SEARCHING FOR SUPERSYMMETRY WITH TWO SAME-SIGN LEPTONS, MULTI-JETS PLUS MISSING TRANSVERSE ENERGY IN ATLAS AT $\sqrt{s} = 10$ TEV

A. Castaneda

Physics Department, University of Wisconsin-Madison, USA

(on behalf of the ATLAS Collaboration.)

Abstract

A search for R-parity conserving supersymmetry using the ATLAS detector is presented. The final state under study includes two same-charge leptons, two jets, and missing transverse energy. We propose a data-driven method to estimate the number of Standard Model background events, and its discovery potential is assessed assuming an integrated luminosity of 200 pb^{-1} and a center of mass energy of 10 TeV.

Introduction

Supersymmetry is one of the prime theories [6] for physics beyond the Standard Model (SM). It predicts a super partner for every known elementary particle in the SM. In our study we consider an R-parity conserving scenario in which the lightest supersymmetric particle (LSP) is stable, It is produced at the end of the cascade decay of other massive particles and escapes detection, causing large missing transverse energy ($\not{E}_T$) in the event. Thus a requirement of $\not{E}_T$ in the event along with other final states particles such as leptons and jets has potential to discover R-parity conserving supersymmetry at the LHC. The production of same-charge lepton pairs at the LHC can be enhanced by events where two gluinos are produced an both subsequently decay to same-sign charginos which decay leptonically. An example of such a gluino decay is given in Figure 1.

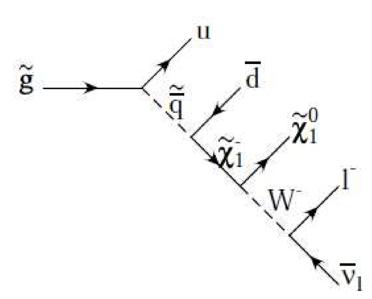

Figure 1: The decay of one of the gluinos in a $\tilde{g}\tilde{g}$ pair production.

Searches for supersymmetry in the same-sign dilepton channel have been performed at Tevatron; details on the limits obtained in these searches can be found in Ref.[1, 2]. It has been shown that same-sign dilepton production can be an important discovery channel for supersymmetry at the LHC as well [7, 3].

Signal and Background Models

Our final state is composed of high P_T same-sign leptons, accompanied by at least two jets and $\not{E}_T$. SM processes that can mimic these final states are: $t\bar{t}$ pair production, W+light-quark jets and Wbb+jets, $b\bar{b}$ production potentially dangerous due to its high production cross-section, single top production, WW, ZZ, WZ, Wγ and Zγ production.
As a potential signal for this analysis we have chosen the mSUGRA model. The mSUGRA parameter space is governed by 5 parameters: the scalar particle's mass (m_0), the gaugino mass ($m_{1/2}$), the ratio of vacuum expectation values of the two Higgs fields that give mass to up-quarks and down-quarks ($\tan\beta$), the trilinear coupling A_0, and the SUSY conserving Higgs mass parameter μ, The mSUGRA models predict SUSY mass scales within the LHC reach [5, 4]. The configurations and cross sections for some of the mSUGRA benchmark points are given in the table below.

Process	m_0(GeV)	$m_{1/2}$(GeV)	$\tan\beta$	A_0	NLO σ (pb)
SU1	70	350	10	0	3.6
SU3	100	300	6	-300	8.1
SU4	200	160	10	-400	164.6
SU6	320	375	50	0	1.8

Figure 2: Parameters for the various mSUGRA benchmark points considered, and their NLO cross sections.

Event Pre-Selection

The event pre-selection consists of the following cuts:

- Exactly 2 leptons with same charge, $P_{T,l1} > 20$ GeV and $P_{T,l2} > 10$ GeV.
- $(M_{ll}) > 5$ GeV to suppress the backgrounds due to reconstruction inefficiencies.
- At least two jets with $P_T > 40$ GeV.
- $\not{E}_T > 50$ GeV. This cut is effective against QCD, di-jet, and Z+jets events.
- Transverse mass (M_T) to study the dominant background processes. It is defined as $M_T = \sqrt{2(P_{T,l1}\not{E}_T(1 - cos\Delta\phi(l1, \not{E}_T))}$.

Background Estimation

After the event preselection cuts, the contribution from the $t\bar{t}$ and W+jets processes are the dominant ones among all of the SM background processes. In order to estimate the SM background in situ, we classify the events that survive the preselection into four different categories. We rely on four different variables that have power to discriminate between signal and background for the categorization. These variables are: $\not{E}_T$, P_T of the second leading jet, P_T of the second leading lepton and M_T.

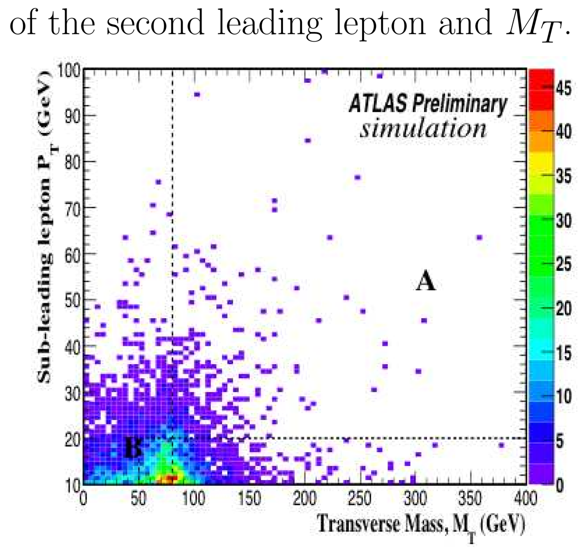

Figure 3: The small box that refers to lower values is called Region B and the higher values of these variables are called Region A.

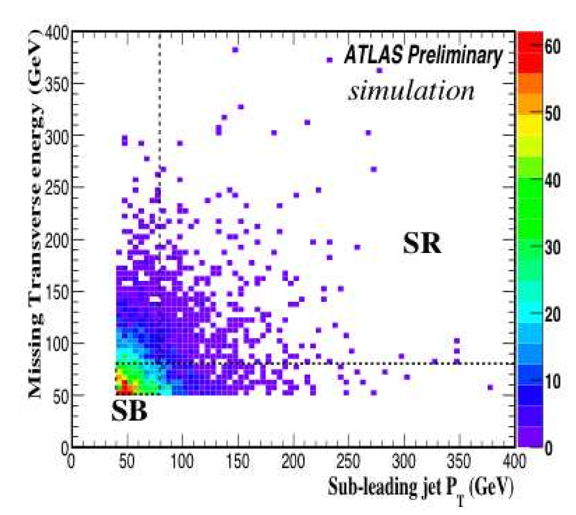

Figure 4: The small box that refers to lower values of these two variables is called Side Band (SB) and the bigger box called the Signal-like region (SR).

We define a signal-like region SR,a sideband region SB and regions A and B as follows:

- SR: $\not{E}_T > 80$ GeV and $P_{T,j2} > 80$ GeV; SB: $50 < \not{E}_T < 80$ GeV and $40 < P_{T,j2} < 80$ GeV.
- A: $P_{T,j2} > 20$ GeV and $M_T > 80$ GeV; B $10 < P_{T,j2} < 20$ GeV and $50 < M_T < 80$ GeV.

A_{SR}, i.e. the signal-like portion of region A, is the actual SUSY signal region, and it is in this region we want to estimate the SM background. The three other regions B_{SR}, A_{SB} and B_{SB} serve as a control region. If the correlation between the variables can be neglected, the following expresion holds $\frac{A_{SB}}{B_{SB}} \simeq \frac{A_{SR}}{B_{SR}}$ and $A'_{SR} \simeq \left(\frac{A_{SB}}{B_{SB}}\right) \times B_{SR}$. Here A'_{SR} is the estimated SM event rate in the signal region and A_{SR} is the expected MC event rate in the signal region. In Figures 3 and 4 we can see all these regions.

Process	A_{SR}	B_{SR}	A_{SB}	B_{SB}
W	-	0.7±0.4	0.9±0.5	2.2±0.7
Z	-	-	0.1±0.1	0.1±0.1
Wbb	-	-	-	0.4±0.2
Wt single top	-	0.3±0.3	-	-
t-chan single top	-	-	0.9±0.6	1.1±0.6
$t\bar{t}$	1.3±0.2	3.0±0.3	3.8±0.3	10.3±0.5
Total SM events	1.3±0.2	4.0±0.6	5.7±0.8	14.0±1.1
SU1	2.4±0.4	0.1±0.1	0.1±0.1	-
SU3	2.7±0.7	-	-	-
SU4	40.2±4.4	8.0±1.9	2.8±1.2	2.4±1.1
SU6	1.1±0.2	0.2±0.1	-	-

Figure 5: The expected number of events in 200 pb^{-1} for different SM and signal processes.

Data Content	Expected Signal Events in A_{SR}	Expected Signal+SM events in A_{SR}	Estimated SM events in A'_{SR}
No SUSY(only SM)	-	1.3±0.2	1.6±1.1
SM+SUSY SU1	2.4±0.4	3.7±0.5	1.6±1.2
SM+SUSY SU3	2.7±0.7	4.0±0.7	1.6±1.1
SM+SUSY SU4	40.2±4.4	41.5±4.4	6.2±3.2
SM+SUSY SU6	1.1±0.2	2.4±0.3	1.6±1.2

Figure 6: The expected and the estimated number of SM events in the signal region A_{SR}.

Discovery Potential

From Table 6 we conclude that if nature has chosen an SU4-like SUSY signal in data, we will be able to observe a clear signature with an integrated luminosity of 200 pb^{-1} at 10 TeV. Figure 7 shows the effective mass distribution for signal and background, defined as $M_{eff} = P_T^{lep} + \not{E}_T + \sum_{jets} P_T^j$ where the sum runs over the leading n(≤ 4) jets with $P_T > 20$ GeV in the event.

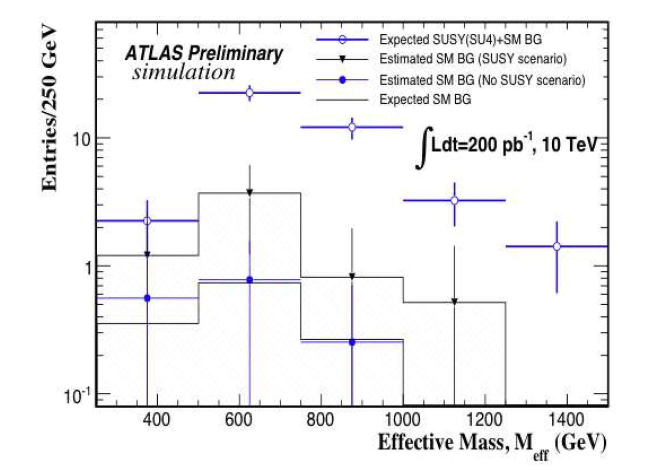

Figure 7: Effective mass distribution for same-sign dileptons in the inclusive two-jet and $\not{E}_T$ final state.

Figures 8 and 9 show the discovery reach for various luminosity scenarios in one of the mSUGRA parameter planes.

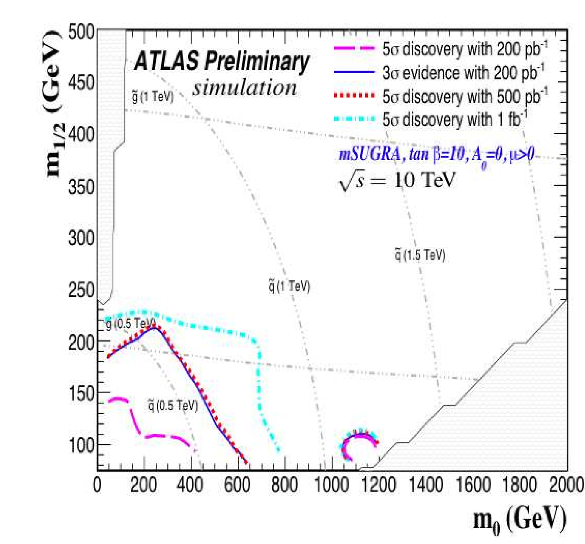

Figure 8: Discovery reach in the mSUGRA m_0 and $m_{1/2}$ plane with the $\tan\beta$=10, $A_0 =$ 0 and $\mu > 0$ configuration.

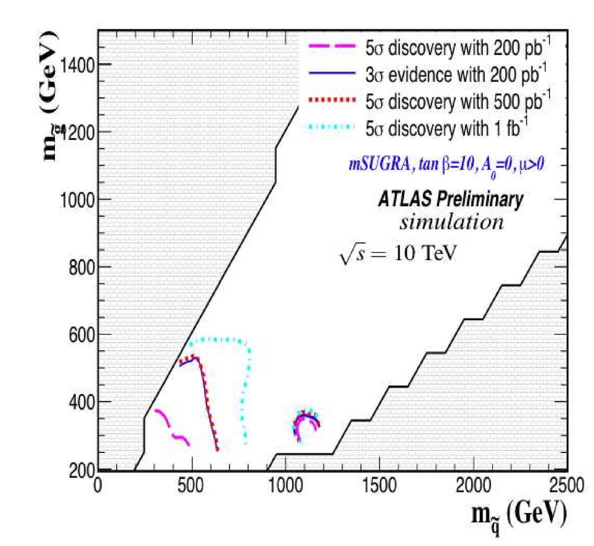

Figure 9: Discovery reach in the squark and gluino masses.

Conclusion

Same-sign dilepton production associated with jets and $\not{E}_T$ is an important channel to discover supersymmetry in the early LHC data. Events with such signatures are scarcely produced in SM processes, providing an almost background-free and powerful channel for discovery of beyond the Standard Model signals. It is shown that we will be able to find evidence of gluinos and squarks of masses up to 500 GeV with a 3 σ significance with as little as 200 pb^{-1} of integrated luminosity and a center of mass energy of 10 TeV.

References

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