CONTACT INTERACTIONS AT HERA

A.F.ŻARNECKI

(on behalf of the H1 and ZEUS collaborations)

Institute of Experimental Physics, Warsaw University

Hoża 69, 00-681 Warszawa, Poland; E-mail: zarnecki@fuw.edu.pl

A search for signatures of physics beyond the Standard Model has been performed with high Q^2 neutral current deep inelastic scattering events, $e^+p \to e^+X$ and $e^-p \to e^-X$, with the H1 and ZEUS detectors at HERA. Various $eeqq$ contact interaction models have been considered, and no significant deviations from Standard Model predictions were observed. Limits on the compositeness scale in general $eeqq$ contact interaction models, mass to the Yukawa coupling ratio for heavy leptoquarks, the effective Planck mass scale in models with large extra dimensions and the effective quark charge radius are presented.

1 Introduction

The HERA ep collider has extended the kinematic range available for the study of deep–inelastic scattering (DIS) by two orders of magnitude to values of Q^2 up to about $50000\,\mathrm{GeV}^2$. Measurements in this domain allow searches for physics processes beyond the Standard Model (SM) at characteristic mass scales in the TeV range. Results presented in this contribution are based on the data samples collected by the H1 and ZEUS Collaborations in years 1994-2000. Integrated luminosity of the analyzed e^+p data is $82\,\mathrm{pb}^{-1}$ for H1 and $112\,\mathrm{pb}^{-1}$ for ZEUS, and for e^-p data $15\,\mathrm{pb}^{-1}$ and $16\,\mathrm{pb}^{-1}$ respectively.

2 Analysis methods

Details of the methods used to set parameter limits for different contact interaction models are described in the published analysis of H1[1] and ZEUS[2].

H1 analysis is based on the comparison of the measured differential cross section $d\sigma/dQ^2$ to the Standard Model predictions and to the deviations expected from the considered models. The experimental and theoretical uncertainties, in particular the impact of different parton densities, are included in the derivation of the χ^2 function used to calculate limits[1].

ZEUS analysis of 1994-97 data is based on the so-called unbinned log-likelihood method. Observed event distribution in (x,y) is compared with the NC DIS Monte Carlo reweighted according to the model expectations. Systematic uncertainties are included in the generation of MC experiments, used to calculate parameter limits[2]. For ZEUS preliminary 1994-2000 results same limit setting method is used, but the likelihood is calculated from the binned event distribution in Q^2.

3 Contact Interactions

Four-fermion contact interactions are an effective theory, which allows us to describe, in the most general way, possible low energy effects coming from "new physics" at much higher energy scales. As strong limits have already been placed on the scalar and tensor terms[3], only the vector $eeqq$ contact interactions are considered at HERA. They can be represented as additional terms in the Standard Model Lagrangian[3]:

$$L_{CI} = \sum_{i,j=L,R} \eta_{ij}^{eq} (\bar{e}_i \gamma^\mu e_i)(\bar{q}_j \gamma_\mu q_j) \quad (1)$$

where the sum runs over electron and quark helicities, and a set of couplings η_{ij}^{eq} describe the helicity and flavor structure of contact interactions. There are four couplings for each quark flavor $q = u,\ d$. Various scenarios, with different chiral structures, were considered by H1 and ZEUS.

4 Results

In the general case (also referred to as compositeness models), limits on the effective "new physics" mass scale Λ (compositeness scale) are extracted assuming the relation $\eta = \pm 4\pi/\Lambda^2$. Figure 1 shows the results obtained by H1[4] and ZEUS[2] for different compositeness models. Limits on the effective mass scale Λ range up to 9.2 TeV.

Contact interactions can be also used to describe the effects of virtual leptoquark production or exchange at HERA, in the limit of large leptoquark mass $M_{LQ} \gg \sqrt{s}$. H1 collaboration have used combined data set 1994-2000 to constrain mass to the Yukawa coupling ratio for different leptoquark types[5]. Results are summarized in Table 1. Possible leptoquark contributions to the NC DIS cross section, as measured by H1, are shown in Figure 2.

For the models with large extra dimensions[6] both collaboration set limits on the effective Planck mass scale M_S. For negative coupling sign scales below 0.93 TeV (H1) and 0.82 TeV (ZEUS) are excluded on 95% CL. For positive couplings the limits are 0.63 TeV and 0.81 TeV respectively. Possible effects of graviton exchange on the Q^2 distribution of NC DIS events, as measured by ZEUS, are shown in Figure 2.

Also, searches for possible quark substructure can be made by measuring the spatial distribution of the quark charge. By using the "classical" form

Table 1. Coupling coefficients η_{ij}^{eq}, fermion number F and 95% CL lower limits on M_{LQ}/λ for scalar (S) and vector(V) leptoquarks. Preliminary results of the H1 Collaboration from the combined 1994-2000 data.

LQ	η^{eu} $[\frac{\lambda^2}{M^2}]$	η^{ed} $[\frac{\lambda^2}{M^2}]$	F	M_{LQ}/λ [GeV]
S_0^L	$\eta_{LL}^{eu} = +\frac{1}{2}$		2	1070
S_0^R	$\eta_{RR}^{eu} = +\frac{1}{2}$		2	960
$\tilde{S}_0^R$		$\eta_{RR}^{ed} = +\frac{1}{2}$	2	290
$S_{1/2}^L$	$\eta_{LR}^{eu} = -\frac{1}{2}$		0	380
$S_{1/2}^R$	$\eta_{RL}^{eu} = -\frac{1}{2}$	$\eta_{RL}^{ed} = -\frac{1}{2}$	0	380
$\tilde{S}_{1/2}^L$		$\eta_{LR}^{ed} = -\frac{1}{2}$	0	650
S_1^L	$\eta_{LL}^{eu} = +\frac{1}{2}$	$\eta_{LL}^{ed} = +1$	2	690
V_0^L		$\eta_{LL}^{ed} = -1$	0	1030
V_0^R		$\eta_{RR}^{ed} = -1$	0	810
$\tilde{V}_0^R$	$\eta_{RR}^{eu} = -1$		0	530
$V_{1/2}^L$		$\eta_{LR}^{ed} = +1$	2	480
$V_{1/2}^R$	$\eta_{RL}^{eu} = +1$	$\eta_{RL}^{ed} = +1$	2	1510
$\tilde{V}_{1/2}^L$	$\eta_{LR}^{eu} = +1$		2	1690
V_1^L	$\eta_{LL}^{eu} = -2$	$\eta_{LL}^{ed} = -1$	0	680

factor approximation, and assuming that both electron and exchanged bosons are point-like, limits on the mean-square radius of the electroweak charge of the quark can be set. From the analysis of combined 1994-2000 data quark radius bigger than $1.6 \cdot 10^{-16}$ cm (H1) and $0.73 \cdot 10^{-16}$ cm (ZEUS) has been excluded at 95% CL.

References

1. The H1 Collaboration, C.Adloff et al., Phys. Lett. B479 (2000) 358.
2. The ZEUS Collaboration, J.Breitweg et al., Eur.Phys.J. C14 (2000) 239.
3. P.Haberl, F.Schrempp, H.U.Martyn, *Proc. Workshop Physics at HERA*, ed. W.Buchmüller and G.Ingelman, Hamburg 1991, Vol. 2, pg. 1133.
4. The H1 Collaboration, ICHEP'2000 abstract #951.
5. W.Buchmüller, R.Rückl and D.Wyler, Phys. Lett. B 191 (1987) 442; Erratum: Phys. Lett. B 448 (1999) 320.
6. N.Arkani-Hamed, S.Dimopoulos and G.Dvali, Phys. Lett. B 429 (1998) 263, Phys. Rev. D 59, (1999) 086004.

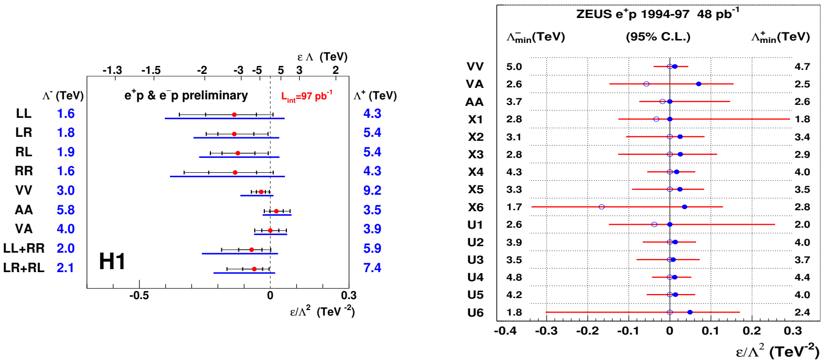

Figure 1. Results for general contact interaction models (compositeness models) using the combined e^+p and e^-p data from H1 (left) and 1994-97 e^+p data from ZEUS (right). Horizontal bars indicate the 95% CL limits on $\eta/4\pi = \varepsilon/\Lambda^2$; values outside these regions are excluded. $\Lambda^\pm$ are the 95% CL limits on the compositeness scale for $\varepsilon = \pm 1$.

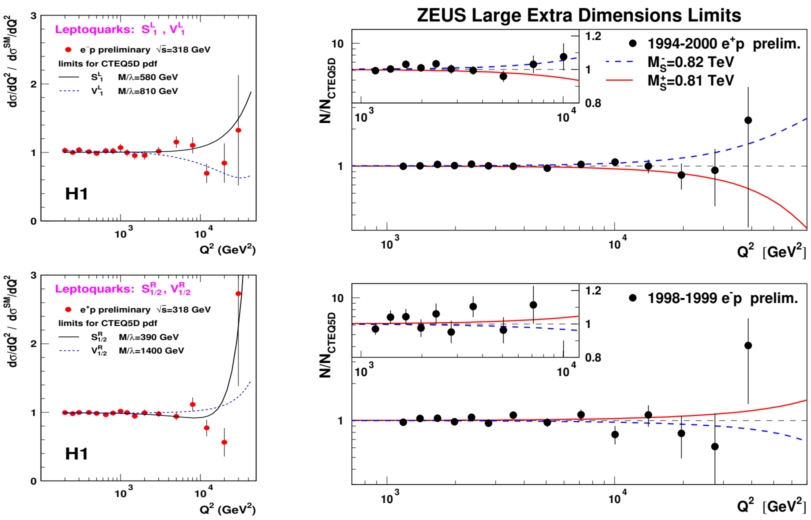

Figure 2. H1 data compared with 95% CL exclusion limits of leptoquarks: e^-p scattering with S_1^L and V_1^L, and e^+p scattering with $S_{1/2}^R$ and $V_{1/2}^R$ (left). ZEUS data compared with 95% CL exclusion limits for the effective Planck mass scale in models with large extra dimensions, for positive (M_S^+) and negative (M_S^-) couplings (right). Results of the experiments are normalized to the Standard Model expectations using CTEQ5D parton distributions.