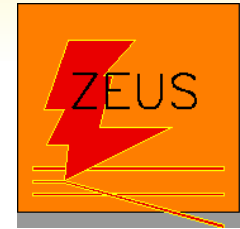


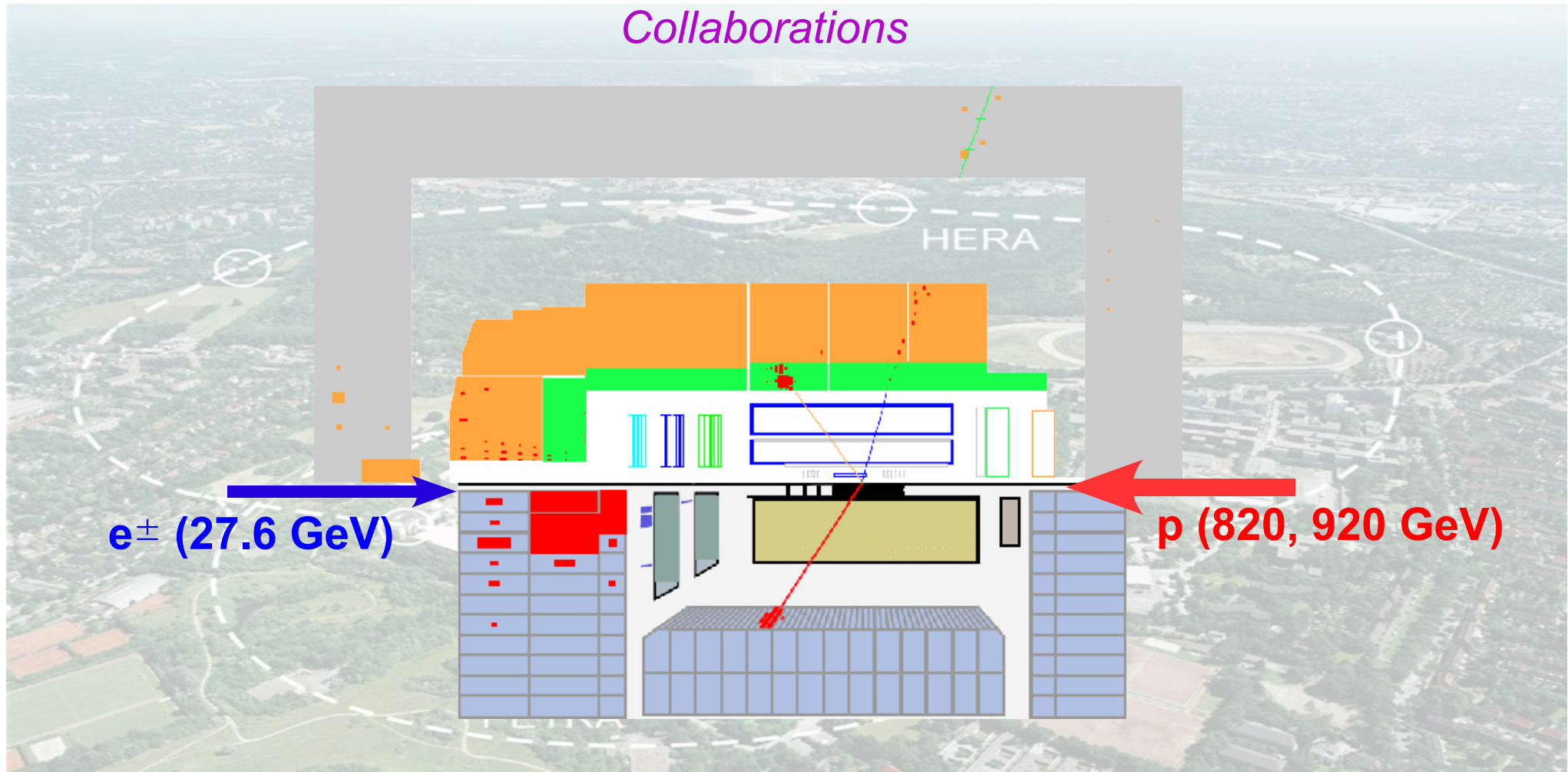
Searches for New Physics at HERA



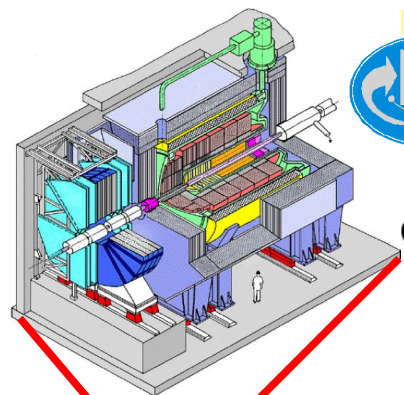
Emmanuel Sauvan
CPPM Marseille



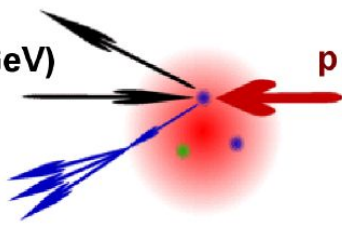
*On behalf of H1 and ZEUS
Collaborations*



The HERA collider

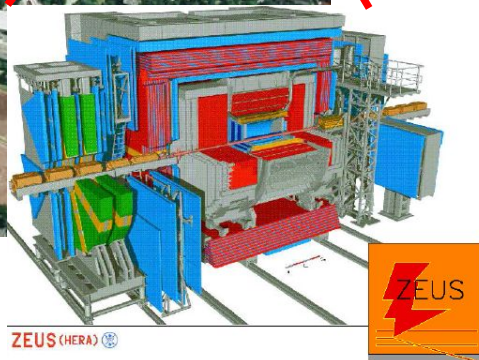
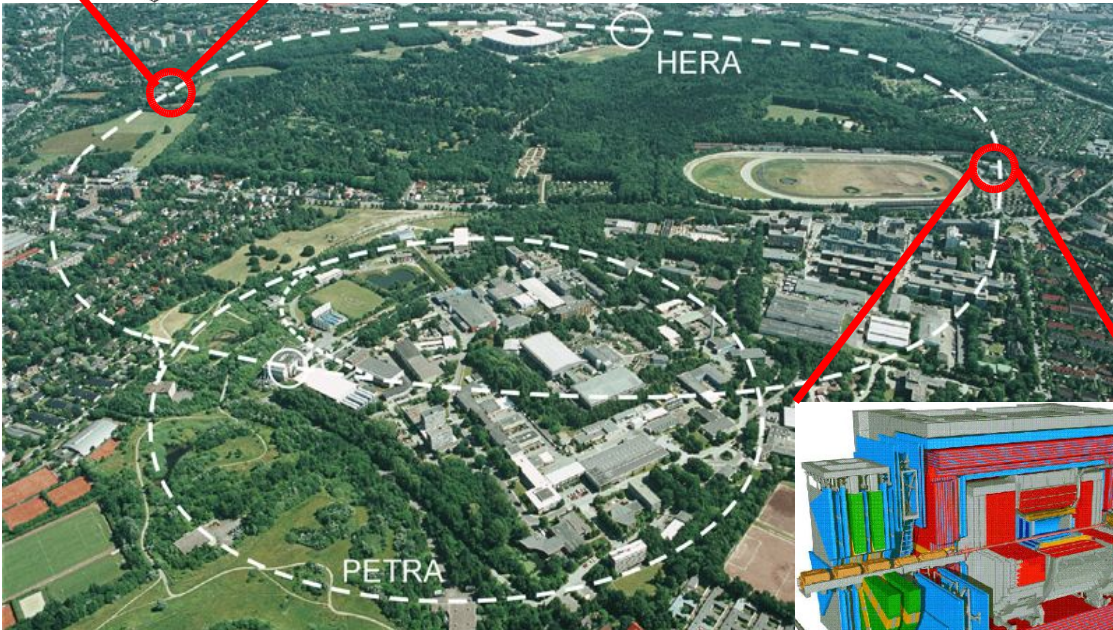
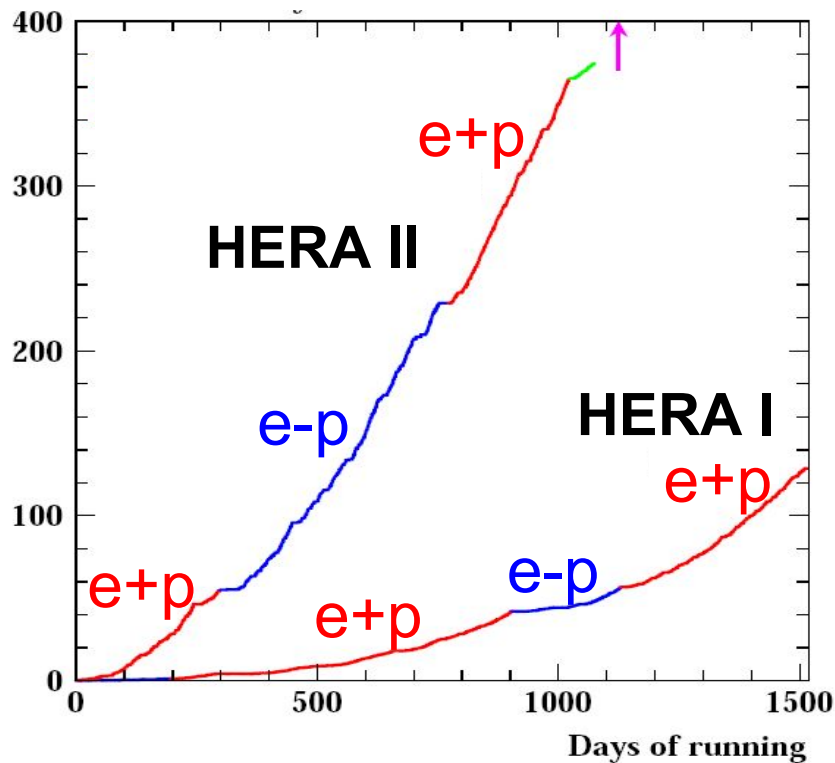


e^\pm (27.6 GeV)



p (820/920 GeV)

H1 Integrated Luminosity / pb^{-1}



- HERA I: 1992-2000, $\sim 120 \text{ pb}^{-1}$ per experiment
- HERA II: luminosity upgrade and polarised lepton beams

→ End of $E_{\text{cm}} = 320 \text{ GeV}$ run: March, 20 2007

→ $\sim 360 \text{ pb}^{-1}$ per experiment in $e^+_{L,R} p$ and $e^-_{L,R} p$

↘ In total H1+ZEUS together accumulated $\sim 1 \text{ fb}^{-1}$

Hunting for New Physics at HERA

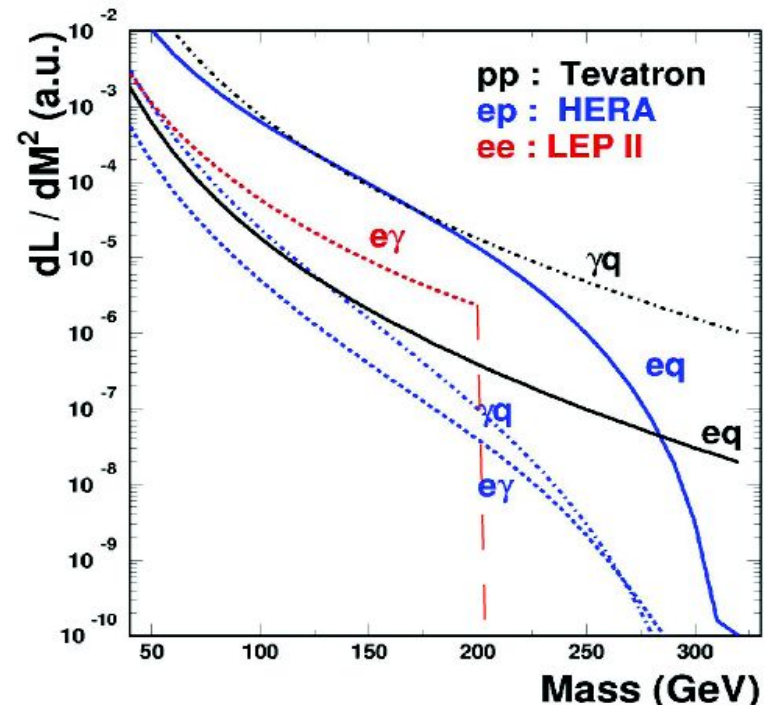
↘ The instrument: HERA is a frontier collider

→ $\mathcal{L} \sim 0.5 \text{ fb}^{-1}$: search for processes with $\sigma < 1 \text{ pb}$

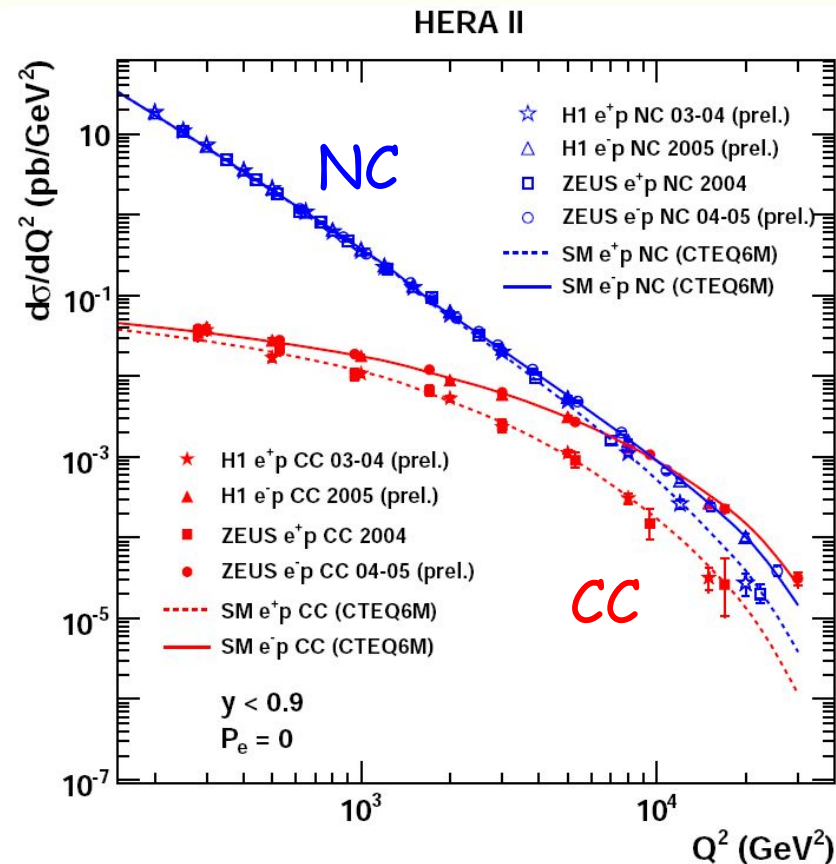
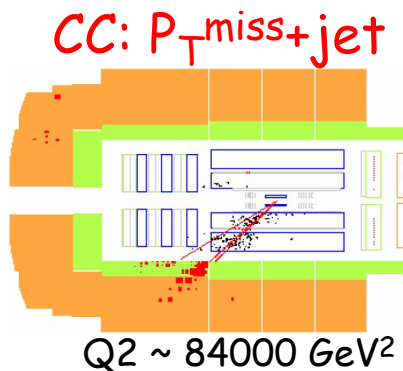
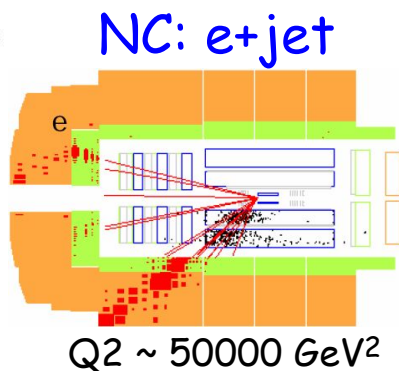
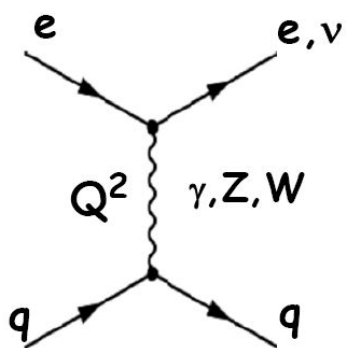
- Parton luminosity:
HERA collides beyond LEP
- Cross-section:
depends on the underlying physics
- Backgrounds:
HERA has less than Tevatron

↘ The methods:

- Look for predicted signatures
 - Single production of particles (depends on the coupling to SM)
 - Non-observation: set limits
- Model independent searches
 - SM processes with a low cross-section
 - Investigate all possible final states, compare to SM



NC and CC DIS at highest Q^2



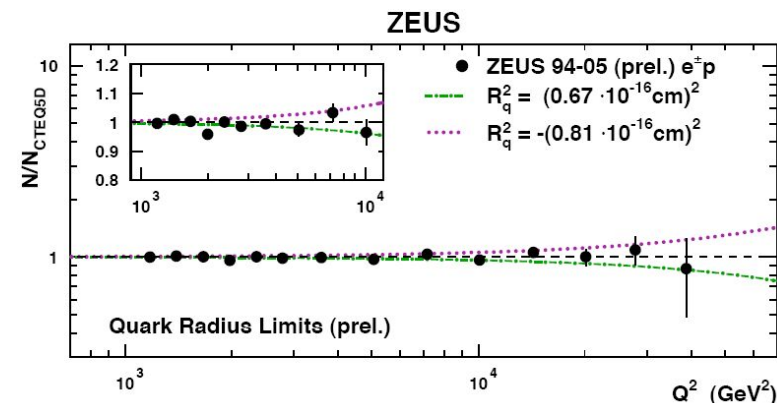
- Measurement of NC, CC DIS cross section at highest Q^2
 - Contains already a lot of informations
 - New currents affecting DIS processes ?

- NC DIS: Effective charge quark radius (ZEUS, 275 pb⁻¹)

→ Assigns a finite size to EW charge distributions

$$\frac{d\sigma}{dQ^2} = \frac{d\sigma^{SM}}{dQ^2} \left(1 - \frac{R_q^2}{6} Q^2 \right)$$

→ $R_q < 0.67 \cdot 10^{-18} \text{ m}$



New Physics in eq → eq amplitude

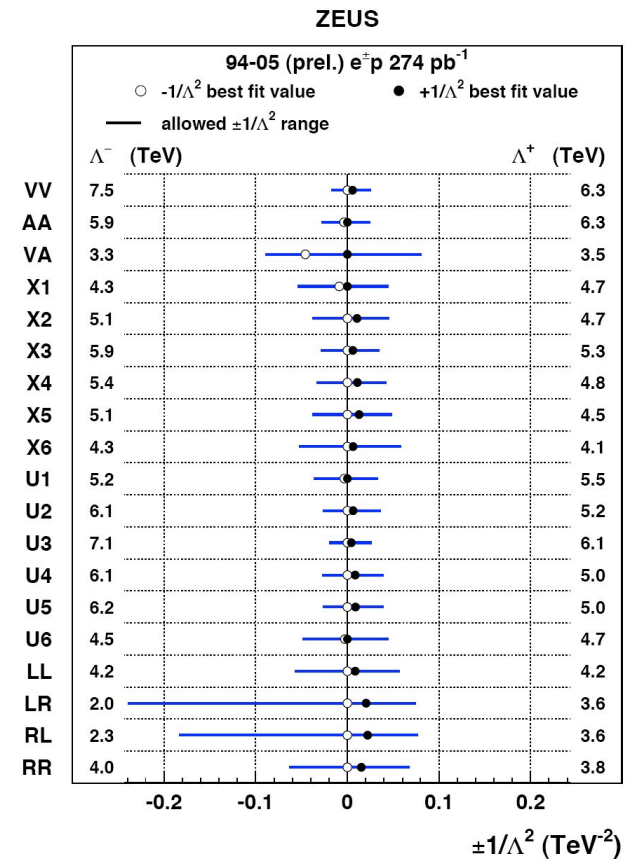
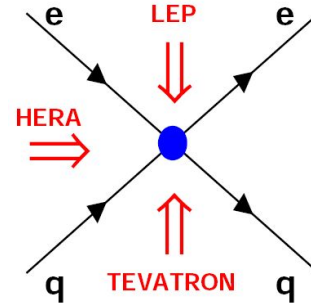
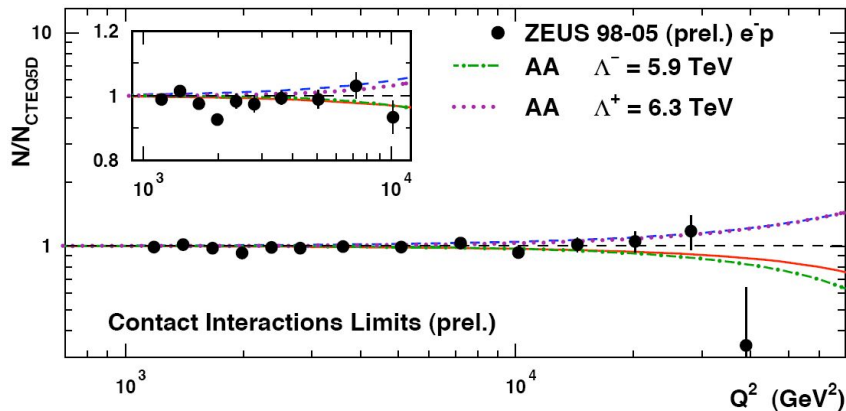
- General contact interactions:
If the scale Λ of NP is large:

→ Effect of NP parametrised as a 4-fermions interaction

$$\mathcal{L}_{CI} = \sum_{i,j=L,R} \eta_{i,j}^{e,q} (\bar{e}_i \gamma^\mu e_i) (\bar{q}_j \gamma_\mu q_j) \quad \eta_{i,j}^{e,q} = \epsilon_{i,j}^{e,q} \frac{4\pi}{\Lambda^2}$$

→ Modification of NC cross-section at high Q^2

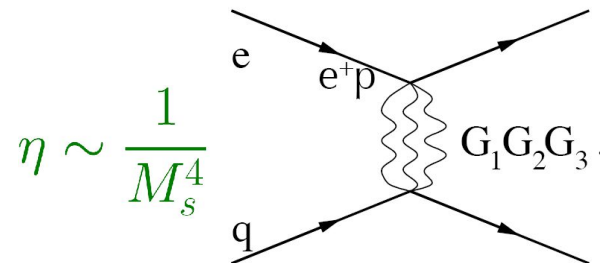
- ZEUS analysis, 1994-2005 data (275 pb⁻¹)



→ Limits on Λ : 2 to 7.5 TeV

- Large extra dimensions:

→ $M_s > \sim 0.9$ TeV

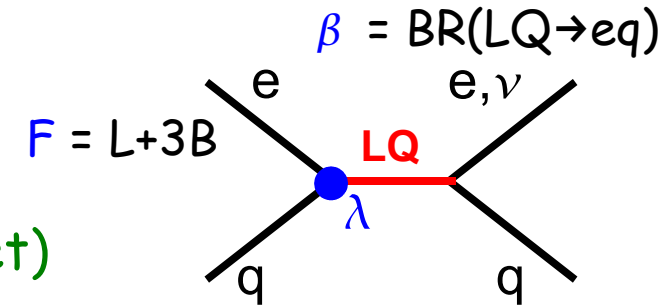


Lepto-quarks

- Leptoquarks: connect lepton and quark sectors

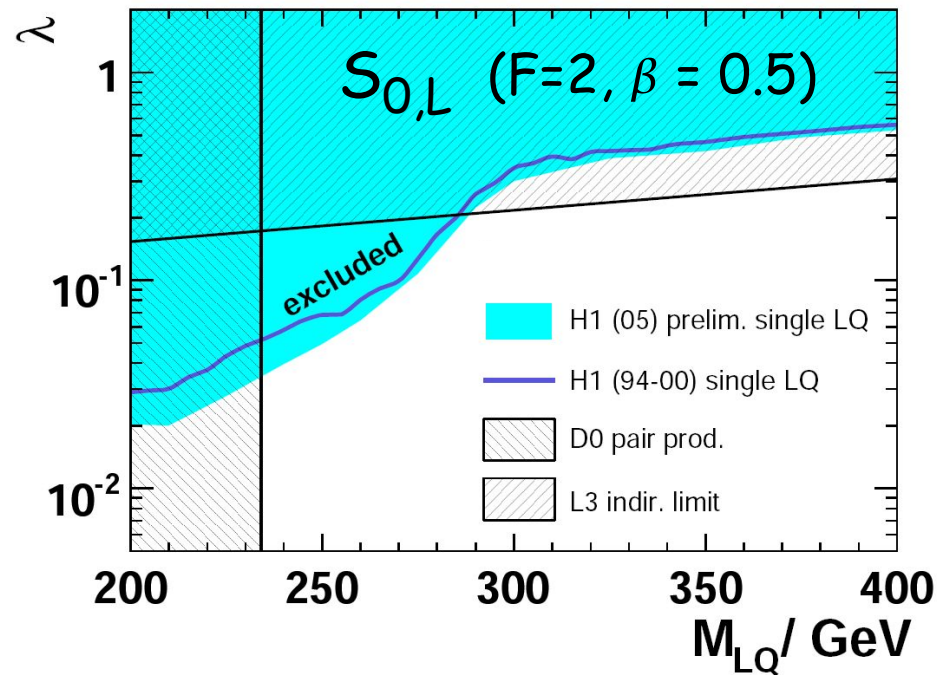
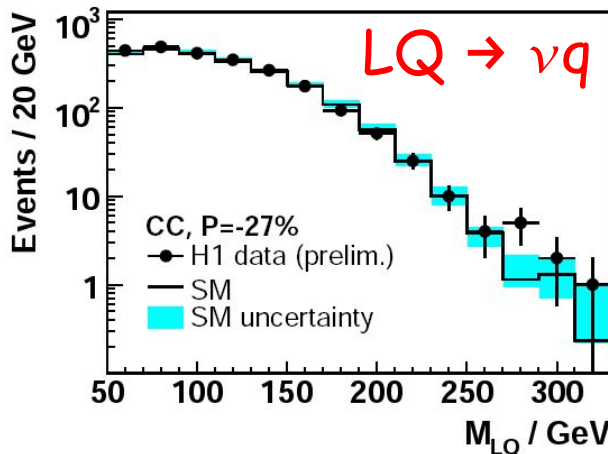
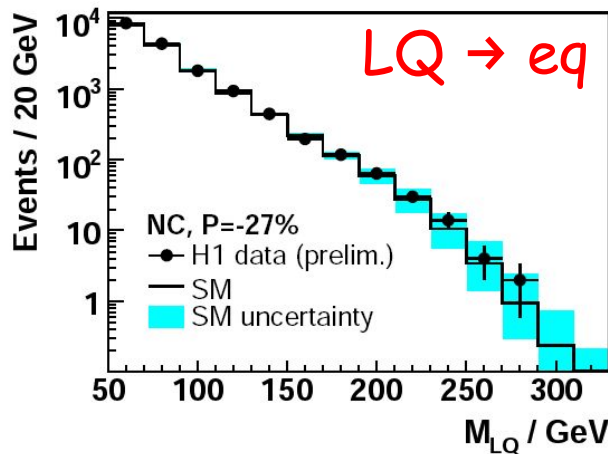
→ Appear in many extension of the SM

↘ Look for Lepton-quark resonances ($e+\text{jet}, \nu+\text{jet}$)



- H1 analysis, HERA II e-p (92 pb^{-1})

→ No excess observed neither in NC nor in CC



↘ Largest part of HERA II data (H1,ZEUS) still being analysed

Compositeness: Excited leptons

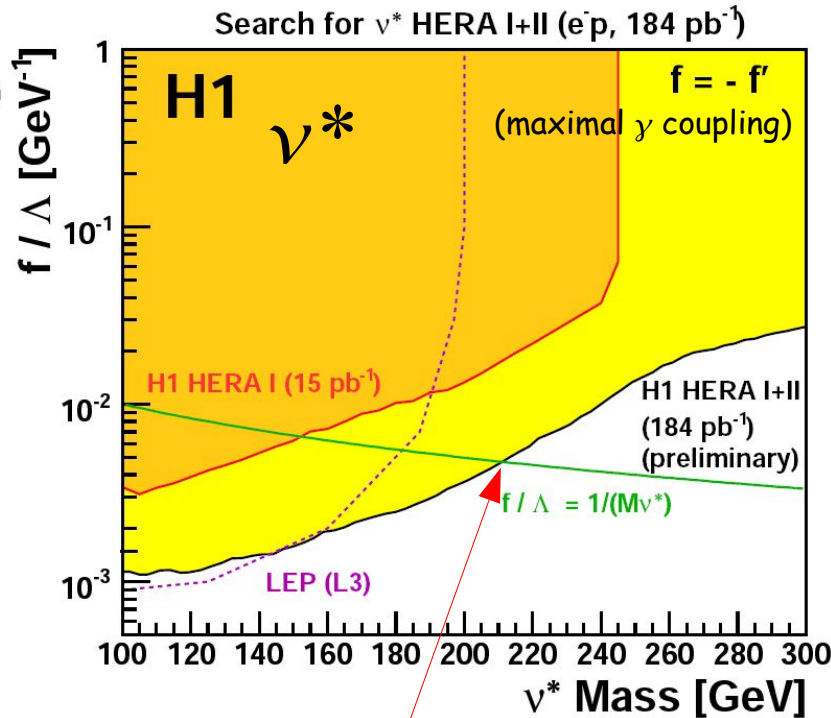
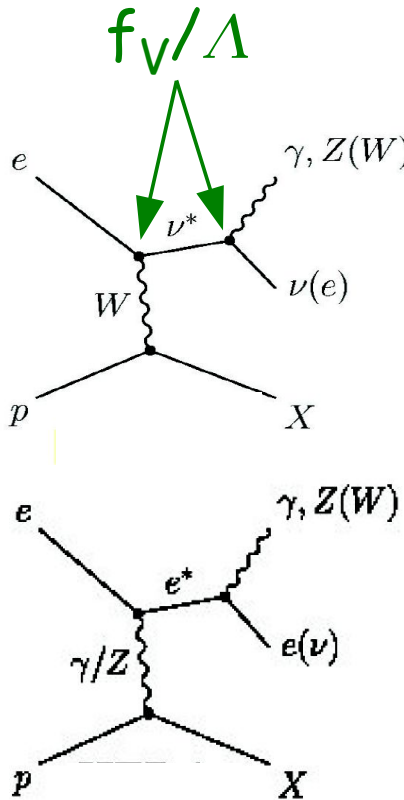
Compositeness scale Λ

Relative strength γ, Z, g :
 f, f', fs

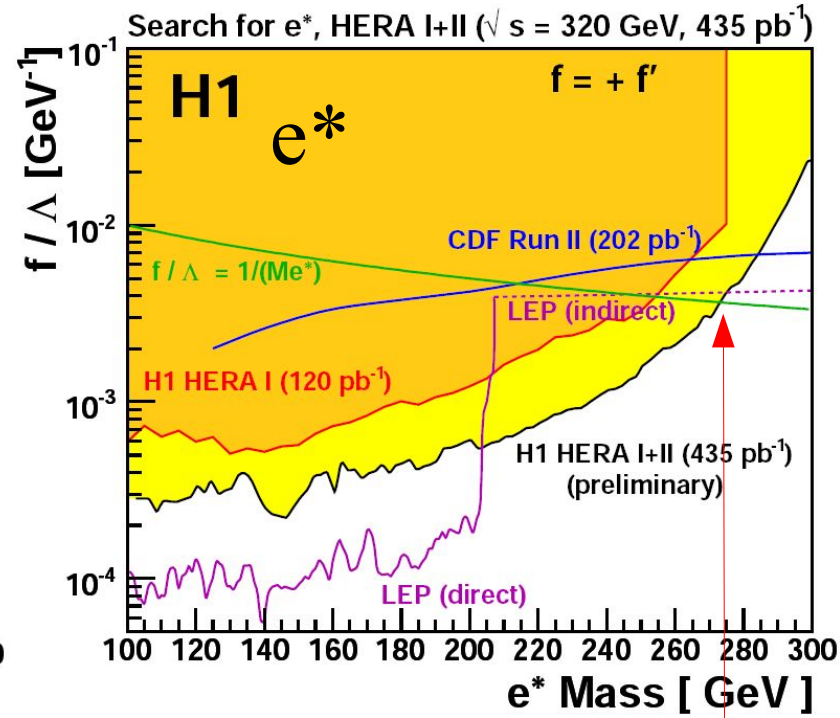
- Excited fermions: direct signature of new scale of matter

↘ Lepton-boson resonances ?

- H1: analysis of all HERA I+II data at $\sqrt{s} = 320$ GeV (435 pb⁻¹)



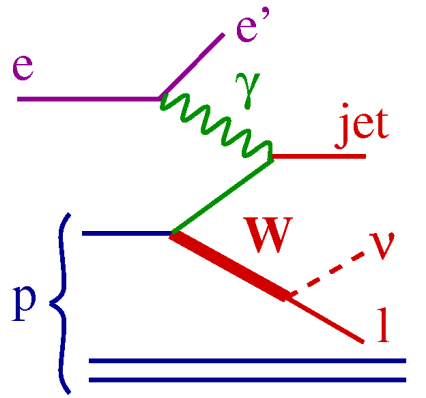
- If $f/\Lambda = 1/M\nu^*$ and $f=-f'$
 $M\nu^* < 211$ GeV excluded



- If $f/\Lambda = 1/Me^*$ and $f=+f'$
 $Me^* < 273$ GeV excluded

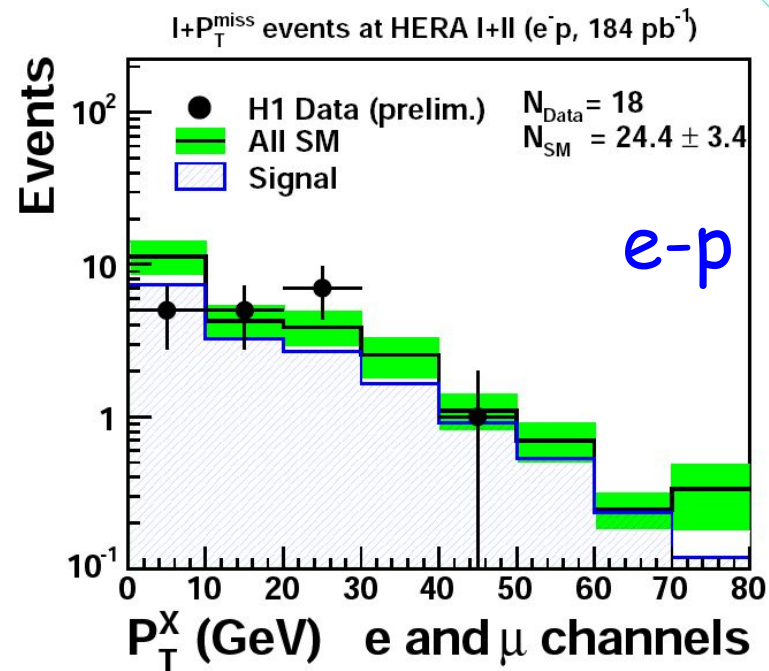
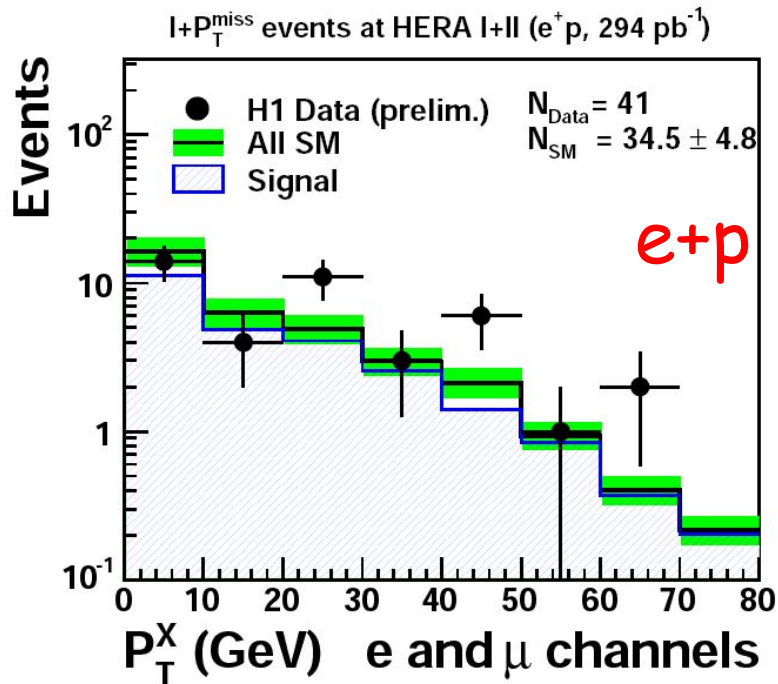
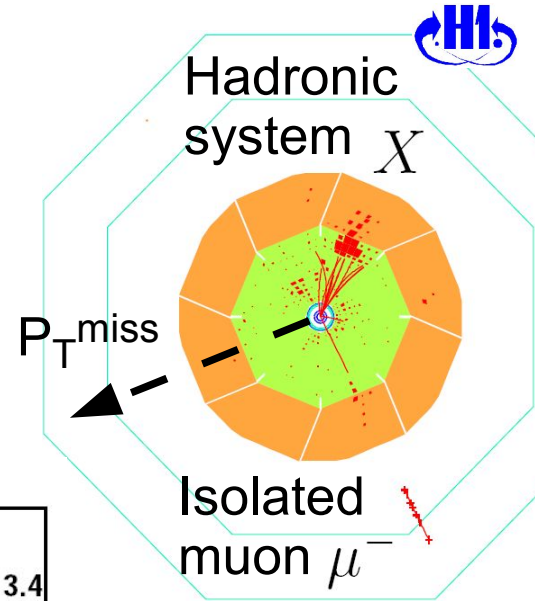
↘ A new territory explored at high mass

W production at HERA ($W \rightarrow e, \mu$)



SM W: $\sigma \sim 1.3$ pb

- Events with high $P_T^{e, \mu}$, P_T^{miss} and hadronic system (P_T^X)
 - HERA I, for $P_T^X > 25$ GeV an excess of data events (3σ)
- All H1 HERA I+II data: 478 pb⁻¹
 - Events at high P_T^X also observed in latest data



↘ Different observations in $e+p$ and $e-p$

H1+ZEUS results for $P_T^X > 25$ GeV

- Analysis also performed by ZEUS, HERA I+II data: 432 pb⁻¹
 → A good agreement with the SM is observed

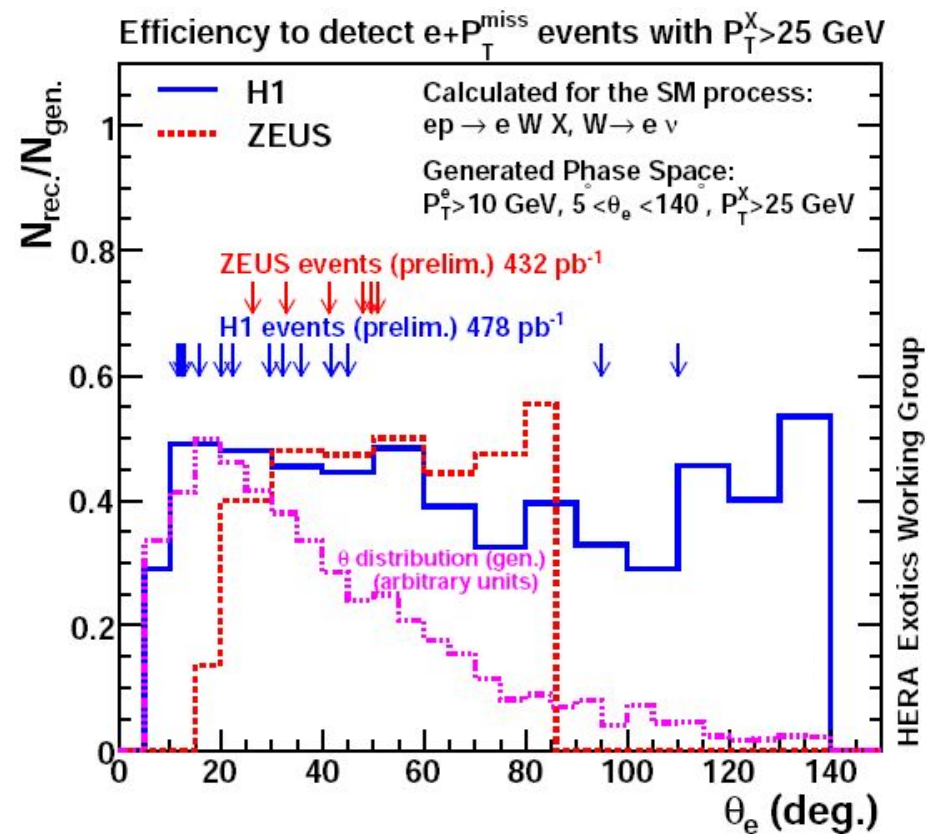
		electrons		muons	
$P_T^X > 25$ GeV		data / SM		data / SM	
e^+	H1	294 pb ⁻¹	11 / 4.7 ± 0.9	10 / 4.2 ± 0.7	
	ZEUS	228 pb ⁻¹	1 / 3.2 ± 0.4	3 / 3.1 ± 0.5	
e^-	H1	184 pb ⁻¹	3 / 3.8 ± 0.6	0 / 3.1 ± 0.5	
	ZEUS	204 pb ⁻¹	5 / 3.8 ± 0.6	2 / 2.2 ± 0.3	

- In $e+p$ H1: 21 / 8.9 ± 1.5 (3 σ)
 ZEUS: agreement with the SM

- In $e-p$ agreement with SM for both H1 and ZEUS

- Smaller acceptance for ZEUS, but → Most H1 events are in it

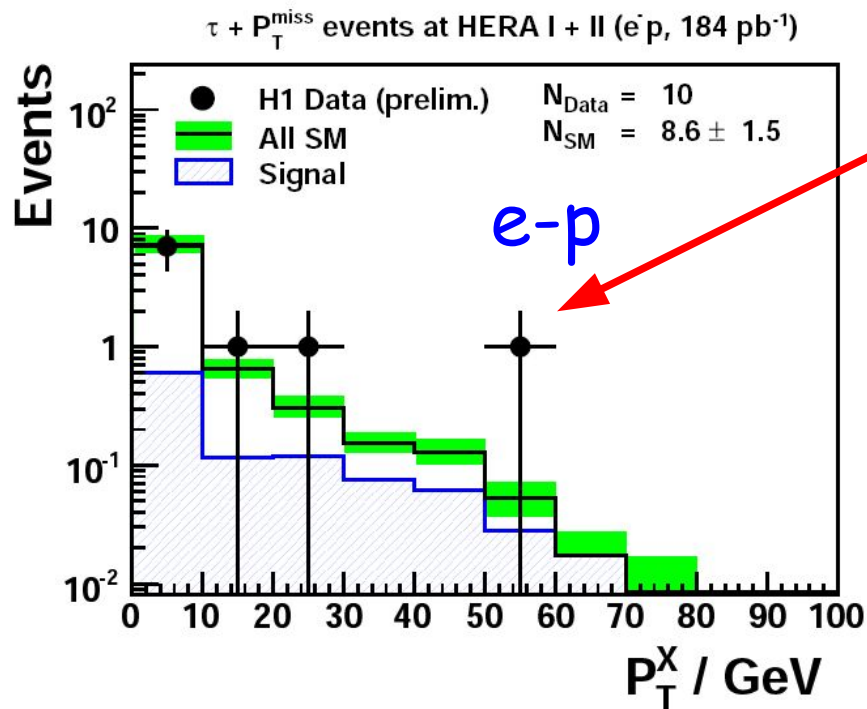
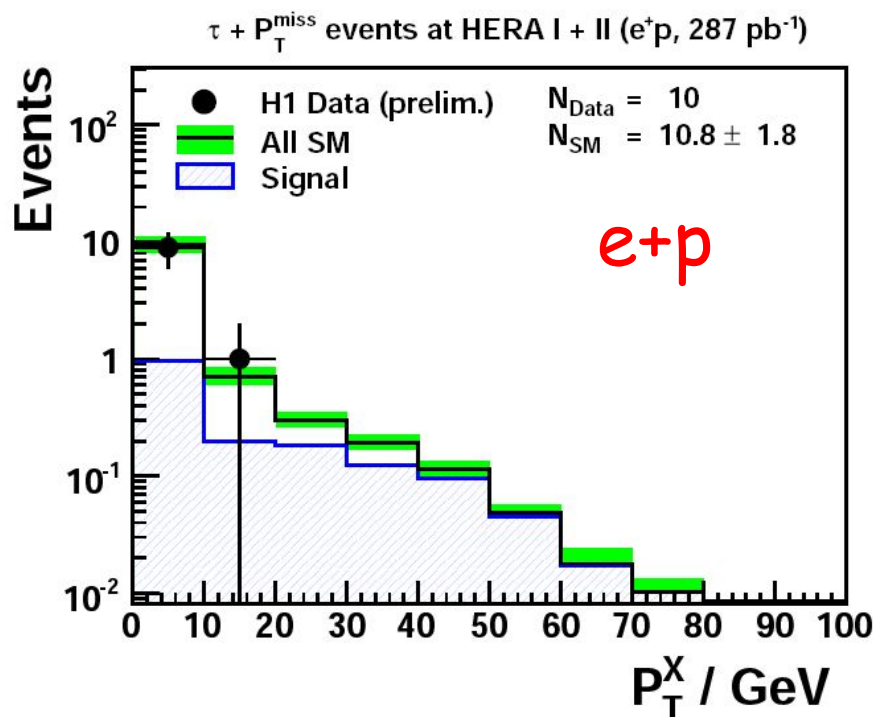
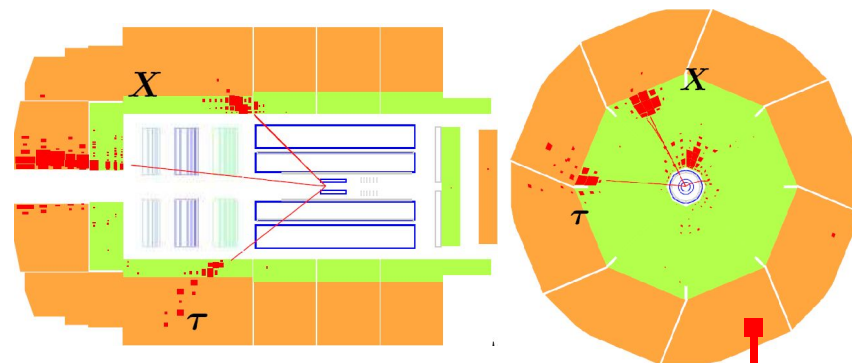
- ↘ H1 excess remains in $e+p$ data at 3 σ level
- ↘ Not clarified with HERA II data



Isolated $\tau + P_T^{\text{miss}}$ events

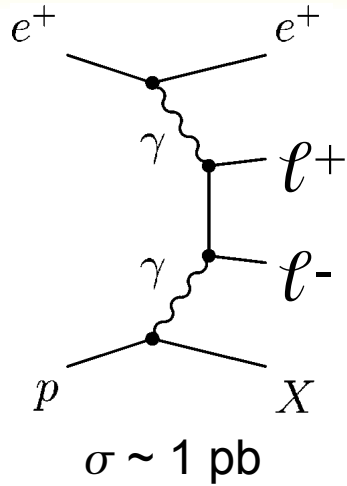
↘ To complement isolated electron and muon channels

- H1 analysis, full HERA I+II (471 pb⁻¹)
- τ identified in the hadronic 1-prong decay
 - Jets with a single track in CC events
 - Large CC background, much lower efficiency than e or μ channels



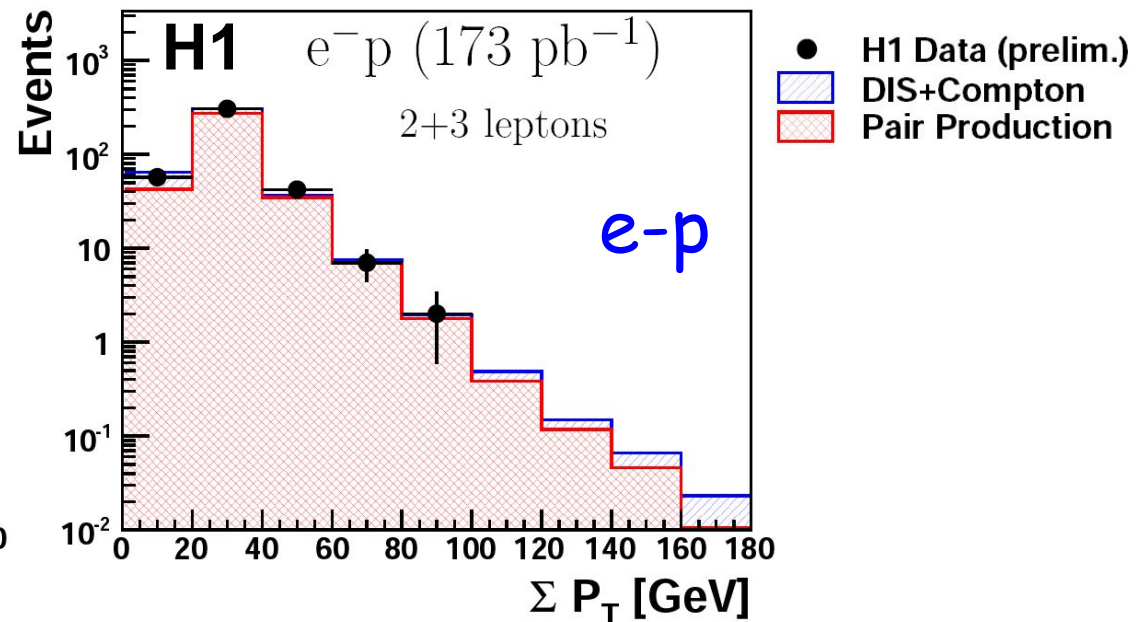
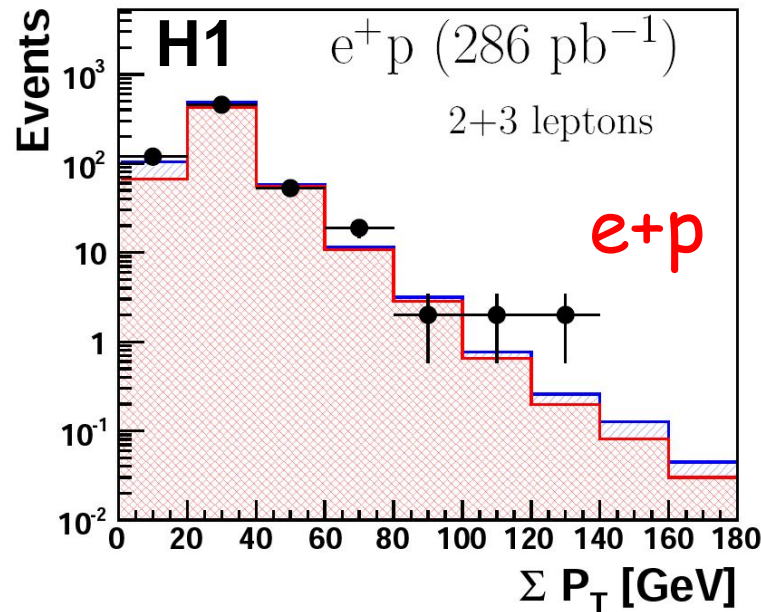
↘ No excess detected $e+p$ or $e-p$

Multi-lepton events (e, μ)



↘ If anomalous W production, what about Z ?

- Look for events with at least 2 isolated high- P_T leptons (e, μ)
 - $ee, eee, e\mu, \mu\mu, e\mu\mu$
- Mainly produced via γ - γ in SM
- H1 analysis performed on all HERA I+II data (459 pb^{-1})
 - ΣP_T : hardness of the events



→ Striking events observed for $\Sigma P_T > 100 \text{ GeV}$

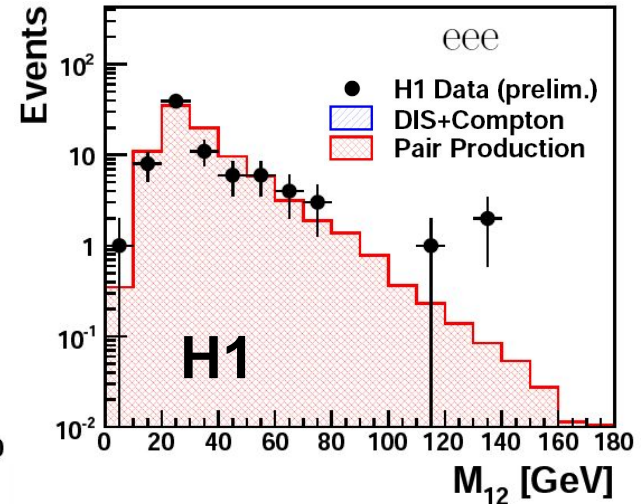
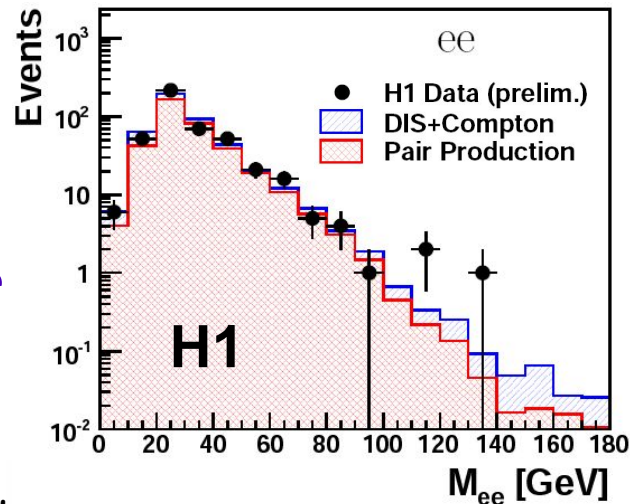
→ In $e+p$ only : $4 / 1.2 \pm 0.2$

Multi-electron events: H1/ZEUS

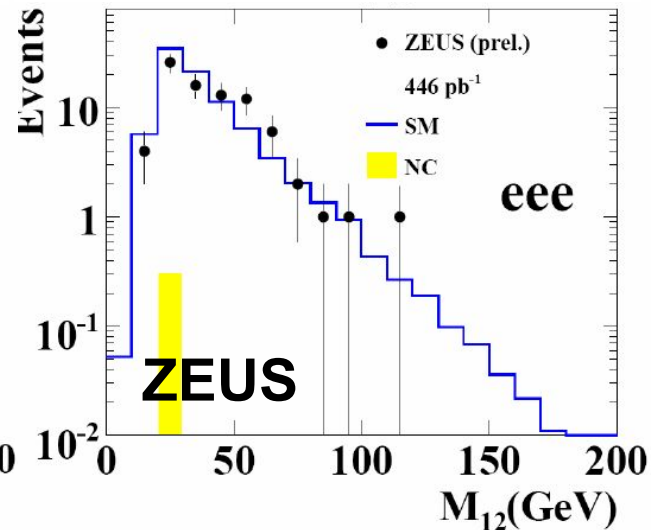
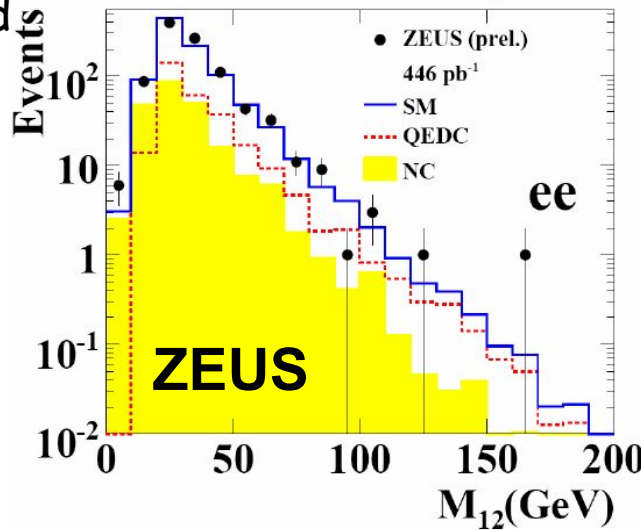
- ZEUS: analysis performed for multi-electron topologies (446 pb⁻¹)

- Phase space similar to H1
- But weaker background rejection at high mass in ee

- For $M_{12} > 100$ GeV



		Signal Background			
		data	SM	Pair prod.	DIS+QEDC
H1					
ee	3	1.5 ± 0.3	0.9 ± 0.2	0.6 ± 0.2	—
eee	3	0.9 ± 0.2	0.9 ± 0.2	—	—
ZEUS					
ee	5	4.3 ± 1.1	1.1 ± 0.2	3.2 ± 1.1	—
eee	1	1.1 ± 0.1	1.1 ± 0.1	< 0.5	—



→ H1: no new ee(e) event, HERA I excess not confirmed

→ ZEUS: good agreement with SM though background(QEDC) dominated in ee

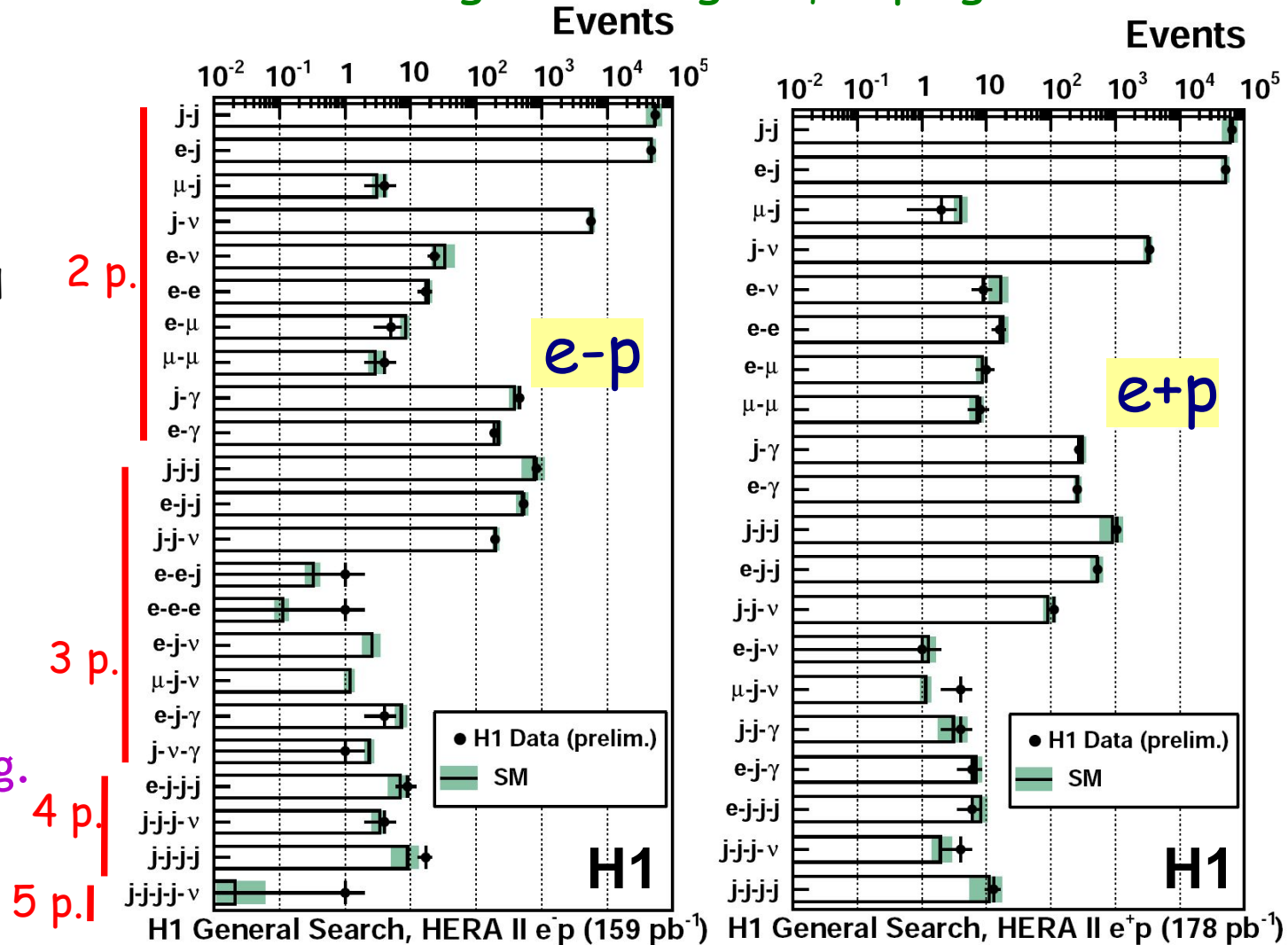
A General Search

→ A signature based search: investigate all high P_T topologies

- H1, full HERA II data (337 pb⁻¹)
HERA I data published (117 pb⁻¹) [PLB 602(2004)14]

- Isolated particles
→ e, γ , μ , jet, ν

- A common phase space
→ $P_{T\text{part}} > 20$ GeV
→ $10 < \theta_{\text{part}} < 140$ deg.



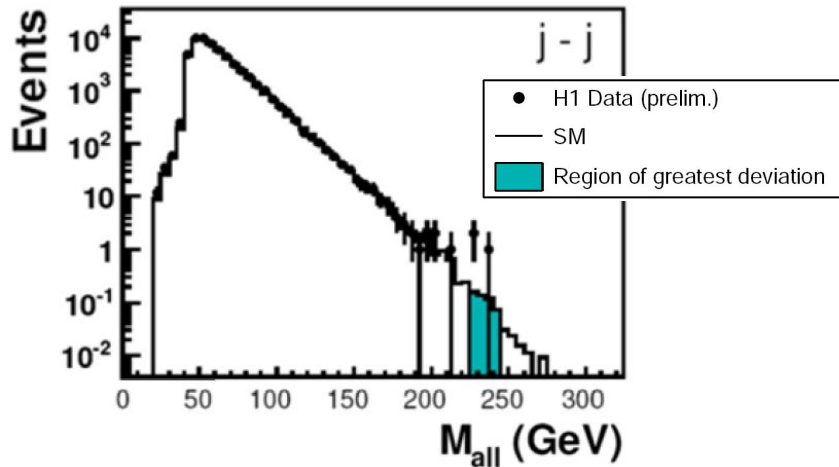
→ Good agreement with SM in most classes

→ Good understanding of the detector and of SM processes

General Search: statistical analysis

- Identify regions of largest deviations data / SM

→ Investigate 1D ΣP_T and M_{all} distributions

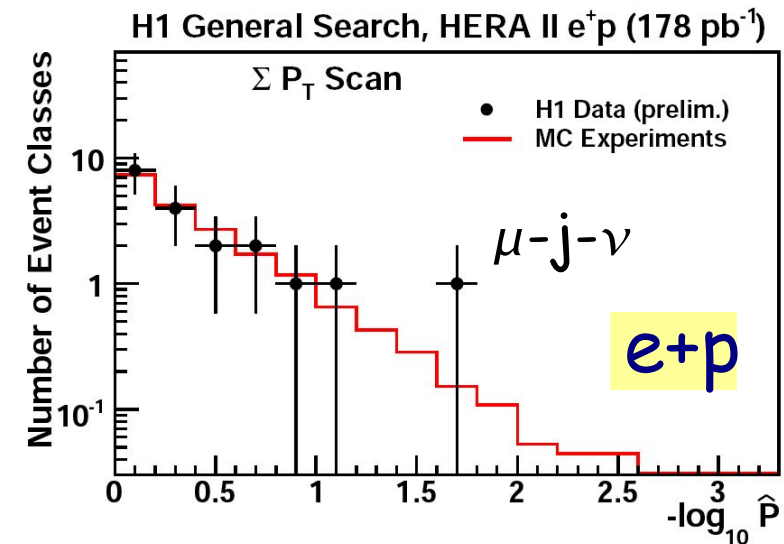
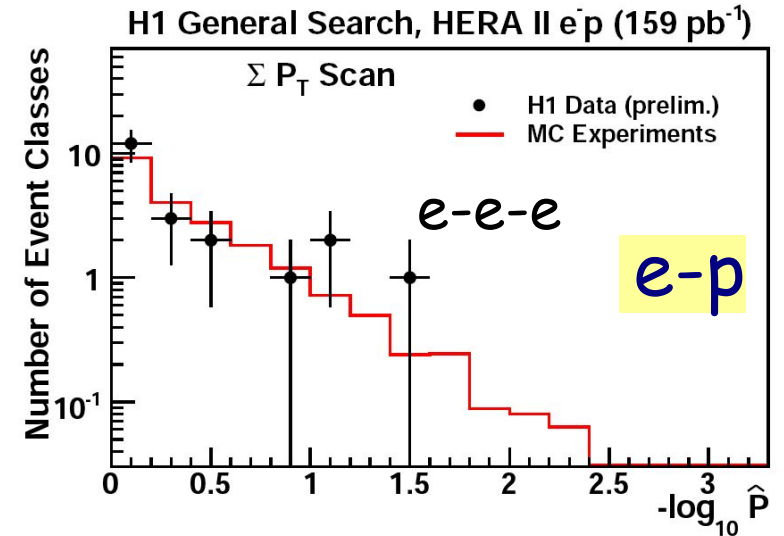


- Statistical analysis to quantify the significance of deviations (\hat{P})

→ Most significant deviation at HERA II: $\mu-j-\nu$ in $e+p$

→ Was also the case in HERA I data ($-\log_{10} \hat{P} \sim 3$)

↘ Corresponds to the topology of isolated leptons events



Summary

- High energy running of HERA ended on March, 20 2007
 - In total: $\sim 1 \text{ fb}^{-1}$ collected by H1 and ZEUS together
- Searches for new physics are ongoing
 - A large number of results already exploits the full data sample
 - No evidence for new physics is found
 - Good complementarity of HERA data with LEP and Tevatron colliders
- A 3σ excess remains in H1 e+p data for isolated leptons
 - The puzzle is not solved by HERA II data ...

↘ Enter now in the era of final analyses