A SEARCH FOR SUPERSYMMETRY AND NEW PHENOMENA AT HERA

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1 Introduction

The *ep* collider HERA, where 27.5 GeV positrons collide with 820 GeV protons, could open a new window for supersymmetric (SUSY) searches and is moreover ideally suited for searches of new heavy states coupling to lepton-quark pairs. This paper reports on a direct search for leptoquarks and supersymmetric partners of the Standard Model (SM) fermions. The analysis presented here is based on an integrated luminosity of 3 pb^{-1} collected by the H1 experiment[1] during 1994 e^+p runs.

2 Search for MSSM particles

In the framework of the minimal supersymmetric extension of the SM (MSSM), the dominant process at HERA is expected to be the slepton($\tilde{e}$)-squark($\tilde{q}$) pair production via a t-channel exchange of neutralinos. The cross-section for such a process mainly depends on the sum of sfermion masses $M_{\tilde{e}} + M_{\tilde{q}}$ and on the parameters of MSSM ($\tan\beta$,μ and M_2 where we use the GUT relation $M_1 = \frac{5}{3}M_2 \tan\theta_W$). The signature under study is the subsequent decay into SM fermions and the lightest supersymmetric particle (LSP) which is assumed to be a neutralino ($\tilde{e} \to e + \chi_1^0, \tilde{q} \to q + \chi_1^0,$). Since in these models the χ_1^0 is stable, event selection mainly requires some missing momentum and a lack of collinearity between the electron and the quark jet.

We found no event satisfying these requirements[2] (also no event from standard Deep Inelastic Scattering (DIS) is expected) and derive 95% confidence level (CL) exclusion limits in the M_2, μ plane (Fig. 1). For $M_{\tilde{e}} + M_{\tilde{q}} \leq 110$ GeV, limits in a new domain of the supersymmetric parameter space are established. This new domain shrinks rapidly when $M_{\tilde{e}} + M_{\tilde{q}}$ exceeds 110 GeV. Depending on M_2, μ and $\tan\beta$ masses of $45 - 55$ GeV for $\tilde{e}$ and $\tilde{q}$ can be excluded thereby exceeding LEP and SLC bounds.

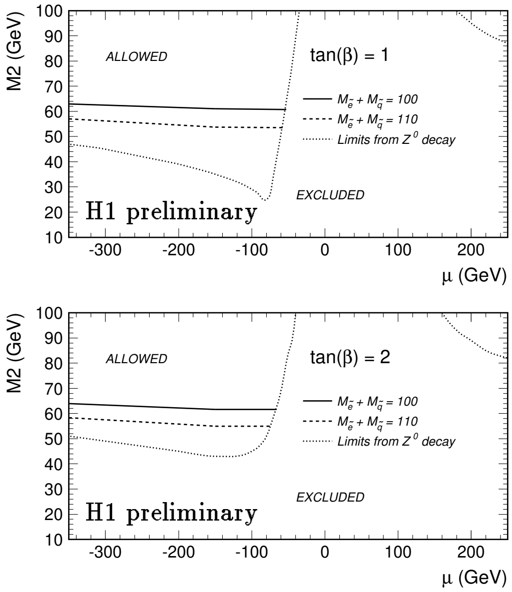

Figure 1: Excluded domains in the $M_2 - \mu$ plane at 95% CL for $\tilde{e}\tilde{q}$ production at HERA. The limits are shown for two values of $\tan\beta$ and for masses $M_{\tilde{e}} + M_{\tilde{q}}$ of 100 GeV and 110 GeV.

3 Searches for R_p-violating SUSY

3.1 Single production of squarks

The most general SUSY extensions of the SM allow for squarks possessing R-parity violating ($\not{R}_p$) Yukawa couplings[3]. Such squarks could be singly produced at HERA up to the kinematic limit of 300 GeV via a lepton number violating coupling λ'_{111} between the incoming lepton and a quark of the incoming proton. We assume that squarks only decay either via their Yukawa coupling into first generation fermions or via their gauge coupling into a quark and a photino $\tilde{\gamma}$ assumed to be the LSP.

When the squark undergoes a $\not{R}_p$ decay, the final state consists of a lepton and a jet and is practically indistinguishable from standard neutral (NC) or charged (CC) current DIS. Statistically, the new signal can be discriminated by the presence of a peak in the invariant mass distribution and by specific spin-dependent angular distribution of decay products[4]. The Bjorken scattering variable y is related to the decay polar angle θ^* in the squark rest frame: $y = \frac{1}{2}(1 + \cos\theta^*)$. Hence $d\sigma/dy$ is flat for a scalar squark whereas it has a y^{-2} dependence for standard DIS events. Event selection for NC-like signatures mainly requires the presence of an isolated electron at large scattering angle balanced in transverse momentum. After a mass dependent y cut, 94 events are found for $M_{\tilde{q}} > 45$ GeV, in excellent agreement with the SM expectation of 93.3 ± 10.3(syst.) events[5].

For gauge decays of the squarks into a quark and a $\tilde{\gamma}$, the $\tilde{\gamma}$ decays dominantly into a $q\bar{q}$ pair and a lepton. This channel, which has a width given by $\Gamma_{\tilde{q}\rightarrow q+\tilde{\gamma}} = \Gamma_{\tilde{q}\rightarrow e+q'} \frac{2e^2 e_q^2}{\lambda'^2}\left(1 - M_{\tilde{\gamma}}^2/M_{\tilde{q}}^2\right)^2$, contributes mainly at low $\tilde{\gamma}$ masses and small λ'_{111}. The final state will then contain a lepton and hadronic activity so the NC-like squark selection can be used.

The number of candidates for squark gauge decays with masses (reconstructed using final state decay products) greater than 45 GeV is 263 where 221 ± 25(syst.) DIS NC background events are expected. Moreover, no wrong sign lepton has been found whilst 50% of e^+ and e^- are expected for a squark signal.

With no evidence for squark production, rejection limits (Fig. 2) on coupling λ'_{111} are derived combining gauge and $\not{R}_p$ decay modes. For $\lambda'_{111} = \sqrt{4\pi\alpha} = 0.3$ we exclude squark masses below 245 GeV.

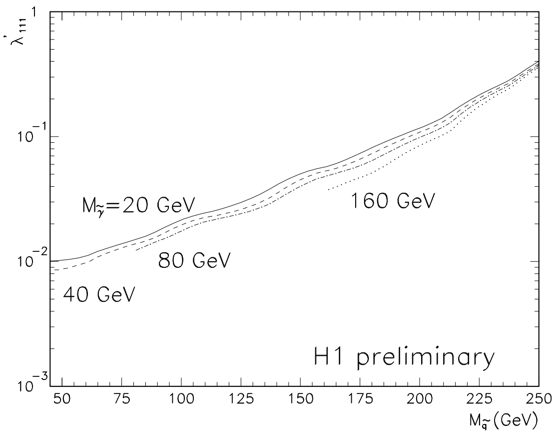

Figure 2: Upper limits at 95% CL as a function of squark mass for various fixed photino masses (regions above the curves are excluded) obtained combining gauge and $\not{R}_p$ decays of the $\tilde{d}$ and $\tilde{u}$.

3.2 *Stop pair production*

In the low mass range, pair production via γ-gluon fusion provides a complementary search insensitive to the Yukawa coupling (provided it is not vanishingly small). Here we consider the stop production. The stop is particular in the sense that a stop mass eigenstate ($\tilde{t}_1$) could exist much lighter than the top and lighter than other squarks. Such a stop mass eigenstate is moreover assumed to be lighter than the lightest chargino. Then the stop undergoes dominantly $\not{R}_p$ decay into an electron and a quark, leading to signatures with mainly two acollinear electrons and two jets. No event is observed[5] satisfying these requirements while 1.0 ± 0.8 event is expected from misidentified DIS NC background. Finally, a stop lighter than 24.4 GeV is excluded at 95% CL.

4 Search for leptoquarks

Leptoquarks (LQ) are colour triplet bosons carrying lepton and baryon numbers. We consider an effective Lagrangian[6] conserving lepton and baryon numbers and obeying the SM symmetries, for scalar and vector LQ with all possible dimensionless Yukawa couplings $\lambda^{L,R}$ to electron-quark pairs. We furthermore assume that couplings are chiral and that LQ are only allowed to decay into leptons and quarks of the first generation, leading to signatures similar to those of a squark undergoing $\not{R}_p$ decay. Hence we can reinterpret the analysis for single squark production and derive limits on the coupling λ for scalar and vector leptoquarks (Fig. 3). For $\lambda = 0.3$, we exclude masses below 250 (210) GeV for LQ formed in the s-channel with valence (sea) quarks[7].

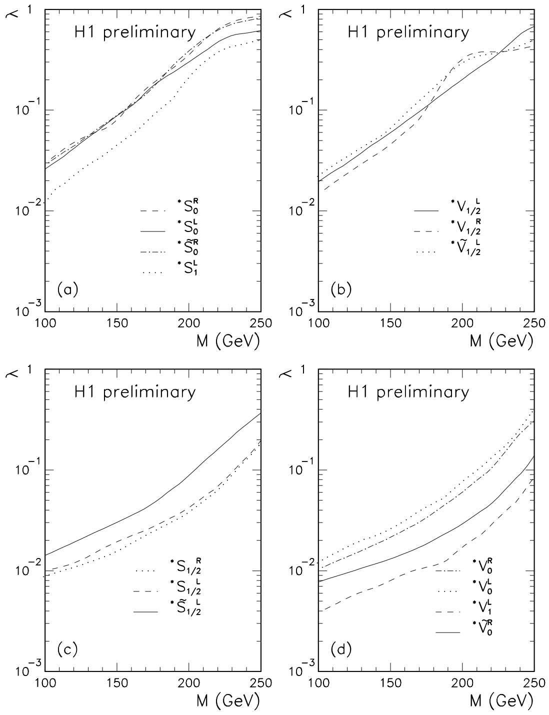

Figure 3: Upper limits at 95% CL as a function of mass on the coupling λ^L or λ^R for scalar and vector LQ decaying into lepton + $\bar{q}$ (a,b) and lepton + q (c,d). Regions above the curves are excluded.

References

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