PROCEEDINGS OF SCIENCE

Search for Squark Production in R-parity Violating Supersymmetry at HERA

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A search for squarks in R-parity violating supersymmetry is performed in $e^{\pm}p$ collisions at HERA using the H1 detector. The full data sample available is used for the analysis. It corresponds to an integrated luminosity of 438 pb^{-1}. The resonant production of squarks via a Yukawa-type coupling λ' is considered, taking into account direct and indirect R-parity violating decay modes. No evidence for squark production is found in the many different final state topologies investigated. Mass dependent limits on λ'_{1j1} and λ'_{11k} $(j,k=1,2)$ are obtained in the framework of the Minimal Supersymmetric Standard Model. At 95% confidence level squarks of the first two generations with masses up to 275 GeV are excluded for a Yukawa-type coupling of electromagnetic strength.

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1. Experimental Setup and R-parity Violating Supersymmetry

The HERA collider at DESY in Hamburg is ideally suited to search for the production of squarks in R-parity violating supersymmetric models. The data used in this analysis were recorded at a centre-of-mass energy of $\sqrt{s} = 318$ GeV with the H1 detector in the years 1998-2007 and correspond to integrated luminosities of 255 pb^{-1} for e^+p and 183 pb^{-1} for e^-p collisions.

In the most general superpotential for supersymmetric theories that allows for baryon and lepton number violating processes, the relevant part is:

$$W_{\not{R}_p} = \lambda LL\bar{E} + \lambda' LQ\bar{D} + \lambda'' \bar{U}\bar{D}\bar{D}$$

where L, Q denote the left-handed lepton and quark superfields and E, U, D the right-handed lepton, up-type and down-type quark superfields. In order to be consistent with the current non-observation of these types of interactions, a new multiplicative quantum number R-parity (R_p) is introduced, which if conserved leads to the exclusion of the mentioned interactions from the theory. It is defined as $R_p = (-1)^{3B+L+2S}$, where B denotes the baryon number, L the lepton number and S the spin of a particle. Especially important for physics at HERA is the $\lambda'_{ijk} L_i Q_j \bar{D}_k$ term in the superpotential, because the single resonant production of squarks in ep-interactions becomes possible via the Yukawa-type couplings λ'_{ijk} and squarks with masses up to the kinematic limit of $\sqrt{s}$ may be produced.

If a squark is produced via this mechanism it can directly decay to lepton-quark pairs via the R-parity violating coupling or first undergo R_p conserving decays into gauginos and Standard Model particles, before the lightest supersymmetric particle then decays via a R-parity violating coupling. The direct decays will lead to signatures similar to neutral and charged current events, with only an electron or neutrino and a jet in the detector (eq and νq), while the decays involving gauginos lead to the production of additional jets and leptons.

2. Results and Interpretation in the MSSM

Total numbers of events selected in the different topologies are summarised in table 1. In topologies based on a high P_T electron, background events mainly come from neutral current events, while topologies based on missing P_T originating from neutrinos are dominated by charged current events. A small amount of photoproduction background also enters the selection via misreconstruction/ misidentification (e.g. jets identified as an electron). An invariant mass of the squark candidate is reconstructed for any given channel using the method with the best resolution. A search for deviations from the Standard Model is performed using the resulting mass spectra. An additional sliding mass window technique is used in channels with high Standard Model background. No significant deviation has been observed for the different channels in the analysis.

In absence of a signal, limits on the strength of the Yukawa-type couplings are derived. The efficiencies for the selection of signal events in the different channels are taken into account, parameterised as functions of squark and gaugino masses. Table 1 also contains the efficiencies for the topologies. For each investigated scenario the branching ratios are calculated using the SUSYGEN3 [2] event generator and convoluted with the corresponding selection efficiencies. The limit

is derived by combining the observations in all channels simultaneously by a frequentist method using 95% confidence levels.

In figure 1 (left) an example of a limit set in a special scenario is given, where the choice of parameters leads to a neutralino dominated by its photino component. In this case the limit is dominated by the observation in the *eMJ* channels and for the high masses by the eq and νq channels. The branching ratios are shown in figure 1 (right) as well as the sum of the branching fractions of all final states considered in this analysis. In order to examine the behaviour of the limits over a wide range in parameter space, scans in the mass parameter μ and the SU(2) mass scale M_2 at a fixed ratio of Higgs vacuum expectation values $\tan\beta$ are performed. In the investigated range the weakest and strongest limits are determined. The resulting exclusion domains for first and second generation up-type (down-type) squarks are shown in figure 2 (left) ((right)). In comparision with the previous H1 limits an improvement over the whole accessible mass range due to the increased integrated luminosity of the measurement is visible for both types. Limits on the Yukawa-type couplings from low-energy observables are also indicated. The limits are over a wide range of the order of 10^{-2} but decrease for squark masses near the kinematic limit of HERA. Assuming a coupling of electromagnetic coupling strength (ie. $\lambda' = \sqrt{4\pi\alpha_{QED}} \approx 0.3$), first and second generation up-type (down-type) squarks can be excluded up to masses 275 GeV (290 GeV).

References

[1] A. Aktas *et al.* [H1 Collaboration], "Search for squark production in R parity violating supersymmetry at HERA," Eur. Phys. J. C **36** (2004) 425, hep-ex/0403027.

[2] N. Ghodbane, S. Katsanevas, P. Morawitz, E. Perez, "'SUSYGEN3, an Event Generator for Linear Colliders", hep-ph/9909499.

[3] J. Haller, "Search for Squark Production in *R*-Parity Violating Supersymmetry at HERA", Ph.D. Thesis, University of Heidelberg, Germany, October 2003, DESY-THESIS-2003-035.

H1 (Preliminary) — Search for Squarks in RPV SUSY					
	e^+p (255 pb^{-1})		e^-p (183 pb^{-1})		
Channel	Data	**SM Expectation**	Data	SM Expectation	Efficiency
eq	2116	2120 ± 260	2127	2190 ± 270	$25-40\%$
νq	–	–	3191	3320 ± 400	$45-65\%$
eMJ (RC)	225	219 ± 33	197	210 ± 32	$10-50\%$
eMJ (WC)	1	0.6 ± 0.4	0	1.3 ± 0.3	$10-20\%$
eeMJ	2	1.7 ± 0.5	0	1.5 ± 0.5	$10-40\%$
$e\mu MJ$	0	0.03 ± 0.02	0	0.03 ± 0.02	$10-20\%$
νeMJ	5	8.2 ± 2.0	3	5.6 ± 1.2	$10-40\%$
$\nu\mu MJ$	0	0.06 ± 0.03	0	0.05 ± 0.03	$10-20\%$

Table 1: Observed and predicted event yields for all $\tilde{q}$ decay channels considered in the analysis for the e^+p and e^-p data samples. $\tilde{u}_L$-type squarks (generated in e^+p collisions) cannot decay to νq.

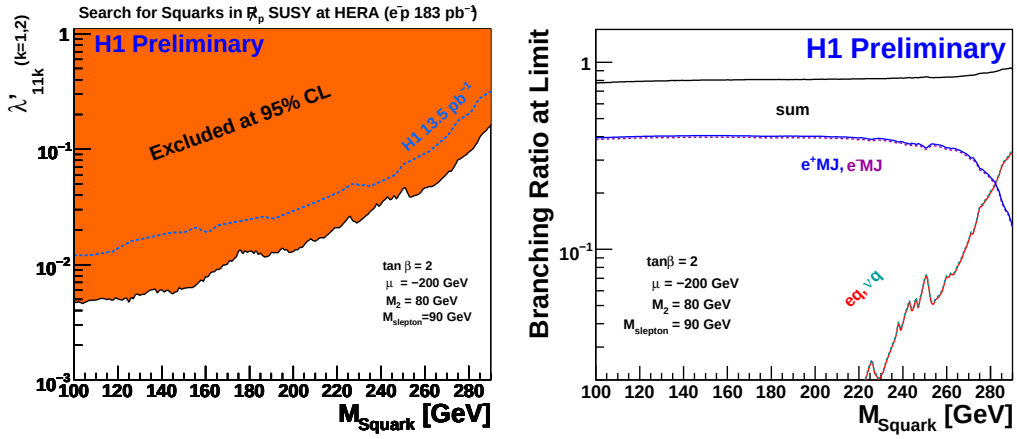

Figure 1: Exclusion limits at 95% CL on $\lambda'_{11k}\,(k=1,2)$ for a photinolike neutralino (left). A slepton mass of 90 GeV is assumed. For comparison, the corresponding limit from the HERA-I analysis [1, 3] is also indicated. Branching ratios to the decay channels considered in the analysis for λ' values at the observed limit (right).

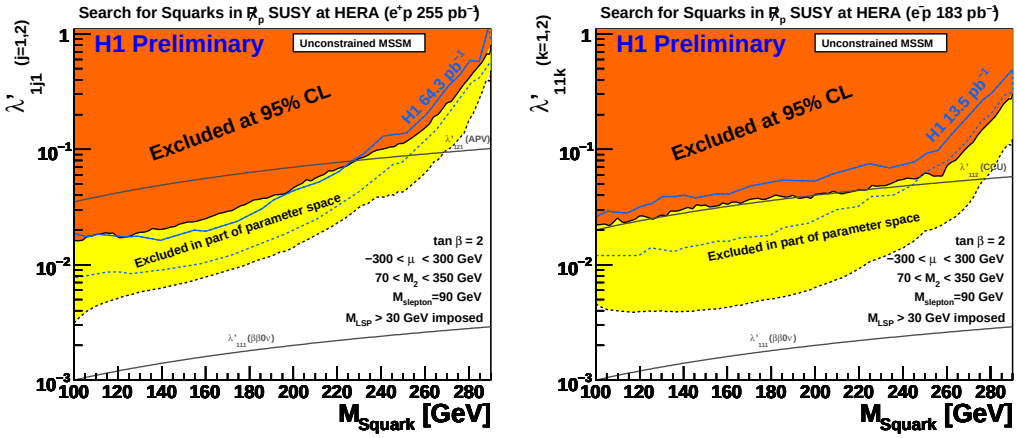

Figure 2: Exclusion limits (95 % CL) on λ'_{1j1} for $j=1,2$ (left) and λ'_{11k} for $k=1,2$ (right) as a function of the squark mass from a scan of the MSSM parameter space as indicated in the figures. The limits obtained in [1, 3] are compared. Indirect limits from atomic parity violation (APV), charged current universality (CCU) and neutrinoless double beta decay experiments ($\beta\beta0\nu$) are also indicated.