Scanning the mSUGRA Parameter Space for Different SUSY Signatures and Study of Lepton Isolation for an Inclusive Search for Supersymmetry in Trilepton Events

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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). Many different SUSY models have been developed, mSUGRA being the model studied here.
In the mSUGRA model with R-parity conservation the lightest supersymmetric particle (LSP), 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 (cf. Fig. 1).

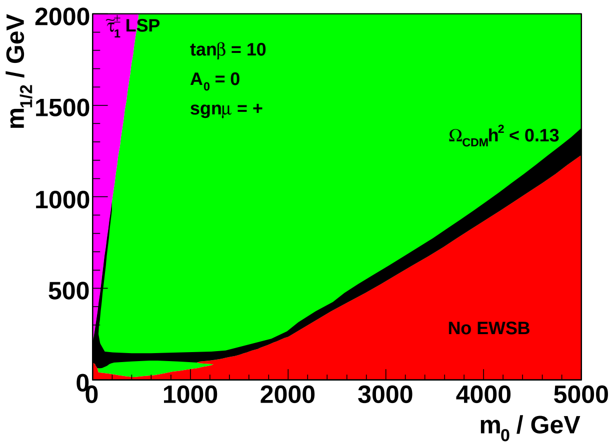

Fig. 1: m_0-$m_{1/2}$-plane for $tan\beta = 10$, $A_0 = 0$ and $sgn\mu = +$. In the red region, electroweak symmetry breaking does not occur: this part of the parameter space is thus excluded. The purple region is also excluded because it has a charged LSP which is incompatible with dark matter observations. 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 [1].

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 the Monte Carlo Generator PYTHIA [2] while scanning the parameter space, we search for same-sign dilepton and for 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). Fig. 2 shows the fraction of trilepton events of all SUSY events. In the region of the parameter space around $m_0 = 1000$ GeV and $m_{1/2} = 500$ GeV long SUSY decay chains starting from gluinos or squarks are dominant. In these long decay chains many leptons can be produced, leading to multileptonic events. In the band with a relatively high percentage of trilepton events at low m_0 the next-to-lightest neutralino ($\tilde{\chi}_2^0$) decays into a slepton, which is lighter than the neutralino only in this region of the parameter space. This decay and the decay of the slepton lead to additional charged leptons in the final state [3].

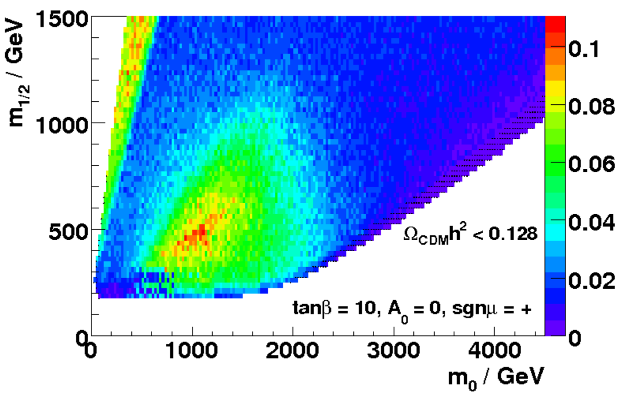

Fig. 2: m_0-$m_{1/2}$-plane for $tan\beta = 10$, $A_0 = 0$ and $sgn\mu = +$. The fraction of trilepton events of all SUSY events is shown.

The main background for trilepton SUSY searches are $t\bar{t}$ events. It is therefore crucial to understand why some $t\bar{t}$ events survive the signal selection cuts. In order to not only rely on Monte Carlo generators for these studies we are currently developing a method for the determination of the $t\bar{t}$ background to trilepton SUSY events from data. The standard trilepton analysis cuts require three isolated leptons in the final state. $t\bar{t}$ events should not contain more than two isolated leptons. The third lepton seen in those events therefore has to be an object misidentified as a lepton or a lepton from a decay inside a jet. In both cases the "lepton" should not be isolated. By changing the standard cuts on the isolation of the leptons we generate a sample of events with properties similar to the events in the signal region. This so-called control sample should contain as few signal events and as many $t\bar{t}$ background events as possible. With the selection of cuts studied until now, we are able to significantly raise the number of $t\bar{t}$ events with respect to the number of signal events in our control region.

References

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[2] Torbjörn Sjöstrand *et al.*, JHEP **05** (2006) 026
[3] J. de Graat, "Suche nach Gebieten auffälliger Signaturen im SUSY Parameterraum", diploma thesis