Search for Leptoquarks and Lepton Flavor Violation at HERA

- Introduction
- Searches for 1st generation Leptoquarks
- Searches for lepton flavour violation
- Summary

References:

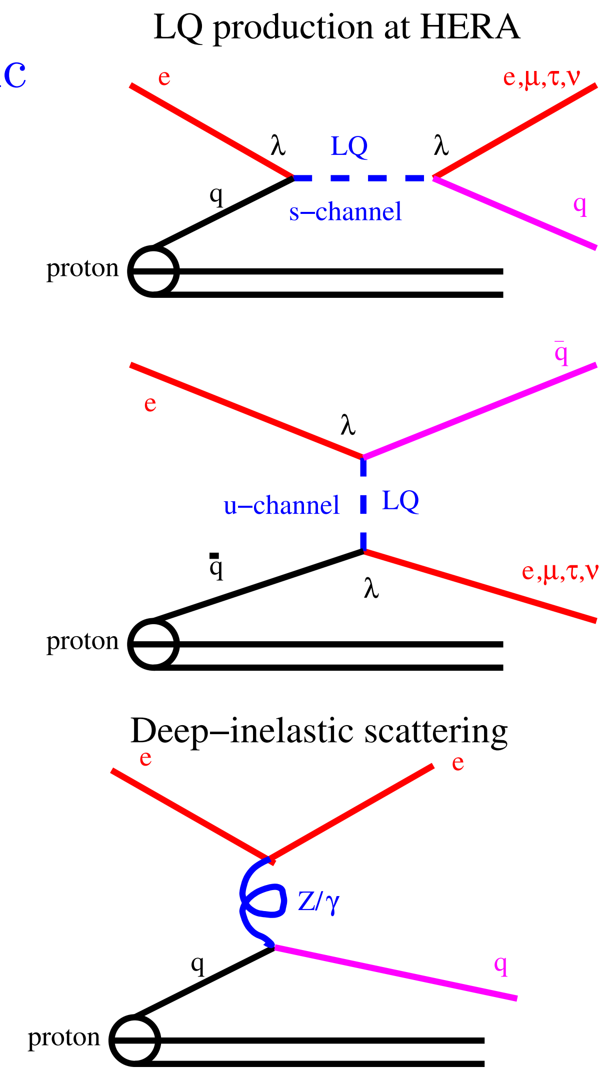
ZEUS collab., DESY-05-016

H1 collab., DESY-05-087

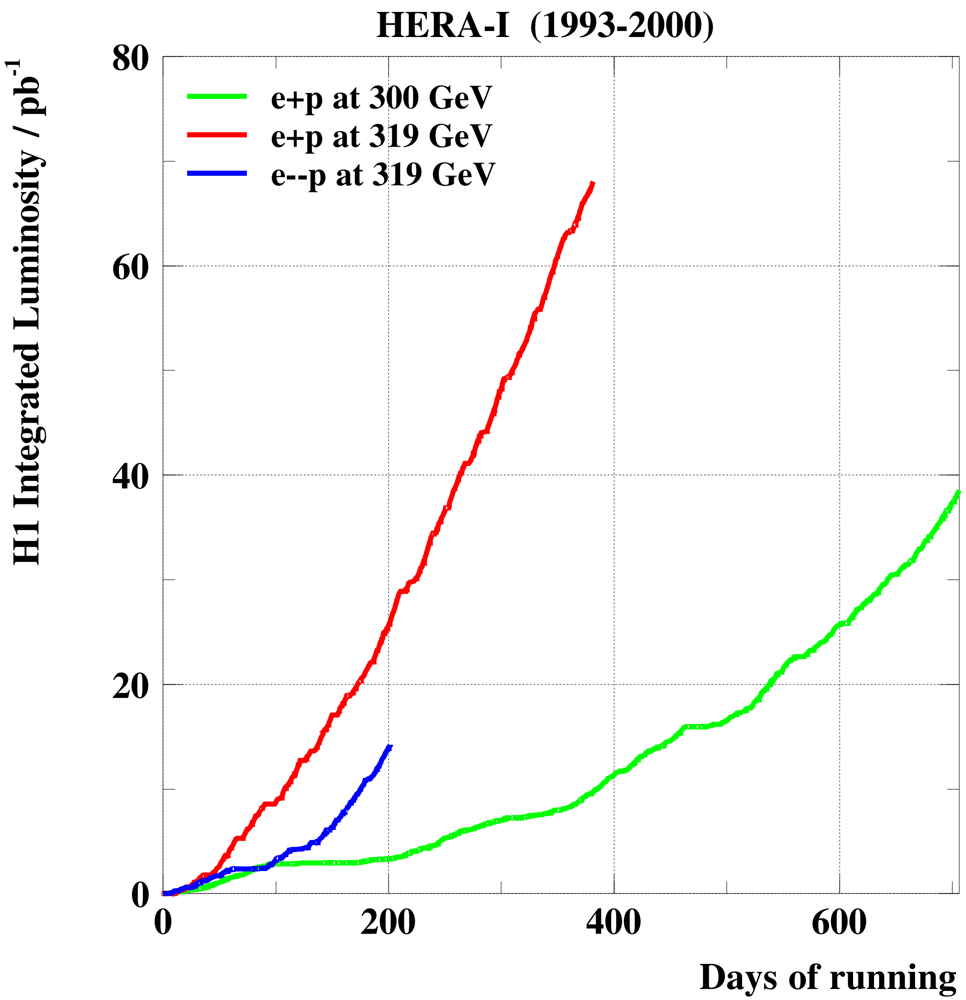
H1 collab., H1prelim-04-162

Introduction

- Leptoquark (LQ): boson with baryonic and leptonic quantum numbers.
- Define Fermion number $F = 3B + L$
- LQ at HERA: single production
  - $E_{cm} < 300$ GeV: resonant production (F=0 in e^+p and F=2 in e^-p)
  - $E_{cm} \gg 300$ GeV: contact interaction
- Search for 7 scalar and 7 vector LQs
- Production: coupling to e and u, d
- Decay: coupling to e, ν, μ, τ and q'

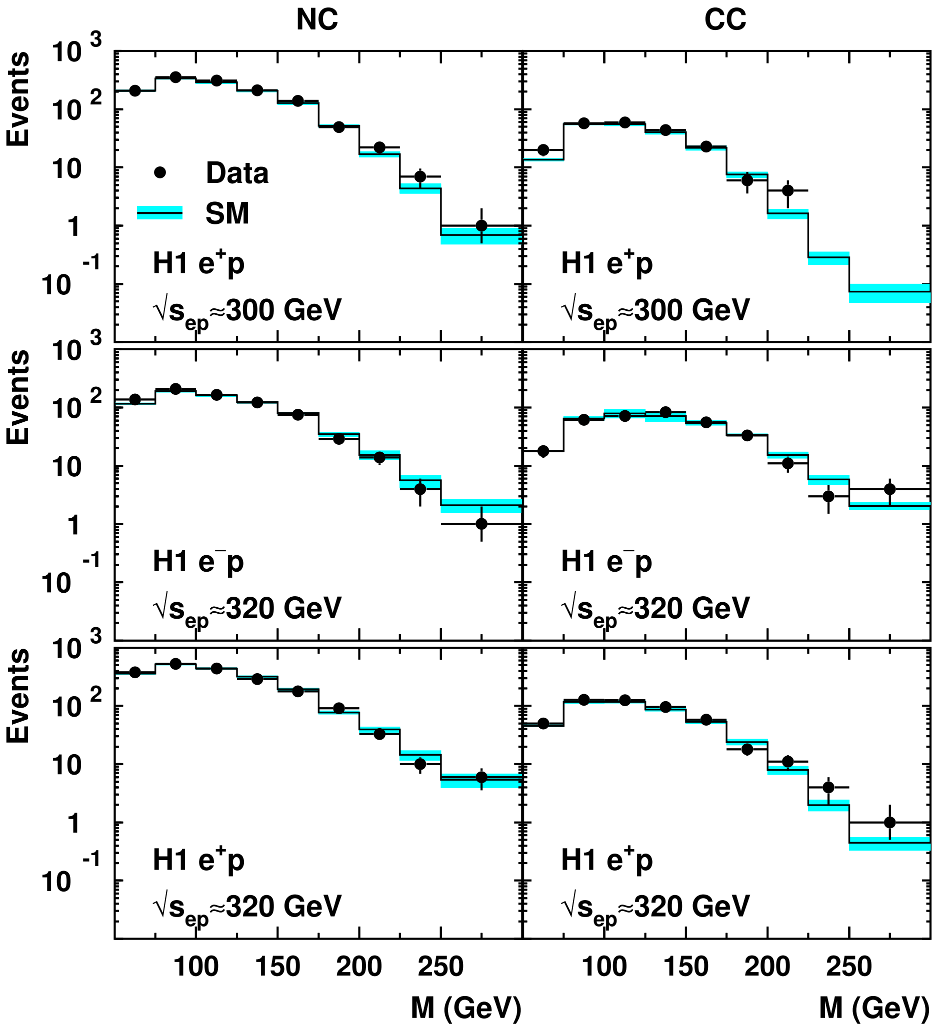


HERA and the collider experiments H1 and ZEUS



- HERA: $e^{\pm}p$ collider, $E_{cm} = 319$ GeV
- HERA I: 100 pb^{-1} in e^+p and 15 pb^{-1} in e^-p
  This talk: results from HERA I
- HERA II: luminosity upgrade and longitudinally polarised leptons.
  Data-taking ongoing (see talk by Hiroshi Kaji for first results)
- ZEUS/H1 experiments: multi-purpose detectors to record all types of ep reactions

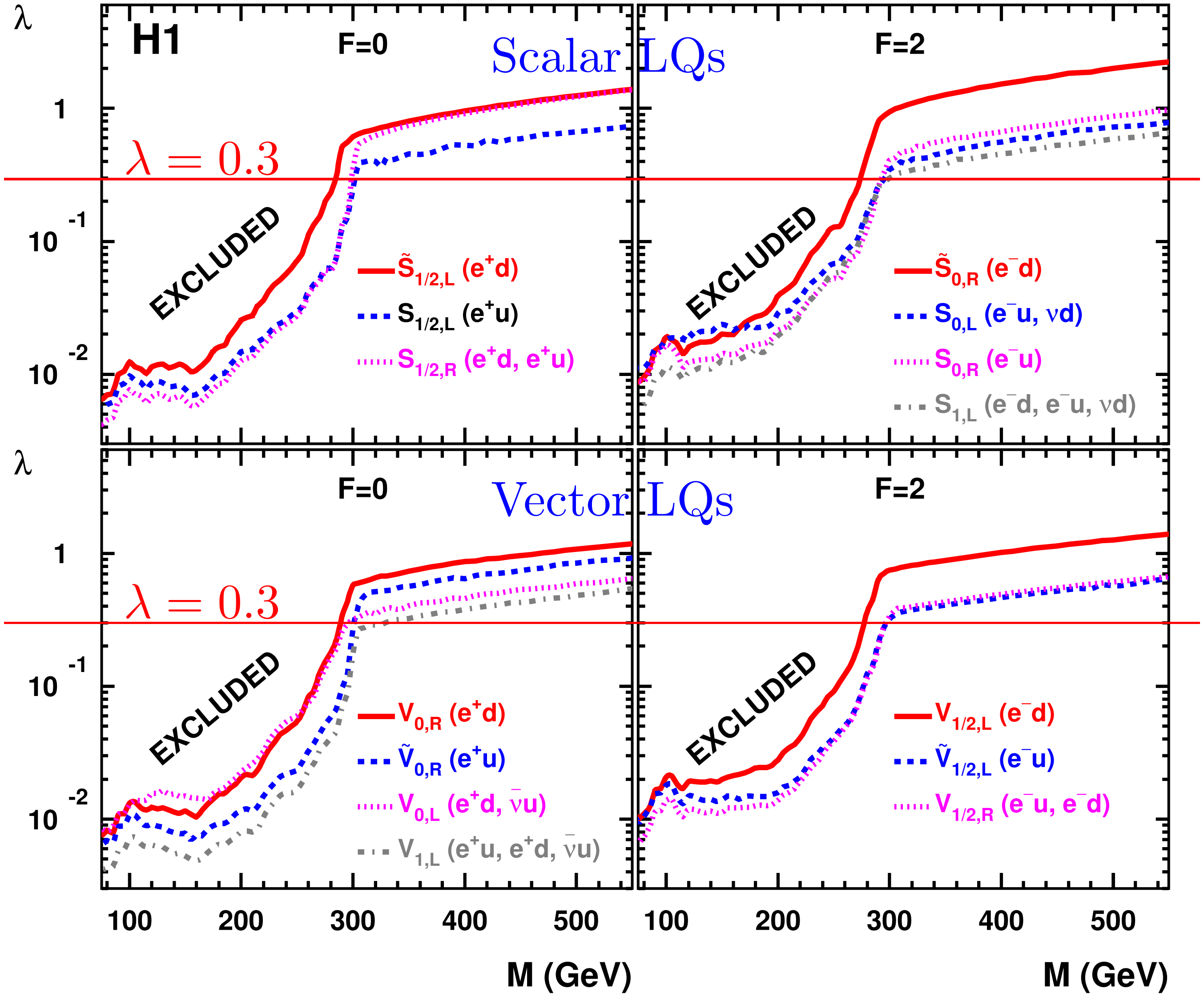
Search for first-generation LQs



- Processes:
  NC: $ep \to eX$
  CC: $ep \to \nu X$
- Look for enhancement in LQ mass spectra
  Irreducible background from deep inelastic scattering
  include interference terms in analysis
- No evidence for signal
- Set limits:
  2-dimensional analysis of mass and decay angle

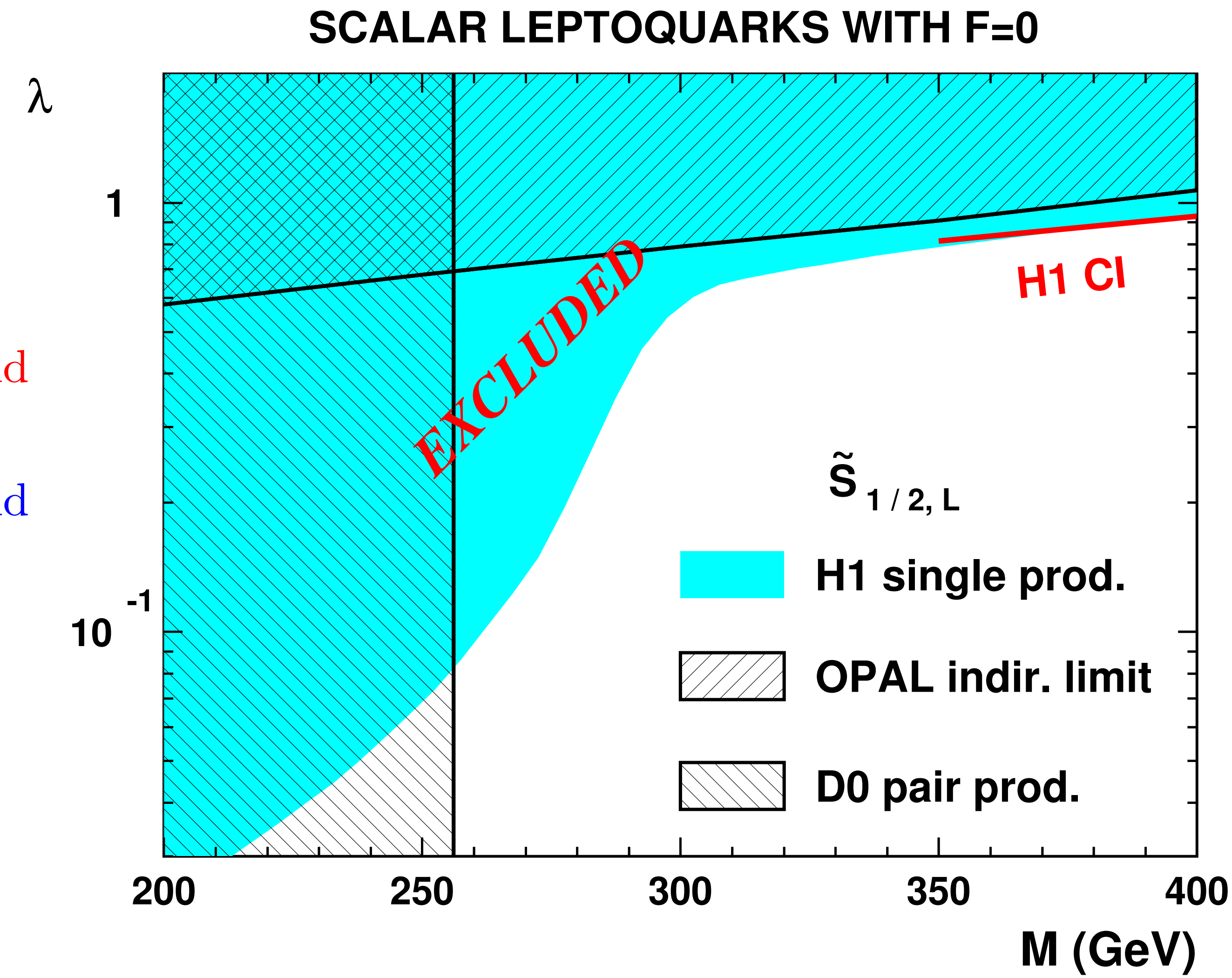
Search for first-generation LQs: results

- Limits on the coupling λ as a function of the LQ mass M
- Coupling of EM strength corresponds to $\lambda = 0.3$: exclude masses of order 300 GeV
- for $M < 300$ GeV: resonant production
- for $M > 300$ GeV: smooth transition to contact interaction (coupling constant $\frac{\lambda^2}{M^2}$)
- BRW model: branching ratio NC/CC fixed



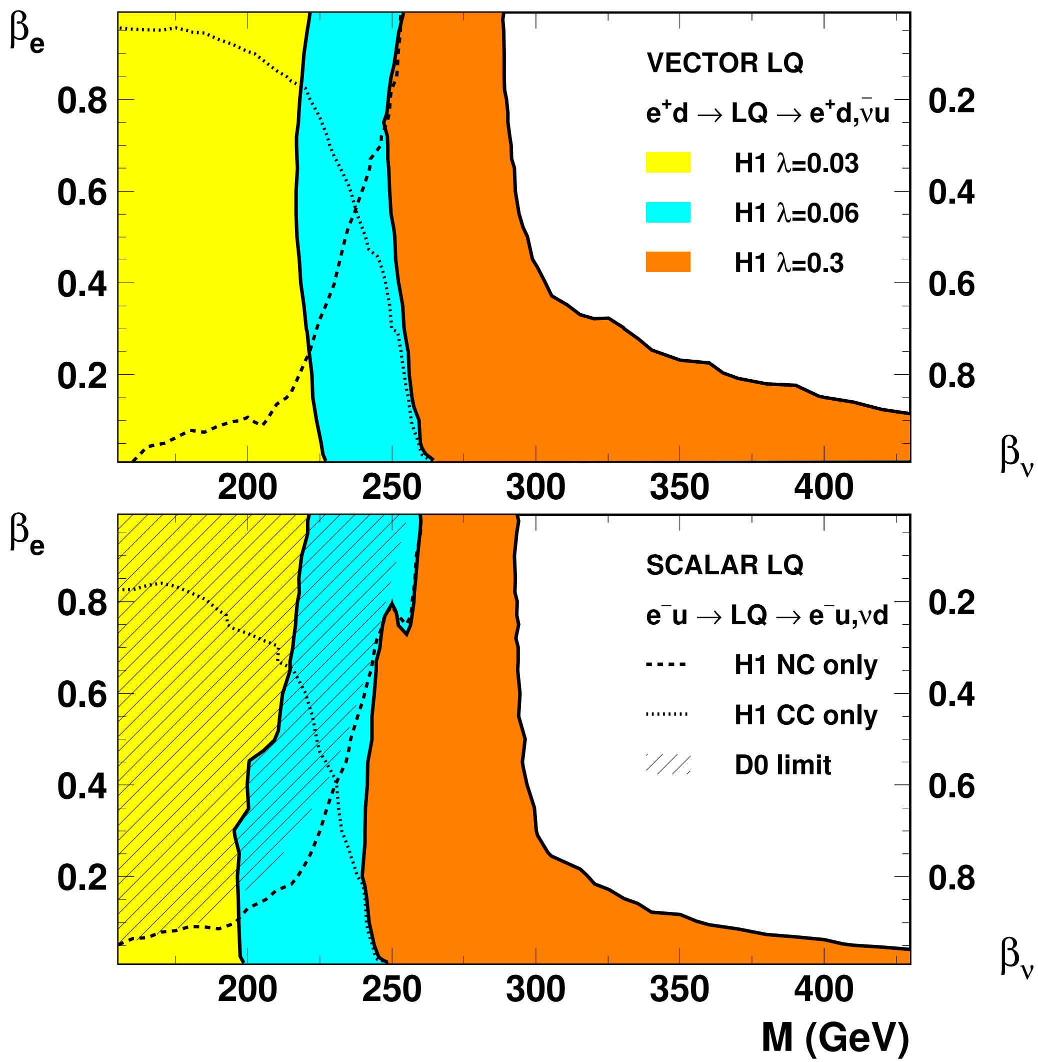
First generation LQ: comparison to LEP and Tevatron

- Tevatron: pair production
- LEP: contact interaction
- HERA: single production and contact interaction
  Sensitivity at high masses and high couplings

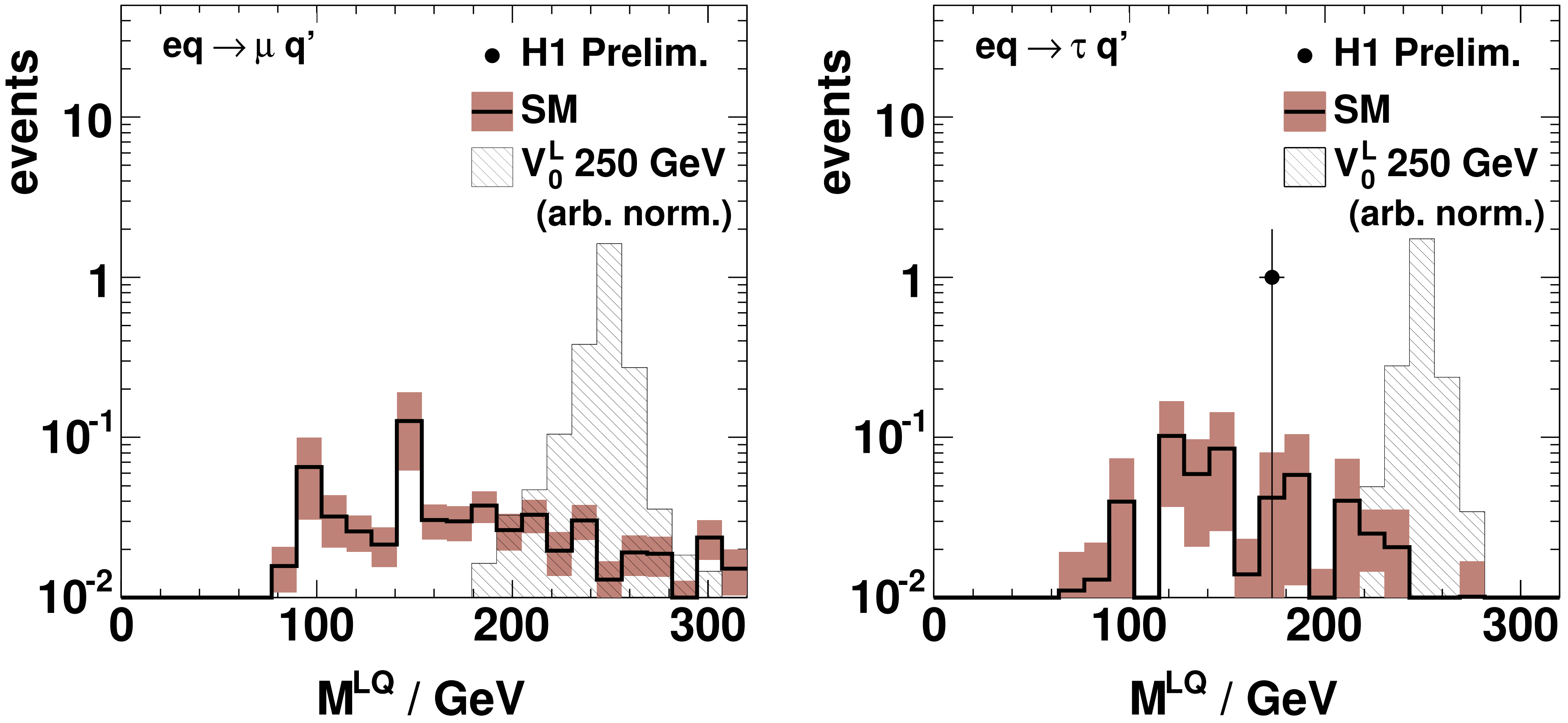


First generation LQ in more general models

- Look for LQ decaying to (e,jet) (NC) or (ν,jet) (CC)
- Vary branching ratio $\beta_e = \frac{\lambda_e^2}{\lambda_e^2+\lambda_\nu^2}$ with fixed *eq* coupling $\lambda = \lambda_e$
- at low mass: Limit is approx. independent of β_e (because sensitivity in NC/CC is very similar)
- at high masses: transition to contact interaction
  4-fermion coupling $\frac{\lambda_e\sqrt{\lambda_e^2+\lambda_\nu^2}}{M^2} = \frac{\lambda_e^2}{\sqrt{\beta_e}M^2}$



HERA searches for lepton-flavour violation in LQ decays

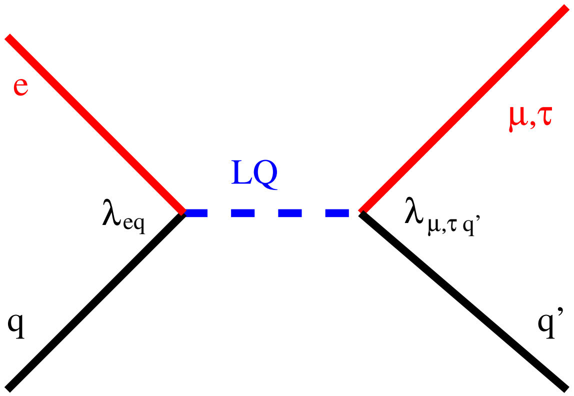


Look for μ+jet or τ+jet. Low background, good sensitivity.

No evidence for a signal → set limits

Limits on lepton-flavour violating LQs

Two couplings λ_{eq} and $\lambda_{\mu,\tau q'}$



For $M < 300$ GeV (resonant prod.): limits on

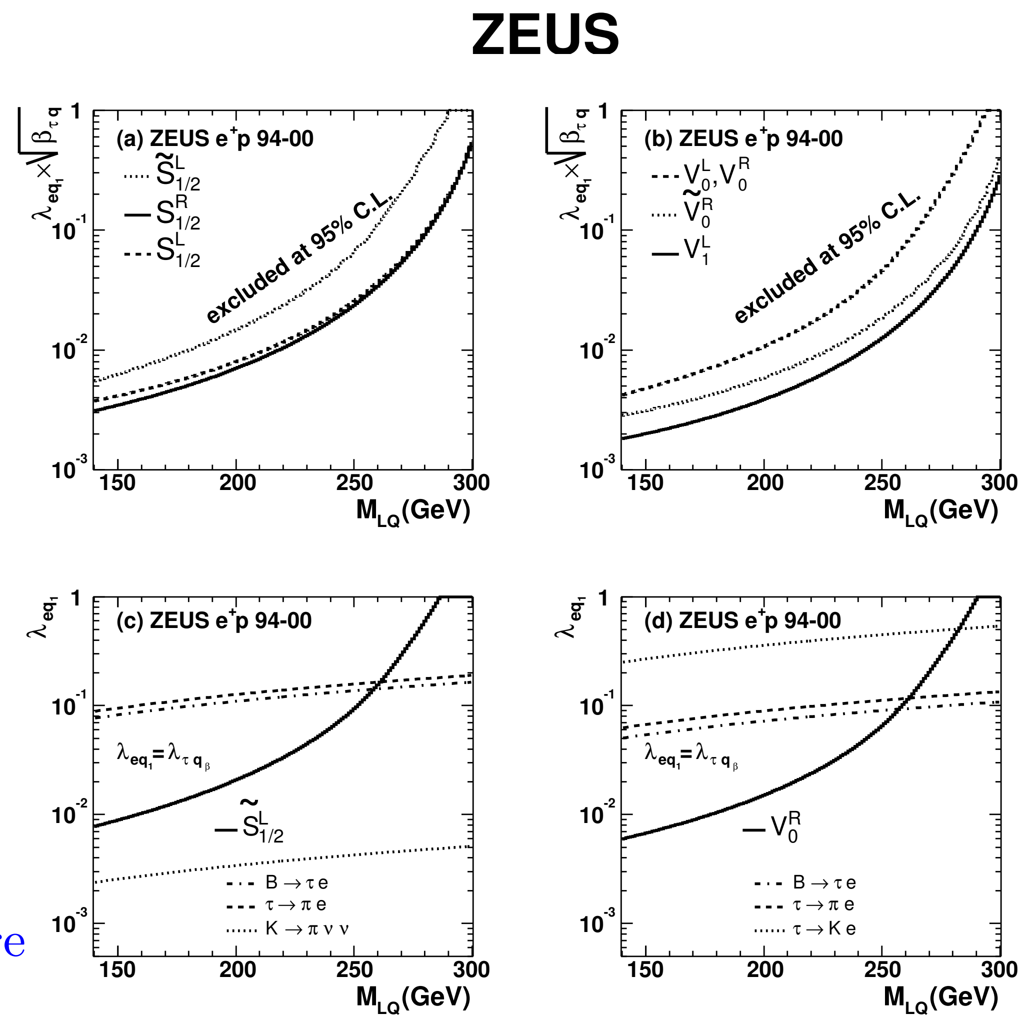
$$\lambda_{eq} \times \sqrt{\beta_{\mu,\tau q'}}$$

Plot: ZEUS limits for τ search (F=0)

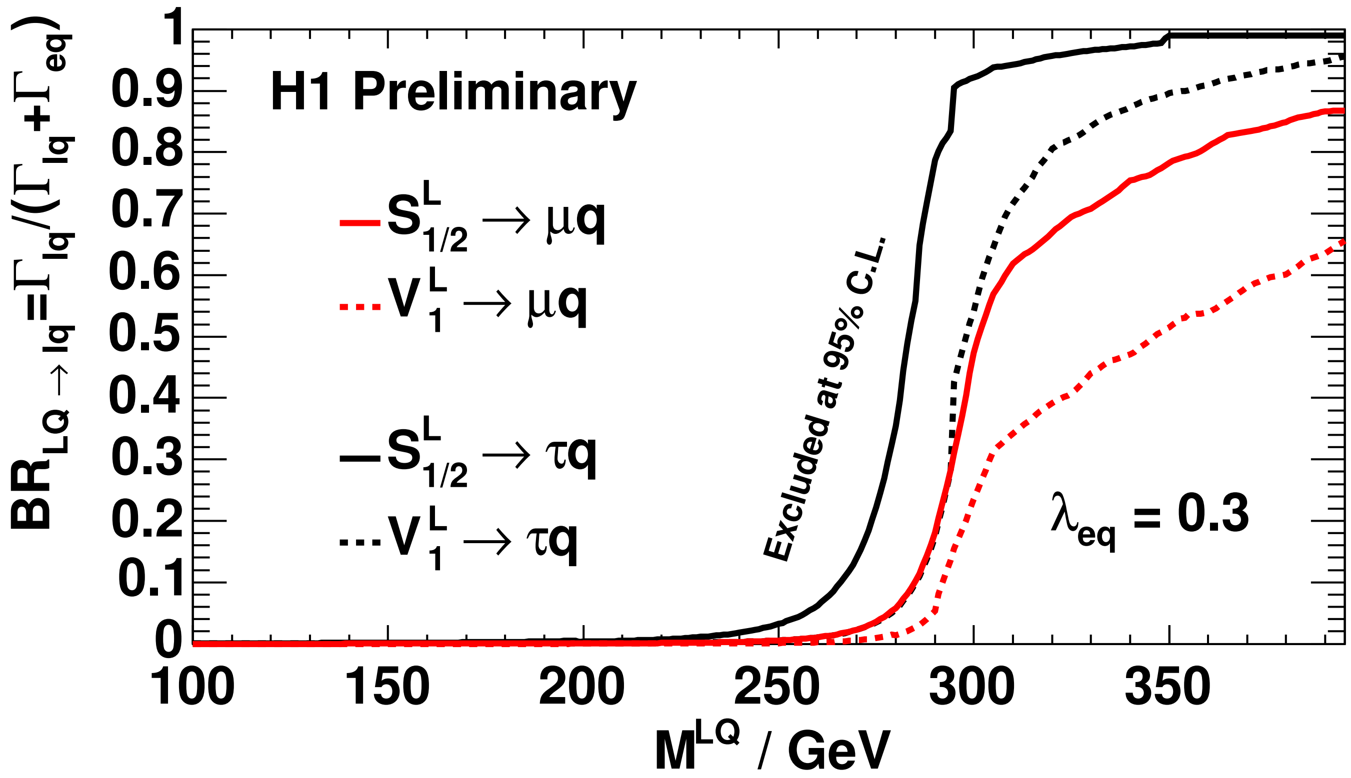
Conventional assumption

$$\lambda_{eq} = \lambda_{\mu q'} \text{ or } \lambda_{eq} = \lambda_{\tau q'}$$

For coupling $\lambda = 0.3$ masses up to 299 GeV are excluded.



Limits on lepton-flavour violating LQs (2)



Plot: H1 mass limit for variable lepton-flavour violationg coupling and fixed $\lambda_{eq} = 0.3$

μ channel: masses up to 350 GeV excluded for $\mathcal{BR}(\mu) = 0.5$

Higher masses: contact interactions

Contact interaction limits on lepton-flavour violating LQs

- $M \gg 300$ GeV: contact interaction limits (4-Fermion interaction)
- Limit is set on
$$\frac{\lambda_{eq_\alpha}\lambda_{\mu,\tau q_\beta}}{M^2_{LQ}}.$$
- Limit depends on initial/final state quark flavours $\alpha, \beta = 1, 2, 3$.
- HERA limits are complementary to low energy data
  Example:
  $\tilde{V}_0^R$, $\alpha, \beta = 1, 2$: limit $1.6\,\mathrm{TeV}^{-2}$

  $\rightarrow$ for $\lambda_{eu} = \lambda_{\tau c} = 1$
  exclude $M < 790\,\mathrm{GeV}$

$e \rightarrow \tau$			ZEUS $e^\pm p$ 94-00		limits in TeV^{-2}		$F = 0$
$\alpha\beta$	$S^L_{1/2}$ $e^-\bar{u}$ e^+u	$S^R_{1/2}$ $e^-(\bar{u}+\bar{d})$ $e^+(u+d)$	$\tilde{S}^L_{1/2}$ $e^-\bar{d}$ e^+d	V^L_0 $e^-\bar{d}$ e^+d	V^R_0 $e^-\bar{d}$ e^+d	$\tilde{V}^R_0$ $e^-\bar{u}$ e^+u	V^L_1 $e^-(\sqrt{2}\bar{u}+\bar{d})$ $e^+(\sqrt{2}u+d)$
1 1	$\tau \rightarrow \pi e$ 0.4 **1.8**	$\tau \rightarrow \pi e$ 0.2 **1.5**	$\tau \rightarrow \pi e$ 0.4 **2.7**	$\tau \rightarrow \pi e$ 0.2 **1.7**	$\tau \rightarrow \pi e$ 0.2 **1.7**	$\tau \rightarrow \pi e$ 0.2 **1.3**	$\tau \rightarrow \pi e$ 0.06 **0.6**
1 2	**1.9**	$\tau \rightarrow Ke$ 6.3 **1.6**	$K \rightarrow \pi\nu\bar{\nu}$ 5.8×10^{-4} **2.9**	$\tau \rightarrow Ke$ 3.2 **2.1**	$\tau \rightarrow Ke$ 3.2 **2.1**	**1.6**	$K \rightarrow \pi\nu\bar{\nu}$ 1.5×10^{-4} **0.8**
1 3	*	$B \rightarrow \tau\bar{e}$ 0.3 **3.2**	$B \rightarrow \tau\bar{e}$ 0.3 **3.3**	$B \rightarrow \tau\bar{e}$ 0.13 **2.6**	$B \rightarrow \tau\bar{e}$ 0.13 **2.6**	*	$B \rightarrow \tau\bar{e}$ 0.13 **2.6**
2 1	**6.0**	$\tau \rightarrow Ke$ 6.3 **4.1**	$K \rightarrow \pi\nu\bar{\nu}$ 5.8×10^{-4} **5.2**	$\tau \rightarrow Ke$ 3.2 **2.3**	$\tau \rightarrow Ke$ 3.2 **2.3**	**2.1**	$K \rightarrow \pi\nu\bar{\nu}$ 1.5×10^{-4} **0.9**
2 2	$\tau \rightarrow 3e$ 5 **10**	$\tau \rightarrow 3e$ 8 **5.6**	$\tau \rightarrow 3e$ 17 **6.5**	$\tau \rightarrow 3e$ 9 **3.4**	$\tau \rightarrow 3e$ 9 **3.4**	$\tau \rightarrow 3e$ 3 **5.5**	$\tau \rightarrow 3e$ 1.6 **2.1**
2 3	*	$B \rightarrow \tau\bar{e}X$ 14 **8.1**	$B \rightarrow \tau\bar{e}X$ 14 **7.8**	$B \rightarrow \tau\bar{e}X$ 7.2 **5.5**	$B \rightarrow \tau\bar{e}X$ 7.2 **5.5**	*	$B \rightarrow \tau\bar{e}X$ 7.2 **5.5**
3 1	*	$B \rightarrow \tau\bar{e}$ 0.3 **7.8**	$B \rightarrow \tau\bar{e}$ 0.3 **7.2**	V_{ub} 0.12 **2.5**	$B \rightarrow \tau\bar{e}$ 0.13 **2.5**	*	V_{ub} 0.12 **2.5**
3 2	*	$B \rightarrow \tau\bar{e}X$ 14 **11**	$B \rightarrow \tau\bar{e}X$ 14 **10**	$B \rightarrow \tau\bar{e}X$ 7.2 **4.2**	$B \rightarrow \tau\bar{e}X$ 7.2 **4.2**	*	$B \rightarrow \tau\bar{e}X$ 7.2 **4.2**
3 3	*	$\tau \rightarrow 3e$ 8 **15**	$\tau \rightarrow 3e$ 17 **14**	$\tau \rightarrow 3e$ 9 **8.1**	$\tau \rightarrow 3e$ 9 **8.1**	*	$\tau \rightarrow 3e$ 1.6 **8.1**

Conclusions

- Searches at HERA for LQs in all lepton channels

  → no sign of LQ production found

- HERA limits on LQ production reach to 300 GeV and beyond for couplings of EM strength

- Complementary to LEP/Tevatron searches

- High sensitivity in the ν+jet channel: limits are independent of the LQ decay

- New limits in the μ+jet and τ+jet channel

Outlook

- HERA II data-taking ongoing: high luminosity and lepton polarisation

→ continue to search for LQs