Single Sbottom/Scharm Production at HERA in an $R$-Parity Breaking Supersymmetric Model

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Abstract

We investigate the production process of the single scalar bottom quark (sbottom) and scalar charm quark (scharm) at HERA. The sbottom and scharm could be produced via an $R$-parity breaking interactions $\lambda_{123} \neq 0$ in the Minimal Supersymmetric Standard Model (MSSM). These processes give a slight excess in the invariant mass $M_{eq}$ distribution of the high $Q^2$ deep inelastic scattering for sufficiently heavy gauginos and the scalar top (stop). For the light gauginos and stop, it is shown that the tagging of $b/c$-quarks and charged leptons with high transverse energies will be indispensable to search for the processes.
1 Introduction

The HERA accelerator is the only existing electron–proton collider with the center of mass energy of 300GeV (318GeV since 1998) produced by 27.5GeV electrons and 820GeV (920GeV since 1998) protons [1]. The luminosity has steadily increased and the integrated luminosity of $e^+p$ collisions during 1994 – 1997 has reached 36.5pb$^{-1}$ and 47.7pb$^{-1}$ for H1 and ZEUS, respectively. One of the most attractive features of the HERA is to provide a unique possibility to search for new phenomena revealing the physics beyond the standard model (SM) through rare topologies in the final states characteristic to electron – proton collisions.

In this paper we investigate a single scalar bottom quark (sbottom) and a scalar charm quark (scharm) production which is feasible at HERA $ep \to \tilde{b} X(\tilde{c}X)$. Our theoretical framework is on the basis of the Minimal Supersymmetric (SUSY) Standard Model (MSSM) with $R$-parity breaking (RB) interactions [4].

In 1997 both the H1 [5] and ZEUS [6] collaborations reported an event excess in comparison with the SM expectations in the deep inelastic scattering (DIS) $e^+p \to e^+X$ at large $x$ and high $Q^2$. The news very much excited high energy physics community. Various possibilities to understand the anomaly have extensively been examined by theoreticians since then [2, 3, 4]. We have also proposed an interpretation of the anomalous event by the scalar top quark (stop) production in the SUSY models with RB interactions [7, 8]. Contrary to initial expectation, the novel features have gradually faded in the whole data sample with increasing experimental data. However, this fact shows that HERA could have the potentiality exploring physics beyond the SM.

Here we are concerned with $ep \to \tilde{b}/\tilde{c}X$ in contrast with $ep \to \tilde{t}X$ in a previous work. The experimental signature of the present process has a large variety corresponding to decay modes of the sbottom/scharm. When decay modes $\tilde{b} \to ec$ and $\tilde{c} \to eb$ are dominant, the slight excess will be understood by the present scenario. On the other hand, if the gaugino modes dominate over previous ones, high $P_T$ lepton(s) and $b/c$-quarks would be typical signatures of our processes. In this respect, we are interested in the high $P_T$ leptons observed by the H1 [9].

Throughout the present work whole calculations of decay widths and cross sections have been performed by using the GRACE-SUSY system, an automatic computation program for SUSY processes [10]. While the GRACE-SUSY system is originally designed to treat such elementary sub-processes as $e^+e^-$, $eq$ and $qq$ collisions, we have recently succeeded in extending to $ep$ and $pp$ collisions. We use the extended new versions which includes an interface to the PDFLIB too. For the parton distribution function we have used CTEQ4M [11].

In this paper the term "electron" is used to describe generically electrons or positrons if not specified.
2 Models and constraints

We start from the interaction Lagrangian based on the MSSM with an RB interaction

\[ L = \lambda'_{ijk} \bar{u}_{jL} \bar{d}_{kR} P_L e - \bar{d}_{kR} P_L u_j + h.c, \]  

where \( P_{L,R} \) read left and right handed chiral projection operators, respectively. The interaction Lagrangian (1) has been derived from the general RB superpotential [12]:

\[ W_R = \lambda_{ijk} \hat{L}_i \hat{L}_j \hat{E}_c^k + \lambda'_{ijk} \hat{L}_i \hat{Q}_j \hat{D}_c^k + \lambda''_{ijk} \hat{U}_c \hat{D}_c \hat{D}_c^k, \]  

where \( i, j \) and \( k \) are generation indices. The first two terms violate the lepton number \( L \) and the last term violates the baryon number \( B \). Incorporating RB interactions into the MSSM we have a possibility to unveil yet unresolved problems as (i) the cosmic baryon number violation, (ii) the origin of the masses and the magnetic moments of neutrinos and (iii) some interesting rare processes induced by the \( L \) and/or \( B \) violation. The realization of the coupling among participating particles in Eq. (1) will be most suitable for the \( ep \) collider HERA because the squark \( \tilde{u}_{jL} \) or \( \tilde{d}_{kR} \) will be produced in the \( s \)-channel in \( e^+ - q \) sub-processes.

\[ e^+ + d_k \rightarrow \tilde{u}_{jL} \]  
\[ e^+ + \tilde{u}_j \rightarrow \tilde{d}_{kR}. \]

The upper bounds on the coupling constants \( \lambda'_{ijk} \) have already been settled by, for instance, neutrinoless double beta decay [13, 14], charged current universality [12, 15], atomic parity violation (APV) [12, 15, 16] and \( \nu_e \) mass [17]. Some of possible nine coupling constants \( \lambda'_{ijk} \) are severely constrained by experiments mentioned above.

Here we pay attention to the single sbottom and scharm production,

\[ e^+ + \tilde{e} \rightarrow \tilde{b}_R \]  
\[ e^+ + b \rightarrow \tilde{c}_L, \]

which are realized via a non-zero \( R \)-parity breaking coupling \( \lambda'_{123} \). The most stringent upper bound on \( \lambda'_{123} \) comes from the charged current universality experiments [12],

\[ \lambda'_{123} \lesssim 0.1 \]  

for \( m_{\tilde{b}_{R}} \simeq 200 \text{GeV} \).

Sbottoms \( \tilde{b}_{L,R} \) as well as stops are naturally mixed each other due to a large Yukawa coupling to their partner quark. The left- and right-handed sbottom \( \tilde{b}_{L,R} \) are expressed in terms of the mass eigenstates \( \tilde{b}_1, \tilde{b}_2 \) through a mixing angle \( \theta_b \).

\[ \tilde{b}_L = \tilde{b}_1 \cos \theta_b - \tilde{b}_2 \sin \theta_b \]  
\[ \tilde{b}_R = \tilde{b}_1 \sin \theta_b + \tilde{b}_2 \cos \theta_b. \]
We should note that the sbottom mixing is considered to be natural in the case of large $\tan \beta$, because the off-diagonal terms of the sbottom mass matrix are proportional to $m_b (A_b + \mu \tan \beta)$, where $A_b$ and $\mu$, respectively, denote the trilinear coupling and the SUSY Higgs mass. Then the interaction Lagrangian (11) can easily be rewritten in terms of the mass eigenstates ($\tilde{b}_1$, $\tilde{b}_2$). In particular, it is worthy to note that both sbottoms $\tilde{b}_1$ and $\tilde{b}_2$ could be produced in the $eq$ collisions through

$$L_{\tilde{b}ec} = -\lambda'_{123} (\sin \theta_b b_1 e^c p_L c + \cos \theta_b b_2 e^c P_L c) + h.c.$$  \hspace{1cm} (10)

We would emphasize that only one species of scharm $\tilde{c}_L$ can couple to $e^+b$ in our scenario with $\lambda'_{123} \neq 0$.

Interestingly, there exists a theoretical upper bound on the mass of the lighter sbottom $\tilde{b}_1$. In the MSSM, since the left handed stop $\tilde{t}_L$ and sbottom $\tilde{b}_L$ form an $SU(2)$ doublet, their masses include the same contribution from a soft scalar breaking mass $\tilde{m}_{Q_3}$. We obtain an upper bound on the sbottom mass $m_{\tilde{b}_1}^2$ as

$$m_{\tilde{b}_1}^2 \leq m_{\tilde{t}_2}^2 - m_{\tilde{t}_1}^2 + m_b^2 - m_W^2 \cos 2\beta.$$  \hspace{1cm} (11)

The lighter sbottom $\tilde{b}_1$ cannot be heavy for relatively light $\tilde{t}_2$. As we consider the single sbottom and scharm production, we should take into account consistent model parameter sets allowing $m_{\tilde{b}_1}, m_{\tilde{c}} \sim 200\text{GeV}$. For example, in order to obtain $m_{\tilde{b}_1} \gtrsim 200\text{GeV}$, the heavier stop must be rather heavy $m_{\tilde{t}_2} \gtrsim 250\text{GeV}$. This means that the lighter stop must be lighter than about 250GeV.

Next we examine the decay modes of the sbottom and scharm. We assume that the sbottom can decay through $\tilde{b}_{1,2} \rightarrow e c, b \tilde{\chi}_i^0$ and $W \tilde{t}_1$, where $\tilde{\chi}_i^0$ denotes neutralinos ($i = 1 \sim 4$). On the other hand, the scharm can decay into $\tilde{c}_L \rightarrow e b, c \tilde{\chi}_1^0$ and $s \tilde{\chi}_{1,2}^+$. The first decay mode for both sbottom and scharm occurs via the $R$-parity breaking mode and the others proceed through $R$-parity conserving interactions.

At present, we know that the most stringent mass bound on the sbottom with the dominant decay mode $\tilde{b}_1 \rightarrow ec$ is $m_{\tilde{b}_1} > 242(204)\text{GeV}$ for $\text{Br}(\tilde{b}_1 \rightarrow ec) = 1 (0.5)$. This has been obtained by the combined experimental results of the leptoquark searches by the CDF and D0 experiments at Tevatron [18]. It should be noted that the mass bound could become lower when the branching ratio of the $R$-parity breaking mode $\tilde{b}_1 \rightarrow ec$ is smaller.

We are aware of constraints from the precision measurements at LEP1. Potentially, contributions to the $\Delta \rho$ from the $\tilde{t}_L$ and $\tilde{b}_L$ becomes large if their masses are not so different from the weak mass scale of $m_Z$. We have checked contributions to the $\Delta \rho$ from the $\tilde{t}_i$ and $\tilde{b}_j$ [19] could become small to such extent as $7 \times 10^{-4}$ for $m_{\tilde{b}_1} = 200\text{GeV}$, $m_{\tilde{t}_1} = 100\text{GeV}$ and $m_{\tilde{t}_2} = 250\text{GeV}$. 

4
3 Numerical results

In Table I we show two typical input parameter sets adopted throughout our numerical calculations. Output mass parameters of the neutralinos and the lighter chargino are also presented for reference.

Table I  Typical input parameter sets

| masses in GeV | A  | B  |
|---------------|----|----|
| $M_2$         | 300| 150|
| tan $\beta$   | 12 | 2  |
| $\mu$         | -300| -300|
| $m_{c_L}$     | 235| 230|
| $m_{t_1}$     | 250| 90 |
| $m_{t_2}$     | 400| 300|
| $\theta_t$    | 0.42| 1.0|
| $\theta_b$    | 1.2| 1.0|
| $m_{\tilde{\chi}_1^0}$ | 143.4| 76.2|
| $m_{\tilde{\chi}_2^0}$ | 254.4| 158.3|
| $m_{\tilde{\chi}_1^+}$ | 254.4| 158.4|

For these parameter sets, we first calculate the decay branching ratios of sbottoms and the left-handed scharm (see Table II), where we take $\lambda'_{123} = 0.2[0.1]$ and $m_{\tilde{b}_1} = 225[200]$GeV for the set (A) [(B)].

Table II  Branching ratios

|                  | A  | B  |
|------------------|----|----|
| $b_1 \rightarrow e c$ | 0.688| 0.084|
| $\tilde{b}_1 \rightarrow b \tilde{\chi}_1^0$ | 0.312| 0.334|
| $\tilde{b}_1 \rightarrow b \tilde{\chi}_2^0$ | 0.0| 0.181|
| $\tilde{b}_1 \rightarrow W t_1$ | 0.0| 0.401|
| $\tilde{b}_1$ total width | 0.090GeV| 0.164GeV|
| $b_2 \rightarrow e c$ | 0.693| 0.075|
| $\tilde{b}_2 \rightarrow b \tilde{\chi}_1^0$ | 0.307| 0.095|
| $\tilde{b}_2 \rightarrow b \tilde{\chi}_2^0$ | 0.0| 0.278|
| $\tilde{b}_2 \rightarrow W t_1$ | 0.0| 0.551|
| $\tilde{b}_2$ total width | 0.179GeV| 0.352GeV|
| $c_L \rightarrow e b$ | 0.959| 0.006|
| $\tilde{c}_L \rightarrow c \tilde{\chi}_1^0$ | 0.041| 0.069|
| $\tilde{c}_L \rightarrow c \tilde{\chi}_2^0$ | 0.0| 0.291|
| $\tilde{c}_L \rightarrow s \tilde{\chi}_1^+$ | 0.0| 0.634|
| $\tilde{c}_L$ total width | 0.191GeV| 0.697|
From Tables I and II, we find that the set(A) is characterized by the dominant decay modes $\bar{b}_{1,2} \rightarrow e c$ and $\bar{c}_{L} \rightarrow e b$. On the other hand, the SUSY decay modes $\bar{b}_{1,2} \rightarrow b \chi_{i}^{0}$ and $\bar{b}_{1} \rightarrow W \tilde{t}_{1}$ are dominated in the set(B). These properties are originated from the different values of the SU(2) gaugino SUSY breaking mass $M_{2}$ and the lighter stop mass $m_{\tilde{t}_{1}}$. Large $M_{2}$ in the set(A) corresponds to heavy neutralinos $\tilde{\chi}_{i}^{0}$. The $R$-parity conserving decay modes of the sbottoms/scharm are kinematically forbidden in this case.

![Graph](image)

Figure 1: $\lambda'_{123}$ dependence of the total cross section for $e^{+}p \rightarrow e^{+}qX$. We adopt parameter set(A) and $m_{\tilde{b}_{1}} = 225$GeV.

In Fig.1 we show the $\lambda'_{123}$ dependence of the total cross section for the process,

$$e^{+}p \rightarrow e^{+}qX,$$

where we take the set(A) and $m_{\tilde{b}_{1}} = 225$GeV is assumed. To extract the relevant signal we adopt kinematical cuts $Q^{2} > 10^{4}$GeV$^{2}$ and $M_{eq} > 200$GeV. In our calculation two kinds of cuts on $\theta^{*}$, the angle between the outgoing and incoming positron in the $eq$ rest frame, are introduced. As clearly seen from Fig.1, the cross section is more sensitive to the $\lambda'_{123}$ for the more restrictive cut $\cos \theta^{*} < 0$. In another words, more restrictive cut on $\cos \theta^{*}$ would be efficient to extract the signal from background.

In Fig.2 we show the differential cross section against $M_{eq}$ for the set(A), $\lambda'_{123} = 0.2$, $m_{\tilde{b}_{1}} = 225$GeV, $Q^{2} > 10^{4}$GeV$^{2}$ and $\cos \theta^{*} < 0.5$. It will be seen from Fig.2(a)
Figure 2: $M_{eq}$ distribution for set (A), $\lambda'_{123} = 0.2$, $m_{\tilde{b}_1} = 225\text{GeV}$ $Q^2 > 10^4\text{GeV}^2$ and $\cos \theta^* < 0.5$. (a) $e^+ p \rightarrow e^+ \tau X$ (solid line) and $e^+ p \rightarrow e^+ b X$ (dotted line) including contributions from $\tilde{b}_{1,2}$ and $\tilde{c}_L$, respectively. (b) the signal (solid line) and the SM background (dotted line) for $e^+ p \rightarrow e^+ q X$. 
that only the sbottom/scharm production contributes to the relevant signal. As
the masses of two sbottoms and left-handed scharm are in the set(A) almost de-
generate, three peaks corresponding to their masses appear in the range of $M_{eq} = 220 \sim 240 \text{GeV}$. Summing up all sub-process contributions we obtain the observable differential cross section represented by Fig.2(b). We can clearly see a slight excess of the cross section in the range of $M_{eq} = 220 \sim 240 \text{GeV}$. Apparent peak structures, however, cannot be identified.

![Figure 3](image)

Figure 3: The sbottom mass $m_{\tilde{b}_1}$ dependence of the sbottom total production cross sections with different final states. The set(B) and $\lambda'_{123} = 0.1$ are assumed.

The mass $m_{\tilde{b}_1}$ dependence of the total production cross sections of the sbottom with different final states is shown in Fig.3, where the set(B) and $\lambda'_{123} = 0.1$ have been adopted. We should note that $\text{Br}(\tilde{b}_1 \rightarrow ee) \approx 0.1$ and even the light sbottom $m_{\tilde{b}_1} \approx 100 \text{GeV}$ is not excluded from the leptoquark searches at Tevatron. Then signatures relevant to the sbottom production have a large variety of characteristic features. Relatively light sbottom $m_{\tilde{b}_1} \approx 150 \text{GeV}$ dominantly decays into $b\tilde{\chi}^0_1$ and the heavier sbottom also decays into $W\tilde{t}_1$ and $b\tilde{\chi}^0_2$. As the lightest neutralino $\tilde{\chi}^0_1$ can decay into the ordinary particles $e^\pm cb$ or $bs\nu_e$, the decay chains leading to relevant signatures are written as follows,

\begin{align}
\tilde{b}_1 X & \rightarrow b\tilde{\chi}^0_1 X \rightarrow b(e^\pm cb)X, b(bs\nu_e)X \\
& \rightarrow b\tilde{\chi}^0_3 X \rightarrow b(\ell^+\ell^-\tilde{\chi}^0_1)X \rightarrow b(\ell^+\ell^- (e^\pm cb))X, b(\ell^+\ell^- (bs\nu_e))X \\
& \rightarrow b\tilde{\chi}^0_2 X \rightarrow b(bs\tilde{\chi}^0_1)X \rightarrow b(bs(e^\pm cb))X, b(bs(bs\nu_e))X \\
& \rightarrow W\tilde{t}_1 X \rightarrow (\ell \nu_\ell)(c\tilde{\chi}^0_1)X \rightarrow (\ell \nu_\ell)(c(e^\pm cb))X, (\ell \nu_\ell)(c(bs\nu_e))X. 
\end{align}

\[13, 14, 15, 16\]
High $P_T$ charged lepton(s) and/or $b/c$-jet(s) are typical signatures of these processes. Especially, multi-charged leptons and $b/c$-jets are almost the SM background free signals and they could effectively serve us in the sbottom search.

Figure 4: Transverse momentum distributions of the final muon $P_T(\mu)$ (a) and the $c$-quark $P_T(q)$ (b) for the process $e^- p \to \bar{t}_1 X \to W^+ \bar{t} X \to (\mu^- \nu_\mu)X$ (solid line). The set(B), $m_{\bar{t}_1} = 200\text{GeV}$ and $\lambda'_{123} = 0.1$ are assumed. Dotted and dashed lines, respectively, correspond to the backgrounds $e^- p \to e_{esc} W^- q X \to e_{esc}(\mu^- \nu_\mu)qX$ and $e^- p \to e_{esc} W^- c X \to e_{esc}(\mu^- \nu_\mu)cX$.

In Fig.4 we show the differential cross sections for transverse momentum of the final muon $P_T(\mu)$ and the $c$-quark $P_T(q)$ for the process (16) as an example. Here we take the set(B), $m_{\bar{t}_1} = 200\text{GeV}$ and $\lambda'_{123} = 0.1$. When we use the inclusive cross section of the muon to extract the signal, the single $W$ production, $ep \to e_{esc} WX \to e_{esc}(\mu^\nu_\mu)qX$, is severe background, where $e_{esc}$ means the final electron escaped into
the beam pipe. As seen from Fig.4, the background cross section is much larger than
the signal. However, if we can tag the c-quark, the background should be restricted
to \( ep \rightarrow e_{\text{esc}}WcX \rightarrow e_{\text{esc}}(\mu\nu_\mu)cX \) and its cross section is comparable to the signal.
In fact we can expect the event excess in both \( P_T(\mu) \) and \( P_T(c) \) distributions. In
addition to the muon and the c-quark, the information of the \( b \)-quark and/or the
high \( P_T \) electrons (positrons) coming from the neutralino \( \tilde{\chi}_1^0 \) decays is available for
us. All these informations make easier to extract the signals which we are searching
for.

4 Concluding remarks

We have investigated a possible scenario to understand an excess of large \( x \) and
high \( Q^2 \) events in the \( e^+p \rightarrow e^+X \) observed by the H1 and ZEUS experiments at
HERA. Our reasoning is based upon the resonance production of the sbottoms and
the scharm with an \( R \)-parity breaking interaction in the framework of the MSSM.
We have focussed our attention upon its broad mass \( M_{eq} \) distribution characteristic
of the HERA events in addition to large \( x \) and high \( Q^2 \). Assuming almost degenerate
three mass eigenstates \( \tilde{b}_1, \tilde{b}_2 \) and \( \tilde{c}_L \), we have simulated the mass distribution on the
basis of our specific scenario. In the case of large \( M_2 \) and \( m_{\tilde{\tau}_1} \) the present scenario
has its validity. If this is not the case, the sbottom decay dominantly into lighter
sparticles. Then signals are characterized by high \( P_T \) charged lepton(s) and/or \( b/c \)-jet(s).
Now planning vertex detectors at the H1 and ZEUS provide us the efficient
\( b/c \) tagging. Together with a luminosity upgrade bringing integrated luminosities,
for instance, to the level of \( 1 \text{fb}^{-1} \), it is expected that an event excess will be confirmed
and our MSSM approach opens a new horizon.

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References

[1] K. Long, talk at Workshop on electron proton interactions with high transverse
energy, KEK, 28 – 29 March 2000

[2] J. L. Hewett, "Research Directions for the Decade", Proc. of 1990 Summer
Study on High Energy Physics, Snowmass, 1990, ed. E. L. Berger, (World Scienti-
cific, Singapore, 1992), p.566

[3] J. Butterworth and H. Dreiner, Proc. of the HERA Workshop : "Physics at
HERA" 1991, eds. W. Buchmüller and G. Ingelman, Vol.2, p.1079 ; Nucl. Phys.
B397, 3 (1993)
[4] M. Besancon and E. Dudas et al., ”Report of the GDR working group on the R-parity violation”, hep-ph/9810232, related references will be found therein.

[5] C. Adloff et al., H1 Collab., Z. Phys. C74, 191 (1997)

[6] J. Breitweg et al., ZEUS Collab., Z. Phys. C74, 207 (1997)

[7] T. Kon and T. Kobayashi, Phys. Lett. B270, 81 (1991); T. Kon, T. Kobayashi and K. Nakamura, Proc. of the HERA Workshop : ”Physics at HERA” 1991, eds. W. Buchmüller and G. Ingelman, Vol.2, p.1088

[8] T. Kon and T. Kobayashi, Phys. Lett. B409, 265 (1997)

[9] C. Adloff et al., H1 Collab., Eur.Phys.J. C5 575 (1998)

[10] Minami-Tateya Collab.,
http://www-sc.kek.jp/minami/gracesusy.html

[11] H. L. Lai et al., Phys. Rev. D51, 4763 (1995)

[12] V. Barger, G. F. Giudice and T. Han, Phys. Rev. D40, 2987 (1989)

[13] M Hirsch, H. V. Klapdor-Kleingrothaus and S. G. Kovalenko, Phys. Rev. Lett. 75 17 (1995); Phys. Rev. D53, 1329 (1996)

[14] R. N. Mohapatra, Phys. Rev. D34, 3457 (1986); K. S. Babu and R. N. Mohapatra, Phys. Rev. Lett. 75, 2276 (1995)

[15] S. Davidson, D. Bailey and B. A. Campbell, Z. Phys. C61, 613 (1994)

[16] P Langacker, Phys. Lett. B256, 277 (1991); C. S. Wood et al., Science 275, 1759 (1997)

[17] R. M. Godbole, P. Roy and X. Tata, Nucl. Phys. B401, 67 (1993)

[18] Leptoquark Limit Combination Working Group (for the CDF and D0 Collaborations), hep-ex/9810015

[19] C. S. Lim, T. Inami and N. Sakai, Phys. Rev. D29, 1488 (1984); M. Drees and K. Hagiwara, Phys. Rev. D42, 1709 (1990)