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LEPTOQUARKS SEARCHES AT HERA*

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Results from the leptoquark searches at HERA using the reaction $e^{\pm}p \to e^{\pm}(\nu)X$, are reported. The data was collected by the H1 and ZEUS experiments from 1994 to 2000, at c.m. energies of 300 and 318 GeV and correspond to a total integrated luminosity $\sim$ 120 pb^{-1} for each experiment. No signal was seen and limits were set on leptoquark Yukawa couplings for leptoquark masses both above and below $\sqrt{s}$. The results are compared to those obtained in direct and indirect searches at other colliders.

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1. Introduction

The *ep* collider HERA is an unique place to search for new particles coupling to a lepton–quark pair. Such particles, called leptoquarks (LQ), appear in many extensions of the Standard Model (SM). They carry both colour and a fractional electric charge as well as a lepton and baryon number. The general classification of leptoquark states proposed by Buchmüller, Rückl and Wyler (BRW) [1] is used. There are 7 scalar and 7 vector leptoquarks states. All of them can couple to an *eq* pair and can contribute to NC DIS events. In addition 4 states couple to both *eq* and νq and so can contribute to CC DIS.

This note reviews results for the leptoquarks searches at HERA based on the data collected by H1 and ZEUS from 1994 to 2000.

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2. Leptoquark production

At HERA, LQ may be produced directly from s-channel $e^{\pm}$–quark fusion with subsequent decay into $e^{\pm}$–quark, or $\nu(\bar{\nu})$–quark yielding peaks in the lepton-jet invariant mass spectrum for the $e^{\pm}p \to e^{\pm}(\nu)X$ reactions. LQ may also be exchanged in the u-channel, which effects the high Q^2 cross section for NC (CC) DIS, mainly due to the interference with the SM t-channel exchange of Z^0/γ $(W^{\pm})$. The diagrams are shown in Fig. 1. Resonant LQ

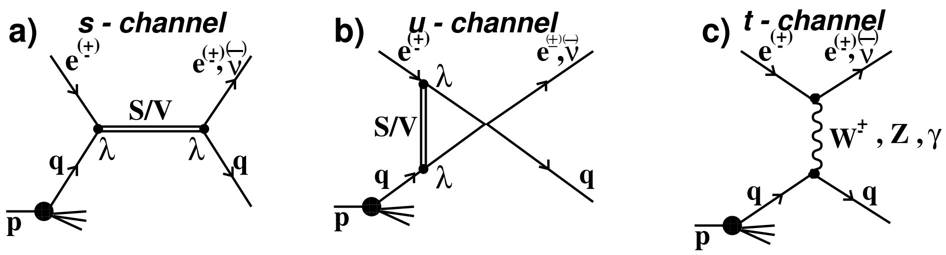


Fig. 1. Processes with $e\nu$ -jet final states in $e^{\pm}p$ collisions. A scalar (S) or vector (V) intermediate state can contribute to such final states via (a) s-channel or (b) u-channel exchange. DIS processes (c) form the primary background to these processes.

production for masses up to $\sqrt{s}$ dominates the cross section if the LQ is produced from a valence quark (production of $F = 2$ leptoquarks in e^-p scattering and $F = 0$ in the e^+p case). In the narrow-width approximation, which is valid for small Yukawa coupling λ, the LQ production cross section is given by [1]:

$$\sigma^{\rm NWA} = (J+1)\frac{\pi}{4s}\lambda^2 q(x_0,\mu)\,, \tag{1}$$

where J represents the spin of the LQ, $q(x_0,\mu)$ is the quark density evaluated at $x_0 = m_{\rm LQ}^2/s$ and with the scale set to $\mu = m_{\rm LQ}^2$.

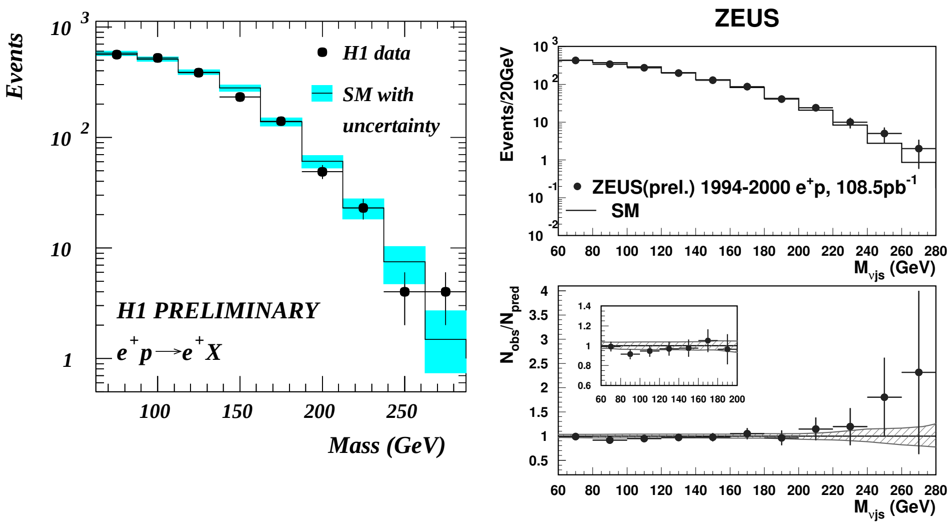
The u-channel exchange and interference terms become important for large leptoquark masses, $m_{\rm LQ} > \sqrt{s}$, and result in deviation of high-x NC and CC DIS cross section from the SM predictions. Either, increase or decrease of the cross section is possible, depending on the sign of the interference term.

3. Event reconstruction

Assuming no QED or QCD radiation, the invariant mass M of the scattered lepton–quark pair and the scattering angle in the lepton–quark center-of-mass system $\theta^\star$ can be calculated from the kinematics of DIS events, as:

$$M^2 = \frac{Q_e^2}{y_e}\,, \qquad y_e = 0.5\,(1 - \cos\theta^\star)\,, \tag{2}$$

where, the kinematic variables are obtained using the electron information. This method is used by H1 [2]. In the ZEUS analysis the invariant mass is calculated from the measured four-momenta of the outgoing lepton and of the hadronic final state [3]. In case of CC DIS events, the energy and angle of the scattered ν is reconstructed assuming energy-momentum conservation [4]. The mass distributions for NC and CC DIS events measured by H1 and ZEUS, respectively, are shown in Fig. 2. The more details has been reported in [5, 6] The data are in good agreement with the Standard Model predictions.



(a) (b)

Fig. 2. (a) — the e-jet mass distribution for the data (points) and SM expectation (histograms) for H1. (b) — the ν-jet mass distribution for the data (points) and SM expectation (histograms) and the ratio of the number of events observed to the number expected, $N^{\rm obs}/N^{\rm exp}$ for ZEUS.

4. Results

Since there is no evidence for a resonant production, or cross section deviations at high masses, limits on LQ couplings were derived for different BRW LQs. Both collaborations extract the limits on the Yukawa coupling λ as a function of the LQ mass using the two-dimensional distribution in the plane $M_{\rm LQ} - \cos\theta^\star$ of the NC and CC events. The limit setting procedure has been described in [5, 6].

Fig. 3 shows for a scalar and vector LQ species with fermion number $F = 0$, the 95% CL exclusion limits in the mass-coupling plane as obtained by H1 and ZEUS. The areas above the curves are excluded.

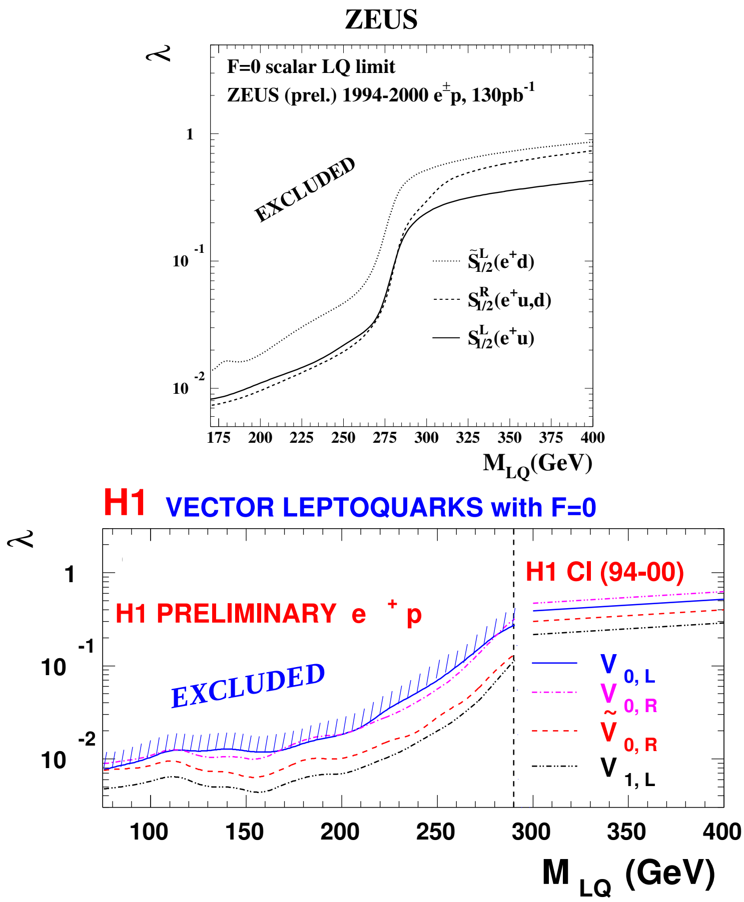


Fig. 3. Coupling limit as a function of LQs mass for $F = 0$ BRW LQ. The limits on scalar LQs are shown in the upper plot while the limits on vector LQs in the lower one.

Fig. 4 compares the H1 and ZEUS results for two selected scalar leptoquarks ($S_0^{\rm L}$ and $S_{1/2}^{\rm R}$), with limits from other experiments. The coupling independent limits come from $p\bar{p}$ collision at the Tevatron [8], where leptoquark pairs can be produced via the standard gauge couplings ($p\bar{p} \to$ LQ$\bar{\rm L}$QX). The $S_0^{\rm L}$ ($S_{1/2}^{\rm R}$) scalar leptoquarks with masses 213 (245) GeV are excluded at 95% confidence level. Indirect limits on leptoquarks from LEP [7] have been obtained by t-channel and u-channel contribution to quark-pair production ($e^+e^- \to q\bar{q}$). The leptoquark limits at HERA are complementary to Tevatron limits and better than LEP limits.

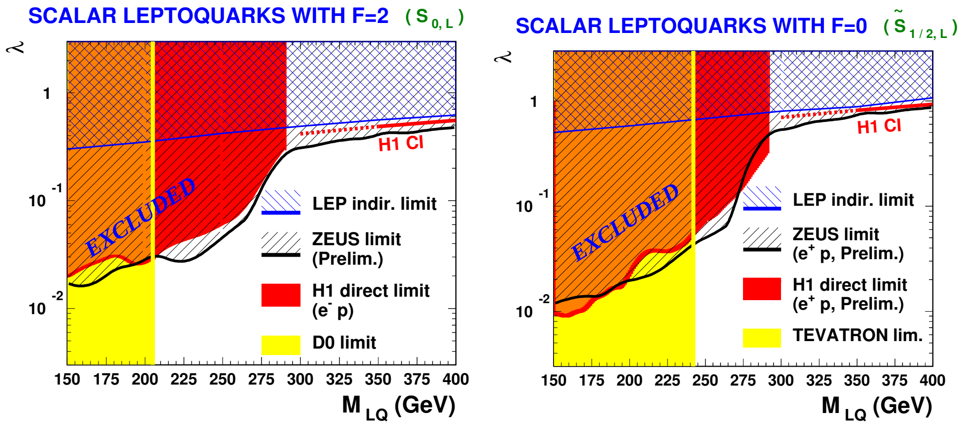


Fig. 4. Comparison of excluded regions in the mass-coupling plane for the $S_0^{\rm L}$ and $S_{1/2}^{\rm R}$ leptoquarks from HERA, Tevatron and LEP. Constraints on LQs with masses above $\sqrt{s}$ obtained from H1 Contact Interaction analysis, are shown as a dashed line in the rightmost part of each plot.

5. Conclusion

Results for the leptoquark searches at HERA, with the ZEUS and H1 experiment, from the reaction $e^{\pm} \to e^{\pm}(\nu)X$, are reported. The data correspond to a total integrated luminosity ~ 120 pb^{-1} for each experiment. No evidence for a signal was found. Limits were set on leptoquark Yukawa couplings for leptoquark masses below and above $\sqrt{s}$. The results are compared to those obtained in direct and indirect searches at other colliders.

None of the research reported here would have been possible without the dedicated efforts of the HERA crew, and of all those who contributed to design, construction, maintenance and operation of the detectors. I would like to thank my colleagues of the working groups for particle searches in H1 and ZEUS.

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