Searching the Higgs boson in Susy decay chains

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Abstract

In spite of the large QCD background, searches for a boosted Higgs, decaying into a pair of bottom quarks and produced in supersymmetric decay chains are quite promising for the LHC. Such boosted Higgs bosons are frequent in the MSSM, since they are produced from decays of heavy colored supersymmetric particles. In this talk, I report on a study of the prospects of observing the lightest MSSM Higgs boson in the $b\bar{b}$ channel in regions of parameter space that are consistent with a neutralino dark matter relic density.

1 Introduction

Unveiling the origin of Electroweak Symmetry Breaking (EWSB) is of central importance for the LHC. If the Minimal Supersymmetric Standard Model (MSSM) is realized in nature, the lightest Higgs boson responsible of EWSB has to be light ($M_h \leq 130$ GeV) and with Standard Model (SM)-like properties in most of the parameter space. Searches for the light MSSM Higgs boson at the LHC may proceed in the standard production channels, including gluon-gluon fusion, with Higgs decaying into a pair of photons, as well as into neutral and charged gauge bosons, and weak boson fusion with the Higgs decaying into a pair of tau leptons. Preliminary analysis suggest that probing a very light Higgs, with a mass close to the LEP bound (~ 114 GeV) becomes challenging at the early run of the LHC. For these reasons, it is very important to study alternative production and decay channels.

In these proceedings I report on an analysis of the production of a light Higgs through the decay of supersymmetric particles [1]. Such a production is associated with hard b-jets coming from the decay of the Higgs and large missing energy. The produced Higgs boson is generically boosted. Quite recently, a dedicated analysis of the possibility of observing boosted Higgs bosons in supersymmetric particle decays was presented [2]. Here we analyze how general is the production of a (generically boosted) Higgs boson in the MSSM parameter space, focusing on those regions that predict a suitable Dark Matter (DM) candidate.

2 Neutralino Dark Matter

Assuming gaugino mass unification at the GUT scale and a trivial flavor structure in the squark sector, the phenomenology of the model only depends on the five parameters: M_1, μ, $\tan\beta$, M_A, $m_{\tilde{q}}$, and $m_{\tilde{\ell}}$, where $m_{\tilde{q}}$ and $m_{\tilde{\ell}}$ are the common squark and slepton mass parameter. The remaining gaugino masses are determined by the universality relation, which at the TeV scale is given by $M_3 \simeq 3M_2 \simeq 6M_1$. Our analysis does not depend significantly on the slepton mass scale, as long as they are heavier than the two neutralinos $\tilde{N}_{2,3}$, i.e. above ~ 500 GeV. In the remainder of these proceedings we will assume that sleptons (as well as squarks) are at the TeV scale[1].

In spite of the fact that the MSSM with R-parity provides naturally a dark matter candidate, the predicted relic abundance does not easily agree with the value obtained by WMAP, $\Omega h^2 = 0.1123 \pm 0.0035$ [3]. Assuming gaugino mass universality, the LSP (the lightest neutralino) is a linear combination of higgsino and bino states, so that the mass and composition of the LSP depend mainly on M_1 and μ. In Fig. 1 we show the calculated relic abundance as a function of M_1 and μ for the two reference masses $M_A = 300$ GeV (left) and $M_A = 1$ TeV (right) and having fixed $\tan\beta = 10$. Two regions can reproduce a correct relic abundance: the region at $M_1 \sim \mu$, in which the LSP is a strongly mixed bino-higgsino state and the region $\mu \gg M_1$, $M_1 \sim M_A/2$ in which a bino-like lightest neutralino can annihilate resonantly into heavy Higgs bosons. The grey region in the figure is excluded by the present Xenon100 bounds [4] on the spin independent scattering cross section of DM on a nucleon. Spin independent neutralino nucleon scattering is mediated by CP-even Higgs boson exchange and, at large values of $\tan\beta$ and small M_A has a cross section $\propto \tan^2\beta/M_A^4$.

3 Higgs Production through Squark Decay Chains

Since gluinos mainly decay to squark-quark pairs, the fraction of sparticle cascades that contain a Higgs boson is mostly determined by the probability for a squark decay to produce a Higgs boson. In first approximation, this is given by

$$\mathrm{P}(\tilde{q} \to h + X) = \sum_{\chi_i} \mathrm{Br}(\tilde{q} \to \chi_i + q) \times \mathrm{Br}(\chi_i \to h + \chi_j)\,, \tag{1}$$

where χ_i denotes either a neutralino or a chargino.

Fig. 2 shows the branching ratios of the decay of first two generation left-handed up squarks (left) and stops (right) into the lightest Higgs boson. These branchings are largely independent of the value of $\tan\beta$ and M_A, so for our calculation we are

[1] Light sleptons would lead to the decays of neutralinos and charginos to slepton-lepton pairs, depleting in such a way the Higgs production cross section (see [1] for more details).

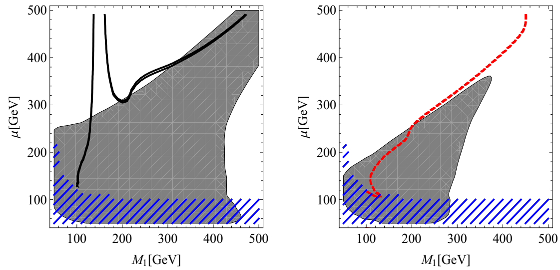

Figure 1: Dark matter relic density for $\tan\beta = 10$ and $M_A = 1$ TeV (right), $M_A = 300$ GeV (left). In the thin region between the solid lines the relic density agrees with the experiments. The hatched region is excluded by LEP bounds on neutralino and chargino masses. The gray regions are excluded by the Xenon100 bounds.

simply fixing the two parameters to 10 and 300 GeV, respectively. In the two panels we are overlapping the contours at constant cross section with the regions in which the lightest neutralino has a correct relic abundance for $M_A = 1$ TeV (in red) and for $M_A = 300$ GeV (in black). For large M_A only left-handed squark decay chains contribute sizably to the production of the Higgs boson. Lowering M_A, the relevant region in parameter space gets shifted to higher values of μ. In the vicinity of the resonance, both the left-handed squarks and the stops give a sizable amount of Higgs bosons. In both cases we can satisfy the constraint coming from Xenon100 (see Fig. 1).

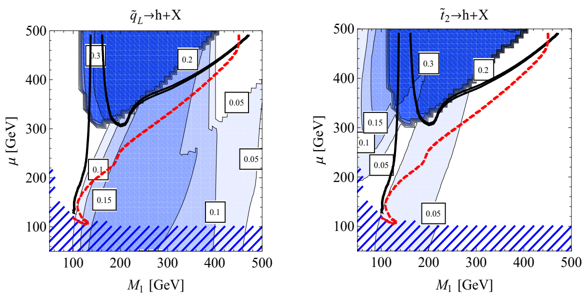

Figure 2: Probability for a Higgs boson in squark decay chains. The gray hatched area is excluded by LEP. Superimposed are the regions of correct relic density for $M_A = 300$ GeV (black) and $M_A = 1$ TeV (in red).

It is interesting to investigate how large Higgs production cross section one could get at the 7 and 14 TeV LHC. Performing basic cuts to reduce the Z + jets and W + jets backgrounds ($\not{E}_T > 200$ GeV, and at least two jets with $p_{T1} > 300$ GeV and $p_{T2} > 200$ GeV), we obtain cross sections as large as 0.3pb at the 14 TeV LHC in the case of $M_A = 300$ GeV and with gluinos just a bit below the TeV. Thus we can conclude that in this particular case the 14 TeV LHC could easily discover such a light Higgs boson even with conventional cut based analysis, also in the regions where the lightest neutralino is a good DM candidate. More challenging is the possibility of having a discovery at the 7 TeV LHC: in order to get a sizable production cross section, squarks and gluinos should be rather light. Fixing their mass to 800 GeV, we find that cross sections as high as ~ 40 fb are still possible, giving some hope for the discovery of a Higgs boson in the boosted regime.

4 Summary

Due to the large QCD background, searches for a light Higgs, decaying into a pair of bottom quarks, appear very challenging at the LHC. However, the $b\bar{b}$ decay channel may be observed by selecting boosted Higgs bosons, which may be easily identified from the QCD background. Such boosted Higgs bosons are frequent in the MSSM, since they can be produced from decays of heavy colored supersymmetric particles. Previous works have emphasized the possibility of observing boosted Higgs bosons in the light higgsino region. Here, we studied the same question in the regions of parameter space consistent with a neutralino dark matter relic density. We conclude that, provided sleptons are heavier than the second lightest neutralinos, the presence of boosted Higgs is a common MSSM feature, implying excellent prospects for observation of the light MSSM Higgs boson in the near future at LHC.

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References

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