# Scanning the mSUGRA Parameter Space for Different SUSY Signatures

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Although the Standard Model (SM) is a very successful theory, it has many drawbacks, like the hierarchy problem. Therefore the Standard Model is considered to be only a low energy approximation of a more fundamental theory. One of the best motivated theories beyond the Standard Model is Supersymmetry (SUSY). For every Standard Model particle, Supersymmetry predicts a partner having the same quantum numbers except for the spin, which differs by 1/2. These new particles have not been observed yet and thus Supersymmetry must be broken. Many Supersymmetry breaking models (mSUGRA, GMSB, AMSB, ...) have been developed, mSUGRA being the model studied here.

The mSUGRA model has 5 free parameters:

- $m_0$, the universal sfermion mass at the Grand Unification (GUT) scale
- $m_{1/2}$, the universal gaugino mass at the GUT scale
- $tan\beta$, the ratio of the Higgs vacuum expectation values
- $sgn\mu$, the Higgsino mass parameter sign
- $A_0$, the universal trilinear coupling at the GUT scale

In this analysis, R-parity conservation is assumed and therefore the lightest supersymmetric particle (LSP), which is the lightest neutralino ($\tilde{\chi}_1^0$) in most parts of the parameter space, must be stable. The observed cold dark matter in the universe, which must be in the form of neutral, massive and weakly interacting particles, can be explained as consisting of these LSPs. Requiring $\Omega_{CDM}h^2$, i.e. the relic density of the LSP, to be in the measured range strongly constrains the mSUGRA parameter space.

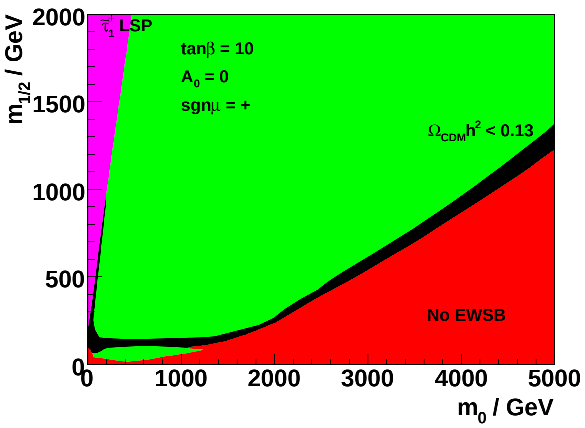


Fig. 1: $m_0$-$m_{1/2}$-plane for $tan\beta = 10$, $A_0 = 0$ and $sgn\mu = +$. In the red region, electroweak symmetry breaking does not occur: this part of the parameter space is thus excluded. The purple region is also excluded because it has a charged LSP which is incompatible with dark matter observations. The green region is the allowed region without further constraints. Only in the black region is the LSP a $\tilde{\chi}_1^0$ with a value of $\Omega_{CDM}h^2$ below the upper experimental limit [3].

In this analysis, we scan the mSUGRA parameter space to determine which areas exhibit signatures that can be seen in the ATLAS detector at the LHC. Scans of the $m_0$-$m_{1/2}$-plane for different values of the other parameters are performed using, in turn: SOFTSUSY [1], to calculate the SUSY spectrum, PYTHIA [2], to generate Monte Carlo events and, finally, micrOMEGAs [3], to calculate the value of $\Omega_{CDM}h^2$ based on the SUSY spectrum and to indicate the constraints on the sparticle masses from the LEP experiment. Figures 1 and 2 show examples of scans performed for two different values of $tan\beta$. As can be seen on these Figures and as stated before, the value of $\Omega_{CDM}h^2$ strongly constrains the parameter space. However, the rest of the analysis will not be confined to this constrained part of the parameter space.

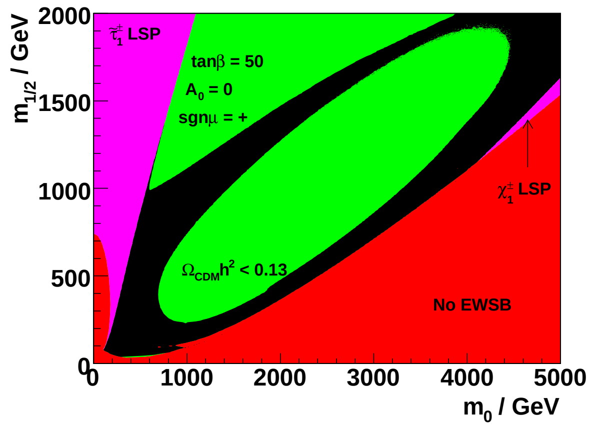


Fig. 2: $m_0$-$m_{1/2}$-plane for $tan\beta = 50$, $A_0 = 0$ and $sgn\mu = +$. The colour code used here is the same as in Fig. 1.

While scanning the parameter space, we search for same-sign dilepton and trilepton signals, i.e. signals with either two leptons with the same electric charge or three leptons in the final state (the leptons considered here being electrons or muons). First scans show that requiring a third lepton in multileptonic analyses reduces the expected event rate by a factor of 2-4 for most of the parameter space. A cut on the invariant mass of opposite sign same flavour (OSSF) leptons between 80 and 100 GeV was also performed to study the influence of $Z^0$ background rejection. This cut does not strongly affect the signal rates, especially in the region in accordance with the cosmological constraints. Additionally a veto on jets with $p_T > 50$ GeV was studied for the same-sign dilepton and the trilepton signals. For both signals this cut drastically reduces the event rate.

## References


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[2] T. Sjöstrand *et al.*, JHEP **05** (2006) 026

[3] G. Bélanger, F. Boudjema, A. Pukhov, A. Semenov, Comput. Phys. Commun. **176** (2007) 367, hep-ph/0607059