Search for physics beyond the SM in ep collisions at HERA

L.Bellagamba (INFN Bologna)
on behalf of the H1 and ZEUS Collaboration

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Outline

- HERA data are suitable to look for new physics in phase space corners where the SM expectations are small

- Typically one selects clear topology involving one ore more leptons and/or missing transverse momentum and looks for deviations or measures cross section for rare processes

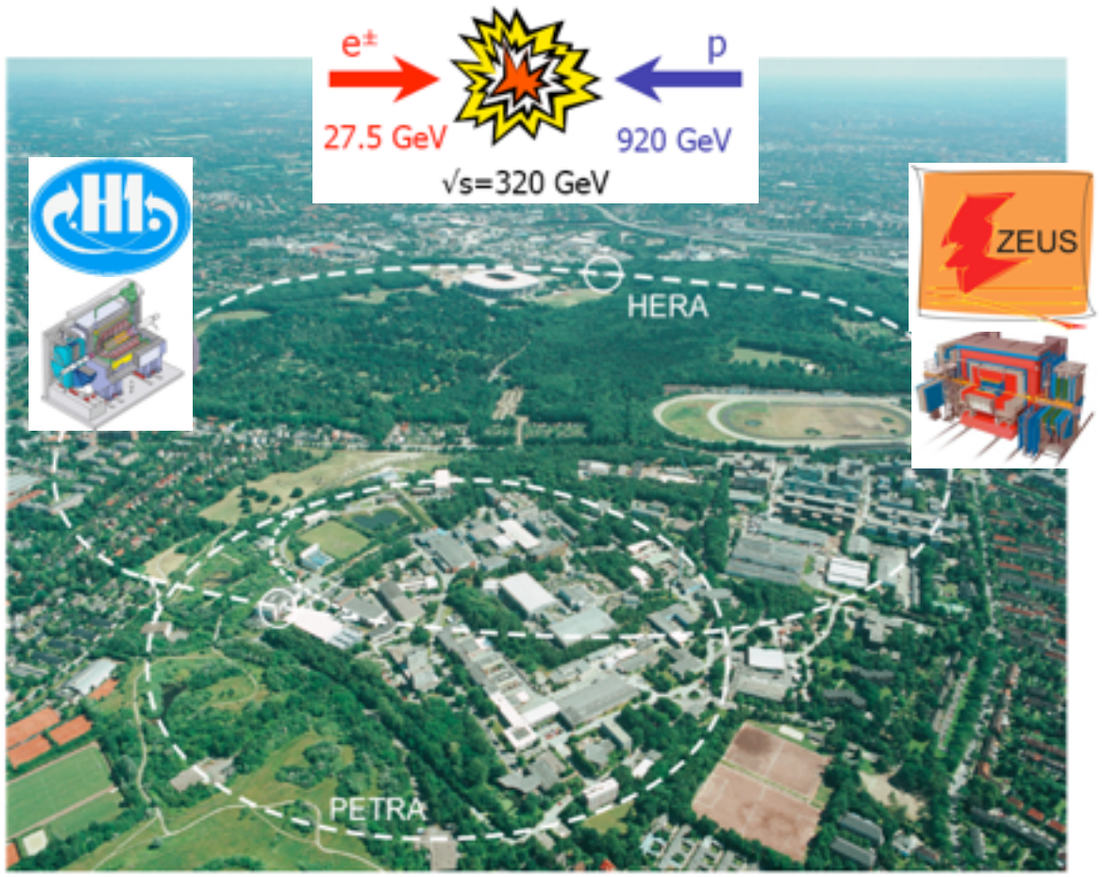
In this talk a review of recent results of such searches is presented:

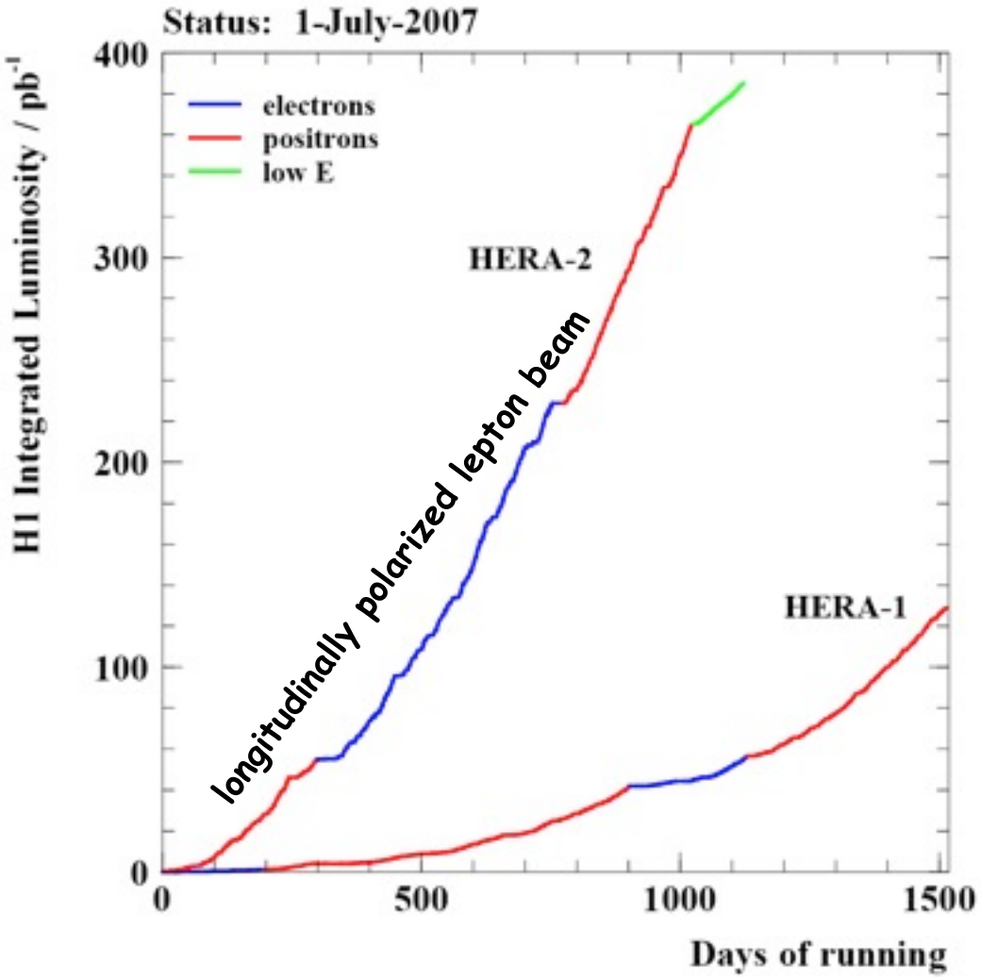
- leptoquarks (e-jet, P_t^{miss}-jet)
- ditaus
- high pt leptons (e/μ) and P_t^{miss} (H1+ZEUS) and constraints on single top production via FCNC couplings

HERA experiments and data taking summary

DATA TAKING 1992-2007

1992-2000 (HERA I) L~130 pb^{-1} (mostly e+p)
2002-2007 (HERA II) L~370 pb^{-1} (polarization ~30%, e+/e-p balanced)





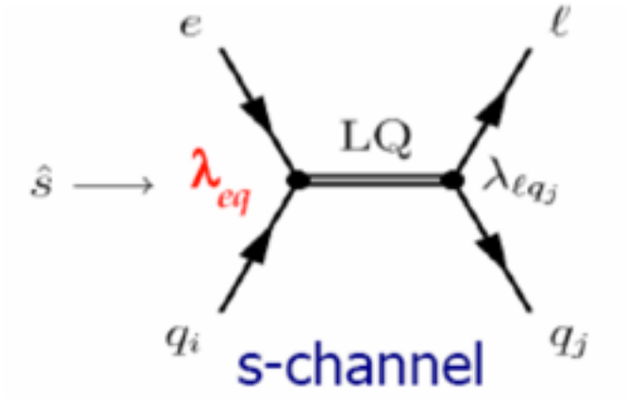
Two multi-purpose experiments (H1 and ZEUS) located at the ep interaction points

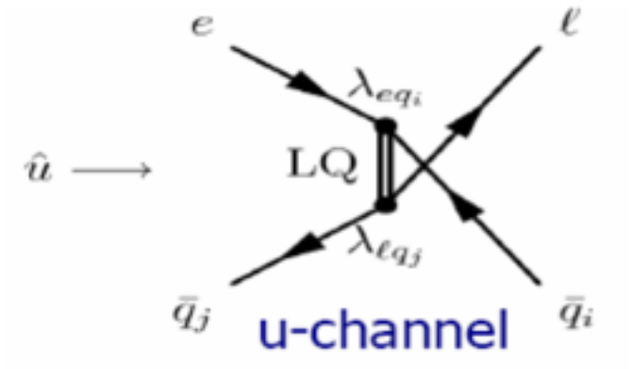
About 0.5 fb^{-1} data collected by each experiment

Leptoquarks

- Hypothetical bosons connecting the quark and the lepton sectors.
- Naturally arise in unified models where quarks and leptons are arranged in common multiplets.
- Carry SU(3) colour, fractional electric charge and both lepton (L) and baryon (B) number: fermion number F = 3B + L = 0,2 spin=0,1

At HERA can be resonantly produced in the s-channel for $M_{LQ}<\sqrt{s}$ or exchanged in the u-channel, then can decay to eq or νq

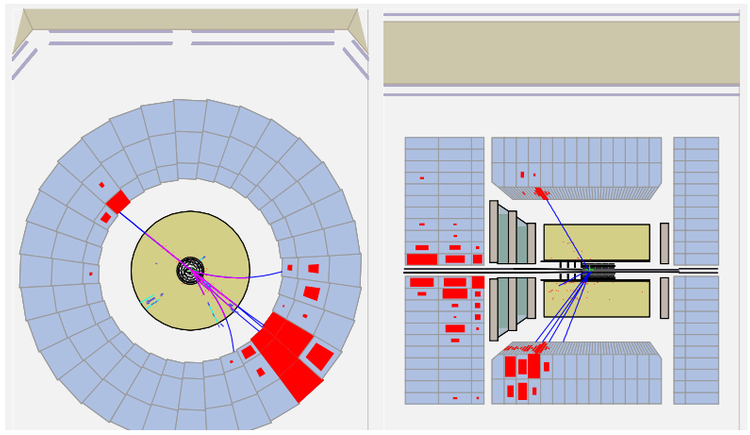




Signature similar to NC or CC DIS

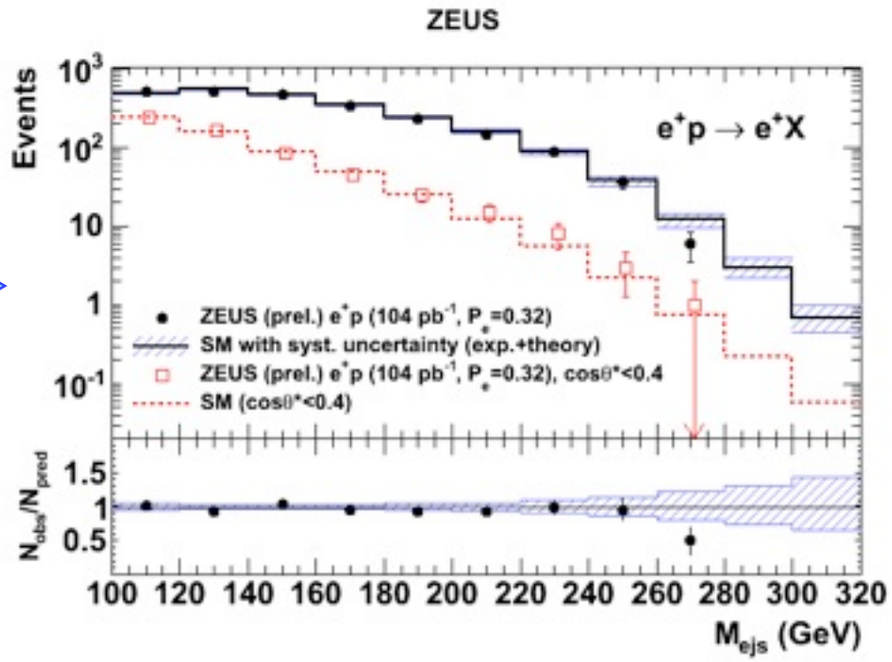
Analysis look for possible deviations from SM in e-jet or ν-jet invariant mass also exploiting different angular distribution for a resonance decay respect to SM DIS

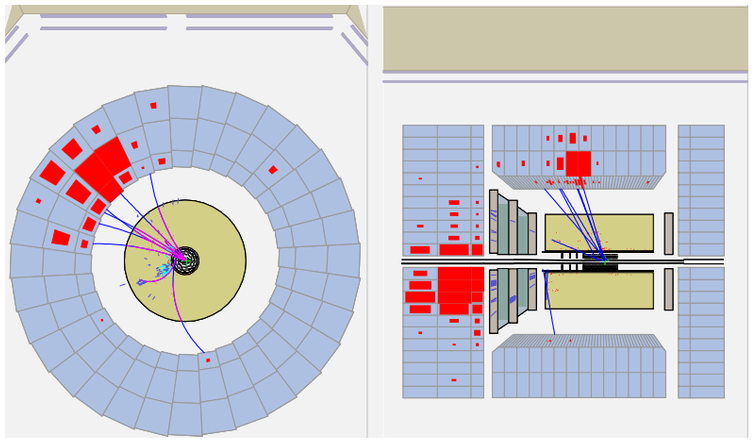
LQ search: final state invariant mass



NC event: e+jet final state

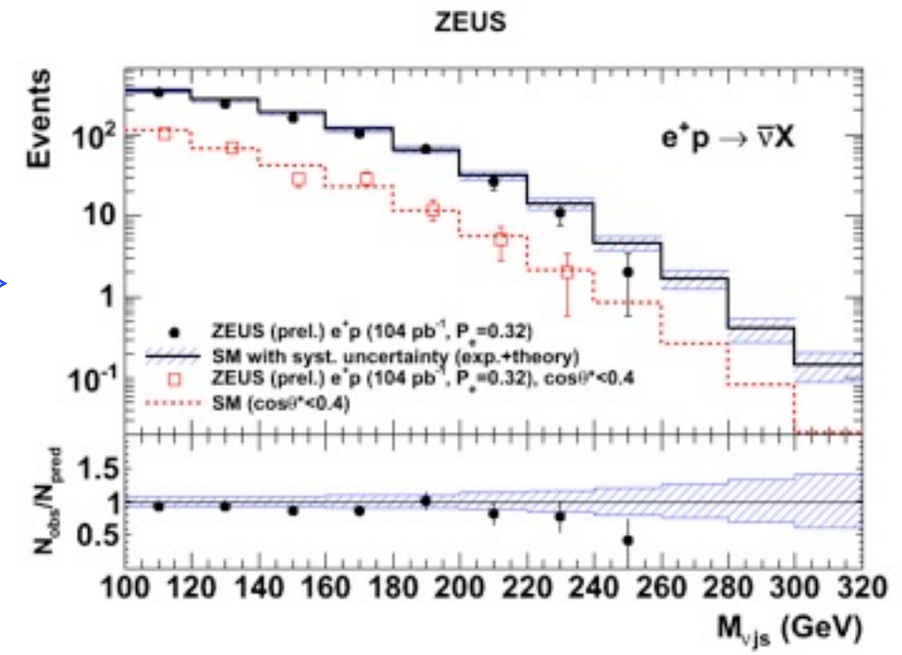
$M_{e\text{-jet}}$





CC event: P_t^{miss}+jet final state

$M_{\nu\text{-jet}}$



All HERA data analysed no deviations found

LQ limits

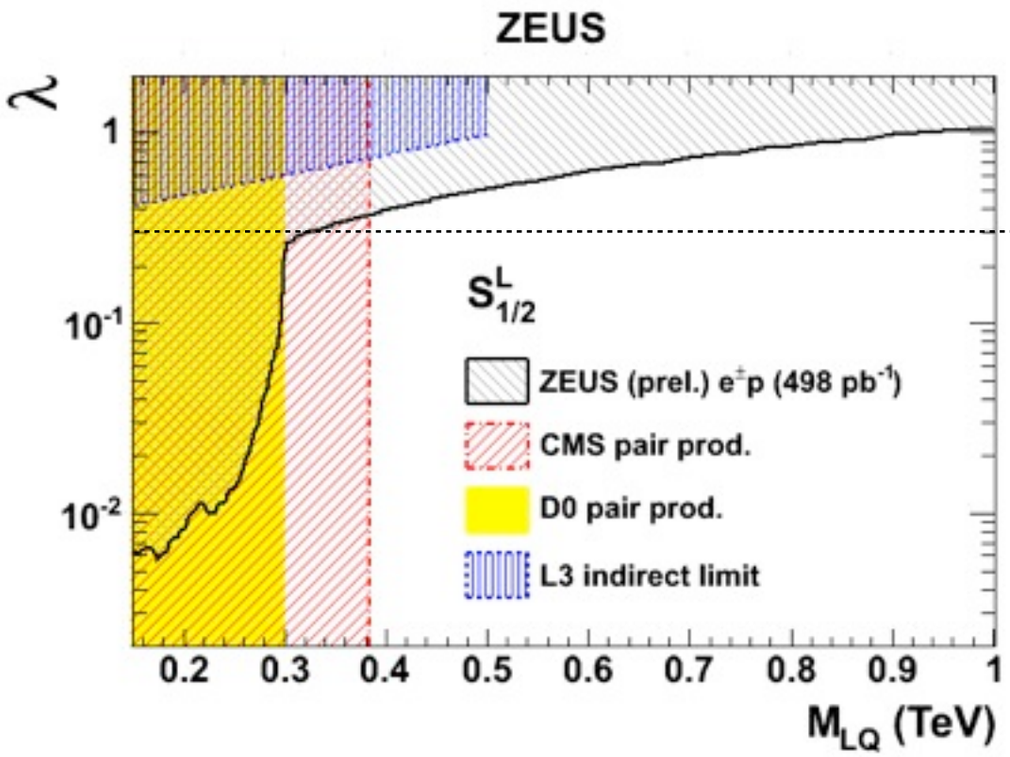
Phenomenological model of Buchmuller-Ruckl-Wyler used in limit setting

- $U(1)_Y \times SU(2)_L \times SU(3)_c$ invariance
- lepton and baryon number conservation
- either left- or right-handed coupling to lepton but not both (strong bounds from rare decays)

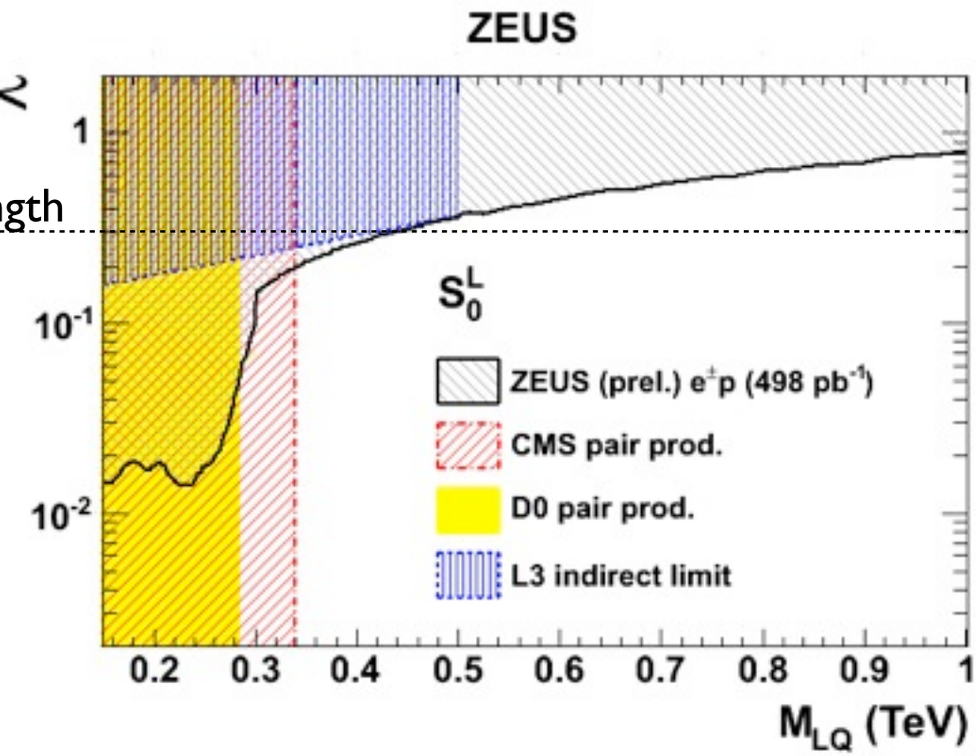
→ - 7 scalar + 7 vector states
- decay to eq or νq with Br=0,1/2,1

LQ Type (F=0)	V_0^L	V_0^R	$\tilde{V}_0^R$	V_1^L	$S_{1/2}^L$	$S_{1/2}^R$	$\tilde{S}_{1/2}^L$
M_{LQ}(GeV) ZEUS (prel.)	504	293	343	629	322	300	293
LQ Type (F=2)	S_0^L	S_0^R	$\tilde{S}_0^R$	S_1^L	$V_{1/2}^L$	$V_{1/2}^R$	$\tilde{V}_{1/2}^L$
M_{LQ}(GeV) ZEUS (prel.)	435	326	291	466	292	324	409

Mass limit (95% C.L.) assuming λ = 0.3 (e.m. strength)



e.m. strength



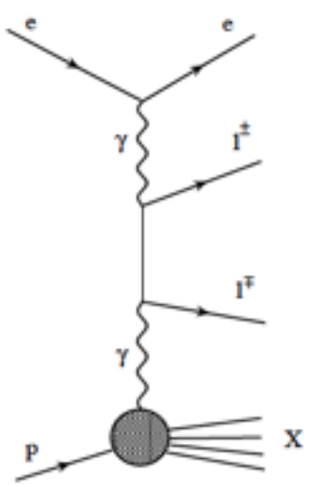
For masses beyond 300 GeV, HERA limits still the best in a large part of the λ-M plane
At a coupling of em strength masses up to 630 GeV are excluded (95%CL)

Study of tau pairs production

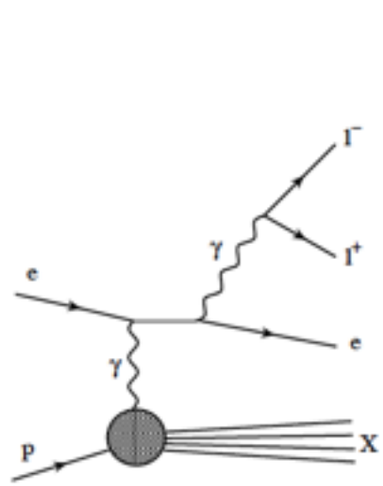
HERA II data (0.33 fb^{-1}) [JHEP 02 (2011) 117]

$\tau \longrightarrow$ e,μ,h every decay channel considered in all combinations except ee, μμ (large background from $\gamma\gamma \rightarrow ee,\mu\mu$)
only elastic process (inelastic DIS huge background)

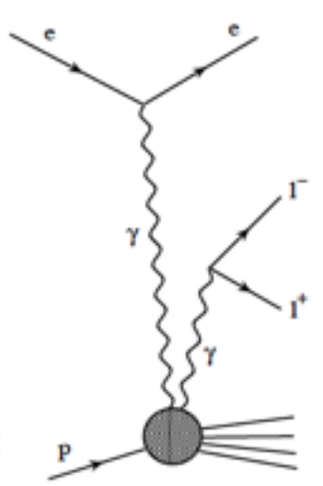
- Multivariate discriminant technique used to separate τ-jets from QCD-jets, exploiting the differences in jet shape
- Selection requires 2 among 3(e,h,μ) objects no deposits in the forward beam pipe region and, in case, the scattered electron



Bethe-Heitler

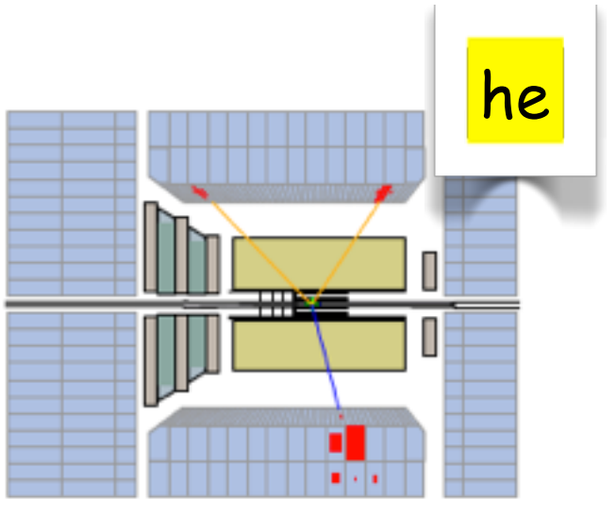


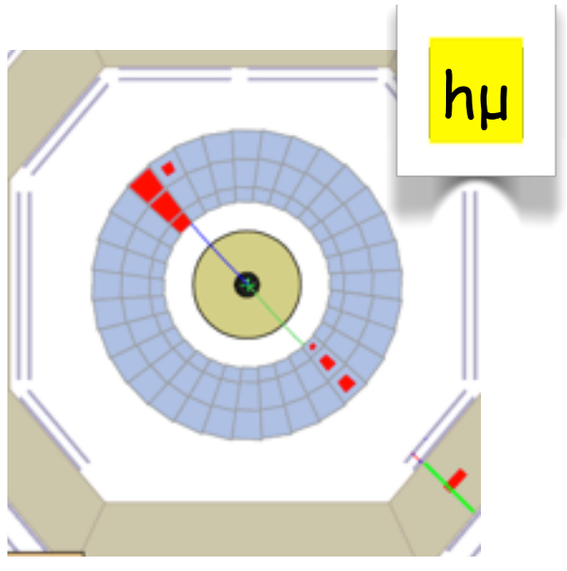
Cabibbo-Parisi

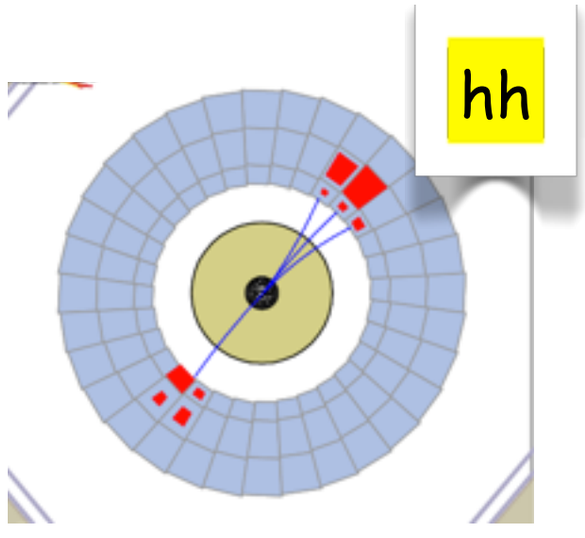


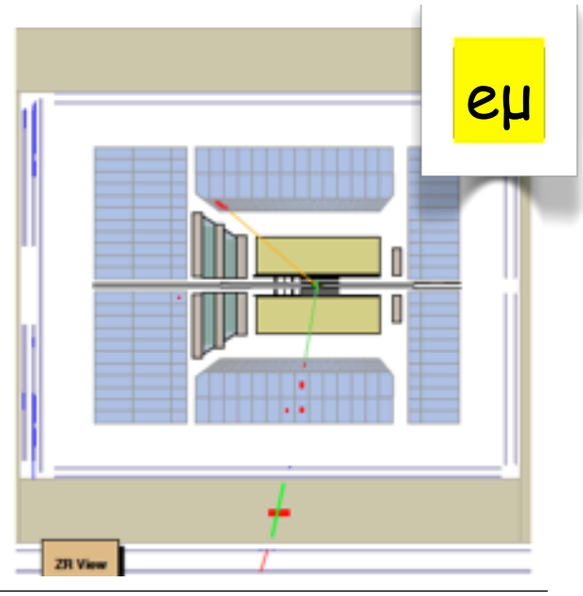
Drell-Yan

dilepton production at HERA







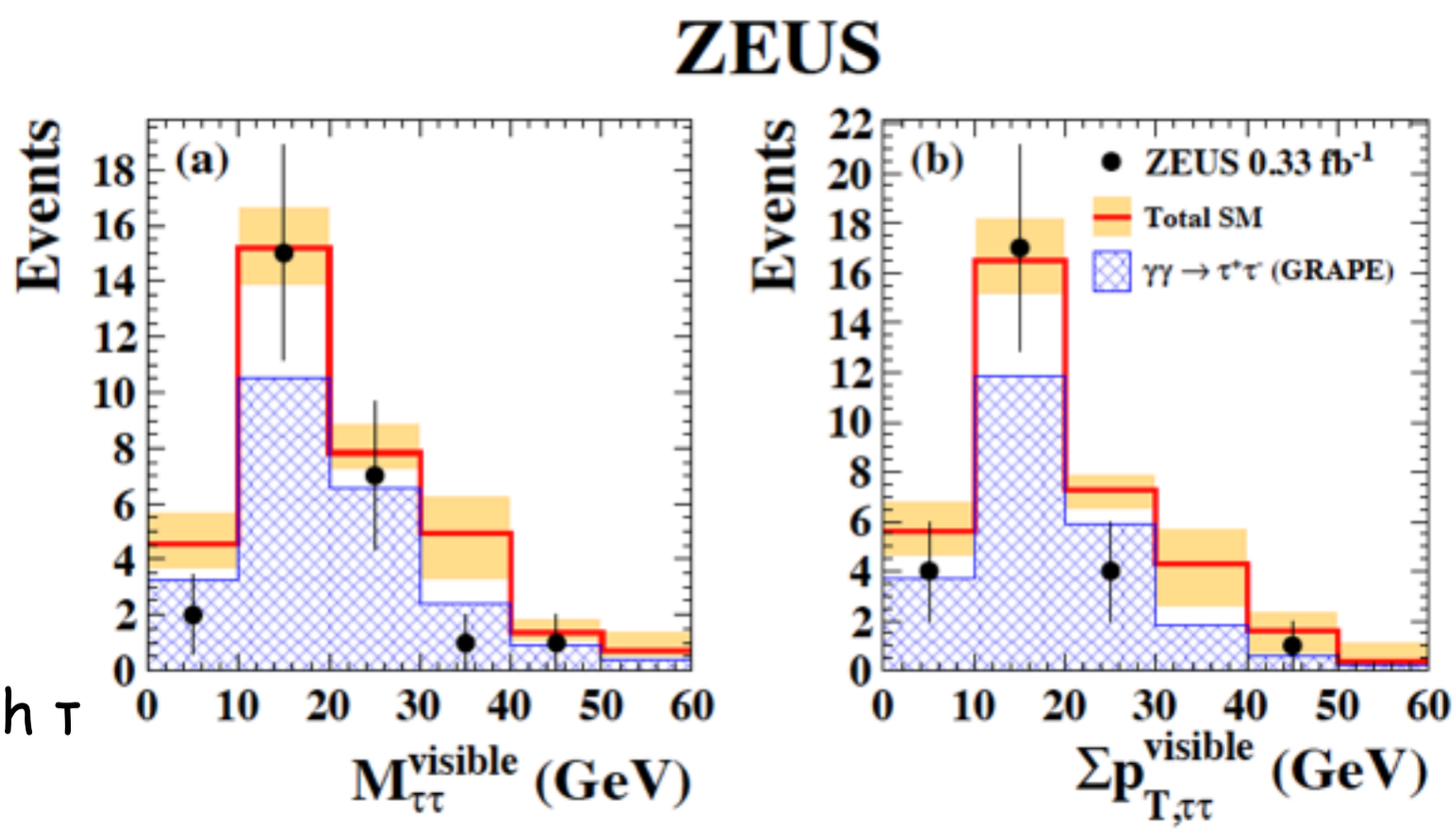


tau pairs results

ZEUS ditau events HERA II data (L=0.33 fb^{-1})

Topology	(e-)e-μ	(e-)e-jet	(e-)μ-jet	(e-)jet-jet	Total
Data	4	7	4	10	25
Total MC	$3.6^{+1.3}_{-0.3}$	$8.8^{+1.8}_{-0.8}$	$8.0^{+2.2}_{-1.2}$	$14.4^{+2.2}_{-3.5}$	$34.8^{+3.9}_{-3.8}$
$\tau^+\tau^-$ MC	$3.0^{+0.3}_{-0.2}$	$5.3^{+0.3}_{-0.2}$	$5.9^{+0.5}_{-0.5}$	$9.0^{+0.4}_{-0.3}$	$23.2^{+0.7}_{-0.7}$

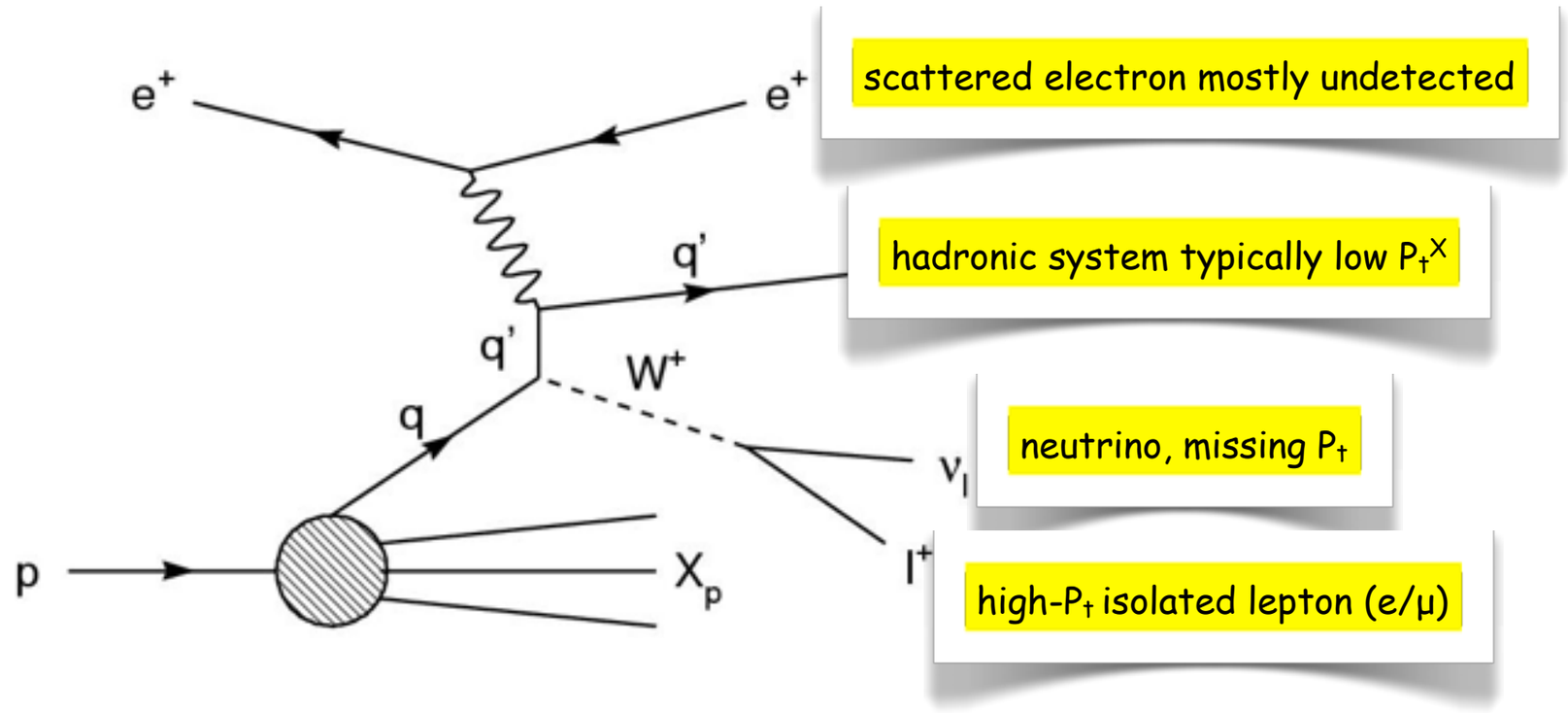
- 25 ditau events selected with ~ 70% purity
- good agreement with SM predictions, no surprise at high mass or large P_t
- cross section measured in the kinematic region:
$p_t(\tau)>5$ GeV, $17^0<\vartheta(\tau)<160^0$ for both τ



σ=3.3 ±1.3(stat.) $^{+1.0}_{-0.7}$(syst.) pb SM σ=5.67 ±0.16(theor.) pb

Search for isolated leptons and missing P_t

The main SM process producing a final state with single high-P_t lepton and missing P_t is the W production



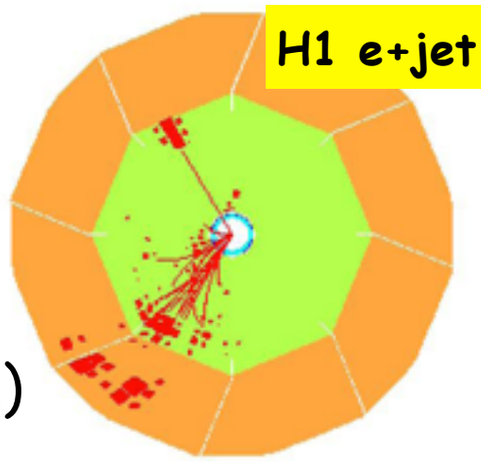
- Total cross section ~ 1.3 pb with ~ 11% of W decays to each lepton flavor
- Process modelled using the EPVEC generator reweighted at NLO, uncertainty 15%
- Main SM background NC-DIS, CC-DIS and lepton-pair QED production

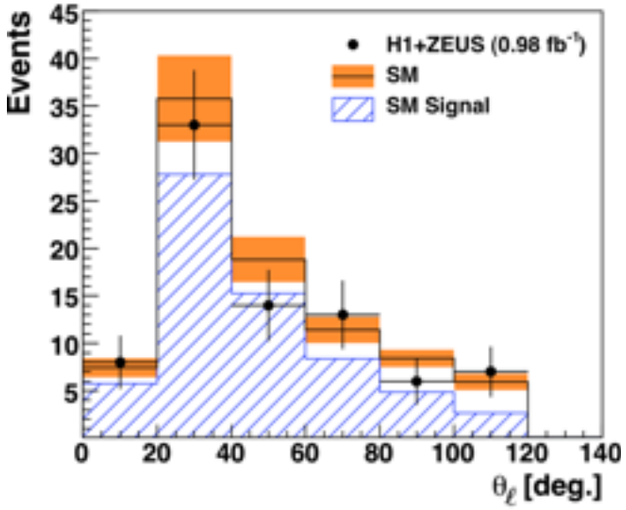
Analysis performed combining H1 and ZEUS data [JHEP 03 (2010) 1]
Integrated luminosity ~ 1 fb^{-1}

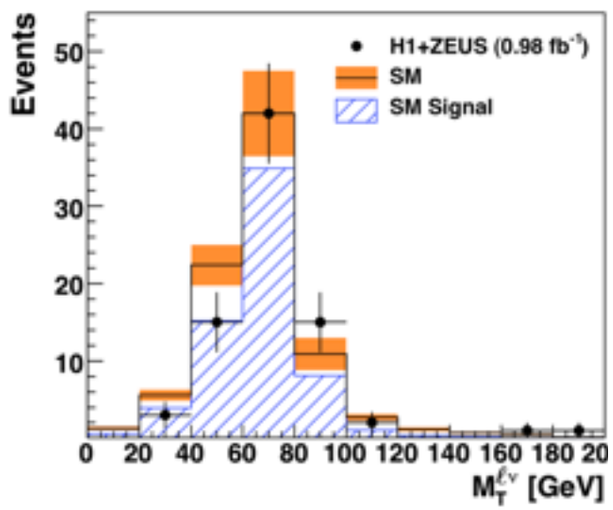
Isolated leptons overall results

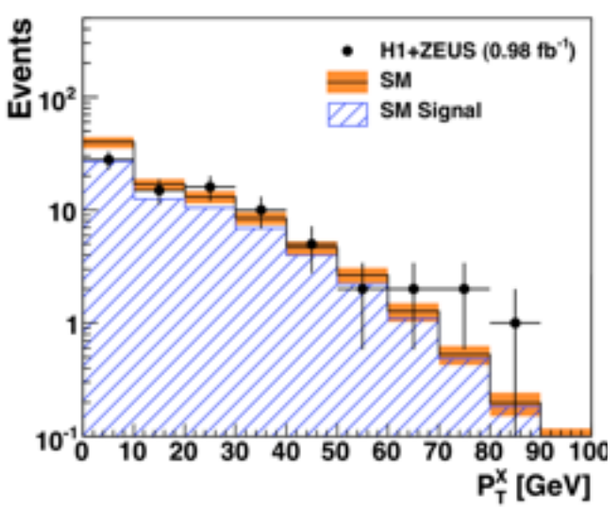
Selection in common H1+ZEUS phase space:

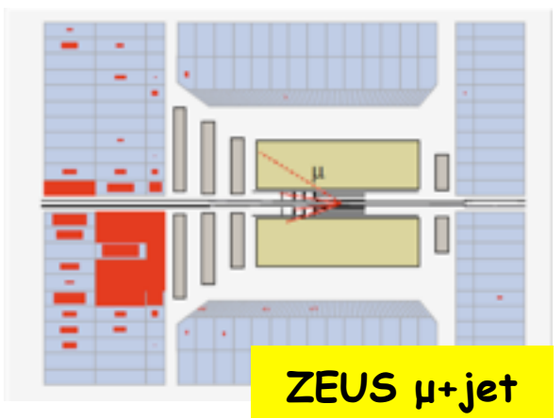
- e/μ → P_t>10 GeV, $15^0 < \vartheta < 120^0$, P_t^{miss} > 12 GeV
- lepton well isolated from other tracks or jets
- dedicated cut to reject back-to-back topology (NC-DIS and dilepton bg.)









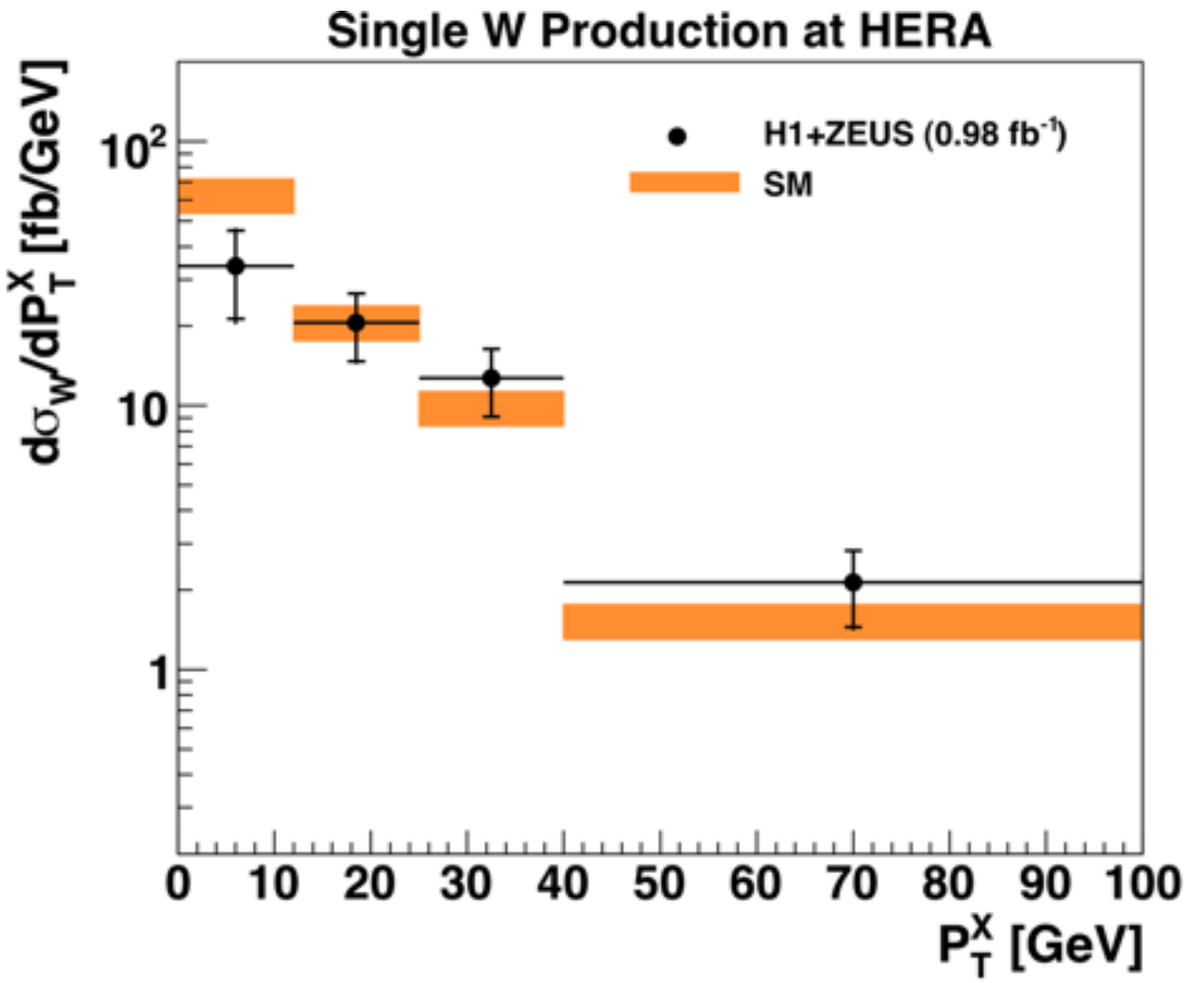


H1+ZEUS 1994–2007 $e^{\pm}p$ 0.98 fb^{-1}		Data	SM Expectation	SM Signal	Other SM Processes
Electron	Total	61	69.2 ± 8.2	48.3 ± 7.4	20.9 ± 3.2
	$P_T^X > 25$ GeV	16	13.0 ± 1.7	10.0 ± 1.6	3.1 ± 0.7
Muon	Total	20	18.6 ± 2.7	16.4 ± 2.6	2.2 ± 0.5
	$P_T^X > 25$ GeV	13	11.0 ± 1.6	9.8 ± 1.6	1.2 ± 0.3
Combined	Total	81	87.8 ± 11.0	64.7 ± 9.9	23.1 ± 3.3
	$P_T^X > 25$ GeV	29	24.0 ± 3.2	19.7 ± 3.1	4.3 ± 0.8

Overall good agreement with SM predictions

Single W production cross section

- Combined measurement of W production cross section performed in common phase space
- Measurement done differentially in different P_t^X bins
- No measurement in muon channel for $P_t^X < 12$ GeV, electron data used assuming lepton universality



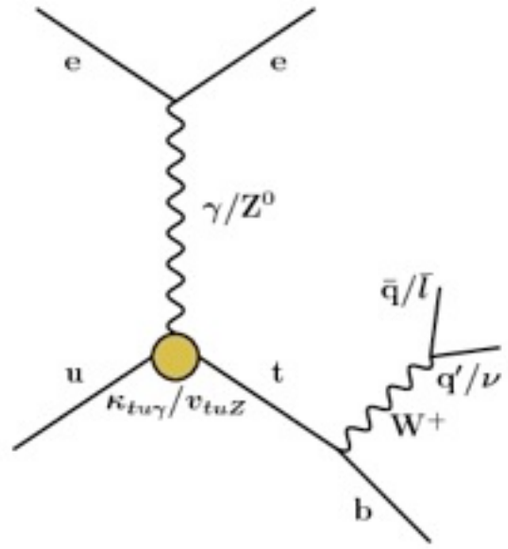
Inclusive single W cross section

$$\sigma_{ep\to WX} = 1.06 \pm 0.16(stat.) \pm 0.07(syst.)pb$$

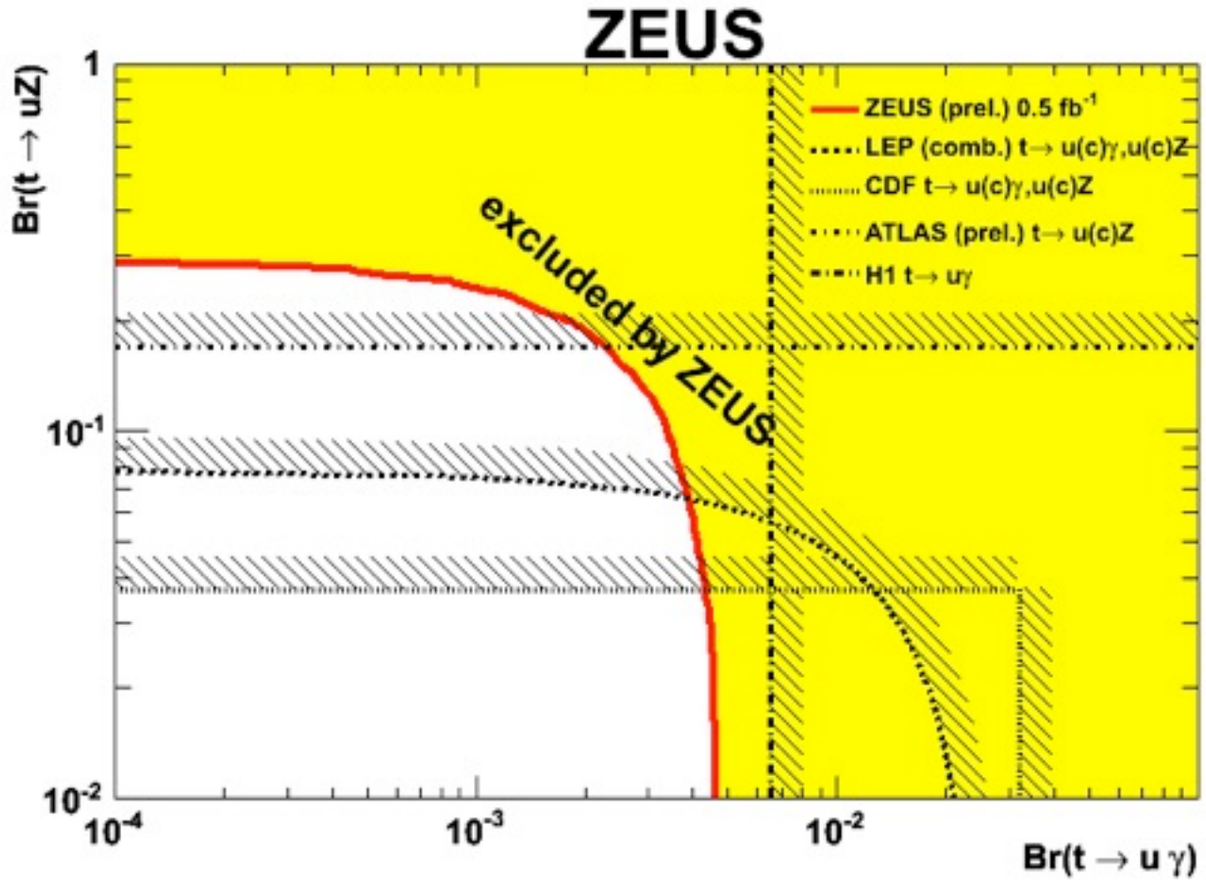
in good agreement with SM prediction at NLO

$$\sigma^{SM}_{ep\to WX} = 1.26 \pm 0.19(theor.)pb$$

Single top production via FCNC



- Within the SM the top-quark can be produced at HERA via the CC-process $ep \rightarrow \nu tX$ with an extremely small cross section ~ 1 fb.
- Anomalous FCNC couplings of the type $tu\gamma/Z$ can enhance top production.
- At HERA the sensitivity is higher for the $tu\gamma$ coupling.
- Looking at the leptonic decay of the W from the top, the topology is very similar to that of the single-W production, the only remarkable difference being a high P_t^X due to the b-quark from the top.
- ZEUS has recently produced constraints on top anomalous decay to $u\gamma$ and uZ using the full HERA data ~ 0.5 fb^{-1}.



For low values of the Br to uZ (up to 0.03-0.04) ZEUS constraints are the best to date

Summary

- A review on recent HERA results on searches beyond SM involving high-pt leptons has been presented.

- In general SM predictions describe the data well
  → no evidence for new physics

- Hera constraints on searches are still competitive with the rest of the world.