# Search for Exotic Phenomena at H1

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The investigation of rare event topologies in the final state of $ep$-interactions provides a unique possibility to search for signs of new physics like $R_p$-violating supersymmetry or excited fermion states . Recent H1 results of such investigations are presented and the unexpected observation of events with a high energy isolated lepton and large missing transverse momentum is reported.

## 1. INTRODUCTION

The HERA collider is ideally suited to search for new, exotic phenomena with the study of rare topologies in the final state of $ep$-interactions. Such topologies are expected with the existence of excited fermion states or in supersymmetric models where R-parity is violated. In this note, the most recent H1 results of such investigations are reported. The presented results are based on the 1994-1997 $e^+p$-data corresponding to an integrated luminosity of $L \approx 37$ pb$^{-1}$.

## 2. SQUARKS

The most general SUSY theory which preserves gauge invariance of the Standard Model (SM) allows for Yukawa couplings between one scalar squark ($\tilde{q}$) or slepton ($\tilde{l}$) and two known SM fermions, inducing violation of the R-parity ($R_p$). Of special interest for HERA are those Yukawa vertices where a squark couples to a lepton-quark pair via $\lambda'_{ijk}$, with $i$, $j$, $k$ being generation indices [1]. In $e^+p$ collisions squarks would then be dominantly produced via $e^+d \rightarrow \tilde{u}_L$ since the production of scalar down-type squarks would require a $\bar{u}$ from the sea at large Bjorken-x.

At H1, squark searches have been made and exclusion limits have been derived [2] assuming (a) the lightest supersymmetric particle (LSP) to be the lightest neutralino $\chi_1^0$, (b) gluinos to be heavier than squarks such that $\tilde{q} \rightarrow q\tilde{g}$ is kinematically forbidden, and (c) that one of the couplings $\lambda'_{1jk}$ dominates. Since the squarks would then decay either via their $R_p$-violating Yukawa couplings into two SM fermions or via a MSSM gauge decay $\tilde{q} \rightarrow q\chi^{0,\pm}$, one expects numerous event topologies [3] of which three have been studied.

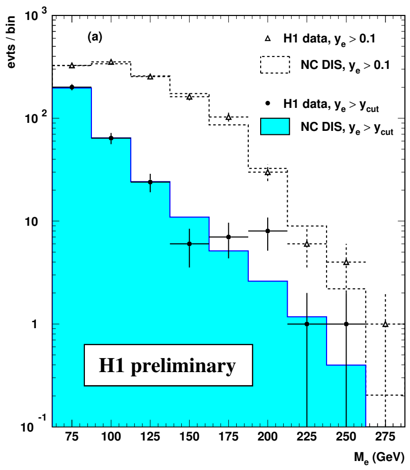


Figure 1. Mass spectrum for $eq$ final state for data (symbols) and SM expectation (histogram). Shown are spectra for a fixed cut on $y > 0.1$ and a mass dependent $y$-cut optimizing signal-to-background ratios [2].

If the resonantly produced squark decays into a quark and a lepton, one expects a neutral current like topology. The selection requirements are similar to those used for the dedicated leptoquark search [4] and are based on the requirements of an isolated positron, momentum balance, and the conditions $Q^2 > 2500$ GeV$^2$ and $0.1 < y < 0.9$. The measured $M_{eq}$ mass spectrum is shown in Fig. 1. For an optimized selection using a mass dependent $y$-cut, general agreement between data and Monte Carlo expectation is found. However, the earlier reported [5] excess of events at masses of $M_{eq} \approx 200$ GeV, although less pronounced, remains. For squark decays into a quark and a neutralino or chargino with $\chi^{0,\pm} \to eqq(qq)$ one expects an '$e^{\pm}$ + jets' topology. The data are again found to be in good agreement with SM expectations.

Assuming the observed deviations to be statistical fluctuations limits have been derived for $M_{squark}$ as a function of $\lambda'_{1j1}$. The exclusion domains for a Zino and Photino dominated LSP with masses of 40, 100 and 150 GeV are shown in Fig. 2, together with the most stringent indirect limits from atomic parity violation [6] and double beta decay experiments [7].

## 3. EXCITED FERMIONS

In $eq$-scattering, magnetic transition couplings to a gauge boson would allow single production of $e^*$, $q^*$ or $\nu^*$ through $t$-channel $\gamma/Z$ or $W$ exchange. Such excited fermion states would then decay, via radiation of these same gauge bosons, leading to numerous exotic final states.

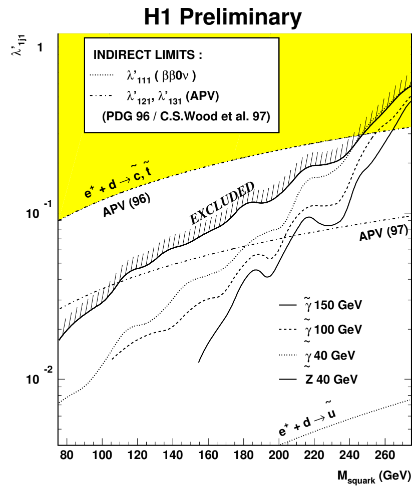


Figure 2. Exclusion upper limits at 95% confidence level for $\lambda'_{1j1}$ as a function of the quark mass and mixtures of the $\chi_1^0$; the most stringent indirect limits on $\lambda'_{1j1}$ are also presented.

Table 1
Analysed decay modes and number of observed events per signature for data and Monte Carlo.

| Channel | Number of events in Data | Number of events in Monte Carlo |
|---|---|---|
| $e^* \to e\gamma$ | 223 | $239 \pm 6$ |
| $\nu^* \to \nu\gamma$ | 0 | $1.3 \pm 0.7$ |
| $q^* \to q\gamma$ | 35 | $34.3 \pm 5.7$ |
| $e^* \to eZ_{\hookrightarrow ee}$ | 3 | $1.4 \pm 0.3$ |
| $q^* \to qW_{\hookrightarrow e\nu}$ | 1 | $1.4 \pm 0.3$ |
| $e^* \to eZ_{\hookrightarrow \nu\nu}$, $e^* \to \nu W_{\hookrightarrow e\nu}$ | 1 | $3.6 \pm 0.7$ |
| $\nu^* \to \nu Z_{\hookrightarrow ee}$, $\nu^* \to eW_{\hookrightarrow e\nu}$ | 0 | $0.4 \pm 0.2$ |
| $e^* \to \nu W_{\hookrightarrow qq}$, $\nu^* \to \nu Z_{\hookrightarrow qq}$ | 3 | $3.8 \pm 0.5$ |
| $e^* \to eZ_{\hookrightarrow qq}$, $\nu^* \to eW_{\hookrightarrow qq}$ | 38 | $48 \pm 3$ |

H1 has examined the decay modes summarized in Table 1, observing in general good agreement with the SM expectation [8]. From the results upper limits on the product of the excited fermion production cross section and the decay branching ratio have been derived at the 95% confidence level as shown in Fig. 3.

## 4. HIGH-$P_t$ LEPTON EVENTS

H1 has searched [9] for high energy isolated leptons in events with missing transverse momentum ($P_t$). The analysis is based on a charged current sample which is purely inclusive with respect to the presence of isolated leptons. However, when applying certain isolation criteria [9], six events remain with a high-$P_t$ isolated track. Of these tracks, 5 are identified as muons and one as a positron candidate. The corresponding SM expectations are $0.8 \pm 0.2$ and $2.4 \pm 0.5$, respectively, indicating a clear excess in the muon channel.

The dominant source for such kind of events comes from single $W$-production, where the $W$ decays leptonically [10]. For the muon case a further, non-negligible contribution is expected from $\gamma\gamma \to \mu\mu$. Three of the muon events are found in a rather unlikely region of phase space w.r.t.

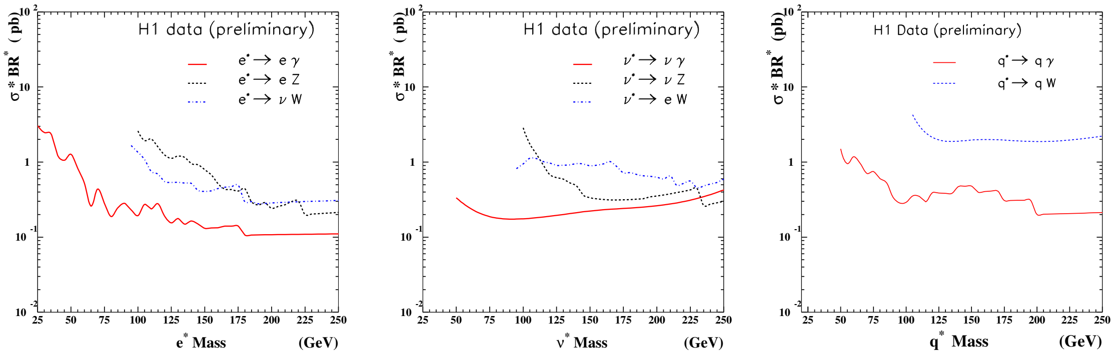


Figure 3. Upper limits on the product of the cross section and decay channel branching ration for excited fermion production at 95% confidence level. Limits are given for the different decay modes analysed.

the W/$\gamma\gamma$-hypothesis. This can be seen from the correlation of the transverse invariant mass $M_T^{\mu\nu}$ and the transverse momentum $P_T^X$ of the recoiling hadronic system shown in Fig. 4.

Possible explanations of these events were recently considered in [11] as anomalous production of $t$-quarks, and by Kon et al. [12] in a rather interesting scenario which could simultaneously explain the excess observed in the $M_{eq}$ spectrum shown in Fig. 1 and the described high-$P_t$ muon events. In the latter they propose the existence of a very heavy $\chi^+$ and a light $\tilde{b}$ such that the $\tilde{t}$ is left with the decay modes $\tilde{t} \to e^+ d$ and $\tilde{t} \to \tilde{b} W^+$. Such an approach can be tested with $e^- p$-scattering, since no high-$P_T$ lepton events would then be expected. Preliminary studies of the most recent HERA data from 1998 and 1999 ($L = 5.1\ pb^{-1}$), where electrons have been used, indicate none of these outstanding events, compared to an expectation of about 0.5. However, more statistics are needed to allow for any definite conclusions.

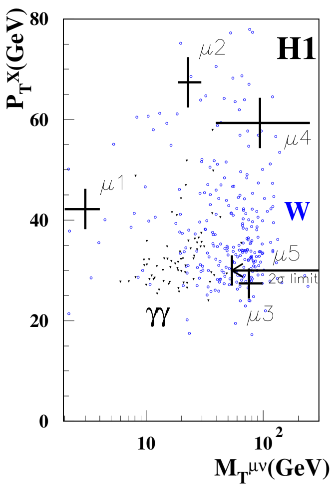


Figure 4. Distribution of muon events (crosses) in $P_T^X$ and $M_T^{\mu\nu}$. The dominate SM contributions are shown for an accumulated luminosity which is a factor 500 higher than in the data.

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