Search for Leptoquarks and LFV at the H1 Experiment

Linus Lindfeld, University of Zürich

H1 Collaboration

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Outline

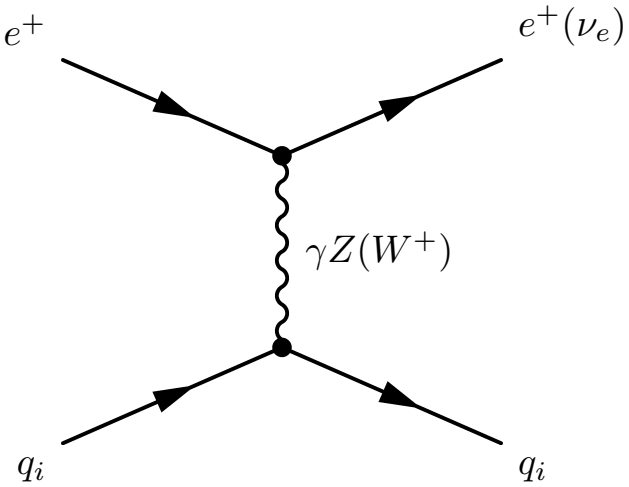
- Leptoquarks at HERA
- Search for Lepton Flavor Violation (LFV)
- Search for first generation LQs
- Conclusions

Leptoquarks at HERA

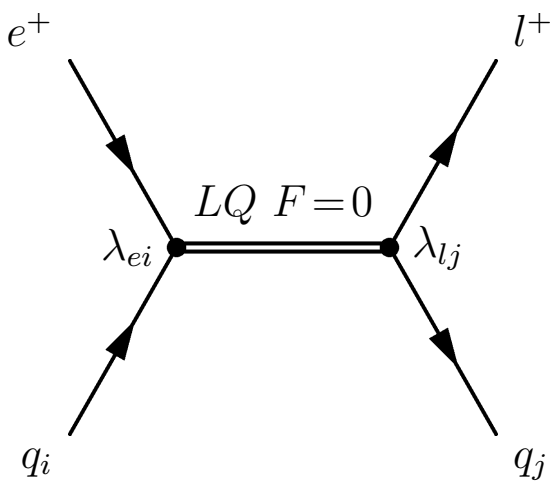
Leptoquarks
color triplet bosons
fractional charge
Both lepton and baryon number ≠0

Parameters
mass
coupling
quantum numbers

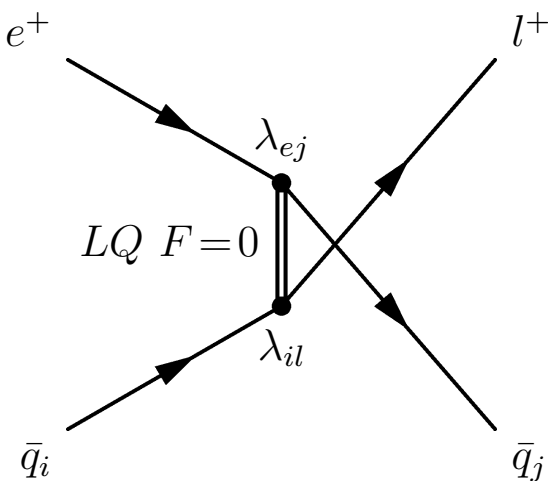
Leptoquarks couple to both quarks and leptons (LFV, if LQ → μ,τ + q)



SM DIS



s-channel $\sigma \sim \lambda^2$



u-channel $\sigma \sim \lambda^4$

narrow s-channel resonance in *x* at: $x_0 = \frac{M_{LQ}^2}{s}$ width:

$$\Gamma_{J=0} = \frac{1}{16\pi}\lambda_{L,R}^2 M_{LQ}$$

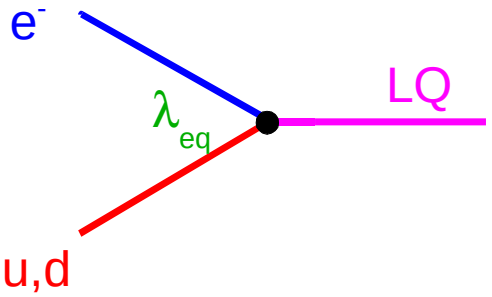
$$\Gamma_{J=1} = \frac{1}{24\pi}\lambda_{L,R}^2 M_{LQ}$$

Leptoquark production (BRW)

The most general LQ interactions with respect to SM symmetry groups $SU(3)_c \times SU(2)_L \times U(1)_Y$ yield 14 LQ-types classified by weak isospin, spin, chirality and fermion number: $F = |L + 3B| = 0, 2$

(Buchmüller, Rückl, Wyler, Phys. Lett. B191, 442, 1987)

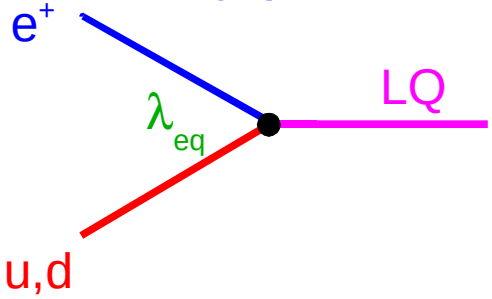
e^-p: Predominantly F=2 LQs are resonantly produced



Scalars, if $e_L q_L / e_R q_R$: $S_0^L,\ S_0^R,\ \tilde{S}_0^L,\ S_1^L$

Vectors, if $e_R q_L / e_L q_R$: $V_{1/2}^L,\ V_{1/2}^R, \tilde{V}_{1/2}^L$

e^+p: Predominantly F=0 LQs are resonantly produced



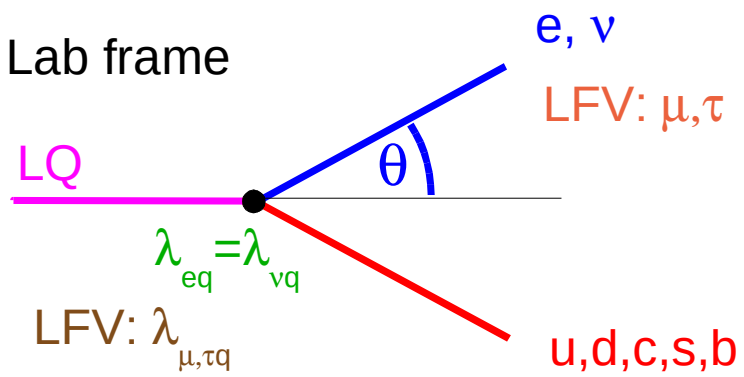
Scalars, if $e_L q_L / e_R q_R$: $S_{1/2}^L,\ S_{1/2}^R,\ \tilde{S}_{1/2}^L$

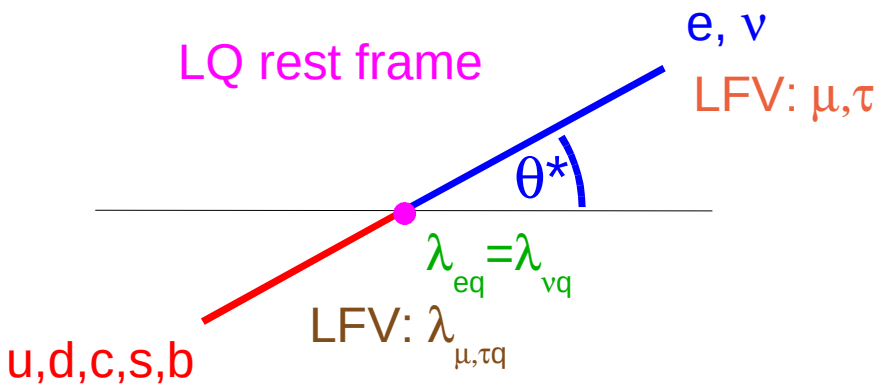
Vectors, if $e_R q_L / e_L q_R$: $V_0^L,\ V_0^R,\ \tilde{V}_0^L,\ V_1^L$

N.B.: In certain SUSY scenarios R_p-violating squarks couple as some scalar LQs, i.e.

$S_0^R: \quad e^- u \longrightarrow \tilde{d}_R,\ \tilde{d}_R,\ \tilde{b}_R,\ with\ \lambda'_{11k}$ $\qquad$ $\tilde{S}_{1/2}^L: \quad e^+ d \longrightarrow \tilde{u}_L,\ \tilde{c}_L,\ \tilde{t}_L,\ with\ \lambda'_{1j1}$

Leptoquark decay





s-channel scalar LQ: isotropic decay
s-channel vector LQ: $\sigma \sim (1 + \cos\theta^*)^2$

u-channel scalar LQ: $\sigma \sim (1 + \cos\theta^*)^2$
u-channel vector LQ: isotropic decay

LQ → eq, νq:

- NC and CC contributions considered for some LQs with CC decay channels
- interference with SM NC/CC included

BRW: gauge invariance leads to NC/CC branching ratio:

LQs with LQ → eq only: $\beta(\nu q) = 0$

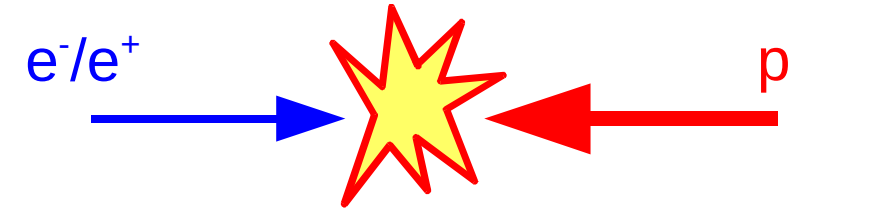
LQ → eq, νq: $\beta(\nu q) = 0.5$

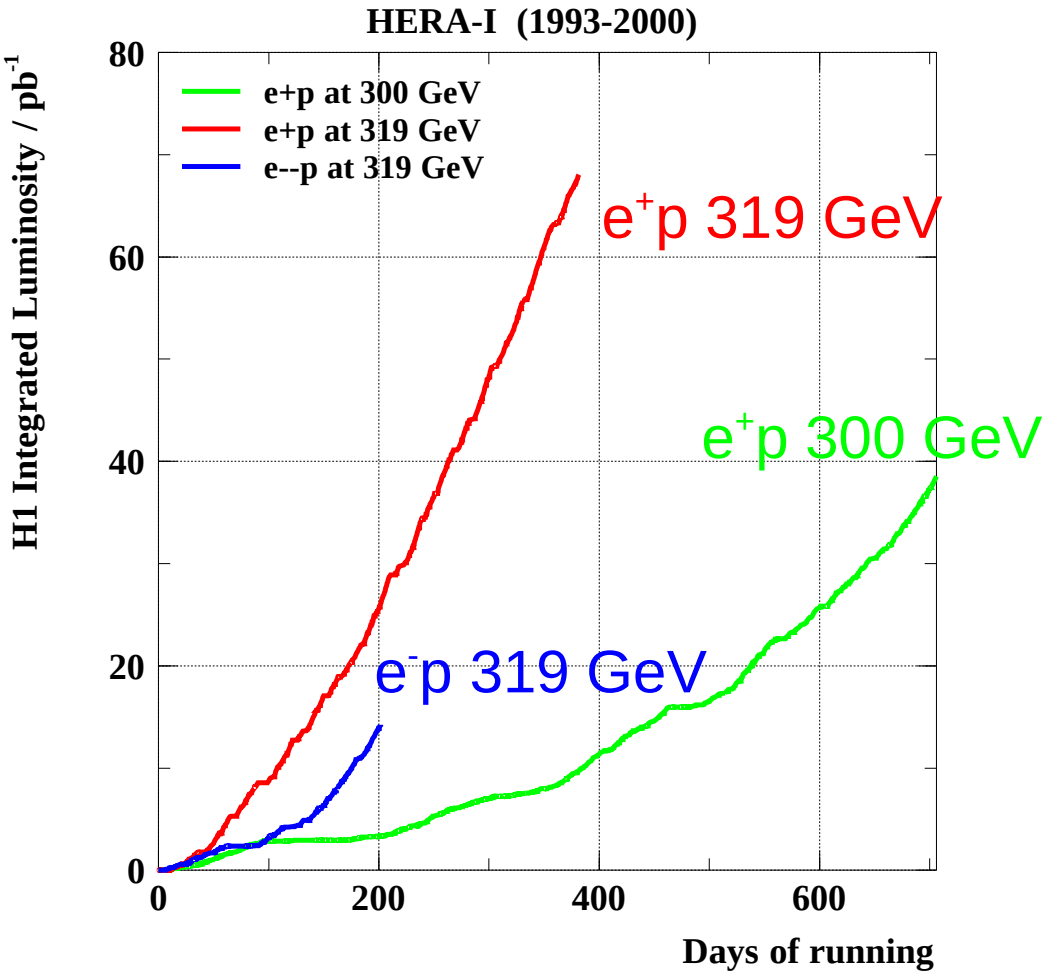
LFV:

- No CC contributions considered, neutrino flavors not detected

if lepton universality valid:
LFV branching ratio $BR_{LFV} = 0.5$

Data Analysis





Presented results refer to:

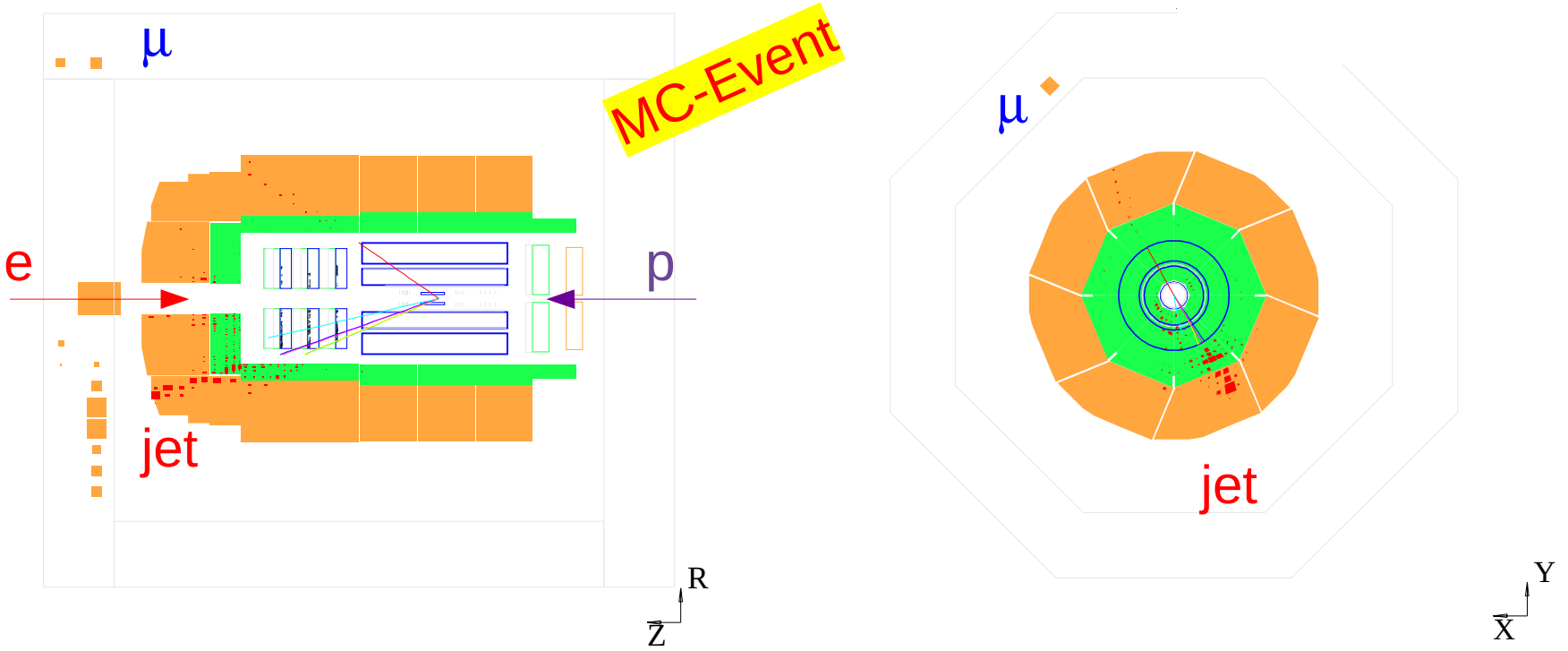
	H1 Luminosity
1994-97 e^+p:	37 pb^{-1}
1998-99 e^-p:	15 pb^{-1}
1999-00 e^+p:	65 pb^{-1}

Three Searches

- Search for LFV via LQ → μq
  - e^+p data from 1999-00: L = 65 pb^{-1}
- Search for LFV via LQ → τq
  - e^+p data from 1999-00: L = 65 pb^{-1}
  - Only hadronic decay channels of τ considered
- Search for LQs with LQ → eq, νq
  - e^-p and e^+p data from 94-00: L = 117 pb^{-1}

LFV: $ep \rightarrow \mu X$

Signature: isolated high p_T muon (no electron) back-to-back to high p_T jet



Main selection criteria:

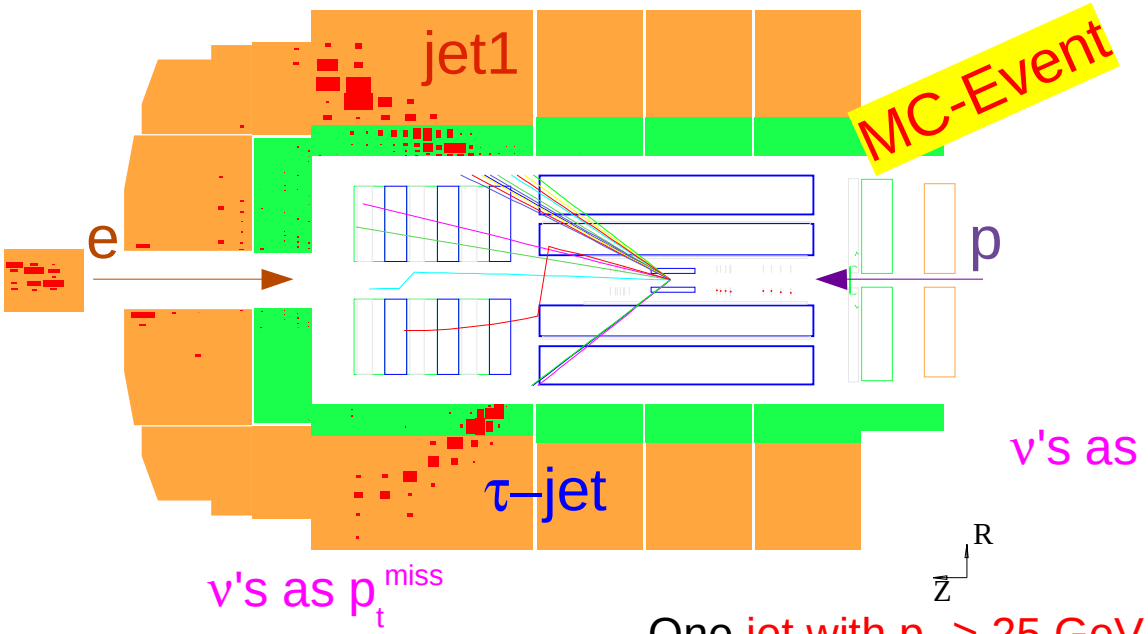
- One isolated muon with high transverse momentum: $P_T^{\mu} > 10$ GeV
- Muon escapes calorimeter: $P_T^{calo} > 25$ GeV
- Jet and muon acoplanar: $\Delta\phi(X\text{-}\mu) > 170^{o}$

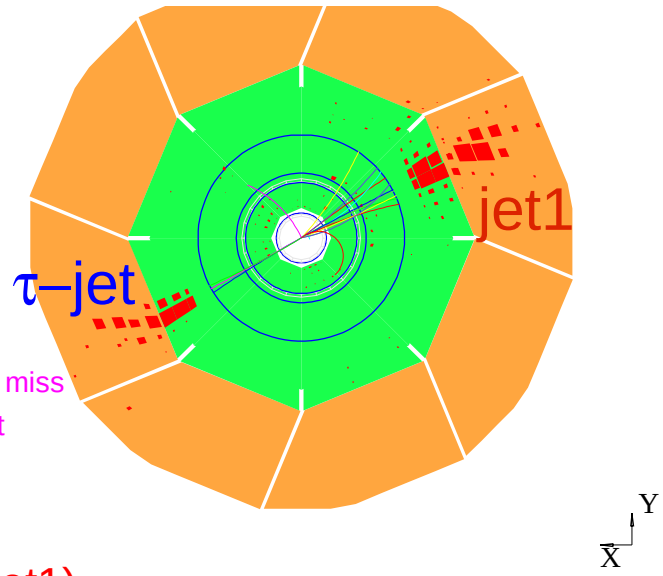
LFV: ep → τX

high-p_T preselection (CC-trigger, high Q^2-NC-trigger), veto electrons

"pencil-like" jet with 1-3 tracks to jet: narrow and hadronic

LQ specific: high p_t^{miss}, one high-p_T-jet & "τ-jet" aligned with p_t^{miss}





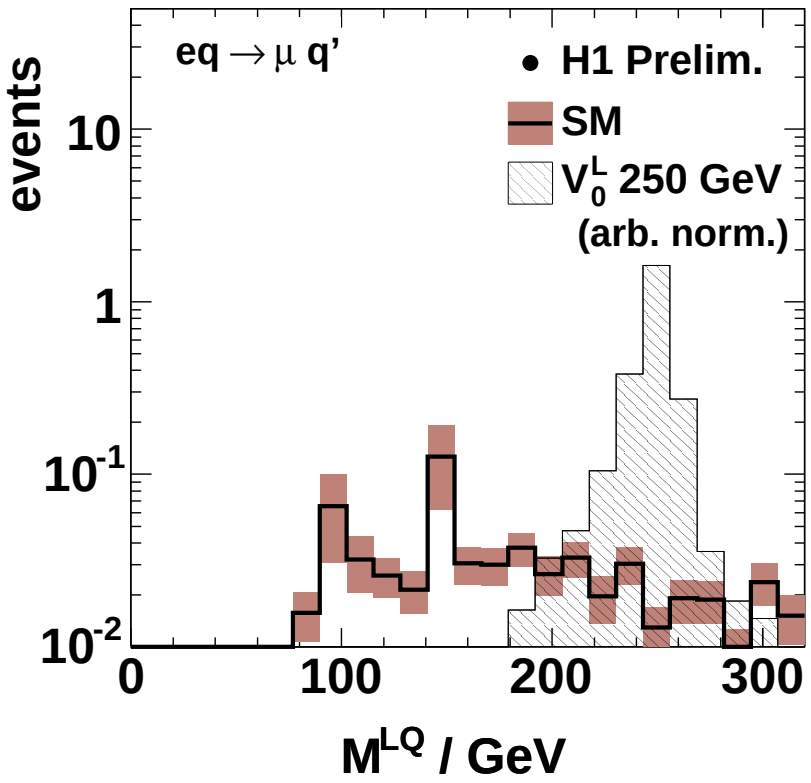
Main selection criteria:

- One jet with p_T > 25 GeV (jet1)
- Another *narrow* jet with p_T > 15 GeV (jet2), low track multiplicity
- Missing transverse momentum: p_T^{miss} > 20 GeV

LFV: Mass Spectra

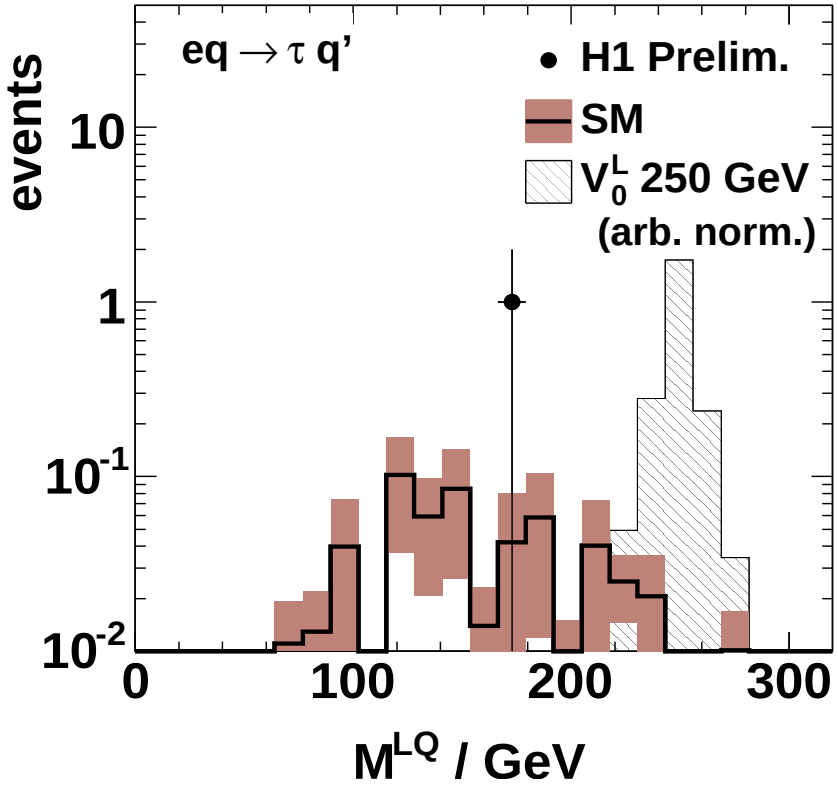
Muon

0 / 0.74 ± 0.25 events (obs. / exp.)
(background dominated by γγ → μμ)



Tau

1 / 0.56 ± 0.16 events (obs. / exp.)
(background dominated by NC, γP)

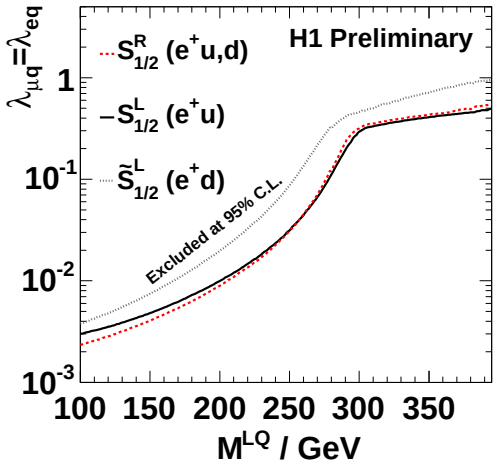


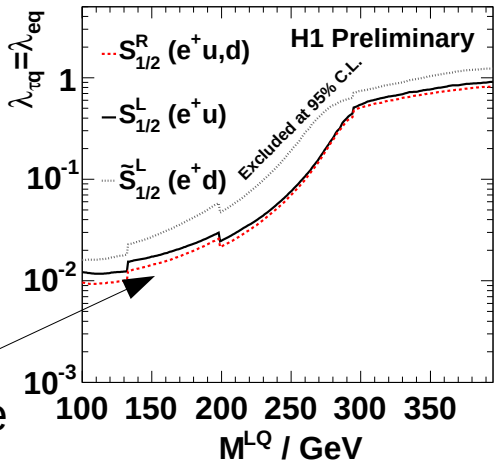
where $M_{LQ} = \sqrt{sx}$ reconstructed with double-angle method

LFV Limits on F=0 LQs

Muon | **Tau**

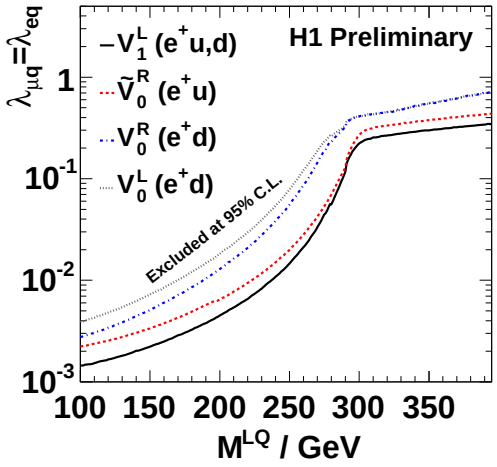
Scalar:

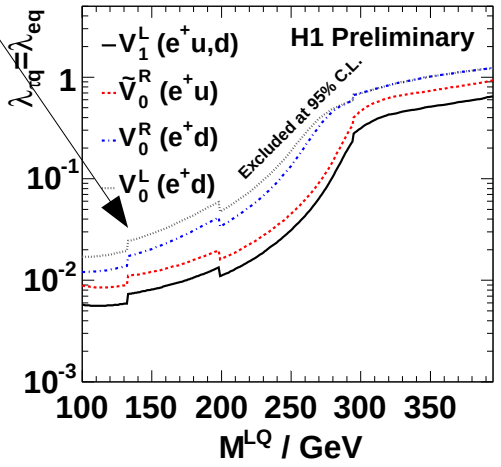




candidate event

Vector:

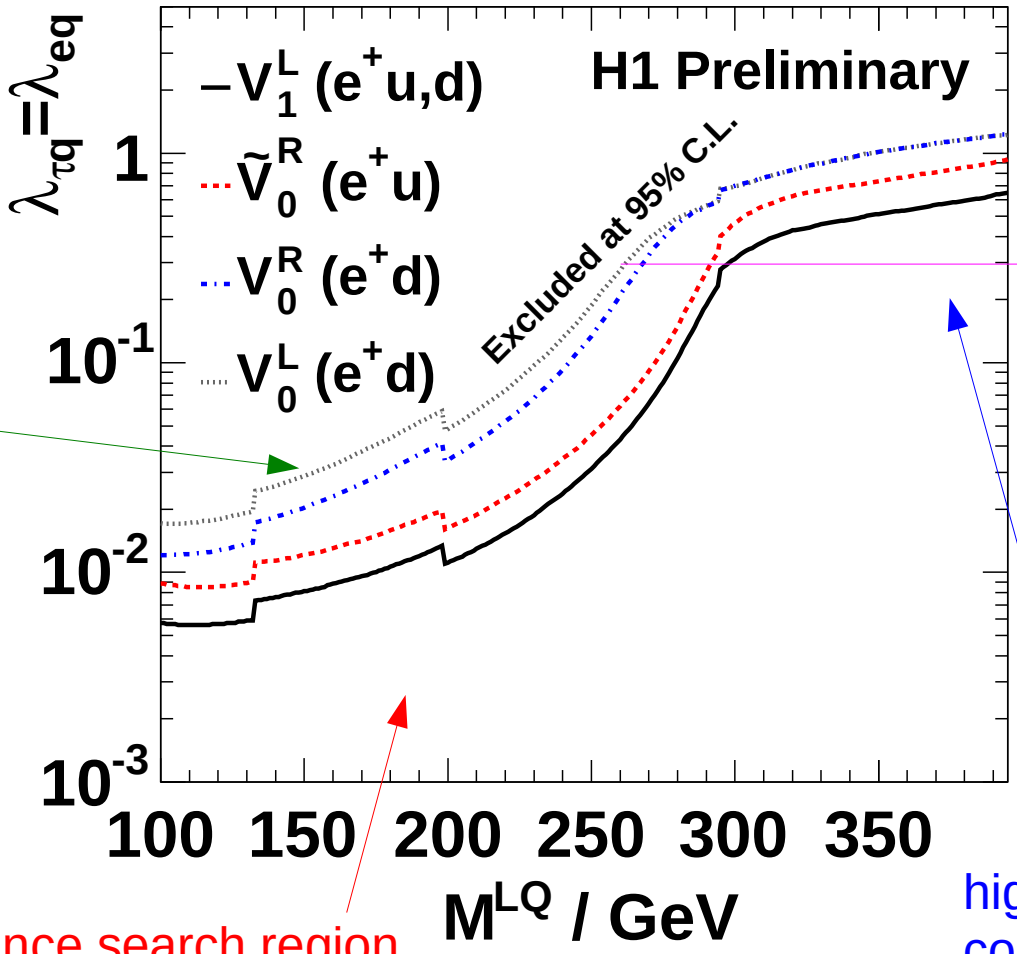




Limits shown on coupling $\lambda_{\mu q}=\lambda_{eq}$ and $\lambda_{\tau q}=\lambda_{eq}$

LFV Limits on F=0 LQs

Enlarged example: F=0 Vector LQs → τq



effect of τ-candidate event

e.g.:
for $\lambda_{\tau q}=\lambda_{eq}=0.3$, LFV mediated by $V_1^L \rightarrow \tau q$ is excluded up to 298 GeV

resonance search region

high mass limit:
contact interaction (CI) region

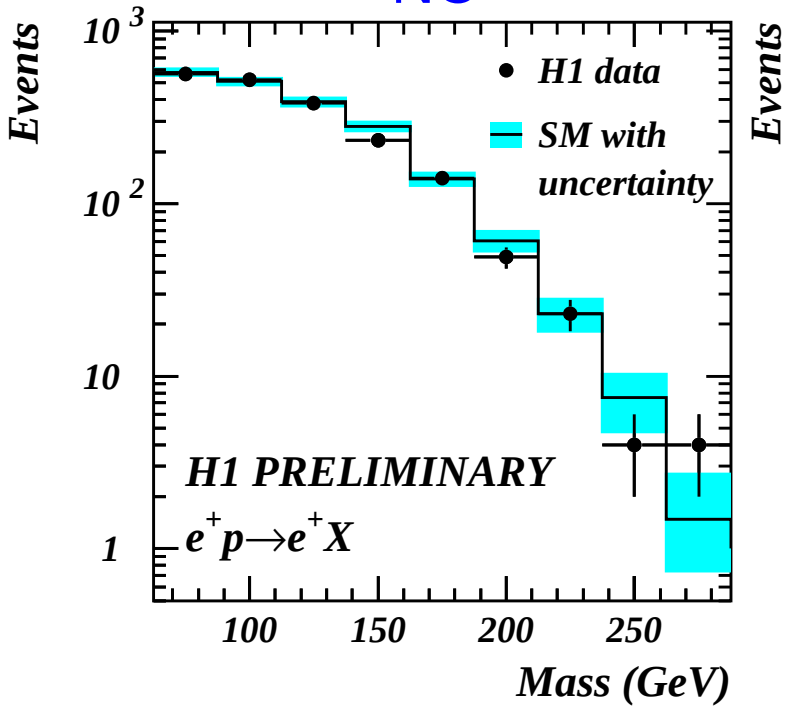
Search for LQ → eq, νq

Standard NC/CC selection with main cuts:

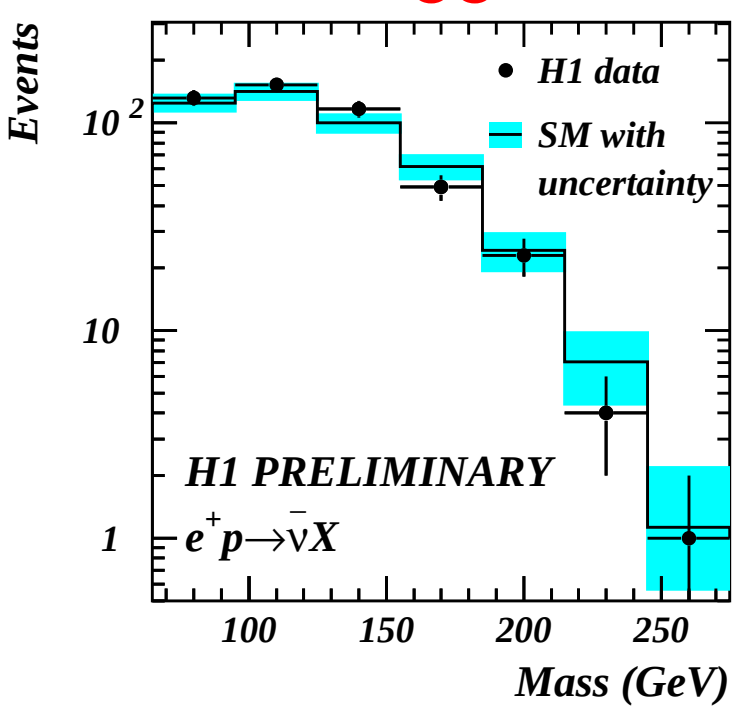
- $Q^2 > 2500\ GeV^2$ NC: $P_t(elec) > 15\ GeV$
- $0.1 < y < 0.9$ CC: $P_t(miss) > 25\ GeV$

Invariant LQ mass spectra from e^+p data (e^-p data similar):

NC



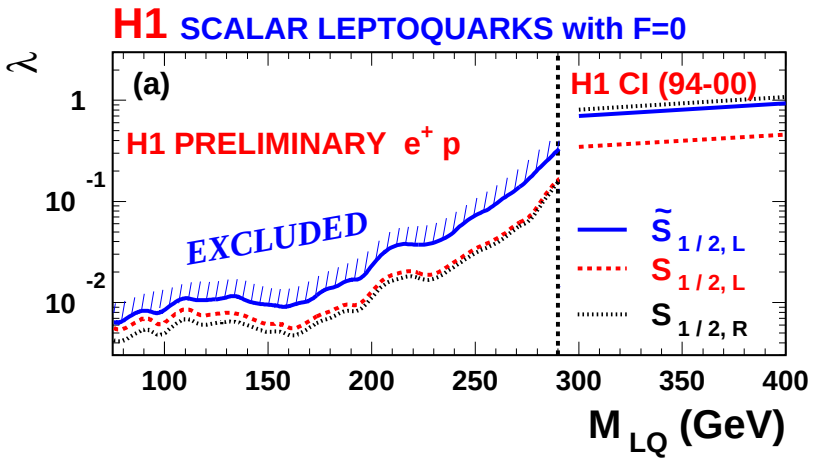
CC

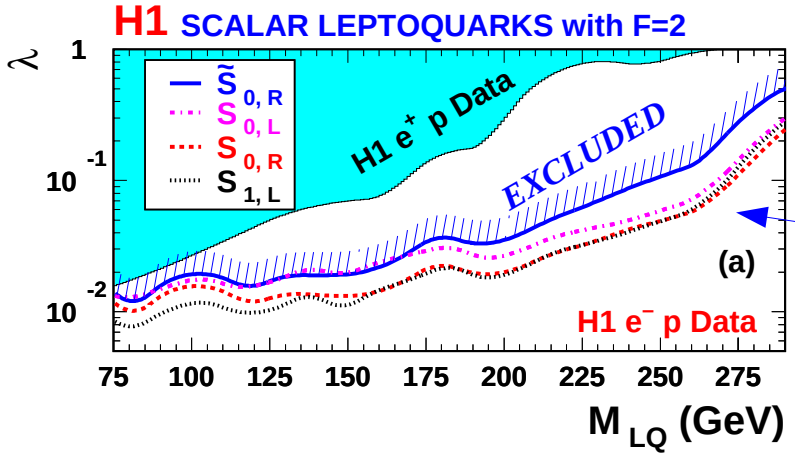


No significant deviation from SM

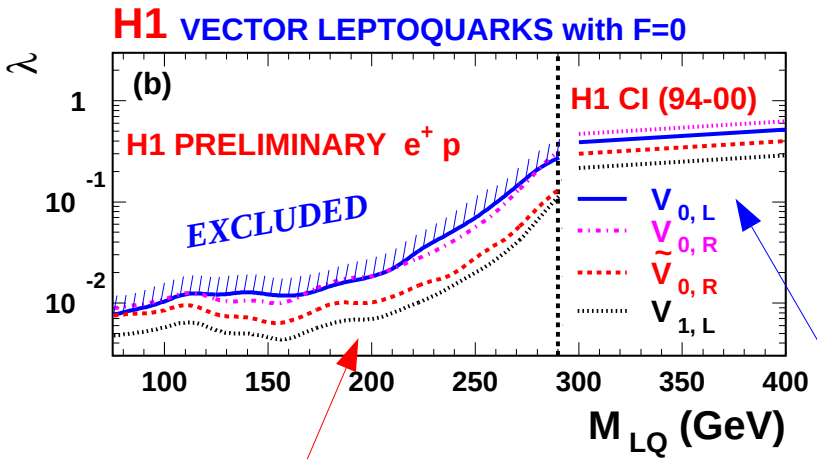
Search channels dominated by SM background

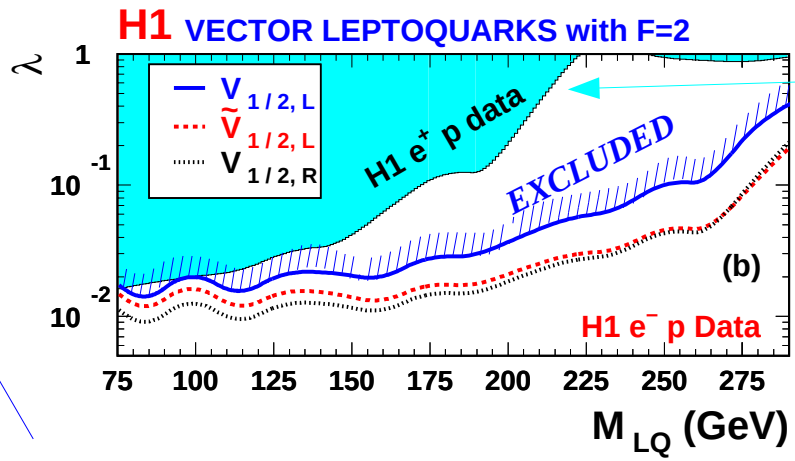
Limits on LQ → eq, νq





e⁻p data (98-99) sensitive to F=2 LQs



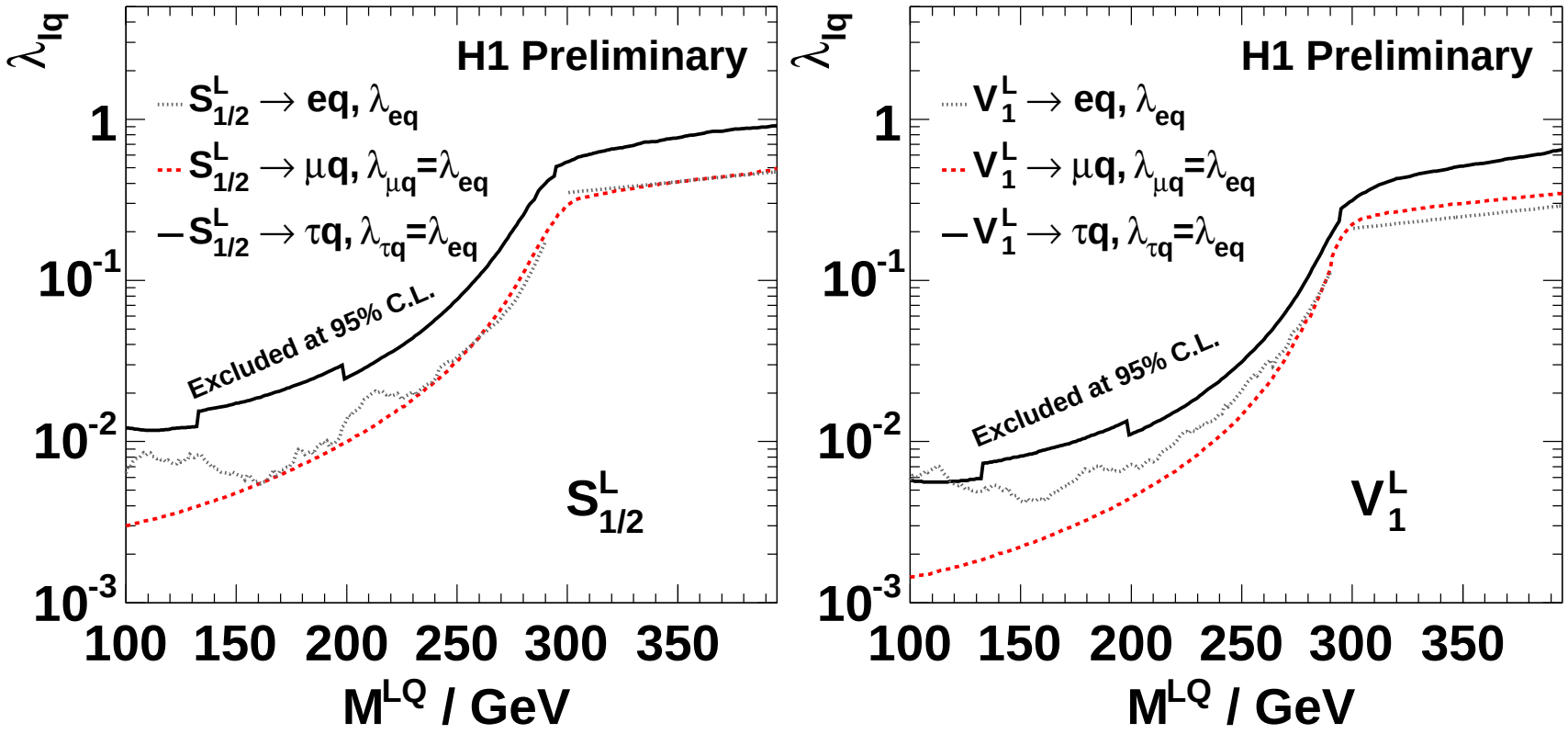


comparison shown to e⁺p data (94-97)

resonance search region

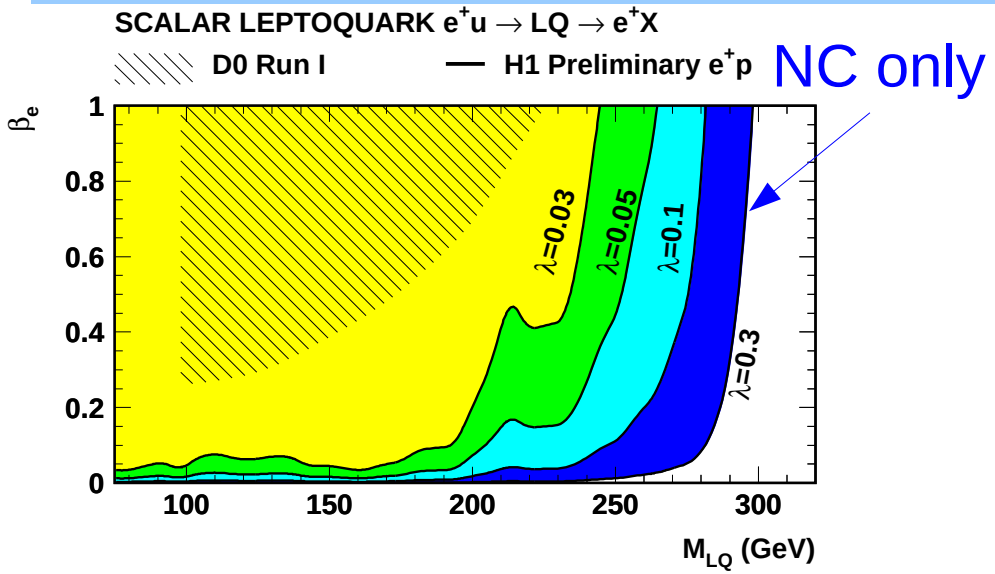
high mass limit: contact interaction (CI) region

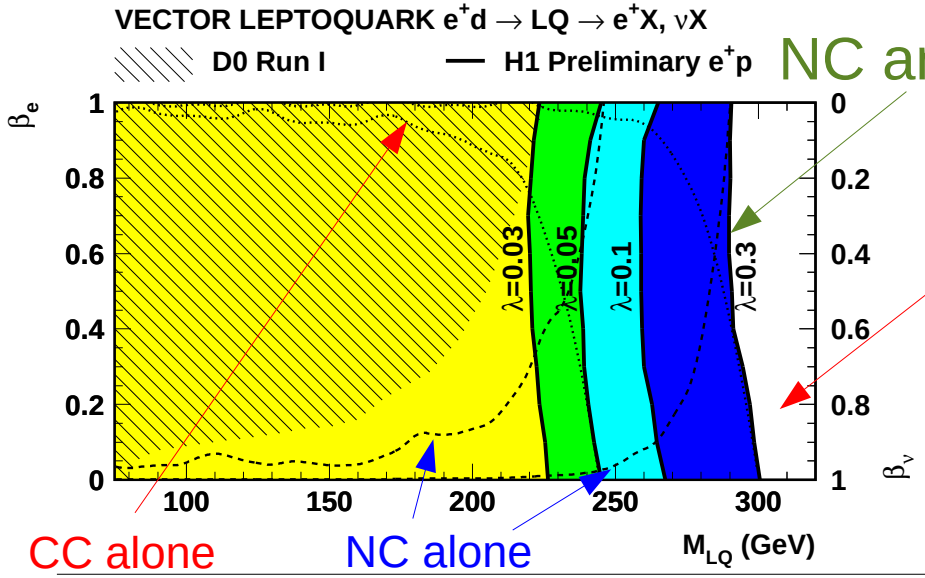
Results in Comparison



All three analyses give similar limits for both vector and scalar LQs

Extended model: free β





LQ → eq, νq with

- relaxed assumption w.r.t. BRW
- β is free parameter

LQs up to 300 GeV at λ=0.3 can be excluded

CC channels as sensitive as NC channels, combined limit independent of β

Compare to DØ Run I+II (hep-ex/0412029):

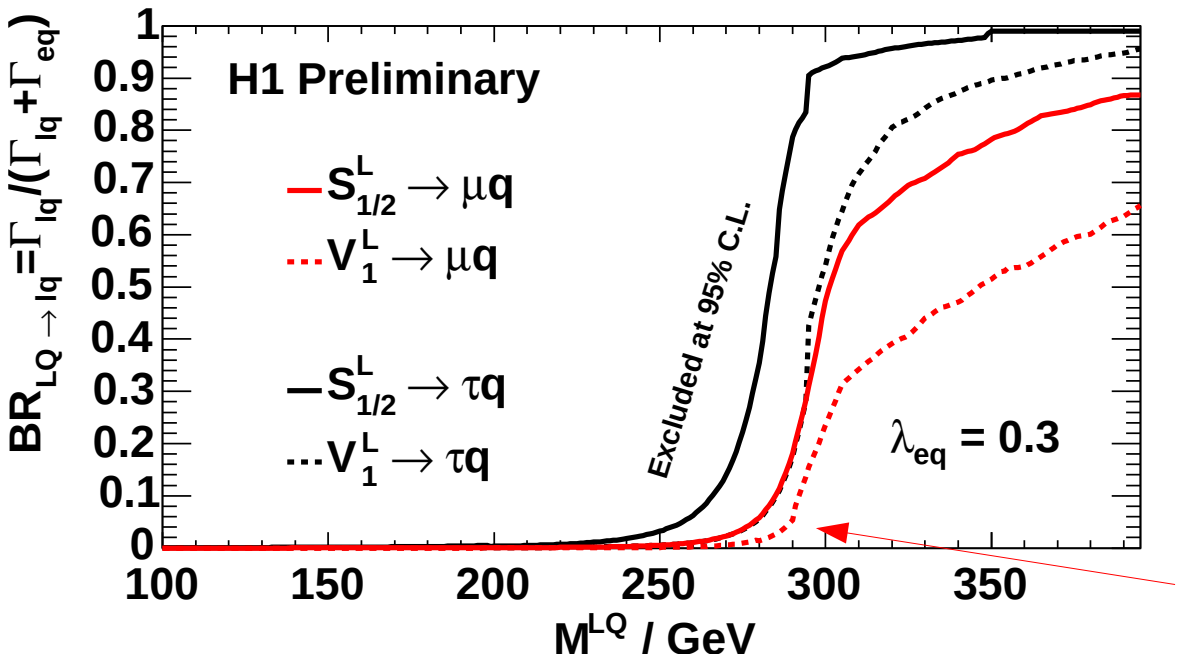
- $M_{LQ,\,sca} > 256$ GeV at $\beta_e = 1$
- $M_{LQ,\,sca} > 206$ GeV at $\beta_e = 0.2$
- limited sensitivity at low β_e

Extended model: free BR_{LFV}

LFV: LQ → μq, τq with

- no lepton universality
- BR_{LFV} free

LQ → μq, τq dominant



LQ → eq dominant

$$BR_{LQ \to lq} = \Gamma_{lq} / (\Gamma_{lq}+\Gamma_{eq})$$

e.g.:
for $BR_{LQ \to \mu q}$ down to 5%,
LFV mediated by $V_1^L \to \mu q$
is excluded up to 290 GeV
from μ–channel alone

Note: limits derived for exclusive channels only

Summary

- Searches for LQs and LFV have been performed at H1
- No evidence for LQs or LFV could be found
- Limits have been set on LFV mediated by LQs with F=0 in both the muon- and the tau-channel
- Competitive limits could be set on all types of LQs decaying to eq or νq final states
- Complementary HERA/Tevatron:
  - HERA needs some minimal coupling λ_{eq}
  - Tevatron needs some minimal branching ratio β