Searches for New Physics at HERA

Matthias E. Janssen

on behalf of the H1 and ZEUS Collaborations

signature driven:

- events with isolated leptons and missing p^T
- multi lepton events
- general searches

model driven:

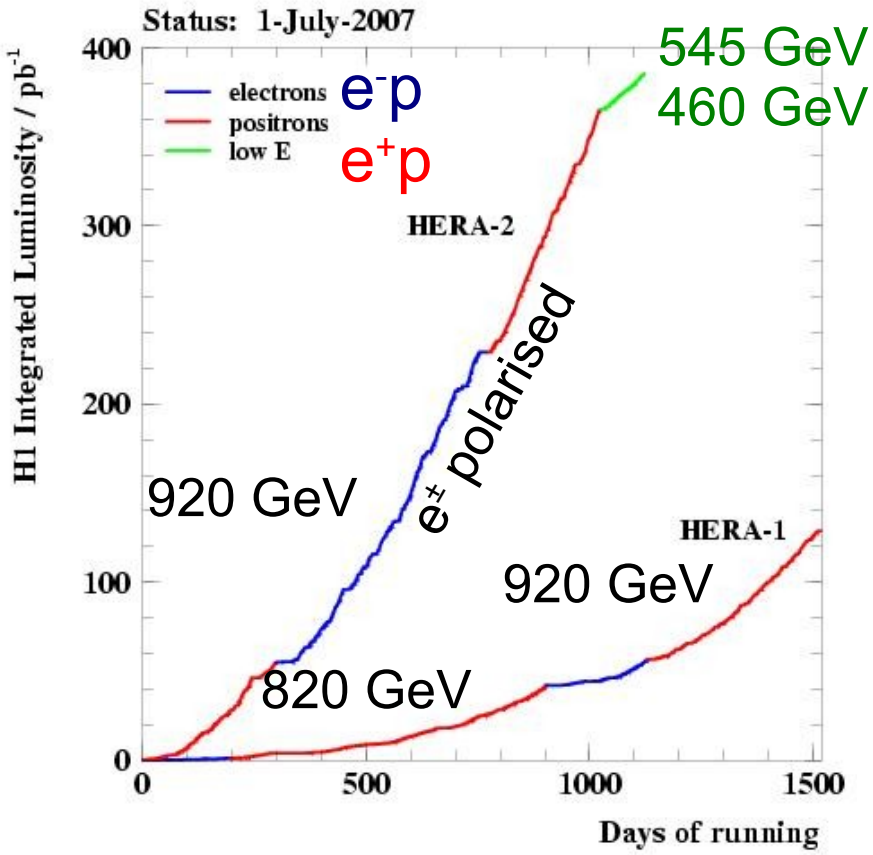
- excited leptons
- leptoquarks
  - lepton flavour violation
- NC DIS: quark radius, heavy leptoquarks

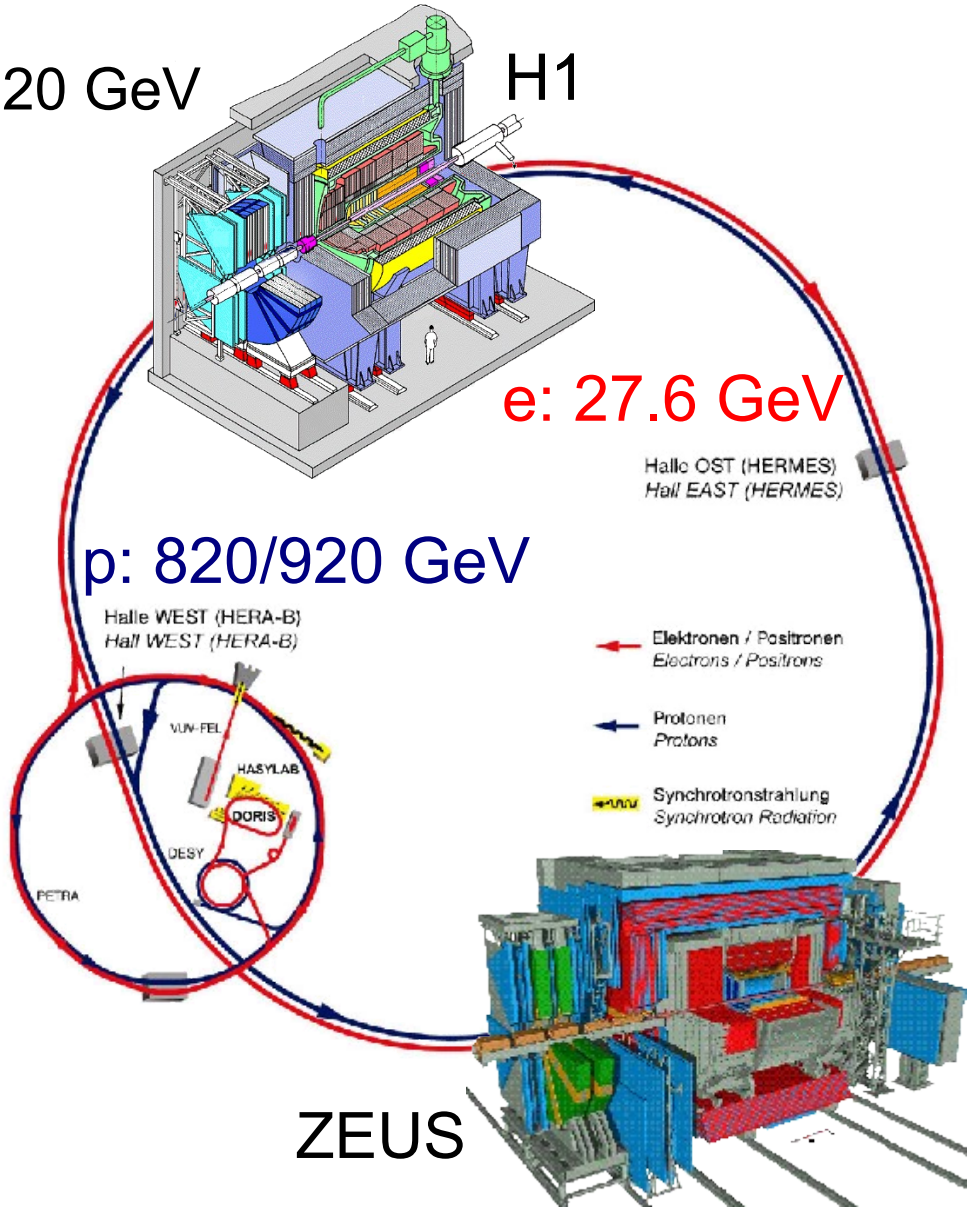
The HERA Collider

the only ep collider in the world: $\sqrt{s}$ = 320 GeV

running from 1992 – 2007

integrated luminosity H1+ZEUS: ≈1fb^{-1}

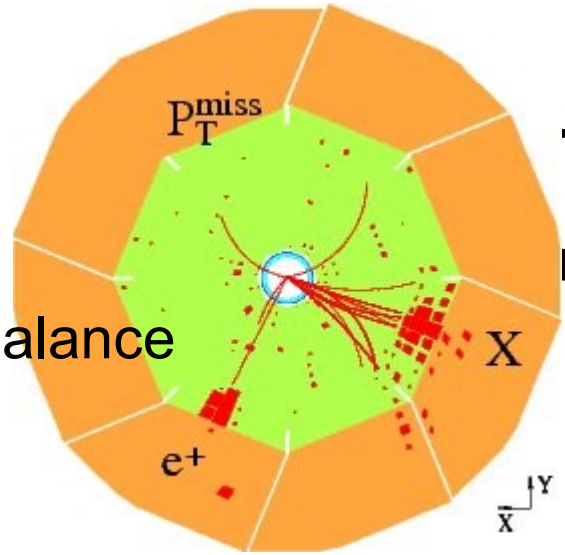




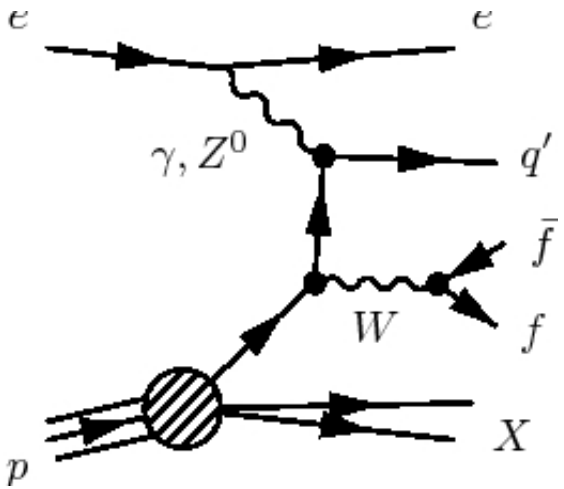
Isolated Leptons and p_T^{miss}

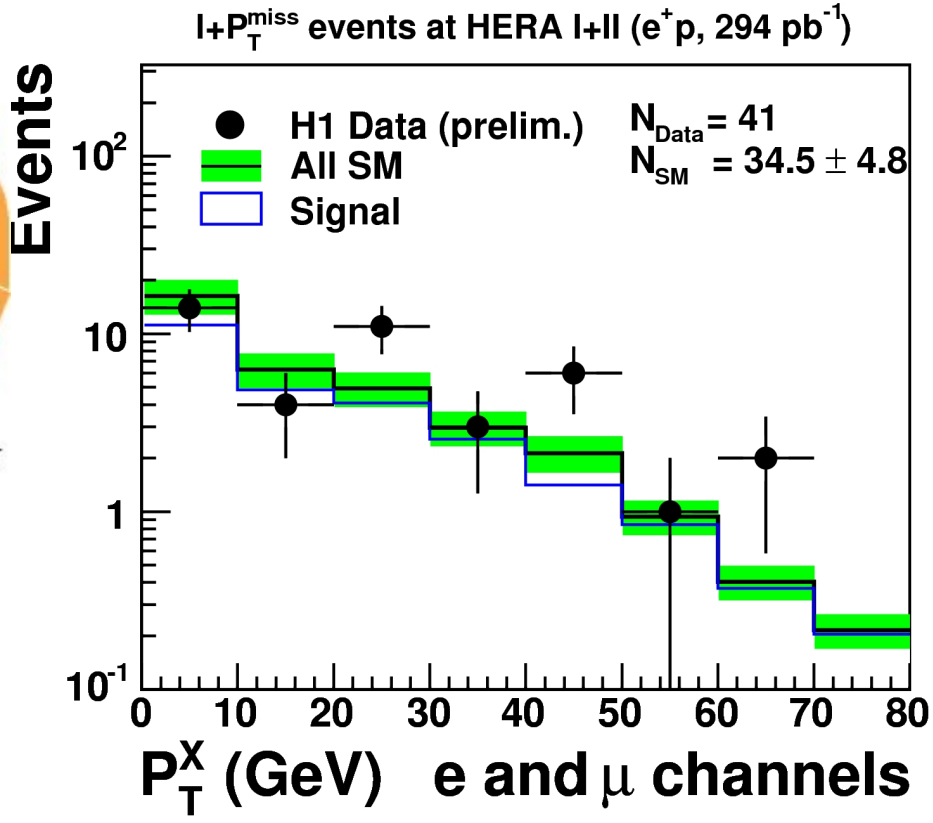
event selection

- lepton isolation $P_t^l > 10$ GeV,
- momentum imbalance $P_T^{miss} > 12$ GeV



Standard Model process: single W production



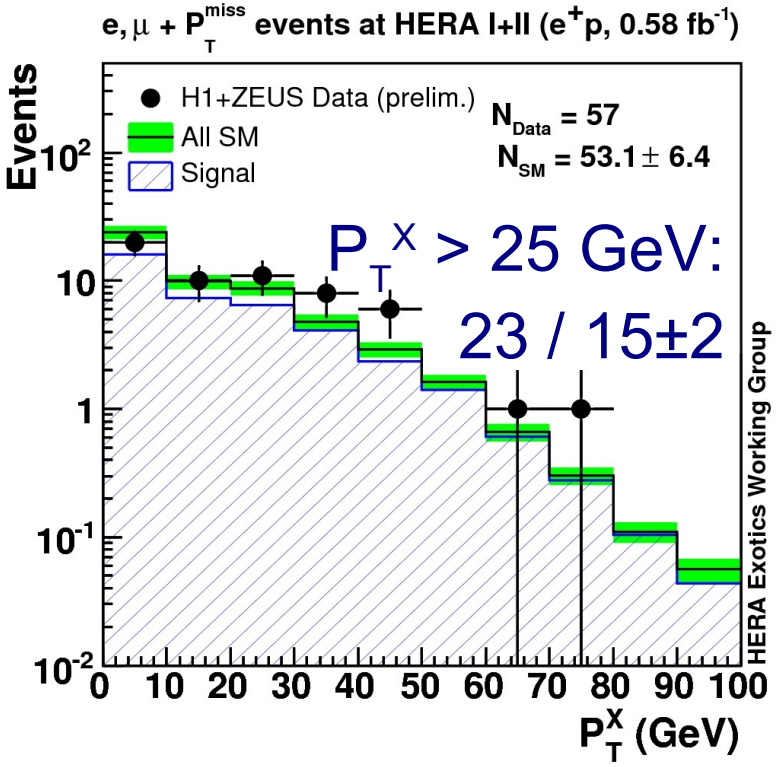


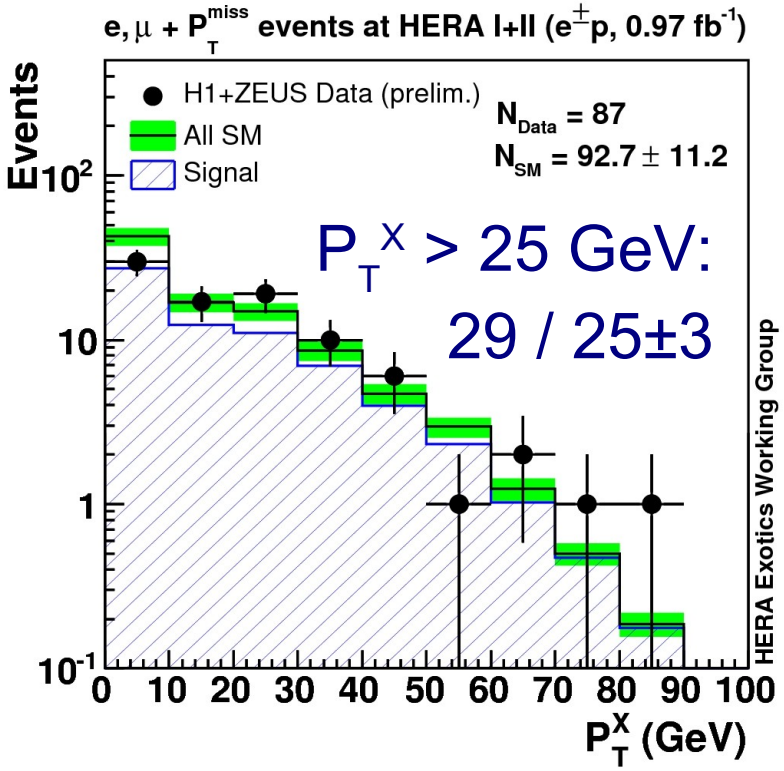
in e^+p and for $P_T^X > 25$ GeV:

- H1: 21 events for 9±1.5 expected: 3.0 σ
- ZEUS observe no deviation from SM

Isolated Leptons and p_T^{miss}

H1 an ZEUS combined in a common phase space



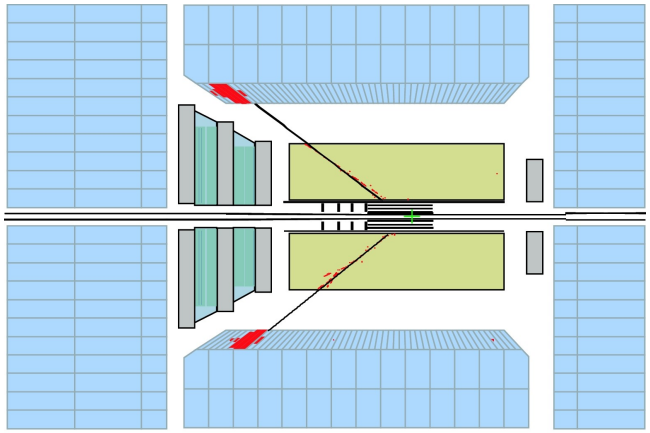


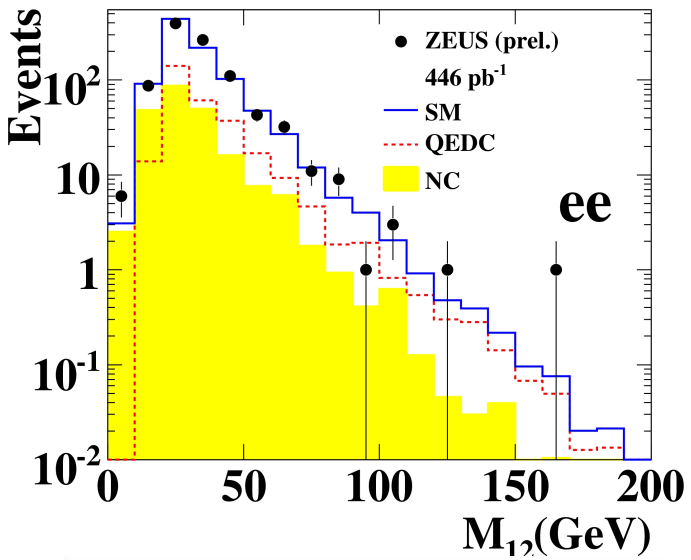
- excess at $P_T^X > 25$ GeV in the e^+p data
  - remains with 1.8 σ, but is not seen in the total sample (including e^-p data)
- single W production has been seen at HERA

Multi-Leptons

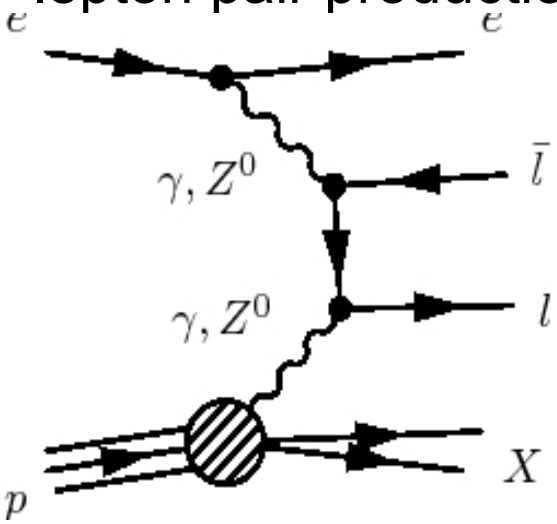
topology:

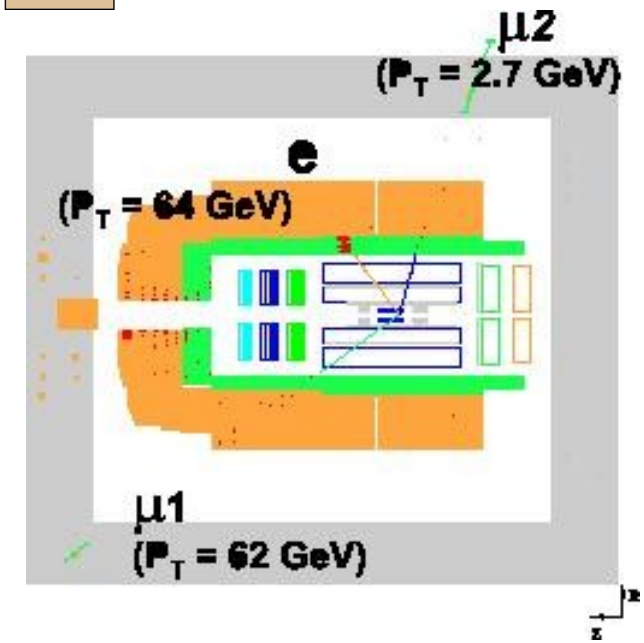
- ee, eee
- eμ, eμμ, μμ (H1 only)

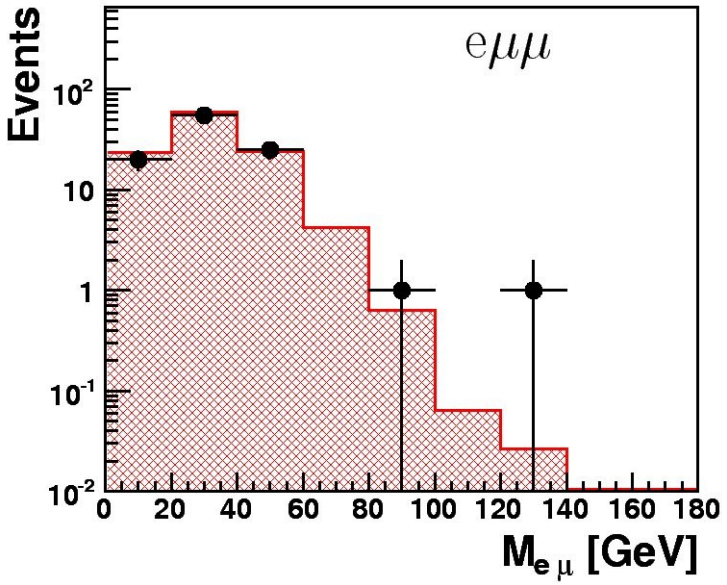




SM process:
lepton pair production







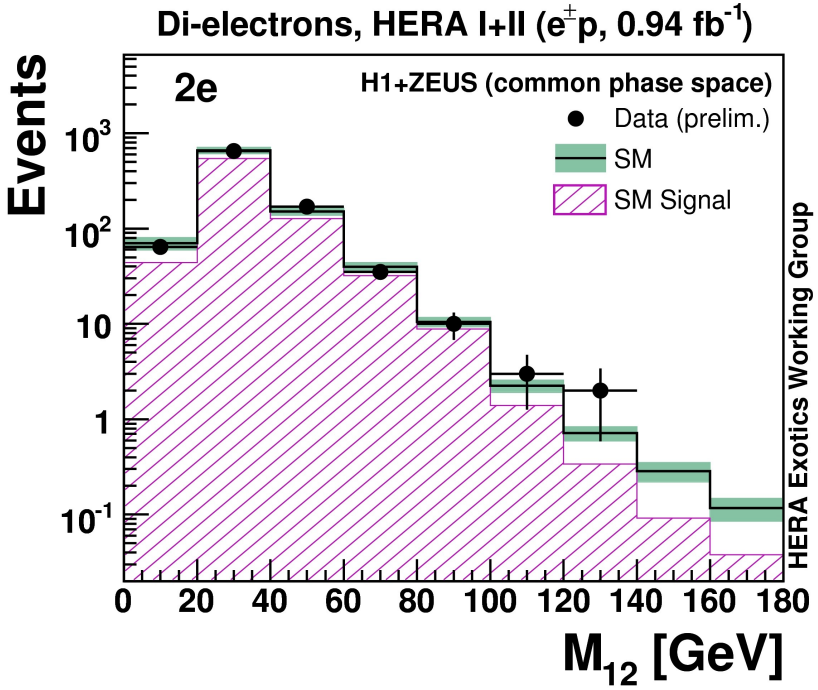
Multi-Leptons

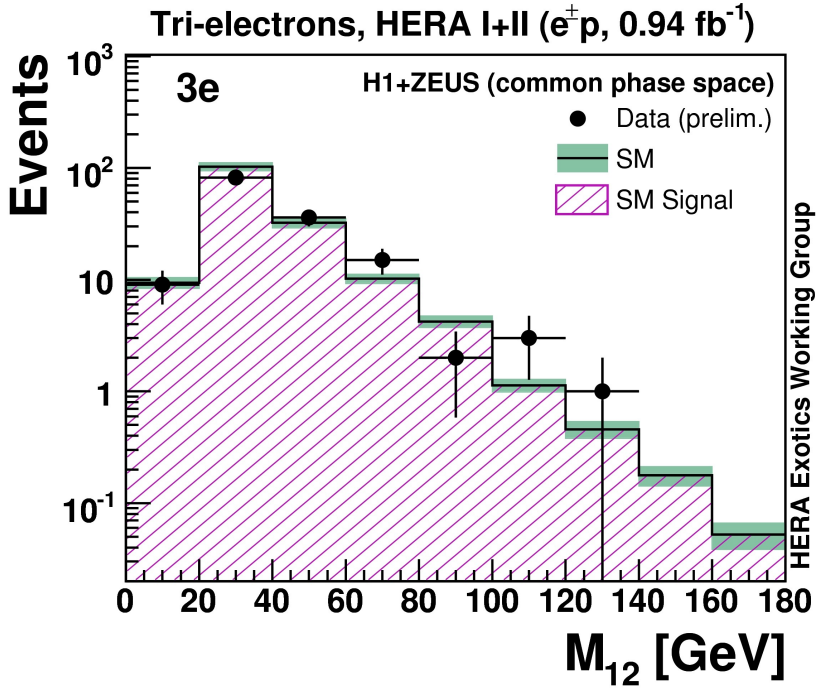
H1 and ZEUS combined in common phase space

- overall a good agreement between data and SM
- some interesting events at high masses

$M_{12} > 100\,\text{GeV}$

Selection	data	SM
e^+p		
2e	4	1.97±0.22
3e	4	1.10±0.12
e^-p		
2e	1	1.44±0.15
3e	0	0.75±0.08





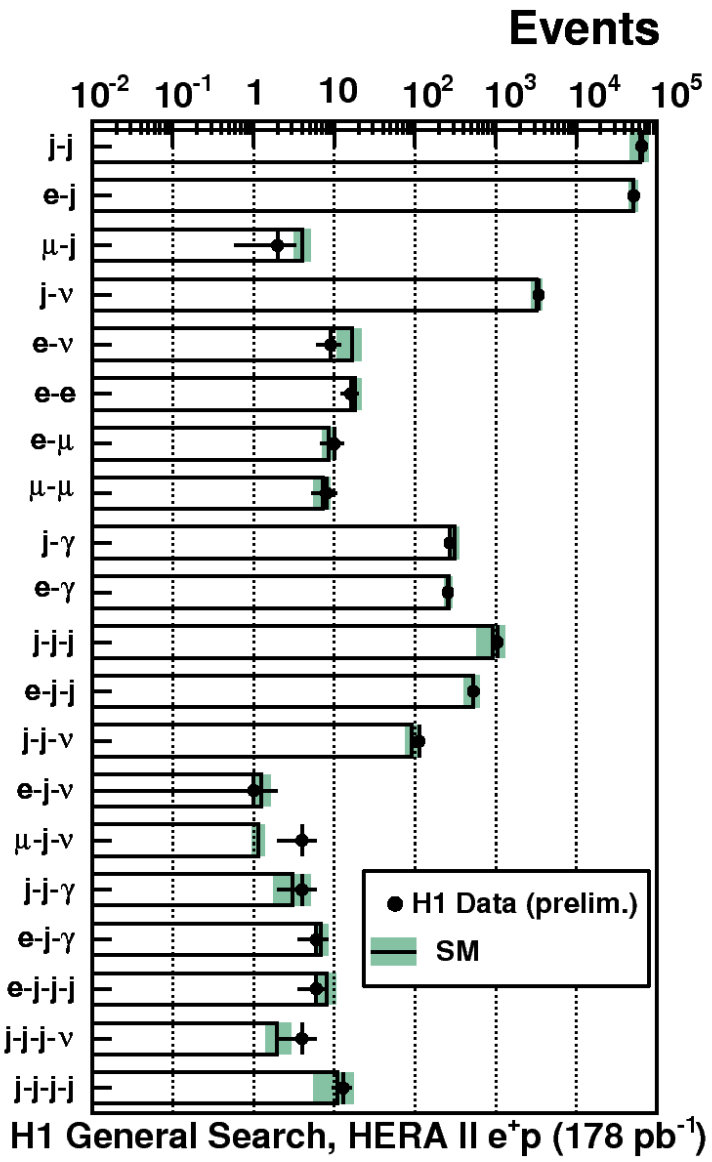
General Search

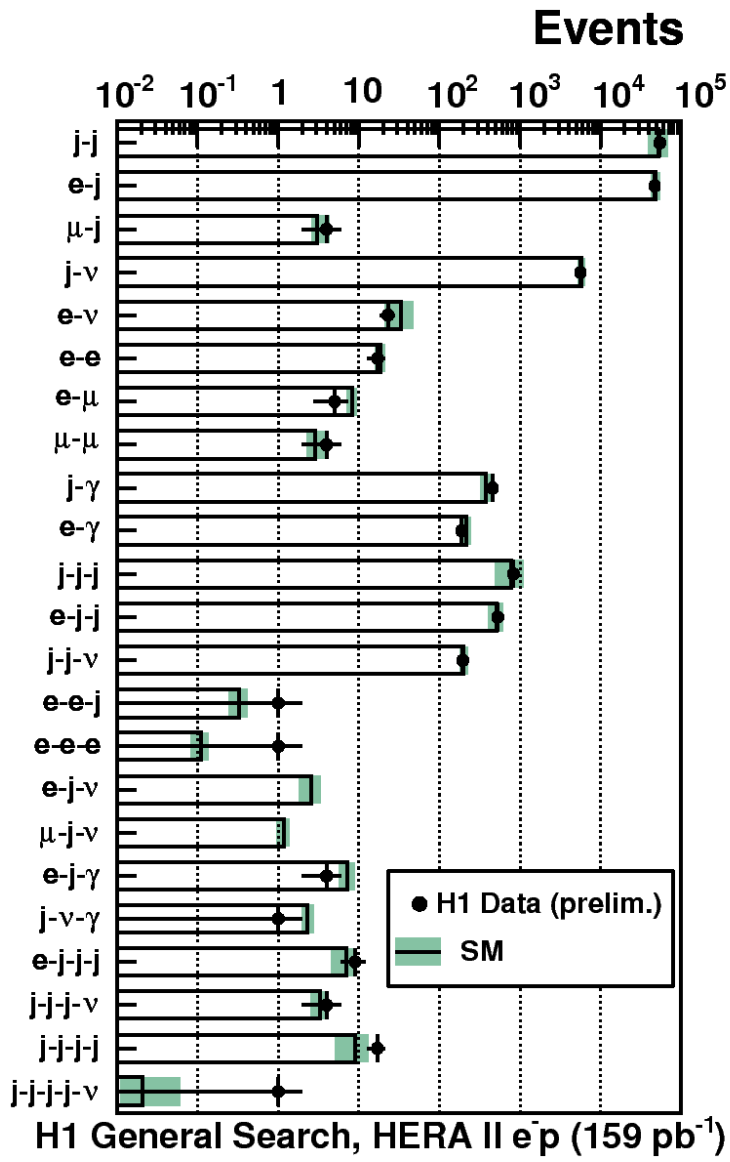
all particles

- P_T > 20GeV
- 10° < θ < 140 °
- Δ(ηθ) > 1
- E-P_z < 75 GeV

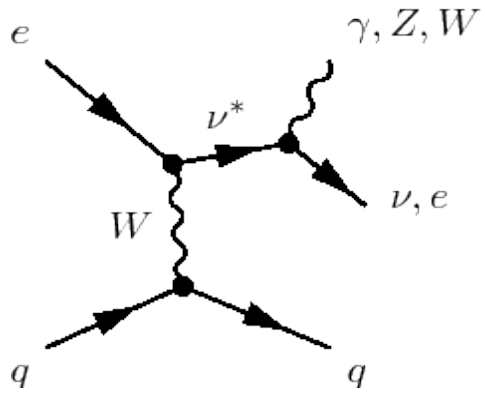
largest fluctuation: μ-jet-ν

in most channels good agreement between data and SM



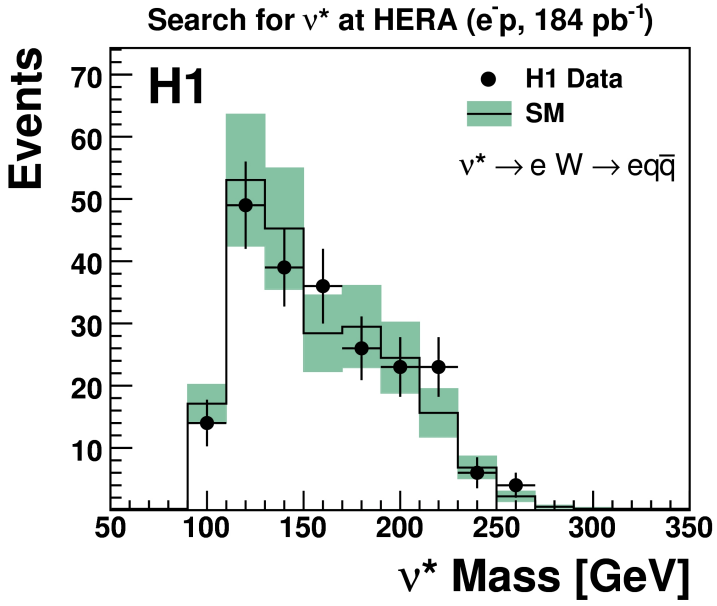


Excited Neutrinos



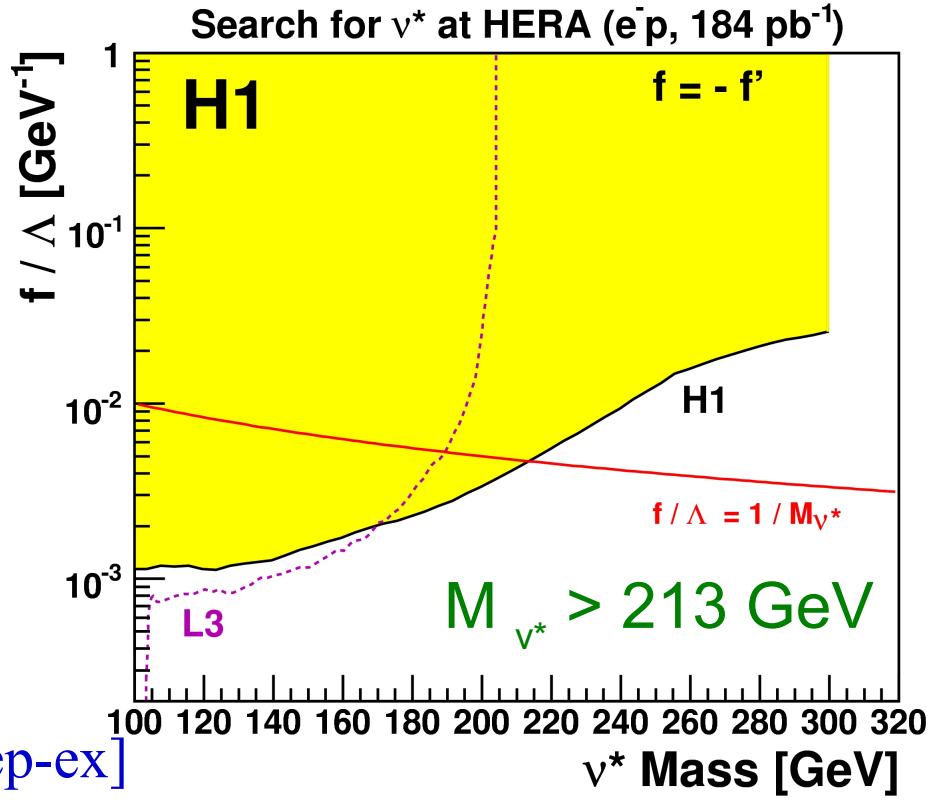
ν* composite fermion at scale Λ
cross section proportional to coupling
f and f' (similar to electroweak: g and g')

- data well described by SM prediction: no evidence for excited neutrinos



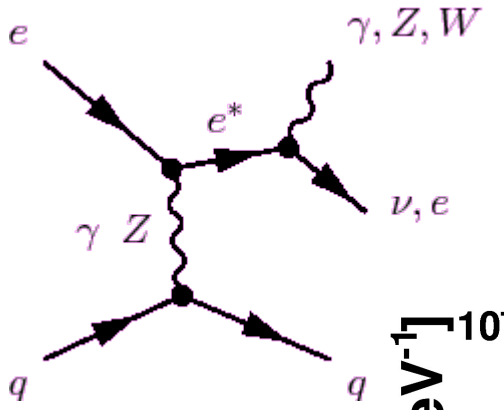
limits:

- nearly coverage of LEP (L3) resuts
- paper submitted: arXiv:0802.1858 [hep-ex]

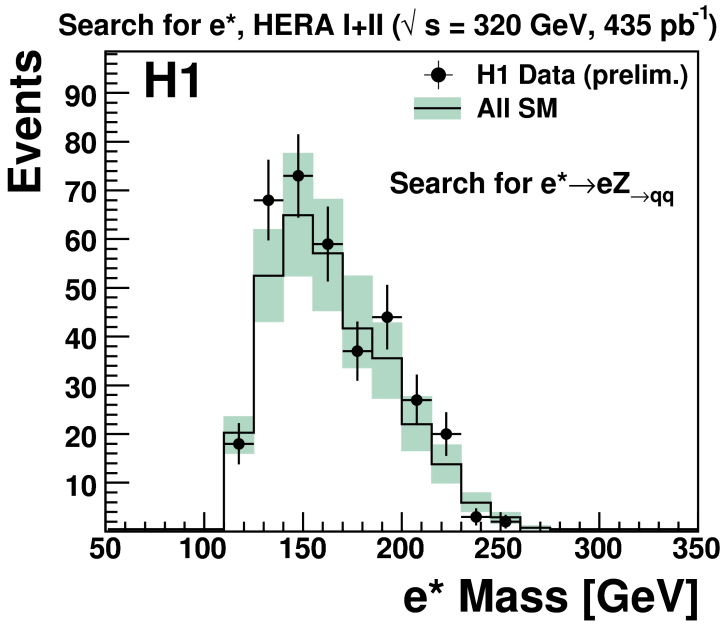


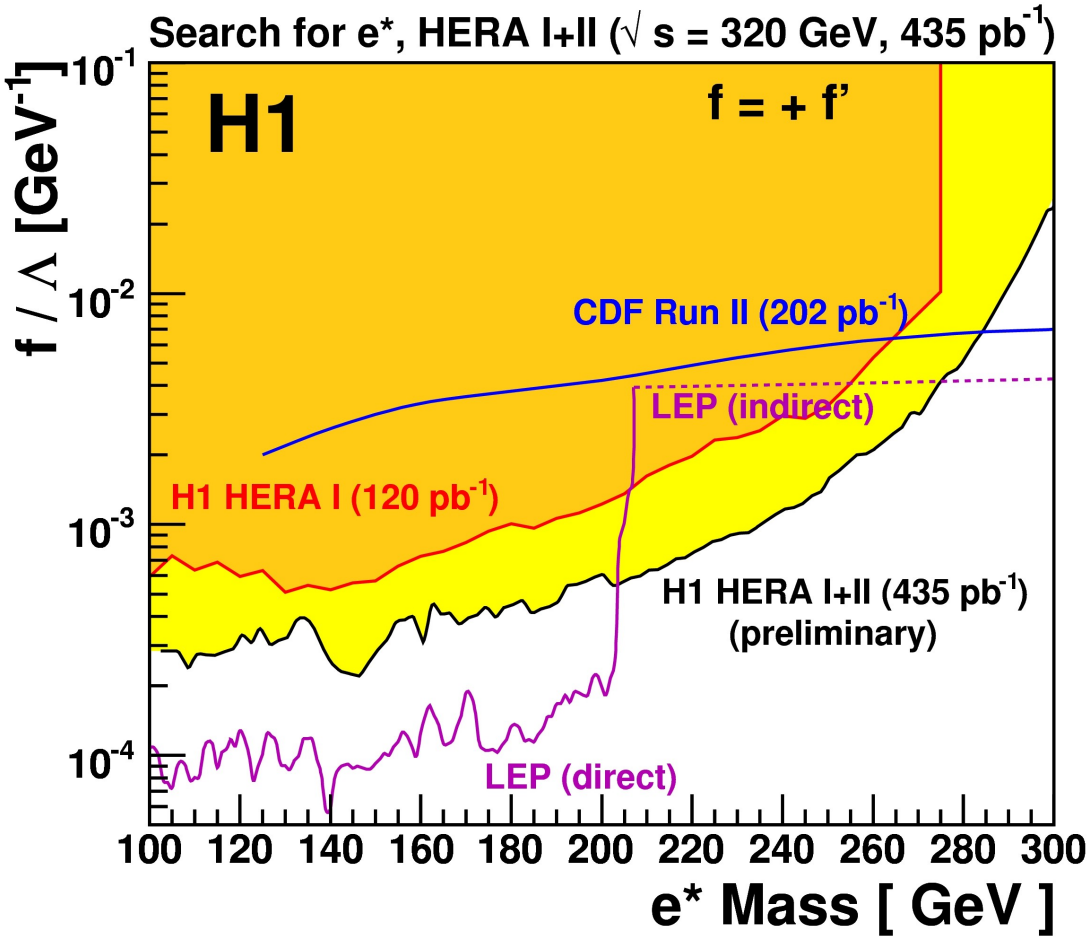
Excited Electrons

similar process:



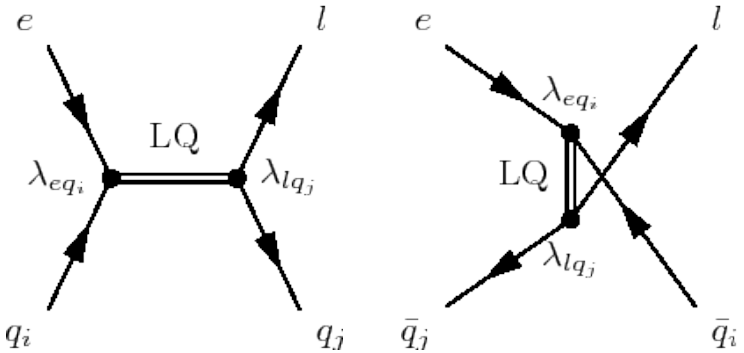
- no evidence for excited electrons
- limits: increase of sensitivity by HERA II data



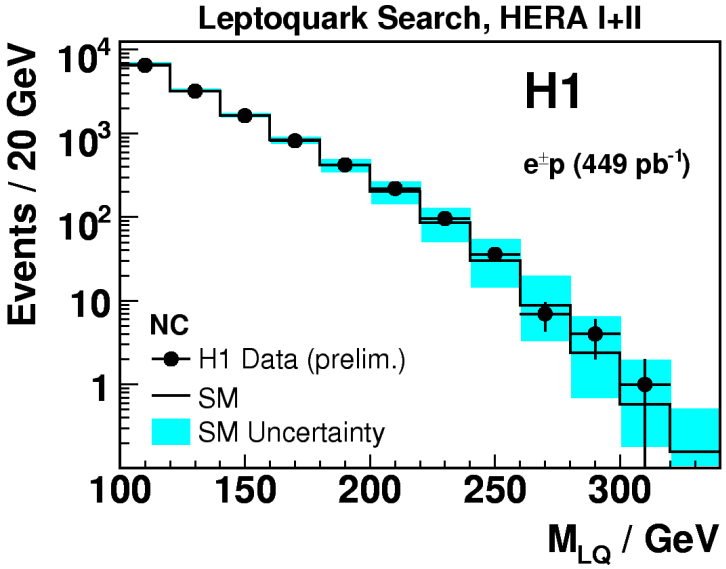


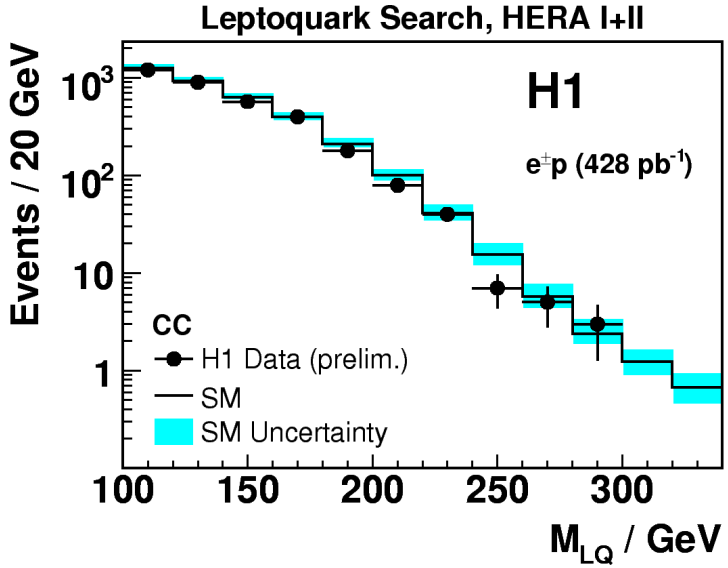
Leptoquarks

lepton and quark at the same vertex

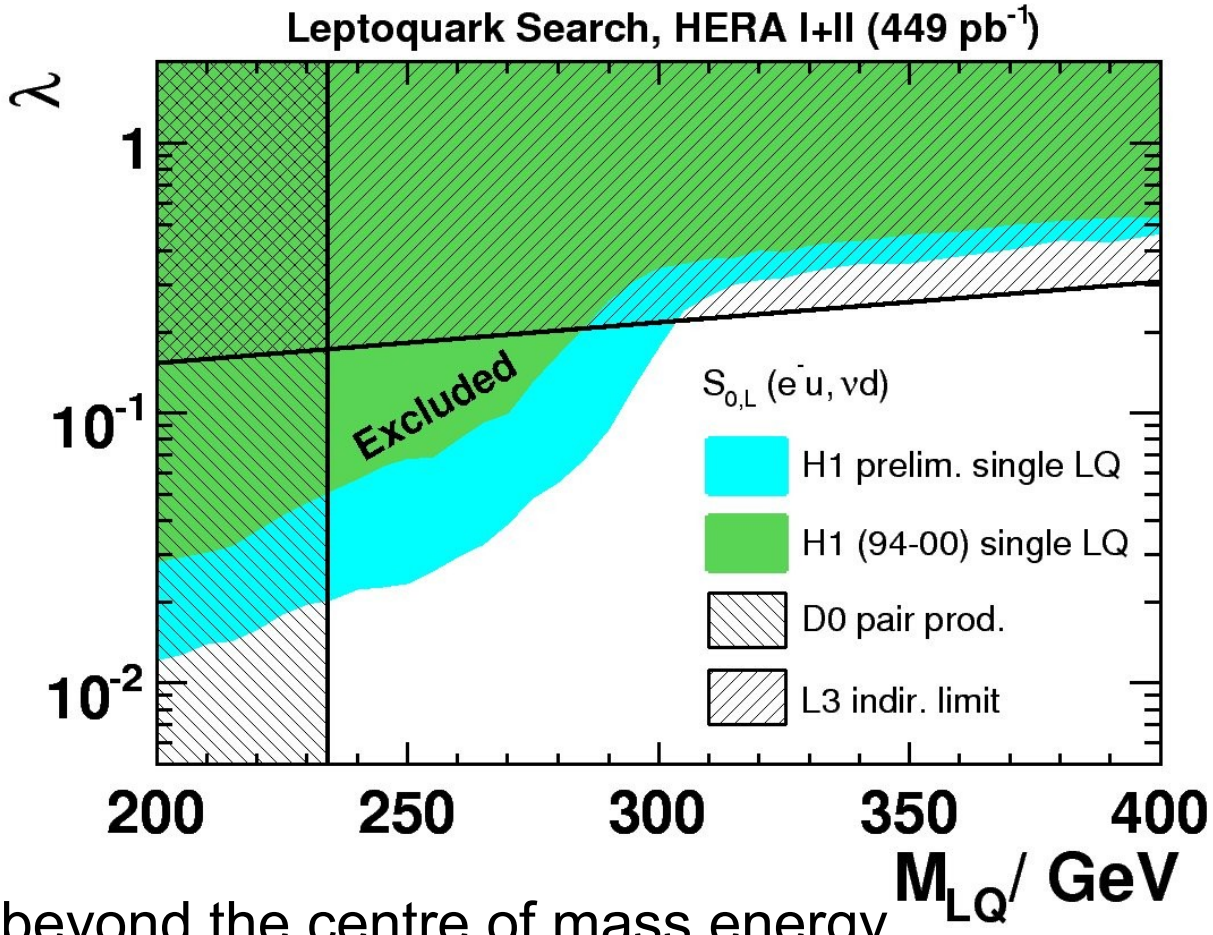


- Buchmüller Rückl Wyler model:
  - e^+p: 7 leptoquarks (F=0)
  - e^-p: 7 leptoquarks (F=2)
- first generation LQ (outgoing lepton: e, ν)
  - final state similar to NC/CC DIS: interference terms modify cross section
- signal: resonance in mass spectra
- no evidence for a leptoquark





Leptoquarks

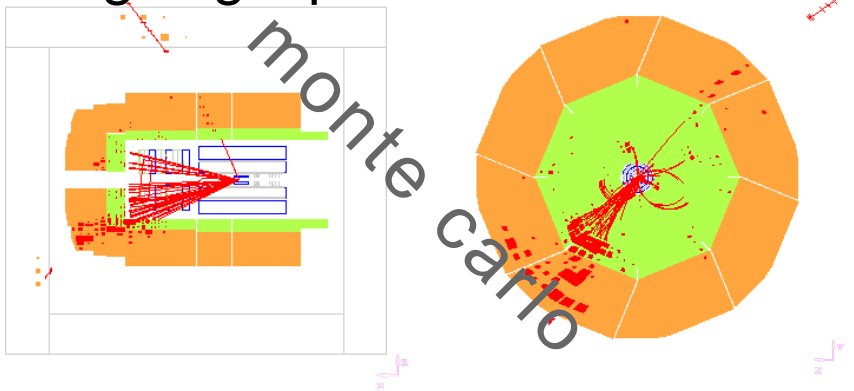


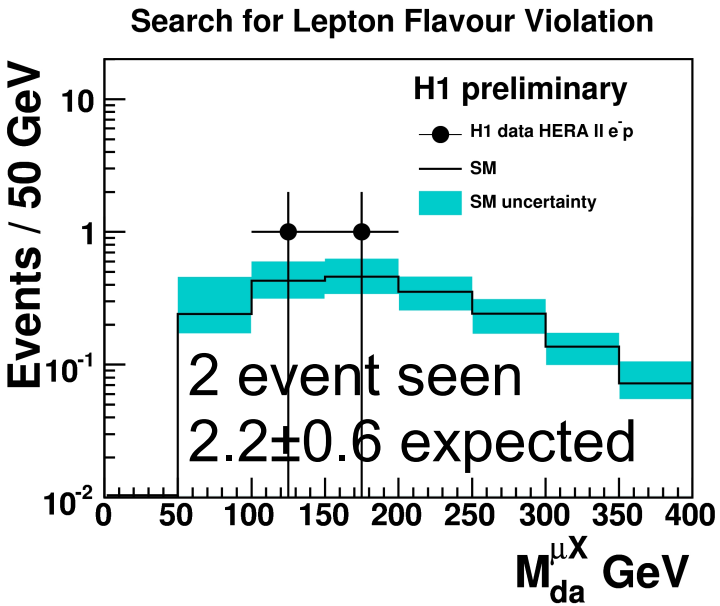
- sensitivity beyond the centre of mass energy due to virtual effect (u channel)
- assuming λ=0.3: M_{LQ} > 300 GeV
- better than the OPAL limit

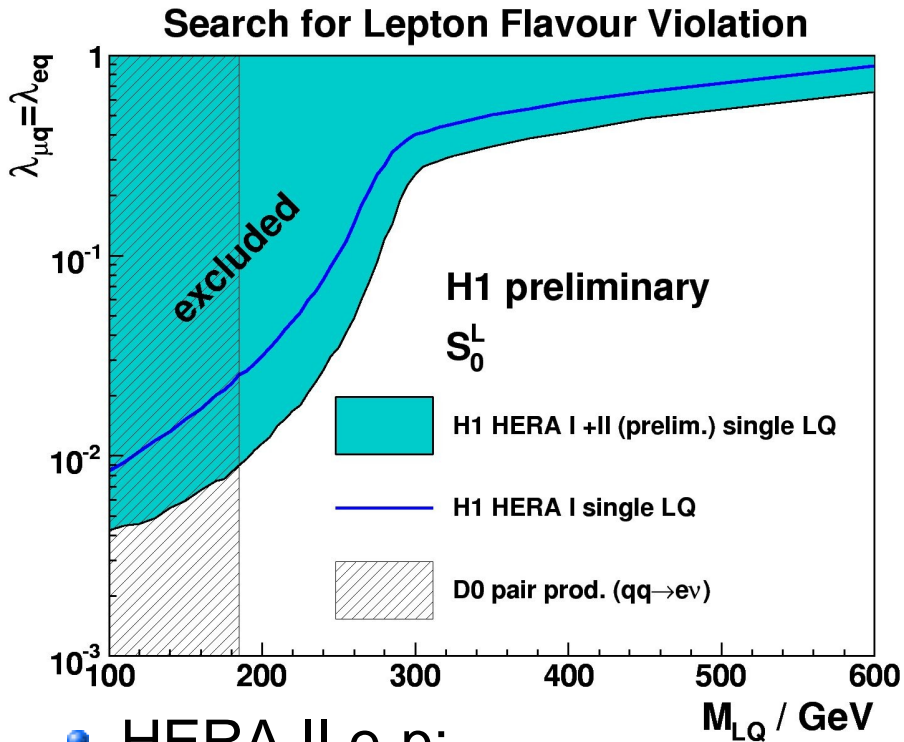
Lepton Flavour Violation

lepton flavour violation can be mediated by leptoquarks

- outgoing lepton a muon/tau instead of an electron







- HERA II e-p:
  10 times more luminosity
- pushing the limit down

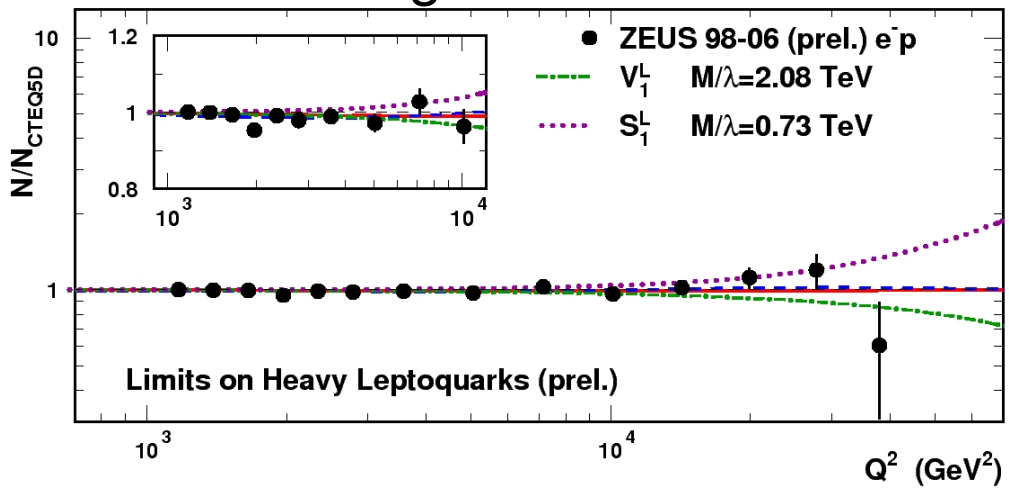
Contact Interaction

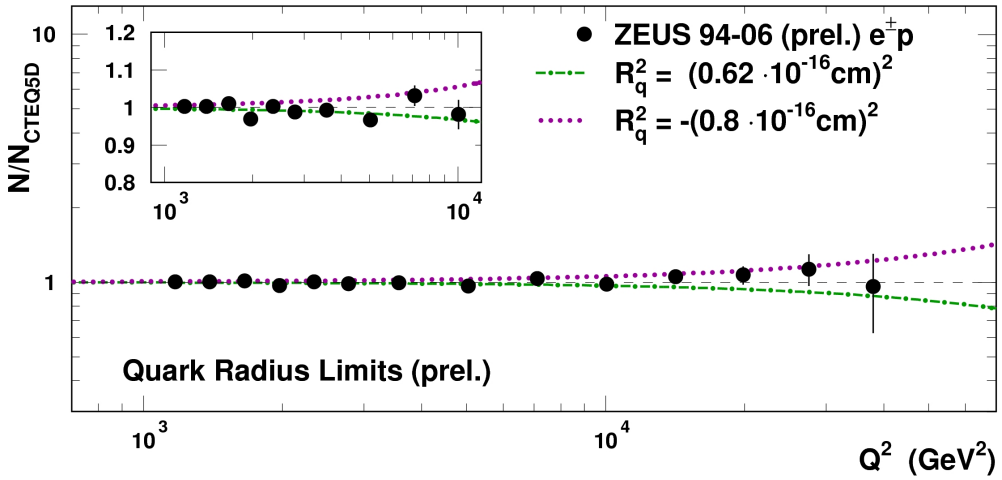
new interaction between electron and quark involving mass scales above centre-of-mass energy can modify cross section at high Q^2

- four-fermion interaction
- heavy leptoquarks
- graviton of extra large dimensions
- finite charge radius of the quark

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

- limit:
  below 1/1000 of a proton radius





Summary

- HERA data taking ended on June 30, 2007
  after 15 years of successful operation
  both experiments together have collected ≈1fb^{-1} of high quantity data
- comprehensive searches for new physics phenomena
  using all data and combining H1 and ZEUS are ongoing

- some interesting excess in rare signatures:
  isolated lepton and multi leptons
- newest limits on various theories:
  excited fermions, leptoquarks, quark radius

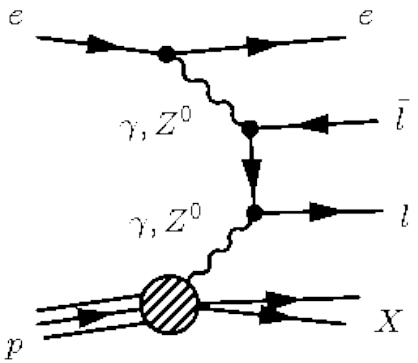
- HERA is competitive and unique

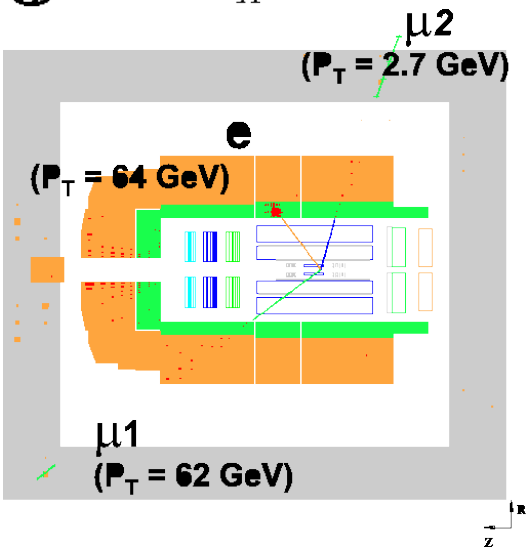
Backup

Multi-Leptons

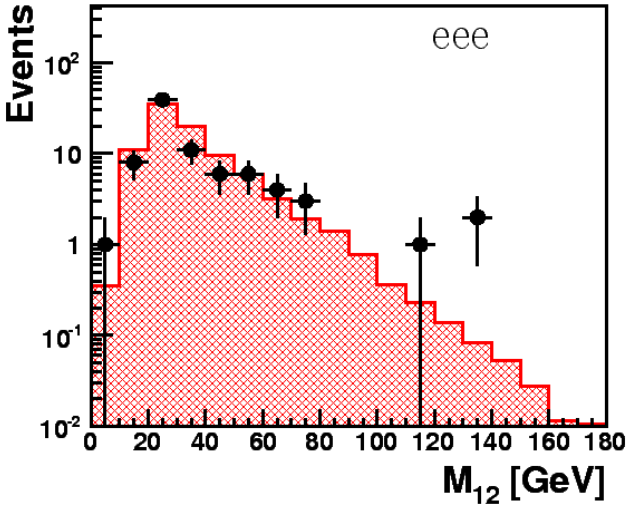
topology: 2 or 3 e/μ

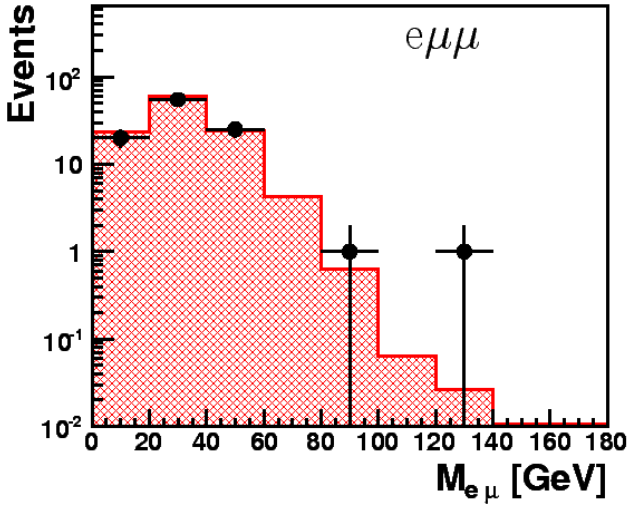
SM process:
lepton pair production

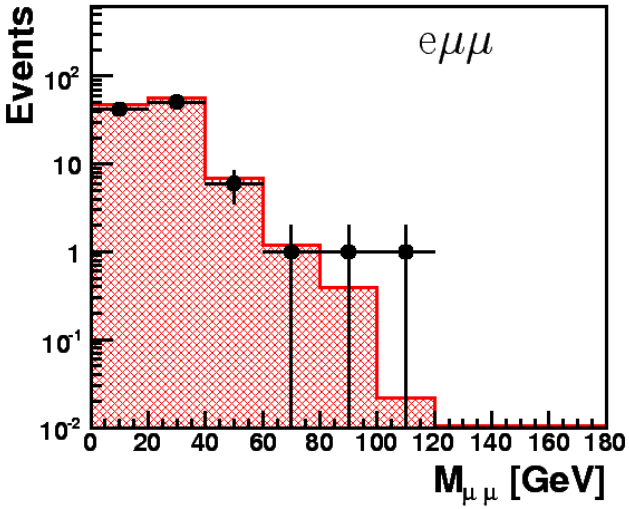




H1 Multi-lepton analysis HERA I+II (459 pb^{-1})







H1 Data (prelim.)
DIS+Compton
Pair Production

H1 sees 5 events with M_{ij} > 100 GeV

SM expectation: 1.0

Multi-Leptons

H1+ZEUS Multi-electron analysis HERA I+II (0.94 fb^{-1}, preliminary)

Selection	Data	SM	Pair Production	NC-DIS + Compton
2e	937	937 ± 67	756 ± 48	181 ± 39
3e	148	161 ± 10	160 ± 10	0.4 ± 0.01
All	1085	1098 ± 75	916 ± 58	182 ± 39

H1+ZEUS Multi-electron analysis HERA I+II (preliminary)

$M_{12} > 100$ GeV				
Selection	Data	SM	Pair Production	NC-DIS + Compton
e^+p collisions (0.56 fb^{-1})				
2e	4	1.97 ± 0.22	1.10 ± 0.21	0.87 ± 0.18
3e	4	1.10 ± 0.12	1.10 ± 0.12	—
e^-p collisions (0.38 fb^{-1})				
2e	1	1.44 ± 0.15	0.77 ± 0.10	0.67 ± 0.12
3e	0	0.75 ± 0.08	0.75 ± 0.08	—
$e^\pm$ collisions (0.94 fb^{-1})				
2e	5	3.41 ± 0.37	1.87 ± 0.25	1.54 ± 0.29
3e	4	1.85 ± 0.24	1.85 ± 0.24	—

Isolated Leptons and p_T^{miss}

H1+ZEUS Preliminary l+P_T^{miss} events at HERA I+II		Electron obs./exp. (Signal contribution)	Muon obs./exp. (Signal contribution)	Combined obs./exp. (Signal contribution)
1994-2007 e^+p 0.58 fb^{-1}	Full Sample	39 / 41.3 ± 5.0 (70%)	18 / 11.8 ± 1.6 (85%)	57 / 53.1 ± 6.4 (73%)
	$P_T^X > 25$ GeV	12 / 7.4 ± 1.0 (78%)	11 / 7.2 ± 1.0 (85%)	23 / 14.6 ± 1.9 (81%)
1998-2006 e^-p 0.39 fb^{-1}	Full Sample	25 / 31.6 ± 4.1 (63%)	5 / 8.0 ± 1.1 (86%)	30 / 39.6 ± 5.0 (68%)
	$P_T^X > 25$ GeV	4 / 6.0 ± 0.8 (67%)	2 / 4.8 ± 0.7 (87%)	6 / 10.6 ± 1.4 (76%)
1994-2007 $e^\pm p$ 0.97 fb^{-1}	Full Sample	64 / 72.9 ± 8.9 (67%)	23 / 19.9 ± 2.6 (85%)	87 / 92.7 ± 11.2 (71%)
	$P_T^X > 25$ GeV	16 / 13.3 ± 1.7 (73%)	13 / 12.0 ± 1.6 (86%)	29 / 25.3 ± 3.2 (79%)

W - Polarisation

with isolated lepton analysis the W polarisation can be measured:

- longitudinal F_0,
- left handed F_- and right handed F_+

$$\frac{dN}{d\cos\theta^*} \propto \overbrace{(1-F_--F_0)}^{F_+}\cdot\frac{3}{8}(1+\cos\theta^*)^2 + F_0\cdot\frac{3}{4}(1+\cos^2\theta^*) + F_-\cdot\frac{3}{8}(1-\cos\theta^*)^2$$