Searches at ZEUS

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The results of recent searches for scalar and vector leptoquarks and anomalous single top production in $e^\pm$ collisions at HERA are presented. The searches make use of the full ZEUS data set corresponding to 0.5 fb$^{-1}$. No evidence for leptoquarks signals is found and limits are set on the Yukawa coupling, $\lambda$, as a function of the leptoquark mass for different leptoquark types within the Buchmüller-Rückl-Wyler model. No evidence for top production is found and upper limits on the single top cross section via flavour changing neutral current and on the anomalous coupling $\kappa_{tu\gamma}$ are set.

1 Search for leptoquarks

Many extensions of the Standard Model (SM) predict the existence of particles, such as leptoquarks (LQs), carrying both lepton and baryon numbers [1]. At HERA, LQs could be resonantly produced in the $s$-channel or exchanged in the $u$-channel between the initial state lepton of energy $27.6$ GeV and a quark coming from the proton of energy up to $920$ GeV with subsequent decays into electron and quark or neutrino and quark, Fig. 1. These decays have a topology similar to deep-inelastic scattering (DIS) neutral current (NC) or charged current (CC).

Analysis searches for deviations from the SM in the lepton-jet invariant mass spectrum at different lepton scattering angle ($\theta^*$) in the lepton-jet scattering frame to reduce DIS background. Two plots of mass spectra measured for NC-like and CC-like events for 106 pb$^{-1}$ data set are showed in Fig. 2.

Since no evidence for any leptoquark signal is found, limits are derived on the Yukawa coupling $\lambda$ as a function of the mass for different leptoquark states as described by the Buchmüller-Rückl-Wyler model (BRW) [1]. Limits are evaluated including also data recorded with the ZEUS detector in 1994-2000, as published in [2], for a total of 0.5 fb$^{-1}$. Table 3 shows mass limit for the 14 BRW LQs at $\lambda = 0.3$. Figures 4 show the limits on the $S_{L0}^q$ and $S_{L1/2}^q$ compared to the limits from CMS [3], D0 [4] and L3 [5]. Assuming $\lambda = 0.3$, the mass limits range from 291 to 629 GeV.

Figure 1: Leptoquark diagrams: $s$-channel LQ production (left) and $u$-channel LQ exchange (right).
2 Search for single top production

In ep collisions at HERA, the production of single top quarks is possible due to the large centre of mass energy, $\sqrt{s} = 318$ GeV. The dominant process for SM single top production, charged cur-
rent process $ep \rightarrow \nu tX$, has a cross section of less than 1 fb \cite{6,7} so no sizeable production is expected and any excess can be attributed to new physics. In several extensions of the SM \cite{8}, single top production can happen via a flavour changing neutral current (FCNC) process mediated by an effective coupling which allows a $u-t$ transition via a neutral vector boson $\gamma \left( tu\gamma \right)$ or $Z \left( tuZ \right)$, see Fig. 5. Due to the large $Z$ mass the process is more sensitive to a coupling $\kappa_\gamma \nu_t$. Furthermore, the production of single top quark is most sensitive to the $tu\gamma$ coupling because large values of $x$, the fraction of the proton momentum carried by the struck quark, are needed to produce a top quark and, at large $x$, $u$-quark parton distribution function (PDF) of the proton is dominant.

The search has been performed in the electron and muon channels. Figure 6 shows the preselection plots in the muon (left) and electron (right) channels.

Since no excess of events above the SM expectations is observed, a further selection is made to improve the limit on FCNC cross section under the assumption of no signals. The 95% C.L. limit on the cross section is found to be: $\sigma < 0.24$ pb at $\sqrt{s} = 318$ GeV. The limit on the cross section is converted into a limit on the coupling $\kappa_\gamma$: $\kappa_\gamma < 0.18$ (95% C.L.). This result has been combined with a previous ZEUS result \cite{9} giving the following results: $\sigma < 0.13$ pb and $\kappa_\gamma < 0.13$ (95 % C.L.) \cite{10}. Constraints on the anomalous top branching ratios (Br) $t \rightarrow u\gamma$ and $t \rightarrow uZ$ were also evaluated assuming a non-zero $v_Z$. Figure 7 shows the ZEUS boundary in the $(Br_\gamma, Br_Z)$ plane compared to limits from H1 \cite{11}, ALEPH \cite{14}, CDF \cite{12}, D0 \cite{13}. For low values of $v_Z$, resulting in branching ratios of $t \rightarrow uZ$ of less than 4%, this paper provides the current best limits.
Figure 7: ZEUS boundary in the (Br_u\gamma, Br_uZ) plane. Also shown are boundaries of H1 [11], CDF [12], D0 [13] and ALEPH [14]. The shaded area is excluded. The dark shaded region denotes the area uniquely excluded by ZEUS.

References