Higgs searches in SUSY cascade with the ATLAS detector

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In the context of Supersymmetric extensions of the Standard Model, the lightest Higgs boson can be produced via cascade decays of supersymmetric particles. We investigated the possibility of observing such events with the ATLAS detector at the LHC. We showed that, for some regions of the Minimal Super-Gravity parameter space compatibles with the last LEP searches, the lightest Higgs boson can be discovered with less than 10 fb^{-1}, giving results competitive with standard Higgs production channels. The possibility of reconstructing the supersymmetric particles mass spectrum in these scenarios has also been studied.

1. Introduction

In supersymmetric (SUSY) theories the properties of bosons are related to those of fermions so that each particle has a partner with spin differing by 1/2. Supersymmetric extensions of the Standard Model [1,2] are very appealing since they offer a solution to the hierarchy problem. Indeed, the quadratic divergence in the Higgs mass radiative correction appearing in the Standard Model is exactly canceled by the supersymmetric particles contribution, leaving only a logarithmic term:

$$\Delta m_h^2 \propto m_{susy}^2 \ln{(\Lambda_{UV}/m_{susy})}, \qquad (1)$$

where m_{susy} is the mass splitting between the Standard Model particles and their supersymmetric partners and Λ_{UV} is an ultraviolet cutoff.

This equation tells us that the masses of the new SUSY particles should not be much bigger then the TeV scale, otherwise the correction to the Higgs mass would be unnaturally large compared to the electroweak breaking scale ($\sim$ 100 GeV) and the hierarchy problem would appear again. So, these new particles can be produced at the LHC and generate by successive decays a cascade of SUSY particles, ending with the lightest supersymmetric particle, which is often the stable and weakly interacting lightest neutralino, implying a missing transverse energy signature.

During the cascade process, the lightest neutral Higgs boson (h) may also be emitted. In this case, the missing transverse energy produced in association with the Higgs can be exploited to reduce the background, making it possible to study the dominant decay channel $h \to b\bar{b}$, otherwise covered by the enormous QCD continuum.

2. Higgs searches in the $h \to b\bar{b}$ channel

Exploiting the capabilities of the ATLAS detector [3,4] in missing transverse energy measurement and b-tagging, the passage of weakly interacting particles may be revealed and a bb pair with invariant mass peaking around the Higgs mass can be reconstructed. The following selection cuts were applied:

- $E_T^{miss} > 300$ GeV;
- exactly 2 b-jets with $p_T > 50$ GeV;
- two light flavoured jets with $p_T > 100$ GeV;
- no leptons with $p_T > 10$ GeV.

The main sources of background are SUSY events themselves, as they contain lot of b-jets, both true and mistagged, and Standard Model top production. Moreover, the minimization of fake high transverse missing energy signals produced by instrumental effects is mandatory to control the QCD background.

For the Minimal Supergravity (mSUGRA) [5] point ($m_0 = 300$ GeV, $m_{1/2} = 425$ GeV, $A =$

200 GeV, $\tan\beta = 20$, $\mu > 0$), which is compatible with the last searches at LEP [6], a signal significance ($S/\sqrt{B}$) of order 10 can be achieved after 10 fb^{-1}. Figure 1 shows the invariant mass distribution of the bb pair for this scenario.

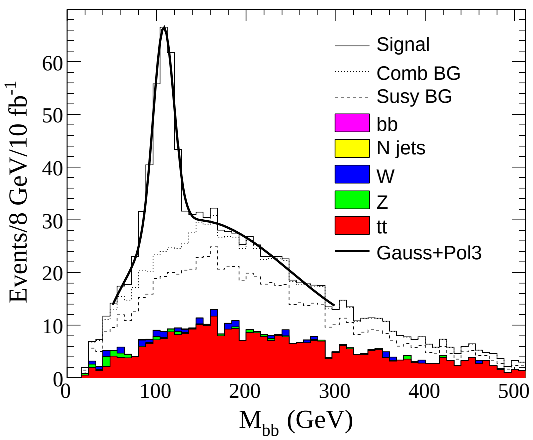

Figure 1. Invariant mass distributions of the bb pair.

3. SUSY parameter determination

Once beyond the Standard Model phenomena are discovered, it is important to determine the masses and couplings of the new observed particles. At the LHC, mass informations are provided by thresholds and edges in the invariant mass plots of particles produced in SUSY cascades.

In the case under study, the Higgs is mainly produced by the cascade:

$$\tilde{q}_L \to \tilde{\chi}_2^0 q \to \tilde{\chi}_1^0 hq. \qquad (2)$$

As a consequence of two-body kinematics, the invariant mass of the Higgs-quark pair shows both a minimum and maximum value, related to different combinations of the masses of the involved SUSY particles.

Figure 2 shows the bb+jet invariant mass distribution, where the jet is the one minimizing the invariant mass, selected between the two with hardest p_T in the event. The mass edge is clearly visible and its value can be obtained by a Gaussian convoluted triangular shape fit. The mass threshold can be measured in the same way by replacing the jet with the one maximizing the invariant mass.

The statistical error on the two values after 100 fb^{-1} is estimated to be of order 5 GeV and a systematic error of about 1% is expected on the jet energy scale.

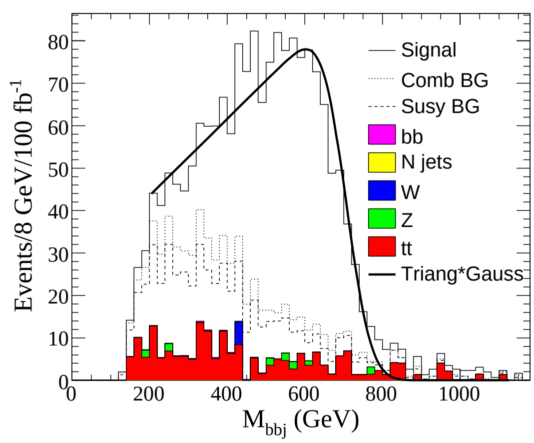

Figure 2. Invariant mass distributions of the bb+jet system.

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