

# Isolated lepton signatures at HERA

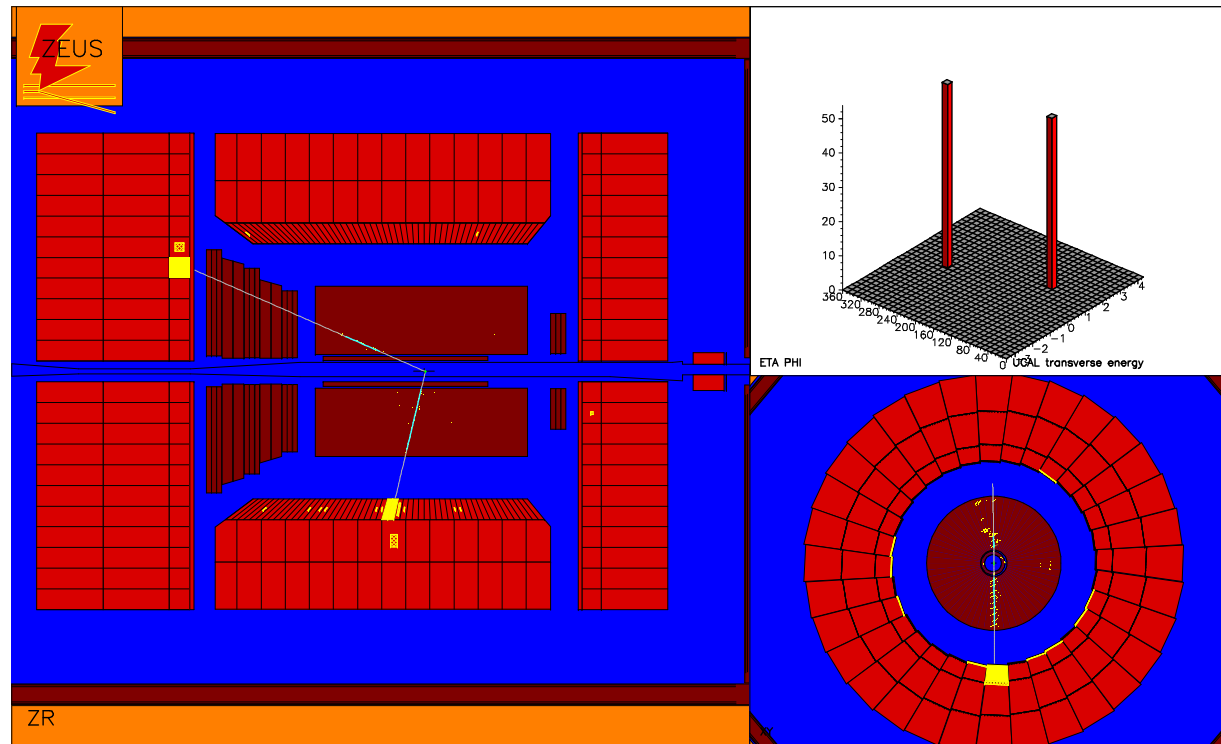
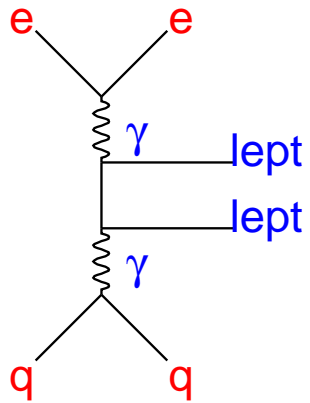
Elisabetta Gallo (INFN Firenze)  
HCP 2002, Karlsruhe, 3.10.2002

- Multilepton signatures
- Isolated lepton and missing  $p_T$  signature

based on  $\simeq 130 \text{ pb}^{-1}$  collected by H1 and ZEUS in 94-00 at  $\sqrt{s} \simeq 300 - 320 \text{ GeV}$

# Search for new physics in multilepton events

Main SM process:

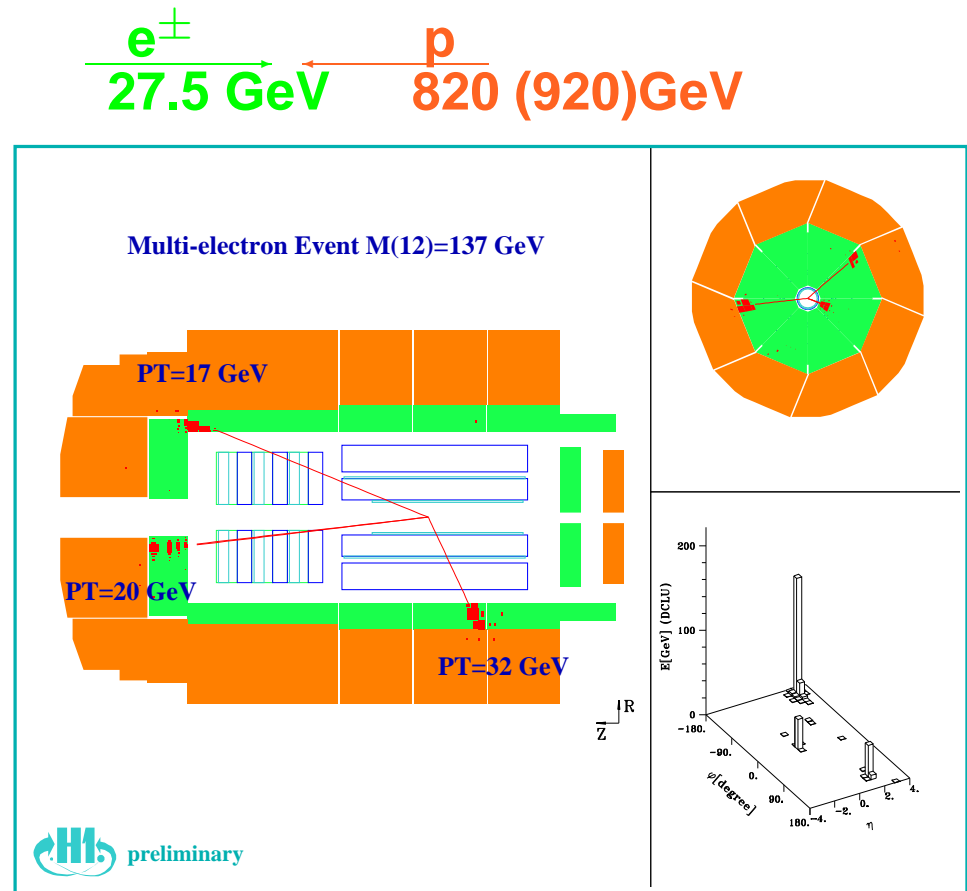


a dielectron event in ZEUS

# Multi-electron events

## Main selection criteria:

- 2 isolated electrons, one with  $p_T > 10 \text{ GeV}$
- **H1:**  $20^\circ < \theta_e < 150^\circ$   
**ZEUS:**  $17^\circ < \theta_e < 164^\circ$   
→ different acceptance for SM expectation
- 3rd electron allowed in  $5^\circ < \theta_e < 175^\circ$



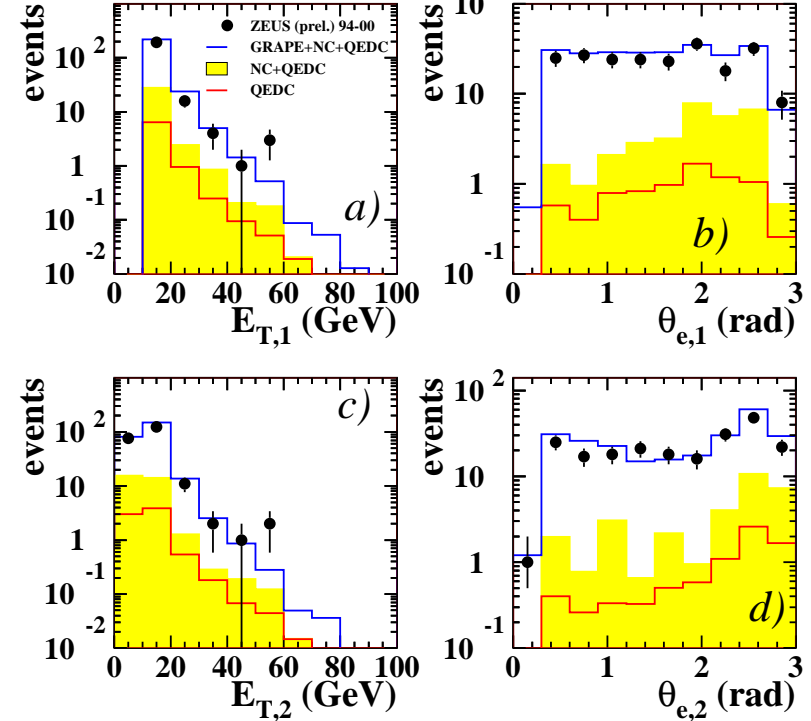
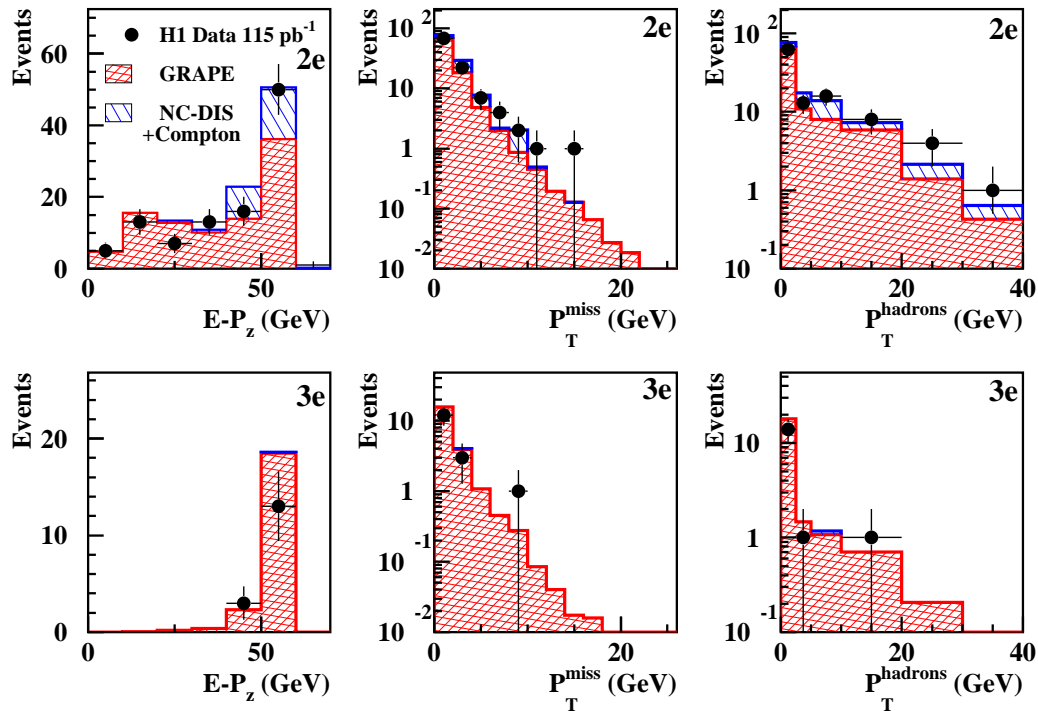
a 3e candidate event in H1

# Multi-electron events

H1 Preliminary

Multi-electron Analysis

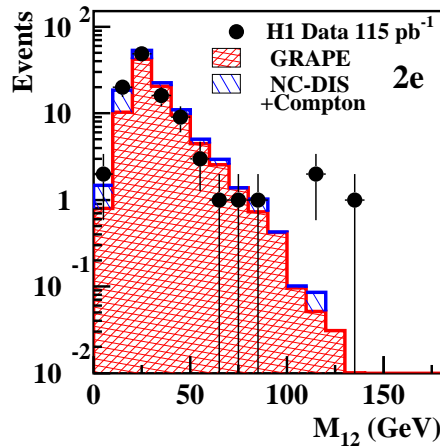
ZEUS



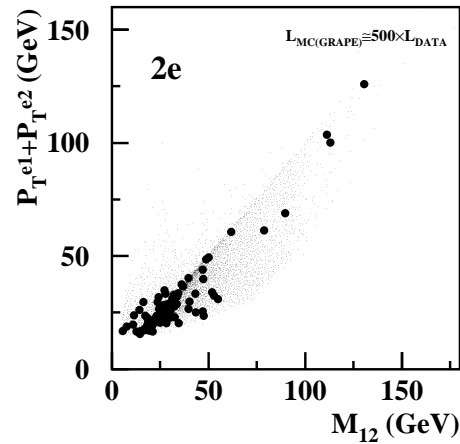
$\approx 100 - 200$  events selected, in general good agreement with the SM

# Multi-electron events

H1 Preliminary



Multi-electron Analysis



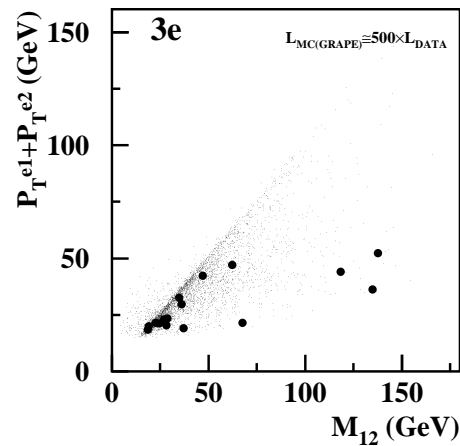
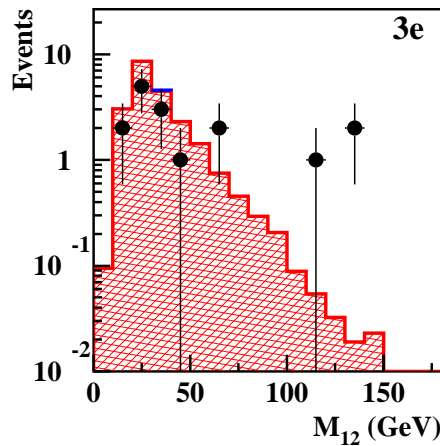
H1 Total

Sample	Data	SM
2 e total	105	$118.2 \pm 12.8$
3 e total	16	$21.6 \pm 3.0$

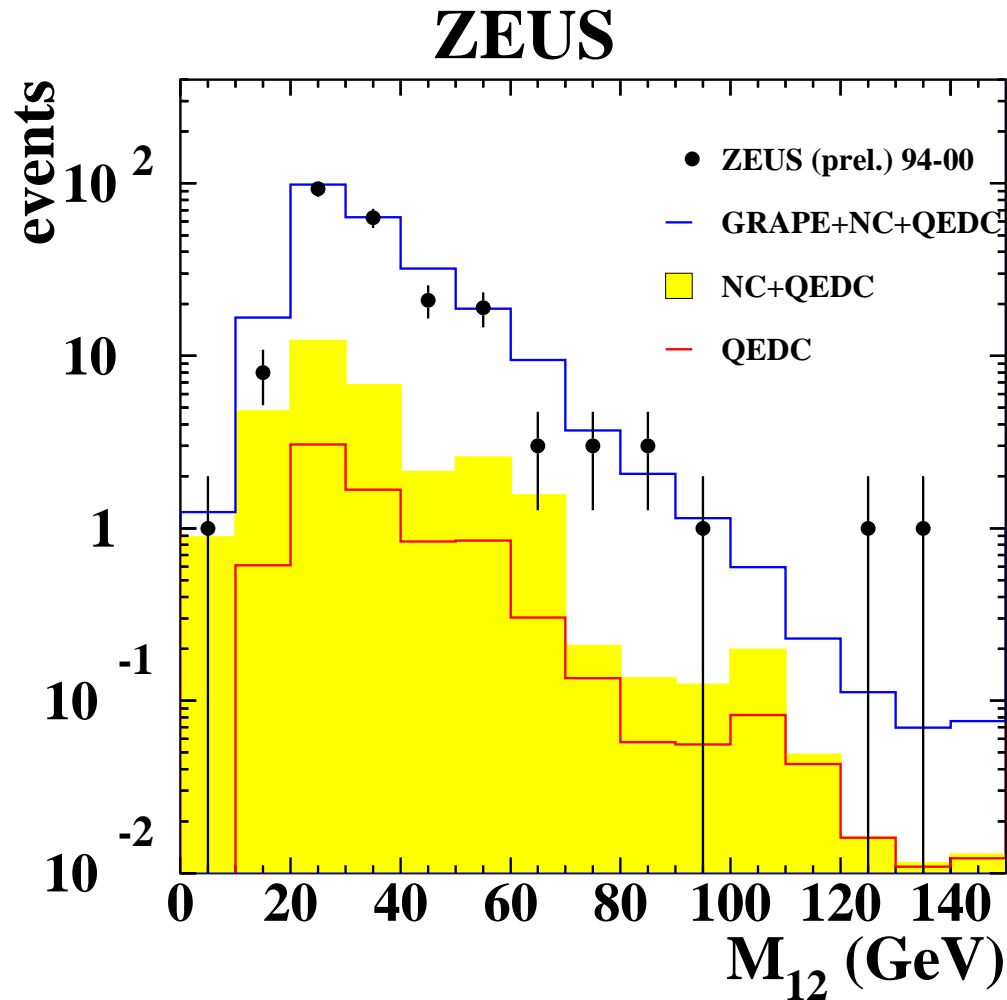
H1  $M_{12} > 100 \text{ GeV}$

Sample	Data	SM
2 e	3	$0.25 \pm 0.05$
3 e	3	$0.23 \pm 0.04$

6 outstanding events at  $M_{12} > 100 \text{ GeV}$



# Multi-electron events



## ZEUS Total

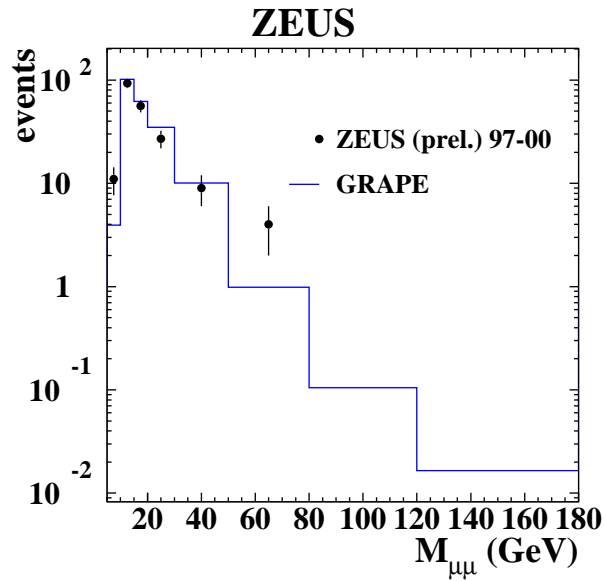
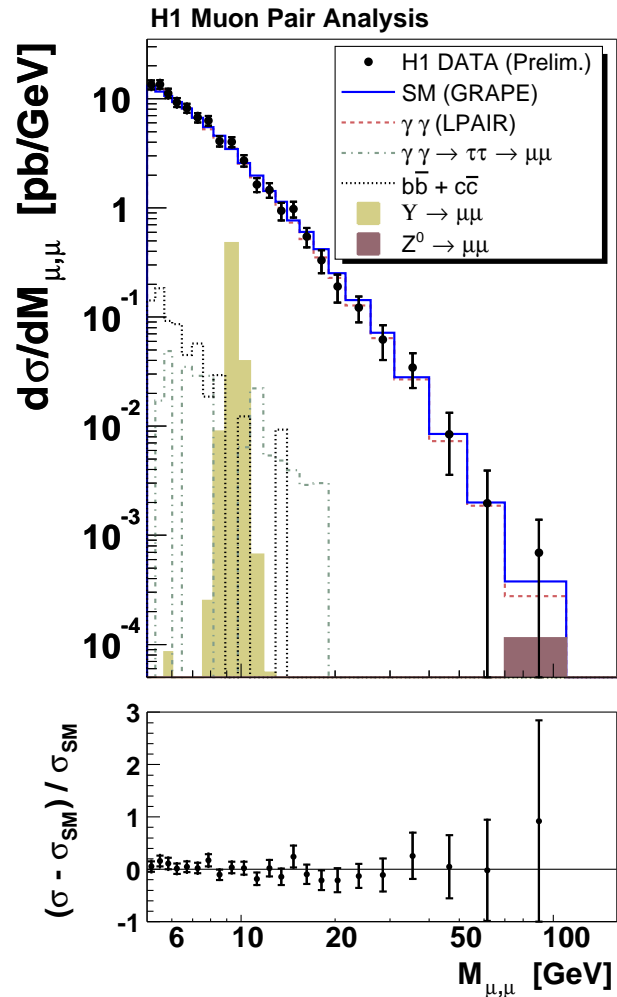
Sample	Data	SM
2 e total	191	$213.9 \pm 3.9$
3 e total	26	$34.7 \pm 0.5$

## ZEUS $M_{12} > 100 \text{ GeV}$

Sample	Data	SM
2 e	2	$0.77 \pm 0.08$
3 e	0	$0.37 \pm 0.04$

Good agreement with the SM prediction

# Dimuon events



Both ZEUS and H1 see no dimuon-events at  $M_{12} > 100 \text{ GeV}$

From the  $3ee$  events observed, H1 expects

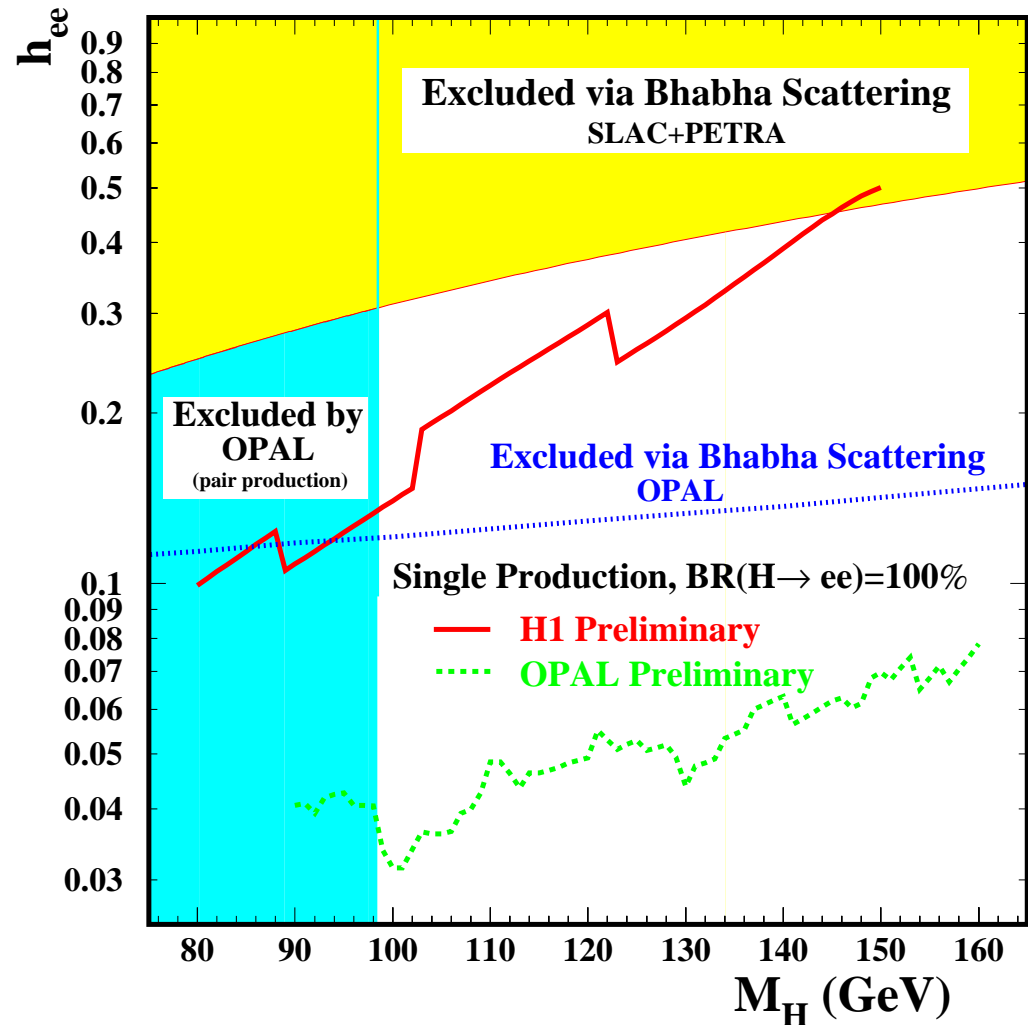
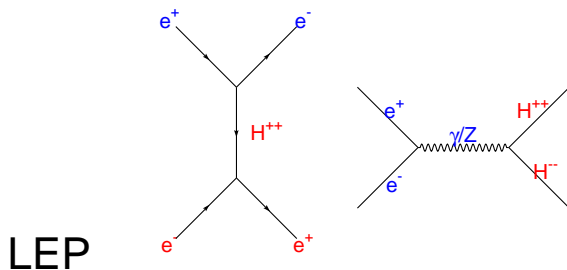
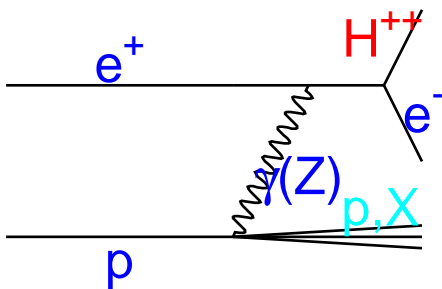
$$3 \cdot \frac{\mathcal{L}\epsilon(\mu\mu)}{\mathcal{L}\epsilon(ee)} \simeq 1 \mu\mu, \text{ comparison not conclusive}$$

# Doubly charged Higgs at HERA

Possible BSM interpretation:

$$e^+p \rightarrow e^- H^{++} X, H^{++} \rightarrow l^+ l^+$$

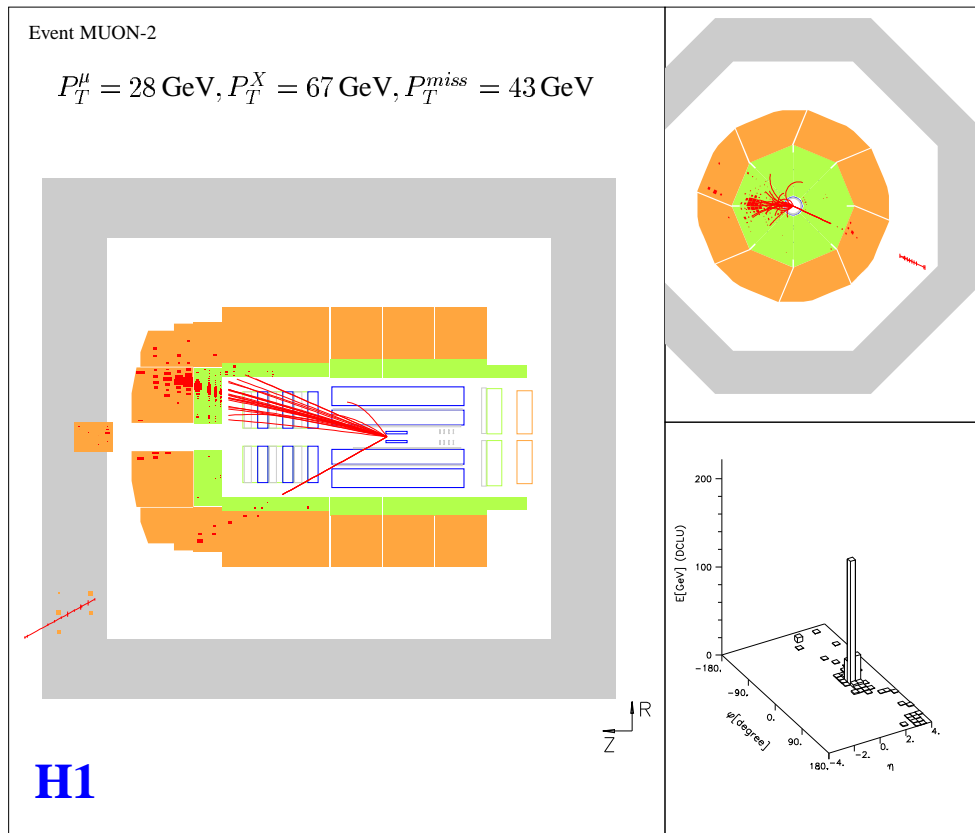
dedicated search by H1: large ( $p_t^{e1} + p_t^{e2}$ ), same-charge leptons, 1 event passes the cuts





# Isolated lepton and missing $p_T$ events at HERA

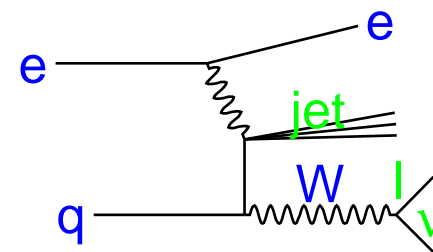
$$e^+p \rightarrow \mu^+ X$$



Spectacular events found by H1  
in  $e^+p$  collisions

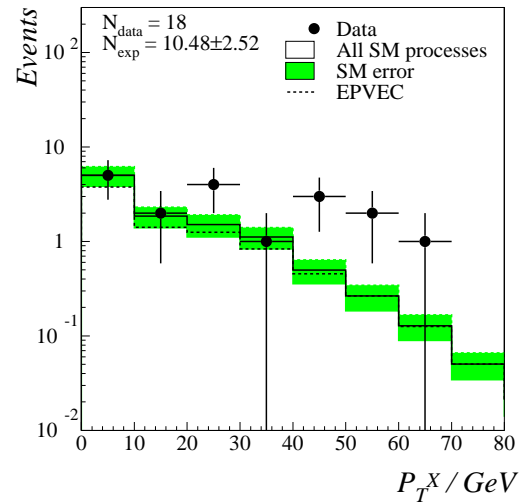
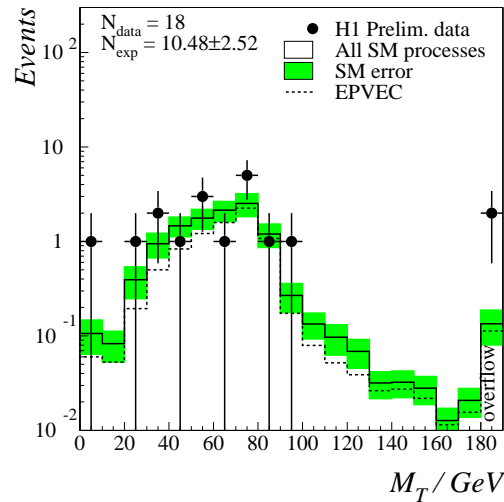
1 isolated lepton ( $\mu, e$ ),  
with high  $p_T$ ,  $p_T^{\text{miss}}$ , jet (X)

Main SM process:



$p_T^X$ , transverse momentum of the hadronic jet

# Isolated lepton events in H1

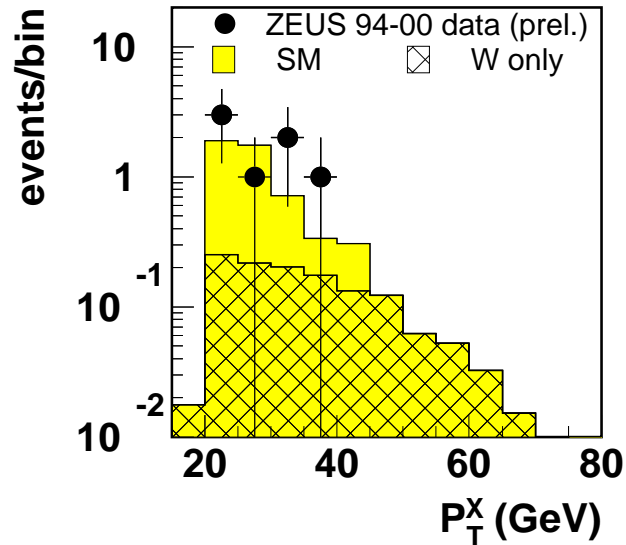


H1 preliminary 94-00 $e^+p$ ( $101.6 \text{ pb}^{-1}$ )	Electron obs./exp. (W)	Muon obs./exp. (W)
$p_T^X > 25 \text{ GeV}$	4 / $1.29 \pm 0.33$ (1.05)	6 / $1.54 \pm 0.41$ (1.29)
$p_T^X > 40 \text{ GeV}$	2 / $0.41 \pm 0.12$ (0.40)	4 / $0.58 \pm 0.16$ (0.53)

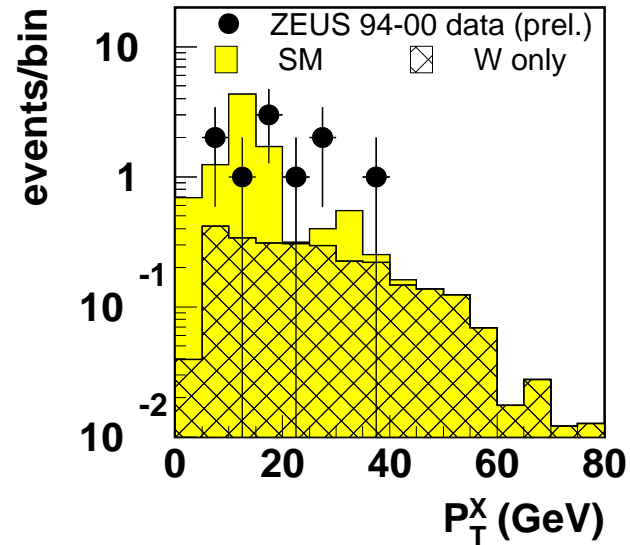
Excess at high  $p_T^X$  (transverse momentum of hadronic jet) seen

# Isolated lepton events in ZEUS

Preselection  $\mu$ -events



$e$ -events



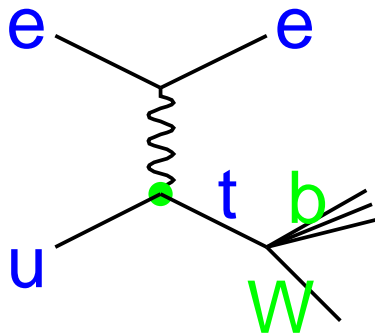
ZEUS preliminary 94-00 $e^\pm p$ ( $130.5 \text{ pb}^{-1}$ )	Electron obs./exp. (W)	Muon obs./exp. (W)
$p_T^X > 25 \text{ GeV}$	1 / $1.14 \pm 0.06$ (1.10)	1 / $1.29 \pm 0.16$ (0.95)
$p_T^X > 40 \text{ GeV}$	0 / $0.46 \pm 0.03$ (0.46)	0 / $0.50 \pm 0.08$ (0.41)

Good agreement seen with the SM

# Isolated leptons in H1

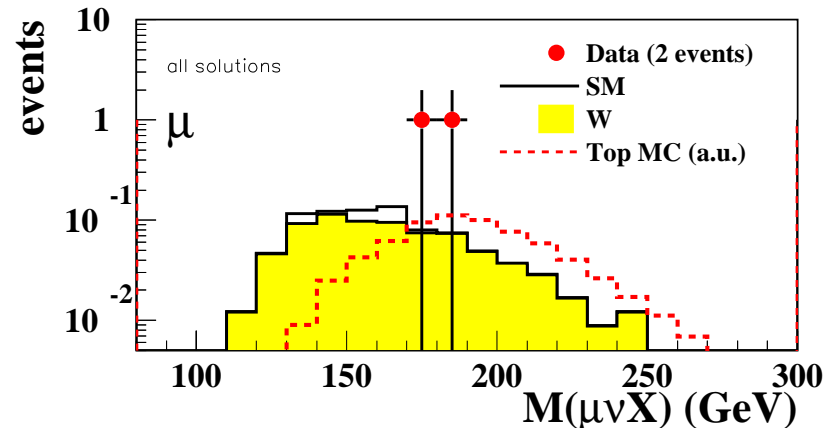
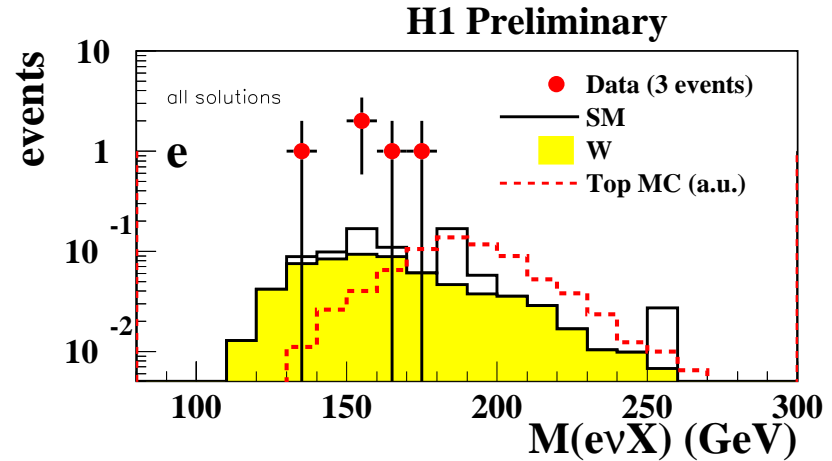
Possible BSM interpretation:

single-top production with anomalous  $k_{tu\gamma}$  FCNC coupling (SM cross-section  $1fb^{-1}$ )



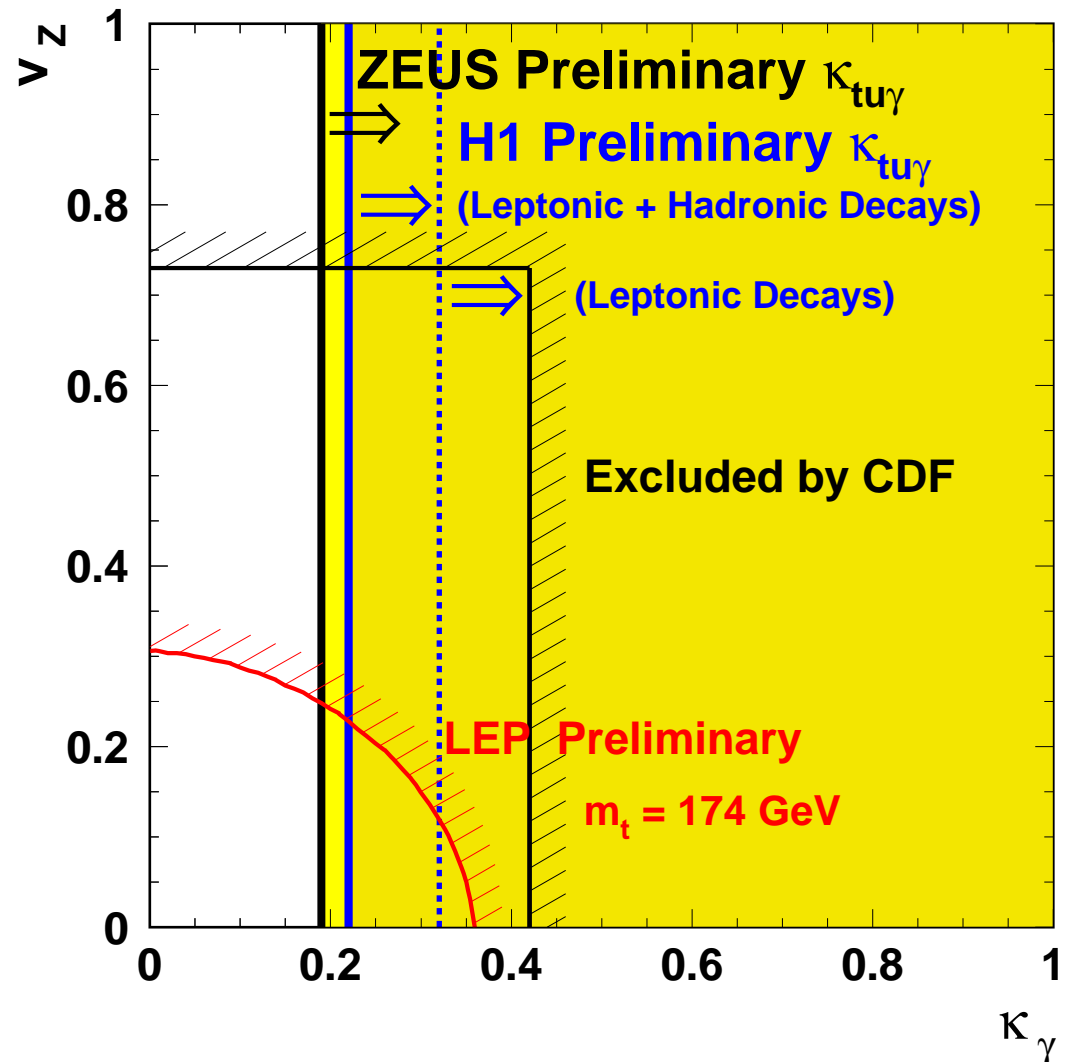
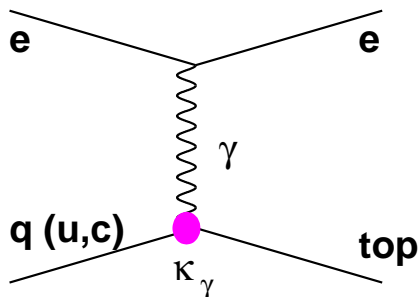
Heavy top mass  $\rightarrow$  high  $p_T^X$

Apply additional top-selection cuts: 5 events (3e, 2 $\mu$ ) survive



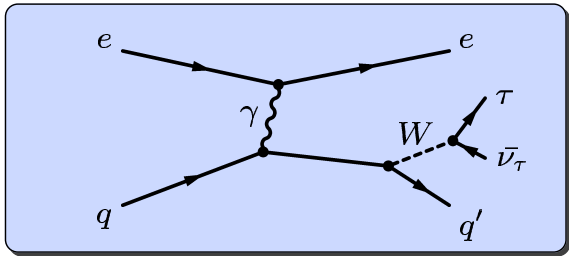
# Limits on FCNC

- No deviation from SM is seen in the **W hadronic-decay** channel (not shown)
- No deviation from SM is seen by ZEUS
- → put limits on the **FCNC coupling**

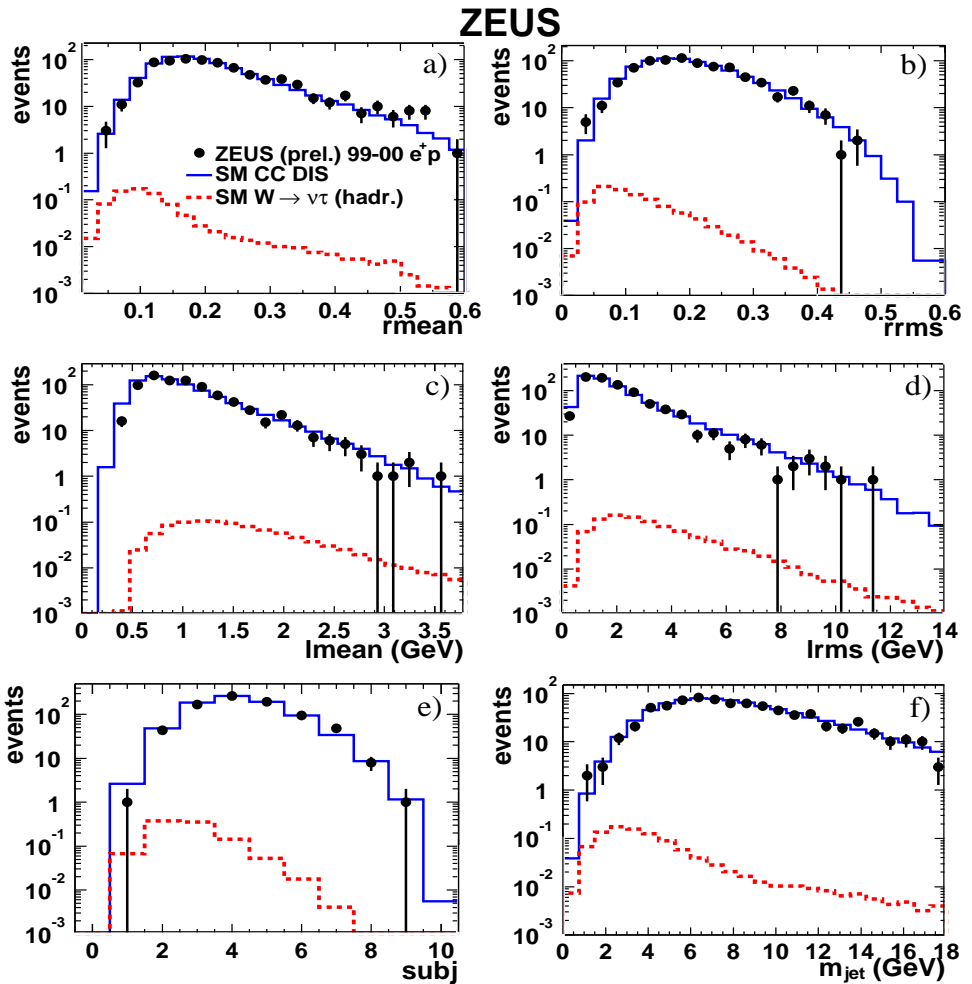


# Isolated $\tau$ events in ZEUS

Previous search extended to the  $\tau$  (hadronic decay)

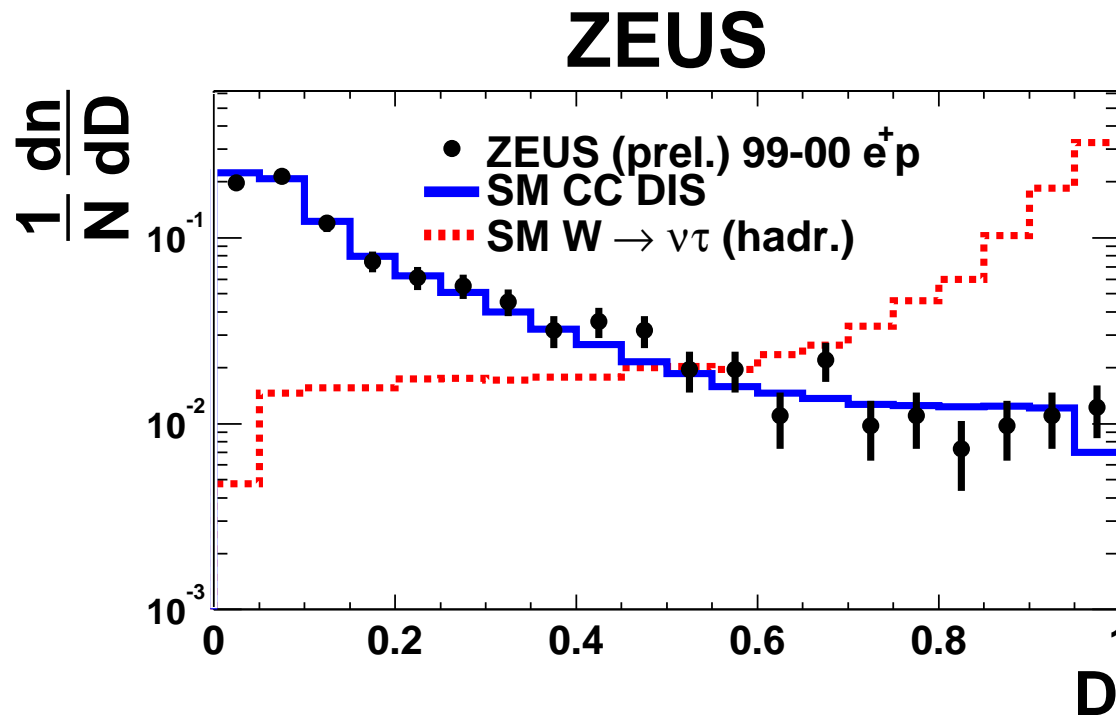


Pencil-like jets, low multiplicity, 6 variables used to discriminate them from quark/gluon-induced jets



# $\tau$ -discriminator

Define a discriminator  $D$  from these 6 observables (see B. Koblitz's talk tomorrow)



$D \rightarrow 0$ , CC DIS-jets candidate

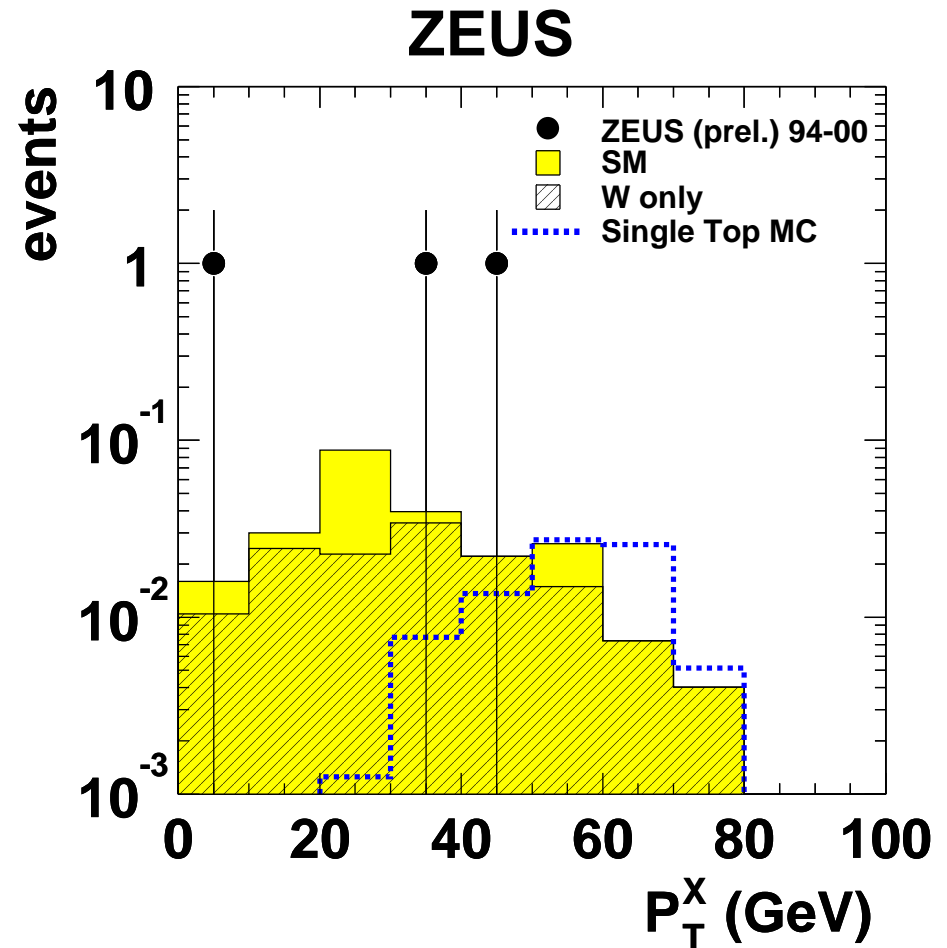
$D \rightarrow 1$ ,  $W \rightarrow \nu\tau$ -jets candidate

$\tau$ -jets selected with high-efficiency and good separation from CC-DIS

# Isolated $\tau$ events in ZEUS

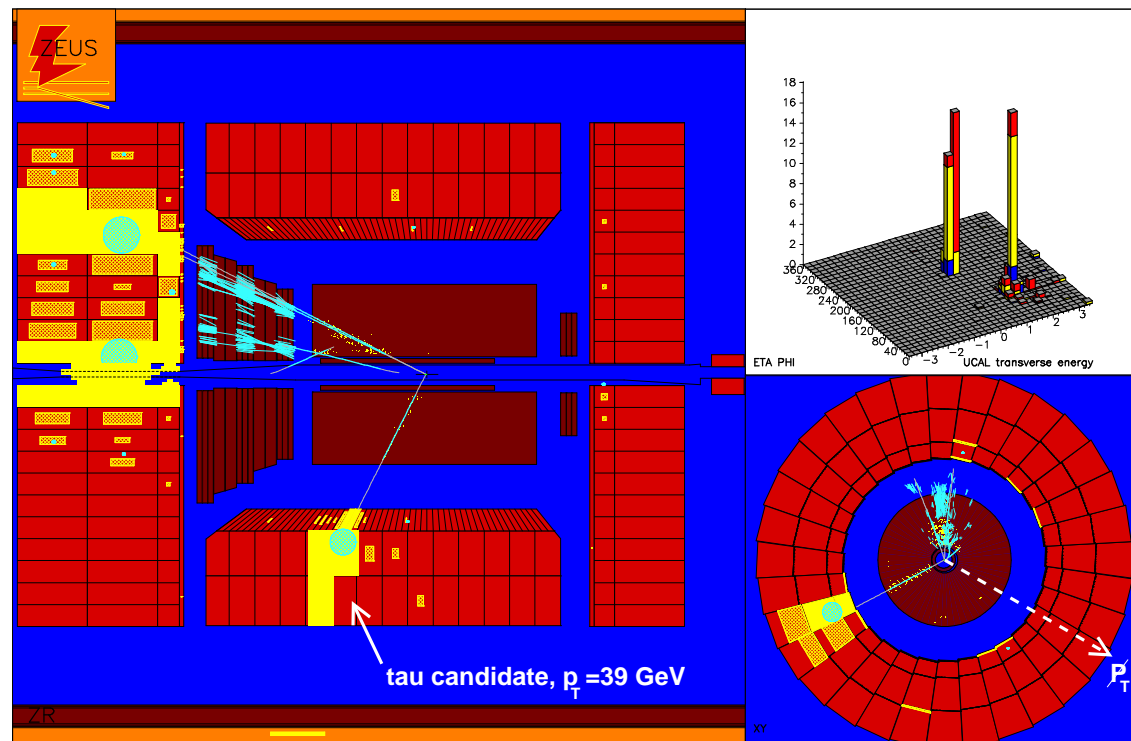
Back to our isolated tracks:

- Standard isolated track + missing  $p_T$  selection
- exclude tracks which are either  $e$  or  $\mu$
- to remaining tracks apply  $D > 0.95$   
3 events observed/ $0.23 \pm 0.06$  expected
- $p_T^X > 25 \text{ GeV}$   
2 events observed/ $0.12 \pm 0.02$  expected (Poisson prob= $6.4 \times 10^{-3}$ )



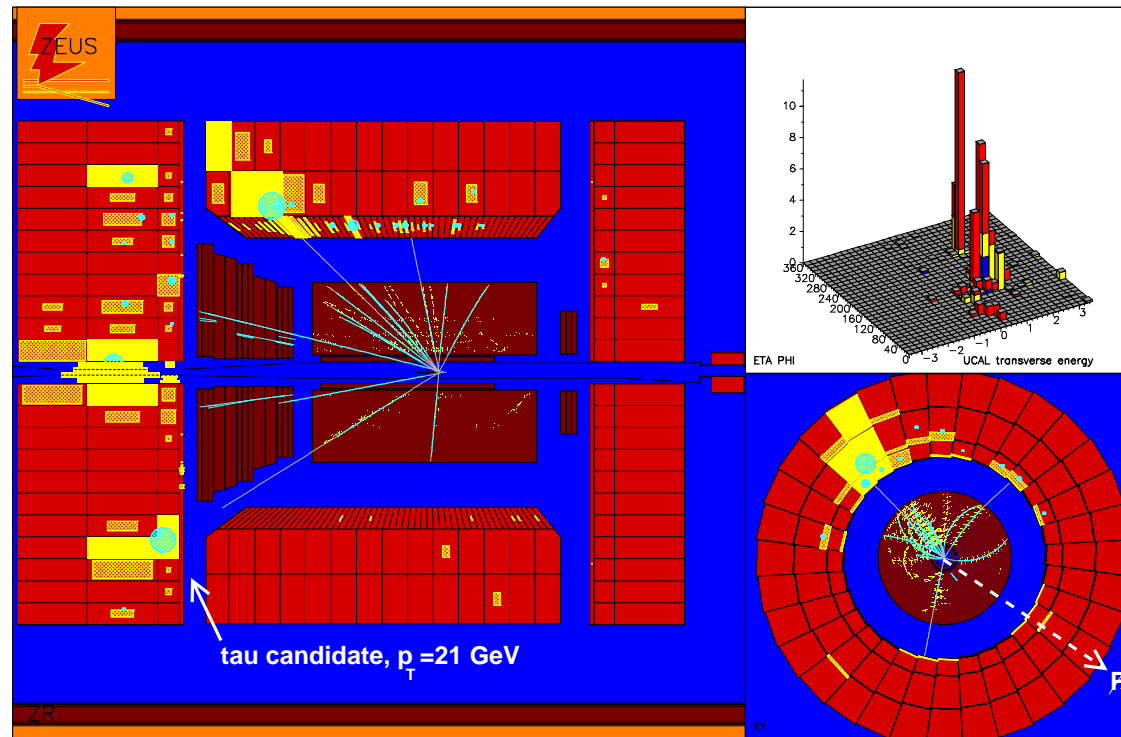


# $\tau$ -candidate 1 (1999 $e^+p$ data)



$$p_T^{miss} = 39 \text{ GeV}, p_T^X = 37 \text{ GeV}, p_{\tau-jet} = 39 \text{ GeV}, M_T = 68 \text{ GeV}$$

# $\tau$ -candidate 2 (1999 $e^+p$ data)



$$p_T^{miss} = 37 \text{ GeV}, p_T^X = 48 \text{ GeV}, p_{\tau-jet} = 21 \text{ GeV}, M_T = 32 \text{ GeV}$$

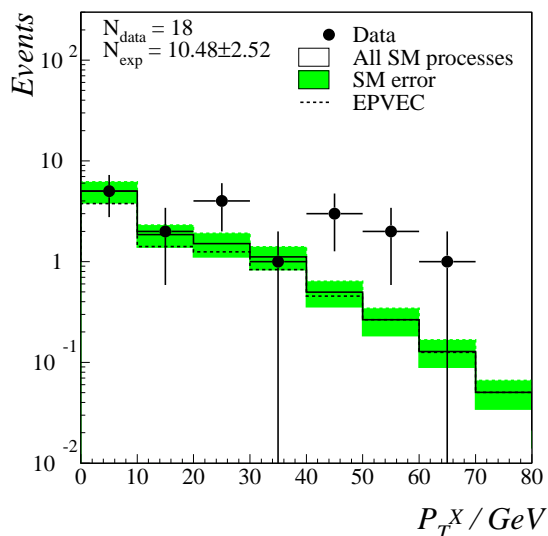
These 2  $\tau$ -events are unlikely to be explained by single-top anomalous production, as their cross-section is higher than the excluded cross section of  $\sigma(ep \rightarrow etX) < 0.25 \text{ pb}(\sqrt{s} = 320 \text{ GeV})$ , obtained from the  $e/\mu/jet$ -channels.

# Summary on isolated leptons at HERA I

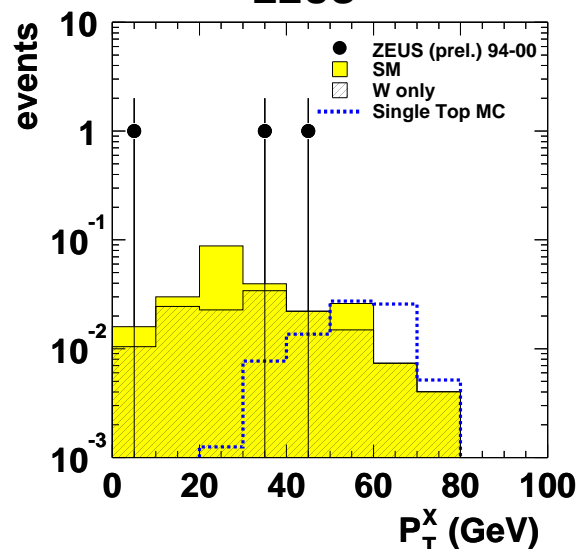
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ZEUS preliminary 94-00 $e^\pm p$ ( $130.5 \text{ pb}^{-1}$ )	Electron obs./exp. (W)	Muon obs./exp. (W)	Tau obs./exp. (W)
$p_T^X > 25 \text{ GeV}$	1 / $1.14 \pm 0.06$ (1.10)	1 / $1.29 \pm 0.16$ (0.95)	2 / $0.12 \pm 0.02$ (0.10)
$p_T^X > 40 \text{ GeV}$	0 / $0.46 \pm 0.03$ (0.46)	0 / $0.50 \pm 0.08$ (0.41)	1 / $0.06 \pm 0.01$ (0.05)

H1(e and  $\mu$  events)



ZEUS



# Summary

Interesting puzzles from HERA I data from search for new physics with isolated leptons events:

- H1 observes  $3ee$  and  $3eee$  outstanding events with  $M_{12} > 100 \text{ GeV}$ , not compatible however with a doubly-charged Higgs signal
- H1 observes 6 events with isolated  $e, \mu$ , missing  $p_T$  and high  $p_T^X > 40 \text{ GeV}$ , ZEUS observes 2 isolated  $\tau$  events, with  $p_T^X > 25 \text{ GeV}$ . These 2  $\tau$ -events are unlikely to be explained by single-top anomalous production.

Looking forward to the high luminosity with HERA II