Search for Leptoquarks and Lepton Flavor Violation at the H1 experiment

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Abstract.
We review recent preliminary results of searches for leptoquarks (LQs) with the H1 experiment at HERA. A search for first generation leptoquarks was performed using the e^-p and e^+p scattering data collected between 1994-2000 corresponding to an integrated luminosity $\mathscr{L}_{\text{int}} = 117\,\text{pb}^{-1}$. In addition, the e^+p H1 data set of the period 1999-2000 ($\mathscr{L}_{\text{int}} = 66\,\text{pb}^{-1}$) was used to search for lepton flavor violating (LFV) processes mediated by second and third generation LQs. No evidence for direct or indirect production of LQs was found in either analysis. The analyses established constraints on the Yukawa coupling of LQs and LFV processes.

Keywords: H1, Leptoquark, LQ, LFV, BRW
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INTRODUCTION

Leptoquark (LQ) color triplet bosons appear naturally in many extensions of the standard model (SM). The ep-collider HERA provides a unique possibility to search for such new particles which couple to lepton-quark pairs. By the fusion of the initial state lepton of energy 27.6 GeV with a quark from the incoming proton of energy 820 GeV (1994-1997) or 920 GeV (1998-2000), single LQs of masses up to the centre-of-mass energy $\sqrt{s} = 319\,\text{GeV}$ can be resonantly produced. The phenomenology of LQs is described in detail in [1].

Singly produced LQs could also decay to a muon-quark pair or a tau-quark pair. Therefore, LQs are a convenient concept to explain such hypothetical exotic signatures inducing LFV at HERA.

SEARCH FOR LEPTOQUARKS (LQ)

Processes in ep-scattering involving a LQ decaying to an electron-quark or neutrino-quark pair lead to similar final states to those of NC and CC DIS at very high Q^2, the negative four-momentum tranfer squared. The differential cross section involves LQ, interference and SM contributions. The search is based on inclusive NC and CC DIS data in the kinematic domain $Q^2 > 2500\,\text{GeV}$ and $0.1 > y > 0.9$, where the ineleasticity variable y is defined as $y = Q^2/M^2_{\text{LQ}}$. The NC selection including an identified electron with transverse momentum above 15 GeV is decribed in [1]. The selection of CC-like events with a missing transverse momentum exceeding 25 GeV follows closely that presented in [1, 2].

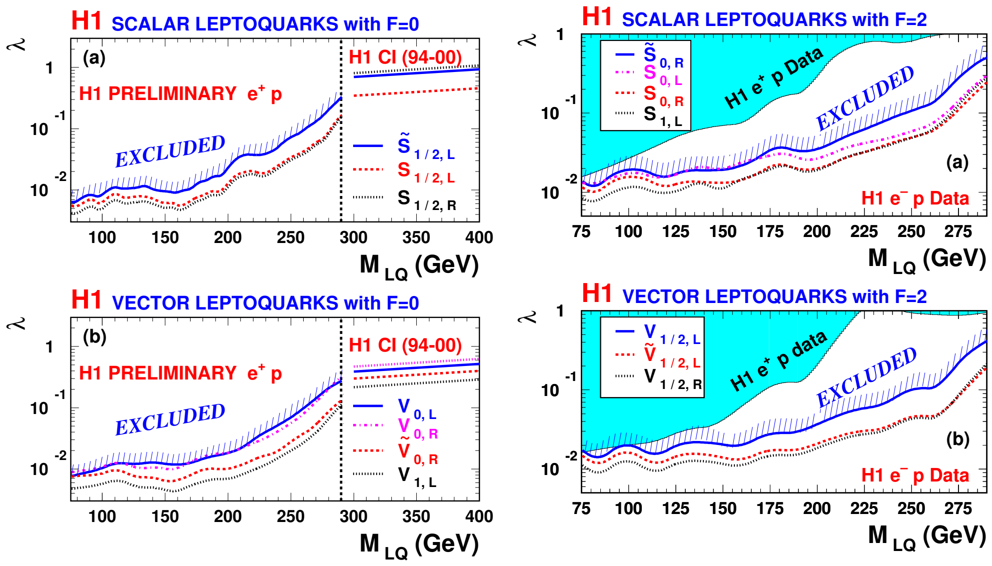

FIGURE 1. 95% CL exclusion limits on the Yukawa coupling λ as a function of the LQ mass for each of the 14 LQs described in the BRW model. Figures on the left-hand side show preliminary limits on $F = 0$ LQs up to a LQ mass of 290 GeV derived from e^+p data. Above the centre-of-mass energy of $\sqrt{s} = 319$ GeV, published limits for contact interaction (CI) processes are shown in addition. On the right-hand side published limits refer to $F = 2$ LQs derived from e^-p data.

The SM predictions, obtained using a DJANGO Monte Carlo [3] with CTEQ5D parametrisation [4] of the parton densities, describe the mass spectra of both NC- and CC-like data events very well. Since no evidence for LQ production is observed, constraints on LQs are set. To exploit fully the sensitivity to a LQ signal, all selected events are analysed in bins in the $M - y$ plane with varying size adapted to the experimental resolution and optimised with respect to the signal selection efficiency. Assuming poisson distributions for the SM expectation and the LQ signal, upper limits at 95% confidence level (CL) on the LQ production are deduced following a modified frequentist approach [5] to constrain LQ models.

Figure 1 shows limits on the Yukawa coupling λ of an electron[1]-quark pair to a LQ derived within the phenomenological model proposed by Buchmüller, Rückl and Wyler (BRW) [6]. In addition to the BRW model, where the branching ratio β_e (β_ν) is fixed to 0.5, constraints are derived on generic models where β_e (β_ν) is not fixed (see figure 2).

SEARCH FOR LEPTON FLAVOR VIOLATION (LFV)

In these analyses, searches for LFV in e^+p collisions mediated by LQs are performed. Only LQs with fermion number $F = |L + 3B| = 0$ are considered here[2]. For the de-

[1] electron or positron depending on the data taking period
[2] where L is the lepton number and B is the baryon number

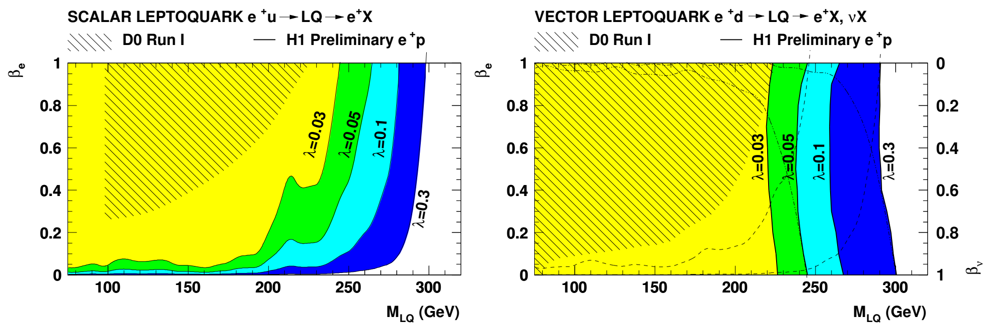

FIGURE 2. Mass dependent exclusion limits (95% CL) on generic models where the branching ratio β_e (β_ν) is not fixed. Left: Constraints on β_e of a scalar LQ which couples to e^+u (same quantum numbers as $S_{1/2,L}$). Right: Domains ruled out by combination of the NC (alone: lower dashed lines) and CC analyses (alone: upper dashed lines), for a vector LQ which couples to e^+d (same quantum numbers as $V_{0,L}$) and decays to eq and νq final states. Both figures show the resulting limits for four different Yukawa couplings λ. Hatched: Superceded coupling-independent limit of the DØ experiment (see latest results in [7]).

termination of the signal detection efficiencies the LEGO [8] event generator is used and the complete H1 detector response is simulated. The contributions from several SM background processes which may mimic the signal through measurement fluctuations are evaluated in this analysis. These processes include NC DIS, lepton pair production, W-production, photoprodution and CC DIS.

LQs with couplings to second generation leptons, leading to $\mu + q$ final states, exhibit a clear signature in the detector. Namely, an isolated high P_T muon "back-to-back" in the azimuthal angle, ϕ, with respect to the hadronic final state (HFS) is balanced in P_T with the HFS. In general, a muon deposits only a very small fraction of its energy in the LAr calorimeter, so the signal is expected to exhibit large P_T^{Calo}, where P_T^{Calo} is the measured P_T reconstructed from all clusters recorded in the calorimeter. A detailed description of the selection criteria can be found in [9].

The search for LQs possessing couplings to a third generation lepton leading to $\tau + q$ final states is restricted to hadronic decays of the tau. Hadronic decays of a high P_T tau lead to a typical signature of a "pencil-like" τ-jet. This τ-jet is characterised by a narrow shape in the calorimeter and low track multiplicity, i.e. one to three tracks in the identification cone of the jet. The signal topology is a dijet event with no leptons. The missing transverse momentum in the event carried by the neutrino(s) from the tau decay is aligned with the second highest P_T jet (jet2), which has to fulfil the τ-jet criteria. A detailed description of the selection criteria can be found in [10].

The results of the selections in the muon and tau channel are summarised in table 1. In order to set limits on the signal cross section, the mass spectra are scanned for signals using a sliding mass window with optimised borders. Within this window the number of data events, background events and the selection efficiency are used to calculate an upper limit on the signal at a 95% CL [5]. Applying the BRW model to second and third generation leptons, these limits are converted into limits on the couplings $\lambda_{\mu q}$ and $\lambda_{\tau q}$. The obtained limits are shown in figure 3 for one of the scalar and one of the vector LQs with an assumed LFV branching ratio of $BR_{\mathrm{LQ}\to\mu q,\tau q} = BR_{\mathrm{LQ}\to eq}$. The constraints on LQs coupling to first generation leptons only are shown as comparison.

TABLE 1. Results of the search for LFV. Statistical and systematic errors are added in quadrature.

$\mathscr{L} = 66\,\text{pb}^{-1}$	**H1 Data***	**SM Total**	**NC DIS**	**Lepton Pairs**	**Photo-Production**	**W-Production**
$\text{LQ} \to \mu + q$	0	0.74 ± 0.25	0.09 ± 0.05	0.50 ± 0.24	0.06 ± 0.07	0.08 ± 0.02
$\text{LQ} \to \tau + q$	1	0.56 ± 0.16	0.37 ± 0.13	< 0.01	0.13 ± 0.04	0.06 ± 0.02

* preliminary

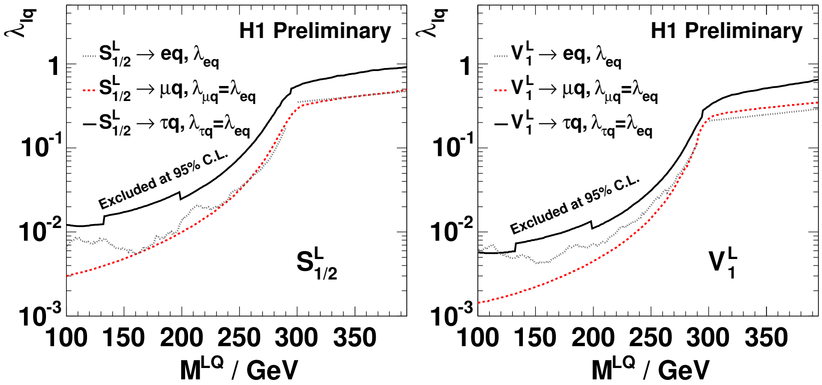

FIGURE 3. Limits on the coupling strength λ_{lq} at 95% C.L. for $S^L_{1/2}$ and V^L_1.

CONCLUSIONS

In recent searches for LQs with the H1 experiment at HERA no signal has been observed and constraints have been set. LQs up to a mass of 290 GeV and a Yukawa coupling of electromagnetic strength could be ruled out.

Also, a search for LFV mediated by LQs coupling to second and third generation leptons in e^+p collisions has been performed. No evidence has been found for lepton flavor violation in neither the muon nor the tau decay channel. Assuming a Yukawa coupling of electromagnetic strength, couplings of scalar (vector) LQs with masses up to 275-300 (288-330) GeV to second generation leptons, and couplings of scalar (vector) LQs with masses up to 260-284 (278-300) GeV to third generation leptons are excluded.

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