Search for physics beyond the SM in ep collisions at HERA

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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

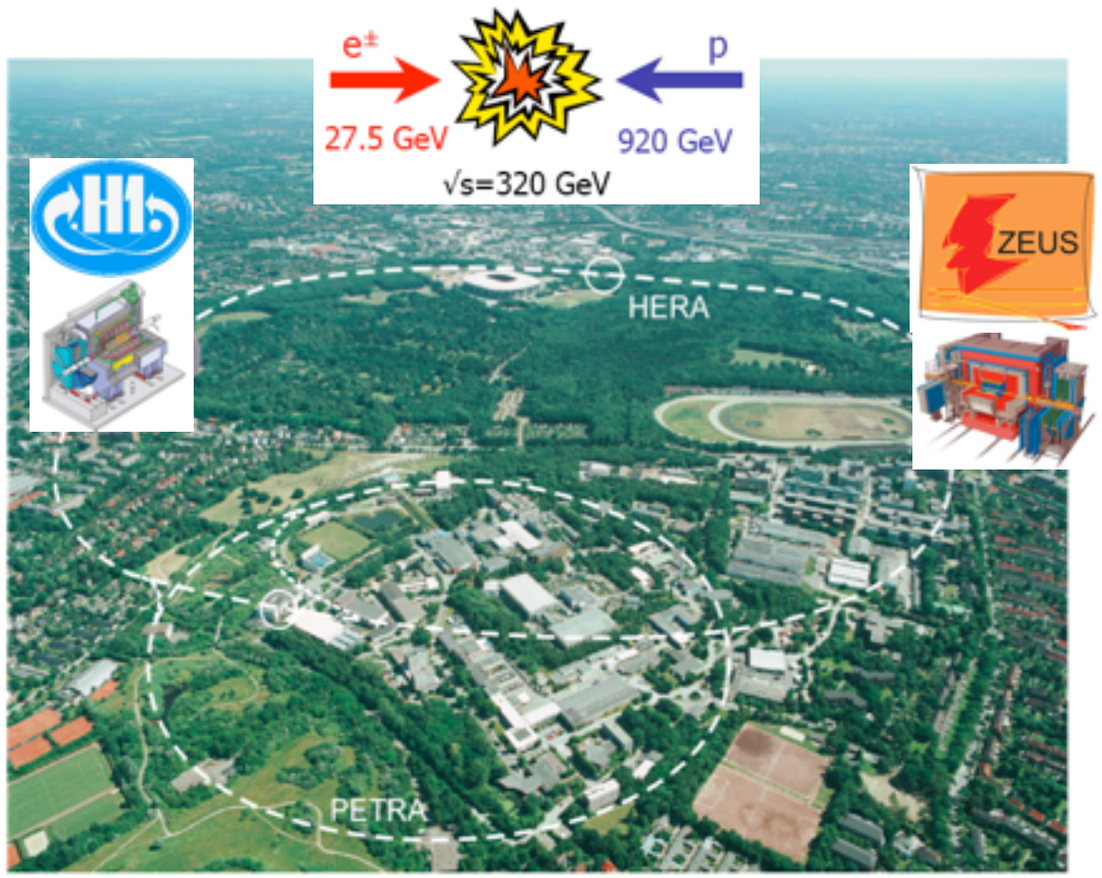
In this talk a review of recent results of such searches is presented:

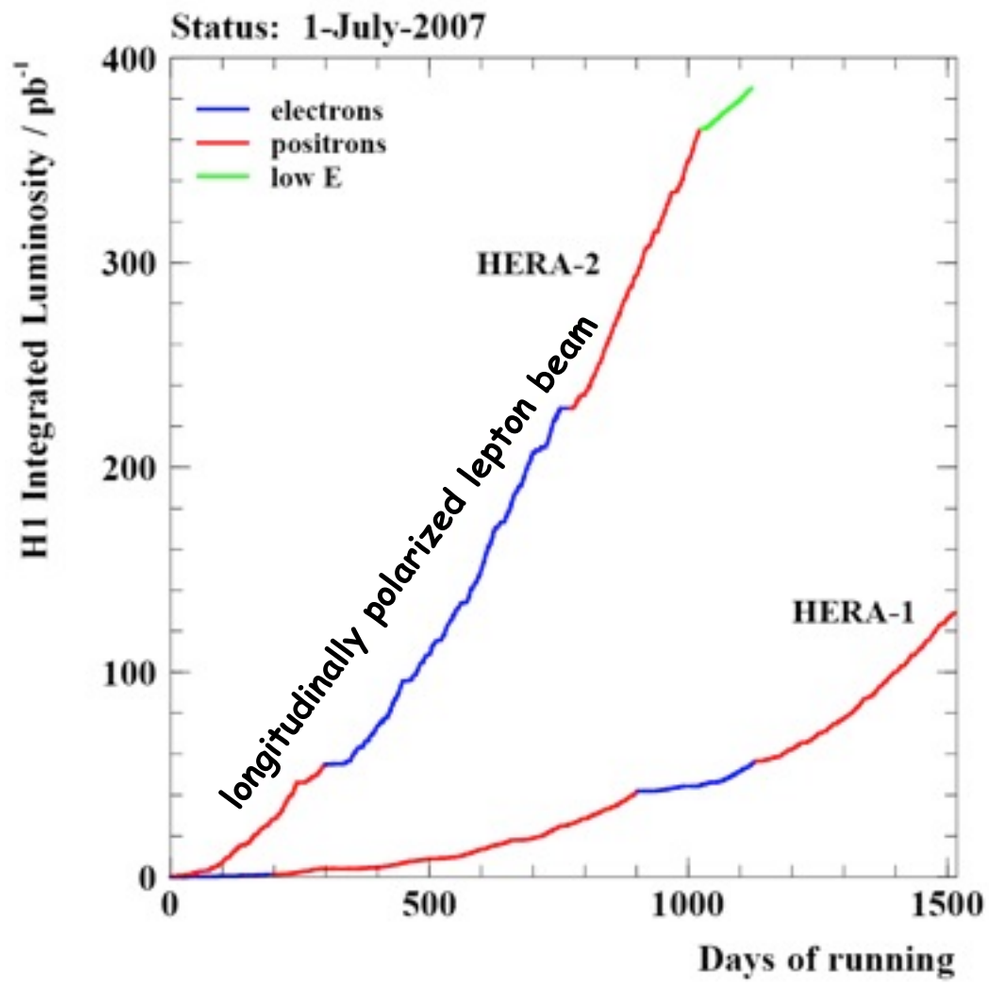
- leptoquarks (e-jet, P_t^{miss}-jet)
- ditaus
- high pt leptons (e/μ) and P_t^{miss} (H1+ZEUS) and constraints on single top production via FCNC couplings

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)





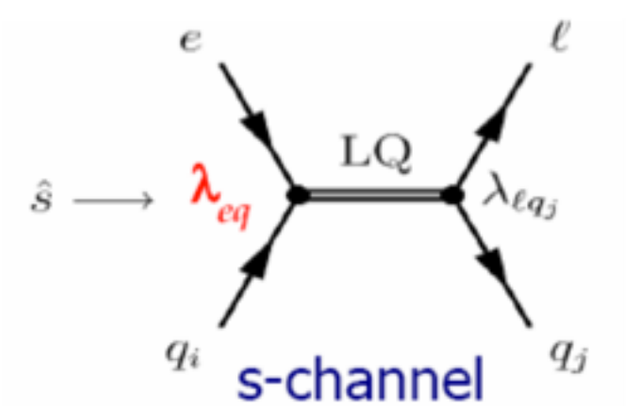
Two multi-purpose experiments (H1 and ZEUS) located at the ep interaction points

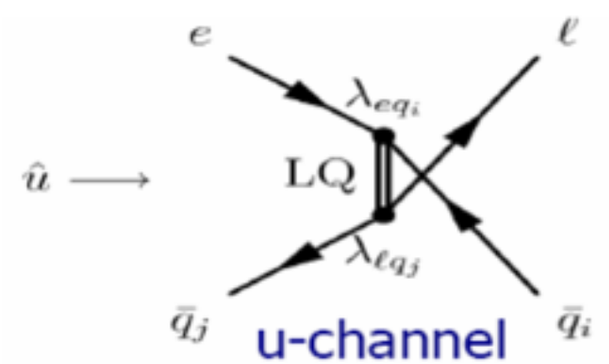
About 0.5 fb^{-1} data collected by each experiment

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

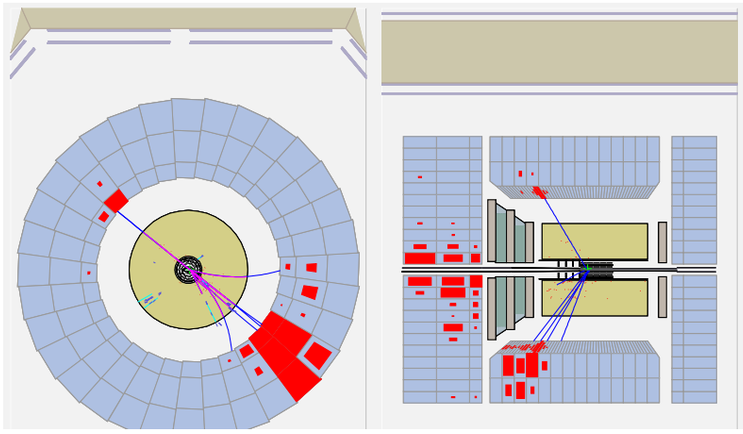




Signature similar to NC or CC DIS

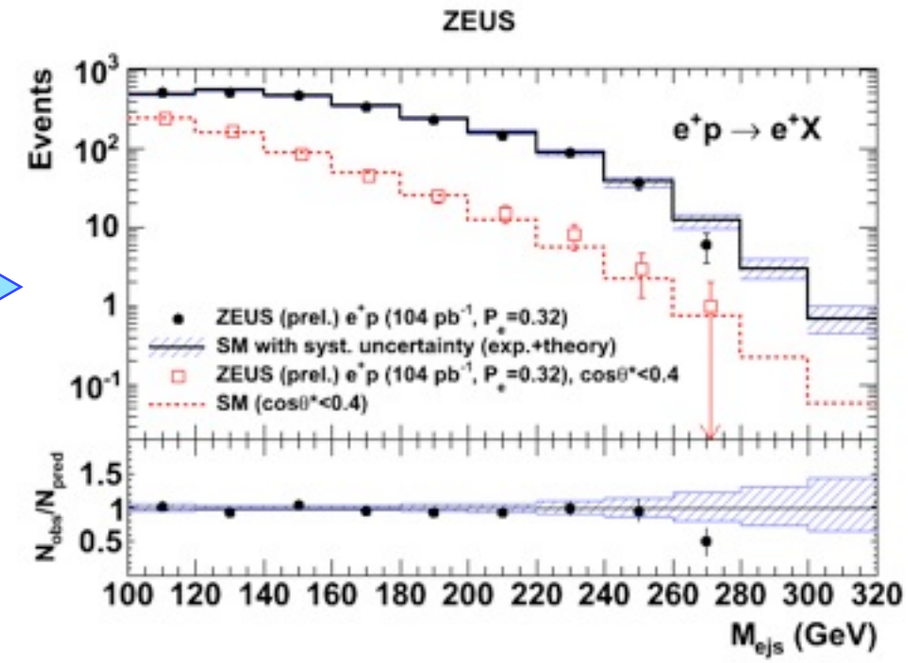
Analysis look for possible deviations from SM in e-jet or ν-jet invariant mass also exploiting different angular distribution for a resonance decay respect to SM DIS

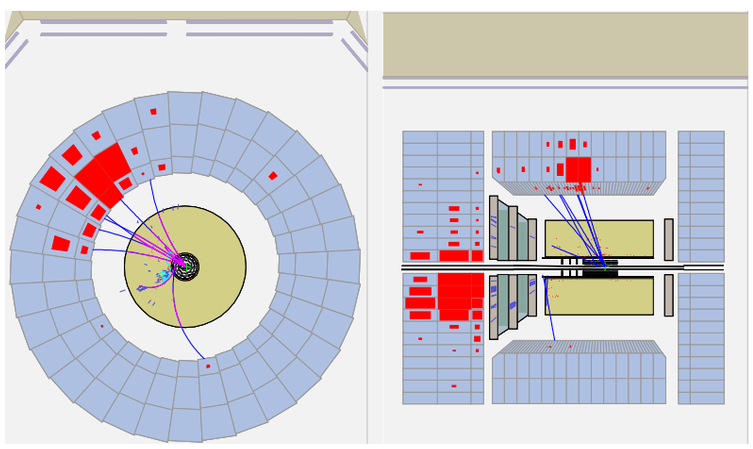
LQ search: final state invariant mass



NC event: e+jet final state

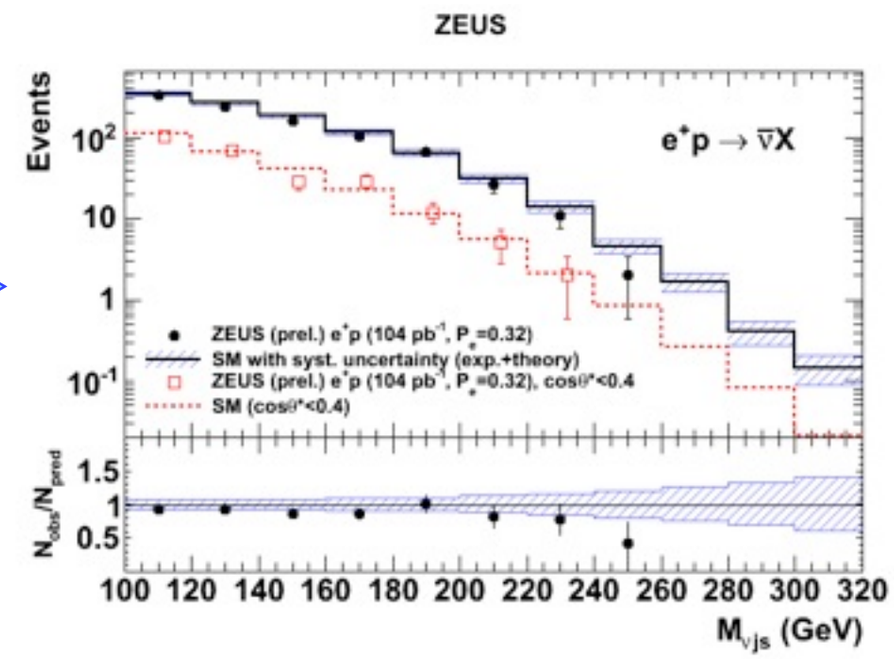
$M_{e\text{-}jet}$





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

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



All HERA data analysed no deviations found

LQ limits

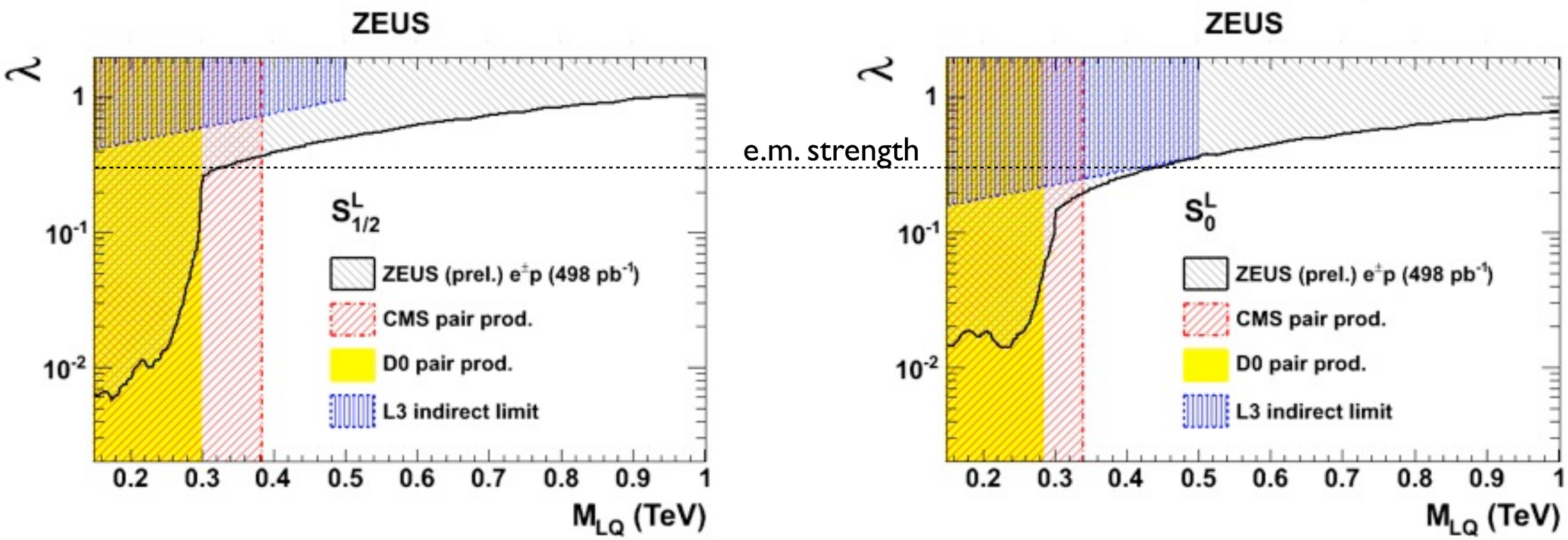
Phenomenological model of Buchmuller-Ruckl-Wyler used in limit setting

- $U(1)_Y \times SU(2)_L \times SU(3)_c$ 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)



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)

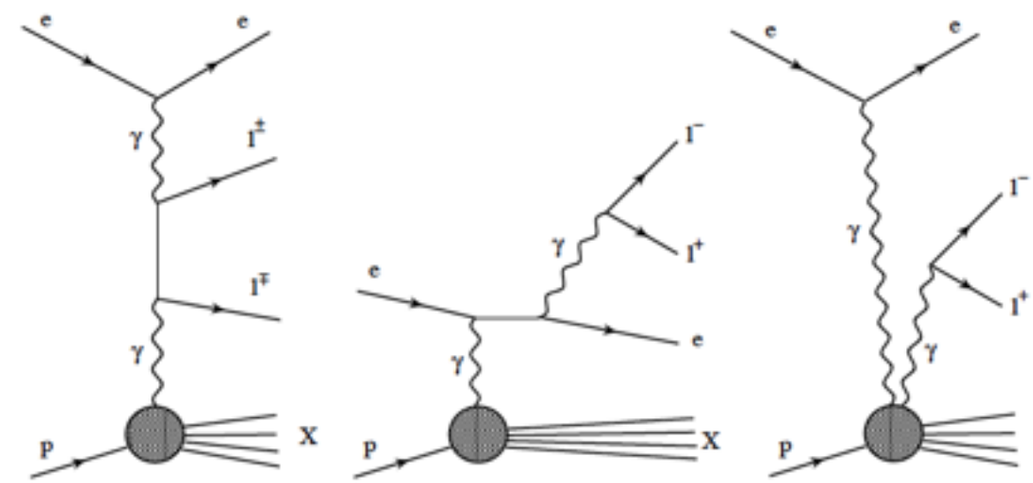
Study of tau pairs production

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

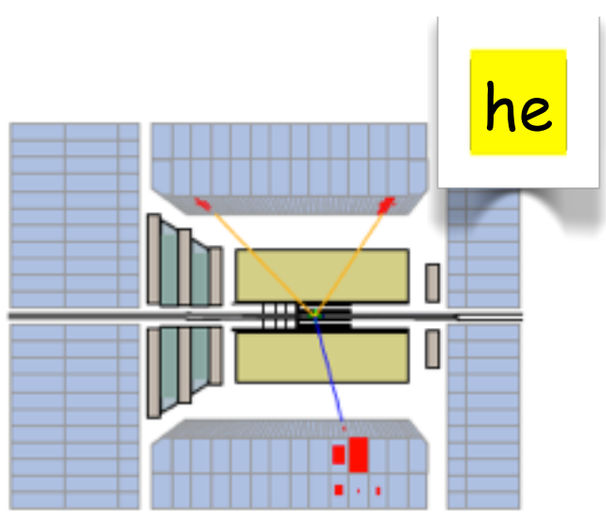
$\tau \longrightarrow$ e,μ,h every decay channel considered in all combinations except ee, μμ (large background from $\gamma\gamma \rightarrow$ee,μμ)

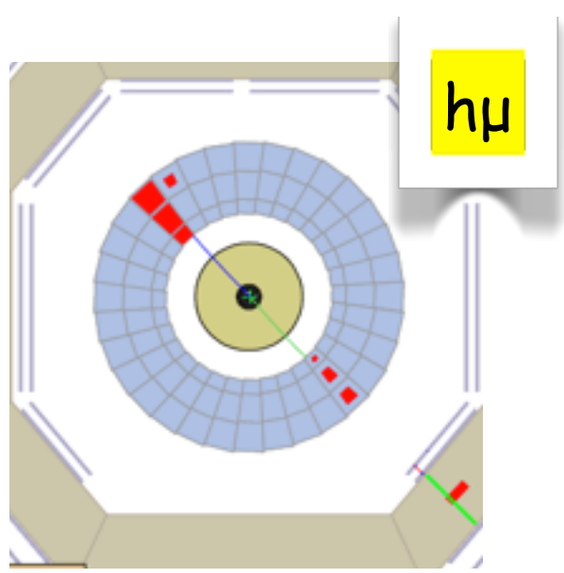
only elastic process (inelastic DIS huge background)

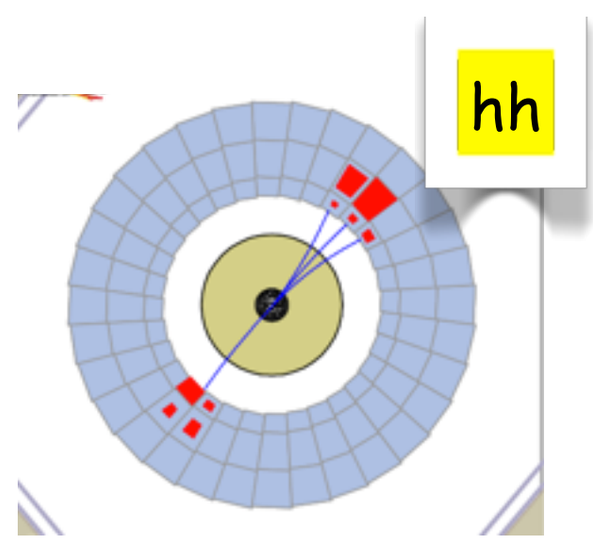
- Multivariate discriminant technique used to separate τ-jets from QCD-jets, exploiting the differences in jet shape
- Selection requires 2 among 3(e,h,μ) objects no deposits in the forward beam pipe region and, in case, the scattered electron

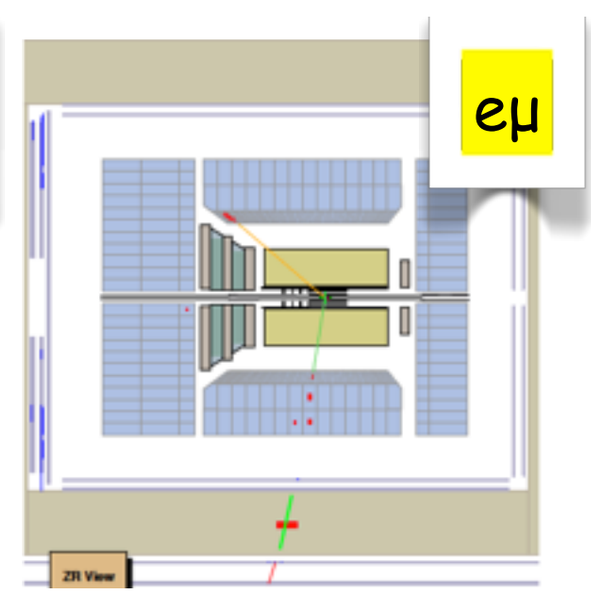


dilepton production at HERA









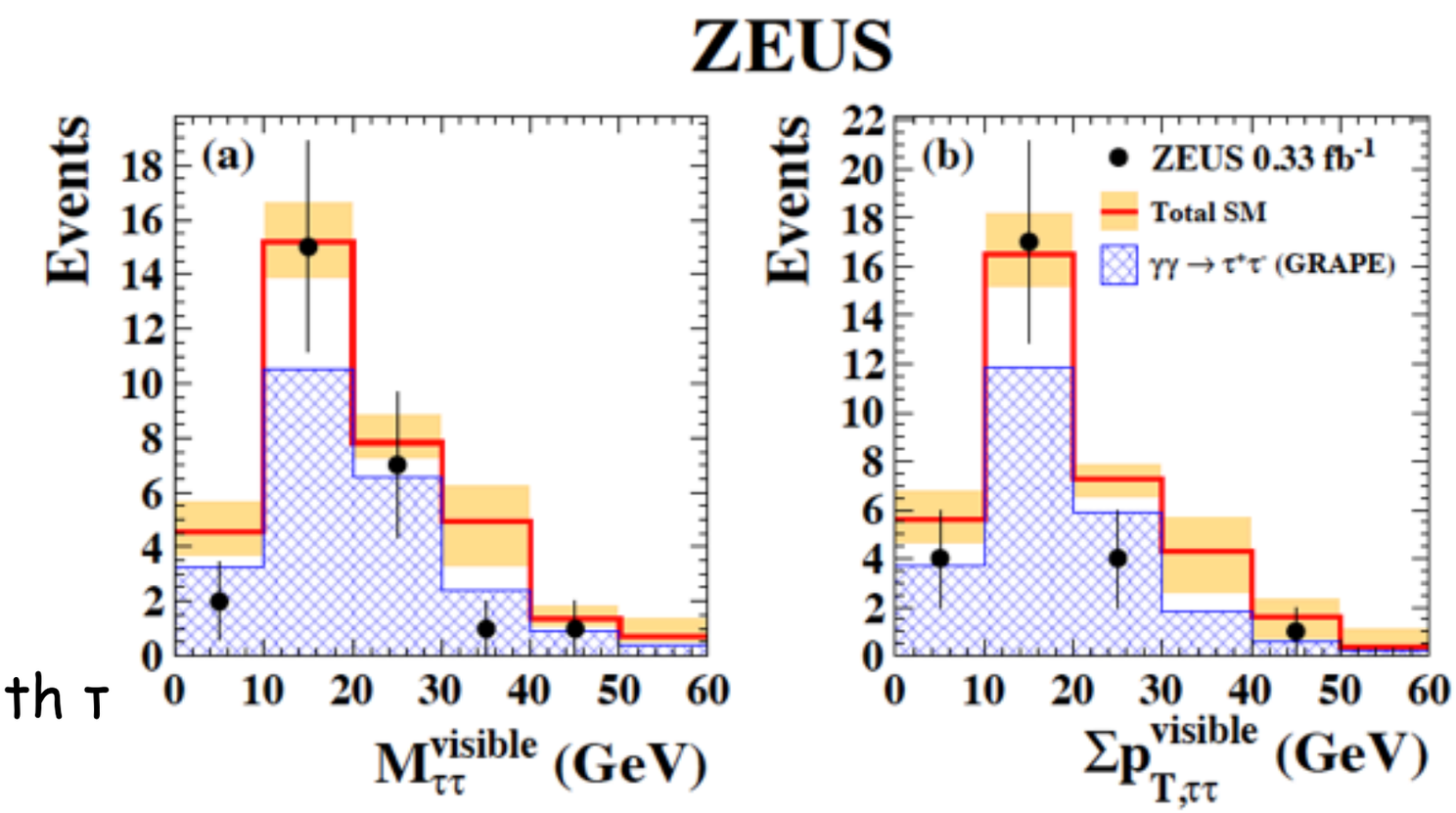
tau pairs results

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:

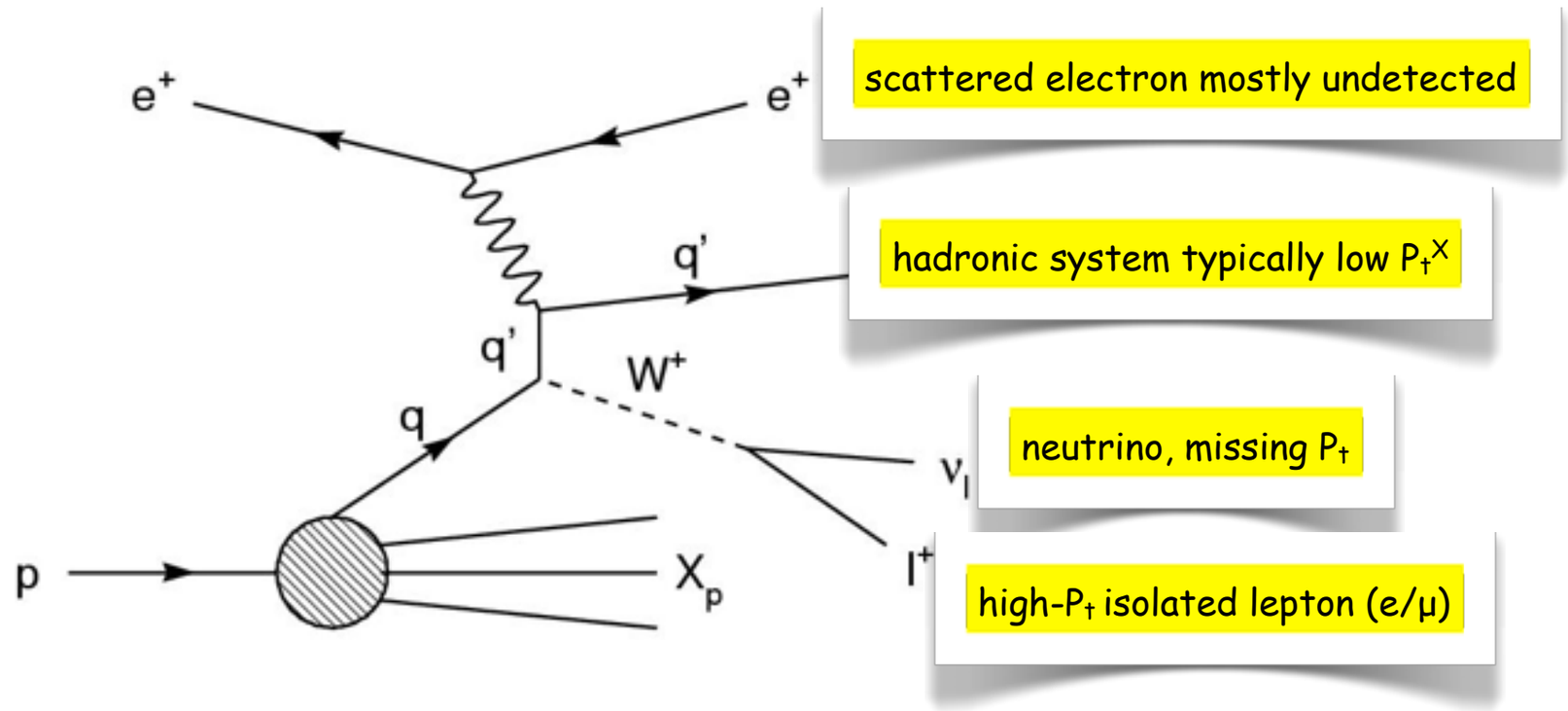
$p_t(\tau)>5$ GeV, $17^0<\vartheta(\tau)<160^0$ for both τ



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



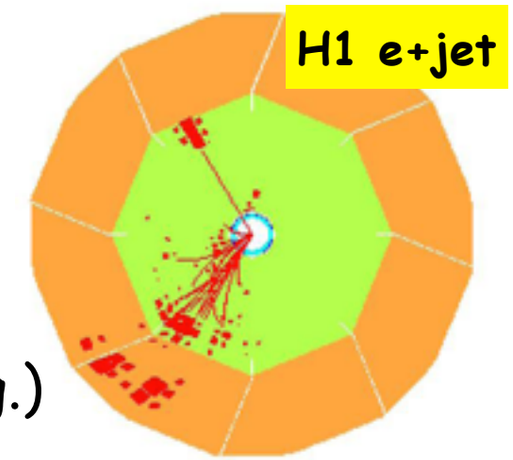
- Total cross section ~ 1.3 pb with ~ 11% of W decays to each lepton flavor
- Process modelled using the EPVEC generator reweighted at NLO, uncertainty 15%
- Main SM background NC-DIS, CC-DIS and lepton-pair QED production

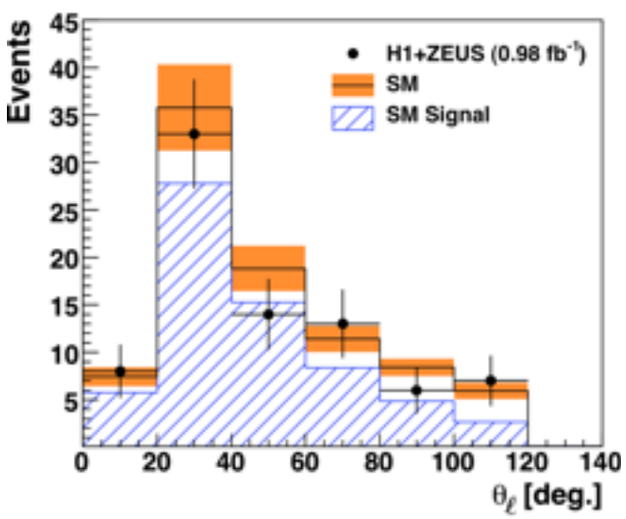
Analysis performed combining H1 and ZEUS data [JHEP 03 (2010) 1]
Integrated luminosity ~ 1 fb^{-1}

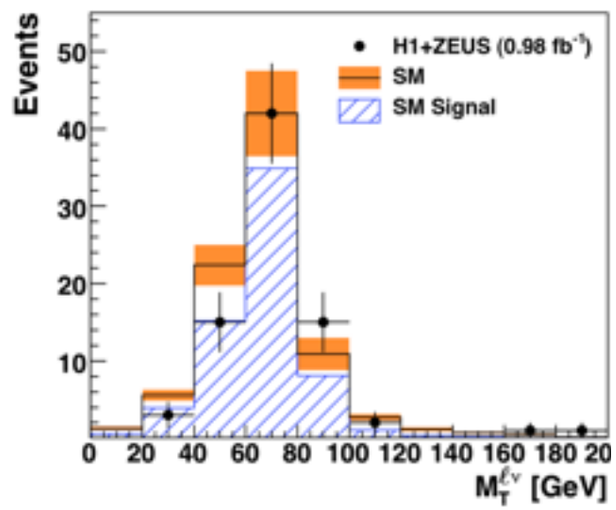
Isolated leptons overall results

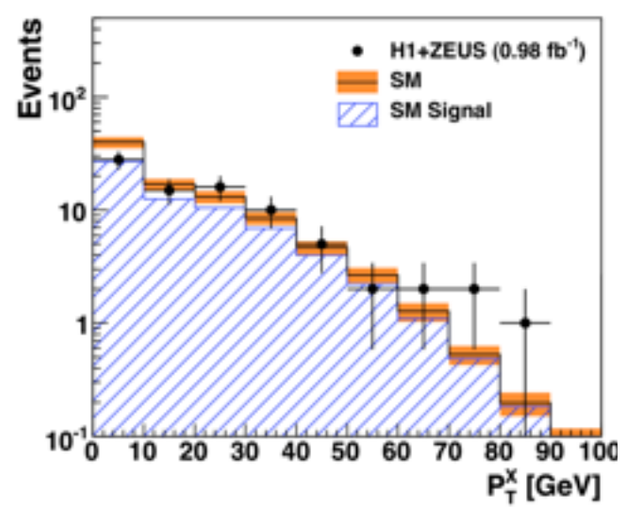
Selection in common H1+ZEUS phase space:

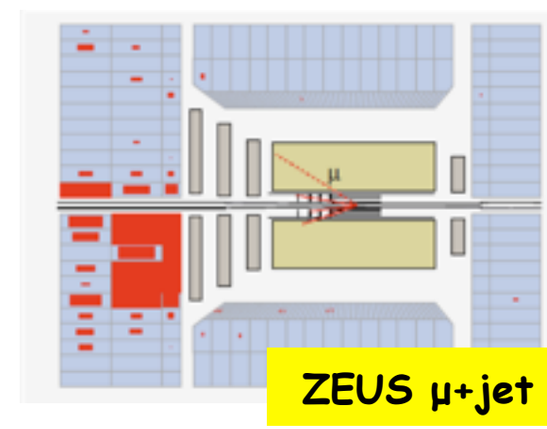
- $e/\mu \rightarrow P_t > 10$ GeV, $15^0 < \vartheta < 120^0$, $P_t^{miss} > 12$ GeV
- lepton well isolated from other tracks or jets
- dedicated cut to reject back-to-back topology (NC-DIS and dilepton bg.)









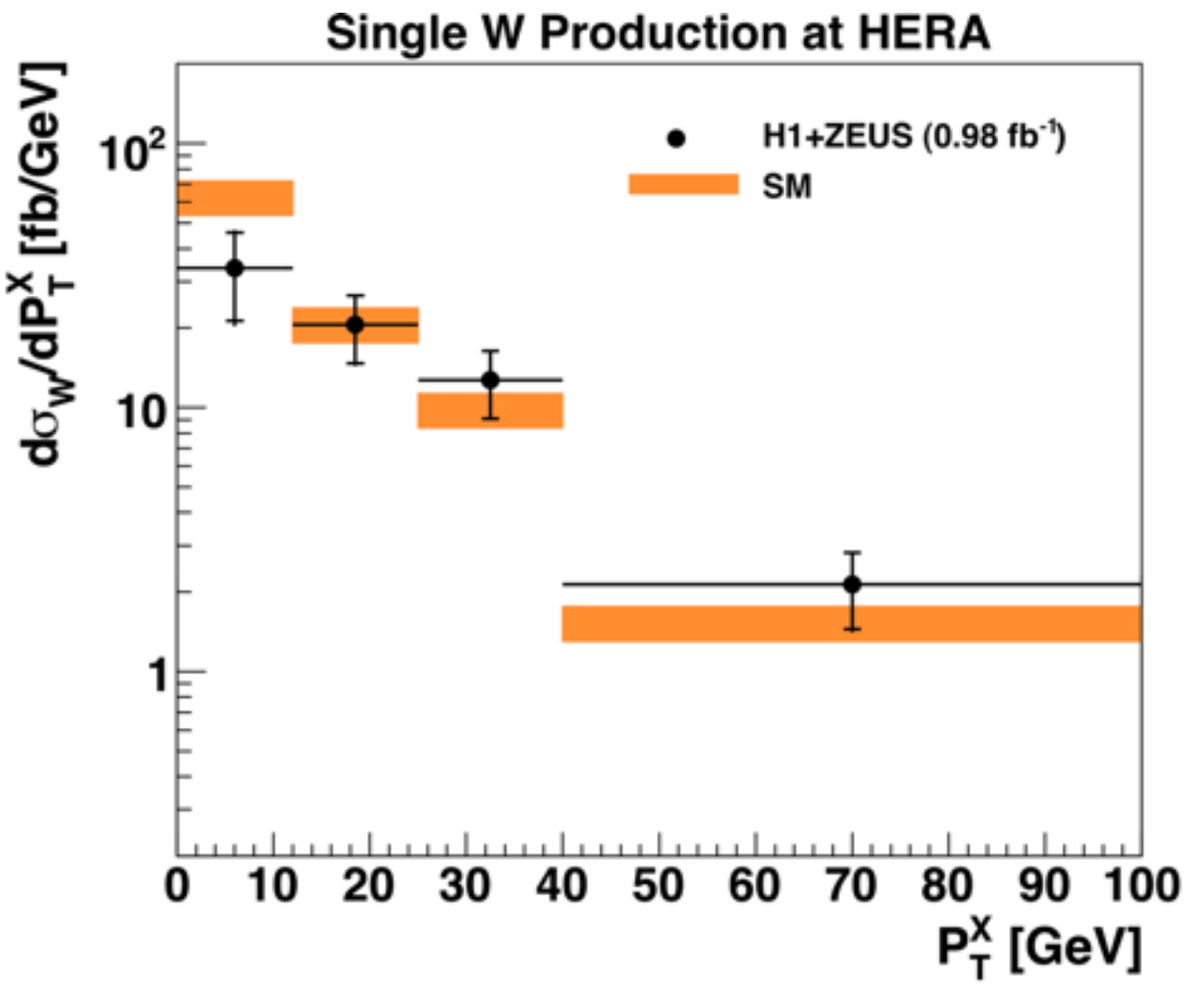


H1+ZEUS 1994–2007 $e^{\pm}p$ 0.98 fb^{-1}		Data	SM Expectation	SM Signal	Other SM Processes
Electron	Total	61	69.2 ± 8.2	48.3 ± 7.4	20.9 ± 3.2
	$P_T^X > 25$ GeV	16	13.0 ± 1.7	10.0 ± 1.6	3.1 ± 0.7
Muon	Total	20	18.6 ± 2.7	16.4 ± 2.6	2.2 ± 0.5
	$P_T^X > 25$ GeV	13	11.0 ± 1.6	9.8 ± 1.6	1.2 ± 0.3
Combined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



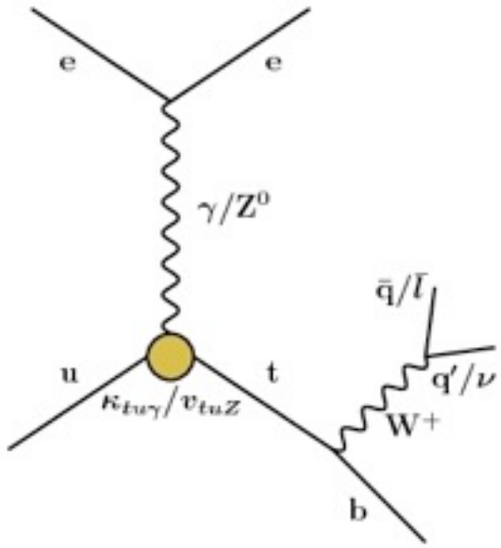
Inclusive single W cross section

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

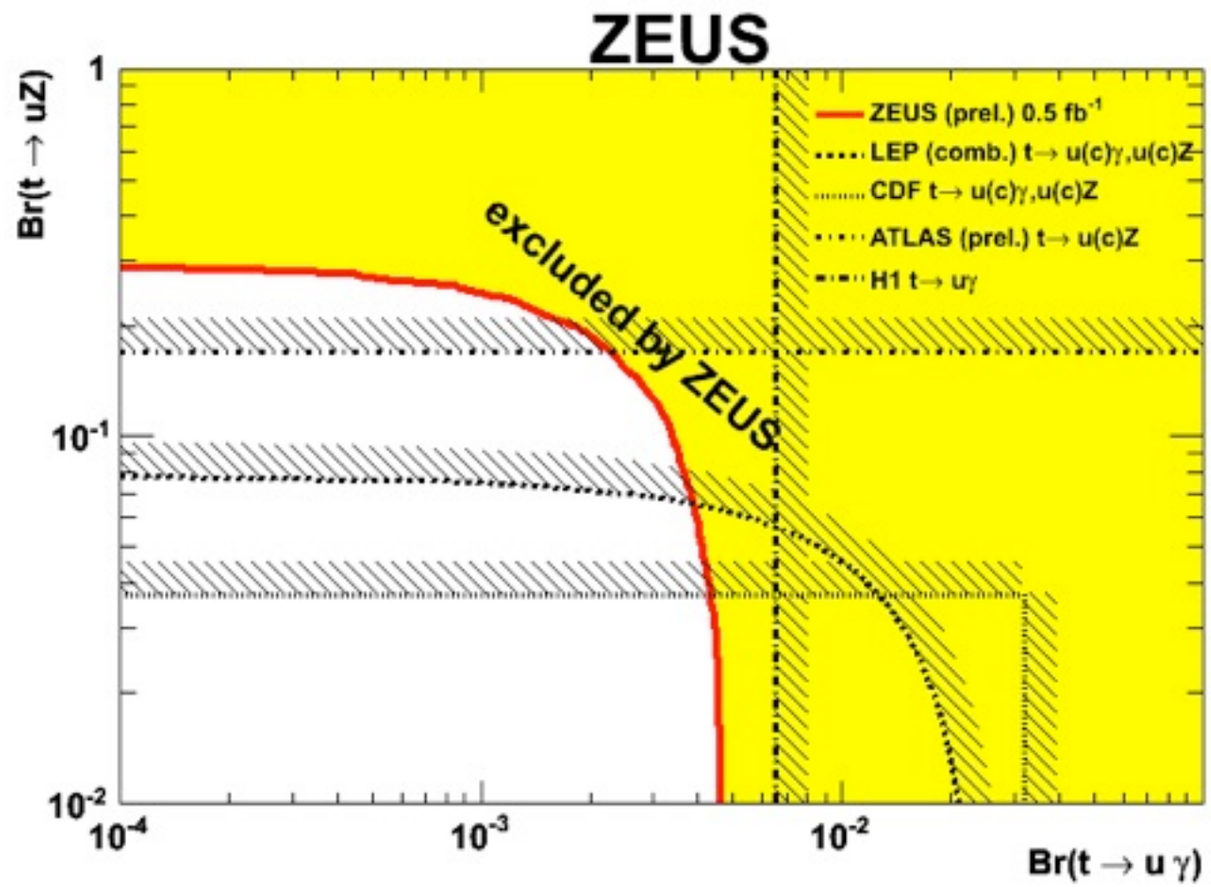
in good agreement with SM prediction at NLO

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

Single top production via FCNC



- Within the SM the top-quark can be produced at HERA via the CC-process ep → νtX with an extremely small cross section ~ 1 fb.
- Anomalous FCNC couplings of the type tuγ/Z can enhance top production.
- At HERA the sensitivity is higher for the tuγ 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 uγ 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.