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SUSY SEARCHES USING THE ATLAS DETECTOR AT THE LHC

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We discuss the status of preparations for SUSY searches at ATLAS. This includes inclusive techniques designed for discovery of SUSY via missing energy signatures, and prospects for measurements of SUSY model parameters such as sparticle masses. Results of the analysis of 5 fb^{-1} of fully simulated Monte Carlo data are shown.

Keywords: ATLAS; LHC; Supersymmetry.

The motivations for supersymmetric extensions to the Standard Model are well known. SUSY is the maximal extension of the Lorentz group. Furthermore, it is a property inherent to most string theories, which appear to represent our best hope for incorporating gravity into a fundamental unified theory. Weak-scale SUSY is also well-motivated as a solution to the gauge hierarchy problem, and appears to allow for gauge-coupling unification at very high energies. R-Parity conserving (RPC) SUSY models provide a good cold dark matter (CDM) candidate in the form of the lightest supersymmetric particle, usually the lightest neutralino. CDM is now well established by recent results from WMAP[1], which provide improved constraints on the parameter spaces of SUSY models. In RPC models, each supersymmetric decay chain results in the production of one LSP; the canonical signature for supersymmetry is therefore the presence of large missing energy.

The Minimal Supersymmetric Standard Model (MSSM) has 105 free parameters in addition to those of the Standard Model. To complicate matters further, there are different classes of SUSY models, depending on how SUSY is broken (in some hidden sector) and how the SUSY breaking is mediated to the MSSM sector: studies of gravity-mediated (SUGRA), gauge-mediated (GMSB) and anomaly-mediated (AMSB) SUSY at ATLAS are all in progress. For each class of model there is some minimal model that relies on only a few parameters. Here, we focus on the minimal supergravity (mSUGRA) model which has five parameters, m_0, $m_{1/2}$, A_0, $\tan\beta$ and

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sgn(μ). However, certain analyses discussed here are "quasi model independent" in that they rely only on the existence of a particular signature (e.g. missing energy) and an adequate SUSY production cross-section, as discussed below.

Much work has been undertaken over the past decade, in preparation for SUSY searches at the LHC. For much of the standard parameter space the discovery of SUSY at the LHC requires only a modest amount of data. For example, a standard technique is to select events with highly-energetic jets and large missing energy transverse to the beam ($\not{E}_T$). This yields a sample "enriched" in SUSY events. For each of these events one can calculate an effective mass as the scalar sum of the p_T of the jets and the missing transverse energy, $M_{eff} = \sum_i |p_T^i| + \not{E}_T$. This distribution should peak at about twice the SUSY mass scale ($M_{\rm SUSY}$), defined as the cross-section weighted mean SUSY particle mass. The result of an analysis of 5 fb^{-1} of fully simulated Monte Carlo data is shown in Fig. 1a, for mSUGRA with $m_0 = 100$ GeV, $m_{1/2} = 300$ GeV, $A_0 = 300$ GeV, tan$\beta = 6$ and $\mu > 0$. This technique relies only on the existence of the missing energy signature and a total SUSY cross-section large enough to produce a signal above the SM background, which falls rapidly with increasing M_{eff}. It is thus, in principle, also applicable to models with gauge- or anomaly-mediated SUSY breaking, provided the missing energy signature is present and the SUSY cross-section is sufficient. Since the normalization of the SUSY signal is strongly correlated to the total SUSY cross-section, such an analysis will provide the first information on the details of the SUSY model.

Once SUSY has been observed, the next task will be to attempt to measure model parameters such as sparticle masses. Although precision measurements will eventually be performed at a future linear collider, much work is already being devoted to developing methods allowing good measurements to be done already at the LHC. The most established of these[3] rely on the reconstruction of the "dilepton edge" in the decay $\tilde{\chi}_2^0 \to \tilde{\ell}\ell \to \ell\ell\tilde{\chi}_1^0$. Measurement of the position of this endpoint (see Fig. 1b) provides a constraint on the masses of the $\tilde{\chi}_2^0$, $\tilde{\chi}_1^0$ and $\tilde{\ell}_R$. This technique can also be applied to other endpoints and thresholds; for the decay sequence $\tilde{q}_L \to q\tilde{\chi}_2^0 \to q\tilde{\ell}\ell \to q\ell\ell\tilde{\chi}_1^0$ multiple constraints on the sparticle masses can be obtained from measurements of edges and thresholds of various combinations of quarks and leptons. These constraints can then be used to extract the $\tilde{\chi}_2^0$, $\tilde{\chi}_1^0$, $\tilde{\ell}_R$ and $\tilde{q}_L$ masses in a model-independent way.

Other techniques not relying on the dilepton-edge reconstruction have also been developed[4]. The masses of right handed squarks ($\tilde{q}_R$) can be reconstructed from the decay $\tilde{q}_R \to \tilde{\chi}_1^0 q$ using the so-called "stransverse mass" technique[5]. Gluino masses can be determined using the "mass-relation" technique, applied (for example) to the decay sequence $\tilde{g} \to \tilde{b}b \to \tilde{\chi}_2^0 bb \to \tilde{\ell}bb\ell \to \tilde{\chi}_1^0 bb\ell\ell$. Assuming that the $\tilde{\chi}_2^0$, $\tilde{\chi}_1^0$ and $\tilde{\ell}$ masses have been determined from other techniques, the kinematic equations for this decay sequence yield five equations for six unknowns: $M_{\tilde{g}}$, $M_{\tilde{b}}$ and $p(\tilde{\chi}_1^0)$. If the kinematics of two events are combined, there are ten equations and ten unknowns and one can solve for these quantities. This technique can be generalized to use all

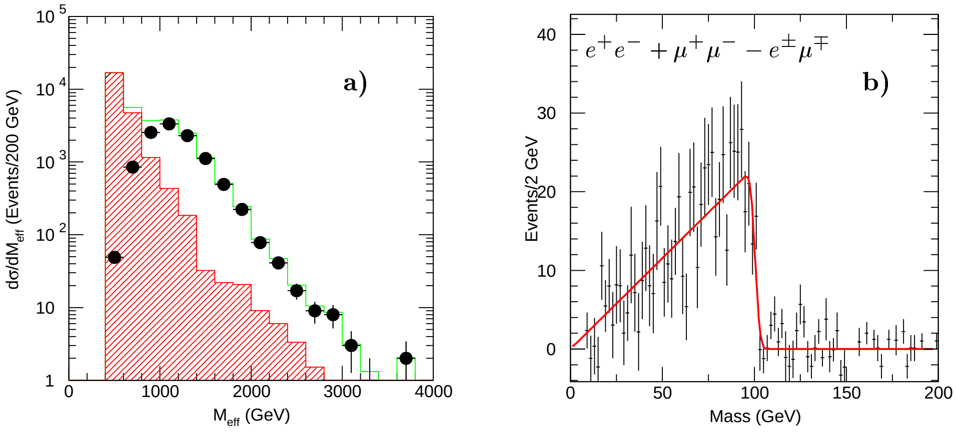

Fig. 1. Results[2] of the analysis of 5 fb^{-1} of fully simulated Monte Carlo events for the mSUGRA model described in the text: a) shows the M_{eff} distribution, which exhibits a large excess over the SM background contribution (shaded histogram). b) shows the (wrong-flavour subtracted) di-lepton invariant mass distribution from which the di-lepton edge measurement is obtained.

possible combinations of a sample of events.

The mass of the $\tilde{\chi}_1^+$ can be reconstructed using the decay $\tilde{\chi}_1^+ \to W^+\tilde{\chi}_1^0$, when the opposite side of the event contains a standard di-lepton decay chain. Techniques described above allow reconstruction of the four-momentum of the $\tilde{\chi}_1^0$ at the end of the di-lepton chain, and therefore, via the $\not{E}_T$, the four-momentum of the $\tilde{\chi}_1^0$ produced in the $\tilde{\chi}_1^+$ decay. From this, the $\tilde{\chi}_1^+$ mass can be reconstructed.

Recently, WMAP results have focused interest on specific regions of SUSY parameter space that are most consistent with the result $\Omega_{CDM}h^2 = 0.1126^{+0.0161}_{-0.0181}$ (2σ), particularly the so-called co-annihilation and focus-point regions of the $(m_0, m_{1/2})$ plane. In the co-annihilation region sleptons are almost degenerate with the LSP yielding rather low momentum leptons, complicating the reconstruction of the standard di-lepton chain. The focus-point region is particularly challenging as the $\tilde{q}$ and $\tilde{g}$ cross-sections are quite low. The large m_0 values in this region yield very high scalar masses. However, gaugino masses remain relatively low. Dilepton edge measurements from $\tilde{\chi}_n^0 \to \tilde{\chi}_1^0\ell\ell$ are under investigation as is light gluino reconstruction in the decay $\tilde{g} \to \tilde{\chi}qq^{(\prime)}$. Studies of these special regions are ongoing.

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