Prospects for SUSY Discovery and Measurements with the ATLAS Detector at the LHC

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Abstract

We present searches for generic SUSY models with R-parity conservation in the ATLAS detector at the LHC, based on signatures including missing transverse energy from undetected neutralinos, multiple jets and leptons or τ- and b-jets. We also show the techniques developed to reconstruct the decays of SUSY particles. We concentrate on strategies to be applied to the first fb^{-1} of ATLAS data.

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1. Introduction

Supersymmetric (SUSY) extensions of the Standard Model (SM) [1,2] are among the best motivated models of new physics and predict a large spectrum of new, unobserved particles with mass at the TeV scale, which are therefore expected to be produced at the LHC.

The Minimal Supersymmetric Standard Model (MSSM) contains the minimal possible addition of particles. It associates to each SM particle a partner with spin differing by half a unit. Moreover, in order to avoid couplings that lead to a rapid proton decay, a new discrete symmetry, R-parity, is introduced. It turns out that all the ordinary SM particles and the Higgs bosons have positive R-parity, while their supersymmetric partners have $R = -1$. Three important phenomenological implications follow: in collider experiments, SUSY particles are produced in even number; each SUSY particle can decay only into a state containing an odd number of SUSY particles; the lightest SUSY particle (LSP) is stable.

The experimental signature of supersymmetry at collider detectors is different depending on the nature of the LSP. In this work, we will concentrate on models wih neutral and

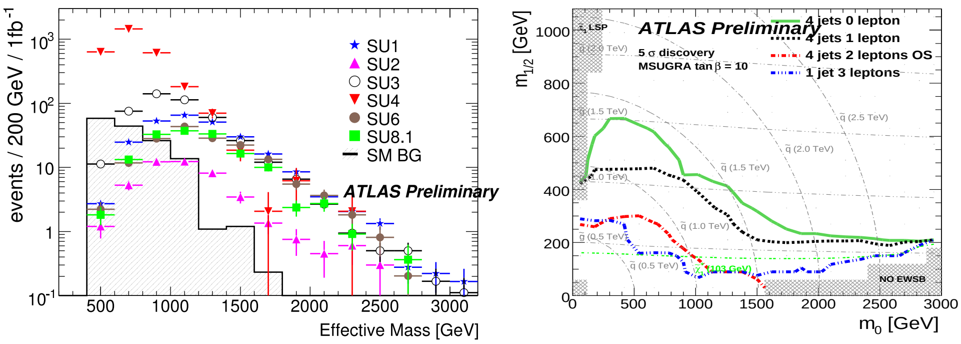

Fig. 1. Left: effective mass distribution for a set of benchmark scenarios and for the SM background, in the 1-lepton and 4-jet channel. Right: discovery contours in the Minimal Supergravity parameter space, for different search channels and for an integrated luminosity of 1 fb^{-1}.

weakly interacting LSP's, that escape the detector without leaving any trace or energy deposit. However, thanks to the hermetic coverage of the ATLAS detector, an imbalance of the total transverse energy measured, called missing transverse energy ($E_T^{\rm miss}$), can be reconstructed.

2. Inclusive searches

Strongly interacting SUSY particles, such as squarks and gluinos, will dominate the SUSY production at the LHC if their mass is in the TeV range. Their decay products will contain two LSP's and a number of SM particles, in particular highly energetic quarks and gluons. Typical SUSY signatures are therefore based on large missing transverse energy and hard jets. Detailed studies have been carried out for a wide range of channels, including 0-, 1-, multi-lepton modes, as well as signatures involving τ- and b-jets. Selection cuts are discussed in [3]. After applying a set of selection cuts, SUSY production is evident in the distribution of the effective mass, defined as the scalar sum of $E_T^{\rm miss}$ and the transverse momentum of each of the requested particles.

Figure 1 shows such distribution for a set of benchmark scenarios and for the SM background in the 1-lepton and 4-jet channel. In most of the cases, a noticeable excess of events is observable at high effective mass values already with 1 fb^{-1} of integrated luminosity, an amount of data that is expected to be collected within the first one or two years of LHC running.

The right plot of Figure 1 shows the discovery contours for the same luminosity in the $(m_0, m_{1/2})$ parameter space of the Minimal Supergravity model [2]. The remaining parameters are fixed to $\tan\beta = 10$, $A_0 = 0$ GeV and positive μ. Squark and gluino masses of the order of up to 1 TeV can be reached.

3. Exclusive measurements

Since the cascade chain of SUSY particles always ends up with an LSP that escapes detection, no invariant mass peak of supersymmetric particles can be reconstructed at

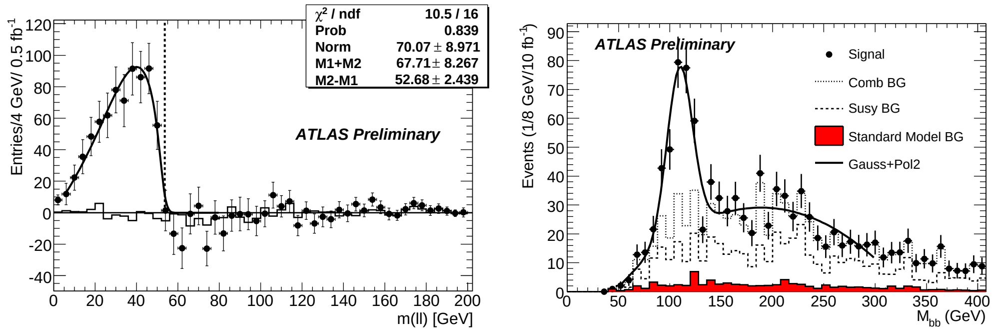

Fig. 2. Left: reconstructed $\ell^+\ell^-$ invariant mass distribution for a benchmark scenario and after background subtraction. Right: reconstructed $b\bar{b}$ invariant mass distribution for a benchmark scenario and for the SM background.

the LHC. Invariant masses of two or more particles coming from the same cascade may, however, show structures, such as thresholds and edges, that can provide information about the mass spectrum of the model.

The cleaner, thus more powerful, channel is the di-leptonic signature. Figure 1 shows the reconstructed $\ell^+\ell^-$ invariant mass distribution for a benchmark scenario and after background subtraction. The endpoint corresponds in this case to the mass difference between the lightest and the next-to-lightest neutralino. With 1 fb^{-1} of data, its value can be measured with an uncertainty of less than 3 GeV, dominated by statistical effects.

Similar investigations have been performed for channels containing leptons plus jets or a pair of τ-jets.

A particularly interesting signature arises from the emission of a Higgs boson during the cascade decay of a SUSY particle. In this case, the missing transverse energy produced in association with the Higgs boson can be exploited to reduce the background, making it possible to study the dominant decay $h \to b\bar{b}$, otherwise hidden by the enormous QCD continuum. The reconstructed $b\bar{b}$ invariant mass distribution for a benchmark scenario is reported in the right plot of Figure 2. For 10 fb^{-1}, the Higgs resonance peak is clearly visible over the background.

4. Conclusions

Supersymmetry with R-parity conservation with particle masses below the TeV scale should be accessible by the ATLAS experiment with a few years of running. A broad spectrum of search channels have been investigated to cover many different SUSY signatures. Once a signal is established, kinematic endpoints in specific SUSY decay chains can be exploited to reconstruct the mass spectrum of the model.

References

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