Exotic Searches with the ZEUS Detector

Raphael Galea [a] (for the ZEUS Collaboration)

[a]University of Toronto, Dept. of Physics,Toronto,Ont.,Canada

Exotic Searches have been performed using the ZEUS detector at HERA. Results from a resonance search are presented in terms of Leptoquark and R-parity violating SUSY interpretations, using an event sample corresponding to $47pb^{-1}$ of e^+p data taken between 1994 and 1997. No significant evidence for a resonance was found in either scenario and limits were derived for leptoquark and squark production. The first measurement of the W production cross section in ep collisions is summarized. An explicit upper limit on the W production cross section has been derived and has been translated into constraints on anomalous $WW\gamma$ couplings. Finally, preliminary results are shown for the e^-p data collected in 1998 and 1999 at HERA. No deviations from the Standard Model were observed both in a search for events with an isolated high P_T lepton and in the high-Q^2 neutral current (NC) analyses.

1. RESONANCE SEARCH

At HERA the s-channel production of an eq resonance (leptoquark, LQ) could happen as $eq \to LQ \to eq$. The ZEUS collaboration reported preliminary results of the $LQ \to eq$ search [1], presenting coupling limits as a function of leptoquark mass for several leptoquark species and limits on $\sigma\times$ Branching Ratio $(LQ \to eq)$ as functions of the leptoquark mass. The latter limits are valid for any scalar particle. If this hypothetical scalar particle is interpreted as an R-parity violating ($\not{R}_p$) squark, then R-parity conserving decays are also possible, yielding a $BR(\tilde{q} \to eq) < 1$.

1.1. R-Parity Violating Squarks

R-Parity is a multiplicative discrete quantum number defined as $R_p = (-1)^{3B+L+2S} = 1$ ($R_p = 1$ for particles and $R_p = -1$ for sparticles), where S denotes the spin, B the baryon number and L the lepton number. At HERA, $\not{R}_p$ terms $\lambda'_{ijk}L_iQ_j\bar{D}_k$[1] of the superpotential are of particular interest because of the leptonic and baryonic quantum numbers in the initial state [2].

The consequences of R_p violation are twofold. First the sparticles can be singly produced thereby making the more accessible kinematically and second, the lightest supersymmetric particle (LSP) is not necessarily stable and can decay within the detector.

The ZEUS analysis makes the following assumptions.

1. Only one of λ'_{ijk} is non-zero; i.e. only the decay channels $\tilde{q} \to e^+q$ and $\tilde{q} \to q\tilde{\chi}^0_1$ are considered and the LSP can decay via $\not{R}_p$ as $\chi^0_1 \to e^\pm qq'$. A smaller branching fraction of the LSP to neutrinos is not searched for in this analysis.
2. The LSP is the lightest neutralino.
3. The lightest neutralino is a pure photino: this assumption allows for a simplification in the partial widths of the squarks.

A more general treatment can be found in [3].

1.2. Event Selection and Results

The data are preselected by applying an NC-like selection requiring $Q^{2\dagger} > 800$ GeV^2, an electron[2] candidate of energy greater than 15 GeV and at least one jet, with $E_T{}^\ddagger > 30$ GeV and pseudorapidity $(\eta) < 2.5$, found with the KT

[1]By convention the ijk indices correspond to generations of the superfields, L_i,Q_j and $\bar{D}_k$, the left-handed lepton doublet, quark doublet and the right-handed quark singlet, respectively.

†The four momentum transfer of the exchanged boson at the lepton vertex.

[2]Unless otherwise stated "electron" is used to to either e^+ or e^-.

‡The transverse energy of an object calculated as the scalar sum of calorimeter deposits associated with that object. The object can be a jet, electron or all the hadronic activity in the calorimeter cells.

algorithm. Finally an invariant mass [3] of more than 100 GeV is required.

Three criteria are used to further classify the events:

1. At least 1 jet with $E_{T,jet} > 40$ GeV and $\eta_{jet} < 2.5$
2. At least 2 jets with $E_{T,jet} > 20$ GeV and $\eta_{jet} < 2.5$
3. The electron track is negative at the 3σ-level.

Events were classified into three groups. The topology of $e^- qqq$ required all three criteria as well as $(P_T/E_T)_{had}$[††] < 0.75 to select multijet events and reject NC background, and $0.4 < y$[‡‡] < 0.95 to further reject background coming from NC and photoproduction. The $e^+ qqq$ topology had the same requirements except for the third criteria. The leptoquark-like signal eq is selected if they do not pass the first two criteria and then further cuts are applied such as $P_T^e > 30$ GeV and an optimized y-cut as a function of the reconstructed mass ($y > y_{cut}(M)$); the cut is optimized from leptoquark Monte Carlo simulation.

Topology	Observed	Expected
$e^- qqq$	0	0.06
$e^+ qqq$	33	33.6
eq	78	88.3

Table 1
Numbers of events observed in data and expected from NC and photoproduction background Monte Carlo simulation for each of the topologies considered.

As no deviation from the Standard Model is observed, limits were set on the $R\!\!\!/_p$ coupling λ' as a function of the squark mass (see fig. 1).

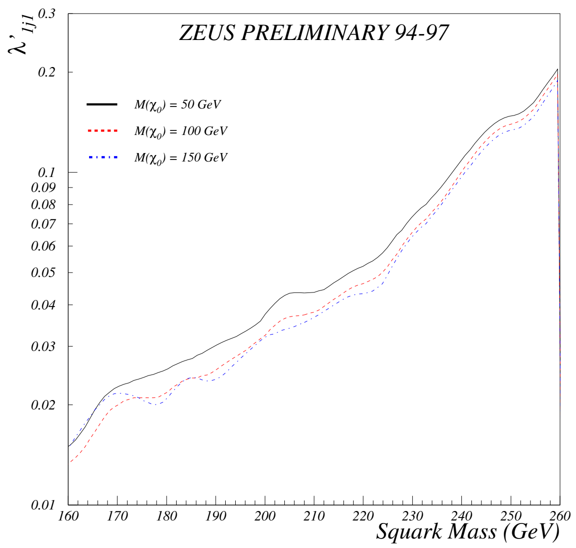

Figure 1. The 95% C.L. upper limit on λ'_{1j1} versus the $\tilde{q}$ mass for $M_{\tilde{\chi}_0} = 50, 100, 150$ GeV

2. W SEARCH

Events with high-P_T leptons and missing P_T are a signature for production of real W bosons.

2.1. Electron channel $W \to e\nu$

Events with an isolated electron with $P_T^e > 10$ GeV and the polar angle of the electron $(\theta^e) < 1.5$ rad, missing $P_T > 20$ GeV and acoplanarity > 0.3 rad were selected. Three events survived the selection, while 1.1 events are expected from processes other than W production. The properties of these three events are shown in the fig. 2.

With an efficiency for selecting $W \to e\nu$ events of 38%, the cross section for W production is determined to be $\sigma(e^+ p \to e^+ W^{\pm} X) = 0.9^{+1.0}_{-0.7}(stat.) \pm 0.2(sys.)\ pb$ [4], in good agreement

[3] $Mass = \sqrt{2E_e(E+Pz)}$, where E_e is the initial electron beam energy and $E+Pz$ is computed from the electron and jet kinematics in the event. This method of *longitudinally constrained* mass reconstruction d resulted in a good mass resolution across a wide range of $\tilde{q}$ masses.

[††] Ratio of transverse momentum and transverse energy of the hadronic system. An object's P_T is calculated as the vector sum of calorimeter deposits associated with that object.

[‡‡] The fractional energy transfer from the proton to lepton in the proton rest frame.

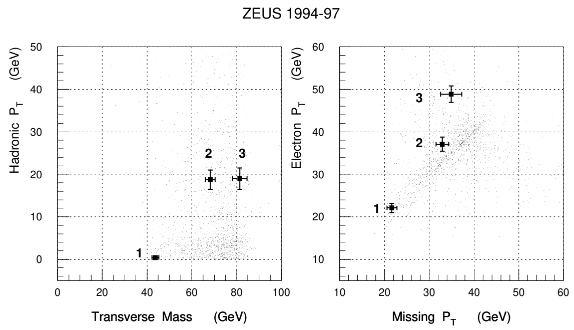

Figure 2. The three surviving events in the missing P_T plus electron sample (*square points*) and W production Monte Carlo simulation corresponding to $50 fb^{-1}$ (*dots*) after all cuts.

with the Standard Model expectation of 0.95 *pb*. In addition, an explicit upper limit on the W production cross section has been derived at the 95% C.L. to be $\sigma(W) < 3.3$ *pb*.

2.2. Muon channel $W \to \mu\nu$

For this channel an isolated muon of P_T^{track}[§] $>$ 5 GeV and $\theta^{\mu} < 2$ rad was required in events with missing $P_T > 15$ GeV. No events were found, while 0.76 are expected from W production and 0.65 are expected from background processes. The efficiency for selecting $W \to \mu\nu$ events is 13% It is lower than the corresponding efficiency in the electron channel due to the calorimeter P_T requirement in the pre-selection. The upper limit derived at the 95% C.L. for this channel is $\sigma(W) < 3.7$ *pb*.

2.3. Anomalous $WW\gamma$ couplings

Combining the final electron and muon events having a large hadronic P_T results in the upper limit at 95% C.L. of $\sigma(e^+p \to e^+W^{\pm}X, P_T^X > 20 \text{ GeV}) < 0.58$ *pb*. This upper limit is subsequently used to obtain the following anomalous coupling constraints:

$$-4.7 < \Delta\kappa < 1.5(\lambda = 0)$$
$$-3.2 < \lambda < 3.2(\Delta\kappa = 0)$$

[§]The transverse momentum of a track in the Central Tracking Detector.

At HERA there is sensitivity to the $WW\gamma$ coupling and the effect of the WWZ^0 coupling is negligible. There are more stringent limits from Tevatron [6] and LEP [7] but they usually make additional assumptions as they are sensitive to both $WW\gamma$ and WWZ^0 couplings.

2.4. Isolated Track Search

The H1 collaboration has reported [5] an observation of an excess of events containing an isolated high P_T muon and large hadronic P_T. Events with a similar topology have been searched for in the ZEUS experiment. The main cuts included missing $P_T > 20$ GeV, $P_T^{track} >$ 10 GeV, $\theta^{track} < 2$ rad and acoplanarity< 0.2 in order to reduce NC background. Three events were found, all of which were positron candidates [4]. This is in agreement with Standard Model expectation. Two of the events are classified as $W \to e\nu$ candidates and the other was a NC-like event with large energy leakage from the calorimeter.

3. A FIRST LOOK AT 1998/99 e^-p DATA

In 1998 HERA began colliding electron beams, rather than positrons, on higher energy (920 GeV instead of 820 GeV) proton beams. New physics could be sensitive to the charge of the lepton beam.

3.1. Isolated High P_T Tracks

ZEUS searched for lepton and missing P_T events using 5.1 pb^{-1} of e^-p data. One event was found with a well isolated high-P_T track, in agreement with the Standard Model expectation of 0.50 ± 0.14. This event is classified as a NC-like event with a large energy leakage from the calorimeter.

3.2. High Q^2 Neutral Current

ZEUS searched for High Q^2 NC events in 8.6 pb^{-1} of e^-p data. One event was found at $Q^2 > 30000$ GeV^2 where 1.1 was expected from the Standard Model.

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