Studies of Neutralino Decays in ATLAS

S. Chouridou, D. Schaile, R. Ströhmer, and T. Trefzger

One of the best motivated extensions of the Standard Model (SM) is Supersymmetry (SUSY) [1]. It is a purely theoretical invention that generalizes the space-time symmetries of quantum field theory by transforming fermions into bosons and vice versa. That is spin-$\frac{1}{2}$ fermions, leptons and quarks have spin-0 superpartners, while spin-1 bosons, like the photon, have spin-$\frac{1}{2}$ superpartners. But SUSY is not a static symmetry of nature, otherwise the superpartners would have the same mass as their partners and they would have been detected easily long time ago. Rather SUSY is a dynamic symmetry. There are different theoretical models that describe the breaking of SUSY and one of them is the Minimal Supergravity model (mSUGRA) [2].

The masses of the superpartners are expected to be in the order of 1 TeV, thus their discovery potential at the Large Hadron Collider at CERN, where the center-of-mass energy in the particle collisions is 14 TeV, is very large.

The Supersymmetry (SUSY) discovery potential of the ATLAS detector through the production of the next-to lightest neutralino ($\tilde{\chi}_2^0$) was studied. Within the Minimal Supergravity model (mSUGRA) of SUSY, five parameters are used in order to determine the masses and the couplings of the particles: m_0 the common scalar mass, $m_{1/2}$ the common gauginos and Higgsinos mass, A_0 the trilinear Higgs-sfermion-sfermion couplings, $tan\beta$ the ratio of the two Higgs vacuum expectation values and $sign(\mu)$ the sign of the Higgsino mass parameter. At one of six typical points of mSUGRA selected by the LHC Committee and the ATLAS Collaboration for detailed studies, characterized by

$$m_0 = 800 \text{ GeV},\ m_{1/2} = 200 \text{ GeV},\ A_0 = 0,\ tan\beta = 10,\ \mu > 0\ ,$$

the $\tilde{\chi}_2^0$ has a three body decay ($\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 l^+ l^-$) through a virtual Z^* with a branching ratio of 5%.

This decay and its potential SUSY and SM backgrounds were studied. Two versions of the Monte Carlo generator PYTHIA were used: PYTHIA 6.158 and PYTHIA 6.160. In both of these, the supersymmetric extension of PYTHIA (SPYTHIA [3]) that can perform simulations in mSUGRA is implemented. The main difference between the two versions is that although in 6.158 the decays of sparticles are purely phase space treated, in 6.160 the spin-averaged matrix element is included in these decays, thus taking into account the spin of the neutralinos, as well as the propagator (Z^*).

The generated events were passed through the standard fast simulation of the ATLAS Collaboration, ATLFAST [4]. For an integrated luminosity of $3 \cdot 10^4$ pb^{-1}, we reconstructed the invariant mass of opposite-sign same-flavour (OS-SF) lepton pairs, i.e. e^+e^- or $\mu^+\mu^-$, at point 4 for both PYTHIA versions. Subsequently we applied stringent selection criteria in the distributions obtained (Fig.1). In both cases around 6500 SUSY events (OS-SF) remain while the SM $t\bar{t}$ background is reduced to only 250 events. The main background left comes from other SUSY processes e.g. chargino decays (SUSY background). This combinatorial background contribution can be estimated by using a sample of events selected with the same selection criteria, except that the two leptons are required to have opposite sign and opposite flavour (OS-OF), i.e. $e^+\mu^-$ or $e^-\mu^+$. About 3300 such events are expected from SUSY production at Point 4 for an integrated luminosity of $3 \cdot 10^4$ pb^{-1}.

A more quantitative comparison between the invariant mass spectra of the two PYTHIA versions is made by fitting the two distributions with the same function and compare its parameters. After several attempts, we obtained the following fitting function:

$$F(x) = p_1 \cdot e^{\frac{(x-p_2)}{p_3} - e^{\frac{x-p_2}{p_3}}} + P \qquad (1)$$

where p_i (i = 1,2,3) are the parameters determined by the fit, while P is a fixed polynomial of 6th degree that describes the combinatorial background and is obtained from a fit to the OS-OF sample. The parameter p_1 serves as a normalisation parameter for the size of the distribution, the p_2 is the peak position and finally p_3 characterizes the width of the distribution.

The same procedure was followed for three other points of the $(m_0, m_{1/2})$ space (where the mass difference between the two lightest neutralinos is the same as at point 4, $M_{l^+l^-}^{max} = M_{\tilde{\chi}_2^0} - M_{\tilde{\chi}_1^0} \simeq 72$ GeV) as well as for a few more points of the mSUGRA parameter space where we changed also the $tan\beta$ and the $sign(\mu)$. After comparing the invariant mass distributions obtained, we concluded that in general it is possible to distinguish between a phase space decay and a spin-averaged matrix element neutralino decay. The channel $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 l^+ l^-$ can be successfully used for SUSY studies in large regions of the parameter space.

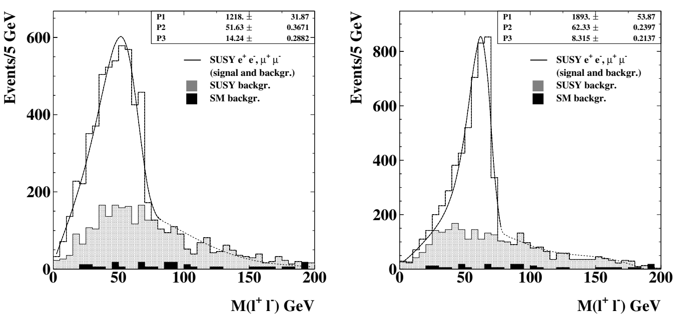

Fig. 1: Expected dilepton invariant mass distributions for SUSY events containing opposite-sign same-flavour lepton pairs at Point 4 (full histogram) and for the $t\bar{t}$ background (dashed black histogram), for an integrated luminosity of $3 \cdot 10^4$ pb^{-1} for (a) PYTHIA 6.158, and (b) PYTHIA 6.160. In both Figures the SUSY background consisting of opposite-sign same-flavour lepton pairs is also indicated (dashed grey histogram). The fitted function is plotted as a solid line in the mass region used in the fit.

References

[1] J. Wess and B. Zumino: Nucl. Phys. **B78** (1974) 39
[2] J. Ellis *et al.*, Phys. Lett. **B121** (1983) 123
[3] SPYTHIA: A Supersymmetric Extension of PYTHIA 5.7, ANL-HEP-PR-96-63, 1996.
[4] E. Richter-Was *et al.*, ATLFAST 2.0: a fast simulation package for ATLAS, Atlas Note ATL-PHYS-98-131, CERN, 1998.