arXiv:1212.3328v1 [hep-ph] 13 Dec 2012

CERN-PH-TH/2012-320, DESY 12-231

Light non-degenerate squarks at the LHC

Rakhi Mahbubani,[1] Michele Papucci,[2, 3] Gilad Perez,[1, 4] Joshua T. Ruderman,[2, 3] and Andreas Weiler[5]
[1] *Theory Division, CERN, 1211 Geneva 23, Switzerland*
[2] *Theoretical Physics Group, Lawrence Berkeley National Laboratory, Berkeley CA 94720*
[3] *Department of Physics, University of California, Berkeley CA 94720*
[4] *Department of Particle Physics and Astrophysics,*
Weizmann Institute of Science, Rehovot 76100, Israel
[5] *DESY, Notkestrasse 85, D-22607 Hamburg, Germany*

Experimental bounds on squarks of the first two generations assume their masses to be eightfold degenerate, and consequently constrain them to be heavier than ~ 1.4 TeV when the gluino is lighter than 2.5 TeV. The assumption of squark-mass universality is neither a direct consequence of Minimal Flavor Violation (MFV), which allows for splittings within squark generations, nor a prediction of supersymmetric alignment models, which allow for splittings between generations. We reinterpret a recent CMS multijet plus missing energy search allowing for deviations from $U(2)$ universality, and find significantly weakened squark bounds: a 400 GeV second-generation squark singlet is allowed, even with exclusive decays to a massless neutralino; and in an MFV scenario, the down-type squark singlets can be as light as 600 GeV provided the up-type singlets are pushed up to 1.8 TeV, for a 1.5 TeV gluino and decoupled doublet squarks.

Introduction: As a solution to the electroweak gauge hierarchy problem in the Standard Model (SM), supersymmetry (SUSY) is an immensely compelling paradigm. However its most popular incarnation, the Minimal Supersymmetric Standard Model (MSSM), has a huge parameter space with over a hundred independent parameters. A rather small subset of this parameter space is constrained by naturalness [1–3], and it is possible to reinterpret current searches in the context of an effective theory containing only the most relevant degrees of freedom [4, 5]. The requirement of naturalness, however, gives no guidance regarding the vast majority of parameters of the MSSM or its extensions: those related to the squarks of the first two generations are largely insignificant to the naturalness argument due to the smallness of their Yukawa couplings. At face value, ATLAS and CMS simplified model searches disfavor first- and second-generation squarks below ~ 1.4 TeV, for a gluino mass of 2.5 TeV or less. However, these limits assume an eightfold degeneracy for the masses of two flavors of electroweak doublets, $\tilde{Q}_{1,2}$, and up- and down-type singlets, $(\tilde{u}_R, \tilde{c}_R)$ and $(\tilde{d}_R, \tilde{s}_R)$. We will argue below that this assumption is not justified.

One might wonder how drastic the practical consequences of relaxing this assumption would be. A naive rescaling, assuming that the squark production cross section goes like $m_{\tilde{q}}^{-6}$, would suggest that the bound on a single squark degree of freedom should be around $8^{-1/6} \sim 30\%$ smaller than the current limit, hardly a dramatic change. This estimate fails to take into account two important effects: the first is the drop in signal efficiency at low squark mass due to the hard cuts necessary to minimize SM backgrounds; the second is due to Parton Distribution Functions (PDFs), which, for non-decoupled gluinos, result in the cross sections for second-generation squark production being smaller than the corresponding ones for the first generation (previously noted in the context of Dirac gluinos by [6, 7]). Both these effects work in concert to further weaken the bound on a second-generation squark with respect to the naive expectation, and make, in themselves, a strong case for reanalyzing the data in the context of non-degenerate light squarks.

Adding the theoretical perspective only makes the case more compelling. Squark-mass universality is motivated solely by high scale SUSY breaking models such as Minimal Supergravity, and is not required to solve the SUSY flavor problem. Indeed it is not a direct consequence of Minimal Flavor Violation (MFV) (see *e.g.* [8, 9]), which allows for splittings between squarks belonging to different representations of the SM gauge group, lifting the eightfold degeneracy to a $4 + 2 + 2$ pattern. Furthermore, SUSY alignment models, which address the SM flavor puzzle as well as the SUSY flavor problem, naturally predict an anarchic sfermion spectrum, with O(1) splittings between squarks. This is achieved by assigning particular $U(1)$ charges to the different squark generations under a new set of flavor ('horizontal') symmetries [10], which forces the squark doublet soft masses to 'align with' (be diagonal in) the down Yukawa mass basis, trivially satisfying the most severe constraints from CP violation in the Kaon and B systems and relaxing the constraint on the mass splitting (see *e.g.* [11]). The latter was previously thought to be strongly constrained at the percent level [12, 13], due to a combination of bounds from $K - \bar{K}$ and $D - \bar{D}$ mixing. However, it was recently understood that the bounds from CP-violating processes are largely avoided by successful alignment models [14], leading to a much weaker constraint on squark mass non-degeneracies, for doublets as well as singlets.

To summarize, there is strong practical, as well as theoretical, motivation for re-examining the experimental bounds on the masses of the first two generations of