SEARCH FOR CONTACT INTERACTIONS AND LEPTOQUARKS AT HERA

C. NIEBUHR

on behalf of the H1 and ZEUS collaborations

DESY, Notkestr. 85, D-22603 Hamburg

E-mail: niebuhr@mail.desy.de

Recent results on searches for contact interactions and for leptoquarks from the ep collider HERA are presented which are based on about 100 pb^{-1} of data collected in the years 1994-2000 by the H1 and ZEUS collaborations. No signals are observed which allows upper limits to be placed on parameters of theories extending beyond the Standard Model which are more restrictive than existing limits obtained at LEP and the TeVatron.

1 Introduction

The kinematic domain for deep-inelastic scattering (DIS) accessible at the ep collider HERA leads to sensitivity to new physics beyond the Standard Model (SM) competitive and in several areas beyond what has been obtained at LEP or at the TeVatron. At HERA electrons or positrons with an energy of 27.5 GeV have been brought into collision with protons of 820 or 920 GeV. Up to now both colliding beam experiments, H1 and ZEUS, each have collected ≈ 45 pb^{-1} of e^+p data at a center of mass energy of $\sqrt{s} = 300$ GeV. After raising the proton beam energy to 920 GeV in 1998 both experiments further collected ≈ 15 pb^{-1} of e^-p and another ≈ 45 pb^{-1} of e^+p data at $\sqrt{s} = 318$ GeV. As the appearance of new physics may be dependent on the lepton charge or on a given energy threshold the analysis of the recent data is of particular interest.

2 Search for Contact Interactions

In many scenarios for new physics anomalous eq interactions are indistinguishable from SM Neutral Current deep-inelastic scattering (NC DIS) on an event by event basis. However, at sufficiently large scale they can manifest themselves in distortions of the differential NC DIS cross section through their interference with the Standard Model. Possible deviations can be analysed in terms of four-fermion pointlike $eq \to eq$ contact interactions (CI) representing the low energy limit of a new interaction. The general chiral invariant (vectorlike) contact interaction Lagrange density can be written as:

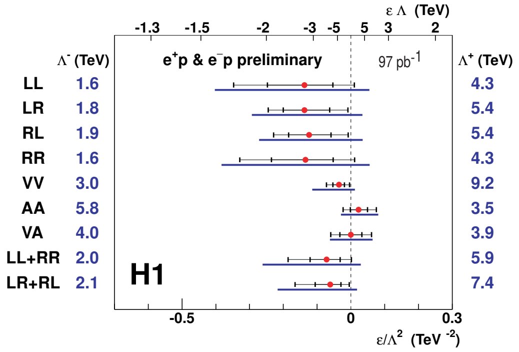

Figure 1. CI limits at 95% CL for ε/Λ^2 for a number of models resulting from the analysis of 97 pb^{-1} $e^{\pm}p$ data from H1.

$$\mathcal{L}_{CI} = \frac{g^2}{\Lambda^2} \sum_{a,b=L,R} \varepsilon_{ab}^q (\bar{e}_a \gamma^\mu e_a)(\bar{q}_b \gamma_\mu q_b) \quad (1)$$

where Λ is the effective mass scale, g the coupling strength and ε_{ab}^q determines the relative sign of the individual terms ($g^2 = 4\pi$ and $|\varepsilon_{ab}^q| = 0, \pm 1$). A large variety of different models have been tested by ZEUS[1] and H1[2]. No significant deviations from the SM have been observed by the two collabo-

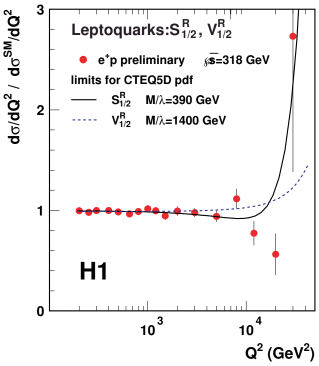

Figure 2. NC cross section at $\sqrt{s} = 318$ GeV normalised to the SM expectation using CTEQ5D parton distributions. The H1 data are compared with 95% CL exclusion limits of leptoquarks for the cases $S^R_{1/2}$ and $V^R_{1/2}$.

rations. By combining up to 97pb^{-1} of $e^{\pm}p$ data exclusion limits on ε/Λ^2 between 1.6 and 9.2 TeV depending on the chiral structure of the model are obtained as shown in fig. 1.

2.1 Searches for Leptoquarks in Contact Interactions

Leptoquarks (LQs) are scalar or vector bosons which carry baryon (B) and lepton (L) numbers and can couple to both quarks and leptons. In the Buchmüller-Rückl-Wyler model [3] the 14 possible LQs are classified according to the fermion number, $F = 3B + L$, and their branching ratios into eq or νq (0, 1/2 or 1). As an illustration of the sensitivity of the existing data to the effect of LQs fig. 2 shows the measured e^+p NC DIS cross section normalised to the SM expectation (using CTEQ5D) as a function of Q^2 together with the 95% exclusion limits for the two examples $S^R_{1/2}$ $(F = 0)$ and $V^R_{1/2}$ $(F = 2)$. Using this indirect method limits on the ratio of leptoquark mass and coupling, M_{LQ}/λ in the range $0.3 - 1.7$ TeV can be set, depending on the LQ type.

2.2 Limits on Low Scale Gravitational Effects

Recently an interesting idea on how to circumvent the hierarchy problem in $4 + n$ dimensional string theory was proposed [4]: the fundamental Planck scale, where gravity becomes comparable in strength to the other interactions is assumed to be near the weak scale $M_S = \mathcal{O}(\mathrm{TeV})$. The weakness of gravity results from the fact that only gravitons can propagate into the bulk while SM particles are confined to the 3+1 dimensional subspace. The huge $1/M_{Planck}$ suppression of the graviton coupling to SM particles gets in this model compensated by the summation over a large multiplicity of Kaluza-Klein modes leading to an effective CI coupling $\eta_G = \lambda/M_S^4$. Using the combination of all data sets H1 derives [2] 95% CL limits of $M_S > 0.93(0.63)$ TeV assuming $\lambda = -1(+1)$.

3 Leptoquarks in resonance decays

Below the kinematical limit $\sqrt{s}$ at HERA LQs can be produced in the s-channel and decay with a distinct resonant structure in the Bjorken-x distribution at a value $x \simeq M^2_{LQ}/s$. Interference with the SM and the finite width of the LQ resonance lead to sensitivity even somewhat beyond $\sqrt{s}$. DIS background can be suppressed by employing the characteristics of the y (inelasticity) distribution of the different processes. In the 1994-1997 e^+p NC data a slight excess of events was observed around masses of 200 GeV which however is not confirmed by the new data taken in 1999-2000 (see fig. 3). ZEUS also observed a few outstanding events in the high-x, high-y region in the earlier e^+p data, but the new data do not contain such events [5], as shown in fig. 3. The ZEUS collaboration has combined the searches [6] in the $e^+p \to e^+X$ and $e^+p \to \bar{\nu}X$ channel and converted the resulting cross section limits to mass dependent limits on the coupling strength as shown for example in fig. 4.

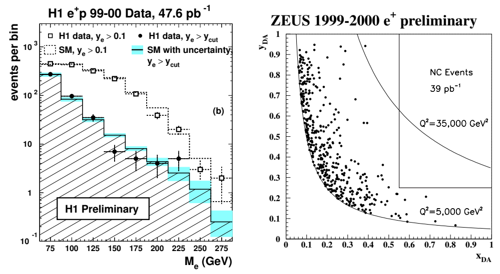

Figure 3. Mass spectra for NC DIS like final states e^+p H1 data and MC expectation before and after a cut on y (left). Event distribution in x and y for $Q^2 > 5000$ GeV^2 for 1999-2000 ZEUS data (right).

For a coupling of electromagnetic strength,

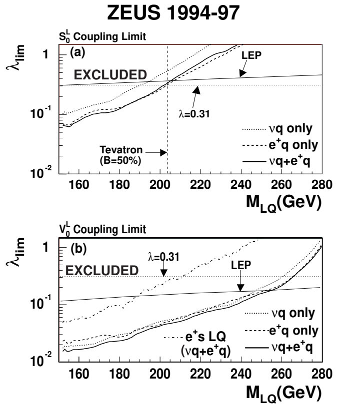

Figure 4. Limits on the coupling λ_{lim} for S_0^L (a) and V_0^L (b). The results are shown seperately for the $\bar{\nu}q$ and e^+q channel as well as for the combination of both.

$\lambda = 0.31$, LQ masses in the range $M_{LQ} \geq 150 - 290$ GeV can be excluded depending on the LQ type. Finally fig. 5 summarizes the present HERA, LEP and TeVatron mass limits [7] for two LQ types as derived from direct searches and indirect methods. A significant part of the area is presently only excluded by the HERA data.

Both experiments also searched for lepton-flavor-violating LQs which lead to a μ or a τ in the final state. No significant signal is observed which is translated [8] into limits on the ratio of coupling and LQ mass, $\lambda_{eq}\lambda_{\mu/\tau q}/M_{LQ}^2$.

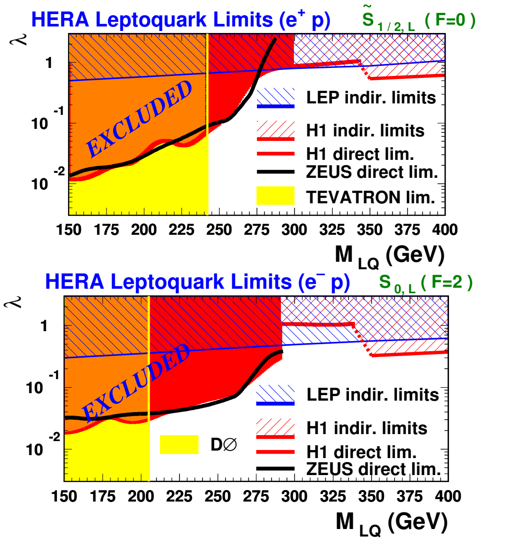

Figure 5. Summary of exclusion limits at 95% CL on the Yukawa coupling λ as a function of the LQ mass for a scalar LQ with $F = 0$ (top) and for a scalar LQ with $F = 2$ (bottom) in the framework of the BRW model.

Enhanced sensitivity to new physics can be expected after the year 2001 when the upgraded HERA will be operated at higher luminosity and $e^{\pm}$ polarization will be available.

References

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