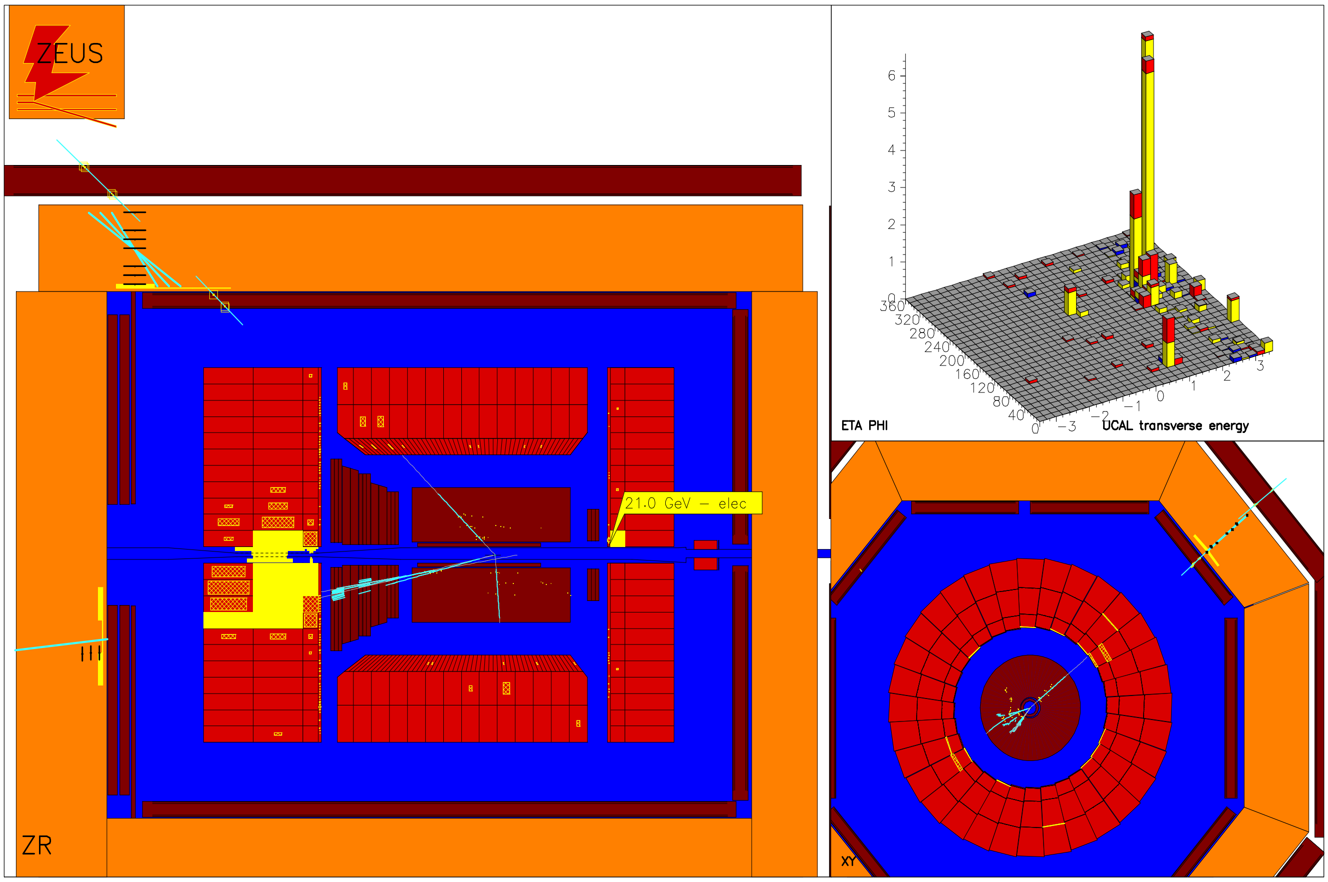
ZEUS 1999 result : 18 pb^{-1} e^+p data



$2\ e,\ 4\ \mu$

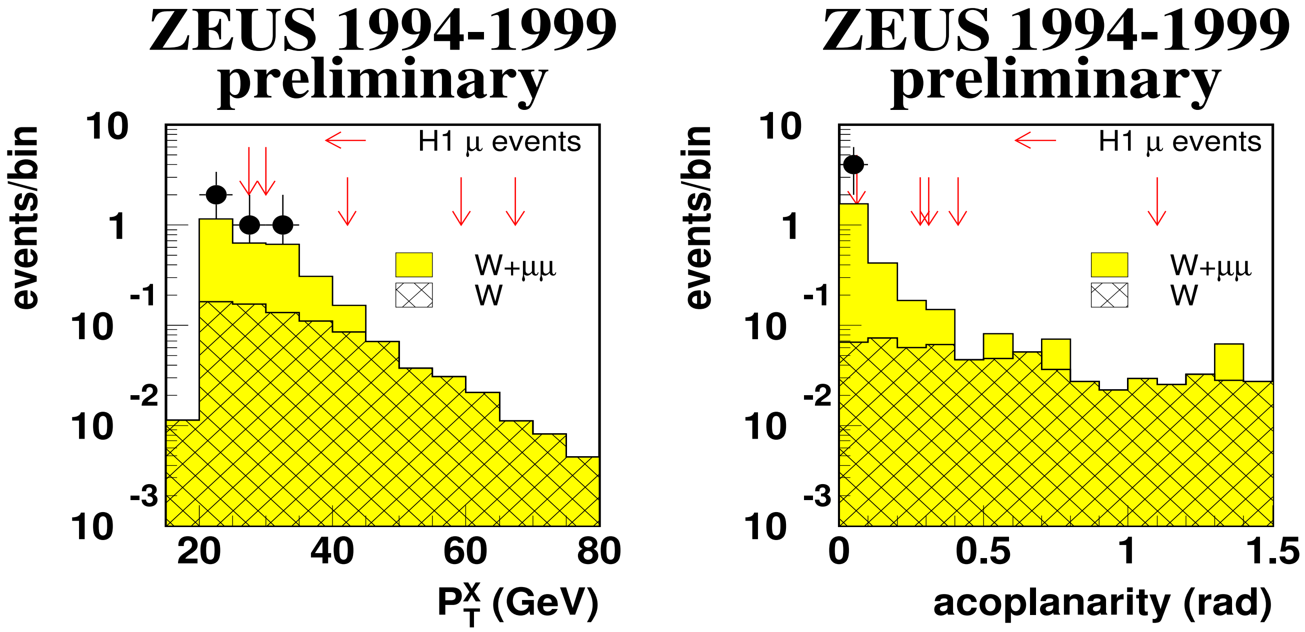
cf. $1.8{\pm}0.4$ (e)

and $0.9{\pm}0.1$ (μ)



A ZEUS muon event

ZEUS combined result : 94 - 99 data

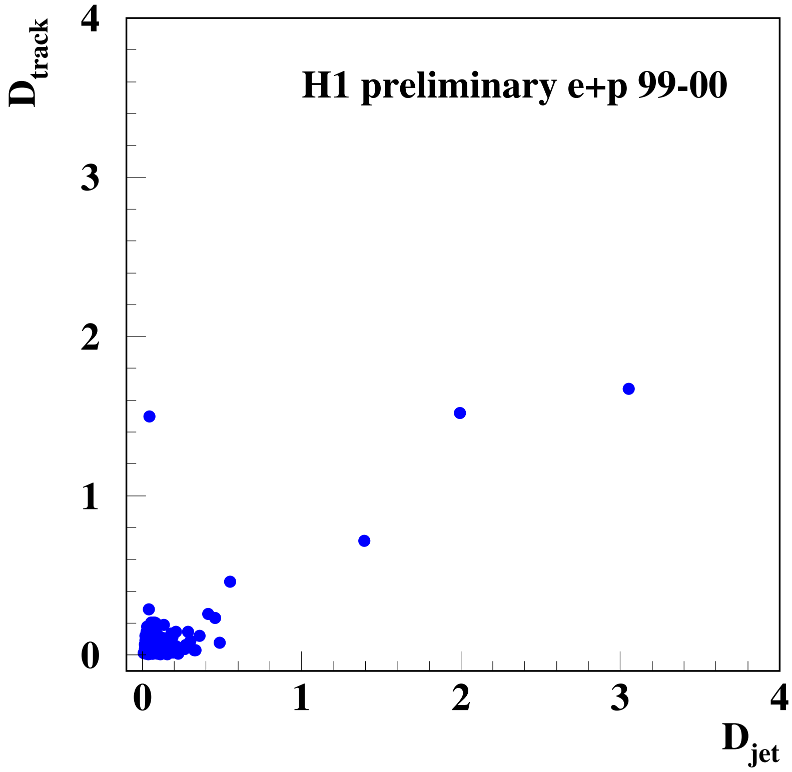


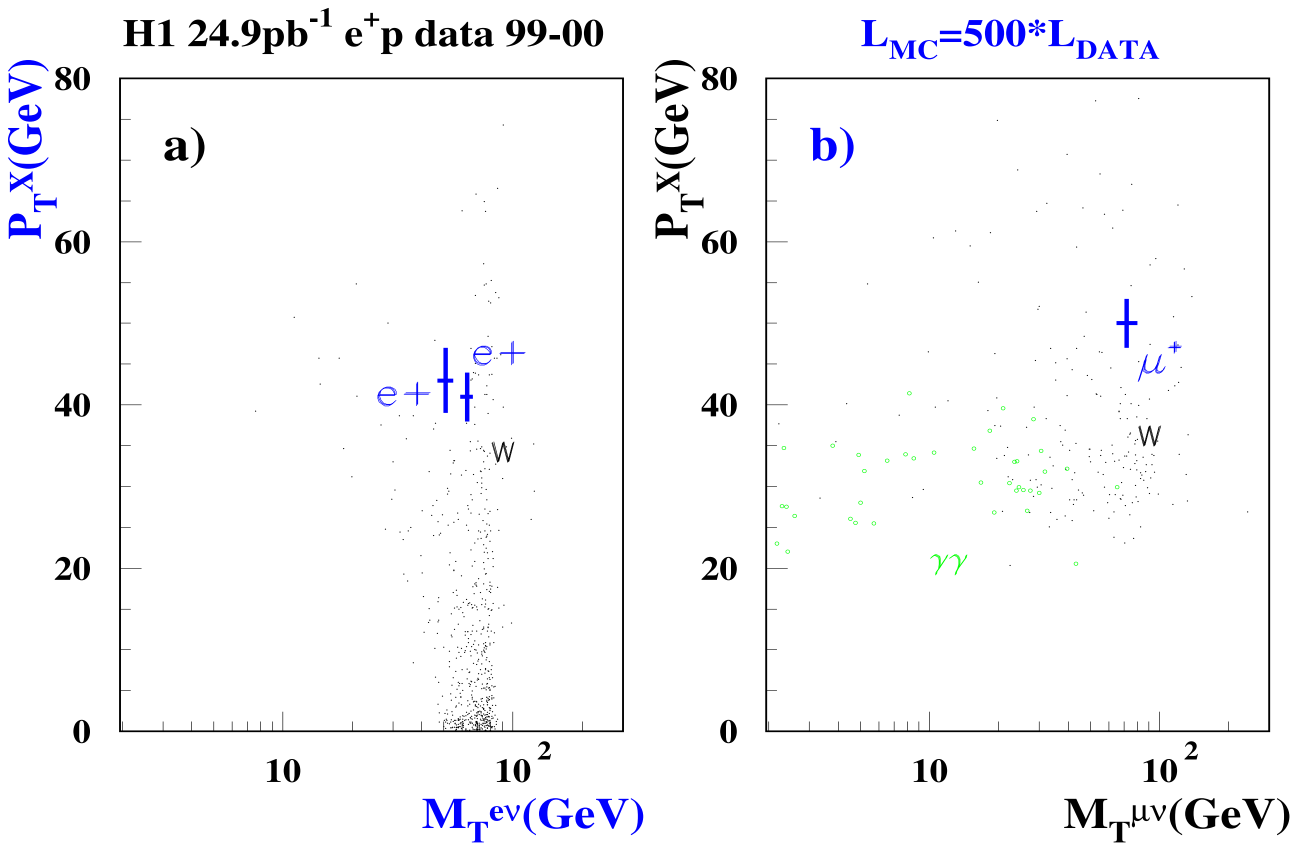
4 muons at low acoplanarity → muon and jet back-to-back

	Electrons	Muons
1994-97 e^+p (48 pb^{-1}, published)	3 (3.5±0.7)	0 (2.0±0.4)
1998-99 e^-p (16 pb^{-1}, preliminary)	2 (0.8±0.4)	0 (0.8±0.1)
1999 e^+p (18 pb^{-1}, preliminary)	2 (1.8±0.4)	4 (0.9±0.1)
Total (82 pb^{-1})	7 (6.1±0.9)	4 (3.7±0.4)

Overall agreement

H1 99-00 result : 24.9 pb^{-1}





H1 99-00 result : 24.9 pb^{-1}

In extended phase space find:

Electron	Data	St. Model	W
$P_T^X > 0$ GeV	2	2.77 ±0.62	1.88 ±0.57
$P_T^X > 12$ GeV	2	1.00 ±0.26	0.75 ±0.22
$P_T^X > 25$ GeV	2	0.60 ±0.17	0.40 ±0.12

P_T^X = Hadronic Recoil

Muon	Data	St. Model	W
$P_T^X > 12$ GeV	3	0.95 ± 0.24	0.74 ± 0.23
$P_T^X > 25$ GeV	1	0.51 ± 0.13	0.42 ± 0.13

H1 : $e + \mu$ channels combined 94-00

$P_T^X > 25$ GeV

Data period	Data	SM
94-97 e^+p ($36.5 pb^{-1}$)	5	1.06±0.26
98-99 e^-p ($12.6 pb^{-1}$)	0	0.49±0.11
99-00 e^+p ($24.9 pb^{-1}$)	3	1.11±0.28
$\Sigma\ e^+$	8	2.17±0.52
$\Sigma\ e^+ + e^-$	8	2.66±0.60

H1 Preliminary

e^+p : Data / SM changed from 5/1.1 to 8/2.2

e^-p : Luminosity too low to draw strong conclusions

Summary : H1 and ZEUS

Events with a high P_T lepton and missing transverse momentum have been observed in both experiments at HERA

Such events are interpreted within the Standard Model as W production with subsequent leptonic decay

Integrated over the period 1994-1999, and both e^+p and e^-p collisions, ZEUS observe 7 events with an electron and 4 events with a muon, in agreement with the SM prediction of 6.1$\pm$0.9 and 3.7$\pm$0.4

Integrated over the period 1994-2000, and both e^+p and e^-p collisions, H1 observe 8 events with an electron or muon, and large hadronic recoil (P_T^X >25 GeV), compared to the SM prediction of 2.66$\pm$0.60

The current e^+p data, and what follows the upgrade will throw more light on these intriguing phenomena