Leptoquark Searches at H1

Ilias Papagoulias

On behalf of the H1 Collaboration
National Technical University of Athens - Dept of Physics
Zografou Campus, GR15780 Zografou - Greece

Recent results of searches for leptoquarks with the H1 experiment at HERA are presented. A search for scalar and vector leptoquarks coupling to first generation fermions is performed using the full $e^+p$ and $e^-p$ scattering data collected by the H1 experiment between 1994 and 2007. A search for lepton flavor violating processes $ep \rightarrow \mu X$ is performed using all HERA II $e^-p$ data. No evidence for the direct or indirect production of such particles is found. The results are interpreted in terms of limits on the Yukawa coupling of leptoquarks and lepton flavor violating processes.

1 Introduction

The $ep$ collider HERA offers the unique possibility to search for the resonant production of new particles which couple directly to a lepton and a parton. Leptoquarks (LQs), colour triplet bosons, which appear naturally in various unifying theories beyond the Standard Model (SM) are such an example. At HERA, LQs could be resonantly produced in the s-channel or exchanged in the u-channel between the initial state lepton of energy 27.6 GeV and a quark coming from the proton of energy up to 920 GeV. Results derived from $117$ pb$^{-1}$ of data have been reported earlier [2]. This note presents a preliminary search for LQs coupling to first generation fermions with fermion numbers $F = 0$ and $F = 2$ in scattering of longitudinally polarised electrons or positron on protons at a centre-of-mass energy of $\sqrt{s_{ep}} \approx 320$ GeV, using the full HERA data collected by the H1 experiment which correspond to a total integrated luminosity of $449$ pb$^{-1}$.

The LQ concept can also be used to search for lepton flavor violation (LFV) processes in electron-proton collisions. In $ep$ collisions at HERA, LFV processes $eq \rightarrow LQ \rightarrow \mu\bar{q}$ and $eq \rightarrow LQ \rightarrow \tau\bar{q}$ may lead to final states with a muon or a tau lepton. Results derived from $80$ pb$^{-1}$ of $e^+p$ data have been reported in [3]. New preliminary results are presented here for the decay $eq \rightarrow LQ \rightarrow \mu q$, using $158$ pb$^{-1}$ of $e^-p$ data.

2 Search for Leptoquarks

Due to the more favourable quark-densities of quarks with respect to anti-quarks at high $x$, the $e^-p$ data sets are mostly sensitive to LQs with fermion number $F = 2$, whereas $e^+p$ collisions are more favourable for the production of $F = 0$ LQs. The fermion number $F$ is given by $F = |B + L|$ with $B$ and $L$ being the baryon and lepton number respectively. The search reported here considers the decays $LQ \rightarrow eq$ and $LQ \rightarrow \nu\bar{q}$. These LQ decays lead to final states similar to those of deep-inelastic scattering (DIS) neutral current (NC) and charged current (CC) interactions at very high $Q^2$, the negative four-momentum transfer squared. If the final state is of type $eq$, the LQ mass is reconstructed from the measured kinematics of the scattered electron. If the final state is of type $\nu\bar{q}$, the LQ mass is reconstructed from the hadronic final state [2].
This search is based on inclusive NC and CC DIS data in the kinematic domain $Q^2 > 500 \text{ GeV}^2$ and $0.1 < y < 0.9$, where the inelasticity variable $y$ is defined as $y = Q^2/M^2_{LQ}$, and $M_{LQ}$ is the reconstructed mass of the $eq$ system. The mass spectra measured for NC-like and CC-like events obtained by combining all data sets are shown in Figure 2. The data are found to be in good agreement with the Standard Model (SM) predictions, based on a Monte-Carlo calculation [4] and the CTEQ6D parametrisation [5] for the parton densities. No evidence for LQ production is observed in either the NC or CC data samples. Further sensitivity to the LQ production is obtained using the inelasticity variable $y$. To make use of the different distributions for DIS, scalar and vector leptoquarks, all selected events are analysed in the $M - y$ plane, with a procedure designed to fully exploit the sensitivity to the signal. The statistical method has been described in detail in [2].

The resulting limits on the LQ coupling as a function of the LQ mass are shown in Figure 2. A total of 14 LQ types were investigated, as described by the Buchmüller–Rückel and Wyler (BRW) model [6]. The areas above the curves are excluded at 95% confidence level. The strongest constraints on the coupling $\lambda$ can be set for LQ masses below the kinematic limit of HERA. At higher masses the production is not resonant anymore but contact interaction–like and the cross-section scale approximately with $(\lambda/M_{LQ})^4$. For a coupling of electromagnetic strength $\alpha_{em}$ ($\lambda = \sqrt{4\pi\alpha_{em}} = 0.3$) this analy-

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**Figure 1:** Mass spectra of the complete HERA I+II $e^\pm p$ data for Neutral Current and Charged Current events in the H1 leptoquark analysis. The points are the data, which are compared to the SM expectation (histogram). The shaded band indicates the uncertainty on the SM expectation.

**Figure 2:** Exclusion limits for the 14 LQs described by the BRW model. The limits are expressed at 95% CL on the coupling $\lambda$ as a function of the leptoquark mass. Domains above the curves are excluded.
sis rules out LQ masses below 291 to 330 GeV, depending on the LQ type.

Figure 3 summarises the constraints on the $\tilde{S}_{1/2,L}$ and $S_{0,L}$ obtained by H1, by the L3 experiment at LEP [8], and by the D0 experiment at the Tevatron [9]. The limits shown from LEP are from indirect constraints on $e^+e^- \to q\bar{q}$. The limits from the Tevatron are independent of the coupling $\lambda$ as they were derived from pair production processes. The published H1 results [2] from the HERA I phase are shown for comparison. An unique domain is probed at HERA for LQ masses above Tevatron mass reach and LQ couplings outside the LEP sensitivity.

3 Search for Lepton Flavor Violation

This analysis presents a search for LFV mediated by LQs with $F = 2$. Only the decay $LQ \rightarrow \mu X$ is considered. LQs with couplings to the first and second generation leptons can be produced in $ep$ collisions and may decay to a muon and a quark. The signature is an isolated muon with large transverse momentum which is back-to-back in the transverse plane with the hadronic final state. The fact that a high energetic muon only leaves a minimal energy deposit in the calorimeter leads to a high net transverse momentum, $p_{T}^{\mu}$, reconstructed from all clusters recorded in the LAr calorimeter. The background is dominated by lepton pair production and W boson production.

The leptoquark mass spectrum obtained after the final selection is shown in Figure 4. Two candidate events are observed in the data. Both events are consistent with background lepton pair production processes.

As no evidence for LQ production is observed, limits are set on the couplings of LQs to first and second generation leptons. Upper limits on the the coupling $\lambda_{\mu q}$ of the 7 LQ types coupling to a muon-quark pair with $F = 2$ are determined as a function of the LQ mass. Assuming lepton universality the couplings $\lambda_{\mu q}$ are taken to be equal to $\lambda_{e q}$. The resulting constraints are shown in Figure 5.
4 Conclusion

A search for leptoquarks production is performed using the polarized $e^-$ and $e^+$ data recorded by H1 at HERA II in the period 2003-2007. No signal is observed, in agreement with previous investigations at HERA I. Constraints on leptoquarks are set, which extend beyond the domains previously excluded. For a coupling of electromagnetic strength, LQ masses below 291 -- 330 GeV can be ruled out, depending on the LQ type.

No signal for the LFV process $e p \rightarrow \mu X$, mediated by LQs, is found analysing the complete $e^-$ data set from HERA II running fase. For couplings of electromagnetic strength, LQ mediating lepton flavor violating process $e \rightarrow \mu$ can be ruled out up to mass of 433 GeV.

References

[1] Slides: http://indico.cern.ch/materialDisplay.py?contribId=102&sessionId=15&materialId=slides&confId=94657

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