Search for Contact Interactions at HERA

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Abstract. A search for physics beyond the Standard Model in neutral current deep inelastic scattering at high Q^2 is performed in $e^{\pm}p$ collisions at HERA. The full H1 data sample corresponding to an integrated luminosity of 440 pb^{-1} is used. No significant deviation from the Standard Model is observed. Limits are derived on the compositeness scale for general contact interactions, on the ratio of mass to the Yukawa coupling for heavy-leptoquark models, on the effective Plank-mass scale in models with large extra dimensions and on the quark radius.

1. INTRODUCTION

Deep inelastic neutral current scattering $ep \to eX$ at high squared momentum transfer Q^2 allows one to study the structure of eq interactions at short distances and to search for new phenomena beyond the Standard Model (SM). The concept of four-fermion contact interactions (CI) provides a convenient method to investigate the interference of any new particle field associated to large scales with the γ and Z fields of the SM. The analysis presented here is based on $e^{\pm}p$ H1 data collected during the whole HERA operating period 1994-2007 and correspond to the integrated luminosity of $440 pb^{-1}$ [1, 2, 3, 4].

2. CONTACT INTERACTIONS

Four-fermion CIs represent an effective theory which describes low-energy effects due to new physics at much higher energy scales. The most general chiral invariant Lagrangian for neutral current vector-like four-fermion contact interactions can be written in the form:

$$L_{CI} = \sum_{q} \sum_{a,b=L,R} \eta^{q}_{ab} (\overline{e}_a \gamma_\mu e_a)(\overline{q}_b \gamma^\mu q_b), \tag{1}$$

where a and b indicate the left-handed and right-handed fermion helicities and q indicates the flavour of the quark. Various scenarios, with different chiral structures, were considered. Neutral current deep inelastic scattering (NC DIS) cross section dependence of Q^2 is compared to SM predictions. No significant deviations from the SM predictions was observed, that alowed to derive limits on the various CI models parameters. Details of the analyses are described elsewhere [5, 6].

3. RESULTS

Lower limits at 95%CL on the eq compositeness scale parameter Λ are derived assuming $\eta = \pm 4\pi/\Lambda^2$. They range between $3.7 TeV$ and $7.4 TeV$ depending on the chiral structure. Figure 1 shows the results for various compositeness models [6].

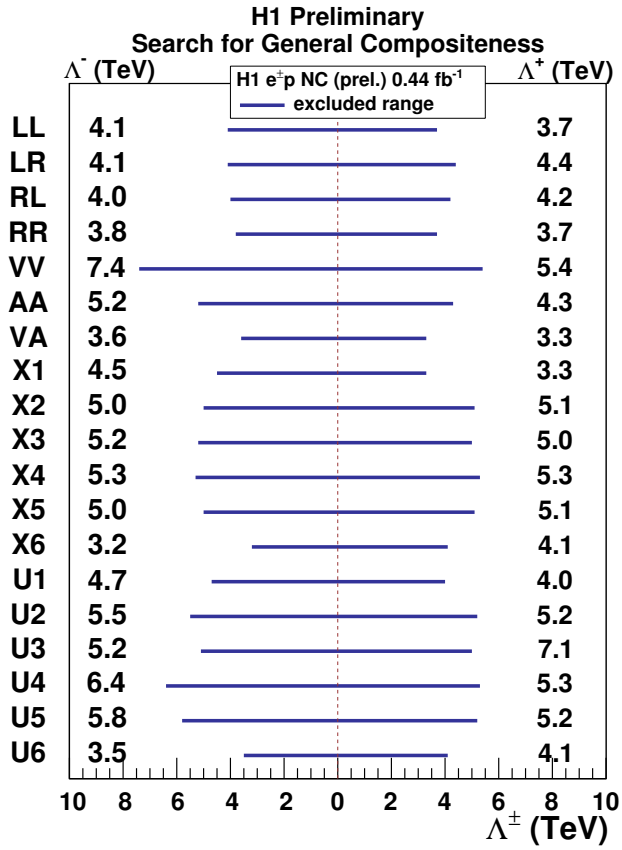

FIGURE 1. Exclusion regions and lower limits (95%CL) on thw compositeness scale parameter $\Lambda^{\pm}$ for various chiral models obtained from the combined $e^{\pm}p$ data applying a frequentist method.

Contact interactions can also be used to describe the effects of virtual leptoquark production or exchange at HERA, in the limit of large leptoquark mass $M_{LQ} \gg \sqrt{s}$. The Buchmüler, Rückl, Wyler (BRW) framework [7] was used for the leptoquarks classification. According to the BRW framework there are 14 different types of leptoquarks (scalar and vector). The lower limits on the ratio between leptoquark mass and Yukawa coupling range from $0.4 TeV$ up to $1.94 TeV$. An example of the effect on the Q^2 distribution of the NC DIS cross section due to virtual leptoquark exchange is shown in figure 2.

The limits on heavy leptoquarks can also be interpreted in terms of squarks in R-parity violating supersymmetry with masses satisfying $M_{\tilde{u}}/\lambda_{1j1} < 0.94 TeV$ and $M_{\tilde{d}}/\lambda_{11k} < 0.58 TeV$ can be excluded at 95%CL.

Possible effects of low scale quantum gravity with gravitons propagating into extra spatial dimensions are searched for. Lower limits at 95%CL on the effective Planck scale

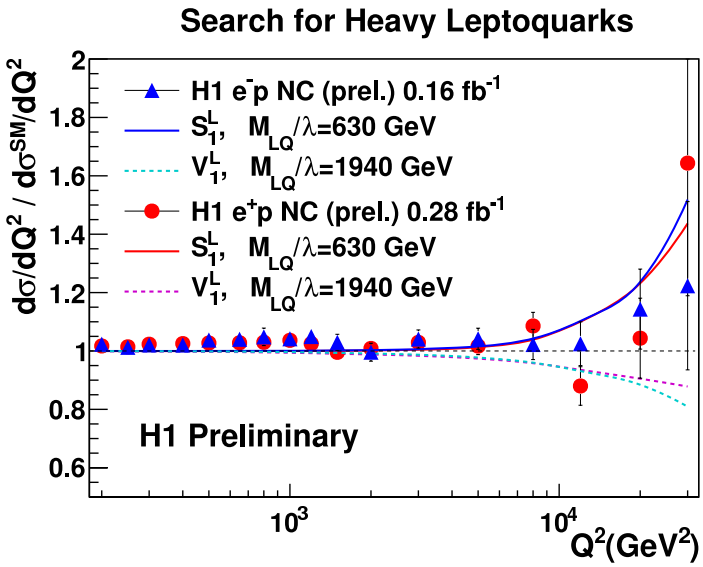

FIGURE 2. The H1 $e^{\pm}p$ scattering data are compared with 95%CL exclusion limits for the mass to coupling ratio M/λ of leptoquarks S_1^L and V_1^L obtained from e^+ and e^- data simultaneosly. The results are normalised to the Standard Model expectation.

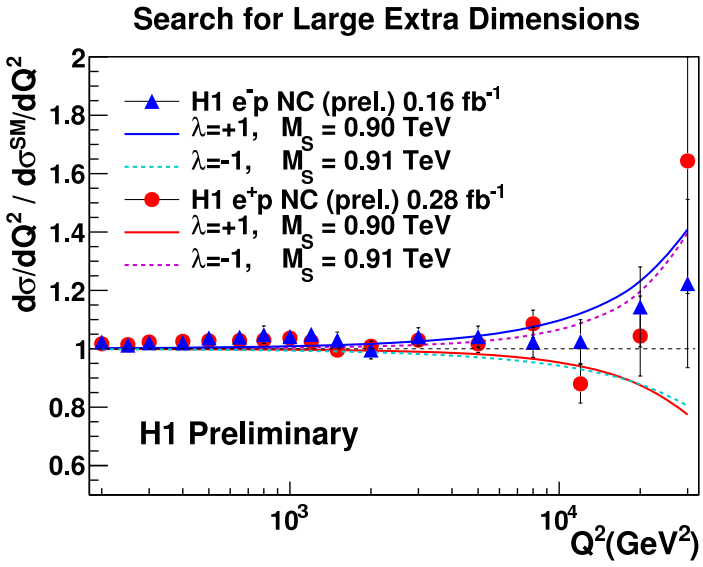

FIGURE 3. H1 $e^{\pm}p$ scattering data are compared with 95%CL exclusion limits for gravitational scale M_s assuming positive ($\lambda = +1$) or negative ($\lambda = -1$) couplings obtained from e^+ and e^- data simultaneosly. The results are normalised to the Standard Model expectation.

M_S of $0.90 - 0.91 TeV$ depending on the sign of the coupling are found. Possible effects of graviton exchange on the NC DIS $e^{\pm}p$ cross section Q^2 distribution is presented in figure 3.

Searches for possible quark substructure can be made by measuring the spatial distribution of the quark electroweak charge. By using the classical form factor approxima-

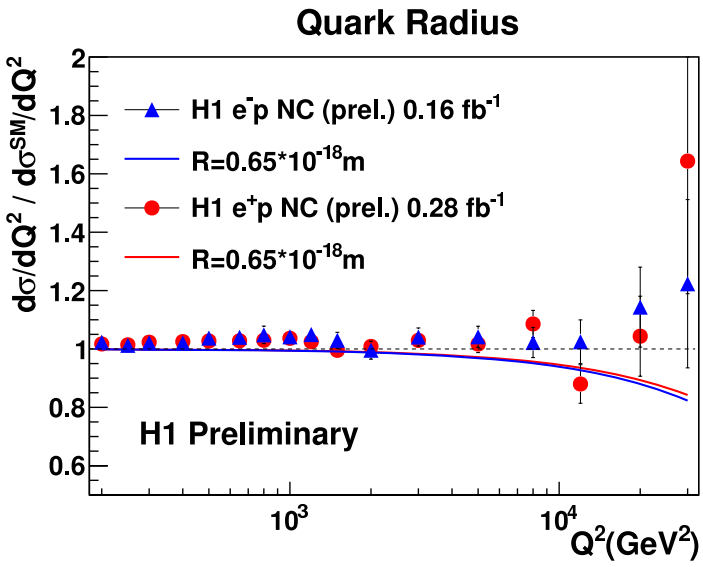

FIGURE 4. H1 data are compared with exclusion limits for the effective mean square radius of the electroweak charge of the quark obtained from e^+ and e^- data simultaneosly. The results are normalised to the Standard Model expectation

tion, limits on the mean-square radius of the electroweak charge of the quark can be set. The form factor approach yields an upper limit on the size of light u and d quarks of $R_q < 0.65 \cdot 10^{-18} m$ assuming point-like electrons. Figure 4 shows the 95%*CL* exclusion limits for the effective radius of the quark.

4. CONCLUSIONS

NC DIS $e^- p$ and $e^+ p$ scattering cross section measurements are analysed to search for new phenomena mediated through CI. The data are well described by the SM expectations. No signal or large deviations from the SM predictions have been found and corresponding limits on a variety of models have been derived.

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