

Pheno 2007
Madison, Wisconsin, May 7-9, 2007

Search for New Physics in ep Collisions at HERA

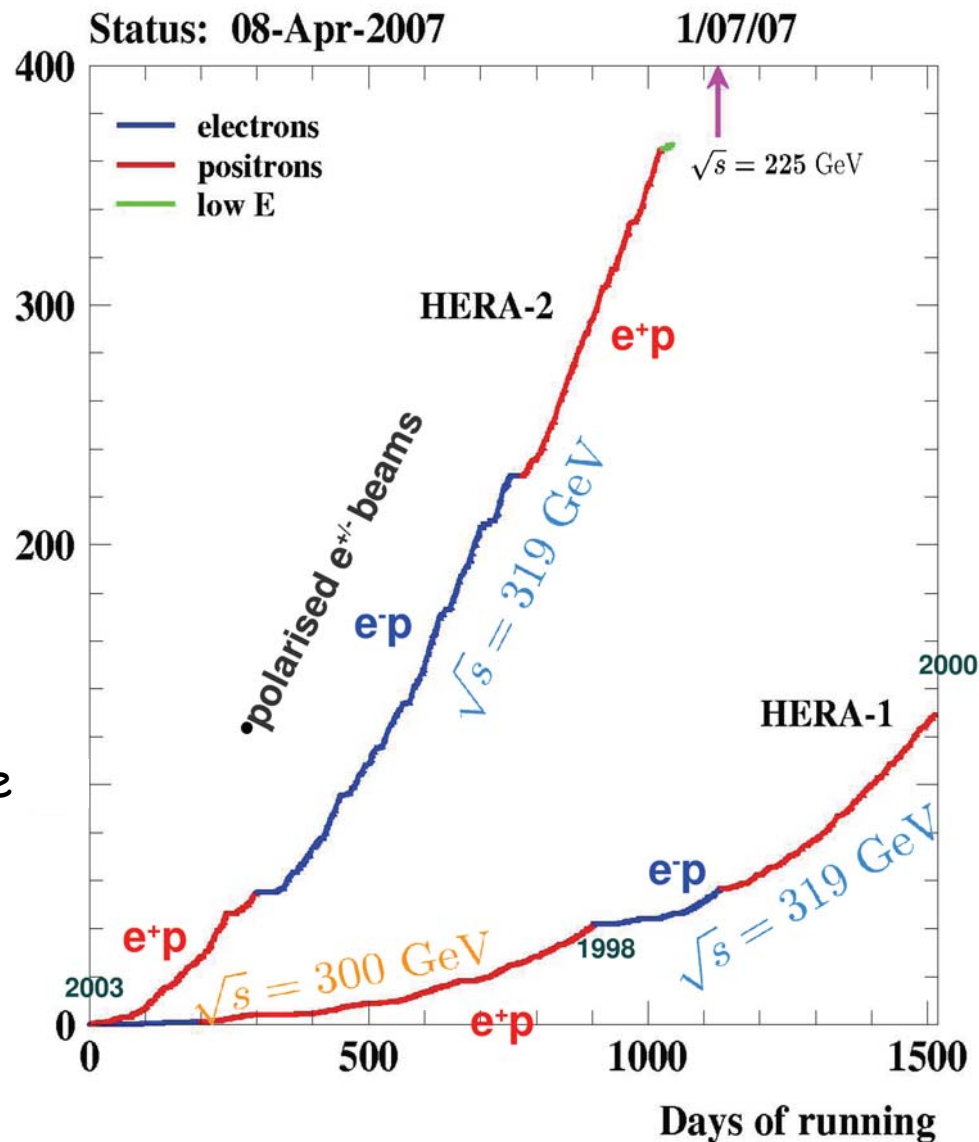
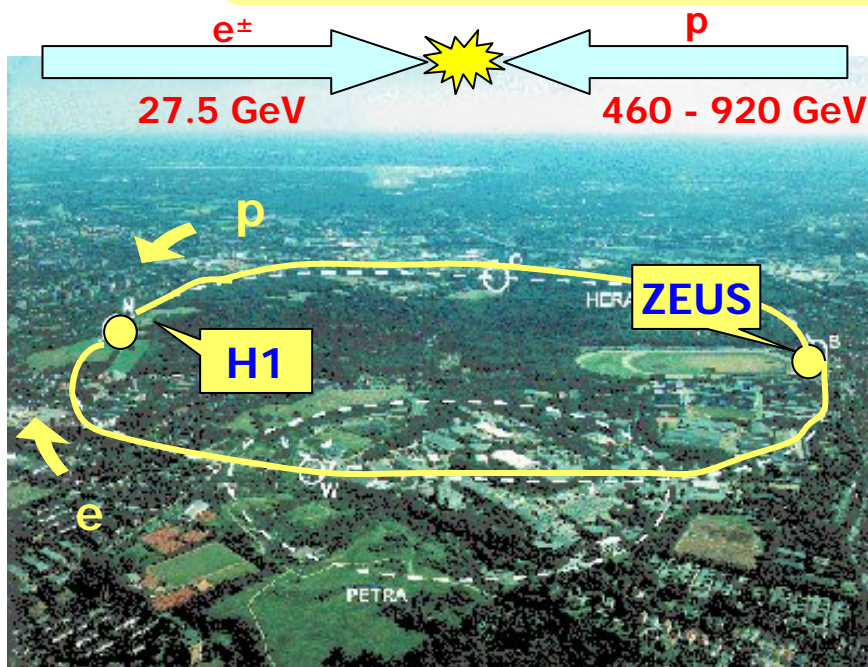
Bob Olivier
Max Planck Institute for Physics, Munich

on behalf of

H1 and ZEUS Collaborations



The HERA Collider

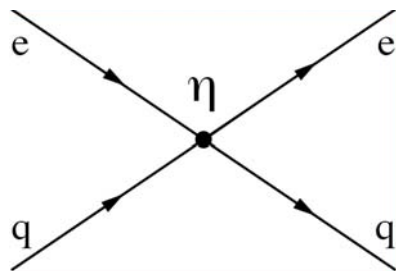


- HERA I 1992-2000 $L \sim 120 \text{ pb}^{-1}/\text{expt}$
 - HERA II 2003-2007 luminosity upgrade and polarised lepton beam
- End of $E_{\text{cm}} = 320 \text{ GeV}$ run March 20, 2007
- $L \sim 360 \text{ pb}^{-1}/\text{expt}$ in $e^+_{L,R} p$ and $e^-_{L,R} p$
- H1+ZEUS together accumulated 1 fb^{-1}

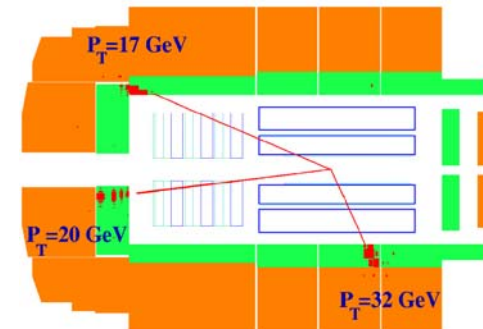
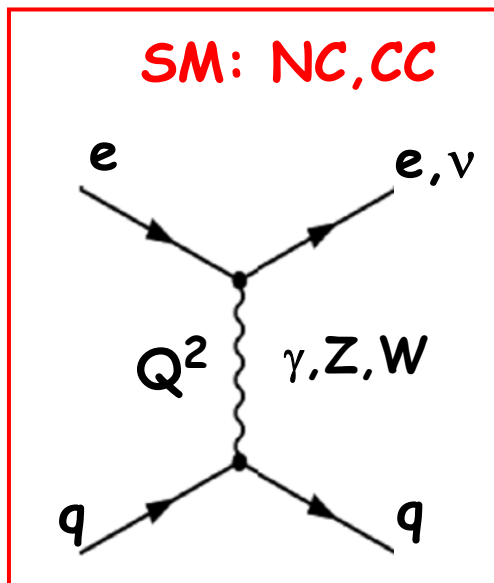
Entering now exciting period of final analyses

Searching for New Physics at HERA

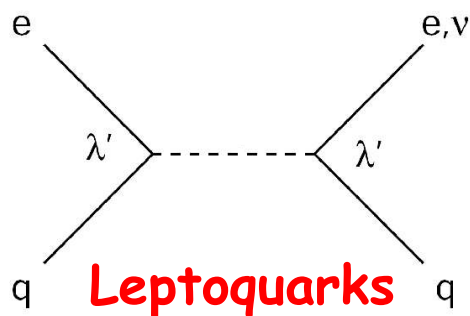
$L \sim 1\text{fb}^{-1}$ search for processes with $\sigma < 1\text{ pb}$



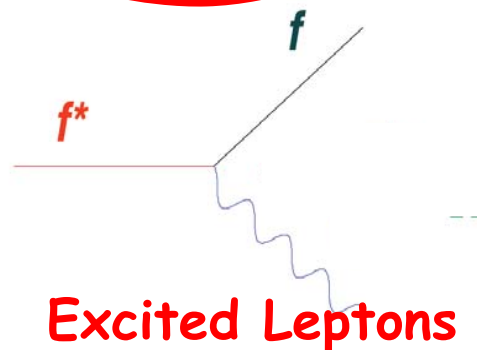
Contact Interactions
Quark Radius
Large Extra Dimensions



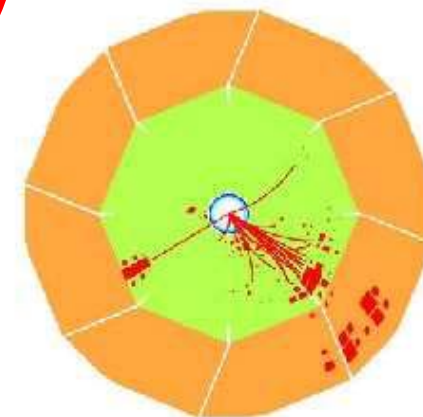
Multi-Leptons



Leptoquarks



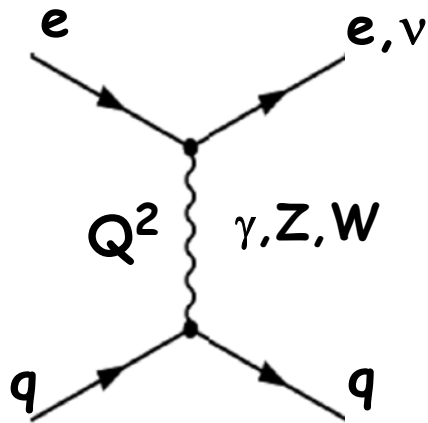
Excited Leptons



Isolated Leptons
+ P_T miss

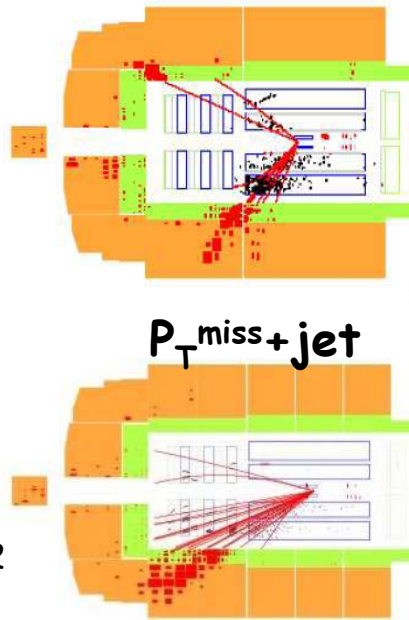
Contact Interaction: Introduction

SM: NC, CC

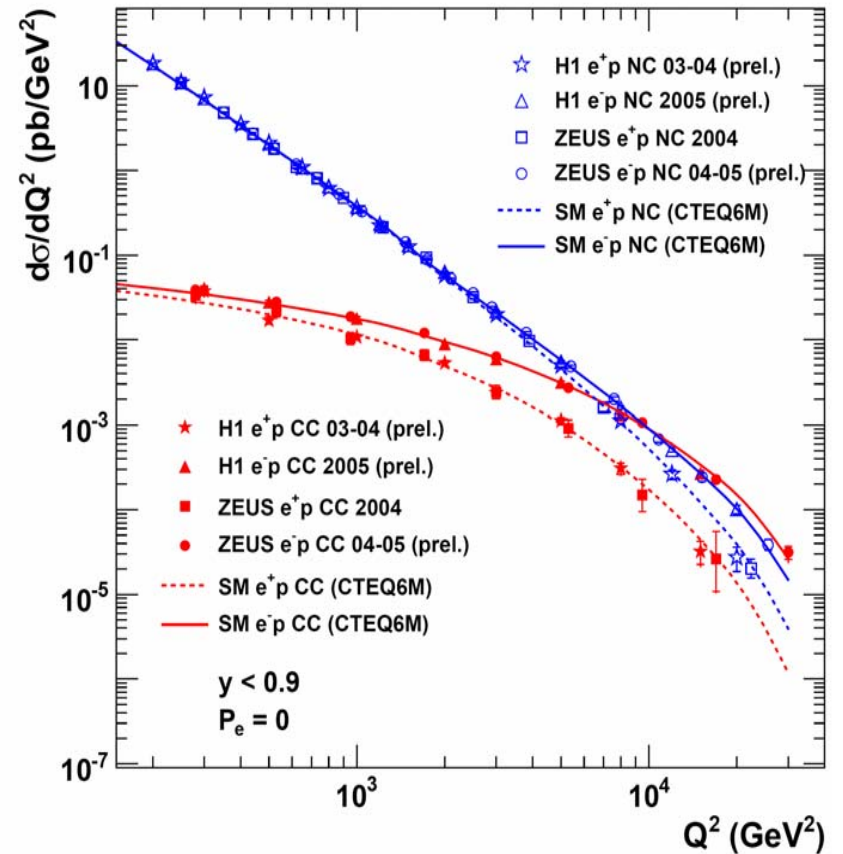


- Large Q^2 domain covered by HERA up to $\sim 4 \cdot 10^4 \text{ GeV}^2$
- New Physics would create deviations from SM at high Q^2

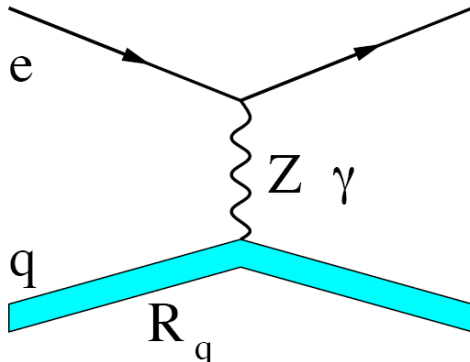
e+jet



HERA II



CI: Quark Radius form factor



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

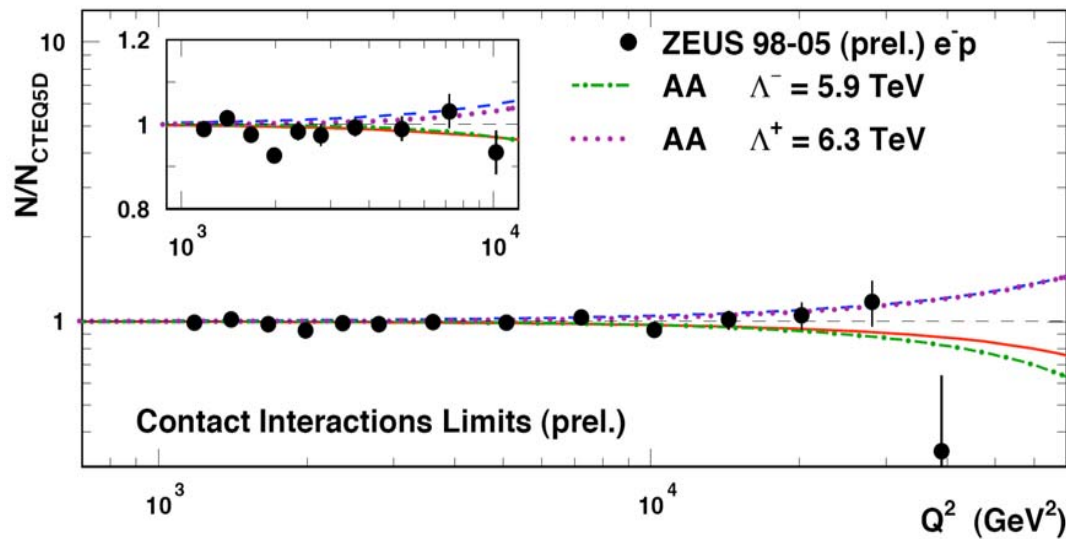
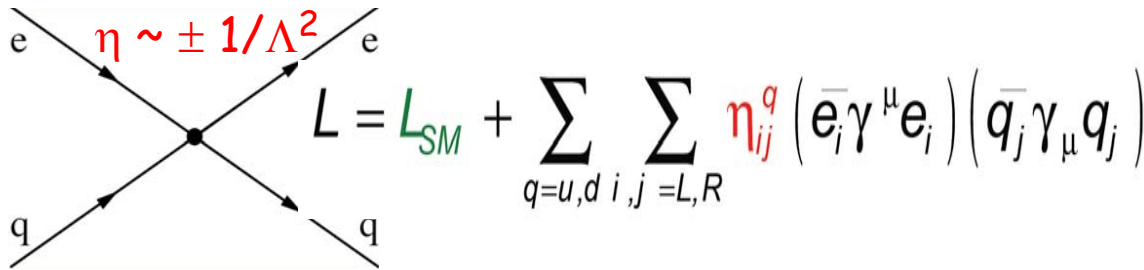
ZEUS 94-05

$$R_q < 0.67 \cdot 10^{-3} \text{ fm}$$

Contact Interaction

HERA I+II
274 pb⁻¹

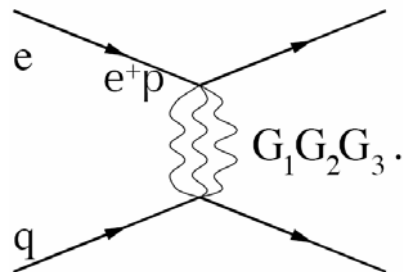
Contact interaction at a large scale Λ :



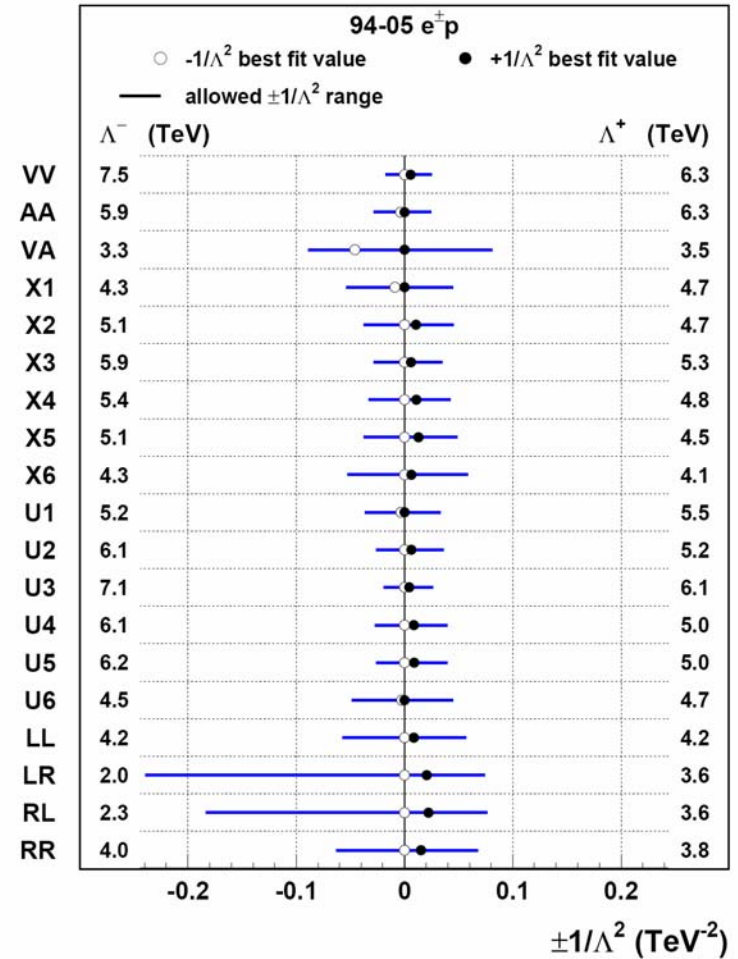
Large extra dimensions:

$$\eta \sim 1/M_S^4$$

$$M_S > 0.9 \text{ TeV}$$



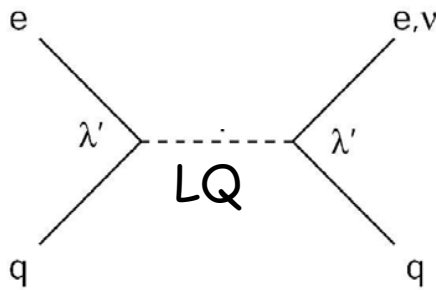
ZEUS Preliminary



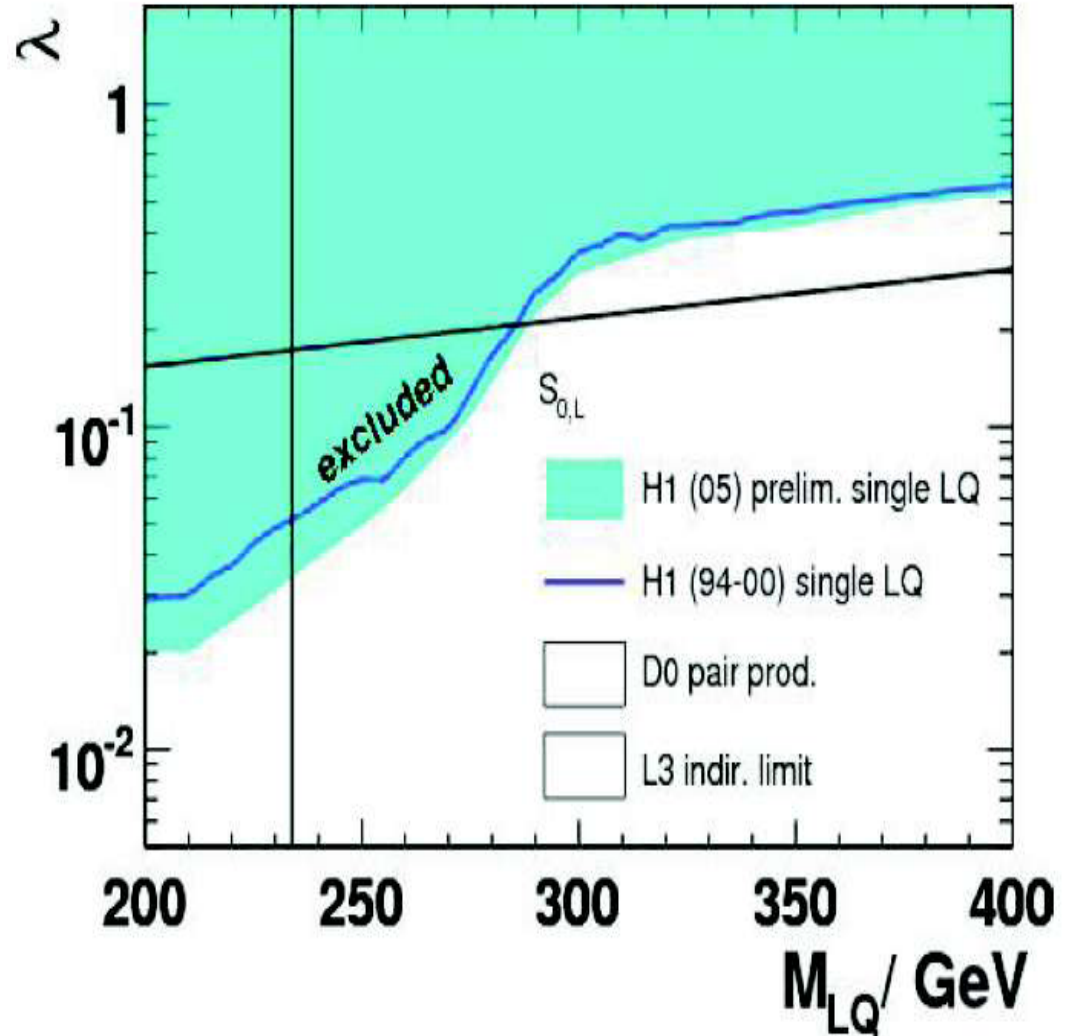
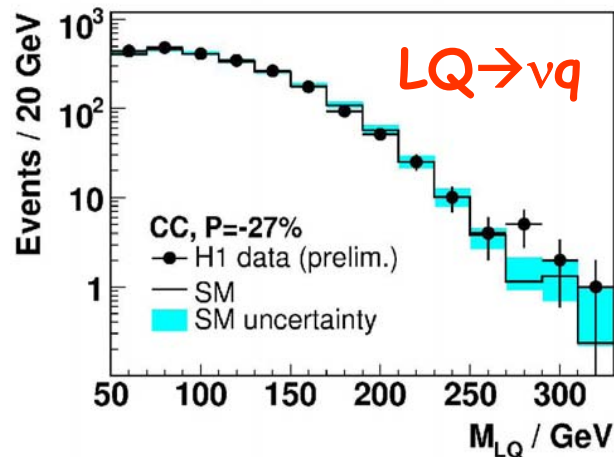
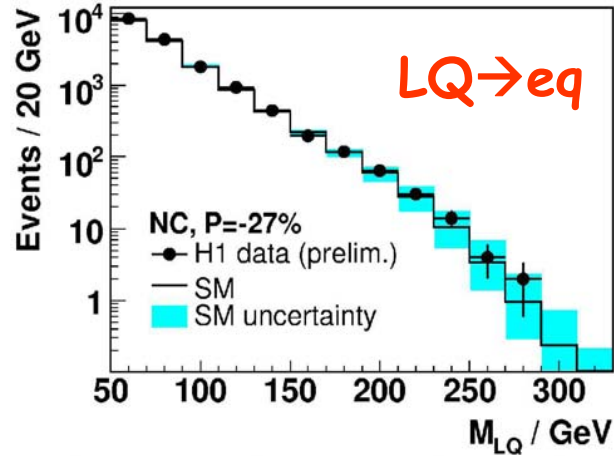
Limits on Λ 2 - 7.5 TeV

Leptoquarks

HERA II
e-p 92pb⁻¹



Lepton-jet resonance



More data, e⁺/e⁻p, (x2)
final domain to explore

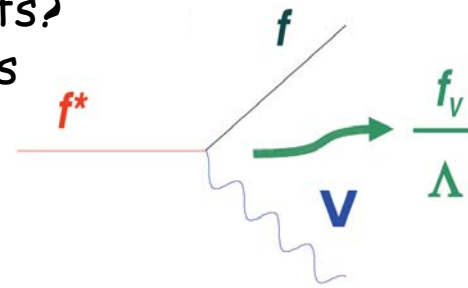
Search for Excited Leptons

Full HERA
I+II lumi

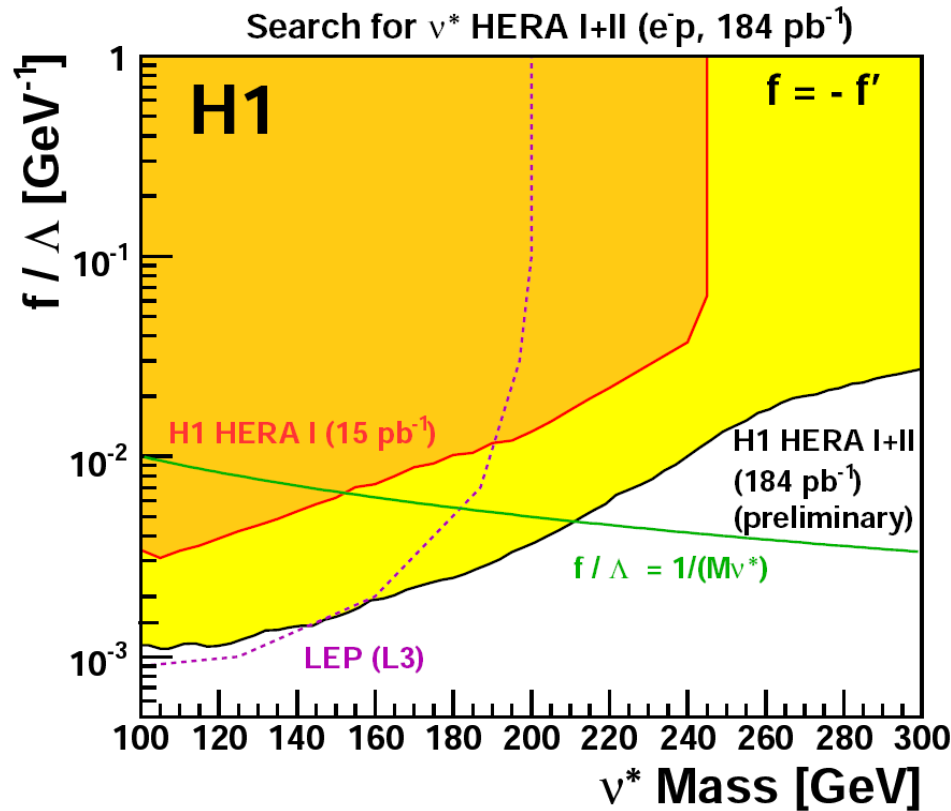
Leptons made of smaller constituents?
direct observation of excited states

Lepton-Boson Resonances

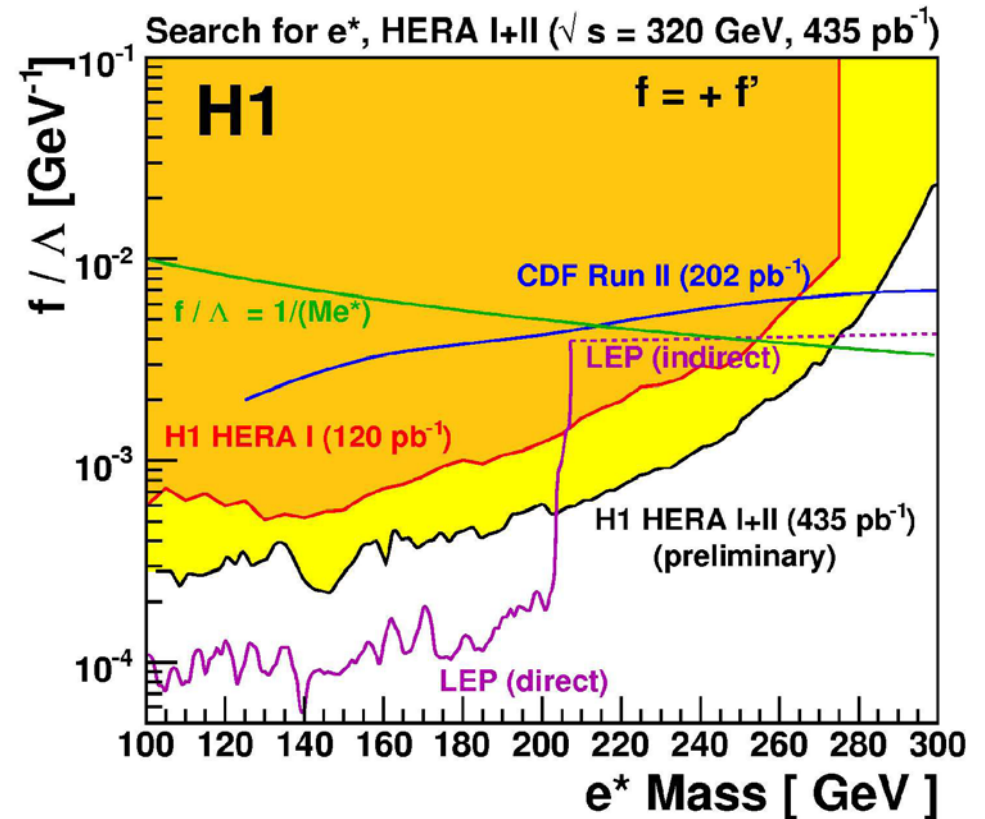
$\nu^* \rightarrow \nu\gamma, eW, \nu Z$ $e^* \rightarrow e\gamma, \nu W, eZ$



Λ compositeness scale
Relative strength γ, Z, W, g
couplings f, f', f_s



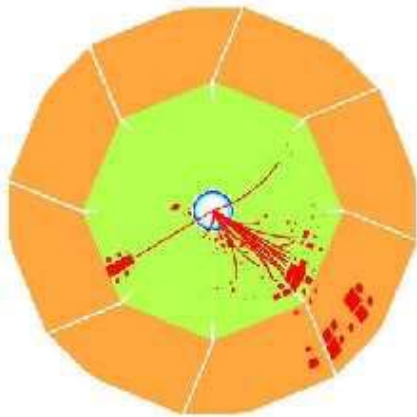
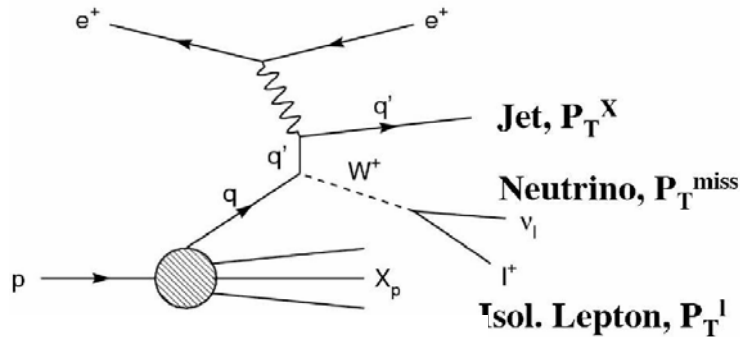
$f/\Lambda = 1/M_{\nu^*}$
 $M_{\nu^*} > 211 \text{ GeV}$



$f/\Lambda = 1/M_{e^*}$
 $M_{e^*} > 273 \text{ GeV}$

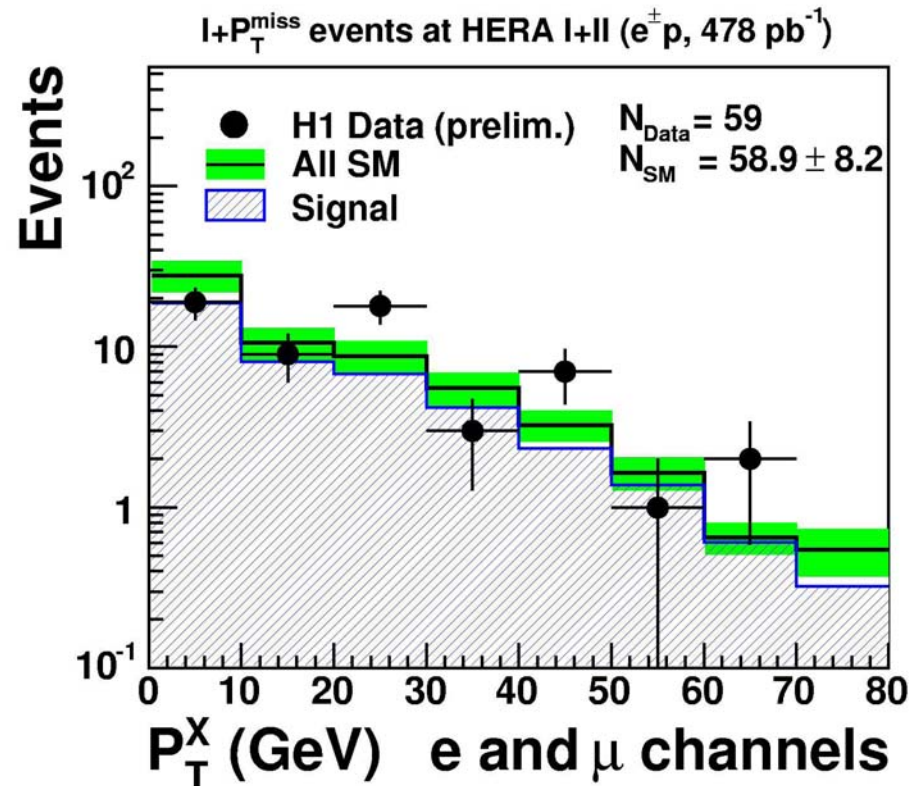
Events with isolated e or μ and P_T^{miss}

SM W: Total Cross Section ~ 1 pb
 \rightarrow few events with e or μ



H1 HERA I (118 pb⁻¹, mainly e⁺p)
 $P_T^X > 25$ GeV
 11 (Data) / 3.5 ± 0.6 (SM) (3σ)

Full HERA I+II Luminosity



Evidence for W production at HERA
 Continue to observe events at high P_T^X
 \rightarrow Look more differentially in e⁺p/e⁻p data samples

Isolated leptons: H1+ZEUS Results

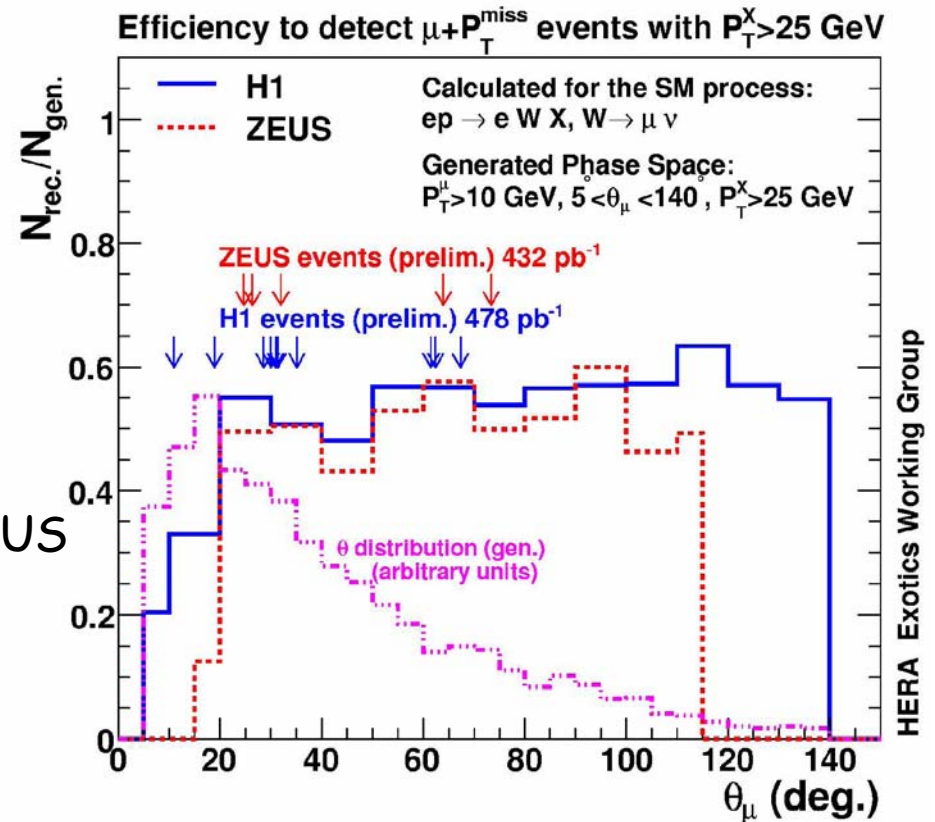
		$P_T^X > 25 \text{ GeV}$	electrons Data/SM	muons Data/SM
e^+p	H1	294 pb ⁻¹	11/4.7±0.9	10/4.2±0.7
	ZEUS	228 pb ⁻¹	1/3.2±0.4	3/3.1±0.5
e^-p	H1	184 pb ⁻¹	3/3.8±0.6	0/3.1±0.5
	ZEUS	204 pb ⁻¹	5/3.8±0.6	2/2.2±0.3

e^+p H1 observation: $21/8.9 \pm 1.5$ (3.0σ)
 no events in excess observed by ZEUS
 e^-p Agreement with SM (H1 and ZEUS)

Most of H1 events in ZEUS acceptance
 (though smaller)

H1 excess remains at high P_T^X in e^+p data at 3.0σ level,

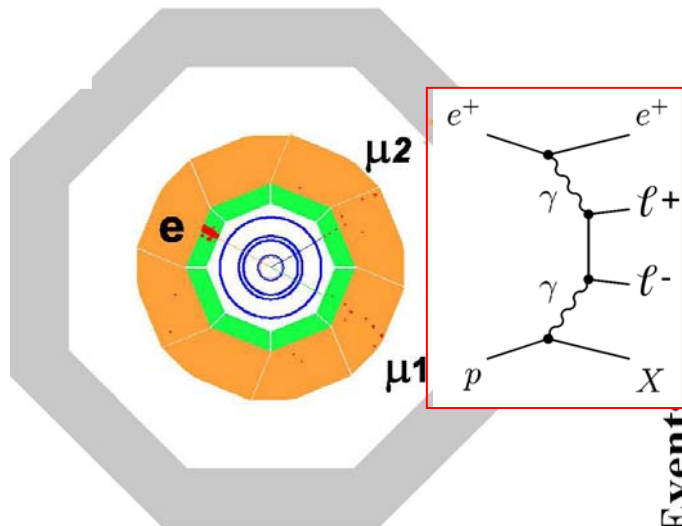
Isolated Taus + $P_{T\text{miss}}$: no excess (H1 and ZEUS)



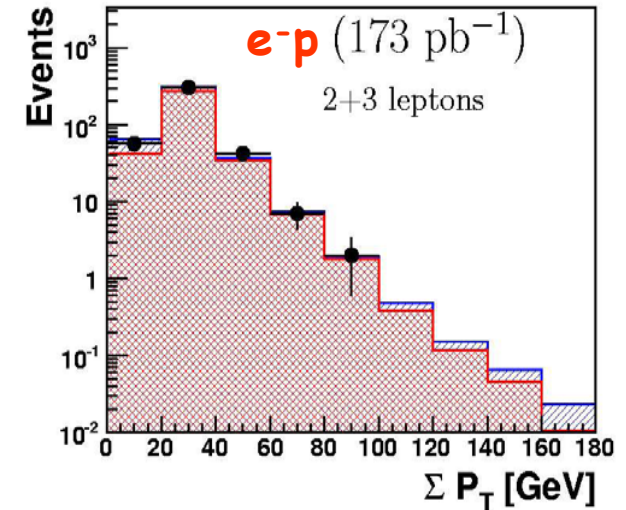
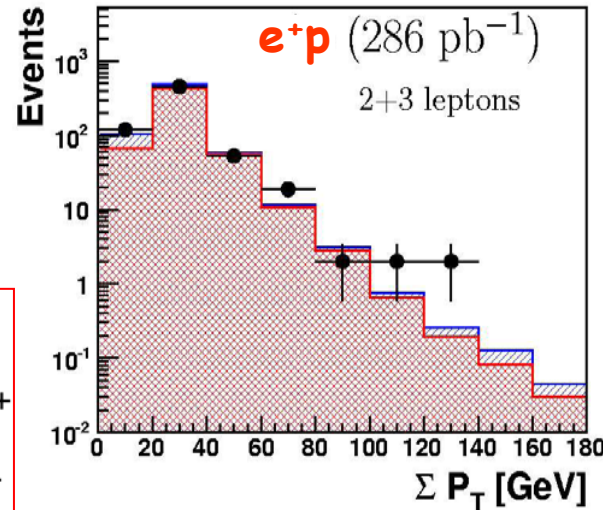
Multi Leptons Events

Full HERA
I+II lumi

H1/HERA I: excess of $ee(e)$ events at high mass
Include μ ; combinations:
 $ee, e\mu, \mu\mu, eee, e\mu\mu$



H1 Multi-lepton analysis HERA I+II (459 pb⁻¹)



H1/HERA I+II:

$\Sigma P_T > 100$ GeV

e^+p data: $4/1.2 \pm 0.2$

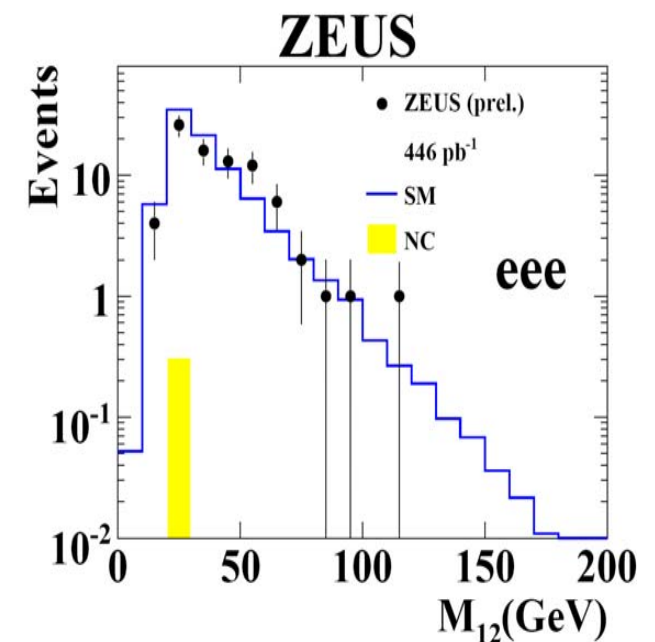
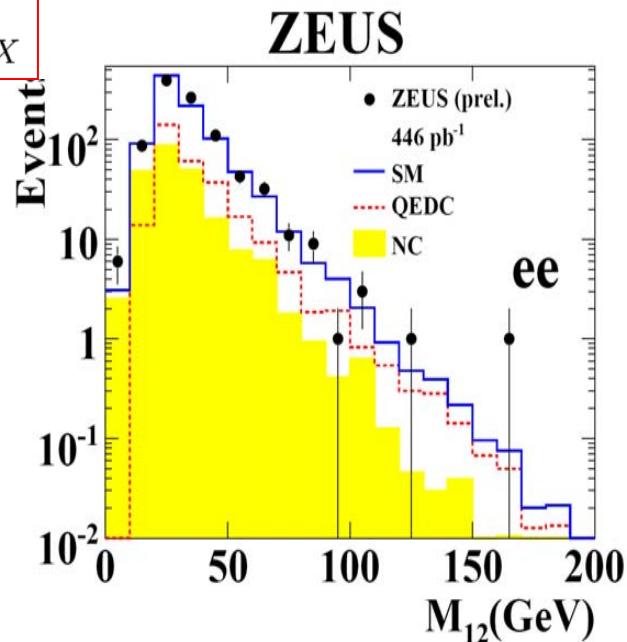
no new $ee(e)$ event!

HERA I excess not

confirmed

ZEUS: good agreement

Bob Olivier

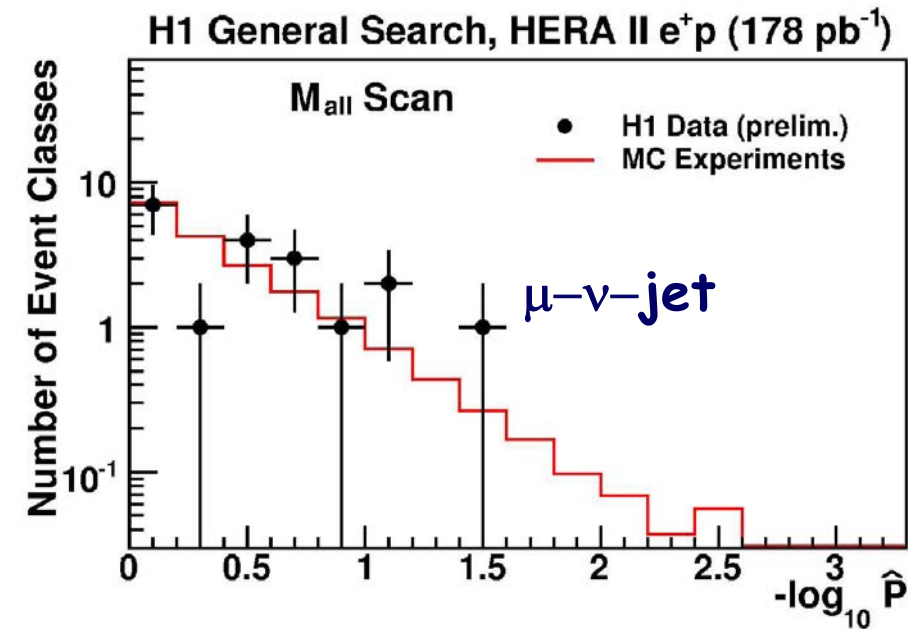


General Searches

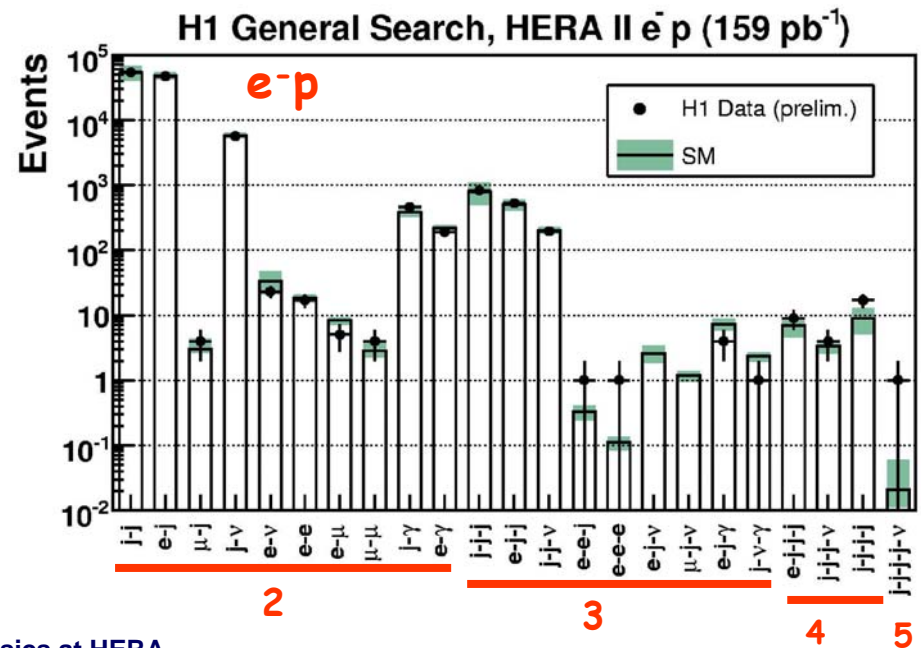
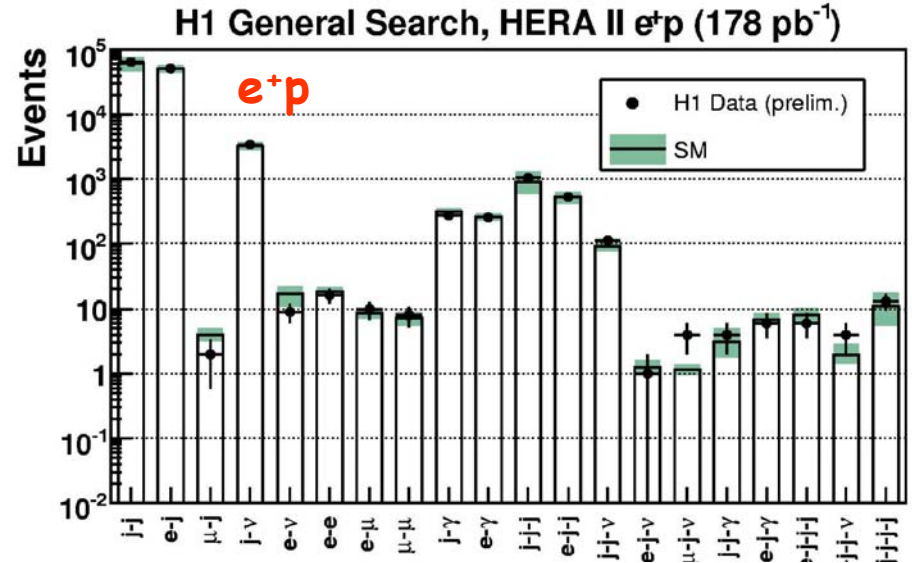
Search for isolated particles at high P_T
 $e \ \gamma \ \mu \ \nu \ \text{jets}$

Common phase space
 $P_T > 20 \text{ GeV} \quad 10^\circ < \theta < 140^\circ$

Statistical analysis to quantify
 significance of deviations



Full HERA II lumi



Conclusions

20.3.2007: End of the HERA II at $E_{\text{cm}} = 320 \text{ GeV}$, yielded $\sim 360 \text{ pb}^{-1}$ per experiment

H1 and ZEUS have collected together $\sim 1 \text{ fb}^{-1}$ good HERA data

Searches for new physics ongoing

Some analyses already use full luminosity

3σ excess on isolated leptons remains (H1)

Now enter era of final analyses

new surprises still possible

Backup slides

Isolated and multi-leptons

• R-parity violation interpretation of isolated and multi-lepton events observed by H1

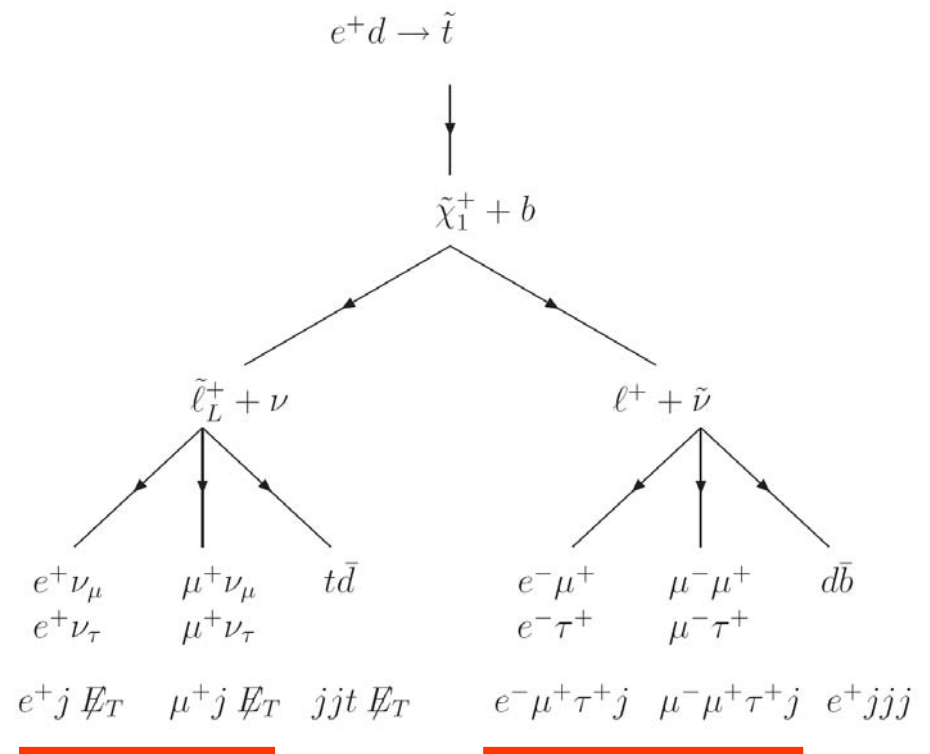
hep-ph/0612302

• Mixed RPV/RPC scenario

• Stop production via RPV coupling λ'

• RPC decay of stop

• Decay of sleptons via RPV coupling λ



Isolated leptons+missing E_T

Multi-leptons