Lepton Flavour Violation at HERA

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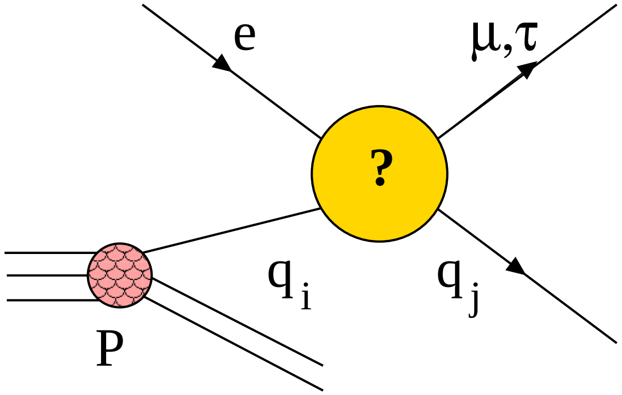
on behalf of

Contents:

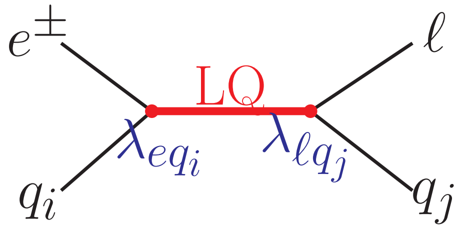
- LFV
- Experimental signature
- H1 and ZEUS published limits
- New ZEUS results with bigger luminosity (~ 130 pb^{-1})

Lepton Flavour Violation



- Evidence of neutrino oscillations reported recently → LFV could be also in charged lepton channel
- Many extensions of SM allow LFV (LQ, SUSY violating R-parity..): HERA is an ideal place to search for both $e \to \mu$ and $e \to \tau$ processes
- Quantitative description of LFV search: LQs coupling to different generations. → Buchmüller-Rückl-Wyler model: 14 LQ types with fermion number 0, 2 (F=L+3B)

Low mass LQs ($M_{LQ} < \sqrt{s}$)–Narrow Width Approximation



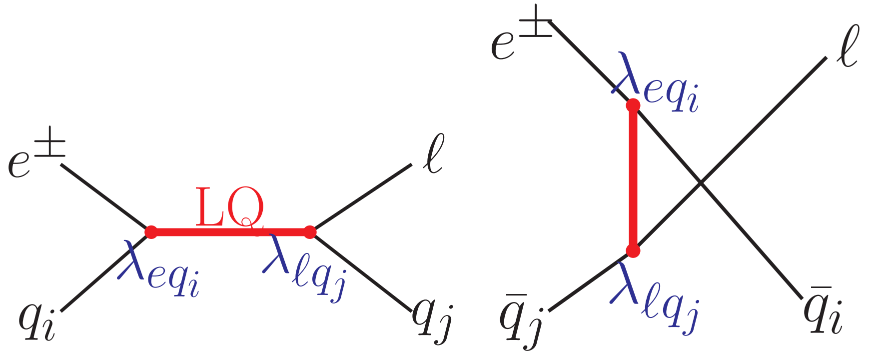
$$\sigma^{\mathrm{NWA}}(\lambda_{eq_1}, M_{\mathrm{LQ}}) = (J+1)\frac{\pi\lambda_{eq_1}^2}{4s}\sum_{I_3=-I}^{I} cq_1\left(x = \frac{M_{\mathrm{LQ}}^2}{s}, Q_0^2\right)\beta(\mathrm{LQ} \rightarrow lq_j)$$

Signatures:

- High p_t isolated lepton
- Peak in the lepton–jet mass spectrum.

F=0 LQs are produced from e^+ valence quark interaction $\rightarrow$ only F=0 LQs considered for e^+p data

High mass LQs ($M_{LQ} >> \sqrt{s}$)–High Mass Approximation



$$\sigma^{\mathrm{HMA}} = \frac{s}{32\pi}\left(\frac{\lambda_{eq_i}\lambda_{lq_j}}{M_{\mathrm{LQ}}^2}\right)^2 \left(\int dxdy\, x\, q_i(x,\widehat{s})f(y) + \int dxdyx\bar{q}_j(x,u)g(y)\right)$$

Signature:

- Isolated lepton with softer p_t distribution

Both F=0 and F=2 LQs are considered

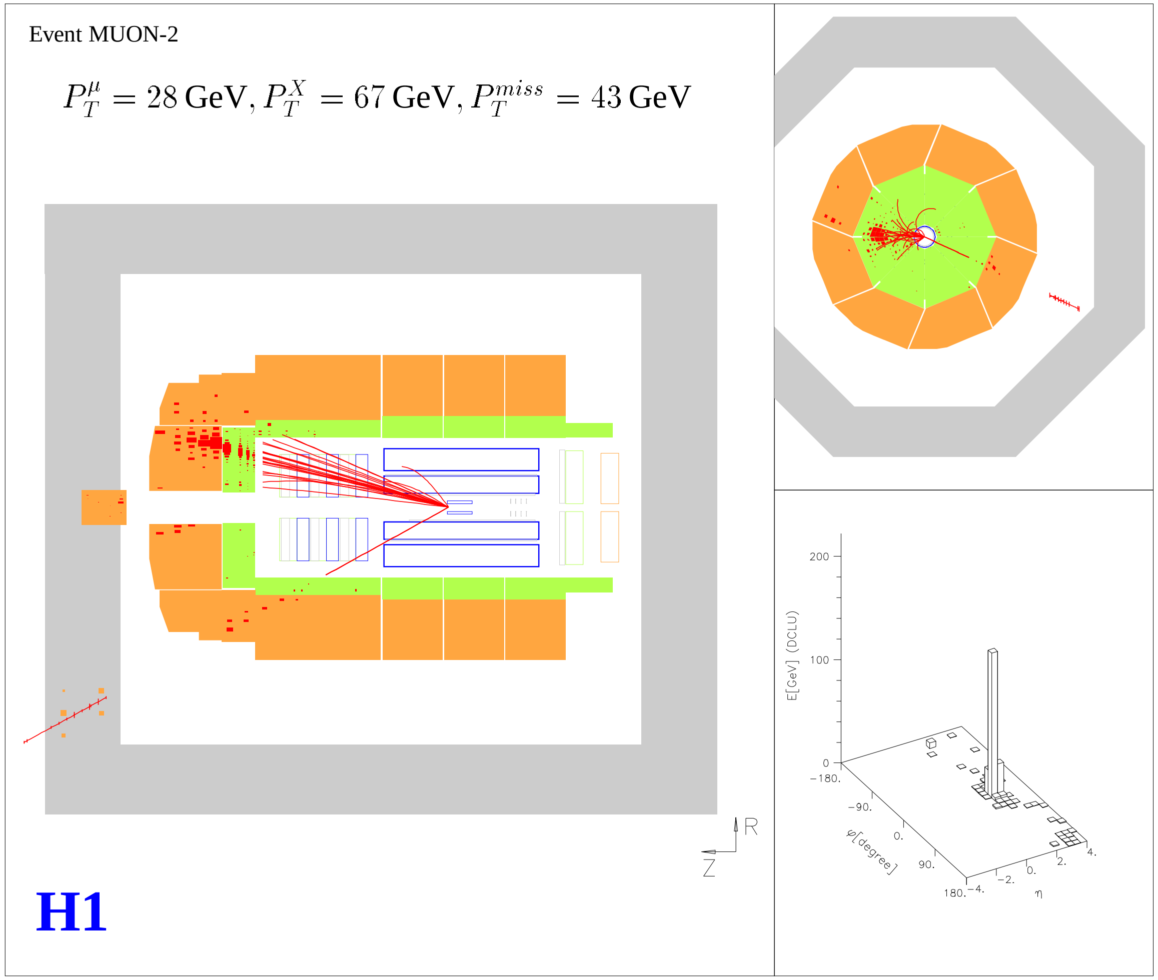
LFV– μ channel signature

Isolated μ in the missing P_t ($\not{P}_t$) direction

Basically no S.M. background

Very high selection efficiency ($\sim$ 40% – 60% for low mass LQs)

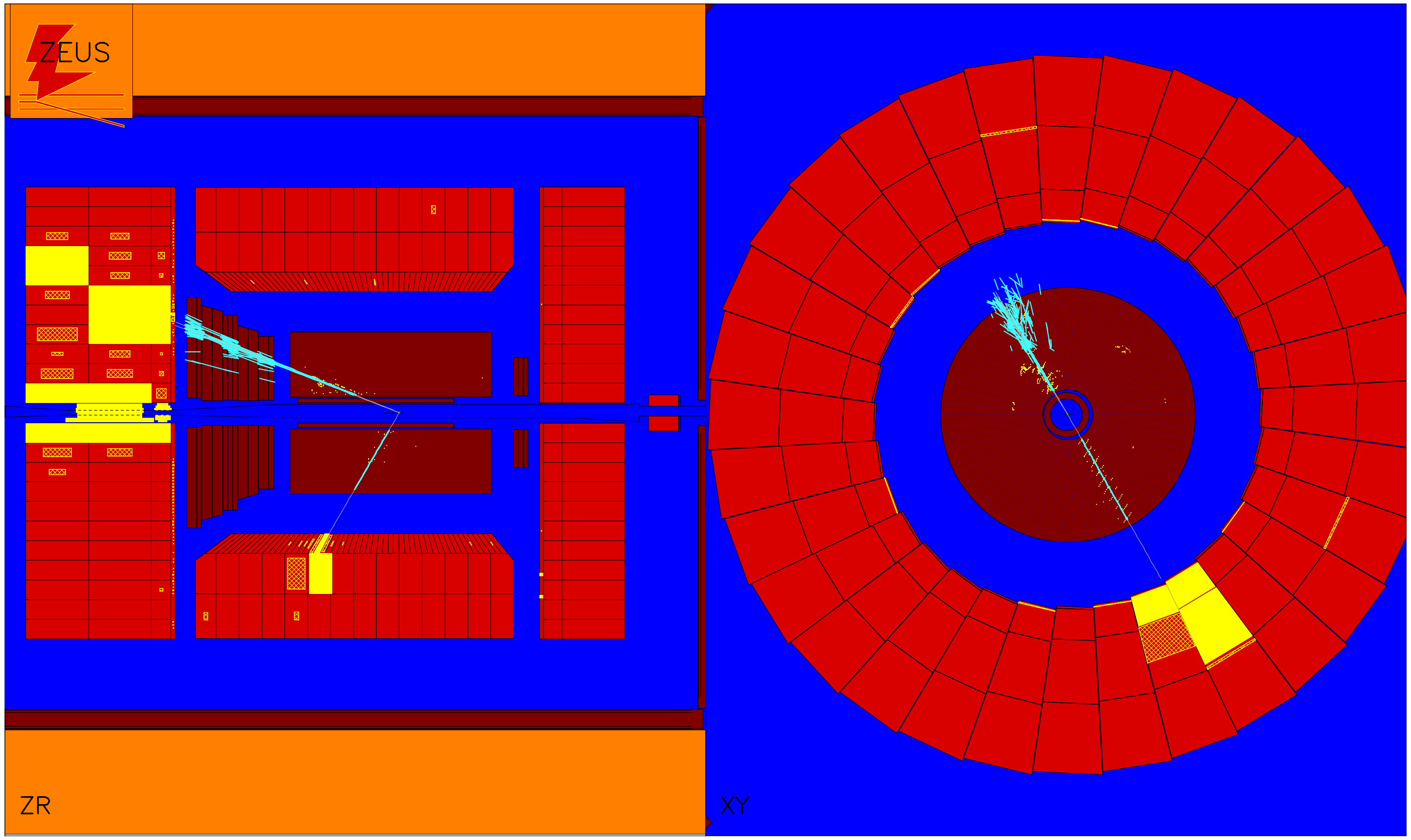
$$e^+p \to \mu^+ X$$



LFV– τ channel signature

Signature:

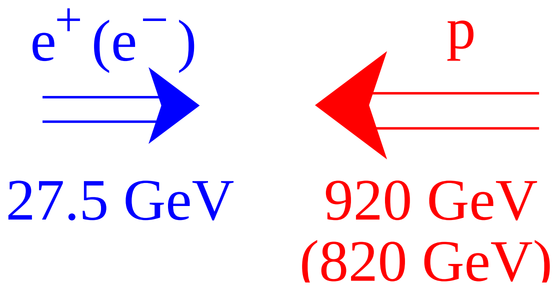
- high p_t e in $\not{P}_t$ direction
- high p_t μ in $\not{P}_t$ direction
- narrow jet with 1-3 tracks to the cal. deposit in $\not{P}_t$ direction



Low background.

Efficiency $\sim 25\% - 30\%$.

Data analysis



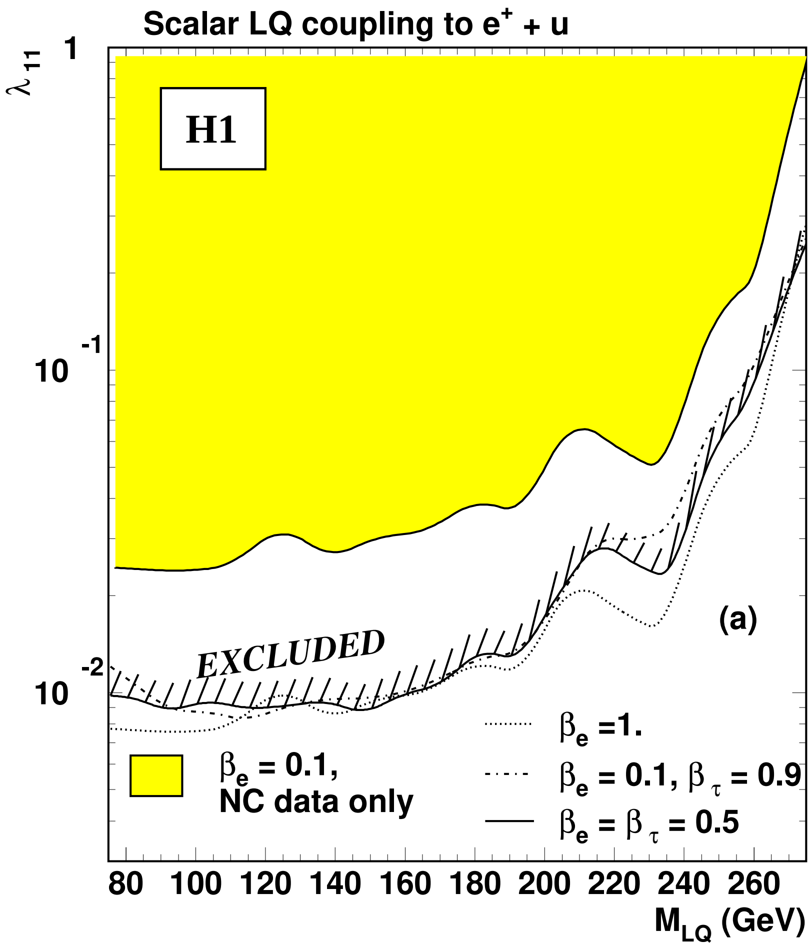
- 1994–97 data.
  H1 and ZEUS searched for μq and τq.
- 1994–00 data.
  ZEUS searched for μq.

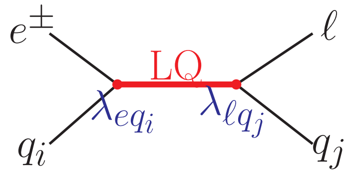
Year	Beam	C.M. Energy	ZEUS int. luminosity	H1 int. luminosity
94-97	e^+	300 GeV	47.7 pb^{-1}	37 pb^{-1}
98-99	e^-	318 GeV	16.7 pb^{-1}	14 pb^{-1}
99-00	e^+	318 GeV	65.5 pb^{-1}	68 pb^{-1}

No evidence of LFV found.

$\longrightarrow$ set limits on characteristic Yukawa coupling

Search for $e^+p \to \tau X$: H1 low mass limits





H1 Collab., C. Adloff et al., Phys. Lett. B462 (1999) 440-452

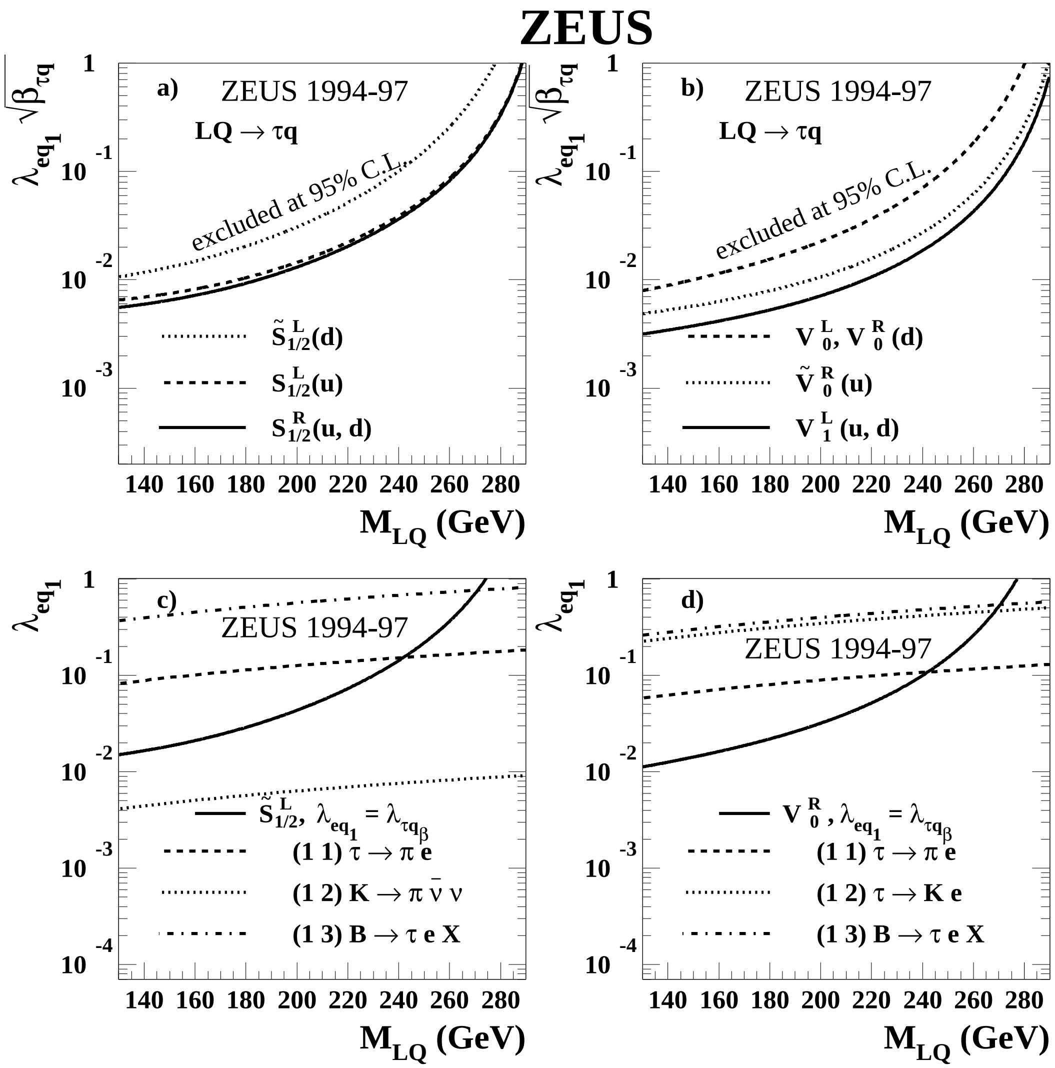
$S^L_{1/2}$ limits.

Both e^+ + jet and τ^+ + jet channels combined.

95 % C.L. limits on λ_{11} fixing β_e and β_τ.

$M_{LQ} > 275$ GeV assuming a e.m. coupling and $\beta_e + \beta_\tau = 1$.

Search for $e^+p \to \tau X$: ZEUS low mass limits



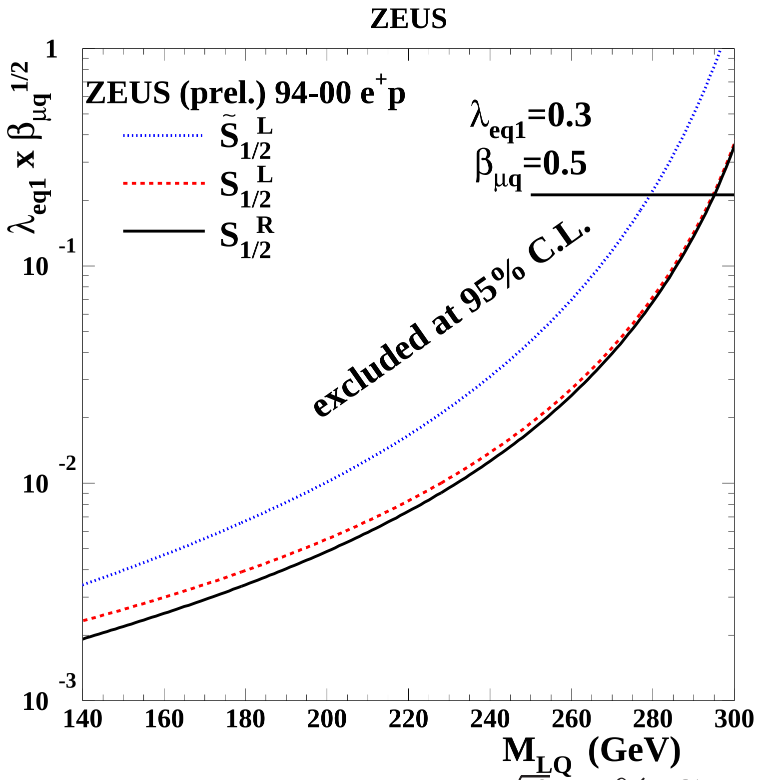
DESY–01–222

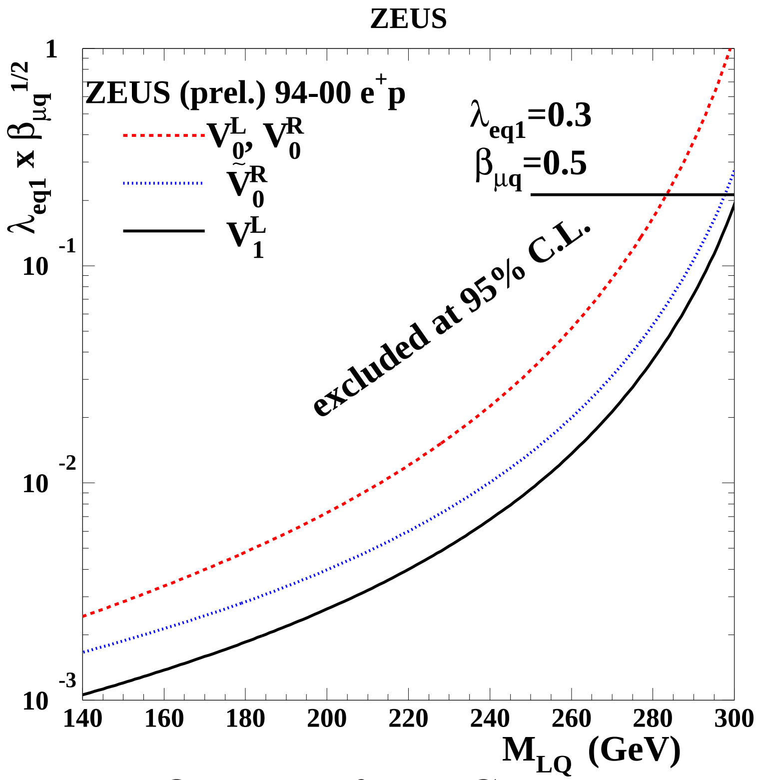
Lower mass limit at 95% C.L by assuming $\lambda_{eq1} = 0.3$ and limit on λ x $\sqrt{\beta}$ 95% C.L. assuming a LQ mass of 250 GeV.

LQ type	$S^L_{1/2}$	$S^R_{1/2}$	$\tilde{S}^L_{1/2}$
Mass limits (GeV)	275	276	258
Limits on $\lambda \cdot \sqrt{\beta}$	0.054	0.051	0.15

LQ type	V^L_0	V^R_0	$\tilde{V}^L_0$	V^L_1
Mass limits (GeV)	259	263	277	282
Limits on $\lambda \cdot \sqrt{\beta}$	0.10	0.10	0.038	0.027

New results from full data set (μ channel)



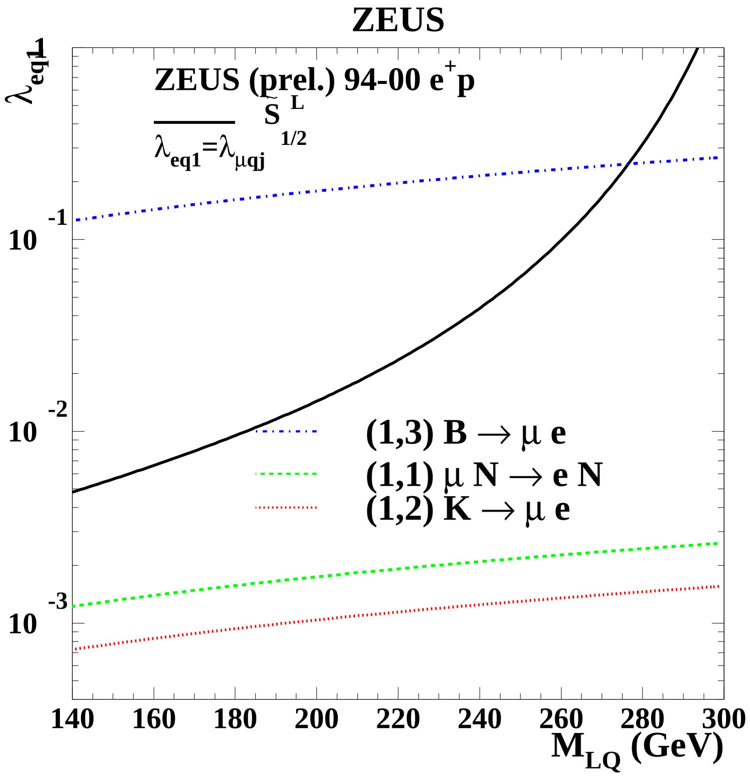


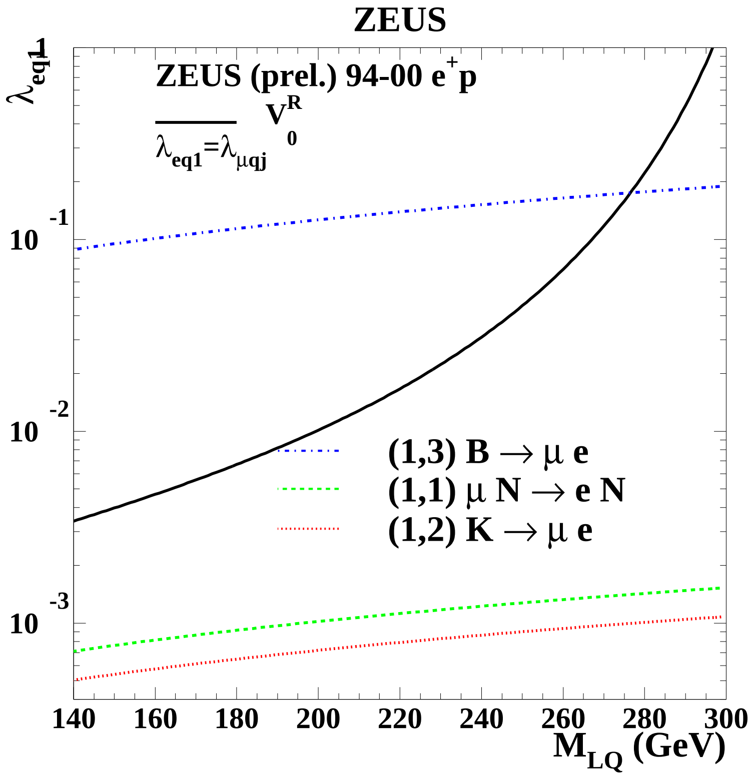
Limit on λ x $\sqrt{\beta}$ 95% C.L. assuming a LQ mass of 250 GeV.

LQ type	$S^L_{1/2}$	$S^R_{1/2}$	$\tilde{S}^L_{1/2}$	V^L_0	V^R_0	$\tilde{V}^L_0$	V^L_1
$\lambda \cdot \sqrt{\beta}$ limits	0.019	0.017	0.045	0.033	0.033	0.014	0.0094

New results from full data set (μ channel)

ZEUS limits competitive if 3rd quark generation involved





Lower mass limit at 95% C.L by assuming $\lambda_{eq1} = 0.3$

LQ type	$S^L_{1/2}$	$S^R_{1/2}$	$\tilde{S}^L_{1/2}$	V^L_0	V^R_0	$\tilde{V}^L_0$	V^L_1
Mass limits (GeV)	296	296	280	279	284	298	301

High mass limits

- Contact interaction cross section:
  $\sigma^{HMA}(\lambda, M_{LQ}) \propto \left[\frac{\lambda_{eq_i}\lambda_{lq_j}}{M_{LQ}^2}\right]^2$
- Selection efficiency for $M_{LQ} \gg \sqrt{s}$ is independent of M_{LQ} but varies with the generation of quarks
- New preliminary results from ZEUS using all 94-00 e^+p/e^-p data

$F=0$	Zeus Preliminary (94-00 combined limits)						$\frac{\lambda_{eq_i}\lambda_{\mu q_j}}{M^2_{LQ}}$ (TeV^{-2})
$q_i q_j$	$S^L_{1/2}$ $e^-\bar{u}$ 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	$\mu N\to eN$ 7.6×10^{-5} **1.1**	$\mu N\to eN$ 2.6×10^{-5} **0.9**	$\mu N\to eN$ 7.6×10^{-5} **1.6**	$\mu N\to eN$ 2.6×10^{-5} **1.0**	$\mu N\to eN$ 2.6×10^{-5} **1.0**	$\mu N\to eN$ 2.6×10^{-5} **0.8**	$\mu N\to eN$ 1.1×10^{-5} **0.4**
1 2	$D\to\mu\bar{e}$ 4 $\boxed{\mathbf{1.2}}$	$K\to\mu\bar{e}$ 2.7×10^{-5} **1.0**	$K\to\mu\bar{e}$ 2.7×10^{-5} **1.7**	$K\to\mu\bar{e}$ 1.3×10^{-5} **1.2**	$K\to\mu\bar{e}$ $.3\times10^{-5}$ **1.2**	$D\to\mu\bar{e}$ 2 $\boxed{\mathbf{1.0}}$	$K\to\mu\bar{e}$ 1.3×10^{-5} **0.5**
1 3	*	$B\to\mu\bar{e}$ 0.8 **1.8**	$B\to\mu\bar{e}$ 0.8 **1.8**	V_{ub} 0.2 **1.5**	$B\to\mu\bar{e}$ 0.4 **1.5**	*	V_{ub} 0.2 **1.5**
2 1	$D\to\mu\bar{e}$ 4 $\boxed{\mathbf{3.6}}$	$K\to\mu\bar{e}$ 2.7×10^{-5} **2.4**	$K\to\mu\bar{e}$ 2.7×10^{-5} **3.2**	$K\to\mu\bar{e}$ 1.3×10^{-5} **1.3**	$K\to\mu\bar{e}$ 1.3×10^{-5} **1.3**	$D\to\mu\bar{e}$ 2 $\boxed{\mathbf{1.3}}$	$K\to\mu\bar{e}$ 1.3×10^{-5} **0.6**
2 2	$\mu\to3e$ 5×10^{-3} **5.8**	$\mu\to3e$ 7.3×10^{-3} **3.1**	$\mu\to3e$ 1.6×10^{-2} **3.8**	$\mu\to3e$ 8×10^{-3} **1.9**	$\mu\to3e$ 8×10^{-3} **1.9**	$\mu\to3e$ 2.5×10^{-3} **2.9**	$\mu\to3e$ 1.5×10^{-3} **1.2**
2 3	*	$B\to\bar{\mu}eK$ 0.6 **4.4**	$B\to\bar{\mu}eK$ 0.6 **4.4**	$B\to\bar{\mu}eK$ 0.3 **2.9**	$B\to\bar{\mu}eK$ 0.3 **2.9**	*	$B\to\bar{\mu}eK$ 0.3 **2.9**
3 1	*	$B\to\mu\bar{e}$ 0.8 **4.3**	$B\to\mu\bar{e}$ 0.8 **4.3**	V_{ub} 0.2 **1.4**	$B\to\mu\bar{e}$ 0.4 **1.4**	*	V_{ub} 0.2 **1.4**
3 2	*	$B\to\bar{\mu}eK$ 0.6 **5.8**	$B\to\bar{\mu}eK$ 0.6 **5.8**	$B\to\bar{\mu}eK$ 0.3 **2.2**	$B\to\bar{\mu}eK$ 0.3 **2.2**	*	$B\to\bar{\mu}eK$ 0.3 **2.2**
3 3	*	$\mu\to3e$ 7.3×10^{-3} **7.7**	$\mu\to3e$ 1.6×10^{-2} **7.7**	$\mu\to3e$ 8×10^{-3} **3.9**	$\mu\to3e$ 8×10^{-3} **3.9**	*	$\mu\to3e$ 1.5×10^{-3} **3.9**

$F = 2$	Zeus Preliminary (94-00 combined limits)						$\frac{\lambda_{eq_i}\lambda_{\mu q_j}}{M^2_{LQ}}$ (TeV^{-2})
$q_i q_j$	S_0^L $e^- u$ $e^+ \bar{u}$	S_0^R $e^- u$ $e^+ \bar{u}$	$\tilde{S}_0^R$ $e^- d$ $e^+ \bar{d}$	S_1^L $e^- (u + \sqrt{2}d)$ $e^+ (\bar{u} + \sqrt{2}\bar{d})$	$V_{1/2}^L$ $e^- d$ $e^+ \bar{d}$	$V_{1/2}^R$ $e^- (u + d)$ $e^+ (\bar{u} + \bar{d})$	$\tilde{V}_{1/2}^L$ $e^- u$ $e^+ \bar{u}$
1 1	$\mu N \to eN$ 7.6×10^{-5} **1.6**	$\mu N \to eN$ 7.6×10^{-5} **1.6**	$\mu N \to eN$ 7.6×10^{-5} **2.1**	$\mu N \to eN$ 2.3×10^{-5} **0.9**	$\mu N \to eN$ 2.6×10^{-5} **0.9**	$\mu N \to eN$ 1.3×10^{-5} **0.5**	$\mu N \to eN$ 2.6×10^{-5} **0.6**
1 2	$K \to \pi\nu\bar{\nu}$ 10^{-3} **2.4**	$D \to \mu\bar{e}$ 4 $\boxed{\mathbf{2.4}}$	$K \to \mu\bar{e}$ 2.7×10^{-5} **2.6**	$K \to \mu\bar{e}$ 2.7×10^{-5} **1.1**	$K \to \mu\bar{e}$ 1.3×10^{-5} **1.6**	$K \to \mu\bar{e}$ 1.3×10^{-5} **1.2**	$D \to \mu\bar{e}$ 2 $\boxed{\mathbf{1.7}}$
1 3	V_{ub} 0.4 *	*	$B \to \mu\bar{e}$ 0.8 **2.8**	V_{ub} 0.4 **1.4**	$B \to \mu\bar{e}$ 0.4 **2.1**	$B \to \mu\bar{e}$ 0.4 **2.1**	*
2 1	$K \to \pi\nu\bar{\nu}$ 10^{-3} **2.1**	$D \to \mu\bar{e}$ 4 $\boxed{\mathbf{2.1}}$	$K \to \mu\bar{e}$ 2.7×10^{-5} **2.6**	$K \to \mu\bar{e}$ 2.7×10^{-5} **1.1**	$K \to \mu\bar{e}$ 1.3×10^{-5} **0.9**	$K \to \mu\bar{e}$ 1.3×10^{-5} **0.5**	$D \to \mu\bar{e}$ 2 $\boxed{\mathbf{0.6}}$
2 2	$\mu \to 3e$ 5×10^{-3} **5.7**	$\mu \to 3e$ 5×10^{-3} **5.7**	$\mu \to 3e$ 1.6×10^{-2} **3.8**	$\mu \to 3e$ 1.3×10^{-2} **1.8**	$\mu \to 3e$ 8×10^{-3} **1.9**	$\mu \to 3e$ 3.7×10^{-3} **1.6**	$\mu \to 3e$ 2.5×10^{-3} **2.9**
2 3	$B \to l\nu X$ 4 *	*	$B \to \bar{\mu}eK$ 0.6 **4.3**	$B \to \bar{\mu}eK$ 0.3 **2.1**	$B \to \bar{\mu}eK$ 0.3 **2.9**	$B \to \bar{\mu}eK$ 0.3 **2.9**	*
3 1	V_{ub} 0.4 *	*	$B \to \mu\bar{e}$ 0.8 **3.1**	V_{ub} 0.4 **1.5**	$B \to \mu\bar{e}$ 0.4 **1.0**	$B \to \mu\bar{e}$ 0.4 **1.0**	*
3 2	$B \to l\nu X$ 4 *	*	$B \to \bar{\mu}eK$ 0.6 **5.8**	$B \to \bar{\mu}eK$ 0.3 **2.9**	$B \to \bar{\mu}eK$ 0.3 **2.2**	$B \to \bar{\mu}eK$ 0.3 **2.2**	*
3 3	*	*	$\mu \to 3e$ 1.6×10^{-2} **7.6**	$\mu \to 3e$ 1.3×10^{-2} **3.8**	$\mu \to 3e$ 8×10^{-3} **4.0**	$\mu \to 3e$ 3.7×10^{-3} **4.0**	*

Conclusions

* HERA I searched for LFV interactions both in the μ and τ channel.
* No evidence for LFV found at HERA up to now.
* Limits competitive with low energy experiments.
* Up to 3 times better limits with HERA upgrade