

ep physics at high Q^2

Thomas Hadig
on behalf of the H1 and ZEUS Collaborations

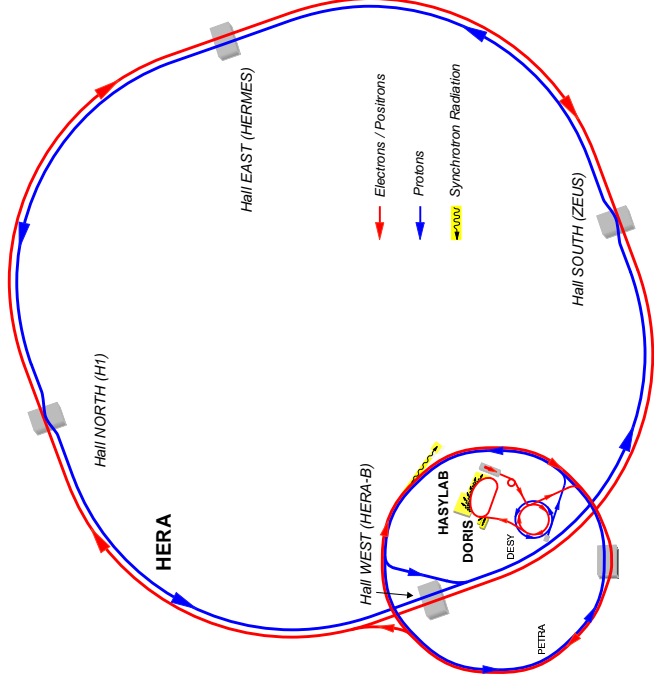
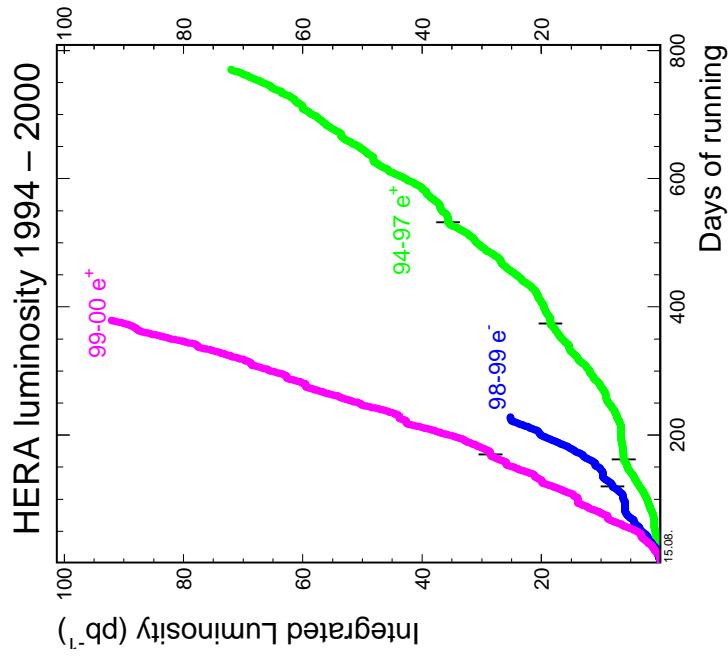
August, 24th 2000



- HERA
- Standard Model
 - + Inclusive Cross Section
- Beyond the Standard Model
 - + Isolated Lepton Events
 - + Single Top Production
 - + R_p Processes
- Summary

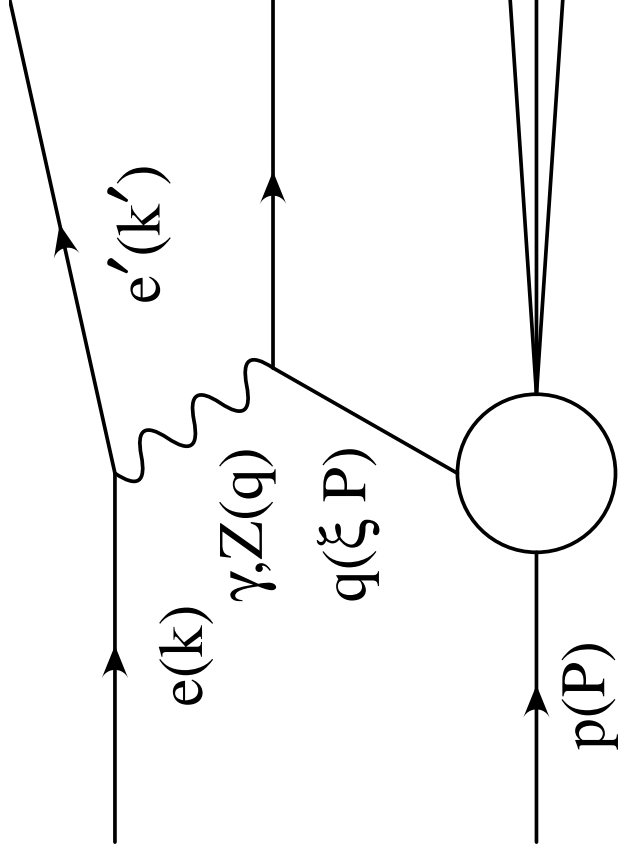
Thomas Hadig, SLAC Summer Institute, 24.8.2000

HERA



World only ep collider: $e^{\pm}@27.5\text{GeV}$ $p@920\text{GeV}$ $\sqrt{s} = 320\text{GeV}$ (98 – 00)
 Each experiment collected more than 100 pb^{-1} of data.

Kinematics



$Q^2 = -q^2$ virtuality of photon
 ξ momentum fraction of
 parton wrt. proton

$$y = \frac{P(k - k')}{Pk_e} \text{ inelasticity}$$

$$x = \frac{Q^2}{ys}$$

High Q^2 means high x or y

In first approximation: $x = \xi$

Neutral Current Cross Section

NC (neutral current) : exchange of γ or Z, observation of scattered e

$$\frac{d^2\sigma_{NC}^{\pm}}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4} \left[Y_+ \tilde{F}_2 \mp Y_- x \tilde{F}_3 - y^2 \tilde{F}_L \right]$$

$$Y_{\pm} = 1 \pm (1-y)^2$$

Global dependence: $\frac{1}{Q^4}$.

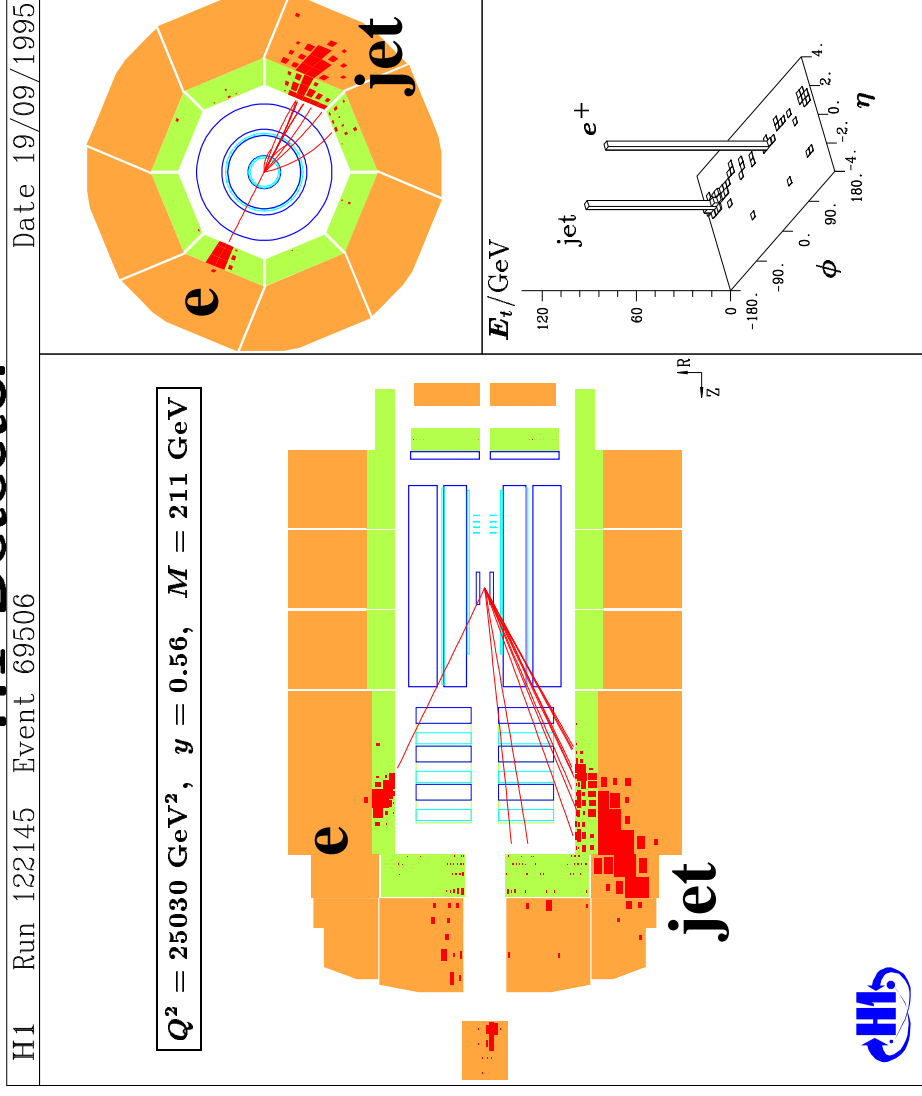
At high y : Contributions from F_L , but F_L decreases for increasing Q^2

$x\tilde{F}_3$: parity violating term from Z and γ Z interference graphs

At high x : Contributions from \tilde{F}_3

Sign of $x\tilde{F}_3$ contribution depends on incoming lepton charge

H1 Detector



NC (neutral current) : exchange of γ or Z, observation of scattered e

Charged Current Cross Section

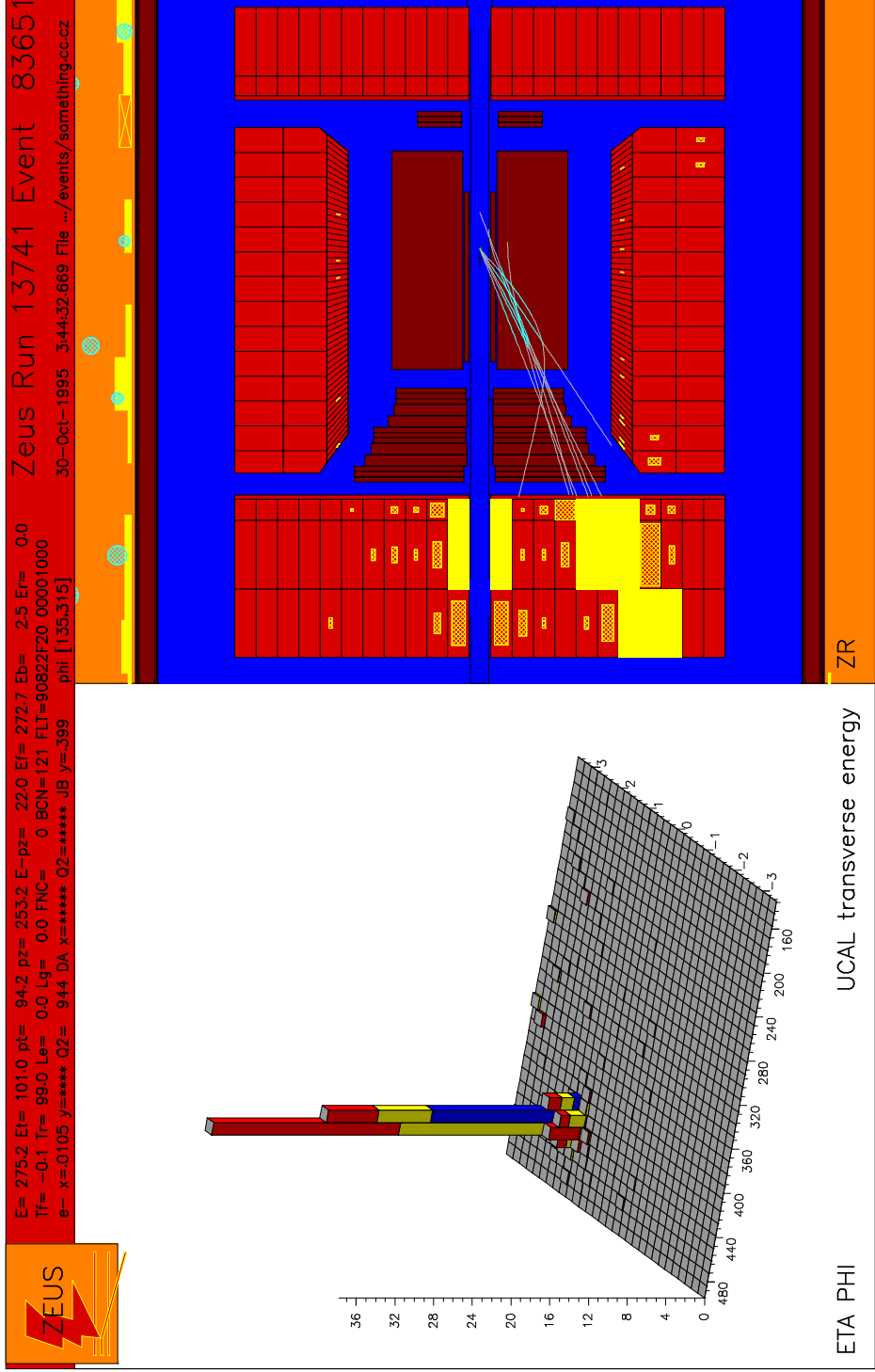
$$\frac{d^2\sigma_{NC}^{\pm}}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4} \left[Y_+ \tilde{F}_2 \mp Y_- x \tilde{F}_3 - y^2 \tilde{F}_L \right]$$

CC (charged current) : exchange of W^{\pm} , ν leaves undetected (missing p_t)

$$\frac{d^2\sigma_{CC}^{\pm}}{dx dQ^2} = \frac{G_F^2}{2\pi x} \left(\frac{M_W^2}{M_W^2 + Q^2} \right)^2 x \left[(u + c) + (1 - y^2)(\bar{d} + \bar{s}) \right]$$

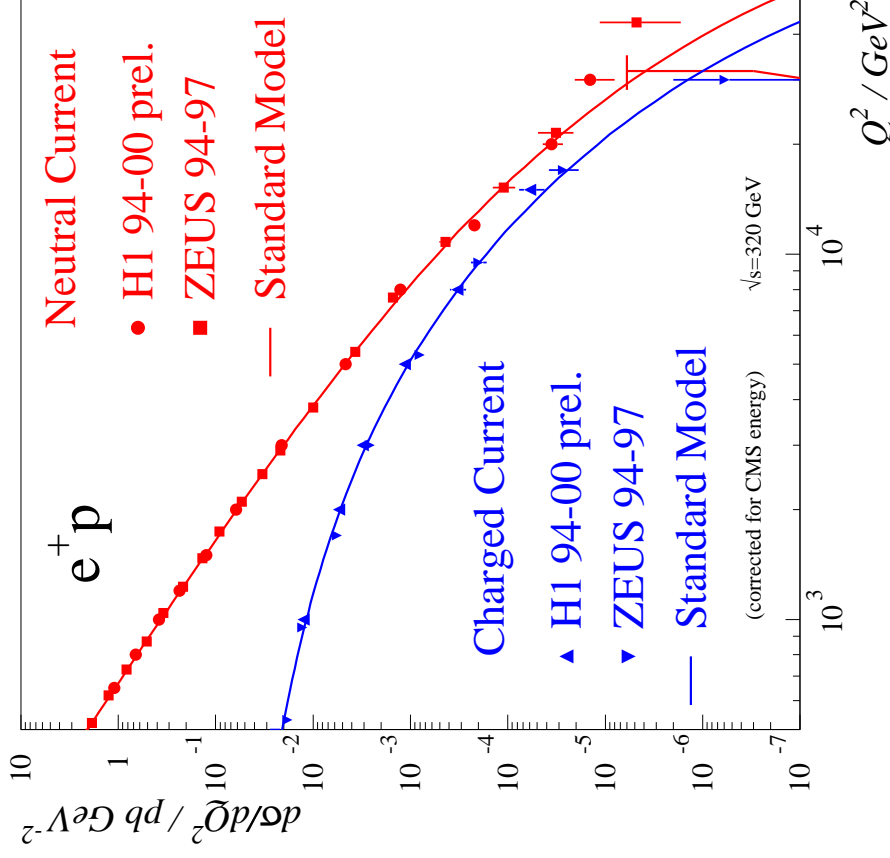
At low Q^2 : CC process suppressed wrt. NC
 Up and Charm density in the proton
 Down and Strange density in the proton

ZEUS Detector



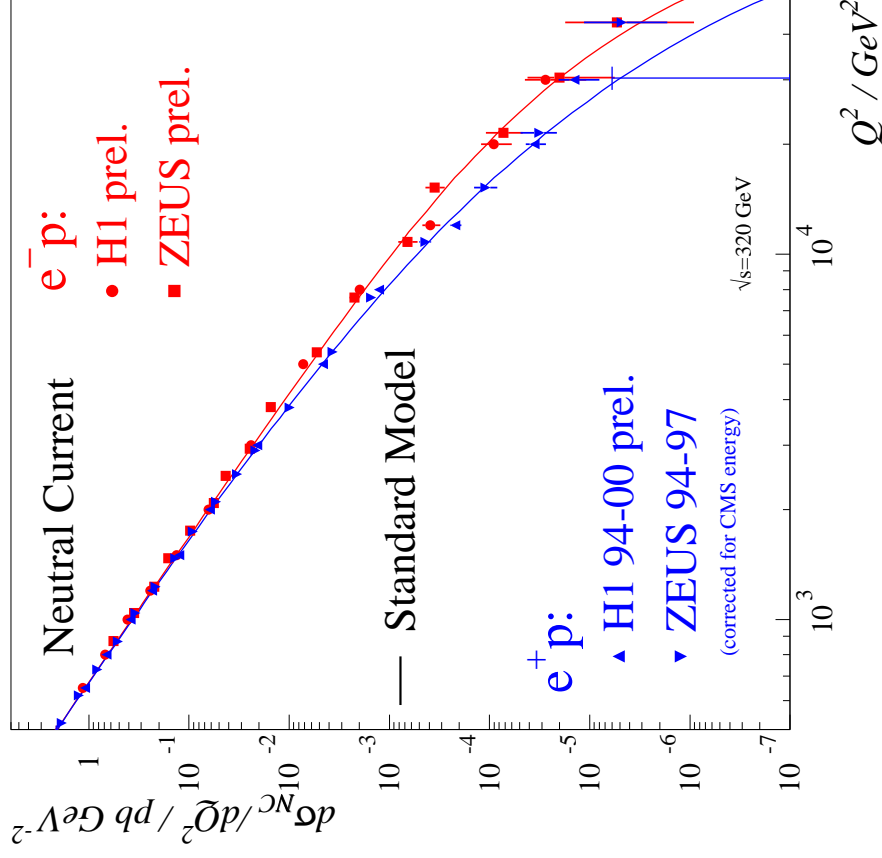
CC (charged current) : exchange of W^{\pm} , ν leaves undetected (missing p_t)

Comparison : NC vs. CC



Neutral current and
Charged Current cross section
well described by Standard Model
CC suppressed wrt. NC
At high Q^2 suppression is smaller.
Electroweak unification: $\sigma_{\gamma,Z} \approx \sigma_W$

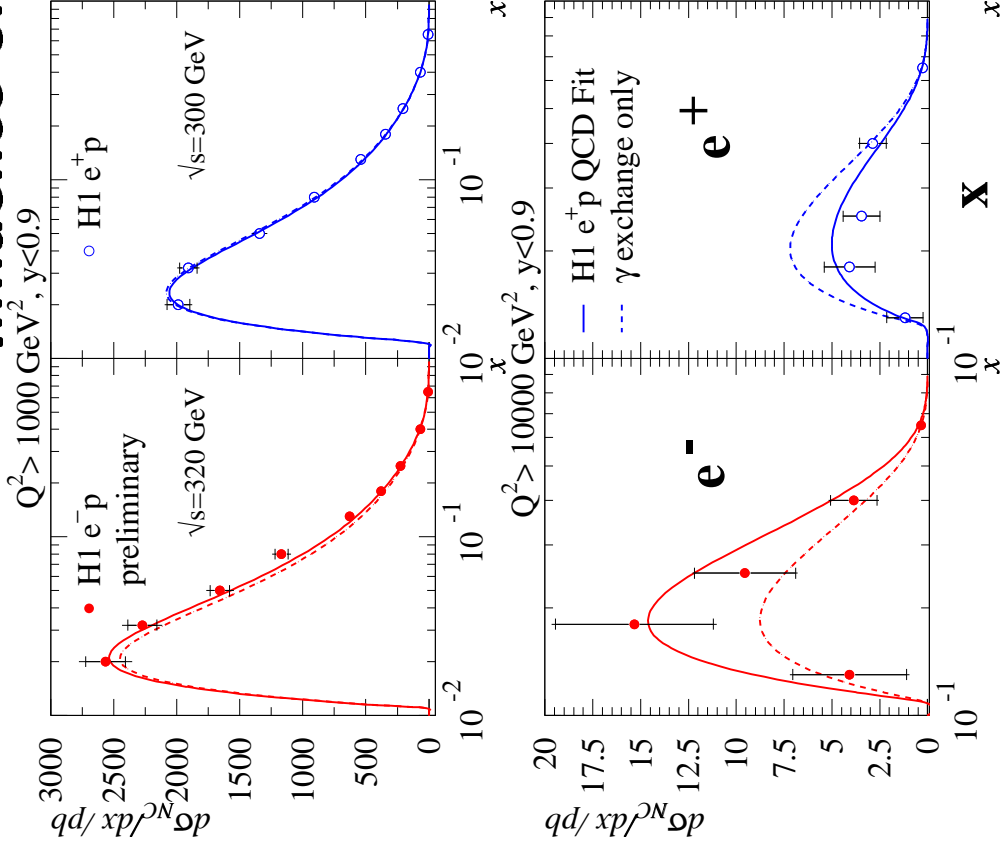
Comparison : Incoming Electron vs. Positron



e^+p and e^-p NC cross section is well described by Standard Model

Difference in σ_{e^+p} and σ_{e^-p} seen at high Q^2 (high x).

Influence of Z exchange

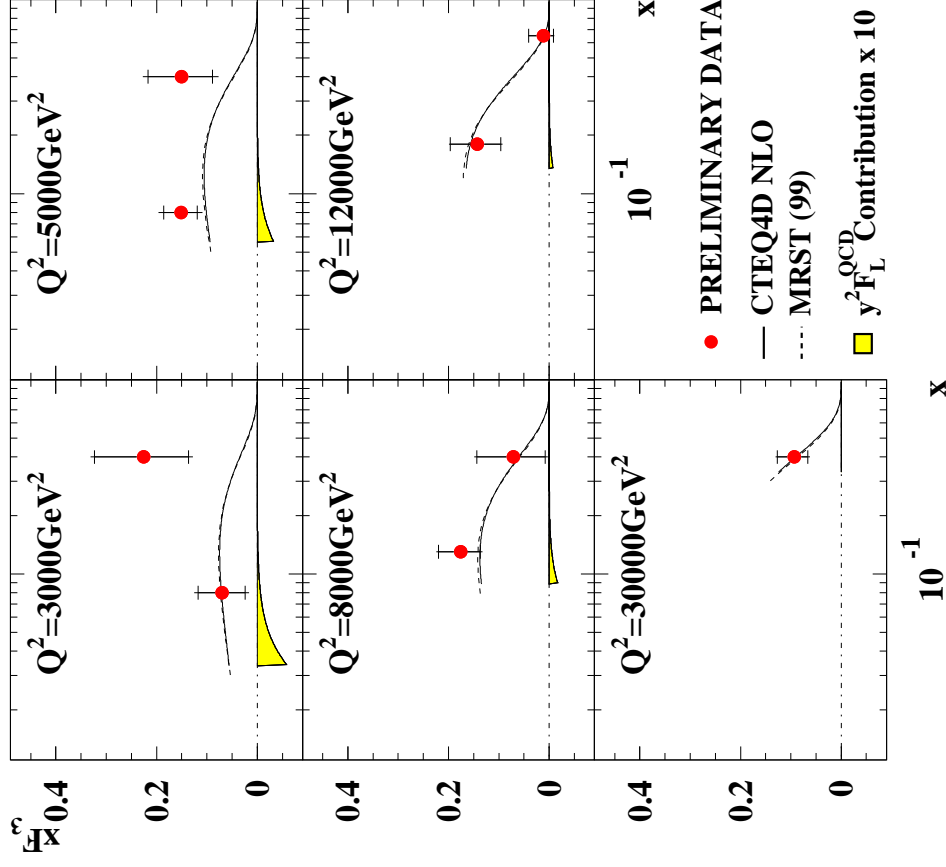


NC cross section is mainly dominated by photon exchange.

Influence of Z seen at high Q^2 .

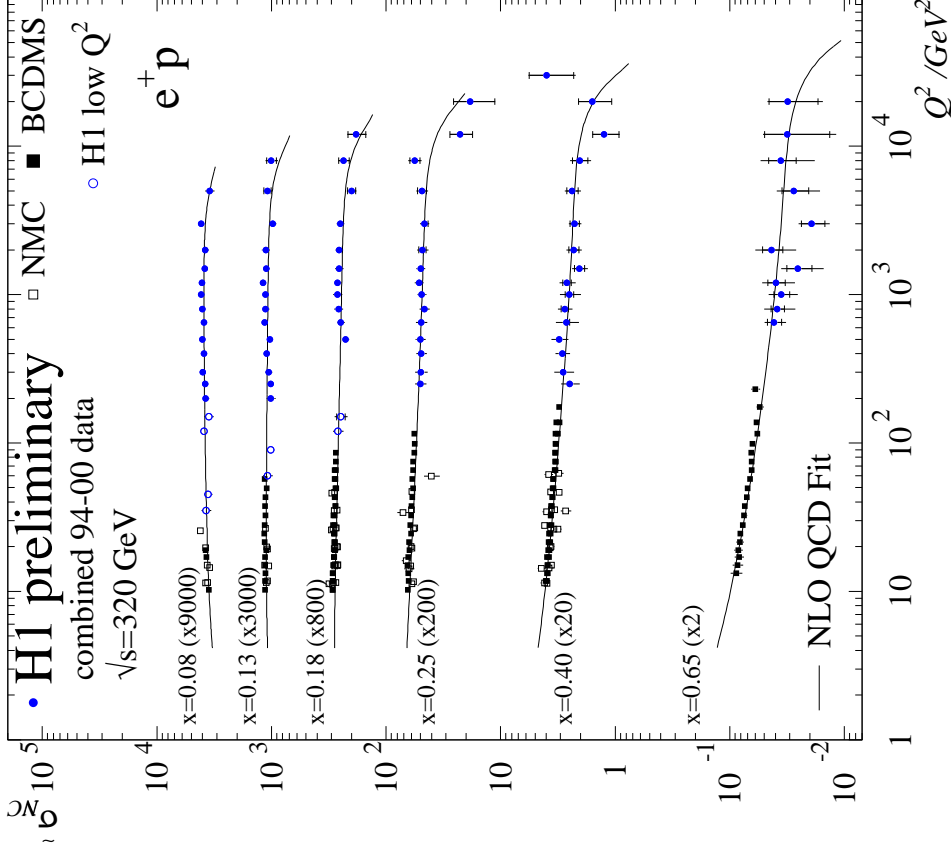
Interference of photon and Z is different for e^+ and e^- .

ZEUS NC 1996–99 $x F_3$ Extraction



Extraction of $x F_3(x, Q^2)$ at high x
 NLO QCD calculation describes data
 $y^2 F_L$ contribution negligible
 (only at small x , i.e. high y)

Reduced Cross Section



Removing kinem. factors from σ_{NC}

$$\tilde{\sigma}(x, Q^2) = \frac{1}{Y_+} \frac{Q^4 x}{2\pi\alpha^2} \frac{d^2\sigma_{\text{NC}}}{dx dQ^2}$$

Data connect well to fixed target data.

At small and medium Q^2 :

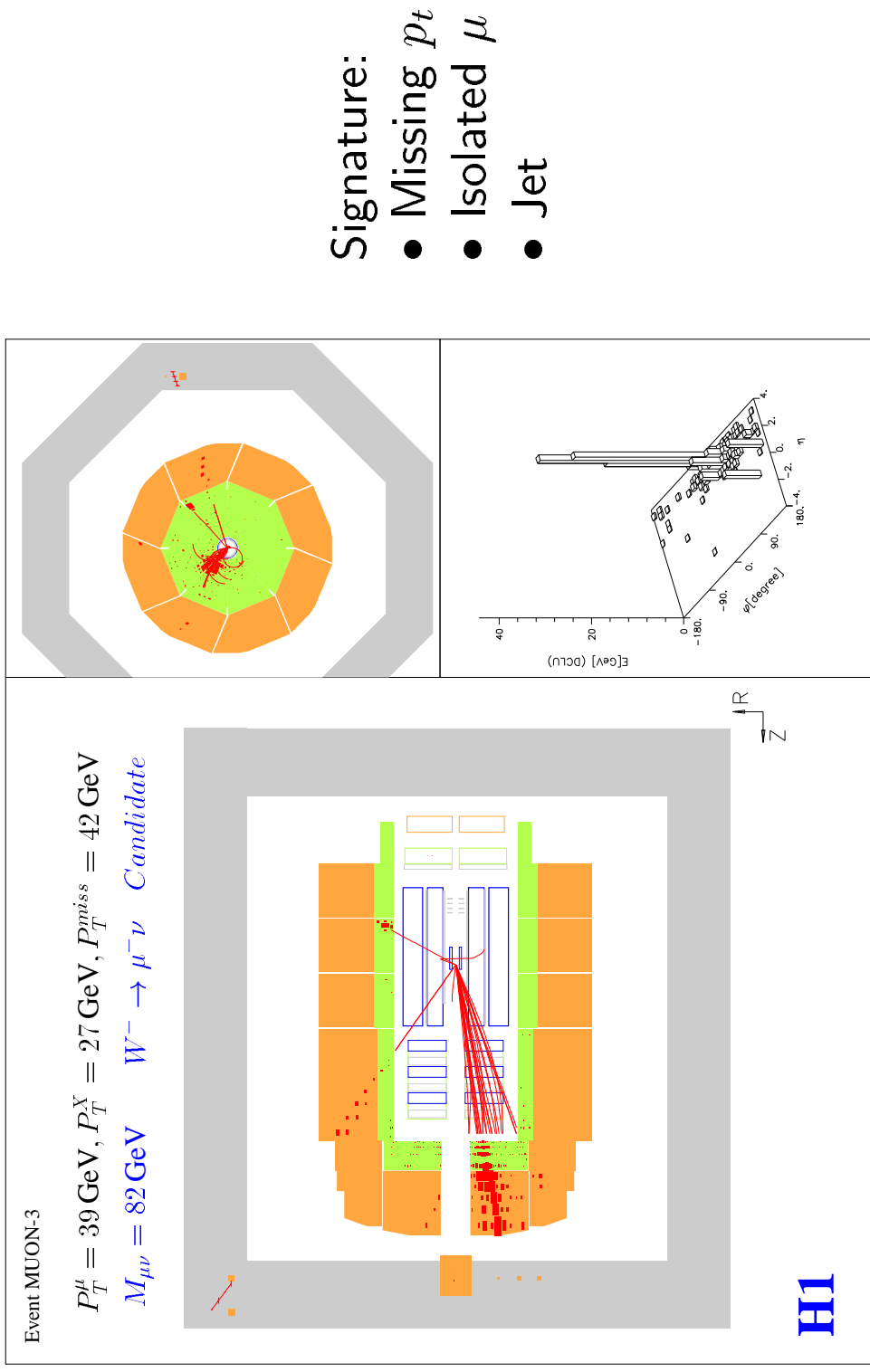
approximately flat line

At high Q^2 :

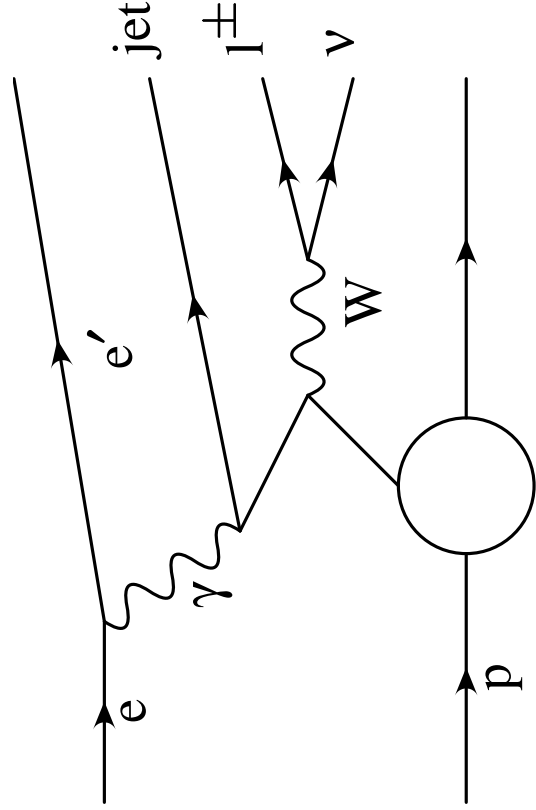
electro-weak effects

\Rightarrow Now: Looking at final states for physics Beyond the Standard Model

Isolated Lepton Events



Isolated Lepton Events



Explanation in Standard Model:

W production

$$\sigma = 1 \text{ pb} \pm 30\%$$

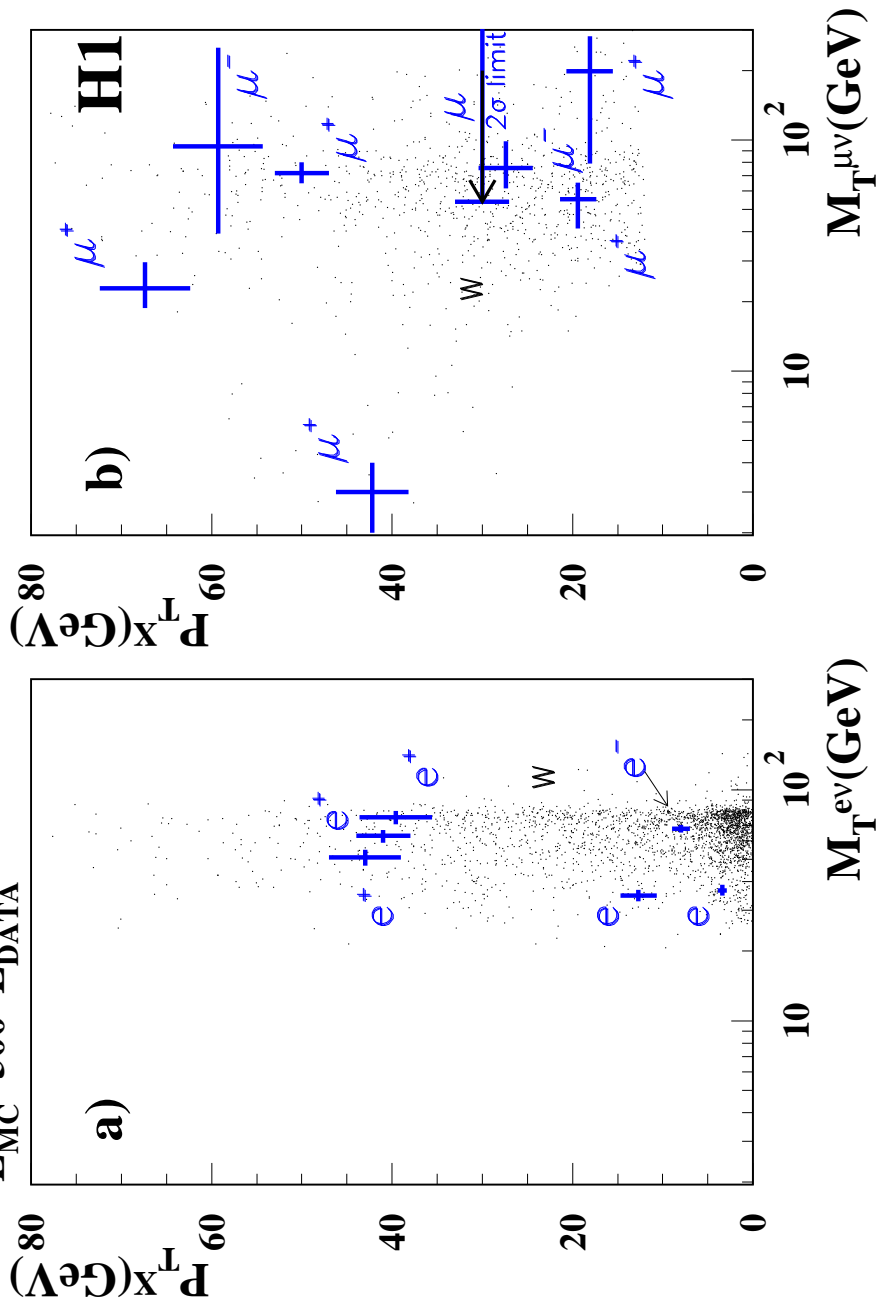
Signature:

- Scattered beam electron (mostly unobserved)
- Missing p_t^{miss}
- Jet, measured, **small** P_T^X
- Isolated lepton
- ν and lepton: $M_{l\nu} \approx M_W$

Isolated Lepton Events

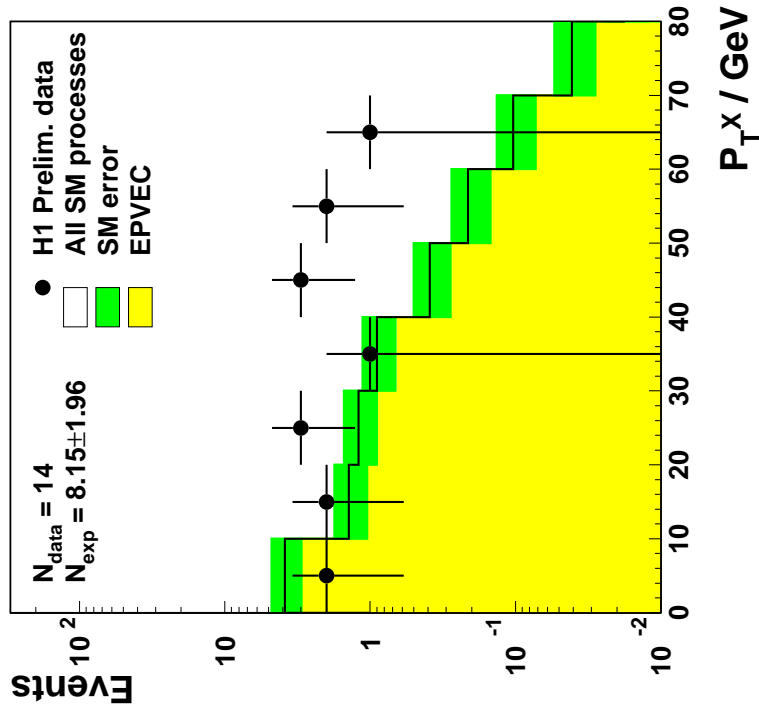
H1 PRELIMINARY 81.6pb⁻¹ e⁺ p data 94-00

L_{MC}=500*L_{DATA}



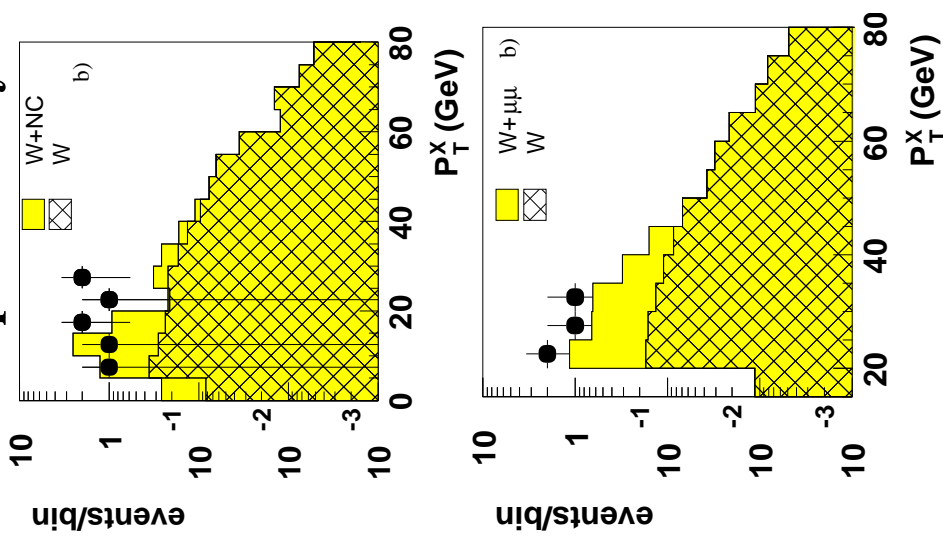
Isolated Lepton Events

H1 W Production



H1 combined channels: excess at high p_t
 ZEUS: e (top) and μ (bottom) channels

ZEUS 1994-1999 preliminary



Isolated Lepton Events

Default analysis (combined e and μ channels):

H1 preliminary, 94-00, e^+p only, 82 pb^{-1}
seen 9 events, expected 2.3 ± 0.6 events

H1 sees excess at large p_t

ZEUS, 94-99, e^+p and e^-p data, 82 pb^{-1}
seen 11 events, expected 9.8 ± 1.3 events

ZEUS is consistent with Standard Model

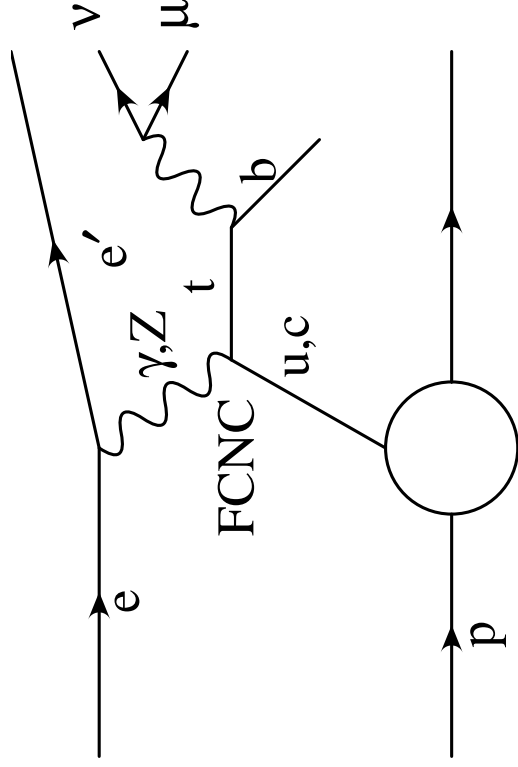
For comparison: using similar cuts for H1 and ZEUS:

ZEUS: seen 1 event, expected 1.60

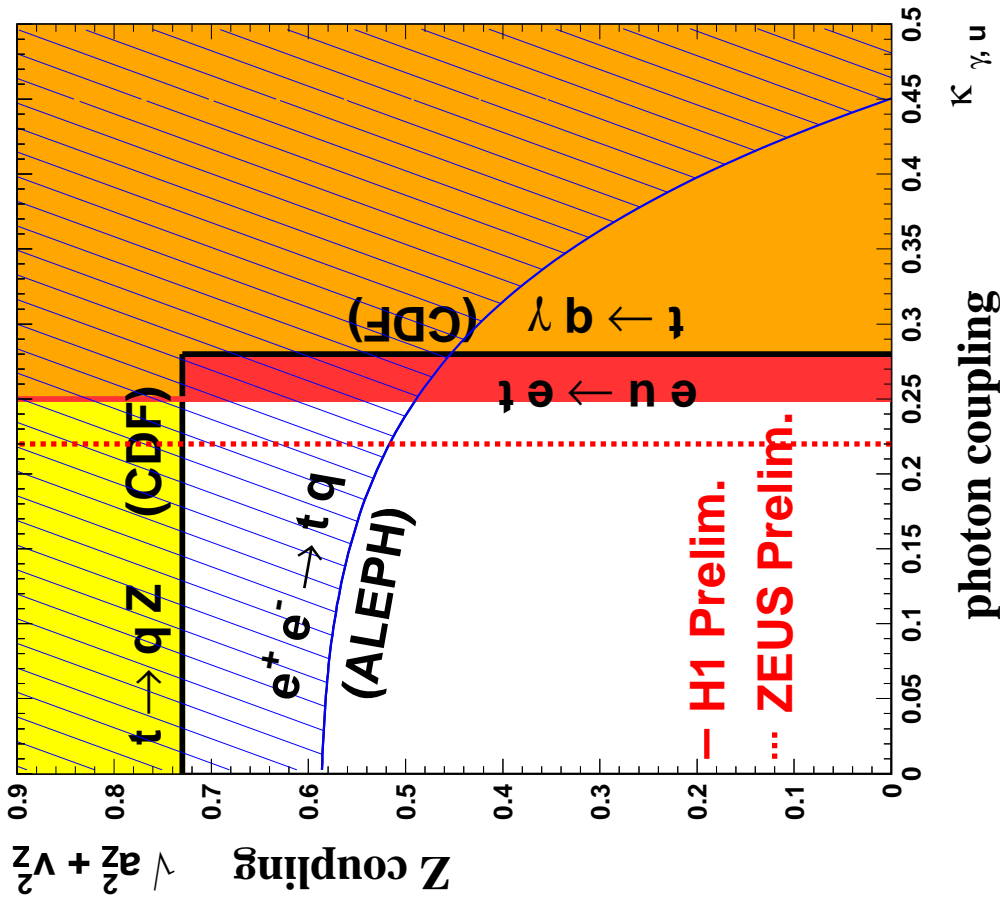
H1: seen 9 events, expected 1.78

Background expectation of H1 and ZEUS consistent

Single Top Production



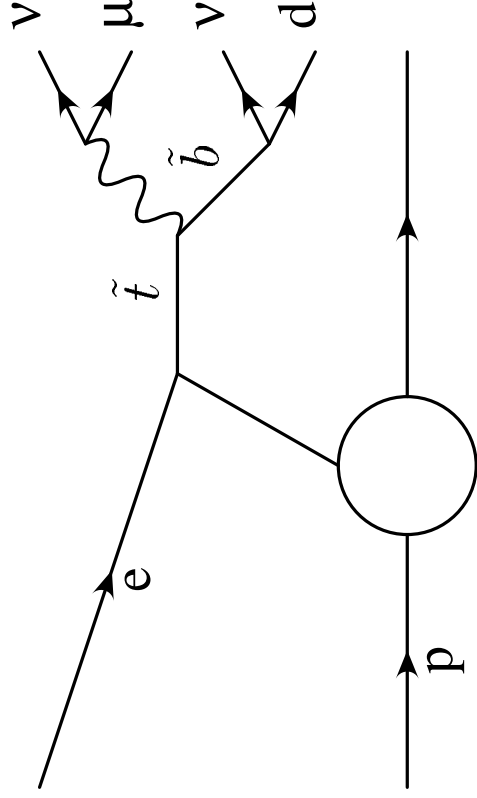
No signal found
 \Rightarrow setting limits on
 FCNC photon coupling



R_p SUSY Processes

R-Parity: $R_p = (-1)^{3B+L+2S}$

SM particles: $R_p = +1$, SUSY particles: $R_p = -1$



$$\begin{aligned}
 W R_p &= \lambda_{ijk} L_i L_j \bar{E}_k \quad (\text{LEP}) \\
 &+ \lambda'_{ijk} L_i Q_j \bar{D}_k \quad (\text{HERA}) \\
 &+ \lambda''_{ijk} \bar{U}_i \bar{U}_j \bar{D}_k \quad (\text{TeVatron})
 \end{aligned}$$

L_i : left-handed lepton doublets

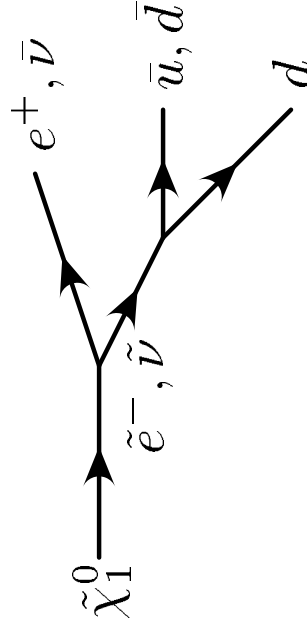
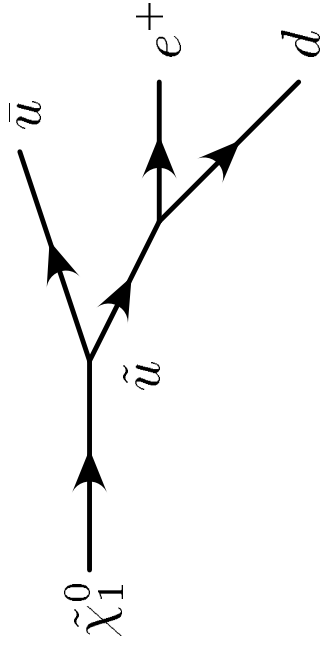
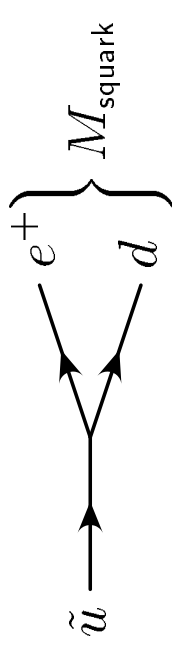
Q_i : left-handed quark doublets

\bar{E} : right-handed lepton singlets

\bar{D}, \bar{U} : right-handed quark singlets

\cancel{R}_p SUSY Processes

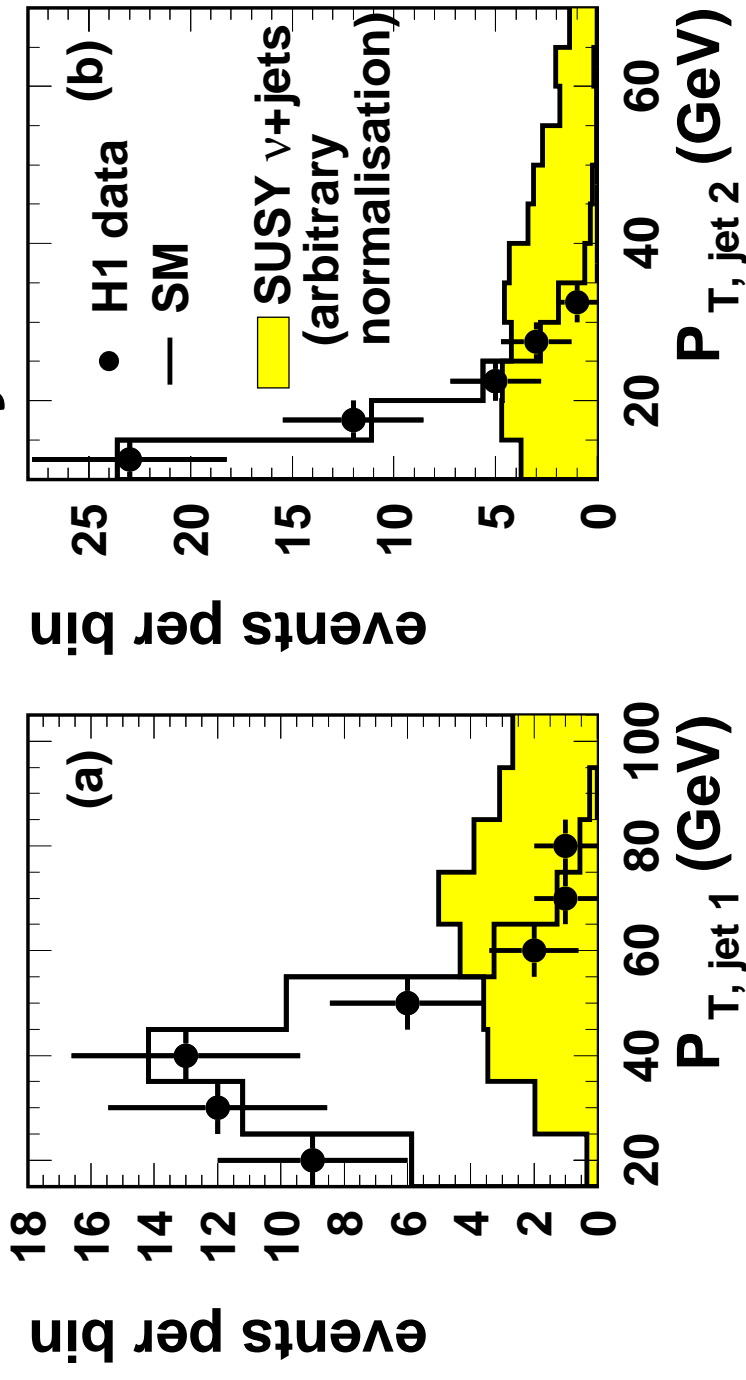
Looking at different decay channels:



...

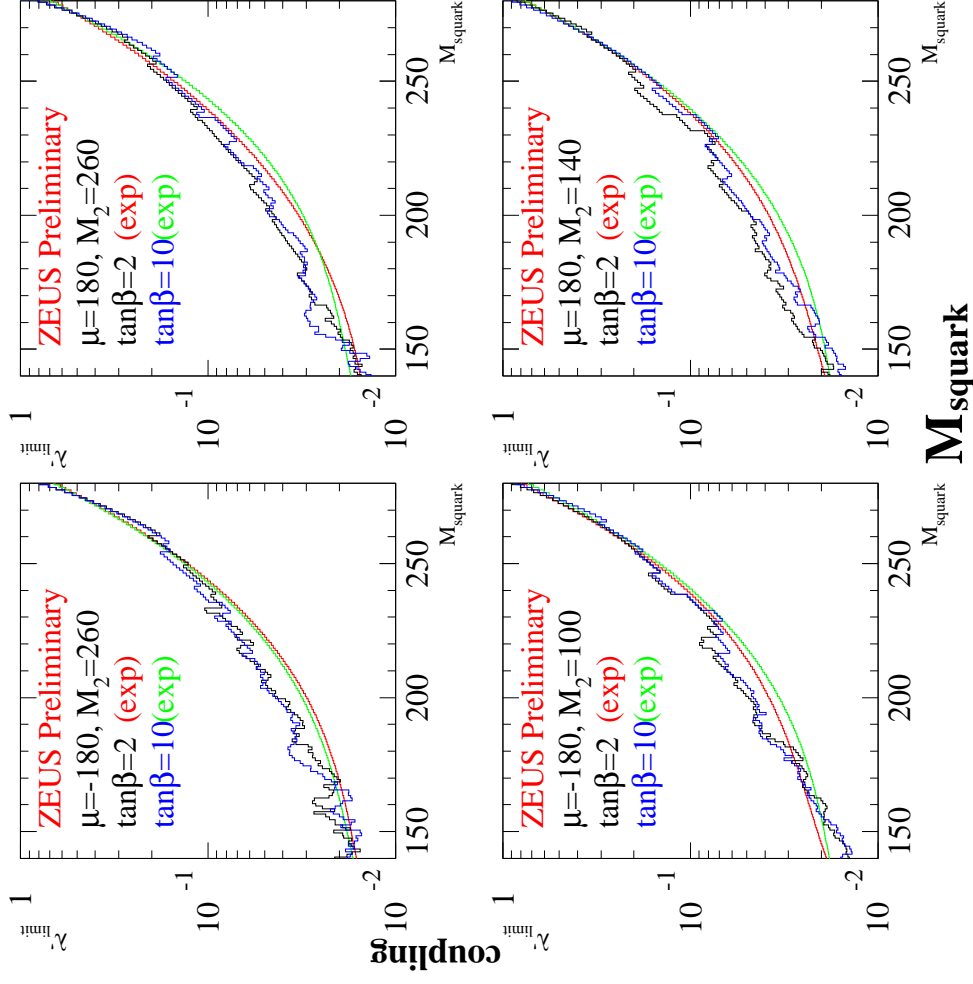
R_p SUSY Processes

H1 Preliminary



One example channel : ν + multiple jets

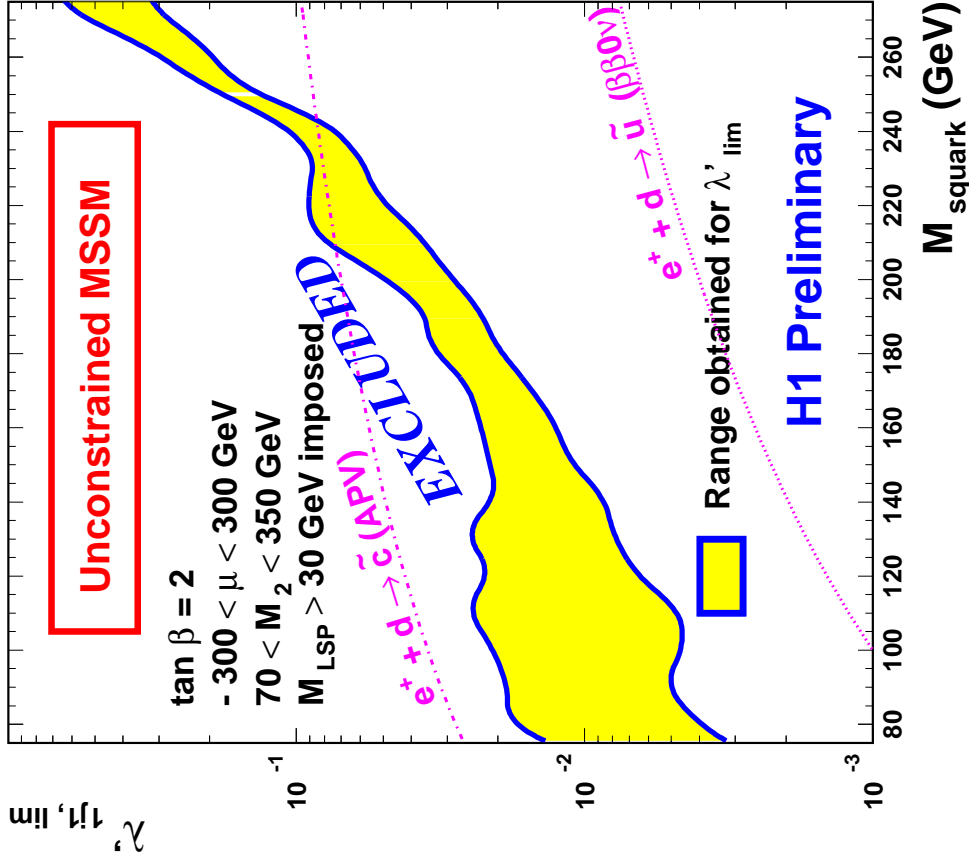
R_p SUSY Limits



95% confidence level limit on λ'
observed (black, blue)
expected (red, green)

plots show limits for different
values for the parameters.
 \Rightarrow Limits nearly independent on
choice of parameters.

R_p SUSY Limits



Scan through parameter region:
 excluded region nearly
 independent of parameter set.

$\beta\beta 0\nu$ (neutrino-less double beta decay)
 sets limits on first generation
 APV (atomic parity violation)
 sets limits on second gen.

Summary

HERA

- Inclusive data well described by Standard Model
- Important testing ground for Beyond the Standard Model processes

Results

- Limits on
 - + R_p SUSY
 - + Single Top production \Rightarrow setting best limits available
- Excess of isolated lepton events @ H1 exciting
but not confirmed by ZEUS
- \Rightarrow Only data after luminosity upgrade will resolve this puzzle

More information:

<http://www-h1.desy.de/> and <http://www-zeus.desy.de/>