Search for Contact Interactions and Leptoquarks at HERA

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The measured single differential cross section $\mathrm{d}\sigma/\mathrm{d}Q^2$ is compared to the Standard Model expectation and analyzed to search for $(\bar{e}\,e)(\bar{q}\,q)$ contact interactions. No significant deviation is observed and limits on lepton–quark compositeness scales and virtual leptoquark exchange are presented.

1. INTRODUCTION

New currents or heavy bosons may produce indirect effects through the interference of a *virtual* particle exchange with the γ and Z fields of the Standard Model. For particle masses well above the available production energy, such indirect signatures may be investigated by searching for a 4–fermion pointlike $(\bar{e}\,e)(\bar{q}\,q)$ contact interaction. The Contact Interaction Lagrangian [1] including only vector terms contains 8 coupling coefficients η^q_{if} where the indices $i, f = \{L, R\}$ denote the left–handed and right–handed fermion helicities and $q = \{u, d\}$. The general ansatz [1] can be applied to any new phenomena, e. g. $(e\,q)$ compositeness, leptoquarks or new gauge bosons, by an appropriate choice of the coupling coefficients. Possible deviations of the measured cross section from the Standard Model are analyzed in terms of contact interactions. Figure 1 shows the measured single differential cross section $\mathrm{d}\sigma/\mathrm{d}Q^2$ [2], which is well described over six orders of magnitude by the Standard Model expectation. Choosing different parton distributions (CTEQ4D, MRST, GRV 94) [3] for the cross section calculation, does not change the shape of the Q^2 spectrum significantly, but rather the normalisation by up to 1.2%.

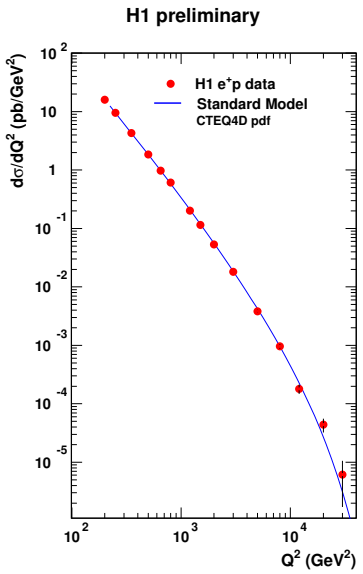

Figure 1. Differential NC cross sections $d\sigma/dQ^2$. H1 data (•) are compared with the Standard Model expectation (—) using CTEQ4D parton distributions.

2. COMPOSITENESS SCALES

A possible fermion compositeness or substructure can be expressed by the coupling coefficients $\eta_{if} \equiv \pm g^2/{\Lambda^{\pm}_{if}}^2$, where the signs indicate positive and negative interference with the Standard Model currents. The coupling strength is conventionally chosen as $g^2 = 4\pi$ and Λ denotes the compositeness scale. Both u and d quarks are assumed to contribute with the same scale.

The results of the χ^2 fits for different chiral structures are compiled in table 1. The dominant correlated systematic errors, i. e. the experimental uncertainty of the lepton energy scale, the scattering angle and the theoretical uncertainty due

to the uncertainty of α_s, are taken into account in the fit procedure. The pure chiral couplings prefer negative interference resp. negative values of η as a consequence of the trend of the data being slightly low compared to the Standard Model prediction around $Q^2 \simeq 5,000$ GeV^2 followed by an upward fluctuation at higher Q^2 (fig. 2). The LR model gives a best description of the data, however the couplings $\eta/4\pi$ for all investigated chiral structures are compatible with the Standard Model within two standard deviations.

Table 1
95% cl lower limits on compositeness scale parameters $\Lambda^{\pm}$

H1 Preliminary		
coupling	Λ^+ [TeV]	Λ^- [TeV]
LL	2.3	1.2
LR	3.0	1.5
RL	3.0	1.5
RR	2.3	1.2
VV	5.0	1.9
AA	2.0	3.4
VA	2.6	2.6
LL+RR	3.1	1.3
LR+RL	4.1	1.8

Limits on the compositeness scale parameters are derived by fitting Λ^+ and Λ^- with the appropriate interference signs and taking the corresponding changes in χ^2 with respect to the fit to the Standard Model, which provides a good description of the data.

The most conservative values of $\Lambda^{\pm}$ obtained from a variation of the parton distributions are quoted in table 1. The limits on compositeness scale parameters vary between 1.2 TeV and 5.0 TeV depending on the chiral structure of the model. The data are particularly sensitive to the VV, AA and VA models, where all chiral structures contribute with different relative signs. In general the limits of Λ^+ are more restrictive compared to Λ^- due to the preference of negative interference.

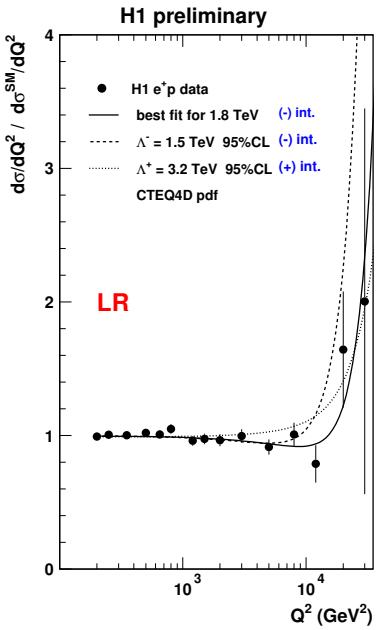

Figure 2. Cross section $d\sigma/dQ^2$ normalised to the Standard Model expectation (CTEQ4D); H1 data (•) compared to the best fit (—) resp. limits Λ^+ and Λ^- of the LR model

3. LEPTOQUARKS

Leptoquarks are colour triplet bosons of spin 0 or 1, carrying lepton (L) and baryon (B) number and fractional electric charge. The leptoquark mass M_{LQ} and its coupling λ is related to the contact interaction coefficients $\eta^q_{if} = c^q_{if}(\lambda/M_{LQ})^2$. The notation [1] and the coupling coefficients η_{if} for leptoquarks of the Buchmüller-Rückl-Wyler Model [4] are given in table 2.

The differential cross section analysis shows no evidence for a virtual leptoquark signal. The resulting lower limits on M_{LQ}/λ, which is the only unknown parameter, is summarized in table 2. They include all experimental systematics and represent the most conservative values obtained from a variation of different parton densities. In general vector leptoquarks which couple to u quarks with positive interference provide the most restrictive limits of $M_{LQ}/\lambda \sim \mathcal{O}(1.0$ TeV).

Table 2
Coupling coefficients η^q_{if}, fermion number F and 95% cl lower limits on M_{LQ}/λ for scalar (S) and vector (V) leptoquarks of the Buchmüller-Rückl-Wyler Model. The used notation indicates the lepton chirality L, R and weak isospin $I = 0,\ 1/2,\ 1$. $\tilde{S}$ and $\tilde{V}$ differ by two units of hypercharge from S and V. (Sign errors of the coupling coefficients for the $F = 2$ scalar leptoquarks and the $F = 0$ vector leptoquarks in [1] are corrected [5].)

H1 Preliminary

leptoquark	coupling to u quark [GeV^{-2}]	coupling to d quark [GeV^{-2}]	$F = 3B + L$	M_{LQ}/λ [GeV]
S_0^L	$\eta^u_{LL} = +\frac{1}{2}\ (\lambda/M_{LQ})^2$		2	598
S_0^R	$\eta^u_{RR} = +\frac{1}{2}\ (\lambda/M_{LQ})^2$		2	554
$\tilde{S}_0^R$		$\eta^d_{RR} = +\frac{1}{2}\ (\lambda/M_{LQ})^2$	2	202
$S_{1/2}^L$	$\eta^u_{LR} = -\frac{1}{2}\ (\lambda/M_{LQ})^2$		0	294
$S_{1/2}^R$	$\eta^u_{RL} = -\frac{1}{2}\ (\lambda/M_{LQ})^2$	$\eta^d_{RL} = -\frac{1}{2}\ (\lambda/M_{LQ})^2$	0	308
$\tilde{S}_{1/2}^L$		$\eta^d_{LR} = -\frac{1}{2}\ (\lambda/M_{LQ})^2$	0	416
S_1^L	$\eta^u_{LL} = +\frac{1}{2}\ (\lambda/M_{LQ})^2$	$\eta^d_{LL} = +1\ (\lambda/M_{LQ})^2$	2	385
V_0^L		$\eta^d_{LL} = -1\ (\lambda/M_{LQ})^2$	0	655
V_0^R		$\eta^d_{RR} = -1\ (\lambda/M_{LQ})^2$	0	547
$\tilde{V}_0^R$	$\eta^u_{RR} = -1\ (\lambda/M_{LQ})^2$		0	299
$V_{1/2}^L$		$\eta^d_{LR} = +1\ (\lambda/M_{LQ})^2$	2	345
$V_{1/2}^R$	$\eta^u_{RL} = +1\ (\lambda/M_{LQ})^2$	$\eta^d_{RL} = +1\ (\lambda/M_{LQ})^2$	2	859
$\tilde{V}_{1/2}^L$	$\eta^u_{LR} = +1\ (\lambda/M_{LQ})^2$		2	952
V_1^L	$\eta^u_{LL} = -2\ (\lambda/M_{LQ})^2$	$\eta^d_{LL} = -1\ (\lambda/M_{LQ})^2$	0	400

It should be emphasized that upper bounds on the coupling strength λ can only be set for leptoquark masses exceeding the accessible center of mass energy of HERA. Masses around 300 GeV are excluded for almost all types of leptoquarks with a coupling of $\lambda \gtrsim 1$. Complementary limits coming from direct search for leptoquarks at HERA can be found elsewhere [6].

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