Katarzyna Wichmann
on behalf of
the H1 and ZEUS Collaboration

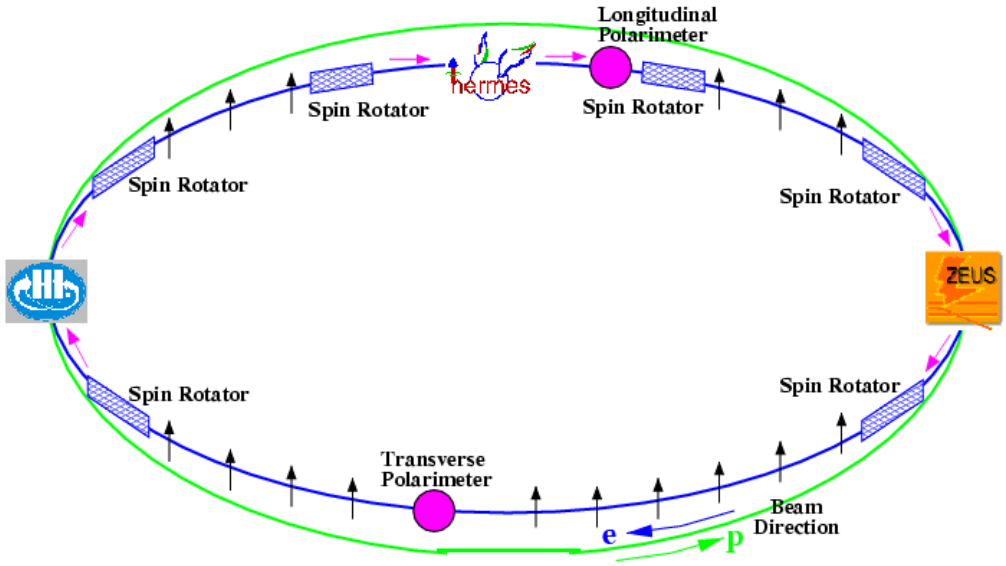
Searches at HERA

PHOTON2013

HERA Accelerator

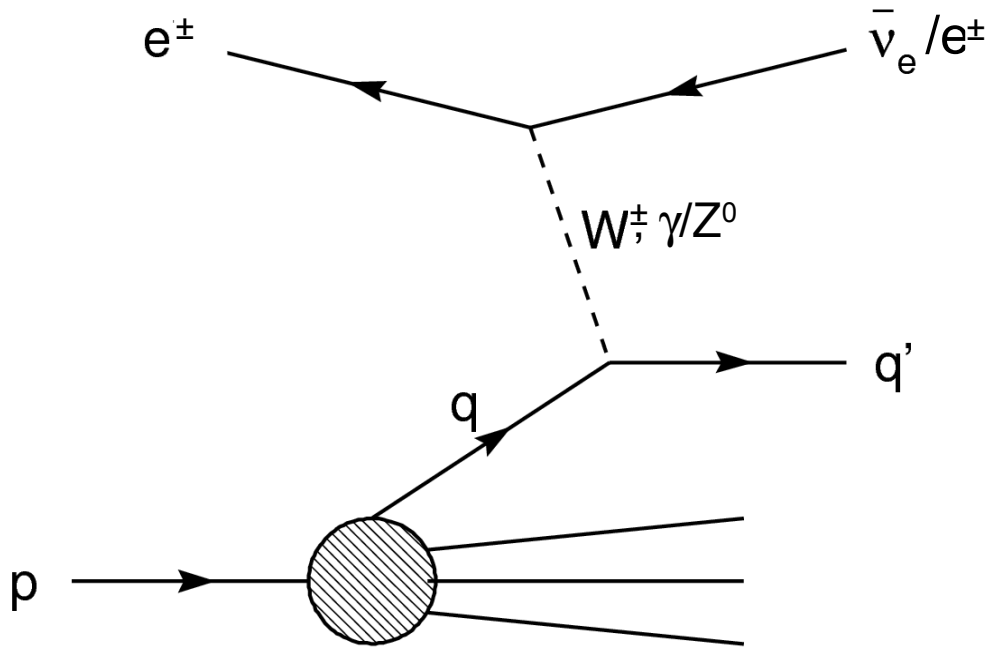
Polarization @ HERA

- From 2003 polarized lepton beam
  - Positive and negative helicities possible
  - Polarization of ~30-55% achieved
- 2 colliding-beam experiments: H1 & ZEUS



Collected 0.5 fb^{-1}/exp of luminosity
Final results on BSM searches

Deep Inelastic Scattering @ HERA



- Neutral Current (NC):

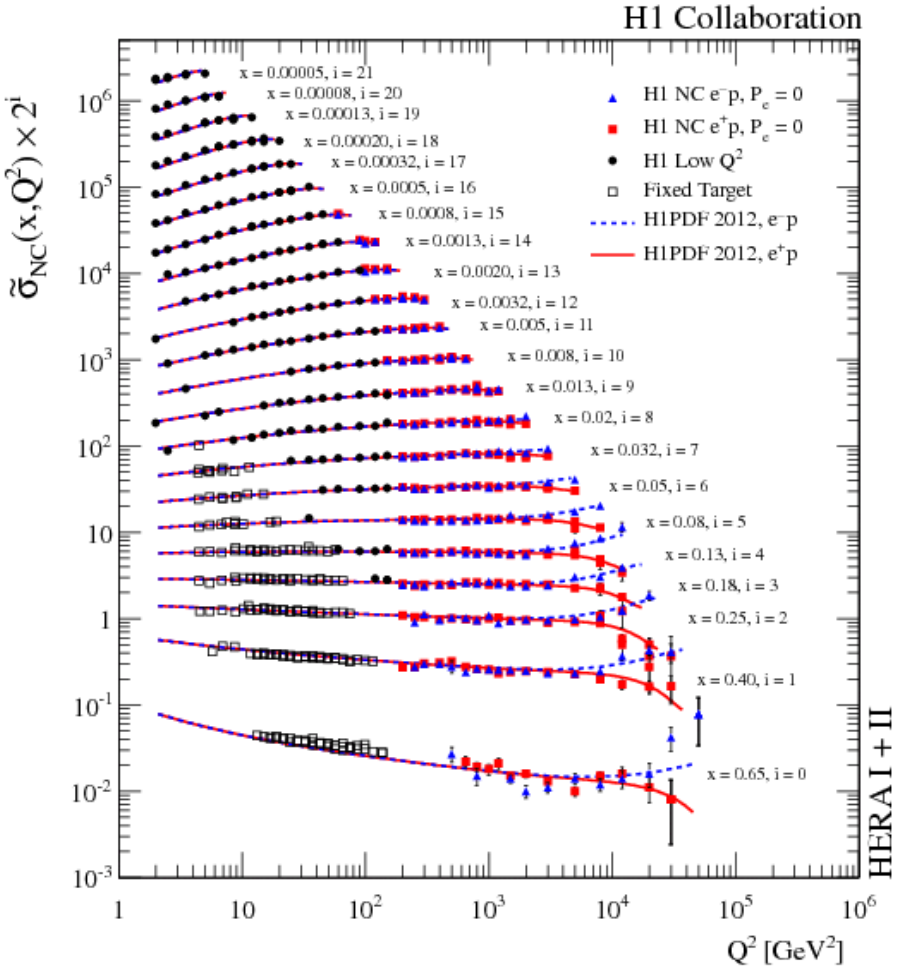
  γ, Z^0 exchange

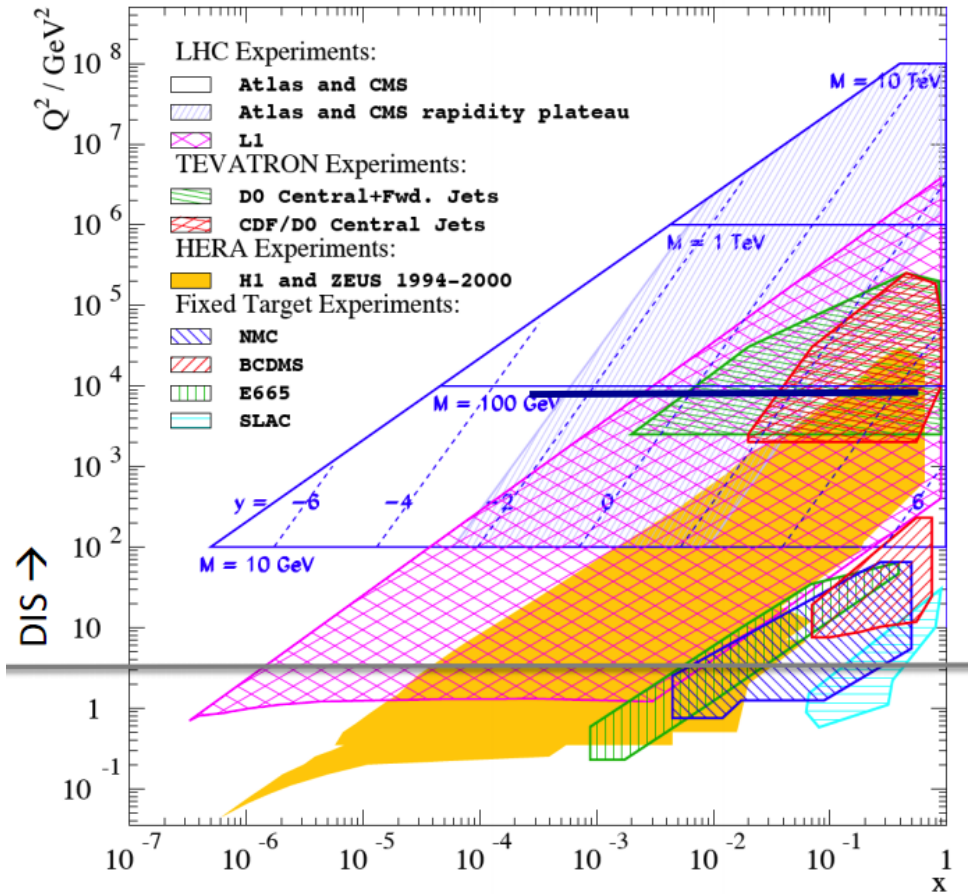
- Charged Current (CC):

  $W^{\pm}$ exchange

HERA High-Precision DIS Data

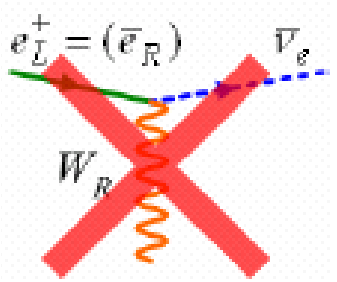
- Precise data, final results from both experiments
- Wide kinematic plane, intersecting with Tevatron and LHC
- Explored for final results on searches for physics BSM

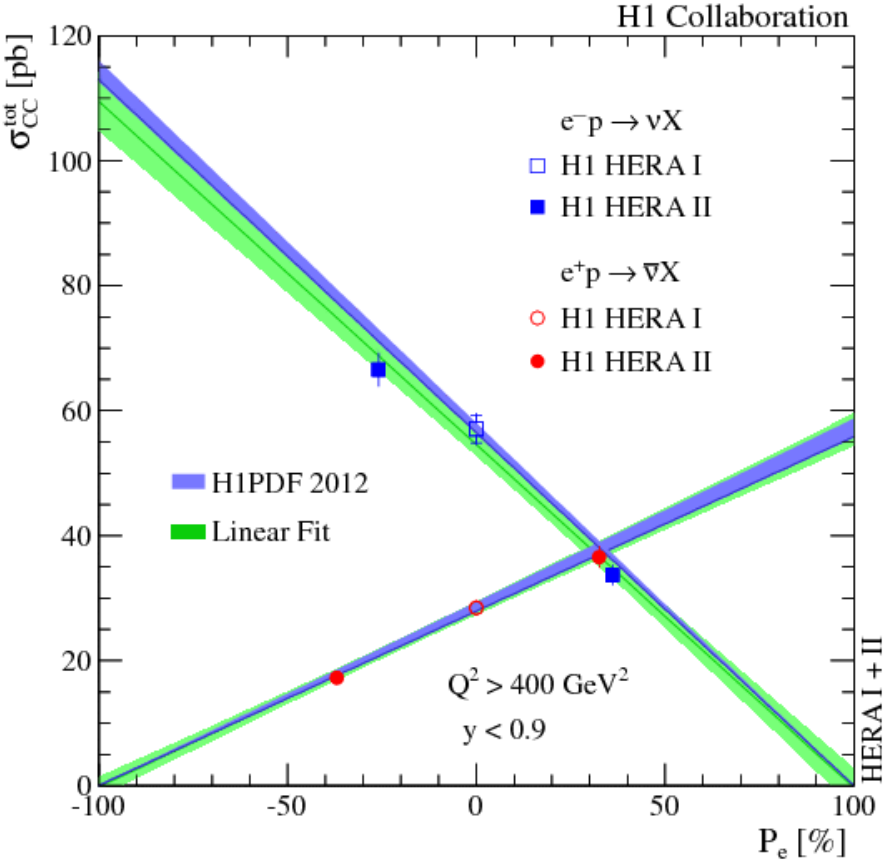




Limits on right-handed W

SM CC: $$\frac{\mathrm{d}^2\sigma^{\pm}_{CC}(P_e)}{\mathrm{d}x\mathrm{d}Q^2} = (1 \pm P_e)\frac{\mathrm{d}^2\sigma^{\pm}_{CC}}{\mathrm{d}x\mathrm{d}Q^2}$$



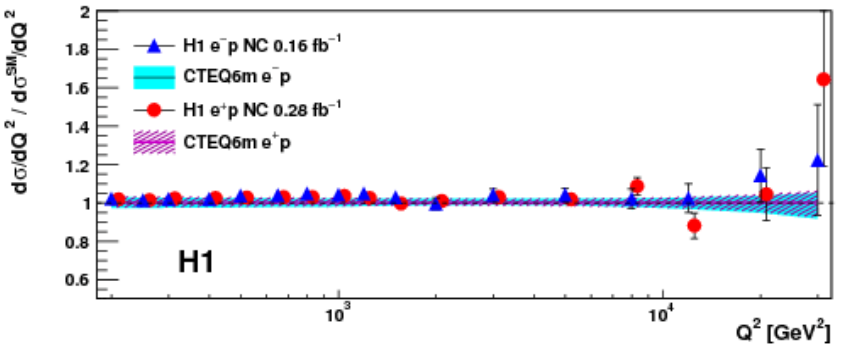


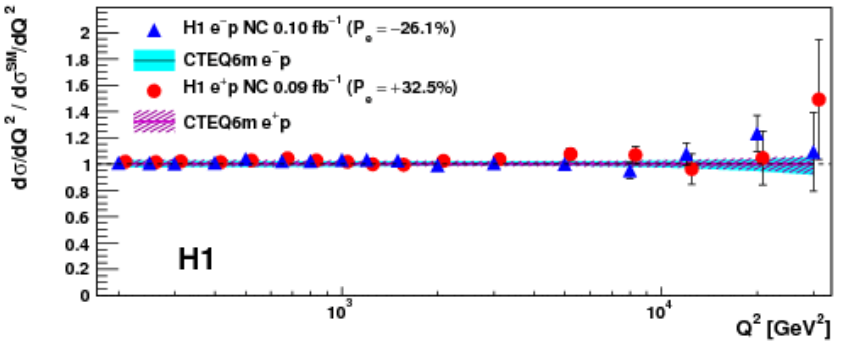
- H1 limits on right-handed charged currents:

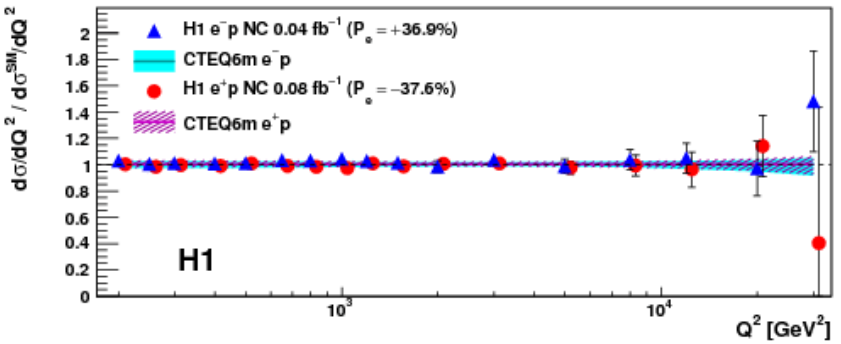
$$M_W^R < 214GeV \quad e^-p$$
$$< 194GeV \quad e^+p$$

$$\sigma^{\mathrm{tot}}_{\mathrm{CC}}(P_e = +1, e^-p) = -1.3 \pm 2.4_{\mathrm{exp}} \pm 1.5_{\mathrm{lumi}} \pm 1.2_{\mathrm{pol}}\,\mathrm{pb}$$
$$\sigma^{\mathrm{tot}}_{\mathrm{CC}}(P_e = -1, e^+p) = -0.5 \pm 1.3_{\mathrm{exp}} \pm 0.7_{\mathrm{lumi}} \pm 0.4_{\mathrm{pol}}\,\mathrm{pb}$$

Contact Interactions

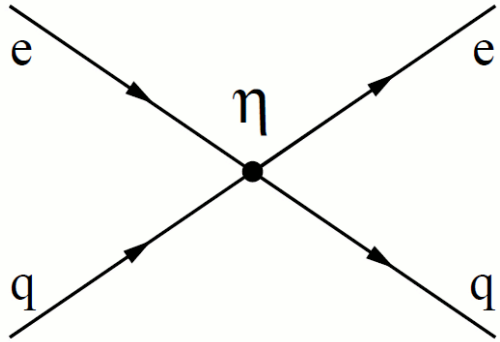






No deviation from SM found – limits set

- $\sqrt{s}$ much smaller than new physics scale Λ



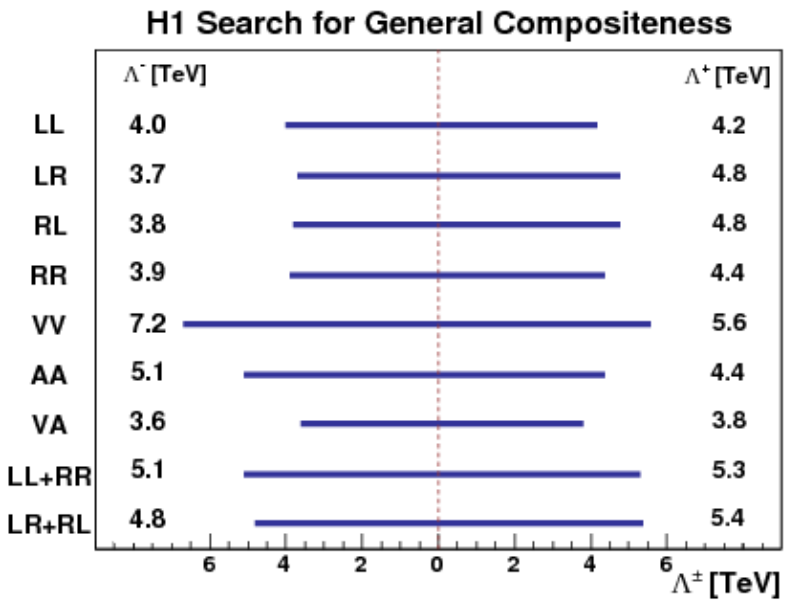
$eeqq$ contact interactions (CI)

- Effective Lagrangian for vector eeqq CI

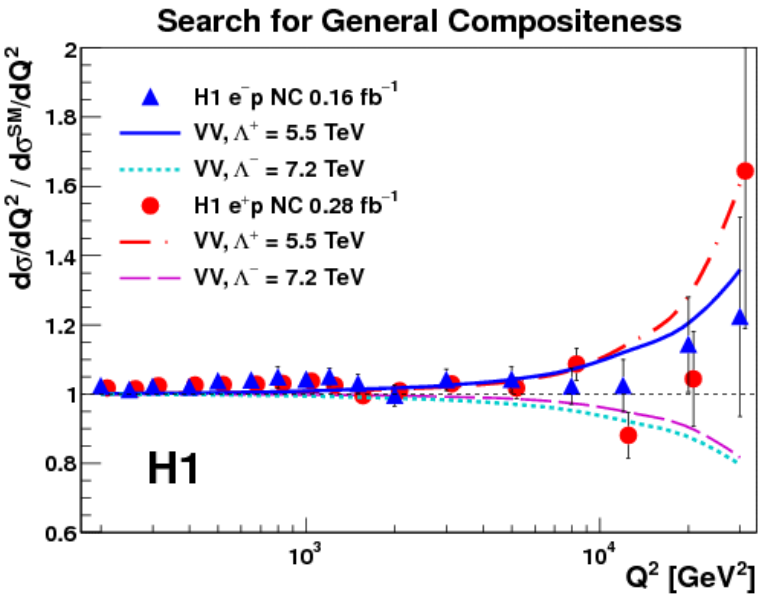
$$\mathcal{L}_{CI} = \sum_{\substack{\alpha,\beta=L,R \\ q}} \eta^{eq}_{\alpha\beta} \cdot (\bar{e}_\alpha \gamma^\mu e_\alpha)(\bar{q}_\beta \gamma_\mu q_\beta)$$

$\eta^{eq}_{\alpha\beta}$ - 4 possible couplings for every flavor

CI: Compositeness scale



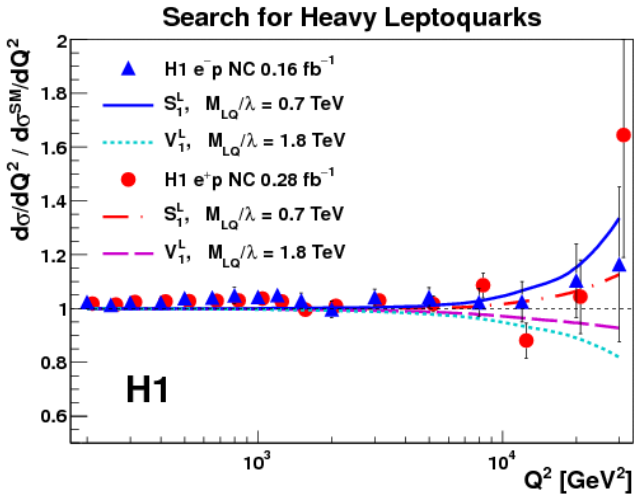
$$\eta_{ij}^{eq} = \pm \frac{4\pi}{\Lambda^2}$$



- Limits on compositeness scale in general CI model
  - Depend on chiral structure

Λ > 3.6 – 7.2 TeV @ 95% CL

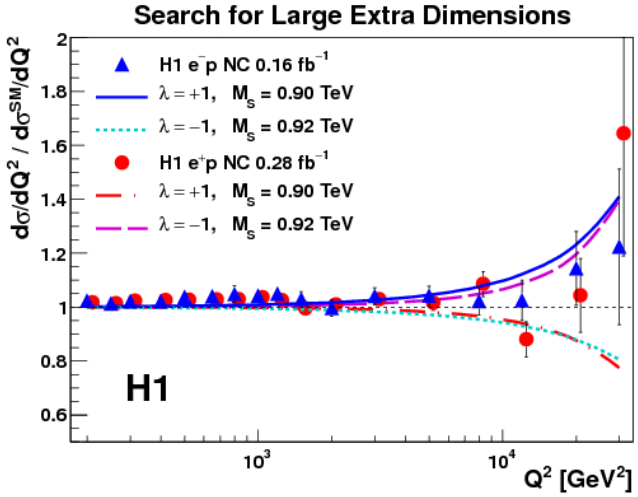
Contact Interactions limits



$$\eta_{ij}^{eq} = a_{ij}^{eq}\left(\frac{\lambda_{LQ}}{M_{LQ}}\right)^2$$

- Heavy Leptoquarks

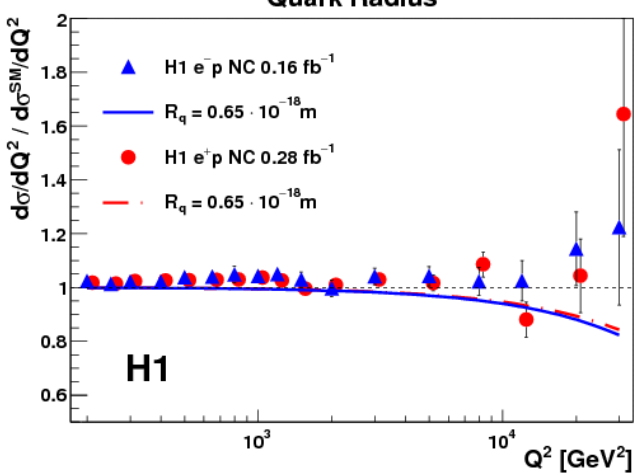
M_{LQ}/λ > 0.41 – 1.86 TeV



$$\eta_G = \frac{\lambda}{M_S^4}$$

- Large Extra Dimensions

M_S > 0.9 TeV



- Quark radius

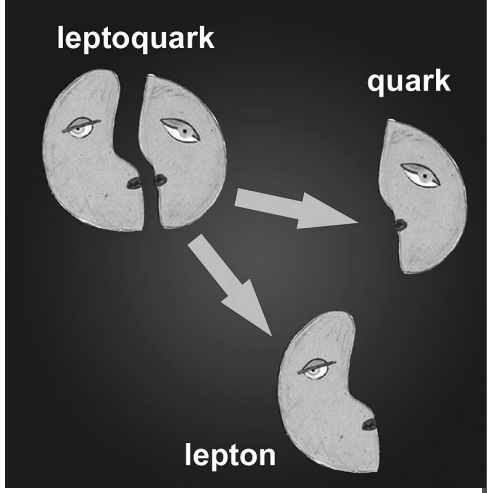
R_q < 0.65 x 10^{-18} m

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

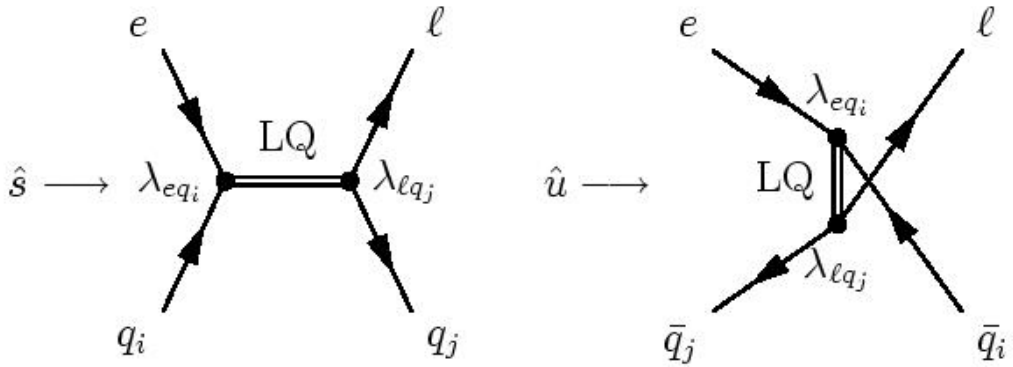
electron point-like

Limit below 1/1000 of proton radius

Leptoquarks @ HERA



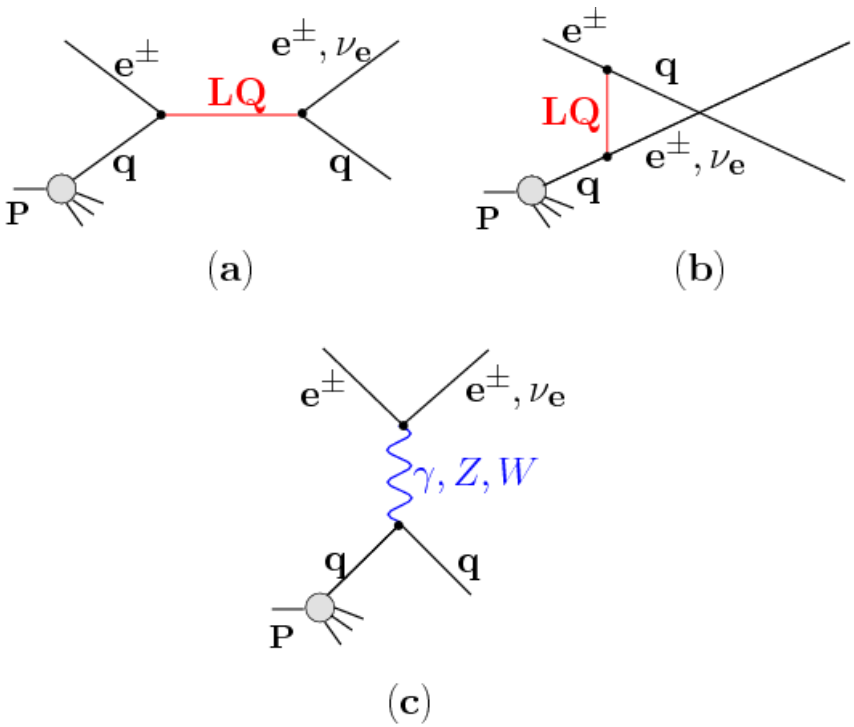
- Leptoquarks - scalar or vector colour triplet bosons, carrying both lepton (L) and baryon (B) number
  - HERA is well suited for leptoquark searches
  - Fermion number: F=L+3B, (F=0,2)
  - Spin: 0, 1
- Leptoquarks @ HERA
  - produced in s-channel for $M_{LQ} < \sqrt{s}$
  - exchanged in u-channel



1st generation: eq → LQ → e(υ)q
2nd generation: eq → LQ → e(υ)q
3rd generation: eq → LQ → e(υ)q
LFV

1st generation Leptoquarks @ HERA

- LQs @ HERA have the same initial & final state as NC/CC DIS
  - e-jet or υ-jet in the final state
    → interfere with the SM

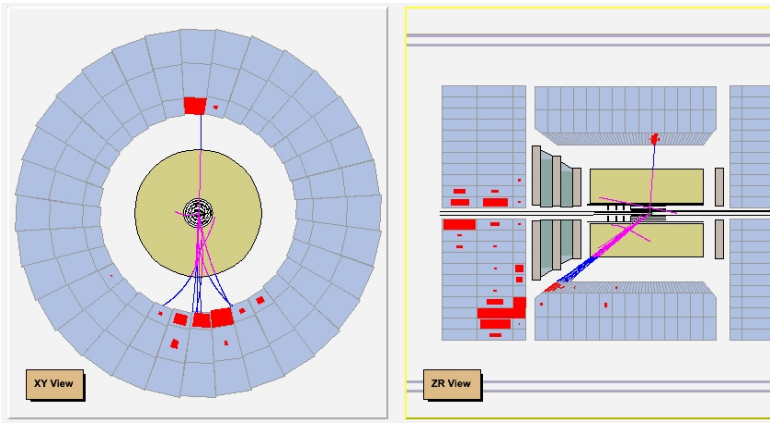


- LQs – chiral particles

→ gain at sensitivity at HERAII due to polarized lepton beams
→ data samples with different polarization examined separately

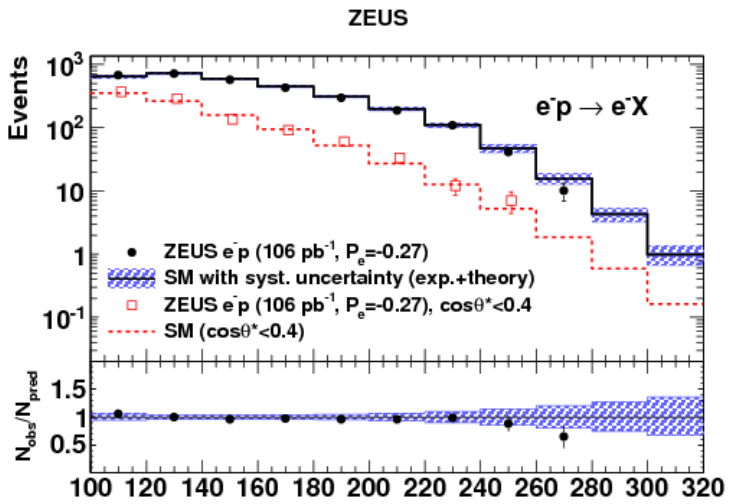
Look for LQ-deviations from SM in NC & CC distributions

Search strategy

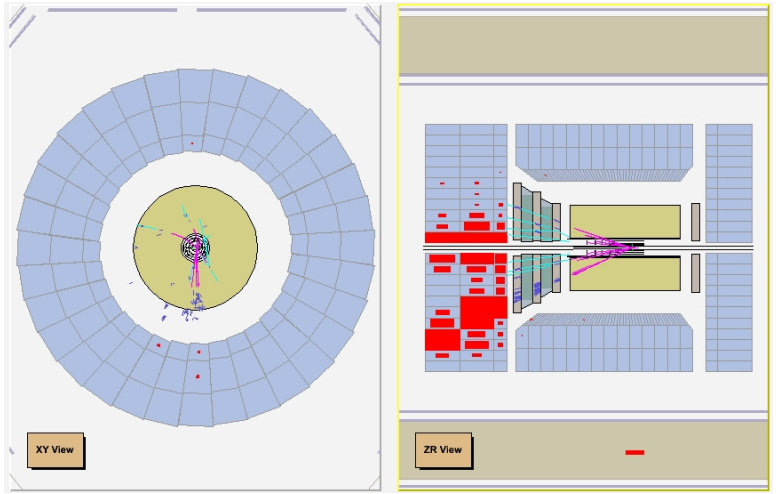


$M_{e\text{-jet}}$

e+jet final state

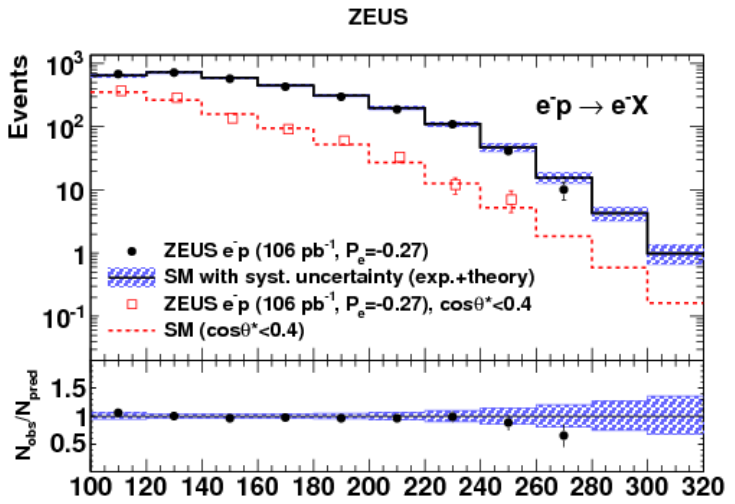


M_{ejs} (GeV)



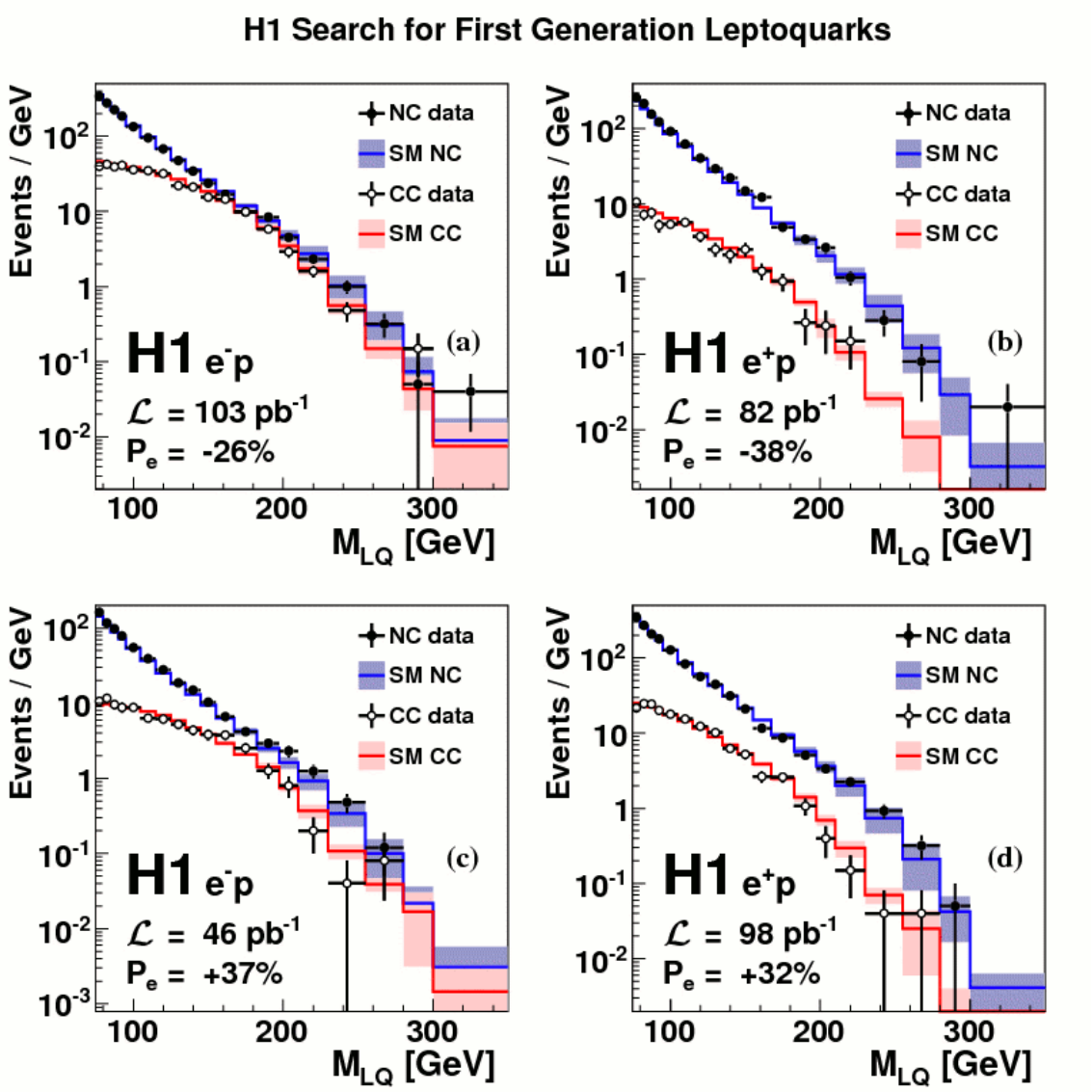
$M_{\upsilon\text{-jet}}$

υ+jet final state



$M_{\upsilon js}$ (GeV)

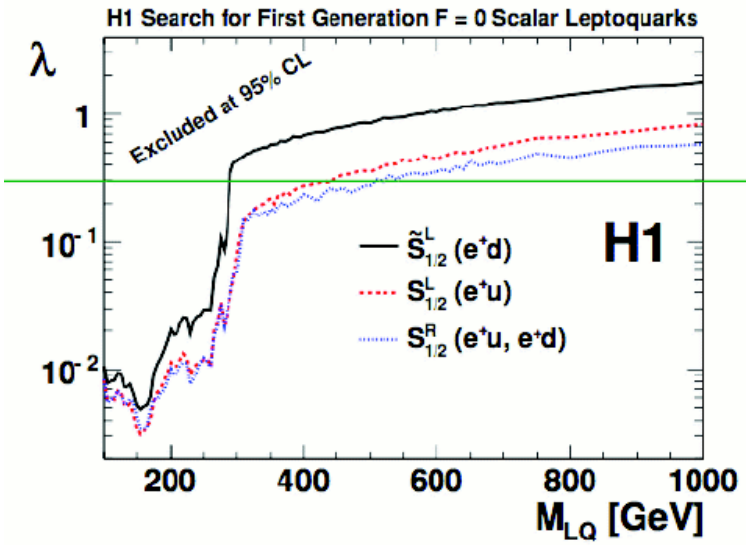
NC/CC Invariant Mass Distributions

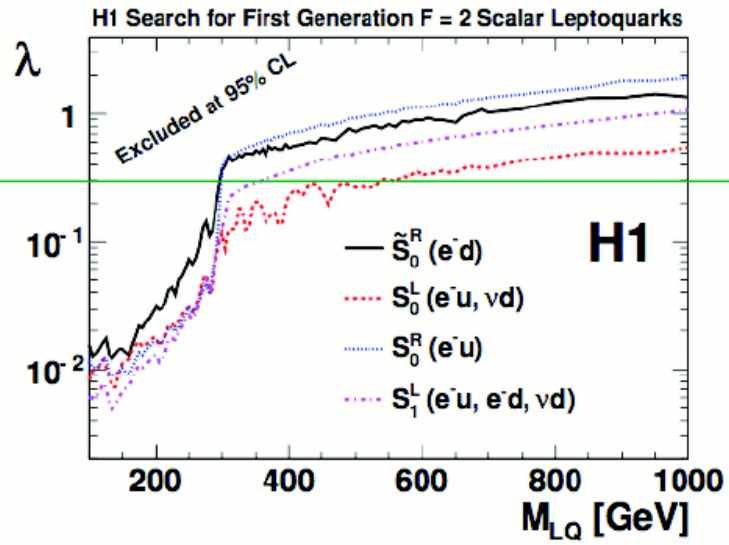


- Good agreement between data and MC → no evidence for LQs
- Limits set within BRW model
- 7 scalar and 7 vector 1st generation LQs

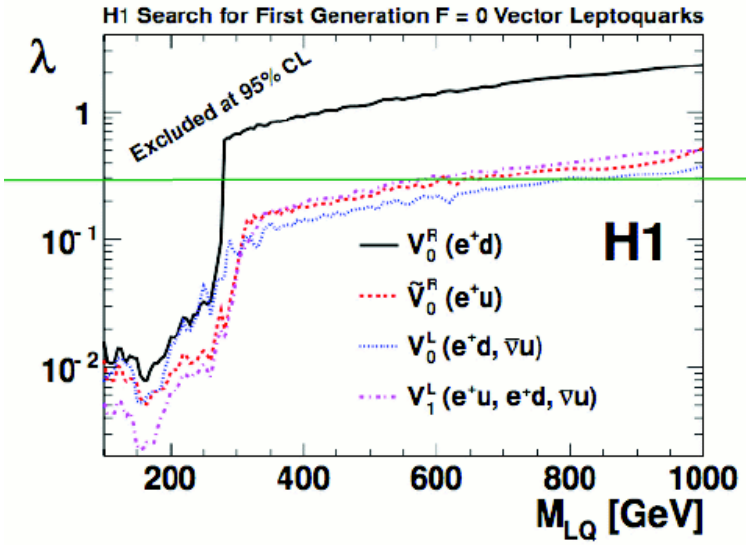
Full HERA statistics of 0.5 fb^{-1} used for limit setting

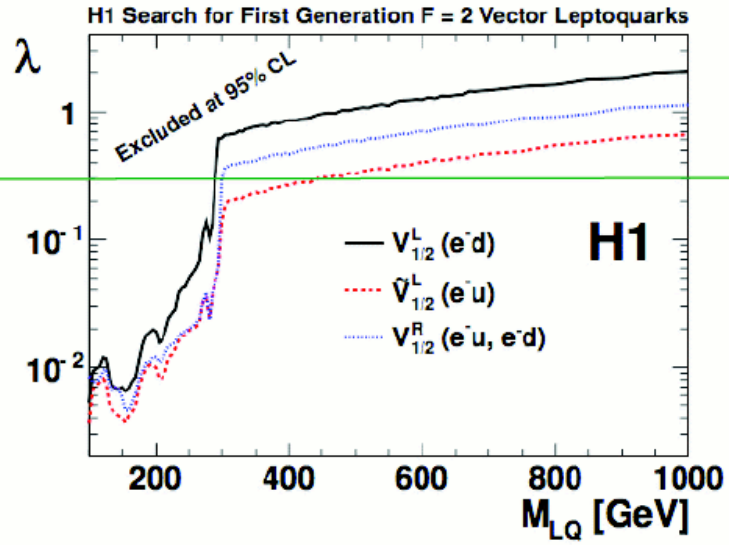
Limits for LQs from H1





λ = 0.3

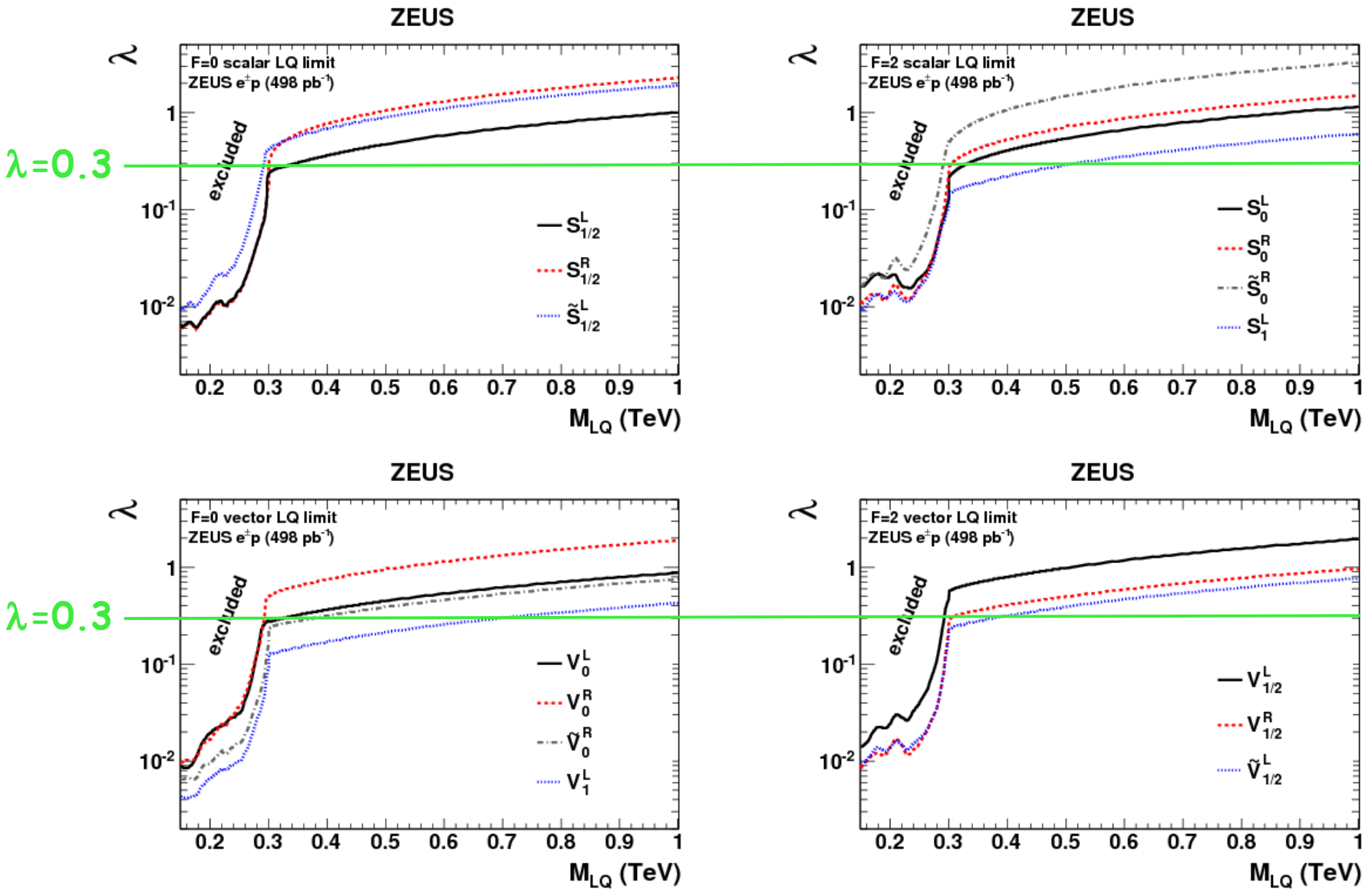




λ = 0.3

For λ = 0.3 LQ masses up to 800 GeV ruled out @ 95% CL

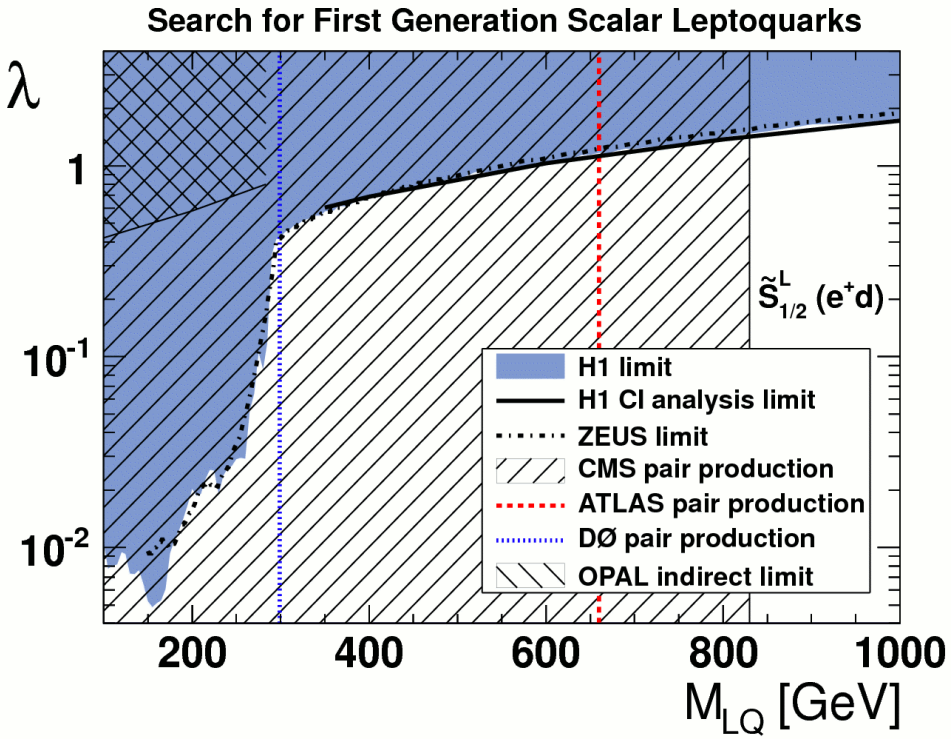
Limits for LQs from ZEUS

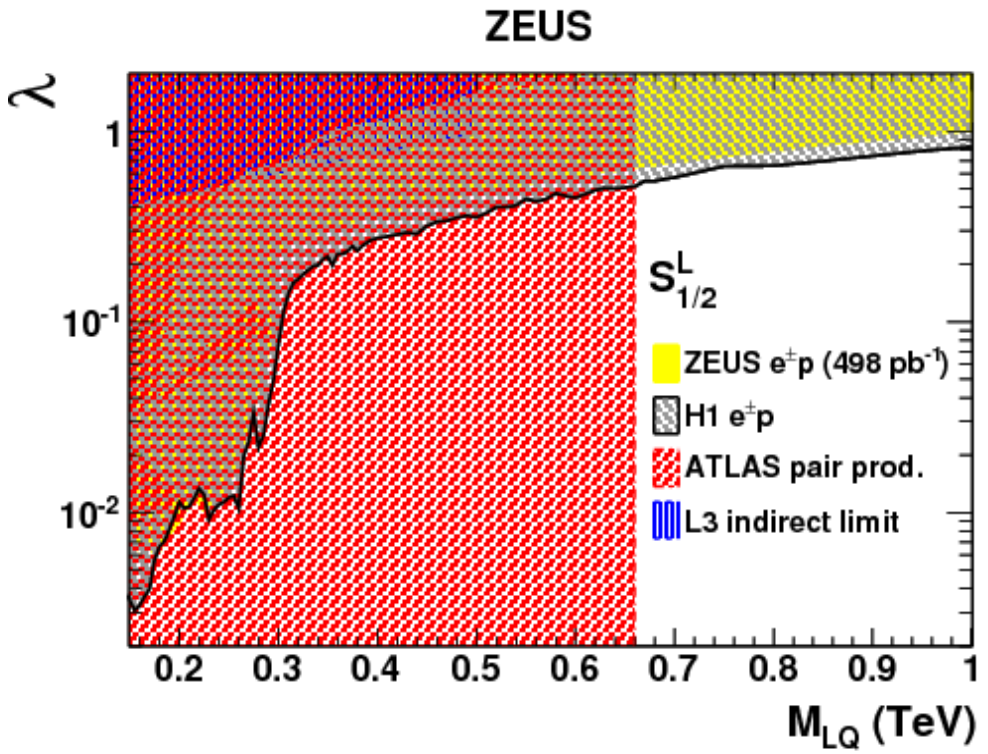


For λ = 0.3 LQ masses up to 700 GeV ruled out

Limits for LQs

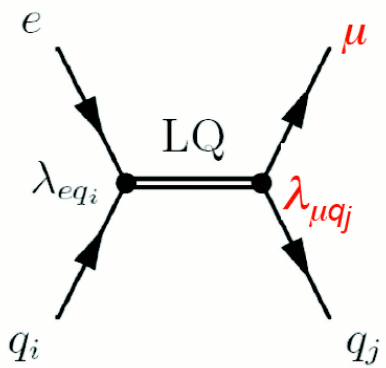
- New results from H1 & ZEUS using full HERA luminosity of 0.5 fb^{-1}
- No evidence of LQs seen → **various limits set as function of LQ mass**

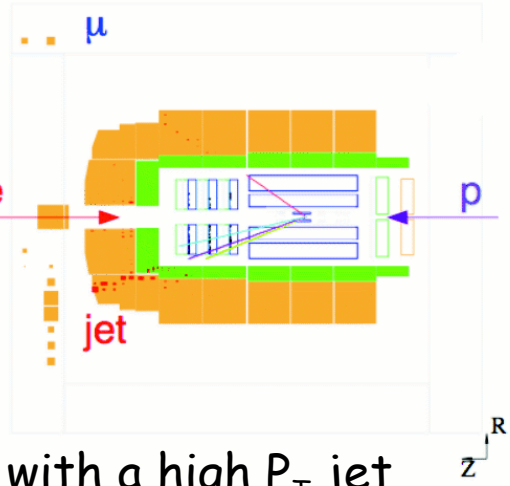


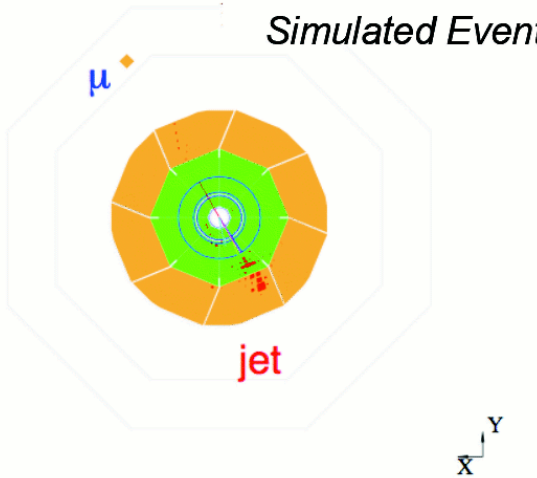


HERA limits are the best to date at high masses

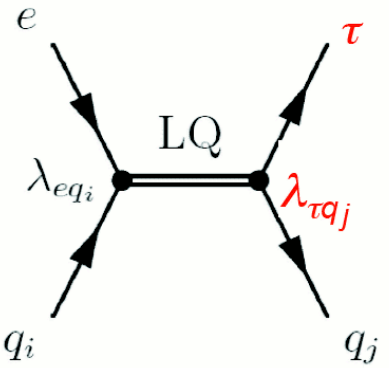
Lepton Flavor Violation

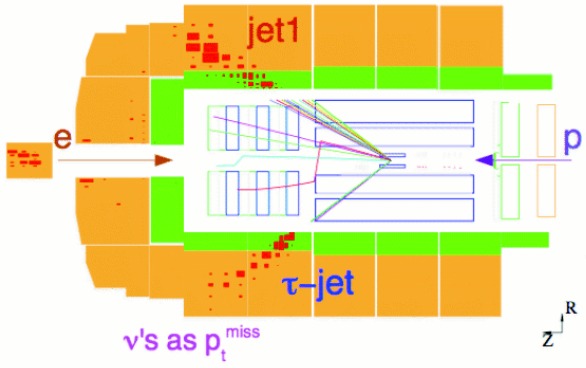


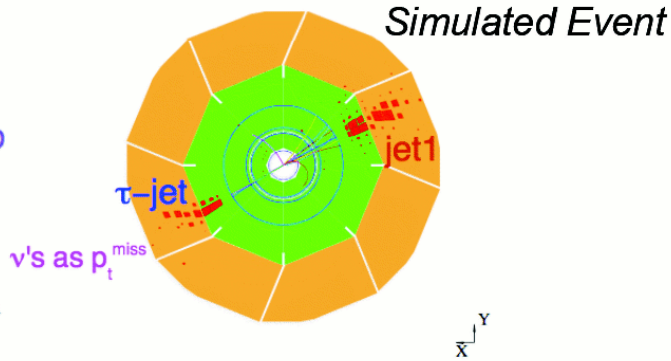




- High P_T muon back-to-back with a high P_T jet
- After all selection cuts: 1 event observed / 2.0 ± 0.4 from background processes

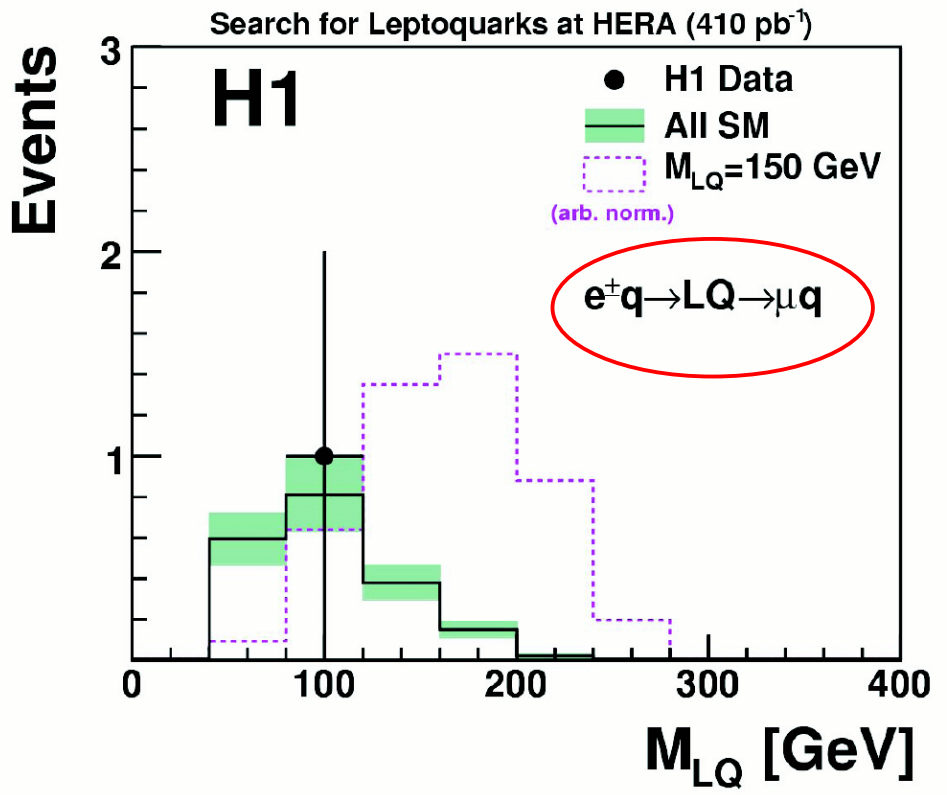


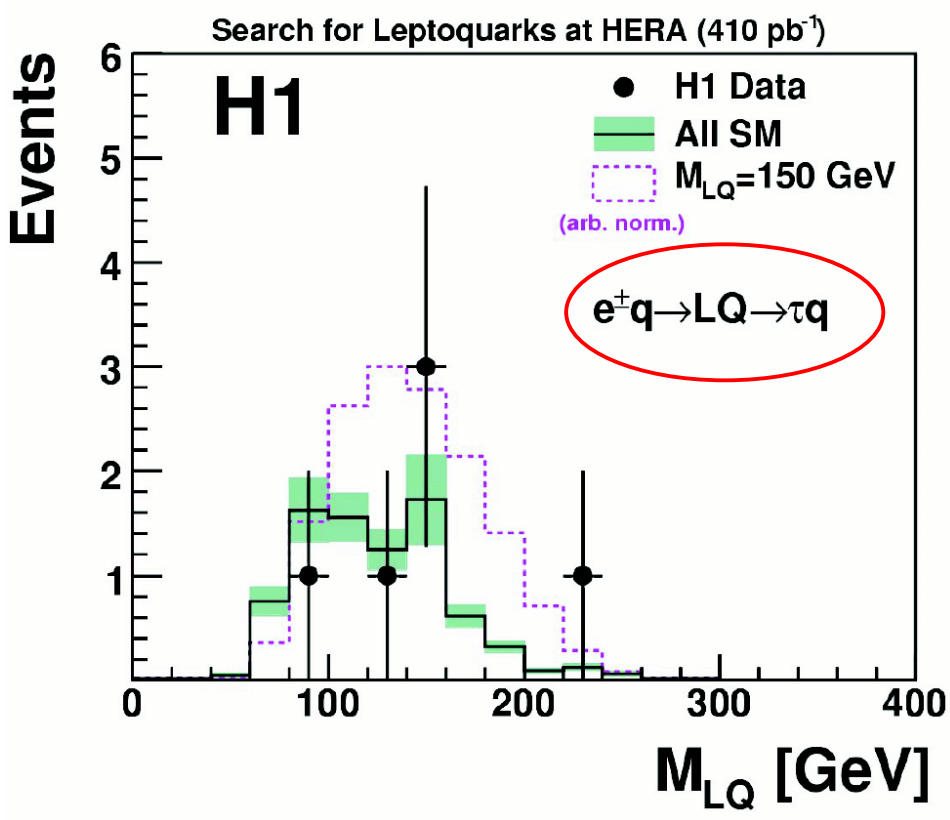




- Tau lepton with hadronic decay: search covers 1 prong decays, BR about 50%
  - Narrow, pencil-like jet with one track back-to-back with a hadronic jet
- After all selection cuts: 6 events observed / 8.2 ± 1.1 from background processes

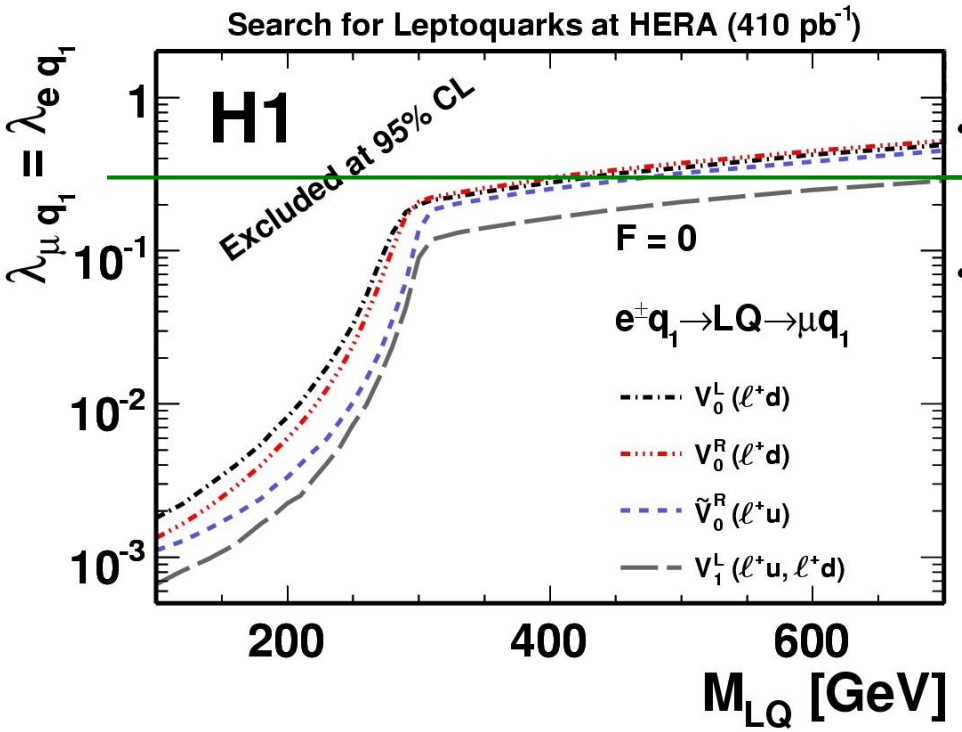
Lepton Flavor Violation

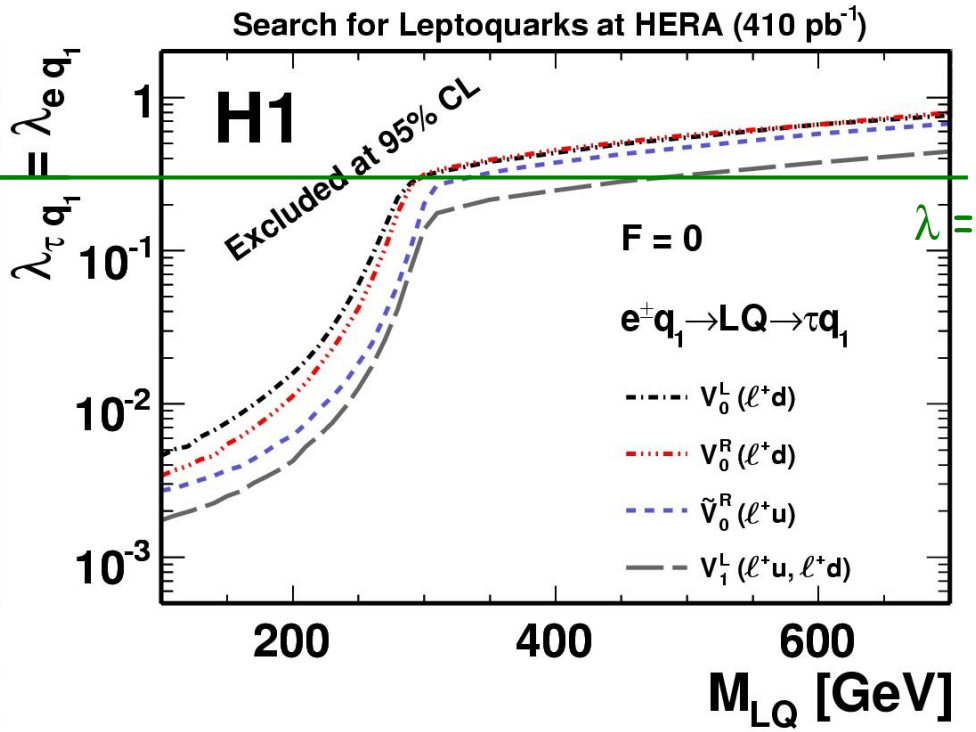




- No evidence for LQ signal: interpret results in terms of exclusion limits
- Third generation search <u>also includes</u> second generation search result in limits

Most stringent H1 limits





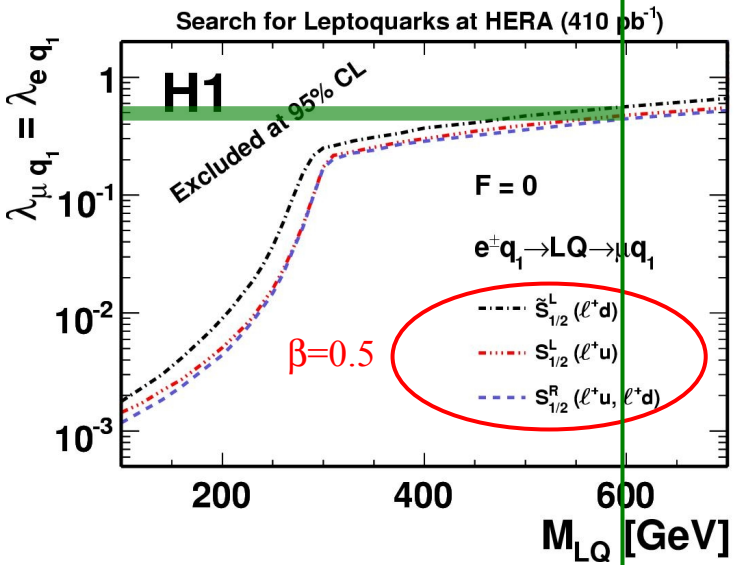
$\lambda = 0.3$

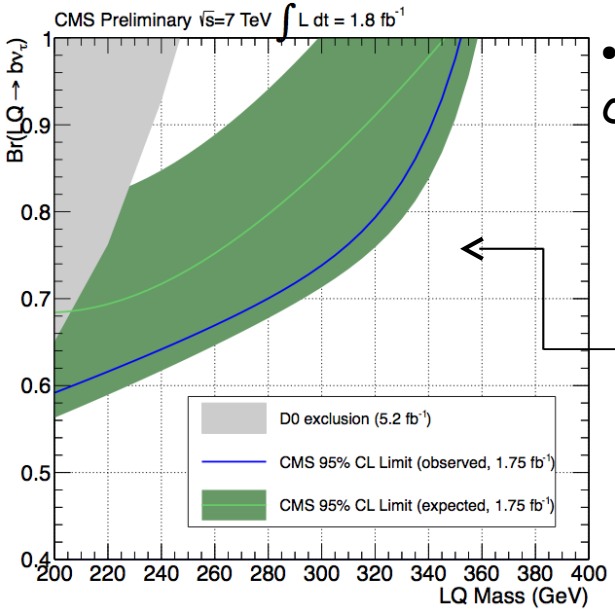
- V_1^L LQ has most stringent limits, sensitivity to both u and d quarks
- For a coupling of electromagnetic strength $\lambda = 0.3$ LQs mediating LFV via:

$eq \to LQ \to \mu q$ are ruled out up to 712 GeV
$eq \to LQ \to \tau q$ are ruled out up to 479 GeV

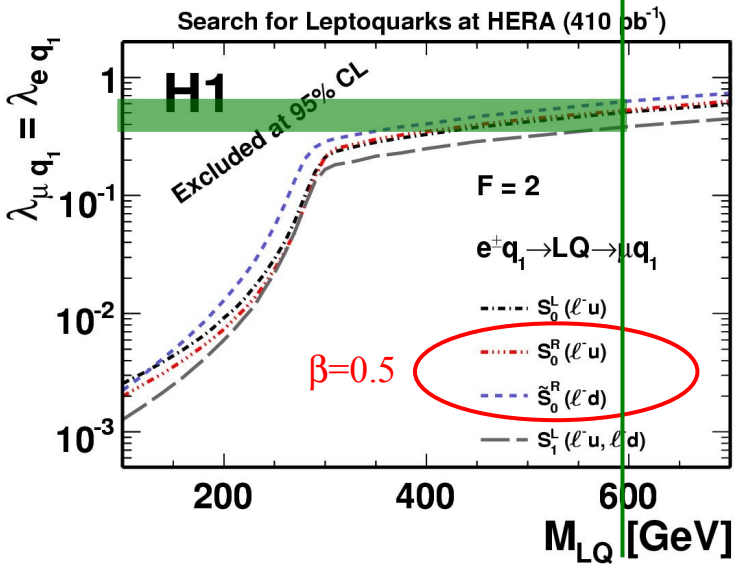
Comparison of H1 LFV limits with those from hadron colliders

- Leptoquark produced in pairs at the Tevatron or the LHC
  - No sensitivity from such decays to the coupling λ
- Highest excluded mass in a 3rd generation search
  - 350 GeV for β = 1 from 2012 CMS scalar LQ search
  - 317 GeV for β = 1 from 2007 CDF vector LQ search (YM coupling)
- Highest excluded mass in a 2nd generation search
  - 685 GeV for β = 1 from 2012 ATLAS scalar LQ search



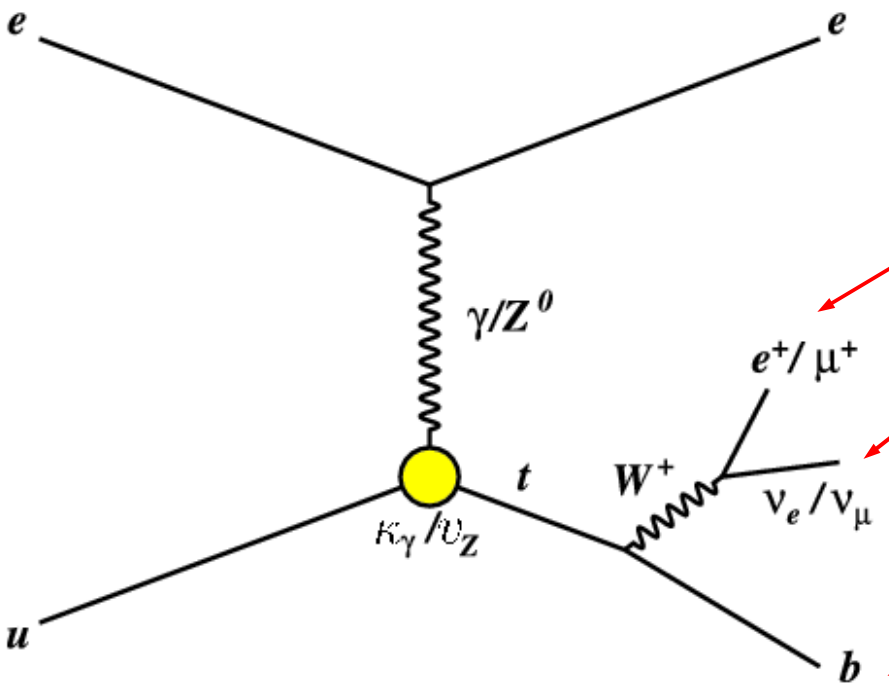


- Most appropriate value to compare to HERA is β = 0.5
  - Second generation limit from ATLAS is 595 GeV
  - For this mass, and for such LQs, H1 excludes couplings in the range λ = 0.35-0.7
  - Best third generation limit is from CMS, still below 200 GeV for β = 0.5



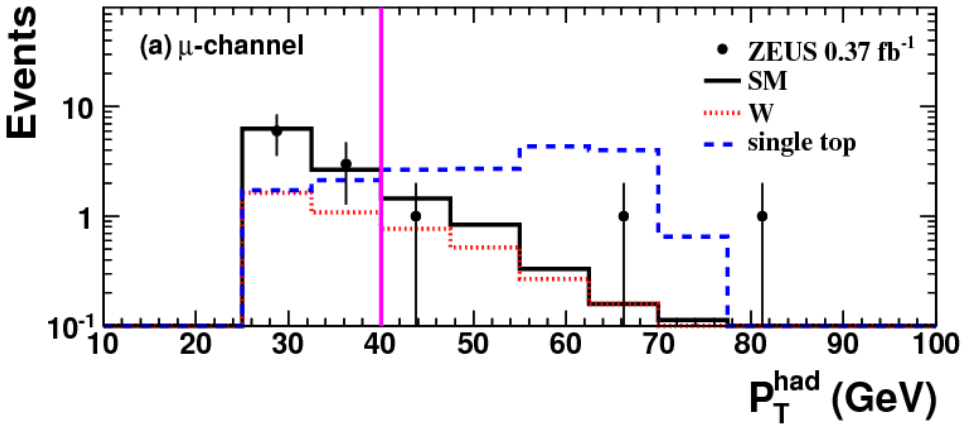
Single-top production

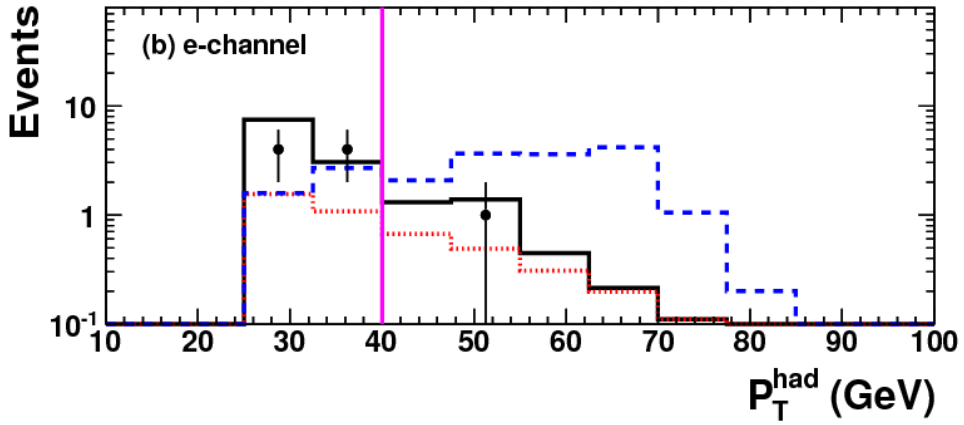
- SM cross section below 1 fb^{-1}
- FCNC couplings can induce single-top production BSM



- Signature of $t \to bl\upsilon$
  - High-p_T isolated lepton
  - missing E_T (from neutrino)
  - Large hadron transverse momentum p_T^{had} (from b-jet)
    - Background suppression

Single-top production

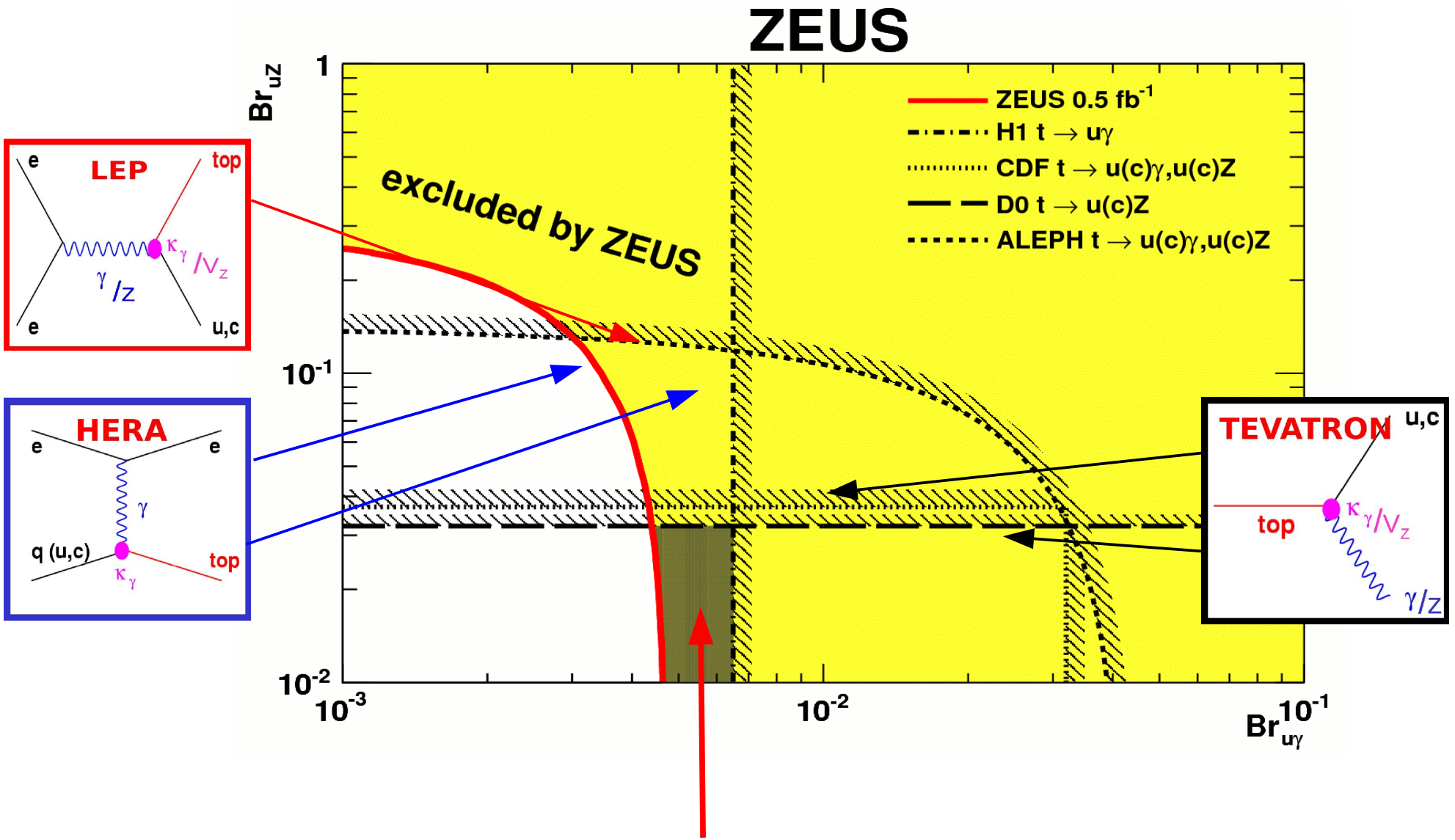




- no evidence of single top found
- limits set on cross section and anomalous single top production

$\sigma < 0.13$ pb (95% CL)

Single-top production: limits



Dark shaded area uniquely excluded by ZEUS

Bibliography

Results Shown Here

- H1 Collaboration, "Inclusive deep inelastic scattering at High Q2 with longitudinally polarised lepton beams at HERA", JHEP 09 (2012) 061
- H1 Collaboration, "Search for First Generation Leptoquarks in ep Collisions at HERA", Phys. Lett. B704 (2011) 388
- H1 Collaboration, "Search for Lepton Flavour Violation at HERA", Phys. Lett. B701 (2011) 20
- H1 Collaboration, "Search for Contact Interactions in ep Collisions at HERA", Phys. Lett. B705 (2011) 52
- ZEUS Collaboration, "Search for Single-Top Production in ep Collisions at HERA", Phys. Lett. B 708 (2012) 27-36

Summary of HERA searches

- HERA finalizes searches for new physics using luminosity of 0.5 fb^{-1}/experiment
- No deviation from SM observed
- In various regions of kinematic/parameter phase-space HERA limits still competitive or complementary