Isolated High Energy Lepton and Missing Transverse Momentum at ZEUS

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Outline

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2) 1994–1997 W analysis
3) 1994–2000 Inclusive analysis
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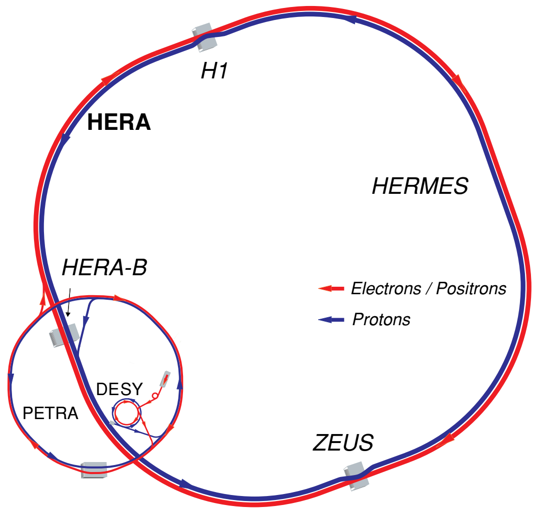
Introduction

HERA

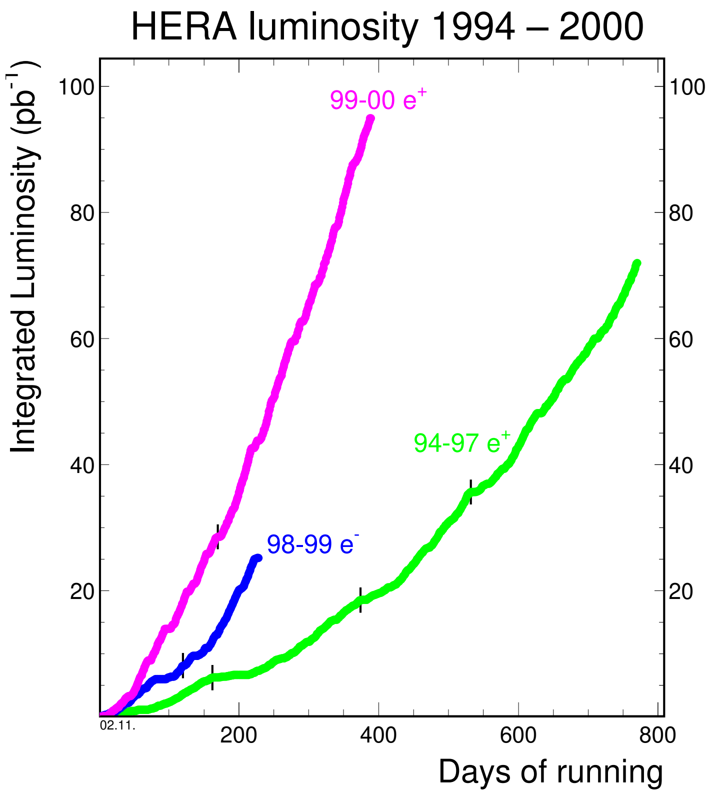
Electron proton collider at DESY, Hamburg:

- $E_e = 27.5$ GeV.
- $E_p = 920$ (820) GeV.
- $E_{cm} = 318$ (300) GeV.



ZEUS Data

- 1994 – 1997: e^+p at $E_{cm} = 300$ GeV
  48 pb^{-1}
- 1998 – 1999: e^-p at $E_{cm} = 318$ GeV
  16 pb^{-1}
- 1999 – 2000: e^+p at $E_{cm} = 318$ GeV
  66 pb^{-1}

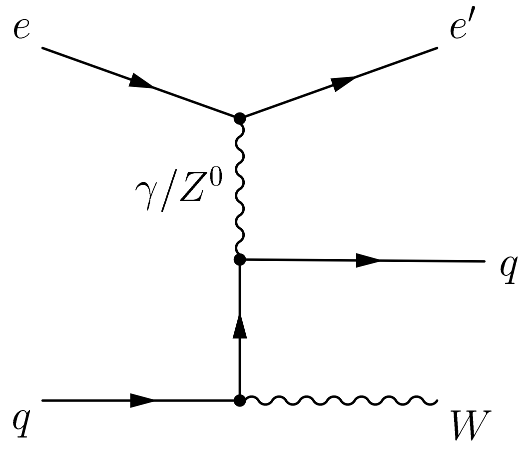


Sensitivity to rare Standard Model physics processes, e.g. single-W production.

Single-W production

- Rare Standard Model process at HERA.
  - $\sigma(ep \to eW^{\pm}X) \simeq 1.0$ pb
    (leading order calculation, EPVEC)
  - Uncertainties on proton/photon structure functions and QCD scale give $\simeq$ 30% uncertainty on W cross section
  - NLO calculation is underway.
    (M. Spira, HERA MC workshop, p.623)
  - Leptonic decay of W results in an event with high-energy lepton and missing transverse momentum.
  - Event distribution falls off sharply as hadronic transverse momentum increases.

single-W production



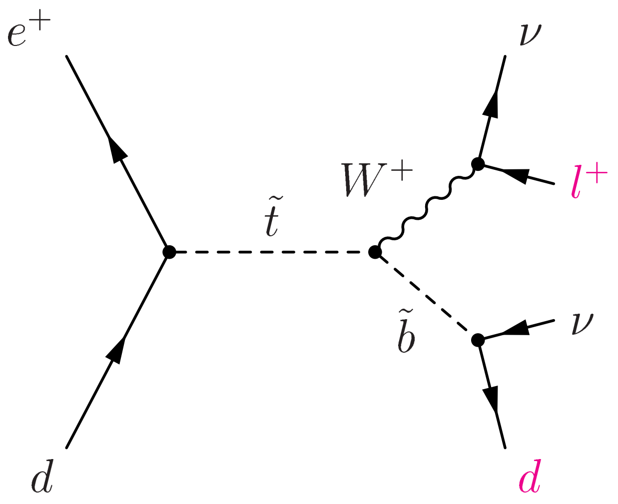
New physics

Single-W production and its leptonic decay is a major background to searches for new physics which has the same final state, e.g.

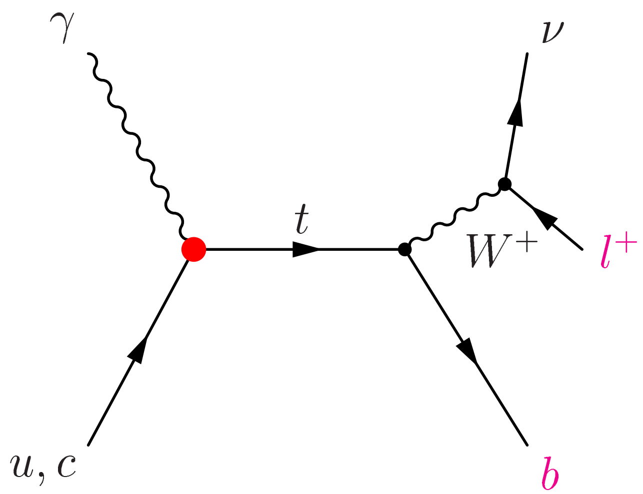
- R-parity violating supersymmetry.
- single-top production through anomalous flavour changing neutral current coupling.

➠ Both example expects large hadronic transverse momentum

Stop and sbottom production

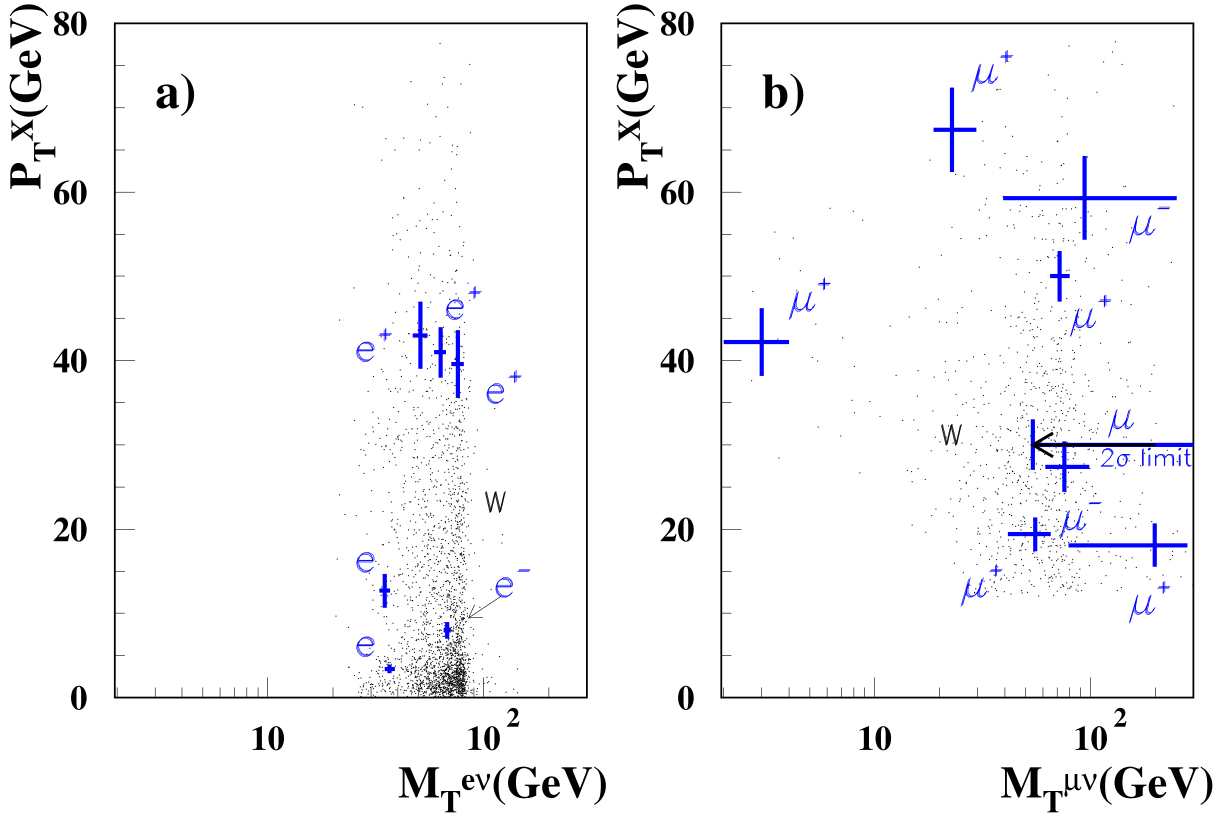


Single top production



H1 events with lepton and missing transverse momentum

- H1 observed interesting events in 81.6 pb^{-1} of e^+p data. (up to summer 2000)
- 9 events (3 e, 6 μ) observed in $P_T^X > 25$ GeV, where SM prediction is small.



- Expectation from SM processes is 2.3 (1.1 e, 1.2 μ), W contribution is 1.8

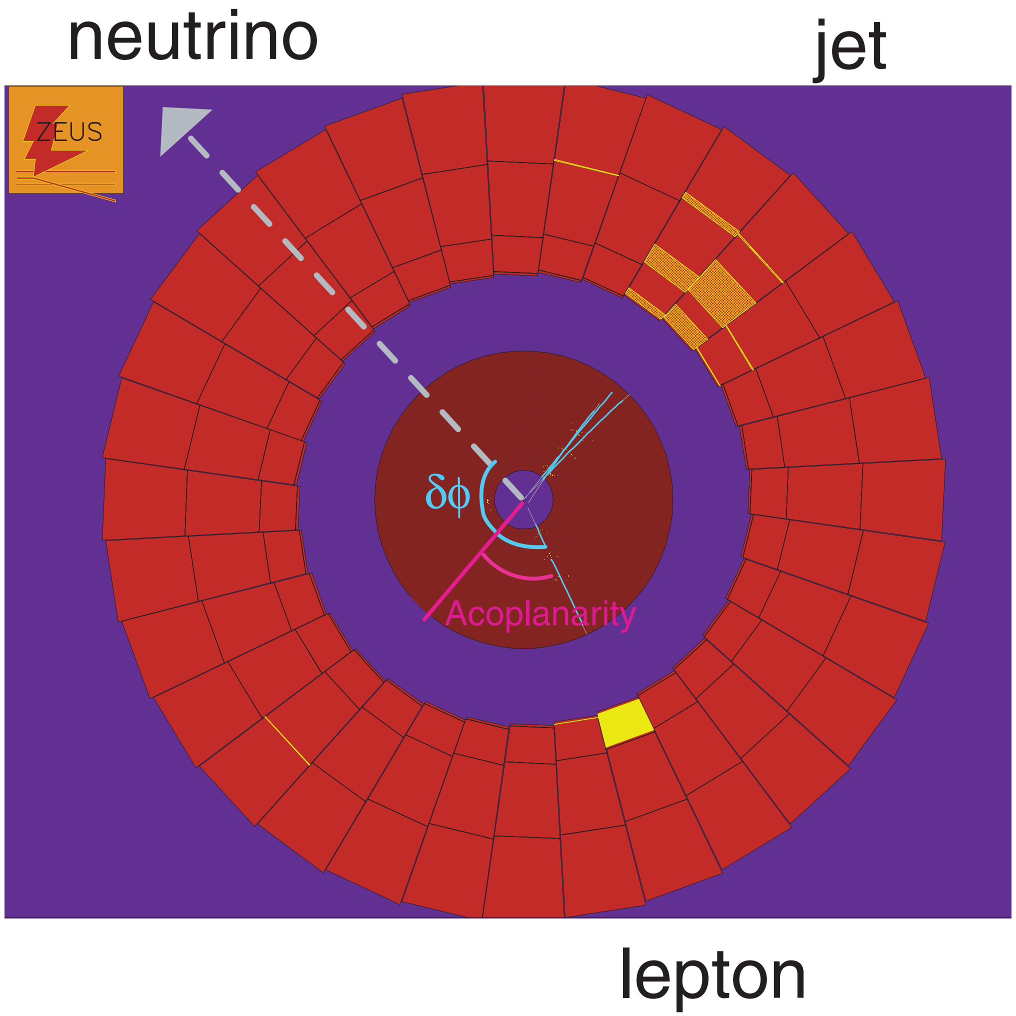
See the following talk on H1 results by C. Diaconu.

1994–1997 W analysis

Searched for single-W production using leptonic channels with 48 pb^{-1} of 1994–1997 data. Phys. Lett. B471 (2000) 411

$W \to l\nu$ kinematics

- $P_T^{\mathrm{CAL}} = \sqrt{\overrightarrow{P_X}^2 + \overrightarrow{P_Y}^2}$
  $\overrightarrow{P_X} = \sum E_i \sin\theta_i \cos\phi_i$
  $\overrightarrow{P_Y} = \sum E_i \sin\theta_i \sin\phi_i$
- $P_T^X = P_T^{\mathrm{CAL}}$ without lepton
  $\Rightarrow$ small P_T^X for $W \to l\nu$
- *Acoplanarity* $= \pi - |\phi_l - \phi_h|$
  $\Rightarrow \sim 0$ for NC DIS
- $M_T = \sqrt{2P_T^l \not{P}_T \,(1 - \cos(\delta\phi))}$
  for e, $\not{P}_T = P_T^{\mathrm{CAL}}$
  for μ, $\not{P}_T = |\overrightarrow{P_T^X} + \overrightarrow{p_t^{track}}|$
  $\Rightarrow$ Jacobian peak for $W \to l\nu$



e-channel

Main selection cuts

- $P_T^{CAL} > 20$ GeV
- $P_T^e > 10$ GeV
- $\theta^e < 1.5$ rad.
- $Acoplanarity > 0.3$ rad.

Results

Data: 3

W MC: 2.1 $(\epsilon = 38\%)$

B.G. MC: 1.1 $\pm$ 0.3 (NC/CC DIS)

Cross section evaluation:

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

Cross section limit:

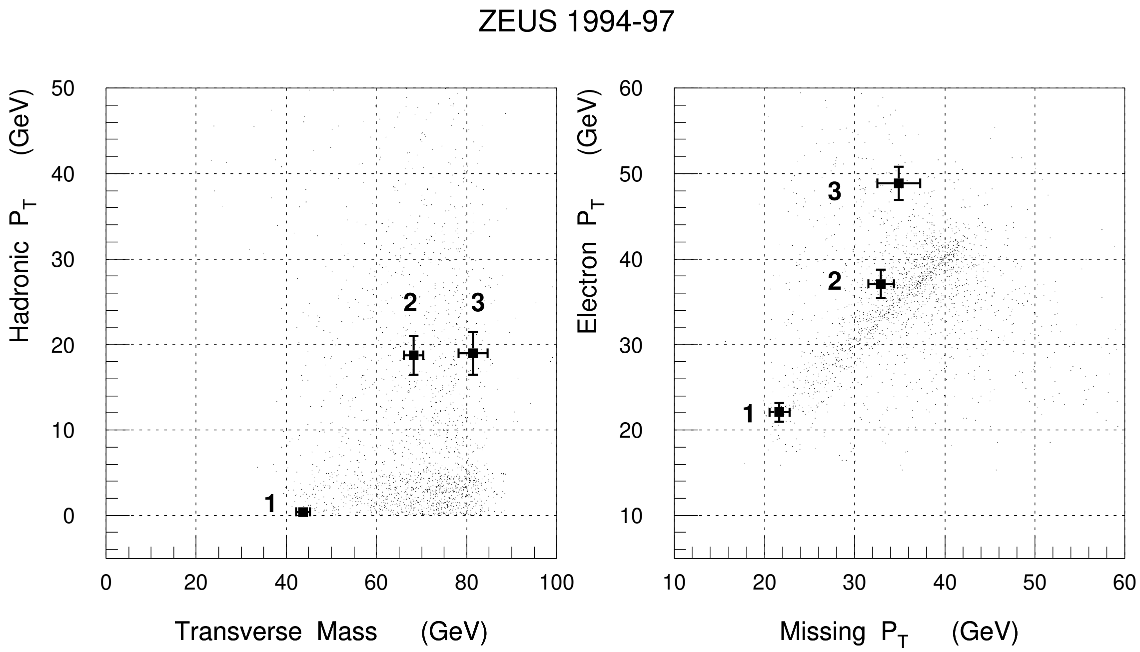
< 3.3 pb @95% CL

... e-channel

Event kinematics

• : $W \to e\nu$, ▪ : data,
MC stat. = 1000 x Data $\mathcal{L}$

Data points are in agreement with W kinematics



μ-channel

Main selection cuts

- $P_T^{CAL} > 15$ GeV
- $p_t^{track} > 5$ GeV
- $\theta^{\mu} < 2.$ rad.
- MIP cluster in Calorimeter

Results

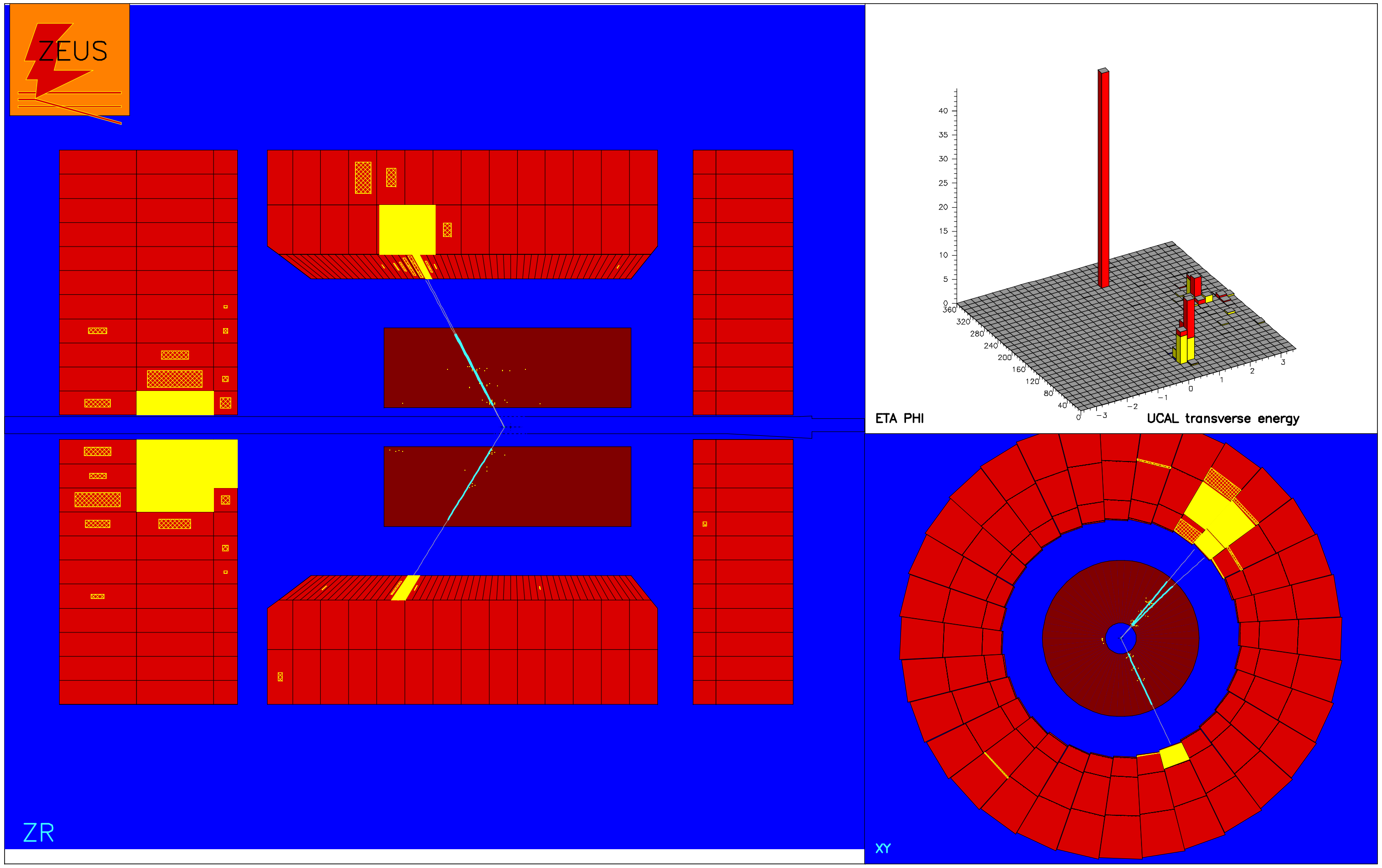
Data: 0
W MC: 0.76 $(\epsilon = 13\%)$
B.G. MC: 0.65 ± 0.22 (CC DIS/di-muon)

Cross section limit:

$\sigma(W) <$ 3.7 pb @95% CL

Event display: $W \to e\nu$

P_T=34.9 GeV, P_T^X=19.0 GeV, M_T=81.4 GeV, E_T^e=48.8 GeV



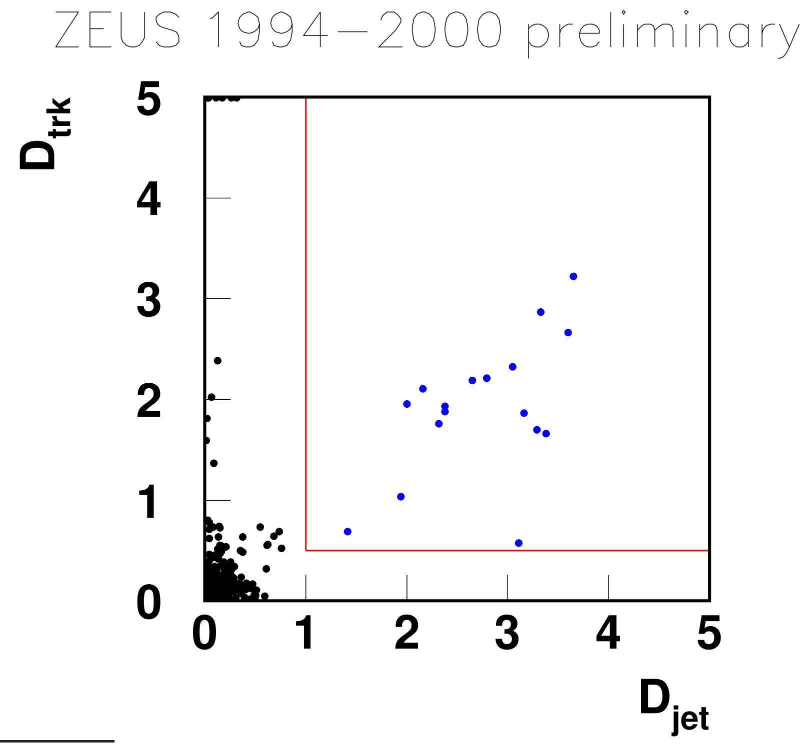
1994–2000 Inclusive analysis

So far no excess; with 82pb^{-1} of 1994–1999 data

Update with 48pb^{-1} of 2000 data

Search for high-p_t tracks in large P_T^{CAL} sample

- $P_T^{CAL} > 25$ GeV
- $p_t^{track} > 10$ GeV



Check isolation of high-p_t tracks with respect to other tracks (D_{track}) and jets (D_{jet}) $D_{track/jet} = \sqrt{\Delta\eta^2 + \Delta\phi^2}$

10 e and 7 μ

(2 e and 3 μ from 2000 data)

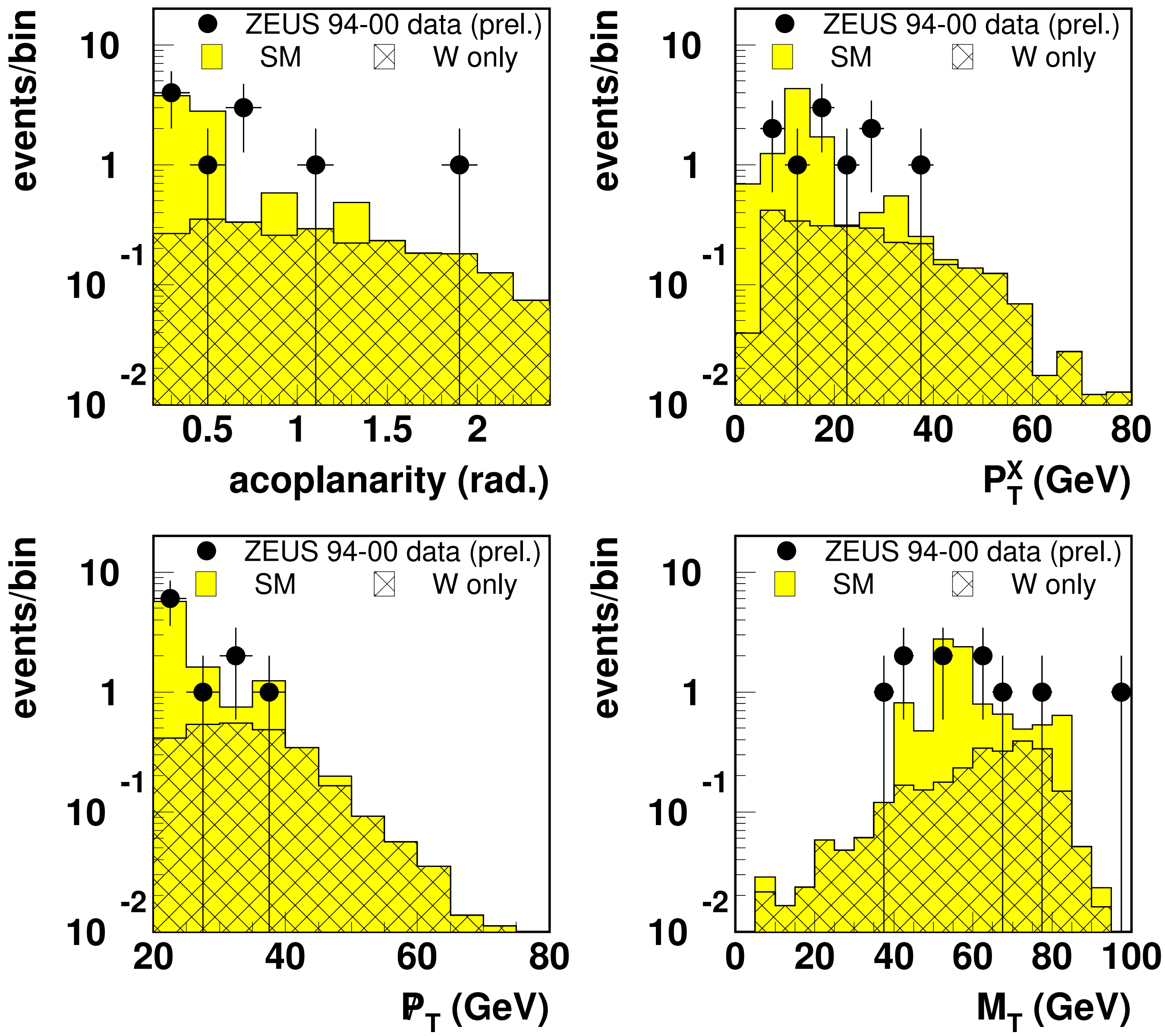
Event rate consistent with SM prediction

ZEUS preliminary 1994–2000	Electrons Observed/expected (W)	Muons Observed/Expected (W)
e^+p 114 pb^{-1}	7 / 9.9±1.6 (2.4)	7 / 4.6±0.6 (1.1)
e^-p 16 pb^{-1}	3 / 1.1±0.4 (0.3)	0 / 0.8±0.1 (0.2)
Total 130 pb^{-1}	10 / 11.0±1.6 (2.7)	7 / 5.4±0.7 (1.3)

Event Kinematics: e

- Event kinematics consistent with SM predictions.

- NC DIS is dominant
  - Small acoplanarity
  - Small missing P_T

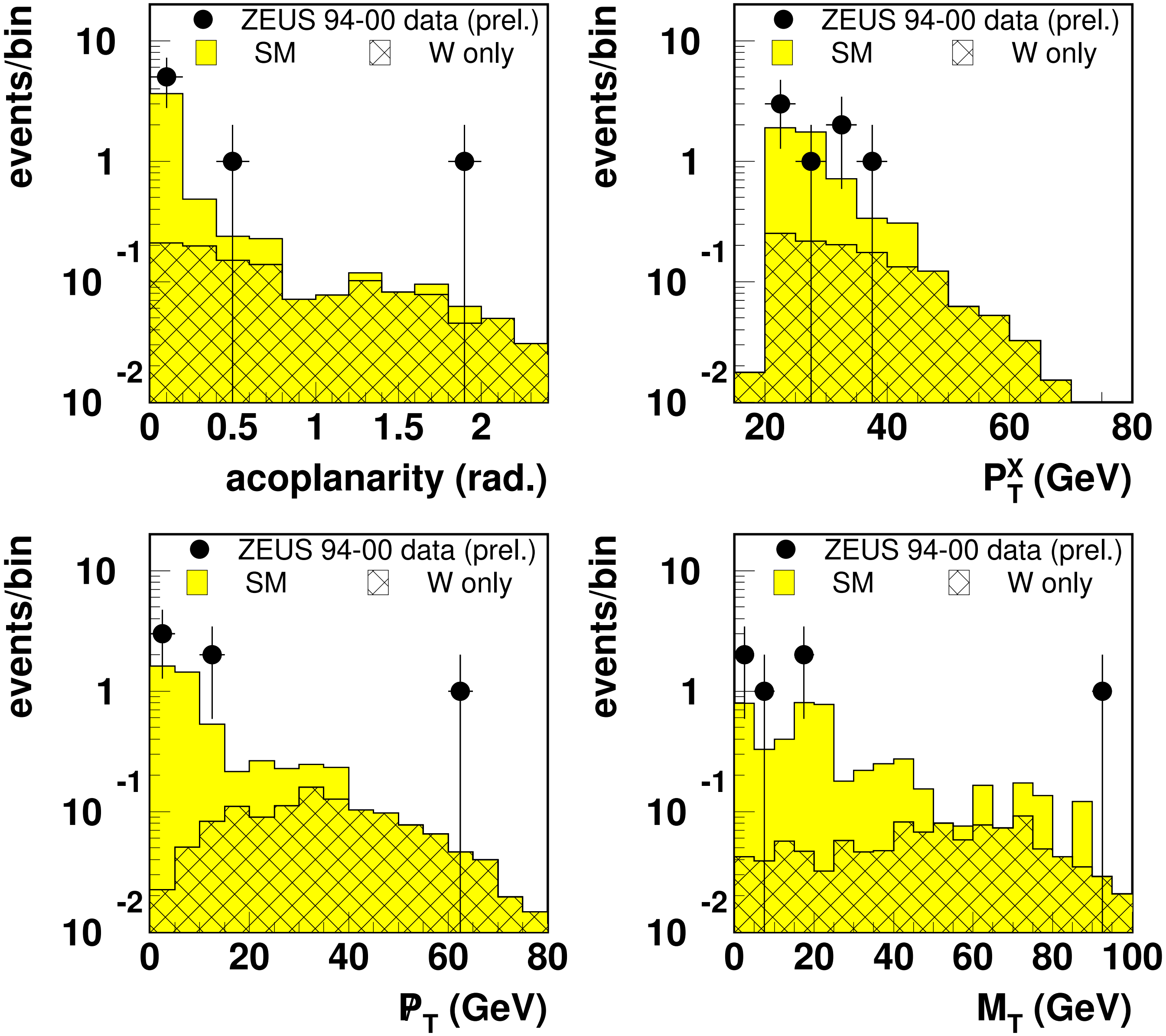


Event Kinematics: μ

- Event kinematics consistent with SM predictions.

- $\gamma\gamma \to \mu\mu$ is dominant
  - Small acoplanarity
  - Small missing P_T

- One outstanding event



W enhanced cut

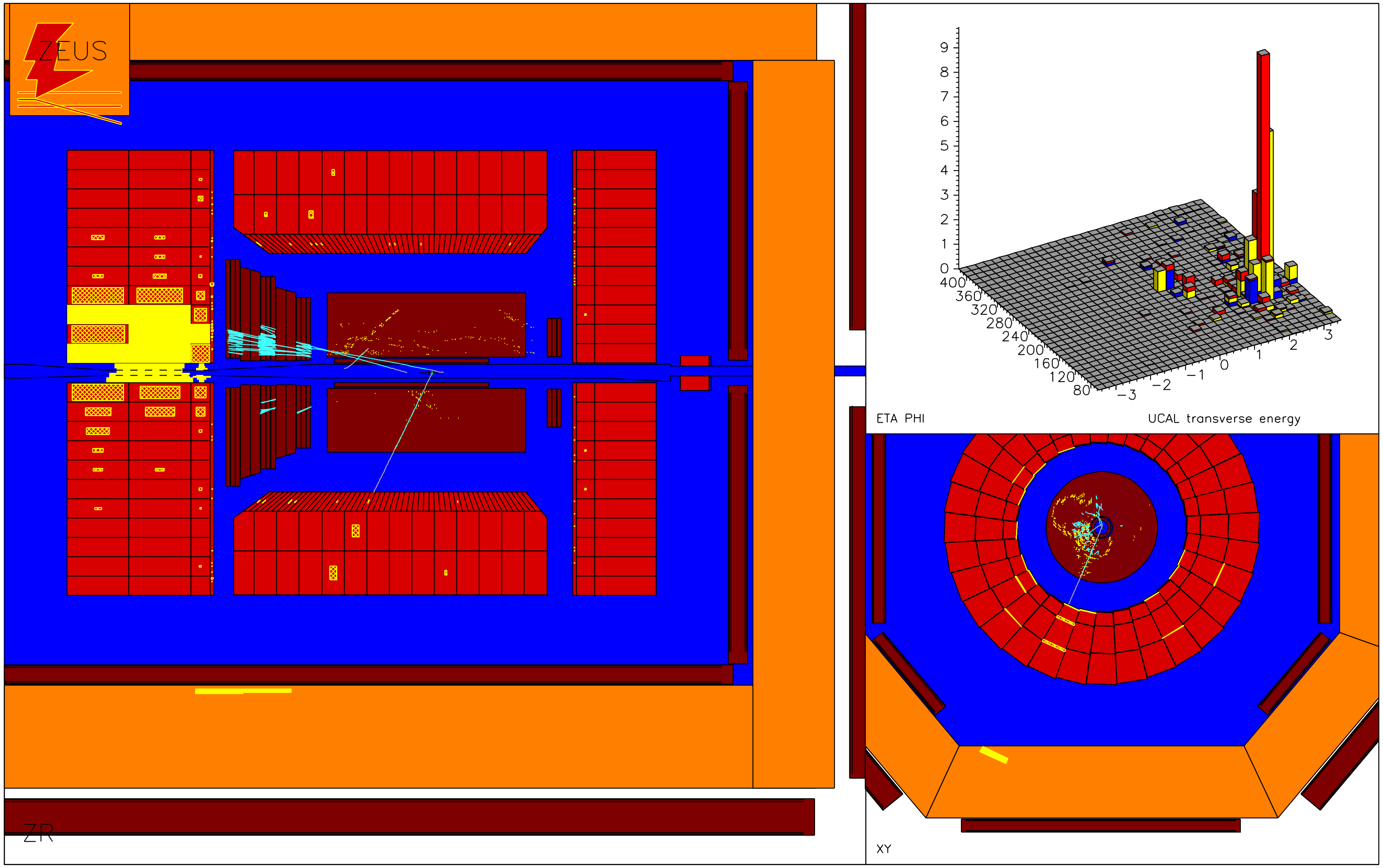
- Enhance W event with further cuts.
  - NC DIS suppression
    Require $E - p_z < 45$ GeV for e events.
  - $\gamma\gamma \to \mu\mu$ suppression
    Reject if 2nd μ found.
    Require net missing $P_T > 12$ GeV for μ events.

ZEUS preliminary 1994–2000 $e^{\pm}p$ 130 pb^{-1}	Electrons Observed/expected (W)	Muons Observed/Expected (W)
$P_T^X > 25$ GeV	1 / 1.14±0.06 (1.10)	1 / 1.29±0.16 (0.95)
$P_T^X > 40$ GeV	0 / 0.46±0.03 (0.46)	0 / 0.50±0.08 (0.41)

One μ event at $P_T^X > 25$ GeV from 2000 data, but consistent with total expectation.

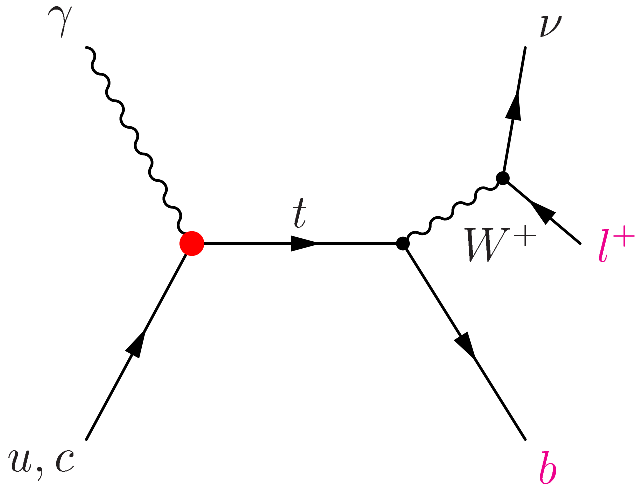
Outstanding μ event

$P_T(\mu^+)$=38^{+20}_{-10} GeV, P_T^X=36 GeV, $Acoplanarity$=1.9, $\not{P}_T$=61^{+17}_{-8} GeV, M_T=91^{+39}_{-19} GeV



Search for single top production

Single-top production with anomalous flavour changing neutral current coupling. (SM contribution is negligible)



Leptonic channel:

Final state with high P_T lepton, missing P_T and large P_T^X.

- Requires D$_{\text{track}} > 0.5$, D$_{\text{jet}} > 1.0$ and $P_T^X > 40$ GeV
  - P_T^X cut optimised with MC simulation

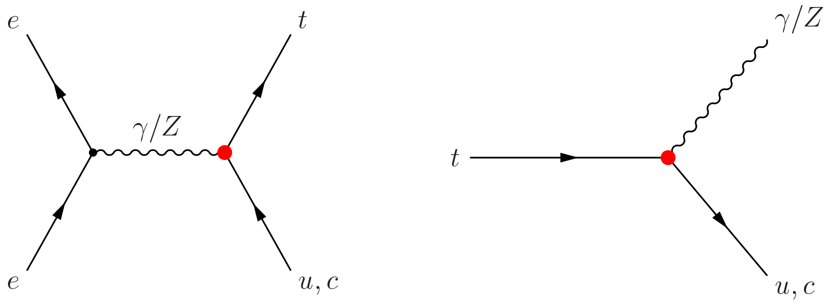
0 events observed, 1.1 expected

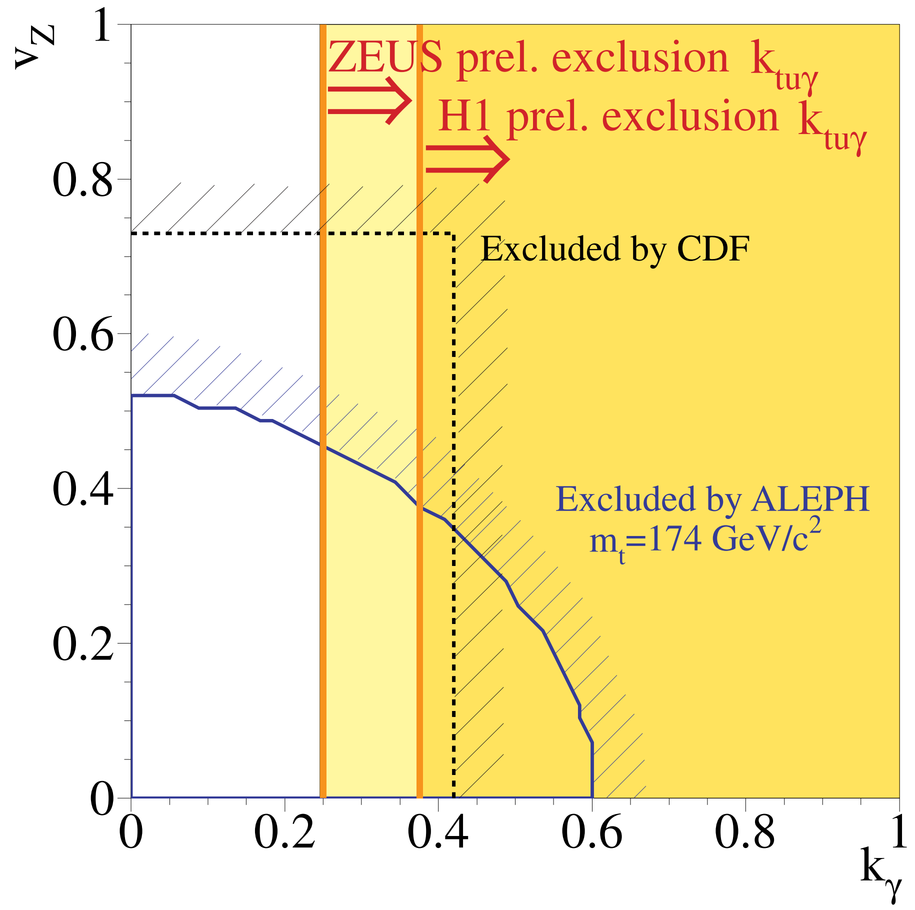
Sets limit on anomalous coupling, $\kappa_{tu\gamma}$, from cross-section limits

– See Belyaev and Kidonakis, hep-ph/0102072 for recent calculation

– Change of m_t by $\pm$ 5 GeV changes σ by 20%

Limits for anomalous FCNC couplings





- LEP: $e^+e^- \to tc, tu$ limits represented in γ- and Z-couplings plane
- TeVatron: rare top decay $t \to q\gamma, qZ$ separate limits on γ- and Z-couplings from different rare decays
- HERA: limits obtained only for γ coupling, valid only for t-u FCNC (not t-c)

Very competitive results.

Summary and Outlook

- Search for leptonic decay of single-W production with 48 pb^{-1} of 1994–1997 data.
  ➠ Event rate and kinematics are consistent with SM expectation.

- Inclusive search for events with lepton and missing P_T with 130 pb^{-1} of 1994–2000 data.
  ➠ Event rate and kinematics are consistent with SM expectation.
  ➠ Results with W enriched cut agrees with SM prediction.
  ➠ Searched for single top production and set limit on anomalous FCNC coupling. Very competitive with other experiments.

- HERA upgrade will enable more detailed analysis of events with lepton and missing P_T, single-W production.
- Discover something new at HERA.