SEARCH FOR EXCITED FERMIONS AT HERA

Mireille SCHNEIDER
CPPM, 163, avenue de Luminy, case 907, 13288 Marseille cedex 9, France
E-mail: schneide@cppm.in2p3.fr

Recent results on searches for excited fermions obtained by the H1 and ZEUS experiments are reported here. No evidence of excited fermion production has been observed, therefore limits have been derived.

1 Introduction

Some SM extensions propose that fermions have a substructure. If so, the decay of their excited states can be observed. In 1994-97 HERA collided 27.6 GeV positrons on 820 GeV protons. In 1998 the proton energy was raised to 920 GeV. In 1998 and in the first months of 1999, HERA ran with electrons. In May 1999 HERA switched back to positrons. The total HERA-1 data set corresponds to an integrated luminosity of 105 (114) pb^{-1} for e^+p collisions and 15 (16.4) pb^{-1} for e^-p collisions for H1 (ZEUS) experiment. Latest results on searches for excited fermions in the full HERA-1 data set are reported here.

2 Excited fermion model

In various extensions of the SM, excited states of fermions are expected. Their excitations and de-excitations are described by an effective Lagrangian proposed by Hagiwara, Komamiya and Zeppenfeld [1]:

$$\mathcal{L}_{int} = \frac{1}{2\Lambda}\overline{F}^*_R\sigma^{\mu\nu}\left[gf\frac{\tau^a}{2}W^a_{\mu\nu} + g'f'\frac{Y}{2}B_{\mu\nu} + g_sf_s\frac{\lambda^a}{2}G^a_{\mu\nu}\right]F_L$$

where F^*_R (F_L) is the right-handed (left-handed) component of the excited fermions form weak isodoublets, $W^a_{\mu\nu}$, $B_{\mu\nu}$ and $G^a_{\mu\nu}$ are the field-strength tensors of the respective gauge groups SU(2), U(1) and SU(3). g, g' and g_s are the SM couplings. f, f' and f_s determine the coupling strength between the excited fermions and the bosons corresponding to the groups SU(2), U(1) and SU(3) respectively. τ^a are the Pauli matrices, Y the weak hypercharge operator, λ^a the Gell-Mann matrices and Λ the compositeness scale. The production cross sections and the decay branching ratios of the various excited fermions are determined by the combinations of the couplings f, f', f_s and the scale Λ.

At HERA, searches for excited electrons, neutrinos and quarks have been performed. They de-excite by emission of γ, Z or W bosons. W and Z bosons then subsequently decay into hadrons ($W \to q\overline{q}'$, $Z \to q\overline{q}$) or leptons ($W \to \ell\nu$, $Z \to \ell^+\ell^-$) giving rise to final states containing leptons and jets at large transverse momenta. Most of these configurations have been considered.

3 Search for excited electrons

In the search for excited electrons, all $e^{\pm}p$ data have been analysed. Three channels have been investigated here: $e^* \to e + \gamma$, $e^* \to e + Z_{\to q\overline{q}}$ and $e^* \to \nu + W_{\to q\overline{q}'}$. No deviation from SM is observed, therefore upper limits at 95 % CL on the ratio f/Λ are established [2, 3]. The resulting limits on f/Λ are presented in the figure 1 (left figure) as a function of the excited electron mass assuming $f = f'$. Results are compared to those coming from LEP [4]. HERA limits are seen to be competitive with LEP for high excited electron masses. H1 has also obtained less model-dependent limits on f/Λ as a function of the ratio f'/f for different values of the excited electron mass. These limits are shown in the figure 1 (right figure). For $f = f'$, the main contribution comes from the channel $e^* \to e + \gamma$ whereas for $f = -f'$ only the channel $e^* \to e + Z$ contributes (vanishing electromagnetic coupling at $f = -f'$).

Recent Tevatron studies of the process $p\overline{p} \to e\gamma e$ assuming $f = 1$ and $M_{e^*} = \Lambda$ (large f/Λ) exclude the excited electrons masses below 785 GeV [5].

4 Search for excited neutrinos

In the search for excited neutrinos, mainly e^-p data have been considered due to a larger production cross-section than in e^+p collisions. Three channels have been investigated here: $\nu^* \to \nu + \gamma$, $\nu^* \to \nu + Z_{\to q\overline{q}}$ and $\nu^* \to e + W_{\to q\overline{q}'}$. In all channels a good agreement between the experimental data and the SM prediction is observed, therefore limits on the ratio f/Λ are derived. ZEUS and H1 limits are shown in the figure 2 as a function of the excited neutrino mass, for $f = \pm f'$. The comparison with LEP limits [6] shows the unique sensitivity of HERA on the ratio f/Λ at high excited neutrino masses.

Less model dependent limits are also obtained by not assuming a fixed ratio of f'/f [7]. Figure 3 shows the limits on f/Λ as a function of this ratio for different values of the excited neutrino mass. The point of weakest limit is chosen as the f/Λ limit for the considered value of the excited neutrino mass, so that limits are obtained versus the excited neutrino mass for $-5 < f'/f < 5$.

5 Search for excited quarks

The search for excited quarks has been performed using 94-97 e^+p data ($\sqrt{s} =$ 300 GeV). The investigated channels are $q^* \to q + \gamma$, $q^* \to q + Z_{\to \ell^+\ell^-, q\bar{q}}$ and $q^* \to q + W_{\to \ell\nu, q\bar{q}'}$. No deviation from the SM is observed, therefore limits on the ratio f/Λ are deduced. In a first step $f_s = 0$ is assumed as HERA is not sensitive to the production of excited quark by a gluon exchange. Moreover $f = f'$ is assumed and limits on f/Λ are calculated as a function of the excited quark mass. Results obtained by the ZEUS collaboration are shown in the figure 4 (left). The limits are compared to LEP limits obtained by DELPHI [8]. It can be seen that HERA limits have a higher mass reach.

Under the assumption $f = f'$ and $\Lambda = M_{q^*}$, H1 limits on f are calculated as a function of the excited quark mass for different values of f_s [9]. Results are shown in the figure 4 and compared to Tevatron limits coming from CDF [10]. HERA limits on the gauge group weight f are seen to be more sensitive than Tevatron limits if small values of f_s are considered. Complementary, for large values of f_s Tevatron has a higher sensitivity.

6 Conclusion and future prospects

The search for excited fermions has been performed using the full HERA-1 data set. No deviation from the SM has been observed, therefore new constraints on the weights f, f' and f_s and the compositeness scale Λ have been set.

HERA limits are seen to be competitive with and complementary to the LEP and Tevatron searches. Increased data statistics of the HERA-2 running period will increase the sensitivity to excited fermions at higher masses and smaller couplings, especially in the case of excited neutrinos when more e^-p data will be collected.

Acknowledgements

I wish to thank my H1 and ZEUS colleagues who contributed to the results presented here as well as people who helped me in preparing this talk.

References

[1] Hagiwara, K., Zeppenfeld, D. and Komamiya, S., EXCITED LEPTON PRODUCTION AT LEP AND HERA, Z. Phys., C29, 1985, 115

[2] Adloff, C. and others, H1 Collaboration, Search for excited electrons at HERA, Phys. Lett., B548, 2002, 35-44, hep-ex/0207038

[3] Chekanov, S. and others, ZEUS Collaboration, Searches for excited fermions in *ep* collisions at HERA, Phys. Lett., B549, 2002, 32-47, hep-ex/0109018

[4] W. Adam, ADLO Collaboration, Search for excited leptons: update of the combined results of the LEP experiments, talk at ICHEP'2002

[5] A. Munar, CDF Collaboration, Search for New Physics with CDF, talk at DIS'2003

[6] Acciarri, M. and others, L3 Collaboration, Search for excited leptons in e^+e^- interactions at $\sqrt{s}$ = 192 GeV - 202-GeV, Phys. Lett., B502, 2001, 37-50, hep-ex/0011068

[7] Adloff, C. and others, H1 Collaboration, Search for excited neutrinos at HERA, Phys. Lett., B525, 2002, 9-16, hep-ex/0110037

[8] P. Abreu *et al.*, DELPHI Collaboration, Search for composite and exotic fermions at LEP-2, Eur. Phys. J., C8, 1999, 41-58

[9] Adloff, C. and others, H1 Collaboration, A search for excited fermions at HERA, Eur. Phys. J., C17, 2000, 567-581, hep-ex/0007035

[10] F. Abe *et al.*, CDF Collaboration, Search for excited quarks in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV, Phys. Rev. Lett., 72, 1994, 3004-3008

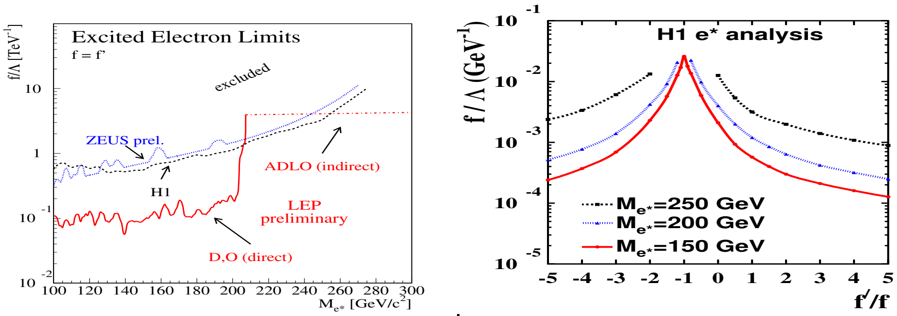

Figure 1: *Left figure: limits on f/Λ versus the e^* mass. Right figure: limits on f/Λ as a function of f'/f for various values of the e^* mass (94-00 $e^{\pm}p$ data).*

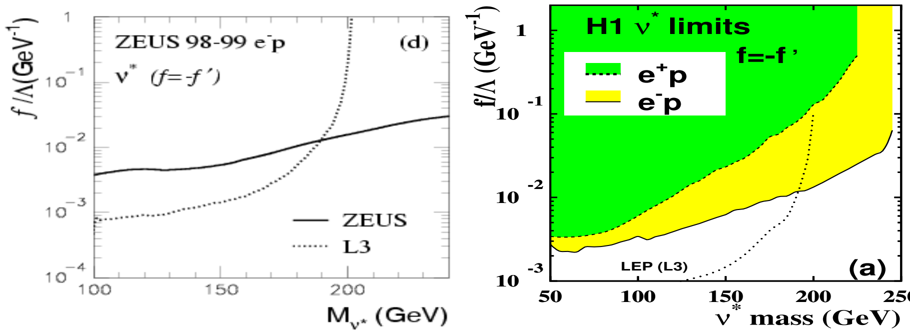

Figure 2: *Left (right) figure: ZEUS (H1) limits on f/Λ versus the ν^* mass using 98-99 e^-p data (full $e^{\pm}p$ data), for $f = -f'$.*

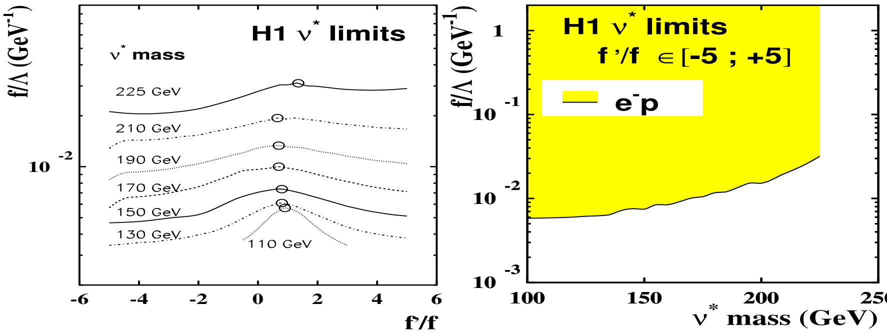

Figure 3: *Left figure: H1 limits on f/Λ versus f'/f and the ν^* mass. Right figure: H1 limits on f/Λ in the full range $-5 < f'/f < 5$ versus the ν^*mass (98-99 e^-p data).*

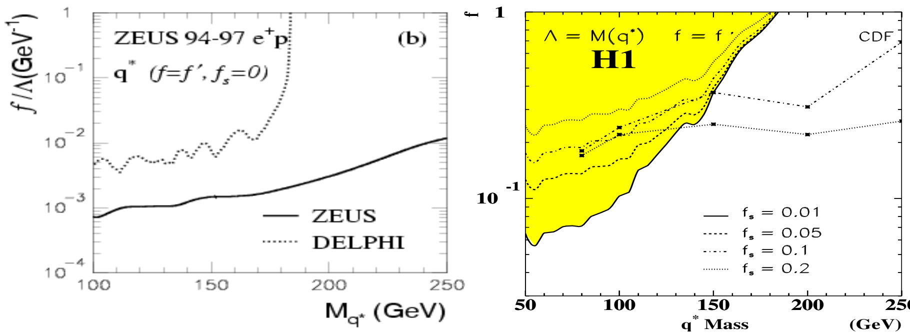

Figure 4: *Left figure: ZEUS limits on f/Λ assuming f_s=0 versus the q^* mass. Right figure: H1 limits on f fixing $\Lambda = M_{q^*}$ versus the q^* mass for various values of f_s (94-97 e^+p data).*