PROCEEDINGS OF SCIENCE

SUSY signatures at ATLAS

Iris Borjanovic[*][†] **for the ATLAS collaboration**
University of Lecce, Italy
Institute of physics, Serbia and Montenegro
E-mail: `iris@phy.bg.ac.yu`

In this report recent studies made to understand the capability to discover and measure properties of supersymmetric particles with the ATLAS detector at LHC are presented. In the £rst part we discuss the characteristic signatures of supersymmetric models in the stau coannihilation and focus point regions of minimal Supergravity parameter space. We focus on signatures involving lepton and heavy quark invariant mass endpoints and ditau signatures involving soft taus, and identify the challenges which such signatures present for the experiment and reconstruction algorithms. In the second part we discuss the characteristic signatures of supersymmetric models with light stop squarks. We focus on heavy quark signatures and discuss the prospects for measurement of supersymmetric particle masses in different scenarios.

International Europhysics Conference on High Energy Physics
July 21st - 27th 2005
Lisboa, Portugal

[*]Speaker.

[†]Material presented here represents the work of several individuals of the ATLAS collaboration. The author wishes to thank the ATLAS collaboration members for useful discussions. The physics analysis framework and tools used here are the result of collaboration-wide efforts. The author specially wishes to thank T. Lari and D. Tovey for help in preparing this presentation.

1. Stau coannihilation and focus point regions

Minimal Supergravity (mSUGRA) parameter space is highly constrained by the latest experimental data [1]. Various experimentally challenging points in the mSUGRA parameter space have been chosen for study and preliminary full simulation studies of stau coannihilation point and focus point are reported here. Full simulations provide better understanding of SUSY events as they would actually appear when reconstructed by the ATLAS detector, hence we have rather limited produced statistics. Geant-4 simulation of the full ATLAS detector was used. Full simulations also serve as a tool to test and evaluate the reconstruction software. The coannihilation point is challenging due to the soft leptons present in the £nal state, while the focus point has complex events with lots of heavy ¤avour.

In the stau coannihilation region, the lightest stau slepton $\tilde{\tau}_1$ is slightly heavier then the lightest neutralino $\tilde{\chi}_1^0$ and an acceptable relic density of cold Dark Matter is obtained through enhanced stau-neutralino coannihilation processes. The point selected for study has parameters: $m_0 = 70\ GeV,\ m_{1/2} = 350\ GeV,\quad A_0 = 0\ GeV,\quad tan\beta = 10,\quad sgn\mu = +$. The main characteristics of this point is the small mass difference between sleptons and neutralinos. Consequently, soft leptons are present in the £nal state. Cascade decay of left squark is analysed $\tilde{q}_L \to \tilde{\chi}_2^0 q \to \tilde{l}^{\pm}_{L,R} l^{\mp} q \to l^+ l^- q\ \tilde{\chi}_1^0$. Decay of second lightest neutralino to both left and right sleptons is open, hence endpoints have left-right structure. One of the £nal state leptons is soft. Events with two same ¤avor-opposite sign leptons are selected. Few kinematic endpoints are reconstructed: the maximum dilepton invariant mass M_{ll}^{max}, the maximum of the $M(llq)$ invariant mass M_{llq}^{max}, the maximum of the lower of the two l^+q, l^-q invariant masses $(M_{lq}^{low})^{max}$ and the maximum of the higher of the two l^+q, l^-q invariant masses $(M_{lq}^{high})^{max}$. Reconstructed endpoints are at the expected positions. Flavor subtracted $(e^+e^- + \mu^+\mu^- - e^+\mu^- - e^-\mu^+)$ dilepton mass distribution for integral luminosity $L = 20 fb^{-1}$ is displayed on Figure 1. Expected dilepton endpoints for left and right sleptons are $M_{ll}^{max}(L) = 56$ GeV and $M_{ll}^{max}(R) = 98$ GeV. Decay of second lightest neutralino to lighter stau slepton $\tilde{\chi}_2^0 \to \tilde{\tau}_1^{\pm}\tau^{\mp} \to \tau^+\tau^-\tilde{\chi}_1^0$ is allowed. The tau lepton from stau decay has low transverse momenta. Ditau invariant mass has endpoint structure. Only hadronic tau decays are analysed. Events with two opposite sign tau leptons are selected. The available statistics for ditau invariant mass is very low even for 20 fb^{-1} of data. If instead, hard tau lepton with $p_T > 40$ GeV is combined with any track having $p_T > 6$ GeV and no other track with $p_T > 1$ GeV in cone $R < 0.4$, the resulting invariant mass for tau lepton and tau track has a clear endpoint. Algorithm for soft tau reconstruction is further developing. Right squark pairs $\tilde{q}_R\tilde{q}_R$ have a simple £nal state characterized by two high transverse momenta jets and missing transverse energy: $\tilde{q}_R\tilde{q}_R \to qq\tilde{\chi}_1^0\tilde{\chi}_1^0$. Stransverse mass [2] is de£ned as:

$$M_{T2}^2 = min[\ max\{\ m_T^2(\ p_{T,j1}, E_{T1}^{miss}, M(\tilde{\chi}_1^0)),\ \ m_T^2(\ p_{T,j2}, E_{T2}^{miss}, M(\tilde{\chi}_1^0)\ )\ \}\ ]\ ,$$

where missing transverse energy is partitioned $E_T^{miss} = E_{T1}^{miss} + E_{T2}^{miss}$ in all possible ways, transverse masses of two jets with transverse momenta $p_{T,j1}$ and $p_{T,j2}$ are computed and the minimum of larger transverse mass is taken. The endpoint of the stransverse mass M_{T2} gives the right squark mass. Events with $E_T^{miss} > 400$ GeV, two jets with $p_T > 200$ GeV and $\Delta R(j1, j2) > 1$ are selected and the resulting M_{T2} distribution is shown on Figure 2. The position of the £tted endpoint is $M(\tilde{q}_R)^{fit} = 711 \pm 5$ GeV and the actual value of right squark mass is $M(\tilde{q}_R) = 735$ GeV.

The focus point region is characterized by large values (in the multi-TeV range) of the scalar mass parameter m_0. Rapid s-channel neutralino annihilation in the early universe kept the relic density at acceptably low values. Multi-TeV squark and slepton masses are predicted. The point selected for more detailed study has parameters $m_0 = 3550$ GeV, $m_{1/2} = 300$ GeV, $A_0 = 0$ GeV, $tan\beta = 10$, $sgn\mu = +$. Squarks and sleptons have masses above 2 TeV. Dominant SUSY production is of gaugino pairs, but these events are very dif£cult to isolate from the SM background. Gluino pairs produced in 10% of all SUSY events decay to gauginos and jets. Gauginos decay directly to leptons. Decays of third and second lightest neutralino to leptons are analysed: $\tilde{\chi}_3^0 \rightarrow l^+ l^- \tilde{\chi}_1^0$, $\tilde{\chi}_2^0 \rightarrow l^+ l^- \tilde{\chi}_1^0$. Dilepton endpoints measure the mass difference between gauginos: $\Delta m_{31} = m(\tilde{\chi}_3^0) - m(\tilde{\chi}_1^0) = 76\ GeV$, $\Delta m_{21} = m(\tilde{\chi}_2^0) - m(\tilde{\chi}_1^0) = 57\ GeV$. Events with two same ¤avor-opposite sign leptons are selected. Dilepton invariant mass is shown on Figure 3. Integral luminosity is $L = 7\ fb^{-1}$. Two reconstructed endpoints are at the expected positions and the Z peak is also visible. If we apply cuts against Standard Model (SM) background obtained with fast simulation studies, $E_T^{miss} > 100$ GeV, $p_T(j1, j2) > 100$ GeV, $p_T(j3, j4, j5, j6) > 50$ GeV, the available statistics are drastically reduced , but the edge structure still emerge.

2. Models with light stop squark

Models with light stop squark predict an abundant production of heavy ¤avors, stop and sbottom squarks, which play an important role in determining properties of underlying supersymmetric (SUSY) models. All studies are fast simulation.

Snowmass point 5 (SPS5), de£ned by parameters: $m_0 = 150$ GeV, $m_{1/2} = 300$ GeV, $A_0 = -1000$ GeV, $\tan\beta = 5$, $\mu > 0$, predicts light stop squark with mass $m(\tilde{t}_1)$=236 GeV. The gluino decay chain: $\tilde{g} \rightarrow \tilde{t}_1\ t \rightarrow t\ b\ \tilde{\chi}_1^{\pm}$, with a top quark decaying hadronically via $t \rightarrow bW \rightarrow bjj$ can give a detectable signal.Top-bottom invariant mass has endpoint structure and the endpoint is a function of the gluino, chargino and stop masses. Events with missing transverse energy $E_T^{miss} > 200\ \ GeV$, two b jets with transverse momenta $30 < p_T(b1) < 150$ GeV and $30 < p_T(b2) < 50$ GeV, number of light quark jets > 3 with $p_T(j1) > 300$ GeV, $p_T(j2, j3, ...) > 30$ GeV and rapidity $|\eta| < 3$ are selected. The top decay is reconstructed by searching for jets with an invariant mass compatible with $t \rightarrow Wb \rightarrow jjb$. The combinatorial background is estimated and subtracted with the W sideband technique [3]. The expected shape of the top - bottom invariant mass distribution after sideband subtraction is presented on Figure 4. Fitted endpoint $(M_{tb}^{max})^{fit} = 260.0 \pm 0.5(stat)$ GeV is consistent with the calculated value of 255 GeV.

3. Conclusions

In this contribution new preliminary studies of mSUGRA signatures using new full simulation data of the ATLAS detector have been shown. Many exclusive studies can be carried out with only a few fb^{-1} of data, i.e. ~ 1 year at low luminosity for stau coannihilation point and focus point. Still a lot of work is ahead: study of cuts to reject SM background, study of reconstruction ef£ciencies, acceptances, calibration and trigger, study of £t to distributions. Current emphasis is on large statistics full simulation SM background studies. At the point SPS5, top-bottom endpoint can be measured which allows constraints to be put on the masses of the SUSY particles. More work is in progress.

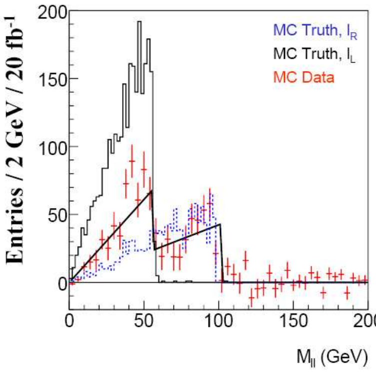

Figure 1: Flavor subtracted ($e^+e^- + \mu^+\mu^- - e^+\mu^- - e^-\mu^+$) dilepton invariant mass. The black (blue) line denote Monte Carlo truth events from the decay of left (right) slepton. The red line represents Monte Carlo data.

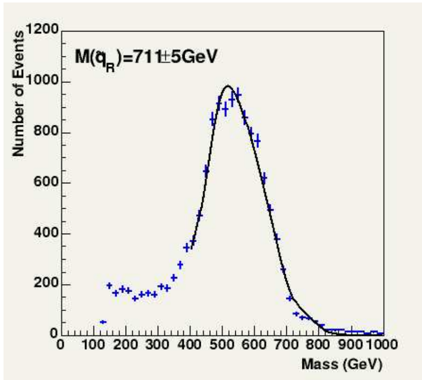

Figure 2: Distribution of M_{T2} for the events passing the cuts. Superimposed is the £t. The integral luminosity in the plot is L=20 fb^{-1}.

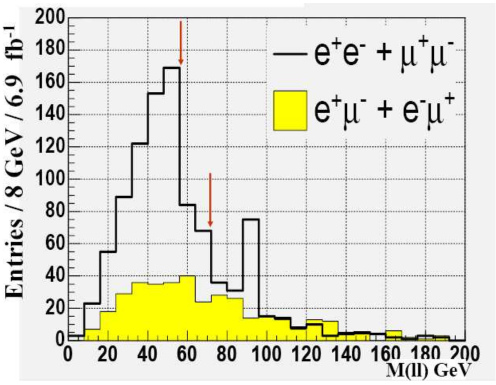

Figure 3: Dilepton invariant mass for the same ¤avor-opposite sign lepton pairs (white shading) and opposite ¤avor-opposite sign lepton pairs. (yellow shading). The arrows indicate the calculated endpoint position.

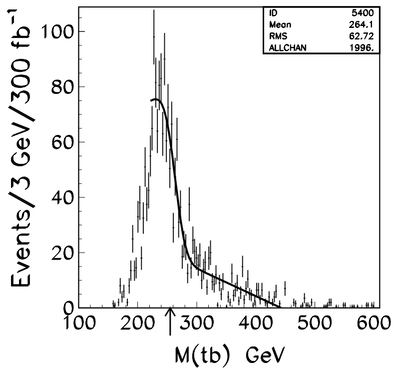

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Figure 4: Fitted top-bottom invariant mass after W sideband subtraction. The arrow indicates the calculated endpoint position.

References

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