Search for a heavy top partner in final states with two leptons with a multi-variate analysis technique in the ATLAS detector at LHC

M.Bianco[1 2] , E.Gorini[1,2], M.Primavera[1], A.Ventura[1,2] (and the ATLAS Collaboration)

[1]Istituto Nazionale di Fisica Nucleare, sezione di Lecce, Italy,

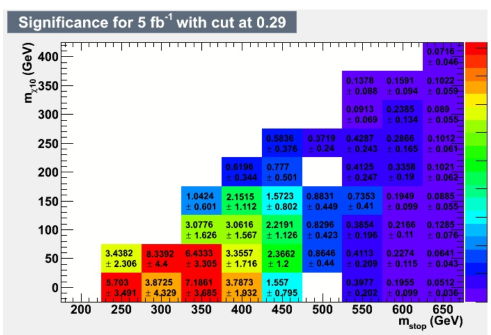
[2]Dipartimento di Fisica, Università del Salento, Italy

1. Introduction

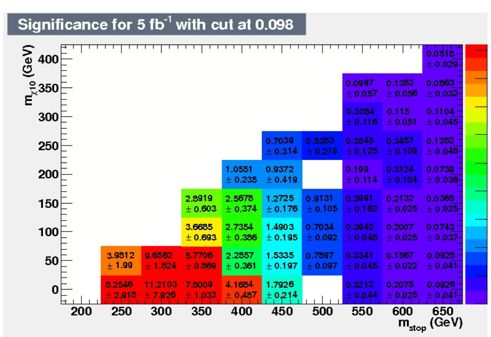
The super-partners of third generation quarks are required to be lighter than approximately 500 GeV, and the existing LEP and Tevatron limits for such particles are between 100 GeV and 200 GeV depending on the SUSY scenario. Generic searches for SUSY particles look for squark and gluino production asking for events with large missing transverse momentum E_T^{miss} and jets plus possibly one or more leptons. Typical selection criteria require hard cuts on E_T^{miss} and on the transverse momenta of the jets, which have typically rather low efficiencies for sparticles lighter than 400 GeV. Therefore, it is important to perform dedicated exclusive searches of these particles, and to find out both discriminating variables which are able to separate the signal from the background as much efficiently as possible and a powerful method which can exploit the information contained in these variables in the best way. Multivariate analysis techniques allow in principle to do this, thus providing a more efficient method to enhance the signal-to-background ratio with respect to the traditional cut-based analysis method. The Toolkit for Multivariate Analysis (TMVA) provides a ROOT-integrated [1] environment for the application of multivariate classification. All multivariate techniques in TMVA belong to the family of supervised learning algorithms. They make use of a training phase in which the algorithm examines events for which the desired output is known and determines a mapping function which is used in the application phase to perform the decision about the event classification for a sample containing a signal and background (unknown) mixture.

A feasibility study to apply this tecnique in an analysis searching for evidence of a heavy partner of the top quark (stop), where each of the stop partners decays into a b-jet, a lepton, and weakly interacting particles which escape detection, has been carried out in the ATLAS experiment [2].

The analysis is sensitive to the process: $\tilde{t}\bar{\tilde{t}} \rightarrow \tilde{\chi}_1^0 t \tilde{\chi}_1^0 \bar{t} \rightarrow \tilde{\chi}_1^0 b l^+ \nu \tilde{\chi}_1^0 \bar{b} l^- \nu$ where $\tilde{t}$ is the supersymmetric scalar top quark and $\tilde{\chi}_1^0$ is the lightest neutralino. The process requires $m(\tilde{t}) - m(\tilde{\chi}_1^0) > m(t)$. The background to this channel comes mainly from $t\bar{t}$, Z+jets, single top, Drell-Yan and dibosons production. A Monte Carlo signal grid in the (mass of the stop-mass of neutralino) plane was generated, with stop masses up to 800 GeV and neutralino masses up to 550 GeV in steps of 50 GeV, together with several Monte Carlo background samples. A preselection of the signal and background events was performed, based on E_T^{miss} (> 50 GeV), m_{eff} (> 300 GeV), where m_{eff} is defined as the scalar sum of E_T^{miss} and the transverse momenta of the two leptons and of the two most energetic jets in the event, and on the request to have only 2 "golden" leptons (electrons or muons) in the event [3]. Then, a set of 6 variables was provided to TMVA training in order to produce the mapping function: E_T^{miss}, m_{eff}, p_T of the second lepton, p_T of the second jet, the dilepton mass and M_{T2}, which is exploited in the case where two identical particles (legs) are produced in the event, and both decay into an invisible particle. The definition of M_{T2} and the explanation of its discriminating power can be found in [3]. In general, two criteria must be followed in selecting variables: to maximize the difference between signal and background and to minimize correlations among the chosen variables. With respect to these criteria, the variables are ranked in TMVA in positions of decreasing importance. In our case, E_T^{miss} and M_{T2} were the most important and the most useful for the training. Several TMVA training were performed, for different choices of the TMVA method to be applied for signal-background discrimination and different points on the signal grid, in order to find out the most powerful method and the signal point which maximize this discrimination through the whole grid. Then, the most performing method, for which the signal efficiency versus the background rejection was found the best one, was furtherly optimized with respect to the parameter setting in the algorithm. Electrons and muons were separately used for training. Finally, the method Boosted Decision Trees with gradient boosting (BDTG) was found to be the most sensitive for signal-background separation, assuming as estimator of the method power the statistical significance, normalized to 5 fb^{-1} (i.e. the integrated luminosity collected by ATLAS in 2011) and defined as: $S = N_s/\sqrt{N_b + \delta N_b}$, where N_s and N_b are the signal and background events surviving for each point on the signal grid after cutting on a suitable BDTG value, unique for the whole grid, to discriminate signals and background. The term δN_b was added in order to take into account the systematic uncertainty on the background, assumed to be 60%. The most promising points over the signal grid to perform the training phase were found to be: the one with a stop mass of 350 GeV and a netralino mass of 0 GeV and the one with a stop mass of 300 GeV and a netralino mass of 50 GeV, both for electrons and muons. In fig. 1 the significance is shown with its error for all the points of the signal grid for the electron (a) and the muon (b) channel. Even with different results for the electron and muon scenarios, a 5σ discovery is possible for a favourable range of stop and neutralino masses.



(a)



(b)

Figure 1. Expected signal significance as a function of the scalar top and neutralino masses for the decay $\tilde{t} \to \tilde{\chi}_1^0 t$, obtained with TMVA package with the BDTG method. Figure (a) is for the electron channel and figure (b) is for the muon channel.

REFERENCES

1. A. Hoecker, P. Speckmayer, J. Stelzer, J. Therhaag, E. von Toerne, H. Voss, TMVA 4 USERS GUIDE, arXiv:physics/0703039, CERN-OPEN-2007-007.
2. ATLAS Collaboration, JINST 3 S08003 (2008).
3. M. Bianco et al., Search for a heavy top partner in final states with two leptons (supporting INT note), ATL-COM-PHYS-2012-022 (2012).