New Physics Searches at HERA

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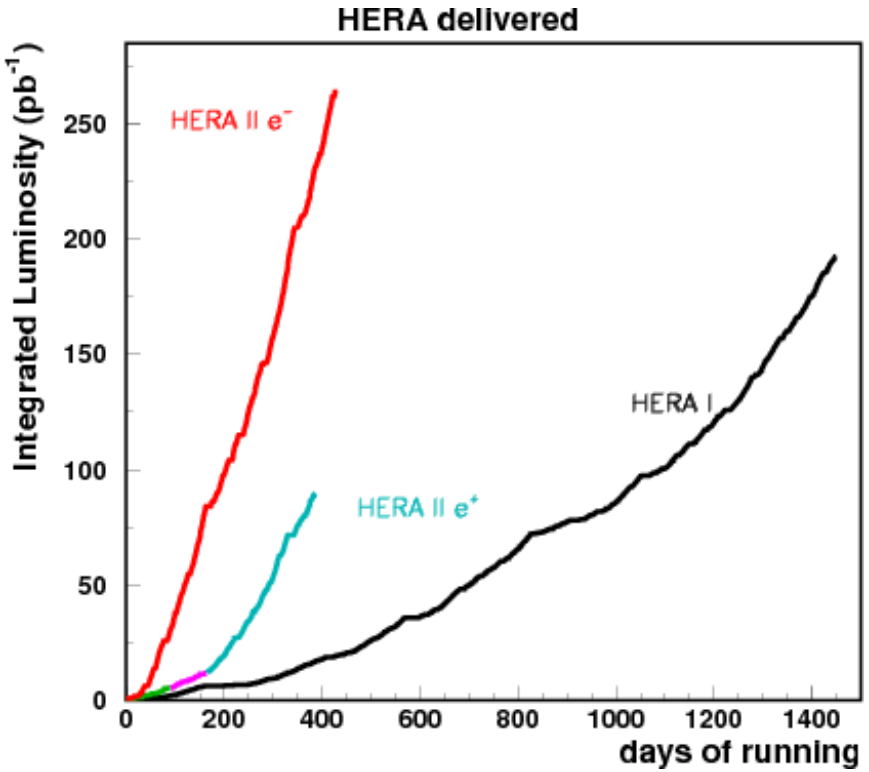
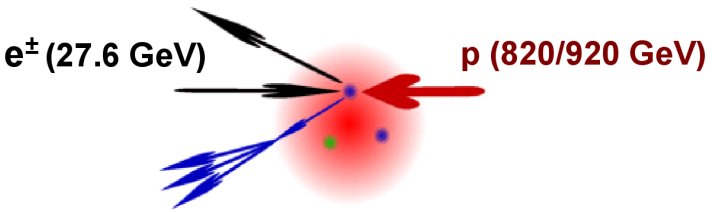
On behalf of the ZEUS and H1 Collaborations

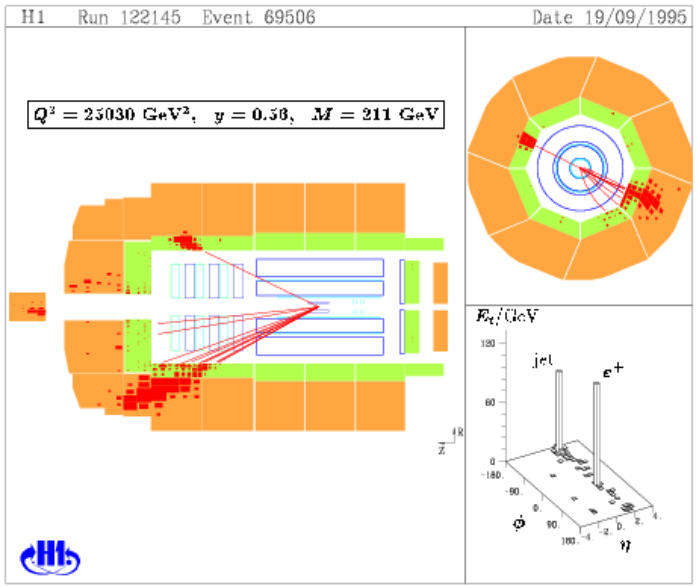
Outline

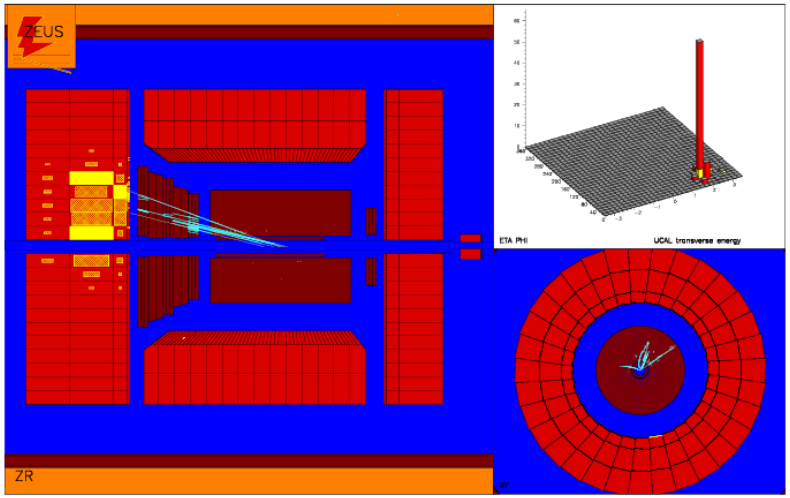


At HERA $e^{\pm}$ are collided with protons at the interaction points of H1 and ZEUS with $\sqrt{s} \approx 320$ GeV



HERA I: ZEUS $\mathcal{L} \sim 130\ \mathrm{pb}^{-1}$
HERA II: ZEUS $\mathcal{L} \sim 230\ \mathrm{pb}^{-1}$
In HERA II the lepton beam is longitudinally polarised





H1

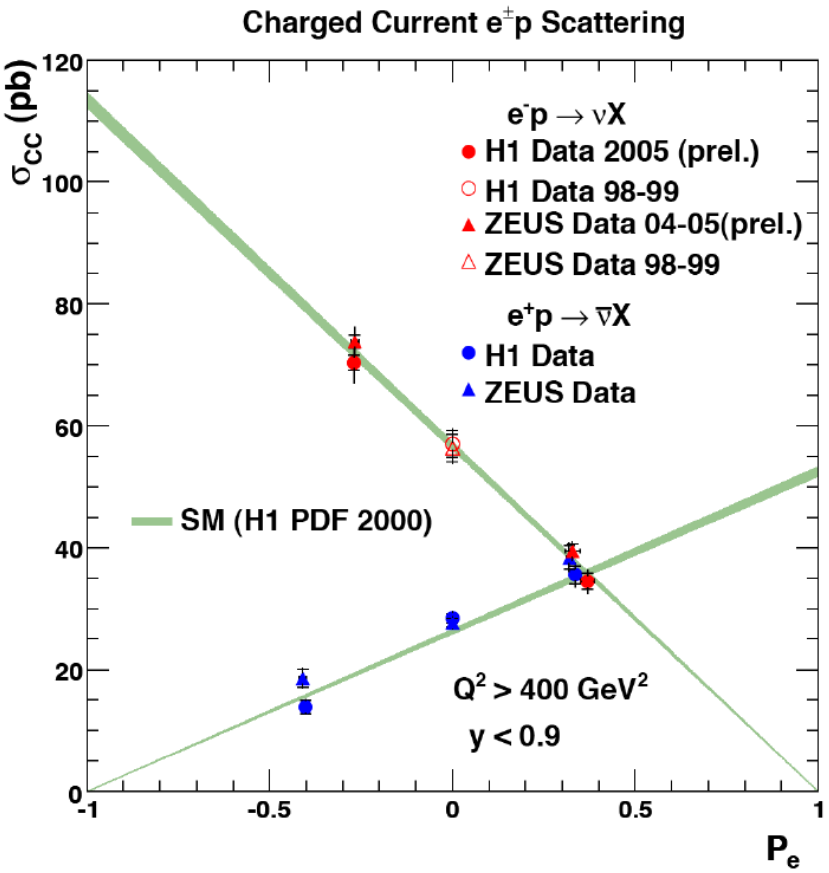
- Liquid Argon Calorimeter
- Optimised for precision measurement of the scattered lepton

ZEUS

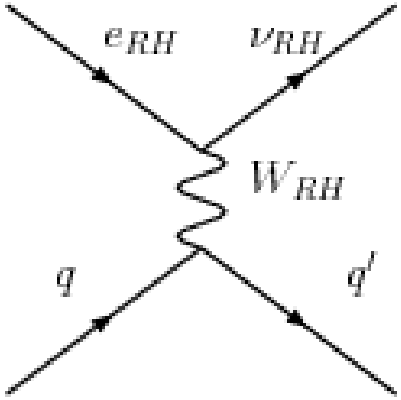
- Depleted Uranium Calorimeter
- Optimised for precision measurement of the hadronic final state

Several ways to search for BSM physics at HERA:

- Searches for new currents affecting DIS processes:
  - Charged Current DIS
  - Neutral Current DIS
- Model dependent searches for new particles:
  - HERA is not an annihilation machine $\longrightarrow$ the cross section for pair producing heavy new particles is small
  - Single particle production is usually investigated
  - Limits depend on coupling of new particle to SM ones $\longrightarrow$ no absolute mass limits
- Model Independent Searches for new physics:
  - Study SM processes with a low cross-section
  - investigate all possible final states, compare data to SM expectation



$$\sigma_{CC} \propto (1 \pm \mathcal{P}_e)$$



polarised CC sensitive to W_{RH}
Compatible with no W_{RH}

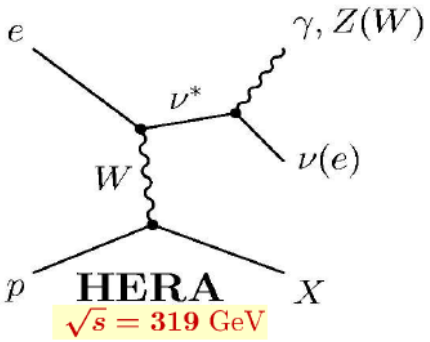
ZEUS Limit on σ^{CC}_{RH}

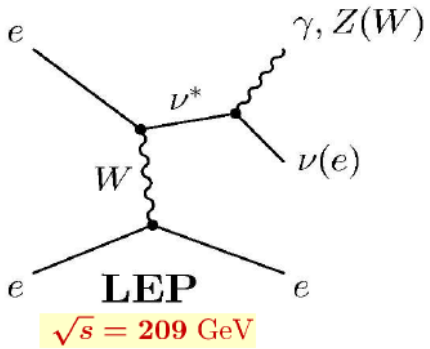
$\sigma_{RH} = 0.8 \pm 3.1(\text{stat.}) \pm 5.0(\text{sys.})\text{pb}$

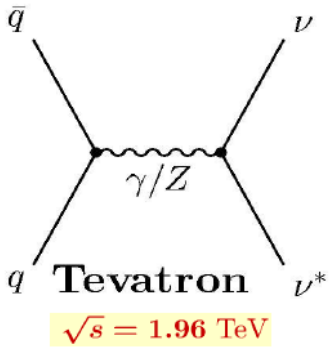
$\sigma_{RH} < 7.48$ pb (95% C.L.)

$\rightarrow M(W_{RH} > 180)$ GeV

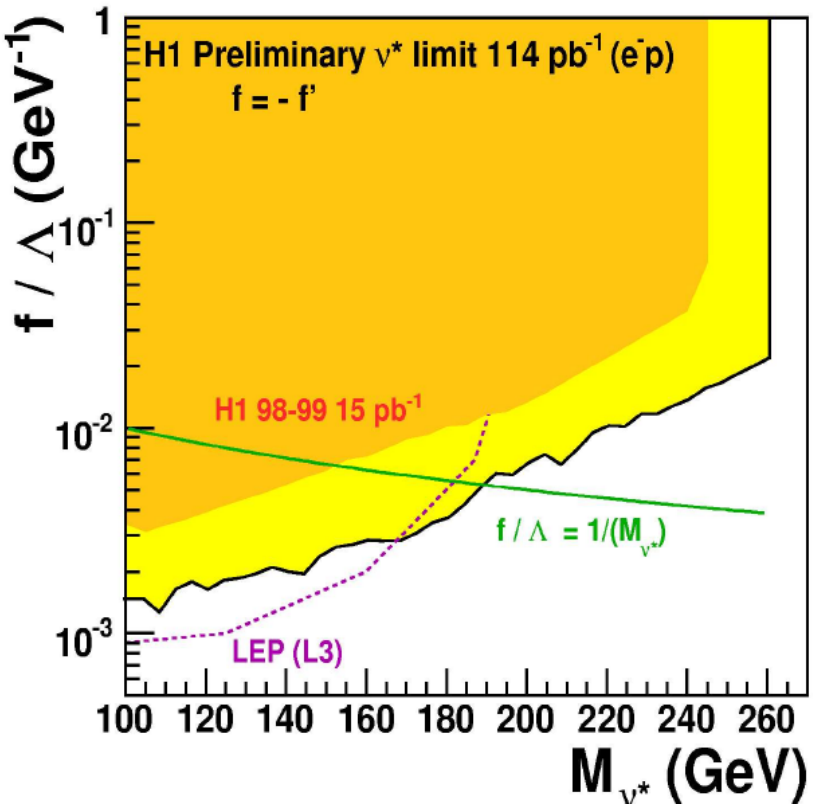
ZEUS limit comparable to H1 limit.

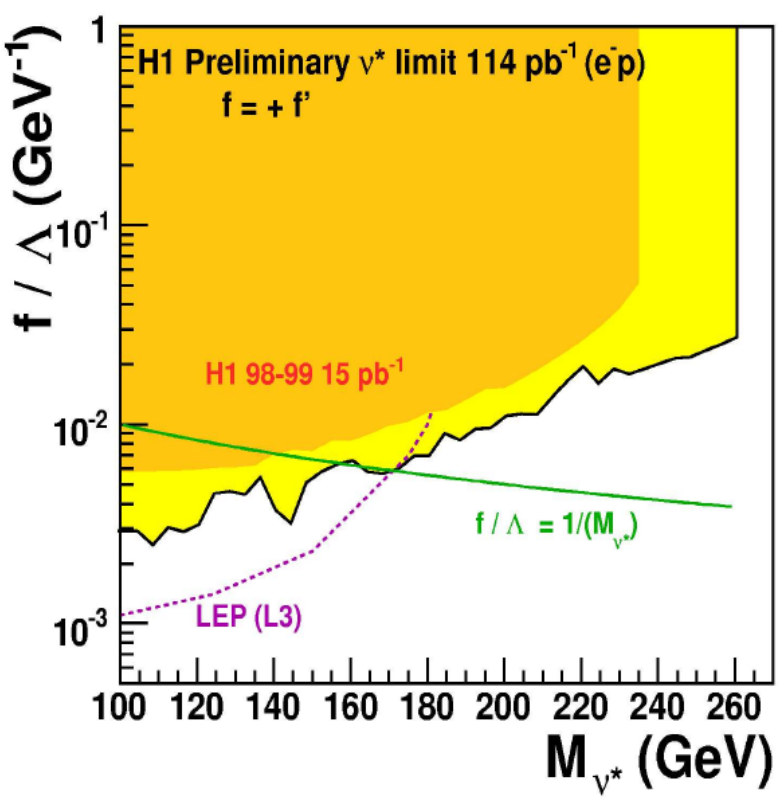




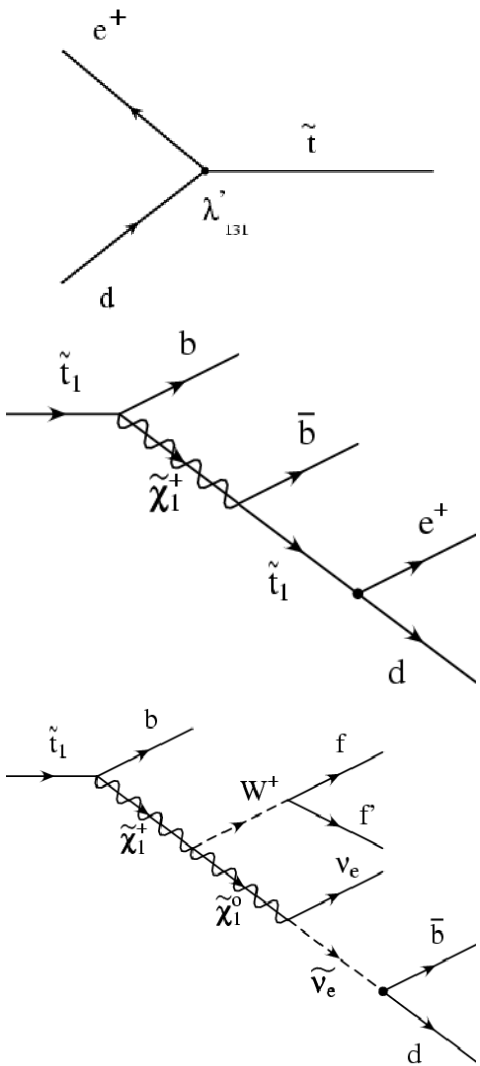


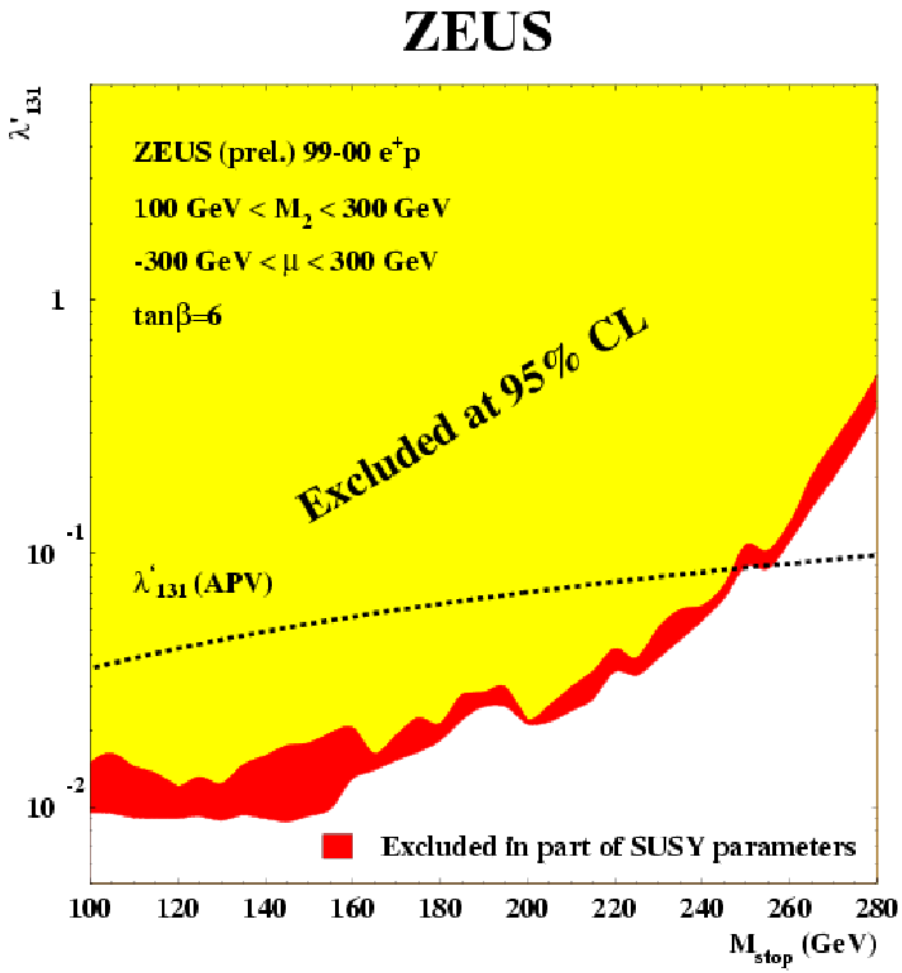
- Discovery of ν^* would be direct proof of compositeness
- At HERA ν^* are produced in CC like interactions
- Extra jets in the event besides ν^* decay products
- Cross section much larger in $e^- p$ ($\mathcal{O}(10^2)$) due to favourable u-quarks and helcity enhancement (like CC)
- in 2004-5 HERA data we have $\mathcal{O}(10)$ more $e^- p$ luminosity





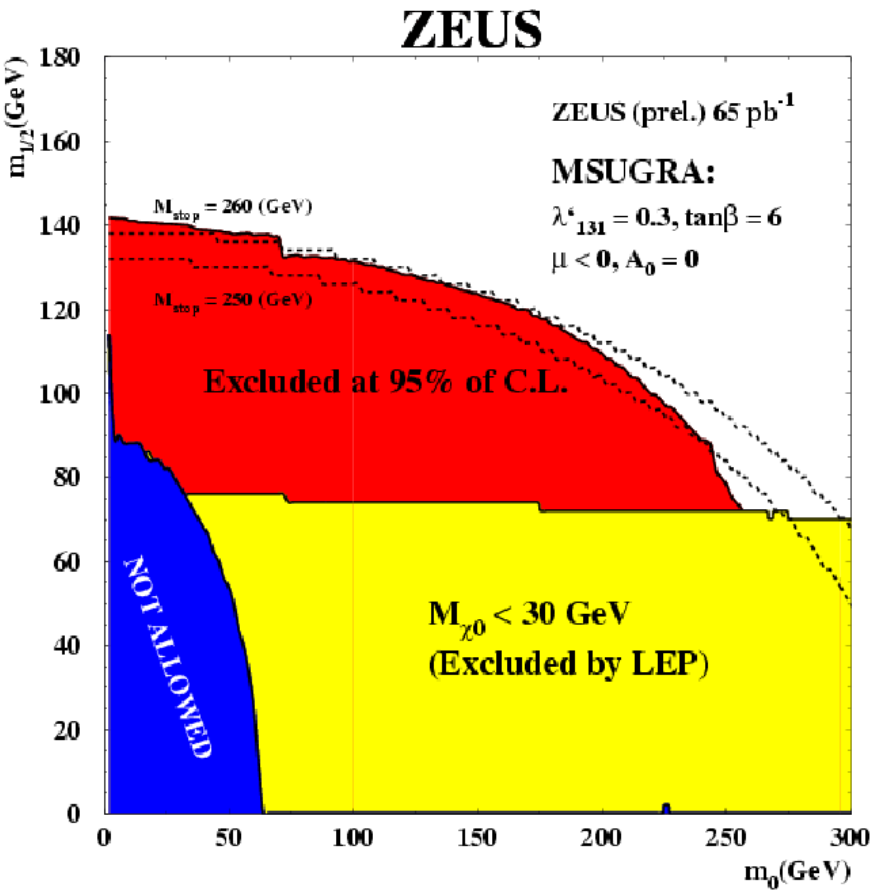
- $f = -f' \rightarrow$ maximal photon coupling, $\Lambda =$ compositeness scale

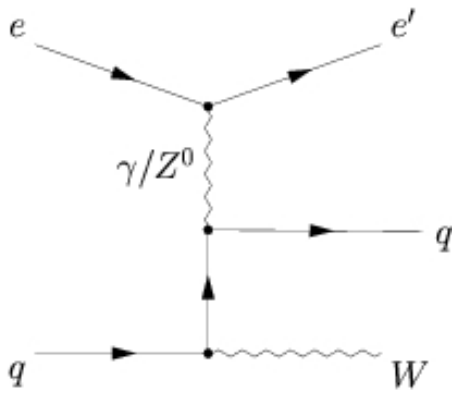




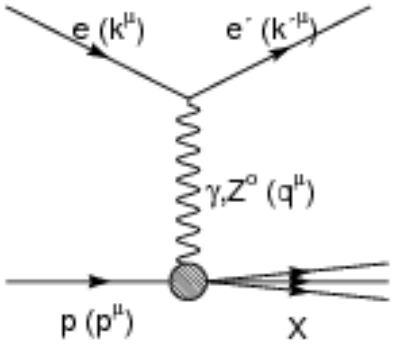
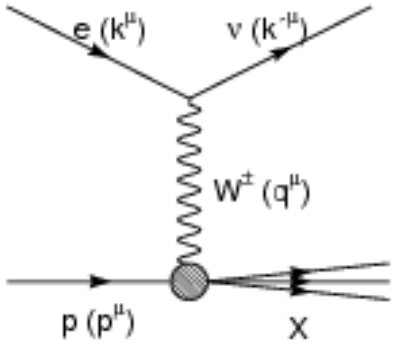
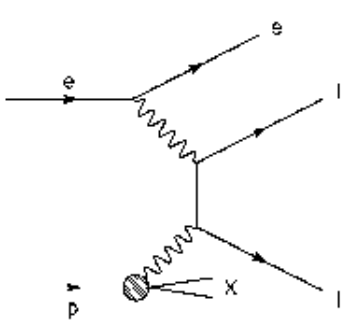
- λ_{131}, direct RPV coupling

- Limits made for mSUGRA scenario
- Red: Excluded at 95% C.L.
- Yellow: Already excluded by LEP
- Blue: forbidden region

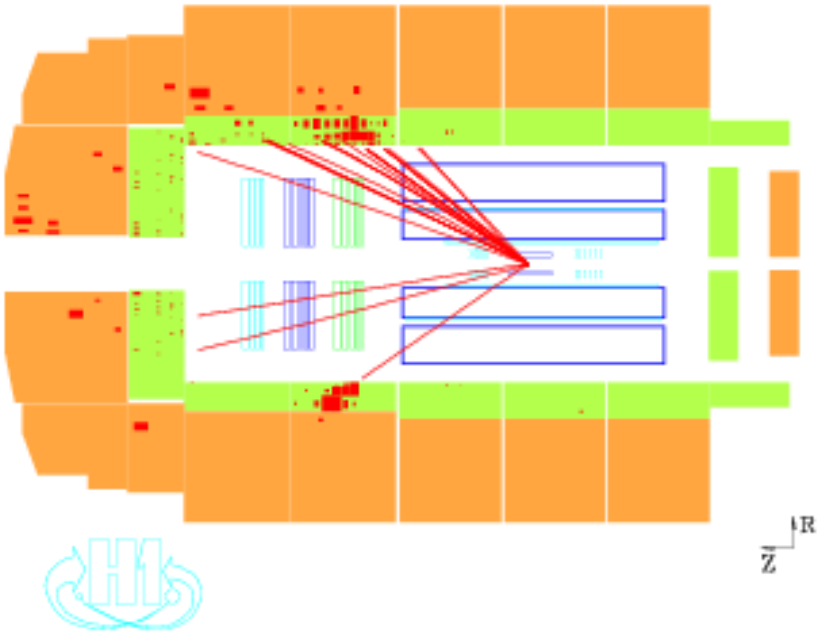


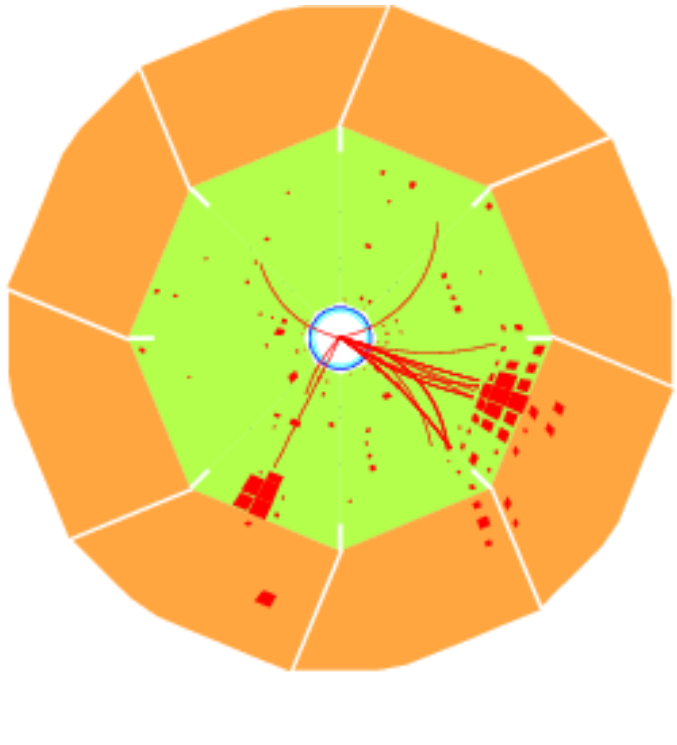


High P_T Isolated leptons in events with large missing P_T are the signature of many BSM processes at HERA
SM source at HERA is Single W production:
At HERA σ(W production) $\approx$ 1.1 pb

NC DIS	CC DIS	Dilepton production
		
Genuine electron and fake P_T^{miss} due to mismeasurement	misidentified lepton and genuine P_T^{miss}	Genuine μ and fake P_T^{miss} due to mismeasurement

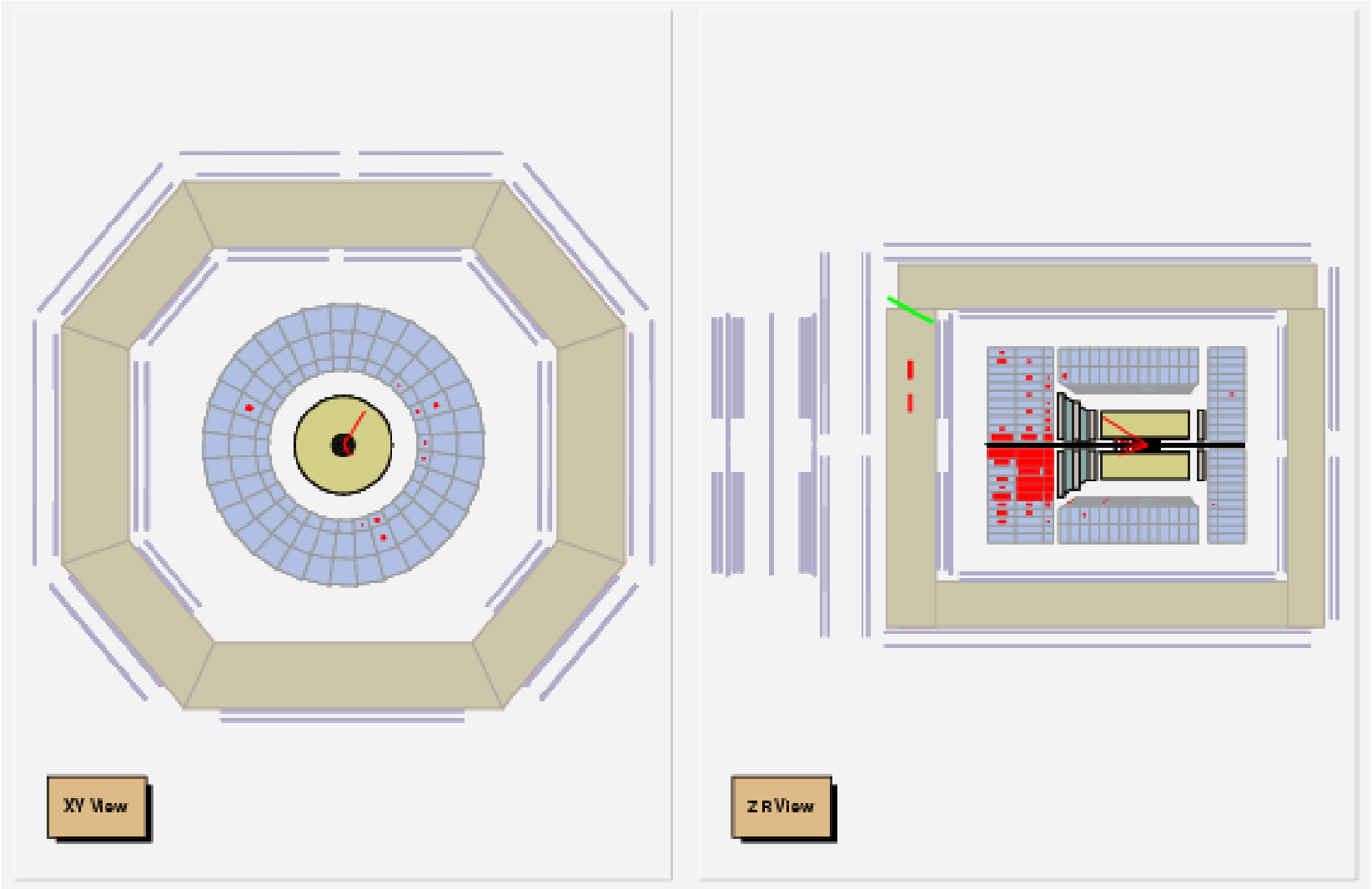
Example e Event

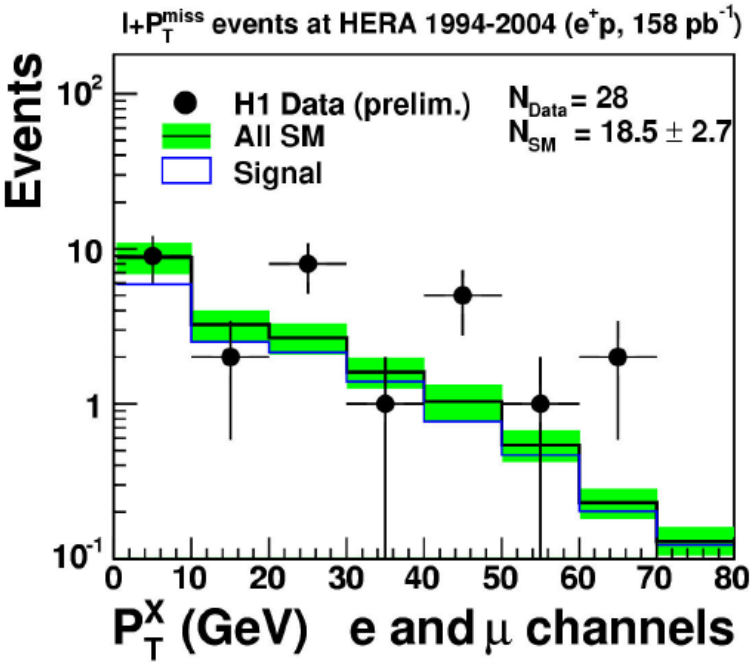


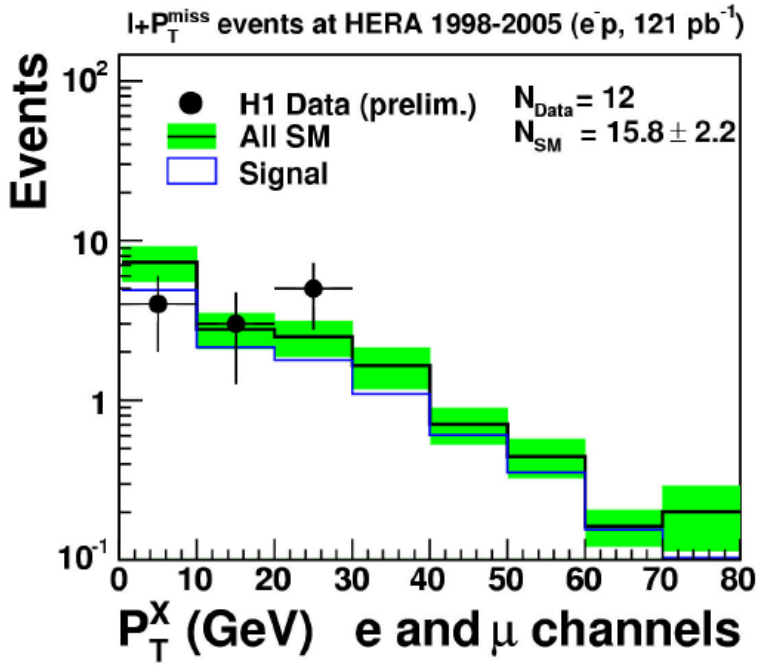


Example μ Event

ZEUS

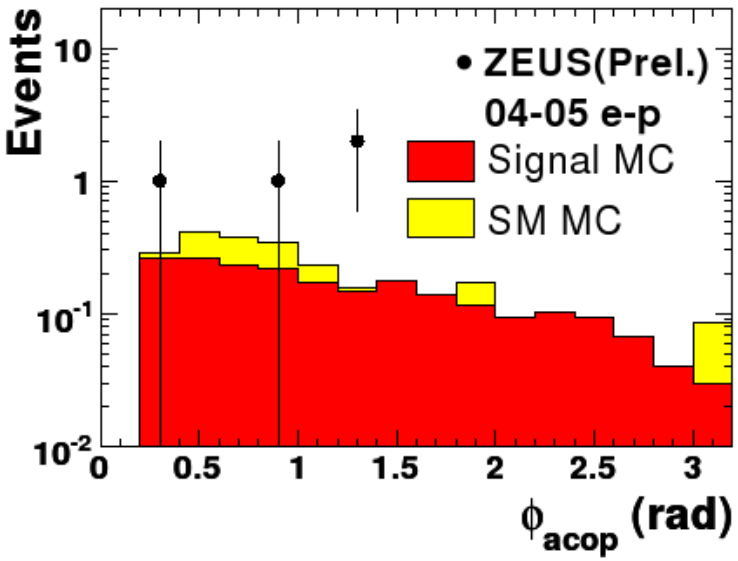


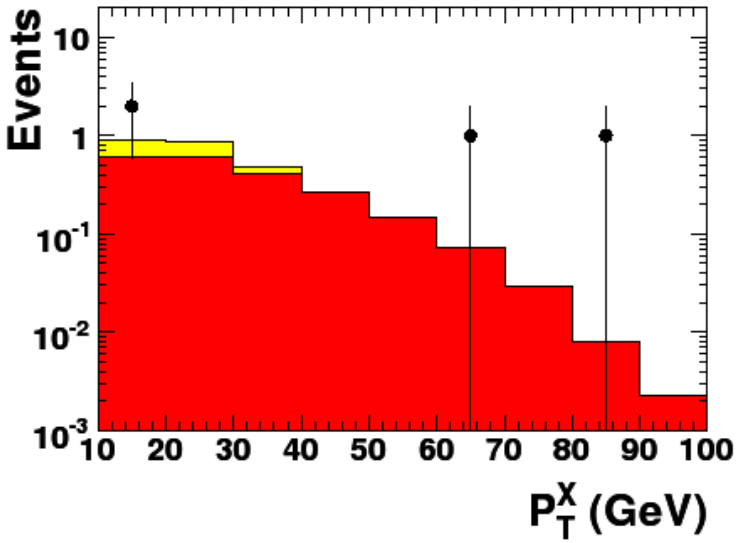




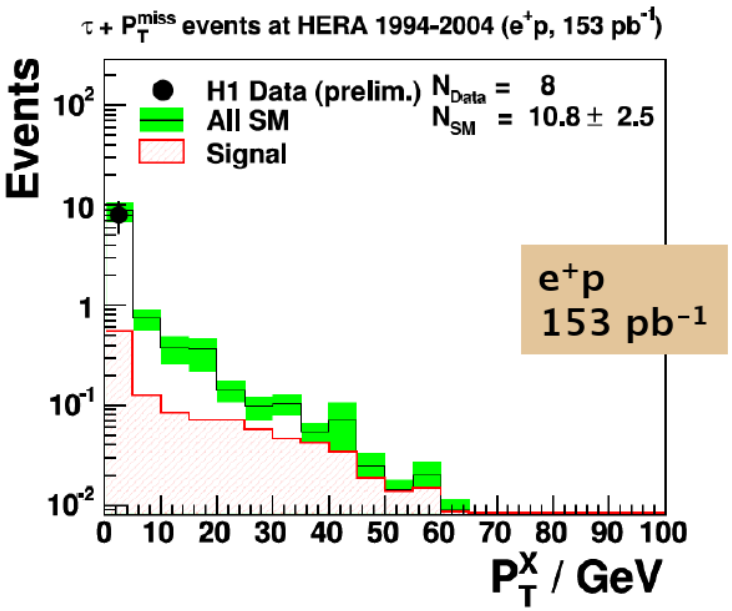
H1 e$^{\pm}$p data HERA I+II (279 pb^{-1})	e channel obs. / exp. (signal)	μ channel obs. / exp. (signal)	e and μ channels obs. / exp. (signal)
Full sample	30 / 27.2 ± 3.8 (68%)	10 / 7.2 ± 1.1 (81%)	40 / 34.3 ± 4.8 (71%)
P_T^X > 25 GeV	11 / 4.7 ± 0.9 (69%)	6 / 4.3 ± 0.7 (78%)	17 / 9.0 ± 1.5 (73%)

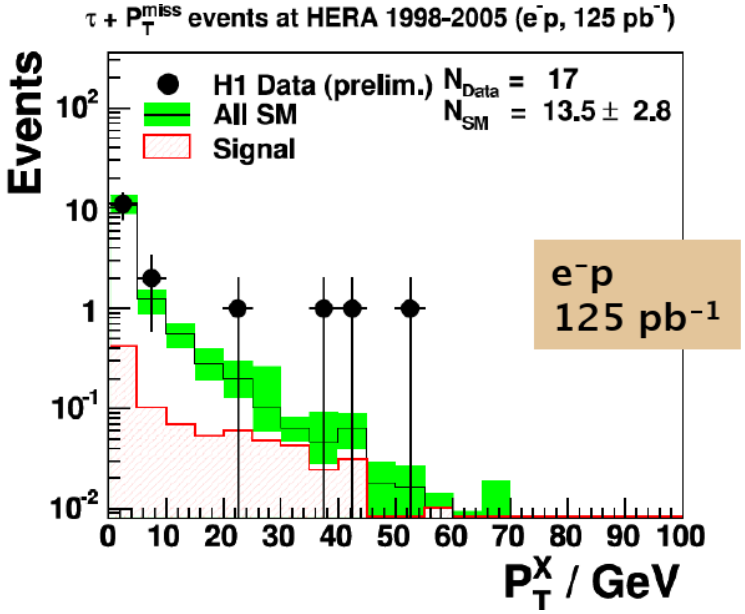
Isolated e candidates	$12 < P_T^X < 25$ GeV	$P_T^X > 25$ GeV
ZEUS (prel.) 98-05 $e^- p$ (143 pb^{-1})	$4/1.98 \pm 0.36(58\%)$	$3/2.86 \pm 0.46(53\%)$
ZEUS (prel.) 99-04 $e^+ p$ (106 pb^{-1})	$1/1.50 \pm 0.15(59\%)$	$1/1.50^{+0.12}_{-0.13}(78\%)$
ZEUS (prel.) 98-05 $e^\pm p$ (249 pb^{-1})	$5/3.5 \pm 0.4(58\%)$	$4/4.4 \pm 0.5(61\%)$
H1 (prel.) 1994-2005 $e^\pm p$ (279 pb^{-1})	-	$11/4.7 \pm 0.9(69\%)$



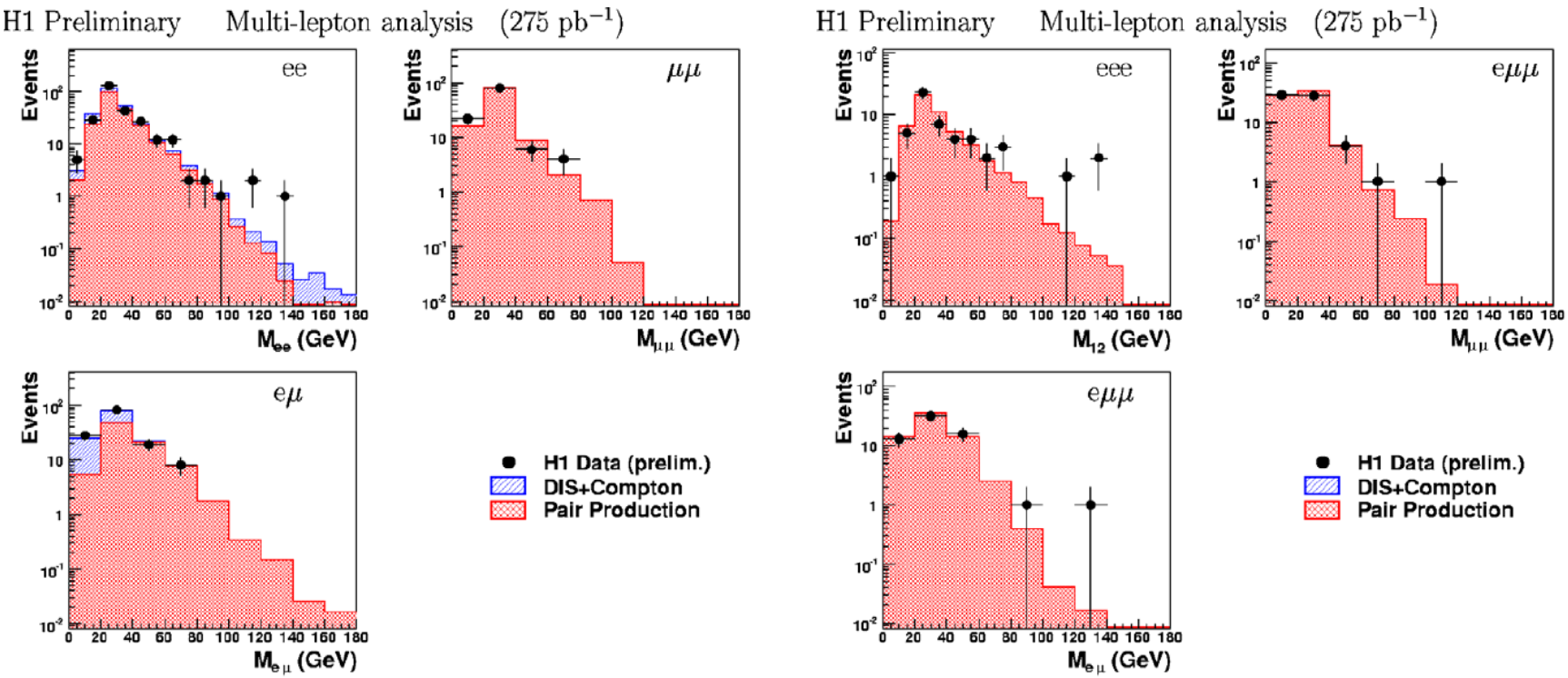


Isolated μ candidates	$12 < p_T^X < 25$ GeV	$p_T^X > 25$ GeV
ZEUS (prel.) 04-05 $e^- p$ (126 pb^{-1})	2/1.4 ± 0.2 (68%)	2/1.4 ± 0.2 (86%)





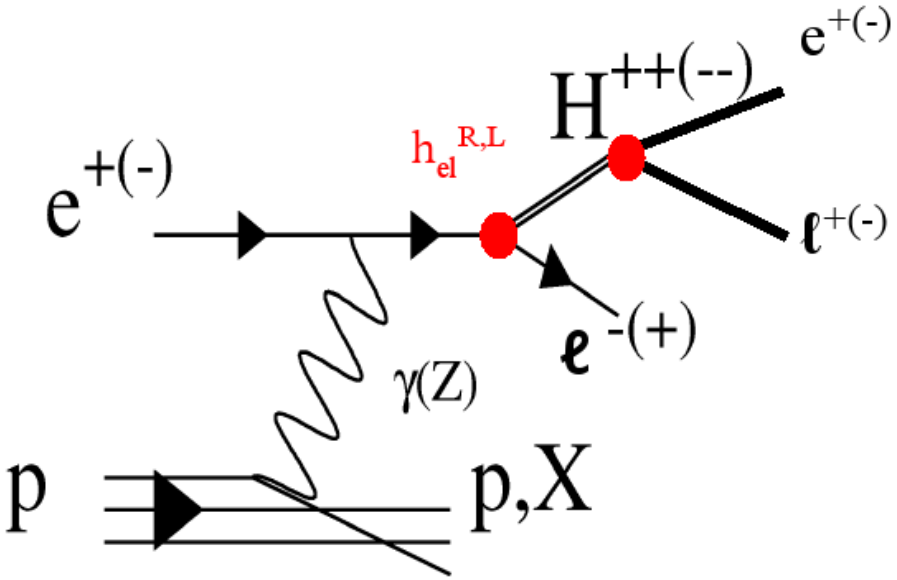
H1 Preliminary		H1 Data	Total SM expectation	SM signal (W)	Other SM Processes
94–04 e^+p 153 pb^{-1}	Total	8	10.6 ± 2.9	1.1 ± 0.23	9.5 ± 2.9
	P_T^X>25 GeV	0	0.40 ± 0.10	0.24 ± 0.05	0.15 ± 0.09
98–05 e^-p 125 pb^{-1}	Total	17	13.5 ± 2.6	0.9 ± 0.15	12.6 ± 2.6
	P_T^X>25 GeV	3	0.35 ± 0.09	0.19 ± 0.03	0.16 ± 0.09



in *ee* channel, for $M_{12} > 100$ GeV $3/0.44 \pm 0.10$ events observed

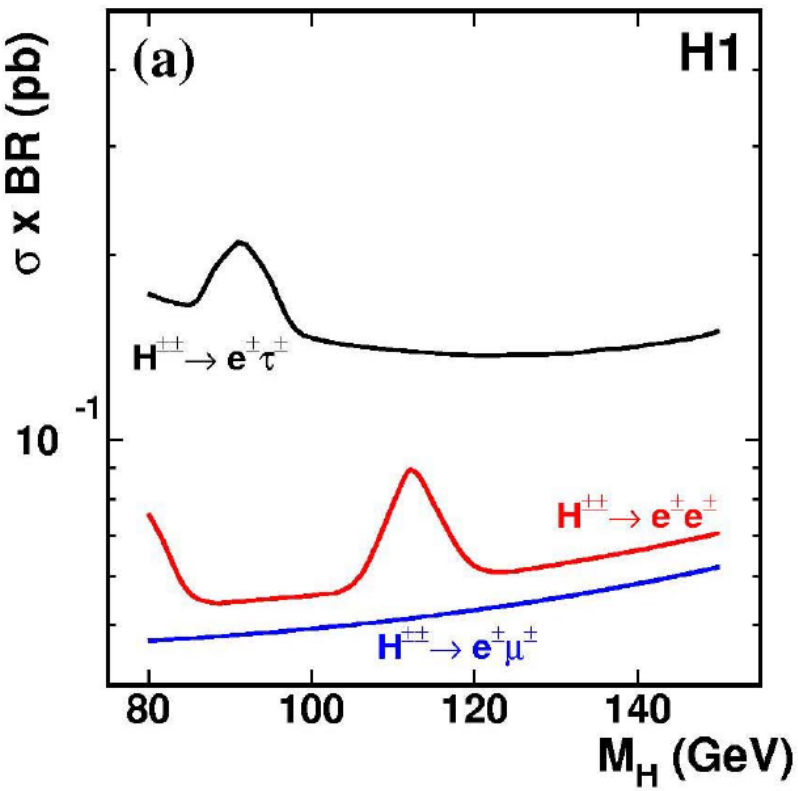
in *eee* channel, for $M_{12} > 100$ GeV $3/0.29 \pm 0.06$ events observed

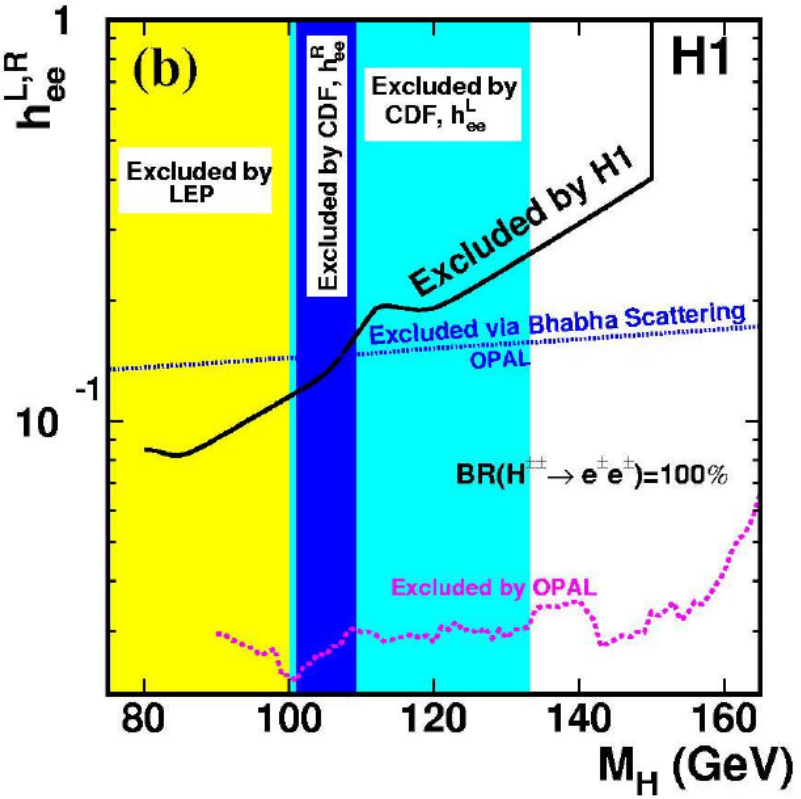
no significant excess in other channels



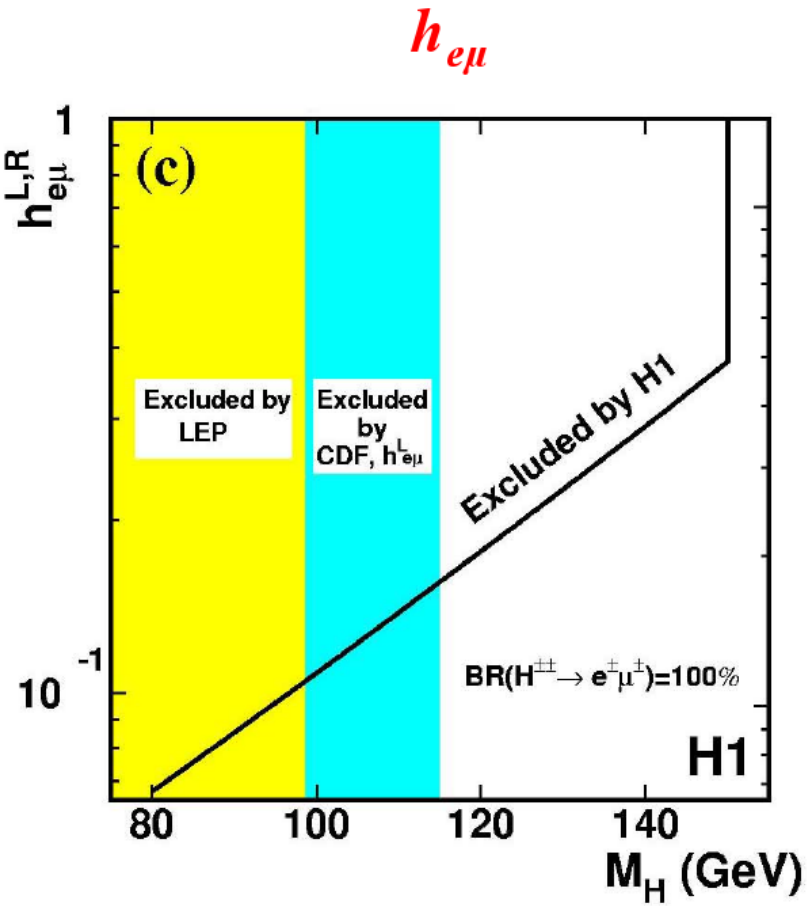
Look for ee,$e\mu$ or $e\tau$ pairs of high -P_T leptons with like charge.
For $M_{el} > 65$ GeV':

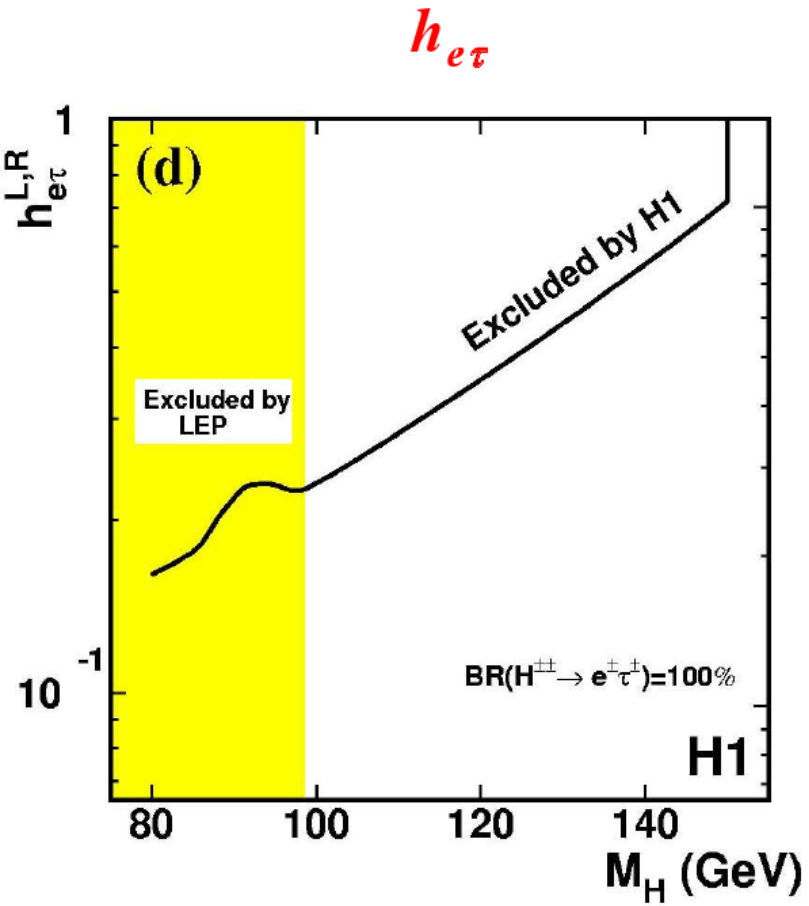
- $3/2.45 \pm 0.11$ ee candidates
- $1/4.17 \pm 0.44$ $e\mu$ candidates
- $1/2.07 \pm 0.54$ $e\tau$ candidates





Confirms that excess is unlikely to come from H^{++}

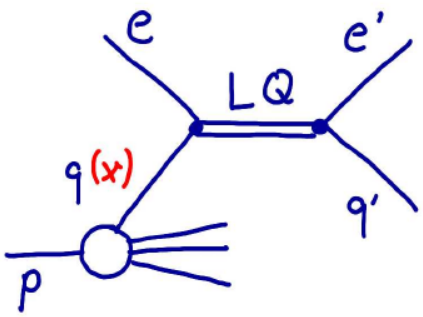


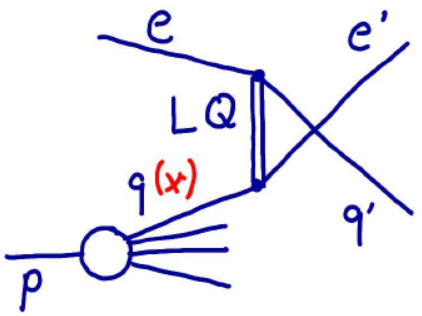


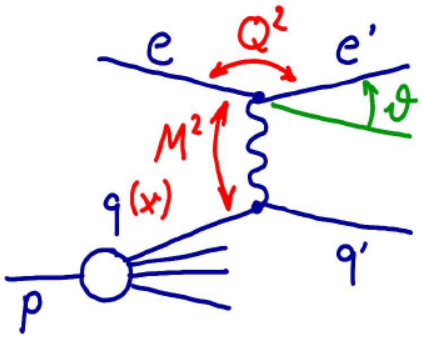
H1 limits extend the excluded regions

- New limits on parameter space of many BSM models have been set by the HERA experiments
- Intriguing excesses over the Standard Model remain in high P_T lepton searches
- In many cases H1 and ZEUS provide the world's best limits
- With new data still coming in at a faster rate than ever, HERA experiments can explore many regions of physics beyond the Standard Model

Leptoquarks I

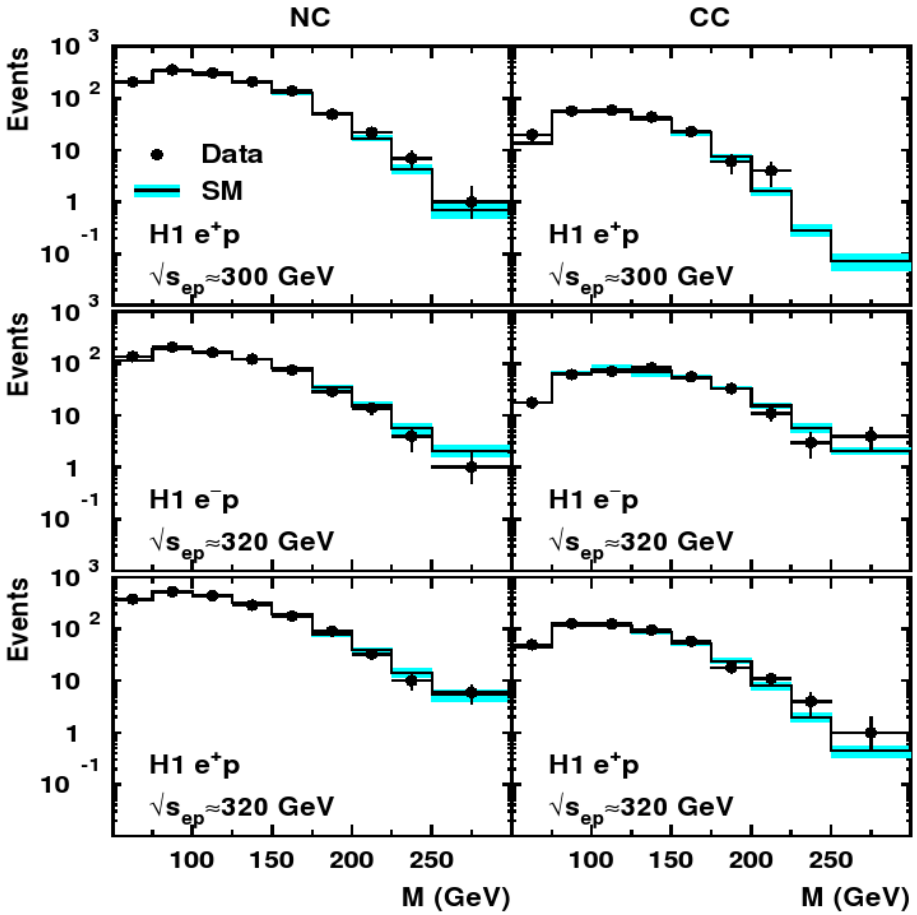




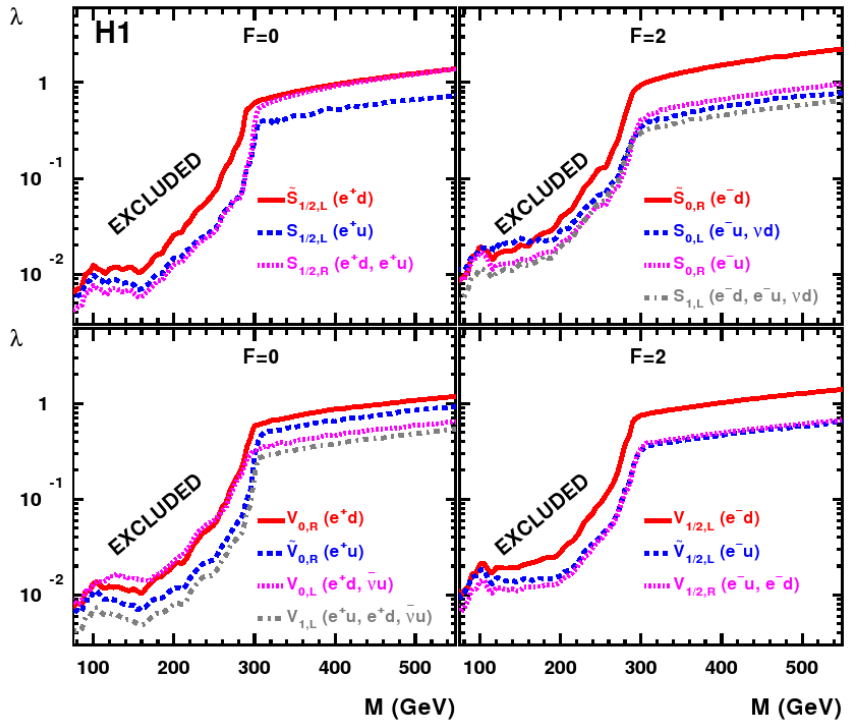


- Leptoquarks appear in many SM extensions e;g; compositeness, technicolour
- Connect Lepton and Quark sectors
- Scalar or Vector colour triplet bosons
- Carry both L & B, have fractional EM charge
- Classified by Buchmüller, Ruckl and Wyler according to their quantum numbers
  - LQs couple only to SM fermions and bosons
  - pure chiral couplings
  - family diagonal couplings
- HERA can produce Leptoquarks resonantly in s-channel
- signature one jet, one e/ν

Leptoquarks II



$37\ \mathrm{pb}^{-1}$ (e^+p, $\sqrt{s} \approx 300$ GeV)
$15\ \mathrm{pb}^{-1}$ (e^-p, $\sqrt{s} \approx 320$ GeV)
$65\ \mathrm{pb}^{-1}$ (e^+p, $\sqrt{s} \approx 320$ GeV)



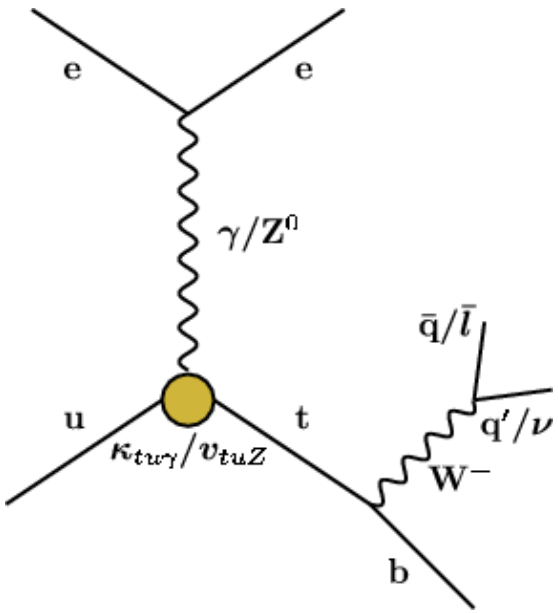
- hep-ex/0506044
- No sign of Leptoquarks - limits on 14 types of LQ set
- new e^-p data can improve F=2 limits significantly

Back up slides follow

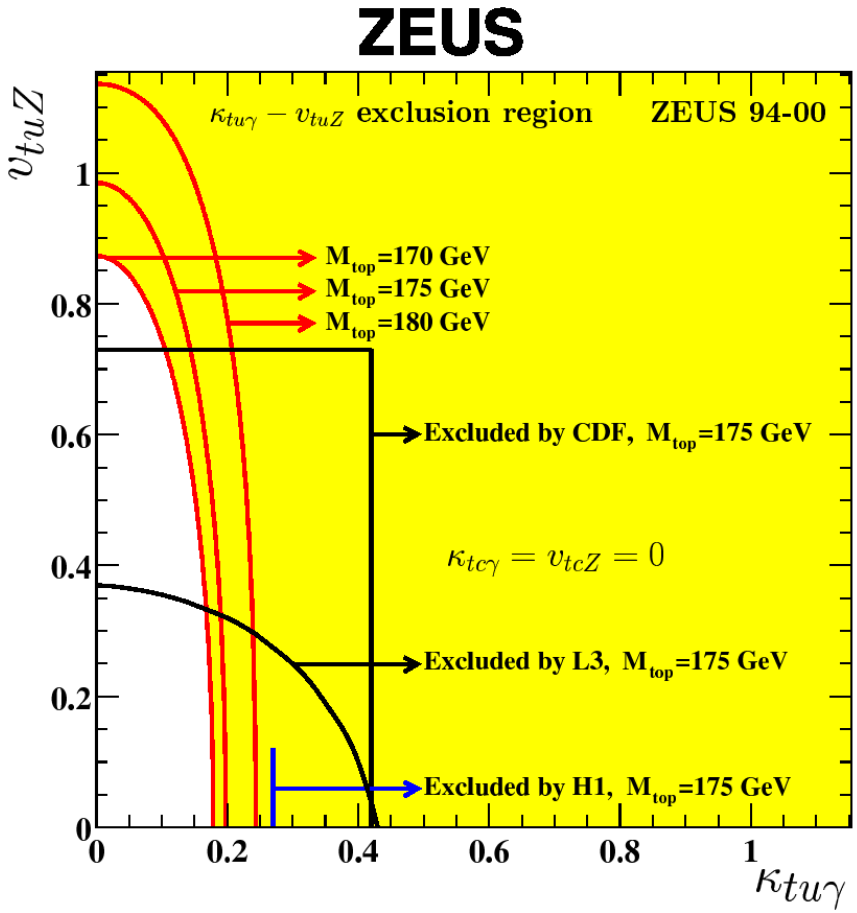
- Perform linear least squares fit to σ vs. $1 - \mathcal{P}$ with stat. errors
  - Intersect from fit gives central value for σ_{RH} and the error on the intersect from the fit gives statistical error
- Perform systematic checks:
  - Shift unpolarised point up & down by syst. error and re-fit
  - Shift polarised points up & down together (correlated) by syst. and lumi. errors
  - shift polarised points up & down together by their error on $|\mathcal{P}|$ (anti-correlated to $\mathcal{P}$)
- add in quadrature for syst. error
- Find 95% limit
- Use HECTOR to change M_W on propagator and convert limit on σ_{RH} to limit on $M(W_{RH})$

Sensitivity to Isolated Leptons

BSM candidate for excess of high P_T isolated leptons at large P_T^X is single top production via anomalous FCNC



LEP and TeVatron are sensitive to these couplings too



H1 excess compatible with FCNC limits from L3 & CDF